

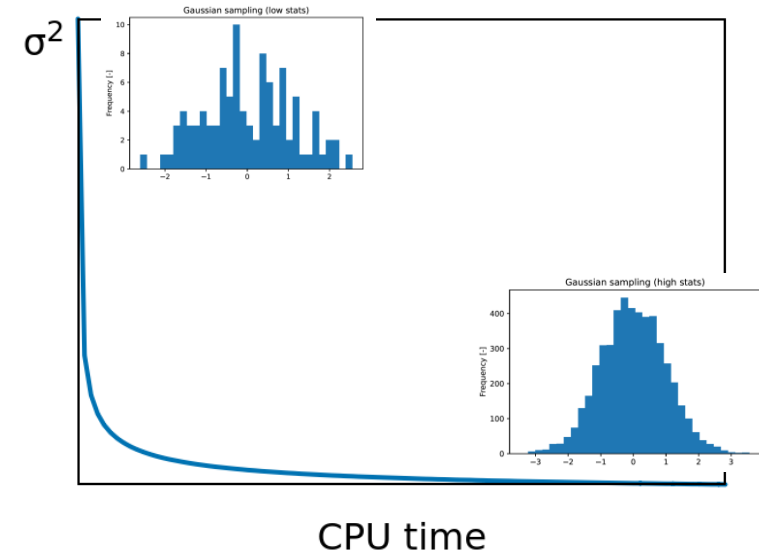


Biassing techniques in FLUKA

Concept introduction and basic applications

What is biasing?

- It is the use of “*Variance Reduction Technique(s)*” that...
distort distributions and apply weights to particles to correct for the bias
- VRTs alter simulation parameters in order to reduce variance σ^2 or CPU time t
- Usually, reducing one quantity increases the other
- Usually, more than one VRT is applied at the same time
- Goodness of simulations can be estimated with a Figure of Merit: $FoM=1/(\sigma^2 \cdot t)$
the larger the better: less time and smaller uncertainty



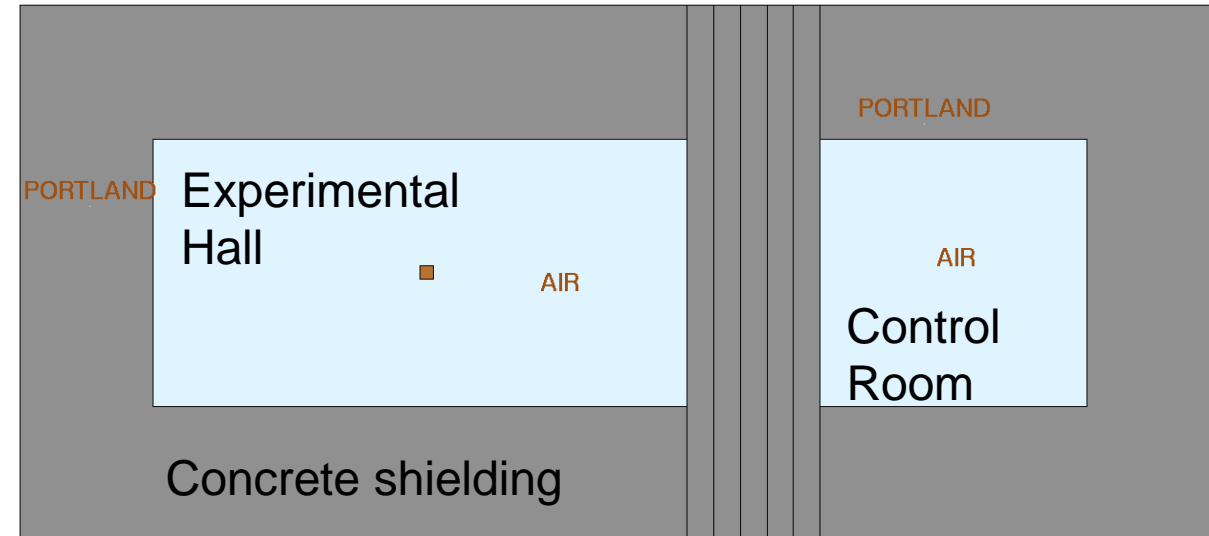
Non-biased Monte Carlo simulations

Characteristics

- Samples from
 actual phase-space distributions
- Preserves correlations
- Reproduces fluctuations

Drawbacks

- Converges slowly
- Rare events are... “rare”



Non-biased Monte Carlo simulations

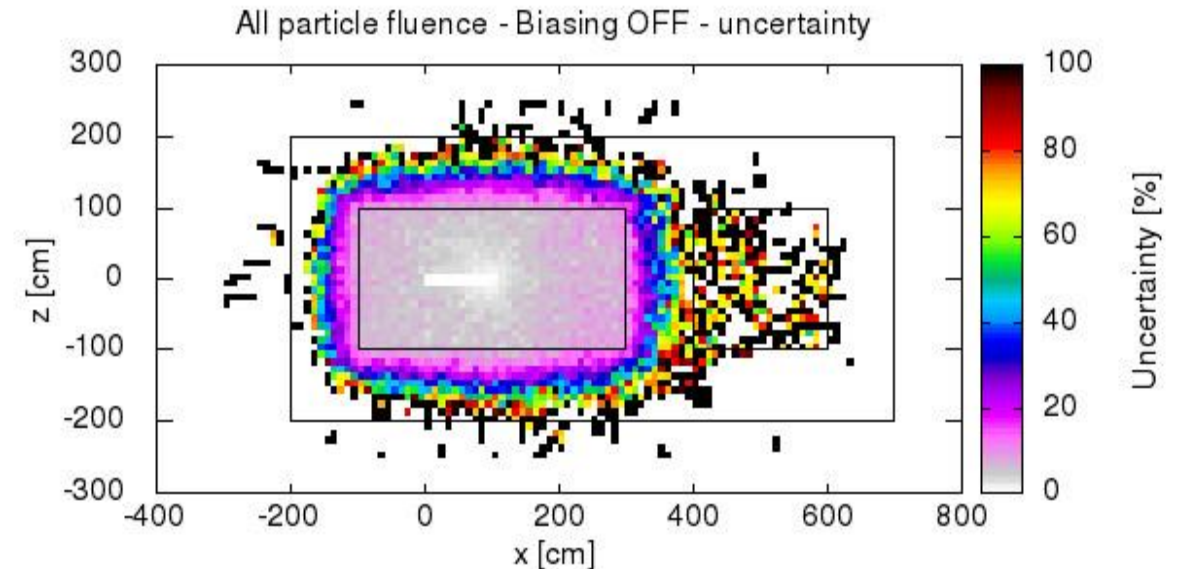
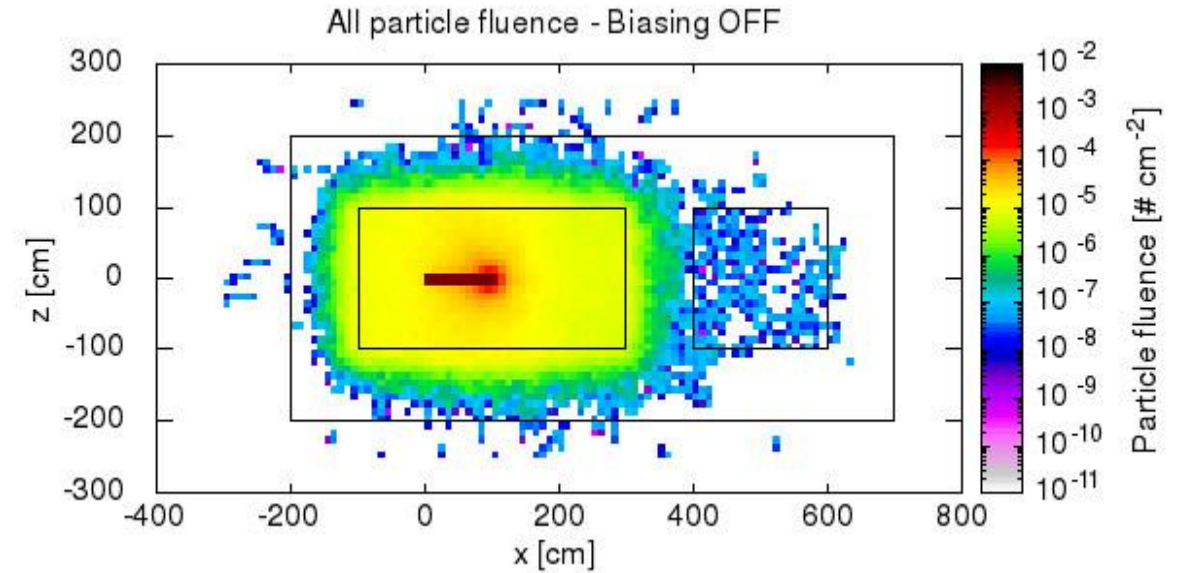
200000 primaries

Characteristics

- Samples uniformly from the phase-space distribution
- Preserves correlations
- Reproduces fluctuations

Drawbacks

- Converges slowly
- Rare events are... “rare”



Biased Monte Carlo simulations

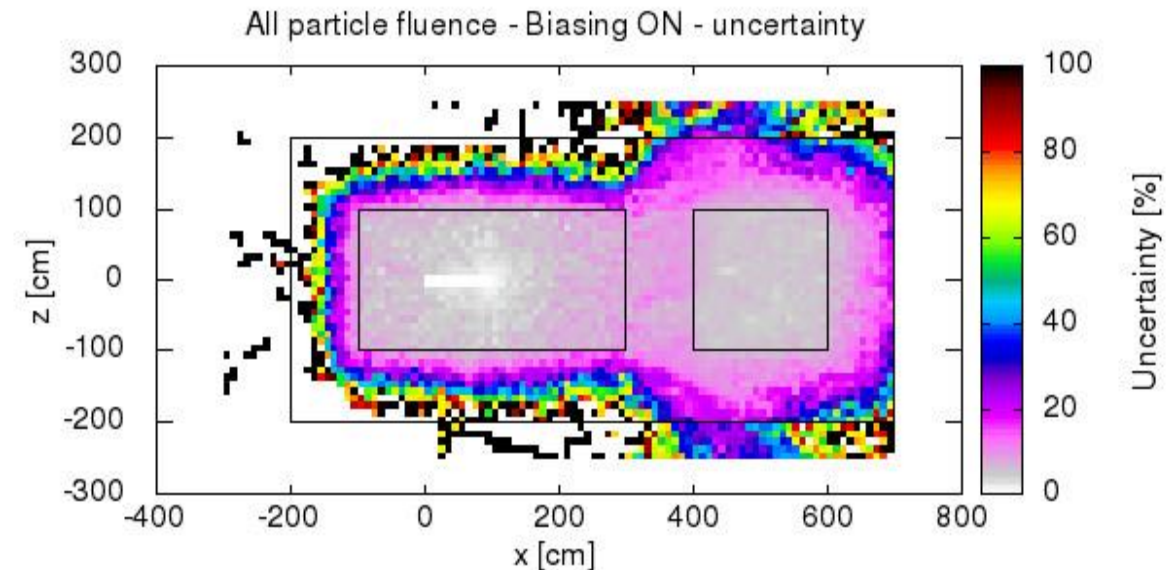
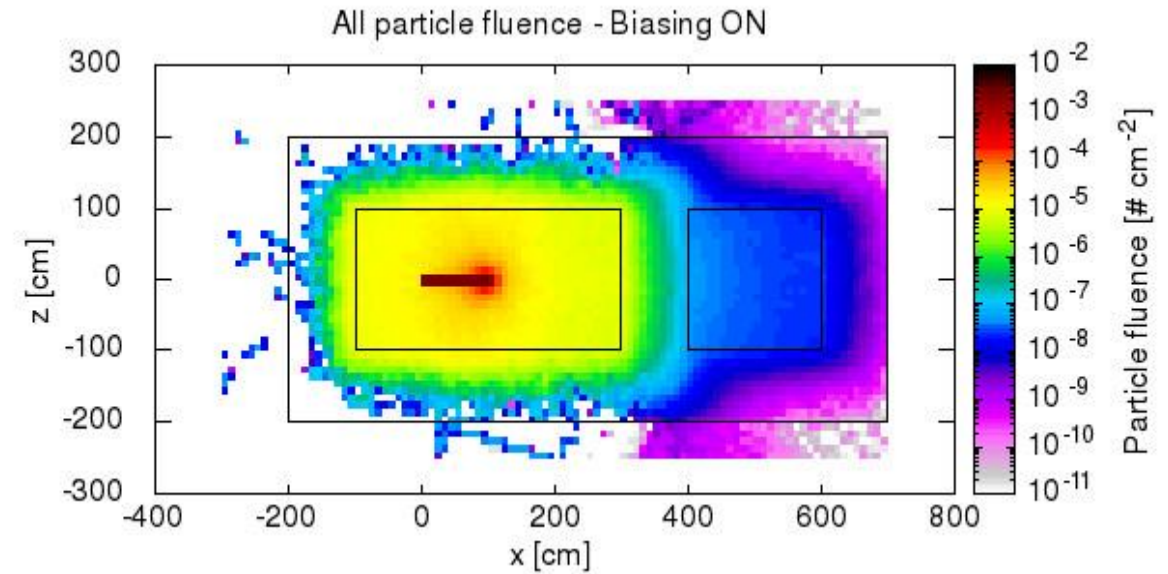
200000 primaries

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



Biassing techniques in FLUKA

- *Region Importance Biassing* (**BIASING**)
 - *Mean Free Path Biassing* (**LAM-BIAS**)
 - Leading Particle Biassing (**EMF-BIAS**)
 - Multiplicity Tuning (**BIASING**)
 - Lifetime / Decay-length Biassing (**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 biassing (`usbset.f`, `usimbs.f`)
- During this lesson we will only look at these 2 types

Region Importance Biasing

Input card: **BIASING**

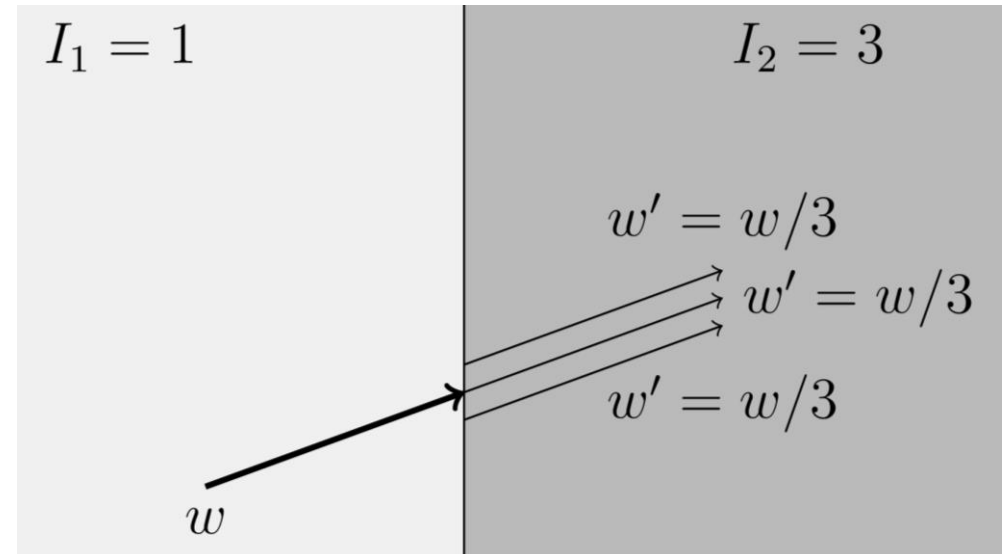
Region Importance Biasing

- 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:
$$R = i_2/i_1 = \text{“importance of Region2”} / \text{“importance of Region1”}$$
- 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

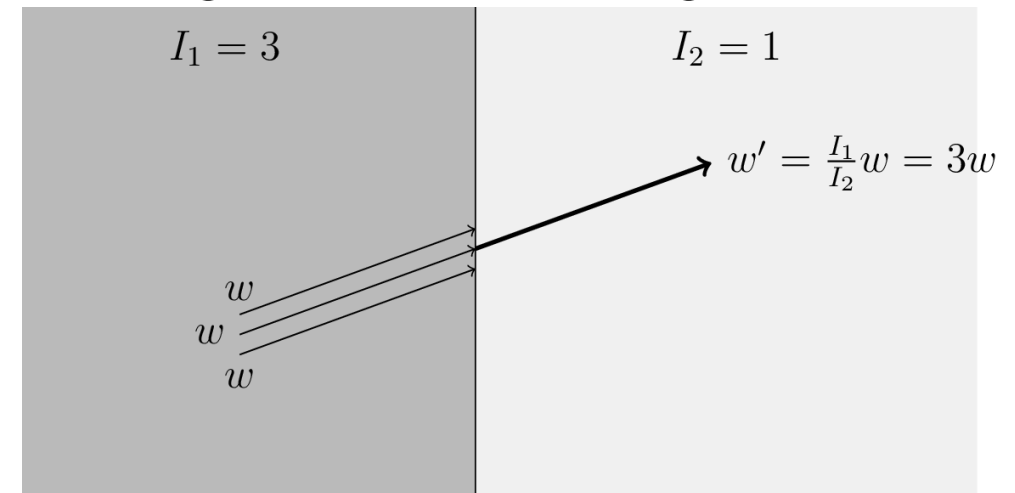
- Moving toward a higher importance region, $R > 1$
- $n = R = i_2/i_1$ particle *replicas* are created
- *Weight* of replicas is $w = 1/R = i_1/i_2 < 1$
- Total weight of all replicas is equal to the weight of the original particles
- FLUKA allowed values: $5^{-1} \leq R \leq 5$



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

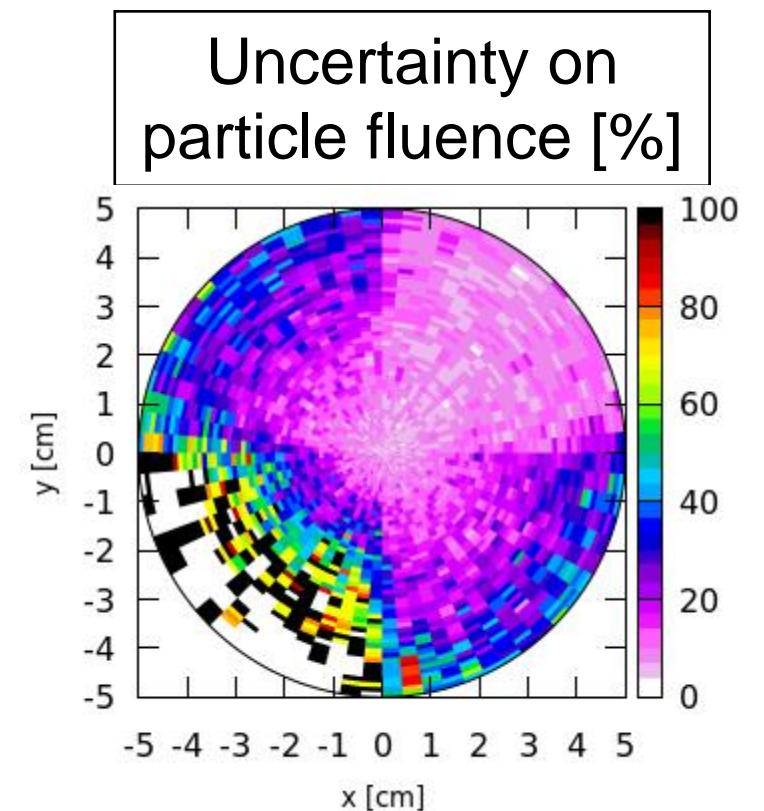
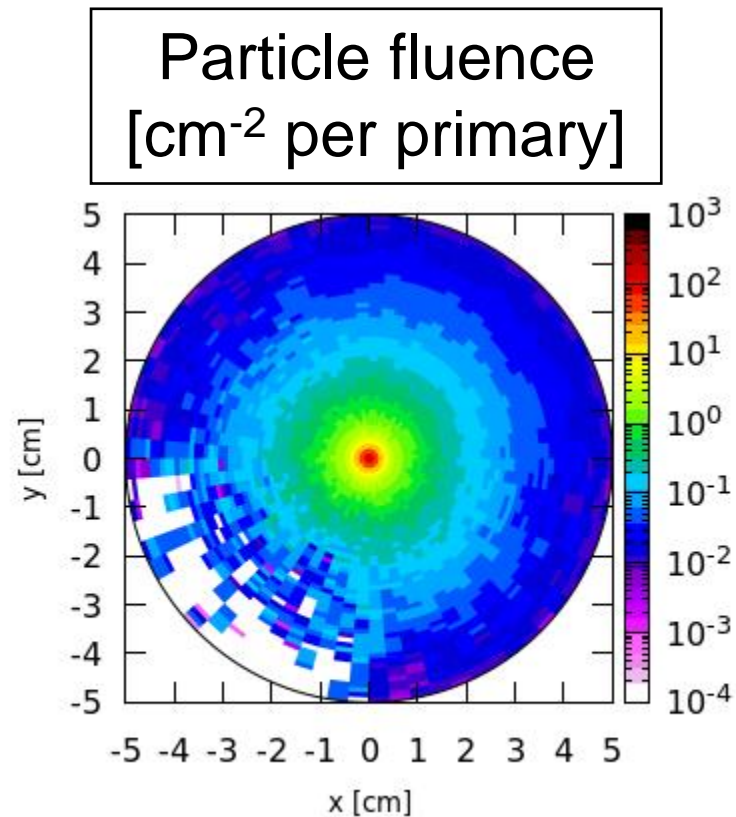
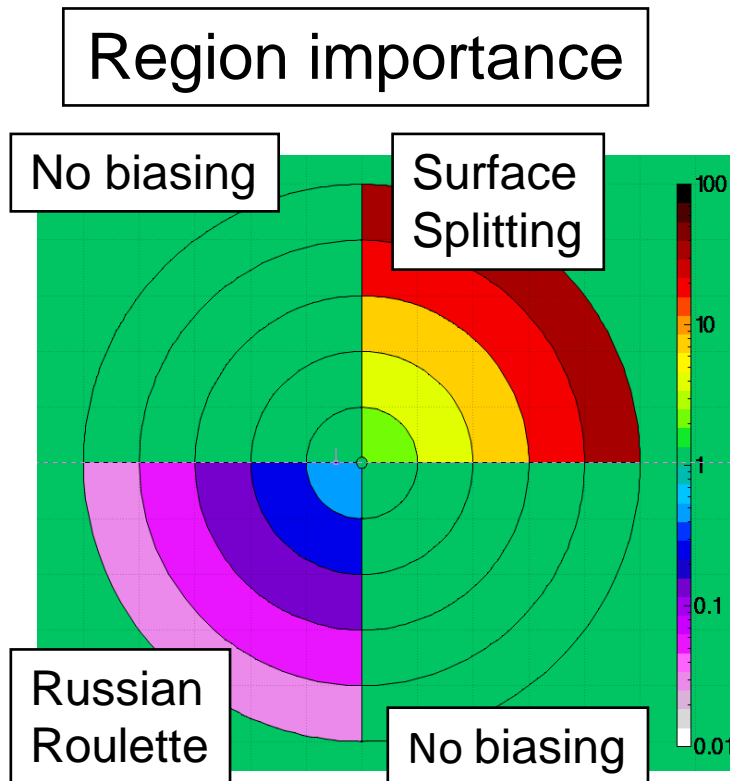
Particle survives with probability $I_2/I_1 = 1/3$

Surviving particle weight increased by $I_1/I_2 = 3$

Region Importance Biasing

Example

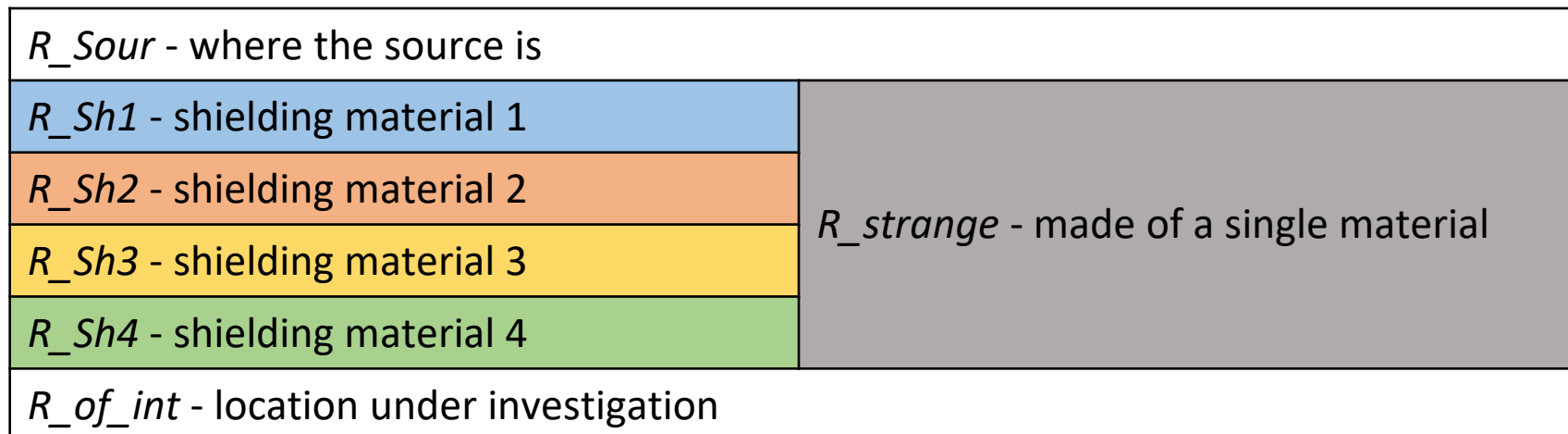
- 200 MeV electrons on a cylindrical copper target (5 cm radius, 10 cm deep)
- 5000 primaries



Region Importance 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?



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

<i>R_Sour</i> - region_importance=1	
<i>R_Sh1</i> - region_importance=2	<i>R_strange</i> - region_importance=?
<i>R_Sh2</i> - region_importance=4	
<i>R_Sh3</i> - region_importance=8	
<i>R_Sh4</i> - region_importance=16	
<i>R_of_int</i> - region_importance=32	

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

Example explanation:

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:

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

Mean Free Path Biasing

Input card: **LAM-BIAS**

- *Type*
 - <empty>
- × *mean life*
 - Doesn't apply
- × 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)

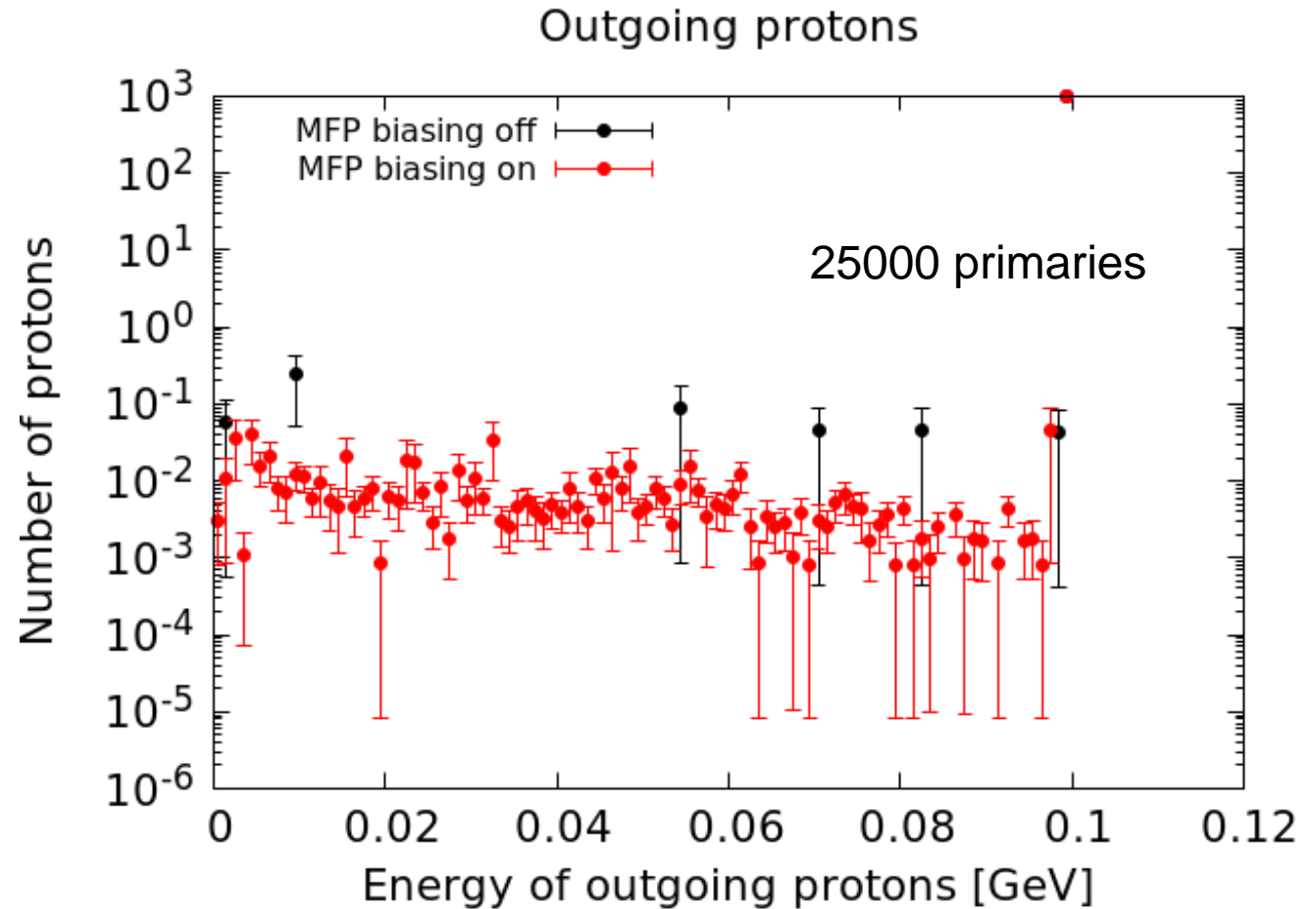


◇ **LAM-BIAS** **Type:** ▼ × **mean life:** × **λ inelastic:** **0.02**
Mat: **BERYLLIU** ▼ **Part:** **PROTON** ▼ **to Part:** ▼ **Step:**

Mean Free Path Biasing

Input card: **LAM-BIAS**

- Primaries: 100 MeV protons
- Target: 0.1 mm thick beryllium disk
- Spectrum of outgoing protons
- Black: no biasing applied
- Red: MFP biasing applied



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

Summary of the input cards seen

Summary of the input cards seen

- **BIASING**

- Region Importance biasing (Surface Splitting and Russian Roulette)

- **LAM-BIAS**

- Mean free path biasing (interaction length)
- Lifetime / Decay-length biasing (not shown in these slides)

