TCLM4 mask optimization for magnet protection effectiveness and optics flexibility

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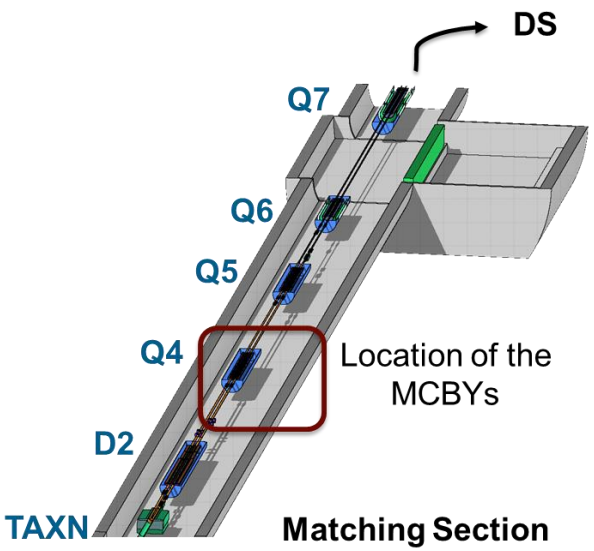
WP10

Energy deposition & R2E

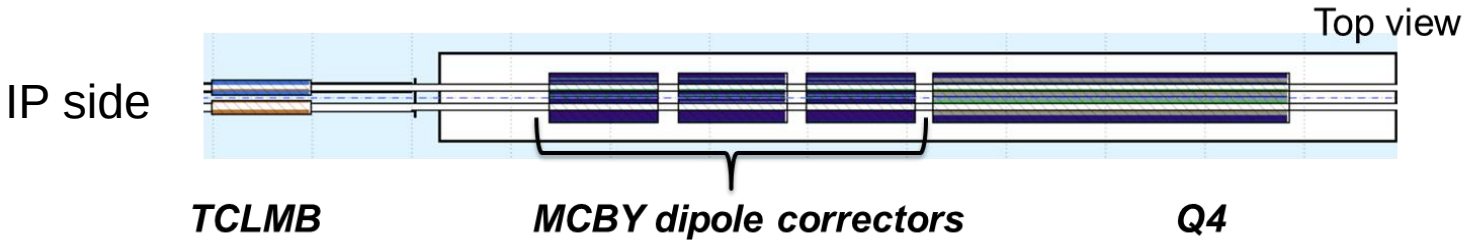
Deep acknowledgments: C. Accettura, R. De Maria, E. Grenier-Boley, F.X. Nuiry, R. Tomas Garcia, …

The context



- **MCBY**s: correctors in Q4-assembly.
- Less radiation resistant than Q4.
- TCLMB mask designed to reduce the radiation due to p-p collision debris.

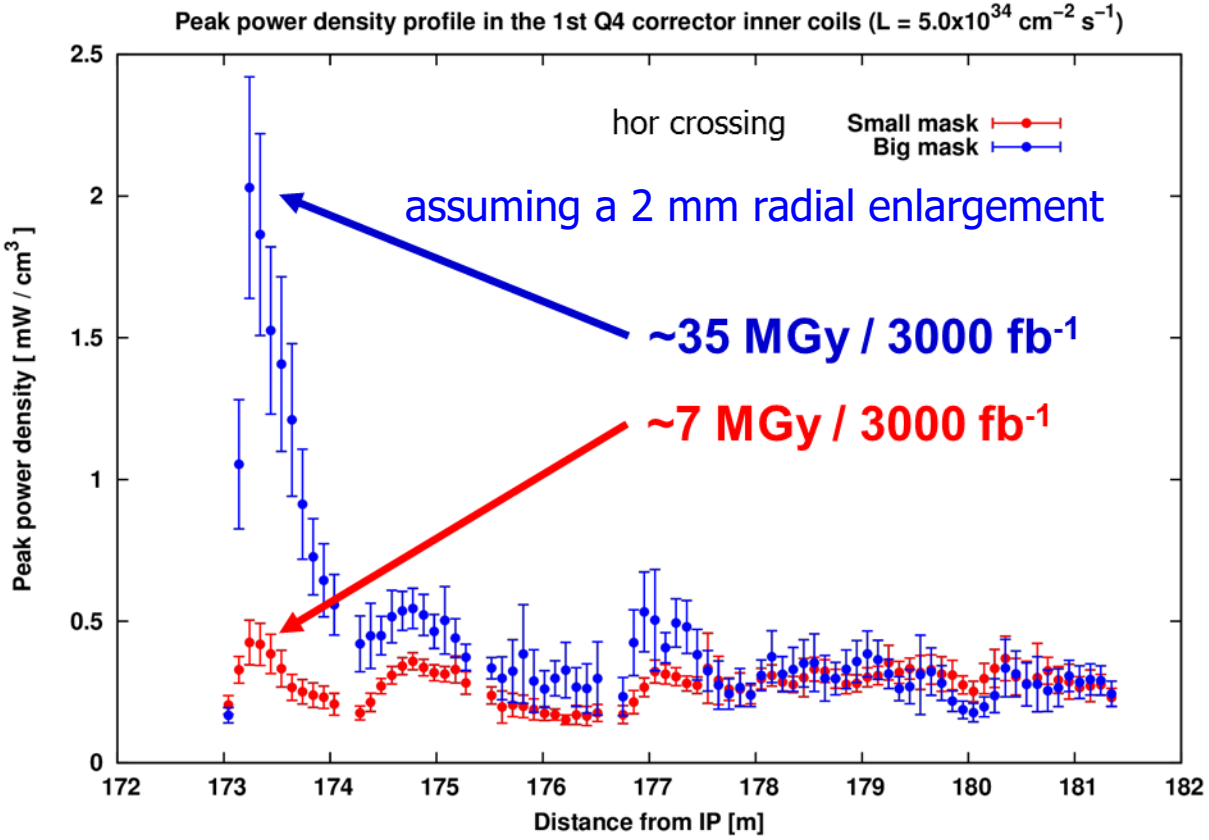
- HL-LHC optics version 1.5 (Nov.19) for IR1/5
- Fixed half crossing angle of 250 μrad.
- p-p collisions (σ = 85 mb) at 7+7 TeV.



https://indico.cern.ch/event/1167566 Jun 7th, 2022

An object known to be delicate

7th HL-LHC Collaboration Meeting, CIEMAT, Madrid Nov 14th, 2017



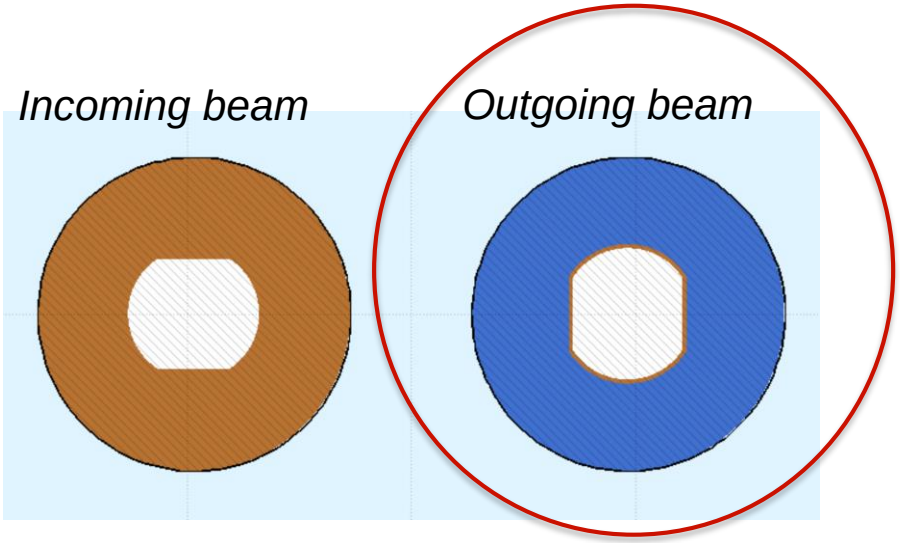
TCLMB model: considered modifications

Baseline

Δx = 5.06 cm flat separation

R_{in}= 3.01 cm circle radius

Cu pipe thickness = 1 mm



Larger aperture to account for mechanical tolerances

Δx = 5.22 cm

R_{in}= 3.09 cm

Cu pipe thickness = 1.8 mm

WP2 **WP10**

WP5

Limit scenario of the baseline configuration including mechanical/alignment tolerances

Reduced aperture to better protect the MCBYs

Δx = 4.9 cm

R_{in}= 2.93 cm

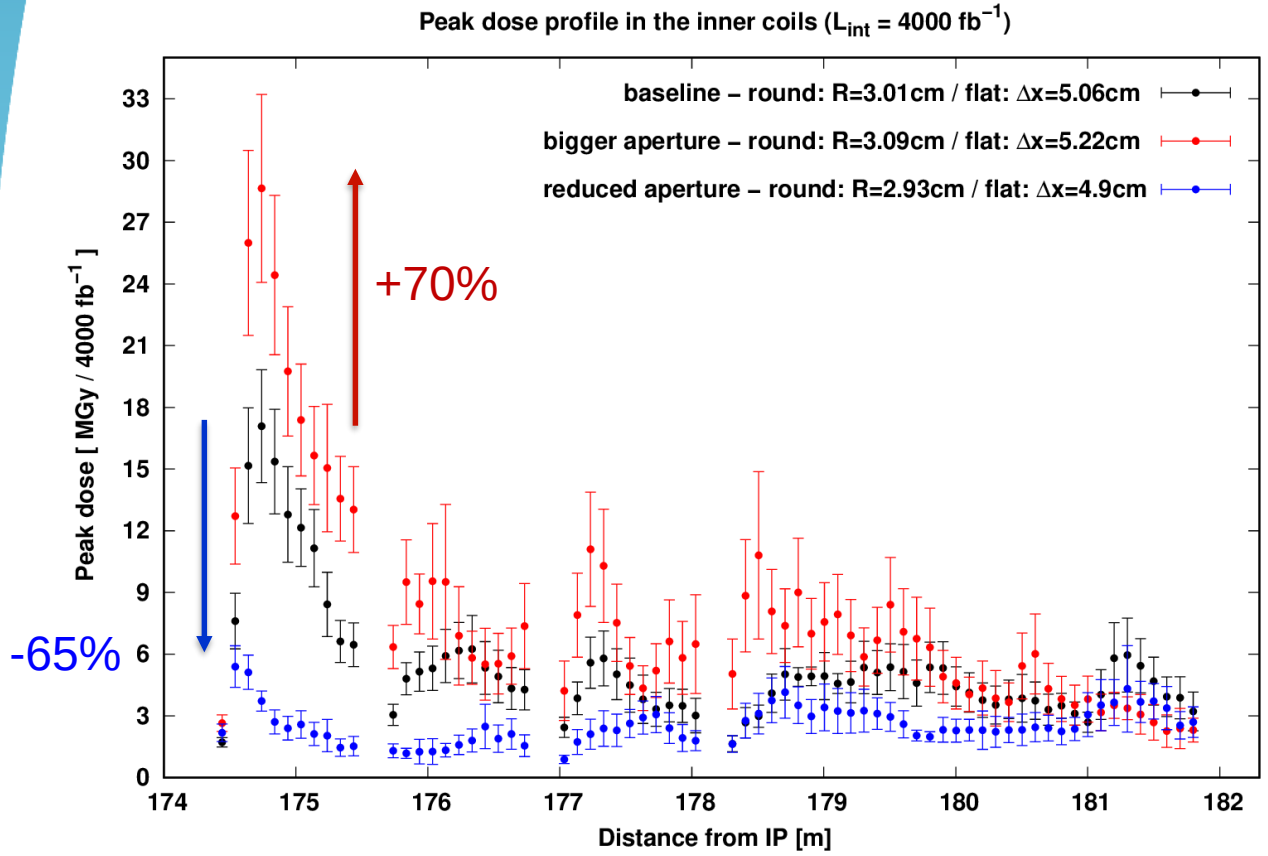
Cu pipe thickness = 1.8 mm

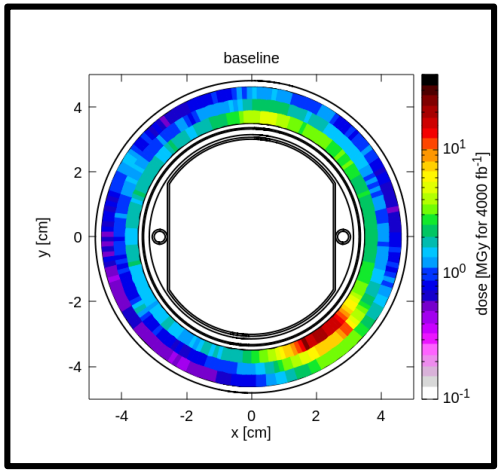
WP2 **WP10**

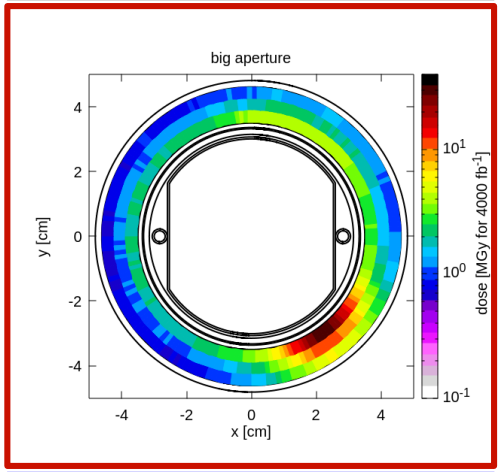
WP5

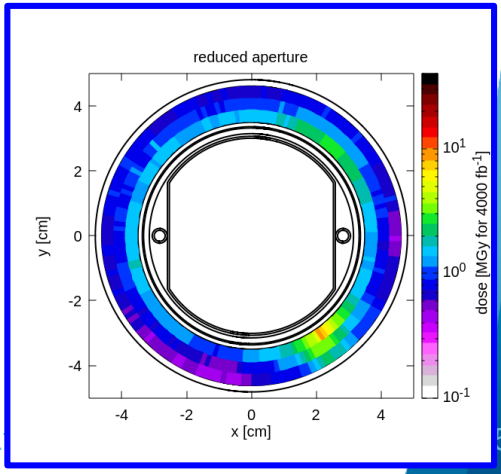
Offering room to allocate tolerances up to reaching in the worst-case the baseline configuration

Peak dose profile for the different apertures: IR5 – VC with +250 μrad half crossing angle



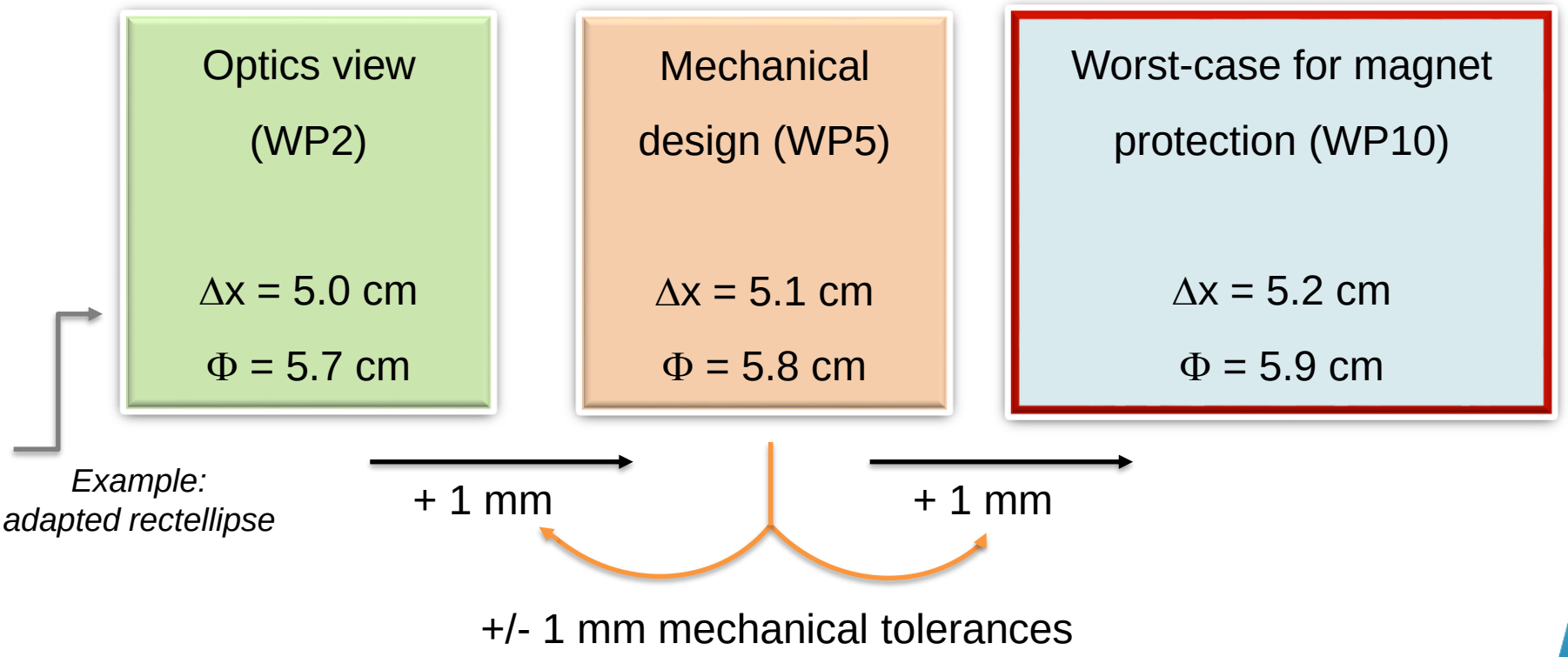




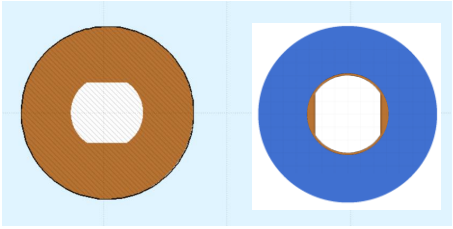


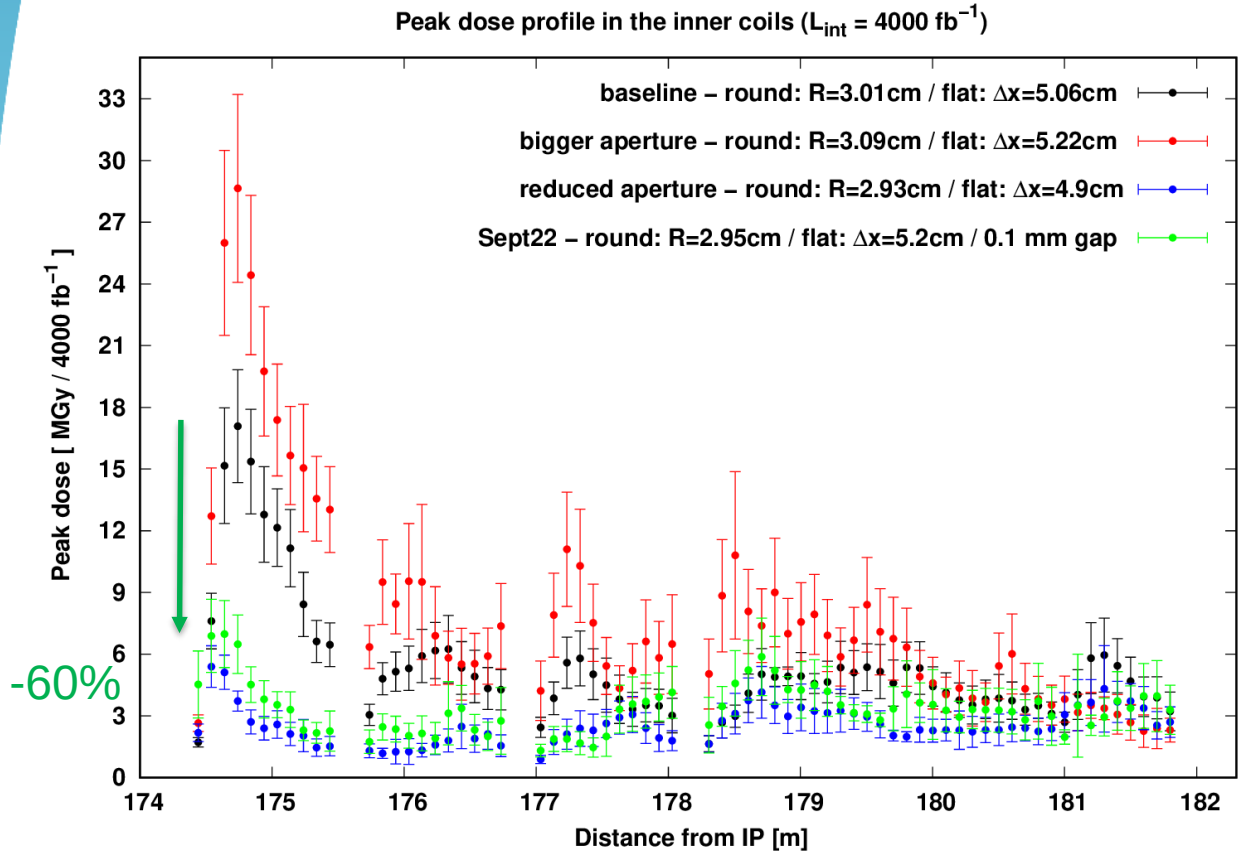
Aperture bargain: dimension assumptions

The dimensions of the mask aperture retained in the following for magnet dose calculations correspond to the worst-case scenario from the magnet protection point of view, where all tolerances maximize the actual mask aperture.

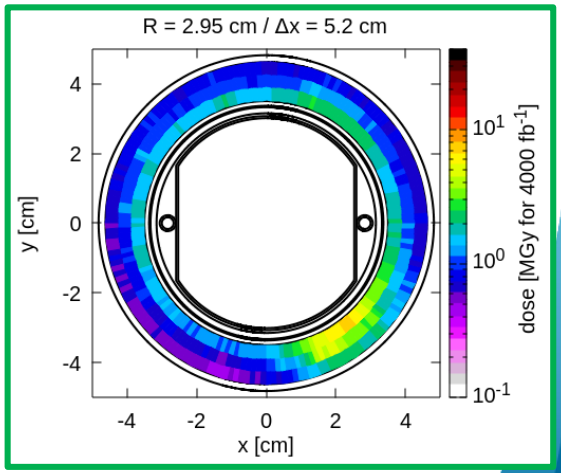


Peak dose profile for the different apertures: IR5 – VC with +250 μrad half crossing angle

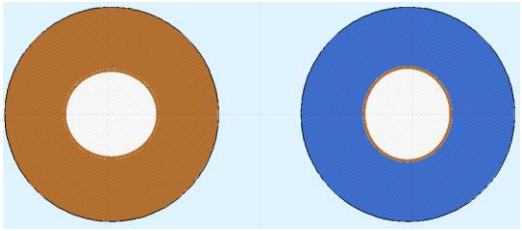


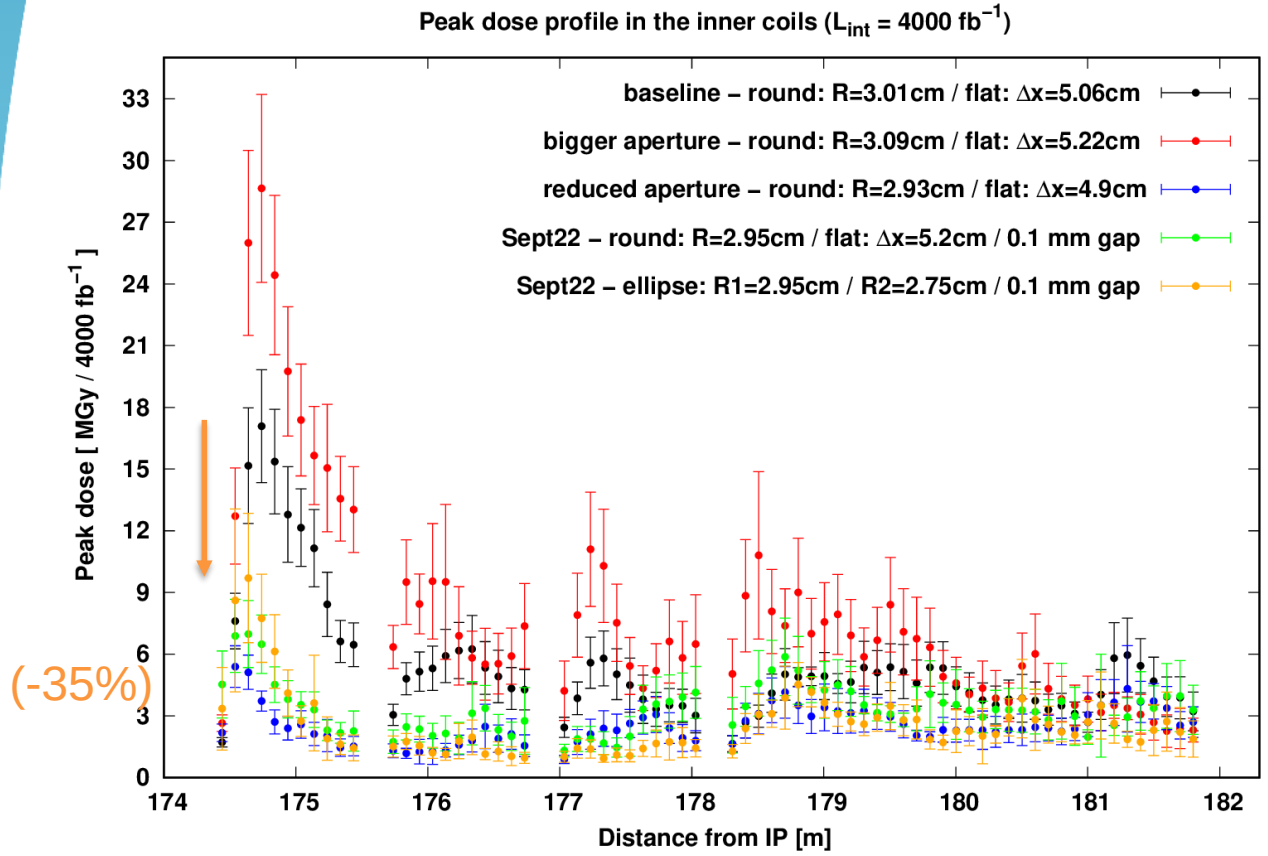


- Adapt the rectellipse by increasing the flat separation to gain beam aperture: from *Dx = 5.06* to *Dx = 5.2 cm*.
- and reducing the circle radius to lower the peak dose: from *R=3.01* cm to *R = 2.95 cm*.
- Inclusion of a **0.1 mm gap** between the Cu chamber and the inermet block.

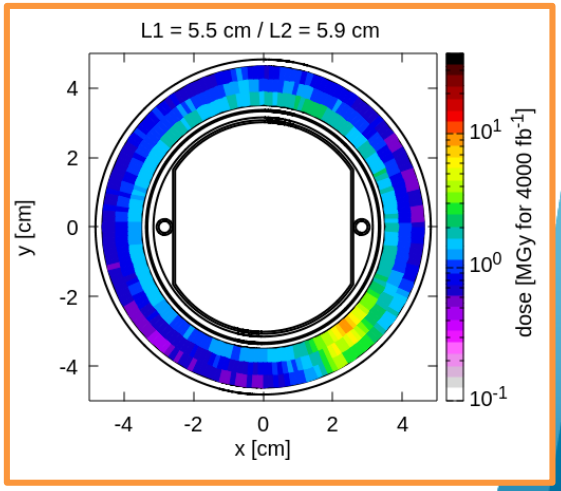


Peak dose profile for the different apertures: IR5 – VC with +250 μrad half crossing angle

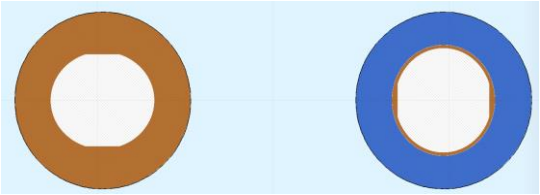


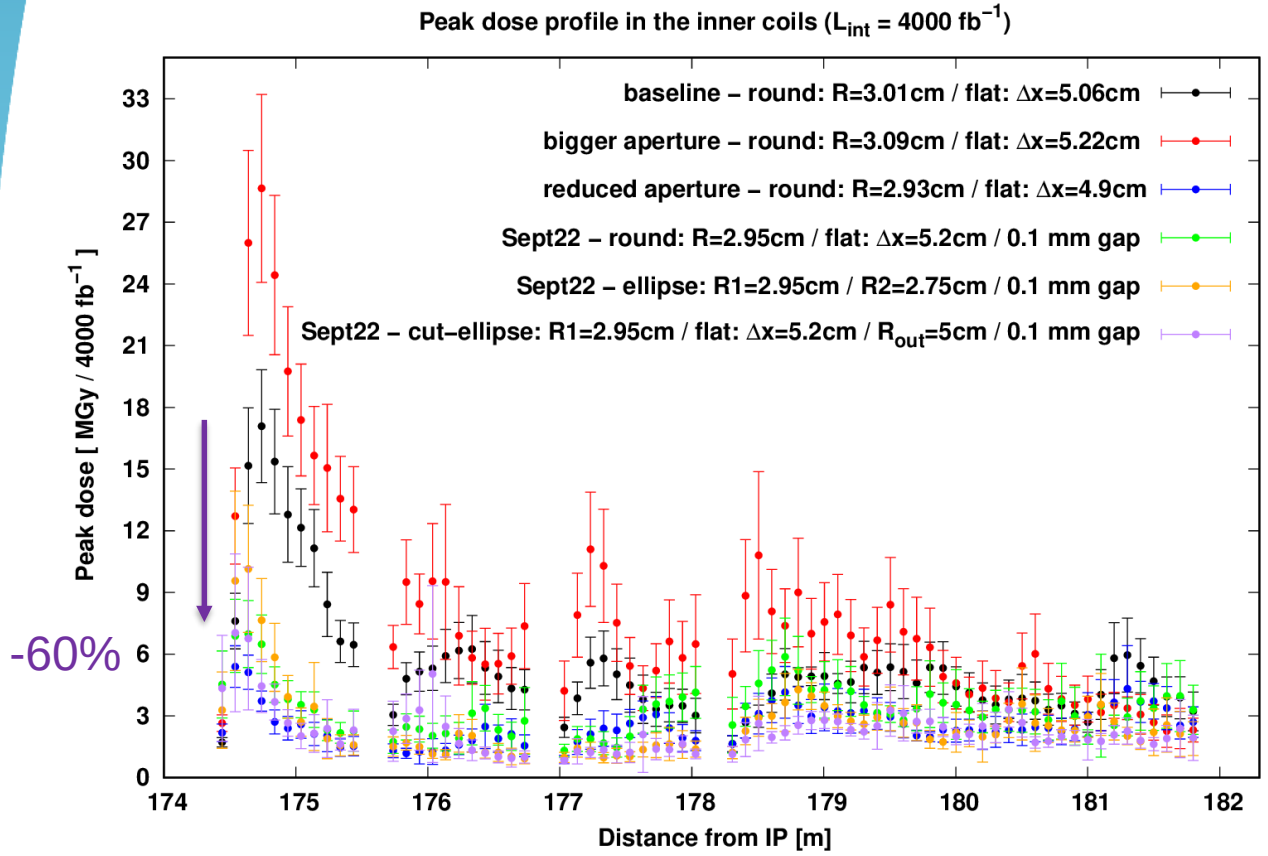


- Replace the rectellipse with a purely elliptical shape of:
  - *minor axis = 5.5 cm*
  - *major axis = 5.9 cm*
- Keep the 0.1 mm gap between the Cu chamber and the inermet block.



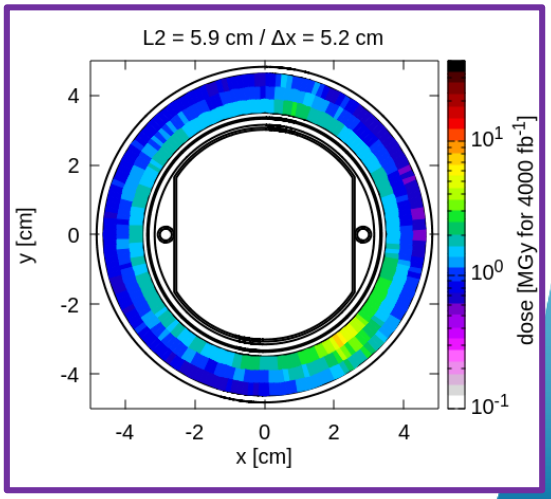
Peak dose profile for the different apertures: IR5 – VC with +250 μrad half crossing angle



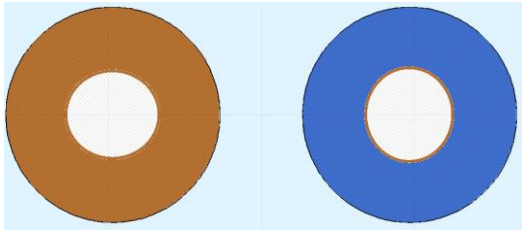


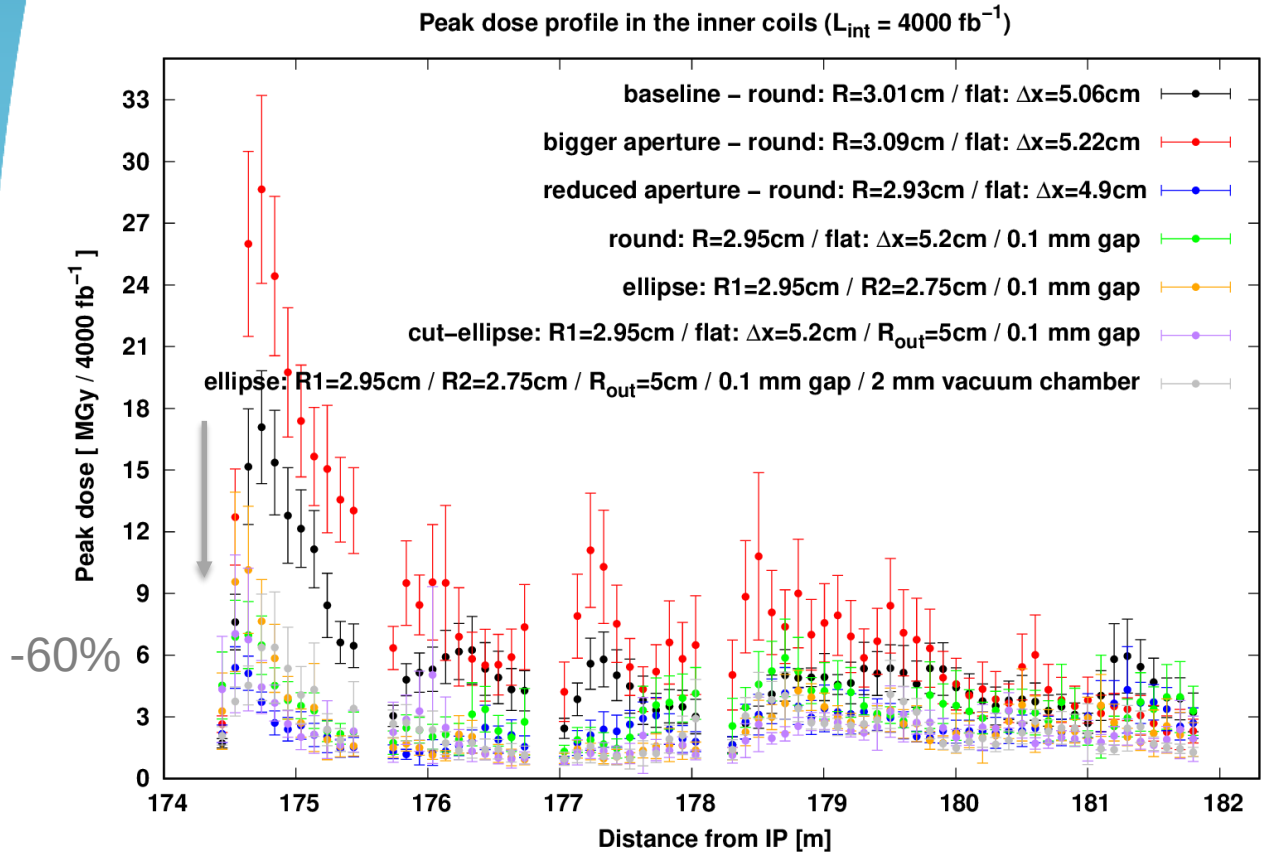
-60%

- Replace the rectellipse with a cut elliptical shape of:
  - *minor axis = 5.5 cm*
  - *→ Dx = 5.2 cm*
  - *major axis = 5.9 cm*
- Keep the 0.1 mm gap between the Cu chamber and the inermet block.
- Limit the external radius to 5 cm.

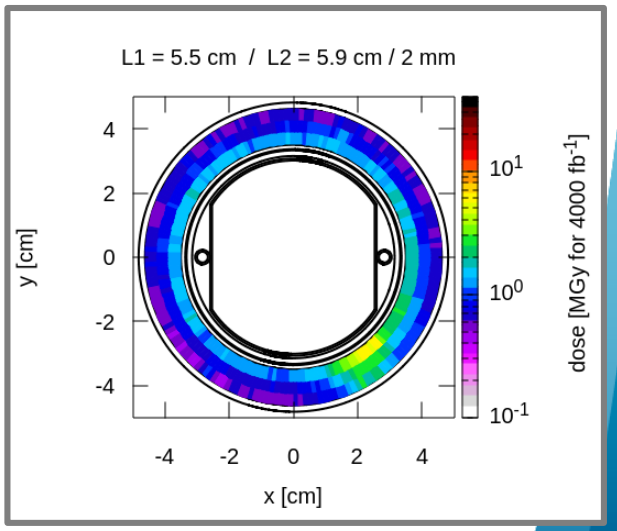


Peak dose profile for the different apertures: IR5 – VC with +250 μrad half crossing angle

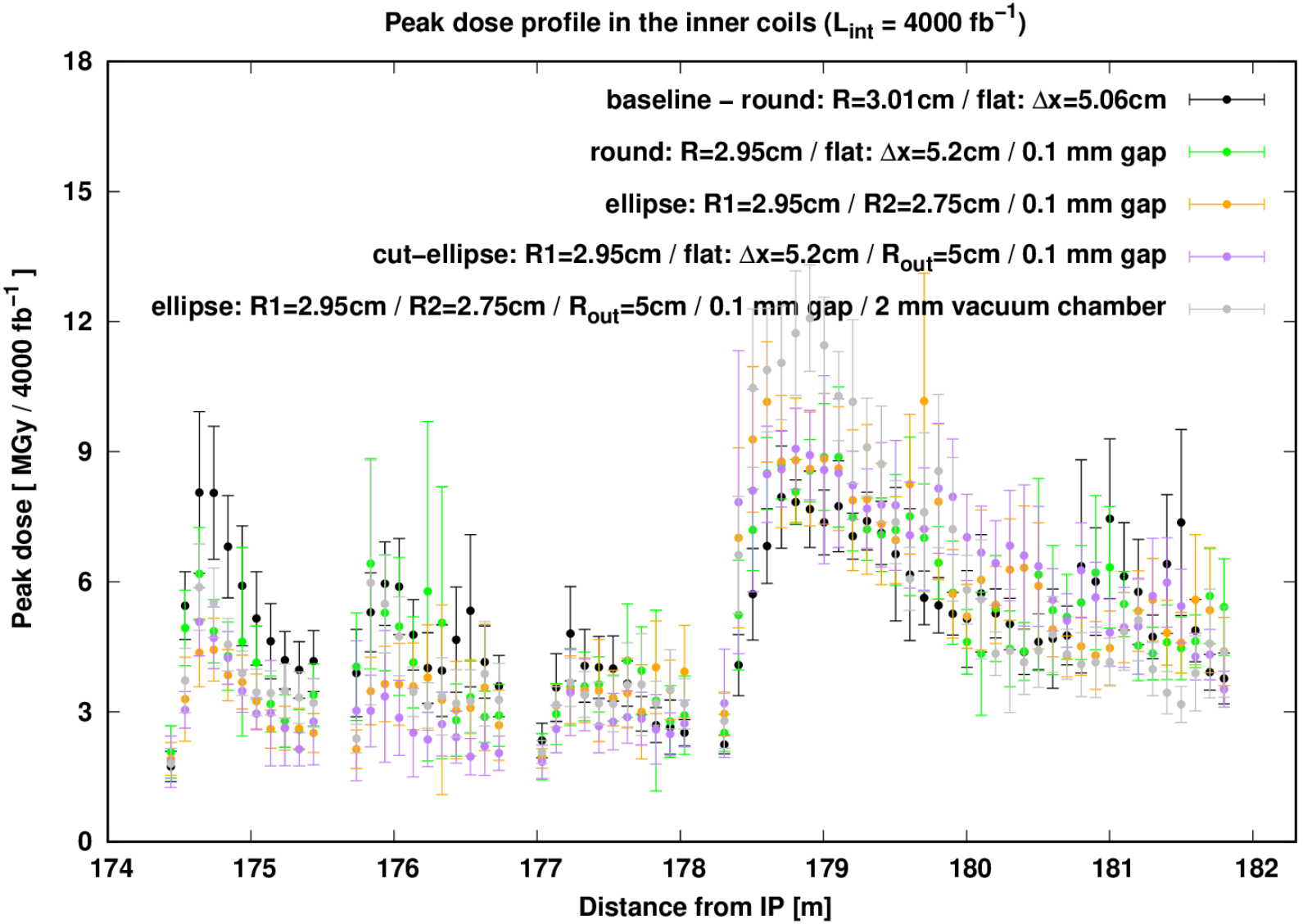




- Elliptical shape of:
  - *minor axis = 5.5 cm*
  - *major axis = 5.9 cm*
- Keep the 0.1 mm gap between the Cu chamber and the inermet block.
- Keep 5 cm external radius.
- Increase the **Cu chamber** thickness to **2 mm**.



Peak dose profile for the different apertures: IR1 – HC with 250 μrad half crossing angle



-20%

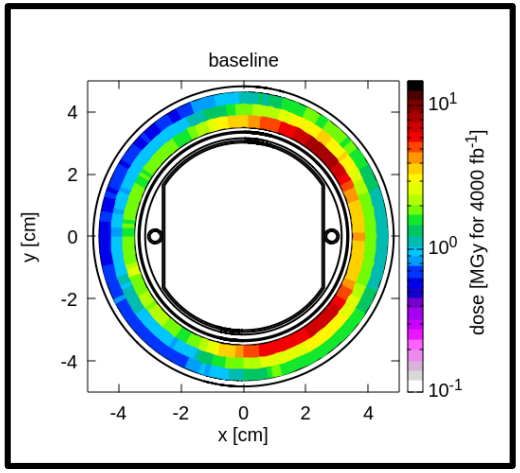
-45%

-35%

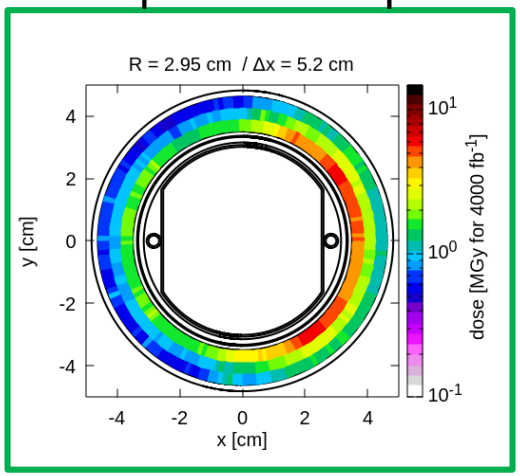
-25%

2D dose distribution at peak for the different apertures: IR1 – HC with 250 μrad half crossing angle

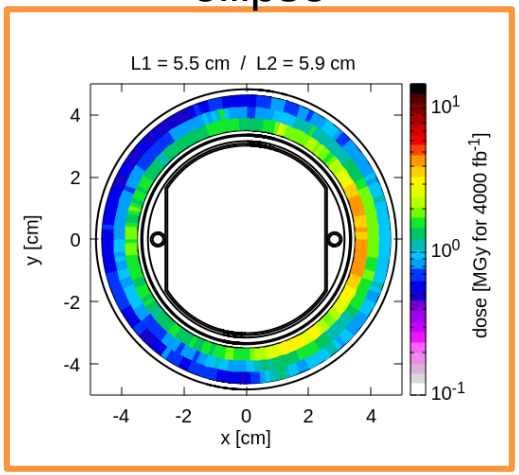
baseline



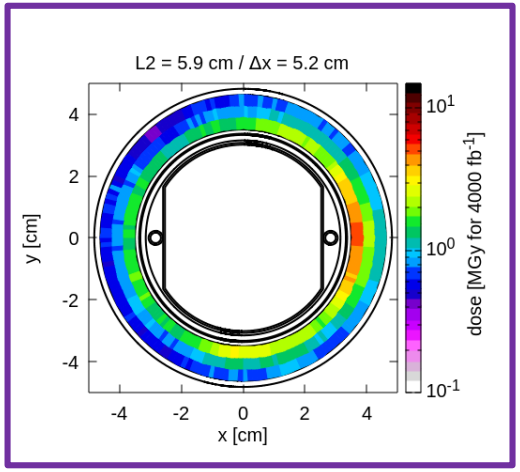
adapted rectellipse



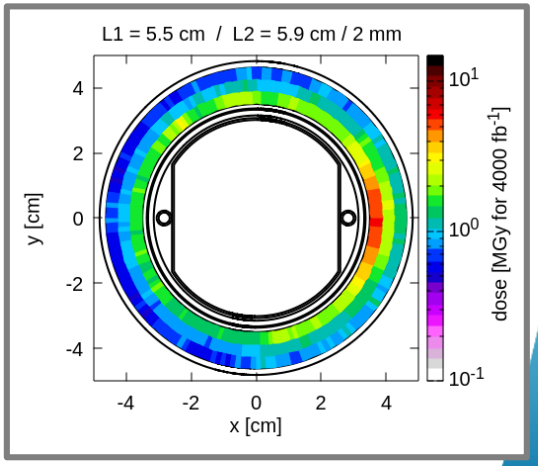
ellipse



cut ellipse



ellipse with 2mm Cu chamber



Cumulative dose for the full HL-LHC lifetime

Peak dose (MGy) after 3000 fb^{-1} / 4000 fb^{-1}	Aperture dimensions	HC	VC up+down
Baseline	Δx = 5.06 cm	6.0	6.4
	Φ = 6.02 cm	**8.0**	**8.6**
Adapted rectellipse	Δx = 5.2 cm	4.7	3.5
	Φ = 5.9 cm	**6.2**	**4.6**
Ellipse	L1 = 5.5 cm	3.3	4.3
	L2 = 5.9 cm	**4.4**	**5.7**
Cut Ellipse	Δx = 5.2 cm	3.8	3.2
	L2 = 5.9 cm	**5.0**	**4.3**
Ellipse with 2 mm Cu chamber	L1 = 5.5 cm	4.4	2.9
	L2 = 5.9 cm	**5.9**	**3.9**

Cumulative dose until each LS

Peak dose (MGy)	Run 4 560 fb^{-1}	Run 5 924 fb^{-1} / 1465 fb^{-1}	Run 6 1440 fb^{-1} / 1780 fb^{-1}	Total 3000 fb^{-1} / 4000 fb^{-1}
Baseline Δx = 5.06 cm / Φ = 6.02 cm	1.1 1.2	1.8 / **2.9** 2.0 / **3.1**	2.9 / **3.6** 3.1 / **3.8**	6.0 / **8.0** 6.4 / **8.6**
Adapted rectellipse Δx = 5.2 cm / Φ = 5.9 cm	0.9 0.6	1.4 / **2.3** 1.1 / **1.7**	2.2 / **2.8** 1.7 / **2.0**	4.7 / **6.2** 3.5 / **4.6**
Ellipse L1 = 5.5 cm / L2 = 5.9 cm	0.6 0.8	1.0 / **1.6** 1.3 / **2.1**	1.6 / **2.0** 2.1 / **2.5**	3.3 / **4.4** 4.3 / **5.7**
Cut Ellipse Δx = 5.2 cm / L2 = 5.9 cm	0.7 0.6	1.2 / **1.8** 1.0 / **1.6**	1.8 / **2.2** 1.5 / **1.9**	3.8 / **5.0** 3.2 / **4.3**
Ellipse with 2 mm Cu chamber	0.8 0.5	1.4 / **2.2** 0.9 / **1.4**	2.1 / **2.6** 1.4 / **1.7**	4.4 / **5.9** 2.9 / **3.9**

*HC *VC up+down

Summary

- Various shapes of the TCLMB aperture for the outgoing beam were studied in FLUKA:
  1. Adapted rectellipse with increased flat separation and reduced circle radius;
  2. Plain ellipse;
  3. Cut ellipse with flat separation as 1.;
  4. Same ellipse as 2. with Cu chamber thickness increased to standard 2 mm.

- The simulation include in all cases the worst-case tolerances (+ 1 mm) as well as a 0.1 mm gap between the Cu chamber and the inermet block.

- For 3. and 4., the mask external radius was reduced from 7 to 5 cm.

- From the magnet protection point of view, all cases result in a *significant improvement* with respect to the baseline presented at the 111th TCC, being the **cut ellipse** (with 1.8 mm thick Cu chamber) the best solution.