



Energy deposition study for the Betatron Cleaning Insertion of the HE-LHC machine



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Tracking input from BE-ABP;

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FCC STUDY / COLLIMATION
SYSTEM OF HE-LHC MACHINE

- **Introduction**
- **Global picture of the Energy deposition in the IR7 (warm section)**
- **Power density on the collimators**
- **Power loaded on the warm magnets**

Introduction

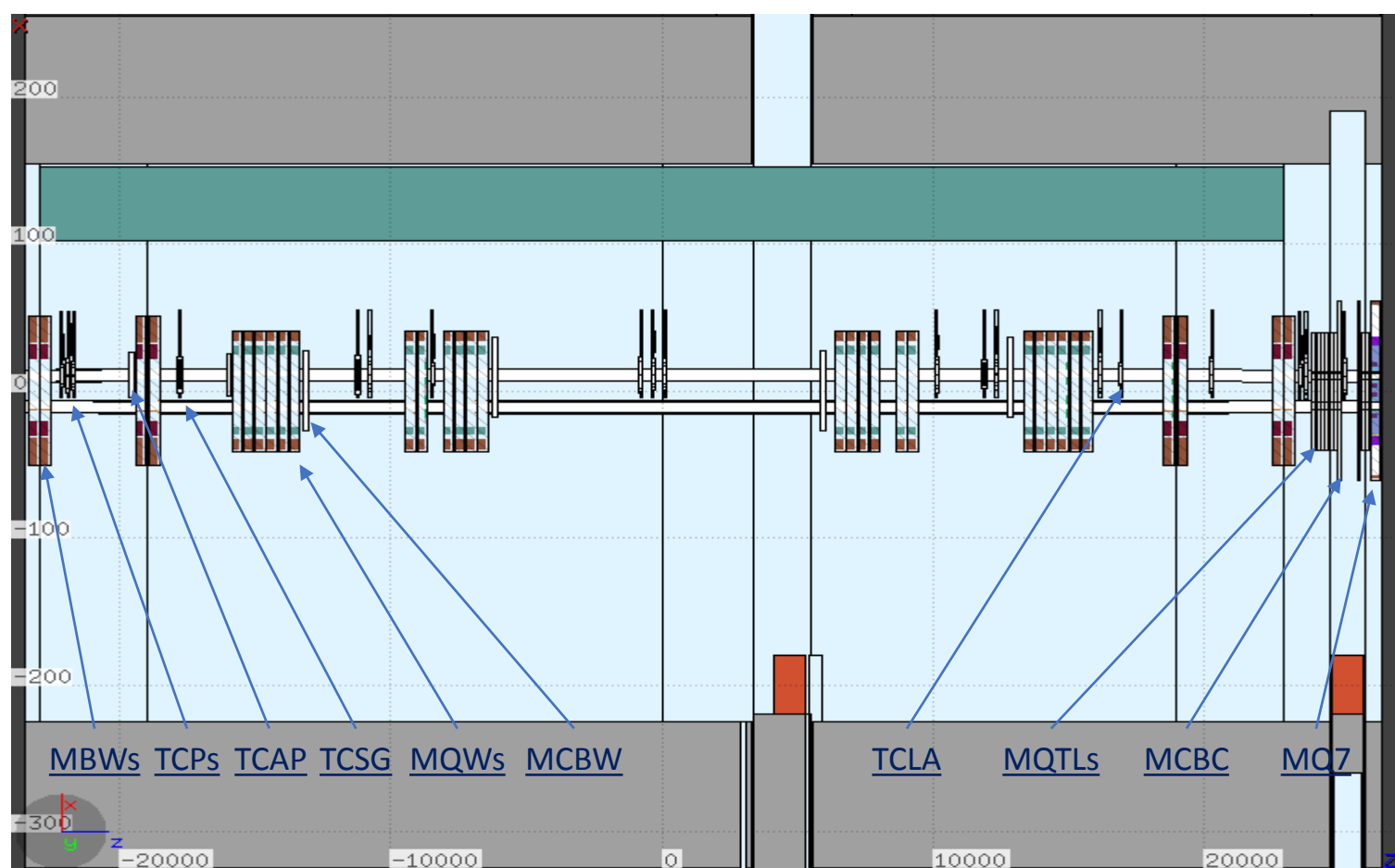
- Center-of-mass energy of 27 TeV ($\approx 2 \times \text{LHC}$)
 - 2808 Number of Bunches
 - 2.2×10^{11} Bunch Population
 - Stored beam energy is 1.3 GJ ($\approx 3.7 \times \text{LHC}$)
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- In this study the loss scenario of 12 minutes BLT is considered (at 13.5 TeV beam energy)
 - Total power loss will be 1.9 MW
 - From SixTrack-FLUKA coupling, for Vertical Halo we get $2.27 \frac{\#touch}{\#loss}$ in average
 - As first stage, the same collimation design as LHC machine is used

IR7; warm section

about 30m longer w.r.t. LHC warm section

- 8 warm dipoles
- 24 warm quadrupoles
- Beam-Beam separation (bbs):
204 mm before dogleg (194 mm for LHC)
224 mm after dogleg (same as LHC)

3 Passive absorbers (1 m, 20 cm, 60 cm)
in front of MBW.B6L, MBW.A6L, and MQWV.F5L,
respectively

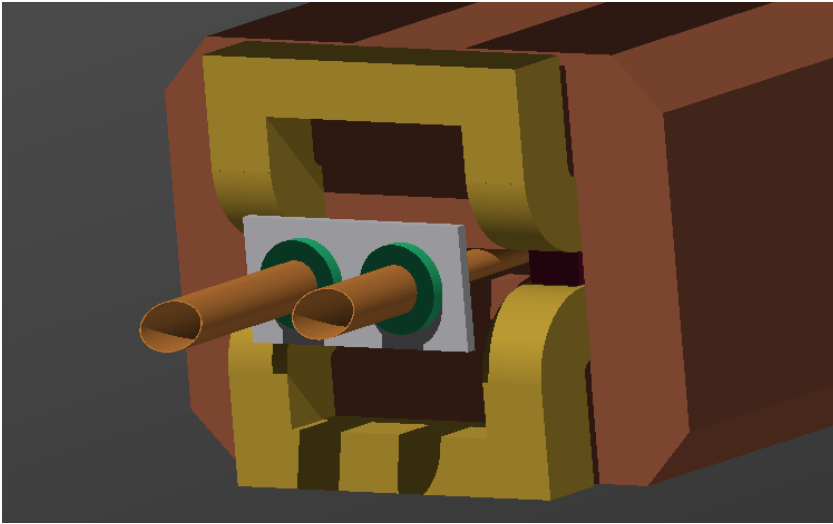


Collimators	Length (cm)	Aperture (σ)	Material	Number
TCP	60	6.7	CFC	3
TCSG	100	9.1	CFC	11
TCLA	100	11.5	tungsten	5

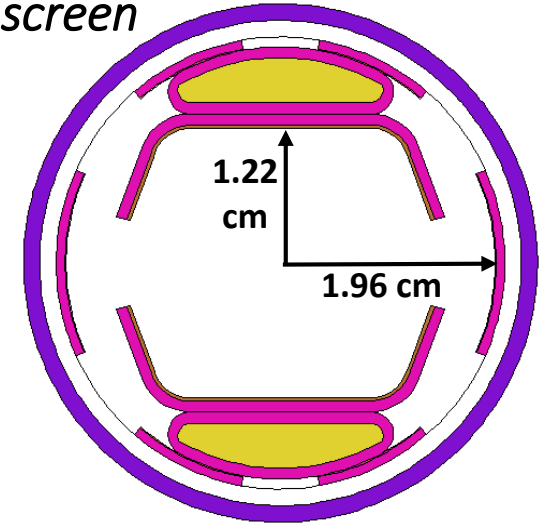
Warm Section	HE-LHC	LHC	Comments
MBW	3.4 m	3.4 m	<i>different return coils</i>
MQW	3.5 m	3.1 m	<i>different length</i>
Collimators & TCAP			<i>the same</i>
MQTLH/I	1.3 m	1.3 m	<i>different bbs, beam screen</i>
MCBCH/V	0.9 m	0.9 m	<i>different bbs, beam screen</i>
MQ7	3.5 m	3.1 m	<i>different length, material</i>

MBW's return coil and downstream Beam Screen

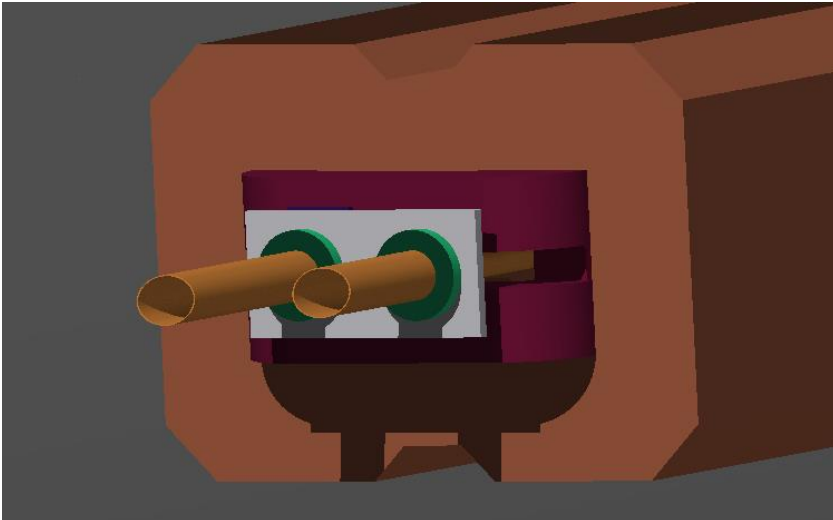
HE-LHC's
MBW



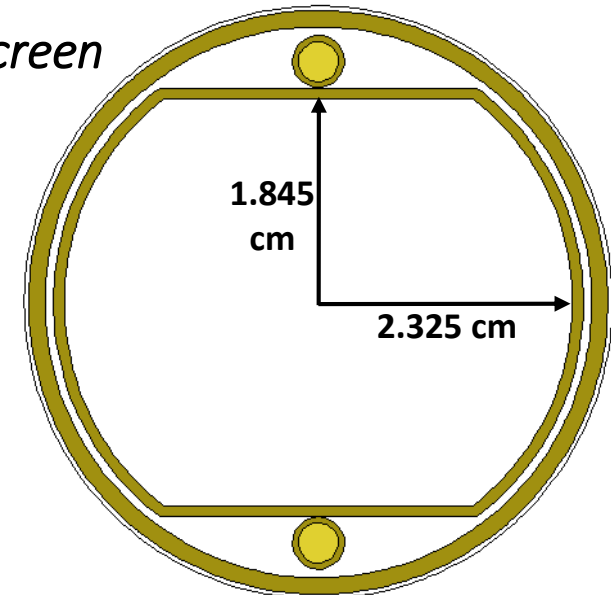
HE-LHC beam screen



LHC's
MBW



LHC beam screen



Power fraction on different elements at IR7

ELEMENTS	HE-LHC	LHC
<i>TCP & TCS jaws</i>	11.7%	10%
<i>MBW</i>	6.5%	8.5%
<i>MQW</i>	20.0%	9.5%
<i>TCAP</i>	11.8%	13%
<i>Beam pipe</i>	9.2%	8.6%
<i>Tunnel</i>	30.5%	33.1%
<i>Other elements</i>	8.6%	9.4%
<i>AIR</i>	0.5%	0.5%
<i>Cables</i>	1.8%	0.9%

Power on collimators & absorbers

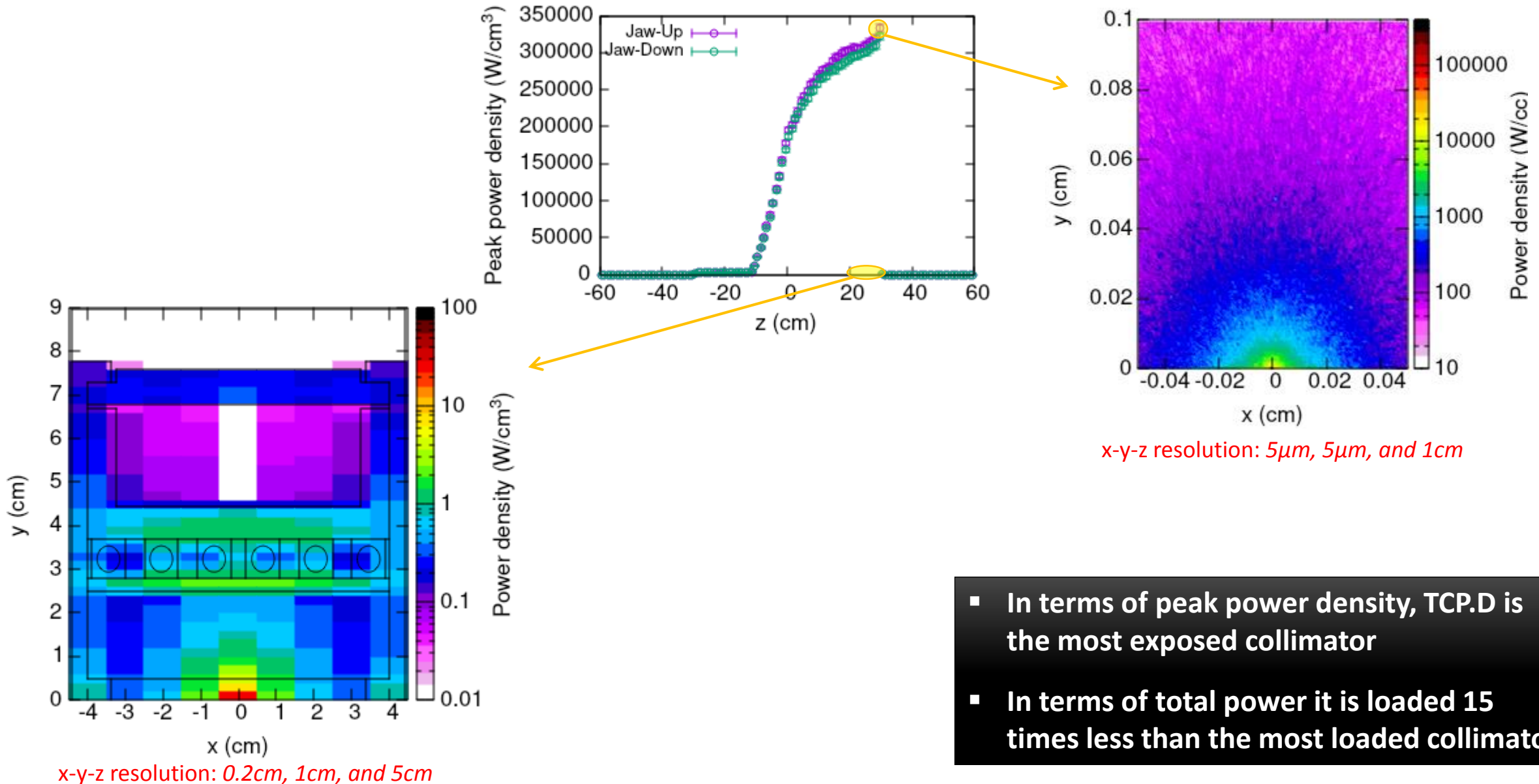
Collimator Jaws	Total power (kW)
Primaries	
TCP.D6L (CPD6L1_i & _j)	3.7
TCP.C6L (CPC6L1_i & _j)	29.5
TCP.B6L (CPB6L1_i & _j)	53.1
Secondaries	
TCSG.A6L (CSGA6L1i & j)	56.1
TCSG.B5L (CSGB5L1i & j)	12.6
TCSG.A5L (CSGA5L1i & j)	37.3
TCSG.D4L (CSGD4L1i & j)	6.9
TCSG.B4L (CSGB4L1i & j)	3.7
TCSG.A4L (CSGA4L1i & j)	4.9
TCSG.A4R (CSGA4R1i & j)	5.3
TCSG.B5R (CSGB5R1i & j)	0.5
TCSG.D5R (CSGD5R1i & j)	1.2
TCSG.E5R (CSGE5R1i & j)	1.9
TCSG.6R (CSG6R1i & j)	0.2

Active absorbers	Total power (kW)
TCLA.A6R (CLAA6R1i & j)	3.0
TCLA.B6R (CLAB6R1i & j)	0.3
TCLA.C6R (CLAC6R1i & j)	0.1
TCLA.D6R (CLAD6R1i & j)	0.1
TCLA.A7R (CLAD6R1i & j)	0.03
Passive absorbers	
TCAPA.6L (CAPA6L1)	59.8
TCAPB.6L (CAPB6L1)	8.0
TCAPC.6L (CAPC6L1)	150.3

MAX !
In front of the most exposed MQW

For LHC at 6.5TeV, with 0.5 MW total power loss, the max load is about 15 kW

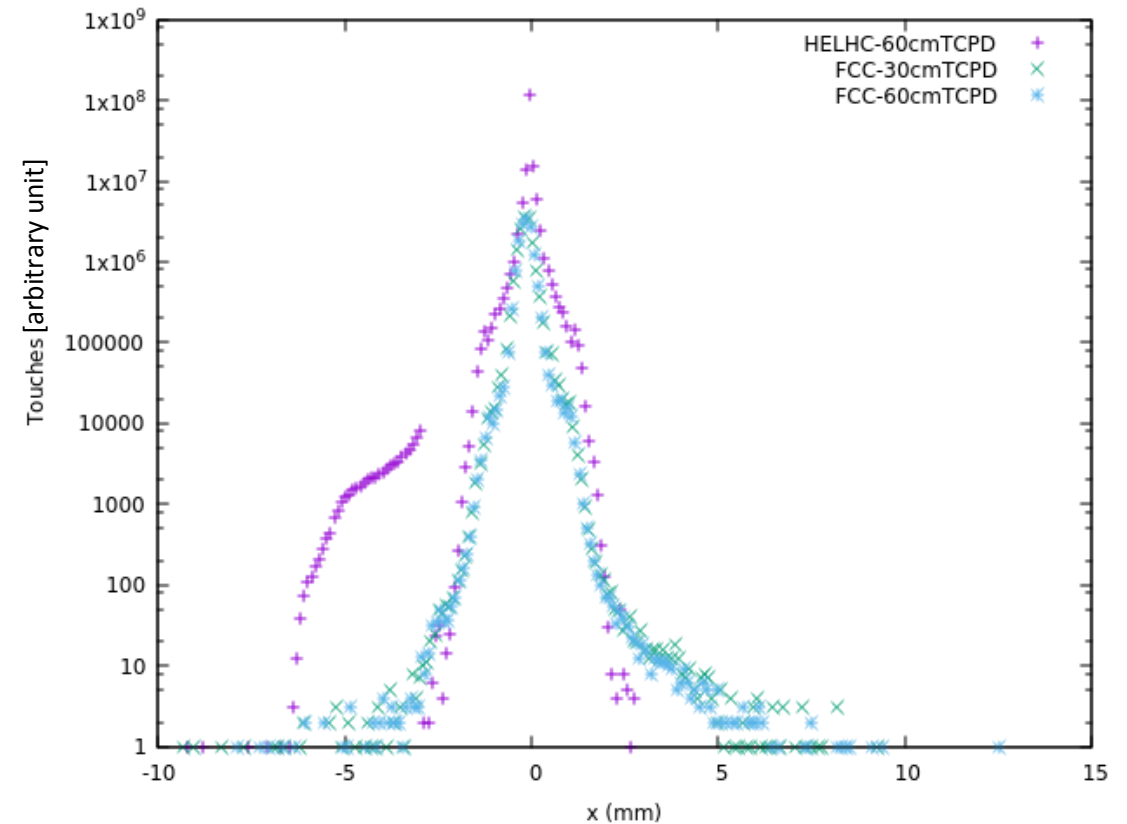
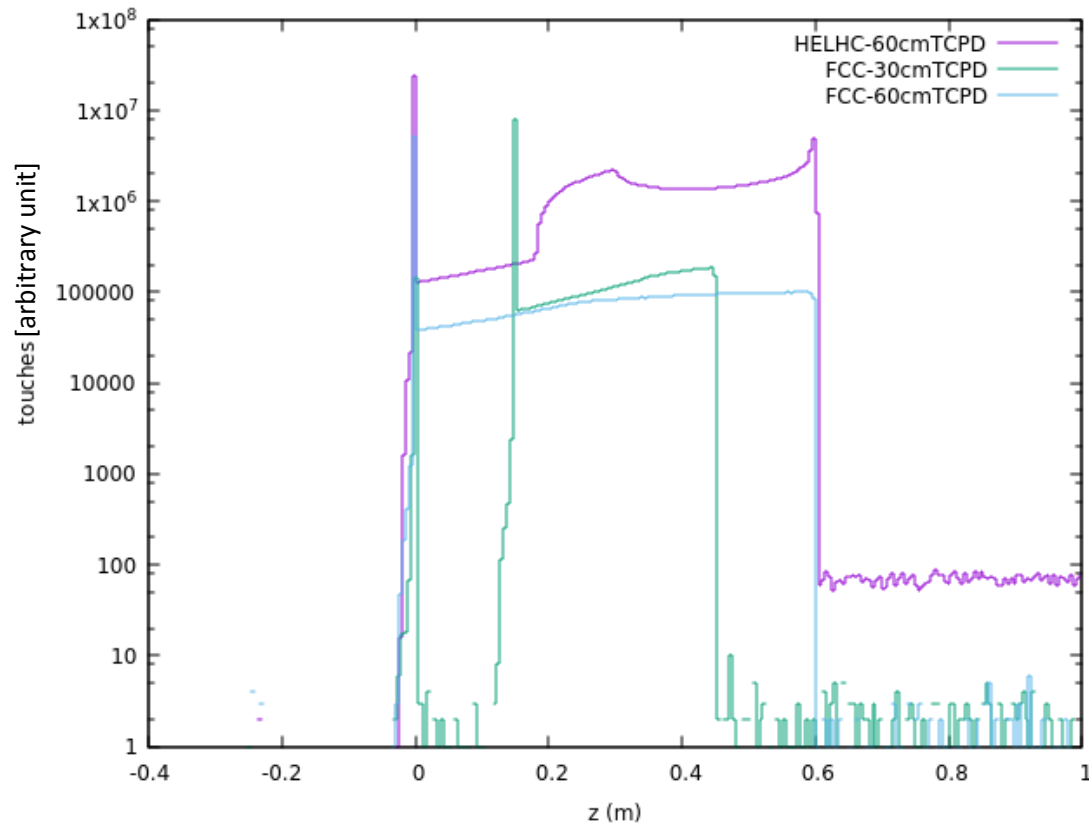
Peak power density on the directly impacted primary



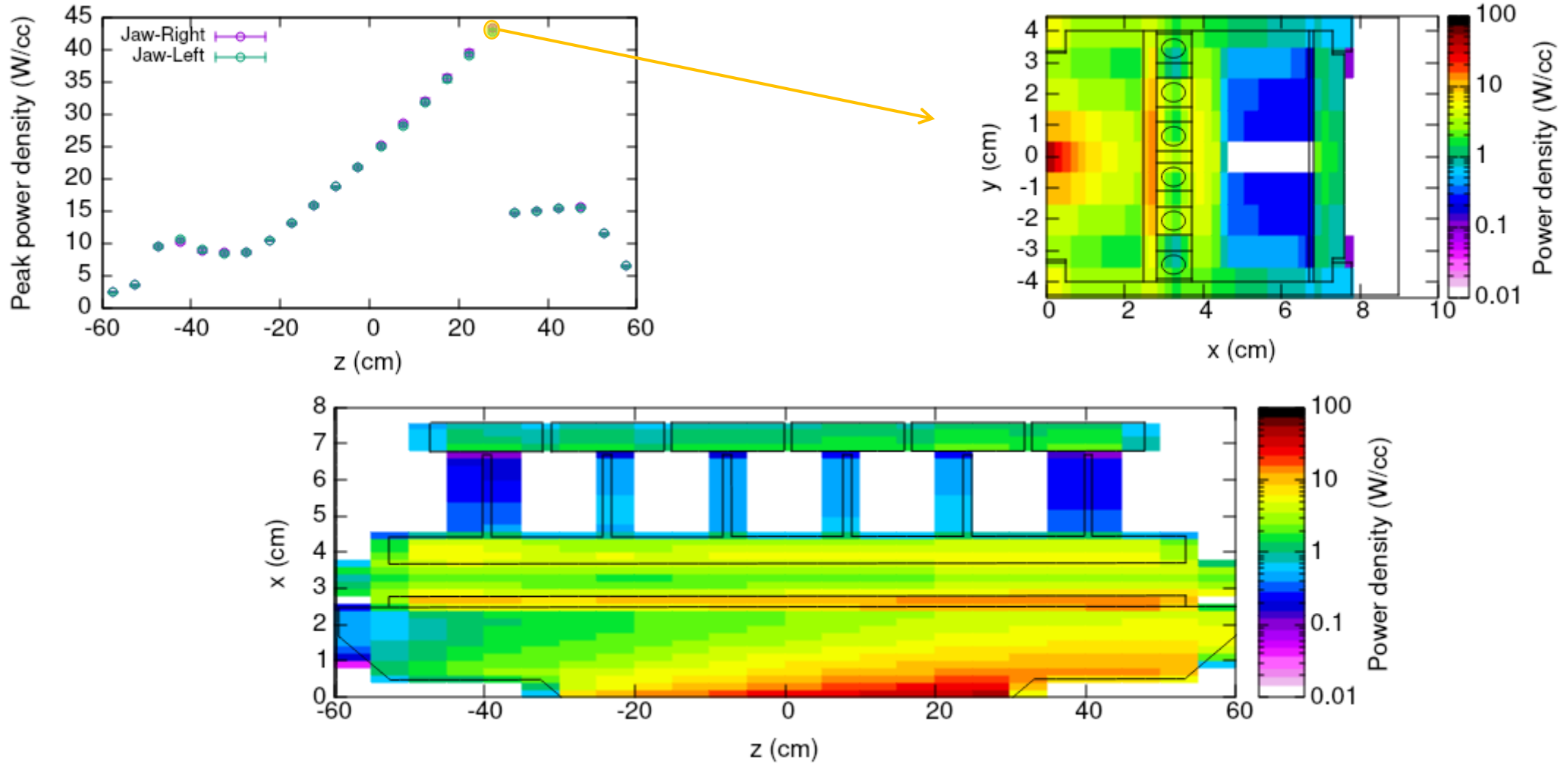
- In terms of peak power density, TCP.D is the most exposed collimator
- In terms of total power it is loaded 15 times less than the most loaded collimator

Distribution of touches coming from SixTrack

On the vertical collimator!

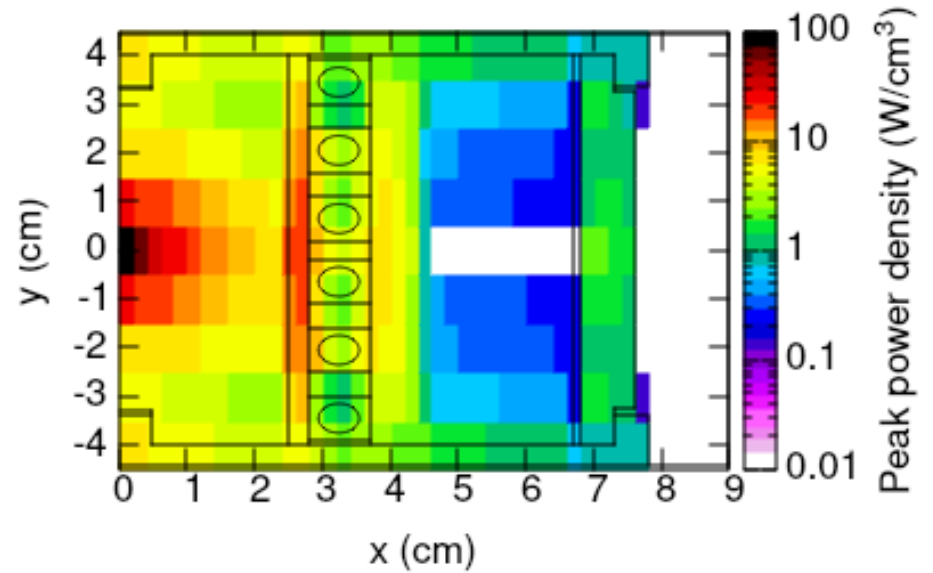
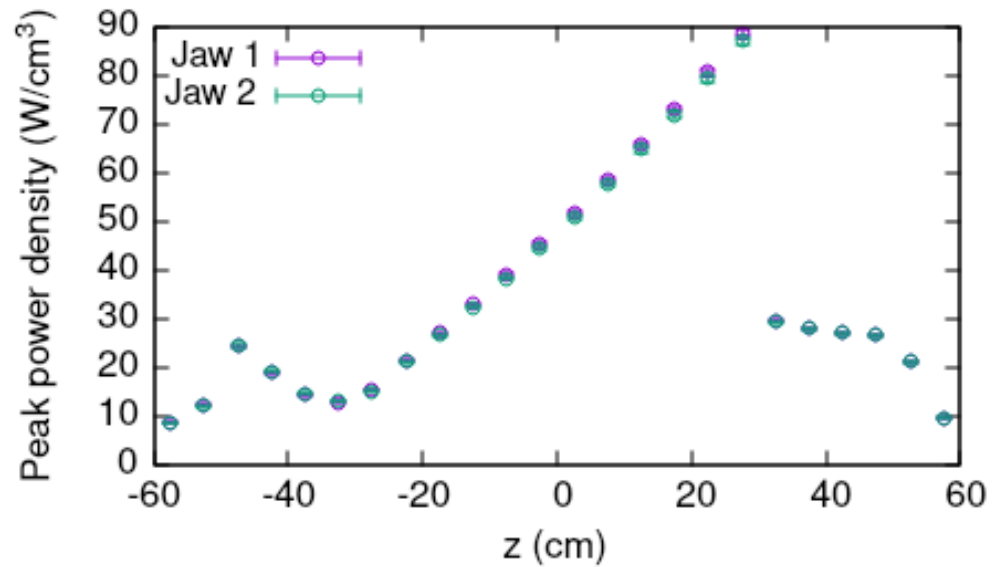


Power density on the horizontal primary collimator



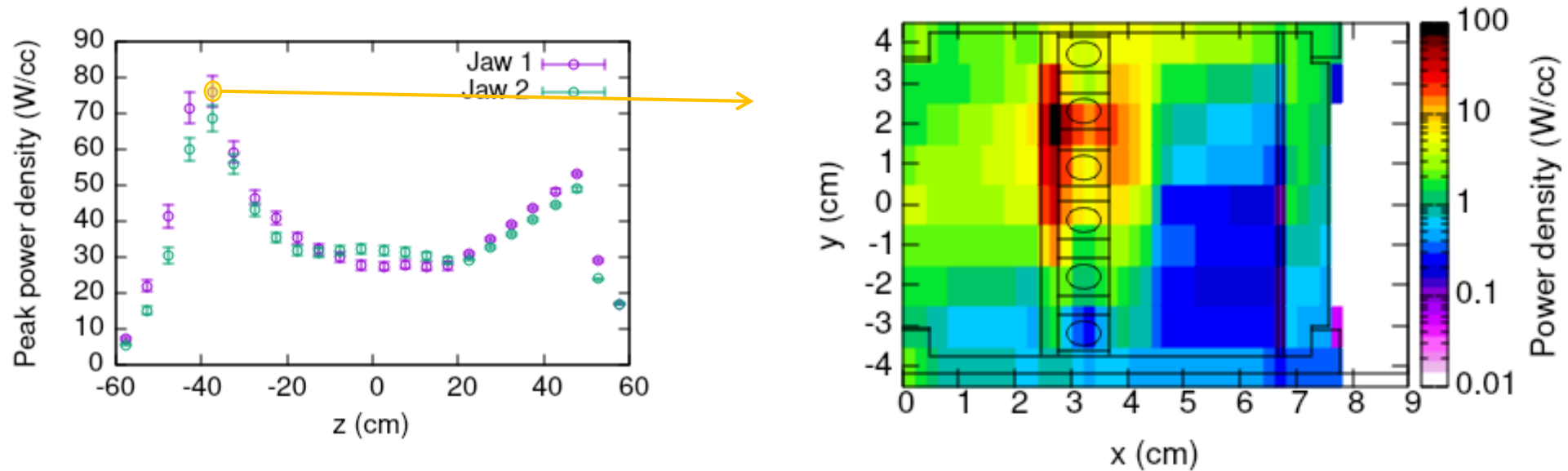
x-y-z resolution: 0.2cm, 1cm, and 5cm

The most exposed primary collimator (3rd TCP)



x-y-z resolution: 0.2cm, 1cm, and 5cm

Most loaded secondary collimator (1st TCSG)



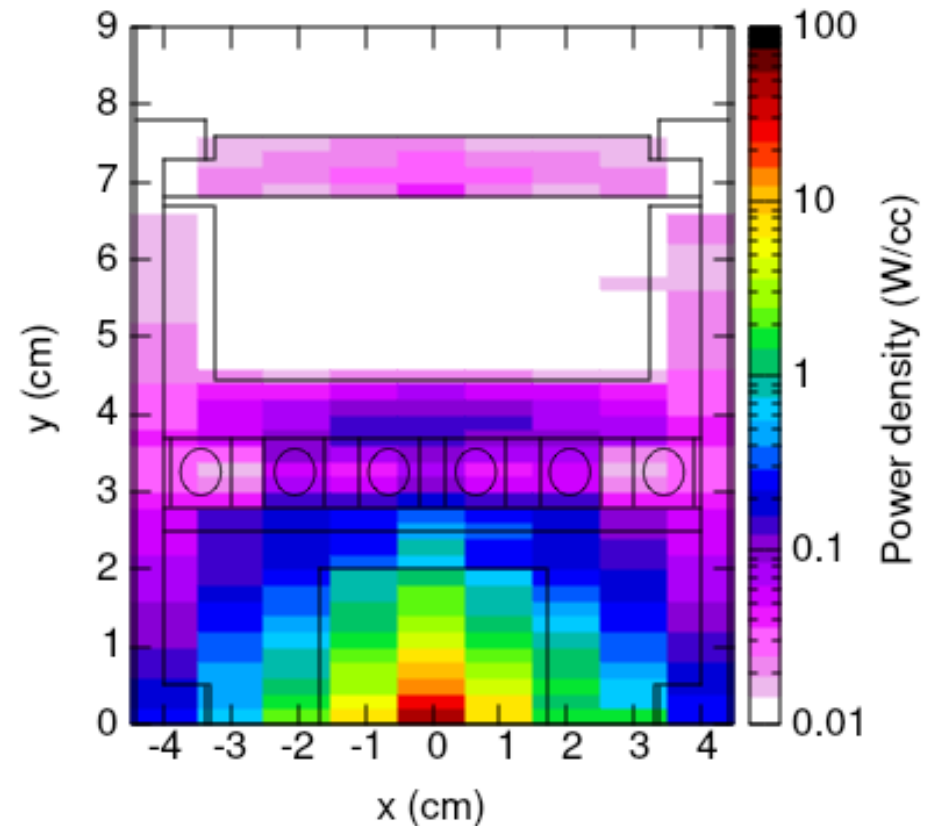
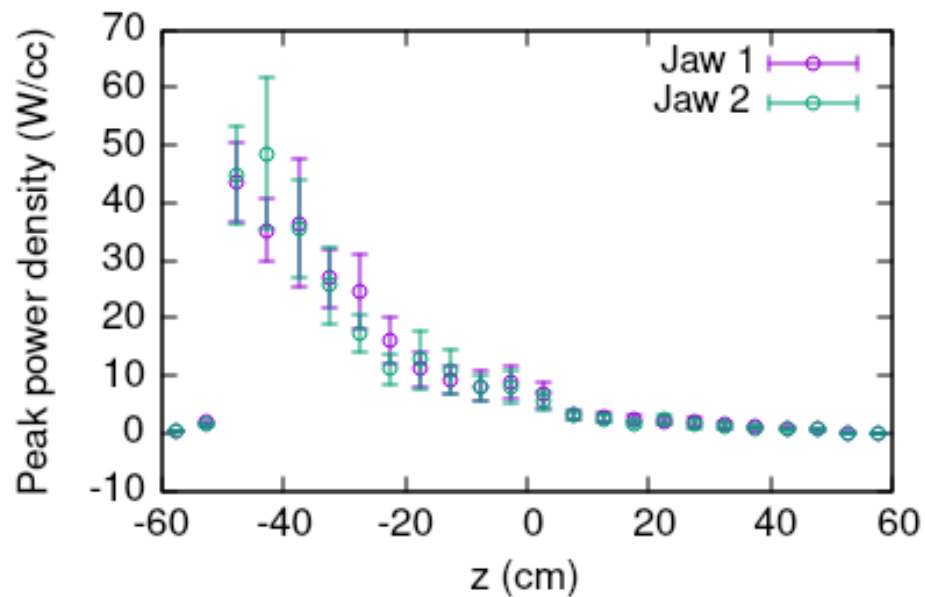
Max power density on the SUPPORT → 76 Wcm^{-3}

LHC's first Secondary → 10 Wcm^{-3}

The maximum is on the metallic support!
new design with thicker jaws is mandatory

0.2cm, 1cm, and 10cm (x-y-z resolution)

The most loaded active absorber (1st TCLA)



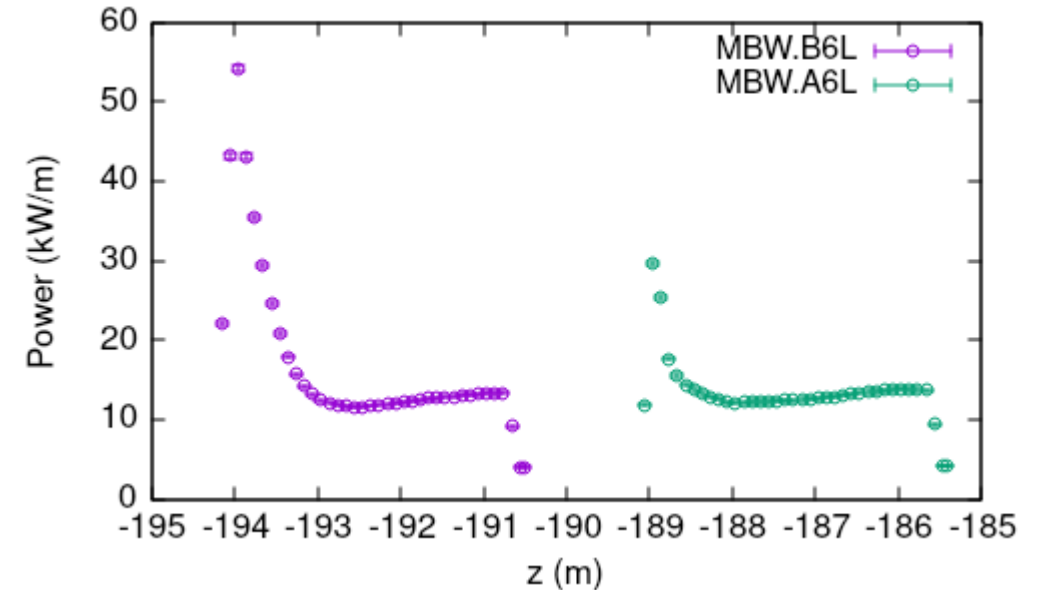
x-y-z resolution: 0.2cm, 1cm, and 5cm

Power loaded on the warm magnets

Most exposed warm magnets

Modules	Total power (kW)
MBW.B6L	66.36
MBW.A6L	53.57
Warm Quadrupoles	
MQWVF5L	95.14
MQWVE5L	39.01
MQWVD5L	31.05
MQWVC5L	26.76
MQWVB5L	23.49
MQWVA5L	21.11
MQWHF4L	57.63
MQWHE4L	16.39
MQWHD4L	27.75

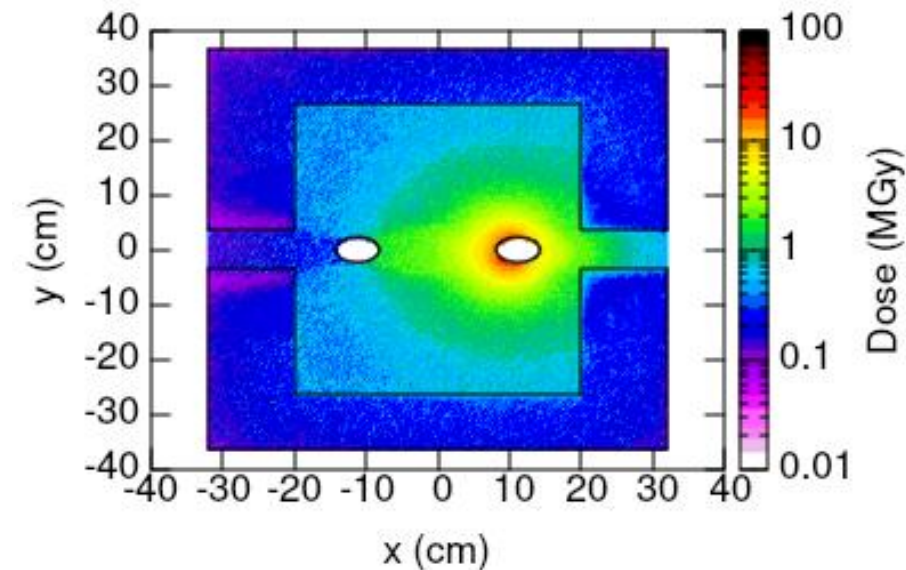
The two MBWs downstream the TCPs take more than **99%** of the total (120kW) on dipoles !



- **Maximum Power per Meter → 54 kW/m**
(The bulk is below 14 kW/m)
- **Maximum Total Power → 66 kW**
✓ **LHC (@ 6.5 TeV) → 22 kW**

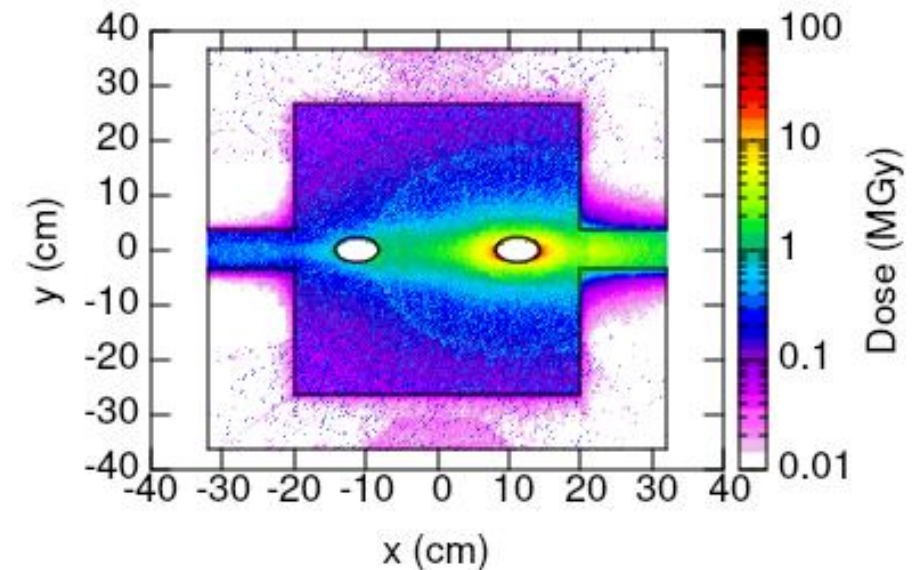
Coils in the most loaded warm dipole

Dose on the MBW.B6L's front/end face
(for $1e16$ proton lost per year)

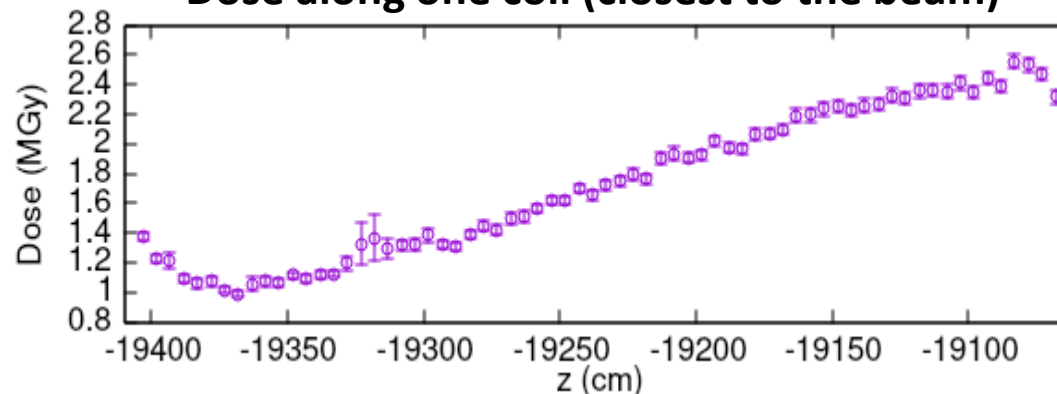


➤ By moving away from the beam pipe, a factor of **10** less dose on the return coil can be seen

Scoring on the return coil considers
[x,y,z] grid of [0.25, 0.25, 7.25] cm

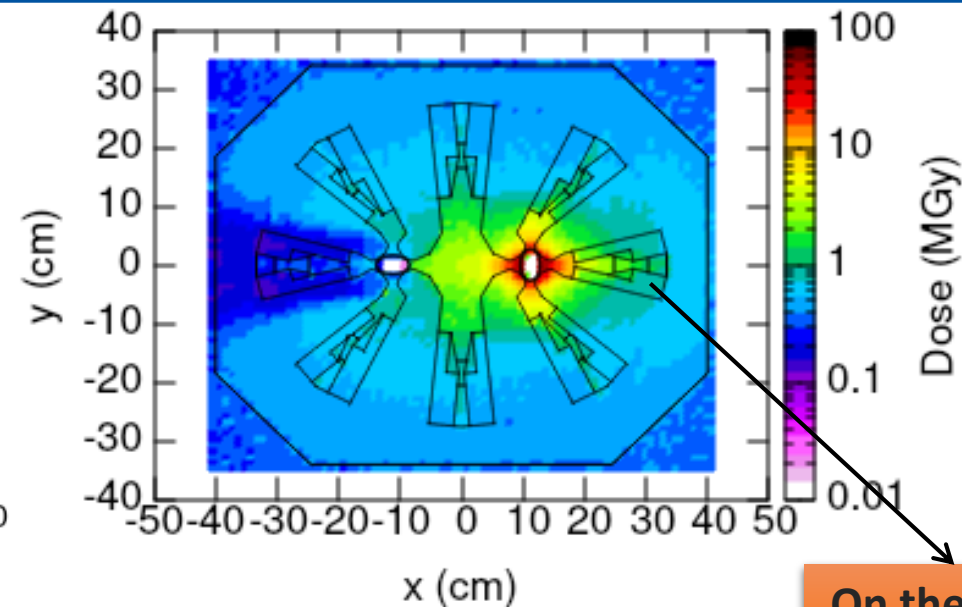
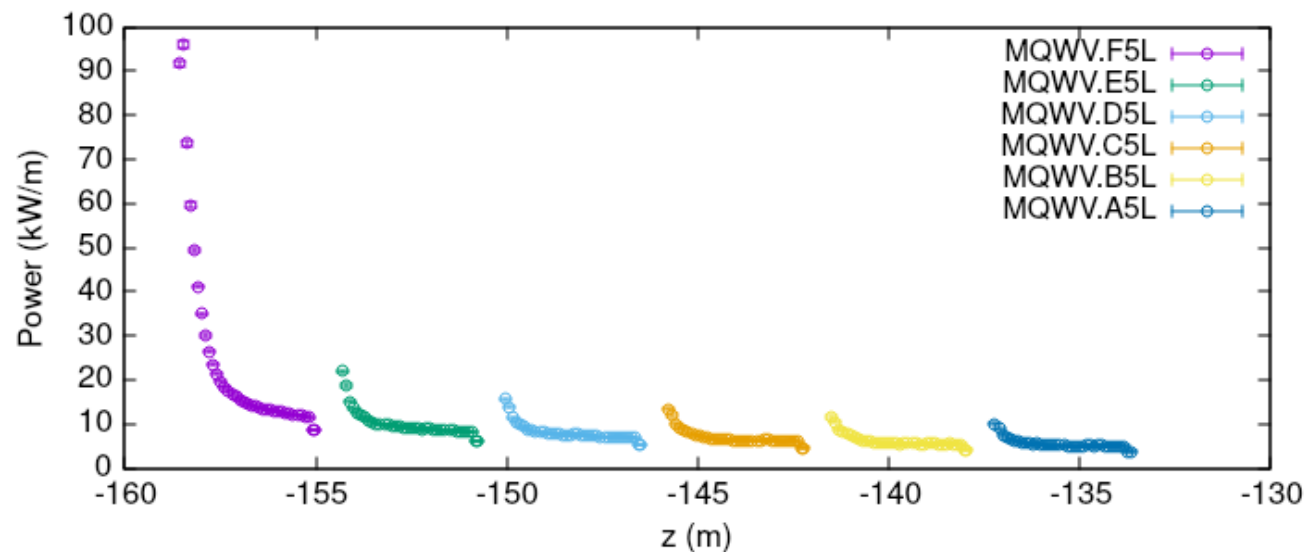


Dose along one coil (closest to the beam)



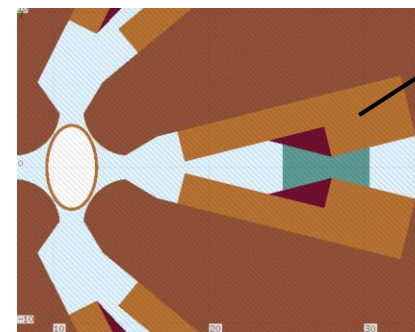
0.25cm, 0.25cm, 5cm
(x-y-z resolution)

Warm quadrupoles



- Plastic spacer would get damaged when exposed to more than 10 MGy!
- Material dose limits? (50 MGy for the coils and 10 MGy for the spacers)

**On the coils:
About 4 MGy**



For the LHC, shielding was used...

- The maximum power collected by a collimator **for a 12 min BLT** is **below 60 kW**
- The very **surface** of TCPD (directly impacted collimator), is at **hundreds of kW/cc**
- For the first TCSG, the max power density is on the metallic structure! A new design with thicker jaws would address the issue!
- **For 1h BLT**, the 3.4m **dogleg warm dipoles**, are subject to **about 10 kW** power
- Ongoing:
 - DPA in the first 4 collimators (*results are ready, only the analysis remained*)
 - Energy deposition study in the Cold section
- To be done:
 - Impacts of the dog-leg removal (caused by the Neutrons coming from collimators)



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