Detector Radiation Studies

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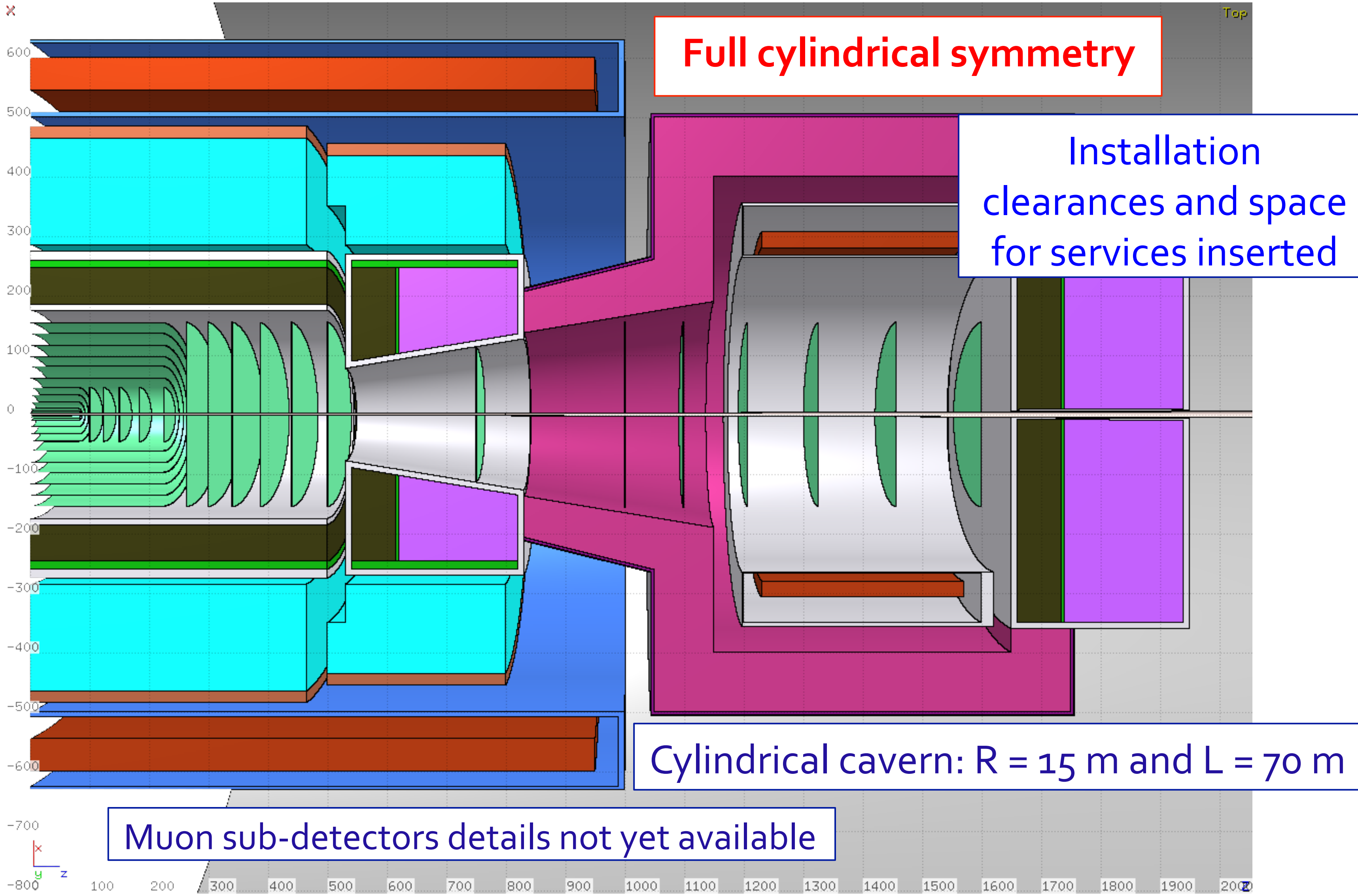
Outline

- Brief update on the detector geometry:
  - muon chambers
- Shielding:
  - motivations
  - possible conceptual design
- Radiation levels:
  - charged particle fluence rate
  - neutron fluence rate
  - photon fluence rate
  - 1 MeV neutron equivalent fluence
  - dose
  - → **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
- Conclusions

(charged particle, neutron and photon fluence rate:) for an instantaneous luminosity of **$30\ 10^{34}\ cm^{-2}s^{-1}$**

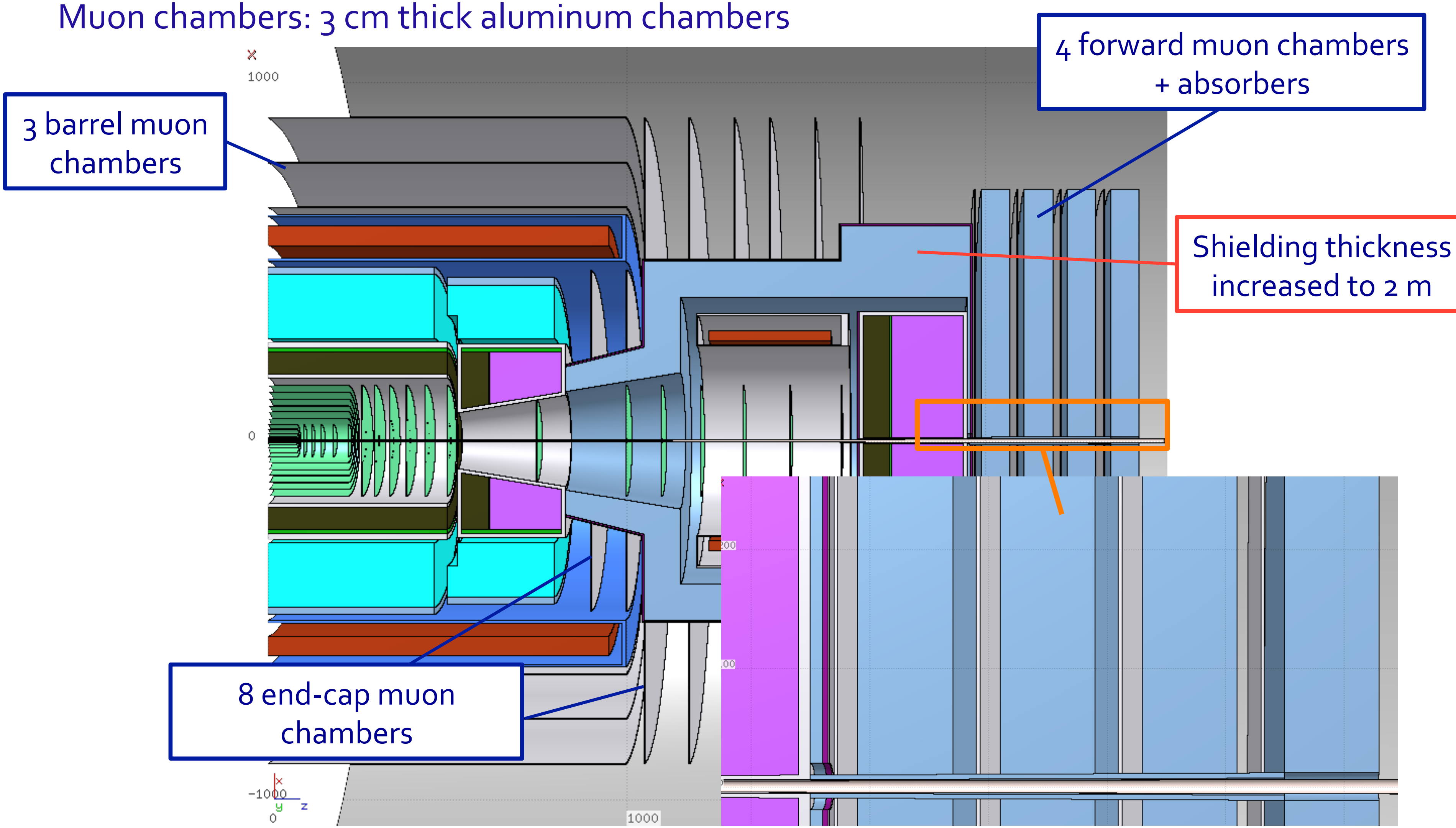
(1 MeV neutron equivalent fluence and dose:) for an integrated luminosity of **$30\ ab^{-1}$**

Detector Layout up to last Meeting:



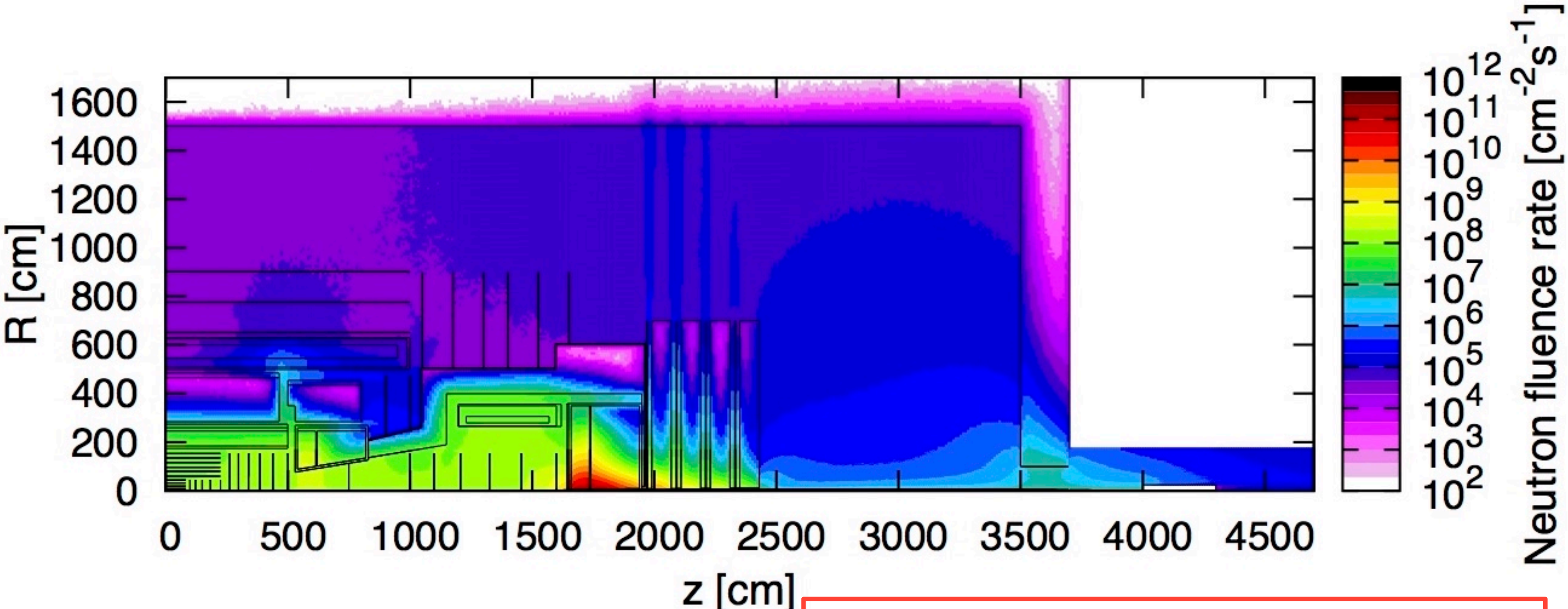
Muon Chambers

Muon chambers: 3 cm thick aluminum chambers



Shielding Needs: Neutron Fluence Rate I

- Leakage from the forward part of the detector and from the cavern wall → repopulation of muon chambers

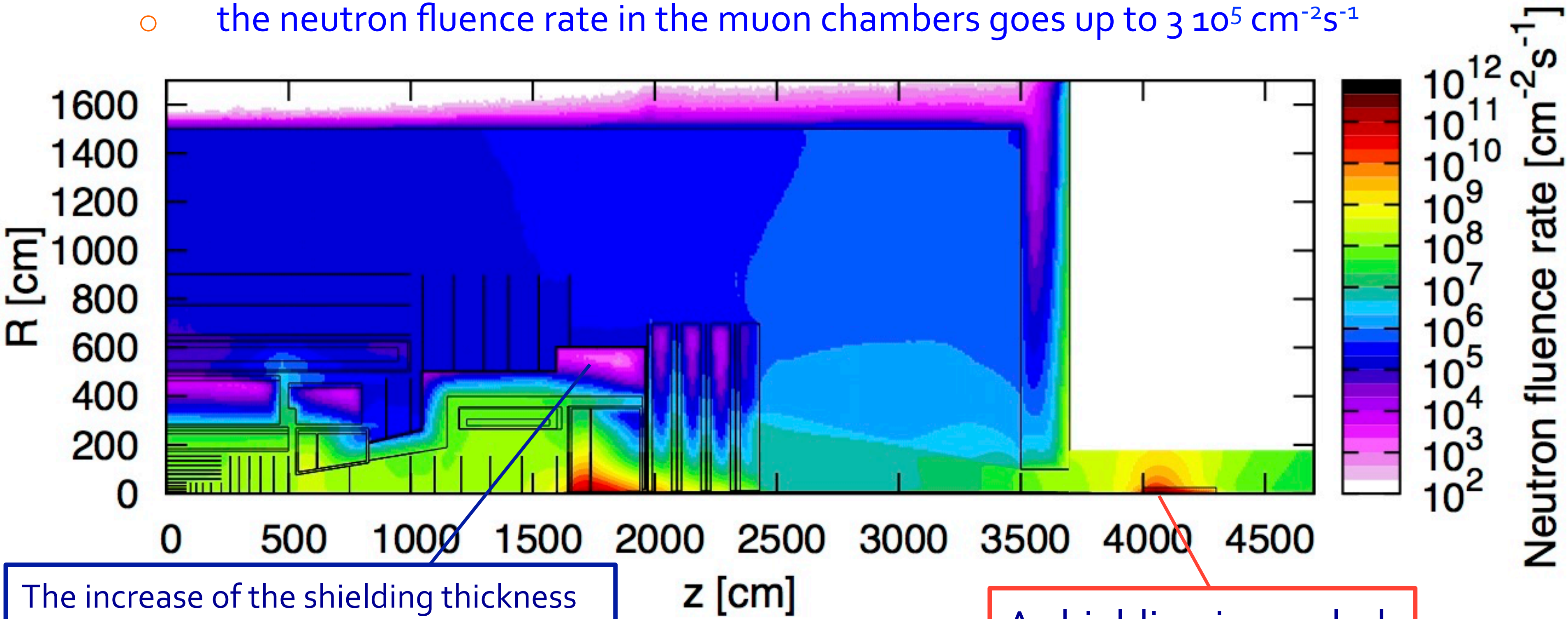


No TAS contribution taken into account here: the TAS is set to "black-hole": everything impacting on it is completely absorbed.

See next slide....

Shielding Needs: Neutron Fluence Rate II

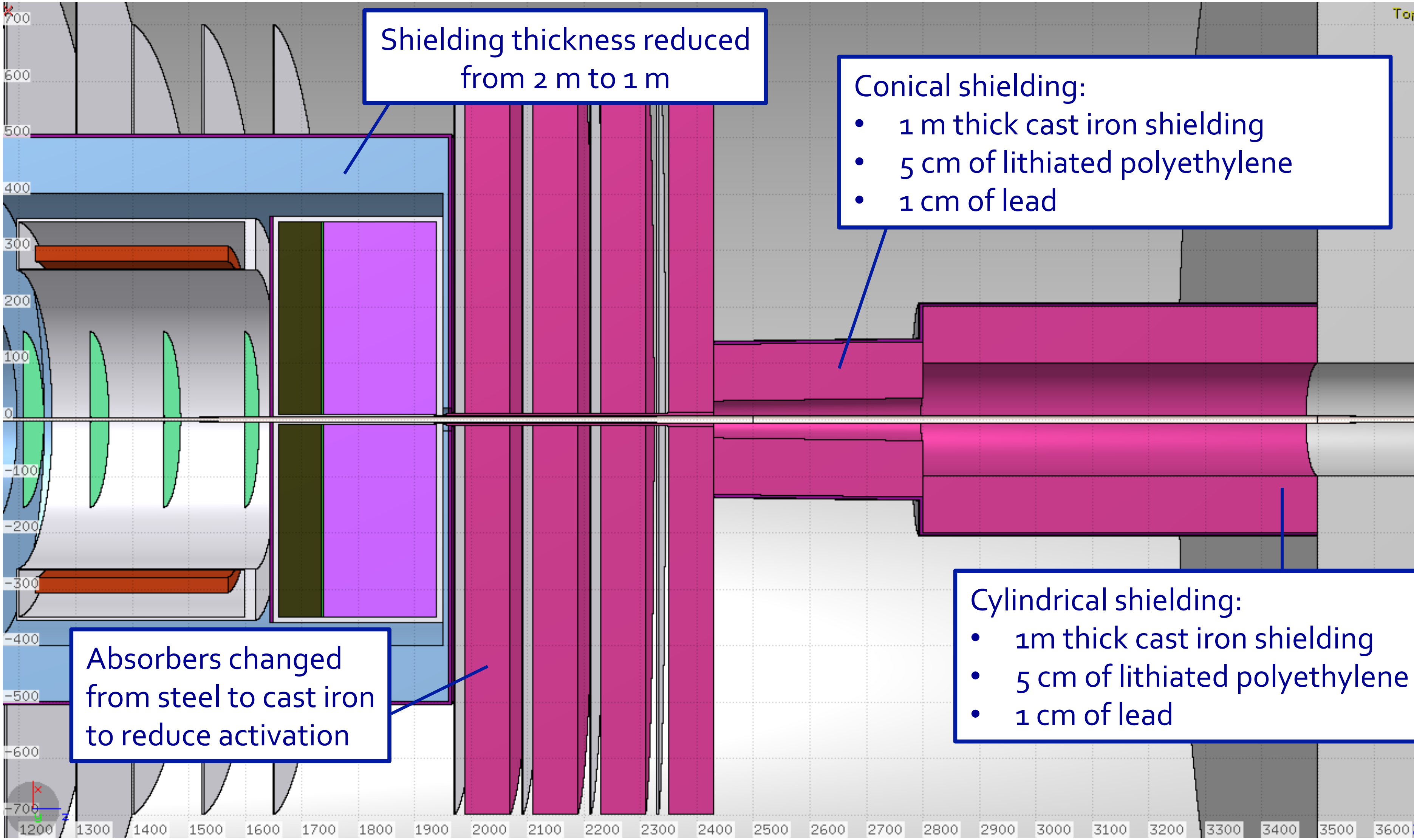
- The leakage is even more important when the TAS contribution is taken into account:
  - the TAS is a hot spot for neutron production
  - the neutron fluence rate in the muon chambers goes up to 3 10^5 $cm^{-2}s^{-1}$



The increase of the shielding thickness to 2 m is not really needed. Without the dipole field the fluence rate spread along x is much lower.

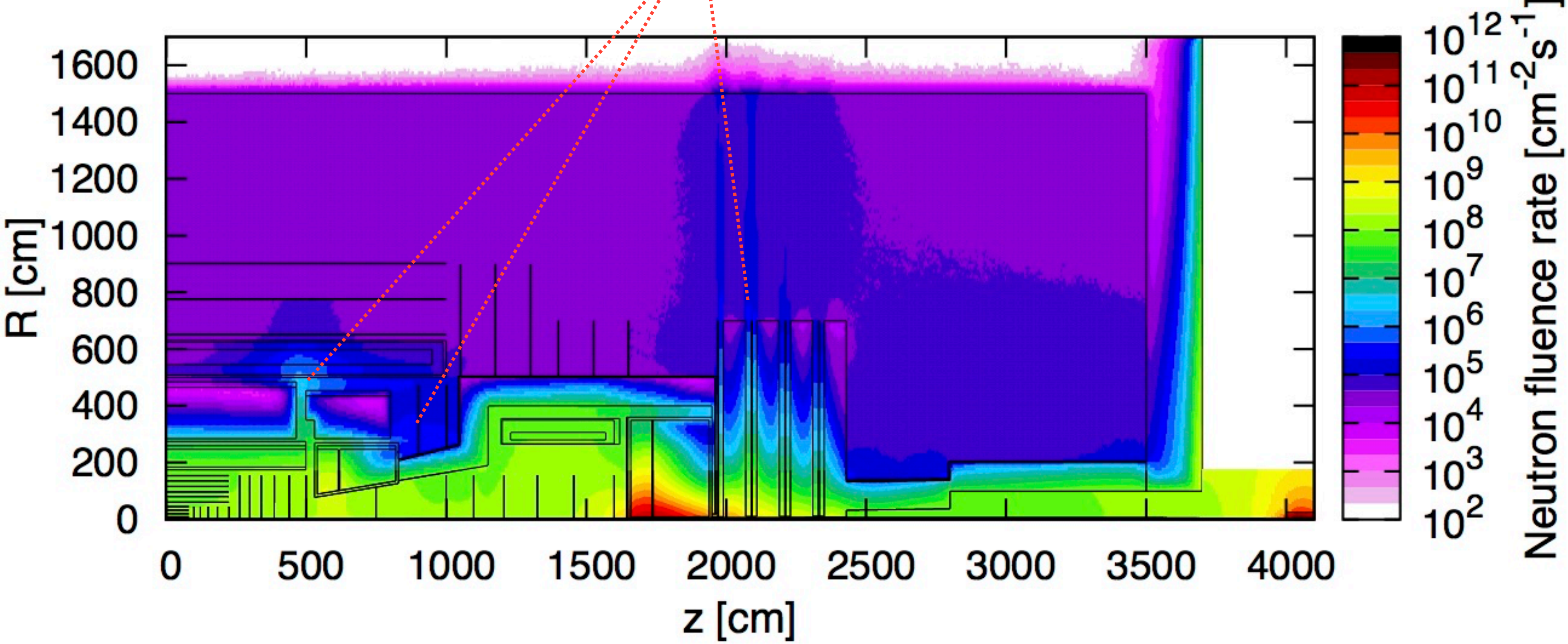
A shielding is needed

Shielding in the Forward Region



Neutron Fluence Rates with Shielding

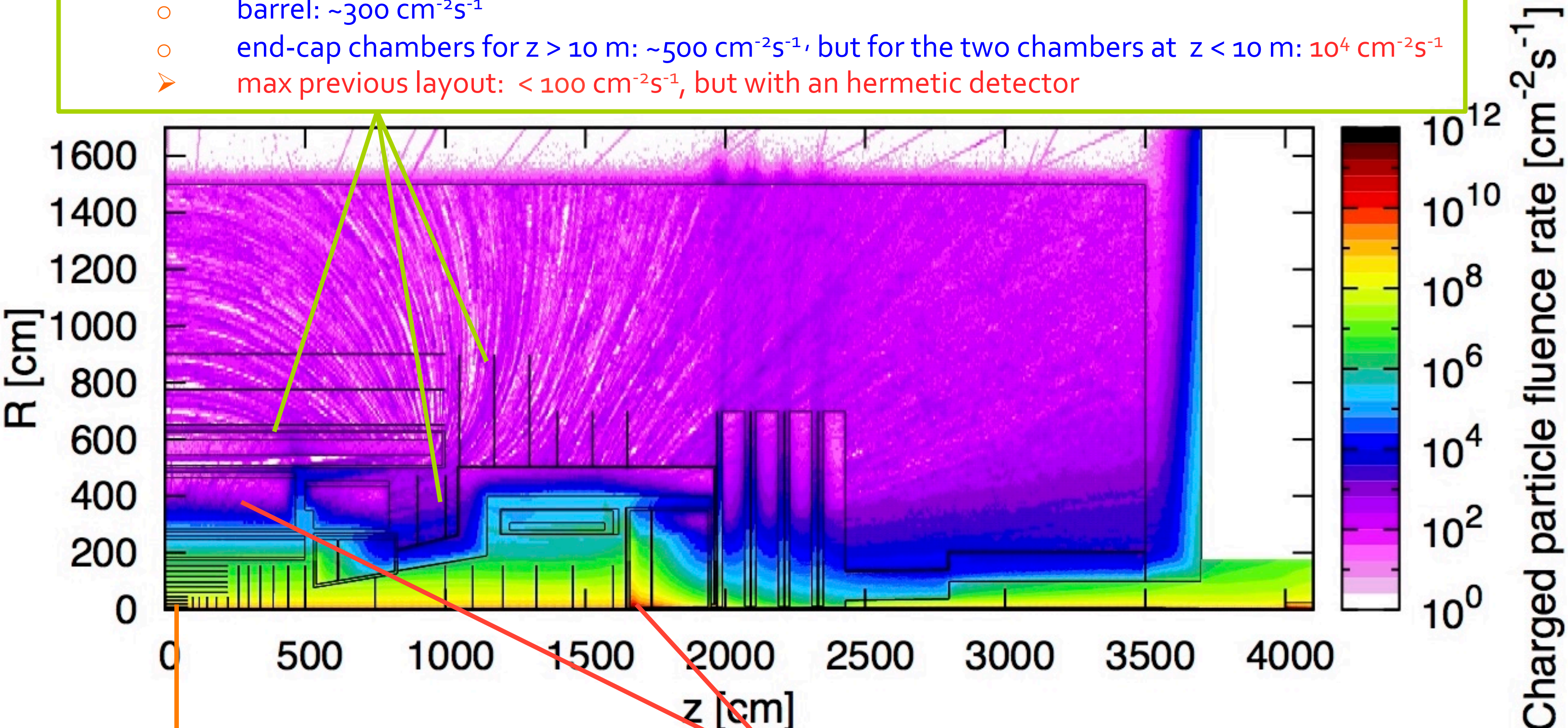
- The shielding in the forward region is effective in reducing the neutron fluence rate
  - the fluence rate on the external muon chambers are reduced to 4 10^4 cm^{-2} s^{-1}
- However there are localized **leakage points** that have a significant impact on the rates observed in the muon chambers



All Charged Particles Fluence Rate

Fluence rates in the 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 layout: < 100 $cm^{-2}s^{-1}$, but with an hermetic detector



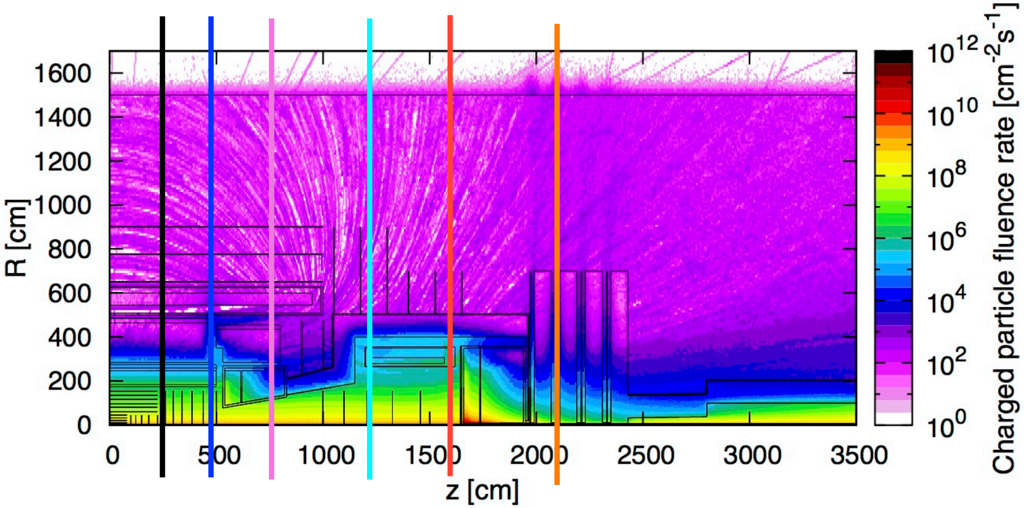
Fluence rates in the tracker:

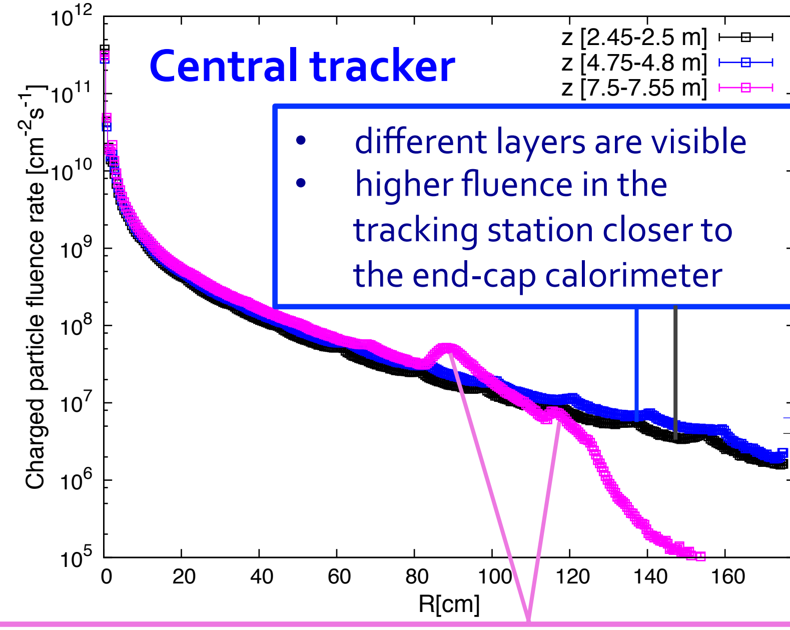
- first IB layer (2.5 cm): ~ 1.2 10^{10} $cm^{-2}s^{-1}$
- external part: 3 10^6 $cm^{-2}s^{-1}$

Fluence rates in the calorimeters:

- minimum in the barrel HAD-calo: ~ 100 $cm^{-2}s^{-1}$
- max in the forward calorimeters: 10^{11} $cm^{-2}s^{-1}$

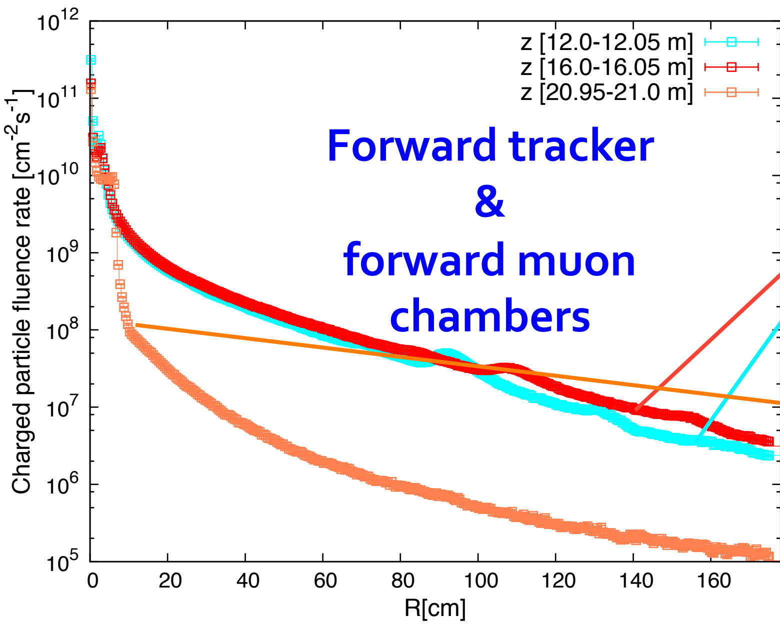
1-D Distributions





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

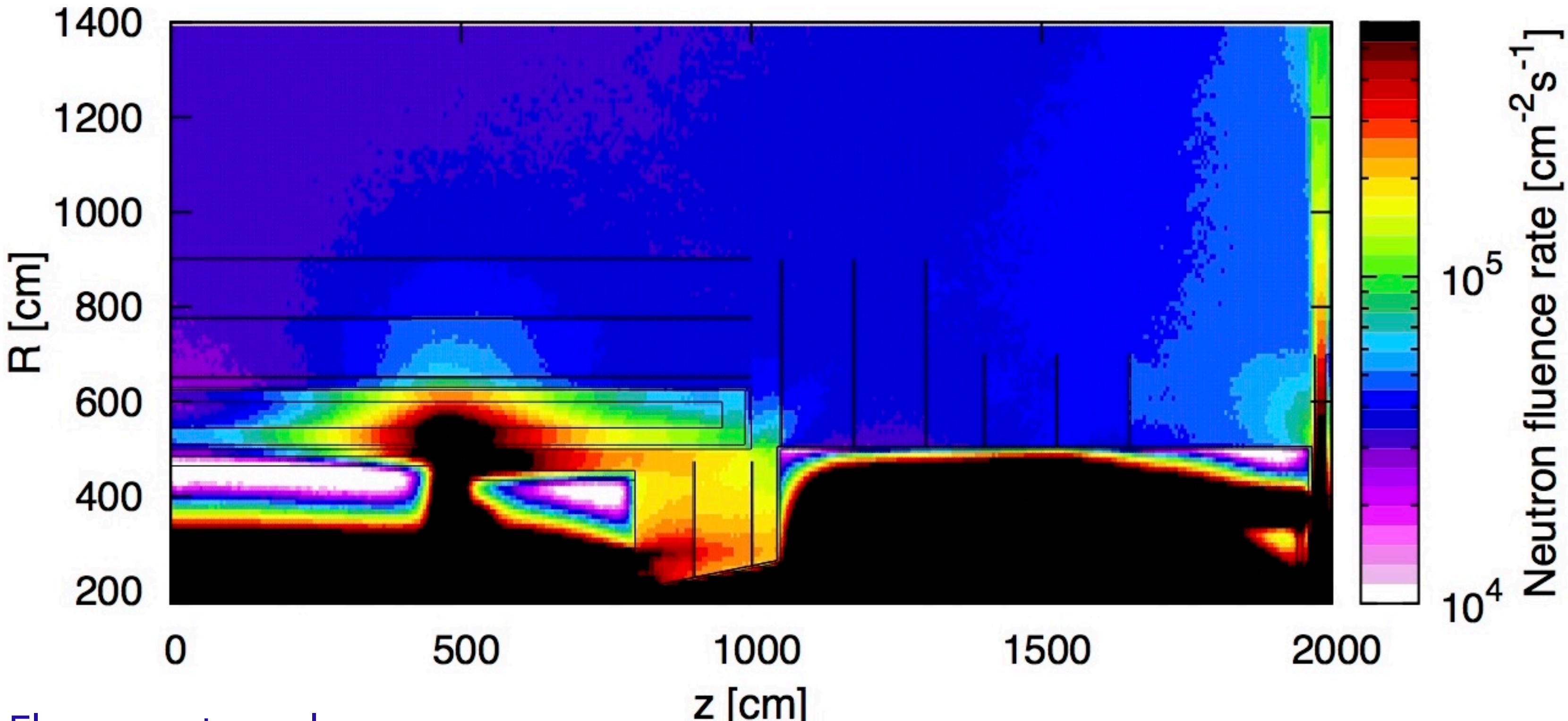
- first bump due to particles coming from the hot spot in the end-cap EM calorimeter
- second bump at the entrance of the end-cap hadronic calorimeter



- fluence rates in the forward tracking stations: slightly higher in the tracking station closer to the forward calorimeters

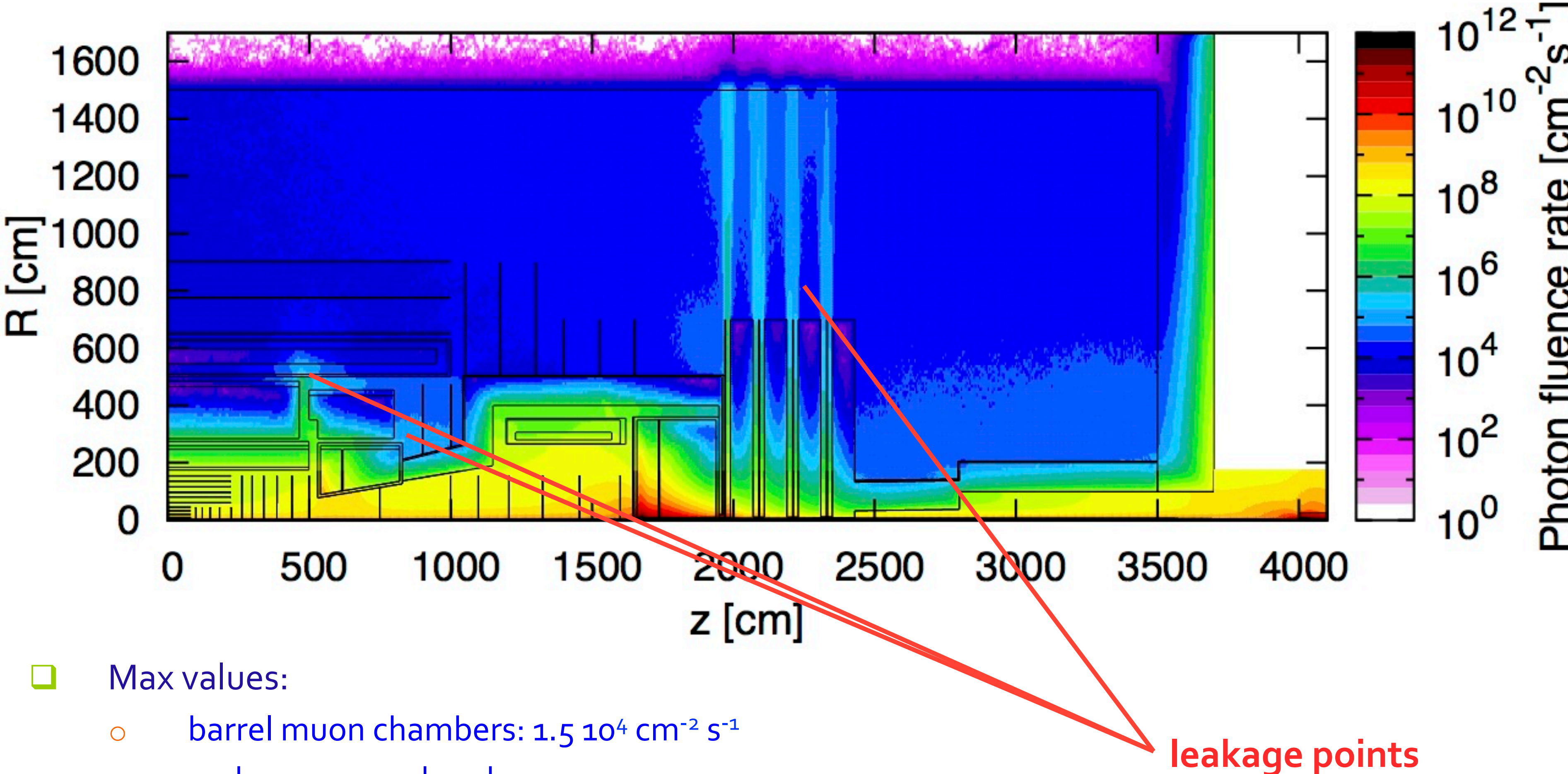
- in the forward muon chambers it is clearly visible the impact of the shielding around the beam pipe

Neutron Fluence Rate in Muon Chambers



- Fluence rates values:
  - barrel muon chambers: 7 10^4 cm^{-2} s^{-1}, due to the leakage from the crack in the calorimeter for the cables
  - end-cap muon chambers:
    - 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 Hz cm^{-2}, compared to ~ 10 Hz cm^{-2} of the previous layout

Photon Fluence Rate

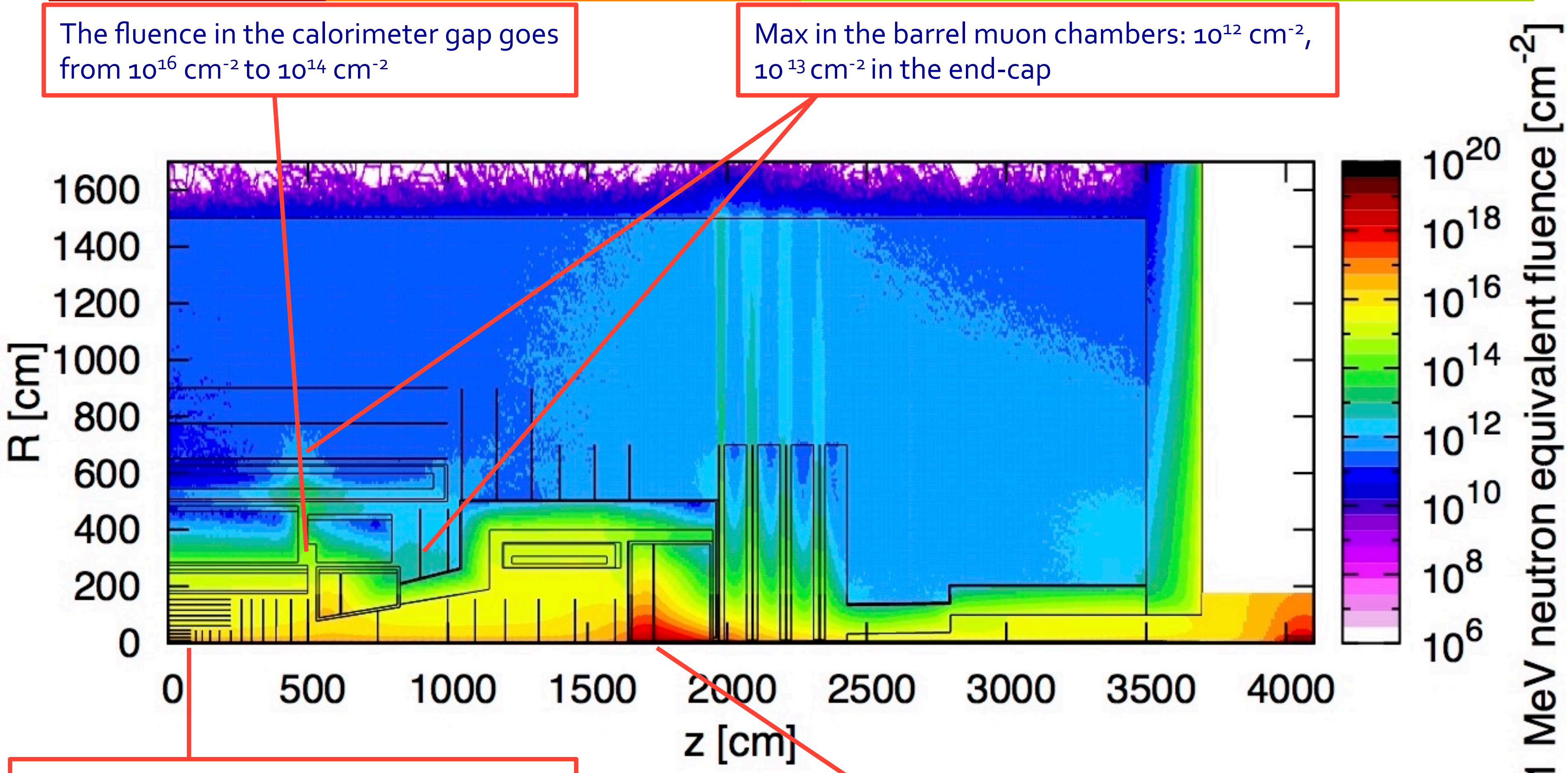


- Max values:
  - barrel muon chambers: 1.5 10^4 cm^{-2} s^{-1}
  - end-cap muon chambers:
    - six chambers at z > 10 m: 2 10^4 cm^{-2} s^{-1}
    - two chambers at z < 10 m: ~10^5 cm^{-2} s^{-1}
- expected rate in muon chambers up to 1 kHz cm^{-2}, compared to 20 Hz cm^{-2} of previous layout

1 MeV Neutron Equivalent Fluence

The fluence in the calorimeter gap goes from 10^{16} cm^{-2} to 10^{14} cm^{-2}

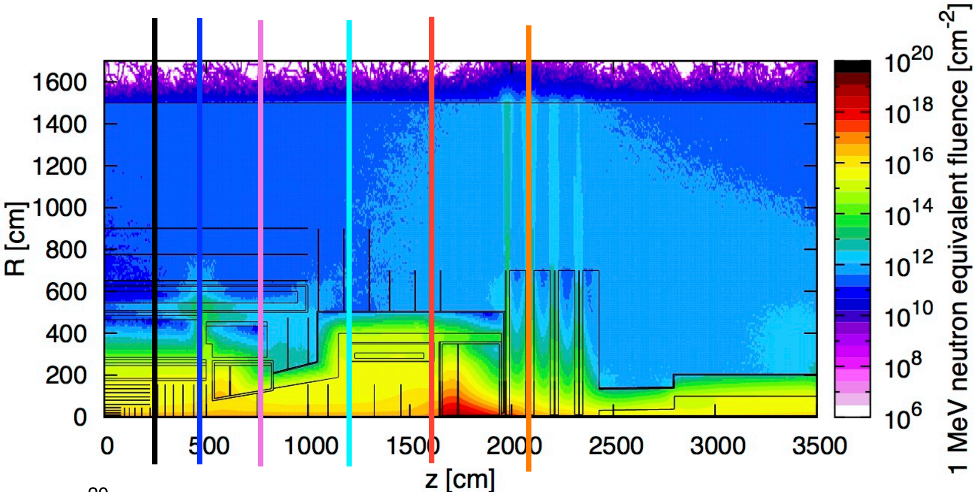
Max in the barrel muon chambers: 10^{12} cm^{-2}, 10^{13} cm^{-2} in the end-cap

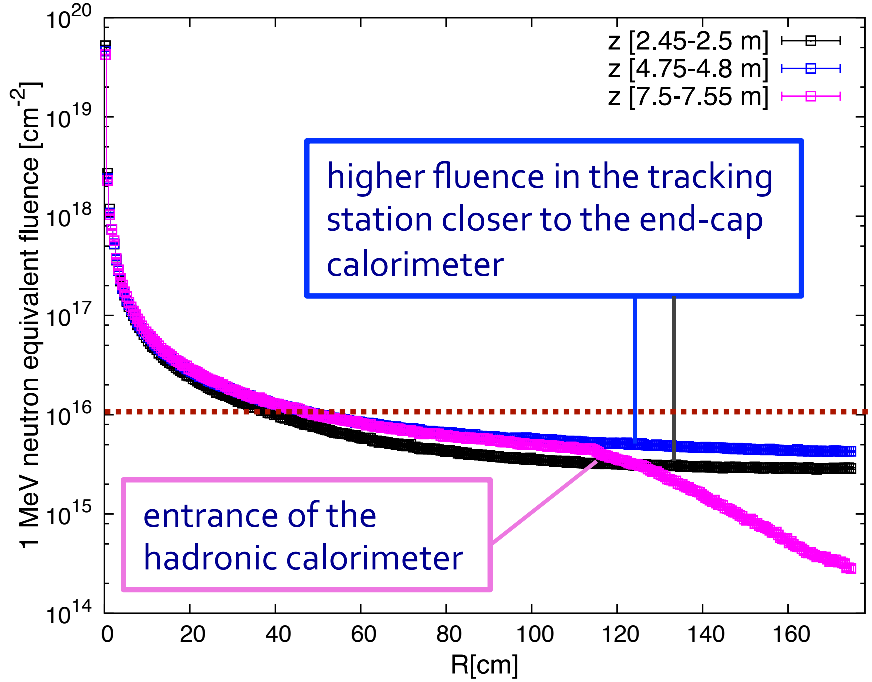


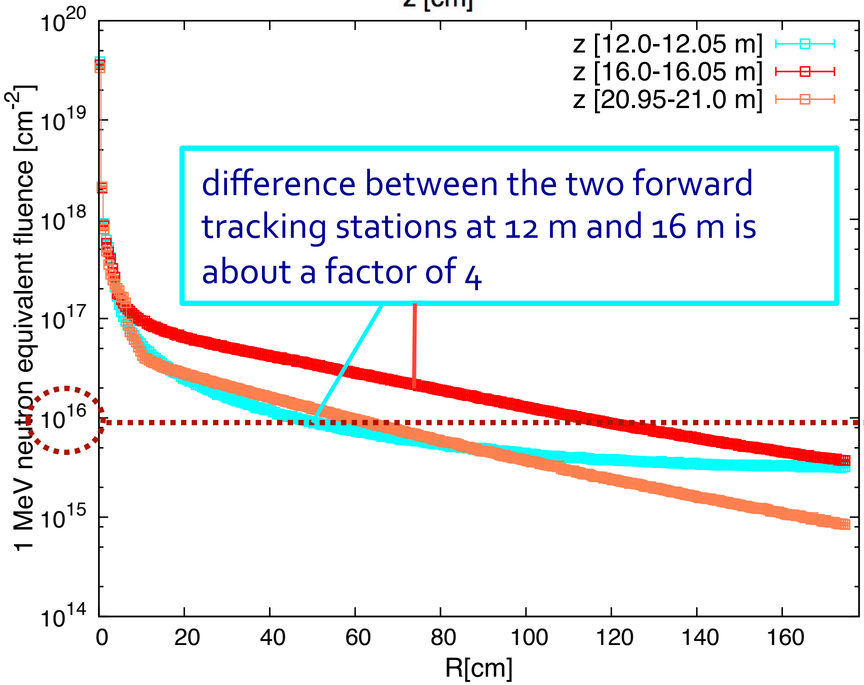
Fluence in the first IB layer: ~5-6 10^{17} cm^{-2}

Max in the forward calorimeters: ~5 10^{18} cm^{-2} for both the EM and the HAD-calo (slightly higher in the HAD calo)
→ previous simulations: 7 10^{18} cm^{-2} EM calo and 4 10^{18} cm^{-2} HAD calo

1D distributions: Tracking Chambers

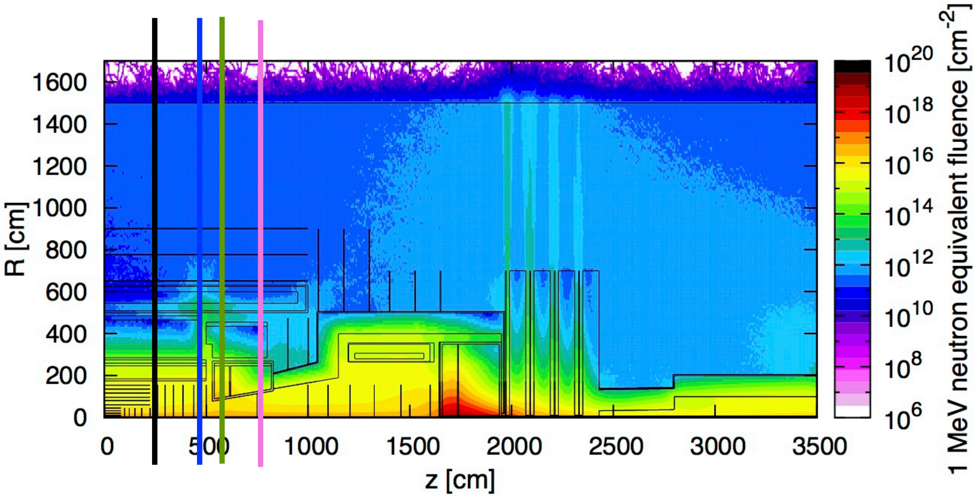


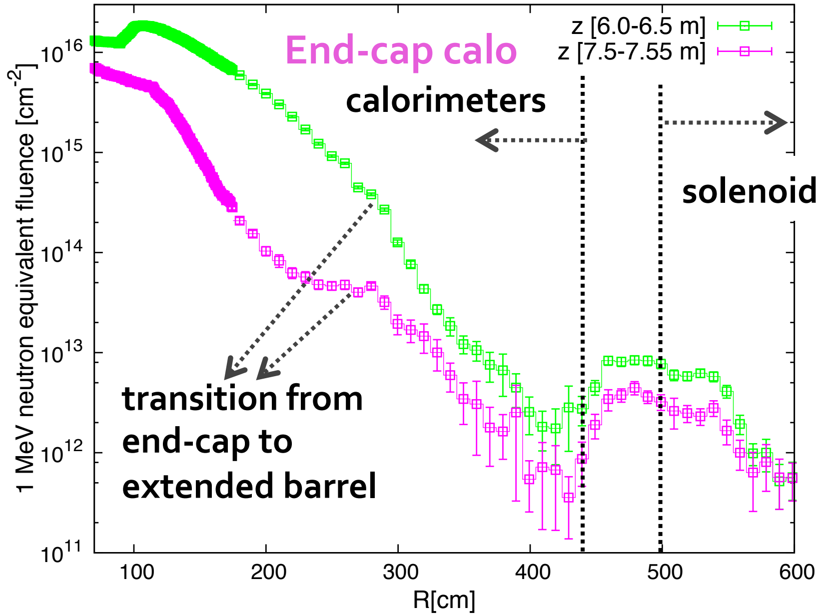


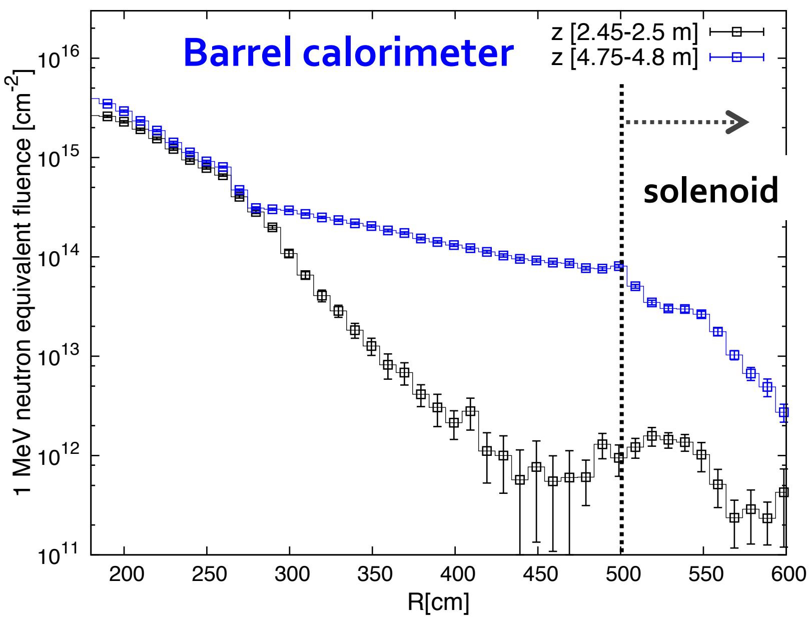


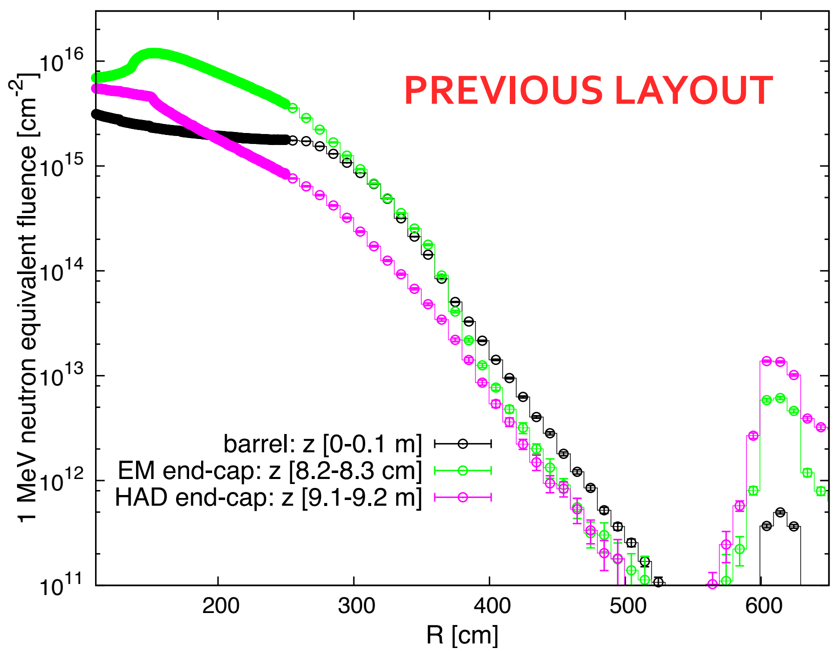
- For radii< 50-60 cm the fluence exceeds the value expected at HL-LHC (10^{16}cm^{-2}) by ~2 orders of magnitude
- In the tracking station closer to the forward calorimeter (at 16 m) the fluence is higher up to R=1.2 m
  - previous layout the values were higher up to a radius of 2.5 m

Calorimeters I

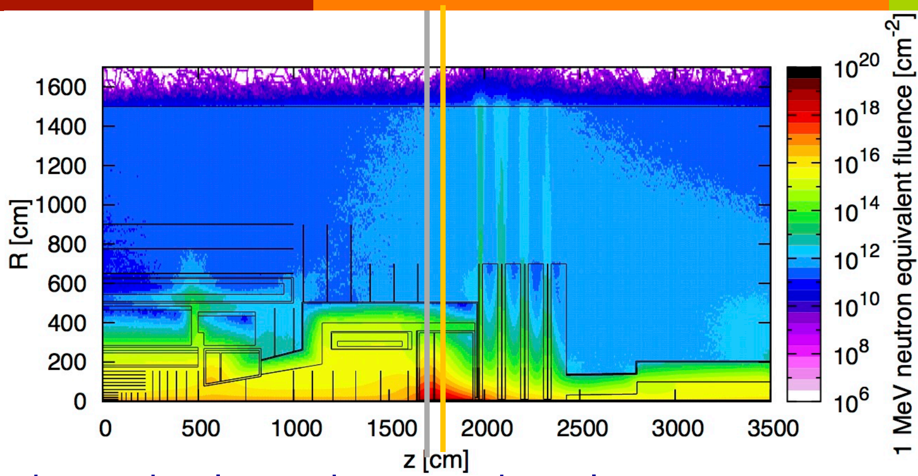


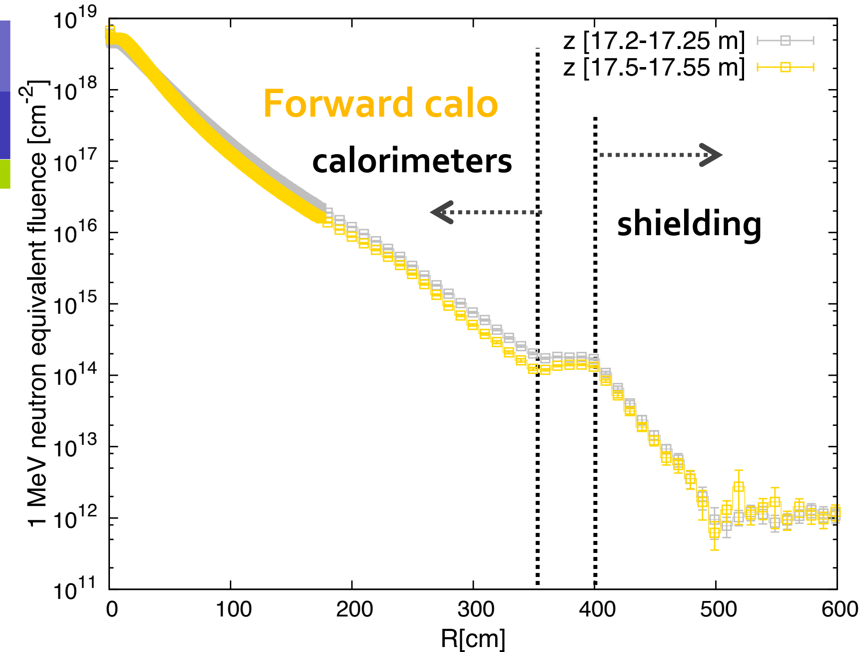




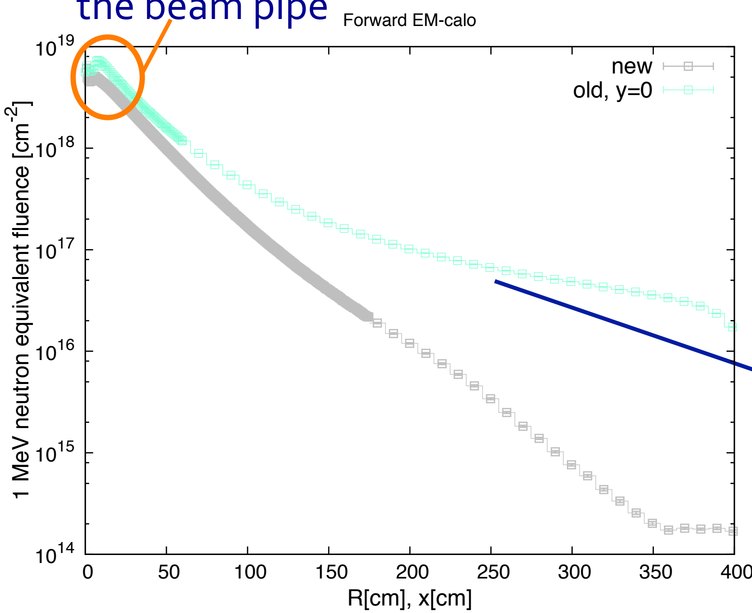


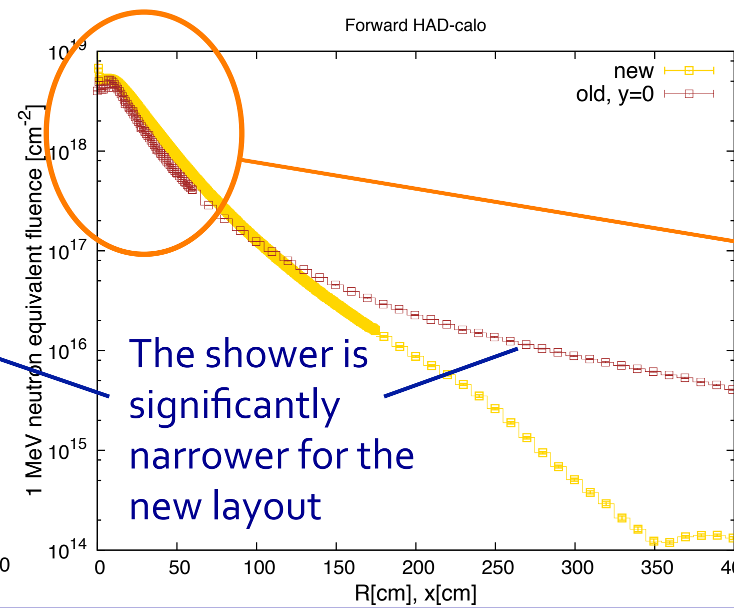
Calorimeters II





The peak is lower, because the calorimeters are now up to η=6, while before they were going up to the beam pipe

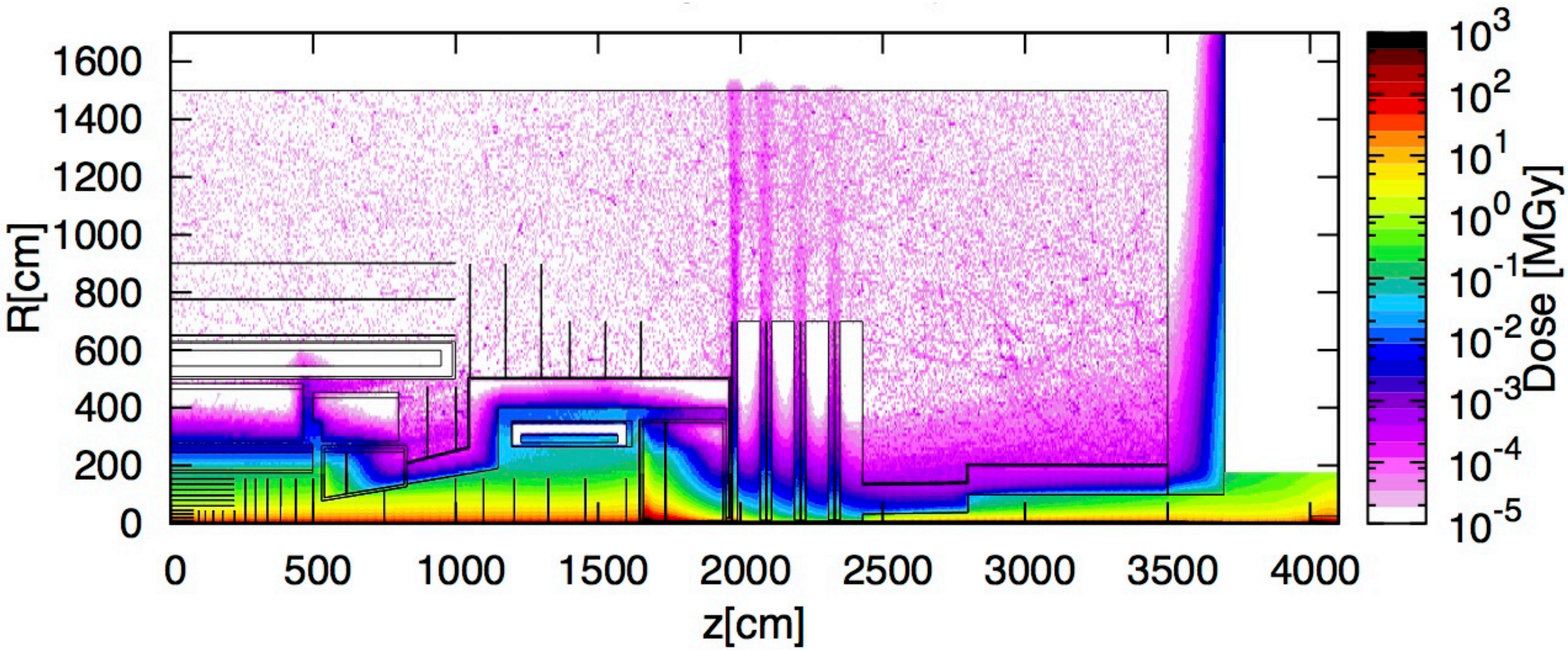




The shower is significantly narrower for the new layout

The values in the forward hadron calorimeters are higher than in the previous layout and they are more similar to the values observed in the EM calorimeter

Dose



	Dose [MGy]
first layer of the IB (R =2.5 cm)	~400
max in forward calorimeters	5 10^{3}

Conclusions

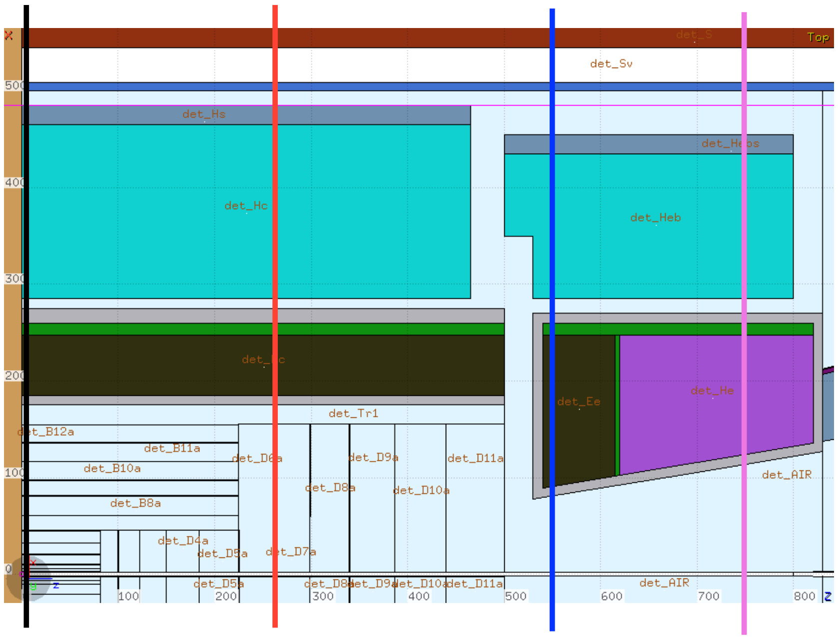
- First radiation studies for the second version of FCC detector have been shown today
  - the contribution coming from the TAS is taken into account
  - results have been shown in terms of:
    - charged particles fluence rates
    - neutron fluence rates
    - photon fluence rates
    - 1 MeV neutron equivalent fluence
    - dose
    - other quantities are available, like charged hadrons and high energy hadrons fluence rates
  - I have prepared a map of the charged particle fluence for the tracker:
    - /eos/project/f/fcc-hh/data/Detector/Tracker/FCChh-Fluka-Charged_RZ.02.March_2017.dat
    - if we agree on the format I can produce similar files for all the relevant quantities

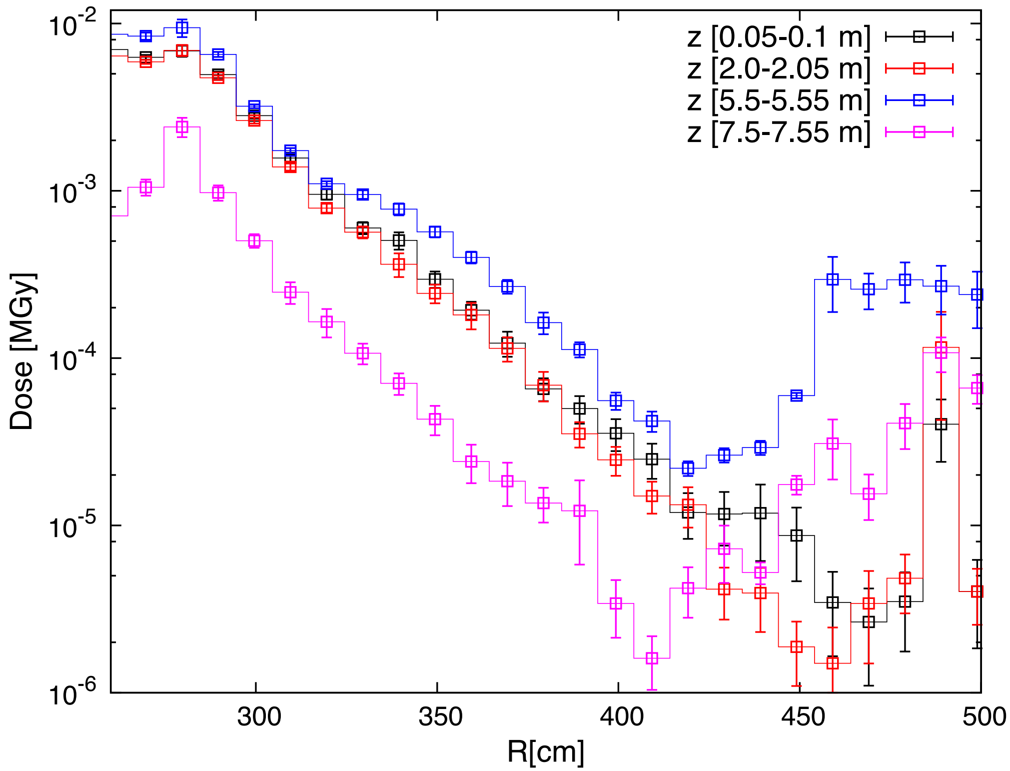
- A shielding strategy has been proposed to protect the muon chambers against the leakage from the forward part of the detector and against the back-scattering from the TAS:
  - the shielding is effective, but there are localized leakage points that affect fluence values in the muon chambers

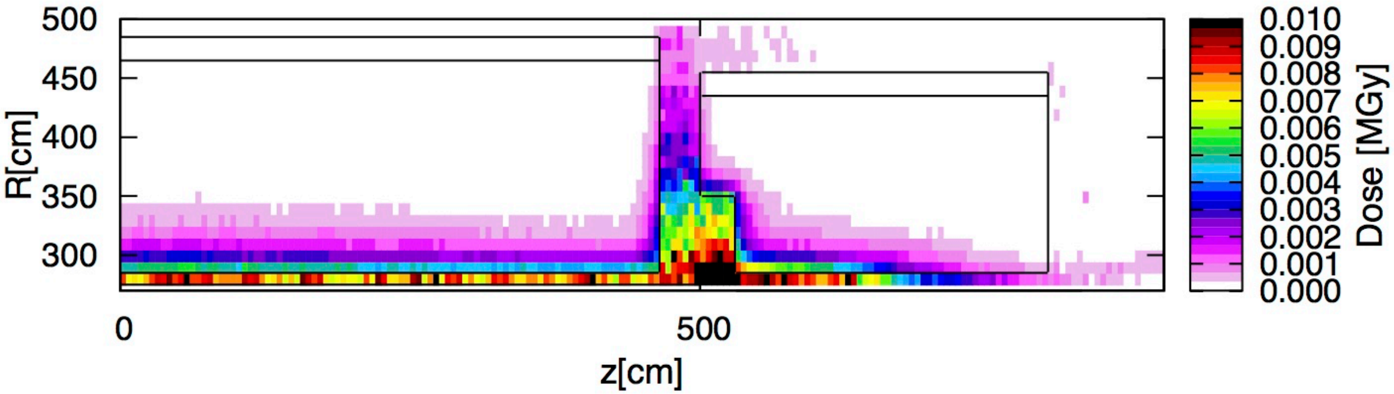
Back-up

Dose in the Hadronic Calorimeter

Values for 30 ab^{-1}:







Long Term Damage for Tracker

Values for 30 ab^{-1}:

R [mm]	z[m]	Dose [MGy]	1 MeV equivalent Fluence [cm^{-2}]
25	0	320	$5.5\ 10^{17}$
60	0	88	$1.25\ 10^{17}$
100	0	40	$6\ 10^{16}$
150	0	23	$3.3\ 10^{16}$
270	0	8.8	$1.51\ 10^{16}$
900	0	0.65	$3.2\ 10^{15}$
25	5	410	$3.7\ 10^{17}$
50	16	250	$2\ 10^{17}$