
CERN

Energy Deposition Studies

cold section of the collimation insertion (HE-LHC & FCC-hh)

M. Varasteh and F. Cerutti

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

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

FCC collimation design meeting #23

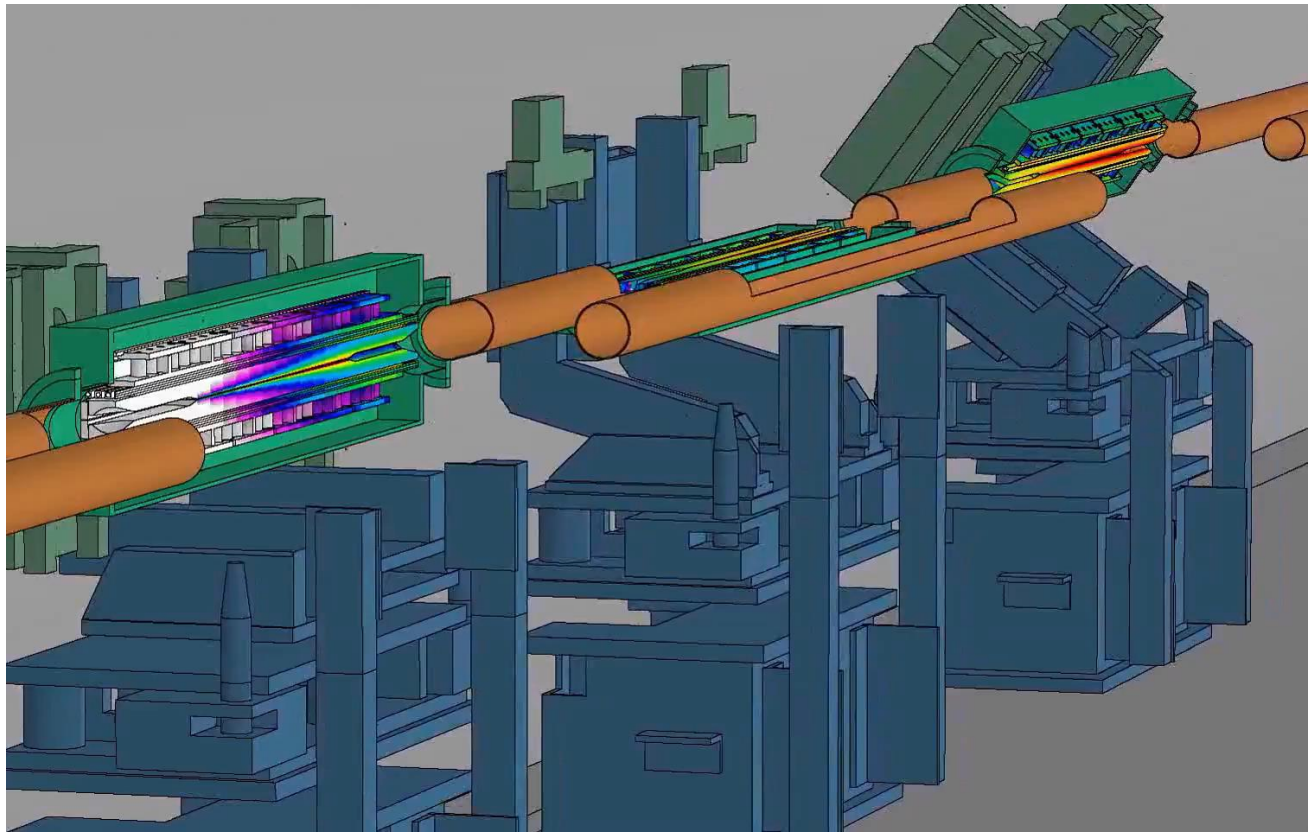
Outline

- Quick recap of the HE-LHC warm section (IR7)
- **Energy deposition in the cold section**
- **Impact of the dog-leg removal**
- Recap of the FCC-hh warm section (IRJ)
- **Losses on the 16 T dipoles**

Parameters

	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 HE-LHC warm section (IR7)



M. Varasteh (collimation design meeting #22)

Collimator Jaws	Total power (kW)
Primaries	
TCP.D	3.7
TCP.C	29.5
TCP.B	53.1
1st Secondary	
TCSG.A	56.1

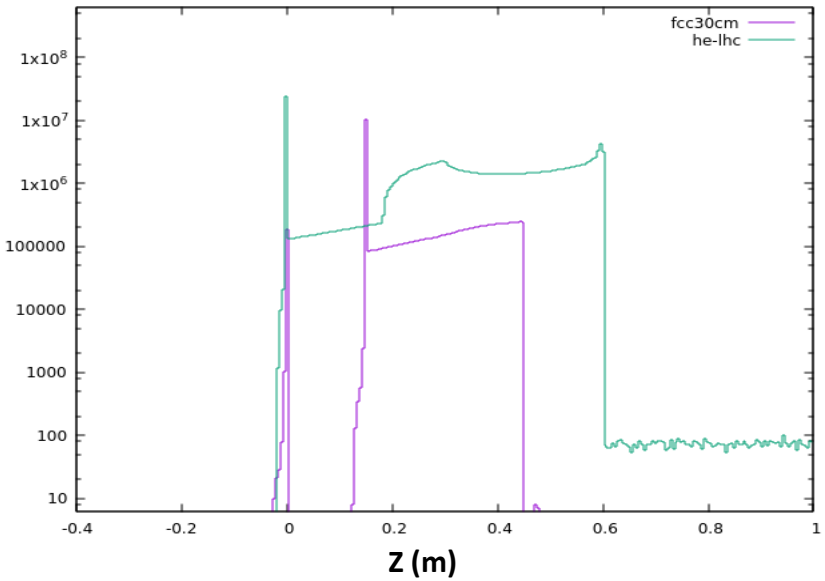
For LHC at 6.5TeV, the max load is about 15 kW

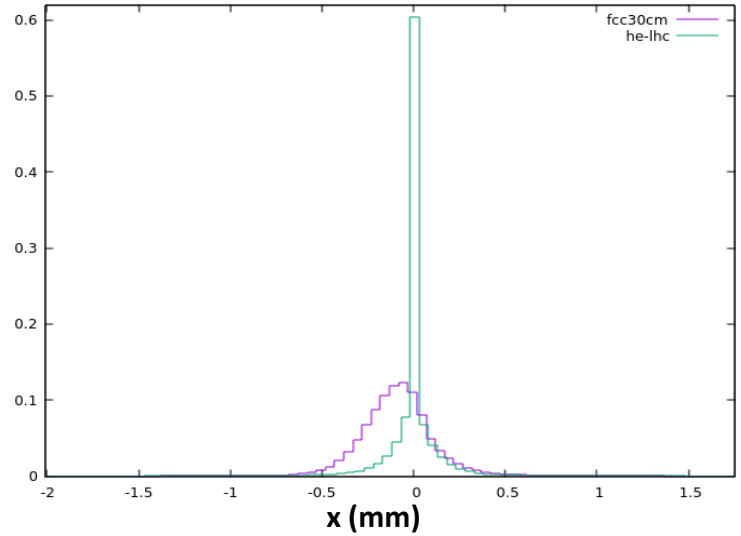
Also the maximum *power density* was seen to be on the metallic support of the TCSG.A

***** new design with thicker jaws is required *****

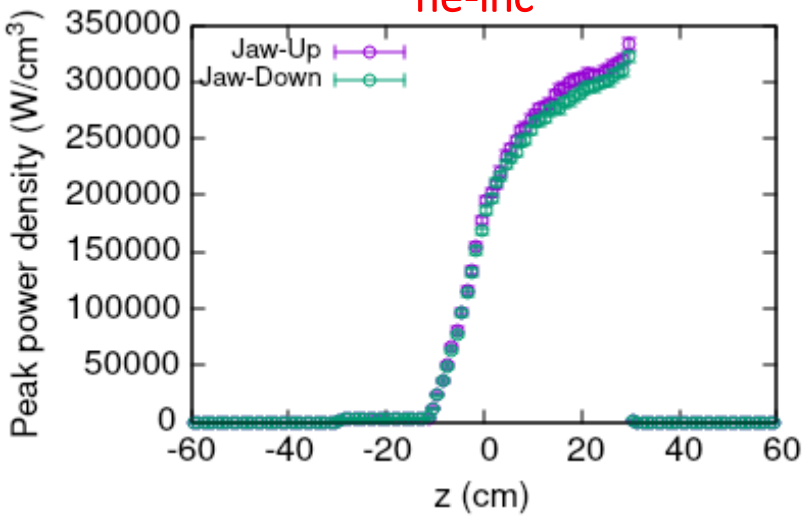
(we have seen a 60% reduction of the total power in case of the FCC-hh)

Vertical primary collimator (directly impacted)

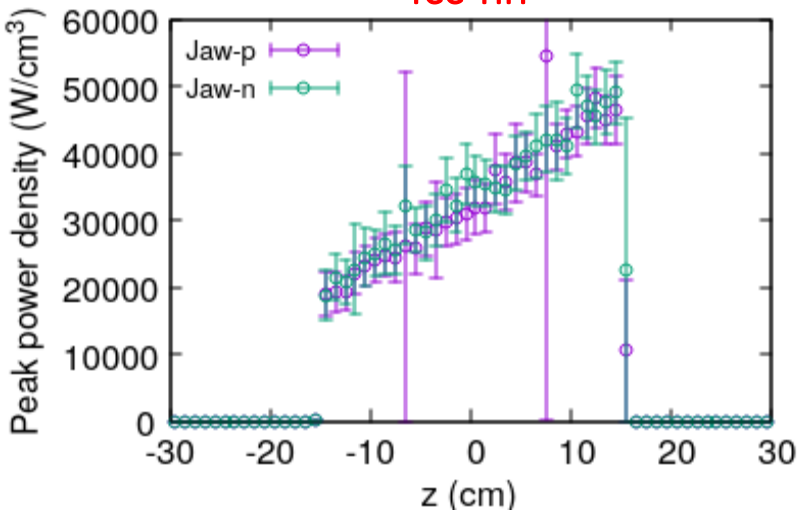




he-lhc

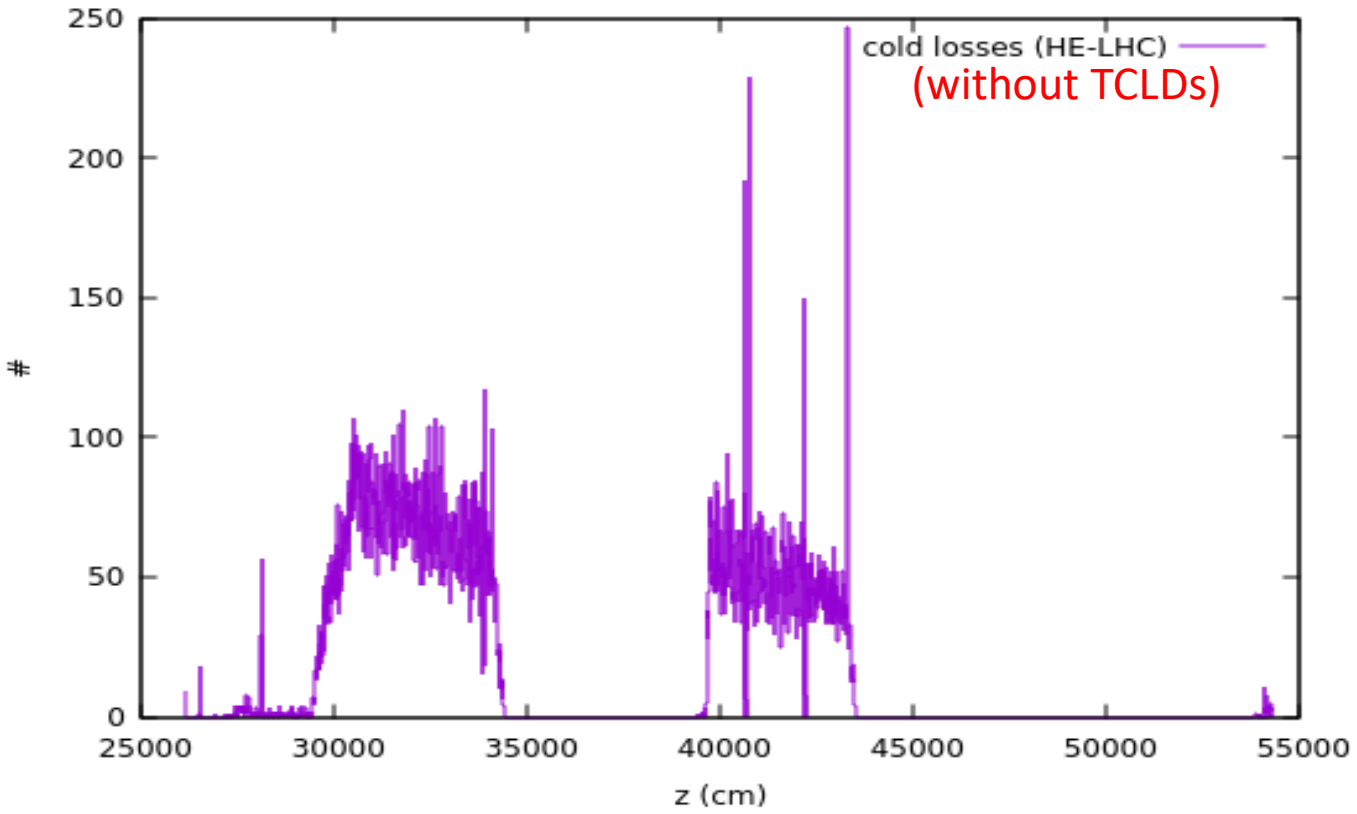


fcc-hh



Cold losses, with & without TCLDs (HE-LHC)

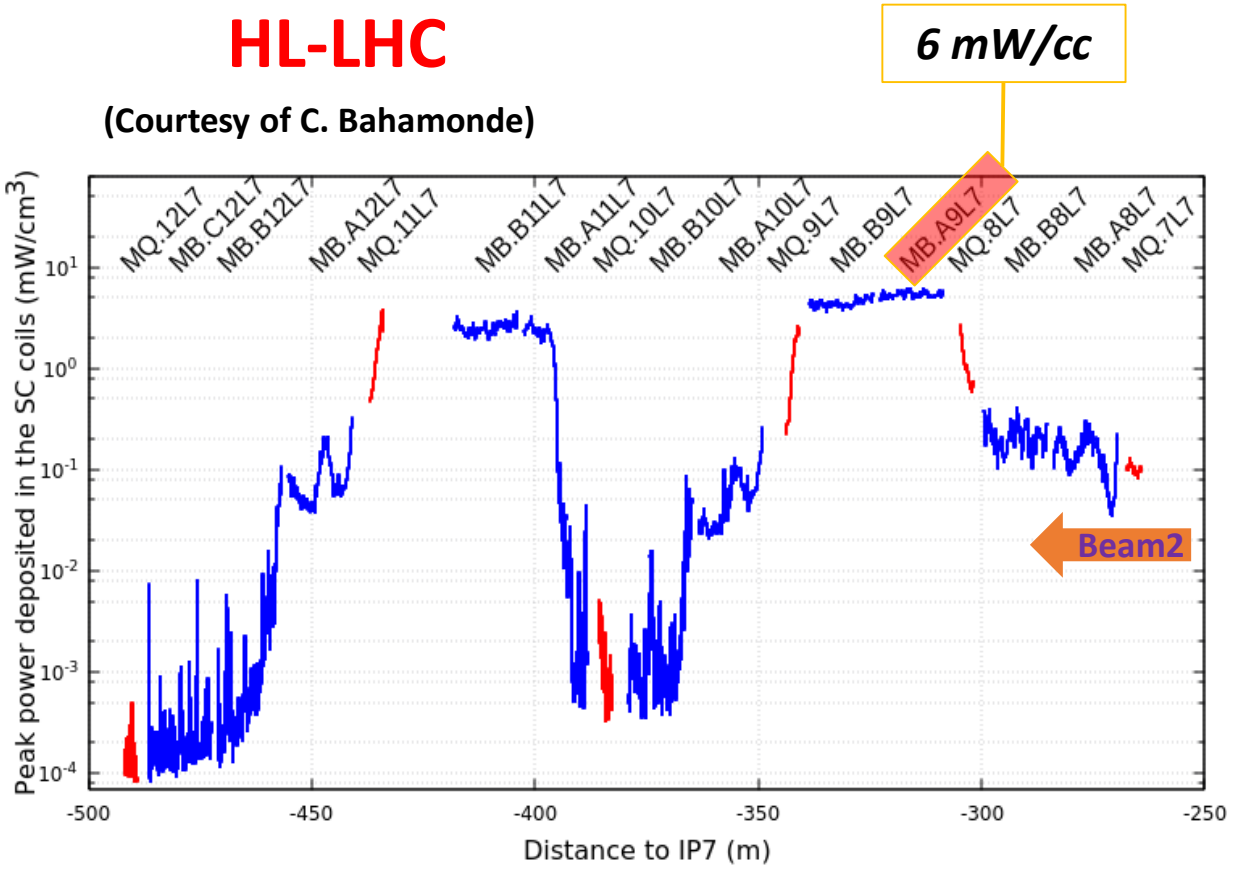
- Loading the touches on the collimators in the warm section
- Dumping the particles that will hit the aperture in the cold section
- Using the dumped particles for showering calculation in the cold section



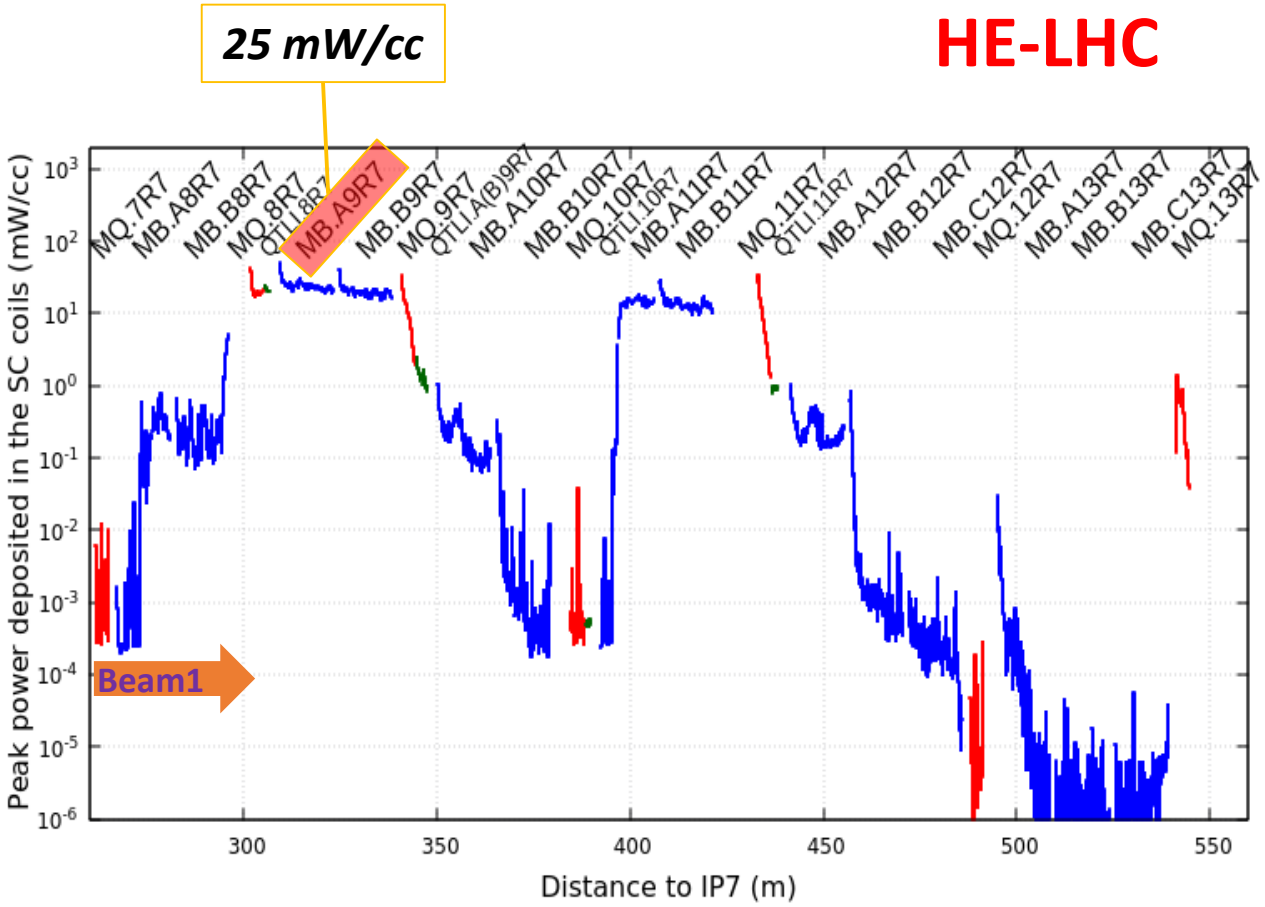
Power density in the cold section, no TCLDs

HL-LHC

(Courtesy of C. Bahamonde)



HE-LHC



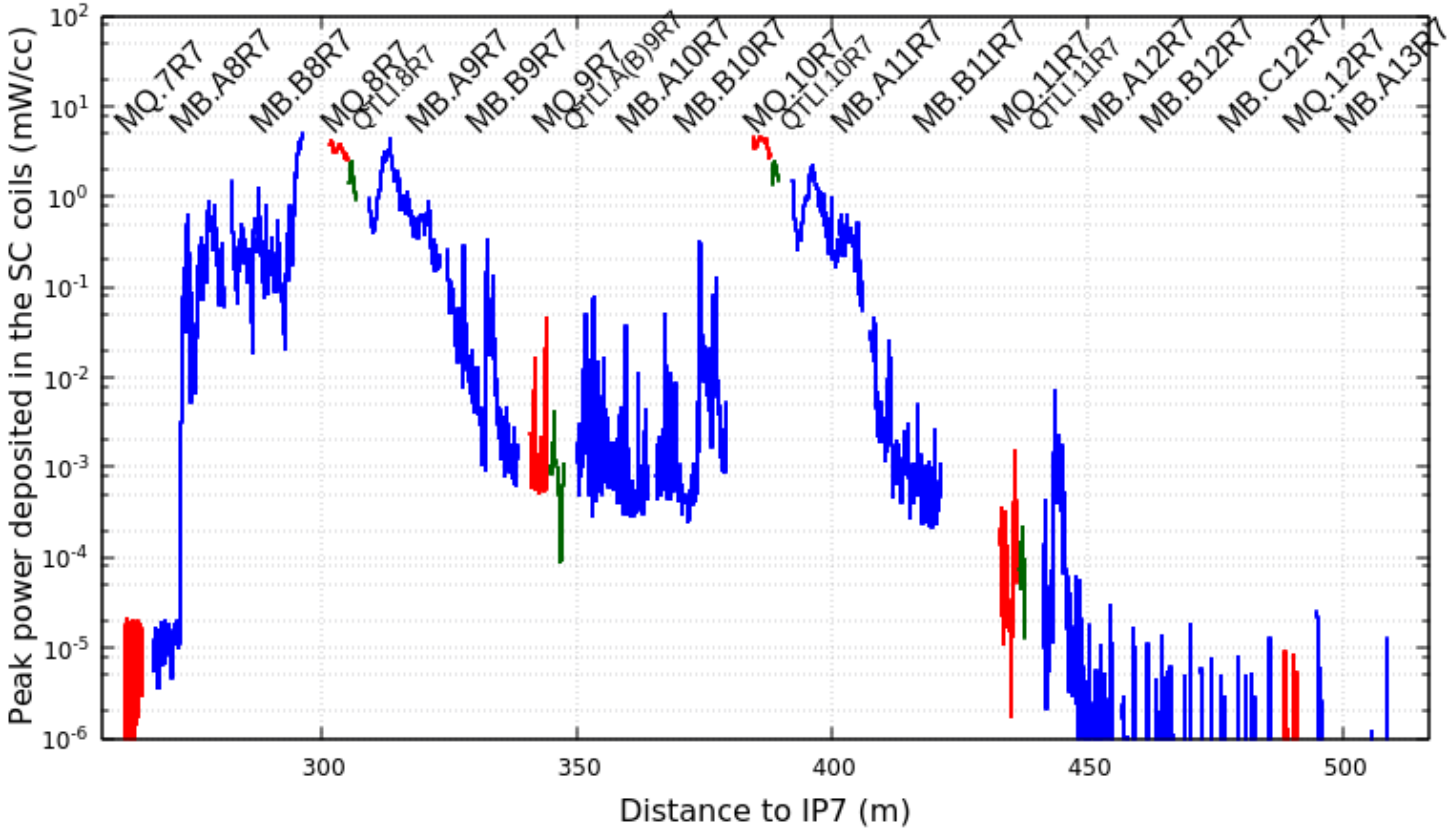
**** in LHC, the DS losses are deemed to be underestimated by a factor of 3 in the ideal machine simulation**

Values are for the 12 min BLT !

With TCLDs (HE-LHC)

By inserting two collimators (TCLDs), before MQ8 and MQ10, the maximum peak power density reduces to *≈ 5 mW/cc*

Beam1

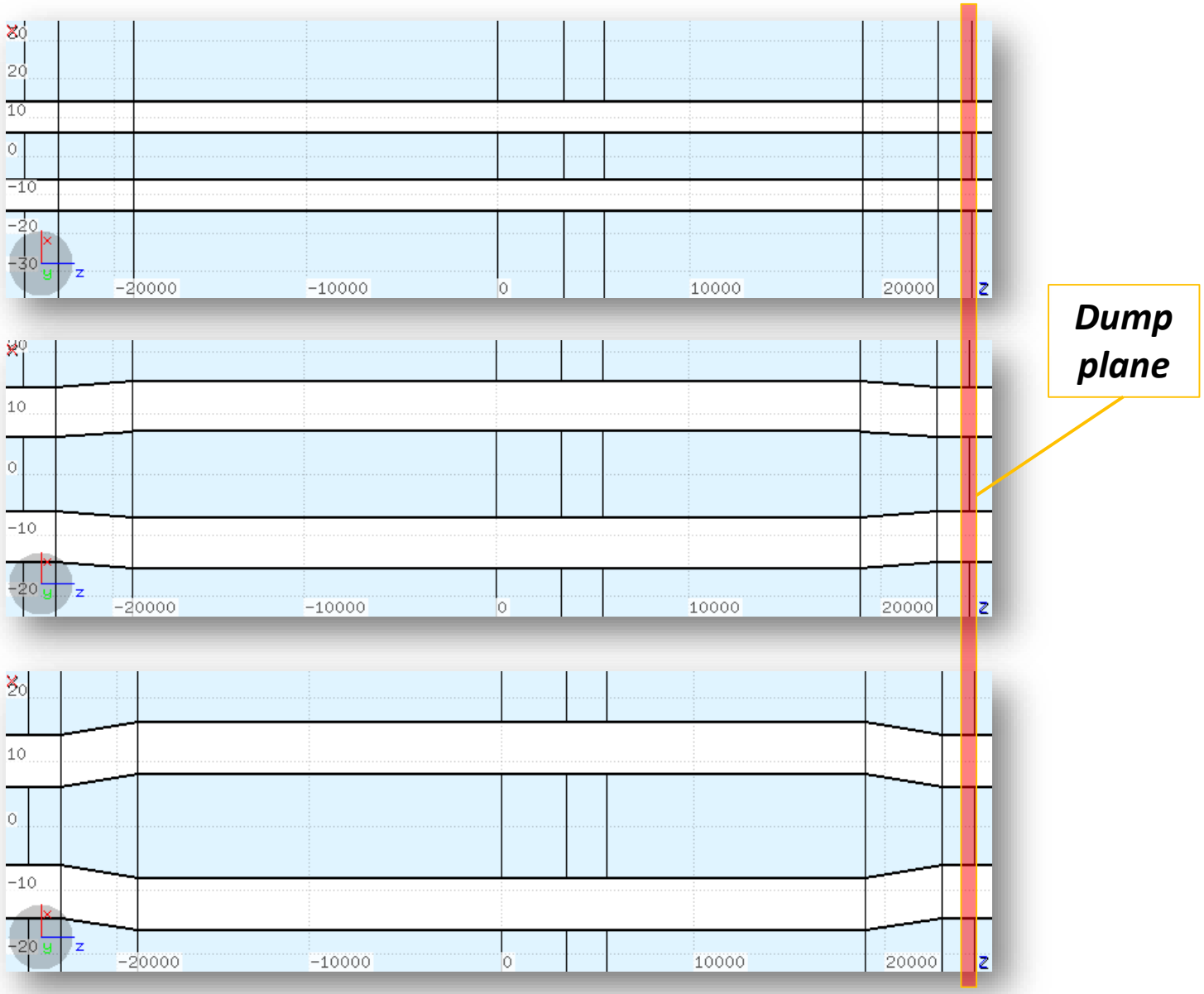


Impact of the dogleg removal (HE-LHC) - I

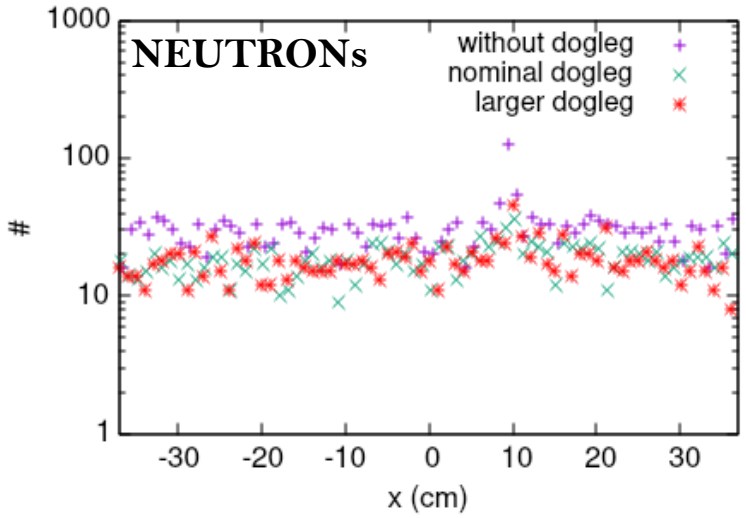
204mm bbs (no dogleg)

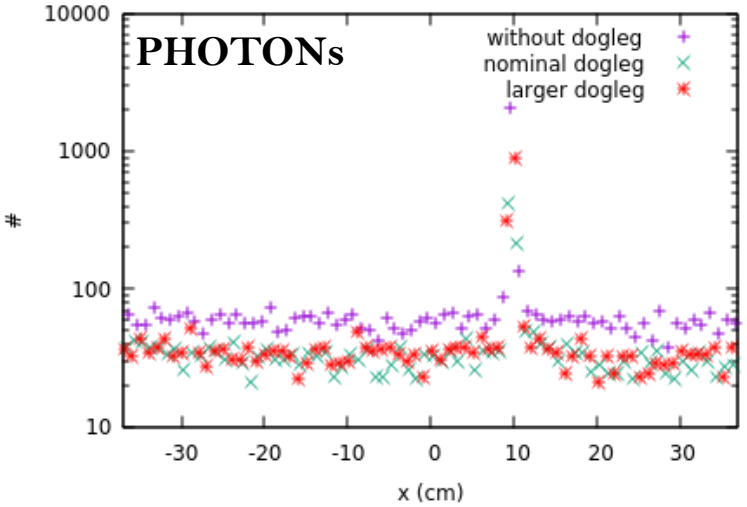
224mm bbs (nominal dogleg)

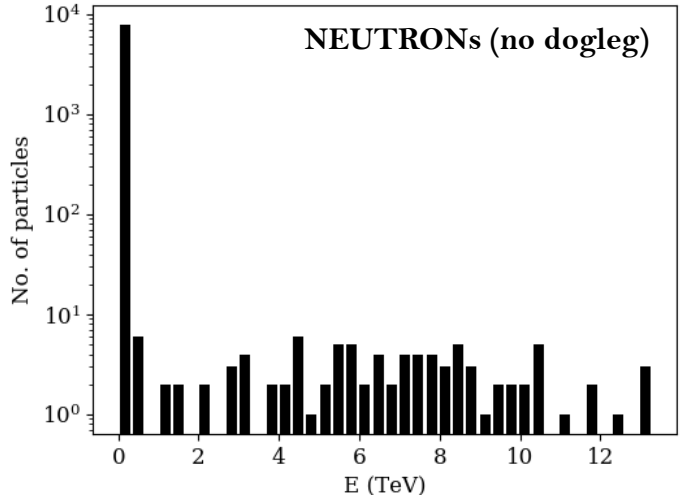
244mm bbs (larger dogleg)

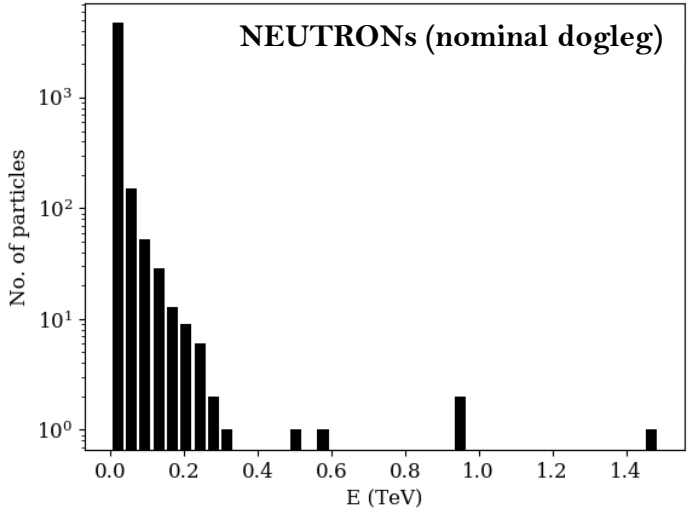


Impact of the dogleg removal (HE-LHC) - II



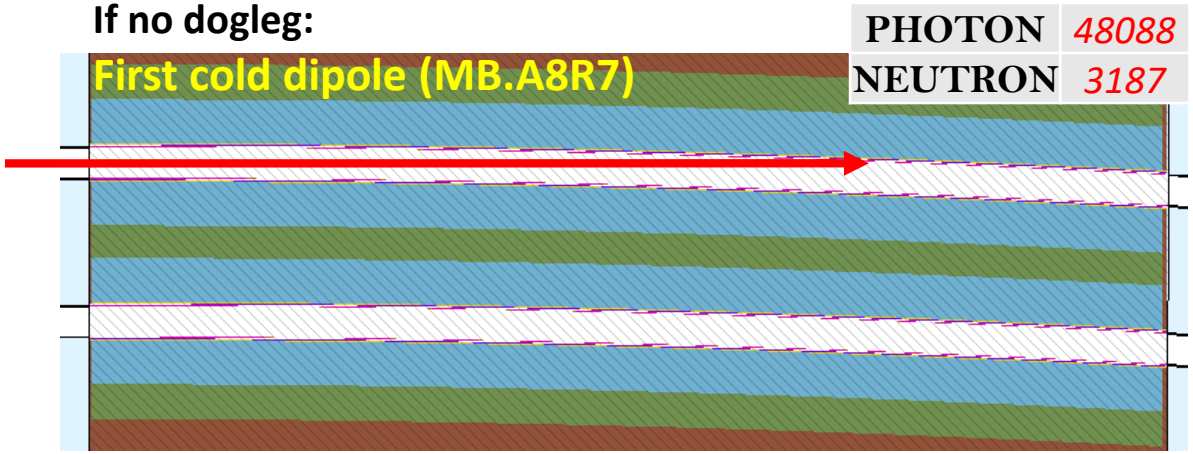


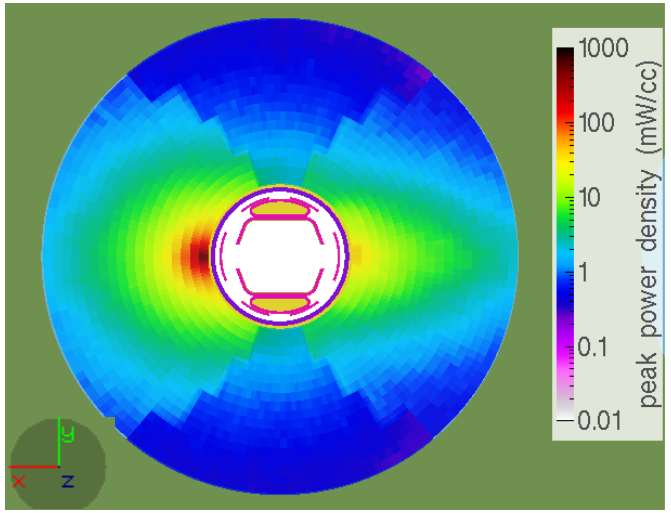




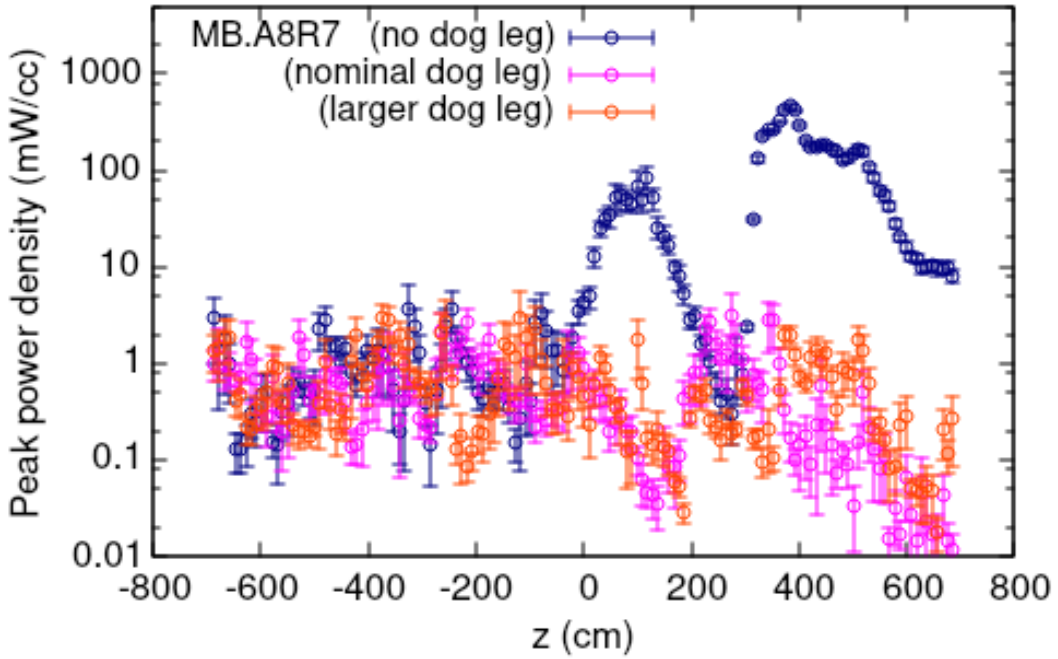
Impact of the dogleg removal (HE-LHC) - III

If no dogleg:





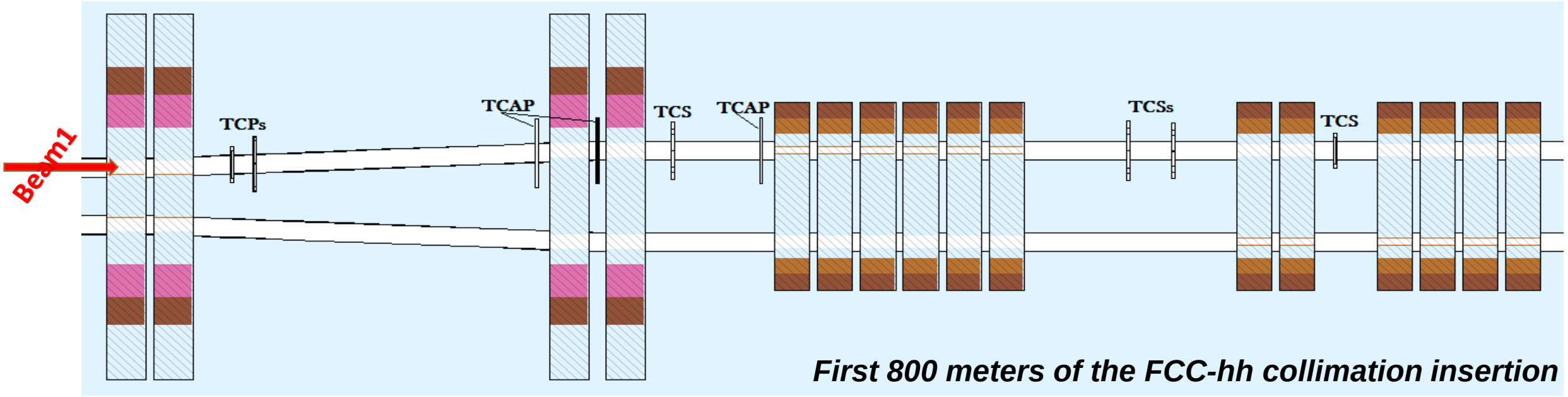
Total power (W)		
beam separation in warm section	**MQ7**	**MBA8**
204mm (no dogleg)	***7.1***	***419.3***
224mm (nominal)	***5.9***	***12.7***
244mm (larger dogleg)	***4.8***	***12.1***



Values are for the 12 min BLT !

FCC-hh
cold loss assessment

Recap of the FCC-hh IRJ warm section



First 800 meters of the FCC-hh collimation insertion

Collimators	Power (kW)
TCP.D	*6.5*
TCP.C	*79.7*
TCSG.A	*92.4*

about a factor of 5 higher than LHC

With shorter (and less) primaries and thicker jaws, the maximum total power collected by a collimator (for 12 min BLT) is below 100 kW.

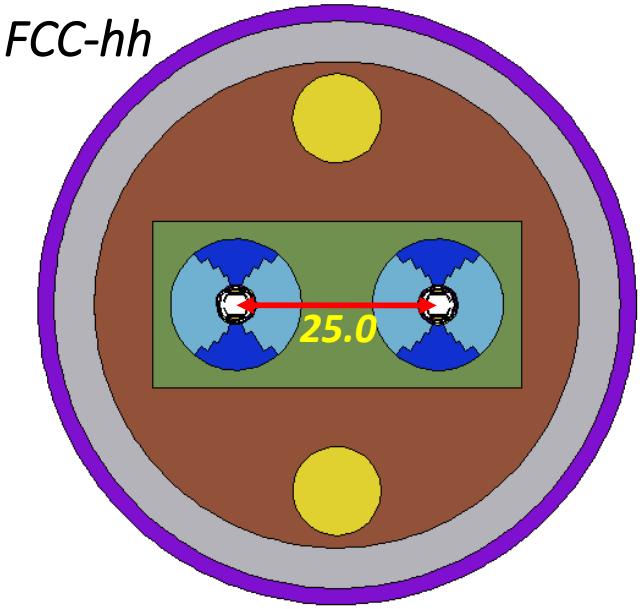
M. Varasteh et al. (FCC Week 2018)

Cold loss assessment

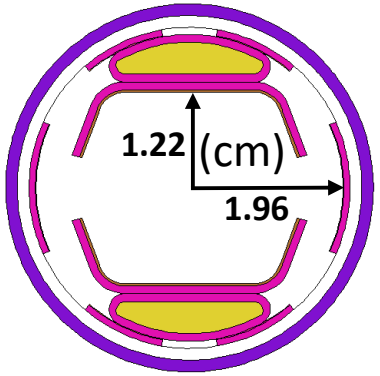
- **Quench limit is normally given in terms of peak power density**
- **A correlation between "power density" and the respective proton loss density rate (p/m/s) would give the possibility to approximately indicate what we can tolerate on the cold magnets**
- **How the picture will change according to the Machine, Energy, Geometry, and the Coil Composition** *(HE-LHC, FCC-hh, and HL-LHC)*
- **Considering the worse scenario** *(open TCLD, 12 min BLT)*

Main SC dipole

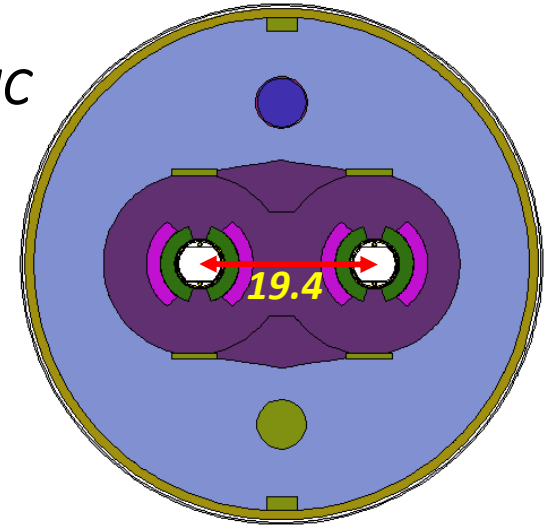
FCC-hh



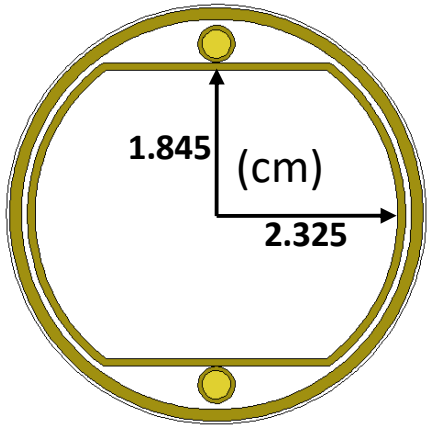
FCChh & HELHC's beam screen



LHC



LHC beam screen



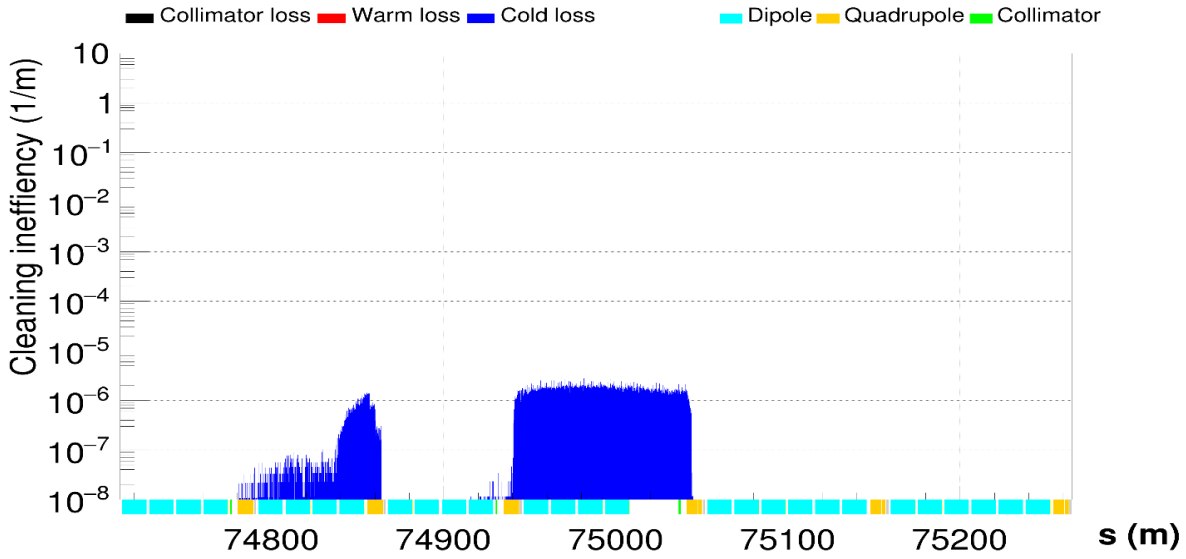
	FCC-hh	*HE-LHC*	*HL-LHC*
Magnetic length (m)	14.18	13.83	14.3
Type	RBEDN	SBEND	SBEDN
Beam separation in arc (mm)	250	204	194
Coil thickness (cm)	5.6	5.6	2*1.56
Bore nominal field (T)	16	16	8.33
Yoke outer diameter (cm)	60	60	55
Coil Material	Nb3Sn	Nb3Sn	NBTi
Coil density (g/cc)	7.95	7.95	7.12
Radiation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

Cold losses (FCC-hh)

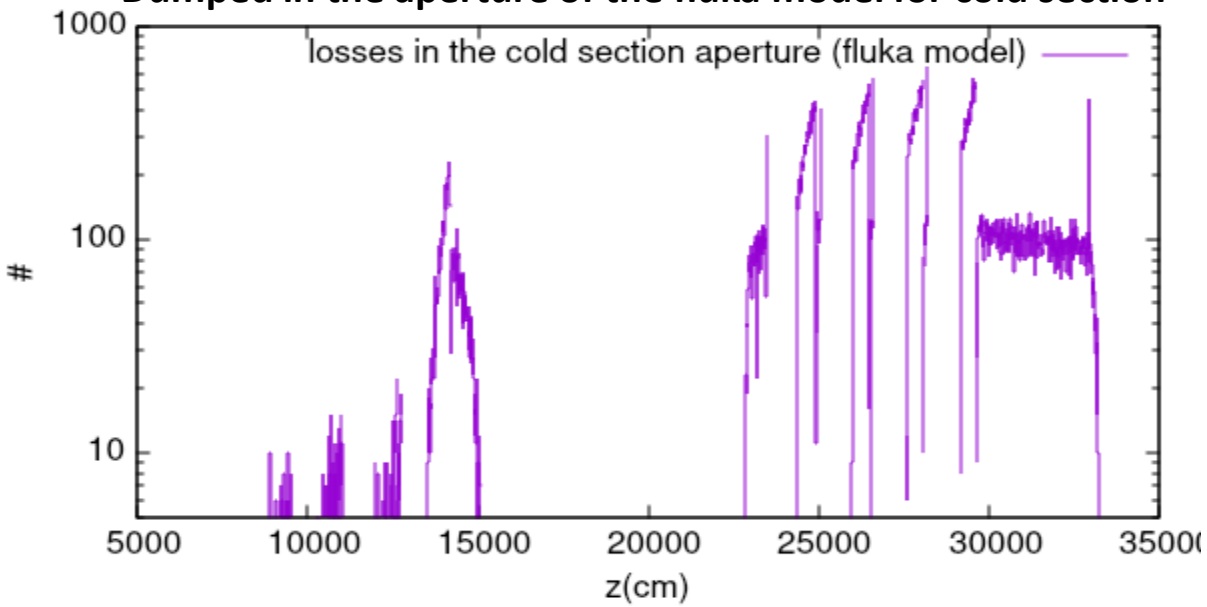
- Dumping the cold losses at the start of DS (with **open TCLDs**) by SixTrack-FLUKA coupling
- Identifying the DS magnets which receive the high losses
- FLUKA showering calculation up to the end of the cell 11

❖ SixTrack-fluka coupling simulation considers **BENT dipoles**

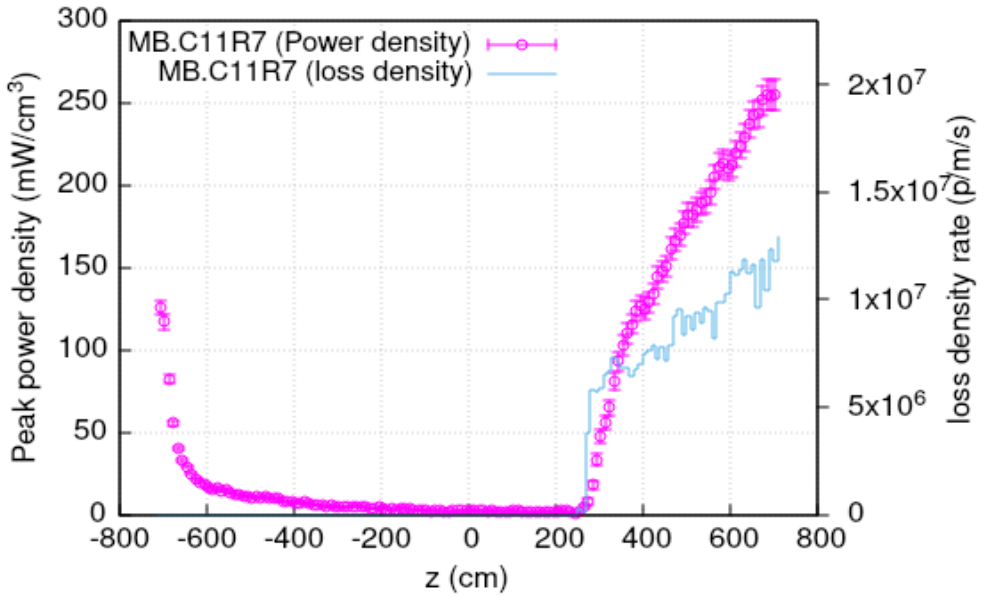
From SixTrack-FLUKA coupling



Dumped in the aperture of the fluka model for cold section

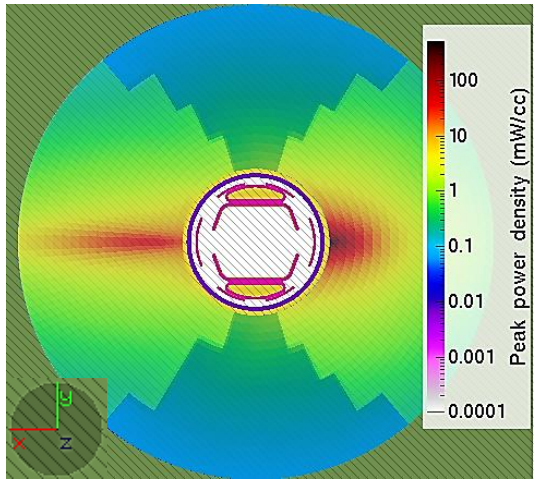


FCC-hh cell 11RJ



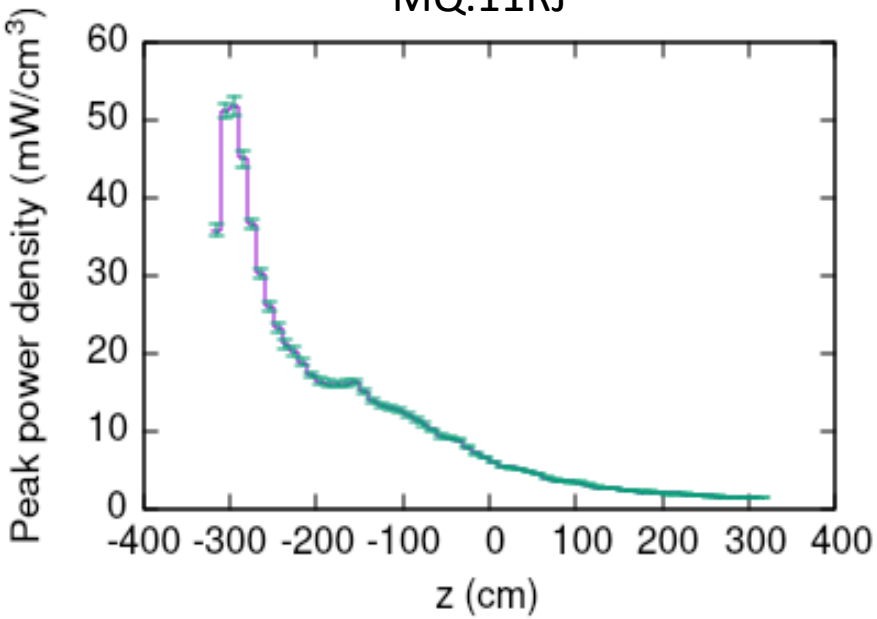
- Peak power density deposited in the *superconducting* coil is about ***250 mW/cc*** *at the end of the coil!*

For FCChh → r-φ-z resolution: **2.9mm, 2°, 10cm**



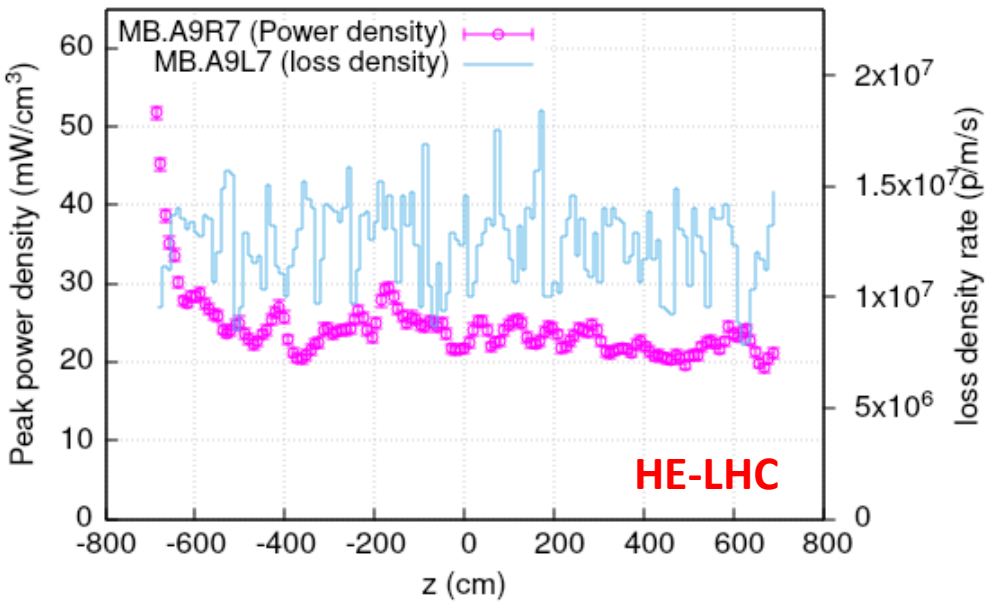
- **If we radially average over 1.9cm, then the peak power density will reduce to about 80mW/cc (≈ 250/3)**

MQ.11RJ



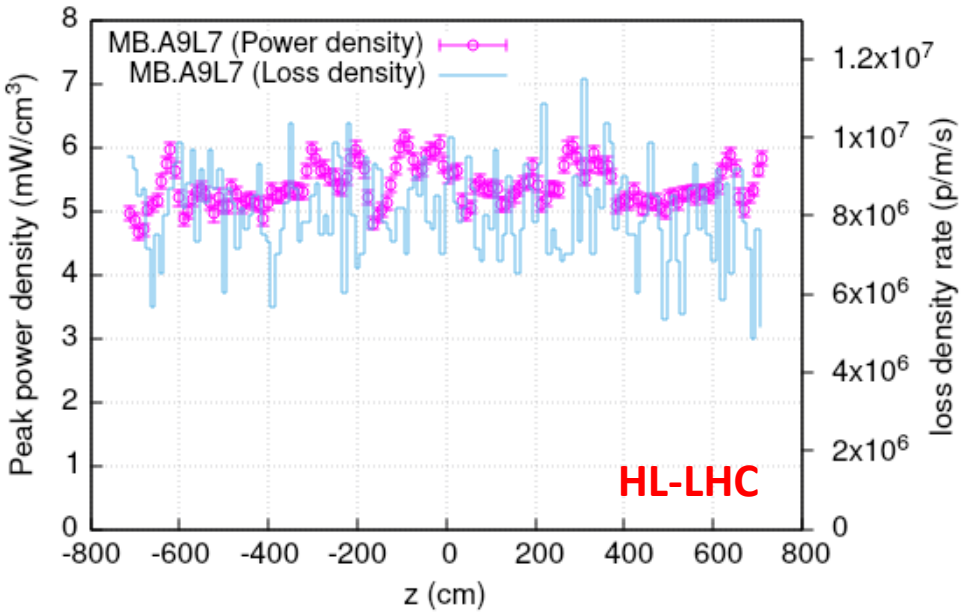
(radial bins of 1.6 cm)

HE-LHC and HL-LHC

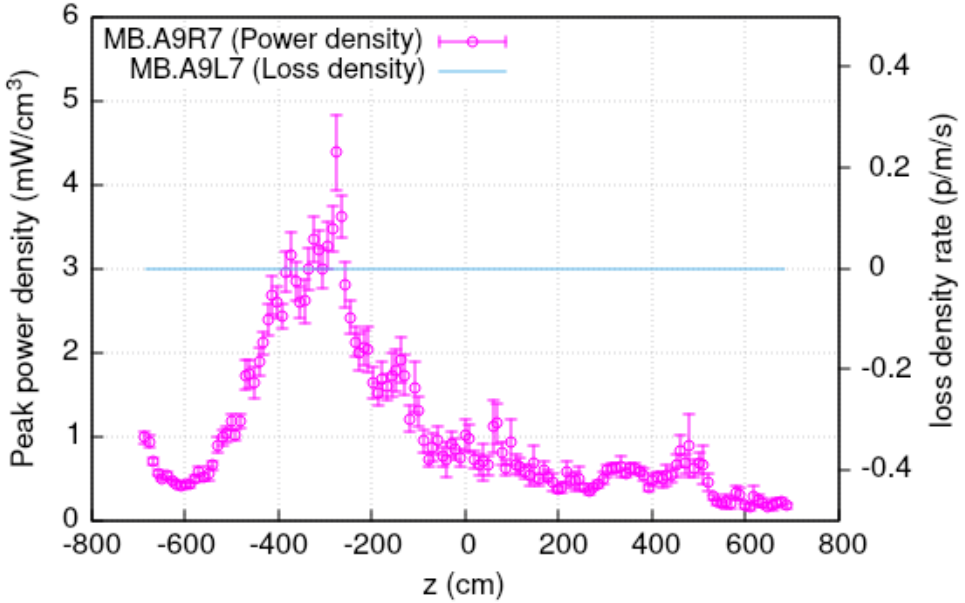


Combining loss and energy increase

a factor of 5 higher than HL-LHC



HE-LHC with TCLDs

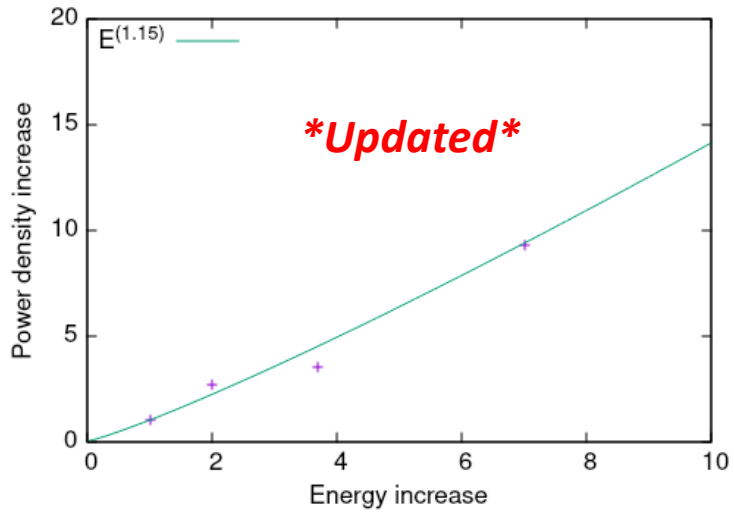


HL-LHC: two radial bins of 1.56 cm
HE-LHC: three radial bins of 1.9 cm

Summary

- **For HE-LHC, by using two collimators (TCLDs), before MQ8 and MQ10, the maximum peak power density reduces to *≈ 5 mW/cc***
- **Dogleg removal will result in a high increase of the peak power density in the first cold dipole (caused by neutrons and photons)**

- **For a loss density rate in the order of 1e7 (p/m/s) we got a factor of 40 more power density in FCC-hh cold dipole w.r.t HL-LHC**
- **By increasing the energy → the power density will increase according to $E^{1.15}$**



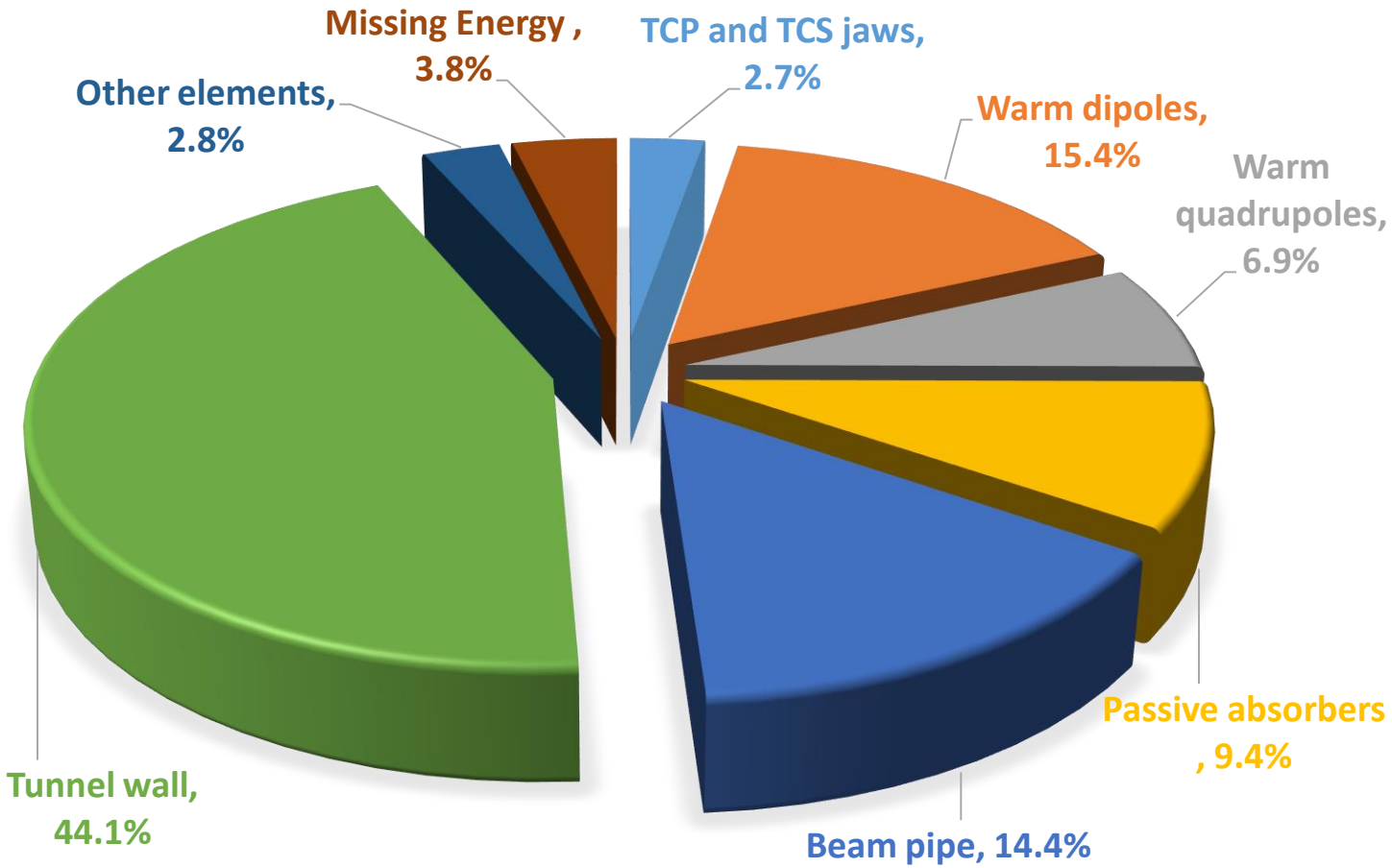
Mohammad Varasteh

CERN / EN-STI-BMI

m.varasteh @ cern.ch

Backup Slides

Power fraction in the FCChh collimation system



Impact of the dogleg removal (HE-LHC)

Particles hitting the MB.A8R7

	204mm (no dogleg)	224mm (nominal)	244mm (larger dogleg)
Number of particles hitting the MB.A8R7			
PROTON	268	147	
PHOTON	*48088*	1085	5829
NEUTRON	*3187*		101
ANEUTRON	154		
PION+	118		94
PION-	334		
LAMBDA	433