Synchrotron Radiation Monte Carlo Sample for 5 and 10 GeV

Temporary Workaround

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Overview

Current SR MC Production Status:

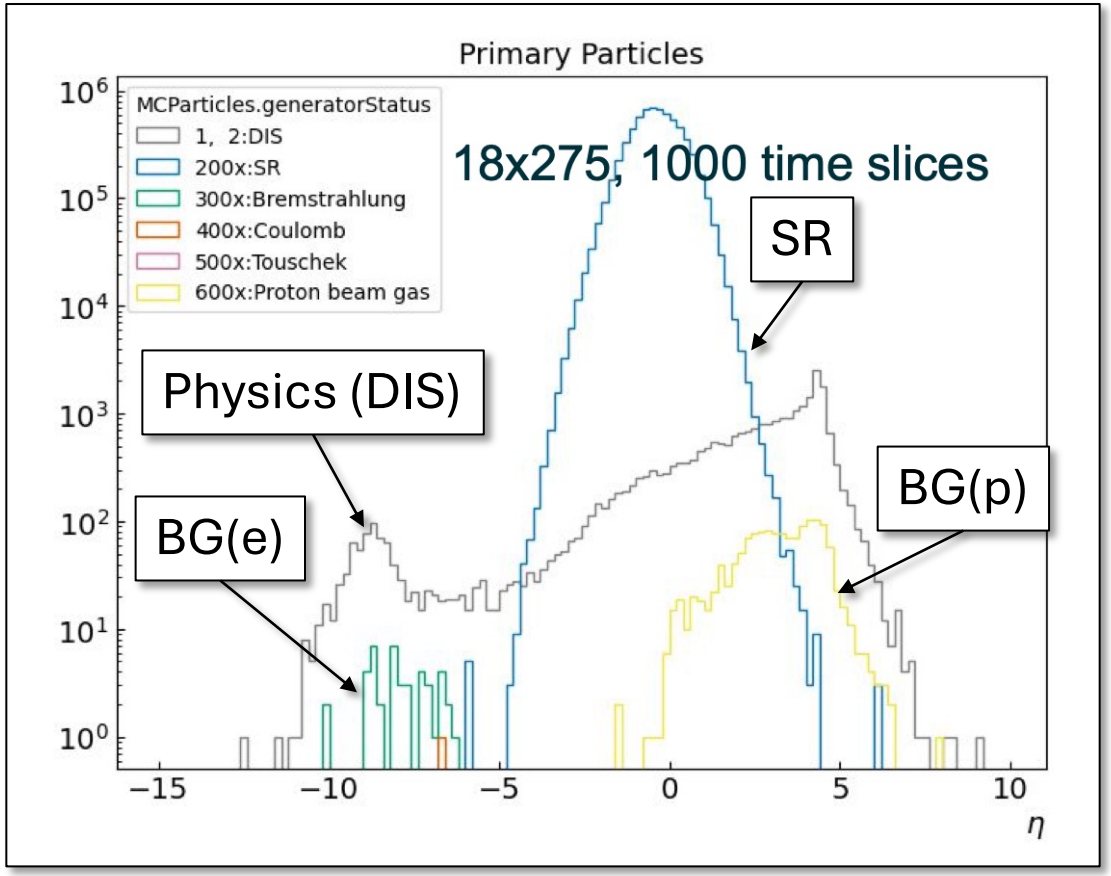
- Produced **one SR MC sample at 18 GeV** for detector performance studies
  - **High statistics:** 10^{11} electrons through IR6
  - **CPU usage:** ~10^{6} CPU·hours (~10 days)
- Beam pipe design is outdated → **needs improvements** to reduce SR and mitigate IR6 impedance issues
- To avoid excessive CPU costs, **no 5/10 GeV samples** were produced
- For a complete detector performance study, **5 and 10 GeV samples are still required**

Temporary workaround:

➢ Use **scaled 18 GeV sample** until IR6 beam pipe is updated

Open Question:

❑ *How should we scale the 18 GeV MC sample to 5 and 10 GeV settings?*



MC sample used for the study. 1 slice = 2 μs, Deep-inelastic scattering (DIS) at $Q^2 > 1$ GeV^2; Background (BG): SR, ESR Beam-gas+Touschek, HSR Beam-gas). Shujie Li (LBNL)

Generated Spectrum

Main contribution:

- Most X-rays reaching the IP6 beam pipe originate from the **three upstream dipoles (~30 m from IP6)**

Spectrum behavior:

- While the SR spectrum depends on beam energy, **normalization by critical energy shows energy-independent shape** (expected)

Open Question:

❑ *Can we scale the IP6 photon sample using **critical energy ratios** to generate the missing 5 and 10 GeV samples?*

Beam Energy [GeV]	Beam current [A]	Weighted SR critical energy from the triplet [keV]
5	2.5	1.3
10	2.5	9.3
18	0.227	56.3

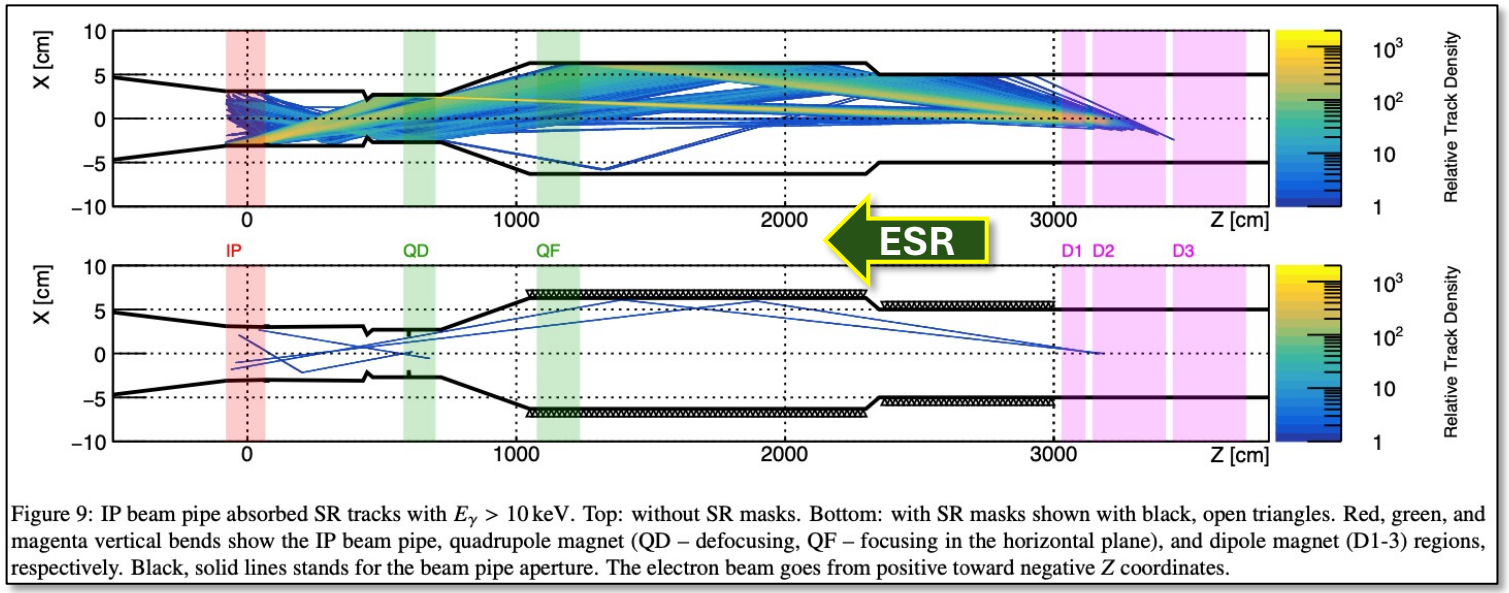
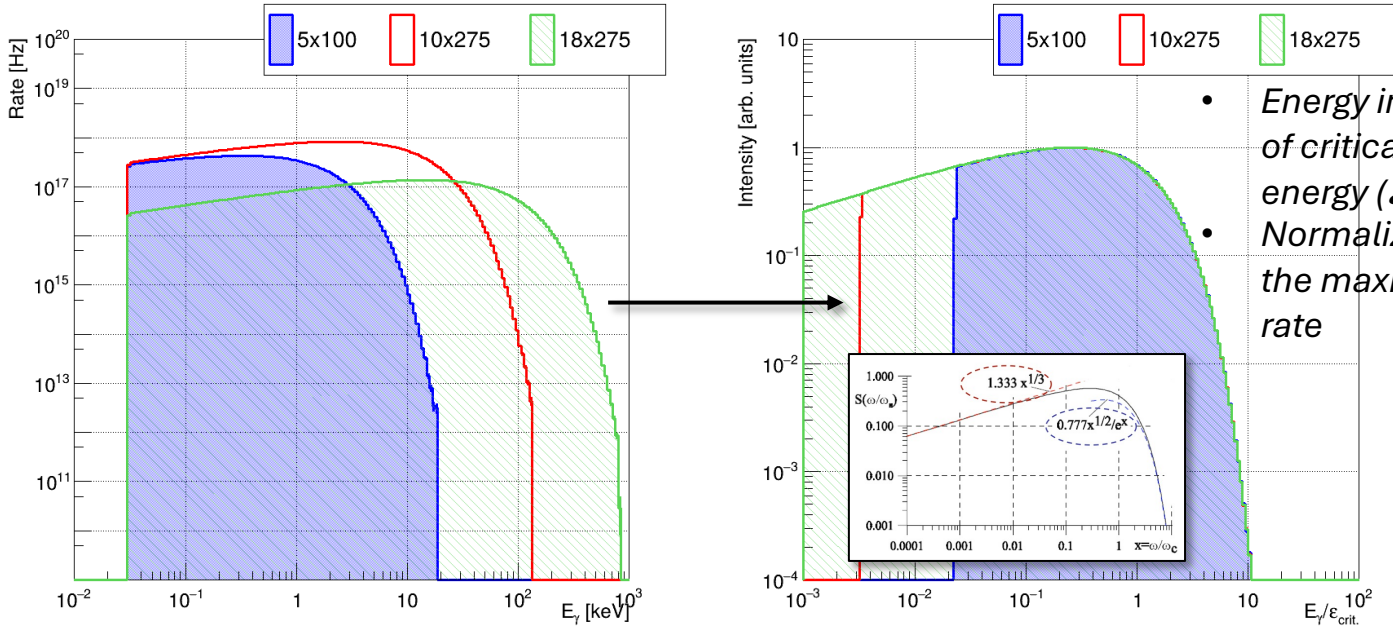


Figure 9: IP beam pipe absorbed SR tracks with $E_\gamma > 10$ keV. Top: without SR masks. Bottom: with SR masks shown with black, open triangles. Red, green, and magenta vertical bends show the IP beam pipe, quadrupole magnet (QD – defocusing, QF – focusing in the horizontal plane), and dipole magnet (D1-3) regions, respectively. Black, solid lines stands for the beam pipe aperture. The electron beam goes from positive toward negative Z coordinates.



- *Energy in units of critical energy ($\varepsilon_{crit.}$)*
- *Normalized by the maximum rate*

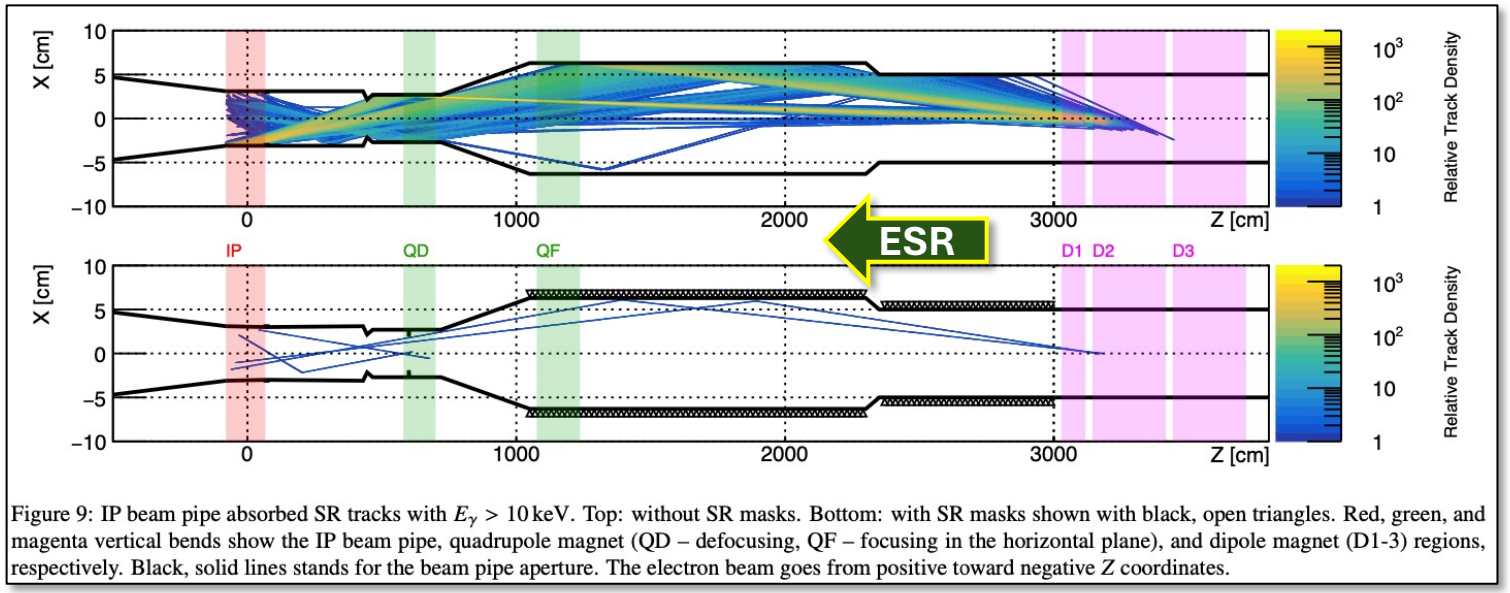
SR generated by the upstream dipole triplet

Absorbed Spectrum

- **Narrower spectrum & reduced rate** due to SR masks
- **Energy scaling does not behave as expected**
- Original (not scaled) spectra appear **already similar in shape** → only **rate scaling** (at fixed energy) seems necessary

Open Question:

❑ *Why?*



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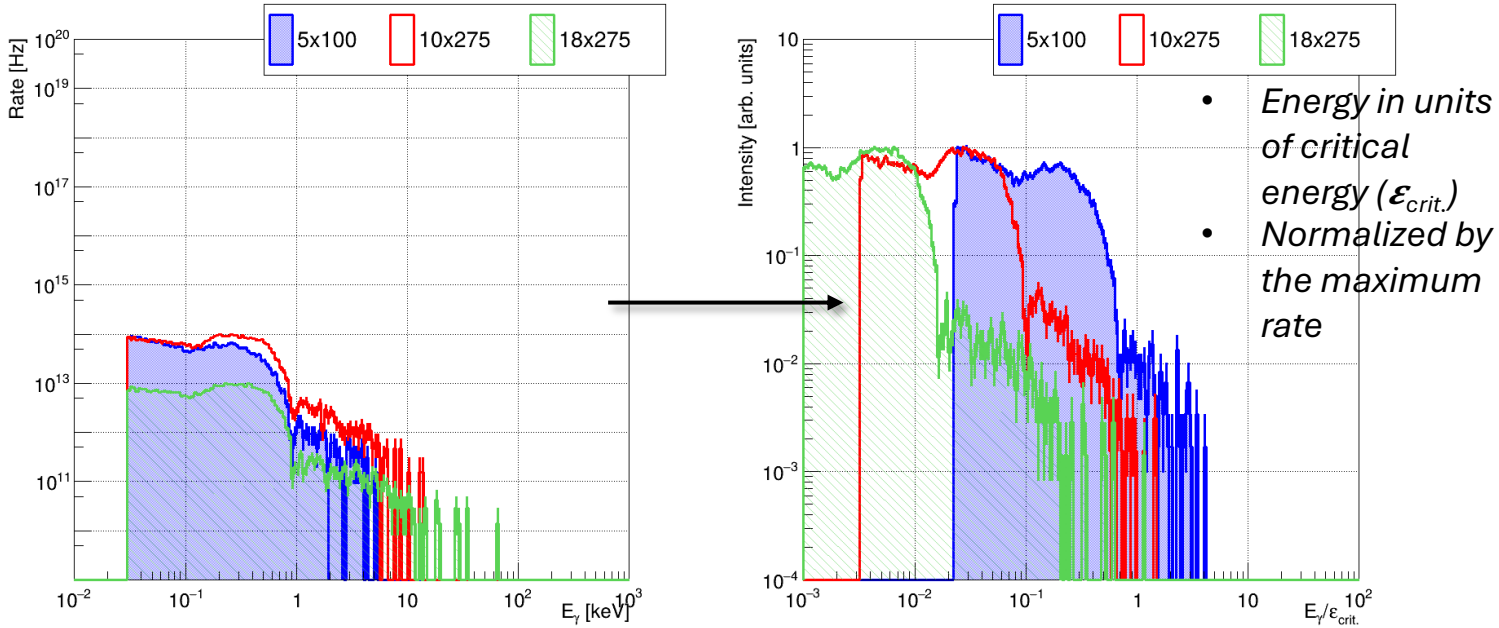

- *Energy in units of critical energy ($\varepsilon_{crit.}$)*
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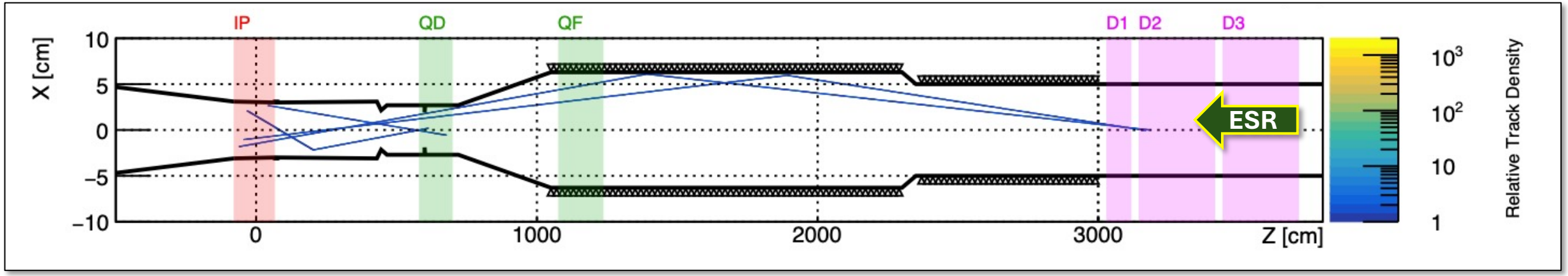
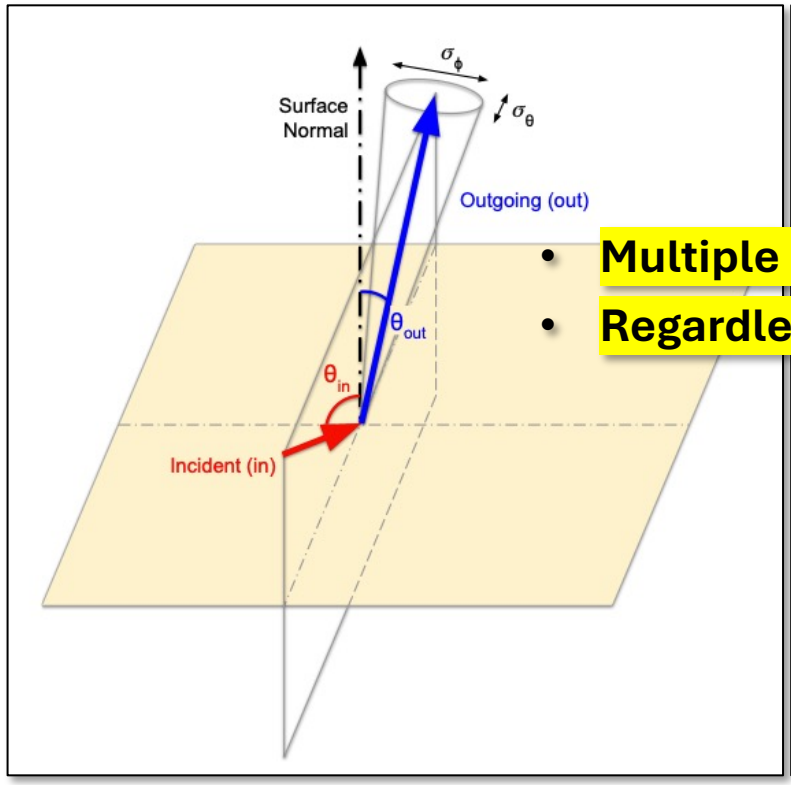
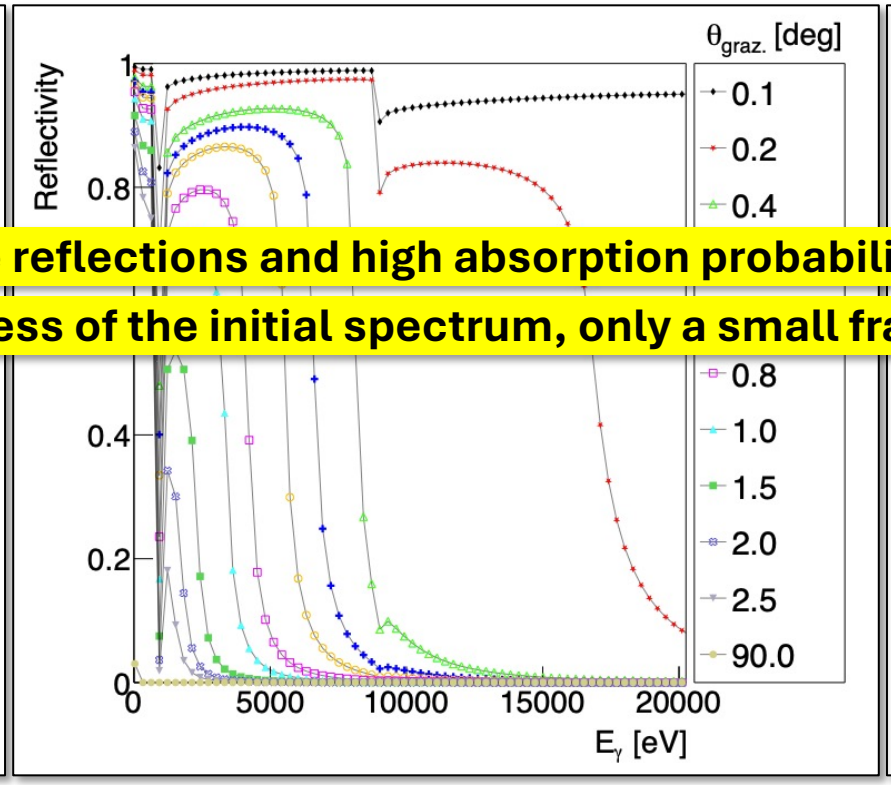
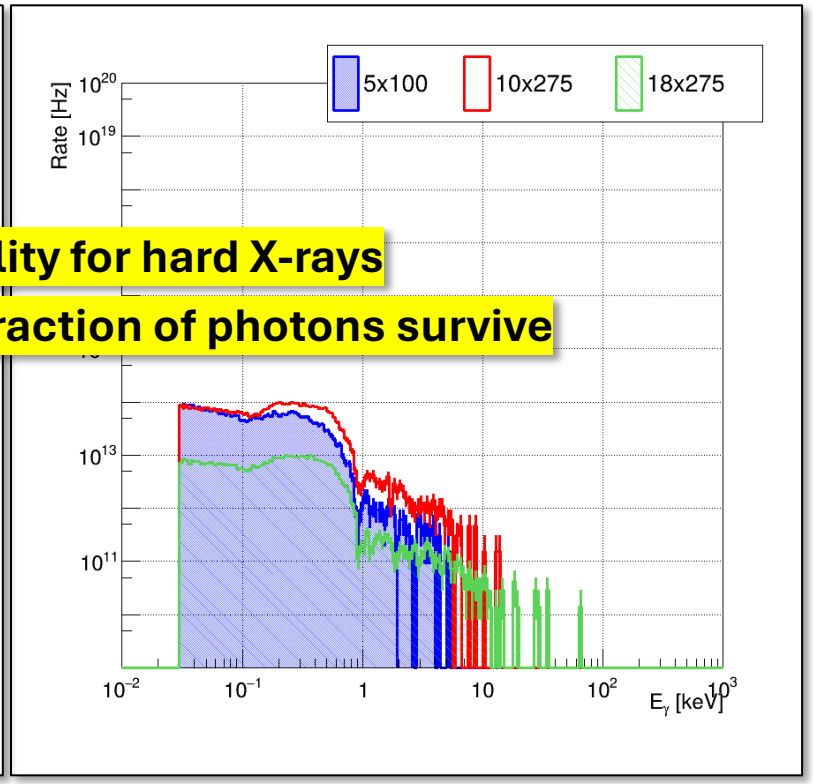
SR absorbed at the IP6 beam pipe

X-ray Reflection









- **Multiple reflections and high absorption probability for hard X-rays**
- **Regardless of the initial spectrum, only a small fraction of photons survive**

Scaling

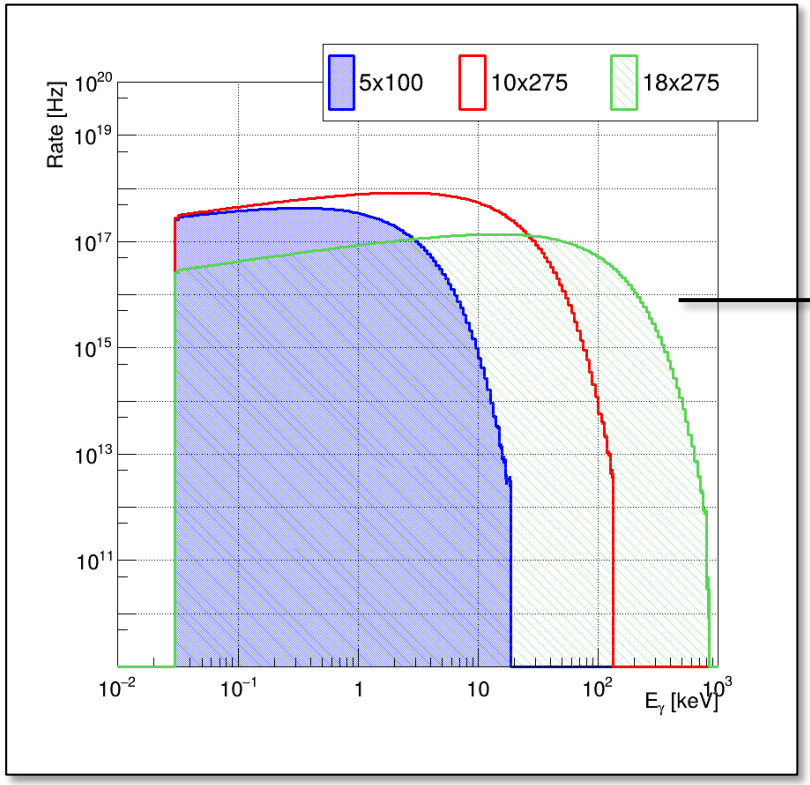
Take 18 GeV

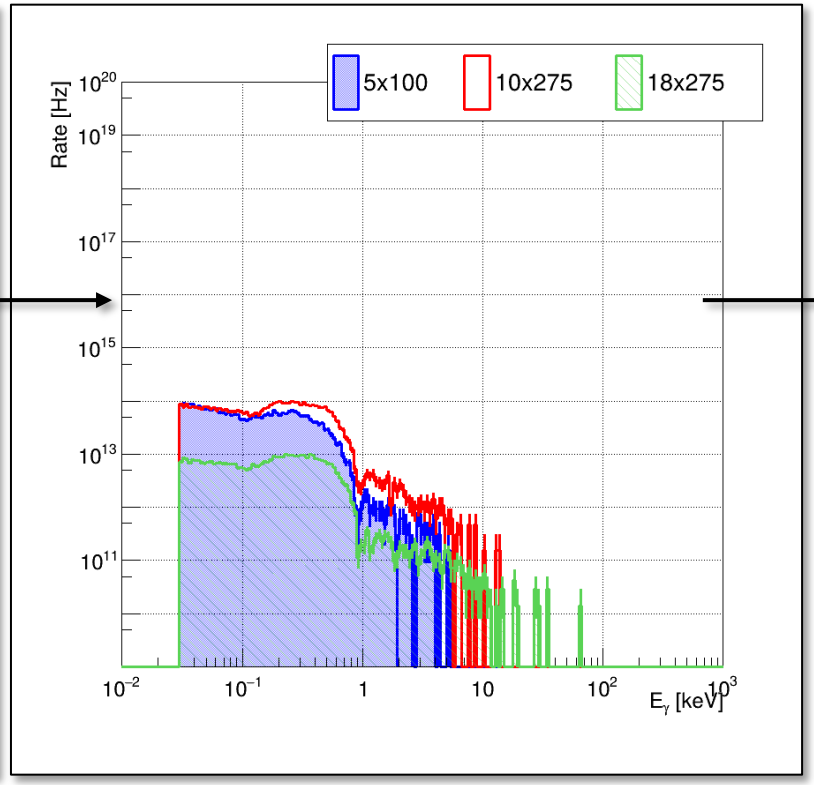
→ Scale its mixing frequency:
3’324 MHz → (2.5 / 0.227) x 3324 = 36’608 MHz

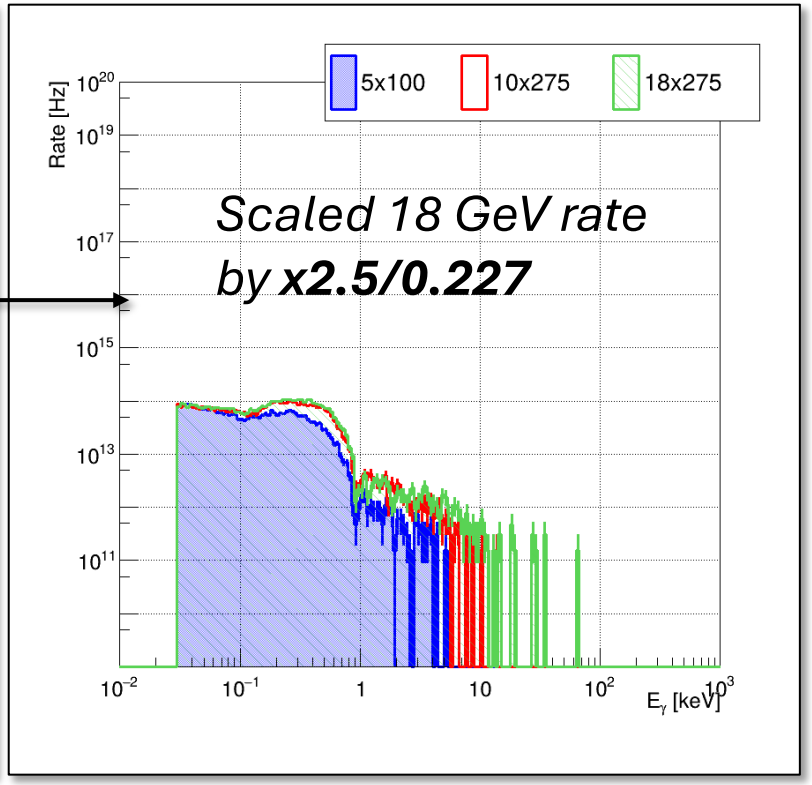
→ Use for 5 and 10 GeV

rates in kHz	5x41 GeV	5x100 GeV	10x100 GeV	10x275 GeV	18x275 GeV	Vacuum
Total ep	12.5 kHz	129 kHz	184 kHz	500 kHz	83 kHz	
hadron beam gas	12.2kHz	22.0kHz	31.9kHz	32.6kHz	22.5kHz	10000Ahr
	131.1kHz	236.4kHz	342.8kHz	350.3kHz	241.8kHz	100Ahr
electron beam gas (Bremsstrahlung scatterings)	2181.97 kHz	2826.38 kHz	3177.25 kHz	3177.25 kHz	316.94 kHz	10000Ahr
electron beam gas (Coulomb losses - w/ collimators)		116.57 kHz		29.56 kHz	0.86 kHz	10000Ahr
electron intrabeam (Touschek losses - w/ collimators)		1112.3 kHz		233.5 kHz	0.55 kHz	
DIS eA	kHz	kHz	kHz	/	/	
hadron beam (Au) gas	7.36kHz	10.3kHz	10.3kHz	/	/	10000Ahr
	79.1kHz	110.7kHz	110.7kHz	/	/	100Ahr
electron SR					3324 MHz	

https://wiki.bnl.gov/EPIC/index.php?title=Background



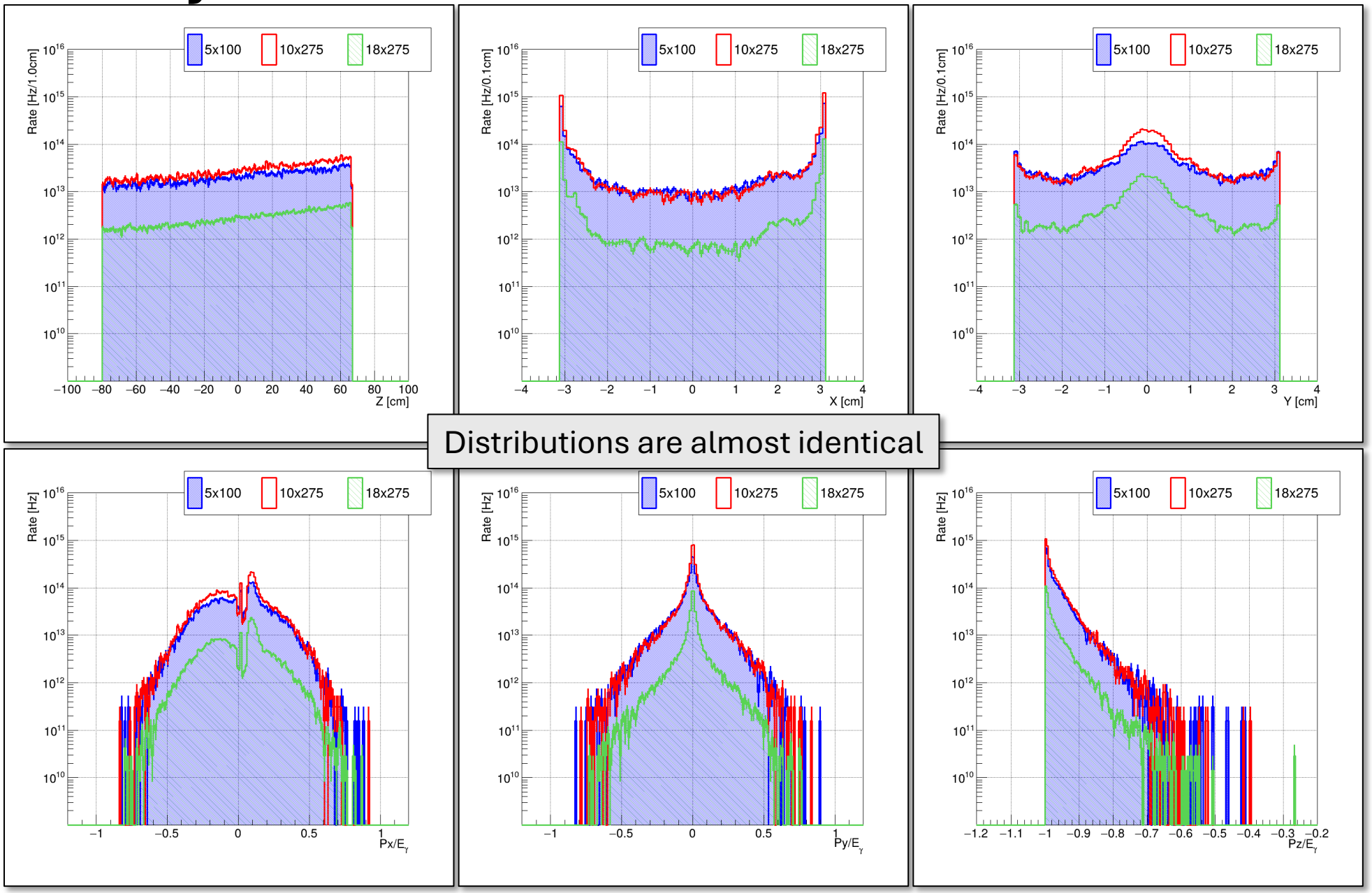




SR generated by the upstream dipole triplet

SR absorbed at the IP6 beam pipe

Absorbed X-ray Coordinates



Distributions are almost identical

Procedure

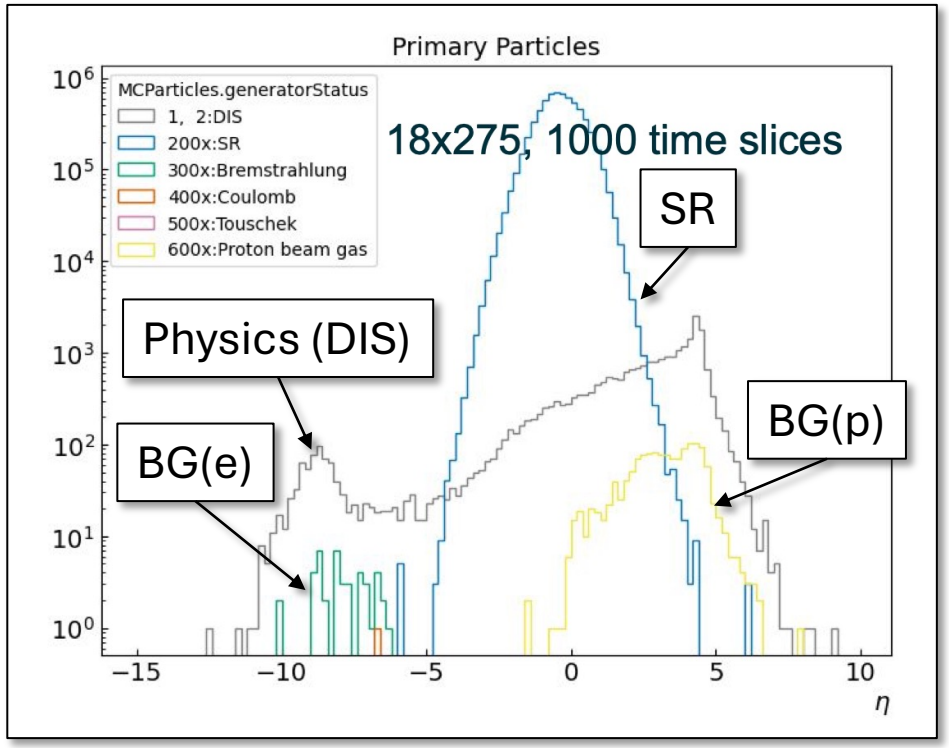
Take **18 GeV**

Scale its mixing frequency:
3’324 MHz → (2.5 / 0.227) x 3324 = **36’608 MHz**

Remove photons > **30 keV** → Use for **5 GeV**

$> 20 \cdot \varepsilon_{crit.}$

Remove photons > **200 keV** → Use for **10 GeV**



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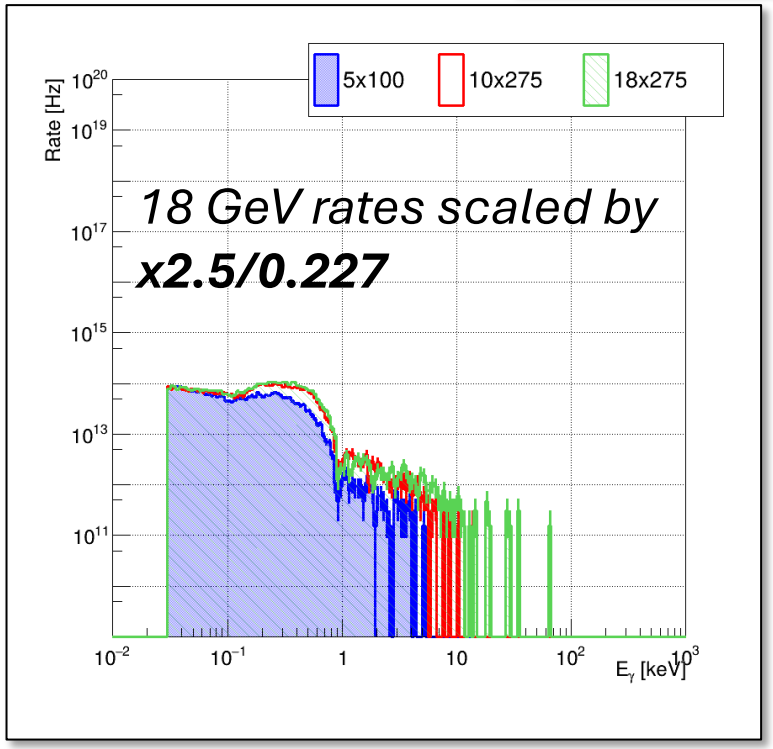
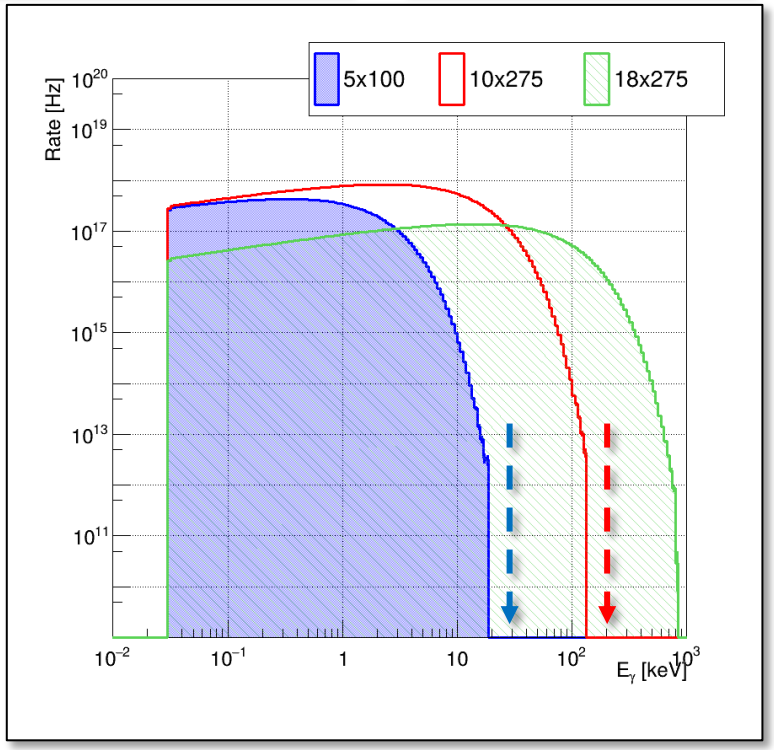
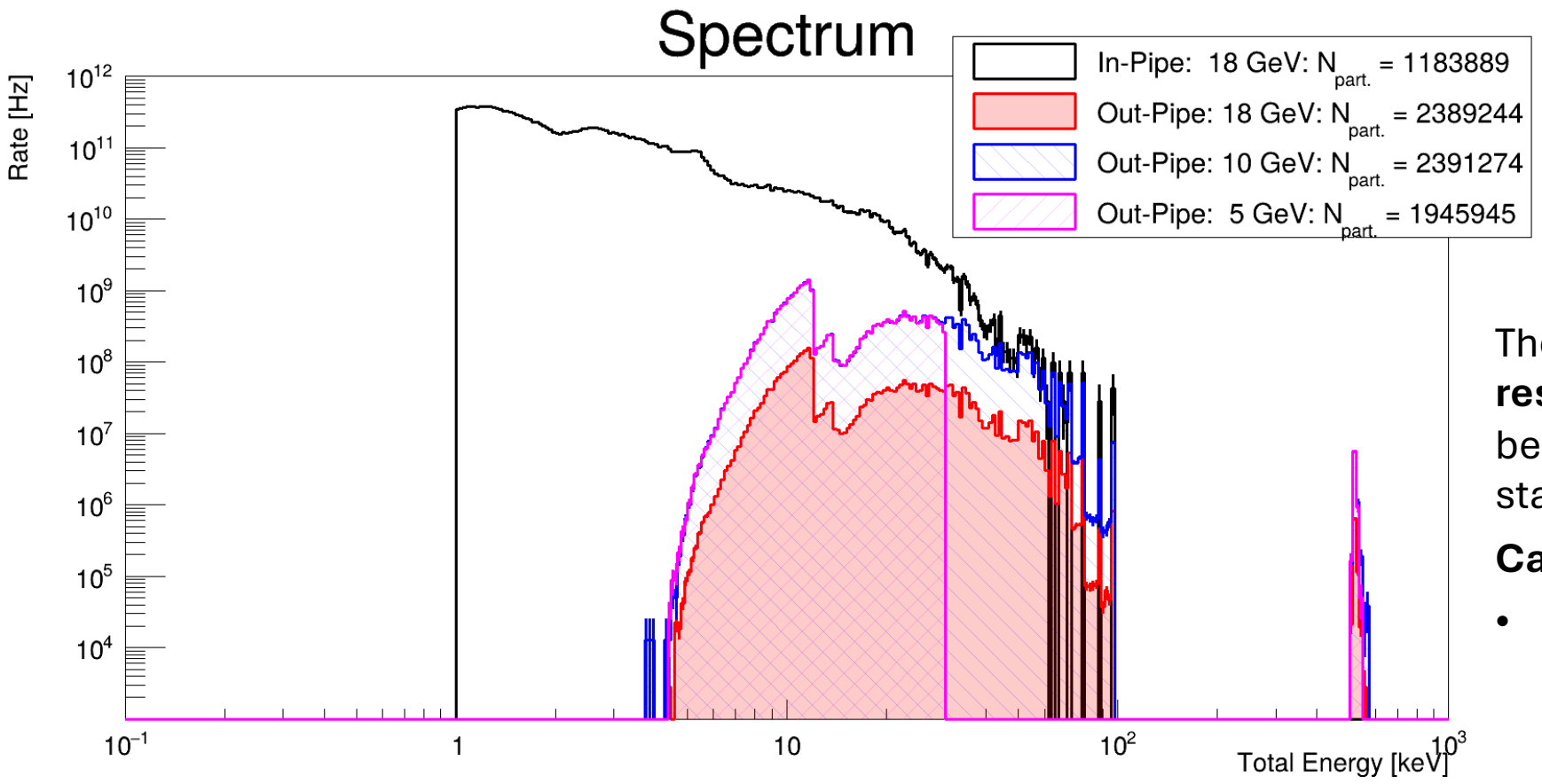


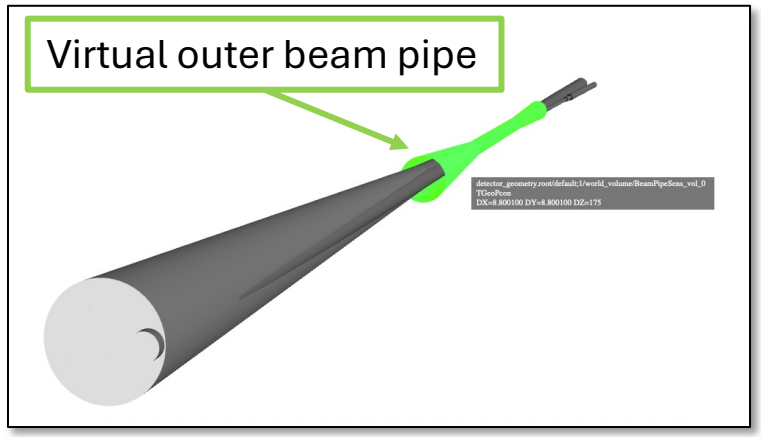
SR absorbed at the IP6 beam pipe



SR generated by the upstream dipole triplet

MC Sample for SR at 5, 10, and 18 GeV





The workaround provides **satisfactory results** until an updated beam pipe becomes available and new high-statistics samples are produced.

Caveats:

- Different angular distributions of SR generated at 5, 10, and 18 GeV (~1/**γ**) in magnets → affects X-ray reflection.
- Overestimation of high-energy X-ray rates after scaling (at 5 and 10 GeV).

18 GeV: /gpfs02/eic/anatochii/SynradG4_HepMC_Files_SR_on_IP6/data/synrad/dataprod_rel_1.0.0/18x275/dataprod_rel_1.0.0_synrad_18x275_run001.preproc_10000repeats.hepmc3.tree.root

10 GeV: /gpfs02/eic/anatochii/SynradG4_HepMC_Files_SR_on_IP6/data/synrad/dataprod_rel_1.0.0/10x275/dataprod_rel_1.0.0_synrad_10x275_run001.preproc_10000repeats.hepmc3.tree.root

5 GeV: /gpfs02/eic/anatochii/SynradG4_HepMC_Files_SR_on_IP6/data/synrad/dataprod_rel_1.0.0/5x100/dataprod_rel_1.0.0_synrad_5x100_run001.preproc_10000repeats.hepmc3.tree.root