Optics Robustness of the ATLAS Tile Calorimeter

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on behalf of the ATLAS Collaboration

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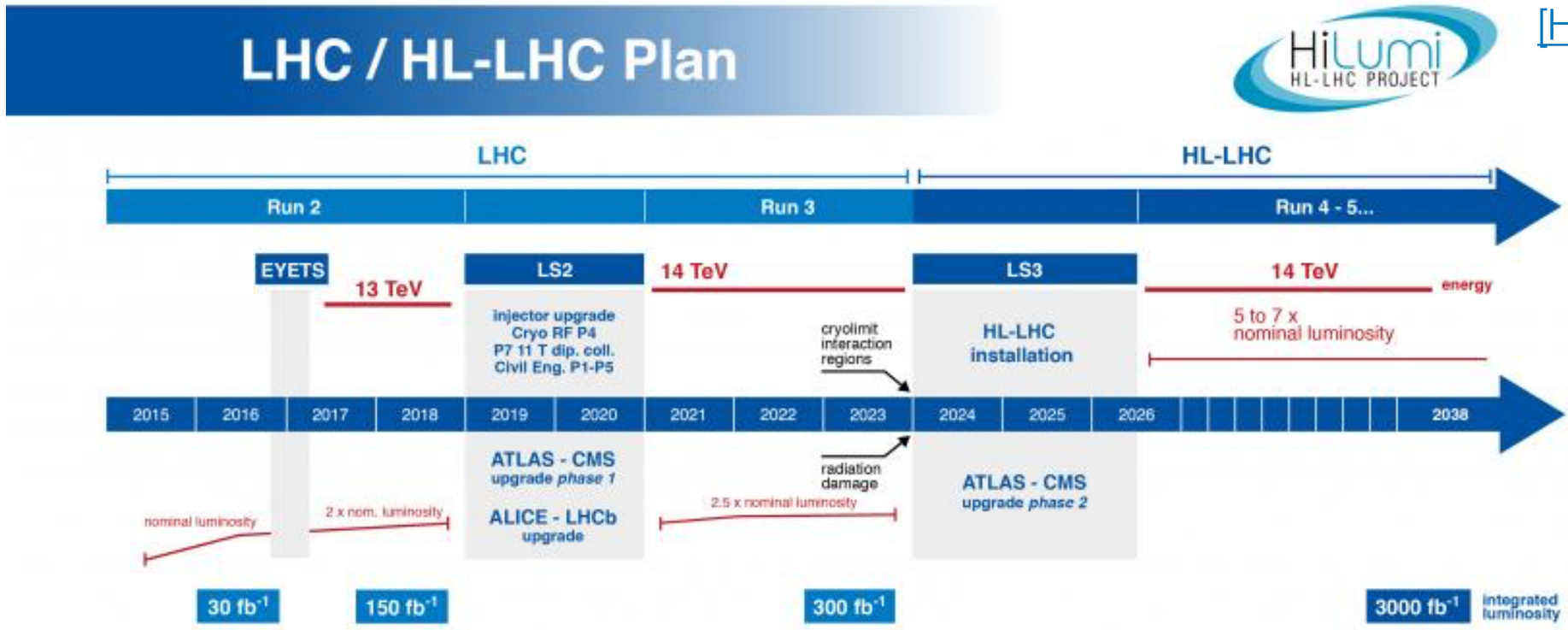
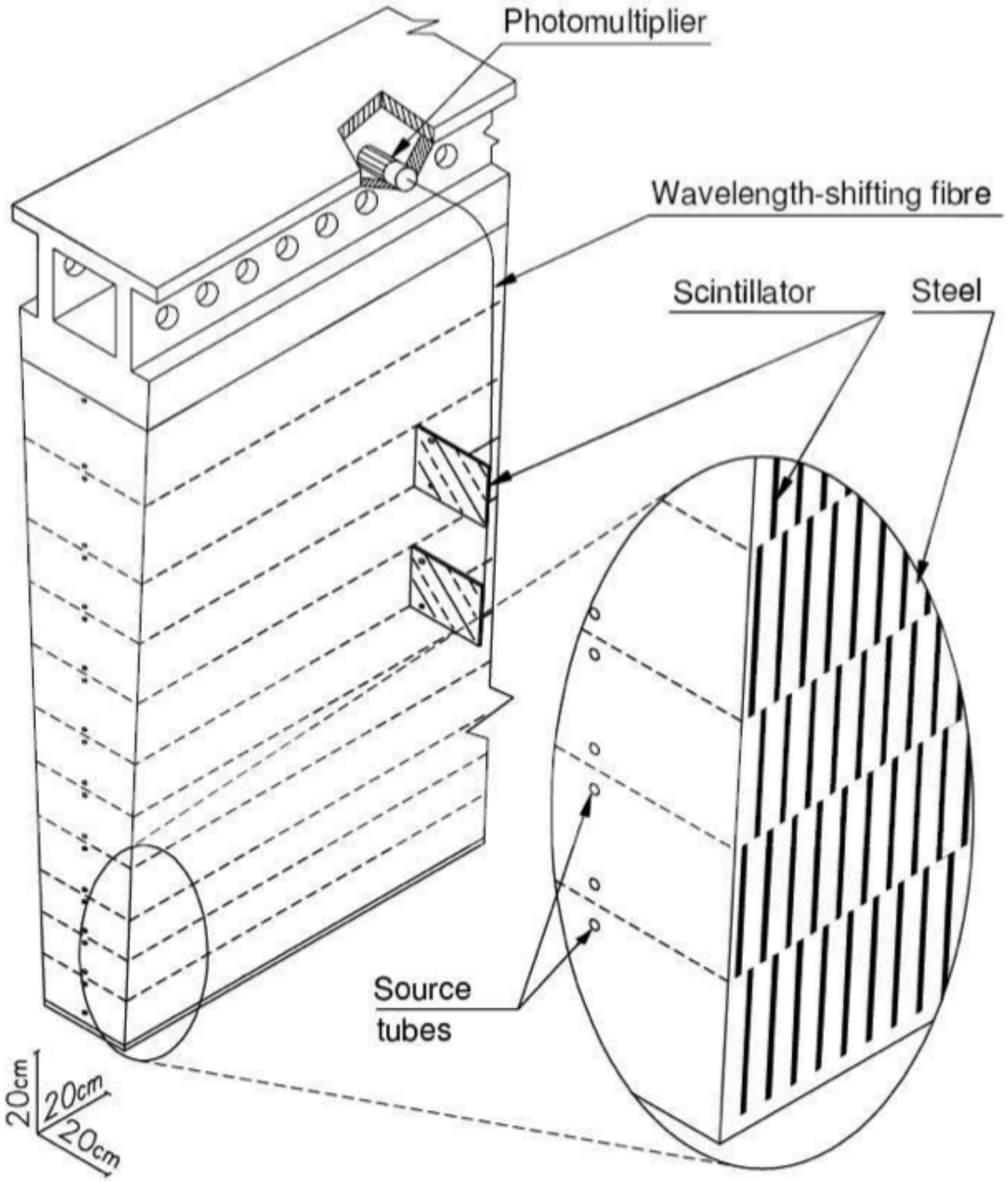
Introduction



[HL-LHC schedule]

- **HL-LHC** needs operational detectors for an **extra 10 years**
- Used **in-situ data** to study the **radiation hardness** of the TileCal optics in Run 2
- Goal is to **predict the performance of the calorimeter** for the HL-LHC

ATLAS Tile Calorimeter

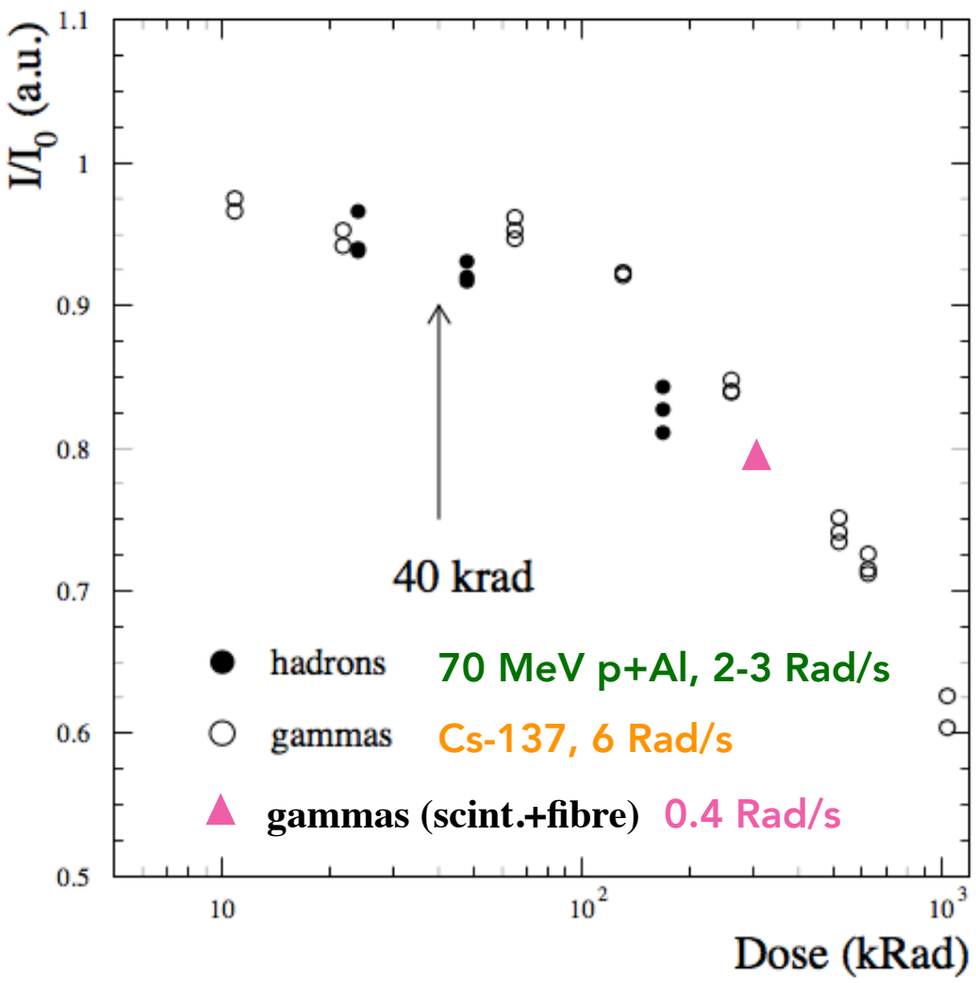


- **Steel as absorber**
- **Active medium:** plastic scintillator tiles
  - Ordinary cells: **Polystyrene** PSM-115 or BASF165H + PTP(1.5%) + POPOP(0.05%)
  - Variable **size**: 10-20 x 20-40 (cm^2)
- Readout by **wavelength shifting (WLS) fibres**: Kuraray Y11 MSJ
- Photodetectors: Hamamatsu R7877 **photomultipliers**
- Tiles and WLS fibres **can not be replaced**

Optics robustness: past studies

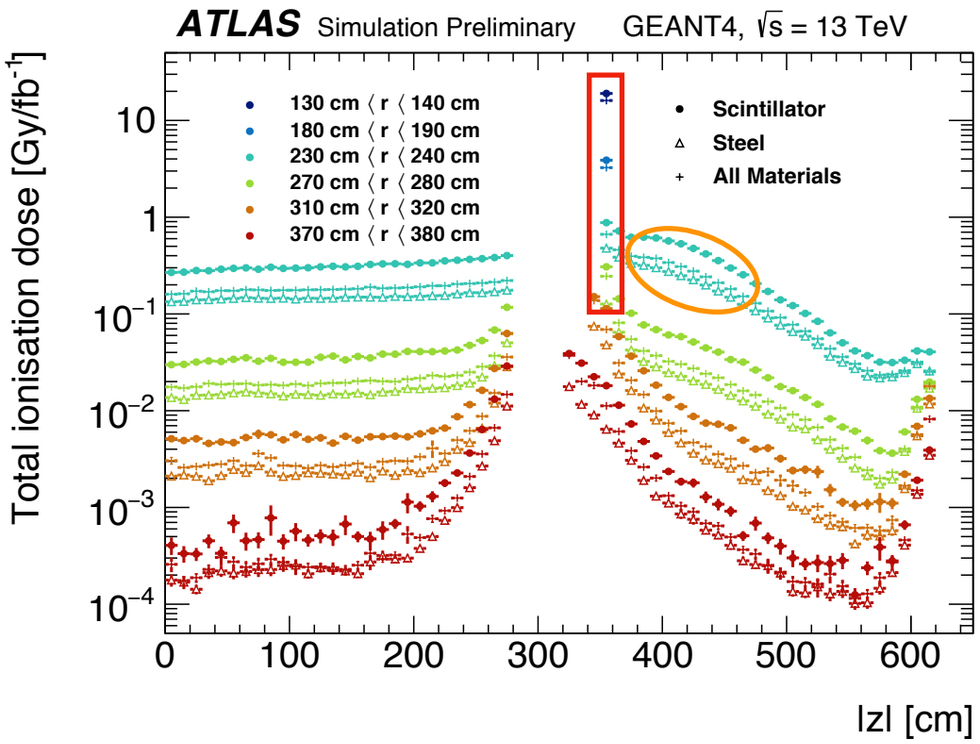
- **Scintillators** tested in the 1990's at IHEP, Protvino
  - Artificially accelerated **ageing: < 1%/year**
  - Irradiations, relative light yield after 1 month annealing
  - Most exposed tiles: **10% light loss expected after 400 Gy** (10y of LHC operation)
- **WLS fibres** tested at Lisbon, 1990's
  - Natural **ageing < 1%/year** [NIM A580 (2007) 318-321]
  - Radiation hardness: **10% light loss after 1.4 kGy** (180 cm long) Nuc. Phys. B (Proc. Suppl.) 54B (1997) 222-228
- **Scintillators** + **WLS fibres** tested at Lisbon, 1990's
  - **19%** light loss after **3000 Gy** CERN/LHCC 96-042

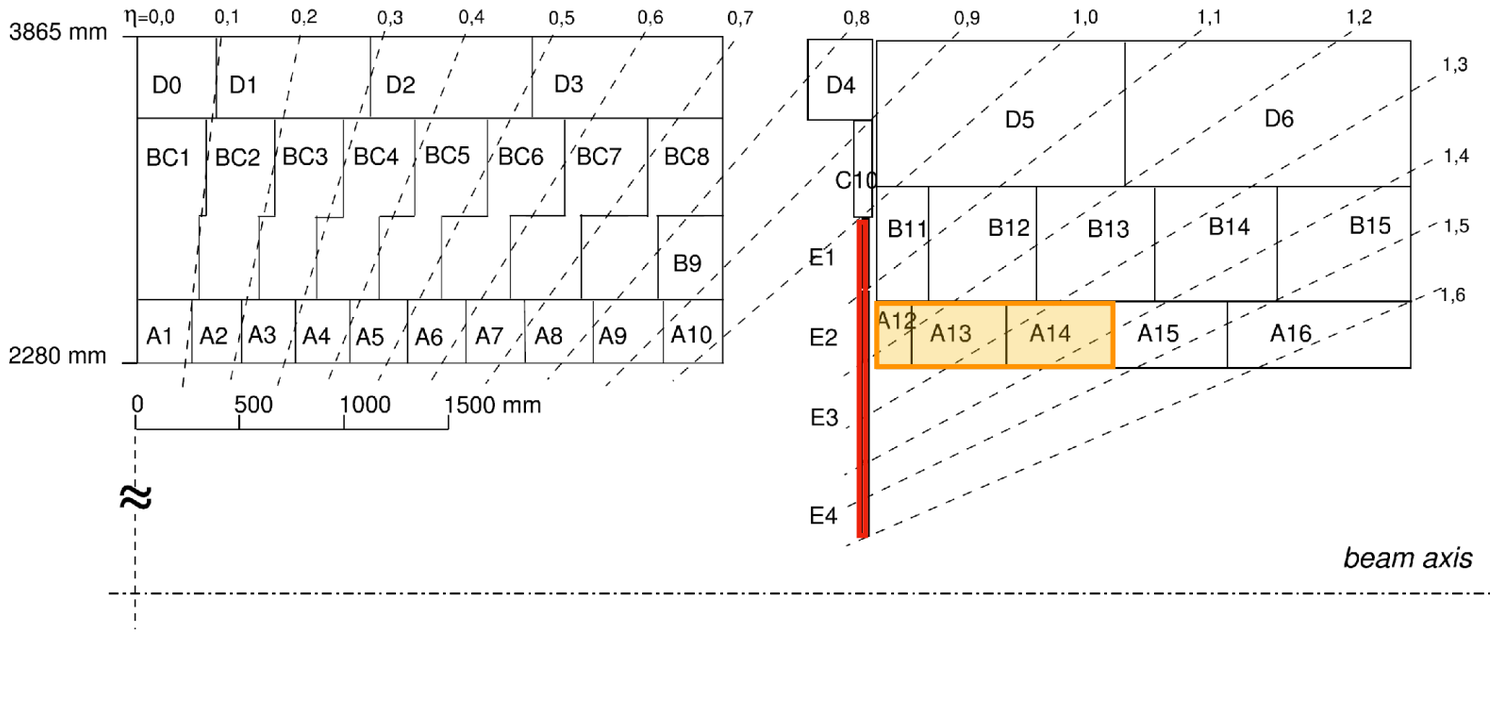
[ATL-TILECAL-PUB-2007-010]



Opportunity to study ageing and radiation hardness of scintillators and fibres materials with in-situ conditions

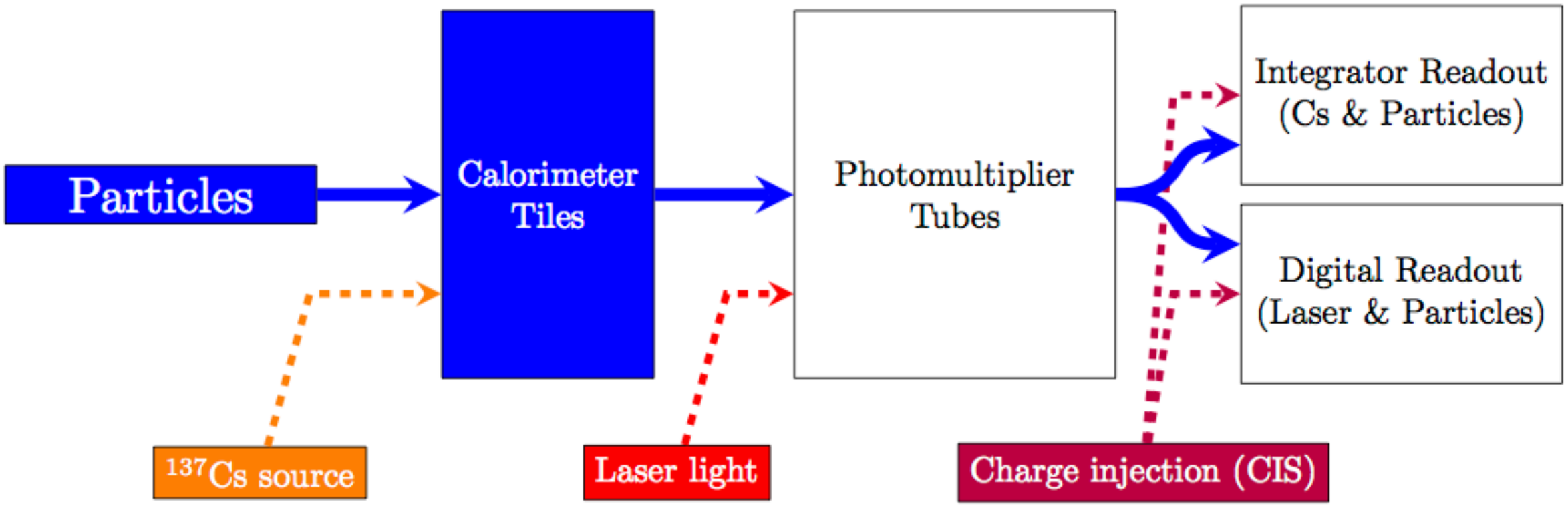
Dose simulation





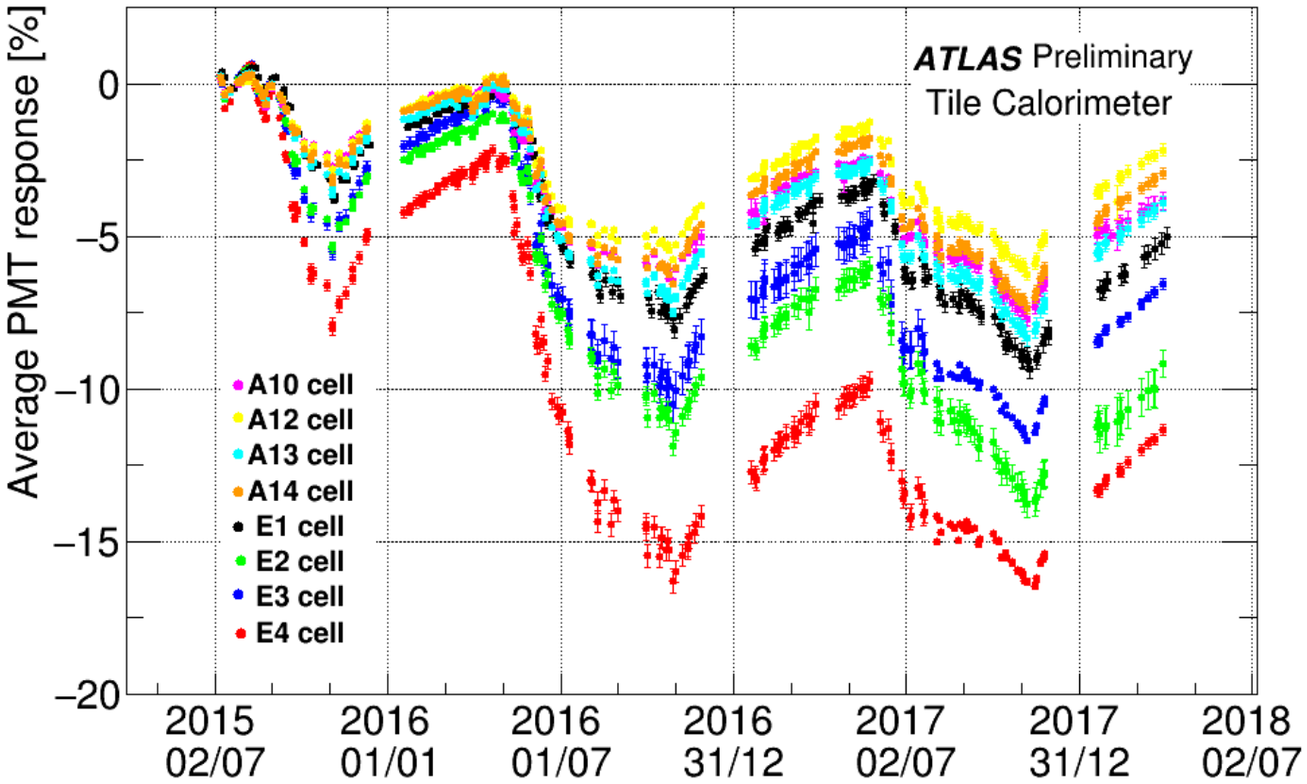
- **LHC Run 2** conditions and **ATLAS Run 2 geometry**
  - 13 TeV minimum bias events simulated with Pythia8 **+ GEANT4** simulation
- **Most irradiated cells**:
  - **A12, A13, A14** cells
  - **E cells** of the gap/crack region

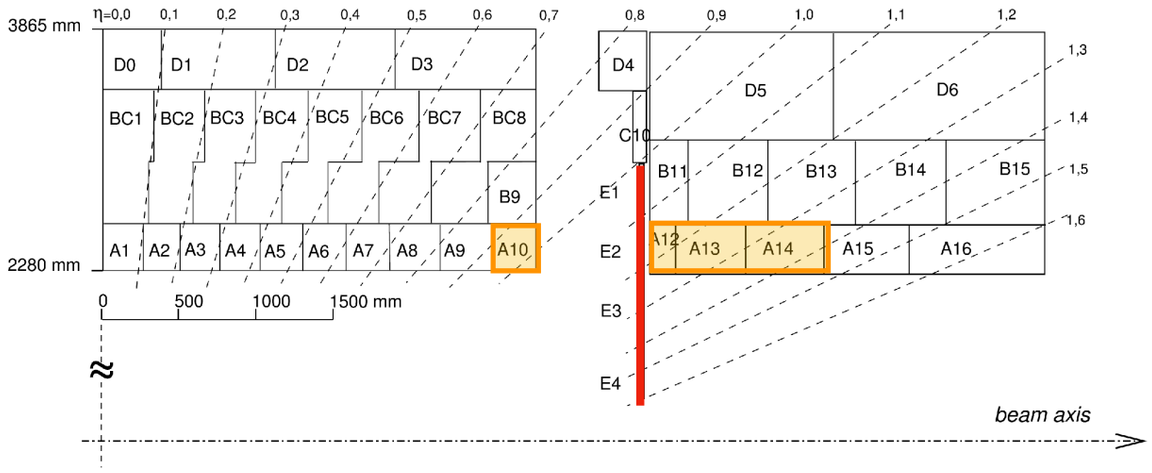
TileCal calibration systems



- A dedicated **system to monitor each step** of the readout chain
- Collision data also used for monitoring:
  - Dominant **minimum bias** process: **energy deposition proportional to instantaneous luminosity**
  - Factorize out the dependence on instant. luminosity by normalising to stable cell (D6, less irradiated)

PMT monitoring with the Laser system





- Studied **time evolution of the response of PMTs** reading most exposed cells
- Observe a **down drift of the PMT** response during **pp collisions**
- Partial **recovery during shut-down**

Modelling of these effects (more on **F. Scuri talk**):

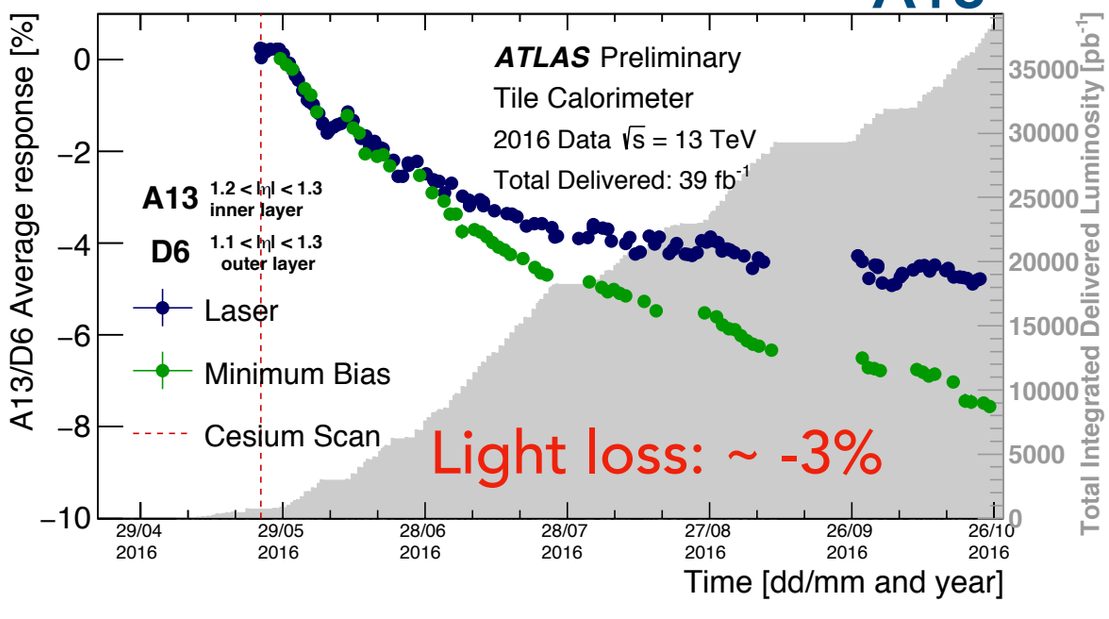
- **Slow loss rate of 0.08%/C** on integrated charge

Monitoring with Laser and Minimum Bias currents

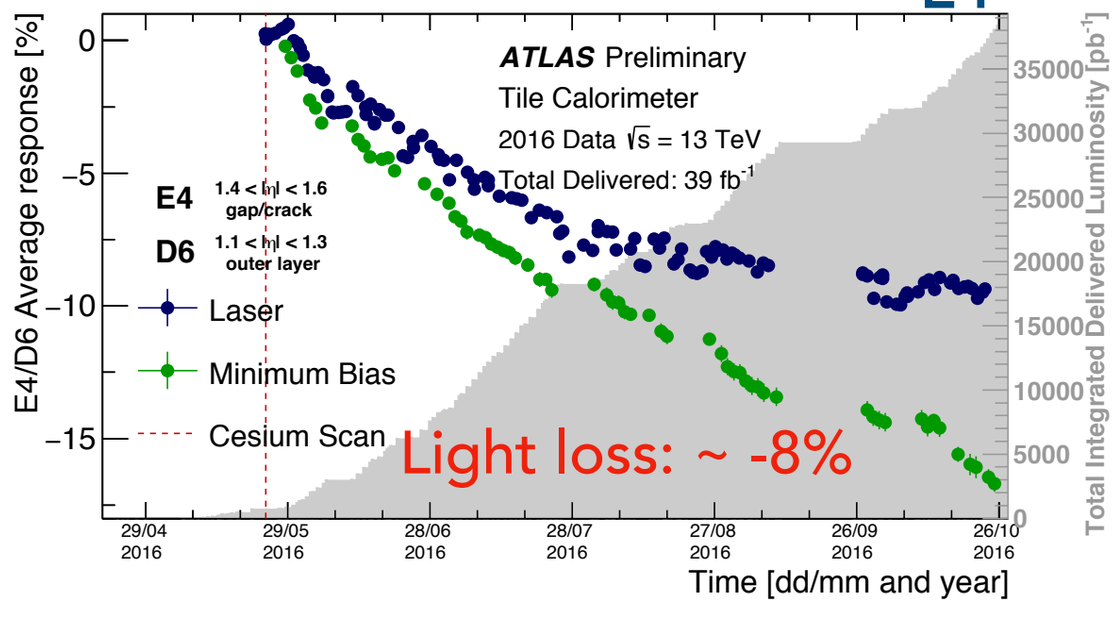
2016 data

- Data **averaged** over different 128 modules, **in φ**
- Response relative to D6 cell:
  - PMT (laser system)
  - Scintillators + fibres + PMTs (minimum bias currents)
- **Difference in response to Min bias** events **and laser** pulses
  - Measure **light yield loss of scintillators and fibres**
  - Note that these components **cannot be replaced**, unlike PMTs

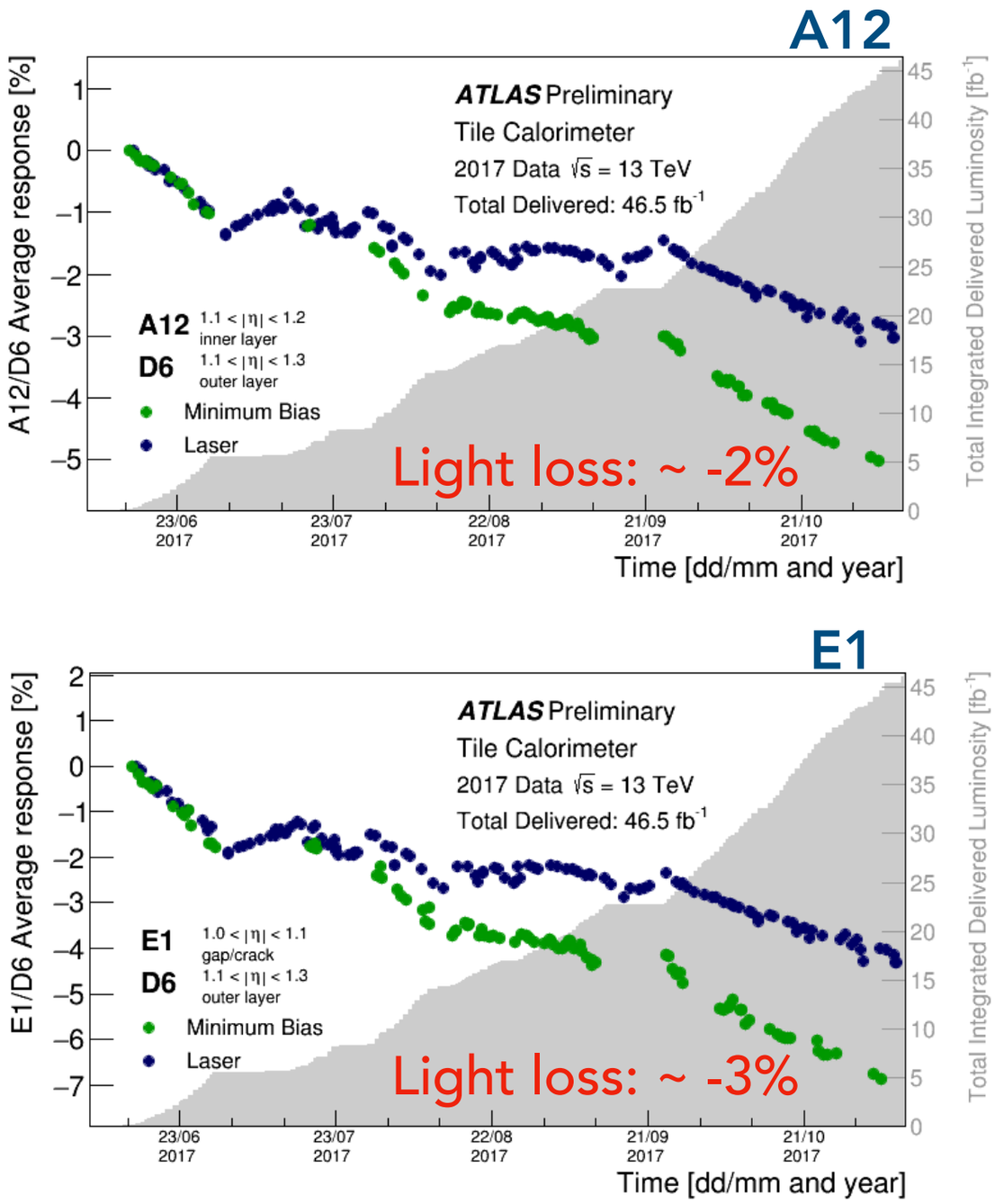
A13

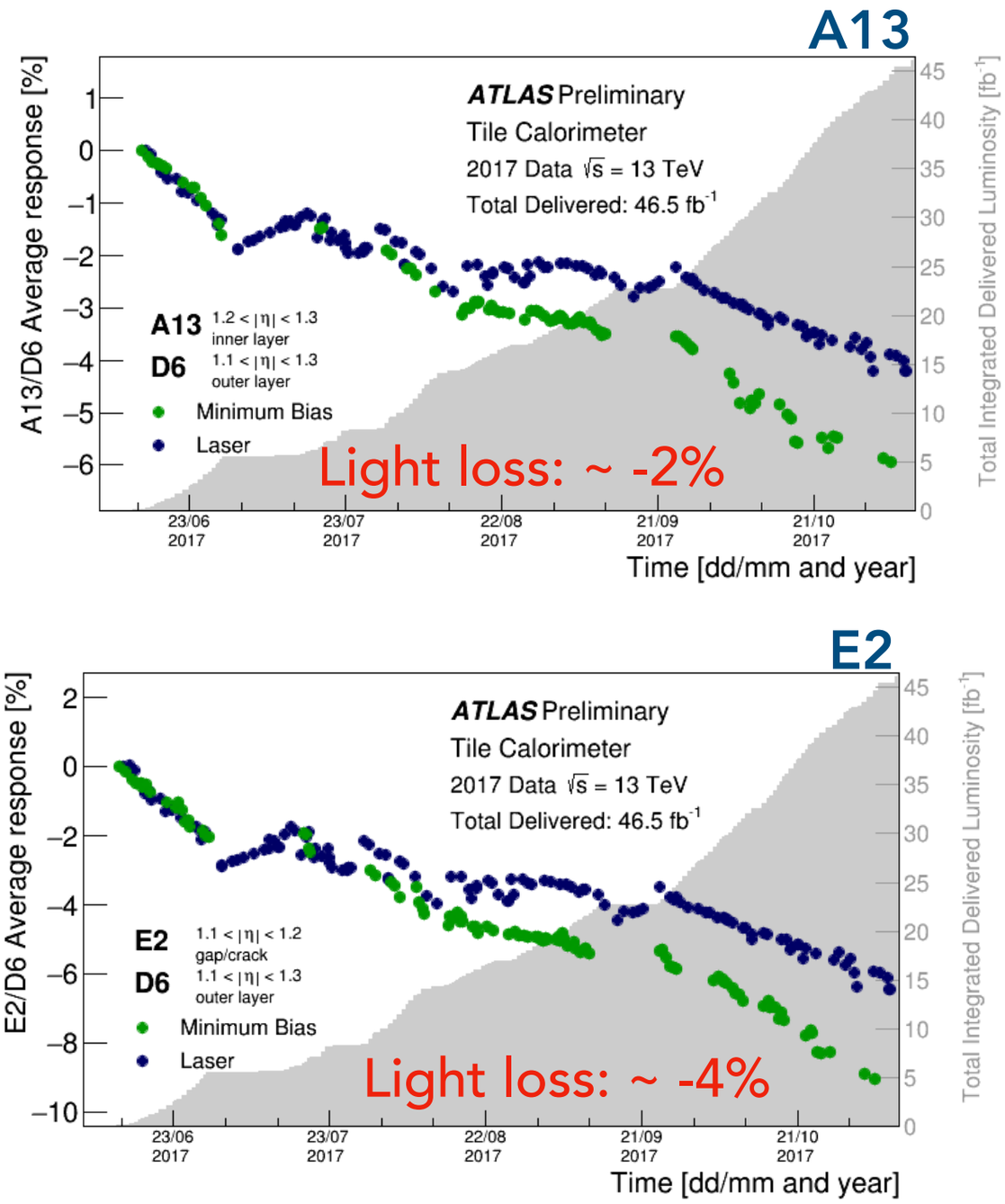


E4



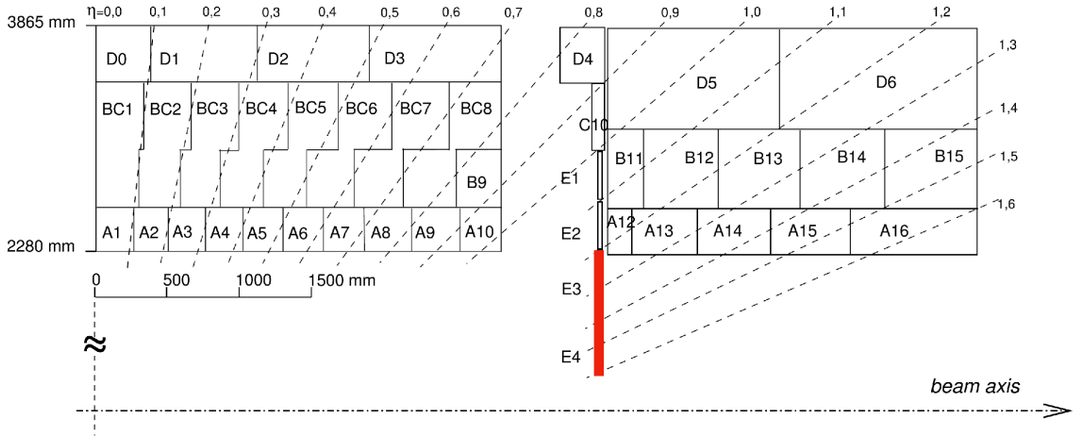
Monitoring with laser and Minimum bias - **2017**

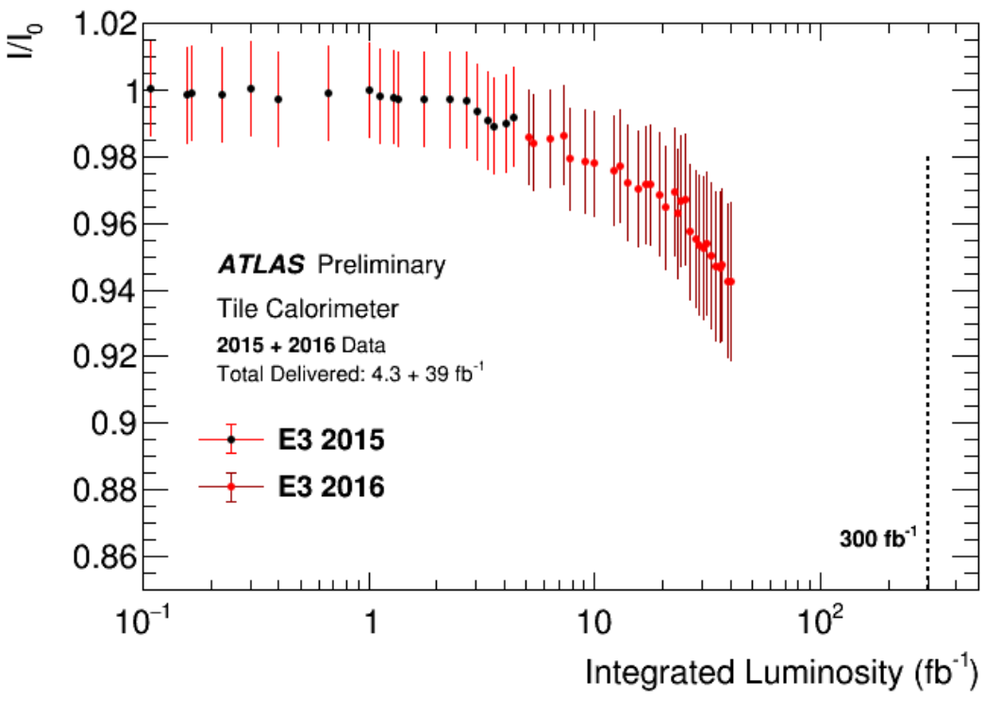


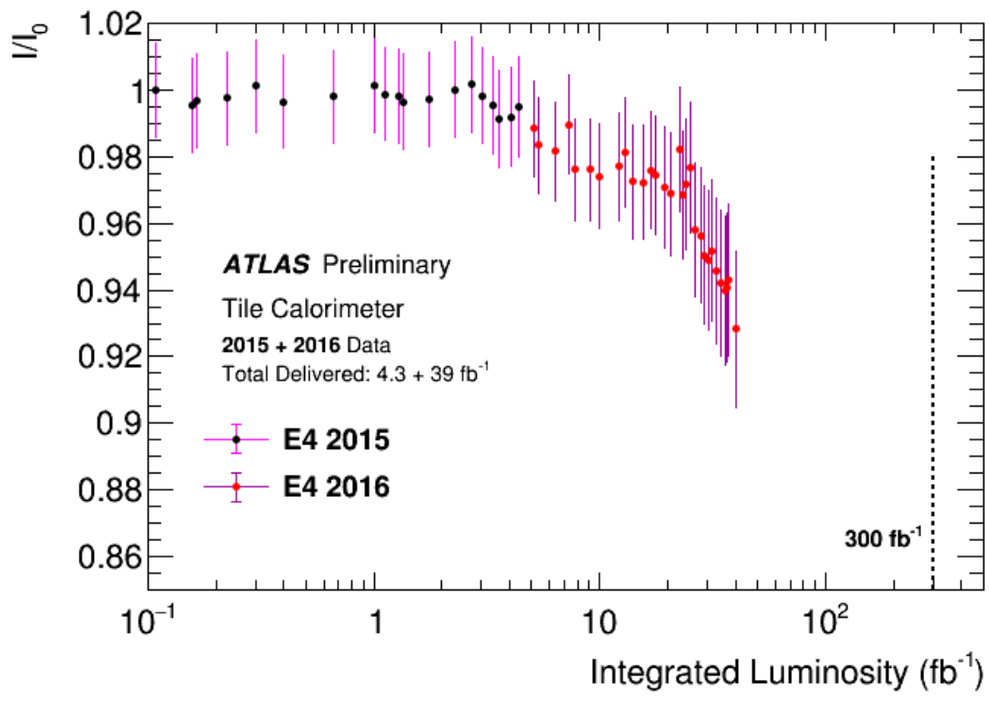


Light yield of scintillators + fibres

- Considering **systematic uncertainties** on the response to Laser pulses and Min bias events
  - **Laser system**: up to **1.2%**
  - **Integrator** of Min bias currents: **1.2%**





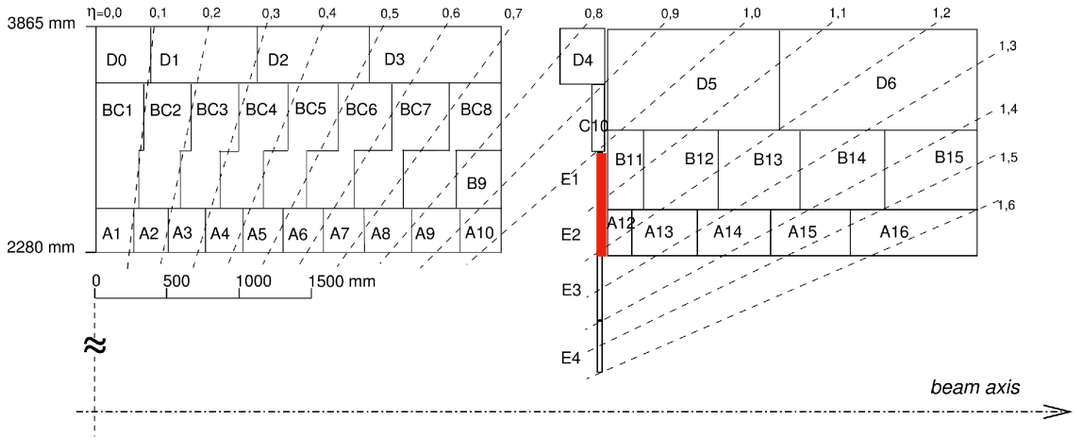


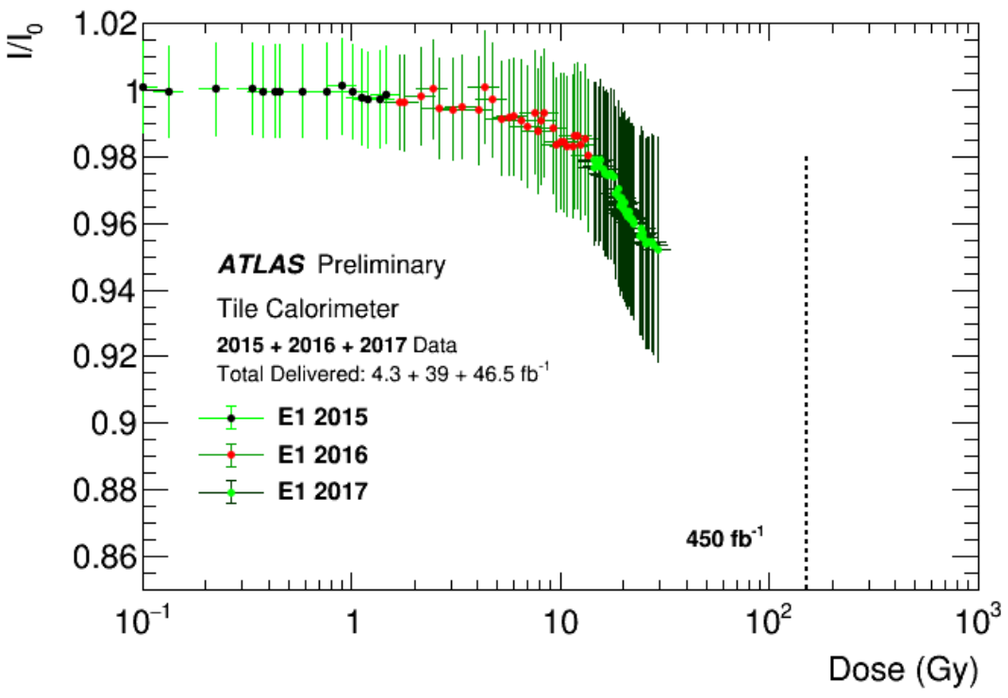
Total **light yield degradation** (2015+2016): **~8%, assuming no evolution of light yield** during LHC shutdown

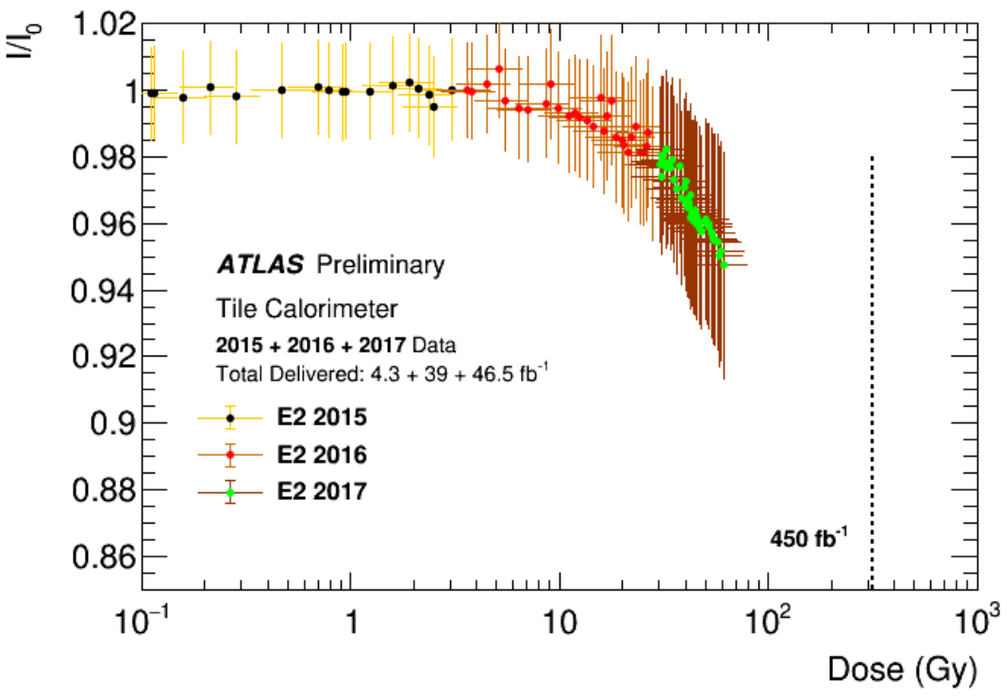
- **Extreme irradiation** conditions -> will be **replaced at the end Run 2**
- **Different material and larger size scintillators**: polystyrene-based (UPS-923A)

Light Yield vs Dose [Gy]

- **Large dose gradient** in the scintillators' **volume**
  - Horizontal bar is the RMS of the dose distribution



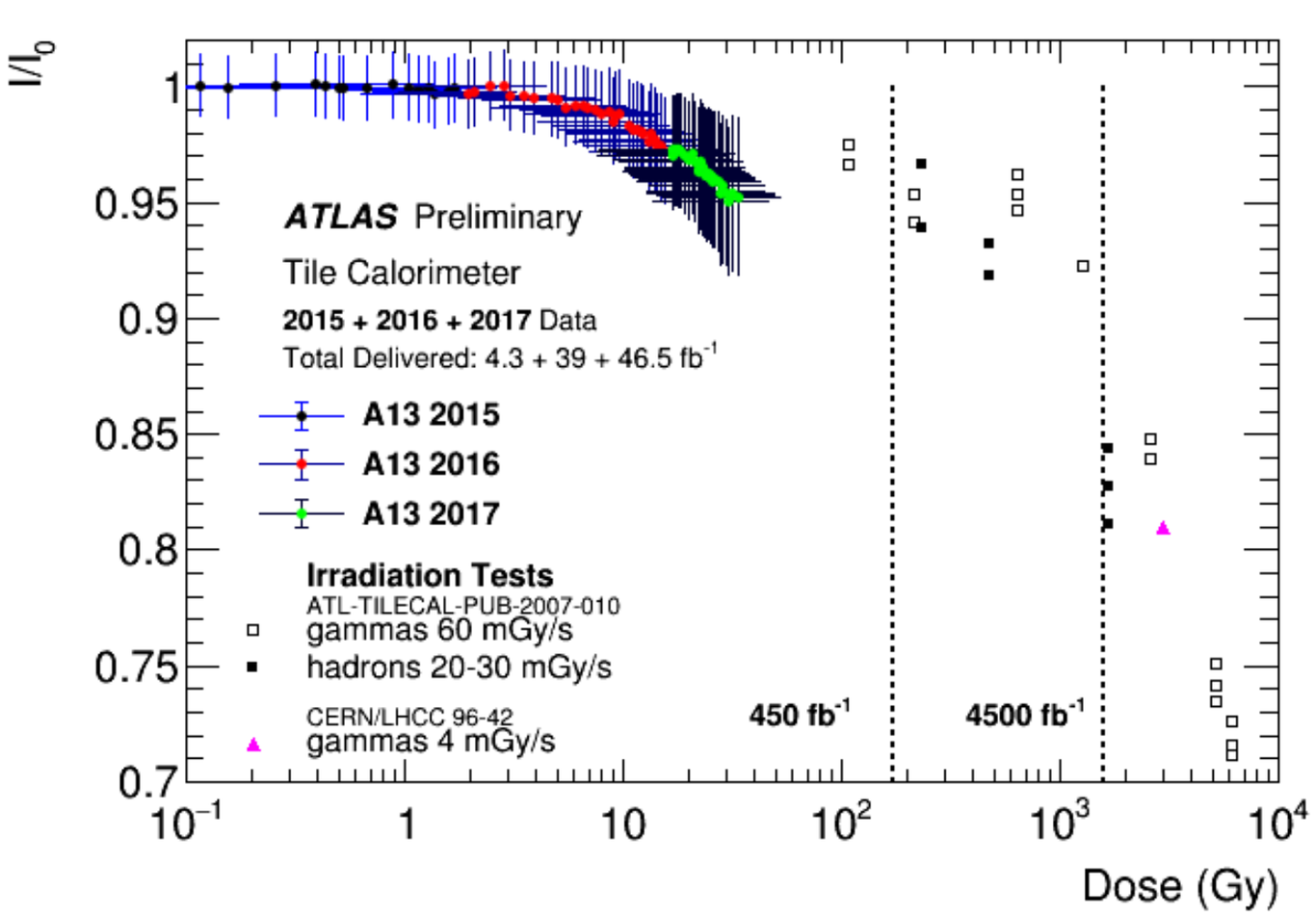


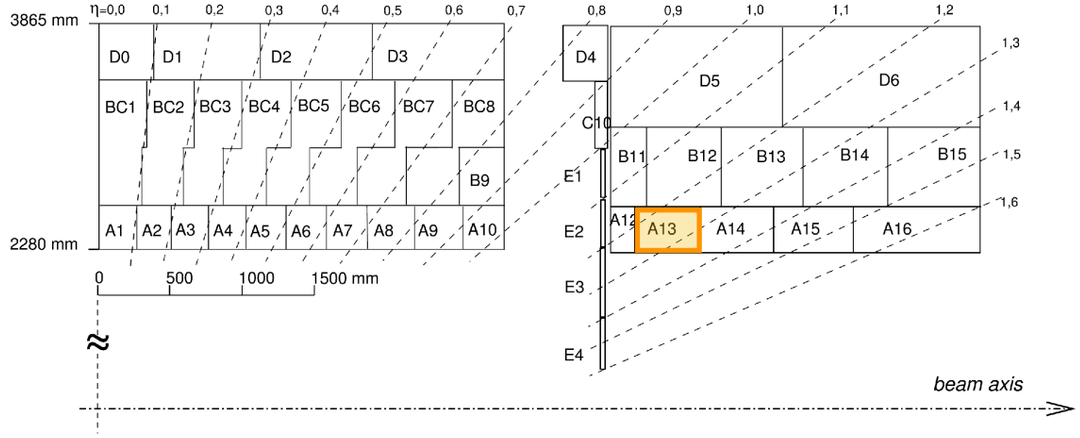


Total **light yield degradation** (2015+2016+2017): **~5%**

- **Extrapolation** to the end of Run 3 **challenging -> 2018 data will show the way**
- **Different material and larger size scintillators**: PVT-based (UPS-923A)

Light Yield vs Dose [Gy]



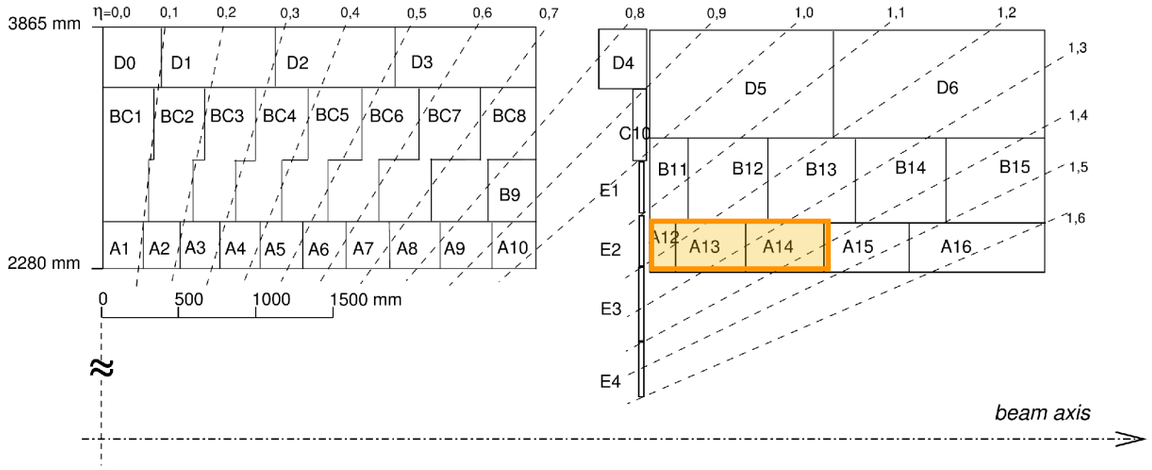


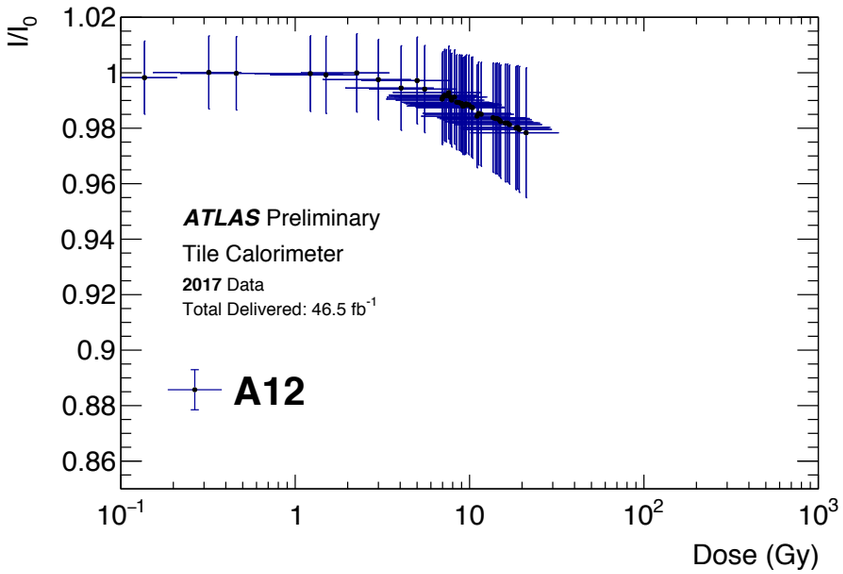
- Data from laboratory **irradiations of scintillators only** (same material):
  - Interpolation with 1700 Gy expected for A13 **at HL-LHC (4500 fb^{-1}): >25% light loss**
  - (Results from irradiation of **scintillators + fibres** not very different)
- **TileCal in-situ measurements**:
  - Results indicate a **faster light loss rate** than laboratory data
  - **Uncertainties** of the order of the effect we want to measure -> Challenge of this analysis: **reduce systematics**

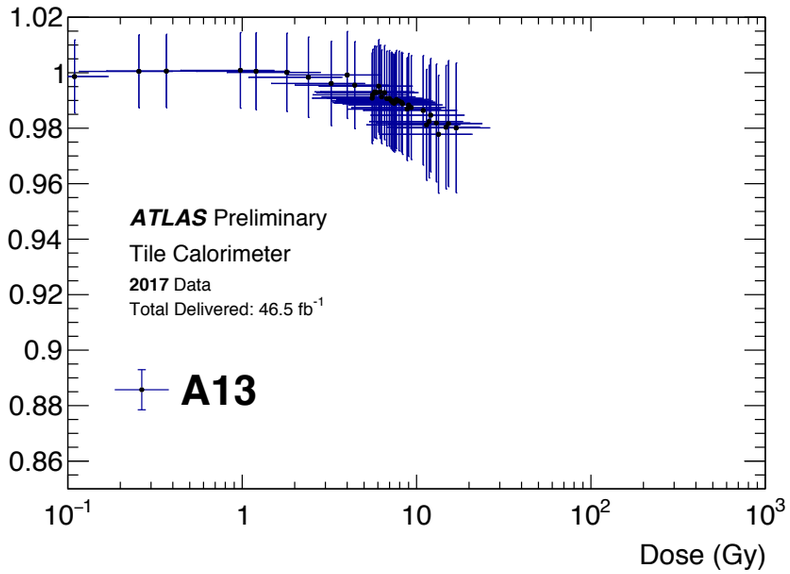
Light Yield vs Dose [Gy]

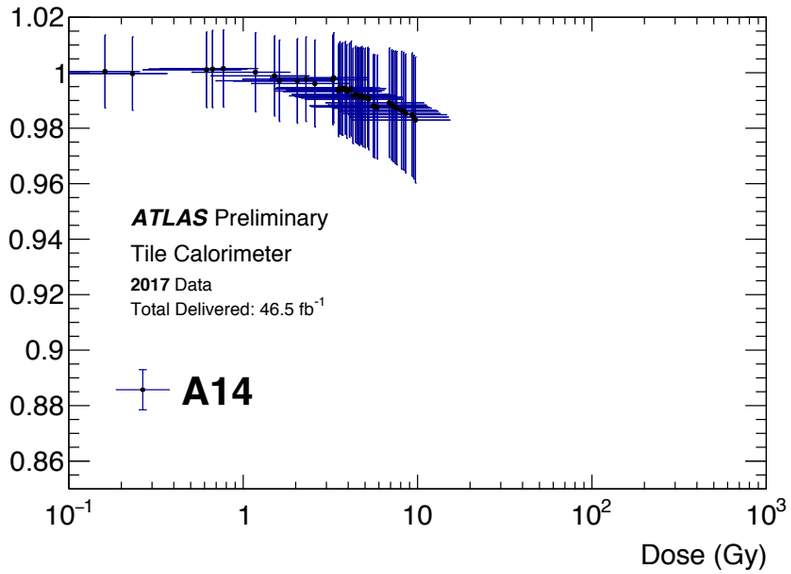
- Comparing A12, A13 and A14
  - **~same** scintillator tile **size** and **fibre length**
  - **Dose rates (D) vary** slightly**:**

    D(A12) = 2 x D(A14)
  - Same light loss at the end of 2017 -> **no dose rate effects (within uncertainties)**



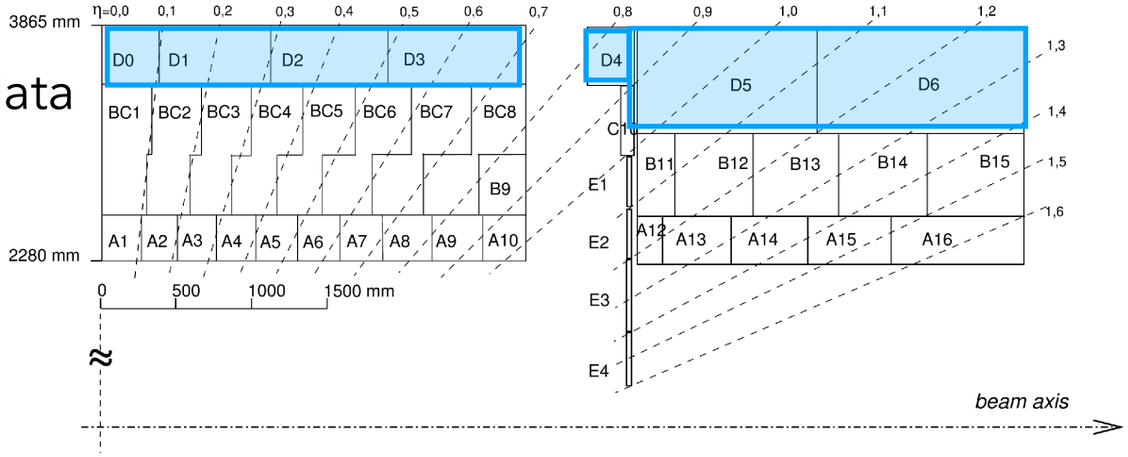


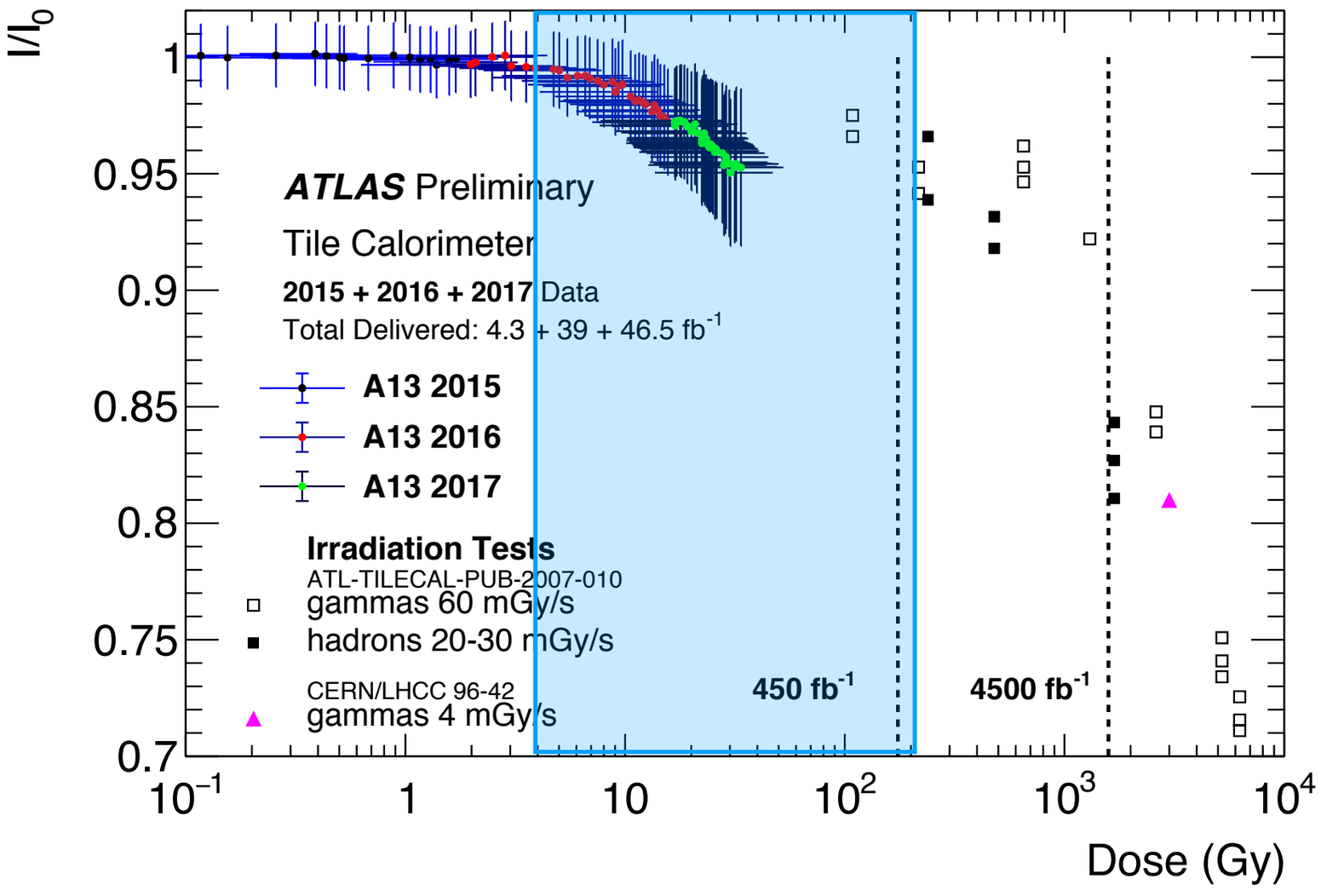




Extrapolation to HL-LHC

- **Predict performance** of less irradiated cells from current data
  - **Considering no dose rate effects**
  - Dose predicted for each cell relative to A13
  - Dose ratios are ~independent from simulation models





- **D cells**
  - Majority: **< 10% loss**
  - **0.8<η<0.9:** add **2018 data**

Extrapolation to HL-LHC

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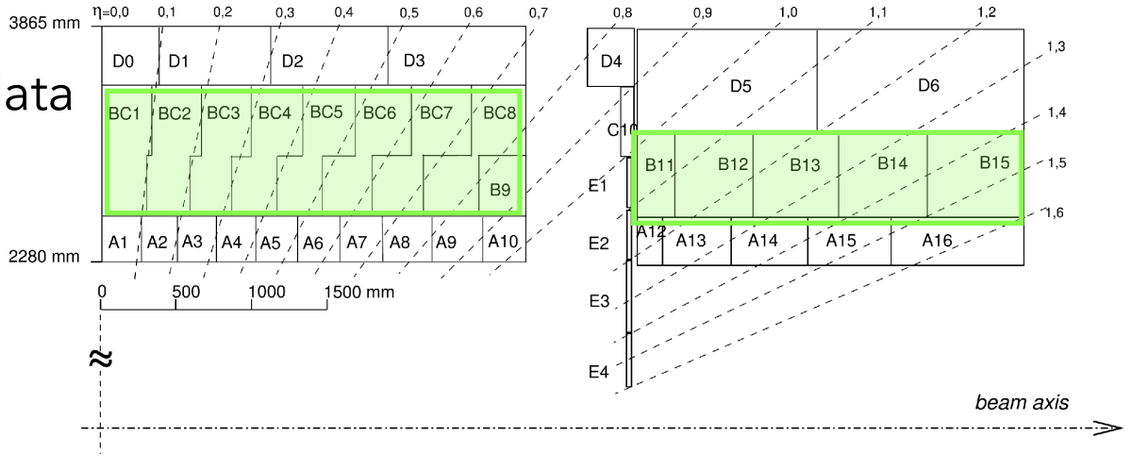

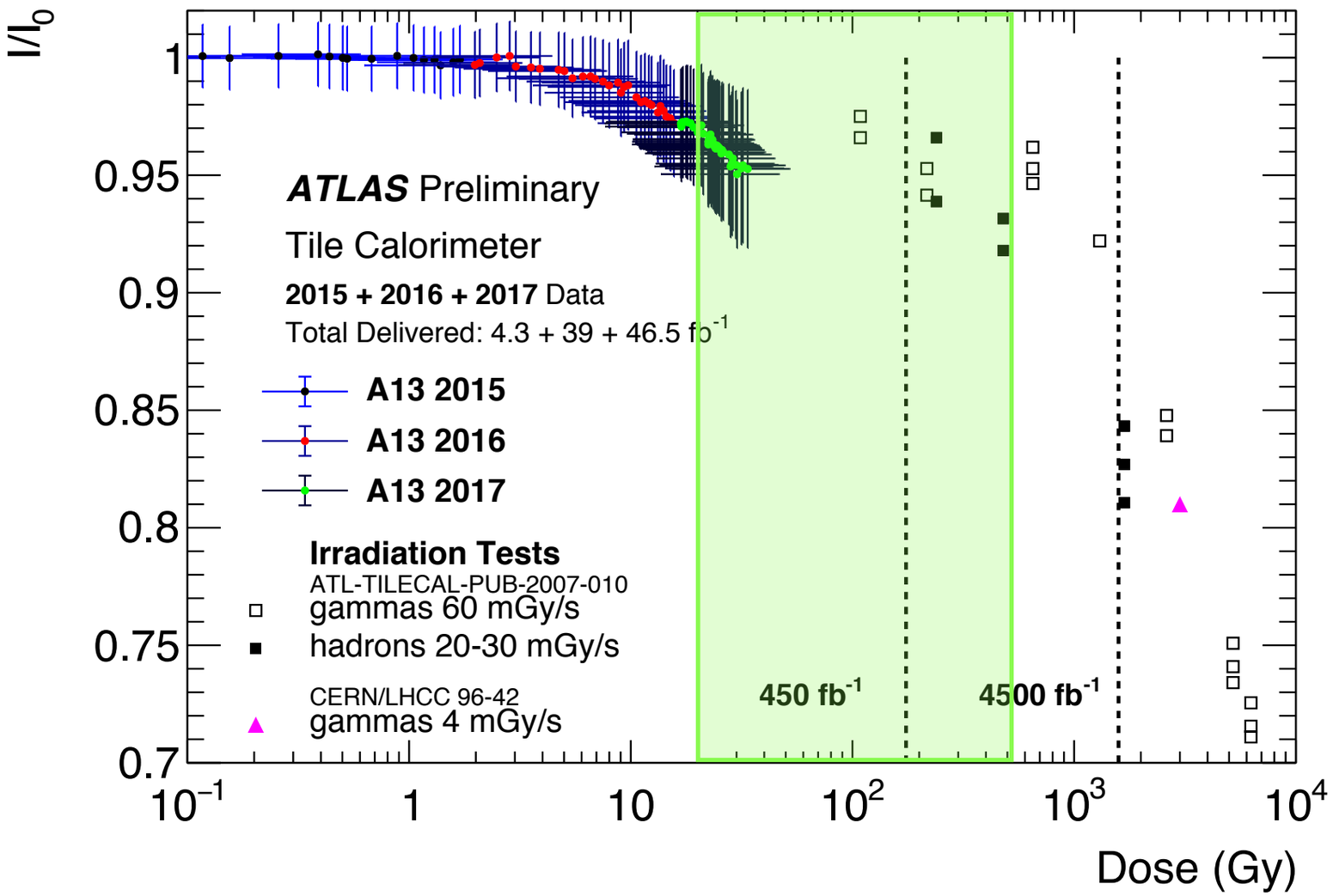

- **B/C layers**
  - For less exposed: **< 10% loss**

Extrapolation to HL-LHC

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  - **Considering no dose rate effects**
  - Dose predicted for each cell relative to A13
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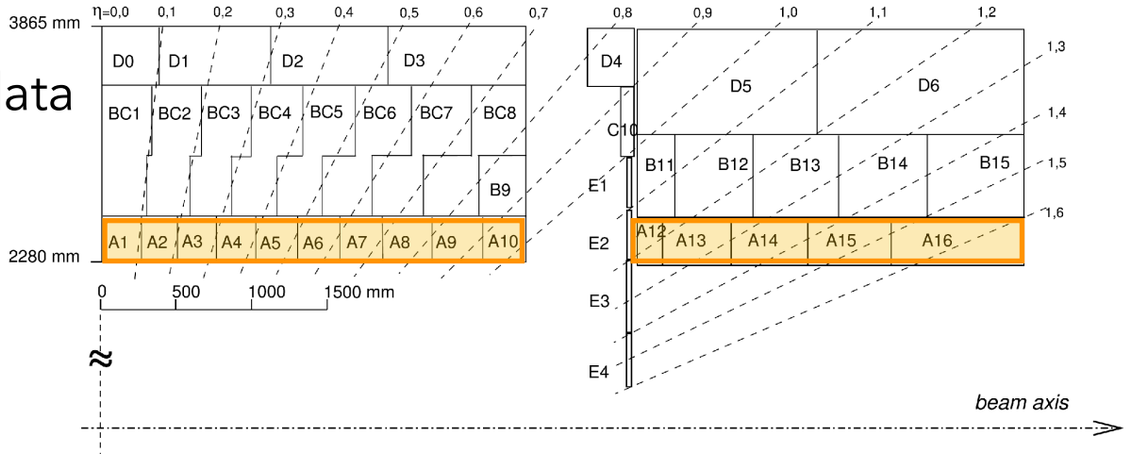

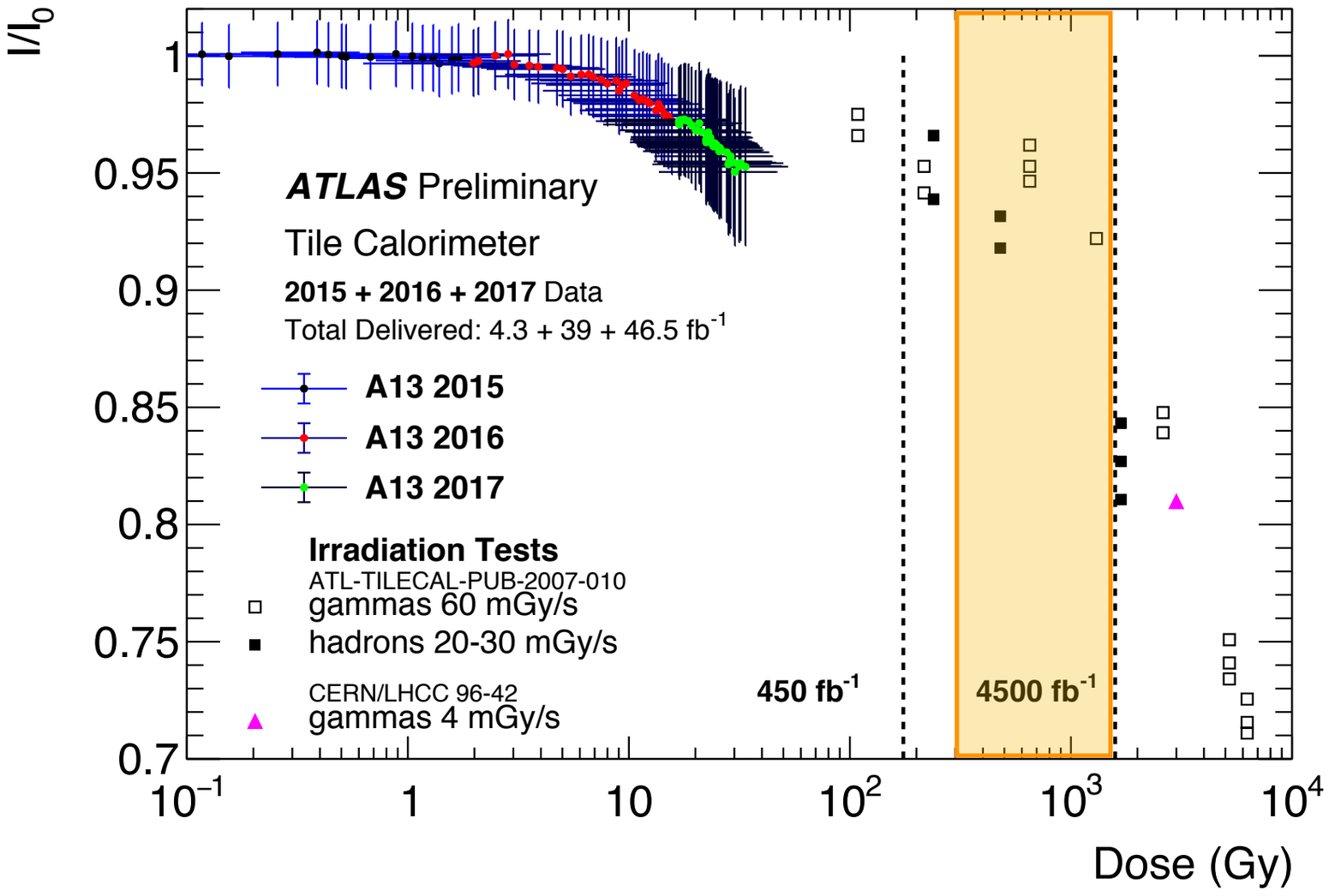

- **A layer**
  - Need more information to extrapolate

Conclusions

- TileCal **calibration data** were **analysed**
  - 2015 to 2017
  - For the 5 cells most exposed to irradiation

- **PMTs**: **Slow loss rate of 0.08%/C** on integrated charge

- **Scintillators** and **WLS fibres**
  - **B/C and D layers** (60% of the TileCal cells):

    < 15% light loss at HL-LHC
  - **A layer:**

    Extrapolation needs better **understanding of the systematics**

    To be done **with 2018 data**