The FLUKA User Routines: how to tailor FLUKA to specific user's needs.

User programming in the FLUKA environment

6th FLUKA Course

CERN, June 23-27, 2008

Why User Routines

- Unlike some other Monte Carlo particle transport codes, Fluka gets its input mainly from a simple file. It offers a rich choice of options for scoring most quantities of possible interest and for applying different variance reduction techniques, without requiring the users to write a single line of code.
- However, although normally there is no need for any "user code", there are special cases where this is unavoidable, either because of the complexity of the problem, or because the desired information is too unusual or too problem-specific to be offered as a standard option.
- And on the other hand, even when this is not strictly necessary, experienced programmers may like to create customised input/output interfaces.
- A number of user routines (available on LINUX and UNIX platforms in directory usermvax) allow to define non-standard input and output, and in some cases even to modify to a limited extent the normal particle transport.
- Most of them are already present in the Fluka library as dummy or template routines, and require a special command in the standard input file to be activated.
- Users can modify any one of these routines, and even insert into them further calls to their own private ones, or to external packages (at their own risk!).
- This increased flexibility must be balanced against the advantage of using as far as possible the Fluka standard facilities, which are known to be reliable and well tested.

What is available for the users

- Flair is able to help the user in managing editing, compiling and linking of user routines to build a user-specific FLUKA executable

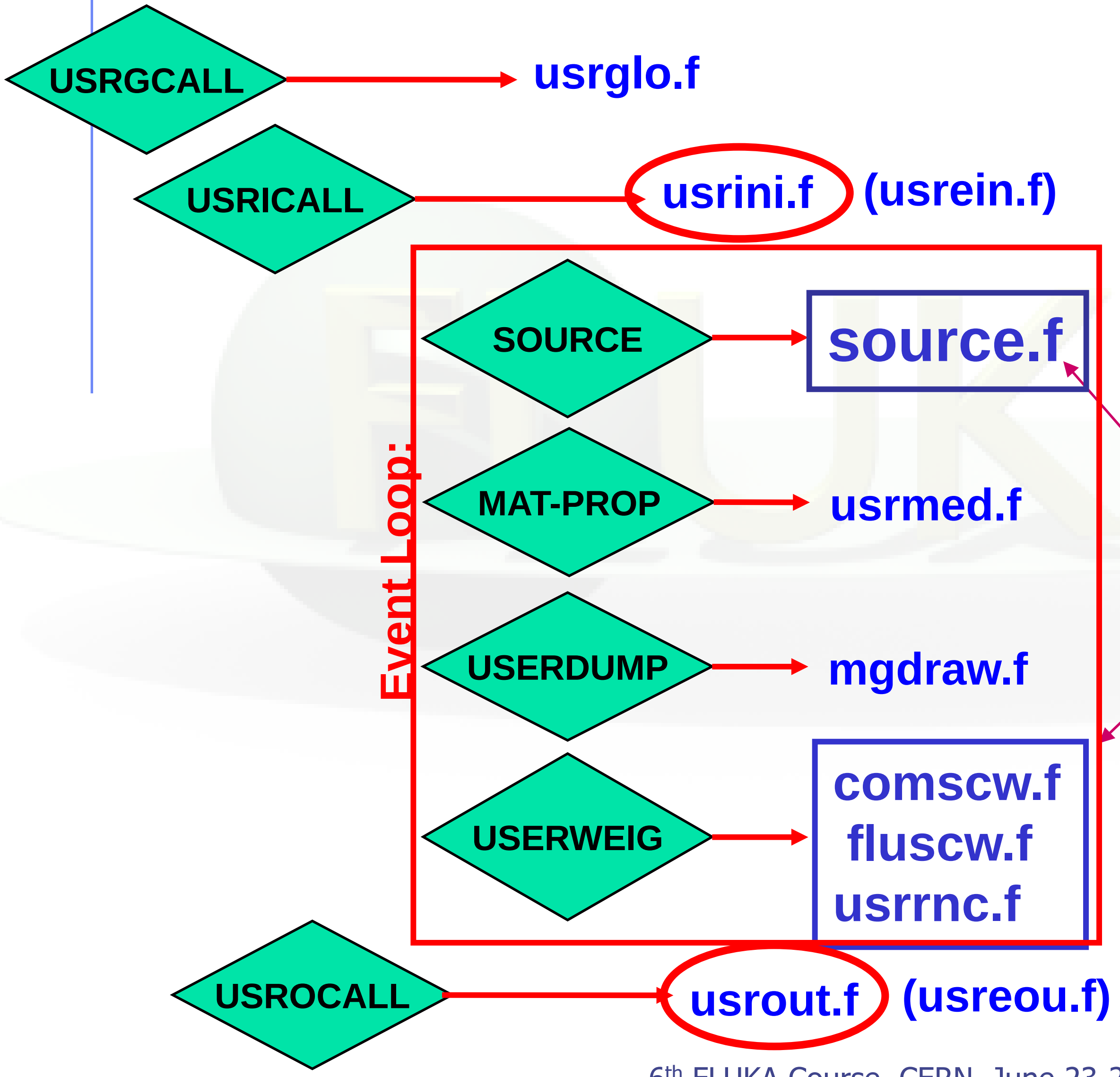
However the user has better to be aware that:

- The "skeleton" of all possible user routines in $FLUPRO/usermvax
- The include files containing the COMMON blocks with all relevant variables to access particle stack, secondary products and their kinematics, particle and material properties, etc. in $FLUPRO/flukapro (see later)
- The compiling and linking scripts which are in $FLUPRO/flutil

Something more that users need

- **The "theoretical" background and the proper know-how to implement a correct algorithm for the specific user problem**
- **The "rules" to achieve a good programming style inside FLUKA**
- **The knowledge of a certain number of utilities already existing in FLUKA (mathematics, random number, general utilities, etc.)**

A first look to the correspondence between some of the user routines and FLUKA commands



Emphasis of this lecture is here

But many other correspondences exist as explained later

The full list of user routines

- abscff.f
- comscw.f
- dffcff.f
- endscp.f
- fldscp.f
- fluscw.f
- formfu.f
- frghns.f
- fusrbv.f
- lattic.f
- lusrbl.f
- magfld.f
- mdstck.f
- mgdraw.f
- musrbr.f
- ophbdx.f
- pshckp.f
- queffc.f
- rflctv.f
- rfrndx.f
- soevsv.f
- source.f
- stupre.f
- stuprf.f
- ubsset.f
- udcdrl.f
- usimbs.f
- usrein.f
- usreou.f
- usrini.f
- usrmed.f
- usrout.f
- usrrnc.f
- ustckv.f
- usrglo.f

A possible classification in terms of their use (1)

User run control

- usrini.f
- usrein.f
- usrout.f
- usreou.f

Event generation, physics, kinematics

- source.f
- soevsv.f
- udcdrl.f
- formfu.f

Properties of medium

- magfld.f
- usrmed.f

User global settings

- usrglo.f

A possible classification in terms of their use (2)

in association to FLUKA output

- comscw.f
- fluscw.f
- endscp.f
- fldscp.f
- musrbr.f
- lusrbl.f
- fusrbv.f
- usrrnc.f

Intercepting particle stack

- mdstck.f
- stupre.f
- stuprf.f

Biasing

- usbset.f
- usimbs.f

A possible classification in terms of their use (3)

To drive optical photon transport

- abscff.f
- dffcff.f
- frghns.f
- ophbdx.f
- queffc.f
- rflctv.f
- rfrndx.f

To manage lattice geometry

- lattic.f

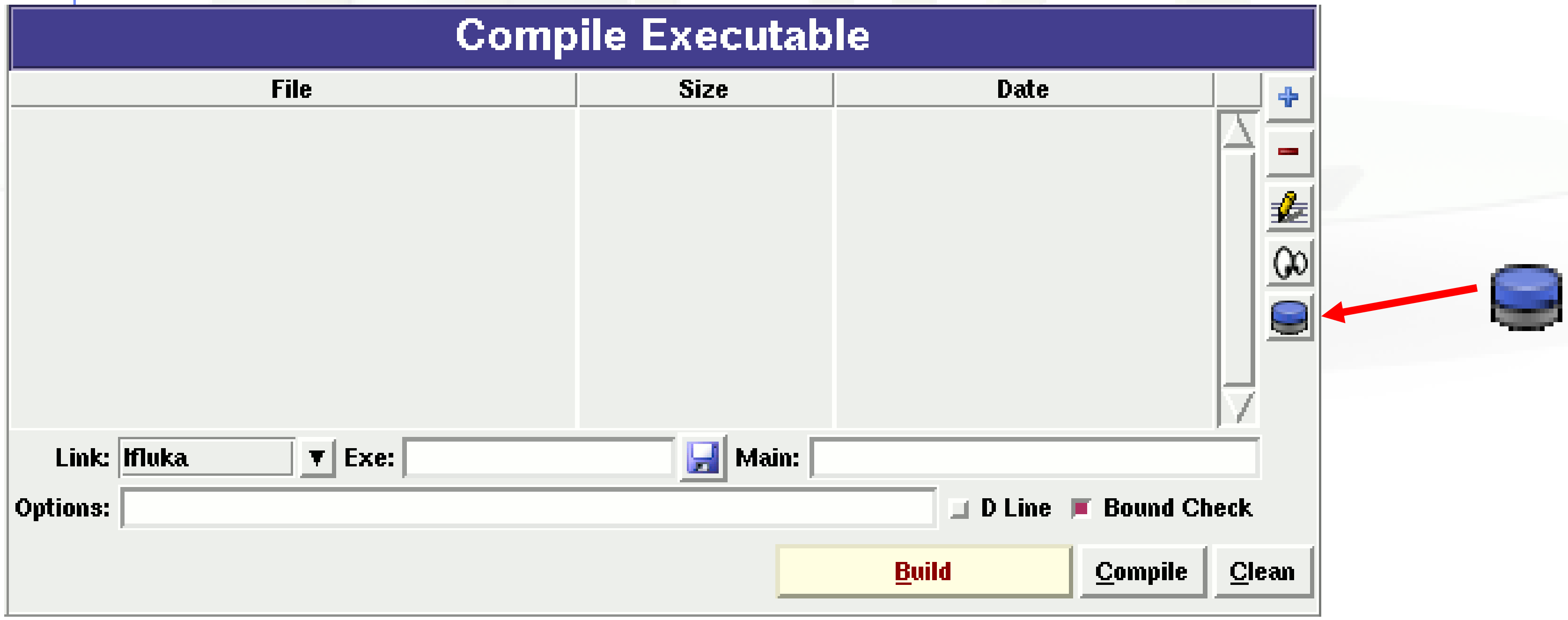
The access to (almost) everything

- mgdraw.f

See the relevant chap. of manual

Help by FLAIR

- The new version of FLAIR has a button in the **Compile frame** which allows to scan the input file for possible cards that demand the use of a user routine
- It then proposes the user to copy the standard routine from **$FLUPRO/usermvax** to the project directory

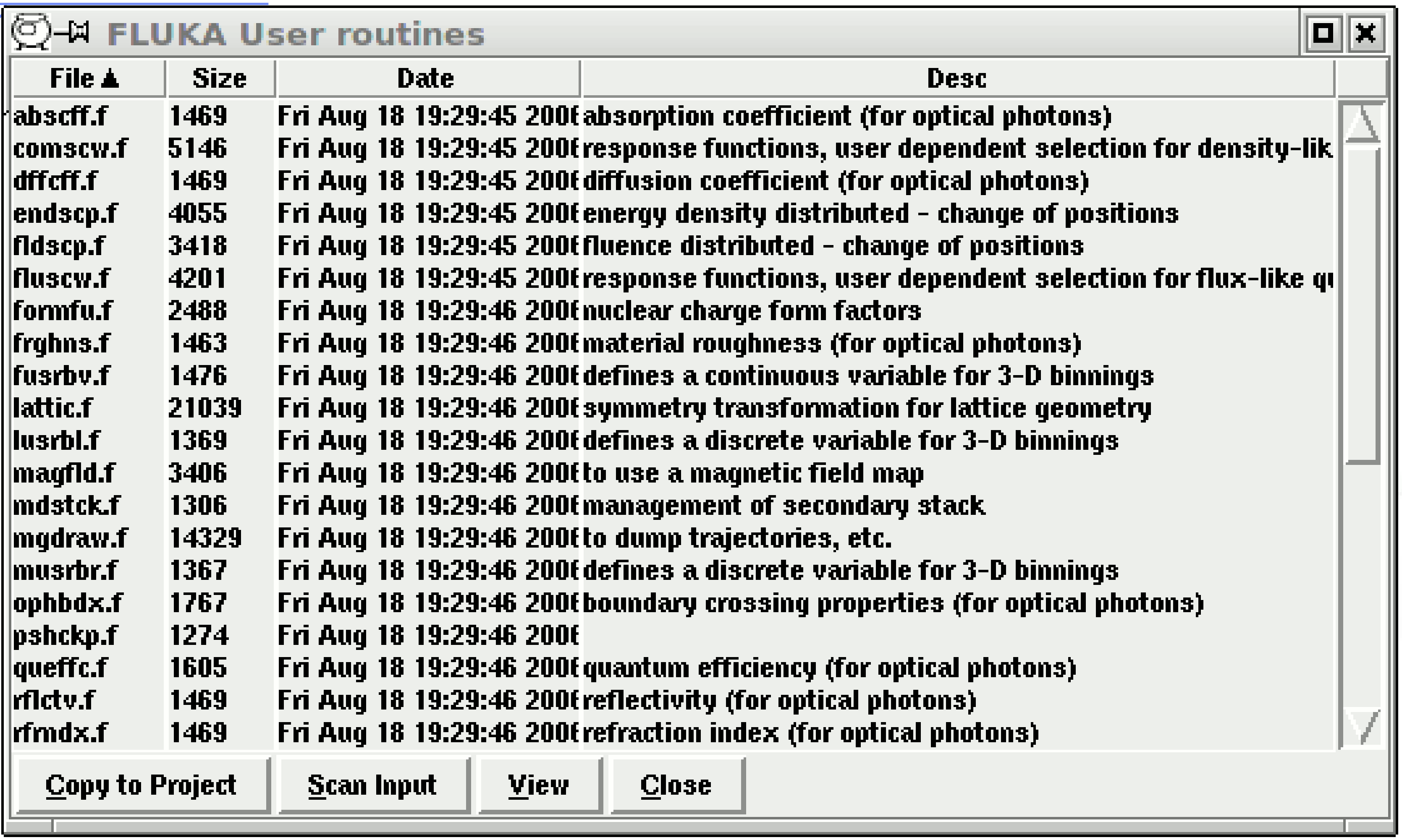


Compile Executable

File	Size	Date

Link: lfluka Exe: Main:

Options: D Line Bound Check



File ▲	Size	Date	Desc
abscff.f	1469	Fri Aug 18 19:29:45 200(	absorption coefficient (for optical photons)
comscw.f	5146	Fri Aug 18 19:29:45 200(	response functions, user dependent selection for density-lik
dffcff.f	1469	Fri Aug 18 19:29:45 200(	diffusion coefficient (for optical photons)
endscp.f	4055	Fri Aug 18 19:29:45 200(	energy density distributed - change of positions
fldscp.f	3418	Fri Aug 18 19:29:45 200(	fluence distributed - change of positions
fluscw.f	4201	Fri Aug 18 19:29:45 200(	response functions, user dependent selection for flux-like qu
formfu.f	2488	Fri Aug 18 19:29:46 200(	nuclear charge form factors
frghns.f	1463	Fri Aug 18 19:29:46 200(	material roughness (for optical photons)
fusrbv.f	1476	Fri Aug 18 19:29:46 200(	defines a continuous variable for 3-D binnings
lattic.f	21039	Fri Aug 18 19:29:46 200(	symmetry transformation for lattice geometry
lusrbl.f	1369	Fri Aug 18 19:29:46 200(	defines a discrete variable for 3-D binnings
magfld.f	3406	Fri Aug 18 19:29:46 200(	to use a magnetic field map
mdstck.f	1306	Fri Aug 18 19:29:46 200(	management of secondary stack
mgdraw.f	14329	Fri Aug 18 19:29:46 200(	to dump trajectories, etc.
musrbr.f	1367	Fri Aug 18 19:29:46 200(	defines a discrete variable for 3-D binnings
ophbdx.f	1767	Fri Aug 18 19:29:46 200(	boundary crossing properties (for optical photons)
pshckp.f	1274	Fri Aug 18 19:29:46 200(	
queffc.f	1605	Fri Aug 18 19:29:46 200(	quantum efficiency (for optical photons)
rflctv.f	1469	Fri Aug 18 19:29:46 200(	reflectivity (for optical photons)
rfrndx.f	1469	Fri Aug 18 19:29:46 200(	refraction index (for optical photons)

Basic news about FLUKA routines/functions

- **written in Fortran 77**
- **Double Precision everywhere (Real*8), except for variables beginning with a letter within (i-n)**
- **May have arguments**
- **Most variables passed through common blocks**
- **Common blocks are in files which are charged by INCLUDE statement**
- **All include files of common blocks are in $FLUPRO/flukapro**
- **Common blocks have names which correspond to include files.**
- **Each routine has at the least the following includes/common blocks:**

```
INCLUDE '(DBLPRC)'
INCLUDE '(DIMPAR)'
INCLUDE '(IOUNIT)'
```

Note the parentheses which are an integral part of the Fluka INCLUDE file names

- **The user may add his own common which may reside in different places**

Fundamental FLUKA Common Blocks

DBLPRC: included in all routines of Fluka, contains (as **PARAMETERS**) the **most common physical and mathematical constants** and the declaration **IMPLICIT DOUBLE PRECISION (A-H,O-Z)**

DIMPAR: dimensions of the most important arrays

IOUNIT: logical input and output unit numbers (FLUKA uses from 1 to 19, they must be considered as reserved)

- Users are strongly encouraged to adhere to "Fluka style" by using systematically double precision (except for very good reasons such as calling external single precision scoring packages), and to use constants defined in this file for maximum accuracy.
- **Important:** take some time to study the content of **DBLPRC**

Other important COMMON blocks in short (1)

BEAMCM: properties of primary particles as defined by options BEAM and BEAMPOS

CASLIM: number of primary particles followed (needed for normalisation)

EMFSTK: particle stack for electrons and photons

SOURCM: user variables and information for a user-written source

EVTFLG: event flags

FHEAVY: stack of heavy secondaries created in nuclear evaporation

GENSTK: properties of each secondary created in a hadronic event

LTCLCM: LaTtice CeLl CoMmon (needed when writing symmetry transformations for Lattice Geometry)

FLKMAT: material properties

FLKSTK: main Fluka particle stack

Other important COMMON blocks in short (2)

SOUEVT: **variables concerning the source event: useful when primary particles (source particles) are taken from an external file or event generator**

TRACKR: **variables concerning the properties of transported particle (track) at run time**

PAPROP: **particle properties**

SCOHLP: **variables concerning the current estimator type**

USRBDX: **variables related to USRBDX scoring**

USRYLD: **variables related to USRYIELD scoring**

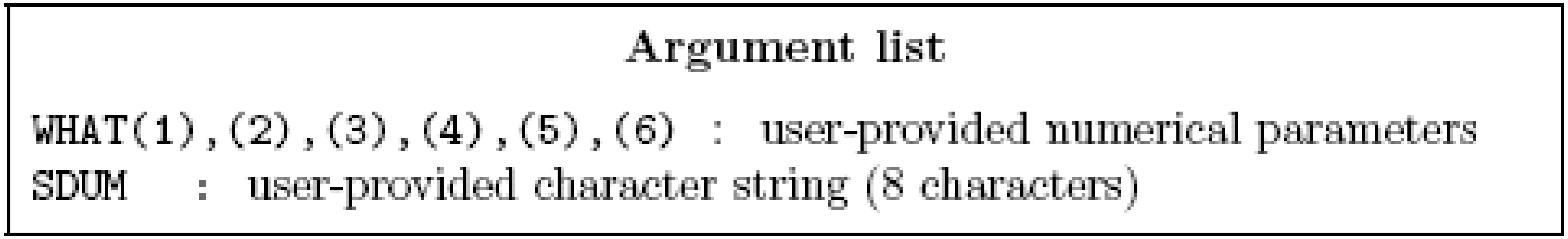
USRBIN: **variables related to USRBIN scoring**

USRTRK: **variables related to USRTRACK scoring**

Names and Numbers

- FLUKA converts all Names given in the input file to Numbers: all the corresponding arguments that you will find in user routines are numeric (except of in the case of SDUMs)

usrini (USeR INItialization)



Argument list

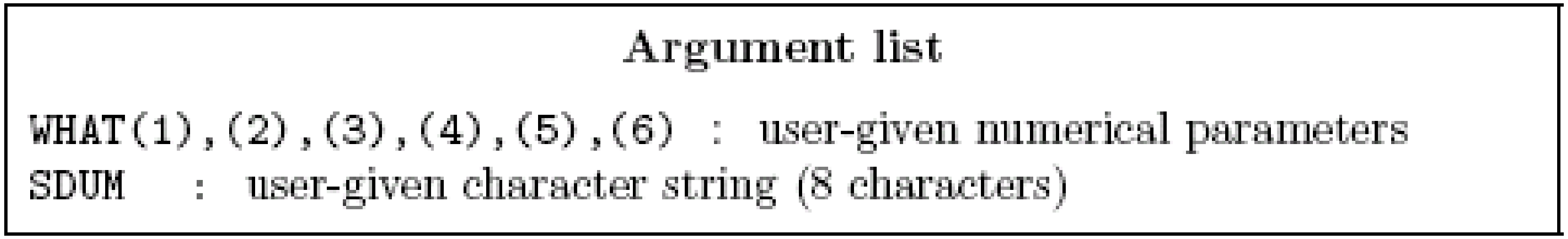
```
WHAT(1),(2),(3),(4),(5),(6)  :  user-provided numerical parameters
SDUM   :  user-provided character string (8 characters)
```

Subroutine USRINI is called every time a USRICALL card is read in input. It can be used to do any kind of initialisation: reading and manipulating data from one or more files, calling other private routines, etc.
The calling parameters can carry any kind of useful information or can be used as flags to choose between different possible actions to be performed before any particle transport takes place.

usrein (USeR Event INitialization)

Subroutine USREIN is called just before the first source particle of an event is unloaded from stack and begins to be transported. An event is the full history of a group of related particles and their descendants.
If primaries are loaded into stack by the input option BEAM, there is only one source particle per event; but there can be more if the user routine SOURCE is used to load particles into stack. USREIN does not need any special command to be activated, but the default version of USREIN does nothing: the user can write here any kind of initialisation.

usrout (USeR OUTput)



Argument list

WHAT(1),(2),(3),(4),(5),(6) : user-given numerical parameters
SDUM : user-given character string (8 characters)

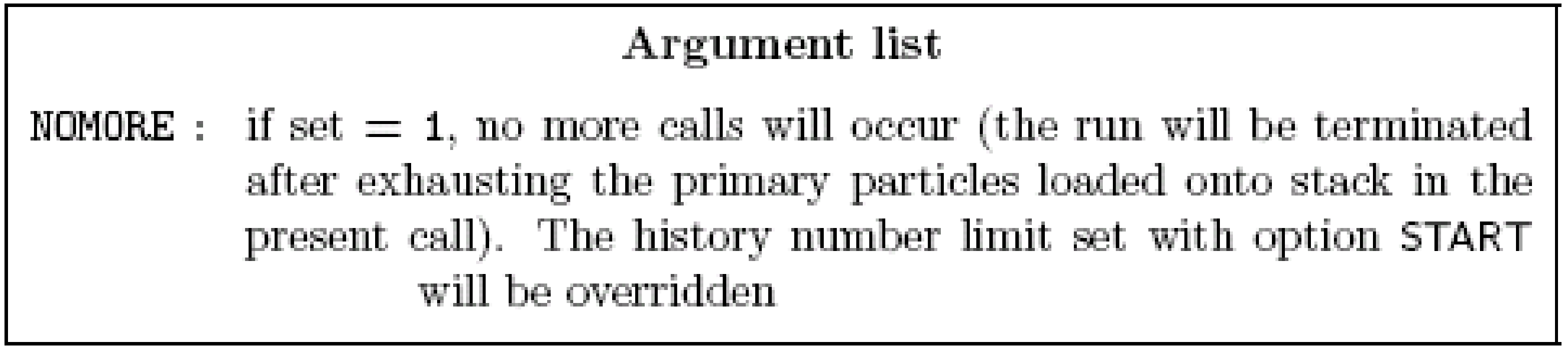
Subroutine USROUT is called every time a USROCALL card is read in input. It is used to print special user-written output in addition to the standard one provided by default. The calling parameters can carry any kind of useful information or can be used as flags to choose between different possible actions to be performed after all particle transport has taken place.

usreou (USeR Event OUtput)

Subroutine USREOU is called at the end of each event, namely after all event primary particles and their descendants have been transported. ***(See USREIN above for a definition of an event).***

USREOU does not need any special command to be activated, but the default version of USREOU does nothing: the user can write here any kind of event analysis, output, etc.

source (user written source: generation of initial kinematics)



Argument list

NOMORE : if set = 1, no more calls will occur (the run will be terminated after exhausting the primary particles loaded onto stack in the present call). The history number limit set with option START will be overridden

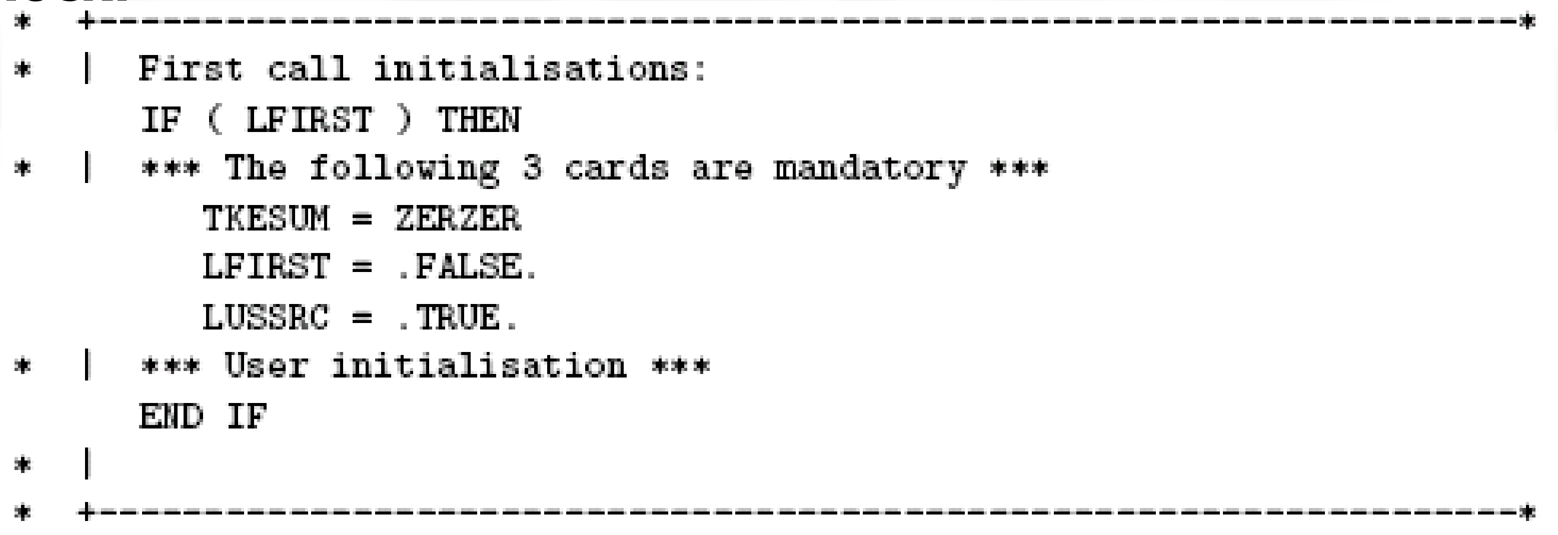
Subroutine SOURCE is probably the most frequently used user routine. It is activated by option SOURCE and is used to sample primary particle properties from distributions (in space, energy, time, direction or mixture of particles) too complicated to be described with the BEAM, BEAMPOS and BEAMAXES cards alone. For each phase-space variable, a value must be loaded onto COMMON FLKSTK (particle bank) before returning control. These values can be read from a file, generated by some sampling algorithm, or just assigned.

Using source

Option SOURCE allows the user to input up to 18 numerical values (WHASOU(1),(2). . . (18)) and one 8-character string (SDUSOU) which can be accessed by the subroutine by including the following line:

INCLUDE '(SOURCM)'

The user can insert any initialization within the following IF block:



```
*  +-------------------------------------------------------------------*
*  |  First call initialisations:
      IF ( LFIRST ) THEN
*  |  *** The following 3 cards are mandatory ***
         TKESUM = ZERZER
         LFIRST = .FALSE.
         LUSSRC = .TRUE.
*  |  *** User initialisation ***
      END IF
*  |
*  +-------------------------------------------------------------------*
```

Using source (continues...)

The user can load onto the FLKSTK stack one or more source particles at each call: for each particle loaded the pointer must be increased by 1.

```
NPFLKA = NPFLKA + 1                    !  increases the pointer
```

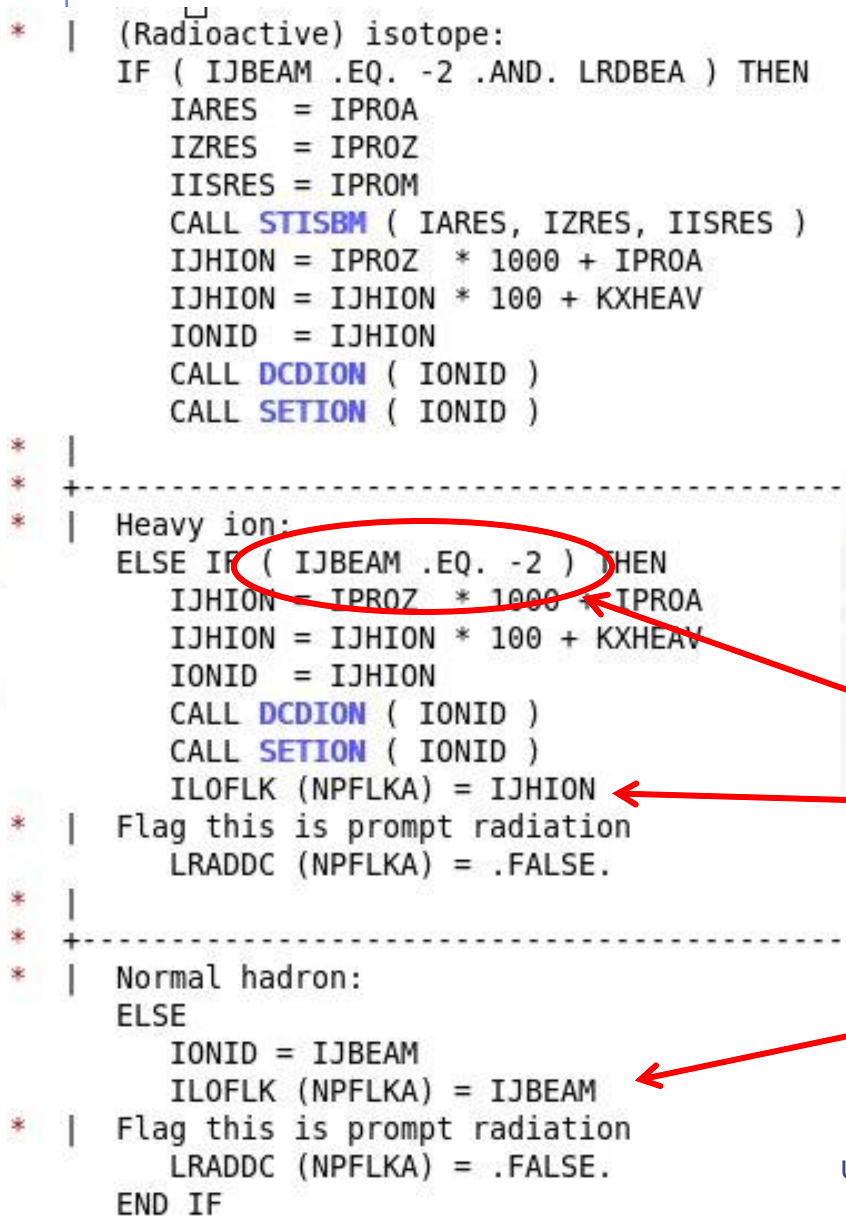
sets the weight of the particle (values different from 1 →advanced users)

```
WTFLK (NPFLKA) = ONEONE
```

update the total weight of the primaries (don't change):

```
WEIPRI = WEIPRI + WTFLK (NPFLKA)
```

Using source (continues…)



```
*  |  (Radioactive) isotope:
      IF ( IJBEAM .EQ. -2 .AND. LRDBEA ) THEN
         IARES  = IPROA
         IZRES  = IPROZ
         IISRES = IPROM
         CALL STISBM ( IARES, IZRES, IISRES )
         IJHION = IPROZ  * 1000 + IPROA
         IJHION = IJHION * 100 + KXHEAV
         IONID  = IJHION
         CALL DCDION ( IONID )
         CALL SETION ( IONID )
*  |
*  +-------------------------------------------
*  |  Heavy ion:
      ELSE IF ( IJBEAM .EQ. -2 ) THEN
         IJHION = IPROZ  * 1000 + IPROA
         IJHION = IJHION * 100 + KXHEAV
         IONID  = IJHION
         CALL DCDION ( IONID )
         CALL SETION ( IONID )
         ILOFLK (NPFLKA) = IJHION
*  |  Flag this is prompt radiation
         LRADDC (NPFLKA) = .FALSE.
*  |
*  +-------------------------------------------
*  |  Normal hadron:
      ELSE
         IONID = IJBEAM
         ILOFLK (NPFLKA) = IJBEAM
*  |  Flag this is prompt radiation
         LRADDC (NPFLKA) = .FALSE.
      END IF
```

by default sets the type of particle equal to the one defined by the BEAM card (plus HI-PRO if this is the case). If no BEAM card is given in input, IJBEAM is = 1 (proton).

Otherwise can be set inside the source (may be different event by event

Heavy ion

“Normal” particle

Using source (continues...)

Never change the following lines:

```
* From this point ....
      LOFLK (NPFLKA) = 1              !  Generation is 1 for source particles
      LOUSE (NPFLKA) = 0              !  User variables: the user can set
      DO 100 ISPR = 1, MKBMX1         !  different values in the STUPRF or
         SPAREK (1,NPFLKA) = ZERZER   !  STUPRE routine, but it is better
 100  CONTINUE                        !  not to do it here
      DO 200 ISPR = 1, MKBMX2
         ISPARK (ISPR,NPFLKA) = 0     !  More user variables (integer)
 200  CONTINUE
      NPARMA = NPARMA + 1             !  Updating the maximum particle number
      NUMPAR (NPFLKA) = NPARMA        !  Setting the current particle number
      NEVENT (NPFLKA) = 0             !  Resetting the current event number
      DFNEAR (NPFLKA) = +ZERZER       !  Resetting the distance to the
                                      !  nearest boundary
* ... to this point: don't change anything
```

Using source (continues...)

The following lines can remain at their standard

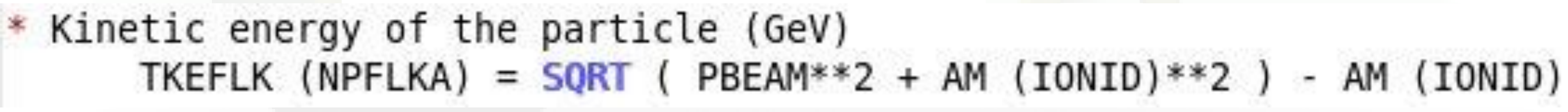
```
AGESTK (NPFLKA) = +ZERZER        !  Particle age is zero by default
AKNSHR (NPFLKA) = -TWOTWO        !  Resets the Kshort component of
                                 !  K0/K0bar. Usually not to be changed.
IGROUP (NPFLKA) = 0              !  Group number for low-energy
                                 !  neutrons: if set to 0, the program
                                 !  derives it from the kinetic energy
```

Using source (continues…)

<u>Assigning momentum/energy</u>

In the template routine, the momentum is assumed to be assigned by BEAM option (its value, PBEAM, is taken from COMMON BEAMCM, which contains all values defined by options BEAM and BEAMPOS.

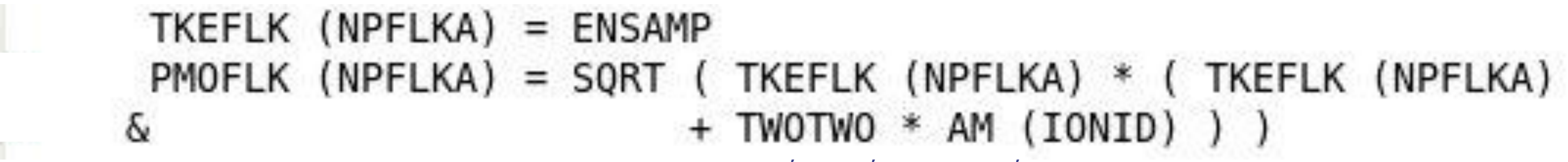
```
PMOFLK (NPFLKA) = PBEAM
```



```
* Kinetic energy of the particle (GeV)
      TKEFLK (NPFLKA) = SQRT ( PBEAM**2 + AM (IONID)**2 ) - AM (IONID)
```

<u>Here the user can make direct assignment of momentum, read from an external file or introduce code lines to sample from a distribution</u>

Alternatively the user can make sample kinetic energy and derive the momentum. Be coherent!



```
      TKEFLK (NPFLKA) = ENSAMP
      PMOFLK (NPFLKA) = SQRT ( TKEFLK (NPFLKA) * ( TKEFLK (NPFLKA)
     &                       + TWOTWO * AM (IONID) ) )
```

Using source (continues...)

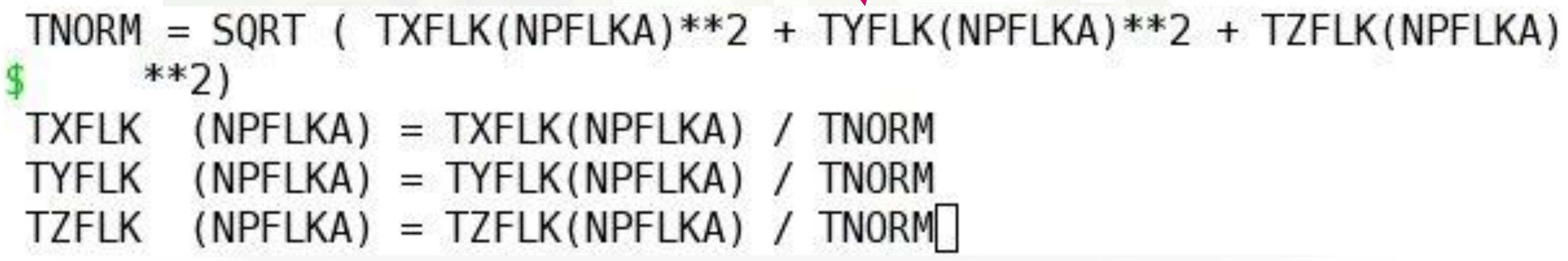
Here direction cosines are assigned/read/sampled:

```
TXFLK (NPFLKA) = UBEAM                 !  Assumed here to be the same as
TYFLK (NPFLKA) = VBEAM                 !  defined by option BEAMPOS. UBEAM,
TZFLK (NPFLKA) = WBEAM                 !  VBEAM, WBEAM are some among the beam
                                       !  properties in COMMON BEAMCM
```

Be careful to ensure the proper normalization within machine accuracy!!

Beware of the normalization of direction cosines!

Note that in any case the direction cosines must be properly normalised in double precision.
A good algorithm is the following:



```
 TNORM = SQRT ( TXFLK(NPFLKA)**2 + TYFLK(NPFLKA)**2 + TZFLK(NPFLKA)
$      **2)
 TXFLK  (NPFLKA) = TXFLK(NPFLKA) / TNORM
 TYFLK  (NPFLKA) = TYFLK(NPFLKA) / TNORM
 TZFLK  (NPFLKA) = TZFLK(NPFLKA) / TNORM
```

The need for an high accuracy normalization of direction cosines is a general rule in FLUKA: there are checks that in case of bad normalization produce a lot of error messages (and time loss…)

Using source (continues...)

It is also possible to assign a polarization:

```
TXPOL (NPFLKA) = -TWOTWO        ! -2 is a flag for "no polarisation"
TYPOL (NPFLKA) = +ZERZER
TZPOL (NPFLKA) = +ZERZER
```

Finally, initial space coordinate assigned/read/sampled:

```
XFLK (NPFLKA) = XBEAM           !  Assumed here to be the same as
YFLK (NPFLKA) = YBEAM           !  defined by option BEAMPOS. XBEAM,
ZFLK (NPFLKA) = ZBEAM           !  YBEAM, ZBEAM are also in COMMON BEAMCM
```

Using source (continues...)

The last line calls the SOEVSV user routine to save the stack for possible further use.

The values of beam characteristics defined by commands BEAM and POLARIZAti are available in COMMON BEAMCM: the angular divergence (variable DIVBM), beam width (XSPOT and YSPOT), and the polarisation vector (UBMPOL, VBMPOL, WBMPOL) can help to set up a scheme to sample the corresponding quantities from user-defined distributions. But sampling from the distributions pre-defined by BEAM and POLARIZAti is not simply inherited by subroutine SOURCE: it is the responsibility of the user to write such a scheme! For this task, it may be useful to define a "beam reference frame" by means of option BEAMAXES.

Using source (continues...)

- **Very Important:**

when using SOURCE, remember that the use of the BEAM card remains mandatory:

In that case the momentum (or energy) in WHAT(1) is meant as the maximum possible value of momentum (or energy) of your problem: this is used by FLUKA at initialization time to perform tabulations.

If, at run time, an energy greater than the maximum established in BEAM is sampled, an abort will be generated.

Exercise and homework

- Study the BEAMCM, SOURCM, SOUEVT commons
- Write your own source to generate a gaussian spread in energy of a beam (possible also just with BEAM card, but just to verify your capabilities...)

Using FLUKA Random Number Generator in user routines

- **Fundamental for SOURCE!!! No other external random generators must be used, otherwise the reproducibility of histories is lost**
- **… = FLRNDM(XDUMMY)**

returns a 64-bit random number (0-1)

- **CALL FLNRRN (RGAUSS)**

returns a normally distributed random number RGAUSS

- **CALL FLNRR2 (RGAUS1,RGAUS2)**

returns an uncorrelated pair of normally distributed random numbers: RGAUS1 and RGAUS2

- **CALL SFECFE(SINT,COST)**

returns a pair of random numbers, SINT and COST such that: SINT**2+COST**2 = 1.D+00

- **CALL RACO (TXX, TYY, TZZ)**

returns a random 3D direction (TXX, TYY, TZZ) such that: TXX**2+TYY**2 + TZZ**2= 1.D+00

A useful routine to be used in source for cosmic ray problems

- **CALL SFLOOD (XXX, YYY, ZZZ, UXXX, VYYY, WZZZ)**

  returns in XXX, YYY, ZZZ a random position ON the surface of a sphere of radius 1 and center 0 (multiply XXX, YYY, ZZZ by the actual radius and add the center coordinates) and UXXX, VYYY, WZZZ are random cosines according to a diffusive distribution
- **properly distributed so that to generate an uniform and isotropic fluence inside the sphere (of course in absence of material inside the sphere), numerically given by**

$$1/(\pi R^2)$$

R being the sphere radius.

Mathematical library in FLUKA

- **FLUKA contains many mathematical routines of general utility, so in general there should not be the need to call external mathematical libraries:**

flgaus:	**Gaussian adaptative integration**
simpsn:	**Simpson integration**
gamfun:	**Gamma fuction**
radcub:	**Real solutions of 3rd order algebric equation**
flgndr:	**Legendre polinomials**
yinter, finter:	**interpolation routines**
splinw:	**Spline interpolation**
rordin, rordde:	**Sorting of vector values**

…

Also: expansion in Laguerre and Chebyshev polynomials, Bezier fit, and many others…

For users who access FLUKA source: they are in mathmvax directory

At some time it will be possible to have a short-writeup for their use.

Other useful routines

- **CALL OAUXFI ('file', LUN, 'CHOPT', IERR)**

to open an auxiliary file (to read data or parameters) looking automatically for the file in some default locations (temporary directory, working directory, $FLUPRO, $HOME) without the need of giving the full path

- **CALL FLABRT('name','message')**

this allows to force a FLUKA abort on user request: it might be useful to perform a debugging (using gdb for instance)

Compiling and linking FLUKA user routines

- **A FLUKA executable with user routines is in general application specific. It has to be named and kept separately from the standard FLUKA**

- **Everything is managed today by FLAIR, however it is important to know the following details (managed automatically inside FLAIR):**

$FLUPRO/flutil/fff is the compiling script which jas the right definition of the path to the include subdirectory and all the necessary list of g77 options

Example: $FLUPRO/flutil/fff usrini.f generates usrini.o

then $FLUPRO/flutil/lfluka –m fluka –o flukamy usrini.o will perform the proper linking generating the executable here called flukamy

Tip: $FLUPRO/flutil/lfluka –m fluka –o flukamy usrini.f will automatically call $FLUPRO/flutil/fff

comscw (weighting energy or star deposit)

Argument list (all variables are input only)

IJ	:	particle type (1 = proton, 8 = neutron, etc.: see code in 5.1)
XA,YA,ZA	:	current particle position
MREG	:	current geometry region
RULL	:	amount to be deposited (unweighted)
LLO	:	particle generation
ICALL	:	internal code calling flag (not for general use)

This function is activated by option USERWEIG with WHAT(6) > 0.0. Energy and star densities obtained via SCORE and USRBIN, energy and stars obtained via EVENTBIN and production of residual nuclei obtained via RESNUCLEi are multiplied by the value returned by this function. The user can implement any desired logic to differentiate the returned value according to any information contained in the argument list (particle type, position, region, amount deposited, particle generation), or information available in COMMON SCOHLP (binning number, type of scored quantity). The scored quantity is given by the flag ISCRNG (in SCOHLP):

ISCRNG = 1 $\rightarrow$ Energy density binning
ISCRNG = 2 $\rightarrow$ Star density binning
ISCRNG = 3 $\rightarrow$ Residual nuclei scoring

comscw (continues…)

The binning/detector number is given by JSCRNG (in SCOHLP) and is printed in output between the estimator type and the detector name:

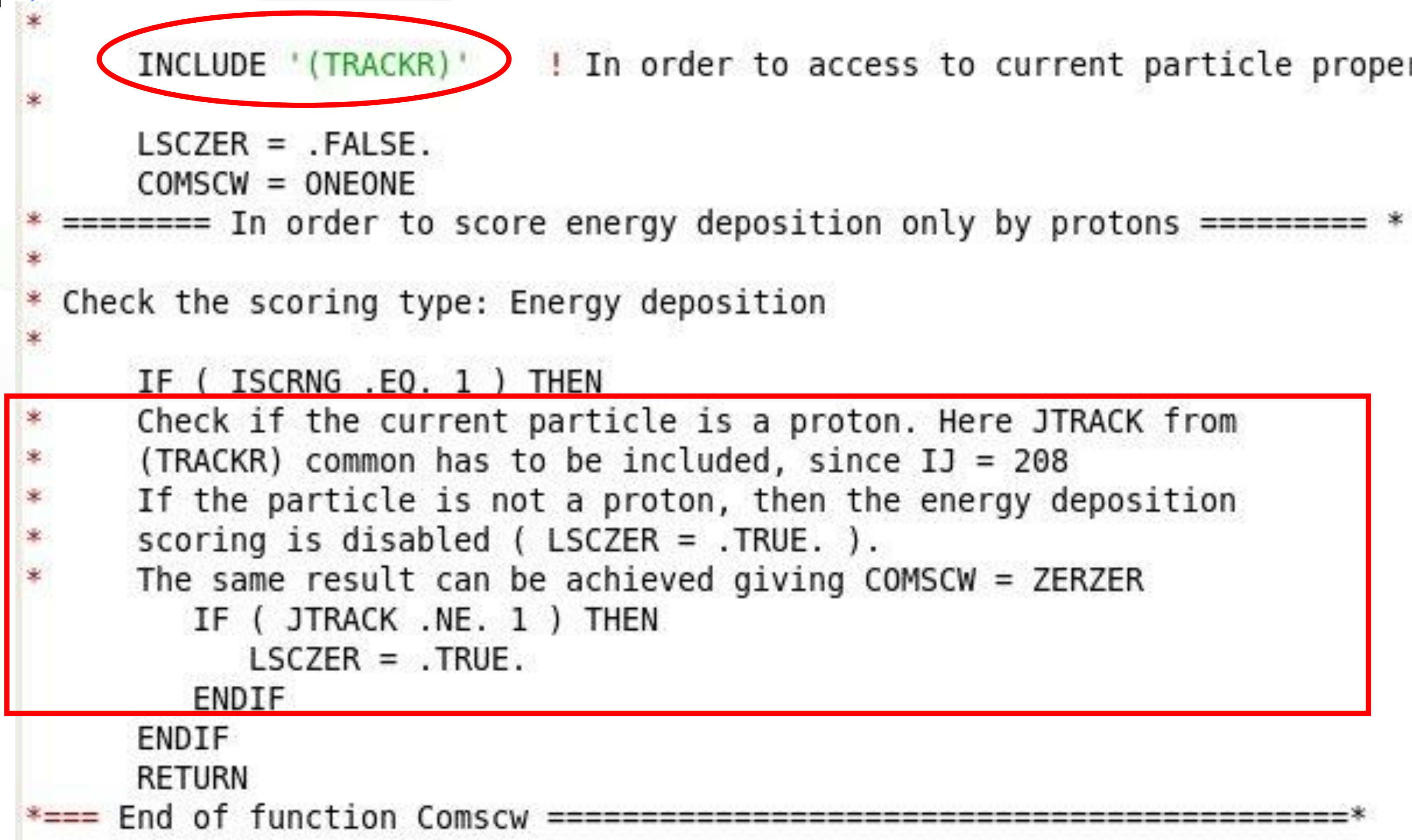
Note that a detector of residual nuclei can have the same JSCRNG number as a binning (use the value of ISCRNG to discriminate).

Further information can be obtained including COMMON TRACKR (for instance particle's total energy, direction cosines, age). TRACKR contains also special user variables (both integer and in double precision) which can be used to save information about particles which have undergone some particular event.

If data concerning the current material are needed, it can be accessed as MEDIUM(MREG) if file (FLKMAT) is included.

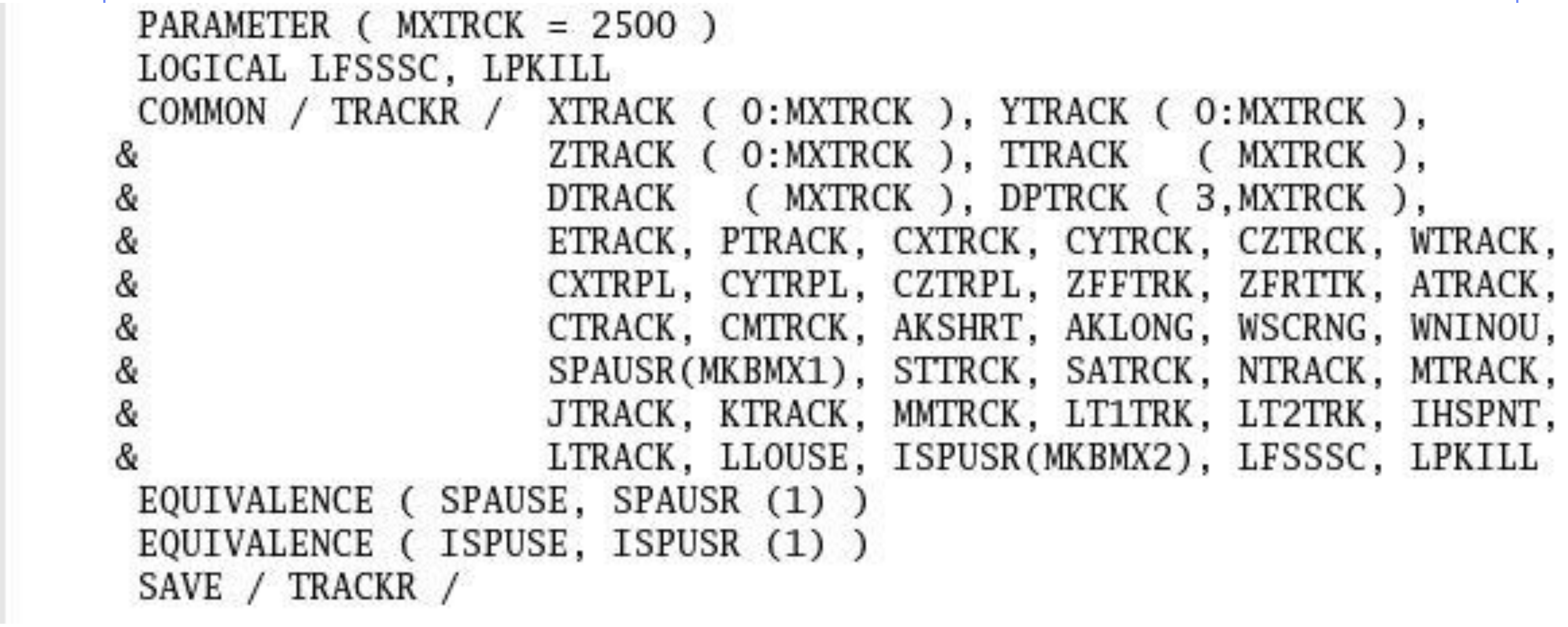
typical example of the use of comscw

A common simple application of COMSCW is to renormalize energy deposition to different units or to allow energy deposition scoring only for selected cases. For example, let us select energy deposition only by protons:



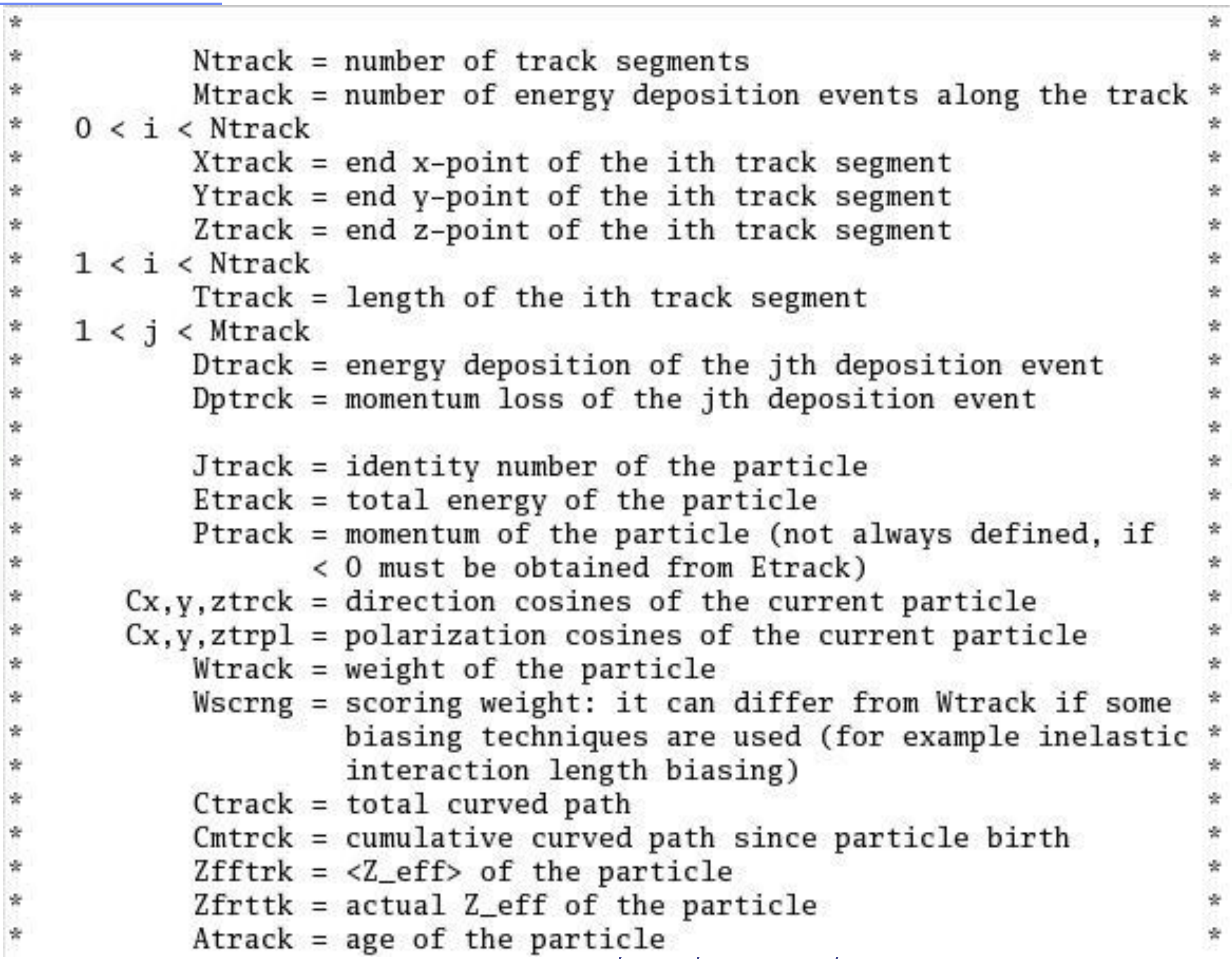
```
*
      INCLUDE '(TRACKR)'     ! In order to access to current particle properties
*
      LSCZER = .FALSE.
      COMSCW = ONEONE
* ======== In order to score energy deposition only by protons ========= *
*
* Check the scoring type: Energy deposition
*
      IF ( ISCRNG .EQ. 1 ) THEN
*     Check if the current particle is a proton. Here JTRACK from
*     (TRACKR) common has to be included, since IJ = 208
*     If the particle is not a proton, then the energy deposition
*     scoring is disabled ( LSCZER = .TRUE. ).
*     The same result can be achieved giving COMSCW = ZERZER
         IF ( JTRACK .NE. 1 ) THEN
            LSCZER = .TRUE.
         ENDIF
      ENDIF
      RETURN
*=== End of function Comscw ===================================*
```

Let’s give a look to the (TRACKR) include



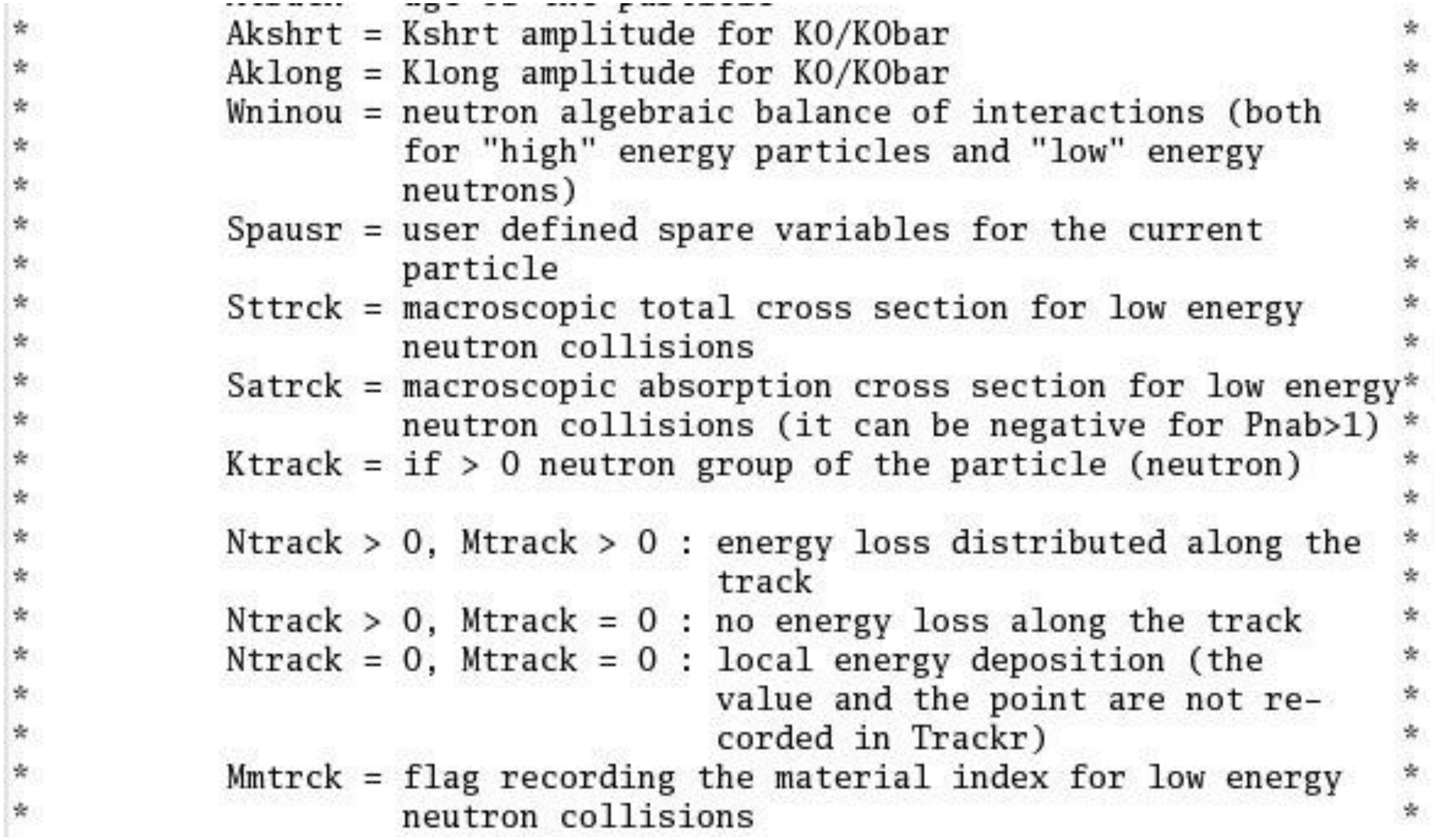
```
      PARAMETER ( MXTRCK = 2500 )
      LOGICAL LFSSSC, LPKILL
      COMMON / TRACKR /  XTRACK ( 0:MXTRCK ), YTRACK ( 0:MXTRCK ),
     &                   ZTRACK ( 0:MXTRCK ), TTRACK   ( MXTRCK ),
     &                   DTRACK   ( MXTRCK ), DPTRCK ( 3,MXTRCK ),
     &                   ETRACK, PTRACK, CXTRCK, CYTRCK, CZTRCK, WTRACK,
     &                   CXTRPL, CYTRPL, CZTRPL, ZFFTRK, ZFRTTK, ATRACK,
     &                   CTRACK, CMTRCK, AKSHRT, AKLONG, WSCRNG, WNINOU,
     &                   SPAUSR(MKBMX1), STTRCK, SATRCK, NTRACK, MTRACK,
     &                   JTRACK, KTRACK, MMTRCK, LT1TRK, LT2TRK, IHSPNT,
     &                   LTRACK, LLOUSE, ISPUSR(MKBMX2), LFSSSC, LPKILL
      EQUIVALENCE ( SPAUSE, SPAUSR (1) )
      EQUIVALENCE ( ISPUSE, ISPUSR (1) )
      SAVE / TRACKR /
```

TRACKR (continues...)



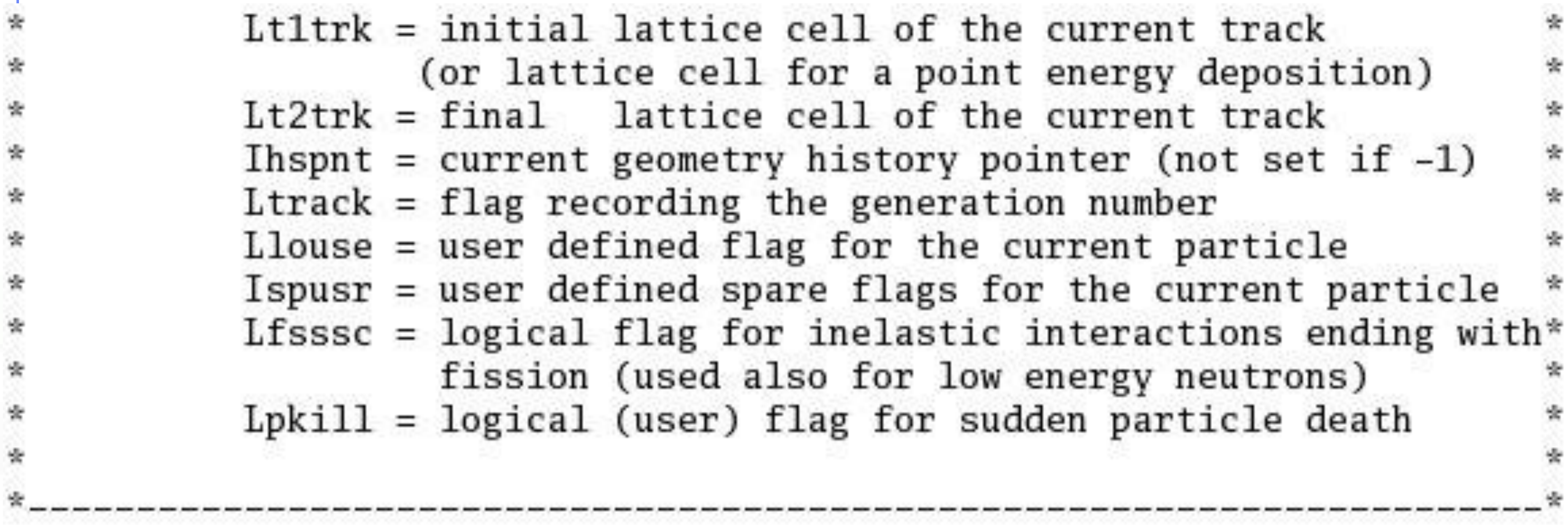
```
*                                                                      *
*          Ntrack = number of track segments                           *
*          Mtrack = number of energy deposition events along the track *
*   0 < i < Ntrack                                                     *
*          Xtrack = end x-point of the ith track segment               *
*          Ytrack = end y-point of the ith track segment               *
*          Ztrack = end z-point of the ith track segment               *
*   1 < i < Ntrack                                                     *
*          Ttrack = length of the ith track segment                    *
*   1 < j < Mtrack                                                     *
*          Dtrack = energy deposition of the jth deposition event      *
*          Dptrck = momentum loss of the jth deposition event          *
*                                                                      *
*          Jtrack = identity number of the particle                    *
*          Etrack = total energy of the particle                       *
*          Ptrack = momentum of the particle (not always defined, if   *
*                 < 0 must be obtained from Etrack)                    *
*      Cx,y,ztrck = direction cosines of the current particle          *
*      Cx,y,ztrpl = polarization cosines of the current particle       *
*          Wtrack = weight of the particle                             *
*          Wscrng = scoring weight: it can differ from Wtrack if some  *
*                   biasing techniques are used (for example inelastic *
*                   interaction length biasing)                        *
*          Ctrack = total curved path                                  *
*          Cmtrck = cumulative curved path since particle birth        *
*          Zfftrk = <Z_eff> of the particle                            *
*          Zfrttk = actual Z_eff of the particle                       *
*          Atrack = age of the particle                                *
```

TRACKR (continues...)



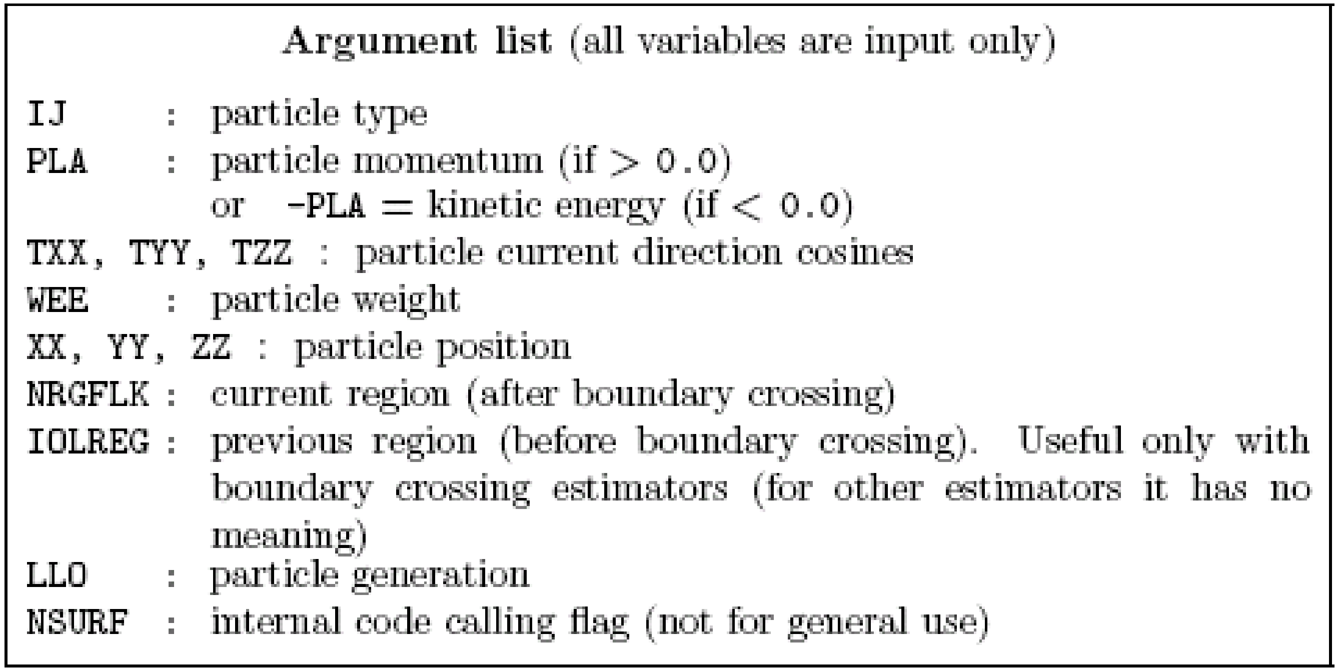
```
*          Akshrt = Kshrt amplitude for K0/K0bar                          *
*          Aklong = Klong amplitude for K0/K0bar                          *
*          Wninou = neutron algebraic balance of interactions (both       *
*                   for "high" energy particles and "low" energy          *
*                   neutrons)                                             *
*          Spausr = user defined spare variables for the current          *
*                   particle                                              *
*          Sttrck = macroscopic total cross section for low energy        *
*                   neutron collisions                                    *
*          Satrck = macroscopic absorption cross section for low energy*
*                   neutron collisions (it can be negative for Pnab>1) *
*          Ktrack = if > 0 neutron group of the particle (neutron)        *
*                                                                         *
*          Ntrack > 0, Mtrack > 0 : energy loss distributed along the     *
*                                   track                                 *
*          Ntrack > 0, Mtrack = 0 : no energy loss along the track        *
*          Ntrack = 0, Mtrack = 0 : local energy deposition (the          *
*                                   value and the point are not re-       *
*                                   corded in Trackr)                     *
*          Mmtrck = flag recording the material index for low energy      *
*                   neutron collisions                                    *
```

TRACKR (continues...)



```
*          Lt1trk = initial lattice cell of the current track          *
*                   (or lattice cell for a point energy deposition)    *
*          Lt2trk = final   lattice cell of the current track          *
*          Ihspnt = current geometry history pointer (not set if -1)   *
*          Ltrack = flag recording the generation number               *
*          Llouse = user defined flag for the current particle         *
*          Ispusr = user defined spare flags for the current particle  *
*          Lfsssc = logical flag for inelastic interactions ending with*
*                   fission (used also for low energy neutrons)        *
*          Lpkill = logical (user) flag for sudden particle death      *
*                                                                      *
*----------------------------------------------------------------------*
```

fluscw (weighting fluence, current and yield)



Argument list (all variables are input only)

IJ	particle type
PLA	particle momentum (if > 0.0) or -PLA = kinetic energy (if < 0.0)
TXX, TYY, TZZ	particle current direction cosines
WEE	particle weight
XX, YY, ZZ	particle position
NRGFLK	current region (after boundary crossing)
IOLREG	previous region (before boundary crossing). Useful only with boundary crossing estimators (for other estimators it has no meaning)
LLO	particle generation
NSURF	internal code calling flag (not for general use)

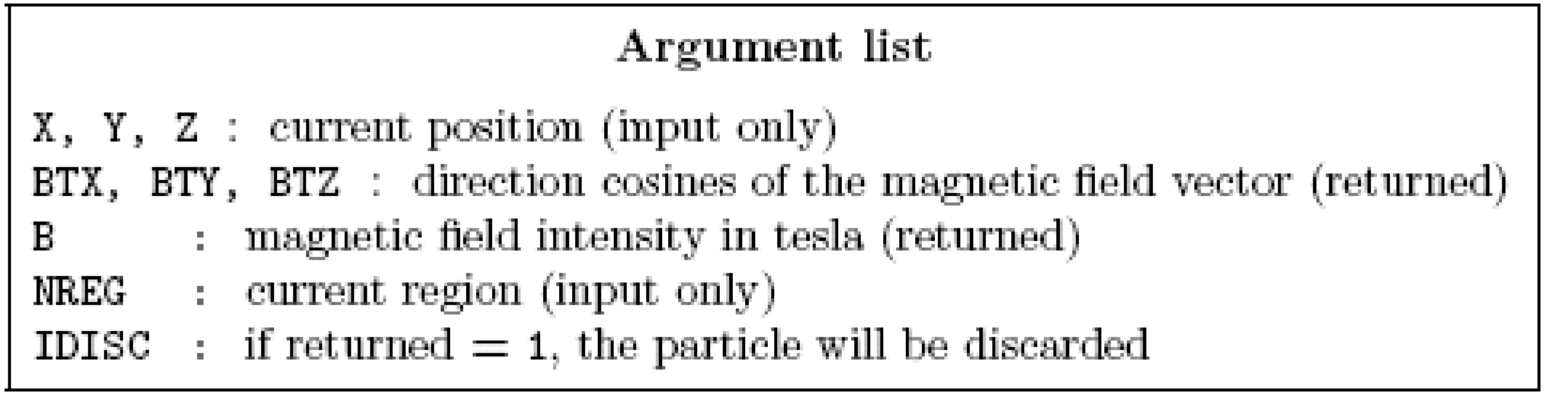
Similar to COMSCW. Function FLUSCW is activated by option USERWEIG, with WHAT(3) > 0.0. Yields obtained via USRYIELD, fluences calculated with USRBDX, USRTRACK, USRCOLL, USRBIN, and currents calculated with USRBDX are multiplied by the value returned by this function.

fluscw (continues...)

The user can implement any desired logic to differentiate the returned value according to any information contained in the argument list (particle type, energy, direction, weight, position, region, boundary, particle generation), or information available in COMMON SCOHLP (binning or detector number, estimator type). The estimator type is given by the flag ISCRNG (in COMMON SCOHLP):

ISCRNG = 1 $\rightarrow$ Boundary crossing estimator
ISCRNG = 2 $\rightarrow$ Track-length binning
ISCRNG = 3 $\rightarrow$ Track-length estimator
ISCRNG = 4 $\rightarrow$ Collision density estimator
ISCRNG = 5 $\rightarrow$ Yield estimator

magfld (definition of a magnetic field)



Argument list

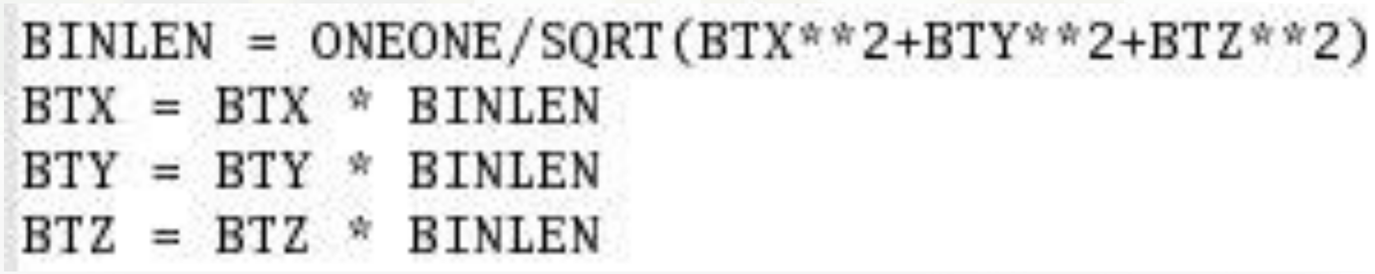
X, Y, Z	:	current position (input only)
BTX, BTY, BTZ	:	direction cosines of the magnetic field vector (returned)
B	:	magnetic field intensity in tesla (returned)
NREG	:	current region (input only)
IDISC	:	if returned = 1, the particle will be discarded

MAGFLD is activated by option MGNFIELD with WHAT(4-6)=0.0 and is used to return intensity and direction of a magnetic field based on the current position and region. It is called only if the current region has been flagged as having a non-zero magnetic field by option ASSIGNMAt , with WHAT(5) = 1.0.

The magnetic field spatial distribution is often read and interpolated from an external field map.

Beware of the usual need for the normalization of direction cosines!

Note that in any case the direction cosines must be properly normalised in double precision even if B = 0.0.
The recommended algorithm is:

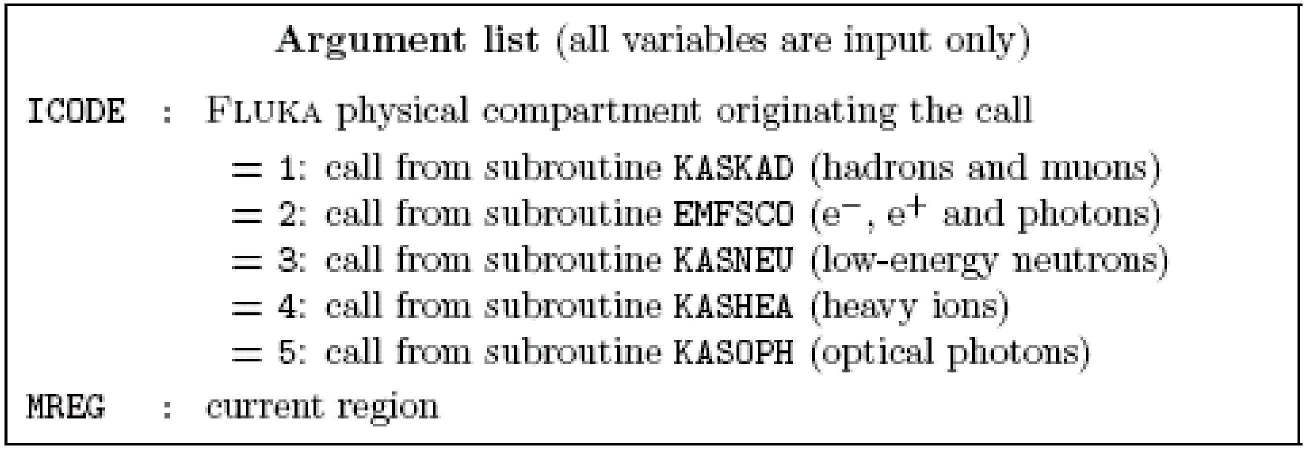


```
BINLEN = ONEONE/SQRT(BTX**2+BTY**2+BTZ**2)
BTX = BTX * BINLEN
BTY = BTY * BINLEN
BTZ = BTZ * BINLEN
```

A very special user routine: mgdraw.f

mgdraw (general event interface)

The most general interface to FLUKA content (if you know how to use it...)



Argument list (all variables are input only)

ICODE : FLUKA physical compartment originating the call

= 1: call from subroutine KASKAD (hadrons and muons)
= 2: call from subroutine EMFSCO (e^-, e^+ and photons)
= 3: call from subroutine KASNEU (low-energy neutrons)
= 4: call from subroutine KASHEA (heavy ions)
= 5: call from subroutine KASOPH (optical photons)

MREG : current region

Subroutine MGDRAW, activated by option USERDUMP with WHAT(1)≥100.0, usually writes a “collision tape”, i.e., a file where all or selected transport events are recorded. The default version (unmodified by the user) offers several possibilities, selected by WHAT(3) in USERDUMP.

mgdraw (continues...)

The different ENTRY points of MGDRAW

Additional flexibility is offered by a user entry USDRAW, interfaced with the most important physical events happening during particle transport.

The user can modify of course also any other entry of this subroutine:
BXDRAW called at boundary crossings,
EEDRAW called at event end,
MGDRAW for trajectory drawing,
ENDRAW for recording of energy deposition events
SODRAW for recording of source events:

mgdraw (continues...)

Possibilities: the format of the output file can be changed, and different combinations of events can be written to file.

But the most interesting aspect of the routine is that the six entries (all of which, if desired, can be activated at the same time by setting USERDUMP with WHAT(3) =0.0 and WHAT(4)≥1.0) constitute a complete interface to the whole Fluka transport. Therefore, MGDRAW can be used not only to write a collision tape, but to do any kind of complex analysis. Typical: event by event output (common for HEP applications).

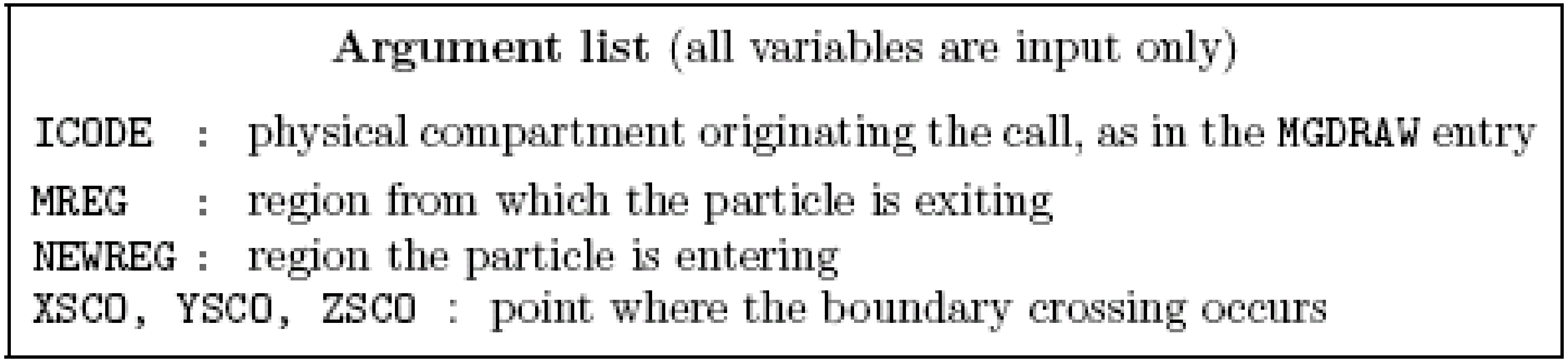
mgdraw: the MGDRAW entry

MTRACK: **number of energy deposition events along the track**
JTRACK: **type of particle**
ETRACK: **total energy of the particle**
WTRACK: **weight of the particle**
NTRACK: **values of XTRACK, YTRACK, ZTRACK: end of each track segment**
MTRACK: **values of DTRACK: energy deposited at each deposition event**
CTRACK: **total length of the curved path**

Other variables are available in TRACKR (but not written by MGDRAW unless the latter is modified by the user: particle momentum, direction cosines, cosines of the polarisation vector, age, generation, etc. (see a full list in the comment in the INCLUDE file).

mgdraw: the BXDRAW entry

Called at Boundary Crossings

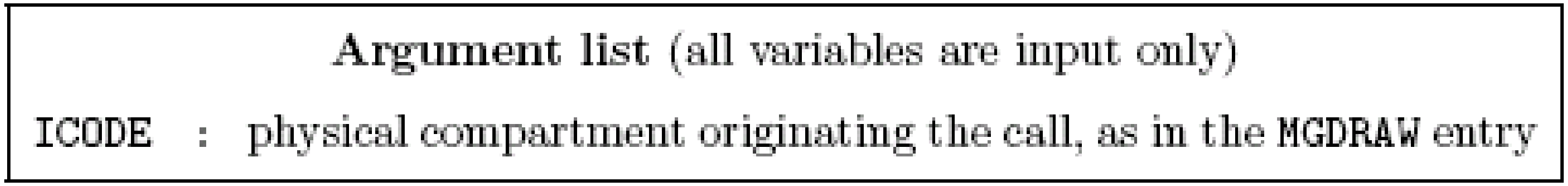


Argument list (all variables are input only)

`ICODE` :	physical compartment originating the call, as in the `MGDRAW` entry
`MREG` :	region from which the particle is exiting
`NEWREG` :	region the particle is entering
`XSCO, YSCO, ZSCO` :	point where the boundary crossing occurs

mgdraw: the EEDRAW entry

Called at Event End



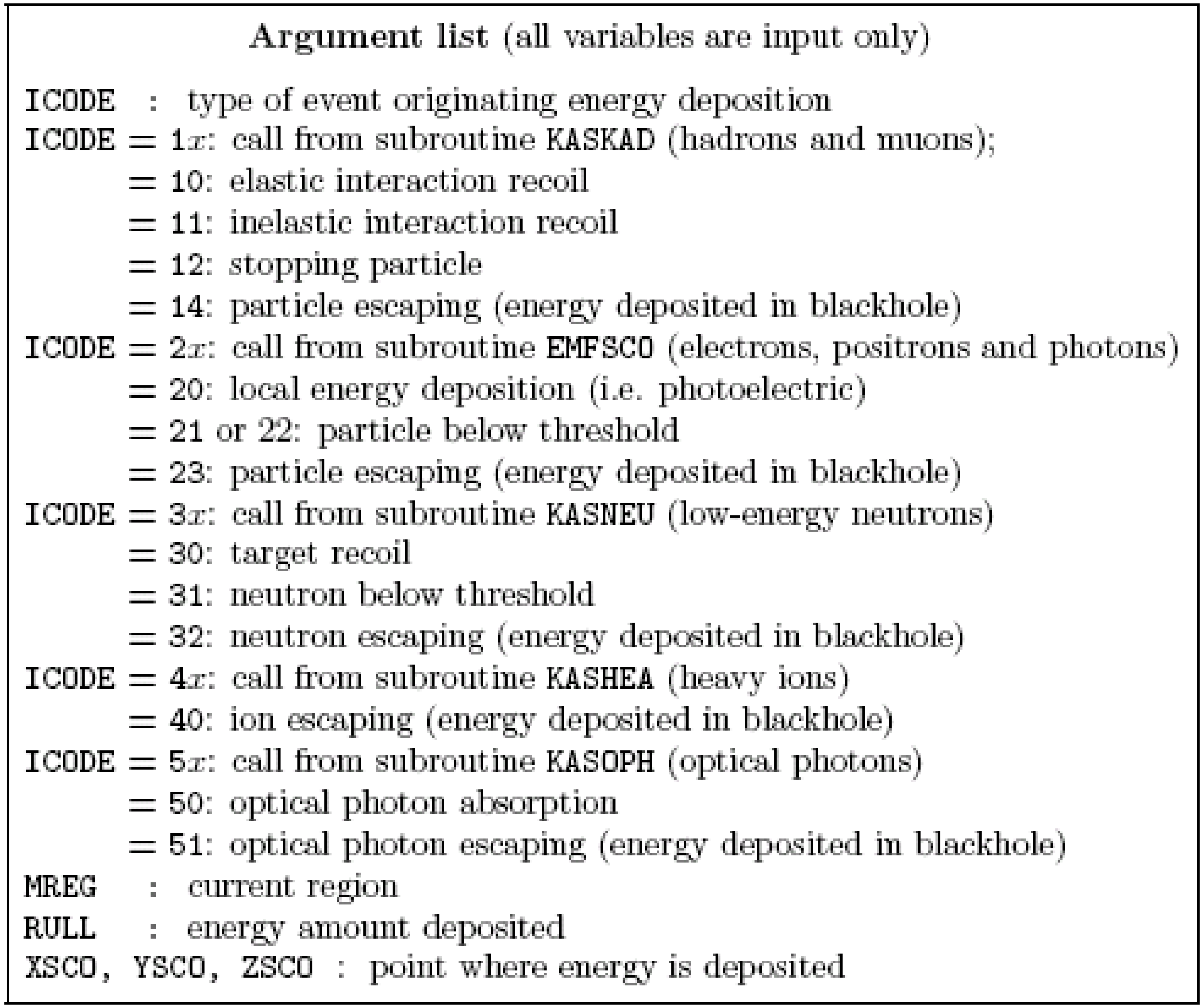
Argument list (all variables are input only)

`ICODE`	:	physical compartment originating the call, as in the `MGDRAW` entry

mgdraw: the ENDRAW entry

Called at pointlike Energy Deposition dumps

(for example: stopping particles, photoelectric eff., etc.)



Argument list (all variables are input only)

ICODE : type of event originating energy deposition

ICODE = $1x$: call from subroutine KASKAD (hadrons and muons);
- = 10: elastic interaction recoil
- = 11: inelastic interaction recoil
- = 12: stopping particle
- = 14: particle escaping (energy deposited in blackhole)

ICODE = $2x$: call from subroutine EMFSCO (electrons, positrons and photons)
- = 20: local energy deposition (i.e. photoelectric)
- = 21 or 22: particle below threshold
- = 23: particle escaping (energy deposited in blackhole)

ICODE = $3x$: call from subroutine KASNEU (low-energy neutrons)
- = 30: target recoil
- = 31: neutron below threshold
- = 32: neutron escaping (energy deposited in blackhole)

ICODE = $4x$: call from subroutine KASHEA (heavy ions)
- = 40: ion escaping (energy deposited in blackhole)

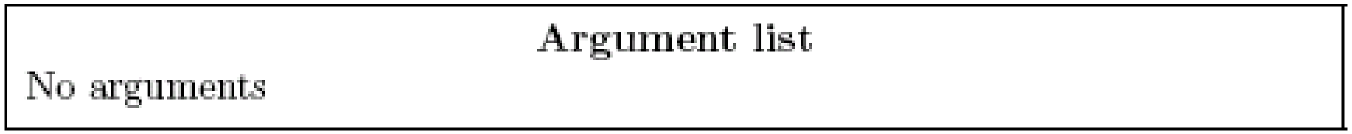
ICODE = $5x$: call from subroutine KASOPH (optical photons)
- = 50: optical photon absorption
- = 51: optical photon escaping (energy deposited in blackhole)

MREG : current region

RULL : energy amount deposited

XSCO, YSCO, ZSCO : point where energy is deposited

mgdraw: the SODRAW entry



Argument list
No arguments

SODRAW writes by default, for each source or beam particle:

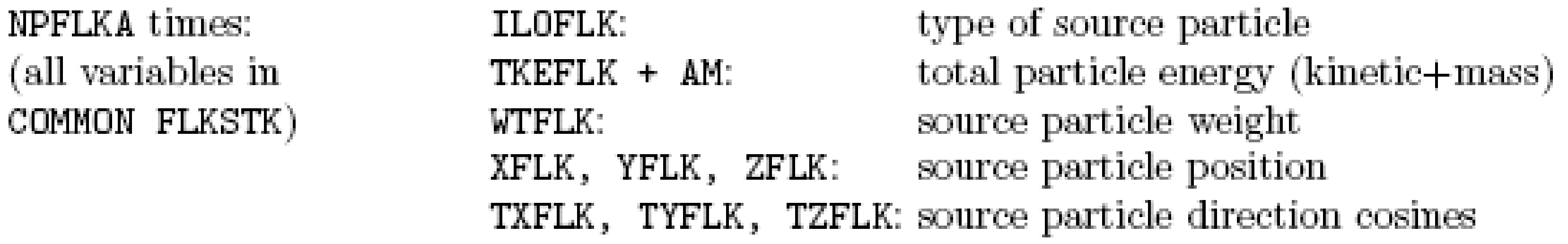
NCASE: **(in COMMON CASLIM, with a minus sign to identify SODRAW output) number of primaries followed so far**

NPFLKA: **(in COMMON FLKSTK) stack pointer**

NSTMAX: **(in COMMON FLKSTK) highest value of the stack pointer encountered so far**

TKESUM: **(in COMMON SOURCM) total kinetic energy of the primaries of a user written source, if applicable. Otherwise = 0.0**

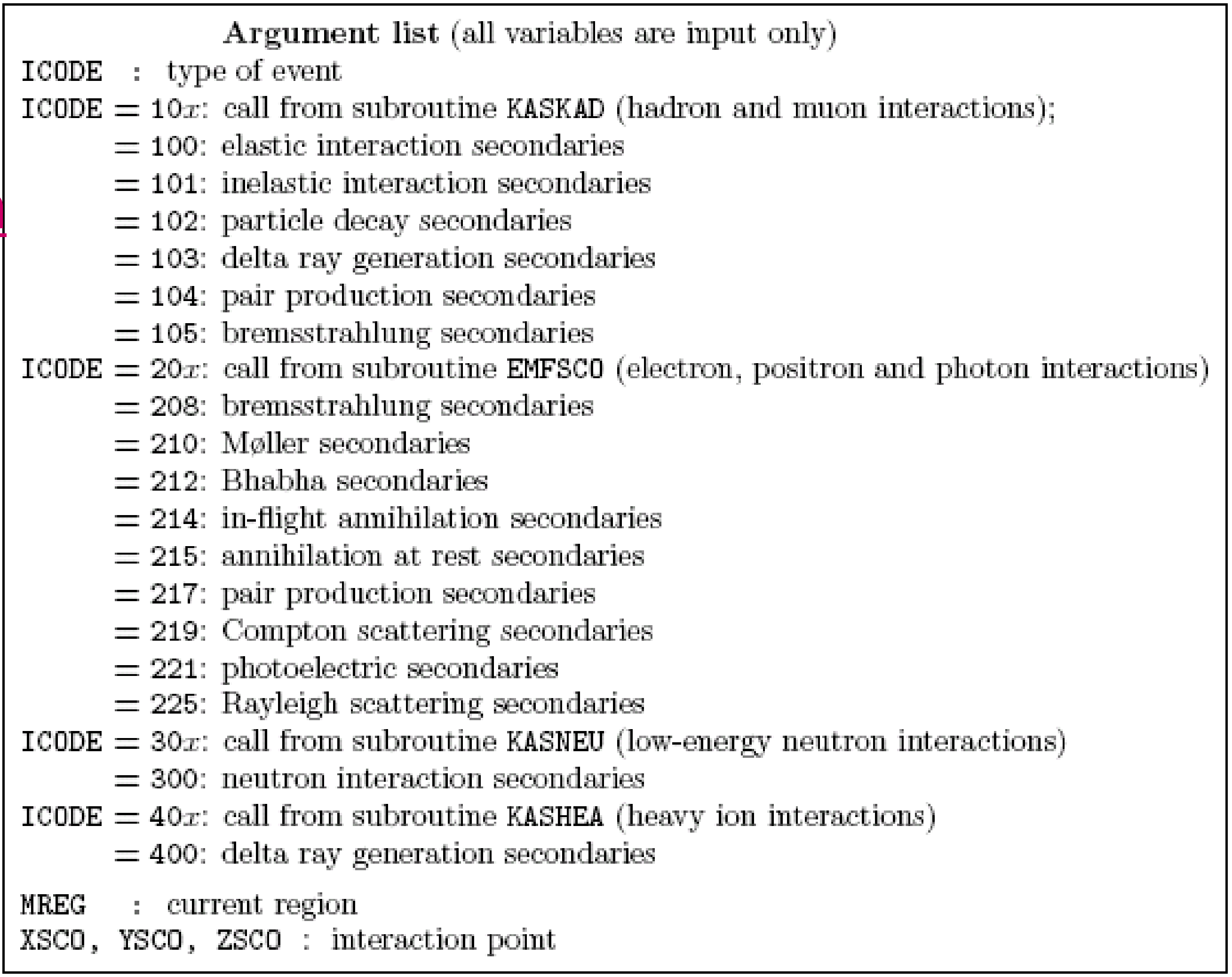
WEIPRI: **(in COMMON SUMCOU) total weight of the primaries handled so far**



NPFLKA times:	ILOFLK:	type of source particle
(all variables in	TKEFLK + AM:	total particle energy (kinetic+mass)
COMMON FLKSTK)	WTFLK:	source particle weight
	XFLK, YFLK, ZFLK:	source particle position
	TXFLK, TYFLK, TZFLK:	source particle direction cosines

mgdraw: the USDRAW entry

USDRAW is called after each particle interaction (requested by the user with option USERDUMP, WHAT(4)≥1.0)



Argument list (all variables are input only)

ICODE :	type of event
ICODE = 10x:	call from subroutine KASKAD (hadron and muon interactions);
= 100:	elastic interaction secondaries
= 101:	inelastic interaction secondaries
= 102:	particle decay secondaries
= 103:	delta ray generation secondaries
= 104:	pair production secondaries
= 105:	bremsstrahlung secondaries
ICODE = 20x:	call from subroutine EMFSCO (electron, positron and photon interactions)
= 208:	bremsstrahlung secondaries
= 210:	Møller secondaries
= 212:	Bhabha secondaries
= 214:	in-flight annihilation secondaries
= 215:	annihilation at rest secondaries
= 217:	pair production secondaries
= 219:	Compton scattering secondaries
= 221:	photoelectric secondaries
= 225:	Rayleigh scattering secondaries
ICODE = 30x:	call from subroutine KASNEU (low-energy neutron interactions)
= 300:	neutron interaction secondaries
ICODE = 40x:	call from subroutine KASHEA (heavy ion interactions)
= 400:	delta ray generation secondaries
MREG :	current region
XSCO, YSCO, ZSCO :	interaction point

When mgdraw should never be used

- When biasing is requested
- Whenever low-energy neutrons (E<20 MeV) are used

(or at least one has to be a real very experienced user to manage these cases without making mistakes...)

Converting Names↔Number regions in users routines

To get the number starting from a region name

```
CALL GEON2R ( REGNAM, NREG, IERR )
*     Input variable:
*        Regnam    = region name   (CHAR*8)
*
*     Output variables:
*        Nreg      = region number
*        Ierr      = error code (0 on success, 1 on failure)
```

To get the name of a region when you know the number:

```
CALL GEOR2N ( NREG, REGNAM, IERR )
*     Input variable:
*        Nreg    = region number
*
*     Output variables:
*        Regname  = region name  (CHAR*8)
*        Ierr      = error code (0 on success, 1 on failure)
```

Similar routines for lattice geometry