CERN

Baseline EIR: Energy Deposition Studies for L* = 40m

Angelo Infantino, Jacqueline Keintzel, Francesco Cerutti
CERN EN/STI-FDA
FLUKA Team

European Organization for Nuclear Research (CERN), Geneva, Switzerland

Outline

- Update of the beam optics (L*= 40 m)
- Update of the FLUKA model
- Radiation load for L* = 40 m & comparison with L* = 45 m
- Summary

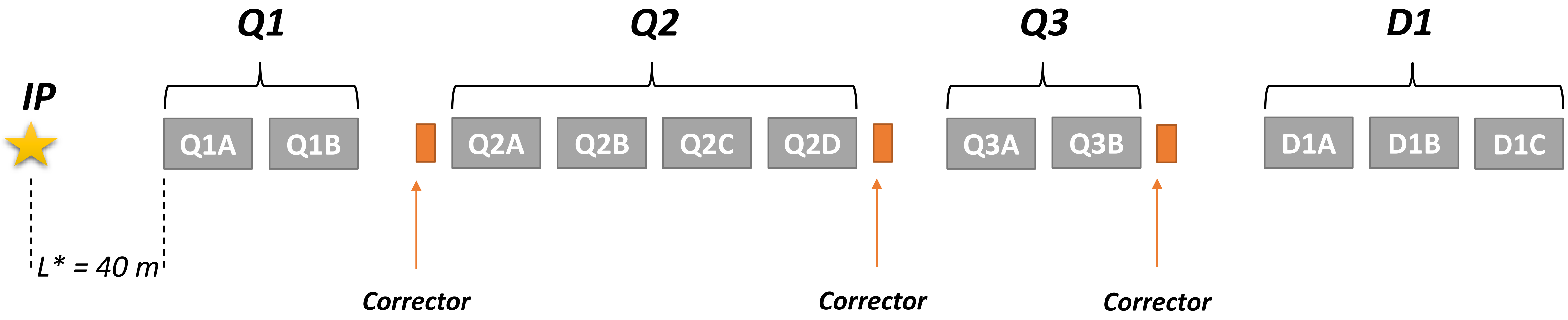
What's New: Optics and Lattice

Interaction Region parameters:

- ***Main interaction region (point A)***
- ***L* = 40 m***

Lattice:

- Significant change from previous calculations for L* = 45 m (quadrupoles splitting) [Ref: M.I. Besana - Overview and Status of the Radiation Load Studies Focused on Magnets]



What's New: Apertures

TAS

- Length: ***3.0 m***
- Aperture: ***40 mm*** diameter

Q1A and Q1B

- Magnetic Length/Field: ***14.3 m*** - 126 T/m gradient
- Aperture: ***164 mm*** coil diameter + ***15 mm*** tungsten (INERMET180) shielding

Q2A to Q2D

- Magnetic Length/Field: ***12.5 m*** - 101 T/m gradient
- Aperture: ***210 mm*** coil diameter + ***15 mm*** tungsten (INERMET180) shielding

Q3A and Q3B

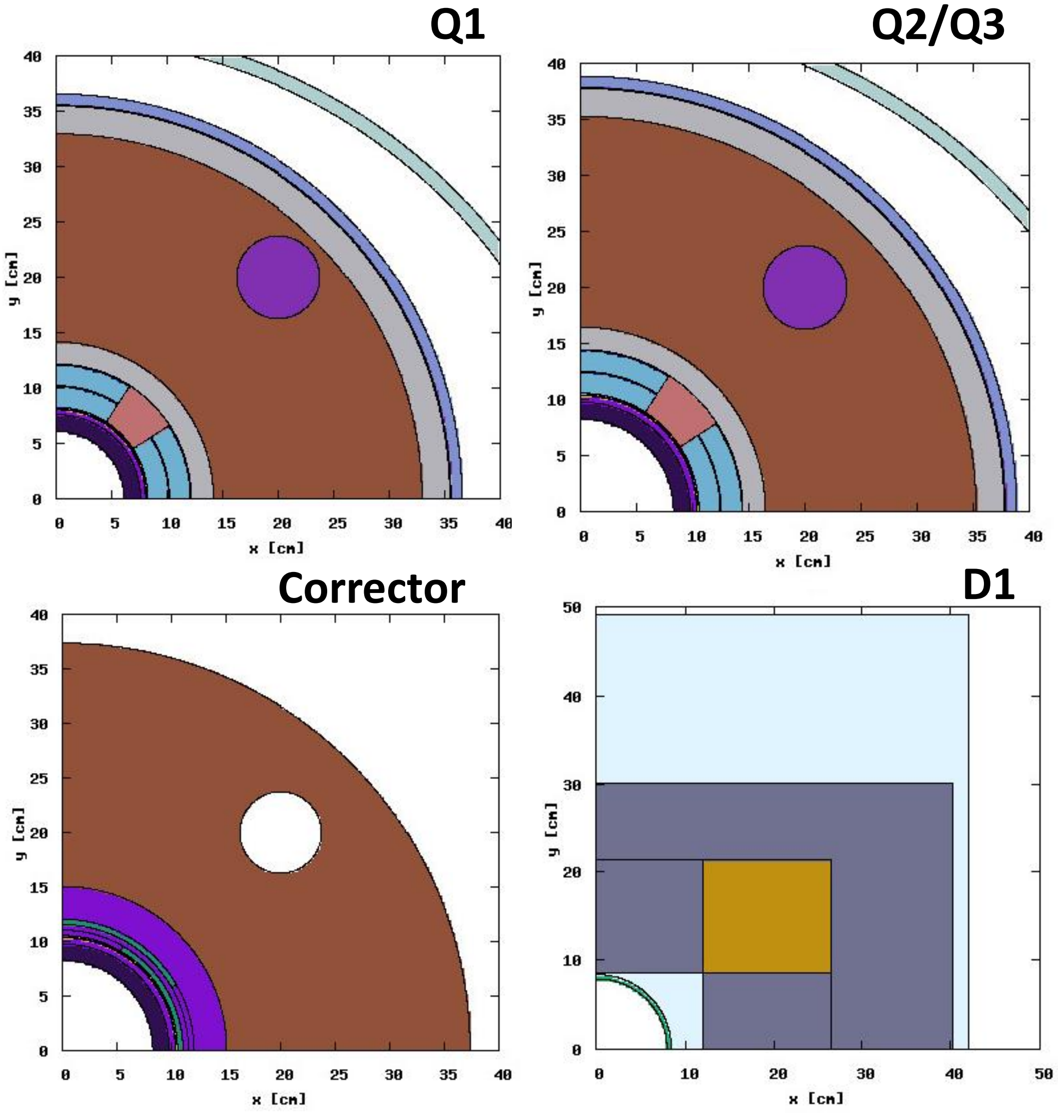
- Magnetic Length/Field: ***14.3 m*** - 100 T/m gradient
- Aperture: ***210 mm*** coil diameter + ***15 mm*** tungsten (INERMET180) shielding

Orbit Corrector

- Magnetic Length/Field: ***1.3 m***
- Aperture: ***210 mm*** coil diameter + ***15 mm*** tungsten (INERMET180) shielding

D1A to D1C:

- Magnetic Length/Field: ***12.5 m*** - 1.9 T field
- Aperture: ***170 mm*** pole tip aperture + ***5 mm*** thick vacuum chamber



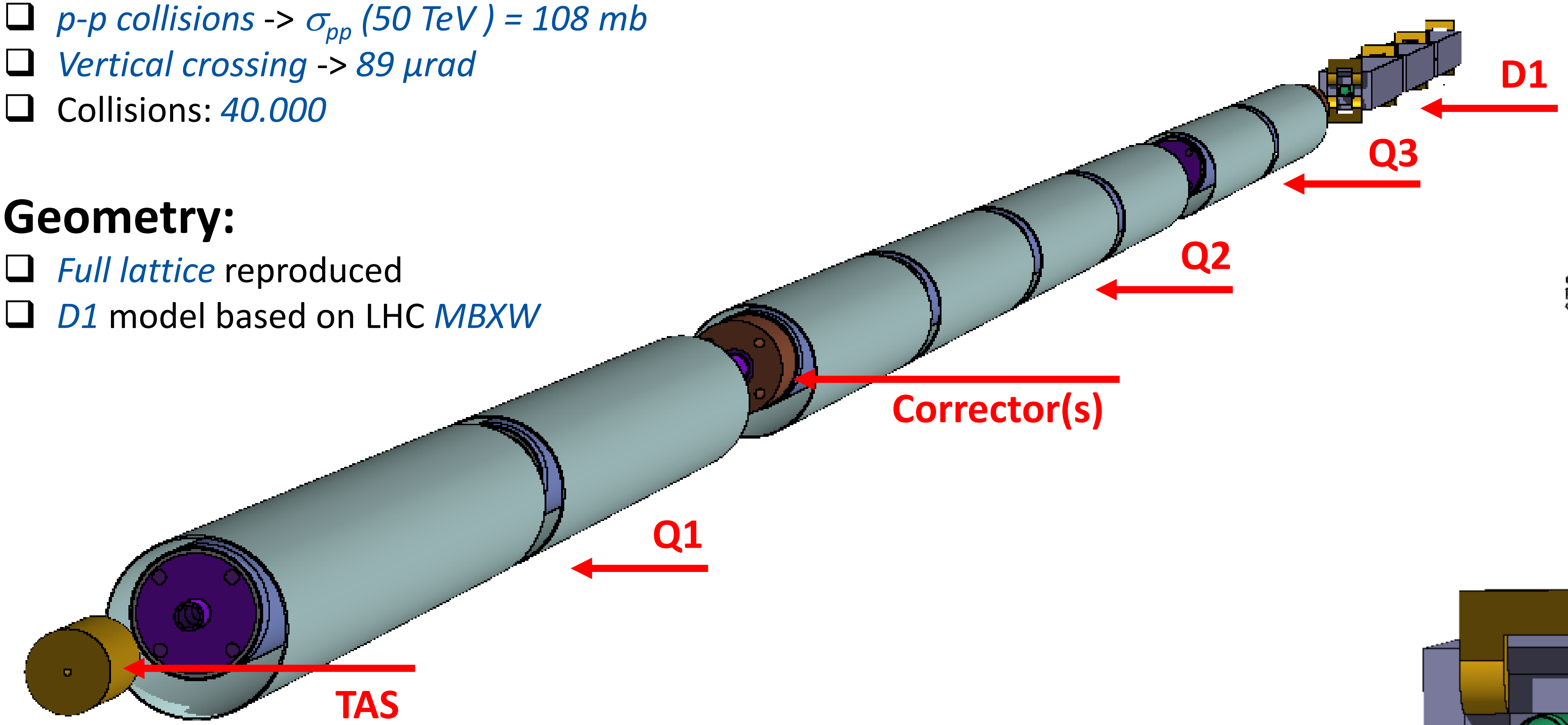
FLUKA model

Source Term:

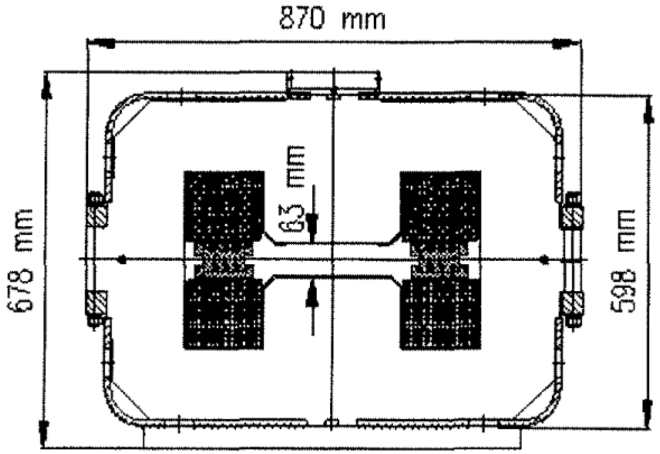
- ❑ *p-p collisions* -> σ_{pp} *(50 TeV) = 108 mb*
- ❑ *Vertical crossing* -> *89 µrad*
- ❑ Collisions: *40.000*

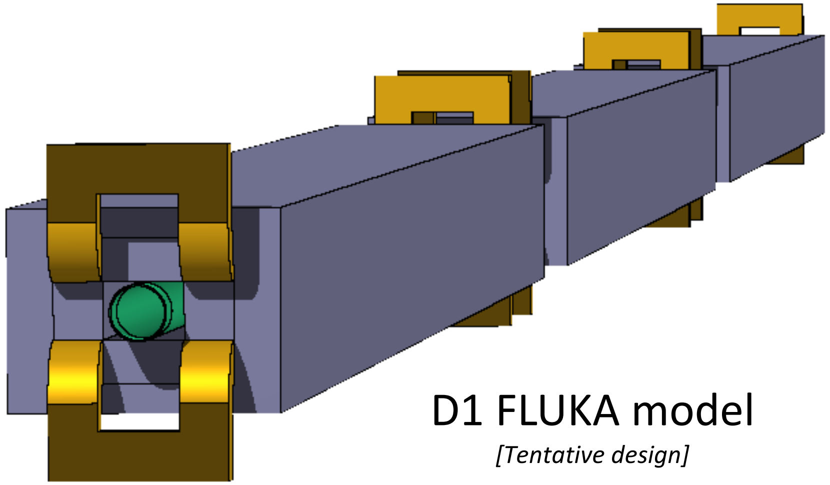
Geometry:

- ❑ *Full lattice* reproduced
- ❑ *D1* model based on LHC *MBXW*



LHC MBXW
[Ref: LHC Design Report]





D1 FLUKA model
[Tentative design]

Normalization:

- ✓ *Peak power density* -> Instantaneous Luminosity $5x10^{34}$ cm^{-2} s^{-1}
- ✓ *Peak dose* -> Integrated Luminosity 5 ab^{-1}

Radiation Load: Total Power

Total Power [kW] - Vertical Crossing						
Magnet	***L* = 45 m***			***L* = 40 m***		
	Total	***Shielding***	***Cold Mass***	***Total***	***Shielding***	***Cold Mass***
Q1	2.7	2.0	0.72	2.86	2.11	0.75
C1	0.14	0.11	0.04	0.07	0.05	0.02
Q2 A	0.5	0.34	0.14	0.52	0.39	0.13
Q2 B	2.15	1.6	0.51	2.04	1.57	0.47
Q3	1.8	1.4	0.4	2.09	1.61	0.48
C2	0.17	0.11	0.06	0.15	0.11	0.04

Note: Statistical error ~few percent

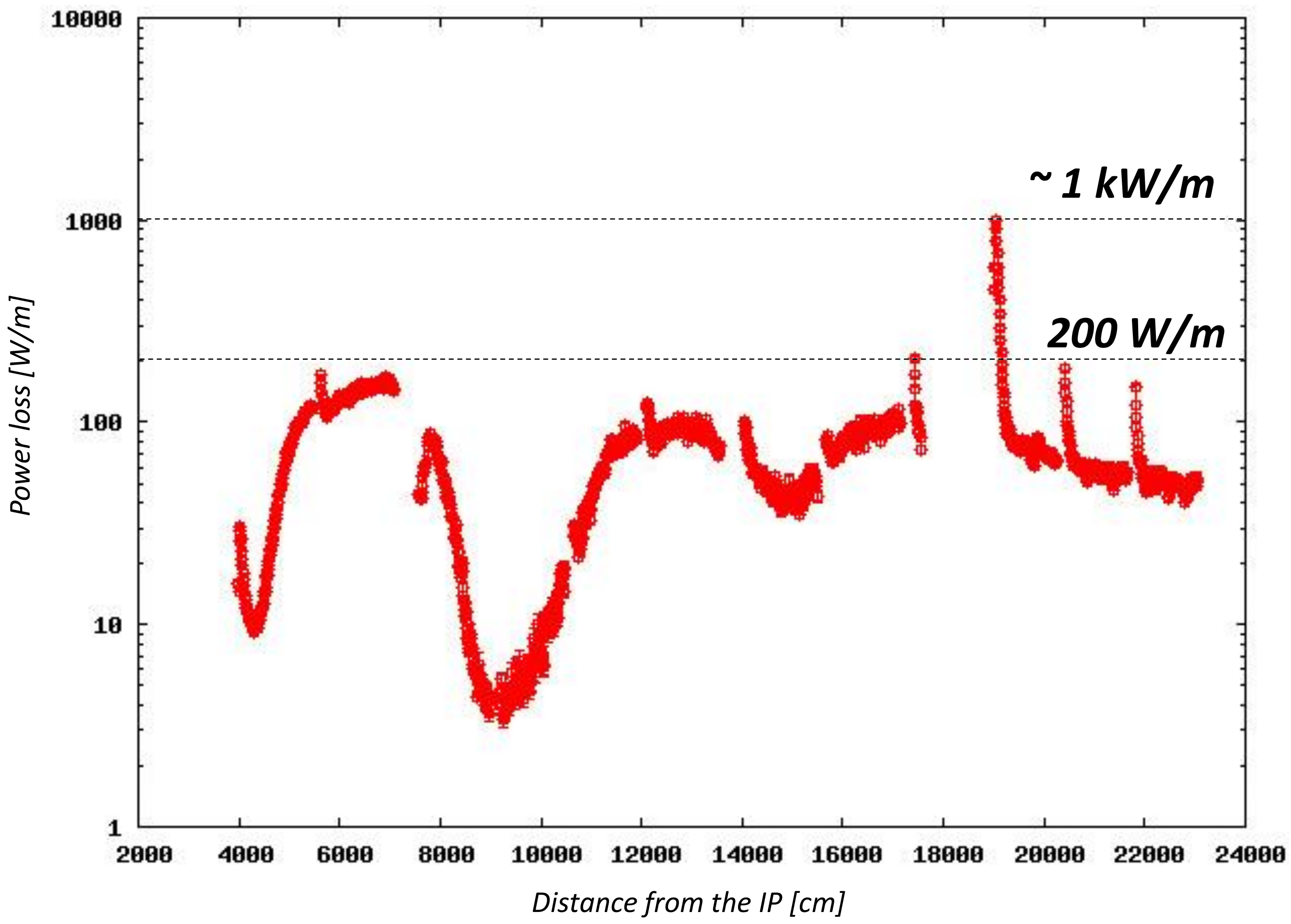
DIFFERENCES < 15%

Radiation Load: Total Power

Total Power [kW] vertical crossing							
Magnet	***Total***	***Shielding***	***Cold Mass***	***Magnet***	***Total***	***Shielding***	***Cold Mass***
Q1A	0.74	0.53	0.21	Q3A	0.77	0.57	0.2
Q1B	2.12	1.58	0.54	Q3B	1.32	1.04	0.28
C1	0.07	0.05	0.02	C3	0.15	0.11	0.04
Q2A	0.42	0.31	0.11	D1A	1.75		
Q2B	0.1	0.08	0.02	D1B	0.79		
Q2C	0.8	0.62	0.18	D1C	0.66		
Q2D	1.24	0.95	0.29				
C2	0.11	0.09	0.02				

Note: Statistical error ~few percent

Radiation Load: Power Loss Distribution

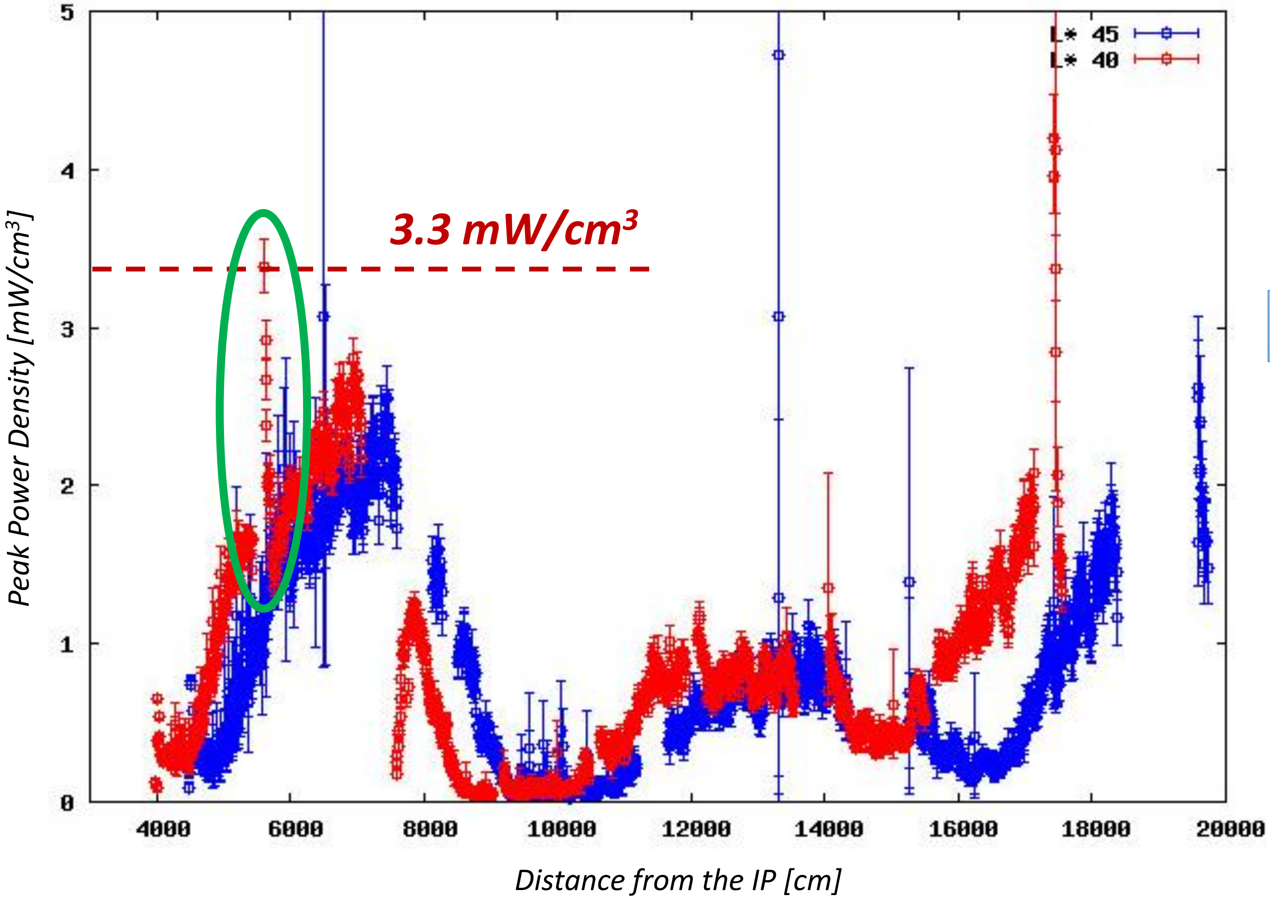


LHC/HL

(order of magnitude)

- LHC: *~ 10 W/m*
- HL-LHC: *few tens W/m*

Radiation Load: Peak Power Density



Estimated quench limit* for Nb_3Sn: 5 mW/cm^3

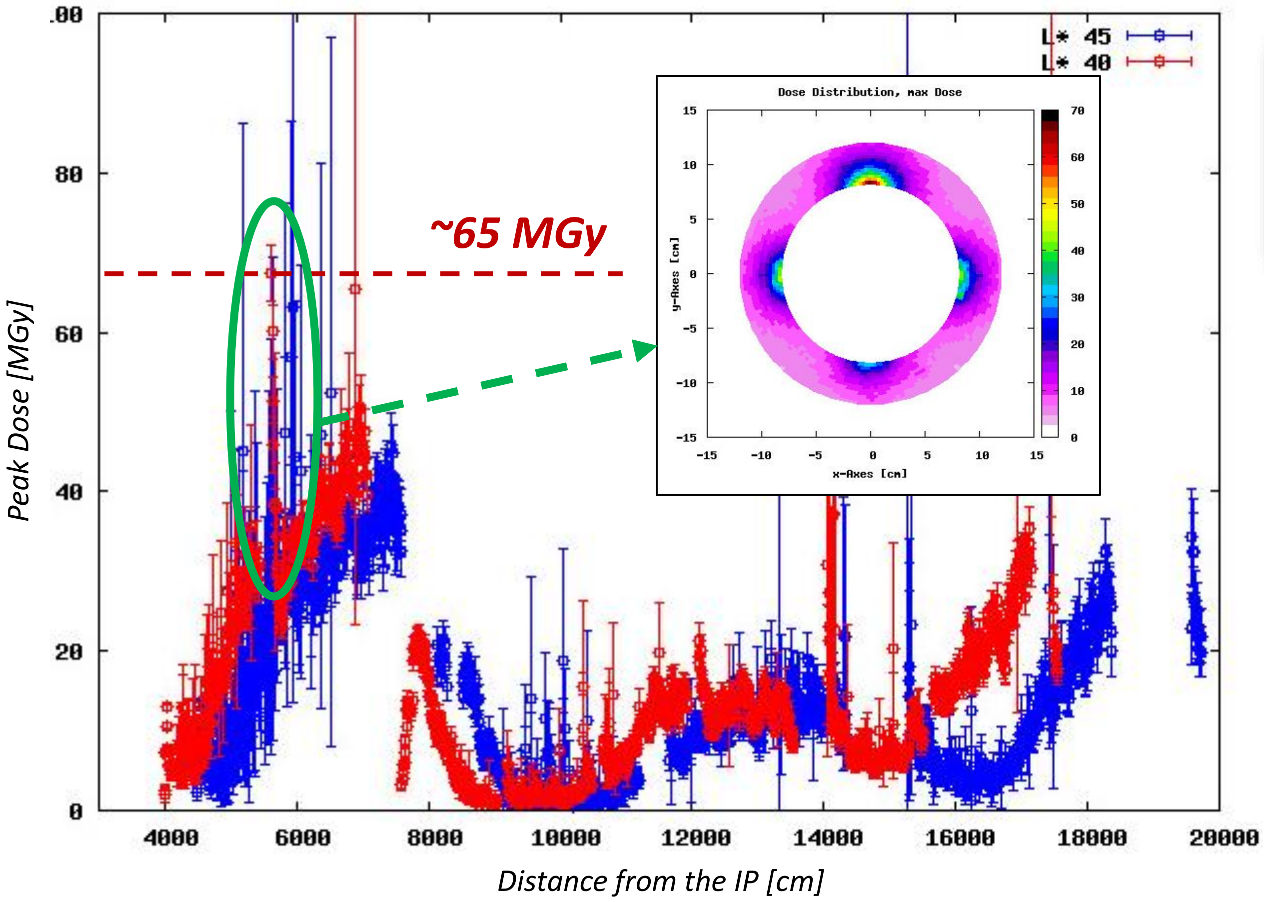
[Ref: Daniel Schoerling - Review of peak power limits for high luminosity IR triplet magnets]

L* 40 Vs 45 m

- ❑ L* = 45 m: *2.3 mW/cm^3* @ *end of Q1*
- ❑ L* = 40 m: *3.3 mW/cm^3* @ *beginning Q1B*

GAP Q1A-Q1B

Radiation Load: Peak Dose for 5 ab^{-1}

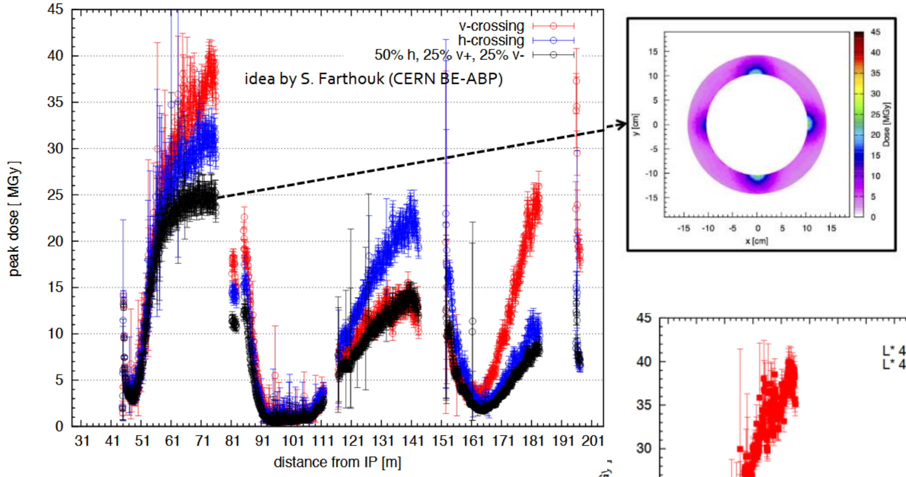


Baseline magnet dose limit: 30 MGy

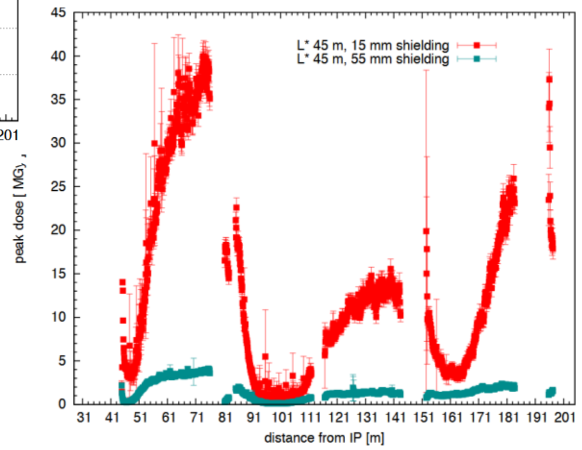
[Ref: Daniel Schoerling - Review of peak power limits for high luminosity IR triplet magnets]

Magnet Lifetime: How to increase?

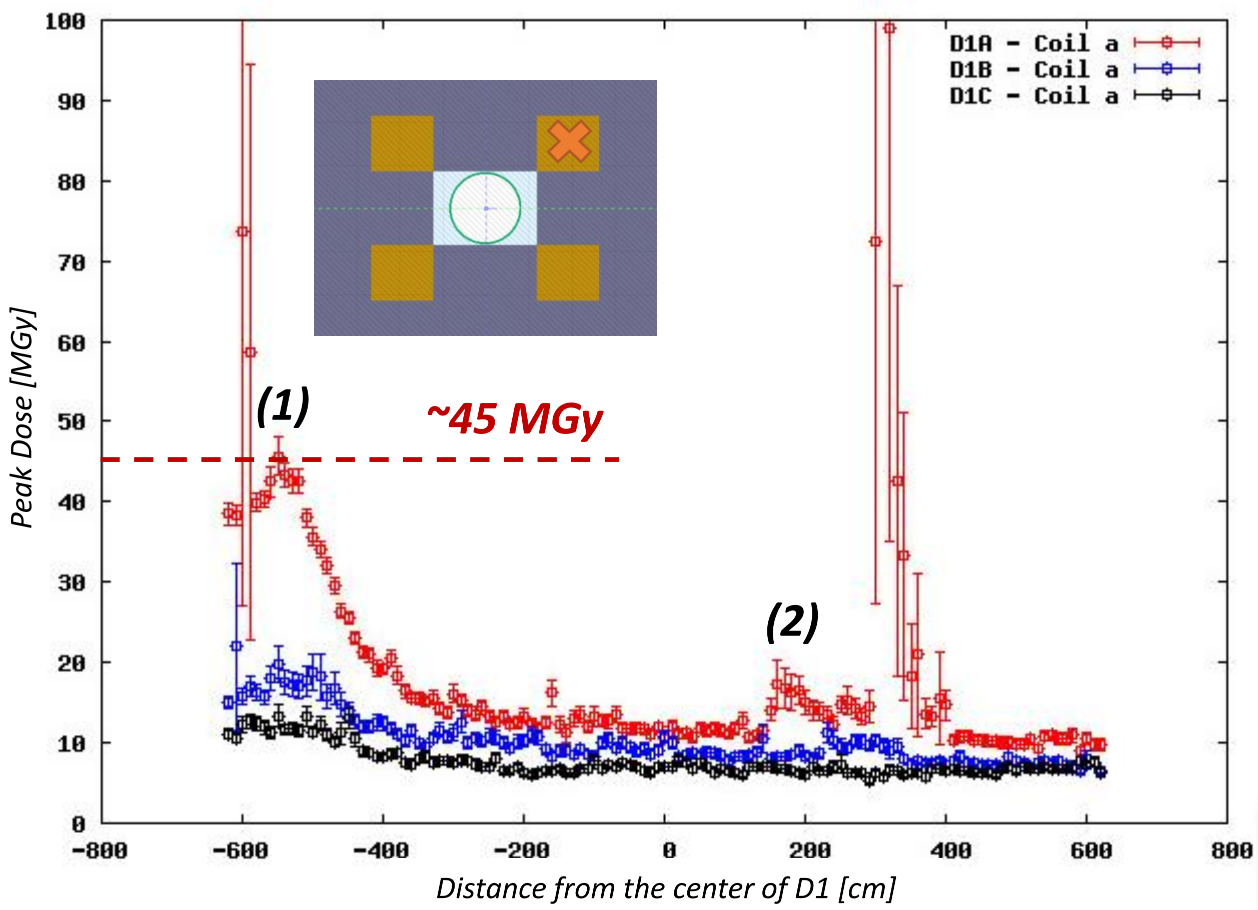
- *Crossing scheme techniques* (e.g. 50% h, 25% v+, 25% v-)
- *Shielding thickness* (possible technical challenges)
- *Radiation hard insulator (250 MGy)*

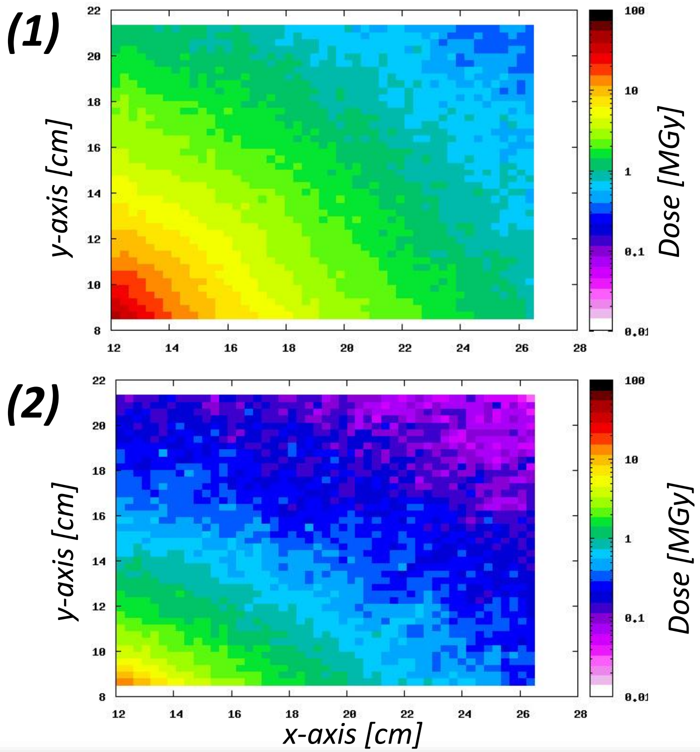


[Ref: M.I. Besana - Overview and Status of the Radiation Load Studies Focused on Magnets]



Radiation Load: Peak Dose for 5 ab^{-1}





Baseline magnet dose limit: 30 MGy

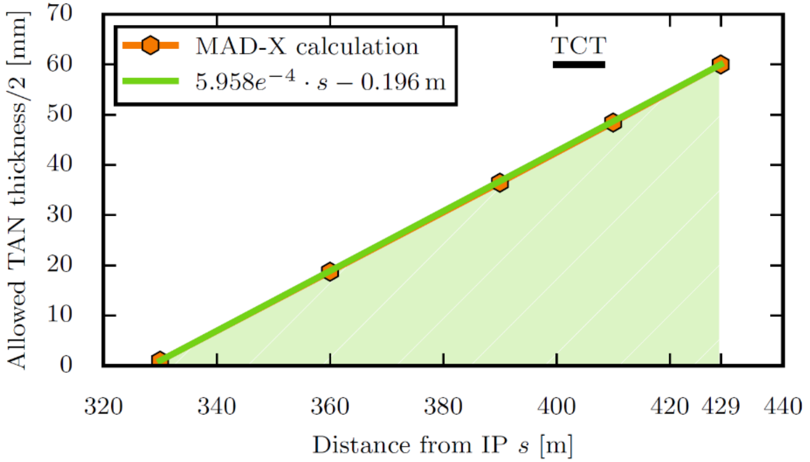
[Ref: Daniel Schoerling - *Review of peak power limits for high luminosity IR triplet magnets*]

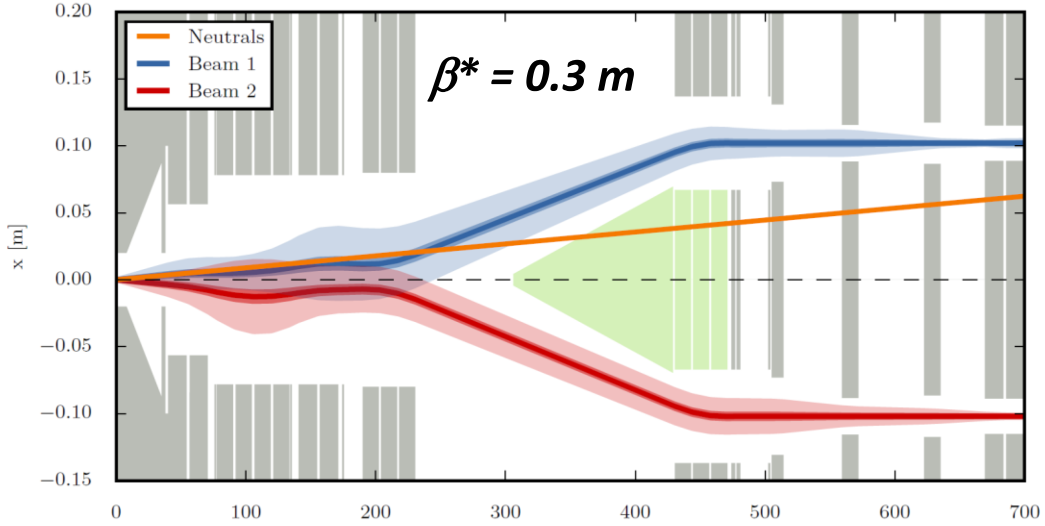
Magnet Lifetime: How to increase?

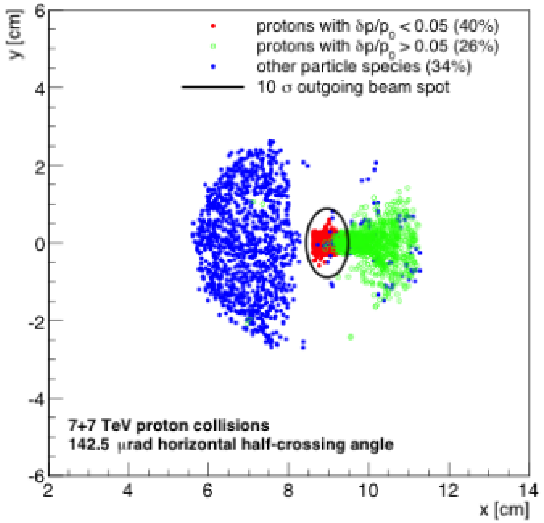
- *Crossing scheme techniques* -> not useful due to symmetry
- *Aperture* -> currently, reduction from Q3!
- *Return coils* -> avoid proximity to the beam
- *Design of mask* -> to be carefully investigated

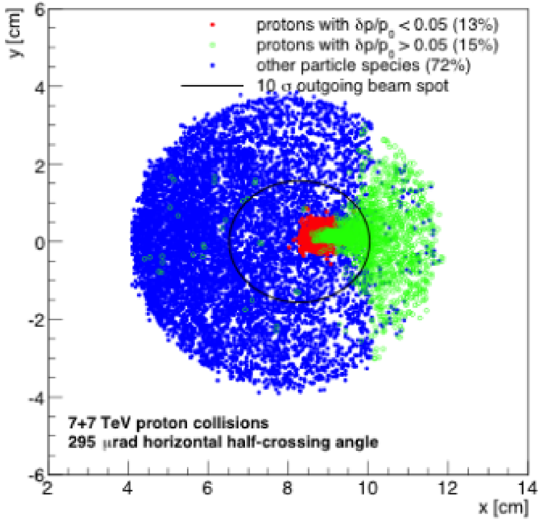
TAN Considerations

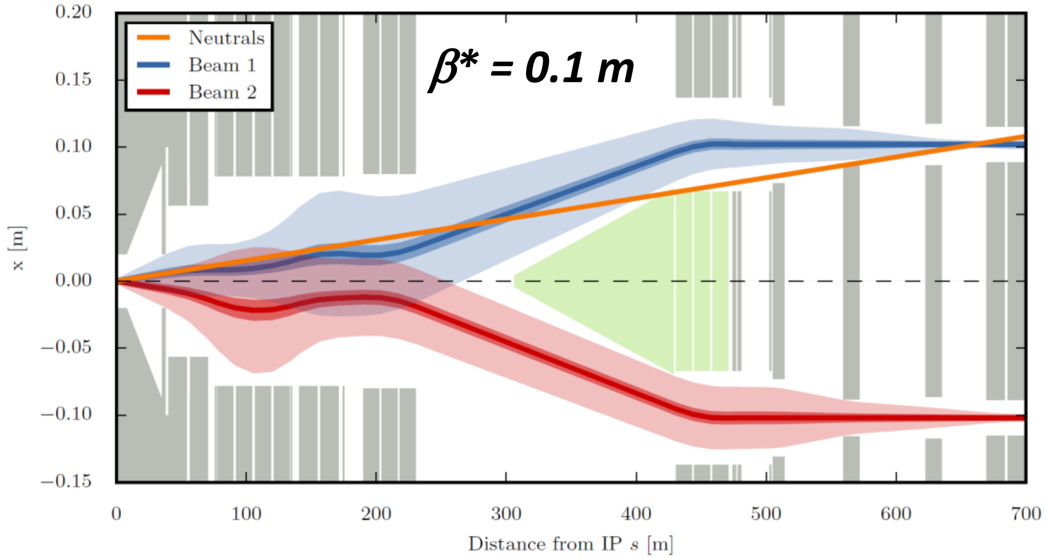
Plots courtesy of R. Martin











Ref: *High-Luminosity Large Hadron Collider (HL-LHC) Technical Design Report V. 0.1* (CERN-2017-007-M)

Take-Home Message:

TRIPLET

- ✓ *L* = 40 m* does not present a significant change in the total power deposition: difference from L* = 45 m *within 15%*
- ✓ *Peak power density*: *max ~ 3.3 mW/cm^3 (< limit 5 mW/cm3)* and *shift of the peak* at the beginning of Q1B *due to quadrupole splitting*
- ✓ *Dose peak* of *~65 MGy* at the beginning of Q1B: *crossing scheme techniques* and *shielding thickness* can increase the magnet lifetime

D1

- ✓ *Power loss distribution* shows a peak at the beginning of the first module (D1A), with a *max ~1 kW/m*
- ✓ *Peak dose* in the coils is *~45 MGy*
- ✓ *Magnet lifetime and cooling*: *Different mitigation techniques* might be adopted (e.g. *increasing the aperture*, *mask* at the beginning of D1A, *return coil* far from the beam)

Future actions: TAN + D2

- ✓ Implementation of the *optics up to the D2* is ongoing
- ✓ *TAN design is under consideration*

www.cern.ch

Angelo Infantino

CERN EN/STI-FDA
FLUKA Team - R2E Project
angelo.infantino@cern.ch

Backup: Power Loss Distribution

55 mm Shielding V-Crossing: Power

Total power for 5 10^{34} $cm^{-2}s^{-1}$ [kW]:

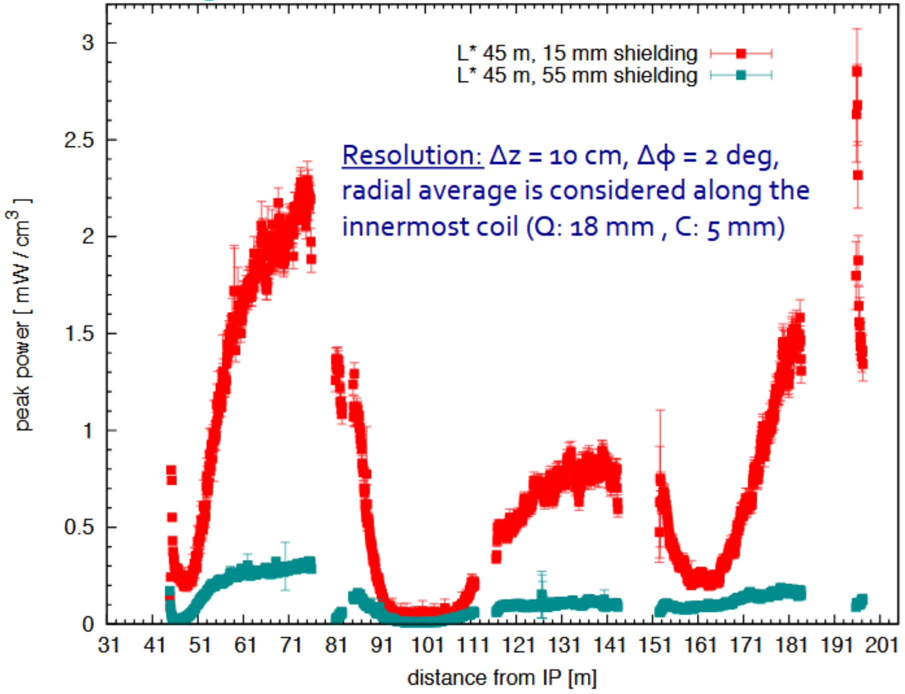
Magnet	Total	Shielding	Cold Mass
Q1	4.1	3.7	0.37
C1	0.061	0.056	0.005
Q2A	0.76	0.7	0.07
Q2B	2.3	2.1	0.17
Q3	2.5	2.3	0.18
C2	0.13	0.12	0.01

Ratio of the power on the cold mass wrt the 15 mm thick shielding case:

Q1	0.5
C1	0.11
Q2A	0.5
Q2B	0.3
Q3	0.4
C2	0.17

Peak power density for 5 10^{34} $cm^{-2}s^{-1}$:

for baseline luminosity the maximum peak power is 0.3 $mWcm^{-3}$.



The expected peak power density for 30 10^{34} $cm^{-2}s^{-1}$ is ~2 $mWcm^{-3}$

[Ref: M.I. Besana - *Overview and Status of the Radiation Load Studies Focused on Magnets*]

Backup: Power Loss Distribution