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An Approach to Automatic Indexing of Scientific Publications in High Energy Physics for Database SPIRES-HEP

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Abstract

Methods of using keywords in the indexing and retrieval of non-book scientific literature are in practice in particle physics for well over forty years. In High Energy Physics (HEP), keywording has been done manually at the German research laboratory DESY (Deutsches Elektronen-Synchrotron) using the intellectual indexing method and DESY-HEPI thesaurus, a list of keywords. These keywords are incorporated in the database SPIRES (Stanford Public Information REtrieval System), maintained at the high energy physics laboratory SLAC (Stanford Linear Accelerator Center), which is being used extensively in search and retrieval of HEP documents. With the rapid increase in the number of scientific publications, most of which are prepared using electronic text programmes, and a well-maintained central repository of E-prints in HEP and related fields now based at Cornell University, there is an urgent need to develop methods of automatic indexing. We describe our approach to automatic indexing of HEP E-prints. The principal feature of our method is the development of a system parser to find associative patterns in the E-print text. Our system is supplied with a dictionary translating from the scientific language of the documents to a language of controlled vocabulary of keywords, the DESY-HEPI thesaurus. Detailed comparisons, based on E-prints in specific areas of HEP, between the classical DESY-SPIRES indexing reports and the ones generated by the automatic (electronic-based) indexing are presented. These comparisons encourage us to hope that with further development automatic indexing methods will become an essential tool in keywording HEP E-literature in future.

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1 Introduction

Indexing, as a method of content-based representation of documents for the purpose of archiving and subsequent retrieval, has been an integral part of bibliographic science. The classical card catalogues, which we all know from our school and local libraries, were used to search for literature which we knew already existed in the printed form. With the advent of electronic publishing, the library card catalogues have given way to databases, which are used not only to search for a particular document and have access to it, but they are now also increasingly used to find documents on a specific topic and retrieve them. While the former searches can be effectively done by using the author-based or source-based (such as a journal or book reference) retrieval systems, the latter make use of subject-based keyword indexing. Keywords, as the name implies, summarize the main results of a document in a well-defined area of intellectual activity. Keyword indexing is usually done at a place (a research institute or a publishing company) which either acts itself as the central repository of literature in a specific field, or else works in close collaboration with such repositories. In the case of High Energy Physics (HEP), this has been done at the German High Energy Physics Laboratory DESY (Deutsches Elektronen-Synchrotron), based in Hamburg, which has developed and maintained the High Energy Physics Index (HEPI) since 1963. The DESY-HEPI keywords are included in all records (published papers, preprints, conference proceedings and books) in the HEP database called SPIRES (Stanford Public Information REtrieval System), maintained at the high energy physics laboratory SLAC (Stanford Linear Accelerator Center), based in Palo Alto, California. The keyword indexing has been done exclusively using the so-called intellectual method in the Scientific Documentation Group at DESY, involving a team which includes some members with high energy physics background. The thesaurus used in HEPI is based on approximately 2500 terms, and is occasionally updated.

The methods of automatic indexing based on word frequency and the use of linguistic surfaces in documents were first formulated in the 1950s in the pioneering works of Luhn [Luhn 1957] and Baxendale [Baxendale 1958]. Since then, a lot of efforts has gone into improving the statistical and mechanical approaches. The advent of the electronic publishing era, and a transition to what is now called paperless publishing, has given a big boost to automatic indexing methods. Accessibility to electronic databases and World Wide Web, fast web-based search engines, use of the electronic text languages in preparing documents for publication, such as TeX and LaTeX, advances in software-based techniques, and development of algorithms to work with linguistic surfaces of documents have

brought the goal of completely automatic indexing closer to its realization. In fact, with the rapid growth of literature, a very large fraction of which is put out in the electronic form, automatic indexing is in the long term the only realistic and economically viable method of keyword indexing. However, despite all the technological progress and, what concerns high energy physics and several related fields, the availability of E-prints from the electronic archives dating back to the pioneering work of Ginsparg done at the Los Alamos National Laboratory in New Mexico in 1991 [Ginsparg 1991], there is no fully automatic indexing system in HEP available yet. In the recent past, there have been some attempts in this direction, mostly based at CERN (the European Laboratory for Particle Physics) in Geneva. The first of these approaches called SOCRATES was an attempt to incorporate software for automatic indexing [Dallman/Meur 1999], based on constructing a set of the longest noun-type phrases from the abstracts of the documents. This approach was, however, abandoned at the end of 2000 due to the difficulties of integrating its software into the database system of the CERN library. This was followed by a second research and development (R&D) project called HEPindexer, in which the first step aimed at the generation of the DESY-HEPI keywords [HEPI] has been implemented following a statistical method [Ráez/Dallman 2001]. The results of HEPindexer, which was trained on some 2400 high energy physics papers and tested so far on some 1200 additional documents, is quite impressive in that the results were close to 60% in precision and recall benchmarked against the HEPI-SPIRES method of keyword indexing [SPIRES].

We describe in this report our approach to automatic indexing of HEP E-prints, which has been developed in collaboration with Dr. Alexander Averin, a theoretical high energy physicist and software engineer based in Moscow. The method of our approach involves the use of an effective *system parser* which browses the selected parts (title, abstract, section- and subsection titles) or the full text of a document to find *associative patterns*. The *system parser* (or syntax analyzer) is a software module, which works with English as the system language. It reads the input data source files (the whole text or parts of it using a built-in pointer), uses the LaTeX grammar rules while analyzing characters from the input, and matches the characters in the input with the ones in the *associative patterns*. Central to our approach is the Associative Patterns Dictionary (APD), which we have developed and encoded. The system provides a software module called the APD Manager, which recognizes, edits and deletes the existing patterns in the system database, adds new patterns to the database and makes a link from the patterns to the set of *keychains*, defined as two *keywords*, joined by a comma or a blank as a delimiter. The *keywords* are considered as basic components to

construct *keychains*, and the latter have a direct functional role in making index reports for the documents (E-prints). As the system is flexible, there is a possibility of introducing new keywords. The system requirements include an SQL database server (for example, MySQL), a virtual host working in the Apache web server environment, a Perl interpretor, and a C-Compiler.
Our software package, henceforth called Automatic Indexer of High Energy Physics Documents (AI-HEPD) has been tested so far in a limited area of high energy physics, namely Neutrino physics and physics of the Axion (a light pseudoscalar boson advocated by Peccei and Quinn [Peccei/Quinn 1977] to solve the strong-CP problem in present theories of particle physics). This choice is based on our expertise and HEP background, as both the authors were working in the past in these fields. This gives us an advantage over purely software-based approaches, as we are confidant about how best to index our own scientific papers and some others in related fields. Judging from the number of E-prints in these fields, our project covers about 10% of the E-prints in HEP. This is also reflected in the number of the keywords presently encoded in our package (approximately 250) compared to approximately 2500 of the DESY-HEPI thesaurus. We have tested our software package on about 100 E-prints in these fields and have compared the results of our automatic indexer with the ones generated using the SPIRES-HEP database. Representive results of our approach (AI-HEPD) and the ones based on the intellectual method of keyword indexing (SPIRES-HEPI), are shown in the Appendices. These results are very encouraging and we trust that we are on the right track.

This report is organized as follows: In section 2, we give an introduction to automatic indexing and discuss some known methods of automatic indexing. In section 3, we review the important milestones in the development of documentation in HEP, which include DESY-HEPI, SPIRES and the Los Alamos E-print archives, all of which play a central role in our work described subsequently. In section 4, we explain the salient features of our Automatic Indexer of HEP Documents. Section 5, named "Associative Pattern Dictionary" includes the dictionary and describes the system conception in its first stage. We summarize our work in Section 6. Notations and technical details have been relegated to the Appendices A and B, while Appendix C contains the results of a detailed comparative study of our automatic indexer, the SPIRES-based indexer, and a model indexer which we have introduced as a bench mark.

2 Automatic Indexing

2.1 Intellectual Indexing

Indexing was considered classically as a manual and intellectual method of evaluation of documents, leading to a content-based representation of documents, which could subsequently be accessed using a descriptor-based information retrieval system. These descriptors are taken as a rule from a well-defined and controlled vocabulary (indexing language), which would be periodically updated to reflect new fields, and new trends within the established fields. The intellectual approach follows the conceptual opening up of a document content, leaving the linguistic surface level of the text, and representing instead its meaningful content through descriptors. Thus, intellectual indexing implies the following two essential steps [Nohr 2001]:

1. The conceptual grasp of the contents of an existing document (content analysis),

2. Transcribing the contents in terms of the elements of an indexing language (for example, through the descriptors of a thesaurus).

The central point is that the intellectual indexing procedures of documents require a content analysis, i.e., an understanding of the documents being indexed. Historically, this was the only method of indexing the literature, as all publishing and related bibliographical work was done with papers. This classic form of document analysis is still widely used, and is particularly important in the circumstances where the texts are available in a non-electronic form or for documents which are based on graphic forms (pictures, photographs, films etc.).

2.2 Why Automatic Indexing?

Growing use of the information processing machines (computers, PC's etc.), their enormous storage capacity (disk space), developments of electronic-based languages for writing the text (such as TeX and LaTeX), and a constant increase in the number of electronic texts being produced have led to the approach of automatic indexing. The beginning of this automation is associated with the pioneering works of H.P. Luhn and P. Baxendale [Luhn 1957, Baxendale 1958]. In contrast to the intellectual methods mentioned above, the methods of automatic indexing operate more or less with the linguistic surface of documents, i.e., with terms considered as character chains but not as meaning carriers. Thus, under automatic indexing, one understands methods which analyze fully automatically

documents and, based on this analysis, either extract selected index terms from a document (*extraction procedure*), or assign to a document the descriptors of a well-defined indexing language as its content representation (*adding procedure*).

As an intermediate step between the intellectual and automatic indexing procedures, one can also implement *semi*-automatic indexing methods. In semi-automatic indexing, the mechanically produced index terms are considered as suggestions which are then controlled (improved) by a person. In principle, any indexing system can be used in the procedure of semi-automatic indexing. The difference between the fully automatic and semi-automatic procedures is not so much in the differing systems or classifications that they employ, but rather in the implementation of different indexing procedures at the organizational level.

Of course, without the development of electronic publishing and a global transition from the conventional form of publishing (i.e., using papers as the main form of publishing and distributing documents) to what is now called *paperless publishing*, which uses electronic files as the medium of dissemination of documents, automatic indexing methods would remain academic exercises. Since the pioneering works of Luhn and Baxendale [Luhn 1957, Baxendale 1958], a true revolution has taken place in the field of publishing and information transfer and distribution methods. Technical breakthroughs involving both the information technology hard- and software aspects, but equally important the global reach and accessibility of the electronic publications, even in the most far flung and in the conventional economic sense less developed areas of the world, have led to a fundamental change in the perception on how information is to be accessed. What concerns natural sciences, which this author knows from close quarters, very few scientific papers are now issued and retrieved in the classical paper form.

Since the inception of automatic indexing, the intellectual (classic) and automatic indexing procedures are in concurrence with each other. This concurrence seems unending and inconclusive, as both methods have fundamentally different starting points and invoke very different basic assumptions. The differences between the two approaches can be described as follows [Nohr 2000].

Intellectual Methods aim at a correct and consistent representation of the contents of documents, so that in the process of the content analysis they describe recognized objects in terms of the standardized elements of an indexing language (descriptors).

Automatic Methods prepare the documents in a way that these documents

can be efficiently found in the subsequent retrievals with the help of index terms.

Thus, methods of automatic document analysis do not carry out in the first step a content analysis in the sense of understanding a document, which is the essential prerequisite for the intellectual indexing method [Nohr 2001]. In contrast, in automatic indexing, the analysis of the documents is oriented on statistical (or linguistic) criteria, or it follows a certain well laid-out pattern identification. These methods are in principle extraction methods, i.e., they work with the linguistic surface, or expressions in the original text, interpreted as stringy objects. For the purpose of retrieval, only the linguistic surfaces, or these stingy objects, are deterministic. This could be a drawback in some cases, as a document may not use the specific index terms which would represent its content optimally. In the intellectual method of indexing, such a situation could be easily rectified by the manual intervention and interpretation of a qualified indexer. The down side of the intellectual method is that human-based judgment errors can not always be avoided. In automatic indexing methods, the choice of keywords to characterize a document has to be restricted to those keywords which actually appear. From the multitude of terms present in a document, one makes a choice through which the contents of a document are best described. This choice could follow statistical methods, for example the multiplicity of appearance of a certain term, or through synonyms sought by the use of an electronic dictionary. Another method to make the choice of keywords is pattern matching. This, for example, could be the case for some well-defined mathematical symbols or functions.

2.3 Methods of Automatic Indexing

The procedures adopted in automatic indexing allow themselves to be divided in basically five categories which differ in terms of their underlying methodical approaches. While the entire list can be seen elsewhere [Nohr 2001], here we restrict ourselves to discussing three of them most commonly discussed in the literature:

- **Statistical methods** appeared historically among indexing methods as the first ones. These days, one finds various variations on the basic approach, however all of them are built on Luhn's basic assumption formulated in his famous paper "A statistical approach to mechanized encoding and searching of literary information" [Luhn 1957], in which he proposed that the frequency of word occurrence in an article furnishes a useful measure of word significance.

Statistical methods represent the most widespread procedures class [Luhn 1957, Salton 1987]. These methods of automatic indexing are integrated in many contemporary databases- and information retrieval systems.

- **Pattern matching methods** are based on the pattern identification procedures, through which pattern terms or term groups can be recognized inside the document text [Volk 1992]. The search engine uses matching algorithms to identify patterns within text which can then be matched with similar patterns from other data sources. The identified patterns (concept agents) can improve their ability to find similar relevant patterns by "learning" which hits the user prefers, enabling the search engine to improve the relevance of its search hits with each search performed. Automatic indexing procedures whose main analysis approach is based on *pattern matching*, on one hand, comprise a very interesting subject for investigation, on the other hand, they are seldom used, being in the stage of research and development. These procedures possess a high potential in future, both for automatic indexing of electronic text documents and especially for the graphic form of documents, such as pictures and films.

- **Concept-oriented methods** are essentially based on *adding procedures*. They are in fact closer to the intellectual indexing as *extraction procedure*. Indeed, they simulate the working methods of a person in the sense that they try to determine a *meaning* of a text and represent it afterwards in terms of commensurate index terms.

In any case, automatic indexing is a learning process and one has to use clever algorithms to avoid redundancies associated with the linguistic surfaces and restrict the choice to a manageable number of search terms. The efficiency of an algorithm is, in the final analysis, crutual in making the automatic indexing procedures generally acceptable.

Fortunately, in the field of natural sciences, in particular physics, automatic indexing can and does make use of the enormous experience collected in the course of intellectual indexing. Much of this bibliographical information while generated manually is now available in an electronic form. In particular, the indexing of the high energy physics documents carried out at the German high energy physics laboratory DESY in Hamburg [DESY, HEPI] and incorporated in the Stanford-based database system called SPIRES is a huge advantage. Among the various search modes, SPIRES [SPIRES] also makes use of keywords based searches of documents. Thus, one can use the SPIRES-based indexing as a benchmark for

automatic indexing algorithms in high energy physics, some of which will be described here. In our opinion, with the advent of concept-oriented software, fast search engines and speedy algorithms, time is now ripe for moving on to completely automatic indexing methods in high energy physics.

3 High Energy Particle Physics Literature

3.1 Development of Literature Documentation

Since its foundation in 1962, the **SLAC** (**S**tanford **L**inear **A**ccelerator **C**enter) Library[1] has been collecting scientific and technical preprints[2] . The details of each preprint were entered into a card catalogue, including the information on the author. From this catalogue, the library published a weekly list of new preprints for the SLAC community. The same year **DESY** (**D**eutsches **E**lektronen **S**ynchrotron)[3] had begun to publish a monthly reference journal named *"***H***igh* **E***nergy* **P***hysics – An* **I***ndex" (***HEPI***)* covering the field of particle physics and related topics. Included in this monthly reference journal was both the published literature and unpublished preprints (whereas SLAC concentrated initially on preprints only). Like SLAC, DESY provided the titles, authors and dates of arrival of documents, but instead of references, HEPI staff physicists assigned to each paper on the average ten keywords chosen from a controlled list.

In 1967 work began at the Stanford University on a computer database system which would be able to handle practically unlimited number of large bibliographic records. In 1968 the SLAC Library began participating in the development and testing of **SPIRES** (**S**tanford **P**ublic **I**nformation **RE**trieval **S**ystem). SPIRES was envisioned as a fully searchable database, and each bibliographic record would contain the preprint's author list (with each author's affiliation), title, report number and date.

The SLAC and DESY teams decided to work together in their coverage of the particle physics literature, and so preparations for this began. By 1975 specifications for the conversion of the DESY data to the SPIRES format were completed.

3.1.1 SPIRES 1969-1990

In 1968 the decision was made to publish at SLAC a weekly preprint list for the entire particle physics community. In January 1969 the first Preprints in Particles and Fields (PPF) list was sent out to over a thousand subscribers, which gave the possibility of making a work (or at least the title of the work) known to high energy physics community. A similar list has been distributed by DESY since

[1] http://www.slac.stanford.edu/library/

[2] This and the next subsection draw heavily on a recent paper written by Heath B. O'Connell [O'Connell 2002].

[3] http://www.desy.de/library/

1971. This established the idea of a central repository for preprints.

By 1975 both the SLAC and DESY libraries were working on the single HEP (High Energy Physics) database, and comprehensively cataloging preprints, and by extension, the published literature in high-energy physics. The SPIRES database allowed searches by date, author, institution, report number, title, keywords (assigned by DESY) and a number of other fields. A program, QSPIRES [QSPIRES], developed in 1985, allowed physicists to search the SPIRES database using E-mail and other bitnet message protocols. By sending E-mail query to the database one could get a quick reply what made an enormous difference for people outside SLAC, especially those outside the U.S. At DESY a SPIRES mirror of the SLAC HEP database was installed in 1988. Users from outside DESY were given access to the HEP database by special accounts for restricted login.

By 1990, lists of new articles were being sent to physicists by E-mail and people were searching for articles in the SPIRES database via E-mail. Everything was organized in a best (electronic) way except the fact when one wanted to read a paper. In this case, the reader would have to request that an author send a copy by mail which required quite some time.

3.1.2 Los Alamos E-print Archives

With the SPIRES-HEP database and the invention of the Los Alamos E-print archives in 1991, the HEP community pioneered the trend to "paperless publishing" and the trend to paperless access; in other words, the idea of "virtual library" took its first large scale implementation [O'Connell 2002]. With preprint list distribution, SPIRES database searches, requests for papers, and even the transfer of these papers being done through E-mail, all stages of the process were electronic. However SLAC and DESY were still receiving the E-prints as "hard-copy". Some authors had begun sending their preprints as TEX files, but for some researchers this would unfortunately lead to overstuffed electronic mailboxes. This problem was solved in 1991 at the Los Alamos National Laboratory (LANL) by Paul Ginsparg [Ginsparg 1991], the author of the electronic arXives. The e-print arXiv since its inception in 1991 has become a major forum for dissemination of results in physics and mathematics. This resource has been entirely scientist driven.

The evolution from preprints to E-prints had another important step. The E-prints were assigned a unique number of the form archive/yymmnnn (e.g., hep-ph/ 9501251 for the 251st paper in January 1995 in the high energy physics - phenomenology series of E-prints), which was considered by SLAC Library as a

new element in each record in the SPIRES database. The standardized E-print number appearing in reference lists has changed the general situation in many aspects, in particular, citations to some unpublished works could be registered. This started a new role for the SPIRES database, namely it became increasingly popular to use the SPIRES-generated citation index in assigning a degree of scientific impact to publications. In fact, the SPIRES citation index goes much beyond that. Now the entire publishing record of an author is available in the public domain. While it adds a certain transparency to the scientific activity of an individual, it also raises some interesting questions concerning the reliability of simple counting techniques (essentially counting the number of hits that a paper entry gets) as an objective measure of the scientific impact of ideas and experimental observations. It has now become customary that an annual list of the top-cited papers published in a certain period of time (1 year, 5 years, 10 years) or all times is issued by SPIRES, supplemented by a detailed analysis and commentary by the SLAC theorist Michael Peskin. These top-citation lists and the attendant commentary are immensely popular in the high energy physics community, and are very often used as "evidence" of scientific impact of an individual physicist or an experimental collaboration, and even in highlighting some areas of research.

While somewhat removed from our main topic, namely automatic keyword indexing of the SPIRES-based documents, it is not out of place to comment on the SPIRES-based citation index, which is a different facet of a completely automatic (electronic) database system. Lacking any other quantitative yardstick for scientific evaluation of published papers which could be accessed globally with the same ease as offered by SPIRES, the SPIRES-citation index has become *de facto* the yardstick in high energy physics and related fields. Often applicants for faculty or research positions include the SPIRES-generated profile of their citation record, or refer to it as a seal of quality of their publications. However, this citation index, while certainly helpful as an order of magnitude measure, is still far from being a true mirror of the impact of scientific papers. There are good grounds for this skepticism. First of all, only papers having an E-print archive number or journal reference are searched for citations. This is a serious drawback, as it leaves out an entire category of papers which are published in books, conference proceedings, study reports etc., but which do not have an E-print number. A glaring example of the inadequacy of the SPIRES citation index is the world renowned paper by Abdus Salam [Salam 1968], in which the electroweak standard model was independently formulated. This work won him a Nobel Prize together with Sheldon Glashow and Steven Weinberg in 1978. However, Salam's epoch-making paper is not entitled to any citation by SPIRES (!),

as it was published in the proceedings of a conference and as such it lacked either an E-print number or a journal reference. Also for obvious reasons, the SPIRES citation index is only a scalar counter; in particular references to papers having wrong or irreproducible results have the same weight as the ones reporting correct results, verified by subsequent research work. One must conclude that the SPIRES-citation index is not a substitute for the time-honoured scientific peer review system, though it has its place as a measure of scientific activity and as such it will remain very popular. For the newcomers in the field, the message is clear: E-print your paper or perish!

3.2 High Energy Physics Indexing at DESY

3.2.1 Deutsches Elektronen-Synchrotron DESY

Before discussing the pioneering work in high energy physics indexing conducted at DESY, it is appropriate to say a few words about DESY itself, which also explains the interest of DESY in HEP-indexing.

The German high energy physics laboratory (called Deutsches Elektronen-Synchrotron DESY) [DESY] was founded on December 18, 1959. In its 42-years history, DESY has developed from a small university-affiliated research facility, with close ties to the University of Hamburg, into one of the world's leading centers for high energy physics based on particle accelerators. In addition, it also runs the Hamburg Synchrotron Radiation Laboratory (HASYLAB), used by a large scientific community consisting of molecular biologists, medical researchers, condensed matter physicists, geophysicists and chemists. A second location of DESY started in early 1992 after the unification of Germany, when the Institute for High Energy Physics in Zeuthen (Brandenburg) got formally affiliated with DESY and became a part of it. The scientists from DESY-Zeuthen take part in the development of detectors and analysis of data from experiments at DESY (Hamburg), the Large-Electron-Positron (LEP) collider at the European Research Centre for High Energy Physics (CERN in Geneva), and in the construction and operation of a large neutrino telescope AMANDA deep in the Antarctic ice. With the help of AMANDA, sources of high energy cosmic radiation will be located and their characteristics studied to understand one of the big open questions in this field, namely the origin of the high energy cosmic radiation.
DESY is a member of the Hermann von Helmholtz Association of National Research Centers in Germany. The DESY permanent staff is 1390 members (300 scientists) in Hamburg and 170 members (75 scientists) in Zeuthen. Each year, around 3400 scientists from 35 countries (280 institutes) come to work here. Many

come to conduct basic research work at the particle physics experiments at the HERA storage ring facility, and now many more come to use the synchrotron radiation facility HASYLAB. Yet others are helping to develop TESLA - DESY's future electron-positron linear collider project with a center of mass energy of initially 500 GeV, which can be upgraded to 800 GeV. If approved, this would be a unique facility of its kind, whose primary goal is to unravel the mechanism of spontaneous symmetry breaking (Higgs boson physics, in the more popular jargon). Last but by no means least, DESY has two active theoretical physics groups in Hamburg and Zeuthen, whose members are working in close contact with experiments in and beyond DESY in developing and testing theories for high energy physics and cosmology. DESY has set up a high performance computer centre in Zeuthen to carry out large scale simulations for quantitative studies of Quantum chromodynamics QCD, the theory of strong interactions.

From this account, it is obvious that DESY is one of the main HEP laboratories in the world and hence it is natural that DESY takes great interest in the indexing of HEP documents.

3.2.2 Indexing of HEP Literature

After this scientific detour, we return to the questions related to the bibliographic aspects of scientific documents in high energy physics. There are several databases being used in the bibliographic work and documentation in high energy physics and related fields. We briefly describe them in the following.

- **HEP or PREPRINTS** is the name of a bibliographic database of journal articles, monographs, preprints, conference papers, theses, etc. on high energy physics and neighboring fields like quantum gravity. It is jointly produced by the SLAC Library and the DESY Documentation Group. The DESY documentation is responsible for running a mirror of the database. Each paper or monograph is indexed with a number of keywords (see Keyword List below) which reflect its physical contents.

- **CONF**(Conferences in High Energy Physics and related topics) is supplied and maintained by the SLAC Library (with input from DESY).

- **BOOKS** is the DESY Library's online public access catalogue and is therefore of interest not only for particle physicists.

- **ABSTRACT** is a bibliographic database with abstracts of the electronic preprints which are stored at the SLAC or DESY Servers.

- **INSTITUTIONS** is a database of information on affiliations or institutions appearing in the HEP Database.

The SPIRES database system uses English commands. The entries in the databases are also in English, except for the BOOKS database, which contains bibliographic data in the monographs original languages (if Latin script).
The database, SPIRES-HEP, now contains over 450,000 high-energy physics related research articles, including journal papers, preprints, e-prints, technical reports, conference papers and theses, comprehensively indexed by the SLAC and DESY libraries since 1974. Almost 50 % of these are linked to the full text electronic versions, with this percentage steadily increasing with time (this site now has over 15 000 search hits per day).
The HEP literature from the following fields is indexed at DESY:

- elementary particle physics (experiment, phenomenology),
- quantum field theory,
- physics and technology of accelerators and detectors,
- high energy nuclear physics,
- high energy astrophysics, cosmology and cosmic radiation.

The indexing takes place intellectually only and is based on a controlled vocabulary in the form of a Keyword List (The HIGH ENERGY PHYSICS INDEX Keywords [HEPI]). The Keyword List of SPIRES-HEP database contains 2500 keywords. Keywords may be used singly or joined by comma and blank (a detailed description is given in Section 5). Using of keywords coupled with each other gives a possibility, on one hand, to keep Keyword List visible to work with, on the other hand, it allows to express information more precisely.

The SPIRES database located at SLAC and DESY (and now at several other mirror sites in Europe and Asia) can be used to search for documents in the fields stated above. This search now takes place online using internet and WWW hypertext language, and has many simple forms. We concentrate on the keywords based searches. Here, one enters HEP related keywords supplied by the DESY documentation group interlinked with Boolean algebra. The database will return all papers that have those keywords added to that record.

HEP database list of the standard keywords is presented in the alphabetical order (see, for example, http://www-library.desy.de/schlagw2.html). There are three

types of entries in this list:

< blank > **main keyword**
* *descriptive keyword*
– non-keyword

We present here an example from Keyword List:

neutrino/e
neutrino/L (used for the heavy lepton neutrino)
neutrino/mu
neutrino/tau
– neutrinoless double-beta decay (double-beta decay, (0neutrino))
* *neutrinoproduction* (used for production by neutrinos or antineutrinos)
– neutron (use 'n')
new interaction
or:
* *gluino* (postulated particle, gluino)
gluon
gluon gluon
– gluon photon (photon gluon)
– gluon quark (quark gluon)
or:
* *noncompact* (group theory, noncompact)
* *nondiffractive*
– nonleptonic decay (since 1996 use 'hadronic decay')
* *nonlinear*

For some *main keywords* like **neutrino/L** or *descriptive keywords* like *neutrinoproduction, noncompact* explanations or examples of usage are given, *non-keywords* are supplied with references on corresponding *main keyword*.

Beside indexing, the papers are classified with topical fields chosen from a set of 16 which are grouped in four general parts: Experimental Physics, Technology and Techniques in High Energy Physics, Theoretical Physics, Monographs and Conferences Proceedings. A paper can get one main and any number of secondary fields[HEPI].

With this background, high energy physics documentation and its current indexing procedures have been adequately described. This brings us to the main point of this work – Conception of an automatic indexing procedure of HEP documents which we discuss and elaborate in the rest of this report.

4 Automatic Indexer of High Energy Physics Documents

In this section we present a general scheme of Automatic Indexer of High Energy Physics Documents (AI-HEPD), which we have developed.

Keywords List

Keywords List is a list of keywords in HEP documents presented in the alphabetical order.
Each keyword (Appendix A) can be either a separate word:
axion
astrophysics
neutrino
or a combination of some words:
dispersion relations
radiative decay
interpretation of experiments ...

The system provides a Keywords Manager that enables to:

- add new keywords to the database,
- edit/delete any existing keyword from database,
- make a search for keywords using the flexible filters,
- order keywords in alphabetical order.

Keychains

Keychain (Appendix A) is defined as two *keywords* joined by a by comma and a blank *keywords* as a delimiter. In the case one *keyword* in the connection is absent *keychain* represents the *keyword*. However our database principle is based on a certain distinction between *keywords* and *keychains*. *Keywords* are considered as components to construct *keychains* but they do not have a direct functional role in making the index reports for the papers.
The system provides a Keychain Manager that:

- adds new keychains to the database

- edits/deletes any existing keychain
- makes a search for keychains using the flexible filters

Associative Patterns Dictionary (APD)

The main idea behind our approach is to develop a system parser which looks through the paper or its selected parts to find associative patterns – chunks of the text (Appendix A). The search is based on an Associative Patterns Dictionary (APD).

The system provides an APD Manager that allows to:

- add new patterns to the database,
- edit/delete any existing pattern,
- make a link from a pattern to a keychain (set of keychains).

Parser of Natural Language (English) Including LaTeX Tags

The parser (or syntax analyzer) is a software module that:

1. reads the input data source (the whole text or pointed out parts),
2. uses LaTeX grammar rules while analyzing characters from the input,
3. matches characters in the input with associative patterns.

When a character in the input matches with an associative pattern the program returns the *keychain(s)*. The *keychains* are added to the index report of the publication.

Reports on the worked out papers

After being processed each paper is stored in the system database. The paper index is stored as well. There will be developed a search engine that allows to search and order indexed papers according to a set of criteria.

Tools and Technologies

The system will process in two modes:

1. Stand alone mode (on the place of installation),
2. Distributed on-line mode that allows to work anywhere via Internet.

Command line interface as well as browser based interface will be implemented. System requirements include:

- A SQL database server (e.g. MySQL),
- A virtual host under Apache web server environment,
- A Perl Interpretor,
- A C – Compiler.

5 Associative Patterns Dictionary (APD)

As it was mentioned in Section 4 we aim to develop a system parser looking through a paper or its selected parts to find associative patterns (Subsection 5.3, Appendix A). The system has a "dictionary" at its disposal which "translates" a paper from a language of scientific publication into a language of limited controlled vocabulary of *keychains* (Appendix A). So, developing of such a "dictionary" and making the whole system to work in a way that this "dictionary" is used most effectively for the purpose of scientific indexing is our main goal.

Associative Patterns Dictionary (APD) contains eight parts:

1. Definitions
2. Comments
3. Mapping "Associative Patterns → Keychains"
4. Disabling the mapping of "Associative Patterns → Keychains"
5. Files to read
6. Pipelining keychains and words to specific files
7. Files to read on request
8. "When-ignore" (a filter to ignore keychains)

out of which the part called *Mapping "Associative Patterns → Keychains"* is the main dictionary. Three other parts: *Disabling the mapping of "Associative Patterns → Keychains"*, *Files to read* and *Files to read on request* are organized in the form of the dictionary, but the system needs special instructions to work with them. These instructions, for example, may force the system to look for some particular attributes in the text when further specifications to given keywords are needed. In the following we shall take a more detailed look on each part of APD and its function in the system.

5.1 Definitions

The purpose of the part *"Definitions"* is to ease the use of the main dictionary from processing redundant information, by establishing the equivalence of some word forms in the text (singular and plural forms, for example). In other words, we reduce substantially the definition of *keychains* in term of *associative patterns*. This is a common practice in the automatic indexing systems. At this stage of

system development, only the equivalence of singular and plural forms is enforced. For example, by defining:

axion = axions
dispersion = dispersions
relation = relations;

as equal, we reduce the definition of *keychain* in APD. Thus, for example, for the *keychain*:

axion, dispersion relations

the following five *associative patterns*:

axion dispersion
axion dispersions
dispersion relation for axion
dispersion relation for axions
dispersion relations for axions

are made equivalent to the following two keywords:

axion dispersion
dispersion relation for axions.

5.2 Comments

Here, instructions are given to the system on which parts of the paper have to be worked out in automatic indexing. The system has to restrict the application of its "dictionary" to specific part(s) *title, abstract, sections, subsections, captions*. Moreover, it looks for some characteristic sentences ("linguistic surfaces") used by physicists in formulating the main goal or result of their paper. Examples of such linguistic surfaces are:

As an illustration, we consider
Below we estimate
In this letter we have studied
In this letter we investigate
In this paper we analyze
In summary, we have shown
Motivated by these considerations, in this work we
Our final result will be
The purpose of our work is
.....

These parts of the text usually (though not always!) contain an important information on the purpose of investigations and/or the results obtained in the paper.

A reference is given to read the whole paper looking for *associative patterns* pointed out in the file *File to read*.

5.3 Mapping "Associative patterns → Keychains"

Associative pattern may be either a single word like:

- astrophysics
- axion
- neutrino

or abbreviation:

- GRB (= gamma ray burst)
- QCD (= quantum chromodynamics)
- IBBN (= inhomogeneous big bang nucleosynthesis)

or several words:

- axion emission
- neutrino magnetic moment
- dispersion relation for axion
- neutrino energy and momentum loss

or even an entire sentence:

- astrophysical and cosmological limits on the Peccei-Quinn scale
- effective interaction of a pseudoscalar particle with two photons in an external electromagnetic field in the general case of all external particles being off the mass shell

As already mentioned, the part *Mapping "Associative patterns → keychains"* represents the main "dictionary" the system uses for the translation into *keychains*. The "translation" takes place from the language of *associative patterns* into the language of *keychains*. On the paper printed form it is easier to present the "dictionary" in the alphabetic order concerning keychains:

- **neutrino, magnetic moment** $\Longrightarrow$ *associative cell*
- **neutrino, massive** $\Longrightarrow$ *associative cell*
- **neutrino, massless** $\Longrightarrow$ *associative cell*
- **neutrino, oscillation** $\Longrightarrow$ *associative cell*
- **neutrino, pair production** $\Longrightarrow$ *associative cell*

The reason for this is a simplicity in the organization of the dictionary. Illustrative parts of *Mapping "Associative patterns → keychains"* dictionary are given in Appendix B.1. The term associative cell is introduced locally here. The *associative cell* includes all the *associative patterns* corresponding to a given *keychain*. Here, and in what follows, the expressions given in the box represent *associative cells*, whereas the *keychains* always appear in bold face. Let us present an *associative cell* corresponding to the *keychain* "*neutrino, massive*".

associative cell **neutrino, massive**	≡	massive neutrino massive neutrino–antineutrino pair neutrinos are as massive as recently reported specific neutrino masses specific neutrino masses .....

It is obvious that with the increasing number of papers worked out, the number of *associative patterns* which belong to a *keychain*, or, in other words, the "size" of the *associative cell*, will also increase. However this "size" will reach at some point a saturation stage. So, clearly this is a training process in which a large number of differing linguistic surfaces will be asymptotically optimally binned in an *associative cell* associated with the *keychain(s)*.

In the example given above, the *associative cell* contains five *associative patterns*, the last two of them "specific neutrino masses" have no noticeable difference. The point is that the difference can not be seen in the printed paper form (the postscript file) and is connected with some difference in writing the LaTeX file (for example, in this particular case, the author added a sign inside a word).

The previous example showed the main principle how the dictionary is organized. Now we introduce some different types of *dictionary cells = keychains + associative patterns*.

Type I: (a) *keychain* has the minimal length – one *keyword*:

• **astrophysics**	⟹	astrophysics astrophysical applications astrophysical cataclysm astrophysical consequences astrophysical manifestation astrophysical objects astrophysical phenomena astrophysically important early Universe
• **nuclear matter**	⟹	nuclear matter nuclear medium

(b) *keychain* has the maximal possible length – two *keywords*. The example was already shown.

Type II: Two *keychains* correspond to one *associative cell*:

astrophysics, white dwarf **magnetic field, external field**	⟹	magnetic WDs magnetic white dwarfs magnetized WDs magnetized white dwarfs
plasmon, dispersion relations **plasmon, longitudinal**	⟹	longitudinal-plasmon dispersion longitudinal plasmon dispersion dispersion relation for longitudinal plasmons

Type III: three *keychains* correspond to one *associative cell*:

photon, decay **neutrino, pair production** **photon → neutrino antineutrino**	⟹	photon decay into neutrino - antineutrino pair | photon decay into the neutrino - antineutrino pair | photon splitting into the neutrino pair | photon splitting probability into the neutrino pair | $\gamma \to \nu\,\overline{\nu}$ | $\gamma \to \nu_i \bar{\nu}_j$ | $\gamma \to \nu\tilde{\nu}$ | $\gamma \to \nu\bar{\nu}$
nucleon, electric moment **nucleon, magnetic moment** **moment, dipole**	⟹	electric and magnetic dipole moments of the nucleons | nucleons in these walls have anomalous electric and magnetic dipole moments

Type IV: four *keychains* correspond to one *associative cell*:

neutrino, pair production **neutrino, photoproduction** **photon, off-shell** **photon → neutrino antineutrino**	⟹	neutrino pair production by a virtual photon | $\gamma \rightarrow \nu\bar{\nu}$

Type V: five *keychains* correspond to one *associative cell*:

neutrino, transition **photon, radiation** **electron, pair production** **neutrino → neutrino photon** **neutrino → positron electron neutrino**	⟹	neutrino transitions with the photon and electron-positron pair creation | neutrino transitions $\nu \rightarrow \nu\gamma$, $\nu \rightarrow \nu e^+e^-$

Notice that only the types we have dealt with are presented here (theoretically there is no constraints on the number of *keychains*).

5.4 Disabling the mapping of "Associative patterns → Keychains"

For the time being this part is the smallest one. The idea behind this is to make some *associative patterns*, which have no direct relation to the subject studied in the paper, neutral to the dictionary, in other words to avoid some *keychains* which otherwise would be given. One way to train the system on disabling the mapping "associative patterns → keychains" is by locating similarity patterns in the text.

For example:

- effect is closely related to photon splitting
  ignore keychains:
  photon, radiative decay
  final state, 2photon
  photon → 2photon

It is clear from the *associative patterns* that some other process, not the photon splitting is discussed, a similarity is mentioned only. For this particular case an *associative patterns photon splitting* and its translation into *keychains* are out of place. One also notices here that our automatic indexing tries to incorporate some features of intellectual procedure of indexing.

5.5 Files to read

The system is supposed to read the whole paper looking for *associative patterns* pointed out in this file. If a match takes place some keychains like:

Feynman graph
numerical calculations

will be given. The reason why the separate file is organized to look for them is that:

1. their indication occurs quite seldom in titles, abstracts, titles of sections and subsections of papers;

2. these keychains are given very often by intellectual indexing;
   for example, the results of SPIRES on 31.07.02 are:
   Feynman graph – 17727 DOCUMENTS
   numerical calculations –115828 DOCUMENTS.

Clearly, one has to make very restrictive use of this option, as indiscriminate use will greatly reduce effectivity of the indexing system.

5.6 Pipelining keychains and words to specific files

The idea to have this file reflects in part how the method of intellectual indexing works, where one can find out the phenomena or methods important for the problem being discussed in the text but they are not mentioned either in the abstract, title or conclusion. In the intellectual indexing procedure indexing is by definition content-based. Thus, for example, the following circumstances may hold:

i) The important intermediate steps are written clear enough in the paper (a special accent is put);

ii) The subject is known to a person working with the text, and attention is paid to keywording it from the very beginning.

In our case, these files are playing the role of an "attentive indexer". For example, if *keychains "magnetic field"* and *"photon"* are given the system has to apply to the file "photon-properties" to find out in the whole text body if some important phenomena as photon dispersion, vacuum polarization and others are under discussions. Here we present a part from this file. For the case of simplification we organized it in the form of a table:

keychains, words	*files to read on request*
astrophysics and **neutrino, energy loss**	"astrophysical applications"
axion, decay or **axion, decay modes** or **axion, leptonic decay** or **axion, radiative decay** and **yield, enhancement**	"axion lifetime"
axion, lifetime	"axion coupling"

5.7 Files to read on request

These files are organized in the form of a dictionary, the same as in APD. The only difference is that there is a bigger variety of *associative patterns*, corresponding to a *keychain* as shown in Appendix B.

5.8 "When-ignore" (a filter to ignore keychains)

This part presents a final stage of the work when a report on the paper is done. Its purpose is to "polish" the report in the sense to remove redundant information, when a *keychain* does not contain substantially new information about the paper content and is in fact a further additional information to the existing *keychains*. For example, from two *keychains*: *"magnetic field, induced"* and *"external field, induced"*, the second chain is a redundant one. In the file "When-ignore" (Appendix B.3) the indication is given to ignore this *keychain*. For example, when two *keychains* are present:

magnetic field, induced
external field, induced

then the system is instructed to ignore the *keychain*: **external field, induced**.

Having explained the main parts of our automatic indexing procedure, we display in Appendix C the results of keyindexing some selected high energy physics documents (E-prints), using this procedure. In doing this, we have shown in a few cases the complete anatomy of the automatic indexing procedure, and have compared the results with the ones obtained from the DESY-HEPI intellectual

indexing as well as with a Model Report which we produced by manually indexing these papers ourselves. The picture that emerges is that if we restrict the indexing to only the title and abstract of the papers, the overlap is remarkably impressive.

6 Summary

We summarize the main points of our report. In the first part of this work, we have described the intellectual keyword indexing method in use in HEP documents. The HEPI keywording is done in the Scientific Documentation Group at DESY and is incorporated in the SPIRES HEP database. While this indexing method has proven its worth in search and retrieval of HEP documents, the irreversible transition to electronic publishing, in particular the ever increasing role of E-prints in HEP and related fields, it was time to move on to the electronic-based methods of keyword indexing, based on the principles of automatic indexing. First attempts along these directions have already been made [Dallman/Meur 1999] and [Ráez/Dallman 2001]. The latter of the two, based on statistical methods, is quite promising and the software programme developed called HEPindexer [Ráez/Dallman 2001] is currently an R&D project of the CERN Educational and Technology Transfer Division. Our approach to automatic indexing differs from both the approaches cited above. While we use the method of finding *associative patterns* to "return" *keywords*, our approach is closer to the so-called concept-oriented method of indexing discussed in a preceding section. We have described the essential features of the software package called *AI-HEPD* in this report. The main *workhorse* of our approach is a text parsing technique based on *associative patterns* matching, which makes use of a *Associative Patterns Dictionary* supplied to the system.

We have applied our automatic indexer in a limited area of HEP, namely Neutrino and Axion physics. The generated keywords reports are compared with the ones from the SPIRES-HEPI intellectual indexing method. The overlap between the two is quite impressive, though it is not our goal to reach a perfect overlap with the SPIRES-based keyword reports. We have illustrated this point by also carrying out comparisons with a so-called *Model Reports*, based on our professional physics experience. The *Model Reports* presented in Appendix-C also serve to illustrate the internal working of our automatic indexer, where a pointer is used to show which parts of a manuscript , title (t), abstract (a), special parts of the text (text), or a file with specific keychains to read the entire text (file-to-read) have been used in keyword indexing. This profile is necessary to have a quantitative measure of the so-called *recall effectivity*. Clearly, the demands on the *efficiency* and *recall effectivity* are in spirit opposite to each other. The profiles based on *Model Reports* will help us in reaching an optimal compromise. However, we have not yet carried out a quantitative analysis of the *recall effectiveness*, a point to which we shall return in subsequent R&D work.

The work reported here is to be interpreted as a pilot project. We have shown that our method of automatic indexing of the HEP documents works. Its application at this stage is restricted only to the fields of Neutrino physics and physics of the axion. However, the important point is that ours is an independent approach, in spirit close to the concept-oriented methods, and all the necessary ingredients of our software package are already in place and tested. Clearly, the field of automatic indexing all the E-prints in HEP and related fields is still in the offings. The development from the pilot project, reported here, to a full-scale automatic package, to be used by indexers in this field requires lot more work. In particular, it requires commitment of scientific resources at the major research laboratories, such as DESY, CERN, Fermilab, and SLAC, which produce a large fraction of scientific papers in HEP and related fields.

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A Appendix: Glossary

- **APD** – Associative Pattern Dictionary.
- **associative cell** – the whole set of *associative patterns* corresponding to a given *keychain* or *keychains* set.
- **associative pattern** – a chunks of the paper text, a string of words of any length; it may be either a single word or a whole sentence:
  astrophysics
  neutron stars
  search for galactic dark matter
  axion decay into charged fermion-antifermion pair
  it can also be presented as a formula:
  $\nu \to \nu\gamma$
  $\nu \to \nu e^+ e^-$
  $a \to \gamma \to e^+ e^-$.
- **automatic indexing** is the process of producing the descriptors (index terms, keywords of DESY-HEPI thesaurus) of a text automatically.
- **keychain** is defined generally as two *keywords*, written in one line and connected with each other through comma and blank, for example:

$$\overbrace{\underbrace{\textbf{neutrino}}_{keyword}, \underbrace{\textbf{magnetic moment}}_{keyword}}^{key\,chain}$$

  Evidently, *keychain* becomes equivalent to a *keyword* then one of two "*key*" componets in the chain is absent.
- **keyword** – an index term, an element of a controlled vocabulary, *Keywords List*. The *keyword* can be either a separate word:
  neutrino
  or a combination of some words:
  dispersion relations
  interpretation of experiments.
- **Keywords List** – a controlled vocabulary of the indexing language, DESY-HEPI thesaurus for the database SPIRES-HEP.

B Appendix: APD (some examples)

B.1 Mapping "Associative Patterns → Keychains"

- **axion, decay constant**
  $\Longrightarrow$ axion decay constant

- **axion, decay modes**
  $\Longrightarrow$ axion decays

- **axion, density**
  $\Longrightarrow$ axion density

- **axion, dispersion relations**
  $\Longrightarrow$ axion dispersion
  dispersion relation for axions

- **axion, dispersion relations**
  photon, dispersion relations
  $\Longrightarrow$ photon and axion dispersion

- **axion, dispersion relations**
  plasmon, dispersion relations
  plasmon, longitudinal
  $\Longrightarrow$ axion and longitudinal plasmon dispersion
  axion and longitudinal-plasmon dispersion
  axion and the longitudinal plasmon dispersion
  axion with the longitudinal plasmon dispersion

- **axion, emission**
  $\Longrightarrow$ axion emission
  axion emissivity
  axion production mechanism
  emission of axions
  emitted axion
  emitting axions
  emission rate of axions

- **axion, emission**
  bremsstrahlung
  $\Longrightarrow$ axion bremsstrahlung emission
  bremsstrahlung emission of axions

- **axion, emission**
  bremsstrahlung
  nucleon nucleon, interaction
  $\Longrightarrow$ Nucleon-nucleon bremsstrahlung emission of axions

  .....

- **axion, leptonic decay**
  electron, pair production
  axion → positron electron
  $\Longrightarrow$ axion decay into electron-positron pair
  axion decay $a \to e^+e^-$
  electron-positron pair production by axion

- **axion, leptonic decay**
  electron, pair production
  photon, propagator
  axion → positron electron
  $\Longrightarrow$ $a \to \gamma \to e^+e^-$

  .....

- **axion, radiative decay**
  axion → 2photon
  $\Longrightarrow$ axion decay into two photons
  radiative axion decay
  radiative decay of the axion
  radiative decay $a \to \gamma\gamma$ of the axion
  .....

- **coupling, (electron axion)**
  $\Longrightarrow$ axion electron coupling
  axion-electron coupling

- **coupling, (lepton axion)**
  coupling, induced
  $\Longrightarrow$ induced axion coupling to leptons
  axions have only induced coupling to leptons

- **coupling, (axion photon)**
  $\Longrightarrow$ axion-photon coupling
  axion-photon interaction
  axion-photon Lagrangian
  axion interactions with photons

- **coupling, (axion photon)**
  coupling, induced
  $\Longrightarrow$ induced modification of the axion-photon coupling

- **coupling, (axion photon)**
  effective Lagrangian
  $\Longrightarrow$ effective axion-photon interaction
  effective axion-photon Lagrangian
  effective axion-photon vertex

- **coupling, (axion photon)**
  coupling, (nucleon axion)
  coupling, (axion electron)
  $\Longrightarrow$ axion interactions with photons, nucleons, and electrons

- **coupling, (fermion axion)**
  $\Longrightarrow$ axion-fermion coupling
  axion-fermion interaction
  axion couples to both quarks and leptons
  couplings between the fermions and the axion
  DFSZ model axion
  .....

- **electromagnetic field, external field**
  $\Longrightarrow$ arbitrary configuration of electromagnetic fields
  arbitrary electromagnetic field
  circularly polarized electromagnetic wave
  constant electromagnetic field
  crossed field
  external electromagnetic field
  external wave field
  field of an electromagnetic wave
  homogeneous electromagnetic field
  monochromatic circularly polarized wave
  plane monochromatic wave
  plane monochromatic wave's field

- **electromagnetic field, induced**
  $\Longrightarrow$ induces electromagnetic fields

- **electromagnetic field, longitudinal**
  longitudinal components of electromagnetic field

- **electromagnetic field, longitudinal**
  electromagnetic field, transverse
  neutrino, momentum
  transversal (in respect to the neutrino momentum) and also the longitudinal components of electromagnetic field

  .....

- **electron positron, gas**
  $\Longrightarrow$ electron-positron gas

- **electroweak interaction**
  $\Longrightarrow$ framework of the SM
  framework of the Standard Model
  in the frame of the standard model
  in the lepton sector of the Standard Model
  no physics beyond the standard model
  with only standard-model couplings
  within the standard model
  within the Standard theory

- **electroweak interaction**
  plasma
  $\Longrightarrow$ electroweak plasma

- **emission, resonance**
  $\Longrightarrow$ resonant emissivity
  emission process in the resonance

- **energy, dissipation**
  $\Longrightarrow$ energy dissipation
  dissipation energy
  dissipates its whole energy
  dissipate their energies
  energy of the field is dissipated

  .....

- **magnetic field, external field**

$\Longrightarrow$ constant magnetic field
constant uniform magnetic field
external magnetic field
external magnetic-field
homogenious magnetic field
magnetic field intensity lower than critical
primordial magnetic fields are strong

- **magnetic field, external field**
  magnetic field, high
  $\Longrightarrow$ strong constant magnetic field
  strong external magnetic field
  strong uniform magnetic field

- **magnetic field, galaxy**
  $\Longrightarrow$ galactic magnetic fields

- **magnetic field, high**
  $\Longrightarrow$ strong magnetic field
  superstrong magnetic field
  strongly magnetized

- **magnetic field, induced**
  $\Longrightarrow$ is induced in an axion star by relatively strong magnetic field
  magnetic-field induced

- **magnetic field, production**
  $\Longrightarrow$ generation of magnetic fields
  mechanism to generate large-scale magnetic fields
  mechanism for generating primordial magnetic fields
  production of magnetic field

  .....

- **neutrino, luminosity**
  $\Longrightarrow$ neutrino luminosity

- **neutrino, magnetic moment**
  $\Longrightarrow$ magnetic moment of neutrino
  neutrino magnetic moment
  neutrinos with a magnetic moment
  neutrinos with magnetic moment

- **neutrino, massive**
  $\Longrightarrow$ neutrinos are as massive as recently reported
  massive neutrino–antineutrino pair
  massive neutrino
  specific neutrino masses
  specific neutrino masses

- **neutrino, massless**
  $\Longrightarrow$ massless, chiral neutrinos
  massless neutrino
  neutrinos are taken to be massless

- **neutrino, oscillation**
  $\Longrightarrow$ neutrino oscillations
  oscillations of neutrino

- **neutrino, oscillation**
  neutrino, left-handed
  neutrino, right-handed
  $\Longrightarrow$ Oscillations of neutrinos $\nu_L \leftrightarrow \nu_R$

  .....

- **neutrino, pair production**
  neutrino, massive
  $\Longrightarrow$ production of a massive neutrino–antineutrino pair

- **neutrino, pair production**
  neutrino, photoproduction
  photon → neutrino antineutrino
  $\Longrightarrow$ $\gamma \to \nu\bar{\nu}$

- **neutrino, pair production**
  neutrino, photoproduction
  photon, off-shell
  photon → neutrino antineutrino
  $\Longrightarrow$ neutrino pair production by a virtual photon

- **neutrino, transition**
  neutrino, massless
  photon, radiation
  neutrino → neutrino photon
  $\Longrightarrow$ radiative transition of massless neutrino

.....

- **photon, gas**
  photon, energy loss
  $\Longrightarrow$ energy-loss rate per unit volume of the photon gas

- **photon, off-shell**
  $\Longrightarrow$ virtual photon

- **photon, polarization**
  $\Longrightarrow$ photon of only one polarization
  photon polarization
  photon with the first polarization
  photons of different polarizations
  photons with polarization
  photons with various polarizations
  polarized photon

- **photon, polarization**
  photon, off-shell
  $\Longrightarrow$ virtual polarized photon

- **photon, polarization**
  polarization, longitudinal
  $\Longrightarrow$ longitudinal photons
  $\|$ photon mode

.....

- **transition, axion photon**
  $\Longrightarrow$ axion conversion into a photon
  photon - axion transition
  conversion of axions into photons

- **transition, axion photon**
  transition, resonance
  $\Longrightarrow$ resonant photon - axion transition

- **transition, (plasmon axion)**
  $\Longrightarrow$ plasmon-axion conversion
  plasmon-axion transition
  transition of thermally excited plasmons into axions
  transition between longitudinal plasmons and axions

.....

- **yield, enhancement**
  $\Longrightarrow$ decay catalysis
  effect of significant enhancement
  electromagnetic catalysis
  field catalyzes substantially
  get enhanced
  gigantic enhancement
  is enhanced by several orders of magnitude
  resonant enhancement
  significant enhancement
  strong catalysis
  strong catalyzing influence
  strong enhancement
  strongly catalyzed

- **vertex function, (axion 2photon)**
  $\Longrightarrow$ effective axion-photon vertex
  effective $a\gamma\gamma$ interaction
  effective $a\gamma\gamma$-interaction
  two-photon-axion interaction vertex
  vertex $a\gamma\gamma$
  $a\gamma\gamma$ vertex
  $a\gamma\gamma$-vertex

- **vertex function, (2neutrino photon)**
  $\Longrightarrow$ effective ν_i-ν_j-γ vertex
  $\nu\nu\gamma$ amplitude
  $\nu\nu\gamma$ vertex

B.2 Pipelining keychains and words to specific files

"axion coupling":

- **coupling, (axion fermion)**
  axion-fermion coupling:

- **coupling, (axion photon)**
  - axion-photon coupling can be presented in the form
  - it is necessary to take into account the influence of the field on both the axion-photon coupling
  - Lagrangian describing the axion-photon coupling can be presented in the form
  - Lagrangian describing the axion-photon coupling in the presence of an external field can be presented as
  - Lagrangian describing the effective axion-photon coupling is
  - We express the axion-photon coupling as $g_{a\gamma} = m_{\mathrm{eV}}/0.69 \times 10^{10}$ GeV for typical axion models

- **coupling, (axion photon)**
  effective Lagrangian
  - contribution via a virtual photon exists due to an effective axion-photon interaction
  - effective Lagrangian describing the axion-photon coupling in the presence of an external field can be presented as
  - effective axion-photon coupling constant in the presence of an external field is then written as
  - field-induced contribution to the effective axion-photon coupling
  - Here, $\bar{g}_{a\gamma} = \alpha\bar{\xi}/2\pi f_a$ is an effective axion-photon coupling
  - This channel becomes possible due to an effective axion-photon interaction with the Lagrangian

- **effective Lagrangian**
  effective Lagrangian

Notice: when it simplifies one can use identity:
effective axion-photon interaction =
effective axion-photon coupling =
effective axion-photon Lagrangian

"astrophysical applications":

- **momentum, asymmetry**
  asymmetry of the neutrino momentum
- **velocity, pulsar**
  velocity of order 150 km/s for a pulsar
- **gamma ray burst**
  mechanism generating the gamma ray burst
  energy reaches one observed in gamma ray burst
  radiations associated with gamma ray burst

"axion lifetime":

- **axion, lifetime**
  corresponding expression for the axion lifetime is
  minimal value for the axion lifetime is
  we present the results of our calculations for the axion lifetime
  axion lifetime is reduced to seconds as in previous case
  expression for the lifetime is
  expressions for the axion lifetime is
  axions lifetime in the external field is reduced to
  we obtain the following estimation for the axion lifetime
  axion lifetime in DFSZ model is reduced to
  we estimate the axion lifetime in a hot plasma
  we obtain the following estimation for the axion lifetime

B.3 When-ignore

- when keychains:
  electromagnetic field, external field
  magnetic field, external field
  ignore keychain:
  electromagnetic field, external field

- when keychains:
  external field, induced
  magnetic field, induced
  ignore keychain:
  external field, induced

- when keychains:
  flavor, violation
  lepton, interference
  lepton, mixing angle
  ignore keychain:
  lepton, interference

- when keychains:
  magnetic field, external field
  magnetic field, high
  magnetic field, induced
  ignore keychain:
  magnetic field, induced

- when keychains:
  matter, effect
  matter, induced
  ignore keychain:
  matter, induced

C Automatic Indexing Reports (Examples)

In this Appendix we describe in detail various stages in the work done on selected HEP documents (E-prints). It will also give an idea how APD is filled.

C.1 hep-ph/9803486: a detailed analysis

Title: Axion Emission by Magnetic-Field Induced Conversion of Longitudinal Plasmons

Abstract

Magnetic fields mix axions with photons, allowing for the cyclotron process $e^- \to e^- a$ by virtue of an intermediate plasmon even if axions do not couple to electrons at tree level. The axion and longitudinal-plasmon dispersion relations always cross for a certain wave-number, leading to a resonant enhancement of this process. Even then, however, it cannot quite compete with the usual nucleon processes in a supernova core. The well-known axion window 10^{-5} eV $\leq m_a \leq 10^{-2}$ eV remains open and axions may still constitute the cosmic dark matter.

At first stage we select *associative phrases* from the title and abstract and identify them with corresponding *keychains*.

Title:

Axion Emission	$\longrightarrow$	**axion, emission**
Magnetic-Field Induced	$\longrightarrow$	**magnetic field, induced**
Longitudinal Plasmons	$\longrightarrow$	**plasmon, longitudinal**

Abstract:

Magnetic fields	$\longrightarrow$	**magnetic field**
$e^- \to e^- a$ mix axions with photons, allowing for the cyclotron process	$\longrightarrow$	**axion, emission** **cyclotron, emission** **electron → electron axion**
intermediate plasmon	$\longrightarrow$	**plasmon, propagator**
even if axions do not couple to electrons at tree level	$\longrightarrow$	read file "axion coupling"

longitudinal-plasmon dispersion	$\longrightarrow$	**plasmon, dispersion relations** **plasmon, longitudinal**
axion and longitudinal-plasmon dispersion	$\longrightarrow$	**axion, dispersion relations** **plasmon, dispersion relations** **plasmon, longitudinal**
resonant enhancement	$\longrightarrow$	**yield, enhancement**
supernova	$\longrightarrow$	**astrophysics, supernova**
axion window (*equation*) remains	$\longrightarrow$	**axion, mass**
dark matter	$\longrightarrow$	**astrophysics, missing-mass**

Here and below we neglect writing *keychains* like *"axion"*, *" dispersion relations"* and so on. Let us analyze the same way titles of sections, subsections and captions.

Sections:

I. *Introduction*
II. *Cyclotron Process*
III. *Plasmon-Axion Conversion* $\longrightarrow$ **transition, (plasmon axion)**
IV. *Discussion and Summary*

Subsections:

A. Axion-Photon Coupling	$\longrightarrow$	**coupling, (axion photon)**
B. Matrix Element		
C. Resonant Transition Rate	$\longrightarrow$	**transition, resonance**
D. Axion Emissivity	$\longrightarrow$	**axion, emission**

Captions:

FIG.1 Dispersion relation $\omega^2 = \omega_L^2(k)$ for longitudinal plasmons (solid line), axions $\omega^2 = k^2 + m_a^2$ (short dashes), and vacuum photons $\omega = k$ (long dashes).
$\longrightarrow$ **dispersion relations**
plasmon, longitudinal

FIG.2 Cyclotron emission process
$\longrightarrow$ **cyclotron, emission**

FIG.3 Magnetic-field induced modification of the axion-photon coupling
⟶ **magnetic field, induced**
coupling, (axion photon)

Now we rewrite the title and abstract with underlined *associative phrases* and give corresponding *keychains* report.

Title: Axion Emission by Magnetic-Field Induced Conversion of Longitudinal Plasmons

Abstract

Magnetic fields mix axions with photons, allowing for the cyclotron process $e^- \to e^- a$ by virtue of an intermediate plasmon even if axions do not couple to electrons at tree level. The axion and longitudinal-plasmon dispersion relations always cross for a certain wave-number, leading to a resonant enhancement of this process. Even then, however, it cannot quite compete with the usual nucleon processes in a supernova core. The well-known axion window 10^{-5} eV $\leq m_a \leq 10^{-2}$ eV remains open and axions may still constitute the cosmic dark matter.

axion, emission	⟶	a	t	♢
cyclotron, emission	⟶	a		♢
magnetic field, induced	⟶	a	t	♢
axion, dispersion relations	⟶	a		
plasmon, dispersion relations	⟶	a		
plasmon, longitudinal	⟶	a	t	♢
plasmon, propagator	⟶	a		
coupling, (axion photon)	⟶			♢
transition, (plasmon axion)	⟶			♢
transition, resonance	⟶			♢
yield, enhancement	⟶	a		
axion, mass	⟶	a		
astrophysics, supernova	⟶	a		
astrophysics, missing-mass	⟶	a		
electron → electron axion	⟶	a		

where, *keychains* are given from: a – abstract, t – title, ♢ – sections, subsections and captions.

Let us now select the important sentences and analyze them the same way.

1. We here study a related process which is induced by a strong magnetic field, the axion cyclotron emission $e^- \to e^- a$ via a plasmon intermediate state.

   strong magnetic field ⟶ **magnetic field, high**
   induced by a strong magnetic field ⟶ **magnetic field, high**
   magnetic field, induced
   axion cyclotron emission ⟶ **axion, emission**
   cyclotron, emission
   electron → electron axion
   via a plasmon ⟶ **plasmon, propagator**
   plasmon intermediate state

2. The main motivation why our process could be expected to be non-negligible is that it is resonant at a particular energy of the emitted axion, provided that the intermediate plasmon is longitudinal, because the axion and the longitudinal plasmon dispersion relations always cross for a certain wavenumber (Fig. 1).

   why our process could be expected to be non-negligible is that it is resonant ⟶ **yield, enhancement**

   emitted axion ⟶ **axion, emission**
   intermediate plasmon is longitudinal ⟶ **plasmon, longitudinal**
   plasmon, propagator

   axion and the longitudinal plasmon dispersion ⟶ **axion, dispersion relations**
   plasmon, dispersion relations
   plasmon, longitudinal

3. In Sec. II we calculate the emission rate when our effect is pictured as a cyclotron process $e^- \to e^- a$.

4. In Sec. III we calculate it again, picturing it as a plasmon-axion oscillation phenomenon.

   plasmon-axion oscillation phenomenon ⟶ **oscillation, (plasmon axion)**

5. Sec. IV we summarize our findings.

6. We conclude that the axion emissivity Eq. (..), which we calculated for an ultrarelativistic degenerate plasma, *is actually valid in the general case.*

   axion emissivity ⟶ **axion, emission**

7. We have calculated the axion emissivity of a plasma in the presence of a strong magnetic field due to the resonant transition between longitudinal plasmons and axions.

axion emissivity of a plasma	⟶	**axion, emission plasma**
strong magnetic field	⟶	**magnetic field, high**
resonant transition	⟶	**transition, resonance**
transition between longitudinal plasmons and axions	⟶	**transition, (plasmon axion) plasmon, longitudinal**

8. We have computed the emission rate as a cyclotron process $e^- \to e^- a$ with an intermediate plasmon on resonance, and also directly as a transition of thermally excited plasmons into axions.

intermediate plasmon	⟶	**plasmon, propagator**
transition of thermally excited plasmons into axions	⟶	**transition, (plasmon axion)**

9. We may turn this finding around and conclude that the axion "window of opportunity" remains open. Even huge magnetic fields in a SN core do not seem to change the usual picture that axions are emitted primarily by fluctuating nucleon spins.

axion "window of opportunity" remains	⟶	**axion, mass**
Even huge magnetic fields in a SN core do not seem to change	⟶	**magnetic field, high astrophysics, supernova**

In the work with the abstract, the instruction was given to read the file "axion coupling". This file is given in Appendix B.2, here we present only some chunks from the paper text taken to APD as the *associative phrases*.

- effective Lagrangian describing the axion-photon coupling in the presence of an external field can be presented as

- effective axion-photon coupling constant in the presence of an external field is then written as

- Starting from the effective Lagrangian
  $\longrightarrow$ **effective Lagrangian**
  coupling, (axion photon)

Next step is the matching with "File to read":

- For a numerical evaluation
- Comparing this number with
  $\longrightarrow$ **numerical calculations**
- is shown in Fig. 2, where double lines correspond to the electron wave functions
- which derives from the diagram of Fig. 3
- corresponding to the diagram of Fig. 2
  $\longrightarrow$ **Feynman graph**

Model Report:

axion, emission	$\longrightarrow$	a	t	$\diamondsuit$	text	
cyclotron, emission	$\longrightarrow$	a		$\diamondsuit$	text	
magnetic field, high	$\longrightarrow$				text	
magnetic field, induced	$\longrightarrow$	a	t	$\diamondsuit$	text	
axion, dispersion relations	$\longrightarrow$	a			text	
plasmon, dispersion relations	$\longrightarrow$	a			text	
plasmon, longitudinal	$\longrightarrow$	a	t	$\diamondsuit$	text	
plasmon, propagator	$\longrightarrow$	a			text	
coupling, (axion photon)	$\longrightarrow$			$\diamondsuit$		on-request
coupling, induced	$\longrightarrow$			$\diamondsuit$		
effective Lagrangian	$\longrightarrow$					on-request
transition, (plasmon axion)	$\longrightarrow$			$\diamondsuit$	text	
oscillation, (plasmon axion)	$\longrightarrow$				text	to ignore !
transition, resonance	$\longrightarrow$			$\diamondsuit$	text	
yield, enhancement	$\longrightarrow$	a			text	
plasma	$\longrightarrow$				text	
axion, mass	$\longrightarrow$	a			text	
astrophysics, supernova	$\longrightarrow$	a			text	
astrophysics, missing-mass	$\longrightarrow$	a				
Feynman graph	$\longrightarrow$					file-to-read
numerical calculations	$\longrightarrow$					file-to-read
electron $\rightarrow$ electron axion	$\longrightarrow$	a			text	

where, a *keychain* is given from: a – abstract, t – title, ♢ – sections, subsections and captions, text – sentences, on-request – files to read on request, file-to-read – files to read. From two *keychains*: *"transition, (plasmon axion)"* and *"oscillation, (plasmon axion)"*, the second contains a redundant information and can be neglected.

The result of automating indexing of this paper now follows:

AI-HEPD Report:

axion, emission	⟶	a	t	♢
cyclotron, emission	⟶	a		♢
magnetic field, induced	⟶	a	t	♢
axion, dispersion relations	⟶	a		
plasmon, dispersion relations	⟶	a		
plasmon, longitudinal	⟶	a	t	♢
plasmon, propagator	⟶	a		
coupling, (axion photon)	⟶			♢
coupling, induced	⟶			♢
transition, (plasmon axion)	⟶			♢
oscillation, (plasmon axion)	⟶			
transition, resonance	⟶			♢
yield, enhancement	⟶	a		
axion, mass	⟶	a		
astrophysics, supernova	⟶	a		
astrophysics, missing-mass	⟶	a		
electron → electron axion	⟶	a		

Our conclusion:

1. The system was requested to work with title and abstract of the paper, and with titles of sections, subsections and captions of figures and tables.

2. Let us compare AI-HEPD Report with a report already existing in SPIRES:

AI-HEPD Report:		SPIRES report:
axion, emission		`axion, emission`
cyclotron, emission		
magnetic field, high		
magnetic field, induced	±	`magnetic field`
axion, dispersion relations		`dispersion relations, axion`
plasmon, dispersion relations		
plasmon, longitudinal		
plasmon, propagator		
coupling, (axion photon)		`coupling, (axion photon)`
coupling, induced		
transition, (plasmon axion)		
transition, resonance		
yield, enhancement		`yield, enhancement`
axion, mass		`mass, axion`
astrophysics, supernova		`astrophysics, supernova`
astrophysics, missing-mass		`astrophysics, missing-mass`
electron → electron axion		
		`effective Lagrangian`
		`plasma`
	0	`thermodynamics`
		`numerical calculations`

Here, the sign "±" means that a matching is not complete, and the symbol "0" means that this particular *keychain* has no relation to the paper.
The remark we would like to make is that the AI-HEPD Report does not have at this stage the *keyword* "plasma" but has three *keychains* with *keyword* "plasmon" which reflect better the content of the paper.

C.2 hep-ph/9702285: a detailed analysis

Title: Resonance neutrino bremsstrahlung $\nu \to \nu\gamma$ in a strong magnetic field

Abstract

High energy neutrino bremsstrahlung $\nu \to \nu + \gamma$ in a strong magnetic field ($B \gg B_s$) is studied in the framework of the Standard Model (SM). A resonance probability and a four-vector of the neutrino energy and momentum loss are presented. A possible manifestation of the neutrino bremsstrahlung in astrophysical cataclysm of type of a supernova explosion or a merger of neutron stars, as an origin of cosmological γ-burst is briefly discussed.

Title:

Resonance neutrino bremsstrahlung	$\longrightarrow$	**neutrino, bremsstrahlung resonance**
$\nu \to \nu\gamma$	$\longrightarrow$	**neutrino, radiative decay flavor, conservation law neutrino → neutrino photon**
strong magnetic field	$\longrightarrow$	**magnetic field, high**

abstract:

High energy neutrino	$\longrightarrow$	**neutrino, relativistic**
neutrino bremsstrahlung	$\longrightarrow$	**neutrino, bremsstrahlung**
$\nu \to \nu + \gamma$	$\longrightarrow$	**neutrino → neutrino photon**
strong magnetic field	$\longrightarrow$	**magnetic field, high**
framework of the Standard Model	$\longrightarrow$	**electroweak interaction**
resonance probability	$\longrightarrow$	**resonance**
neutrino energy and momentum loss	$\longrightarrow$	**neutrino, energy loss neutrino, energy-momentum**
astrophysical cataclysm	$\longrightarrow$	**astrophysics**
supernova	$\longrightarrow$	**astrophysics, supernova**
neutron stars	$\longrightarrow$	**n, matter**
γ-burst	$\longrightarrow$	**gamma ray burst**

when keychains:		*read file:*
neutrino, energy loss astrophysics	$\longrightarrow$	"astrophysical applications"
magnetic field photon	$\longrightarrow$	"photon-properties"

Important sentensies:

1. In this paper we study the high energy neutrino bremsstrahlung in the strong constant magnetic field in the framework of the SM.
   $\longrightarrow$ **neutrino, relativistic**
   neutrino, bremsstrahlung
   magnetic field, external field
   magnetic field, high
   electroweak interaction

2. We stress the principle importance of taking account of the photon wave function renormalization Eq.
   $\longrightarrow$ **photon, wave function**
   wave function, renormalization

3. This means that many-loops quantum corrections are of great importance in the vicinity of the resonance.
   $\longrightarrow$ **radiative correction**
   resonance

4. It is of more practical importance for some astrophysical applications to calculate the four-vector of the neutrino energy and momentum loss in the process of the neutrino bremsstrahlung:
   $\longrightarrow$ **neutrino, energy loss**
   neutrino, energy-momentum
   neutrino, bremsstrahlung
   astrophysics

5. To illustrate a possible application of our results we estimate below the neutrino energy loss in some astrophysical cataclysm of type of a supernova explosion or a merger of neutron stars.
   $\longrightarrow$ **neutrino, energy loss**
   astrophysics
   astrophysics, supernova
   n, matter

from file:		*keychains*
"astrophysical applications"	$\longrightarrow$	**gamma ray burst**
		astrophysics
"photon-properties"	$\longrightarrow$	**photon, dispersion relations**
		photon, polarization
		radiative correction
		vacuum polarization

from file "when-ignore":

when keychains:	*ignore keychains:*
photon, wave function	**photon, wave function**
wave function, renormalization	**wave function, renormalization**
radiative correction	
vacuum polarization	

Model Report:

neutrino, radiative decay	⟶		t		
flavor, conservation law	⟶		t		
neutrino, bremsstrahlung	⟶	a	t	text	
resonance	⟶	a	t	text	
neutrino, relativistic	⟶	a		text	
magnetic field, external field	⟶			text	
magnetic field, high	⟶	a	t	text	
electroweak interaction	⟶	a		text	
neutrino, energy-momentum	⟶	a		text	
neutrino, energy loss	⟶	a		text	
photon, dispersion relations	⟶				on-request
photon, polarization	⟶				on-request
radiative correction	⟶			text	on-request
vacuum polarization	⟶				on-request
astrophysics, supernova	⟶	a		text	
n, matter	⟶	a		text	
gamma ray burst	⟶	a			on-request
neutrino → neutrino photon	⟶	a	t		

AI-HEPD Report:

neutrino, radiative decay	$\longrightarrow$	t
flavor, conservation law	$\longrightarrow$	t
neutrino, bremsstrahlung	$\longrightarrow$	a t
resonance	$\longrightarrow$	a t
neutrino, relativistic	$\longrightarrow$	a
magnetic field, high	$\longrightarrow$	a t
electroweak interaction	$\longrightarrow$	a
neutrino, energy-momentum	$\longrightarrow$	a
neutrino, energy loss	$\longrightarrow$	a
astrophysics, supernova	$\longrightarrow$	a
n, matter	$\longrightarrow$	a
gamma ray burst	$\longrightarrow$	a
neutrino → neutrino photon	$\longrightarrow$	a t

The conclusion:

1. The system gives all *keychains* which the article is supposed to get from title and abstract.

2. The system caught all the *keychains* contained in SPIRES report and gave additional ones. 100 % matching

AI-HEPD Report:		SPIRES Report:
neutrino, radiative decay		
flavor, conservation law		
neutrino, bremsstrahlung		`neutrino, bremsstrahlung`
resonance		`resonance`
neutrino, relativistic		
magnetic field, high		`magnetic field, high`
electroweak interaction		`electroweak interaction`
neutrino, energy-momentum	$\pm$	`neutrino, momentum`
neutrino, energy loss		`neutrino, energy loss`
astrophysics, supernova		
n, matter		
gamma ray burst		
neutrino → neutrino photon		
	0	`photon, cosmic radiation`

C.3 hep-ph/9803281: a detailed analysis

Title: Emission of Axions in strongly magnetized stars

Abstract

We show that the axion decay constant does not get any correction at any order by external magnetic fields. On the other hand, in the context of the Wilsonian effective action under external magnetic fields, the axial currents get a finite correction. We then calculate the effect of strong magnetic fields $B > 10^{18}G$ on the axion-nucleon coupling and find that if $B > 10^{20}$ G in strongly magnetized neutron and white dwarf stars, the emission rate of axions is enhanced by several orders of magnitude.

axion, decay constant	$\longrightarrow$	a
magnetic field, external field	$\longrightarrow$	a
magnetic field, high	$\longrightarrow$	a t
effective action	$\longrightarrow$	a
current, axial	$\longrightarrow$	a
correction, current	$\longrightarrow$	a
correction, magnetic field	$\longrightarrow$	a
coupling, (nucleon axion)	$\longrightarrow$	a
axion, emission	$\longrightarrow$	a t
n, matter	$\longrightarrow$	a
matter, magnetic	$\longrightarrow$	a
astrophysics, white dwarf	$\longrightarrow$	a
yield, enhancement	$\longrightarrow$	a

Important sentensies:

1. In this letter, we calculate the corrections to the emission rate of axions by nucleons in a strongly magnetized neutron or WD star whose magnetic field is stronger than the critical field, $B > B_c$, such that the Landau gap is larger than the rest mass energy or Λ_{QCD}.
   $\longrightarrow$ **axion, emission**
   n, matter
   matter, magnetic
   magnetic field, high
   astrophysics, white dwarf

2. In conclusion, we have shown that the axion decay constant does not get a correction by the external magnetic field and we have calculated the cor-

rection to the axion-nucleon coupling due to external magnetic fields.

⟶ **axion, decay constant**
coupling, (nucleon axion)
correction, magnetic field
magnetic field, external field

Model Report:

axion, decay constant	⟶	a		text		
magnetic field, external field	⟶	a		text		
magnetic field, high	⟶	a	t	text		
effective action	⟶	a				
current, axial	⟶	a				
correction, current	⟶	a				
correction, magnetic field	⟶	a		text		
coupling, (nucleon axion)	⟶	a		text		
axion, emission	⟶	a	t	text		capt
bremsstrahlung	⟶					capt
n, matter	⟶	a		text		
matter, magnetic	⟶	a		text		
astrophysics, white dwarf	⟶	a		text		
yield, enhancement	⟶	a				
Feynman graph	⟶					file-to-read

The conclusion:

1. The system gives all *keychains* which the article is supposed to get from title and abstract.

2. At this stage the system does not give *keychain* ‘‘`Feynman graph`’’ contained in SPIRES report but gives additional *keychains*. ‘‘`Feynman graph`’’ as well as the othes will be written in AI-HEPD Report at the next stage when the main program will be applied to the text. At this stage the system caught 88 % of the SPIRES report. If we compare AI-HEPD Report (AI-HEPD) and SPIRES report (SR) with a Model Report (MR), the result is the following: (AI-HEPD)/(MR) = 0.86, (SR)/(MR) = 0.53.

AI-HEPD Report:		SPIRES report:
axion, decay constant		`axion, decay constant`
magnetic field, external field		`magnetic field, external field`
magnetic field, high		`magnetic field, high`
effective action		
current, axial		`current, axial`
correction, current		
correction, magnetic field		
coupling, (nucleon axion)		`coupling, (nucleon axion)`
axion, emission		`axion, emission`
bremsstrahlung		
transition, axion photon		
n, matter	±	`matter`
matter, magnetic		
astrophysics, white dwarf	±	`astrophysics`
yield, enhancement		
		`Feynman graph`
	0	`axion, radiative decay`

C.4 hep-ph/0102158

Title: Primordial galactic magnetic fields: An application of QCD domain walls.

Abstract

We present a mechanism for generating primordial magnetic fields with large correlation lengths on the order of 100 kpc today. The mechanism is based on recently conjectured QCD domain walls or similar CP violating domain walls with QCD scale structure. Such domain walls align the electric and magnetic dipole moments of the nucleons shortly after the QCD phase transition, producing electromagnetic fields correlated along the domain walls. Through the Kibble mechanism, the domain walls attain Hubble-scale correlations which they transfer to the aligned electromagnetic fields. Due to the CP violation, the Hubble-scale walls produce helical (non-zero Chern-Simons) magnetohydrodynamic turbulence which then undergoes an inverse cascade, allowing the correlation lengths to grow to 100 kpc today. We present an estimate the magnitude of the generated electromagnetic fields in terms of the QCD parameters. We also discuss some other unexplained astrophysical phenomena which may be related to this mechanism. In particular, we discuss the relation between primordial

magnetic fields and the Greisen-Zatsepin-Kuzmin (GZK) cutoff violations. We also outline how, by creating inhomogeneities in the nucleon density, QCD domain walls may lead to inhomogeneous big bang nucleosynthesis (IBBN) explaining the Ω_B excess recently measured through cosmic microwave background (CMB) distortions.

AI-HEPD Report:	SPIRES report:
magnetic field, production	`magnetic field, production`
magnetic field, galaxy	`magnetic field, galaxy`
quantum chromodynamics, (→)	`quantum chromodynamics (→)`
domain wall	`domain wall`
quantum chromodynamics, (→)	
critical phenomena	
correlation, length	`correlation, length`
violation, CP	`violation, CP`
nucleon, electric moment	`nucleon, electric moment`
nucleon, magnetic moment	`nucleon, magnetic moment`
moment, dipole	
electromagnetic field	`electromagnetic field`
turbulence, hydrodynamical	
turbulence, magnetic	`turbulence, magnetic`
helicity	
GZK effect	`GZK effect`
astrophysics, model	
light nucleus, production	`light nucleus, production`
cosmic radiation, background	`cosmic radiation, background`
numerical calculations	
electromagnetic field, production	
domain wall, decay	
spin, alignment	`spin, alignment`

Under the line on the left we write *keychains* absent in AI-HEPD Report and present in Model Report; on the right are *keychains* present in SPIRES report but not matching with AI-HEPD Report.

C.5 hep-ph/0103015

Title: Covariant Treatment of Neutrino Spin (Flavour) Conversion in Matter under the Influence of Electromagnetic Fields

Abstract

Within the recently proposed [1,2] Lorentz invariant formalism for description of neutrino spin evolution in presence of an arbitrary electromagnetic fields effects of matter motion and polarization are considered.

AI-HEPD Report:	SPIRES report:
neutrino, transition	`neutrino, oscillation`
neutrino, spin	`neutrino, spin`
spin, flavor	
invariance, Lorentz	`invariance, Lorentz`
electromagnetic field, external field	`electromagnetic field, external field`
matter, effect	`matter, effect`
matter, polarization	

---

effective Lagrangian

C.6 hep-ph/0103176

Title: Neutrino kinetics in a magnetized dense plasma

Abstract

The relativistic kinetic equations (RKE) for lepton plasma in the presence of a strong external magnetic field are derived in Vlasov approximation. The new RKE for the electron spin distribution function includes the weak interaction with neutrinos originated by the axial vector current ($\sim c_A$) and provided by the parity nonconservation. In a polarized electron gas Bloch equation describing the evolution of the magnetization density perturbation is derived from the electron spin RKE being modified in the presence of neutrino fluxes. Such modified hydrodynamical equation allows to obtain the new dispersion equation in a magnetized plasma from which *the neutrino driven instability of spin waves* can be found. It is shown that this instability is more efficient e.g. in a magnetized supernova than the analogous one for Langmuir waves enhanced in an isotropic plasma.

AI-HEPD Report:	SPIRES report:
kinetics, relativistic	`neutrino, kinematics`
lepton, plasma	`lepton, plasma`
plasma, magnetic	
magnetic field, external field	`magnetic field, external field`
magnetic field, high	`magnetic field, high`
Vlasov equation	`Vlasov equation`
electron, spin	`electron, spin`
neutrino, interaction	`neutrino electron, interaction`
current, axial-vector	
parity, violation	
electron, gas	`electron, gas`
electron, polarization	`electron, polarization`
density, perturbation	`density, perturbation`
neutrino, beam	`neutrino, beam`
neutrino, flux	
dispersion relations	`dispersion`
stability	`stability`

AI-HEPD Report:	SPIRES report:
astrophysics, supernova	
lepton, current	
	`neutrino, form factor`
	`neutrino, charge`
	`charge, induced`

C.7 hep-ph/0106101

Title: Neutrino Oscillations in Moving and Polarized Matter under the Influence of Electromagnetic Fields

Abstract

Within the recently proposed Lorentz invariant formalism for description of neutrino spin evolution in presence of an arbitrary electromagnetic fields matter motion and polarization effects are considered. It is shown that in the case of matter moving with relativistic speed parallel to neutrino propagation, matter effects in neutrino spin (and also flavour) oscillations are suppressed. In the case of relativistic motion of matter in the opposite direction in respect to neutrino propagation, sufficient increase of effects of matter in neutrino oscillations is predicted. These phenomena could have important consequences in different astrophysical environments.

AI-HEPD Report:		SPIRES Report:
neutrino, oscillation		`neutrino, oscillation`
electromagnetic field, external field	$\pm$	`electromagnetic field`
matter, effect		
matter, polarization		`matter, polarization`
matter, velocity		
neutrino, spin		`neutrino, spin`
neutrino, flavor		
kinematics		
invariance, Lorentz		`invariance, Lorentz`
		`neutrino, magnetic moment`

C.8 hep-ph/0107109

Title: Parametric Resonance Amplification of Neutrino Oscillations in Electromagnetic Wave with Varying Amplitude and "Castle Wall" Magnetic Field

Abstract

Within the Lorentz invariant formalizm for description of neutrino evolution in electromagnetic fields and matter we consider neutrino spin oscillations in the electromagnetic wave with varying amplitude and in "castle wall" magnetic field. It is shown for the first time that the parametric resonances of neutrino oscillations in such systems can occur.

AI-HEPD Report:		SPIRES report:
neutrino, oscillation		`neutrino, oscillation`
resonance, oscillation		`resonance`
electromagnetic field, external field		`electromagnetic field, external field`
magnetic field, external field	±	`magnetic field`
invariance, Lorentz		
neutrino, spin		`neutrino, spin`
spin, oscillation		
matter		

C.9 hep-ph/0107258

Title: Familon emission by dense magnetized plasma

Abstract

Emission of a familon caused by the processes $e^- \to e^- + \phi$, $e^- \to \mu^- + \phi$ in dense magnetized plasma is investigated in the model in which a familon have both direct and no direct coupling to leptons via plasmon. The process probabilities and the integral familon action on plasma are calculated. It is shown that the P odd interference phenomenon in the process $e^- \to \mu^- + \phi$ leads to the familon force acting on plasma along the magnetic field.

AI-HEPD Report:		SPIRES report:
familon, emission		`familon, emission`
cyclotron, emission		`cyclotron, emission`
plasma, magnetic	±	`plasma`
magnetic field, external field	±	`magnetic field`
plasmon, propagator		
flavor, violation		`flavor, violation`
effective Lagrangian		`effective Lagrangian`
coupling, (familon lepton)		
coupling, (familon photon)		
coupling, induced		
parity, interference		
Feynman graph		
numerical calculations		`numerical calculations`
electron → familon electron		`electron → familon electron`
electron → familon muon-		`electron → familon muon-`
magnetic field, induced		
fermion, propagator		
propagator, external field		
plasma, energy loss	±	`energy loss`
plasma, energy-momentum		
astrophysics, supernova		`supernova`
pulsar, velocity		
		`symmetry, family`
		`symmetry, spontaneously broken`
		`muon-`
		`S-matrix`

C.10 hep-ph/0001069

Title: Matter effects on neutrino oscillations in gravitational and magnetic fields

Abstract

When neutrinos propagate in a background, their gravitational couplings are modified by their weak interactions with the particles in the background. In a medium that contains electrons but no muons or taons, the matter-induced gravitational couplings of neutrinos are different for the various neutrino flavors, and they must be taken into account in describing the phenomena associated with the neutrino oscillations in the presence of strong gravitational fields. Here we incorporate those couplings in that description, including also the effects of a magnetic field, and consider the implications that they have for the emission of high energy neutrinos in the vicinity of Active Galactic Nuclei.

AI-HEPD Report:	SPIRES report:
neutrino, oscillation	`neutrino, oscillation`
matter, effect	`matter, effect`
neutrino, coupling	`neutrino, coupling`
coupling, gravitation	
matter, induced	
neutrino, flavor	`neutrino, flavor`
gravitation, external field	`gravitation, external field`
magnetic field, external field	`magnetic field, external field`
neutrino, emission	
neutrino, relativistic	
galaxy, AGN	`galaxy, AGN`
transition, resonance	`resonance, transition`
neutrino, right-handed	
numerical calculations	`numerical calculations`
	`neutrino, flux`

C.11 hep-ph/0001210

Title: Mass Shift of Axion in Magnetic Field

Abstract

A mass-shift of the axion propagating in an external constant homogenious magnetic field is calculated. The contributions via an electron loop and a virtual photon are examined. It is shown that the virtual photon contribution dominates substantially over the electron-loop one. Under the conditions of the early Universe the electron-loop contribution to the massless axion mass-shift is equal to zero while the virtual photon contribution is finite and can be of order of the recent restrictions on the axion mass.

AI-HEPD Report:	SPIRES report:
axion, mass	`axion, mass`
radiative correction	
magnetic field, external field	`magnetic field, external field`
electron, propagator	
photon, propagator	
astrophysics	`astrophysics, model`
axion, massless	
Feynman graph	`Feynman graph, higher-order`
numerical calculations	

C.12 hep-ph/0003216

Title: Lepton pair production by high-energy neutrino in an external electromagnetic field

Abstract

The process of the lepton pair production by a neutrino propagating in an external electromagnetic field is investigated in the framework of the Standard Model. Relatively simple exact expression for the probability as the single integral is obtained, which is suitable for a quantitative analysis.

AI-HEPD Report:	SPIRES report:
neutrino, leptonic decay	`neutrino, leptonic decay`
lepton, pair production	`lepton, pair production`
neutrino, relativistic	
electromagnetic field, external field	`electromagnetic field, external field`
electroweak interaction	`electroweak interaction`
neutrino, flavor	`neutrino, flavor`
lepton, charged particle	
charged lepton, flavor	
numerical calculations	`numerical calculations`
neutrino → neutrino lepton antilepton	

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effective Lagrangian

C.13 hep-ph/0004051

Title: Primordial Galactic Magnetic Fields from Domain Walls at the QCD Phase Transition.

Abstract

We propose a mechanism to generate large-scale magnetic fields with correlation lengths of 100 kpc. Domain walls with QCD-scale internal structure form and coalesce obtaining Hubble-scale correlations while aligning nucleon spins. Because of strong CP violation, the walls are ferromagnetic, which induces electromagnetic fields with Hubble size correlations. The CP violation also induces a maximal helicity (Chern-Simons) which supports an inverse cascade, allowing the initial correlations to grow to 100 kpc today. We estimate the generated electromagnetic fields in terms of the QCD parameters and discuss the effects of the resulting fields.

AI-HEPD Report:		SPIRES report:
magnetic field, galaxy	±	`galaxy`
magnetic field, production		`magnetic field, production`
electromagnetic field		
quantum chromodynamics,		`quantum chromodynamics`
critical phenomena		`critical phenomena`
domain wall, ferromagnet		
nucleon, spin		
spin, alignment		
strong interaction, CP		
violation, CP		`violation, CP`
helicity		
correlation, length		`correlation, length`
numerical calculations		
domain wall, axion		`axion, domain wall`

C.14 hep-ph/0005192

Title: Neutrino self-energy in a magnetized medium in arbitrary ξ-gauge

Abstract

We calculate the one-loop neutrino self-energy in a magnetized plasma to all orders in the magnetic field. The calculation is done in a general gauge. We obtain the dispersion relation and effective potential for neutrinos in a CP-symmetric plasma under various conditions, and show that, while the self-energy depends on the gauge parameter ξ, the dispersion relation and effective potential to leading order are independent of it.

AI-HEPD Report:		SPIRES report:
neutrino, propagator		`neutrino, propagator`
propagator, renormalization		`renormalization`
plasma, magnetic	±	`plasma`
magnetic field, external field	±	`magnetic field`
neutrino, dispersion relations	±	`dispersion relations`
neutrino, effective potential	±	`effective potential`
invariance, CP		`invariance, CP`
dependence, gauge		
transformation, gauge		`transformation, gauge`
scalar particle, propagator		
W, propagator		
Feynman graph, tadpole	±	`Feynman graph`

---

fermion, propagator
neutrino, Dirac
neutrino, massless

C.15 hep-ph/0007033

Title: Neutrino Self-Energy and Index of Refraction in Strong Magnetic Field: A New Approach

Abstract

The Ritus' E_p eigenfunction method is extended to the case of spin-1 charged particles in a constant electromagnetic field and used to calculate the one-loop neutrino self-energy in the presence of a strong magnetic field. From the obtained self-energy, the neutrino dispersion relation and index of refraction in the magnetized vacuum are determined within the field range $m_e^2 \ll eB \ll M_W^2$. The propagation of neutrinos in the magnetized vacuum is anisotropic due to the dependence of the index of refraction on the angle between the directions of the neutrino momentum and the external field. Possible cosmological implications of the results are discussed.

AI-HEPD Report:		SPIRES report:
neutrino, propagator		neutrino, propagator
propagator, renormalization		propagator, renormalization
magnetic field, high		magnetic field, high
electromagnetic field, external field		electromagnetic field, external field
neutrino, dispersion relations		neutrino, dispersion relations
neutrino, refraction		
mathematical methods		
approximation, strong field		
electron, propagator		
W, propagator		W, propagator
charged particle, spin	$\pm$	charged particle
spin, 1		spin, 1
vacuum state, magnetic		vacuum state, magnetic
neutrino, momentum		
kinematics		angular dependence
astrophysics		
		neutrino, oscillation
		bibliography

C.16 hep-ph/0008297

Title: Ultra High Energy Cosmic Rays and Gamma Ray Bursts from Axion Stars

Abstract

We propose a model in which ultra high energy cosmic rays and gamma ray bursts are produced by collisions between neutron stars and axion stars. The acceleration of such a cosmic ray is made by the electric field, $\sim 10^{15}\ (B/10^{12}\,\mathrm{G})$ eV cm^{-1}, which is induced in an axion star by relatively strong magnetic field $B > 10^{12}$ G of a neutron star. On the other hand, similar collisions generate gamma ray bursts when magnetic field is relatively small, e.g. $\leq 10^{10}$ G. Assuming that the axion mass is $\sim 10^{-9}$ eV, we can explain huge energies of the gamma ray bursts $\sim 10^{54}$ erg as well as the ultra high energies of the cosmic rays $\sim 10^{20}$ eV. We estimate rate of energy release in the collisions and we find that the rate roughly agrees with observations. In addition, we show that these axion stars are plausible candidates for MACHOs. Since the axion star induces oscillating electric current under the magnetic field, observable monochromatic radiations are emitted.

AI-HEPD Report:		SPIRES report:
cosmic radiation, production		cosmic radiation, production
cosmic radiation, acceleration		cosmic radiation, acceleration
gamma ray burst		gamma ray burst
axion, star		axion, star
astrophysics		
n, matter		n, matter
magnetic field, external field		magnetic field, external field
magnetic field, high		
magnetic field, induced		
electric field, external field		electric field, induced
current, electric		
current, oscillation		
current, induced		
radiation, emission		photon, cosmic radiation
axion, mass		
energy loss	$\pm$	energy
MACHO		MACHO
numerical calculations	$\pm$	numerical calculations, ($\rightarrow$) interpretation of experiments
		star, scattering

C.17 hep-ph/0008318

Title: Primordial galactic magnetic fields from the QCD phase transition

Abstract

In this letter, we propose a mechanism to generate large-scale magnetic fields with correlation lengths of 100 kpc. Domain walls with QCD scale internal structure form and coalesce obtaining Hubble scale correlations and align nucleon spins. Due to strong CP violation, nucleons in these walls have anomalous electric and magnetic dipole moments and thus the walls are ferromagnetic. This induces electromagnetic fields with Hubble size correlations. The same CP violation also induces a maximal helicity (Chern-Simons) correlated through the Hubble volume which supports an "inverse cascade" allowing the initial correlations to grow to 100 kpc today. We estimate the generated electromagnetic fields in terms of the QCD parameters and discuss the effects of the resulting fields.

AI-HEPD Report:	SPIRES report:
magnetic field, galaxy	`magnetic field, galaxy`
magnetic field, production	`magnetic field, production`
quantum chromodynamics, (→)	`quantum chromodynamics (→)`
critical phenomena	`critical phenomena`
correlation, length	`correlation, length`
nucleon, spin	
spin, alignment	`spin, alignment`
strong interaction, CP	`strong interaction, CP`
violation, CP	
nucleon, electric moment	
nucleon, magnetic moment	`nucleon, magnetic moment`
moment, dipole	
domain wall, coalescence	`domain wall, coalescence`
domain wall, ferromagnet	
electromagnetic field, induced	
helicity	`helicity`
domain wall, background	
	`turbulence`

C.18 hep-ph/0009304

Title: Non-Perturbative Effects of Strong Magnetic Fields on Neutrino Self-energy: A New Approach

Abstract

The Ritus' E_p eigenfunction method is extended to the case of spin-1 charged particles in a constant electromagnetic field and used to calculate the one-loop neutrino self-energy in the strong-field approximation $m_e^2 \ll eB \ll M_W^2$. The implications of the obtained results for neutrino oscillations in the early Universe, assuming the existence of a sufficiently large ($m_e^2 \ll eB \ll m_\mu^2$) primordial magnetic field, are discussed.

AI-HEPD Report:	SPIRES report:
neutrino, propagator	`neutrino, propagator`
propagator, renormalization	
magnetic field, high	`magnetic field, high`
electromagnetic field, external field	
effect, nonperturbative	`effect, nonperturbative`
mathematical methods	
approximation, strong field	
charged particle, spin	
spin, 1	
neutrino, oscillation	`neutrino, oscillation`
astrophysics	
	`W, propagator`

C.19 hep-ph/9901396

Title: Axionic Boson Stars in Magnetized Conducting Media

Abstract

Axions are possible candidates of dark matter in the present Universe. They have been argued to form axionic boson stars with small masses $10^{-14}M_\odot \sim 10^{-11}M_\odot$. Since they possess oscillating electric fields in a magnetic field, they dissipate their energies in magnetized conducting media such as white dwarfs or neutron stars. At the same time the oscillating electric fields generate a monochromatic radiation with energy equal to mass of the axion. We argue that the effect of the energy dissipation can be seen in the old white dwarfs. In particular, we show that colliding with sufficiently cooled white dwarfs, plausible candidates of MACHO, the axionic boson stars dissipate their energies in the dwarfs and heat up the dwarfs. Consequently the white dwarfs in the halo can emit detectable amount of thermal radiations with the collision. On the other hand, the monochromatic radiations can be seen only during the collision; a period of the dwarf passing the axionic boson star. Assuming that MACHO are dark white dwarfs, we show that there is a threshold in luminosity function of the white dwarfs below which the number of the white dwarfs in the halo increase discontinuously. The threshold in the luminosity function is expected to be located around $10^{-5.5}L_\odot \sim 10^{-7}L_\odot$. Its precise value is determined by the mass of the axionic boson stars dominant in the halo.

AI-HEPD Report:	SPIRES report:
axion, star	`matter, axion`
boson, matter	`boson, matter`
star, mass	
dependence, mass	
electric field, oscillation	`electric field, oscillation`
magnetic field	`magnetic field, external field`
astrophysics, missing-mass	
astrophysics, white dwarf	`astrophysics, white dwarf`
energy, dissipation	`energy, dissipation`
matter, magnetic	
n, matter	`n, matter`
axion, mass	
MACHO	

AI-HEPD Report:		SPIRES report:
radiation, emission		`radiation, emission`
luminosity, threshold		`luminosity, threshold`
numerical calculations		

radiation, luminosity

C.20 hep-ph/9901424

Title: Cherenkov radiation by neutrinos

Abstract

We discuss the Cherenkov process $\nu \to \nu\gamma$ in the presence of a homogeneous magnetic field. The neutrinos are taken to be massless with only standard-model couplings. The magnetic field fulfills the dual purpose of inducing an effective neutrino-photon vertex and of modifying the photon dispersion relation such that the Cherenkov condition $\omega < |\mathbf{k}|$ is fulfilled. For a field strength $B_{\rm crit} = m_e^2/e = 4.41 \times 10^{13}$ Gauss and for $E = 2m_e$ the Cherenkov rate is about 6×10^{-11} s^{-1}.

AI-HEPD Report:		SPIRES report:
radiation, Cherenkov		`radiation, Cherenkov`
neutrino, radiative decay	±	`neutrino`
magnetic field, external field		`magnetic field, external field`
neutrino, massless		
electroweak interaction		
vertex function, (neutrino photon)		`vertex function, (neutrino photon)`
photon, dispersion relations		
photon, yield		`photon, yield`
neutrino → neutrino photon		`neutrino --> neutrino photon`

Feynman graph

C.21 hep-ph/9902269

Title: Effective Magnetic Moment of Neutrinos in Strong Magnetic Fields

Abstract

We compute the effective magnetic moment of neutrino in the highly dense and strongly magnetized media. It is shown that this magnetic moment is generated due to the effective mass of neutrino and gives sufficiently high value of the magnetic moment in the core of neutron stars.

AI-HEPD Report:	SPIRES report:
astrophysics	`astrophysics`
neutrino, magnetic moment	`neutrino, magnetic moment`
magnetic moment, induced	
magnetic field, high	`magnetic field, external field`
matter, magnetic	`matter, density`
density, high	
neutrino, mass	`neutrino, mass`
mass, induced	
n, matter	`n, matter`
electron, propagator	
W, propagator	
neutrino, propagator	
numerical calculations	`numerical calculations`

C.22 hep-ph/9903210

Title: Comment on the paper: 'Neutrino pair production by a virtual photon in an external magnetic field' by Zhukovskii et al.

Abstract

We point out some serious mistakes in the investigation of Zhukovskii et al. Both the amplitude and the probability of the process were calculated wrongly, that is, the problem of the neutrino pair production by a virtual photon in an external magnetic field is still unsolved.

AI-HEPD Report:	SPIRES report:
neutrino, pair production	`neutrino, pair production`
neutrino, photoproduction	
photon, off-shell	`photon, off-shell`
magnetic field, external field	`magnetic field, external field`
photon → neutrino antineutrino	`photon --> neutrino antineutrino`
effective Lagrangian, weak interaction	`effective Lagrangian, weak interaction`
Feynman graph, higher-order	`Feynman graph, higher-order`

C.23 hep-ph/9903356

Title: Massive Neutrino Decays

Abstract

Lecture given at the Vth Viet Nam School of Physics, Hanoi 28 December 1998 - 9 January 1999. Neutrino physics is used as an illustrative example for an elementary introduction to the computational method of Feynman loop-diagrams and decay rates.

If the neutrinos are as massive as recently reported by the Super-Kamiokande results, the heaviest neutrino ν_H would not be stable. Although chargeless, it could decay – by quantum loop effect – into a lighter neutrino ν_L by emitting a photon: $\nu_H \to \nu_L + \gamma$. If kinematically possible, the $\nu_H \to \nu_L + e^+ + e^-$ mode could occur at the tree diagram level and furthermore get enhanced, at one-loop radiative corrections, by a large logarithm of the electron mass acting as an infrared cutoff.

AI-HEPD Report:	SPIRES report:
neutrino, decay modes	
flavor, violation	
neutrino, massive	`neutrino, massive`
vertex function, (2neutrino photon)	
neutrino, radiative decay	`neutrino, radiative decay`
photon, emission	
neutrino, leptonic decay	
electron, pair production	`electron, pair production`
mathematical methods	
kinematics	
yield, enhancement	
radiative correction	`radiative correction`
renormalization	`renormalization`
Feynman graph, higher-order	`Feynman graph, higher-order`
interpretation of experiments, (→)	
KAMIOKANDE	
neutrino → neutrino photon	`neutrino → neutrino photon`
neutrino → positron electron neutrino	`neutrino → positron electron neutrino`
effective Lagrangian	
	`neutrino, electromagnetic decay`
	`neutrino, width`
	`transformation, gauge`

C.24 hep-ph/9903401

Title: Axion Decay of a Photon in an External Electromagnetic Field

Abstract

An interaction of a pseudoscalar particle with two photons induced by an external electromagnetic field is used to study the photon decay $\gamma \to \gamma a$ where a is a pseudoscalar particle associated with the Peccei-Quinn $U(1)$ symmetry. The field-induced axion emission by photon is analyzed as a possible source of energy losses by astrophysical objects.

AI-HEPD Report:	SPIRES report:
photon, decay	`photon, decay`
axion, emission	`axion, emission`
electromagnetic field, induced	
electromagnetic field, external field	`electromagnetic field, external field`
photon, dispersion relations	
vertex function, (pseudoscalar particle 2photon)	
astrophysics	
energy loss	`energy loss`
photon → axion photon	`photon → axion photon`
photon, polarization	
axion, luminosity	
neutrino, luminosity	
numerical calculations	
	0 `photon, mass`

C.25 hep-ph/9903415

Title: Axion in an External Electromagnetic Field

Abstract

We investigate the effective interaction of a pseudoscalar particle with two photons in an external electromagnetic field in the general case of all external particles being off the mass shell. This interaction is used to study the radiative decay $a \to \gamma\gamma$ of the axion, a pseudoscalar particle associated with the Peccei-Quinn symmetry, and the crossing channel of photon splitting $\gamma \to \gamma a$. It is shown that the external field removes the suppression associated with the smallness of the axion mass and so leads to the strong catalysis of these processes. The field-induced axion emission by the photon is analyzed as one more possible source of energy losses by astrophysical objects.

AI-HEPD Report:		SPIRES report:
vertex function,		`vertex function,`
(pseudoscalar particle 2photon)		`(axion 2photon)`
electromagnetic field, external field		`electromagnetic field, external field`
pseudoscalar particle, off-shell		
coupling, (axion photon)		`effective Lagrangian`
effective Lagrangian		
photon, off-shell		
fermion, propagator		`fermion, propagator`
propagator, external field		
axion, radiative decay		`axion, radiative decay`
photon, decay		
photon, dispersion relations		
axion, emission		`axion, emission`
axion, mass		`axion, mass`
yield, enhancement		
external field, induced		
energy loss		
astrophysics		
Feynman graph, higher-order	$\pm$	`Feynman graph`
axion → 2photon		`axion → 2photon`
photon → axion photon		`photon → axion photon`

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coupling, (axion fermion)
axion, dispersion relations

AI-HEPD Report:		SPIRES report:
luminosity, axion		
kinematics		
numerical calculations		`numerical calculations`
	0	`bibliography`
	0	`axion, electromagnetic decay`

C.26 hep-ph/9904356

Title: Propagation of axions in a strongly magnetized medium

Abstract

The polarization operator of an axion in a degenerate gas of electrons occupying the ground-state Landau level in a superstrong magnetic field $H \gg H_0 = m_e^2 c^3/e\hbar = 4.41 \cdot 10^{13}$ G is investigated in a model with a tree-level axion-electron coupling. It is shown that a dynamic axion mass, which can fall within the allowed range of values (10^{-5} eV $\leq m_a \leq 10^{-2}$ eV), is generated under the conditions of strongly magnetized neutron stars. As a result, the dispersion relation for axions is appreciably different from that in a vacuum.

AI-HEPD Report:		SPIRES report:
axion, mass		`axion, mass`
magnetic field, high		`magnetic field, high`
polarization, operator		`polarization, operator`
electron, gas		`electron, gas`
astrophysics		
n, matter		`n, matter`
matter, magnetic		
electron, energy levels		
energy, ground state		
coupling, (axion electron)		`coupling, (axion electron)`
axion, dispersion relations	$\pm$	`dispersion relations`
numerical calculations		

C.27 hep-ph/9904415

Title: TeV neutrinos in a dense medium

Abstract

The dispersion relation of energetic (few TeV) neutrinos traversing a medium is studied. We use the real time formalism of thermal field theory and we include the effects from the propagator of the W gauge boson. We consider then the MSW oscillations for cosmic neutrinos traversing the Earth, adopting for the neutrino parameters values suggested by the LSND results. It is found that the ν_μ flux, for neutrinos passing through the center of the Earth, will appear reduced by 15% for energies around 10 TeV.

AI-HEPD Report:		SPIRES report:
neutrino, dispersion relations		`neutrino, dispersion relations`
neutrino, relativistic		
field theory, finite temperature		`field theory, finite temperature`
neutrino, oscillation		`neutrino, oscillation`
MSW effect		`matter, effect`
neutrino, cosmic radiation	$\pm$	`cosmic radiation`
neutrino, mass difference		
neutrino, mixing angle		
neutrino/mu, flux		`neutrino/mu, flux`
W, propagator		`W, propagator`
geophysics, effect		`geophysics, effect`
numerical calculations		`numerical calculations`
experimental results		
		`neutrino, propagator`

C.28 hep-ph/9904453

Title: Neutrino - electron processes in a strong magnetic field and plasma

Abstract

The total set of the neutrino - electron processes in a presence of both components of an active medium, hot dense plasma and strong magnetic field, is investigated for the first time. The contribution of the processes $\nu e^- \to \nu e^-$, $\nu e^+ \to \nu e^+$, $\nu \to \nu e^- e^+$, $\nu e^- e^+ \to \nu$ is shown to dominate and not to depend on the chemical potential of electron-positron gas. Relatively simple expressions for the probability and mean losses of the neutrino energy and momentum are obtained, which are suitable for a quantitative analysis.

AI-HEPD Report:		SPIRES report:
neutrino electron, interaction		`neutrino electron, interaction`
plasma, magnetic		
magnetic field, high	±	`magnetic field`
neutrino positron, interaction		
neutrino, leptonic decay		
electron, pair production		
flavor, conservation law		
potential, chemical		`potential, chemical`
electron positron, gas		`electron positron, plasma`
neutrino, energy loss		`neutrino, energy loss`
neutrino, energy-momentum	±	`neutrino, momentum`
neutrino → positron electron neutrino		
neutrino electron positron → neutrino		
effective Lagrangian		
		`astrophysics`
	0	`thermodynamics`

In the Model Report we have *plasma, magnetic* but not *plasma*.

C.29 hep-ph/9907398

Title: Right handed neutrino production in dense and hot plasmas

Abstract

For Dirac neutrinos with magnetic moment, we compute the production rate for right-handed neutrinos in a hot and dense QED plasma containing an initial population of left-handed neutrinos thermally distributed. The most important mechanisms for ν_L depolarization, or production of right-handed neutrinos, are the $\nu_L \to \nu_R$ chirality flip and the plasmon decay to $\bar{\nu}_L + \nu_R$. The rates for these processes are computed in terms of a resummed photon propagator which consistently incorporates the background effects to leading order. Applying the results to the cases of supernovae core collapse and the primordial nucleosynthesis in the early universe, we obtain upper limits on the neutrino magnetic moment.

AI-HEPD Report:		SPIRES report:
neutrino, Dirac		neutrino, Dirac
neutrino, magnetic moment		neutrino, magnetic moment
upper limit		
neutrino, right-handed		neutrino, right-handed
neutrino, left-handed		neutrino, left-handed
quantum electrodynamics, plasma		quantum electrodynamics, plasma
thermodynamics		thermodynamics
neutrino, depolarization		
dispersion relations		dispersion relations
neutrino, production		neutrino, production
neutrino, transition	$\pm$	transition
plasmon, decay		
neutrino, pair production		
photon, propagator		photon, propagator
neutrino, propagator		neutrino, propagator
renormalization		
astrophysics, supernova		supernova
		astrophysics, model
light nucleus, production		
numerical calculations		numerical calculations
Feynman graph		Feynman graph
		neutrino, yield
		neutrino, energy spectrum

C.30 hep-ph/9907493

Title: Plasma influence on the neutrino - electron processes in a strong magnetic field

Abstract

An influence of the magnetized electron - positron plasma on the absorption and loss of the energy and momentum in a process of neutrino propagation is investigated. A total contribution of all crossed processes, $\nu \to \nu e^- e^+$, $\nu e^- \to \nu e^-$, $\nu e^+ \to \nu e^+$, $\nu e^- e^+ \to \nu$, is found for the first time, which appears not to depend on the chemical potential of electron-positron gas. Relatively simple expressions for the probability and mean losses of the neutrino energy and momentum are obtained, which are suitable for a quantitative analysis.

AI-HEPD Report:		SPIRES report:
neutrino electron, interaction		
neutrino positron, interaction		
plasma, magnetic	±	plasma
magnetic field, high		magnetic field, external field
neutrino, leptonic decay		neutrino, leptonic decay
electron, pair production		electron, pair production
flavor, conservation law		
electron positron, gas		electron positron, gas
neutrino, energy loss		neutrino, energy loss
neutrino, energy-momentum		
potential, chemical		potential, chemical
absorption		neutrino, absorption
astrophysics		astrophysics, supernova
neutrino → positron electron neutrino		neutrino → positron electron neutrino
neutrino electron positron → neutrino		neutrino electron positron → neutrino
effective Lagrangian		
numerical calculations		
		neutrino electron, elastic scattering
		scattering, neutrino electron positron
		interaction, (→)
		(positron electron neutrino)
	0	neutrino, massive

C.31 hep-ph/9908468

Title: Emission of Radio Waves in Gamma Ray Bursts and Axionic Boson Stars

Abstract

We point out that the bursts of photons with the energy of the axion mass may appear coincidentally with gamma ray bursts if the gamma ray bursts are caused by collisions between neutron stars and axionic boson stars. In this mechanism, jets are formed in the collisions with large Lorentz factors $\geq 10^2$. We explain qualitatively time-dependent complex structures of gamma ray bursts as well as the large energy problem. Therefore, with detection of the monochromatic photons we can test the model and determine the axion mass.

AI-HEPD Report:		SPIRES report:
gamma ray burst		
n, matter		`n, matter`
		`matter, scattering`
axion, star		
boson, matter		`axion, matter`
photon, cosmic radiation		`photon, cosmic radiation`
jet, production	$\pm$	`jet`
axion, mass		`axion, mass`
astrophysics		`astrophysics, missing-mass`

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radiation, luminosity
numerical calculations

C.32 hep-ph/9910476

Title: Neutrino Oscillations in Electromagnetic Fields

Abstract

Oscillations of neutrinos $\nu_L \leftrightarrow \nu_R$ in presence of an arbitrary electromagnetic field are considered. We introduce the Hamiltonian for the neutrino spin evolution equation that accounts for possible effects of interaction of neutrino magnetic μ and electric ϵ dipole moments with the transversal (in respect to the neutrino momentum) and also the longitudinal components of electromagnetic field. Using this Hamiltonian we predict the new types of resonances in the neutrino oscillations $\nu_L \leftrightarrow \nu_R$ in the presence of the field of an electromagnetic wave and in combination of an electromagnetic wave and constant magnetic field. The possible influence of the longitudinal magnetic field on neutrino oscillations is emphasized.

AI-HEPD Report:		SPIRES report:
neutrino, oscillation		`neutrino, oscillation`
neutrino, left-handed		
neutrino, right-handed		
electromagnetic field, external field	±	`electromagnetic field`
electromagnetic field, longitudinal		
electromagnetic field, transversal		
magnetic field, external field		
magnetic field, longitudinal		
neutrino, momentum		
neutrino, spin		`neutrino, spin`
effective Hamiltonian		
neutrino, magnetic moment		`neutrino, magnetic moment`
neutrino, electric moment		
moment, dipole		
resonance		

C.33 hep-ph/9801402

Title: $a \to e^+e^-$ decay in a model with induced coupling to leptons

Abstract

The process of electron-positron pair production by axion propagating in an external magnetic field is investigated in a model with only induced axion coupling to leptons. Contributions of the lowest and higher Landau levels are analyzed. The results we have obtained demonstrate a strong catalyzing influence of the field.

AI-HEPD Report:	SPIRES report:
axion, leptonic decay	`axion, electromagnetic decay`
electron, pair production	`electron, pair production`
coupling, (axion lepton)	`coupling, (axion lepton)`
coupling, induced	
magnetic field, external field	`magnetic field, external field`
energy levels	
energy, ground state	
energy, excited state	
yield, enhancement	
axion → positron electron	`axion --> positron electron`
axion, lifetime	`axion, lifetime`
astrophysics	`astrophysics`
Feynman graph	

C.34 hep-ph/9803374

Title: Energy Dissipation of Axionic Boson Stars in Magnetized Conducting Media

Abstract

Axions are possible candidates of dark matter in the present Universe. They have been argued to form axionic boson stars with small masses $\sim 10^{-12} M_{\odot}$. Since they possess oscillating electric fields in a magnetic field, they dissipate their energies in magnetized conducting media. We show that colliding with a magnetized white dwarf, the axionic boson stars dissipate their energies and heat the white dwarf. Consequently the white dwarf cooled sufficiently can emit detectable amount of radiations with the collision. Using a recent evaluation of the population of the white dwarfs as candidates of MACHOs, we estimate the event rate of the collisions and obtain a result that the rate is large to be detectable.

AI Report:	SPIRES report:
astrophysics, missing-mass	astrophysics, missing-mass
axion, star	
star, mass	
boson, matter	boson, matter
electric field, oscillation	
magnetic field, external field	magnetic field, white dwarf
energy, dissipation	energy loss
matter, magnetic	
astrophysics, white dwarf	
energy, dissipation	
radiation, emission	
MACHO	
numerical calculations	numerical calculations
	matter, axion

C.35 hep-ph/9804230

Title: Bound on the neutrino magnetic moment from chirality flip in supernovae

Abstract

For neutrinos with a magnetic moment, we show that the collisions in a hot and dense plasma act as an efficient mechanism for the conversion of ν_L into ν_R. The production rate for right-handed neutrinos is computed in terms of a resummed photon propagator which consistently incorporates the background effects. Assuming that the entire energy in a supernova collapse is not carried away by the ν_R, our results can be used to place an upper limit on the neutrino magnetic moment $\mu_\nu < (0.1 - 0.4) \times 10^{-11} \mu_B$.

AI-HEPD Report:	SPIRES report:
neutrino, magnetic moment	`neutrino, magnetic moment`
upper limit	
plasma	`plasma, relativistic`
neutrino, left-handed	`neutrino, left-handed`
neutrino, right-handed	`neutrino, right-handed`
neutrino, transition	`neutrino, transition`
neutrino, production	`neutrino, production`
photon, propagator	`photon, propagator`
effect, background	
energy loss	`energy loss`
astrophysics, supernova	`astrophysics, supernova`
numerical calculations	`numerical calculations`
	`quantum electrodynamics`
	`yield, energy dependence`

C.36 hep-ph/9804318

Title: Neutrino self-energy and dispersion in a medium with magnetic field

Abstract

We calculate the one-loop thermal self-energy of a neutrino in a constant and homogeneous magnetic field to all orders in the magnetic field strength using Schwinger's proper time method. We obtain the dispersion relation under various conditions.

AI-HEPD Report:		SPIRES report:
neutrino, propagator		`neutrino, propagator`
propagator, renormalization		`propagator, renormalization`
neutrino, dispersion relations	±	`dispersion relations`
matter		
magnetic field, external field		`magnetic field, external field`
mathematical methods		
finite temperature		`finite temperature`
asymmetry, CP		`asymmetry, CP`
invariance, CP		
W, propagator		
scalar particle, propagator		
Feynman graph, tadpole		`Feynman graph, higher-order`
electron, gas		
gas, nonrelativistic		
neutrino, massless		
neutrino, Dirac		
		`plasma`

In the final version of the report we intend to have *chain field theory*, *finite temperature*, not *finite temperature*. We authoths write in the "Introduction" that they use "the real-time method of finite temperature field theory".

C.37 hep-ph/9804369

Title: Radiations from Oscillating Axionic Boson Stars in an External Magnetic Field

Abstract

We solve numerically a field equation of axions coupled with gravity and show solutions representing oscillating axionic boson stars with small mass $\sim 10^{-12} M_\odot$ and large radius $\sim 10^8$ cm. We present explicitly a relation between the mass and the radius of the boson stars with such a small mass. These axionic boson stars are shown to possess oscillating electric currents in an external magnetic field and to radiate electromagnetic fields with a frequency given by mass of the axions. We estimate roughly the luminosity of the radiation in a strong magnetic field 10^{12}G of neutron stars, it is $\sim 10^{34}$ erg/s with the axion mass 10^{-5}eV.

AI-HEPD Report:	SPIRES Report:
axion, star	
boson, matter	`boson, matter`
star, oscillation	
coupling, axion	`coupling, axion`
gravitation	`gravitation`
magnetic field, external field	`magnetic field, external field`
magnetic field, high	
astrophysics	
n, matter	
field equations, solution	`field equations, solution`
current, electric	
current, oscillation	`current, oscillation`
axion, mass	`axion, mass`
star, mass	
radiation, luminosity	`radiation, luminosity`
numerical calculations	

Einstein equation

C.38 hep-ph/9807232

Title: Axionic Boson Stars in Magnetized Conducting Media and Monochromatic Radiations

Abstract

Axions have been argued to form coherent axionic boson stars as well as incoherent axion gas. These are ones of most plausible candidates of dark matters. Since the axionic boson stars generate oscillating electric fields in an external magnetic field, they induce oscillating currents in magnetized conducting media, which result in emitting radiations. We show that colliding with a magnetic white dwarf, an axionic boson star can emit a monochromatic radiation with a frequency given by a mass of the axion.

AI-HEPD Report:	SPIRES report:
axion, star	`axion`
boson, matter	`boson, matter`
axion, mass	`mass, axion`
matter, magnetic	`matter, magnetic`
astrophysics, missing-mass	`astrophysics, missing-mass`
astrophysics, white dwarf	`astrophysics, white dwarf`
magnetic field, external field	
electric field, oscillation	
current, oscillation	`current, oscillation`
radiation, emission	`radiation, emission`
radiation, luminosity	
numerical calculations	
	`coherence`

C.39 hep-ph/9808246

Title: The transitions $\gamma\gamma \to \nu\bar{\nu}$ and $\gamma \to \gamma\gamma$ in a strong magnetic field

Abstract

The photon-neutrino process $\gamma\gamma \to \nu\bar{\nu}$ and photon splitting are considered in a strong magnetic field. The partial polarization amplitudes are calculated within the standard model in the limit of a strong field. The amplitudes do not depend on the field strength in this limit. Using the vector parts of the amplitudes, the process of the photon splitting $\gamma \to \gamma\gamma$ is investigated both below and above the pair creation threshold. The splitting probabilities are calculated taking account of the photon dispersion and large radiative corrections near the resonance.

AI-HEPD Report:	SPIRES report:
photon photon, exclusive reaction	photon photon, exclusive reaction
neutrino, pair production	neutrino, pair production
photon, radiative decay	photon, decay
final state, (2photon)	photon, pair production
magnetic field, high	magnetic field, external field
electroweak interaction	
threshold, pair production	
photon, dispersion relations	
radiative correction	radiative correction
resonance	
photon photon →	photon photon →
neutrino antineutrino	neutrino antineutrino
photon → 2photon	photon → 2photon
photon, polarization	
vacuum polarization	
Feynman graph, higher-order	Feynman graph, higher-order
numerical calculations	
	vertex function, (→)
	(neutrino antineutrino 2photon)
	electron, propagator
	helicity, amplitude analysis
0	photon, polarized beam

C.40 hep-ph/9810342

Title:

Neutrino pair production by virtual photon in external magnetic field

Abstract

Production of a massive neutrino–antineutrino pair by a virtual polarized photon in the Weiberg–Salam model with mixing is studied. The rate of the neutrino production by photons with various polarizations is found at values of the magnetic field intensity lower than critical.

AI-HEPD Report:		SPIRES report:
neutrino, photoproduction		`neutrino, photoproduction`
neutrino, pair production		`neutrino, pair production`
neutrino, massive		`neutrino, massive`
photon, polarization	±	`polarization`
photon, off-shell		`photon, off-shell`
Salam-Weinberg model		`Salam-Weinberg model`
magnetic field, external field		`magnetic field, external field`
photon → neutrino antineutrino		
		`Feynman gauge`

C.41 hep-ph/9812391

Title: Field-induced axion emission via process $e^+e^- \to a$ in plasma

Abstract

The annihilation into axion $e^+e^- \to a$ is investigated in a plasma and an external magnetic field. This process via a plasmon intermediate state has a resonant character at a particular energy of the emitted axion. The emissivity by $e^+e^- \to a$ is compared with the axion cyclotron emissivity.

AI-HEPD Report:	SPIRES report:
electron positron, annihilation	`electron positron, annihilation`
axion, emission	`axion, emission`
external field, induced	
resonance	
magnetic field, external field	`magnetic field, external field`
plasma	`plasma`
S-matrix	`S-matrix`
coupling, (axion photon)	
plasmon, longitudinal	
plasmon, dispersion relations	
axion, dispersion relations	
plasmon, propagator	
energy, axion	`energy, axion`
cyclotron, emission (*)	
electron positron → axion	
electron → electron axion (*)	
coupling, (axion fermion)	
numerical calculations	`numerical calculations`

(*) means that these *keychains* have no direct relation to calculations performed. In this case the process studied is compared to the process $e^- \to e^- a$.

C.42 hep-ph/9812408

Title: Field-induced axion decay $a \to e^+e^-$ via plasmon

Abstract

The axion decay $a \to e^+e^-$ via a plasmon is investigated in an external magnetic field. The results we have obtained demonstrate a strong catalyzing influence of the field as the axion lifetime in the magnetic field of order 10^{15} G and at temperature of order 10 MeV is reduced to 10^4 sec.

AI-HEPD Report:	SPIRES report:
axion, leptonic decay	`axion, leptonic decay`
electron, pair production	
magnetic field, external field	`magnetic field, external field`
yield, enhancement	
plasmon, propagator	`plasma`
axion, dispersion relations	`dispersion relations`
plasmon, dispersion relations	
plasmon, longitudinal	
axion, lifetime	`axion, lifetime`
temperature	
numerical calculations	`numerical calculations`
axion → positron electron	
Feynman graph	
axion → positron electron	

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coupling, (axion photon)
plasma

C.43 hep-ph/9812425

Title: Field-induced axion decay $a \to e^+e^-$ in plasma

Abstract

The axion decay $a \to e^+e^-$ is investigated in the presence of a plasma and an external magnetic field. The results demonstrate a strong catalyzing influence of medium. The axion lifetime in the magnetic field of order 10^{15} G and at the temperature of order 10 MeV is reduced to 10^4 s.

AI-HEPD Report:		SPIRES report:
axion, leptonic decay	±	`axion, decay`
electron, pair production		
plasma		`plasma`
magnetic field, external field		`magnetic field, external field`
temperature		
yield, enhancement		
axion, lifetime		`axion, lifetime`
numerical calculations		
axion → positron electron		`axion → positron electron`
plasmon, propagator		
resonance		
coupling, (axion photon)		
coupling, (axion fermion)		
axion, dispersion relations		
plasmon, dispersion relations		
plasmon, longitudinal		
Feynman graph		

C.44 hep-ph/9702284

Title: Electromagnetic Catalysis of the Radiative Decay of the Axion

Abstract

The radiative decay of the axion $a \to \gamma\gamma$ is investigated in an external electromagnetic field in DFSZ model in which axion couples to both quarks and leptons at tree level. The decay probability is strongly catalyzed by the external field, namely, the field removes the main suppression caused by the smallness of the axion mass.

AI-HEPD Report:	SPIRES report:
axion, radiative decay	`axion, radiative decay`
electromagnetic field, external field	`electromagnetic field, external field`
coupling, (fermion axion)	`coupling, (quark axion)`
	`coupling, (lepton axion)`
yield, enhancement	
axion, mass	`axion, mass`
axion → 2photon	`axion --> 2photon`
fermion, propagator	
numerical calculation	`numerical calculations`

Remark: For the description of axion coupling with quarks and leptons we use the *keychain* "*coupling, (fermion axion)*"; in SPIRES report two *keychains* are used: "*coupling, (quark axion)*" and "*coupling, (lepton axion)*".

C.45 hep-ph/9702317

Title: Neutrino Magnetic Moment Behaviour in a Renormalizable Model

Abstract

We have shown in [1] that a neutrino magnetic moment form factor $\mu_\nu(q^2)$ could be considerably amplified at low momentum transfer, $q^2 \leq m_N^2$, at the cost of introducing an extra light neutral fermion N with mass m_N and nonzero magnetic moment. It was assumed that the magnetic moment of N would originate in a renormalizable way at a heavy scale M. While the enhancement of the neutrino magnetic moment was unambiguous, we stressed that in this effective Lagrangian approach an uncertainty persisted about the behaviour of $\mu_\nu(q^2)$ in the interval $m_N^2 \ll q^2 \ll M^2$. This is not unexpected in presence of a nonrenormalizable effective theory (a particle with bare magnetic moment). We show in a simple renormalizable model for the magnetic moment of particle N how a 2 loop calculation solves the ambiguity. In the domain $m_N^2 \ll q^2 \ll M^2$ we confirm the result obtained in [1] using a sharp cut-off . It is amusing that the correct results are given, as expected, through dimensional regularization in the full theory, but NOT in the effective lagrangian approach.

AI-HEPD Report:	SPIRES report:
neutrino, magnetic moment	`neutrino, magnetic moment`
neutrino, form factor	`neutrino, form factor`
form factor, magnetic	
form factor, electromagnetic	
momentum transfer, low	`momentum transfer, low`
fermion, neutral particle	`fermion, neutral particle`
fermion, mass	
fermion, magnetic moment	
effective Lagrangian	`effective Lagrangian`
radiative correction, higher-order	
model, renormalizable	`model, renormalizable`
regularization, dimensional	`regularization, dimensional`
Feynman graph, higher-order	

C.46 hep-ph/9702326

Title: Axion decay $a \to f\tilde{f}$ in a strong magnetic field

Abstract

The axion decay into charged fermion-antifermion pair $a \to f\ \tilde{f}$ is studied in external crossed and magnetic fields. The result we have obtained can be of use to re-examine the lower limit on the axion mass in case of possible existence of strong magnetic fields at the early Universe stage.

AI-HEPD Report:	SPIRES report:
axion, decay	`decay, axion`
fermion, pair production	`fermion, pair production`
magnetic field, external field	
magnetic field, high	`magnetic field, high`
electromagnetic field, external field	
axion, mass	`mass, axion`
lower limit	`lower limit`
astrophysics	`astrophysics, model`
numerical calculation	
axion → fermion antifermion	
coupling, (axion fermion)	
axion, lifetime	`axion, lifetime`
plasma	

±

C.47 hep-ph/9703237

Title: Ferromagnetism of Axion Domain Wall

Abstract

AI-HEPD Report:		SPIRES report:
domain wall, axion		`domain wall, axion`
domain wall, ferromagnet		`domain wall, ferromagnet`
baryon number		
lepton number		
electron, bound state		`electron, bound state`
p, bound state		`p, bound state`
spin, alignment		
potential, induced		
coupling, pseudovector		
coupling, (fermion axion)		`coupling, (fermion axion)`
axion, hadronic		
magnetic field	±	`magnetic field`

numerical calculations

In Model Report we have *keychain "magnetic field, production"*.

C.48 hep-ph/9705232

Title: Neutrinos in strong magnetic fields

Abstract

We compute the dispersion curves for neutrinos propagating in an extremely dense electroweak plasma, in the presence of very strong magnetic fields of order $B \leq M_W^2/e$. The neutrino self-energy is calculated in the one-loop approximation. We consider only contributions of the first Landau level to the propagator of the W-bosons, and distinguish between motion parallel or perpendicular to the external magnetic field. We find that the neutrino dispersion curve for parallel propagation to the field suggests a superfluid behavior. An interesting analogy with fractional QHE is pointed out. We obtain a neutrino effective mass which increases with the magnetic field.

AI-HEPD Report:		SPIRES report:
neutrino, dispersion relations	$\pm$	`dispersion relations`
electroweak interaction		`electroweak interaction, plasma`
plasma		
density, high		
magnetic field, high		`magnetic field, high`
magnetic field, external field		
neutrino, propagator		`neutrino, propagator`
propagator, renormalization		`propagator, renormalization`
energy levels		
energy, ground state		
W, propagator		`W, condensation`
superfluid		`superfluid`
kinematics		
		`perturbation theory, higher-order`
		`critical phenomena`
		`mass, operator`
		`symmetry, spontaneously broken`
		`numerical calculations`

C.49 hep-ph/9705456

Title: Spontaneous Magnetization of Axion Domain Wall and Primordial Magnetic Field

Abstract

We show that axion domain walls gain spontaneous magnetization in early universe by trapping either electrons or positrons with their spins polarized. The reason is that the walls produces an attractive potential for these particles. We argue that the wall bounded by an axionic superconducting string leaves a magnetic field after its decay. We obtain a field $\sim 10^{-23}$ Gauss on the scale of horizon at the recombination.

AI-HEPD Report:	SPIRES report:
domain wall, axion	`domain wall, axion`
domain wall, magnetic	`domain wall, magnetic`
astrophysics	`astrophysics, model`
electron, polarization	`electron, polarization`
positron, polarization	`positron, polarization`
spin, polarization	
potential, induced	
axion, string	
superconducting, string	`superconducting, string`
magnetic field	`magnetic field`

domain wall, decay
numerical calculationst

C.50 hep-ph/9708293

Title: About an influence of external electromagnetic fields on the axion decays

Abstract

Some results of an external electromagnetic field influence on axion decays are presented. It is shown that the field catalyzes substantially these processes. The result describing the axion decay $a \to f\tilde{f}$ we have obtained can be of use to re-examine the lower limit on the axion mass in case of possible existence of strong magnetic fields at the early Universe stage.

AI-HEPD Report:	SPIRES report:
axion, decay modes	`axion, decay modes`
electromagnetic field, external field	`electromagnetic field, external field`
magnetic field, high	
yield, enhancement	
fermion, pair production	`fermion, pair production`
axion, mass	`axion, mass`
lower limit	`lower limit`
astrophysics	`astrophysics`
numerical calculations	
axion → fermion antifermion	
axion, lifetime	`axion, lifetime`
coupling, (axion fermion)	
	`axion, radiative decay`

C.51 hep-ph/9708391

Title: Nucleon contribution to the neutrino electromagnetic vertex in matter

Abstract

We calculate the nucleon contribution to the electromagnetic vertex of a neutrino in a background of particles, including the effect of the anomalous magnetic moment of the nucleons. Explicit formulas for the form factors are given in various physical limits of practical interest. Several applications of the results are mentioned, including the effect of an external magnetic field on the dispersion relation of a neutrino in matter.

AI-HEPD Report:	SPIRES report:
vertex function, (2neutrino photon)	`vertex function, (2neutrino photon)`
vertex function, electromagnetic	`electromagnetic`
nucleon, magnetic moment	`nucleon, magnetic moment`
magnetic moment, anomaly	
form factor	`form factor`
magnetic field, external field	`magnetic field, effect`
neutrino, dispersion relations	`neutrino, dispersion relations`
dispersion relations, matter	
dispersion relations, magnetic field	
coupling, neutral current	
coupling, electromagnetic	
nucleon, coupling	
nucleon, off-shell	
Feynman graph, higher order	
	`matter, background`

C.52 hep-ph/9709218

Title: Radiative transition of massless neutrino in strong magnetic field

Abstract

Radiative transition of massless neutrino $\nu_l \to \nu_l + \gamma$ $(l = e, \mu, \tau)$ in a strong magnetic field is investigated in the framework of the Standard Model. The process probability and the mean values of the neutrino energy and momentum loss are presented. Possible astrophysical manifestation of the process considered is analysed.

AI-HEPD Report:	SPIRES report:
neutrino, transition	`neutrino, bremsstrahlung`
neutrino, massless	`neutrino, massless`
photon, radiation	`neutrino, radiative decay`
magnetic field, high	`magnetic field, high`
electroweak interaction	`electroweak interaction`
neutrino, energy loss	`neutrino, energy loss`
neutrino, energy-momentum	
astrophysics	
photon, dispersion relations	
neutrino → neutrino photon	

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gamma ray burst
vacuum polarization

C.53 hep-ph/9709268

Title: Creation of photons and electron - positron pairs by a neutrino in a strong magnetic field

Abstract

The processes of the photon and electron–positron pair production by a neutrino propagating in a strong magnetic field are investigated in the framework of the Standard Model. The process probabilities and the mean values of the neutrino energy and momentum loss are calculated. Possible astrophysical manifestations of the processes considered are briefly analysed.

AI-HEPD Report:	SPIRES report:
neutrino, transition	`transition, electromagnetic`
flavor, conservation law	
neutrino, radiative decay	`neutrino, radiative decay`
photon, radiation	`photon, emission`
neutrino, leptonic decay	
electron, pair production	`electron, pair production`
magnetic field, high	`magnetic field, strong field`
electroweak interaction	`electroweak interaction`
neutrino, energy loss	`energy loss, momentum`
neutrino, energy-momentum	
astrophysics	`astrophysics, supernova`
plasma	`plasma`
numerical calculations	
neutrino → neutrino photon	
neutrino → positron electron neutrino	
angular distribution, asymmetry	
pulsar, velocity	
gamma ray burst	
	`vertex function, (2neutrino photon)`
	`four-fermion interaction`
	`Feynman graph`
	`n, matter`

C.54 hep-ph/9709420

Title: Photon-neutrino interactions in magnetic fields

Abstract

The low-energy two neutrino-two photon interactions in the presence of homogeneous magnetic field are studied. The cross sections in external magnetic field are shown to be larger than in vacuum by factor $\sim (m_W\ /m_e)^4\,(B/B_c)^2$. The energy-loss rate due to the process $\gamma\gamma \to \nu\overline{\nu}$ in magnetic field is obtained.

AI-HEPD Report:		SPIRES report:
vertex function, (2neutrino 2photon)		
magnetic field, external field	±	`magnetic field`
photon photon, exclusive reaction		`photon photon, exclusive reaction`
neutrino, pair production		`neutrino, pair production`
channel cross section		`channel cross section`
energy loss		
photon photon → neutrino antineutrino		
effective Lagrangian		`effective Lagrangian`
		`scattering, photon neutrino`

C.55 hep-ph/9710219

Title: Neutrino transitions $\nu \to \nu\gamma$, $\nu \to \nu e^+e^-$ in a strong magnetic field as a possible origin of cosmological γ-burst

Abstract

The high energy neutrino transitions with the photon and electron-positron pair creation in a strong magnetic field in the framework of the Standard Model are investigated. The process probabilities and the mean values of the neutrino energy and momentum loss are presented. The asymmetry of outgoing neutrinos, as a possible source of sufficient recoil "kick" velocity of a remnant and the emission of e^+e^--pairs and γ-quanta in a "polar cap" region of a remnant, as a possible origin of cosmological γ-burst are discussed.

AI-HEPD Report:	SPIRES report:
neutrino, transition	
neutrino, radiative decay	neutrino, radiative decay
neutrino, leptonic decay	neutrino, leptonic decay
electron, pair production	lepton, pair production
flavor, conservation law	
neutrino, relativistic	
magnetic field, high	magnetic field, external field
electroweak interaction	electroweak interaction
neutrino, energy loss	neutrino, energy loss
neutrino, energy-momentum	
neutrino, emission	
angular distribution, asymmetry	
pulsar, velocity	
gamma ray burst	
neutrino → neutrino photon	neutrino → neutrino photon
neutrino → positron electron neutrino	neutrino → positron electron neutrino
	astrophysics, supernova
	n, matter
	0 neutrino, massive
	0 photon, cosmic radiation

C.56 hep-ph/9710305

Title: Nucleon effects on the photon dispersion relations in matter

Abstract

We calculate the nucleon contribution to the photon self-energy in a plasma, including the effect of the anomalous magnetic moment of the nucleons. General formulas for the transverse and longitudinal components of the self-energy are obtained and we give explicit results in various limits of physical interest. The formulas are relevant for the study of the photon dispersion relations and the dynamical susceptibility in a nuclear medium such as the core of a supernova, and has implications with regard to the recent suggestion that the Cerenkov process $\nu \to \nu\gamma$ can take place in such a system.

AI-HEPD Report:		SPIRES report:
photon, dispersion relations	±	`dispersion relations`
nuclear matter		`nuclear matter`
plasma		`fplasma`
photon, propagator		`photon, propagator`
renormalization		`renormalization`
nucleon, magnetic moment		`nucleon, magnetic moment`
magnetic moment, anomaly		
propagator, longitudinal		
propagator, transverse		
nucleon, off-shell		
susceptibility		`susceptibility`
astrophysics, supernova		`astrophysics, supernova`
radiation, Cherenkov		
neutrino, radiative decay		
fermion, gas		`fermion, gas`
background, electron		`background, electron`
neutrino → neutrino photon		

C.57 hep-ph/9712289

Title: Photon decay $\gamma \to \nu\bar{\nu}$ in an external magnetic field

Abstract

The process of the photon decay into the neutrino - antineutrino pair in a magnetic field is investigated. The amplitude and the probability are analysed in the limits of relatively small and strong fields. The probability is suppressed by a factor $(G_F\ m_e^2)^2$ as compared with the probability of the pure electromagnetic process $\gamma \to e^- e^+$. However, the process with neutrinos could play a role of an additional channel of stellar energy-loss.

AI-HEPD Report:	SPIRES report:
photon, decay	`photon, decay`
neutrino, pair production	`neutrino, pair production`
magnetic field, external field	`magnetic field, external field`
electron, propagator	
propagator, magnetic field	
star, energy loss	`photon, energy loss`
Feynman graph	`Feynman graph`
photon → neutrino antineutrino	`photon --> neutrino antineutrino`
photon, dispersion relations	
photon, polarization	`photon, polarization`
electroweak interaction	
neutrino, luminosity	
astrophysics	
	`neutrino, current`
	`form factor`
	`photon, width`

C.58 hep-ph/9712423

Title: Field-induced axion decay $a \to e^+e^-$ in KSVZ-model

Abstract

The axion decay into electron-positron pair $a \to e^+e^-$ is studied in an external magnetic field in KSVZ-model where axions have only induced coupling to leptons. The axion lifetime in the field decreases with energy and field strength to seconds.

AI-HEPD Report:	SPIRES report:
axion, leptonic decay	`axion, leptonic decay`
electron, pair production	`electron, pair production`
magnetic field, external field	`magnetic field, external field`
coupling, (lepton axion)	
coupling, induced	
axion, hadronic	`axion, hadronic`
axion, lifetime	`axion, lifetime`
axion → positron electron	
numerical calculations	

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photon, propagator

C.59 hep-ph/9604028

Title: Photon Splitting in a Very Strong Magnetic Field

Abstract

Photon splitting in a very strong magnetic field is analyzed for energy $\omega < 2m$. The amplitude obtained on the base of operator-diagram technique is used. It is shown that in a magnetic field much higher than critical one the splitting amplitude is independent on the field. Our calculation is in a good agreement with previous results of Adler and in a strong contradiction with recent paper of Mentzel et al.

AI-HEPD Report:	SPIRES report:
photon, radiative decay	
final state, (2photon)	
magnetic field, high	`magnetic field, strong field`
operator, mathematical methods	
energy dependence	
photon → 2photon	
photon, polarization	
	`electron positron, annihilation`
	`effective Lagrangian`
	`scattering amplitude`

C.60 hep-ph/9608266

Title: Stimulated Neutrino Conversion and Bounds on Neutrino Magnetic Moments

Abstract

Recent experiment proposed to observe induced radiative neutrino transitions are confronted to existing bounds on neutrino magnetic moments from earth-based experiments. These are found to exclude any observation by several orders of magnitude, unless the magnetic moments are assumed to be strongly momentum dependent. This possibility is discussed in some generality, and we find that nontrivial dependence of the neutrino form factor may indeed occur, leading to quite unexpected effects, although this is insufficient by orders of magnitude to justify the experiments.

AI-HEPD Report:		SPIRES report:
neutrino, transition		`neutrino, transition`
transition, induced		
photon, radiation		
neutrino, magnetic moment		`neutrino, magnetic moment`
magnetic moment, momentum dependence	±	`momentum dependence`
neutrino, form factor		`neutrino, form factor`
form factor, dependence		
interpretation of experiments		
numerical calculations		
neutrino → neutrino photon		
form factor, magnetic		
interpretation of experiments		`interpretation of experiments`

C.61 hep-ph/9610219

Title: The radiative decay of the massive neutrino in the external electromagnetic fields

Abstract

The radiative decay of the massive neutrino $\nu_i \to \nu_j \gamma$ is investigated in the framework of the Standard Model in external electromagnetic fields of various configurations: constant crossed field, constant uniform magnetic

field, plane monochromatic wave's field. The effect of significant enhancement of the neutrino decay probability by the external field (electromagnetic catalysis) is discussed. An especially strong enhancement occurs in the case of the ultrarelativistic neutrino decay, since in this case the decay probability does not contain suppression caused by the smallness of the decaying neutrino mass. The ultrarelativistic neutrino decay catalysis is significant even in a relatively weak external field ($F/F_e \ll 1$, where F_e is the critical Schwinger value). The expression for the photon splitting probability into the neutrino pair $\gamma \to \nu_i \bar{\nu}_j$ in the wave field is given. The estimations of a number of gamma-quanta produced in a volume filled with an electromagnetic field and the neutrino lifetime in a strong magnetic field are presented.

AI-HEPD Report:	SPIRES report:
neutrino, radiative decay	`neutrino, radiative decay`
neutrino, massive	`neutrino, massive`
flavor, violation	
electroweak interaction	`electroweak interaction`
electromagnetic field, external field	`electromagnetic field, external field`
magnetic field, external field	
magnetic field, high	`magnetic field, high`
yield, enhancement	
neutrino, relativistic	`neutrino, relativistic`
photon, decay	
neutrino, pair production	`neutrino, pair production`
neutrino, lifetime	`neutrino, lifetime`
numerical calculations	
neutrino → neutrino photon	`neutrino → neutrino photon`
photon → neutrino antineutrino	`photon → 2neutrino`

Feynman graph

C.62 hep-ph/9610253

Title: Neutrino Radiative Decay in an External Electromagnetic Field via Vector Leptoquark

Abstract

The massive neutrino radiative decay $\nu_i \to \nu_j \gamma$ $(i \neq j)$ is investigated within the Minimal Quark-Lepton Symmetry of the Pati-Salam type based on the $SU(4)_V \times SU(2)_L \times G_R$ group in an external constant crossed field $(\vec{\mathcal{E}} \perp \vec{H},\ \mathcal{E} = H)$. The matrix element $\Delta M^{(X)}$ and the decay probability $W^{(X)}$ due to the leptoquark X contribution are analysed. The effect of significant enhancement of the neutrino decay by the crossed field takes place. It is shown that the leptoquark contribution to the decay probability can dominate over the W-boson one in the case of strong suppression of the lepton mixing in the framework of the SM.

AI-HEPD Report:	SPIRES report:
neutrino, radiative decay	`neutrino, radiative decay`
flavor, violation	
neutrino, massive	`neutrino, massive`
electromagnetic field, external field	`electromagnetic field, external field`
lepton quark, symmetry	`lepton quark, symmetry`
leptoquark, vector	`leptoquark`
symmetry, $SU(4)_V \times SU(2)_L \times G_R$	`symmetry,` $SU(4) \times SU(2)$
effective Lagrangian	
lepton quark, interaction	
yield, enhancement	
lepton, interference (*)	
electroweak interaction (*)	
neutrino, relativistic	
neutrino → neutrino photon	`neutrino → neutrino photon`
	`amplitude analysis, decay`

C.63 hep-ph/9610253

Title: Radiative neutrino decays in very strong magnetic fields

Abstract

The radiative decay $\nu_H \to \nu_L + \gamma$ of massive neutrinos is analyzed in the framework of the standard model with lepton mixing for very strong magnetic fields $B \gg B_{\rm cr} = m_e^2/e \sim 4.14 \times 10^{13}$ G. The analysis is based on the approximate decay amplitude obtained by Gvozdev *et al.* Numerical results as well as analytical approximations for the decay rate are obtained for energies of the initial neutrino below and *above* the electron-positron pair creation threshold $2m_e$.

AI-HEPD Report:		SPIRES report:
neutrino, radiative decay		`neutrino, radiative decay`
neutrino, massive	±	`neutrino, mass`
magnetic field, high	±	`magnetic field`
flavor, violation		
electroweak interaction		
lepton, interference		`neutrino, interference`
amplitude analysis, decay		
electron, pair production		
threshold, pair production		
numerical calculations		`numerical calculations`
neutrino → neutrino photon		`neutrino → neutrino photon`
four-fermion interaction		`four-fermion interaction`
electron, propagator		
neutrino, lifetime		`neutrino, width`
Feynman graph		`Feynman graph`
		`energy spectrum, (photon)`
		`astrophysics, model`

C.64 hep-ph/9612285

Title: Cherenkov radiation by massless neutrinos in a magnetic field

Abstract

We calculate the Cherenkov process $\nu \to \nu\gamma$ in the presence of a homogeneous magnetic field. The neutrinos are taken to be massless with only standard-model couplings. The magnetic field fulfills the dual purpose of inducing an effective neutrino-photon vertex and of modifying the photon dispersion relation such that the Cherenkov condition $\omega < |\mathbf{k}|$ is fulfilled. Our effect is closely related to photon splitting that occurs in magnetic fields and that may be astrophysically important in the strong magnetic fields of pulsars. It is also closely related to magnetic-field enhanced radiative decays $\nu \to \nu'\gamma$ that have been extensively discussed in the recent literature. In the appropriate limits we agree with these results, but we disagree with earlier explicit calculations of the Cherenkov process. For a field strength $B_{\rm crit} = m_e^2/e = 4.41 \times 10^{13}$ Gauss and for $E = 2m_e$ the Cherenkov rate is about 6×10^{-11} s^{-1} and thus too small to be of practical importance for pulsar physics.

AI-HEPD Report:	SPIRES report:
radiation, Cherenkov	`radiation, Cherenkov`
neutrino, radiative decay	`neutrino, radiative decay`
magnetic field, external field	`magnetic field, external field`
magnetic field, high	
neutrino, massless	`neutrino, massless`
electroweak interaction	
vertex function, (neutrino photon)	`vertex function, (neutrino photon)`
electron, propagator	
propagator, magnetic field	
photon, dispersion relations	`photon, dispersion relations`
astrophysics	
pulsar	
photon, yield	
Feynman graph	
neutrino → neutrino photon	`neutrino --> neutrino photon`
photon, polarization	
numerical calculations	

C.65 hep-ph/9612312

Title: The neutrino energy and momentum loss through the process $\nu \to \nu e^- e^+$ in a strong magnetic field

Abstract

A process of the electron–positron pair production by neutrino propagating in a strong magnetic field is investigated in the framework of the Standard Model. The process probability and the mean values of the neutrino energy and momentum loss are calculated. Possible astrophysical manifestations of the process considered are briefly analysed.

AI-HEPD Report:		SPIRES report:
neutrino, leptonic decay		
electron, pair production		`electron, pair production`
flavor, conservation law		
magnetic field, high	±	`magnetic field`
electroweak interaction		`electroweak interaction`
neutrino, energy loss		`neutrino, energy loss`
neutrino, energy-momentum	±	`neutrino, momentum`
astrophysics		`astrophysics, supernova`
neutrino →		`neutrino -->`
positron electron neutrino		`positron electron neutrino`
		`n, matter`
effective Lagrangian		`effective Lagrangian`
momentum, asymmetry		
velocity, pulsar		

C.66 hep-ph/9509415

Title: Cerenkov radiation by massless neutrinos

Abstract

Due to their weak interactions, neutrinos can polarize a medium and acquire an induced charge. We consider the Cherenkov radiation emitted by neutrinos due to their effective electromagnetic interactions as they pass through a polarizable medium. The effect exists even for massless, chiral neutrinos, where no physics beyond the standard model needs to be assumed.

AI-HEPD Report:	SPIRES report:
matter, polarization	
charge, induced	`neutrino, charge`
radiation, Cherenkov	`radiation, Cherenkov`
neutrino, radiative decay	
neutrino, electromagnetic interaction	`neutrino, electromagnetic interaction`
neutrino, massless	`neutrino, massless`
electroweak interaction	
vertex function, (2neutrino photon)	`vertex function, (2neutrino photon)`
photon, polarization	
polarization, transverse	`photon, transverse`
polarization, longitudinal	`photon, longitudinal`
kinematics	`kinematics`
numerical calculations	`numerical calculations`
neutrino → neutrino photon	
	`photon, emission`

C.67 hep-ph/9506429

Title: Electromagnetic catalysis of a neutrino radiative decay or one more source of information on the lepton mixing angles?

Abstract

The radiative decay of ultrarelativistic massive neutrino $\nu_i \to \nu_j\gamma$ is investigated in electromagnetic fields in the framework of the Standard Model with lepton mixing. Estimates of the decay probability and "decay cross-section" for accelerator neutrinos of high energies in the electric field of nucleus permit one to discuss the general possibility of carrying out the neutrino experiment. Such an experiment could give unique information on mixing angles in the lepton sector of the Standard Model which would be almost independent of the specific neutrino masses.

AI-HEPD Report:	SPIRES report:
neutrino, radiative decay	`neutrino, radiative decay`
flavor, violation	
neutrino, relativistic	
neutrino, massive	`neutrino, massive`
lepton, mixing angle	`lepton, mixing angle`
yield, enhancement	
electromagnetic field	`electromagnetic field, external field`
nucleus, electric field	`nucleus, electric field`
electroweak interaction	
lepton, interference	
cross section, decay	
neutrino → neutrino photon	

C.68 hep-ph/9510211

Title: The Paradox of axions surviving primordial magnetic fields

Abstract

In the presence of primordial magnetic fields the oscillating cosmic axion field drives an oscillating electric field. The ensuing dissipation of axions is found to be inversely proportional to the conductivity of the primordial plasma. This counterintuitive result is essentially equivalent to "Zeno's paradox" or the "watched-pot effect" of quantum mechanics. It implies that the standard predictions of the cosmic axion density remain unaltered even if primordial magnetic fields are strong.

AI-HEPD Report:		SPIRES report:
magnetic field, external field		`magnetic field, external field`
cosmic radiation, axion		`cosmic radiation, axion`
axion, oscillation		
electric field, oscillation		
dissipation, effect		
conductivity, plasma	±	`plasma`
axion, density		`axion, density`

C.69 hep-ph/9404289

Title: The Radiative decay of a high-energy neutrino in the Coulomb field of a nucleus

Abstract

In the framework of the Standard Model with lepton mixing the radiative decay $\nu_i \to \nu_j \gamma$ of a neutrino of high ($E_\nu \sim 100\,GeV$) and super-high ($E_\nu \geq 1\,TeV$) energy is investigated in the Coulomb field of a nucleus. Estimates of the decay probability and "decay cross-section" for neutrinos of these energies in the electric field of a nucleus permit one to discuss the general possibility of carrying out a neutrino experiment, subject to the condition of availability in the future of a beam of neutrinos of these high energies. Such an experiment could give unique information on mixing angles in the lepton sector of the Standard Model which would be independent of the specific neutrino masses if only the threshold factor $(1-m_j^4/m_i^4)$ was not close to zero.

AI-HEPD Report:	SPIRES report:
neutrino, radiative decay	`neutrino, radiative decay`
flavor, violation	
neutrino, relativistic	
neutrino, massive	
external field, Coulomb	
nucleus, electric field	`nucleus, electric field`
electroweak interaction	`electroweak interaction`
lepton, interference	`lepton, interference`
lepton, mixing angle	`lepton, mixing angle`
mass, threshold	
neutrino, beam	
cross section, decay	`cross section, decay`
neutrino → neutrino photon	

C.70 hep-ph/9404290

Title: Electromagnetic catalysis of the radiative transitions of $\nu_i \to \nu_j\gamma$ type in the field of an intense monochromatic wave

Abstract

The radiative decay of the massive neutrino $\nu_i \to \nu_j\gamma$ in a circularly polarized electromagnetic wave is investigated within the Standard theory with lepton mixing. The decay probability in the wave field does not contain a threshold factor $\sim (1 - m_i/m_j)$ as opposed to the decay probability in a vacuum or in a constant uniform external field. The phenomenon of the gigantic enhancement ($\sim 10^{33}$) of the neutrino decay probability in external wave field is discovered. The probability of the photon splitting into the neutrino pair is obtained.

AI-HEPD Report:	SPIRES report:
neutrino, radiative decay	`neutrino, radiative decay`
neutrino, massive	`neutrino, massive`
flavor, violation	
electromagnetic field, external field	`electromagnetic field, polarization`
electroweak interaction	`electroweak interaction`
lepton, interference	`lepton, interference`
mass, threshold	
yield, enhancement	
photon, decay	`photon, decay`
neutrino, pair production	`neutrino, pair production`
neutrino → neutrino photon	
photon → neutrino antineutrino	

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neutrino, relativistic
numerical calculations

C.71 hep-ph/9409447

Title: One more source of information on the lepton mixing angles

Abstract

In the framework of the Standard Model with lepton mixing the radiative decay $\nu_i \to \nu_j \gamma$ of a neutrino of high ($E_\nu \sim 100\,GeV$) and super-high ($E_\nu \geq 1\,TeV$) energy is investigated in the Coulomb field of a nucleus. Estimates of the decay probability and "decay cross-section" for neutrinos of these energies in the electric field of nucleus permit one to discuss the general possibility of carrying out the neutrino experiment, subject to the condition of availability in the future of a beam of neutrinos of that high energies. Such an experiment could give unique information on mixing angles in the lepton sector of the Standard Model which would be independent of the specific neutrino masses if only the threshold factor $(1 - m_j^4/m_i^4)$ was not close to zero.

AI-HEPD Report:		SPIRES report:
lepton, mixing angle		`lepton, mixing angle`
electroweak interaction		`electroweak interaction`
lepton, interference		
neutrino, radiative decay		`neutrino, radiative decay`
flavor, violation		
external field, Coulomb		`potential, Coulomb`
nucleus, electric field		
neutrino, beam		
neutrino, relativistic		
neutrino, mass		`neutrino, massive`
mass, threshold		
cross section, decay	$\pm$	`cross section`
neutrino → neutrino photon		
		`neutrino nucleus, electromagnetic interaction`
		`numerical calculations`
	0	`100 GeV, > 1000 GeV`

C.72 astro-ph/9903251

Title: A Possible Origin of Gamma Ray Bursts and Axionic Boson Stars

Abstract

We indicate a possible mechanism of generating gamma ray bursts. They are generated by a collision between an axionic boson star and a neutron star. The axionic boson star can dissipates its whole energy 10^{50} erg in the magnetized conducting medium of the neutron star. This dissipation arises only around envelope of the neutron star so that a fire ball with small baryon contamination is expected. We have evaluated roughly a rate of the collision per year and per galaxy which is consistent with observations, under plausible assumptions. We also point out that cosmic rays with extremely high energy, 10^{21}eV, can be produced in the similar collisions with the neutron stars with strong magnetic fields $\sim 10^{14}$G.

AI-HEPD Report:	SPIRES report:
gamma ray burst	
axion, star	`axion, matter`
boson, matter	`boson, matter`
n, matter	`n, matter`
astrophysics	`astrophysics, missing-mass`
matter, magnetic	
energy, dissipation	
fireball	
magnetic field, high	
cosmic radiation, production	`cosmic radiation, particle source`
numerical calculations	`numerical calculations`
	`photon, cosmic radiation`
	`matter, scattering`

C.73 astro-ph/9701056

Title: Axion cyclotron emissivity of magnetized white dwarfs and neutron stars

Abstract

The energy loss rate of a magnetized electron gas emitting axions a due to the process $e^- \to e^- + a$ is derived for arbitrary magnetic field strength B. Requiring that for a strongly magnetized neutron star the axion luminosity is smaller than the neutrino luminosity we obtain the bound $g_{ae} < 10^{-10}$ for the axion electron coupling constant. This limit is considerably weaker than the bound derived earlier by Borisov and Grishina using the same method. Applying a similar argument to magnetic white dwarf stars results in the more stringent bound $g_{ae} < 9 \cdot 10^{-13}(T/10^7\mathrm{K})^{5/4}(B/10^{10}\mathrm{G})^{-2}$, where T is the internal temperature of the white dwarf.

AI-HEPD Report:	SPIRES report:
axion, emission	`axion, emission`
cyclotron, emission	
electron, gas	`electron, gas`
energy loss	`electron, energy loss`
magnetic field, external field	`magnetic field, external field`
magnetic field, high	
coupling, (axion electron)	
temperature	
n, matter	`n, matter`
matter, magnetic	
astrophysics, white dwarf	
axion, luminosity	`luminosity, axion`
neutrino, luminosity	
numerical calculations	`numerical calculations`
electron → electron axion	

C.74 astro-ph/9702155

Title: Neutrino pair emission due to scattering of electrons off fluxoids in superfluid neutron star cores

Abstract

We study the emission of neutrinos, resulting from the scattering of electrons off magnetic flux tubes (fluxoids) in the neutron star cores with superfluid (superconducting) protons. In the absence of proton superfluidity ($T \geq T_{cp}$), this process transforms into the well known electron synchrotron emission of neutrino pairs in a locally uniform magnetic field B, with the neutrino energy loss rate Q proportional to B^2T^5. For temperatures T not much below T_{cp}, the synchrotron regime ($Q \propto T^5$) persists and the emissivity Q can be amplified by several orders of magnitude due to the appearance of the fluxoids and associated enhancement of the field within them. For lower T, the synchrotron regime transforms into the bremsstrahlung regime ($Q \propto T^6$) similar to the ordinary neutrino-pair bremsstrahlung of electrons which scatter off atomic nuclei. We calculate Q numerically and represent our results through a suitable analytic fit. In addition, we estimate the emissivities of two other neutrino-production mechanisms which are usually neglected – neutrino-pair bremsstrahlung processes due to electron-proton and electron-electron collisions. We show that the electron-fluxoid and electron-electron scattering can provide the main neutrino production mechanisms in the neutron star cores with highly superfluid protons and neutrons at $T \leq 5\times10^8$ K. The electron-fluxoid scattering is significant if the initial, locally uniform magnetic field $B \geq 10^{13}$ G.

AI-HEPD Report:		SPIRES report:
neutrino, emission		`neutrino, emission`
neutrino, pair production		`neutrino, pair production`
electron, scattering		`electron, scattering`
flux tube, magnetic		`flux tube, magnetic`
n, matter		`n, matter`
p, superfluid		`p, superfluid`
p, superconducting		`p, superconducting`
neutrino, synchrotron radiation	±	`synchrotron radiation`
magnetic field, external field		
neutrino, energy loss	±	`energy loss`
neutrino, bremsstrahlung		`neutrino, bremsstrahlung`
electron p, interaction		`electron p, interaction`
electron electron, interaction		`electron electron, interaction`
astrophysics		
temperature, low		
temperature, high		
numerical calculations		`numerical calculations`

C.75 astro-ph/9708181

Title: Neutrino synchrotron emission from dense magnetized electron gas of neutron stars

Abstract

We study the synchrotron emission of neutrino pairs by relativistic, degenerate electrons in strong magnetic fields. Particular attention is paid to the case in which the dominant contribution comes from one or several lowest cyclotron harmonics. Calculations are performed using the exact quantum formalism and the quasiclassical approach. Simple analytic fits to the neutrino synchrotron emissivity are obtained in the domain of magnetized, degenerate and relativistic electron gas provided the electrons populate either many Landau levels or the ground level alone. The significance of the neutrino synchrotron energy losses in the interiors of cooling neutron stars is discussed.

AI-HEPD Report:		SPIRES report:
neutrino, synchrotron radiation		`neutrino, synchrotron radiation`
neutrino, pair production		
magnetic field, high	±	`magnetic field`
quantum mechanics		`quantum mechanics`
approximation, quasiclassical		`approximation, quasiclassical`
electron, gas		`electron, gas`
gas, magnetic		
gas, relativistic	±	`relativistic`
electron, energy levels		
energy, excited state		
energy, ground state		
neutrino, energy loss	±	`energy loss`
astrophysics		`astrophysics`
n, matter		`n, matter`
temperature		
plasmon, decay		
electron →		
electron neutrino antineutrino		
numerical calculations		`numerical calculations`

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plasma (*)
bremsstrahlung (*)

C.76 astro-ph/9709204

Title: Are strongly magnetized degenerate stars cooling by axion emission?

Abstract

We considered recently as a new axion production mechanism the process $e^- \to e^- + a$ in a strong magnetic field B. Requiring that for a strongly magnetized neutron star the axion luminosity is smaller than the neutrino luminosity we obtained the bound $g_{ae} < 10^{-10}$ for the axion electron coupling constant. This limit is considerably weaker than the bound derived earlier by Borisov and Grishina using the same method. Applying a similar argument to magnetic white dwarf stars we obtained $g_{ae} < 9 \cdot 10^{-13}(T/10^7\mathrm{K})^{5/4}(B/10^{10}\mathrm{G})^{-2}$, where T is the internal temperature of the white dwarf. Here we note that the observed lack of magnetized white dwarfs with low-temperature in the galactic disc could also be interpreted as a signature of axion emission. Moreover, we speculate that axion emission could explain why the putative galactic halo population of white dwarfs is so dim.

AI-HEPD Report:		SPIRES report:
axion, emission		`axion, emission`
cyclotron, emission		
magnetic field, external field		`magnetic field, external field`
magnetic field, high		
astrophysics, white dwarf	±	`astrophysics`
n, matter		`n, matter`
matter, magnetic		
temperature		
star, energy loss		
axion, luminosity		`luminosity, axion`
neutrino, luminosity		
coupling, (electron axion)		`coupling constant, (electron axion)`
lower limit		`lower limit`
numerical calculations		`numerical calculations`
electron → electron axion		

electron, gas

C.77 astro-ph/9604117

Title: Neutrino-pair emission due to electron-phonon scattering in a neutron star crust

Abstract

Neutrino-pair bremsstrahlung radiation is considered due to electron–phonon scattering of degenerate, relativistic electrons in a lattice of spherical atomic nuclei in a neutron star crust. The neutrino energy generation rate is calculated taking into account exact spectrum of phonons, the Debye–Waller factor, and the nuclear form–factor in the density range from 10^7 g cm^{-3} to 10^{14} g cm^{-3} at arbitrary nuclear composition for body-centered-cubic and face-centered-cubic Coulomb crystals. The results are fitted by a unified analytic expression. A comparison is given of the neutrino bremsstrahlung energy losses in a neutron star crust composed of ground state and accreted matter, in the solid and liquid phases.

AI-HEPD Report:		SPIRES report:
neutrino, pair production		`neutrino, pair production`
neutrino, bremsstrahlung		`neutrino, bremsstrahlung`
neutrino, emission		
scattering, electron phonon		`scattering, electron phonon`
electron nucleus, interaction		
electron, relativistic		
astrophysics		`astrophysics`
n, matter		`n, matter`
nucleus, lattice		`nucleus, lattice`
nucleon, form factor		
crystal, Coulomb		
neutrino, energy loss	$\pm$	`energy loss`
matter, accretion		
temperature		
numerical calculations		`numerical calculations`
		`fermion, statistics`

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