Energy deposition for HL-LHC v1.1: TAN/D2/Q4

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Acknowledgements: G. Arduini, R. Bruce, P. Fessia, M. Giovannozzi, R. De Maria, S. Redaelli

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Content

- IR5/IR1 after LS3
  - Energy deposition on D2/Q4/crab cavities
  - Mask effectiveness and integration issues
  - Large jaw TCL4 collimator
  - TAXN length and materials
  - Sensitivity to crossing angle, optics scheme and collimator aperture
- IR8 after LS2
  - Energy deposition on D2 and additional absorbers

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- Layout HL-LHC V1.1
- Horizontal crossing
- Collimator opening set to 10 σ for ε=2.5 μm
  →for sake of clarity, apertures are then given both in σ (for ε=3.5 μm) and mm
- New results are now normalised to
  - luminosity of 7.5×10^{34} cm^{-2} s^{-1}
  - integrated luminosity of 4000 fb^{-1}

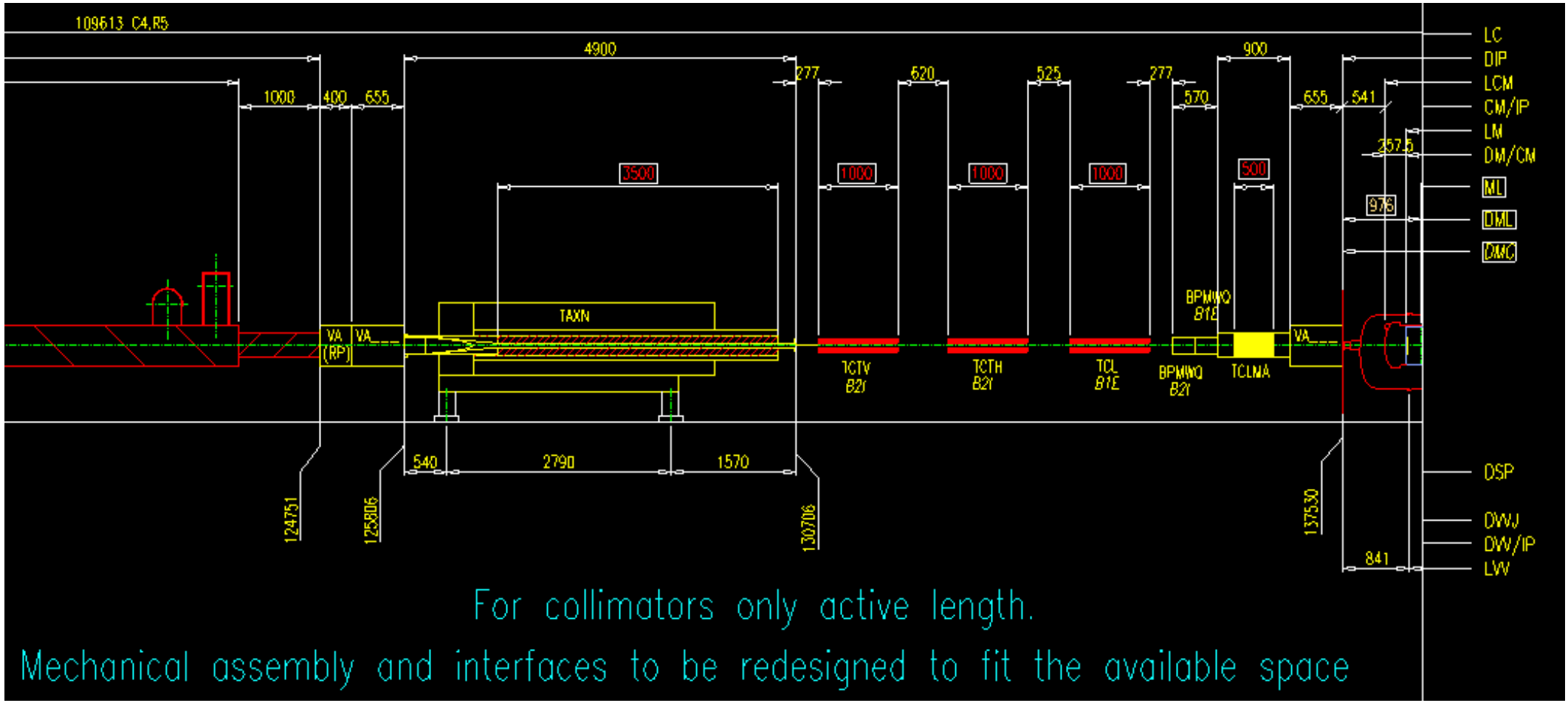
- IR8 after LS2
  - Energy deposition on D2 and additional absorbers

- Nominal LHC optics with 385 μrad horizontal half-crossing angle
- luminosity of 2×10^{33} cm^{-2} s^{-1}
- integrated luminosity of 50 fb^{-1}

TAXN-Q4 region in HL-LHC

HL-LHCV1.1 layout from TAXN to D2

snapshot form drawing LHCLSXH_0010_1



Q5/Q6 protection implies a pair of a TCL and a mask each

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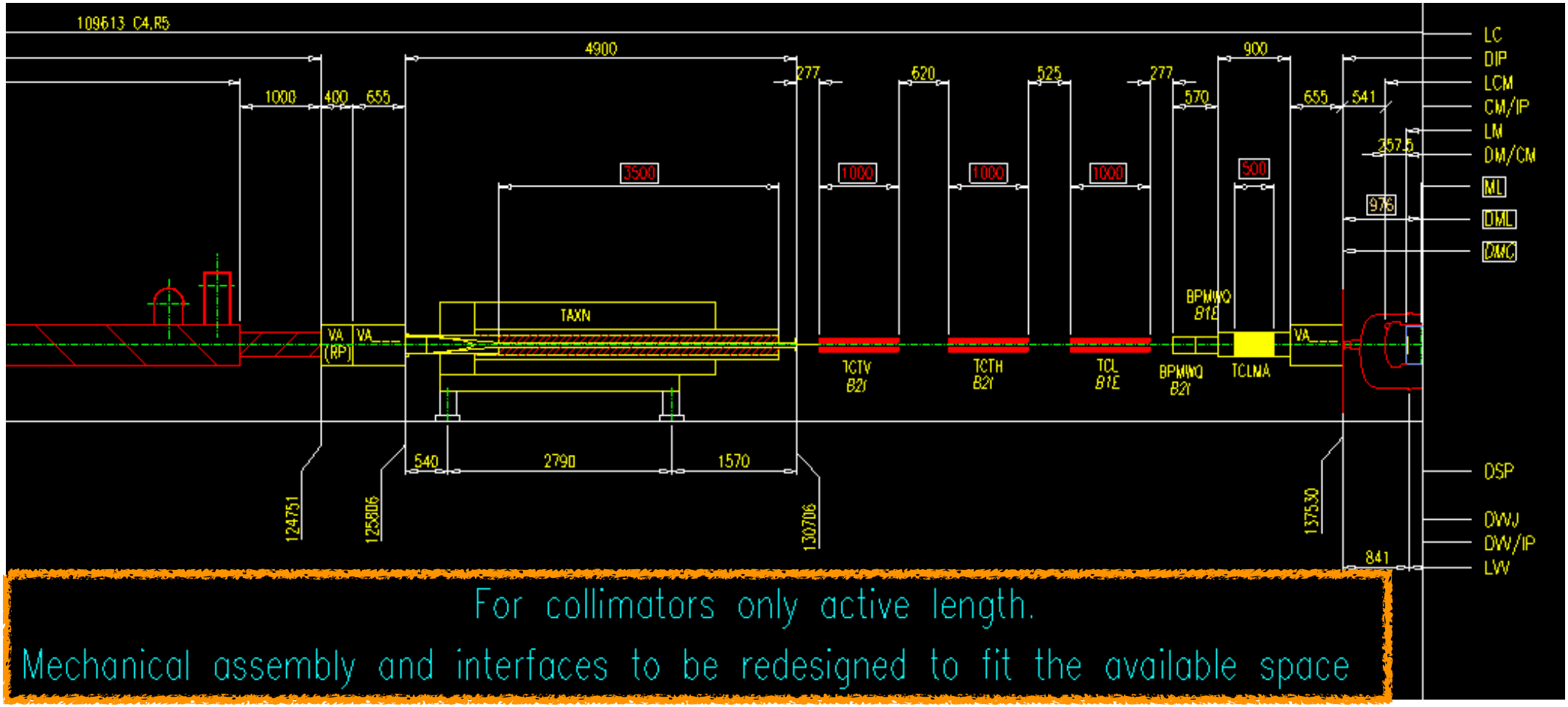

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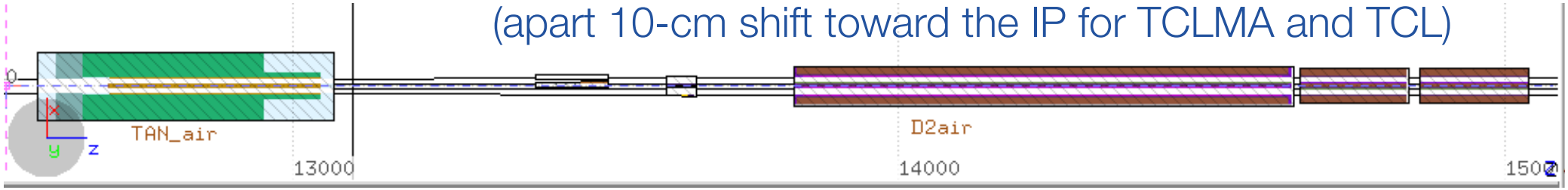
From HL-LHCV1.0 to HL-LHCV1.1

model according to the layout in the previous page

(apart 10-cm shift toward the IP for TCLMA and TCL)



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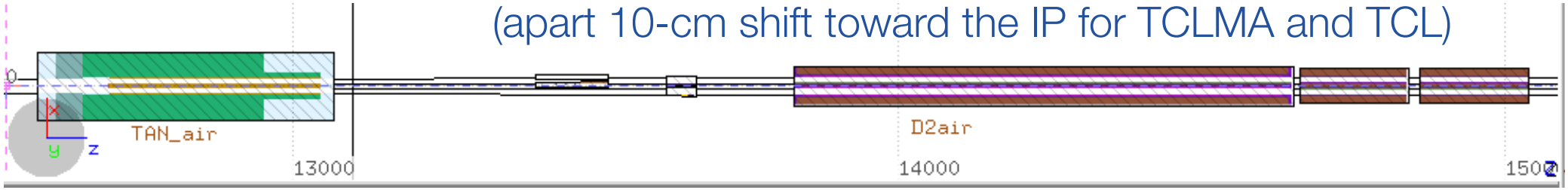

	HL-LHCV1.0 (last simulation Jan 2014)	HL-LHCV1.1
TAXN effective length [m]	3.7	**3.5**
TAXN beam separation [mm]	148mm@IP-side 158.6mm@non-IP-side	**149mm@IP-side** **159mm@non-IP-side**
TAXN aperture radius [mm]	38	**40**
distance TCL/TCLMA from D2	2.88/1.63 m	**3.38/1.83 m**

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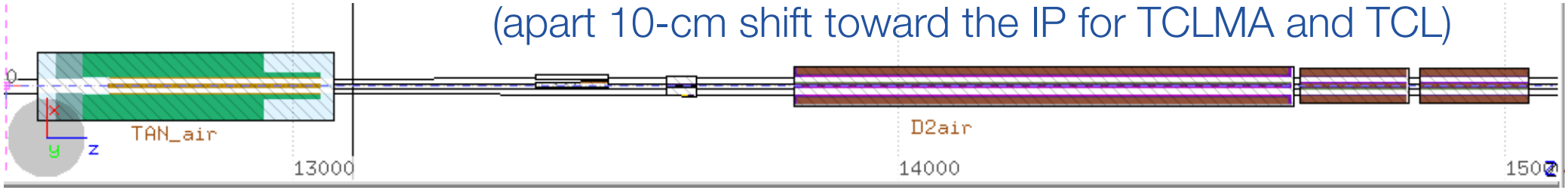

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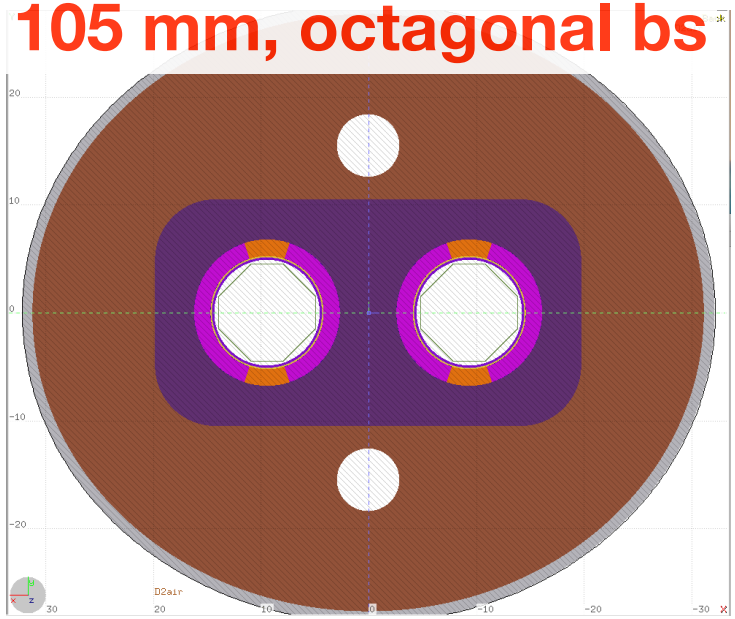
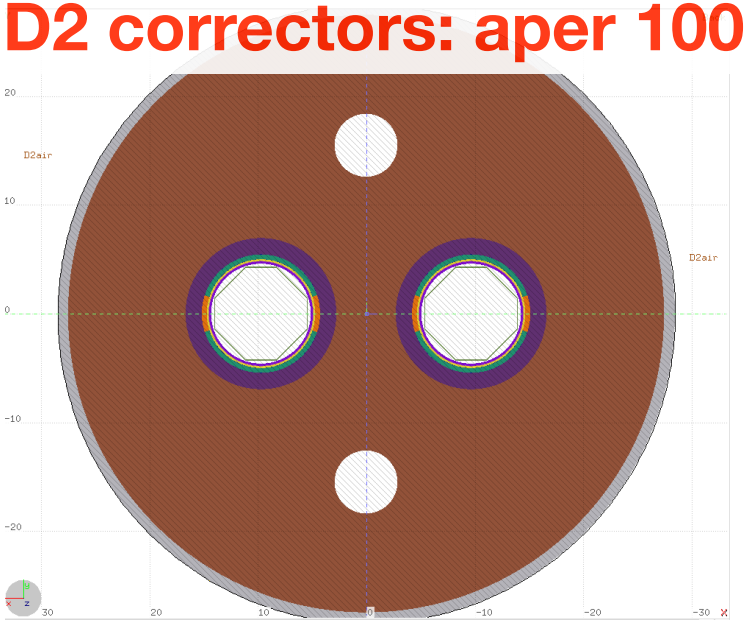
max angle covered by TAXN is (beam_sep/2 - pipe_aperture)/s_TAXN =
(149 mm/2 - 40 mm)/127 m ~ **270 µrad**,
whereas half x-ang = 295 (270) µrad for nominal round (flat) optics

Geometry updates

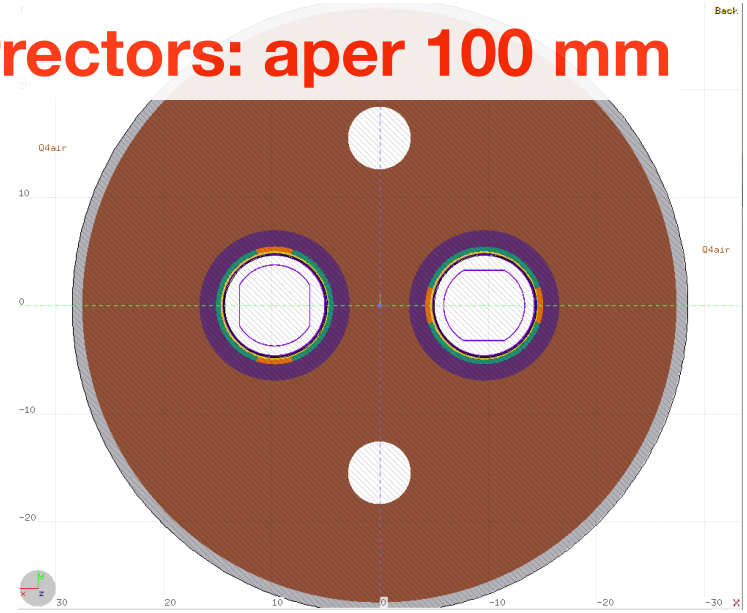
D2: aper 105 mm, octagonal bs



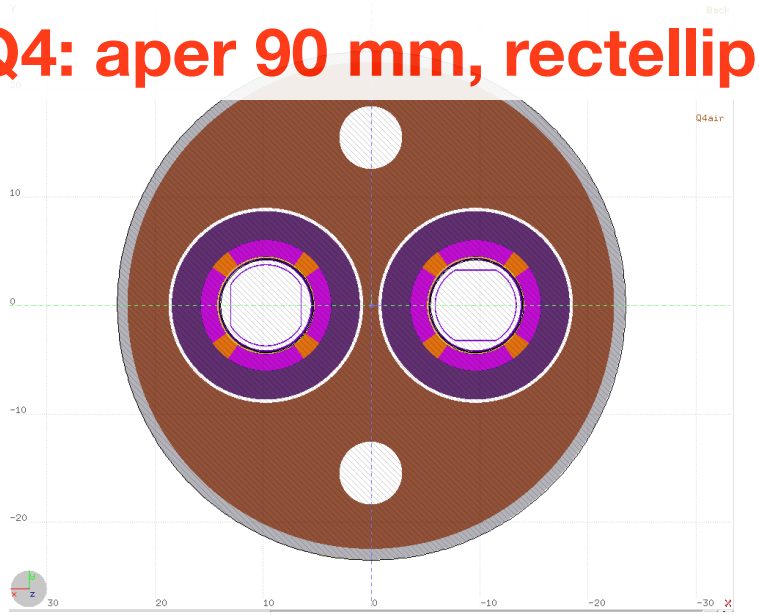
D2 correctors: aper 100 mm



Q4 correctors: aper 100 mm



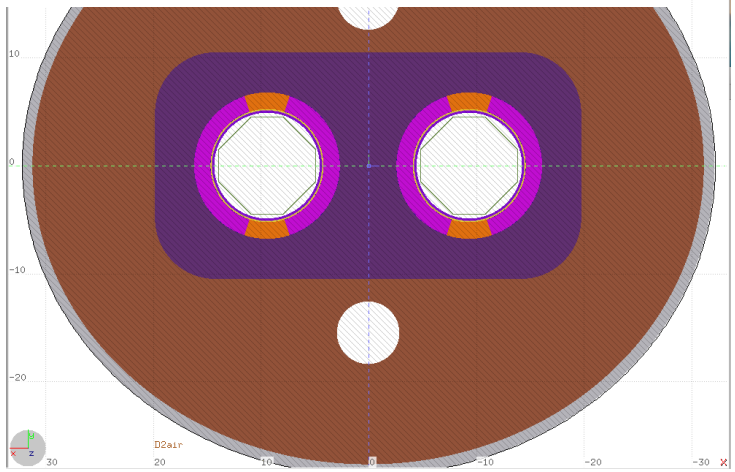
Q4: aper 90 mm, rectellipse bs



Geometry updates

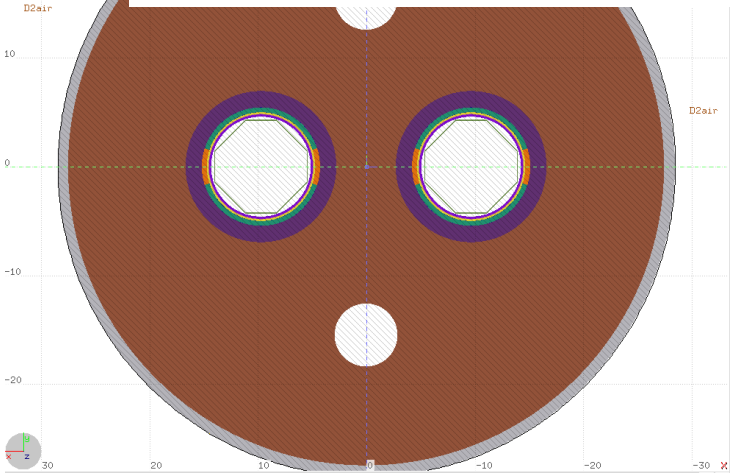
D2: aper 105 mm, octagonal bs

Before: aper 100 mm, rectellipse bs



D2 correctors: aper 100 mm

Before: same aper of D2



Q4 correctors: aper 100 mm

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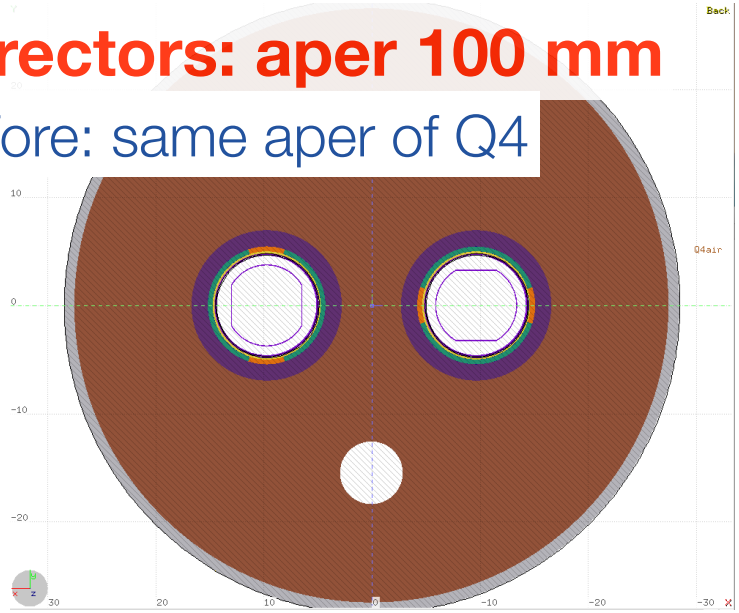

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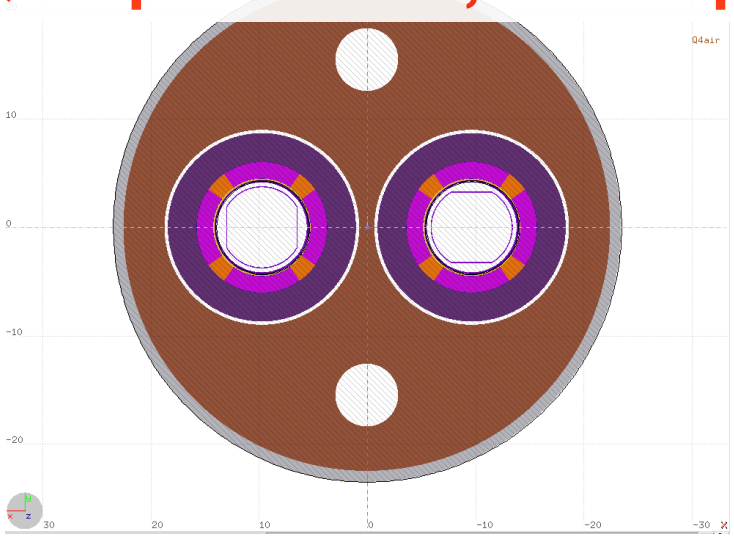
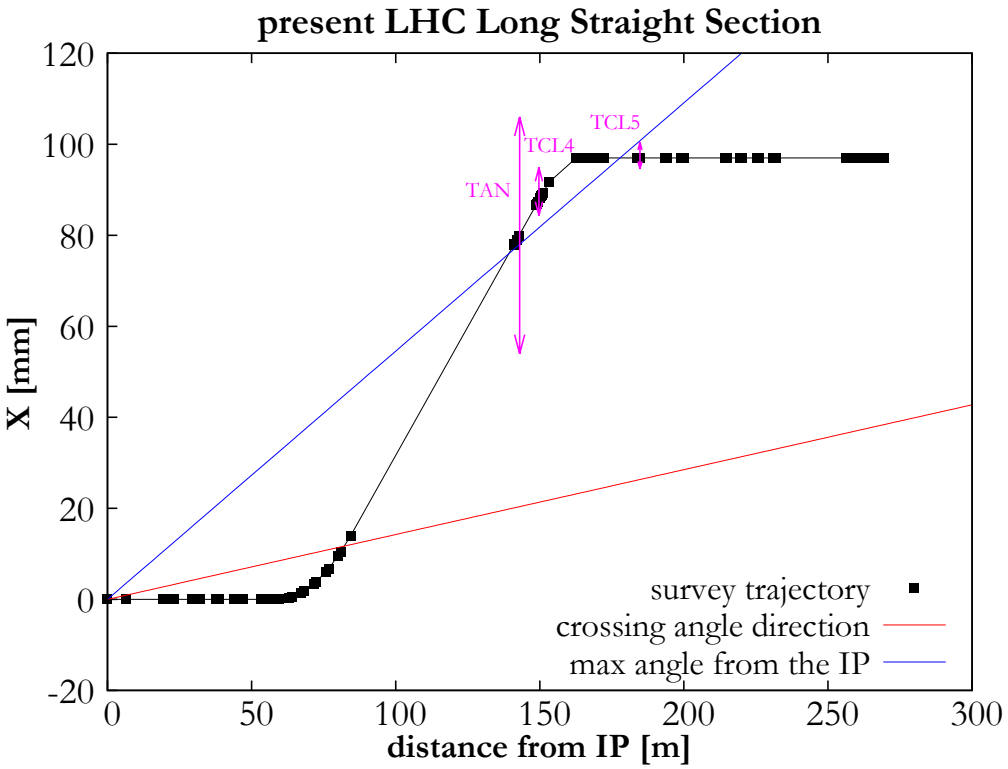
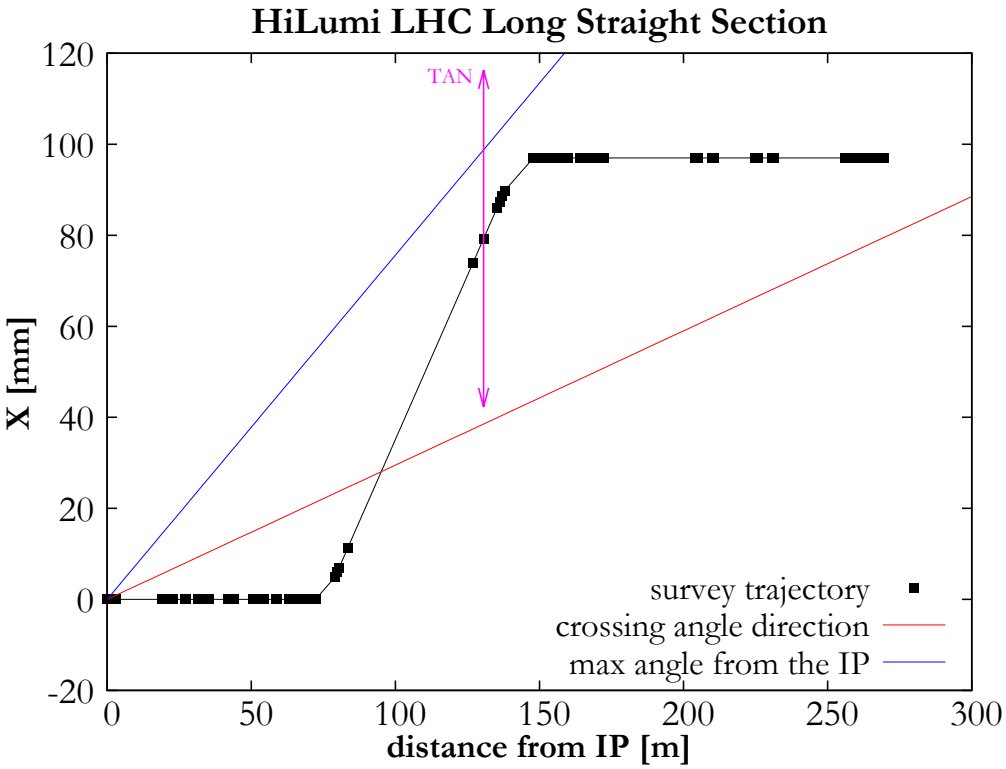


HL-LHC vs LHC





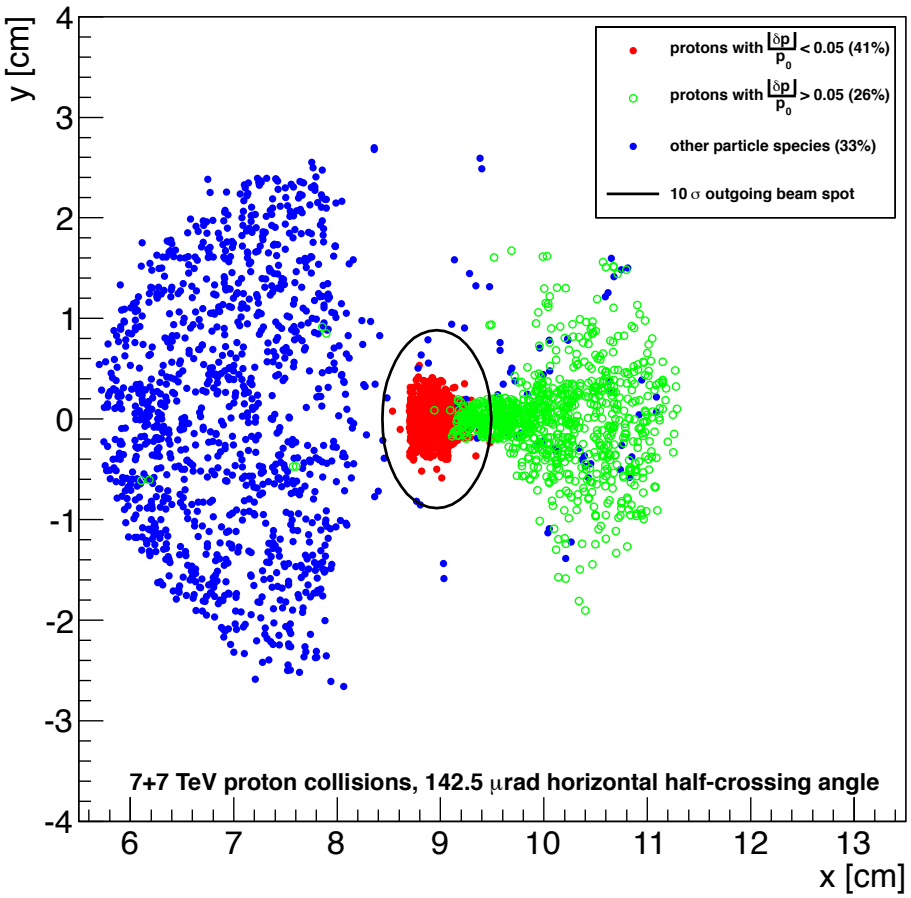
The neutral debris fan coming from the IP is not anymore separated from the proton beam trajectory because of:

- larger crossing angle
- larger upstream aperture
- shorter dogleg length

Debris after the TAN

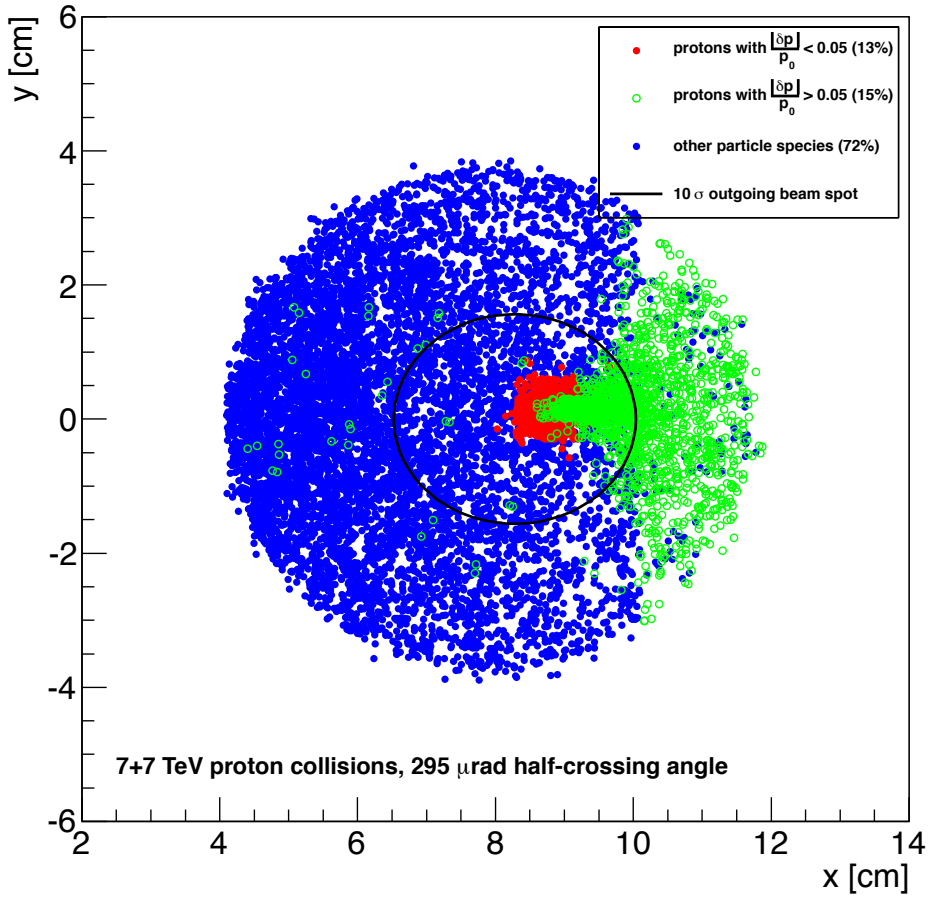
LHC

debris distribution at TCL.4R5 entrance



HL-LHC

debris distribution at TAN.4R5 exit (truncated cone)



Same number of events

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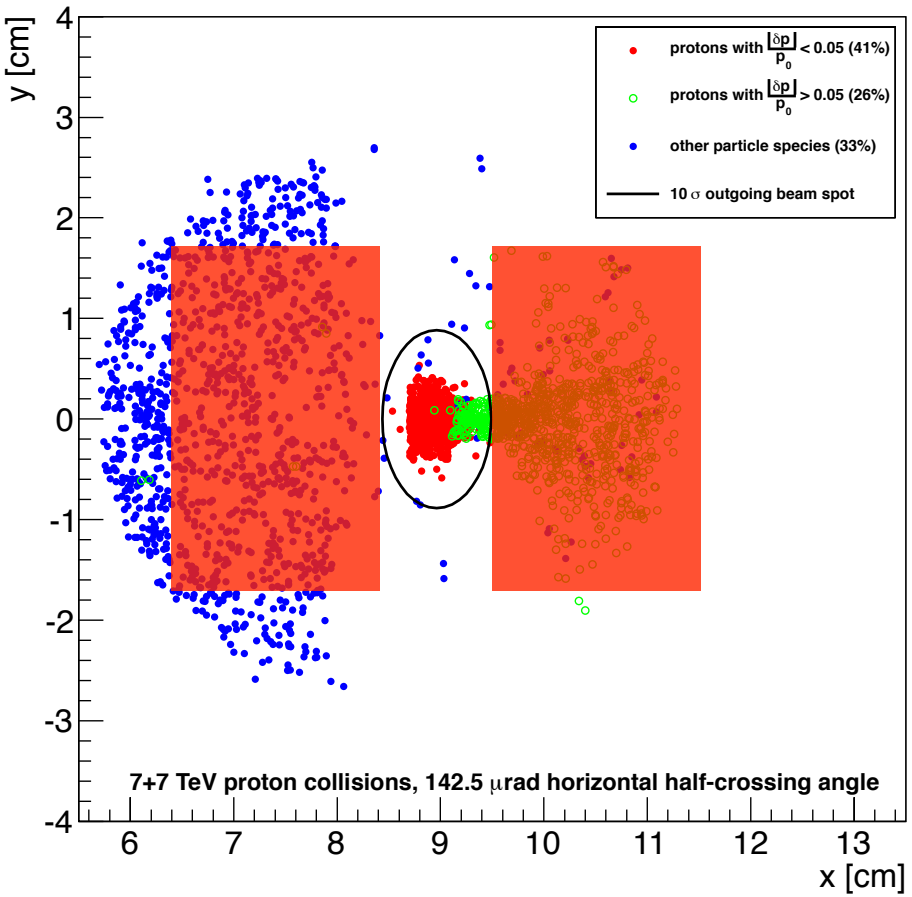

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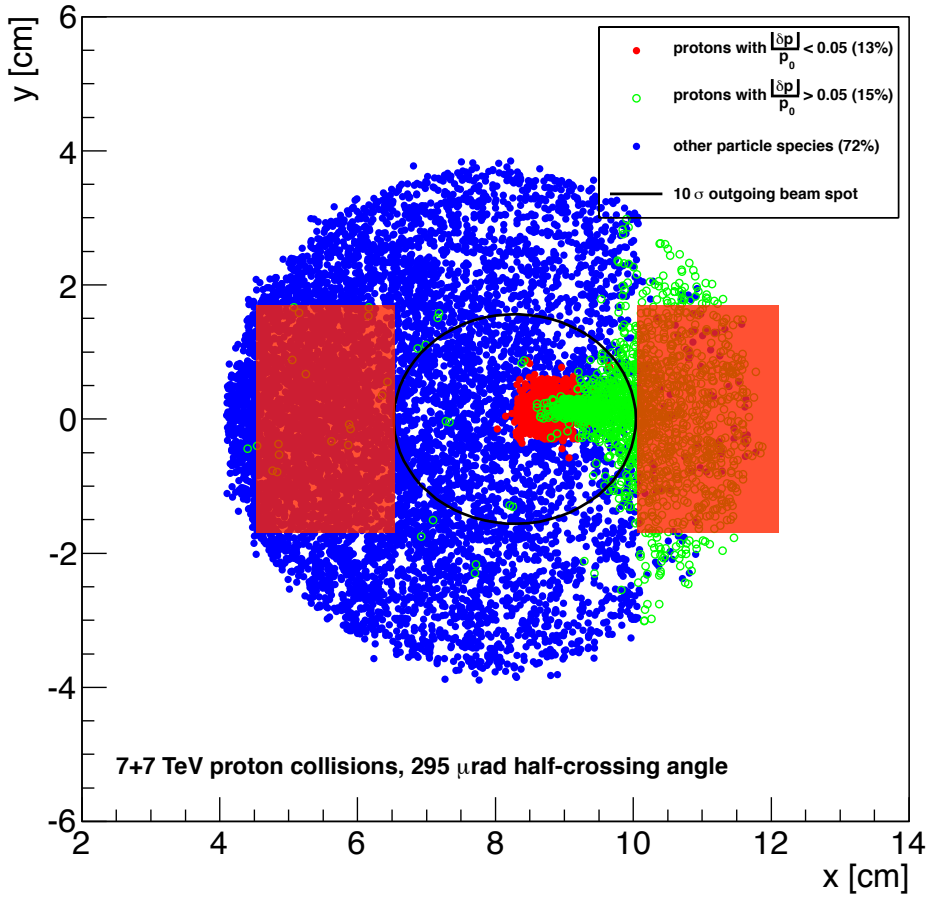


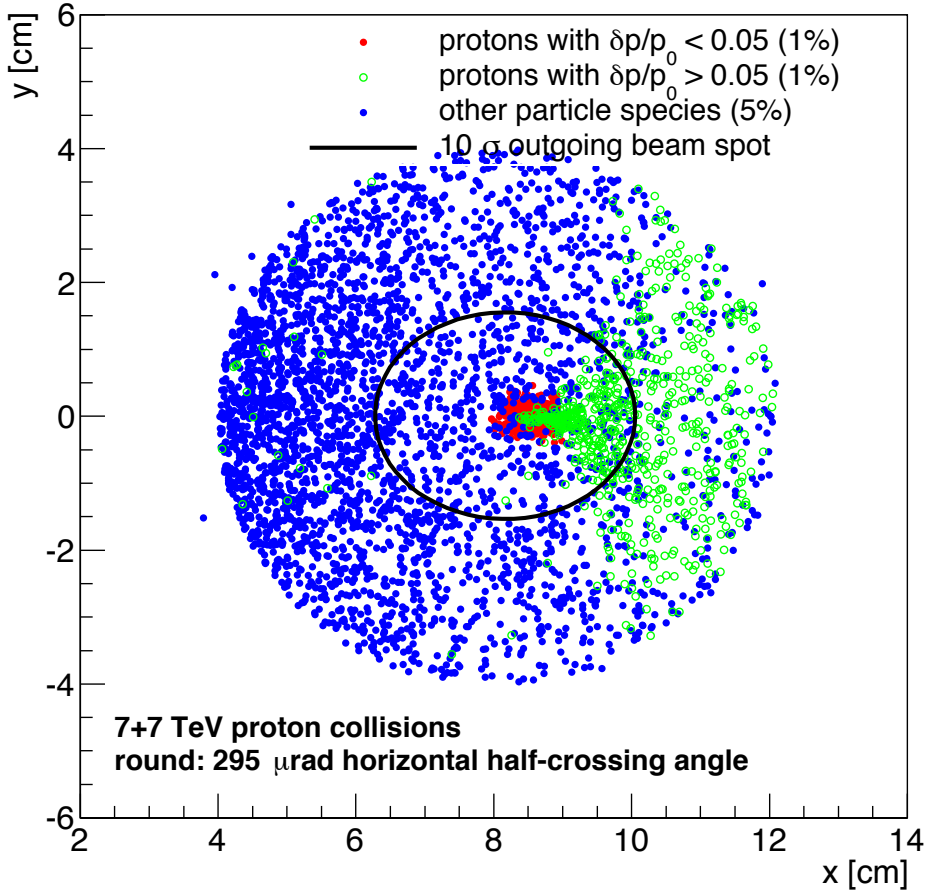
Same number of events

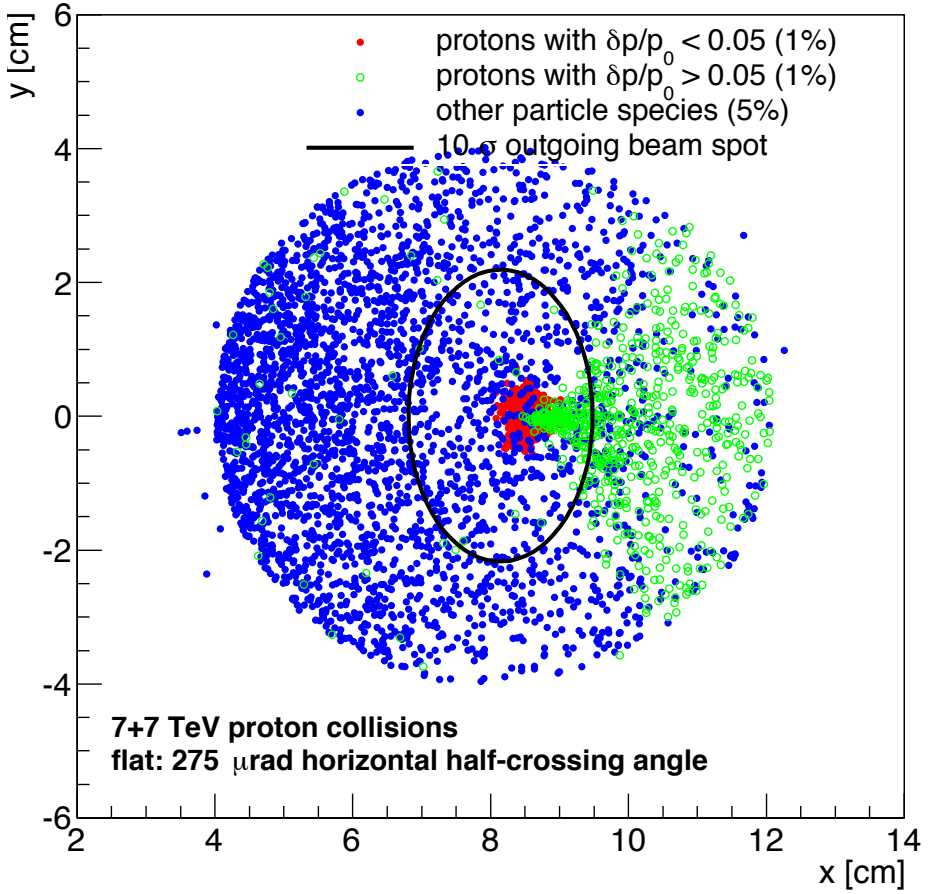
jaws at 10σ

(shown only the tungsten block)

Does present layout provide sufficient protection to operate with different crossing angles and optics schemes (i.e. collimator settings)?

Flat vs round optics





Particle debris distributions at the TAXN exit are similar.
However, in case of the flat optics, the leakage at small X is higher since collimator apertures are set at fixed number of sigmas

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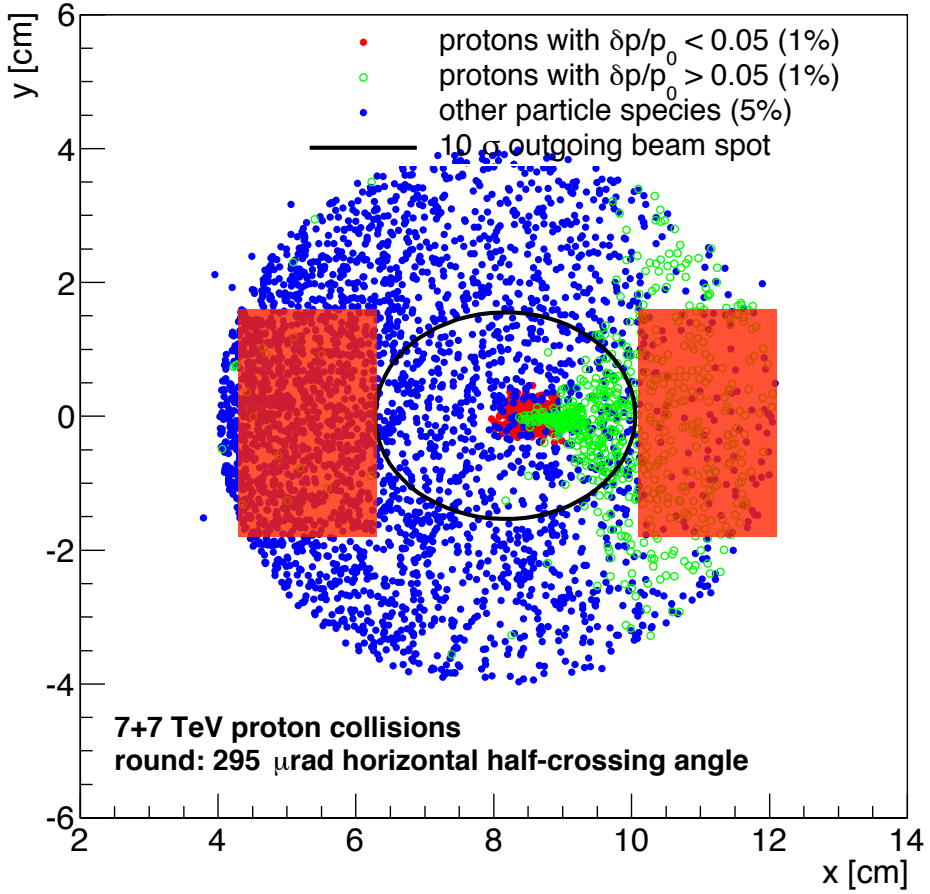

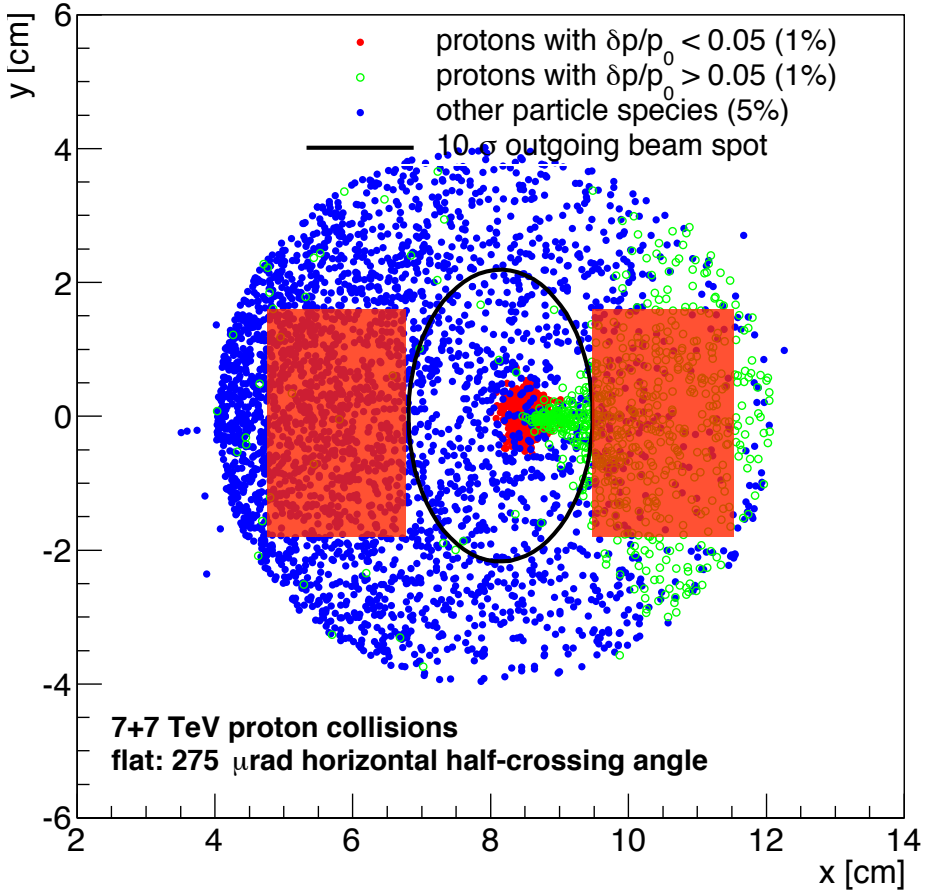

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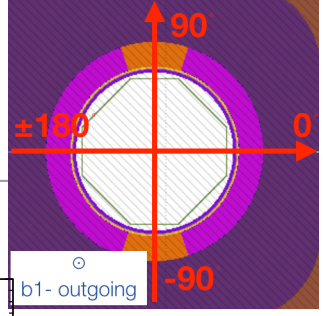
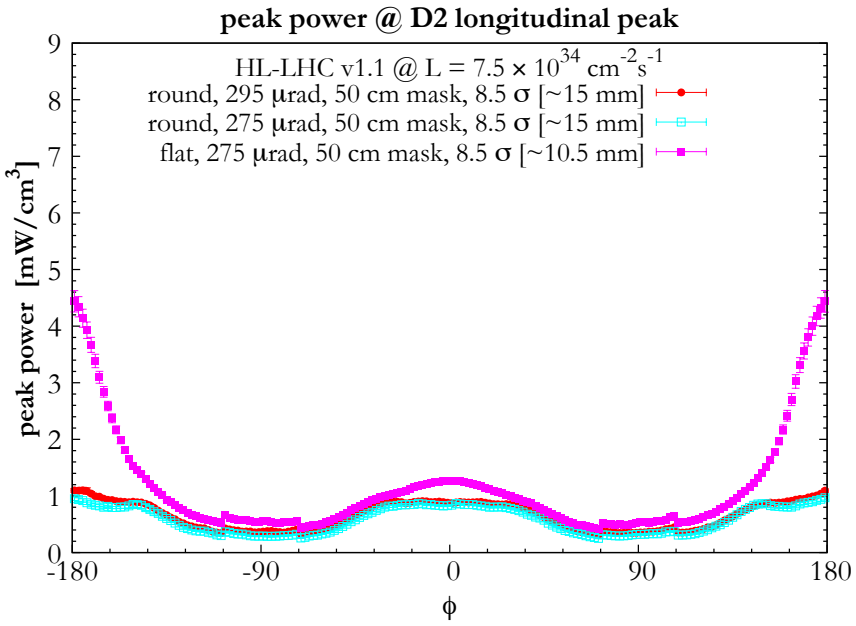
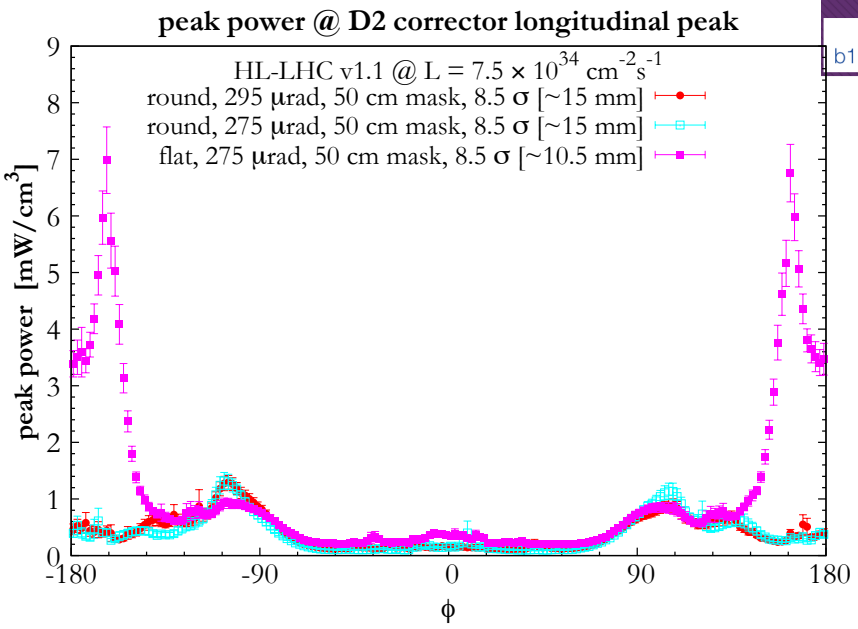
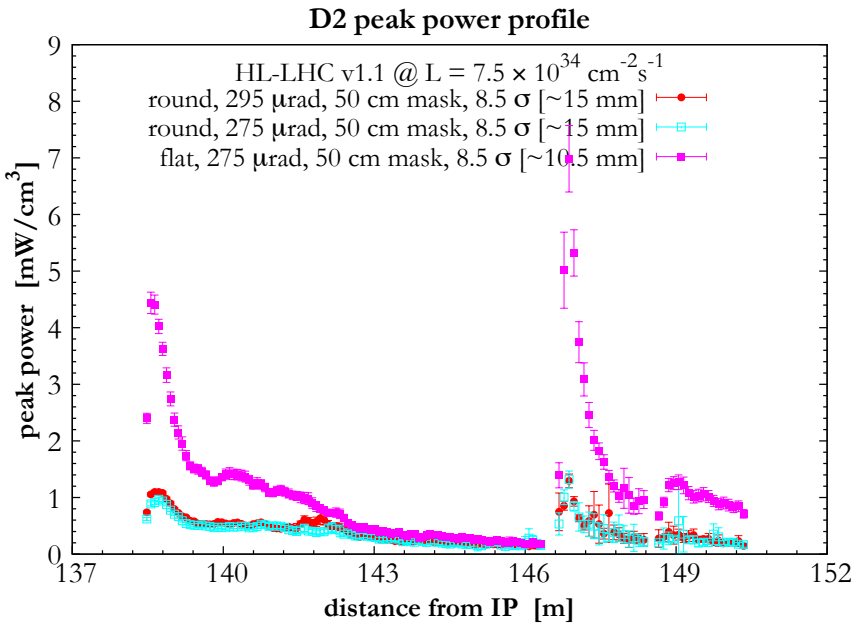
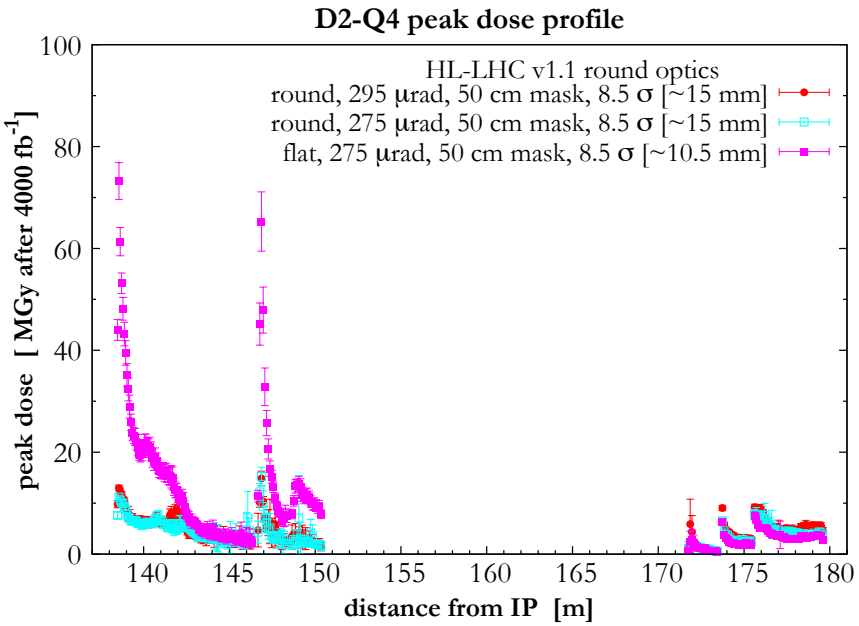
Sensitivity to crossing angle (and optics schemes)



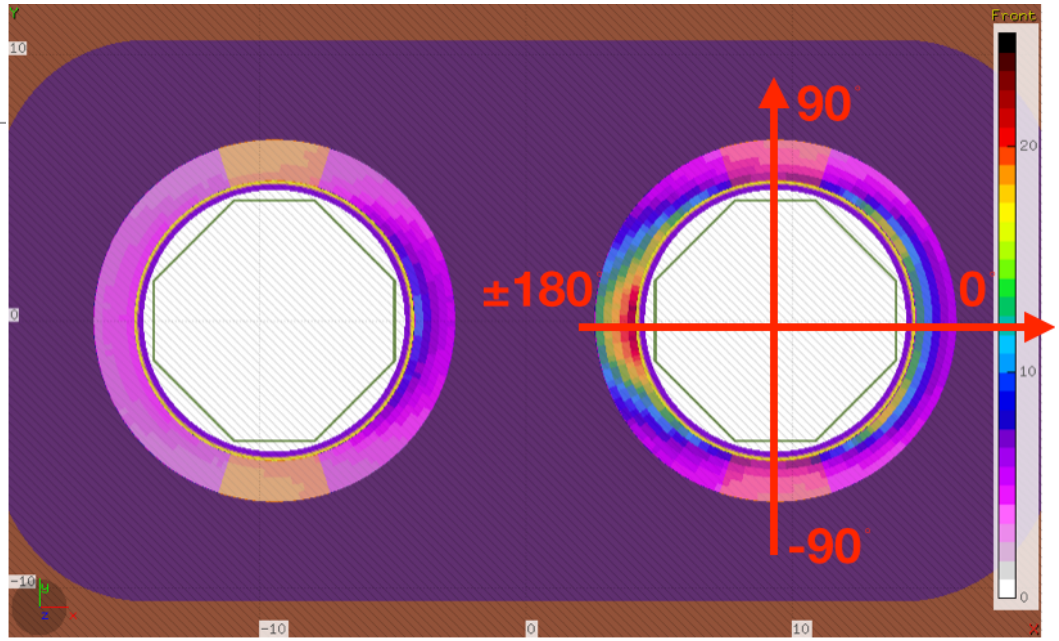






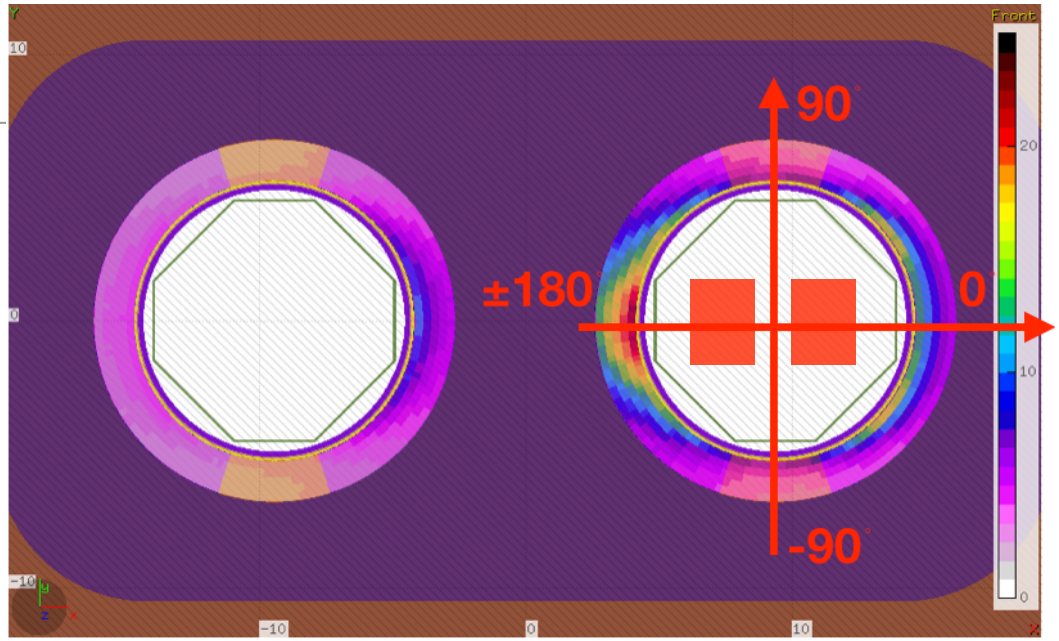


Anticipating the solution



Anticipating the solution

- The leak on the outgoing beam, inner side, external to the inner collimator jaw plays



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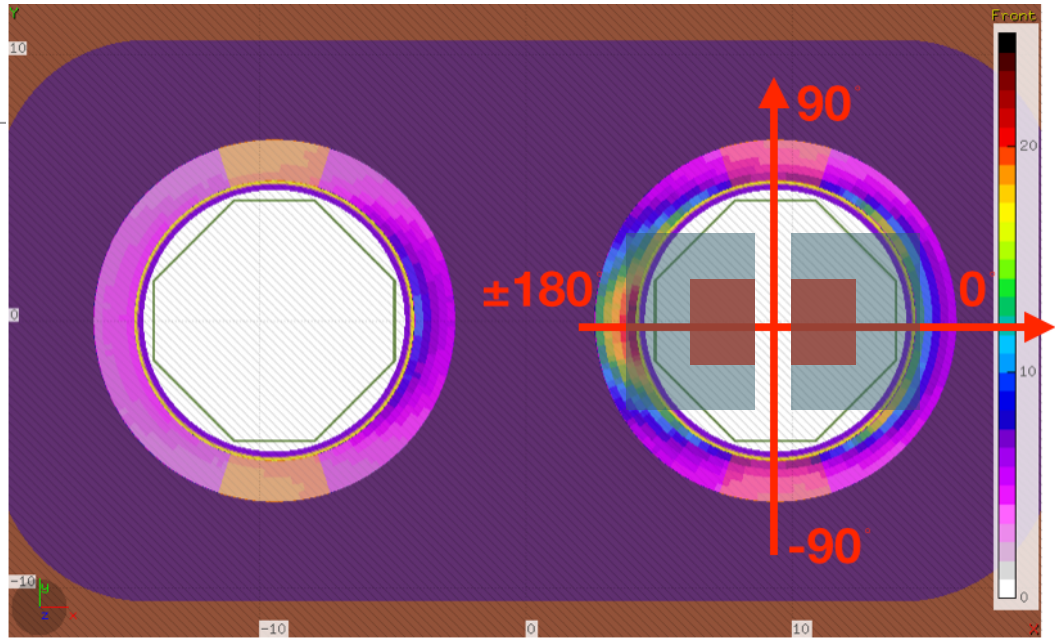
- The leak on the outgoing beam, inner side, external to the inner collimator jaw plays
- This leak can be cured with a larger collimator



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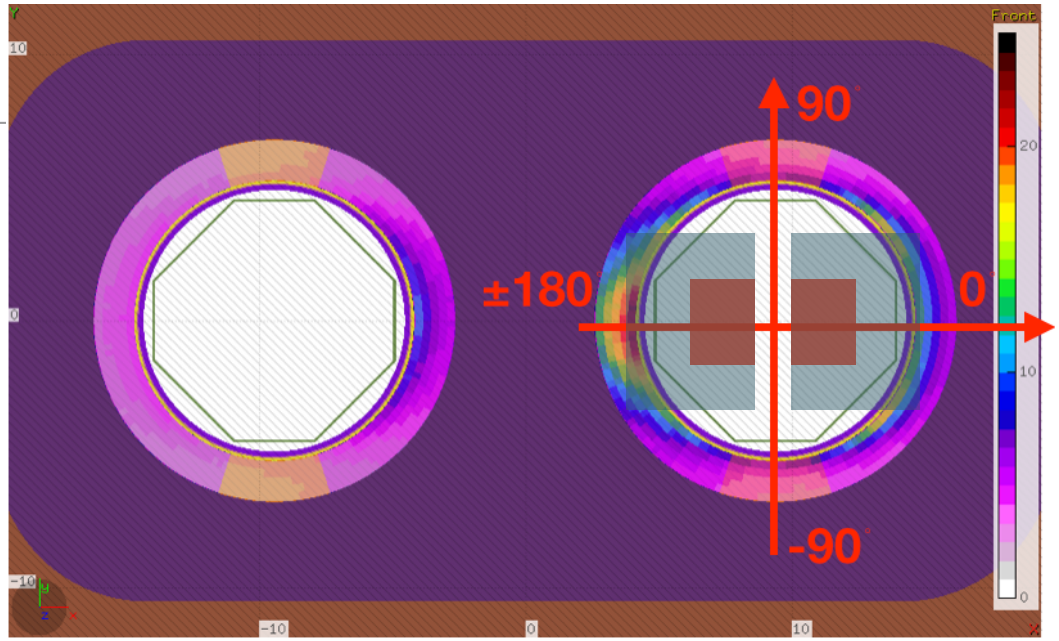
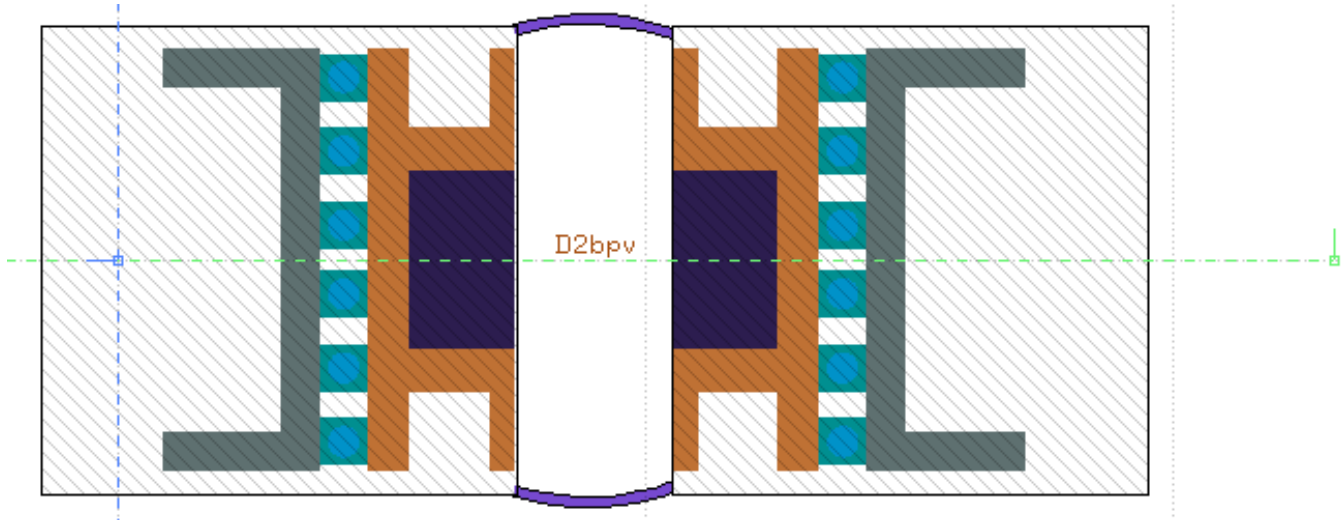


- This leak can be cured with a larger collimator
- If a larger collimator is used, the dependence with the crossing angle goes as expected:
  ⇒ **smaller x-ang, lower energy deposition**
- A minor dependence versus the collimator aperture (set at fixed number of sigmas) still remains
  ⇒ **for flat optics, smaller gap in mm, lower energy deposition**

TCL4 with larger jaws

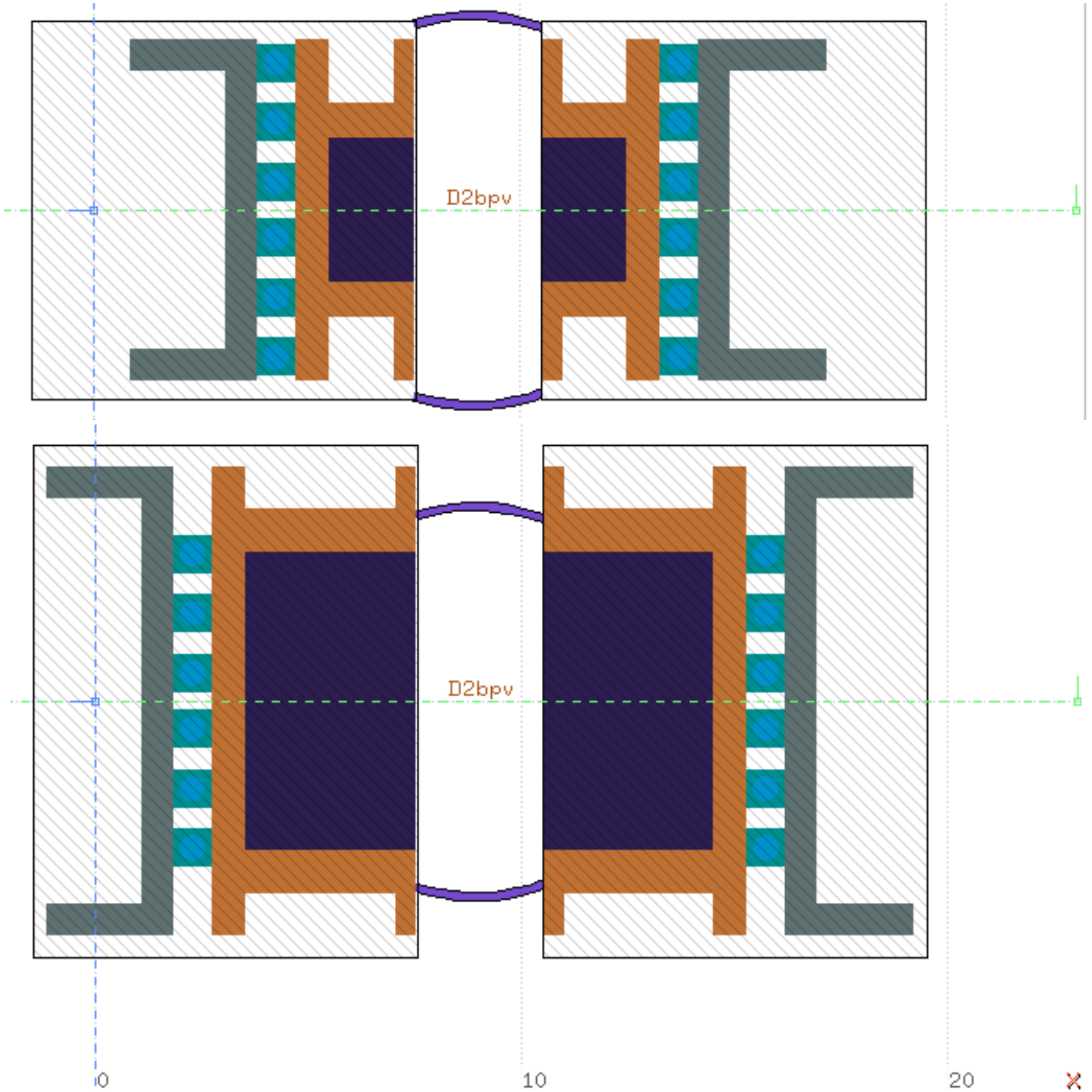
Inermet180 block
2 cm × 3.4 cm



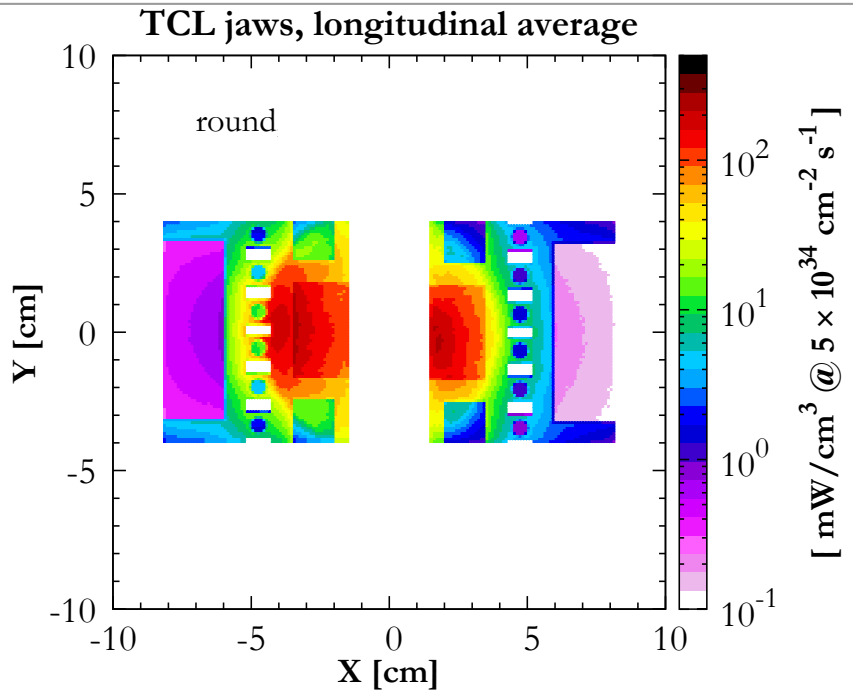
TCL4 with larger jaws

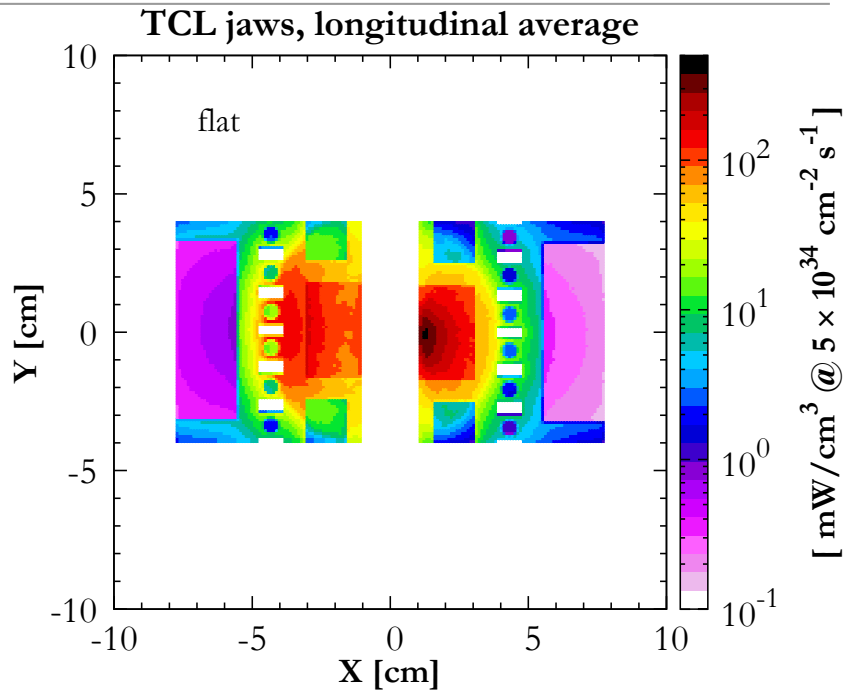
Inermet180 block
2 cm × 3.4 cm

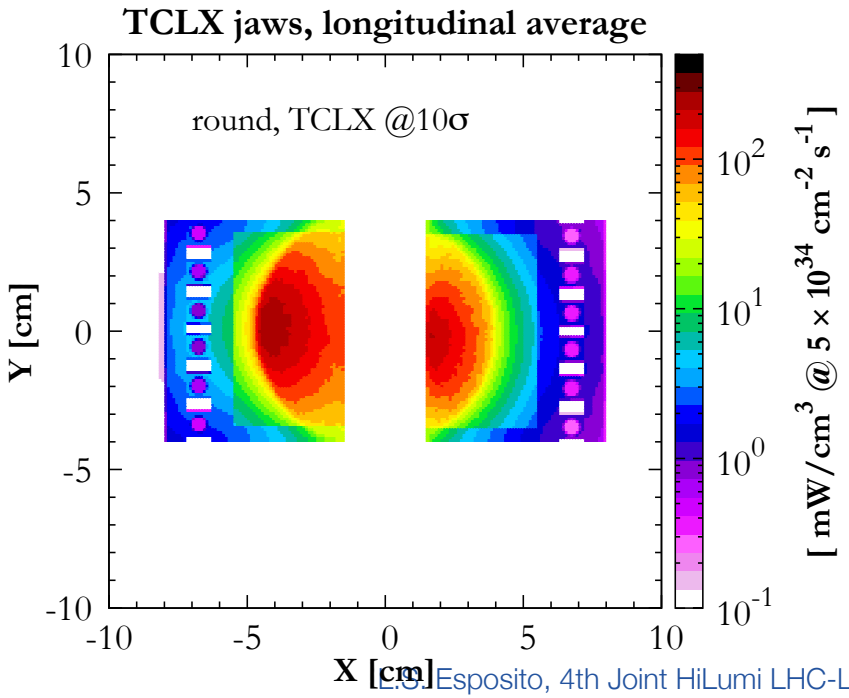
Inermet180 block
4 cm × 7 cm

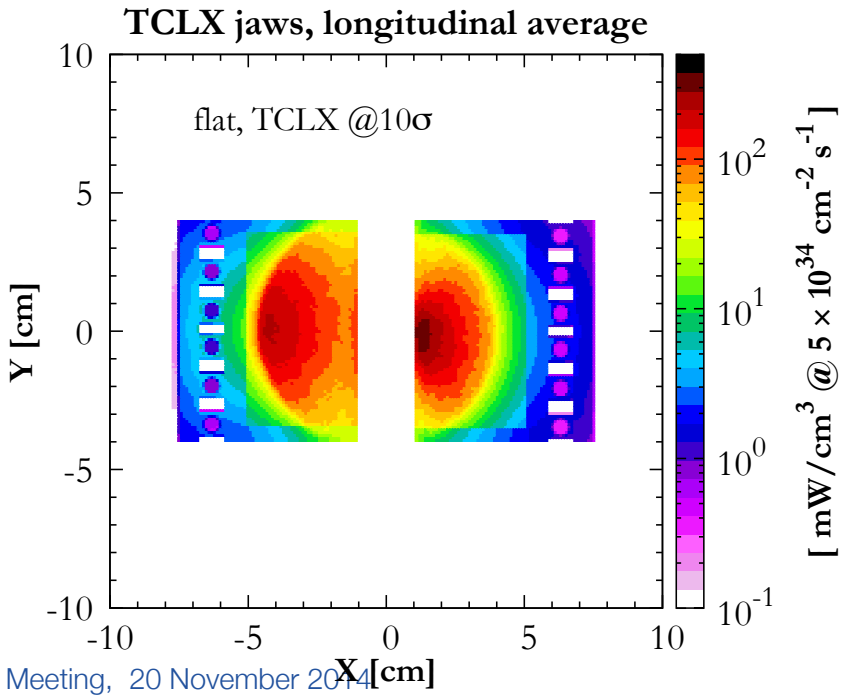


TCL vs TCLX


TCL jaws, longitudinal average
round
Y [cm]
X [cm]
[mW/cm^3 @ 5 × 10^{34} cm^{-2} s^{-1}]


TCL jaws, longitudinal average
flat
Y [cm]
X [cm]
[mW/cm^3 @ 5 × 10^{34} cm^{-2} s^{-1}]


TCLX jaws, longitudinal average
round, TCLX @10σ
Y [cm]
X [cm]
[mW/cm^3 @ 5 × 10^{34} cm^{-2} s^{-1}]


TCLX jaws, longitudinal average
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Y [cm]
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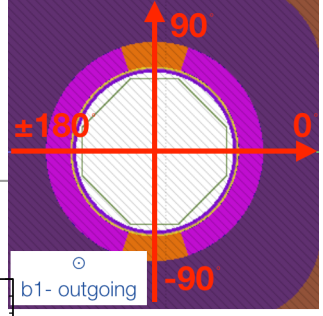
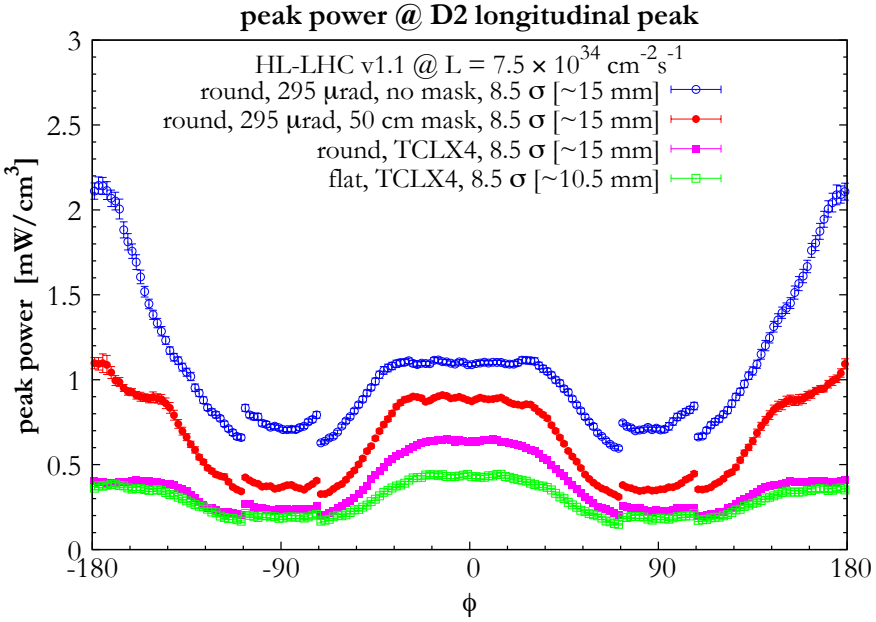
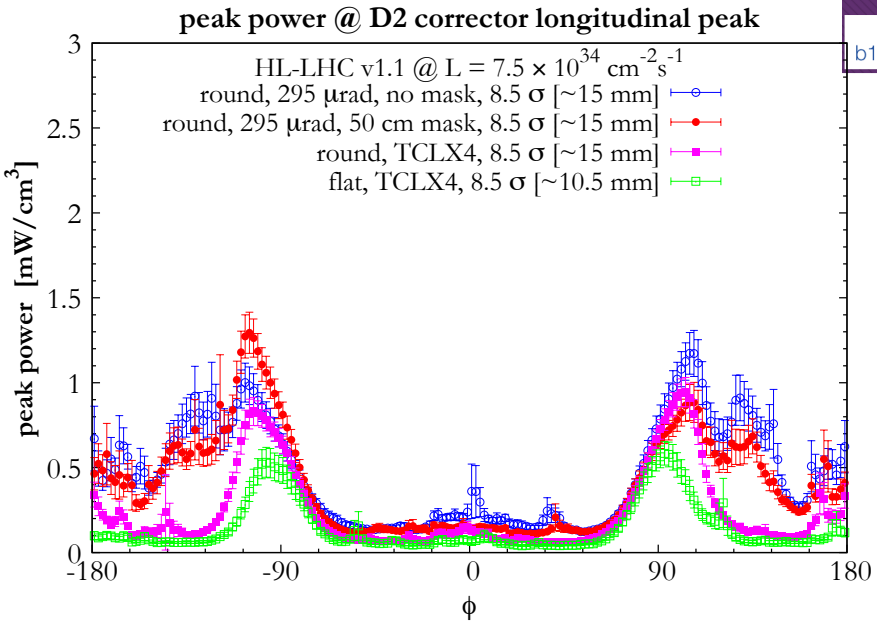
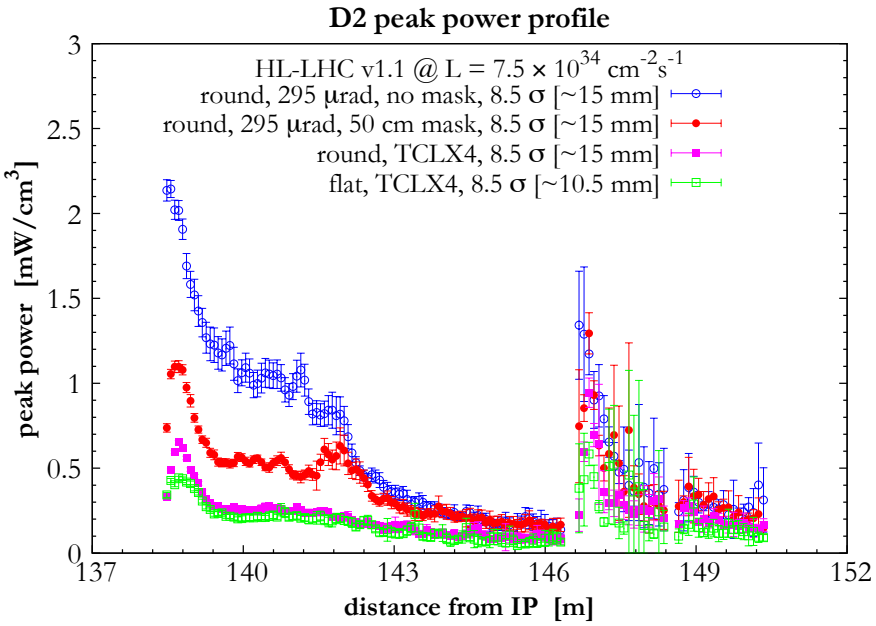
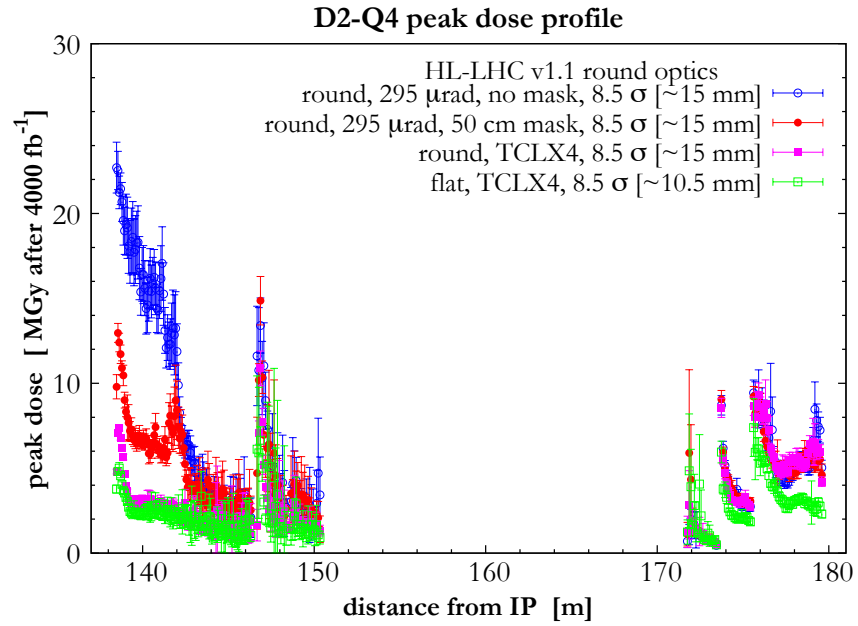
TCLX with larger jaws



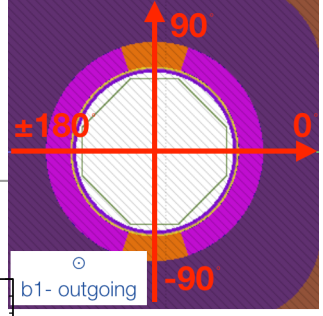


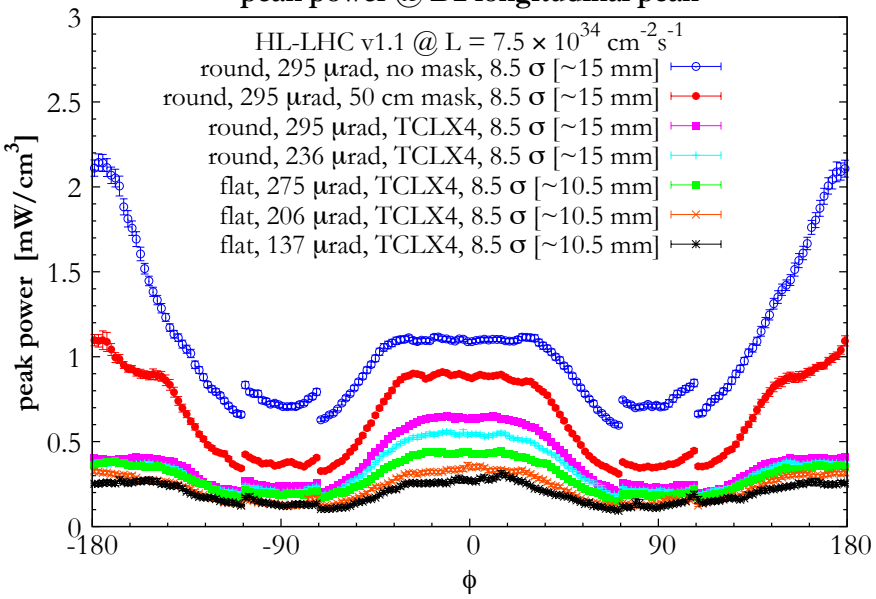


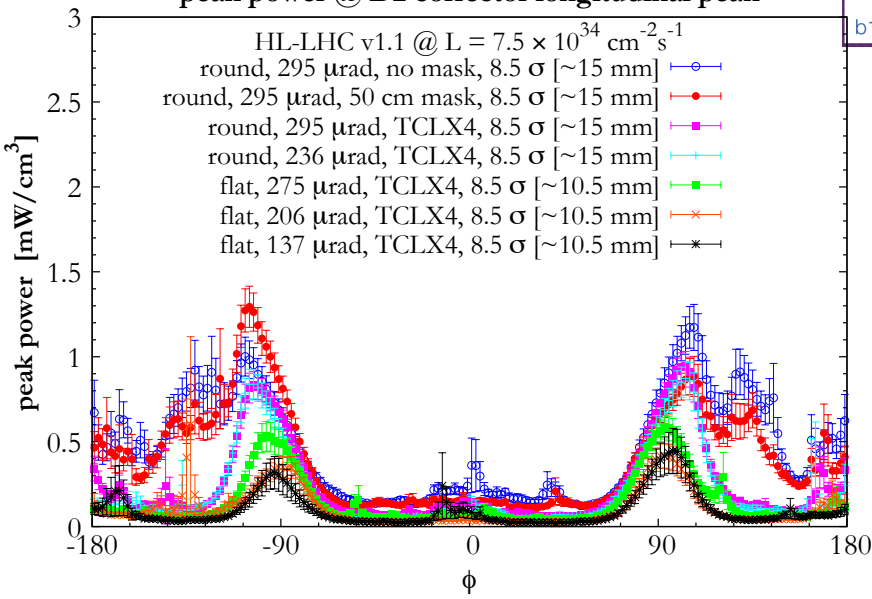


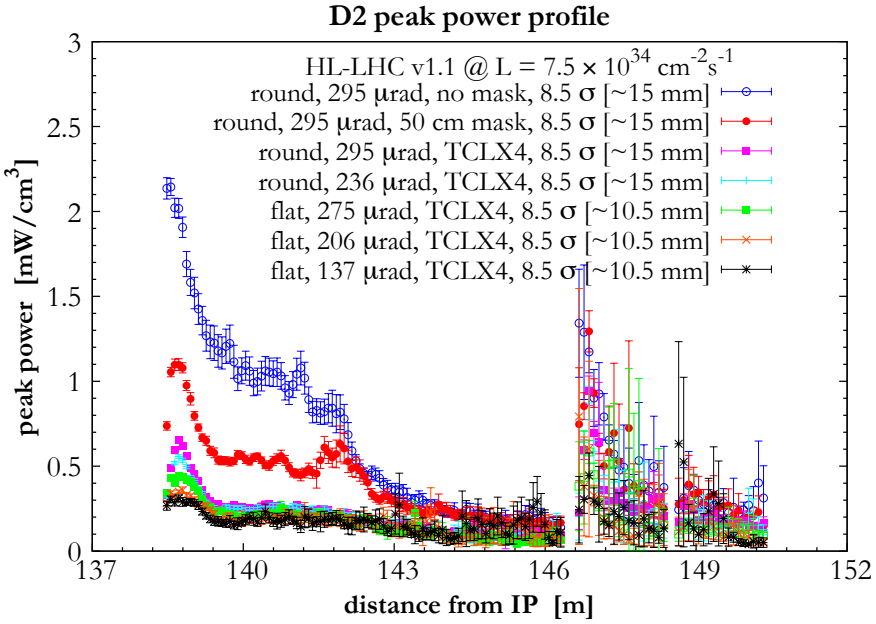


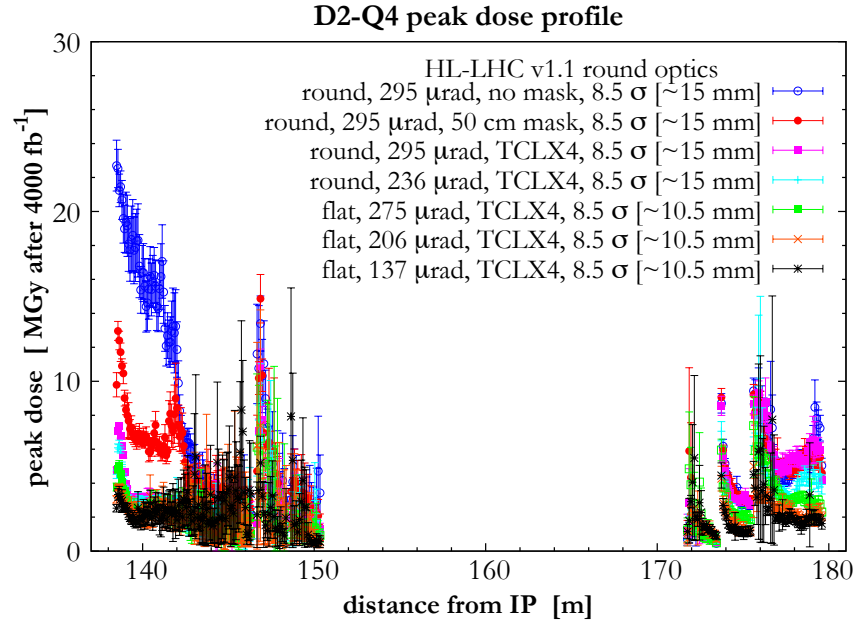
TCLX: crossing angle and optics schemes



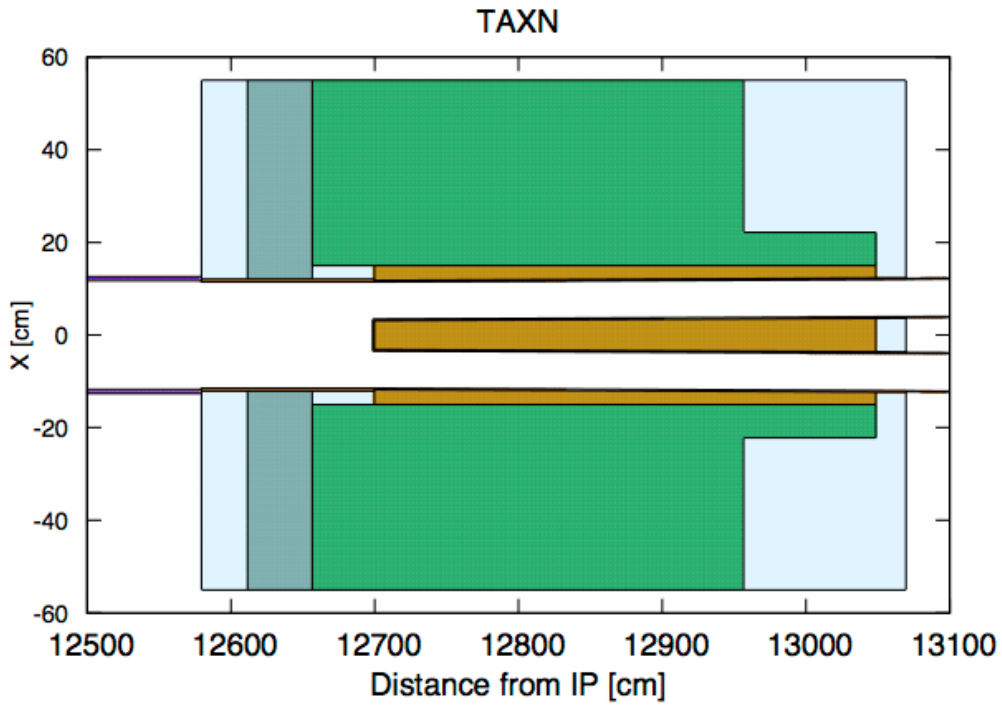


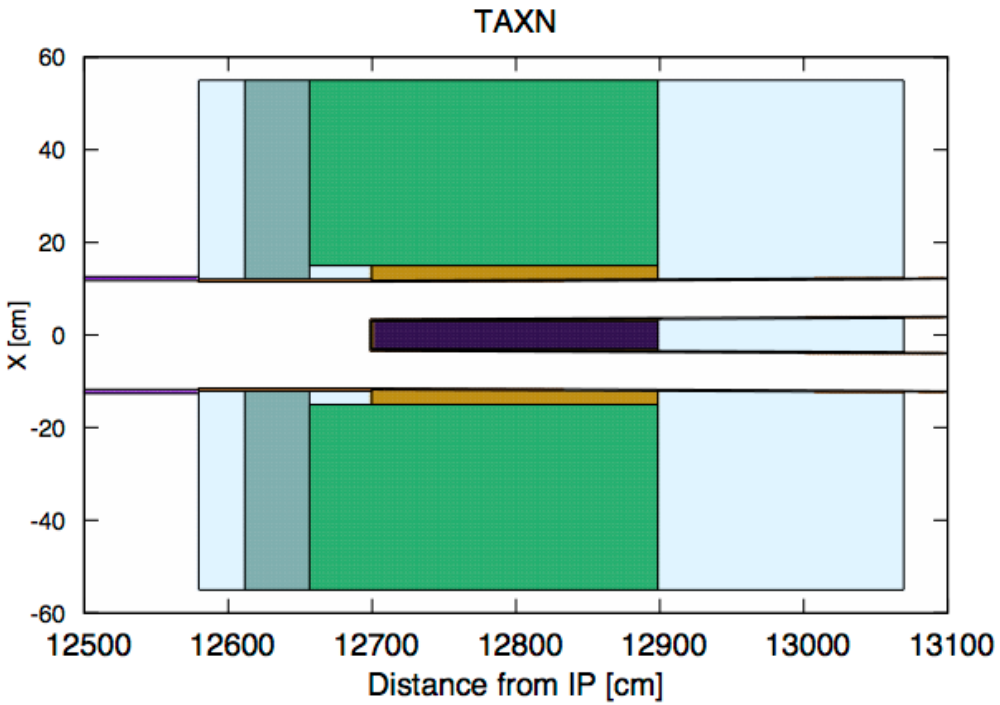






TAXN: optimising the length

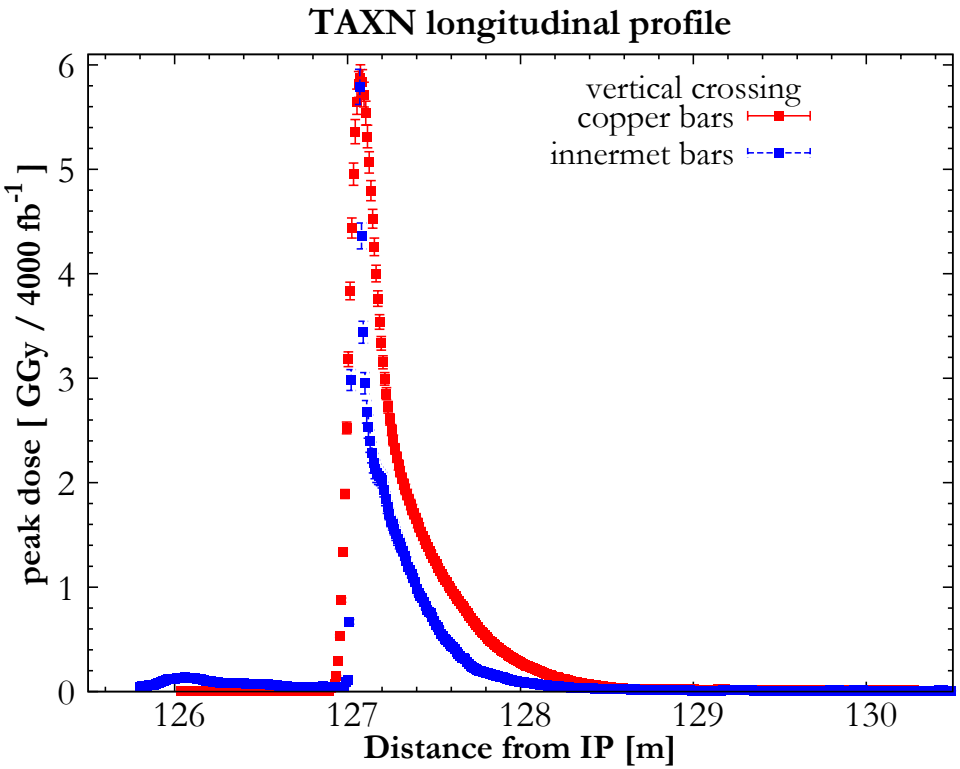


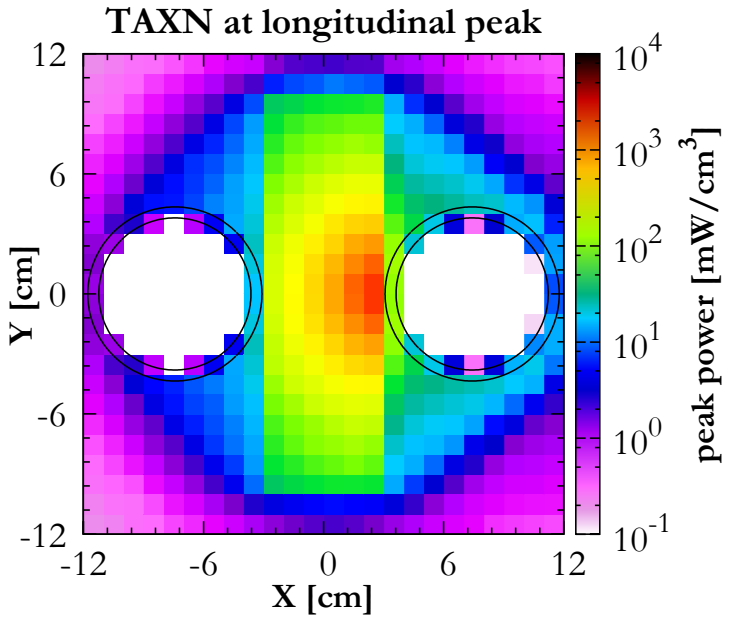


1. Material: from Cu (λ_{int} ~ 14 cm) to Inermet180 (λ_{int} ~ 9 cm)

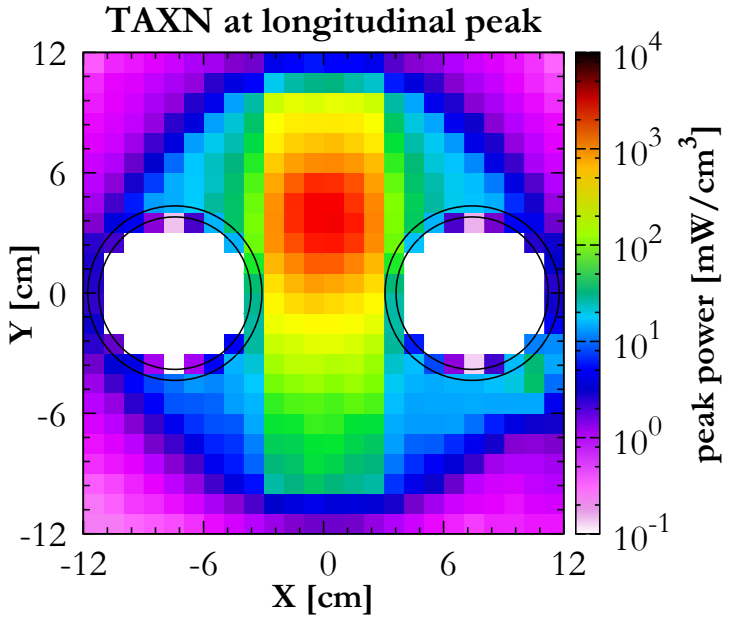
2. Shortening effective length: from 3.5 m (25 λ_{int}) to 2.0 m (22 λ_{int})

TAXN: energy deposition





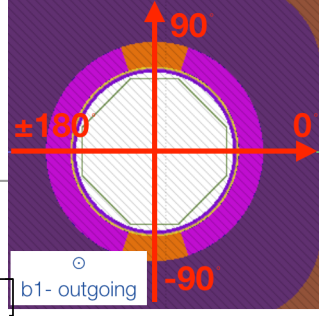
horizontal crossing

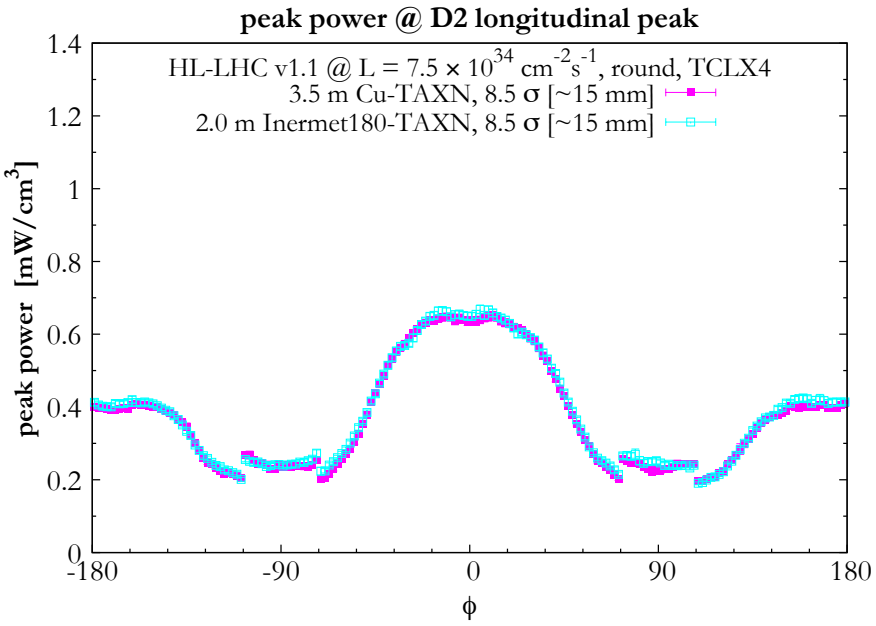


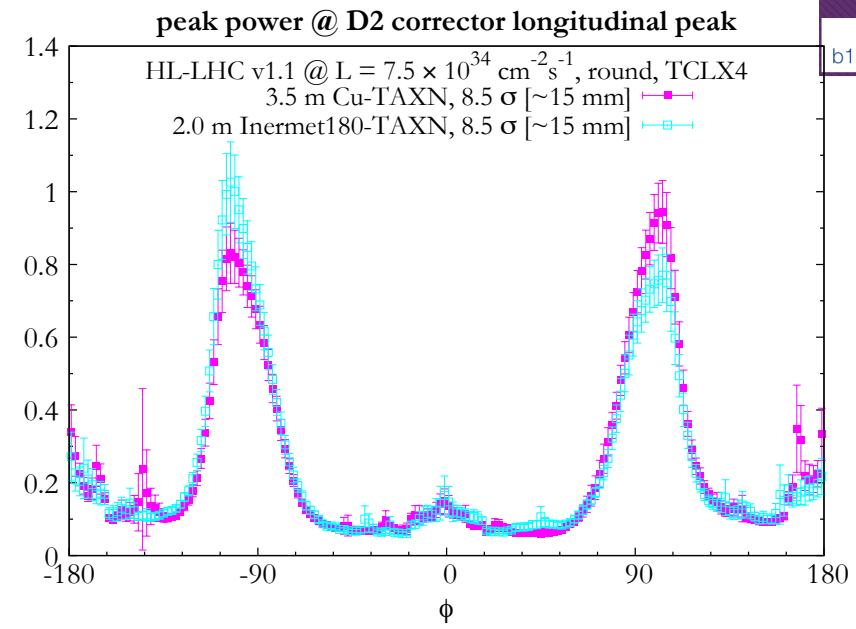
vertical crossing

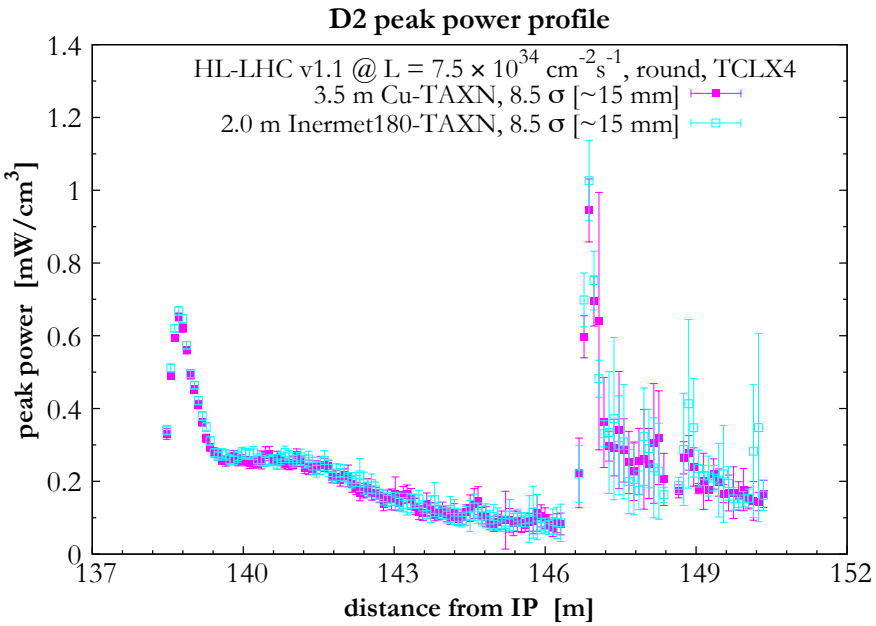
Total power 1800 W @ 7.5 cm^{-2} s^{-1} for vertical crossing

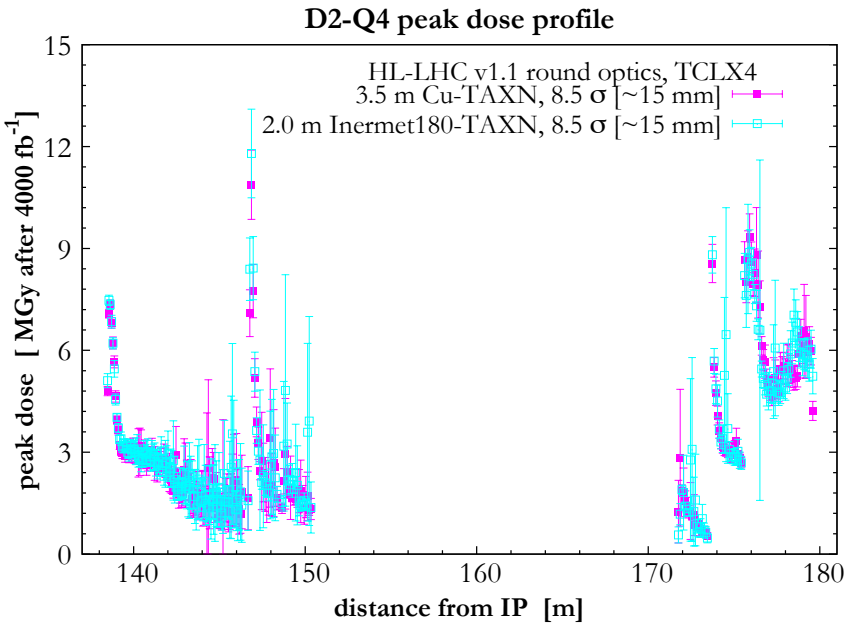
Shorter TAXN and TCLX



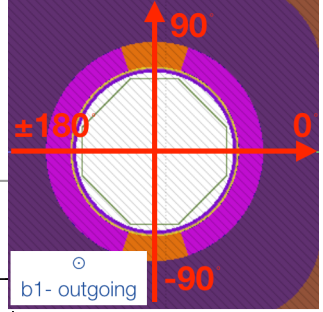


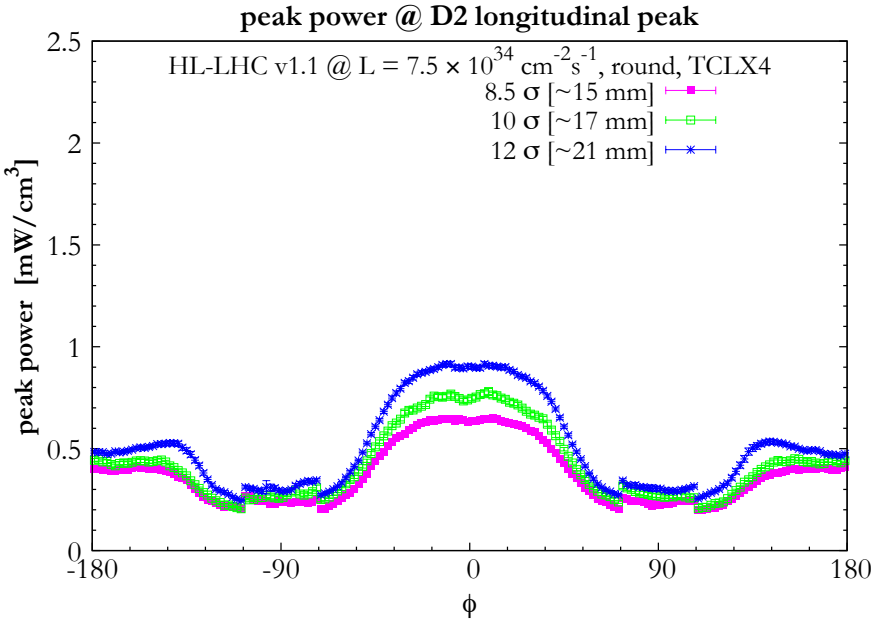


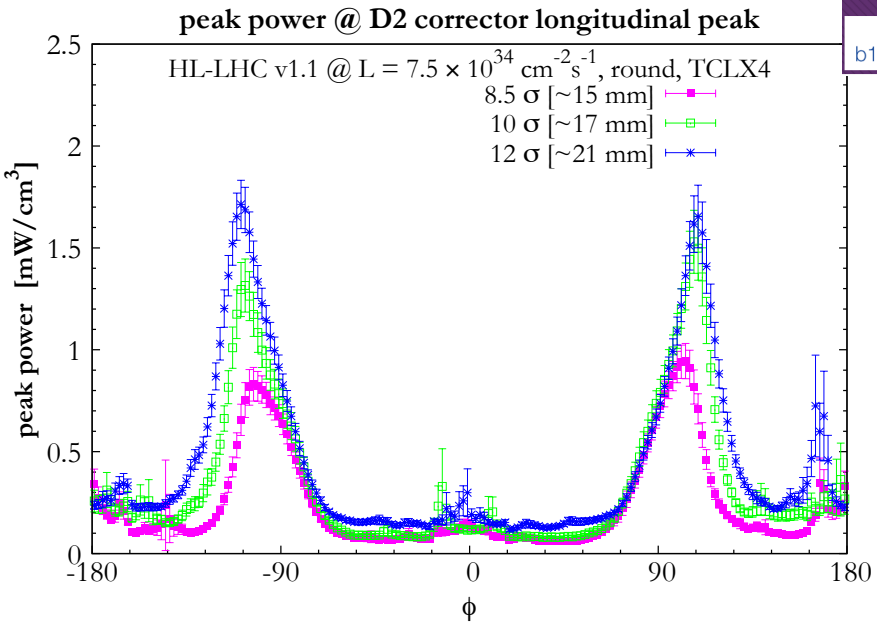


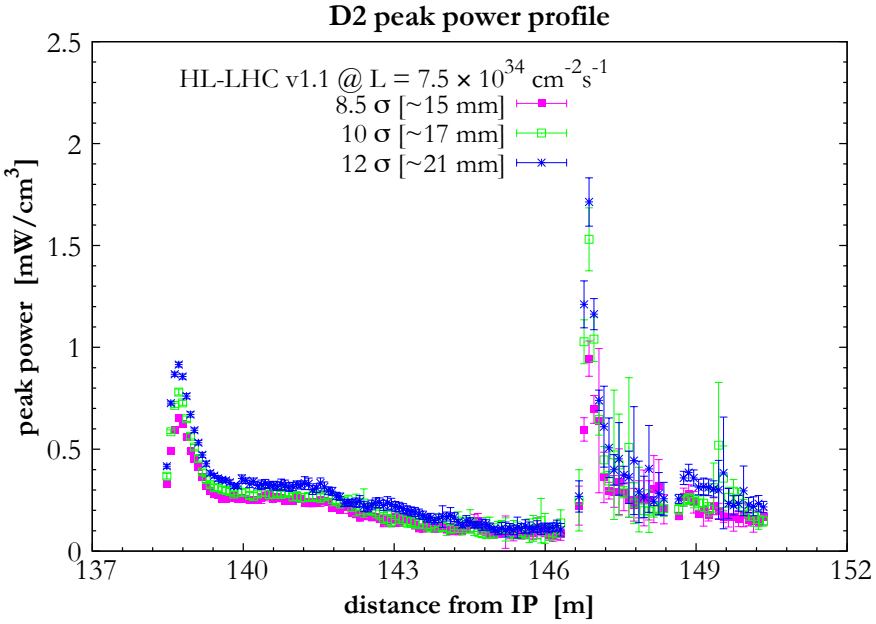


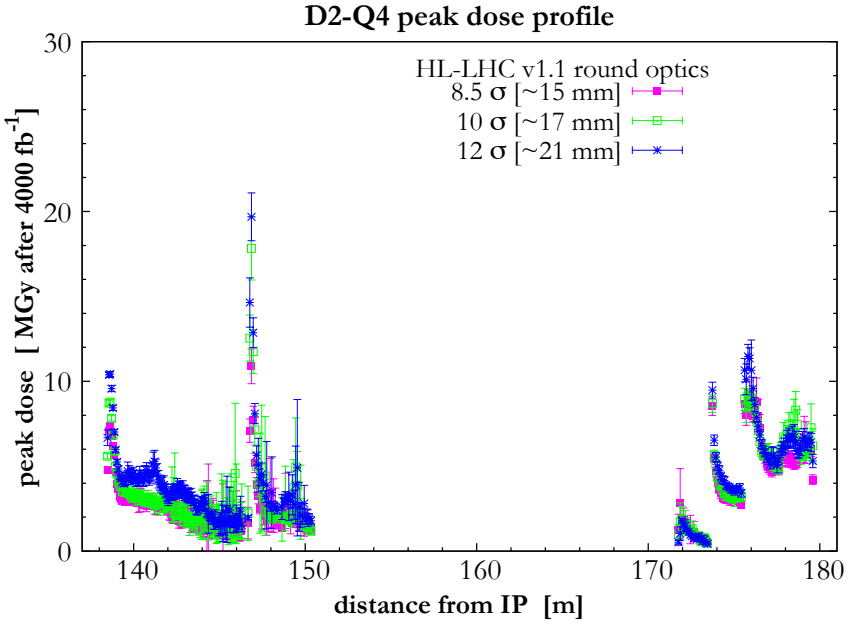
Aperture scan (short TAXN & TCLX)









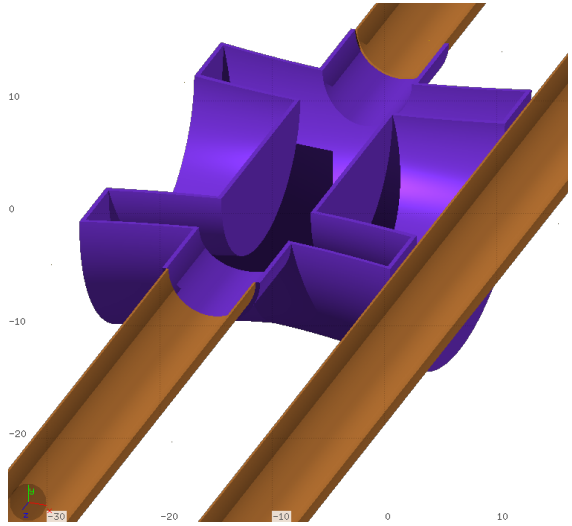


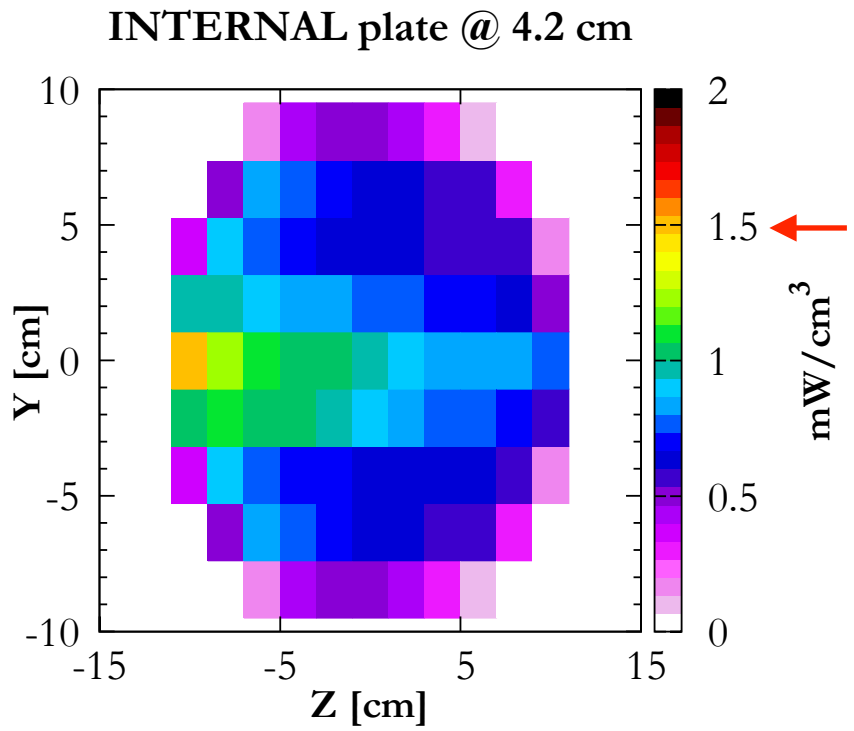
Total power @ 7.5×10^{34} cm^{-2} s^{-1}

Power [W] 7.5E34 cm^{-2} s^{-1}	TCL4 inner jaw	TCL4 outer jaw	TCLMA b1	TCLMA b2	D2+ correctors	correctors+Q4
TCL@8.5 σ, round, w/o mask	255	153	-	-	77+5.5+3	9+4+9
TCL@8.5 σ, round, w/ mask	263	149	10	2.7	53+5+3	9+4.3+9.5
TCLX4@8.5 σ, flat	318	247	-	-	29+3+1.6	4.3+2.5+7.5
TCLX4@8.5 σ, round	330	180	-	-	33+3.6+2.3	8+4+9.5
TCLX4@10 σ, round	305	149	-	-	37+4.2+2.5	9.2+4.3+10.3
TCLX4@12 σ, round	277	113	-	-	42+5+3	9.7+8+11

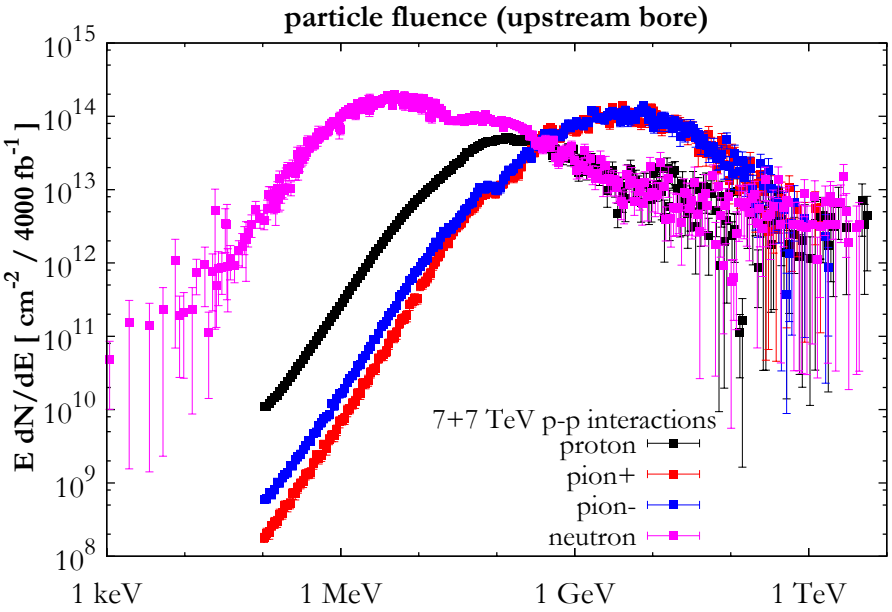
Crab cavities

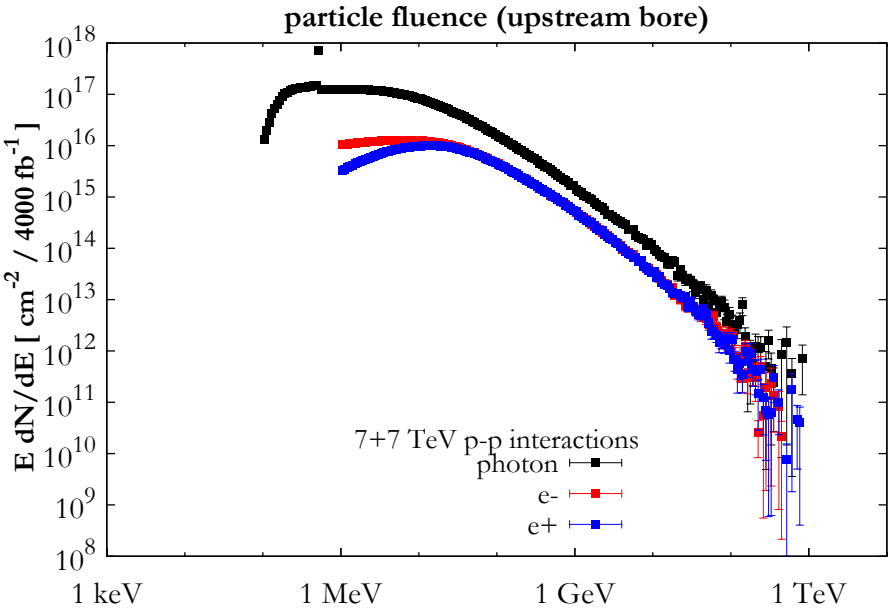
Crab cavities @ 7.5 × 10^{34} cm^{-2} s^{-1}



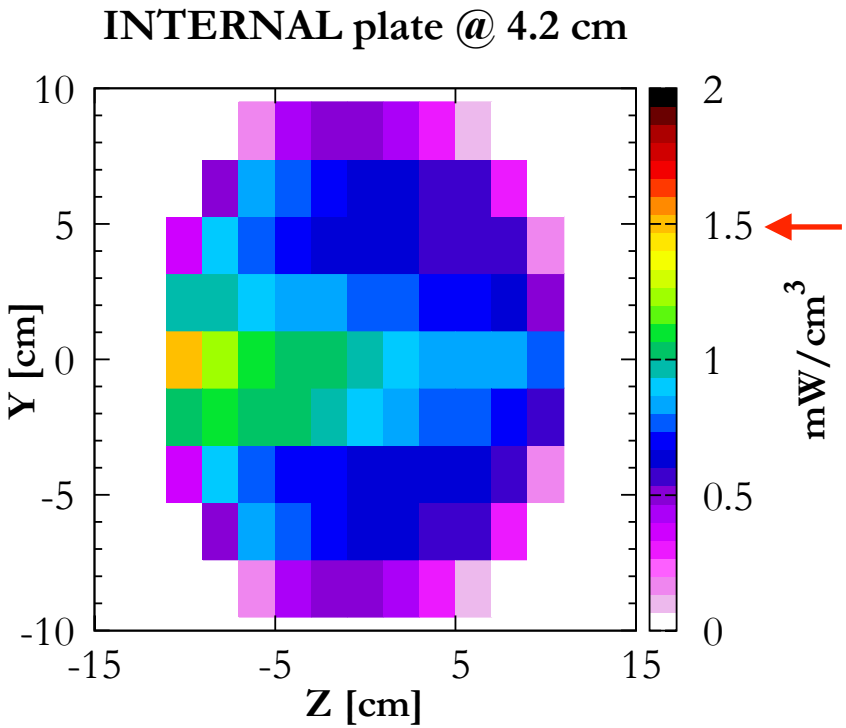


~10 MGy/ 4000 fb^{-1}

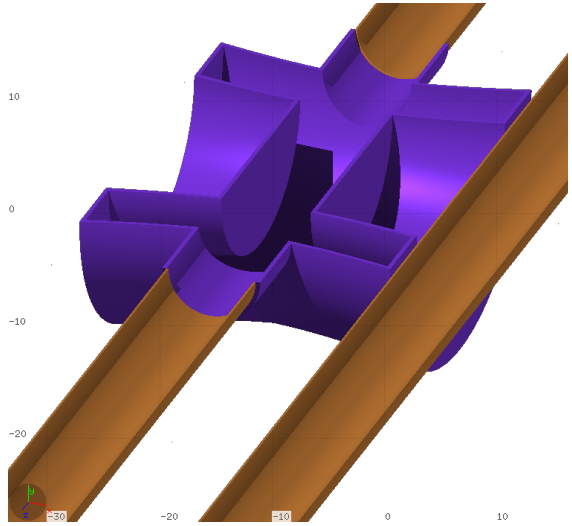




Crab cavities @ 7.5 × 10^{34} cm^{-2} s^{-1}



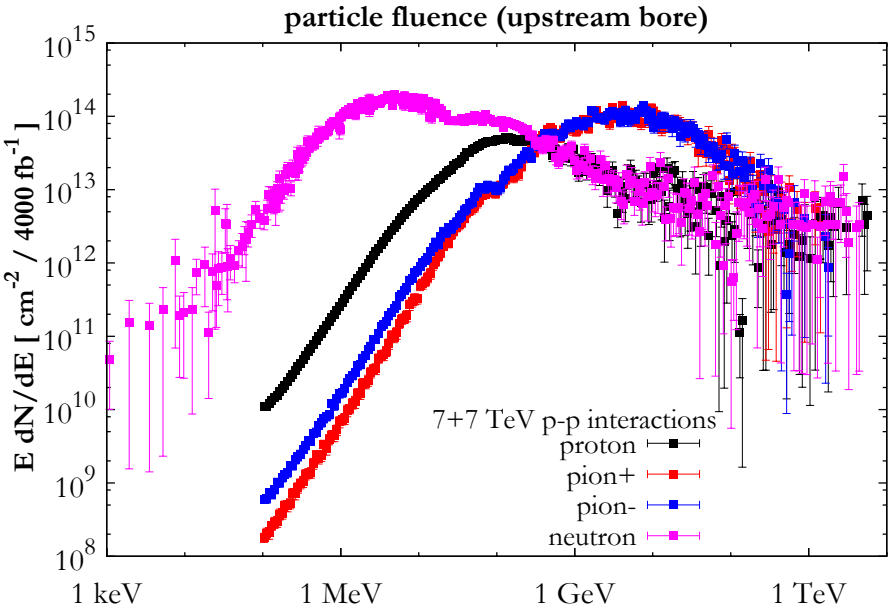
~10 MGy/ 4000 fb^{-1}

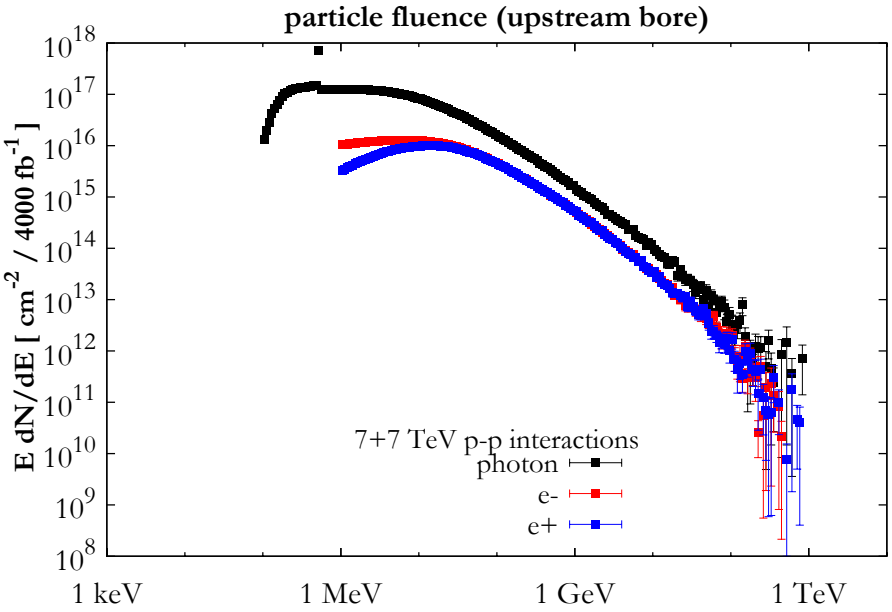


Total power on the most exposed cavity ≳1 W, depending on TCL4 opening, that is 2÷5 times higher than previous calculations.

To be investigated in more detail.

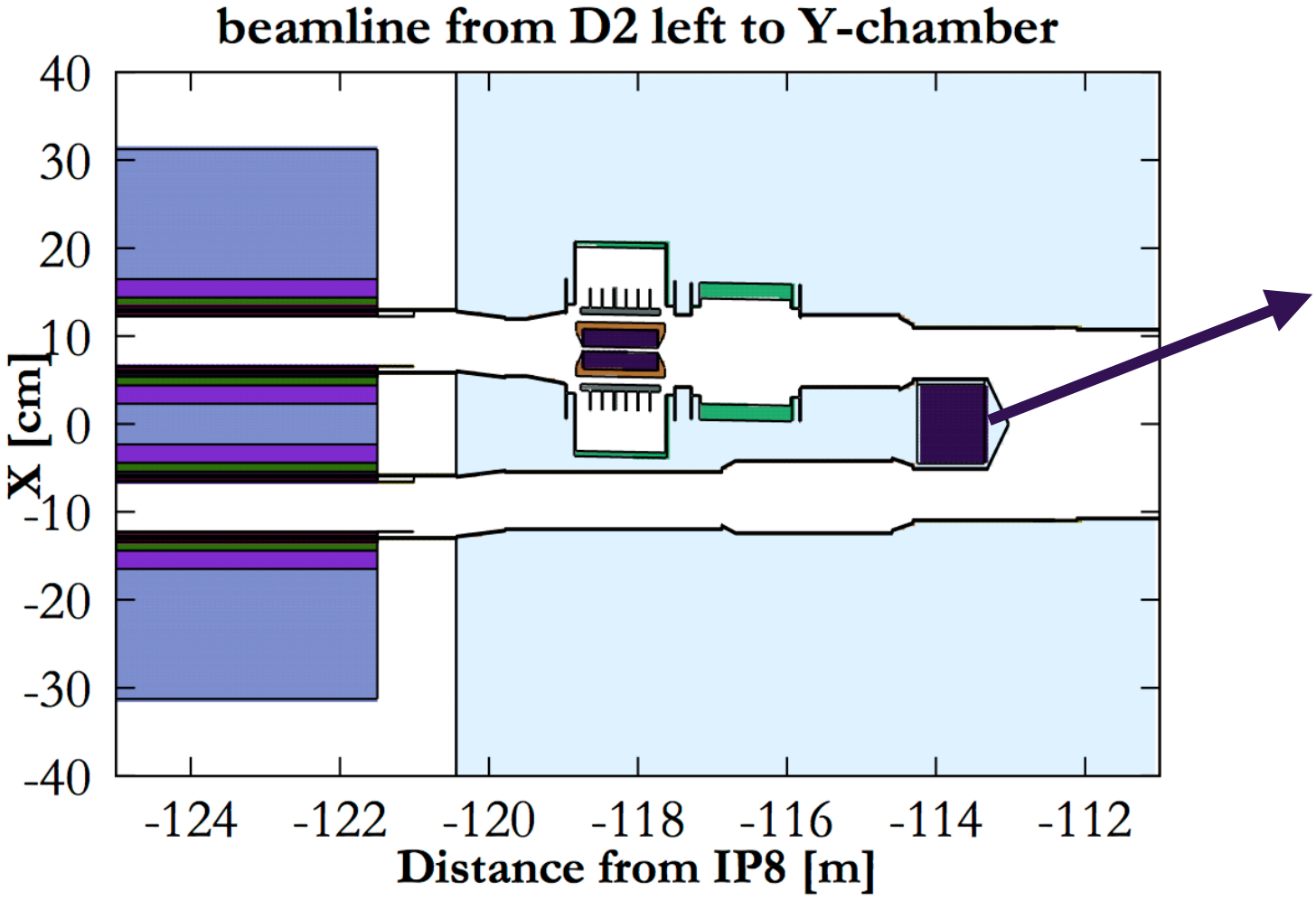
TAN aperture?





TAN-like absorber in Point 8

Absorber in front of D2 in Point 8



absorber block

tungsten (INERMET 180)
9 cm × 12 cm × 90 cm
5 mm clearance with
each beam pipe

presently in this location
is installed the BRAN

TUPRO020 poster at IPAC 2014, CERN-ACC-2014-0142,
A. Santamaria, L. S. Esposito, R. Alemany, H. Burkhardt, F. Cerutti, N.V. Shetty

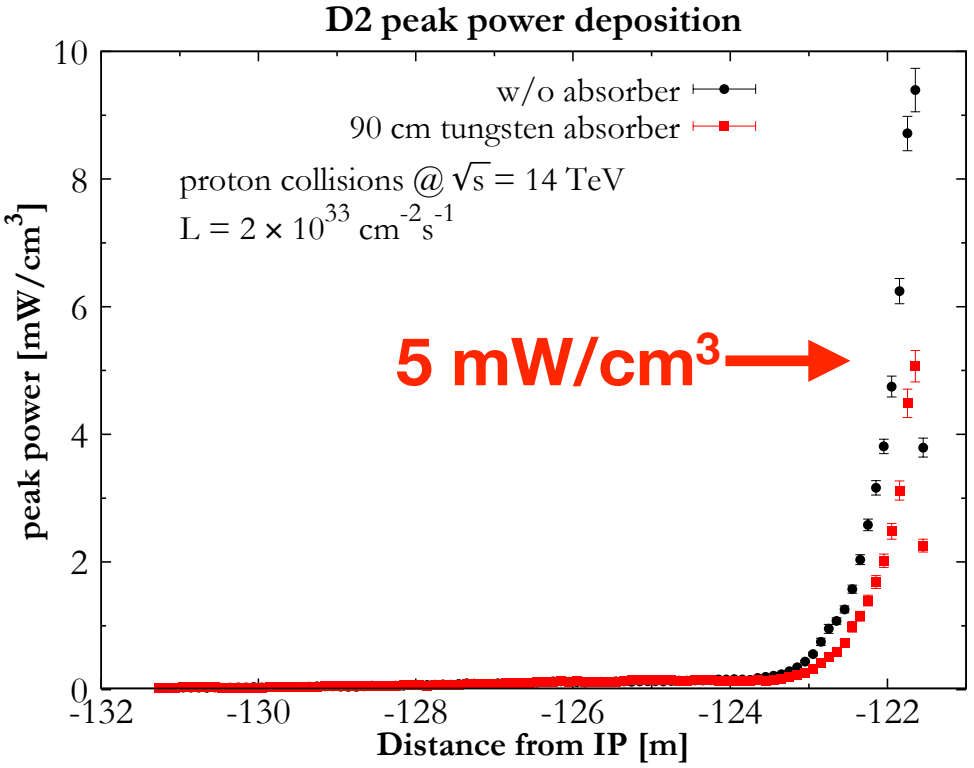
Acknowledgments: C. Collazos, J.P. Corso, P. Fessia and Y. Muttoni

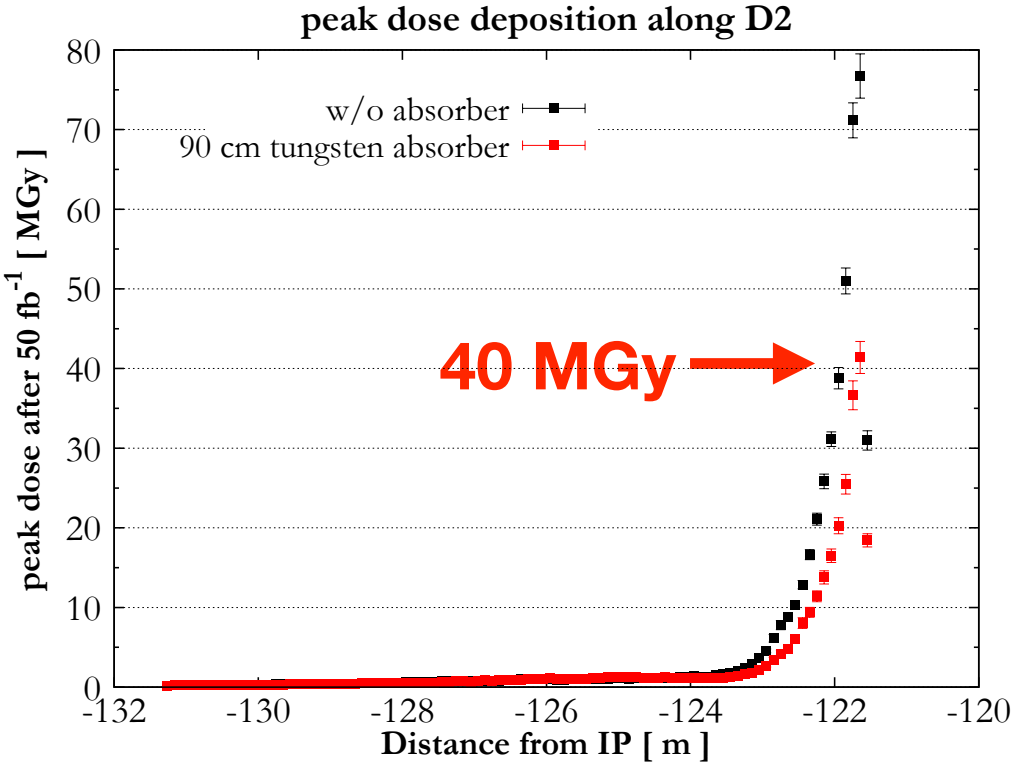
Energy deposition on D2 in Point 8

@ 2 10^{33} cm^{-2} s^{-1} (power), 50 fb-1 (dose)
385 urad half horizontal crossing angle

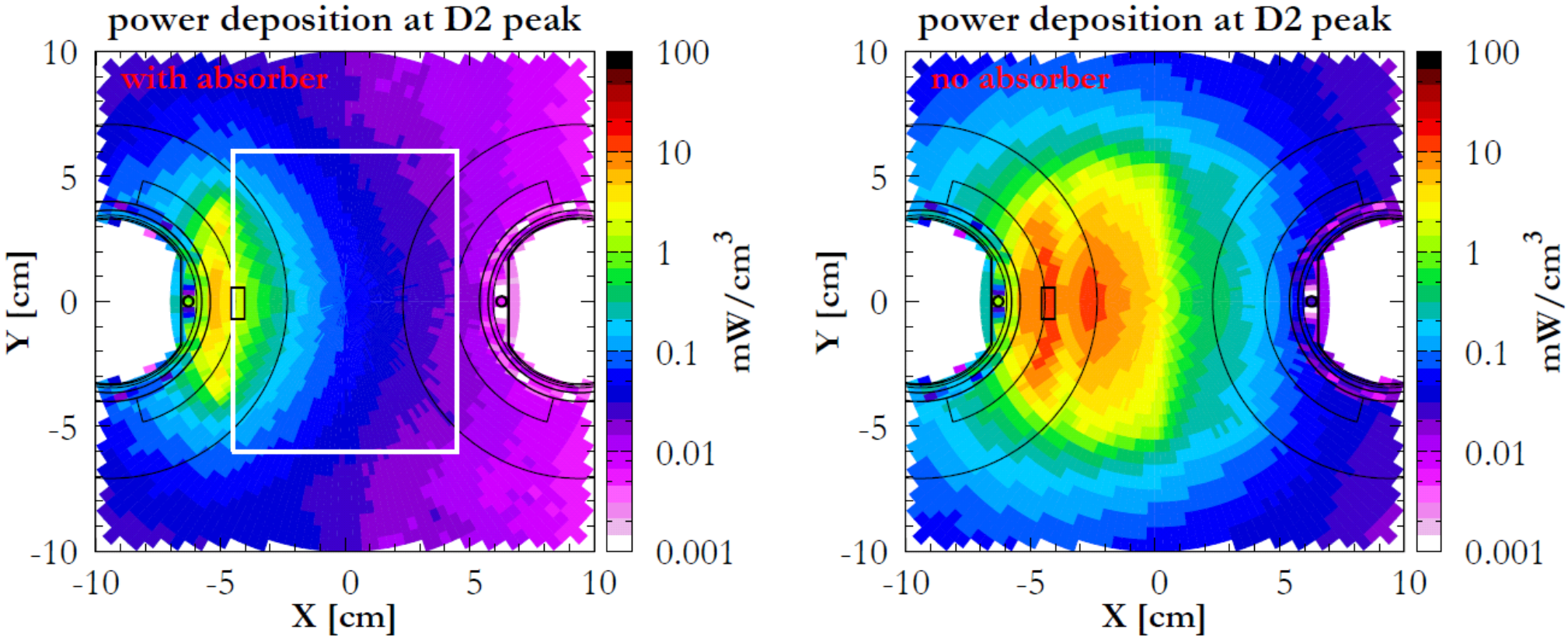
Total Power Deposited [W]

Absorber	None	W
Absorber	-	19
D2	24	8.6





Additional mask



a frontal mask on the IP side of the D2 internal beam tube is recommended in addition

Summary and outlook

- Energy deposition on the D2-Q4 magnets depends on crossing angle and collimator aperture
- Present TCL set to smaller aperture (flat optics) features a leakage external to the inner jaw
- A **larger collimator** can give additional protection, thus allowing to
  ⇒ remove the mask
  ⇒ provide flexibility for different optics schemes
- **Longitudinal space** can be recovered by shortening the TAXN effective length and/or using W inserts
  ⇒ no need to displace TCTs
  ⇒ possibly paving the way for further optimisation (TAXN closer to D2, …)
- **TCLX mechanical design** and **transverse space** for the collimators in the TAXN-D2 still to be addressed
- Is 1÷2 W power on Crab cavities acceptable? Calls for further investigations
- A mini TAN absorber and additional masks are recommended in front of D2's in Point 8
- Calculations ongoing for BBLR capacitor