PROCEEDINGS OF SCIENCE

The ATLAS Forward Proton Time-of-Flight Detector System

Karel Černý, on behalf of ATLAS Forward Detectors[a,*]

[a] *Joint Laboratory of Optics, Palacky University, 17. listopadu 50A, Olomouc, Czech Republic*

E-mail: karel.cerny@upol.cz, karel.cerny@cern.ch

Performance studies of the Time-of-Flight (ToF) subdetector of the ATLAS Forward Proton (AFP) detector at the LHC are presented. Efficiencies and resolutions are measured using data samples collected at low and moderate pile-up in 2017. While low efficiencies are observed, of the order of a few percent, the resolutions of the two ToF detectors measured individually are 21 ps and 28 ps, yielding an expected resolution of the longitudinal position of the interaction, z_{vtx} in the interaction region. This is in agreement with the observed width of the distribution of the difference between z_{vtx} measured independently by the central ATLAS tracker and by the ToF detector, of 6.0 ± 2.0 mm.

ATL-FWD-PROC-2024-008
08/10/2024

42nd International Conference on High Energy Physics (ICHEP2024)
18-24 July 2024
Prague, Czech Republic

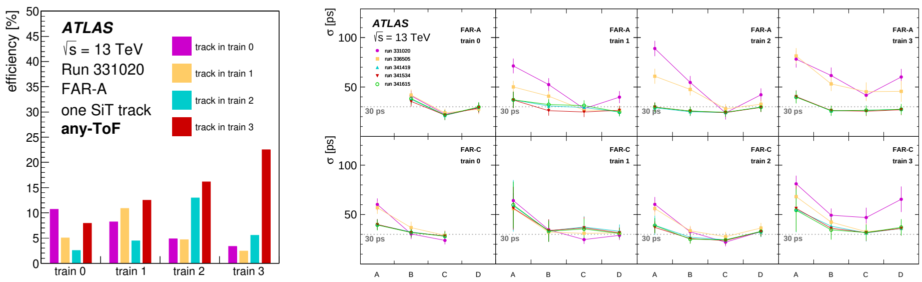
*Speaker

1. Introduction

The processes $pp \to pXp$ are commonly referred to as centrally diffractive (CD) or photon induced processes, where two final state protons are emitted to opposite sides at large rapidity. To measure these protons, final state four AFP detectors are installed in pairs at ~ 210 m on both sides of the ATLAS interaction point [1]. Each AFP station is equipped with the Silicon tracker (SiT, [2]) to measure the positions of the scattered proton. In case of pile-up, multiple protons are produced and the direct relation with the primary interaction is obscured by combinatorics. The longitudinal position of primary interaction can be measured by comparing the arrival times of the two opposite side protons as $z_{\text{vtx}} = \frac{c}{2}(t_C - t_A)$, where $t_{A,C}$ correspond to the times measured on opposite sides. The two outer AFP stations FAR-C and FAR-A are thus equipped with ToF detectors. The ToF is a Cherenkov detector using 4×4 matrix of L-shaped Quartz (LQ) bars [3] as an active material, where four consecutive bars form a so called train. LQ bars are attached to the micro-channel-plate photomultiplier [4] whose voltage signal is processed and digitised in the high-performance time-to-digital converter. The ToF detector is thus able to suppress the combinatorial background, see [5] for more details.

2. Single channel efficiency and time resolution

The train efficiencies at the level of units of percent are measured using event samples with exactly one track reconstructed in the SiT. The fraction of events where ToF trains register signals represents the train efficiency, see Fig. 1(a). The channel time resolutions, σ_i, are deduced from analysis of event-by-event channel time differences in a given ToF train, $\Delta t_{ij} = t_i - t_j$. The widths $\sigma_{ij} = \sqrt{\text{var}(\Delta t_{ij})}$ are parametrized as $\sigma_{ij} = \sqrt{\sigma_i^2 + \sigma_j^2 - 2\rho_{ij}\sigma_i\sigma_j}$, where the correlations between the channel times, ρ_{ij}, whose variations in the range 0 to 0.3, are treated as systematic uncertainty. Minimisation of the difference of the measured σ_{ij} values from the predicted ones, depending on σ_i and σ_j for all channel combinations provides the channel resolutions summarised in Fig. 1(b).

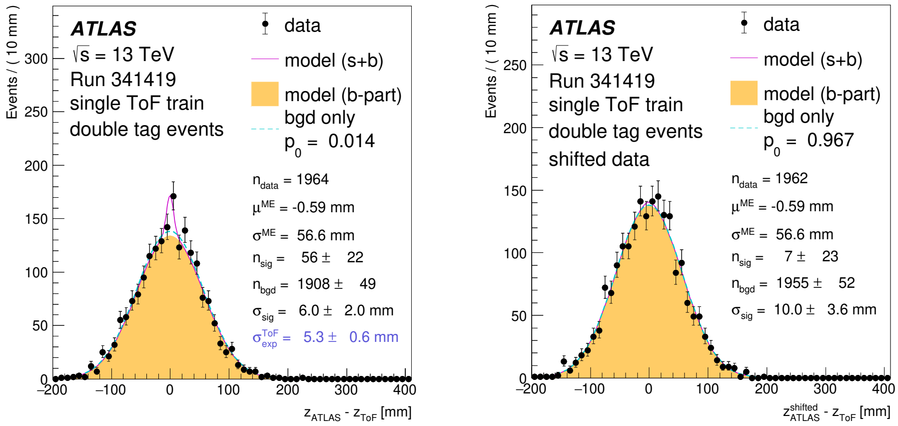


(a) **(b)**

Figure 1: The measured train efficiencies in (a) and single-channel resolutions in (b).

3. Vertex matching

The ToF resolution is also evaluated by analysing the distribution of $z_{\text{ATLAS}} - z_{\text{ToF}}$, where z_{ATLAS} is the primary vertex z−position measured by the ATLAS detector. The background shape is constrained by using event mixing method. The presence of the signal component, in Fig. 2(a), although small is supported by its lack in the signal-free data combination in Fig. 2(b).



(a) **(b)**

Figure 2: The $z_{\mathrm{ATLAS}} - z_{\mathrm{ToF}}$ distributions and fits; nominal with signal component (a) and signal-free (b).

4. Conclusions

The performance of the ToF detector was studied using the ATLAS data collected in 2017. The ToF train efficiencies reaching 20% are observed to degrade to sub-percent levels at the end of 2017. This decrease is explained by exceeded lifetimes of the photomultipliers. The measured single-channel resolutions vary between 23 to 40 ps and average out to 21 ± 3 ps for side A and 28 ± 4 ps for side C and result in the combined z_{vtx} resolution of 5.3 ± 0.6 mm. This value is in agreement with the signal width of 6.0 ± 2.0 mm obtained from the detailed analysis of $z_{\mathrm{ATLAS}} - z_{\mathrm{ToF}}$ distribution. The full version of the presented results can be found in [6].

5. Acknowledgements

The work has been supported by the EU and MEYS (FORTE-CZ.02.01.01/0022_0080004632 and LM2023040) and by the project IGA_PrF_2024_004 of the Palacky University Olomouc.

References

[1] Adamczyk, L. *et al.*, Tech. Rep. ATL-COM-LUM-2011-006, CERN, Geneva (2011).

[2] Lange, J. *et al.*, JINST, 2016, vol. 11, no. 11, pp. 11024.

[3] Nozka, L. *et al.* , Opt. Express, 2014, vol. 22, no. 23, 3815 pp. 28984-28996.

[4] PHOTONIS USA Pensylvania Inc., miniPLANACON XPM85112 datasheet.

[5] Černý, K *et al.*, JINST 16 (2021) 01, P01030.

[6] The ATLAS Collaboration, JINST vol. 19 (2024) P05054.