LUMINOSITY MONITORING IN pp COLLISIONS USING $Z \to \ell\ell$ EVENTS AT $\sqrt{s} = 13$ TeV WITH THE ATLAS DETECTOR

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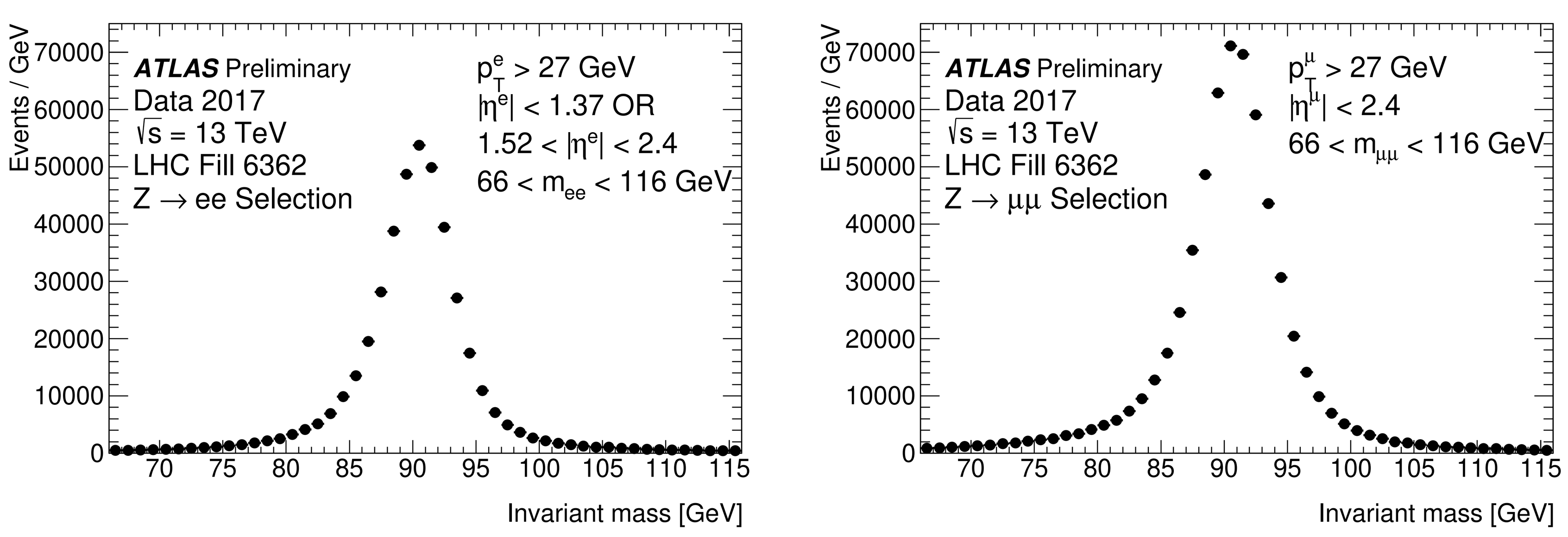
Introduction

The luminosity recorded by ATLAS can be monitored by measuring the production rate of the Z boson by selecting events with two electrons or muons. The Z production rate is corrected using trigger and reconstruction efficiencies determined from data, as well as a Monte Carlo correction for residual detector effects. The main motivations to pursue the Z-counting method are the monitoring of the long term stability of other ATLAS luminosity algorithms, providing a comparison between ATLAS and CMS independent of van der Meer scan calibration and robustness with respect to the mean number of inelastic pp interactions per crossing (pileup, measured from Ref. [1]). This poster illustrates the basic principles of the method and shows the stability of Z-counting in comparison to the ATLAS-preferred luminosity values, primarily coming from the LUCID detector with corrections from other luminosity algorithms [1].

Methodology

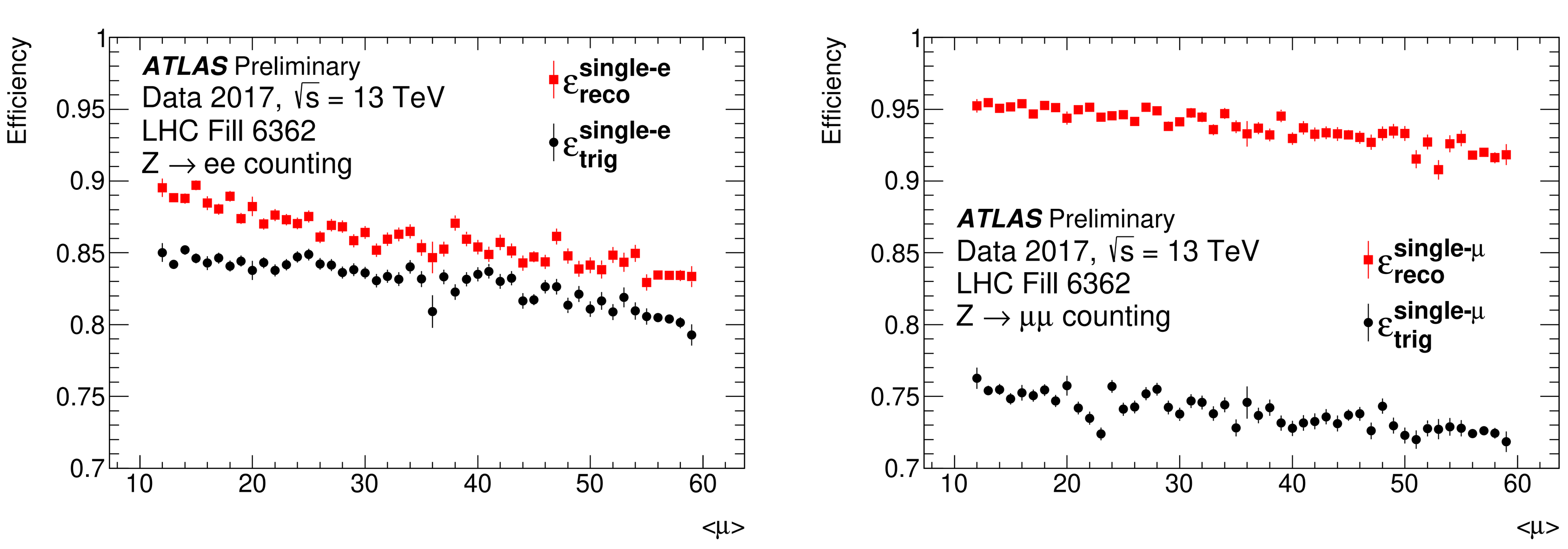
Selected events used in the luminosity determination from the $Z \to \ell^+\ell^-$ counting rate:



$$\mathcal{L}_{Z\to\ell^+\ell^-} = \frac{\overbrace{N_{Z\to\ell^+\ell^-}(t)}^{\text{Z production rate}} \cdot \overbrace{(1-0.005)}^{\text{background correction}}}{\underbrace{F^{MC}(\langle\mu\rangle)}_{\text{MC correction}} \cdot \underbrace{\varepsilon^{T\&P}_{Z\to\ell^+\ell^-}}_{\text{data-derived efficiency}} \times \underbrace{A^{MC}}_{\text{acceptance}} \cdot \underbrace{\sigma_{\text{theory}}}_{\text{theory cross section}}}$$

$A^{MC} = 0.33(Z \to \mu\mu), 0.30(Z \to ee)$,
$\sigma_{\text{theory}} = 1970 \pm 3.5\%$ (PDF) pb NNLO QCD calculation [2] using the CT18ANNLO proton PDF [3]

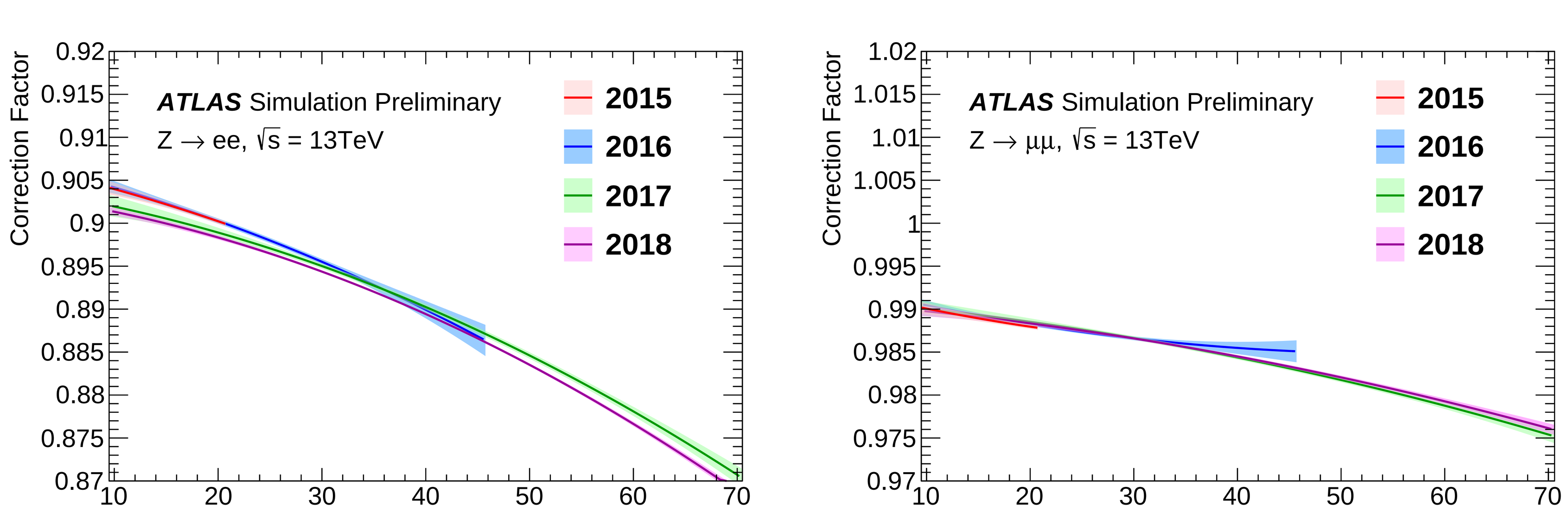
Data-driven single-lepton efficiencies determined using the tag-and-probe (T&P) method:



Single-lepton efficiencies are combined into an event-level efficiency used to correct the $Z \to \ell^+\ell^-$ production rate:

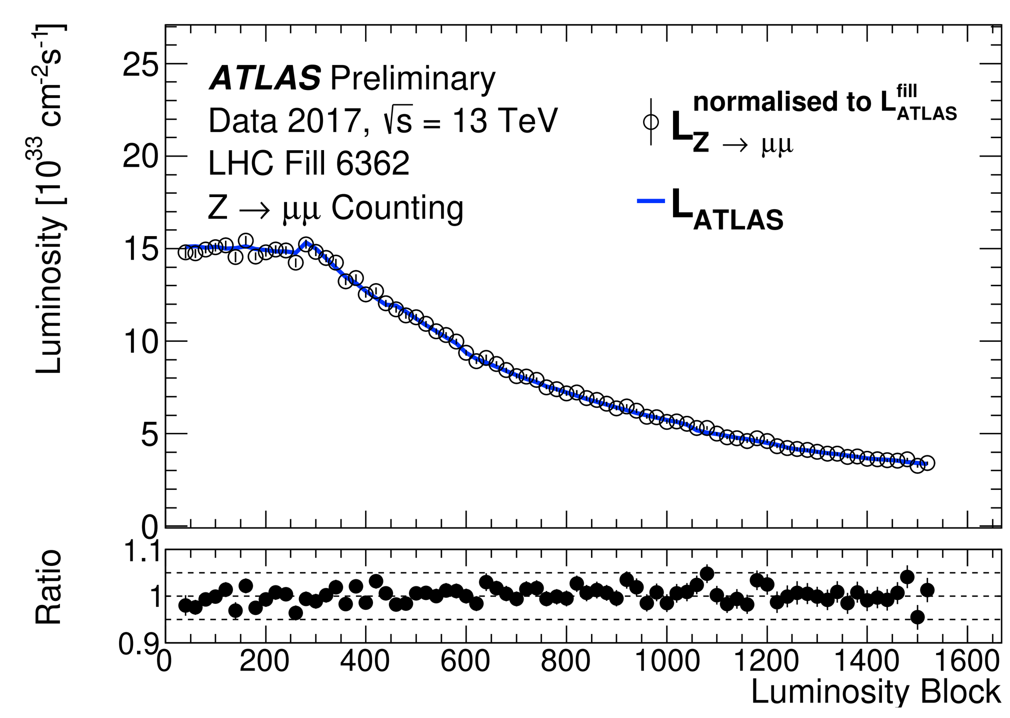
$$\varepsilon^{T\&P}_{Z\to\ell^+\ell^-} = (1 - (1 - \varepsilon_{\text{trig},1\ell})^2) \times \varepsilon^2_{\text{reco},1\ell}$$

Pileup dependent correction factors are determined from simulation in order to correct for effects which are not accounted for in the tag-and-probe efficiency evaluation:



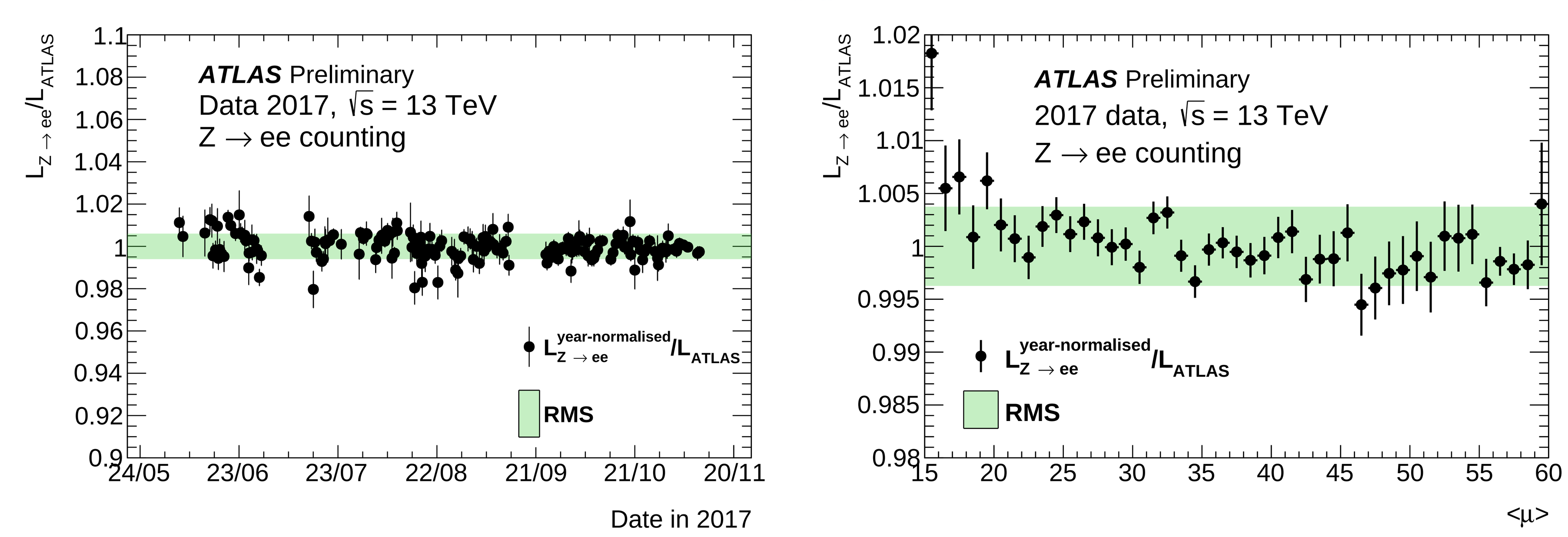
Results

Instantaneous luminosity measurement of a single LHC fill:



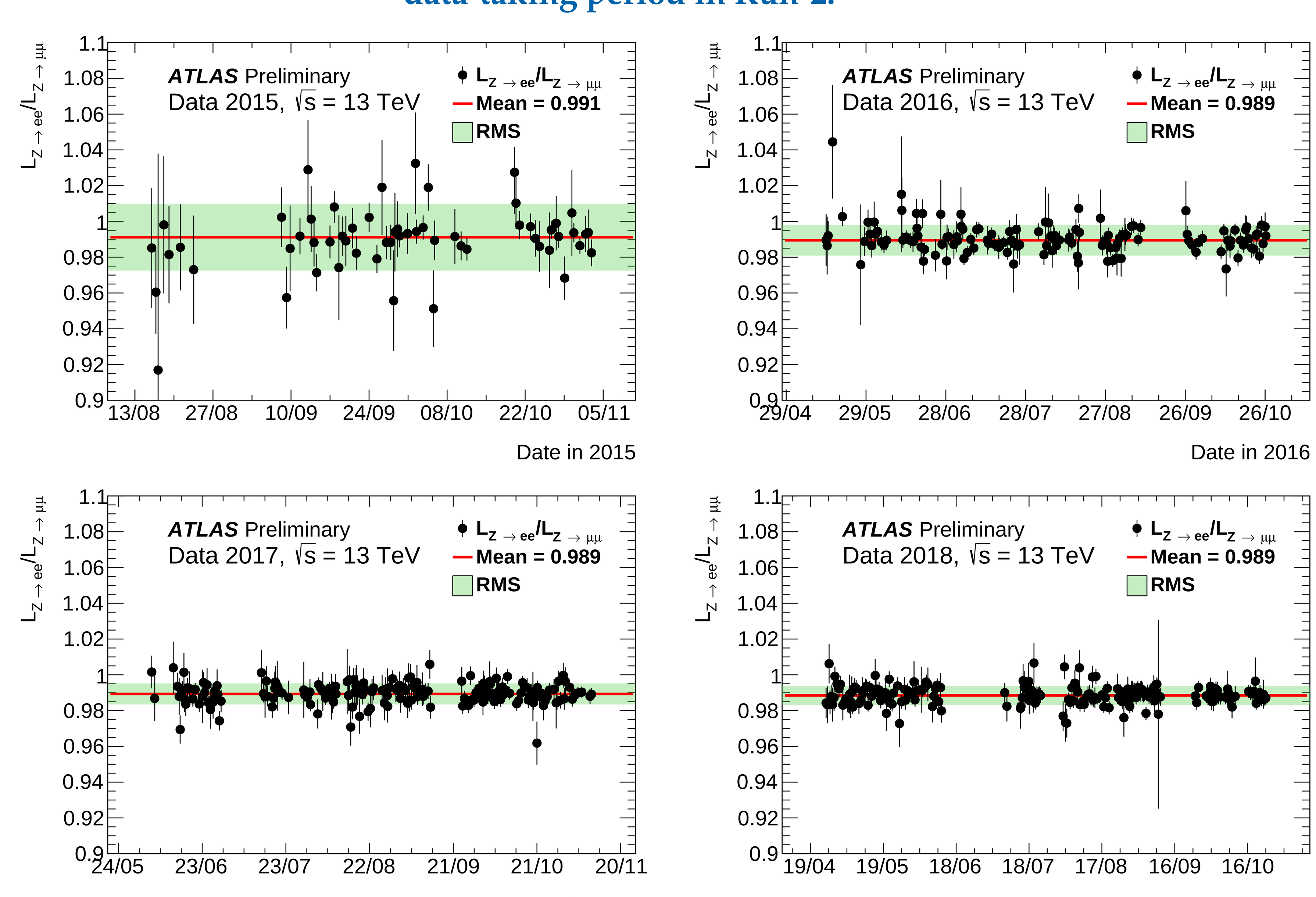
The normalised $\mathcal{L}_{Z\to\ell\ell}/\mathcal{L}_{ATLAS}$ comparison shows good stability over time periods as small as 20 minutes.

Time and pileup dependence of the Z-counting luminosity w.r.t. ATLAS over the 2017 data-taking period:



The Z-counting luminosity is stable w.r.t the ATLAS-preferred luminosity at the level of approximately 0.5% as a function of time and pileup.

Comparison of the $Z \to ee$ and $Z \to \mu\mu$ luminosity measurements across each data-taking period in Run-2:



The mean values are obtained from fits to a constant with $\chi^2/d.o.f.$ values of around 1 for each fit. The average $\mathcal{L}_{Z\to ee}/\mathcal{L}_{Z\to\mu\mu}$ ratios have been determined with negligible statistical errors and the ratio is approximately 0.99 in all data-taking periods.

Conclusion

The normalised comparison of the Z-counting and ATLAS-preferred luminosities is found to be stable within around 0.5% as a function of pileup and time. While these comparisons are only presented for the 2017 dataset, similar levels of agreement are found in the other data-taking periods of Run-2. Comparison between the electron and muon channel luminosity measurements, two distinct methods with rather different efficiencies and background contributions, shows very good agreement at the 1% level.

[1] Luminosity determination in pp collisions at $\sqrt{s} = 13$ TeV using the ATLAS detector at the LHC, ATLAS-CONF-2019-021, CERN, 2019, url: `http://cds.cern.ch/record/2677054`.
[2] Y. Li and F. Petriello, Combining QCD and electroweak corrections to dilepton production in the framework of the FEWZ simulation code, Physical Review D 86 (2012), issn: 1550-2368, url: `http://dx.doi.org/10.1103/PhysRevD.86.094034`.
[3] T. J. Hou et al., New CTEQ global analysis of quantum chromodynamics with high-precision data from the LHC, 2019, arXiv: 1912.10053.