CURSO INTRODUTÓRIO

FLUKA

23 DE JANEIRO A 8 DE MARÇO DE 2023

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AULA 06
Detectores – USRBDX/USRDUMP

Iniciaremos em breve

Código Monte Carlo de interação e transporte de partículas

23 FLUKA 2023

08

CNPEM MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÃO

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Scoring physics quantities [II]

Differential spectra (**USRTRACK**, **USRYIELD**, **USRBDX**)

FLUKA scoring

- It is said that Monte Carlo (MC) is a **“mathematical experiment”**; the MC equivalent of the result of a real experiment (*i.e.*, of a **measurement**) is called an **estimator**

- Just as a real measurement, an estimator is obtained by sampling from a statistical distribution and has a **statistical error** (and in general also a **systematic** one)

- There are often several different techniques to measure the same physical quantity: in the same way, **the same quantity can also be calculated using different kinds of estimators**

- FLUKA offers **numerous different estimators**, *i.e.* **scoring** for various quantities of interest can be requested directly from the input file

FLUKA scoring

What?

Energy deposition and derivatives (dose), fluence or current versus energy, angle or other kinematic variables, time, DPA, residual activity…

Where?

In regions, across boundaries, on region-independent grids

When?

At the end of each cycle or at each event

Output?

Saved in `[inputname]nnn_fort.##` files,
where `nnn` is the cycle number & `##` is the logical unit number chosen by the user

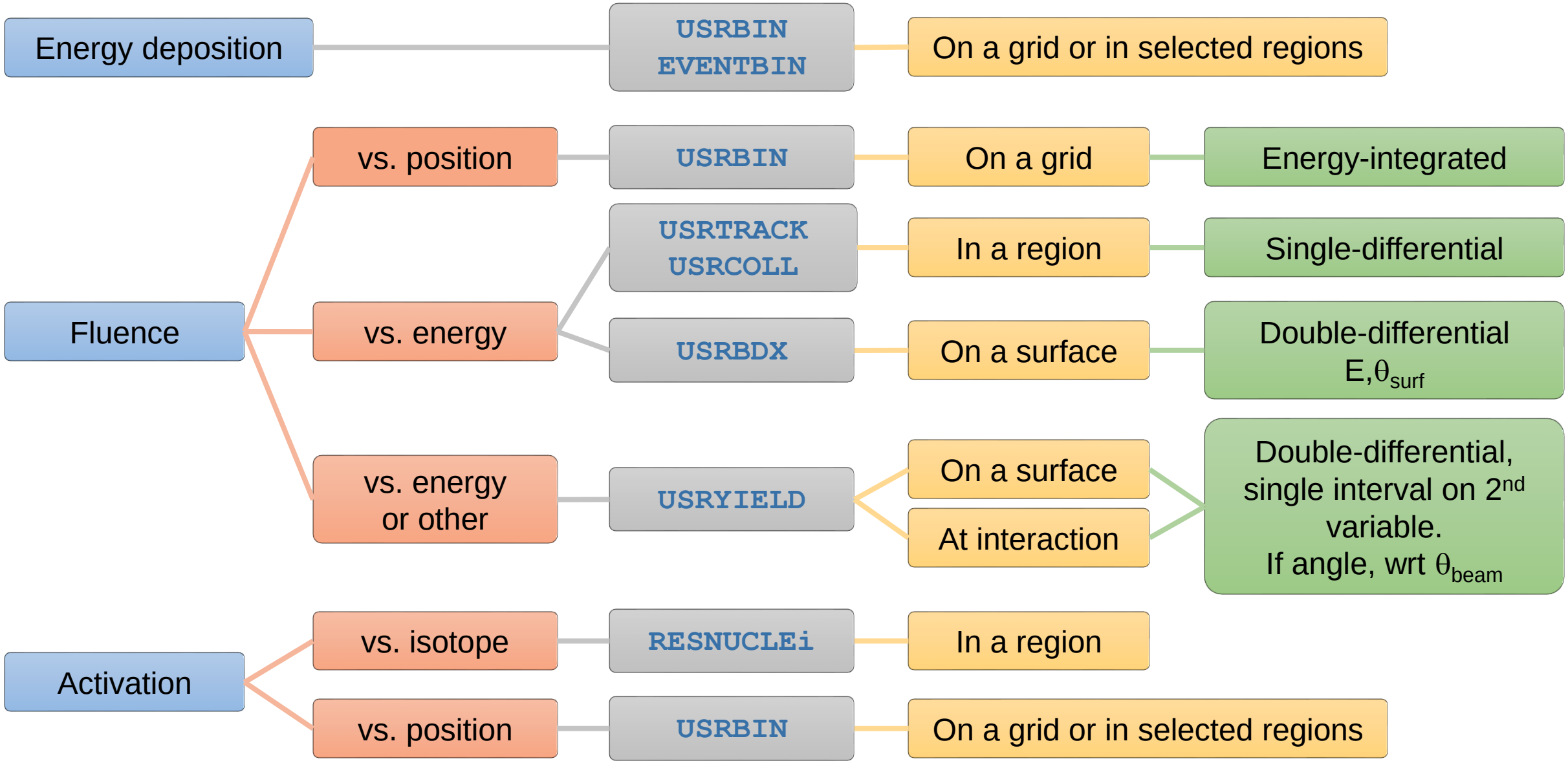
Results?

Post-processing utilities merge cycles, calculate average and rms, provide data files for plotting. Available via **Flair**

Results normalised **per primary**

User code needed for processing of custom scoring!

The FLUKA estimator zoo



More “special” scoring cards

- **DETECT** scores **energy deposition** for each event (primary history) in coincidence or anti-coincidence with a trigger
- **EVENTBIN** is like **USRBIN**, but prints the binning output **after each event** instead of an average over histories
- **TCQUENCH** sets scoring **time cut-offs** and/or **Birks quenching** parameters for binnings (**USRBIN** or **EVENTBIN**) indicated by the user
- **ROTPRBIN** assigns **rotations/translations** for a given user-defined binning (**USRBIN** or **EVENTBIN**) (and sets the **storage precision**, single or double). Useful with **LATTICEs**
- **USERDUMP** defines the events to be written onto a **“collision tape” file**
- **AUXSCORE** defines **filters** and **conversion coefficients**
- **RESNUCLEi** scores **stopping nuclei in a given region**
- **DCYSCORE** assigns cooling times

See lecture on activation

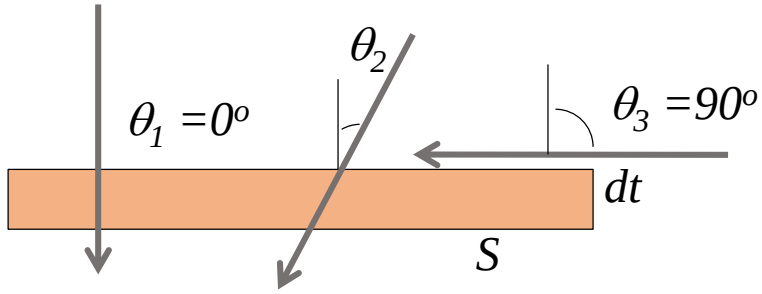
Standard post-processing programs

- To analyse the results of the different scoring options, several programs are made available
- **Behind the scenes, Flair uses these programs**

- The executables are in **`/pathtofluka/bin`**, while the sources are available in **`/pathtofluka/src/tools`** in case modifications are needed
- They assume that the estimator files are **unformatted**, and can calculate standard deviations and average values over many cycles:
  - **`ustsuw.f`** to analyze **`USRTRACK`** and **`USRCOLL`** outputs
  - **`usxsuw.f`** to analyze **`USRBDX`** outputs
  - **`usysuw.f`** to analyze **`USRYIELD`** outputs
  - **`usbsuw.f`** to analyze **`USRBIN`** outputs
  - **`usrsuw.f`** to analyze **`RESNUCLEi`** outputs
  - **`usbrea.f`** to convert **`USRBIN`** outputs to ASCII file

Fluence vs Current (1/2)

Surface crossing estimation



- Consider the volume generated by a surface *S* times an infinitesimal thickness *dt.*

  A particle incident with *an angle θ with respect to the normal to the surface S* travels a segment *dt/cosθ* inside the volume.

- The **average fluence** F over the surface S is defined as*:*

$$\Phi = \lim_{dt \to 0} \frac{\sum_i \frac{dt}{\cos\theta_i}}{S\,dt}$$

total tracklength inside the volume

volume

- While the **average current** J over the surface S is given by the number of particles crossing the surface divided by the surface area:

$$J = N/S$$

Fluence vs Current (2/2)

- Fluence is **independent** of the orientation of the surface S, while current is **not** !
  - On a flat surface in an isotropic particle field J = F/2

- Current is meaningful in case one needs to count particles (e.g. for a signal trigger)

- But to estimate dose, activation, radiation damage, instrument response… the relevant quantity to be used is fluence, since it is proportional to the interaction rate

Main FLUKA estimators

- **USRBIN** scores the **spatial distribution** of **energy density** or **fluence** (or star density) in a **regular mesh** (cylindrical, Cartesian, or by region) described by the user
- **USRBDX** scores average **$d^2\Phi/dEd\Omega$ (double-differential fluence or current)** of a given type or family of particles on a **given surface**
- **USRTRACK** (**USRCOLL**) scores average **$d\Phi/dE$ (differential fluence)** of a given type or family of particles in a **given region**
- **USRYIELD** scores a **double differential yield** of particles on a **given surface**
  - The distribution can be with respect to energy and angle, but also other more “exotic” quantities
- All scorings write their results into **logical output units assigned by the user**
  - the unit numbers must be **>20**
  - The only exception is **SCORE** – which scores **energy deposition** (or number of stars) in all regions – whose output is printed in the **standard output**

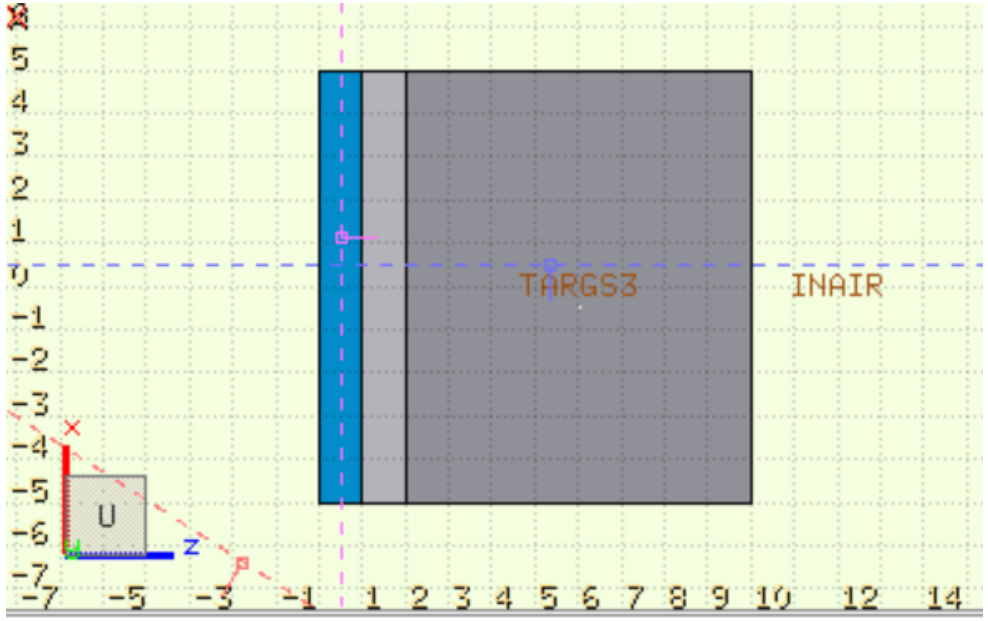
Result units

- FLUKA does not calculate **region** volumes and areas.
- As scoring particle *fluence* with **USRTRACK** (**USRBDX**, **USRYIELD**), the resulting value will actually be in cm^{-2} only if the user has provided the region volume (area) in the respective card field. Nevertheless, this is far from being needed, since the desired normalization can be naturally applied at post-processing level.

- Results from **USRTRACK** (**USRCOLL**) are given as differential distributions in energy, in units of GeV^{-1}.
  - To obtain integral results, one has to multiply the value *dN/dE* of each energy bin by the bin width *dE* : $N = \int \frac{dN}{dE} dE$, which is already done in the respective *_sum.lis file !
  - When scoring neutrons, the energy bins below 20 MeV are automatically set and cannot be altered, since they must match the multi-group structure applying to low energy neutron transport
- Results from **USRBDX** and **USRYIELD** are given as double differential distributions.

USRBDX scoring

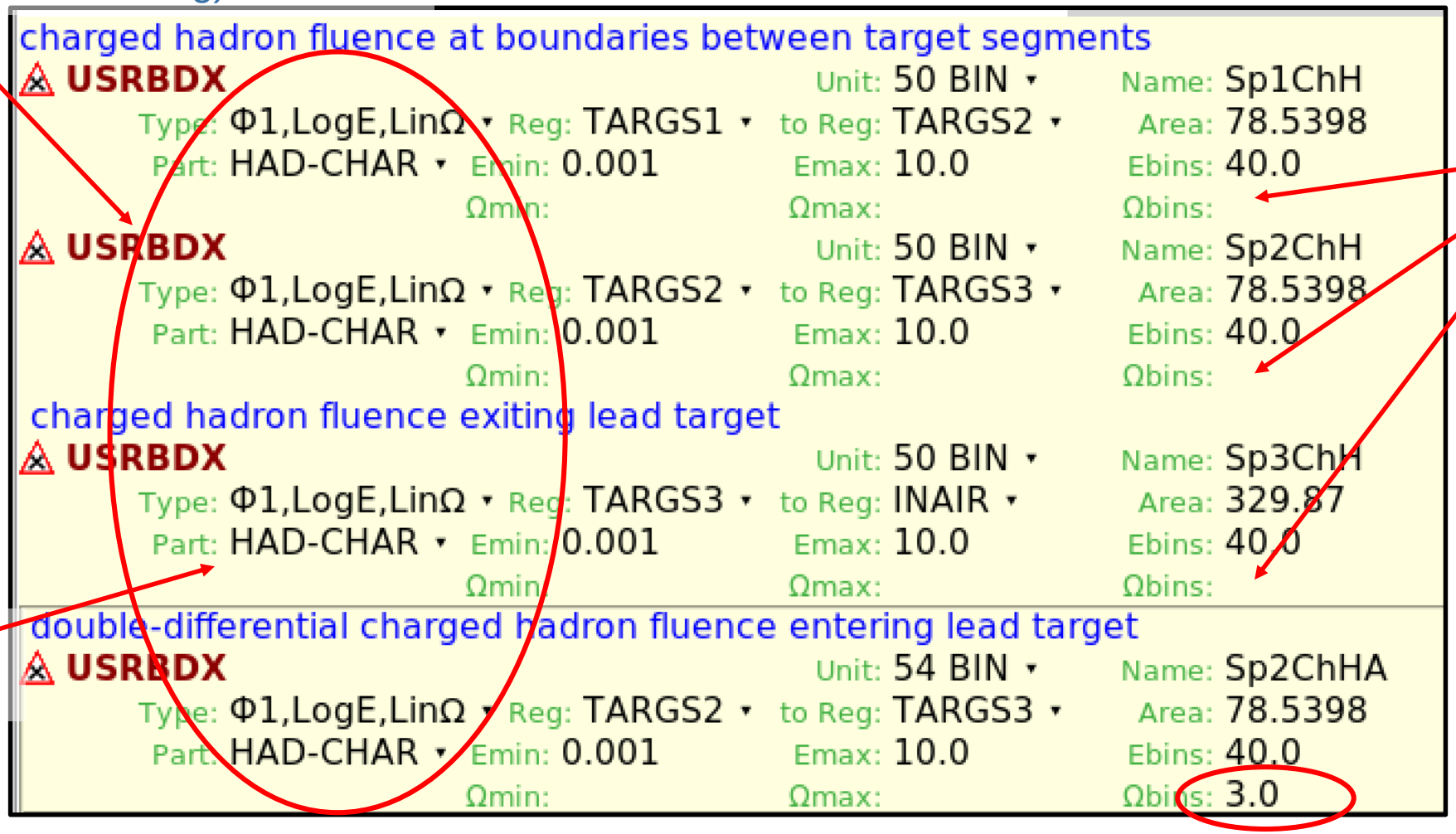
```
beam definitions
BEAM          Beam: Energy ▾    E: 3.5          Part: PROTON ▾
   Δp: Gauss ▾  Δp(FWHM): 0.8   Δϕ: Gauss ▾  Δϕ (FWHM): 1.7
Shape(X): Rectangular ▾  Δx:   Shape(Y): Rectangular ▾  Δy:
BEAMPOS       x:              y:              z: -0.1
              cosx:           cosy:           Type: POSITIVE ▾
```



3.5 GeV protons on water
→ aluminum → lead

USRBDX scoring (boundary crossing) definition

One-way fluence across boundary, differential in energy (log binning) and angle (linear binning)

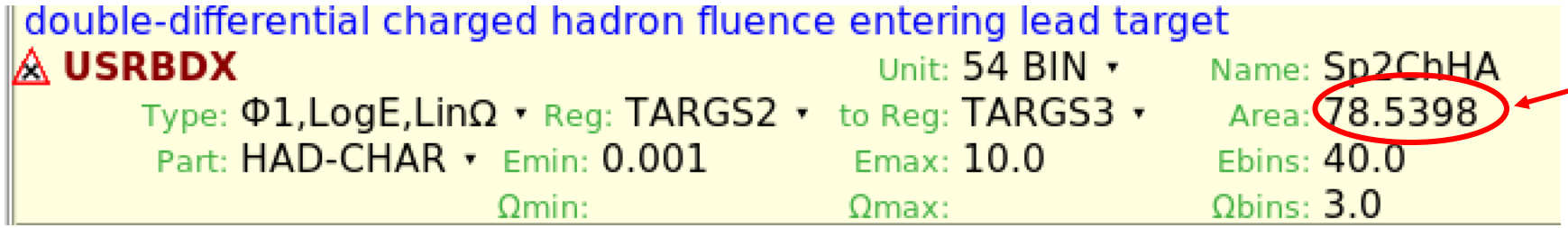


By default ONE angular bin (no angular distribution)

Particle type: charged hadrons

3 angular bins

USRBDX scoring (boundary crossing) output



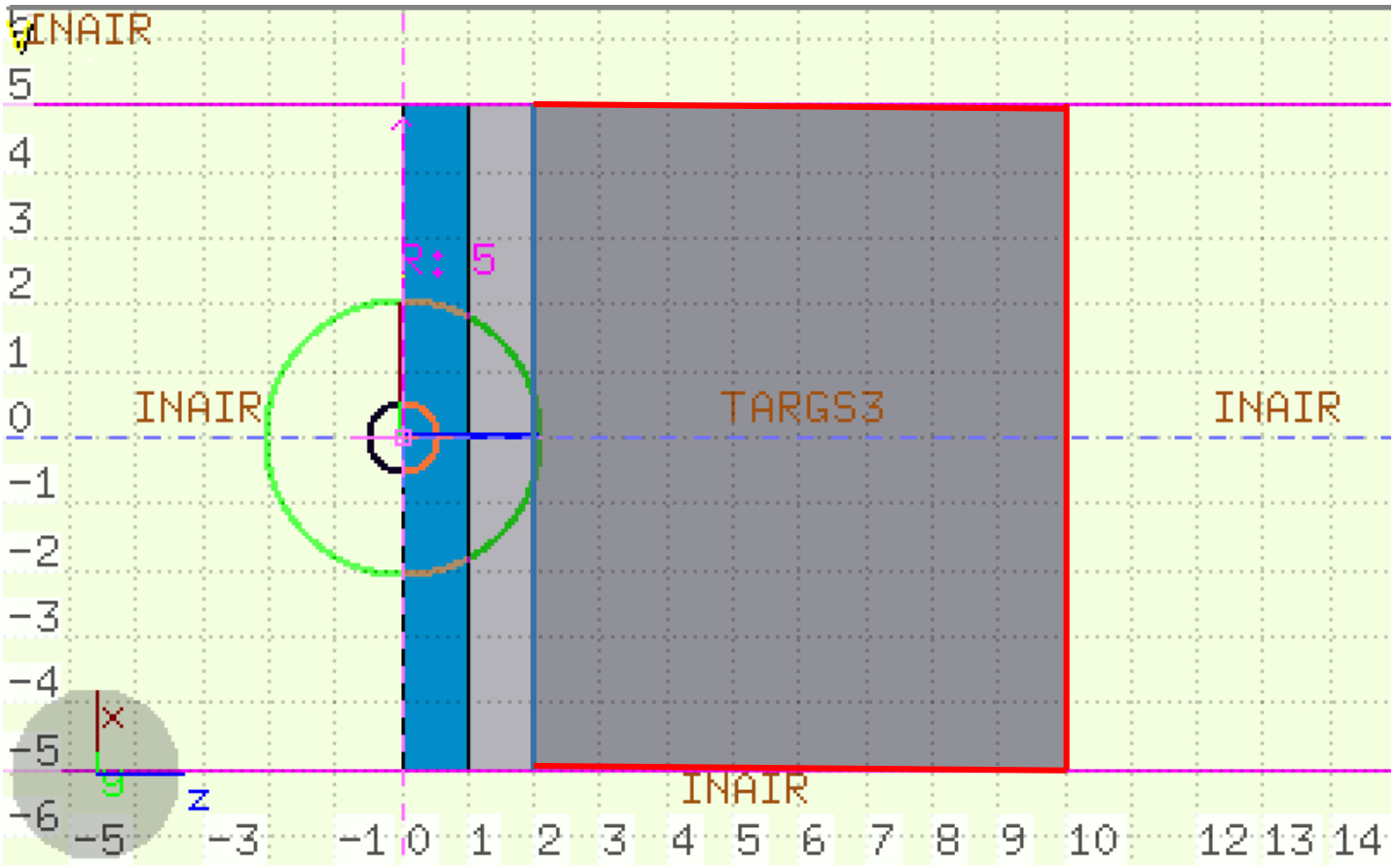
Surface area [cm^2] normalization, which can be independently done at post-processing

The merging/processing action will create 3 files for each **USRBDX** unit:

- **demo_scoring_54.bnx**: binary file containing the merged data from several runs
  [it can replace the N unformatted estimator files for further postprocessing]
- **demo_scoring_54_sum.lis**: ascii file containing all information and in addition energy-integrated cumulative spectra
  demo_scoring_54_tab.lis: ascii file containing the double differential fluence and angle-integrated fluence in tabulated form for immediate plotting → Flair uses this file

Note: even if only one angular bin was requested, differential spectra are always double differential in GeV^{-1} **sr^{-1}**

USRBDX area normalization

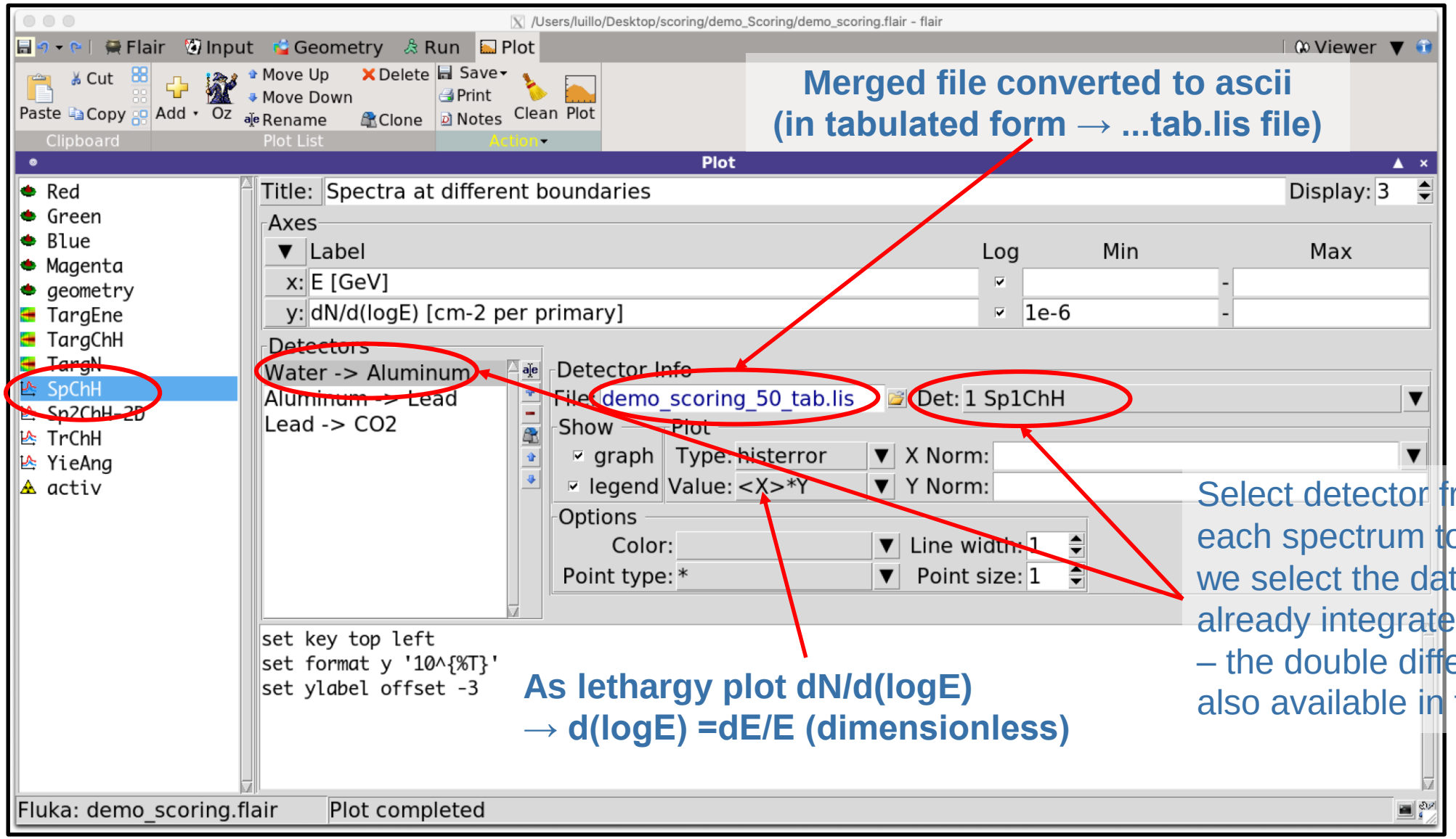


R_{TARG} = 5 cm
ΔZ_{TARGS1} = 1 cm
ΔZ_{TARGS2} = 1 cm
ΔZ_{TARGS3} = 8 cm

Area between TARGS2 and TARGS3: $\pi R_{TARG}^2 = 78.5398\ cm^2$

Area between TARGS3 and INAIR: $2\pi R_{TARG}\ \Delta Z_{TARGS3} + \pi R_{TARG}^2 = 329.87\ cm^2$

Plotting – charged hadron spectra (USRBDX)



Merged file converted to ascii (in tabulated form → ...tab.lis file)

As lethargy plot dN/d(logE) → d(logE) =dE/E (dimensionless)

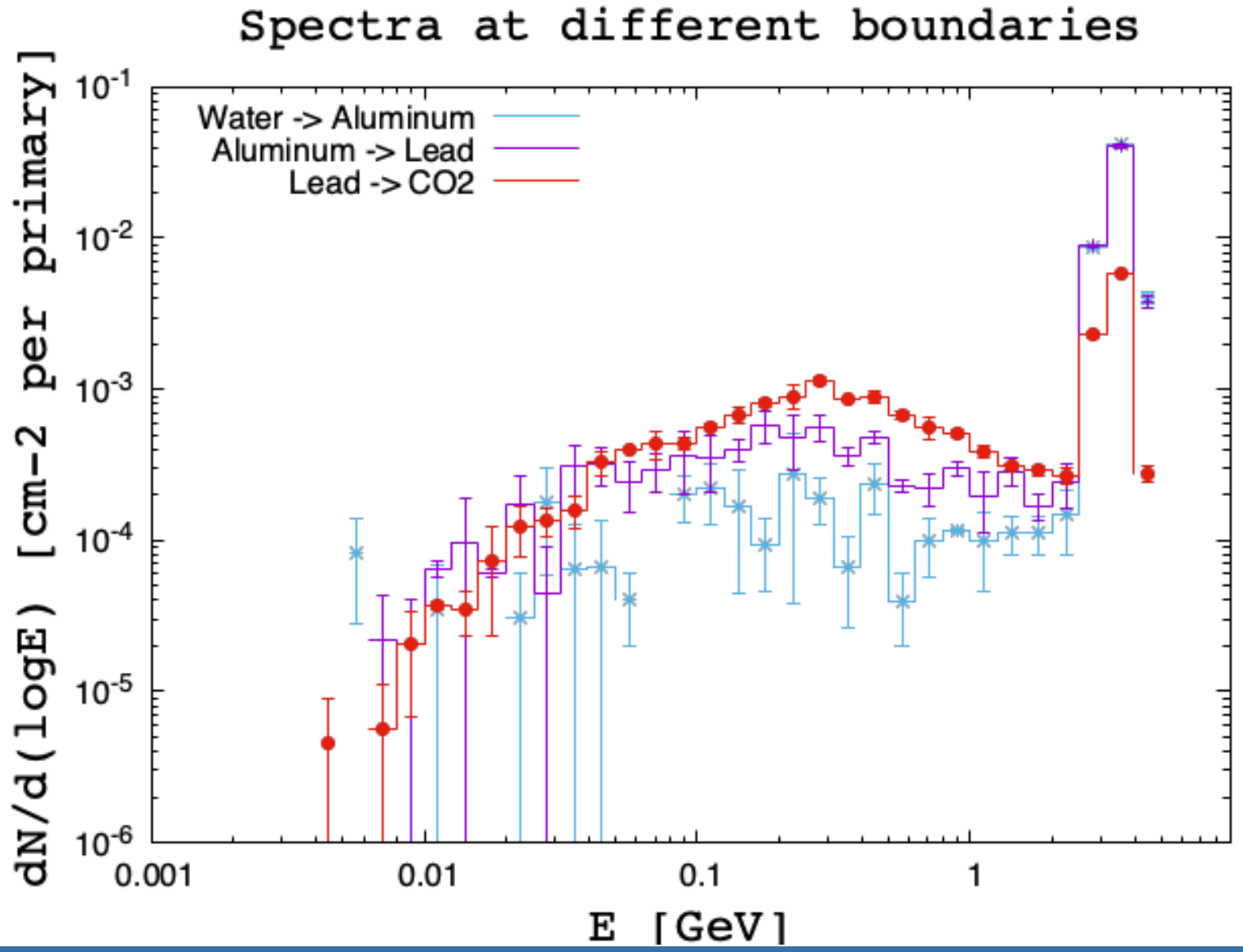
Select detector from file for each spectrum to be plotted (note: we select the data set that is already integrated over solid angle – the double differential spectrum is also available in the same file)

Plot result – charged hadron spectra (USRBDX)

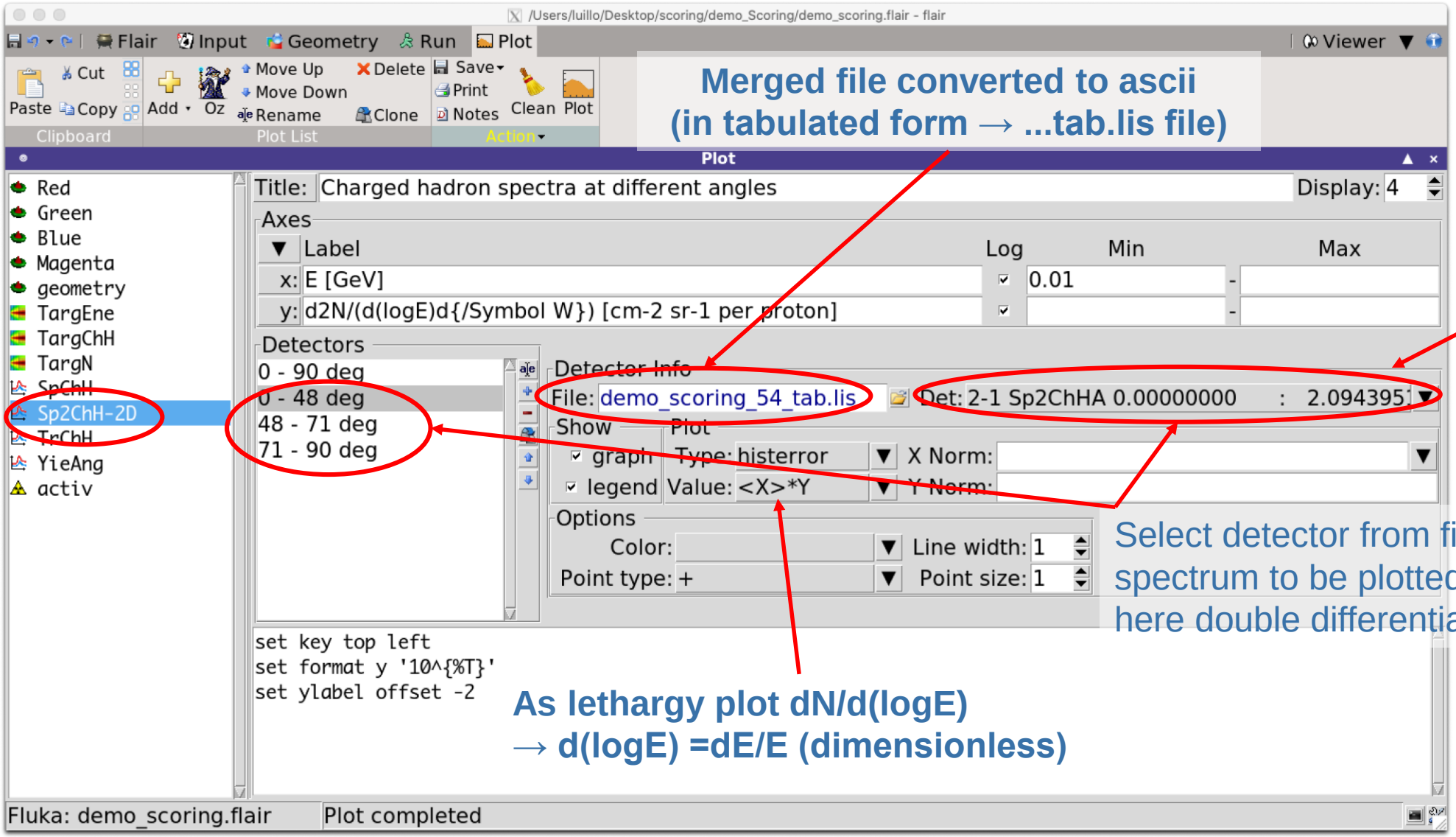
$$y = \frac{dN}{d(logE)} = E\frac{dN}{dE}$$

Value: <X>*Y

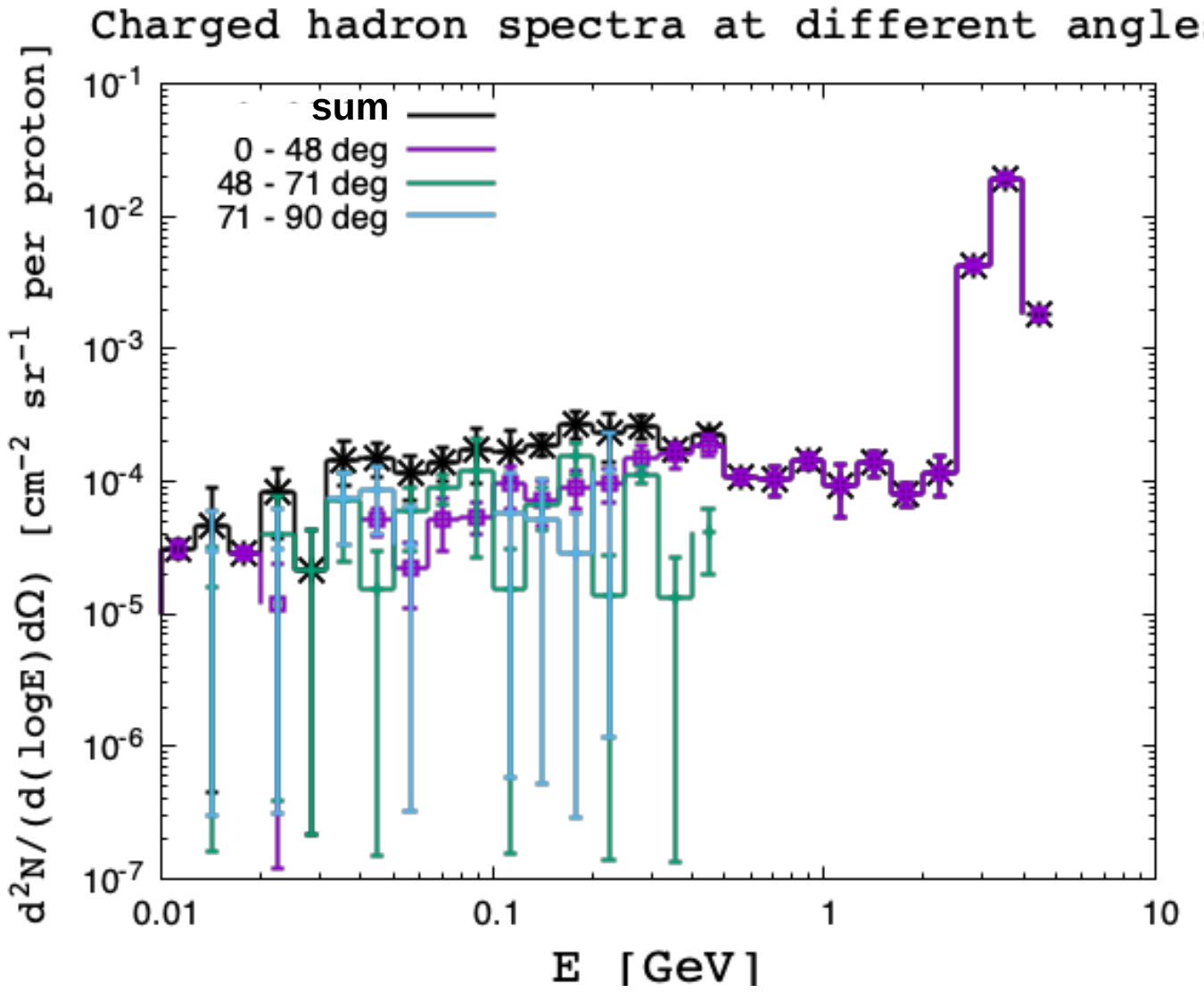
Lethargy plot



Plotting – double differential fluence (USRBDX)



Plot result – double differential fluence (USRBDX)



CURSO INTRODUTÓRIO

FLUKA

23 DE JANEIRO
A 8 DE MARÇO
DE 2023

Código Monte Carlo de interação e transporte de partículas

Pausa

Voltamos em 15 minutos

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USRDUMP

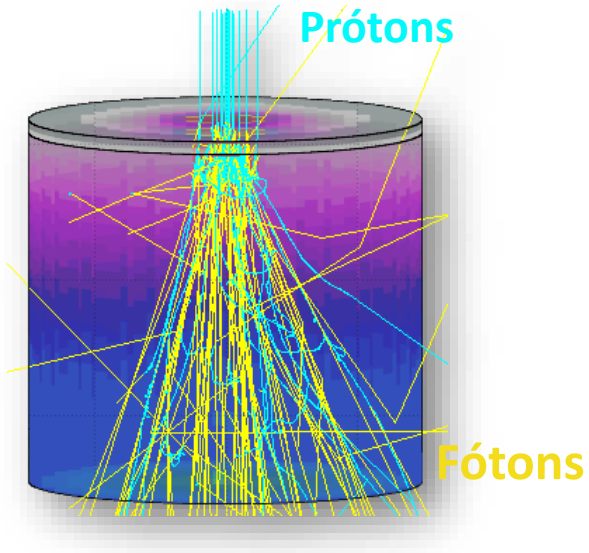
É possível visualizar a trajetória das partículas na simulação com um cartão chamado **USRDUMP**.

Ao ativar o cartão, você:

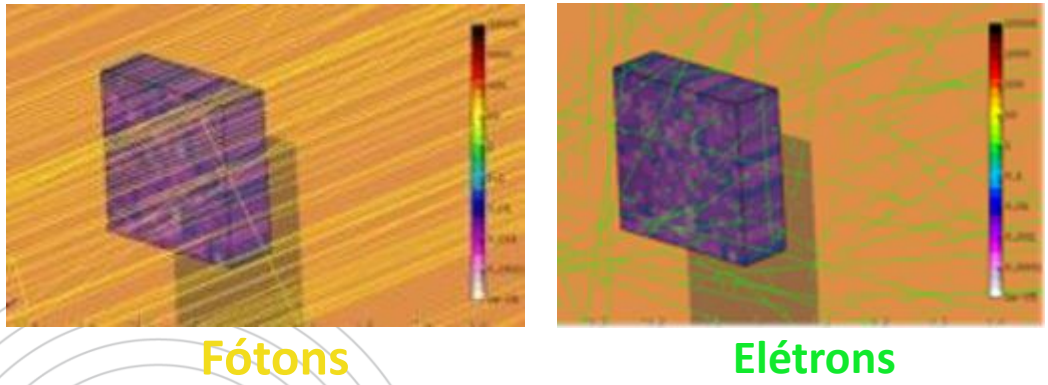
- Ativa a rotina MGDRAW
- Gera arquivos sem formatação com um ou mais itens da lista abaixo:
  - Todas as partículas
  - Todas as trajetórias
  - Todos os eventos de deposição de energia
  - Outros eventos definidos pelo usuário

Muito cuidado ao ativar esse cartão!
Você pode gerar dezenas de Gb
(e além) em poucos segundos

Visualização em conjunto:

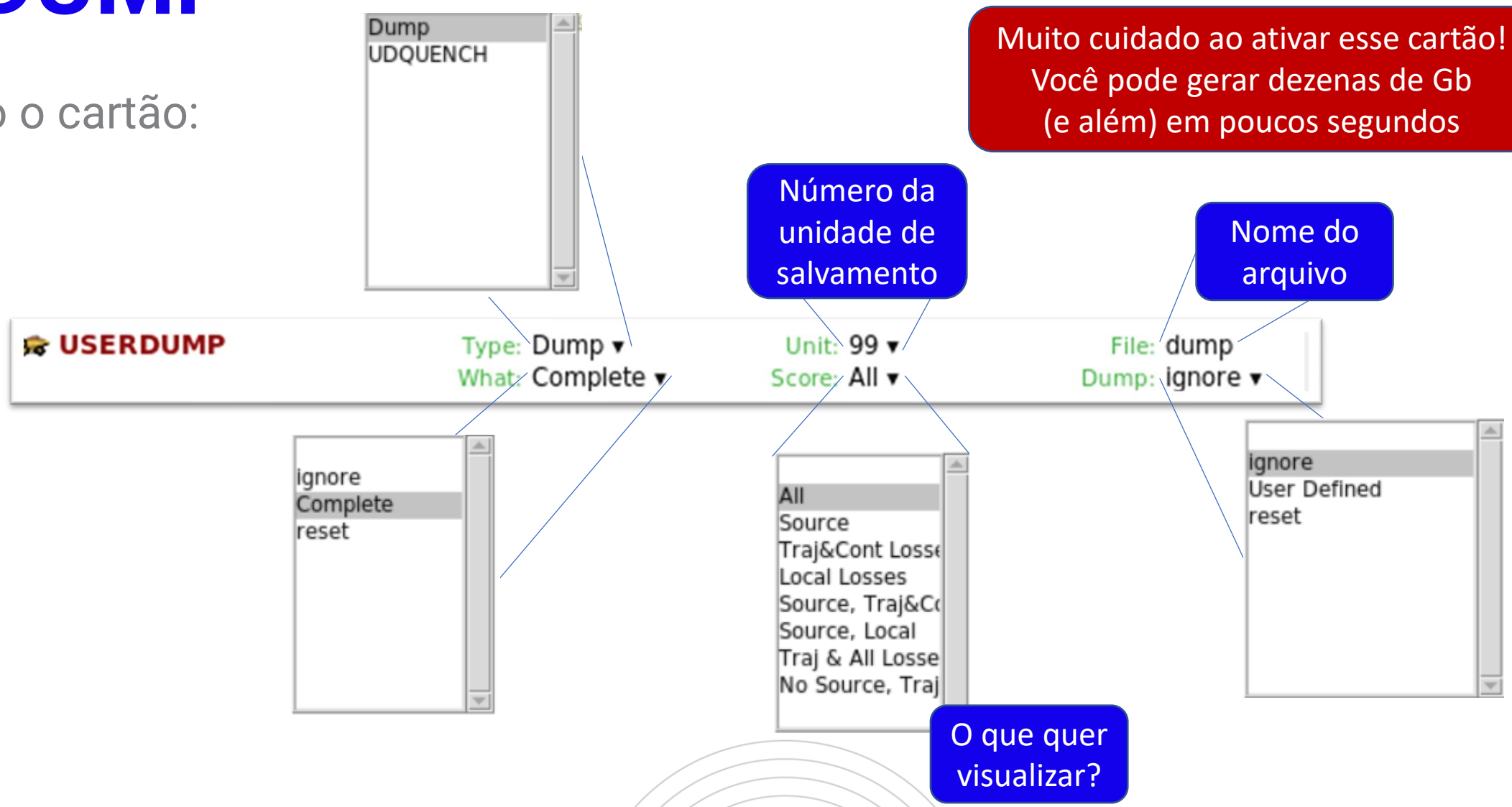


Visualização individual:



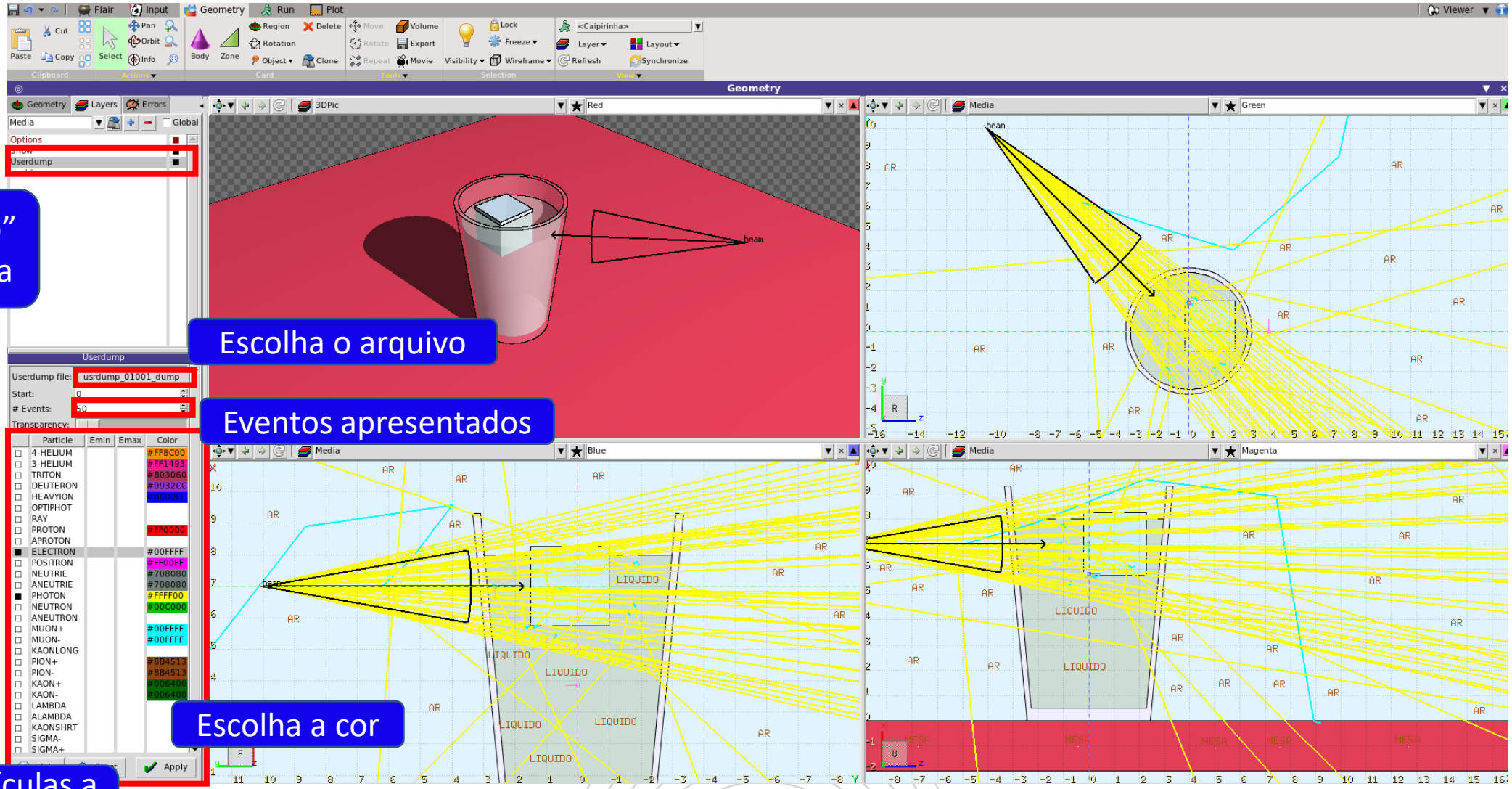
USRDUMP

Montando o cartão:



USRDUMP

Plotando:



Aula 6 – USRBDX/USRDUMP

- Utilize o **USRDUMP** para visualizar:
  - O feixe de **fótons incidente**
  - Os **elétrons espalhados** no copo
  - Comparem a proporção de partículas para **diferentes quantidades de eventos**

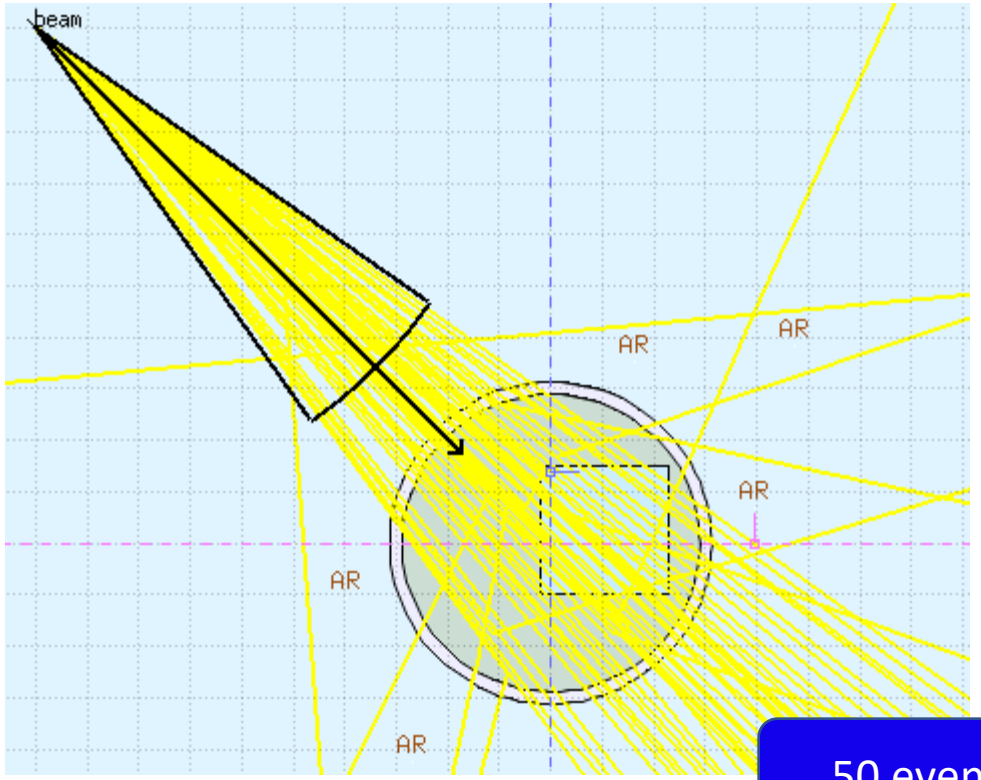
Muito cuidado ao ativar esse cartão!
Você pode gerar dezenas de Gb
(e além) em poucos segundos

- Utilize o **USRBDX** para visualizar o **espectro de incidência** para:
  - **Menor** energia (1.17 MeV)
  - **Maior** energia (1.33 MeV)
- Escolha uma das energias e simule para:
  - Dispersão energética **flat** com **Δp=0.5 MeV**
  - Dispersão energética **gaussiana** com **FWHM=0.5 MeV**

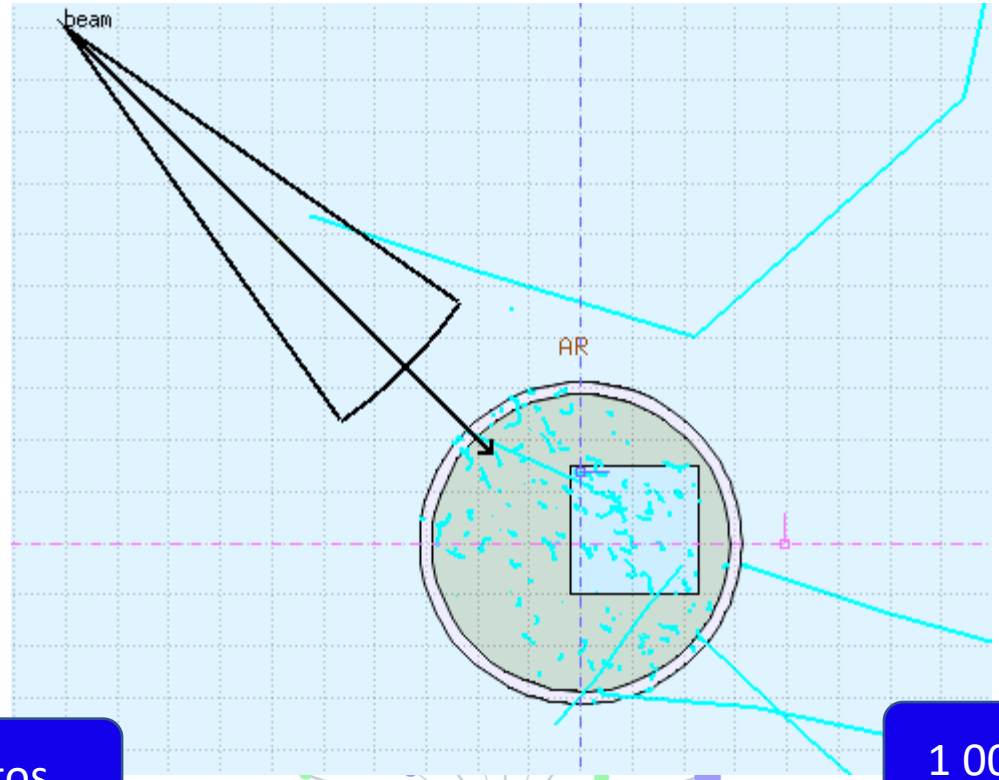
```
#define   cos_ang_xy   : 0
#define   cos_ang_yz   : =cosd(45)
#define   ener_min     :
---------- PARAMETROS DO FEIXE ----------
#if       ener_min
    Define the beam characteristics
    BEAM        Beam: Energy    E: 0.00117    Part: PHOTON
      Δp: Flat      Δp:         Δϕ: Flat      Δϕ: 350.0
    Shape(X): Rectangular  Δx:  Shape(Y): Rectangular  Δy:
#else
    Define the beam characteristics
    BEAM        Beam: Energy    E: 0.00133    Part: PHOTON
      Δp: Flat      Δp:         Δϕ: Flat      Δϕ: 350.0
    Shape(X): Rectangular  Δx:  Shape(Y): Rectangular  Δy:
#endif
```

Aula 6 – USRBDX/USRDUMP

Solução:



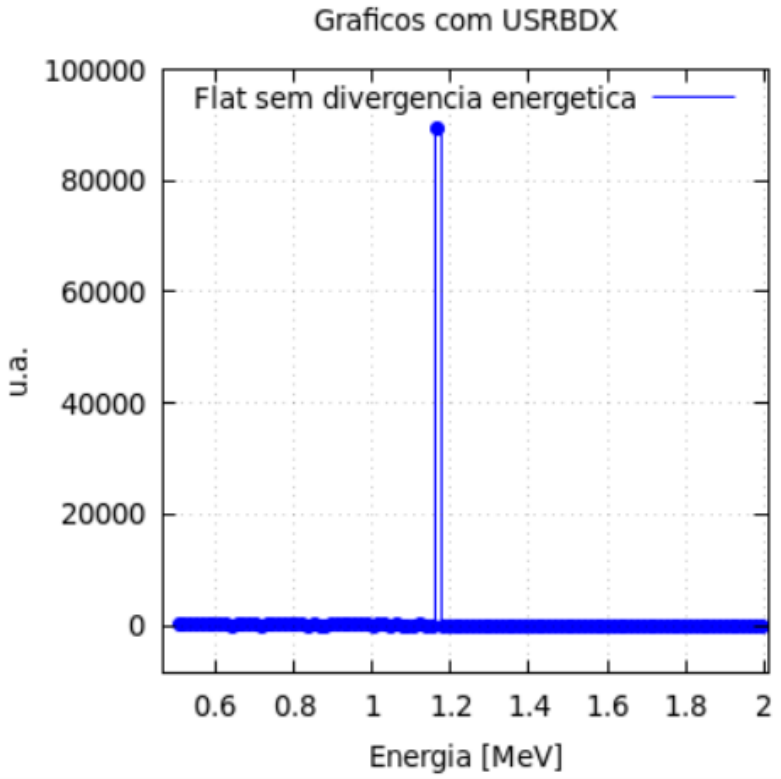
50 eventos

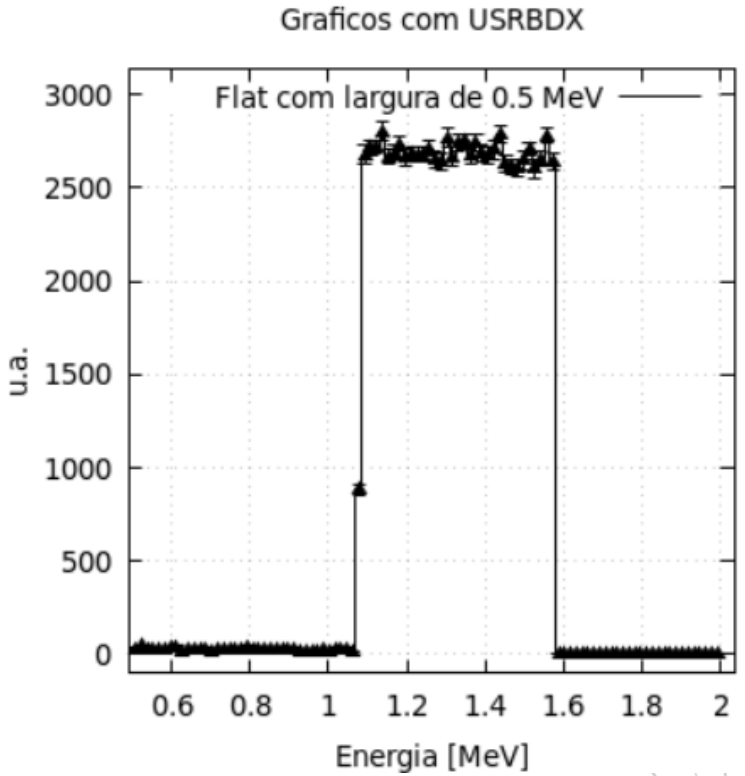


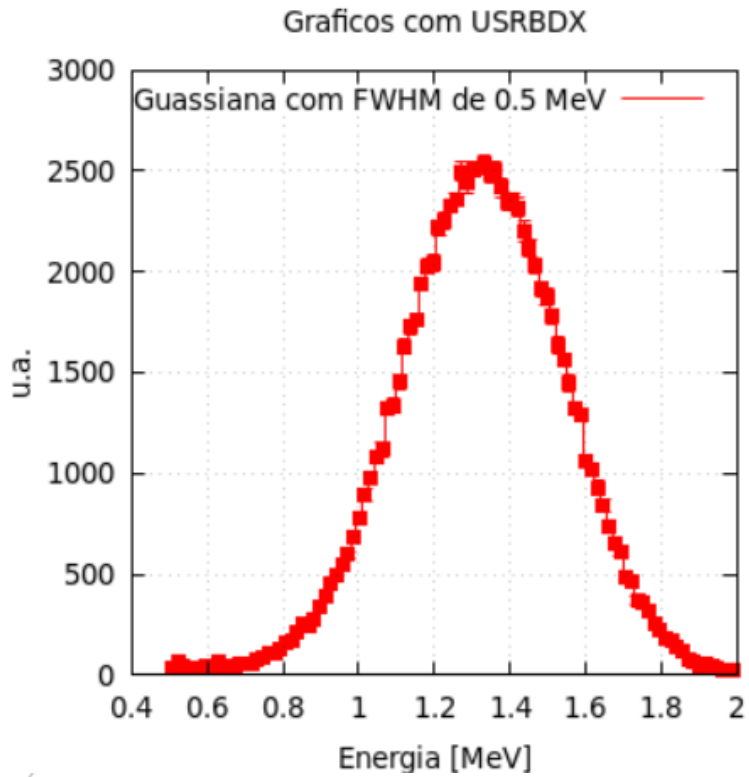
1 000 eventos

Aula 6 – USRBDX/USRDUMP

Solução:







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AULA 06
Detectores – USRBDX/USRDUMP

Obrigada pela participação!

Código Monte Carlo de interação e transporte de partículas

23 FLUKA 2023 08

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