Internal Report
DESY F15-85-02
August 1985

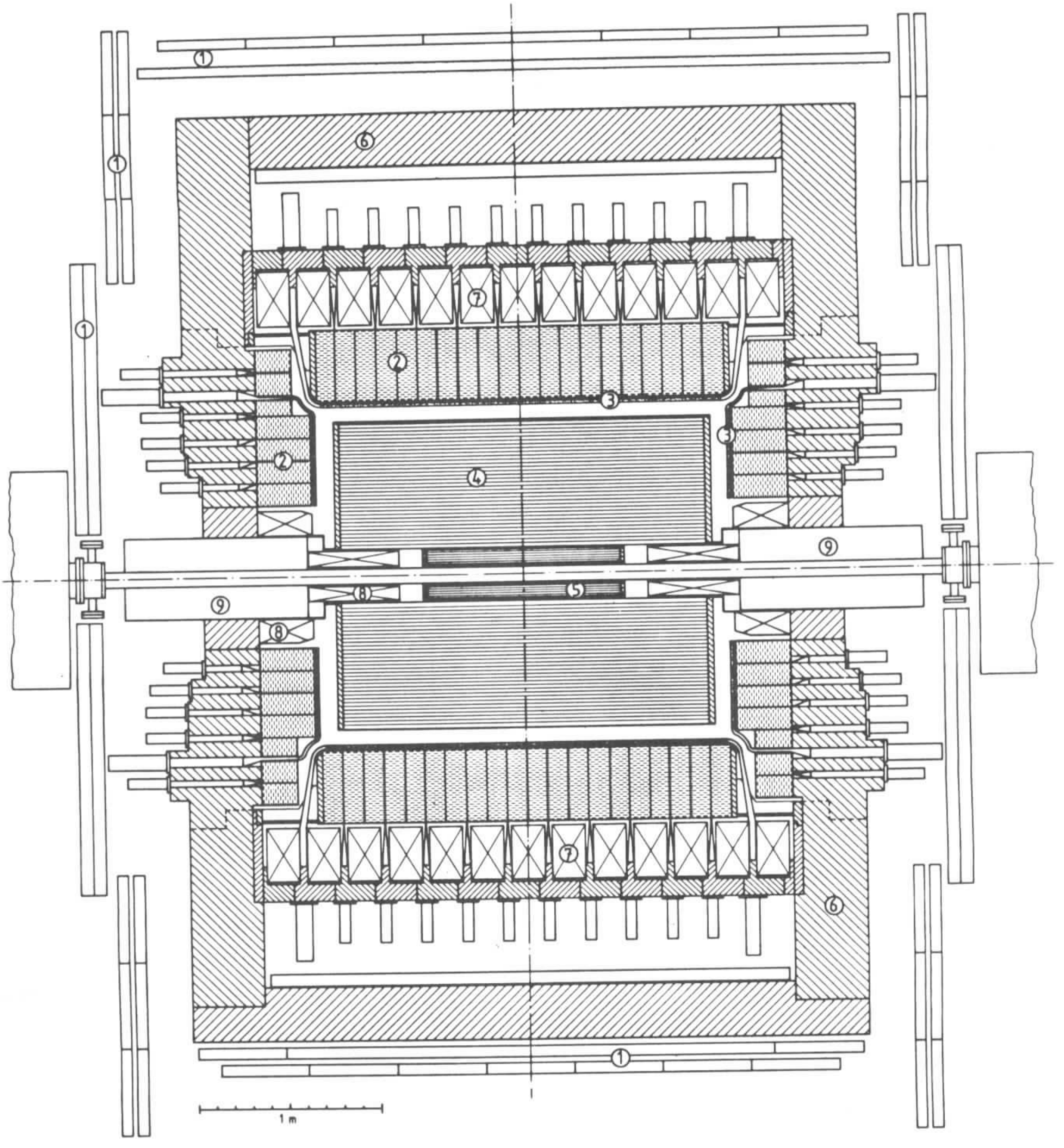
SIMARG

A Program to simulate the ARGUS Detector

by

H. Gennow

ARGUS



38269

1. Muon cambers
2. Shower counters
3. Time of flight counters
4. Drift chamber
5. Vertex chamber
6. Iron yoke
7. Solenoid coils
8. Compensation coils
9. Mini beta quadrupole

TABLE OF CONTENTS

Appendix

1. INTRODUCTION

SIMARG is a simulation program for the ARGUS detector. It is based upon the general CERN program GEANT[1]. GEANT itself is just a framework which the user has to fill with the details of the detector configuration. He also has to supply the physics routines, i.e. how particles passing through any media actually interact with it (electromagnetic and hadronic interactions) as well as the decay properties of unstable particles. Briefly SIMARG performs the following tasks:

1. Reads or generates the kinematics of an event.
2. Tracks particles through the apparatus until they stop or leave the detector fiducial limits and records the energy deposited in the shower counters and TOF counters as well as coordinates along the track.
3. Uses the track coordinates to intersect tracks with the various detectors storing the resulting points.
4. Calculates from the intersection points which wires were hit in the Vertex Chamber (VDC), Drift Chamber (DC) and the muon chambers (drift tubes).
5. Creates an event record with the same format as a real data record.

The last step of a complete simulation consist of processing the events generated with the normal reconstruction program. It is at this stage that efficiency and smearing according to the resolution of the various chambers are applied.

Practical hints needed to run a SIMARG job as well as the following reconstruction job are given in chapter 2. That should be enough if one just wants to use the program as a black box. A more detailed description is given in the following chapters. Things not described here can be found in the GEANT manual.

Many people have contributed to this program. I will not try to list their names in order to avoid the risk of forgetting somebody, but only mention that the very first version was set up by P.Böckmann (LUND).

2. THE ESSENTIALS

A short description of SIMARG is given in member DOCUM in the source library, F15ARG.SIM200.S. The information given here is essentially what is given there. A summary of modifications to the program can be found in member UPDATE, which contains the history of all SIMARG versions. SIMARG consists at present (version 2.00) of the following libraries (on the IBM):

Library files:	F15ARG.SIM200.S/L
Macro file:	F15ARG.SIM200.MA
LKED libraries needed:	F15ARG.SIMARG.UL R01UTL.CERN.PACKLIB4
Machine dependend routines:	MTIME (time left in 100 μs) XPANDB,DAY,IAND2

SIMARG needs input from the following files:

Title file:	F15ARG.GEOMETRY.V850128
(Corresponding member to expand:	F15ARG.SIMARG.DA ($GEOMV2))
Input Little Track Finder (LTF):	F15HDS.MASKAR.DAT

2.1 Job deck example.

As an example, a job to generate phase space events could look like:

```
// JOB 10315215,GENNOW,CLASS=A,TIME=(1,00),MSGCLASS=T
//*MAIN LINES=(15),RELPRI=MED
//*MAIN ORG=EXT
//*EXEC NEWFAST
// EXEC FCLG,PARM.FORT=XL,LKED='SIZE=(500000,8400)',
// REGION.FORT=(900K),REGION.GO=(1200K)
%MACRO MAIN
%MACRO RNDM
%MACRO RDMIN
//LKED.SYSLIB DD
// DD DSN=F15ARG.SIM200.GEN.L,DISP=SHR,UNIT=FAST
// DD DSN=F15ARG.SIM200.L,DISP=SHR,UNIT=FAST
// DD DSN=F15ARG.SIMARG.UL,DISP=SHR,UNIT=FAST
// DD DSN=R01UTL.CERN.PACKLIB4,DISP=SHR
//LKED.SYSPRINT DD SYSOUT=*
//PRINT.FORTRAN DD DUMMY
//GO.SYSIN DD *
```

```
LIST
TRIG 1000
EVEN 1
TIME 5
DEBU 1 2
DEBP 1=1
SWIT 0 0 0 0
EXPERIMENT PARAMETERS -1 2
GENERATOR 10000
PART 4 1 3 4 6
SHOF 1
HADI 2
DRME 11
DRMH 9
START 1
TAPE WRITING 1
BEAM PARAMETERS 0.0 0.0 5.0 0.000511 0. 0. -5. .000511 0. 0.
VERTEX 0.0 0.0 0.0 0. 0. 0.
TEST 10
RNDM 0 0
STOP
//GO.FT04F001 DD DSN=F15HDS.MASKAR.DAT ,UNIT=FAST,DISP=SHR
//GO.FT22F001 DD DSN=F15ARG.GEOMETRY.V 850128,UNIT=FAST,DISP=SHR
//**
//* INPUT UNIT IS 13: (which is not needed in this example)
//**
//** OUTPUT UNIT IS 03:
//**
//GO.FT03F001 DD DSN=F15GEN.MCDATA.PHASP4.V01,
// DISP=(NEW,CATLG,DELETE),DCB=R01DCB.VBS,UNIT=FAST,
// SPACE=(TRK,(30,20),RLSE)
```

To process events from an outside generator you can use the deck #JSIMARG on the source library. It is set up to process MOPEK [2] events.

2.2 Data cards

Key word	Parameters	Action
ANGR	n al ah	Get mu,tau,bhabha and gamma pairs with al<cos<ah. Flat distribution if n= 1. Defaults: n=0, al,ah= -.96,.96 for bhabha and gamma, -1.,1. for mu and tau (n has no meaning for radiative pairs).
BEAM	px py pz m px py pz m de de	Of positron. Defaults=0. 0. 5. .0005 Of electron. Defaults=0. 0. -5. .0005 Beam smearing. Defaults=0. 0. (no smearing).
COSM	nt it e eh	Generate cosmic μ, e,p,γ. nt=4 ,it=0 gives all. nt=2, it=2 selects only e. Energies between e and eh (GeV).
CUTE	z1,z2,r2,r3	Geometrical limits for thresholds given on card 'THRE'. Limits for yoke(z1), compcoil(z2,r2),main coil(r3), i.e. for z> zyoke+z1,r .. etc, use above thresholds. Defaults: .5,7.,2.,.5 cm resp.
DEBA	n	In connection with DEBP. Printing starts with track NTRA (see GTRA) during tracking.
DEBC	i=n	Sets debug flag i to value n. To switch on various debuging possibilities and checks see A6.
DEBP	i=n	Sets print flag i to value n. Print out for various routines as defined in A6. Print flags are activated from the first event given on card DEBU .
DRME DRMH	n n	For e,γ resp. hadrons. Switch off specified detector part(s): n=1 minibeta =2 yoke/main coi =4 shower counters =8 outer compcoil =16 inner compcoil, e.g. 3 means 1+2, i.e. when particle reaches minibeta or yoke/main coil tracking of it stops. Default values 9/1 for DRME /DRMH.

Key word	Parameters	Action
DRDC	i1 i2 ..i20	List of id's for particles that should be traced as any other particle but that was allready decayed by outside generator (decay products simply deleted).
ELOS	n	Switch off energy-loss (not DE/dx simulation for DC) if n=-1 (default 1= on).
EXPE	n1 n2	n1=exp no, n2=run no.
EVEN	n	Sets first event number to n if card 'FETC l', l> 0 given. First event number is set to the value given on card 'STAR' if n=0.
FETC	n	=1 Fetch events from lun 13,old two jet (on file F15GEN.MCSOUR.TQJ01). =2 Fetch events from lun 13, MOPEK. =6 Fetch events from lun 13, others.(See GET. Used for LUND events.)
FLDS	a b	Modify field scale: set TIFLAV,TIFLFA in CTIMFL and FLDSCA in CSINPA (for yoke). Any change must be followed by one in the reconstruction also!
GENE	abccc	a=0 Beam gas. =1 Phase space. Type of particles to be defined on card 'PART'. =2 MOPEK (+NAKADA) events. =3 A pair of particles (as given on card 'PART'. Angular range as given on card 'ANGR'). =4 Bhabha. =5 Muon pairs. =6 Tau pairs. =7 Gamma pairs. =8 Cosmic. =9 LUND 3 gluon and 2 gluon+photon b=1, radiative corrections included (ccc not used at present).
GENF	a,b	To set parameters for GENFIL (TLFLI3,GNFRCU in block CSINPA. See GENFIL).
GETP	a,b,c,d	To set parameters for GET/GETVTX (GETINC, GETSTL,TLFLI1,TLFLI2 in block CSINPA.) See GET/GETVTX for meaning of parameters.

Key word	Parameters	Action
HADI	n	To switch on/off hadronic interactions. Default = 2 (no fermi). Other possible values are -1=off, 1= no interactions for muons and no fermi smearing, 3=all. The treatment of fermi smearing does not conserve energy in the present version. However it is of vital importance for the simulation of a hadronic shower detector.
LUND	a	To select different types of events generated by the LUND program. a=0 All events used (default). =1 Only 3 gluon. =2 Only 2 gluon + photon. =3 1+2 . =4 Only 2 gluon.
PART	ntot id1..idn	Card to define particles to be generated (not for events on tape). ntot=number of particles. id1..=particle identifiers.
PRDE	n1 n2	n1,n2 > 0 gives plots of DE/dx simulation.
SELP	i1 i2 ..i20	List of id's of particles for selection of events on external file. If the event does not contain any of the particles in the list, the event is skipped.
SHOF	n	n=1: To use inhomogenous field in shower counters for e, γ. Default: n=0 means field at center of barrel and end cap.
SAVM	n	n=1: To save into bank JMT also all decay products (default=0. See GTRA for present criteria for saving).
STAR	n	n is first event to read from tape.
TAPE	n	n> 0: Write events on LUN 3.

Key word	Parameters	Action
THLV	n	To raise thresholds for e,γ in shower counters. region. Saves some time (40% in shower counters for n=1). n=0 is default. Thresh: 3.,1.6 for e/γ. =1 Thresh: 6.,1.6 =2 Thresh:12.,3.2 All in units of m_e. For n=2 π^0's can not be used, but the only intention is to still have overlaps with charged tracks etc. For n=1 the shower counter scale factor in the reconstruction program has to be slightly modified (more for n=2).
TMNG	i=n	To switch on timing for various routines. See A6.
THRE	e1,e2	Energy thresholds in units of m_e to be used for regions like yoke etc. See card CUTE. Defaults: 9.,4.8 (=3* standard).
TRIG	n	Number of events to process. (Earlier it was defined as n+ the value on card EVE, but not any longer.)
TIME	n	Jobs stops when n seconds left.
VERT	x y z dx dy dz	Defaults 0.
VDCH	n	To switch VDC on. Default=-1 (off). n=0 only introduces extra material in an average way (no actual simulation done). =1 VDC in but no digitization. =2 VDC complete simulation.

To modify particle table: copy cards from particle table and modify and add them after FFREAD cards (see MOPEK manual[2]).

2.3 Generators

Built in generators are selected by data card 'GENE' (section 2.2) and the available ones are listed in chapter 5.

Some generators exist that can be plugged into SIMARG at execution time by giving one of the following libraries as the first call library:

SIMARG.RBAB.L	Radiative bhabhas
SIMARG.RMUO.L	Radiative muon pairs
SIMARG.RGAM.L	Radiative gamma pairs
SIM200.GEN.L	Beam gas, phase space and cosmic generators

In the main program library there are just dummy routines for these generators.

Each library contains a short description of its routines. Look for a member named $DOCUM or something similar. The source for the radiative lepton pairs has been taken from Berenz and Kleiz [3] but cleaned up a bit to avoid clashes with CERN and other library routines. The phase space generator is essentially the original GEANT routine. The cosmic generator was set up according to available data on studies of cosmic radiation. It gives as output the absolute rate , so that knowing the trigger acceptance one can calculate the actual rate of events accepted by the trigger. The beam gas generator is just a simple generator for deep inelastic eN interactions where measured distributions on pt dependence, multiplicities of various particle species etc are used.

External generators that have been interfaced with SIMARG are MOPEK [2] and LUND [4].

For further details see appendix A7.

2.4 Reconstruction job.

A standard job for the reconstruction of MC events with the normal analysis program can be found in F15GEN.ARGMCP.S:

Jobdeck	SIMARG version	ARGUS version
#MCARLO8	SIM110 - 200	ARG08
#MCARLO0	SIM110 - 200	ARG07
#MCARLO9	SIM109	ARG07

The jobs contains various corrections depending on ARGUS and SIMARG version.

As an example we have the job:

```
// JOB 10315215,CLASS=A,TIME=(1,00),MSGCLASS=T
//*MAIN LINES=(15),RELPRI=MED
// EXEC FCLG,PARM.FORT=XL,REGION.LKED=990K,
// LKED='SIZE=(512K,96K)',REGION.GO=(1200K)
%MACRO ARMAIN
%MACRO DTUNPK05
%MACRO DFMATC8
%MACRO SHMATC8
%MACRO SHIMPA8
%MACRO MCDAUG
%MACRO IOCATF8
%MACRO VXTKIN8
%MACRO RNDMUBI
%MACRO HDCEXT
%MACRO PLOTXX
%MACRO HDCOPY
%MACRO SYSSYM
//LKED.SYSLIB DD
// DD DSN=F15ARG.ARG08.EL,DISP=SHR,UNIT=FAST
// DD DSN=F15ARG.ARG08.UL,DISP=SHR,UNIT=FAST
// DD DSN=R01UTL.CERN.KERNLIB4,DISP=SHR
// DD DSN=R01UTL.CERN.GENLIB4,DISP=SHR
// DD DSN=R01UTL.CERN.PACKLIB4,DISP=SHR
// DD DSN=DESYLIB,DISP=SHR,UNIT=FAST
//LKED.SYSPRINT DD SYSOUT=*
//PRINT.FORTRAN DD DUMMY
//GO.SYSIN DD *
OUTPUT ON
INP SEQ
CU DF TR 1
CU DT DXY 1.5
CU D3 DZ 8.
CU DT MCE .95 MCB 50. MCS .018 MCC .07
CU SH BA 3.0
CU SH END 4.3
TIME 10
GO
//GO.FT01F001 DD DSN=F15GEN.MCDATA. CCB200.V001,DISP=SHR,UNIT=TAPE
//GO.FT02F001 DD DSN=F15GEN. MCDST200.CCB08.D001,UNIT=TAPE,
// DISP=(NEW,CATLG,CATLG),DCB=R01DCB.TP32
//GO.FT11F001 DD DUMMY
//GO.FT21F001 DD DSN=F15GEN.ARG08.CO,UNIT=FAST,DISP=SHR
//GO.FT26F001 DD DSN=F15ARG.RUNFILE,UNIT=FAST,DISP=SHR
```

2.5 Utility package.

There are two routines that gives the connection between reconstructed and generated tracks, namely DFMATC for charged particles and SHMATC for neutral ones. The first uses the information of wires hit in the generated track bank JMT and the second information on shower counters hit. The result of the matching is stored in the JTK bank word 50 for charged particles and in word 3 for neutral ones. In the JMT bank it is stored in word 18. More detailed information on the result of the matching can be found in the JMD, JDM, JSE and JME banks. See the documentation in the above mentioned routines.

In order to facilitate the use of that information some routines have been written to extract information from the MC banks. With the help of these routines one can easily find out if a certain combination of reconstructed tracks actually originated from the particle one wants to find. The routines are:

MDAUHT
MOTHER
MODAUHT
MODEP
DEBJMT
WIRUNP

They can be found in the same library as the reconstruction job, i.e. F15GEN.ARGMCP.S and are self documented.

3. STRUCTURE OF SIMARG

The general layout of SIMARG is shown in fig 3.1. The dashed line gives approximatly the separation between the original GEANT part and the SIMARG part.In the following chapters (4-9) the various stages of the program will be described in more detail. Mainly the additions and modifications will be treated. The reader is refered to the GEANT write up [1].

GEANT uses the ZBOOK/YBOOK [5] package for the dynamical bank structure (in blank common). It is initialized in GZINIT (called from GINPUT) where the length of the structure is defined. The modifications to the dynamical bank as well as the format of the various banks used for input and output to the different stages of the program are described in the appendix. The results of the various stages are stored in another dynamical structure (/CDATA/) which is dumped to tape (by GUTRIG) in the output stage.

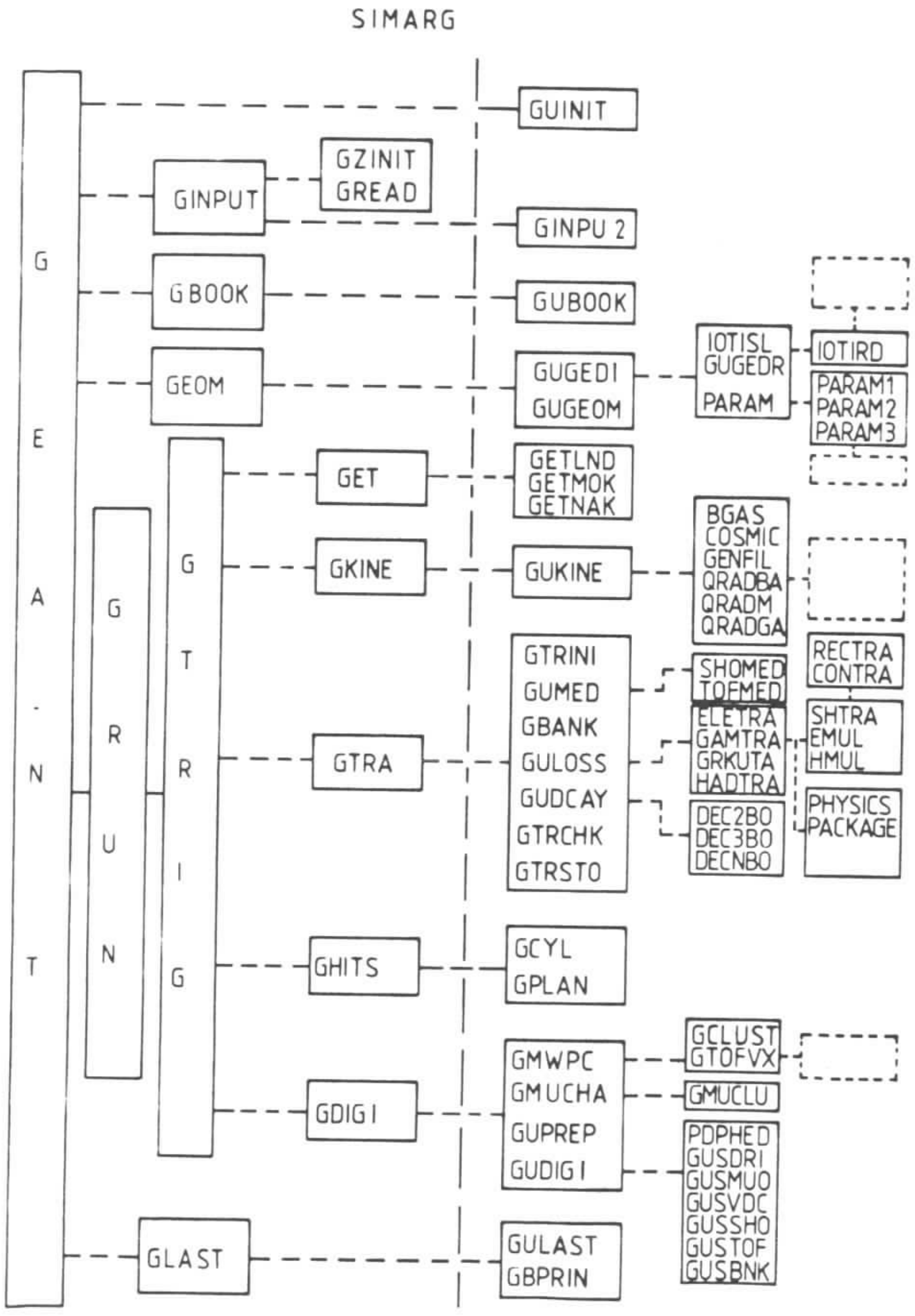


Fig 3.1

4. INITIALISATION STAGE.

The calling sequence is as follows:

```
G  —>  GUINIT   —>  GUINN
E  —>  GINPUT   —>  GZINIT,LTFLOA,GREAD,GINPU2
A  —>  GEOM     —>  GUGEDI,GUGEOM
N  —>  GBOOK    —>  GUBOOK
T
```

GUINIT sets up the bank for the ouput record (COMMON/CGDATA/) and calls GUINN for user initialisation.

GINPUT sets up the dynamical GEANT structure (via GZINIT) and reads standard GEANT data cards via GREAD . GREAD further calls GUREAD for reading of the SIMARG data cards.

Some general variables are also initialised in GINPUT (among other things, the step limits used for the tracking). After reading the data cards GINPU2 is called to modify variables according to the data cards read (flags for tracking, thresholds ,debug flags etc)

The little track finder (LTF) is initialised by LTFLOA which reads data from unit 04 into common blocks /INFOMC/ and /LTFIN/

The initialisation of constants needed for tracking (and physics) as well as the setting up of the geometry is described in the following sections. More details can be found in the appendix.

4.1 General constants/Blockdata.

Constants that can be modified by data cards as well as other essential constants are set in the following blockdata's:

Block name	Initialises
BLOCKDA1	Run flags.
BLOCKDA3	Thresholds, media constants.
BLOCKDA4	Media coding.
BLOCKDEX	Constants for the DE/dx simulation of the D.C.
BLOCKDAH	Cross sections for hadronic shower simulation.
BLOCKHAD	Cuts etc for hadronic shower simulation.
BLOCKVDC	Geometry of VDC.
BLOCKIOT	Constants for title reading routines.
BLOCKERR	Error messages.

The member BLOCKDA2, which contained the particle table, is no longer used but instead read from the title file (by IOTRPT). For the contents of the particle table see MOPEK [2].

4.2 Initialisation of shower processes.

The calculation of runtime cross sections and various rejection functions as well as parameters for energy loss is steered by routine PARAM (called from GUGEDI) which calls

PARAM1	for electromagnetic processes : each media.
PARAM2	as above but for each composite media .
PARAM3	for hadronic processes (calls GHADCR).

PARAM also sets up the functions used for the shower counter light guide corrections.

4.3 Initialisation of geometry.

The definition of the geometry is controlled by GEOM which first calls GUGEDI. GUGEDI reads (via IOTISL) the title file which contains the geometrical constants and calls

Routine	Sets up geometry for	Fills block
GUGEDR	DC.	CCHAPAR
GUGEMU	Muon ch.	CCHAPAR
GUGEVC	VDC.	CCHAPAR,CVDCDI
GUGESH	Shower counters.	CSHODIM
GUGETF	Time of Flight (TOF) counters.	CTOFDIM
GUGEYO	Compensation coils, yoke and detector limits	CIYOKE,CTRESH

The results of the first three routines are used by GUGEOM (called from GEOM) to set up the input to the GEANT bank JPOS used for the intersection and digitisation stages (see GEANT manual [1]). GUGEYO also sets up some geometrical limits used during the tracking stage to signal change of thresholds (by HADTRA etc, see chapter 6). See also appendix A3.

5. KINEMATICS STAGE.

The kinematics of an event is either taken from tape (GET) or generated by help of GUKINE. GET calls the routines GETLND, GETMOP or GETNAK to read LUND, MOPEK or Nakada events (some old two jet events). The format of the input is described in appendix A1. GUKINE steers the selection of event generators via data card 'GENE'. The present in-line generators are:

GENE code	Generator	Main routine
00000	Beam gas	BGAS
10000	Phase space	GENFIL
20000	MOPEK (+NAKADA)	
30000	A pair of particles	GUKINE
40000	Bhabha scattering	GUKINE
41000	Radiative bhabha scattering	QRADBA
50000	Muon pairs	GUKINE
51000	Radiative muon pairs	QRADMU
60000	Tau pairs	GUKINE
70000	Gamma pairs	GUKINE
71000	Radiative gamma pairs	QRADGA
80000	Cosmic	COSMIC
90000	LUND events	

The beam gas, cosmic and phase space generators reside in separate libraries and can be invoked as explained in chapter 2.3. Some details about these generators are given in appendix A7. The generated quantities are stored in the event stack, i.e. bank JTRAKI, by GSTORE. GSTORE also generates a decay length according to the lifetime of the particle (from particle data table, see MOPEK manual). GUKINE also aplies beam smearing upon request.

6. TRACKING STAGE.

The main steering routine is GTRA. It calls the following routines:

Routine	Purpose
GTRINI	Initialisation (once per event)
GUMED	Returns present medium number.
GBANK	Store coordinates into temporary bank.
GUFLDS	Get magnetic field.
GNWMED	Aproximate distance to next media (exact if neutral particle).
GULOSS	Determines which tracking routine to call.
GUDCAY	Allows particle to decay.
GTRCHK	Checks on energy conservation (debug option).
GTRSTO	Store track IT into bank JKITRA(IT).
SHOADD/TOFADD	If track not stored adds energy deposited in shower and TOF counters to mother.
GDEBUG	Print (once per track).
GDISP	Plot (once per event).

The flow chart looks is as follows:

0. Initialisation of tracking.

1. Fetch a track from the stack (bank JTRAKI in block CBLANK) and copy it to the block CSTOTRA (/STOTRA/) at the beginning, thereby releasing the space for the next track to be stored. Classify the particle as

KPART =1 e+-
=2 h+-
=3 photon
=4 h0

Call GUMED and GBANK .

2.

a) If the track is in the shower counter region, call GULOSS directly. If not, calculate the maximum step length from the preset step limit for the medium, the approximate distance to next medium (by GNWMED times some scale factor for charged particles) and the remaining length to the decay point (corrected for energy loss during the tracking). For the DC region the step will normaly be the preset limit(3cm) divided by the cosine of the angle to the beam axis(z axis). This is done to limit the number of points stored in the banks (time comsumption, bank overflows). No precision is lost since the z dependence of the calculation of the closest distance is small.

Then call GULOSS which decides which lower level tracking routine is to be called:

GRKUTA	tracking	in vacuum
ELETRA	-	of electrons/positrons
GAMTRA	-	of photons
HADTRA	-	of hadrons

Neutrinos are not tracked. All tracking takes place in an inhomogenous magnetic field (except for field free regions). Before returning to GTRA GULOSS calls TOFMOD to add up any energy deposited in the TOF counters. Energy deposited in the shower counters is taken care of by the above tracking routines (by calls to SHMODB/SHMODE).

b) If a particle should stop or decay jump to 3. Else jump to a). If the particle is at a medium border, it is simply pushed over by a small displacement. At this stage there is a check to see if the coordinates should be stored. Then continue at a).

3. Output stage. The particle has to pass some selection criteria to decide if it should be saved. The selection criteria is that it passed through any chamber (it will then be needed for the later intersection and digitisation stages) or deposited enough energy in the shower counters (in this case it will depend on from where it actually originated). Particles created at the main vertex are always stored. When finished with the particle GTRA goes to 1 and fetches the last particle stored in the stack.

4. If there are no more particles, a plot of the result of the tracking is produced upon request.

GTRA has been substantially modified. Earlier versions of GTRA defined the step size based on the distance to next medium or next interaction. Now it is normally defined by the preset maximum step size for each medium. The calculation of the distance to the next interaction is made on a lower level and return to GTRA is only made if the particle stopped, hit a medium border or reached the maximum step limit. For the shower counter region, a special (analytic) tracking is made, see section 6.1. The particle is kept on the lower level until it stops or leaves the shower counter region (which consists of several media).

The format of the output banks of GTRA are described in appendix A2. The following sections will deal with the actual tracking routines listed above.

6.1 Analytic tracking.

In the shower counter region the tracking is done analytically. This is because normal tracking finds bordes with a binary search, which is very time consuming for thin media (smaller tolerances needed). In the shower counter region, which consists of many thin media, the distance to the next border is found analytically. This means that one finds the intersection of a helix and a number of planes. The problem with this method is not solving the equations but rather in recognising all possible cases. However, by symmetry considerations the problem can be broken down into a relative small number of cases provided the borders can be defined in a simple way. This is done in GUGESH (common block CSHODIM).

The advantage is, as said, a considerable gain in time. The disadvantage is that the geometry cannot be easily changed, which on the other hand is not normally necessary.

The calculation of the distance to the next border is done by routine SHTRA with the help of RECTRA and CONTRA, where the two latter ones solve the equations for two principal cases (rectangular corners or nonrectangular). For neutral particles the solution is trivial.

The distance that is returned by SHTRA depends on the type of particle. For neutrals the result is exact (except that a small amount is added to be sure that the particle will cross the border). For charged hadrons a small correction is made for the expected energy loss (a correction that depends on how it aproaches the border). For electrons and positrons the problem is more complicated since the energy loss can be quite considerable. If the energy is very small, the multiple scattering is large, and the length is normally just the closest distance to the next border. If the energy is not small, the track is adjusted so as to reach next border in one step if possible but still not allow the particle to pass to far into the next medium (if energy loss gets too big during a step a new call to SHTRA is made).

These corrections have been tuned to produce the right energy deposition in scintilator and lead on the average. The error in the total energy deposited in a shower counter is estimated to be at most .5 % (actually the error from rounding off when summing up many small contributions is as large). If larger errors can be tolerated the time consumption can be further decreased.

6.2 Tracking e+-, γ.

The tracking is handled by ELETRA for electrons and positrons and by GAMTRA for photons. A simplified flow diagram follows:

0\. Initialisation of tracking. The energy of the particle is transformed into units of the electron mass and the step limit to units of the radiation length. If the particle is

not in the shower counter region, the requested step is broken down to substeps if the expected energy loss during the step will be too large.

1.1 If in shower counter region SHTRA is called. Otherwise check the remaining distance to the next border. If the requested step limit is reached or the particle encounters a new medium (for shower counters if outside that region) jump to 3.

1.2 Call SHMODB/SHMODE if energy was lost during the last step and the particle is in the shower counter region.

    2.1 Check to see if the particle lost too much energy. If so, go to 1.1.

    2.2 Calculate the distance to the next interaction point. Transport the particle up to the interaction point applying multiple scattering and continous energy loss (EMUL). Find which type of interaction the partclicle should undergo. Apply it and then go to 2.1 if the particle did not stop and the present (sub-) step is not yet complete. If the (sub-)step is finished go to 1.1, otherwise jump to 3.

3\. Add up energy losses, transform energy and resulting step length back to standard units and return to GULOSS.

The reactions applied are the following:

For e+- :

BREMS	Brems strahlung
POSANN	Positron annihilation
MOLLER	Moller scattering
BHABHA	Bhabha scattering
EMUL	Multiple scattering

For photons:

IPAIR1,2/GAMTRA	Pair production
GAMTRA	Photoelectric effect
ICOMPT/GAMTRA	Compton scattering

When adding up energy losses in the shower counter scintillator, a correction for absorption in the light guides is applied (depending on the position of the particle). These corrections have been determined from measurments. Shortly after a particle enters the main coil or the yoke the thresholds cuts are changed. The thresholds can be changed by data cards, but the default values have been chosen so that one can still get back scattering from the material just behind the shower counters. The same is true for the outer parts of the main coil and the yoke in the neighborhood of the muon chambers. There the thresholds are lower to allow noise in these chambers.

6.3 Tracking hadrons.

The flow diagram is the same as for ELETRA and GAMTRA and will not be repeated here. The only difference is in the physics routines called. Instead of EMUL in ELETRA HMUL is called to transport the particle and calculate energy loss, multiple scattering and delta electron generation. Again, energy loss is randomized. The distance to the next interaction point is found by a call to GHDMCR (CASMU for muons) and the physical processes are applied in HADINT. In the case of stopping antiprotons an extra call to HADINT is made to force annihilation.

The physics routines have been taken from the hadronic shower simulation program GHEISHA [6] but modified in order to fit into the framework of SIMARG. The routines HADINT (former CALIM) , GHDMCR (former INTACT) and MATTER have been modified and the routine GHADCR added for initialisation. MATTER returns the medium parameters according to SIMARG definitions and GHDMCR was changed to give back the distance and not the probability of interaction for a given step length. HADINT accomodates differences between the SIMARG and the GHEISHA event stacks. Also it will only apply interactions and not do tracking as in CALIM. Other changes such as the renaming or modification of common blocks and renaming some utility routines were necessary to avoid clashes with the standard CERN library. In additon some bugs have been removed.

HADINT calls the following physics routines:

Routine	Purpose
CAPTUR	Neutral baryon capture
CASMU	Deep inelastic or elastic scattering of muons.
CASPIP	π^+ - nucleon interactions
CASPIM	π^- . . .
CASKP	K^+ . . .
CASKM	K^- . . .
CASK0	K^0 . . .
CASK0B	$\overline{K}^0$ . . .
CASP	p . . .
CASPB	$\overline{p}$ . . .
CASN	n . . .
CASNB	$\overline{n}$ . . .
CASL0	Λ . . .
CASAL0	$\overline{\Lambda}$ . . .
CASSP	Σ^+ . . .
CASSM	Σ^- . . .
CASASP	$\overline{\Sigma}^+$ . . .
CASASM	$\overline{\Sigma}^-$ . . .
FERMI	Fermi motion smearing.

7. THE INTERSECTION STAGE.

From the points bank (JBANK(IT)) set up by GTRA, the routines GCYL and GPLAN (called from GHITS) are used to find the intersection with the detectors (each layer in the drift chamber is considered a separate detector). These routines have only been slighly modified. GCYL was changed to find the intersection with the potential wires. This allows one to obtain the track length in the cells more or less directly. The result is stored in banks JTRAK(IT) for each track IT and the format of the banks is described in the appendix A2. For more details see the GEANT manual [1].

8. THE DIGITISATION STAGE.

The digitisation stage consists of calculating the distance of closest aproach to the sense wires of the chambers. For the DC the track length is also calculated (if the track crossed only one cell in a layer the length is already known as a result of the previous stage) and from that the DE/dx is simulated [7]. The DE/dx simulation is done in a set of routines named

DEDXM0	**Initialisation.**
DEDXMG	**Initialisation.**
DEDXM1	**First stage of DE/dx simulation.**
DEDXM2	**Second stage of DE/dx simulation.**

The simulation starts from a measured energy loss spectrum in propane.

The steering routine for the digitisation stage is GDIGI which for each detector calls GMWPC for the DC and the VDC and GMUCHA for the muon chambers. For each hit on a detector GMWPC calls GCLUST for the DC and GTOFVX for the VDC.

The essential task for GCLUST is to match points from neighbouring detectors or the same detector in order to calculate the track length. The matching is done with the help of the routines GCLNEX and GCLEXT (puts artificial points on next ,lower, detector to be treated if the track happened to turn over in that detector,in which case there are no points on it). The length in each cell is calculated in GCLOUT by LENCEL. GCLOUT also finds a starting point inside each cell for the closest distance calculation which is done in GCLDIS. GCLDIS follows the procedure of ref. [8] which assumes that the wires are straight. However, knowing the first approximation of the distance to the point of closest aproach one moves that distance along the particle trajectory and then calculates a new closest distance. The result is good to 1 micron or better.

After the calculation of the track length in the cells, the routines DEDXM1 and DEDXM2 are called to obtain corresponding DE/dx values.

With help of VDCELL and GCLOSE, GTOFVX performs the corresponding task for the VDC. It uses a circular approximation to the track to find the closest distance.

All digitizings so obtained for a detector are then sorted (GSORT) and merged (GMERGE) and the result is stored in banks JDUM(1) and JDUM(2) for the DC and the VDC respectively. For the DC there are two words per point (closest distance and DE/dx) while for the VDC one word is enough (closest distance). See also appendix A3, block CBLANK.

The muon chambers are treated in GMUCHA (corresponding to GMWPC) and GMUCLU calculates the actuall tubes hit. The result is stored in the standard GEANT banks JNOTRA,JNODET etc. (via GRDOUT that is called from GDIGI).

9. THE OUTPUT STAGE.

The results of the previous stages are stored in block CGDATA (/CDATA/) by the routine GUDIGI (called from GDIGI). GUDIGI calls the following routines to perform that task:

Routine	Purpose
PDPHED	Fills header bank
GUSDRI	Stores DC TDC's and ADC's
GUSMUO	Stores muon chambers hit.
GUSVDC	Stores VDC TDC's.
GUSTOF	Stores TOF TDC's and ADC's
GUSSHO	Stores shower counter ADC's
GUSLTF	Stores LTF masks hit.
GUSBNK	Stores kinematics of generated and traced tracks

For the DC, the closest distance is transformed into TDC units by using a drift time - space relation taken from actual measurements. The DC DE/dx is transformed into ADC units in the simulation step. For the shower counters, the units are MeV. GUSBNK fills banks JMC, JMG and JMT. The formats of these banks are described in appendix A2. The block /CDATA/ is identical to the ARGUS raw data bank and is described in the ARGUS software notes [9].

The final /CDATA/ structure is written to tape by GUTRIG (called from GTRIG).

Various print outs of the stored information can be obtained via the SIMARG data cards, see section 2.2 and appendix A6.

10. References.

(1) R.Brun et al., GEANT, CERN-DD/78/2 (1978).

(2) R.Waldi, ARGUS software note 27, March 1983.

(3) F.A.Berends and R.Kleiss, DESY preprint, DESY 80/66, July 1980.
R.Kleiss, Ph.D. thesis, LEIDEN, June 1982.

(4) B.Andersson,G.Gustafson,C.Peterson, Nucl.Phys. **B135** (1978), 273.
B.Andersson,G.Gustafson, Z. Phys. **C3** (1980), 223.
T.Sjostrand, LUND preprint, LU TP 82-7, June 1978.

(5) R.Brun et al., ZBOOK, CERN program library, CERN-DD/78/1 (1978).

(6) H.Fesefeldt, GHEISHA program listing,
and DESY talk 1984 .

(7) V.Matveev, ARGUS note, May 1982.

(8) A.D.Johnson.G.H.Trill, LBL report, TG-301, Sept 1976.

(9) H.Schröder, ARGUS software note 3 (1979).

(10) R.Waldi, ARGUS software note 28, March 1983.

(11) FOWL, CERN program library.

(12) H.Messel and D.F.Crawford, Electron-photon shower distribution functions, Pergamon Press, Headington Hill Hall (1970).

(13) W.R.Nelson and R.L.Ford, EGS code, SLAC report (1978).

(14) J.H.Hubbel, National Bureau Standards, NSRDS-NBS **29** (1969),1.

(15) B.Rossi, High Energy Particles, sect 2.3 (Prentice Hall, 1952).

(16) J.C.Butcher and H.Messel, NP **20** (1960), 15.

APPENDIX

A.1 Format of input events.

Events are read with in unformatted read statement:

READ(LIN) LEN,(BUF(I),I=1,LEN) ,

where BUF is equivalenced with IBUF and the working space WSP(401) of the dynamical GEANT bank structure (blank common).

A.1.1 LUND events.

The length of the record is:

LEN = 4 + 5*NPART,

where NPART is the number of particles. The contents of BUF is (IOFF = 5 * (I - 1) , I = 1 , NPART) :

Word	Content
IBUF(1)	9000 (event generator type)
BUF(2)	1.0 (weigth of event)
IBUF(4)	CM energy (GeV)
BUF(IOFF+5)	px (GeV/c)
BUF(IOFF+6)	py (GeV/c)
BUF(IOFF+7)	pz (GeV/c)
BUF(IOFF+8)	generated mass (GeV/c2)
BUF(IOFF+9)	packed word

The packed word contains the following:

Bits	Content
1	=1 if resonance decayed by generator =0 otherwise
2- 7	jet number
8-17	ID of particle
18-27	pointer to mother

A.1.2 MOPEK events.

The input format is described in [10].

A.2 Format of banks.

A.2.1 Bank JPOS.

This bank is filled by GEOM and contains the description of all chambers. The format is defined in the GEANT documentation [1].

A.2.2 Banks JBANK and BANKP.

These banks contain the coordinates of the points saved during the tracking stage. BANKP in common /STOBAN/ is a temporary storage while JBANK is the final storage, only filled if it is decided to save the track. These banks are described in ref. [1].

A.2.3 Bank JTRAKI.

This is the so called event stack. It starts getting filled at the kinematics stage by GSTORE and then continously during the tracking. The pointer to this bank is JT=JTRAKI + ITRATO, ITRATO = LENSTO*(NTRA-1) where NTRA = track number . LENSTO is set in BLOCKDA1 (=15 currently).

B(JT + N)	Content
1	vx
2	vy
3	vz
4	px
5	py
6	pz
7	mass
8	charge
9	decay length (generated)
10	IGENER*(NTRA mother)x10 + IDECAY
11	NTRA of track itself
12	0 (NTRA*1000+NTRACK at end of GTRA)
13	0 (Track length at end of GTRA)
14	ID
15	Length up to vertex.

NTRACK is the numbering of tracks stored in JKITRA by GTRA (A2.5). IDECAY is a flag raised when GUDCAY causes the particle to decay. If the particle is produced in a hadronic interaction, IDECAY is set to 2. IGENER =1 if the particle is created during the tracking stage.

A.2.4 Banks JADCSM,..

These banks in the blank common (the GEANT dynamical structure) contain information on the energy deposited in the shower and TOF counter modules as well as the time of flight. The current pointers are obtained from ITRASH for the shower counters and ITRATF for TOF counters. The pointers reside in /ADCINF/. When the tracking of a particle is finished these pointers are stored in bank JKITRA (see below).

Word	Contents
B(JADCSM+ITRASH)	Shower counter module number
B(JADCSS+ITRASH)	Energy deposit in scintillator
B(JADCSW+ITRASH)	Energy deposit in supports
B(JADCTM+ITRATF)	TOF module number
B(JADCT1+ITRATF)	Time of flight, +z pm
B(JADCT2+ITRATF)	Time of flight, -z pm
B(JADCC1+ITRATF)	Energy seen by +z pm
B(JADCC2+ITRATF)	Energy seen by -z pm

A.2.5 Bank JKITRA.

This bank is set up by GTRA. The format is quite different from that described in the GEANT manual. It contains 61 words. It is partially filled by GUSVDC (words 52- 60). JK=JKITRA(NTRACK) is the pointer for track NTRACK.

B(JK + N)	Content
0	number of words in this bank.
1	vx
2	vy
3	vz
4	px
5	py
6	pz
7	mass
8	charge
9	decay length (generated)
10	(NTRA mother)x10 + IDECAY
11	NTRA of track itself (NTRATO)
12	NTRA*1000+NTRACK
13	Track length (negative if stopping)
14	ID
15	DRCODE (filled by GUPREP)
16	x at entry to drift chamber
17	y -
18	z -
19	px -
20	py -
21	pz -
22-26	WRCODE (filled by GUPREP)
27	number of shower counters hit
28	pointer to JDADCSM,..(shower counters)
29	number of TOF counters hit
30	pointer to array JADCTM,..(TOF)
31	TOFPF
32	TOFPD
33	x at entry to shower counters
34	y -
35	z -
36	px -
37	py -
38	pz -
39	Energy deposited in lead plates
40	Energy deposited in supports
41	TOFLNG
42	x of last point on track
43	y -
44	z -
45	NUMED = medium number of last point
46	x at entry to VDC
47	y -
48	z -
49	px -
50	py -
51	pz -

B(JK + N)	Content
52-60	VCCODE (filled by GUSVDC)
61	p, momentum at entry to shower counters

The meaning of DRCODE,WRCODE and VCCODE are described in appendix A2.7 (JMT bank).

A.2.6 Bank JTRAK.

The format is somewhat different from that described in the GEANT manual. JT = JTRAK(IT) is the address of the hits bank for points on track IT. Each point has NWOUT words (set in GINPUT). This bank is first filled by GCYL or GPLAN but later modified in GDIGI (copies words 5,6 to words 12,13 for the DC detectors) and in GMWPC or GMUCHA (words 4-6, see GEANT manual).

B(JT + N)	Content
For the DC:	
1	number of words in this bank.
2	detector number ND.
3	x - coordinate of track in detector ref system.
4	y - coordinate of track in detector ref system.
5	px/p
6	py/p
7	p, momentum
8	s, length of track up to this detector.
9	z - coordinate of track in detetector ref system.
10	pz/p
11	charged
12	sx
13	sy
For the VDC:	
1 -6	as above
7	z - coordinate of track in detector ref system.
8	dx/ds
9	charge
12,13	not used
For the muon chambers:	
1 -11	as above
12,13	not used

At the digitisation stage (GMWPC, GMUCHA) the content of JTRAK is modified to:

B(JT + N)	Content
5	NCOUNT, current cluster number
6	wire number
7	width
9-11	modified if IDROP (data card DROP) set to 0. (This is however not possible now).

A.2.7 banks JMC, JMG and JMT.

Pointers:

JMC	Header block (17 words)
JMG	Generated tracks (NG*7 words, NG=number oftracks)
JMT(J)	Traced track J

Contents of banks:

IA(JMC + N)	Content
1	nominal CM energy
2	actual CM energy
3	px of e+
4	py of e+
5	pz of e+
6	px of e-
7	py of e-
8	pz of e-
9	vx
10	vy
11	vz
12	number of tracks generated (NG)
13	number of tracks traced (NT)
14	EVENT TYPE (see below)
15	weigth of event
16	SIMARG version
17	MC ERROR CODE (see below)
18	event number from outside generator
19	free

JG=JMG+(I-1)*7 pointer to generated track I :

IA(JG + N)	Content
1	px
2	py
3	pz
4	generated mass (taken from input tape if any)
5	particle ID
6	IGCODE (see below)
7	TRCODE (see below)

JT=JMT(J) pointer to traced track J :

IA(JMT + N)	Content
1	x of origin
2	y of origin
3	z of origin
4	px -
5	py -
6	pz -
7	particle ID
8	track length. > 0 if stopped,< 0 if decayed
9	ITCODE (see below)
10	DRCODE (see below)
11	SHCODE (see below)
12	TFCODE +MUCODE (see below)
13-17	WRCODE (see below)
18	pointer to fitted track in ARGUS analysis
19	pointer to fitted vertex in ARGUS analysis.
20	total energy deposited by track in shower counters (MeV)
21	particle TOF (time vertex-TOF counter in ns)
22	impact point on TOF: dist to +Z end (CM)
23	x at drift chamber inner wall
24	y -
25	z -
26	px -
27	py -
28	pz -
29	x of impact point on shower counter
30	y -
31	z -
32	x at outer muon chamber. If not hit, inner ch.
33	y -
34	z -
35	energy deposited in lead plates
36	energy deposited in supports
37	length of track up to TOF.
38	NUMED at stop point
39	momentum at entry to shower counters

IA(JMT + N)	Content
40	free
41	x at entry to VDC
42	y -
43	z -
44	px -
45	py -
46	pz -
47	number of VDC wires on this track (max 20 stored)
48 - 52	VCCODE (see below)
53 - 55	free

Explanations:

MC ERROR CODE	only 99 tracks can be stored in JMT. Low momentum tracks are dropped first starting with $p < 10$ MeV/c but if this is not enough only the generated traced tracks are stored. CODE= -(no of "old" tracks)
EVENT TYPE	see data cards, section 2.1 (if input tape given it will be taken from that)
IGCODE	ABCD, where AB= pointer to mother in bank JMG CD= jet number or simular
TRCODE	ABC, where AB= pointer to bank JMT C= 0 traced but did not hit drift chamber = 1 traced and hit drift chamber = 2 not traced (resonance)
ITCODE	ABCDEFGHI, where A= 0 for normal decay = 1 part. prod. by scatter of mother = 2 as 0 but not direct from mother (i.e. only grand mother or higher stored) = 3 as 1 with same but as above = 4 from hadronic shower = 5 as 4 with same but as above BC= pointer to bank JMG if >0 DE= pointer to mother in bank JMT if >0 FG= pointer to mother in bank JMG if >0 HI= jet number or similar

DRCODE	no of 0 degree wires hit + (no of $-\alpha$ wires hit)*100+ (no of $+\alpha$ wires hit)*10000
SHCODE	no of c. hit+(1024*NZ+(NPH-1)*16+NR)*2**16 (for 1st c. hit)+(1024*NZ+(NPH-1)*16+NR)*32 (for c. with max ADC)
TFCODE + MUCODE	ID of 1st c. hit +(no of hit muon ch.)*1000
WRCODE	ID of 1st Z wire hit for each layer. word 1= L18+L17*Z1+L16*z2+L15*z3 2= L14+L13*Z1+L12*z2+L11*z3 3= L10+L9 *Z1+L8 *z2+L7 *z3 4= L6 +L5 *Z1+L4 *z2+L3 *z3 5= L2 +L1 *Z1+NDOUB*2**17, z1= 2**8, z2= 2**16, z3=2**24 and where L= layer, NDOUB= no of times the track hit the same layer more than once
VCCODE	packed words with VDC wire numbers: word 1=N1 + N2*600 + N3*600**2 + N4*600**3 2=. . . . 3= . . . . 4= . . . . 5= . . . . 6=. . . . . + N20*600**3 where N1...N20 are VDC cell numbers.

A.3 Common blocks

Only the more important common blocks in SIMARG are descibed here. Concerning the blocks in the hadronic shower routines the user is, with some exceptions, refered to the GHEISHA documentation [6].

%MACRO CADCINF

```
COMMON/ADCINF/NTRASH,ITRASH,NTRATF,ITRATF
```

Pointers to arrays JADCSM etc. See appendix 2.4.

%MACRO CANNIH

```
COMMON /ANNIH/ ALPHAN(50)
```

ALPHAN	Runtime cross section for positron annihilation.

%MACRO CBLANK

```
 DIMENSION IB(6000),IWS(400)
 COMMON//B(1),JVERTX(10),JDUM(7),JBEGIN,JREC, JBUF,JKITRA(500),
+          JBANK(500),JPOS(300),JWS(200) ,JADPLA,JNOPLA,JFILS,JLARGE,
+          JNODET,JNOTRA,JFIPLA(300),JTRAK(500),JSTMED,JSTEBA,
+          JNDTRA(500),JSTMUL,JSTELO,JSTEPM,JRADL,JFIELD
+          ,JTRAKI,JADCSM,JADCSS,JADCSW,JADCTM,JADCT1,JADCT2,JADCC1,
+          JADCC2
+          ,WS(4000)
 EQUIVALENCE (B(1),IB(1)),(WS(1),IWS(1))
```

GEANT dynamical structure. See GEANT manual. Some banks have been added and some modified:

JTRAKI	Event stack. See Appendix 2.3
JADCSM-JADCC2	See Appendix 2.4
JDUM(1)	pointer to ADC and TDC values for DC (2 words per hit cell).
JDUM(2)	pointer to TDC values for VDC.
IB(JDUM(7)+ND)	=k, pointer to JDUM(1) for first hit on detector ND, i.e. B(k+JDUM(1)) = ADC of first hit.
JNOTRA	Now 4 words/ hit wire (see GEANT manual).

%MACRO CBREMS

```
 COMMON /BREMST/ CKMBR(50),ALPHB1(50),ALPHB2(50),DELTB(50),
+       AFBR(50),BFBR(50),W0FRQ2(50),ALGW0(50),ALBS1(50),
+       CMIGD1(22),CMIGD2(22)
```

ALPHB1,2	runtime cross sections for Bremsstrahlung.
AFBR,BFBR	rejection functions.
W0FRQ2	plasma freqency.
CMIGD1,2	Migdal corrections.

%MACRO CCOMPND

```
COMMON/COMPND/NCMPND(20),ICMPND(20)
```

NCMPND	Number of different elements in compound.
ICMPND	Pointer to medium description array for each element (see appendix A5).

%MACRO CCOMPN2

```
COMMON/COMPN2/ACMPND(20)
```

ACMPND	weigthed atomic number for compounds.

%MACRO CCOMPT

```
COMMON /COMPT/ ALPHC(50),ALPHCD(50)
```

ALPHC	runtime cross sections for compton scatt.
ALPHCD	MORK correction factor.

%MACRO CCOSMI

```
 COMMON /CCOSMI/ IDCM,NTYPEC,ITYPEC,ECOSML,ECOSMH,KTYPEC,COSRAT(4)
+          ,COSMEN,RMUO,RELE,RPRO,RGAM,GMU1,GMU2,GELE,GPRO
+          ,GGAM,CHARAT(2),EFAREA,IHDRCO,NCOTRI
```

Block for cosmic generator.

%MACRO CDECAYS

```
COMMON /DECAYS/ IPOIN(300),BRANCH(1510)
DIMENSION IBRANC(1510)
EQUIVALENCE (BRANCH(1),IBRANC(1))
```

Contains list of decay modes and branching ratios. It is used by GUDCAY and GUDCMO.

ID	IPOIN(ID)	BRANCH	Comment
ID1	1	NDEC1	No. of decay modes.
	2	LEN1	No. of decay particles +1, mode 1.
	3	BR1	Branching ratio.
	4	IDD1	ID of daugther 1.
	..	...	ID of daugther ..
	2+LEN1	IDDN	ID of daugther N=LEN1-1
	3+LEN1	LEN2	No. of decay particles +1, mode 2.
	4+	BR2	Branching ratio.
	5+	IDD1	ID of daugther 1.
	..	...	ID of daugther ..
ID2	2+LEN1+..	NDEC2	No. of decay modes,particle ID2.
	.....	....	......

%MACRO CDEEP

```
COMMON/C D E E P/EBEAM ,Q2D,XNUD,ICROSS,IFERMI,IBPROF
+       ,XMI,XMA,YMI,YMA,Q2MIN,Q2MAX,XNUMIN,XNUMAX
+       ,SDITOT,XYMIN
```

Block for beam gas generator.

%MACRO CDETECT

```
COMMON/DETECT/IDET(22,15)
```

Gives the partitioning of the detector. See appendix A4.

%MACRO CELLOSS

```
COMMON/ELLOSS/DEDXPO(9,50),DEDXEL(9,50),DEDXAL(9,50)
```

Continous energy loss for positrons, electrons and both for energies above 100 MeV.

%MACRO CELMUL

```
COMMON /ELMUL/ PEN0,S0,XEDGE,IEND,TXEL(3)
```

Communication between ELETRA and EMUL. IEND is set in EMUL to flag end of (sub-)step. XEDGE is distance to end of (sub-)step in units of radiation length.

%MACRO CELOS2

```
COMMON/CELOS2/ALAND,CLAND1,CLAND2,ALFLA1,ALFLA2,GLANDH(50)
+           ,GLANDE(50)
```

For randomizing continous energy loss. See appendix A8.

%MACRO CEMULT

```
COMMON /EMULT/ CHICP(50), CHICBL(50),TMSTP(50),TMBET(50),TMMOL(50)
+           ,BPRILM,BSLOPE
```

For simulation of multiple scattering of e+-. Used by EMUL. See appendix A8.

%MACRO CGDATA

```
 INTEGER*2 GDATA
DIMENSION IA(15000),GDATA(100)
COMMON/CDATA/MAXGDA,A(1),JHD,JRW,JTK(100),JVX(20),JMC,JMG,JMT(100)
+           ,JDM(10),CWS(32)
EQUIVALENCE (A(1),IA(1)),(CWS(32),GDATA(1))
```

Output bank of SIMARG. This is the ARGUS raw data bank [9].

%MACRO CGDIST

```
COMMON /CGDIST/ COORD(40,4),TNGT(40,4),PMOM,CHRGE
```

Communication between GCLOUT and GCLDIS or LENCEL.

%MACRO CGENIN

```
COMMON/GENIN/PBEAM(3),ABEAM,PTARG(3),ATARG,SIGPB,SIGPT,NPART
+           ,IDEN(18),AMASS(18) ,CHARGE(18),XLIFE(18),VERTEX(3)
+           ,SIGV(3)
```

Input for GENONE. Maximum 18 particles.

%MACRO CGENOUT

```
COMMON/GENOUT/PCM(5,18),PL(5,18),PCMLAB(4),TECM,WT
```

Output from GENONE.

PCM/PL	CM/Lab quantities (px,py,pz,E,p)

%MACRO CGETIN

```
COMMON/CGETIN/ECMN,ECMA,WEIGHT,NTOT,NDOT,NDOTN,PLAB(5,100)
+         ,IDENT(100),ICHAIN(100),ICD(100) ,ICHAI2(100)
+         ,PLGMA(100),PVTX(3,100)
```

Output from GETLND,GETMOP,GETNAK.

ICHAIN/ICHAI2	100*(pointer to mother) +jet number
ICD	flag if particle went through DC (by GTRA)
PLGMA	generated mass
PVTX	vertex of particle
NTOT	total number of particles generated
NDOT	number of particles to be traced

%MACRO CGFLAG

```
COMMON/GFLAG/IDEMIN,IDEMAX,IDEBUG,ITRACK,IHITS,IDIGIT,ISTOP
+         ,IPLOT,IGENER, IMUL,IBOUND,ILOSS,IBANK,IDROP,IEVENT
+         ,NWORDS,MEDNUM ,IGRAF,NDET,NWIN,NWOUT,ISWIT(10)
+         ,IFETCH,ISAVE, MWPC,IDRIFT,NEVENT,IDISP(3,3),RANDOM
+         ,ITEST,ITRIG,K RNDM(2),IPOSI,IEORUN,IEOTRI,IKINE
+         ,ICYLIN,NDETDI ,IDUMMY(4),MUCHMB
```

GEANT flags [1].

%MACRO CGHAEV

```
COMMON /CGHAEV / EVE(1500),NSIZE,NCUR,NEXT,NTOT
```

GHEISHA event stack. Only NEXT is of importance now. NEXT = pointer to next free location (13 words per particle).

%MACRO CGHCON

```
COMMON /CGHCON/ PI,TWPI,PIBTW,MP,MPI,MMU,MEL,MKCH,MK0,SMP,SMPI,
+         SMU,CT,CTKCH,CTK0
+         ,ML0,MSP,MS0,MSM,MX0,MXM, CTL0,CTSP,CTSM,CTX0,CTXM
REAL MP,MPI,MMU,MEL,MKCH,MK0,ML0,MSP,MS0,MSM,MX0,MXM
```

GHEISHA particle masses. Filled by GHADCR.

%MACRO CGHDTR

```
COMMON / CGHDTR / IDSMGH(29),IDGHSM(100)
```

Correspondence between SIMARG and GHEISHA particle ID's.

%MACRO CGHMAT

```
COMMON / CGHMAT / DEN,RADLTH,ATNO,ZNO,ABSL,DDXMIN
```

Media constants for hadronic shower routines.Filled by routine MATTER using normal SIMARG block CMEDPAR.

%MACRO CGHRES

```
COMMON / CGHRES / XEND,YEND,ZEND,RCA,RCE,P,AMAS,SINL,COSL,SINP,
+         COSP,NCH,TOF,EN ,RS,S,AMASQ,DDELTN,IAIR,IPMUFL,ENP(10),
+         ETOT,ETOT1,ITK,NTK
REAL NCH
```

Parameters of current track in hadronic shower routines.

%MACRO CGPAIR

```
COMMON /GPAIR/ ALPHP1(50),ALPHP2(50),DELTP(50),AFPA(50)
+         ,CFPA(50) ,ALPHPG(50),GKMIN1(50),GKMIN2(50),GKMIPA(50),DELPMA(50)
```

ALPHP1,2	Runtime x- sections for pair production.
ALPHPG	Low energy correction.
AFPA,CFPA	Rejection functions.
GKMIN1,..	Kinematical limits.

%MACRO CGUDEX

```
     COMMON/CGUDEX/KPRDEX,IDFIX,PMFIX,DLFIX,ADCFIX,SGFIX
    +         ,NCUSED,LOWCUT,NCCUT,NEVSTA
    +         , DAU1 , DAU2
    +         ,GAMP,ERGAMP , DAMP , SGADC , ADCMAX
    +         , CROMIN , CROFCT
    +         ,NNDEX2,RMDEX2,HHDEX2,RLDEX2,DRDEX2 ,SSDEX2
    +         , RHDEX2,SGDEX2,SPDEX2(200)
```

Block for DE/dx simulation. Input data come from a measured spectrum of 5 GeV/c π^+ (DL=1CM; ITEP results) The accuracy is given by SIGM(DE) /DE = (DAU1*DL **DAU2) * CONST. See also chapter 8.

GAMP	Gas amplification.
ERGAMP	Error in GAMP (normal distribution)
DAMP	All electronic factors (comes from ADCFIX).
SGADC	Sigma for ADC comvertion.
ADCMAX	Max ADC channel.
CROMIN	Min ADC when wire cross-talk exists.
CROFCT	Fraction of ADC as cross -talk (+-1 wire).
NNDEX	Number of channels.
RMDEX	Mean energy loss for this spectrum.
HHDEX	Max height of bin.
RLDEX	Low edge (first chan.) (comes from SGFIX/ADCFIX).
DRDEX	Bin width.
SSDEX	Spectrum integral.
RHDEX	Pick position.
SGDEX	Standard deviation.
SPDEX	Spectrum.

%MACRO CHADSH

```
     COMMON / CHADSH / PLAB(41),CSEL(30,41),CSIN(30,41),
    +         PIMEL(41),PIMIN(41),PIPEL(41),PIPIN(41),
    +         XKAMEL(41),XKAMIN(41),XKAPEL(41),XKAPIN(41),
    +         XK0LEL(41),XK0LIN(41),
    +         PRPEL(41),PRPIN(41),APREL(41),APRIN(41)
```

Hadronic cross sections. See routine GHADCR.

%MACRO CHLOSS

```
     COMMON/CHLOSS/TMIN,TCUT,EHTH,DEHCON(50),DLNEI2(50)
```

Constants for energy loss of hadrons.

TMIN,TCUT	cut offs for delta electron generation
EHTH	kinetic energy threshold to stop tracking hadrons.

%MACRO CLIGHT

```
     COMMON /CLIGHT/ FALIT(9,4),GALIT(9,5),CALIT(9),WALIT(3)
```

Parameters for shower counter light guide correction.

%MACRO CMEDPAR

```
     COMMON/MEDPAR/MEDADR(100),Z(20),A(20),RHO(20),VI(20),STX0(20),
    +         STX1(20),STC(20),STA(20),STM(20),X0(20)
```

Media constants. Initialized in BLOCKDA3. See appendix A5.

%MACRO CMOLLER

```
     COMMON /MOLLE/ ALPHM(50,2),CUTMOL
```

ALPHM	Runtime cross section for Moller scatt.
CUTMOL	Cut off (on energy transfer) to separate distinct interactions from continous E-loss.

%MACRO CPHOTO

```
     COMMON /PHOTO/ BPHO0(50), BPHO1(50), BPHO2(50),EPHOTL(50)
    +         ,EPHOTH(50)
```

Parametrization of photo electric effect. See appendix A8.

%MACRO CSDEBU

```
     COMMON/CSDEBU/KSDEBU,ISDEBU(20)
```

Debug flags. See appendix A6.

%MACRO CSFLAG

```
      COMMON/CSFLAG/IDECAY,KTIMEL,ISVERS,ISVDAT,ISTART,KDOFFE,KDOFFH
     +          ,NUDROP(50),NWANPT,IWANPT(20),NWANDC,IWANDC(20)
     +          ,IEVSTR,KSHOFL,IEVGET,KTHLEV,KLUNDS,KVDCMO
     +          ,KELOSS,KHADIN,KEXPER,KRUNNO,KGENER,KSTART,KTAPE
     +          ,KSAVMC,KSWITS(10)
```

SIMARG flags. Most of these flags can be set by data cards. The corresponding data card is indicated as (NAME) and further description can be found in chapter 2.2.

IDECAY	Flag set when decaying particle (=1)/ when produced in hadronic interaction (=2)
KTIMEL	Time difference for job termination. (TIME)
ISVERS	SIMARG version number.
ISVDAT	SIMARG creation date.
ISTART	Current event read from tape.
KDOFFE	Flag to switch off det. parts for electrons/photons (DRME).
KDOFFH	Flag to switch off det. parts for hadrons (DRMH).
NUDROP	List of media switched off.
NWANPT	No. of various particles req. to be on input tape (SELP).
IWANPT	List of those particles (SELP).
NWANDC	No. of various particles allowed to decay in SIMARG but which had already decayed in the generator (DRDC). (Daughters dropped.)
IWANDC	List of those particles (DRDC).
IEVSTR	First event number (EVEN).
KSHOFL	Flag for use of homogenous/ inhom. magnetic field in shower counters (SHOF).
IEVGET	Event number on tape.
KTHLEV	Energy threshold level wanted for shower c. (THLV).
KLUNDS	Selection of various type of LUND events (LUND).
KVDCMO	VDC selection flag (VDCH).
KELOSS	Flag E-loss on/off (ELOS).
KHADIN	Select levels of hadronic interactions (HADI).
KEXPER	Exp. number (EXP).
KEXPER	Run number (EXP).
KGENER	Type of generator (GENE).
KSTART	First event to read on tape (STAR).
KTAPE	Type of events on tape (TAPE).
KSAVMC	Save all original particles and all their daughters (all generations) into JMT bank (SAVM).
KSWITS	User flags (KSWI).

%MACRO CSGCON

```
      COMMON /CSGCON/ PII,PIIH,TWOPI,DPII,DPIIH,DTWOPI,HBAR
      DOUBLE PRECISION DPII,DPIIH,DTWOPI
```

General constants. Set in GUINIT.

%MACRO CSGENI

```
      COMMON/CSGENI/IRDCAY(100),PVTXTF(100)
```

Communication GET and GUKINE. IRDCAY(I) flags if particle I must decay before tracking starts.

%MACRO CSGLOS

```
      COMMON/CSGLOS/SELSC,SELPB,SELWAB,SELOUT,SEREST,SELNOS
```

Current total E-loss in shower counter scintillator, lead, supports, other media, remaining total E, same but not stopping. This block will be printed if the print flag for GUDIGI is set (appendix A6).

%MACRO CSHPART

```
      COMMON /SHPART/EN,TXE(3),TED(3),Q,FIELD(3),IMED,DELOSS
     +          ,SMASS,SMA2,EMASS,EMA2,KPART,P0STRT
```

Communication block for tracking routines ELETRA,GAMTRA and HADTRA.

EN	energy in units of e-mass.
TXE	current position.
TED	current direction cosines.
IMED	current media.
DELOSS	current energy lost.
SMASS	mass of particle.
KPART	type of particle.

%MACRO CSHTRA
%MACRO CSHTLIM

```
COMMON /CSHTRA/ NSECT,BR,BPRI,YRLIM1,YRLIM2,RHOT,ZLIM,SINZ,COSZ
+          ,THETP,TLIM,TLBM1,LMED,X0REF,IRIN ,IRINN,LMEDN
+          ,NCB,NRZ,BBPRIC,IRLIM,IMEND,IFLEC,EN0
+          ,NSHMDB,NSHMN,IFLTS,TLBM2,NCBN
COMMON/SHTLIM/ SINA2,X,Y,ALF,RLIM1,RLIM2,YLIM1,YLIM2,RC,RS
+          ,RR,BB,BBPRI
DOUBLE PRECISION RR,RC,RS,RLIM1,RLIM2,YLIM1,YLIM2,BB,BBPRI,X,Y
```

Blocks for analytical tracking in the shower counters. Used by SHTRA.

IRIN	Ring no. (1-15)
LMED	Sub-media number (appendix A4)
BR,BPRI, +YRLIM1,YRLIM2	Perpendicular distance to medium boarders (up, down, left,right in R-phi or x-y plane)
BB,BBPRI, +YLIM1,YLIM2	same but after rotation and/or space inversion (in a system with particle at origin , with YLIM1,BB the new y and x axis, part. moving in positive x,y direction and bent clockwise.
NSECT	Quadrant number (counted with respect to R or x dir.)
IFLTS	Flag when multiple scattering sets limit on step.
RLIM1,RLIM2	Parameters that tells if particle is curling around.

%MACRO CSINPA

```
COMMON/CSINPA/KFLAT,THECL,THECH,GETINC,GETSTL
+          ,TLFLI1,TLFLI2,TLFLI3
+          ,GNFRCU,FLDAVE,FLDFLA,FLDSCA
```

Parameters set by data cards 'ANGR','GENF'and 'FLDS'. See chapter 2.2.

%MACRO CSPRIN

```
COMMON/CSPRIN/KSPRIN,ISPRIN(50),INSPRI(50)
```

Print flags. See chapter 2.2 and appendix A6.

%MACRO CBANKP

```
DIMENSION IBANKP(1000)
COMMON/STOBAN/LENBNK,BANKP(2000)
EQUIVALENCE (BANKP(1),IBANKP(1))
```

Temporary storage of points along track (appendix A2.2). Used by GBANK.

%MACRO CSTOTRA

```
COMMON/STOTRA/NTRATO,ITRATO,ITRLAS,LENSTO,STO(20)
DIMENSION ISTO(20)
EQUIVALENCE (STO(1),ISTO(1))
```

Temporary storage for initial values for track being traced. See chapter 6.

%MACRO CTHRESH

```
COMMON/CTHRES/EETH,EGTH,EETHS,EGTHS,EETHHI,EGTHHI
+          ,ZCUT28,ZCUT26,RCUT26,RCUT25
```

Various thresholds for e+- and photons. EETH and EGTH are the current thresholds that can be changed during tracking to other ones (and multiples thereoff). See chapter 2.2 (data card 'THLV') and chapter 6.

%MACRO CTHRES2

```
COMMON/CTHRE2/EHTHS,EHTHL,EETHN,EGTHN,EETH2,EGTH2
```

As above but for hadrons.

A.4 Geometry.

The geometrical constants, defining the layout of the ARGUS detector, reside on the title file which is more or less self explanatory and the description will therefore not be repeated here. An exception is the shower counter geometry. Fig. **A4.1 a)** shows the barrel shower counters in the R- phi plane and defines the main variables used in routine GUGESH. An end-cap counter is shown in Fig. **A4.1** b). In both cases the submedia numbering LMED (=L) is indicated . See further appendix A5.

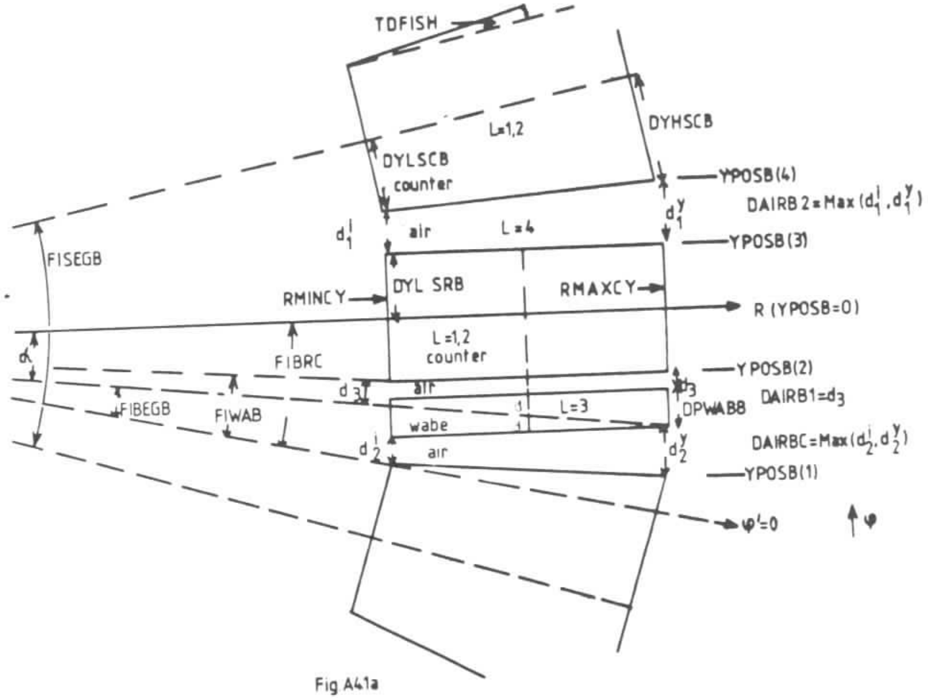


Fig A41a

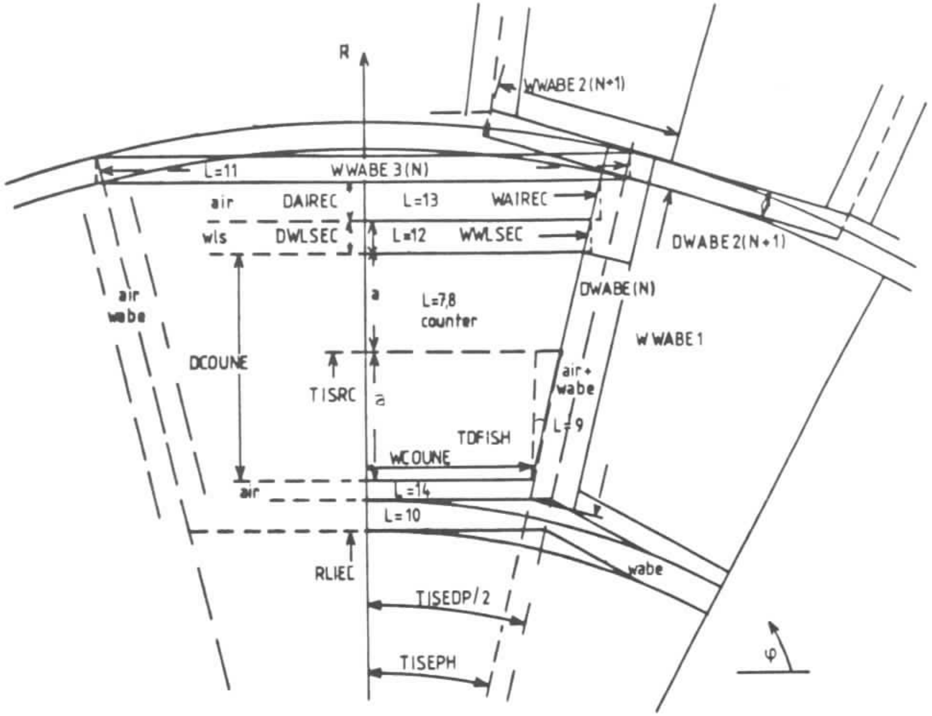


Fig A4.1b

A.5 Media and media coding.

The routine giving the medium for a point in space is GUMED. In the shower counter and TOF counter regions it uses SHOMED and TOFMED. The detector is divided into boxes of 10*10 cm, each box having a pointer (held in block CDETECT) for a jump to further testing of borders. In the shower counter region a further sub-numbering (LMED) is provided by SHOMED (when called from SHTRA). Knowing the media number NUMED the array MEDADR in block CMEDPAR gives the medium type IMED. For compound media the array ICMPND(IMED) gives a sub-media type (JMED) specifying each element in the compound.

The media numbering and the media types are summarized in the following tables.

Medium number NUMED.

NUMED	Region	Magnetic field 1= field on.
34	Outside the detector	0
1	Vacuum in beam tube	1
2	Beam tube wall	1
3	Gas in DC	1
4	AL walls in DC	1
5	Epoxy tube	1
6	TOF	1
7	End -cap TOF light guide	1
8	Air	1
9		1
10	TOF	1
11		1
12		1
13		1
14	Copper	1
15		1
16		1
17		1
18	Barrel shower counter	1
19	End-cap shower counter	1
20		1
21	Corners of yoke	1
22	Mini beta	1
23	Outer compensation coil	1
24	Iron part of coil	1
25	Coil windings	1
26	Inner compensation coil	1
27	Air outside coil	0
28	Yoke	1
29	Outer muon chambers (air)	0
30	Air below DC	1
31	Air outside DC	1
32	Air between TOF/shower counter	1
33	Air outside shower counter	1
35	Inner muon chambers(air)	0
36	Air between tube and comp coil	1
37	Air between e-cap coumter/yoke	1
38	Gas in VDC	1
39	VDC CF inner wall	1
40	VDC SS inner wall	1
41	VDC endplate	1
42	VDC outer wall	1

Internal media numbering for shower counter region.

IMED	LMED	Media	Region
10	1	Pb (lead)	barrel
9	2	SC (scintillator)	.
8	3	Phi-wabe (support perpendicular to z-axis)	.
7	4	Air between counters	.
		in phi diriction	.
8	5	Supports (steel)	.
11	6	WLS	.
10	7	Pb	end cap
9	8	SC	.
8	9	Phi wabe (1) (support)	.
8	10	Lower wabe (2) (support)	.
8	11	Upper wabe (3) (support)	.
11	12	WLS	.
7	13	Air upper gap (AIR2)	.
7	14	Air lower gap (AIR1)	.
4	15	TOF ligth guide	.
8	16	Upper support at light guide	.

Description of media types. The media constants reside in block CMEDPAR (see appendix A3) and are set in BLOCKDA3 (chapter 4).

IMED	Media	Used for
1	Vacuum	Inside beam pipe
2	AL	Beam tube
3	C3H8	Chamber gas
4	AL	DC walls
5	C	Inner DC wall: epoxytube
6	(CH)N	TOF scintilator
7	.8N2/.2O2	Air
8	FE	Yoke
9	C5H8O2	Scintilator shower counter
10	PB	Plates shower counter
11	C5H8O2	WLS
12	CU	Main coil

Specification of elements of compounds.

JMED	Atoms	Compound
13	3C	Propan
14	8H	·
15	C	Polystyren
16	H	·
17	5C	Plexiglas/lucite
18	8H	·
19	2O	·

A6. Print and debug flags

Print flags. Card 'DEBP' (",.." means that other values are possible and the larger the value is the more print out):

Parameter	Value	Print in routine
1=	1,2	GPRIN/GEOM (media/detector summary)
2=	1	GINPUT/GINPU2
3=		GUGEDI: detector geometry for various parts
	1	Title file
	2	Yoke dimensions
	4	DC geometry
	8	Muon chamber geometry
	16	TOF counter geometry
	32	Shower counter geometry
	64	WRCOOR: more on geometry
	3	i.e. 1+2 etc.
	127	To print all
	128	(bit 8) print particle table (IOTRPT)
4=	1,2	PARAM, PARAM1 - PARAM3
5=		Media coding
6=	1,2,...	GET (see GET,GETMOP,...)
7=	1	GUKINE
8=	1,...	GENFIL
9-11=		Free
12=	1,...	GTRIG/GUTRIG
13=	1,...	GHITS/GCYL/GPLAN/GUHITS
14=	1,...	Free
15=	1,...	GDIGI
16=	1,...	GMWPC
17=	1,...	GCLUST/GMWPC
18=	1,...	GTOFVX/GMWPC
19=	1,...	GMUCHA
20=	1,...	GUDIGI
21=	1,...	GUSDRI
22=	1,...	GUSMUO
23=	1,...	GUSVDC
24=	1,...	GUSTOF
25=	1,...	GUSSHO
26=	1,...	GUSLTF
27=	1,...	GUSBNK
28-29=		Free
30=	1	GLAST
31=		Free
32=	1,..	GUDCAY/GUDCMO/DECNBO
33=	1,..	SHMODB/SHMODE/SHOADD
34=	1,..	TOFMOD/TOFADD
35=		Free

Parameter	Value	Print in routine
36=	1,..	GSTORE (also by SWIT 1=1)
37=	1,..	GTRA/GULOSS
38=	1,..	ELETRA/EMUL
39=	1,..	GAMTRA
40=	1,..	HADTRA/HMUL
41=	1,..	HADINT + all hadronic shower routines
42=	1,..	SHTRA
43=	1,..	GRKUTA/GSKUTA
44=	1,..	GUMED/SHOMED
45-50=		Free

Debug flags. Card 'DEBC':

Switches on calls to routines GZDEBA, GZDEBU and GDEBRN as well as calls to SHTCHK and ELECHK (incl. histograms).

Parameter	Value	Print in routine
1=		GZDEBA
	2	From GUTRIG
	4	From GUDIGI
2=		GZDEBU
	1	From GTRIG
	2	GHITS/GDIGI
	4	GTRA
	8	GUKINE
	16	GMWPC
3=		GDEBRN as for flag 2
4=		ZDEBUG as for flag 2
5=	1	SHTCHK: test tracking SHTRA/ELETRA
6=	1	DLICHK: test light guide correction
		+GUCAL : plot energy deposit in shower counter/energy generated
7=	1	Tracking GTRA
8=	1	GCLDIS/LENCEL
9-10=		Free

Timing flags. Card 'TMNG'.

Parameter	Value	Print in routine
1=	1	
2=	1	GTRIG
3=	1	GTRA
4=	1	GULOSS
5=	1	ELETRA
6=	1	GAMTRA
7=	1	HADTRA
8=	1	GUDIGI
9=	1	GDIGI
10=	1	SHTRA
11=	1	EMUL
12=	1	HMUL
13=	1	HADINT
14=	1	SHOADD
15=	1	TOFADD
16=	1	SHMODB/SHMODE
17=	1	
18=	1	TOFMOD
19=	1	GRKUTA/GSKUTA
20=	1	Free
21=	1	
22=	1	GCLUST
23=	1	GTOFVX
24-30=		Free

A.7 Event generators.

1. MOPEK and LUND.

Two external event generators can be used with SIMARG, namely MOPEK [2] and LUND [4]. They will not be described here.

2. Phase space generator.

Of the internal generators the phase space generator (GENONE) originally comes from the program FOWL [11]. It uses the so called Raubold Lynch method. A maximum of 18 particles are allowed. If any of the requested particles is a resonance, the routine GENFIL will give it a random mass according to its lifetime and after a call to GENONE cause the particle to decay before tracking starts.

3. Beam gas generator.

The beam gas generator is a simple generator for deep inelastic eN interactions. The final state is simulated according to measured x and pt spectra as well as measured particle abundances. The multiplicity is generated according to a poisson distribution and the interaction is either on a neutron or a proton. Charge as well as momentum (all components) and energy are conserved. The deep inelastic cross section is taken from measured structure functions F2.

4. Cosmic generator.

The cosmic genrator simulates cosmic electrons, muons , protons and photons in the correct abundance ratios. In fact the program gives the absolute rate. Energy and angular distributions have been taken from several experiments. It gives as default all listed particles but it is possible to choose only one of the species (data card 'COSM', section 2.2).

5. 1 and 2 particles.

The energy of the particle(s) is taken from the beam parameters. The angular range can be chosen by data card 'ANGR' (section 2.2). See also the note about resonances under 2.

6. Radiative lepton pairs.

The radiative lepton generators (bhabha, muon pairs and photon pairs) come from the program of Berenz and Kleis [3]. They include initial as well as final state radiation. The desired angular range can be selected by data card 'ANGR' (section 2.2).

7. Non radiative lepton pairs.

The possible pairs are: bhabha scatters, muon pairs, tau pairs and photon pairs in the lowest order QED processes. Upon request the angular distribution can be forced to be flat by use of data card 'ANGR' (section 2.2).

A.8 Shower processes.

A.8.1 Electromagnetic shower simulation

The simulation of electromagnetic showers follows mainly the treatment of Messel and Crawford [12]. Some modifications have been made along the lines of the EGS [13] code and the treatment is to a large extent not very different. However there is a major difference in the treatment of Bremsstrahlung and pair production in the sense that Messel and Crawford use the Migdal quantum mechanical procedure. The effect of the Migdal correction is negligable for pair production up to some several hundred GeV, while it is noticable at lower energies for Bremsstrahlung.

Another difference between EGS and SIMARG is that the cross sections are not parameterized before run time (i.e. the effect of the rejection functions is evaluated at run time) partly because it is difficult or impossible to do in the Migdal framework and partly to avoid a separate pre-program to SIMARG. The gain in parametrizing the remaining cross sections is not very large since the time to evaluate a cross section is rather small compared to the total time to process a normal hadronic event.

In addition to the treatment in EGS and in Messel and Crawford the so called MORK [14] correction has been included for compton scattering. Also the continous energy loss has been randomized following the procedure of ref. [15]. The treatment of compounds is somewhat different from that of Butcher and Messel [16] and that of EGS. For bremsstrahlung and pair production the type of element to interact with is choosen at runtime (this in fact avoids some approximations).

Extensive comparisons between the two programs have been made and no obvious differences have been found. This comparison was done for the case of no field (treatment in field is not possible with the present EGS version available at DESY). With the normal ARGUS field a small effect appears concerning the shape of the showers. This study has however not been further persued.

A.8.2 Hadronic shower simulation

This has been completely taken over from GHEISHA "without" modifications (see comment in chapter 6.3). The reader is refered to the existing documentation of GHEISHA [6].

A.9 INDEX with cross references and code words.

This index contains a list of all subroutines in SIMARG. If they are described somewhere in this manual there will be a reference to one or more pages. An extremly short explanation will be given if possible (a few words only) as well as from where the routine is called. The abrevation GH indicates that the routine belongs to the hadronic shower package GHEISHA [6].

Key word	Page no	Called from	Code word
ANPOL		GHDMCR	Interpolation(GH).
BGAS	18	GUKINE	Beam gas generator.
BHABBA	22	ELETRA	e+e- scattering.
BPROFI		GUBOOK	Beam profile(for BGAS).
BREMS	22	ELETRA	Bremsstrahlung.
CAMDRI		GUSDRI	DC camac adresses.
CAMVDC		GUSVDC	VDC
CAPTUR	23	HADINT	Capture of neutral baryon.
CASAL0	23	.	$\overline{\Lambda}$ ·N interactions.
CASASM	23	.	$\overline{\Sigma}^-$.
CASASP	23	.	$\overline{\Sigma}^+$.
CASKM	23	.	K^- .
CASKP	23	.	K^+ .
CASK0	23	.	K^0 .
CASK0B	23	.	$\overline{K}^0$.
CASL0	23	.	Λ .
CASMU	23	.	μ .
CASN	23	.	n .
CASNB	23	.	$\overline{n}$.
CASP	23	.	p .
CASPB	23	.	$\overline{p}$.
CASPIM	23	.	π^- .
CASPIP	23	.	π^+ .
CASSM	23	.	Σ^- .
CASSP	23	.	Σ^+ .
CFERMI		GUBOOK	Fermi smearing (for BGAS).
CONTRA	21	SHTRA	Conical intersection.
COSCAT		TWOB	Coherent scattering (GH).
COSMIC	18	GUKINE	Cosmic generator.
CROSEC		DEEPIN	Deep inelastic cross section.
CROSSH		all GH	Cross product (GH).
DADEDX		DEDXMG	Theoretical DE/dx curves.
DEBJMA		GUSBNK	Print JMC,JMG and JMT banks.
DEBSTO		GDEBUG	Print bank JTRAKI.

Key word	Page no	Called from	Code word
DECNBO		GUDCAY	N-body decays
DEC2BO		.	2 .
DEC3BO		.	3 .
DEDXMG	25	DEDXM0	DE/dx simulation DC.
DEDXM0	25	GEOM	Init DE/dx simulation DC.
DEDXM1	25	GMWPC	1st step DE/dx simulation.
DEDXM2	25	GMWPC	2nd .
DEEPIN		BGAS	eN cross section.
DLICHK		ELETRA	Check light guide correction.
DLIGTF		., GAMTRA,HADTRA	For .
DLIGTG		., GAMTRA,HADTRA	for .
DOCUM	4		Short write up.
DSDEDC		CASMU	Differential μ-N x-sect. (GH)
D3WEIT		DEC3BO,WEIMAX	3-body phase space factor
ECOSMI		COSMIC	Cosmic energy spectra.
ELECHK		ELETRA	Check tracking.
ELETRA	20,21,41,48	GULOSS	e+- tracking.
EMUL	22,41,42	ELETRA	.
EXNU		GENXPT,TWOCLU	Nuclear excitation energy (GH).
FBHABH		GUKINE	Non rad. bhabha x- section.
FCTCOS		COSCAT	Double exp. (GH).
FERMI	23	HADINT	Fermi motion.
FGAMMA		GUKINE	Non rad.γ-pair x-section.
FILLWB		LTFSIM	For LTF simulation.
FLPSOR		PHASP	(GH)
FMUTAU		GUKINE	Non rad. μ-pair x-section.
GAMTRA	20,21,22,48	GULOSS	Trackin photons.
GBANK	19,50	GTRA	Store coord. of track.
GBOOK	15	GEANT	Books histograms.
GCAL		GDIGI	Fill plot for cosmic generator.
GCLARC		LENCEL	Arc of circle.
GCLDIS	25,42	GCLOUT	Closest distance DC.
GCLEXT	25	GCLUST	Add artificial point on det.
GCLNEX	25	GCLUST	Find neighbouring point, DC.
GCLOSE	25	GPLAN	Closest point VDC.
GCLOUT	25,42	GCLUST	Closest dist., length DC.
GCLUST	25	GMWPC	Connects points in DC.
GCUBIC		GCYL	Cubic fit.
GCYL	24,34	GHITS	Intersection cylinders.
GDEBRN	56	GTRIG,GTRA,...	Print random seed.
GDEBUG	19	GTRA,GHITS,...	Print various banks.
GDIGI	25,26,34	GTRIG	Steer digit.
GDISP	19	GTRA	Plot of tracks.
GEANT	1	MAIN	Main program.
GENFIL	7,18,59	GUKINE	Steer phase space generator.
GENONE	42,59	GENFIL	Phase space generator.
GENXPT		all GH	Hadronic final state sim.
GEOM	15,31,56	GEANT	Steer geometry.
GERROR		all routines	Error handling.

Key word	Page no	Called from	Code word
GERRPR		GLAST	Print errors.
GET	7,18,48,56	GTRIG	Read kinematics from tape.
GETLND	18,43	GET	Read LUND events.
GETMOP	18,43	GET	Read MOPEK events.
GETNAK	18,43	GET	Read Nakada events.
GETVTX	7	GETMOP,GETLND	Generate 2nd vertex.
GHACRG	16,44,45	all GH	Charge of particle (GH).
GHADCR		PARAM3	Init. hadronic x-sections.
GHADD		all GH	Vector manipulations (GH).
GHADD3		all GH	-
GHANG		all GH	-
GHAPDK		PHASP	Kinematics (GH)
GHDMCR	23	HADINT	Distance hadronic inter. (GH)
GHITS		GTRIG	Steer intersection stage.
GHLENG		all GH	Vector manipulations (GH).
GHLOR		all GH	Lorenz transformation (GH).
GHSUB		all GH	Vector manipulations (GH).
GINPUT	15,56	GEANT	Init., process data cards.
GINPU2	15,56	GINPUT	-
GINVDC		GINPU2	Special VDC simulation.
GKINE		GTRIG	Steer kinematics.
GLAST		GEANT	Output stage GEANT.
GLOREN		GENONE	Lorenz transformation.
GMERGE	25	GMWPC,GMUCHA	Merge hits to clusters.
GMUCHA	25,26,35	GDIGI	Digitisation muon chambers.
GMUCLU	26	GMUCHA	Muon tubes hit.
GMUL		HMUL	Multiple scatt. hadrons.
GMWPC	25,35	GDIGI	Steer digitisation DC, VDC.
GNWMED	19	GTRA,GRKUTA,..	Linear medium search.
GPDK		GENONE	Kinematics.
GPLAN	24,34	GHITS	Intersection planes.
GPLT		GTRA	3D plots tracking.
GPL3D		GPLT	-
GPRIN	56	GINPUT	Print data cards.
GRDOUT	26	GDIGI	Fill bank JNODET etc.
GREAD	15	GINPUT	Read data cards.
GRKUTA	20	GULOSS,...	Runga Kutta tracking.
GRT2		GENONE	Kinematics.
GRUN		GEANT	Steer event processing.
GSETRO		GEOM	Rotation matrix.
GSKUTA		ELETRA,HADTRA	As GRKUTA, no medium search.
GSORT	25	GMWPC	Sort digitizings.
GSTORE	18,31	all tracking	Store into JTRAKI.
GTOFVX	25	GMWPC	Steer digitisation VDC.
GTRA	19,24,32	GTRIG	Steer tracking.
GTRCHK	19	GTRA	Check energy flow.
GTRIG	27	GRUN	Process one event.
GTRINI	19	GTRA	Initialize tracking GTRA.

Key word	Page no	Called from	Code word
GTRSTO	19	GTRA	Store into JKITRA.
GUBOOK	15	GBOOK	Book histograms.
GUCAL		GCAL	User calc. after digitisation.
GUDCAY	19,32,41	GTRA	Decay particle.
GUDCMO	41	GENFIL	Find a decay mode.
GUDIGI	27,48	GDIGI	Steer output stage.
GUEFF		GMUCHA	Wire efficiency.
GUFLD		all tracking	Magn. field+ medium.
GUFLDS	18	all tracking	Magn. field.
GUGEDI	15,16,56	GEOM	Read/inititialize geometry.
GUGEDR	16	GUGEDI	Initialize DC geometry.
GUGEMU	16	GUGEDI	- Mu ch. -
GUGEOM	15	GEOM	Prepare chamber geometry.
GUGESH	16,21,51	GUGEDI	Init shower c. geometry.
GUGETF	16	GUGEDI	- TOF -
GUGEVC	16	GUGEDI	- VDC -
GUGEYO	16	GUGEDI	- yoke -
GUINIT	15	GEANT	Init /CDATA/ + /CSGCON/.
GUINN	15	GUINIT	User initialization.
GUKINE	18,48,56	GKINE	Generate kinematics.
GULAST		GLAST	User termination.
GULOSS	19,22	GTRA	Select tracking type.
GUMED	19,53	all tracking	Medium number.
GUPREP	33	GDIGI	Prepare DC output (JMT).
GUPRIN		GPRIN	Print extra data cards.
GUREAD	15	GREAD	Read SIMARG data cards.
GUSBNK	27	GUDIGI	Store MC banks.
GUSDRI	27	-	- DC -
GUSLTF	27	-	- LTF -
GUSMUO	27	-	- Mu ch. -
GUSSHO	27	-	- Sh. c. -
GUSTOF	27	-	- TOF -
GUSVDC	27,32,34	-	- VDC -
GUTRIG	13,27	GTRIG	Finish event.
GZDEBA	56	all	Debug /CDATA/.
GZDEBU	56	all	Debug blank common.
GZINIT	13,15	GINPUT	Init. GEANT dynamical bank.
HADINT	23	HADTRA	Steer hadronic interactions.
HADRON		HADTRA	-
HADTRA	17,20,48	GULOSS	Tracking hadrons.
HMUL	23	HADTRA	Hadron E-loss, mult. scatt.
ICOMPT	22	GAMTRA	Compton scatt.
INCARD		IOTRPT	Read one card particle table.
IORFST		IOREV	Binary read.
IOTIRD		IOTISL	Read title.
IOTISL	16	GUGEDI	Select title.
IOTRDN		IOTIRD	Read cards title.

Key word	Page no	Called from	Code word
IOTRDO		IOTIRD	-
IOTRDX		IOTIRD	-
IOTRPT	16	IOTIRD	Read particle table.
IOTSKP		IOTIRD	Fast card skip.
IOWEV		GUTRIG	Write record.
IOWFST		IOWEV	Buffer out record.
IPAIR1	22	GAMTRA	Compton rejection func.
IPAIR2	22	GAMTRA	Compton rejection func.
LENCEL	25,42	GCLOUT	Track length DC cell.
LTFLOA	15	GINPUT	Initialize LTF.
LTFMC		GUSLTF	Simulate LTF.
LVMAXI		GSORT	Modified CERN routine.
LVMINI		GSORT	Modified CERN routine.
MASIND		all GH	ID of particle (GH).
MATTER	23,44	GHDMCR	Media constants (GH).
MFLD17		GUFLD(S)	Magn. field DC region.
MOLLER	22	ELETRA	ee scattering
MULTI		HADRON	eN multiplicity.
PAPAIR		GUKINE	Kinematical transform.
PARAM	16,56	GUGEDI	Initialize physics.
PARAM1	16,56	PARAM	Init. electromagn. inter.
PARAM2	16,56	PARAM	-
PARAM3	16,56	PARAM	Init. hadronic interactions.
PDPHED	27	GUDIGI	Fill header /CADATA/.
PHASP		GENXPT,TWOCLU	Phase space generator (GH).
POISSO		TWOCLU	Poisson distribution (GH).
POSANN	22	ELETRA	e+ annihilation.
PREVBU		GUDIGI	Print /CDATA/.
PROPT2		HADRON	pt dependence for eN.
PROZ		HADRON	z dependence for eN.
PUTIN		FILLWB	For LTF simulation.
QBPRIN		GLAST	Print rad. bhabhas.
QBSTRT		GUKINE	Init. -
QGPRIN		GLAST	Print rad. gammas.
QGSTRT		GUKINE	Init. -
QMPRIN		GLAST	Print rad. muons.
QMSTRT		GUKINE	Init. -
QRADBA	18	GUKINE	Generate rad. bhabhas.
QRADGA	18	GUKINE	Generate rad. gammas.
QRADMU	18	GUKINE	Generate rad. muons.
RECTRA	21	SHTRA	Rectangular intersection.
RMASS		all GH	Particle mass (GH).
ROTES2		PHASP	Rotations(GH).
RTMI		COSCAT	Fit routine(GH).
SHMODB	20,22	ELETRA,..	Store E deposit shower c.
SHMODE	20,22	ELETRA,..	-
SHNUM		GUSSHO	Camac adress shower c.
SHOADD	19	GTRA	Add shower counter hits.

Key word	Page no	Called from	Code word
SHOMED	53	GUMED,SHTRA	Shower c. media number.
SHTRA	21,49	ELETRA,..	Analytic tracking shower c.
SHTRAL		SHTRA	Find proper quadrant.
SPANGL		BREMS,..	Direction from scat. angle.
STEPFI		GRKUTA,GSKUTA	Step through hom. field.
STPAIR		all GH	Strange pair production.
THETMU		COSMIC	Cosmic angular distribution.
TOFADD	19	GTRA	Add TOF hits.
TOFMED	53	GUMED	TOF media number.
TOFMOD	20	GULOSS	Store TOF values.
TRANSF		GENONE	Lorenz transformation.
TWOB		all GH	(Quasi) elastic scatt.
TWOCLU		GENXPT	Two cluster model.
UPDATE		none	Summary SIMARG mod.
VDCELL	25	GTOFVX	VDC cell number.
WEIMAX		DEC3BO	Max. 3-body PS weight.
WIRNUM		GCLOUT	DC wire number.
WIRUNA		DEBJMA	Unpack DC wire JMT bank.
WRCOOR		GUGEDI	Print unpacked geometry.
ZMASK		LTFMC	For LTF simulation.