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Cold loss studies for the quench limit assessment

M. Varasteh, R. Bruce, F. Cerutti,
J. Molson, E. Skordis

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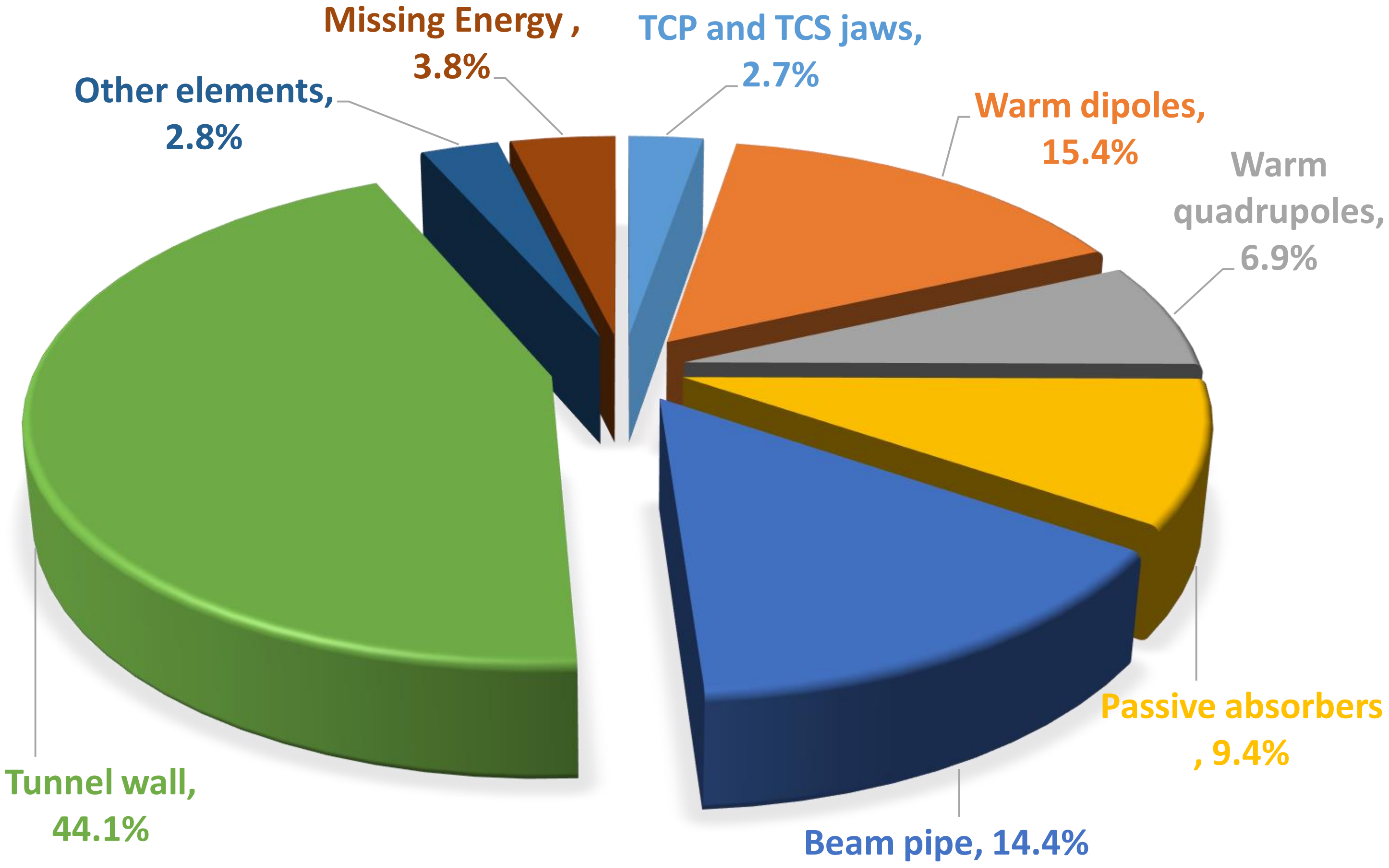
Power fraction in the FCChh collimation system

➢ **Cleaning insertion is in charge of protecting the machine from losses**

- **With shorter (and less) primaries and thicker jaws, the maximum power collected by a collimator (for 12 min BLT) is below 100 kW**
- **Peak power density on the 1st secondary collimator is reduced by a factor of 7**
- **Dogleg warm dipoles (17m), are subject to ~200 kW for 1h BLT → calling for a suitable cooling system**



M. Varasteh et al. (FCC Week 2018)

Outline

- **A short introduction**
- **Impacted cold dipoles in the DS region of FCChh machine**
- **Geometry of the FCChh and LHC’s SC-dipole**
- **Energy deposition study (FCChh vs HL-LHC)**
- **Summary**

Motivation

- **Quench limit is normally given in terms of peak power density**
- **A correlation between "power density" and the respective proton loss density rate (p/m/s) might give the possibility to assess what we can tolerate on the cold magnets**
- **A comparison between FCChh and LHC dipoles** (*soon also with HE-LHC*); ***shows how the picture will change according to the Machine, Energy, Geometry, and Coil Composition…***
- **Considering the worse scenario** (TCLD open and 12 minutes BLT)

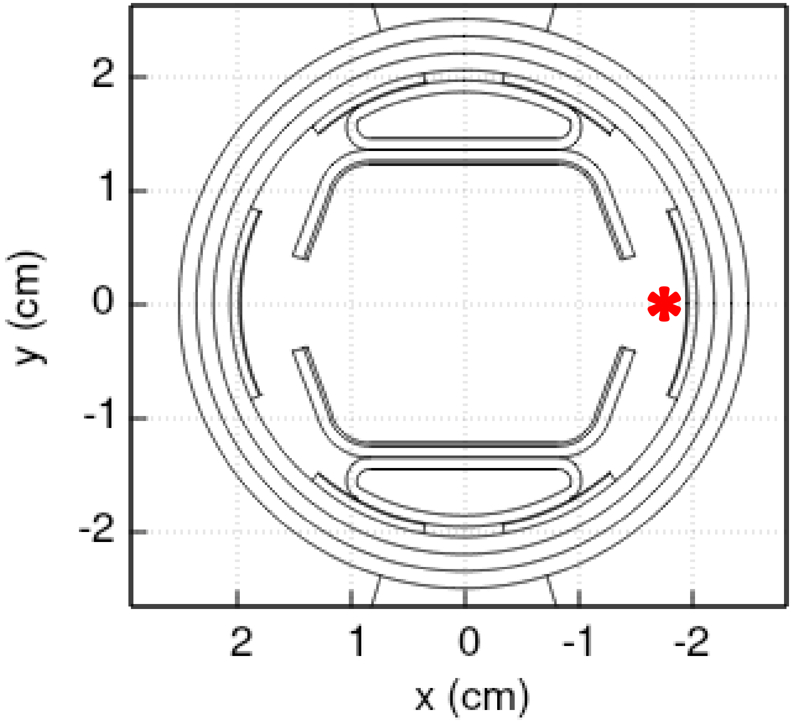
Most impacted dipoles

- Proton losses from FCC-hh betatron collimation region with an **open TCLD**
- Identifying the DS magnet which receives the maximum loss
- Dumping the corresponding losses at the start of the dipole

➢ **Then FLUKA showering calculation takes the loss distribution from SixTrack-FLUKA coupling**

Collimator settings (FCChh optics)

Collimators	Length (m)	Aperture (σ)	Material	Number
Primary	**0.3**	**7.6**	**CFC**	**2**
Secondary	**1.0**	**8.8**	**CFC/MoGr**	**11**
Active Absorbers	**1.0**	**12.6**	**tungsten**	**4**

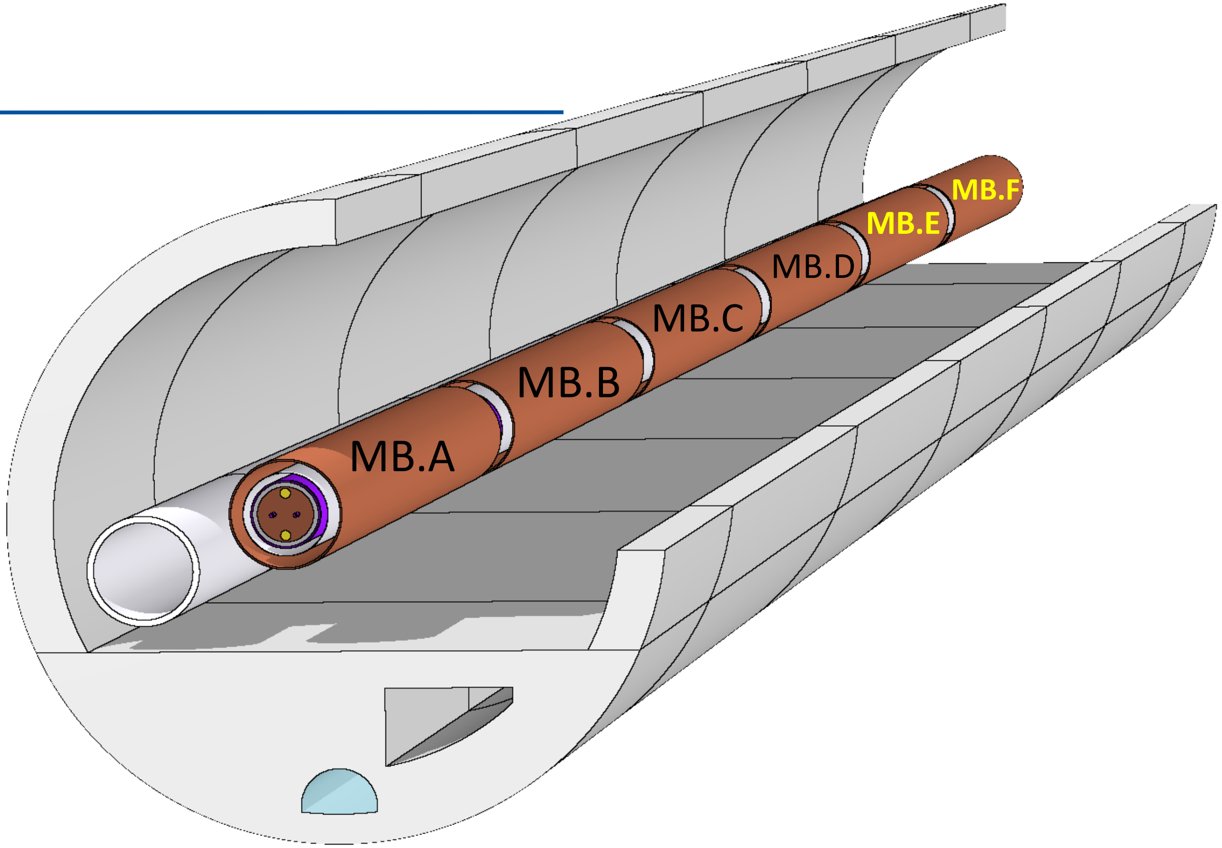


schematic view of the dumped particles at the start of MB.E

FCC-hh cell 13RJ

- In the cell 13RJ we have 6 ***straight SC dipoles***
  - magnetic length: **1424.16 cm (LHC: 1430)**
  - mechanical length: **1435.16 cm**
  - bending angle: **1.347 mrad**

- **+ 6 Corrector Sextupoles + 2 Quadrupoles (*not inserted here*)**

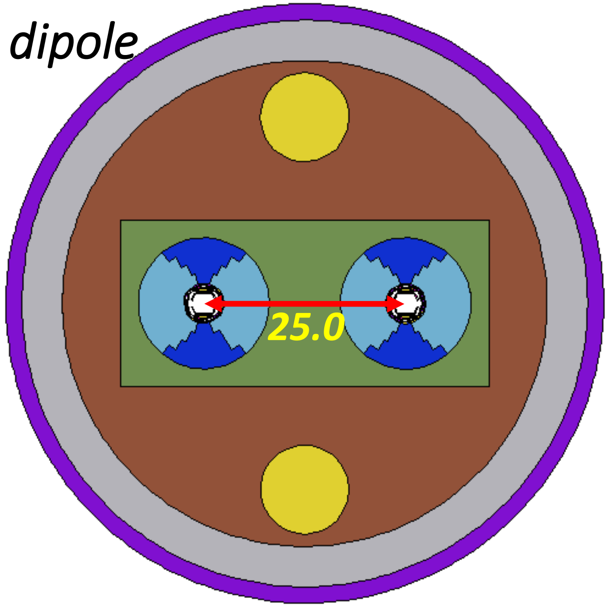


- Dipole layout is updated according to the mechanical design presented by BARBARA CAIFFI in the last FCC week.

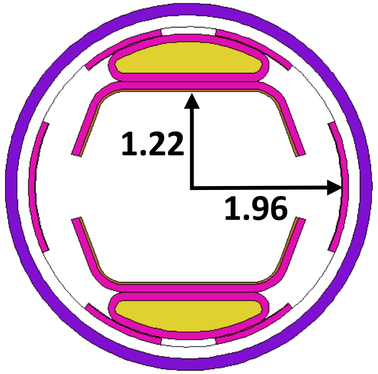
- **Moreover the beam separation is increased to 250 mm (instead of 204 mm)!**

FCC and LHC main SC dipoles

FCC main dipole

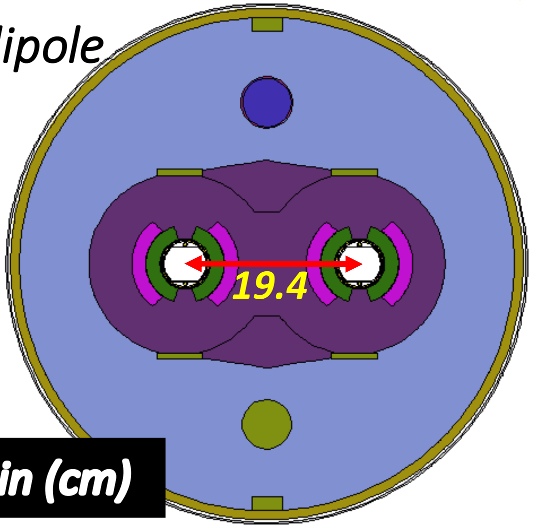


FCC beam screen

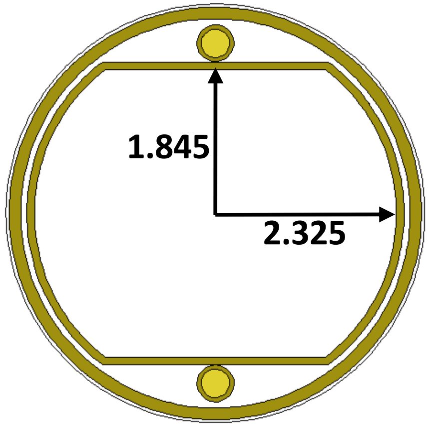


Bore nominal field: 16 T
Yoke outer diameter: 60 cm
Coil Material: **Nb3Sn**
Coil density: 7.95 g/cc
Radiation length: 1.426 cm

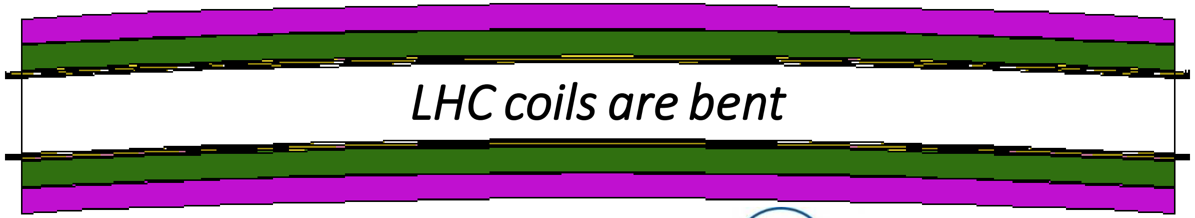
LHC main dipole



LHC beam screen



Bore nominal field: 8.33 T
Yoke outer diameter: 55 cm
Coil Material: **NbTi**
Coil density: 7.12 g/cc
Radiation length: 1.82 cm



All sizes are in (cm)

Few important numbers, used in this study

	Number of bunch	Bunch charge	Machine loss (12 min BLT) s^{-1}
HL-LHC	**2604**	**2.2e11**	**7.9e11**
FCC-pp	**10600**	**1e11**	**14.72e11**

Loss fraction on the example cold magnet in the DS

- **in the cell 9 of HL-LHC →** 1.5e-4
- **in the cell 13 of FCC-hh →** 2.1e-5

MB.E13RJ - MB.F13RJ (FCC-hh)

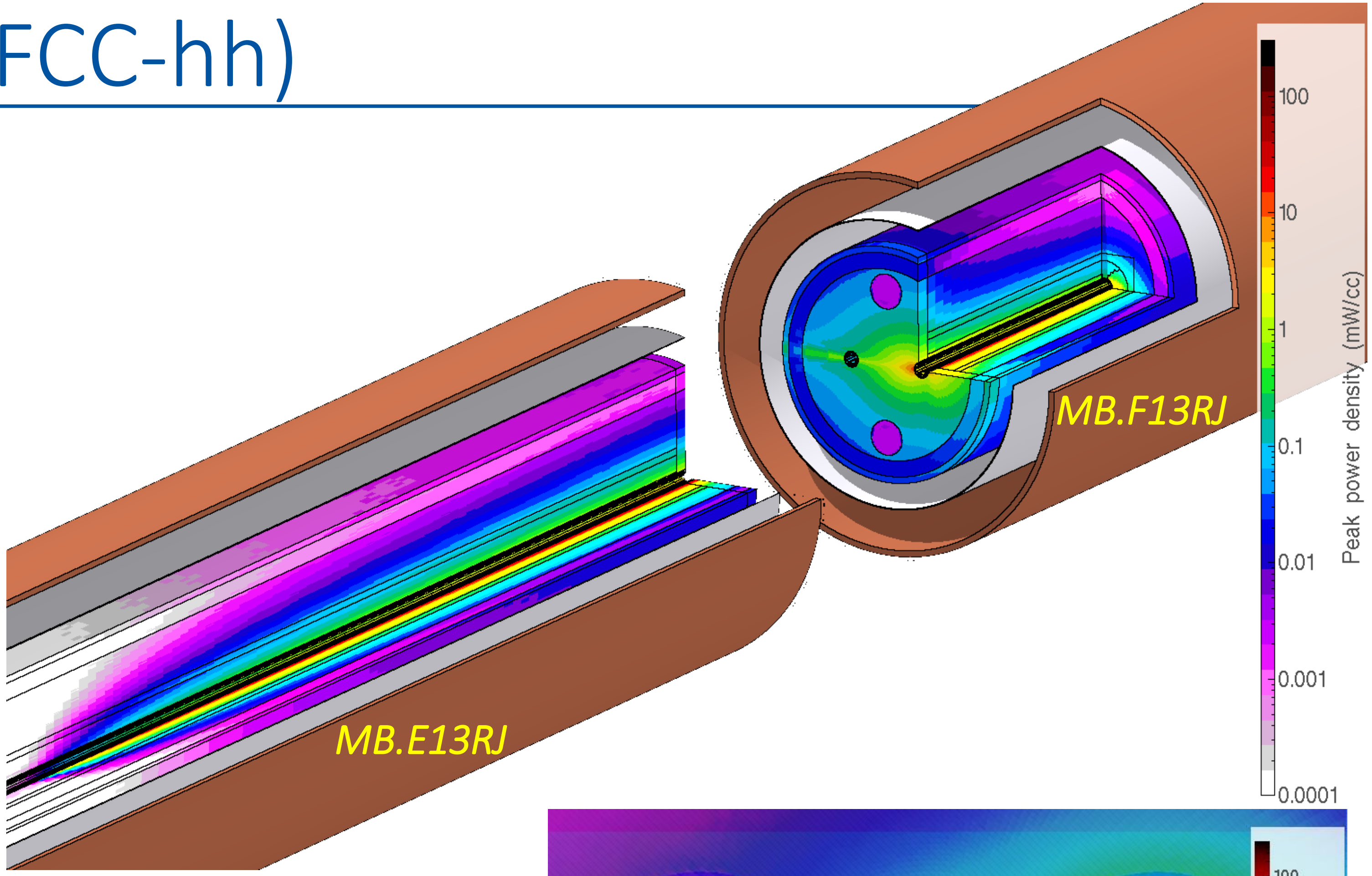
- **Loading the losses corresponding to the MB.E (1st dipole in the figure)**

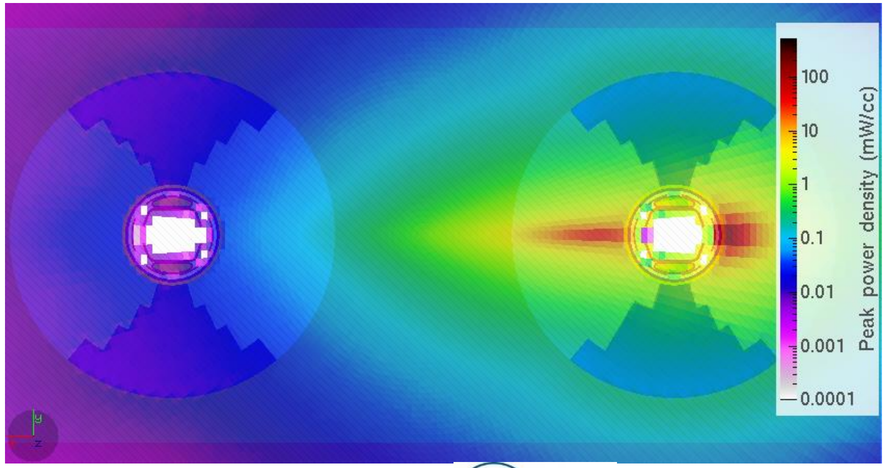
- *Scoring is done with (r-φ-z) grid of (3mm, 180^{o}, 5cm)*

- **We see the peak at the end of 1st dipole**

- **Power deposition in the MB.F (2nd dipole in the figure) is caused by the shower developed in the MB.E13RJ**

Beam direction



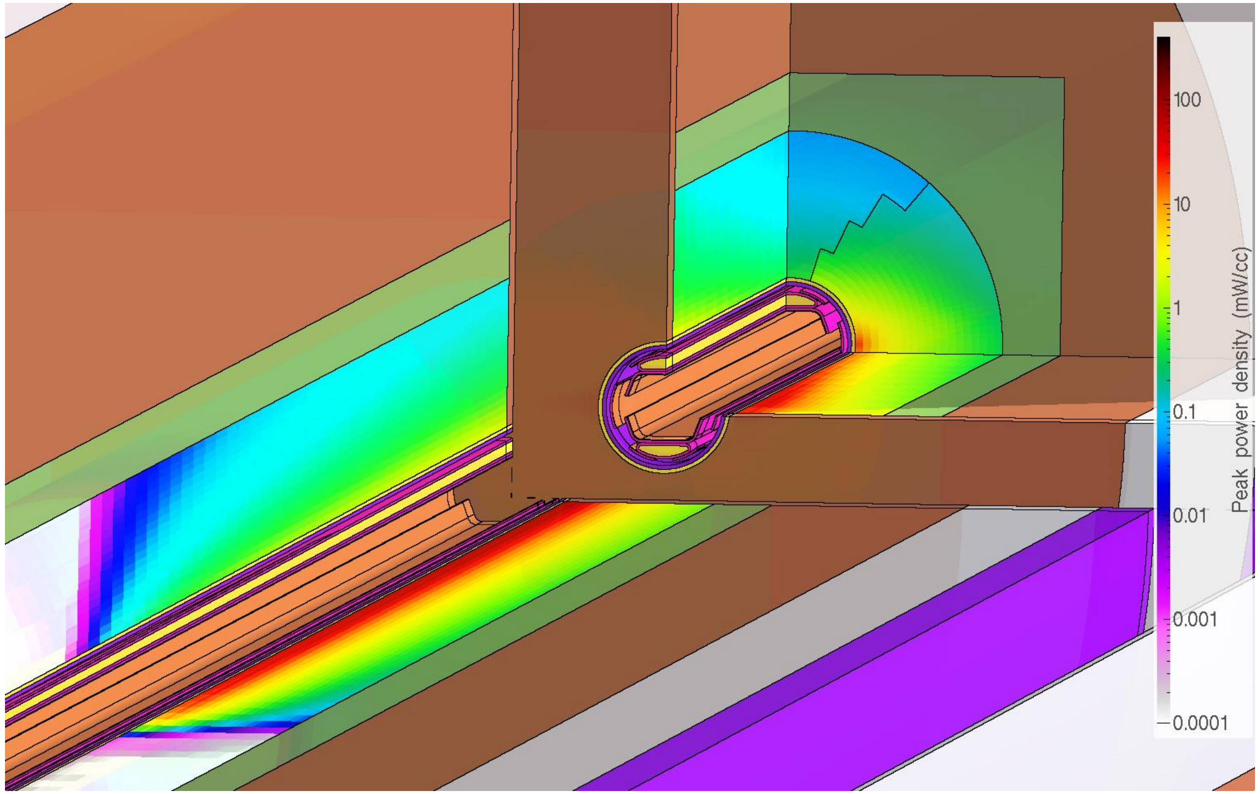


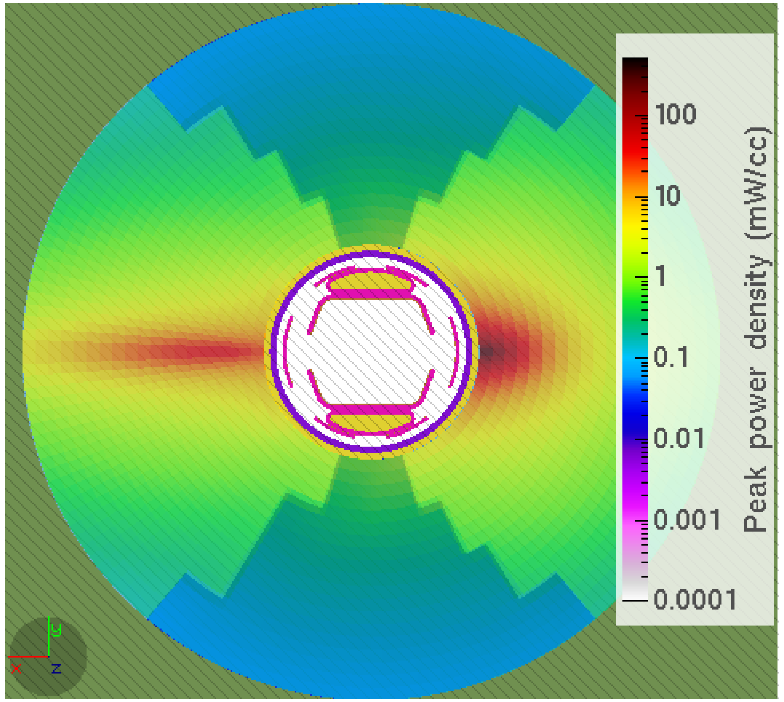
Power deposition in the most impacted superconducting magnets in the DS region

* Values are for 12 minutes beam lifetime…

Induced power density in the SC coils (FCC)

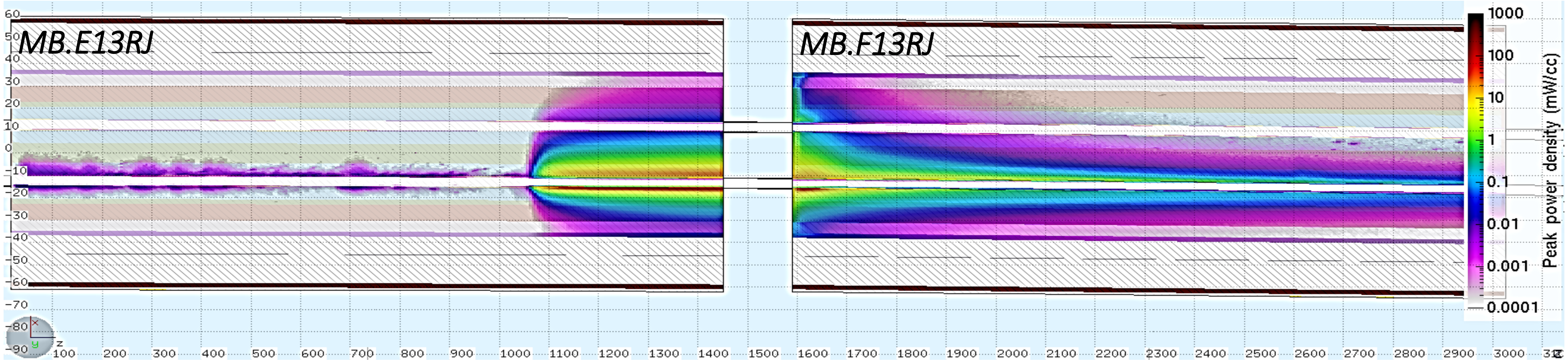
Maximum power density deposited in the *superconducting* coil is about ***230 mW/cc*** *at the very end of the 1st coil.*

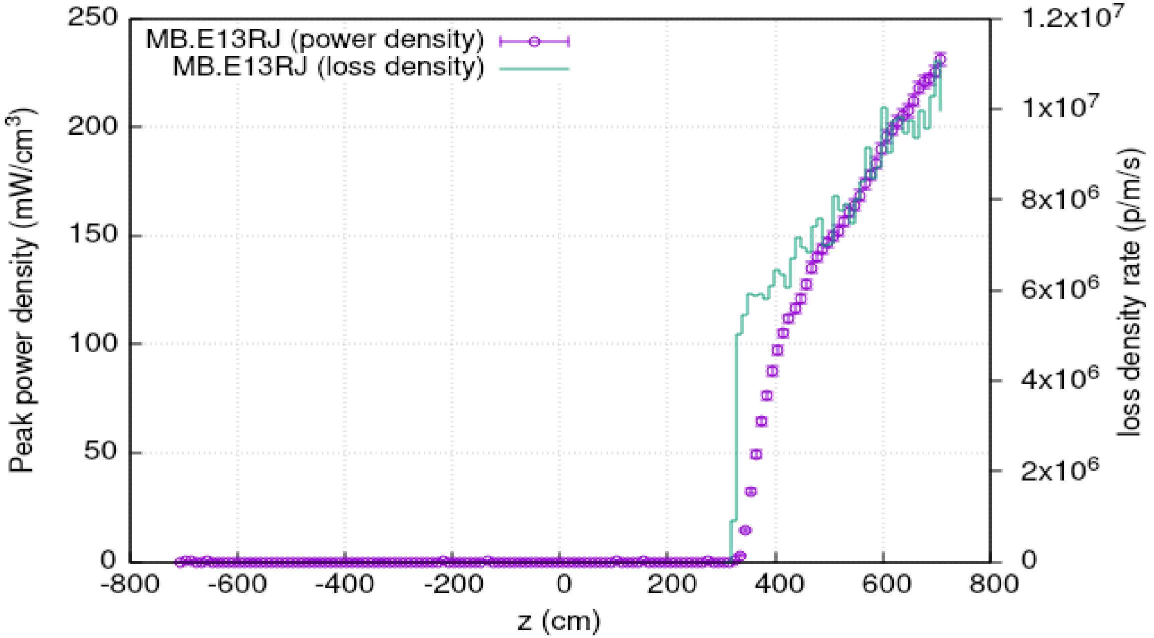


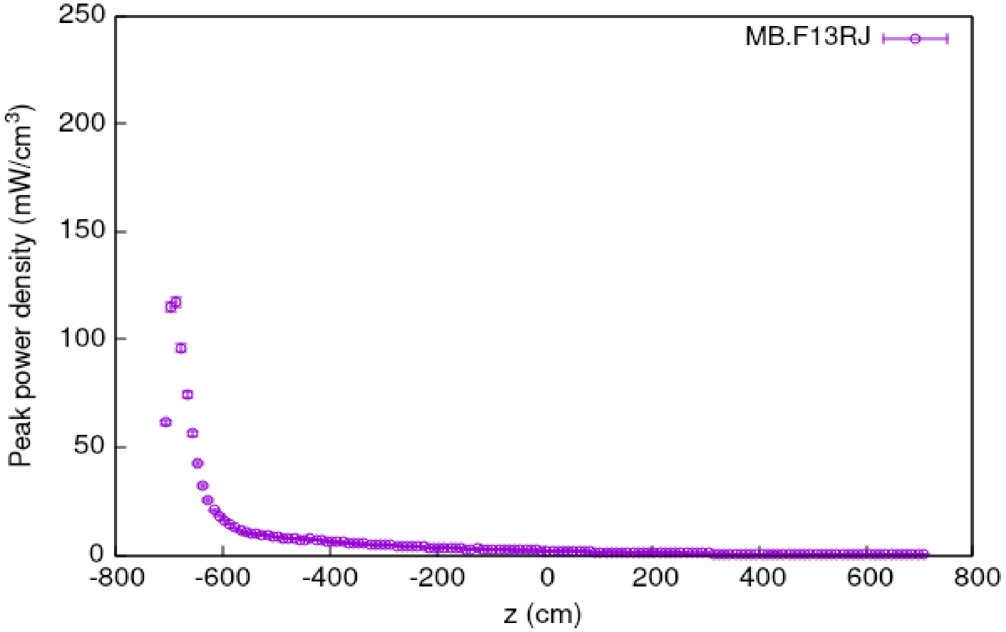


r-φ-z resolution: 2.9mm, 180°, 10cm

Loss density rate & power density (open TCLD)



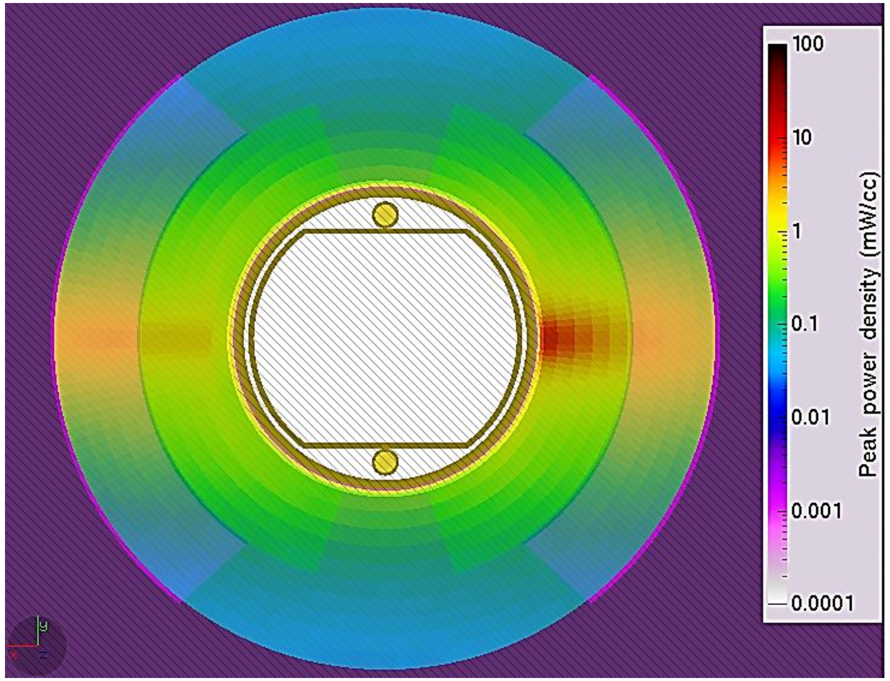


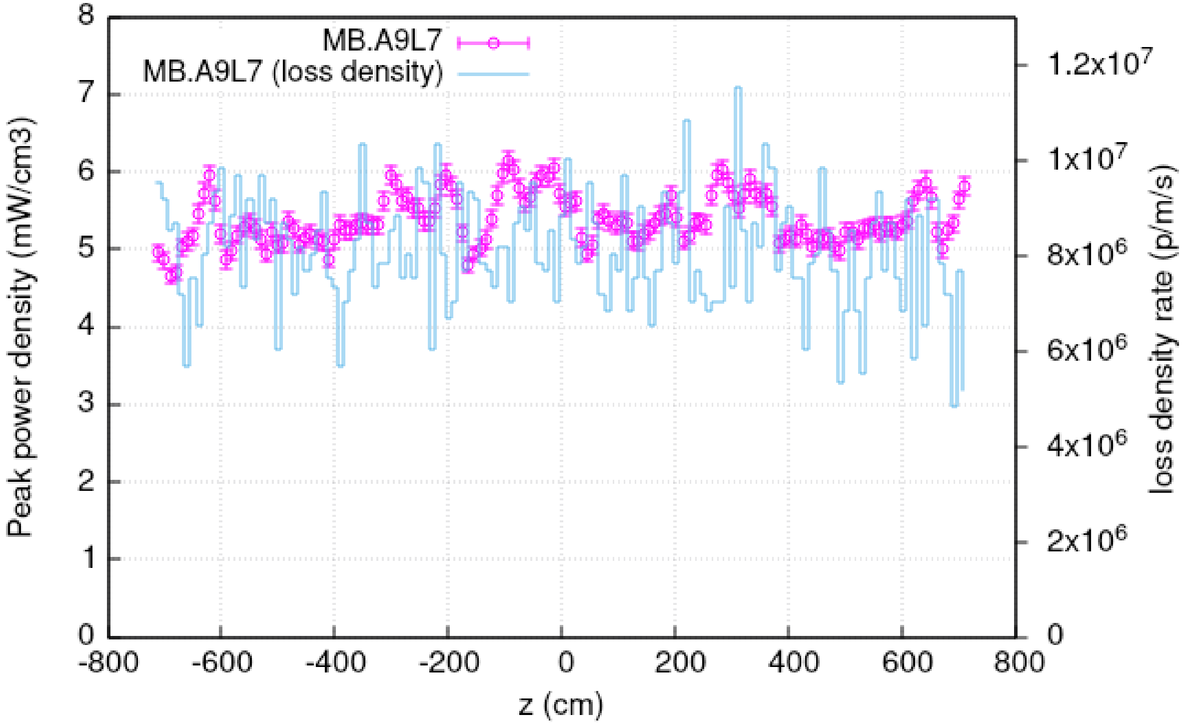


r-φ-z resolution: 2.9mm, 180°, 10cm

LHC dipole: loss density rate & power density (no TCLD)

Plots are driven from a simulation done by C. Bahamonde for HL-LHC!



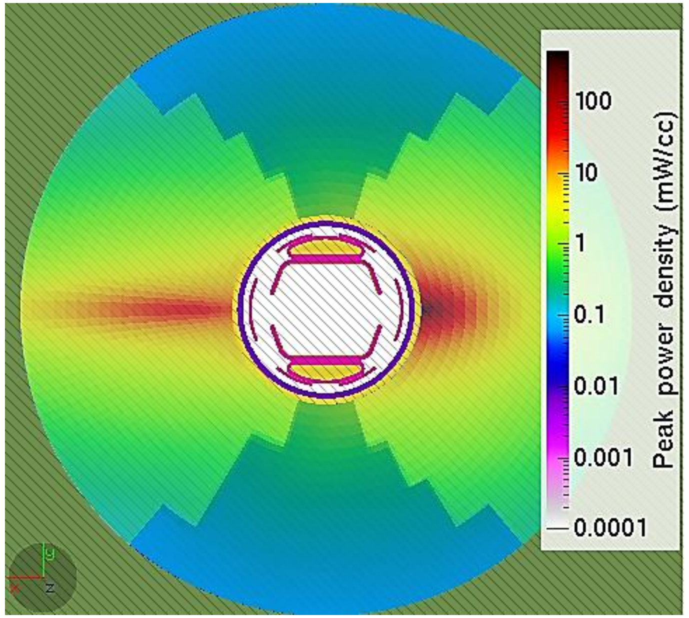


- For similar loss density rate, max power density in the DS on the MB.A9L7 → **6.3 mW/cc**
- With a relaxed collimators setting (***E. Skordis ColUSM 30/01/15***) → **23.5 mW/cc**

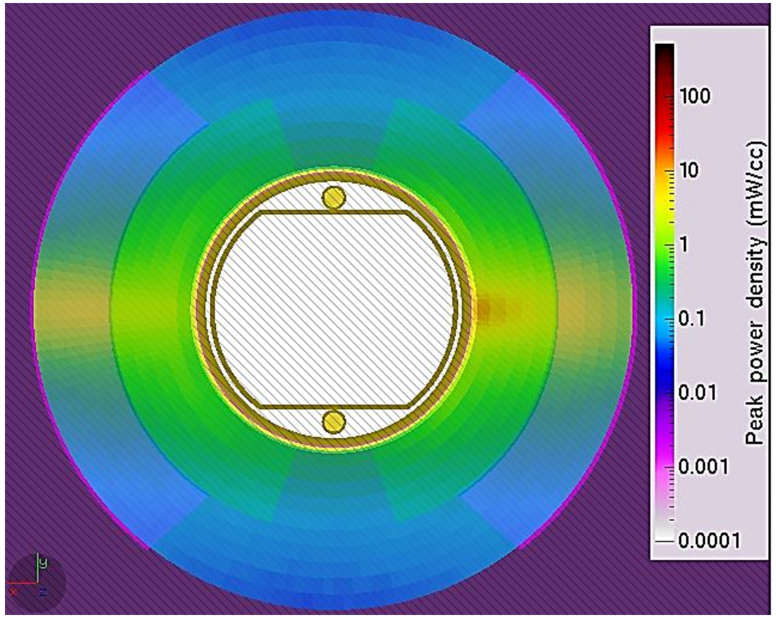
Scoring is done with (r-φ-z) grid of (3.1mm, 180^{o}, 9.9cm)

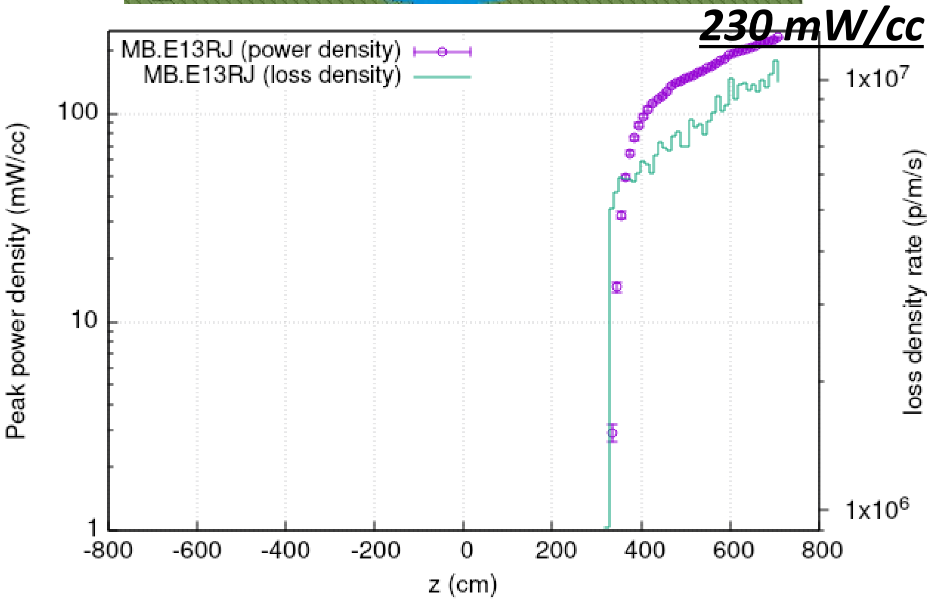
FCC-hh vs HL-LHC

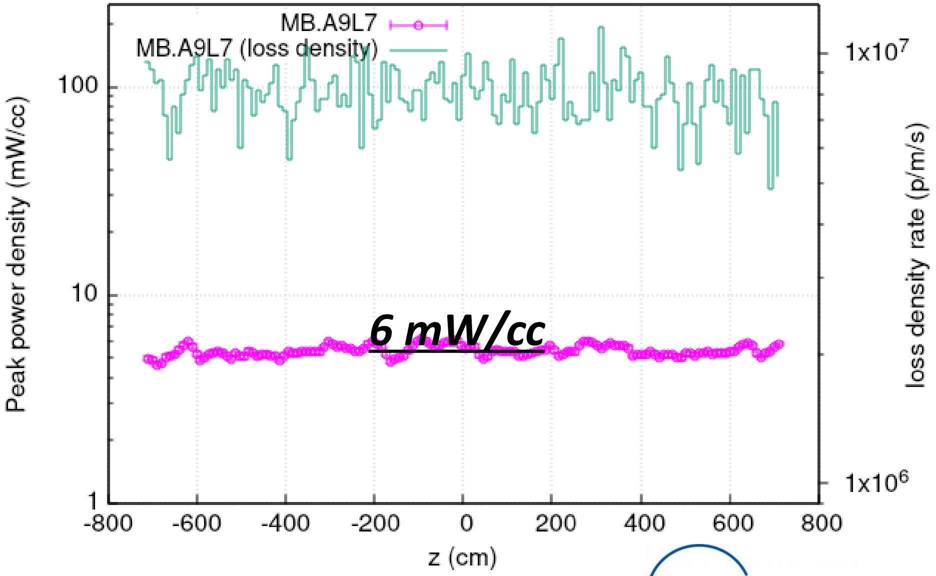
FCC-hh



HL-LHC







Summary

- **Loss rate in the cold section has been studied in order to correlate the "power density" and the respective proton loss density rate (p/m/s)**

- **For a loss density rate in the order of 1e7 (p/m/s) we got a factor of 35 more power density in FCChh cold dipole w.r.t LHC**

Next:

- ***Sextupole correctors are already added in the Geometry, interconnections will be inserted and we are going to take into account the losses corresponding to the drifts and sextupole and repeat the simulation***

- ***Performing the same study for the HE-LHC SC dipole (fluka model is ready)***

Mohammad Varasteh

CERN / EN-STI-BMI
m.varasteh@cern.ch