CURSO INTRODUTÓRIO FLUKA

23 DE JANEIRO A 8 DE MARÇO DE 2023

FLUKA

AULA 10
Técnicas de Biasing

Iniciaremos em breve

Código Monte Carlo de interação e transporte de partículas

23 FLUKA 2023 08

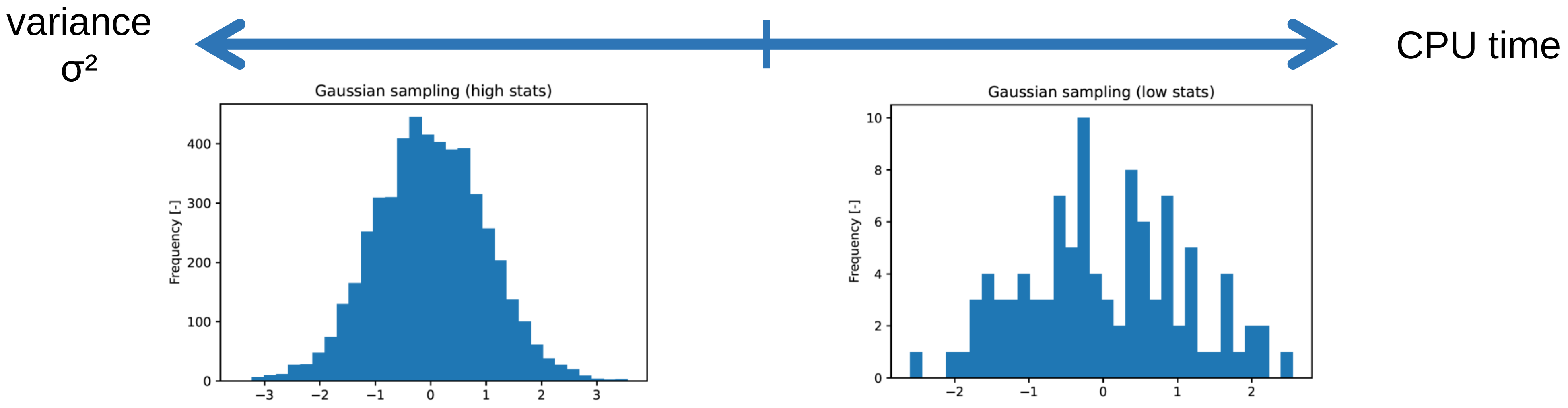
CNPEM MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÃO GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO

Biasing techniques in FLUKA

Concept introduction and basic applications

Introduction to biasing

- Statistical bias: tendency causing a result to differ from the underlying fact
- In the context of FLUKA
  - Deliberately altering simulation parameters to improve variance or CPU time
  - This bias is countered by changing weights of particles



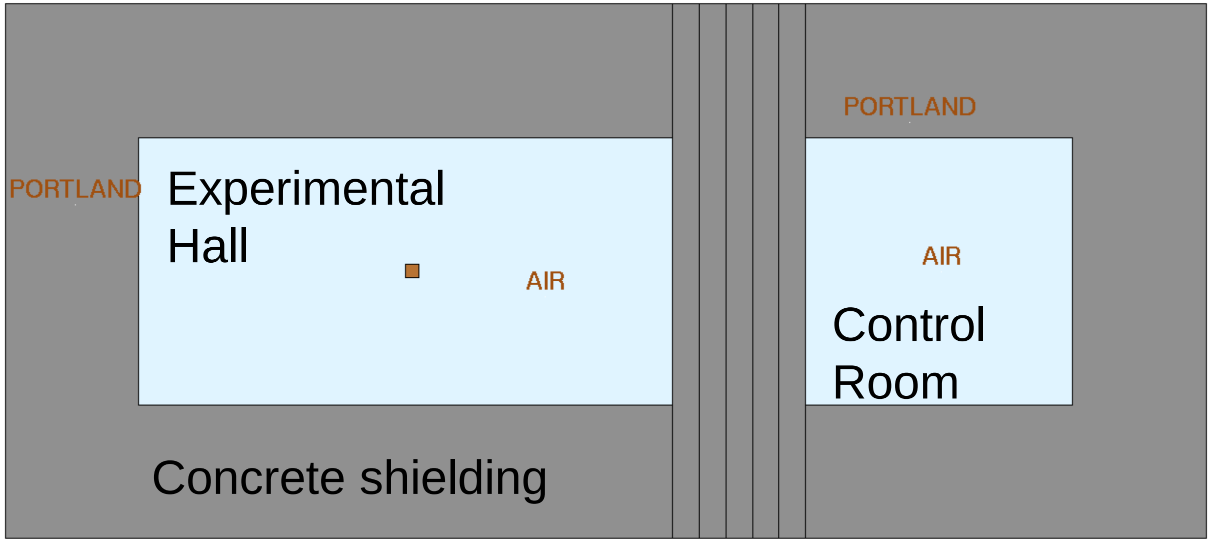
- Goodness of simulations : Figure of Merit = $\frac{1}{\sigma^2 t}$
  - The larger the better

Non-biased Monte Carlo simulations

Characteristics

- Samples from

  actual phase-space distributions
- Preserves correlations
- Reproduces fluctuations



Drawbacks

- Converges slowly
- Rare events are… “rare”

Non-biased Monte Carlo simulations

200000 primaries

Characteristics

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- Preserves correlations
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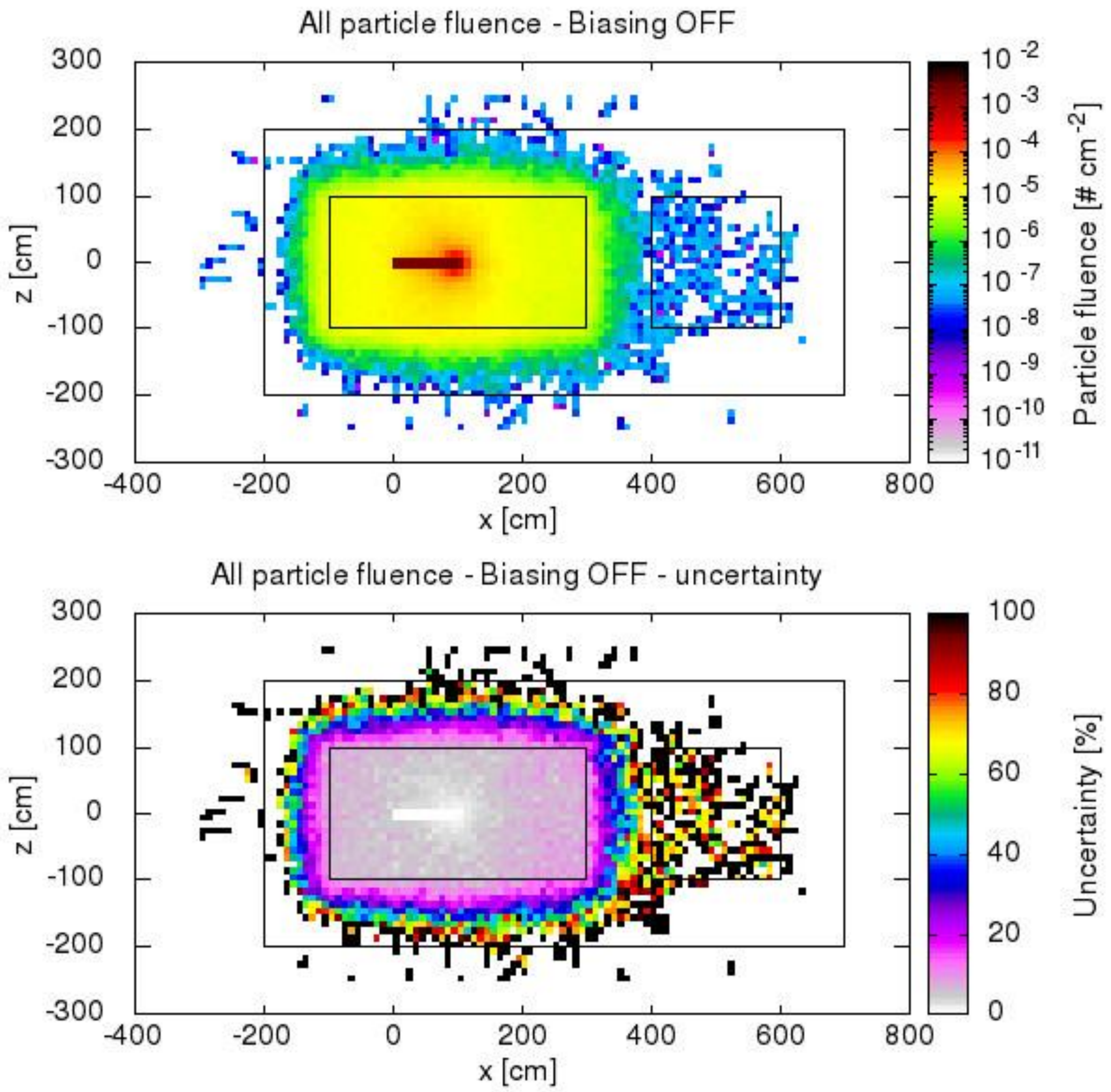


Biased Monte Carlo simulations

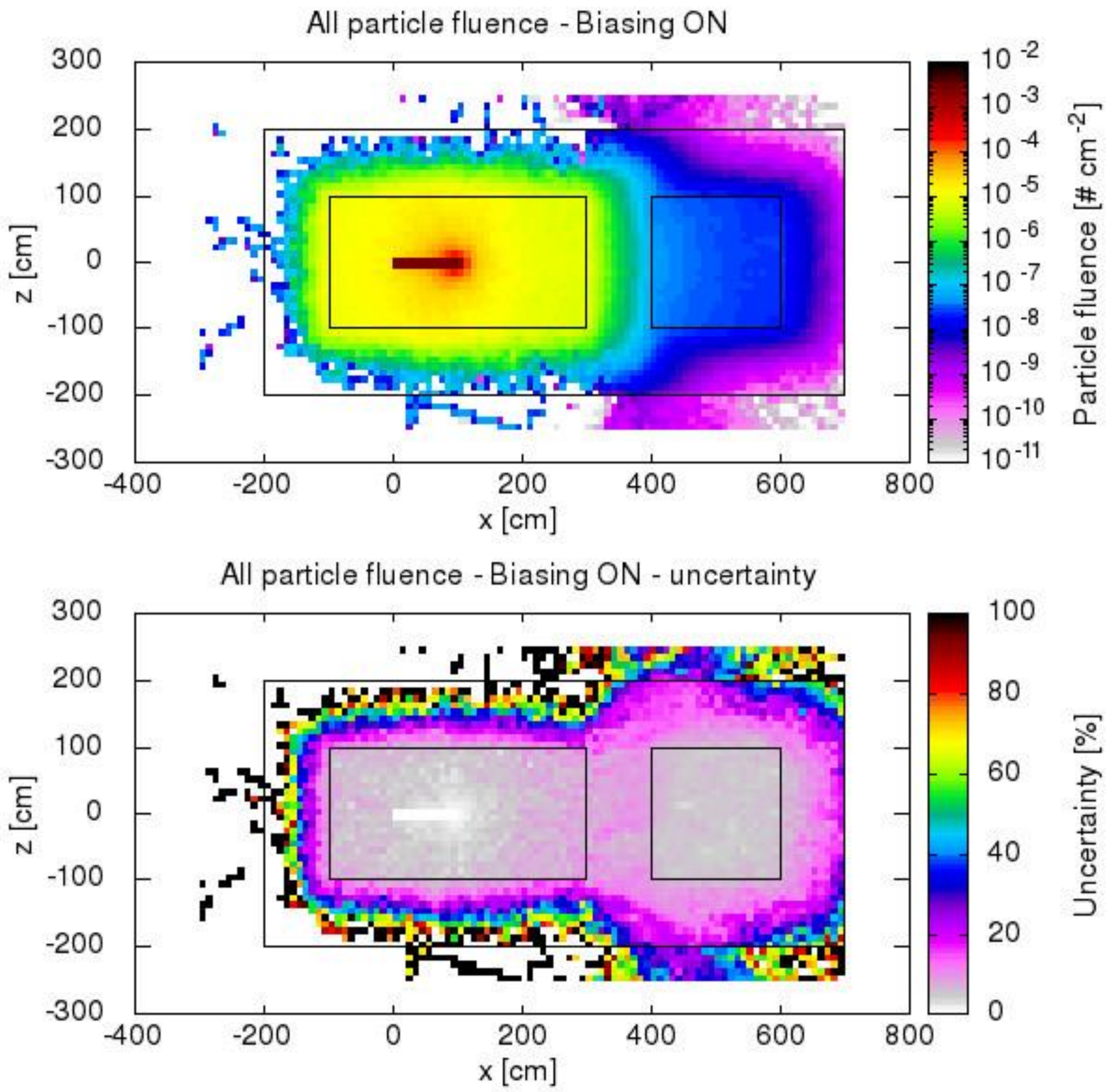
200000 primaries

Characteristics

- Samples from distorted distributions
- Converges “quickly”

Drawbacks

- Cannot reproduce fluctuations and correlations
- Requires active reasoning and experience
- Requires user’s time to be implemented



Biasing techniques in FLUKA

- *Region Importance Biasing* (**BIASING**)
- *Mean Free Path Biasing* (**LAM-BIAS**)

During this lessons we will only look at these 2 types

- Leading Particle Biasing (**EMF-BIAS**)
- Multiplicity Tuning (**BIASING**)
- Lifetime / Decay-length Biasing (**LAM-BIAS**)
- Weight Windows (**WW-FACTO**, **WW-THRES**, **WW-PROFI**)
- Low-energy neutrons non-analogue absorption (**LOW-BIAS**)
- Low-energy neutrons downscattering (**LOW-DOWN**)
- User defined biasing (usbset.f , usimbs.f)

Region Importance Biasing

Input card: **BIASING**

Region Importance Biasing

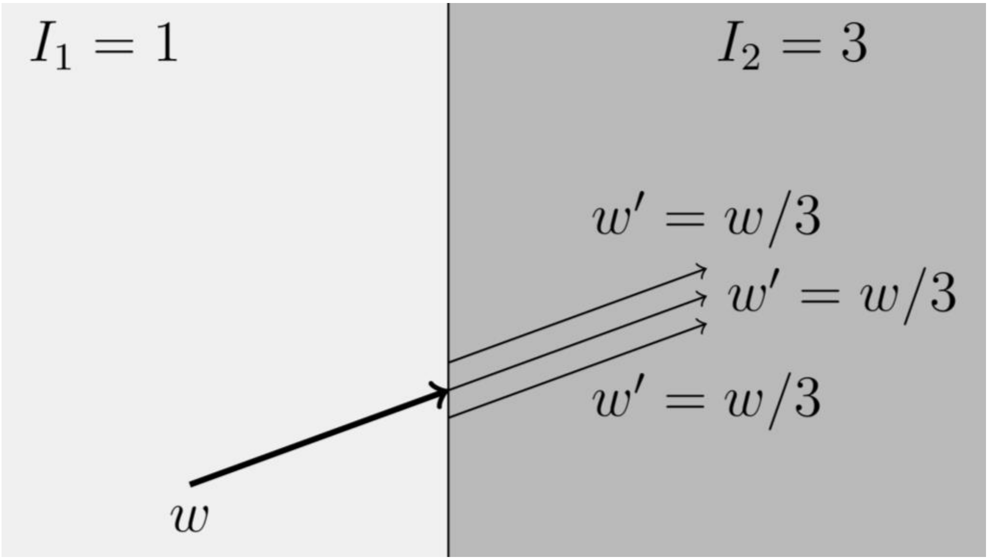
- Input card: **BIASING**
- Simplest form of biasing
- Applied when a particle crosses a region boundary (e.g. from Region1 to Region2)
- Based on *relative importance* of the two adjacent regions:

  $R = i_2/i_1$ = “importance of Region2” / “importance of Region1”
- Combination of two algorithms (see next slides):
  - For R>1: ***Surface Splitting***
  - For R<1: ***Russian Roulette***
- Allows to compensate for attenuation (due to distance or absorption)
- Can maintain a uniform population
- Can be tuned per particle type
- Multiple **BIASING** cards are allowed

Region Importance Biasing

Surface Splitting

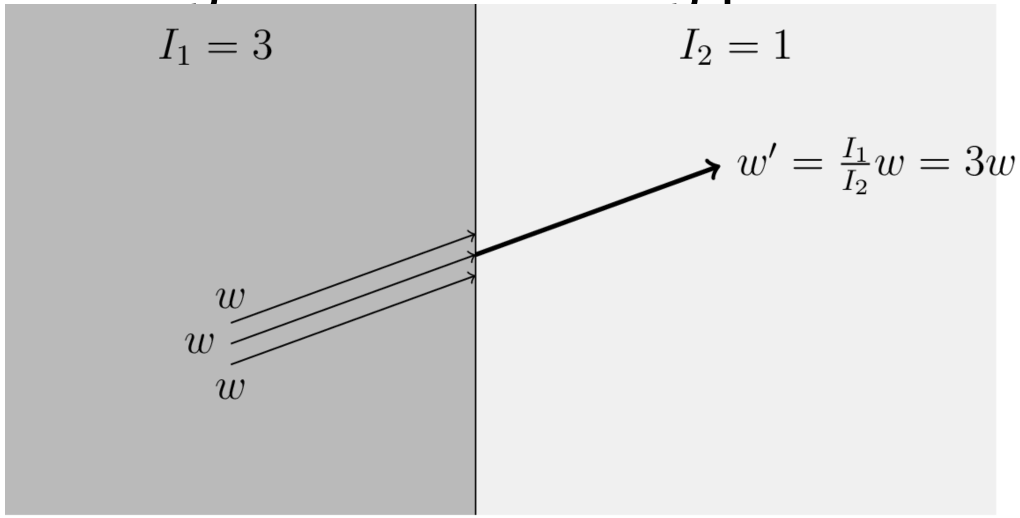
- Moving toward a higher importance region, *R>1*
- $n = R = i_2/i_1$ particle *replicas* are created
- *Weight* of replicas is $w = 1/R = i_1/i_2 < 1$
- Total weight of all replicas is equal to the weight of the original particles
- FLUKA allowed values: $5^{-1} \le R \le 5$



Region Importance Biasing

Russian Roulette

- Moving toward a lower importance region, $R<1$
- Particle have a survival probability $P_s = R = i_2/i_1$
- *Weight* of surviving particles increases: $w = 1/R = i_1/i_2 > 1$
- Weight of all surviving particles is equal to the weight of all incoming particles
- FLUKA allowed values: $5^{-1} \leq R \leq 5$



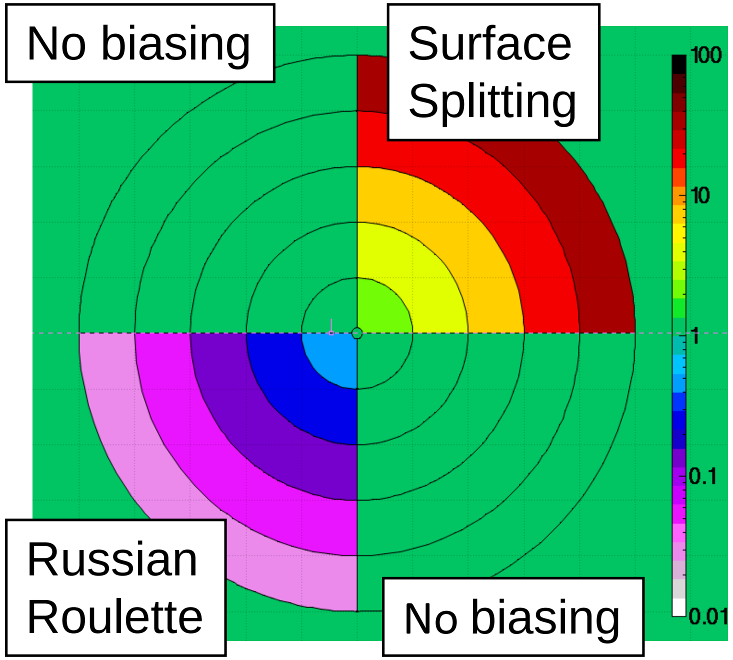
I : importance, w: particle weight
Particle survives with probability $I_2/I_1 = 1/3$
Surviving particle weight increased by $I_1/I_2 = 3$

Region Importance Biasing

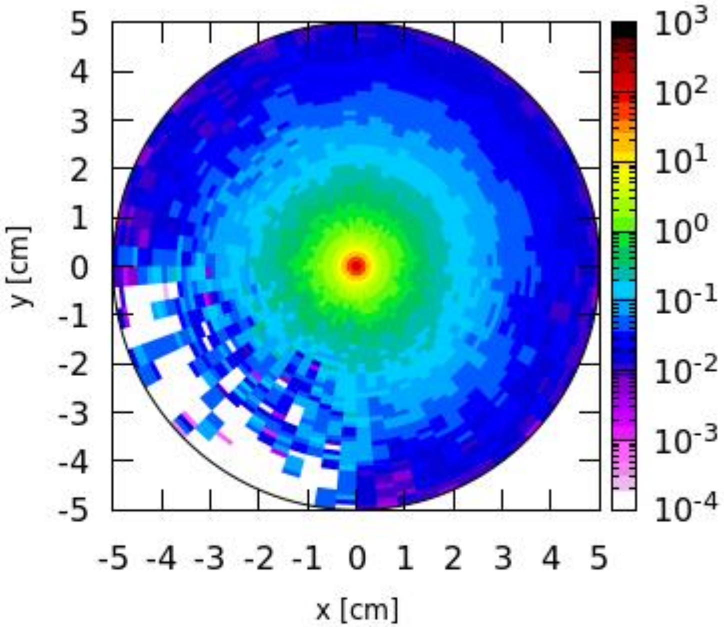
Example

- 200 MeV electrons on a cylindrical copper target (5 cm radius, 10 cm deep)
- 5000 primaries

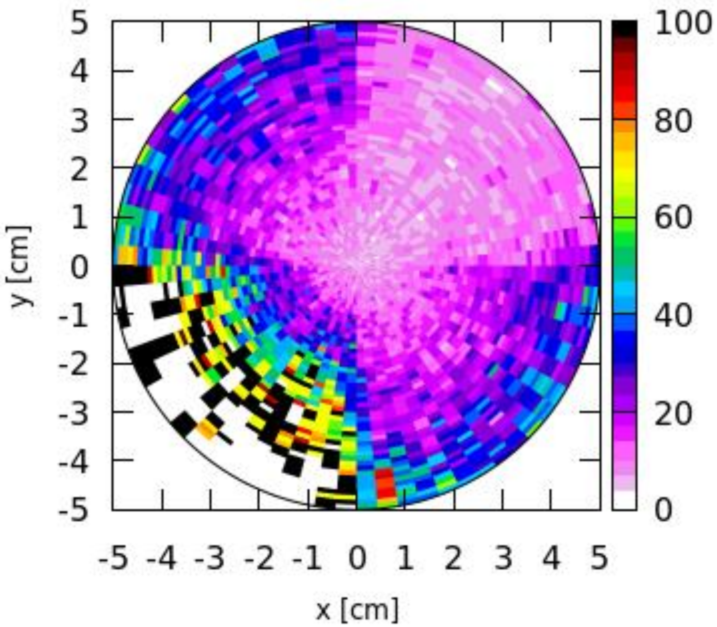
Region importance



Particle fluence [cm^{-2} per primary]



Uncertainty on particle fluence [%]



Region Importance Biasing

Drawbacks

- Replicas histories differ because of dE/dx fluctuations and multiple scattering,

  therefore, when crossing into a low density region (e.g. vacuum, air)

  correlations between replicas can be relevant
- Could require geometry changes

  e.g: how to deal with a geometry like this?

R_Sour - where the source is	
R_Sh1 - shielding material 1	*R_strange* - made of a single material
R_Sh2 - shielding material 2	
R_Sh3 - shielding material 3	
R_Sh4 - shielding material 4	
R_of_int - location under investigation	

Region Importance Biasing

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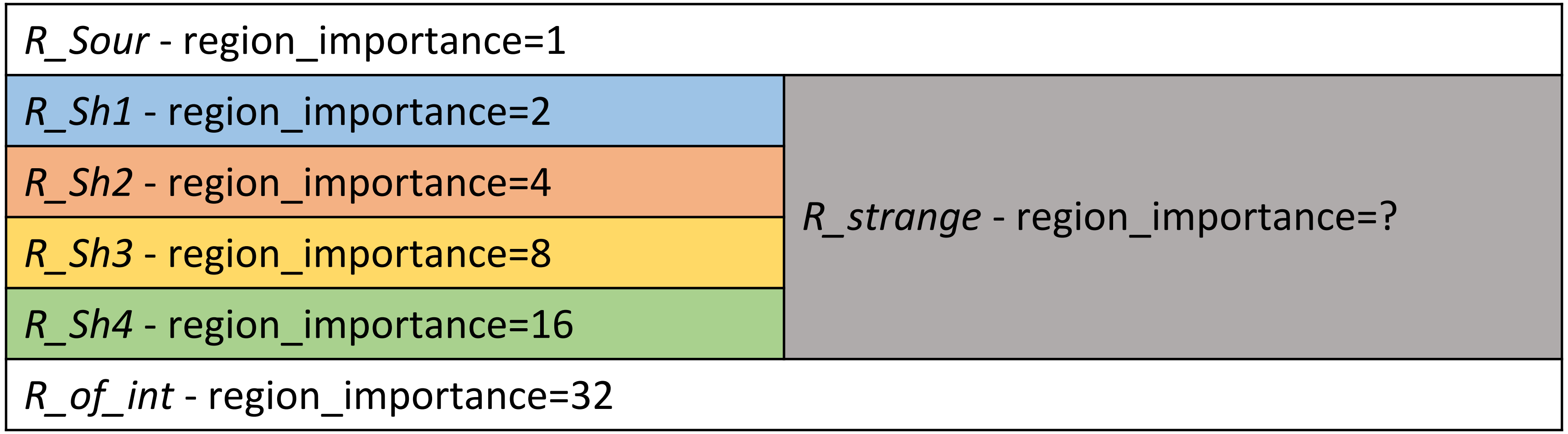

Region Importance Biasing

Input card: **BIASING**

- *Type*
  - all particles
  - Hadrons & muons
  - e+, e-,γ
  - low energy neutrons
- *Reg - to Reg - Step*
  - Standard FLUKA region selection
- *Imp*
  - Importance of the selected region(s)

Example explanation:
An *importance=25* is assigned
to *all particles* within *region=a2*

BIASING	Type: All particles ▾	RR:	Imp: 25
Opt: ▾	Reg: a2 ▾	to Reg: a2 ▾	Step:

Region Importance Biasing

Input card: **BIASING**

- *Type*
  - "all regions"
- *Part - to Part - Step*
  - Standard FLUKA particle range selection
- *Mod. M*
  - Modifying factor M

    Applied to the splitting factor or

    to the Russian Roulette probability

    Practical use: inhibit RIB for a specific particle

<u>Example explanation</u>:
A *modifying factor = 0* is assigned to *all region importances* for protons.
With all region importances set to 0, we ensure that there is no region importance biasing for protons anywhere

BIASING	Type: **All regions ▾**	Mod. M: **0**	
Opt: ▾	Part: **PROTON ▾**	to Part: **PROTON ▾**	Step:

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Código Monte Carlo de interação e transporte de partículas

Pausa

Voltamos em 15 minutos

FLUKA

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FLUKA

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Mean Free Path Biasing

Input card: **`LAM-BIAS`**

Mean Free Path Biasing

- Input card: **`LAM-BIAS`**
- Allows to…
  - *…multiply the inelastic nuclear interaction length of hadrons by a factor λ*
  - *…multiply the nuclear interaction length of photons and muons by a factor λ*
- Useful for thin or low density target problems
- Useful to enhance photonuclear reactions (see **`PHOTONUC`** card)
- Weight is adjusted
- It can be applied to specific materials and/or specific particles
- Multiple **`LAM-BIAS`** cards are allowed

Mean Free Path Biasing

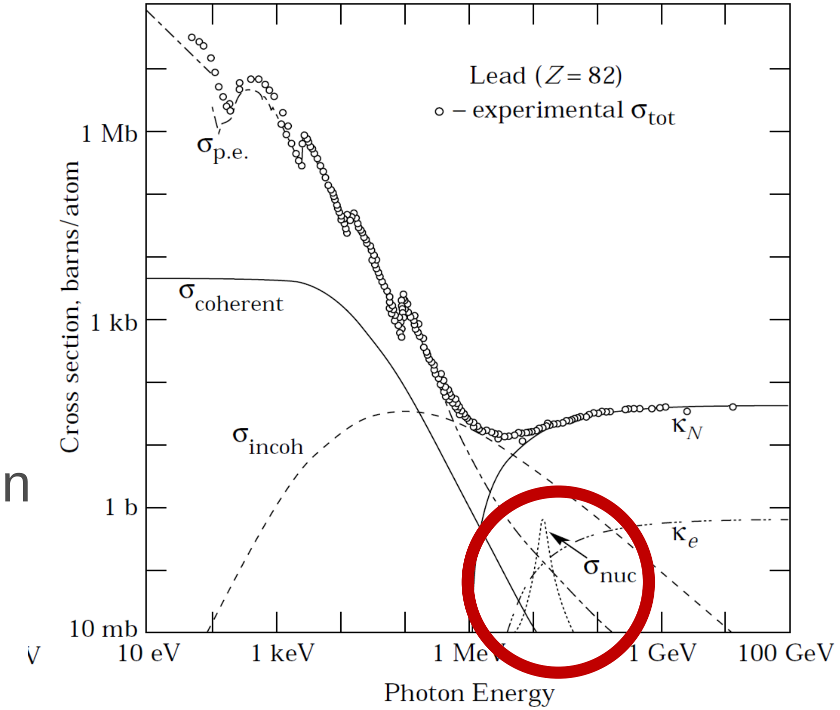
Input card: **`LAM-BIAS`**

- *Type*
  - <empty> *Interaction length biasing*
  - DCDRBIAS Decay direction biasing (advanced topics)
  - DCY-DIRE Decay direction biasing (advanced topics)
  - DECALL Particle generation selection for **`LAM-BIAS`** (advanced topics)
  - DECPRI Particle generation selection for **`LAM-BIAS`** (advanced topics)
  - GDECAY Lifetime / decay-length biasing (advanced topics)
  - INEALL Particle generation selection for **`LAM-BIAS`** (advanced topics)
  - INEPRI Particle generation selection for **`LAM-BIAS`** (advanced topics)
  - N1HSCBS Under development

Where is mean-free-path biasing needed?

- **Reaction yields from thin targets:**
  - E.g. you want to get the neutron spectrum from a thin (~1 mm) ^{7}Li slab under p irradiation
  - Nuclear inelastic scattering lengths are O(10 cm) -> less than 1% probability of sampling the (p,xn) events that are relevant for the above geometry
  - You would have to sample **a lot** of events for a small fraction of relevant events

- **e- machine shielding:**
  - The scenario:
    e- undergo Bremsstrahlung
    → Generated photons can undergo (γ,xn)
    → Radiation protection issue
  - Photonuclear interactions have comparatively low cross section
  - You'd have to sample **a lot** of events for a small fraction of relevant events



The mean-free-path biasing solution

- Artificially shorten the nuclear inelastic scattering length Λ_i, e.g. $\Lambda_i' = \Lambda_i / 100$

  → Nuclear interactions will be more frequently sampled

- This obviously distorts the physics

  → The particle's (statistical) weight is lowered accordingly

Mean Free Path Biasing

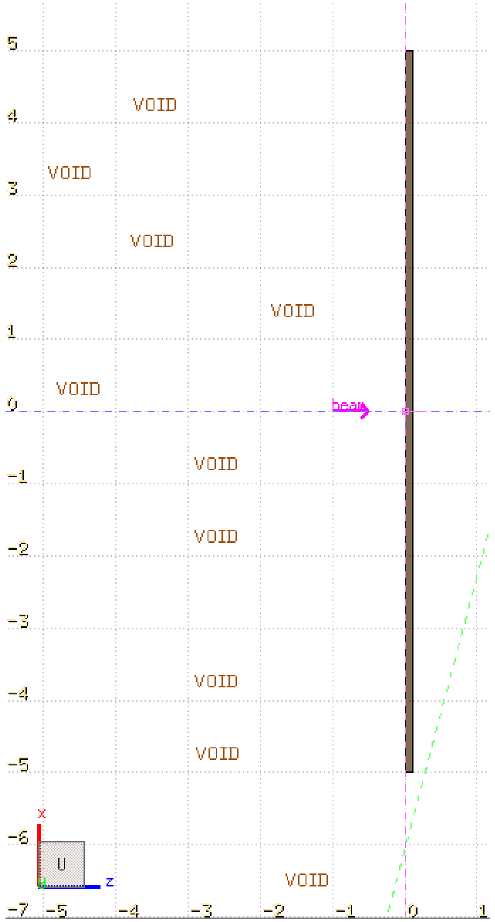
Input card: **LAM-BIAS** **(see manual for more details)**

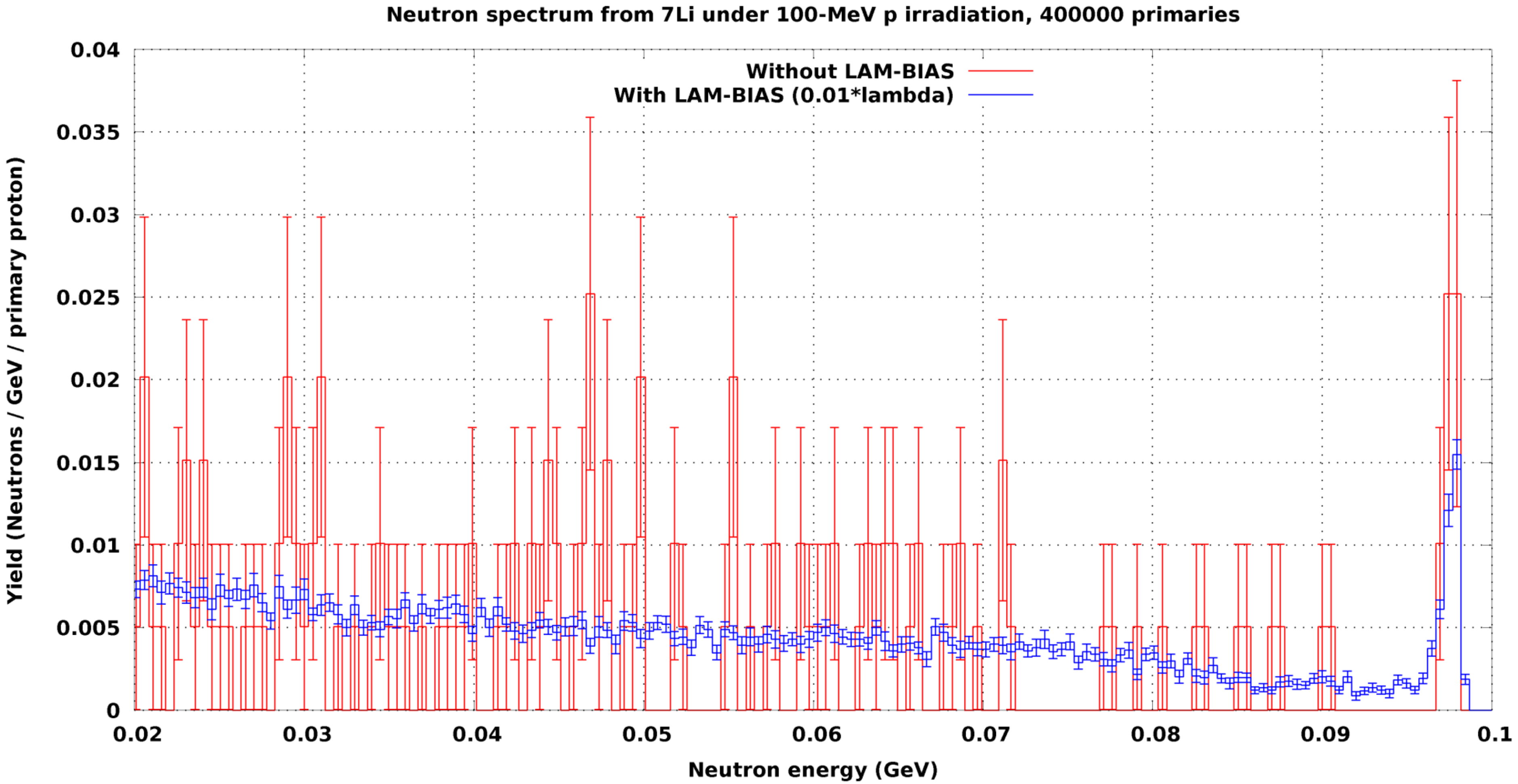
- *Type*
  - <empty>
- *ˣ mean life*
  - Doesn't apply
- *ˣ λ inelastic*
  - Interaction length correction factor
- *Mat*
  - Material where the correction factor applies
- *Part - to Part - Step*
  - Standard FLUKA particle selection

Example explanation:
Proton interaction length in *beryllium* is multiplied by a factor *correction factor=0.02* (reduced by a factor 50)

LAM-BIAS Type: ▼ × mean life: × λ inelastic: 0.02
Mat: BERYLLIU ▼ Part: PROTON ▼ to Part: ▼ Step:

Example: n yield from 1mm 7Li under 100-MeV p





Biasing exercise

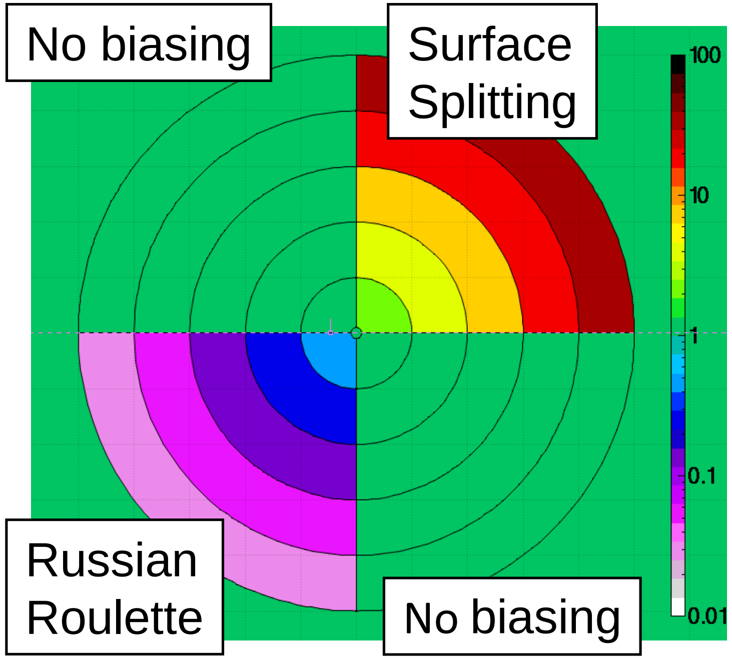
Region importance biasing

Biasing exercise

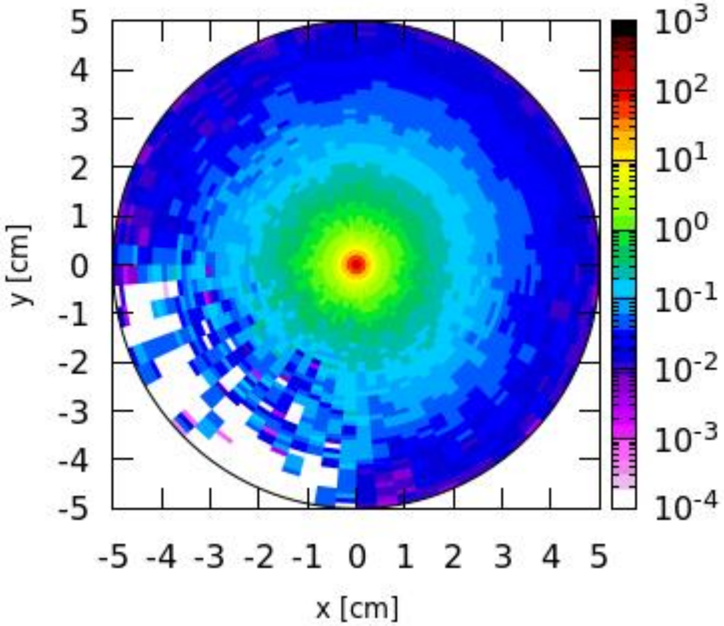
Region importance biasing

- Try to replicate the plots shown in the lecture

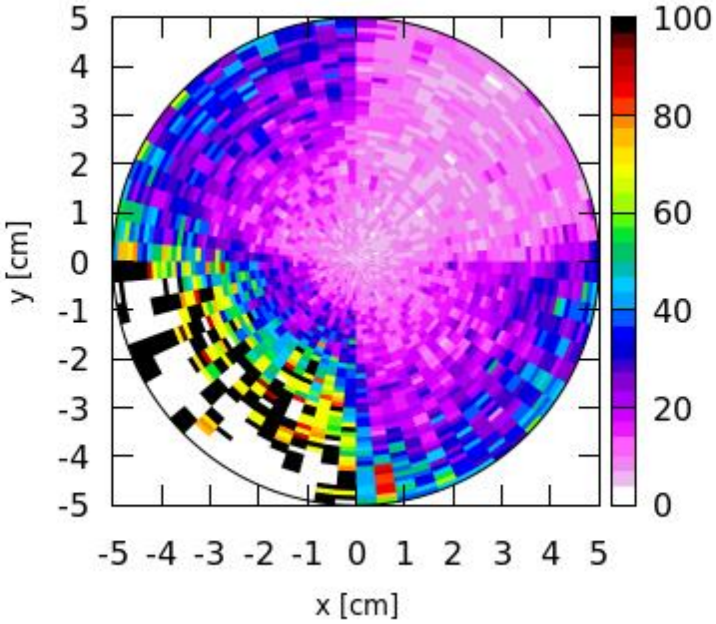
Region importance



Particle fluence [cm^{-2} per primary]



Uncertainty on particle fluence [%]



Biasing exercise – Region importance biasing

Input preparation and running

- Start from the input file provided
- No need to change the geometry
- Leave importance of the innermost cylinder as 1
- In one quarter, *increase* region importance in steps of 2^n (add **BIASING** cards)
- In one quarter, *decrease* region importance in steps of 2^n (add **BIASING** cards)
- Spawn in 2 jobs, run 5 cycles of 500 primaries each (total 5000 primaries)
- Do not forget to merge the results

Biasing exercise – Region importance biasing

Plotting results

- In flair Geometry tab
  - Create a new layer showing "*Importance*" in the color scale
  - Create a new layer to show "**allpart**" fluence and add a USRBIN
  - Select the proper *usrbin* file and the proper detector
  - Select a transversal and a longitudinal view to see the biasing effect
- In flair Plot tab
  - Create two new USRBIN plots
  - Select for both plots the proper *usrbin* file and detector
  - Select for both plots a transversal view with: 1.6 cm < z < 2.0 cm
  - Select for both plots "*aspect ratio*" equal to 1
  - On the first plot show the "**allpart**" fluence
  - On the second plot show the uncertainty on the "**allpart**" fluence

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AULA 10 Técnicas de Biasing

Obrigada pela participação

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