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Energy deposition studies:
30 cm TCP vs 60 cm TCP

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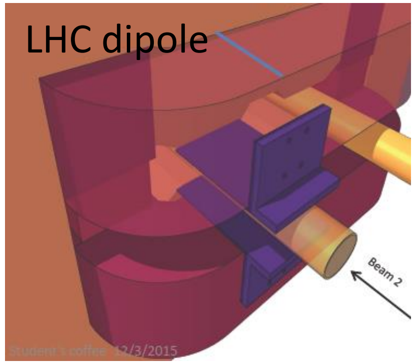
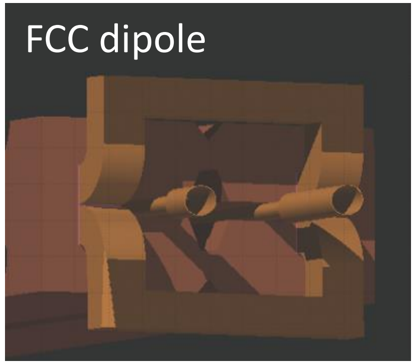
Introduction

2.7km long Betatron cleaning insertion region (≈5 times of LHC)

- Same geometry as previous study which was presented at [FCC collimation design meeting #12]()

- **8 warm dipoles**
  - 17m long and 1.85 T magnetic field
  - return coil → design was changed to protect them from radiation (*A. Milanese*)
  - beam-beam separation → 250mm and 400mm in the dog-leg
  - beam-pipe aperture → 29.5mm x 22mm





- **24 warm quadrupoles**
  - 15.54m long
  - simple design (LHC inspired) → 400mm beam separation
  - beam-pipe aperture → 15.26mm x 26.14mm

Collimators and Absorbers

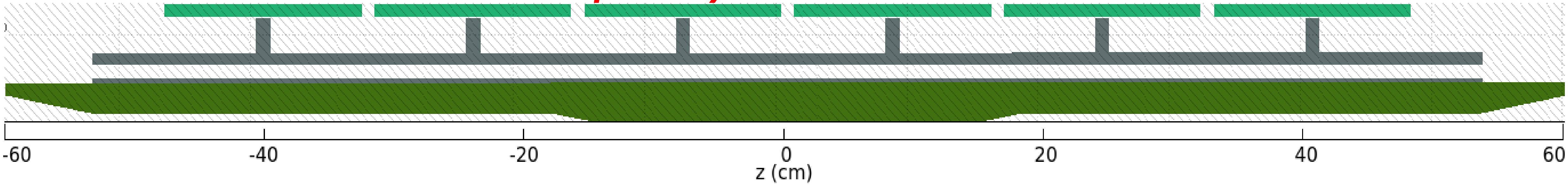
✓ *With the same design and composition as **LHC**!*

Collimators	Length (cm)	Aperture (σ)	Material	Number
Primaries	60	7.6	CFC	3
Secondaries	100	8.8	CFC	11
Active Absorbers	100	12.6	tungsten	4

Passive absorbers:

- TCAPA.6L (1.5m long) → *in front of MBW.B6L*
- TCAPB.6L (0.4m long) → *in front of MBW.A6L*
- TCAPC.6L (1m long) → *in front of MQWA.E5L*

→ 30 cm TCP was proposed in order to reduce the shower development inside the primary collimators



Power distribution in FCC

- FLUKA showering calculation takes the touch distribution from the SixTrack-FLUKA coupling
- Assuming 12 minutes of beam lifetime → total power loss = 11.8MW
- Power sharing between different elements of the warm section for:
  - 60cm TCP, horizontal halo → *presented in April by M.I.Besana*
  - 60cm TCP, vertical halo → *presented in July by M.I.Besana*
  - **30cm TCP, Vertical halo:**

  The active length of the TCP is reduced to 30 cm but the actual length is still 1.2 m!

- Normalization factor $(=\frac{\#touch}{\#loss})$
  - *For 60 cm TCP → 1.58*
  - ***For 30 cm TCP → 2.11***

Power Fraction		
ELEMENTS	TCP 60cm	TCP 30cm
TCP and TCS jaws	6.7%	5.7%
Warm dipoles	13.7%	14.3%
Warm quadrupoles	5.4%	6.9%
Passive absorbers (TCAP)	7.9%	8.8%
Beam pipe	14.2%	13.6%
Tunnel wall	44.9%	43.3%
Other elements	3.3%	3.2%
Neutrinos/E -> m	4%	4.3%

Power deposited on collimator jaws & absorbers

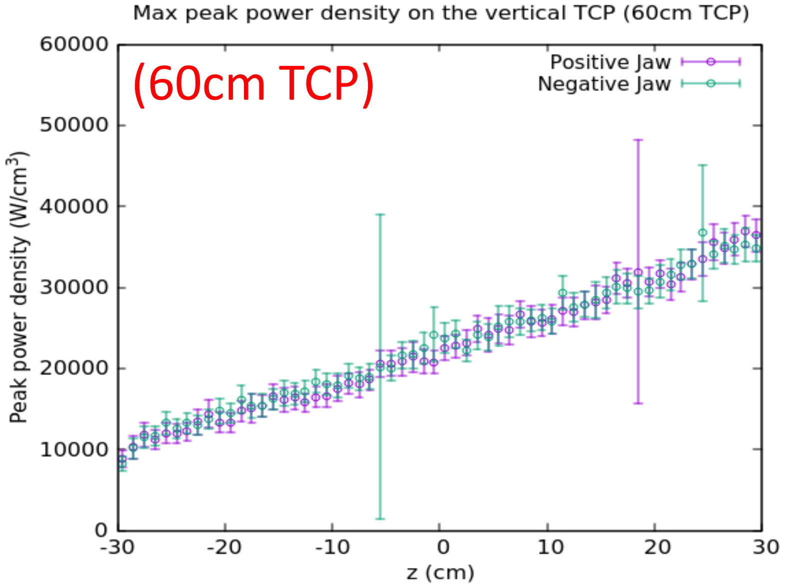
Collimator Jaws	TCP 60cm	TCP 30cm
Primaries (kW)		
TCP.D6L	14.7	7.7
TCP.C6L	158.7	99.2
TCP.B6L	260.8	153.7
Secondaries (kW)		
TCSG.A6L	220.9	226.6
TCSG.B5L	10.6	13.9
TCSG.A5L	40.8	51.2
TCSG.D4L	33	43.5
TCSG.B4L	8.2	11.7
TCSG.A4L	10.8	14.1
TCSG.A4R	13.7	18.2
TCSG.B5R	3.9	5
TCSG.D5R	6.7	9.4
TCSG.E5R	10.9	14.6
TCSG.6R	1.8	2.4

	TCP 60cm	TCP 30cm
Active absorbers (kW)		
TCLA.A6R	23	37.7
TCLA.B6R	1.6	2.7
TCLA.C6R	1.75	2.34
TCLA.D6R	0.46	1.7
Passive absorbers (kW)		
TCAPA.6L	450.8	501.9
TCAPB.6L	73.4	74.8
TCAPC.6L	404.7	455.96

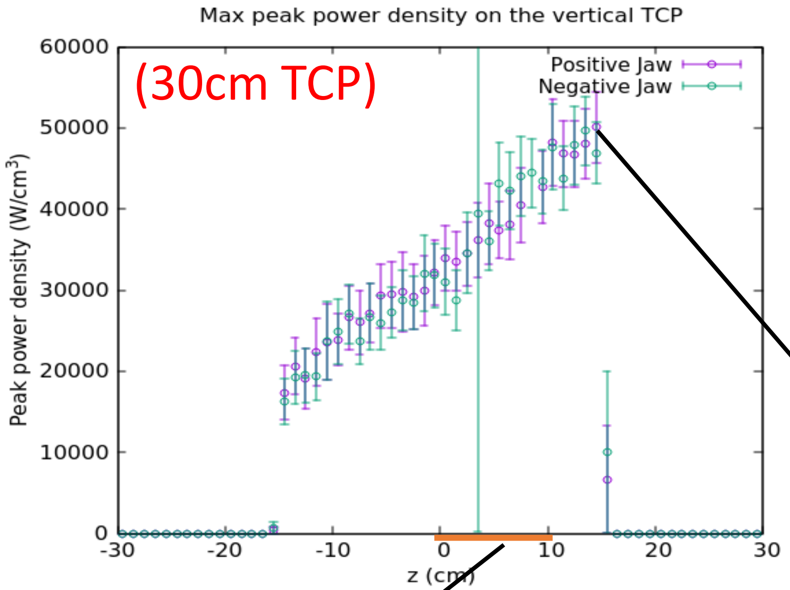
***A factor of 2 reduction only on the** vertical primary collimator!*

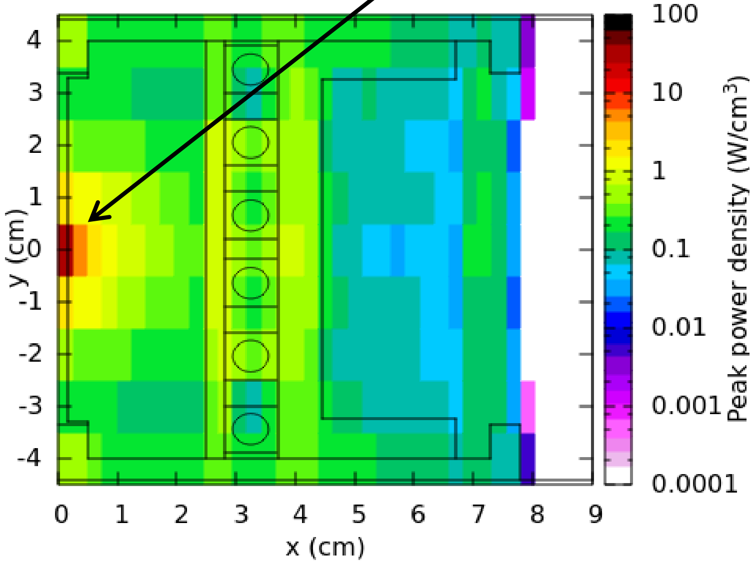
TCSG.A6L → With ticker jaws, can be reduced a lot!

Power density in the jaws of Vertical TCP



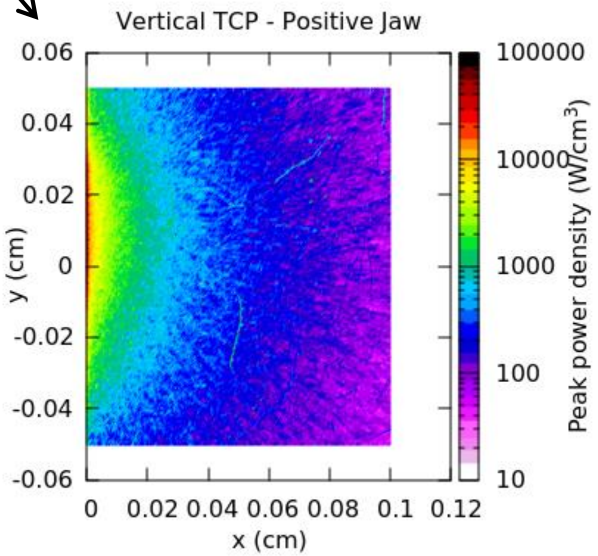
resolution → 5µm, 5µm, 1cm





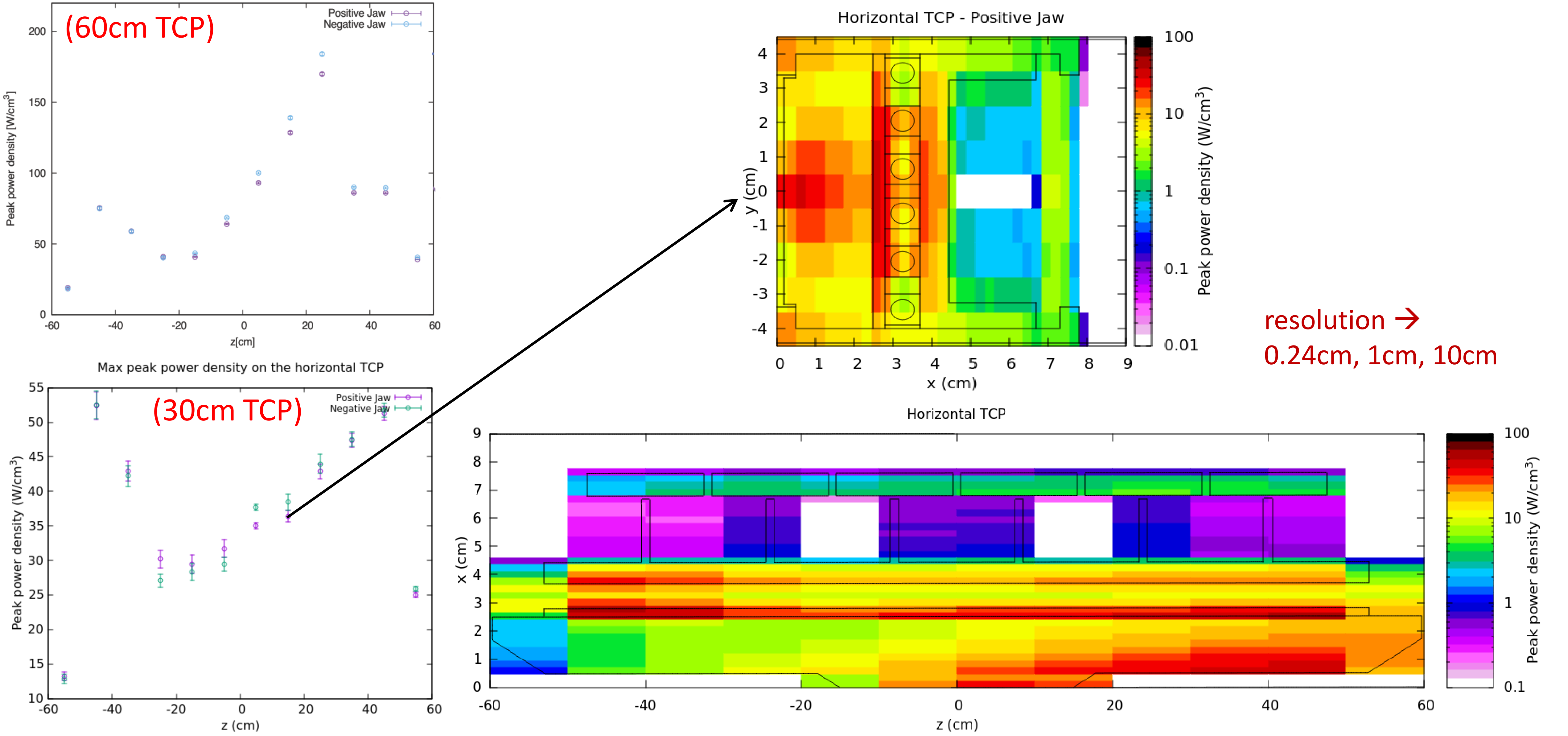
resolution → 0.24cm, 1cm, 10cm

Scoring with resolution of 5µm, 5µm, 1cm



The most exposed collimator in terms of peak power density → TCP.D6L while its total power is more than a factor of 10 below the TCP.C6L!

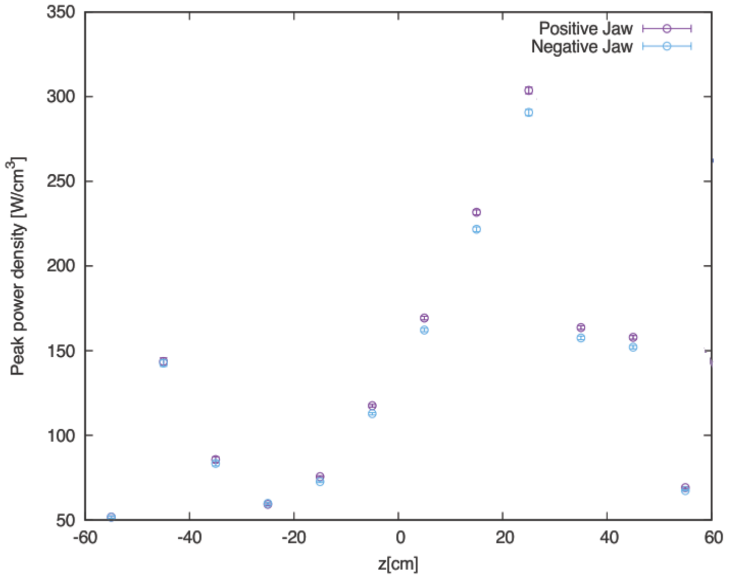
Power density in the jaws of Horizontal TCP



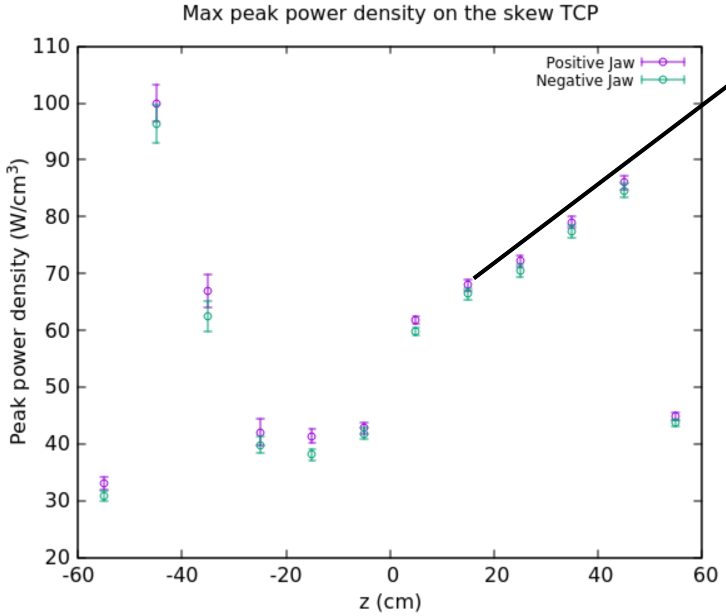
resolution → 0.24cm, 1cm, 10cm

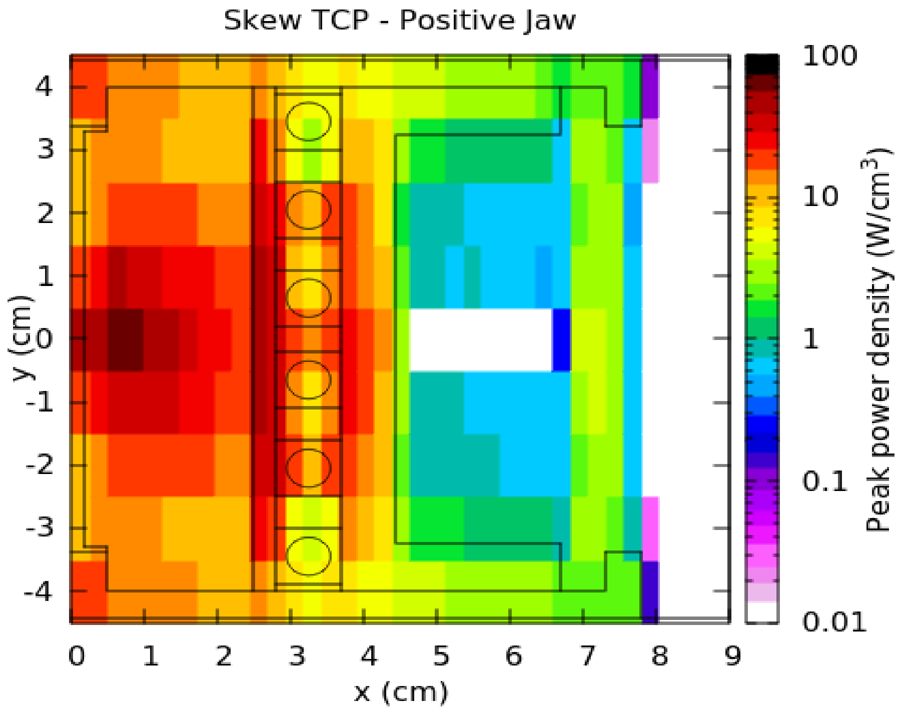
Power density in the jaws of Skew TCP

(60cm TCP)



(30cm TCP)

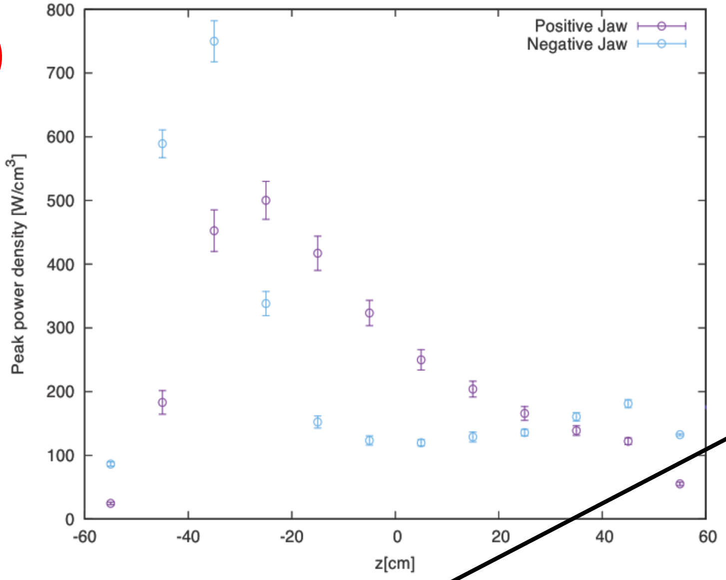




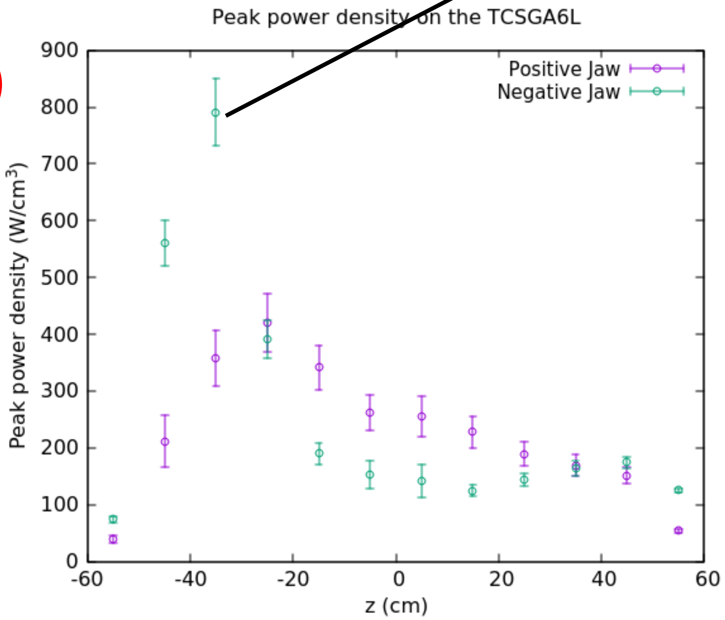
resolution → 0.24cm, 1cm, 10cm

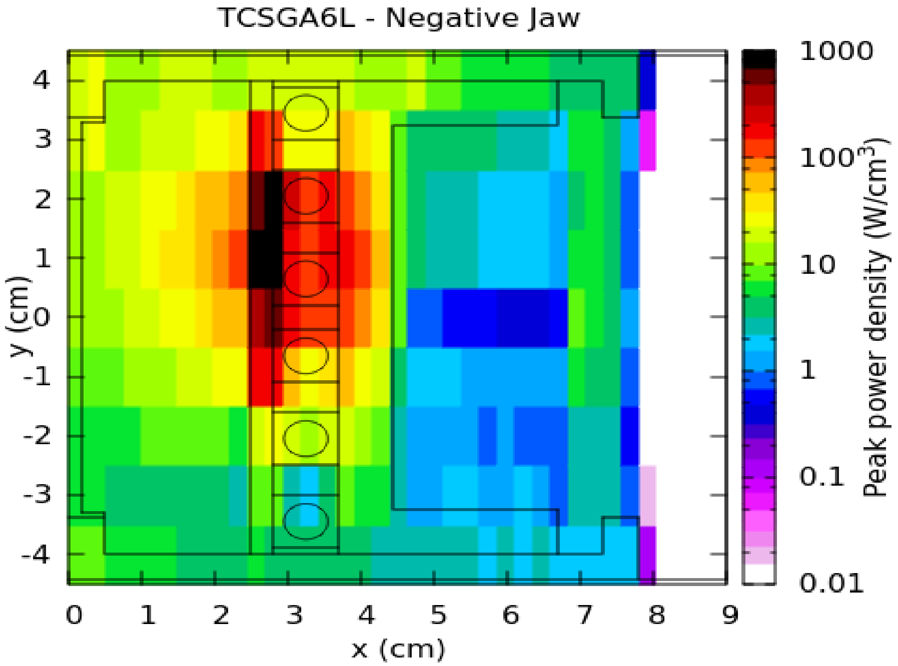
Power density in the jaws of **first TCSG**

(60cm TCP)



(30cm TCP)





The max peak is on the metallic support!

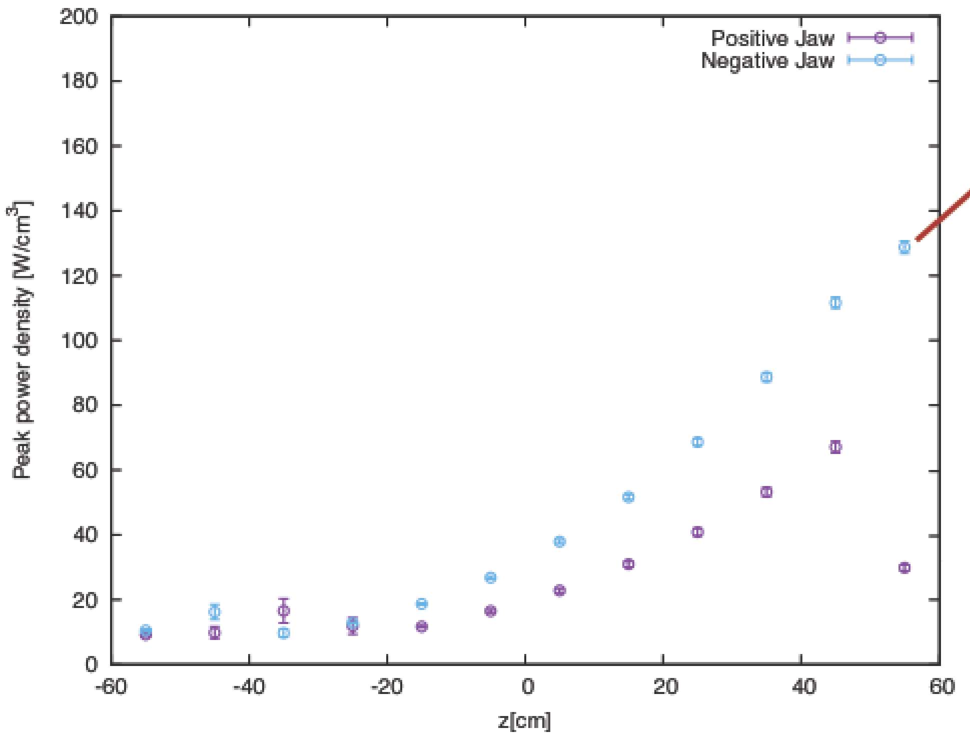
→ Larger jaws improve the situation!

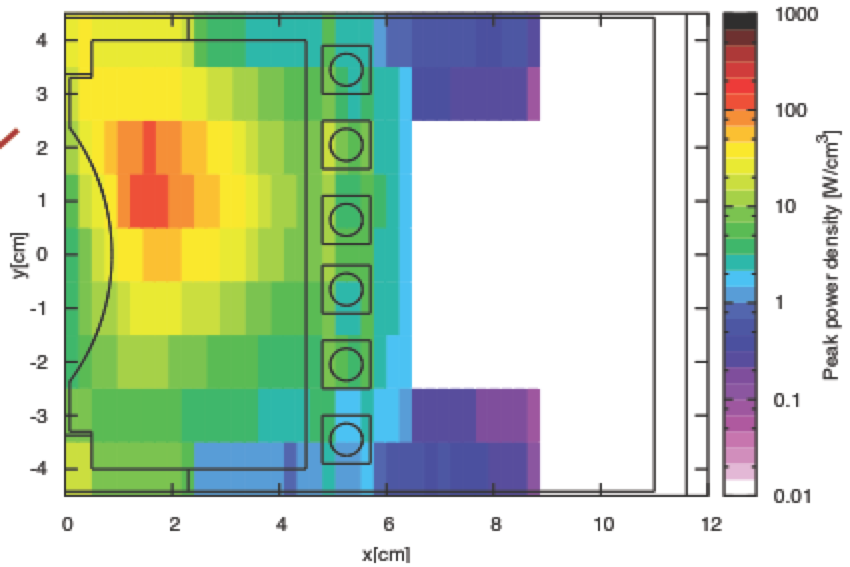
- 800 Wcm^{-3} → TCSG.A6L
- 90 Wcm^{-3} → TCSG.A5L
- 35 Wcm^{-3} → TCSG.D4L
- 10 Wcm^{-3} → LHC

resolution → 0.24cm, 1cm, 10cm

First TCSG with thicker jaws (60cm TCP, v-halo)

➢ **Larger collimator jaws: *4.5 cm instead of 2.5 cm***





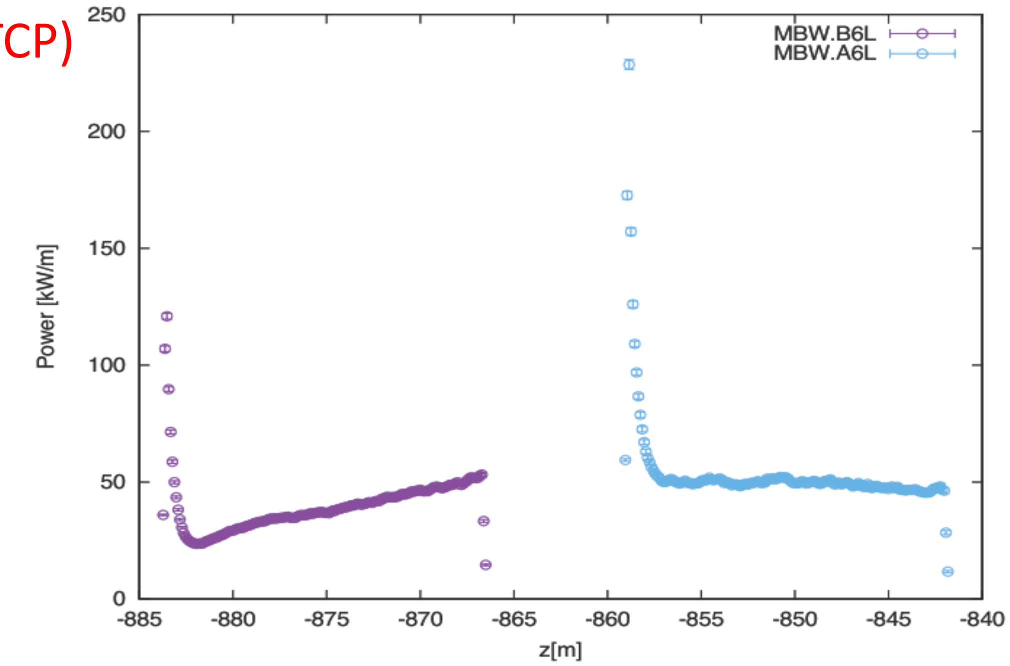
Power Fraction	Vertical	Vertical, thicker TCGS
TCP and TCS jaws	6.7%	5.4%
Warm dipoles	13.7%	13.4%
Warm quadrupoles	5.4%	5.6%
Passive absorbers (TCAP)	7.9%	7.8%
Beam pipe	14.2%	14.7%
Tunnel wall	44.9%	45.8%
Other Elements	3.3%	3.2%
Neutrinos/E → m	4%	4.2%

- ***Max peak power density was on the negative jaw***
  → is reduced from 750 Wcm^{-3} to 130 Wcm^{-3}
- ***Total power on the first TCSG***
  → is reduced from 220.9 kW to 91.6 kW!

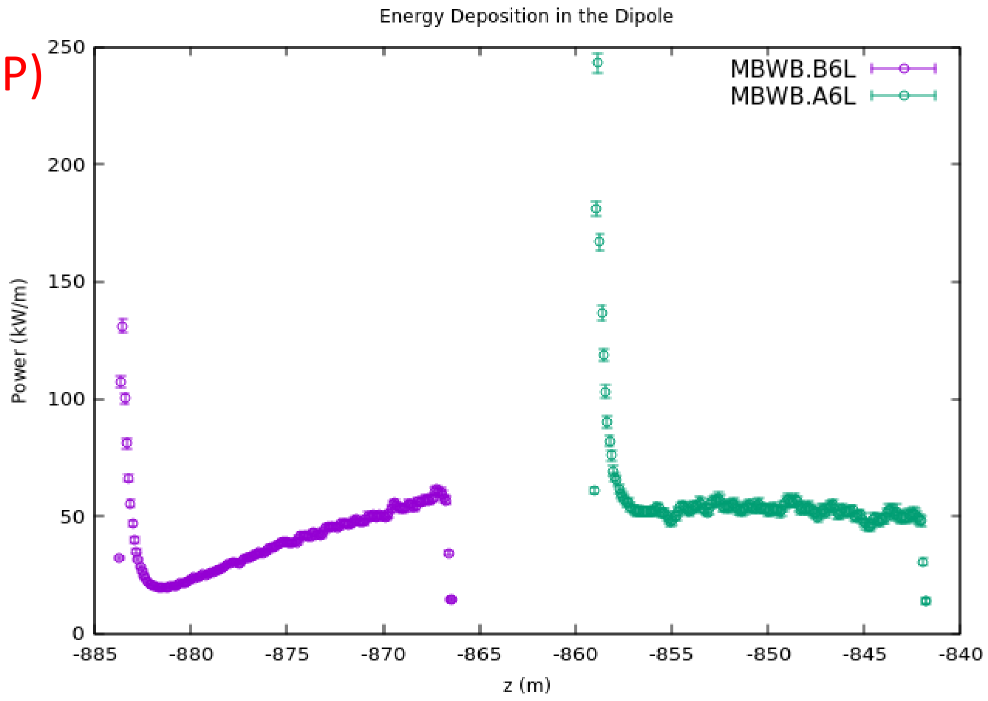
The most exposed dipole modules

The 2 dipoles after the primary collimators take more than 95% of the total power on the dipoles!

(60cm TCP)



(30cm TCP)



Power on the most exposed dipoles		
	TCP 60cm	TCP 30cm
MBW.B6L	0.69 MW	0.7 MW
MBW.A6L	0.93 MW	0.99 MW

Maximum power on dipole ≈ 1 MW
at LHC (6.5 TeV) → 22 kW

Summary

- By reducing the active length of TCPs, the global picture does not change dramatically (impact on the magnets are practically unchanged)
- Situation of directly impacted collimator is worsened → 50 $kWcm^{-3}$ w.r.t. 35 $kWcm^{-3}$
- Afterward collimators:
  - **TCPC & TCPB →** we gain at least a factor of 3 in terms of peak power density
  - **Secondaries →** almost similar as for 60 cm TCP vertical halo
    - Max peak power density is in the metallic part which can be addressed with thicker jaws!
- Values on the downstream collimators starts to get closer to a manageable range (lighter density material could be considered)
- The surface of the directly impacted collimator is at tens of kW/cc

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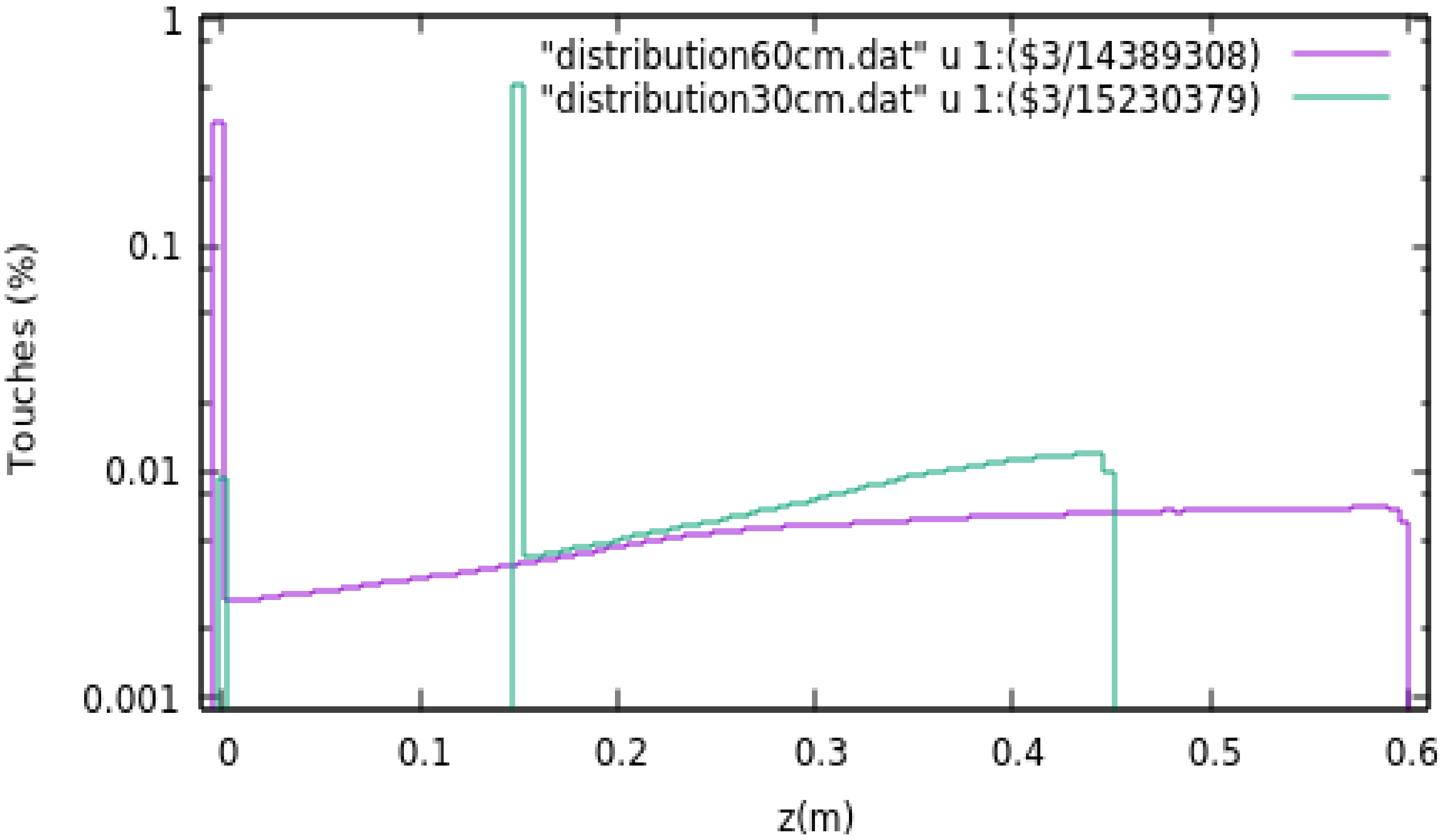
Backup Slides

Distribution of touches (60 cm vs 30 cm)



FCC vs LHC

60 cm TCP

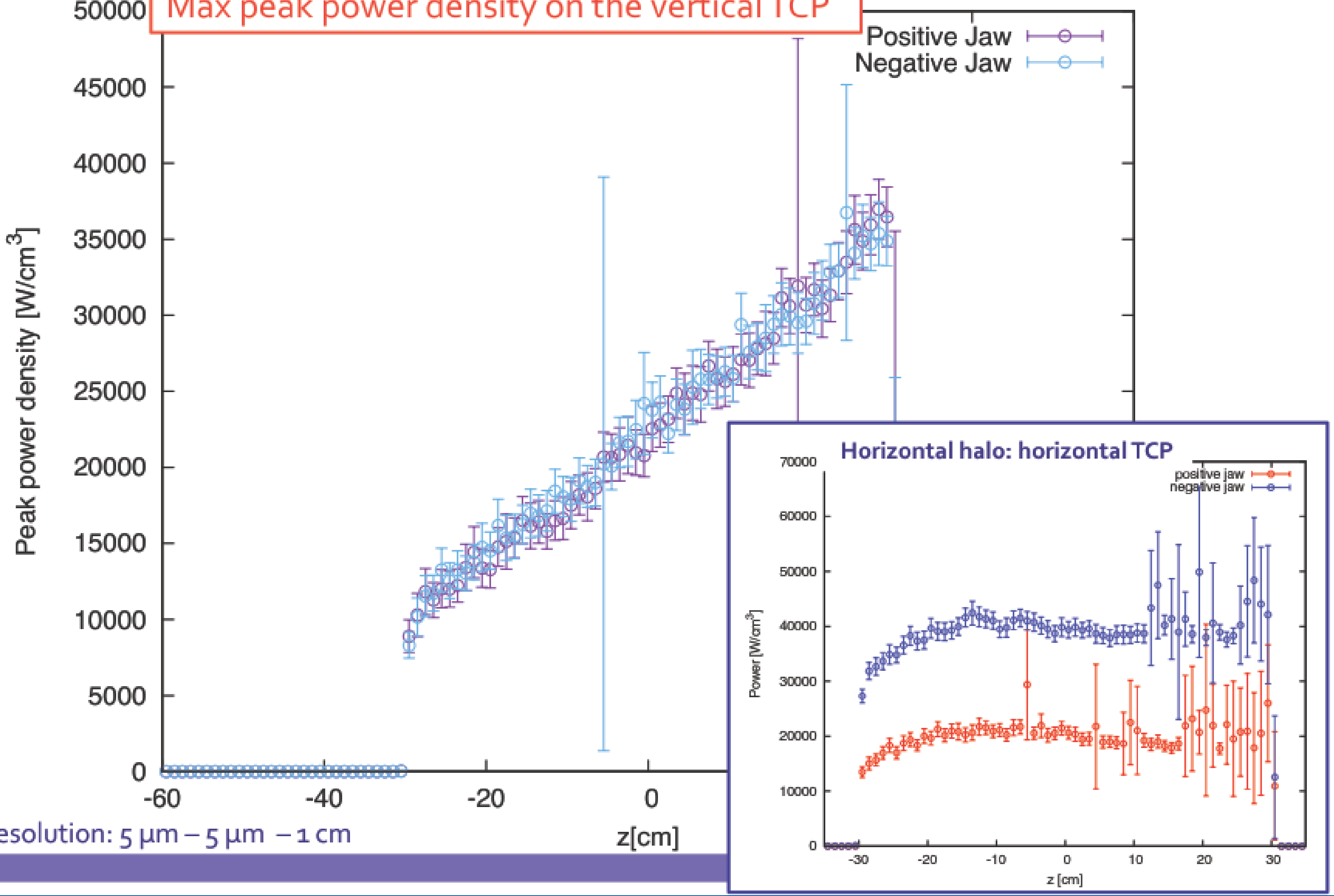
Table 2: Sharing of beam energy deposition in the collimation betatron cleaning insertion for FCC (50 TeV) and LHC (6.5 TeV).

Element	FCC	LHC
Warm dipoles	16%	8.5%
Warm quadrupoles	4.6%	9.5%
TCP and TCS jaws	5.1%	10.5%
Passive absorbers	8.6%	13.5%
Tunnel and other elements	47.5%	42.4%
Beam pipe	14.2%	8.6%
Missing	4%	6.5%

Vertical TCP

60 cm TCP

Max peak power density on the vertical TCP

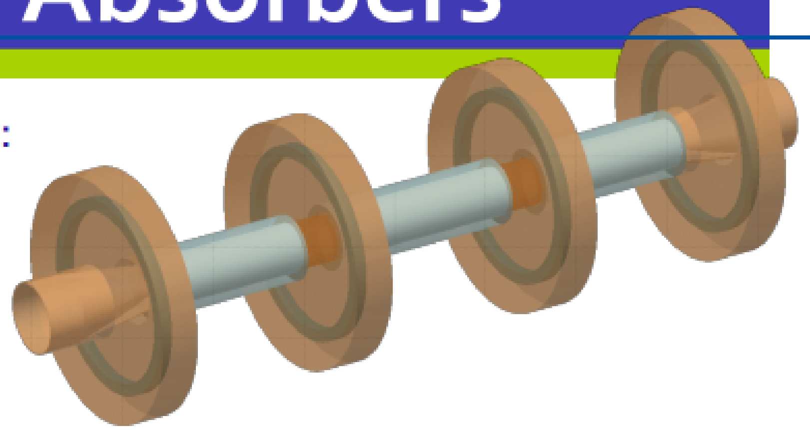


x-y-z resolution: 5 µm – 5 µm – 1 cm

Impact of Passive Absorbers

60 cm TCP

- Passive absorbers put in front of the magnets:
  - design not optimized: LHC models
    - TCAPA.6L in front of MBW.B6L (1.5 m long)
    - TCAPB.6L in front of MBW.A6L (0.4 m long)
    - TCAPC.6L (1 m long)



Power Fraction	FCC w/o TCAP	FCC w TCAP
Power Loss for 12 minutes beam life-time	**11.8 MW**	**11.8 MW**
Passive absorbers (TCAP)	-	8.6%
Warm dipoles	20.3%	16%
Warm quadrupoles	6.6%	4.6%
TCP and TCS jaws	5.5%	5.1%
Tunnel wall	44.4%	44%
Beam pipe	15%	14%

- Max power on a dipole (MBW.A6L): ~1 MW
  - 22 kW at LHC (6.5 TeV)