A few examples with FLUKA

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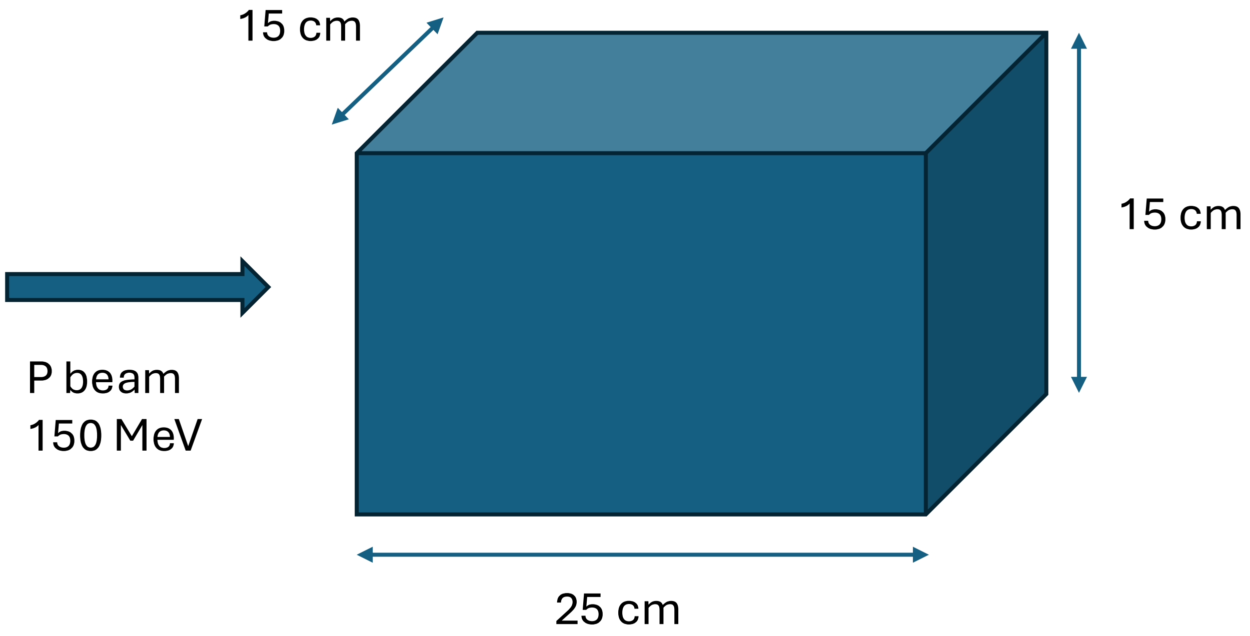
Outline

- Simple radiotherapy exercises: simulated longitudinal Depth Dose Profiles in a water phantom using:
  - Photons
  - Protons
  - ^{12}C ions
- An advanced radiotherapy case: a proton beam on a real patient case
- Simple nuclear medicine example: a ^{18}F source in a water phantom

1) Predicting the Longitudinal Profile of Dose deposited by a proton beam in a water phantom



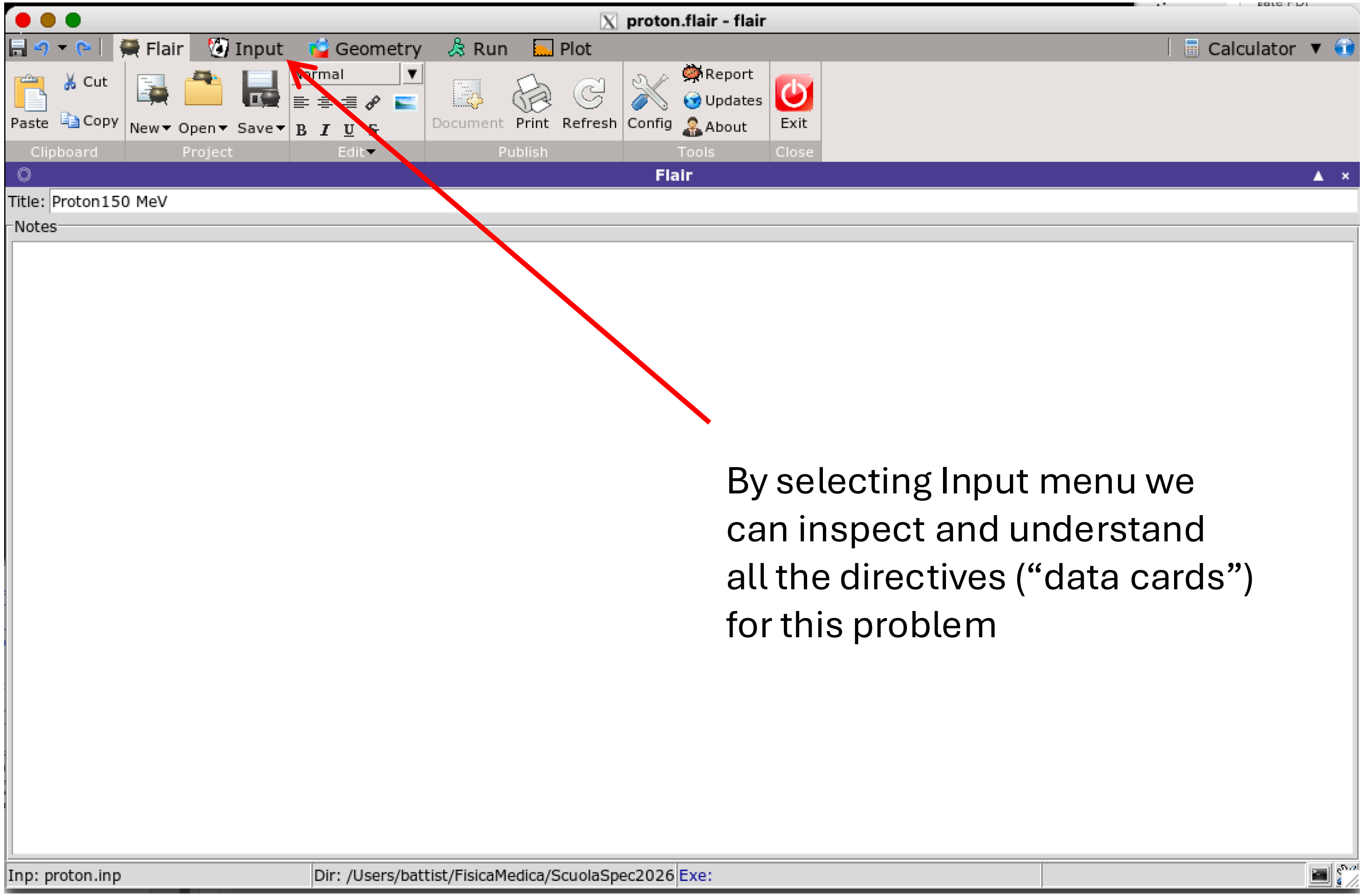
FLUKA input:
proton.inp

We can manage this simple problem by means of Flair, the graphical user interfcace of FLUKA

It is a tool based on Python3, Gnuplot and C++ programming languages which allows users to manage most of simulation cases without any need of code programming

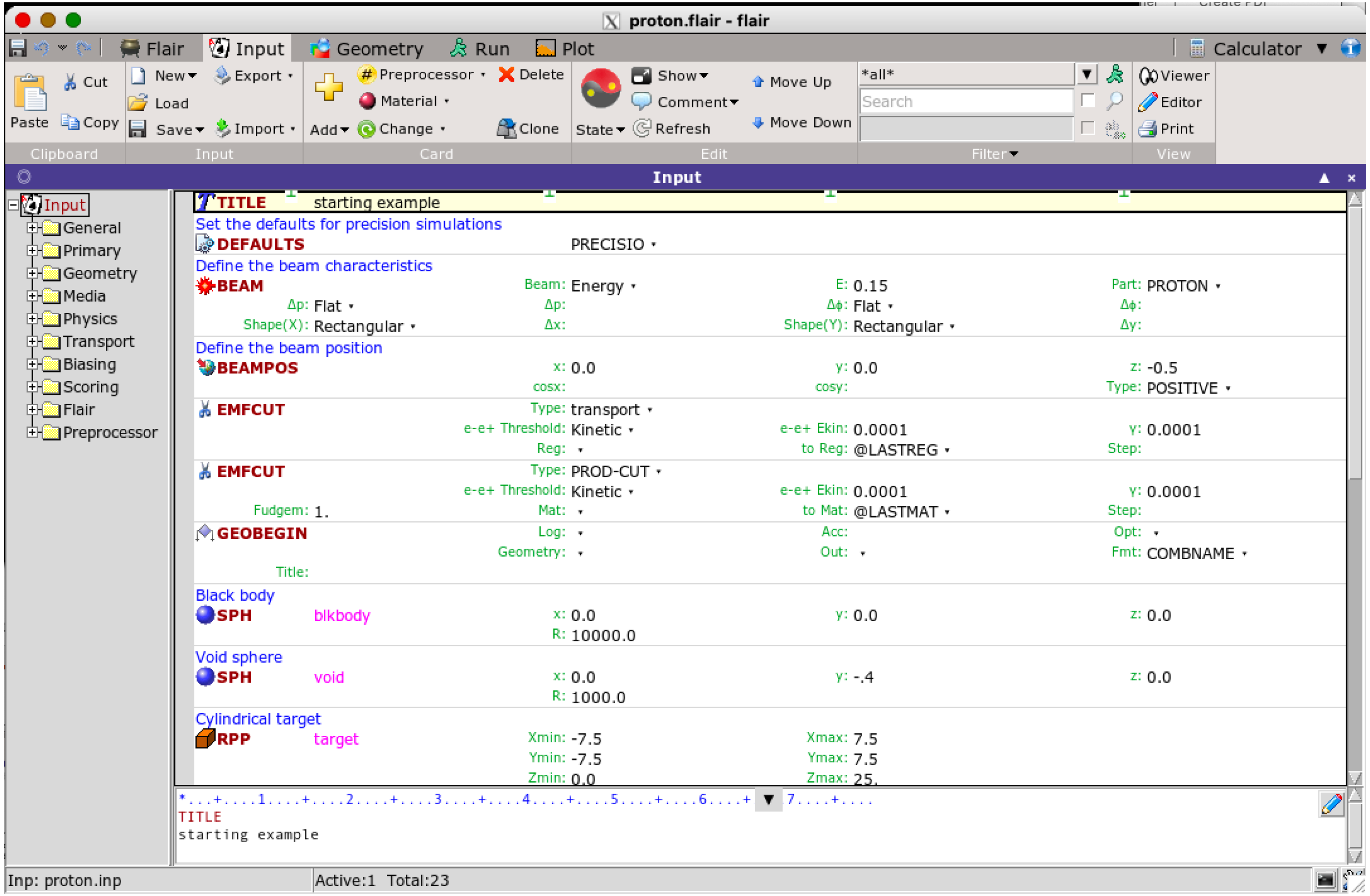
FLAIR

In a terminal window we just give the line command:
flair proton.inp

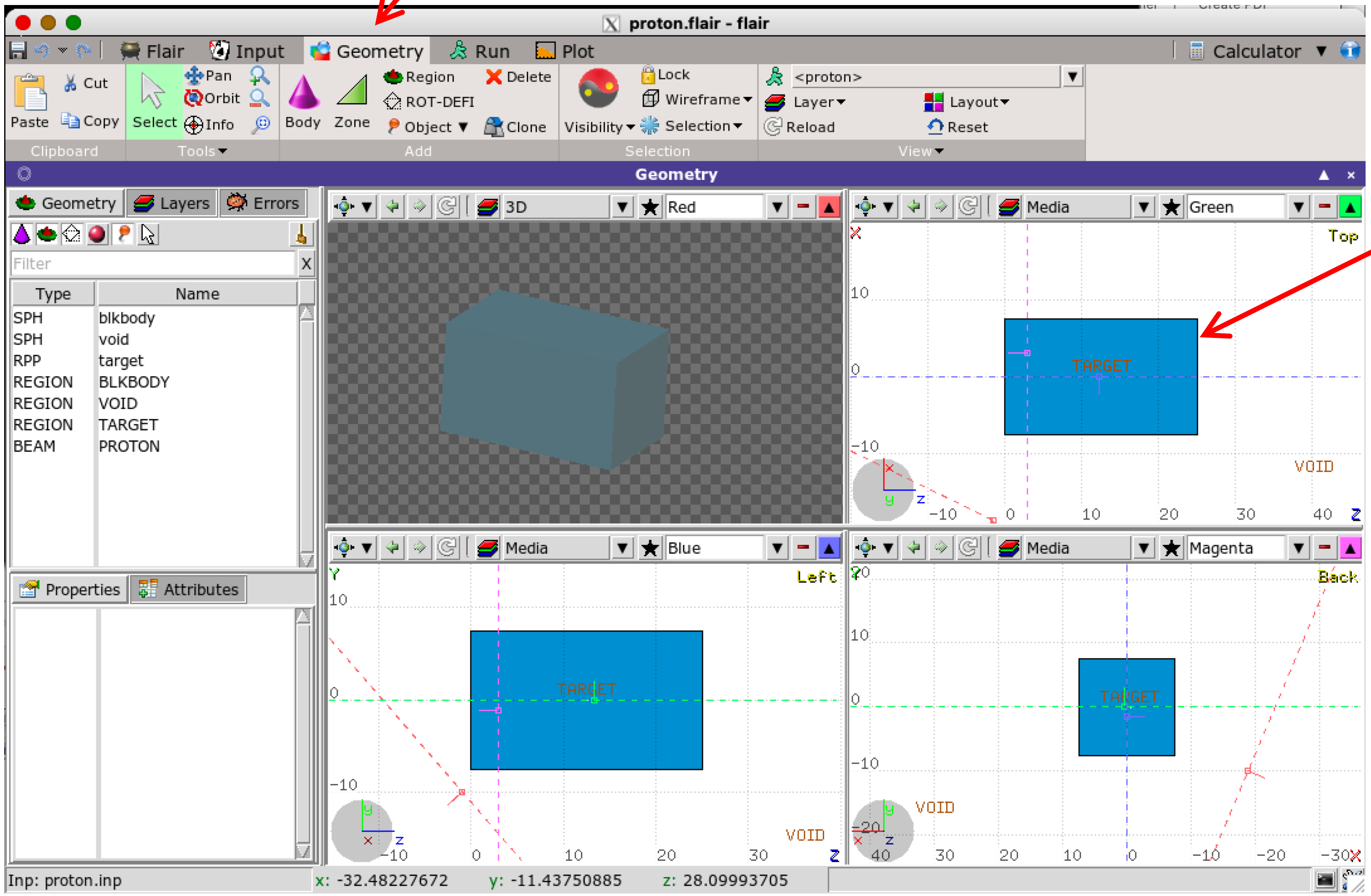


By selecting Input menu we can inspect and understand all the directives ("data cards") for this problem

The input data cards



The geometry viewer



You can have different cartesian projections, 3D views, and other options

Different colors represent different materials

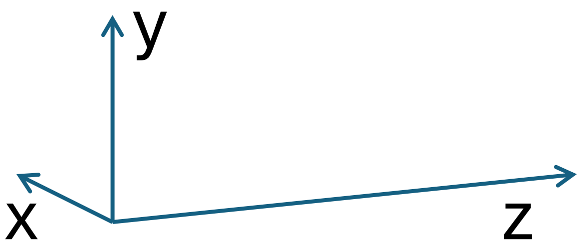
Important to know in advance

FLUKA units

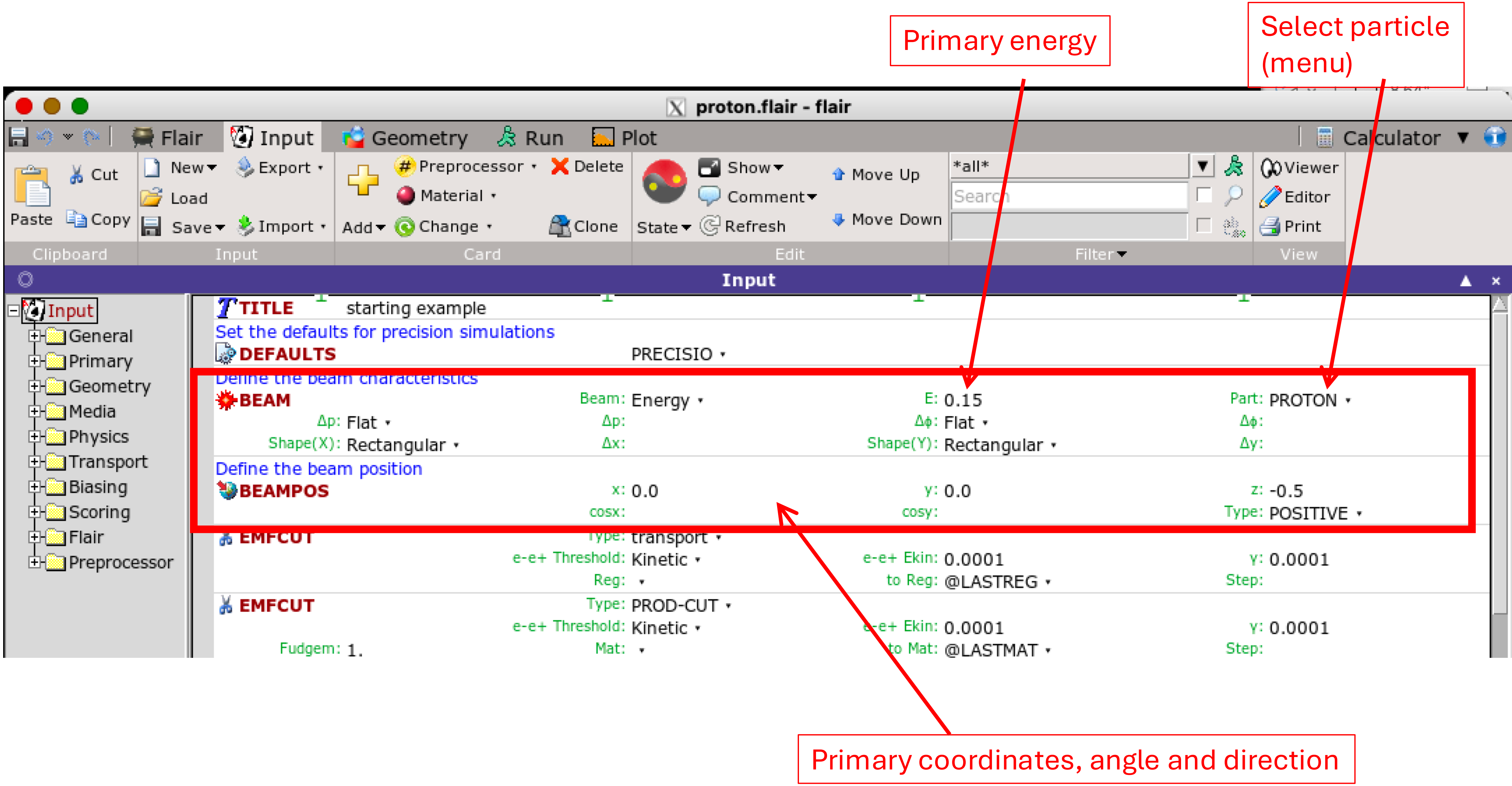
- time ➞ s
- length ➞ cm
- energy ➞ GeV
- masses ➞ GeV/c^2
- B ➞ Tesla

Reference frame (cartesian, right-handed)

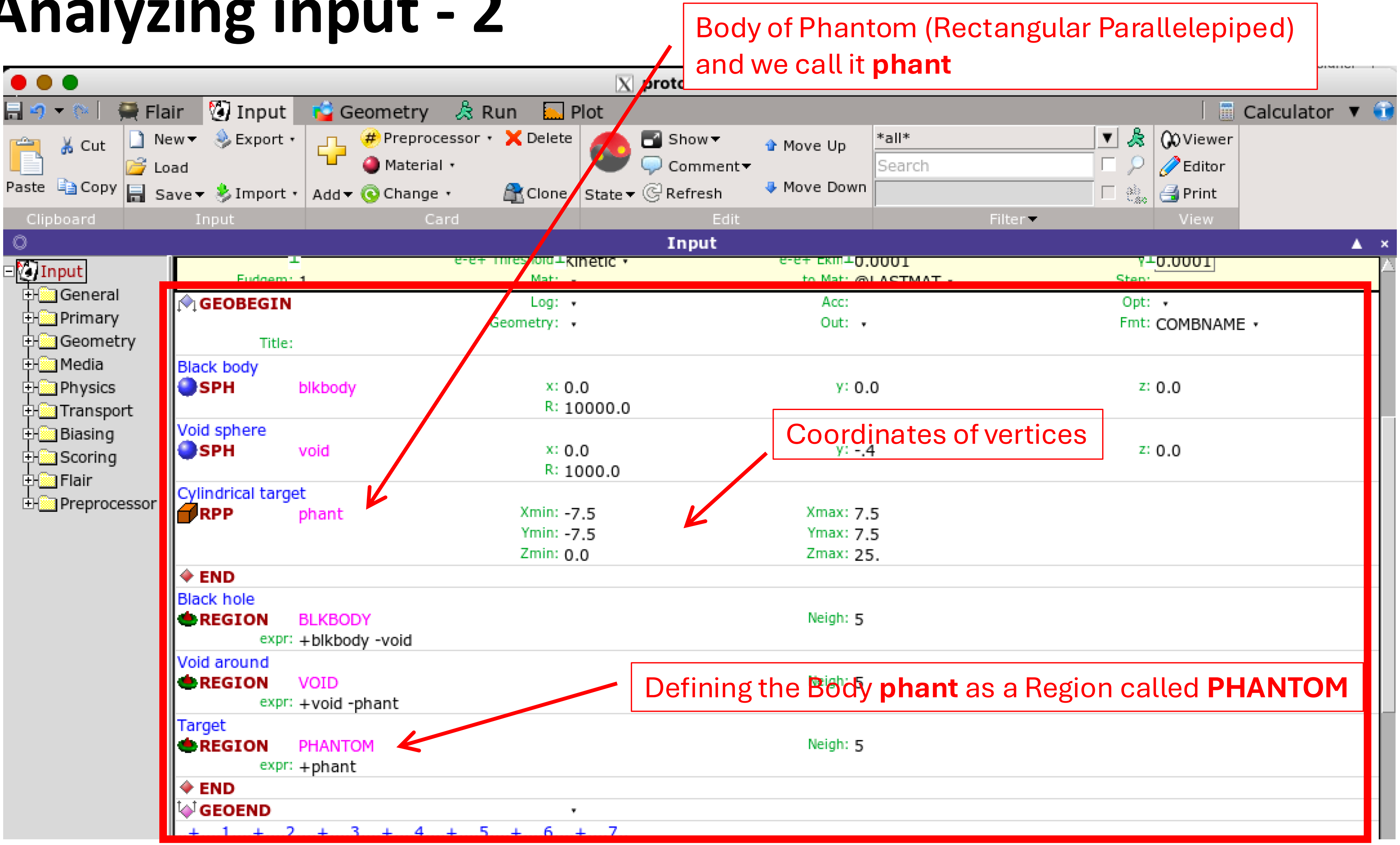
- z is the default primary beam direction (can be changed)
- y is pointing upwards



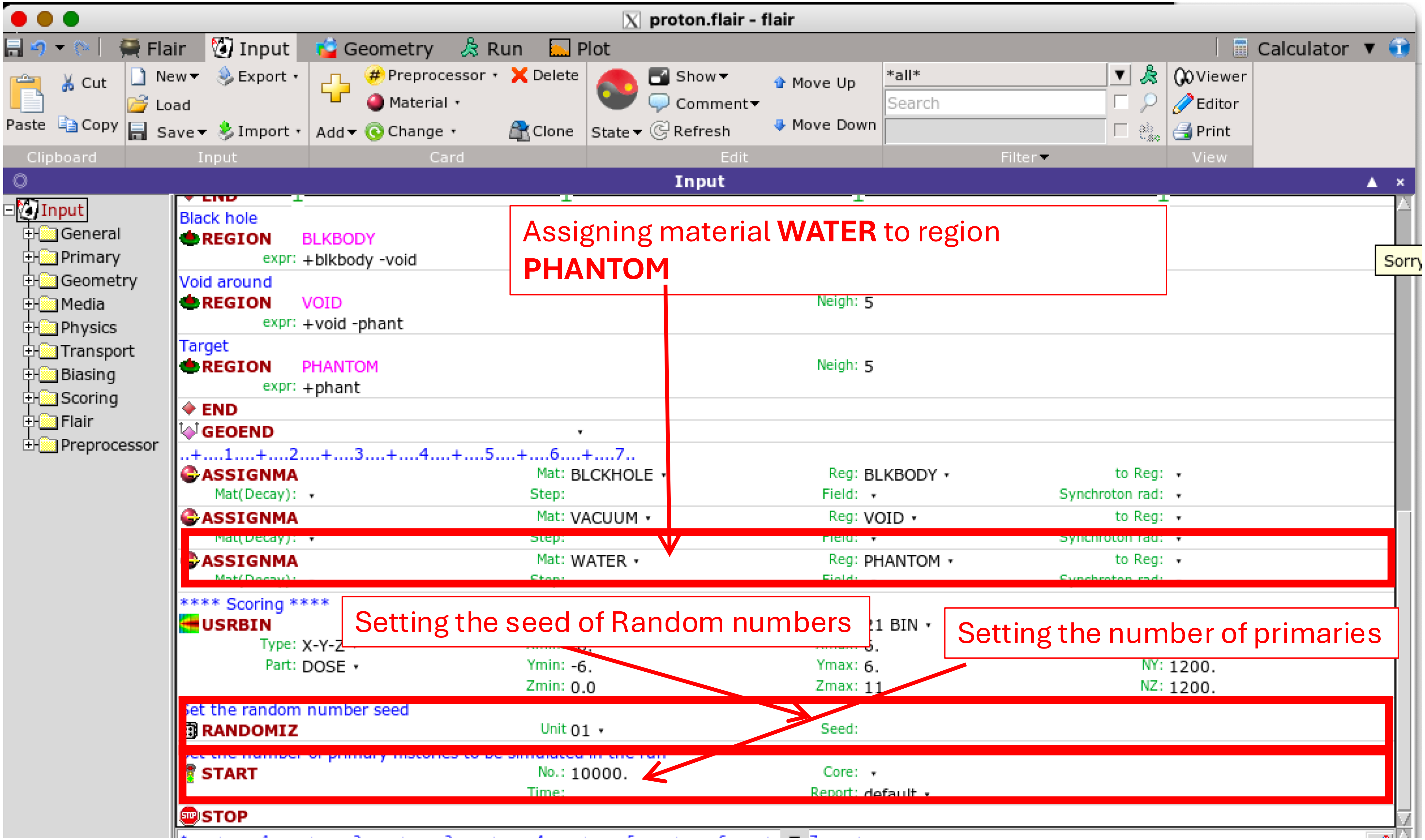
Analyzing input - 1



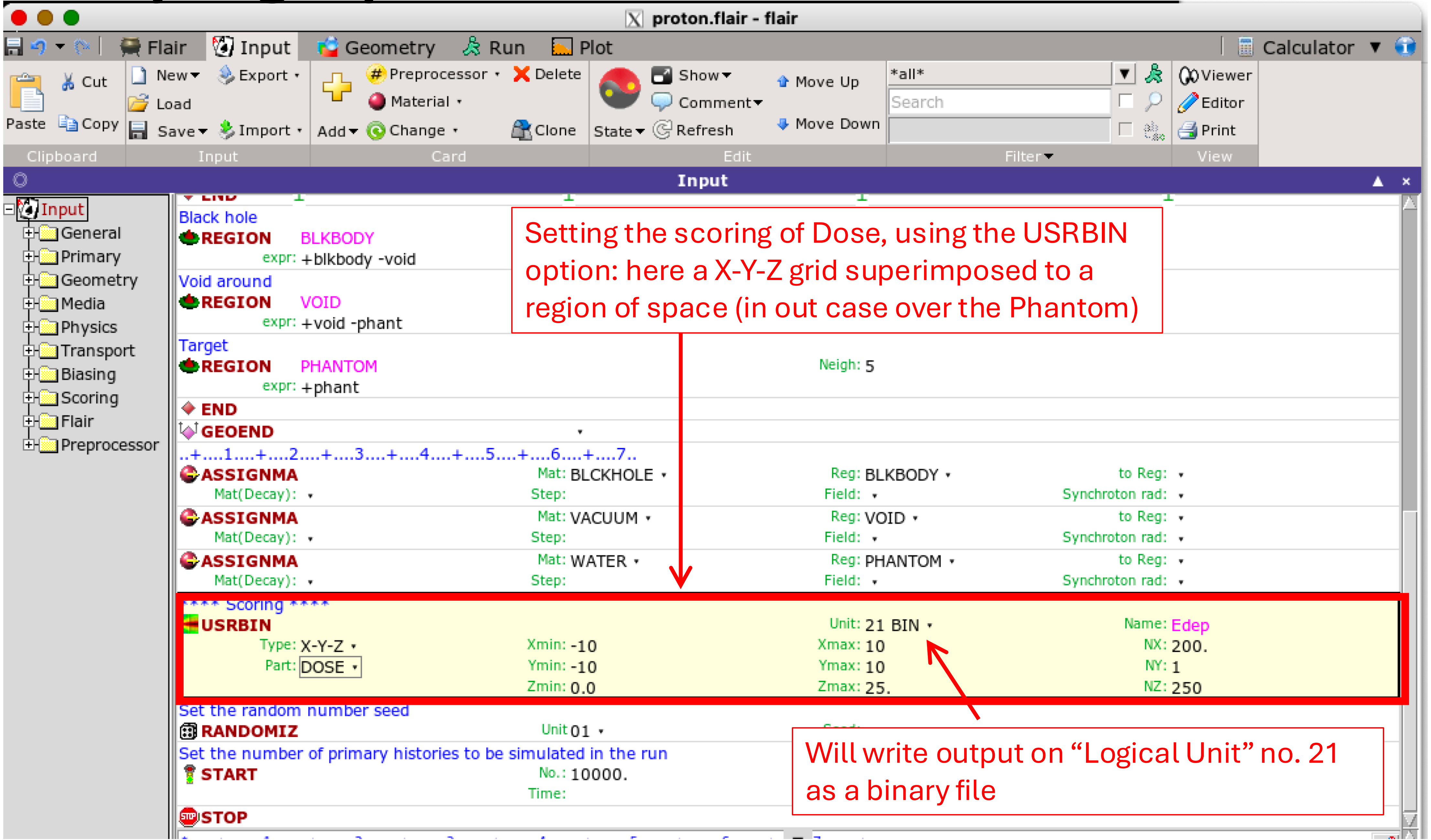
Analyzing input - 2



Analyzing input - 3



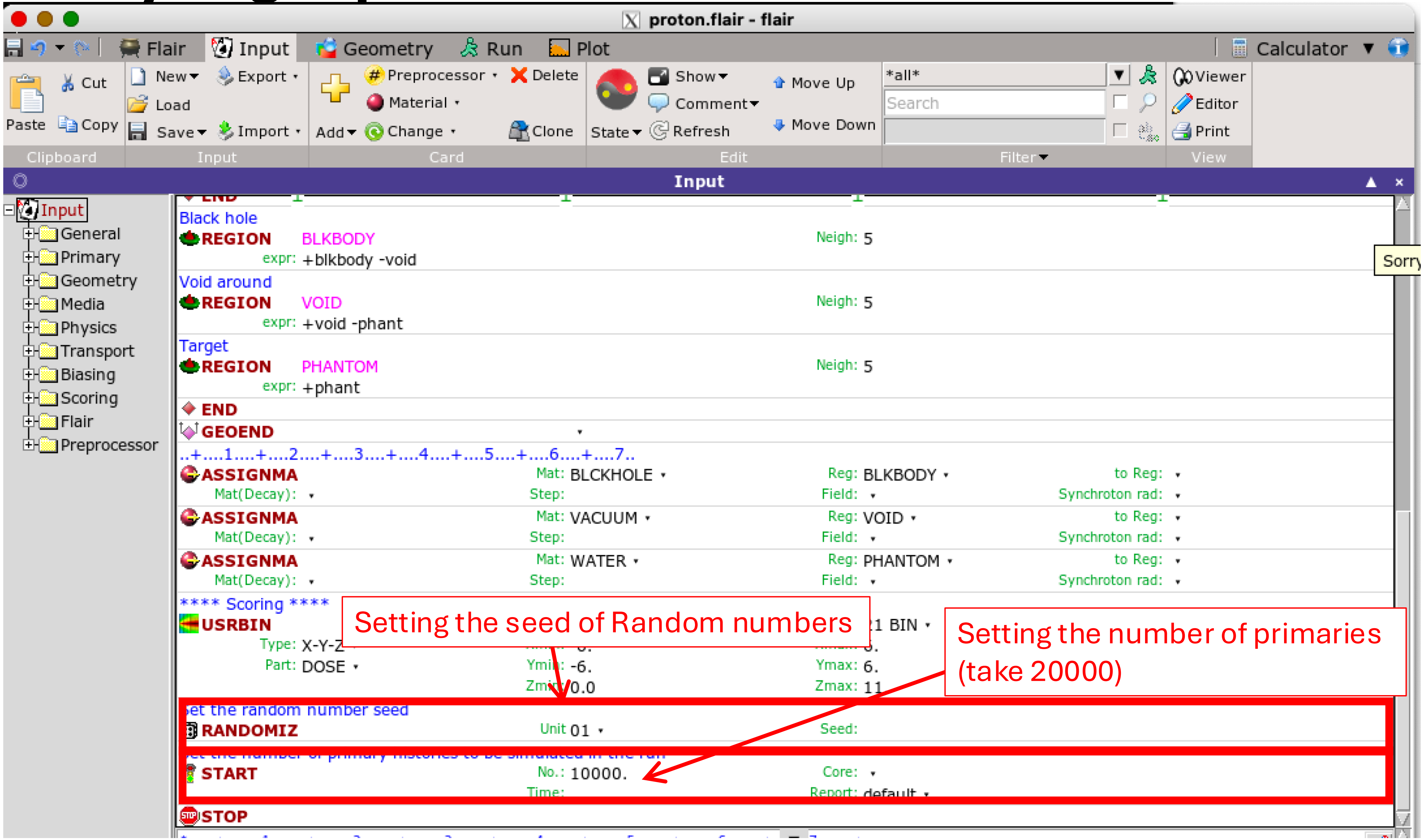
Analyzing input - 4



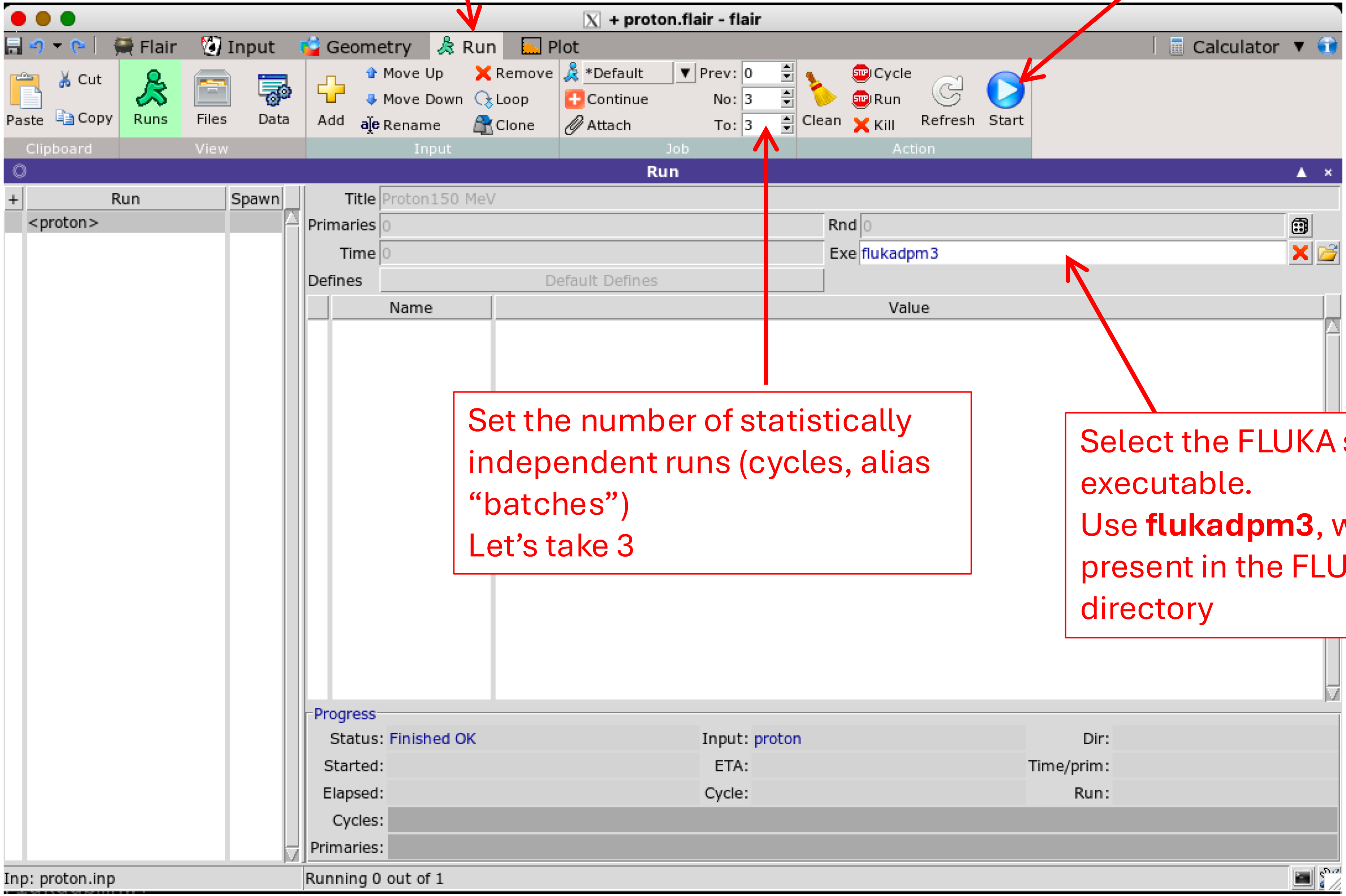
Setting the scoring of Dose, using the USRBIN option: here a X-Y-Z grid superimposed to a region of space (in out case over the Phantom)

Will write output on “Logical Unit” no. 21 as a binary file

Analyzing input - 5



Managing the simulation run

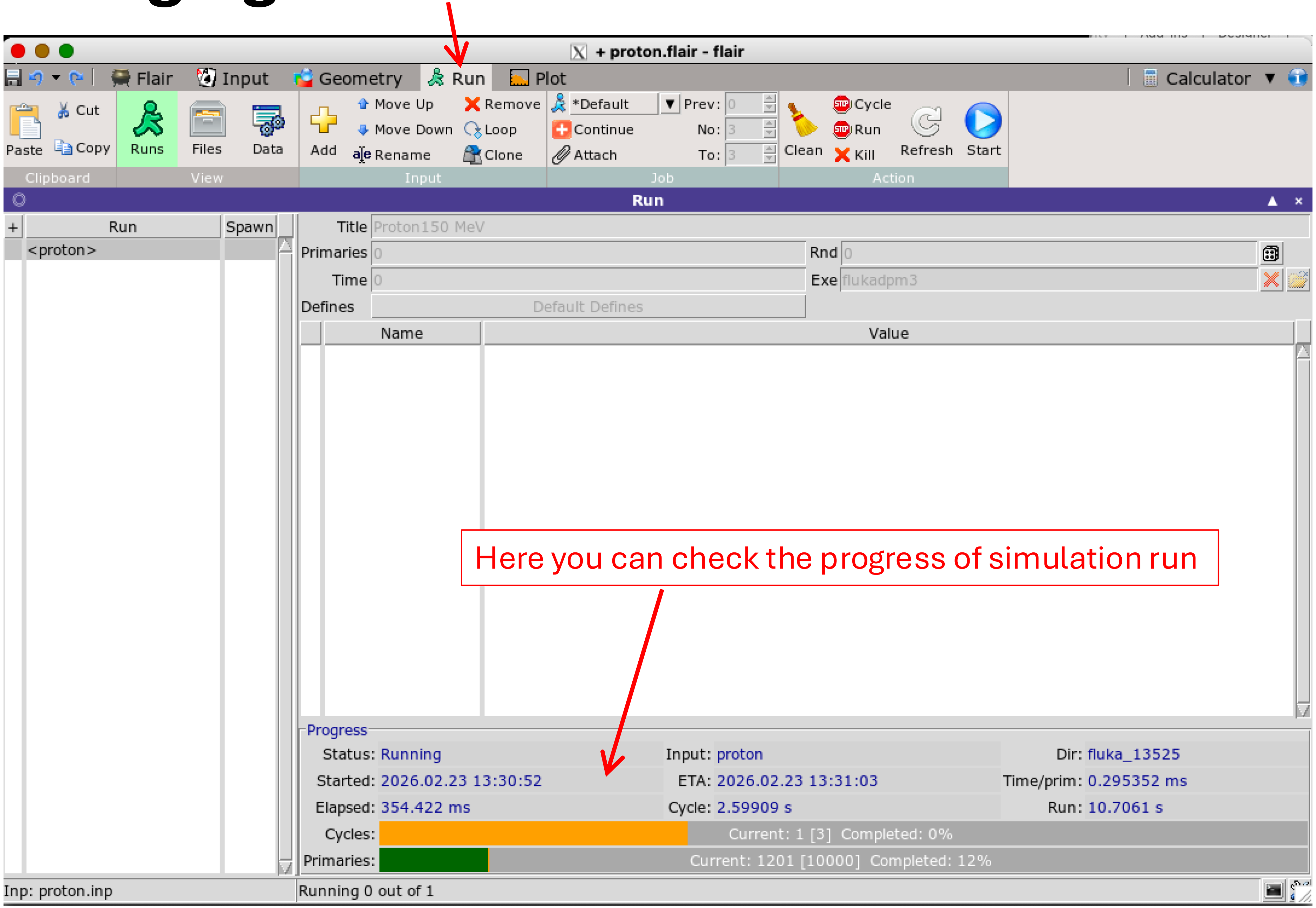


Start button

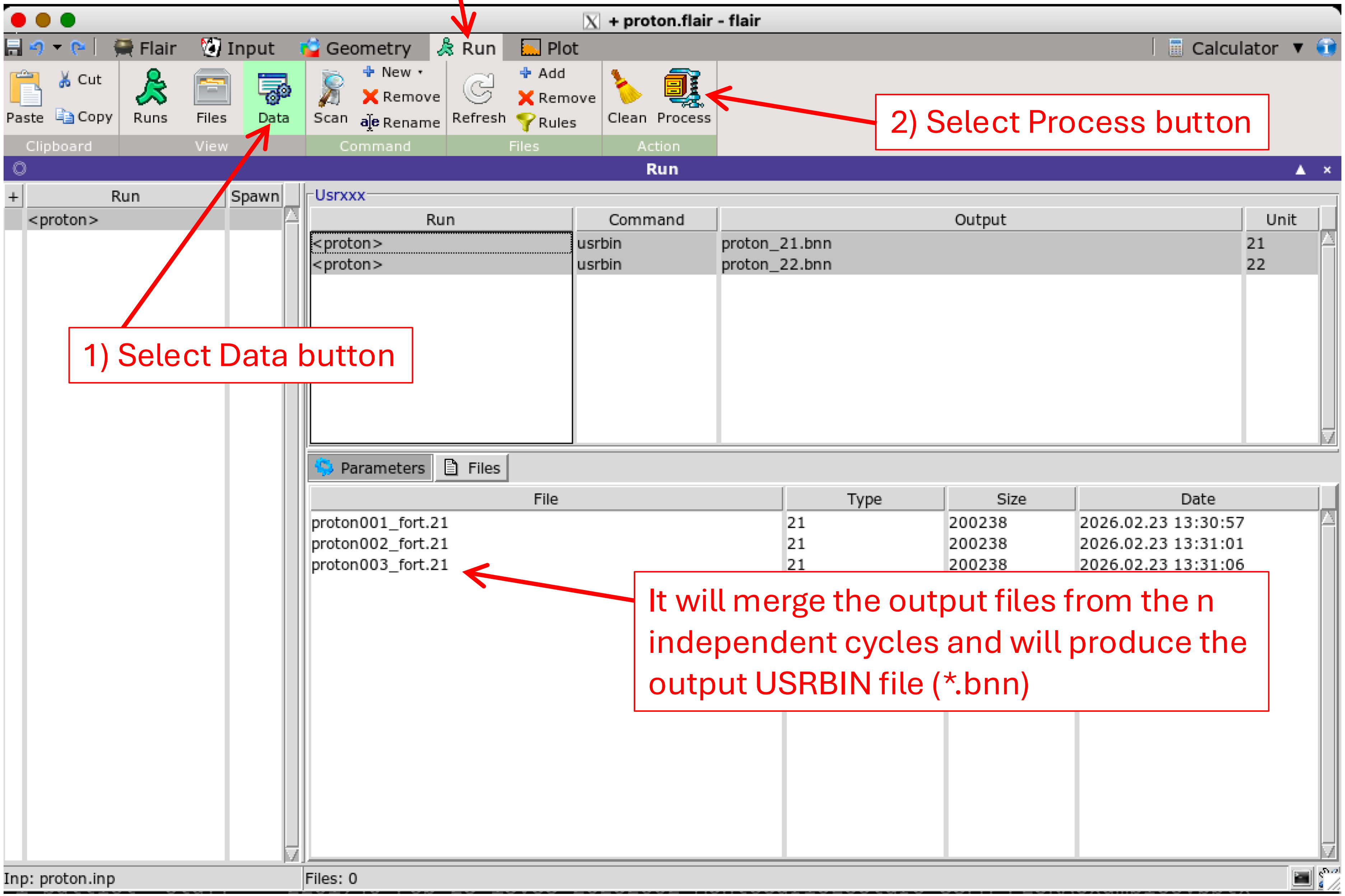
Set the number of statistically independent runs (cycles, alias "batches")
Let's take 3

Select the FLUKA standard executable.
Use **flukadpm3**, which is present in the FLUKA installation directory

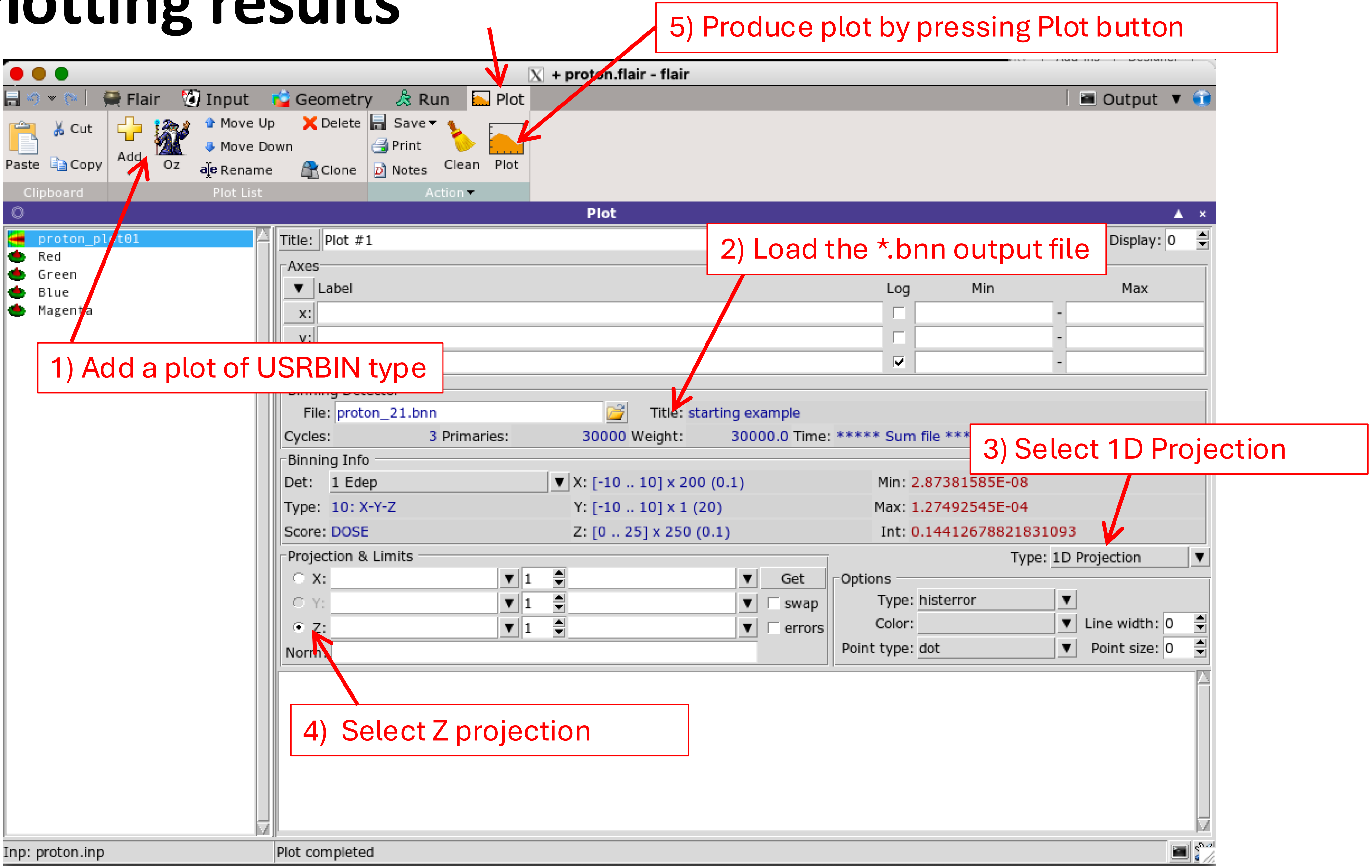
Managing the simulation run



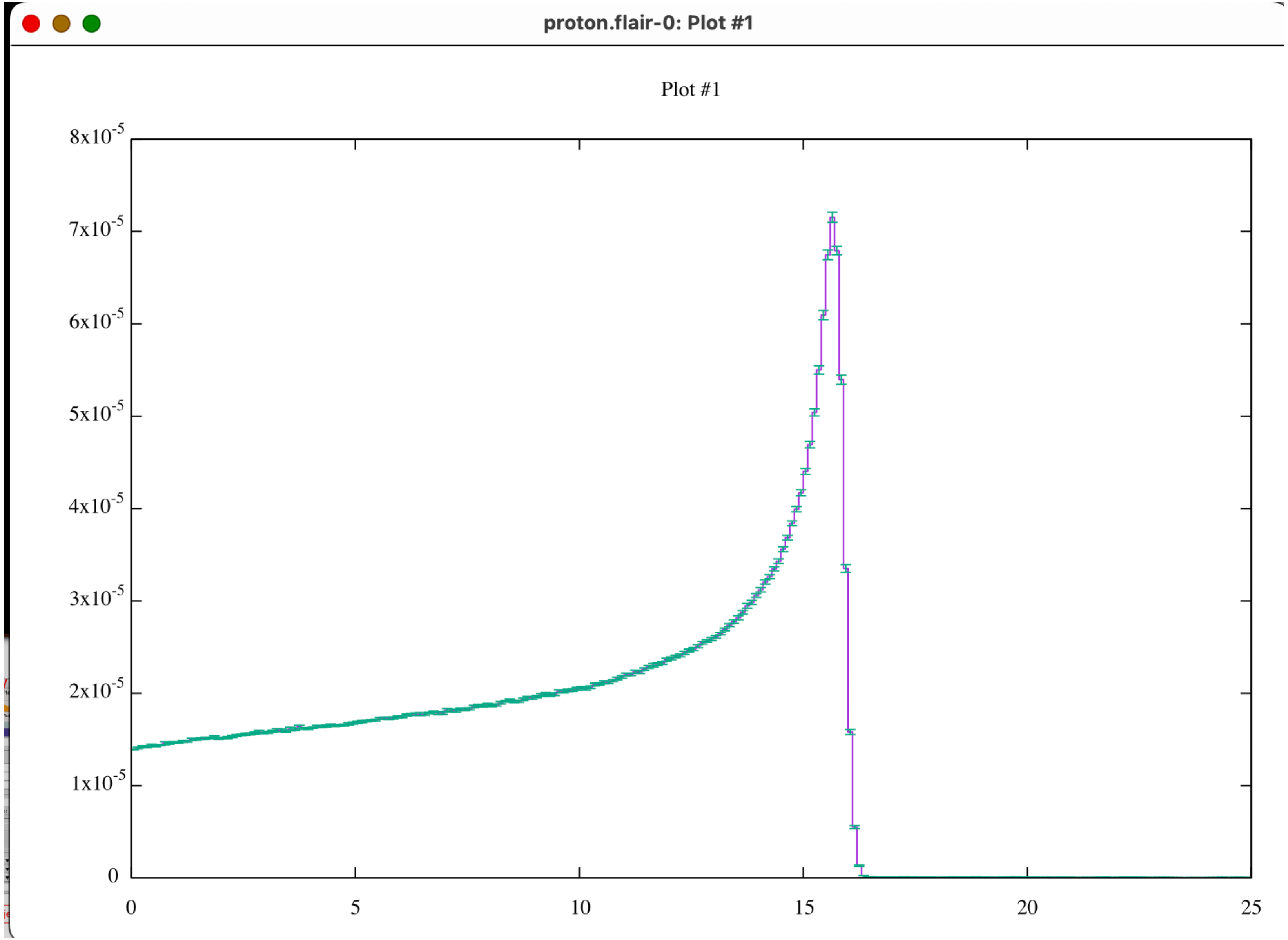
Post-processing of results when the run is finished



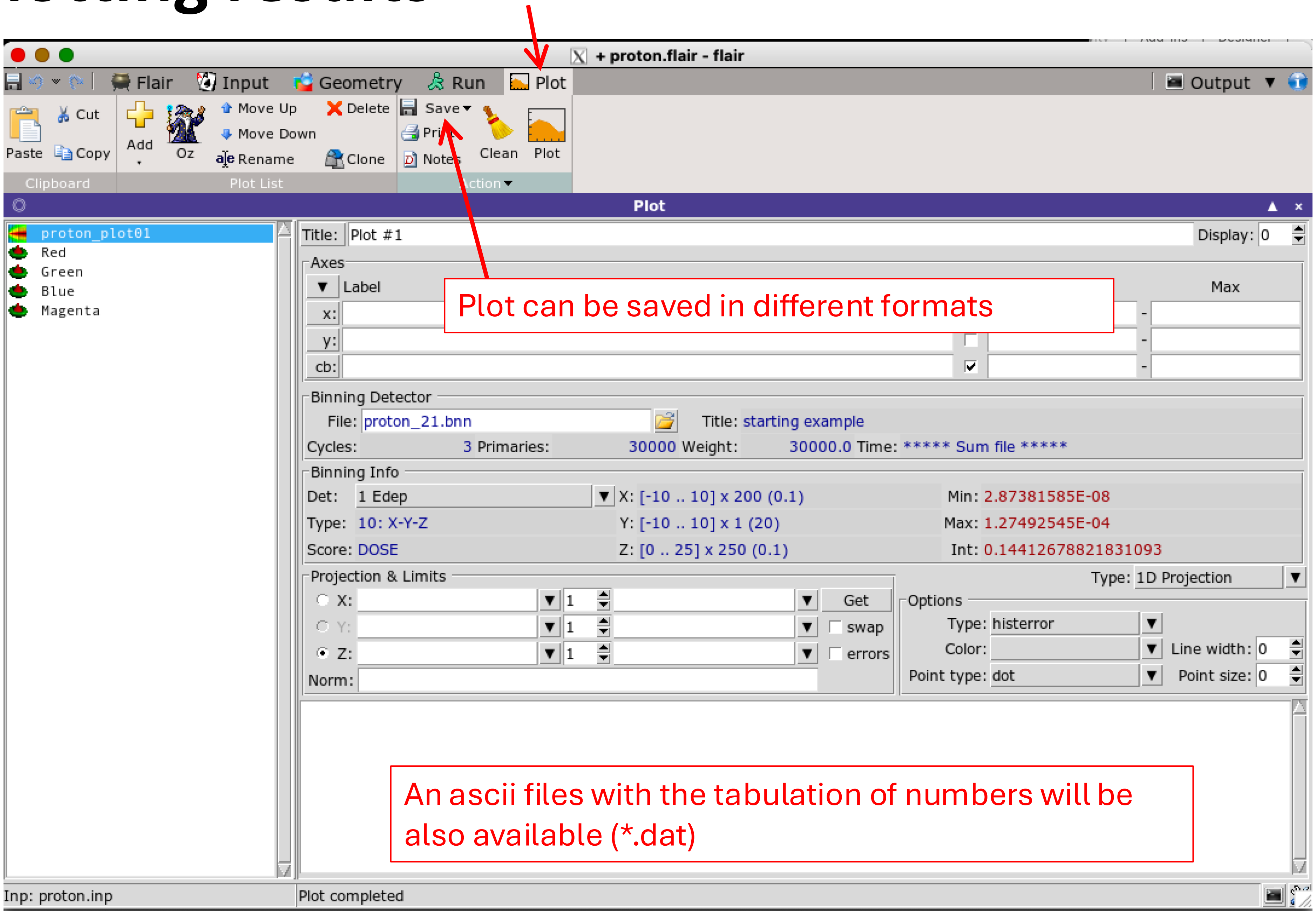
Plotting results



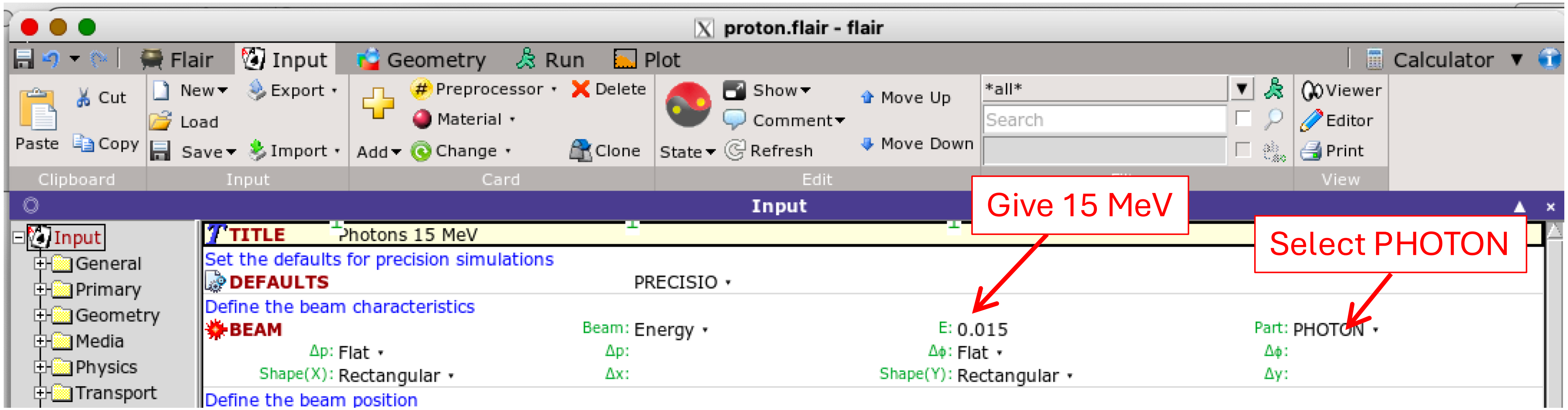
Plotting results



Plotting results

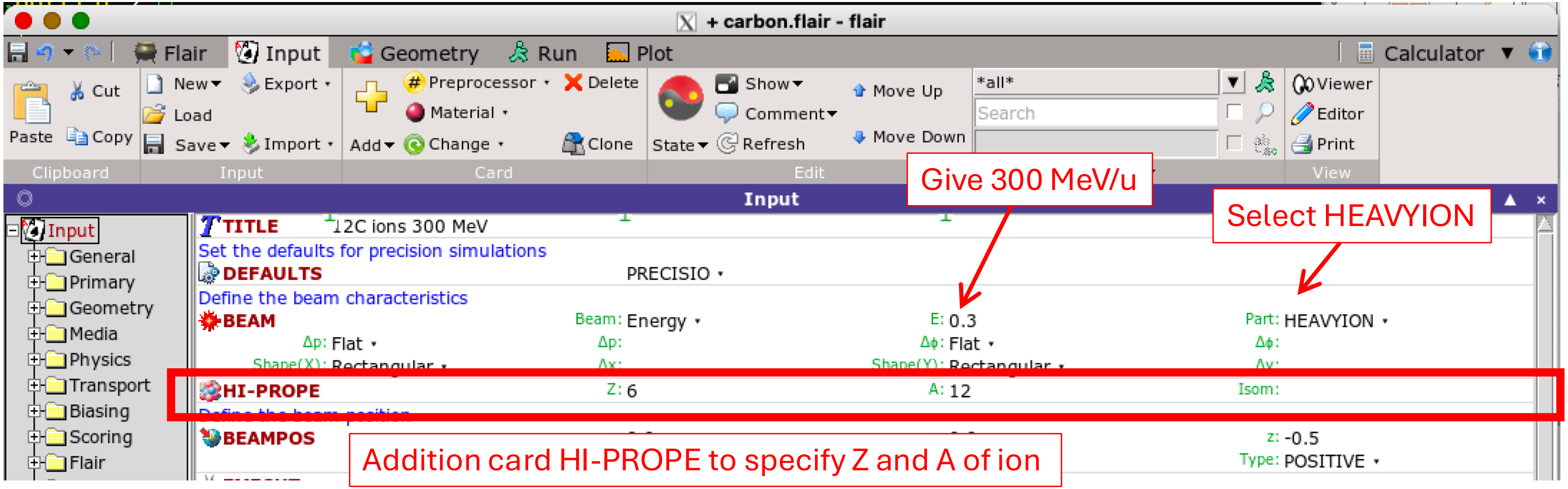


Same exercise for photons



In case of photons use at least 50000 primaries/cycle

Same exercise for ^{12}C ions

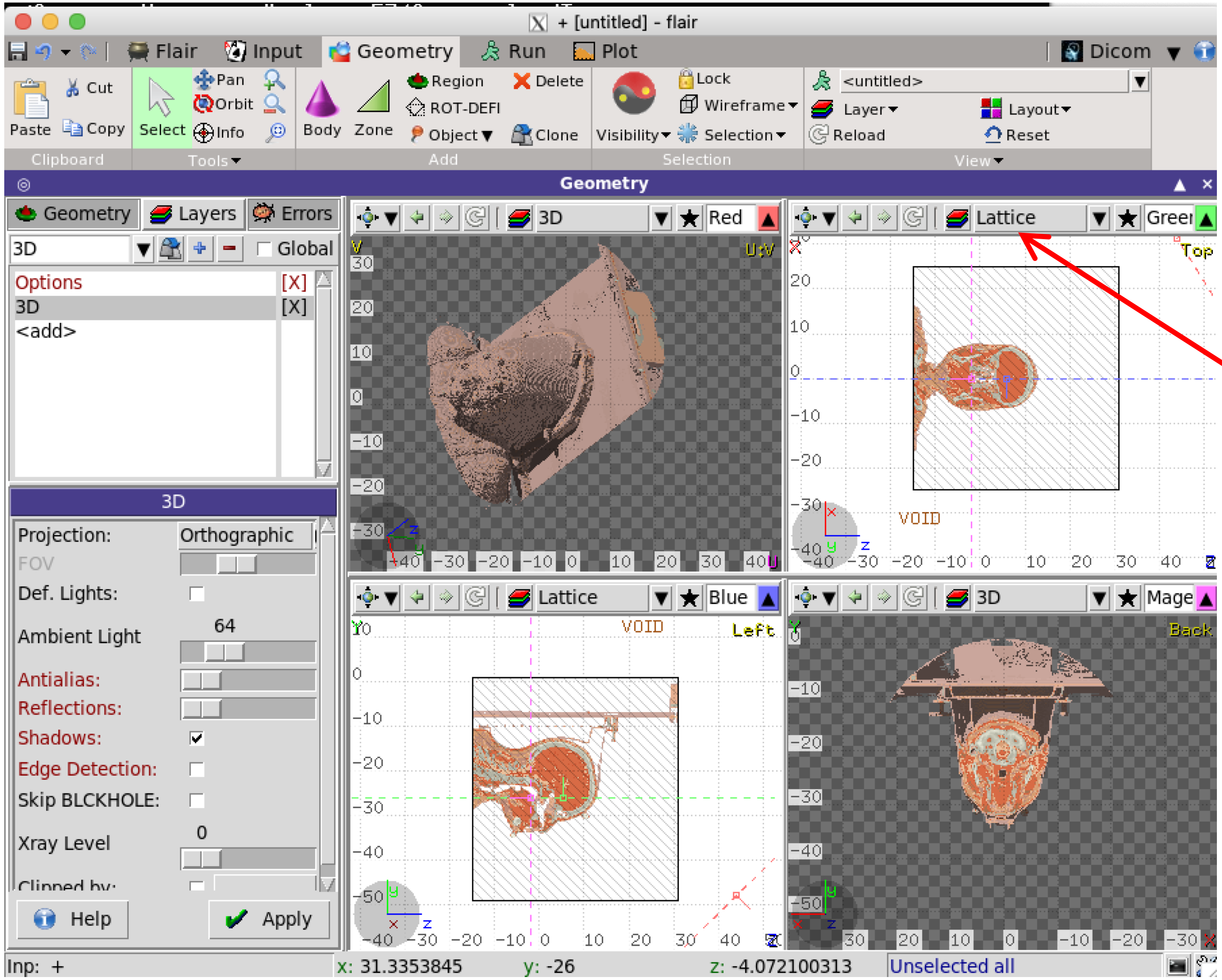


In case of carbon ions use ~5000 primaries/cycle
(longer CPU time/primary is needed for Nucleus-Nucleus interactions)

In the case of nuclei like Deuterium, Tritium, ^{3}He and ^{4}He, specific particles exist, and energy has to be given as total kinetic energy
For all other nuclei, HEAVYION + HI-PROPE have to be used, and kin. energy has to be given as energy/nucleon

2) A patient case example

flair dicom.inp Or even better: flair dicom.flair

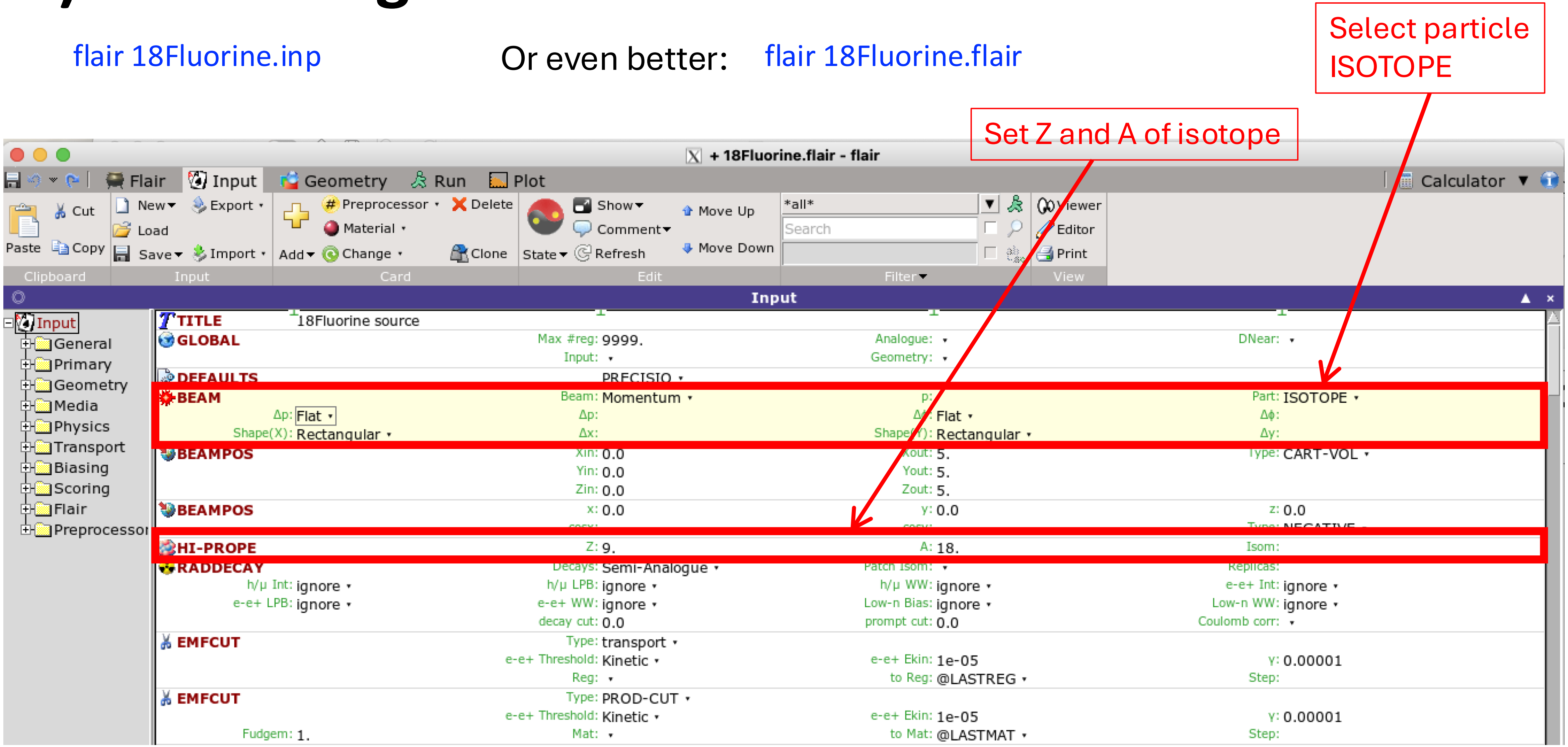


Use 3D or Lattice visualization layers

This is a voxel geometry obtained from a CT dicom file

3) Simulating a radionuclide: ^{18}Fluorine source

flair 18Fluorine.inp Or even better: flair 18Fluorine.flair

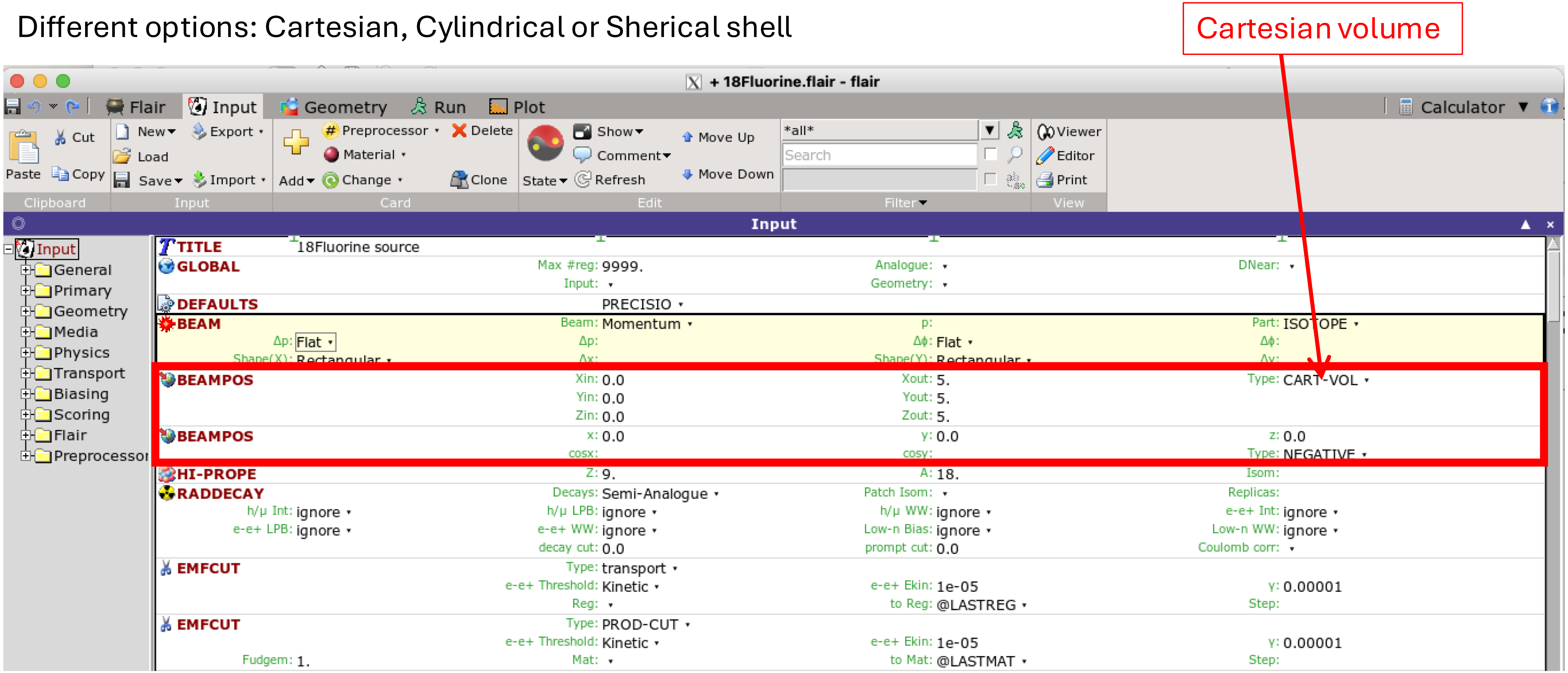


The command defines a spatially extended source shaped as a Cartesian shell with the edges parallel to the axes of the reference.

The outer and the inner parallelepiped are centred at a x,y,z point defined by another BEAMPOSit command, which also sets the particle direction by means of a SDUM blank or = NEGATIVE.

The particle angular distribution, or lack of it, is defined by the BEAM card.

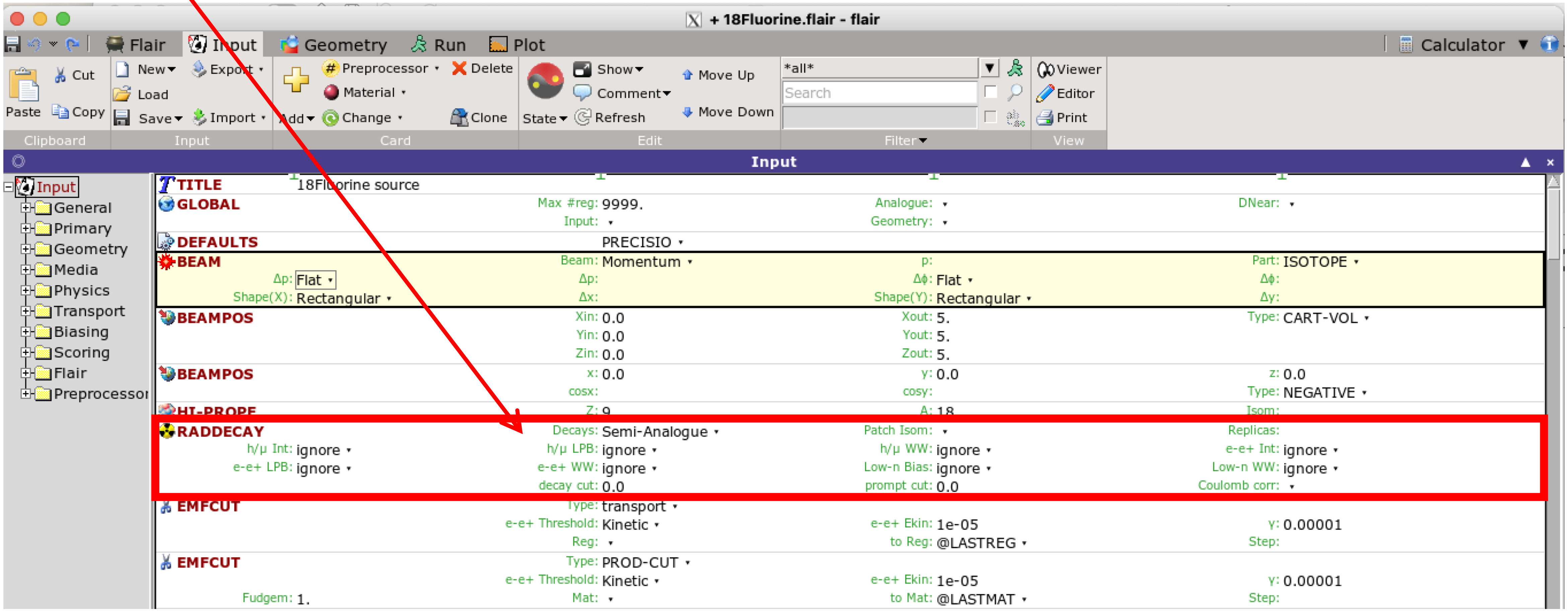
Different options: Cartesian, Cylindrical or Sherical shell



Radioactive decay in semi-analogue mode

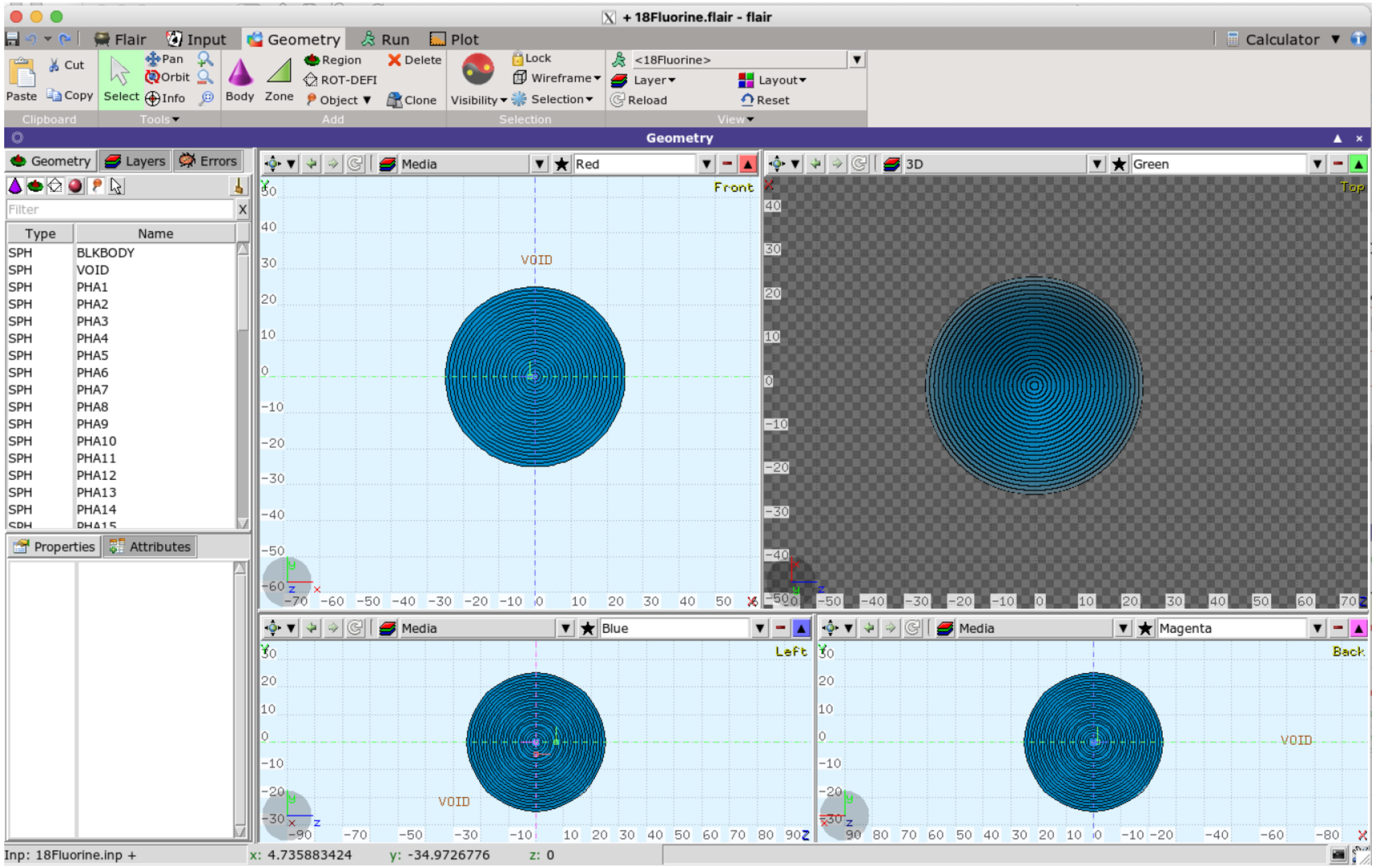
In the semi-analogue mode, each single radioactive nucleus is treated in a Monte Carlo way like all other unstable particles: a random decay time, random daughters, random radiation are selected and tracked.

This allows for event-by-event analysis, with the time structure recorded in the particles age variable.



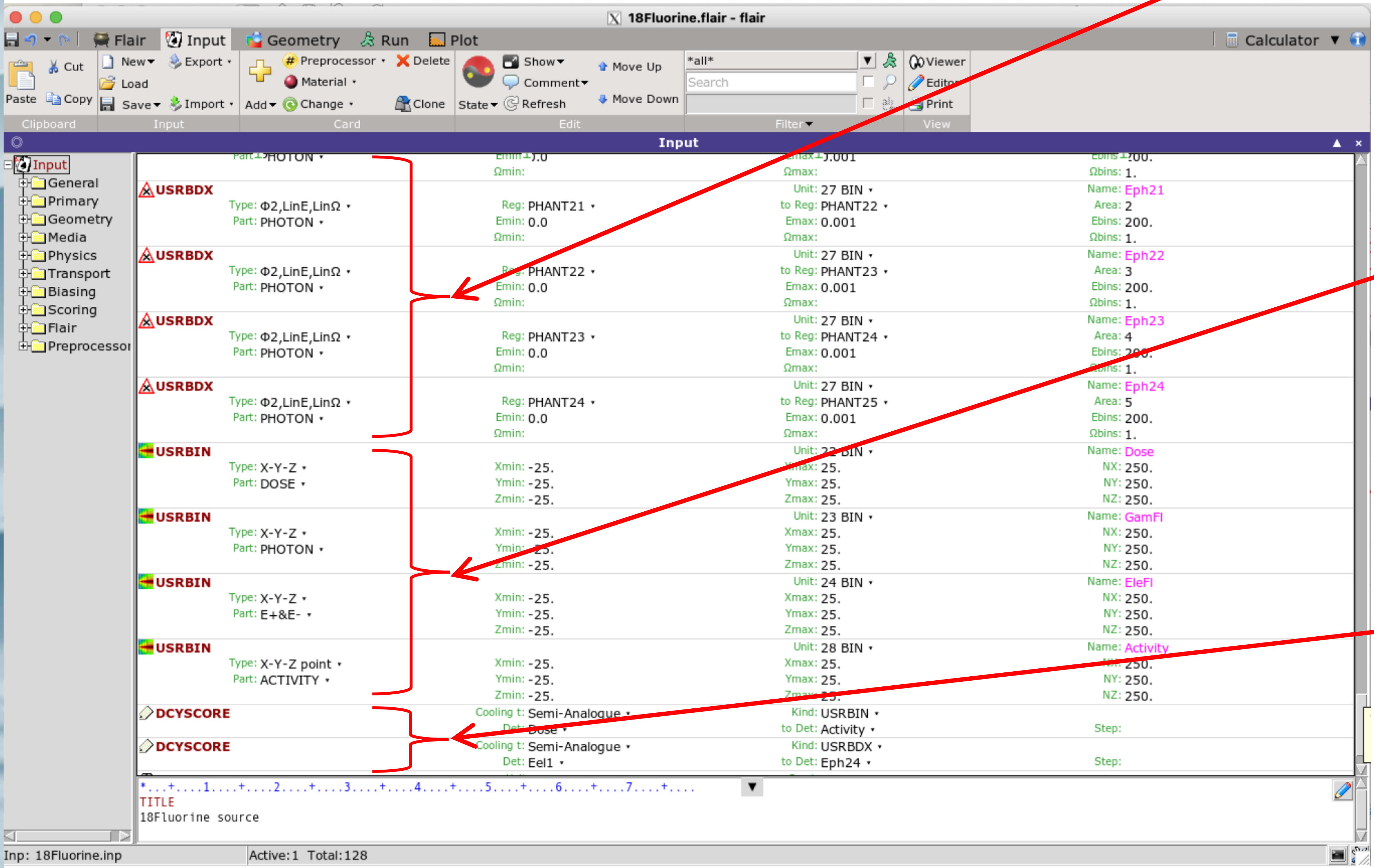
Geometry

Spherical Phantom: water
25 spherical shells



Scoring

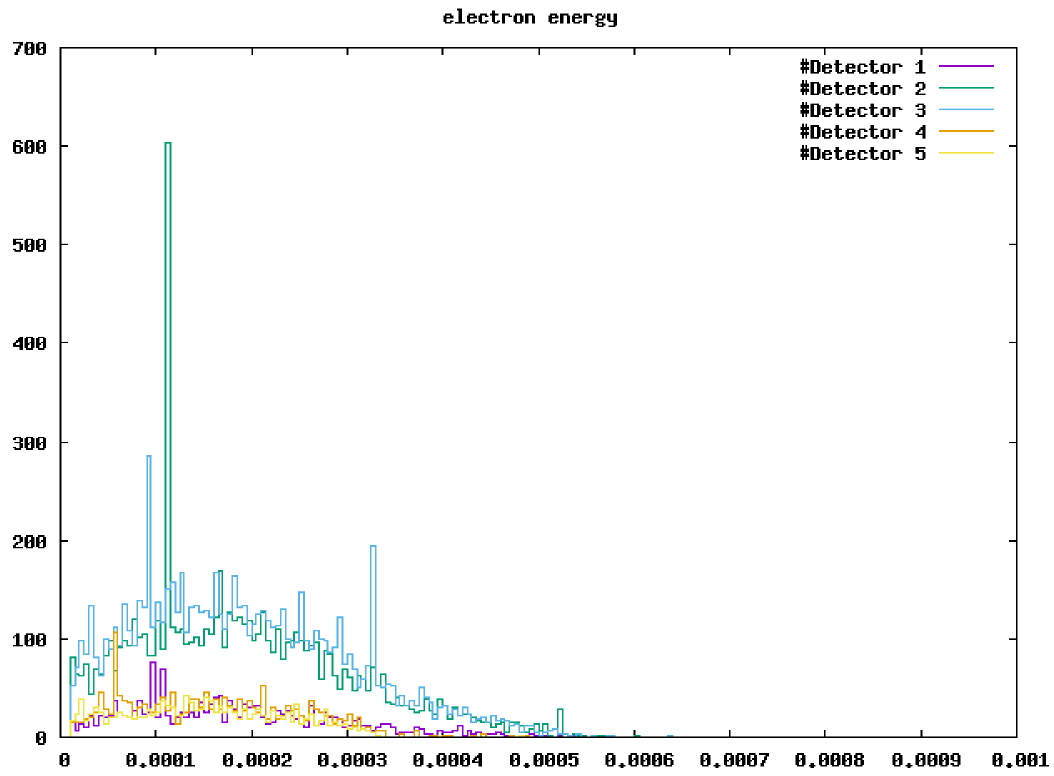
At the boundary of the phantom shells: electrons-positrons (unit 26) and photons (unit 27) two-way fluence scoring (linear binning in energy and solid angle)

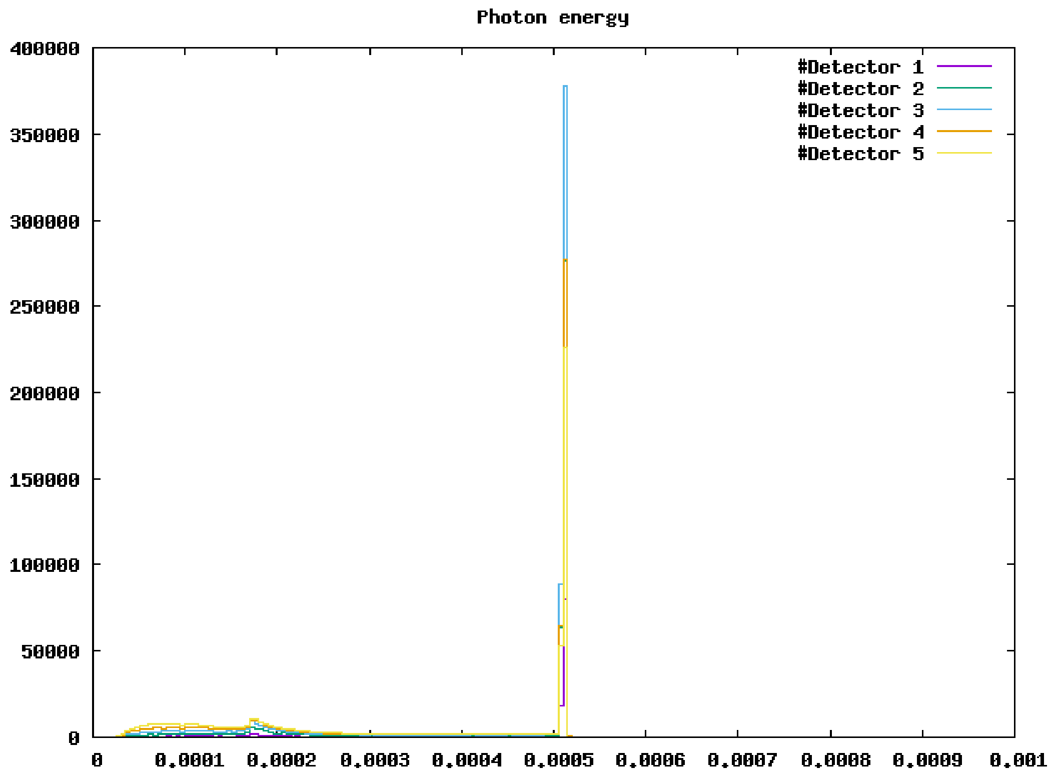


On the source volume:
Dose (unit 22), photon fluence (unit 23), electron-positron fluence (unit 24), activity (unit 28)

DCYSCORE:
Necessary to bound decay products to the scoring

Boundary fluence plots





2-D Dose and fluence plots