# IR1/5 radiation shielding

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**Thanks to the CERN FLUKA team**

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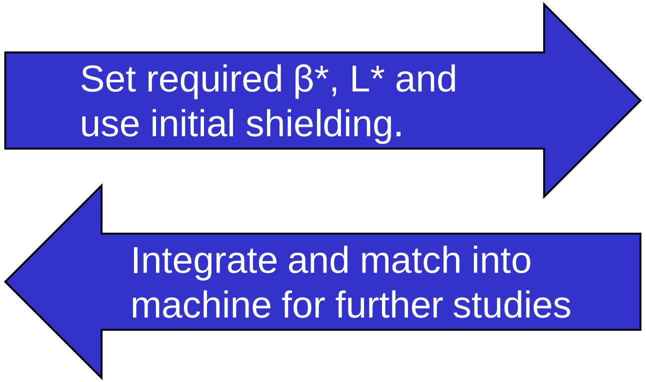
- HE-LHC triplet.
- HE-LHC: dose/power density.
- Dipole separator magnets.

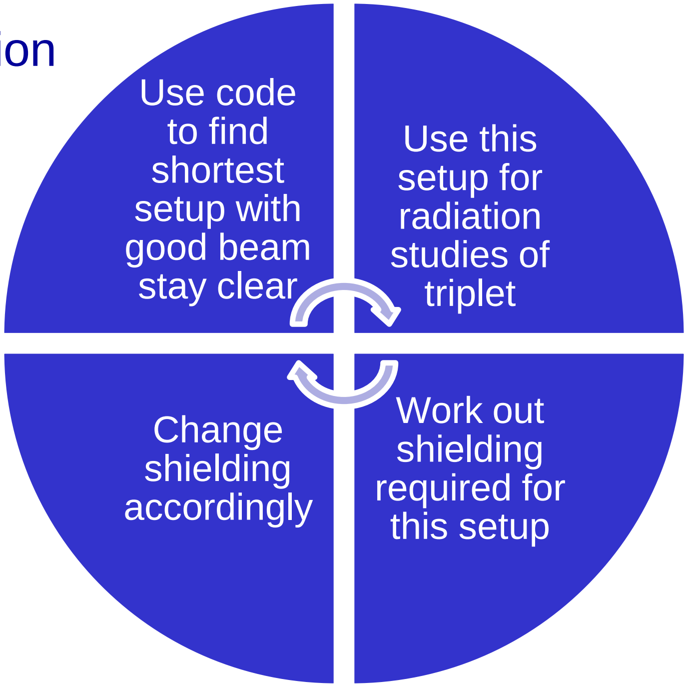
# Triplet optimization

- A triplet for the final-focus HE-LHC has been designed taking into account energy deposition studies.
- This  has been done in a similar way as for the FCC-hh alternative triplet.
- For the energy deposition studies, the FCC FLUKA model of the quadrupoles and the arc dipoles has been adapted.

# Triplet optimization

- Triplet optimization to minimize energy deposition

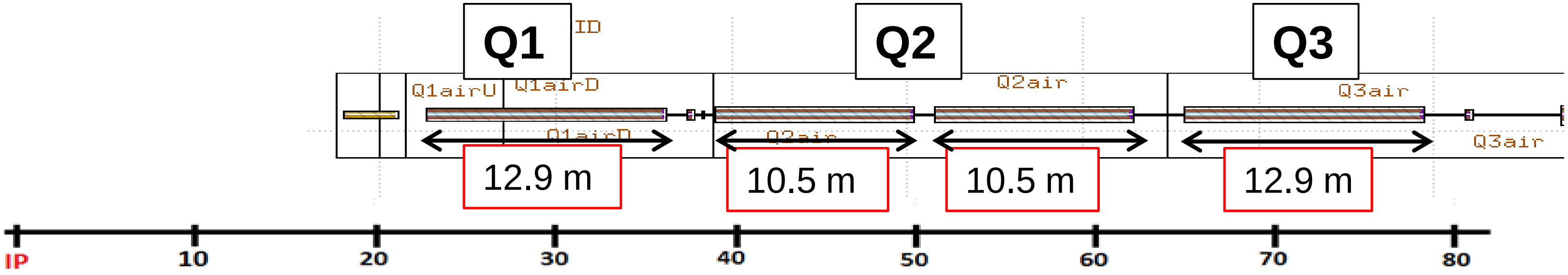


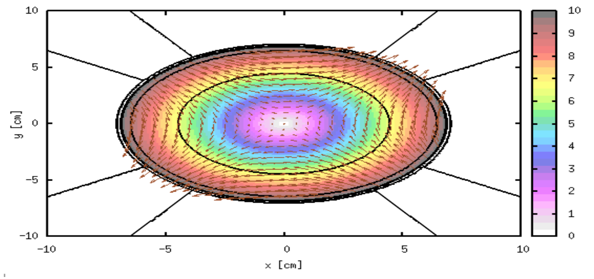

Leon Van-Riesen Haupt,
‘Experimental Interaction Region Optics for the High Energy LHC’ (Thursday)

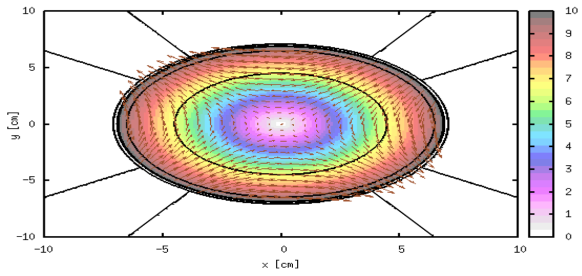
J.L Abelleira
‘Flat beam alternative’ (Tuesday)

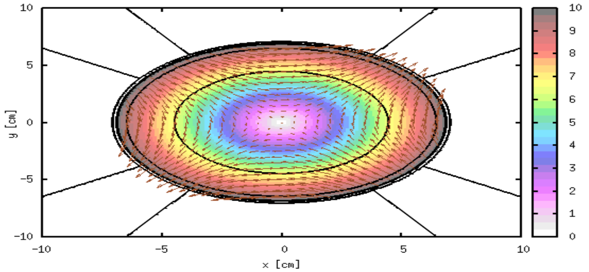
# Triplet optimization




TAS: same as in FCC, 3-m long, 5 cm aperture

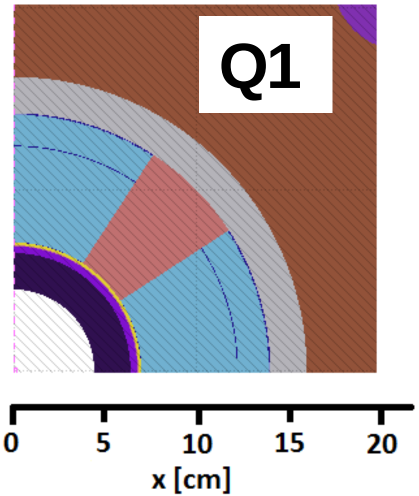


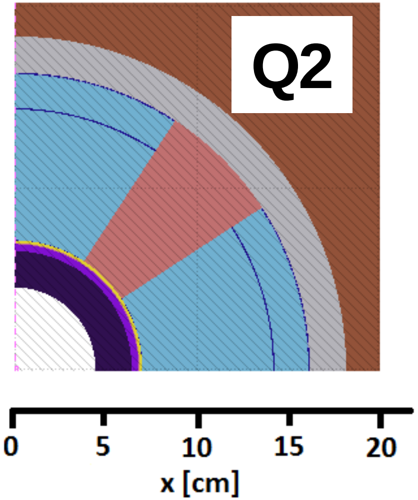



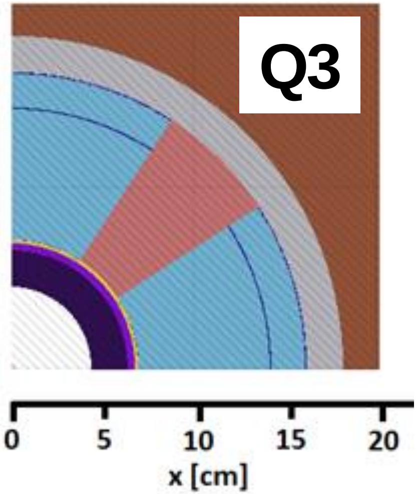



# HE-LHC triplet

- Adapted the FLUKA model of the FCC triplet.
- Optimum set of magnet parameters and shielding (identical for all of them).



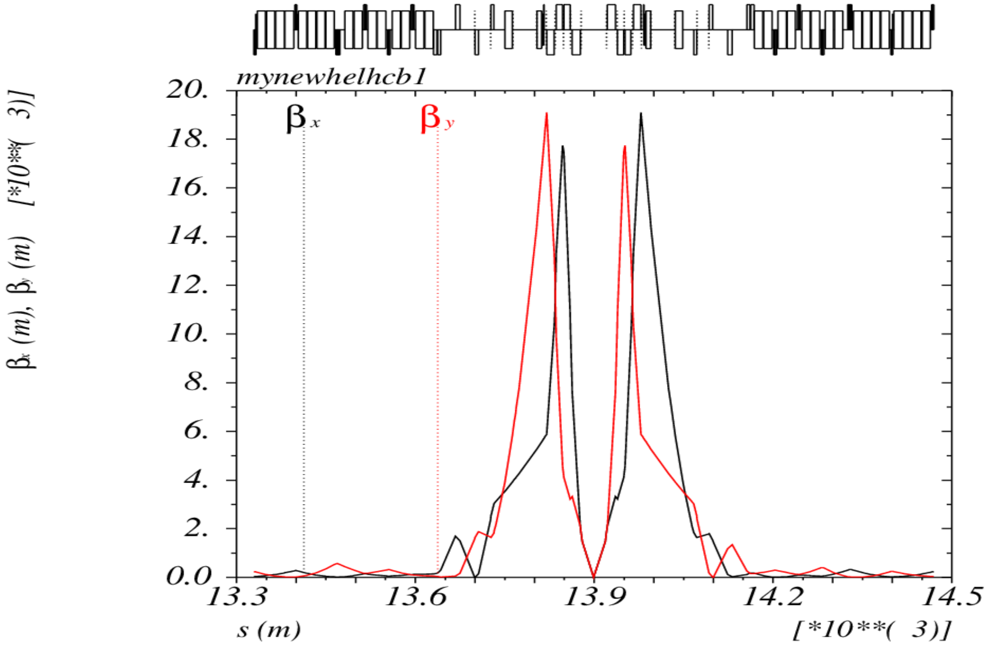



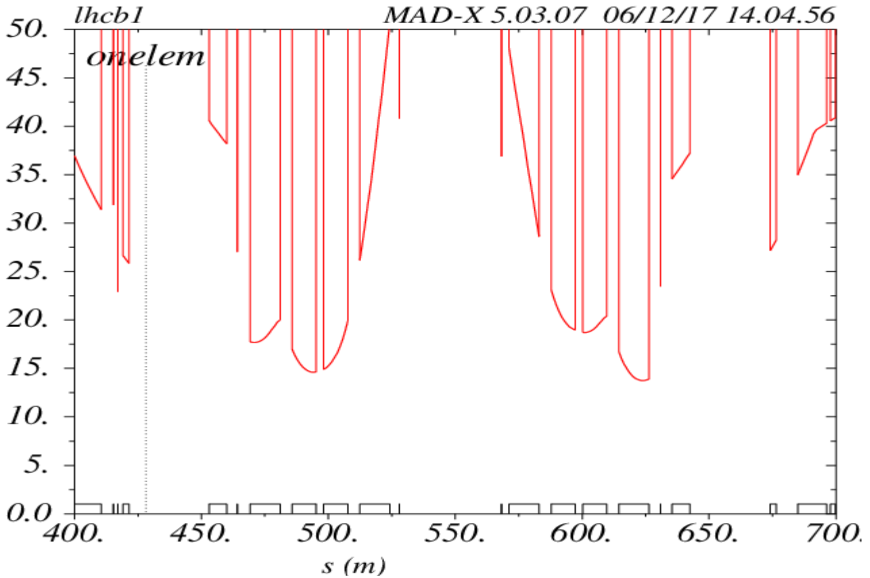

| | g [T/m] | coil, r [cm] | free aper, r [cm] | Abs thickness [cm] |
|---|---|---|---|---|
| Q1 | 146 | 7.04 | 4.46 | 2.0 |
| Q2 | 145 | 7.06 | 4.48 | 2.0 |
| Q3 | 146 | 7.06 | 4.46 | 2.0 |

$B_{peak}$=10.3 T

# HE-LHC triplet: optics

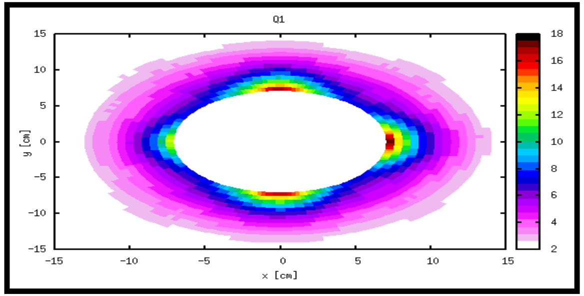
- Optics and beam stay clear, optimized for shielding.

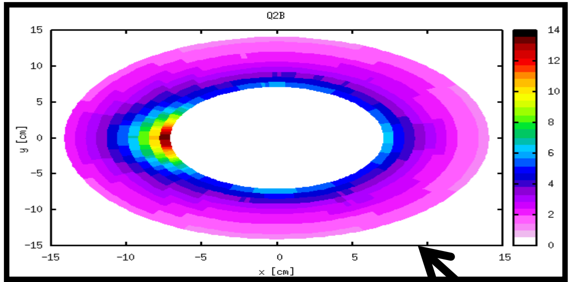


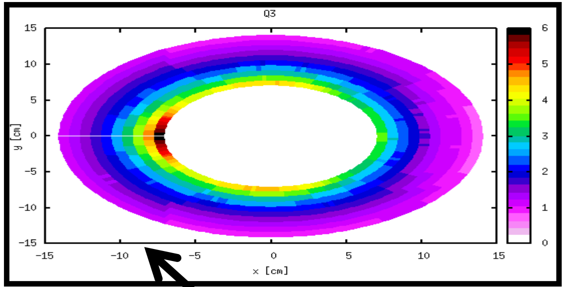




Leon Van-Riesen Haupt

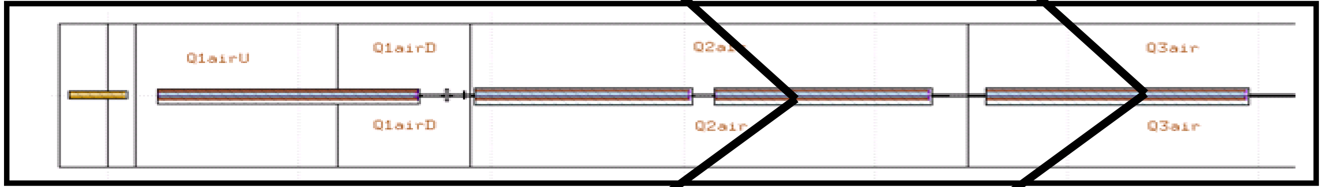
# HE LHC final triplet: dose



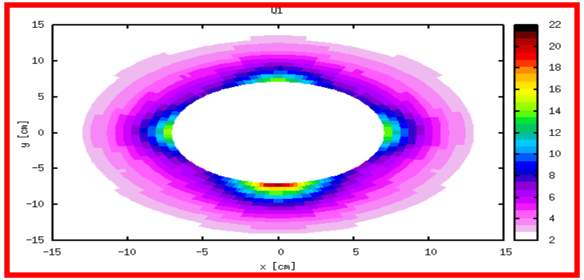



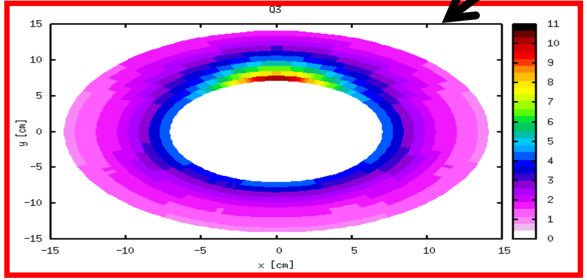



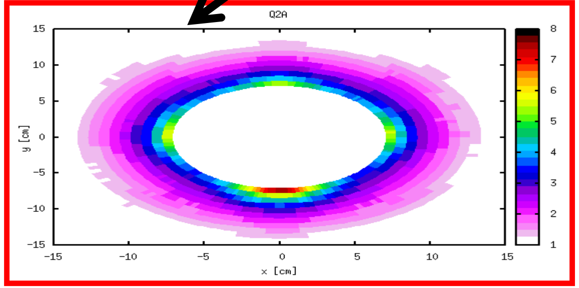

**Horizontal cross.**




**Vertical cross.**

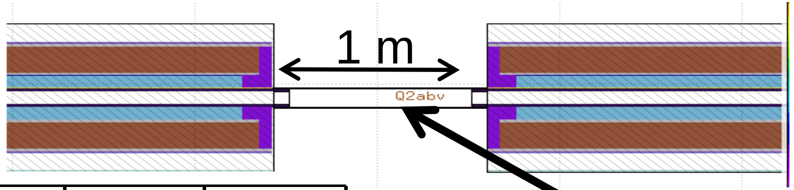


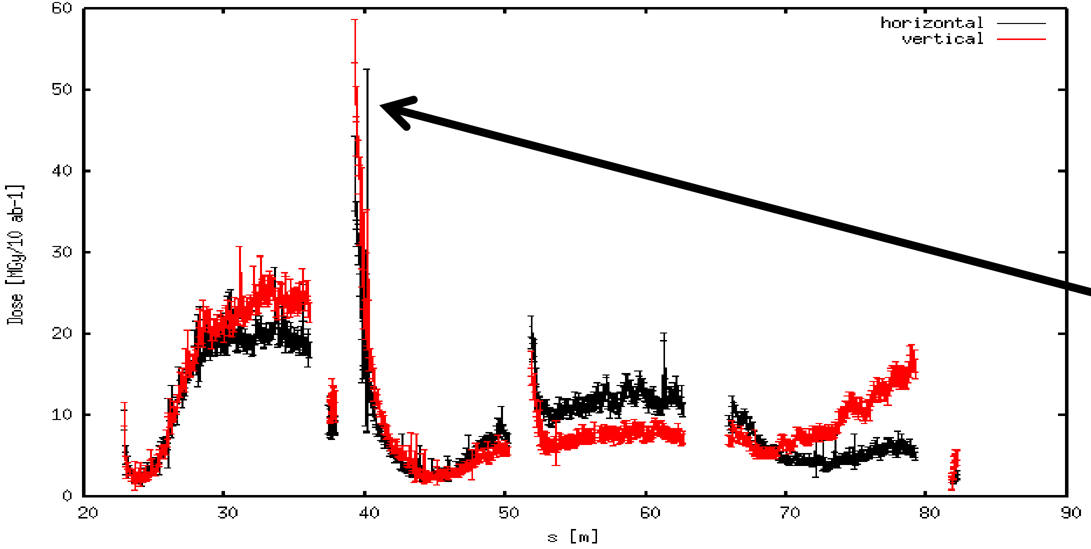



# HE-LHC triplet: dose

- Peak dose for 10 $ab^{-1}$



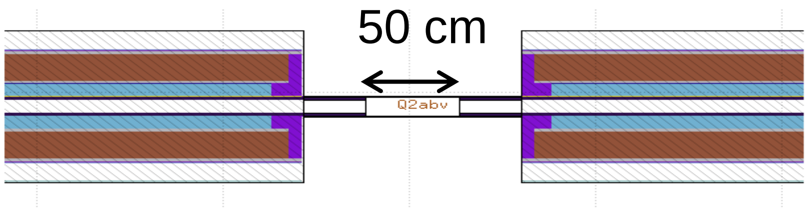

shielding gap (interconnects)

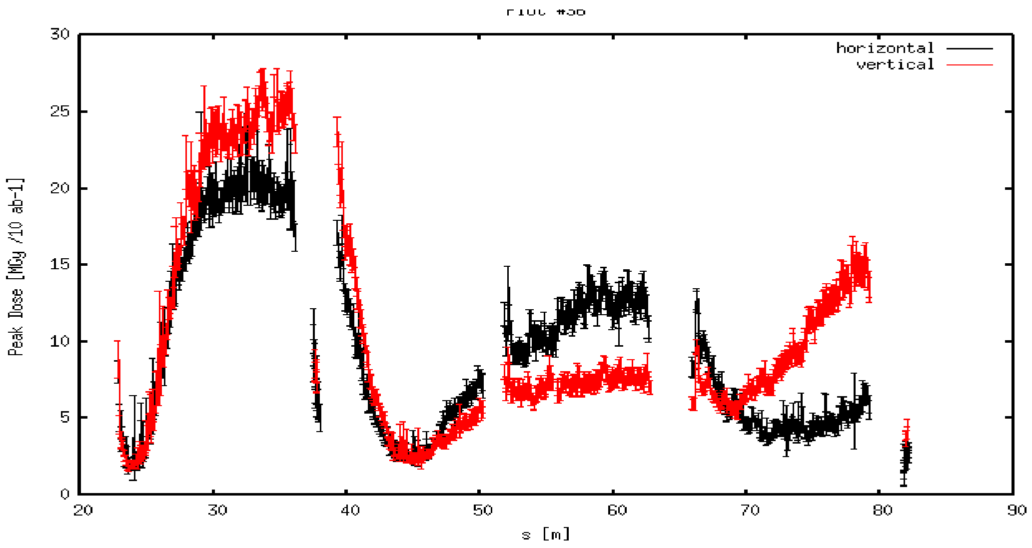
Peak at the beginning of Q2A as a consequence of the shielding removal (interconnects)

- Considerable improvement since Berlin (max dose was ~150 MGy). Shielding 1cm → 2 cm

# HE-LHC: dose

- Below 30 MGy (present limit)
- For flat beams there is no difference in dose*.

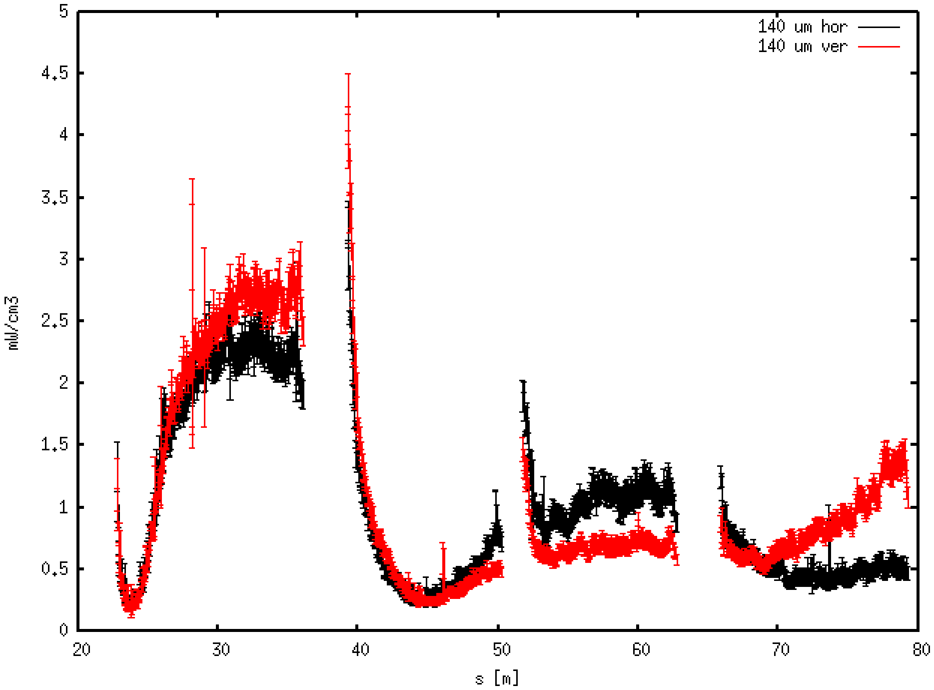



- Assuming less shielding gap, the peaks at the beginning of each magnet get reduced
- Exact length to be given by vacuum and beam instrumentation.
- Hard limit for HL-LHC: 50 cm

# HE-LHC: peak power density

- Peak power density ($L=25 \times 10^{34}\ cm^{-2}s^{-1}$), $\Theta/2$ = 140 μrad
- Quench protected below 3-5 $mW/cm^3$ (F. Cerutti talk: *Beam loss studies in the IP*).

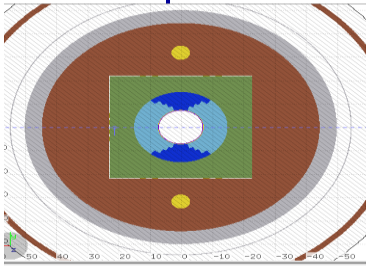


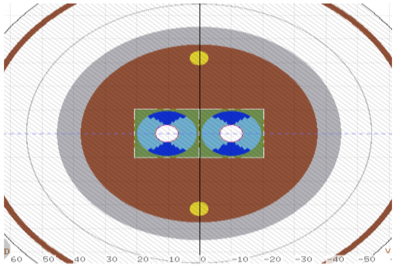
# Dipole separator magnets

- Large fields needed impose superconductor technology.
- We have come out with a first set of magnet parameters for energy deposition studies on the D1 & D2.

| | aperture | B [T] | L [m] | Coil r [cm] |
|---|---|---|---|---|
| D1 | Single | 11.1 | 8 | 7 |
| D2 | Twin | 7.1 | 12.5 | 3.5 |

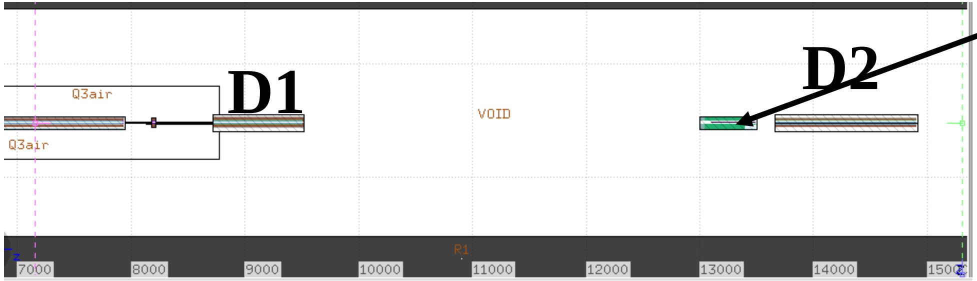
- For the energy deposition simulations, the FCC arc dipole model (provided by the CERN FLUKA team) was modified and transformed to D1 & D2.
- Good estimation as the peak dose is found in the innermost coil layer

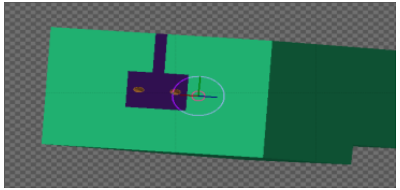




# Dipole separator magnets

- D1 & D2 as single magnets.
- TAN model included (provided by the CERN FLUKA team).



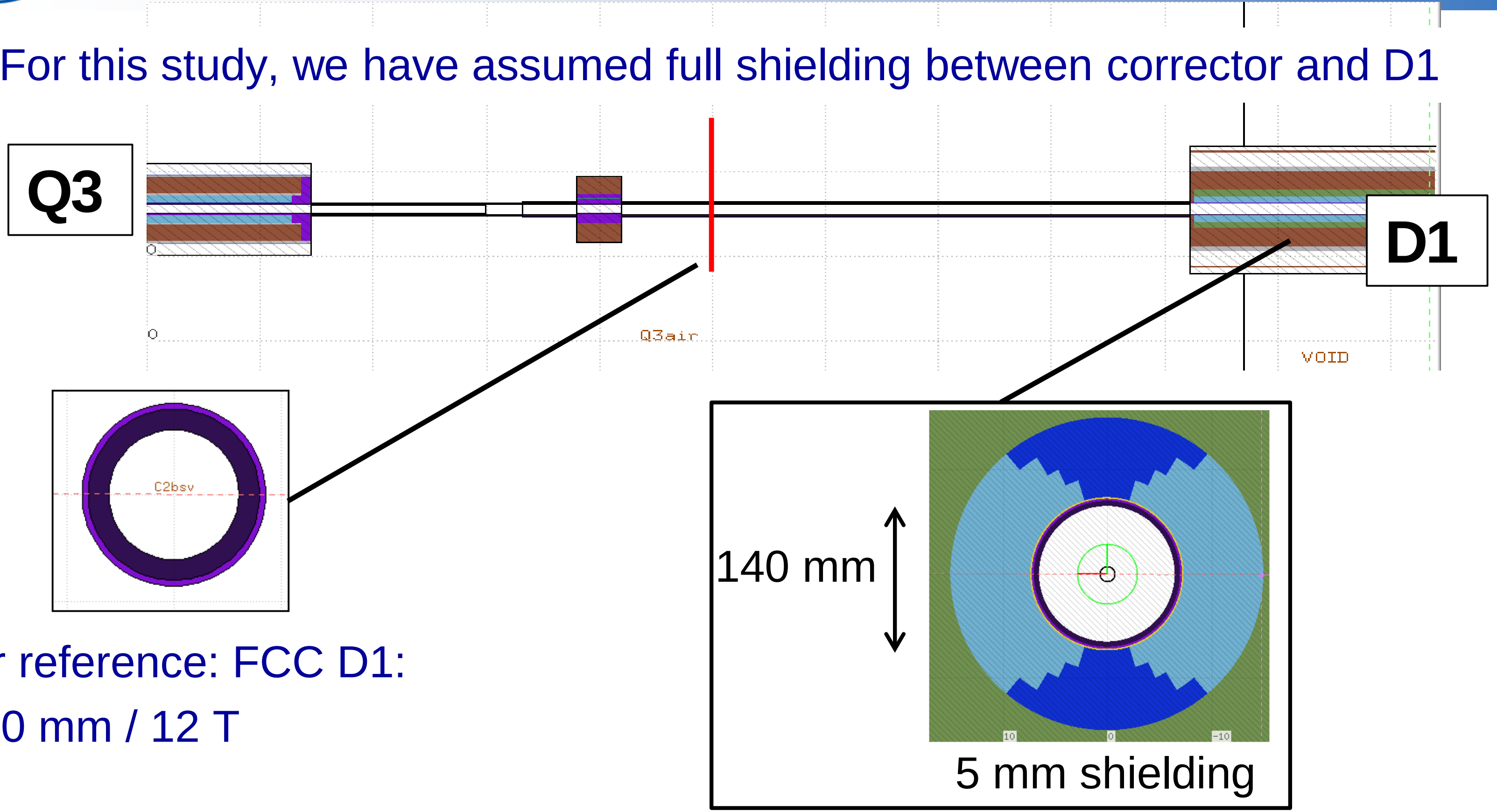



TAN (Target absorber neutrals)

- Radiation protection studies for D2 ongoing.

# Dipole separator magnets

- For this study, we have assumed full shielding between corrector and D1

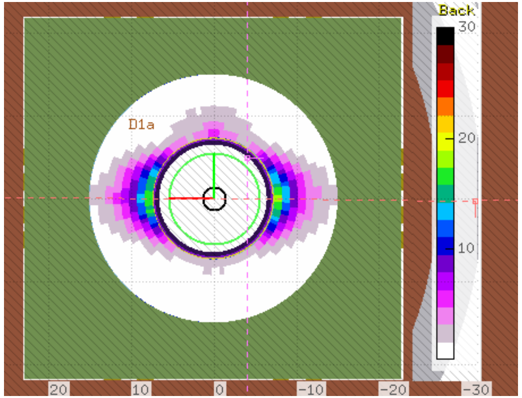


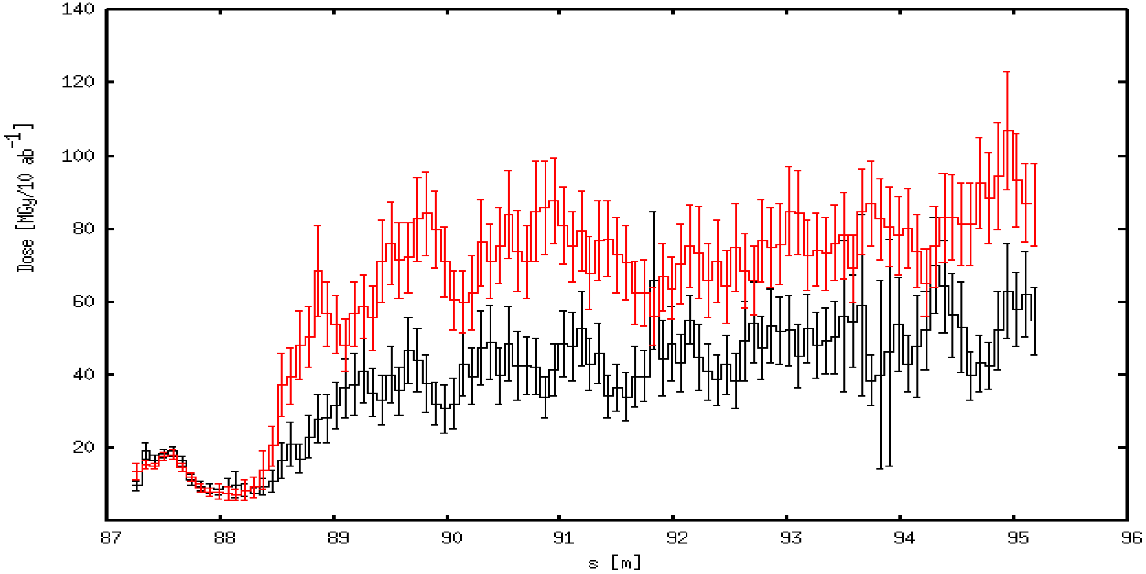

For reference: FCC D1:

100 mm / 12 T

# Dipole separator magnets

## D1




- Excessive dose
- Solutions
  - Increase shielding
  - Split/enlarge magnet
  - More iterations needed

# Dipole separator magnets

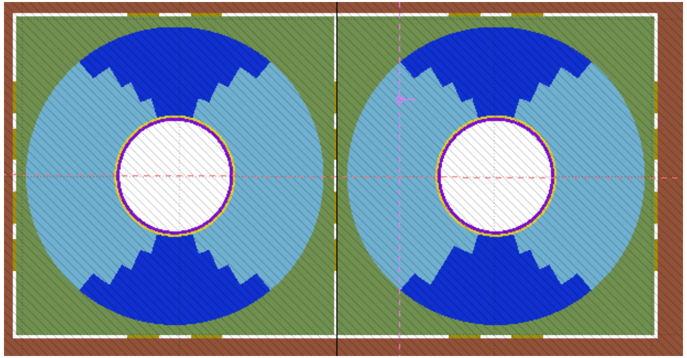
**D2**

- D2 FLUKA model adapted from the FCC arc dipole (provided by CERN FLUKA team)
- Useful to estimate energy deposition, in the absence of a magnet model

For reference:

FCC D2: 60 mm / 10 T

70 mm



# Conclusions

- FCC FLUKA model of the triplet magnets modified for the HE-LHC.
- A new triplet has been designed in order to reduce the peak dose.
- Interconnects length play an important role in peak doses.
- New triplet shows a much reduced dose for the nominal case.
- Peak dose below 30 MGy for 280 μrad full crossing angle.
- The new triplet shows a much reduced dose for the nominal case.
- Peak power density seems also good below 280 μrad.
- First radiation studies on cold D1 & D2, more iterations needed

# *Thank you for your attention*