
CERN

Energy deposition studies for secondary ion beams in FCC-hh

FCC collimation design meeting #24

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With support from:
J. Molson & R. Bruce

Contents

- Introduction
- Energy deposition simulations
- First case in DS
- Matching section
- Multiple collimator tests in DS
- Outlook

Background

Ultra-peripheral electromagnetic interactions in heavy nucleus-nucleus collisions:

Bound-Free Pair Production (BFPP)

(Captures an electron from an e-e+ pair)

$$ {}^{A}X^{Z} + {}^{A}X^{Z} \rightarrow {}^{A}X^{Z} + {}^{A}X^{Z-1} + e^{+} $$

Electro-magnetic Dissociation (EMD)

(Emits a neutron)

$$ {}^{A}X^{Z} + {}^{A}X^{Z} \rightarrow {}^{A}X^{Z} + {}^{A-1}X^{Z} + n $$

Thanks to M. Schaumann
(FCC Week 2019)

Change of magnetic rigidity (charge to mass ratio) results in secondary beams emerging from IP

Background

Beam power proportional to luminosity and energy:

Table 2.8: Beam and machine parameters for operation with ions.

	Unit	Initial		Nominal	
Operation mode	-	Pb-Pb	p-Pb[a]	Pb-Pb	p-Pb[a]
Beam energy	[TeV]	4100	50	4100	50
Centre-of-mass energy per nucleon pair	[TeV]	39.4	62.8	39.4	62.8
No. of bunches	-	2760		5400	
Bunch spacing	[ns]	100		50	
No. of particles per bunch	[10^8]	2	164	2	164
Transverse normalised emittance	[µm.rad]	1.5[b]	3.75[b]	1.5[b]	3.75[b]
Stored energy per beam	[MJ]	362		709	
Stored energy per beam at injection	[MJ]	24		47	
β-function at the IP	[m]	1.1		0.3	
Number of IPs in collision	-	1 or 2		1 or 2	
Initial luminosity	[10^{27}cm^{-2}s^{-1}]	34	2800	248	20400
Peak luminosity[c]	[10^{27}cm^{-2}s^{-1}]	80	13300	320	55500
Integrated luminosity[d] (1 experiment)	[nb^{-1}/run]	35	8000	110	29000
Integrated luminosity[d] (2 experiments)	[nb^{-1}/run]	23	6000	65	18000
Total cross-section	[b]	597	2	597	2
Peak BFPP beam power	[kW]	19	0	75	0

$$P = \sigma L E$$

$L_{LHC} = 6 \times 10^{27}$ cm^{-2} s^{-1}

$L_{FCC} = 320 \times 10^{27}$ cm^{-2} s^{-1}

$\sigma_{BFPP} = 344 \times 10^{-27}$ cm^2

$\sigma_{EMD1} = 119 \times 10^{-27}$ cm^2

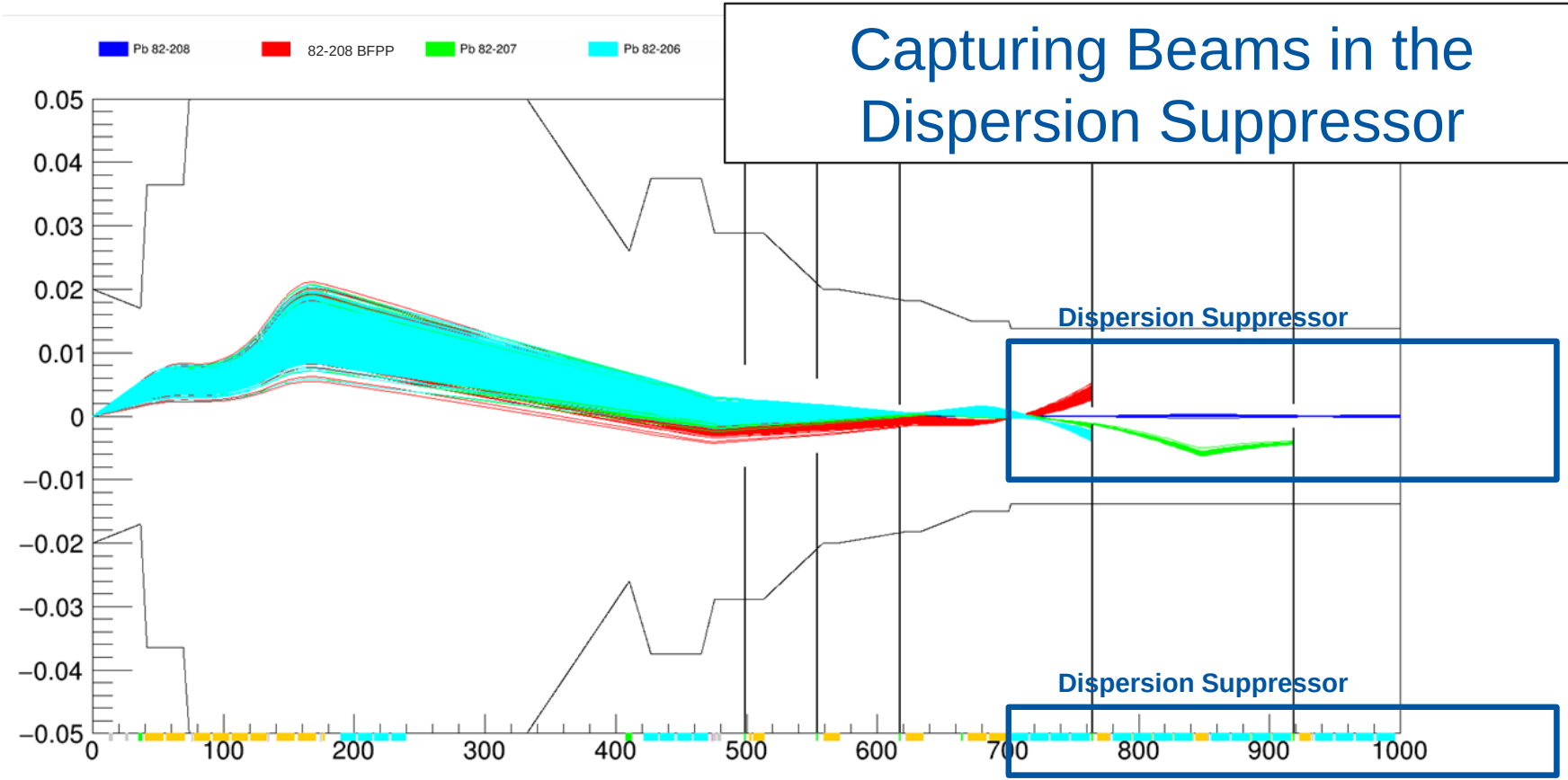
$\sigma_{EMD2} = 37 \times 10^{-27}$ cm^2

BFPP: 72 kW

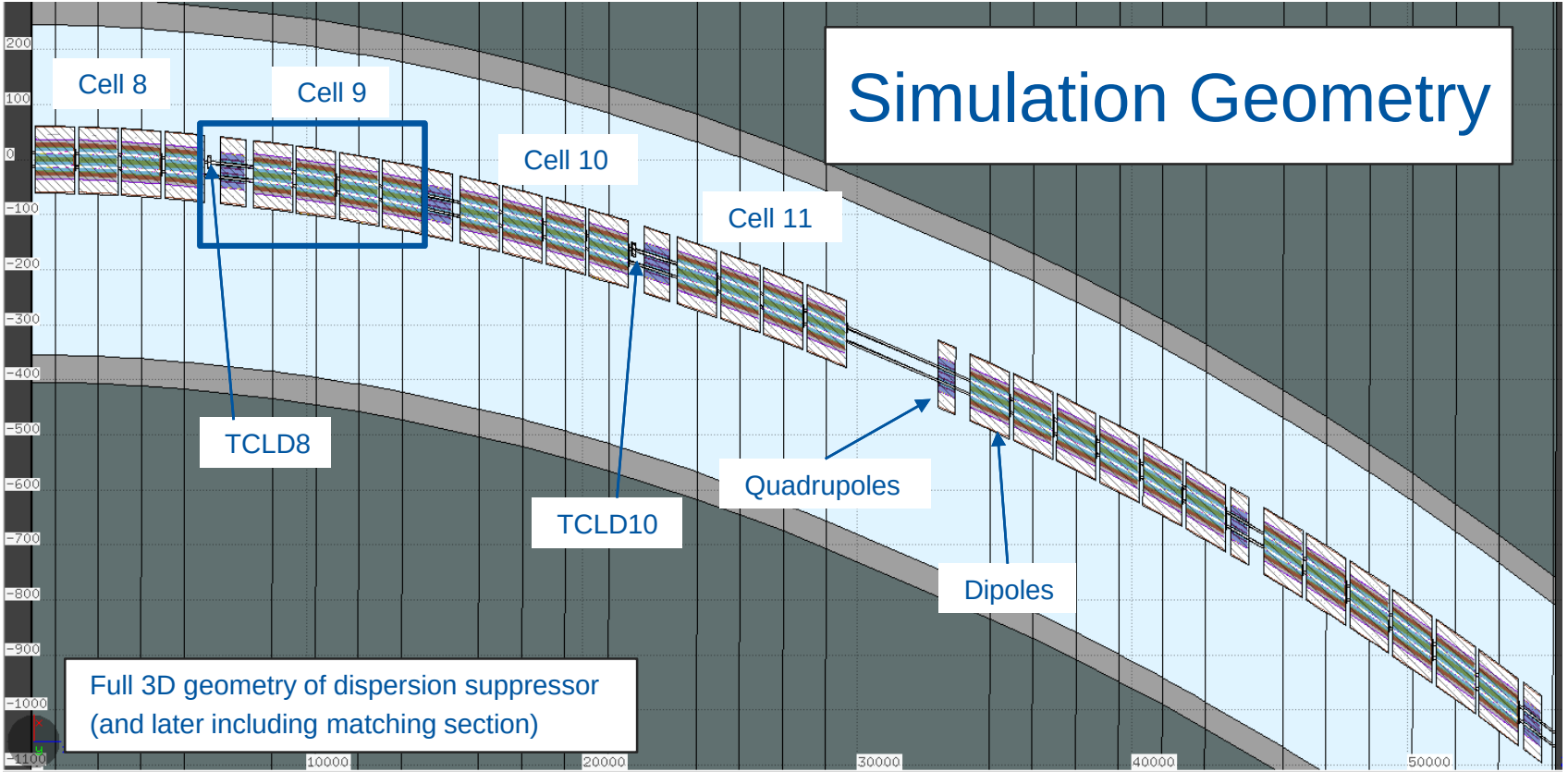
EMD1: 25 kW

EMD2: 7.7 kW

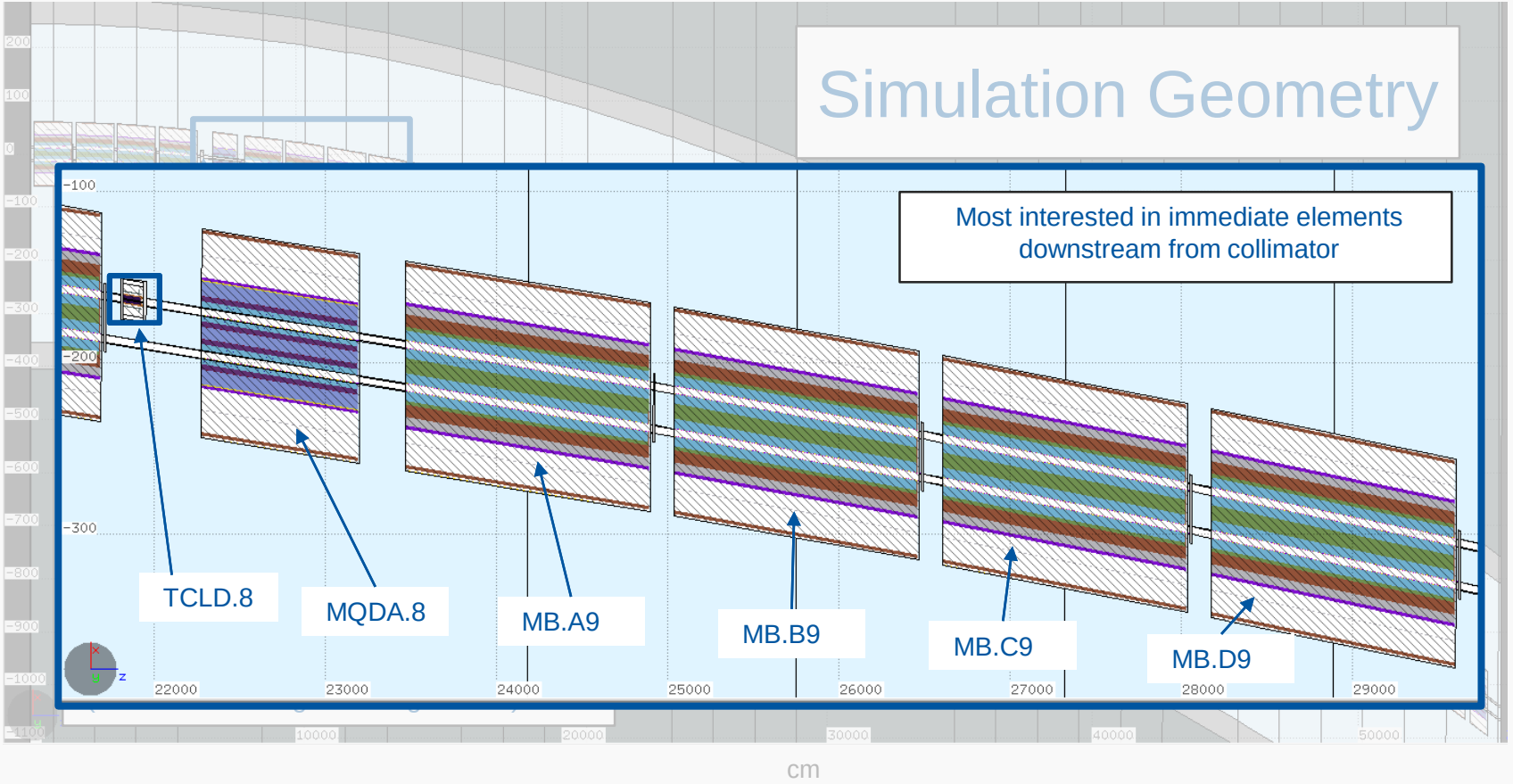
Capturing Beams in the Dispersion Suppressor



Simulation Geometry

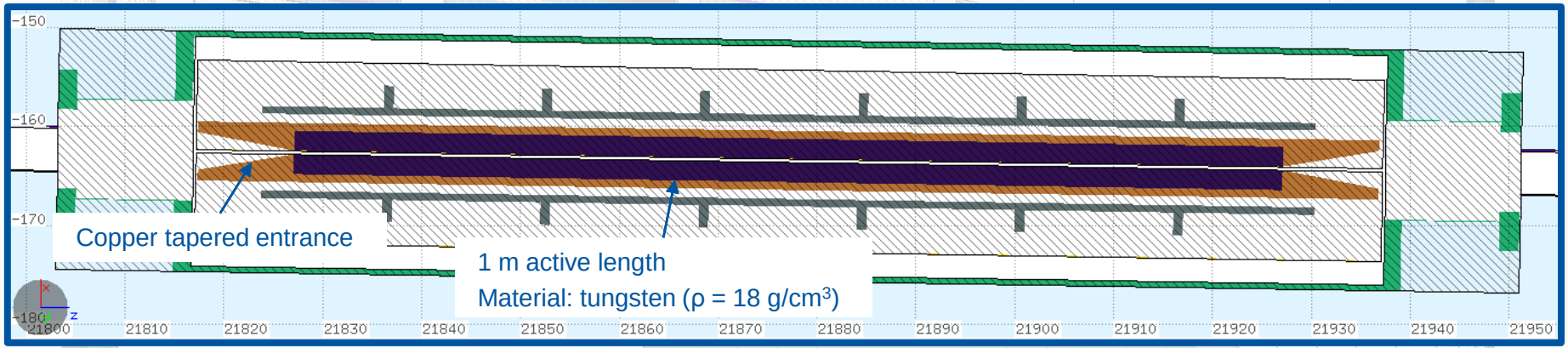


Simulation Geometry

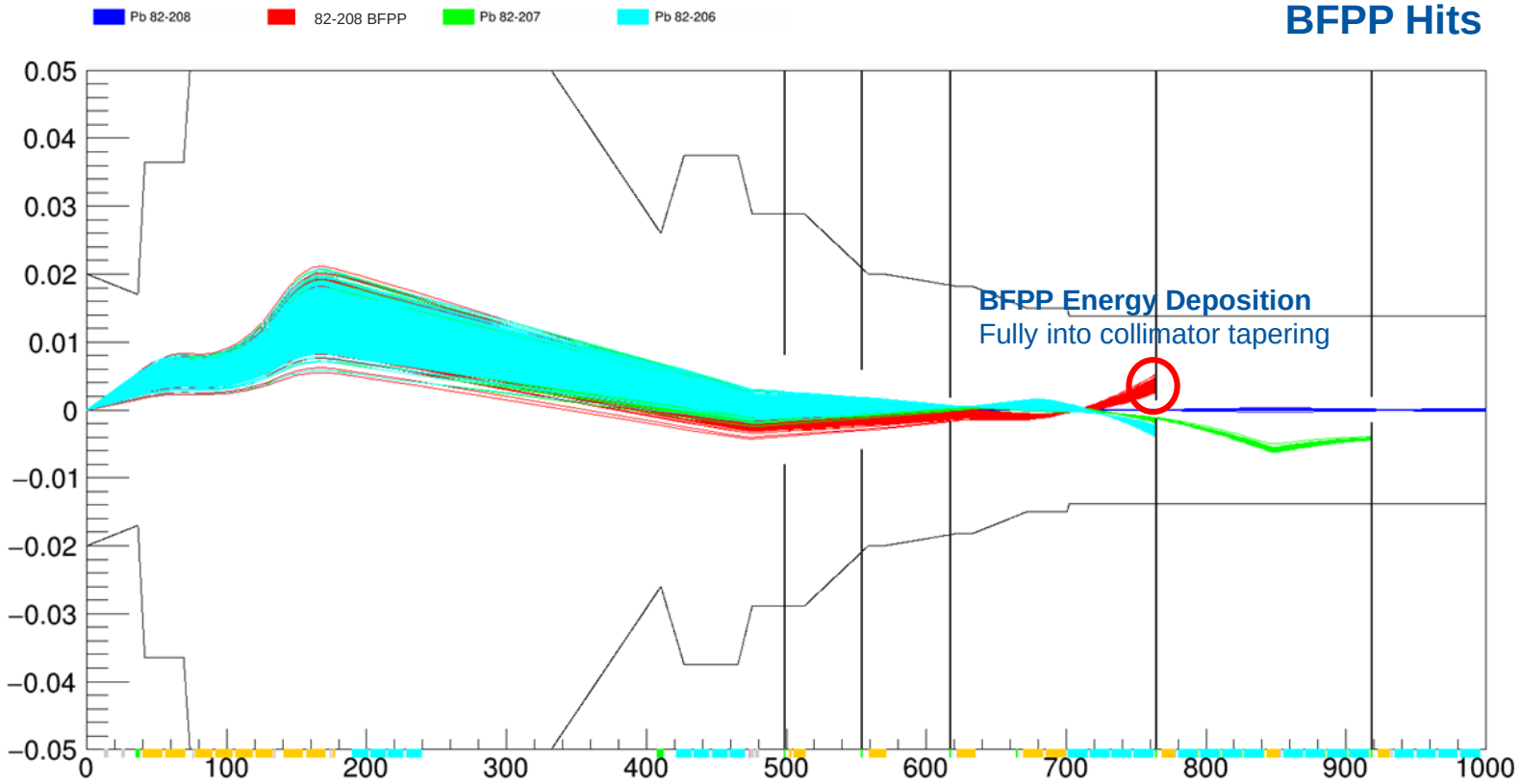


Simulation Geometry

Most interested in immediate elements downstream from collimator

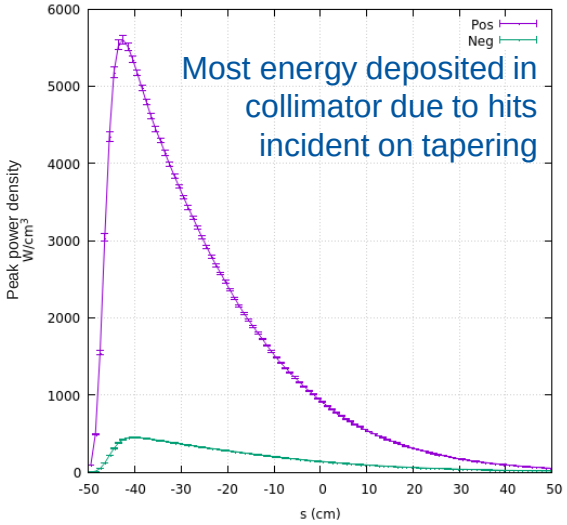


BFPP Hits


Pb 82-208
82-208 BFPP
Pb 82-207
Pb 82-206
0.05
0.04
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
−0.05
0
100
200
300
400
500
600
700
800
900
1000
BFPP Energy Deposition
Fully into collimator tapering

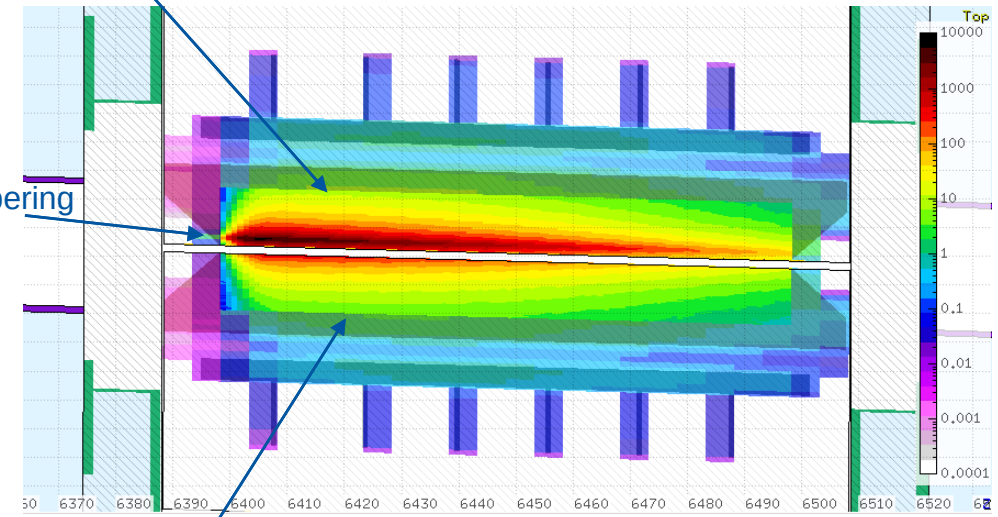
BFPP Results – Dispersion Supressor

Guide value 1 – 2 kW per jaw!



Outer jaw: 43 kW

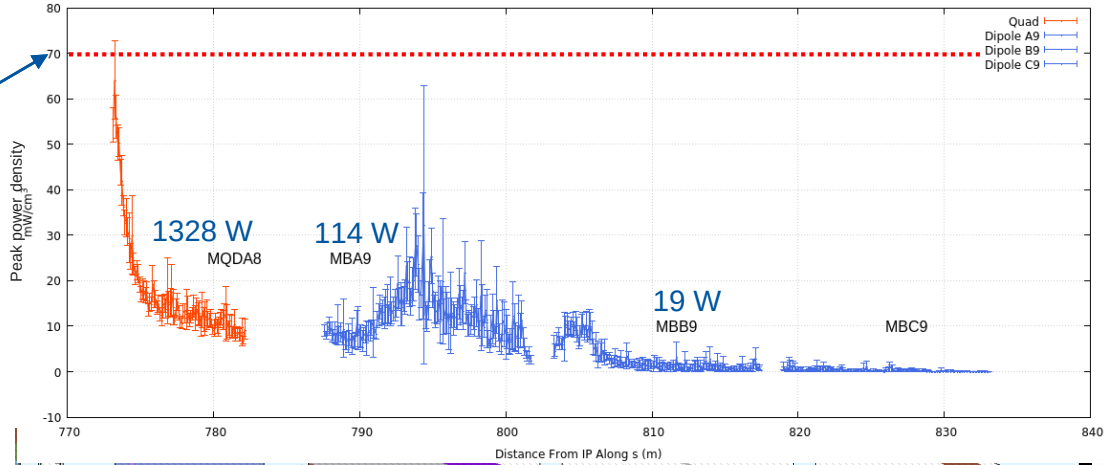
Impact on tapering

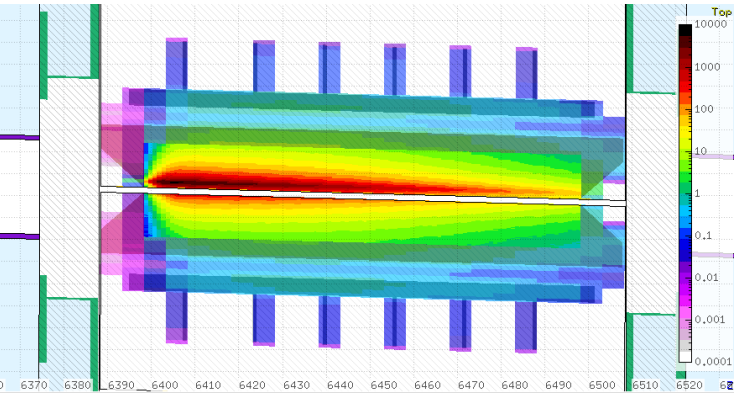


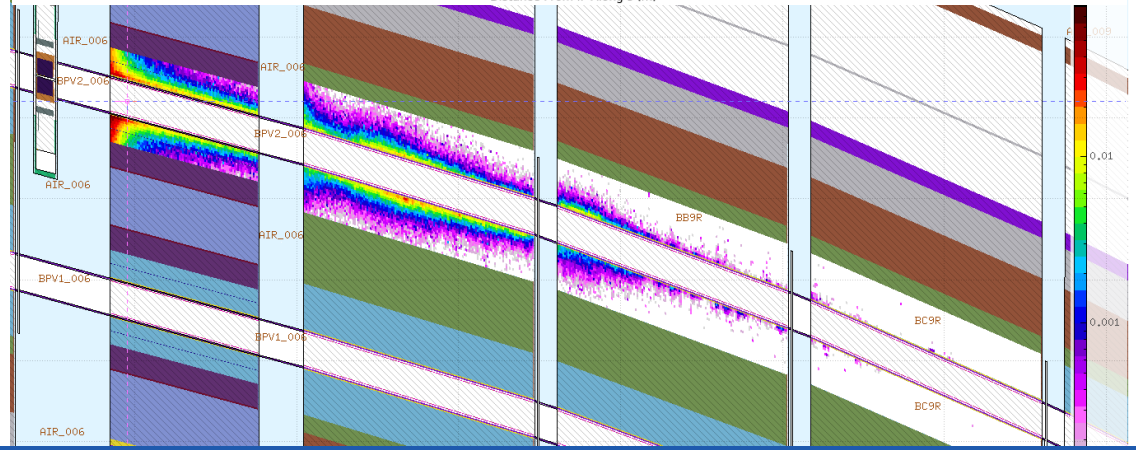
Inner Jaw: 11 kW

BFPP Results – magnetic coils

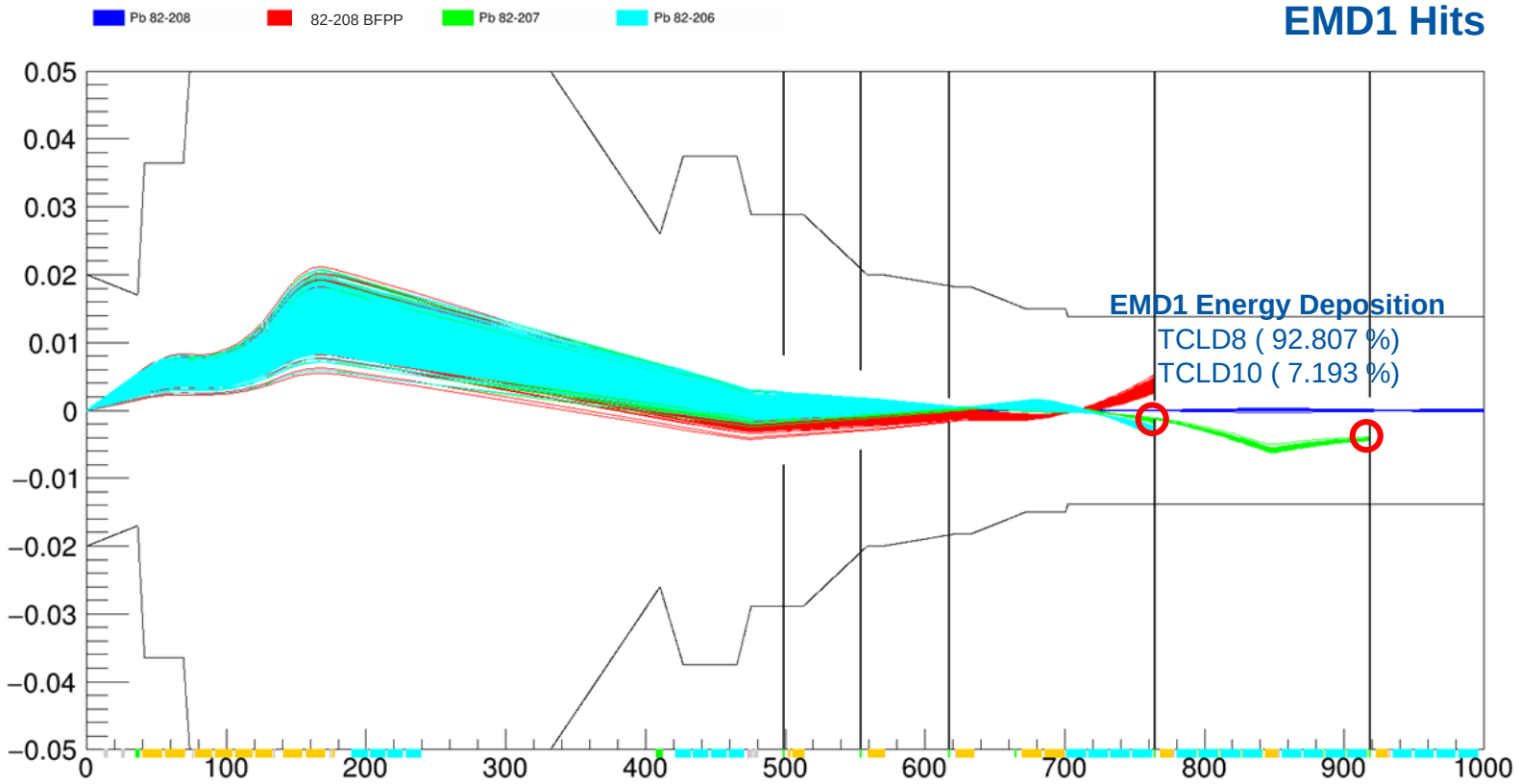
- Scoring on coils with 3 mm resolution
- Guide value for peak power density on coils:
  70 – 100 mW/cm^3
- Results for single beam







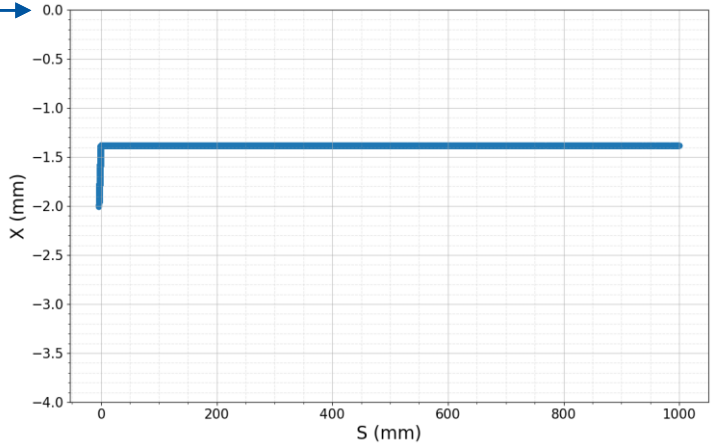
EMD1 Hits


Pb 82-208
82-208 BFPP
Pb 82-207
Pb 82-206
EMD1 Energy Deposition
TCLD8 (92.807 %)
TCLD10 (7.193 %)
0.05
0.04
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
−0.05
0
100
200
300
400
500
600
700
800
900
1000

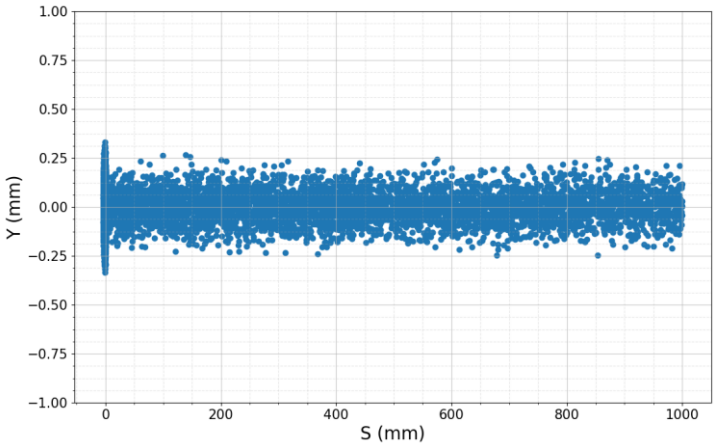
EMD1 Hits – TCLD.8

Primary beam, x = 0 mm

Top View



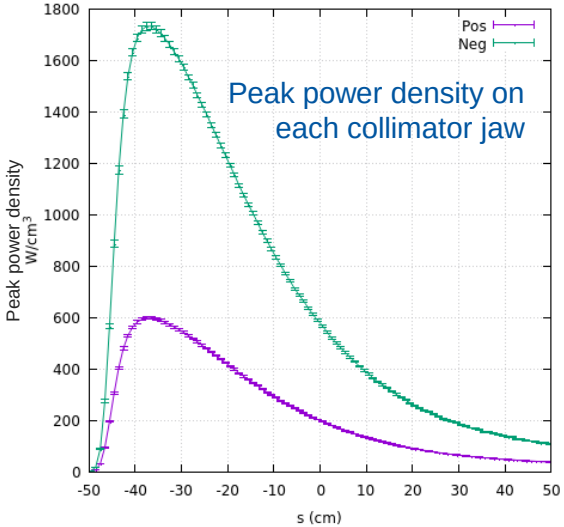
Side View

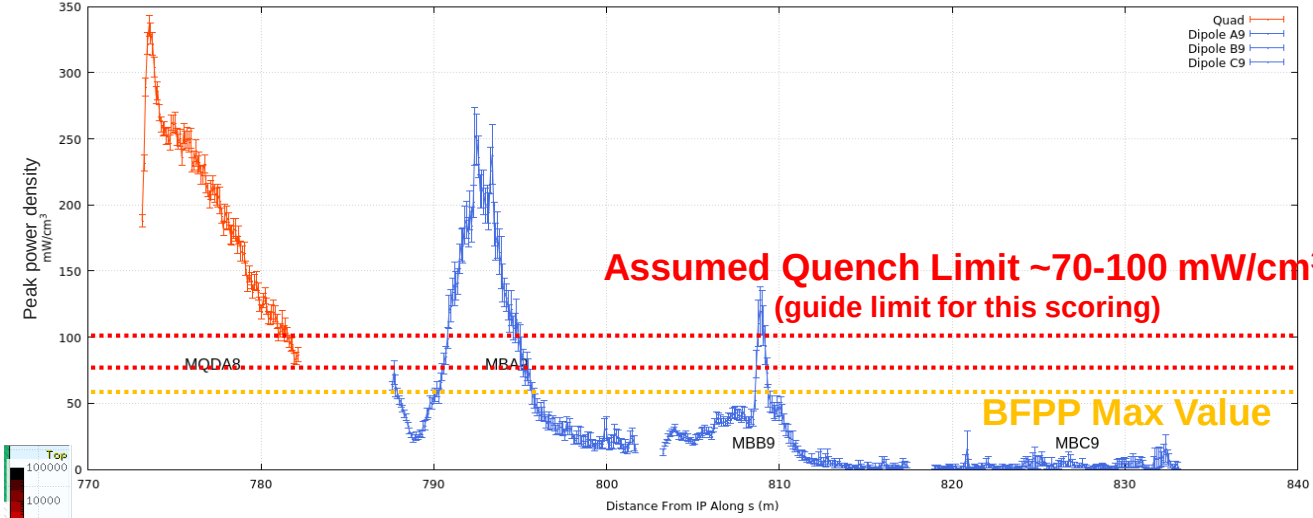


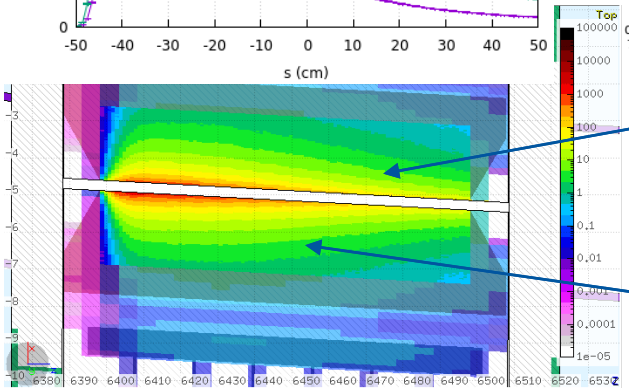
Beam is split, as a result hits are smeared across surface.

(~93% of beam on this collimator)

EMD1 Hits – TCLD.8





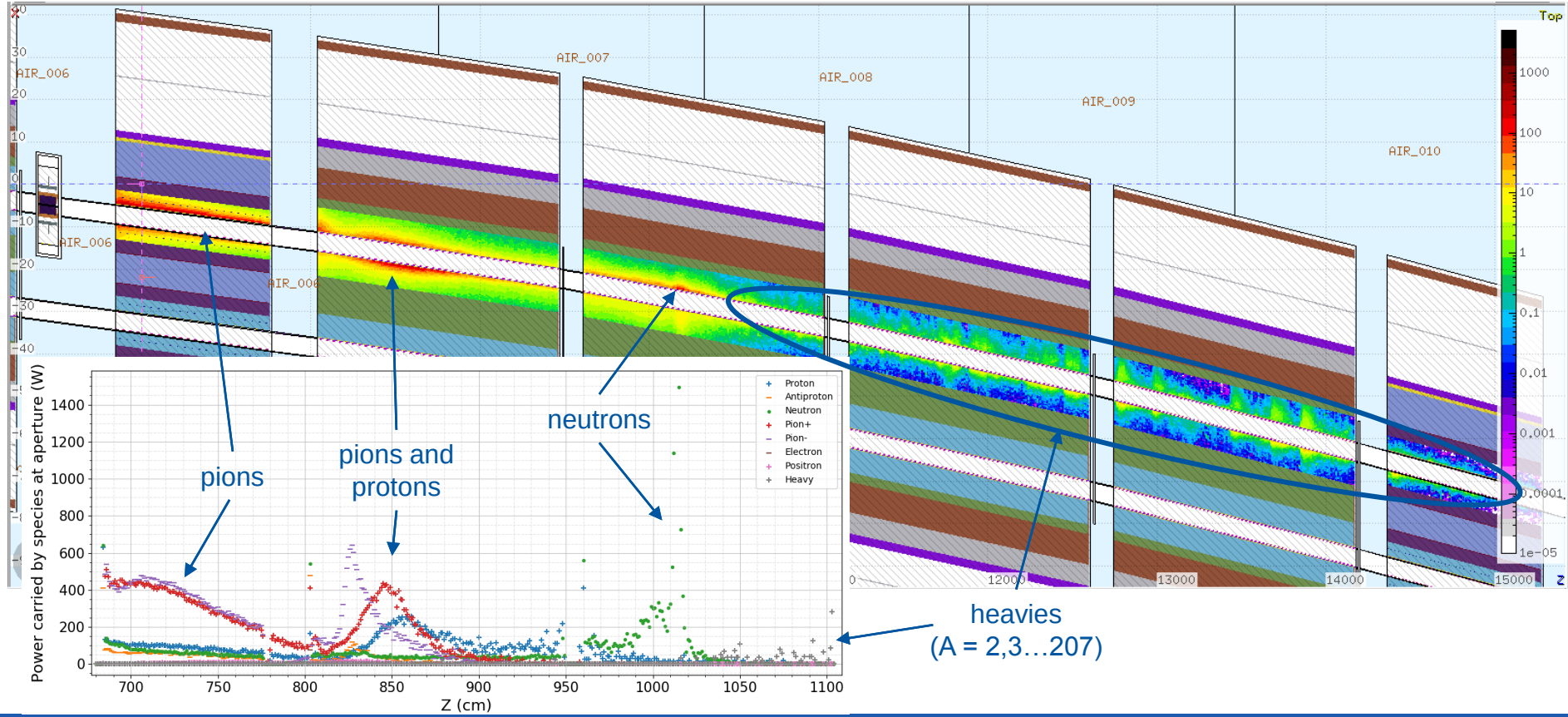


Outer jaw: 6.4 kW

Inner jaw: 8.4 kW

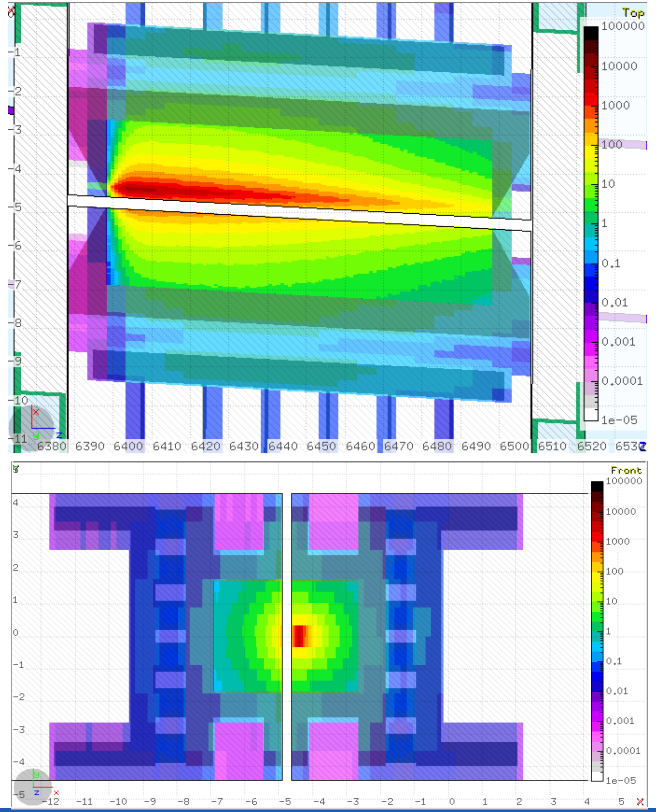
Slicing beam on collimator leads to much higher deposition downstream

EMD1 Hits – TCLD.8

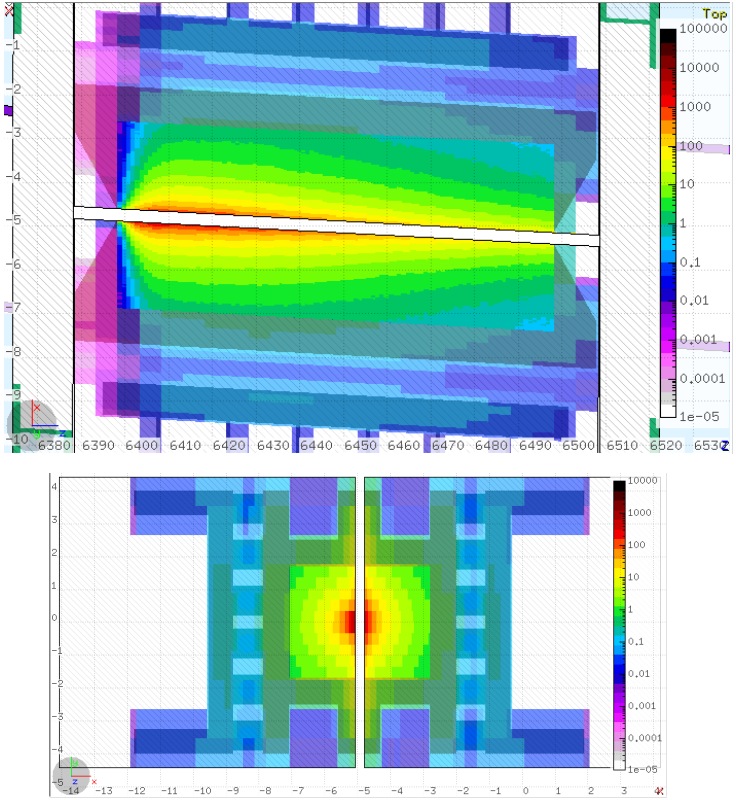


EMD1 BFPP Comparison – TCLD.8

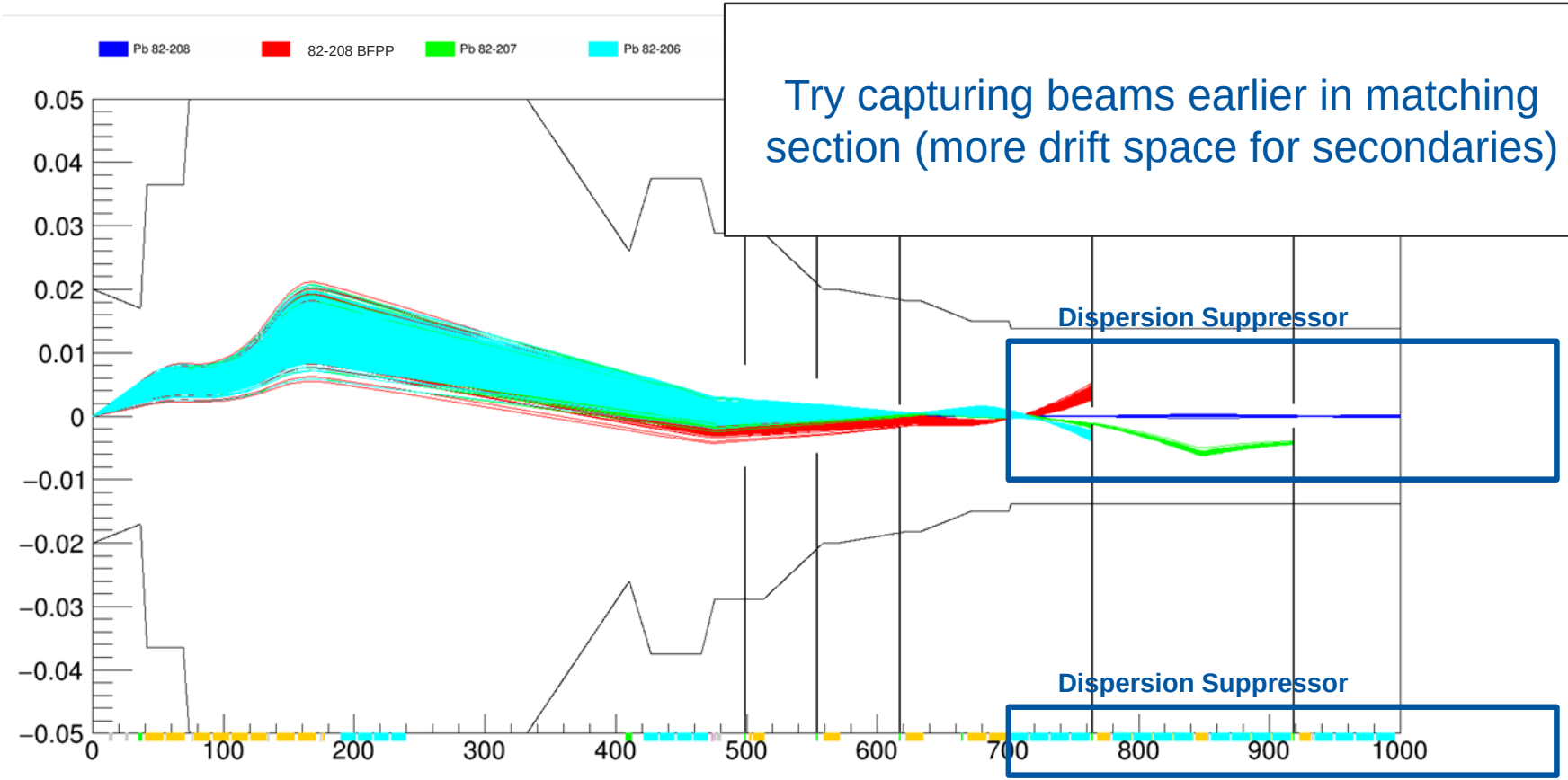
BFPP

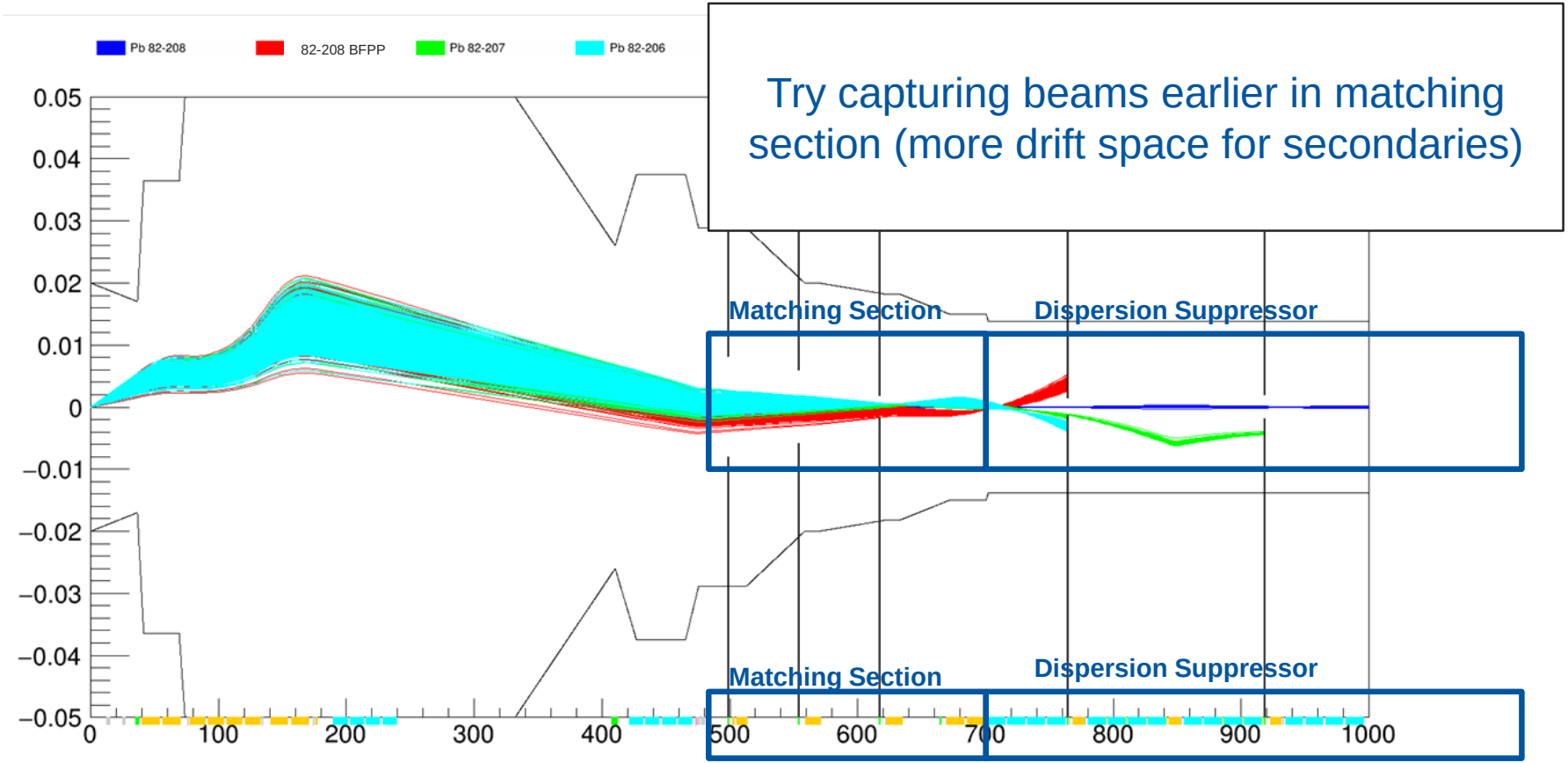


EMD1



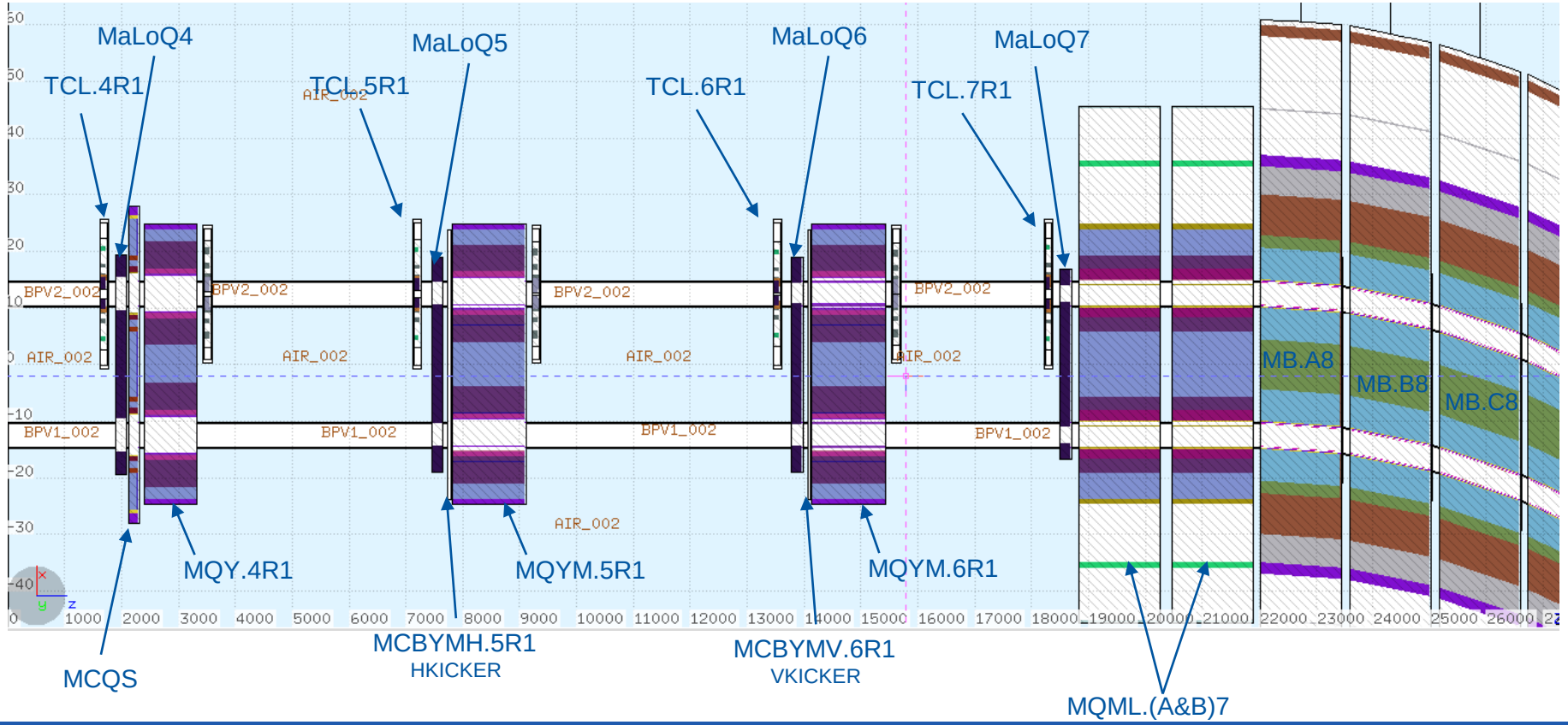
Try capturing beams earlier in matching section (more drift space for secondaries)



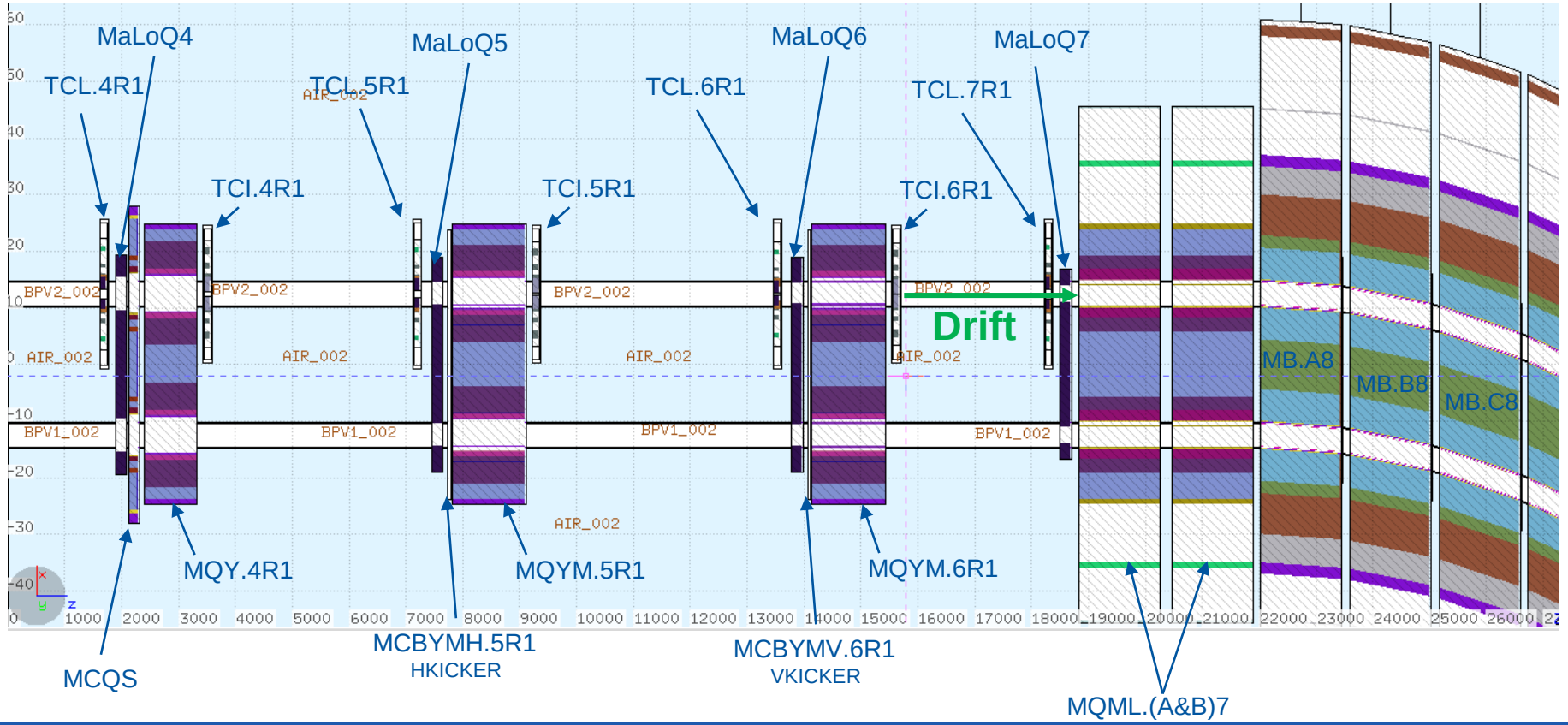


Try capturing beams earlier in matching section (more drift space for secondaries)

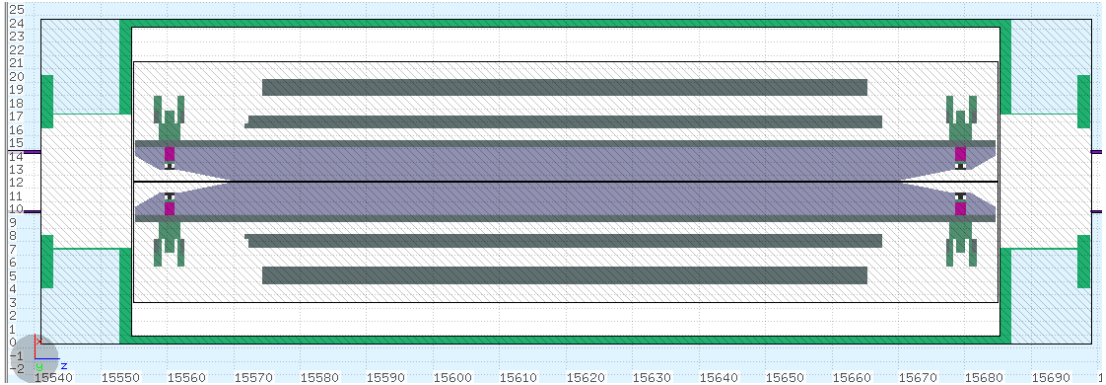
Adding new collimators before long drifts “TCl.4, TCl.5, TCl.6”



Adding new collimators before long drifts “TCl.4, TCl.5, TCl.6”



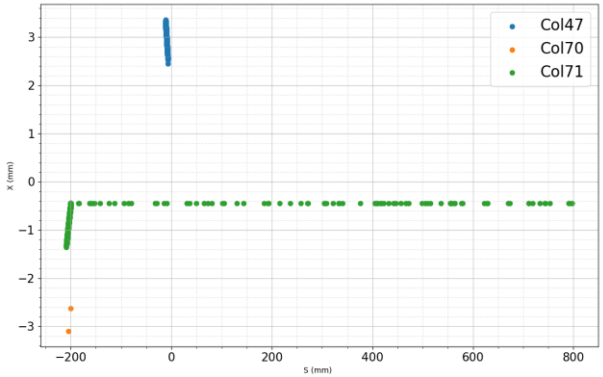
New collimator - TCI



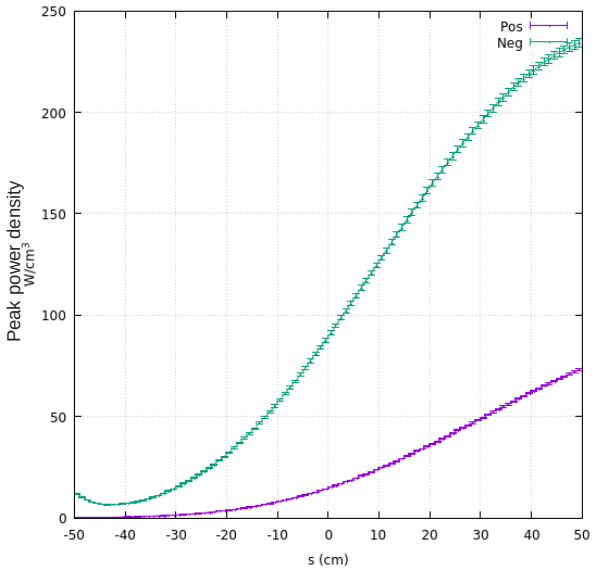
New “TCI” collimator

Active material:
Molybdenum graphite (MoGR)
$\rho = 2.55\ g/cm^3$

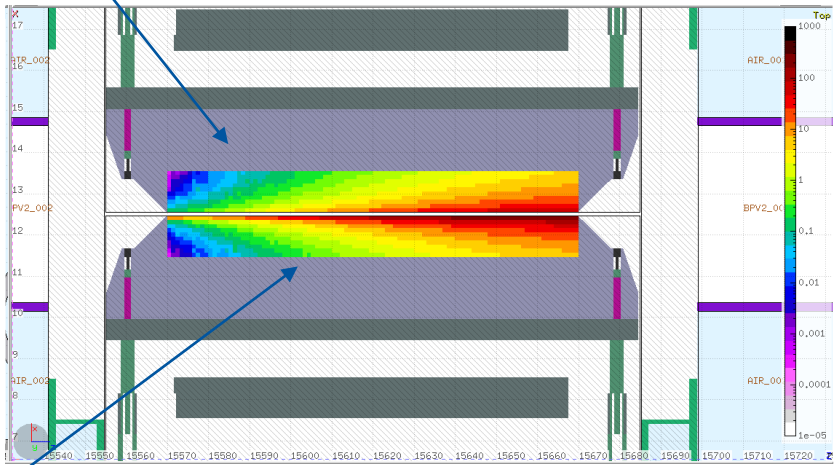
BFPP touches split between TCI.6 and TCLD.8



MoGR Power Load

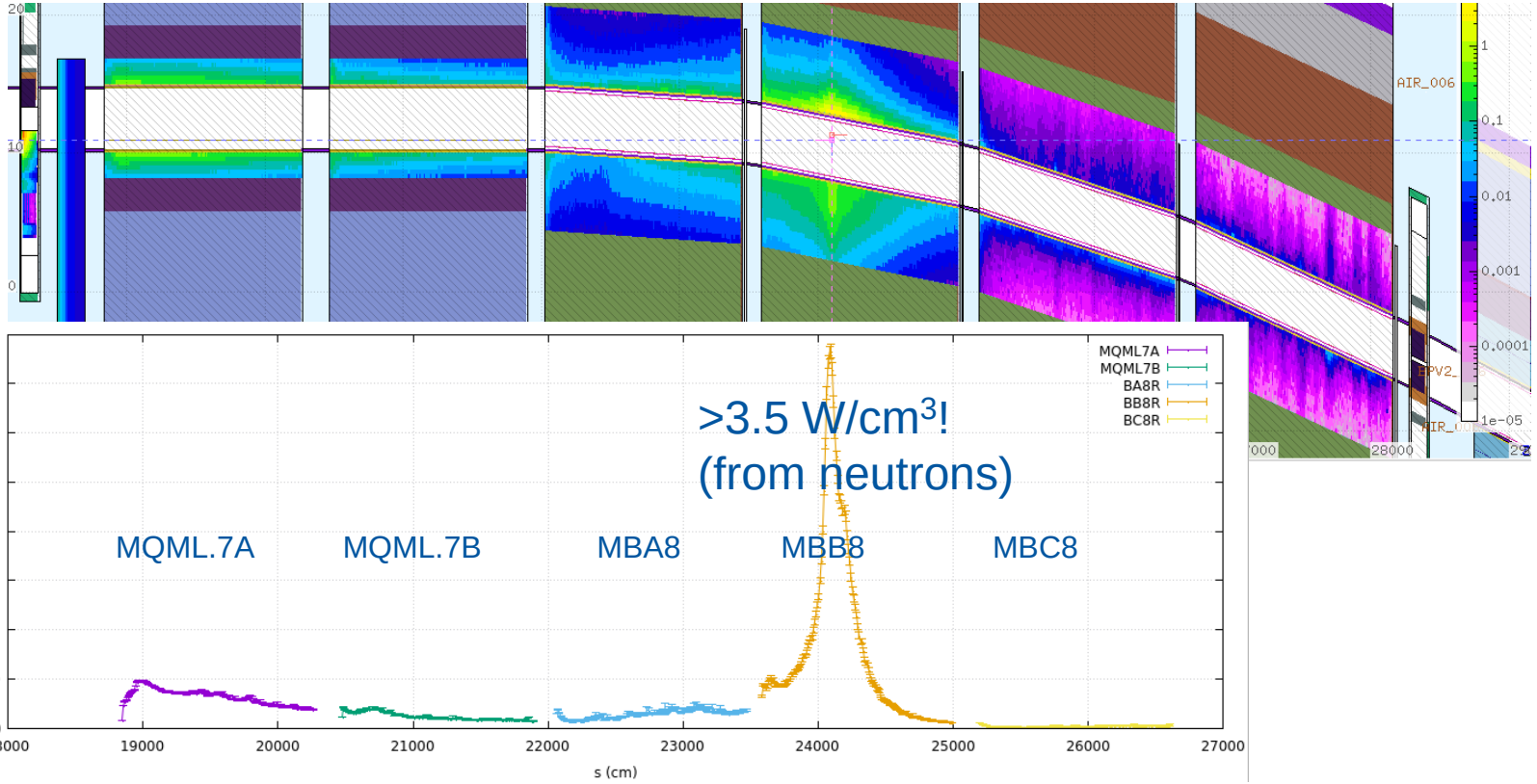


Outer Jaw: 2.2 kW

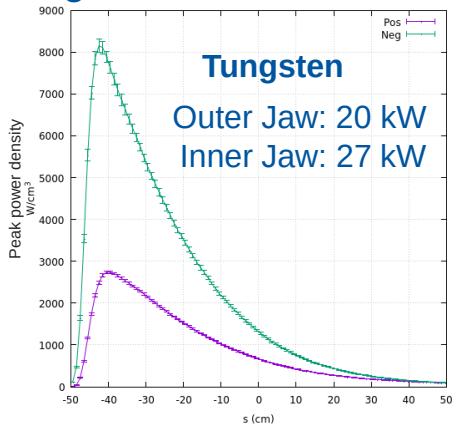


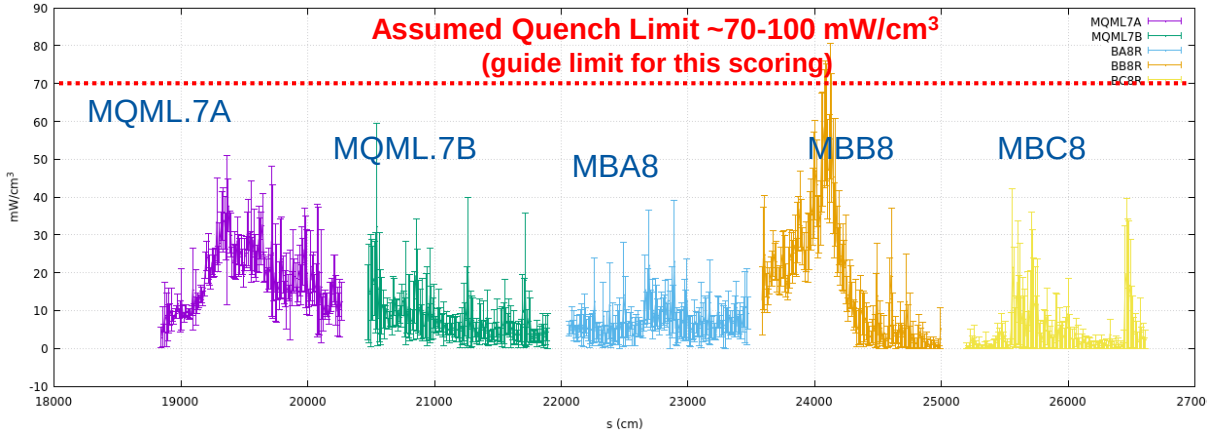
Inner Jaw: 3 kW

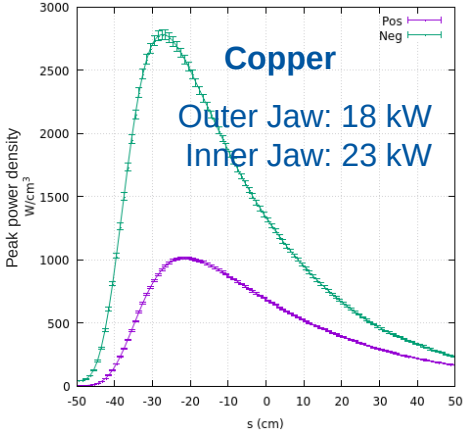
Peak power density in Coils (MoGR Matching Section Collimator)

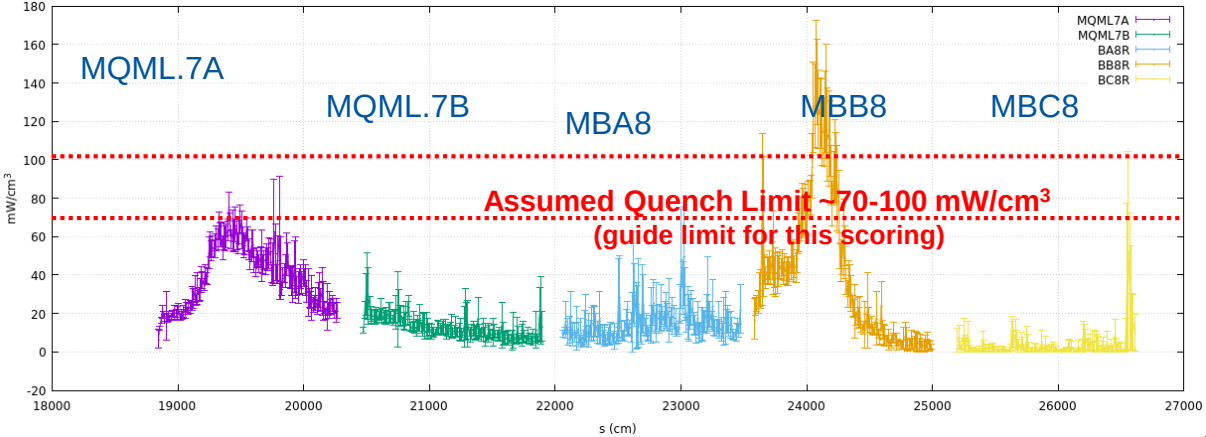


Matching Section Material Change



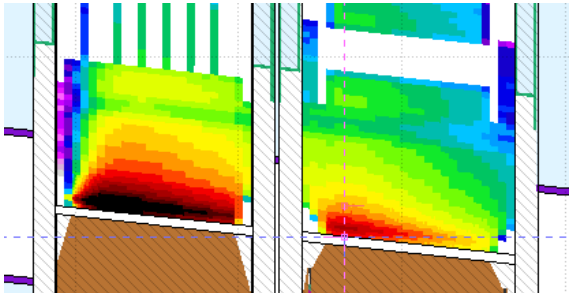


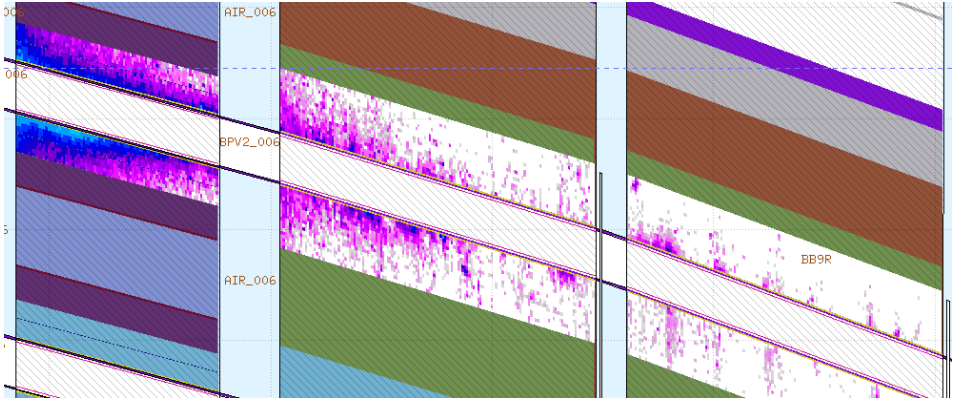


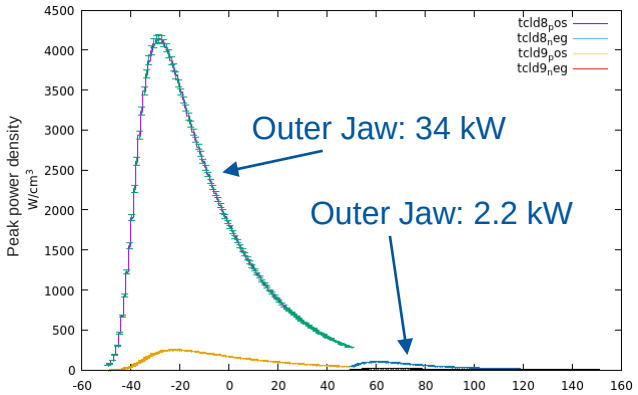


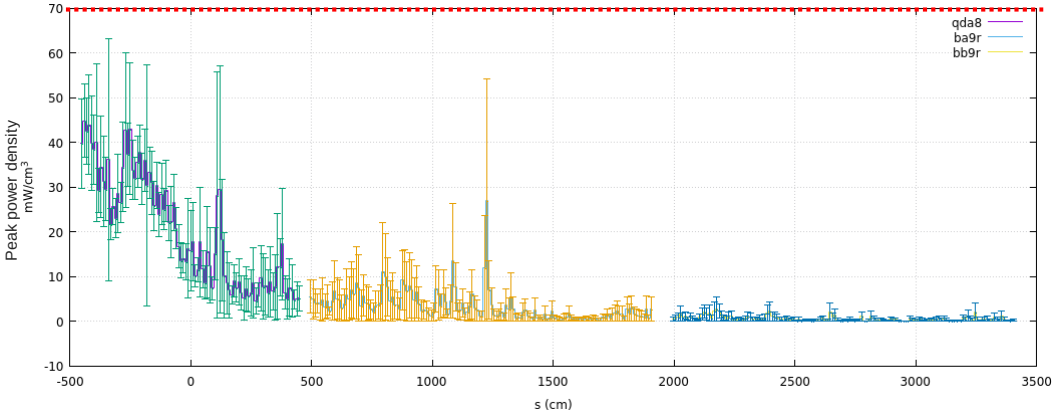
Back to DS…
2 collimators: Copper & Copper

Moving back to dispersion suppressor…
2 collimators, hits fully into tapering

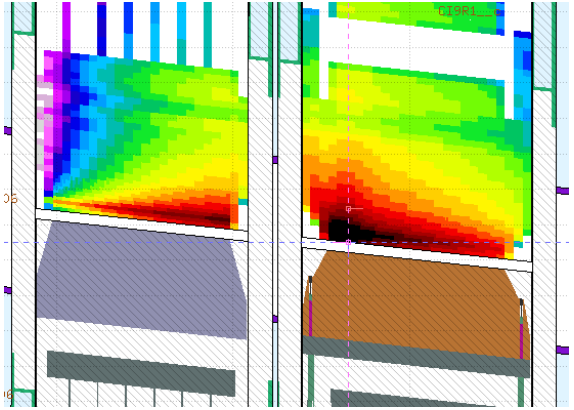


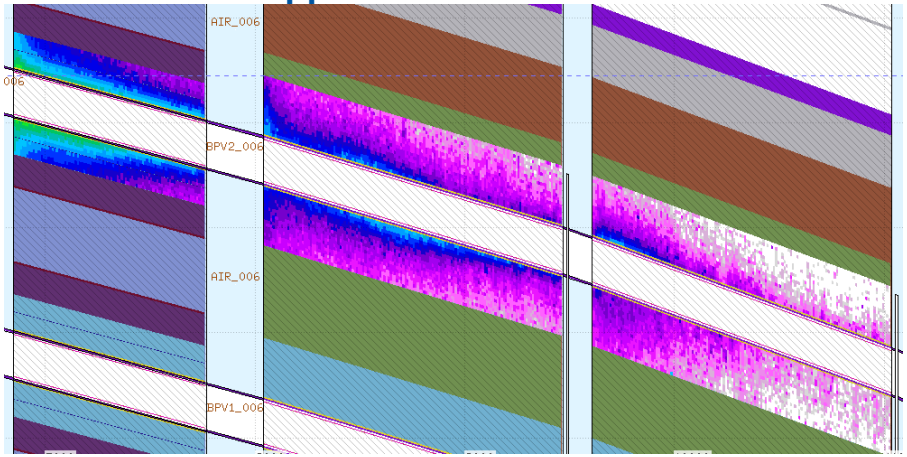


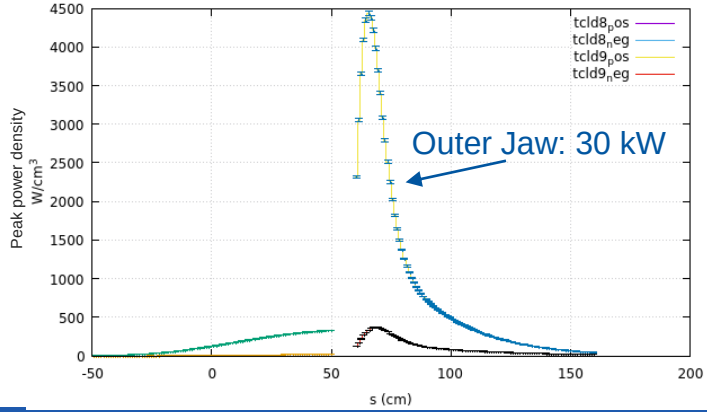


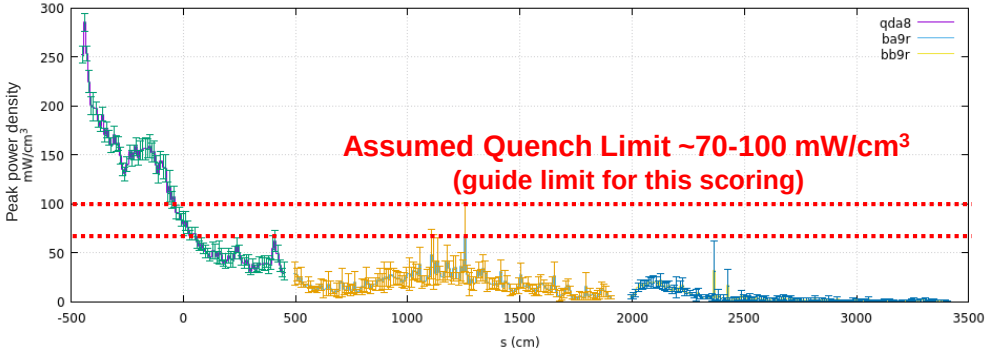


Back to DS…
2 collimators: MoGR and Copper

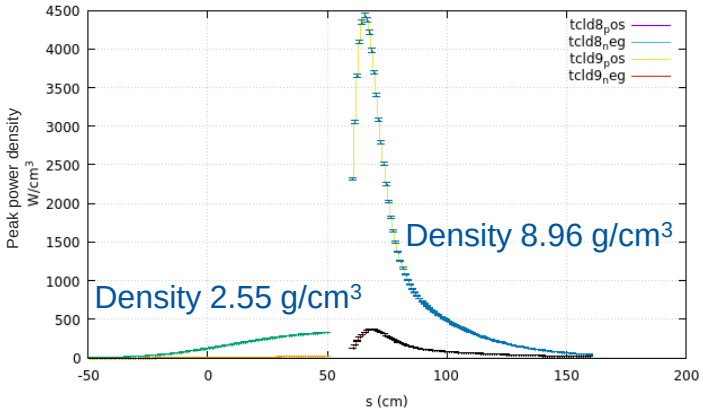








Outlook

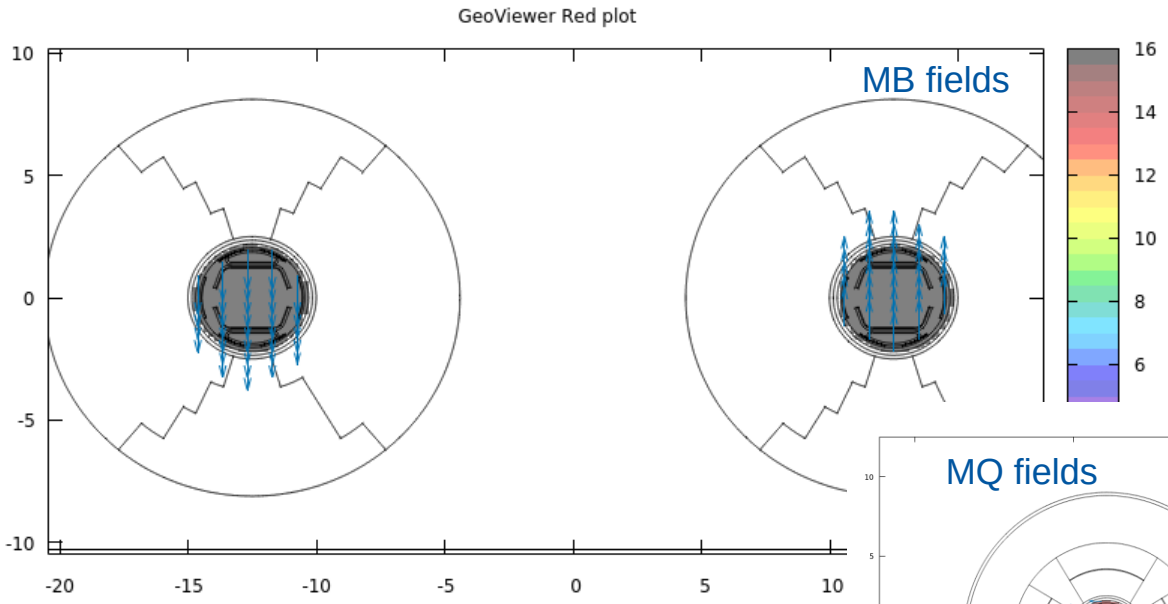


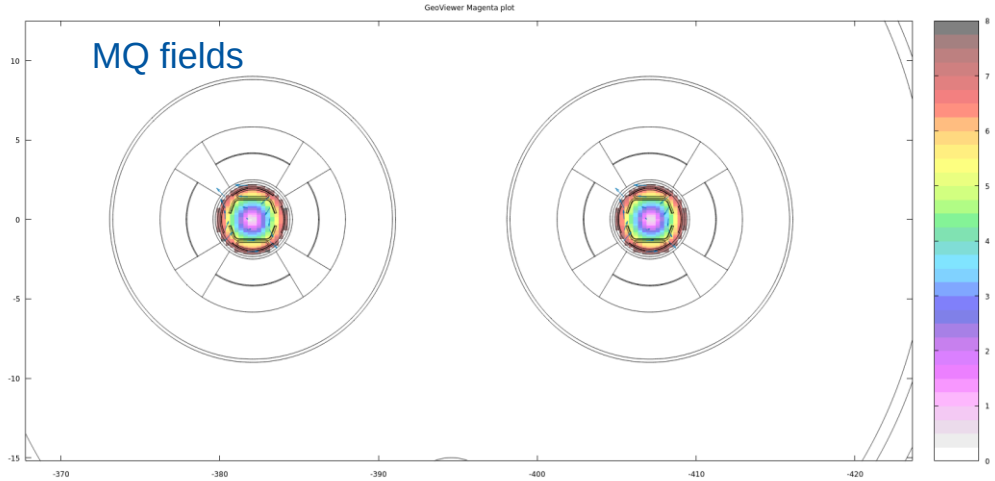
- Seems necessary to extend collimator length
- Combination of lower density material and higher density material?
  - Try Copper-Diamond

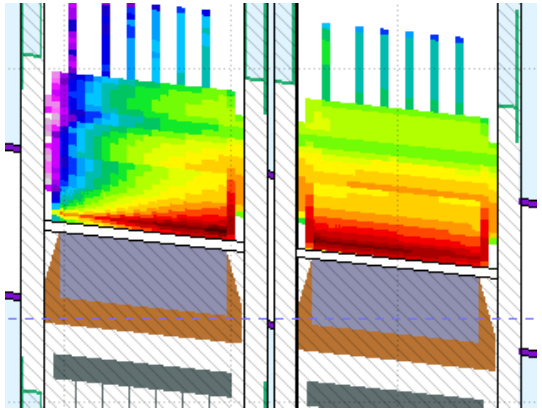
Density of Copper:	8.96 g/cm^3
Density of Copper-Diamond:	5.4 g/cm^3
Density of MoGR:	2.55 g/cm^3
Density of Tungsten:	18 g/cm^3

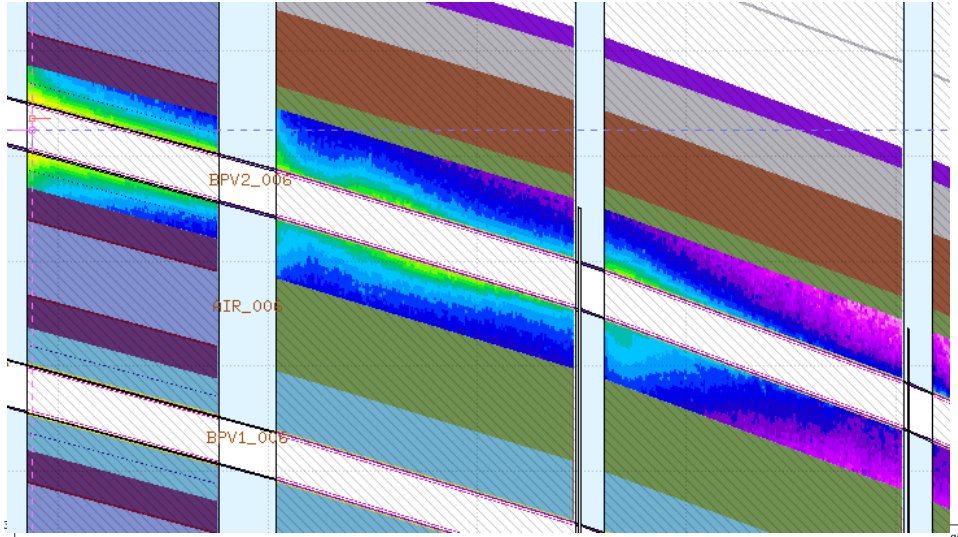
2 m + long collimator, 2 materials CuDiamond & Cu

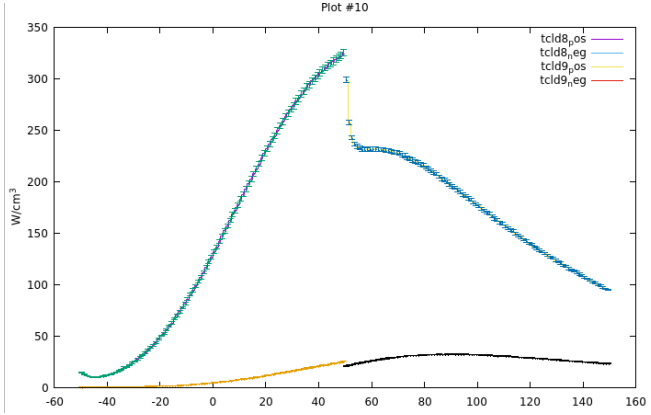
Thanks for listening

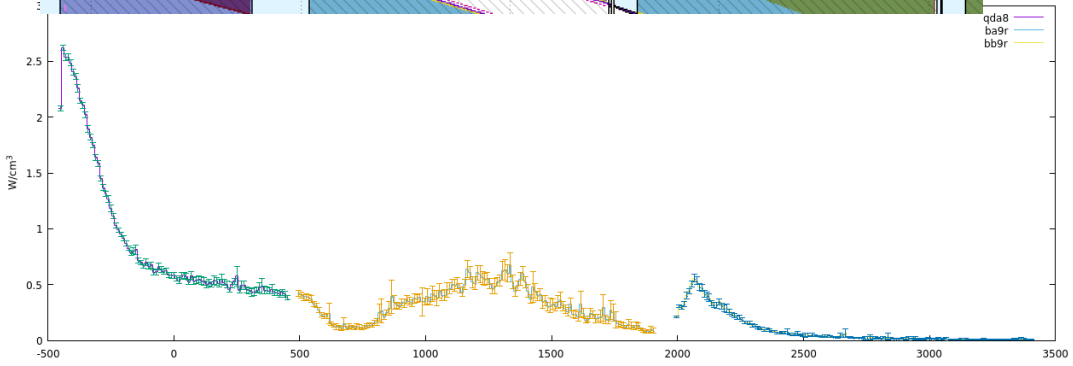

GeoViewer Red plot
MB fields
10
5
0
-5
-10
-20
-15
-10
-5
0
5
10
16
14
12
10
8
6


GeoViewer Magenta plot
MQ fields
-370
-380
-390
-400
-410
-420




BPV2_006
AIR_006
BPV1_006


Plot #10
tcld8_pos
tcld8_neg
tcld9_pos
tcld9_neg
W/cm³
350
300
250
200
150
100
50
0
-60
-40
-20
0
20
40
60
80
100
120
140
160


qda8
ba9r
bb9r
W/cm³
2.5
2
1.5
1
0.5
0
-500
0
500
1000
1500
2000
2500
3000
3500