The FLUKA Code

An Introduction to FLUKA:
a Multipurpose Interaction and Transport MC code

OMA School on Monte Carlo simulations
Ludwig Maximilian University of Munich
6-10 November 2017

FLUKA

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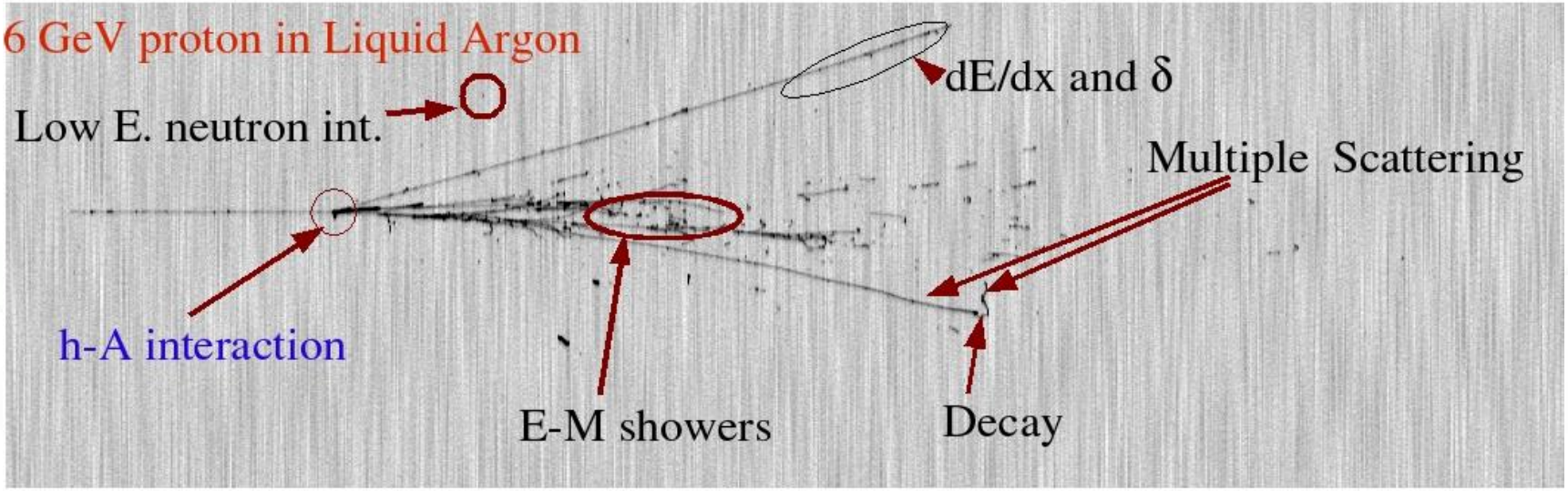

Developed and maintained under an INFN-CERN agreement

>8000 users

http://www.fluka.org

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The History

The early days

The beginning:

1962: Johannes Ranft (Leipzig) and Hans Geibel (CERN): Monte Carlo for high-energy proton beams

The name:

1970: study of event-by-event fluctuations in a NaI calorimeter (FLUktuierende KAskade)

Early 70's to ≈1987: J. Ranft and coworkers (Leipzig University) with contributions from Helsinki University of Technology (J. Routti, P. Aarnio) and CERN (G.R. Stevenson, A. Fassò)

Link with EGS4 in 1986, later abandoned

The modern code: some dates

Since 1989: mostly INFN Milan (A. Ferrari, P.R. Sala): little or no remnants of older versions. Link with the past: J. Ranft and A. Fassò

1990: LAHET / MCNPX: high-energy hadronic FLUKA generator *No further update*

1993: G-FLUKA (the FLUKA hadronic package in GEANT3). *No further update*

1998: FLUGG, interface to GEANT4 geometry

2000: grant from NASA to develop heavy ion interactions and transport

2001: the INFN FLUKA Project

2003: official CERN-INFN collaboration to develop, maintain and distribute FLUKA

The FLUKA Code design - 1

- Sound and updated physics models
  - Based, as far as possible, on original and well-tested microscopic models
  - Optimized by comparing with experimental data at single interaction level: ***"theory driven, benchmarked with data"***
  - Final predictions obtained with minimal free parameters fixed for all energies, targets and projectiles
  - Basic conservation laws fulfilled "a priori"

    ➔ ***Results in complex cases, as well as properties and scaling laws***, arise naturally from the underlying physical models

    ➔ ***Predictivity where no experimental data are directly available***

It is a "condensed history" MC code, however with the possibility to use single instead of multiple scattering

The FLUKA Code design - 2

- Self-consistency
  - Full cross-talk between all components: hadronic, electromagnetic, neutrons, muons, heavy ions
  - Effort to achieve the same level of accuracy:
    - for each component
    - for all energies
  - ➔ Correlations fully preserved within interactions and among shower components
  - ➔ ***FLUKA is NOT a toolkit! Its physical models are fully integrated***

The Physics Content of FLUKA

- **60 different particles + Heavy Ions**
- Nucleus-nucleus interactions from Coulomb barrier up to 10000 TeV/n
- Electron and μ interactions 1 keV – 10000 TeV
- Photon interactions 100 eV - 10000 TeV
- Hadron-hadron and hadron-nucleus interactions 0–10000 TeV
- Neutrino interactions
- Charged particle transport including all relevant processes
- Transport in magnetic fields
- Neutron multigroup transport and interactions 0 – 20 MeV
- Analog calculations, or with variance reduction

The FLUKA course: an Introduction

How:

This course is intended to provide students with the basic knowledge of:

a) The most relevant FLUKA instructions and options
b) The basic principle of combinatorial geometry in FLUKA
c) The physics models adopted in FLUKA
d) The different scoring options embedded in FLUKA
e) The different running options
f) The tools to plot results
g) The right approach to the existing documentation
h) etc. etc.

Practical exercises:

particle accelerators, dose scoring

Method

- There will be 10 hours of formal lectures + 4 hours of practical (simple examples) on Thursday afternoon.
- This course is addressed to beginners.
- If possible we shall try to transform your questions into cases of general interest.

Agenda

	6 Nov	7 Nov	8 Nov	9 Nov	10 Nov
8:30 - 9:00	General introduction (A. Ferrari)	Penelope models (low-energy elctromagnetic) (J.M. Fernández-Varea)	Geometry in FLUKA (E. Skordis)	Heavy ion beams and radioactivity in FLUKA (A. Mairani)	Geant4 for space and medicine (G. Dedes)
9:00 - 9:30	Principles of Monte Carlo calculations and codes (F.Salvat)				
9:30 - 10:00		Electron accelerator modeling with Penelope + Tutor (L. Brualla)	FLUKA models (A. Ferrari)	Monte Carlo treatment planning in FLUKA (A. Mairani)	
10:00 - 10:30					
10:30 - 11:00	coffee break		coffee break	coffee break	coffee break
11:00 - 11:30	Introduction to Geant4 (G. Dedes)	Transfer to Munich + lunch	Ionization and transport in FLUKA (F. Salvat-Pujol)	Scoring in FLUKA (A. Mairani)	Outlook in Penelope (F. Salvat-Pujol)
11:30 - 12:00					
12:00 - 12:30				Transfer to Munich + lunch	
12:30 - 13:00	lunch		lunch		lunch
13:00 - 13:30		Exercises with Penelope			
13:30 - 14:00					
14:00 - 14:30	Structure and operation of PENELOPE (F. Salvat)		Accelerators in FLUKA (E. Skordis)	Exercises with FLUKA	Outlook in GeantV (A. Gheata)
14:30 - 15:00					
15:00 - 15:30	Introduction to FLUKA (A. Ferrari)		Social activity		GeantV: machine learning techniques (S. Vallecorsa)
15:30 - 16:00		Exercises with Geant4			
16:00 - 16:30	coffee break			coffee break	coffee break
16:30 - 17:00	Introduction to Flair (E. Skordis)	Poster session		Exercises: medical applications with FLUKA	Outlook in FLUKA (A. Ferrari)
17:00 - 17:30					
17:30 - 18:00	Geometry in Penelope (F. Salvat)				Closing remarks
18:00 - 18:30					

A glimpse of FLUKA

The FLUKA version

FLUKA20xx.n(y)(.m)

Major version

Minor version

Patch level

Respin

Since 2006 each version is going to be maintained for 2 years max.

In this course we are using FLUKA2011.2c.6

The FLUKA license (it is not GPL):

- Standard download: **binary library + user routines**.
  - FLUKA can be used freely for scientific and academic purposes, ad-hoc agreement for commercial purposes
  - It cannot be used for weapon related applications
  - It is not permitted to redistribute the code (single user, single site)
  - Users can add their own scoring, sources, etc. through a wide set of user routines, provided they do not modify the physics
  - Relevant references for each FLUKA version can be found in the documentation
- It is possible, by explicit signing of license, to download the **source** for researchers of scientific/academic Institutions.
  - FLUKA can neither be copied into other codes (not even partially), nor translated into another language without permission.
  - The user cannot publish results with modified code, unless explicit authorization is granted in advance.
- For **commercial use**, trial version (limited in time and random seeds) available. Commercial license to be negotiated.

Using FLUKA

Platform: Linux with **g77** (in 32bit mode)
and **gfortran** (on 64bit machines)

Work in progress: Mac OSX with gfortran

The code may be compiled/run only using operating systems, compilers (and associated) options tested and approved by the development team

Standard Input:

- Command/options driven by "data cards" (ascii file) .
  Graphical interface is available
- Standard Geometry ("Combinatorial geometry"): input by "data cards"

Standard Output and Scoring:

- Apparently limited but highly flexible and powerful
- Output processing and plotting interface available

The FLUKA mailing lists

- fluka-users@fluka.org

  Users are automatically subscribed here when registering on the web site. It is used to communicate the availability of new versions, patches, etc.

- fluka-discuss@fluka.org

  Users are encouraged to subscribe at registration time, but can uncheck the relevant box. It is used to have user-user and user-expert communication about problems, bugs, general inquiries about the code and its physics content

users are strongly encouraged to keep this subscription

Disclaimer

- A good FLUKA user is **not** one that **only** masters technically the program
- BUT a user that:
  - Indeed masters technically the code;
  - Know its limitations and capabilities;
  - Can tune the simulation to the specific requirements and needs of the problem under study;

  but most of all
  - Has a critical judgment on the results
- Therefore in this course we will equally focus on:
  - The technical aspects of the code
    [building your input, geometry, scoring, biasing, extracting results…]

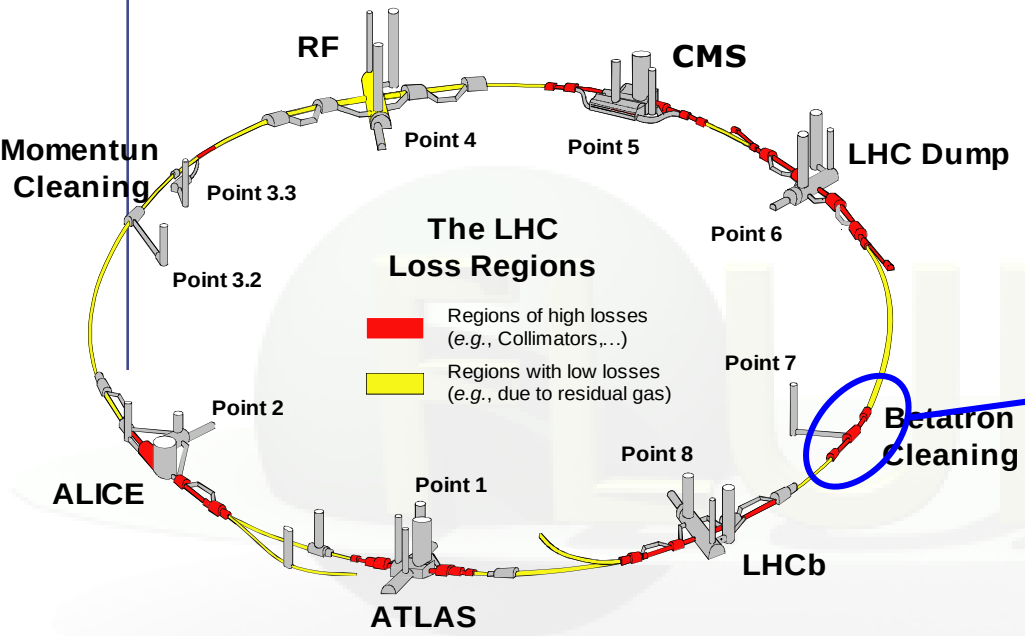
  as well as
  - The underlying physics and MC techniques

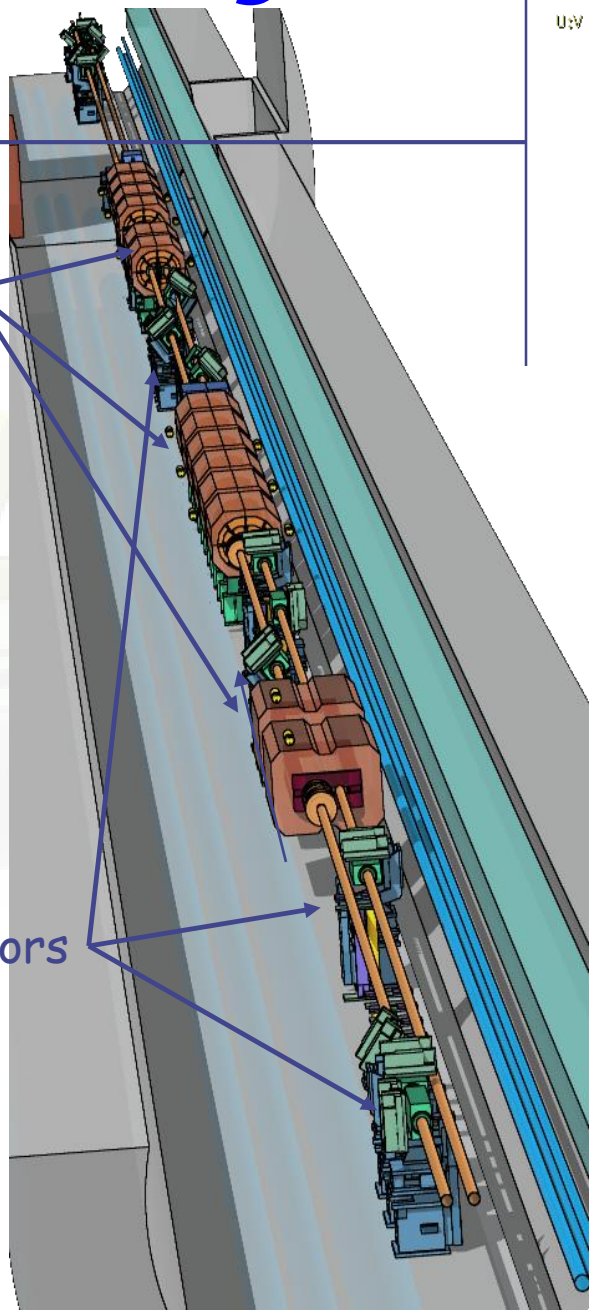
Examples of FLUKA Applications

FLUKA Applications

- Cosmic ray physics
- Neutrino physics
- Accelerator design (→ n_ToF, CNGS, LHC systems)
- Particle physics: calorimetry, tracking and detector simulation etc. (→ ALICE, ICARUS, ...)
- ADS systems, waste transmutation, (→"Energy amplifier", FEAT, TARC,...)
- Shielding design
- Dosimetry and radioprotection
- Radiation damage
- Space radiation
- Hadron therapy
- Neutronics

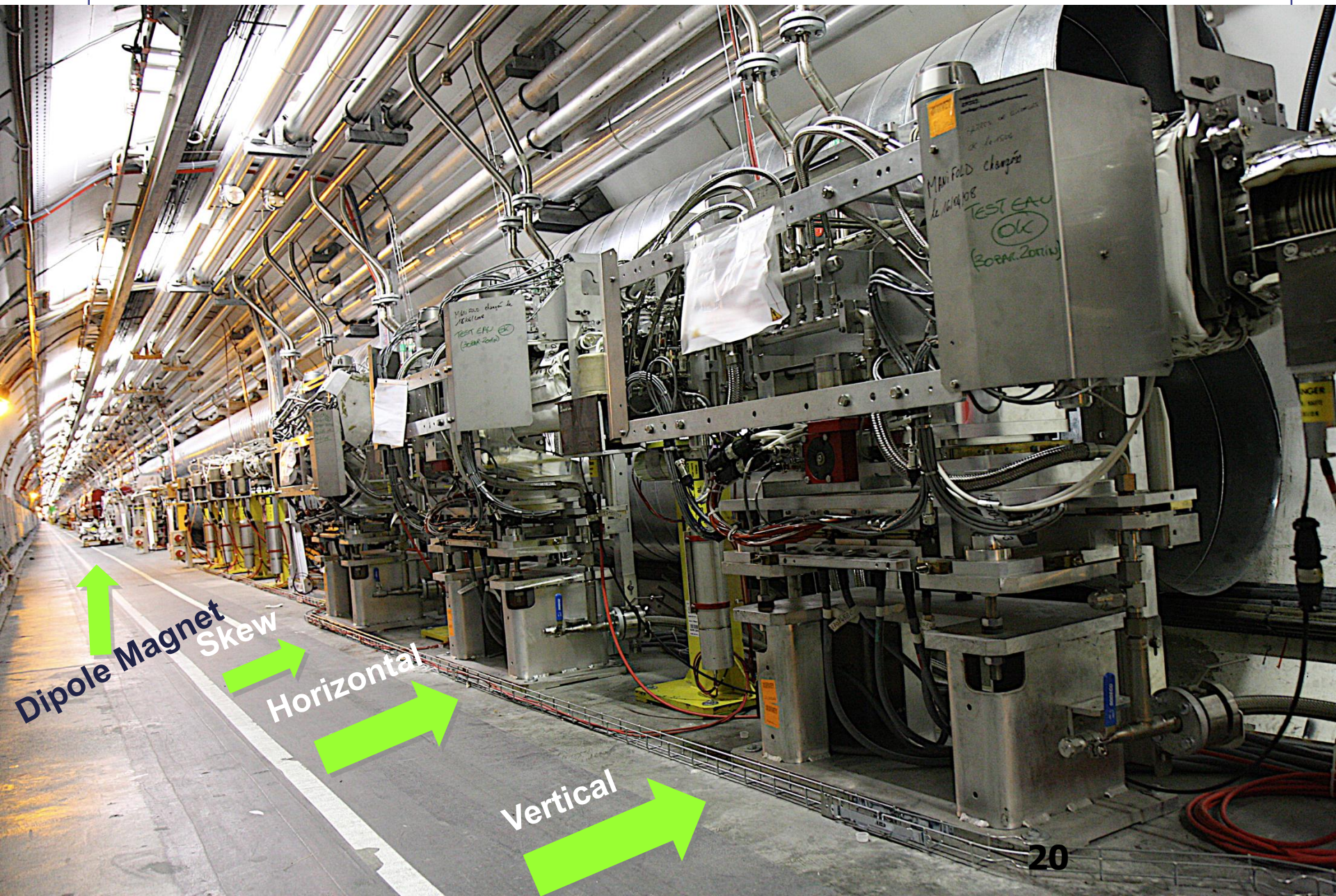
Applications – *LHC collimation region*



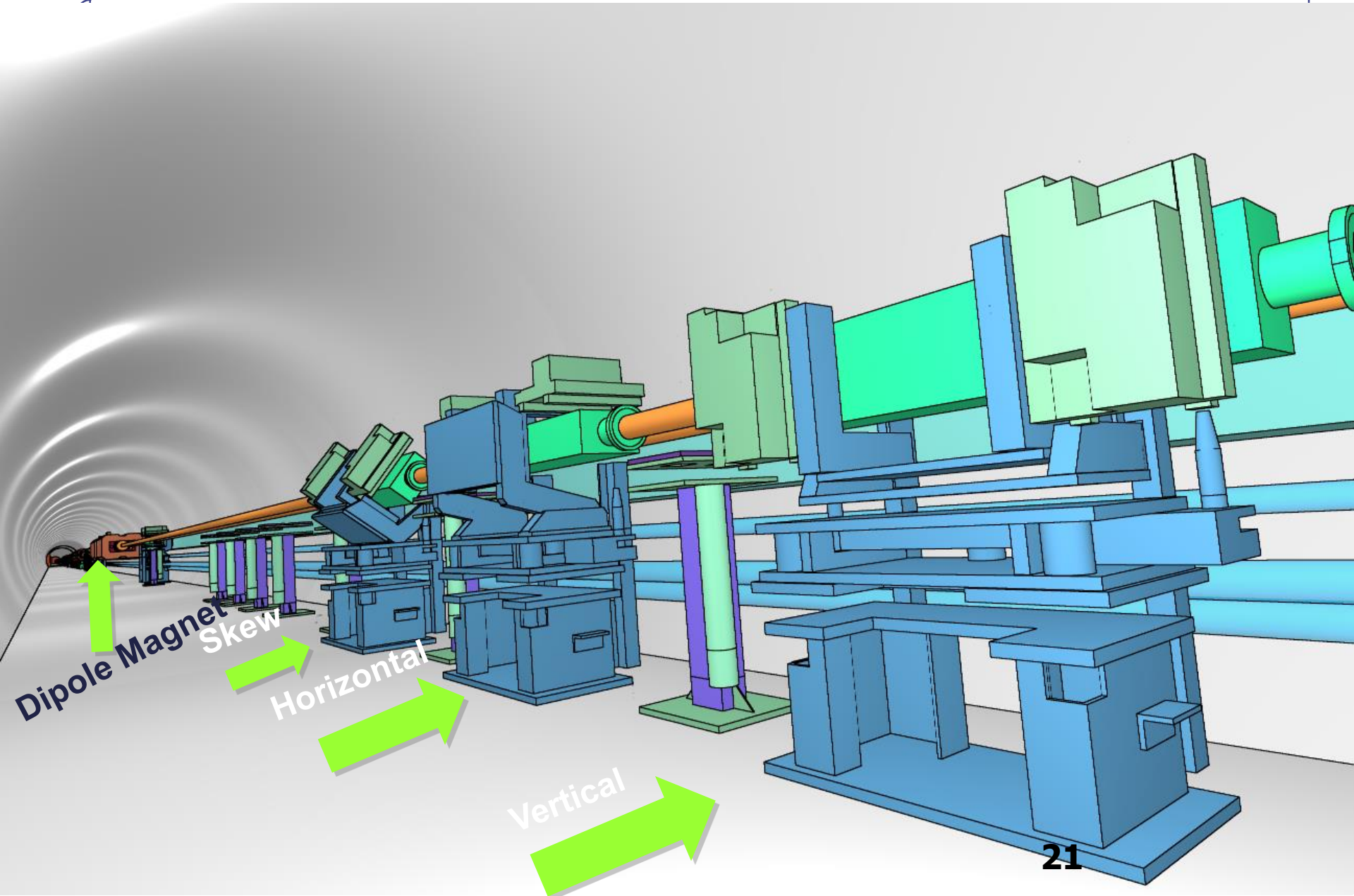


FLUKA geometry visualized with **flair**

Applications: 3 Primary Collimators IR7



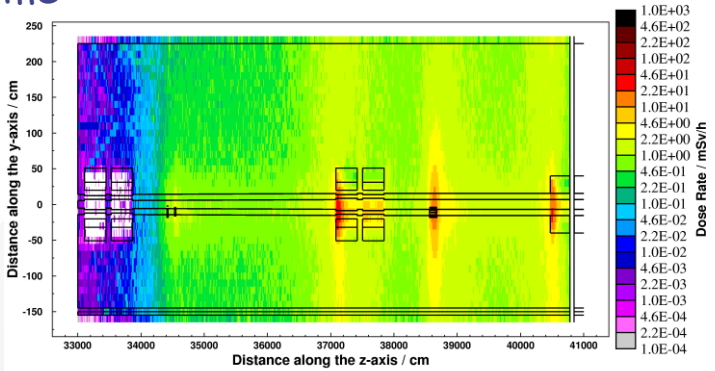
Applications: 3 Primary Collimators IR7



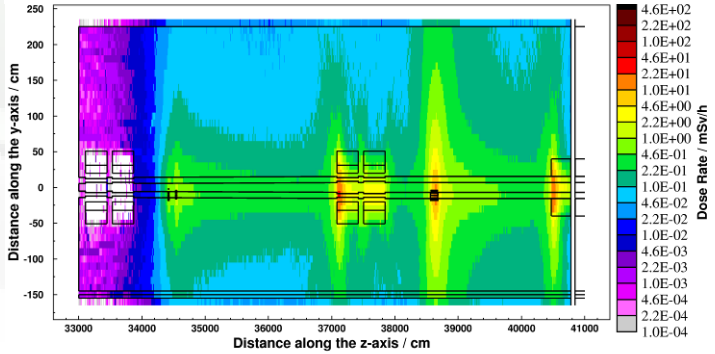
Applications – *LHC collimation region*

Cooling time

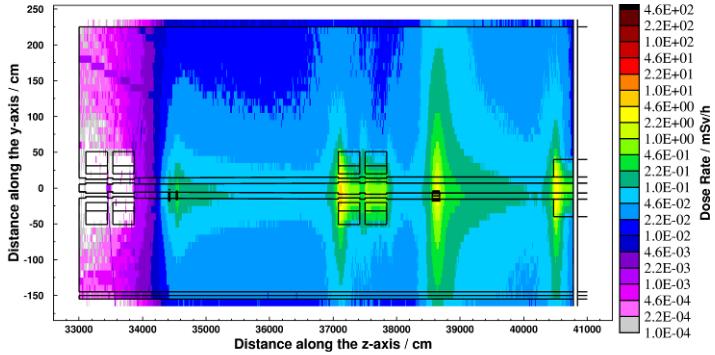
8 hours



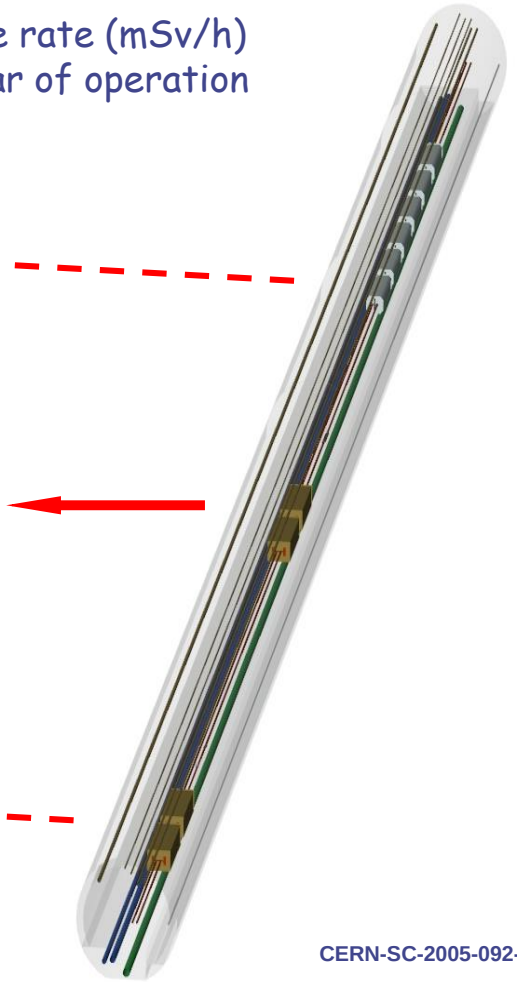
1 week



4 months



Residual dose rate (mSv/h)
after one year of operation



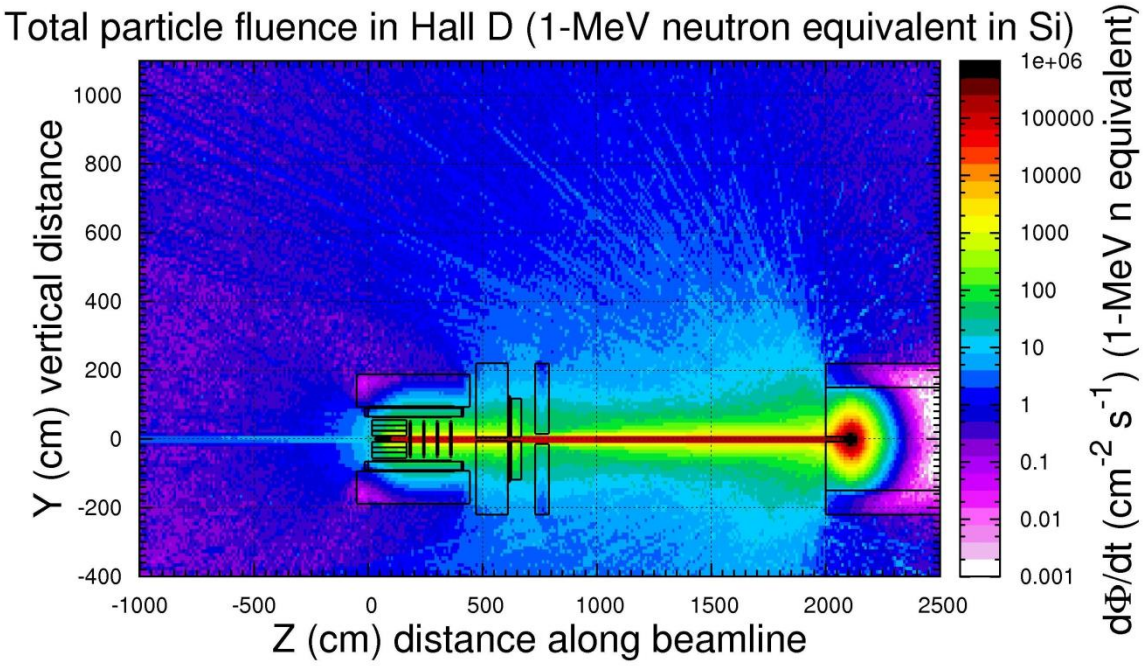
CERN-SC-2005-092-RP-TN

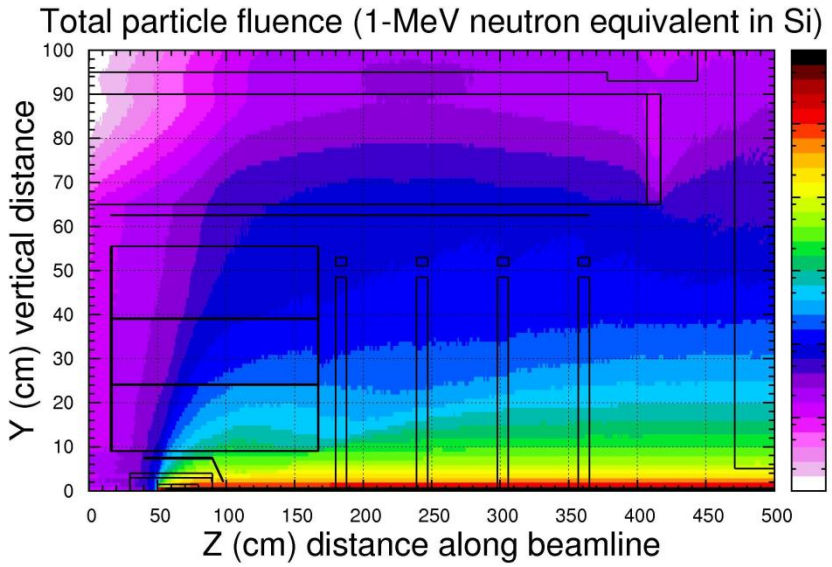
REMANENT DOSE RATE MAPS
OF THE LHC BETATRON CLEANING INSERTION (IR7)

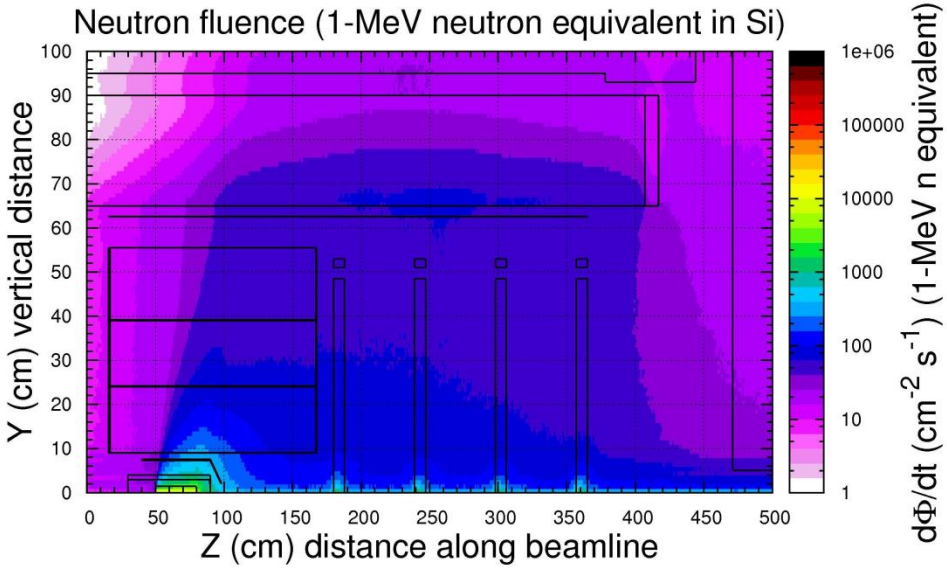
M. Brugger, D. Forkel-Wirth, S. Roesler

Applications – total and Neutron Dose from PHOTON beam

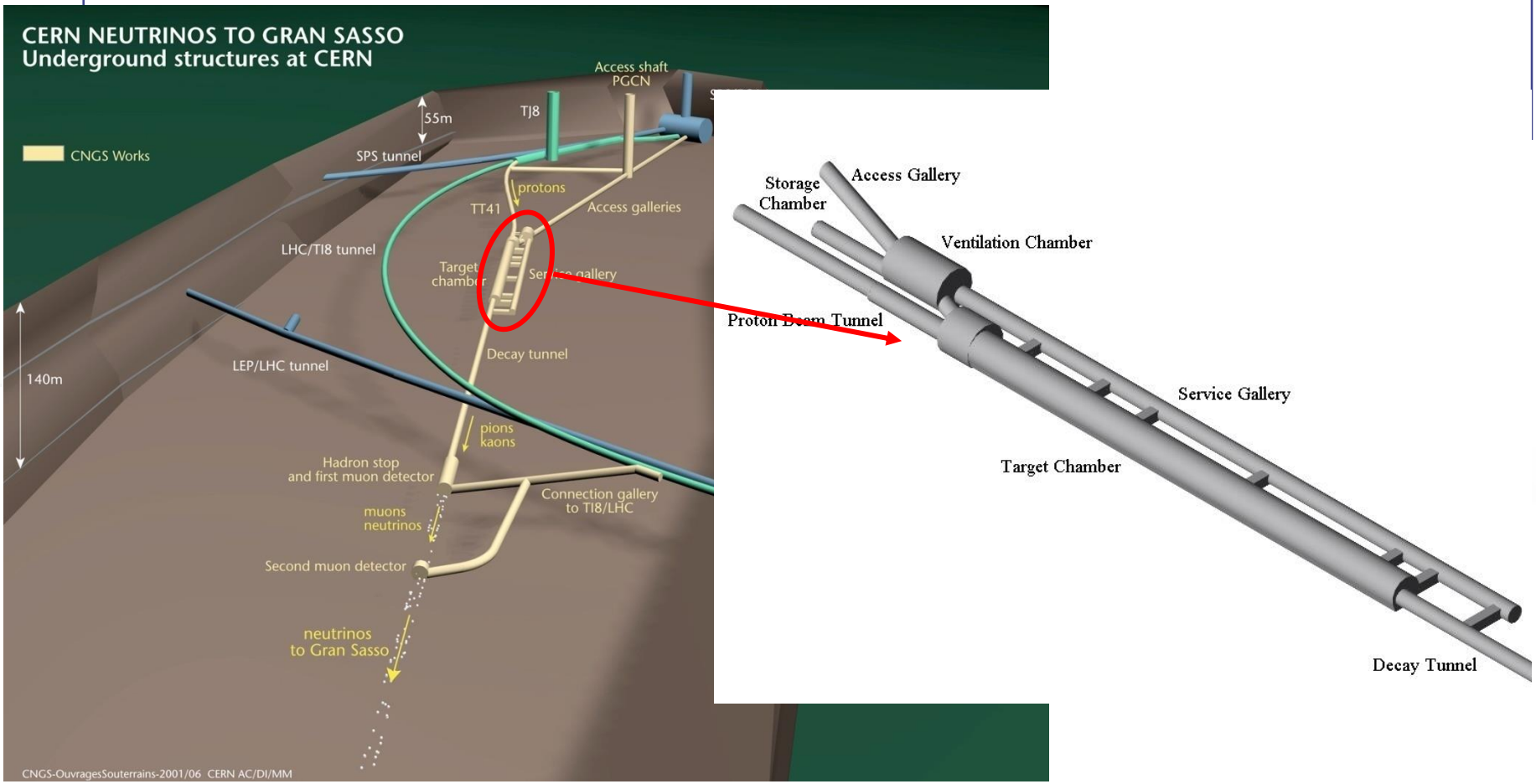
Calculated 1-MeV neutron equivalent fluence rate in Si (GlueX experiment at Jlab)
Beam : 8-9 GeV photons, From the CEBAF electron accelerator



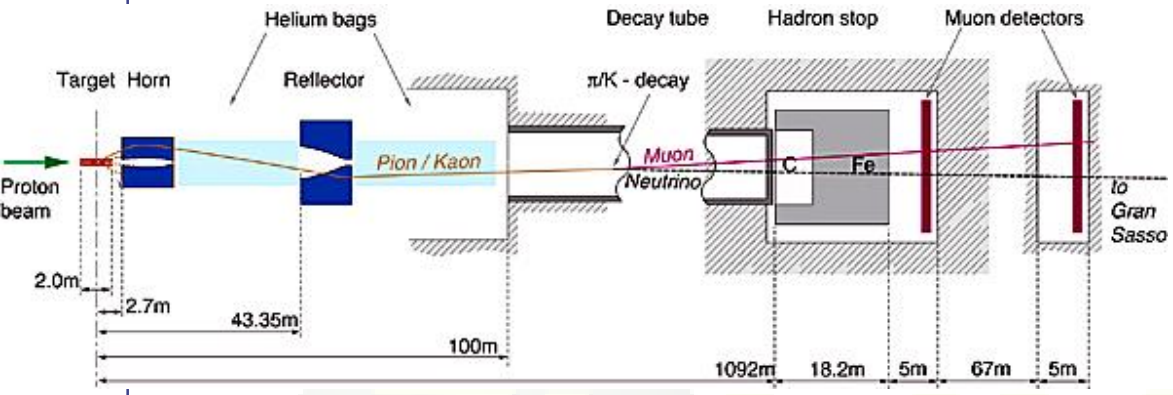


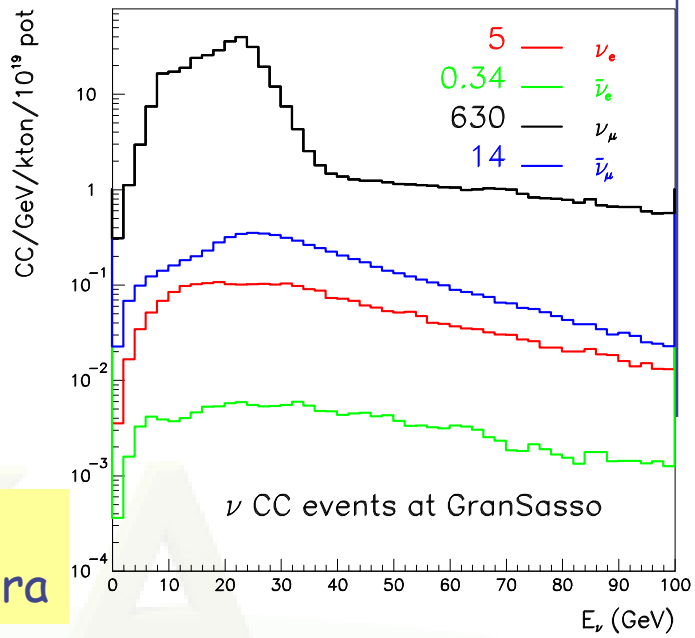


Applications – Cern Neutrino to Gran Sasso

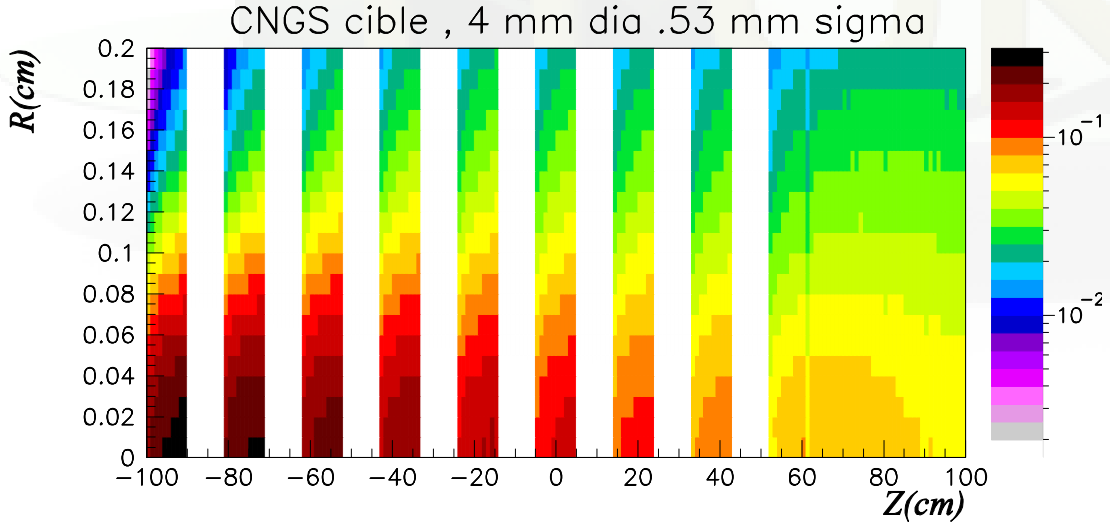


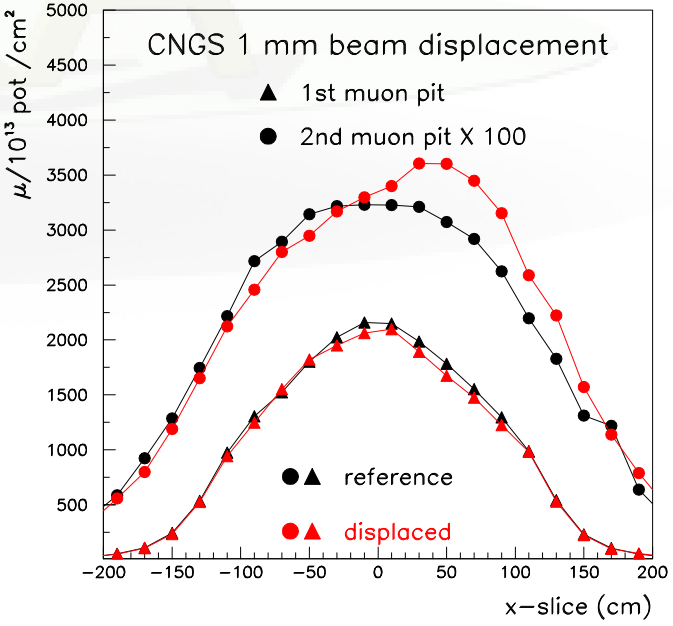
Cern Neutrino to Gran Sasso





Engineering and physics: target heating, shielding, activation, beam monitors, neutrino spectra

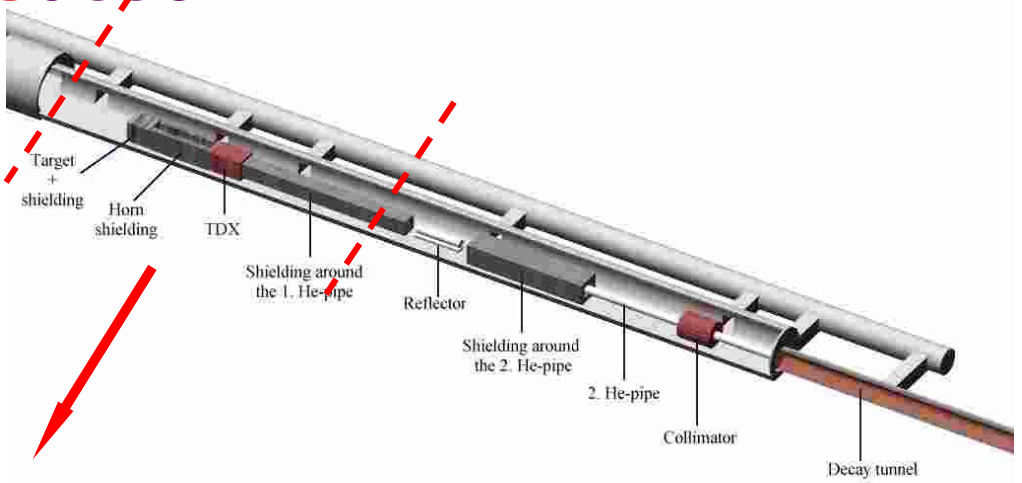




Muons in muon pits: horiz. distribution for beam alignment

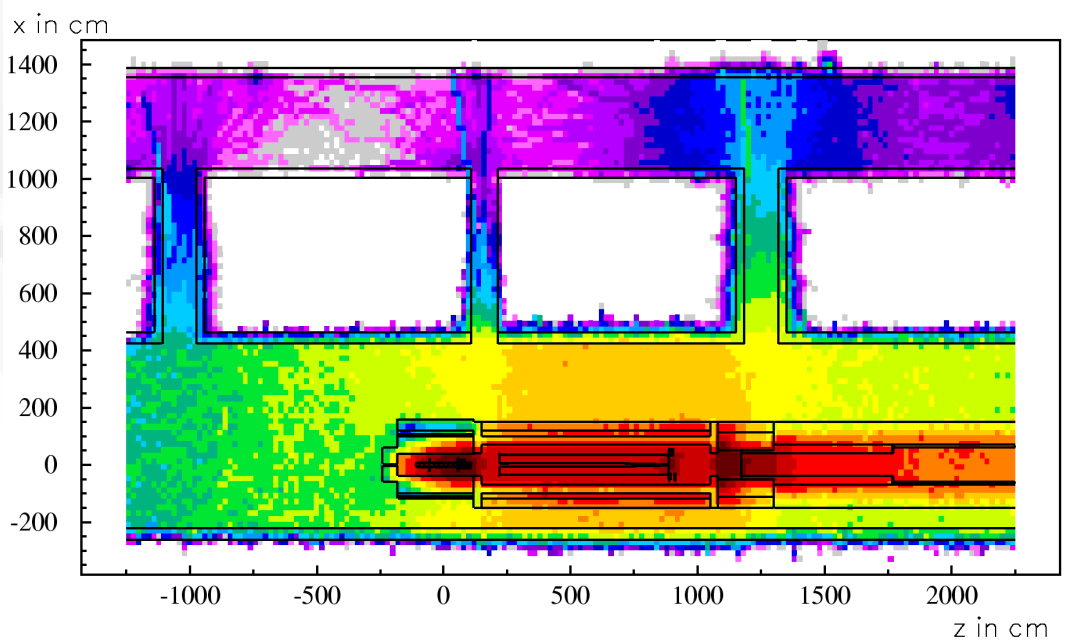
Energy deposition in CNGS target rods, GeV/cm³/pot

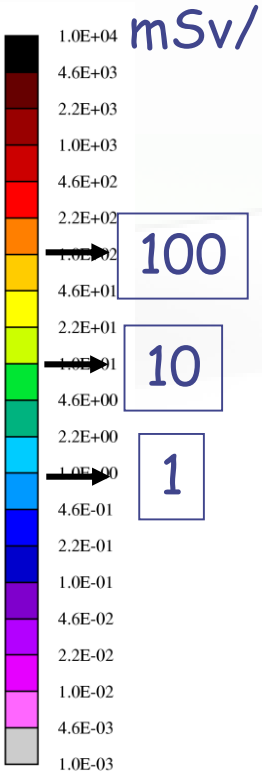
Cern Neutrino to Gran Sasso



Example:

t_{cool} = 1 day



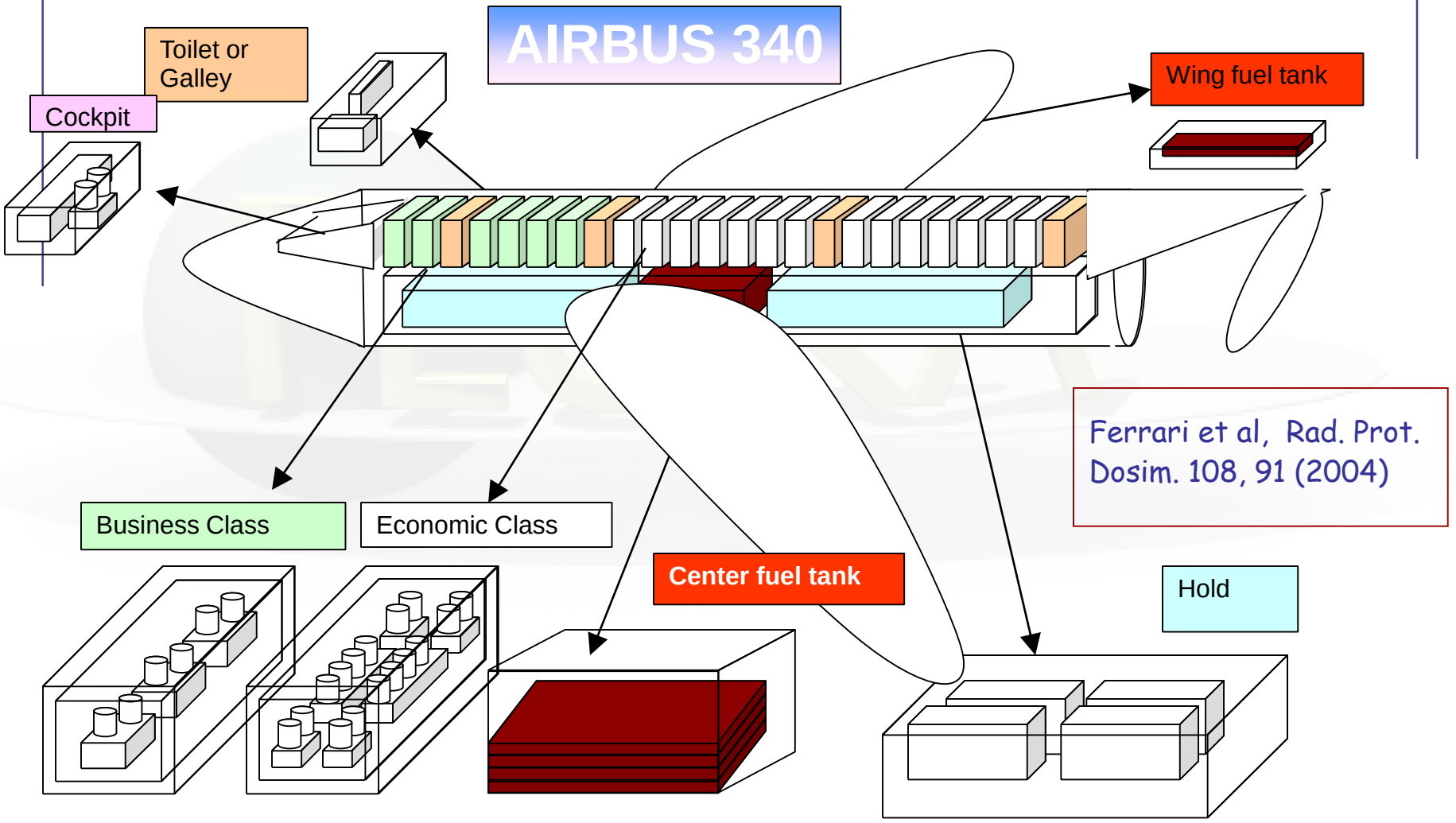


Residual Dose Equivalent Rate (mSv/h)

200 days irradiation, 1 day cooling

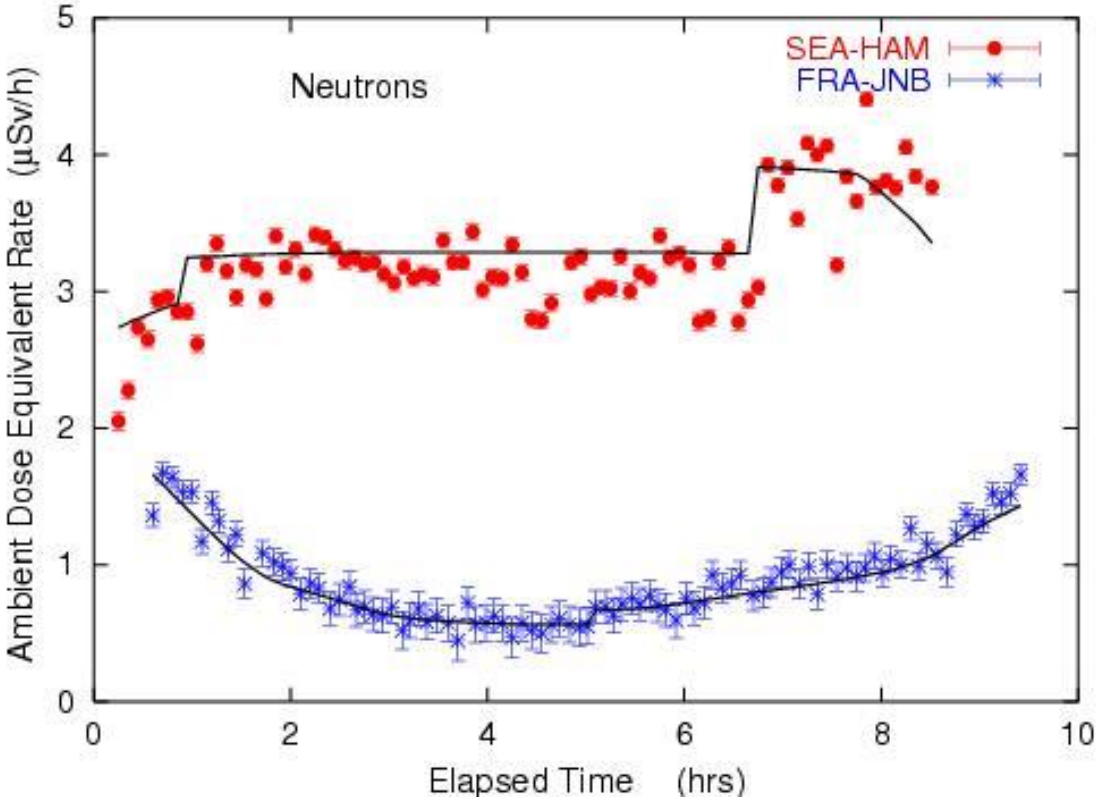
8×10^{12} protons/s

Dosimetry applications: doses to aircrew and passengers



Dosimetry applications

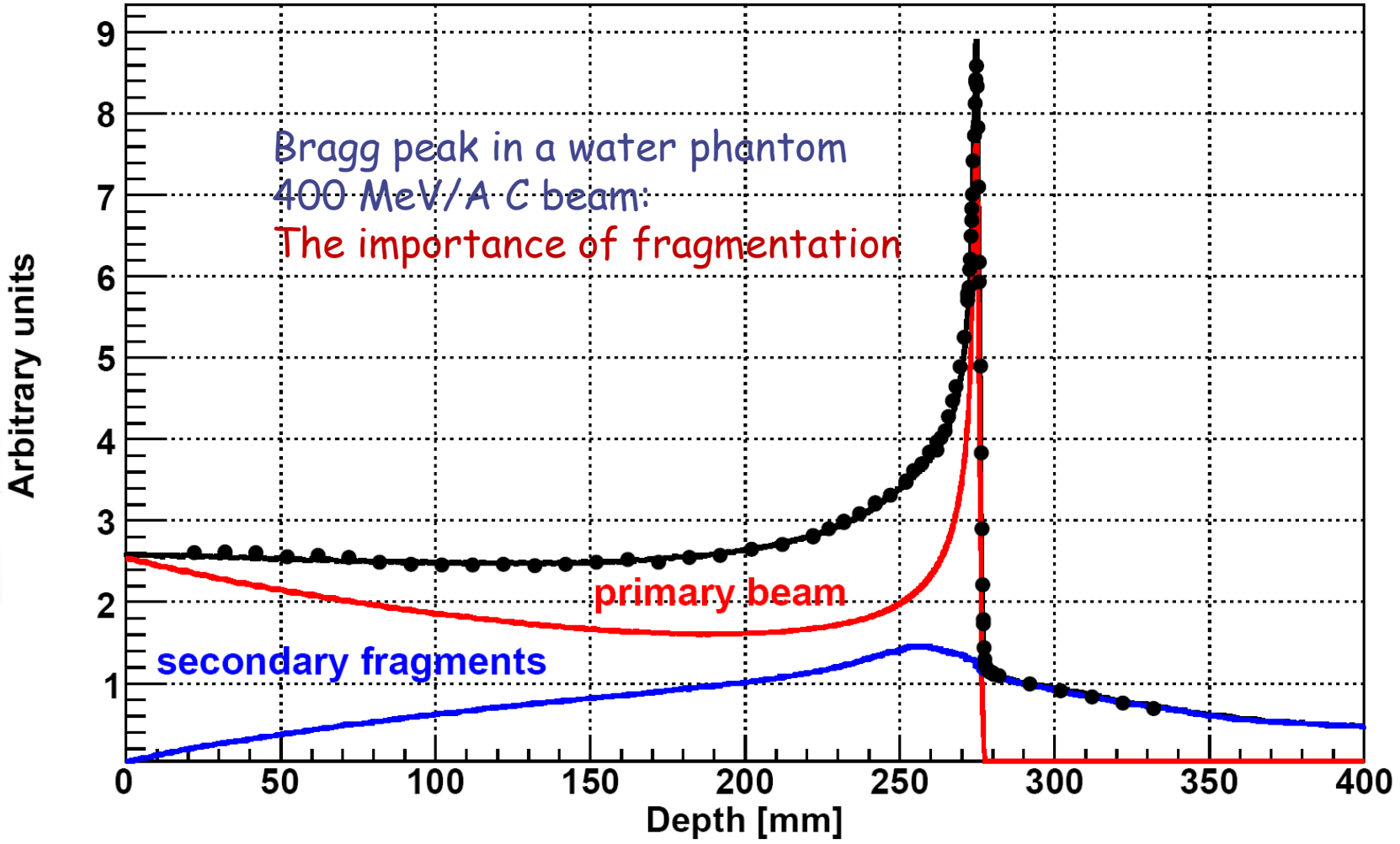
Roesler et al.,
Rad. Prot. Dosim.
98, 367 (2002)



Ambient dose equivalent from neutrons at solar maximum on commercial flights from Seattle to Hamburg and from Frankfurt to Johannesburg.

Solid lines: FLUKA simulation

Medical physics applications : Radiotherapy



Exp. Data (points) from Haettner et al, Rad. Prot. Dos. 2006
Simulation: A. Mairani PhD Thesis, 2007, Nuovo Cimento C, 31, 2008

A brief overview:

your first input

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)

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!

FLUKA and FLAIR

FLUKA users can….

prepare their own input with a text editor
use their own tools for plotting results
submit jobs by command line

FLAIR (Fluka Advanced InteRface) can be used as well

It helps the users with the aforementioned tasks

(see FLAIR lecture)

You can choose your favorite way…

…but a good user should be able to go both ways!

Structure of the input file

General definitions

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

This lecture

Physics settings

Defaults
Physical processes
Transport thresholds
Low energy neutrons
Induced radioactivity

This lecture and many others

Geometry

Geometry lecture

Output settings

Estimators / scoring cards

Scoring lecture

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 command 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

Fixed vs free format [1/2]

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)
- FLAIR takes care of all the alignment problems for you

Names instead of numbers

- FLUKA also allows to use 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, and is again managed by the FLAIR graphical interface

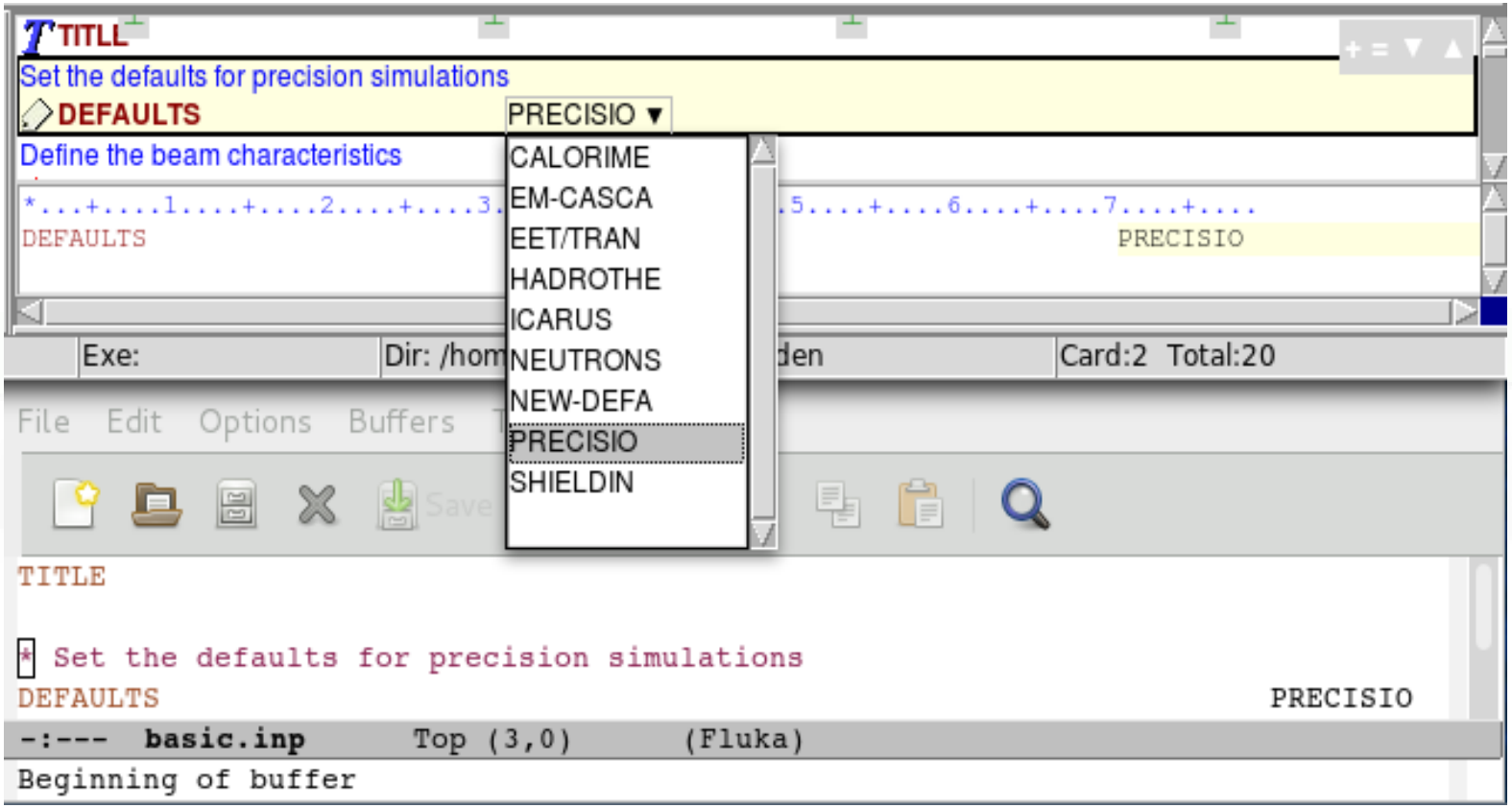
A basic input: step 1: Physics settings

```
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
```

```
TITLE      My Basic Input example
DEFAULTS   PRECISIO ▼
BEAM       Momentum ▼                                   Part: PROTON ▼
  Δp: Gauss ▼   Δp(FWHM): 0.082425   Δφ: Gauss ▼   Δφ: 1.7
  Shape(X): Rectangular ▼   Δx: 0.0   Shape(Y): Rectangular ▼   Δy: 0.0
BEAMPOS    x: 0.0   y: 0.0   z: -0.1
           cosx: 0.0   cosy: 0.0   Type: POSITIVE ▼
GEOBEGIN   Log: ▼   Acc:   Opt: ▼
           Inp: ▼   Out: ▼   Fmt: COMBNAME ▼
  Title:
SPH  blkbody   x: 0.0   y: 0.0   z: 0.0
               R: 100000.0
SPH  void      x: 0.0   y: 0.0   z: 0.0
               R: 10000.0
RCC  target1   x: 0.0   y: 0.0   z: 0.0
               Hx: 0.0   Hy: 0.0   Hz: 10.0
               R: 5.0
RCC  target2   x: 0.0   y: 0.0   z: 20.0
               Hx: 0.0   Hy: 0.0   Hz: 10.0
               R: 5.0
RCC  target3   x: 0.0   y: 0.0   z: 40.0
               Hx: 0.0   Hy: 0.0   Hz: 10.0
               R: 5.0
END
REGION  BLKBODY   Neigh: 5   Volume:
  expr: +blkbody -void
REGION  VOID      Neigh: 5   Volume:
  expr: +void -target1 -target2 -target3
REGION  TARGET1   Neigh: 5   Volume:
  expr: +target1
REGION  TARGET2   Neigh: 5   Volume:
  expr: +target2
REGION  TARGET3   Neigh: 5   Volume:
  expr: +target3
END
GEOEND     ▼
MATERIAL   Name: CHROMIUM   #   ρ: 7.18
  Z: 24.0   Am:   A:   dE/dx: ▼
MATERIAL   Name: AMMONIA   #   ρ: 0.73E-3
  Z: 0.0   Am:   A:   dE/dx: ▼
COMPOUND   Name: AMMONIA ▼   Mix: Atom ▼   Elements: 1..3 ▼
  f1: 1.0   M1: NITROGEN ▼   f2: 3.0   M2: HYDROGEN ▼
  f3:   M3: ▼
ASSIGNMA   Mat: BLCKHOLE ▼   Reg: BLKBODY ▼   to Reg: ▼
           Mat(Decay): ▼   Step:   Field: ▼
ASSIGNMA   Mat: VACUUM ▼   Reg: VOID ▼   to Reg: ▼
           Mat(Decay): ▼   Step:   Field: ▼
ASSIGNMA   Mat: AMMONIA ▼   Reg: TARGET3 ▼   to Reg: ▼
           Mat(Decay): ▼   Step:   Field: ▼
ASSIGNMA   Mat: CHROMIUM ▼   Reg: TARGET1 ▼   to Reg: TARGET2 ▼
           Mat(Decay): ▼   Step: 1.0   Field: ▼
RANDOMIZ   Unit 01 ▼   Seed: 54217137.
START      No.: 1000.   Core: ▼
           Time:   Report: default ▼
STOP
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....
TITLE
My Basic Input example
```

Physics settings: DEFAULTS

Select predefined physics settings (e.g. transport thresholds)



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
```

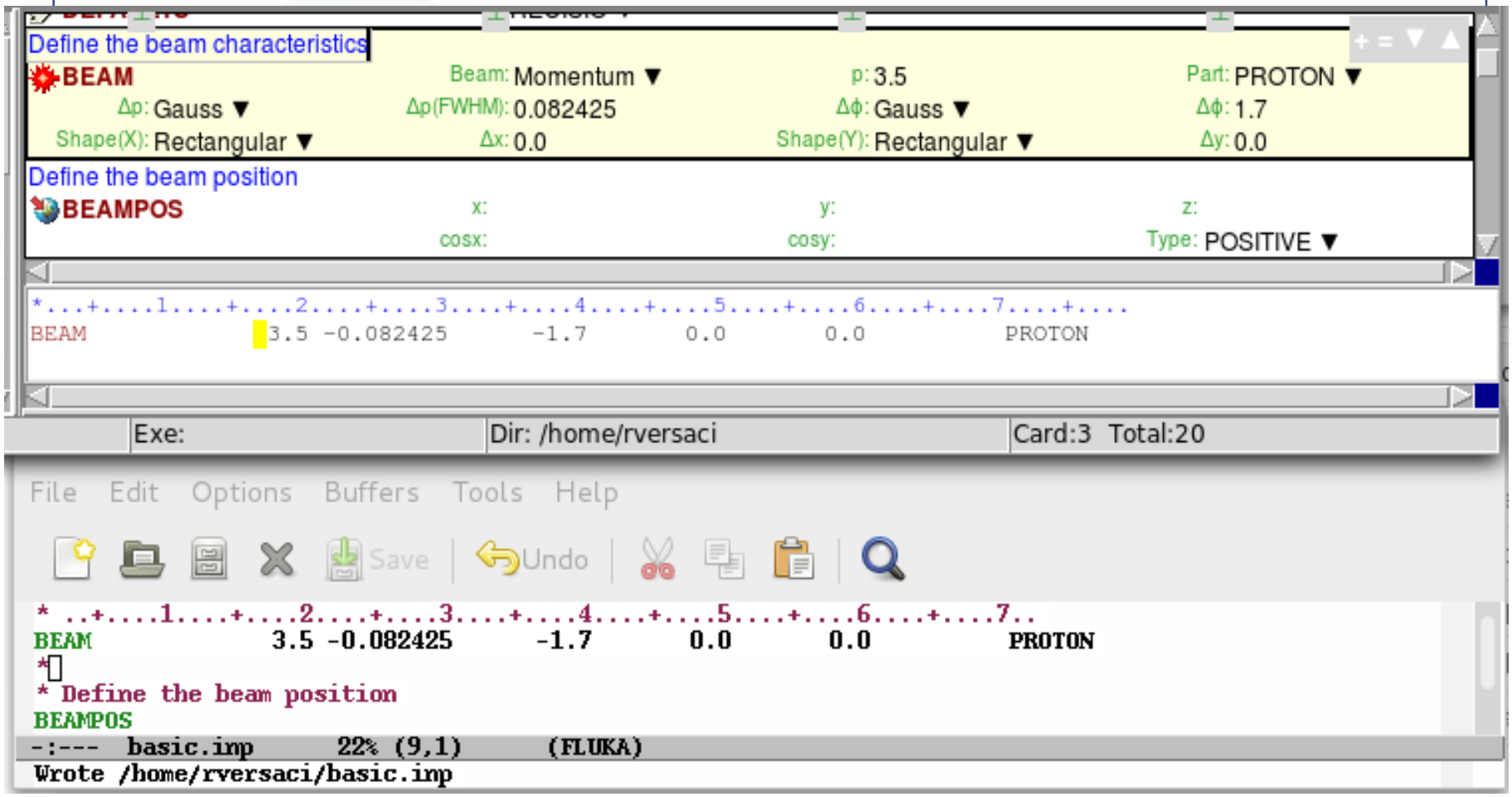
TITLE My Basic Input example
DEFAULTS PRECISIO ▼
BEAM Beam: Momentum ▼ p: 3.5 Part: PROTON ▼
Δp: Gauss ▼ Δp(FWHM): 0.082425 Δϕ: Gauss ▼ Δϕ: 1.7
Shape(X): Rectangular ▼ Δx: 0.0 Shape(Y): Rectangular ▼ Δy: 0.0
BEAMPOS x: 0.0 y: 0.0 z: -0.1
cosx: 0.0 cosy: 0.0 Type: POSITIVE ▼
GEOBEGIN Log: ▼ Acc: Opt: ▼
Inp: ▼ Out: ▼ Fmt: COMBNAME ▼
Title:
SPH blkbody x: 0.0 y: 0.0 z: 0.0
R: 100000.0
SPH void x: 0.0 y: 0.0 z: 0.0
R: 10000.0
RCC target1 x: 0.0 y: 0.0 z: 0.0
Hx: 0.0 Hy: 0.0 Hz: 10.0
R: 5.0
RCC target2 x: 0.0 y: 0.0 z: 20.0
Hx: 0.0 Hy: 0.0 Hz: 10.0
R: 5.0
RCC target3 x: 0.0 y: 0.0 z: 40.0
Hx: 0.0 Hy: 0.0 Hz: 10.0
R: 5.0
END
REGION BLKBODY Neigh: 5 Volume:
expr: +blkbody -void
REGION VOID Neigh: 5 Volume:
expr: +void -target1 -target2 -target3
REGION TARGET1 Neigh: 5 Volume:
expr: +target1
REGION TARGET2 Neigh: 5 Volume:
expr: +target2
REGION TARGET3 Neigh: 5 Volume:
expr: +target3
END
GEOEND ▼
MATERIAL Name: CHROMIUM # ρ: 7.18
Z: 24.0 Am: A: dE/dx: ▼
MATERIAL Name: AMMONIA # ρ: 0.73E-3
Z: 0.0 Am: A: dE/dx: ▼
COMPOUND Name: AMMONIA ▼ Mix: Atom ▼ Elements: 1..3 ▼
f1: 1.0 M1: NITROGEN ▼ f2: 3.0 M2: HYDROGEN ▼
f3: M3: ▼
ASSIGNMA Mat: BLCKHOLE ▼ Reg: BLKBODY ▼ to Reg: ▼
Mat(Decay): ▼ Step: Field: ▼
ASSIGNMA Mat: VACUUM ▼ Reg: VOID ▼ to Reg: ▼
Mat(Decay): ▼ Step: Field: ▼
ASSIGNMA Mat: AMMONIA ▼ Reg: TARGET3 ▼ to Reg: ▼
Mat(Decay): ▼ Step: Field: ▼
ASSIGNMA Mat: CHROMIUM ▼ Reg: TARGET1 ▼ to Reg: TARGET2 ▼
Mat(Decay): ▼ Step: 1.0 Field: ▼
RANDOMIZ Unit 01 ▼ Seed: 54217137.
START No.: 1000. Core: ▼
Time: Report: default ▼
STOP

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....
TITLE
My Basic Input example
```

Beam definition: BEAM

Defines beam characteristics: type of particle, energy or momentum, divergence, spatial profile....

Let's see an example



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..
COMPOUND
*
* ..+....1
ASSIGNMA
ASSIGNMA
ASSIGNMA
*
* ..+....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
```

TITLE My Basic Input example
DEFAULTS PRECISIO
BEAM Beam: Momentum p: 3.5 Part: PROTON
Δp: Gauss Δp(FWHM): 0.082425 Δϕ: Gauss Δϕ: 1.7
Shape(X): Rectangular Δx: 0.0 Shape(Y): Rectangular Δy: 0.0
BEAMPOS x: 0.0 y: 0.0 z: -0.1
cosx: 0.0 cosy: 0.0 Type: POSITIVE
GEOBEGIN Log: Acc: Opt:
Inp: Out: Fmt: COMBNAME
Title:
SPH blkbody x: 0.0 y: 0.0 z: 0.0
R: 100000.0
SPH void x: 0.0 y: 0.0 z: 0.0
R: 10000.0
RCC target1 x: 0.0 y: 0.0 z: 0.0
Hx: 0.0 Hy: 0.0 Hz: 10.0
R: 5.0
RCC target2 x: 0.0 y: 0.0 z: 20.0
Hx: 0.0 Hy: 0.0 Hz: 10.0
R: 5.0
RCC target3 x: 0.0 y: 0.0 z: 40.0
Hx: 0.0 Hy: 0.0 Hz: 10.0
R: 5.0
END
REGION BLKBODY Neigh: 5 Volume:
expr: +blkbody -void
REGION VOID Neigh: 5 Volume:
expr: +void -target1 -target2 -target3
REGION TARGET1 Neigh: 5 Volume:
expr: +target1
REGION TARGET2 Neigh: 5 Volume:
expr: +target2
REGION TARGET3 Neigh: 5 Volume:
expr: +target3
END
GEOEND
MATERIAL Name: CHROMIUM # ρ: 7.18
Z: 24.0 Am: A: dE/dx:
MATERIAL Name: AMMONIA # ρ: 0.73E-3
dE/dx:
Elements: 1..3
M2: HYDROGEN
to Reg:
Field:
to Reg:
Field:
ASSIGNMA Mat: AMMONIA Reg: TARGET3 to Reg:
Mat(Decay): Step: Field:
ASSIGNMA Mat: CHROMIUM Reg: TARGET1 to Reg: TARGET2
Mat(Decay): Step: 1.0 Field:
RANDOMIZ Unit 01 Seed: 54217137.
START No.: 1000. Core:
Time: Report: default
STOP
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....
TITLE
My Basic Input example

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

A basic input: step 4: Materials

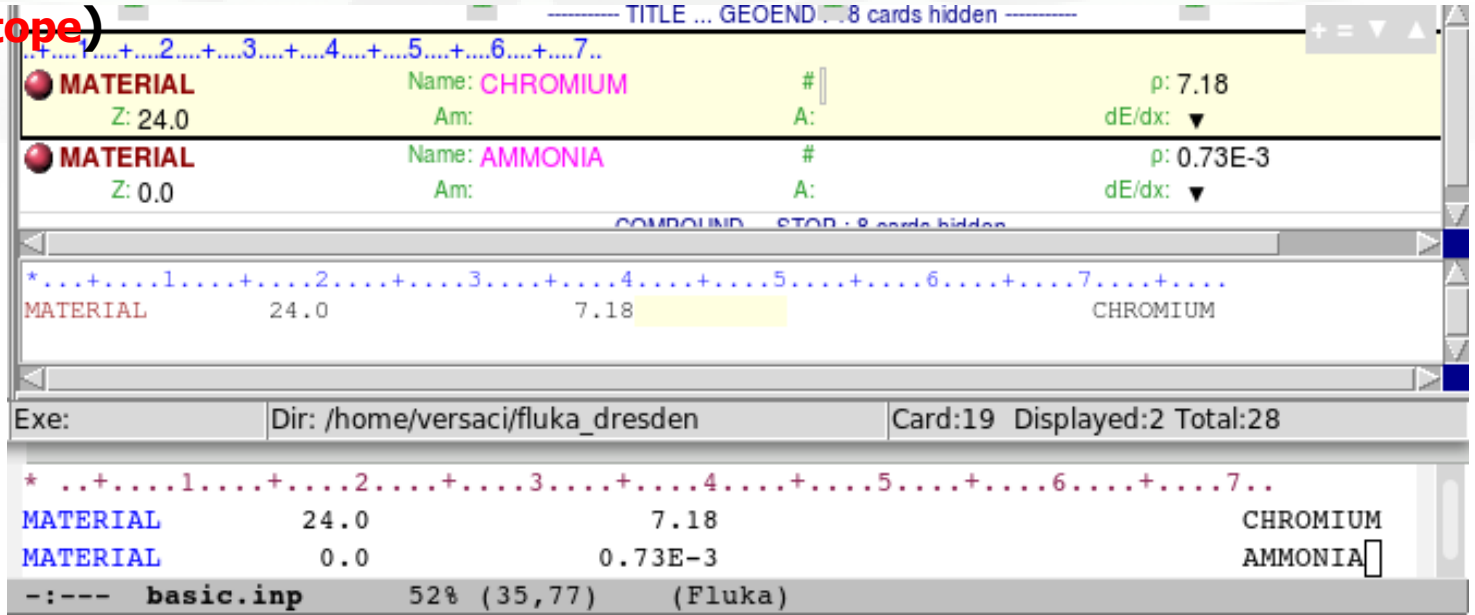
```
TITLE
My Basic Input example
* Set the defaults for precision simulations
DEFAULTS                                                              PRECISIO
* Define the beam characteristics
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
BEAM             3.5 -0.082425      -1.7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

```
TITLE  My Basic Input example
DEFAULTS                    PRECISIO ▼
BEAM      Beam: Momentum ▼   p: 3.5          Part: PROTON ▼
          Δp: Gauss ▼        Δp(FWHM): 0.082425  Δϕ: Gauss ▼   Δϕ: 1.7
          Shape(X): Rectangular ▼  Δx: 0.0   Shape(Y): Rectangular ▼  Δy: 0.0
BEAMPOS   x: 0.0             y: 0.0          z: -0.1
          cosx: 0.0          cosy: 0.0       Type: POSITIVE ▼
GEOBEGIN  Log: ▼             Acc:            Opt: ▼
          Inp: ▼             Out: ▼          Fmt: COMBNAME ▼
          Title:
SPH  blkbody   x: 0.0   y: 0.0   z: 0.0
               R: 100000.0
SPH  void      x: 0.0   y: 0.0   z: 0.0
               R: 10000.0
RCC  target1   x: 0.0   y: 0.0   z: 0.0
               Hx: 0.0  Hy: 0.0  Hz: 10.0
               R: 5.0
RCC  target2   x: 0.0   y: 0.0   z: 20.0
               Hx: 0.0  Hy: 0.0  Hz: 10.0
               R: 5.0
RCC  target3   x: 0.0   y: 0.0   z: 40.0
               Hx: 0.0  Hy: 0.0  Hz: 10.0
               R: 5.0
END
REGION  BLKBODY   Neigh: 5   Volume:
        expr: +blkbody -void
REGION  VOID      Neigh: 5   Volume:
        expr: +void -target1 -target2 -target3
REGION  TARGET1   Neigh: 5   Volume:
        expr: +target1
REGION  TARGET2   Neigh: 5   Volume:
        expr: +target2
REGION  TARGET3   Neigh: 5   Volume:
        expr: +target3
END
GEOEND  ▼
MATERIAL  Name: CHROMIUM   #          ρ: 7.18
          Z: 24.0          Am:        A:        dE/dx: ▼
MATERIAL  Name: AMMONIA    #          ρ: 0.73E-3
          Z: 0.0           Am:        A:        dE/dx: ▼
COMPOUND  Name: AMMONIA ▼  Mix: Atom ▼  Elements: 1..3 ▼
          f1: 1.0  M1: NITROGEN ▼  f2: 3.0  M2: HYDROGEN ▼
          f3:      M3: ▼
ASSIGNMA  Mat: BLCKHOLE ▼  Reg: BLKBODY ▼  to Reg: ▼
          Mat(Decay): ▼    Step:          Field: ▼
ASSIGNMA  Mat: VACUUM ▼    Reg: VOID ▼    to Reg: ▼
          Mat(Decay): ▼    Step:          Field: ▼
ASSIGNMA  Mat: AMMONIA ▼   Reg: TARGET3 ▼ to Reg: ▼
          Mat(Decay): ▼    Step:          Field: ▼
ASSIGNMA  Mat: CHROMIUM ▼  Reg: TARGET1 ▼ to Reg: TARGET2 ▼
          Mat(Decay): ▼    Step: 1.0      Field: ▼
RANDOMIZ  Unit 01 ▼        Seed: 54217137.
START     No.: 1000.       Core: ▼
          Time:            Report: default ▼
STOP
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+....
TITLE
My Basic Input example
```

Material definition: MATERIAL

Defines a new material or override a previous one

- [SDUM] material name
- [WHAT(1)] atomic number Z
- [WHAT(2)] atomic weight (leave it empty)
- [WHAT(3)] density [g/cm³]
- [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)



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

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

Material definition: COMPOUND

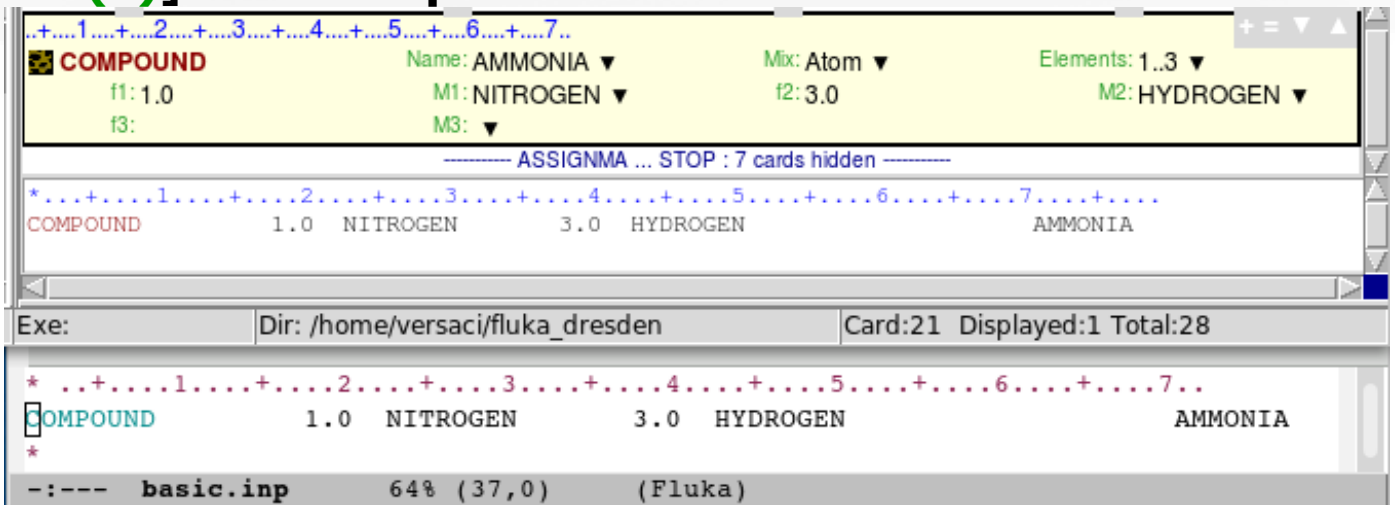
Defines a new compound

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**

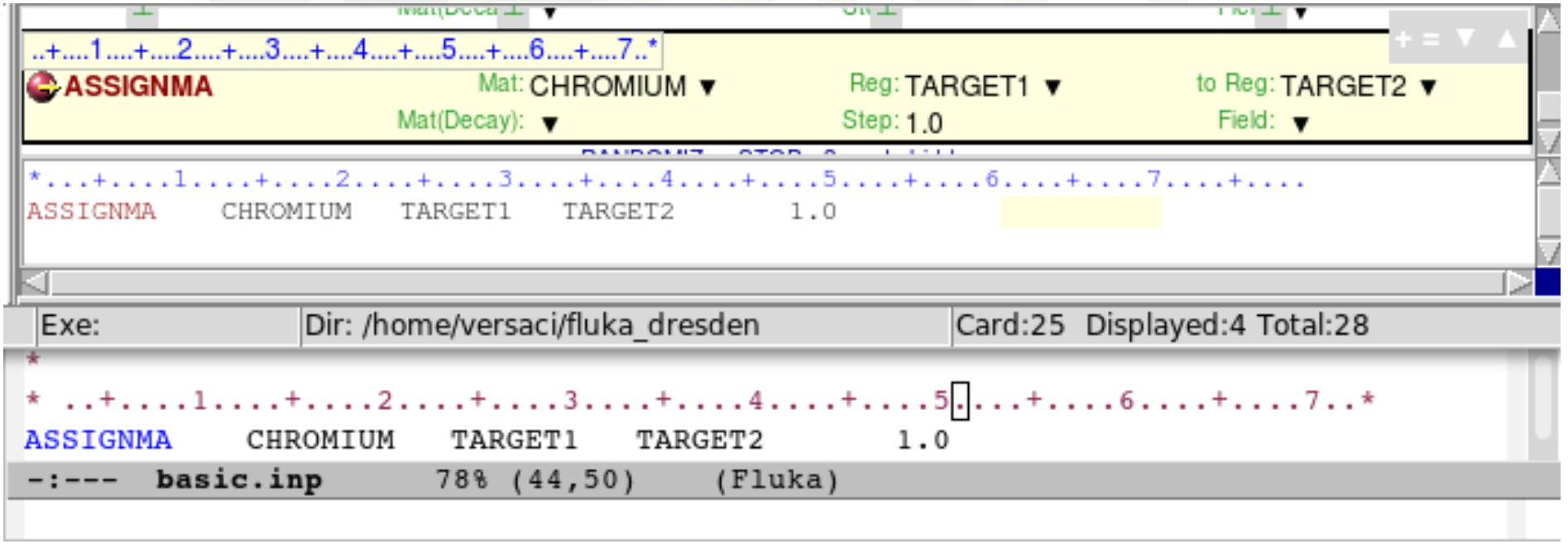
How to define the "amount"?



Material definition: ASSIGNMA

Assign a material to one (or more) region in the geometry
(for the region definition see the geometry lecture or the manual)

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



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

```
TITL
My B
* Se
DEFA
* 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
```

BEAMPOS		x: 0.0	y: 0.0	z: -0.1
		cosx: 0.0	cosy: 0.0	Type: POSITIVE
GEOBEGIN		Log:	Acc:	Opt:
		Inp:	Out:	Fmt: COMBNAME
	Title:			
SPH	blkbody	x: 0.0	y: 0.0	z: 0.0
		R: 100000.0		
SPH	void	x: 0.0	y: 0.0	z: 0.0
		R: 10000.0		
RCC	target1	x: 0.0	y: 0.0	z: 0.0
		Hx: 0.0	Hy: 0.0	Hz: 10.0
		R: 5.0		
RCC	target2	x: 0.0	y: 0.0	z: 20.0
		Hx: 0.0	Hy: 0.0	Hz: 10.0
		R: 5.0		
RCC	target3	x: 0.0	y: 0.0	z: 40.0
		Hx: 0.0	Hy: 0.0	Hz: 10.0
		R: 5.0		
END				
REGION	BLKBODY		Neigh: 5	Volume:
	expr: +blkbody -void			
REGION	VOID		Neigh: 5	Volume:
	expr: +void -target1 -target2 -target3			
REGION	TARGET1		Neigh: 5	Volume:
	expr: +target1			
REGION	TARGET2		Neigh: 5	Volume:
	expr: +target2			
REGION	TARGET3		Neigh: 5	Volume:
	expr: +target3			
END				
GEOEND				
MATERIAL		Name: CHROMIUM	#	ρ: 7.18
	Z: 24.0	Am:	A:	dE/dx:
MATERIAL		Name: AMMONIA	#	ρ: 0.73E-3
	Z: 0.0	Am:	A:	dE/dx:
COMPOUND		Name: AMMONIA	Mix: Atom	Elements: 1..3
	f1: 1.0	M1: NITROGEN	f2: 3.0	M2: HYDROGEN
	f3:	M3:		
ASSIGNMA		Mat: BLCKHOLE	Reg: BLKBODY	to Reg:
		Mat(Decay):	Step:	Field:
ASSIGNMA		Mat: VACUUM	Reg: VOID	to Reg:
		Mat(Decay):	Step:	Field:
ASSIGNMA		Mat: AMMONIA	Reg: TARGET3	to Reg:
		Mat(Decay):	Step:	Field:
ASSIGNMA		Mat: CHROMIUM	Reg: TARGET1	to Reg: TARGET2
		Mat(Decay):	Step: 1.0	Field:
RANDOMIZ		Unit 01	Seed: 54217137.	
START		No.: 1000.	Core:	
		Time:	Report: default	
STOP				

```
TITLE
My Basic Input example
```

A brief overview:

standard output and plotting

The FLUKA Standard Output

- FLUKA provides a standard output file that contains plenty of useful information:

  (fortran unit 11, *inp###.*out from rfluka)

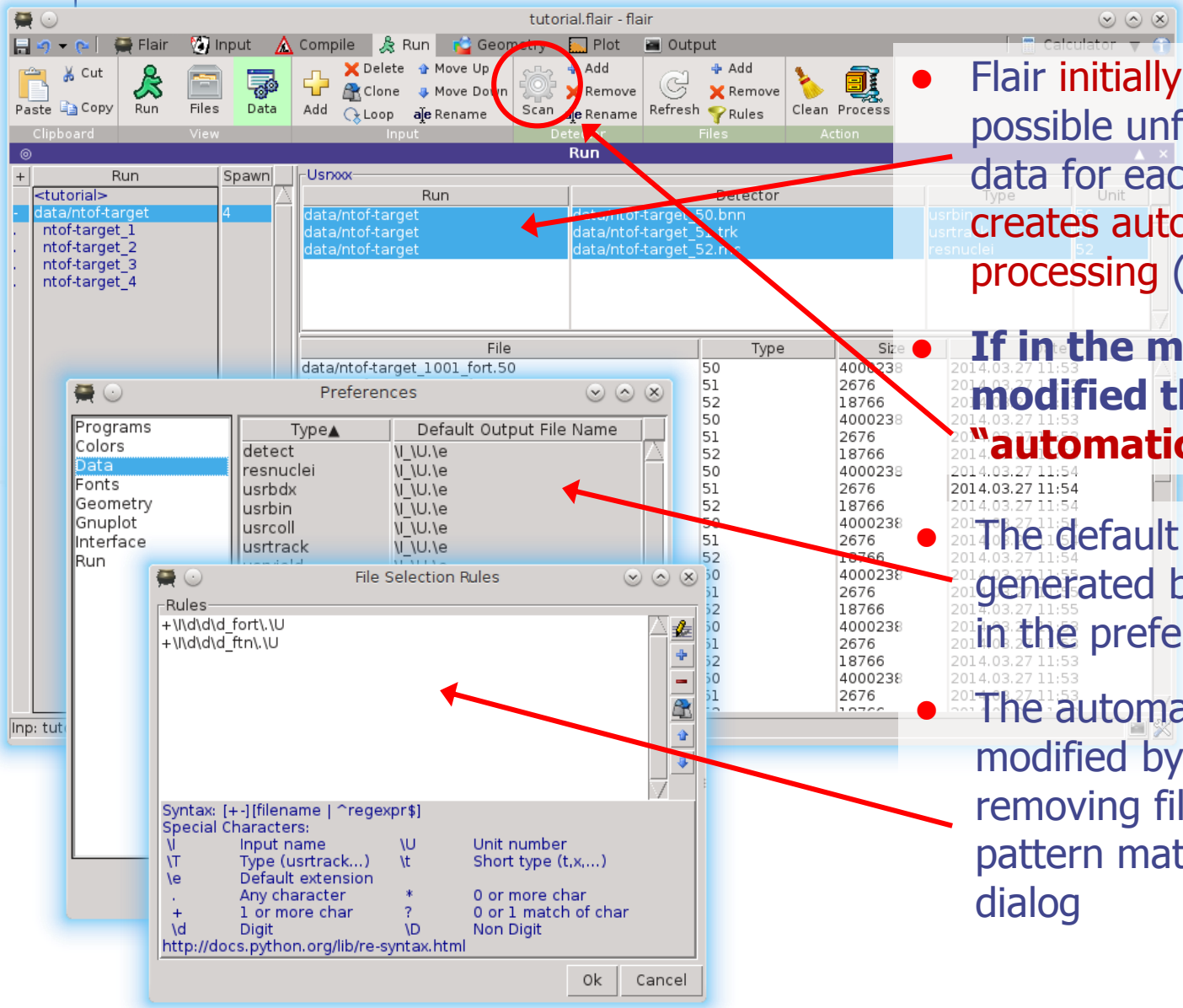
- **It must be checked at least once when setting up a simulation and always in case of doubts/crashes**

  (together with *inp###.err* and *inp###.log* files)

- Let's have a look at ex_3001.out (editor or flair output viewer:

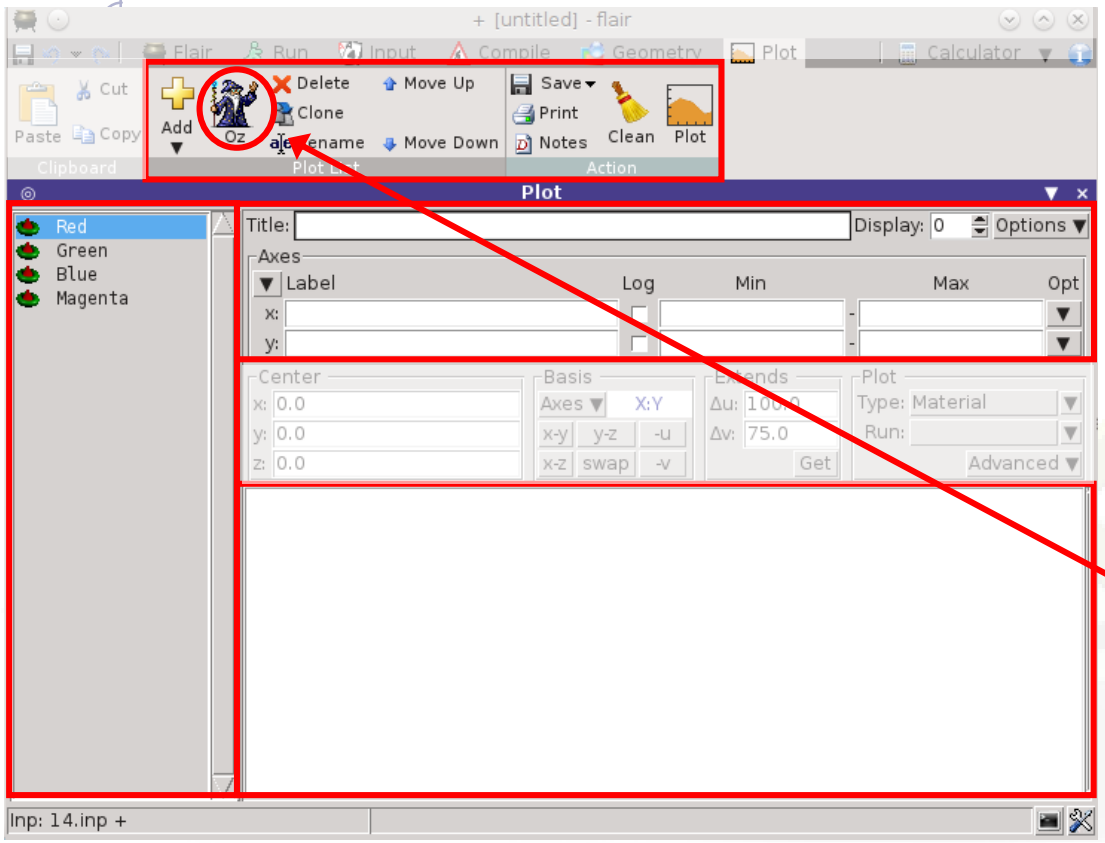
  Process – Files – *select* ***ex_3001.out***

Flair: Data Processing



- Flair initially scans the input for possible unformatted output data for each scoring card. It creates automatic rules for processing (merging).
- **If in the mean time you have modified the input click the "automatic" scan**
- The default names are generated by the rules specified in the preference dialog
- The automatic rules can be modified by manually adding or removing files or by advanced pattern matching with the filter dialog

Plot List

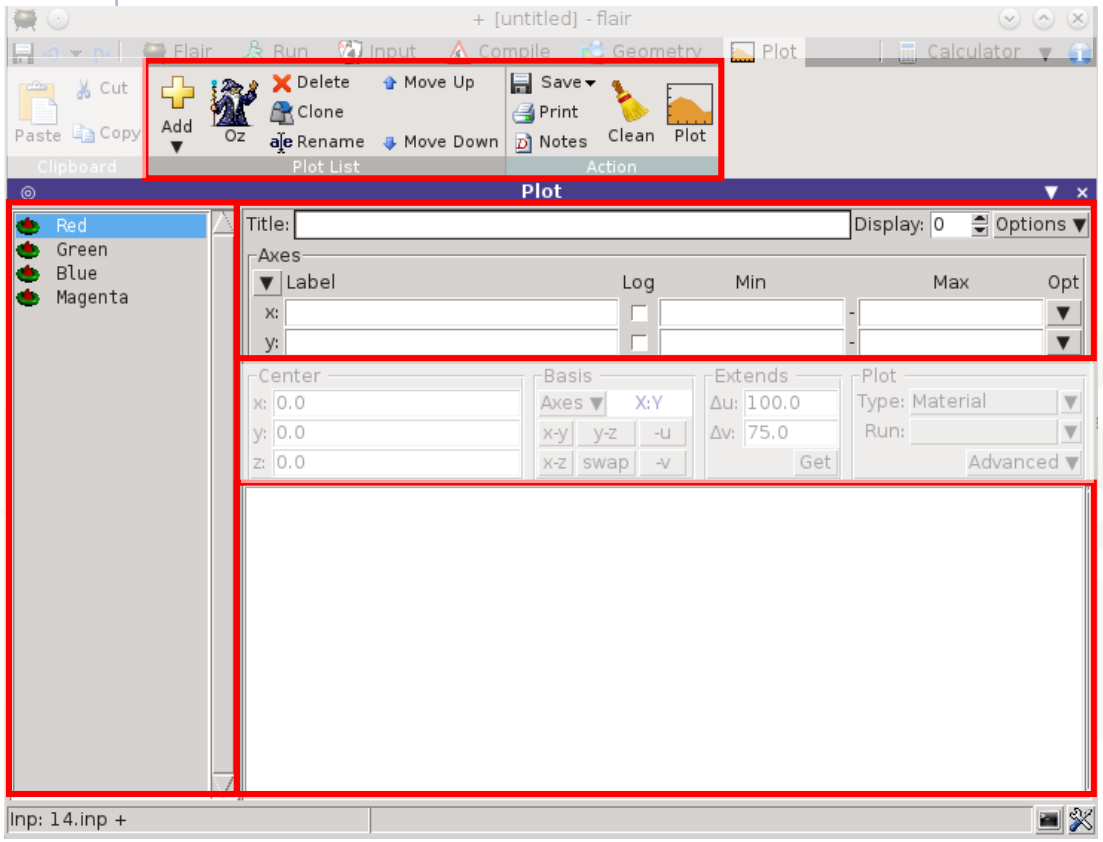


- Plots can be created in the "Plot" list frame. Either Add new plots or Clone from existing ones.
- It is important to set a unique filename for each plot.
  This filename will be used for every auxiliary file that the plot needs (with different extensions)
- The Wizard button creates automatically one plot for each processed unit
- Double click on a plot, or hit Enter or click the Edit icon to display the plotting dialog
- The list box is editable with a "Slow Double Click"
- Right-click brings a popup menu with all options

Plot Types

- Geometry — For geometry plots
- USRBIN — For plotting the output of USRBIN
- USR-1D — To plot single differential quantities from cards USRBDX, USRTRACK, USRCOLL, USRYIELD
- USR-2D — To plot double differential from USRBDX
- RESNUCLE — To plot 1d or 2d distributions of RESNUCLEi
- USERDUMP — To plot the output of USERDUMP. Useful for visualizing the source distribution.

Plotting Frames



- All plot types share some common fields:
  Title + options, Filename, Axis Labels, Legends (Keys) and Gnuplot Commands.
- Plot button (Ctrl-Enter) will generate all the necessary files to display the plot, ONLY if they do not exist.
- All plots are listed in the Plot List
- Notes button adds selected plots to Notes frame at Flair Tab.
- Clean button will remove all files generated by Flair during plotting process.
- Check the Gnuplot manual to provide additional customization commands: e.g. To change the title font to Times size=20, add in the Opt: field the command: font 'Times,20'

General Tips

- To set some default parameters for gnuplot, create a file called ~/.gnuplot
- The output window displays all the commands sent to gnuplot as well as the errors. In case of a problem always consult the output window!
- In the Gnuplot commands you can fully customize the plot by adding manually commands. Please consult the gnuplot manual for available commands
- All buttons and fields have tool tips. Move the cursor on top of a field to get a short description

A brief overview:

biasing

Overview

General concepts:

Analog vs. biased Monte Carlo calculation

Biasing options

(only the most important / common options available in FLUKA)

Importance biasing
Leading particle biasing
Multiplicity tuning
Biasing mean-free paths - decay lengths biasing
- hadronic inelastic interaction lengths

Additional information:

User-written biasing
Weight Windows

Analog vs. Biased - 1

Analog Monte Carlo

- samples from actual phase space distributions
- predicts average quantities and all statistical moments of any order
- preserves correlations and reproduces fluctuations (provided the physics is correct…)
- is *(almost)* safe and can *(sometimes)* be used as "black box"

BUT

- is inefficient and converges very slowly
- fails to predict important contributions due to rare events

Analog vs. Biased - 2

Biased Monte Carlo

- samples from artificial distributions and applies a weight to the particles to correct for the bias
- predicts average quantities, but not the higher moments
  (on the contrary, its goal is to minimize the second moment)
- same mean with smaller variance, *i.e.,* faster convergence

BUT

- cannot reproduce correlations and fluctuations
- requires physical judgment, experience and a good understanding of the problem (it is not a "black box"!)
- in general, a user does not get the definitive result after the first run, but needs to do a series of test runs in order to optimize the biasing parameters

→ balance between user's time and CPU time

Reduce variance or CPU time ?

A Figure of Merit

Computer cost of an estimator = $\sigma^2 \times t$

(σ^2 = Variance, t = CPU time per primary particle)

- some biasing techniques are aiming at reducing σ, others at reducing t
- often reducing σ increases t, and *viceversa*
- therefore, minimizing $\sigma^2 \times t$ means to reduce σ at a faster rate than

  t increases or *viceversa*
- the choice depends on the problem, and sometimes a combination of

  several techniques is most effective
- bad judgment, or excessive "forcing" on one of the two variables can

  have catastrophic consequences on the other one, making

Importance biasing - 1

Input card: BIASING

- it is the simplest, most "safe" and easiest to use of all biasing techniques
- importance biasing combines *two techniques*:

  Surface Splitting (reduces σ but increases *t*)
  Russian Roulette (does the opposite)

- the user assigns a relative importance to each geometry region (the actual absolute value doesn't matter), based on

  1. expected fluence attenuation with respect to other regions
  2. probability of contribution to score by particles entering the region

Importance biasing - 2

Input card: BIASING

Surface Splitting

A particle crosses a region boundary, coming from a region of importance I_1 and entering a region of *higher* importance $I_2 > I_1$:

- the particle is replaced on average by $n=I_2/I_1$ identical particles with the same characteristics
- the weight of each "daughter" is multiplied by I_1/I_2

If I_2/I_1 is too large, excessive splitting may occur with codes which do not provide an appropriate protection .

An internal limit in FLUKA prevents excessive splitting if I_2/I_1 is too large (> 5), a problem found in many biased codes.

Importance biasing - 3

Input card: BIASING

Russian Roulette

A particle crosses a region boundary, coming from a region of importance I_1 and entering a region of *lower* importance $I_2 < I_1$:

- the particle is submitted to a random survival test: with a chance I_2/I_1 the particle survives with its weight increased by a factor I_1/I_2
- with a chance $(1 - I_2/I_1)$ the particle is killed

Importance biasing is commonly used to maintain a uniform particle population, compensating for attenuation due to absorption or distance. In FLUKA it can be tuned per particle type.

Importance biasing - 4

Input card:
BIASING

Note:

In FLUKA, for technical reasons, importances are internally stored as integers. Therefore, importances can only take values between 0.0001 and 100000. An input values 0.00015 is read as 0.0001, 0.00234 is read as 0.0023, *etc.*

There is also a user routine USIMBS which allows to assign importances not only at boundaries, but at each step, according to any logic desired by the user (as a function of position, direction, energy,…).
Very powerful, but *time-consuming* (it is called at each step!). The user must balance the time gained by biasing with that wasted by calls.

Summary of main input cards

BIASING

1) region importance biasing (surface splitting or Russian Roulette)

2) multiplicity tuning at hadronic interactions

EMF-BIAS

leading particle biasing for e+, e- and photon interactions

LAM-BIAS

mean free path biasing (decay length biasing, hadronic interaction length biasing)

A brief overview:

advanced topics

Advance topics

User routines

- source.f (for complex beam geometries, e.g. particle accelerators)
- mgdraw.f
- comscw.f

Implementing Magnetic fields

- blablabla

Import geometries

- CAD
- DICOM (medical applications)
- .....