CERN

Update on R2E and Heat Load Simulations

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EN/STI-BMI and the Infrastructure and Operations Working Group

FCC Week 2019

Thursday, 27th June

Contents

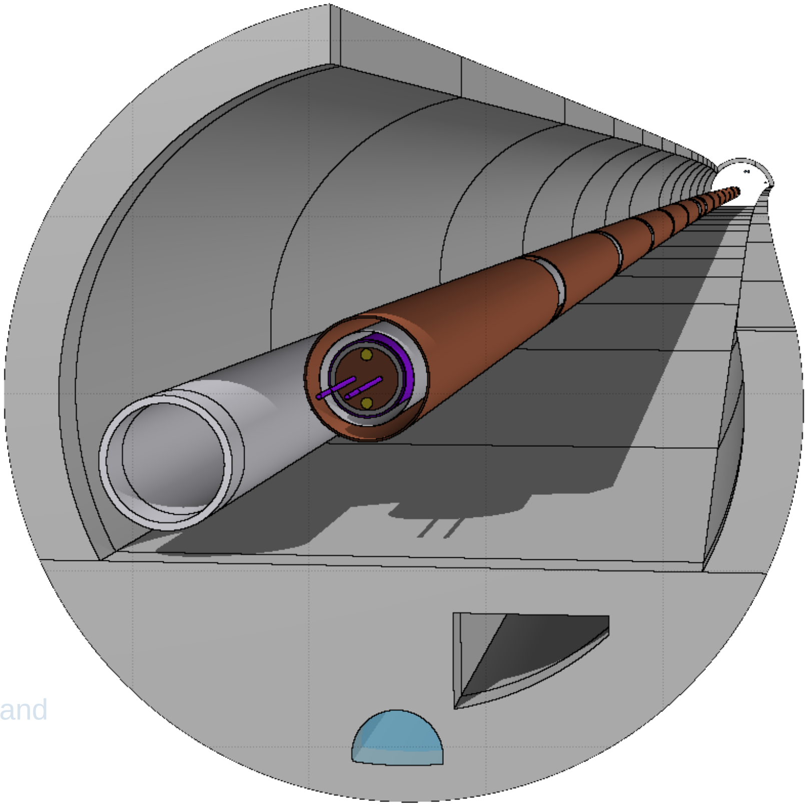
Introduction

- FCC-hh arc cell beam-gas interaction
  - Impact of secondary showers on magnets and electronics.
- Beam lifetime, τ, considering losses due to nuclear scattering with residual gas:

$$\tau = \frac{1}{\sigma_g c n_g} > 100\ h$$

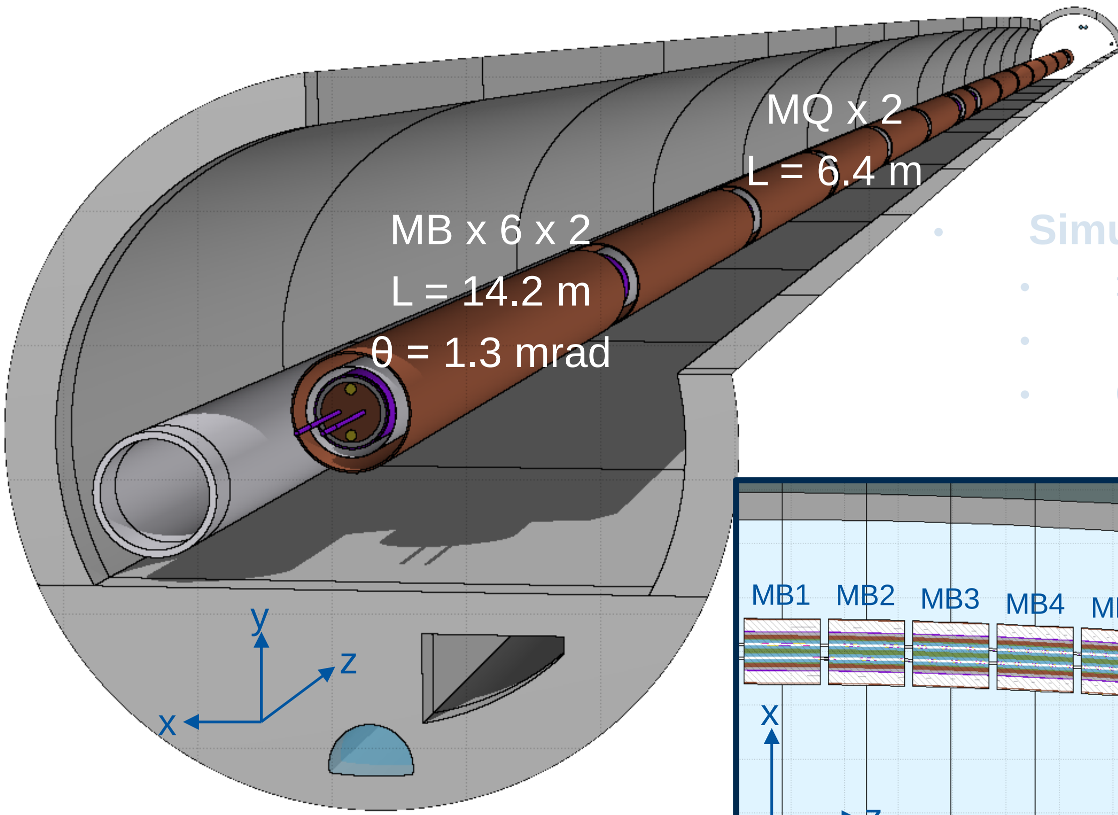
Where:
σ_g nuclear scattering cross section (86.4 mb),
n_g molecular gas density
-> Gives $n_g = 1 \times 10^{15}$ atoms/m^3

- Update on previous work carried out by A. Infantino
  - FCC week 2017: "FLUKA Montecarlo modelling of the FCC arc cell: radiation environment and energy deposition due to beam-gas interactions"
  - FCC week 2018: "Radiation environment assessment in the FCChh and FCCee machines"



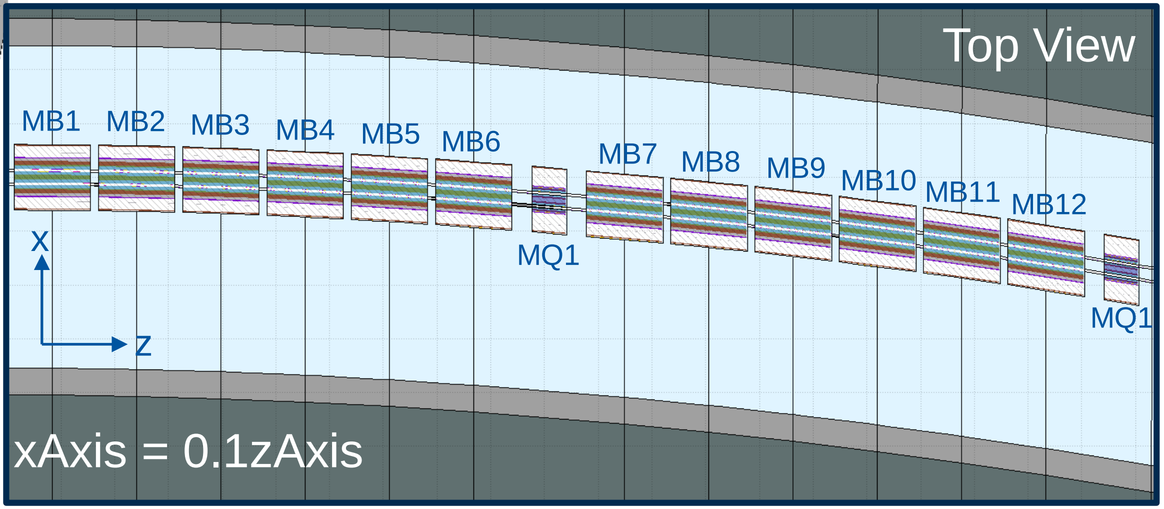
FLUKA Model

FCC-hh arc FODO cell

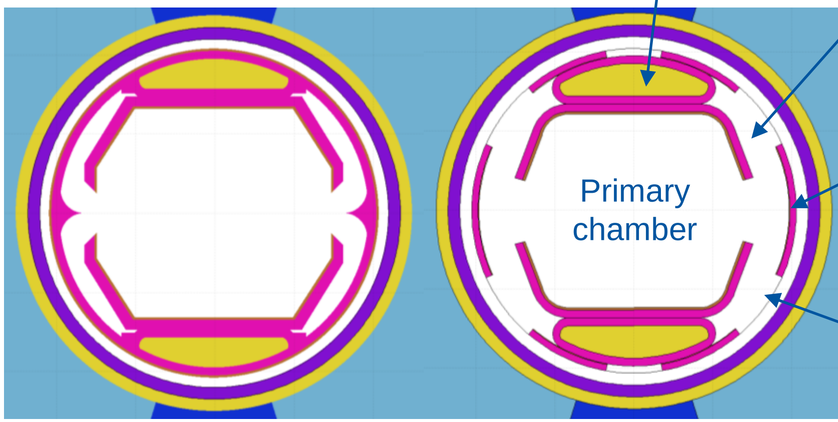


- Lattice based on latest optics, MAD-X TWISS file (R. Martin)
- 214 m in length

- **Simulation Parameters:**
  - >200,000 primaries per beam
  - Boundary condition
  - CPU Time ~120 – 130 seconds per primary



Updates



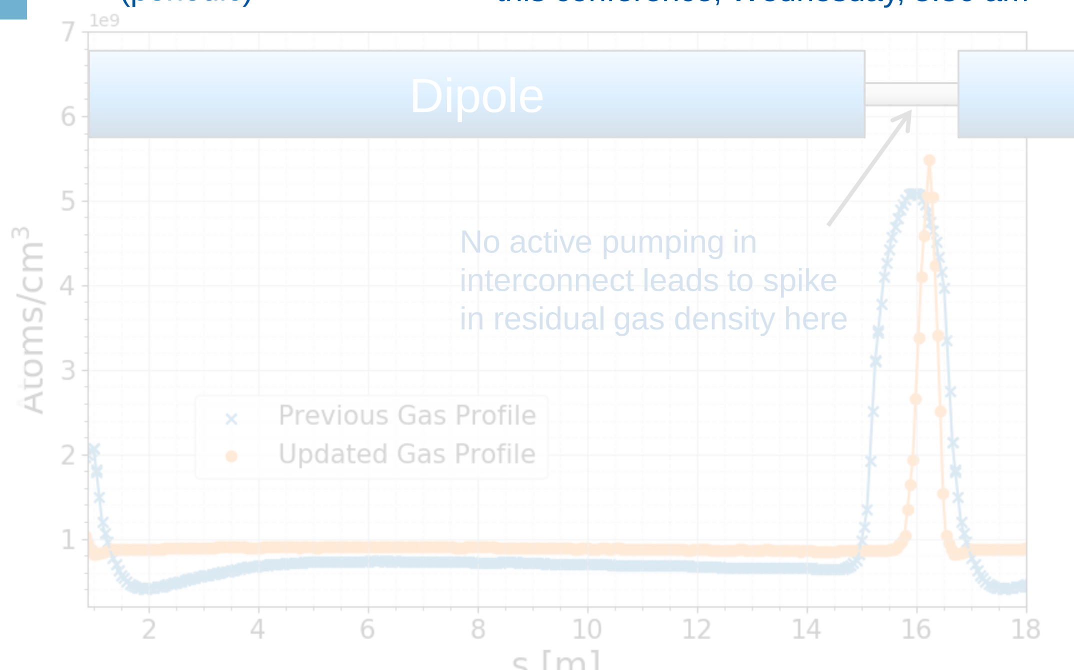
Beam Screen

- New scheme for dealing with synchrotron radiation effects
- Better vacuum quality and lower electron cloud density

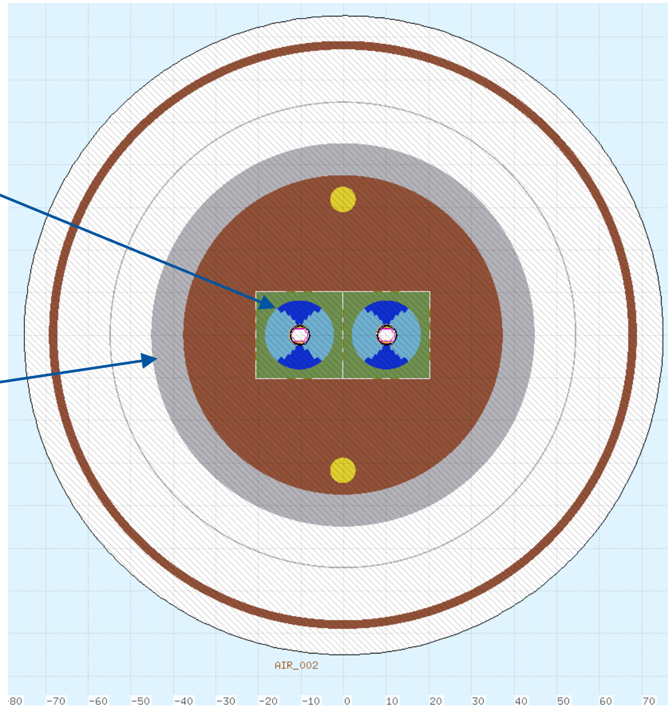
- I. Bellafont: "Study on the beam induced vacuum effects in the FCC-hh beam vacuum chamber", this conference, Wednesday, 8:30 am

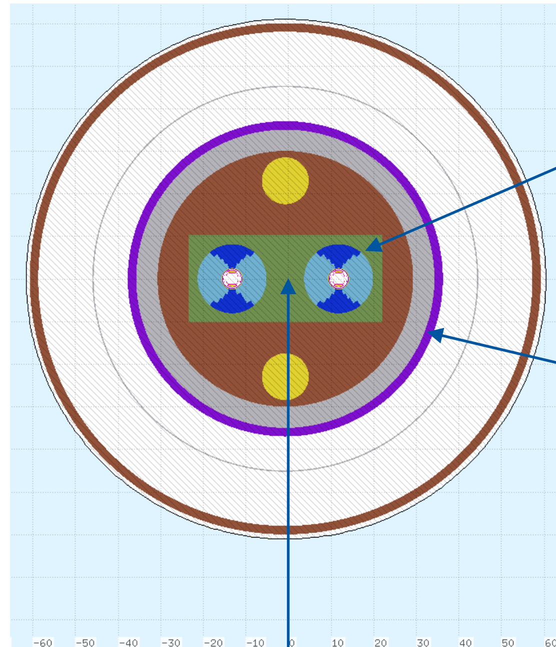
Gas Profile

- Average gas density unchanged (1e9 atoms/cm^3)
- Shorter photon absorber (previously absorbing ~x2 more power than now which led to higher outgassing.)
- Optimised interconnect region geometry, increasing the conductance of the region.



Lattice Element Updates

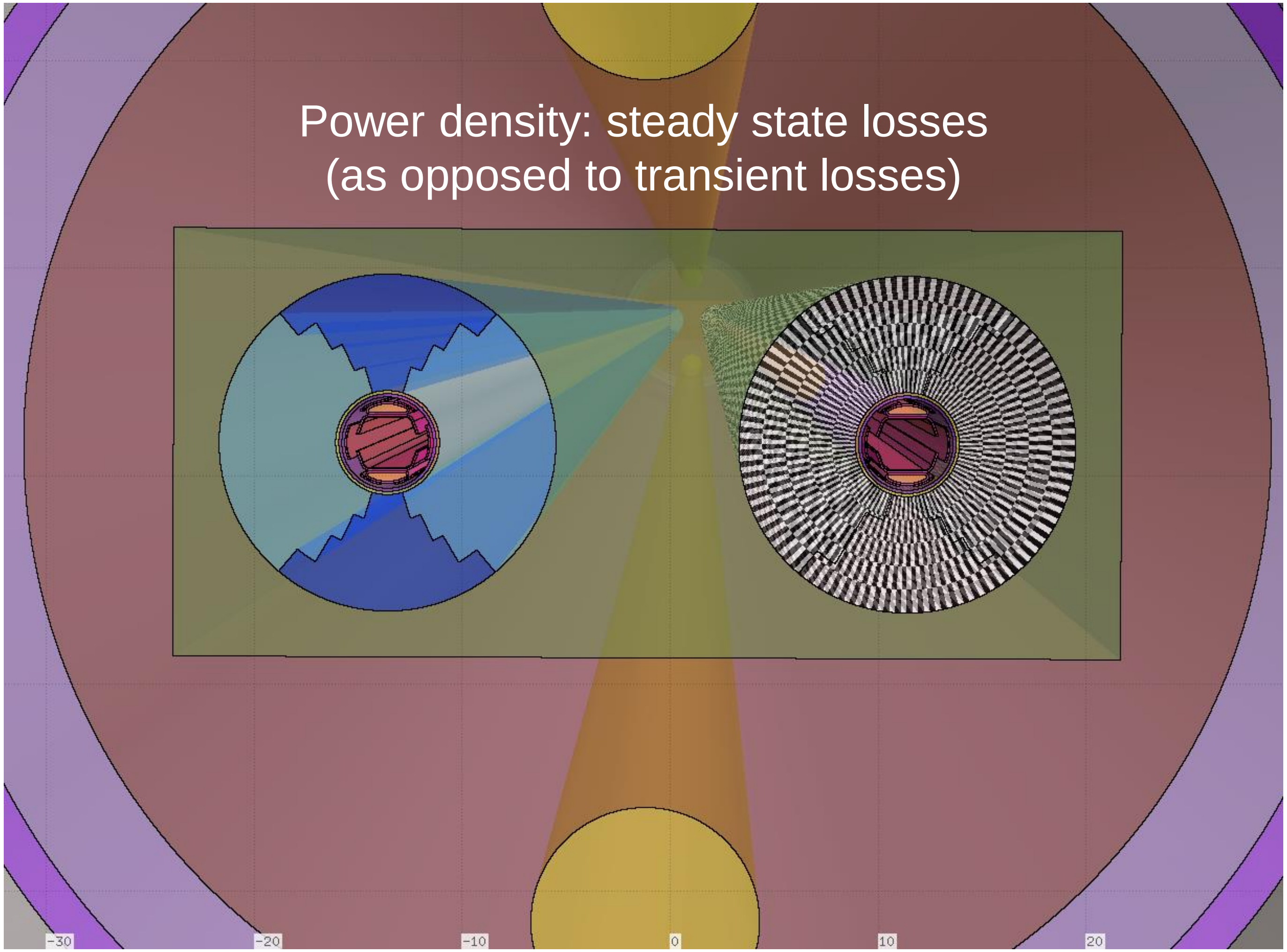




Additional increase in beam – beam separation: 20 -> 25 cm

		Previous Radius [cm]	Updated Radius [cm]
MB	Cold mass	45	37
MQ	Cold mass	32.37	24.87
MB	Coil	8.1	8.1
MQ	Coil	5.672	5.922

Energy Deposition on Coils



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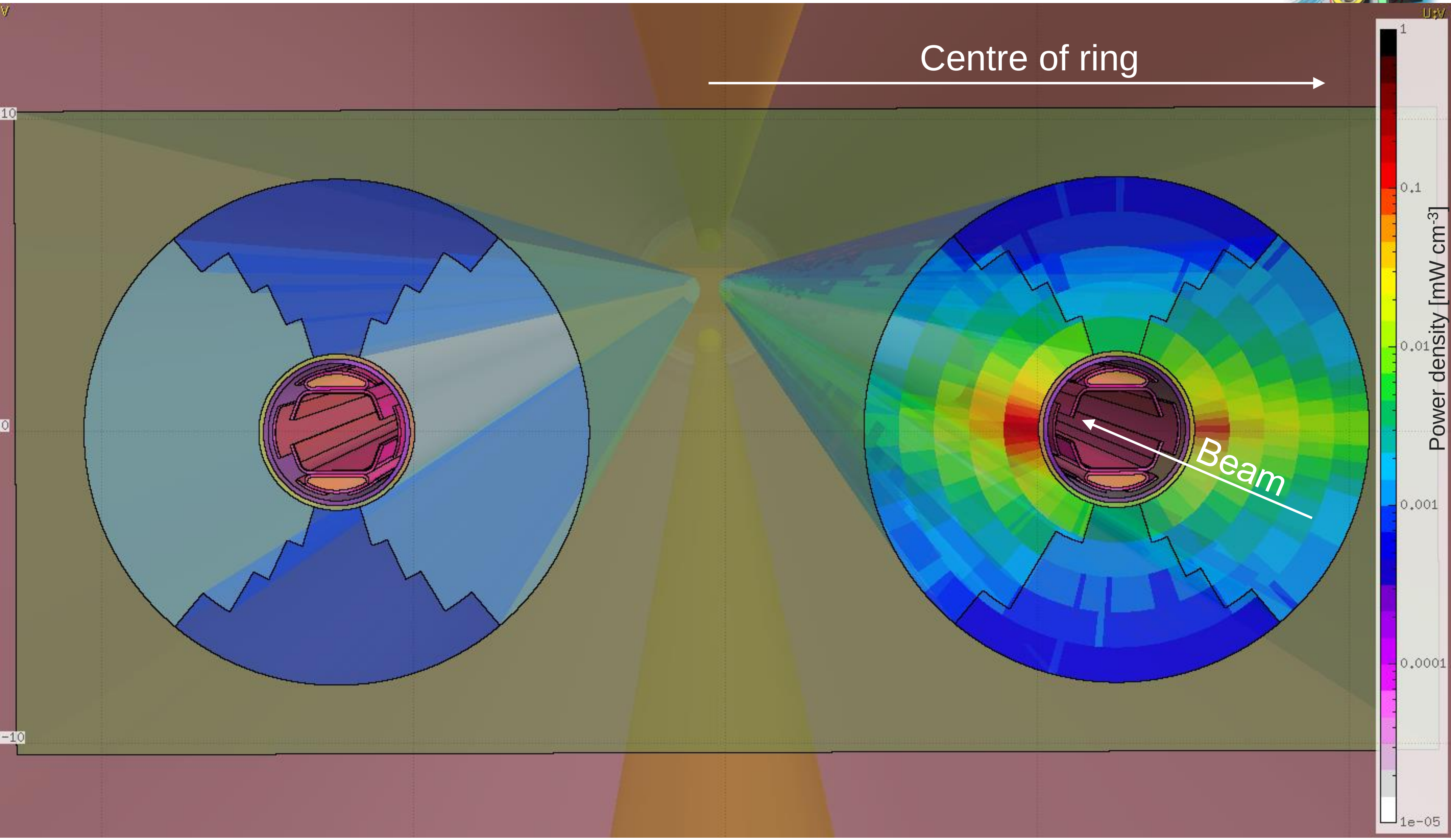
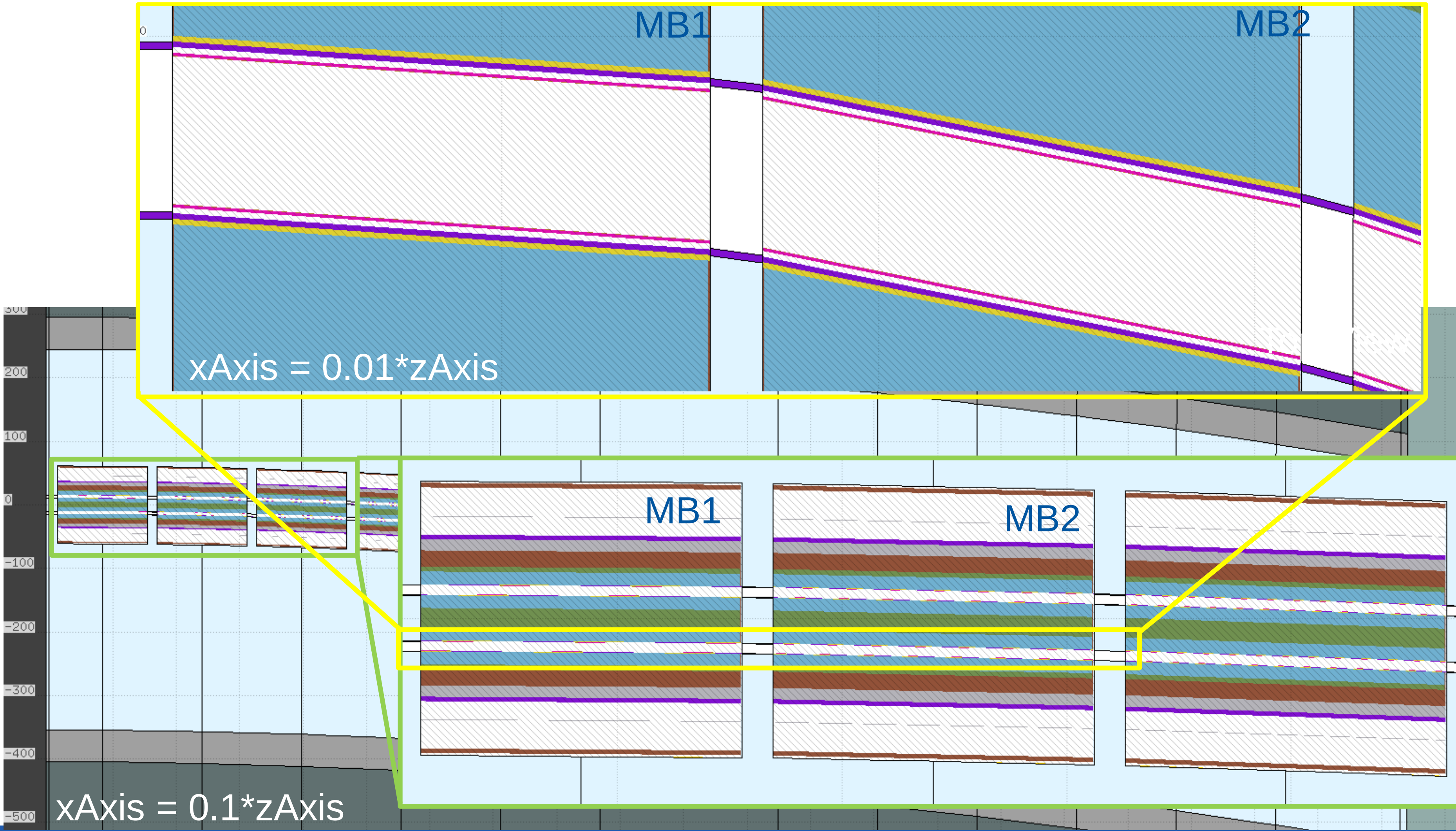


Secondary Trajectories



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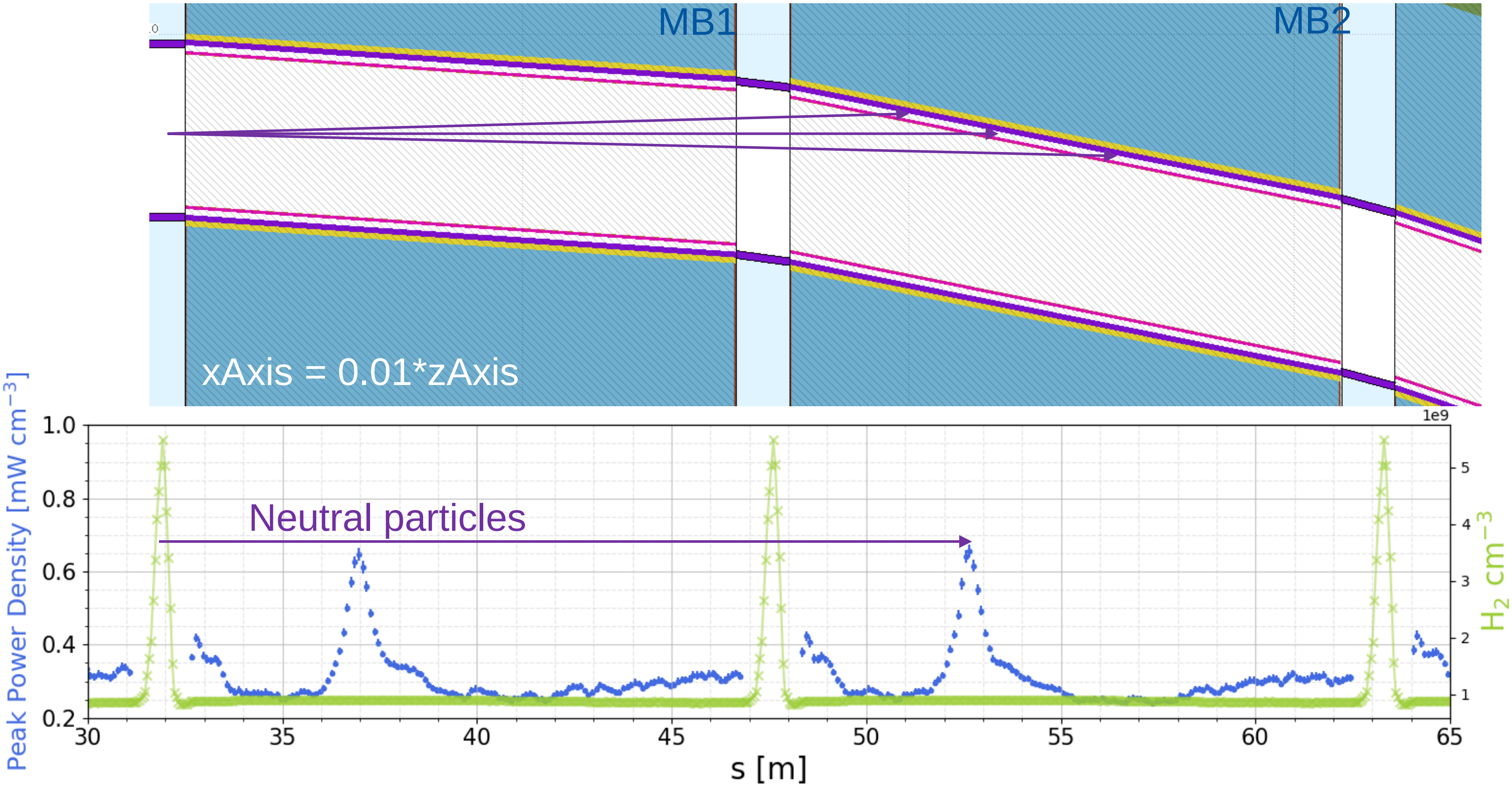

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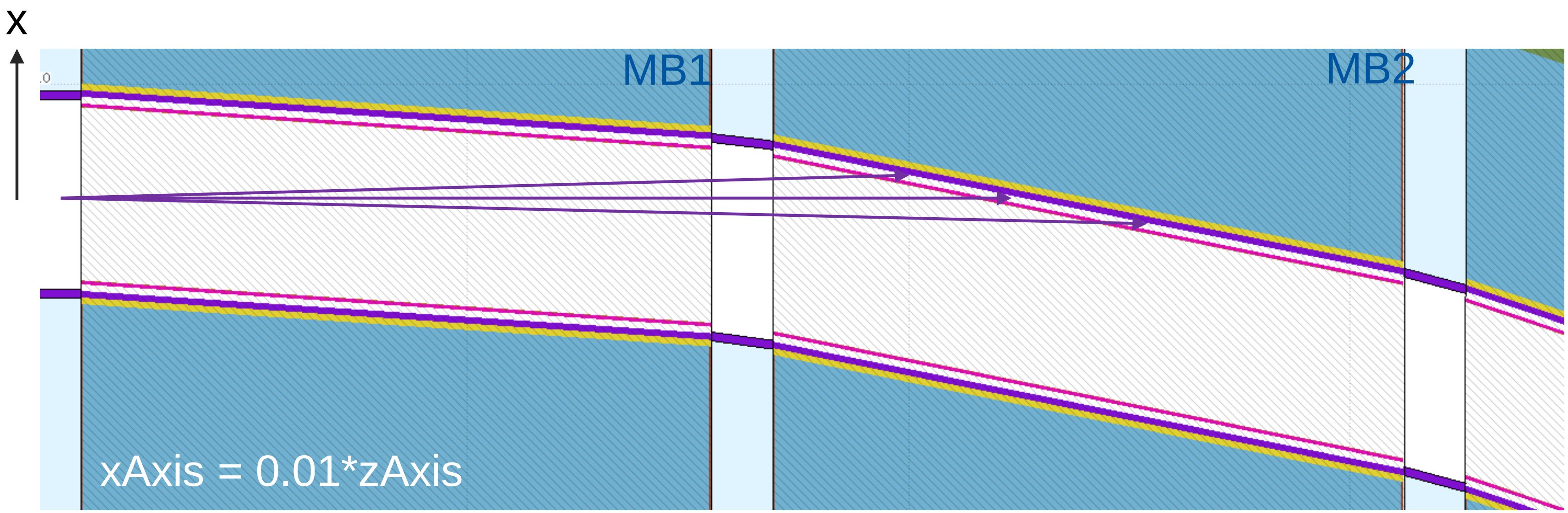
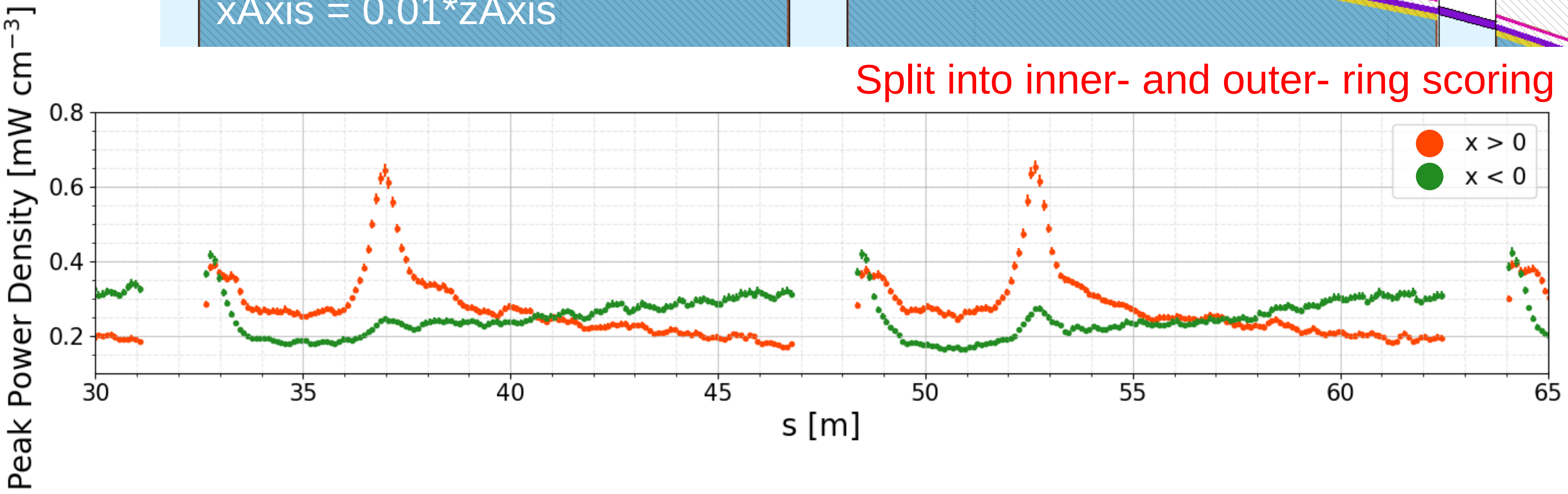


Split into inner- and outer- ring scoring



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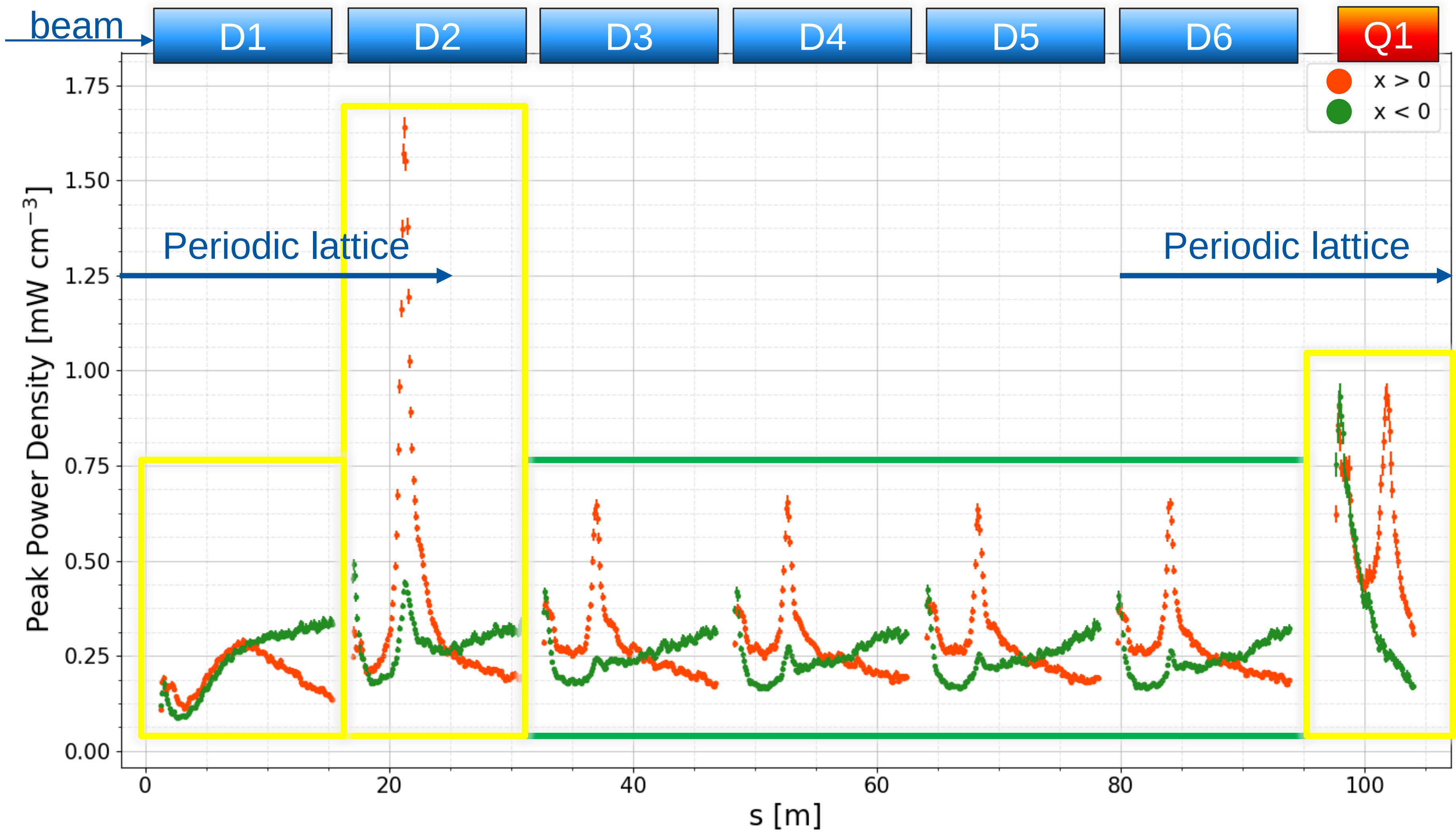

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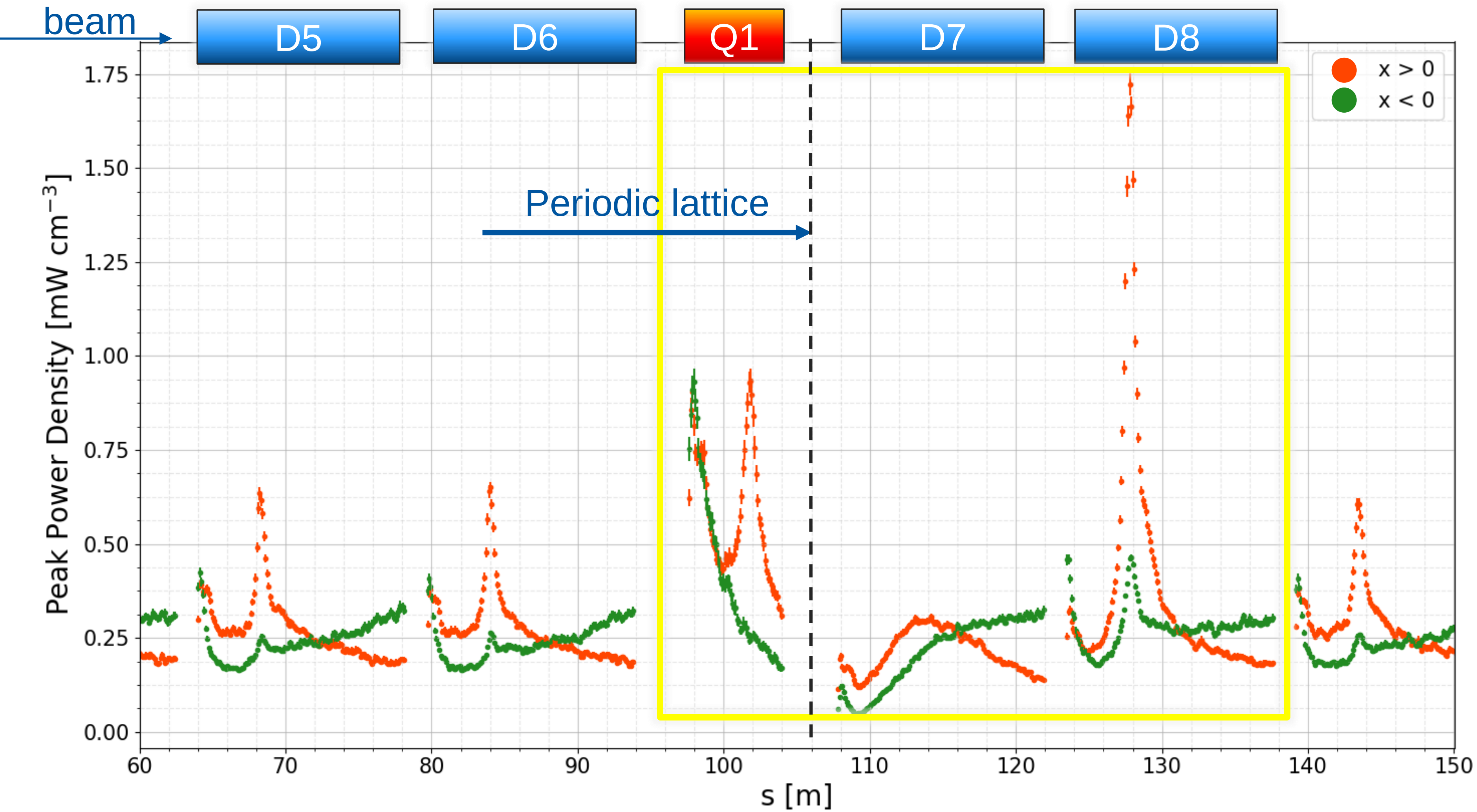

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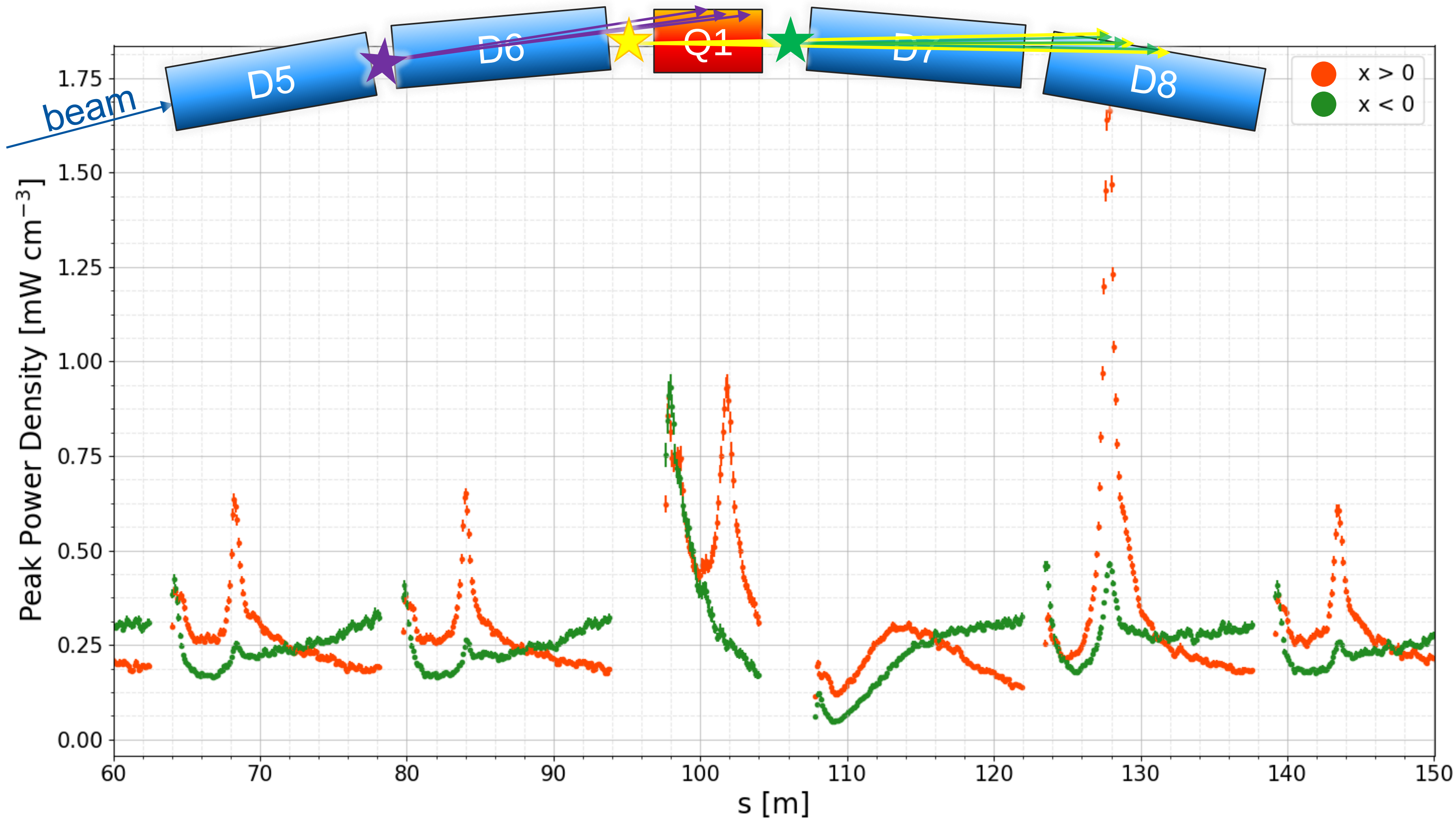
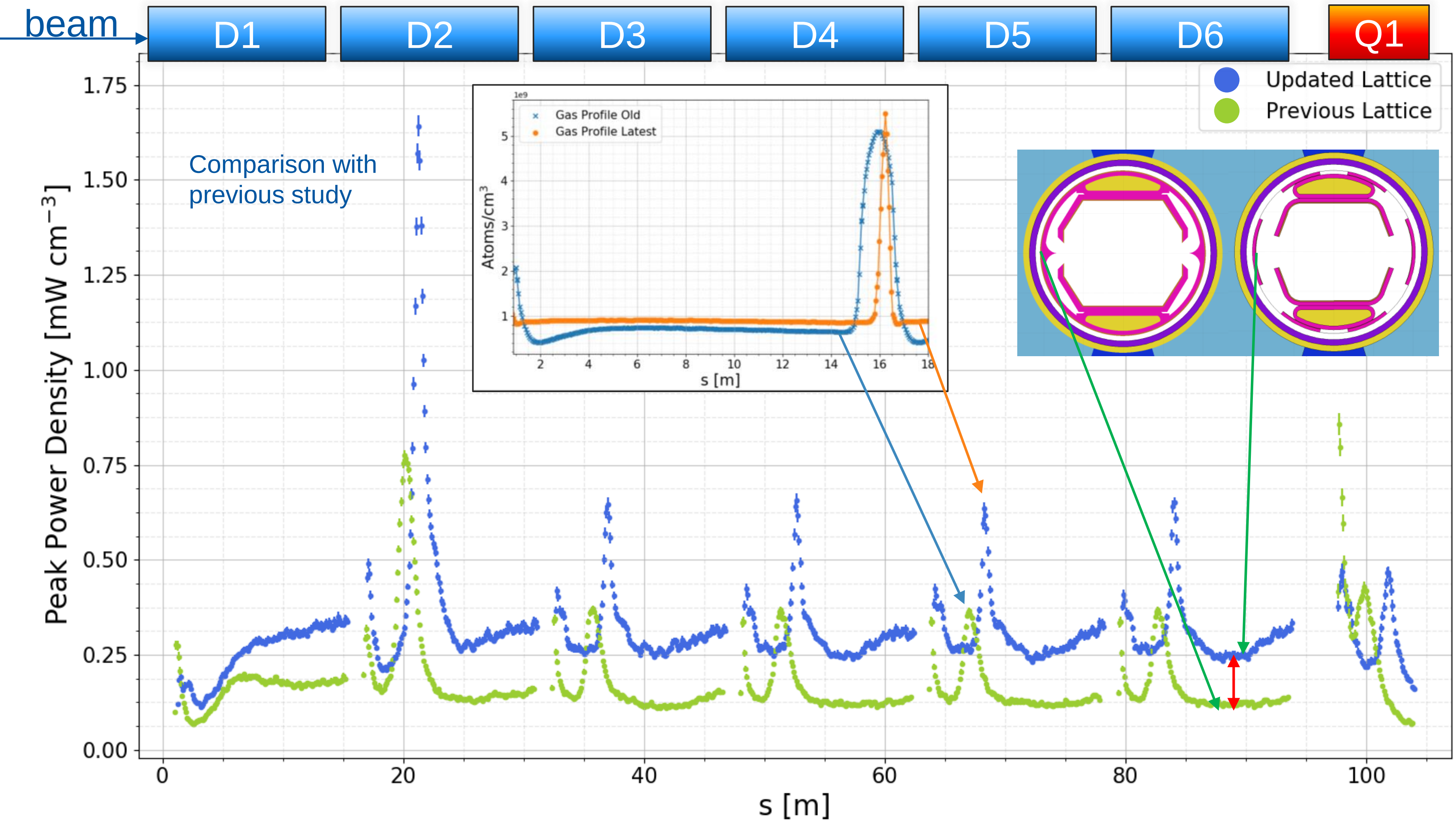
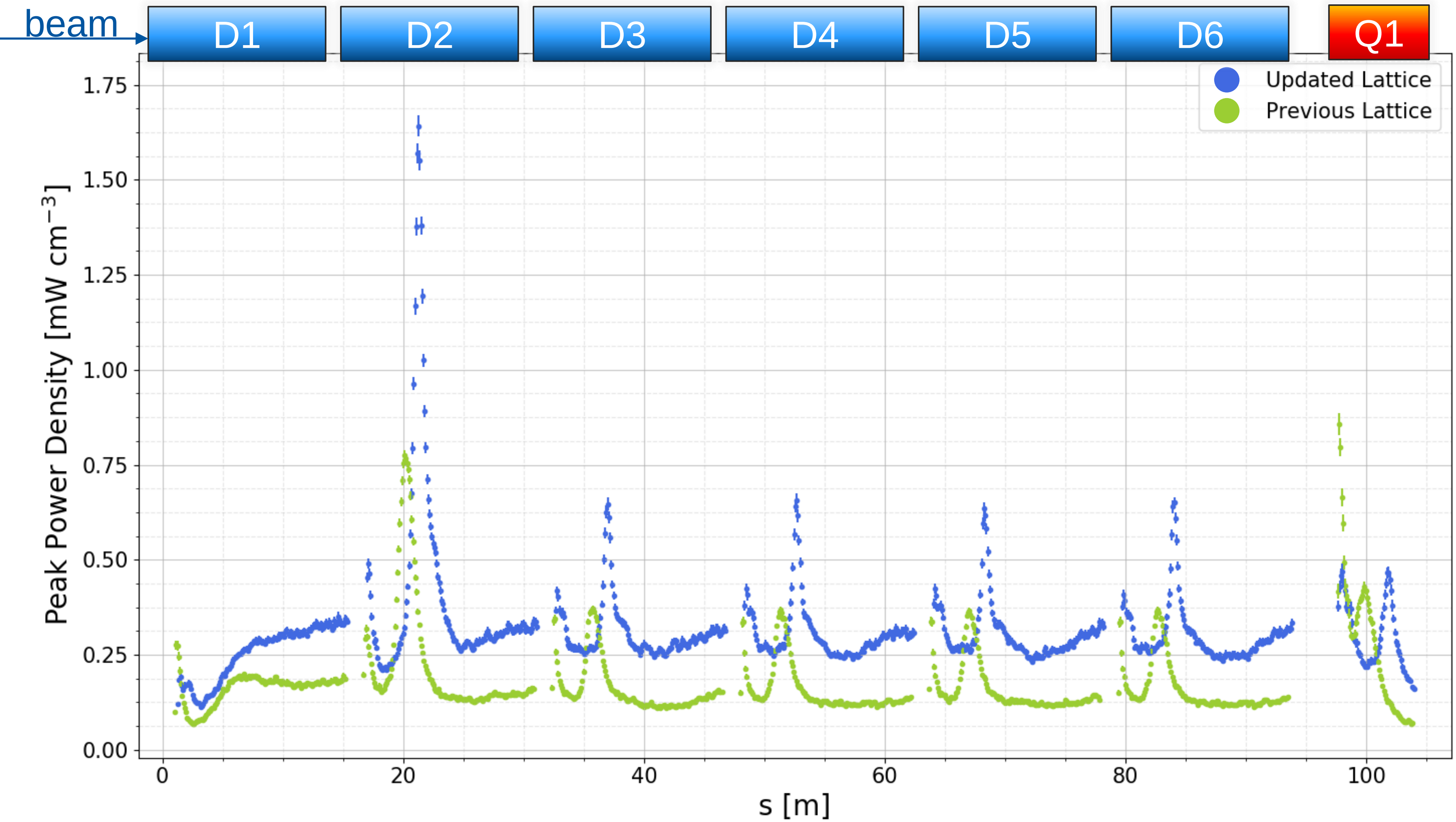


Energy deposition on coils



Energy deposition on coils



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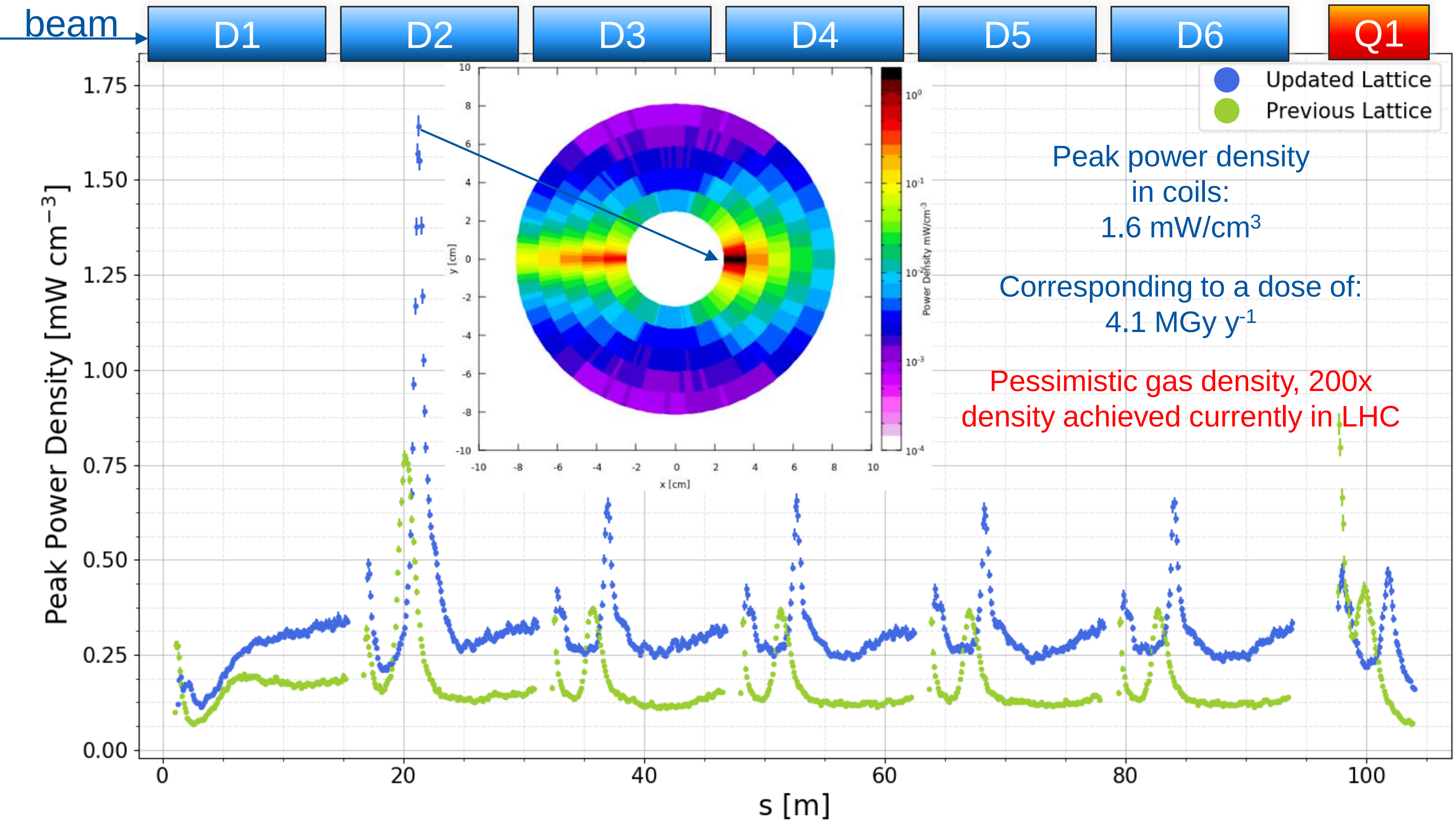


Power Per Element (Cold Mass)

- Updated design of beam screen provides less shielding for coils and cold mass:
  - Each beam screen now absorbing ~**5%** of power loss density as opposed to **16%** previously.
  - **86%** absorbed by cold mass, **73%** previously.

- Average losses along arc cell: **414 mW/m** (2 beams)
- Maximum heat load on most impacted dipole is **476 mW/m** on cold mass (2 beams)

(Current per beam: 0.5 A)

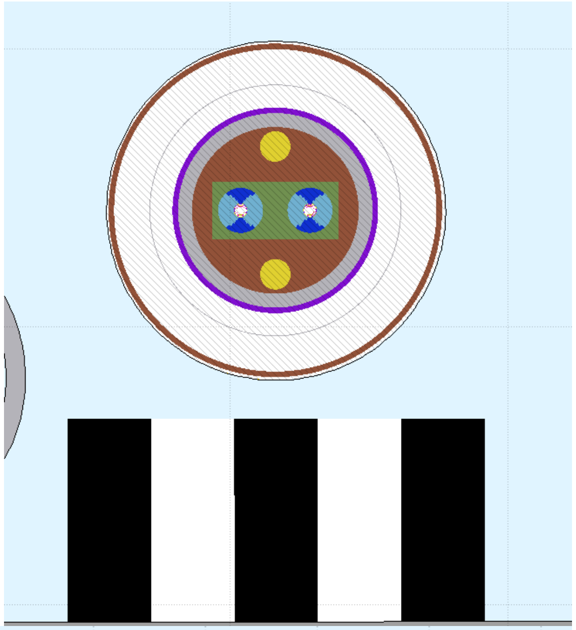
Two Beams Power per Element [W]

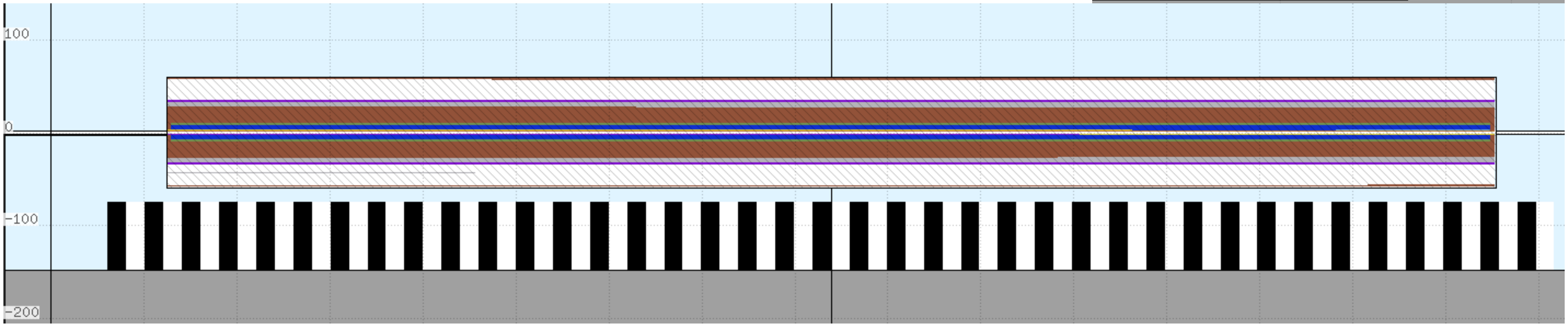
	Element	Beam Screen	Cold Mass
Beam 1	MB1	0.140	5.52
Beam 1	**MB2**	**0.212**	**6.51**
Beam 1	MB3	0.164	5.84
Beam 1	MB4	0.162	5.87
Beam 1	**MB5**	**0.161**	**6.76**
Beam 1	MB6	0.160	5.67
	MQ1	0.113	2.13
Beam 2	MB7	0.131	5.28
Beam 2	**MB8**	**0.211**	**6.41**
Beam 2	MB9	0.160	5.68
Beam 2	MB10	0.159	5.71
Beam 2	**MB11**	**0.157**	**6.57**
Beam 2	MB12	0.156	5.36
Beam 2	MQ1	0.121	2.14

Radiation to Electronics

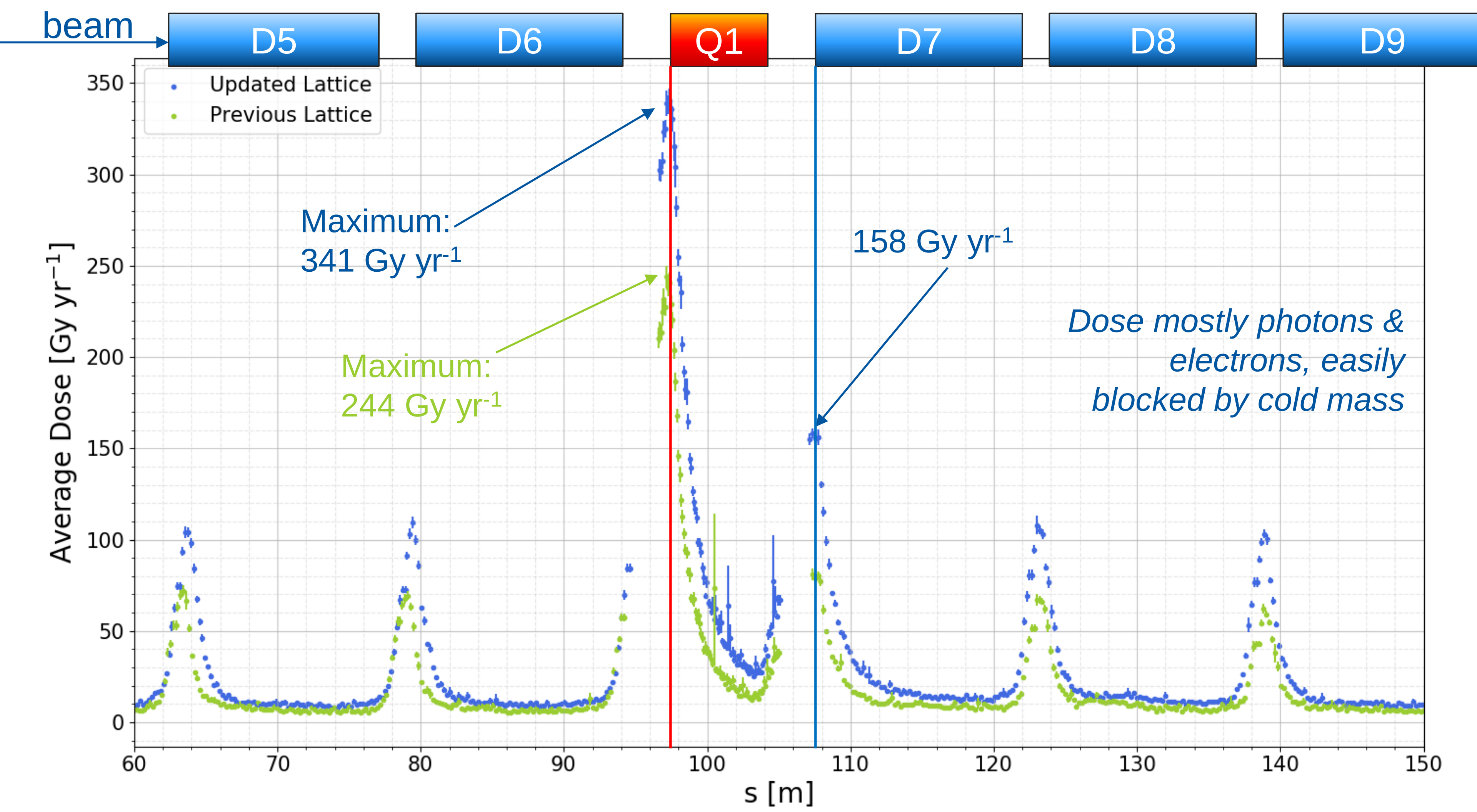
- Scoring mesh in location of power converters/electronics
  - Direct comparison with previous results
- Normalised to 10^7 s
  - ~1 year beam operation

- Total ionizing dose
  - Cumulative effects, long-term radiation damage
- High-energy hadron fluence (HEH):
  - proportional to number of single event upsets (SEUs)

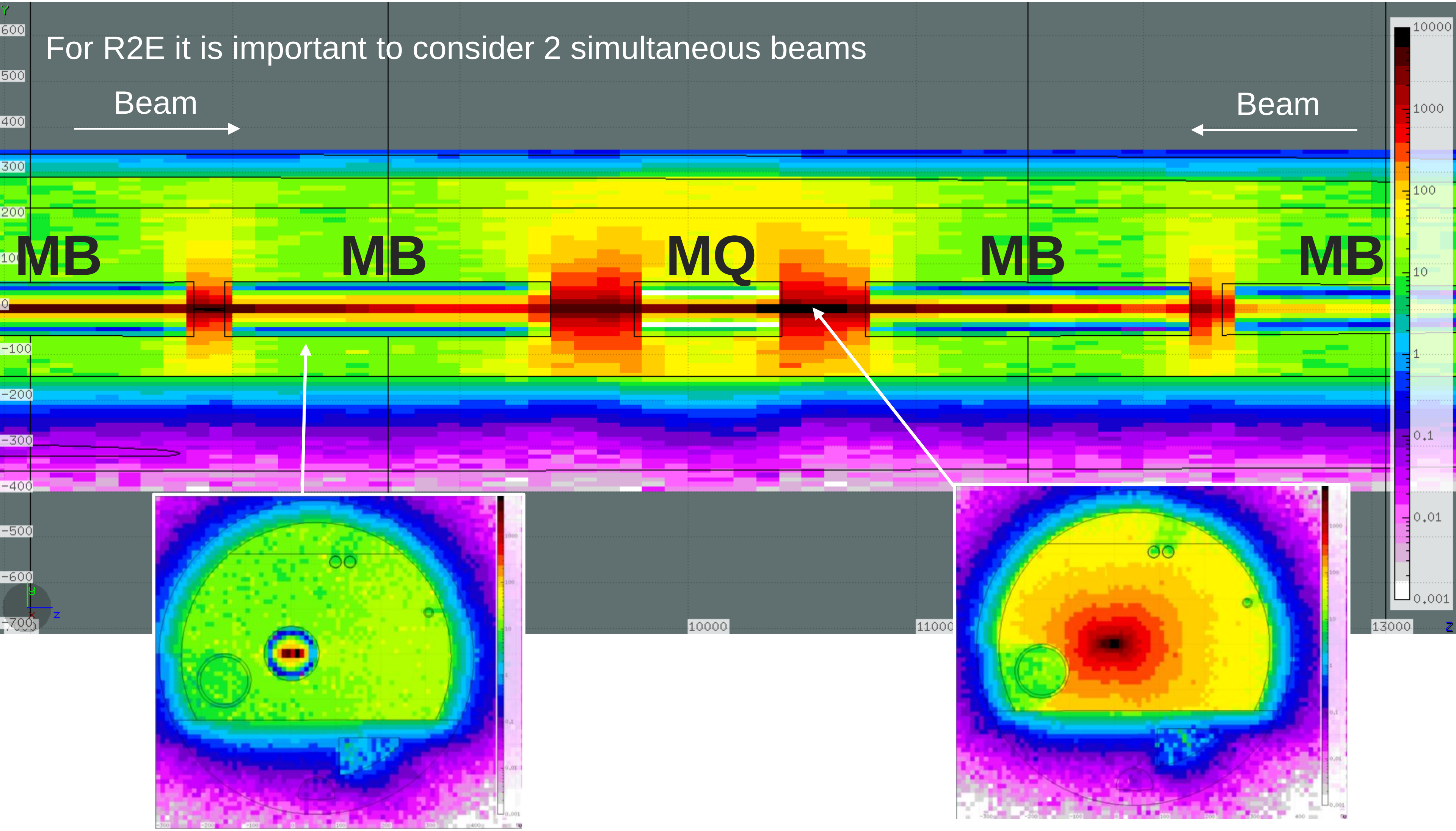




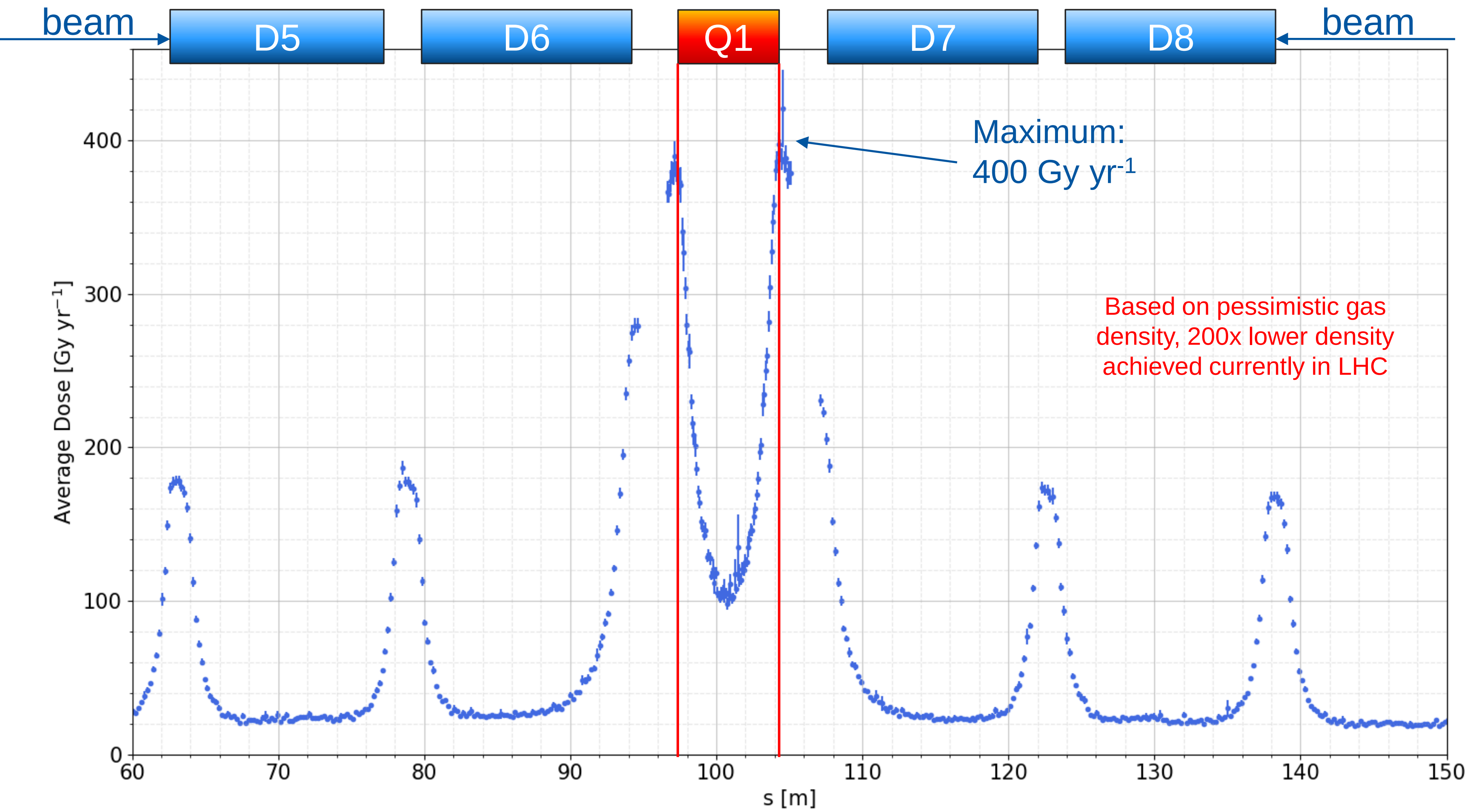
Dose on Electronics



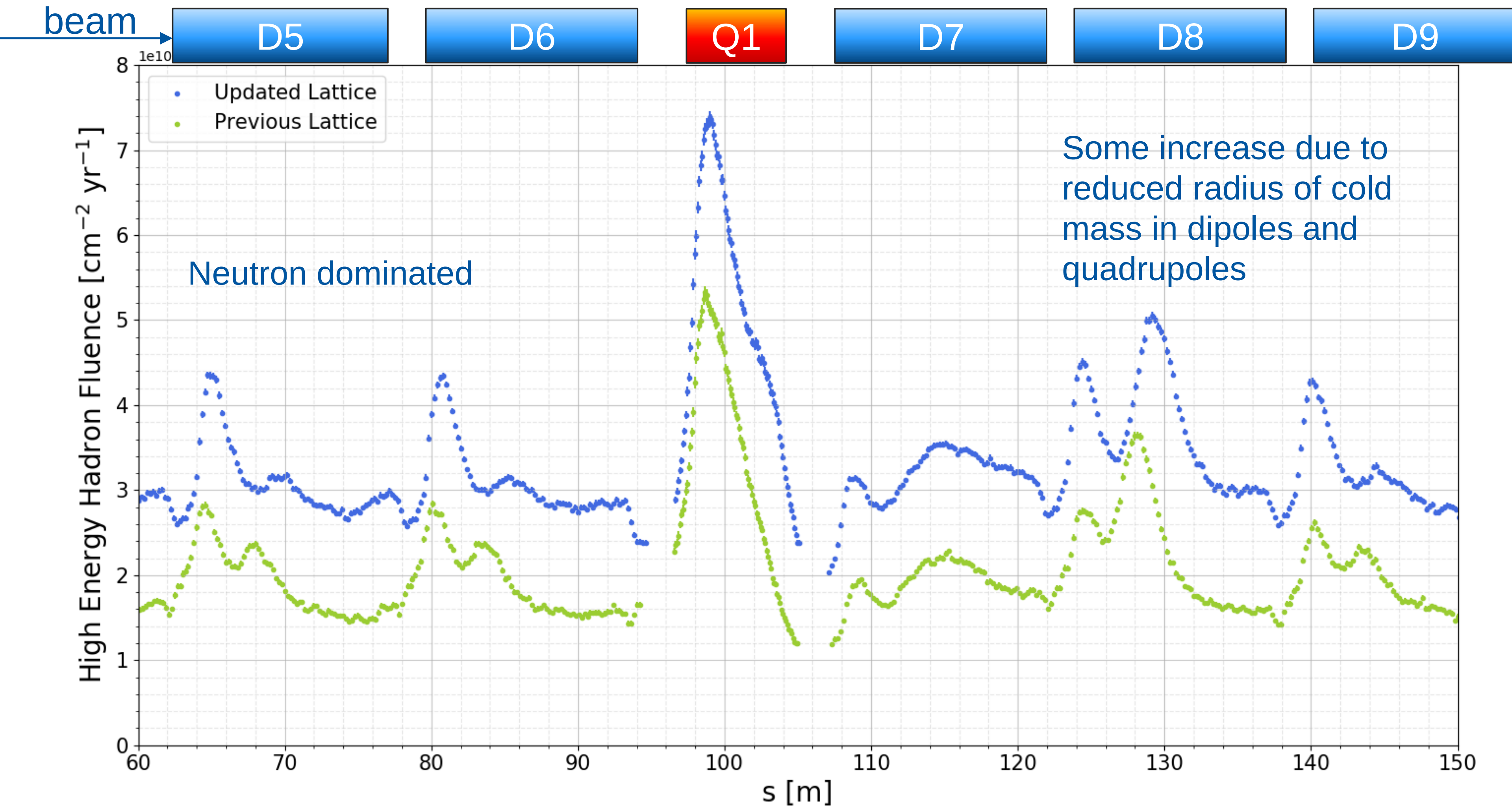
Longitudinal Plots Dose



Dose on Electronics:
Combined Beams



R2E impact - HEH



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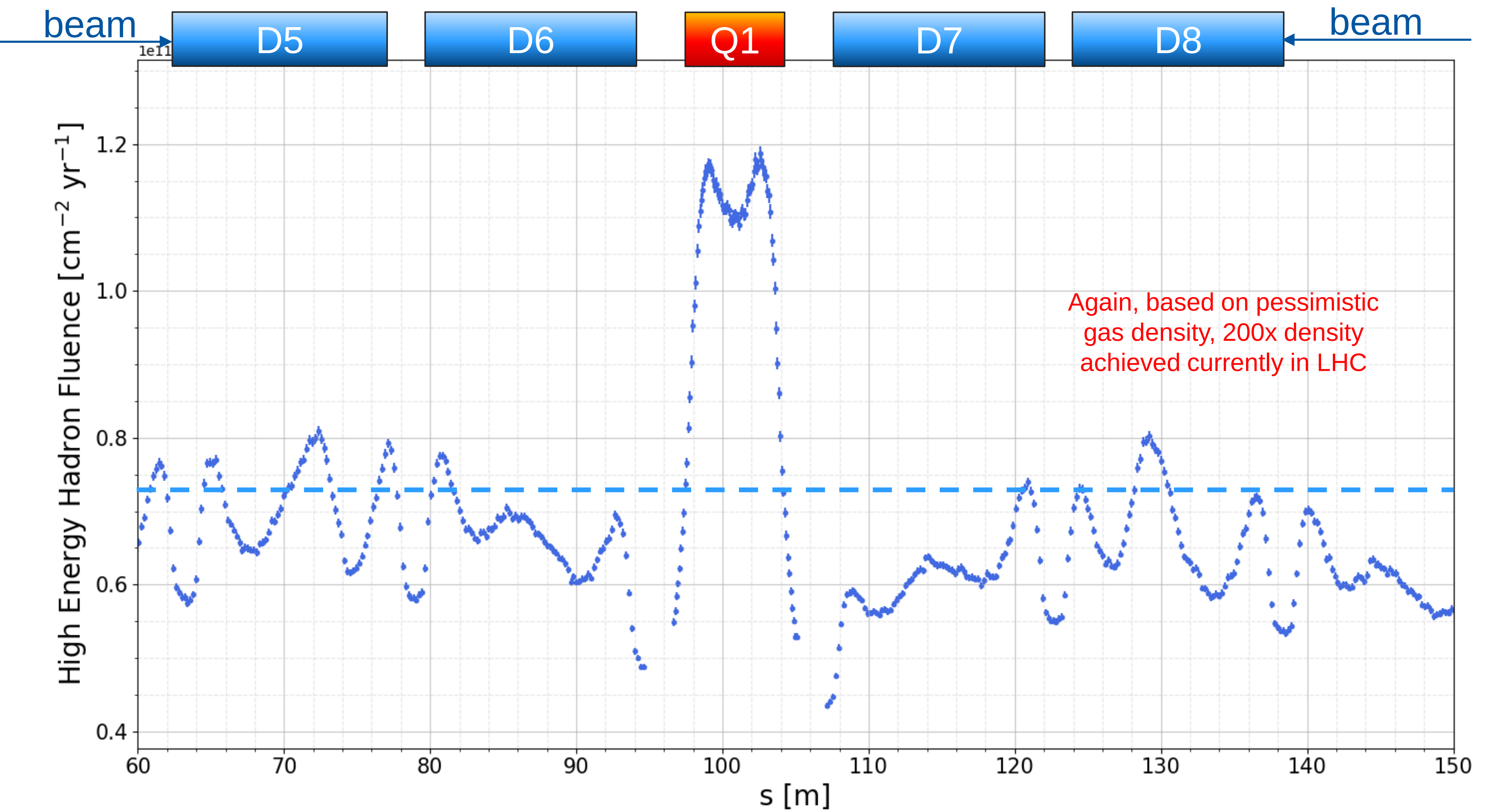

Summary

- New beam screen design has impacted energy deposition on coils and cold mass
  - Now only 5% on beam screen with 86% on cold mass
  - Higher peak power density 1.6 mW/cm^3 on coils

- R2E outcome: an increase in radiation to electronics under beamline
  - Maximum dose: 400 Gy yr^{-1}
  - Maximum high energy hadron fluence: 1.2e11 cm^{-2} yr^{-1}
  - **However,** the gas density used ~200x greater than achieved currently in the LHC

Thanks for listening

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Special thanks to
I. Bellafont

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