Update on Synchrotron Radiation Studies

Chenguang Zhang

2026-07-22

Outline

- Introduction
- Simulation Setup
- SR Studies
  - Issues observed with the Beam Core and Halo
  - Mitigation Optimisation
- Summary

Introduction

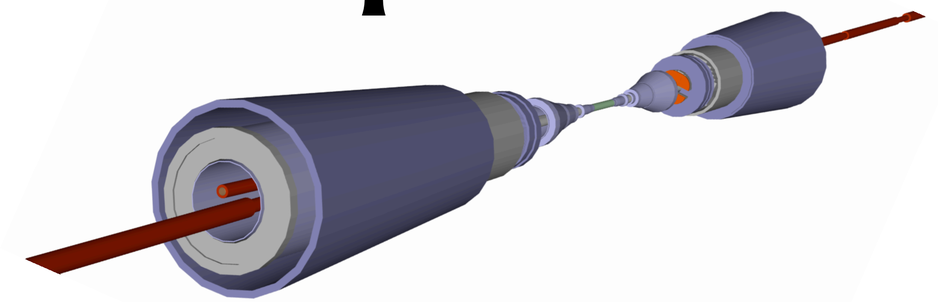
- Beam-induced background is a critical factor in detector performance

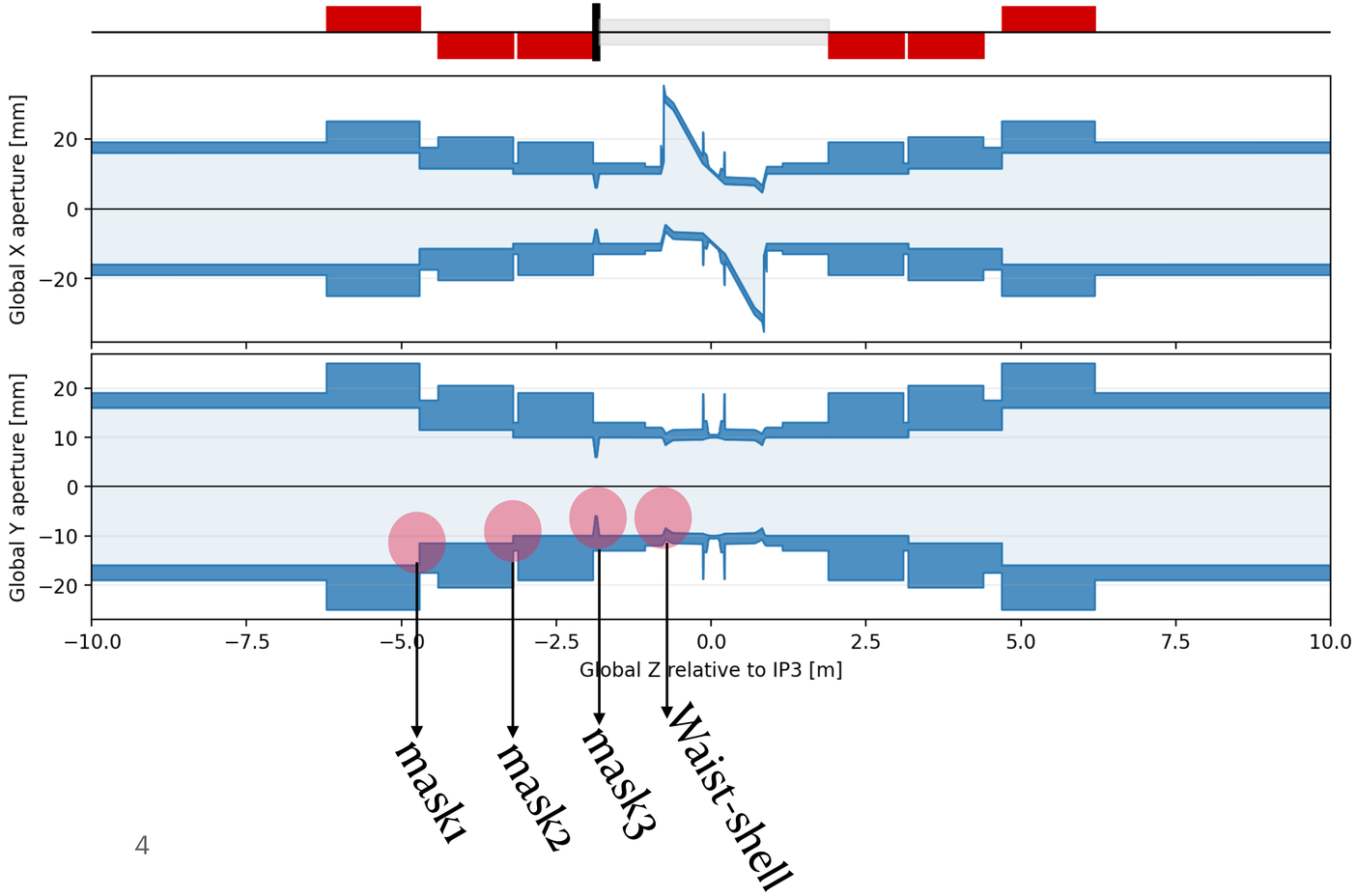
- Since the TDR, the SR simulation framework has been updated
  - It incorporates accelerator particle tracking and particle-matter interaction simulations based on BDSIM (Beam Delivery Simulation)
  - Results from the new framework have been cross-checked against the TDR in terms of SR photon escape rate through the centre pipe

- **Speed up the SR simulation**
  - **Fast iteration enables SR mitigation optimisation**
  - **Enabling betatron oscillations allows the beam halo to be defined more realistically**

Simulation Setup

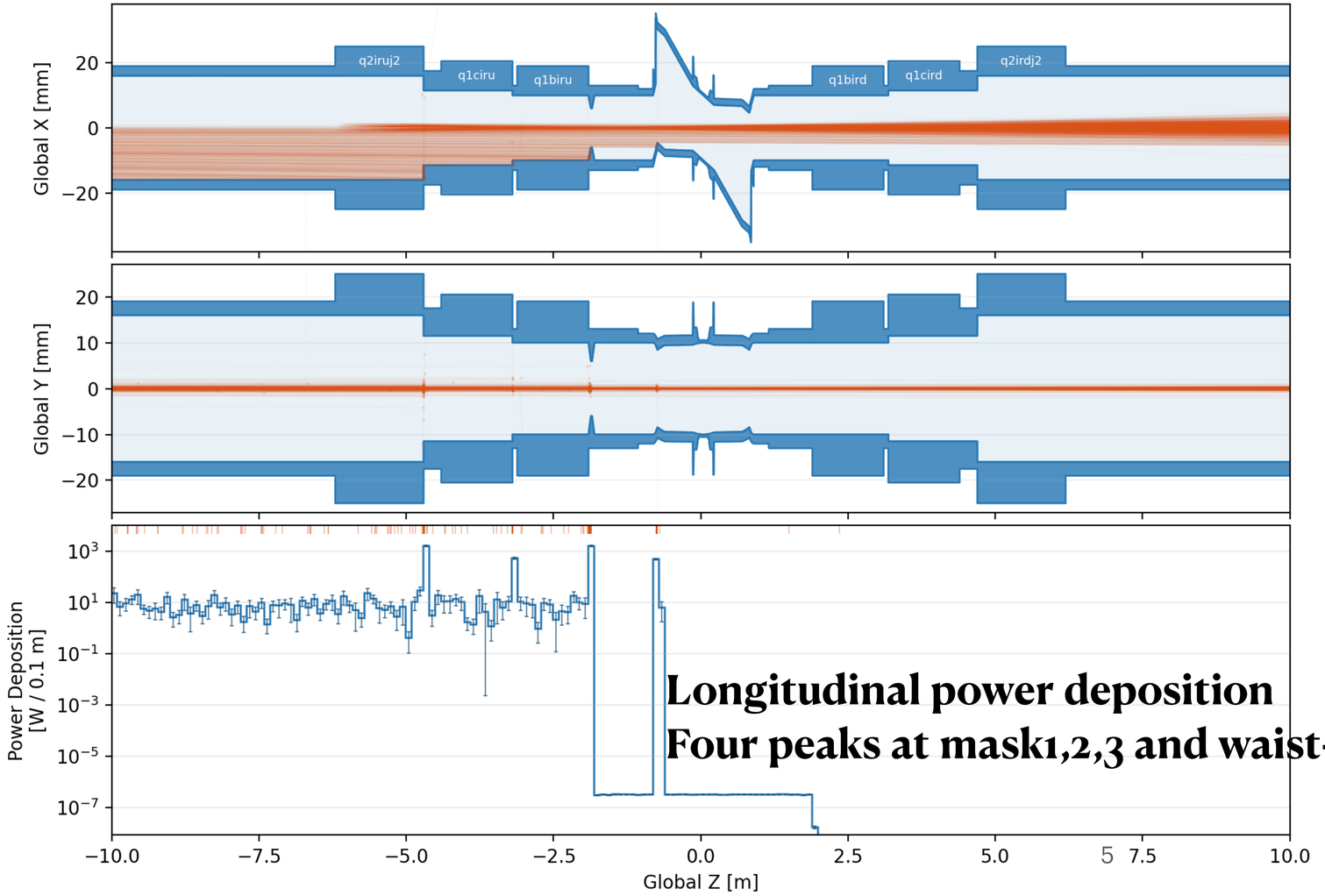
- SR simulation around IR at $\sqrt{s} = 240$ GeV
- Accelerator lattice is connected to the MDI geometry
- A gaussian e^+ beam starts at the beginning of the upstream bend; the beam core and halo are simulated separately, with SR, EM processes enabled
- SR mitigation system (TDR):
  - 10μm golden layer
  - 1 fixed mask [mask3]





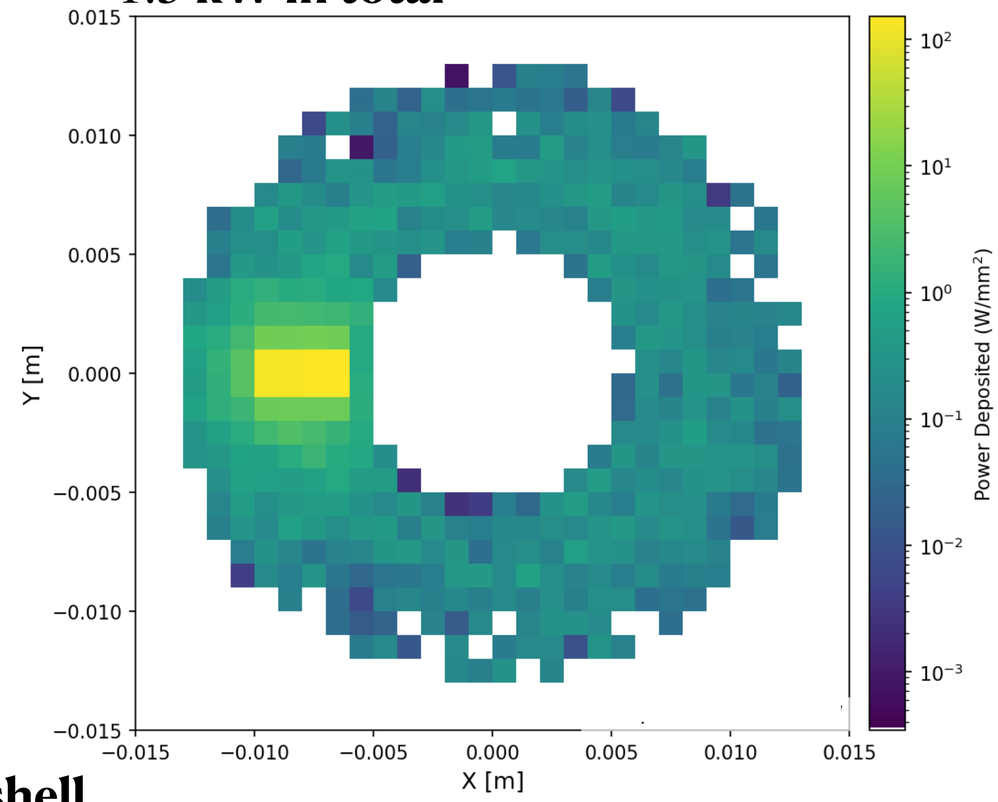
SR Power Deposition [Beam Core]

- Four SR hot spots were identified: SR-mask1,2,3 and waist-shell
  - Power deposition at these hot spots is great than 1 kW



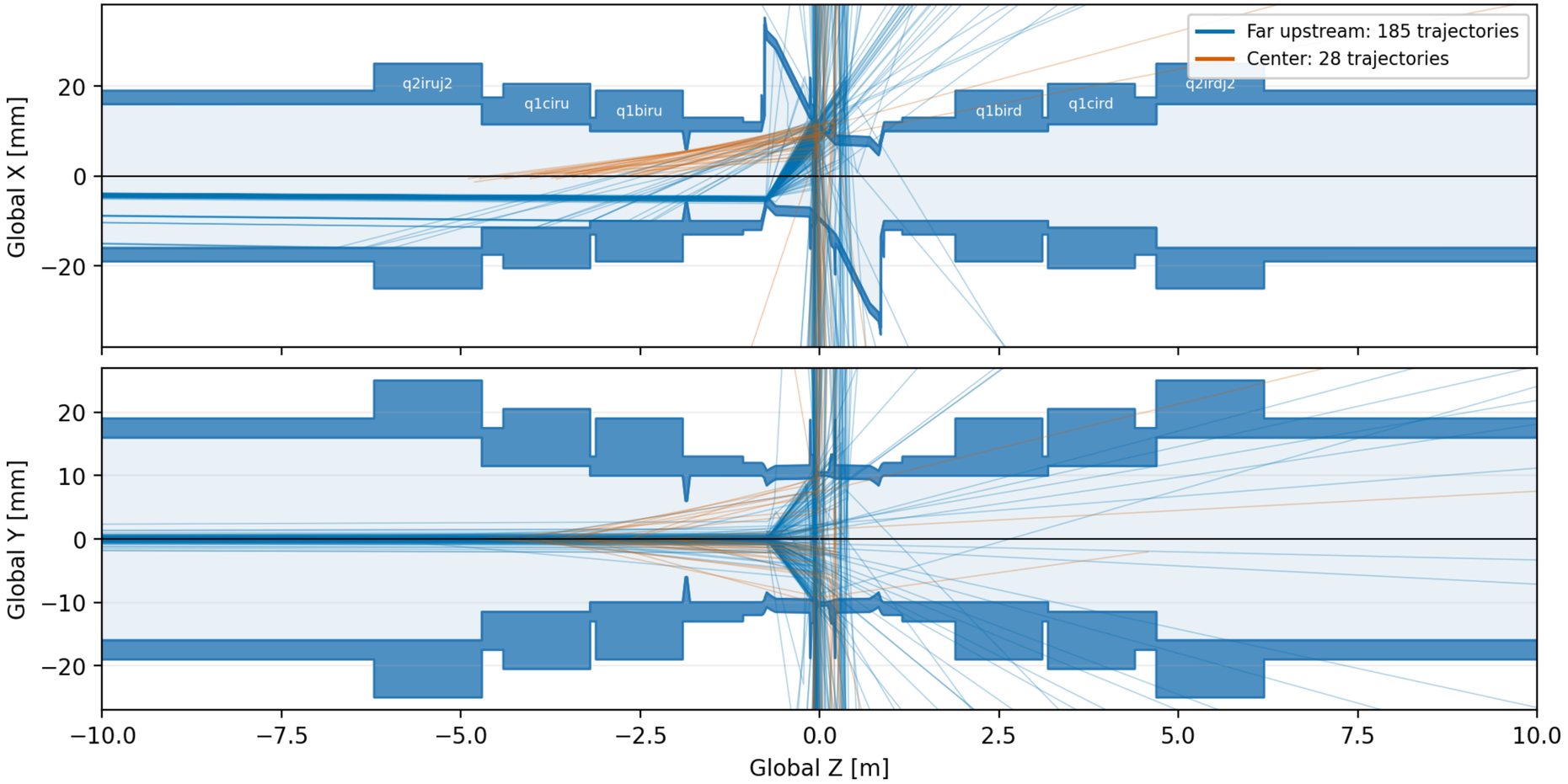
Transverse power deposition at mask3

1.5 **kW in total**



SR Photon Escape Rate [Beam Core]

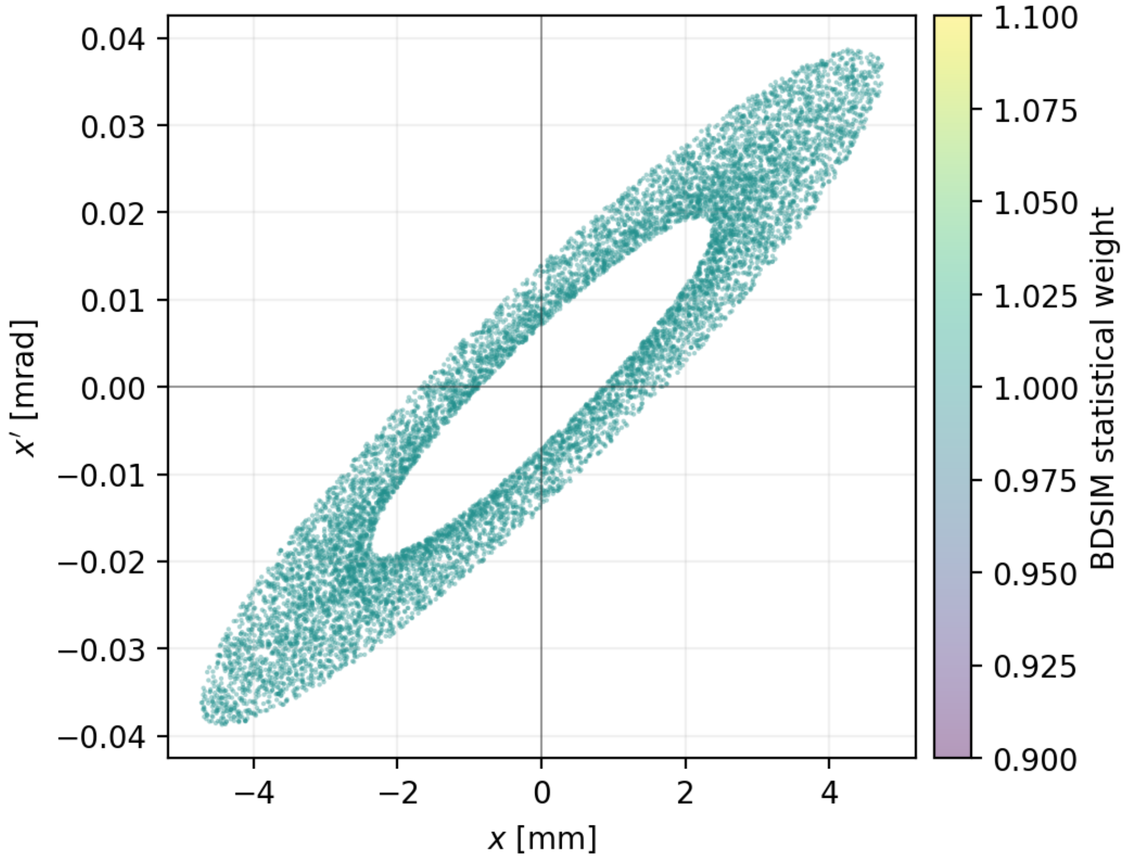
- Photons can contaminate physics signals when they escape through the centre pipe

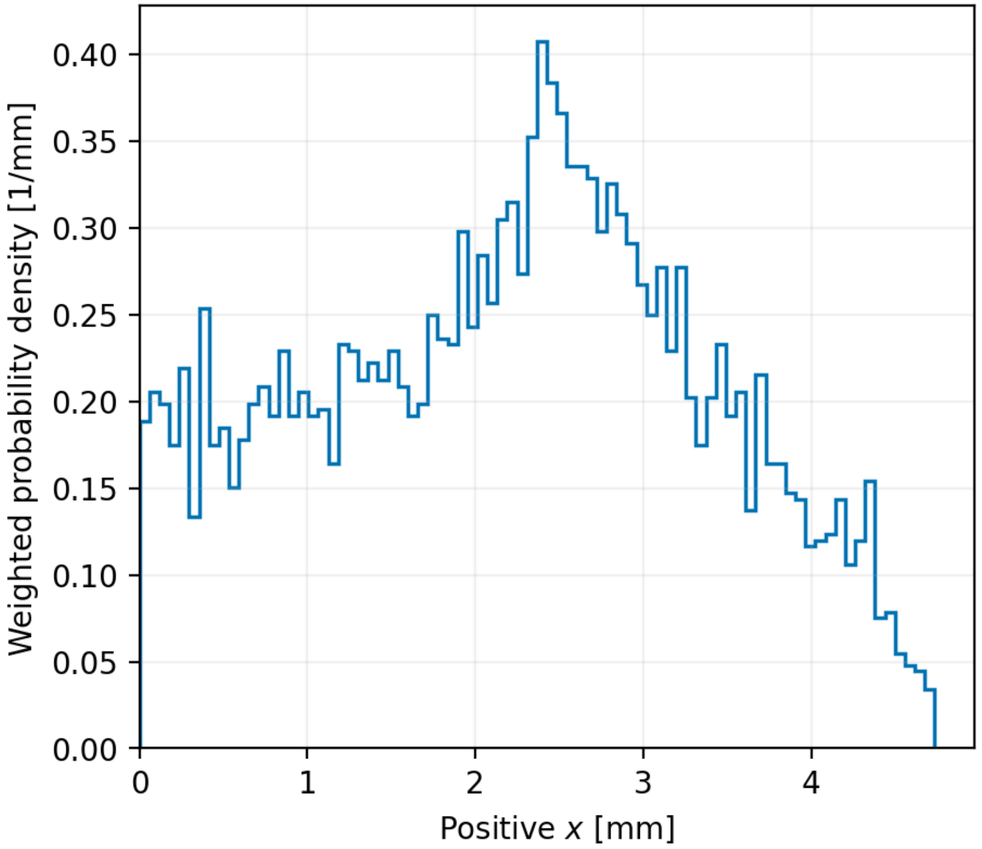


- For 10^9 beam particles, ~ 200 SR photons escape through the centre pipe
- Equivalently; Photon escape rate ~ 20 k/bunch
- 0.42 GeV/bunch
- The upstream dipole and FQs contributions are in a 9:1 ratio

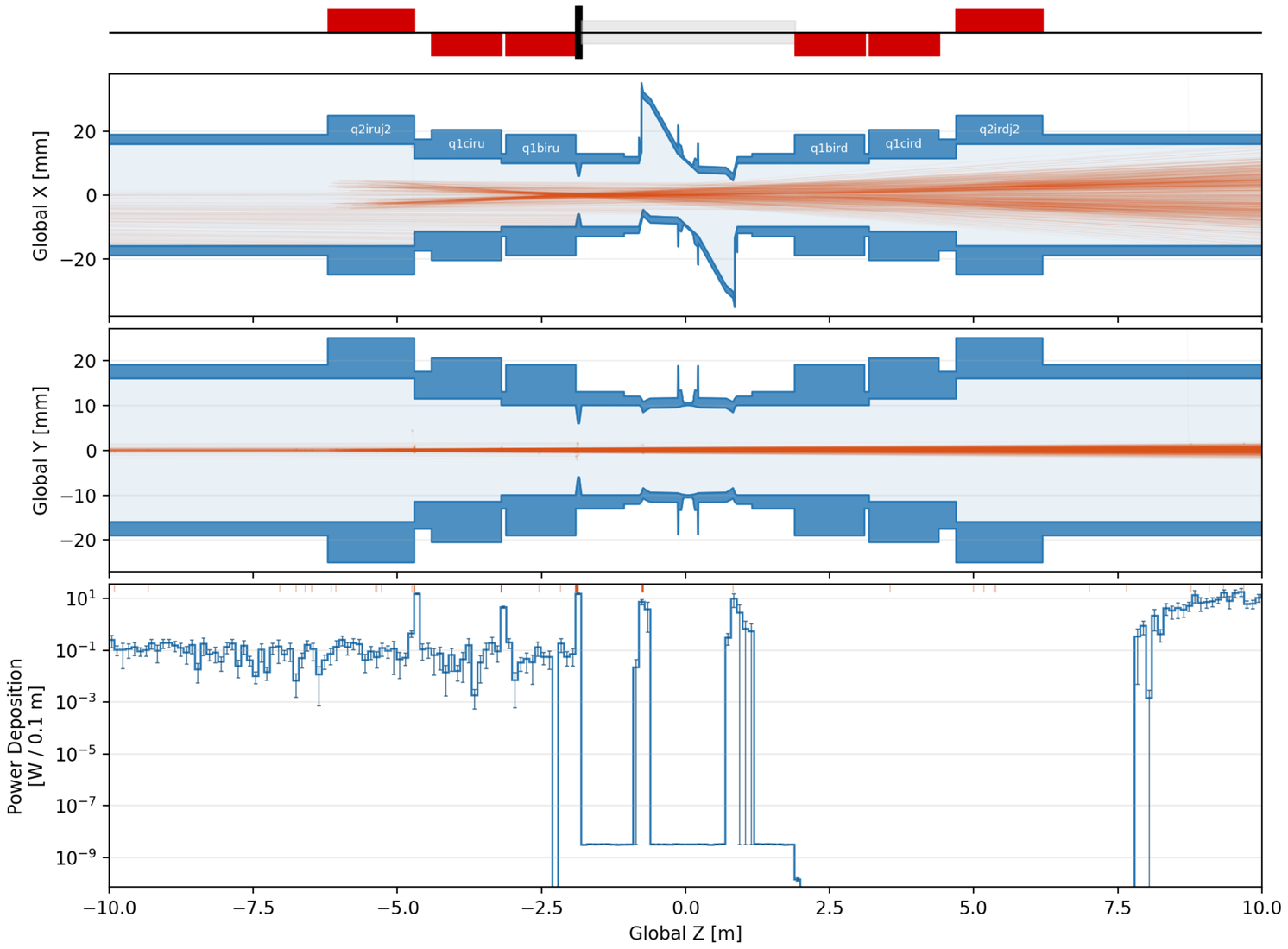
Beam Halo

- Beam halo is generated within 5-10 sigma range in $x - x'$ space
  - Assume 1% of the total beam population, with an exponential tail





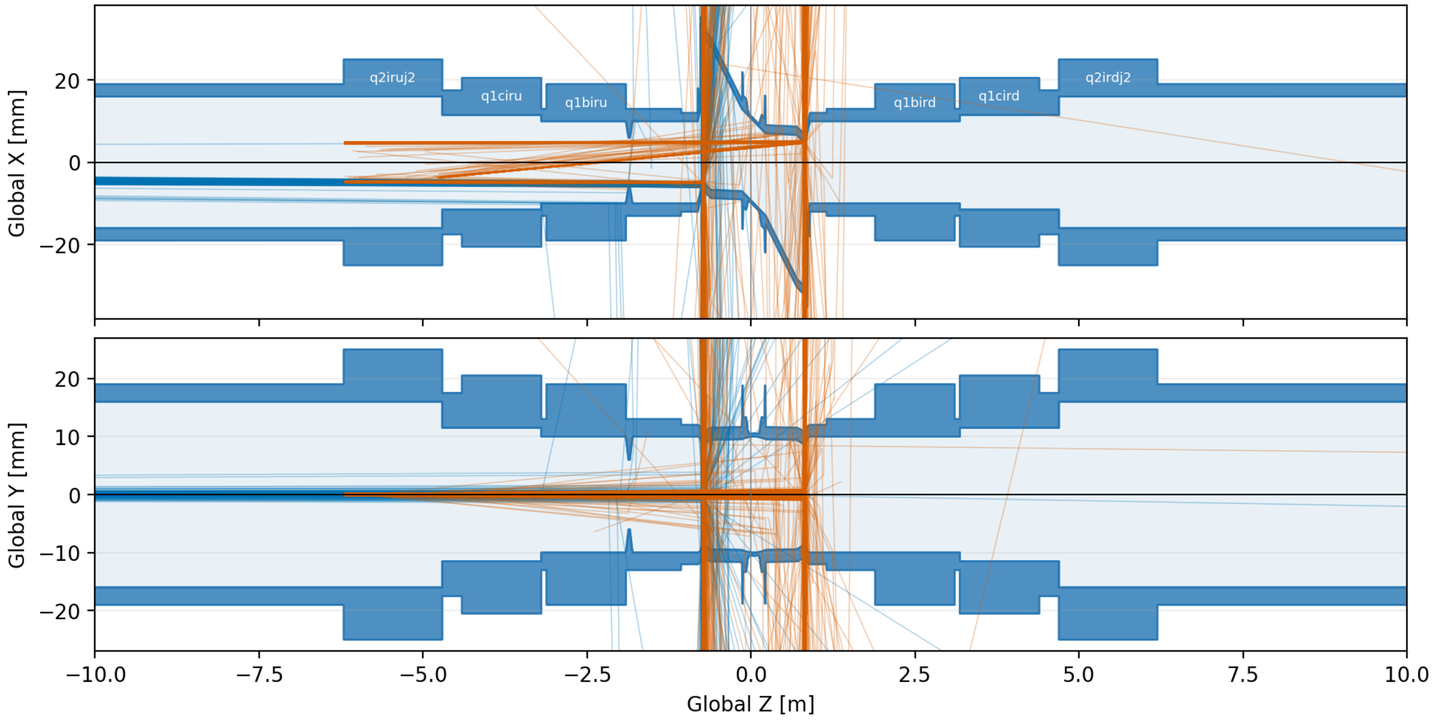
SR Power Deposition [Beam Halo]

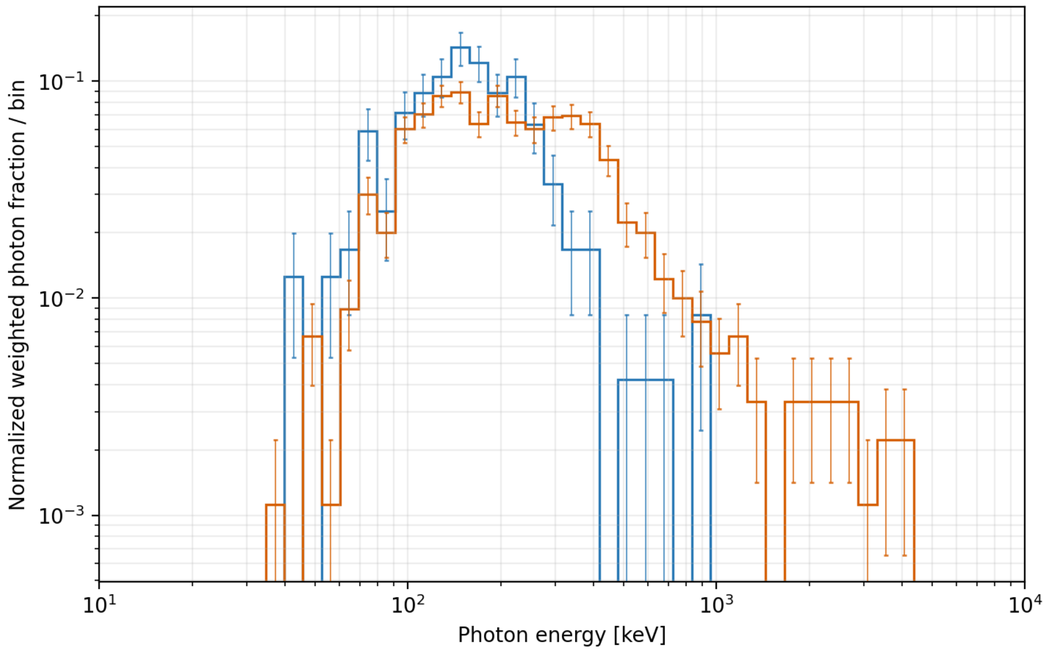


- Power deposition is consistent with the assumed beam halo fraction
  - Beam core (99%) —> 1 kW at the SR-hotspots
  - Beam halo (1%) —> 10 W at the SR-hotspots
- However, a new near-IP hot spot emerges at the downstream waist-shell

SR Photon Escape Rate [Halo]

- SR-photon escape rate demonstrates weak points of the current design
  - For 10^8 beam particles, ~45 k SR-photons escape; Equivalently 450 k/bunch
  - 200 GeV/bunch; No interaction with VXD but instead enter the ITK and the gas chamber





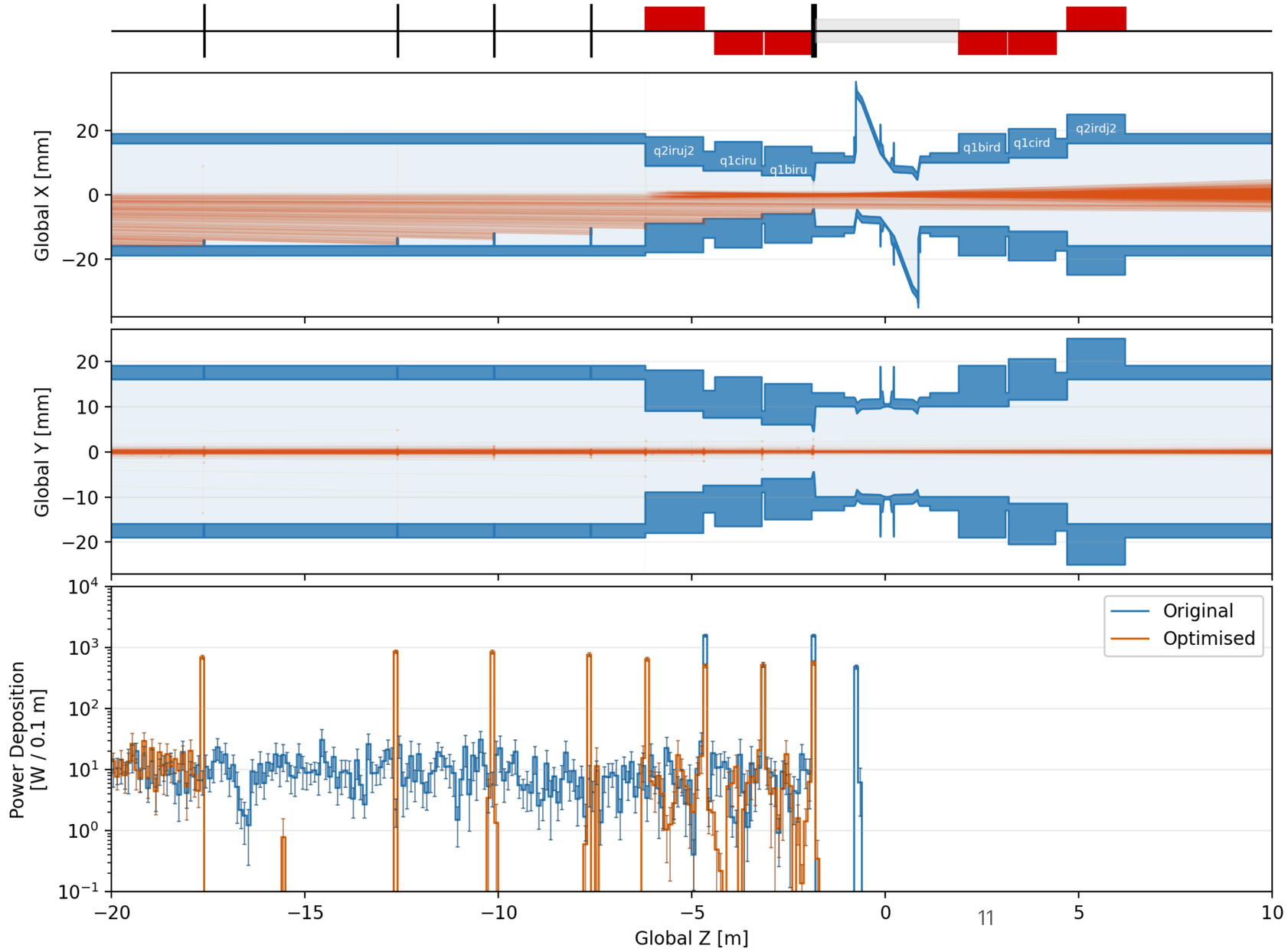
Optimisation

- Both power deposition and photon escape rate need to be optimised
- SR-fan analysis guides the optimisation, rather than a brute simulation scan

	Location/Half-aperture (m/mm)		Deposited power (kW)	
	Original	**Optimised**	**Original**	**Optimised**
jaw-1	Not present; flat drift chamber	-17.6/14.2	Flat drift chamber 0.1 kW/m	0.6 kW
jaw-2		-12.6/13.5		0.8 kW
jaw-3		-10.1/12.0		0.8 kW
jaw-4		-7.6/10.4		0.8 kW
mask0		-6.2/9.0		0.7 kW
mask1	-4.7/11.5	-4.7/7.5	1.6 kW	0.6 kW
mask2	-3.19/10	-3.19/6.0	0.6 kW	0.6 kW
mask3	-1.9/6	-1.9/4.5	1.5 kW	0.6 kW

- Reducing mask3 aperture from 6mm to 4.5mm is expected to improve mitigation efficiency

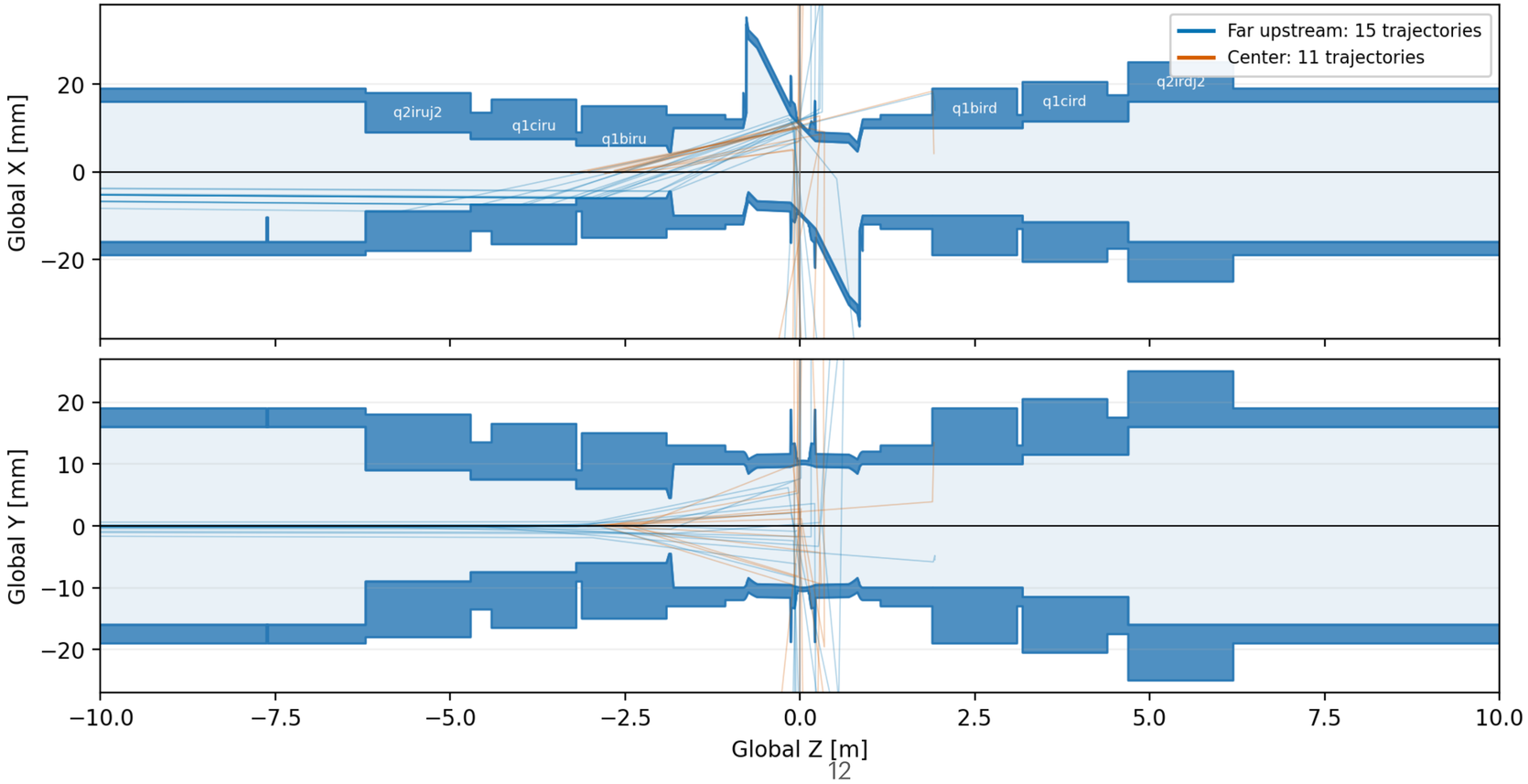
SR Power Deposition [Beam Core]



- After multiple SR shielding elements were introduced in the upstream drift chamber, **the deposited power at the new-IP SR decreased to below 1 kW**
- Trade-off: more SR-hots pots, **but they are far from the IP**

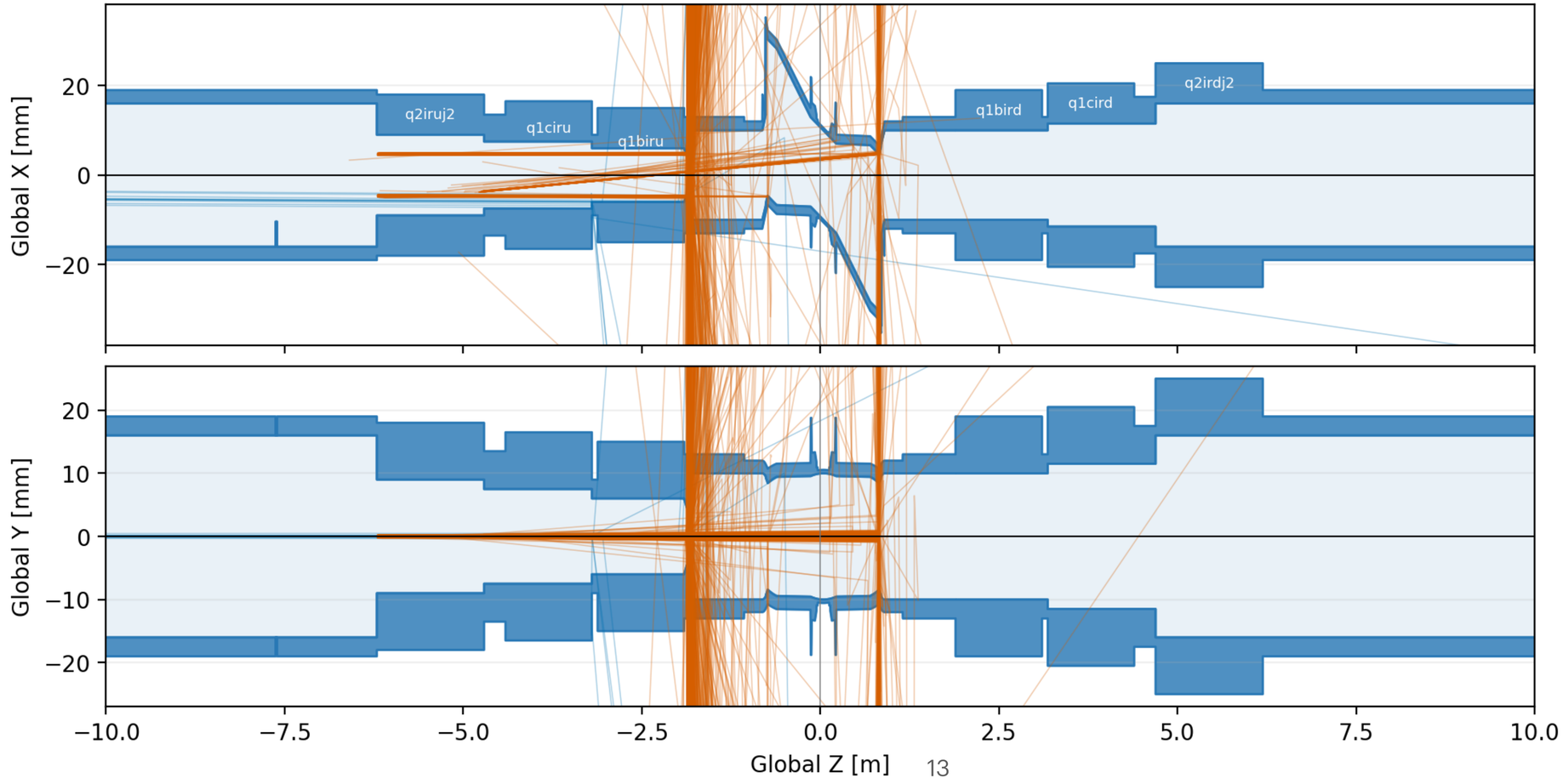
SR Photon Escape Rate [Beam Core]

- Photon escape rate through centre pipe is **reduced from 20 k to 3 k** per bunch
  - A narrower mask3 aperture removes the previous hot spot at the upstream waist-shell
  - It also intercepts some of the SR photons from the FQs

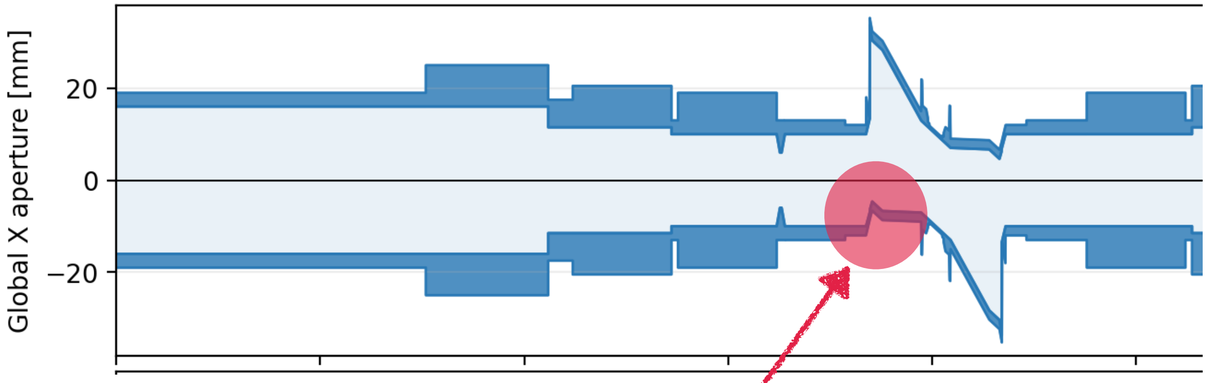


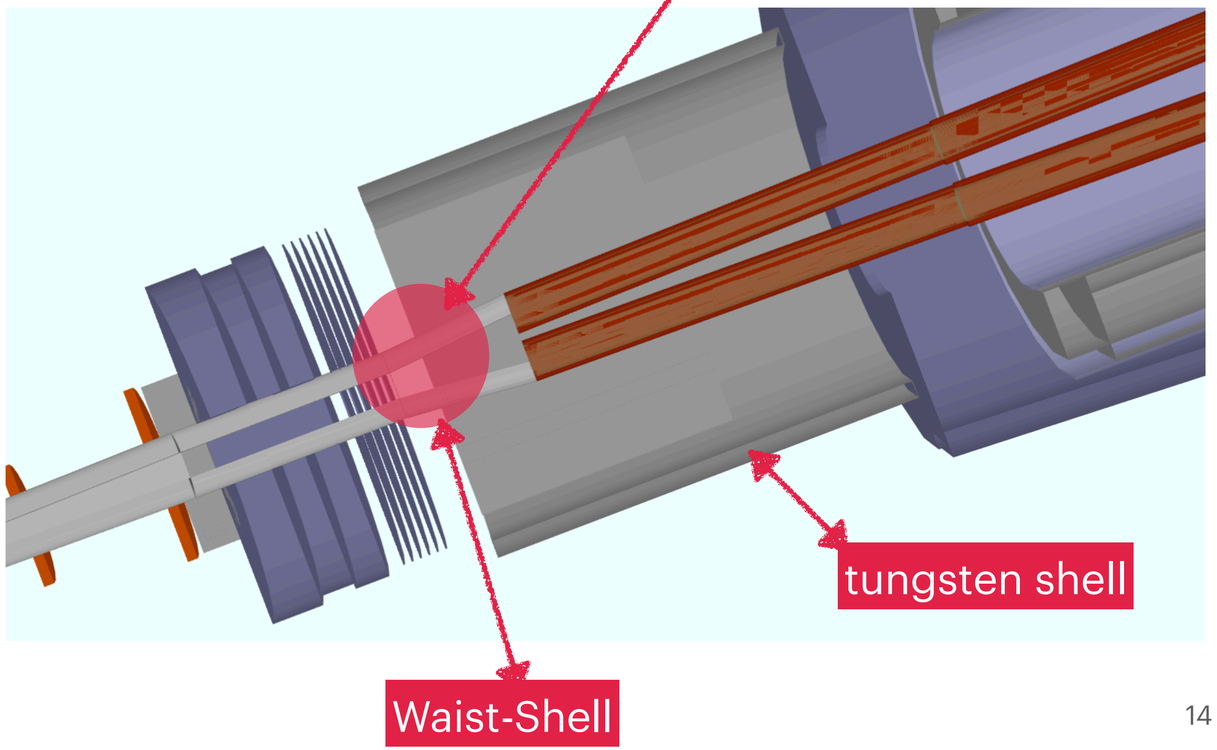
SR Photon Escape Rate [Beam Halo]

- The result is unchanged from before optimisation; 450 k/bunch
  - Due to a narrow mask3 aperture, the hot spots move from upstream waist-shell to mask3
  - A possible solution is to modify the shape of waist-shell directly



Further Optimisation





- The next step is to optimise the shape of waist-shell and extend the outer tungsten shell; This work is ongoing...

Summary & Next Steps

- The new SR simulation software is working well
- A very preliminary optimisation study shows promising results for beam core, but more work needs to be done for the beam halo

- The workflow is proved as inefficient because geometry and simulated events must be exchanged between two software packages.
  - Integration of the beam-simulation software into CEPCSW is in progress, coming soon