Measurements of Luminosity in ATLAS with Tile Calorimeter

Sergio González Fernández

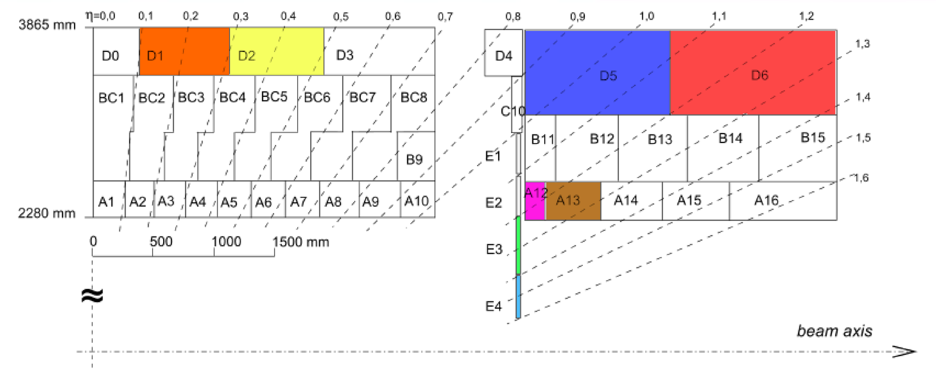
on behalf of the ATLAS Tile Calorimeter System

Institut de Física d'Altes Energies

EXCELENCIA SEVERO OCHOA

BIST Barcelona Institute of Science and Technology

- Luminosity is one of the most fundamental measurements in a particle collider.
- ATLAS has at its disposal many subdetectors that can be use as luminosity-sensitive detectors (luminometers) once they are calibrated.
- The Tile Calorimeter is one of this subdetectors.
  - TileCal integrator based RO is sensitive to luminosities from 3e30 to 3e34 cm^{-2} s^{-1}.
  - The linearity of Tile measurements to Luminosity makes it an attractive luminometer.
  - Tile measurements of Luminosity are stable during long periods of data taking.

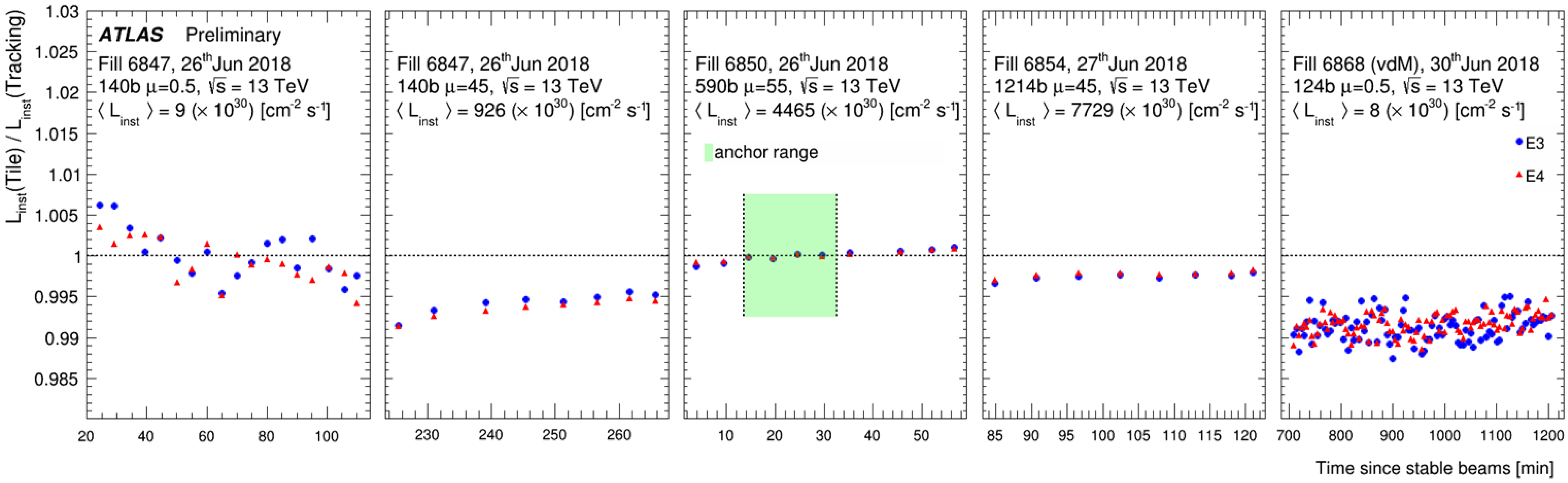


Calibration Transfer

- The absolute calibration for ATLAS luminosity is measured by LUCID using the van der Meer runs. LUCID measurements relate visible interactions per bunch crossing ($\mu_{\rm vis}$) and cross section ($\sigma_{\rm vis}$).

$$\mathcal{L} = f_{\rm LHC}\frac{n_1 n_2}{2\pi\Sigma_x\Sigma_y} \qquad \mathcal{L} = f_{\rm LHC}\frac{\mu_{\rm vis}}{\sigma_{\rm vis}}$$

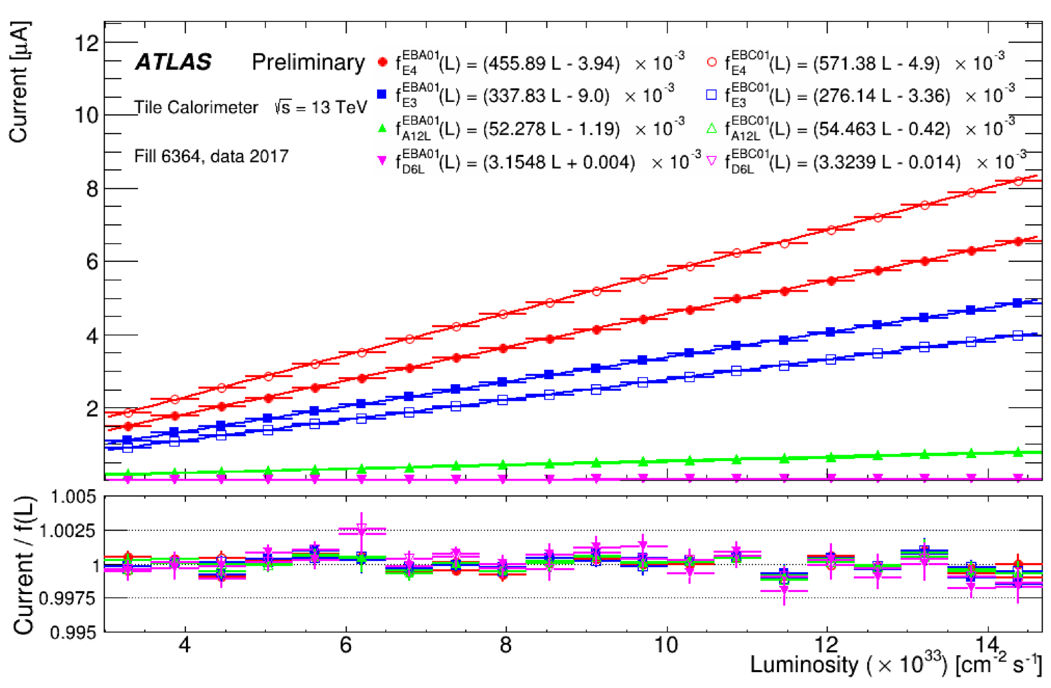
- For a better measurement of the bunch intensity, this is done under very low luminosity and in isolated bunches. The calibration has to be extrapolated to physics data-taking conditions (calibration transfer) and another detector that is not dependent on pileup needs to be used (Tracking).
- An uncertainty is then needed to be assigned to the extrapolation. This is provided using TileCal measurements, since they are also independent on pileup. The deviation between the luminosity measurements provided by TileCal and the Tracking detector provides a measure of the associated uncertainty in the calibration transfer.
- A meticulous analysis of 2018 runs taken at gradually increasing structural complexity indicates a better than 1% uncertainty on the measurement of the luminosity transfer in 2018 and consequently for entire run-2 data.



TileCal Luminosity Computation

- TileCal Luminosity is computed by converting the anode current for a given channel to Luminosity through the calibration constants.
- The anode current is obtained by performing the pedestal subtraction to the ADC counts. This subtraction should account for electronics noise and residual activation. The signal above the pedestal is converted to current by dividing with the gain of the channel.

$$\langle I_{\rm PMT}\rangle = \frac{\langle {\rm ADC}\rangle - {\rm Pedestal}}{\rm gain}$$

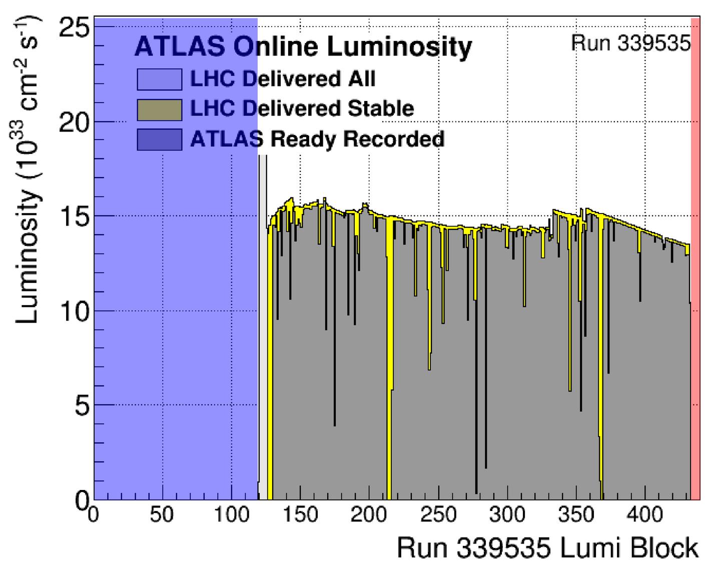


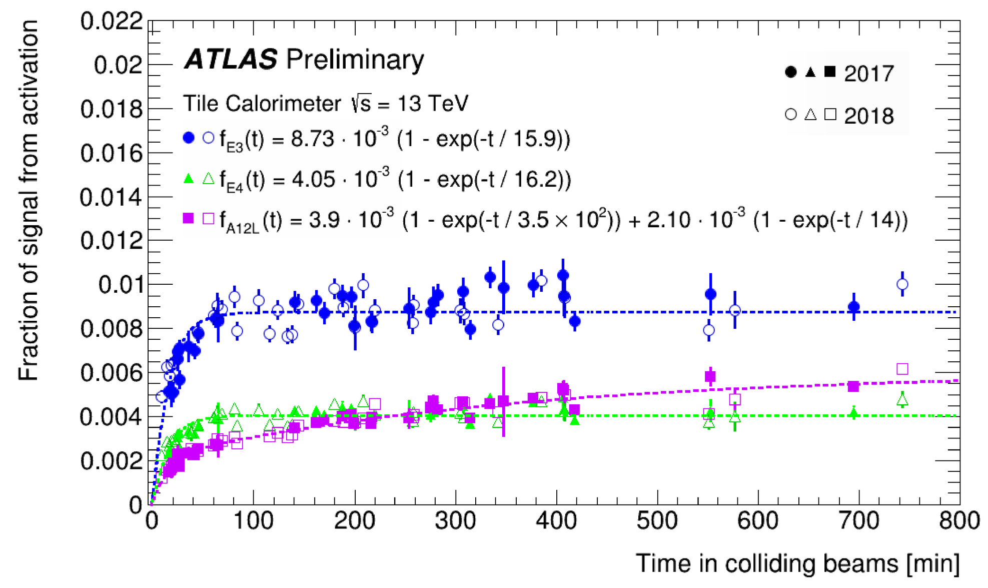
- The anode current is proportional to Luminosity.
- The calibration for TileCal is obtained by normalizing each individual TileCal channel to the Tracking luminosity in an anchor period of a fill.
- Once the calibration constant is obtained, we can compute the Luminosity at any given current:

$$\mathcal{L} = \alpha\,\langle I_{\rm PMT}\rangle$$

Activation

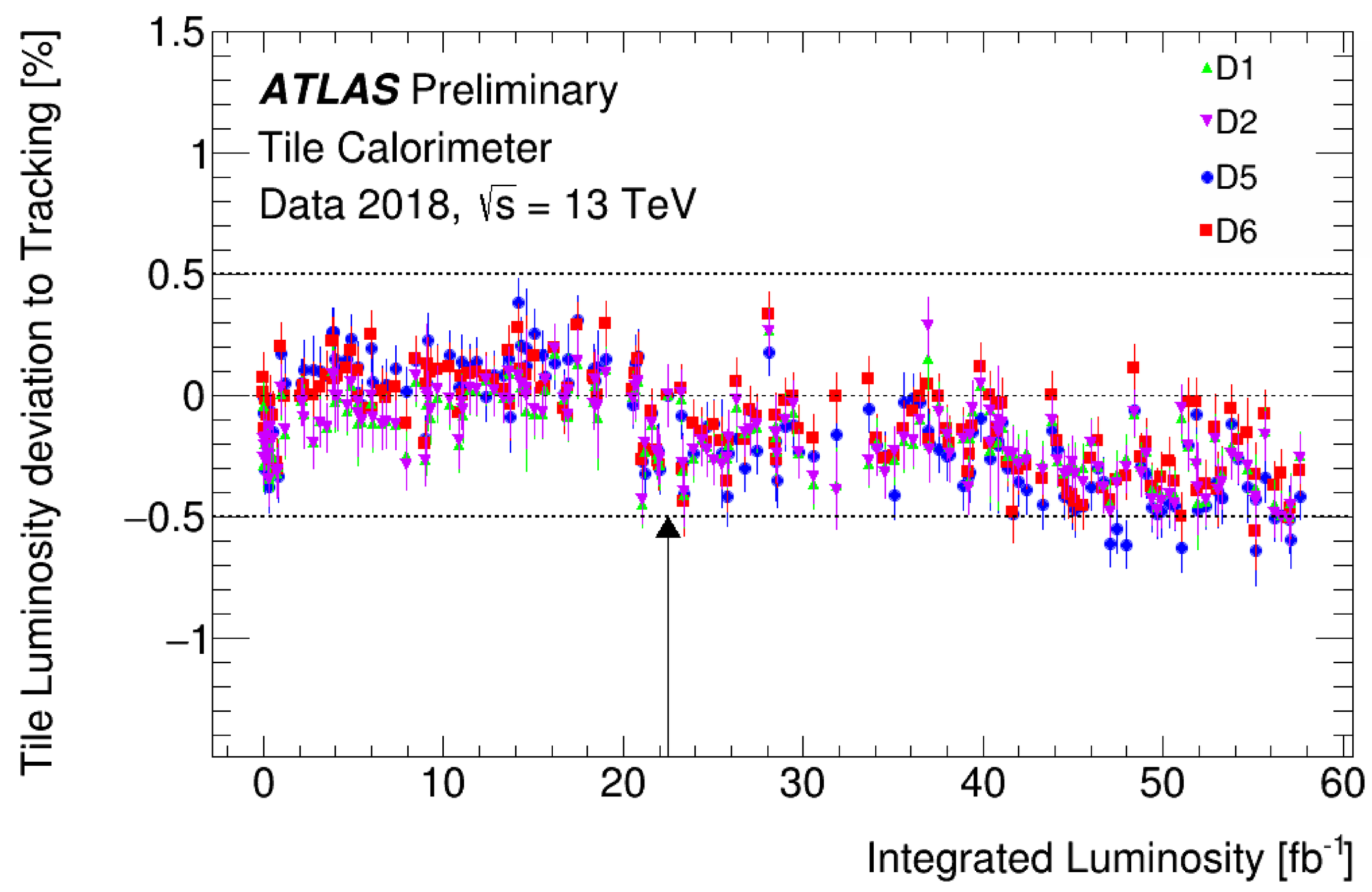
- TileCal measurements can be contaminated by signals from excited material after irradiation at the level of O(1%).
- These activation signals are characterized by their own time constants and some will decay faster than others.
- The fraction of signal from activation can be measured by comparing the pedestals immediately after the run to right before the run.
- The right plot shows the trend of the fraction of signal from activation against the amount of time the detector is under colliding beams.
- Clear activation functions can be fit to the trends. Sometimes only a single time constant is enough (E3, E4) while in some cases a second time constant is needed, suggesting the presence of more significant contributions from materials with a longer half-life.
- A better understanding of activation signal has a positive impact on reducing the uncertainty in the calibration transfer.





Stability

- TileCal has at its disposal a large array of cells that can be used to obtain Luminosity measurements
- If measurements at very low Luminosity are needed, cells that are close to the beam can be used since they are more sensitive.
- However, the more exposed a cell is, the more affected by ageing and radiation; which will decrease the PMT response.
- For Stability measurements, isolated cells such as the D cell family can be used.
- In the right plot, the deviation of the instantaneous Luminosity measured by TileCal D-cell scintillator families to that from the tracking detector is displayed against the integrated luminosity of 2018. The arrow points to the fill where the luminosity measurements by TileCal are normalised to those from the tracking detector.
- No significant deviations beyond half a percent validates excellent stability in two methods of the monitoring of the ATLAS luminosity during 2018.



Conclusions

- TileCal Luminosity measurements play a very important role in ATLAS in the calibration transfer uncertainty.
- The Tile Calorimeter is sensitive to low luminosity conditions (van der Meer runs) and physics data-taking conditions. The deviation between the luminosity measurements provided by TileCal and Tracking detector under a large luminosity range can be used to set an uncertainty on the calibration transfer.
- A better understanding of effects that affect the Luminosity computation, such as activation, helps reduce the calibration transfer uncertainty, which is the dominant uncertainty in some precision analyses.
- The Tile Calorimeter also contributes to the stability studies of the ATLAS run-2 luminosity.

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[1] Luminosity determination in pp collisions at √s=13 TeV using the ATLAS detector at the LHC, ATLAS Collaboration, ATLAS-CONF-2019-021

[2] Calibration and performance of the ATLAS Tile Calorimeter during the LHC Run 2, Pawel Klimek and on behalf of the ATLAS Collaboration 2019, J. Phys.: Conf. Ser. 1162 012003

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