Synchrotron Radiation Study for the CEPC Using BDSIM

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Outline

- Introduction
- BDSIM configuration
  - Geometry, Magnetic Field, Aperture
- Trajectory Analysis
- Summary

Introduction

- SR (Synchrotron Radiation) is curtail for the safety and performance of the detector

  - The CEPC TDR reports the SR effect with a safety number of 10, indicating a conservative estimate due to uncertainties in the results
  - The difficult point is that the beam population is 10^{11} @ $\sqrt{s} = 240\text{GeV}$, and we do not have such a huge computer to simulate them. Therefore we need to develop an efficient method
  - **In TDR study, the simulation is performed using ordinary Geant4, it takes 10 hours and 5000 cpus to simulate 10^{9} events**
    - **Include accelerator [-/+ 150 m, field only] and full detector**

- BDSIM(Beam Delivery Simulation) is used in this study, it is utilized by LHC, photon source projects
  - **Particle tracking in Geant4 is a numerical method**
    - **Particle's motion is represented by many small steps**
  - **Particle motion in accelerator elements can be described analytically**
    - **Particle's motion is represented by an equation of motion**
  - BDSIM combines the two methods and enables communication between them

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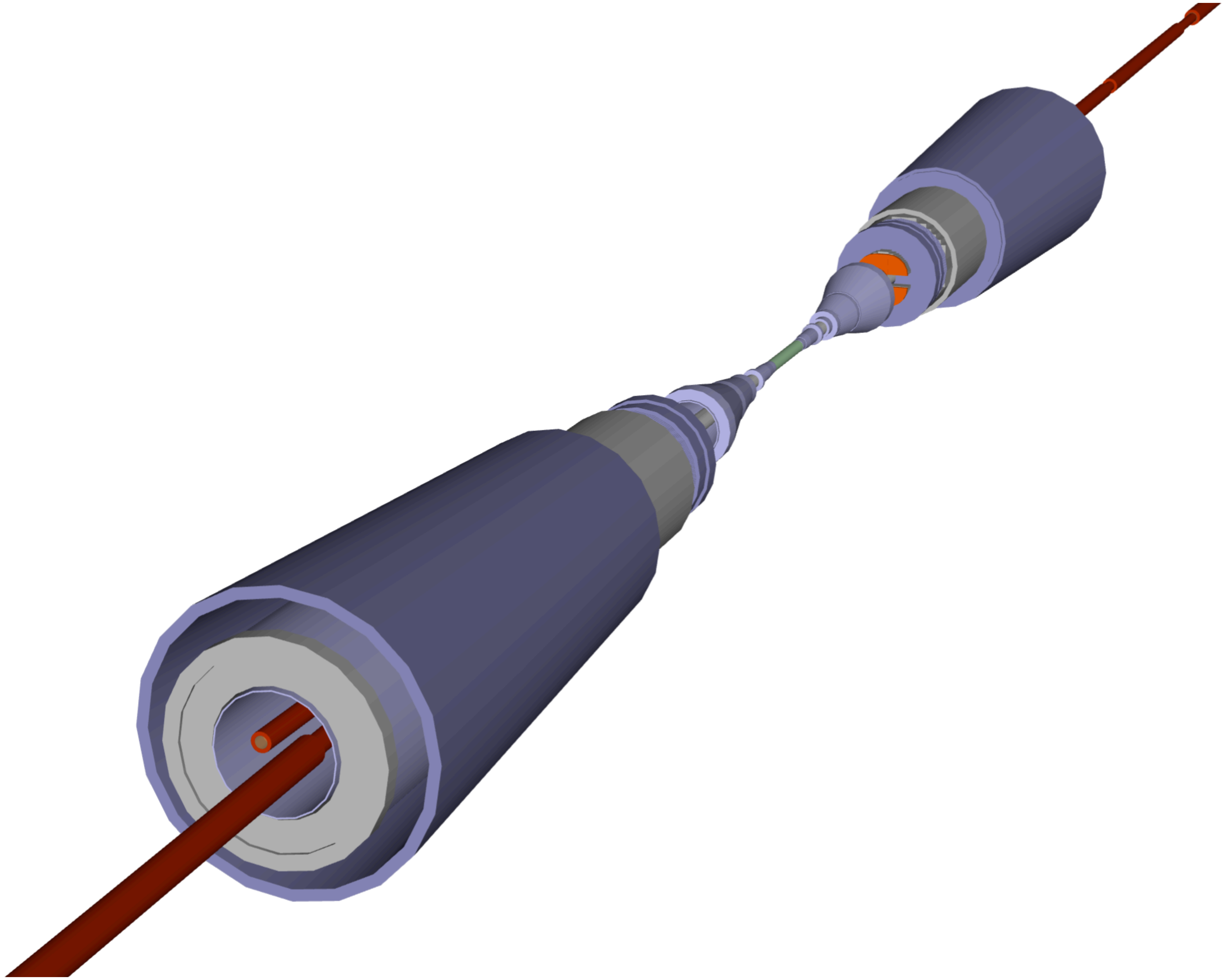
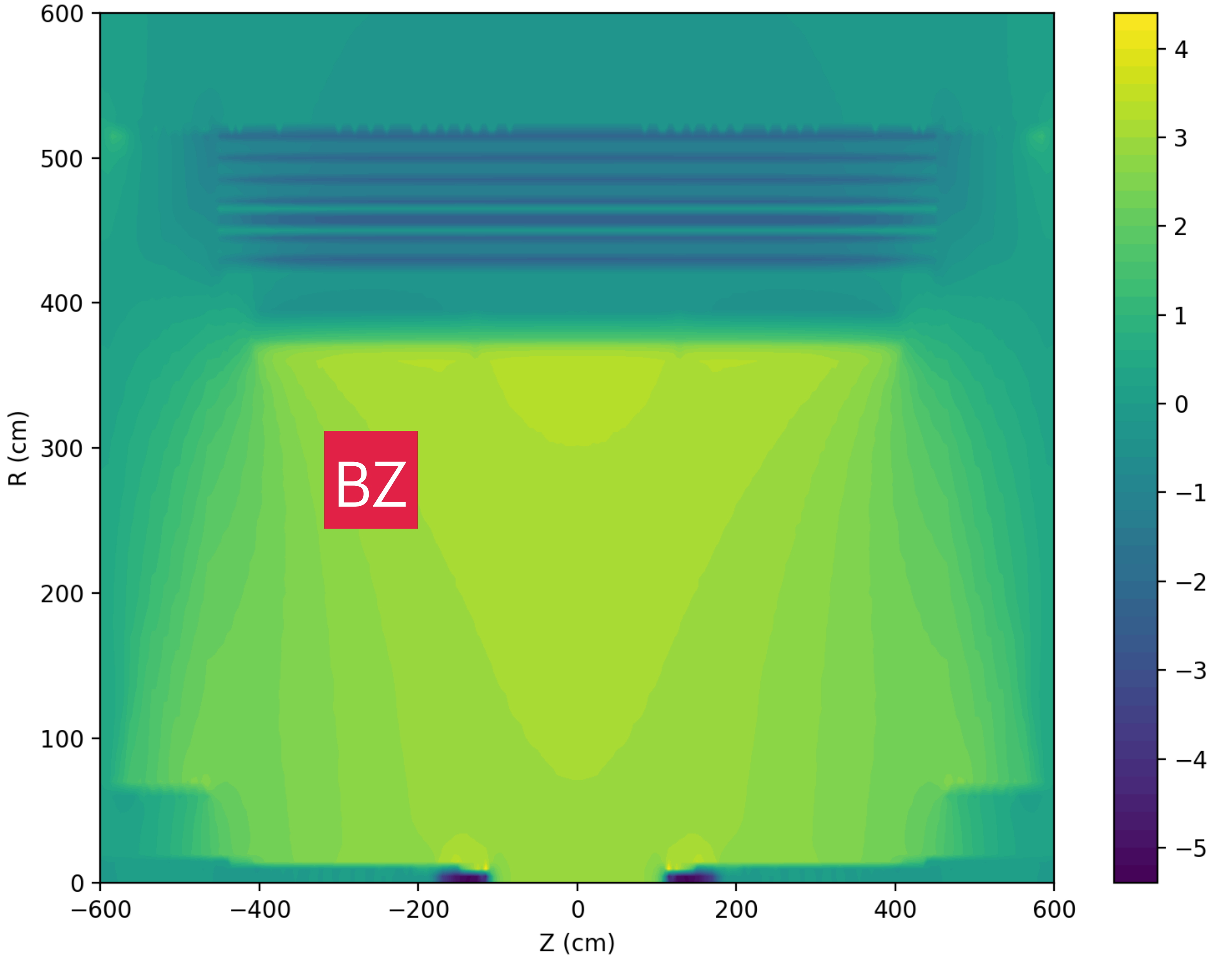
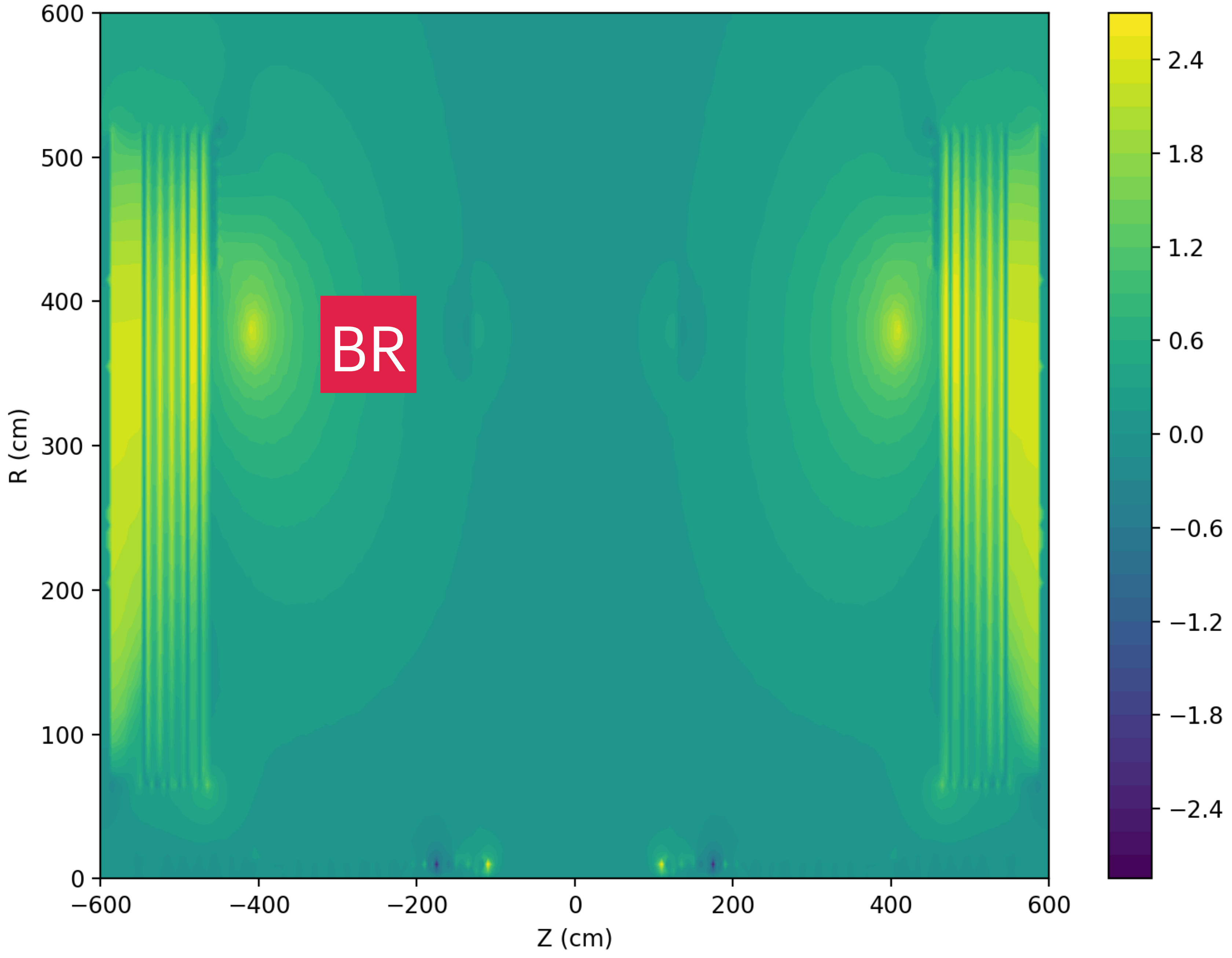
BDSIM (Geometry)



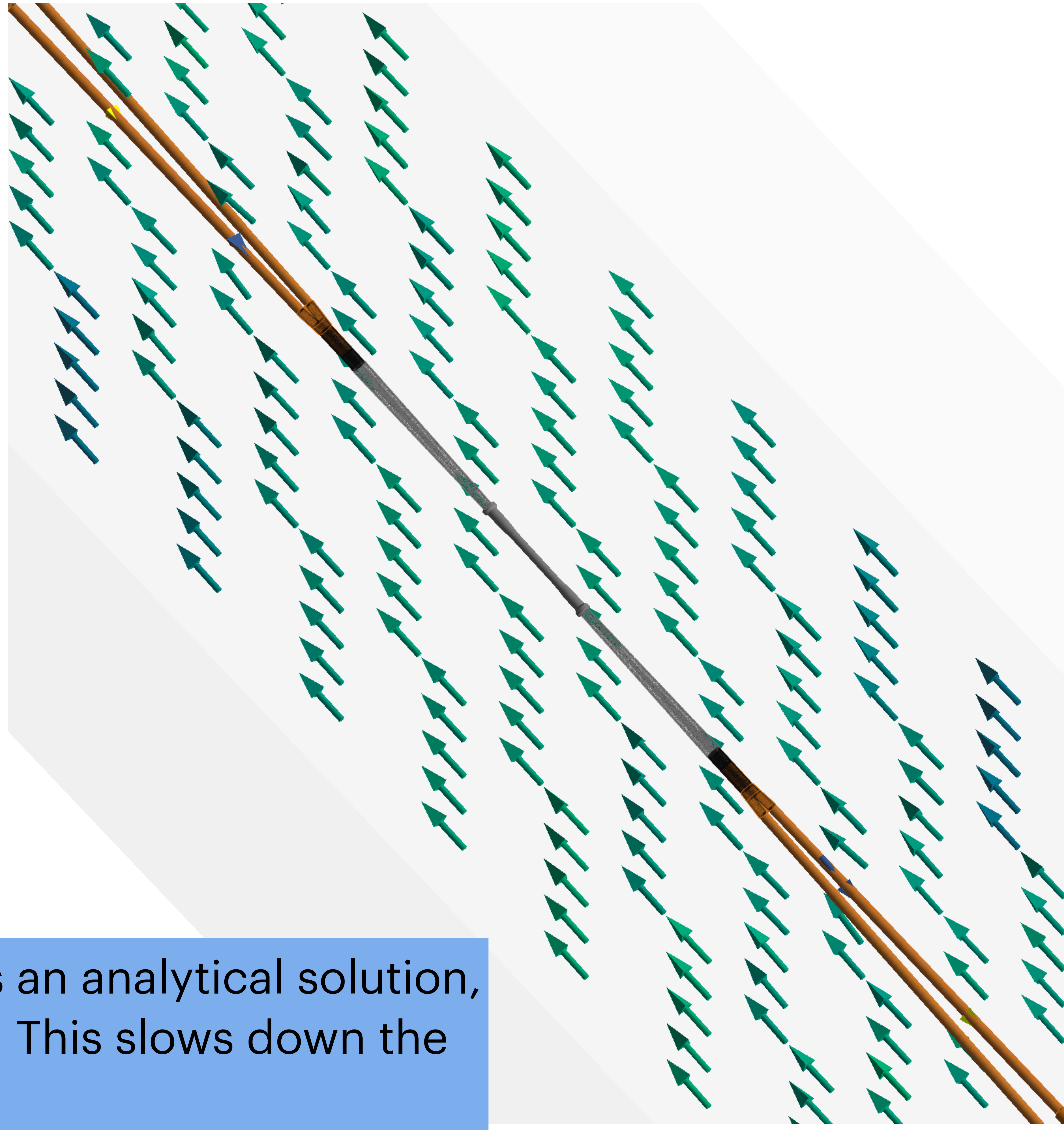
- Accelerator elements within ±150m of the IP are simulated
- BDSIM can not communicate with CEPCSW natively
    - Migrate some MDI components from CEPCSW to BDSIM
    - Geometry of the centre beam pipe between the final quadrupoles [+/- 1.9 m]
    - Include lumical.

BDSIM (B-field)



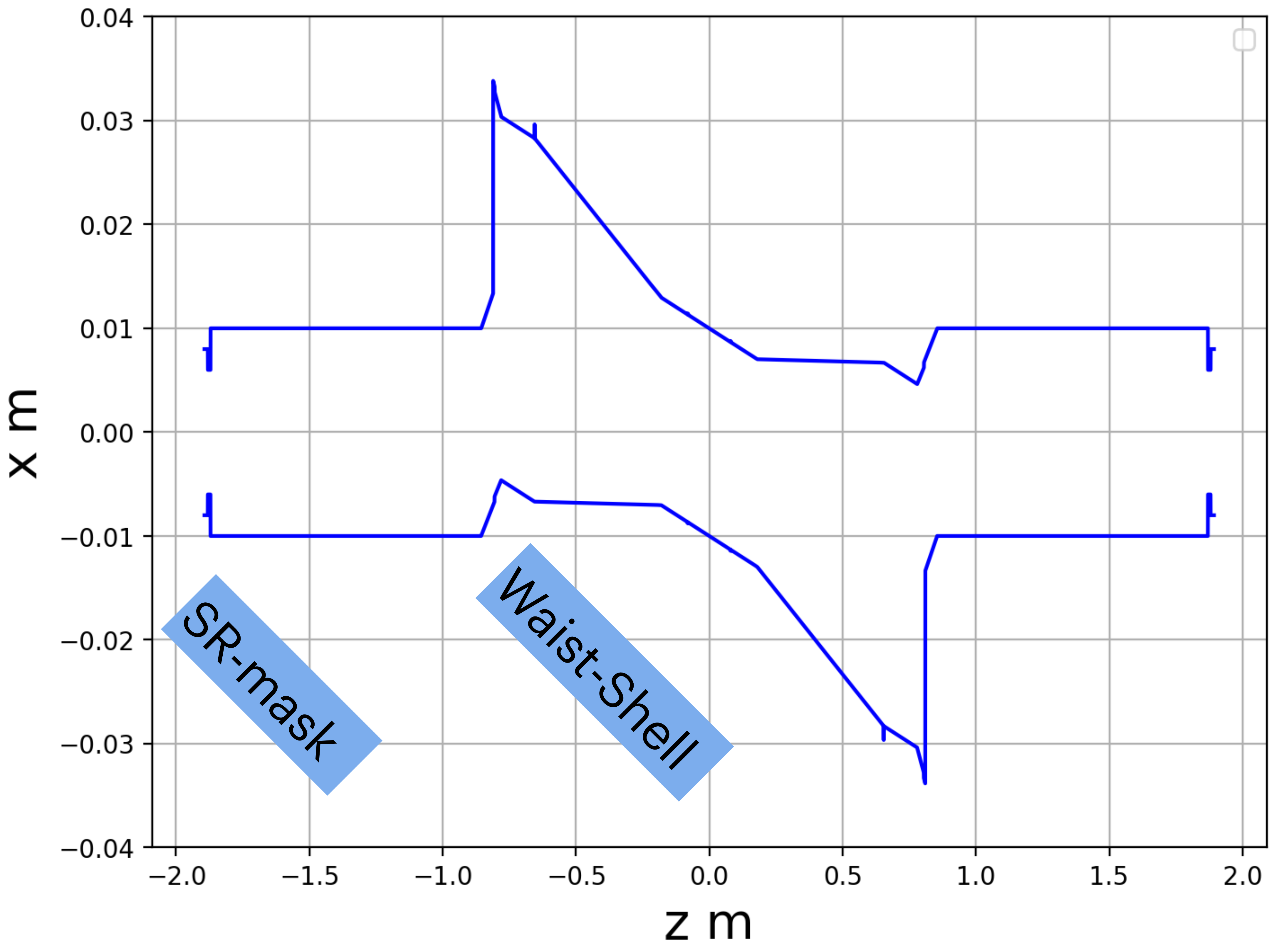


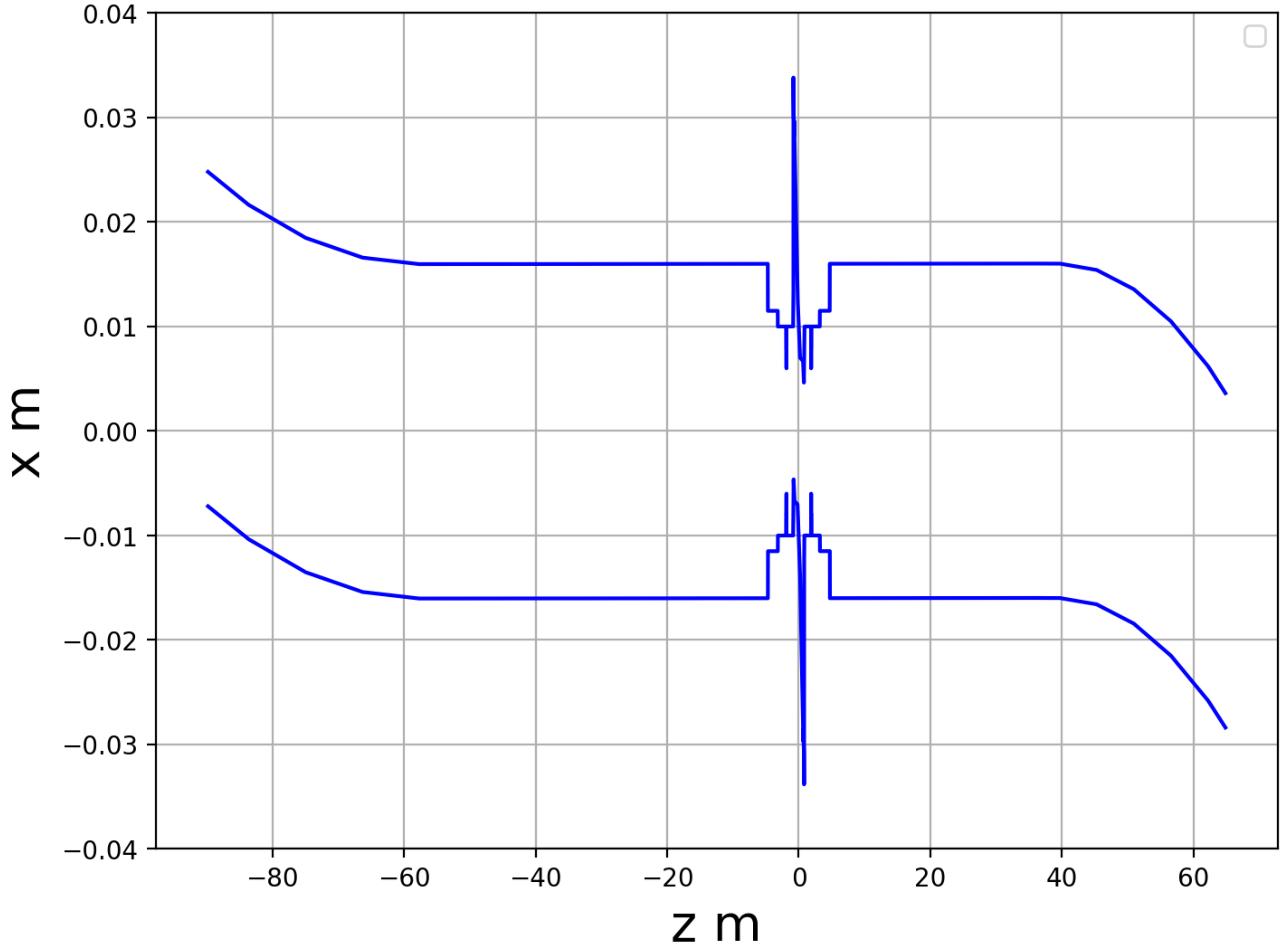
- Left plots show the non-uniform magnetic field from CEPCSW
- Convert them into a suitable format for BDSIM



Particle's motion in B-field has an analytical solution, but not in a non-uniform field. This slows down the simulation a lot

Aperture





- Left: Aperture profiling within a view of +/- 2 m
  - Two incoming pipes merge in the waist area, causing the aperture to narrow there
  - This makes the waist-shell is higher than the SR mask from the beam's point of view
- Right: Aperture profiling within a larger view

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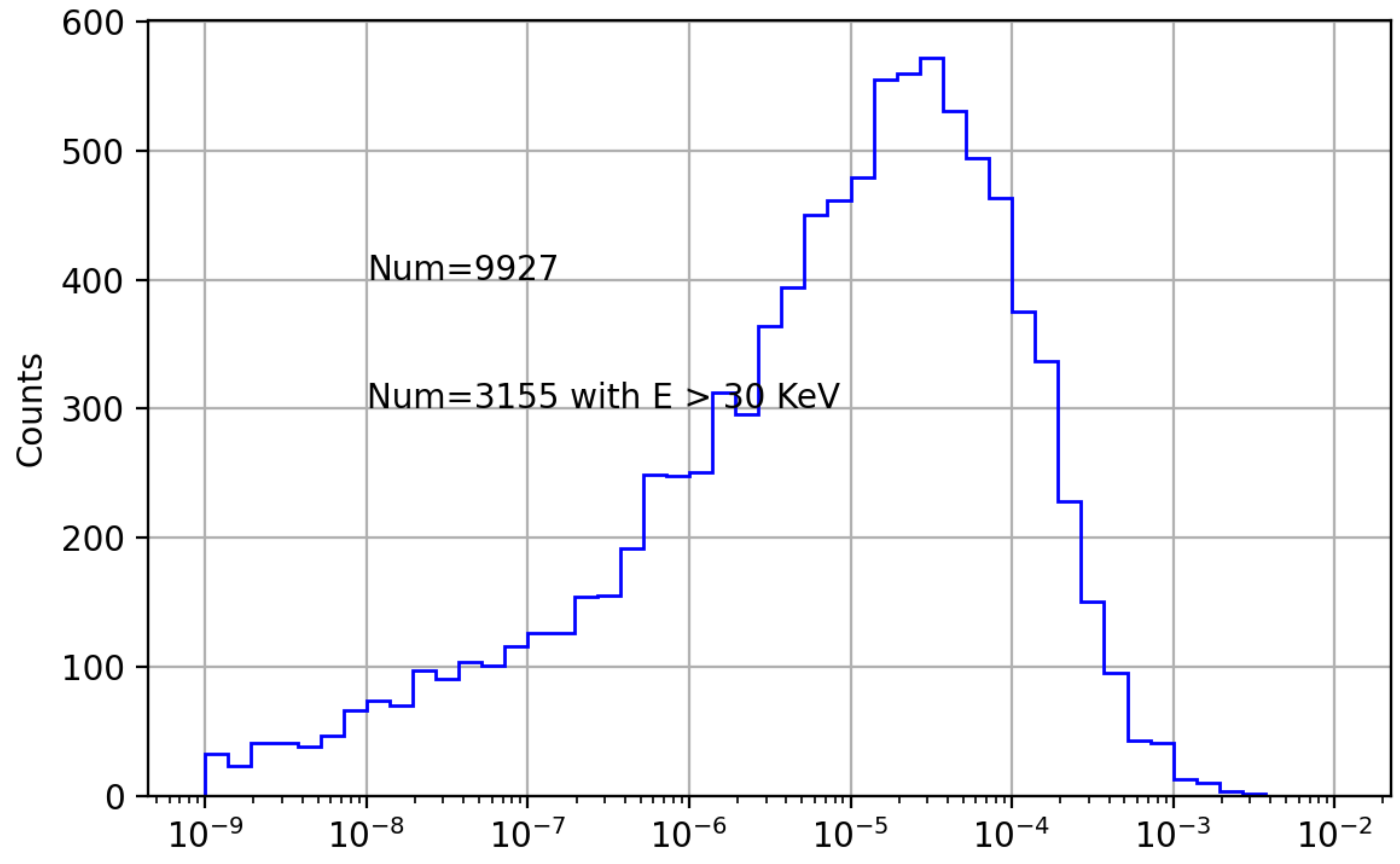
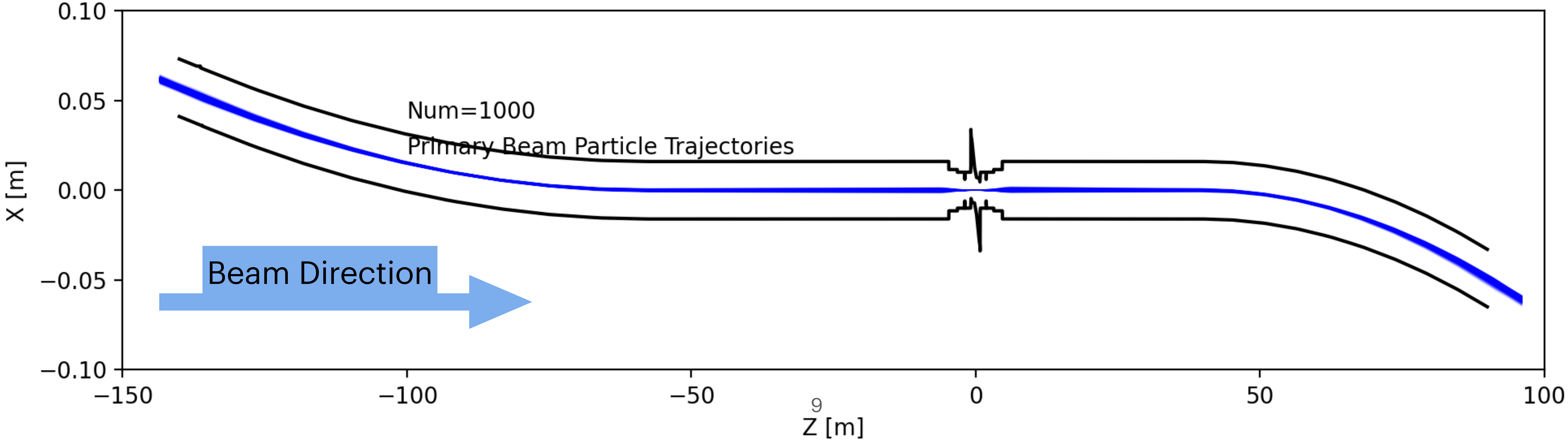
Trajectory

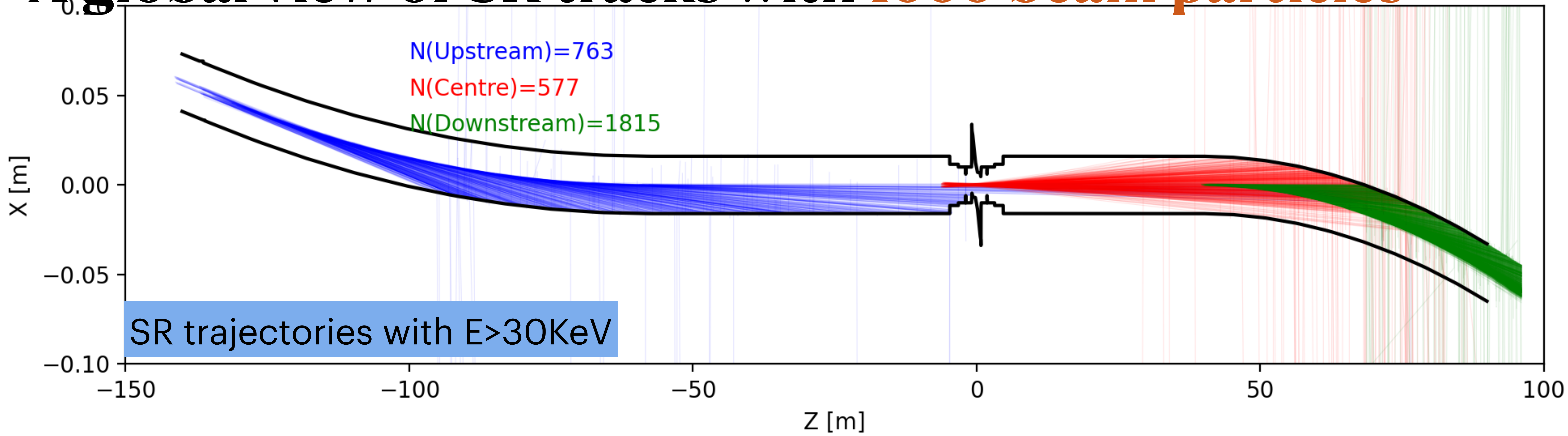
- **1000 beam particles** from left hand side to the right
  - Beam is stable
  - Optical behaviour
- SR Photon yield is the same as the TDR, **3 photons per beam particle**

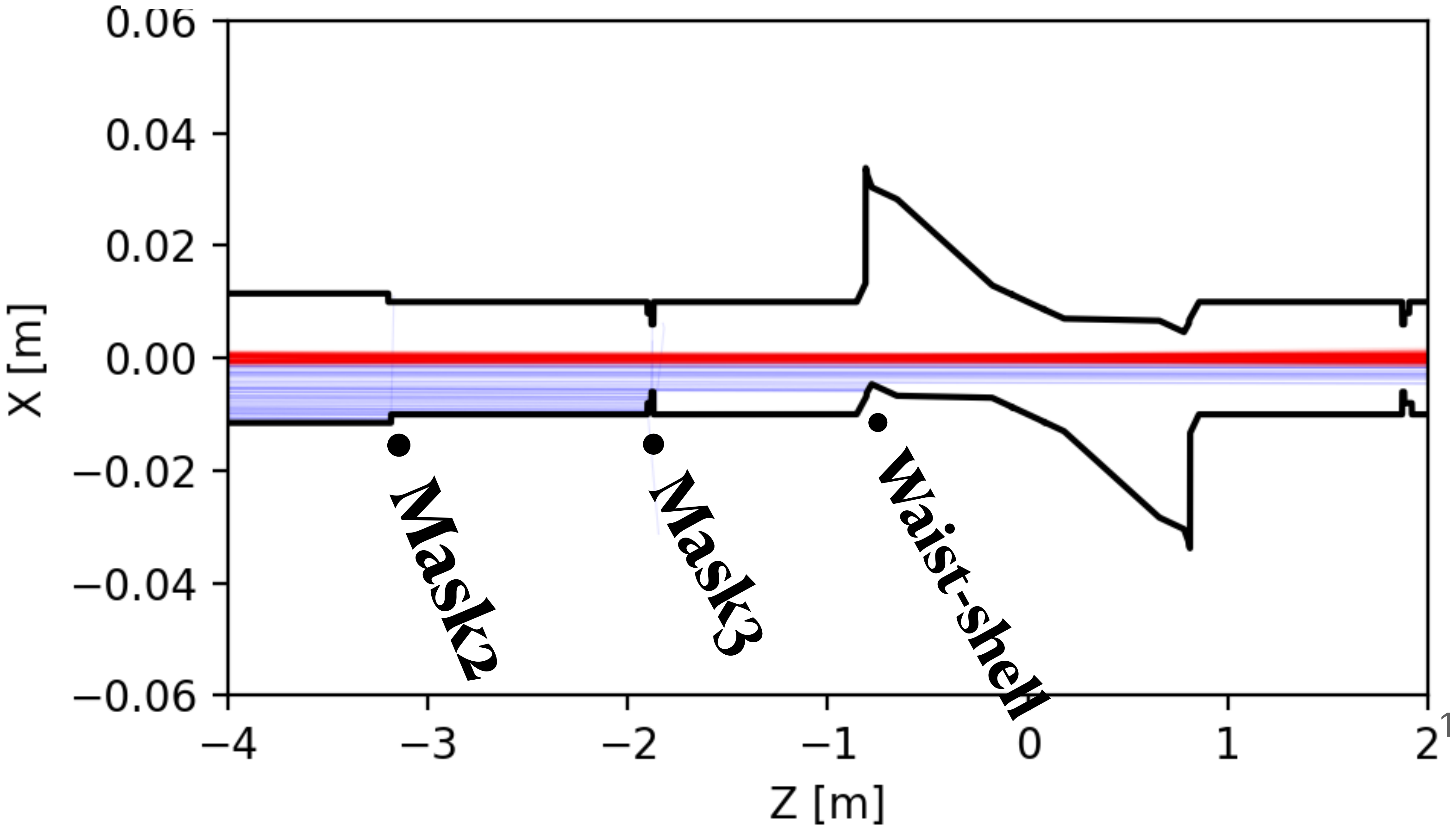




Trajectory

- A global view of SR tracks with 1000 beam particles

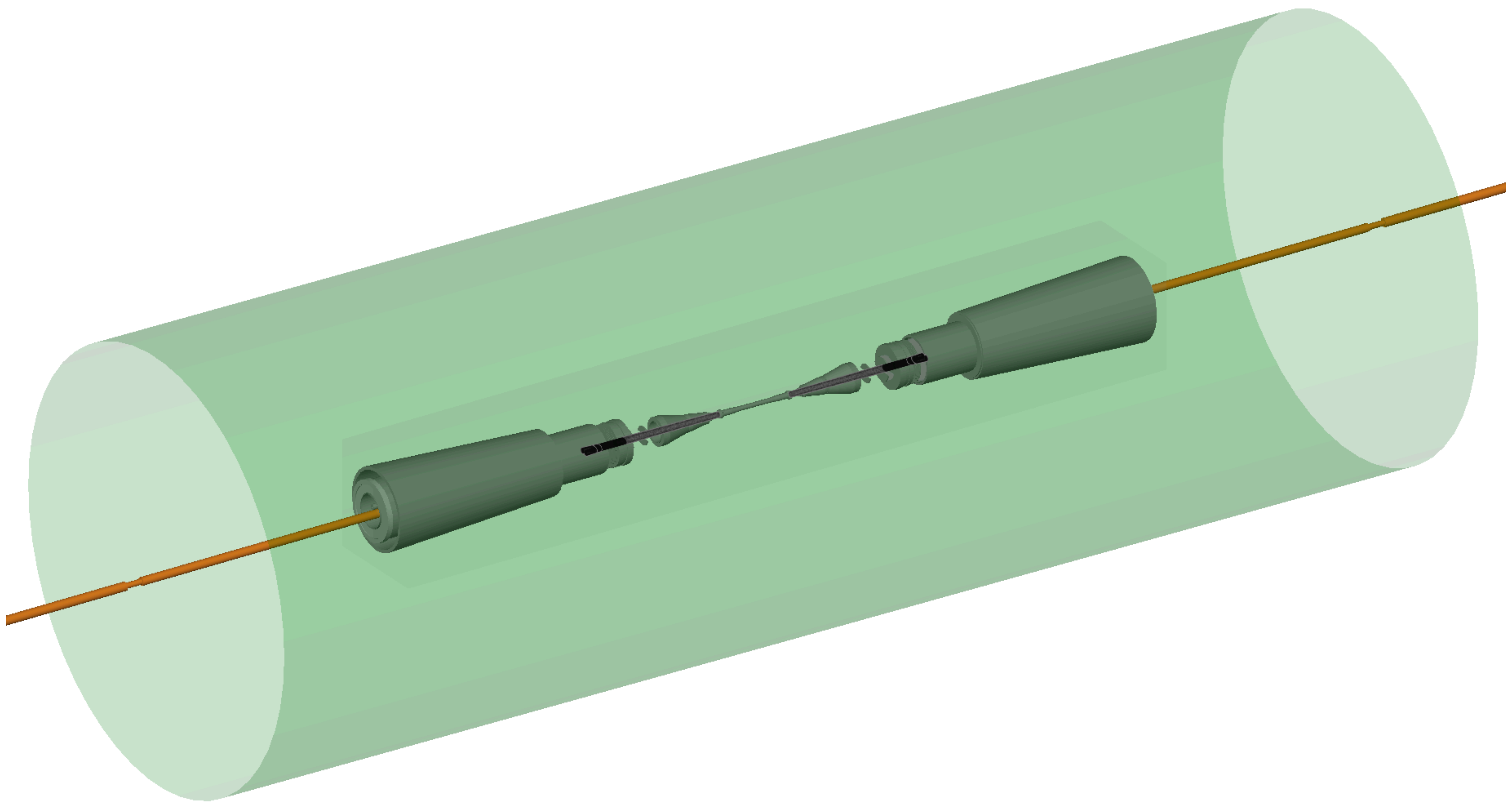




- Mask2, 3 and the waist-shell are exposed to many SR photons and become hotspots as the statistics increase

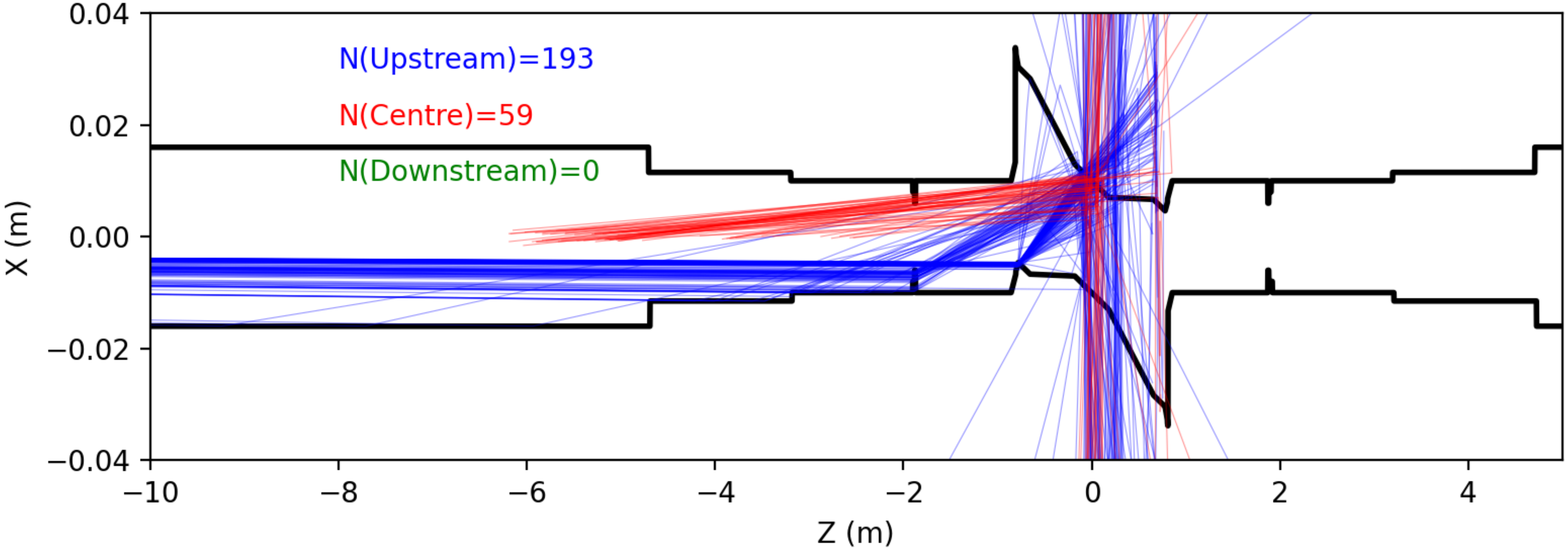
Trajectory

- A concept about SamplerSurface
  - A surface built in BDSIM records all particles passing trough it without material effects
  - The tracker system is not included in this simulation
    - A cylinder surface with length = 161.4 mm and radius = 11.1 mm is used for VTX L1
    - Hit rate of this layer @$\sqrt{s} = 240\text{GeV}$ ~ 112hits / 10^9beam particles

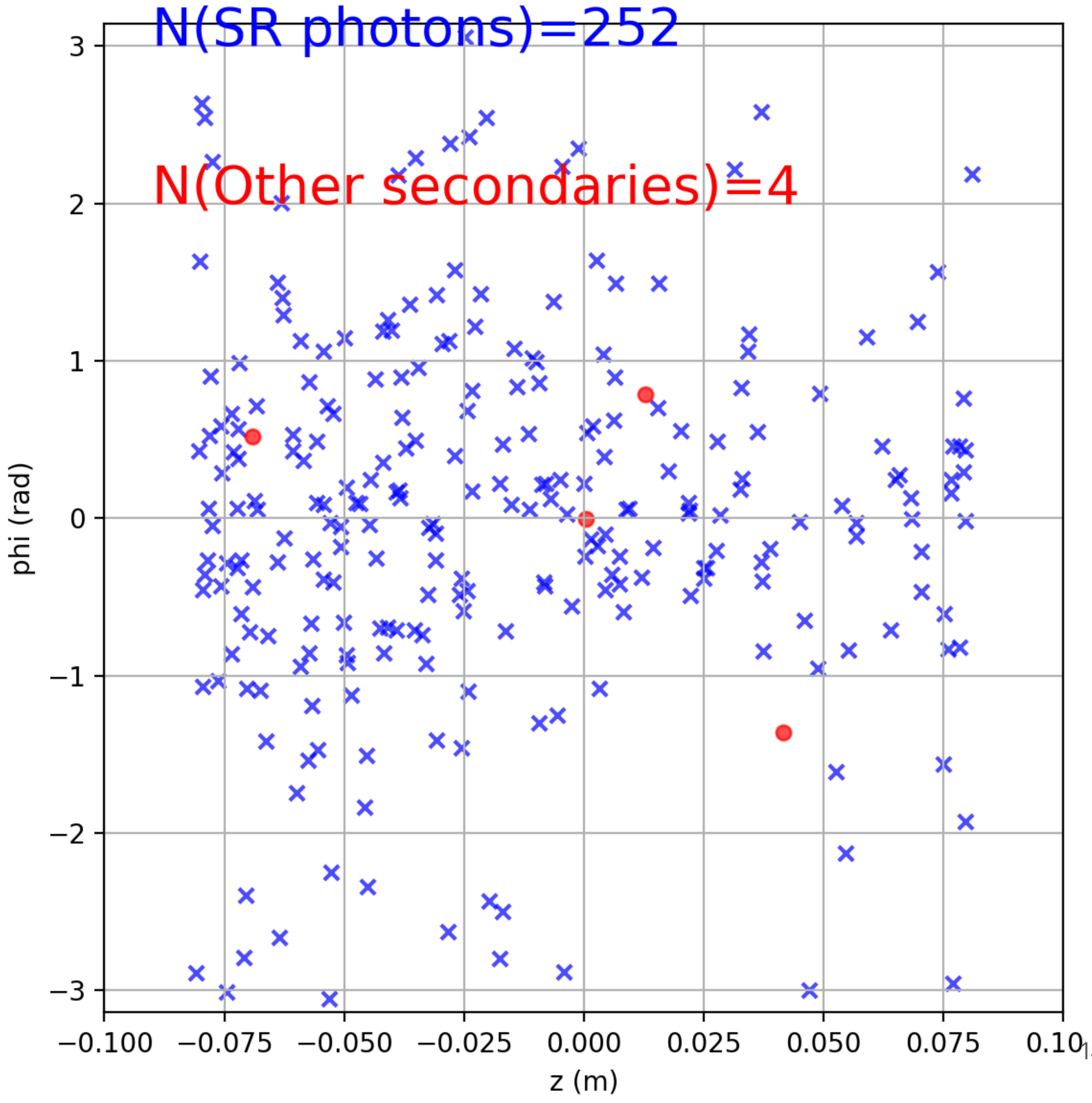


Trajectory

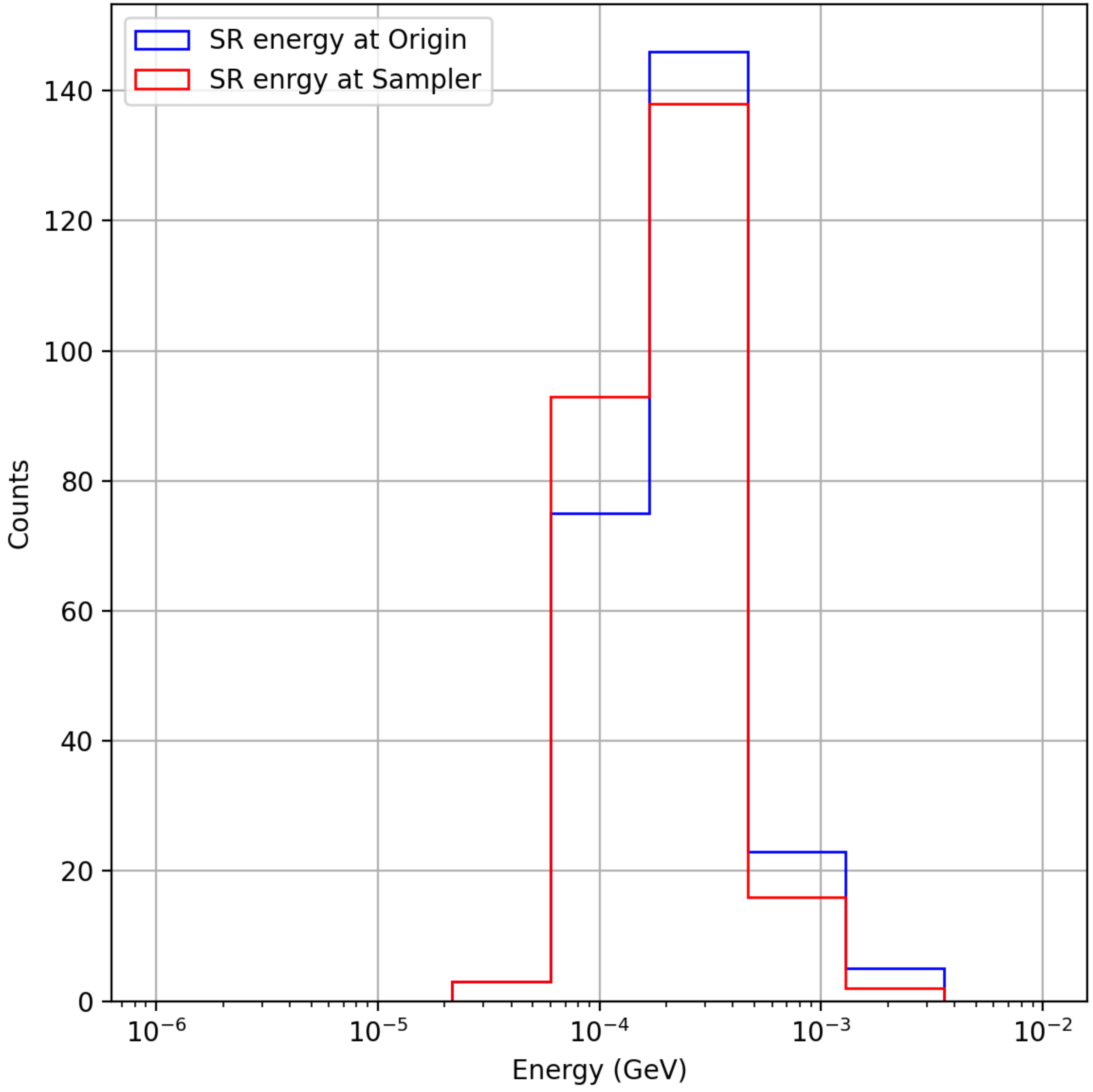
- *The same settings with TDR SR simulation*
  - *± 150 m around IP; SR photon energy threshold: 30KeV; No solenoid field; No magnet yoke*
- *Simulate 10^9 beam particles, only record the trajectories that cross the SamplerSurface*
- *1000 jobs, 1 h*



Trajectory



N(SR photons)=252
N(Other secondaries)=4
phi (rad)
z (m)
3
2
1
0
−1
−2
−3
−0.100
−0.075
−0.050
−0.025
0.000
0.025
0.050
0.075
0.100



SR energy at Origin
SR enrgy at Sampler
Counts
Energy (GeV)
140
120
100
80
60
40
20
0
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}

Trajectory

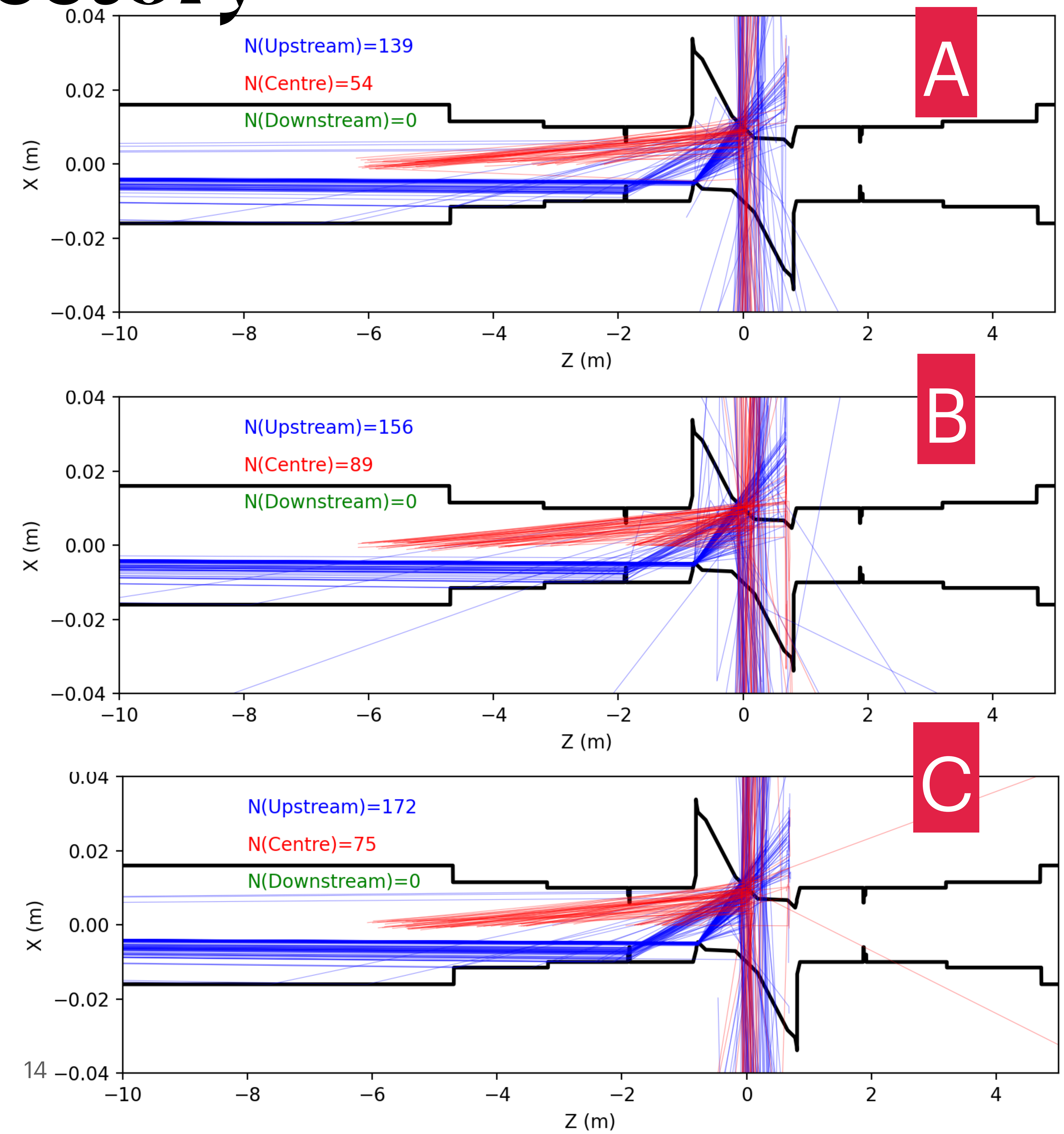
- *Settings of TDR SR simulation*
  - *± 150 m around IP*
  - *SR energy threshold: 30 KeV*
  - *No solenoid field*
  - *No magnet yoke*
  - *10^9 beam particles*

A. *SR threshold: 0 KeV*

B. *Add solenoid field*

C. *Add magnet yoke*

- *Apart from fluctuation, no new pattern is observed*



Cross comparison

- **A new framework for SR study vs. TDR**

10^9 beam particles	Number of CPU	Time	Hit at VXD L1/ 10^9 beam particles	
TDR	5000	10h	112	Full detector simulated
1: BDSIM baseline [the same settings as TDR]	1000	1h	256	Only centre pipe and lumical
2: BDSIM baseline, E_thr = 0	1000	2h	204	
3: BDSIM baseline, E_thr=0, add solenoid	1000	4h	250	
4: BDSIM baseline, E_thr=0, add solenoid and magnet yoke	1000	10h	254	

- **New result agrees with the TDR at the same order of magnitude , more details need to be checked with MDI people**

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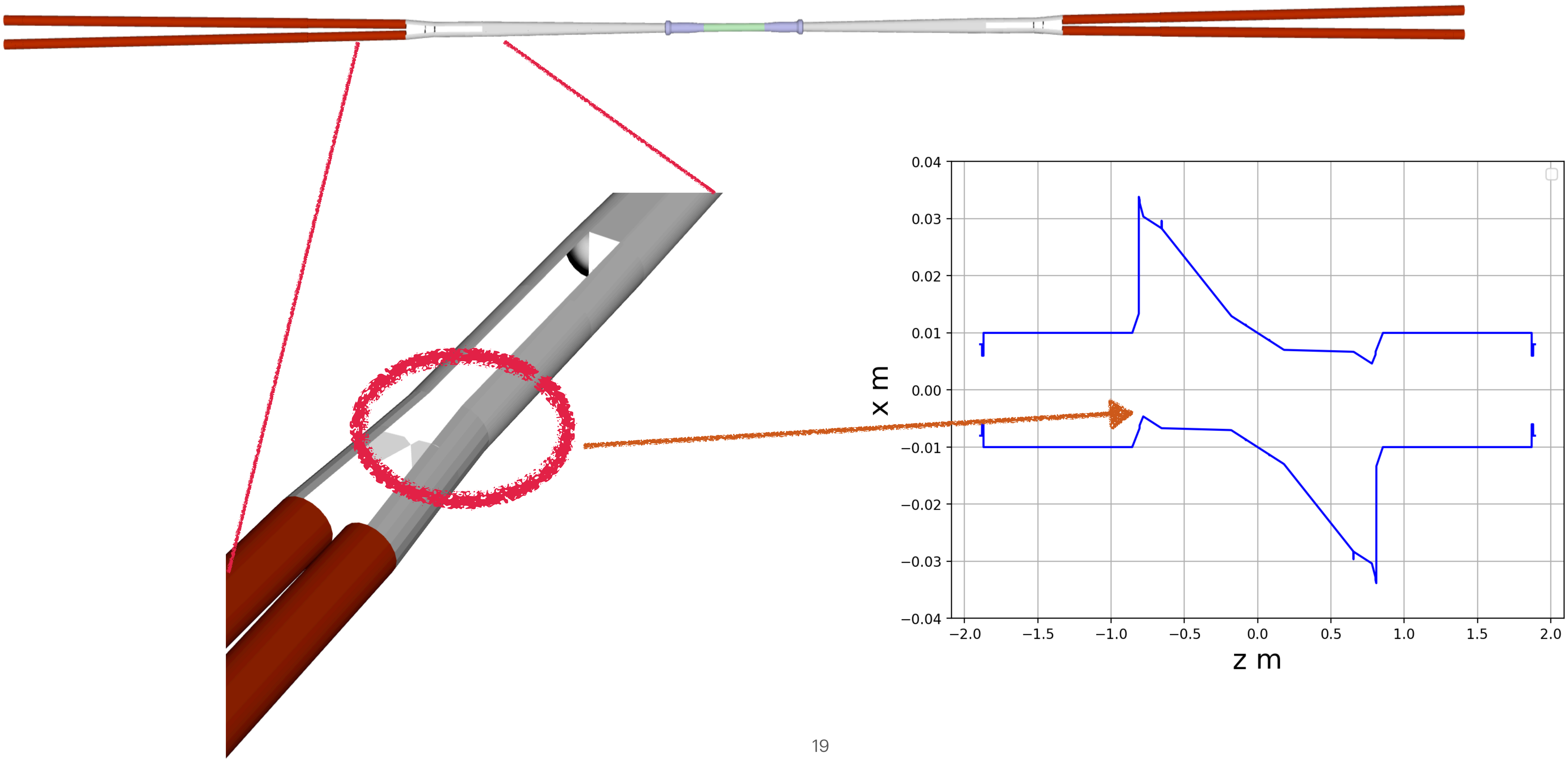
- The new framework works, and the results agree with the TDR within a safety factor of 10
  - However, the new result is about twice the TDR value, and this need further investigation
- The underlaying picture of the SR background is illustrated
  - 3 hotspots: SRMask3, Waist-shell, and the Final Quadrupole
- The new framework can probably speed up the simulation

- Backup

Aperture



Trajectory

- *Comparison with the TDR SR result*
  - *± 150 m around IP*
  - *SR photon energy threshold: 0 KeV*
  - *Add solenoid field*
  - *No magnet yoke*
- *Demonstrate the effects of solenoid field using only 10^3 beam particles*
  - *More SR photons are generated in the centre region*
  - *Most of them go to far downstream*