FLUKA

蘭州大學
LANZHOU UNIVERSITY

Your First Input and Beyond

23rd FLUKA Beginner's Course
Lanzhou University
Lanzhou, China
June 2-7, 2024

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/INFN/SLAC yellow report

ToC, cross-references, and citations are active links

analytical index at the end

ASCII

fluka2024.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 www.fluka.org

Fluka >> | Documentation >> | Download | My Account | Tools >> | Discuss >> | Team >>

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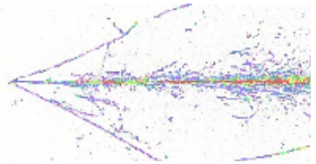
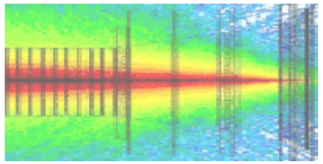
Last version:
FLUKA 2011.2x.2, May 8th 2
(last respin)
flair-2.3-0 28-Apr-2017

News:
Fluka Release
(*08.05.2018*)
FLUKA 2011.2x.2 has been released.

is a fully integrated particle physics MonteCarlo simulation package. It has many applications in high energy experimental physics and engineering,
ng, detector and telescope design, cosmic ray studies, dosimetry, medical physics and radio-biology.





re info see for about page and manuals.

Last updated: 21st of May, 2010

Before starting: FLUKA Manual

Short description of FLUKA

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

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!

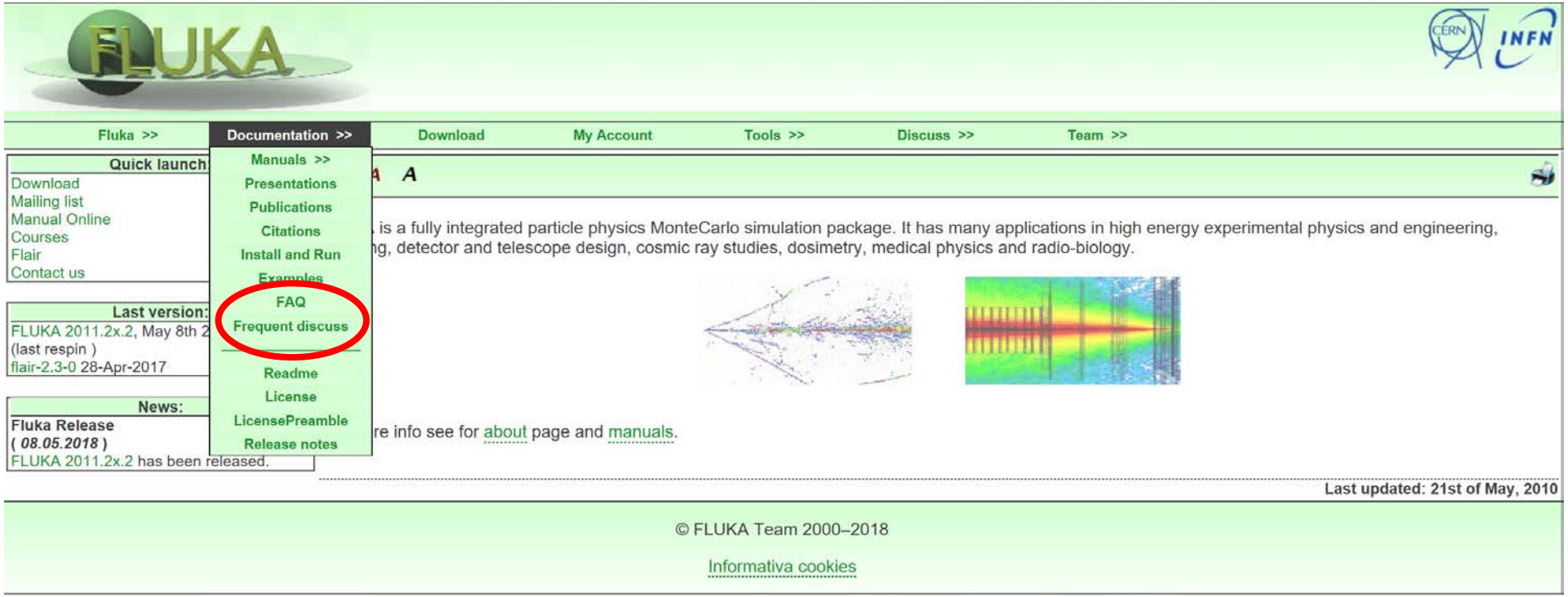
REMEMBER:

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!



Write at : **fluka-discuss@fluka.org**

REMEMBER: send always your input file together with your question to 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

Card:

One keyword (command)

6 WHATs : floating points numbers or names == parameters of the command

one SDUM: string == parameter or qualifier of the command

Example of a FLUKA command (fixed format):

Ruler:helps formatting, it is commented and of course optional

```
*...+....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
```

* In first column: Comment, ignored by FLUKA

FLUKA input file commands

- 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

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): **one WHAT/SDUM every 10 columns**

  Numbers: 9 digits at most can be used

- All WHAT fields are in floating point format, *even integers*. Or, they can be NAMES

  Numbers 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: numbers inside the 10 columns fields

```
*...+....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
```

- 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 aligned

```
*...+....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

Free format: no need to stay in the 10-columns fields!

- Free format can be made *locally* available using option FREE (without any parameter), until the option FIXED restores the fixed format; the opposite can be done either
- Option GLOBAL provides free format for input and/or for the geometry
- 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

Prepare the working space

Remember, don’t run inside the $FLUPRO directory.

Instead, go to your home directory and create a subdirectory named example_basicinput:

mkdir example_basicinput
cd example_basicinput

From the USB pen drive copy (cp) the source example file Exercises/example_basicinput/basicinput.inp .
(you can do it with drag and drop if you are more at ease with it and have a windows-like interface)

Open the FLUKA input file with your preferred editor program (emacs, vim, kwrite, gedit, nedit …).

Prepare the working space, notes for WSL users

Notes for WSL users:
You can choose to work

- In the linux home directory (the one that opens when you open a WSL window) : new directories with the *mkdir* command
- In your standard documents folder, using windows explorer to create subfolders

- From the WSL command prompt, the Windows folders are visible under the /mnt path:
  /mnt/c/Users/*yourusername*/Documents
  /mnt/d (or other letter) : additional/external disks
- From an Explorer window, the WSL home can be reached by typing in the address bar
  - \\wls$\Ubuntu\home

In wsl you can install a friendly editor such as nedit with (needs network!!!)
sudo apt install nedit
Or: from a windows explorer menu, open the file with notepad

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.f, 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....

- [WHAT(1)] = 3.5 GeV/c (average beam momentum)
- [WHAT(2)] = -0.082425 GeV/c FWHM (Gaussian momentum distribution,)
- [WHAT(3)] = -1.7 mrad FWHM (Gaussian angular distribution,)
- [WHAT(4)] = 0.0 (X width) → point-like source
- [WHAT(5)] = 0.0 (X width) → point-like source
- [WHAT(6)] = ignored
- [SDUM] = proton (particle beam)

```
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)] = 0.0 cm (x coordinate of the spot center)
- [WHAT(2)] = 0.0 cm (y coordinate of the spot center)
- [WHAT(3)] = -0.1 cm (z coordinate of the spot center)
- [WHAT(4)] = 0.0 (direction cosine of the beam wrt the x-axis)
- [WHAT(5)] = 0.0 (direction cosine of the beam wrt the y-axis)
- [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
```

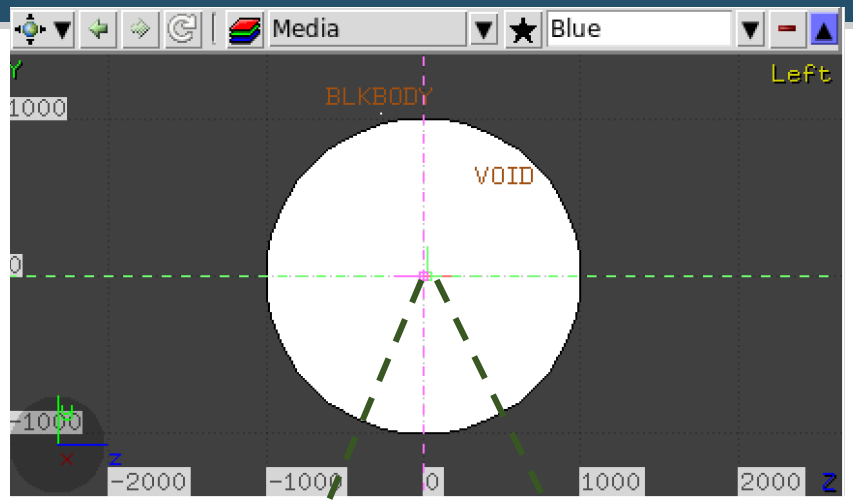
A basic input, step 3: Geometry


```
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..
* ..+....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
```

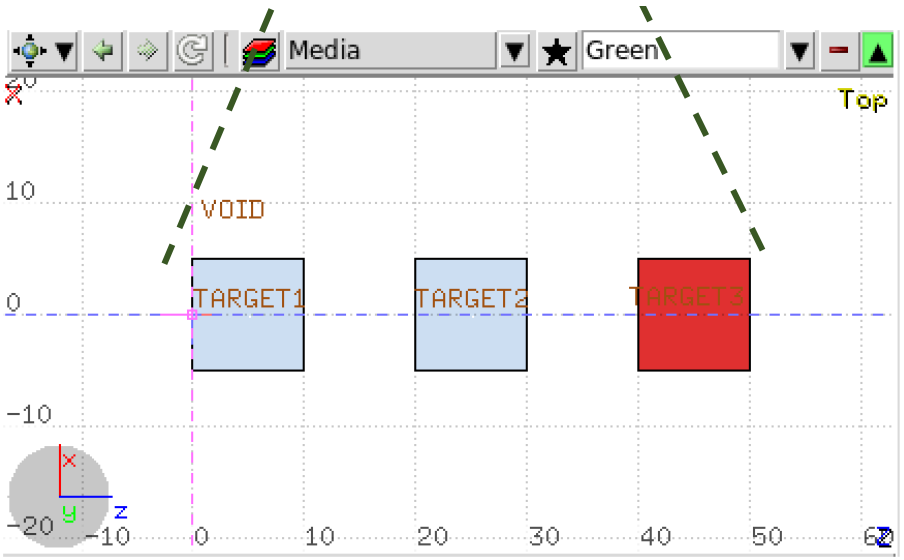
Three targets:
target1
target2
target3

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

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 are predefined, e.g. Carbon, Oxygen, Iron… (check them out in the manual, Chap. 5).

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, e.g. water, PMMA… (see 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 overrides a previous one

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

```
* ..+....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** cards 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: 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

AMMONIA = NH_3

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: 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.

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

Note on loops in cards

Some of the cards (like ASSIGNMAT) accept “loops” in input:
The same quantity/quality can be assigned to several objects, as in a for loop:
“all regions from TARGET1 to TARGET2 are filled with CHROMIUM”

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

- The from, to, increment (step) loop works on the internal numbering
  - Means that the names in the input card are first translated into numbers
  - Assign chromium to all regions between region number 3 and region number 4 in steps of one
- For regions: numbering follows their order in the geometry definition. Conversion can be found in the output file. Be careful if geometry is edited
- For particles: numbering is in the FLUKA manual (particles codes)
- For materials: The numbering in the FLUKA manual for predefined, then as they appear in the input file.
- For estimators: order in input file
- ➔ most useful for contiguous objects not subject to change position in the input
- Or for a whole category, using the special names @LASTMAT or @LASTREG or @LASTPAR as end of the loop

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


```
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
```

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. In the terminal type:

$FLUPRO/flutil/rfluka –N0 –M4 basicinput

Look at the .out file with **less basicinput001.out** or any text editor e.g. **emacs**, **vi, nedit…**

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

The FLUKA Output Files

The FLUKA output consists of:

- A main (standard) output, written on logical output unit LUNOUT (predefined as 11 by default) [*.out]
- A file with the last random number seeds, unit LUNRAN (2 by default) [ran*]
- A file of error messages, unit LUNERR (15 by default) [.err]

- Any number (including zero) of estimator output files. Their logical unit number is defined by the user [*_fort.xx] (see scoring lecture)
- The available range of logical output numbers is: 21-99
- Possible additional output generated by the user in any user routine

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

Definition of constants:

#define VARIABLE1

or #define VARIABLE1 Value

#undef VARIABLE1

One can refer to VARIABLE1 inside the input file (geometry included) using $VARIABLE1

```
#define Ekbeam    100.0
#define Beampart PROTON
...
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....8
BEAM         -$Ekbeam                                              $BeamPart
...
```

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
- The **`#include`** directive can ease the handling of large input files

Definition of constants:

#define VARIABLE1

or #define VARIABLE1 Value

#undef VARIABLE1

One can refer to VARIABLE1 inside the input file (geometry included) using $[VARIABLE1]

Include directive:

#include /home/geometries/target2.geom

Conditional directives

#if VARIABLE1

#elif VARIABLE2

#else

#endif

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

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
```

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

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

Extra Exercise: Basic Input

Lunchtime optional extra, if you are not hungry..:

- Change the type of primary particles from proton to neutrons
- Move the beam position in (0.0, 0.0, -10.0) cm
- Change the material CHROMIUM in WATER (it's pre-defined!!)
- Change the number of primary particles from 1000. to 10000.

Run your input file and see how the .out file has changed.

SPARE, FOR YOUR REFERENCE

Beyond a basic input

Special sources: 3D distributions

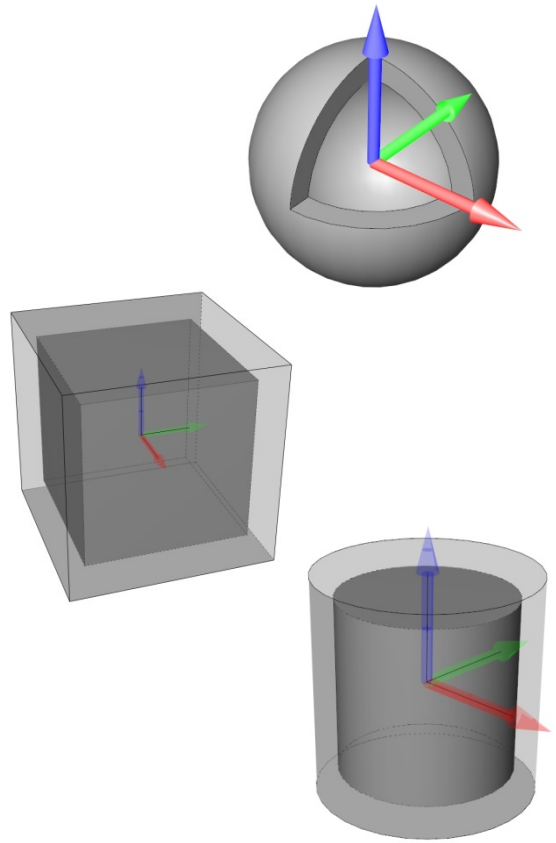
BEAMPOS card allows the user to define some 3D *spatial* distributions of source particles

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 beams

BEAM card allows the user to define some special “beams”:

SDUM = AMBE or **AMB** or **252CF**

select neutron spectra according to an Americium-Beryllium, Americium-Boron, and Californium-252 source respectively.

SDUM = D-D or D-T

select neutron spectra according to a deuterium-deuterium, and deuterium-tritium thick source respectively..

BEAM card can need additional information

SDUM = ISOTOPE or HEAVYION

select radioactive isotope or Heavy ion, need definition of the ion A/Z/Isomer (see lectures/manual).

Special sources: SPECSOUR

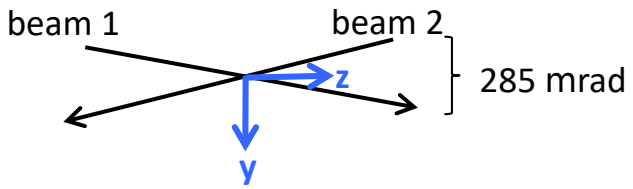
FLUKA allows the definitions of special sources for:

- 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!

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)

See lecture on FLUKA Medical applications

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 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

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