Prospects and Results from the AFP Detector in ATLAS

Grzegorz Gach
on behalf of the ATLAS Collaboration

AGH University of Science and Technology

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Multiple Partonic Interactions at the LHC 2016
ATLAS Forward Detectors

ATLAS Forward Proton

- detectors dedicated for diffractive processes measurements
- four stations — two on each side
- detectors mounted in horizontal roman pots
- 3D pixels and time-of-flight detectors
- acceptance in $\xi = (E - E')/E \approx (0.02, 0.12)$
Possible Measurements

1. proton kinematics
2. rapidity gaps
3. gap survival probability
4. energy flow
5. event shapes
6. jets
7. jet–gap–jet
8. jet–photon
9. Pomeron structure
10. heavy quarks
11. Drell-Yan, $W$
12. exclusive jets
13. exclusive lepton production
14. photon–photon scattering
15. $WW$ production
16. $ZZ$ production
17. resonant production
AFP Installation

AFP 0+2 — 2016

AFP 2+2 — 2017
AFP 0+2 Installation

✓ installation of two stations on one side in the tunnel
✓ installation of tracking detectors in the stations
✓ LHC qualification
✓ integration with ATLAS DCS
✓ integration with ATLAS DAQ
✓ integration with ATLAS triggers
✓ data acquisition in special runs
- 3(4) layers of pixel detectors in each station
- $336 \times 80$ pixels of $50 \times 250 \mu m^2$
- pixel modules are similar to the ones used in ATLAS IBL with proven radiation hardness
- detectors are tilted by $14^\circ$ with respect to vertical direction
- data collected in special low-$\mu$ runs with $\mathcal{L} \approx 500 \text{ nb}^{-1}$
in almost 50% events 2 hits are observed in each plane
very good correlation of hits between two planes (first and second)
- hits in AFP near (205 m) station at $5\sigma + 400 \mu\text{m}$ from the beam centre
- visible pattern of diffractive protons
relatively high cross section
special runs with pile-up free environment provide clean events
single proton detectable in AFP
AFP provides access to so far non-measurable quantities like $\xi = (E - E')/E$ or $t = (P - P')^2$
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- $\sigma_{SD} + DD$ measured together with inelastic cross-section at 7 TeV and 13 TeV using MBTS signal on one side

- combination of ALFA and ATLAS $\sigma_{inelastic}$ at 7 TeV gives $\sigma_{SD}$ for $\xi < 5.1 \times 10^{-6}$
ATLAS dedicated measurement done only at $\sqrt{s} = 7$ TeV
- possible large contribution of double diffraction background
- no measurement of differential cross sections $d\sigma/d\xi$ or $d\sigma/dt$
- improvement and extension of current measurements by tagging protons in 13 TeV
probing Pomeron universality between $ep$ and $pp$ colliders
measurement of gap survival probability
Monte Carlo tuning
AFP 0+2 Summary

- despite challenging schedule the installation was successful
- very good detector performance
- collected more data than initially planned
- good data for soft diffraction analysis
- very good data for detector performance and background studies
AFP 2+2 Installation

- installation of two missing stations on the other side in the tunnel
- installation of tracking detectors
- installation of timing detectors on both sides
- LHC qualification
- integration of timing detectors triggers with ATLAS
- data acquisition in special runs
- data acquisition in standard runs
AFP 2+2 Time-of-Flight Detectors

- time resolution 10 ps or better
- efficiency not smaller than 90%
- fast enough to provide trigger signal
- pile-up background reduction
- useful but not critical in special low-μ run
- necessary in standard runs with high pile-up
only in special low-$\mu$ runs

- clean pile-up free environment
- doubled number of events with respect to AFP 0+2
- special as well as standard runs give access to processes with medium and relatively small cross-sections
- double proton tag with time measurements allows direct observation of central diffraction with suppressed backgrounds (including pile-up)
- direct access to proton kinematics
probing gluon structure of Pomeron
sensitive to gap survival probability
testing Pomeron universality between $ep-pp$ colliders
probing quark structure of Pomeron

- testing Pomeron universality between \(ep\)–\(pp\) colliders
- interesting variables \(p_T\) and \(M = \sqrt{s\xi_1\xi_2}\)
calculations can be done using QCD without Pomeron
no Pomeron remnants
sensitive to unintegrated gluon PDF
sensitive to rescattering corrections
analysis inspired by Khoze, Martin, Ryskin publications
improvement and extension of existing measurements
exclusive lepton production with tagged protons
possible new physics with anomalous quartic couplings (W and Z production)
very good background rejection for $\gamma\gamma$ production
very successful first stage of AFP installation AFP 0+2
data collected in 2016 are interesting not only from detector performance point of view but also physics
next year final installation stage AFP 2+2 will be completed
reach physics program for special low-$\mu$ focused mainly on soft diffraction
timing detectors open access to measuring protons in high pile-up conditions and allow measuring processes with small cross sections