
CERN

Cold losses and deposited power density

M. Varasteh and F. Cerutti

Tracking input from BE-ABP:
M. Crouch, J. Molson, R. Bruce, A. Mereghetti

Acknowledgments: C. Bahamonde, M.I. Besana, E. Skordis, other colleagues in BMI & FLU

FUTURE CIRCULAR COLLIDER
CONFERENCE 2019
Brussels, Belgium

Outline

- **Introduction**
- **16 T dipole geometry**
- **Energy deposition in the cold section**
  - *How the picture will change according to the Machine, Energy, Geometry, and the Coil Composition? (HE-LHC, FCC-hh, and HL-LHC)*
- **Summary**

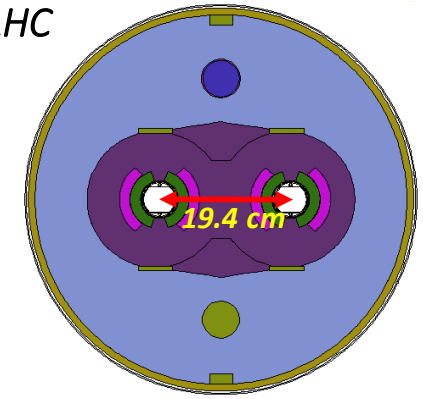
Motivation

- **Quench limit is normally given in terms of peak power density**
- **A correlation between** *peak power density* **and the respective** *proton loss density rate (p/m/s)* **would give the possibility to approximately indicate what can be tolerated on the cold magnets**
- **For this study, collimators in the cold section (TCLDs) are kept open**

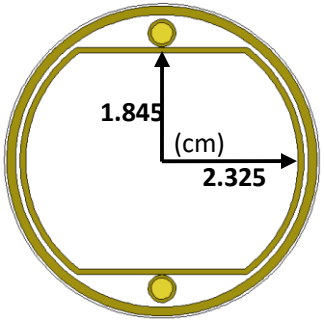
<<< high loss scenario of 0.2h beam life time (BLT) >>>

Main super conducting dipole

LHC

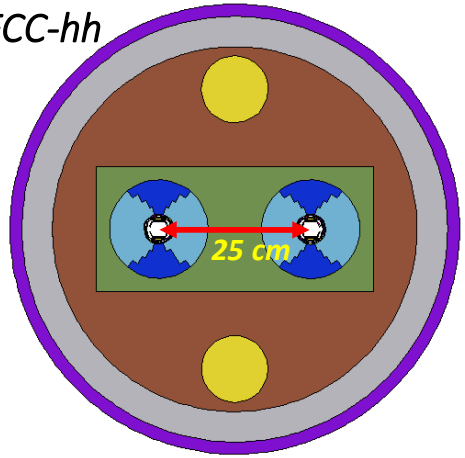


LHC beam screen

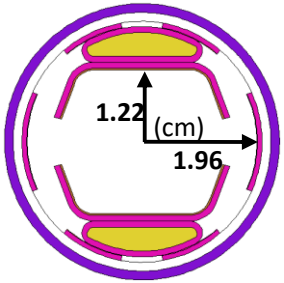


SC dipole	FCC-hh	HE-LHC	LHC
Magnetic length (m)	14.18	13.83	14.3
Type	RBEND	SBEND	SBEND
Beam separation in arc (mm)	250	204	194
Coil thickness (cm)	5.6	5.6	2*1.56
Bore nominal field (T)	16	16	8.33
Yoke outer diameter (cm)	60	60	55
Coil Material	Nb3Sn	Nb3Sn	NBTi
Coil density (g/cc)	7.95	7.95	7.12
Radiation length (cm)	1.426	1.426	1.82

FCC-hh



FCChh & HELHC's beam screen



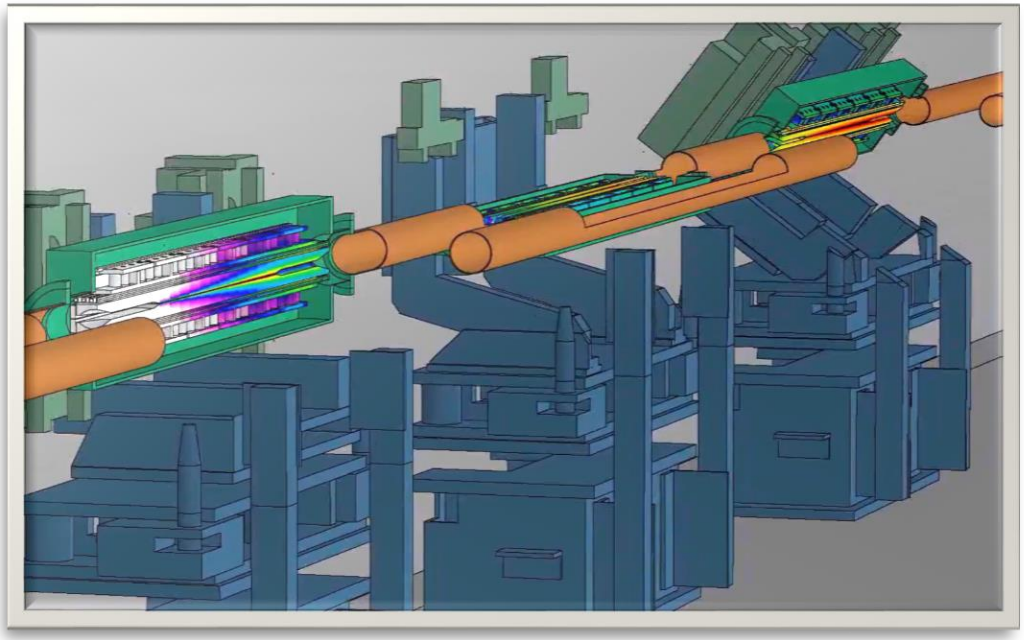
- 16 T dipole layout is updated according to the mechanical design presented by BARBARA CAIFFI in FCC Week 2018.
- Moreover, the beam separation is increased to 250 mm (instead of 204 mm)…

HE-LHC IR7 - Cold Losses

SixTrack-Fluka coupling → distribution of the particles that touch the collimators

FLUKA:
- Uses these touches to dump the particles which will hit the cold section's aperture
- Showering calculation in the cold section

FLUKA model of the IR7



Collimator settings (HE-LHC optics)

Collimators	Length (cm)	Aperture (σ)	Material	Number
Primary	*60*	*6.7*	*CFC*	*3*
Secondary	*100*	*9.1*	*CFC*	*11*
Active Absorbers	*100*	*11.5*	*tungsten*	*5*

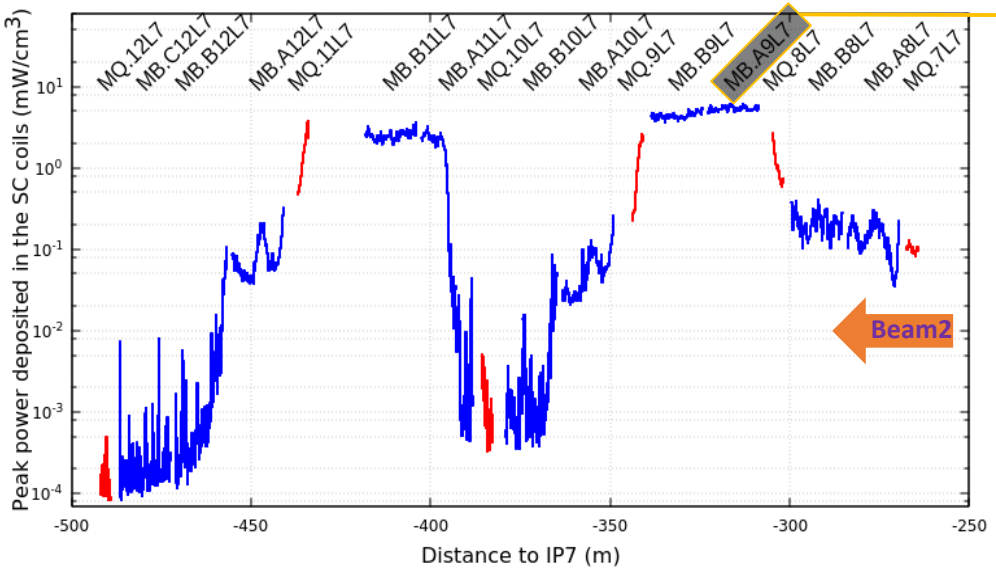
Join my talk this afternoon at 14:15

Room: Harmony (1st floor)

Power density in the cold section, no TCLD

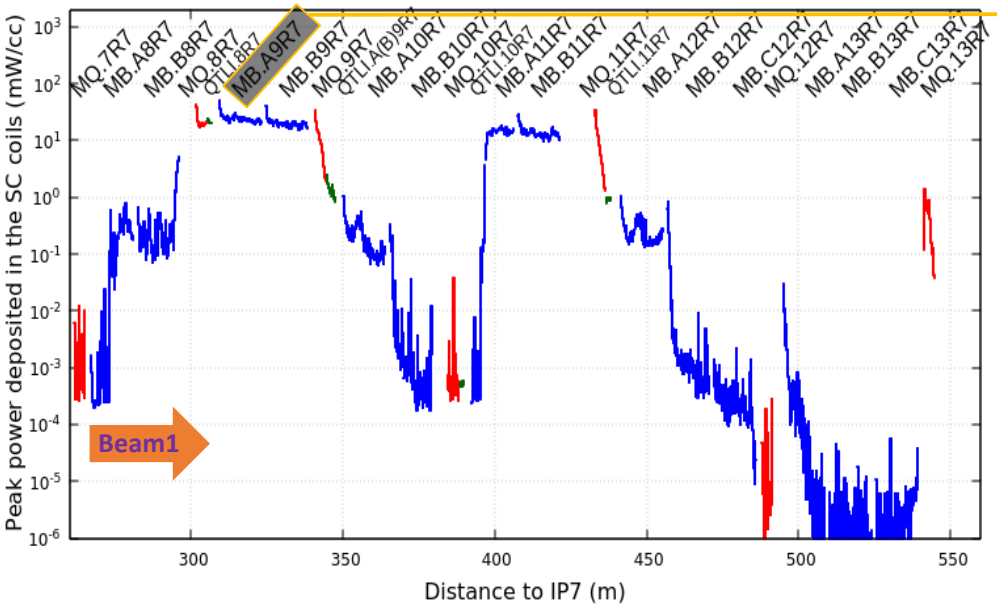
HL-LHC

Courtesy of C. Bahamonde



7 mW/cc

HE-LHC



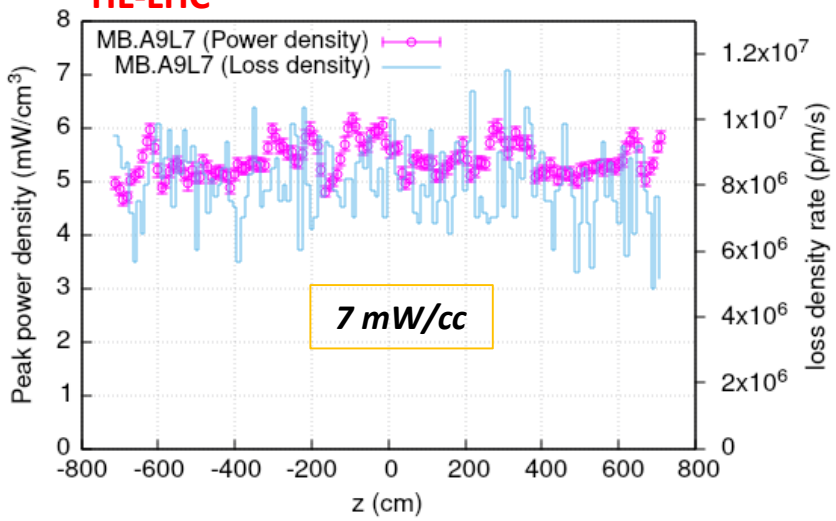
25 mW/cc

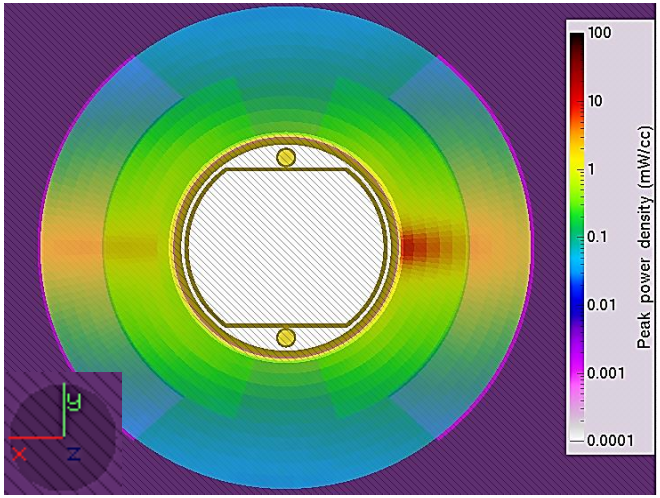
Values are for the 12 min BLT !

HL-LHC: *two radial bins of 1.56 cm*
HE-LHC: *three radial bins of 1.86 cm*

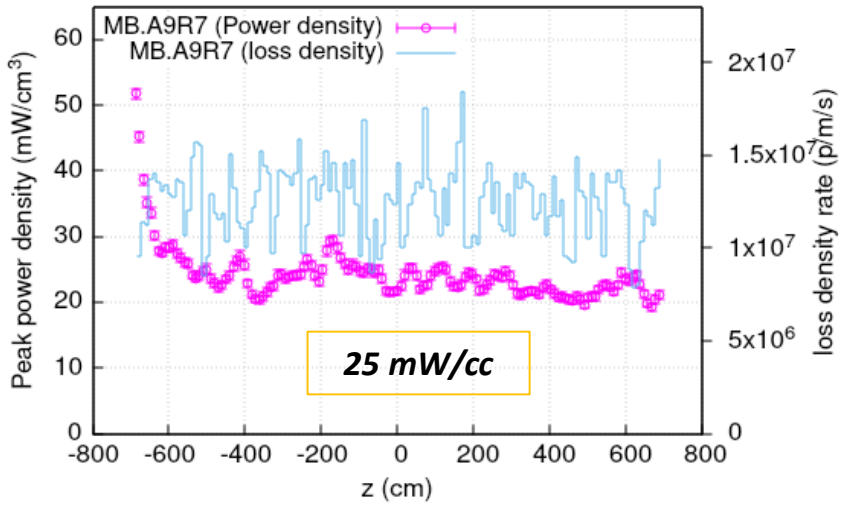
Most exposed SC dipole, no TCLD

HL-LHC





HE-LHC



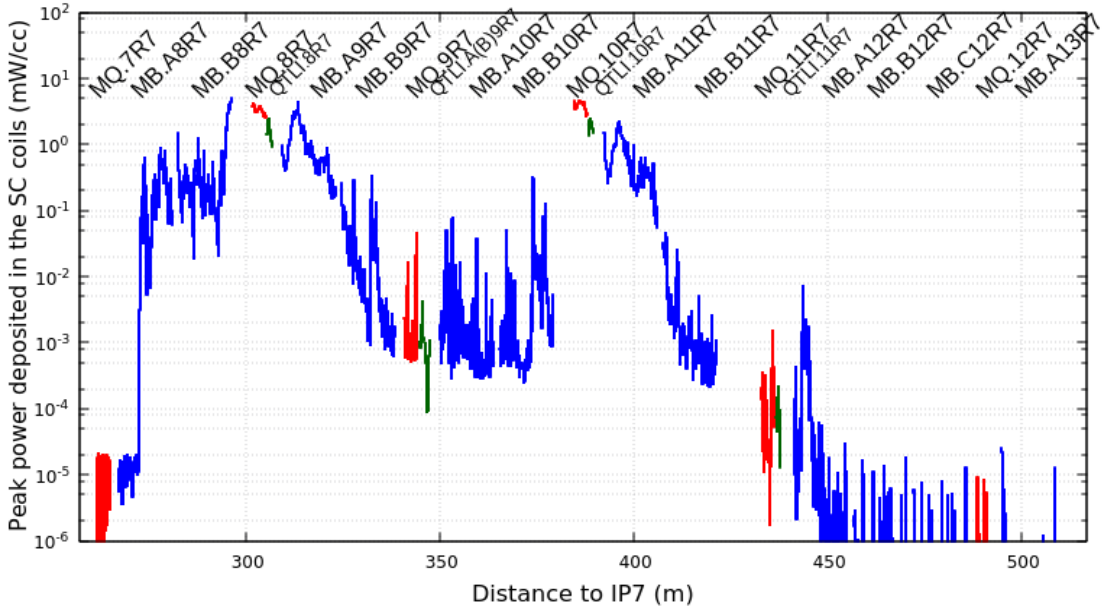
about a factor of 4 higher than HL-LHC
(Combination of loss and energy increase)

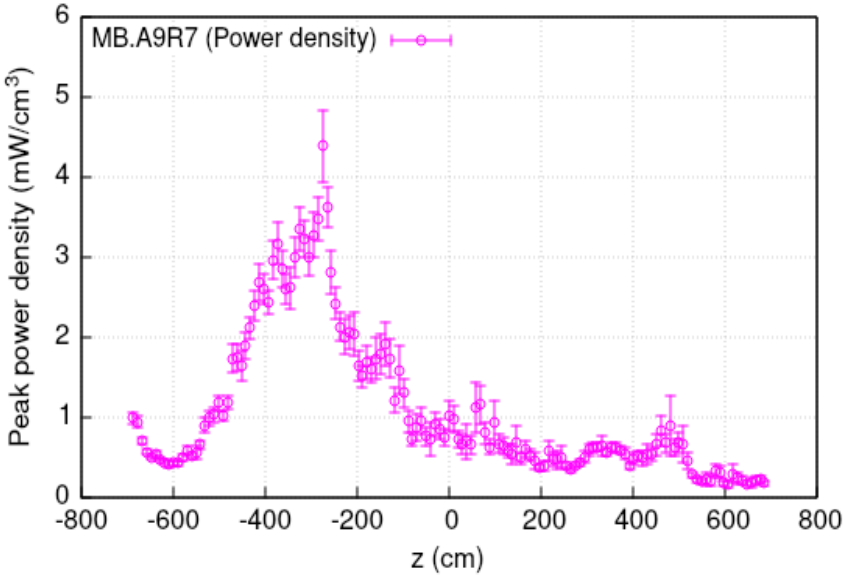
in LHC, the DS losses are deemed to be underestimated by a factor of 3 in the ideal machine simulation

HL-LHC: radial average (1.56 cm bins)
HE-LHC: radial average (1.86 cm bins)

(Quench limit ~ 70mW/cc *at the peak*)

With TCLDs (**HE-LHC**)





Two collimators (TCLDs) before MQ8 and MQ10 are baseline: maximum peak power density would be *5 time less* (≈ 5 mW/cc)

Values are for the **12 min BLT** !

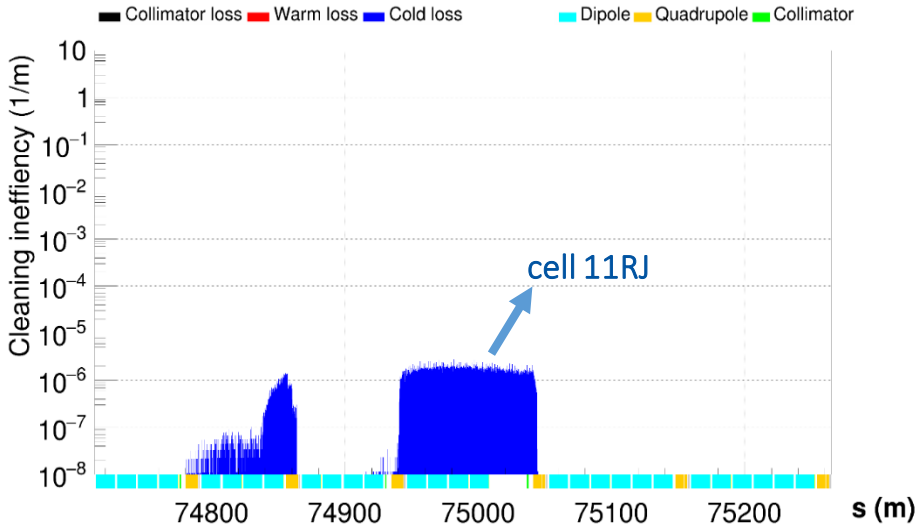
FCC-hh cold losses

Collimator settings (FCC-hh optics)

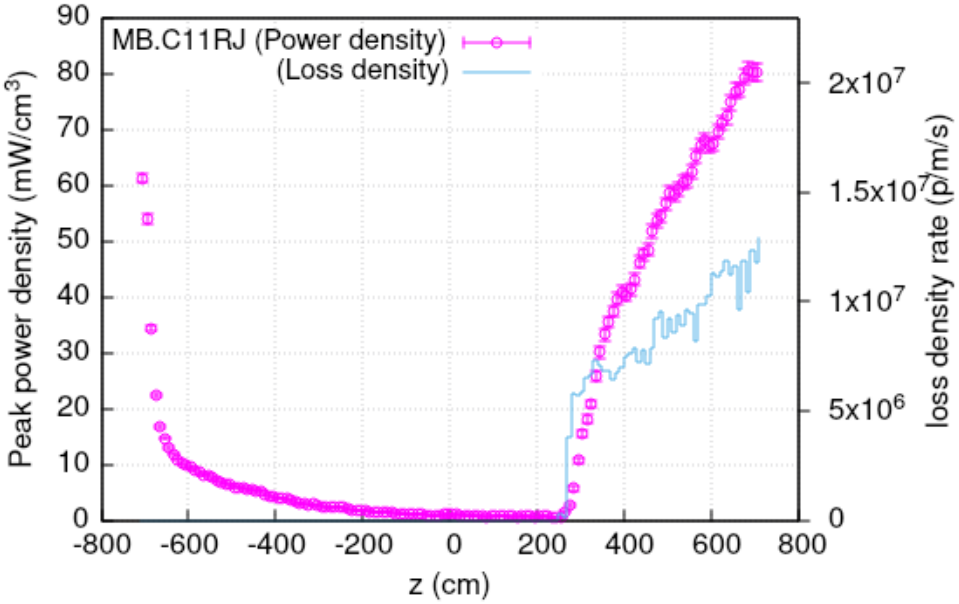
Collimators	Length (m)	Aperture (σ)	Material	Number
Primary	**0.3**	**7.6**	**CFC**	**2**
Secondary	**1.0**	**8.8**	**CFC/MoGr**	**11**
Active Absorbers	**1.0**	**12.6**	**tungsten**	**4**

- Assuming to have no collimators in the cold section
- SixTrack-FLUKA coupling → dump the losses at the start of DS
- FLUKA showering calculation up to the end of the cell 11

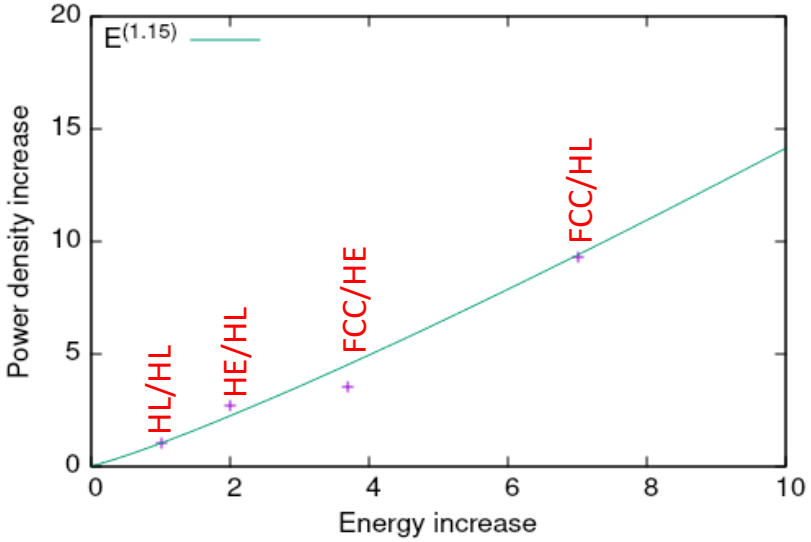
From SixTrack-FLUKA coupling



Induced power density in the most exposed dipole



Maximum power density deposited in **FCC-hh** main dipole is ***80 mW/cc***



By increasing the energy, the peak power density increases as $E^{(1.15)}$ *for low radial resolution* **and as $E^{(1.36)}$** *for 3mm radial bins*

…corrected by the respective loss density ratio…

r-φ-z resolution: 1.86cm, 2^o, 10cm

(three radial bins of 1.86cm)

Summary

- **Losses in the cold section has been studied in order to correlate the** *peak power density* **with the respective** *proton loss density rate (p/m/s)*
- **At HE-LHC (*w/o TCLD*), the peak power density on the SC coil is *≈ 25 mW/cc* *(and a factor of 5 less in case with TCLDs)***
- **For loss density rate in the order of 1.3e7 p/m/s (*w/o TCLD*), the peak power density in the FCC-hh main dipole is about a factor of 3 higher than HE-LHC**
- **Peak power density varies according to $ENERGY^{(1.15)}$ for low radial resolution and as $E^{(1.36)}$ for 3mm radial bins**

Mohammad Varasteh

CERN / EN-STI-BMI

m.varasteh @ cern.ch

Backup Slides

	unit	FCC-hh	HE-LHC	HL-LHC	LHC
center-of-mass energy	TeV	100	27	14	14
arc dipole field	T	16	16	8.33	8.33
bunch population [10^{11}]	ppb	1	2.2	2.2	1.15
number of bunches		10600	2808	2760	2808
stored beam energy	GJ	8.4	1.4	0.7	0.36
total power loss for 12 min BLT	MW	11.8	1.9	0.95	0.5

Recap of the FCC-hh IRJ warm section

Betatron 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…

Collimators	Total power (kW)
Vertical primary	*6.5*
Horizontal primary	*79.7*
First secondary	*92.4*

about a factor of 5 higher than LHC

M. Varasteh et al. (FCC Week 2018)