

# SR background simulation updates

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# Reminder

*from the previous meeting*

1. Beam pipe material matters
2. Overall, SR background rates are very high ~ THz
3. SR masks can significantly reduce the rates
4. The beam pipe geometry is not fixed and needs revision

## Summary (2)

- The latest simulation with the Jan-2024 (v6.2) lattice shows:
  - for the **aluminum beam pipe**, the majority of ePIC rates originate from the region **outside the IP** beam pipe;
  - for the **copper beam pipe**, the majority of ePIC rates originate **from the IP** beam pipe;
    - the copper beam pipe effectively stops SR photons in the energy region of interest (10-100 keV);
  - the overall rate of the **SR background in all sub-detectors is extremely high (THz)**;
  - by placing **a simple SR mask, we can reduce the background rates by at least two orders of magnitude**;
    - we **need a more sophisticated SR mask** to reduce the rate further;
  - adding **additional shielding** around the IR beam pipe could be **another option** to mitigate the SR background;
  - **auxiliary detectors** will be exposed to the **ultrahigh rate of SR (PHz)**;
    - however, the **geometry of the far-backward beam pipe needs revision.**

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## Next steps

- We can continue using the manual approach of the beam pipe geometry description in Geant4 and eic-shell.
  - However, we should consider the advantages of transitioning to a unified 3D CAD drawing used in both frameworks.
- We have to implement a new SR mask and check its impact on the detector background and machine impedance.
- Also, it is essential to revisit the entire IR beam pipe used in Geant4 and eic-shell.
  - To ensure the accuracy of the beam pipe geometry description.
  - Close collaboration with the ePIC software group is desirable.
- For more details and materials regarding the custom-built Geant4 simulation code, please refer to backup slides and past EIC IR Synrad meetings [[SupplementaryMaterials](#)].

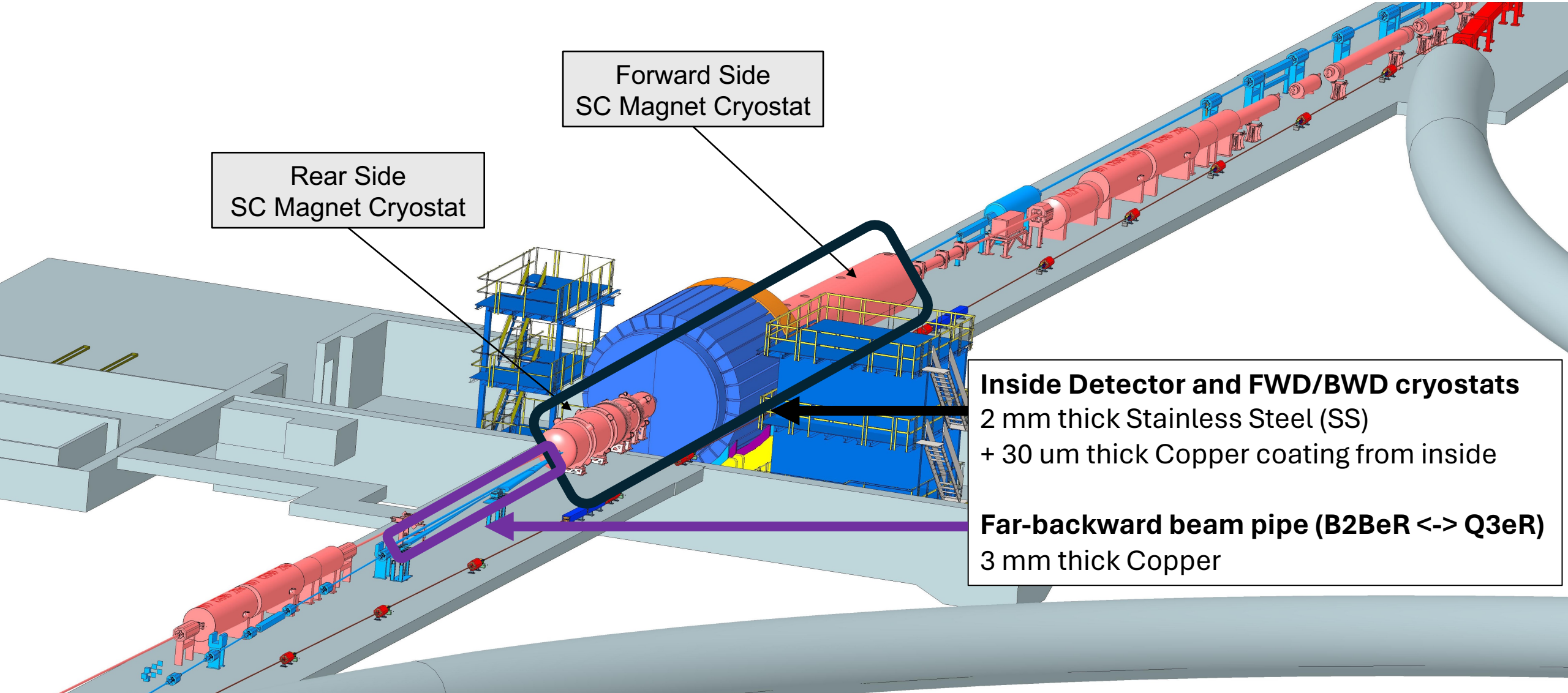
**Thanks for your attention!**

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# Beam pipe material modification



Rear Side  
SC Magnet Cryostat

Forward Side  
SC Magnet Cryostat

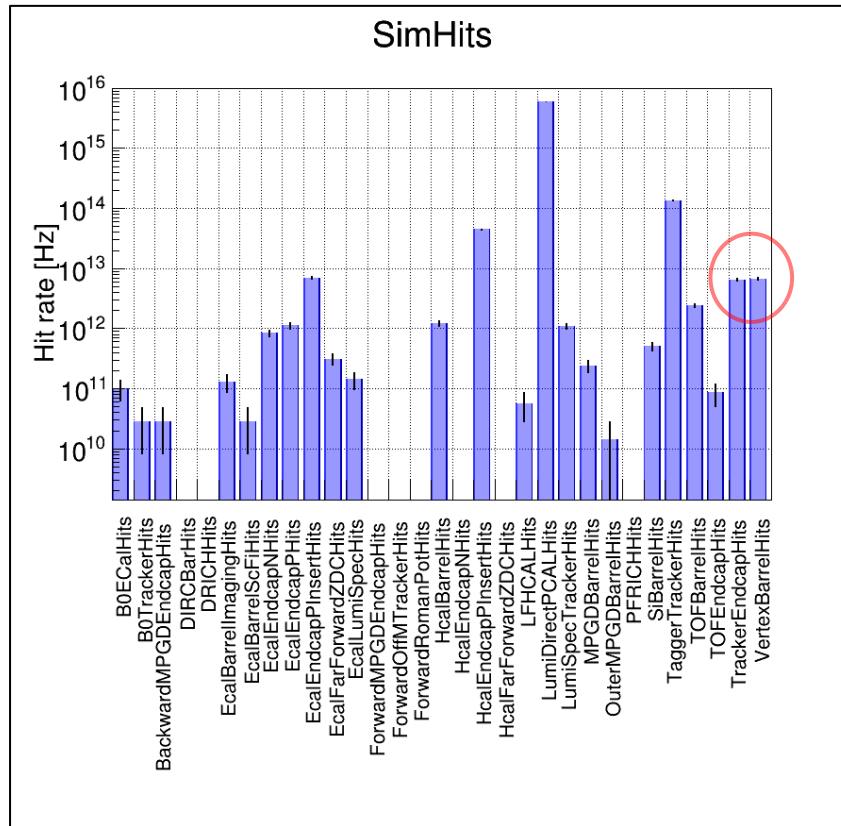
**Inside Detector and FWD/BWD cryostats**  
2 mm thick Stainless Steel (SS)  
+ 30 um thick Copper coating from inside

**Far-backward beam pipe (B2BeR  $\leftrightarrow$  Q3eR)**  
3 mm thick Copper

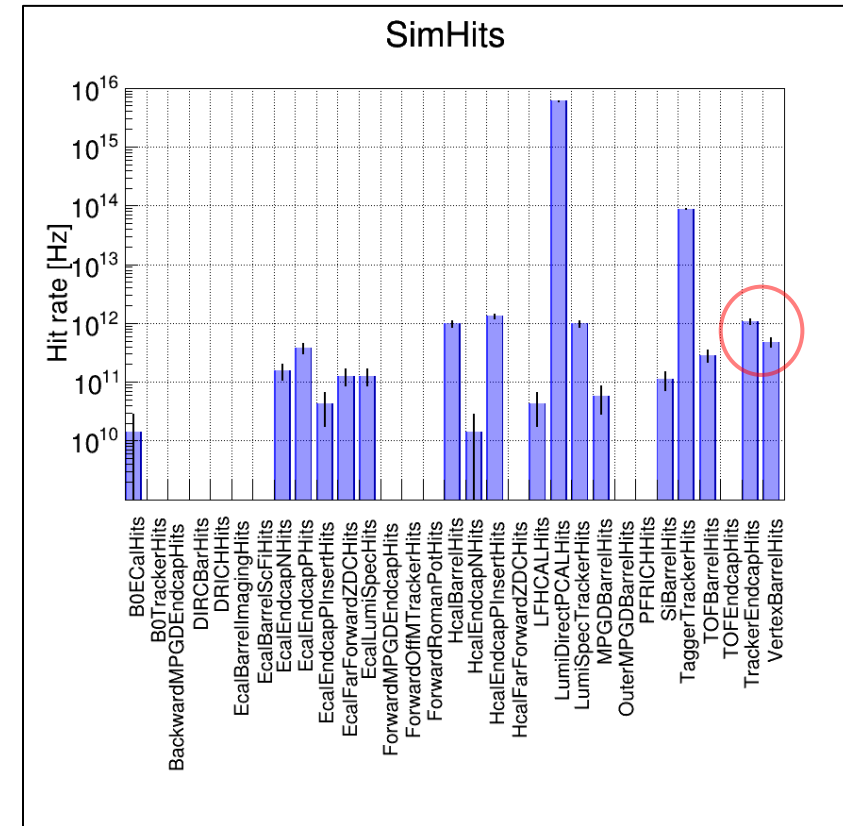
# Beam pipe material impact

By changing the beam pipe material, we reduce SR background rates by an order of magnitude.

**No SR masks  
Al beam pipe**



**No SR masks  
SS+Cu beam pipe**



$I = 0.227 \text{ A}$   
 $-37\text{m} < z < 5\text{m}$   
 $E_\gamma > 1 \text{ keV}$

Lattice file v6.2 | 18 GeV | 2 IPs |  $I = 0.227 \text{ A}$



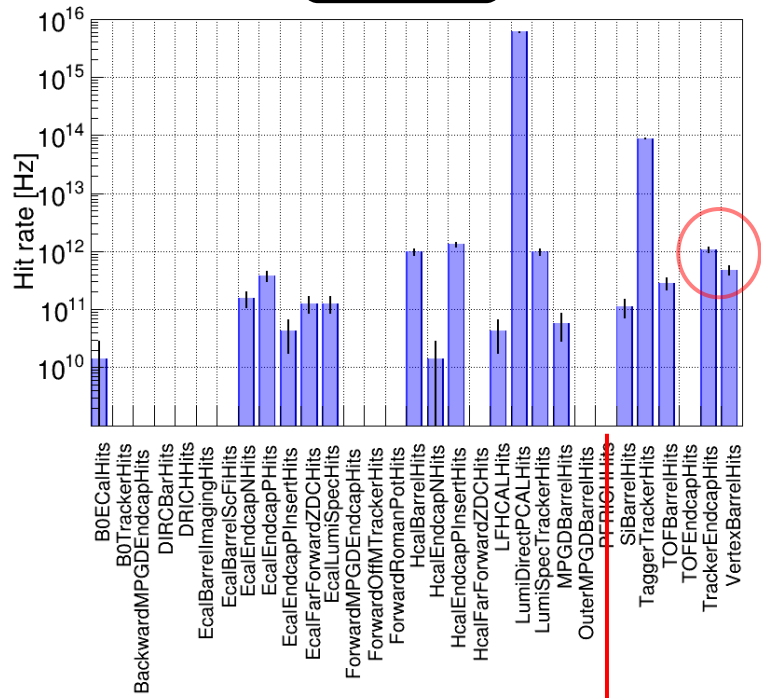
# Background observables

This is presumably what we will see in the experiment

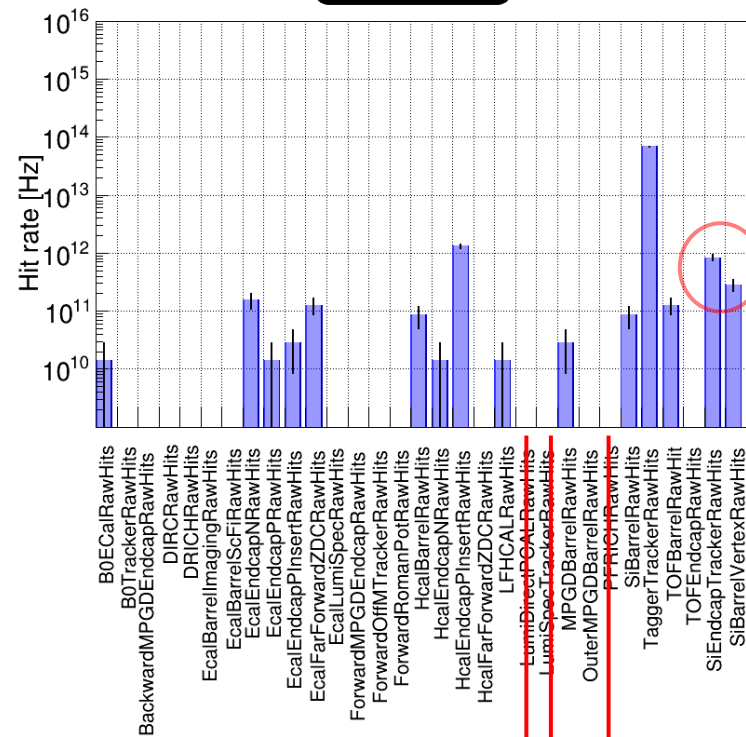
There are three classes of MC variables

- **SimHits** – the Geant4-like hits in each sub-module (sensitive volume)
- **RawHits** – pre-analyzed SimHits with applied sensor calibration thresholds
- **RecHits** – pre-analyzed RawHits with applied channel calibration threshold

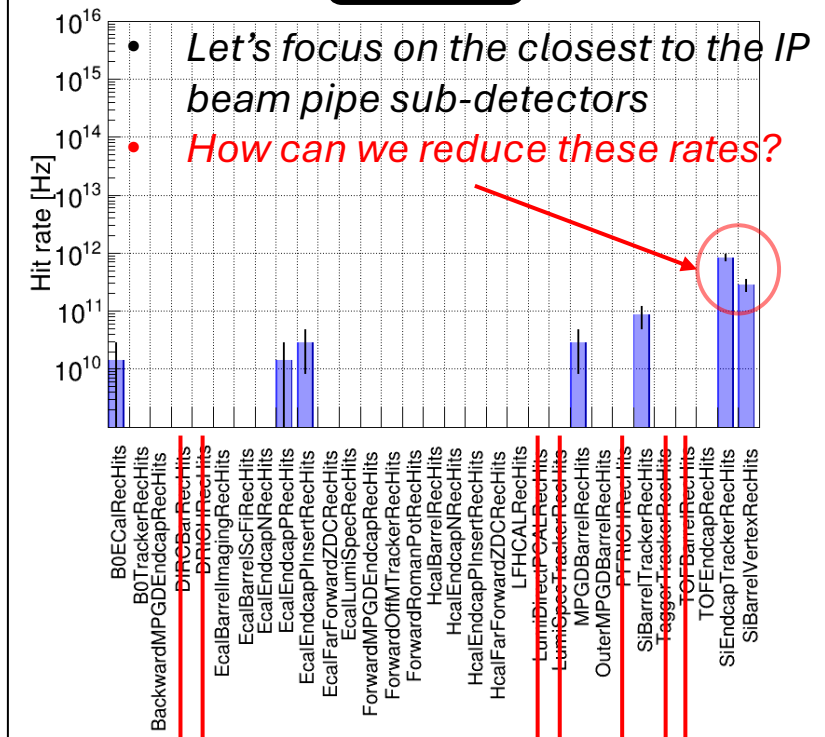
SimHits



RawHits



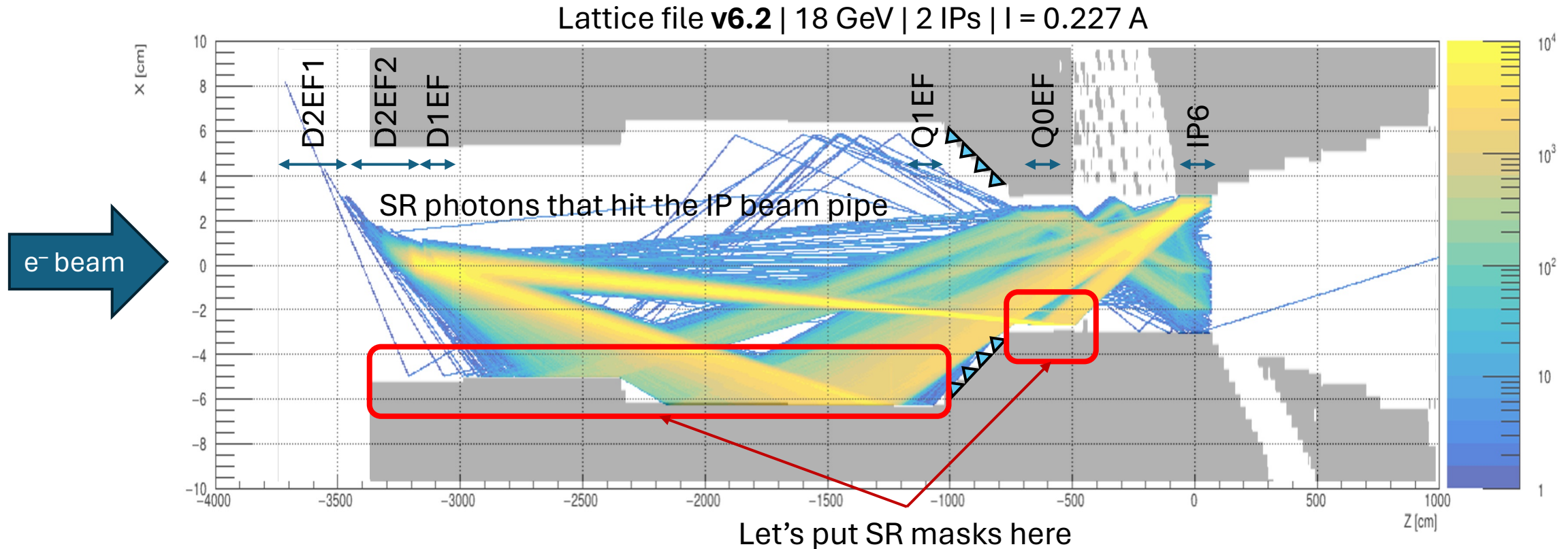
RecHits



# SR background mitigation

To reduce SR background rates in the ePIC detector, we implement the following:

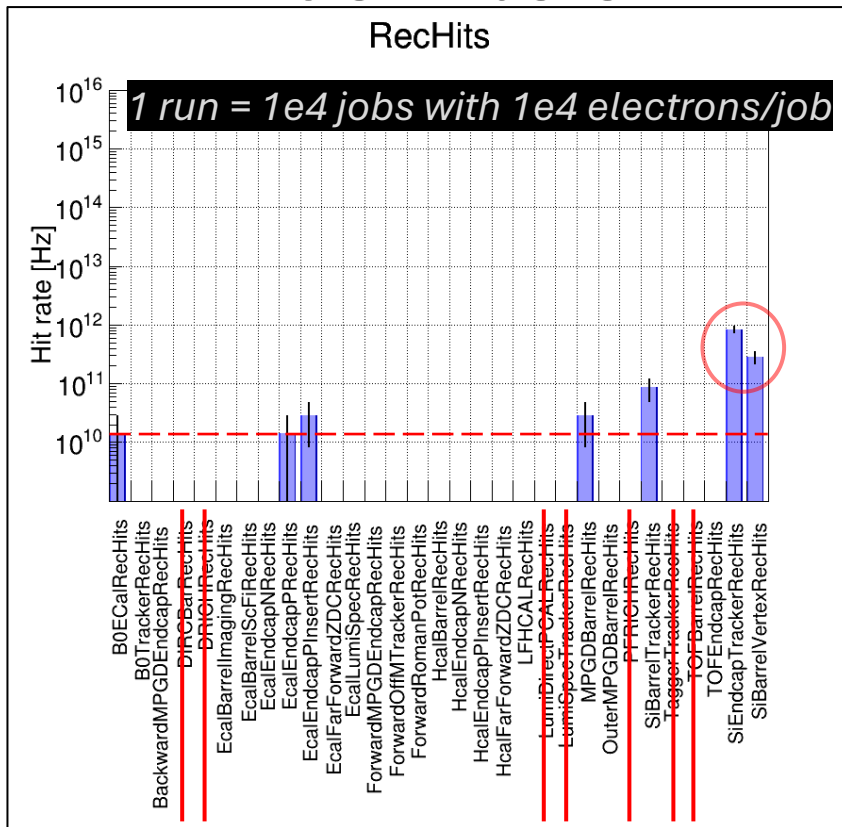
- add additional SR masks along the upstream e-beam pipe;
- add an additional SR mask inside the Q0 magnet, avoiding beam envelope restrictions (see backup slides);
- modify the central beam pipe in both Geant4 and eic-shell avoiding discrepancies and SR leakage, where beam pipes connect (see backup slides).



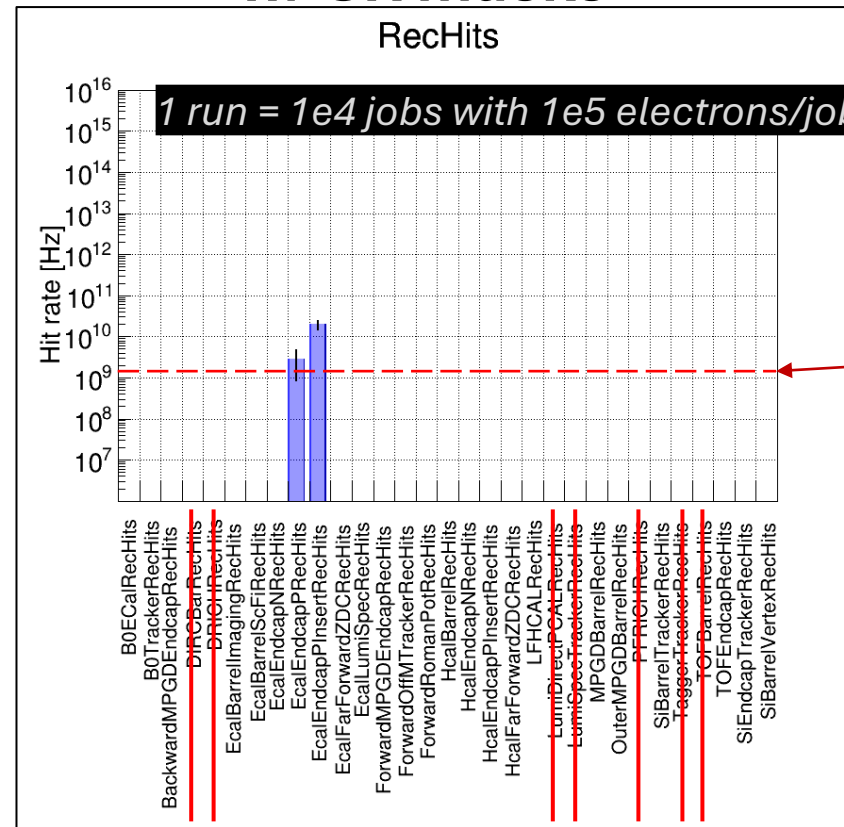
# Reduced SR background and Simulation limits

- The implementation of the new countermeasures has led to a remarkable reduction in the SR background, which scaled down the rates by approximately two orders of magnitude.
- Unfortunately, the given simulation statistics do not allow us to look below **1.4 GHz** =  $0.227\text{A} / (1\text{e}4 \times 1\text{e}5 \times 1.6\text{e-}19\text{C})$ .
- **For the comprehensive SR simulation, we need the final beam pipe design.**
- **To study the SR rate at the MHz level, we have to increase the number of simulated electrons by 3-4 orders.**

w/o SR masks



w/ SR masks



Simulation statistics limit, which corresponds to one hit/run in the detector

$I = 0.227\text{ A}$   
 $-37\text{m} < z < 5\text{m}$   
 $E_\gamma > 1\text{ keV}$

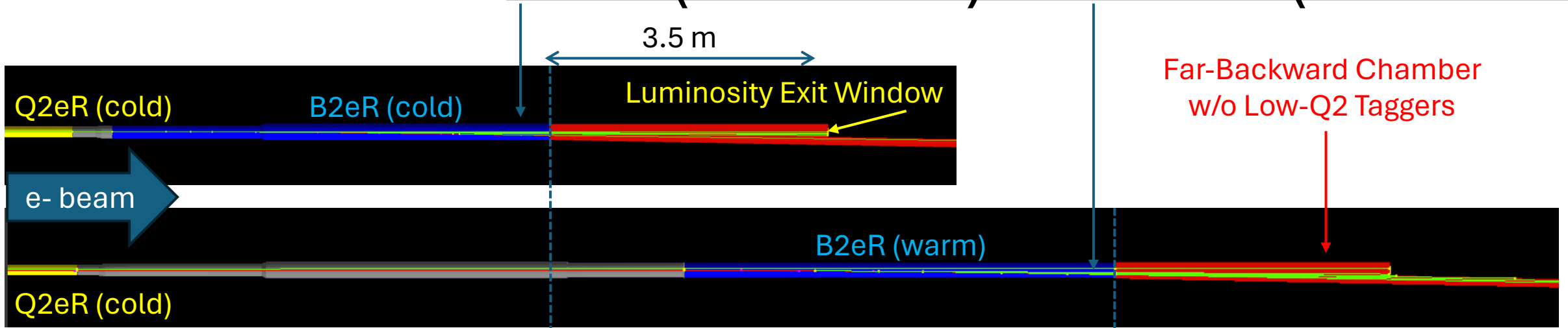
# Possible solutions

- 1. Geant4:** National Energy Research Scientific Computing Center (NERSC) is the largest computer cluster in the US.
  - Total cores: 311,296 (CPU/2.4 GHz)
  - $1e5$  electrons/job = 3 hours
    - $0.227 \text{ A} / (3e5 \text{ jobs} \times 1e5 \text{ electrons} \times 1.6/e-19) = \mathbf{50 \text{ MHz}}$
- 2. Analytically:** Creating SR photons and tracking them in 3D using analytical functions → could potentially speed up the simulation.
- 3. Semi-analytically:** Creating SR photons using analytical functions and tracking them using Geant4 → could speed up the simulation by a factor of 2-3.

ESR lattice impact on the SR  
load in the far-backward region

# Geant4 modeling for SR photon propagation in the vacuum beam pipe

## Lattice file v6.2: Cold (Jan 2024) vs Warm (Mar 2024)

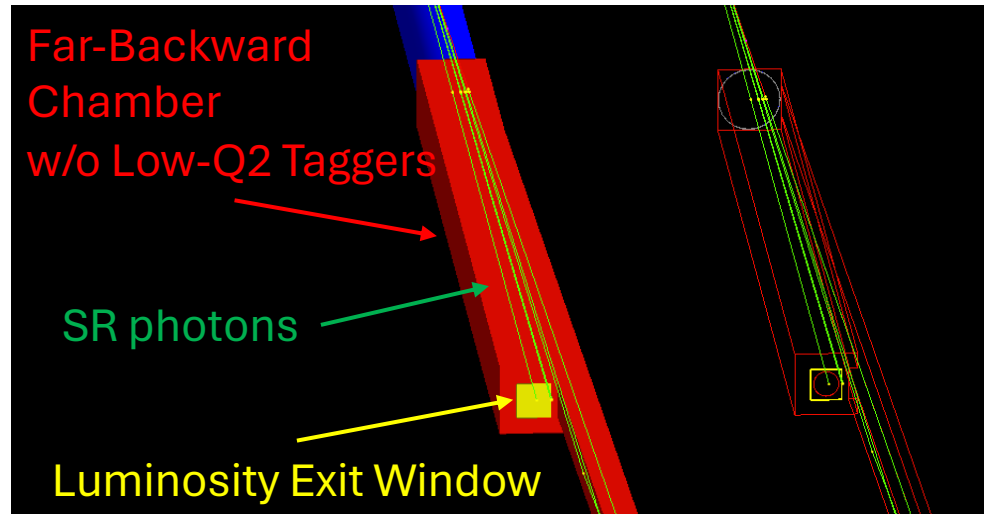


~15 m from the IP6

	Cold	vs	Warm
B2eR: $\theta$	18 mrad		20 mrad
Q2eR: K1L	-0.308 m <sup>-1</sup>		-0.316 m <sup>-1</sup>
Q1eR: K1L	+0.414 m <sup>-1</sup>		+0.410 m <sup>-1</sup>

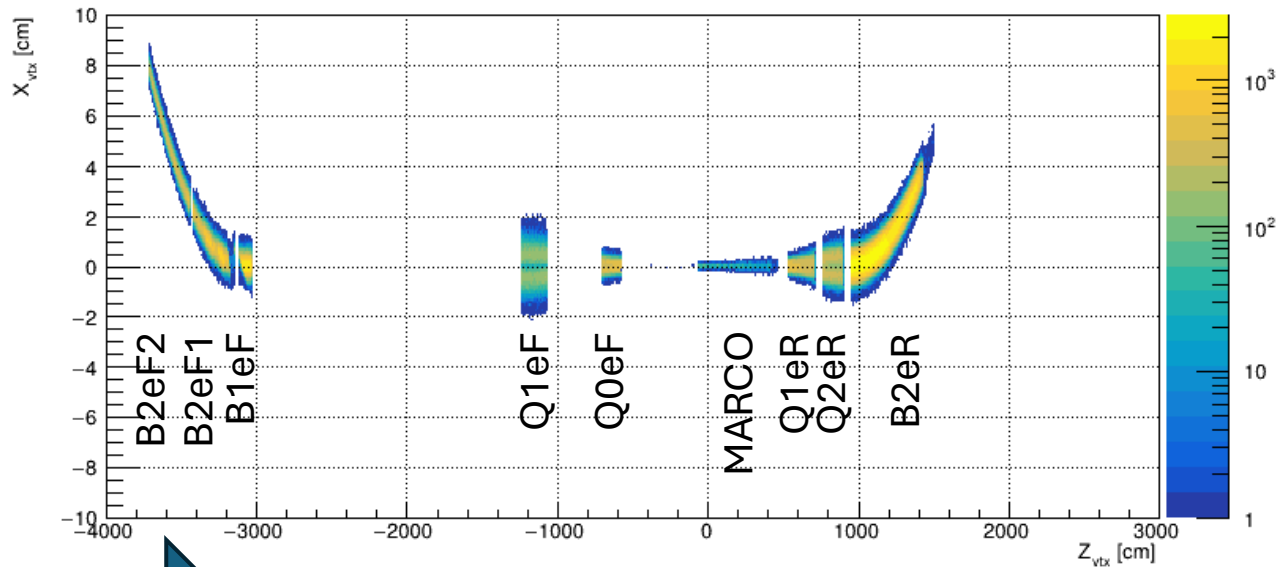
- B2eR:  $\theta$
- Q2eR: K1L
- Q1eR: K1L

~22 m from the IP6

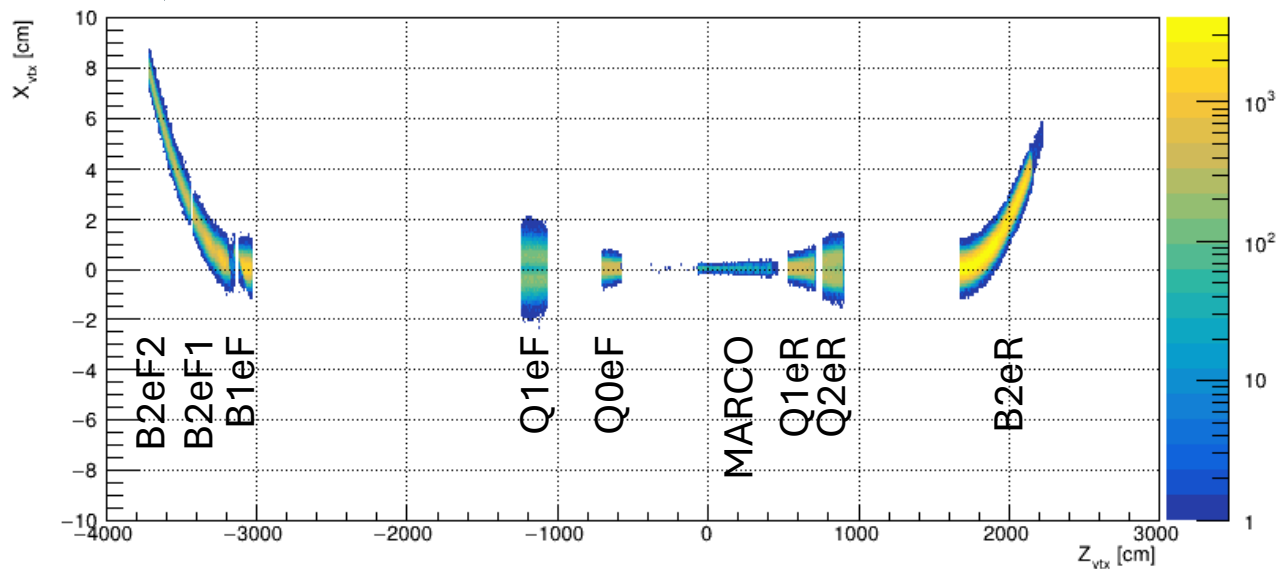




SR production vertex position: Cold

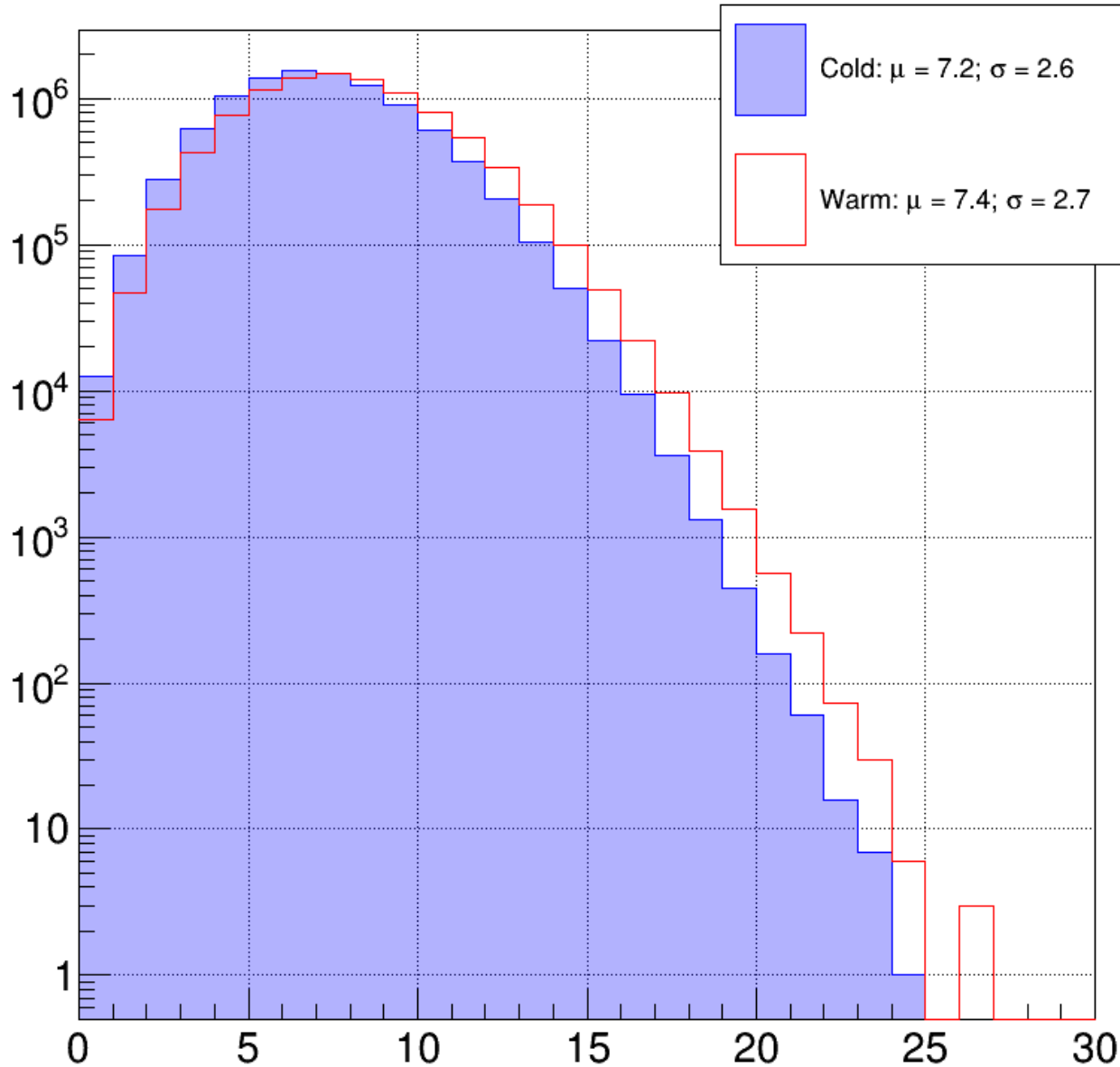


SR production vertex position: Warm



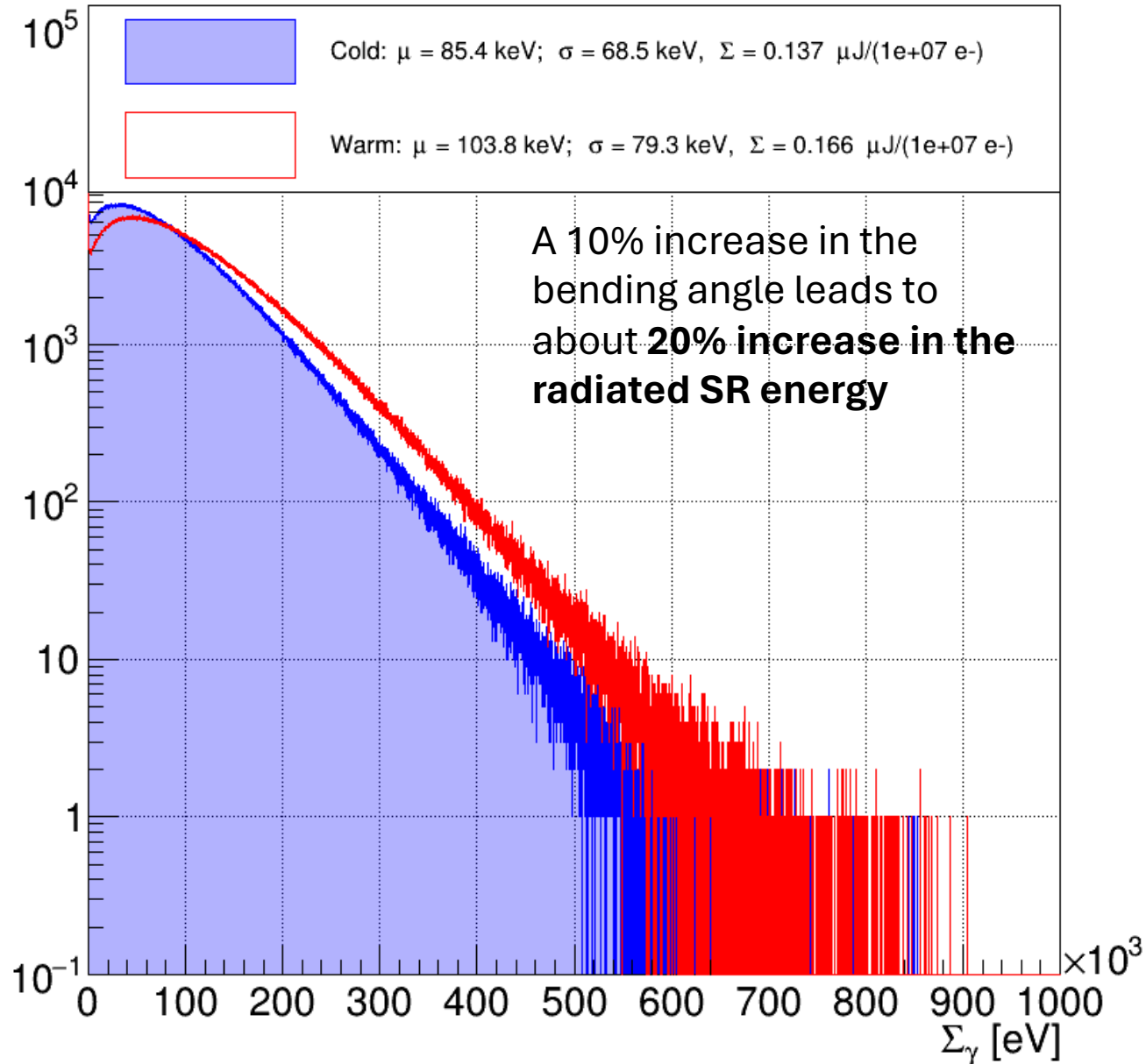
Production vertices of SR photons that were absorbed by the vacuum beam pipe

Number of generated SR photons per event in mag\_D2ER



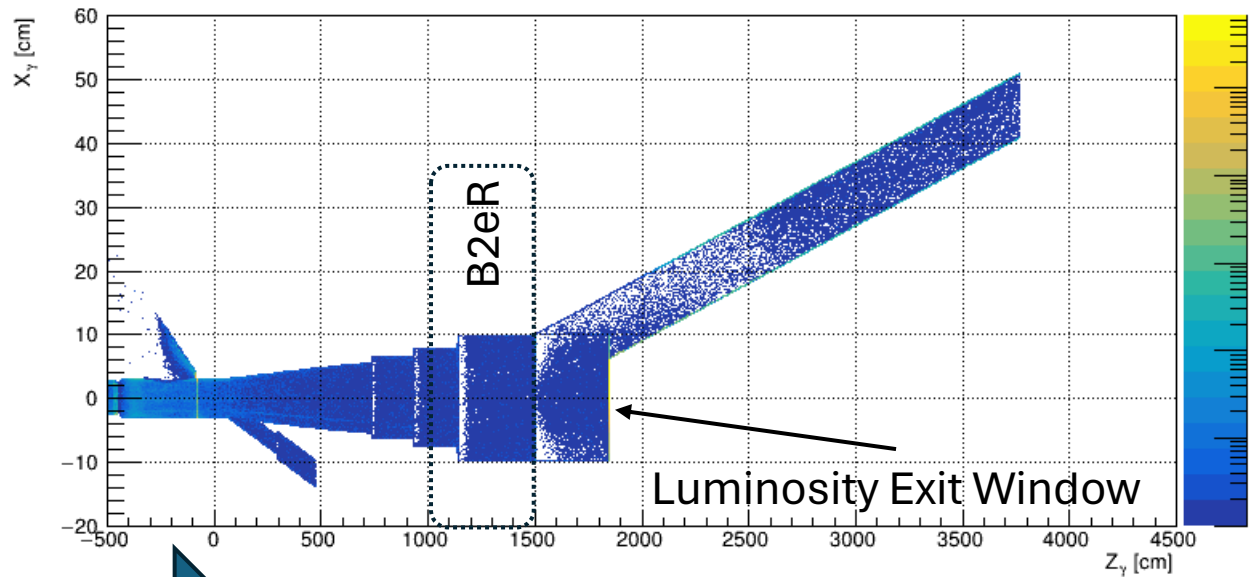
Number of SR photons generated by B2eR per electron

# Energy sum of generated SR photons per event in mag\_D2ER



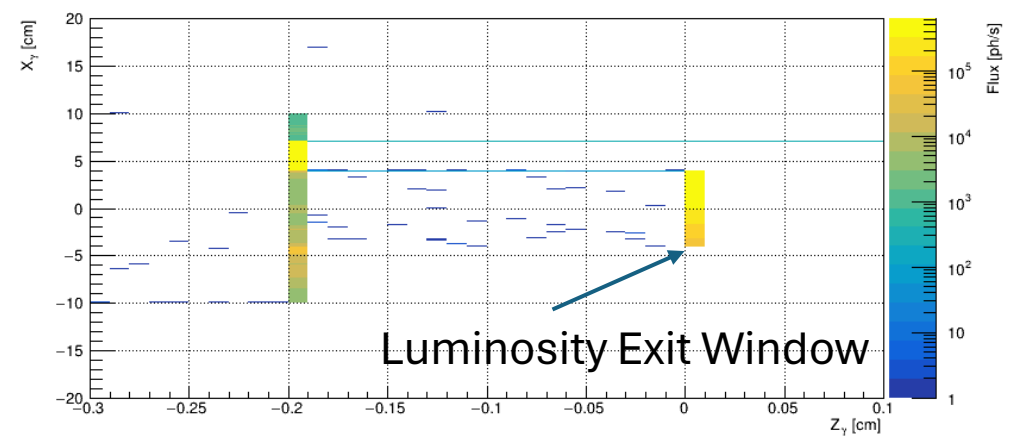
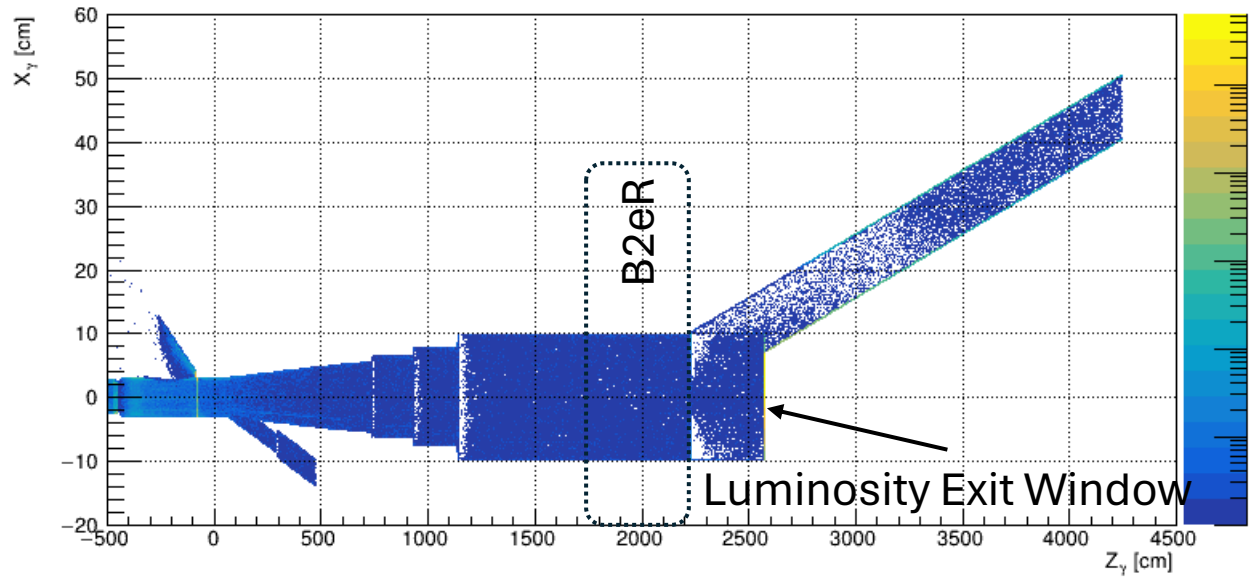
# Total energy of all generated SR photons in B2eR per electron

SR photon position: Cold

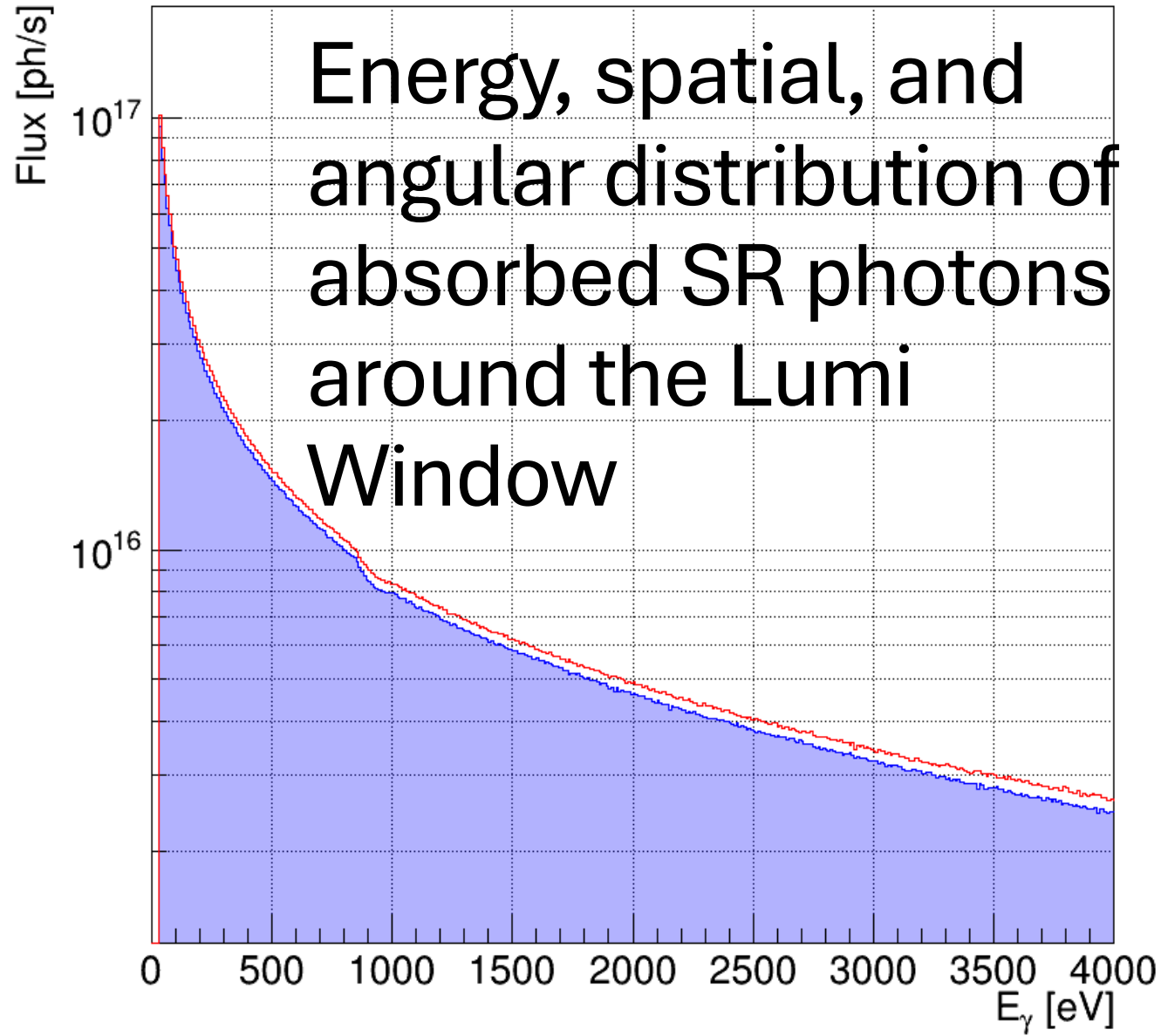
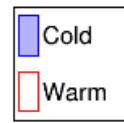


XZ distribution of absorbed SR photons on the inner surface of the vacuum beam pipe

SR photon position: Warm

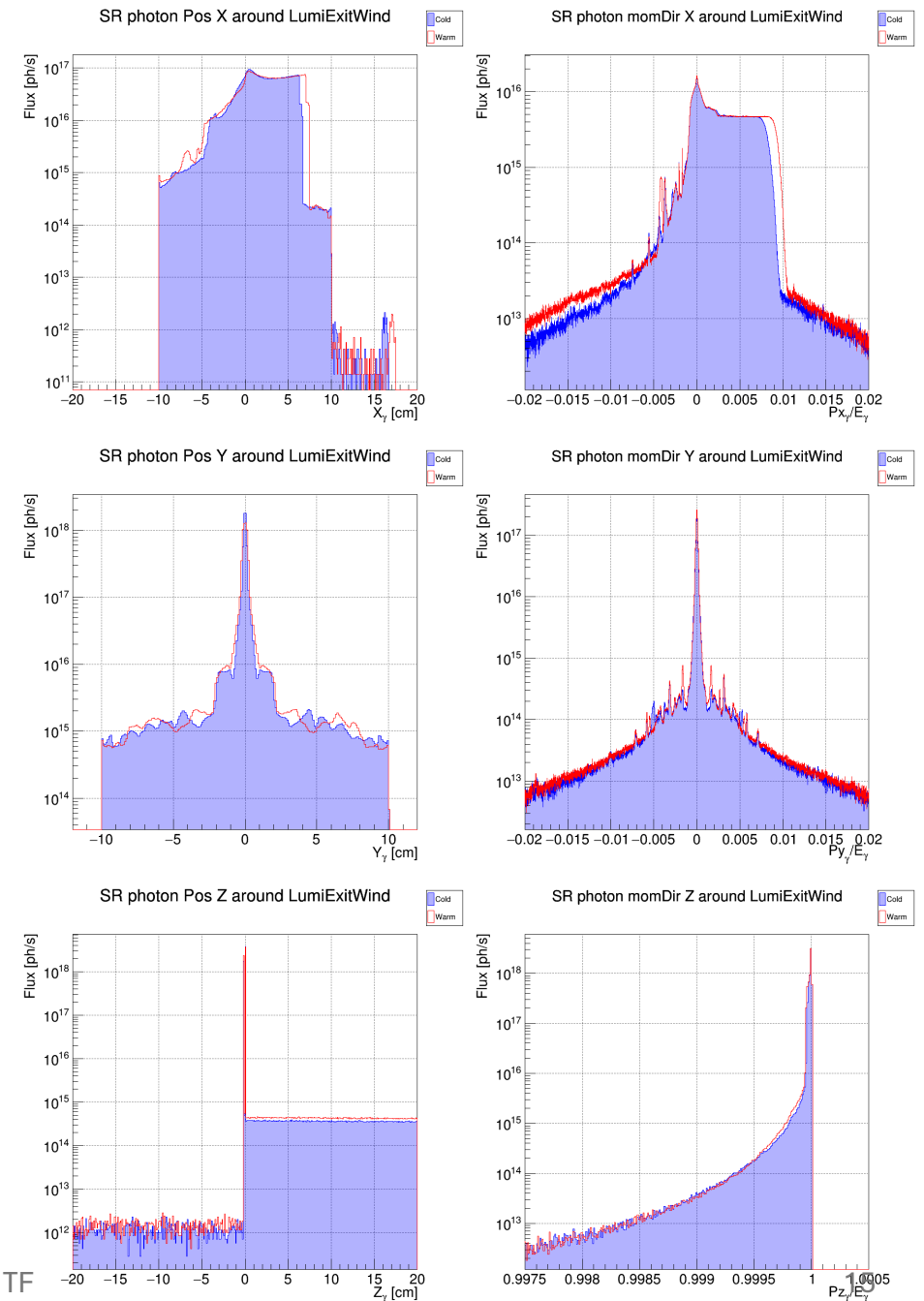


# SR photon energy around LumiExitWind

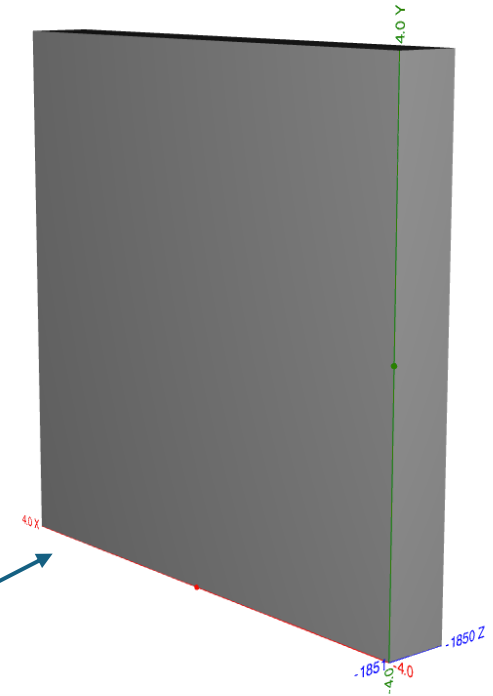
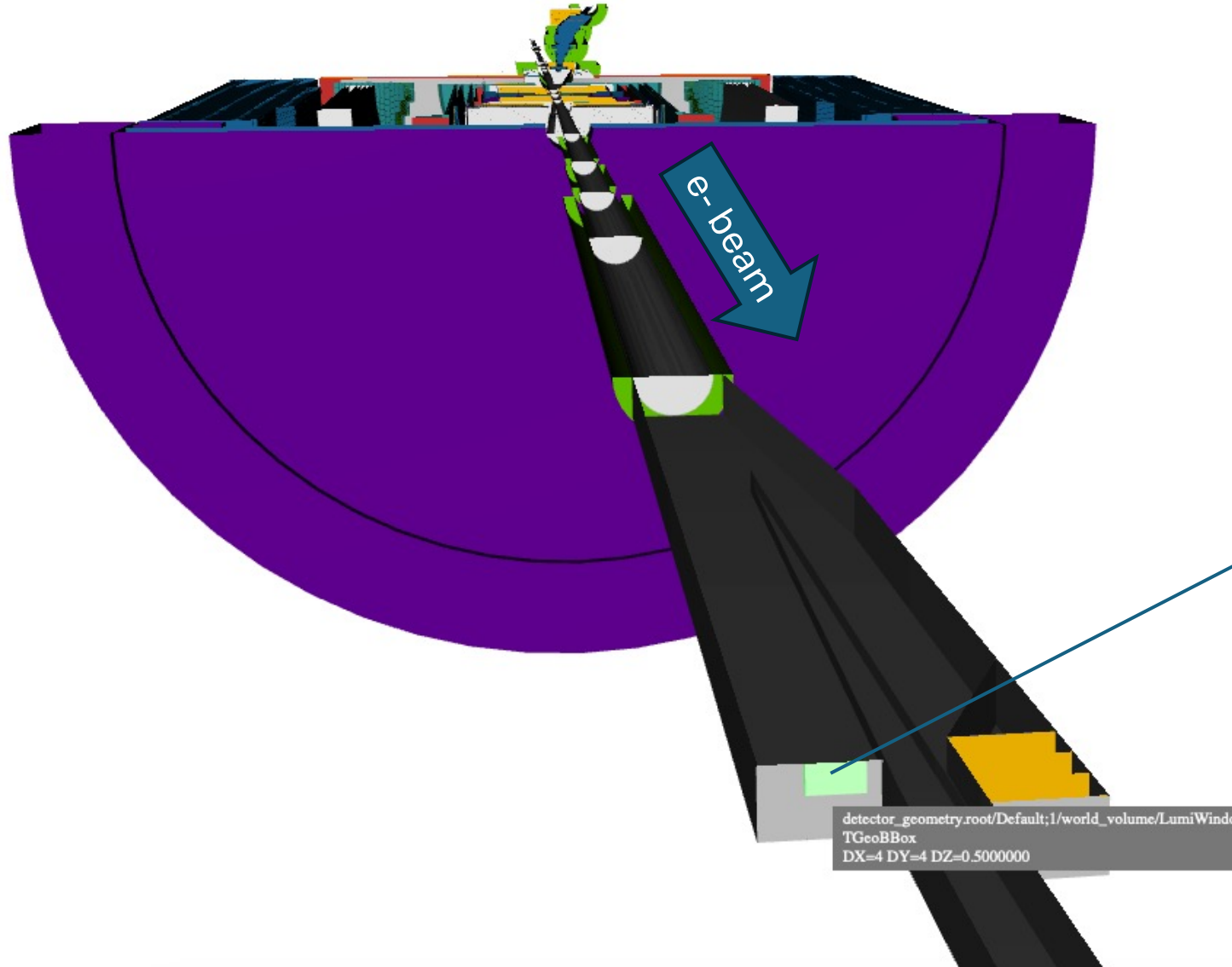


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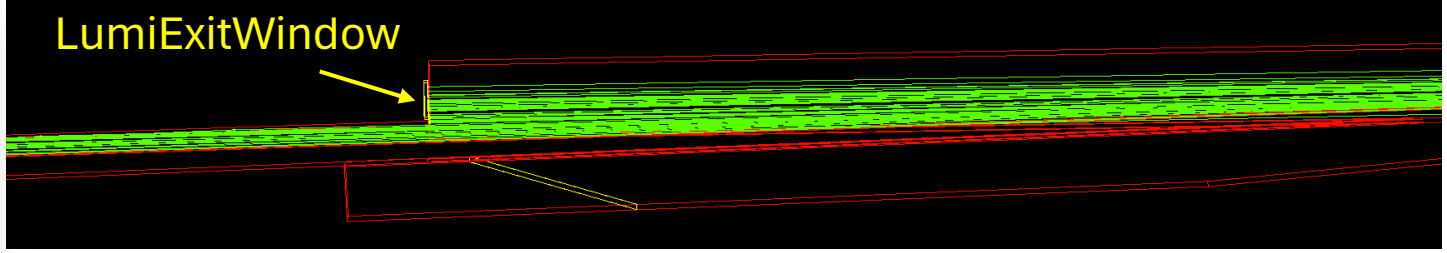
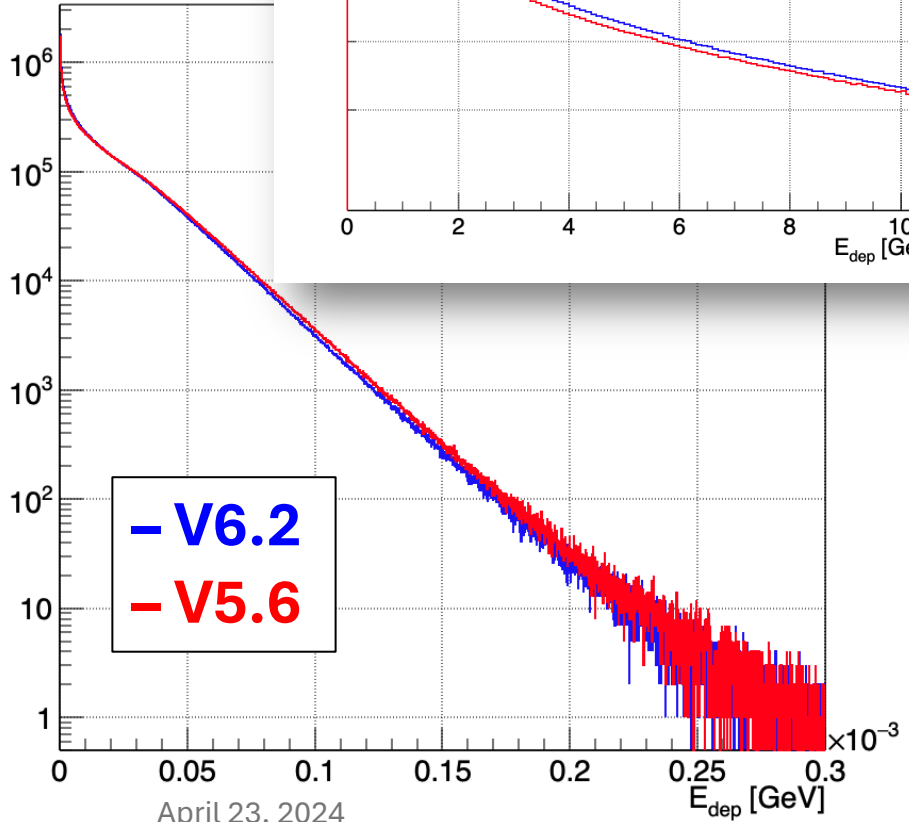
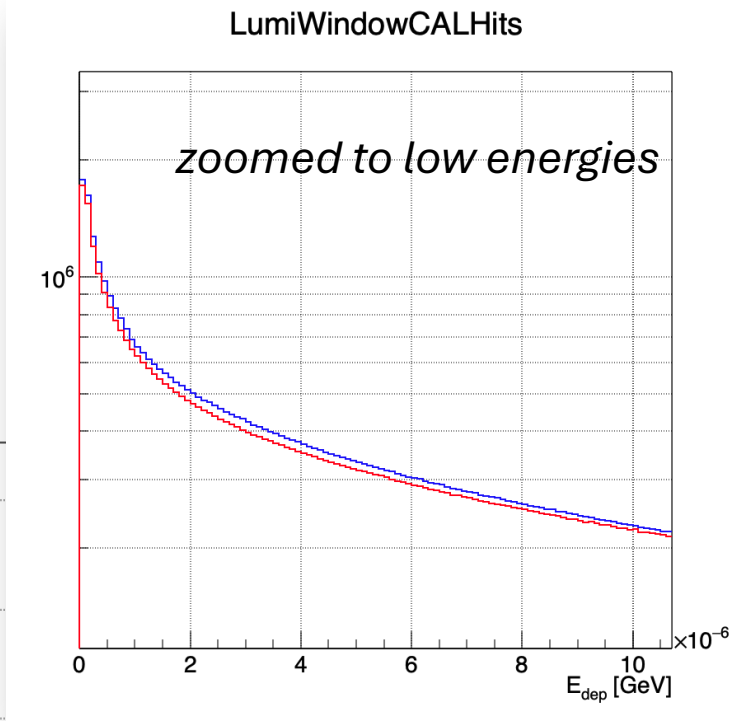
# Luminosity monitor exit window



Material = aluminum  
Size = 8 cm x 8 cm x 1 cm  
Density = 2.7 g/cm<sup>3</sup>  
Mass = 172.8 g  
Heat capacity = 0.9211 J/(g °C)  
**Melting point = 660.3 °C**



# SR energy deposition in the window: Cold B2eR

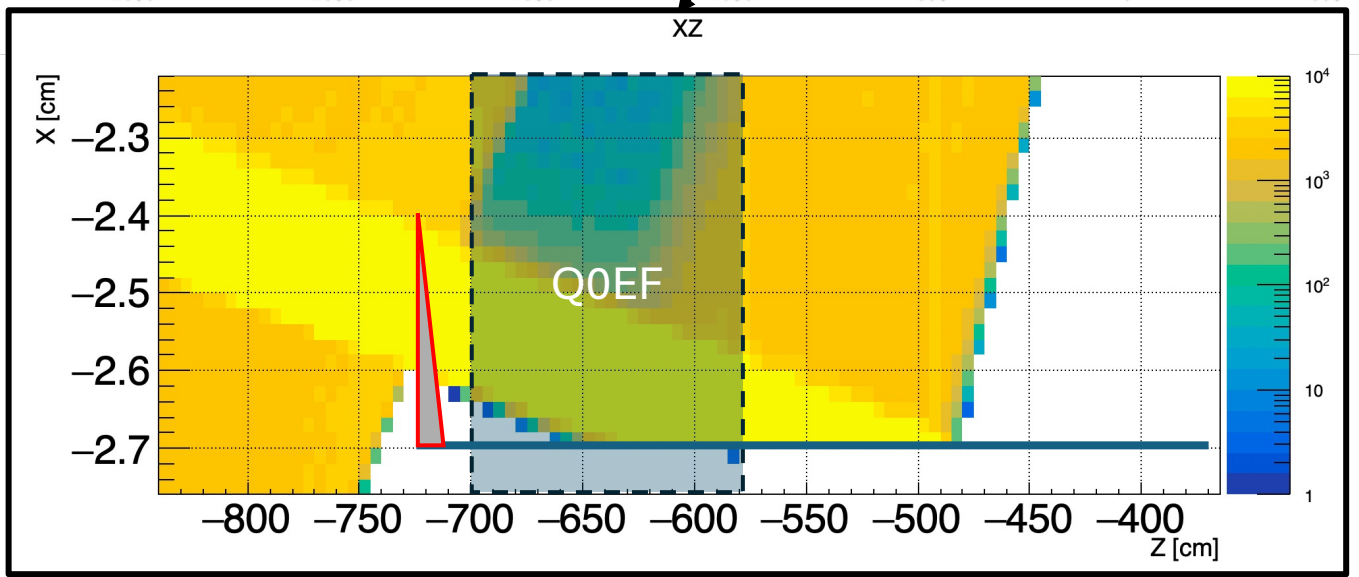
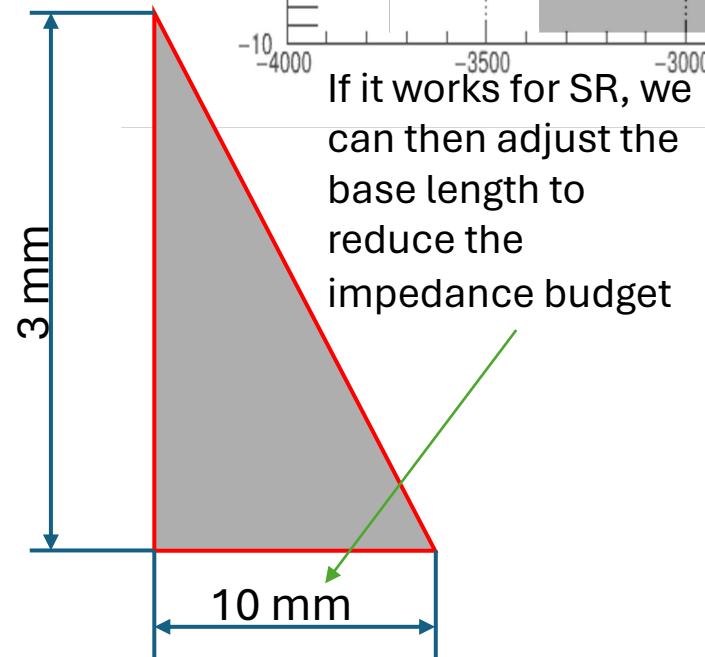
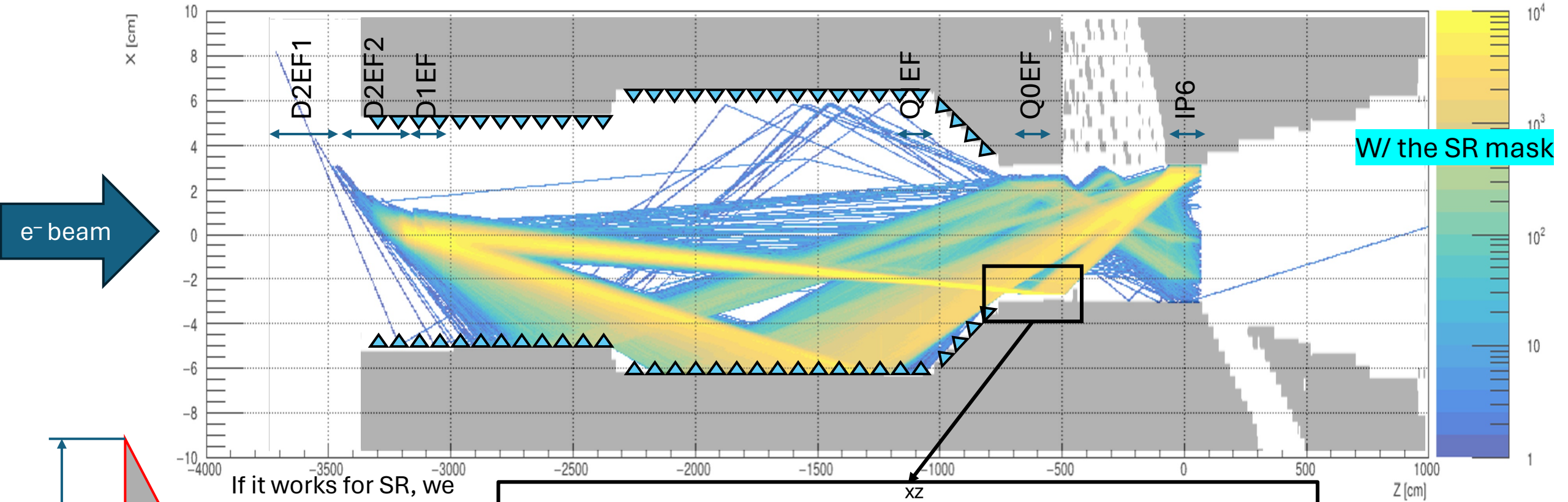


Lattice	V6.2	V5.6
# of simulated 18-GeV electrons	$10^8$	
Simulated beam current [A]	0.227	
# of SimHits	92020517	90907934
$E_{dep}$ [GeV]	$9.2 \pm 0.2$	$9.1 \pm 0.2$
$E_{dep}$ rate [GeV/s]	$1.30e+11 \pm 2.25e+09$	$1.29e+11 \pm 2.16e+09$
Dose rate [kRad/s]	$12.1 \pm 0.2$	$11.9 \pm 0.2$
Wattage [W]	$20.9 \pm 0.4$	$20.6 \pm 0.3$
Temperature rise [°C/hour]	$472.5 \pm 8.2$	$466.7 \pm 7.8$

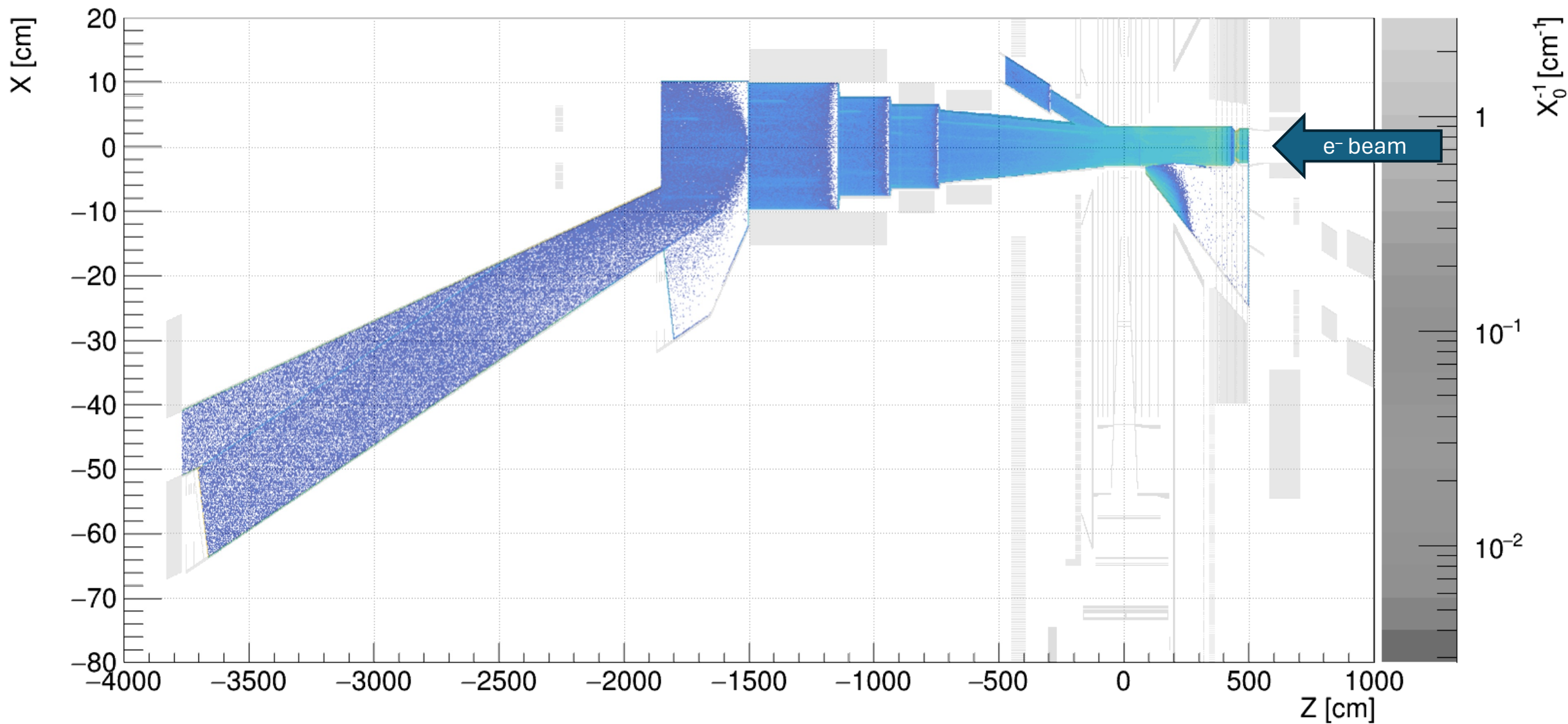
**Without cooling, Lumi Window will melt in less than 2 hours!**

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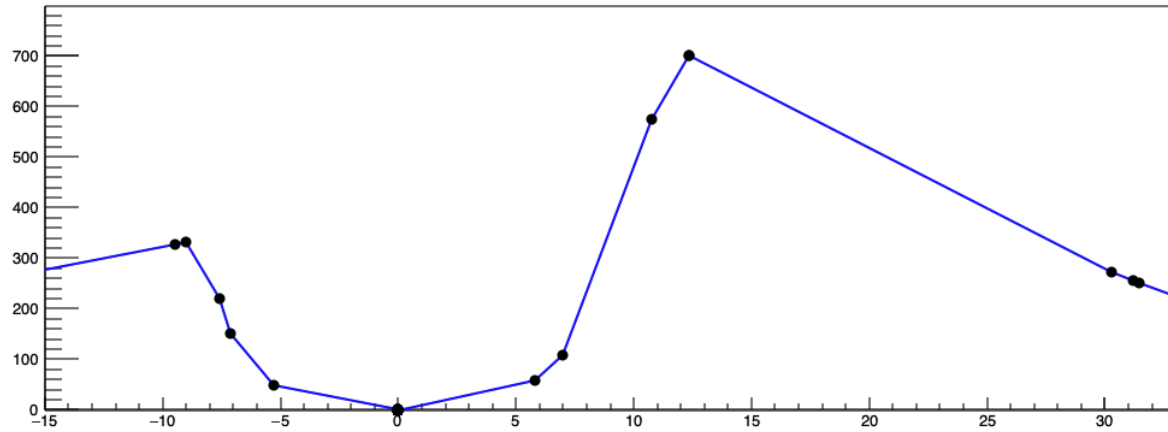
# Backup slides



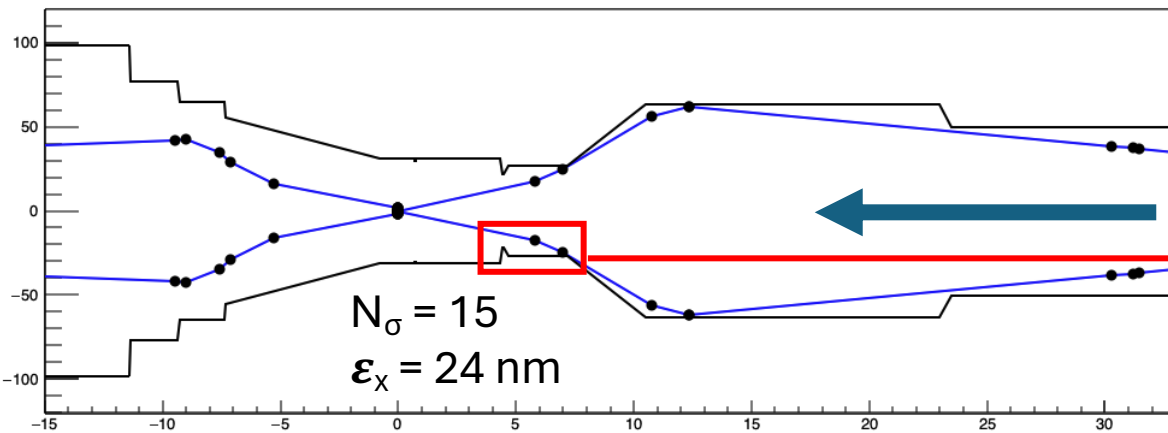
# Apr2024 ePIC (after PR with new beam pipe materials)



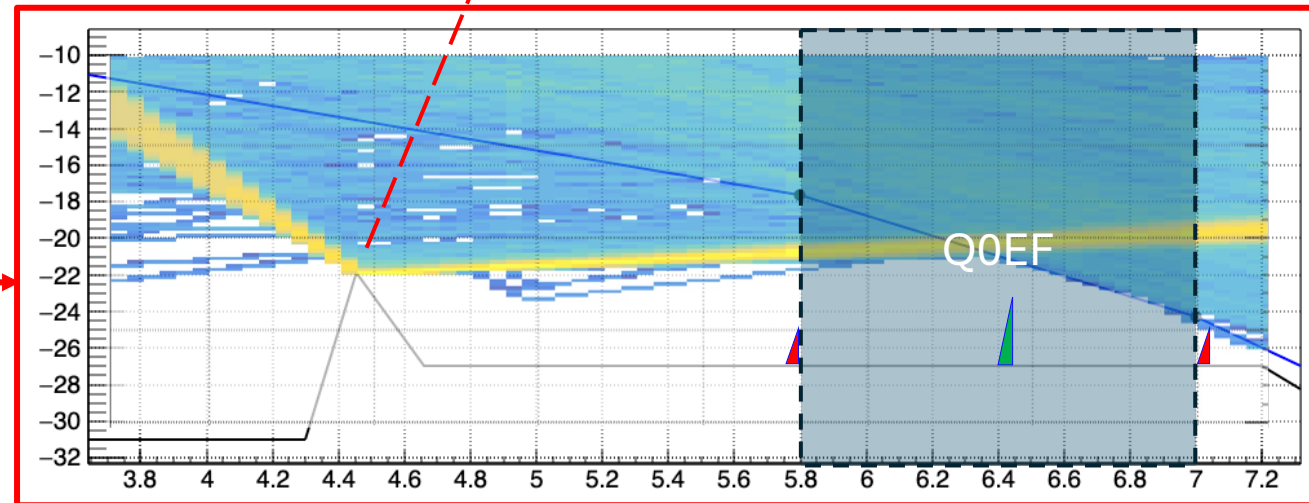
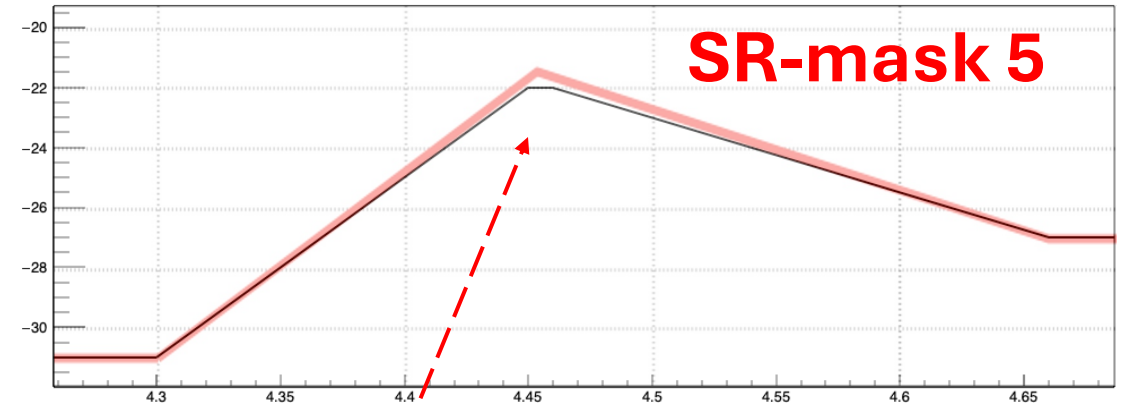
$\beta_x [m]$  vs  $s[m]$



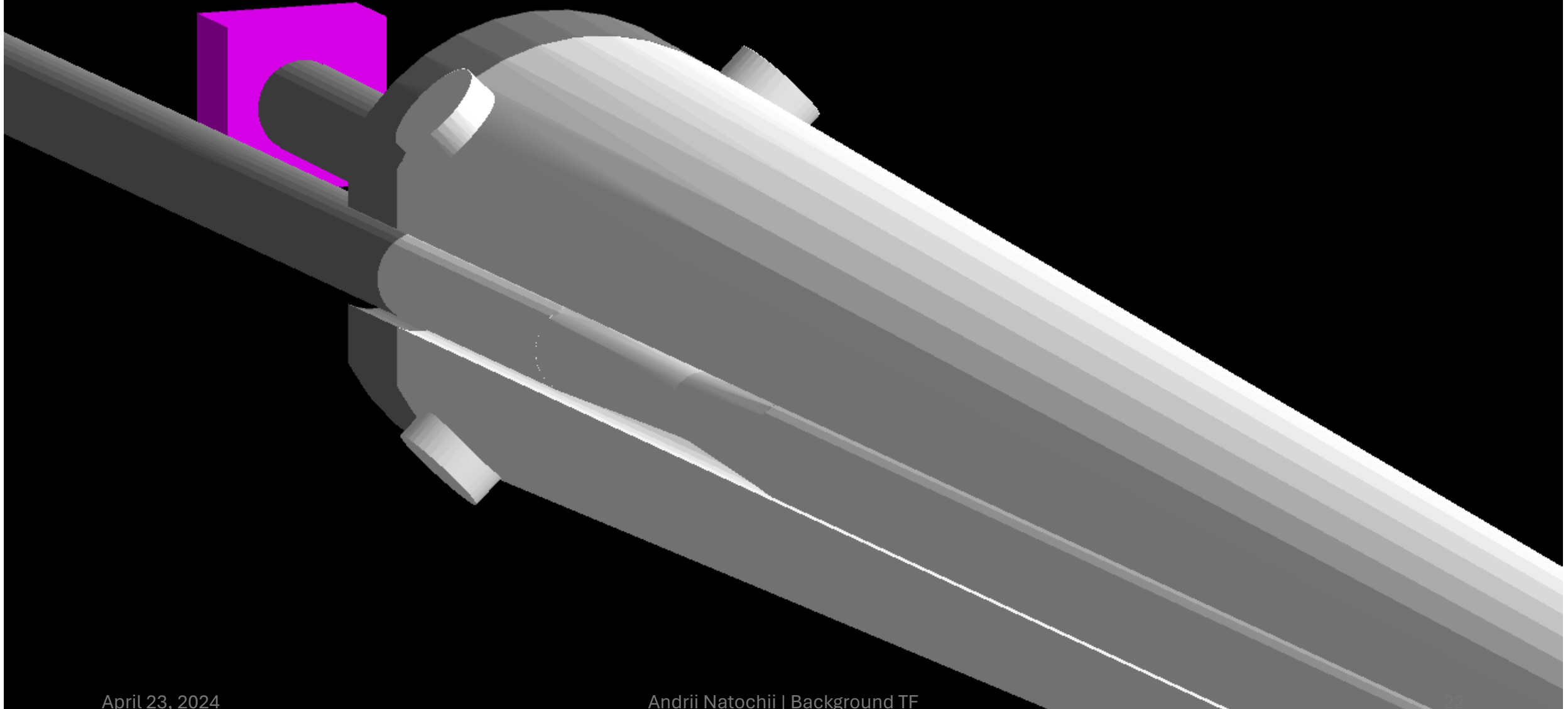
$N_\sigma * (\beta_x * \epsilon_x) [mm]$  vs  $s[m]$



SR-mask 5



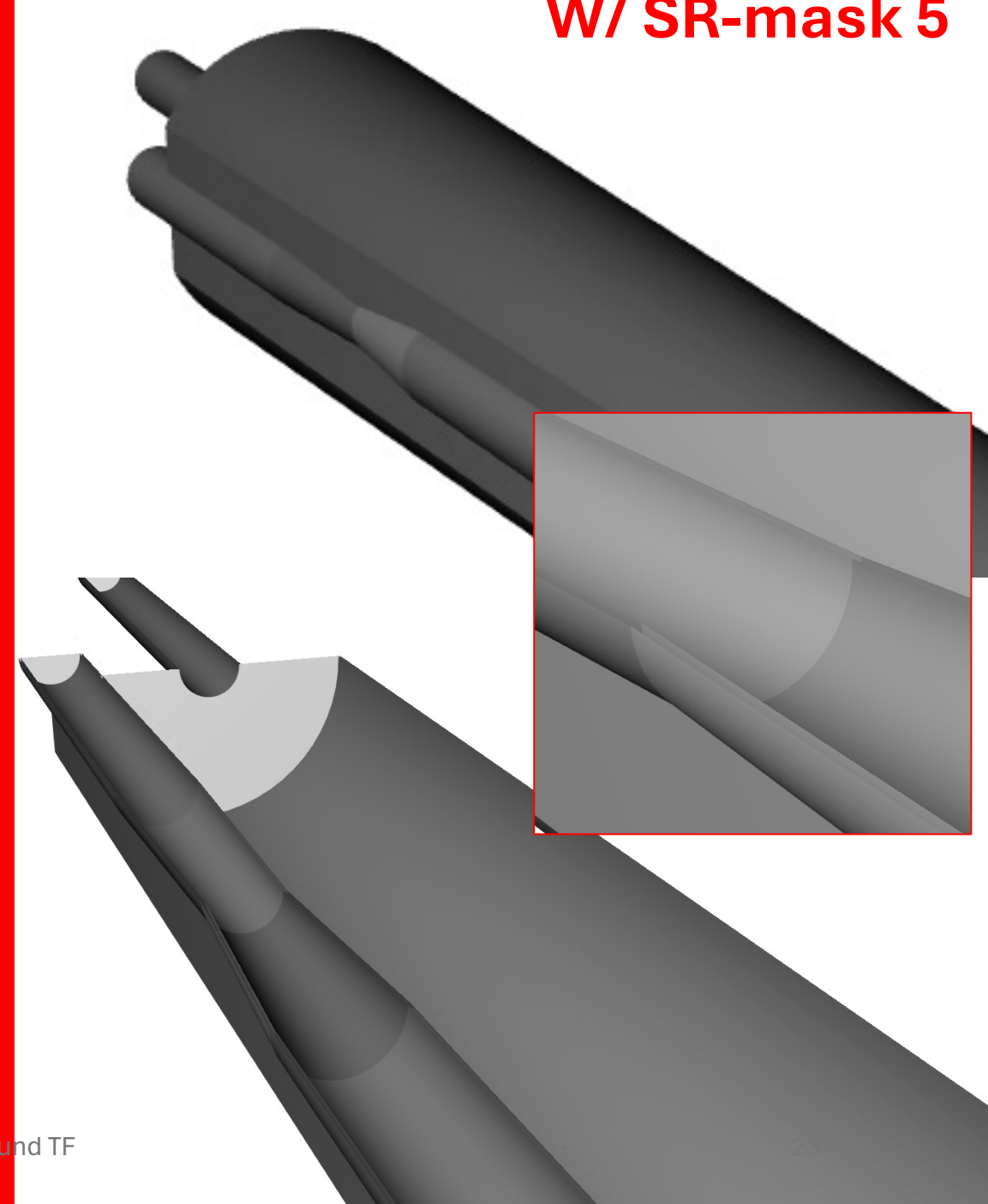
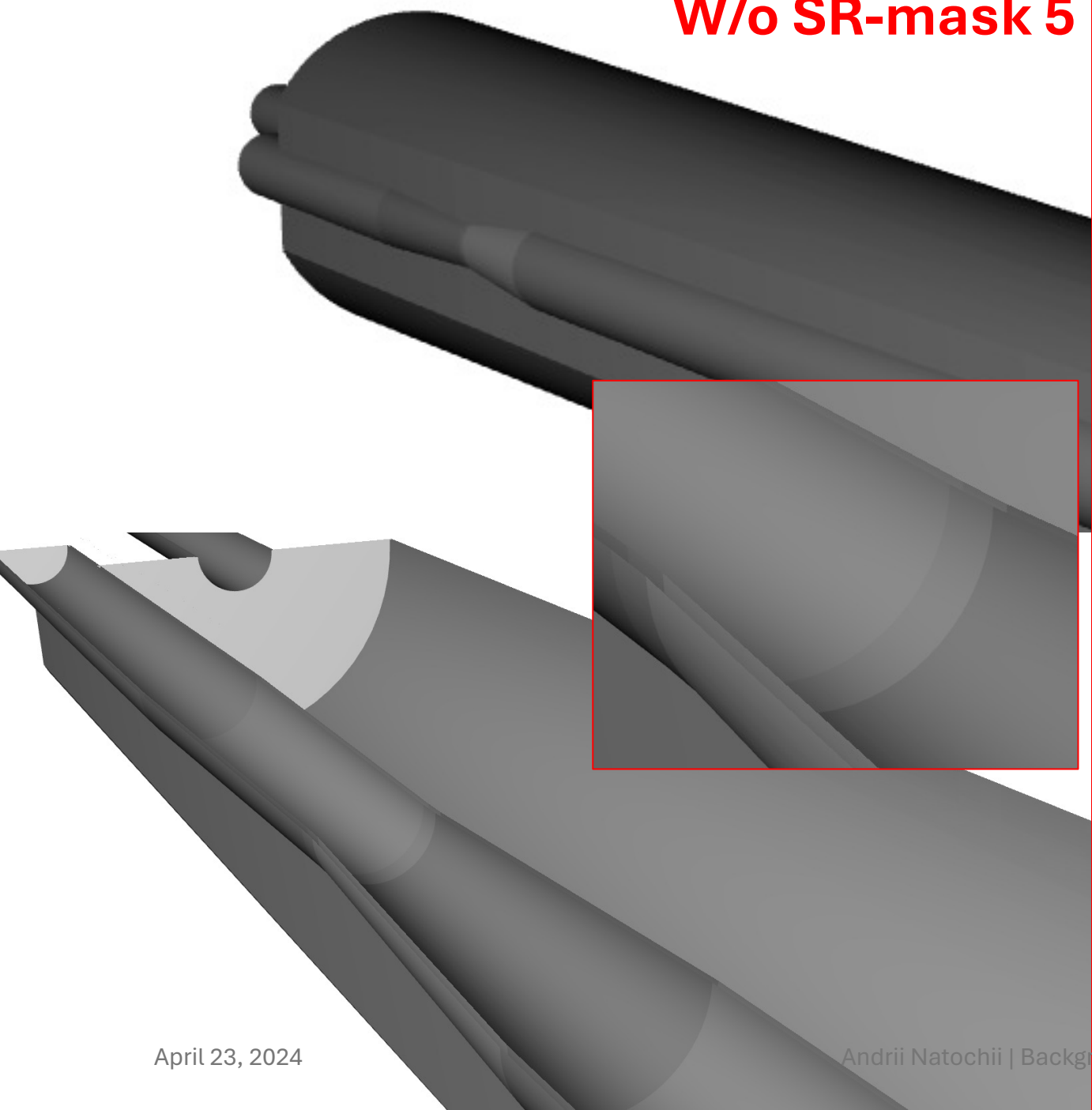
W/ SR-mask 5



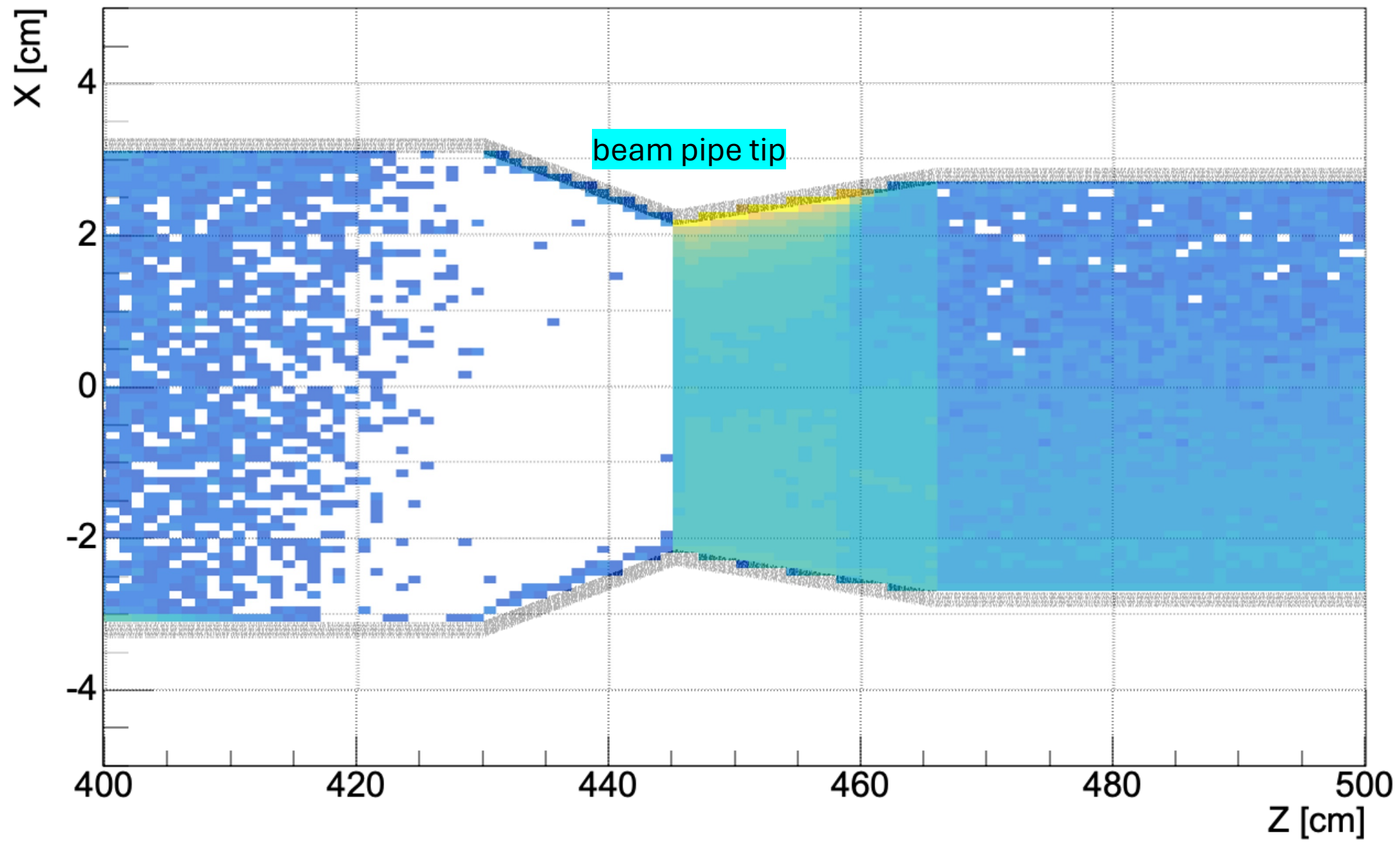


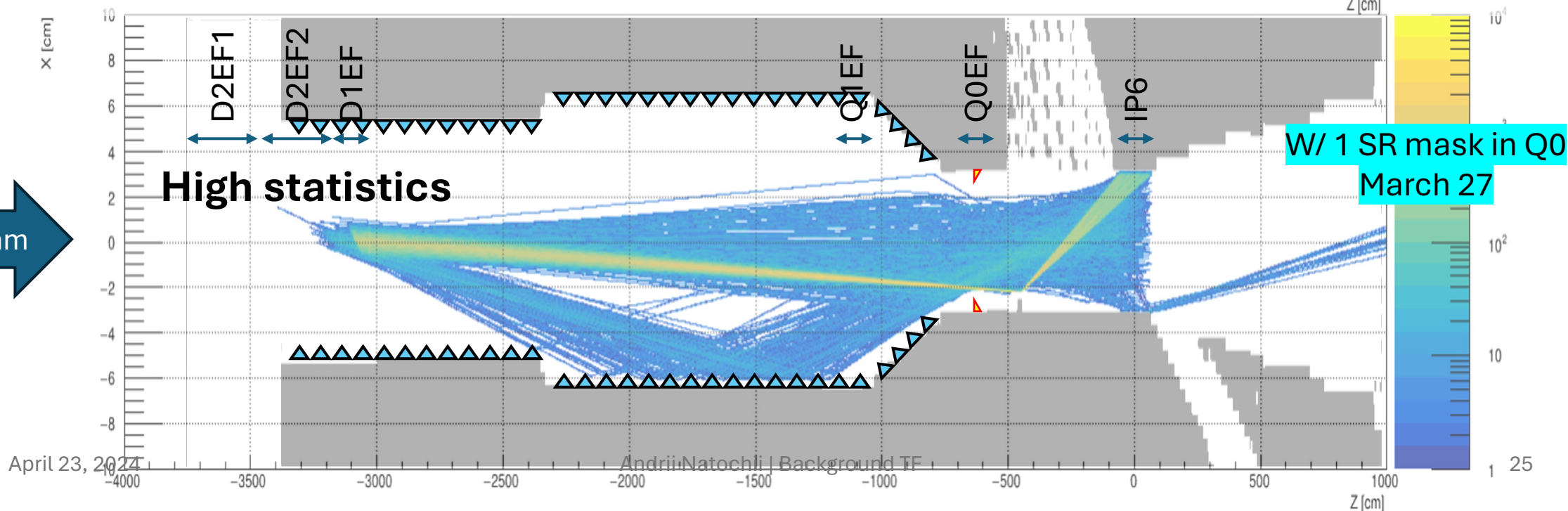
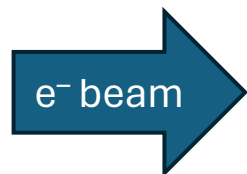
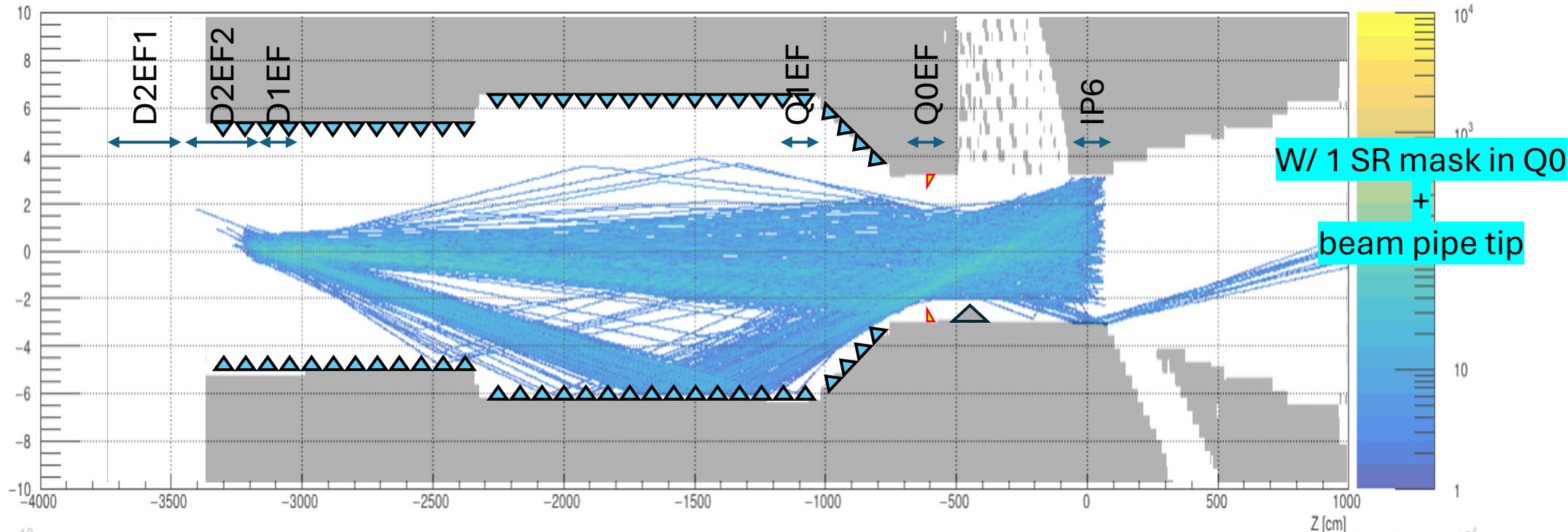
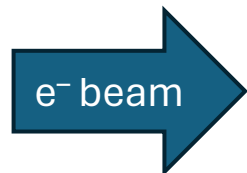
W/o SR-mask 5

W/ SR-mask 5



XZ





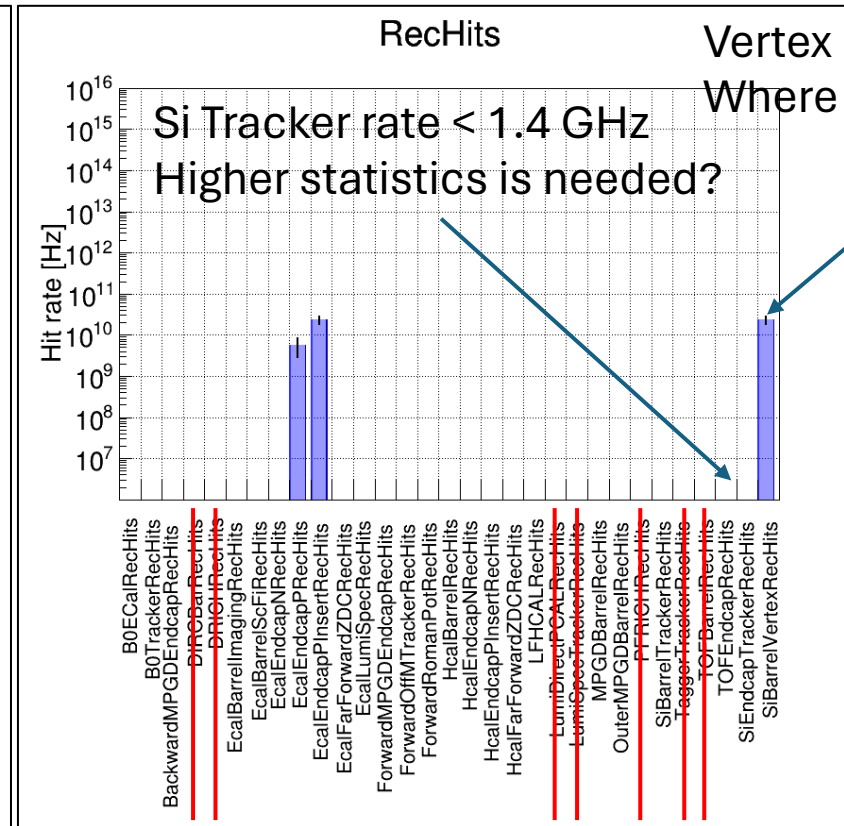
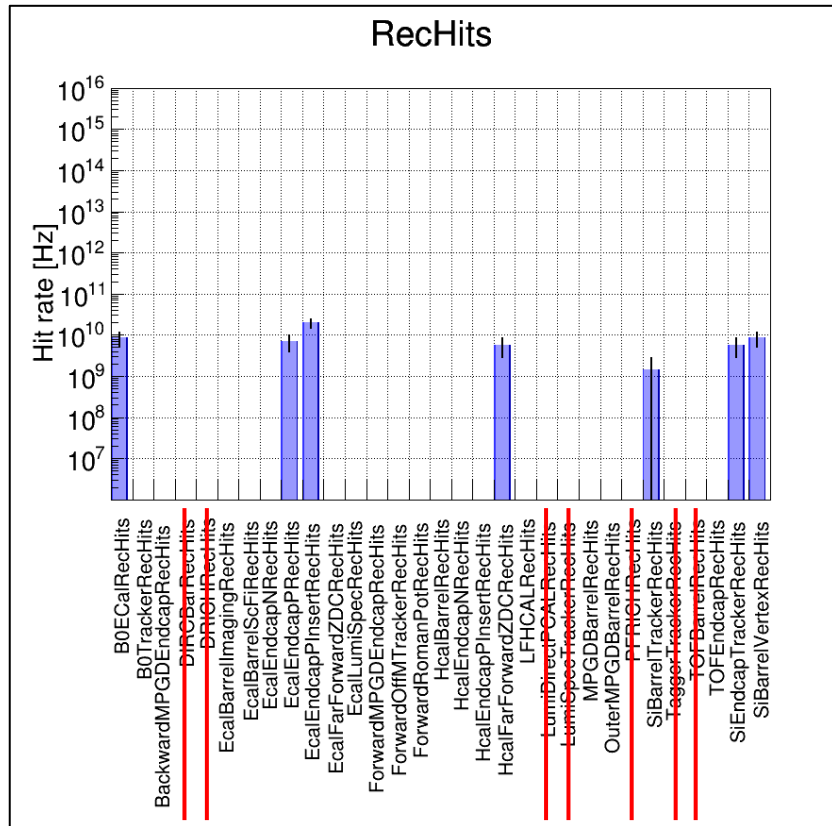
$I = 0.227$  A  
 $-37\text{m} < z < 5\text{m}$   
 $E_\gamma > 30$  eV

Lattice file v6.2 | 18 GeV | 2 IPs |  $I = 0.227$  A

**SS + Cu**  
 beam pipe

# 1 SR mask in Q0

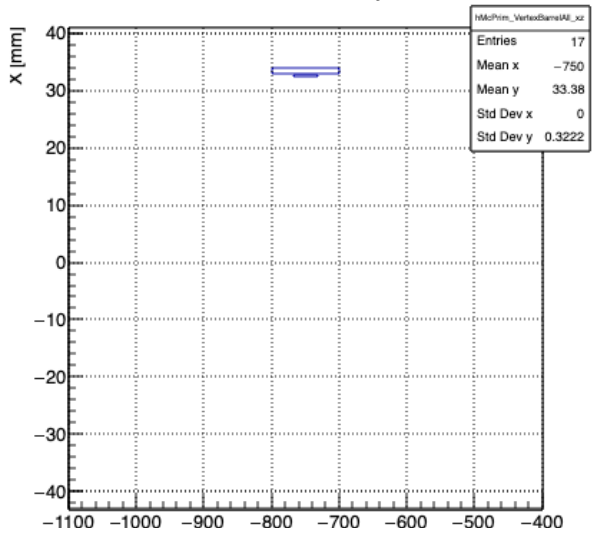
# 1 SR mask in Q0 + beam pipe tip



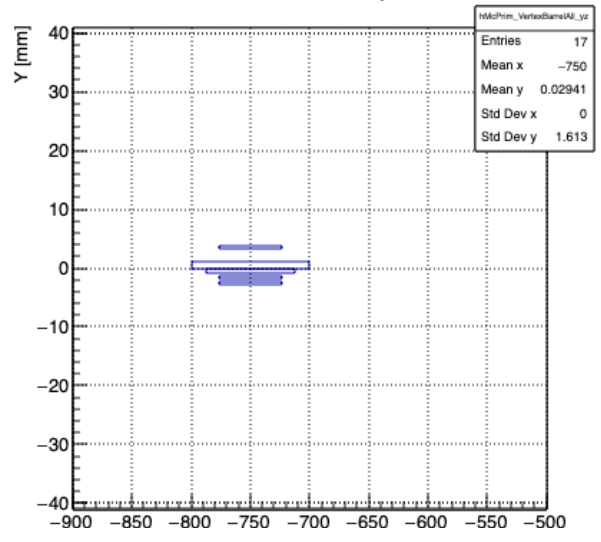


# Absorbed SR photons that caused Vertex hits

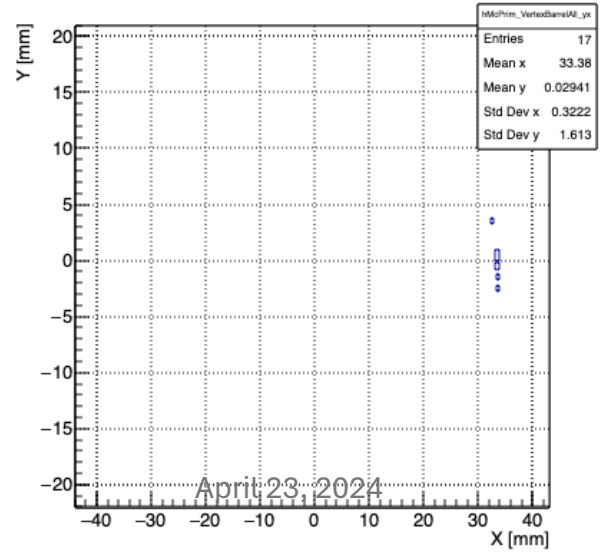
VertexBarrel MCp XZ



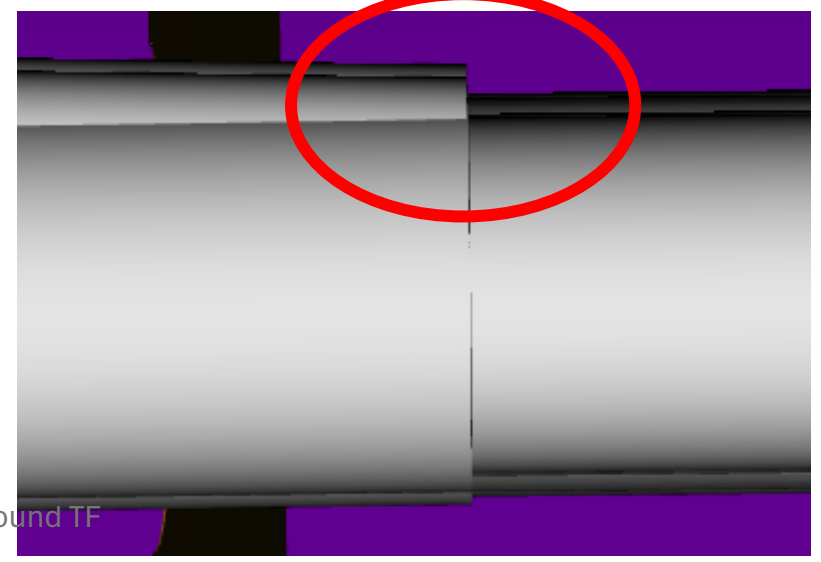
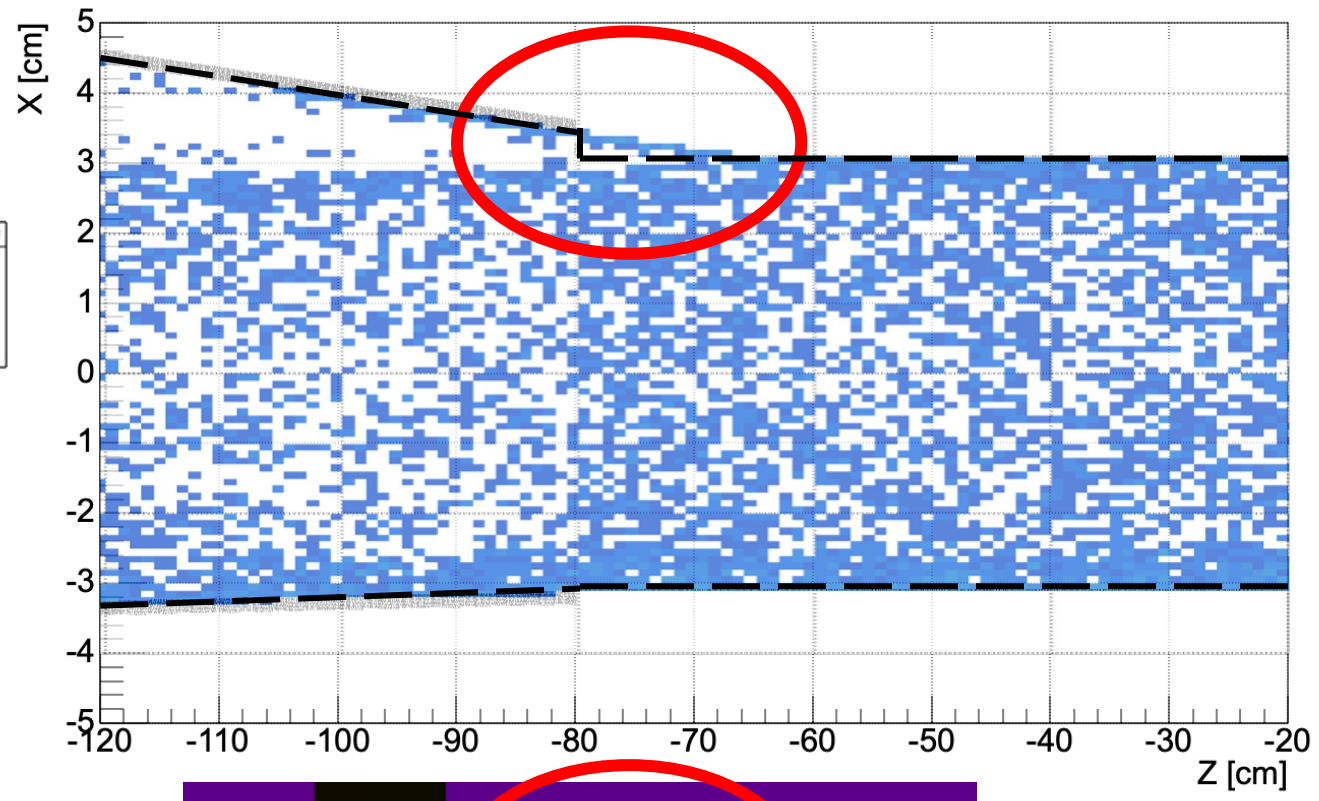
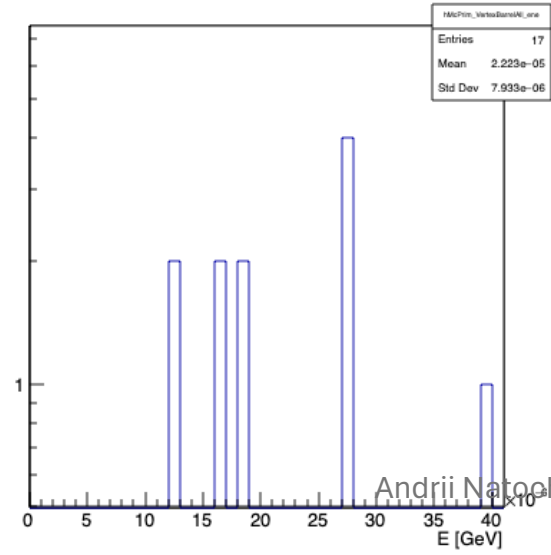
VertexBarrel MCp YZ

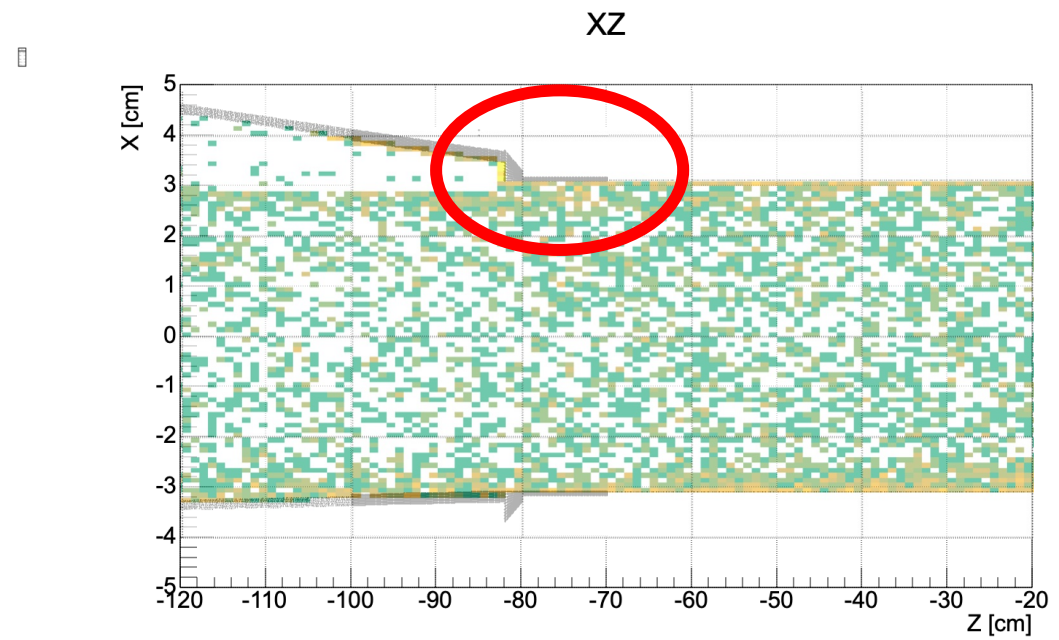
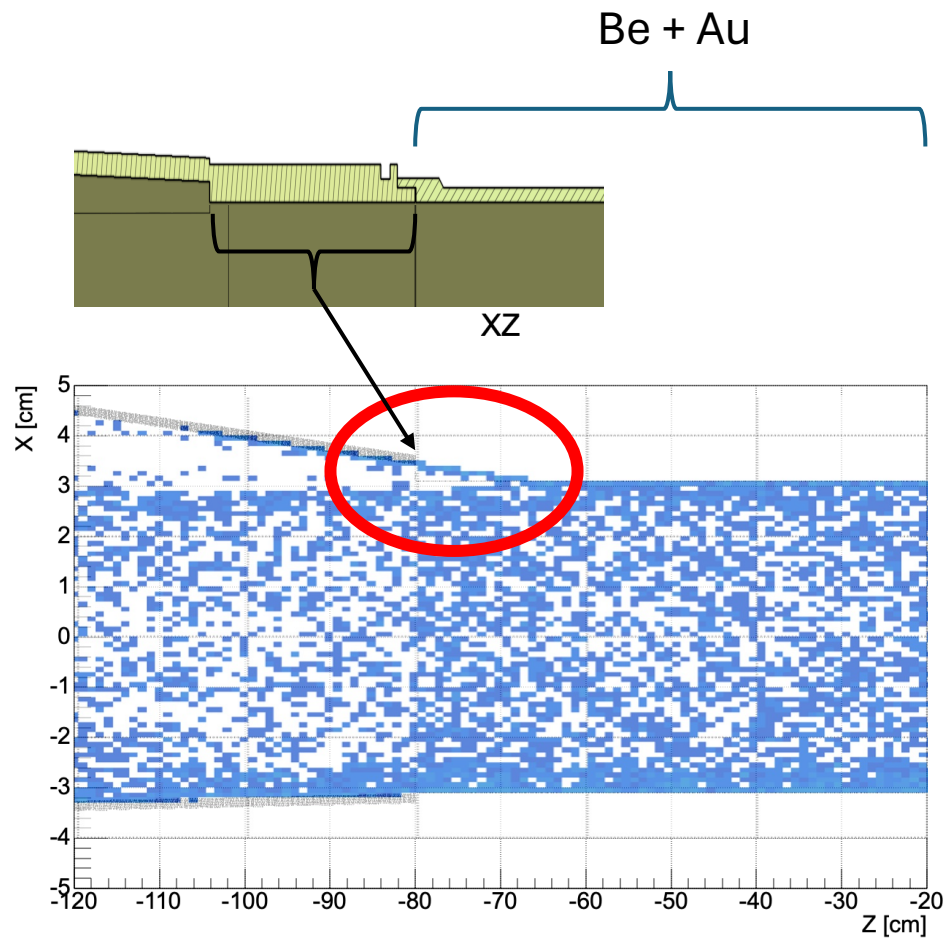


VertexBarrel MCp YX



VertexBarrel MCp E







# 1 SR mask in Q0 + beam pipe tip

# 1 SR mask in Q0 + beam pipe tip

