

# CURSO INTRODUTÓRIO



23 DE JANEIRO  
A 8 DE MARÇO  
DE 2023

FLUKA

FLUKA

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FLUKA

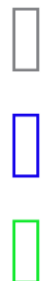
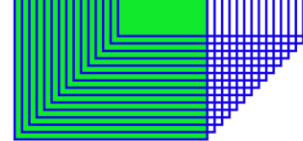
FLUKA

# AULA 06

# Detectores –

# USRBDX/USRDUMP

Iniciaremos em breve



Código Monte Carlo de interação e transporte de partículas

01

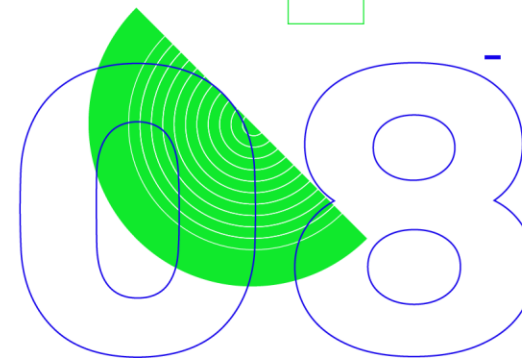
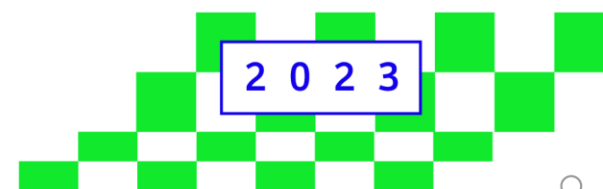
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## Scoring physics quantities [II]

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

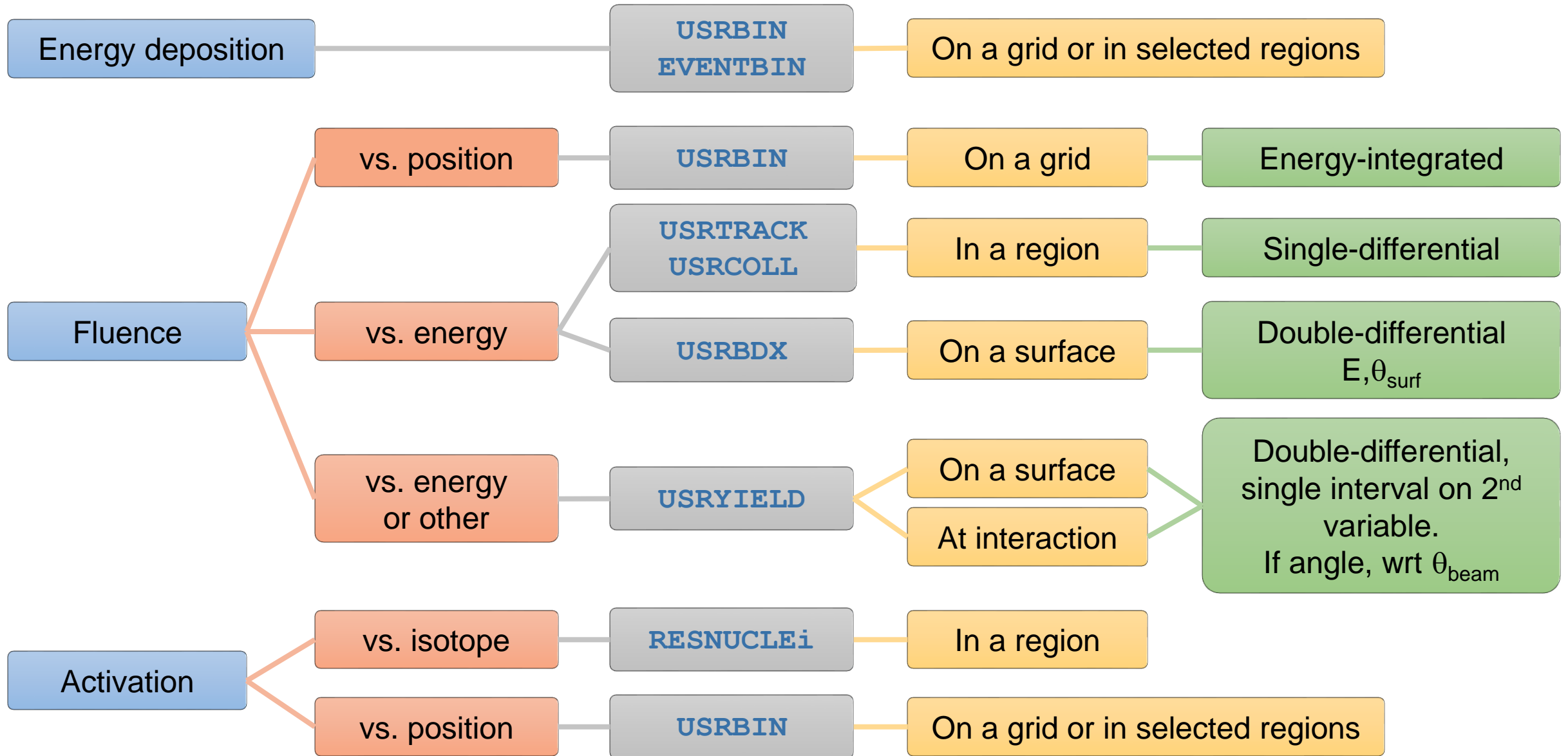
## Results?

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  $\theta$  with respect to*

*the normal to the surface  $S$  travels a segment  $dt/\cos\theta$  inside the volume.*

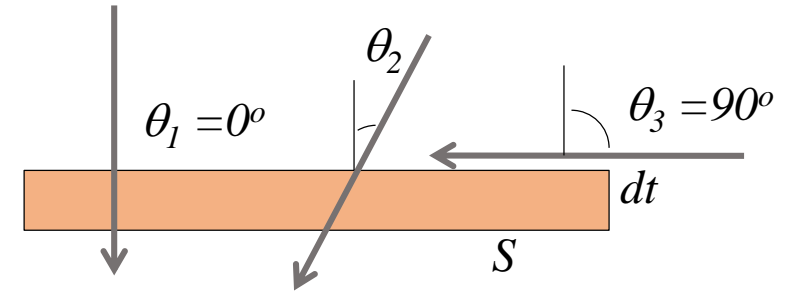
- The **average fluence  $F$**  over the surface  $S$  is defined as:

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

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  **$d^2\Phi/dE d\Omega$**  (**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 ▾

$\Delta p$ : Gauss ▾  $\Delta p$ (FWHM): 0.8

$\Delta\phi$ : Gauss ▾  $\Delta\phi$ (FWHM): 1.7

Shape(X): Rectangular ▾  $\Delta x$ :

Shape(Y): Rectangular ▾  $\Delta y$ :

### BEAMPOS

x:

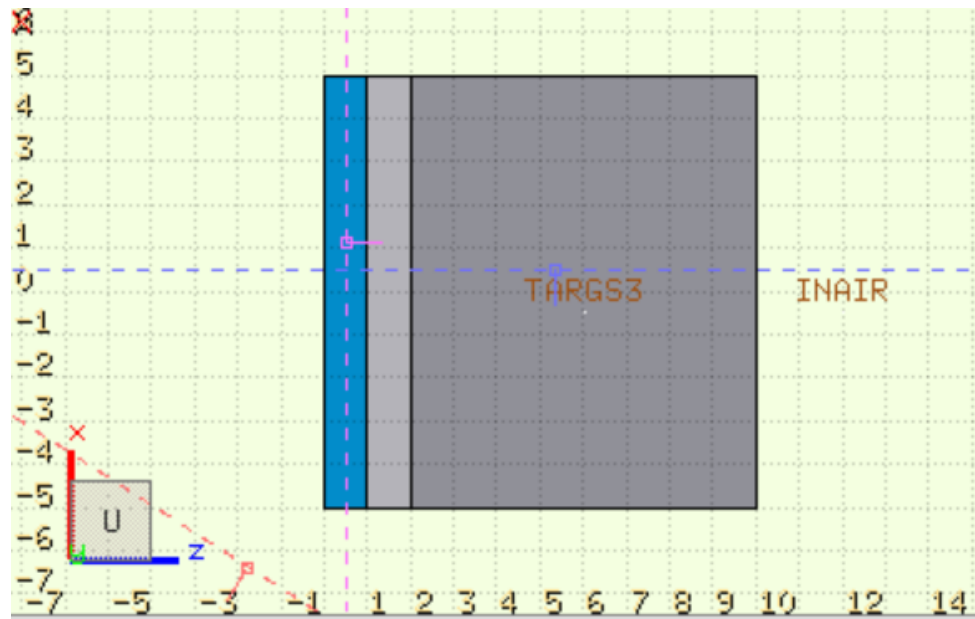
y:

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)

charged hadron fluence at boundaries between target segments			
<b>USRBDX</b>	Unit: 50 BIN	Name: Sp1ChH	
Type: $\Phi$ 1,LogE,Lin $\Omega$	Reg: TARGS1	to Reg: TARGS2	Area: 78.5398
Part: HAD-CHAR	Emin: 0.001	Emax: 10.0	Ebins: 40.0
	$\Omega$ min:	$\Omega$ max:	$\Omega$ bins:
charged hadron fluence entering lead target			
<b>USRBDX</b>	Unit: 50 BIN	Name: Sp2ChH	
Type: $\Phi$ 1,LogE,Lin $\Omega$	Reg: TARGS2	to Reg: TARGS3	Area: 78.5398
Part: HAD-CHAR	Emin: 0.001	Emax: 10.0	Ebins: 40.0
	$\Omega$ min:	$\Omega$ max:	$\Omega$ bins:
charged hadron fluence exiting lead target			
<b>USRBDX</b>	Unit: 50 BIN	Name: Sp3ChH	
Type: $\Phi$ 1,LogE,Lin $\Omega$	Reg: TARGS3	to Reg: INAIR	Area: 329.87
Part: HAD-CHAR	Emin: 0.001	Emax: 10.0	Ebins: 40.0
	$\Omega$ min:	$\Omega$ max:	$\Omega$ bins:
double-differential charged hadron fluence entering lead target			
<b>USRBDX</b>	Unit: 54 BIN	Name: Sp2ChHA	
Type: $\Phi$ 1,LogE,Lin $\Omega$	Reg: TARGS2	to Reg: TARGS3	Area: 78.5398
Part: HAD-CHAR	Emin: 0.001	Emax: 10.0	Ebins: 40.0
	$\Omega$ min:	$\Omega$ max:	$\Omega$ bins: 3.0

Particle type:  
charged hadrons

3 angular bins

# USRBDX scoring (boundary crossing) output

```
double-differential charged hadron fluence entering lead target
⚠ USRBDX                               Unit: 54 BIN ▾      Name: Sp2ChHA
Type: Φ1,LogE,LinΩ ▾ Reg: TARGS2 ▾      to Reg: TARGS3 ▾  Area: 78.5398
Part: HAD-CHAR ▾ Emin: 0.001           Emax: 10.0        Ebins: 40.0
                  Qmin:                Qmax:             Qbins: 3.0
```

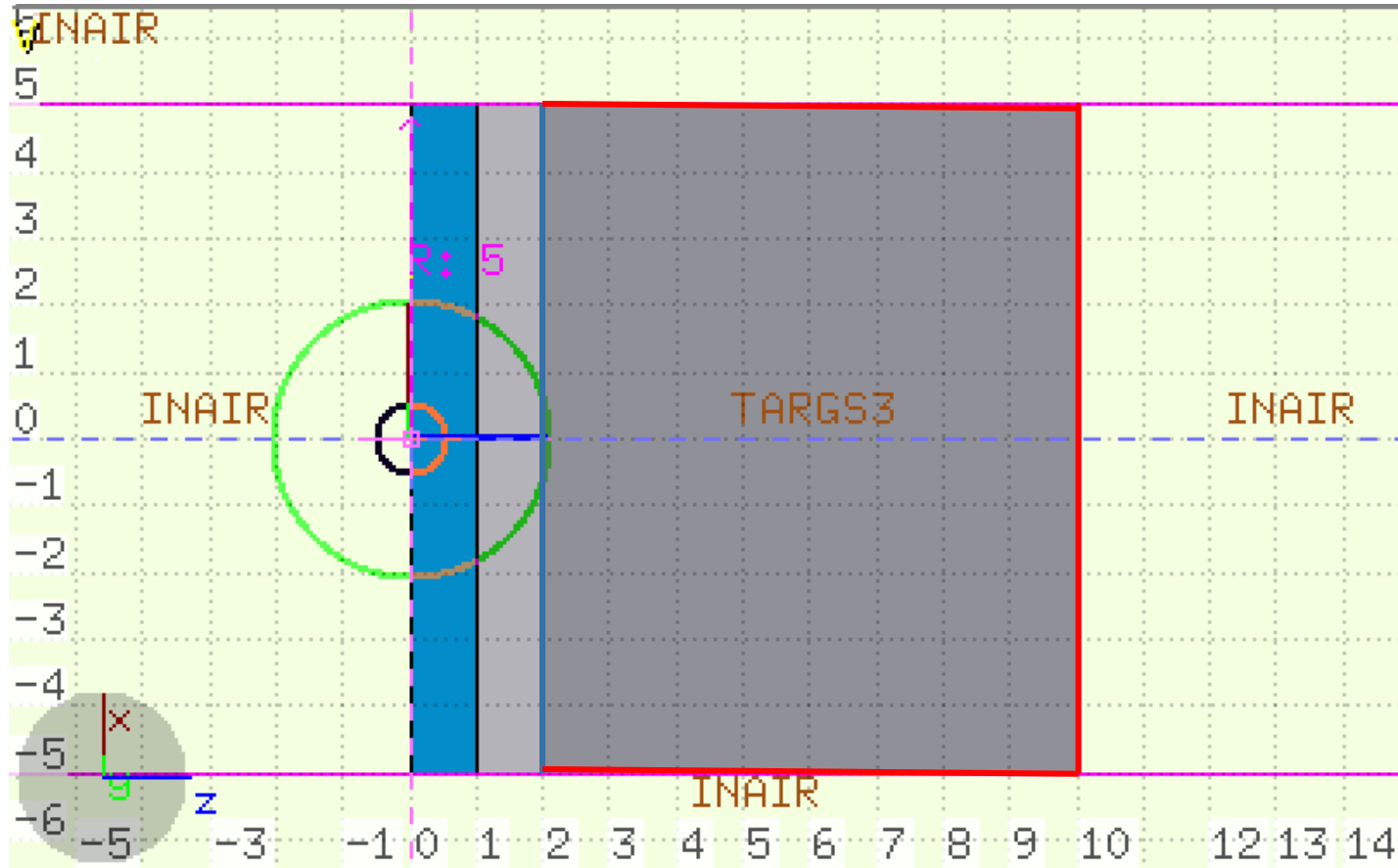
Surface area [cm<sup>2</sup>]  
normalization,  
which can be  
independently done  
at post-processing

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<sup>-1</sup> sr<sup>-1</sup>

# USRBDX area normalization



$$\begin{aligned}R_{\text{TARG}} &= 5 \text{ cm} \\ \Delta Z_{\text{TARGS1}} &= 1 \text{ cm} \\ \Delta Z_{\text{TARGS2}} &= 1 \text{ cm} \\ \Delta Z_{\text{TARGS3}} &= 8 \text{ cm}\end{aligned}$$

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

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

# Plotting – charged hadron spectra (USRBDX)

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

Title: Spectra at different boundaries Display: 3

Axes

Label	Log	Min	Max
x: E [GeV]	<input checked="" type="checkbox"/>		
y: dN/d(logE) [cm-2 per primary]	<input checked="" type="checkbox"/>	1e-6	

Detectors

- Water -> Aluminum
- Aluminum -> Lead
- Lead -> CO2

Detector Info

File: demo\_scoring\_50\_tab.lis Det: 1 Sp1ChH

Show Plot

graph Type: histerror X Norm: Y Norm:

legend Value: <X>\*Y

Options

Color: Line width: 1

Point type: \* Point size: 1

set key top left  
set format y '10^{%T}'  
set ylabel offset -3

As lethargy plot  $dN/d(\log E)$   
→  $d(\log E) = dE/E$  (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)

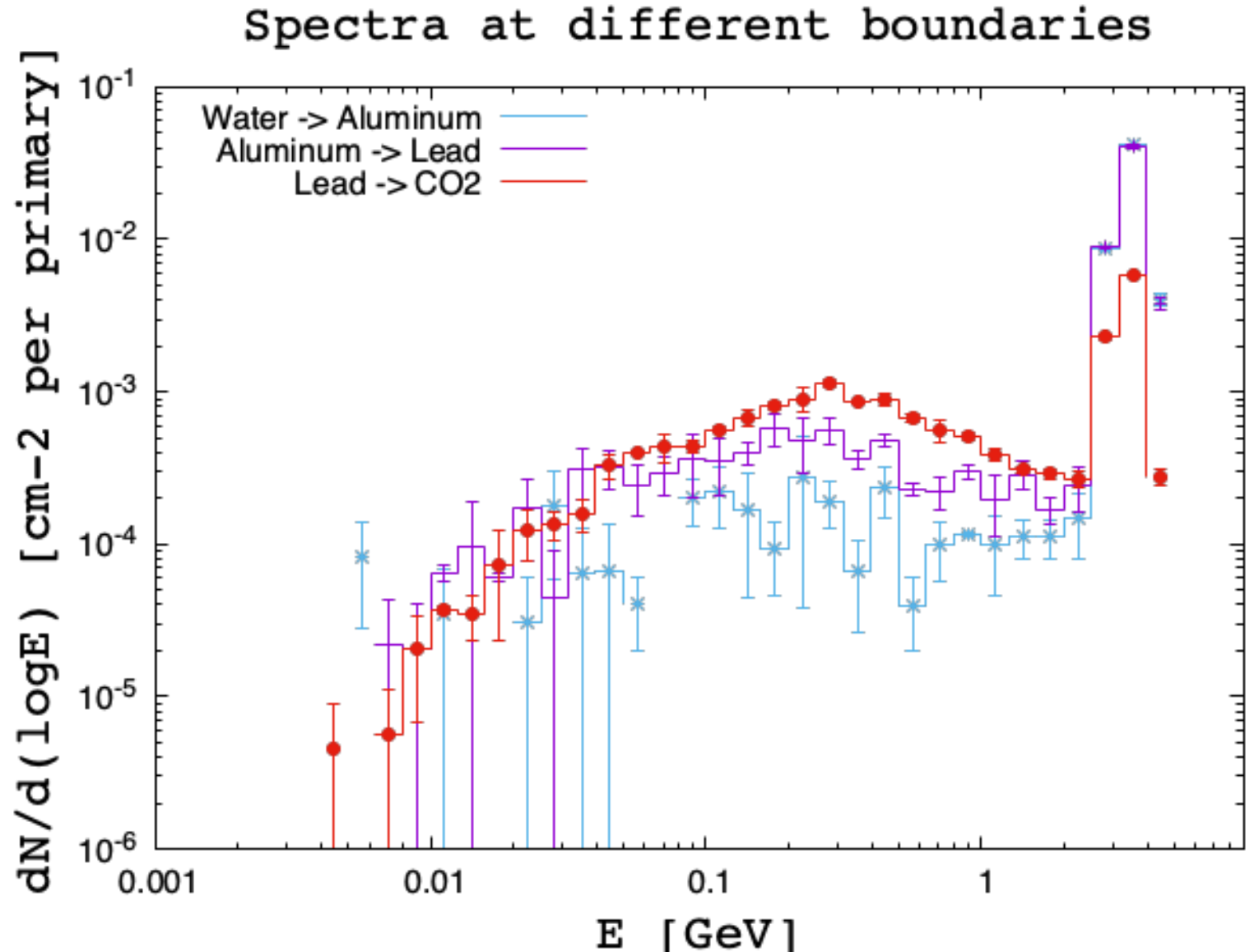
Fluka: demo\_scoring.flair Plot completed

# Plot result – charged hadron spectra (USRBDX)

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

Value: <X>\*Y

Lethargy plot



# Plotting – double differential fluence (USRBDX)

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

Title: Charged hadron spectra at different angles Display: 4

Axes

Label	Log	Min	Max
x: E [GeV]	<input checked="" type="checkbox"/>	0.01	-
y: $d^2N/(d(\log E)d\{\text{Symbol } W\})$ [cm <sup>-2</sup> sr <sup>-1</sup> per proton]	<input checked="" type="checkbox"/>	-	-

Detectors

- 0 - 90 deg
- 0 - 48 deg
- 48 - 71 deg
- 71 - 90 deg

Sp2ChH-2D

Detector Info

File: demo\_scoring\_54\_tab.lis Det: 2-1 Sp2ChHA 0.00000000 : 2.0943951

Show Plot

graph Type: histerror X Norm:   
 legend Value: <X>\*Y Y Norm:   
Options  
Color: Line width: 1  
Point type: + Point size: 1

set key top left  
set format y '10^{%T}'  
set ylabel offset -2

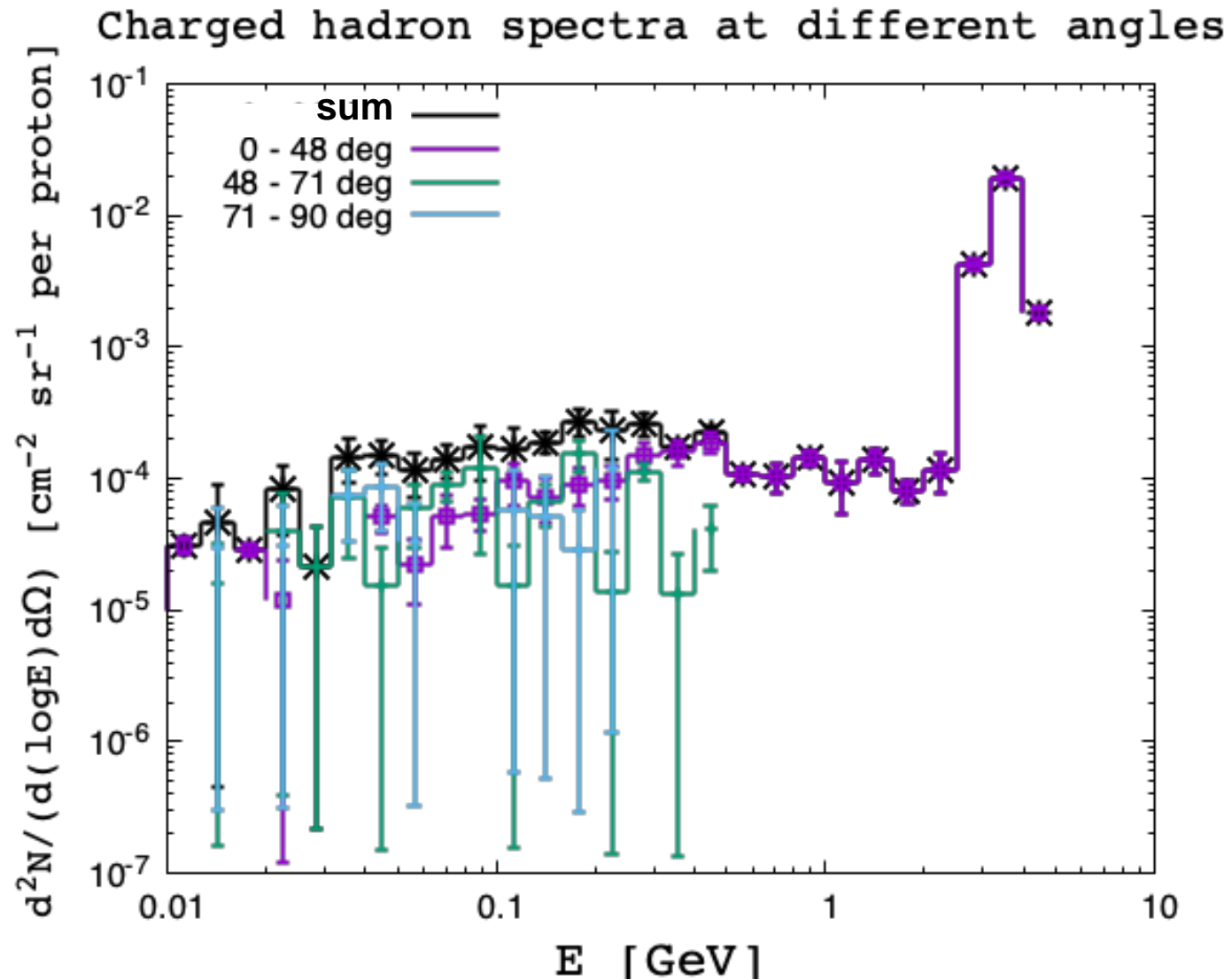
Fluka: demo\_scoring.flair Plot completed

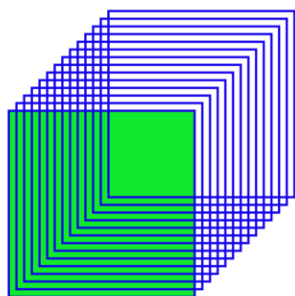
As lethargy plot  $dN/d(\log E)$   
→  $d(\log E) = dE/E$  (dimensionless)

Select detector from file for each spectrum to be plotted (we use here double differential spectra)

2p/3

# Plot result – double differential fluence (USRBDX)





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# CURSO INTRODUTÓRIO



23 DE JANEIRO  
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DE 2023

Código Monte Carlo de interação e transporte de partículas

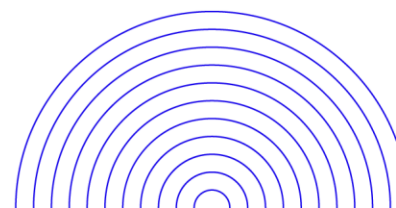
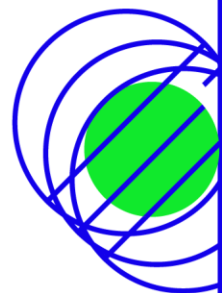
# Pausa

Voltamos em 15 minutos

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MINISTÉRIO DA  
CIÊNCIA, TECNOLOGIA  
E INOVAÇÃO



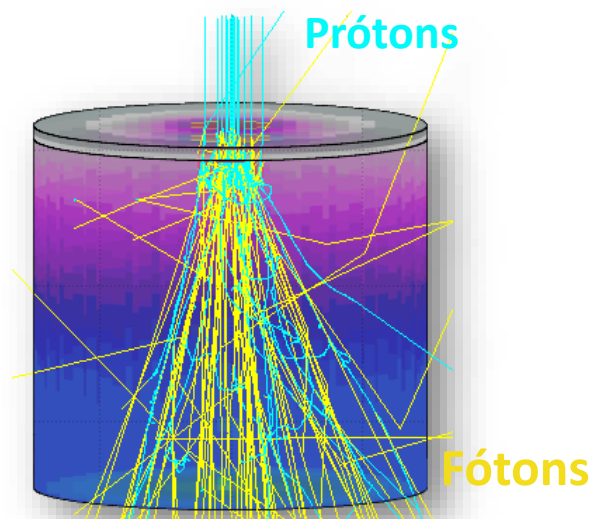
É possível visualizar a trajetória das partículas na simulação com um cartão chamado **USRDUMP**.

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

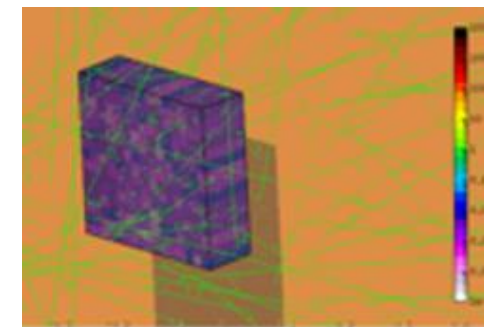
Visualização em conjunto:



Visualização individual:



Fótons

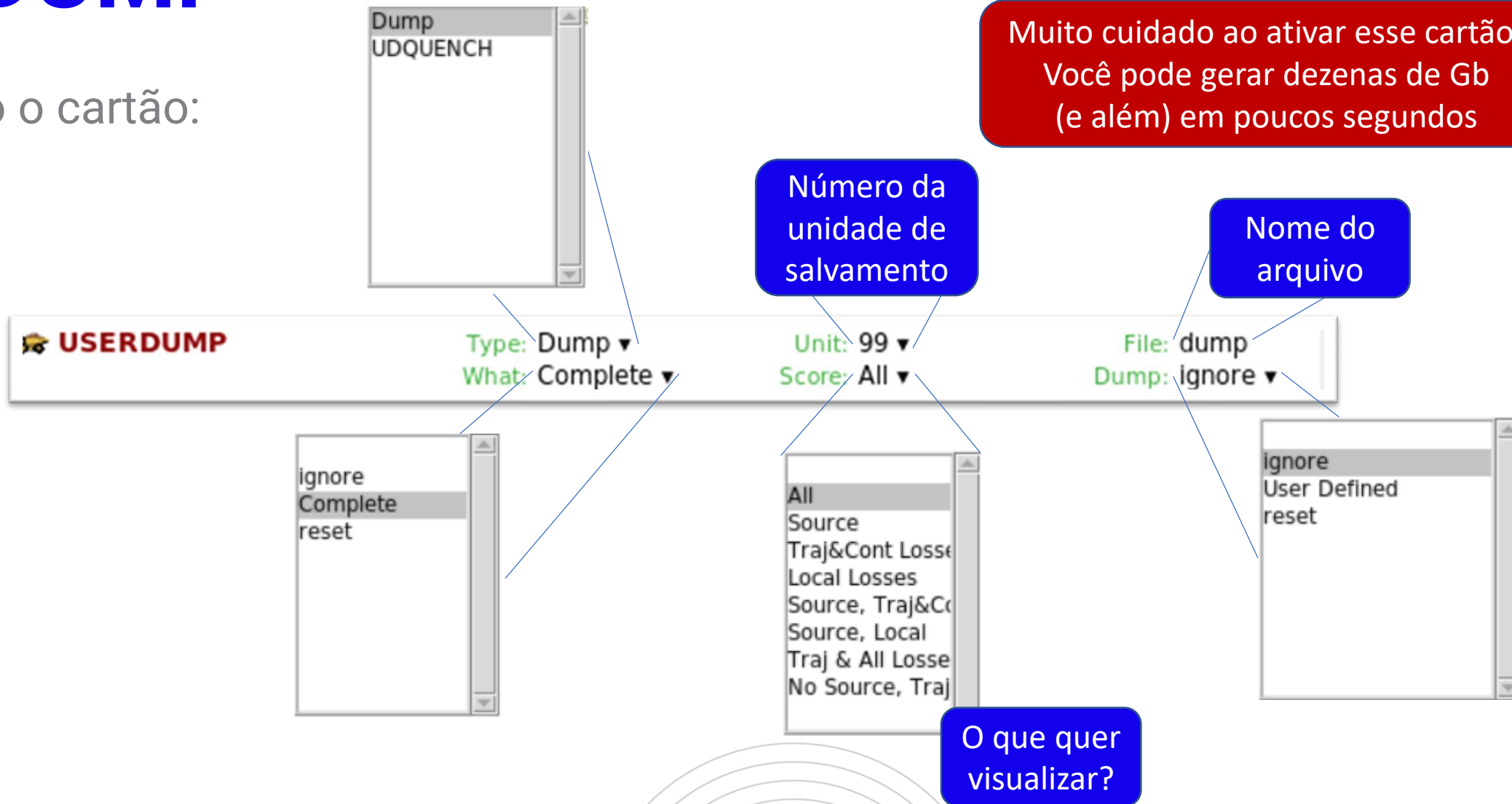


Elétrons

# USRDUMP

Montando o cartão:

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



The screenshot shows the USRDUMP configuration window. The main configuration bar includes:

- Type:** Dump
- What:** Complete
- Unit:** 99
- Score:** All
- File:** dump
- Dump:** ignore

Callouts point to the following elements:

- Dump UDQUENCH:** A list box showing the selected dump type.
- Número da unidade de salvamento:** Points to the 'Unit: 99' dropdown.
- Nome do arquivo:** Points to the 'File: dump' dropdown.
- O que quer visualizar?:** Points to the 'What: Complete' dropdown.

Three additional list boxes are shown below the main configuration bar:

- Left list box:** Contains 'ignore', 'Complete', and 'reset'. 'Complete' is selected.
- Middle list box:** Contains 'All', 'Source', 'Traj&Cont Losses', 'Local Losses', 'Source, Traj&Co', 'Source, Local', 'Traj & All Losses', and 'No Source, Traj'. 'All' is selected.
- Right list box:** Contains 'ignore', 'User Defined', and 'reset'. 'ignore' is selected.

# USRDUMP

Plotando:

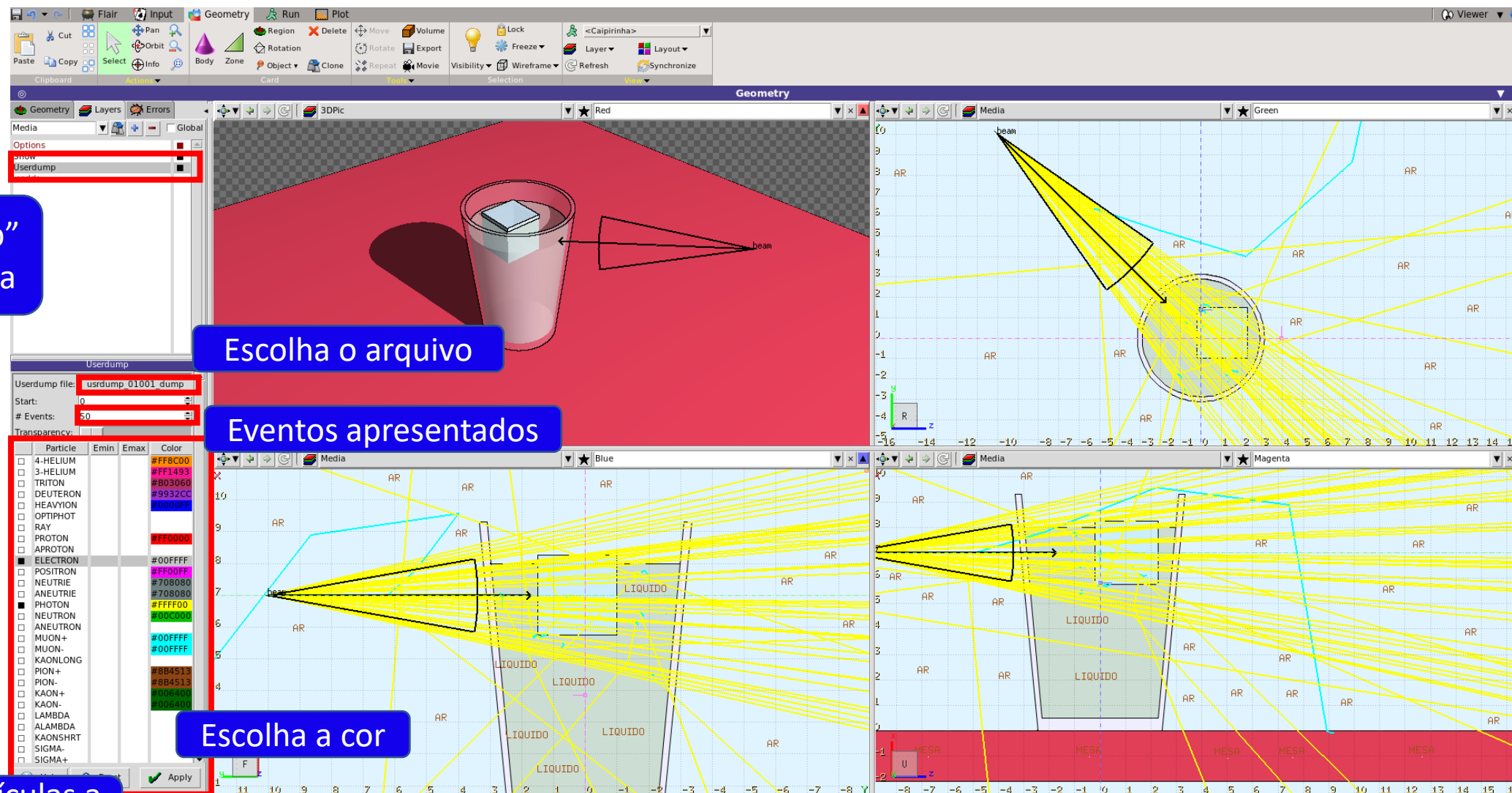
Add "Userdump" em uma camada

Escolha o arquivo

Eventos apresentados

Escolha a cor

Selecione as partículas a serem apresentadas



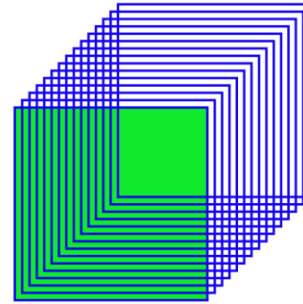
The screenshot displays the FLUKA GUI with the following components and annotations:

- Layers Panel:** A red box highlights the 'Userdump' checkbox under the 'Options' section.
- Userdump Dialog:** A red box highlights the file path 'usrdump\_01001\_dump' and the event count '50'.
- Particle List:** A red box highlights the 'ELECTRON' entry in the list.
- 3D View:** Shows a 3D model of a detector component with a yellow beam entering. A blue callout points to the beam.
- Plot Windows:** Three 2D plots show particle tracks in different colors: Red, Green, and Magenta. A blue callout points to the Red plot.

# Aula 6 – USRBDX/USRDUMP

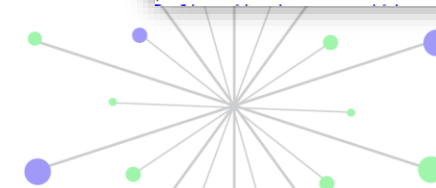
- Utilize o **USRDUMP** para visualizar:
  - O feixe de **fótons incidente**
  - Os **elétrons espalhados** no copo
  - Comparem a proporção de partículas para **diferentes quantidades de eventos**

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



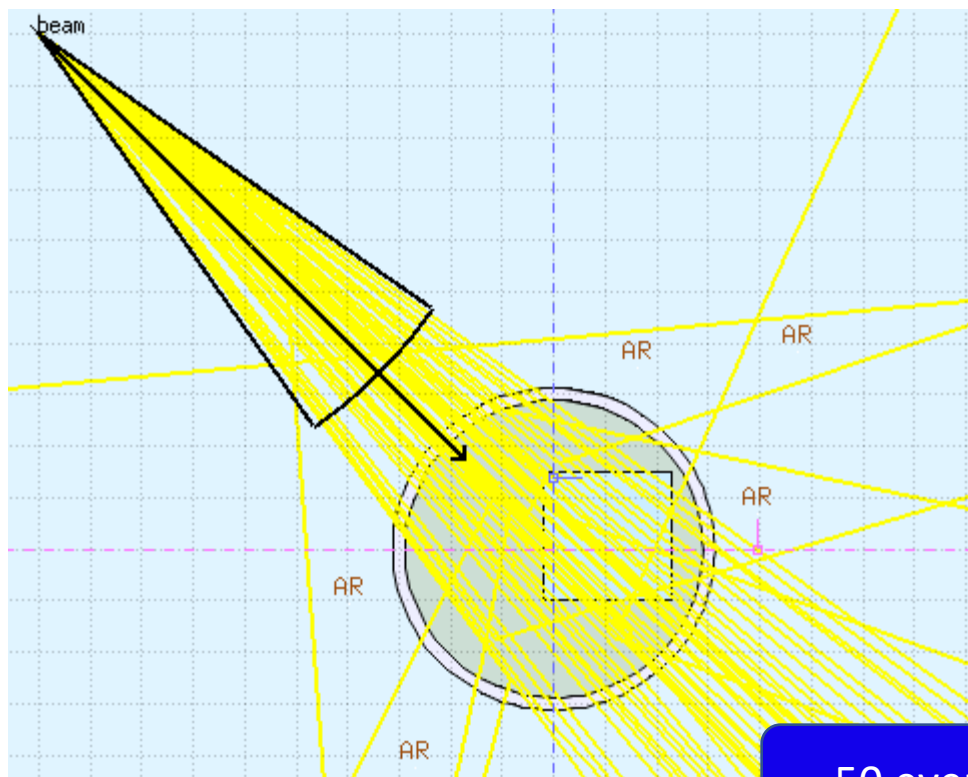
- Utilize o **USRBDX** para visualizar o **espectro de incidência** para:
  - **Menor** energia (1.17 MeV)
  - **Maior** energia (1.33 MeV)
- Escolha uma das energias e simule para:
  - Dispersão energética **flat** com  $\Delta p=0.5$  MeV
  - Dispersão energética **gaussiana** com **FWHM=0.5 MeV**

```
# #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
```

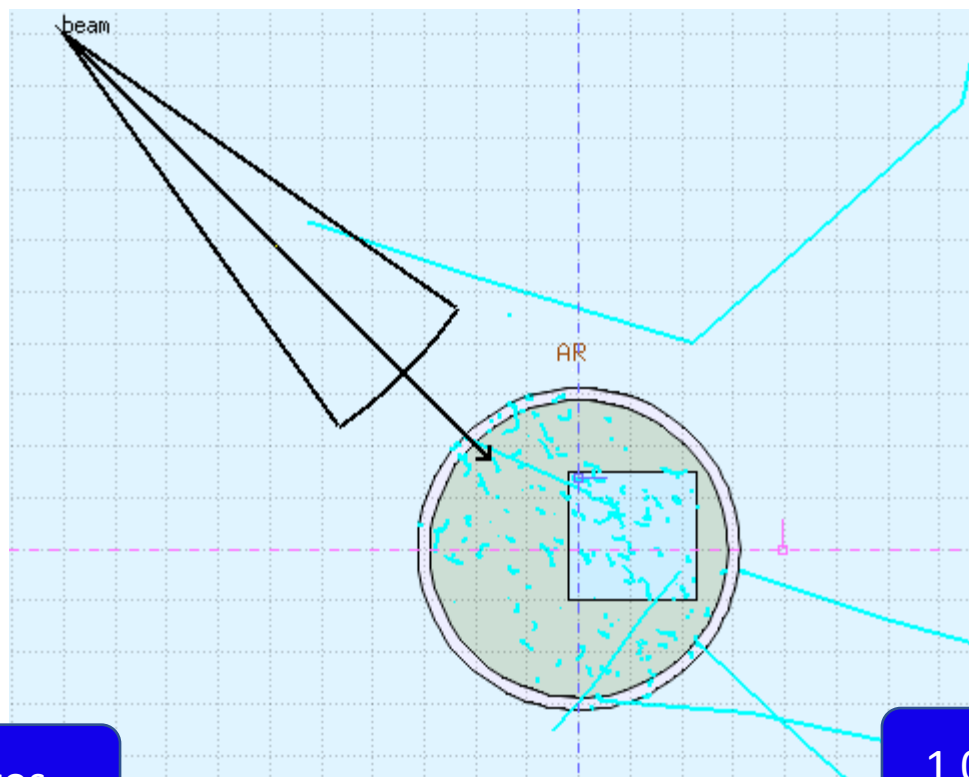


# Aula 6 – USRBDX/USRDUMP

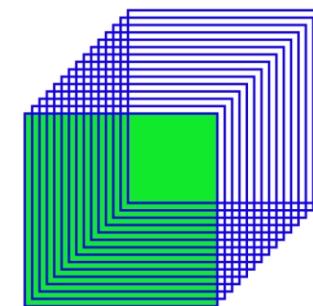
## Solução:



50 eventos



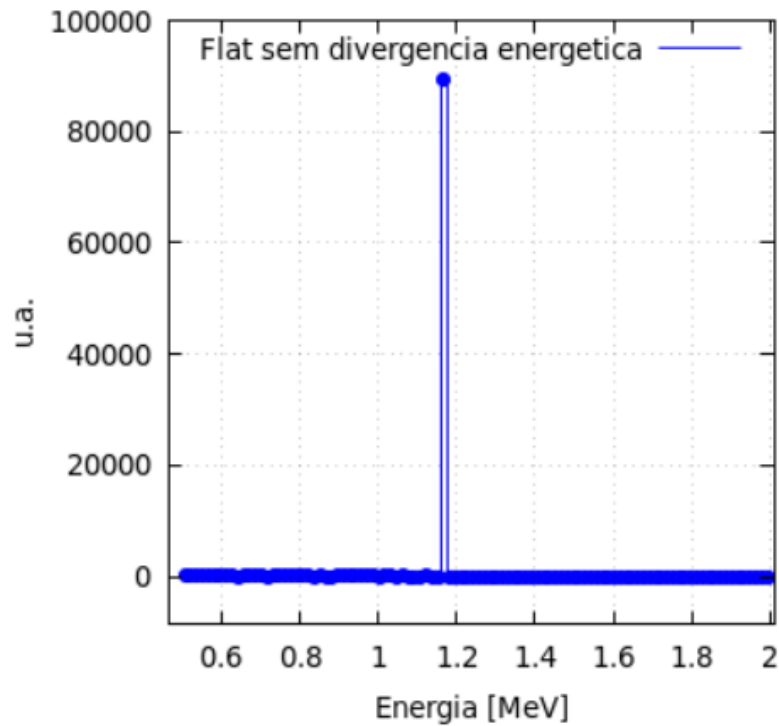
1 000 eventos



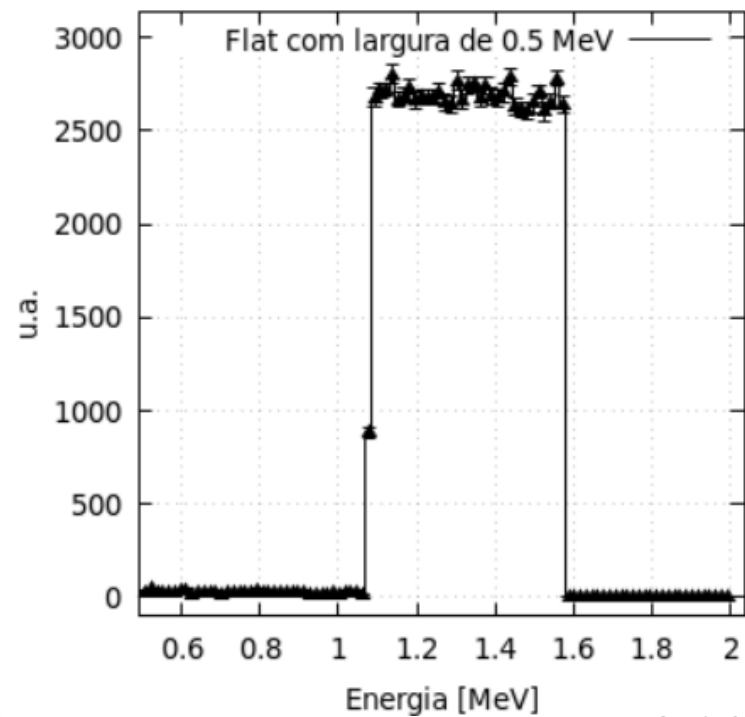
# Aula 6 – USRBDX/USRDUMP

## Solução:

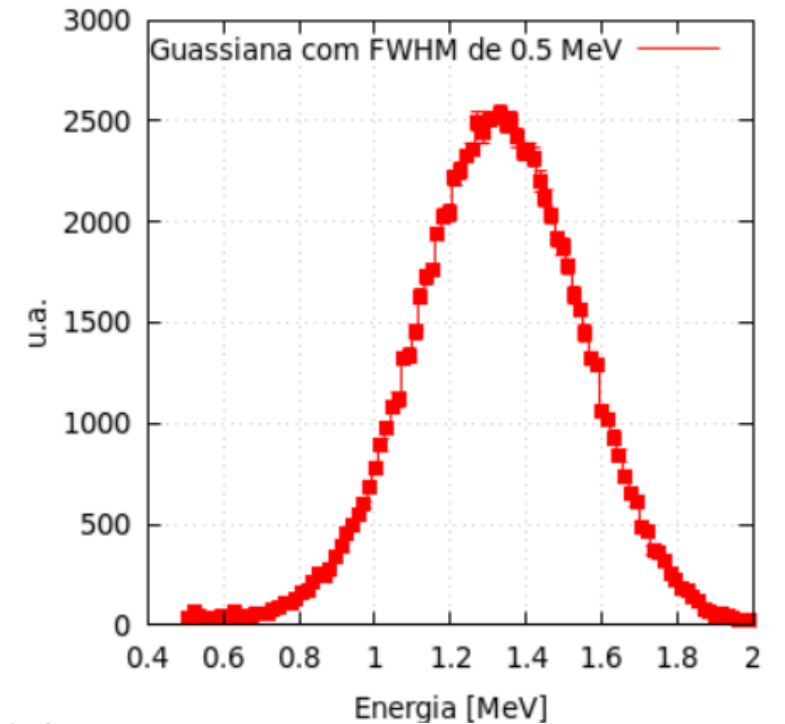
Graficos com USRBDX



Graficos com USRBDX



Graficos com USRBDX



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DE 2023

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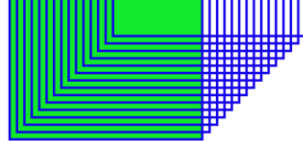
FLUKA

# AULA 06

# Detectores –

# USRBDX/USRDUMP

Obrigada pela participação!



Código Monte Carlo de interação e transporte de partículas



01

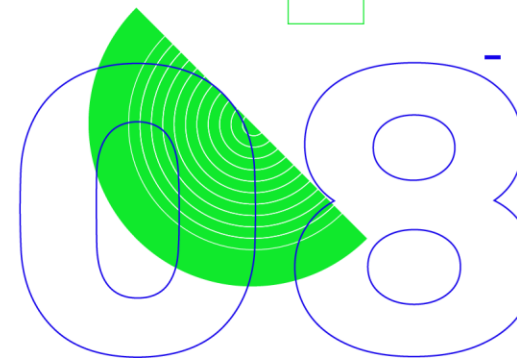
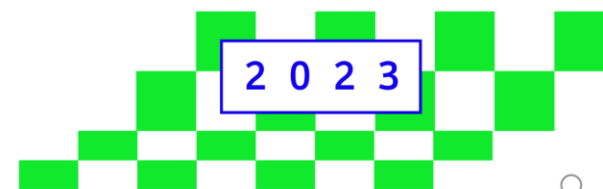
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