

AFP – Forward Protons Detectors for ATLAS

Rafał Staszewski

supported in part by NCN grant UMO-2012/05/B/ST2/02480

Henryk Niewodniczański
Institute of Nuclear Physics
Polish Academy of Sciences
(IFJ PAN Cracow)



DIS 2014

Warsaw, 28 April – 2 May 2014

Contents

AFP – Forward
Protons
Detectors for
ATLAS

R. Staszewski

The AFP
Detectors

The Physics
Programme

AFP status

- 1 The AFP Detectors
- 2 The Physics Programme
- 3 AFP status

Forward protons

AFP – Forward Protons Detectors for ATLAS

R. Staszewski

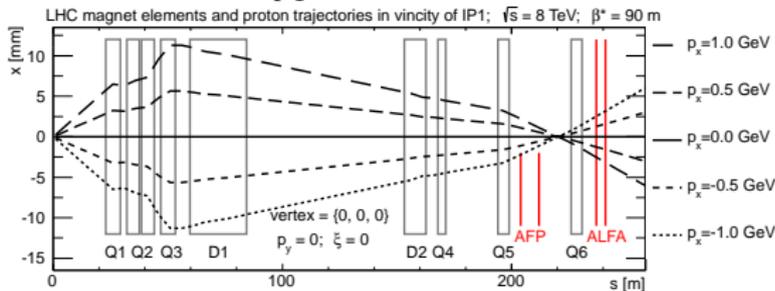
The AFP Detectors

The Physics Programme

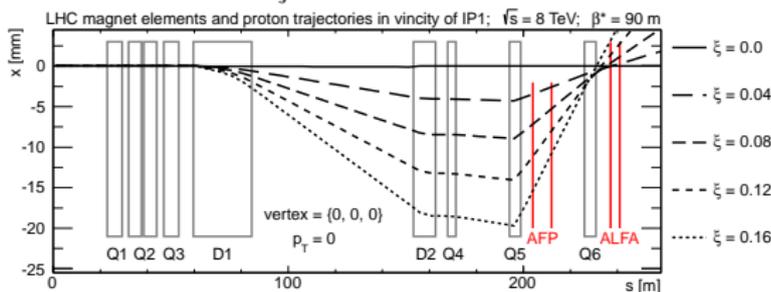
AFP status

- p_T and $\eta \leftrightarrow p_T$ (or $t = p_T^2$) and $\xi = \Delta E/E_0$
- In diffraction, coherent interaction of proton is soft $\rightarrow p_T \sim 1$ GeV, protons are scattered into the beam pipe
- Trajectory of diffractive proton differs from beam trajectory

Difference due to p_T :



Difference due to ξ :



ALFA and AFP Detectors

AFP – Forward
Protons
Detectors for
ATLAS

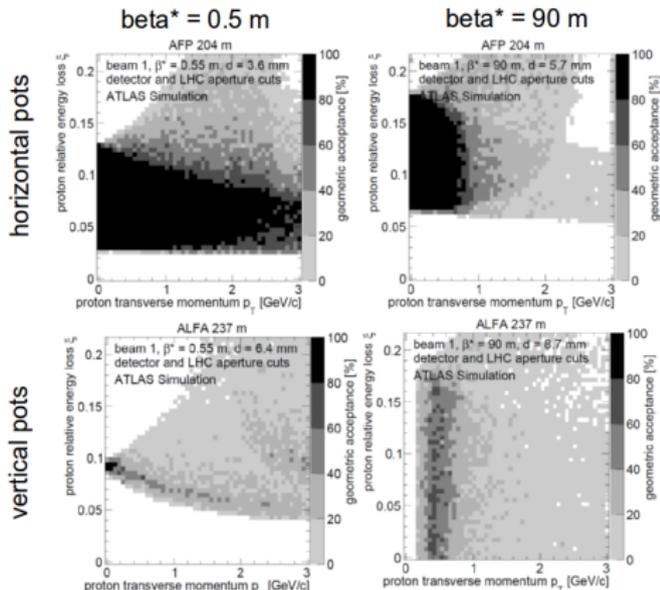
R. Staszewski

The AFP
Detectors

The Physics
Programme

AFP status

- p_T and $\eta \leftrightarrow p_T$ (or $t \approx p_T^2$) and $\xi = \Delta E/E_0$
- Elastic scattering: $\xi = 0$, diffraction: $\xi < 0.2$



AFP – horizontal pots (planned for ATLAS)

- 100% acceptance for small t
- ξ range depends on optics
- low and high luminosity
- low and high β^*

ALFA – vertical pots (present in ATLAS)

- limited acceptance in t
- broad acceptance in ξ
- acceptance for elastics
- only very small luminosity
- only high β^*

AFP Detector System

AFP – Forward Protons Detectors for ATLAS

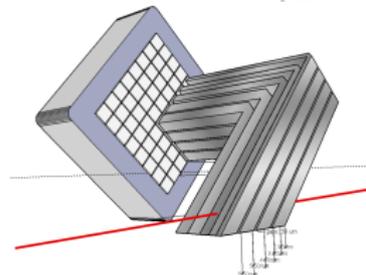
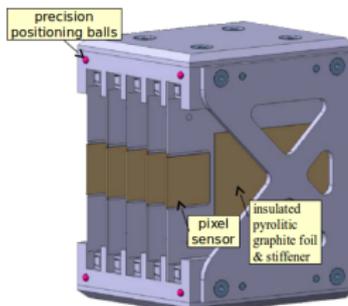
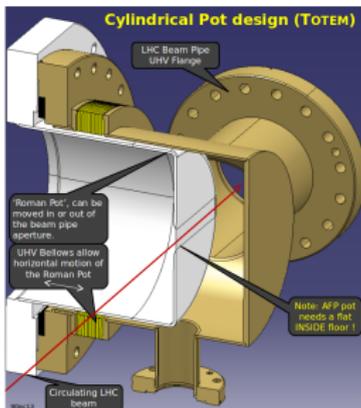
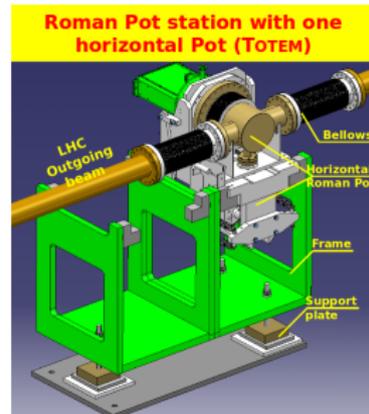
R. Staszewski

The AFP Detectors

The Physics Programme

AFP status

- 4 RPs: stations at 206 and 214 m from IP, on both outgoing beams
- Two stations on each side – trajectory position and direction
- Tracking detectors: IBL sensors + FEI4
- Timing detectors in stations at 214 m: precise (ps) timing for reconstructing longitudinal vertex position



Timing Detectors

AFP – Forward
Protons
Detectors for
ATLAS

R. Staszewski

The AFP
Detectors

The Physics
Programme

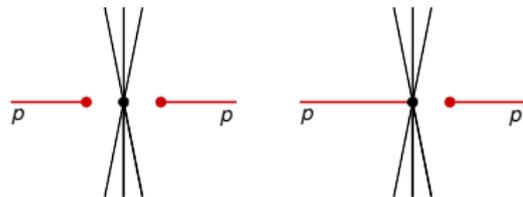
AFP status

- Dominant background for hard diffraction – pile-up

ND + 1 proton from pile-up \rightarrow SD

SD + 1 proton \rightarrow CD (DPE)

ND + 2 protons \rightarrow CD (DPE)



- Orders of magnitude difference in cross sections
- High cross section for min. bias protons
- Negligible only for $\mu < 0.01$

- Precise ToF measurement – correlation between arrival time and vertex position for signal events!
- Resolution of the order of 10 ps needed

AFP Full Simulation

AFP – Forward
Protons
Detectors for
ATLAS

R. Staszewski

The AFP
Detectors

The Physics
Programme

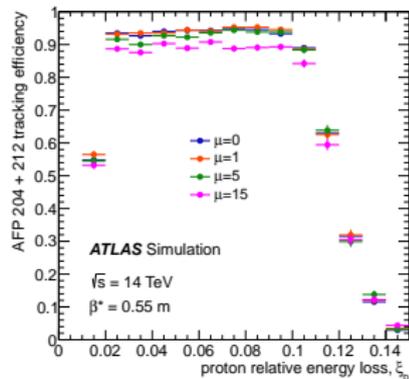
AFP status

- Geant4 simulation of whole forward region
- Beam pipe, magnets, collimators and forward detectors implemented
- Full integration with ATLAS central detector simulation and standard ATLAS simulation chain



Tracking performance

- Results from full simulation of AFP detectors and the whole forward region
- In agreement with previous expectations
- Mild degradation of performance due to pile-up
- Detector capable of running in pile-up conditions



Contents

AFP – Forward
Protons
Detectors for
ATLAS

R. Staszewski

The AFP
Detectors

The Physics
Programme

AFP status

- 1 The AFP Detectors
- 2 The Physics Programme
- 3 AFP status

AFP Physics Programme

AFP – Forward
Protons
Detectors for
ATLAS

R. Staszewski

The AFP
Detectors

The Physics
Programme

AFP status

Dedicated runs

- 1 Low luminosity ($\mu \ll 1$)
 - soft processes
 - diffractive jets (SD)
- 2 Medium luminosity ($\mu \sim 1$)
 - diffractive jets, diffractive jet-gap-jet, exclusive jets
 - diffractive W, Z
 - diffractive photon+jet

Normal running

- High luminosity ($\mu \gg 1$)
 - anomalous quartic gauge boson couplings
($\gamma\gamma\gamma\gamma, \gamma\gamma WW$ and $\gamma\gamma ZZ$)
 - exclusive jets (high p_T)

Soft processes

AFP – Forward Protons Detectors for ATLAS

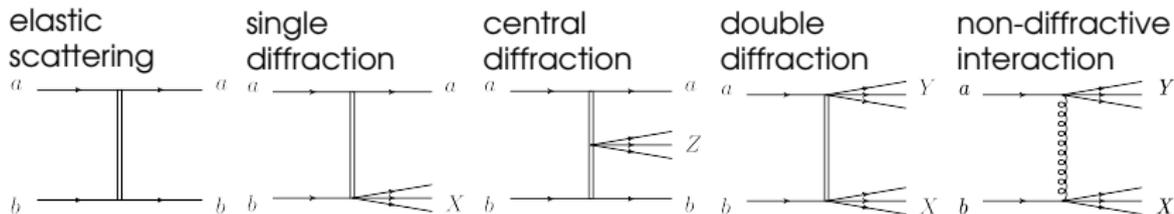
R. Staszewski

The AFP Detectors

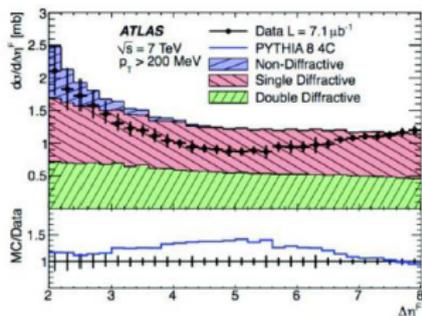
The Physics Programme

AFP status

Minimum bias processes at the LHC:



- Gap measurement in ATLAS does not distinguish SD from DD
- Possible with forward proton tagging
- High cross sections \rightarrow low lumi needed \rightarrow low pile-up possible
- Properties of SD – central and forward
- Central diffraction (DPE – double Pomeron exchange)



Diffractive jets

AFP – Forward Protons Detectors for ATLAS

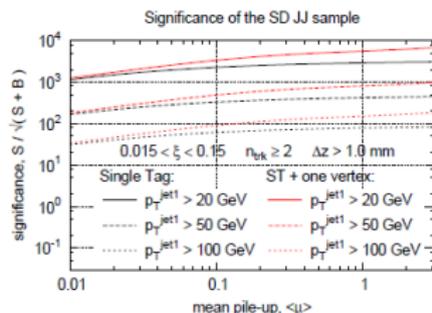
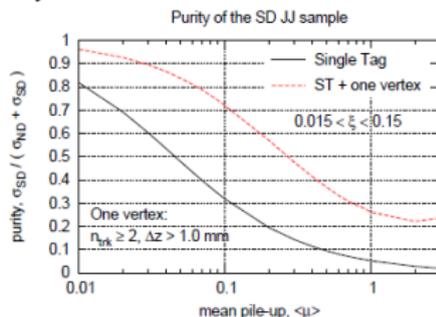
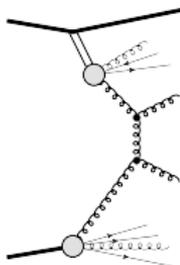
R. Staszewski

The AFP Detectors

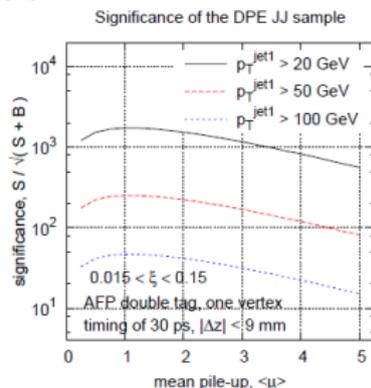
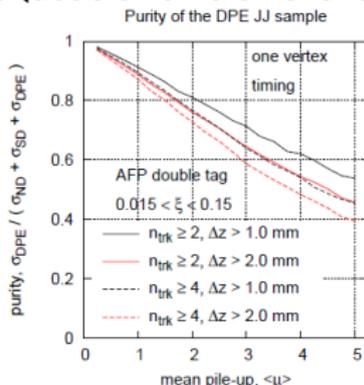
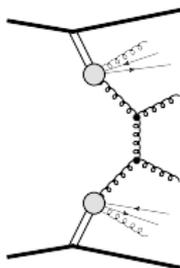
The Physics Programme

AFP status

Single diffractive jets



Central diffractive (double Pomeron exchange) jets



Motivation: gap survival probability, gluon distribution in Pomeron

Exclusive jets

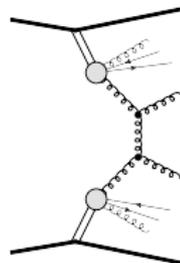
Exclusive jets

- Two intact protons
- No Pomeron remnants
- All particles measured

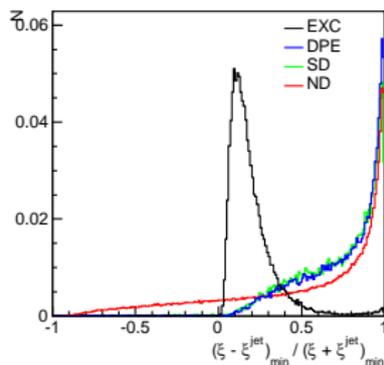


For comparison: CD (DPE) jets

- Two intact protons
- Pomeron remnants
- Remnants escape



- Small cross section for exclusive processes
→ measurement with two proton tags
needs high luminosity
- Low luminosity – only single tag possible, but
less pile-up background
- All particles measured → strong kinematic
constraints between central state and
each of the forward protons
- Motivation: verification of QCD production
models, unintegrated gluon PDFs



Diffractive W

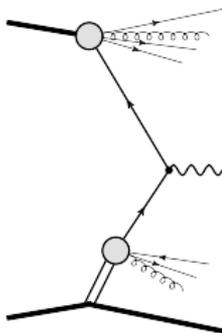
AFP – Forward Protons Detectors for ATLAS

R. Staszewski

The AFP Detectors

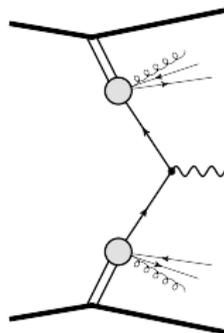
The Physics Programme

AFP status



SD W

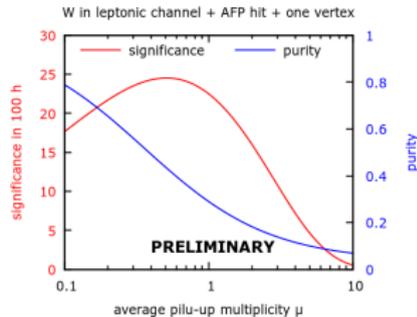
- One intact proton
- One quark from proton, one from Pomeron



CD (DPE) W

- Two intact protons
- Both quarks from Pomeron

- Sensitivity to quarks in Pomeron
- SD W – sensitivity to Pomeron flavour composition (via charge asymmetry)
- CD/DPE W – long running at low luminosity needed – unlikely



Diffraction jet-gap-jet and photon+jet

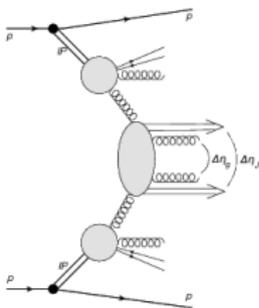
AFP – Forward Protons Detectors for ATLAS

R. Staszewski

The AFP Detectors

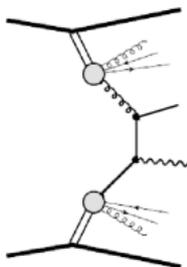
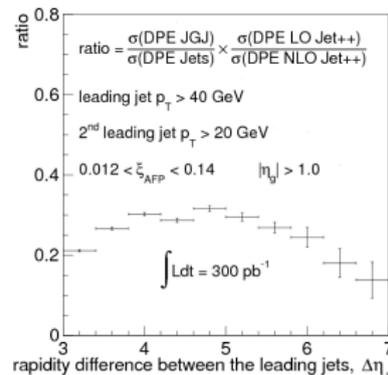
The Physics Programme

AFP status



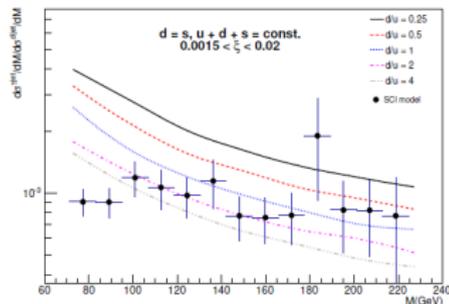
DPE jet-gap-jet

- Two intact protons and gap between jets
- Never measured before
- BFKL dynamics
- Cleaner than j-g-j without forward protons



DPE photon+jet

- Two intact protons
- Never measured before
- Sensitivity to quark in Pomeron and to mechanism of diffraction



High luminosity

AFP – Forward
Protons
Detectors for
ATLAS

R. Staszewski

The AFP
Detectors

The Physics
Programme

AFP status

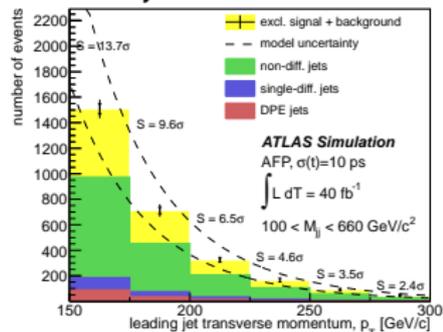
$\gamma\gamma WW$ and $\gamma\gamma ZZ$ couplings

| Coupling | OPAL limits (GeV ⁻²) | Sensitivity for 200 fb ⁻¹ 5 σ 95% CL | |
|-------------------|-------------------------------------|---|---------------------|
| a_0^W/Λ^2 | (-0.020, 0.020) | $2.7 \cdot 10^{-6}$ | $1.4 \cdot 10^{-6}$ |
| a_C^W/Λ^2 | (-0.052, 0.037) | $9.6 \cdot 10^{-6}$ | $5.2 \cdot 10^{-6}$ |
| a_0^Z/Λ^2 | (-0.007, 0.023) | $5.5 \cdot 10^{-6}$ | $2.5 \cdot 10^{-6}$ |
| a_C^Z/Λ^2 | (-0.029, 0.029) | $2.0 \cdot 10^{-5}$ | $9.2 \cdot 10^{-6}$ |

$\gamma\gamma\gamma\gamma$ coupling

| Coupling (GeV ⁻⁴) | 1 conv. γ 5 σ | 1 conv. γ 95% CL | all 95% CL |
|----------------------------------|--------------------------------|----------------------------|--------------------|
| ζ_1 f.f. | $1 \cdot 10^{-13}$ | $7 \cdot 10^{-14}$ | $4 \cdot 10^{-14}$ |
| ζ_1 no f.f. | $3 \cdot 10^{-14}$ | $2 \cdot 10^{-14}$ | $1 \cdot 10^{-14}$ |
| ζ_2 f.f. | $3 \cdot 10^{-13}$ | $1.5 \cdot 10^{-13}$ | $8 \cdot 10^{-14}$ |
| ζ_2 no f.f. | $7 \cdot 10^{-14}$ | $2 \cdot 10^{-14}$ | $2 \cdot 10^{-14}$ |

Excusive jets



- Quartic Gauge Couplings – testing BSM models
- Constrained kinematics → low background
- Reaching limits predicted by string theory and grand unification models (10^{-14} – 10^{-13} for $\gamma\gamma\gamma\gamma$)
- Exc. jets – high p_T , double tag

Contents

AFP – Forward
Protons
Detectors for
ATLAS

R. Staszewski

The AFP
Detectors

The Physics
Programme

AFP status

- 1 The AFP Detectors
- 2 The Physics Programme
- 3 AFP status**

AFP status

AFP – Forward
Protons
Detectors for
ATLAS

R. Staszewski

The AFP
Detectors

The Physics
Programme

AFP status

- Physics review
 - January 2014
 - Physics case – diffractive and QCD topics to be studied in few days of data taken at low luminosity in special runs
 - Positive outcome – program appears achievable from the technical point of view, without strong demands on the timing precision and the alignment; running scenario to be agreed with TOTEM and ALFA; high lumi program to be revisited when data on background in normal running conditions will exist
- Technical review
 - April 2014
 - The reviewers did not identify any substantial problem and therefore encourage the ATLAS Collaboration to approve the AFP project and go to the next stage with the submission of the TDR, provided that all the points mentioned will be addressed in due time.
- Next steps: combined test beam, TDR