Synchrotron Radiation on the Luminosity Exit Window

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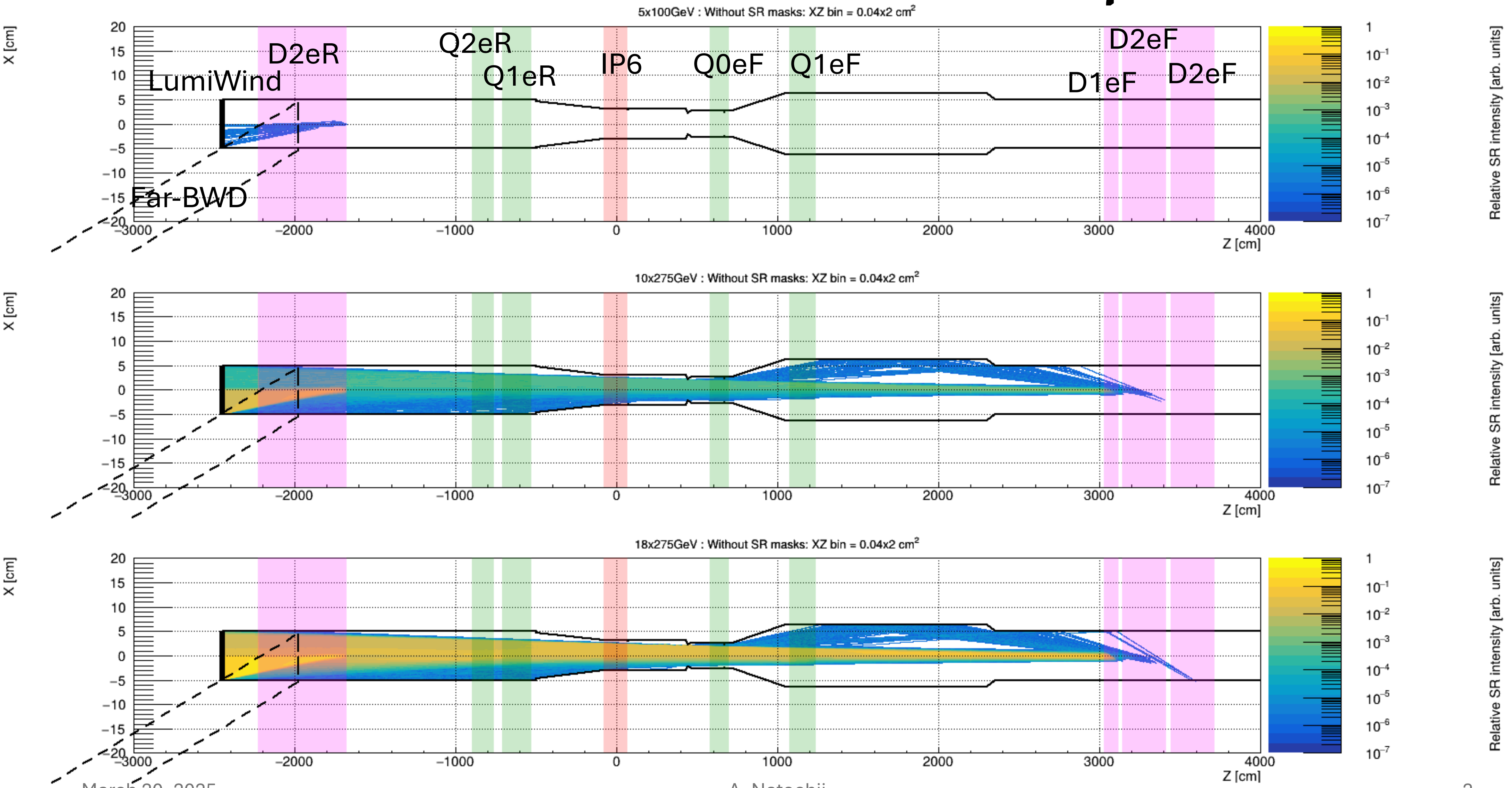
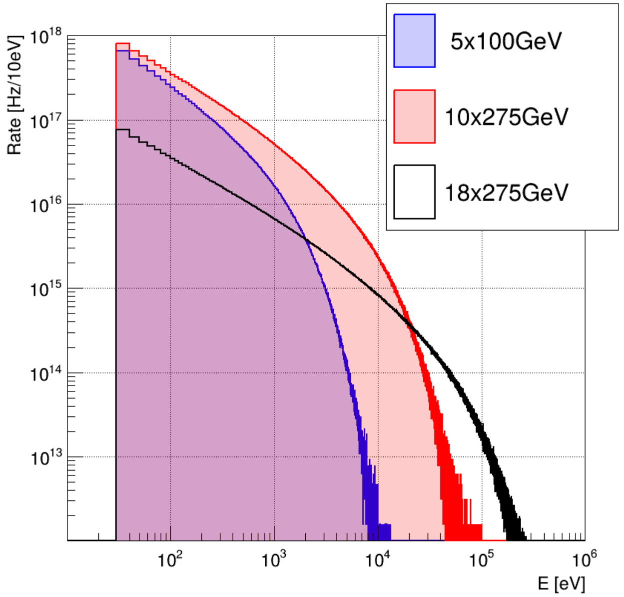
Acknowledgements: Many thanks to D. Marx, C. Hetzel, and S. Kay for provided materials and discussions.

SR Tracks Hitting the Lumi Window ($E_\gamma > 10$ keV)



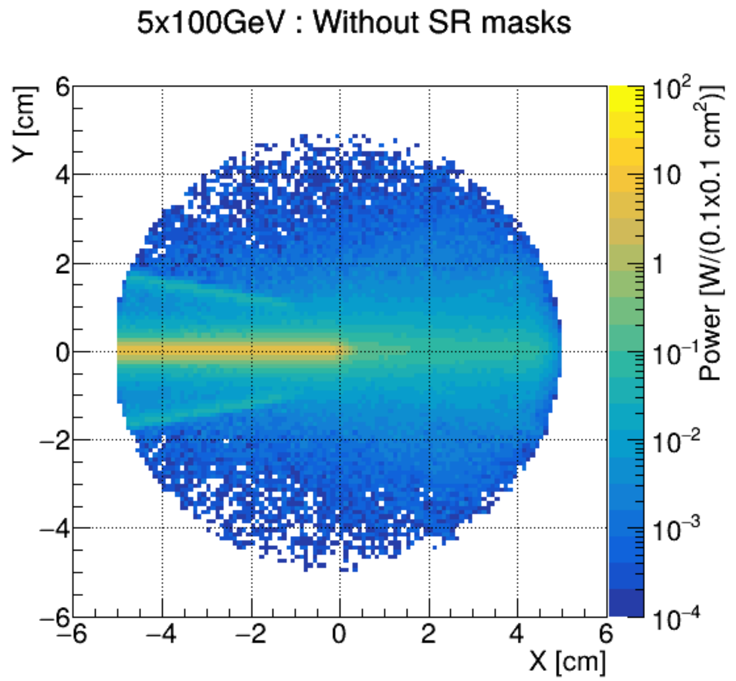
SR Hitting the Lumi Window (E_γ > 30 eV)

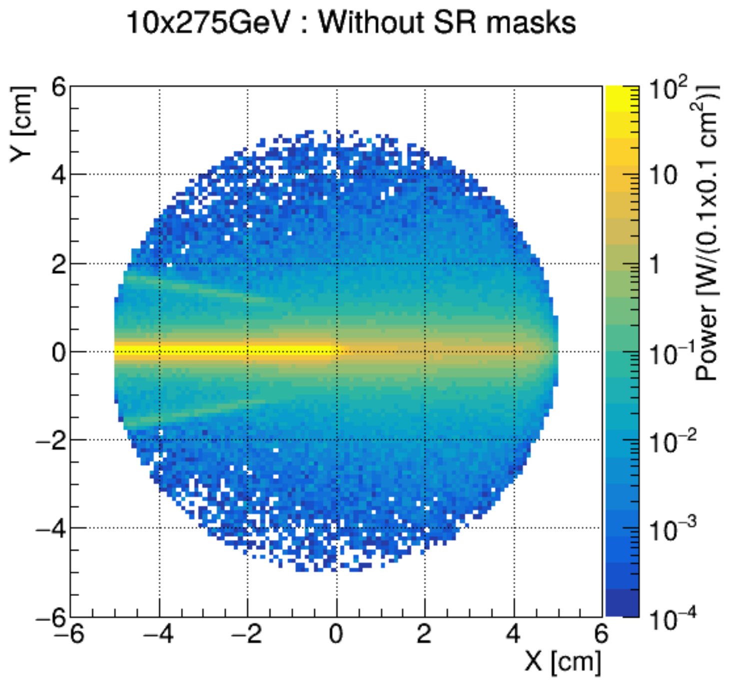


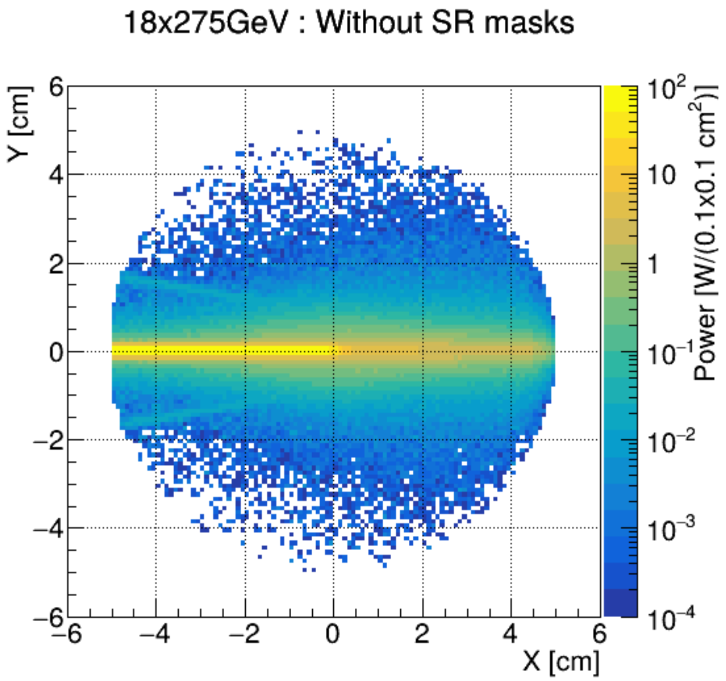
SR power: $P_\gamma \sim \frac{\gamma^4}{\rho^2}$ **Critical photon energy:** $\varepsilon_c \sim \frac{\gamma^3}{\rho}$

Extremely high density

5 GeV @2.500A : P_{max} = 5.9 [W/mm²]; P_{tot} = 676.0 [W]
10 GeV @2.500A : P_{max} = 93.5 [W/mm²]; P_{tot} = 9561.9 [W]
18 GeV @0.227A : P_{max} = 97.8 [W/mm²]; P_{tot} = 9605.8 [W]







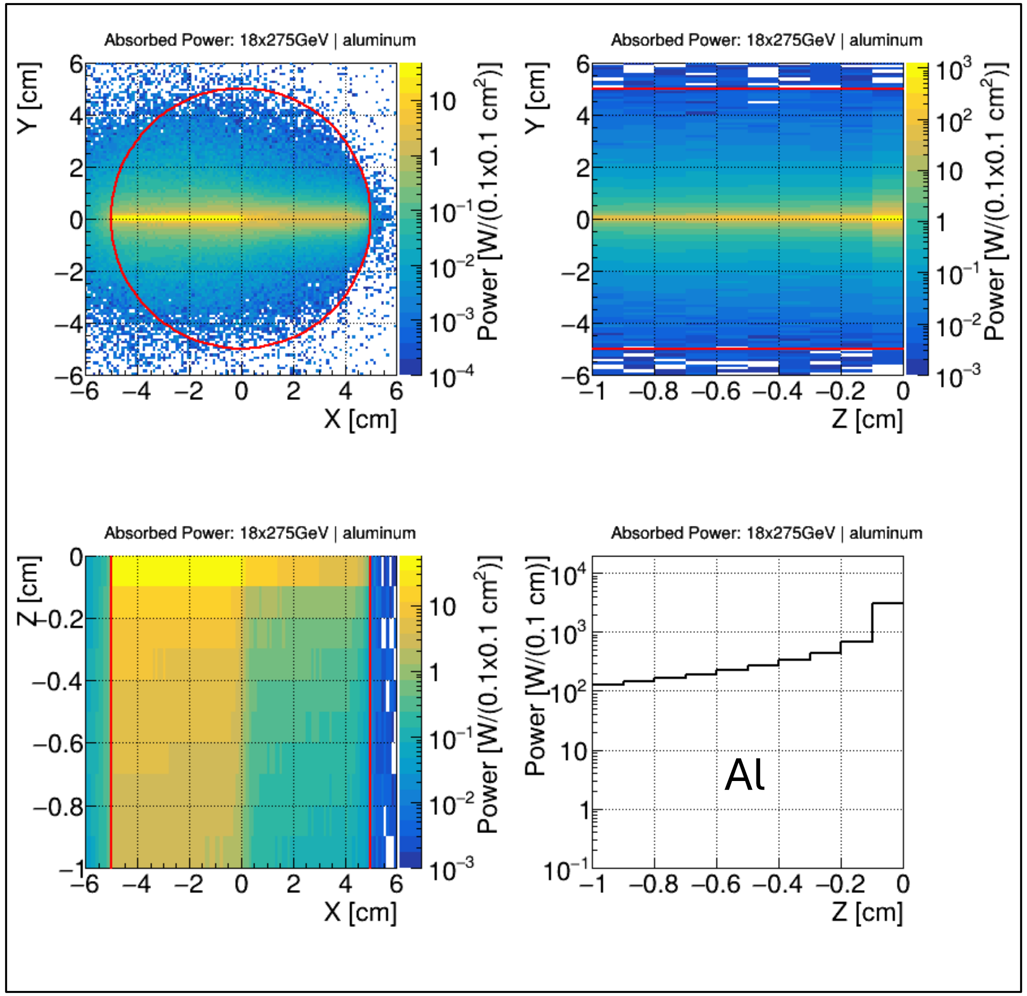
Lumi Window Material Candidates

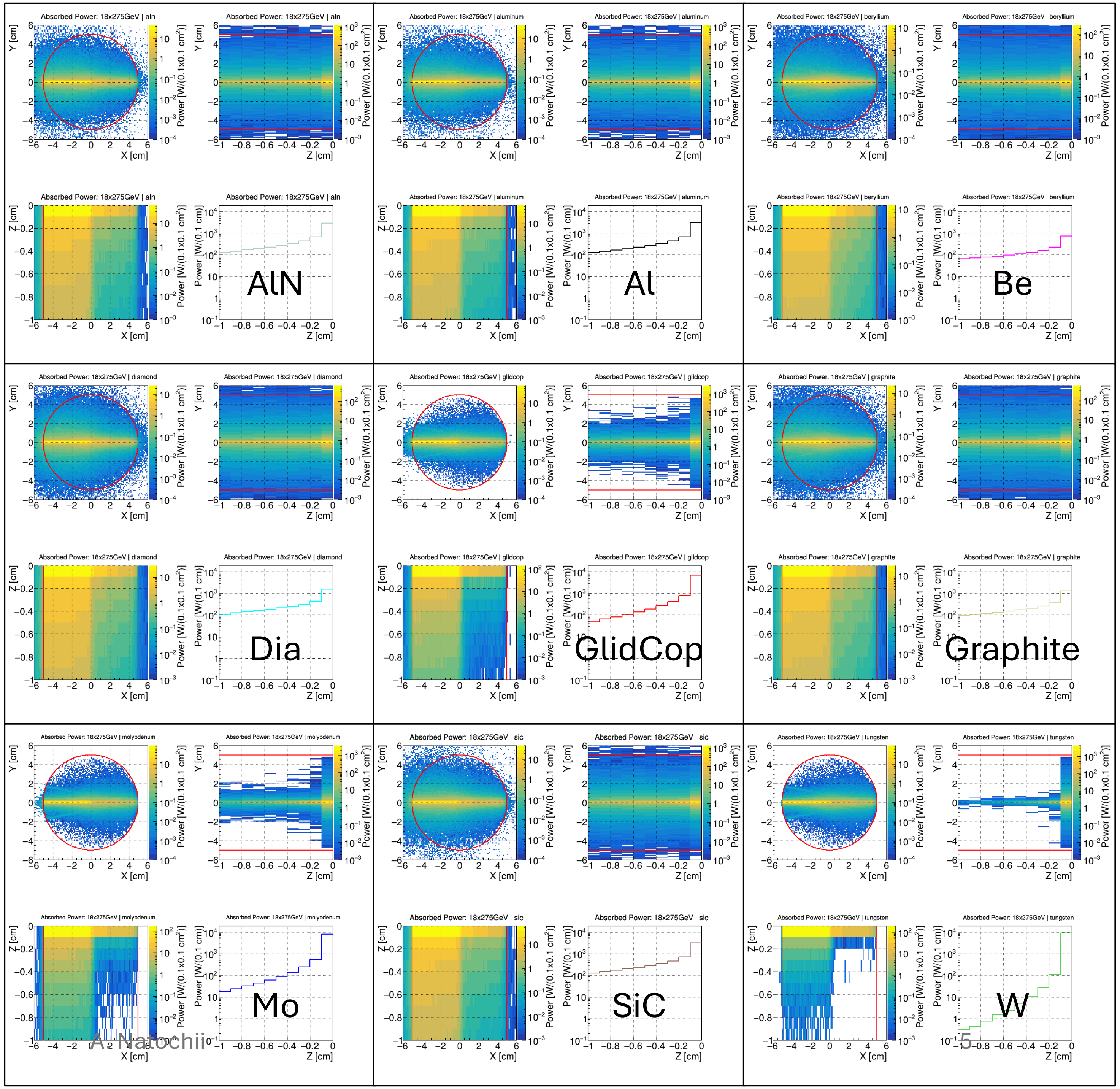
1. **Copper (Cu) & Alloys**: High thermal conductivity, melting point ~1,085°C. Alloys like GlidCop enhance strength.
2. **GlidCop**: Copper alloy with aluminum (Al_2O_3), high thermal conductivity, and improved resistance to high-temperature embrittlement.
3. **Tungsten (W)**: Melting point ~3,422°C, good heat resistance, but lower thermal conductivity than copper.
4. **Molybdenum (Mo)**: High melting point (~2,623°C), decent thermal conductivity, more brittle than Cu or W.
5. **Graphite**: Very high sublimation point (~3,600°C), used in SR beam dumps, variable thermal conductivity.
6. **Beryllium (Be)**: High thermal conductivity, melting point ~1,287°C, lightweight, but toxic.
7. **Diamond**: Extremely high thermal conductivity, used as a coating to enhance heat dissipation.
8. **Ceramics (SiC, AlN)**: High thermal stability, good thermal conductivity, used for thermal management.

The material choice also depends on factors such as cooling system design, mechanical load, and the duration of exposure.

Absorbed SR Power

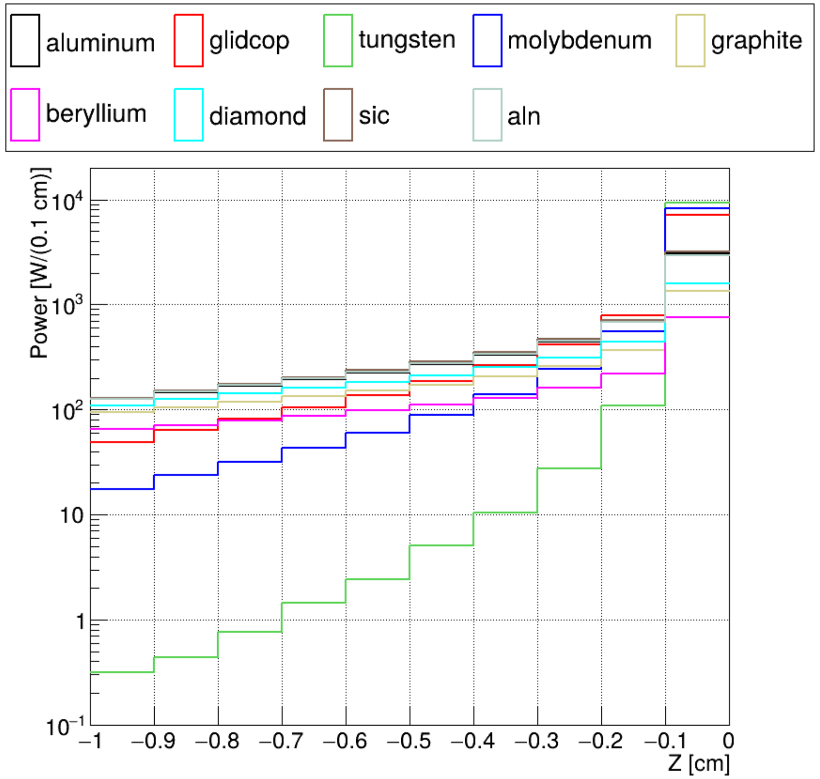
LumiWindow is $12 \times 12 cm^2$



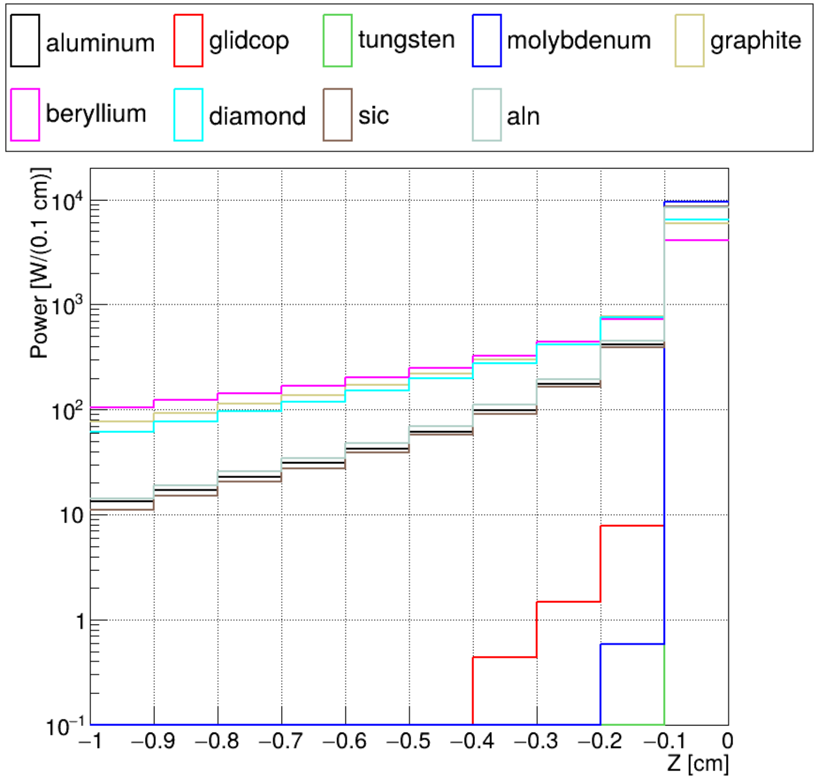


18x275 GeV @ 0.227 A

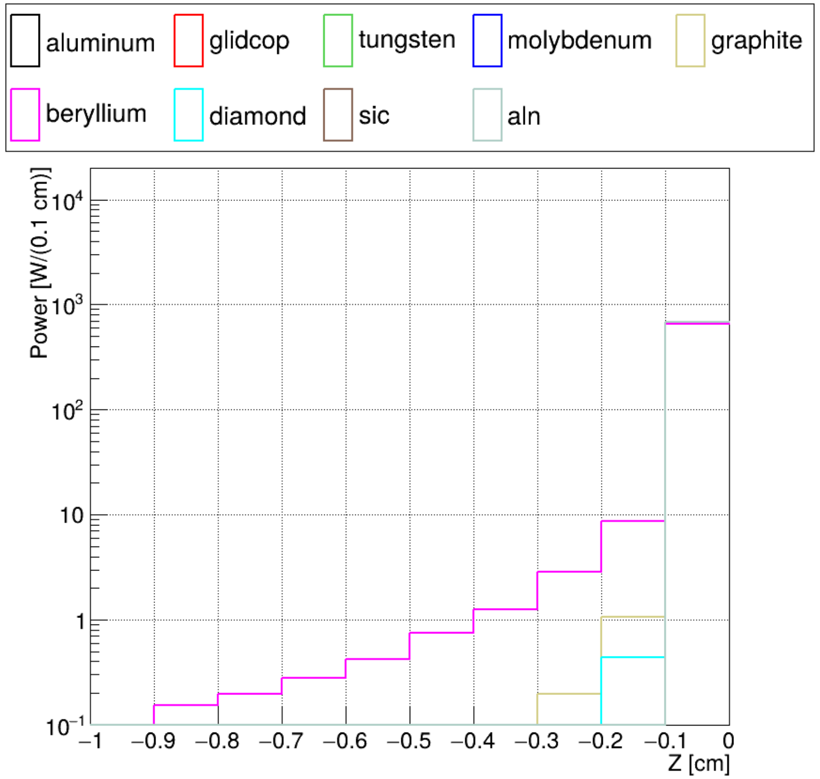
Absorbed SR Power vs Lumi Window Thickness



18x275 GeV @ 0.227 A



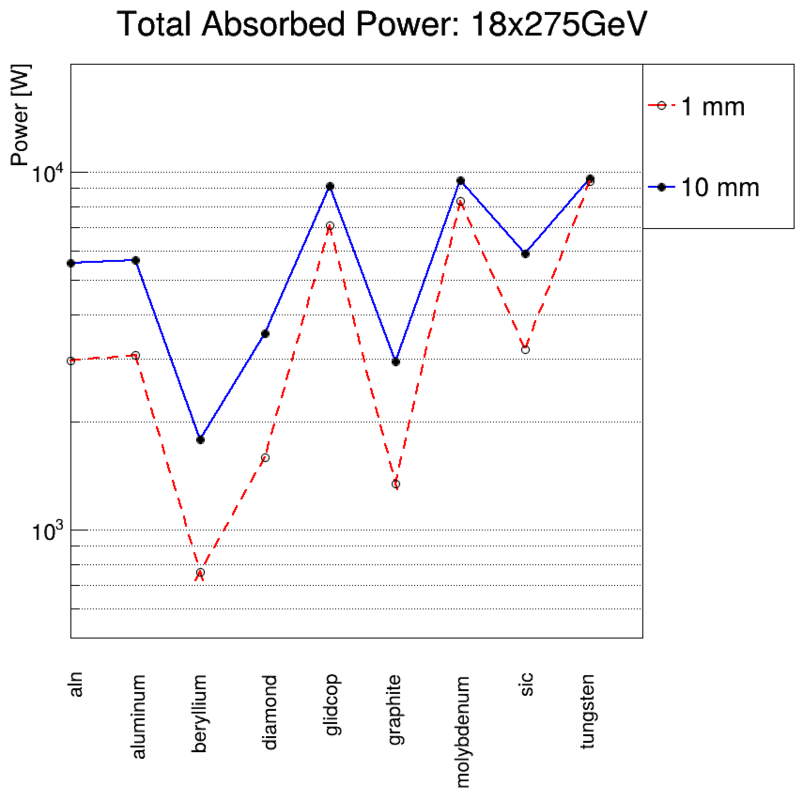
10x275 GeV @ 2.5 A



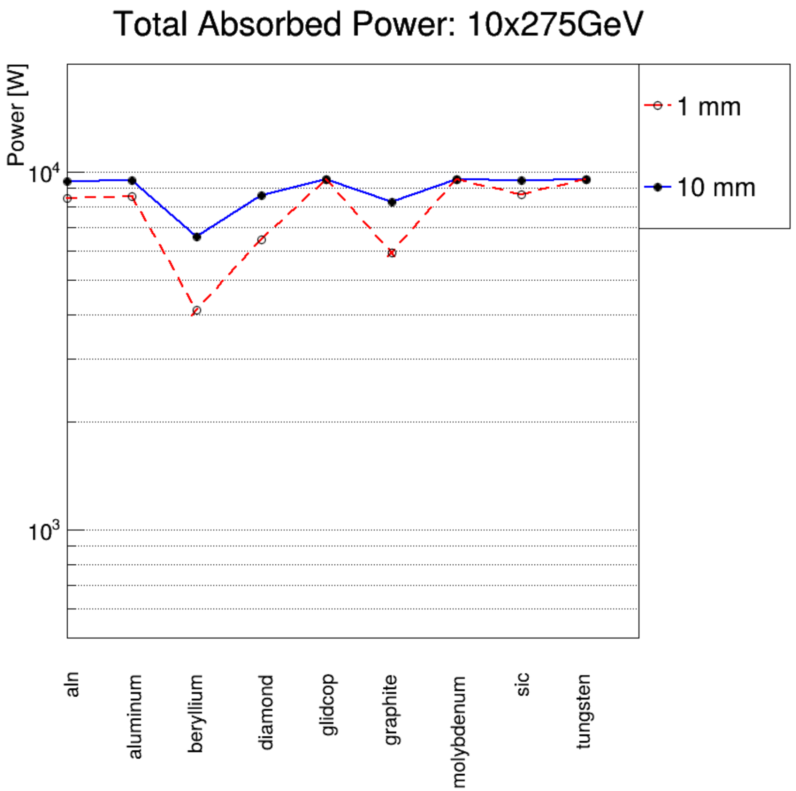
5x100 GeV @ 2.5 A

Total Absorbed SR Power

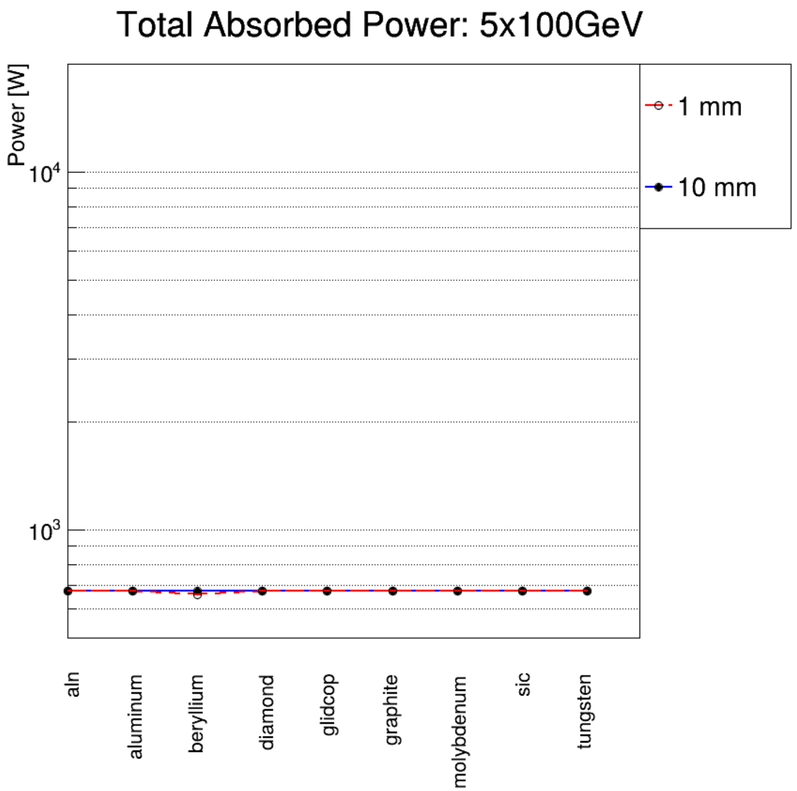
- Based on light source experience, **1-10kW** is a soft limit (manageable depending on the cooling system and thermal conductivity of the window material)
- For all materials at 10 GeV, we are close to the limit



18x275 GeV @ 0.227 A



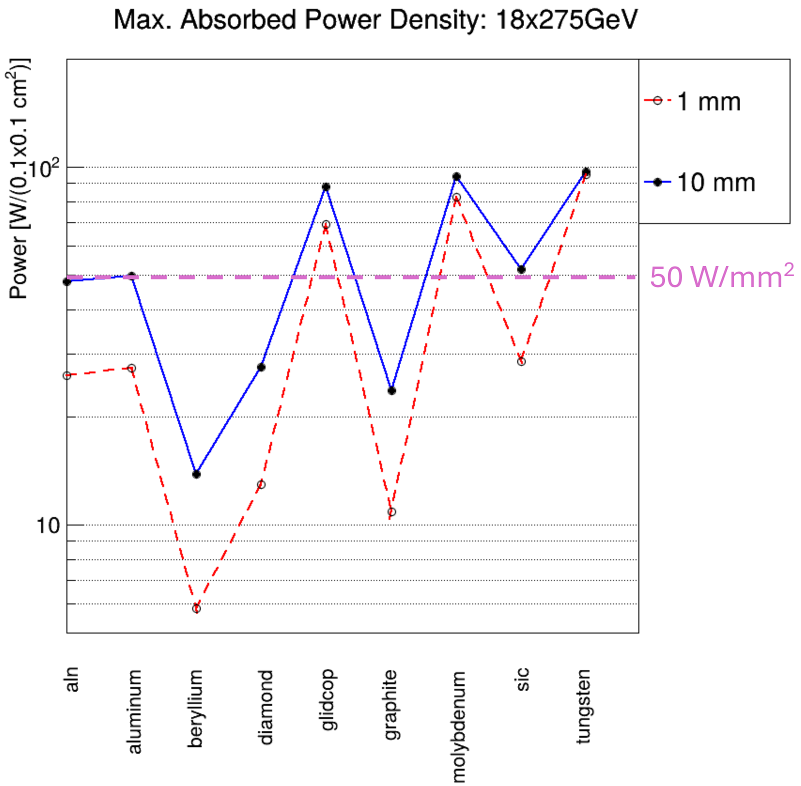
10x275 GeV @ 2.5 A



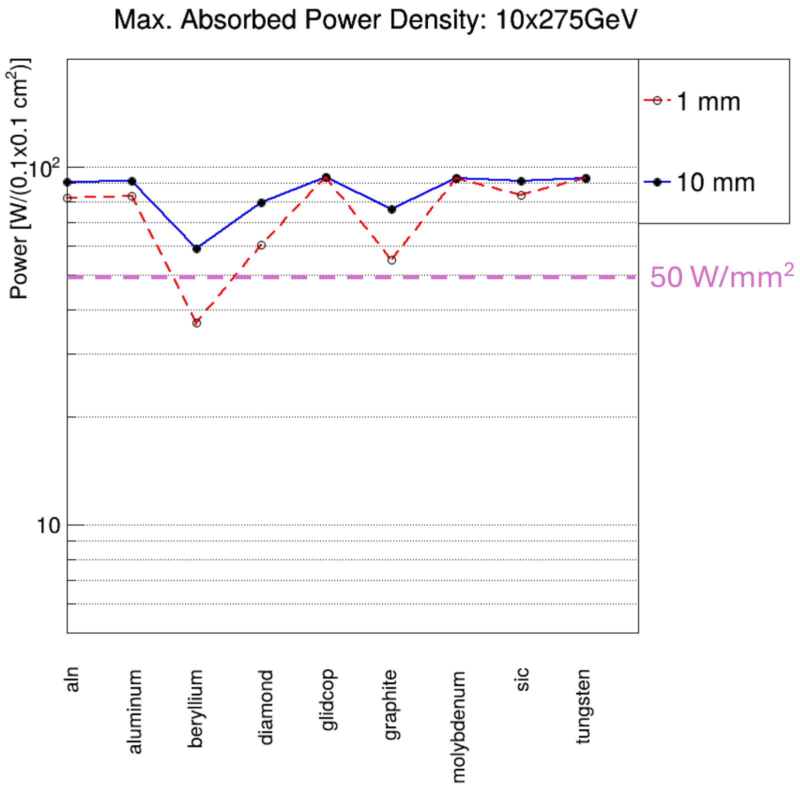
5x100 GeV @ 2.5 A

Maximum Absorbed SR Power Density

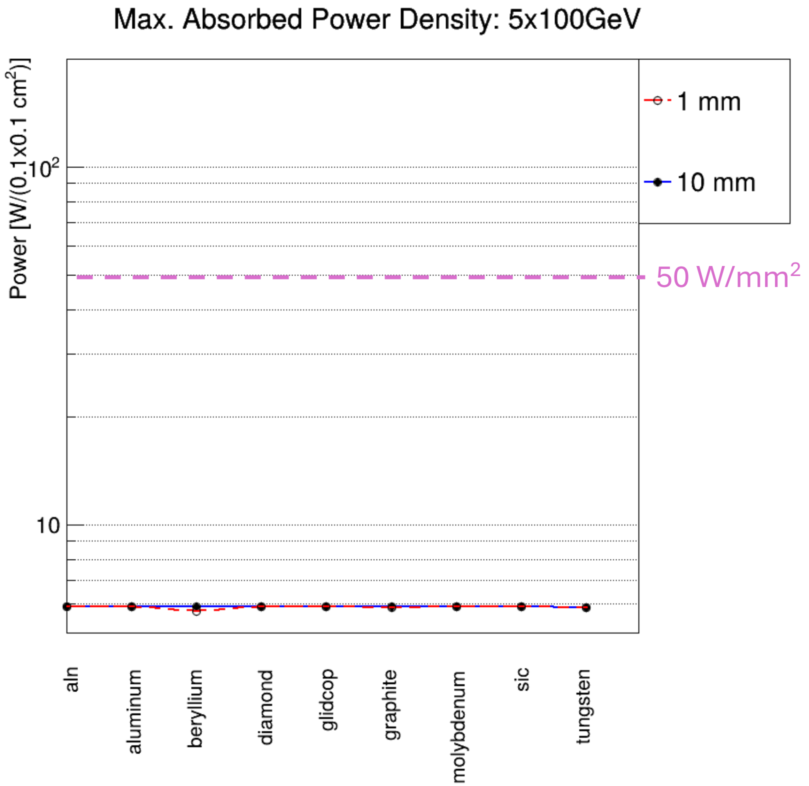
- Based on light source experience, **50 W/mm²** is a hard limit
- At 10 GeV, we are very close or above the limit for all materials



18x275 GeV @ 0.227 A



10x275 GeV @ 2.5 A



5x100 GeV @ 2.5 A

Proposal(part 1):

Critical photon energy:

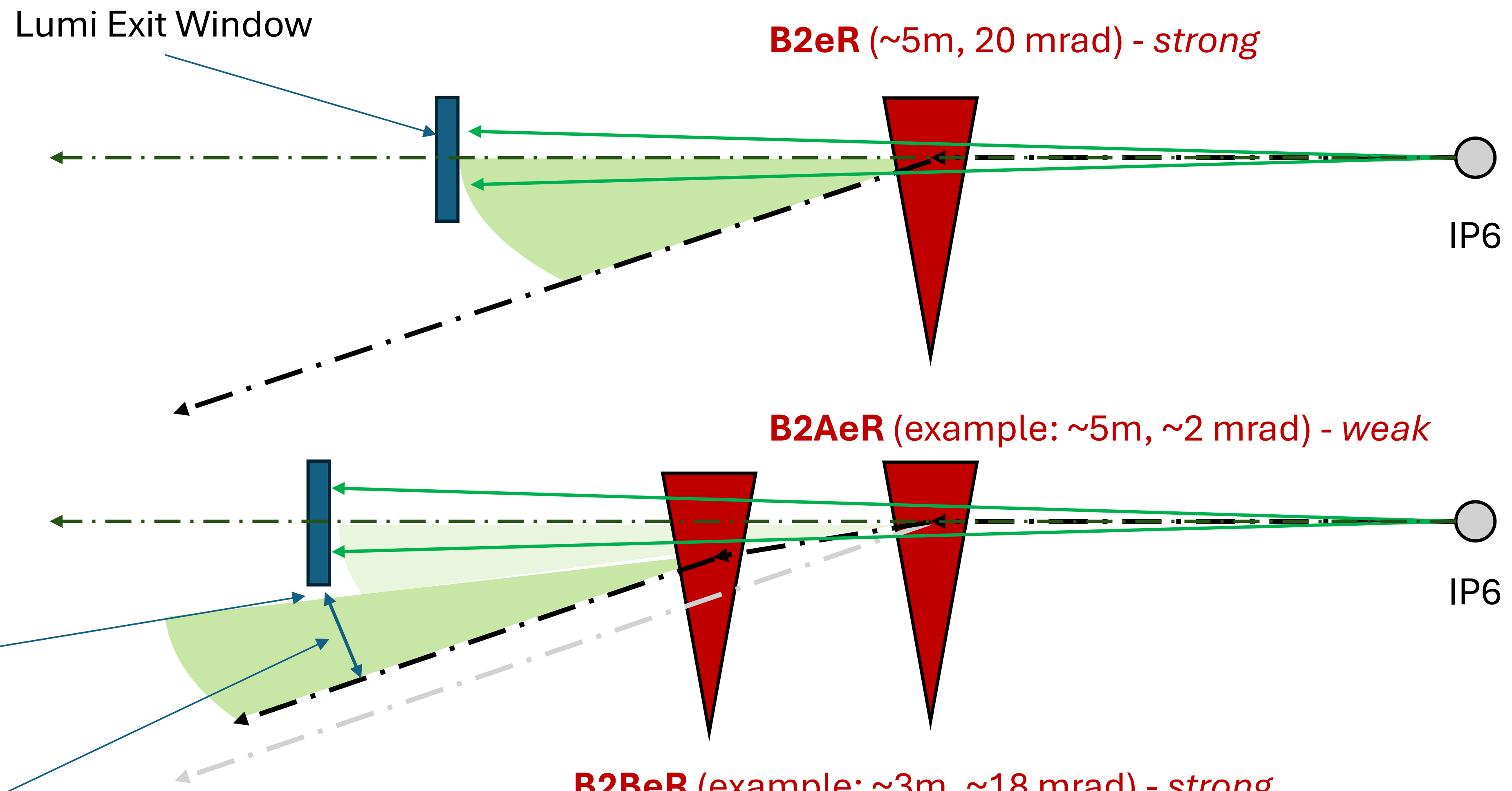
$$\varepsilon_c \sim \frac{\gamma^3}{\rho}$$

SR power:

$$P_\gamma \sim \frac{\gamma^4}{\rho^2}$$

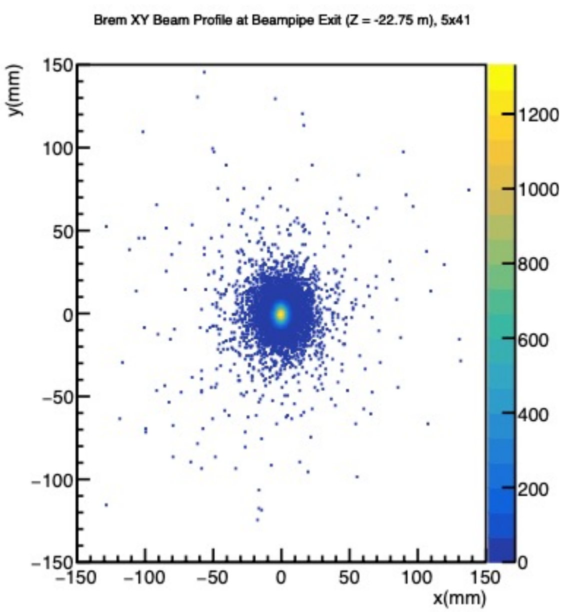
Keep the SR fan from the second dipole outside the lumi window

Keep the beam core away from the window at >14σ_x (see backup slides)

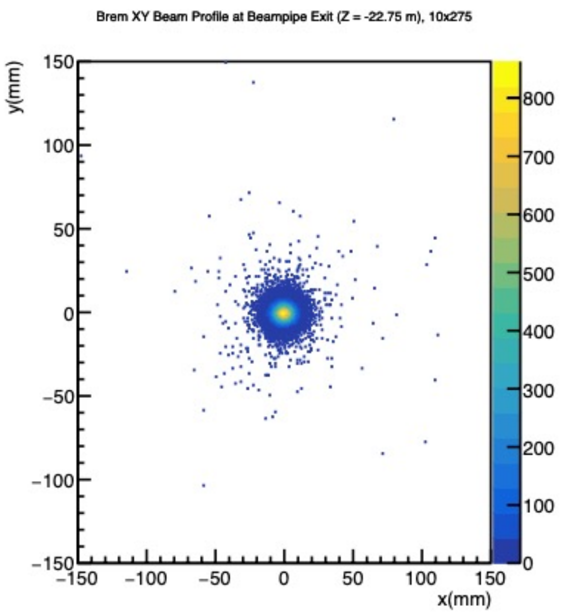


- Making the dipole in front of the lumi window weaker (larger bending radius = small bending angle for the same length) reduces SR power and photon energy hitting the window.

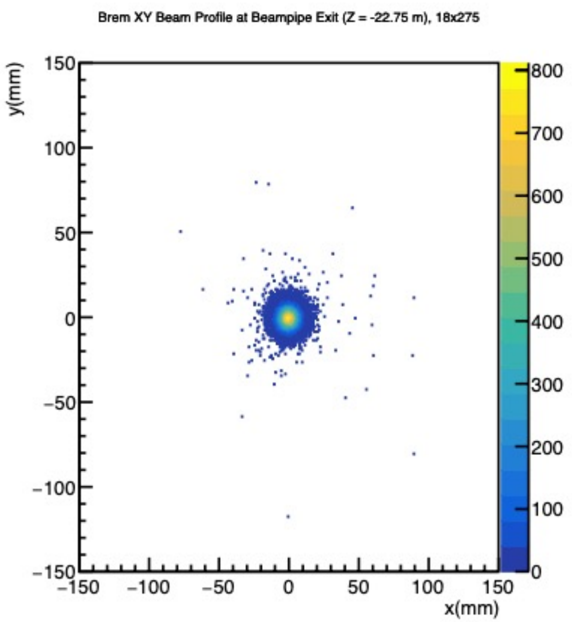
Lumi Photon Distribution at the Window (~23 m from IP6)



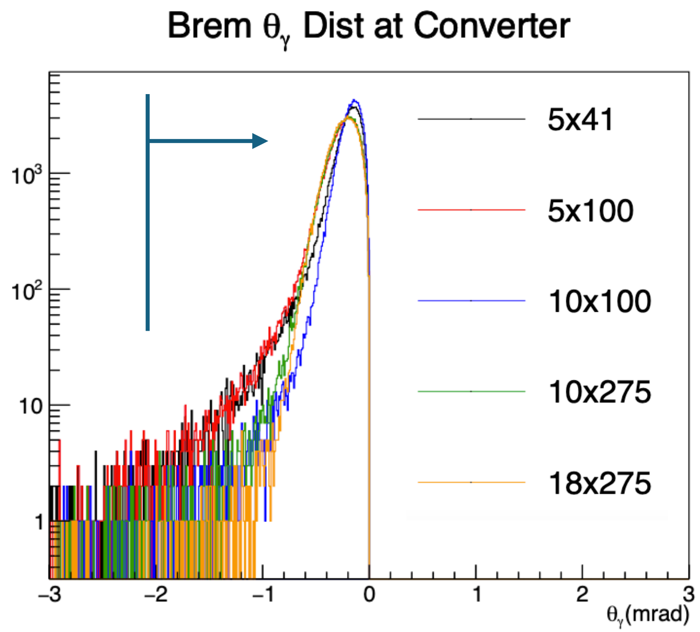
5x41GeV (**largest spot**)



10x275GeV (**highest SR**)

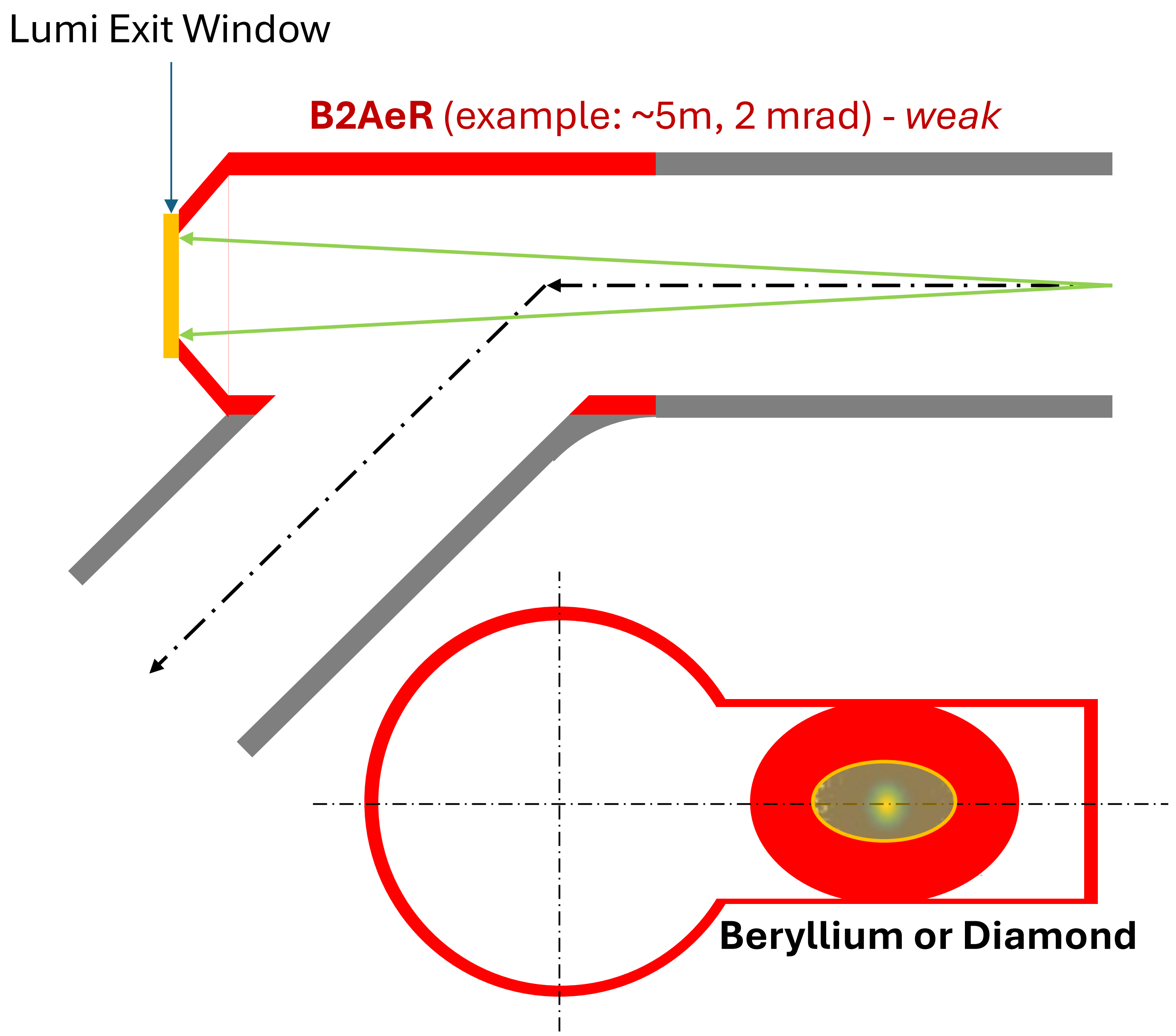


18x275GeV (**narrowest spot**)



- What is the minimum angular acceptance allowed for the lumi window at low (large spot/spread & low SR) and high (small spot/spread & high SR) energies?

Proposal(part 2):

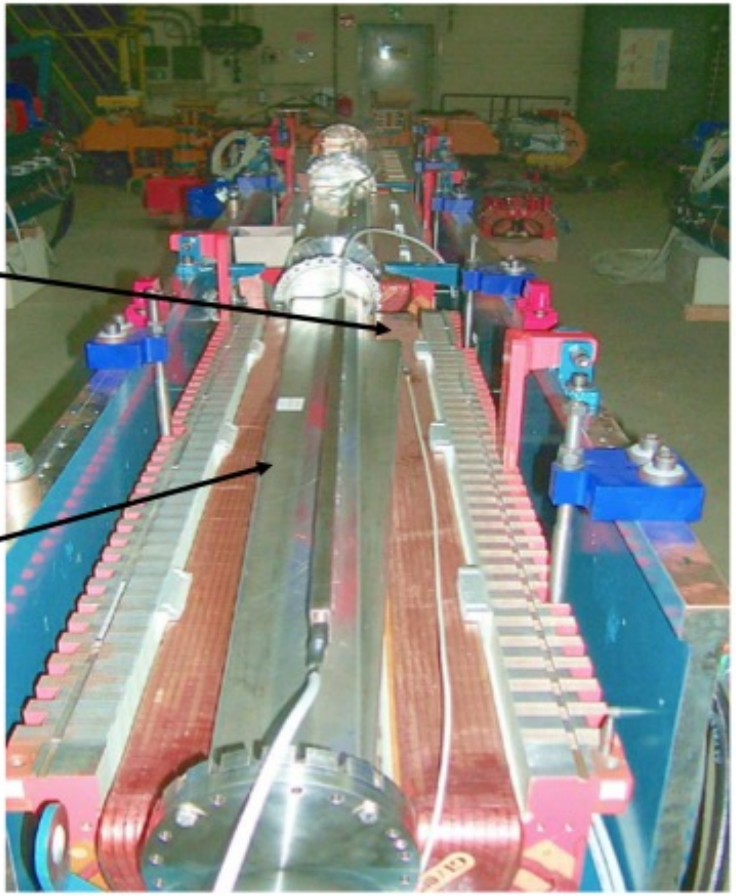


- Instead of using two beam pipes (one is for the main beam, another – for the luminosity photons), we could try building a beam pipe with an **ante-chamber**.
- The ante-chamber will reduce the beam pipe impedance.
  - Horizontal window and ante-chamber size is dictated by the distance between the electron and photon axes
  - The vertical window size is defined by the angular acceptance requirements.
  - For the acceptable impedance, the vertical ante-chamber size should be smaller than the beam pipe diameter.

Vacuum System

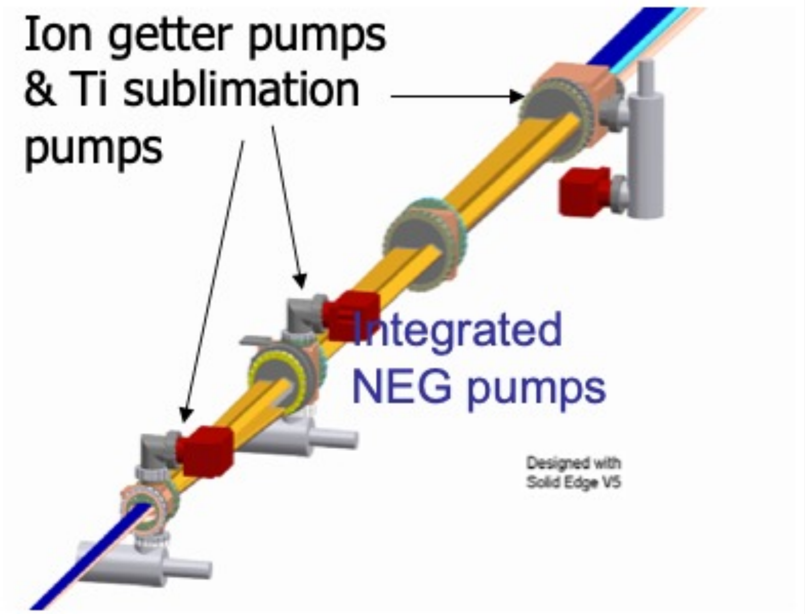
Preassembly in lab

Window for 6m tagger



Space for S.R. fan

Need quite complicated vacuum chambers to accommodate e and p beams and synchrotron radiation fan



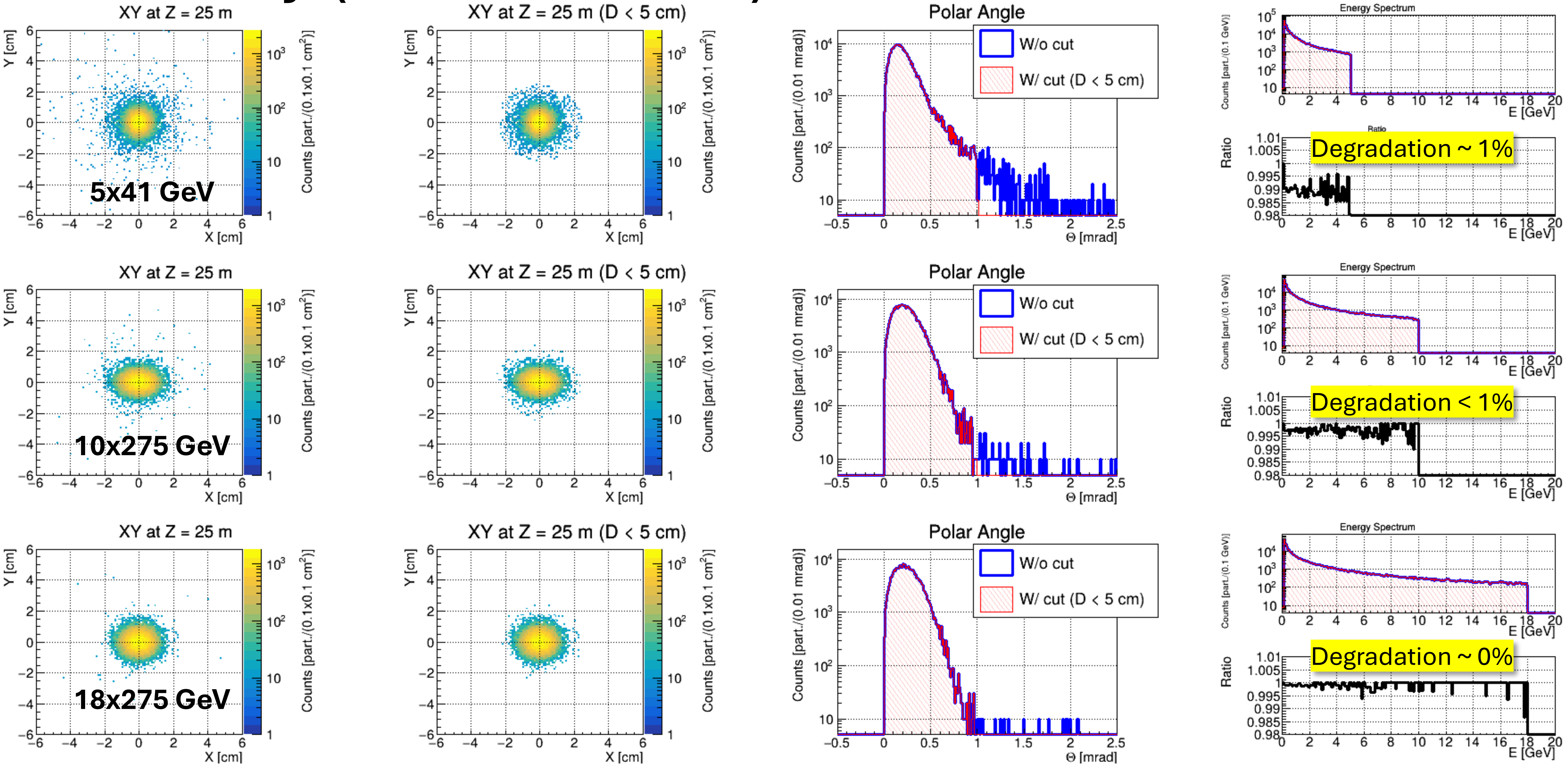
Lumi Exit Window Specs

- Is 50 mm exit window acceptable for the luminosity monitor?

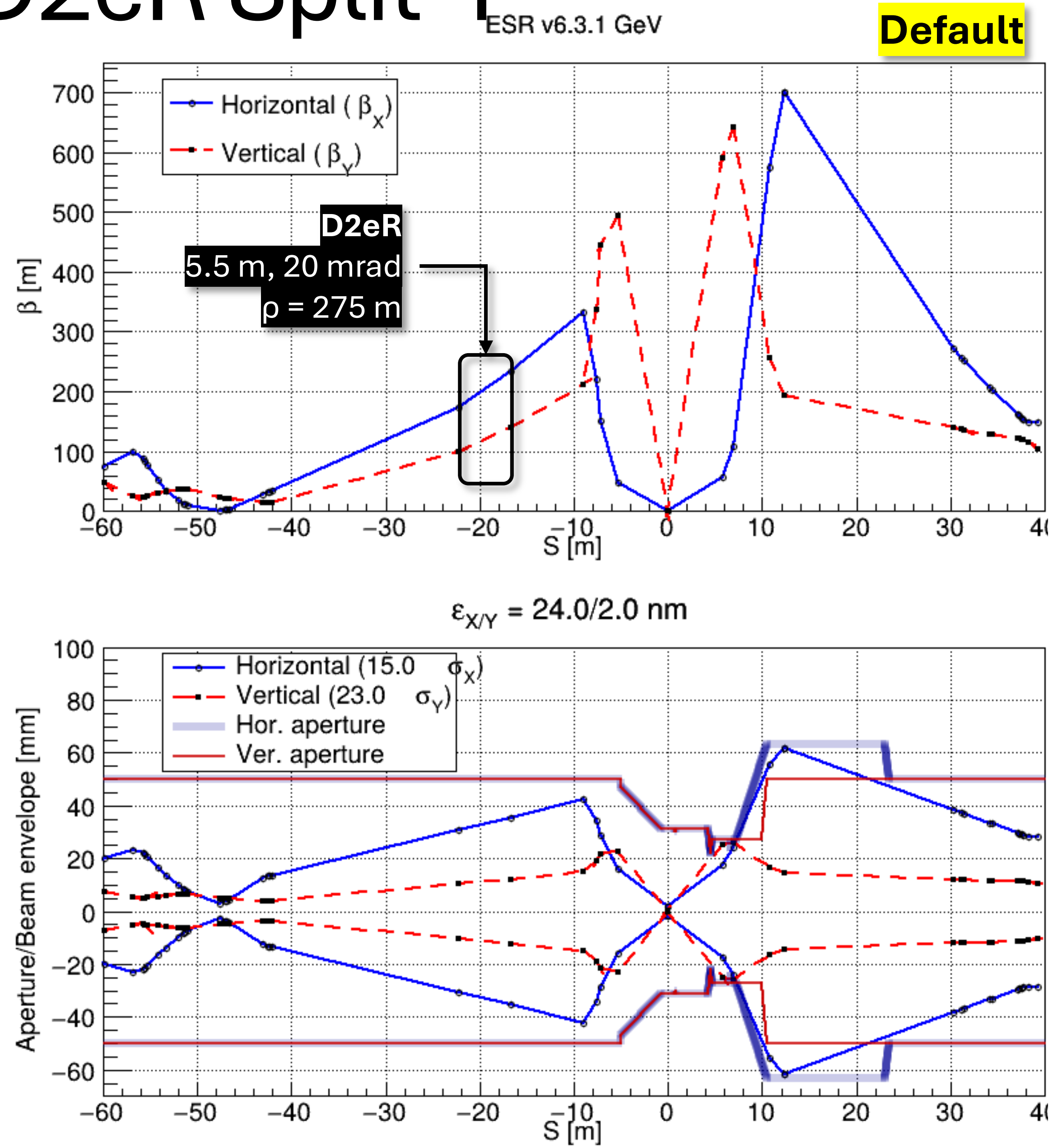
Diamond Infrared Windows: Specifications	
Thickness	300 – 1000 µm
Diameter	5 – 50 mm
Wedge	0-1°
Flatness	< 1 fringe/cm @633 nm
Bakeable	at up to 250°C
Vacuum tightness	He leak rate $<10^{-9}$ mbar l/sec

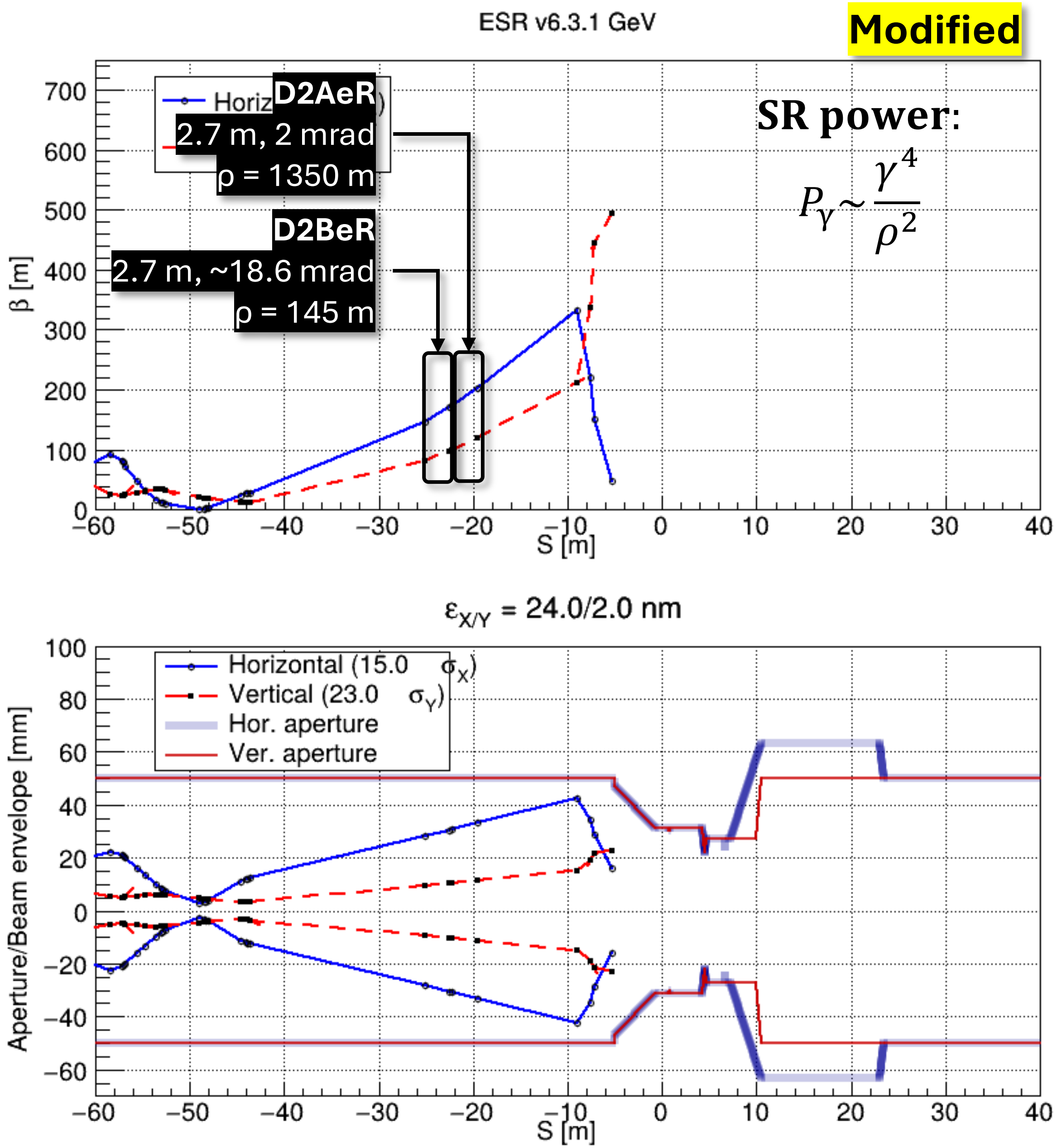
https://www.diamond-materials.com/site/assets/files/1096/cvd_diamond_synchrotron_windows.pdf

Luminosity (Bethe-Heitler) Photon Distribution



D2eR Split-1

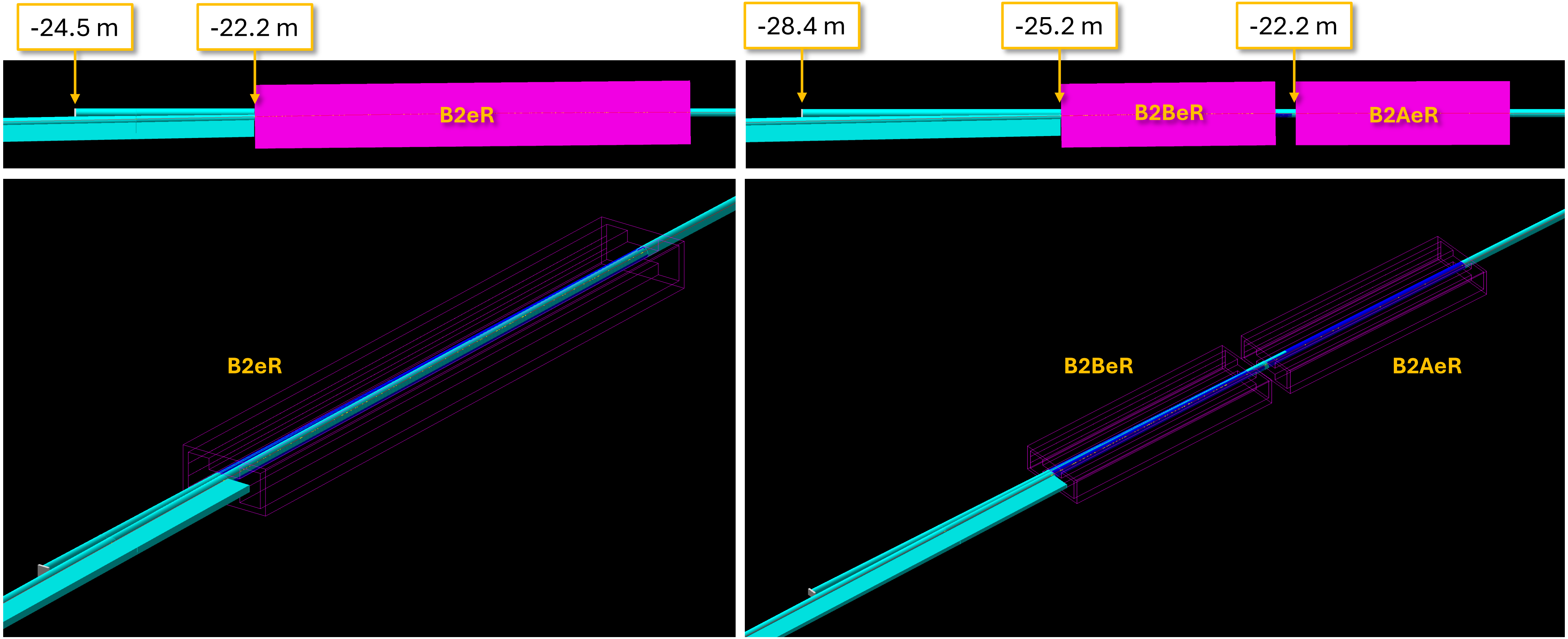




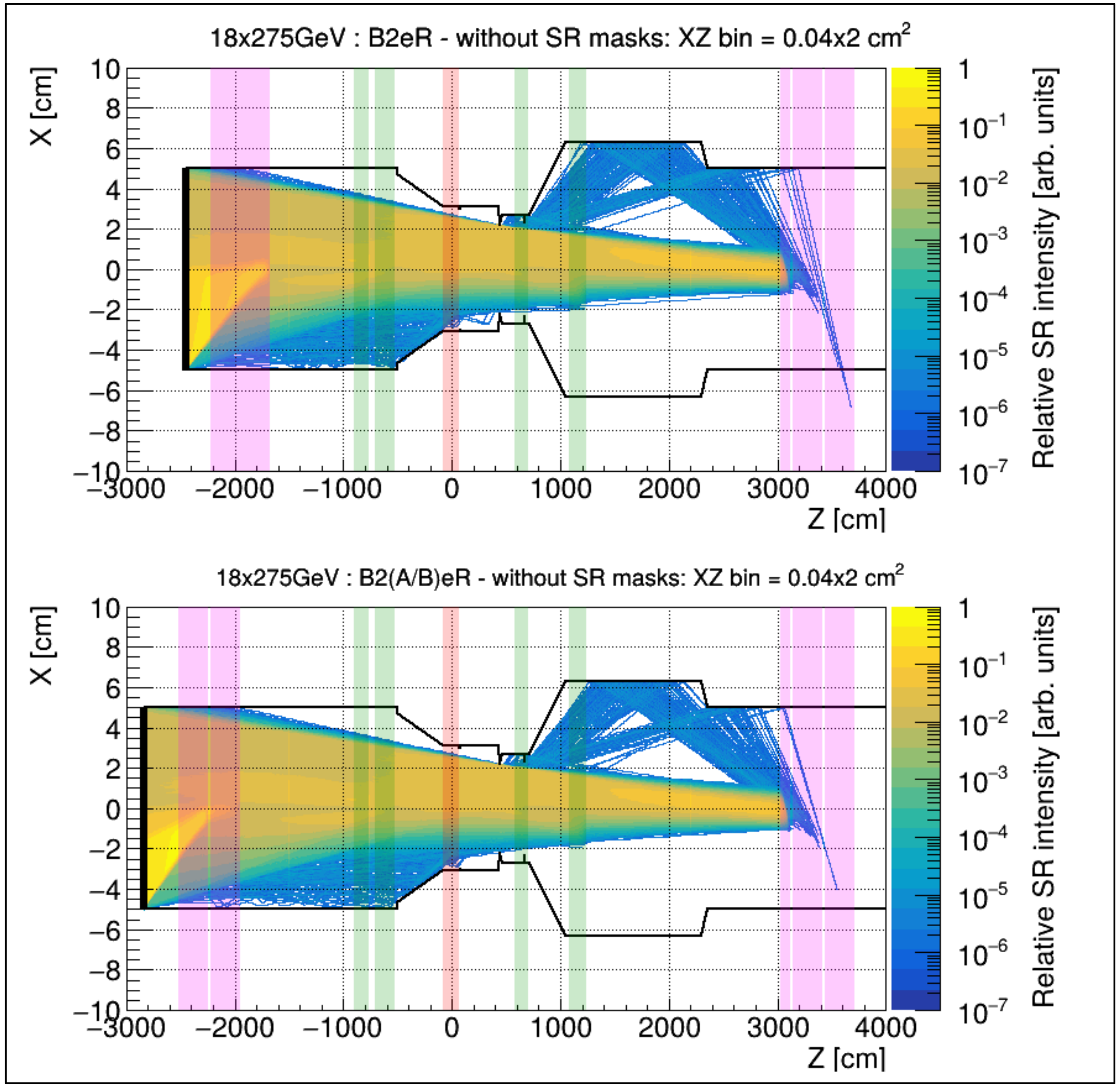
SR power:

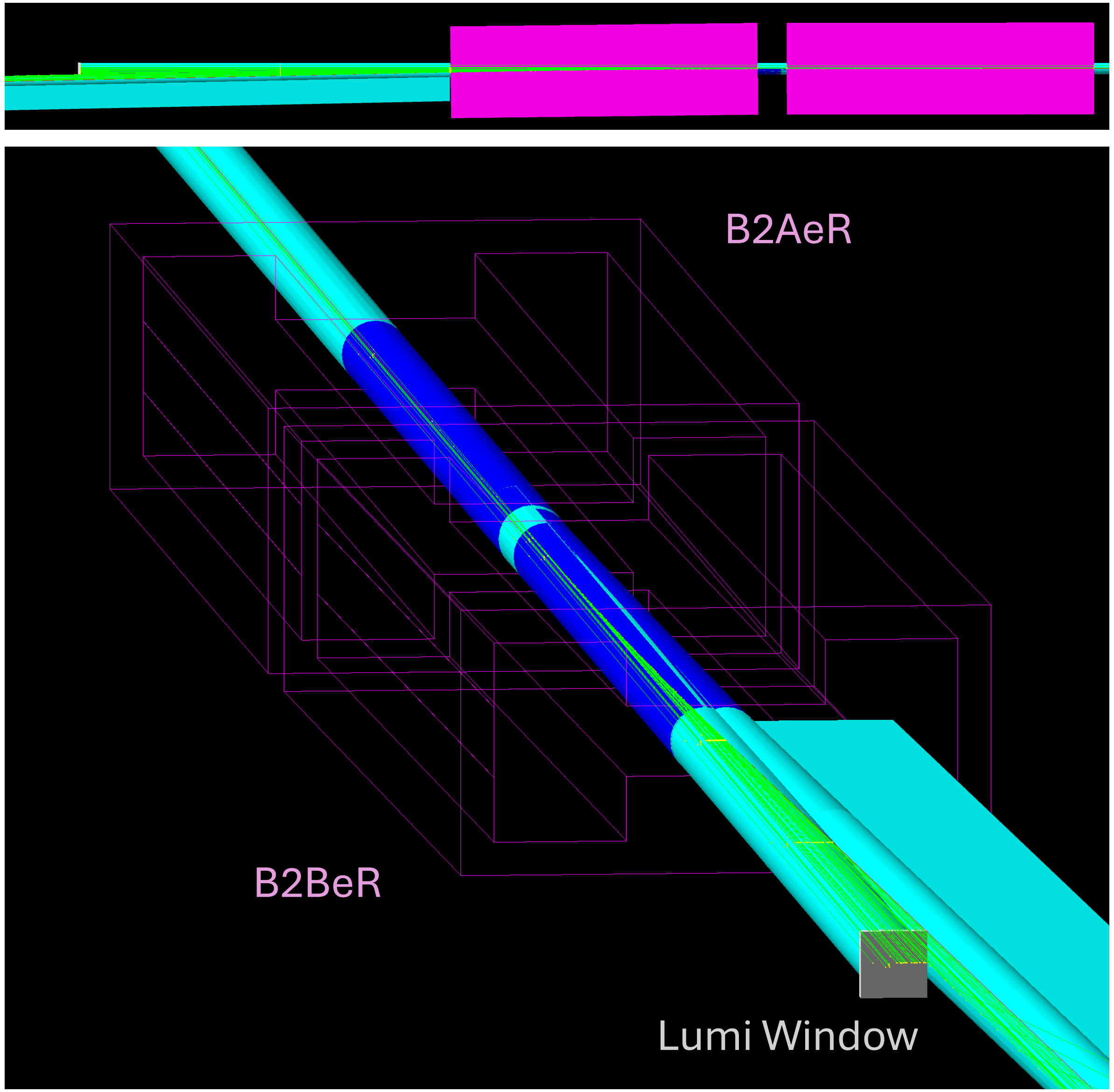
$$P_\gamma \sim \frac{\gamma^4}{\rho^2}$$

SynradG4 Implementation-1

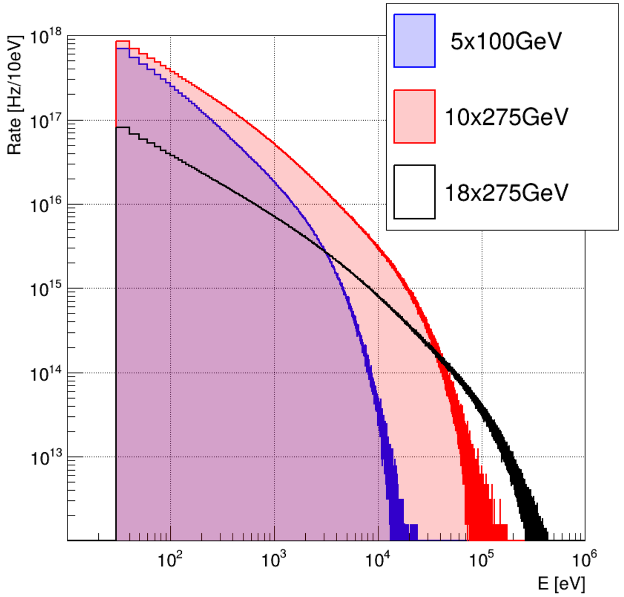


X-ray Tracks Hitting the Window (for E_γ > 10 keV)





SR Hitting the Lumi Window ($E_\gamma > 30$ eV)



SR power: $P_\gamma \sim \frac{\gamma^4}{\rho^2}$

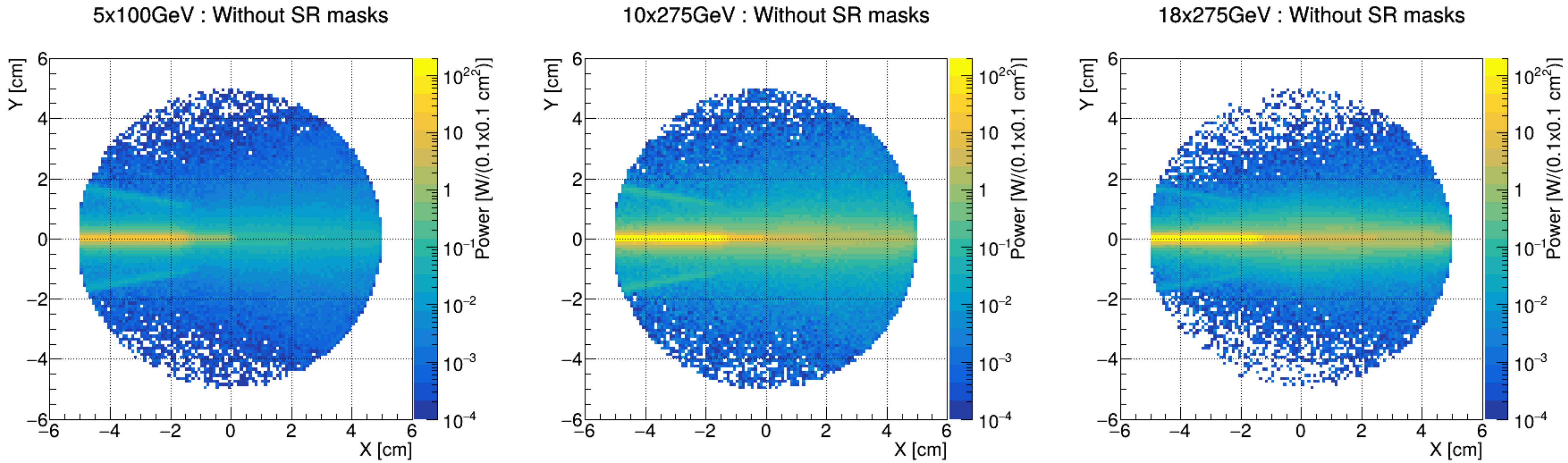
Critical photon energy: $\varepsilon_c \sim \frac{\gamma^3}{\rho}$

Still extremely high density

5 GeV @2.500A : P_{max} = 13.9 [W/mm^2]; P_{tot} = 1097.4 [W]

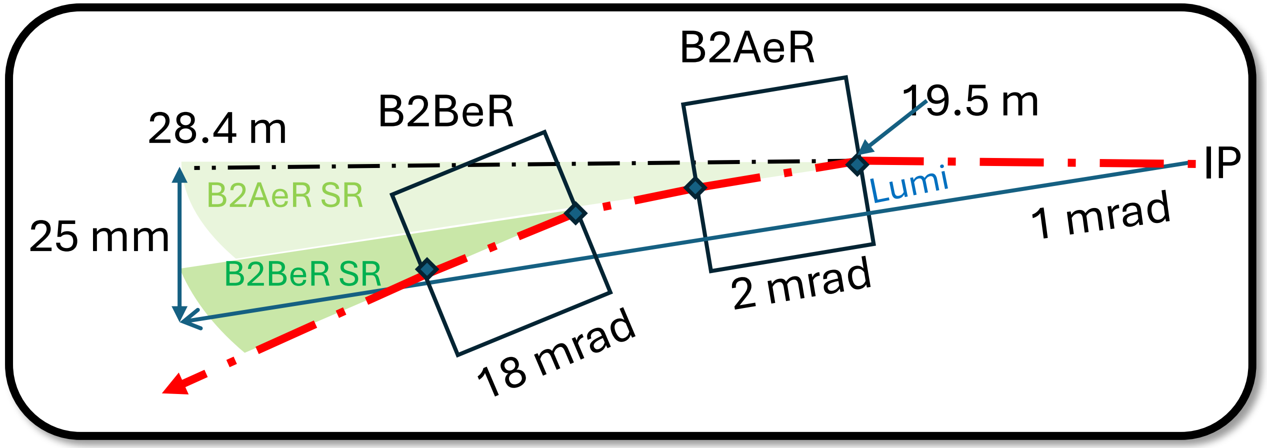
10 GeV @2.500A : P_{max} = 209.1 [W/mm^2]; P_{tot} = 15405.7 [W]

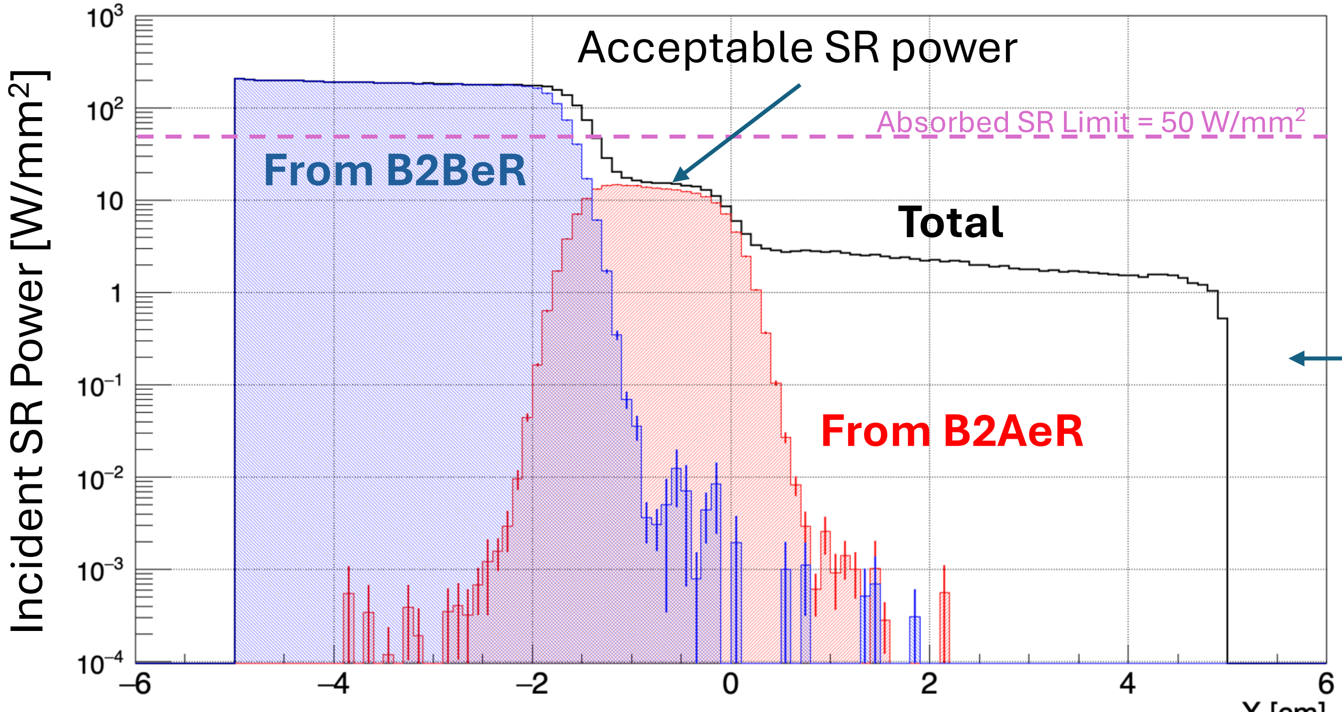
18 GeV @0.227A : P_{max} = 215.4 [W/mm^2]; P_{tot} = 15484.6 [W]



Possible Improvements

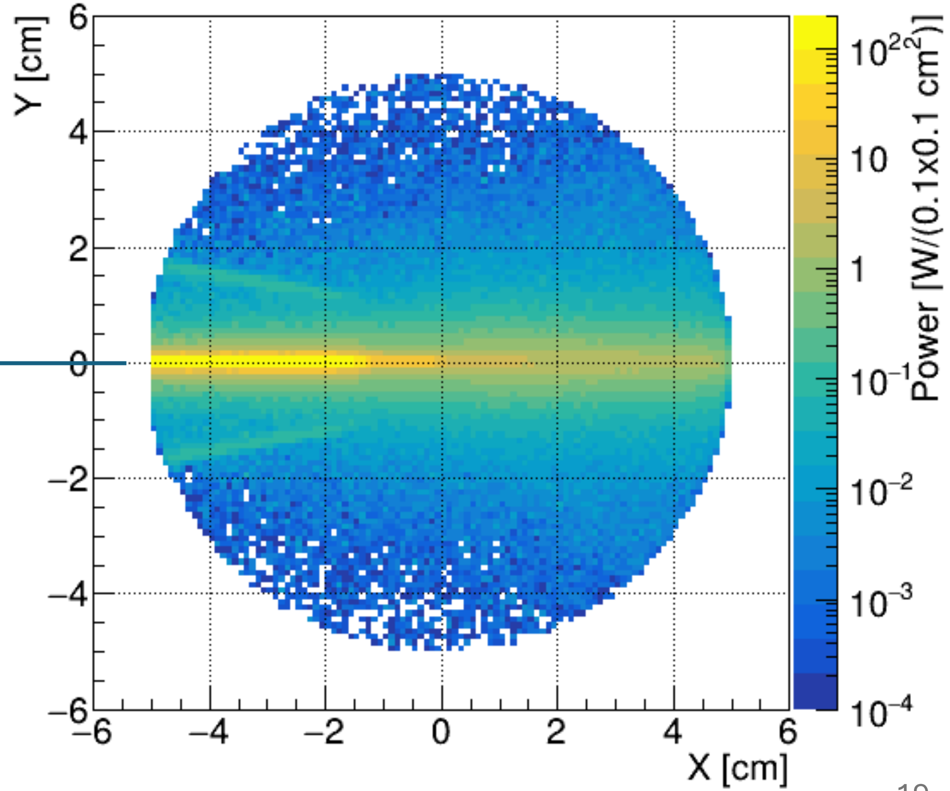
- Let's widen the B2AeR distribution by enlarging the bending angle 2 → 3 mrad
- This should move the B2BeR distribution further away from the luminosity window
- Additionally, placing B2AeR closer to the IP 19.5 → 16 m allows moving the window closer towards the IP reducing the lumi photon spot on the window down to ⌀50 mm





Horizontal distribution of SR hits at Y = 0 cm

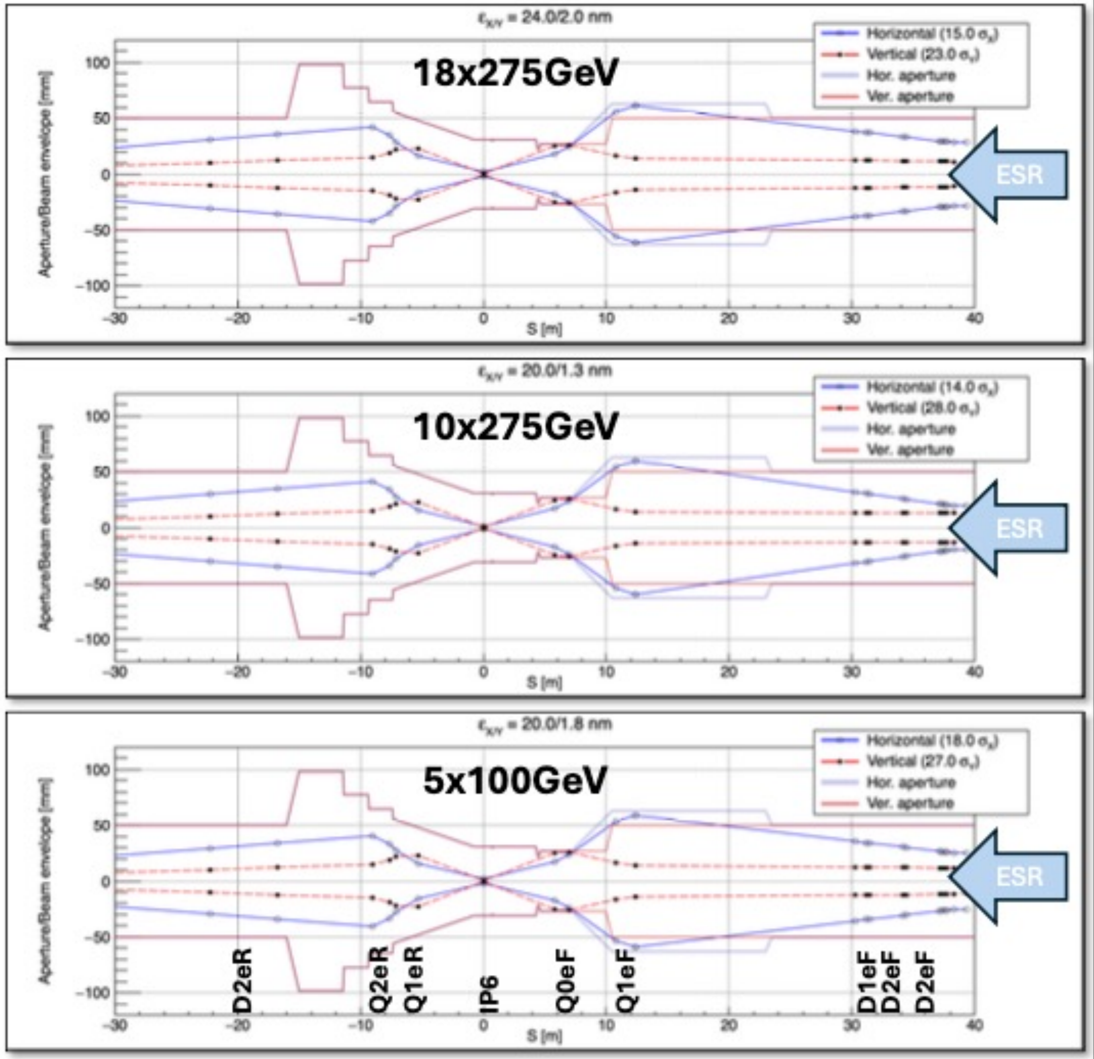
10x275GeV : Without SR masks



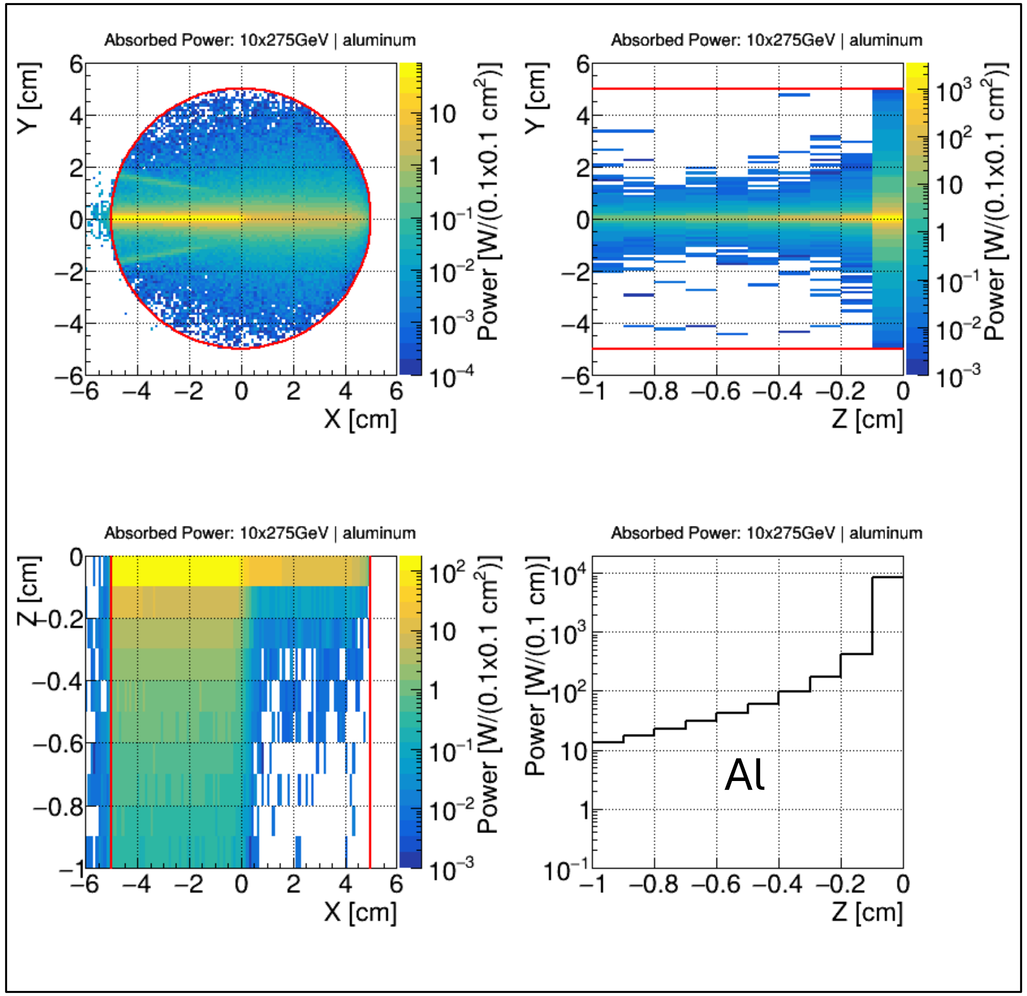
Backup

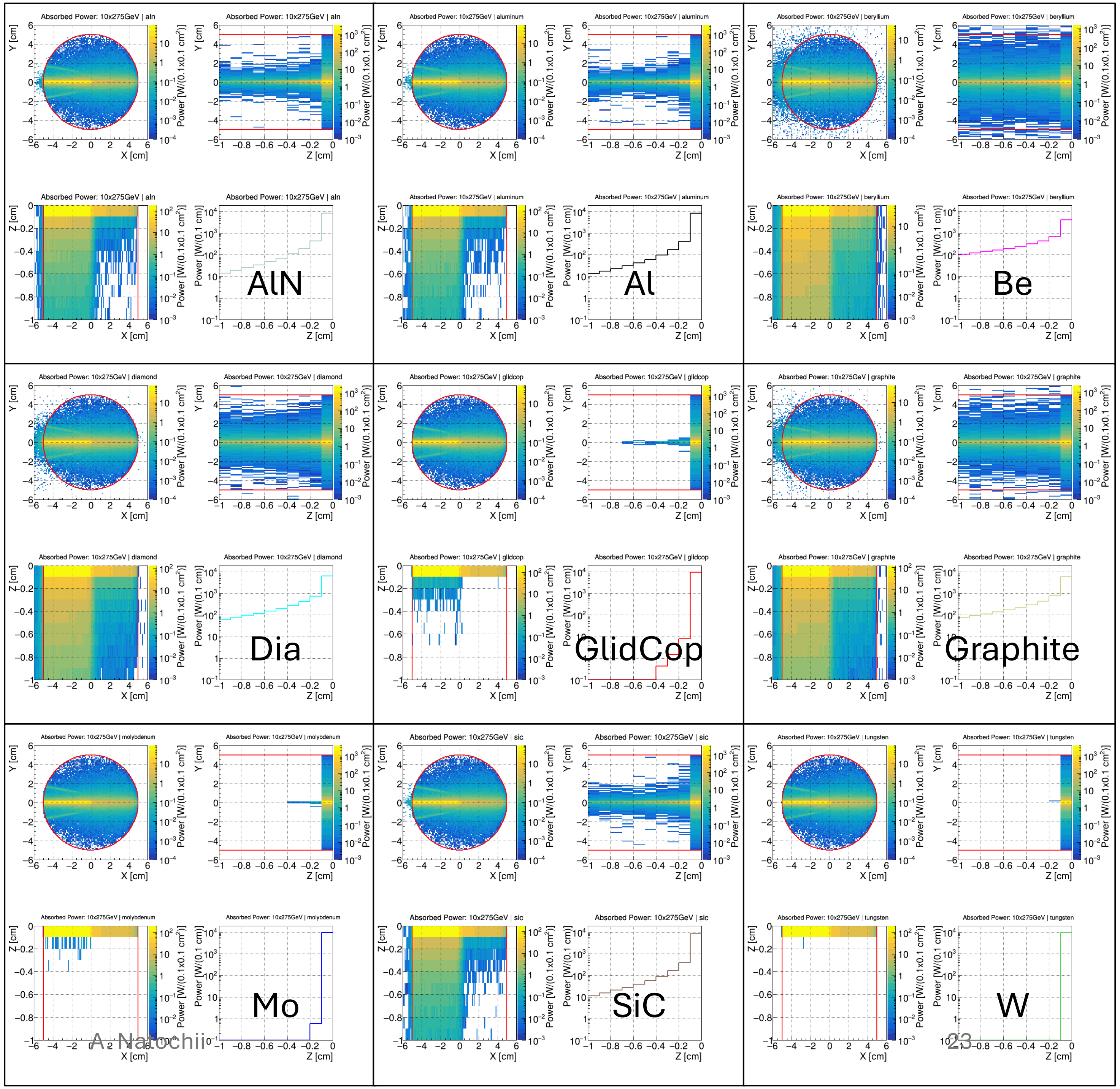
Aperture Change

- Initially, the beam pipe aperture was made relatively large (approximately ⌀20 cm) to allow SR to pass through.
- However, it is now feasible to reduce the aperture to ⌀10 cm (the same as the CRAB cavities), as the **magnet can handle higher SR loads**, like the arc dipoles.
    - This aperture allows the luminosity photons exit the primary vacuum through the Lumi Window within a ±2 mrad cone:
        - **For ~20 m (dipole end) → ±4 cm opening is needed.**
- Despite this adjustment, the BWD beam pipe aperture within the **rear cryostat remains significantly larger** than the maximum beam size, which is dictated by the narrowest aperture in the FWD region.



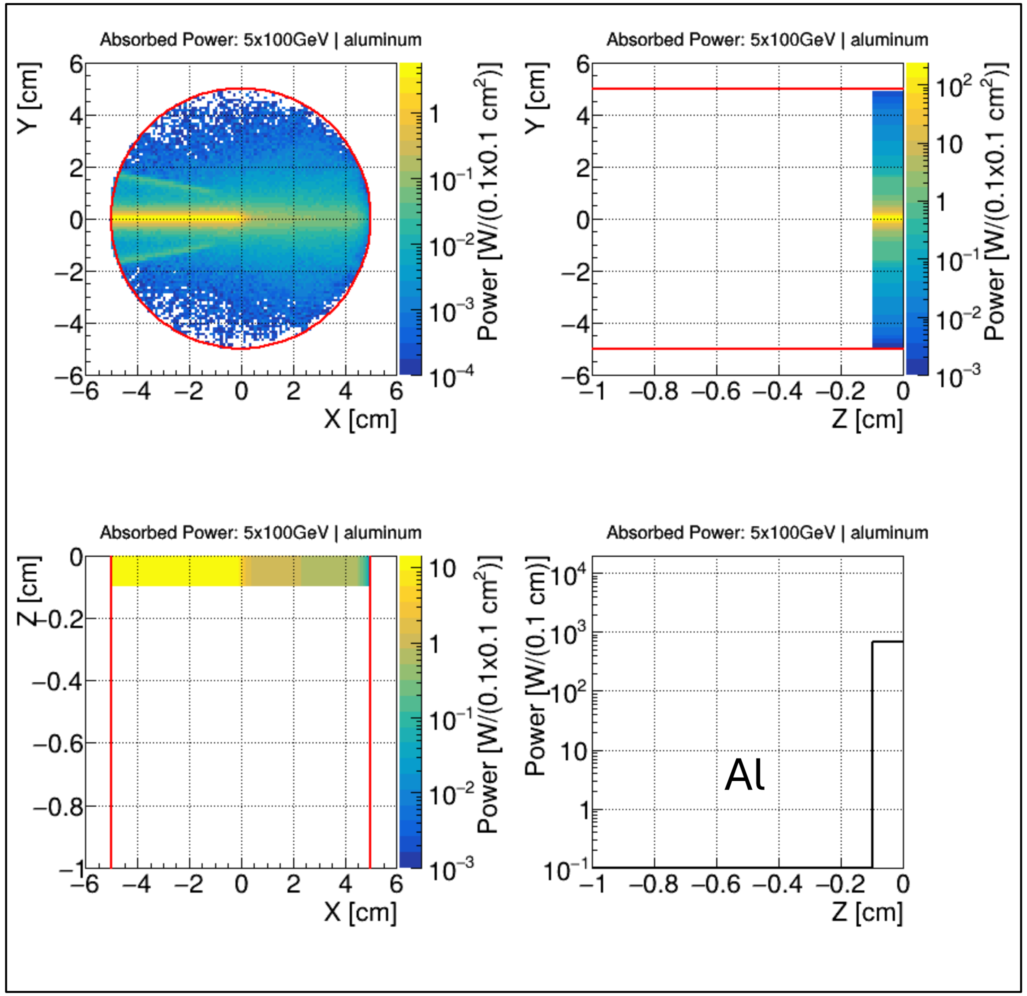
Absorbed SR Power



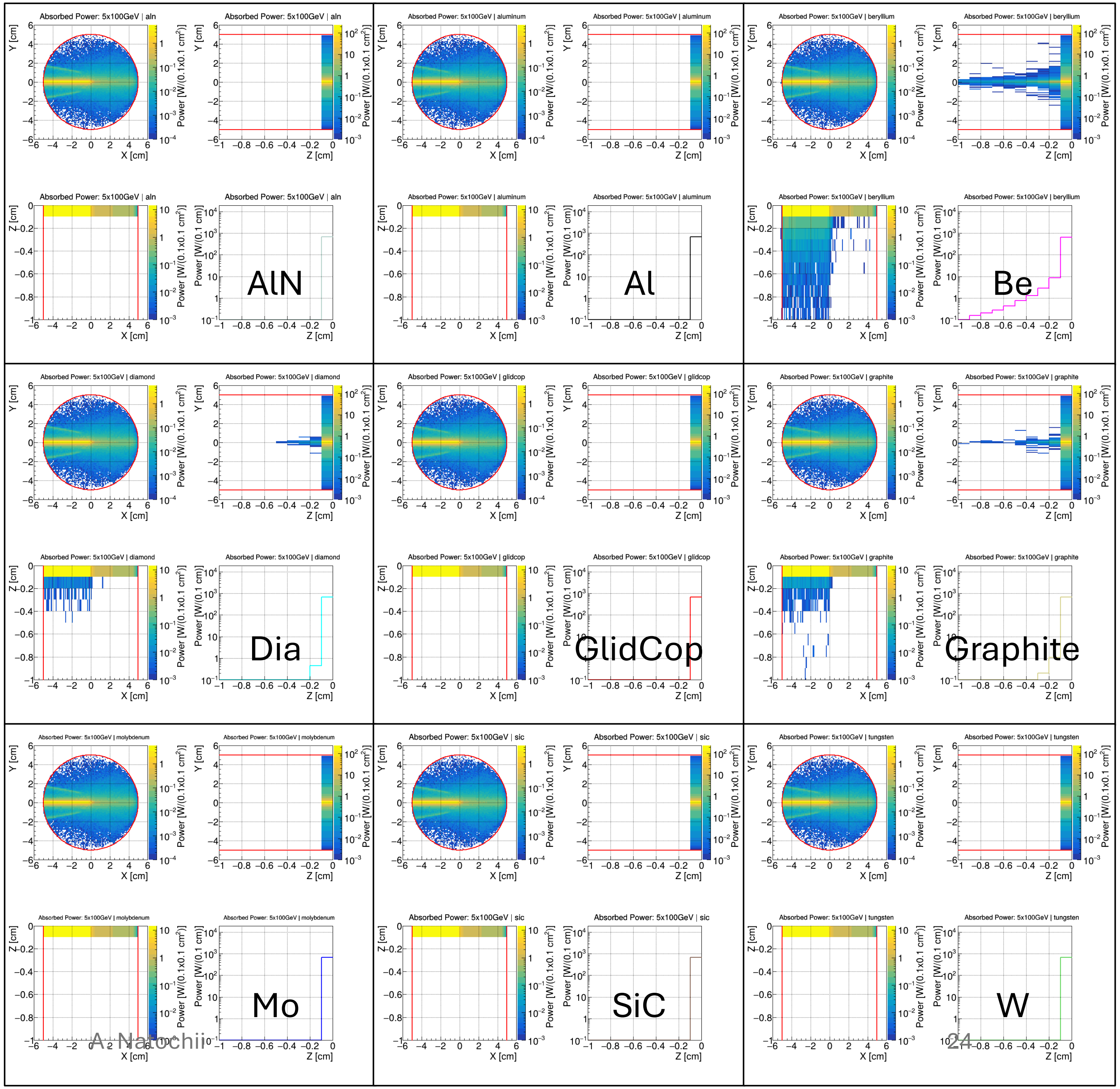


10x275 GeV @ 2.5 A

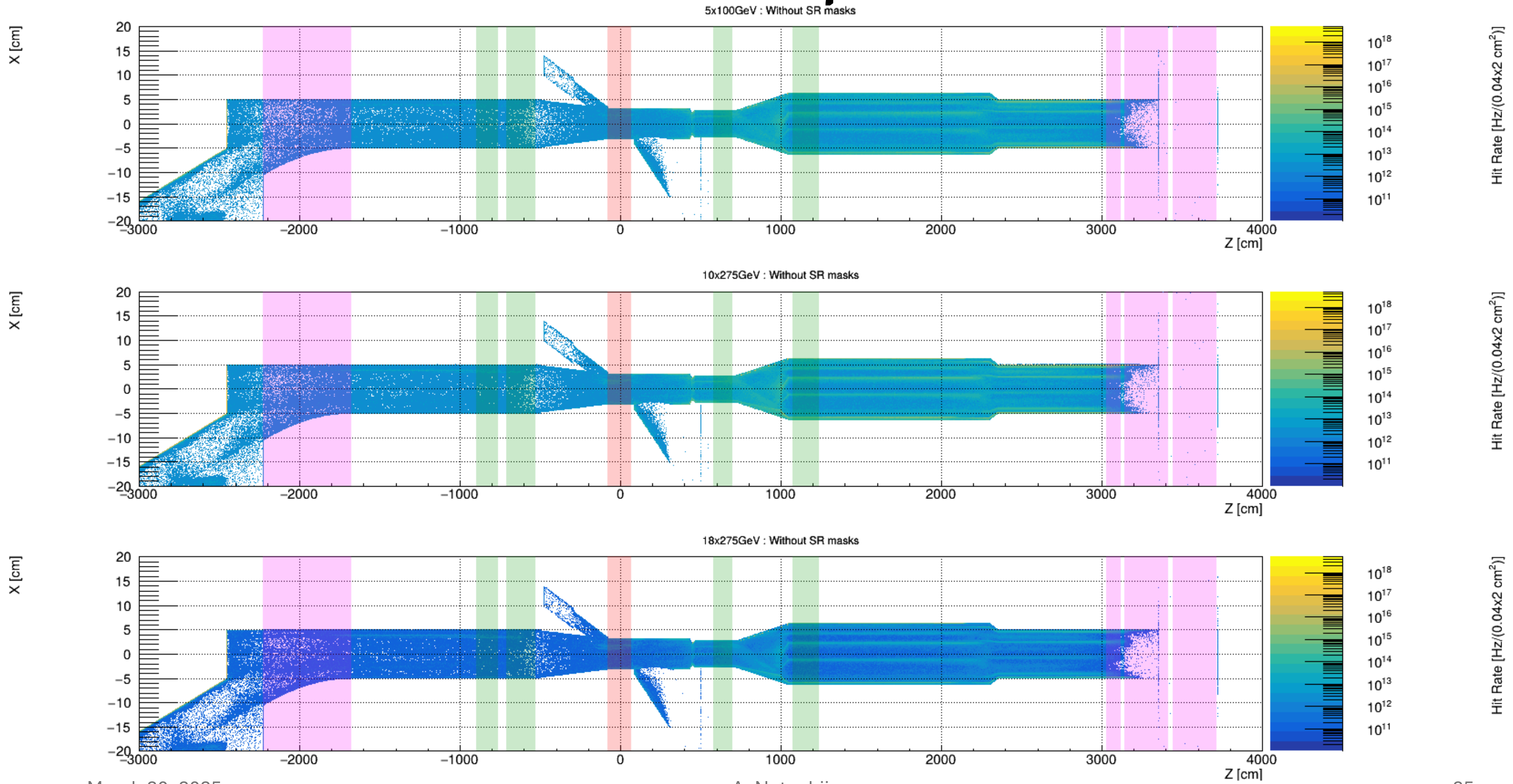
Absorbed SR Power



5x100 GeV @ 2.5 A



SR Hits on the Beam Pipe (E_γ > 30 eV)



SR Hits on the Beam Pipe ($E_\gamma > 30$ eV)-1