Simulation of dose estimates for ECAL - Run2 and LHCb upgrade

Matthias Karacson
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Overview

- **Predictions for Run2:**
  Dose estimates for **current geometry,** focusing on the **maximum dose for central modules**

- **Preliminary predictions for the upgrade:**
  Dose estimates for the same areas for **upgrade conditions with some changes in geometry**.
  (Caveat: final design for neither subdetectors nor neutron shielding is decided yet!)

- **A quick look at hadron fluences** near the central regions of the calorimeters

Estimates for Run2

Estimations are given for **14 TeV c.m. collision energy**, using **pencil beams at no collision angle**, expecting **6 fb^{-1} in 3 years up to LS2** (around 2 fb^{-1} per year).

Simulation results with 20x20x20 cm^3 binning are available over the whole calorimeter system. In addition, **5x5x5 cm^3 binning is available** for central regions around the beam pipe.

Due to a very localized maximum of dose deposition (there will be a peak in the distribution inside a module due to build-up), the **averaging over cubic bins will give a value that is lower than the absolute maximum**. 20x20x20 cm^3 binning in areas next to the beam pipe is generally not appropriate (too steep variations), however 5x5x5 cm^3 should give an idea.

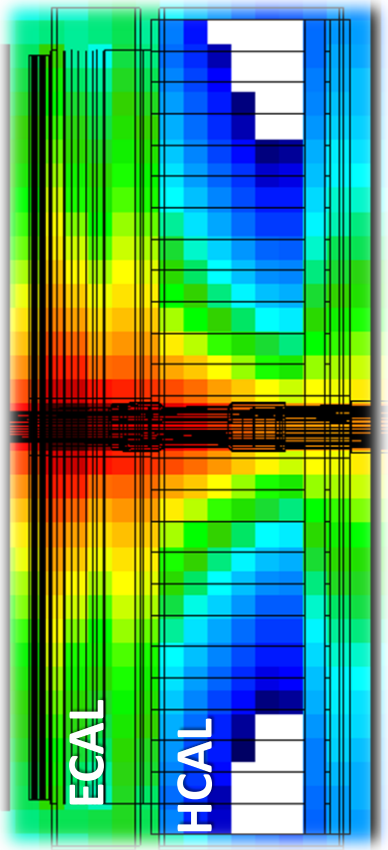
The LHCb magnet deflects charged particles contributing to the dose along the horizontal, therefore the **maximum dose will be located along x on the side of the lead beam plug**.

Estimation of dose close to beam pipe – Run2

Run2: 6 fb^{-1} with current geometry at 14 TeV c.m. collisions - in addition to what was collected in Run 1

Side view

20x20x20 cm^3 binning



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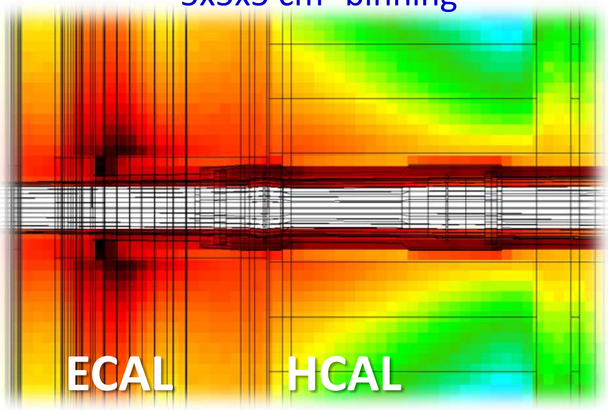
5x5x5 cm^3 binning



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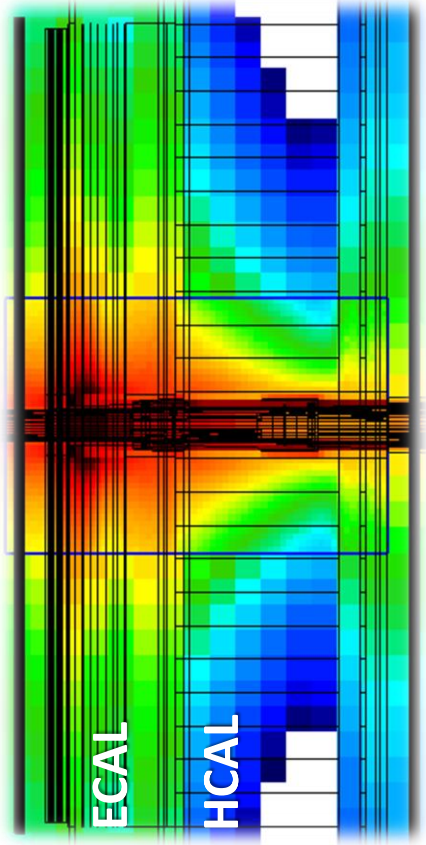
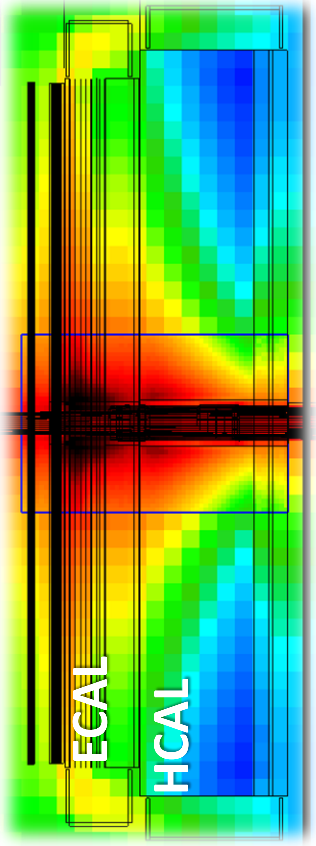
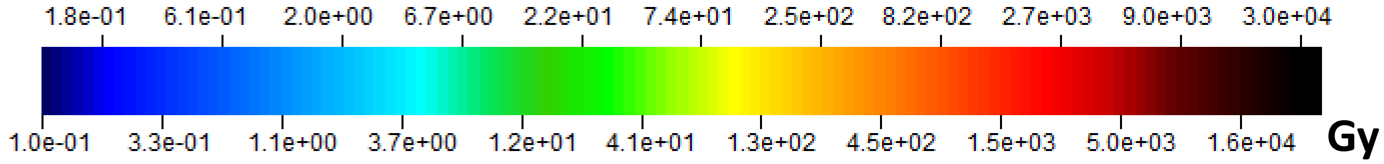
Overlay of both



Dose inside beampipe is 0!
20x20x20 cm^3 binning will give average value including large vacuum area, which **can be orders of magnitude lower** than the actual value close to the beam pipe!

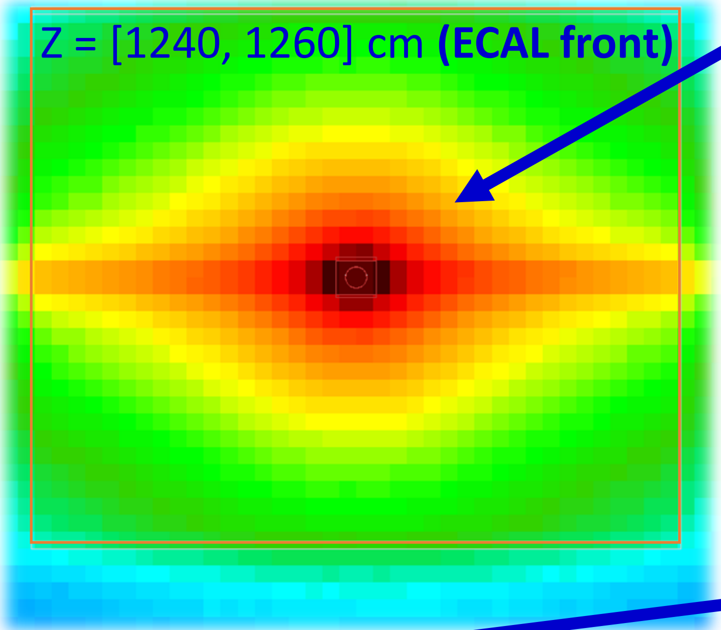
Top view overlay

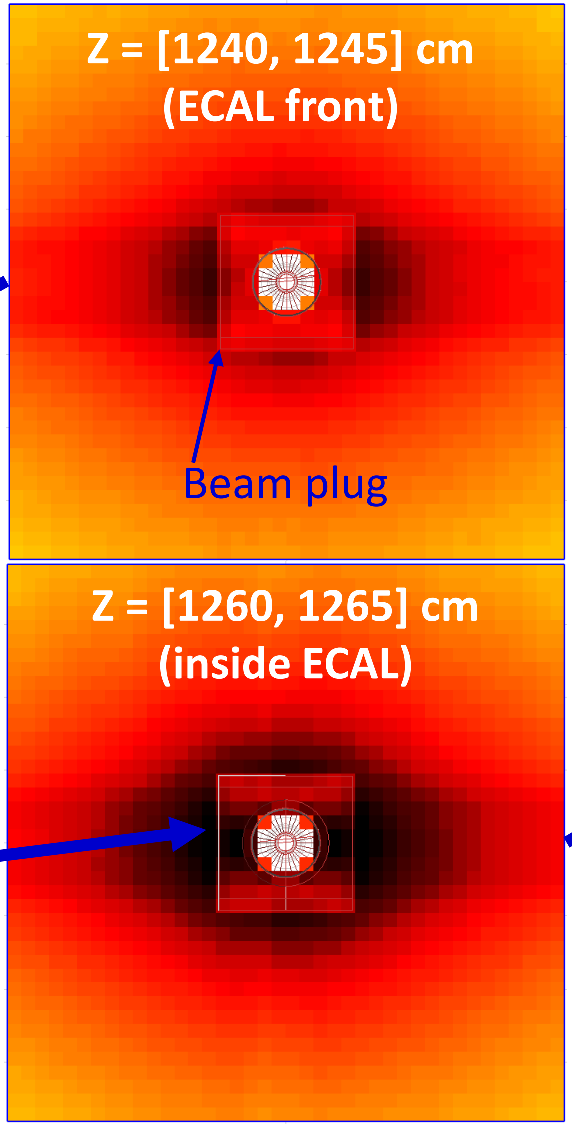


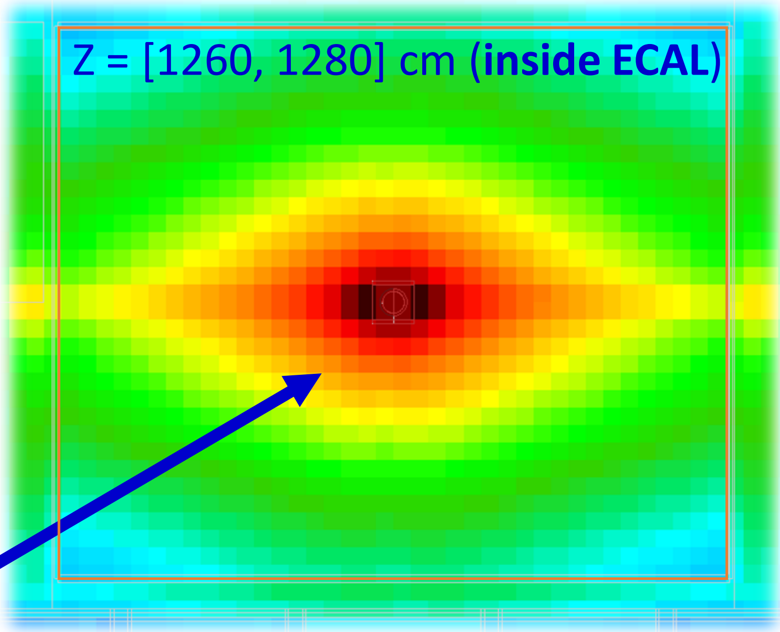


ECAL

Run2: 6 fb^{-1} with current geometry at 14 TeV c.m. collisions

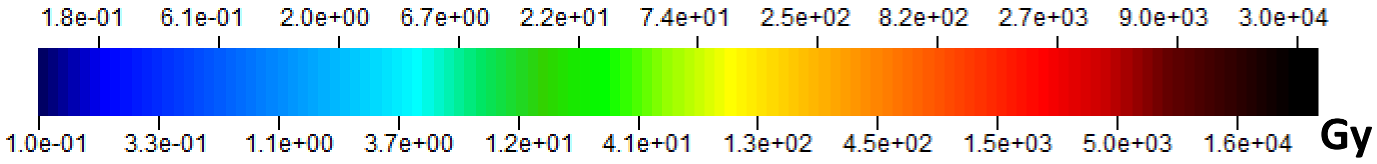






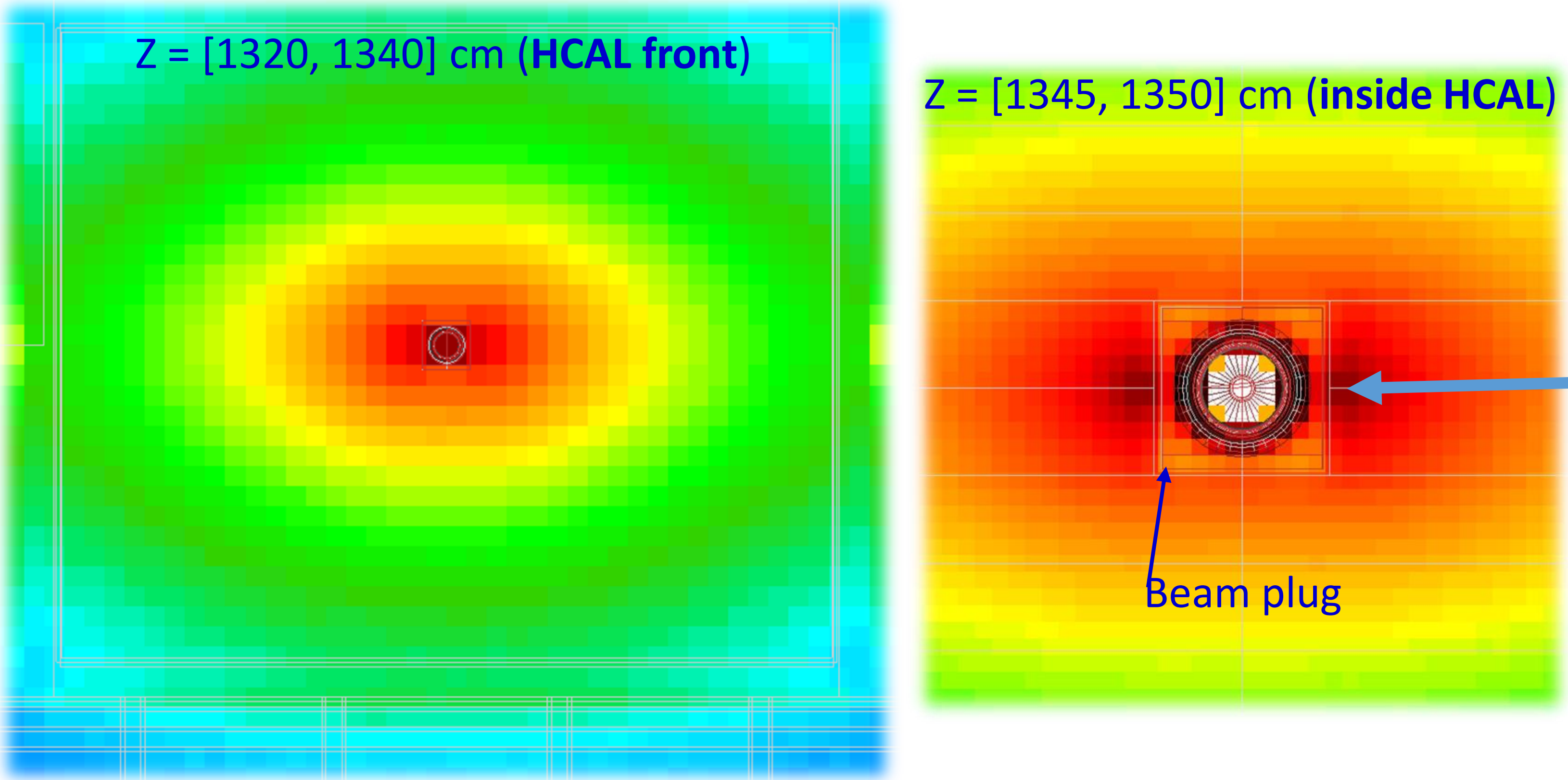
Simulation: max. **24 kGy (no safety)**, might be more on a localized spot within the 5x5x5 cm^3 bin!

Measurements from Run1 showed lower simulation values of up to a factor of 2 -> **Max. dose:** **48 kGy**



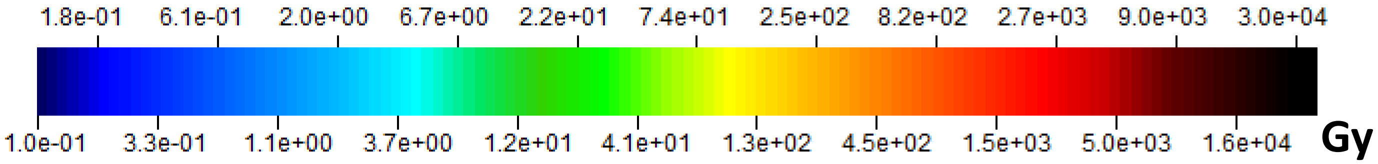
HCAL

Run2: 6 fb^{-1} with current geometry at 14 TeV c.m. collisions



Maximum dose for 6 fb^{-1}:
4 kGy from simulation,
8 kGy (incl. correction)

Additional safety factor recommended!



Estimates for the upgrade

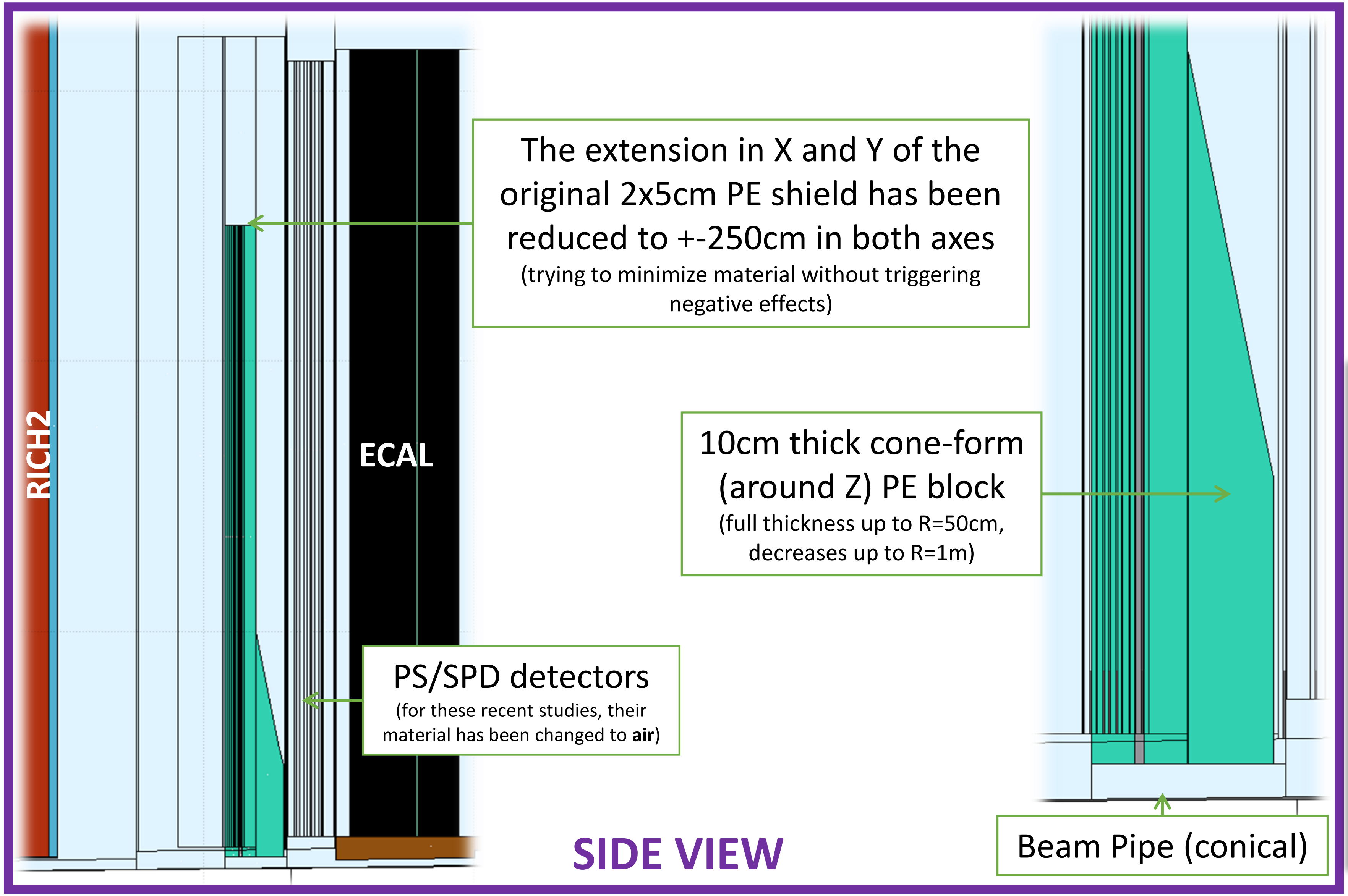
Starting at the end of LS2, expected **integrated luminosity** will be about **5 fb^{-1} per year** up to **50 fb^{-1} in total**. The assumed beam parameters for the simulations are the same as for Run2.

The following preliminary predictions are based on studies for SciFi, where **M1, SPD and PS are removed from the geometry**, and **replaced** by air and a preliminary model of a potential **neutron shielding made of polyethylene**.

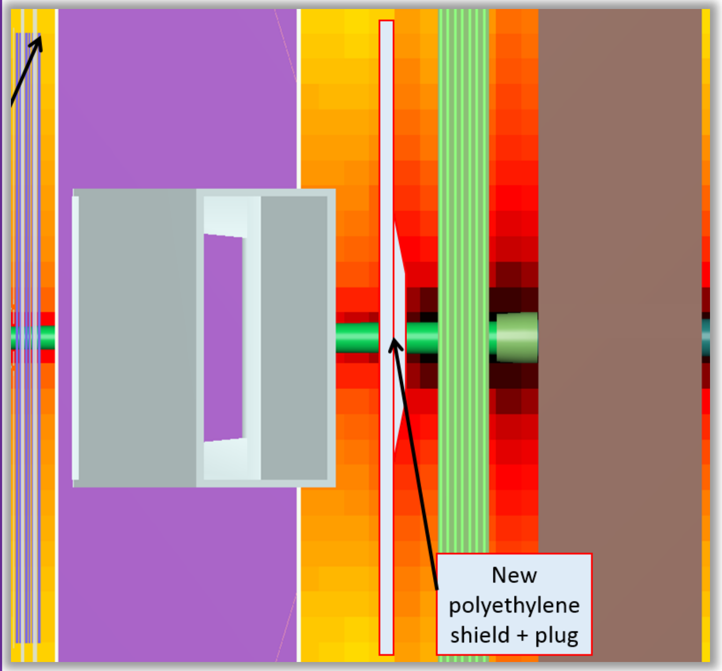
Unfortunately, **no 5x5x5 cm^3 binning is available** at the calorimeters for these studies without M1, SPD and PS. (I had to replace some FLUKA estimators for specific SciFi studies)

The estimations are **based on values from 5x5x5 cm^3 binning for current geometry** (including M1, SPD and PS). Numbers are **multiplied by expected change** which is taken from comparing current geometry 20x20x20 cm^3 binning with the recent studies which include the polyethylene shielding.

Neutron shielding geometry (preliminary model of preferred option)



Currently preferred option for SciFi is a **20 cm thick shielding in front of ECAL**.
Position along z will be closer to ECAL in final configuration, but its influence on the radiation field will stay almost the same.



Influence of neutron shielding

If shielding in **full size** (20cm along z) is installed, then the **dose inside ECAL** only increases by a factor of around 1.5 with respect to the current detector, according to averaged values over 20x20x20 cm^3 bins. Locally, the increase **could be more**.

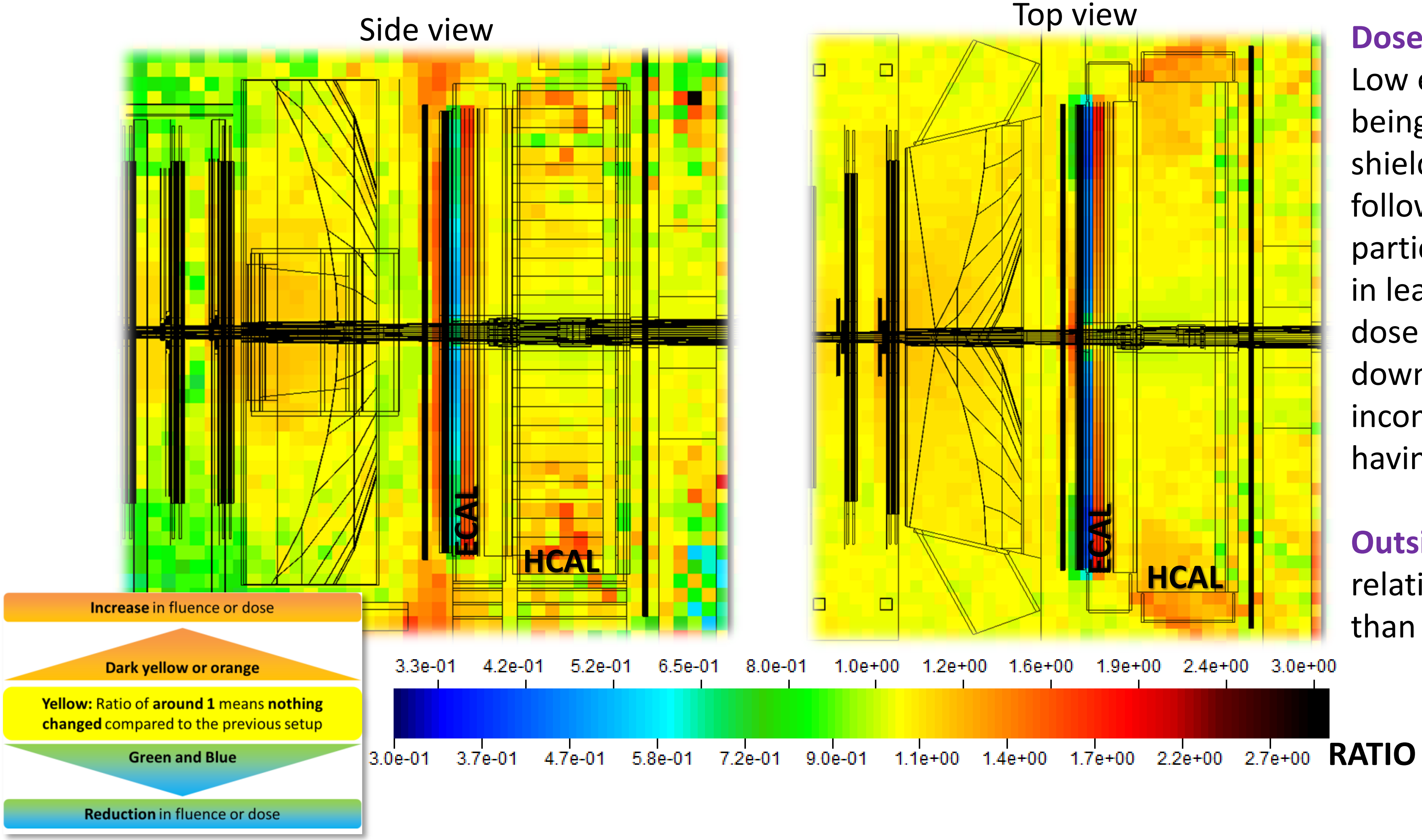
The **front of the shielding will already absorb a lot of low energy electromagnetic particles**. However, at the front of the ECAL, dose values will be lower as the lead plate will be gone, which is responsible for starting strong secondary particle cascades in the current geometry.

In a scenario without shielding, the maximum dose inside ECAL seems actually slightly lower than with shielding, but the surface experiences more dose overall. (different location of maximum, still higher than current detector)

In any case with or without shielding, the **HCAL will not experience significant change in terms of dose**.

Influence of neutron shielding

Dose Ratio Full shielding VS Current LHCb geometry
(20x20x20 cm^3 binning)



Dose deposition is shifted: Low energy particles are being absorbed by the new shielding. Lower dose (blue) follows where currently particle showers are started in lead plate. The maximum dose in ECAL is shifted downstream along z due to incoming charged particles having higher energy.

Outside modules will see relatively more dose, but less than central ones in total.

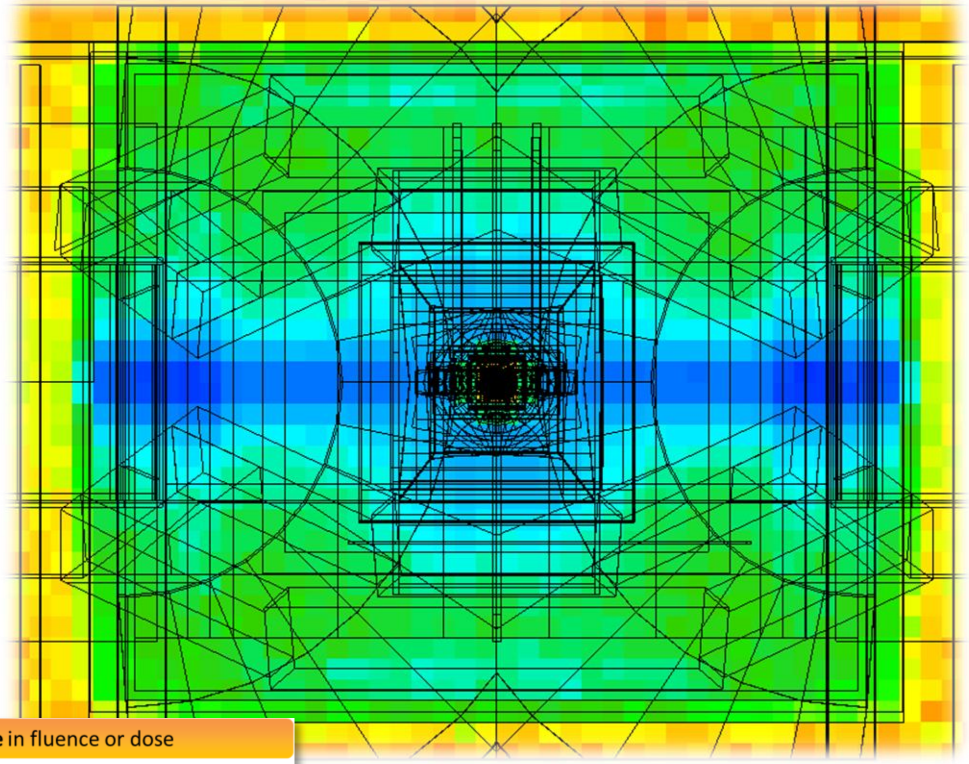
Influence of neutron shielding

Dose Ratio Full shielding VS Current LHCb geometry

(20x20x20 cm^3 binning)

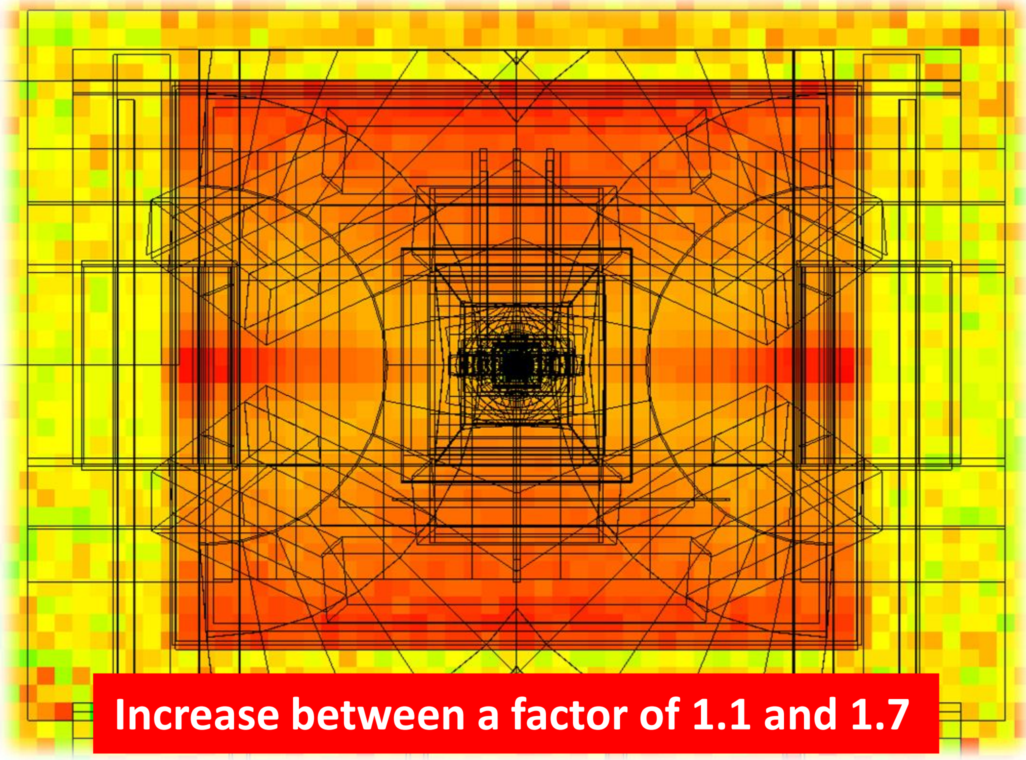
Z=1240

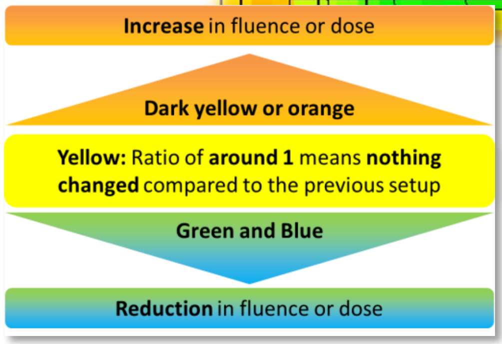
(no more showers started in PS lead plate)

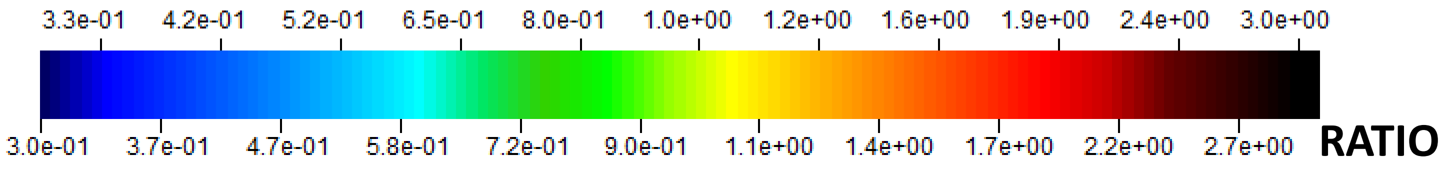


Z=1260

(Inside ECAL)







UPGRADE maximum dose

Recommended to calculate with <u>at least</u> **factor 4** on top of standard geometry results (where 5x5x5 cm^3 is available):

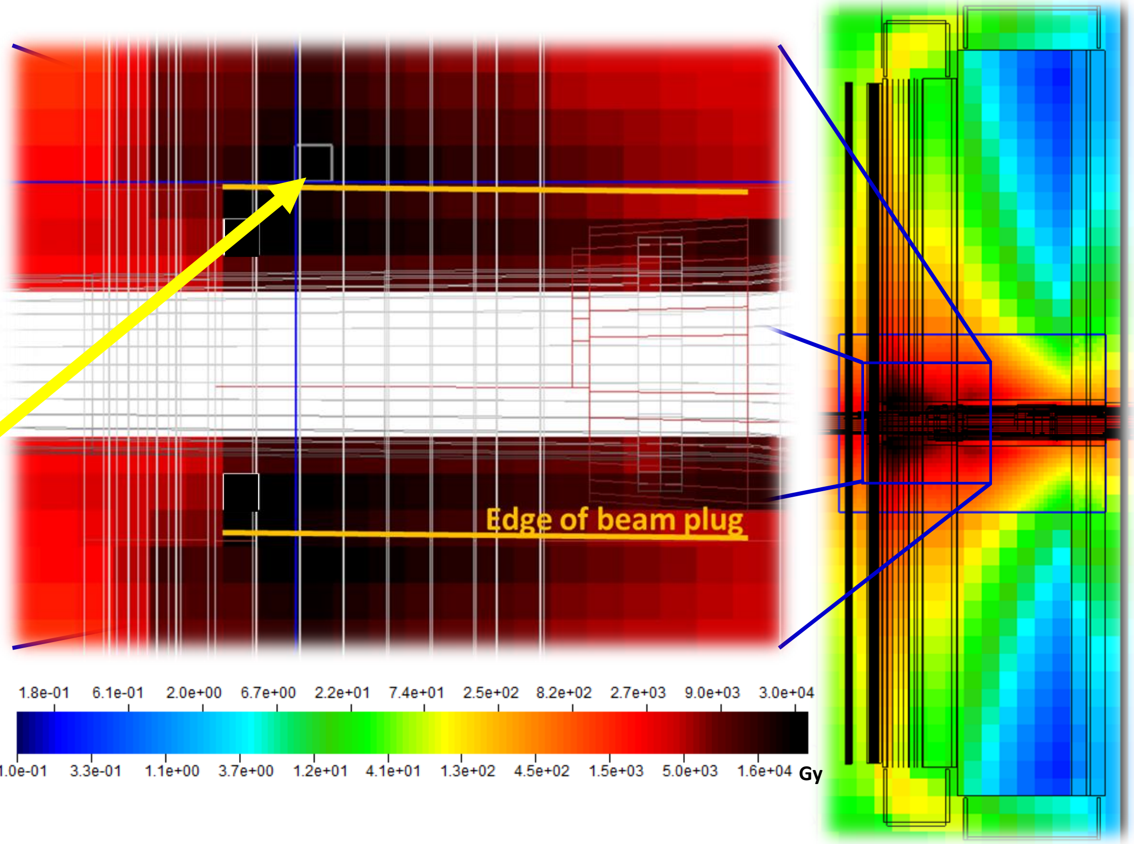
- **x2 for increase by PS and SPD removal** (uncertainty of factor 1.5)
- **x2** for possible **deviation of simulation estimates** according to Run1 measurements

MAXIMUM for 50 fb^{-1} (full upgrade) inside ECAL:

200 kGy x 2 x 2 = 800 kGy

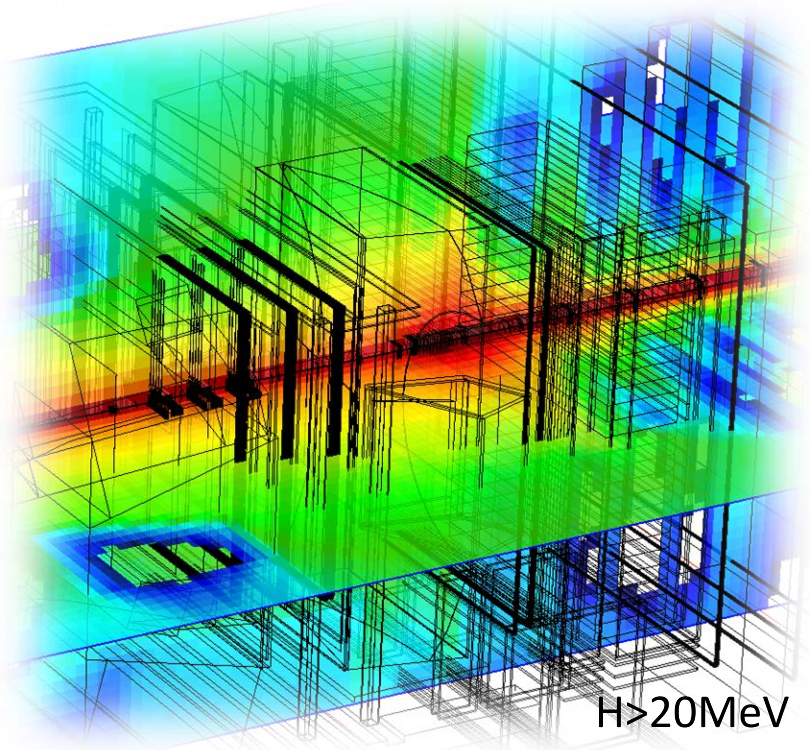
This corresponds to 10 years with 5 fb^{-1} each and can be scaled accordingly (e.g. 3 years = 240 kGy)

ECAL dose top view (current geometry)



HCAL values stay roughly the same with or without shielding

Hadron fluence



Email questions:

- Relevant hadron fluence?

- Which energies?

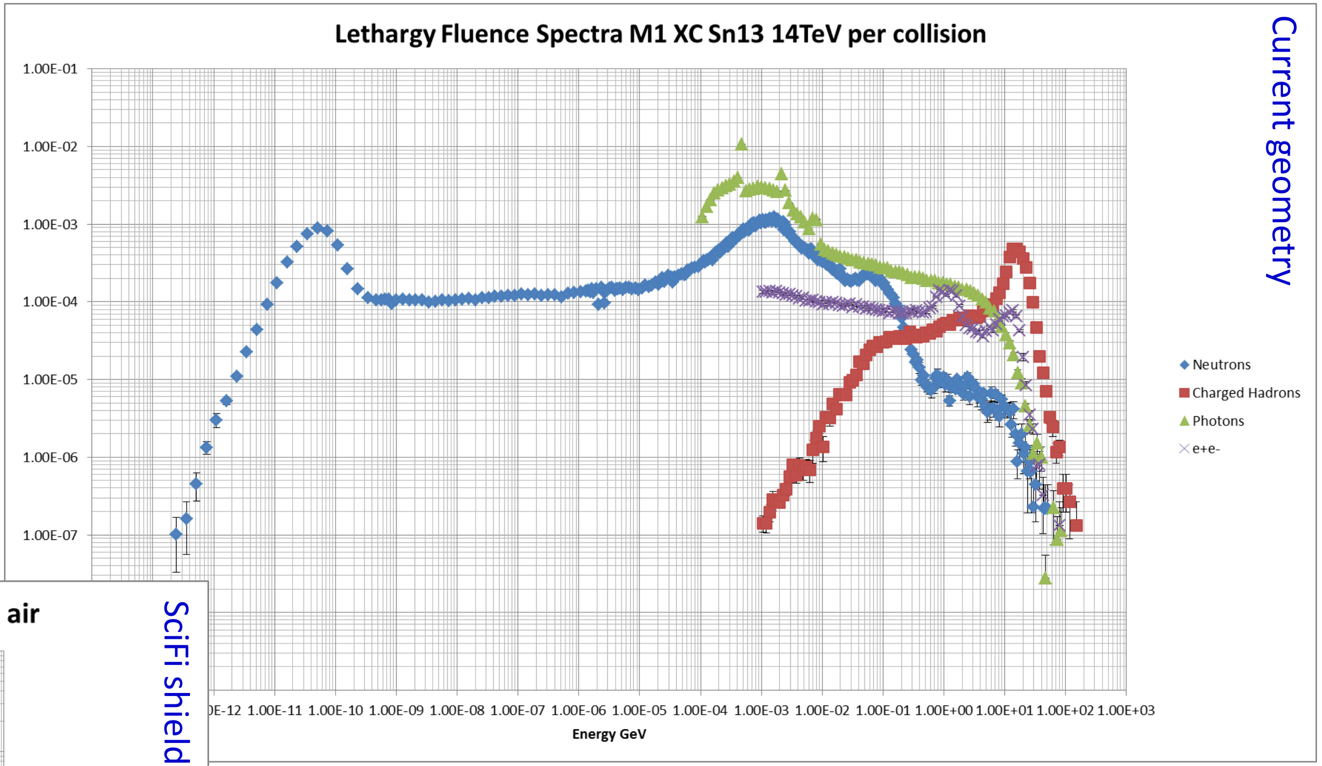
Yes, the main components are:

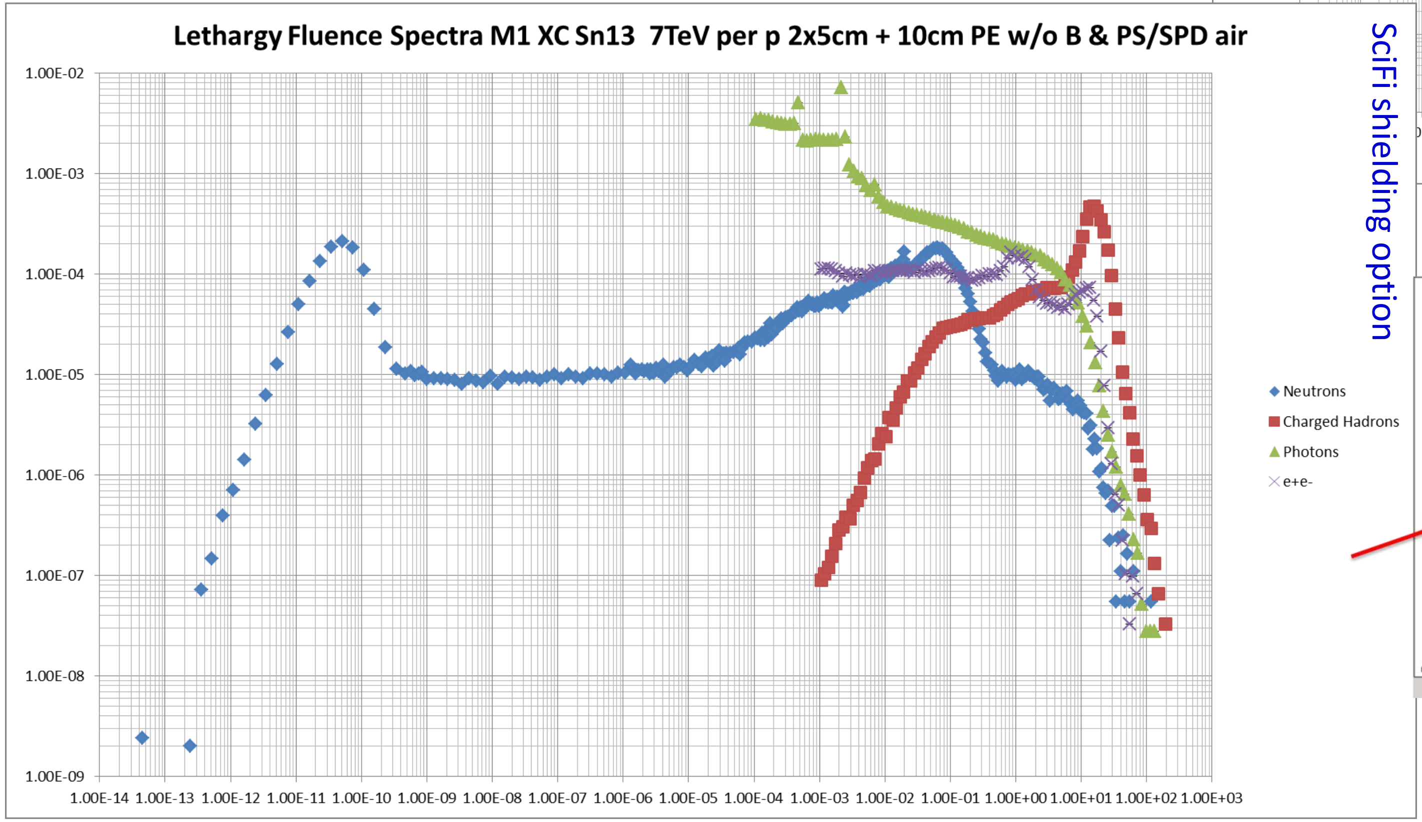
- Neutrons with energies around 1 MeV
- Thermal neutrons
- Charged hadrons at high energies, with peak above 10 GeV

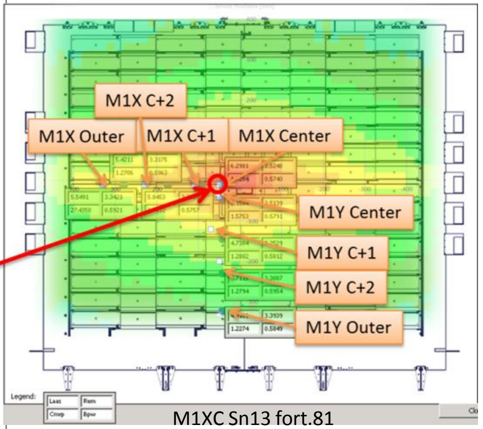
Illustration on next slide:
Spectra of **neutrons**, **charged hadrons**, **e+e-** and **photons** at a position **close to the center of M1**.

M1 center lethargy fluence spectra (upstream of shielding)

- **Neutron distribution** will be different downstream of shielding (in particular inside an ECAL module)
- **Charged hadrons** show peak above 10 GeV –> will be higher at ECAL front because of lower angle to IP







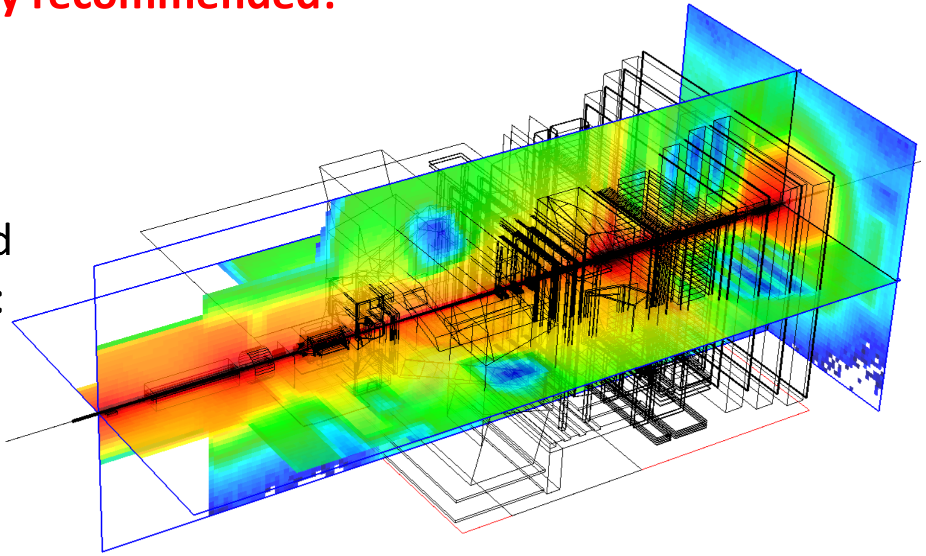
Summary

- ❑ **Maximum value inside central ECAL module** for **Run2 (6 fb^{-1})** is **48 kGy** (corrected)
- ❑ **Maximum value** for the same position **during 10 years of upgrade luminosity (50 fb^{-1})** is **800 kGy** (corrected)

Safety factors are strongly recommended!

Data with similar binning and constraints as described earlier for dose results is also **available on request** for:

- **1 MeV equivalent neutron fluence (Si)**
- **High Energy Hadron fluence (>20MeV)**
  (20x20x20 cm^3 only)

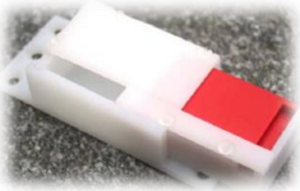


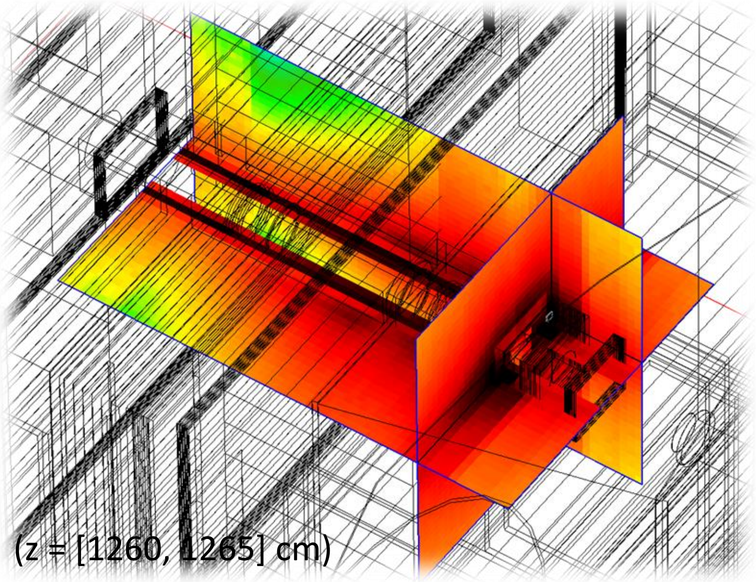
ADDITIONAL SLIDES

Dose values for Run1

Highest **alanine measurements** on **ECAL front**:
3600 Gy (**in total for Run1**)

Corresponding **simulation estimate** on **ECAL front (same spot)**:
2814 Gy (**in total for Run1, no correction**)





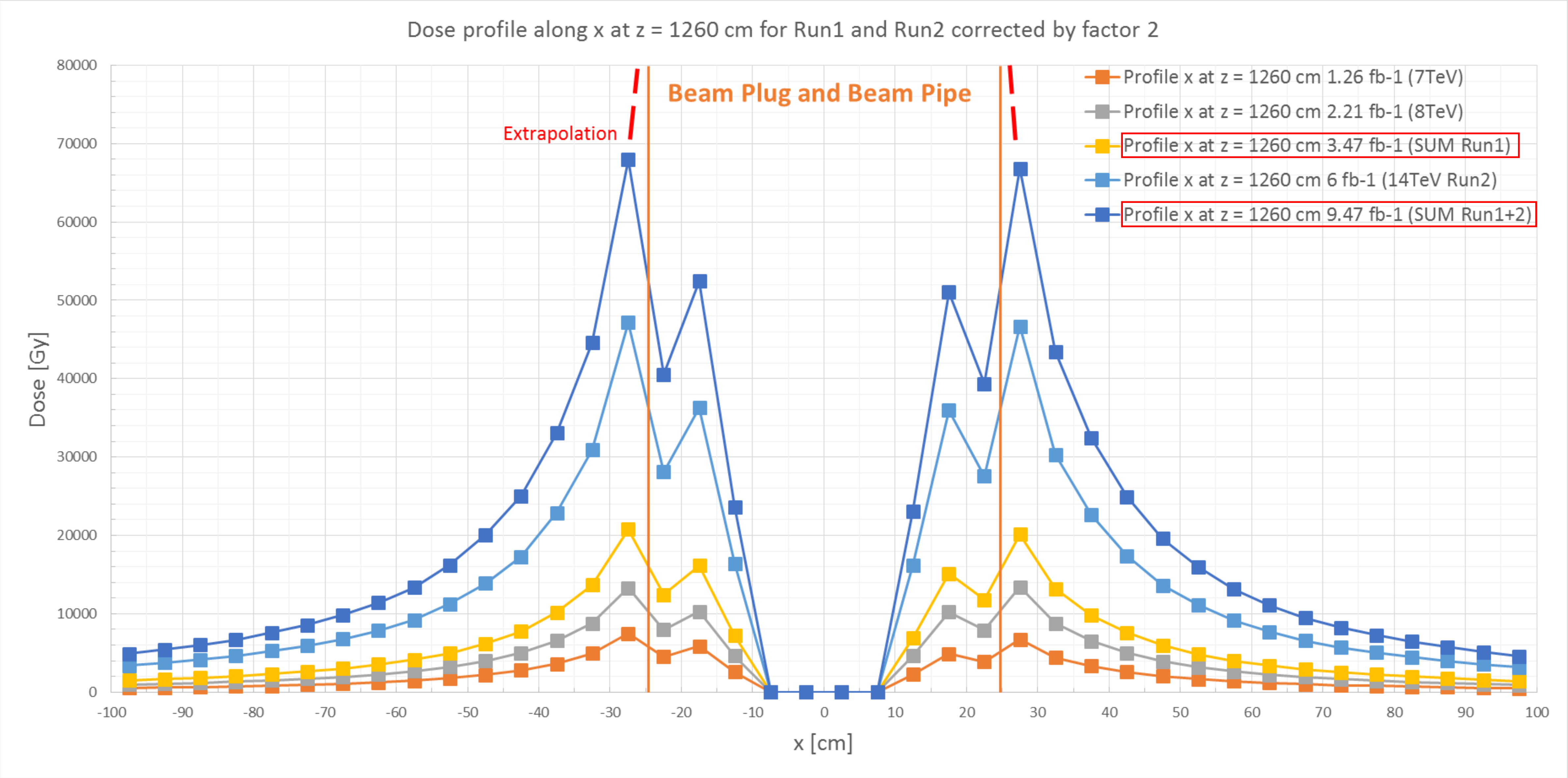
Simulation estimates inside ECAL (max.) for Run1:

3700 Gy for 1.26 fb-1 at 7 TeV c.m.
6800 Gy for 2.21 fb-1 at 8 TeV c.m.

10500 Gy in total for Run 1

21 kGy when applying correction factor of 2

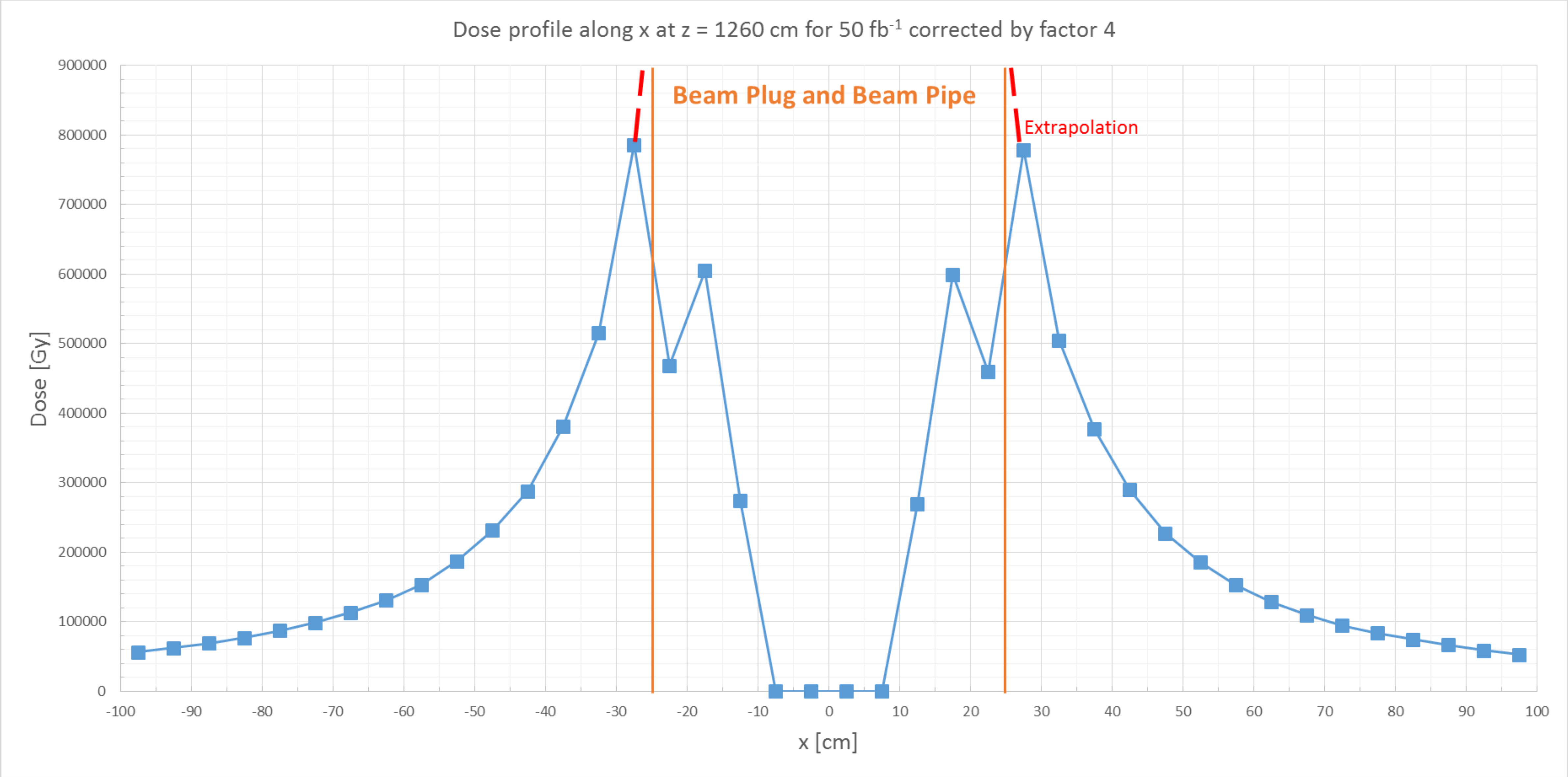
Dose profiles (max.) along x for Run1 (7+8 TeV) and Run2 (14 TeV)



Each datapoint represents the average of a 5x5x5 cm^3 cubic bin

For infos on correction factor please see slides 5 and 12

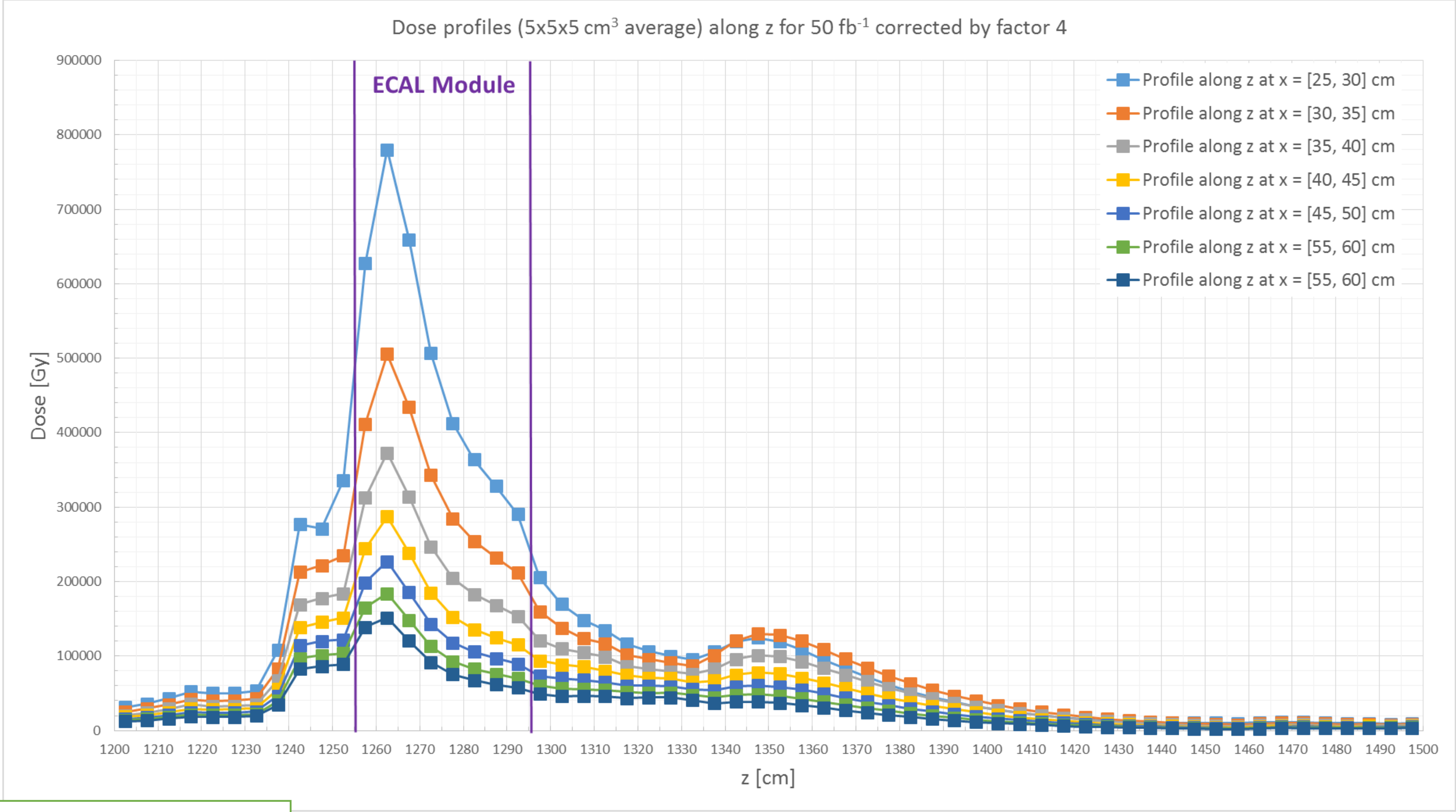
Dose profiles (max.) along x for the upgrade (50 fb^{-1} at 14 TeV)



Each datapoint represents the average of a 5x5x5 cm^3 cubic bin

For infos on correction factor please see slides 5 and 12

Dose profiles along z for the upgrade (50 fb^{-1} at 14 TeV)

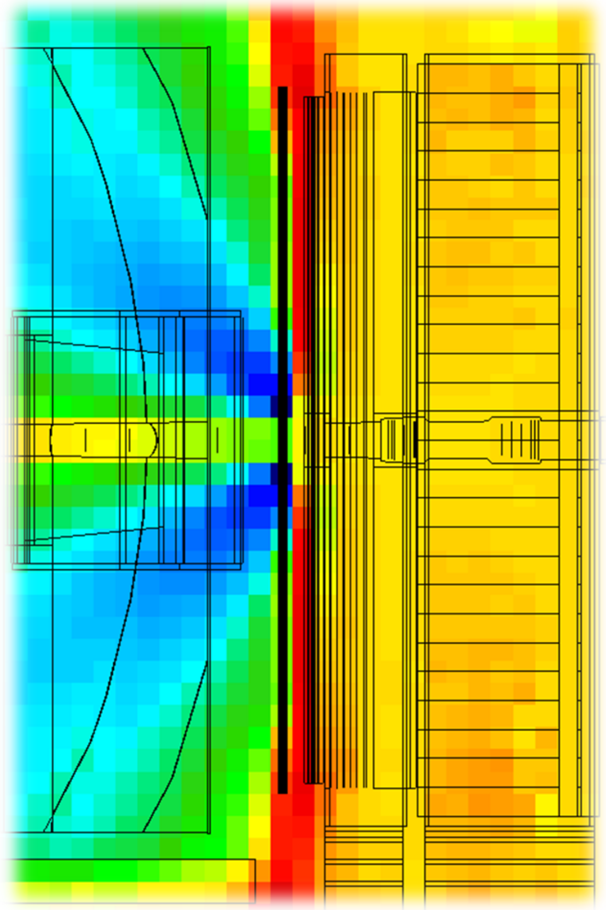


Each datapoint represents the average of a 5x5x5 cm^3 cubic bin

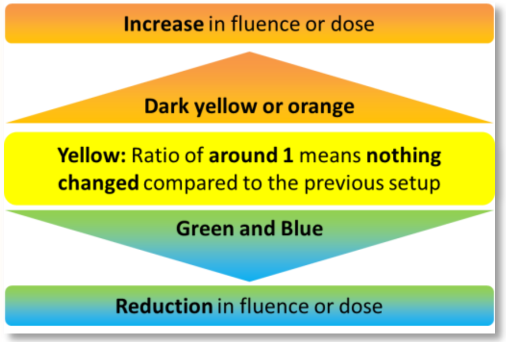
For infos on correction factor please see slides 5 and 12

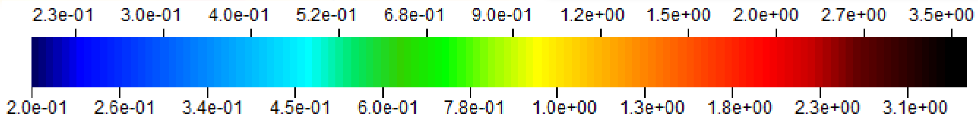
1 MeV equivalent (Si) neutron fluence values for the upgrade

Ratio Full Shielding vs. Standard



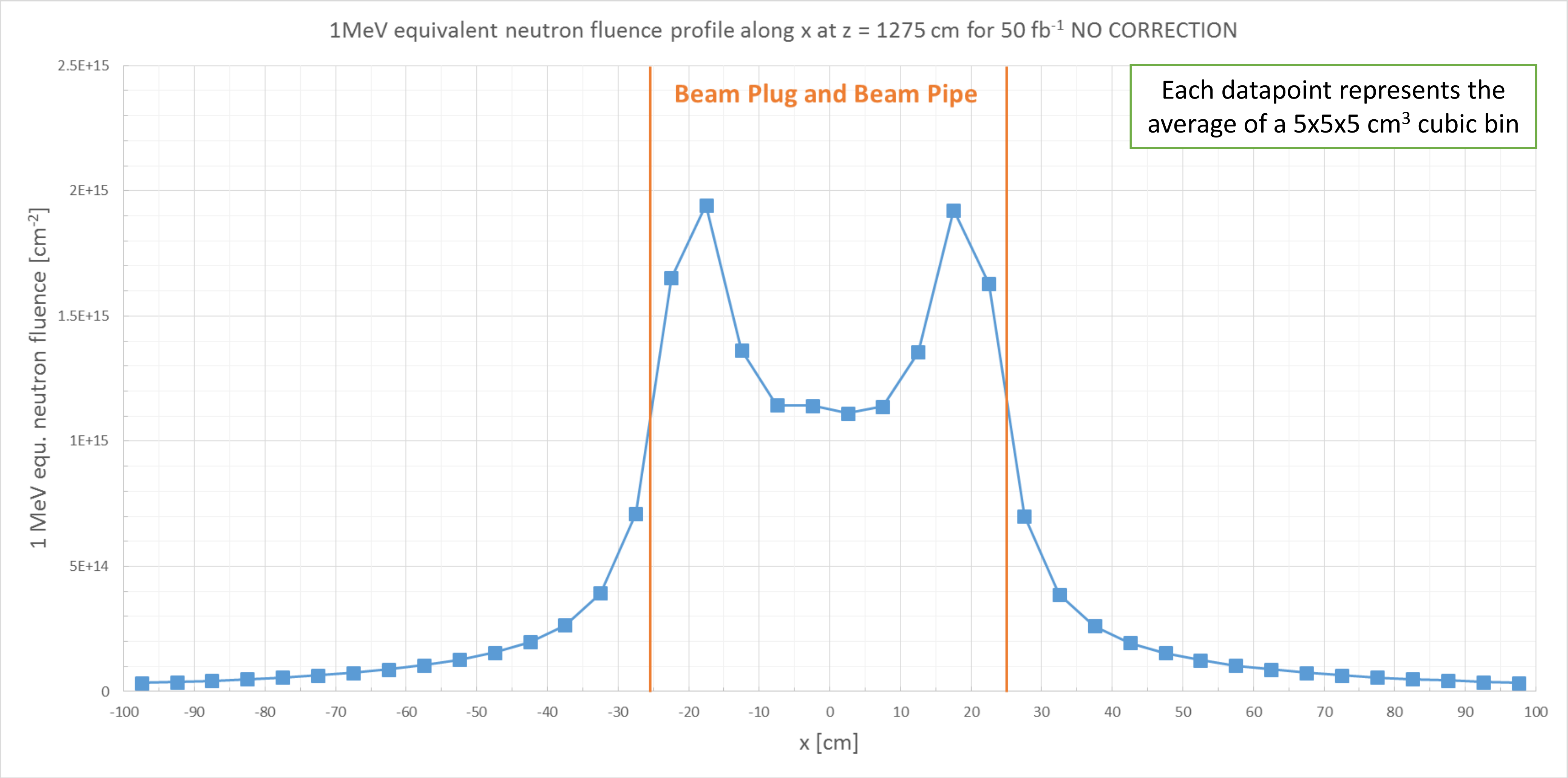
1MeV equ. neutron fluence at ECAL center during upgrade conditions (including a PE shielding) should **stay similar** to conditions during Run2.





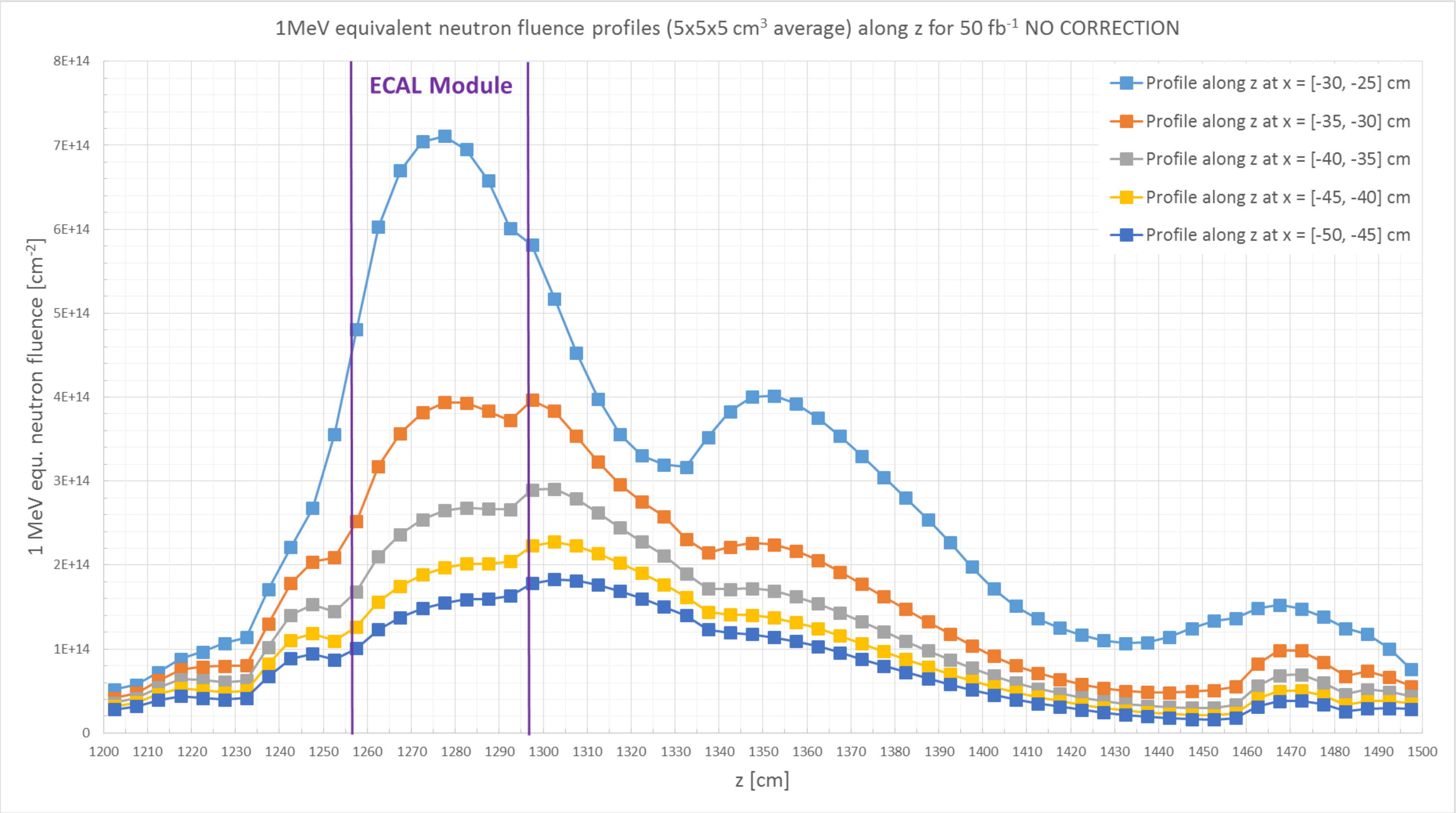
1 MeVne Simulation values for upgrade will be given without correction factors. However a **safety factor of at least 2 is strongly recommended**!

1 MeVne fluence profile along x for the upgrade (50 fb^{-1} at 14 TeV)



In contrast to dose values, the 1 MeV equivalent fluence increases inside the lead beam plug (orange bars).
The expected maximum right at the edge of the plug at z = [1275, 1280] cm is around **1E+15 cm^{-2}**.

1 MeVne fluence profiles along z for the upgrade (50 fb^{-1} at 14 TeV)



Each datapoint represents the average of a 5x5x5 cm^3 cubic bin