TCLM4 design optimization studies

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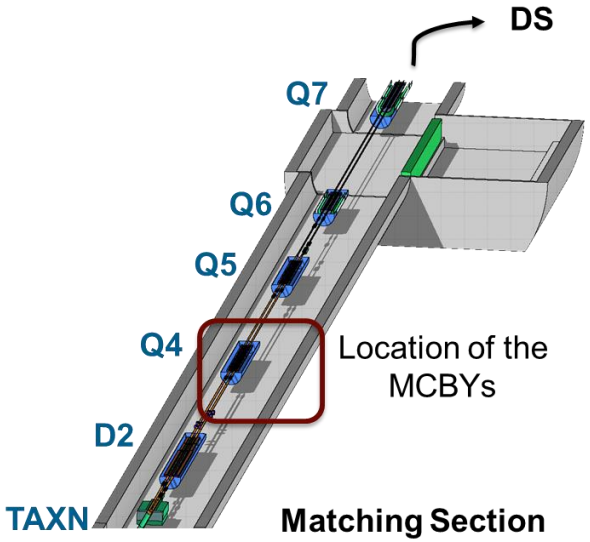
With input from Riccardo De Maria and Francois-Xavier Nuiry

WP10 Energy deposition & R2E

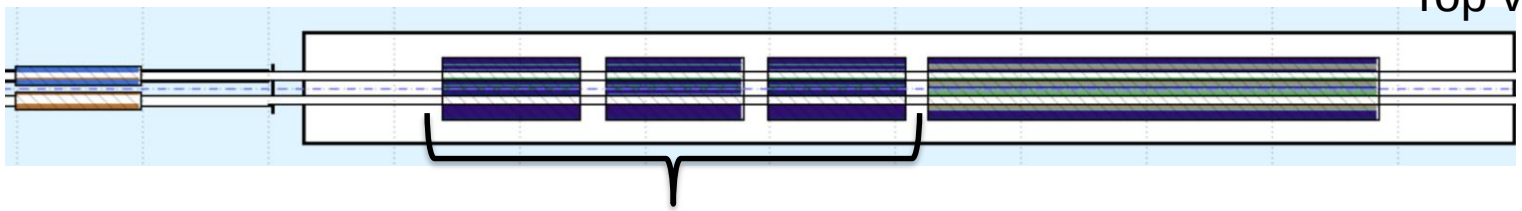
HL-LHC WP2/4/5 joint meeting 7th June 2022

Context of the discussion

- The MCBYs are the dipole correctors in Q4-assembly.
- The technology they are based on is not as radiation resistant as the one for the Q4 in the same assembly.
- TCLMB masks are placed upstream the assembly in order to protect the MCBYs reducing the loads from the p-p collision debris.



Top view



TCLMB ***MCBY dipole correctors*** ***Q4***

FLUKA simulations configuration

Point 1 and 5 for HL-LHC machine.

Horizontal and Vertical crossing angle:

- **Fixed half crossing angle: upper limit at 250 μrad.**

HL-LHC optics version 1.5 (2019).

p-p collisions (σ = 85 mb) at 7+7 TeV.

Integrated luminosity:

- **Ultimate conditions 4000 fb^{-1}.**
- **Run 4/5/6.**

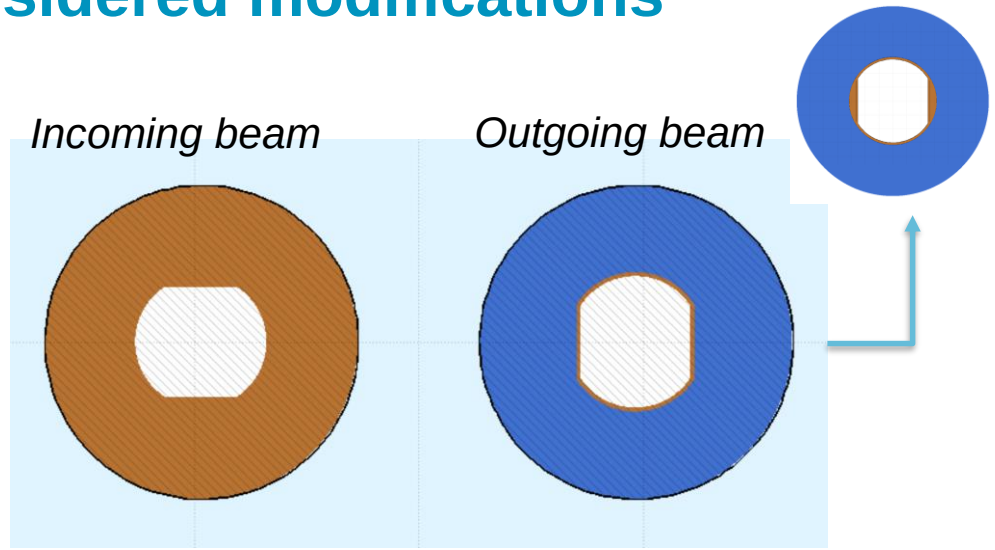
TCLMB model: considered modifications

Baseline

Δx = 5.06 cm

R_{in}= 3.01 cm

Cu pipe thickness pipe = 1 mm



Larger aperture to mimic mechanical/alignment tolerances

Δx = 5.22 cm

R_{in}= 3.09 cm

Cu pipe thickness pipe = 1.8 mm

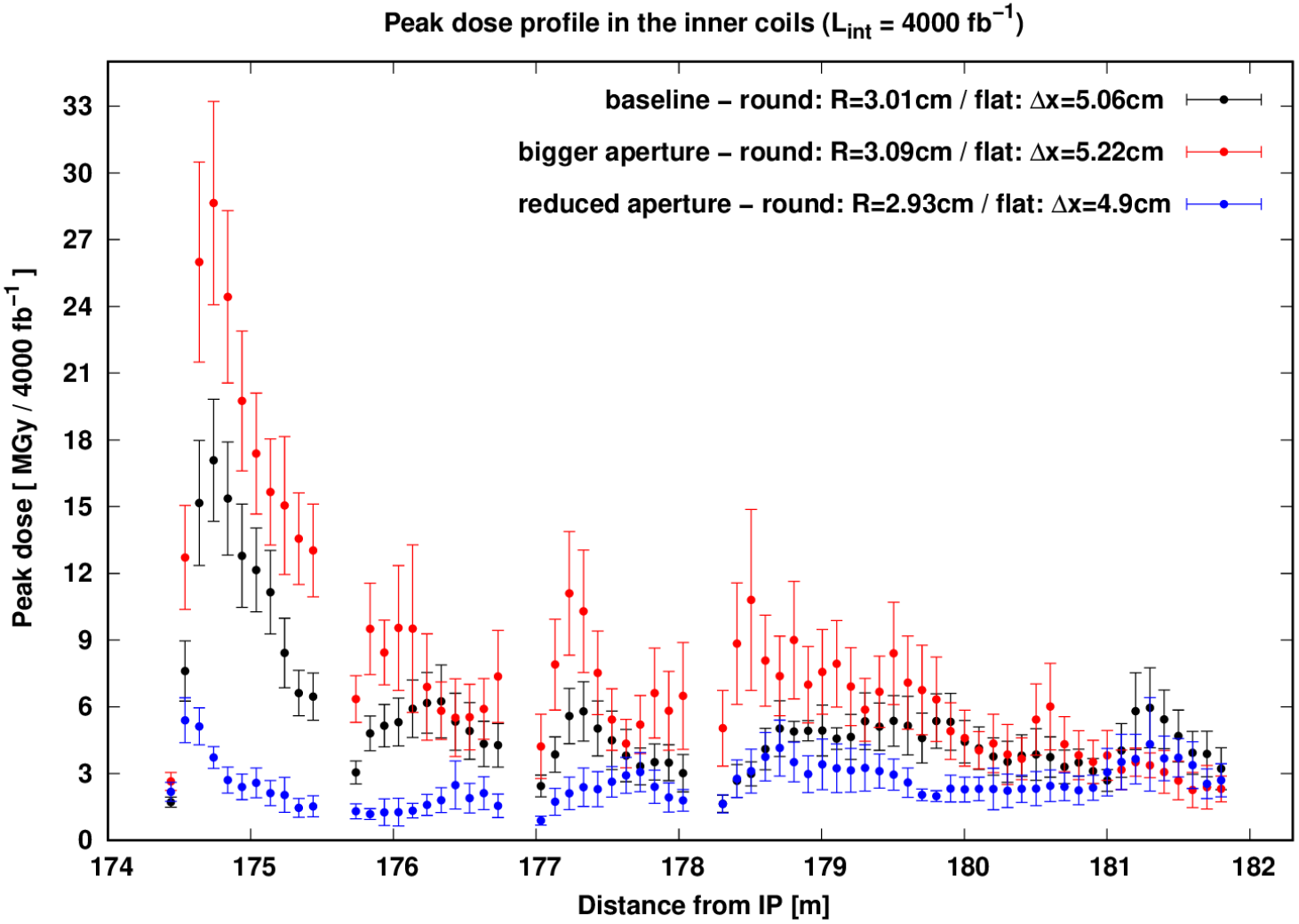
Reduce aperture to better protect the MCBYs

Δx = 4.9 cm

R_{in}= 2.93 cm

Cu pipe thickness pipe = 1.8 mm

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



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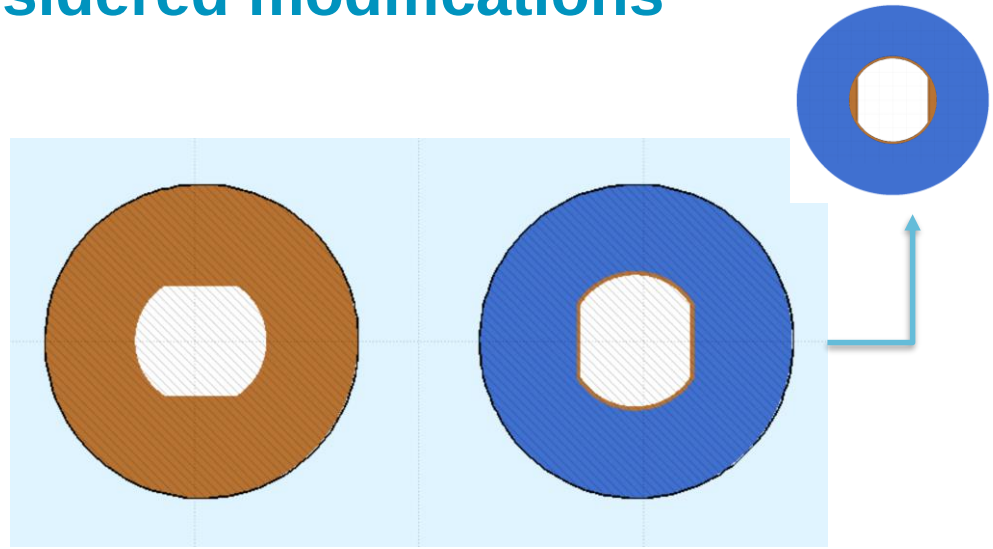

Larger aperture to mimic mechanical tolerances

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WP2 **WP10**

WP5

Limit situation of baseline configuration plus mechanical/alignment tolerances

Reduce aperture to better protect the MCBYs

Δx = 4.9 cm

R_{in}= 2.93 cm

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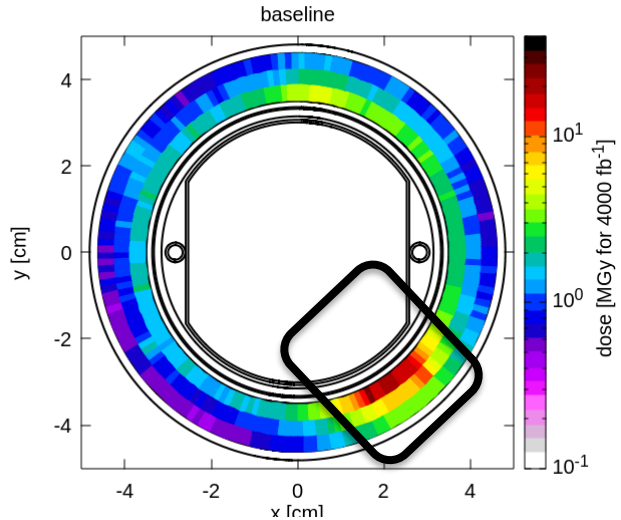
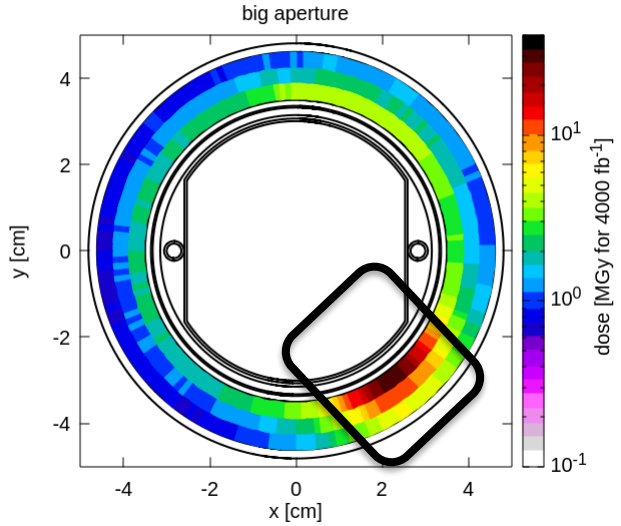
WP2 **WP10**

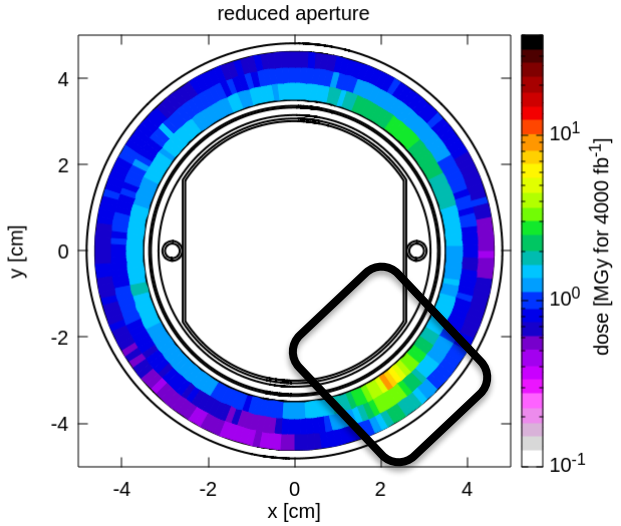
WP5

There is room (up to the baseline configuration) to allocate mechanical/alignment tolerances

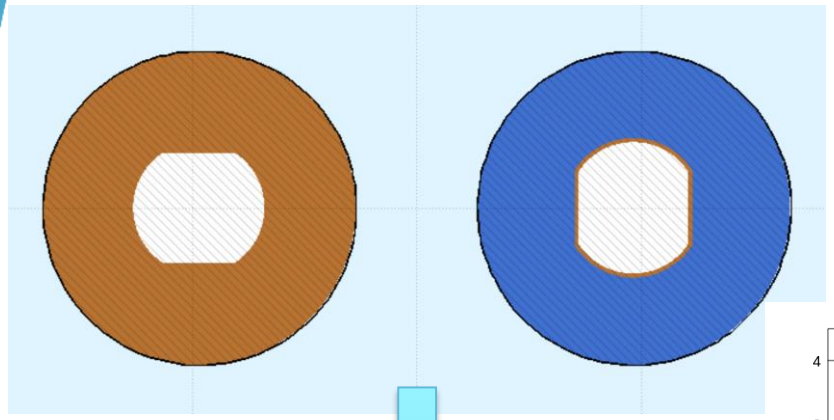
2D distribution of dose at peak in MCBY for VC-up



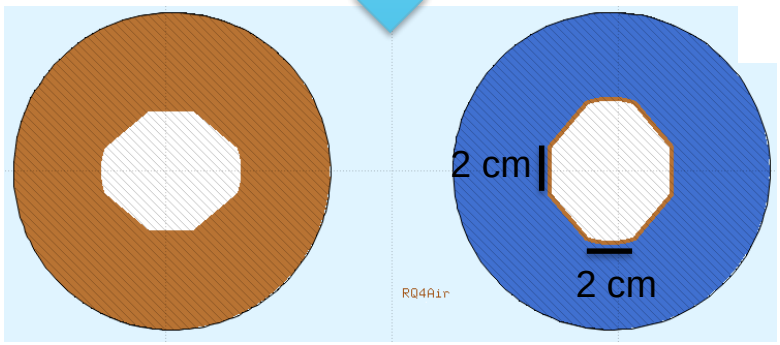


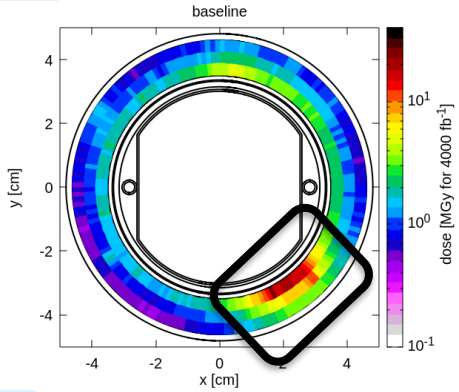


TCLMB model: considered modifications



Thanks to R. De Maria and F-X. Nuiry





Baseline

$\Delta x = 5.06$ cm

$R_{in} = 3.01$ cm

Cu pipe thickness pipe = 1 mm

Shielding + larger aperture

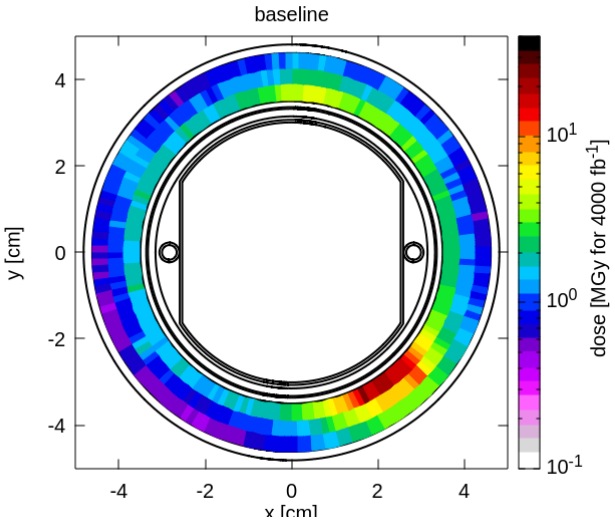
$\Delta x = 5.22$ cm

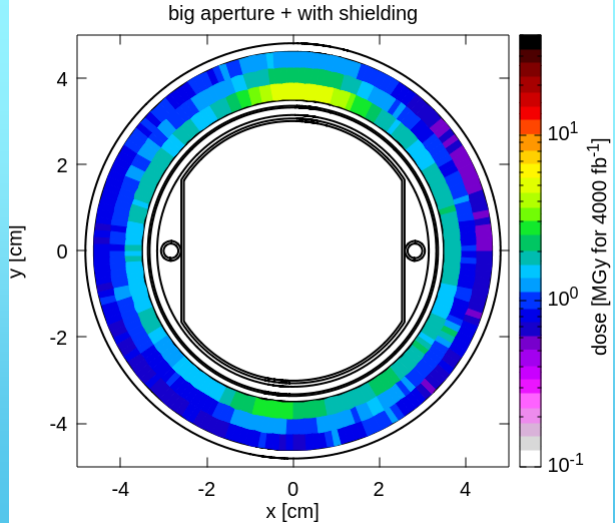
$R_{in} = 3.09$ cm

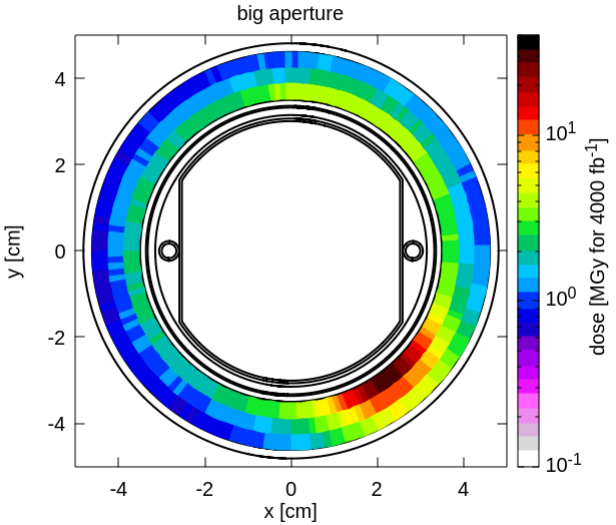
Cu pipe thickness pipe = 1.8 mm

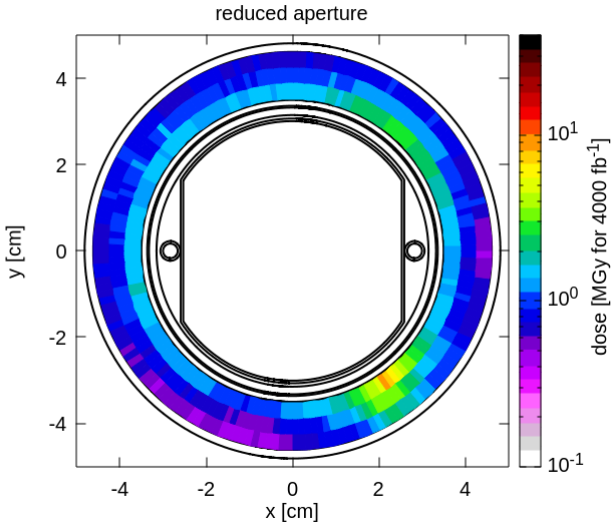
Additional inermet shielding at 40^0-45^0

2D distribution of dose at peak in MCBY for VC-up

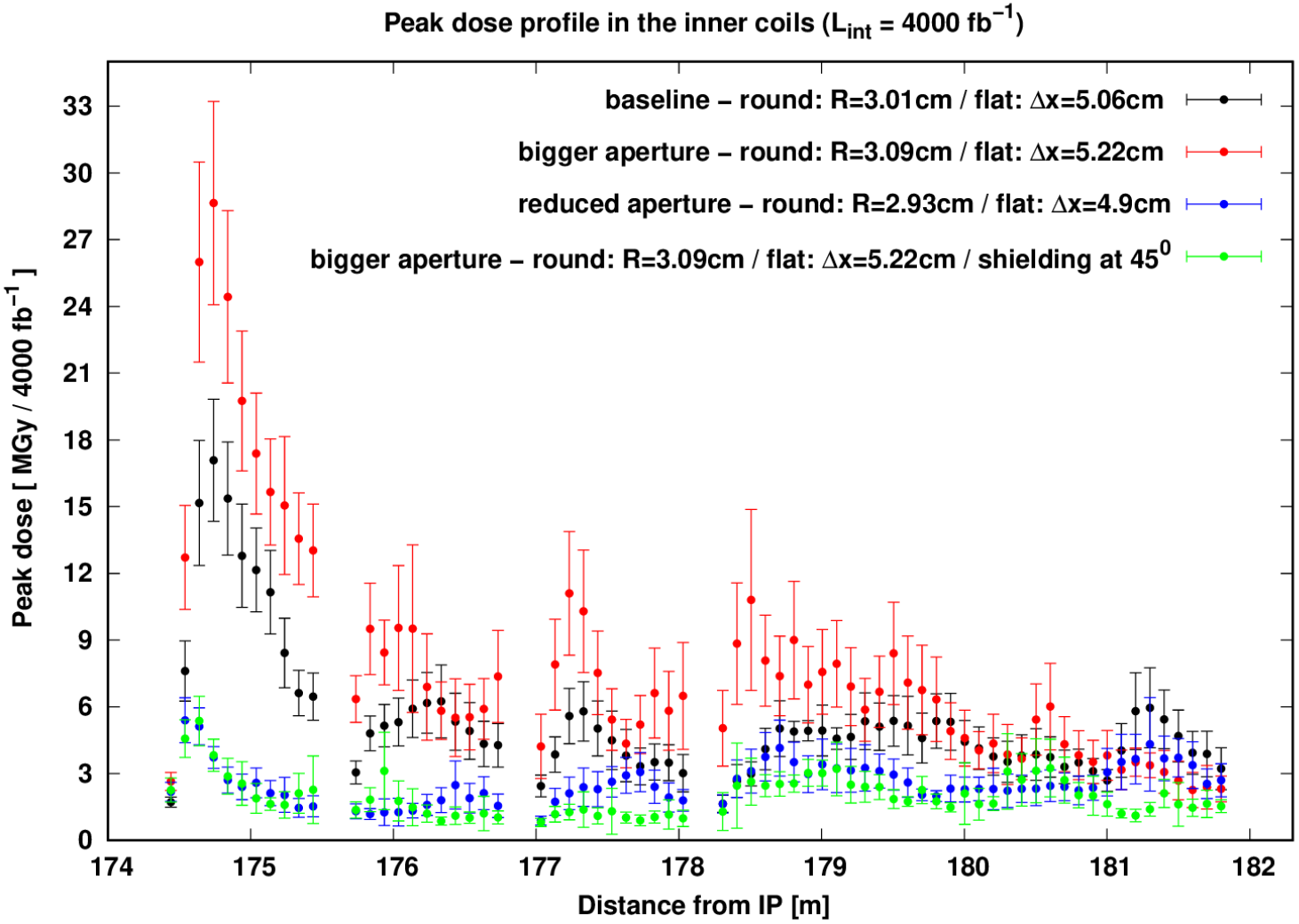




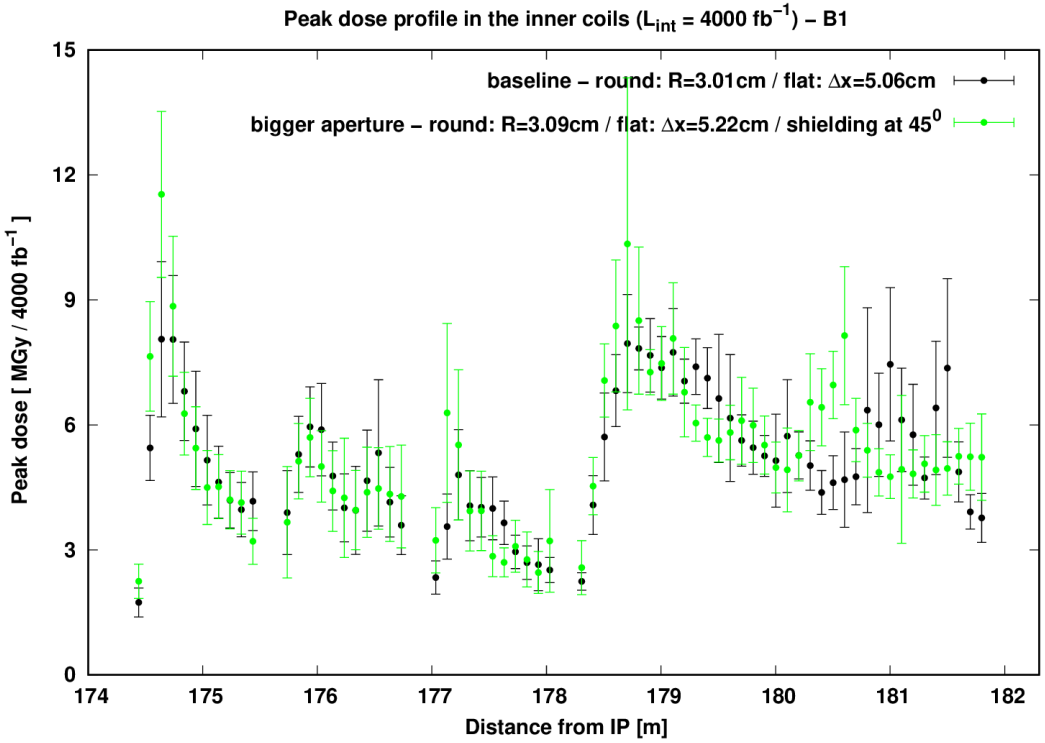


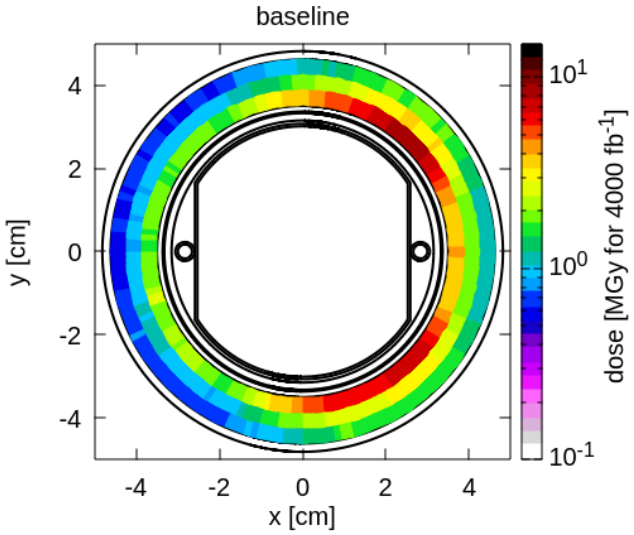


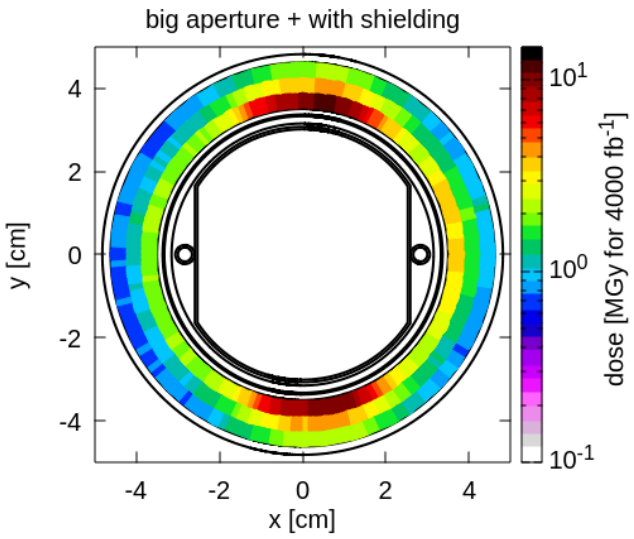
Peak dose distribution for the different configurations: IR5 – VC with +250 μrad half crossing angle



Peak dose distribution for the different configurations: IR1 – HC with +250 μrad half crossing angle







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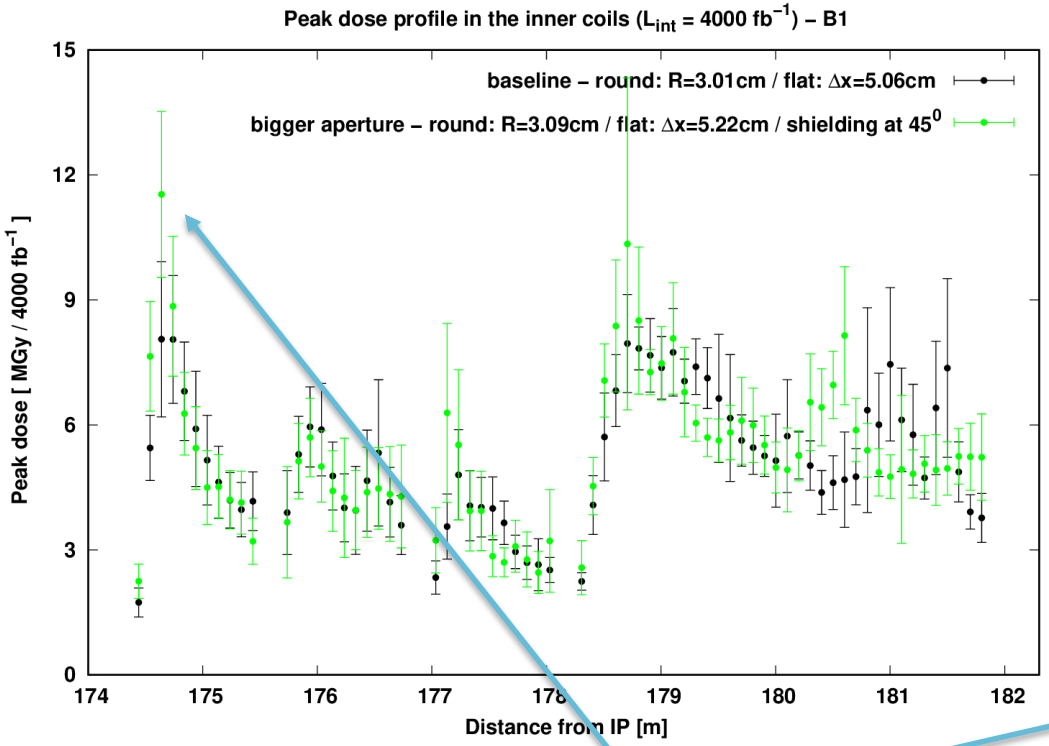

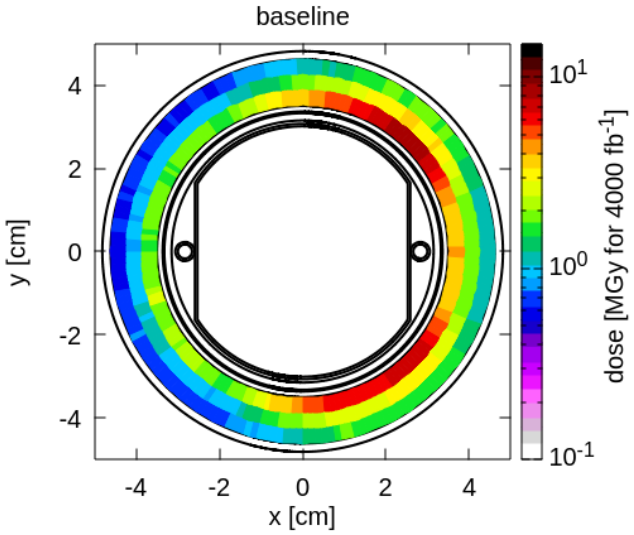

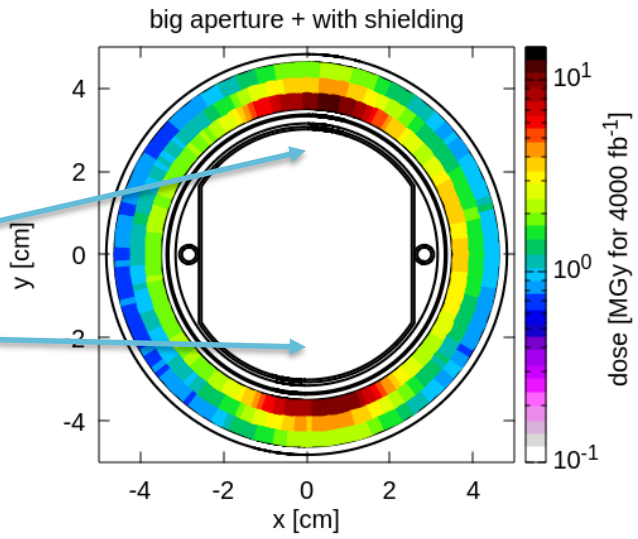

Worsening (+30%) due to the increase of the aperture in the vertical plane.

During Run 4 560 fb^{-1}	Baseline	Big aperture + inermet-shielding
HC	1.1	1.6
VC Up/Down	1.2	0.8

------ LS4 ----------

During Run 5 924 / **1465** fb^{-1}	Baseline	Big aperture + inermet-shielding
HC	1.8 / **2.9**	2.7 / **4.2**
VC Up/Down	2.0 / **3.1**	1.2 / **2.0**

------ LS5 ----------

During Run 6 1440 / **1780** fb^{-1}	Baseline	Big aperture + inermet-shielding
HC	2.8 / **3.5**	4.1 / **5.1**
VC Up/Down	3.1 / **3.8**	1.9 / **2.4**

------ LS6 ----------

Peak dose on the 1st MCBY for Run4/5/6 and integrated for the whole operation of the machine

Total 3000 / **4000** fb^{-1}	Baseline	Big aperture + inermet-shielding	
HC	5.9 / **7.8**	8.6 / **11.5**	**+30%**
VC Up/Down	6.4 / **8.6**	4.1 / **5.5**	**-35%**

Summary (I)

- TCLMB design review triggered by WP5 in order to ensure that the mechanical and alignment tolerances were included in the energy deposition calculations.

- It was found that the peak dose at the first MCBY of Q4-assembly was highly increased when mimicking these tolerances and mechanical constrains. Therefore:
  - Comparison of 3 scenarios:
    - Baseline
    - Aperture reduced by 1.6 mm in both planes:

      → Not compatible with flat optics requirement.
    - Aperture increased by 1.6 mm in both planes:

      → Not fulfilling protection goals.

Summary (II)

- New design of the TCLMB with additional shielding at 40^0-45^0 in order to mitigate the impact on the 1st MCBY hot spot.
  - **IR5-VC: - 35 %** with respect to the baseline configuration.
  - **IR1-HC: + 30 %** with respect to the baseline configuration.

- This design is clearly beneficial for IR5-VC since the most exposed region is now covered by the additional inermet shielding.

- In case of IR1-HC, where the higher loads are in the vertical plane, this solution is worsening the situation if one allocates the mechanical/alignment tolerances.

- In view of these results, the discussion is open …