The ATLAS Forward Proton Detector (AFP)

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on behalf of the AFP Collaboration

• Introduction
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Introduction

• AFP will study events in which intact protons emerge from ATLAS inelastic collisions, with detectors close to the LHC beam at 210 m from the IP.

Many interesting scattering processes characterized by protons emitted at very low angles
• **Tracker** for momentum measurements
• **ToF** to reduce background (at high luminosity)

AFP recently passed physics and technical reviews. Approved by ATLAS EB (pending funding secured).
ALFA and AFP

ALFA: scintillator fiber detectors placed in Roman Pots close to the LHC proton beams at 240m from IP [H. Stenzel talk July 5th 13:00]

- Planned to measure elastic scatter in low $\mu$ spills
- Not optimized for diffractive scattering (total cross section measurement)

CERN/LHCC/2008-004

$M_x = \sqrt{\xi \frac{t}{1-\xi^2}}$

- 5 GeV mass resolution

AFP increases the acceptance of ATLAS in a wide range of resonance mass

[Trzebinski M., CERN-THESIS-2013-166]
Medium luminosity (Low $\beta^*$, $\mu \sim 1$)

- Single diffractive events
  - One proton tag
  - Soft survival probability, rapidity gap spectra

- Double pomeron exchange
  - Lower rate compensated by double tag
    - Dijet (a): constrain gluon content of $P$
    - $\gamma$+Jet (b): constrain quark content of $P$
    - Jet-gap-jet (c): test BFKL $P$

High luminosity

- Exclusive processes
  - Via $\gamma \gamma$ or $gg$: EW and QCD measurements, anomalous couplings, Higgs
AFP Tracker

AFP tracker:
• Mounted as close as possible to the beam to increase physics sensitivity
• Allow mass resolution of ~5 GeV

Expected radiation profile on the tracker sensor for 100/fb (with 2 RP per side):

- ~5x10^{15} p/cm^2
- (~3x10^{15} n_{eq}/cm^2)

Tracker requirements:
• Position resolution of 10 µm (in x)
• Detector with no inactive edge
• Radiation hard (and cope with non-uniform dose) – for high luminosity operation

Silicon detectors:
• 3D pixel sensors
• FE-I4 readout (2x2cm^2)

[Trzebinski M., CERN-THESIS-2013-166]
AFP Tracker: Sensors

**3D sensors**: column-like electrodes penetrate substrate
- Slim edge (closeness to the beam)
- Low bias voltage operation (non-uniform dose)

- AFP based on ATLAS Inner B-Layer 3D pixels:
  - Cut IBL sensors ~1.1mm inactive edge down to 100-150 µm (FE-I4 chip: 80 µm dead region)
  - Slimming sensors with SCP: promising results [A. Micelli, 21st RD50 workshop Nov 2012; S. Grinstein, 8th Trento workshop 2013]
  - For prototypes: standard diamond-saw cut
  - Bump-bond to ATLAS FE-I4B chip (336x80)
  - On-going AFP productions (CNM & FBK)

AFP prototypes (FBK and CNM)

- FZ high resistivity wafers
- Double sided process
- P-bulk 230um thick, 210um columns
AFP Tracker: Performance

Beam tests needed to evaluate detector performance

- Critical parameters are resolution and efficiency
- Both evaluated in testbeams at DESY & CERN

Beam test campaign at DESY during 2013/14

June/July 2013 DESY
- 5 GeV electron beam
- 0 deg incidence
- 2000e threshold, 30V bias

AFP prototype

Average efficiency after slimming: ~98% (similar to IBL)

Edge efficiency

ATLAS preliminary

Removing telescope contribution: ~13 μm

AFP prototypes slimed to ~120 um show excellent position resolution and efficiency until last pixel row
AFP Tracker: Radiation Hardness

For high luminosity program:
Evaluate effect of non-uniform irradiations

Device irradiated at IRRAD1 (CERN) to 4E15 neq/cm²

Beam tests CERN Aug 2012
• Threshold: 1700e
• Bias voltage: 130V
• Temperature: -20°C (approx.)

KIT irradiation 2013 (AIDA)

Good efficiency in irradiated region of AFP prototypes
AFP Timing

• ToF needed to reduce background from multiple proton-proton collisions
• Critical to study system during first phase of AFP (low-medium luminosity)
• From the time difference ($\Delta t$):
  • $Z_{vtx} = c \Delta t/2$, $\sigma_z = (c/\sqrt{2}) \times \sigma_t$
  • Luminous region $\sim 6$ cm, so request 2 mm which means $\sigma_t \sim 10$ ps
• Different technologies under evaluation
  • System based on quartz radiators (MCP–PMT + HPTDC)
  • Silicon/diamond detectors (SAMPIC readout)
AFP Timing: UPTOP

- **Requirements** (for high luminosity)
  - 10 ps resolution, high efficiency
  - Segmentation (multi-proton)
  - Acceptance matching tracker
  - Radiation tolerance
- **UPTOP system** (Ultra Precise Timing Of Protons)
  - Quartz bar read out by MCP-PMT
    - Each bar ~20ps resolution, use 5 bars

Idea M. Albrow (FP420)

Electronic system
CFD + HPTDC (CERN)

Roman Pot with timing and tracking detectors
[M. Rijssenbeek, based on TOTEM design]
AFP Timing: Performance

UPTOP system studied laser and beam tests:
- Long life of MCP-PMT ensured with MCP coating (ALD)
- Full system tests carried out at CERN and FNAL
- Timing + tracking systems to be tested in November 2014 at CERN
- Also test back-up timing systems:

Silicon detectors for ToF
- LGAD detectors with signal gain critical for silicon timing resolution
- SAMPIC readout, already tested in laboratory (~40 ps resolution)

\[ \sigma_t = 14 \text{ ps} \]
Subtracting 14 ps ref. resolution

\[ \Delta t \]

6 Q-bar System
CFD read out by scope

[Mean \(-6.366\), RMS 24.31, Underflow 0, Overflow 0, \(\chi^2 / \text{ndf} = 317.41 / 25\), Constant 676.27 ± 9.14, Mean \(-4.048 \pm 0.246\), Sigma 19.5 ± 0.2]

[RD50 (CNM)]

[Fast Si detectors (g=10) + Charge Sensitive Amplifier SAMPIC 6.4 GSPS, channels self-triggered Offline cross-correlation algorithm]

[M. Saimpert, Trento Workshop 2014]

[S. Grinstein - ICHEP 2014]
Conclusions

- AFP planning to carry out a physics program during Run II (mainly based on $\beta^*=0.55$ m and $\mu<3$ runs)

- AFP tracker sensor qualification completed
  - No loss of efficiency in edge-region after slimming
  - Excellent efficiency after non-uniform irradiation
  - Ongoing productions for final sensors

- Timing system - critical for high luminosity program
  - Need to evaluate system in first AFP running period
  - UPTOP system fully tested and adapted for Roman Pot
  - Other technologies (silicon/diamond) being evaluated

- AFP installation is foreseen during shutdown 2015/16 (if resources available)