CURSO INTRODUTÓRIO FLUKA

23 DE JANEIRO A 8 DE MARÇO DE 2023

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# AULA 05
# Feixes

Iniciaremos em breve

Código Monte Carlo de interação e transporte de partículas

23 FLUKA 2023

CNPEM MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÃO
GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO


# Simple sources and preprocessor

# Outline

## 1. Simple source definition

- Definition of simple beams
  - Beam parameters
  - Beam visualisation
  - Beam rotation
- Volumetric sources
- Further possibilities

## 2. The FLUKA preprocessor

# 1. Simple sources

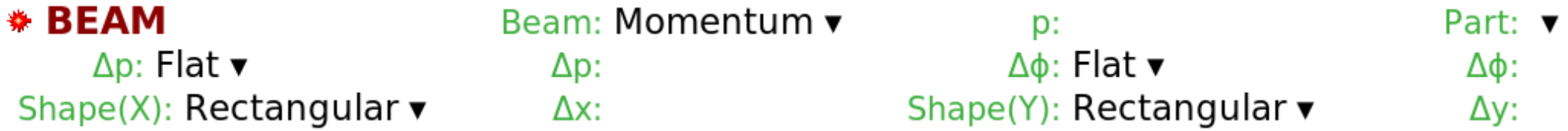
**BEAM** & **BEAMPOS** cards | Visualisation | Volumetric sources

# Required cards

- In the *Basic input & Flair introduction* lecture we already saw two cards related to defining a beam in FLUKA, namely the **BEAM** and **BEAMPOS** cards:

| | | | |
|---|---|---|---|
| **BEAM** | Beam: Momentum ▾ | p: | Part: ▾ |
| Δp: Flat ▾ | Δp: | Δϕ: Flat ▾ | Δϕ: |
| Shape(X): Rectangular ▾ | Δx: | Shape(Y): Rectangular ▾ | Δy: |
| **BEAMPOS** | x: | y: | z: |
| | cosx: | cosy: | Type: POSITIVE ▾ |

# The BEAM card




- The BEAM card allows to specify the following parameters:
  - Particle type
  - Momentum or kinetic energy
  - Momentum distribution
  - Angular distribution
  - Shape in the X-Y plane

# The BEAM card: particle type

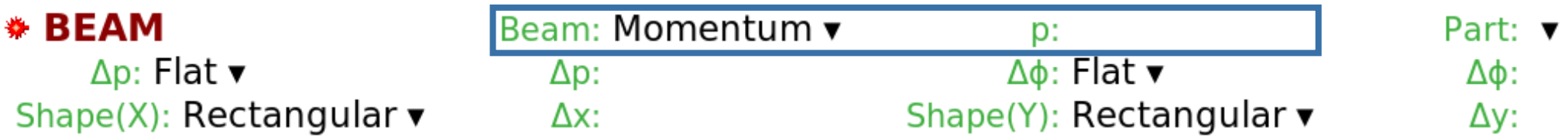

Select particle type from the dropdown menu

*Default particle*: **PROTON**

Non-standard particles:

- **HEAVYION**: Ion beams heavier than $^{4}$He – Requires a **HI-PROPE** card.
- **ISOTOPE**: Radioactive isotope sources – Requires the **HI-PROPE** and **RADDECAY** cards. See the *Activation* lecture

# The BEAM card: momentum/energy definition




Select **Momentum** or **Energy** from the dropdown menu

Enter the **value** in the input field next to it

*Default value*: **200 [GeV/c]**

**Note:** In the case of advanced sources, setting the momentum slightly higher than the maximum momentum used in those sources is **crucial**, since this value is used to initialise the cross section data tables.

(See the *Source routine* and *Advanced sources* lectures)

# The BEAM card: momentum and angular distributions


Momentum distribution types:

- **Flat**: Full width of a rectangular **momentum** distribution centred at beam momentum [GeV/c]
- **Gaussian**: FWHM of a Gaussian **momentum** distribution [GeV/c]

**IMPORTANT**: This is always momentum distribution, even if **Energy** was selected

Angular distribution types:

- **Flat**: Full width of a rectangular angular distribution centred at the beam axis [mrad]
- **Isotropic**: Isotropic distribution
- **Gaussian**: FWHM of a Gaussian angular distribution centred at the beam axis [mrad]

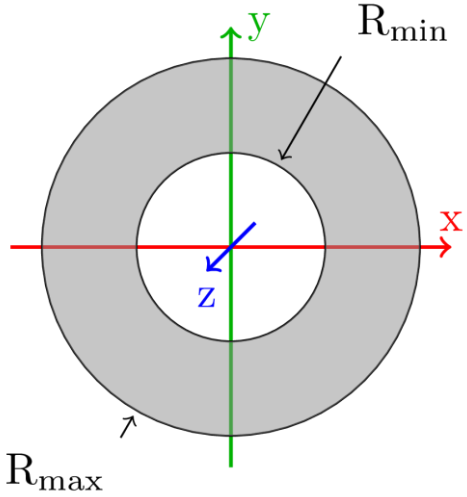
# The BEAM card: beam shape in the X-Y plane

| BEAM | Beam: Momentum ▾ | p: | Part: ▾ |
|---|---|---|---|
| Δp: Flat ▾ | Δp: | Δϕ: Flat ▾ | Δϕ: |
| Shape(X): Rectangular ▾ | Δx: | Shape(Y): Rectangular ▾ | Δy: |

Distribution type:

- **Rectangular**: Full beam width in **x/y** direction centred at the beam axis [cm]
- **Gaussian**: FWHM of a Gaussian distribution in **x/y** direction centred at the beam axis [cm]

  *Default*: **Δx** = 0.0, **Δy** = **Δx**
- **Annular** distribution can be selected in the dropdown menu of **Shape(X)**
  - **Rmin** and **Rmax** are the radii of the distribution
  - The beam particle position is uniformly sampled on the **x**-**y** plane between **Rmin** and **Rmax**
  - For circular beam use **Rmin = 0.0**



# The BEAMPOS card: beam position and direction


Position:

The beam position is defined with its **x**, **y** and **z** coordinates [cm]

*Default:* Origin of the coordinate system

Direction:

The beam axis is defined via direction cosines with respect to the x and y axes

The third direction cosine (**cosz**) is automatically calculated by FLUKA

Note that this is not enough for an unequivocal direction definition; the sign of **cosz** has to be provided as well. Select **POSITIVE** or **NEGATIVE** from the *Type* dropdown

*Default:* Positive z direction

# Default beam

- What happens if the **BEAM** and **BEAMPOS** cards are not filled in or are missing?
- FLUKA will use the built-in default (***note****: may change in the future*):
  - Protons at 200 GeV/c momentum
  - Pencil beam: No divergence, zero radius
  - Starting from the origin of the coordinate system
  - Directed along the positive z axis

- This is almost never what you want!
- Always complete the relevant information in the **BEAM** and **BEAMPOS** card
- It is good practice to confirm what source you have defined by checking the FLUKA output (see the *Standard output* lecture)

# Beam visualisation

- The easiest way to check whether the beam parameters are set correctly is to visualise the beam

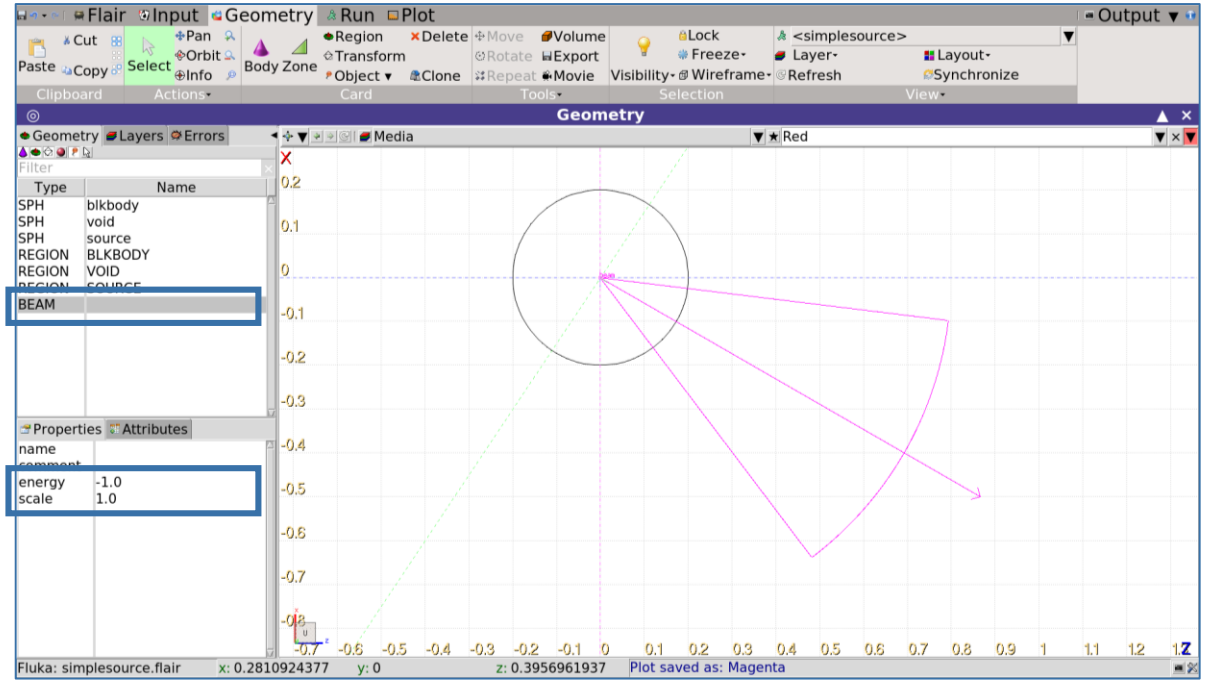
- There are two ways to do this:
  - Use the Geoviewer's BEAM object
  - Use standard FLUKA scorings (See the *Scoring* lectures) with **BEAMPART** as particle type
    - USRBIN for particle location and direction
    - USRBDX for energy spectrum (with a closed surface surrounding the source location)

# Beam visualisation

- **Example 1:** 1 GeV Gaussian beam | 0.1 GeV/c FWHM momentum distribution | 0.4 rad flat angular distribution | rotated around the y axis by -30°

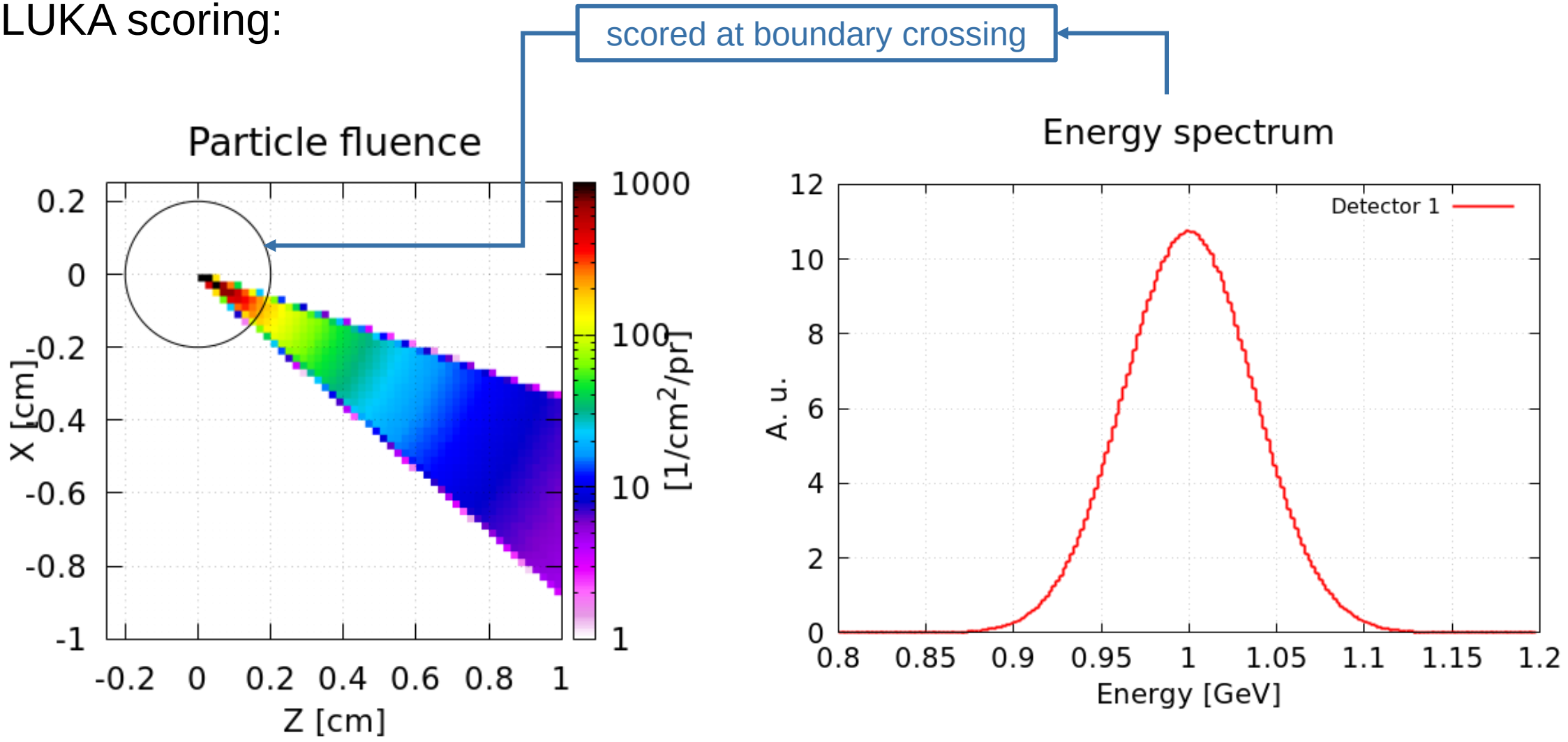
```
BEAM      Beam: Energy ▾      E: 1.0          Part: ▾
   Δp: Gauss ▾   Δp(FWHM): 0.1   Δϕ: Flat ▾   Δϕ: 400.0
Shape(X): Rectangular ▾   Δx:   Shape(Y): Rectangular ▾   Δy:
BEAMPOS      x: 0.0          y: 0.0          z: 0.0
             cosx: -0.5      cosy: 0.0       Type: POSITIVE ▾
```

- Geoviewer BEAM object:
  - Starting point
  - Direction
  - Angular distribution
  - Beam mean energy
  - Default scale: 1 GeV(/c) = 1 cm
    Can be changed with the scale parameter



# Beam visualisation

- FLUKA scoring:

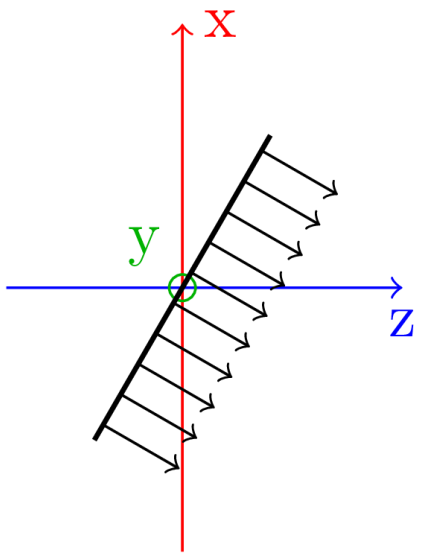


# Beam rotation

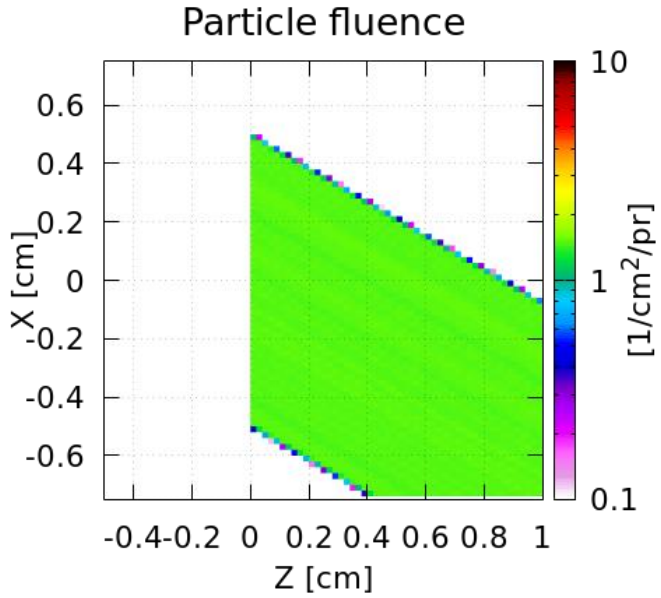
- **Example 2:** R = 0.5 cm cylindrical beam | zero divergence | rotated around y axis by -30°

```
BEAM          Beam: Momentum ▾        p:              Part: ▾
   Δp: Flat ▾      Δp:                Δϕ: Flat ▾      Δϕ:
Shape(X): Annular ▾  Rmin: 0.0        Rmax: 0.5
BEAMPOS          x: 0.0               y: 0.0          z: 0.0
                 cosx: -0.5           cosy: 0.0       Type: POSITIVE ▾
```

Expectation:




Reality:




- *Remember:* the **BEAM** card sets the X-Y shape of the beam, which is not influenced by the beam direction set in the **BEAMPOS** card... so how can we rotate the beam?

# Beam rotation

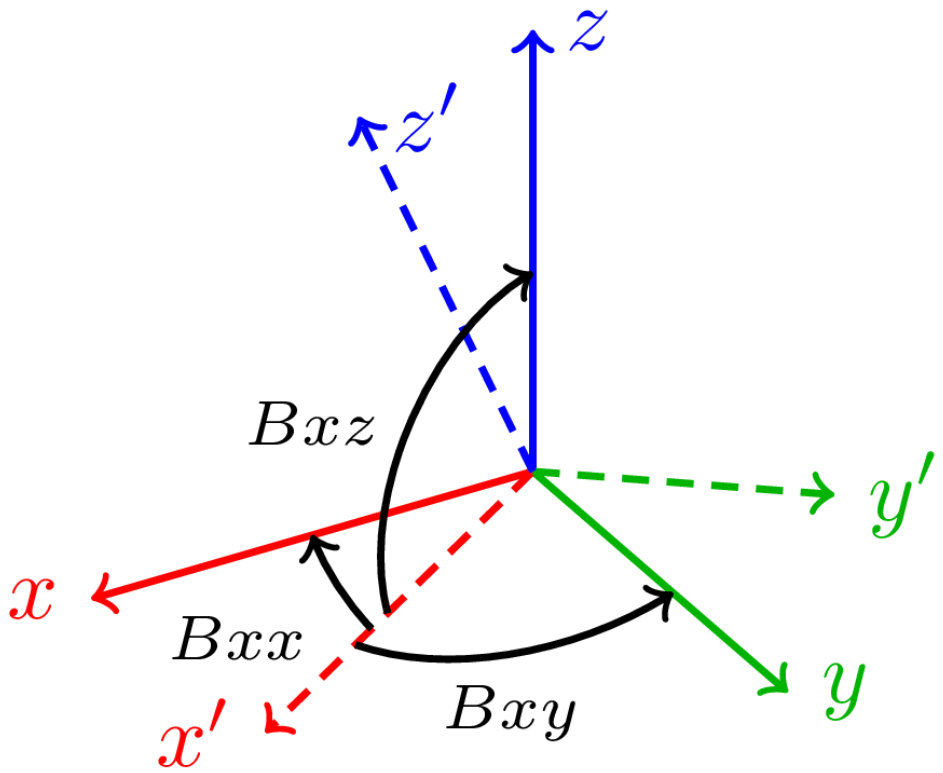
- Input card: **BEAMAXES**

**BEAMAXES** cosBxx: cosBxy: cosBxz:
cosBzx: cosBzy: cosBzz:

Defines the beam coordinate system (**x′, y′, z′**) with respect to the geometry one (**x, y, z**)

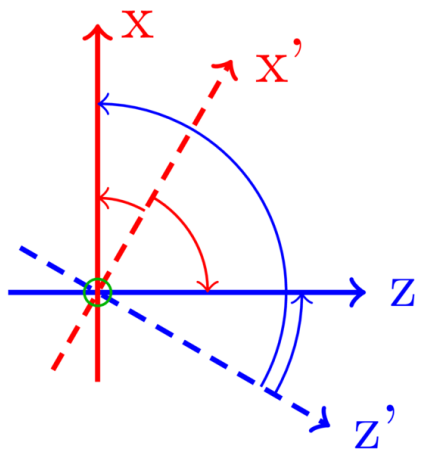
Input fields:

- **cosBxx**: cosine of the angle between **x′** and **x**
- **cosBxy**: cosine of the angle between **x′** and **y**
- **cosBxz**: cosine of the angle between **x′** and **z**
- **cosBzx**: cosine of the angle between **z′** and **x**
- **cosBzy**: cosine of the angle between **z′** and **y**
- **cosBzz**: cosine of the angle between **z′** and **z**

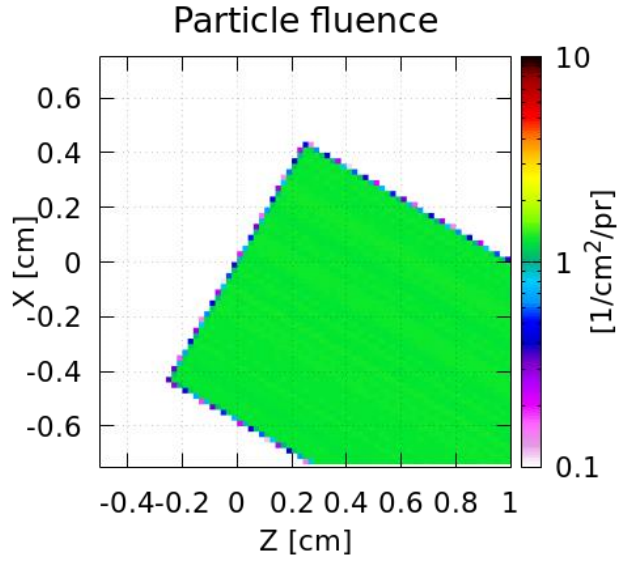


# Beam rotation

- **Example 2:** R = 0.5 cm cylindrical beam | zero divergence | rotated around y axis by -30°




| WHAT | Beam axis | Geo axis | Angle [°] | Cos(Angle) |
|---|---|---|---|---|
| cosBxx | x' | x | 30 | ~0.866 |
| cosBxy | x' | y | 90 | 0 |
| cosBxz | x' | z | -60 | 0.5 |
| cosBzx | z' | x | 120 | -0.5 |
| cosBzy | z' | y | 90 | 0 |
| cosBzz | z' | z | 30 | ~0.866 |




**BEAMAXES** cosBxx: 0.86602540378 cosBxy: 0.0 cosBxz: 0.5
cosBzx: -0.5 cosBzy: 0.0 cosBzz: 0.86602540378

# Volumetric sources

Volumetric sources can be defined with a second **BEAMPOS** card:

- Available types:
  - Spherical shell (**SPHE-VOL**)
  - Cylindrical shell (**CYLI-VOL**)
  - Cartesian shell (**CART-VOL**)
  - Spherical surface (**FLOOD**)

- Volumetric sources are centred around the position defined in the first **BEAMPOS** card
- The location inside the volume is sampled uniformly
- The particle direction and angular distribution set in the first **BEAMPOS** card and the **BEAM** card are still applied
- **Warning:** The spatial distributions specified in the **BEAM** card will be disregarded

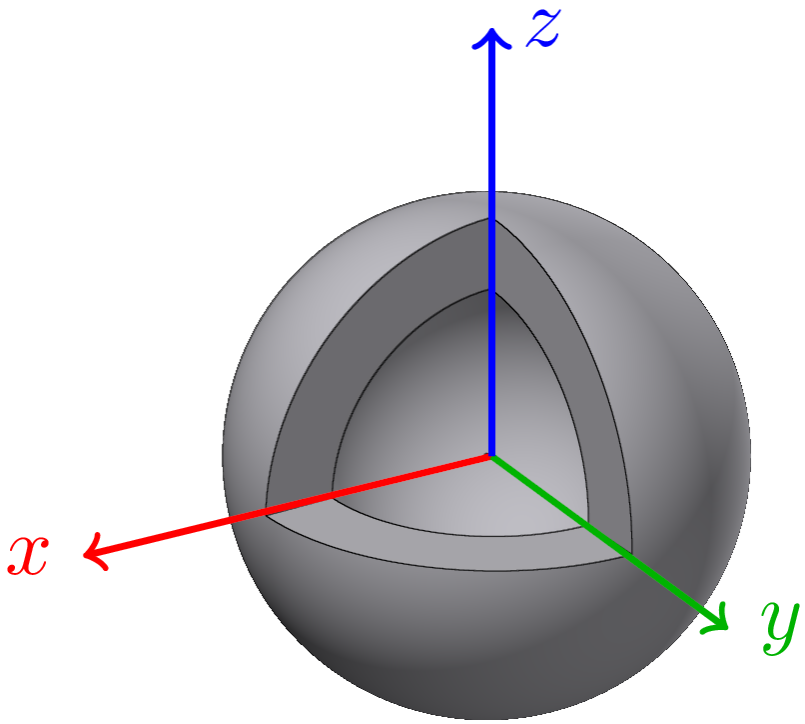
# Volumetric sources – *Spherical shell*

**BEAMPOS** Rin: Rout: Type: SPHE-VOL ▾

Specifies a spherical shell shaped source

Input fields:

- **Rin**: Inner radius [cm]
- **Rout**: Outer radius [cm]



# Volumetric sources – *Cylindrical shell*

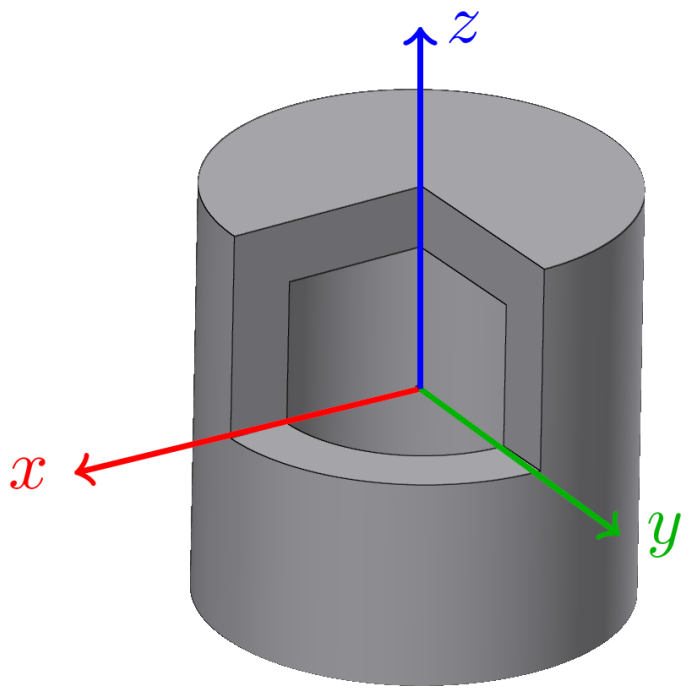
**BEAMPOS** Rin: Rout: Type: CYLI-VOL ▾
Hin: Hout:

Specifies a cylindrical shell shaped source around the **z** axis of the geometry

Input fields:

- **Rin**: Inner radius [cm]
- **Rout**: Outer radius [cm]
- **Hin**: Inner height [cm]
- **Hout**: Outer height [cm]

**Note:** The reference coordinate system can be changed with the **BEAMAXES** card



# Volumetric sources – *Cartesian shell*

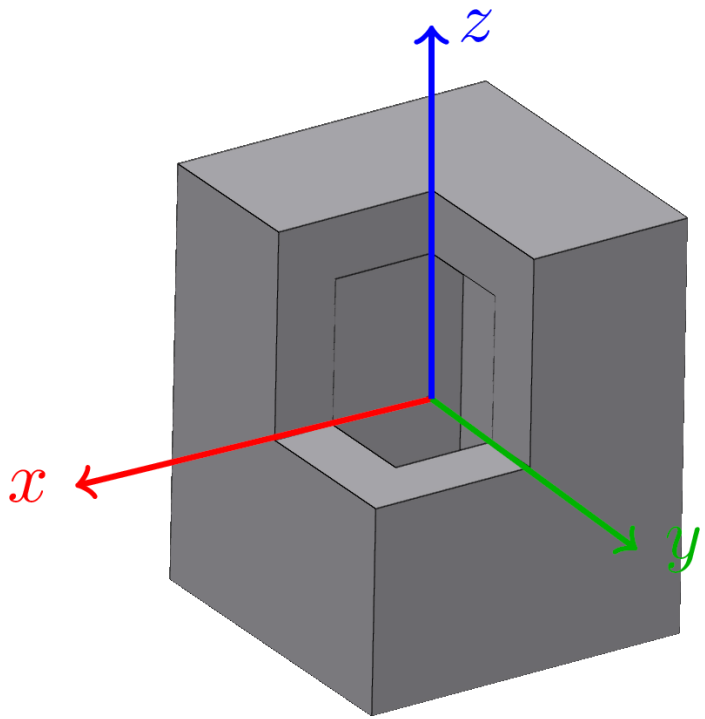
**BEAMPOS** Xin: Xout: Type: CART-VOL ▾
Yin: Yout:
Zin: Zout:

Specifies a Cartesian shell shaped source along the axes of the geometry

Input fields:

- **Xin & Xout**: Inner & outer length of the **x**-sides
- **Yin & Yout**: Inner & outer length of the **y**-sides
- **Zin & Zout**: Inner & outer length of the **z**-sides

**Note:** The reference coordinate system can be changed with the **BEAMAXES** card



# Volumetric sources – *Spherical surface source*

**BEAMPOS** R: Type: FLOOD ▾

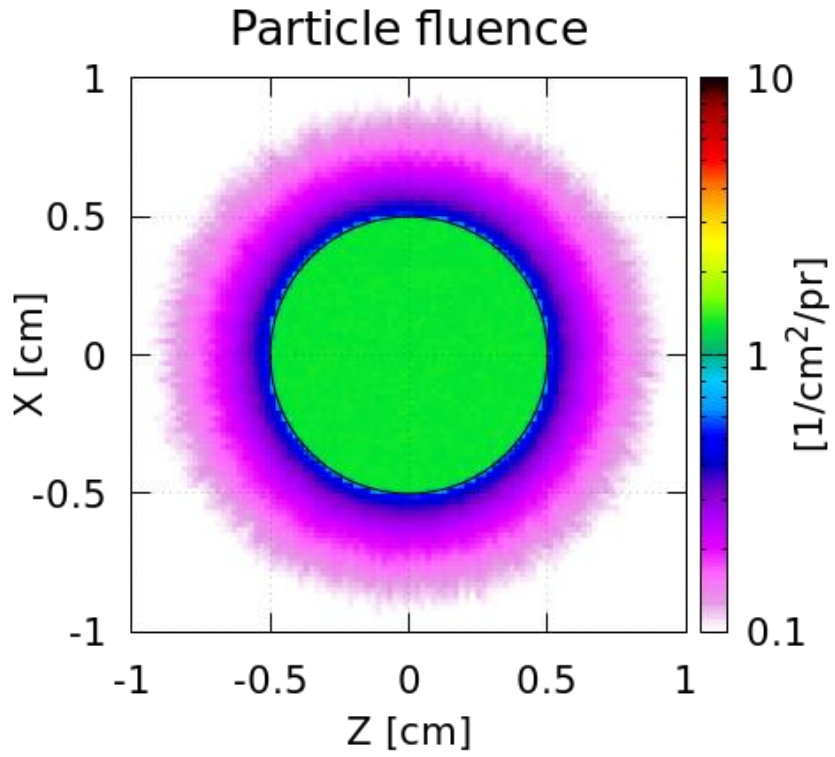
Specifies a spherical surface source in a way that the fluence inside the sphere is **uniform** and **isotropic**

The value of the generated fluence is: $\frac{1}{\pi R^2}$ cm$^{-2}$

Input fields:

- **R**: Radius of the sphere [cm]

**Warning:** The particle direction and angular distribution set on the first **BEAMPOS** and the **BEAM** card are disregarded



# Further possibilities

Sometimes the **BEAM**, **BEAMPOS**, and **BEAMAXES** cards are not enough

- Special sources available in FLUKA
  - Colliding beams
  - Synchrotron radiation
  - Cosmic rays
  - Multiple beam spots
  - USRBIN source

    (See the *Advanced sources* lecture)

- Program your own custom sources

  (See the *Source routine* lecture)

# 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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# Tarefa – Aula 5

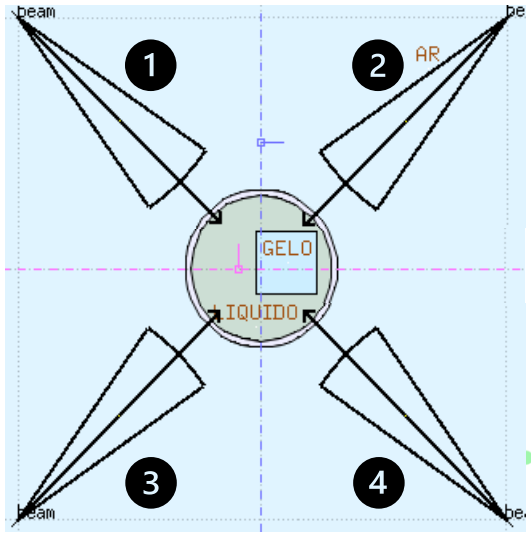


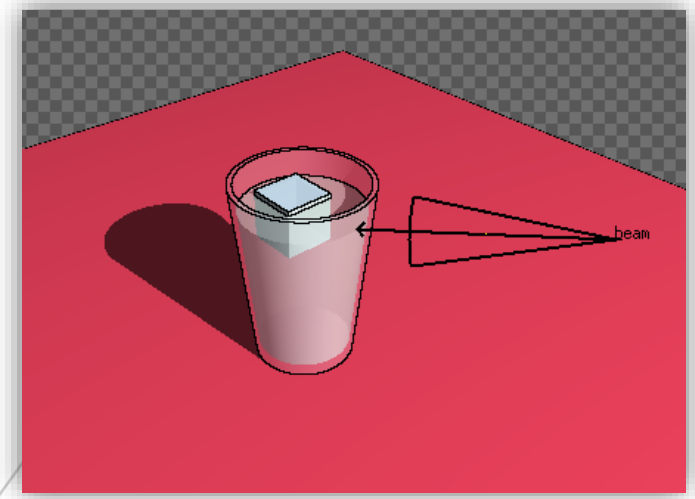
Iremos testar os conceitos apresentados em aula para configurarmos os parâmetros de feixe para uma “radioesterilização” da nossa caipirinha.

Nosso feixe será composto de **fótons** pontual com divergência de **350 mrad** com duas energias: **1.17 MeV e 1.33 MeV**

Utilizaremos quatro campos ao redor do nosso copo:

1. (x, y, z): (7, 10, -10)
2. (x, y, z): (7, 10, 10)
3. (x, y, z): (7, -10, -10)
4. (x, y, z): (7, -10, 10)



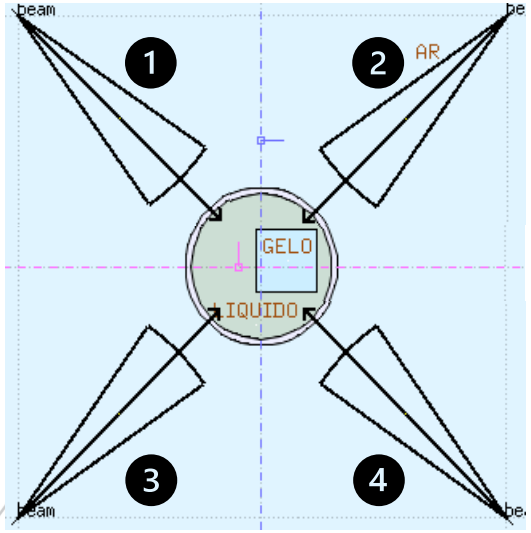



# Tarefa – Aula 5



SOLUÇÃO:

```
#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
Define the beam position
BEAMPOS                  x: 7              y: 10               z: -10
                         cosx: =cos_ang_xy cosy: =-cos_ang_yz  Type: POSITIVE ▾
Define the beam position
BEAMPOS                  x: 7              y: 10               z: 10
                         cosx: =cos_ang_xy cosy: =-cos_ang_yz  Type: NEGATIVE ▾
Define the beam position
BEAMPOS                  x: 7              y: -10              z: -10
                         cosx: =cos_ang_xy cosy: =cos_ang_yz   Type: POSITIVE ▾
Define the beam position
BEAMPOS                  x: 7              y: -10              z: 10
                         cosx: =cos_ang_xy cosy: =cos_ang_yz   Type: NEGATIVE ▾
```



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23 DE JANEIRO A 8 DE MARÇO DE 2023

Tópicos essenciais

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# AULA 05
# Feixes

Obrigada pela participação!

Código Monte Carlo de interação e transporte de partículas

23 FLUKA 2023

08

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