Radiation Environment

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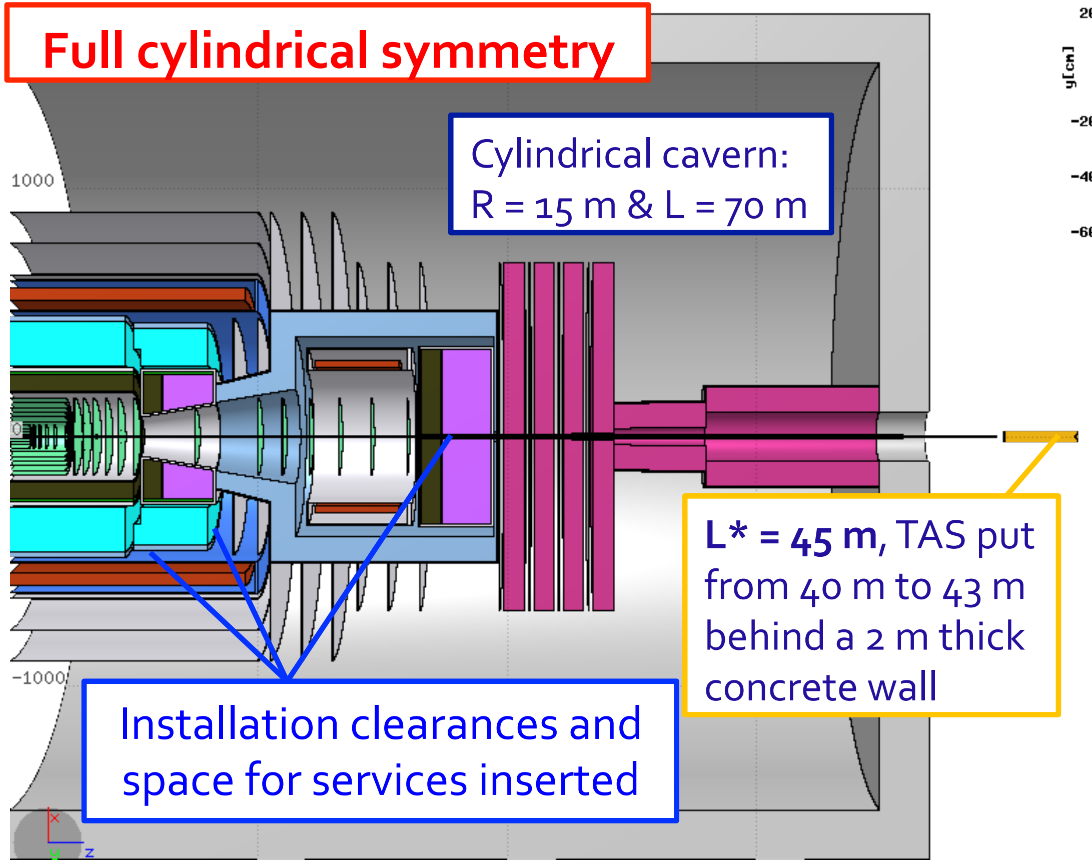
Outline

- Updated detector geometry:
  - with a conceptual design for a forward shielding
- Radiation levels:
  - effect of the shielding: neutron fluence rate
  - charged particle fluence rate
  - 1 MeV neutron equivalent fluence
  - dose
- Alternative geometry:
  - forward calorimeter split into "forward" and "very forward" part
  - forward muon sub-detector: reduced angular acceptance, but space for a thicker inner iron shielding
  - effectiveness quantified in terms of:
    - 1 MeV neutron equivalent fluence in the forward tracking stations
    - charged particle fluence rates in the forward muon chambers
- Conclusions & Outlooks

Detector Geometry I

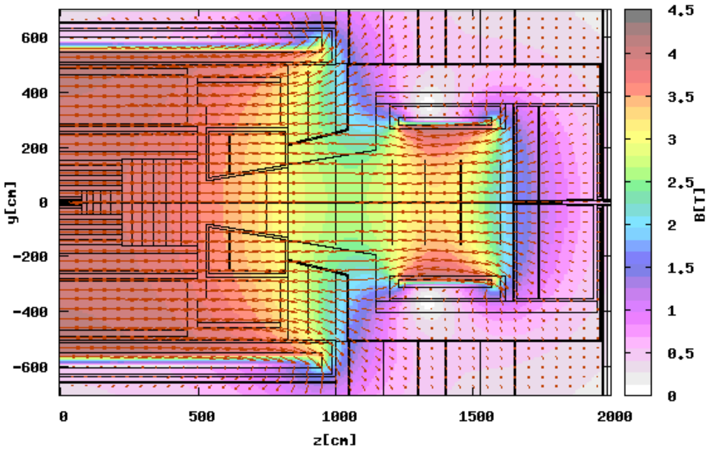
Full cylindrical symmetry



Cylindrical cavern:
R = 15 m & L = 70 m

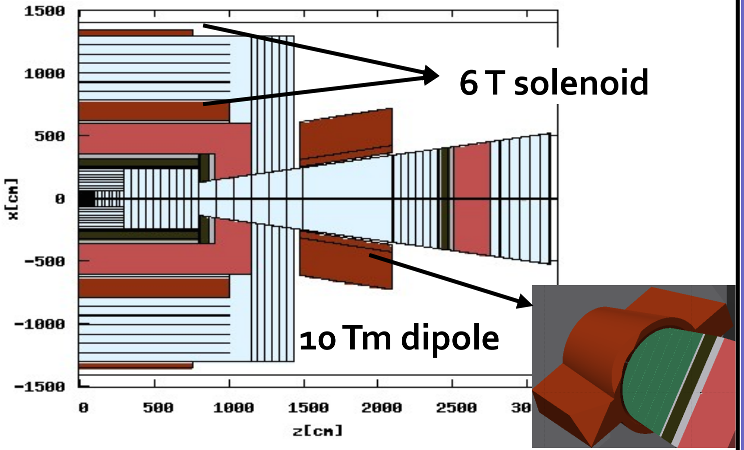
L* = 45 m, TAS put from 40 m to 43 m behind a 2 m thick concrete wall

Installation clearances and space for services inserted

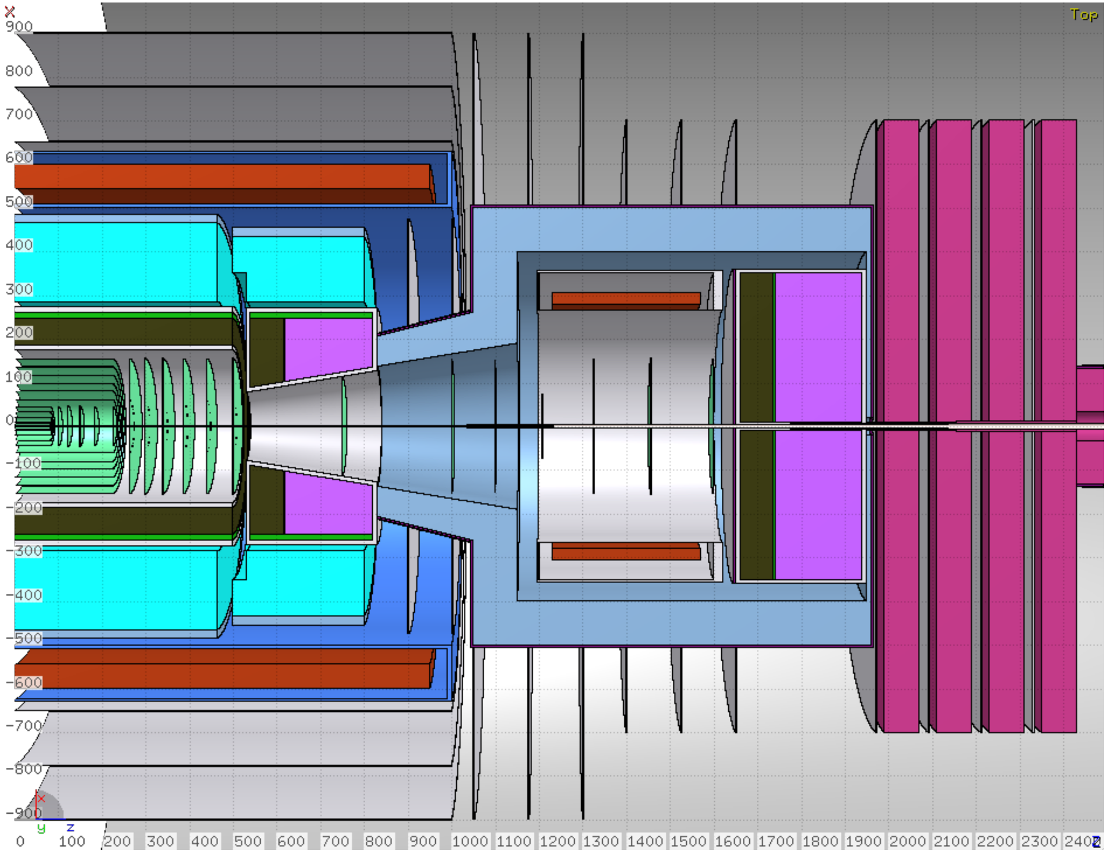


Magnetic field

Old concept: bigger detector, without gaps, no cylindrical symmetry



Detector Geometry II



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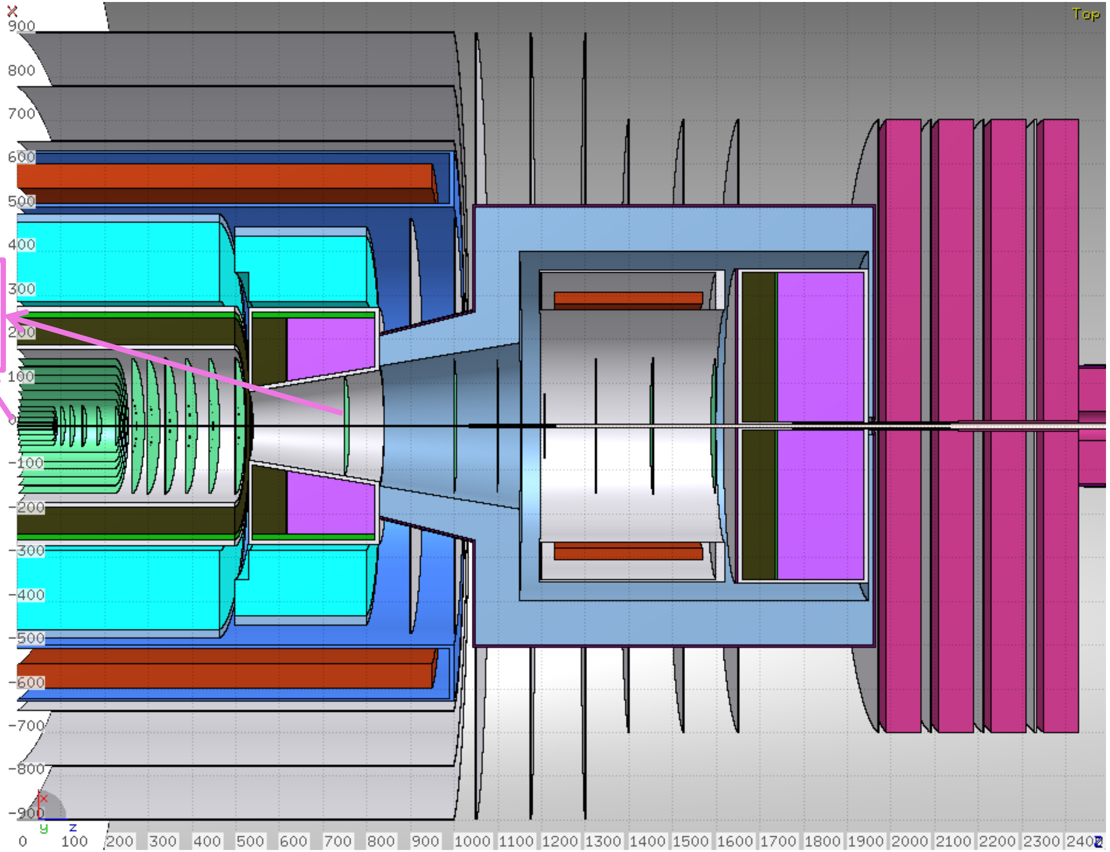
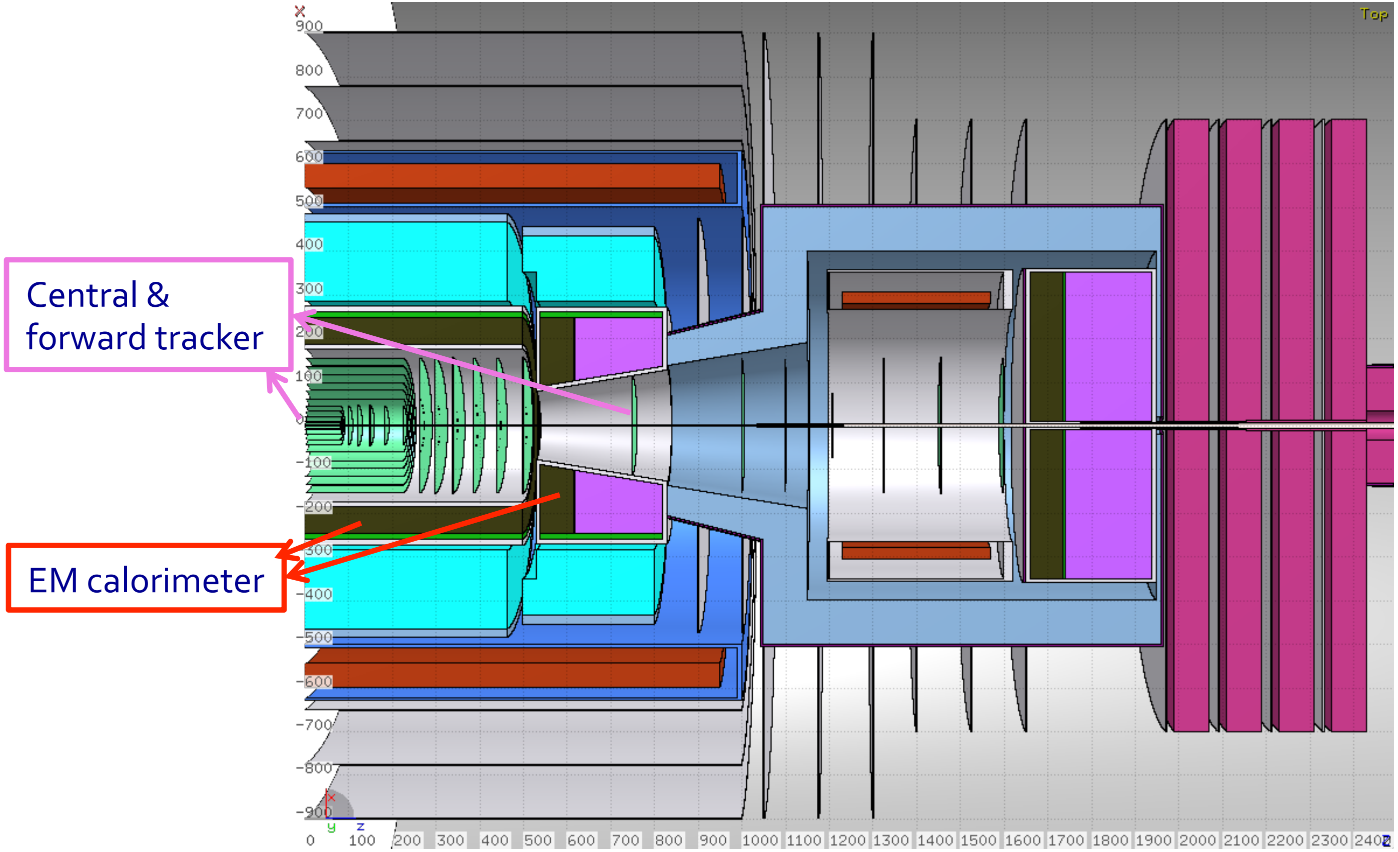


Central & forward tracker

Detector Geometry II



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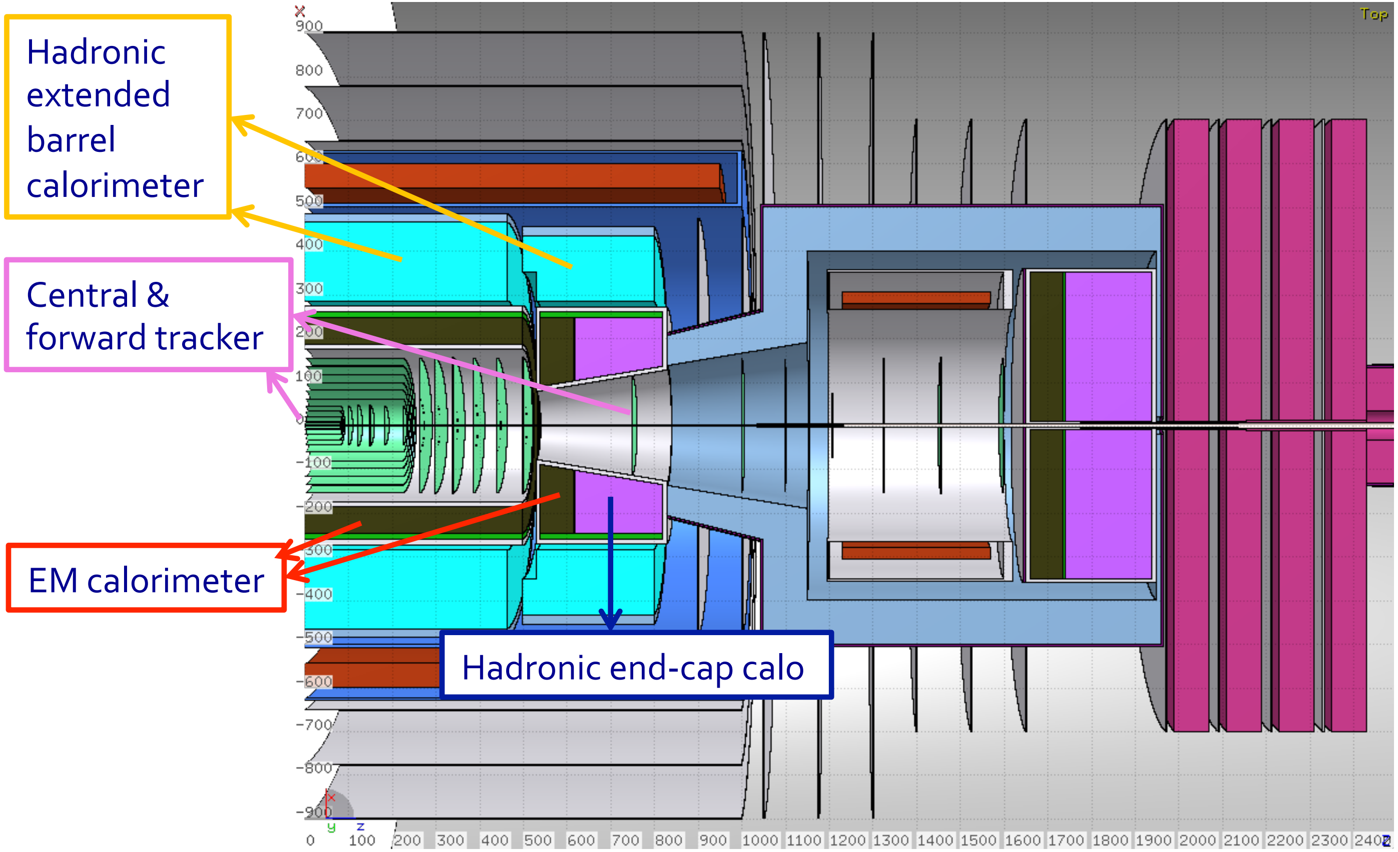
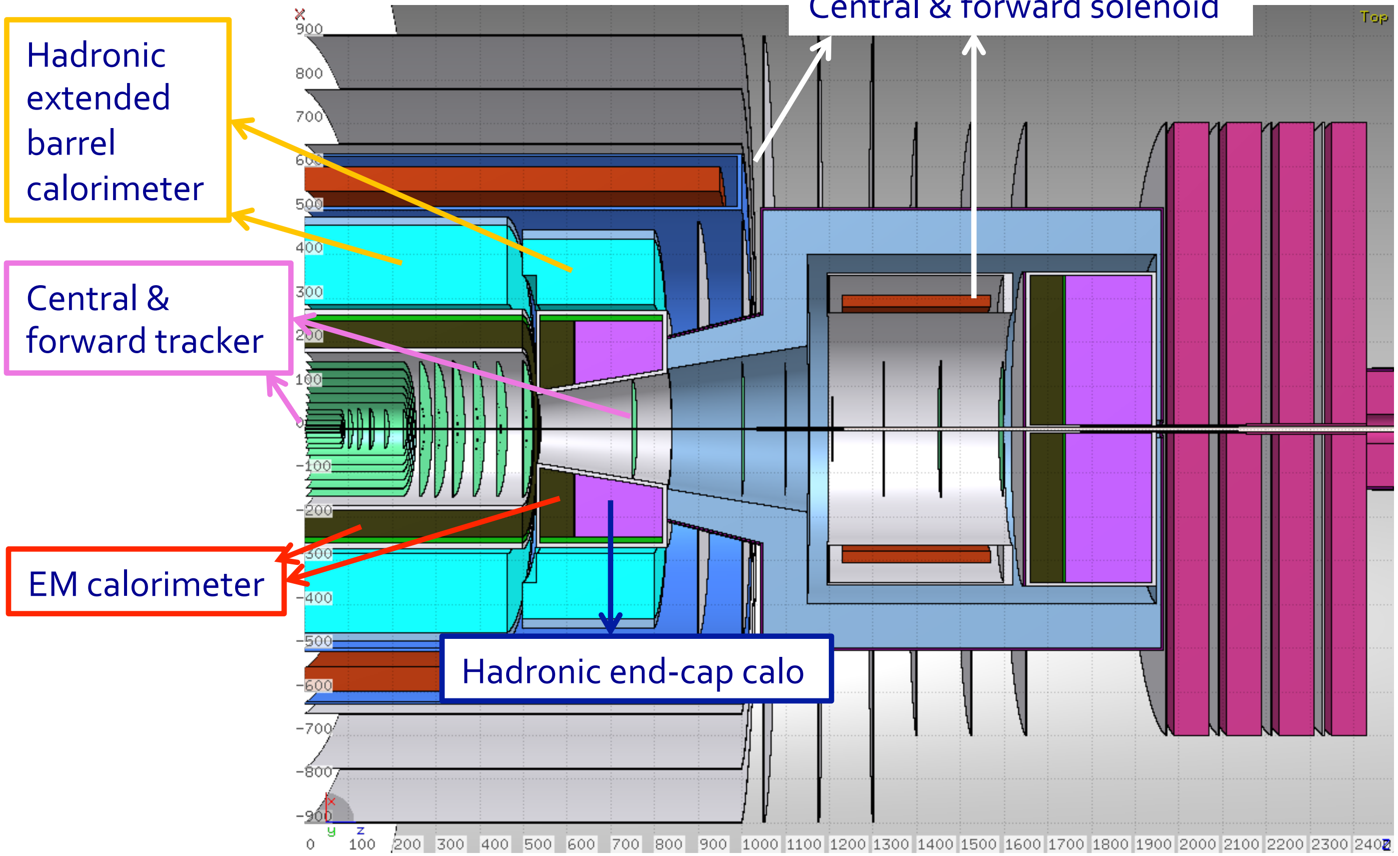
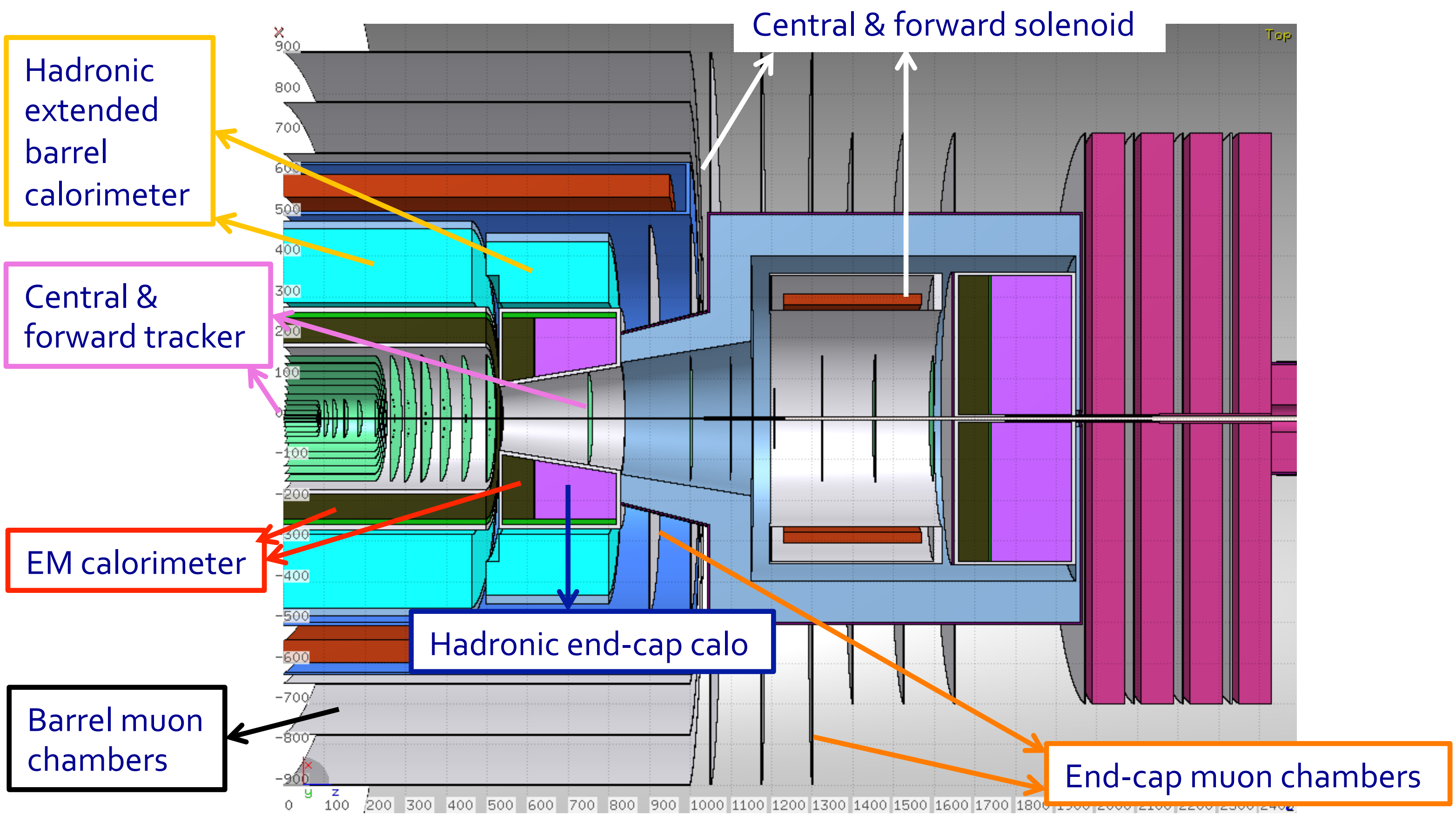


Detector Geometry II



Detector Geometry II



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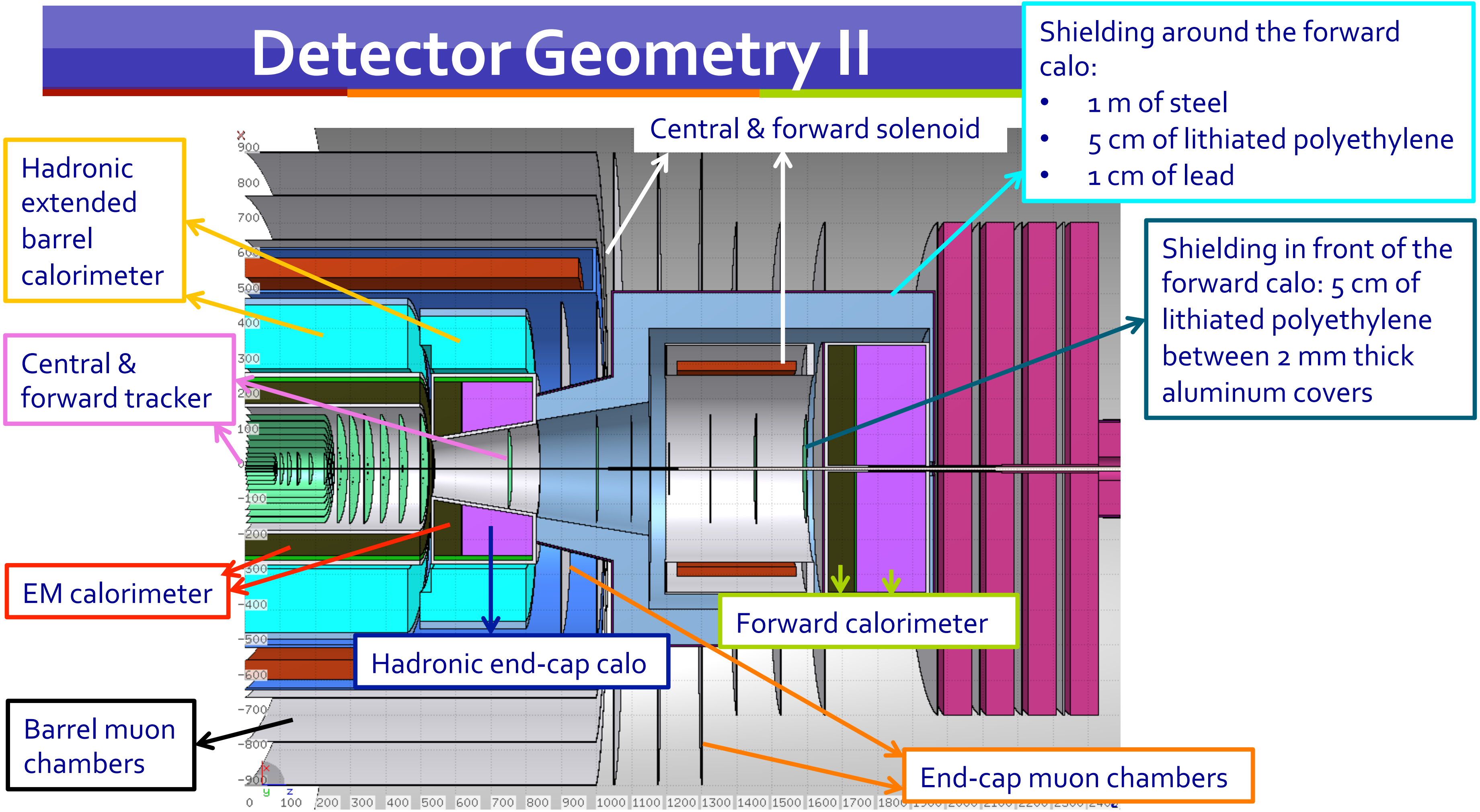
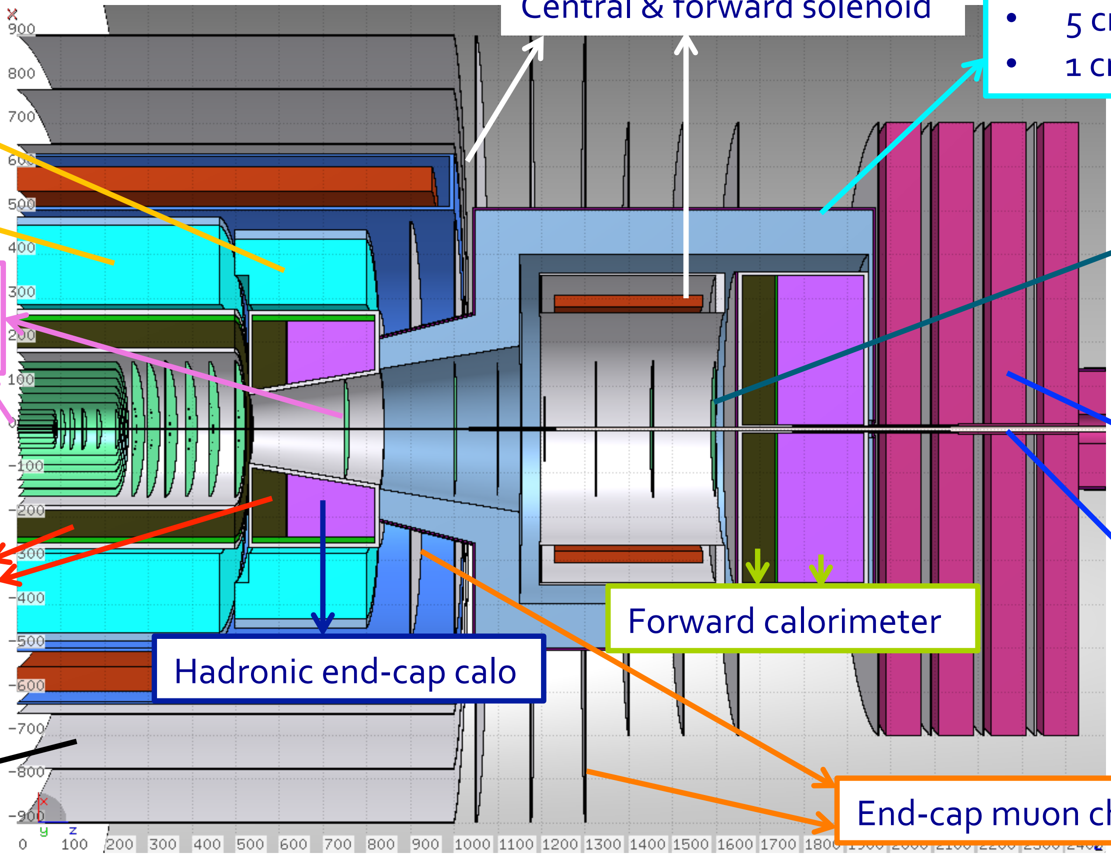
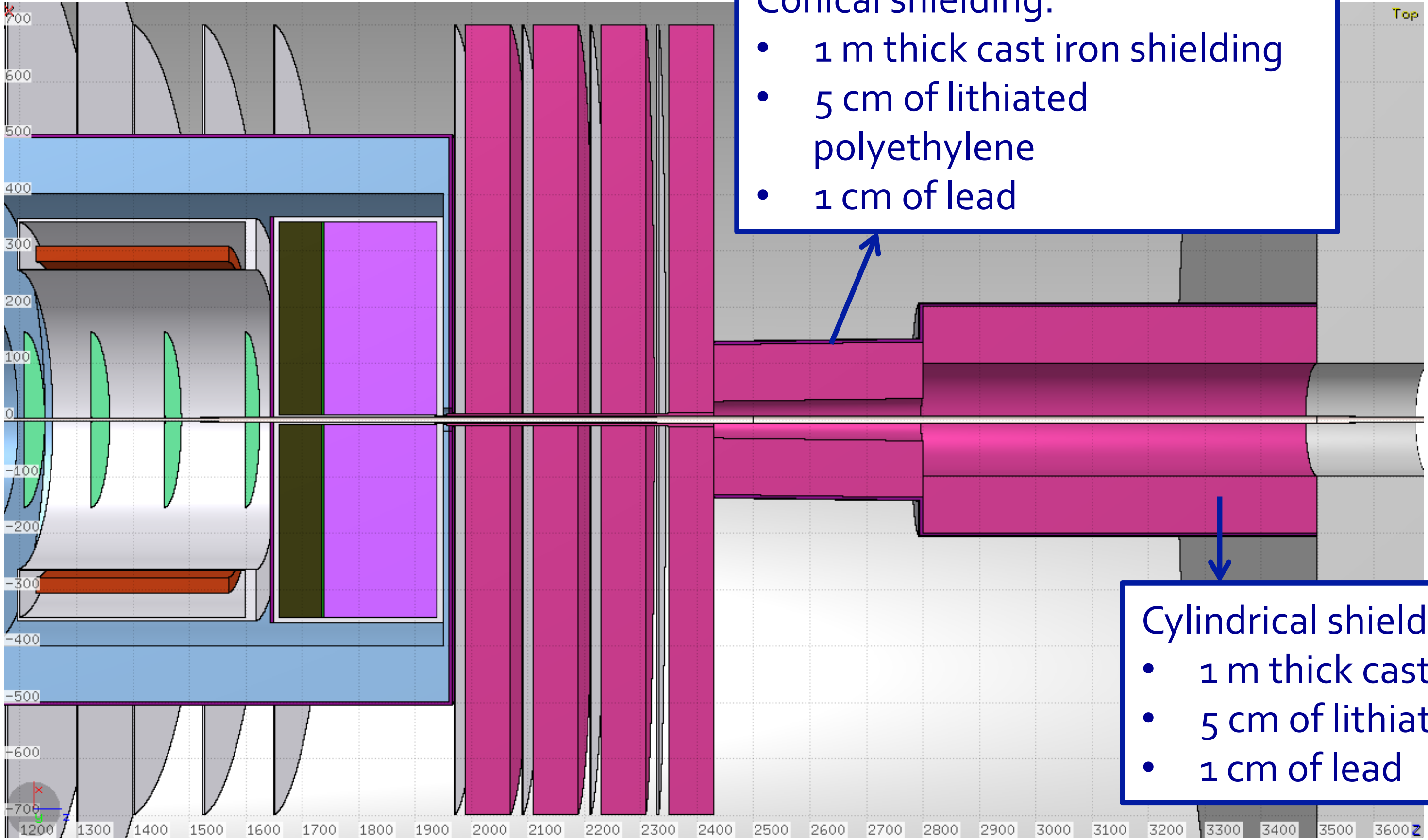


Detector Geometry II



Shielding in the Forward Region



Conical shielding:

- 1 m thick cast iron shielding
- 5 cm of lithiated polyethylene
- 1 cm of lead

Cylindrical shielding:

- 1 m thick cast iron shielding
- 5 cm of lithiated polyethylene
- 1 cm of lead

Details about the Simulation

- FLUKA simulations using DPMJET-III generator
  - c-hadrons included (b-hadrons and W/Z bosons are not included)

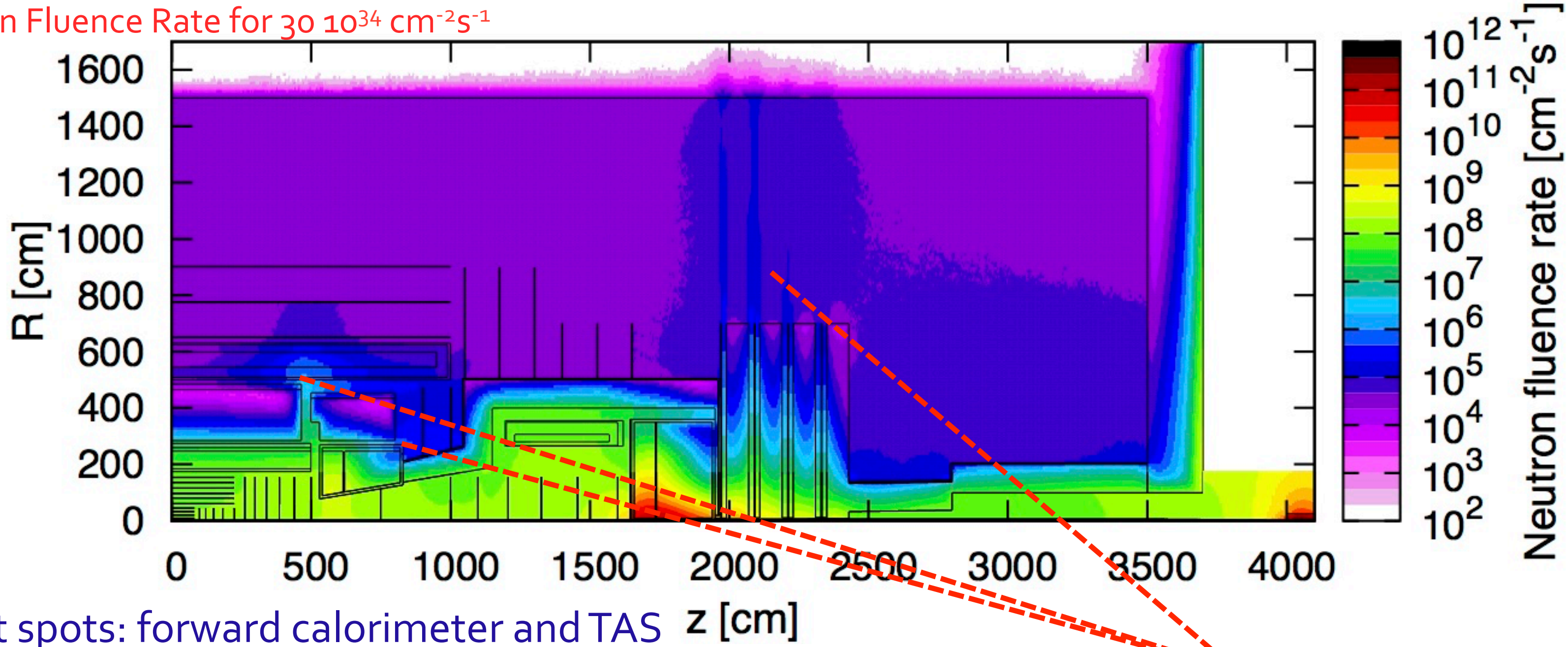
- Normalization:
  - non-elastic proton-proton cross section at 100 TeV of 108 mbarn
  - fluence rates [$cm^{-2}s^{-1}$] for an instantaneous luminosity of 30 10^{34} $cm^{-2}s^{-1}$
  - 1 MeV neutron equivalent fluence [cm^{-2}] and dose [MGy] for an integrated luminosity of 30 ab^{-1}

- Resolution:
  - inner part (R < 175 cm, z < 37 m): R x z: 5 mm x 5 cm
  - external part (R > 175 cm, z < 37 m): R x z: 10 cm x 5 cm
  - forward part (R < 350 cm, 37 m < z < 47 m): R x z: 5 mm x 10 cm

- The contribution coming from the TAS has been included in this simulation
  - NEW! Not included in the previous results

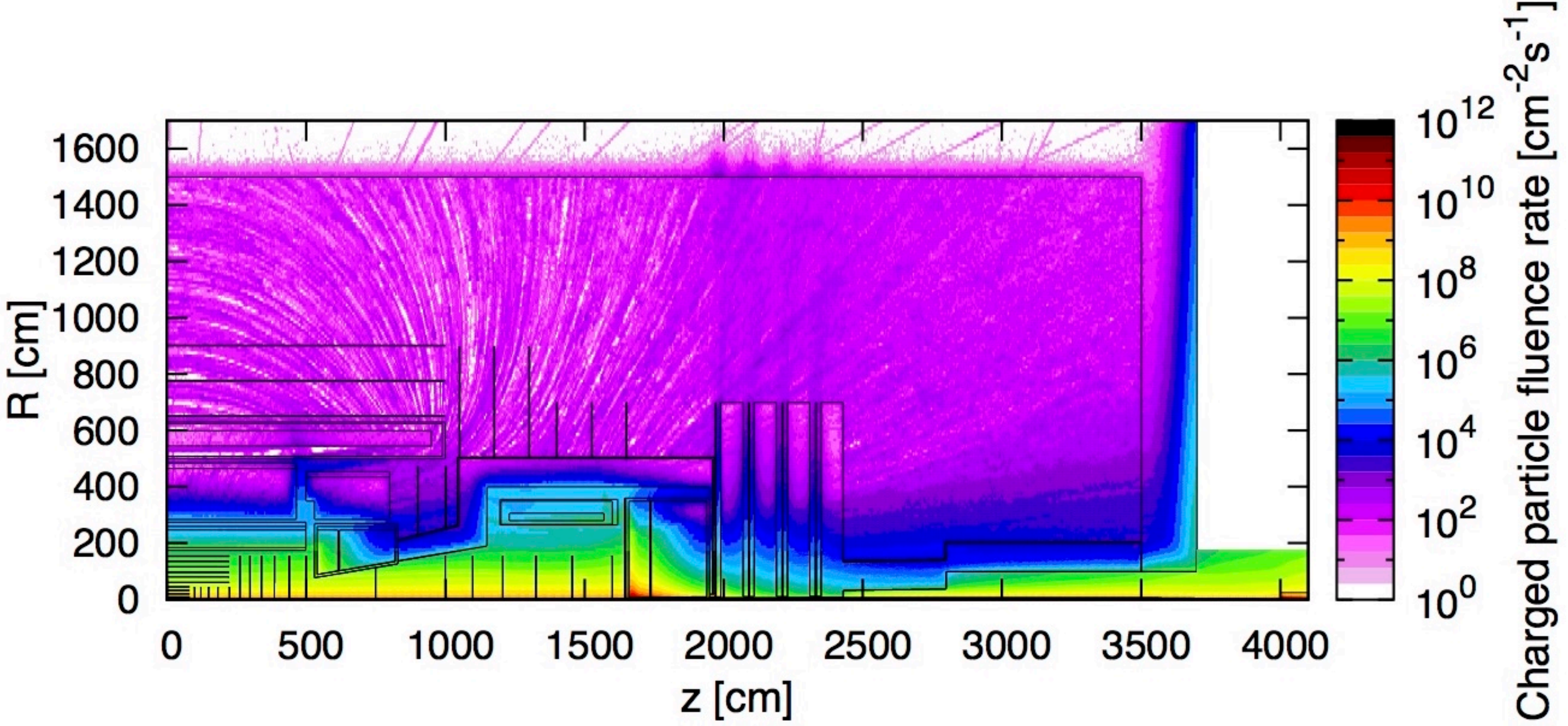
Shielding: Rates in the Muon Chambers

Neutron Fluence Rate for 30 10^{34} $cm^{-2}s^{-1}$



- Hot spots: forward calorimeter and TAS
- Shielding concepts are effective in reducing the rates, but localized **leakage points**, which affect the rates in the **muon chambers**:
  - barrel: 7 10^4 $cm^{-2}s^{-1}$, due to the leakage from the crack in the calorimeter
  - end-cap: six chambers at z > 10 m: 10^5 $cm^{-2}s^{-1}$ & two chambers at z < 10 m: 3 10^5 $cm^{-2}s^{-1}$
  - expected rates: up to 300 $cm^{-2}s^{-1}$, compared to ~10 $cm^{-2}s^{-1}$ of the previous layout

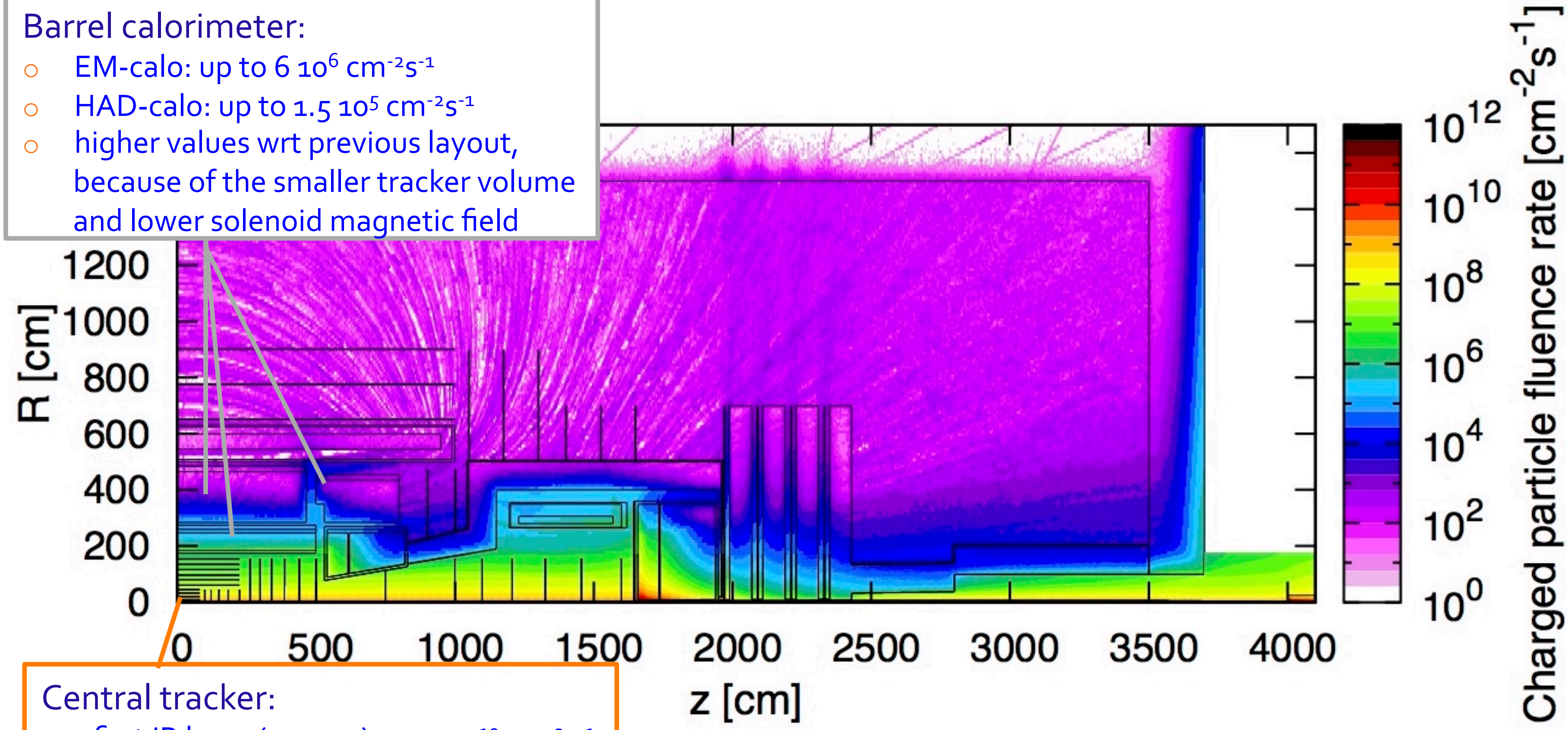
Charged Particle Fluence Rate (30 10^{34} $cm^{-2}s^{-1}$)



Charged Particle Fluence Rate (30 10^{34} $cm^{-2}s^{-1}$)

Barrel calorimeter:

- EM-calo: up to 6 10^6 $cm^{-2}s^{-1}$
- HAD-calo: up to 1.5 10^5 $cm^{-2}s^{-1}$
- higher values wrt previous layout, because of the smaller tracker volume and lower solenoid magnetic field



Central tracker:

- first IB layer (2.5 cm): ~1.2 10^{10} $cm^{-2}s^{-1}$
- external part: 3 10^6 $cm^{-2}s^{-1}$

Charged Particle Fluence Rate (30 10^{34} $cm^{-2}s^{-1}$)

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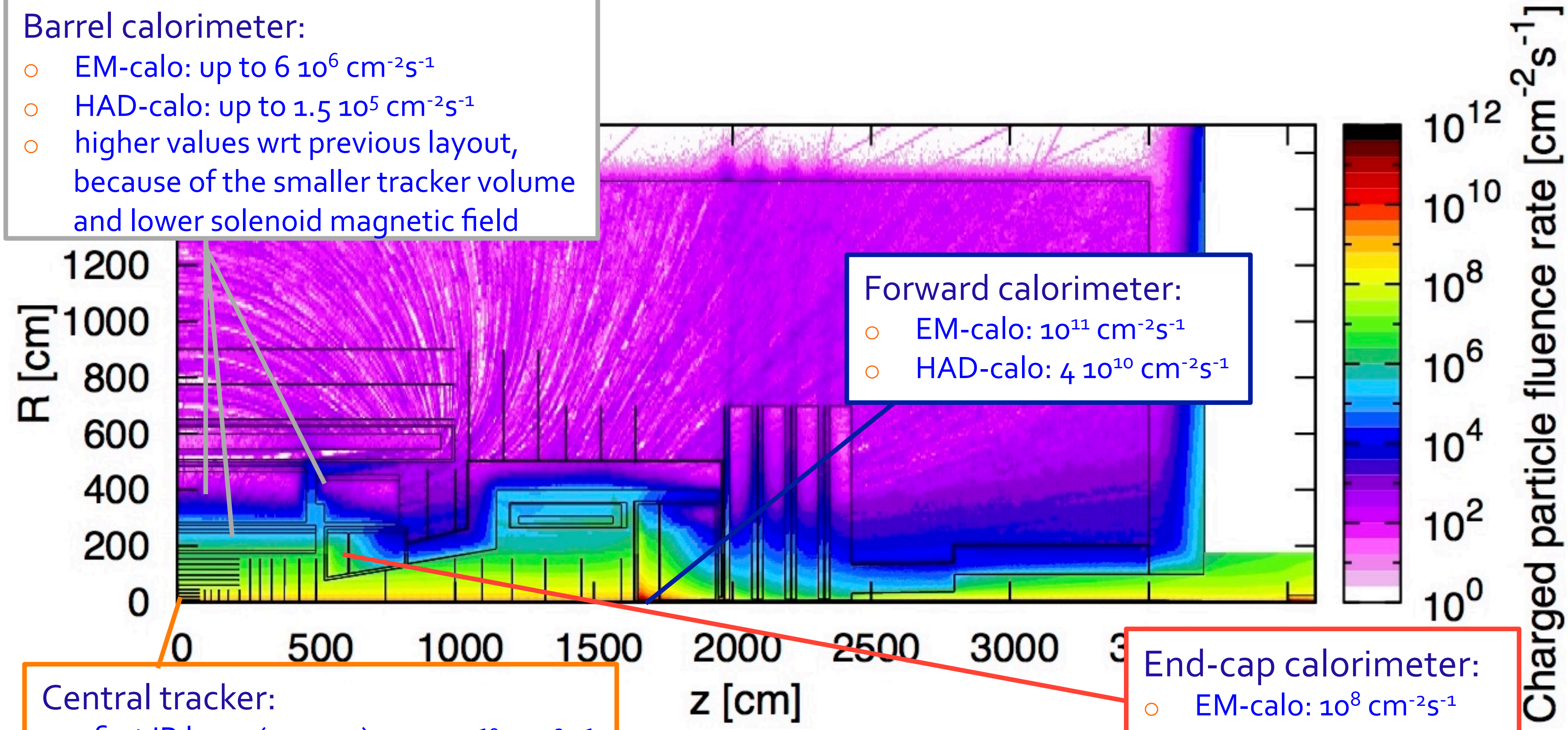


Forward calorimeter:
- EM-calo: 10^{11} $cm^{-2}s^{-1}$
- HAD-calo: 4 10^{10} $cm^{-2}s^{-1}$

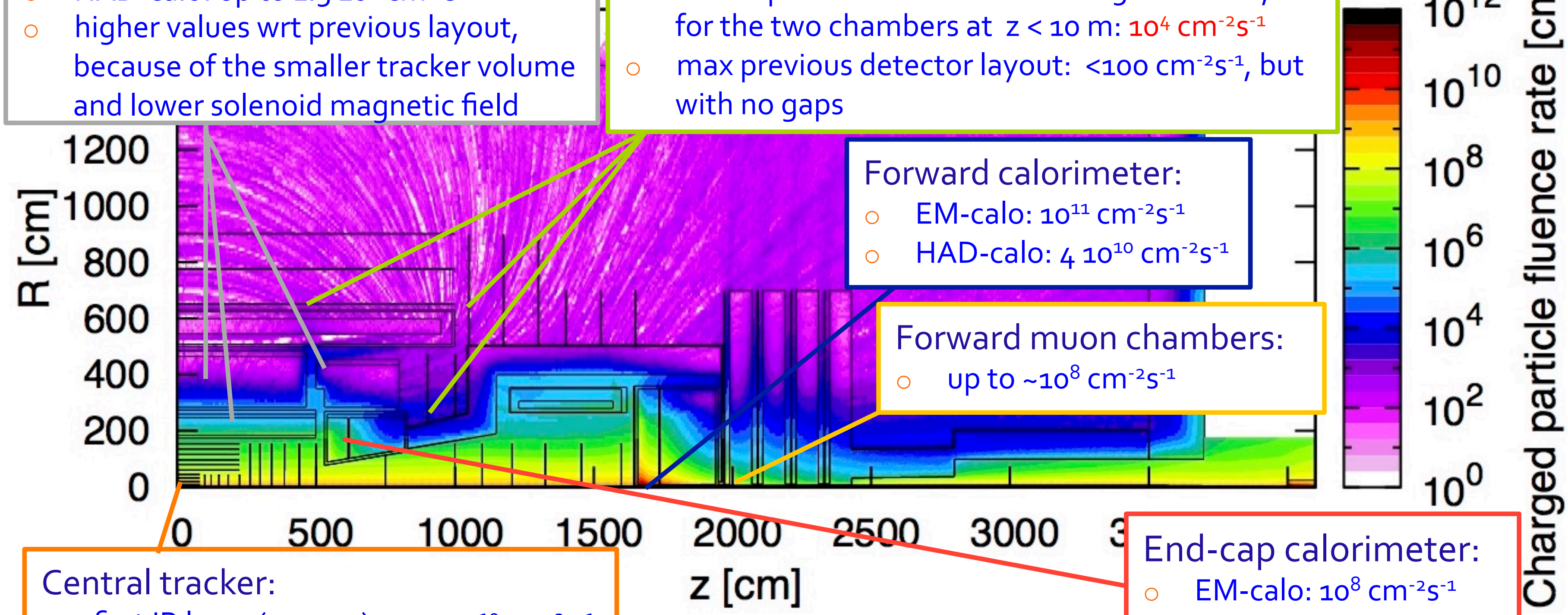
Central tracker:
- first IB layer (2.5 cm): ~1.2 10^{10} $cm^{-2}s^{-1}$
- external part: 3 10^{6} $cm^{-2}s^{-1}$

End-cap calorimeter:
- EM-calo: 10^{8} $cm^{-2}s^{-1}$
- HAD-calo: 10^{7} $cm^{-2}s^{-1}$

Charged Particle Fluence Rate (30 10^{34} $cm^{-2}s^{-1}$)

Barrel calorimeter:
- EM-calo: up to 6 10^6 $cm^{-2}s^{-1}$
- HAD-calo: up to 1.5 10^5 $cm^{-2}s^{-1}$
- higher values wrt previous layout, because of the smaller tracker volume and lower solenoid magnetic field

Barrel and end-cap muon chambers:
- barrel: ~300 $cm^{-2}s^{-1}$
- end-cap chambers for z > 10 m: ~500 $cm^{-2}s^{-1}$, but for the two chambers at z < 10 m: 10^4 $cm^{-2}s^{-1}$
- max previous detector layout: <100 $cm^{-2}s^{-1}$, but with no gaps



Forward calorimeter:
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Forward muon chambers:
- up to ~10^8 $cm^{-2}s^{-1}$

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End-cap calorimeter:
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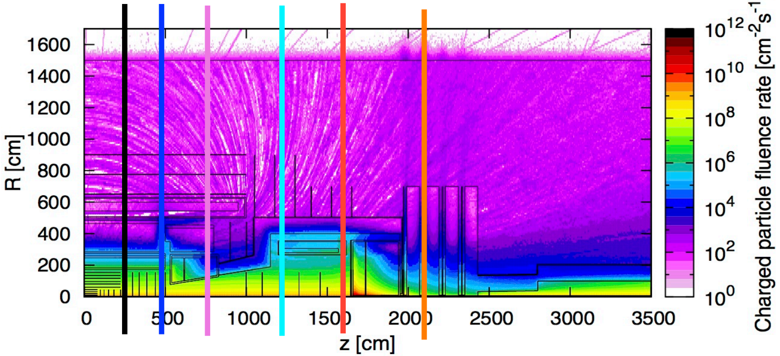
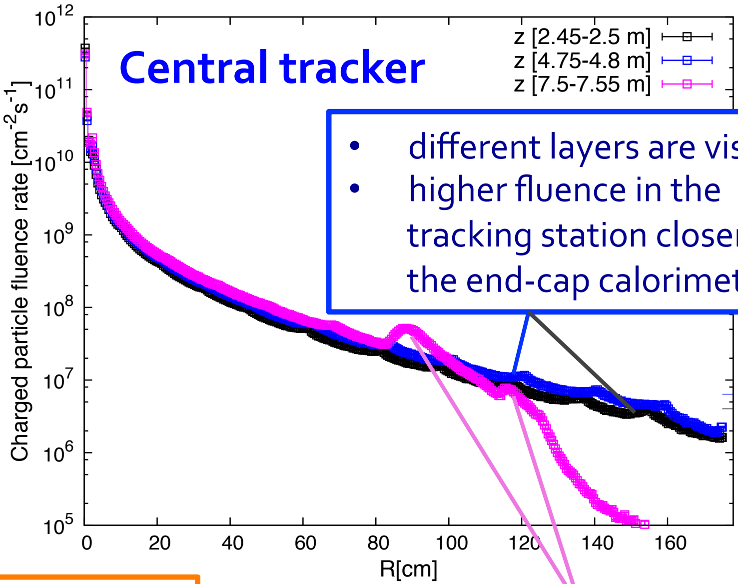
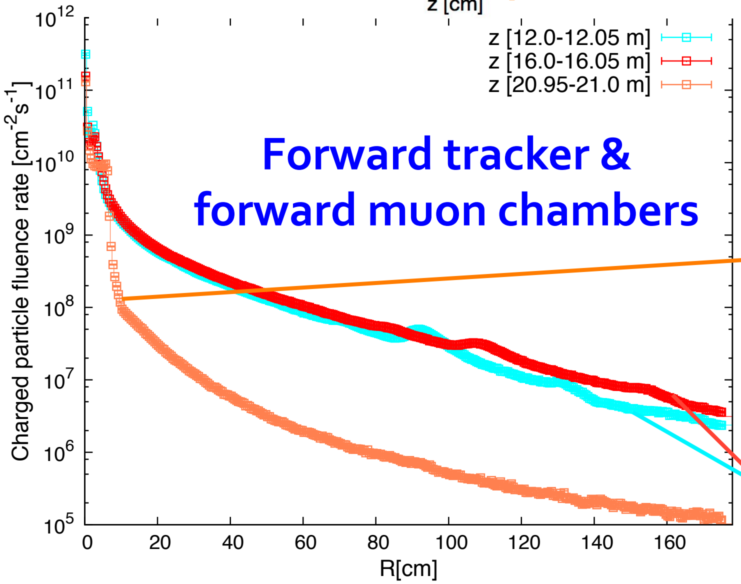
Tracking Stations





- different layers are visible
- higher fluence in the tracking station closer to the end-cap calorimeter

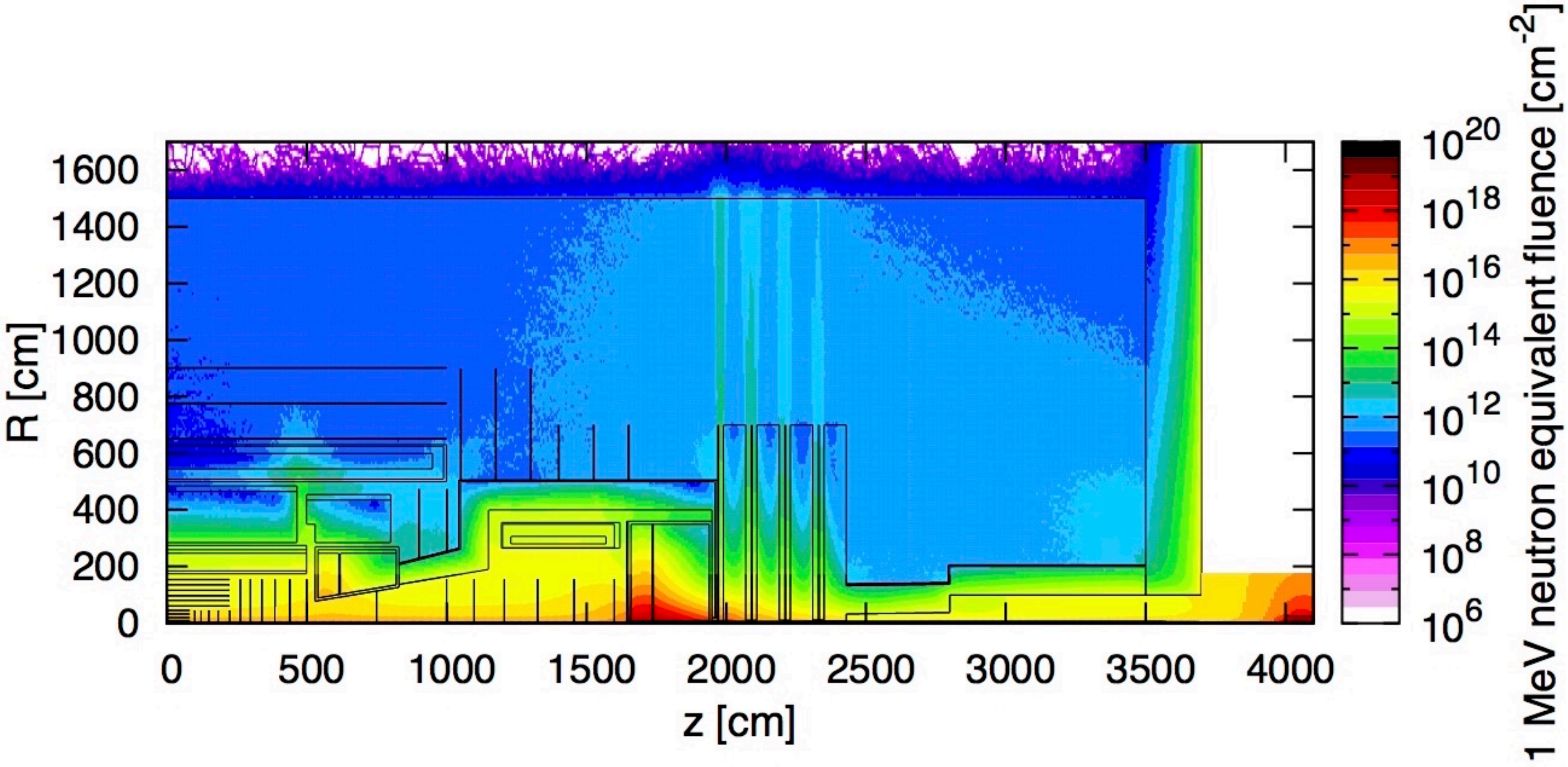


- in the forward muon chambers it is clearly visible the impact of the shielding around the beam pipe

- first bump due to particles coming from the hot spot in the end-cap EM calorimeter
- second bump at the entrance of the end-cap HAD calorimeter

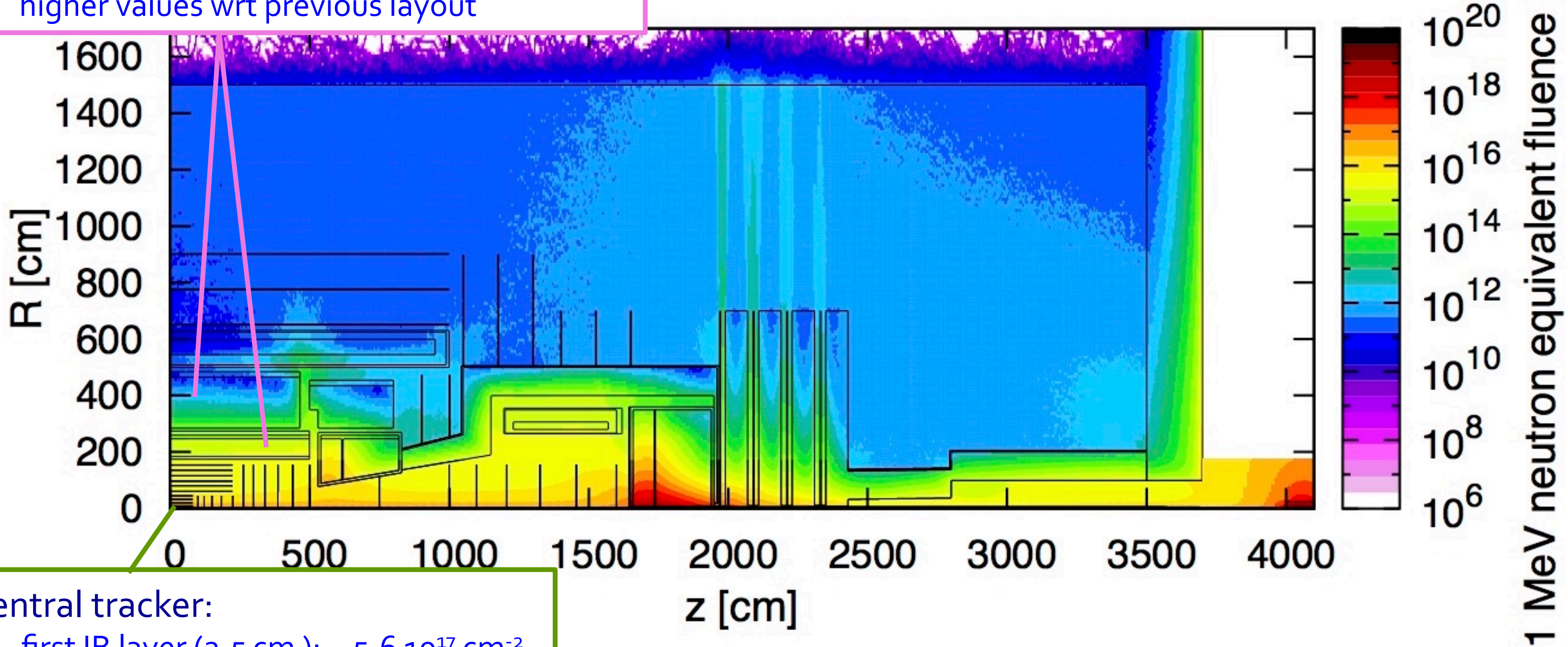
- the fluence rate is slightly higher in the forward tracking station closer to the forward calorimeters

1 MeV Neutron Equivalent Fluence for 30 ab^{-1}



1 MeV Neutron Equivalent Fluence for 30 ab^{-1}

Barrel calorimeter:
- EM-calo: 4 10^{15} cm^{-2} & HAD-calo: 4 10^{14} cm^{-2}
- higher values wrt previous layout



Central tracker:
- first IB layer (2.5 cm): ~5-6 10^{17} cm^{-2}
- external part: ~5 10^{15} cm^{-2}

1 MeV Neutron Equivalent Fluence for 30 ab^{-1}

Barrel calorimeter:

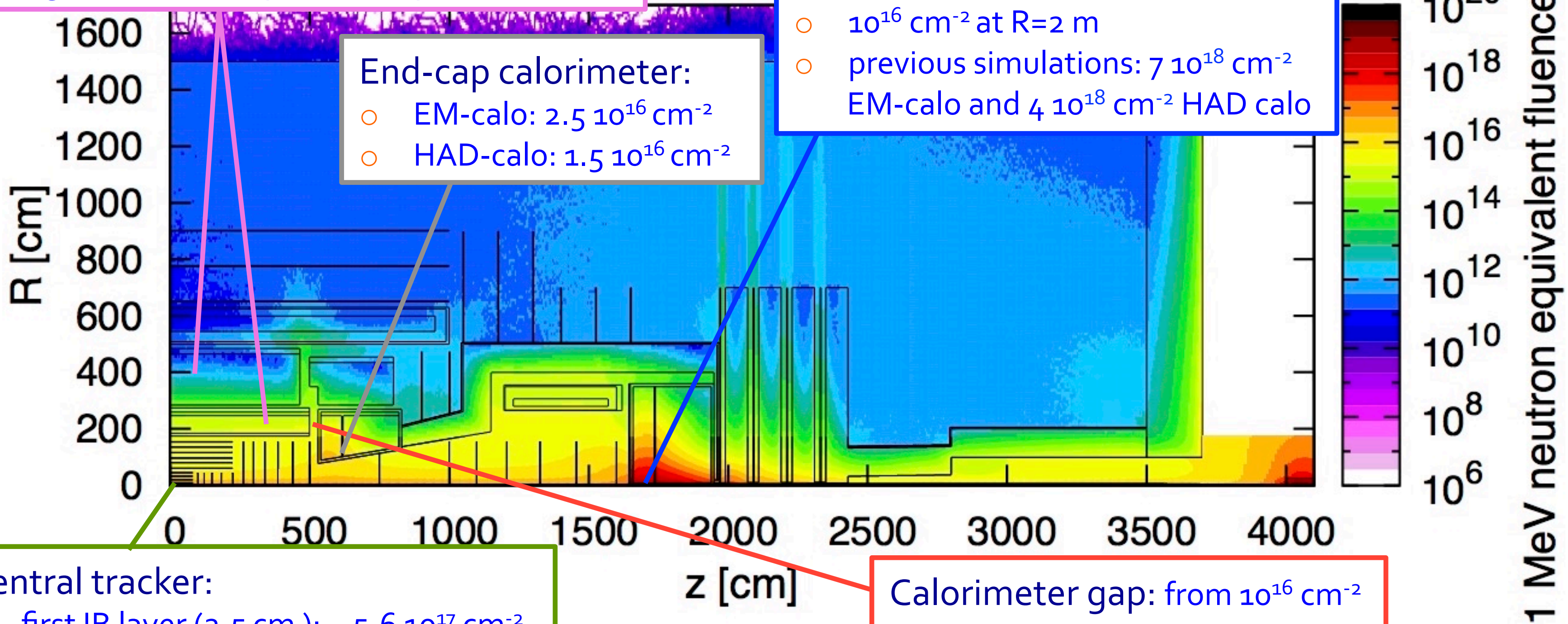
- EM-calo: 4 10^{15} cm^{-2} & HAD-calo: 4 10^{14} cm^{-2}
- higher values wrt previous layout

Forward calorimeters:

- maximum at ~5 10^{18} cm^{-2} for both the EM and the HAD-calo
- 10^{16} cm^{-2} at R=2 m
- previous simulations: 7 10^{18} cm^{-2} EM-calo and 4 10^{18} cm^{-2} HAD calo

End-cap calorimeter:

- EM-calo: 2.5 10^{16} cm^{-2}
- HAD-calo: 1.5 10^{16} cm^{-2}



Central tracker:

- first IB layer (2.5 cm): ~5-6 10^{17} cm^{-2}
- external part: ~5 10^{15} cm^{-2}

Calorimeter gap: from 10^{16} cm^{-2} to 10^{14} cm^{-2}

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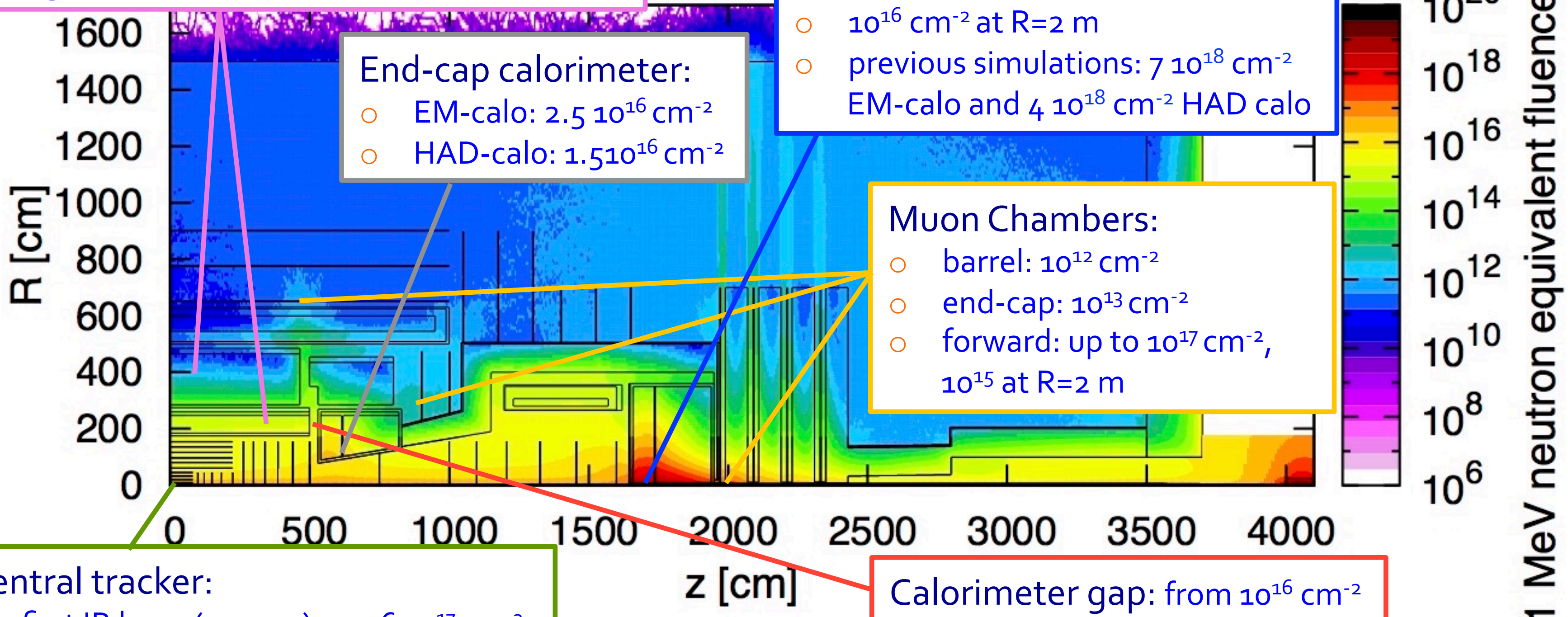
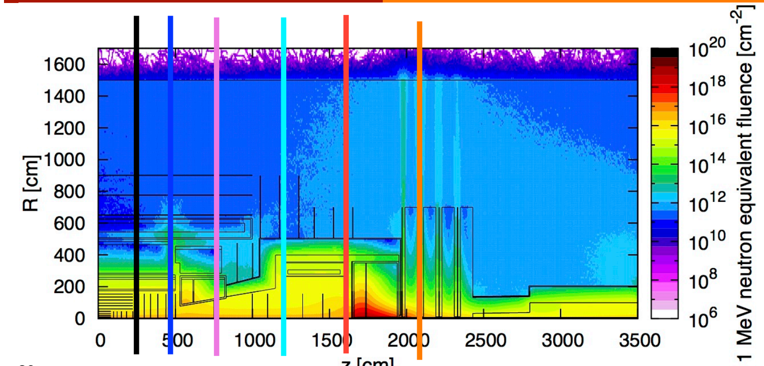


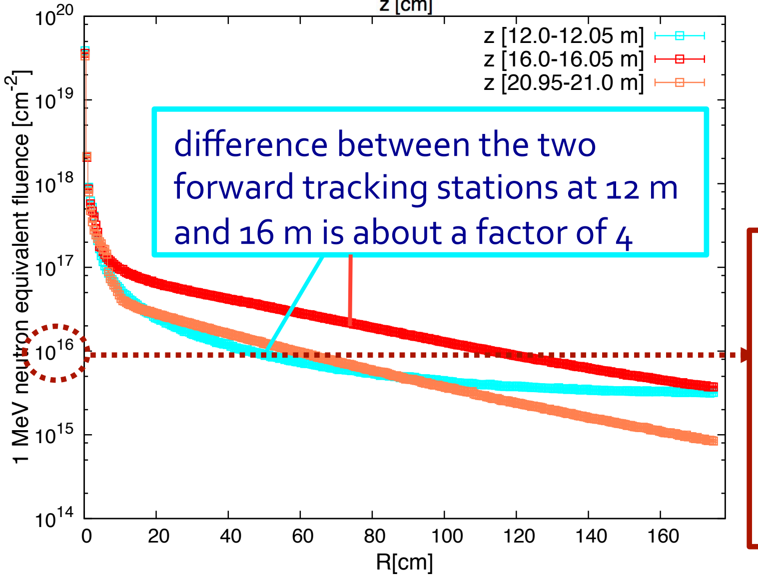
Muon Chambers:
- barrel: 10^{12} cm^{-2}
- end-cap: 10^{13} cm^{-2}
- forward: up to 10^{17} cm^{-2}, 10^{15} at R=2 m

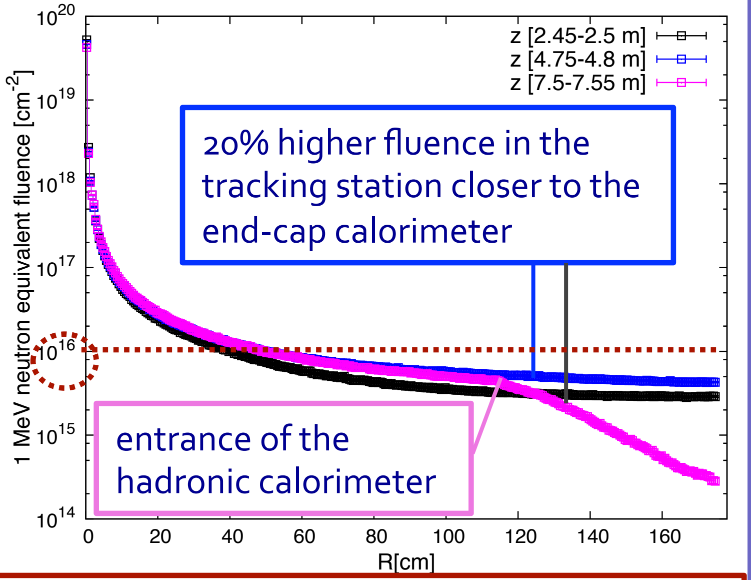
Central tracker:
- first IB layer (2.5 cm): ~5-6 10^{17} cm^{-2}
- external part: ~5 10^{15} cm^{-2}

Calorimeter gap: from 10^{16} cm^{-2} to 10^{14} cm^{-2}

1D distributions: Tracking Chambers

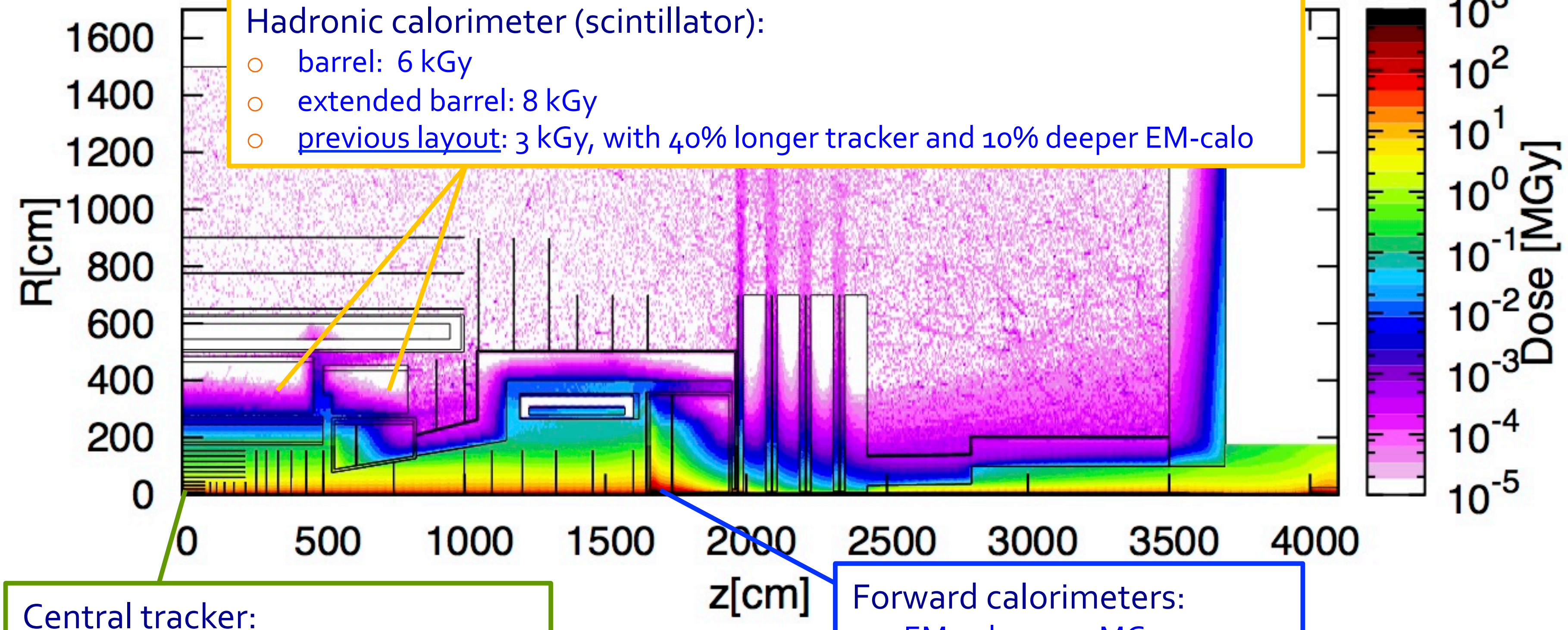






- For radii< 50-60 cm fluence exceeds the value expected at HL-LHC (10^{16}cm^{-2}) by ~2 orders of magnitude
- In the tracking station closer to the forward calo (16 m) the fluence is higher up to R=1.2 m
  - previous layout the values were higher up to a radius of 2.5 m, because of the dipole field

Dose for 30 ab^{-1}

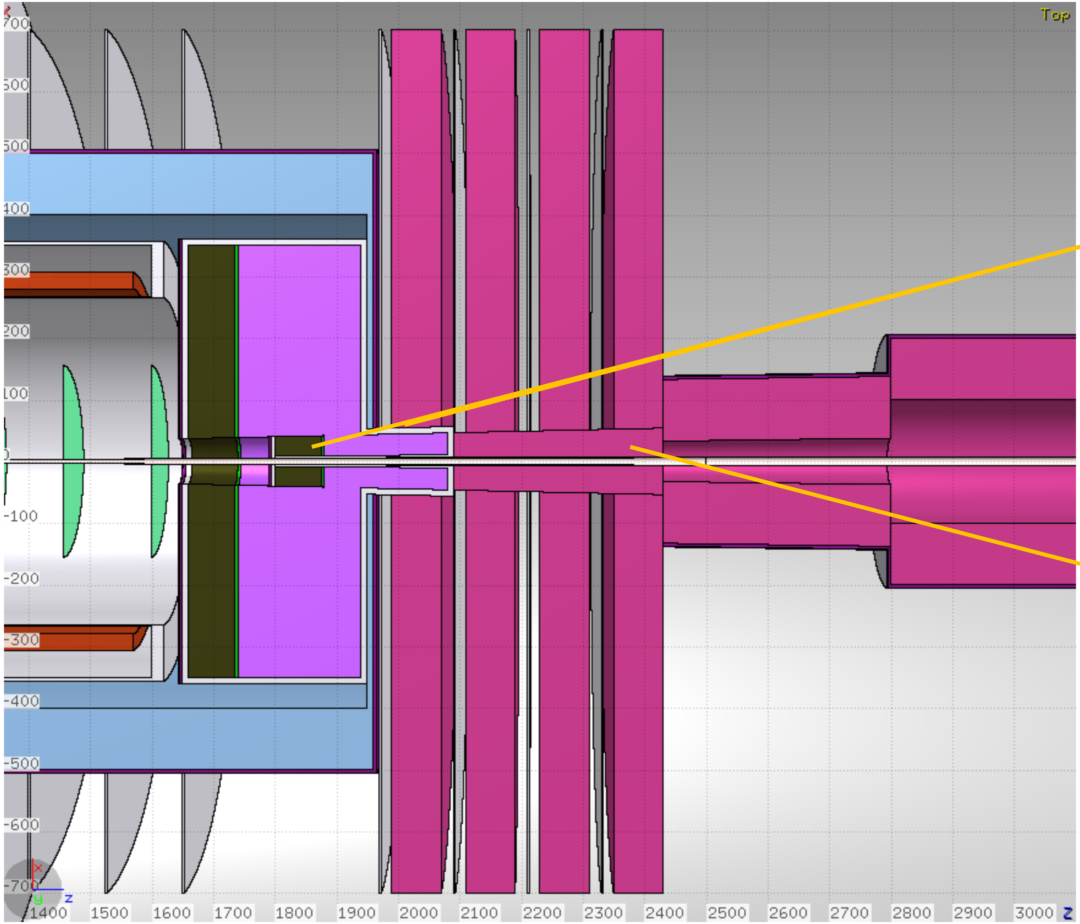


Hadronic calorimeter (scintillator):
- barrel: 6 kGy
- extended barrel: 8 kGy
- previous layout: 3 kGy, with 40% longer tracker and 10% deeper EM-calo

Central tracker:
- first IB layer (2.5 cm): ~400 MGy
- external part: 0.1 MGy

Forward calorimeters:
- EM-calo: 5000 MGy
- HAD-calo: ~1000 MGy
- at R=2 m the dose is ~1 MGy

Alternative Geometry

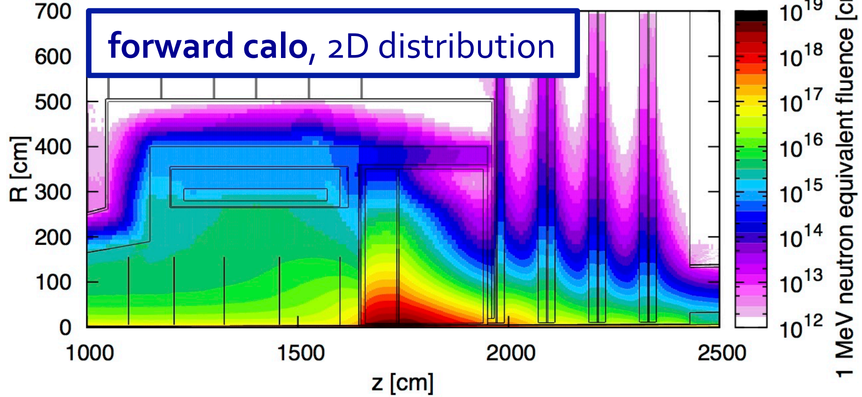


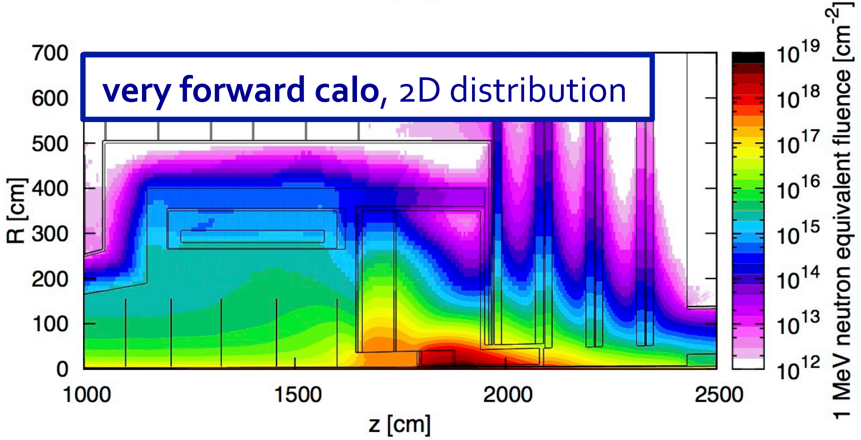
"Very forward" calo for 4.5<|η|<6.0 region, displaced from z=16.5 m to z=18 m).
Same calorimeter thickness and same shielding in front.

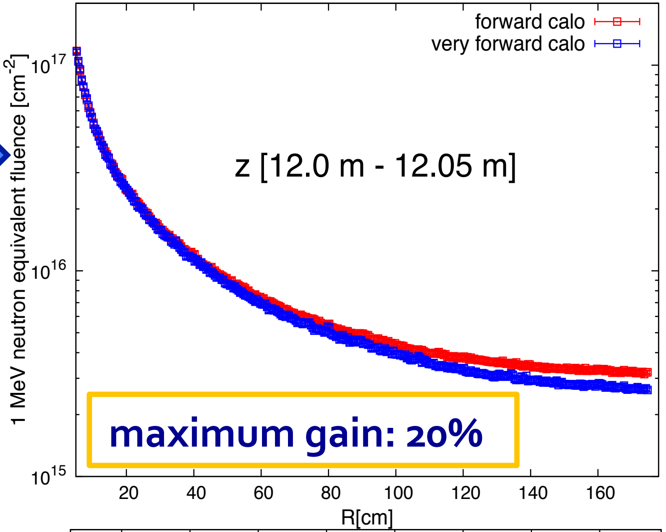
Cast iron shielding from 4.5<|η|<6.5

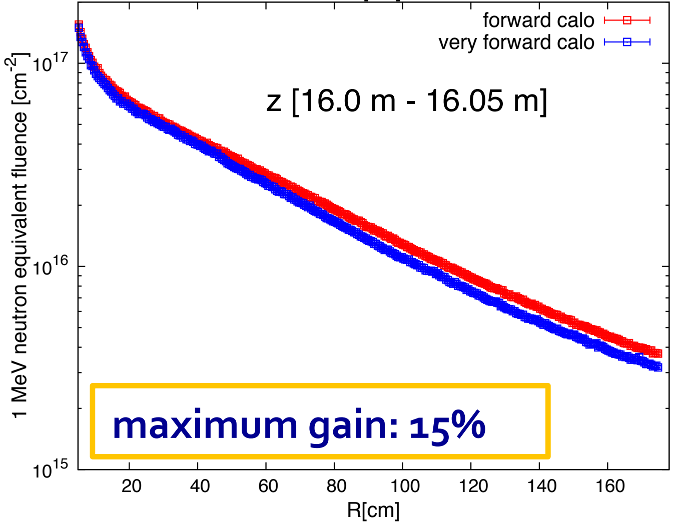
Forward Tracker

- **1 MeV neutron equivalent fluence** in the forward tracker
  - minor reduction with the new layout



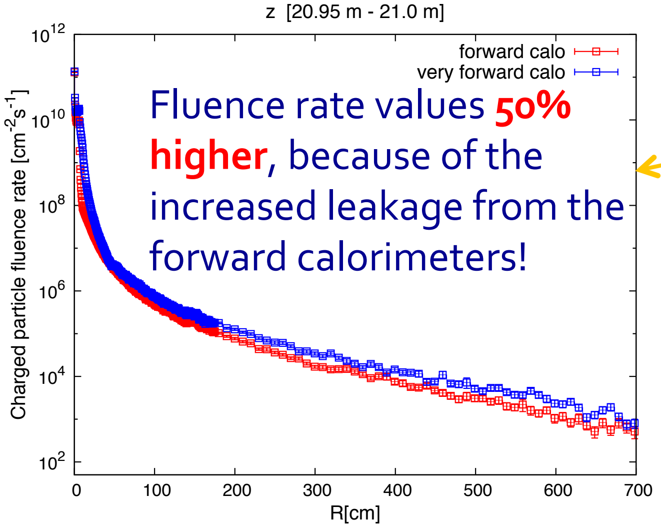


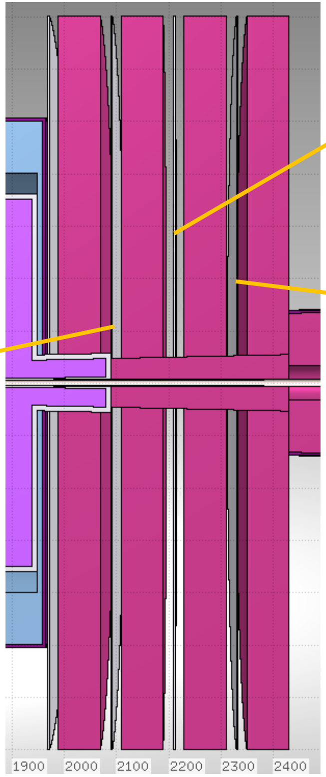


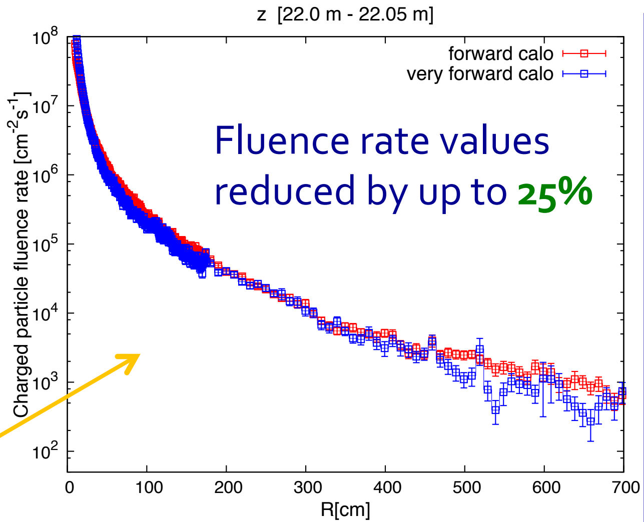


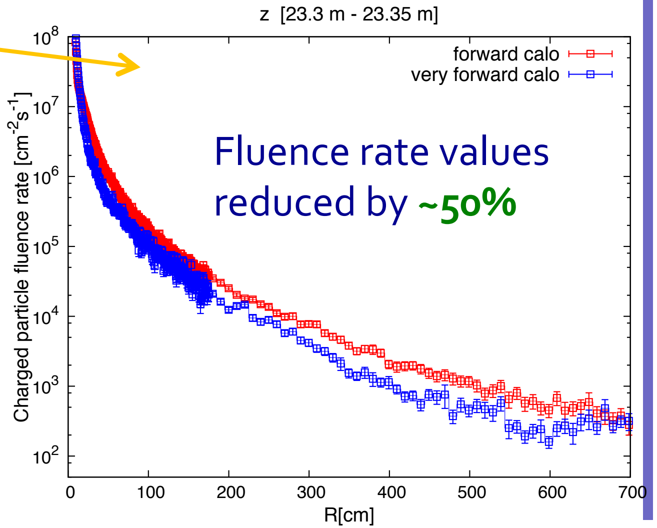
Forward Muon Chambers

- Charged particle fluence rates in the forward muon chambers: comparison between old and new layout
  - higher fluence rate in the first two tracking stations, because of the leakage from the "very forward" calorimeter
  - lower rate in the last two, thanks to thicker inner shielding









Conclusions & Outlooks

Conclusions:

- Radiation studies for the **second version** of FCC detector have been presented
  - the TAS contribution is taken into account
  - results have been shown in terms of:
    - neutron & charged particle fluence rates
    - long term damage: 1 MeV neutron equivalent fluence & dose
    - other quantities available not reported in this talk
  - the expected values pose challenges on detector technology, which will be highlighted in the following talks
- Shielding strategy proposed to protect muon chambers against leakage and back-scattering from forward calo and TAS:
  - the shielding is effective, but the localized leakage points affect fluence values in the muon chambers → higher values wrt the previous layout
- An alternative geometry version has been explored with "very forward" calorimeters and a reduced muon acceptance
  - the calorimeter split is not effective in reducing the fluence in the tracking stations & it has a bad effect on the forward muon chambers
  - the shielding inside the muon chambers has instead a positive impact

Outlooks:

- The "very forward" calorimeter option will be dropped for future studies
- To protect forward muon tracking stations:
  - the increase of the shielding around the beam pipe will be maintained
  - a thicker forward calorimeter will be considered

Thanks for your attention

Back-up