CURSO INTRODUTÓRIO FLUKA

23 DE JANEIRO A 8 DE MARÇO DE 2023

AULA 07 Detectores – USRBIN (parte I)

Iniciaremos em breve

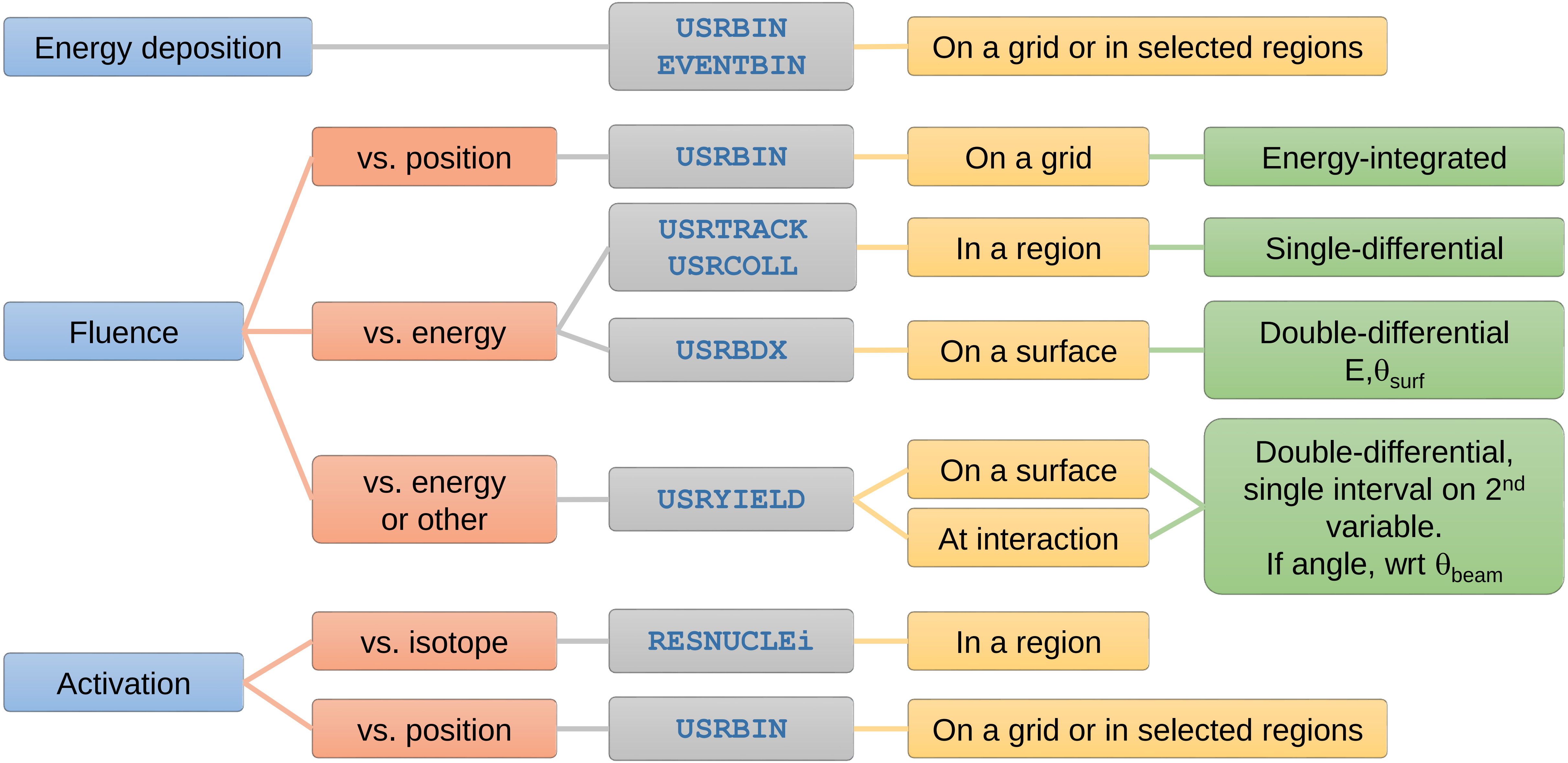
Código Monte Carlo de interação e transporte de partículas

Scoring physical quantities I

Introduction to built-in estimators

3D distributions (**USRBIN**) & 1D-2D plots

The FLUKA estimator zoo



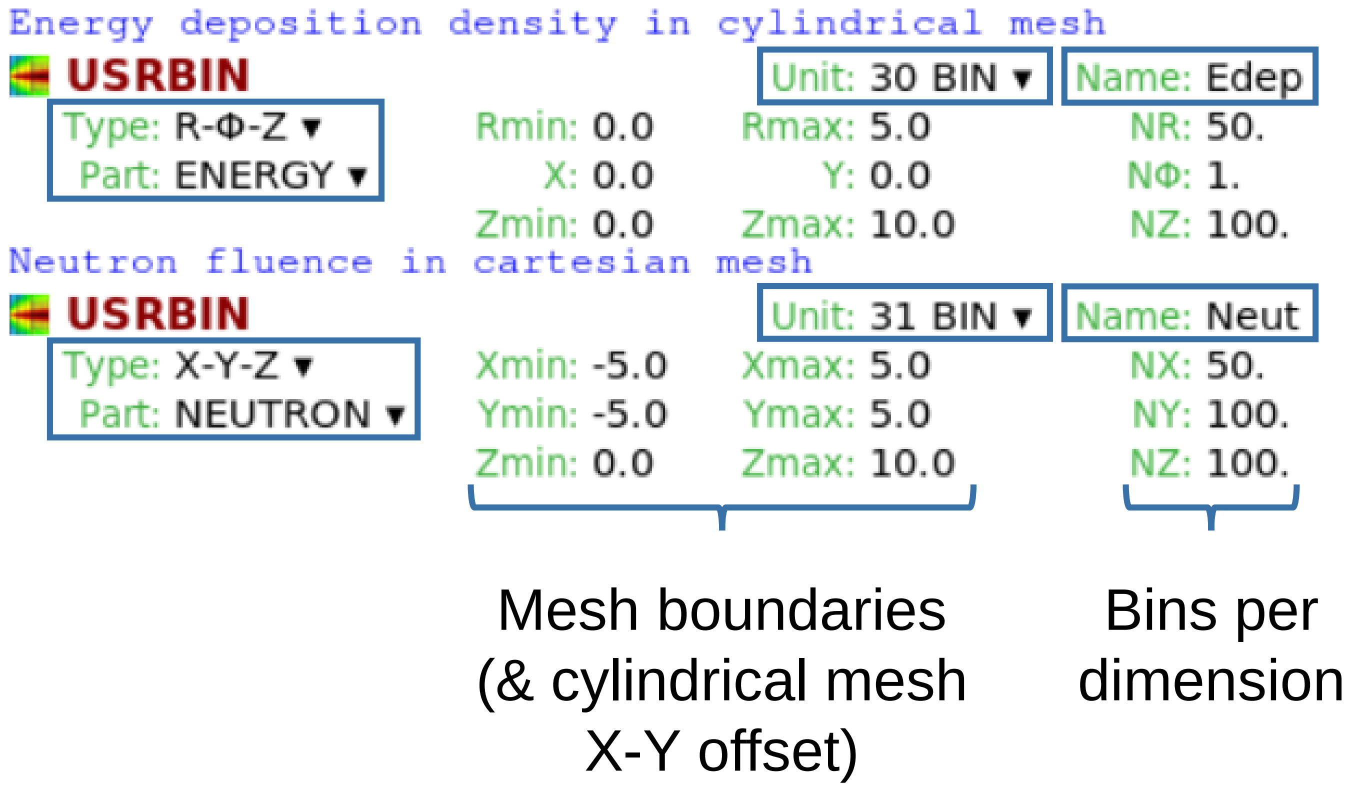
Main FLUKA estimators

- **USRBIN** scores the **spatial distribution** of **energy density** or **fluence** (or star density) in a **region** or **regular mesh** (cylindrical, Cartesian) 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**

USRBIN examples, visualisation and plotting

USRBIN definition - examples

- **Type**: X-Y-Z, R-Φ-Z, Region, …
- **Part**: generalised particle
- **Unit**: logical output unit
  - **BIN** (binary): unformatted output
    Can be post-processed via Flair
  - **ASC** (ASCII): formatted output
    Cannot be post-processed via Flair
- **Name**: 8-character limit



Tipo de Mesh

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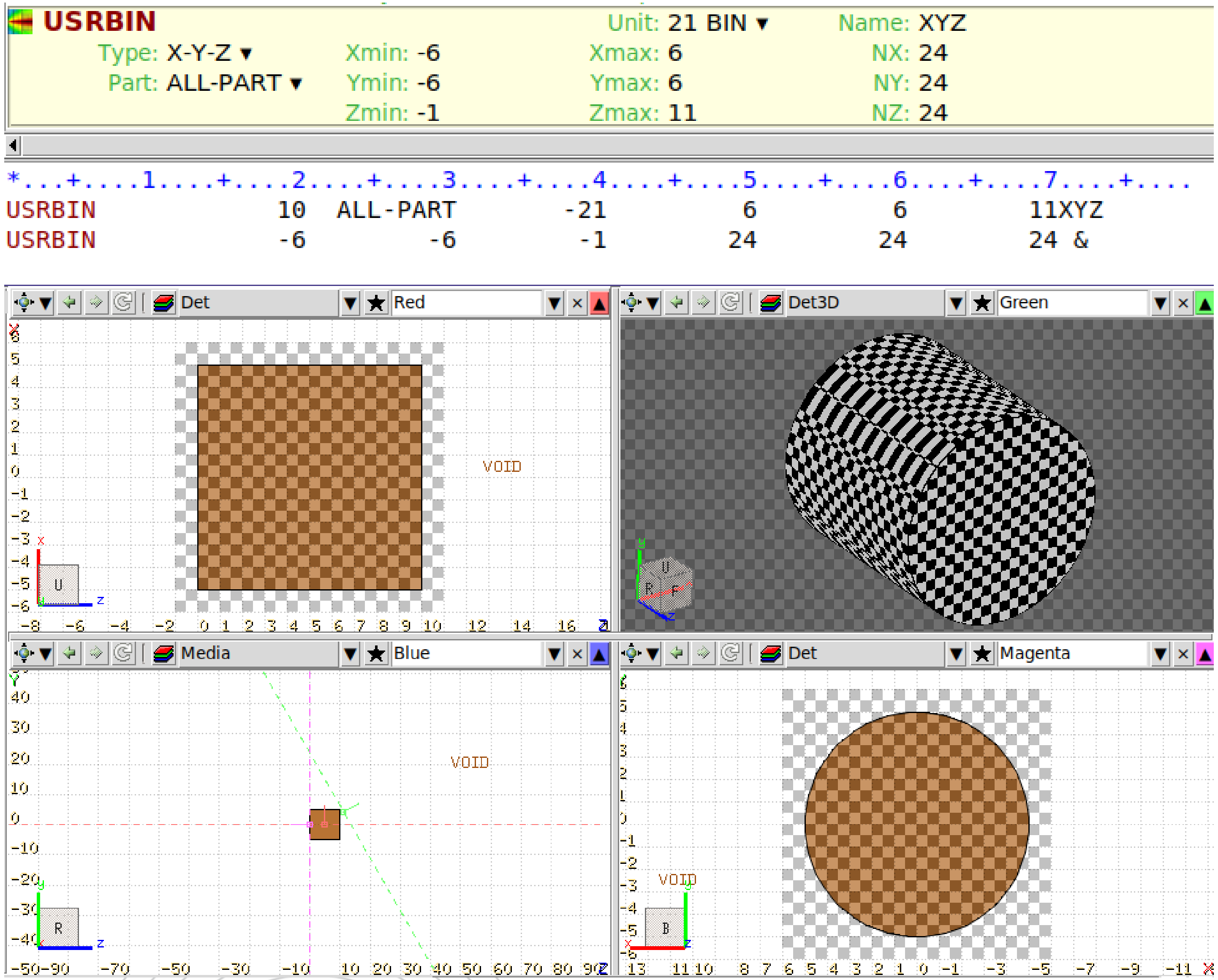

X-Y-Z: Cartesiano

Configura-se os pontos mínimos e máximos de cada eixo;

E o número de *bins* (divisões) do eixo.

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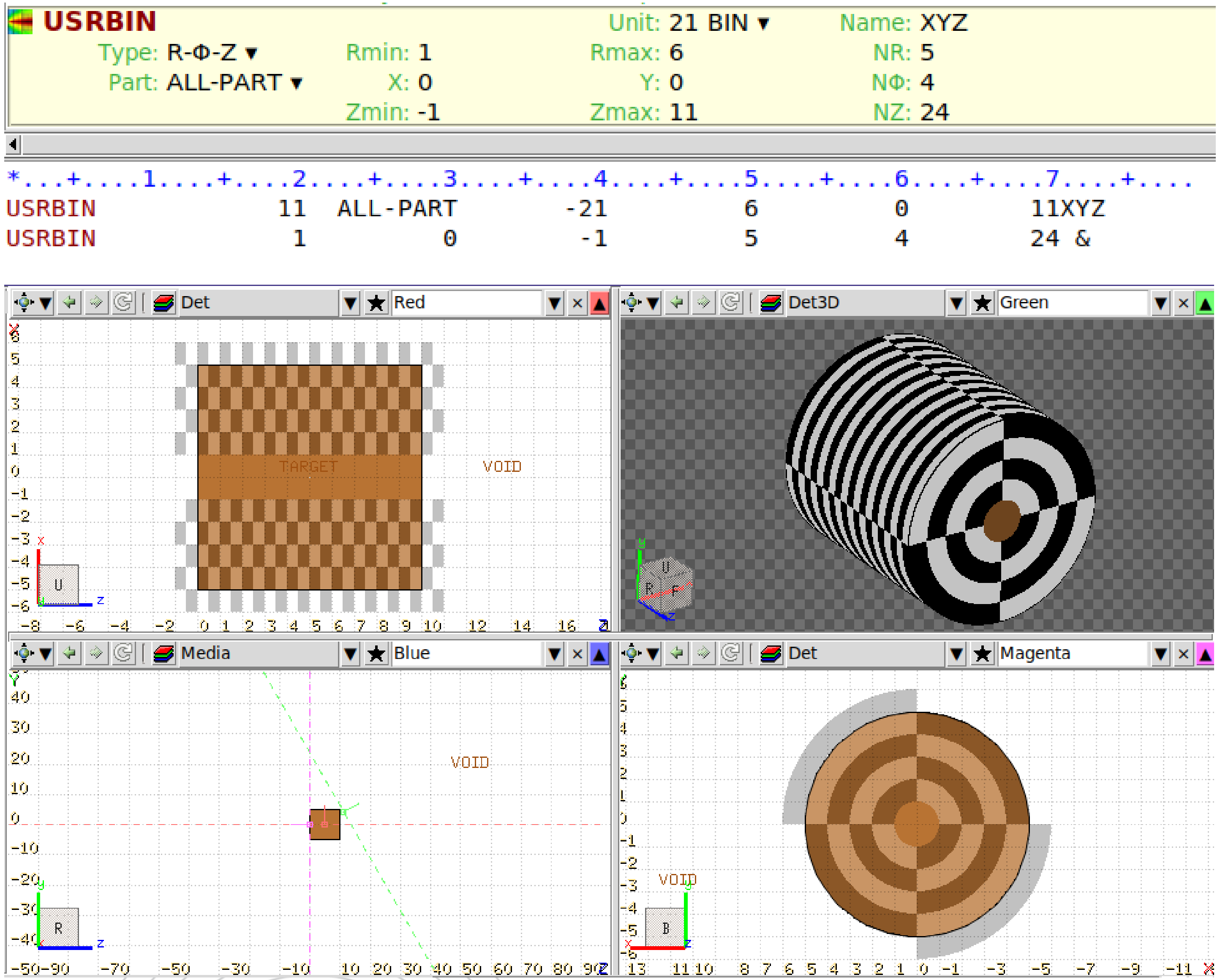
Tipo de Mesh



R-Φ-Z: Cilíndrico

Configura-se os pontos mínimos e máximos do raio e do eixo Z do detector;

O ponto central X-Y;

E o número de *bins* radial, angular e no eixo Z.

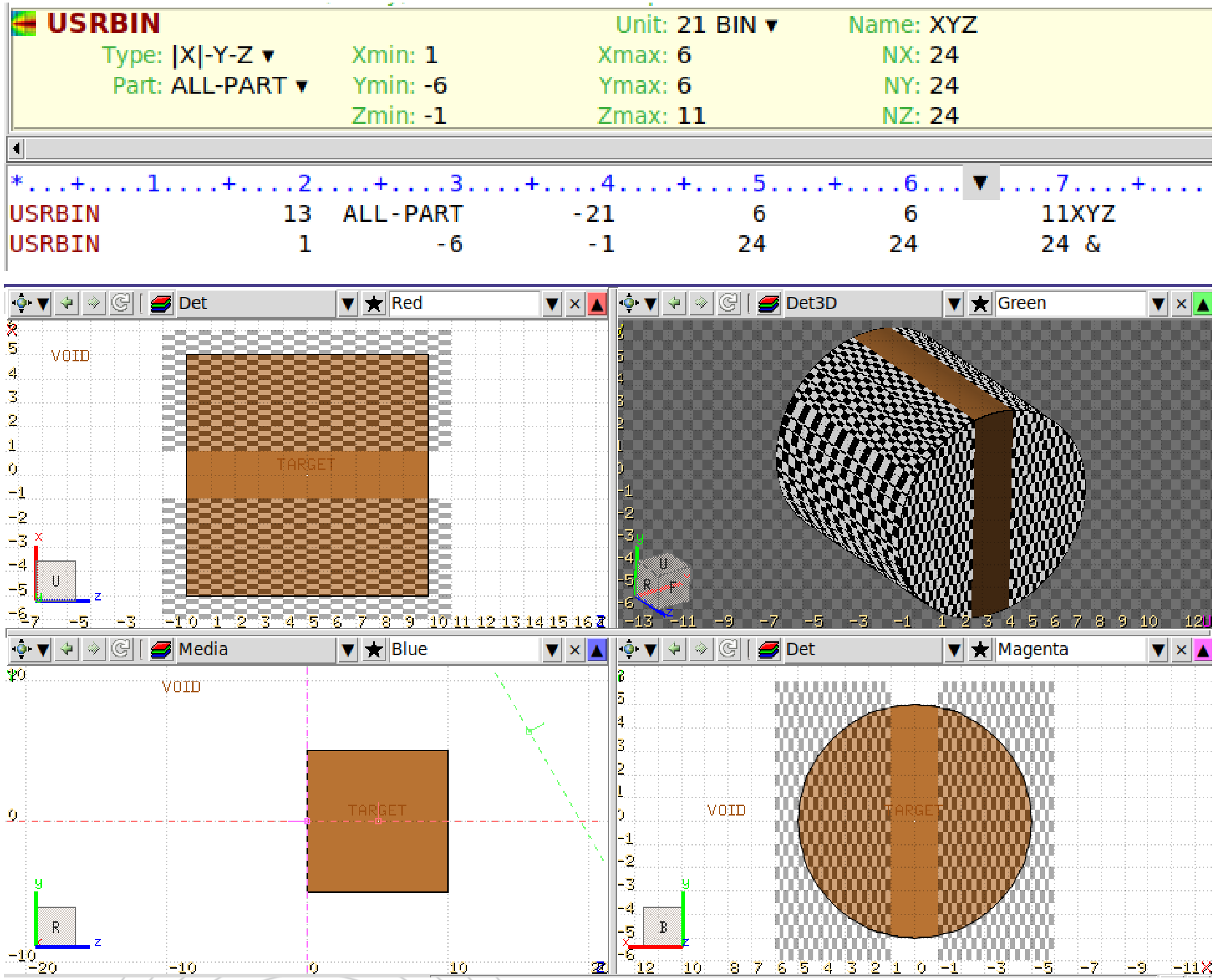
Úteis para geometrias com simetria radial.

Tipo de Mesh

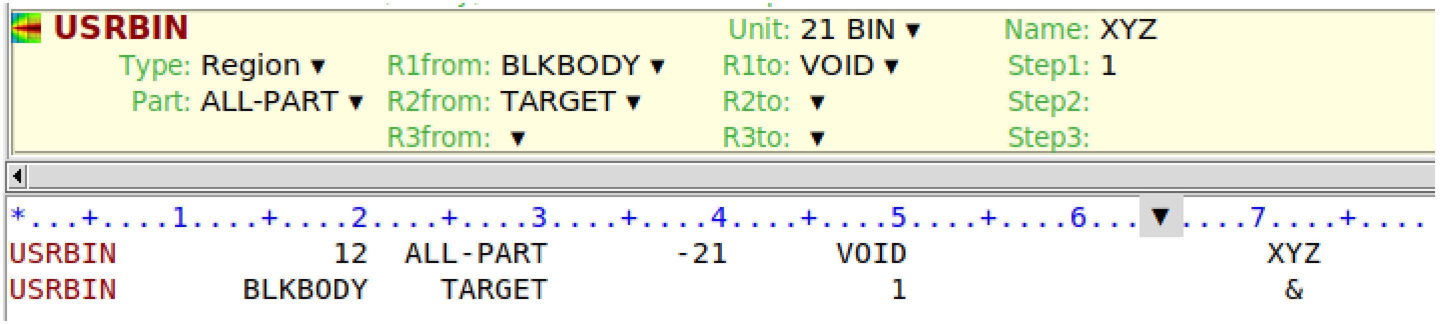
Mesh com módulos:

Iguais aos meshs sem os módulos, mas "espelhado" com os eixos que possuem módulo.

Úteis para geometrias com simetria cartesiana.

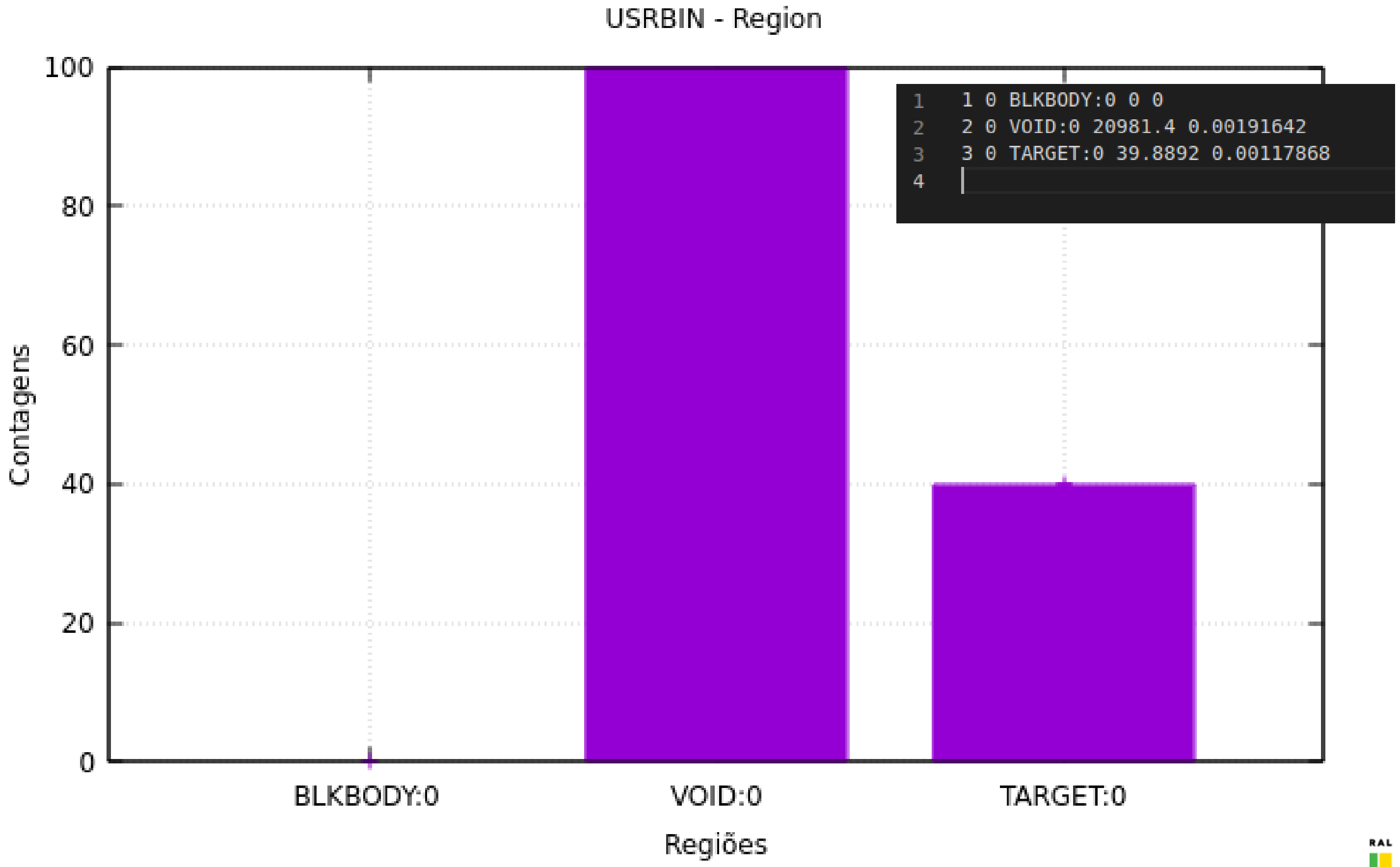


Tipo de Mesh



Region: Por Região

Configura-se as regiões (ou agrupamento de regiões) em que serão contabilizados os valores requisitados.



USRBIN definition - examples

Energy deposition density
(GeV/cm^3 per primary)

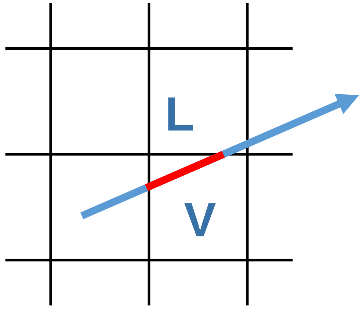
Particle fluence
(1/cm^2 per primary)

Energy deposition density in cylindrical mesh

USRBIN		Unit: 30 BIN ▾	Name: Edep
Type: R-Φ-Z ▾	Rmin: 0.0	Rmax: 5.0	NR: 50.
Part: ENERGY ▾	X: 0.0	Y: 0.0	NΦ: 1.
	Zmin: 0.0	Zmax: 10.0	NZ: 100.

Neutron fluence in cartesian mesh

USRBIN		Unit: 31 BIN ▾	Name: Neut
Type: X-Y-Z ▾	Xmin: -5.0	Xmax: 5.0	NX: 50.
Part: NEUTRON ▾	Ymin: -5.0	Ymax: 5.0	NY: 100.
	Zmin: 0.0	Zmax: 10.0	NZ: 100.

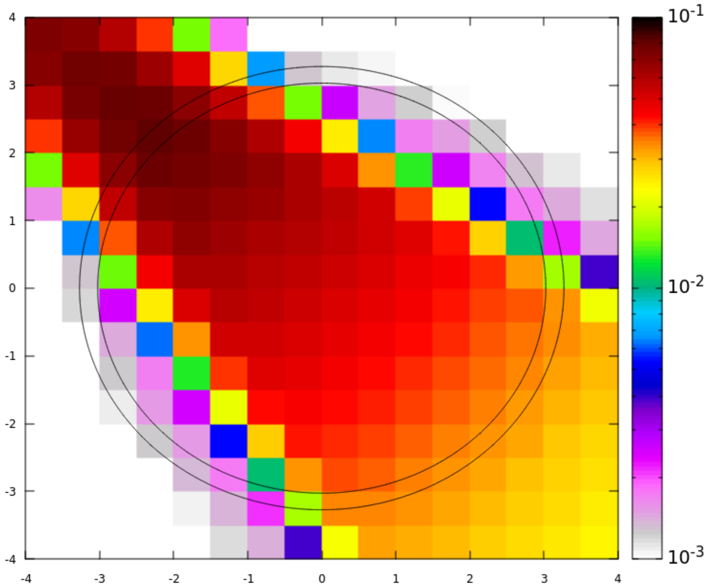


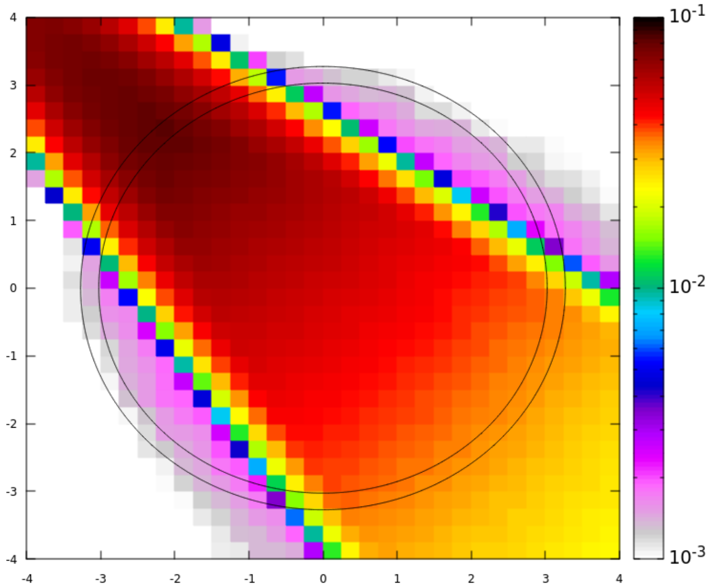
Path length **L** [cm] inside the bin divided by the bin volume **V** [cm^3] → cm / cm^3 = 1/cm^2

Normalização pelo volume

A normalização pelo volume do *bin* permite uma análise mais verdadeira de uma irradiação.

Essa normalização torna os valores obtidos na simulação **independentes do tamanho do *bin*.**





Volume normalisation

- FLUKA does not calculate **region** volumes

- When scoring particle *fluence* (e.g. **`NEUTRON`**) *or energy density* (**`ENERGY`**) with **`USRBIN` by region**, the actual results will give instead *total track-length and energy deposition*, respectively; these differ from the intended quantities by a factor equal to the region volume
  - In other words, the code assumes a volume equal to 1 cm^3

- Conversely, as **`USRBIN`** scoring **on regular (Cartesian, cylindrical) grids** is requested, *particle fluence and energy density* will be automatically provided, since FLUKA performs the bin volume normalisation

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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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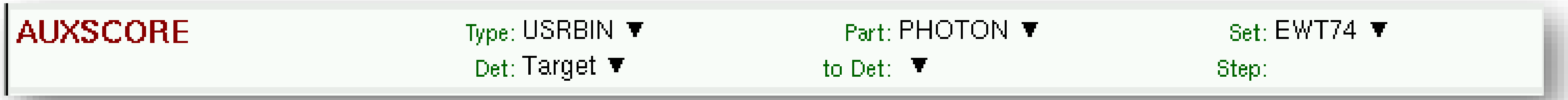
Radiation Protection specific calculations

Relevant Generalized Particle Types

Name	Units	Description
DOSE	GeV/g	Dose (energy deposited per unit mass)
DOSE-EQ	pSv	Dose Equivalent (**AUXSCORE**) Based on ICRU sphere or human phantom (see next slides)
ACTIVITY	Bq/cm^3	Activity per unit volume
ACTOMASS	Bq/g	Activity per unit mass

Input option: AUXSCORE

Association of scoring with scoring with dose equivalent conversion factors



Type	**Type of estimator to associate with** drop down list of estimator types (**USRBIN**, **USRBDX**…)
Part	**Particle or isotope to filter for scoring** Particle or particle family list
Det .. to Det	**Detector range** Drop down list to select detector range of type **Type**
Step	**Step in assigning indices of detector range**
Set	**Conversion factor set for dose equivalent (DOSE-EQ) scoring** Drop down list of available dose conversion sets

Note: This card is NOT just for activation-type scorings. It can be used for prompt radiation.

Fluence-to-dose conversion coefficients

- Several fluence-to-dose conversion coefficients are available

    (many new coefficients added in version 4-2.0)

- Ambient dose equivalent H*(10)
    - Operational quantity for area monitoring (10mm depth in ICRU sphere)
    - "**AMB74**" coefficient set, is the default choice for dose equivalent calculation
    - i.e.: it is possible to score DOSE-EQ without an **AUXSCORE** card (see later)
    - The "**AMB74**" coefficients are based on ICRP74 recommendations and Pelliccioni data
    - M. Pelliccioni, "*Overview of fluence-to-effective dose and fluence-to-ambient dose equivalent conversion coefficients for high energy radiation calculated using the FLUKA code*", Radiation Protection Dosimetry 88 (2000) 279-297

Fluence-to-dose conversion coefficients

- Effective dose is based on human phantoms
  - Conversion coefficients sets depending on different recommendations and weighting factors: e.g. ICRP74, ICRP116, ICRP60, and Pelliccioni
  - Conversion coefficients sets implemented for different irradiation geometries:
    - Anterior-Posterior
    - Rotational
    - Isotropic
    - Posterior-Anterior
    - Right lateral
    - Left lateral
    - WORST ("Working Out Radiation Shielding Thicknesses"):

      It is the worst of all irradiation geometries

      It is recommended to be used for shielding design
  - Implemented for protons, neutrons, charged pions, muons, photons, electrons

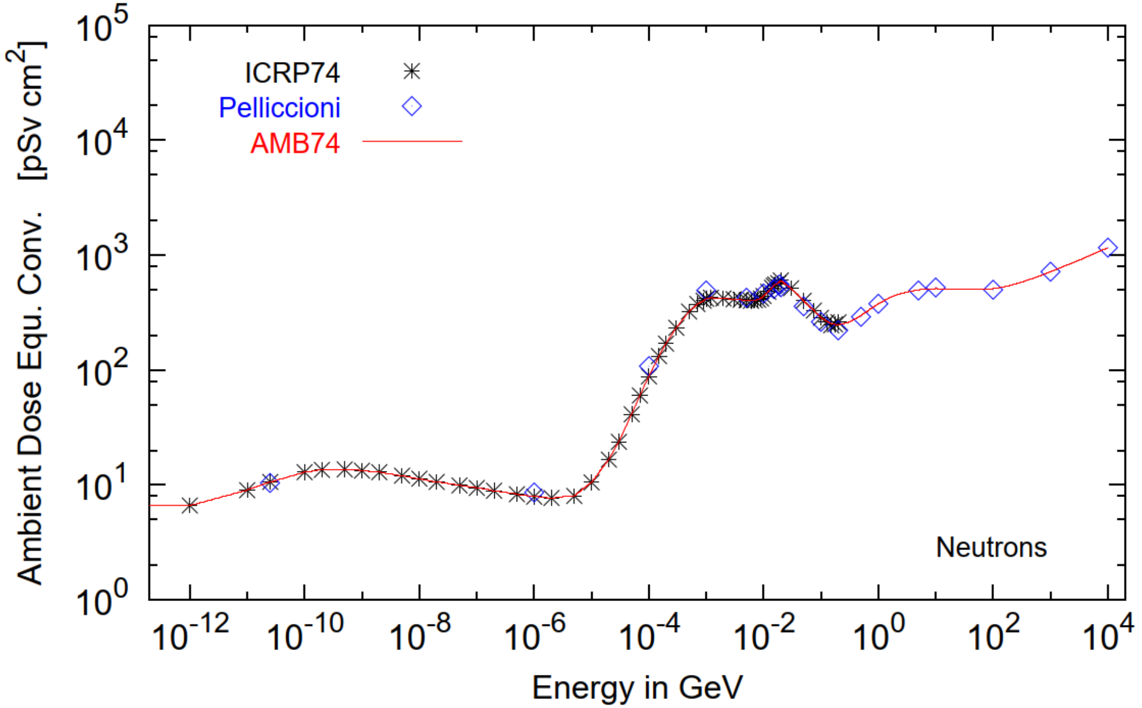
    conversion coefficients for other particles are approximated by these
  - Zero coefficient is applied to all heavy ions

Fluence-to-dose conversion coefficients

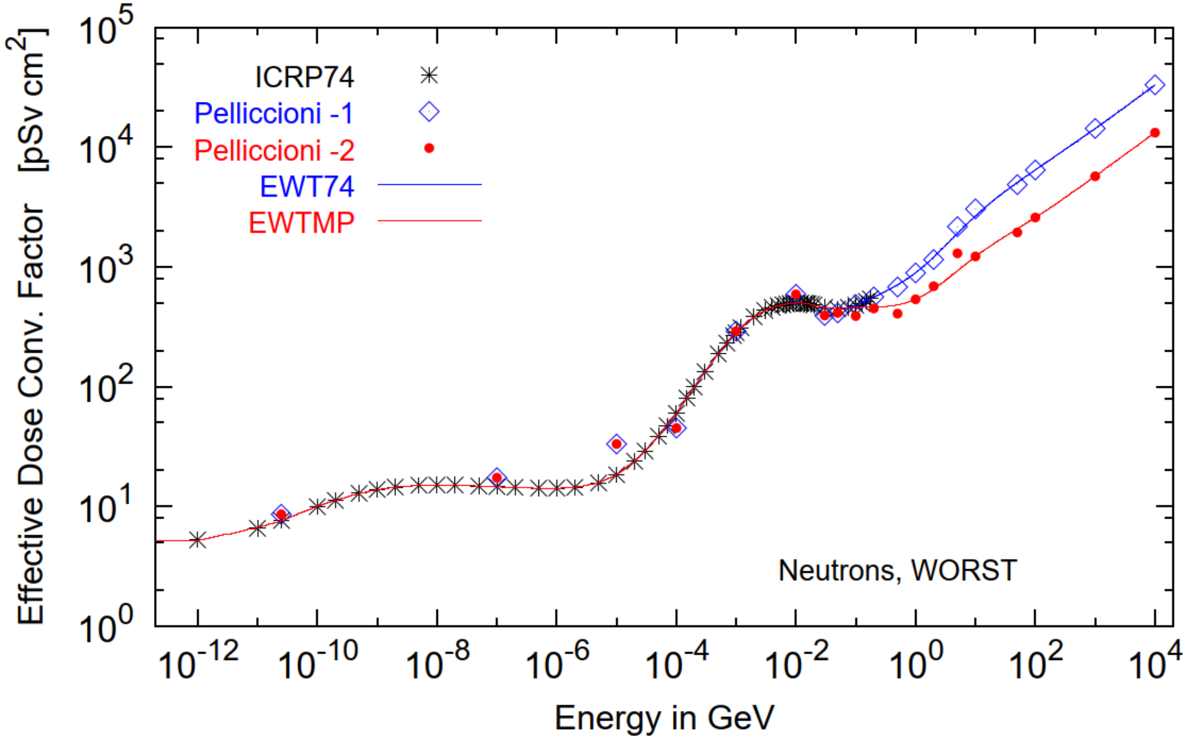
Units: pSv cm^2 (to be folded with fluence [1/(cm^2·primary)] to yield [pSv/primary])

Examples:

Ambient dose equivalent for neutrons



Effective dose for WORST irradiation geometry



For more information please see: https://flukafiles.web.cern.ch/flukafiles/documents/deq2.pdf

Fluence-to-dose conversion coefficients

- Ambient dose
  - Conversion coefficients from ICRU95

- Personal dose
  - 12 different conversion coefficients from ICRU95
  - Depending on the irradiation geometry

- Directional and personal absorbed dose in the lens of the eyes
  - 8 different conversion coefficients from ICRU95

- Directional and personal absorbed dose in the local skin
  - 6 different conversion coefficients from ICRU95

Fluence-to-dose conversion coefficients

- For details on the different fluence-to-dose conversion coefficients sets,
  look in the FLUKA manual

SDUM

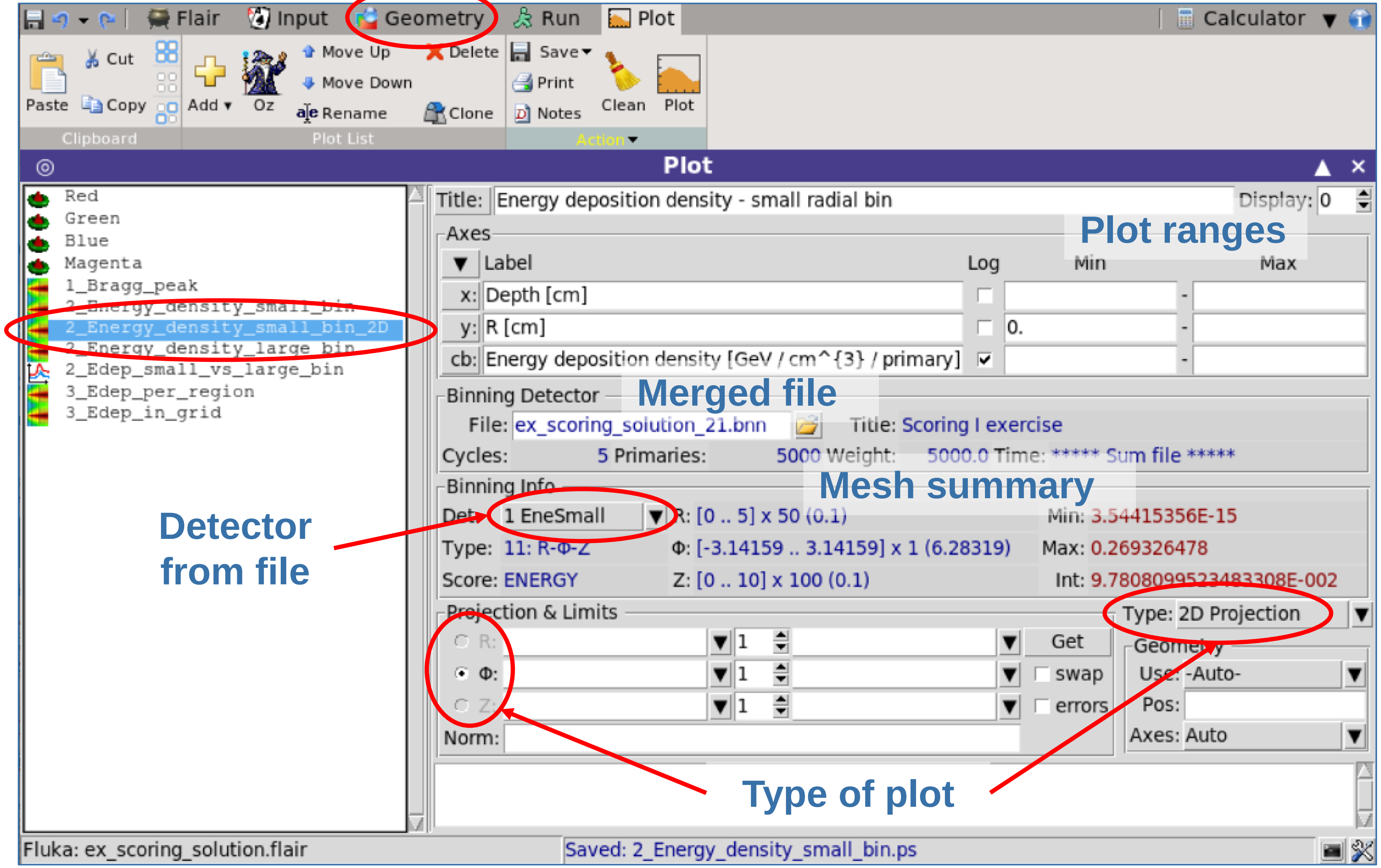
For dose equivalent (DOSE-EQ) scoring, the user can request the energy-dependent coefficients for the conversion of fluence to different dose (equivalent) quantities.

The following dose conversion coefficients sets are available:

1. Effective dose from ICRP74 and Pelliccioni data [Pel00] calculated with ICRP radiation weighting factors Wr for neutrons, protons, charged pions, muons, photons and electrons [Roe06].
   a. `EAP74` : Anterior-Posterior irradiation geometry
   b. `ERT74` : Rotational irradiation geometry
   c. `EWT74` : maximum value of all irradiation geometries (WORST), see Note 2
2. Effective dose from ICRP74 and Pelliccioni data [Pel00] calculated with the Pelliccioni radiation weighting factors Wr for neutrons, protons, charged pions, muons. For photons and electrons the sets from `EAP74` , `ERT74` and `EWT74` will be used respectively [Roe06].
   a. `EAPMP` : Anterior-Posterior irradiation
   b. `ERTMP` : Rotational irradiation geometry
   c. `EWTMP` : maximum value of all irradiation geometries (WORST), see Note 2
3. Ambient dose equivalent from ICRP74 and Pelliccioni data [Pel00] for neutrons, protons, charged pions, muons, photons and electrons [Roe06].
   a. `AMB74` : ambient dose equivalent H*(10)
4. Ambient dose equivalent with old "GRS"-conversion factors for neutrons, protons, charged pions, muons. Photons and electrons are not considered [Roe06].
   a. `AMBGS` : ambient dose equivalent H*(10)
5. Effective dose from ICRP Publication 116 [ICR116] for photons, neutrons, electrons, positrons, protons, charged muons, charged pions and alpha particles (see Note 3). The conversion coefficients have been extrapolated up to 10 TeV for all particles. For energies outside the tabulated ranges see Note 6.
   a. `EDAP` : anterior-posterior irradiation geometry
   b. `EDISO` : isotropic irradiation geometry
   c. `EDLLAT` : left lateral irradiation geometry
   d. `EDPA` : posterior-anterior irradiation geometry
   e. `EDRLAT` : right lateral irradiation geometry
   f. `EDROT` : rotational irradiation geometry
   g. `EDWORST` : maximum value of all irradiation geometries (WORST), see Note 2

   Conversion coefficients for certain irradiation geometries are available only for certain particles (see Note 4)
6. Ambient dose from ICRU Report 95 [ICRU95] for photons, neutrons, electrons, positrons, protons, charged muons, charged pions and alpha particles (see Note 3). The conversion coefficients have been extrapolated up to 10 TeV for all particles. For energies outside the tabulated ranges see Note 6.
   a. `HS` : ambient dose H*
7. Personal dose from ICRU Report 95 [ICRU95] for photons, neutrons, electrons, positrons, protons, charged muons, charged pions and alpha particles for different irradiation geometries (see Note 3). For energies outside the tabulated ranges see Note 6.
   a. `HP000` : personal dose H_p, for angle 0 degree
   b. `HP015` : personal dose H_p, for angle 15 degree
   c. `HP030` : personal dose H_p, for angle 30 degree
   d. `HP045` : personal dose H_p, for angle 45 degree
   e. `HP060` : personal dose H_p, for angle 60 degree
   f. `HP075` : personal dose H_p, for angle 75 degree
   g. `HP090` : personal dose H_p, for angle 90 degree
   h. `HP180` : personal dose H_p, for angle 180 degree
   i. `HPISI` : personal dose H_p, for IS-ISO irradiation geometry
   j. `HPISO` : personal dose H_p, for ISO irradiation geometry
   k. `HPROT` : personal dose H_p, for ROT irradiation geometry
   l. `HPSSI` : personal dose H_p, for SS-ISO irradiation geometry
8. Directional and personal absorbed dose in the lens of the eye from ICRU Report 95 [ICRU95] for electrons, positrons, neutrons and photons (see Note 3). The angle of 180 degree for neutrons is not included in the dataset. For energies outside the tabulated ranges see Note 6.
   a. `DE000` : absorbed dose d_lens for an angle of 0 degree
   b. `DE015` : absorbed dose d_lens for an angle of 15 degree
   c. `DE030` : absorbed dose d_lens for an angle of 30 degree
   d. `DE045` : absorbed dose d_lens for an angle of 45 degree
   e. `DE060` : absorbed dose d_lens for an angle of 60 degree
   f. `DE075` : absorbed dose d_lens for an angle of 75 degree
   g. `DE090` : absorbed dose d_lens for an angle of 90 degree
   h. `DEROT` : absorbed dose d_lens for rotational irradiation geometry
9. Directional and personal absorbed dose in the local skin from ICRU Report 95 [ICRU95] for photons, neutrons, electrons and positrons on the slab phantom (see Note 3). Pillar and rod phantom data sets have not been included. For energies outside the tabulated ranges see Note 6.
   a. `DS000` : absorbed dose d_skin for an angle of 0 degree
   b. `DS015` : absorbed dose d_skin for an angle of 15 degree
   c. `DS030` : absorbed dose d_skin for an angle of 30 degree
   d. `DS045` : absorbed dose d_skin for an angle of 45 degree
   e. `DS060` : absorbed dose d_skin for an angle of 60 degree
   f. `DS075` : absorbed dose d_skin for an angle of 75 degree

Plotting example – energy deposition density



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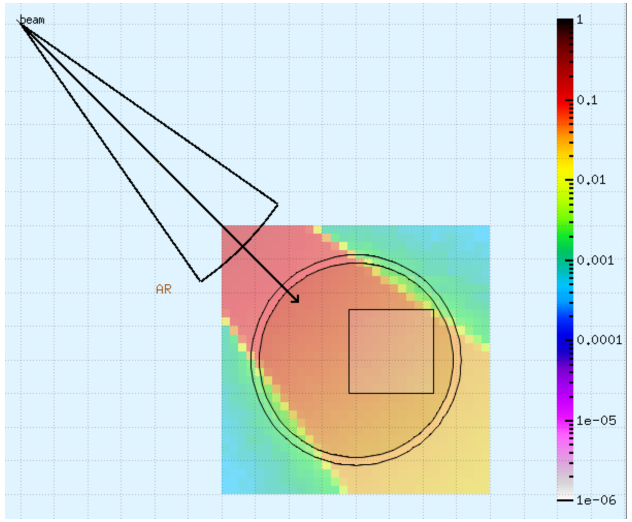
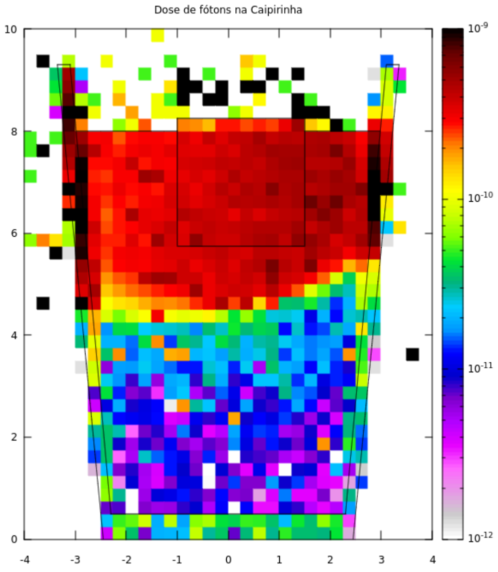
Título

Montem detectores de posição na simulação:

1. Detector cartesiano de fótons com:
   - X: [0, 10] com 20 bins
   - Y: [-4, 4] com 16 bins
   - Z: [-5, 5] com 20 bins
2. Detector de região no copo, no líquido e no gelo, mensurando dose e filtrado por:
   - Fótons
   - Elétrons
   - Todas partículas
3. É possível fazer um detector cilíndrico para casar com a geometria circular do copo que montamos? Como/porque?





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Obrigado pela participação!

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Código Monte Carlo de interação e transporte de partículas

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2023

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