Update on Energy Deposition in Betatron Cleaning Insertion

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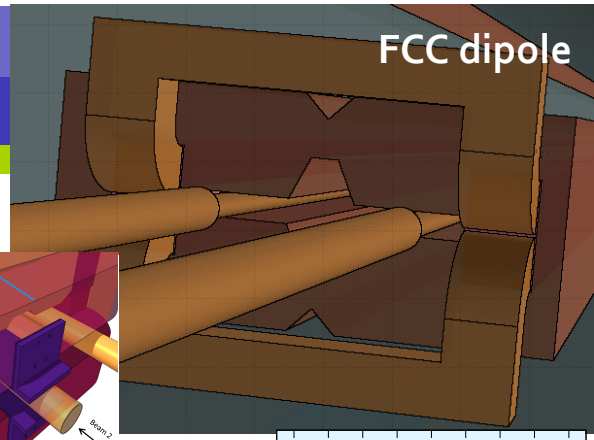
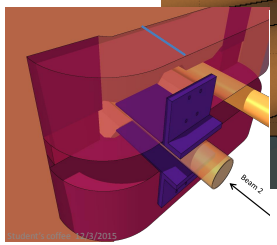
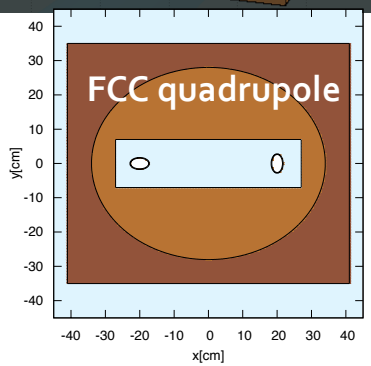
on behalf of the EN STI FLUKA team

Introduction



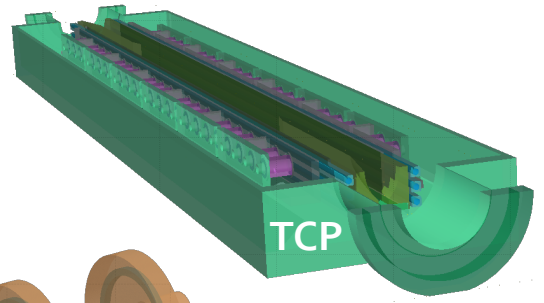




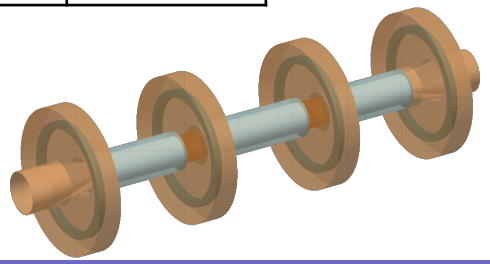
Shower simulations for the Betatron collimation IR (2.7 km):

- Warm magnets
  - 8 dipole modules:
    - 17 m long warm dipoles
    - magnetic field 1.8516 T
    - beam-beam separation: 250 mm and 400 mm
    - changed return coil design, to protect them from radiation (A. Milanese)
  - 24 quadrupole modules:
    - 15.54 m long
    - very simplified design, LHC inspired, with 400 mm beam separation
- Collimators & Absorbers with same design and composition as LHC

Collimators	Length [m]	Aperture [σ]	Material	Number
Primaries	0.6	7.6	CFC	3
Secondaries	1	8.8	CFC	11
Active absorbers	1	12.6	tungsten	4



  - Passive absorbers
    - 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)



FCC Power Sharing

- Expected losses assuming 12 minutes beam lifetime:
  - the total power is **11.8 MW**
- Power sharing between the different elements of the warm section for:
  - horizontal halo (already presented in April)
  - vertical halo → new tracking simulations from Daniele:
    - https://indico.cern.ch/event/636633/contributions/2577517/attachments/1454980/2252891/FCC_cleaning.pdf

Power Fraction	Horizontal	Vertical
TCP and TCS jaws	5.1%	6.7%
Warm dipoles	16%	13.7%
Warm quadrupoles	4.6%	5.4%
Passive absorbers (TCAP)	8.6%	7.9%
Beam pipe	14.2%	14.2%
Tunnel wall	44.4%	44.9%
Other Elements	3.1%	3.3%
Neutrinos/E → m	4%	4%

Power on Collimator Jaws I

Collimator Jaws	Horizontal [kW]	Vertical [kW]
Primaries		
TPC_D6L	0.02	14.7
TPC_C6L	23.1	158.7
TPC_B6L	209.0	260.8
Secondaries		
TCSG_A6L	233.6	220.9
TCSG_B5L	8.2	10.6
TCSG_A5L	35.7	40.8
TCSG_D4L	27.6	33
TCSG_B4L	7.1	8.2
TCSG_A4L	13.1	10.8
TCSG_A4R	15.9	13.7
TCSG_B5R	4.9	3.9
TCSG_D5R	9.0	6.7
TCSG_E5R	15.7	10.9
TCSG_6R	3.5	1.8

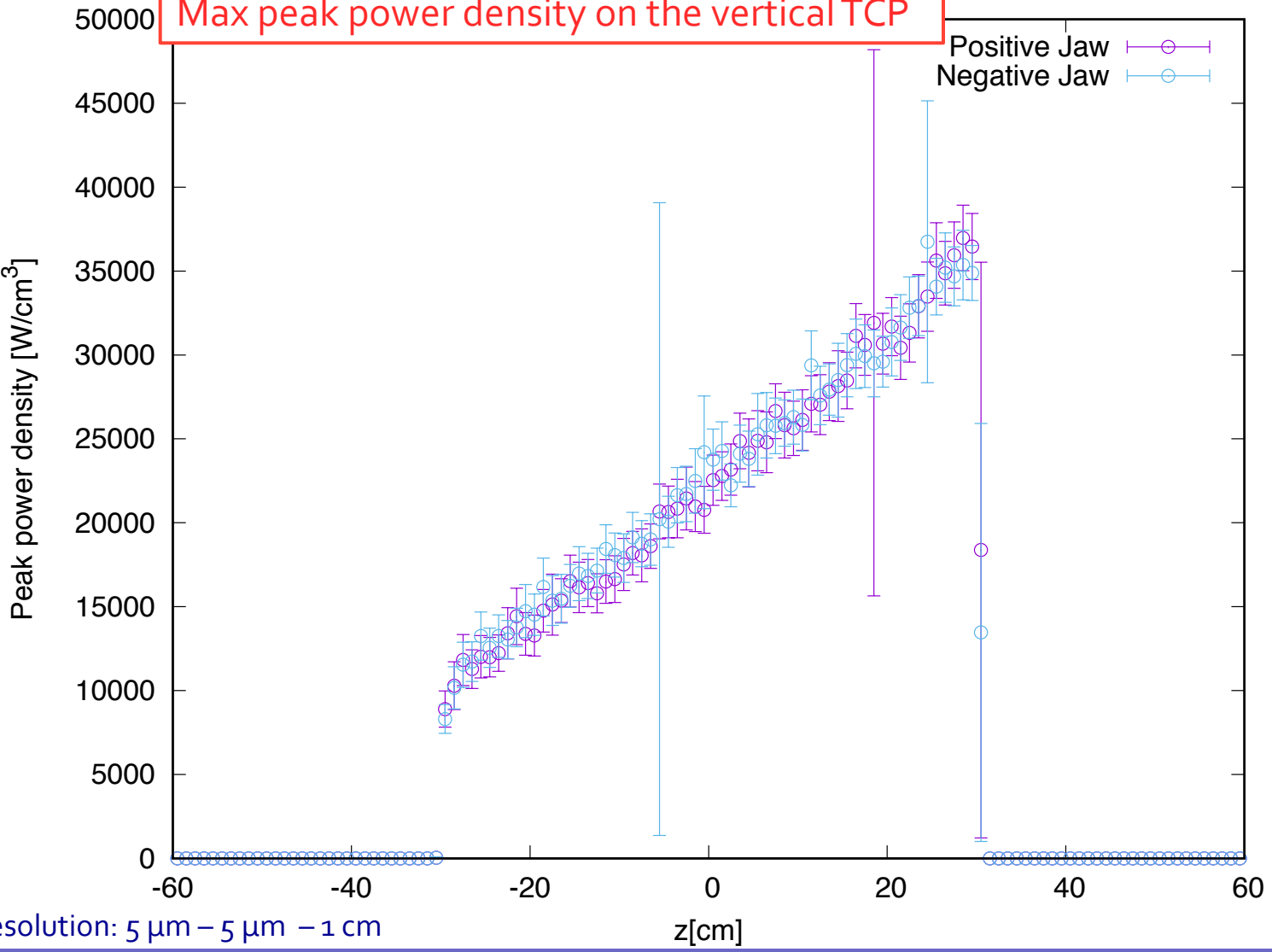
Power on Collimator Jaws II

Active absorbers		
Collimator Jaws	**Horizontal [kW]**	**Vertical [kW]**
TCLA_A6R	74.5	23
TCLA_B6R	13.5	1.6
TCLA_C6R	2.0	1.75
TCLA_D6R	2.6	0.46

Passive absorbers		
Collimator Jaws	**Horizontal [kW]**	**Vertical [kW]**
TCAPA.6L	560.7	450.76
TCAPB.6L	93.4	73.37
TCAPC.6L	359.9	404.74

Vertical TCP

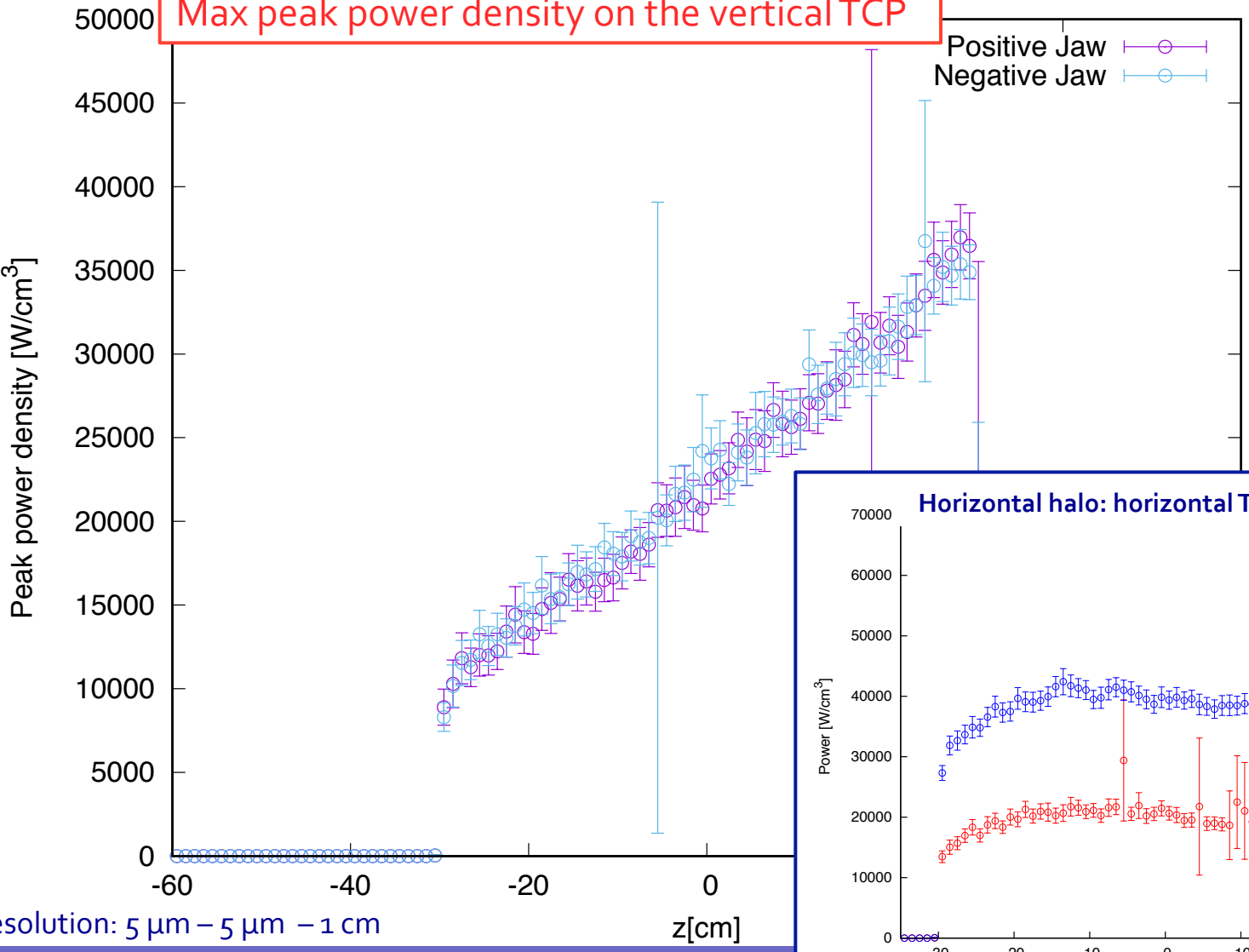
Max peak power density on the vertical TCP



x-y-z resolution: 5 μm – 5 μm – 1 cm

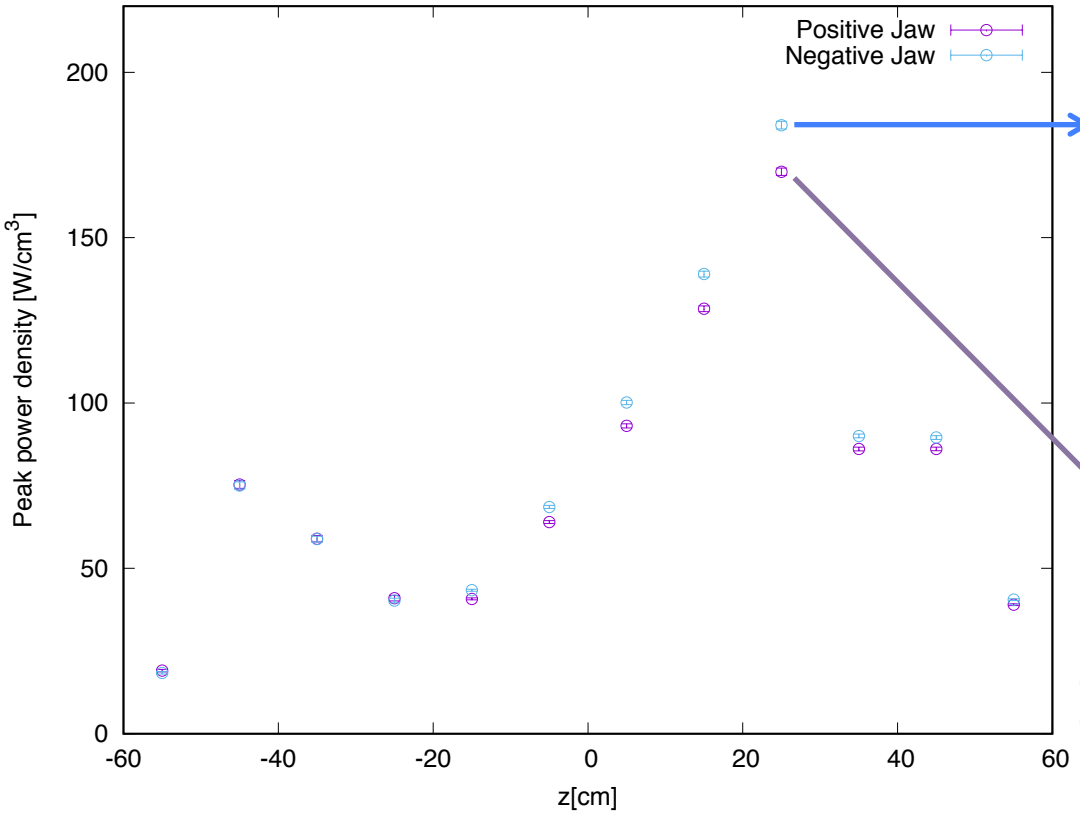
Vertical TCP

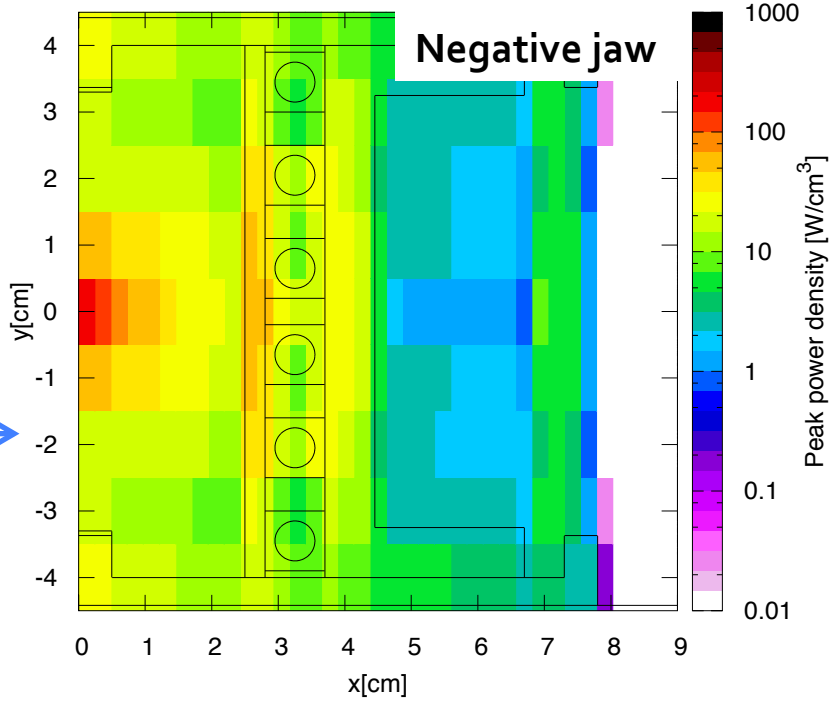
Max peak power density on the vertical TCP

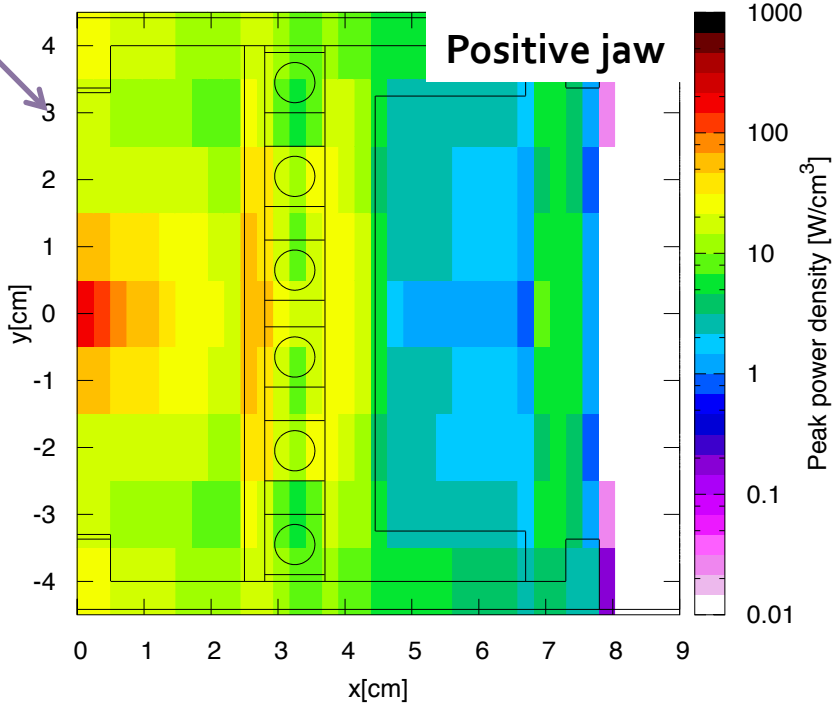


x-y-z resolution: 5 μm – 5 μm – 1 cm

Horizontal TCP

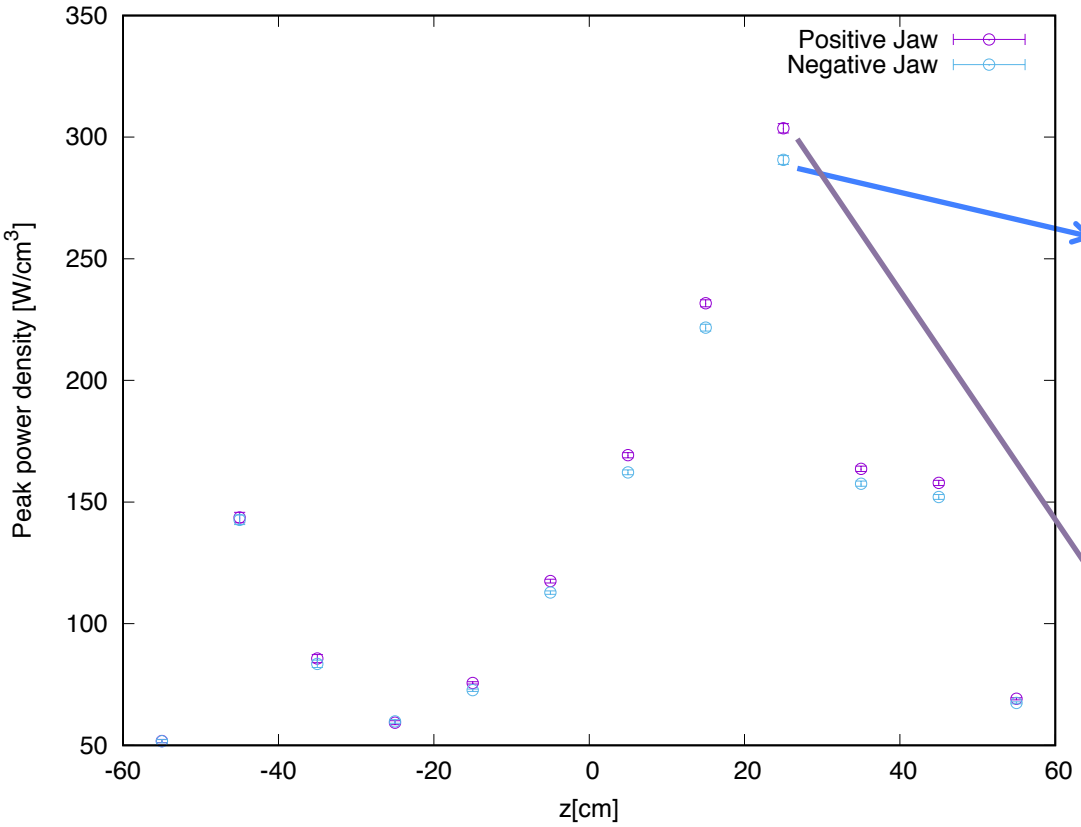


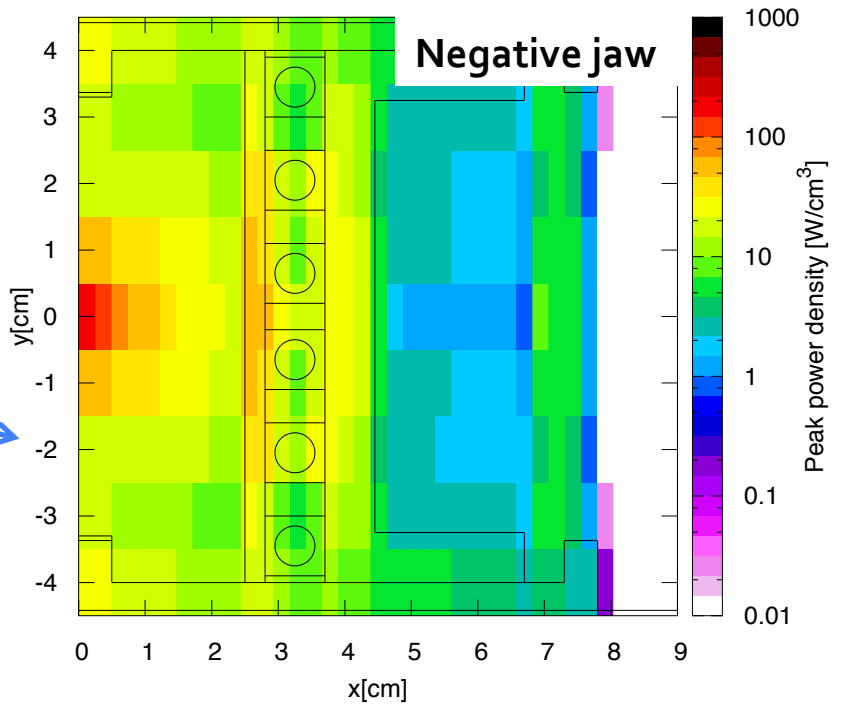


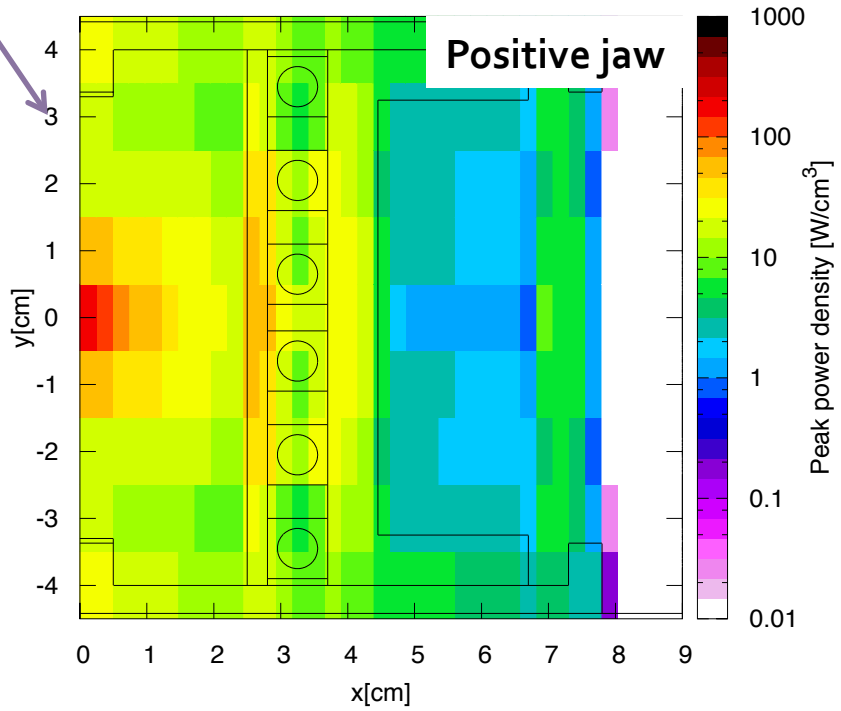


x-y-z resolution: 0.24 cm – 1 cm – 10 cm

Skew TCP



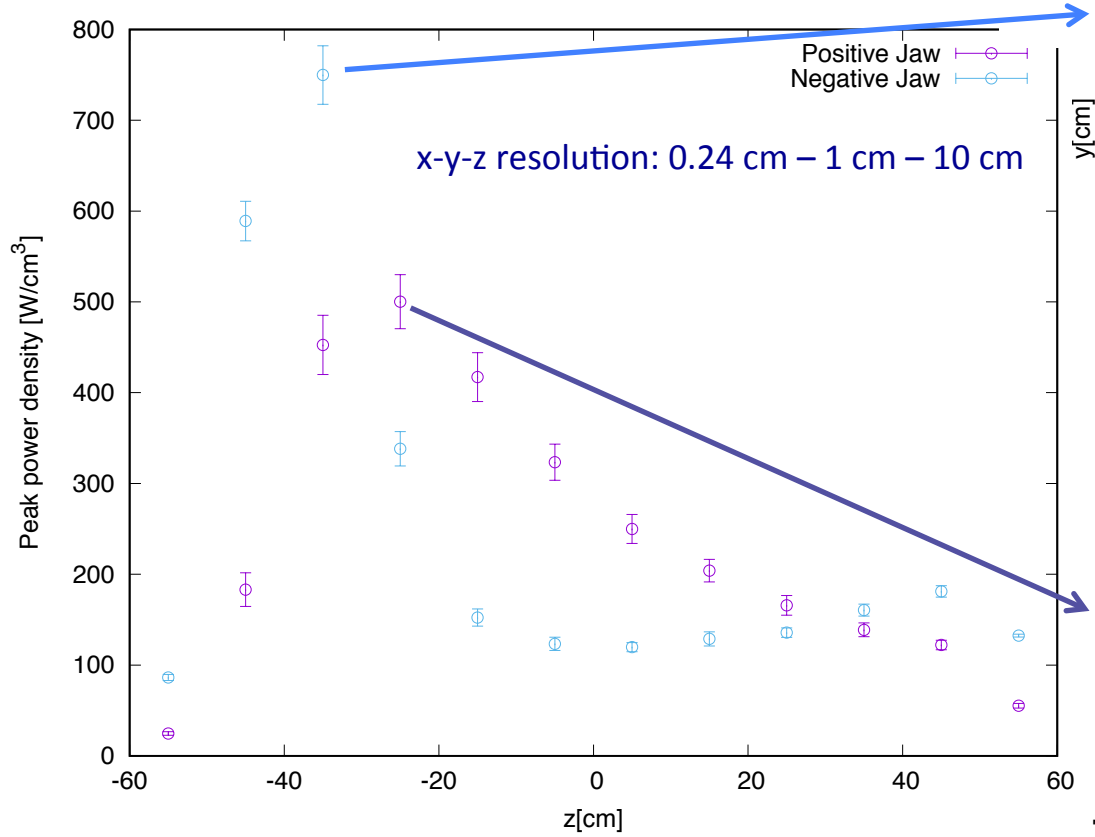


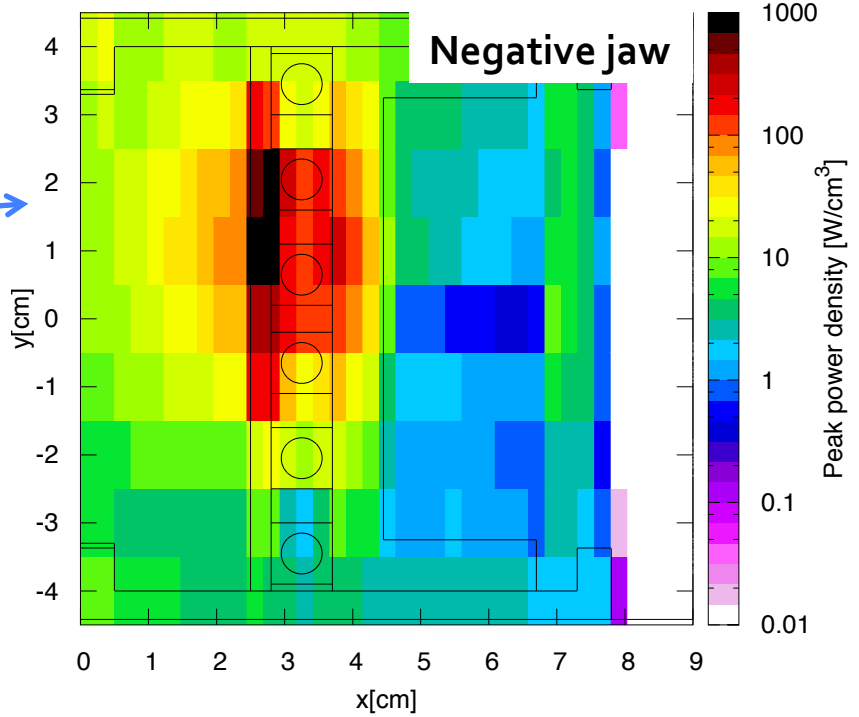


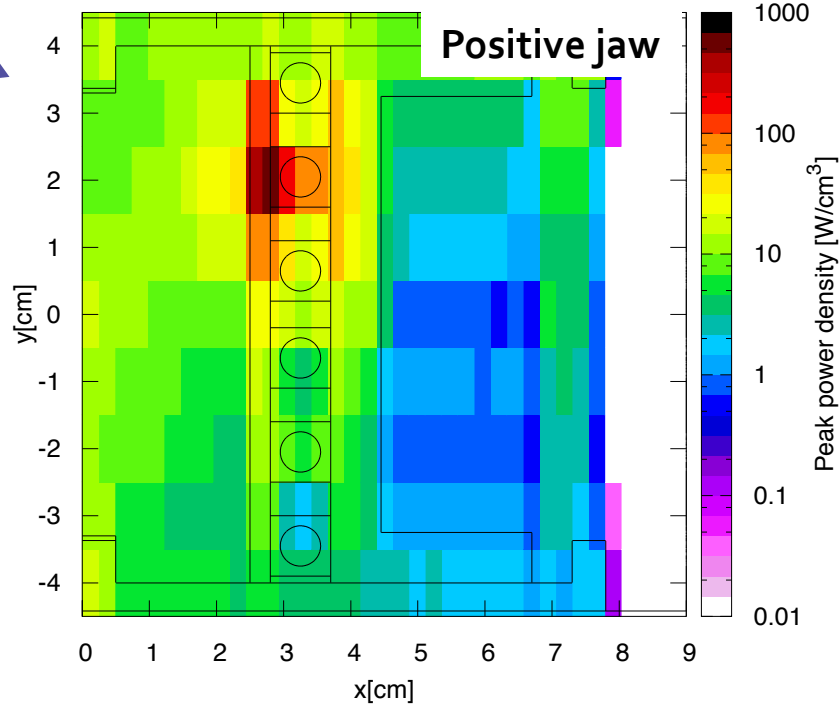
- Peak power density for horizontal losses arrives at 450 Wcm^{-3}.

x-y-z resolution: 0.24 cm – 1 cm – 10 cm

First TCGS



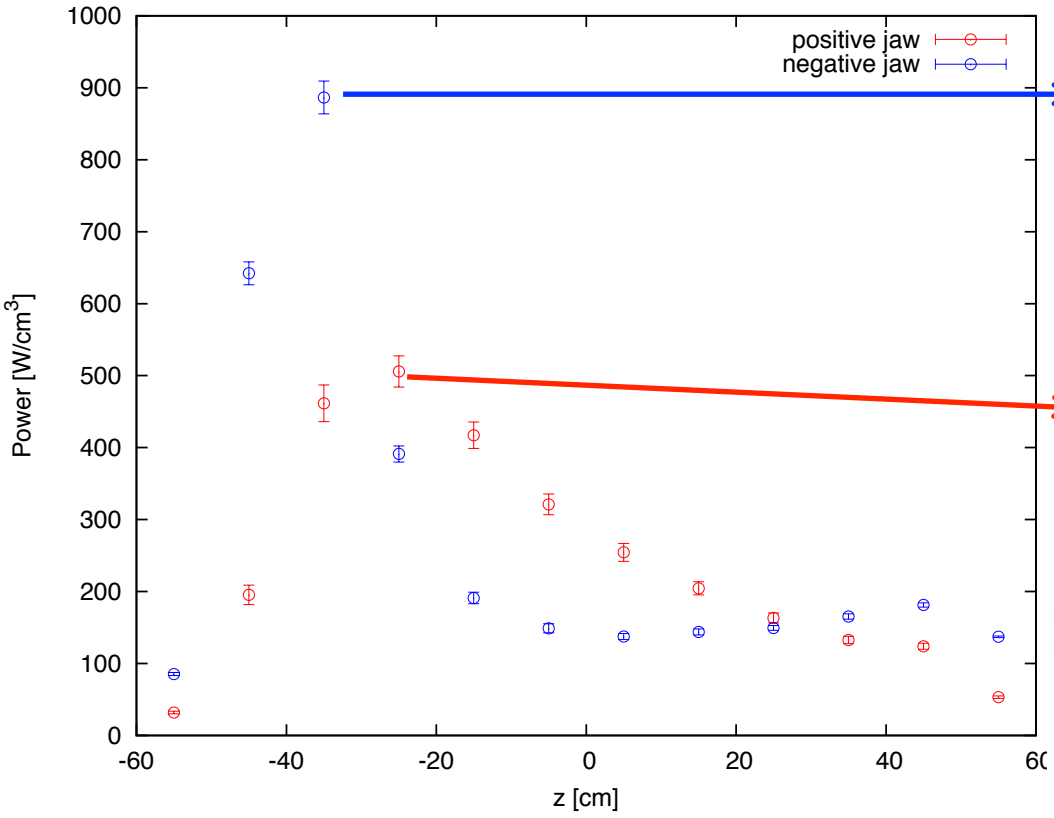


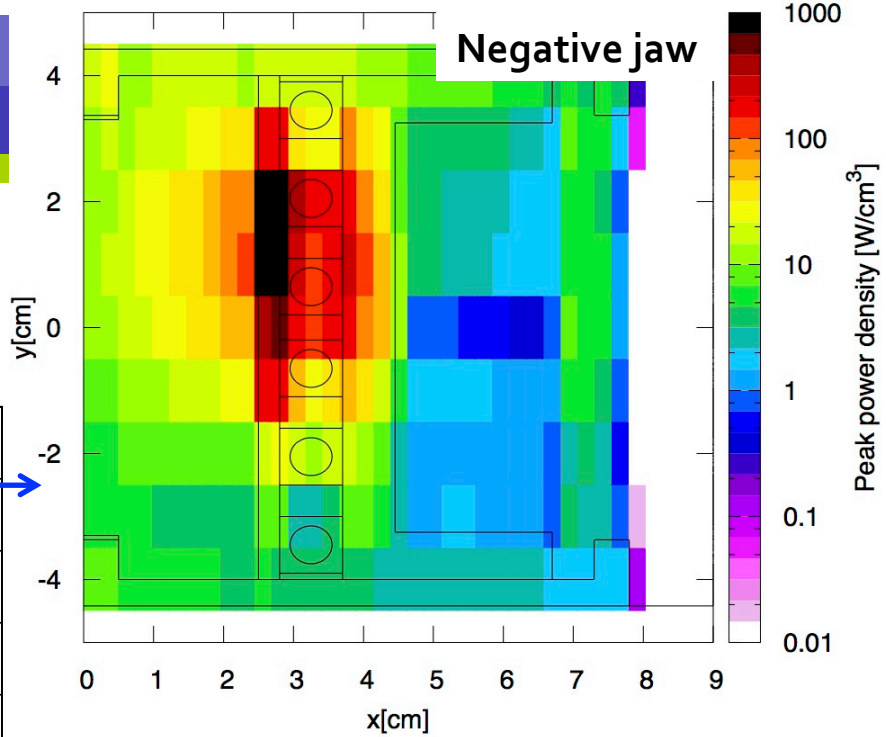


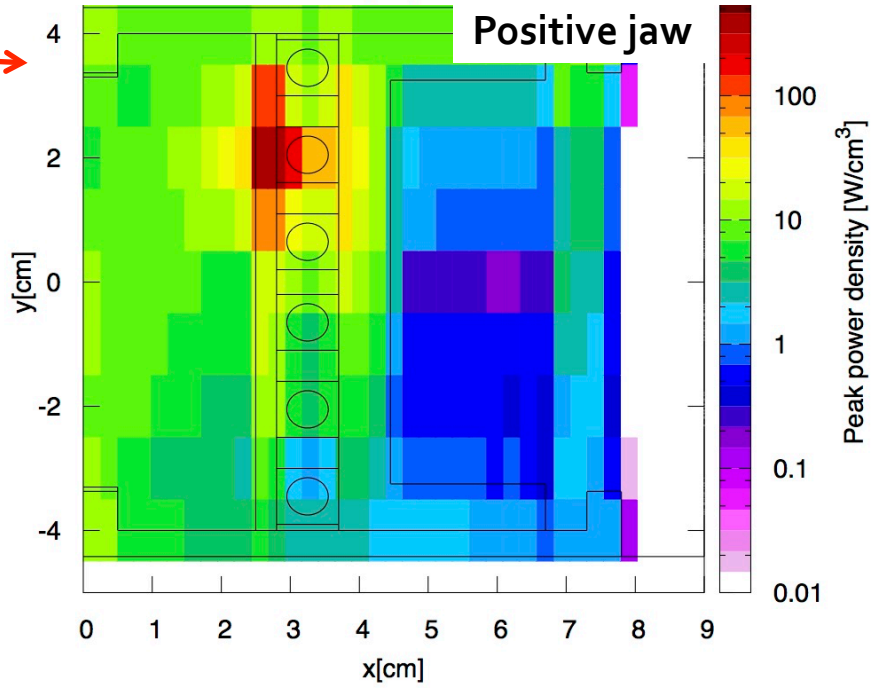
- The maximum peak power density is on the support
  - new simulations ongoing with larger collimator jaws (2.5 cm to 4.5 cm thick jaw)

Horizontal Halo

- Max peak power density on secondaries on the first TCGS:



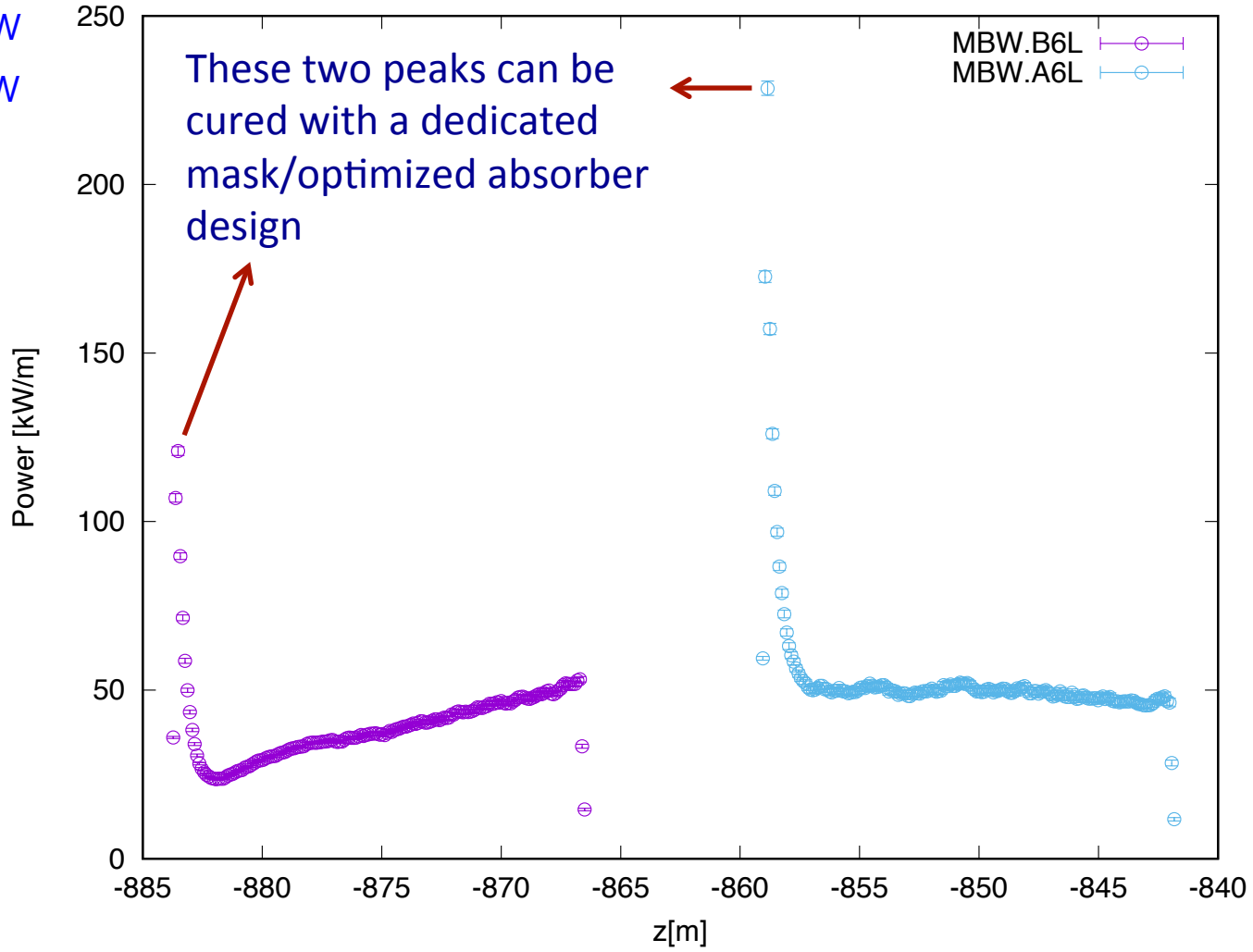




x-y-z resolution: 0.24 cm – 1 cm – 10 cm

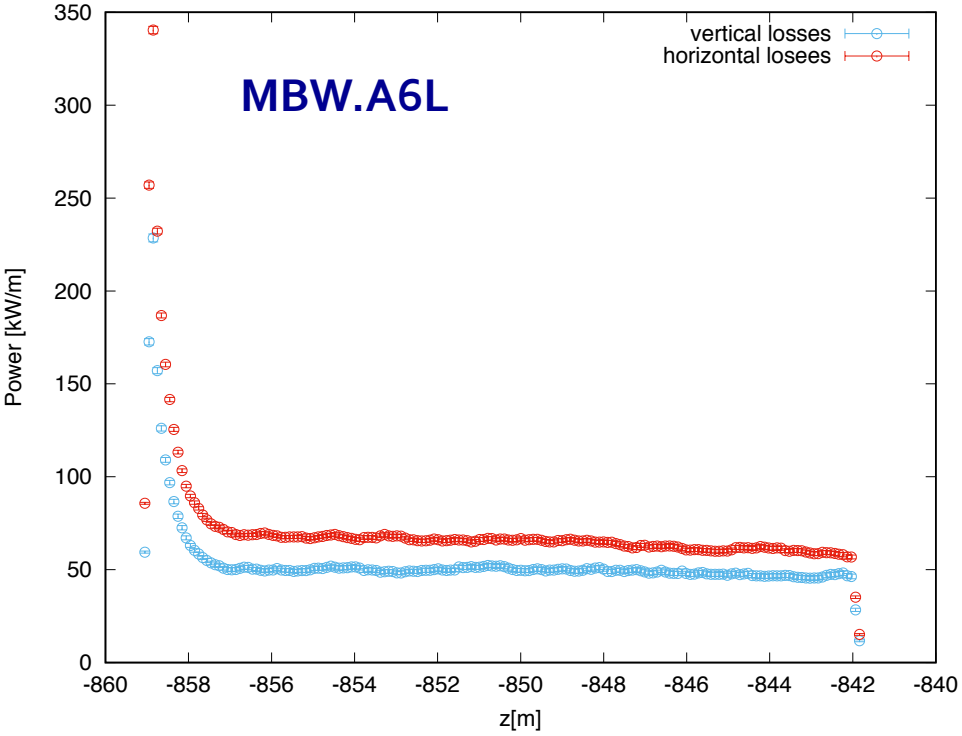
Energy Deposition in the Dipoles I

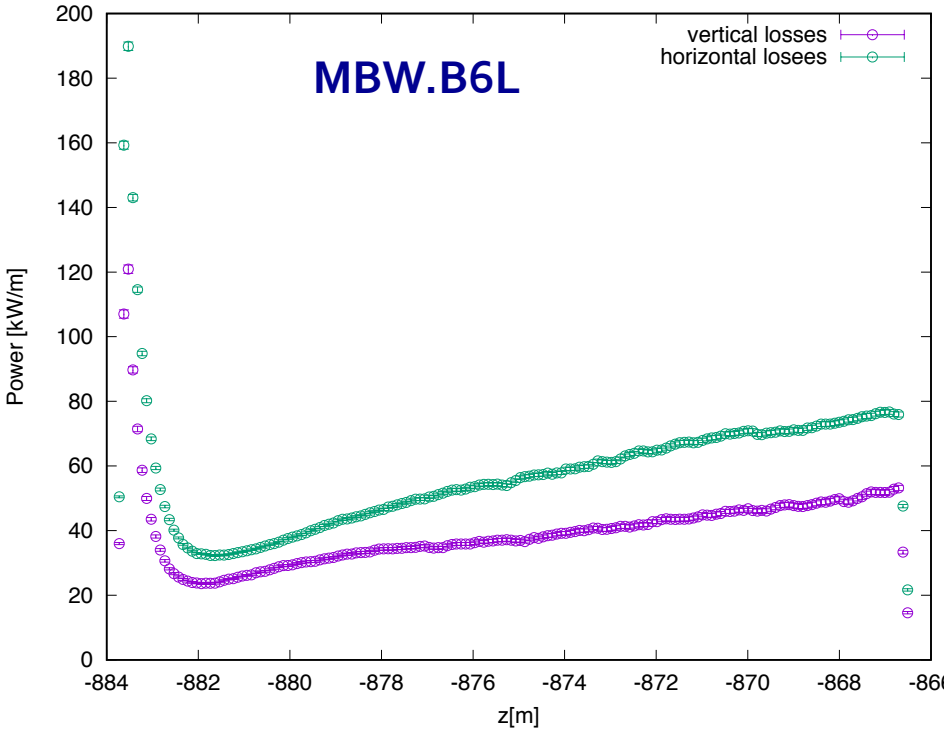
- Two dipole modules downstream the TCPs take more than 95% of the total on dipoles:
  - MBW.B6L: 0.69 MW
  - MBW.A6L: 0.93 MW



Energy Deposition in the Dipoles II

- Most exposed dipole modules for horizontal halo:
  - MBW.B6L: 0.8 MW
  - MBW.A6L: 1 MW





Energy deposition: TCP 30 cm

- The active length of the TCP has been reduced to 30 cm of CFC
  - vertical halo case
    https://indico.cern.ch/event/636633/contributions/2577517/attachments/1454980/2252891/FCC_cleaning.pdf
- Energy sharing between the different elements of the warm section:

Energy Sharing	TCP 60 cm	TCP 30 cm
Warm dipoles	13.7%	11.12%
Warm quadrupoles	5.4%	5.3%
TCP and TCS jaws	6.7%	4.4%
Passive absorbers (TCAP)	7.9%	6.7%
Beam pipe	14.2%	10.6%
Tunnel wall	44.9%	33.6%
Other Elements	3.3%	1.34%
Neutrinos/E → m	4%	3%

11.4 TeV missing, investigation ongoing: new simulations running with the new loss maps file

Conclusions & Outlooks

Conclusions:

- Simulations with vertical halo:
  - power fraction on dipoles reduced from 16% to 13.7% with respect to horizonthal halo case
    - maximum total power on a dipole module = 0.96 MW, maximum power per meter = 250 kW/m, but bulk below 100 kW/m
  - 6.7% of power on the collimators jaws
    - few collimators with total power above 100 kW: horizontal and skew TCP and first TCS
    - higher peak power density on the vertical TCP (x-y-z resolution: 5 µm – 5 µm – 1 cm): 4 $kWcm^{-3}$
    - maximum peak power density on the first TCS on the support (x-y-z resolution: 0.24 cm – 1 cm – 10 cm): 800 $kWcm^{-3}$

Next steps:

- Simulations ongoing:
  - with shorter primaries & new loss maps
  - with 60 cm long primaries & thicker secondaries (4.5 cm thick jaw instead of 2.5 cm)

Back-Up

Power on Collimators and Absorbers

Collimator Jaws	TCP 60 cm	TCP 30 cm
Primaries		
TPC_D6L	14.7	6.0
TPC_C6L	158.7	76.9
TPC_B6L	260.8	119.5
Secondaries		
TCSG_A6L	220.9	173.9
TCSG_B5L	10.6	10.7
TCSG_A5L	40.8	40.1
TCSG_D4L	33	33.7
TCSG_B4L	8.2	8.7
TCSG_A4L	10.8	11.3
TCSG_A4R	13.7	14.0
TCSG_B5R	3.9	4.4
TCSG_D5R	6.7	7.9
TCSG_E5R	10.9	12.3
TCSG_6R	1.8	1.9

Active absorbers		
Collimator Jaws	**TCP 60 cm [kW]**	**TCP 30 cm [kW]**
TCLA_A6R	23	24.4
TCLA_B6R	1.6	2.3
TCLA_C6R	1.75	2.3
TCLA_D6R	0.46	1.2

Passive absorbers		
Collimator Jaws	**TCP 60 cm [kW]**	**TCP 30 cm [kW]**
TCAPA.6L	450.8	384.5
TCAPB.6L	73.4	60.6
TCAPC.6L	404.7	349.6

FCC vs LHC

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%