BMBF-Forschungsschwerpunkt ATLAS-EXPERIMENT
Physik bei höchsten Energien mit dem ATLAS-Experiment am LHC
FSP 103 ATLAS

PIER

Measuring luminosity with track counting in the ATLAS experiment

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Abstract

The precise measurement of the luminosity is one of the key requirements for every ATLAS analysis at the Large Hadron Collider (LHC) at CERN. Particularly in high precision measurements, the uncertainty on the luminosity can be one of the main limitations. Therefore, its reduction is the prime goal of the ATLAS luminosity program, requiring a precise understanding of the contributing factors. The two largest individual components are the calibration transfer (extrapolating the measurement from the calibrated regime to the physics regime) and the long term stability (stability of the measurement over the whole year), both being determined involving the track counting luminosity measurement.

Track Counting Luminosity Measurement

μ_{vis} of Track-Counting Measurement: $\mu_{vis} = \frac{N_{tracks}}{N_{events}} \sim \mu$

Bunch Luminosity: $\mathcal{L}_b = \frac{\mu f_r}{\sigma_{inel}}$

Total Instantaneous Luminosity: $\mathcal{L} = \sum_{b=1}^{n_b} \mathcal{L}_b = n_b \langle \mathcal{L}_b \rangle = n_b \frac{\langle \mu \rangle f_r}{\sigma_{inel}}$

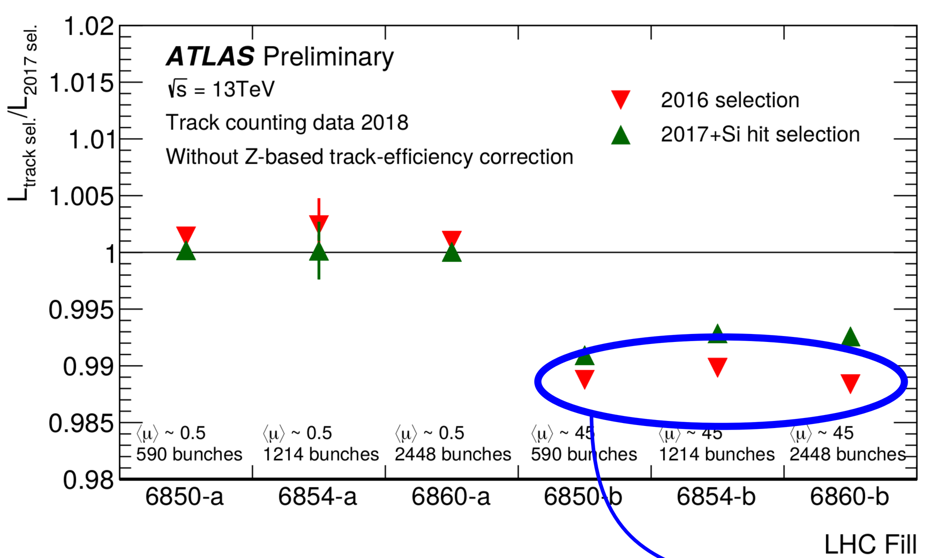
- N_{tracks}: Number of charged particle tracks
- N_{events}: Number of bunch crossings
- μ: Average number of inelastic pp collisions per bunch crossing
- f_r: LHC revolution frequency
- $\langle \mu \rangle$: Bunch averaged pile-up parameter
- σ_{inel}: pp inelastic cross-section
- n_b: Number of colliding bunch pairs

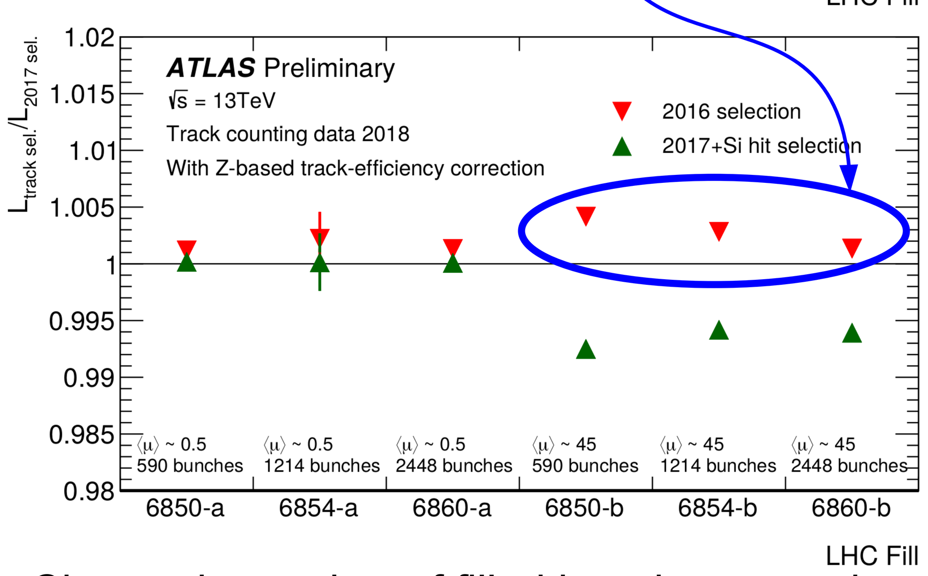
- Track-counting luminosity measurement
  → Use the average number of charged tracks of randomly triggered events in a dedicated event stream to measure the luminosity
- Selections based on track properties
  → Study the stability of track-counting
- μ_{vis} of the different track-counting selections calibrated in special LHC fill:
  → $\langle \mu \rangle \sim 0.5$, isolated bunches, no crossing-angle
  → Extrapolate to physics regime

p_T>900 MeV Tight Primary	2016 selection	2017 selection	2017+Si hit selection
Allowed pixel holes	=0	≤1	≤1 +1 add. silicon hit
Impact parameter	$\lvert d_0/\sigma_{d_0}\rvert<7$	$\lvert d_0/\sigma_{d_0}\rvert<7$	$\lvert d_0/\sigma_{d_0}\rvert<7$
$\lvert\eta\rvert$	$\lvert\eta\rvert<2.5$	$\lvert\eta\rvert<1.0$	$\lvert\eta\rvert<1.0$

Uncertainties in the Track-Counting luminosity measurement

1. Average number of collisions

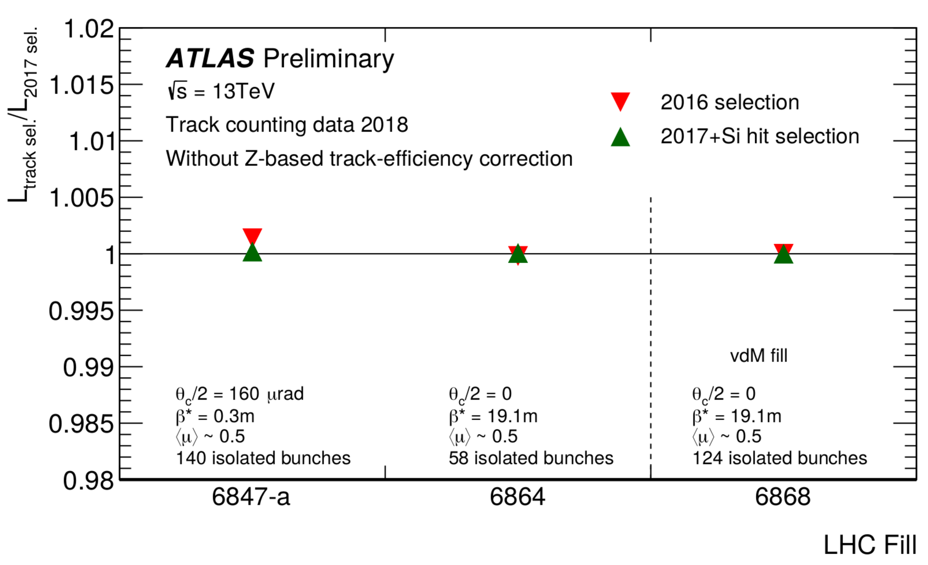




→ Change in number of filled bunches n_b and the average number of pp-collision $\langle \mu \rangle$

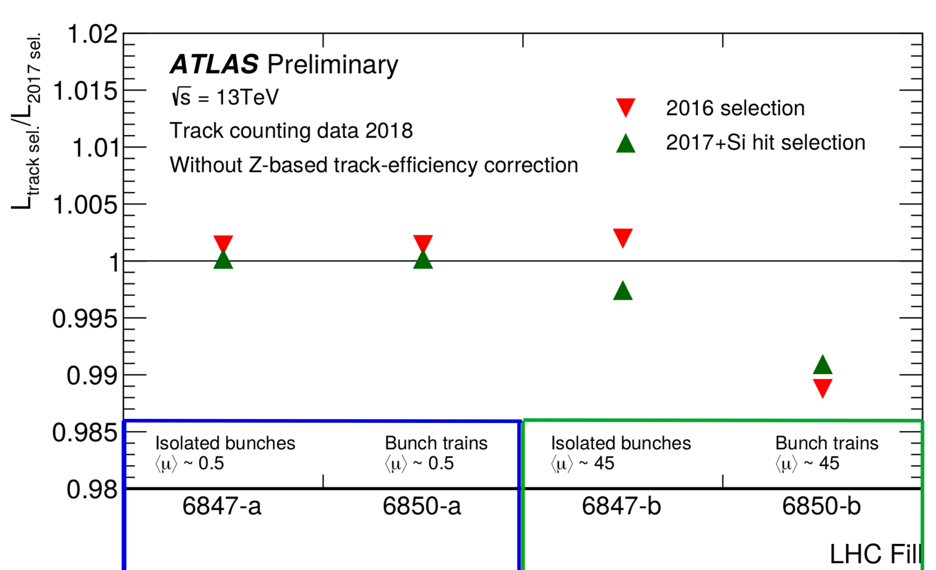
→ Applying $Z\to\mu\mu$ based efficiency corrections

2. Beam Optics



→ Change in crossing-angle θ_c and β-function at the interaction point

3. Bunch Structure



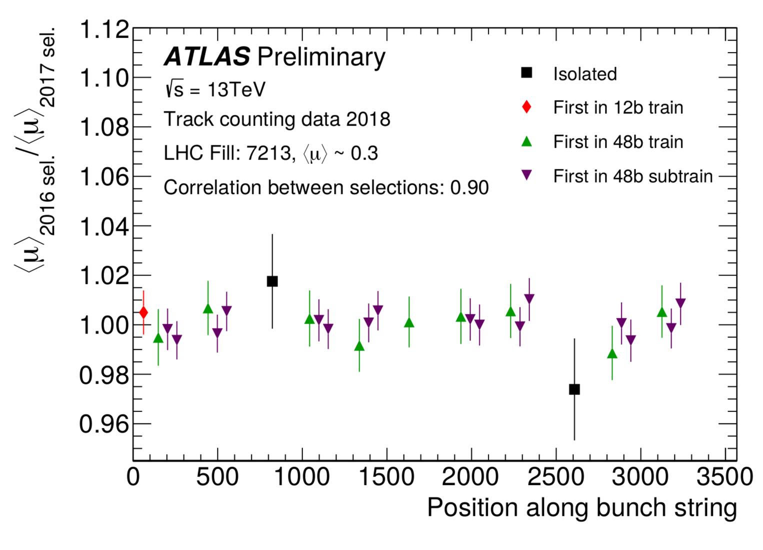
Results

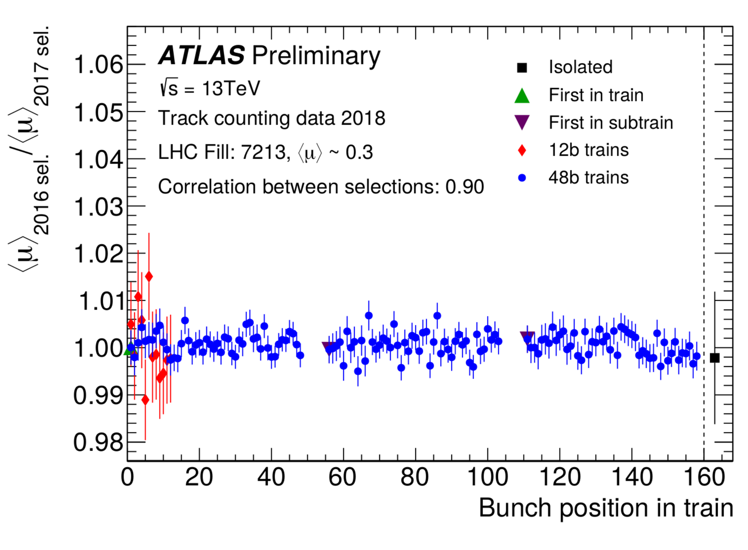
1a) No effect of total number of colliding bunches on track counting luminosity

1b) ~ 1% shift in track counting luminosity calibration between low and high $\langle \mu \rangle$
→ Partially corrected by applying efficiency corrections based on $Z\to\mu\mu$ events on all selections individually (overcorrected by ~ 0.4%)

2) No effect of crossing-angle or β^*value on track counting luminosity

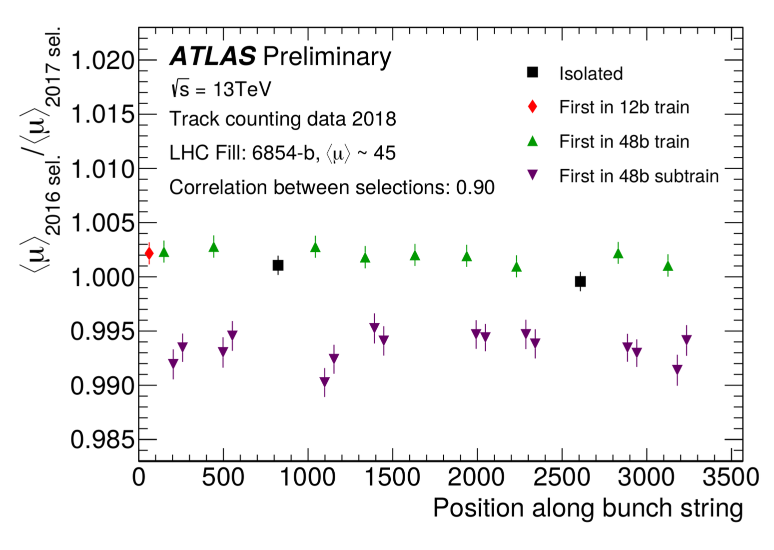
3) ~ 1% shift in track counting luminosity calibration between isolated bunches and bunch trains at high $\langle \mu \rangle$
→ A more precise description of this shift is further investigated in the bunch structure studies

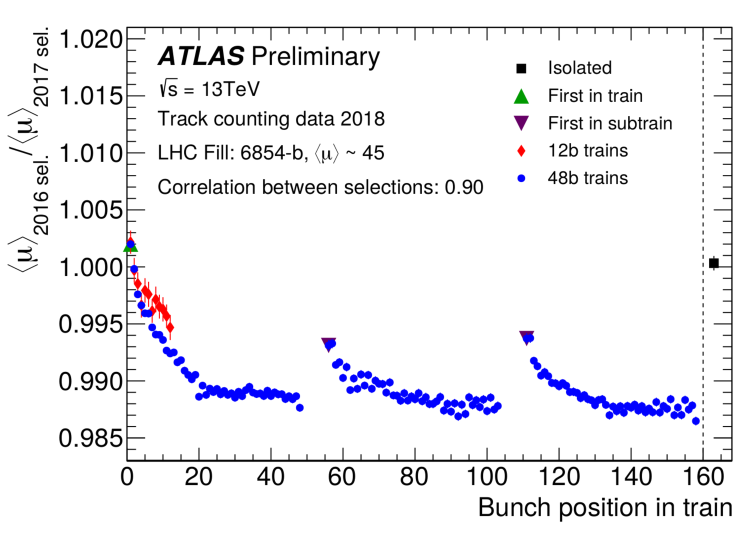




Observations – low $\langle \mu \rangle$

- No different behaviour between isolated bunches and bunches that are first in a train/subtrain
- No dependence inside a train → uniform behaviour





Observations – high $\langle \mu \rangle$

- Similar behaviour between isolated bunches and bunches that are first in a train
- Different behaviour for bunches that are first in subtrain
- Linear decrease in ratio for nearly 20 bunch positions inside train until plateau is reached

Conclusions

It was observed that the track counting luminosity measurement is stable for different LHC configurations within 1.4%. Two significant effects on the track counting luminosity were observed. A shift of around 1% was observed between low and high $\langle \mu \rangle$ and between isolated bunches and bunch trains at high $\langle \mu \rangle$. By applying corrections based on $Z\to\mu\mu$ events, the shift between low and high $\langle \mu \rangle$ in the ratio between the 2016 and 2017 selections could partially be corrected.