Your First Input and beyond

20th FLUKA Beginner's Course

Stellenbosch University

28 May – 01 June 2018

Before starting: FLUKA Manual

in *continuous* development (as the program)!

More a User Guide than a Reference Manual

(only a short summary about physics)

FM.pdf

update of the published CERN yellow report

ToC, cross-references, and citations are active links

analytical index at the end

ASCII

fluka2011.manual (no figures)

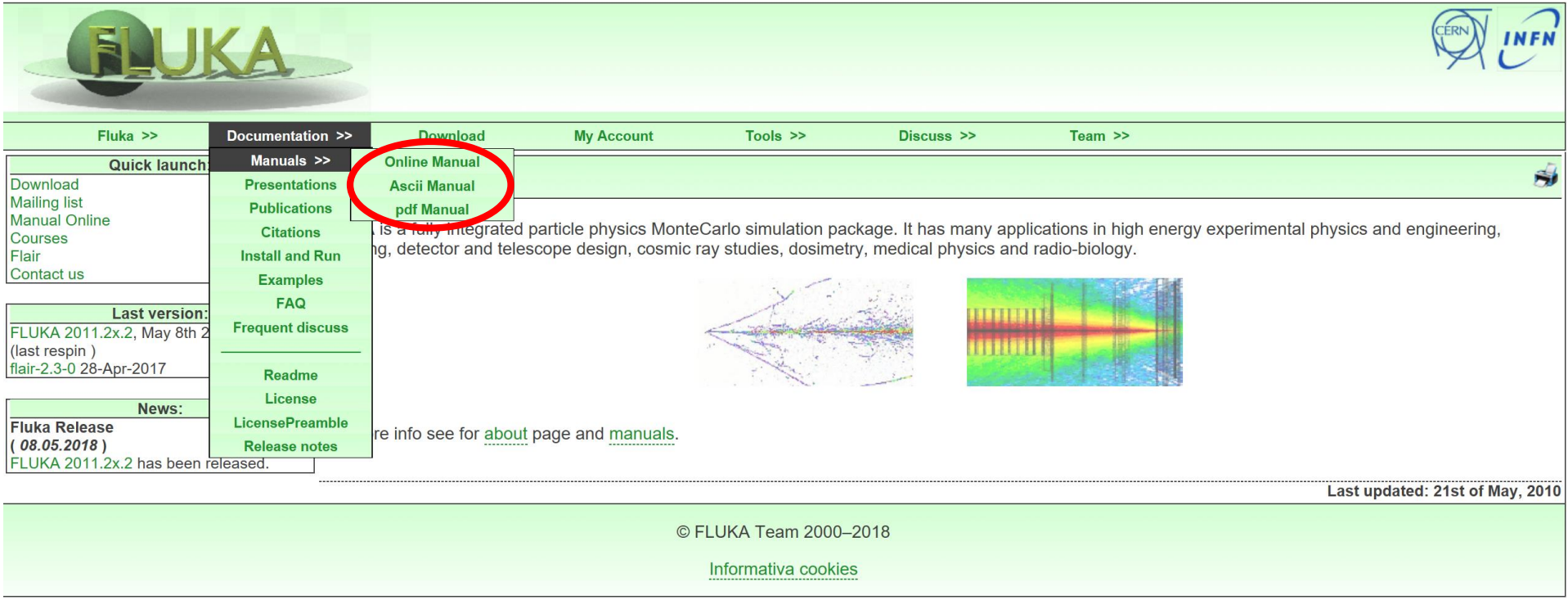
Tk interface accessible through FLAIR or

from command line **`/usr/local/bin/fm`**

(HTML version is available on FLUKA website)

Before starting: FLUKA Manual

FLUKA website at fluka.org



Before starting: FLUKA Manual

Short description of FLUKA

program and its capabilities, implemented physics models, installation...

User guide

- detailed description of input options
- available particles and materials
- combinatorial geometry
- low-energy neutrons library
- how to write/compile/link user routines
- ....and much more!

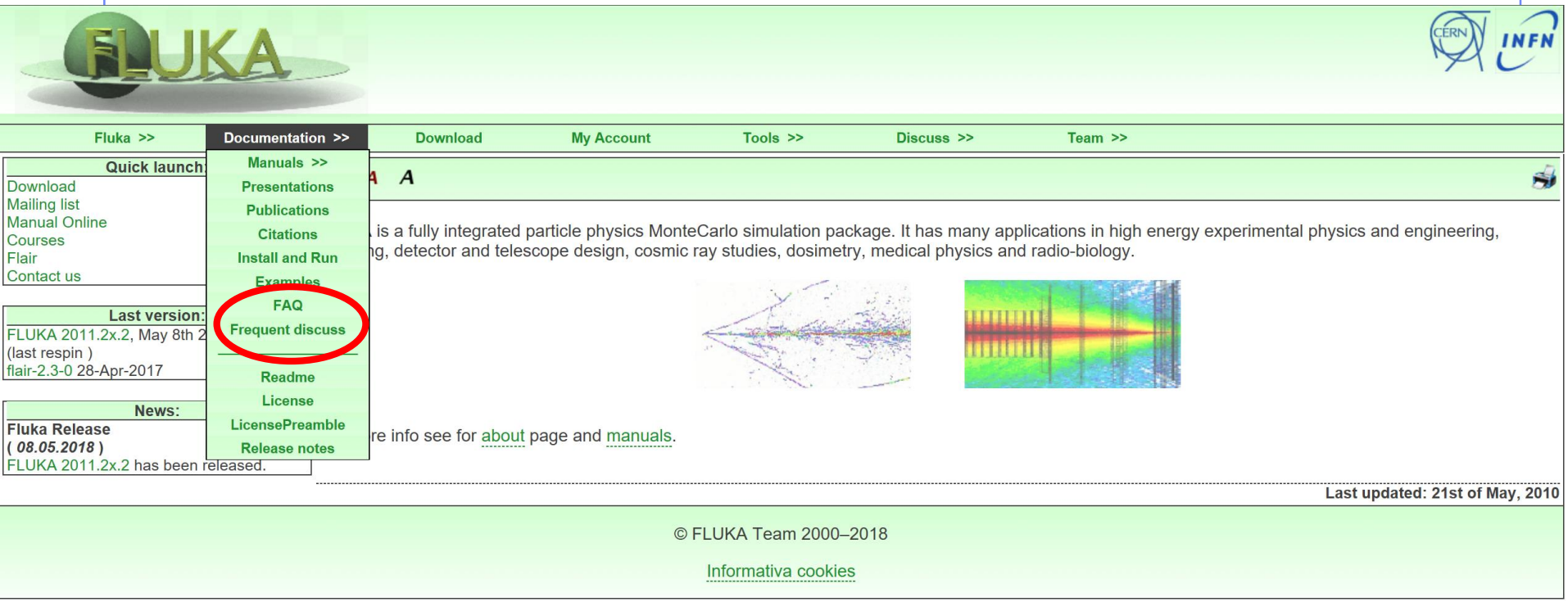
REMEMBER:

The first place to look at when puzzled

...and the very best friend of a beginner user!

Before starting: FLUKA FAQ

FLUKA FAQ and Frequent discuss



The second place to look at when puzzled!

REMEMBER:
send always your input file when ask questions in fluka-discuss

Structure of the input file

General definitions

Beam definition
Materials: definition and assignment
Random number initialization
Start/Stop of simulation

Physics settings

Defaults
Physical processes
Transport thresholds
Low energy neutrons
Induced radioactivity

Biasing

Geometry related biasing
Interaction/decay biasing

Geometry

Setup description
Voxel phantoms

Output settings

Estimators / scoring cards

FLUKA input file commands

Commands aka cards, aka options, aka directives, aka definitions

One keyword (command), 6 floating point numbers (WHATs), one string (SDUM)

Example of a FLUKA command (text editor style)

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+...
BEAM            1.E+04        0.0        0.0        0.0        0.0        0.0PROTON
*keyword     momentum mom.spread  diverg.    X-width    Y-width  ignored particle
*             WHAT(1)    WHAT(2)    WHAT(3)    WHAT(4)    WHAT(5)    WHAT(6)   SDUM
```

- Command keywords MUST be uppercase, numbers MUST have the decimal point
- Some commands require more than one "card"
- Some special commands (like `TITLE` and `OPEN`) are/may be followed by a text line
- With few exceptions, the order of commands is irrelevant
- Most commands can be repeated several times
- Repeated commands can add themselves or override previous commands
- A line with a * character in column 1 is a comment
- Text after an exclamation mark (!) is ignored (does not work within the geometry)
- Almost all the WHAT() have a default value
- Commands can be issued in fixed or free format
- Special commands, called #directives, allow input parametrization

Directives

- Definition of constants

  #define [identifier_name]

  #undef [identifier_name]

- Conditional directives

  #if

  #elif

  #else

  #endif

- Include directive

  #include [path/filename]

Fixed format

Fixed format:

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+...
BEAM            1.E+04    0.0D+00         0.0         0.0         0.0         0.0PROTON
*keyword     momentum mom.spread  diverg.    X-width    Y-width  ignored particle
*             WHAT(1)    WHAT(2)    WHAT(3)    WHAT(4)    WHAT(5)    WHAT(6)   SDUM
```

- The "traditional" FLUKA format is (A8, 2X, 6E10.0, A8)

  Numbers: 9 digits at most can be used
- All WHAT fields are in floating point format, *even integers*

  They must always be written with the decimal point
- Exponential notation numbers (e.g. 1.234E+5), must be right aligned
- Double precision format (e.g. 1.234D+5) is allowed
- Blank numerical fields are read as 0.0

  In most cases (*not all!*) such values are ignored and the corresponding default values are used
- Blank lines NOT ALLOWED in geometry declaration (tolerated elsewhere)

Fixed format - Examples

- Both lines are correct

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+...
BEAM           1.E+04        0.0         0.0         0.0         0.0        0.0PROTON
BEAM           1.E+04     0.0         0.0         0.0         0.0         0.0   PROTON
*keyword     momentum mom.spread  diverg.    X-width    Y-width  ignored particle
*             WHAT(1)    WHAT(2)    WHAT(3)    WHAT(4)    WHAT(5)    WHAT(6)   SDUM
```

- Incorrect: decimal point is missing

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+...
BEAM           1.E+04      1          0          0          0          0      PROTON
```

WHAT(2) would be interpreted as 1000!

- Incorrect: exponential number not correctly alligned

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+...
BEAM        1.E+04         0          0          0          0          0         PROTON
```

WHAT(1) might be interpreted as 1.E+4000!

Fixed vs free format [2/2]

Free format:

- Free format can be made *locally* available issuing option FREE (without any parameter), until the option FIXED restores the fixed format; the opposite can be done either
- Option GLOBAL provides free format also for the geometry input
- In free format input, the different fields are separated by blanks and/or separators (usually commas). *All fields must be present* or at least represented by two successive separators
- Character fields (command name, SDUM) must be input without quotes

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+...
BEAM , 1.234567890E+04 , 0.0 , 0.0 , 0.0 , 0.0 , 0.0 , PROTON
*
*keyword     momentum mom.spread  diverg.   X-width   Y-width   weight particle
*             WHAT(1)   WHAT(2)   WHAT(3)   WHAT(4)   WHAT(5)   WHAT(6)   SDUM
```

Temporarily switching to FREE format is particularly helpful when more than 10 digits are required for precision reasons !!!

Names instead of numbers

- FLUKA also allows the use of keywords (names) - 8 characters maximum length - instead of numbers inside FLUKA commands.
- Examples later (for instance materials, or geometrical region, can be inserted using their name instead of numbers)
- This *helps* the user, improving the *readability* of the input FLUKA file
- Internally, FLUKA works always by NUMBERS, and keeps name-to-number bidirectional tables/functions

A basic input

```
TITLE
My Basic Input example
* Set the defaults for precision simulations
DEFAULTS                                                              PRECISIO
* Define the beam characteristics
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAM             3.5 -0.082425      -1.7       0.0       0.0          PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS          0.0       0.0      -0.1       0.0       0.0
*
GEOBEGIN                                                              COMBNAME
    0    0
* Black body
SPH blkbody    0.0 0.0 0.0 100000.0
* Void sphere
SPH void       0.0 0.0 0.0 10000.0
* Cylindrical target
RCC target1    0.0 0.0  0.0 0.0 0.0 10.0 5.0
RCC target2    0.0 0.0 20.0 0.0 0.0 10.0 5.0
RCC target3    0.0 0.0 40.0 0.0 0.0 10.0 5.0
END
* Black hole
BLKBODY      5 +blkbody -void
* Void around
VOID         5 +void -target1 -target2 -target3
* Target
TARGET1      5 +target1
TARGET2      5 +target2
TARGET3      5 +target3
END
GEOEND
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL        24.0               7.18                               CHROMIUM
MATERIAL         0.0            0.73E-3                               AMMONIA
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
COMPOUND         1.0  NITROGEN       3.0  HYDROGEN                    AMMONIA
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
ASSIGNMA    BLCKHOLE   BLKBODY
ASSIGNMA      VACUUM      VOID
ASSIGNMA     AMMONIA   TARGET3
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..*
ASSIGNMA    CHROMIUM   TARGET1   TARGET2       1.0

* Set the random number seed
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
RANDOMIZ         1.0 54217137.
*
* Set the number of primary histories to be simulated in the run
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
START          1000.
STOP
```

A basic input card by card

A basic input: step 1: Physics settings

```
TITLE
My Basic Input example
* Set the defaults for precision simulations
DEFAULTS                                                              PRECISIO
* Define the beam characteristics
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAM             3.5 -0.082425      -1.7       0.0       0.0          PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS          0.0       0.0      -0.1       0.0       0.0
*
GEOBEGIN                                                              COMBNAME
    0    0
* Black body
SPH blkbody    0.0 0.0 0.0 100000.0
* Void sphere
SPH void       0.0 0.0 0.0 10000.0
* Cylindrical target
RCC target1    0.0 0.0  0.0 0.0 0.0 10.0 5.0
RCC target2    0.0 0.0 20.0 0.0 0.0 10.0 5.0
RCC target3    0.0 0.0 40.0 0.0 0.0 10.0 5.0
END
* Black hole
BLKBODY      5 +blkbody -void
* Void around
VOID         5 +void -target1 -target2 -target3
* Target
TARGET1      5 +target1
TARGET2      5 +target2
TARGET3      5 +target3
END
GEOEND
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL        24.0               7.18                               CHROMIUM
MATERIAL         0.0            0.73E-3                               AMMONIA
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
COMPOUND         1.0  NITROGEN      3.0  HYDROGEN                     AMMONIA
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
ASSIGNMA    BLCKHOLE   BLKBODY
ASSIGNMA      VACUUM      VOID
ASSIGNMA     AMMONIA   TARGET3
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..*
ASSIGNMA    CHROMIUM   TARGET1   TARGET2       1.0

* Set the random number seed
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
RANDOMIZ         1.0 54217137.
*
* Set the number of primary histories to be simulated in the run
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
START          1000.
STOP
```

Physics settings: DEFAULTS

Select predefined physics settings (e.g. transport thresholds) for a specific kind of simulation:

SDUM =

CALORIMEtry : calorimeter simulations
EET/TRANsmut : Energy Transformer or transmutation calculations
EM-CASCAde : pure EM cascades
HADROTHErapy : hadrotherapy calculations
ICARUS : studies related to the ICARUS experiment
NEUTRONS : pure low-energy neutron runs
NEW-DEFAults : minimal set of generic defaults – set by default
PRECISIOn : precision simulations (**recommended**)
SHIELDINg : hadron shielding calculations without gammas

Physics settings: DEFAULTS: PRECISIO

- EM transport on (**EMF** on), production/transport thresholds should always be set by the **EMFCUT!**
- Inelastic form factor correction to Compton scattering on (**EMFRAY** on)
- Detailed photoelectric edge treatment and fluorescence photons activated
- Low energy neutron transport on (**LOW-NEUT** on), threshold 20 MeV, with fully analogue absorption
- All transport threshold = 100keV, but neutrons (10^{-5} eV) and neutrinos (0, but they are discarded)
- Multiple Scattering threshold at minimum allowed energy, for both primary and secondary charged particles
- Delta rays production on, threshold 100keV (**DELTARAY**)
- Restricted ionization energy loss fluctuations for all particles (**IONFLUCT**)
- Tabulation ratio for hadron/muon dp/dx set at 1.04, fraction of the kinetic energy to be lost in a step set at 0.05, number of dp/dx tabulation points set at 80 (**DELTARAY, EMFFIX, FLUKAFIX**)
- e+e- pair production and bremsstrahlung by heavy particles on (**PAIRBREM**)

  Pair threshold =2 m_e , bremsstrahlung threshold = 300keV
- Muon photonuclear interactions on (**MUPHOTON**)

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+
DEFAULTS                                                          PRECISIO
```

A basic input: step 2: Beam

```
TITLE
My Basic Input example
* Set the defaults for precision simulations
DEFAULTS                                                              PRECISIO
* Define the beam characteristics
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAM             3.5 -0.082425      -1.7       0.0       0.0          PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS          0.0       0.0      -0.1       0.0       0.0
*
GEOBEGIN                                                              COMBNAME
    0    0
* Black body
SPH blkbody    0.0 0.0 0.0 100000.0
* Void sphere
SPH void       0.0 0.0 0.0 10000.0
* Cylindrical target
RCC target1    0.0 0.0  0.0 0.0 0.0 10.0 5.0
RCC target2    0.0 0.0 20.0 0.0 0.0 10.0 5.0
RCC target3    0.0 0.0 40.0 0.0 0.0 10.0 5.0
END
* Black hole
BLKBODY      5 +blkbody -void
* Void around
VOID         5 +void -target1 -target2 -target3
* Target
TARGET1      5 +target1
TARGET2      5 +target2
TARGET3      5 +target3
END
GEOEND
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL         24.0                7.18                             CHROMIUM
MATERIAL          0.0             0.73E-3                             AMMONIA
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
COMPOUND          1.0  NITROGEN       3.0  HYDROGEN                   AMMONIA
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
ASSIGNMA    BLCKHOLE   BLKBODY
ASSIGNMA      VACUUM      VOID
ASSIGNMA     AMMONIA   TARGET3
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..*
ASSIGNMA    CHROMIUM   TARGET1   TARGET2       1.0

* Set the random number seed
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
RANDOMIZ         1.0 54217137.
*
* Set the number of primary histories to be simulated in the run
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
START          1000.
STOP
```

A basic input: step 2: Beam

The card BEAM defines the particle type and energy (or momentum).

The card BEAMPOS controls particle starting position and direction.

For complex particle sources (complex distributions in energy, space and direction) a special user routine, SOURCE, can be used*. The card SOURCE has to be added in the input file.

*Some pre-defined cases (volume sources, cosmic ray source, uniform isotropic source etc are already built-in and available via data cards, see the manual)

Example: **BEAM**

Define beam characteristics:

type of particle, energy, divergence, spatial profile....

- [SDUM] proton beam
- [WHAT(1)] average beam momentum, 3.5 GeV/c
- [WHAT(2)] Gaussian momentum distribution, -0.082425 GeV/c FWHM
- [WHAT(3)] Gaussian angular distribution, -1.7 mrad FWHM
- [WHAT(4)] No beam width in X (point-like source)
- [WHAT(5)] No beam width in Y (point-like source)

```
BEAM              3.5 -0.082425      -1.7       0.0       0.0           PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS           0.0       0.0      -0.1       0.0       0.0
```

Example: **BEAMPOS**

Define beam position and direction:

- [WHAT(1)] x coordinate of the spot center, 0.0 cm
- [WHAT(2)] y coordinate of the spot center, 0.0 cm
- [WHAT(3)] z coordinate of the spot center, -0.1 cm
- [WHAT(4)] direction cosine of the beam wrt the x-axis, 0.0
- [WHAT(5)] direction cosine of the beam wrt the y-axis, 0.0
- [SDUM] blank, therefore beam towards positive Z

```
BEAM              3.5 -0.082425      -1.7       0.0       0.0           PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS           0.0       0.0      -0.1       0.0       0.0
```

A basic input: step 3: Geometry

```
TITLE
My Basic Input example
* Set the defaults for precision simulations
DEFAULTS                                                              PRECISIO
* Define the beam characteristics
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAM             3.5 -0.082425      -1.7       0.0       0.0          PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS          0.0       0.0      -0.1       0.0       0.0

GEOBEGIN                                                              COMBNAME
    0    0
* Black body
SPH blkbody    0.0 0.0 0.0 100000.0
* Void sphere
SPH void       0.0 0.0 0.0 10000.0
* Cylindrical target
RCC target1    0.0 0.0  0.0 0.0 0.0 10.0 5.0
RCC target2    0.0 0.0 20.0 0.0 0.0 10.0 5.0
RCC target3    0.0 0.0 40.0 0.0 0.0 10.0 5.0
END
* Black hole
BLKBODY      5 +blkbody -void
* Void around
VOID         5 +void -target1 -target2 -target3
* Target
TARGET1      5 +target1
TARGET2      5 +target2
TARGET3      5 +target3
END
GEOEND
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL         24.0               7.18                              CHROMIUM
MATERIAL          0.0             0.73E-3                             AMMONIA
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
```

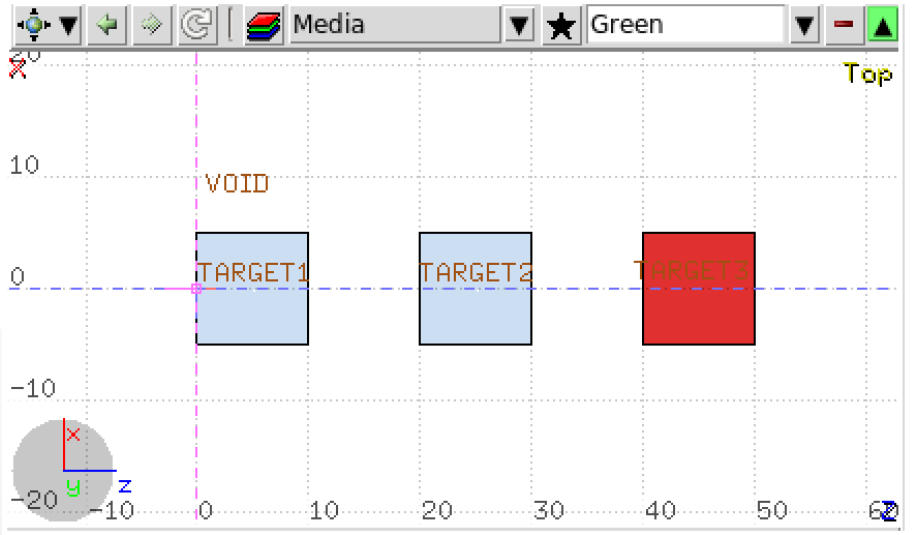
Three targets:
target1
target2
target3

Geometry definition: please, wait for the Geometry lecture on Tuesday morning, but notice the structure

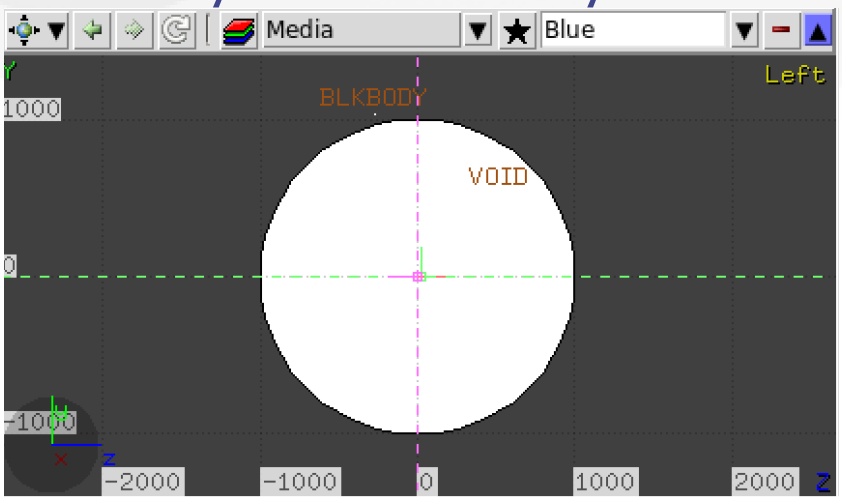
```
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..*
ASSIGNMA    CHROMIUM   TARGET1   TARGET2       1.0

* Set the random number seed
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
RANDOMIZ         1.0 54217137.
*
* Set the number of primary histories to be simulated in the run
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
START          1000.
STOP
```

A basic input: step 3: Geometry



The whole geometry must be surrounded by a region of "blackhole" limited by a closed body.



A basic input: step 3: Geometry

The **Combinatorial Geometry** in FLUKA must be preceded by a GEOBEGIN card and followed by a GEOEND card.

For details on the **Combinatorial Geometry** (bodies, regions and optional region volumes) please wait for the Geometry lecture on Tuesday morning.

A basic input: step 4: Materials

```
TITLE
My Basic Input example
* Set the defaults for precision simulations
DEFAULTS                                                              PRECISIO
* Define the beam characteristics
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAM             3.5 -0.082425      -1.7       0.0       0.0          PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS          0.0       0.0      -0.1       0.0       0.0
*
GEOBEGIN                                                              COMBNAME
    0    0
* Black body
SPH blkbody    0.0 0.0 0.0 100000.0
* Void sphere
SPH void       0.0 0.0 0.0 10000.0
* Cylindrical target
RCC target1    0.0 0.0  0.0 0.0 0.0 10.0 5.0
RCC target2    0.0 0.0 20.0 0.0 0.0 10.0 5.0
RCC target3    0.0 0.0 40.0 0.0 0.0 10.0 5.0
END
* Black hole
BLKBODY      5 +blkbody -void
* Void around
VOID         5 +void -target1 -target2 -target3
* Target
TARGET1      5 +target1
TARGET2      5 +target2
TARGET3      5 +target3
END
GEOEND
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL         24.0               7.18                              CHROMIUM
MATERIAL          0.0            0.73E-3                              AMMONIA
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
COMPOUND          1.0  NITROGEN       3.0  HYDROGEN                   AMMONIA
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
ASSIGNMA    BLCKHOLE   BLKBODY
ASSIGNMA      VACUUM      VOID
ASSIGNMA     AMMONIA   TARGET3
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..*
ASSIGNMA    CHROMIUM   TARGET1   TARGET2       1.0

* Set the random number seed
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
RANDOMIZ         1.0 54217137.
*
* Set the number of primary histories to be simulated in the run
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
START          1000.
STOP
```

Materials

FLUKA handles:

- elemental materials (by default natural composition, the user can set a specific isotope, being aware of low energy neutron cross sections availability)
- compounds (chemical molecules, alloys, mixtures…)

Each material is uniquely identified by an index/name

FLUKA has a set of predefined materials (see FLUKA manual)

Users can both use/modify these and define their own ones

Basic cards:

MATERIAL	material declaration
COMPOUND	compound definition (a **MATERIAL** card is mandatory for a compound declaration)
ASSIGNMA	material assignment to regions of geometry

Predefined materials

In FLUKA 2 special materials +23 natural elements of most common use, e.g. Oxygen, Carbon, Iron… (check them out in the manual, Chap. 5), are predefined

The first two are very important:

- **BLCKHOLE** (mat #1): material with infinite absorbance;
- **VACUUM** (mat #2)

12 compound materials with the composition suggested by ICRU are predefined as well (again, check the manual!)

All predefined materials can be used WITHOUT explicit **MATERIAL** / **COMPOUND** cards

WARNING: user defined **MATERIAL** cards OVERRIDE PREDEFINED materials having the same name

Example: **MATERIAL**

Defines a new material or override a previous one

- [SDUM] CHROMIUM, material name
- [WHAT(1)] 24.0, atomic number Z
- [WHAT(2)] atomic weight (**leave it empty**)
- [WHAT(3)] 7.18 g/cm^3, density
- [WHAT(4)] material number (**leave it empty**)
- [WHAT(5)] alternate material to be used for dE/dx (**normally empty**)
- [WHAT(6)] mass number A (**leave it empty unless you want a specific isotope**)

```
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL         24.0                 7.18                          CHROMIUM
```

Example: COMPOUND

Defines a new compound

Each **COMPOUND** card must be associated to a **MATERIAL** card

More **COMPOUND** card can be used to define a compound

- [SDUM] compound name
- [WHAT(1)] amount of the first component
- [WHAT(2)] first component material
- [WHAT(3)] amount of the second component
- [WHAT(4)] second component material
- [WHAT(5)] amount of the third component
- [WHAT(6)] third component material

atomic number **density (g/cm^3)**

```
MATERIAL          0.0                0.73E-3                              AMMONIA
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
COMPOUND             1.0  NITROGEN          3.0  HYDROGEN                  AMMONIA
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
```

Example: COMPOUND

Defines a new compound

Each **COMPOUND** card must be associated to a **MATERIAL** card

More **COMPOUND** card can be used to define a compound

- [SDUM] compound name
- [WHAT(1)] amount of the first component
- [WHAT(2)] first component material
- [WHAT(3)] amount of the second component
- [WHAT(4)] second component material
- [WHAT(5)] amount of the third component
- [WHAT(6)] third component material

How to define the "amount"?

content > 0	component material > 0	**ATOM content**
content < 0	component material > 0	**MASS content**
content < 0	component material < 0	**VOLUME content**

Names can be preceded by a minus sign!

Example: ASSIGNMA

Assign a material to one (or more) region in the geometry

(for the region definition see the geometry lecture or the manual)

A material must be associated to each of the geometry regions, except to those defined as blackhole.

The assigned material could be either a single element material or a compound

- [WHAT(1)] = material index, or material name
- [WHAT(2)] = first region to be "filled" with the material (Default = 2.0)
- [WHAT(3)] = last region to be "filled" with the material (Default = WHAT(2))
- [WHAT(4)] = step length in assigning indices
- [WHAT(5)] = to activate magnetic and electric fields (see manual)
- [WHAT(6)] = assign another material for radioactive decay products transport. As of now, only vacuum and blackhole are allowed.

```
ASSIGNMA    BLCKHOLE   BLKBODY
ASSIGNMA      VACUUM      VOID
ASSIGNMA     AMMONIA   TARGET3
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..*
ASSIGNMA    CHROMIUM   TARGET1   TARGET2       1.0
```

A basic input: step 5: Random Seed, **START**, and **STOP**

```
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAM             3.5 -0.082425      -1.7       0.0       0.0          PROTON
* Define the beam position
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAMPOS          0.0       0.0      -0.1       0.0       0.0
*
GEOBEGIN                                                              COMBNAME
    0    0
* Black body
SPH blkbody    0.0 0.0 0.0 100000.0
* Void sphere
SPH void       0.0 0.0 0.0 10000.0
* Cylindrical target
RCC target1    0.0 0.0  0.0 0.0 0.0 10.0 5.0
RCC target2    0.0 0.0 20.0 0.0 0.0 10.0 5.0
RCC target3    0.0 0.0 40.0 0.0 0.0 10.0 5.0
END
* Black hole
BLKBODY      5 +blkbody -void
* Void around
VOID         5 +void -target1 -target2 -target3
* Target
TARGET1      5 +target1
TARGET2      5 +target2
TARGET3      5 +target3
END
GEOEND
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
MATERIAL        24.0                7.18                              CHROMIUM
MATERIAL         0.0             0.73E-3                              AMMONIA
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
COMPOUND         1.0  NITROGEN       3.0  HYDROGEN                    AMMONIA
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
ASSIGNMA    BLCKHOLE   BLKBODY
ASSIGNMA      VACUUM      VOID
ASSIGNMA     AMMONIA   TARGET3
*
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..*
ASSIGNMA    CHROMIUM   TARGET1   TARGET2       1.0

* Set the random number seed
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
RANDOMIZ         1.0 54217137.
*
* Set the number of primary histories to be simulated in the run
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
START          1000.
STOP
```

Example: RANDOMIZ

The random number generator is initialized to read a vector of 97 seeds from an external file. Different numbers input will initialize different and independent random number sequences.

[WHAT(1)] : logical file unit from which to read the seeds. Must be 1.0!!
[WHAT(2)] : any number < 9.E8, initialization of the random seed sequences. Different WHAT(2) lead to different sequences allowing to run parallel jobs
[WHAT(3-6), SDUM] : not used

```
* Set the random number seed
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
RANDOMIZ         1.0 54217137.
```

Example: START AND STOP

A START card at the end of the input file is mandatory. It defines the number of particle histories required.
The START card is optionally followed by a STOP card, which stops the execution of the program.

[WHAT(1)] = maximum number of primary histories simulated in the run
[WHAT(2)] = not used
[WHAT(3-6), SDUM] = see manual

```
* Set the number of primary histories to be simulated in the run
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
START          1000.
STOP
```

Exercise: Basic Input

Run example_basicinput.inp:

$FLUPRO/flutil/rfluka –N0 –M4 example_basicinput

Look at the .out file with **less ex1001.out** or any text editor e.g. **emacs**, **vi**

(FLUKA mode available for emacs and vi on the web page http://www.fluka.org/fluka.php?id=tools&mm2=5)

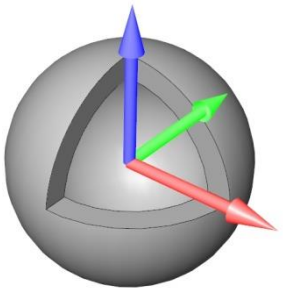
Extra:

- Change the type of primary particles from proton to neutrons
- Move the beam position in (0.0, 0.0, -10.0)
- Change the material CHROMIUM in WATER with density equal to 0.99669 g/cm^3
- Use the card MAT-PROP to set the ionization potential for WATER equal to 78 eV
- Change the number of primary particles from 1000 to 10000

Beyond a basic input

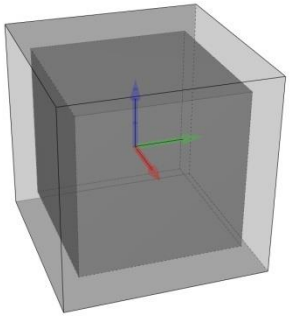
Special sources: 3D distributions

BEAMPOS card allows the user to define some 3D *spatial* distributions of source particles



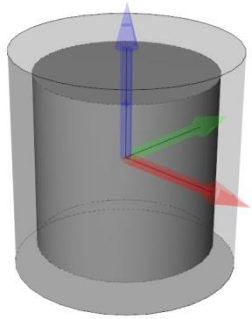
SDUM = SPHE-VOL:

defines a spatially extended source in a spherical shell



SDUM = CART-VOL:

defines a spatially extended source in a Cartesian shell with the sides parallel to the beam frame axes



SDUM = CYLI-VOL:

defines a spatially extended source in a cylindrical shell with the height parallel to the z-axis of the beam frame

SDUM = FLOOD:

defines a source distribution on a spherical surface, such as to produce a uniform and isotropic fluence within the sphere

Special sources: SPECSOUR

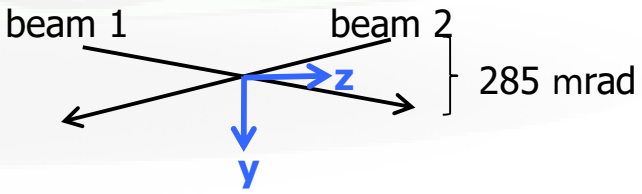
FLUKA allows the definitions of special sources for:

- two colliding beams
- galactic cosmic rays
- solar particles events

Various SDUM allow plenty of opportunities:

PPSOURCE, CROSSASY, CROSSSYM; GCR-IONF, GCR-SPEC, GCR-ALLF; SPE-SPEC, SPE-2003, SPE-2005

Example: LHC proton-proton collision
7 TeV/c, full crossing angle of 285 mrad in yz-plane



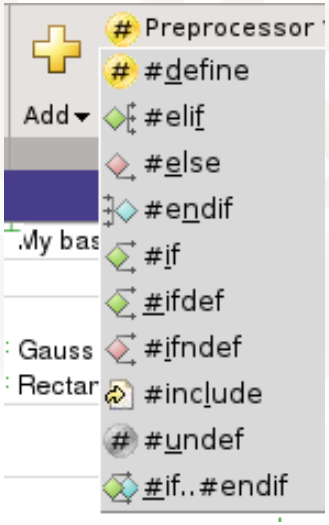
For all these special cases of source distributions, please, refer to the FLUKA manual!

FLUKA Preprocessor

- FLUKA supports preprocessing instructions like those used in C or C++
- This useful feature allows to keep different setups and configurations in a single input file, selecting the desired one when starting a run
- FLAIR supports this feature and allows to run different configurations in an easy way
- The **`#include`** directive can ease the handling of large input files

Conditional directives:

```
#define VARIABLE1
#undef VARIABLE2
#if VARIABLE1
#elif VARIABLE2
#else
#endif
```



Up to 10 nested levels of conditional statements (#if/#else/#endif) are supported

Include directive:

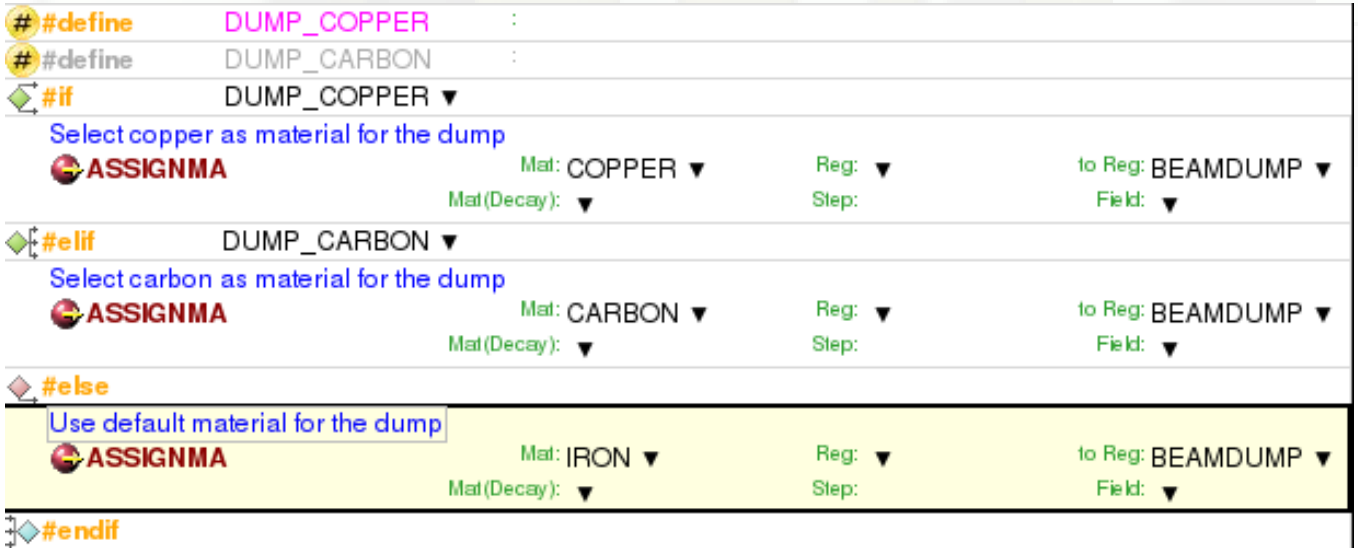
```
#include /home/geometries/target2.geom
```

FLUKA Preprocessor example

```
#define DUMP_COPPER
*#define DUMP_CARBON
*
#if DUMP_COPPER
* Select copper as material for the dump
*...+....1....+....2....+....3....+....4....+....5....+....6
ASSIGNMA      COPPER   BEAMDUMP
#elif DUMP_CARBON
* Select carbon as material for the dump
ASSIGNMA      CARBON   BEAMDUMP
#else
* Use default material for the dump
ASSIGNMA        IRON   BEAMDUMP
#endif
```

#define can be either commented out or undefined e.g.: **#undef DUMP_COPPER**

Depending on the active define (**DUMP_COPPER** or **DUMP_CARBON**) different **ASSIGNMA** card are used



Spare

More Physics settings

Input card **PHYSICS**

Allows to override standard FLUKA defaults for some processes:

- activates coalescence (critical for calculation of residual nuclei)
- activates the new fragmentation model ("evaporation" of fragments up to A=24, critical for calculation of residual nuclei)
- activates PEANUT above 5 GeV
- activates electromagnetic dissociation of heavy ions
- activates charmed particle transport

Input card **PHOTONUC**

- activates photo-nuclear interactions
- activates muon pair production by photons

The use of the **LAM-BIAS** card (see Biasing lecture) coupled to the **PHOTONUC** card is recommended, in order to artificially *increase* the probability to have photonuclear reactions

Transport thresholds

Input card **PART-THR**

- Defines transport cut-offs for hadrons, muons, and neutrinos
- Setting done by particle type, overriding the selected **DEFAULTS**
- For **neutrons**, a <20.0 MeV cut-off is internally translated into the corresponding group energy; On a region basis, the neutron cut-off can be *increased* by the **LOW-BIAS** card (see Neutrons lecture)
- Charged particles (but electrons) are not stopped, but ranged out to rest in an approximate way (if the threshold is < 100 MeV)

Input card **EMFCUT**

For electron, positron, and photon, sets:

- Energy thresholds for production in the selected materials
- Transport cut-offs in the selected regions.
- Use **STRONGLY** recommended

Input card **DELTARAY**

- Activates delta ray production by muons and charged hadrons
- Sets energy threshold for their production

Low energy neutrons (E < 20.0 MeV)

FLUKA transports neutrons with energies lower than 20 MeV by means of a multi-group algorithm, based on 260 groups (See Neutrons lecture)

Input card **LOW-NEUT**

- Activates low-energy neutron transport
  (by default off only in EM-CASCA)
- Requests point-wise cross sections
  (only available for a few elements, see manual)

Input card **LOW-MAT**

- Sets the correspondence between FLUKA materials and low-energy neutron cross-sections
- By default, the link is between the FLUKA material and the first material of the same name present in the library. Therefore, the option is not needed in many cases

Heavy ions: beams and transport

Input card **HI-PROPE**

- When **BEAM**'s SDUM is **ISOTOPE**…

  …specifies the isotope of a radioactive source

  …requires a **RADDECAY** card

- When **BEAM**'s SDUM is **HEAVYION**…

  …specifies the properties of an ion beam:

  in the **BEAM** card, the beam energy is given in GeV/nmu

  (**n**uclear **m**ass **u**nit, i.e. 1/12 of the ^{12}C nucleus mass)

  ^{2}H, ^{3}H, ^{3}He, and ^{4}He beams have dedicated SDUM in the **BEAM** card

Heavy ions: beams and transport

Input card **IONTRANS**

- Is not required when using an heavy ion beam **HEAVYION**
- Activates the ions transport
- Allows to limit it to a subset of light ions (A < 5)
- Switches between approximate and full transport

  …(including nuclear interactions)
- Nucleus-nucleus interactions above 125 MeV/n

  …can be performed only if the event generators

  DPMJET and RQMD are linked to the FLUKA executable
- Below 125 MeV/n…

  …the BME event generator is already linked in the standard executable

Materials special cards

Input card **MAT-PROP**

Allows to provide extra information about materials
(e.g.: gas pressure, effective density, average ionization potential)

Input card **CORRFACT**

Allows to change material density for dE/dx and nuclear processes
on a region-by-region basis
(used in connection with voxel geometries derived from a CT scan)

Induced radioactivity

Input card **RADDECAY**

- Activates the simulation of the decay of generated radioactive nuclides
- Allows to set biasing for radioactive decay products

Input card **IRRPROFI**

- Defines an irradiation profile (i.e. irradiation time and intensity)

Input card **DCYTIMES**

- Defines the decay (cooling) time

Input card **DCYSCORE**

- Associates scoring detectors (radio-nuclides, fluence, dose) with different cooling times