Radiation damage of the optical components in Scintillator Detectors: from the ATLAS/LHC Tile Calorimeter to future experiments

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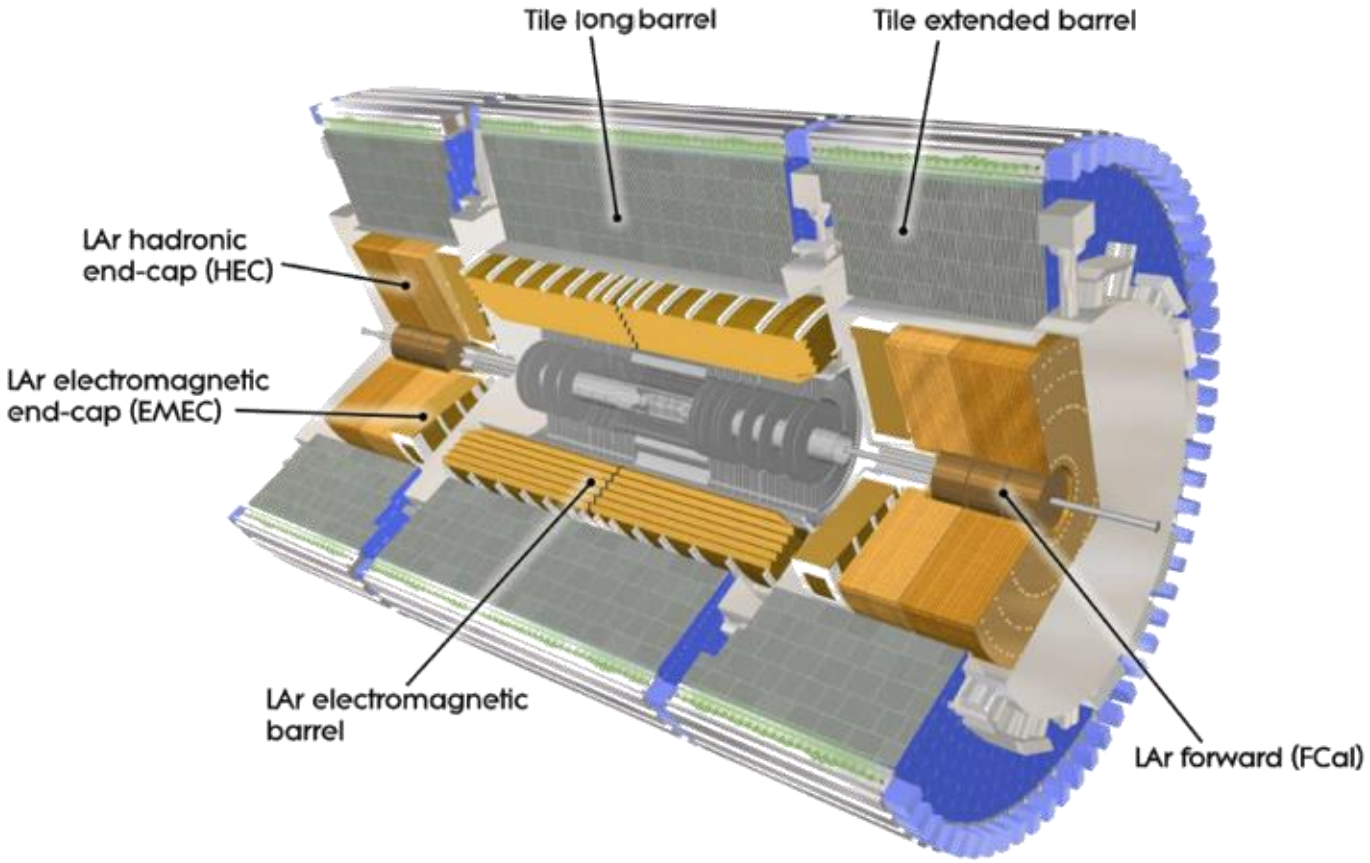
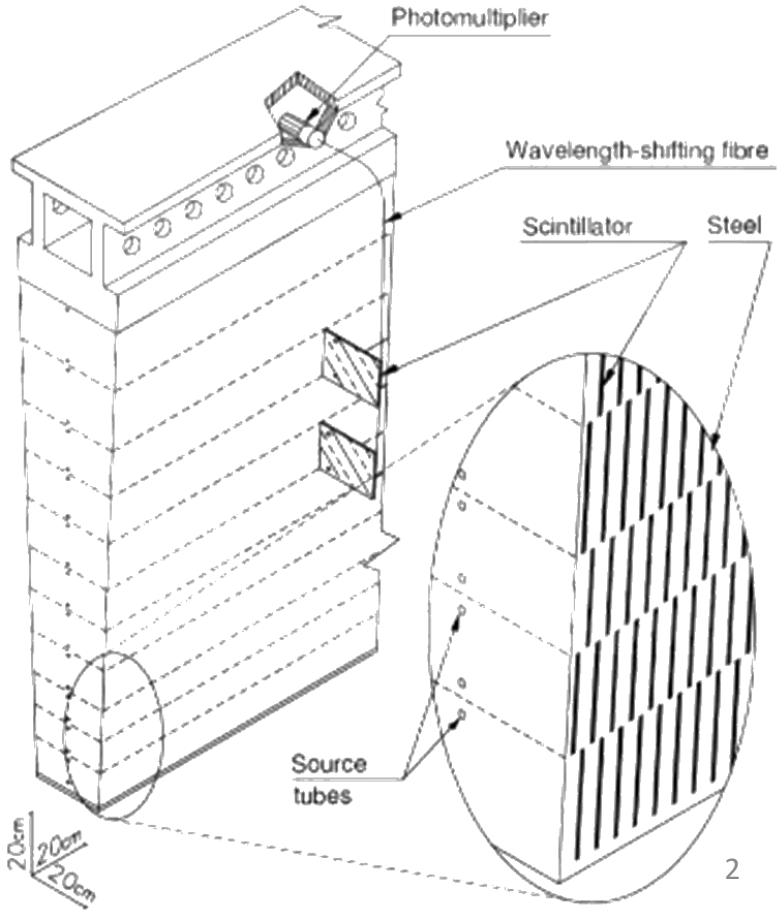
Motivation - TileCal

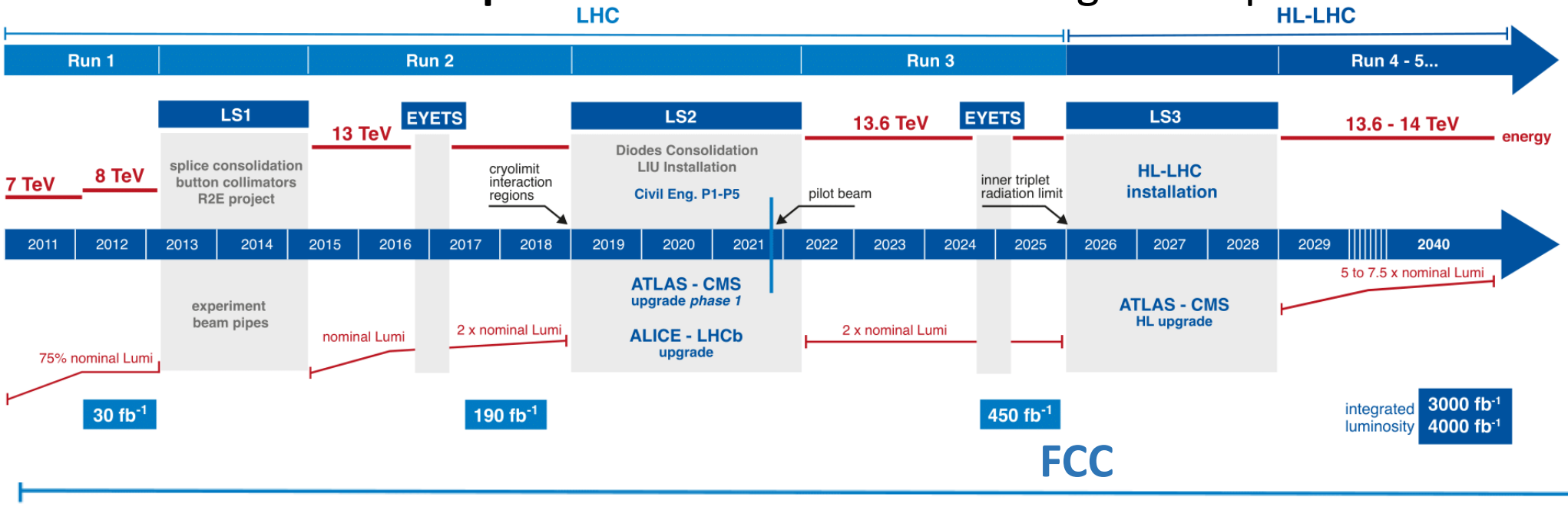
- TileCal is a sampling calorimeter with steel plates and plastic scintillators;
- The plastic scintillator tiles produce light from the interaction with ionising particles;
- The optical components of the TileCal cannot be replaced;
- These components **degrade** with **radiation** exposure:





Motivation

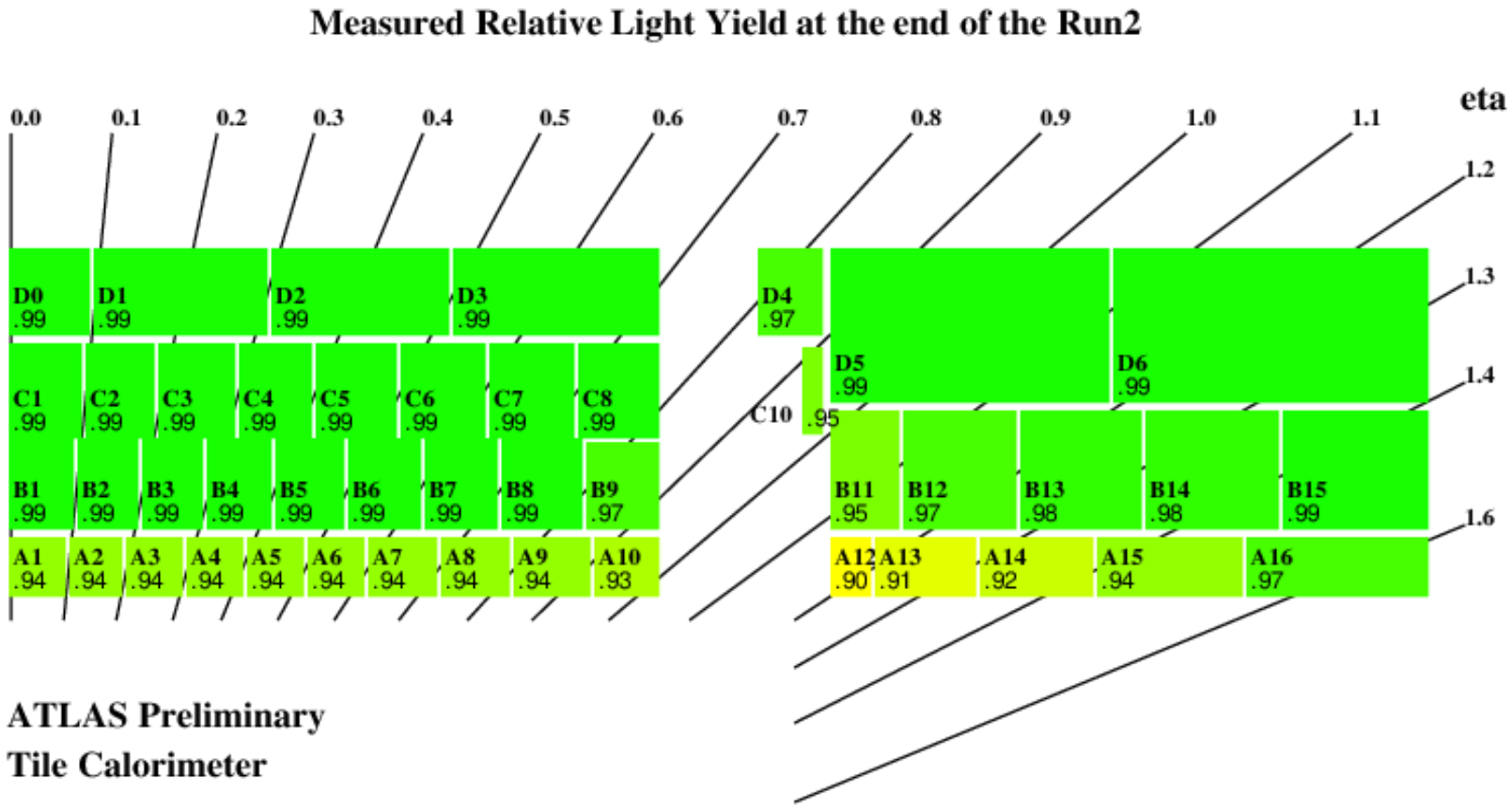
- During the **HL-run** it is expected an increase in the luminosity – **increase of radiation**;
- So it is necessary to **measure and model the degradation** of scintillators and fibres to radiation exposure to devise strategies to mitigate effects on detector performance.
- The good performance of the TileCal lead us to study it in the **FCC-ee** environment;
- Simulation and **performance studies** are being developed in the FCC-ee scope.



Light Yield – Tile and Fibers Degradation Results

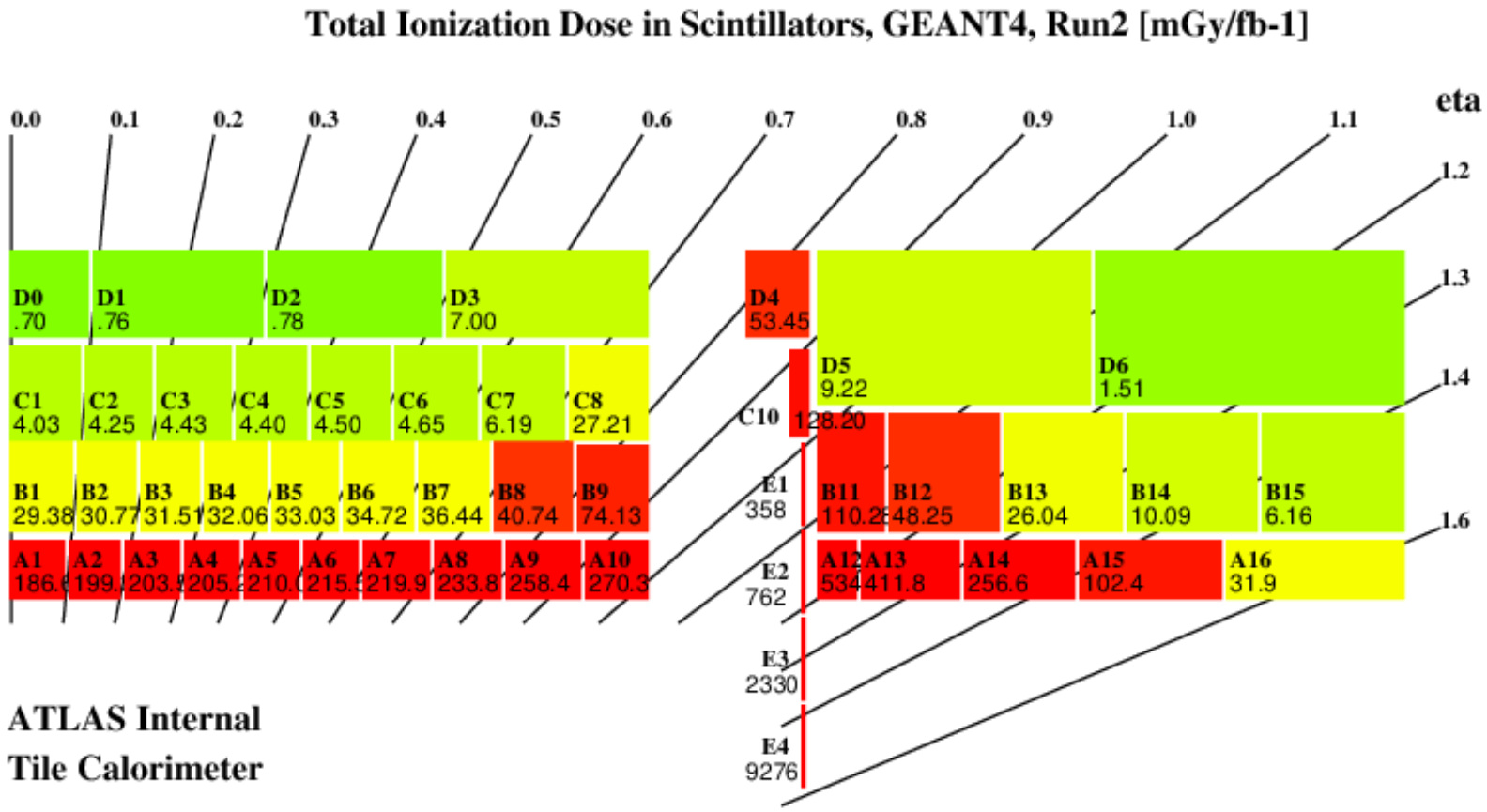
- The light yield (I/I_0) from 2015-2018 was measured using calibration systems:

$$I/I_0 = 1 + \frac{\Delta x_{ch}^{Cs} - \Delta x_{ch}^{Las}}{100\%}$$



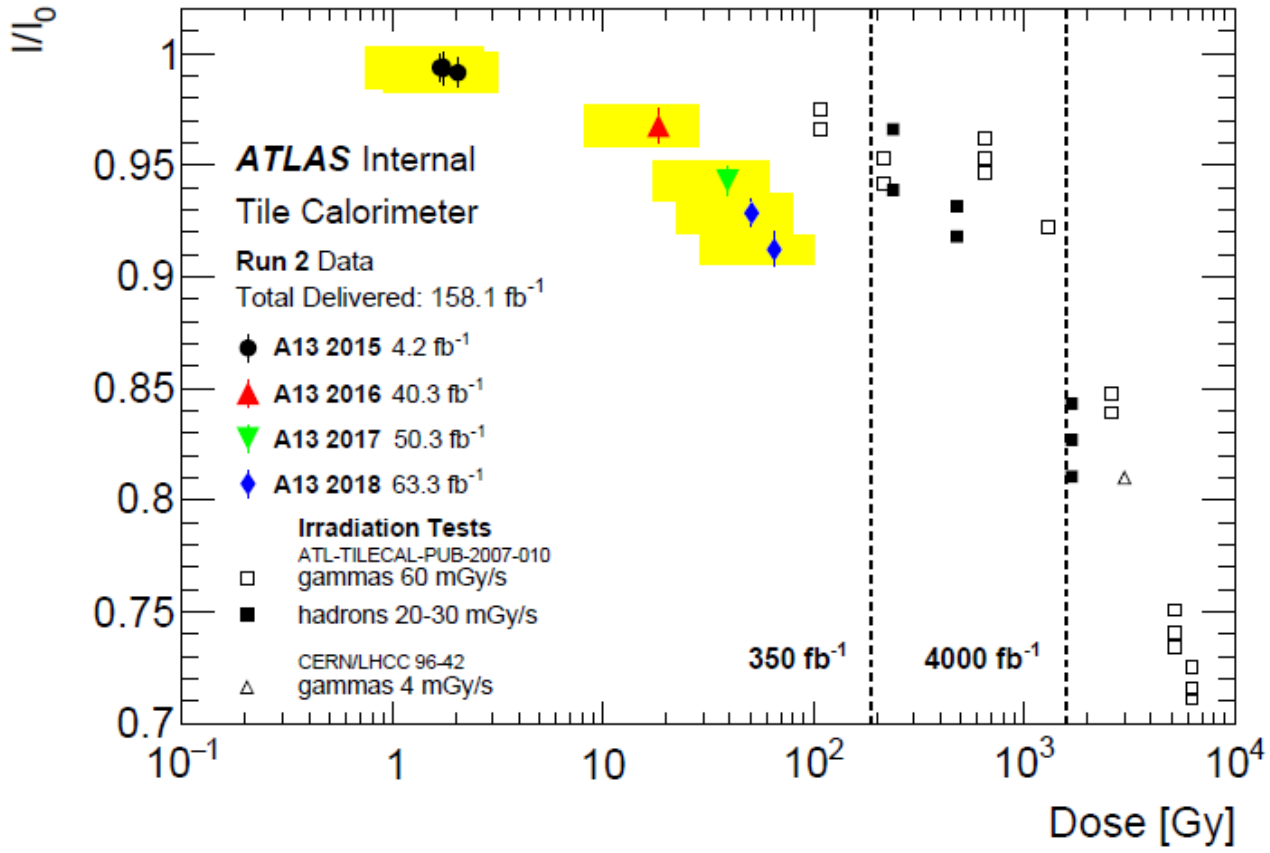
Dose Simulation

- The **degradation model** uses the light yield as a function of the **dose** simulation;
- The total ionisation dose was obtained using a GEANT4 simulation of the Tile calorimeter for p-p generated collisions.

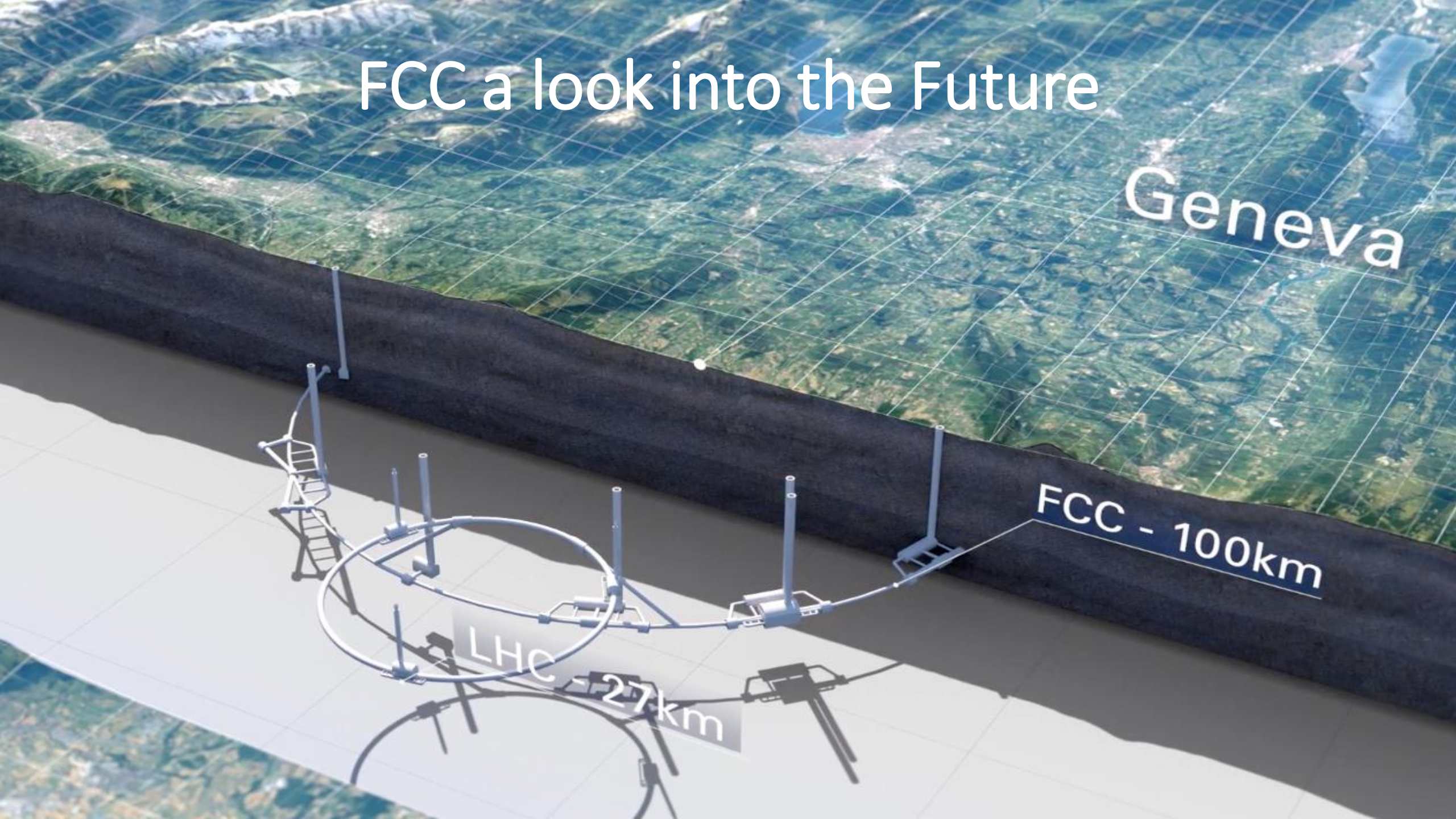


Light Yield – Tile and Fibers Degradation Modelling

- The light yield (I/I_0) as a function of the dose is used to model the degradation of degradation of scintillators and fibres;
- The model will be used to **extrapolate** the degradation to **HL**-run;
- So far, the **large spread of dose** is limiting the extrapolation.

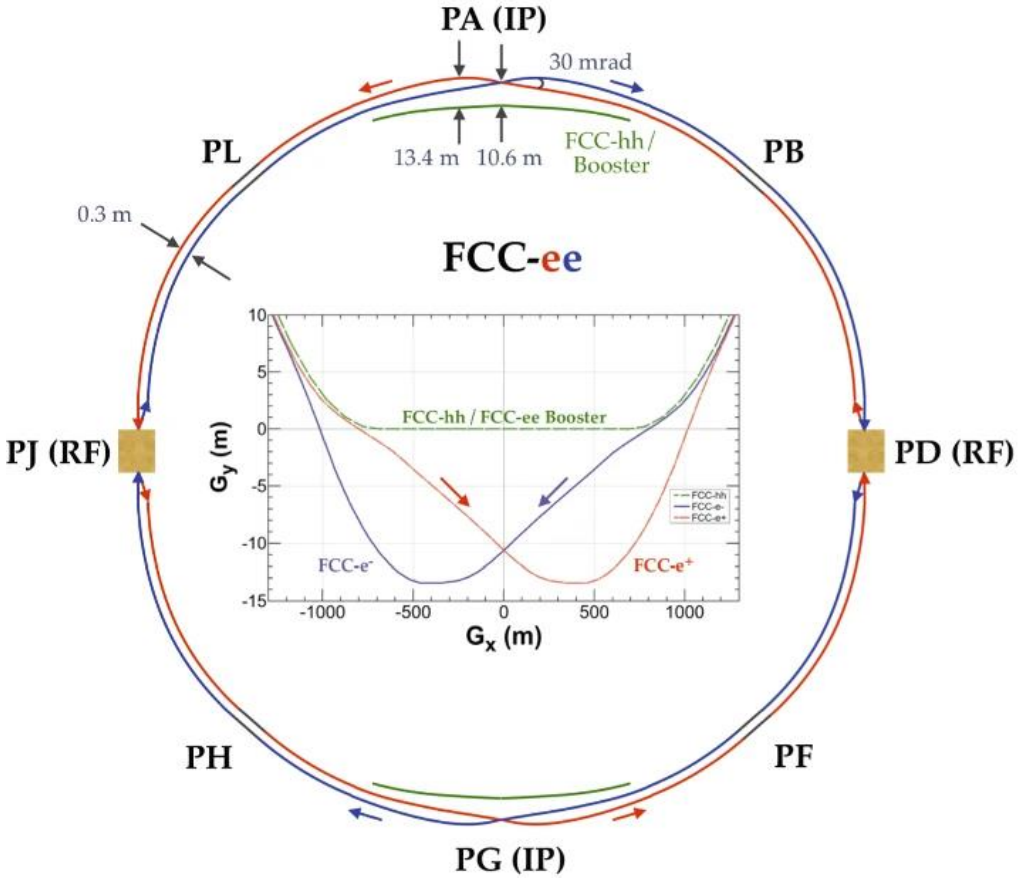


FCC a look into the Future



Future Circular Collider (ee)

- 97,75 km of circumference;
- Beam energy between 46 and 183 GeV;
- High Luminosity up to $230\times10^{34}/cm^2/s$ (HL-LHC $5\text{-}7{,}5\times10^{34}/cm^2/s$);
- Precision measurements as probes of new physics;



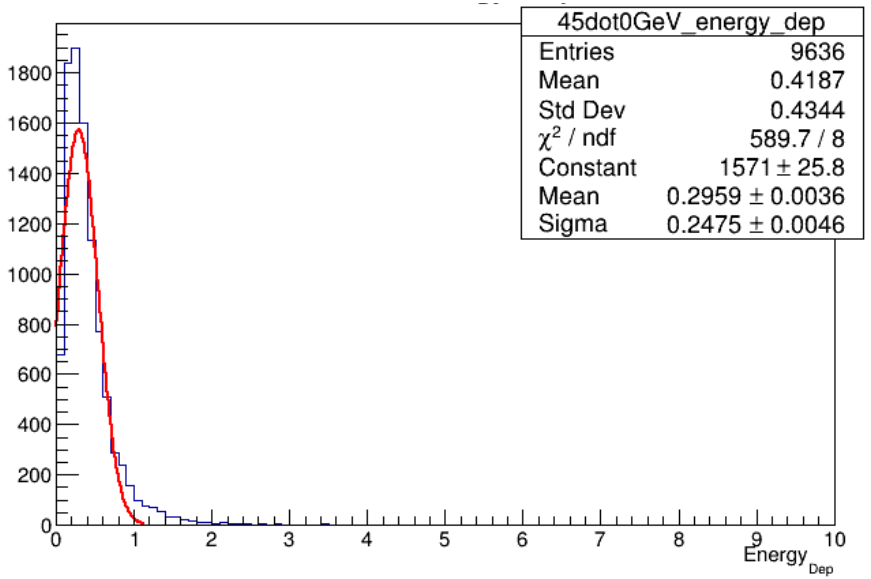
Future Circular Collider (ee) HCal

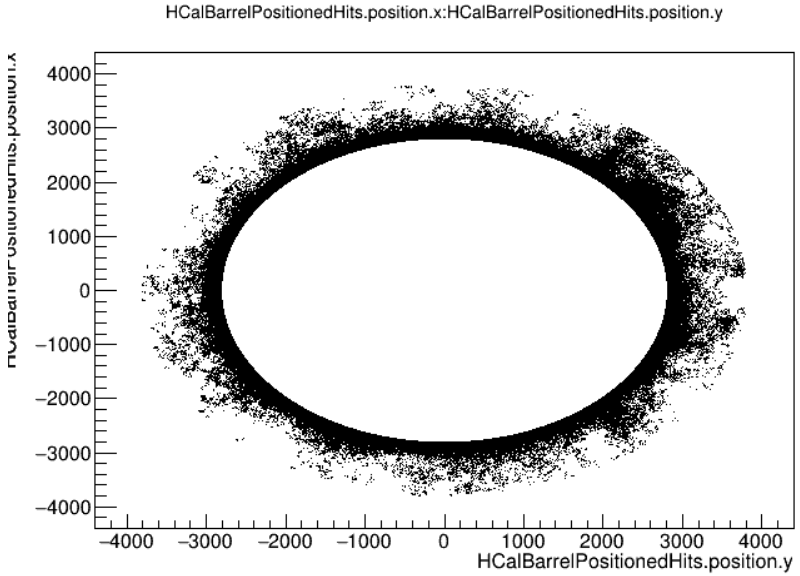
- Study the performance of a TileCal-like design for the FCC-ee HCal;
- For the precision measurements it is necessary to have:
  - High granularity (4 times more granularity than TileCal);
  - Good energy resolution;
- The HCal is composed of:
  - 10 readout layers from R=2800 to 4100 mm;
  - Along z= 2260 mm
  - 5 mm steel;
  - 4 mm lead;
  - 3 mm scintillator plates.

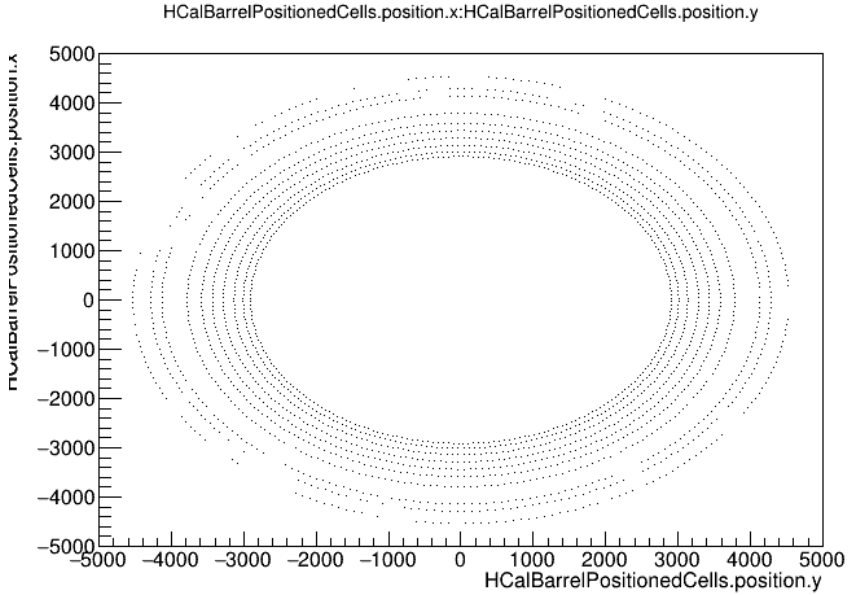
FCC-ee - HCal response to single particles

- I have started simulation of a scintillator tile sampling calorimeter:
  - 20 GeV charged pions;
  - 20 GeV muons;
  - 45 GeV electron.

Energy deposited in the HCal







Conclusion

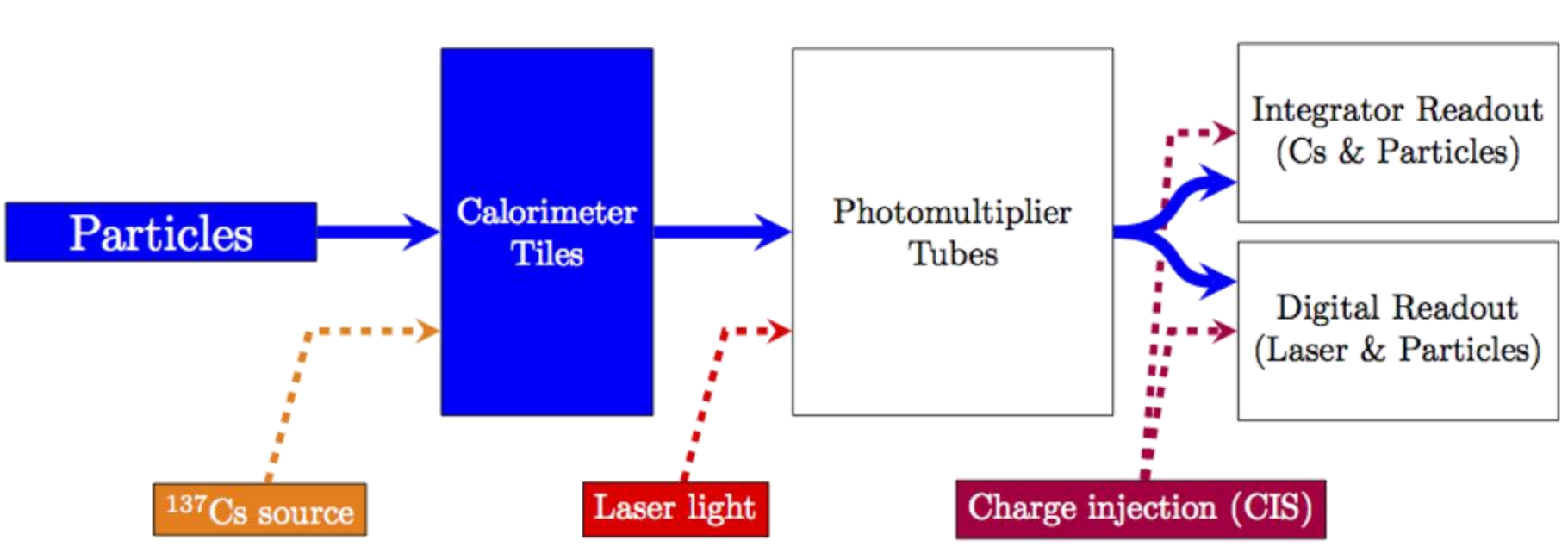
- The goal is to **measure and model** the TileCal's **degradation** of scintillators and fibres to radiation exposure;
- Evaluating the TileCal light yield to future runs is important in **finding mitigation strategies** to compensate the degradation;
- A new method to reduce the large dose spread is being developed;

- The TileCal have proven to have a good performance for the LHC;
- Some simulation of an TileCal-like are starting to see if this can be a solution for the FCC-ee hadronic calorimeter.

Thank you

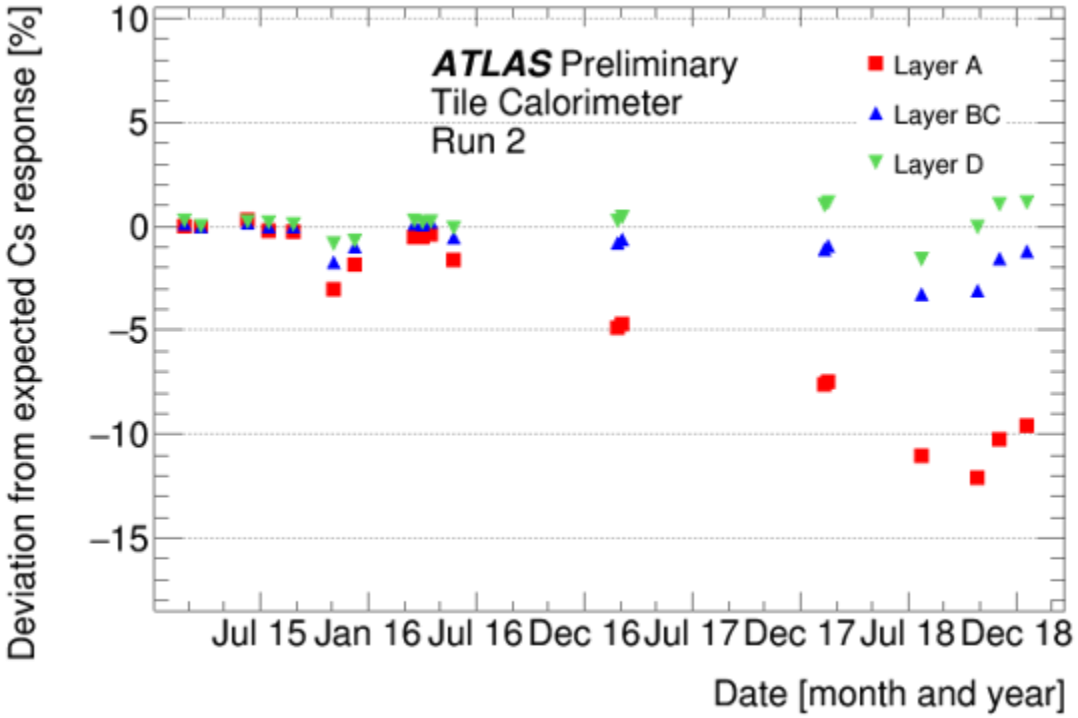
Calibration Systems

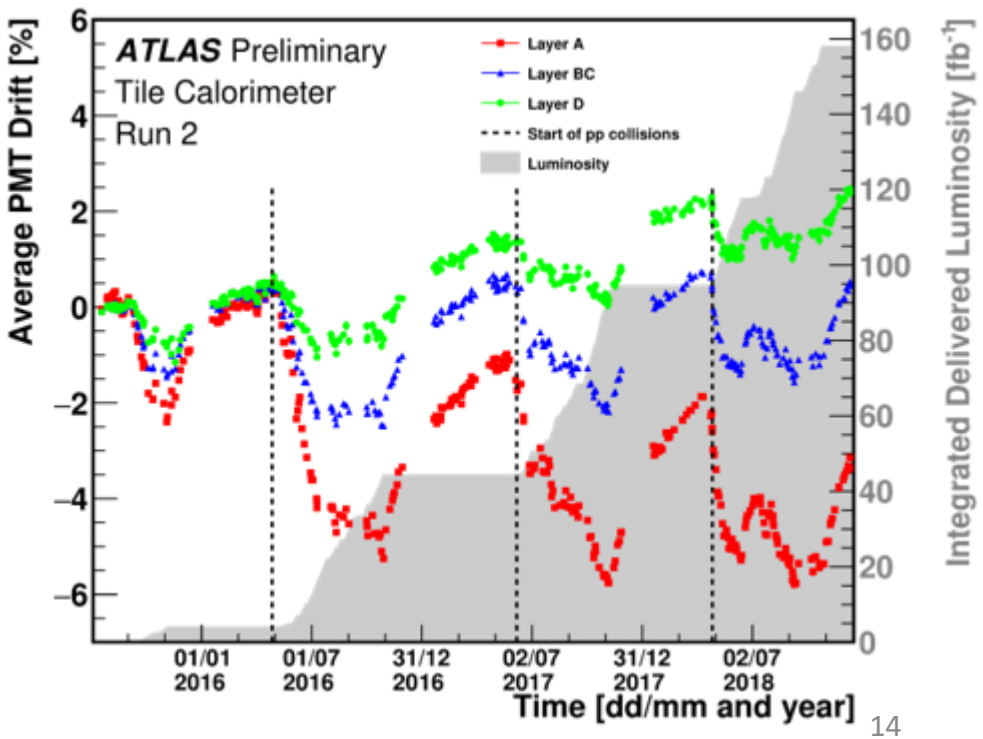
- The TileCal calibration employs dedicated systems to calibrate the energy measurement concerning fluctuations of the response of each readout elements;



Calorimeter Response to the Calibration Systems in Run2

- PMTs – Laser system;
- Scintillators + fibres + PMTs – Cesium or Minimum Bias integrated currents;
- The difference between Cs (or Min Bias) and Laser response corresponds to a variation of the scintillators and fibres response;
- Response decrease is interpreted as the effect of radiation in scintillators and fibres.





Row-based analysis

- The goal is to reduce the dose spread limitation;
- Using the Cs data at the row level.