THE GEANT-CALOR INTERFACE USER'S GUIDE

GCALOR Version 1.05/03

C.Zeitnitz
University of Mainz
and
T.A.Gabriel
Oak Ridge National Laboratory

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Chapter 1

Introduction

The Monte Carlo package GEANT [1] is the most widely used program to study large scale detectors. In the current version 3.16 two different hadronic interaction models are implemented. The GHEISHA [2] program is well tuned to reproduce the average shower shape and energy resolution of standard calorimeters. The FLUKA [3] simulation code calculates the single hadronic interaction in more detail (fragmentation model), but provides, in the frame of GEANT, no information about low energetic neutrons.
The CALOR89 [4] program package simulates hadronic interactions down to 1 MeV for nucleons and charged pions and into the thermal region for neutrons. For high energies (above 10-15 GeV) the FLUKA model is used.
The low energy neutron code MORSE makes CALOR superior for studies, where neutrons play an important role for the detector response.
In order to carry out simulations involving low energetic neutrons in the frame of GEANT an interface to the CALOR package, called *GCALOR* [13] has been developed.
This writeup gives general information about the simulation package CALOR as well as guidance to the use of the program.

Chapter 2

The Program CALOR89

The CALOR code system for analyzing detectors for high energy physics experiments was first distributed in the early 70s. Since than it has been further improved and combined with other simulation codes like EGS and FLUKA. Originally designed for accelerator shielding studies CALOR became a benchmark for particle cascade calculations for general purpose detector studies; e.g. calorimeter design.
The current version CALOR89 consists of the following simulation programs:

HETC (High-Energy-Transport-Code) hadrons up to 10-15 GeV

FLUKA hadrons above the HETC limit

MORSE (Multigroup-Oak-Ridge-Stochastic-Experiment) neutrons below 20MeV
or

MICAP (Monte carlo Ionization Chamber Analysis Package) a point cross-section neutron code. This program is similar to MORSE and will be implemented in the CALOR package in the next version

EGS 4 electrons,positrons and gammas

In addition some programs are analysing the results of the different simulation codes. The relation between the different program parts are shown in figure 2.1. The monte carlo code HETC [5] consists of two parts. The Nucleon-Meson-Transport-Code (NMTC), which is calculating the interaction of nucleons below 3.5GeV and charged pions below 2.5GeV, is based on the intranuclear-cascade-evaporation-model as implemented by Bertini [6, 7]. For Hadron-Hydrogen collisions a special model is used.
In the energy range 3-15GeV the FLUKA model is fading in and the NMTC is fading out (Scaling Model). By this a smooth transition in terms of particle multiplicity and energy is achieved.
The program MORSE [8] is using an energy binning for the neutron cross-sections and secondary energy distributions. Neutrons are generated only with these discrete energies. MORSE does account for particle multiplicities by assigning a weight to the generated neutron or photon.
The MICAP program uses preprocessed ENDF/B (Evaluated Neutron Data Files version B) cross-section data and the number of energy points is not fixed, but depends on the isotope and the availability of cross-section data for this isotope. For details about the MICAP program see the user's guide [11, 12].
The program EGS Version 4 [9, 10] is called after HETC and MORSE to simulate the interaction of the generated photons with the material of the setup.

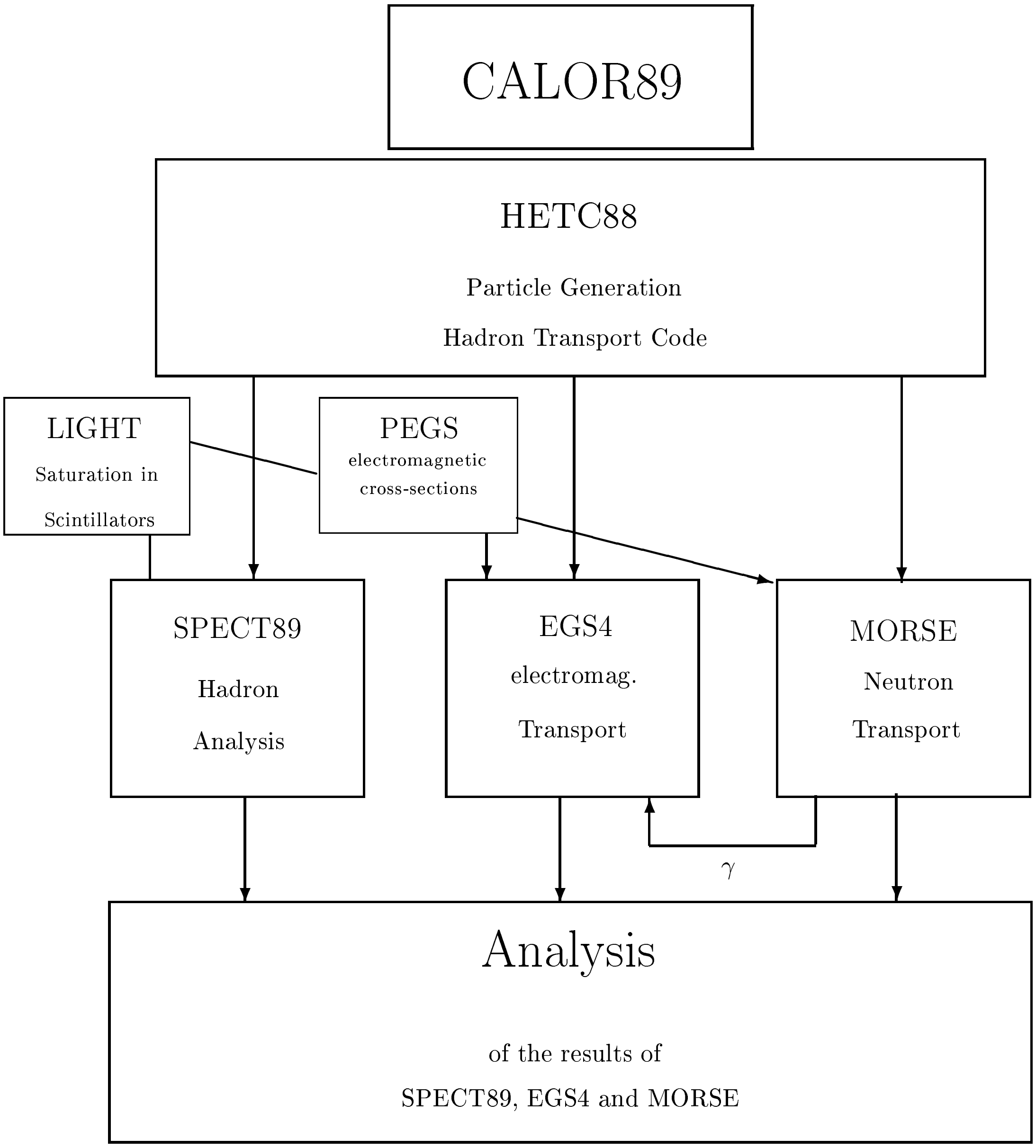

Figure 2.1: Flow diagram of CALOR89

Chapter 3

CALOR in the GEANT frame

In order to incorporate the hadronic interaction calculation from CALOR89 into the GEANT frame, the HETC collision and evaporation model has been extracted from the CALOR code system. For low energy neutrons the MICAP neutron code has been chosen for its mostly analog simulation of the collision of a neutron with a nucleus. For high particle energies the FLUKA model, which is already available in the GEANT package since version 3.15, is utilized.
CALOR in the frame of GEANT consists of:

NMTC nucleons below 3.5 GeV, charged pions below 2.5 GeV

SCALE Scaling Model - 3 GeV to 10 GeV for nucleons and charged pions

MICAP neutrons below 20MeV

FLUKA nucleons and charged pions above 10GeV, and for all energies for particle types not implemented in CALOR

The tracking and storing of the particles is done by GEANT.

All electromagnetic interacting particles are transported by the corresponding GEANT program parts.

All program parts implemented in the interface have been modified to be totally analog. All particle weights have been removed and transferred into particle multiplicity and/or energy. This was mainly necessary in the Scaling Model and the low energy neutron code.

3.1 *The Scaling Model*

In the Scaling energy range (3-10 GeV) a linear probability function is used to determine whether FLUKA or NMTC is called for the current interaction. This insures a smooth transition between NMTC and FLUKA in terms of particle multiplicity and particle types. Scaling is performed in case NMTC is calculating the current interaction.
First NMTC is called with a particle energy of 3.5 GeV for nucleons and 2.5 GeV for charged pions, then the particle multiplicities and particle energies are scaled to the current center of mass energy. The Scaling model is assigning new weights to the generated particles. These weights are resolved into particle multiplicity and particle energy in order to keep the program totally analog.

3.2 *The low energy neutron code MICAP*

Interactions of neutrons with an energy below 20 MeV down to the thermal energy range (down to $10^{-5} eV$) with a nucleus are calculated by the NEUTRON code taken from the MICAP program

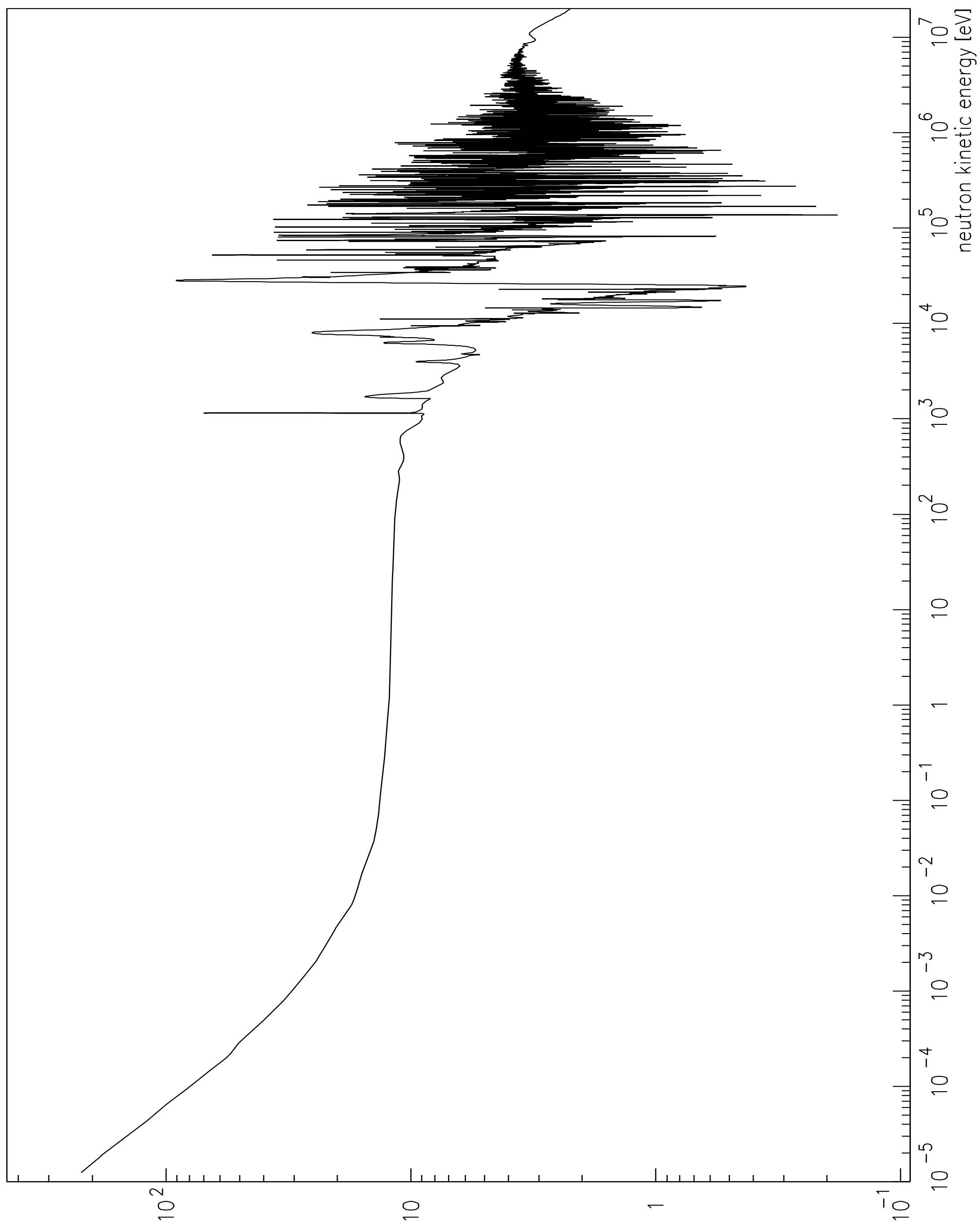

Figure 3.1: Microscopic neutron cross-section for iron

Type of Reaction	final state particles
elastic scatt.	n
(nA,n'A)	n
(nA,2n'A')	2n
(nA,n'αA')	n, α
(nA,2n'αA')	2n, α
(nA,n'pA')	n,p
(nA,n'3αA')	n, 3α
(nA,γA)	γ
(nA,pA')	p
(nA,DA')	D
(nA,TA')	T
(nA,^3HeA')	^3He
(nA,αA')	α
(nA,2αA')	2α
(nA,3αA')	3α
(nA,2pA')	2p
(nA,pαA')	p,α
(nA,T2αA')	T, 2α
(nA,D2αA')	D, 2α
fission	n, p , α

Table 3.1: Process types for neutron-nucleus reaction implemented in the MICAP neutron code

package. This program utilizes all currently available data in the Evaluated Nuclear Data File (ENDF/B) like partial cross-sections, angular distributions and secondary energy distributions (see table 3.2 for the available isotopes). The original ENDF/B data have to be preprocessed in order to be suitable for a Monte Carlo analysis. The partial cross-sections are formatted in linearly interpolable cross section-energy pairs. The angular distributions are formulated into normalized energy dependent cumulative distribution functions. Secondary energy data are either tabulated probability distributions or formatted in a way suitable to sample from one of the ENDF/B secondary energy distributions (Watt-spectrum, evaporation spectrum etc.).
For very low neutron energies, depending on the nucleus, a thermal scattering model based on a free gas model is used. The energy of the neutron after the collision is sampled from a Maxwellian energy distribution with an isotropic direction distribution in the center of mass system of the neutron and the nucleus.
The cross-section data and secondary energy and angular distributions are thinned to an accuracy of 2%, which means that the original ENDF/B-VI data are reproduced by an interpolation with this precision. As an example for the detailed microscopic cross-sections used in the program shows figure 3.1 the cross-section for iron in the energy range from $10^{-5}eV$ to $20MeV$. Since iron has a lot of resonances for neutron energies above ca. $1keV$, more data points are needed to describe this energy range. The total iron data sum up to ca. 316000 Bytes.
The type of processes which are implemented into the MICAP neutron code are listed in table 3.1. If the residual nucleus A' is after the interaction in an excited state, deexcitation photons are generated. The photon energy and the direction is sampled from distributions available in the cross-section file. A specific process can only happen, if a partial cross-section for it is stored in the cross-section file.

The program had to be modified in order to be fully analog in all parts of the code.
The particle weight in the fission process and the secondary photon production has been replaced by the explicit generation of particles. To determine the number of particles to be generated, a Poisson distribution is sampled with a mean of the original particle weight.
In all other interactions with more than one particle (n, p, α, D) in the final state these are generated explicitly with the multiplicity given by the reaction (for example $(n + {}^{12}C) \rightarrow (3\,\alpha + n)$).

Element	Symbol	A	Z	Comment
Hydrogen	H	1,2,3	1	free and H_2O bound
Helium	He	3,4	2	
Lithium	Li	6,7	3	
Beryllium	Be	9	4	
Boron	B	10, 11	5	
Carbon	C	12	6	natural composition
Nitrogen	N	14	7	
Oxygen	O	16	8	
Fluorine	F	19	9	
Sodium	Na	23	11	
Magnesium	Mg	24	12	natural composition
Aluminum	Al	27	13	
Silicon	Si	28	14	natural composition
Phosphorus	P	31	15	
Sulfur	S	32	16	natural composition
Chlorine	Cl	35	17	natural composition
Argon	Ar	40	18	natural composition
Calcium	Ca	40	20	natural composition
Chromium	Cr	52	24	natural composition
Iron	Fe	56	26	natural composition
Nickel	Ni	59	28	natural composition
Copper	Cu	64	29	natural composition
Zinc	Zn	65	30	natural composition
Germanium	Ge	72, 73, 74, 76	32	
Arsenic	As	75	33	
Bromine	Br	79	35	
Krypton	Kr	80, 82, 83, 84, 86	36	
Zirconium	Zr	90, 92, 94, 96	40	
Molybdenum	Mo	96	42	natural composition
Technetium	Tc	98	43	
Silver	Ag	108	47	natural composition
Cadmium	Cd	112	48	natural composition
Tin	Sn	116, 117, 118, 119, 120	50	^{120}Sn second. distributions from ^{119}Sn
Antimony	Sb	122	51	natural composition
Tellurium	Te	128	52	
Iodine	I	127	53	
Xenon	Xe	128, 129, 130, 131, 132, 134, 136	54	
Cesium	Cs	133	55	
Barium	Ba	134, 135, 136, 137, 138	56	
Cerium	Ce	140, 142	58	
Gadolinium	Gd	154, 155, 156, 157, 158,160	64	
Tantalum	Ta	181	73	
Tungsten	W	184	74	natural composition
Gold	Au	197	79	
Lead	Pb	207	82	natural composition
Bismuth	Bi	209	83	
Thorium	Th	232	90	
Uranium	U	235, 238	92	

Table 3.2: List of isotopes for which neutron data are available

Chapter 4

The Interface

The GEANT-CALOR interface is fully compatible with the other hadronic simulation codes used in the frame of GEANT. It works with GEANT 3.16 as well as 3.21 in batch and interactive mode.

4.1 *Installation*

The files needed to run the GEANT-CALOR interface are available via the following WWW-Page from (follow the link to the GCALOR page):

http://www.physik.uni-mainz.de/zeitnitz/homepage.html

The GEANT-CALOR interface GCALOR is available as a CMZ cards image file (GCALOR. CAR) as well as FORTRAN sources for VAX/ALPHA and UNIX machines. If the library has to be created from the CMZ file, follow the CMZ instructions listed below.

- make GCALOR
- arc GCALOR.CAR
- set *.FOR -F F77
- set the computer type (e.g. select VAX)
- sequence CMCDES
- sequence //GEANT/GCDES
- pilot *calor
- set the library (e.g. set GCALOR.OLB -L)
- clib -p

The interface between the CALOR package and GEANT consists of two subroutines which have to be called from the GEANT user subroutine GUHADR and GUPHAD.

CALSIG retrieves the cross-section for the current particle with the current material from CALOR and calculates the distance to the next hadronic interaction. This routine has to be called from the GEANT user routine GUPHAD

```
C-------------------------------------------------------------------
      SUBROUTINE GUHADR
C.
C.    ****************************************************************
C.    *                                                              *
C.    *       User routine to generate one hadronic interaction      *
C.    *                                                              *
C.    *    ==>Called by : GTHADR,GTNEUT                              *
C.    *                                                              *
C.    ****************************************************************
C.
C.
C call gcalor
      Call GCALOR
C this is the original call to GHEISHA
C...      CALL GHEISH
C this is the call to FLUKA
C...      CALL FLUFIN
      RETURN
      END
C-------------------------------------------------------------------
      SUBROUTINE GUPHAD
C.
C.    ****************************************************************
C.    *                                                              *
C.    *       User routine to compute Hadron. inter. probabilities   *
C.    *                                                              *
C.    *    ==>Called by : GTHADR,GTNEUT                              *
C.    *                                                              *
C.    ****************************************************************
C.
C.
C.    ------------------------------------------------------------------
C.
C
C call gcalor  interaction probability subroutine
      CALL CALSIG
C this is the original call to GHEISHA
C...      CALL GPGHEI
C this is the call to FLUKA
C...      CALL FLDIST
      RETURN
      END
C-------------------------------------------------------------------
```

Figure 4.1: Example subroutines GUHADR and GUPHAD

```
      SUBROUTINE USRMAT
C
C  define GEANT materials
C
      DIMENSION AA(6),ZZ(6)
C
         :
         :
         :
C
C define Concrete mixture
C
C    density = 2.35 g/cm^3
C
      AA(1) = 1.00794
      ZZ(1) = 1.00
      WT(1) = 0.004       !  0.4% Hydrogen
      AA(2) = 16.0
      ZZ(2) = 8.00
      WT(2) = 0.509       !  50.9% Oxygen
      AA(3) = 27.0
      ZZ(3) = 13.0
      WT(3) = 0.034       !  3.4% Aluminum
      AA(4) = 40.078
      ZZ(4) = 20.0
      WT(4) = 0.070       !  7.0% Calcium
      AA(5) = 28.0855
      ZZ(5) = 14.0
      WT(5) = 0.345       !  34.5% Silicon
      AA(6) = 55.847
      ZZ(6) = 26.0
      WT(6) = 0.038       !  3.8% Iron
      Call Gsmixt(98,'Concrete$',AA,ZZ,2.35,6,WT)
         :
         :
         :
      RETURN
      END
```

Figure 4.2: Example how to define mixtures in GEANT

GCALOR calculates the hadronic interaction of the current particle with the current material. The routine has to be called from the GEANT user routine GUHADR

The listing in figure 4.1 gives an example how to call GCALOR.
The CALOR package is automatically initialized when either CALSIG or GCALOR is called the first time. During the initialization the intranuclear cascade and evaporation data needed in NMTC are read from a file. For the low energy neutron code the neutron cross-sections and secondary energy and angular distributions, needed for the material used in simulated setup, are extracted from the cross-section file. The two files needed are **CHETC.DAT** and **XSNEUT.DAT**. Both files are expected in the current working directory. If not found there the CERN library subdirectory is checked and in case that one of the files could not be located an error message is printed and the program stops. Both files are standard ASCII files with a record length of 80 characters. The size of the files is ca.662 kBytes for **CHETC.DAT** and 26.6 MBytes for **XSNEUT.DAT**.

Output created by the interface is written to the file **CALOR.OUT**. Error message will be written to this file too. If a fatal error occurs, a message is printed in the GEANT output too.

4.2 *Installation on different Computers*

The GCALOR code has been successfully istalled on the following computer platforms:

VAX under VMS (CMZ: select VAX)

DEC-AXP under VMS (CMZ: select VAX)

IBM-3090 under MVS (CMZ: no selection). The JCL has to assign the needed files to the following unit numbers:
CHETC.DAT - unit 30
XSNEUT.DAT - unit 31
CALOR.OUT - unit 32

UNIX e.g. SGI, HP, IBM RS-6000 (AIX), SUN, ULTRIX, Linux (CMZ: select UNIX)

Some other platforms have been forseen in the program, but not yet tested:

IBM-3090 under VM (CMZ: select IBMVM)

CRAY CMZ: select CRAY

DEC-AXP under OSF (CMZ: select UNIX)

All flags used are consistent with the usage in GEANT and FLUKA. The code for different platforms differs in the handling of the input and output files (subroutines CALINI and MORINI). The rest of the code is written in standard FORTRAN 77 and should cause no problems.

4.3 *How to use NMTC*

The intranuclear cascade and evaporation model will be utilized when the GCALOR code has been called as described in the previous section. No special initialization is required. The geometry and material description should be done as usual. So there is absolutly no difference in the usage of NMTC compared to GHEISHA or FLUKA.

4.4 *How to use the neutron code MICAP*

The MICAP neutron code will be utilized for neutrons with a kinetic energy below 20MeV when the GCALOR code is called. Initialization is done automatically. During the initialization the code extracts the material description of all *tracking* media from the corresponding ZEBRA banks and stores the cross-section and particle multipicities and angular distributions for the selected media in the ZEBRA common. If space is running low in the ZEBRA common and the data can't be stored, GCALOR prints an error message (see figure 4.6) and will give the advice to increase the ZEBRA common.

The simulation of neutrons requires more care than for other particles. This is due to the fact, that the results depend a lot more on the details of the material/media definition and the geometry description.

- Material definition should be done as accurate as possible. This means, that all known elements should be added with the correct weight to the mixture. All materials should be defined as elements only (GSMATE) or as a mixture (GSMIXT). An example is given in figure 4.2 for a concrete mixture. Do not use compounds or mixtures of compounds. Average nuclear number A and charge Z will not give reasonable results.
- Geometry should be described as detailed as possible, because this can have a large effect on the scattering of thermal neutrons
- The energy cut-off for neutral hadrons **CUTNEU** has to be set to a reasonable value. All values down to 10^{-14} GeV are accepted. GEANT will complain about the low cut off value. This warning can be ignored.
- The time cut-off has to be set to a value, which allows to track very low energetic neutrons till they are captured or fall below the energy cut-off.

For a given element in the GEANT material definition the natural isotope composition is used, if data are available in the cross-section file (see table 3.2). For elements which are not available, the data for the element with the closest charge number Z are used and a warning appears in the output file (see example for Neon in figure 4.5). An exception to the rule of natural compositions is uranium. In this case the weights for different isotopes (^{238}U und ^{235}U) have to be provided by the user (call to GSMIXT) explicitly.

In order to switch the automatic selection of natural isotope composition off, a call to the subroutine MICSET has to be included for every single medium with the number MEDNO:

```
CALL MICSET(MEDNO,0)
```

The user should be aware, that this requires a lot of experience, because the weights for all isotopes have to be provided by the user explicitly (via GSMIXT).

4.5 *Some Remarks about the Material definition*

The simulation of neutrons down to thermal energies requires a careful definition of the materials in the simulated setup. The total cross-section can vary easily by an order of magnitude if an important ingredience in the mixture is omitted. Even if a certain element appears only with a few percent in the mixture, it could be important for the simulation.
Be aware, that certain materials are in reality never *pure*. For example iron has always a few percent carbon added, which makes quite a difference in the total cross-section (the, so called, iron window at ca. 100keV is smeared out). In addition is the density very often lower than given in the Particle Data Group listing and/or the GEANT manual (e.g. commercially available iron has

a density of $7.4g/cm^3$).
Special attention should be given to the fraction of hydrogen in the materials. Since hydrogen is mainly responsible for the down scattering of neutrons, hence for the thermalization, it determines the mean free path length and energy spectrum of the neutrons emerging from a medium.
Some materials have a high capture cross-section for neutrons (e.g. boron), and deexcitation photons will be created in this process. In order to obtain the correct response of the detector, low energy cut-offs for electrons and photons are necessary.

4.6 *Access to the Recoil Nucleus*

The recoiling nucleus in a neutron-nucleus interaction will in some dectors yield a measureable signal (e.g. gas chambers). If the recoil nucleus is a proton, α, ^3He, Deuteron or Tritium particle it is returned to GEANT as one of the secondary particles. In all other cases the nucleus is stored in the common CALGEA, or in the corresponding FLUKA common.
In figure 4.3 an example for subroutine GUHADR is given in which the information (kinetic energy, A and Z) is extrated from the common CALGEA (after a call to NMTC, SKALE or MICAP) or FKRES (after a call to FLUKA). Which hadronic code has been called is stored in the variable KCALL. The energy is given in GeV in the case of FLUKA otherwise in MeV.

4.7 *Additional neutron cross-section files*

Starting with version 1.04/00 it is possible to read in additional cross-section data files. There is no limit in the number files, but the ZEBRA common has to be big enough to store the isotope dictionary of all files.
The neutron code MICAP is informed about an additional file by a call to MICFIL:

```
CALL MICFIL('/home/users/zeitnitz/he.dat')
```

4.8 *Output generated by the Interface*

The initialization of the interface is printing a banner in the standard GEANT output (see figure 4.4). The banner contains information about the version of GCALOR and the a brief description of the different program parts.

The MICAP initialization is writing a summary of the media definitions to the file **CALOR.OUT**. Figure 4.5 gives an example of the summary table.

This table contains for every material the composition defined in GEANT and the isotope composition used for the simulation in MICAP. For each isotope the density (atoms/barn/cm) is given as well as the collision length for a 1 MeV neutron. The density is given by $(w_i \cdot \rho \cdot N_{Avo})/A_i$ (w_i : weight of the isotope i in the mixture, ρ : density of the material, A_i : nuclear number of isotope i, N_{Avo} : Avogadro's number multiplied by 10^{-24}).

At the end some comments are added about the cross-section data used and the total amount of words allocated in the ZEBRA common GCBANK is given.

4.9 *Random Number Generators used in GCALOR*

All random numbers needed in the GCALOR code are taken from the GEANT random number generators GRNDM and GPOISS. This ensures, that the random number sequence is synchronized with GEANT and the same random seeds will lead to excactly the same events.

```
      SUBROUTINE GUHADR
C
      PARAMETER(MXCP = 300)
C
      COMMON/ CALGEA / IPINC  , EINC       , UINC(3)   ,NCEL       ,
     +                 HDEN   , AMED(100)  , ZMED(100) ,DMED(100)   ,
     +                 NPHETC ,EKINET(MXCP),IPCAL(MXCP),UCAL(MXCP,3),
     +                 INTCAL , EXMED      , ERMED(100),SIG         ,
     +                 CALTIM(MXCP), ICPROC, NRECOL    ,KCALL       ,
     +                 ATARGT , ZTARGT
C
C
      Real*8           AMNTAR, AMMTAR, AMNZM1, AMMZM1, AMNNM1, AMMNM1,
     &                   ANOW,   ZNOW, ANCOLL, ZNCOLL,   ERES,  EKRES,
     &                 AMNRES, AMMRES,  PTRES,  PXRES,  PYRES,  PZRES,
     &                 PTRES2
C
      COMMON /FKRESN/  AMNTAR, AMMTAR, AMNZM1, AMMZM1, AMNNM1, AMMNM1,
     &                   ANOW,   ZNOW, ANCOLL, ZNCOLL,   ERES,  EKRES,
     &                 AMNRES, AMMRES,  PTRES,  PXRES,  PYRES,  PZRES,
     &                 PTRES2,  KTARP,  KTARN, IGREYP, IGREYN,  ICRES,
     &                  IBRES, IEVAPL, IEVAPH, IEVNEU, IEVPRO, IEVDEU,
     &                 IEVTRI, IEV3HE, IEV4HE, IDEEXG,  IBTAR, ICHTAR,
     &                 IOTHER
C
*KEEP,GCKING.
      INTEGER MXGKIN
      PARAMETER (MXGKIN=100)
      COMMON/GCKING/KCASE,NGKINE,GKIN(5,MXGKIN),
     +                           TOFD(MXGKIN),IFLGK(MXGKIN)
      INTEGER       KCASE,NGKINE ,IFLGK
      REAL          GKIN,TOFD
C
C
      Logical FFLUKA,FMICAP,FNMTC,FSKALE
      SAVE
C
C now call GEANT-CALOR interface
      CALL GCALOR
C which program has been called ?
      FFLUKA = KCALL .EQ. 3 .and. ngkine .gt. 0
      FMICAP = KCALL .EQ. 1 .and. ngkine .gt. 0
      FNMTC  = KCALL .EQ. 0 .and. ngkine .gt. 0
      FSKALE = KCALL .EQ. 2 .and. ngkine .gt. 0
      IF(FFLUKA) THEN
C Fluka calculated the interaction
C Recoil nucleus information in:
C EKRES  : kinetic energy (GeV)
C ANOW   : A of recoil nucleus
C ZNOW   : Z of recoil nucleus
          Call Hfill(100+kcall,sngl(ekres),1.,1.)
          Call Hfill(200+kcall,sngl(anow),1.,1.)
          Call Hfill(300+kcall,sngl(znow),1.,1.)
      ELSE IF(FMICAP.or.FNMTC.or.FSKALE) THEN
C HETC or MICAP calculated the interaction
C Recoil nucleus information in:
C ERMED(I)  : kinetic energy (MeV)
C AMED(I)   : A of recoil nucleus
C ZMED(I)   : Z of recoil nucleus
C NRECOL    : number of heavy recoil products
C ATARGT    : A of target nucleus
C ZTARGT    : Z of target nucleus
          do i=1,nrecol
           Call Hfill(100+kcall,ermed(i)/1000.,1.,1.)
           Call Hfill(200+kcall,amed(i),1.,1.)
           Call Hfill(300+kcall,zmed(i),1.,1.)
          enddo
      ENDIF
      RETURN
      END
```

Figure 4.3: Example subroutine GUHADR to access the recoil nucleus information

```
****************************************************
*                                                  *
*    GEANT - CALOR Interface  Version  1.05/03     *
*    ----------------------------------------      *
*       4. 9.2001  C.Zeitnitz, T.A.Gabriel         *
*                                                  *
*     NMTC is used for hadronic interactions of    *
*        protons,neutrons and charged pions        *
*   up to 3.5 GeV (proton,neutron), 2.5 GeV(pion)  *
*                                                  *
*    A Scaling Model is used for the energy range  *
*                 up to 10 GeV.                    *
*                                                  *
*      MICAP is calculating the interaction of     *
*       Neutrons with an energy below 20 MeV       *
*                                                  *
*   For interactions of hadrons not implemented in *
*        CALOR or with an energy above 10 GeV      *
*                 FLUKA is called                  *
*                                                  *
*  The transport of electrons, positrons and gammas *
*                 is done by GEANT                 *
*                                                  *
*     All output is written to file calor.out      *
*                                                  *
****************************************************
*        Neutron cutoff energy=  0.10E-13 eV       *
****************************************************
```

Figure 4.4: The GCALOR banner

```
                 GEANT-CALOR INTERFACE V 1.05/03 Output File
                 ===========================================

       GEANT Material Parameters                 MICAP Material Parameters
       -------------------------                 -------------------------
 Material                 No/Iso    A     Z  |    A     Z   Density   Coll.Len
-------------------------------------------+---------------------------------
 AIR.................     15/ 1*  14.6    7  |  14.0    7  0.4967E-04 0.846E+04
 Neon................     30/ 1*  20.2   10  |  23.0   11  0.1492E+02 0.211E-01
 DU..................     79/ 1  238.0   92  | 238.1   92  0.4423E-01 0.316E+01
                          79/ 2  235.0   92  | 235.0   92  0.3895E-02 0.369E+02
 Xenon...............     80/ 1  131.3   54  | 127.9   54  0.5542E-03 0.279E+03
                          80/ 2     -     -  | 128.9   54  0.7424E-02 0.207E+02
                          80/ 3     -     -  | 129.9   54  0.1091E-02 0.140E+03
                          80/ 4     -     -  | 130.9   54  0.5686E-02 0.268E+02
                          80/ 5     -     -  | 131.9   54  0.7255E-02 0.209E+02
                          80/ 6     -     -  | 133.9   54  0.2647E-02 0.570E+02
                          80/ 7     -     -  | 135.9   54  0.2347E-02 0.640E+02
 Tin.................     81/ 1  118.7   50  | 115.9   50  0.4413E-02 0.358E+02
                          81/ 2     -     -  | 116.9   50  0.2316E-02 0.687E+02
                          81/ 3     -     -  | 117.9   50  0.6890E-02 0.234E+02
                          81/ 4     -     -  | 118.9   50  0.2530E-02 0.619E+02
                          81/ 5     -     -  | 119.9   50  0.9284E-02 0.435E+04
 CsI.................     82/ 1  132.9   55  | 132.9   55  0.1133E-01 0.134E+02
                          82/ 2  126.9   53  | 126.9   53  0.1186E-01 0.114E+04
 Helium..............     87/ 1    4.0    2  |   4.0    2  0.1355E+00 0.105E+01
                          87/ 2    3.0    2  |   3.0    2  0.2007E-01 0.174E+02
 Concrete............     98/ 1    1.0    1  |   1.0    1  0.5616E-02 0.411E+02
                          98/ 2   16.0    8  |  16.0    8  0.4502E-01 0.270E+01
                          98/ 3   27.0   13  |  27.0   13  0.1782E-02 0.237E+03
                          98/ 4   40.1   20  |  40.1   20  0.2472E-02 0.356E+03
                          98/ 5   28.1   14  |  28.1   14  0.1738E-01 0.130E+02
                          98/ 6   55.8   26  |  55.8   26  0.9629E-03 0.201E+03
 Fe-7.4..............     99/ 1   56.0   26  |  55.8   26  0.7958E-01 0.243E+01
-----------------------------------------------------------------------------
                                                Density in (Atoms/barn/cm)
                                    Collision Length for 1 MeV neutron in (cm)

               *******************************************
               *               W A R N I N G             *
               *  Marked isotopes (*) not found in the   *
               *         cross-section file              *
               *   Cross-sections of the isotope with    *
               *   the closest Z will be used instead    *
               *******************************************


                      COMMENTS ABOUT ISOTOPE DATA
                      ---------------------------

   1) I-127 - Secondary Distributions taken from Xe-128
   2) Sn-120 - Secondary Distributions taken from Sn-119


                  USED NEUTRON CROSS-SECTION FILES
                  --------------------------------

File      : /cern/pro/lib/xsneut.dat
Generated : Wed Nov 24 16:18:19 1999
Comment   : MICAP neutron cross-section file. TOL=2.0% ANG=2.0%   C.Zeitnitz

MICAP :   1060636 words used in GCBANK for neutron x-section tables
```

Figure 4.5: Example of the GCALOR output file CALOR.OUT

```
*****************************************
*           G C A L O R                 *
*   NOT enough space available in ZEBRA  *
*  division  20 to store   633453 words  *
*                                        *
*  INCREASE ZEBRA COMMON SIZE AND RERUN  *
*                                        *
*            RUN TERMINATED              *
*****************************************
```

Figure 4.6: Message in case of insufficient space in the ZEBRA common GCBANK

Chapter 5

A Brief Guide to GCALOR

In order to install the GEANT-CALOR interface on your computer (here an example for an UNIX system), take the following action:

- Copy the files: README.TEXT, GCALOR_UNIX.F, CHETC.DAT, XSNEUT.DAT from *http://www.physik.uni-mainz.de/gcalor/gcalor.html* to your computer. Alternatively copy GCALOR.TAR-GZ and uncompress the file using *gunzip*.
- Compile the GCALOR_UNIX.FOR source and place the object files into a library
- Replace the call to GHEISH in the GEANT user routine GUHADR by a call to GCALOR
- Replace the call to GPGHEI in the GEANT user routine GUPHAD by a call to CALSIG
- Copy the data files CHETC.DAT and XSNEUT.DAT either into the cernlib directory or into the current working directory
- In the case that low energetic neutrons are of interest, set the cut CUTNEU=10^{-14}GeV. Ignore the warning printed by GEANT about the too low cut value
- Set the time cut-off to a reasonable value e.g. 1sec
- Define all materials either as elements or mixtures (GSMIXT). Do not use averaged materials. All materials should contains the correct element compositions
- Increase the size of the common GCBANK
- Link with GEANT 3.16 (3.21) and the CERN program library
- Run the program and check the material composition in the file CALOR.OUT

Chapter 6

Troubleshooting

Here some typical problems and some hints how to solve them:

Decompress problems in decompressing the files *GCALOR.TAR-Z* or *GCALOR.TAR-GZ* appear when the files have been copied in ASCII mode instead of BINARY, or the wrong decompression program is used (*uncompress* for *GCALOR.TAR-Z* and *gunzip* for *GCALOR.TAR-GZ*).

TAR to unpack the *GCALOR.TAR* file use the command *tar xvf GCALOR.TAR*

Compilation compilation errors are usually due to the wrong computer selection in CMZ (machine dependent compilation)

Linking the program is using GEANT and CERNLIB subroutines. If GEANT or GCALOR routines are unresolved, add the library a second time at the end of the link list. This occurs sometimes on UNIX systems

Run time Typical run time errors are :

- if one of the data files CHETC.DAT or XSNEUT.DAT is not available in the CERNLIB directory or in the current working directory at run time, the program will crash
- if the size of the ZEBRA common GCBANK is not sufficient to store the neutron cross-section data, a message as shown in figure 4.6 is printed in the GEANT output and the job stops. Increase the size of GCBANK (parameter KWBANK) and rerun
- sometimes GEANT will abort the tracking of a particle. This should happen rarely and only for neutron (low cut-off energy). If other particles are effected, check the cut-off values for the other particle types (energy cut-off greater or equal 10keV)

In case of a problem contact:

Christian Zeitnitz, Institut für Physik, Universität Mainz, D-55099 Mainz

e-mail: Christian.Zeitnitz@Uni-Mainz.de
CHRISTIAN.ZEITNITZ@CERN.CH

Chapter 7

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