Relative luminosity determination using ATLAS Forward Proton detector

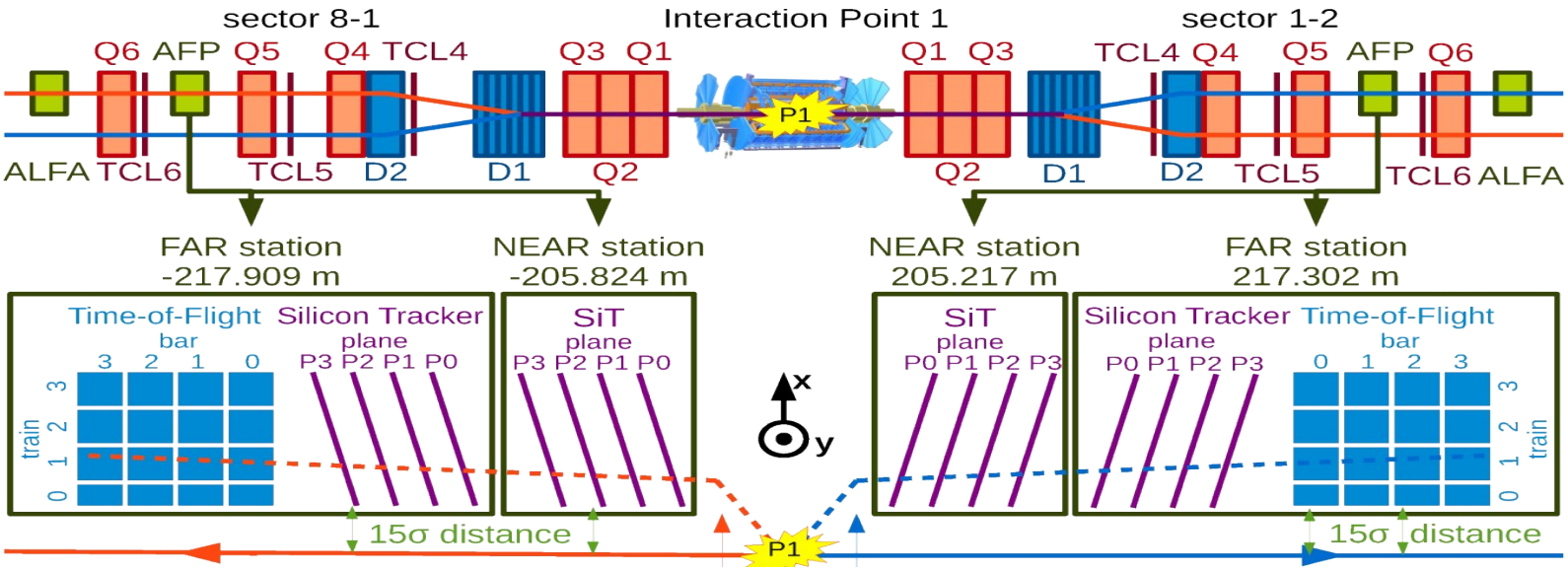
B.Esposito

(On behalf of ATLAS Forward Proton detector Collaboration)

INFN-Laboratori Nazionali di Frascati

LHC Forward Physics meeting 4 March 2021, CERN

ATLAS Forward Proton detector



AFP consists of 4 Si pixel stations, 2 on each side of the interaction point at approximately 205 and 217 m.

In each station X-Y points from the hit pixels in 4 successive planes are associated to form tracks and the tracks in the Near and Far stations are then associated to form a full track.

Motivation

AFP has been realized for the study of the forward physics and was not intended and has never been used before for the luminosity measurement.

However the consideration of the tracking capability, the fine granularity, the low occupancy of the AFP detector suggests the idea that AFP can provide a clean track signal up to the highest luminosity of the next LHC phase and could be used for the accurate measurement of the LHC luminosity.

This idea has motivated the present study, with the purpose of verifying with data the suitability of using AFP for the luminosity measurement and assessing the performance achievable.

2018 AFP Data

The 2018 data provide large samples of random (trigger unbiased) AFP data.

This allows to perform detailed studies of the luminosity measurement.

The approach taken in the study has been to perform in a first phase a simple straightforward analysis to establish the main features of the luminosity measurement.

The results obtained will be presented here.

In a successive phase more elaborated analyses are possible to achieve a deeper understanding of the data and possibly push the performance achievable.

Analysis principle

The purpose of the analysis is to determine the average number of interactions per bunch crossing , **<μ>**, from the measurement of the average track multiplicity in AFP, **<n>**.

The tracks produced in **μ** pp interactions in the same bunch crossing follow the relation **<n> = k <μ>** , with k = constant, to be determined by a calibration with a sample of known **<μ>** .

However the presence of background tracks may modify this simple proportionality relation and detector effects may cause non linearity.

In general, the relation can be expressed by a function

<n> = f(<μ>)

A calibration is needed in order to determine the function **f .**

Analysis method

AFP track multiplicity

- independent analysis of the 4 stations
- no track selection
- track counting and 0-track event counting

AFP calibration

- fit functional relation $\langle n \rangle = f(\langle \mu \rangle) = a \langle \mu \rangle + b \sqrt{\langle \mu \rangle}$
- $\langle n \rangle$ from one run used for calibration
- $\langle \mu \rangle$ from the ATLAS luminometer LUCID

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2019-021/

Measurement of $\langle \mu \rangle$

- $\langle \mu \rangle = f^{-1}(\langle n \rangle)$

Results

We have analyzed 31 runs, collected from beginning of May to end of October 2018.

One run has been used for the calibration.

All the runs have been analyzed applying the calibration parameters determined from the calibration run.

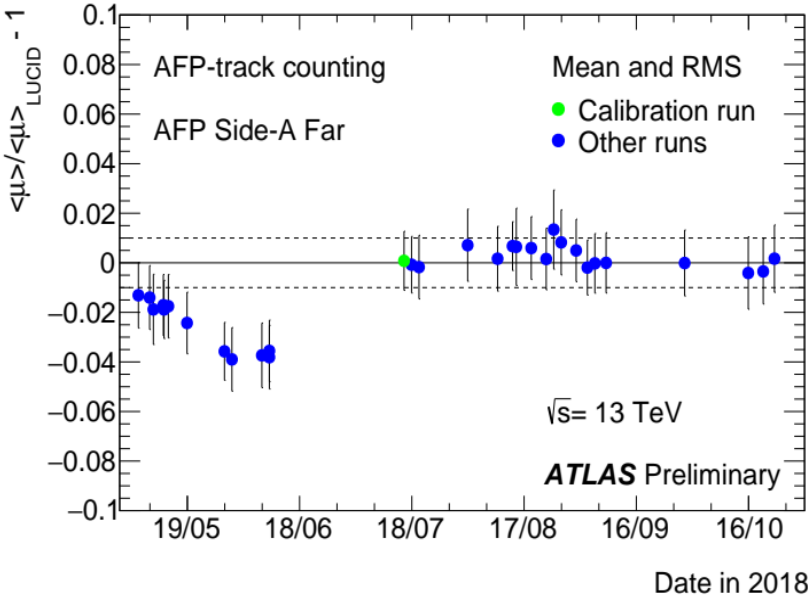
The results for **<μ>** obtained with AFP are compared with the measurements by the ATLAS luminometer LUCID.

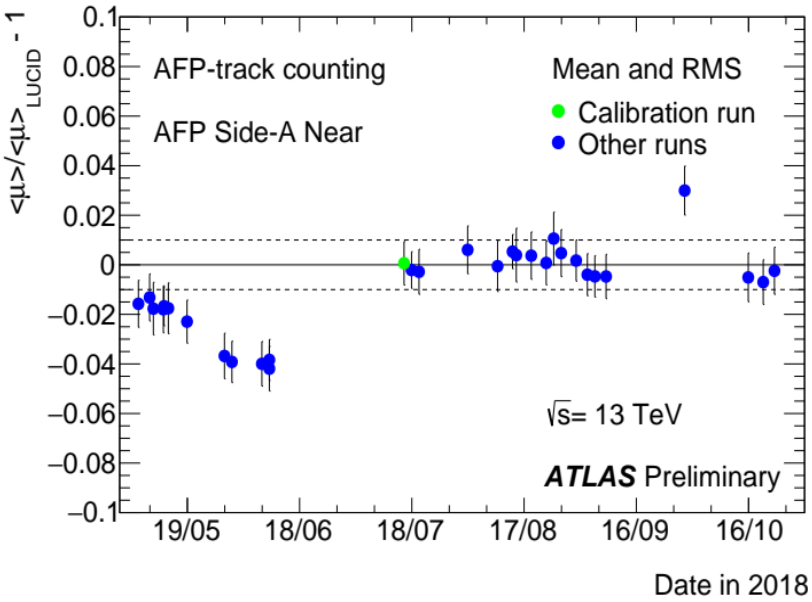
The average number of interactions per bunch crossing, $\langle\mu\rangle$, is determined for each luminosity block.

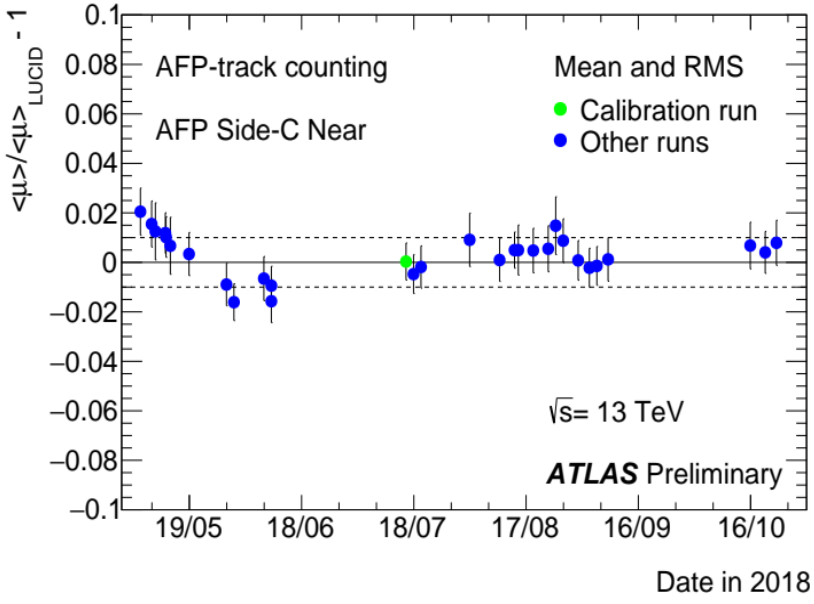
The comparison with LUCID is done in terms the relative difference $(\langle\mu\rangle - \langle\mu\rangle_{Lucid})/\langle\mu\rangle_{Lucid}$.

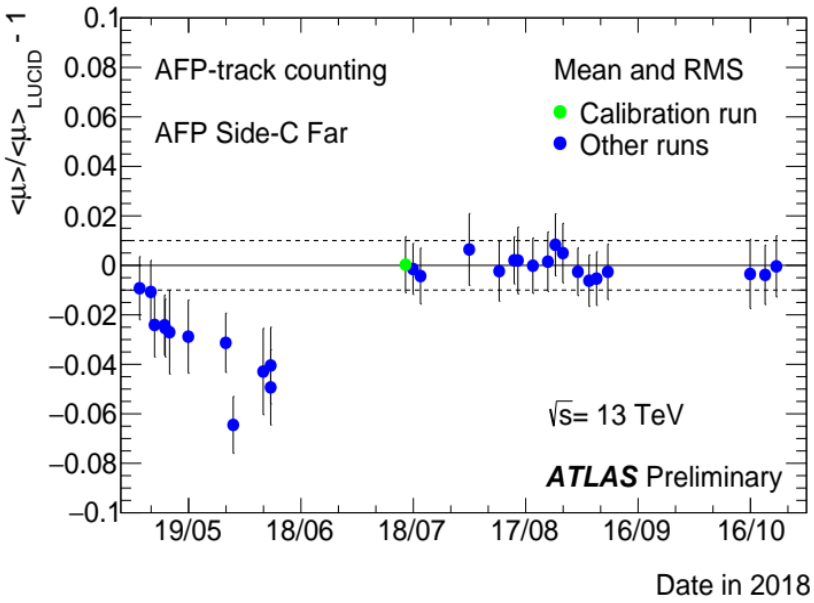
The Mean and RMS of the distribution of the values obtained for the luminosity blocks of a run are reported as a function of the run date (the RMS is shown as error bar).

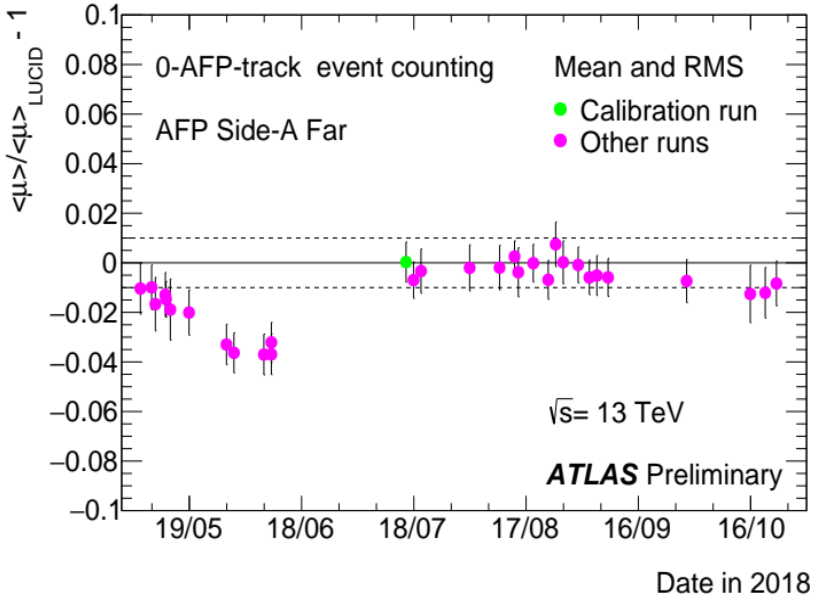
The plots are for the stations A-Far, A-Near, C-Near, C-Far and for the track counting method and the 0-track event counting method.

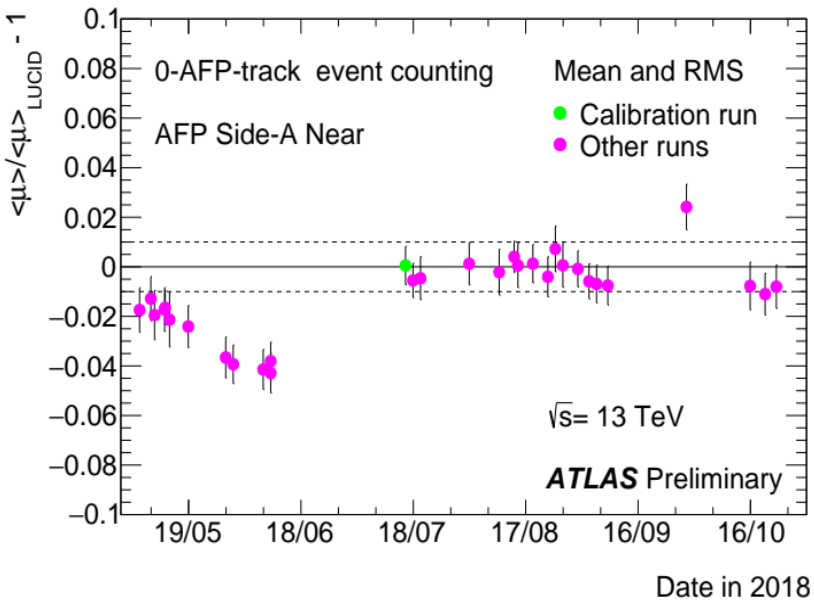

AFP-track counting
AFP Side-A Far
Mean and RMS
Calibration run
Other runs
√s= 13 TeV
ATLAS Preliminary
<μ>/<μ>LUCID - 1
Date in 2018

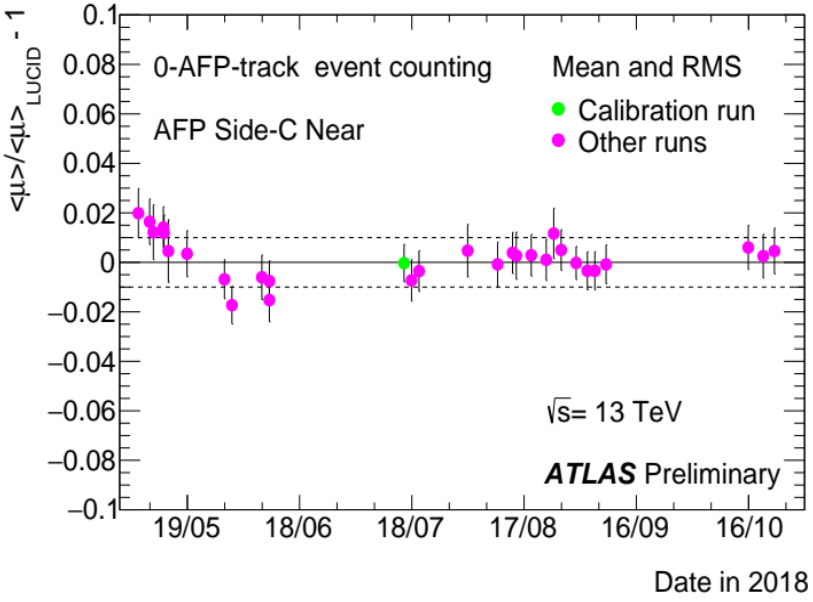

AFP-track counting
AFP Side-A Near
Mean and RMS
Calibration run
Other runs
√s= 13 TeV
ATLAS Preliminary
<μ>/<μ>LUCID - 1
Date in 2018

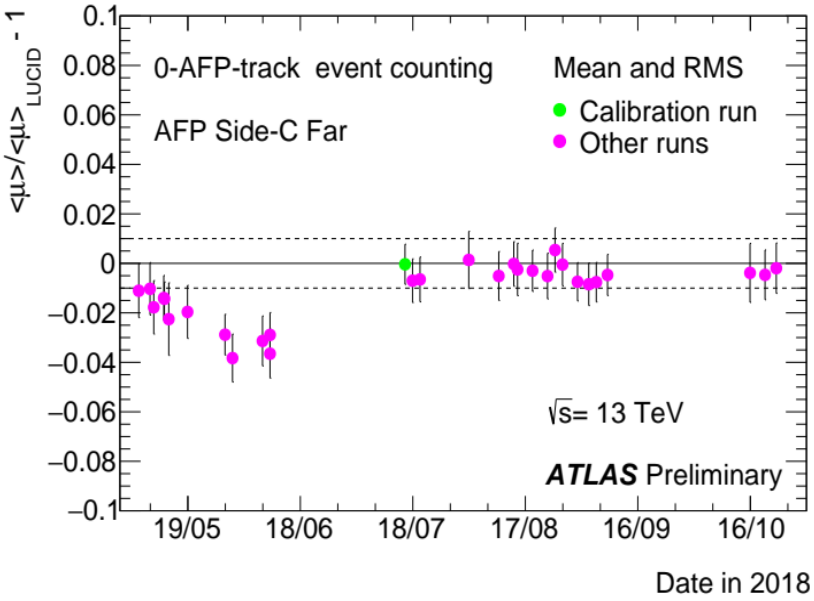

AFP-track counting
AFP Side-C Near
Mean and RMS
Calibration run
Other runs
√s= 13 TeV
ATLAS Preliminary
<μ>/<μ>LUCID - 1
Date in 2018


AFP-track counting
AFP Side-C Far
Mean and RMS
Calibration run
Other runs
√s= 13 TeV
ATLAS Preliminary
<μ>/<μ>LUCID - 1
Date in 2018


0-AFP-track event counting
AFP Side-A Far
Mean and RMS
Calibration run
Other runs
√s= 13 TeV
ATLAS Preliminary
<μ>/<μ>LUCID - 1
Date in 2018


0-AFP-track event counting
AFP Side-A Near
Mean and RMS
Calibration run
Other runs
√s= 13 TeV
ATLAS Preliminary
<μ>/<μ>LUCID - 1
Date in 2018


0-AFP-track event counting
AFP Side-C Near
Mean and RMS
Calibration run
Other runs
√s= 13 TeV
ATLAS Preliminary
<μ>/<μ>LUCID - 1
Date in 2018


0-AFP-track event counting
AFP Side-C Far
Mean and RMS
Calibration run
Other runs
√s= 13 TeV
ATLAS Preliminary
<μ>/<μ>LUCID - 1
Date in 2018

Evaluation of the results

The plots show two groups of runs, separated by an interval in which there was an LHC technical stop. The calibration run is in the second group.

For the runs of the second group the agreement with LUCID is at better than 1% level.

This result indicates that the luminosity measurement with AFP has a very good potential performance.

However, for the runs of the first group the differences from LUCID are up to 4 % - 6% .

This requires further work to understand which are the causes for such a different behavior.

The measurement of $\langle\mu\rangle$ depends on the detector and beam conditions.

When the detector or the beams are not stable with respect to the conditions of the calibration run, systematic differences may arise in the measurement of $\langle\mu\rangle$.

The explanation of the results observed for the first group of runs must be searched there.

As a matter of fact, at a first look it has been found that there are differences in the detector positions with respect to the beam between the runs before and after the technical stop. Further checks and comparisons are to be made.

These first results suggest that AFP can provide a precise luminosity measurement.

At the same time they show the importance of:

- Checking the detector conditions and consequently correcting the measurement for efficiency or acceptance variations.
- Rejecting background to significantly reduce the sensitivity to variations in the beam conditions inducing variations of the background rates.

Next developments

The results presented are obtained with a very simple basic analysis.

There is room for extensions and improvements:

- Selection of signal tracks and rejection of background tracks based on the full track information (X,Y, X',Y').
- Associated analysis of near and far stations for a full track reconstruction
- Study of the properties of the multiplicity track distribution with the aid of a toy Monte Carlo to reproduce the expected and observed distributions
- Study of the correlation between AFP stations
- Search for optimal algorithms to estimate the parameters characterizing the track multiplicity distributions.

Conclusions and perspectives

The measurement of the LHC luminosity with ATLAS Forward Proton detector is being studied, using unbiased AFP data collected in 2018 .

The first results obtained are in good agreement with the ATLAS luminometer LUCID.

These results have been obtained with a very simple basic analysis.

There is room for extensions and improvements, to be developed and exploited in the near future.