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The Modelling of the Electron-Drift Process under General Conditions: Application to the ZEUS Forward Drift Chambers

by

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Abstract

This is a description of the usage of the programs developed to model the behaviour of the ZEUS forward drift chambers under variation of many of the relevant parameters.
The difficult operating conditions for the chamber (very inhomogeneous magnetic field (3D), influence of dielectrics on the 2D/3D electric field) require a program structure which is general enough to be used to design other drift chambers with small cells.
Time consuming parts of the programs are well-vectorized and run both interactively and in batch on DESY's IBM 3090. The batch version was also used on VAX and CRAY systems.
The environment to calculate the required electrostatic field using the computer code PROFI is also described.

1 Introduction

To model the electron drift process in a drift chamber one needs (cf. [PalSad74], [Sauli77]):

- The cross sections of the gases used,
- the electric field inside the drift chamber, and
- the magnetic field applied.

For the forward drift chambers of the ZEUS detector at the electron proton storage ring HERA at DESY in Hamburg [ZeusTP] we have the additional problem of a very inhomogeneous magnetic field (gradients of up to 2 - 3 Tesla/m). Thus we can't apply the customary simplifications but have to solve the underlying mathematical problem (Boltzmann transport equation) almost in its full complexity. Following [PalSad74], a program was developed to fulfill this task [Schnei87], [Dob90]. Several sets of the required gas cross sections are implemented (momentum transfer und inelastic cross sections from different sources). To use other cross sections or gases, only one of the subroutines has to be modified. The various electric and magnetic fields are computed with other codes and are FORTRAN input for our program.

The calculation of the electric field using the program package PROFI is presented in section 2. This program package, version 6.2, runs under licence on DESY's IBM. It was compiled with the IBM VS2 compiler, which allows under the operating system MVS/XA the dynamical management of large virtual memory regions. To solve the POISSON equation with a sufficient accuracy we need often regions of several tens of MBytes.

In section 3, some comments on the magnetic field and its usage are made. We do not compute the magnetic field, but explain how it is involved into our calculations. Again, only one of the subroutines of our program has to be changed to use a magnetic field from another source.

In the last section, we describe the interactive environment required to use the program TRRPNEW modelling the electron drift process on DESY's IBM 3090. In this environment, one can both run the program interactively and submit batch jobs. In each case, one will take advantage of the vector facility, which shortens the execution time by a factor of 2 - 3. The batch version is also available on CRAY and VAX systems.

Notice that all these considerations are instructions for the further usage of the programs in the ZEUS collaboration, but we think that the program structures are general enough to be taken over for similar problems, simply by exchange of the geometry dependent subroutines, the gas cross sections and the electric / magnetic field data.

2 Calculation of the electric field

We performed electric field calculations using the finite difference code PROFI, version 6.2 [Profi82]. The treatment of small wires with a finite difference code is more expensive compared with the usual programs for drift chamber development, but we are able to include dielectrics and 3D calculations.

The 'files' required to compute the electric field inside a 2D cross section of the FTD/RTD are stored in the partitioned data set F12DOB.PDS.PROFI62. Beside other data, it contains the various input members IH..... and IF..... used for the preprocessor PROFCOM2, the Clist (= Command list) @PROFCO2 to start the preprocessor and the Clist @SNAP to make a 'snapshot' of a PROFI direct access output file.

First we will explain the naming conventions for the input members for PROFCOM2 and the output files of PROFI (which are not members of F12DOB.PDS.PROFI62, but independent data sets). Each name consists of 7 letters or digits as shown in figure 1.

The first letter indicates the type of the file. I stands for a PROFCOM2 input file and R for a PROFI 'RETT file' which stores the potential values after a certain number of iterations (the usage

I *R* *D* *S*	*H* *F*	*1* *2* *3* *4*	*M*	*1* *2* *3*	*S* *U*	*(O)* *(1)* *(2)* *(H)*

Figure 1: The letters / digits used in the names of the drift chamber data files.

of 'RETT files' is recommended for really large field problems to split a large job into several smaller ones). The PROFI output is written to a direct access file (D as first letter of the name of the file) and then transformed into a portable sequential file which is denoted by a S.

The second letter states whether the field inside a half cell or a full cell is calculated. H stands for half cell, F stands for full cell. In the first case, the field inside the other part of the cell can be obtained by a point reflection. Nevertheless, with a staggering of the sense wires, this remains an approximation.

Refering to [Dob90], the digit at the third position contains the information about the potential values used for the electrodes. The unoptimised voltages of August 1987 are denoted by 1 and the number 2 stands for the operational voltages of the laser tests in January 1989. The optimised voltages are indicated by the numbers 3 and 4; in the first case the optimization was made automatically [Profi90], in the second one by hand [Dob90].

The next two positions (M followed by a digit) select one of the grids used:

M1 = Coarse grid,
M2 = Fine grid,
M3 = Adapted grid.

A detailed description of the grids and a discussion of the advantages and disadvantages of the different grids is found in [Dob90].

Position 6 specifies the location of the sense wires: U means unstaggered sense wires and S staggered sense wires. Calculations with unstaggered wires are recommended for some special applications.

We use position 7 only for calculations on really large grids, that is the M2 grid over the whole (full) cell. Such a calculation is very time-consuming. Therefore the computation of the potential distribution is split into 3 jobs; the corresponding input members are denoted by O, 1 and 2. Only used for a sequential output file is the ending H (together with a F at position 2): It means the calculation was performed inside a full cell but the results are saved only inside one half of the cell to reduce the storage required.

To understand the scheme of the field calculation consider figure 3: Starting point for each calculation is a input member for the preprocessor PROFCOM2 of PROFI, written in the required language (see [Profi88] and [Dob89]). Within this framework the field defining electrodes, voltages, dielectrics, boundary conditions and the iteration parameters are declared.

The preprocessor PROFCOM2 is started with the command 'EXECUTE @PROFCO2' and prompts for the name of an input member. It generates an IBM job (#PROFI62), a FORTRAN source (PROFI62) and data (%PROFI62) which will be read by the FORTRAN program during the execution. A submission of #PROFI62 includes the members PROFI62 and %PROFI62 automatically. If desired, the potential distribution along the chosen grid is stored in a direct access (DA) file. The parameters of such a DA file can be inspected with 'EXECUTE @SNAP'. The direct access files are

machine dependent and therefore not portable. Using the jobs #MATOSE (for files of 'normal' size) and #HALF (for 'huge' files) we transfer them into sequential files which are written in the ASCII format and can be transmitted to other computers without any complications.

For really large field problems (here: the calculation of the potential distribution in a full cell using the fine grid M2) one needs a large amount of memory (40 - 50 MBytes) during several hours of CPU time. To reduce the computer load such a job should be split into smaller ones. Let's explain it by examples (see also figures 3 and 2). A 'normal sised' field problem is the one defined by the PROFCOM2 input member IF2M1S. After the usage of @PROFCO2 and PROFI one will get the direct access file F12DOB.DF2M1S, which can be transfered to a sequential file (F12DOB.EFLD.SF2M1S) by the job #MATOSE, as shown in figure 3. More complicated becomes the sequence if we go to the fine grid M2 (cf. figures 2 and 3): We start with the input member IF2M2SO and perform a PROFCOM2 / PROFI run. This run calculates the Omega parameter required to enhance the iteration. With the determined Omega parameter (depending only on the grid used) we start the first 3000 iteration steps (input member IF2M2S1) and save the potential distribution to the 'RETT file' F12DOB.RF2M2S.I3000. Then the PROFCOM2 input member IF2M2S2 generates a job which reads the data from this file and produces output to F12DOB.RF2M2S.I6000. As the 6000 iterations are sufficient, also a direct access file is used to receive the final results (F12DOB.DF2M2S). Because of the huge direct access file we apply the job #HALF to save only one half of the values into the sequential file F12DOB.EFLD.SF2M2SH. All of the information can later be retrieved by applying a point reflection.

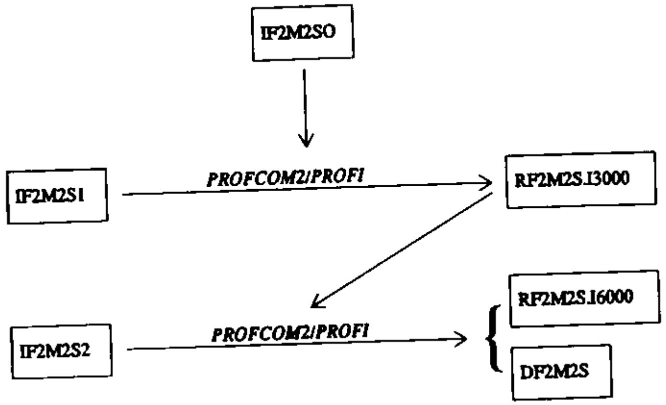


Figure 2: A sequence of files / jobs to solve a large field problem.

#SENDKFA is an example of a job to transmit a sequential EFLD file to another bitnet node; it is prepared to initiate the transmission to the KFA Jülich (node name 'DJUKFA11', user name 'HBN081'), but can be modified easily to reach other users (substitution of node and user name).

#ASYM is a tool to perform the optimisation of the voltages of the field shaping strips. This is only a draft version, but it works. It computes for an 'unstaggered' data set asymmetries of drifttimes at the different wires (see [Dob90]). For optimal voltages all asymmetries should be close to sero.

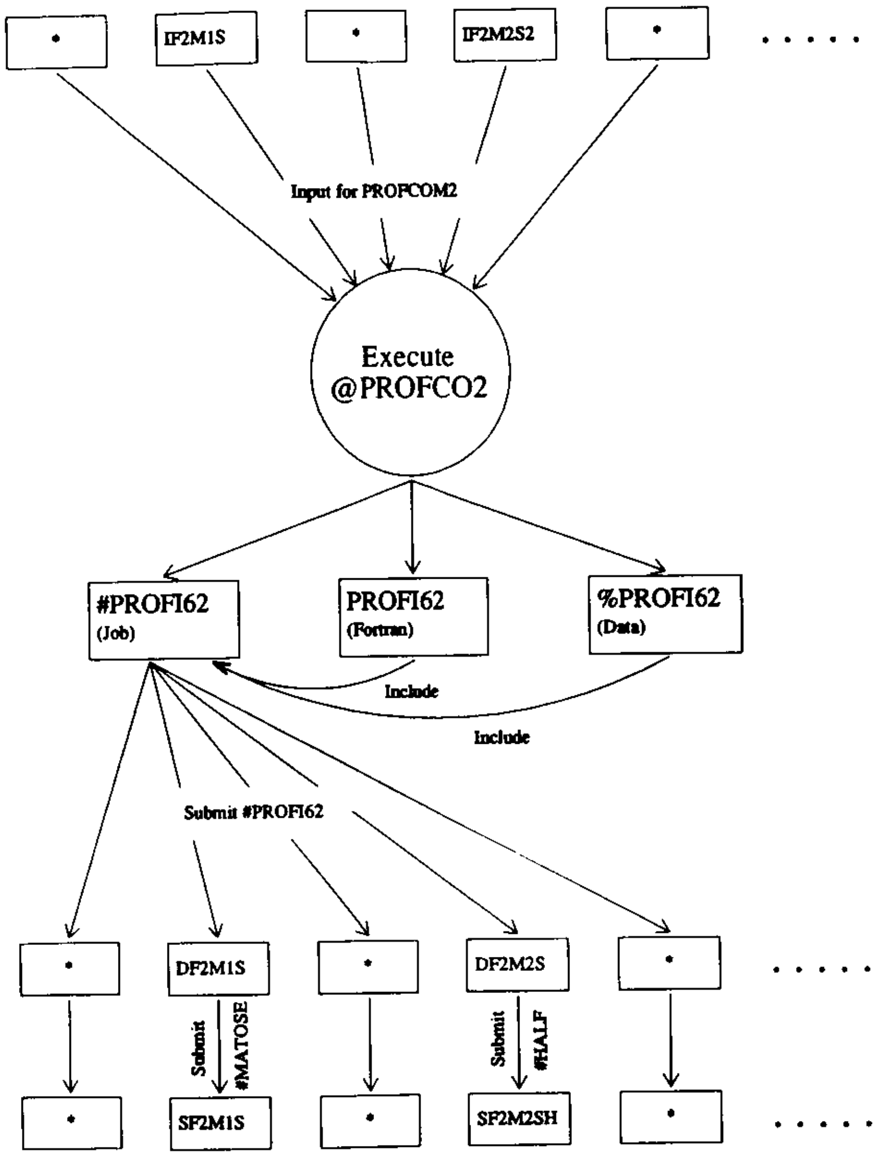


Figure 3: The calculation of the electric field of the drift chamber with the finite difference code PROFI: scheme of the input / output files and the jobs which have to be submitted.

Last, but not least we provide a list of all data sets relevant for the calculation of the electric field inside the ZEUS FTD/RTD. These datasets are declared to be 'holy' to the DESY data set warning system. Therefore they should be available during the next 3000 days.

DATA SET NAME	CONTENT OF THE DATA SET
F12DOB.DF2M1S	Example of a direct access file
F12DOB.DF2M2S	Example of a direct access file
F12DOB.DF3M2S	Example of a direct access file
F12DOB.EFLD.SF2M1S	Example of a sequential file
F12DOB.EFLD.SF2M2SH	Example of a sequential file
F12DOB.EFLD.SF3M2SH	Example of a sequential file
F12DOB.RF2M2S.I3000	Example of a RETT file
F12DOB.RF2M2S.I6000	Example of a RETT file
F12DOB.RF3M2S.I3000	Example of a RETT file
F12DOB.RF3M2S.I6000	Example of a RETT file
F12DOB.PDS.PROFI62	PROFI source library
F12DOB.PDL.PROFI62	PROFI load library
F12DOB.WIRES	Required for #ASYM
F12DOB.ZZ.PDS.PROFI62.B900907	PROFI source library, backup
F12DOB.ZZ.WIRES.B900111	Backup of F12DOB.WIRES

3 Calculation of the magnetic field

We do not calculate the magnetic field, but instead retrieve it from the best data available.

As shown in figure 4, the retrieval of the magnetic field from the FRASCATI field table [ENEA85] is performed with the subroutines BREAD, BLOCAL, BFIELD, GLOBAL, VLOC and ROTATE. Here BREAD and BFIELD are the only routines which use the FRASCATI table directly; the other ones transform between global and local coordinates.

For the future, it is required to substitute the old FRASCATI data by more realistic ones (e.g. the calculations of F. Corriveau, [Corr90]). This is done simply by adapting the BREAD and BFIELD routines and by replacing the input file, from which TRRPNEW gets the magnetic field data.

4 Modelling of the drift process

The program package TRRPNEW [Schnei87], [Dob90] is our instrument to model the electron drift process inside the ZEUS forward drift chambers. In figure 4 we show the hierachy of its subroutines. The parts of the code which are time consuming have vector versions; they are denoted by V. As one sees, the most of the time consumed for the calculations is concentrated in the three subroutines VELOC, ASIMP and TIMES. The groups of routines which are responsible for the retrieval of the electric field and the magnetic field are marked by the two larger boxes E-RETR and B-RETR.

Before a description of the usage of the program we give a list of the tasks of the different subroutines. This is important to know if one wants to implement modifications. We start with the level 1, that are the subroutines, which are called directly by the main program:

1. **INTEST:** Here the steering parameters for the execution of a program run are read.
2. **GASDAT:** Serves to provide the data of the gases used.
3. **BREAD:** Input of the magnetic field table. At the moment, the FRASCATI data [ENEA85] for ZEUS are taken.

4. **READSE:** Reads the electric field data of PROFI / MAFIA. For reasons of compatibility and portability they are not taken directly from a PROFI / MAFIA direct access file, but from a sequential file (c.f. section 2).
5. **WIRFLD:** Calculates the electric surface fields at the six sense wires.
6. **LININI:** Initializes the data structures to compute the space drifttime relations (required for calibration purposes) in the subroutine TIMES.
7. **TRRPV:** Interprets the steering parameters required to calculate the drift trajectories and starts the calculation of the trajectories.
8. **SDRINI:** Initializes the storage area for the space drifttime relations.
9. **TIMES:** Calculates from the trajectory data a complete table of space drifttime relations (SDR table).
10. **SDROUT:** Writes a SDR table to an external file.
11. **PLTRAJ:** Displays the calculated trajectories graphically.
12. **TRAOUT:** Writes the trajectory data to an external file (trajectory card) if desired.

On level 2 of the subroutines we have:

- **CROSS** and **SPLIN3:** In CROSS the gas cross sections are calculated explicitly. The routine SPLIN3 of the CERNLIB [CERN88] is used by both CROSS and GASDAT (see above) for a spline interpolation.
- **DRIFTV:** Determines the path of a trajectory using the electric and magnetic fields.
- **BHOM:** If one wants to use a 'homogenised' magnetic field an average (over the considered cell cross section) is computed in this subroutine.
- **ISMIN:** Determination of the minimum element of a vector. For better vectorisation this task was decoupled as a subroutine for its own.

The other routines are partly grouped together according to their tasks (see figure 4):

- In the box **E-RETR** the routines for the retrieval and interpolation of the electric field are contained. **ELFLD** interpolates the electric field data read by **READSE** over the grid used by PROFI / MAFIA. In this connection **FINDIN** determines the grid indexes next to the considered point inside FTD/RTD, whereas the CERNLIB routine **FINT** [CERN88] performs a multi dimensional interpolation. **FIELD** is a dummy subroutine which represents the coupling to the field calculations of the 'wire programs' (c.f. [Dob90]).
- **BOUNDS, VELOC** and **ASIMP4** serve for the calculation of the drift trajectories. **BOUNDS** checks whether the considered trajectory is still inside the FTD/RTD area and stops the computation if the trajectory is going to leave the FTD/RTD cells. **VELOC** determines at an arbitrary point inside FTD/RTD the vector of the drift velocity by evaluation of the equations described in [PalSad74], [Schnei87] and uses ASIMP4 to perform integrations with the well known Simpson rule.
- The box **B-RETR** contains the subroutines required to provide the magnetic field read in by **BREAD**. **BFIELD** delivers the field in global ZEUS coordinates; it is converted to local FTD/RTD coordinates [Dob88] by **BLOCAL** with help of the transformations **GLOBAL, VLOC** and **ROTATE**.
- **SSCAN** is needed by **BHOM** to define a grid of points uniformly distributed over a FTD/RTD cross section. These points are used to determine an average magnetic field at the considered cell cross section.

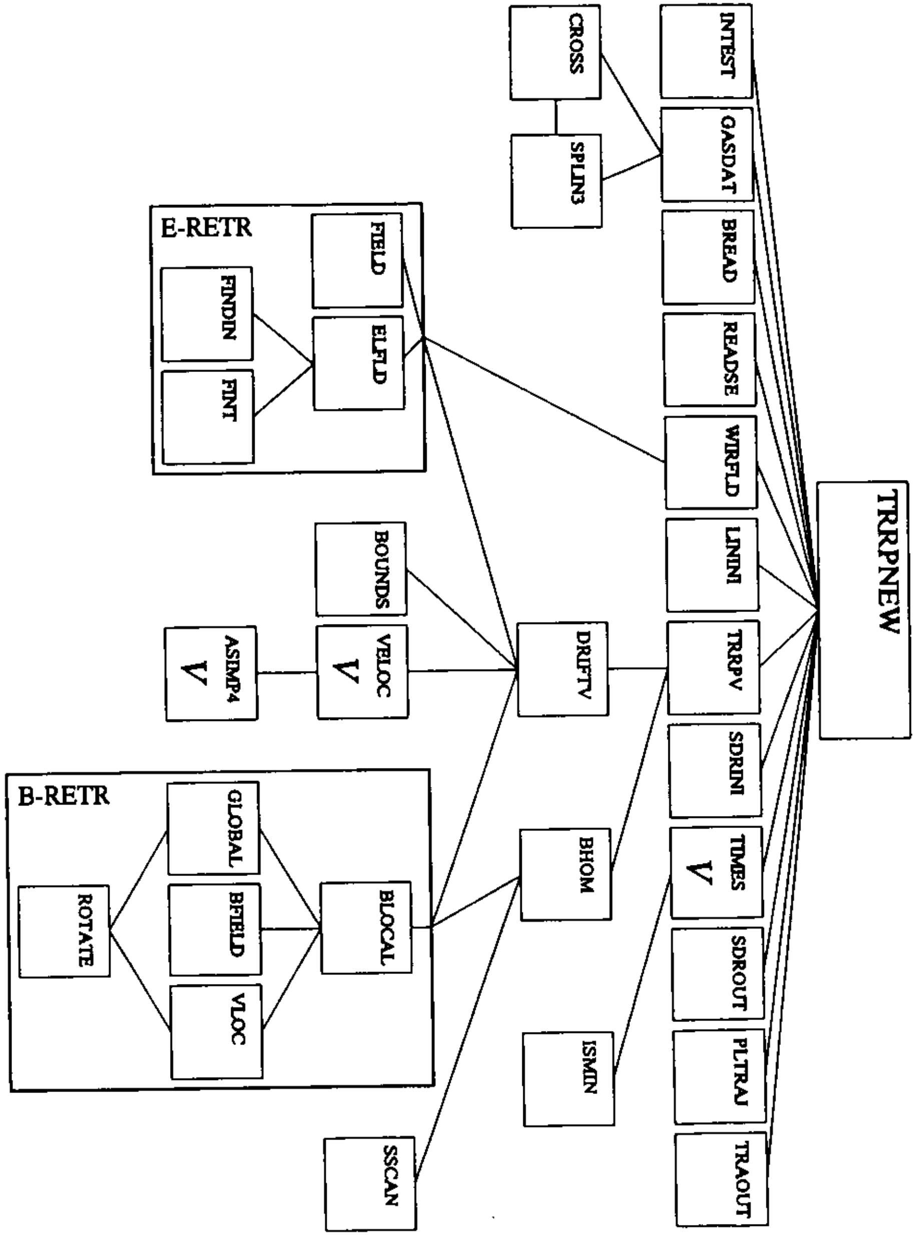


Figure 4: The hierarchy of the subroutines of the code TRRPNEW.

Beside this 'pyramid' of routines we have some subprograms needed by tools required for the interpretation of the data:

- **SDRIN:** Input of a SDR table for further actions.
- **TRAIN:** Input of a trajectory card for further actions.
- **VDEFF:** Determination of an estimated effective drift velocity from a calculated SDR table.

The main tools existing at the moment are the program ($)COMWIR for the comparison of the space drifttime relations at the different wires of one cell section and the program ($)COMTAB for the comparison of the space drifttime relations of two different cell sections. Now a few words about the naming conventions of the members of the source library PDS.TRRPNEW:

1. Jobs start with the letter '#'. These members can be submitted directly to the batch queues. Of special interest are:

Member Name	Purpose of the Job
#TRSECT	Batch run of TRRPNEW (one cell section)
#TRCELL	Batch run of TRRPNEW (several cell sections)
#COMWIR	Batch execution of ($)COMWIR
#COMTAB	Batch execution of ($)COMTAB
#BCORR	Application of corrections for high magnetic fields
#COLOAD	Compiling and loading of a whole source library
#TRLINK	Linking of main programs

2. Main programs and members used for the **interactive version** of TRRPNEW begin with the letter '$'. Most important is the Clist (= Command list) $TRRPNEW to start the interactive execution of TRRPNEW. This is achieved by the command

EXECUTE $TRRPNEW (or shorter EX $TRRPNEW).

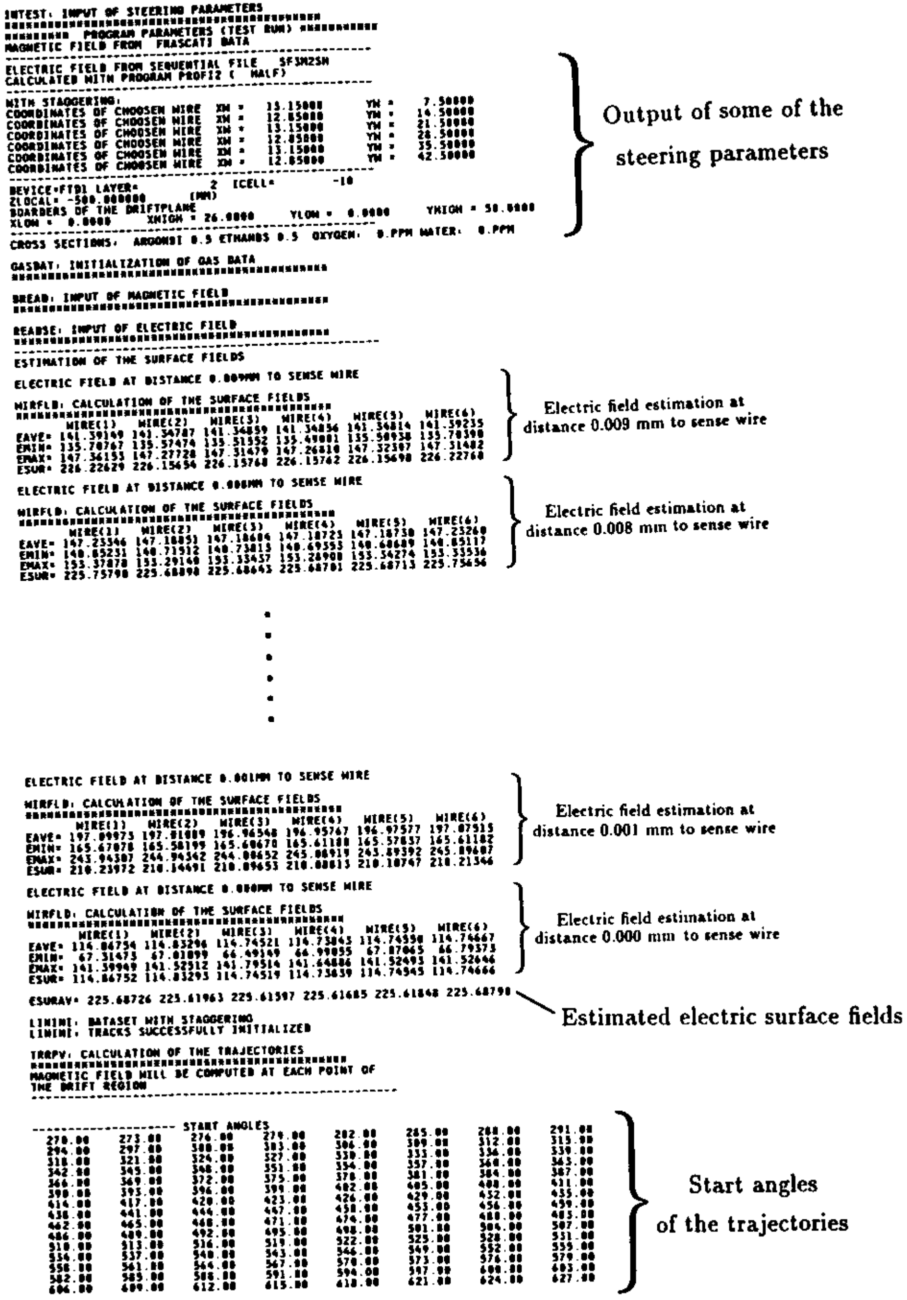
Other '$-members' are used during the execution of $TRRPNEW. *Don't change the members $INFILE and $JOBFILE; they are required in exactly this shape to ensure a correct execution of $TRRPNEW.*

3. All other members are subroutines belonging to the TRRPNEW source library. They have been explained above.

Following this overview we give more detailed explanations of the usage of TRRPNEW, both interactive and batch. There is also a online help included in the interactive version, which one can use for 'learning by doing'.

After starting the Clist $TRRPNEW with the command *EXECUTE $TRRPNEW* one has to insert the steering parameters for the program. Beside the general help (**PF1**) these parameters are explained in special panels (press the **PF2**-key); for this reason we don't give additional explanations here. A default setting for the parameters is selected and inserted into the main menu pressing the **PF12**-key. A suitable setting of the parameters is a prerequisite to start the program execution. In case of interactive execution, the parameters are handed over via the member $INFILE and the data set F12DOB.$INFILE. For batch execution they are used to build a job from the member $JOBFILE, which contains a batch job skeleton.

To prepare a batch job press the **PF6**-key. Then you will get into a member which contains a complete job ready for submission. It can be changed arbitrarily. Submit it and return to the main menu with the **PF9**-key.



```
INTEST: INPUT OF STEERING PARAMETERS
##############################################
#########  PROGRAM PARAMETERS (TEST RUN) ###########
MAGNETIC FIELD FROM  FRASCATI DATA
-------------------------------------------------------
ELECTRIC FIELD FROM SEQUENTIAL FILE   SF3M2SH
CALCULATED WITH PROGRAM PROFI2 (  HALF)
-------------------------------------------------------
WITH STAGGERING:
COORDINATES OF CHOOSEN WIRE  XW =   13.15000       YW =    7.50000
COORDINATES OF CHOOSEN WIRE  XW =   12.85000       YW =   14.50000
COORDINATES OF CHOOSEN WIRE  XW =   13.15000       YW =   21.50000
COORDINATES OF CHOOSEN WIRE  XW =   12.85000       YW =   28.50000
COORDINATES OF CHOOSEN WIRE  XW =   13.15000       YW =   35.50000
COORDINATES OF CHOOSEN WIRE  XW =   12.85000       YW =   42.50000
-------------------------------------------------------
DEVICE=FTD1 LAYER=          2  ICELL=         -10
ZLOCAL= -500.000000      (MM)
BOARDERS OF THE DRIFTPLANE
XLOW =  0.0000     XHIGH = 26.0000     YLOW =  0.0000     YHIGH = 50.0000
-------------------------------------------------------
CROSS SECTIONS:  ARGON80I 0.5 ETHANOS 0.5  OXYGEN:  0.PPM WATER:  0.PPM

GASDAT: INITIALIZATION OF GAS DATA
##############################################

BREAD: INPUT OF MAGNETIC FIELD
##############################################

REABSE: INPUT OF ELECTRIC FIELD
##############################################
-------------------------------------------------------
ESTIMATION OF THE SURFACE FIELDS

ELECTRIC FIELD AT DISTANCE 0.009MM TO SENSE WIRE

WIRFLD: CALCULATION OF THE SURFACE FIELDS
##############################################
        WIRE(1)   WIRE(2)   WIRE(3)   WIRE(4)   WIRE(5)   WIRE(6)
EAVE= 141.39149 141.34787 141.34859 141.34856 141.34814 141.39235
EMIN= 135.70767 135.57474 135.51552 135.49001 135.50938 135.70390
EMAX= 147.36155 147.27728 147.31479 147.26810 147.32387 147.31482
ESUR= 226.22629 226.15654 226.15768 226.15742 226.15698 226.22768

ELECTRIC FIELD AT DISTANCE 0.008MM TO SENSE WIRE

WIRFLD: CALCULATION OF THE SURFACE FIELDS
##############################################
        WIRE(1)   WIRE(2)   WIRE(3)   WIRE(4)   WIRE(5)   WIRE(6)
EAVE= 147.23346 147.18851 147.18604 147.18723 147.18738 147.23260
EMIN= 140.85231 140.71912 140.73813 140.69555 140.68689 140.85117
EMAX= 153.37878 153.29148 153.33457 153.28908 153.34274 153.33536
ESUR= 225.75798 225.68898 225.68643 225.68701 225.68713 225.75656

                              .
                              .
                              .
                              .
                              .
                              .

ELECTRIC FIELD AT DISTANCE 0.001MM TO SENSE WIRE

WIRFLD: CALCULATION OF THE SURFACE FIELDS
##############################################
        WIRE(1)   WIRE(2)   WIRE(3)   WIRE(4)   WIRE(5)   WIRE(6)
EAVE= 197.09973 197.01009 196.96548 196.95767 196.97577 197.07515
EMIN= 165.67078 165.58199 165.60670 165.61180 165.57837 165.61182
EMAX= 243.94307 244.94342 244.00652 245.00919 243.89392 245.09607
ESUR= 210.23972 210.14491 210.09653 210.08813 210.10747 210.21346

ELECTRIC FIELD AT DISTANCE 0.000MM TO SENSE WIRE

WIRFLD: CALCULATION OF THE SURFACE FIELDS
##############################################
        WIRE(1)   WIRE(2)   WIRE(3)   WIRE(4)   WIRE(5)   WIRE(6)
EAVE= 114.86754 114.83296 114.74521 114.73845 114.74558 114.74667
EMIN=  67.31473  67.01099  66.49149  66.99055  67.07065  66.79373
EMAX= 141.39949 141.52512 141.79514 141.64886 141.52493 141.52646
ESUR= 114.86752 114.83293 114.74519 114.73839 114.74545 114.74666

ESURAV= 225.68726 225.61963 225.61597 225.61685 225.61848 225.68798

LININI: DATASET WITH STAGGERING
LININI: TRACKS SUCCESSFULLY INITIALIZED

TRRPV: CALCULATION OF THE TRAJECTORIES
##############################################
MAGNETIC FIELD WILL BE COMPUTED AT EACH POINT OF
THE DRIFT REGION
-------------------------------------------------------

--------------------- START ANGLES
   270.00     273.00     276.00     279.00     282.00     285.00     288.00     291.00
   294.00     297.00     300.00     303.00     306.00     309.00     312.00     315.00
   318.00     321.00     324.00     327.00     330.00     333.00     336.00     339.00
   342.00     345.00     348.00     351.00     354.00     357.00     360.00     363.00
   366.00     369.00     372.00     375.00     378.00     381.00     384.00     387.00
   390.00     393.00     396.00     399.00     402.00     405.00     408.00     411.00
   414.00     417.00     420.00     423.00     426.00     429.00     432.00     435.00
   438.00     441.00     444.00     447.00     450.00     453.00     456.00     459.00
   462.00     465.00     468.00     471.00     474.00     477.00     480.00     483.00
   486.00     489.00     492.00     495.00     498.00     501.00     504.00     507.00
   510.00     513.00     516.00     519.00     522.00     525.00     528.00     531.00
   534.00     537.00     540.00     543.00     546.00     549.00     552.00     555.00
   558.00     561.00     564.00     567.00     570.00     573.00     576.00     579.00
   582.00     585.00     588.00     591.00     594.00     597.00     600.00     603.00
   606.00     609.00     612.00     615.00     618.00     621.00     624.00     627.00
```

Output of some of the steering parameters
Electric field estimation at distance 0.009 mm to sense wire
Electric field estimation at distance 0.008 mm to sense wire
Electric field estimation at distance 0.001 mm to sense wire
Electric field estimation at distance 0.000 mm to sense wire
Estimated electric surface fields
Start angles of the trajectories

Figure 5: Parts of the FORTRAN output of a TRRPNEW run.

For the interactive execution it is necessary to allocate first the required data sets. Allocate the data sets with the PF10-key; if a data set doesn't exist, create it by pressing PF5. After that the program run is initiated with the PF4-key. As in a batch job, you will get first some information about the program parameters selected and the electric field (see figure 5). Then you have to specify the GKS output device (c.f. HELP GKS on DESY's IBM system), e.g.

workstation type = 5003 and connection identifier = 1 (for an IBM graphic terminal),
workstation type = 4703 and connection identifier = 52 (for an ATARI as IPS workstation).

If you have specified 'GRAPHICS = YES' as steering parameter, the trajectory generation is then shown at the display (two 2D projections in space). For 'GRAPHICS = NO' the trajectories are also computed, but not displayed. After that you are prompted for a continuation of the run. If you specify 'YES', then a SDR table and/or a trajectory card is created (depending on the steering parameters). Otherwise, the run is stopped immediately and you will return to the main menu.

Now a few words to the FORTRAN output shown in figure 5. The main purpose of this printout is to check the program running. Each subroutine prints a control statement during its execution, e.g. 'READSE: INPUT OF ELECTRIC FIELD'. The only physics content is the information about the surface fields at the six sense wires (much more details on the physics of the drift chamber are contained in the shape of the drift trajectories and in the SDR table generated). As described in [Dob90], appendix C, for each sense wire the electric field is determined as average over a circle around the considered wire. For the different radii (r = 0.009 mm , ..., r = 0.000 mm) the minimum values EMIN, the maximum values EMAX and the average values EAVE are printed. Furthermore, an estimation of the electric fields at the surfaces of the sense wires is given (ESUR). From the ESUR's at the radii r=0.009mm, r=0.008mm and r=0.007mm we get the final estimation of the surface field (ESURAV) as an average.

The last important point is the comparison of SDR tables. The corresponding submenu is reached by pressing the PF8-key. You can compare two SDR tables (c.f. [Dob90]), appendix B) wire by wire: Insert simply the names of the data sets containing the SDR tables to be compared in the submenu and press PF6. The typical printout is shown in figure 6. The different 'columns' represent the six sense wires, whereas the 13 'rows' have to be identified with different 'maximum distances' covered by the comparison. More in detail, the printed number IMAX is related to the 'maximum distance' by

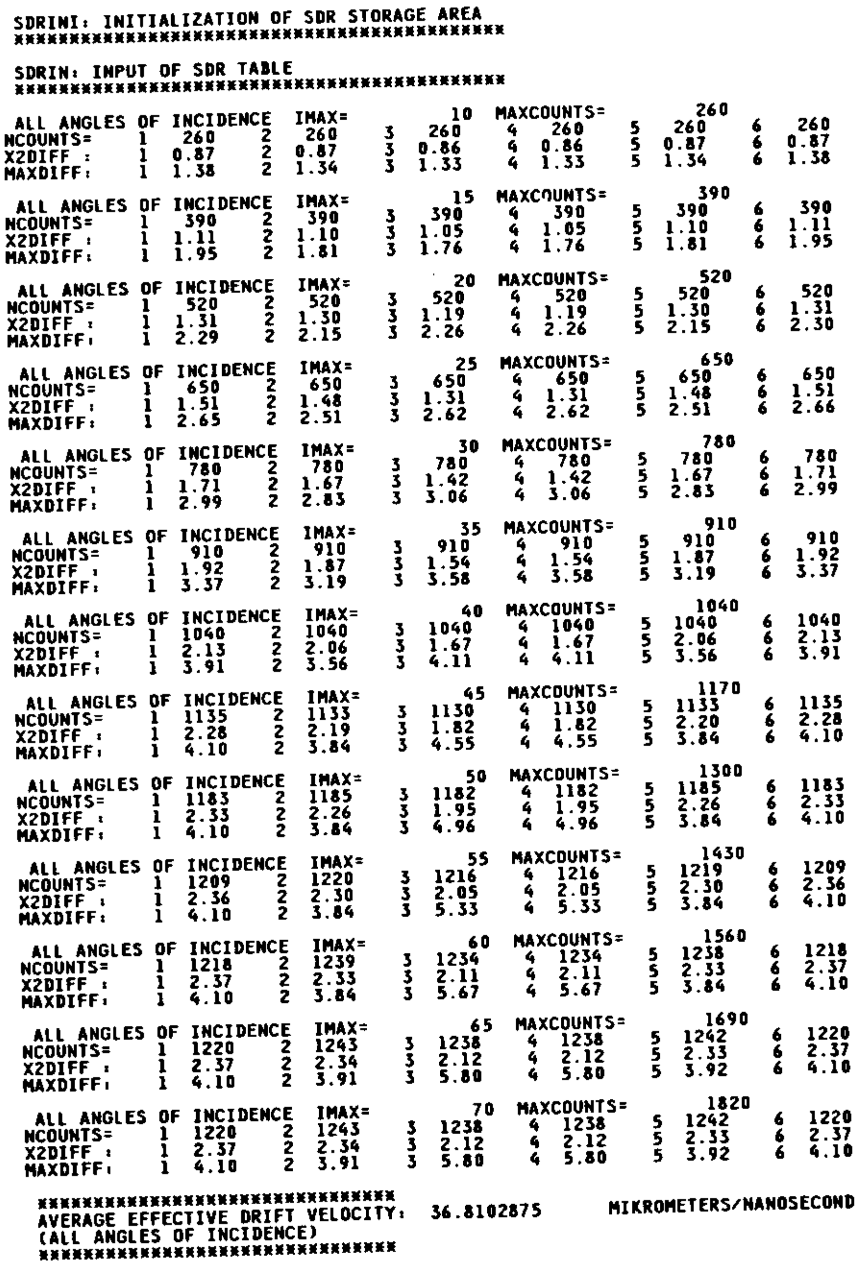
$$\text{maximum distance} = 0.25 + \text{IMAX} \times 0.25 \text{ [mm]},$$

where the maximum distance has to be measured perpendicular to the plane of the potential wires and with respect to the sense wire considered as in [Dob90], appendix B. For each maximum distance and each wire we have the maximum difference MAXDIFF and the mean square root X2DIFF of the differences of the drifttimes, both printed in units of nanoseconds. At the end of the comparison, an average effective drift velocity is estimated from all used space drifttime relations and printed.

The whole procedure described is performed twice: once for all angles of incidence of the primary track (−30°, .., +30°) and a second time for vanishing angle of incidence.

For some purposes (e.g., the optimization of the operational voltages of the field shaping strips, study of the inhomogeneity of the applied magnetic field) it is desirable to compare the space drifttime relations of the different wires of one SDR table. This is achieved by inserting the name of the data set containing the desired SDR table and pressing the PF4-key in the submenu for the comparison of SDR tables. The produced output is similar to that one shown in figure 6. The main difference is that the maximum differences are not calculated absolutely, but with sign to see the tendency of the deviations between the different wires. Therefore we have instead of the declaration of MAXDIFF the two differences MAXDIFF and MINDIFF.

To avoid additional difficulties, for one SDR table only equal-staggered wires are compared: wire 2, 4 and 6 with respect to wire 4 and wire 1, 3 and 5 with respect to wire 3. Because of this reason the differences at the wires 3 and 4 are always zero.



```
SDRINI: INITIALIZATION OF SDR STORAGE AREA
****************************************

SDRIN: INPUT OF SDR TABLE
****************************************

 ALL ANGLES OF INCIDENCE  IMAX=        10  MAXCOUNTS=       260
NCOUNTS=    1   260     2   260     3   260    4   260     5   260     6   260
X2DIFF :    1  0.87     2  0.87     3  0.86    4  0.86     5  0.87     6  0.87
MAXDIFF:    1  1.38     2  1.34     3  1.33    4  1.33     5  1.34     6  1.38

 ALL ANGLES OF INCIDENCE  IMAX=        15  MAXCOUNTS=       390
NCOUNTS=    1   390     2   390     3   390    4   390     5   390     6   390
X2DIFF :    1  1.11     2  1.10     3  1.05    4  1.05     5  1.10     6  1.11
MAXDIFF:    1  1.95     2  1.81     3  1.76    4  1.76     5  1.81     6  1.95

 ALL ANGLES OF INCIDENCE  IMAX=        20  MAXCOUNTS=       520
NCOUNTS=    1   520     2   520     3   520    4   520     5   520     6   520
X2DIFF :    1  1.31     2  1.30     3  1.19    4  1.19     5  1.30     6  1.31
MAXDIFF:    1  2.29     2  2.15     3  2.26    4  2.26     5  2.15     6  2.30

 ALL ANGLES OF INCIDENCE  IMAX=        25  MAXCOUNTS=       650
NCOUNTS=    1   650     2   650     3   650    4   650     5   650     6   650
X2DIFF :    1  1.51     2  1.48     3  1.31    4  1.31     5  1.48     6  1.51
MAXDIFF:    1  2.65     2  2.51     3  2.62    4  2.62     5  2.51     6  2.66

 ALL ANGLES OF INCIDENCE  IMAX=        30  MAXCOUNTS=       780
NCOUNTS=    1   780     2   780     3   780    4   780     5   780     6   780
X2DIFF :    1  1.71     2  1.67     3  1.42    4  1.42     5  1.67     6  1.71
MAXDIFF:    1  2.99     2  2.83     3  3.06    4  3.06     5  2.83     6  2.99

 ALL ANGLES OF INCIDENCE  IMAX=        35  MAXCOUNTS=       910
NCOUNTS=    1   910     2   910     3   910    4   910     5   910     6   910
X2DIFF :    1  1.92     2  1.87     3  1.54    4  1.54     5  1.87     6  1.92
MAXDIFF:    1  3.37     2  3.19     3  3.58    4  3.58     5  3.19     6  3.37

 ALL ANGLES OF INCIDENCE  IMAX=        40  MAXCOUNTS=      1040
NCOUNTS=    1  1040     2  1040     3  1040    4  1040     5  1040     6  1040
X2DIFF :    1  2.13     2  2.06     3  1.67    4  1.67     5  2.06     6  2.13
MAXDIFF:    1  3.91     2  3.56     3  4.11    4  4.11     5  3.56     6  3.91

 ALL ANGLES OF INCIDENCE  IMAX=        45  MAXCOUNTS=      1170
NCOUNTS=    1  1135     2  1133     3  1130    4  1130     5  1133     6  1135
X2DIFF :    1  2.28     2  2.19     3  1.82    4  1.82     5  2.20     6  2.28
MAXDIFF:    1  4.10     2  3.84     3  4.55    4  4.55     5  3.84     6  4.10

 ALL ANGLES OF INCIDENCE  IMAX=        50  MAXCOUNTS=      1300
NCOUNTS=    1  1183     2  1185     3  1182    4  1182     5  1185     6  1183
X2DIFF :    1  2.33     2  2.26     3  1.95    4  1.95     5  2.26     6  2.33
MAXDIFF:    1  4.10     2  3.84     3  4.96    4  4.96     5  3.84     6  4.10

 ALL ANGLES OF INCIDENCE  IMAX=        55  MAXCOUNTS=      1430
NCOUNTS=    1  1209     2  1220     3  1216    4  1216     5  1219     6  1209
X2DIFF :    1  2.36     2  2.30     3  2.05    4  2.05     5  2.30     6  2.36
MAXDIFF:    1  4.10     2  3.84     3  5.33    4  5.33     5  3.84     6  4.10

 ALL ANGLES OF INCIDENCE  IMAX=        60  MAXCOUNTS=      1560
NCOUNTS=    1  1218     2  1239     3  1234    4  1234     5  1238     6  1218
X2DIFF :    1  2.37     2  2.33     3  2.11    4  2.11     5  2.33     6  2.37
MAXDIFF:    1  4.10     2  3.84     3  5.67    4  5.67     5  3.84     6  4.10

 ALL ANGLES OF INCIDENCE  IMAX=        65  MAXCOUNTS=      1690
NCOUNTS=    1  1220     2  1243     3  1238    4  1238     5  1242     6  1220
X2DIFF :    1  2.37     2  2.34     3  2.12    4  2.12     5  2.33     6  2.37
MAXDIFF:    1  4.10     2  3.91     3  5.80    4  5.80     5  3.92     6  4.10

 ALL ANGLES OF INCIDENCE  IMAX=        70  MAXCOUNTS=      1820
NCOUNTS=    1  1220     2  1243     3  1238    4  1238     5  1242     6  1220
X2DIFF :    1  2.37     2  2.34     3  2.12    4  2.12     5  2.33     6  2.37
MAXDIFF:    1  4.10     2  3.91     3  5.80    4  5.80     5  3.92     6  4.10

  *********************************
  AVERAGE EFFECTIVE DRIFT VELOCITY:  36.8102875     MIKROMETERS/NANOSECOND
  (ALL ANGLES OF INCIDENCE)
  *********************************
```

Figure 6: The comparison of two SDR tables: output data for all angles of incidence of the incoming particle.

At the end of this section, again the list of the 'holy' data sets belonging to TRRPNEW:

DATA SET NAME	CONTENT OF THE DATA SET
F12DOB.ODB.SF2M2SH	Example of a SDR table
F12DOB.ODB.SF3M2SH	Example of a SDR table
F12DOB.CARD.DAT	Example of a trajectory card
F12DOB.GHH.DAT	Example of a graphics metafile
F12DOB.PDS.TRRPNEW	TRRPNEW source library
F12DOB.PDL.TRRPNEW	TRRPNEW load library
F12DOB.PDL.TRRPNEWV	TRRPNEW load library, vectorised
F12DOB.BMAP	Frascati magnetic field data
F12DOB.$INFILE	Input for interactive TRRPNEW
F12DOB.ZZ.PDS.TRRPNEW.B900918	TRRPNEW source library, backup
F12DOB.ZZ.BMAP.B900910	Frascati magnetic field, backup

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