

Physics goals and status of AFP

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on behalf of the ATLAS Collaboration

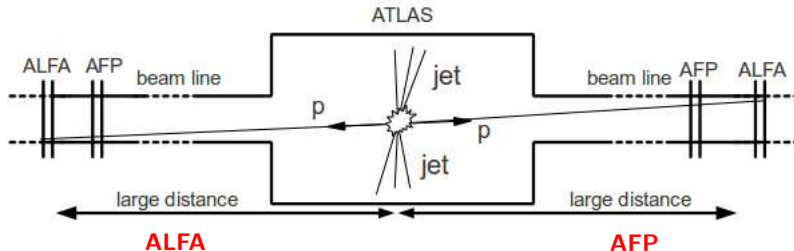
Institute of Nuclear Physics
Polish Academy of Sciences



**Workshop on Forward Physics and High-energy Scattering at Zero
Degrees**

Nagoya, 12th September 2015

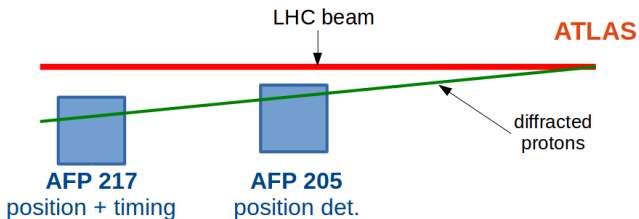
Intact protons → natural diffractive signature → usually scattered at very small angles (μrad) → detectors must be located far from the Interaction Point.



- **Absolute Luminosity For ATLAS**
- exist, 240 m from ATLAS IP
- soft diffraction (elastic scattering)
- special runs (high β^* optics)
- vertically inserted Roman Pots
- tracking detectors, resolution:
 $\sigma_x = \sigma_y = 30 \mu\text{m}$

- **ATLAS Forward Proton**
- planned, 210 m from ATLAS IP
- hard diffraction
- nominal runs (collision optics)
- horizontally inserted Roman Pots
- tracking detectors, resolution:
 $\sigma_x = 10 \mu\text{m}, \sigma_y = 30 \mu\text{m}$
- timing detectors, resolution:
 $\sigma_t \sim 20 \text{ps}$

Similar Devices @ IP5: CMS-TOTEM.

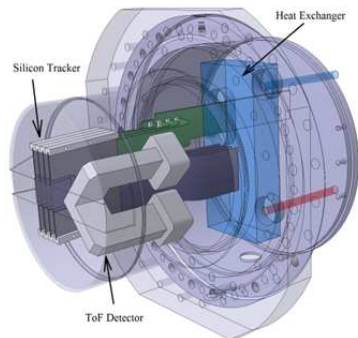


Near station (205 m from ATLAS IP):

- position detectors: 4 layers, staggered.

Far station (217 m from ATLAS IP):

- position detectors,
- ToF detectors: 4 x 4 bars.



Goals:

- debug the detector; explore the environment close to the LHC beam,
- special runs at low- μ , focusing on high-rate diffractive physics processes,
- staged installation:
 - Winter 2015-2016 shutdown – installation of a single AFP arm with two Roman pot stations, the 0+2 AFP configuration (AFP0+2),
 - Winter 2016-2017 shutdown – installation of the second detector arm.

AFP 0+2:

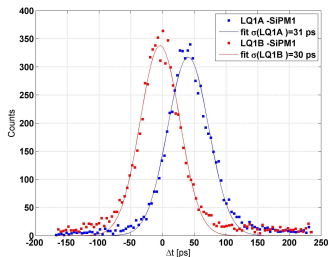
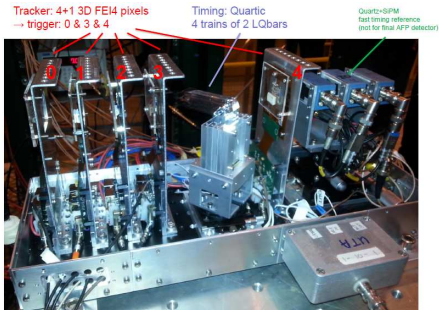
- two silicon tracking detectors and a Level-1 Trigger,
- physics (**low pile-up**): soft single diffraction, single diffractive jets, W/Z , jet-gap-jet, exclusive jet production (one tag),

AFP 2+2:

- two silicon tracking detectors on second arm and time-of-flight detectors on both far stations,
- physics:
 - **low pile-up**: soft central diffraction, double Pomeron exchange jets, W/Z , jet-gap-jet, γ +jet, exclusive jet production (single tag),
 - **high pile-up** ($\mu \gtrsim 23$): exclusive jet production (double tag), anomalous couplings.

First integrated AFP was tested in November 2014 at CERN-SPS (120 GeV pions).

AFP prototype: five tracking planes and a Quartic timing system.

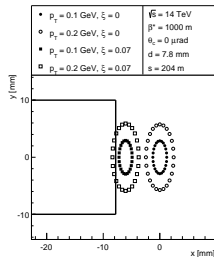
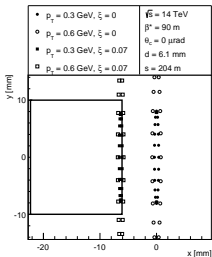
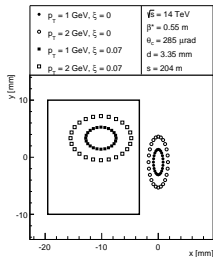
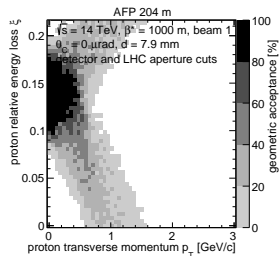
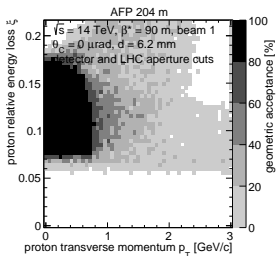
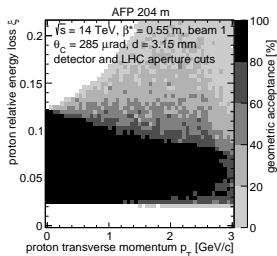


The time differences between the LQbars of the first train (1A and 1B) and a fast SiPM reference at $V_{MCP-PMT} = 1900$ V measured with the oscilloscope.

Results and outlook:

- **successful integration**: recorded tracking and timing data are correlated with each other,
- **good performances** of the tracking and timing systems were found,
- **next AFP beam test: September 2015.**

Ratio of the number of protons with a given relative energy loss (ξ) and transverse momentum (p_T) that crossed the active detector area to the total number of the scattered protons having ξ and p_T .

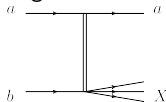


Simulation; distance from the beam was set to 10σ ($\beta^* = 0.55 \text{ m}$) or 15σ ($\beta^* = 90$ and 1000 m).

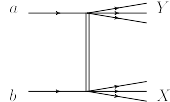
Diffraction Measurements

AFP 0+2

Single Diffraction



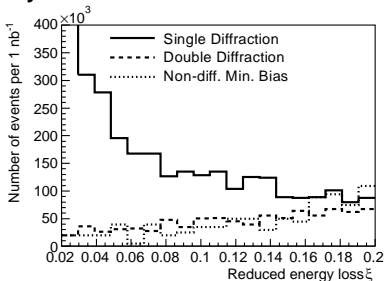
Double Diffraction



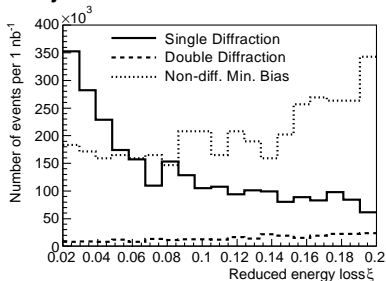
Motivation:

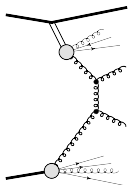
- Significant differences between MC generators.
- High- ξ protons in ND and DD events due to hadronisation (baryon number conservation).

Pythia



Phojet

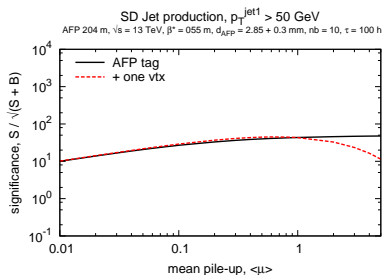
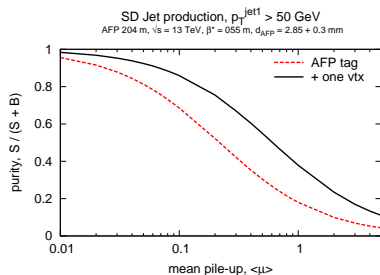




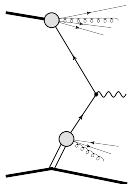
Motivation:

- measure cross section and gap survival probability,
- search for the presence of an additional contribution from Reggeon exchange,
- check Pomeron universality between ep and pp colliders.

Example: purity and statistical significance for AFP and $\beta^* = 0.55$ m.



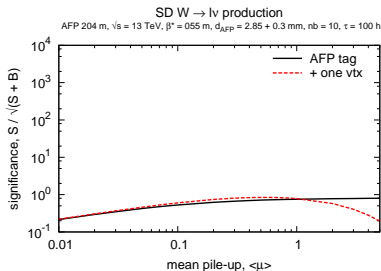
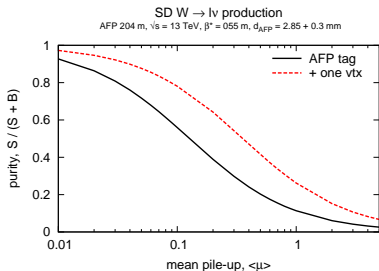
Significance calculated for $n_{\text{bunch}} \times \text{time [h]} = 1000$.
To be published in CERN Yellow Report.



Motivation:

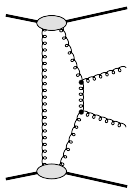
- measure cross section and gap survival probability,
- measure Pomeron structure and flavor composition,
- search for charge-asymmetry.

Example: $W \rightarrow l\nu$ – purity and stat. significance for AFP and $\beta^* = 0.55$ m.



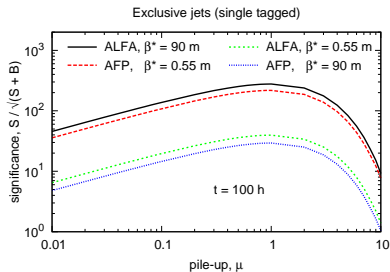
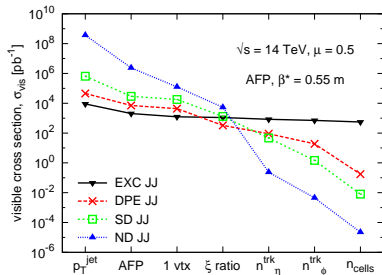
W asymmetry studies published in: Phys.Rev. D 84 (2011) 114006

To be published in CERN Yellow Report.



Motivation:

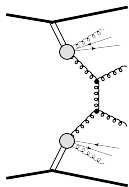
- cross section measurement,
- constrain other exclusive productions (e.g. Higgs).



Published in: Eur. Phys. J. C 75 (2015) 320

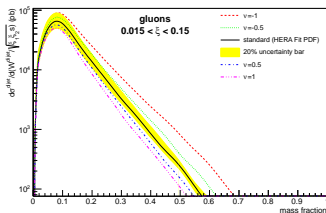
Diffraction Measurements

AFP 2+2

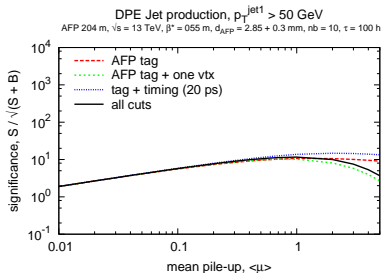
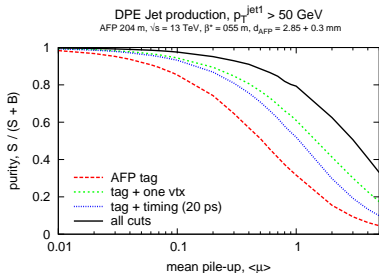


Motivation:

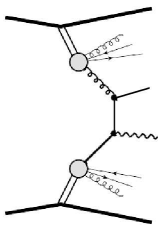
- measure cross section and gap survival probability,
- search for the presence of an additional contribution from Reggeon exchange,
- investigate gluon structure of the Pomeron.



Example: purity and statistical significance for AFP and $\beta^* = 0.55$ m.

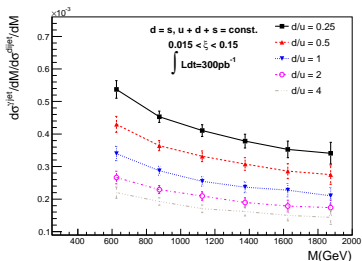
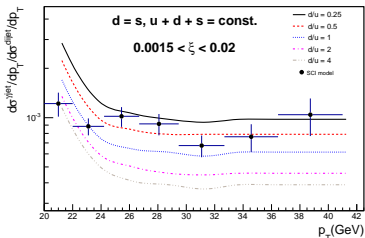


To be published in CERN Yellow Report.



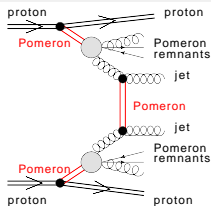
Motivation:

- measure cross section and gap survival probability,
- sensitive to quark content in Pomeron (at HERA it was assumed that $u = d = s = \bar{u} = \bar{d} = \bar{s}$).



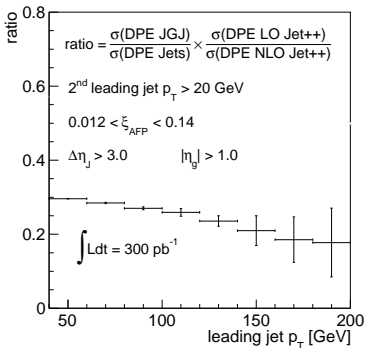
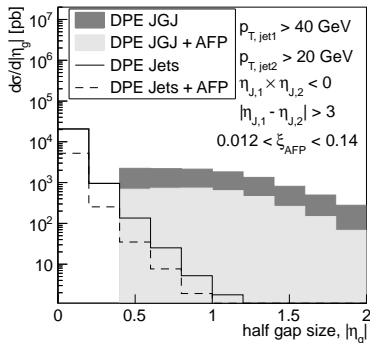
Published in: Phys.Rev. D 88 (2013) 7, 074029

Double Pomeron Exchange Jet-Gap-Jet Production

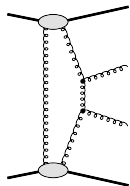


Motivation:

- measure cross section and gap survival probability,
- test BFKL model.

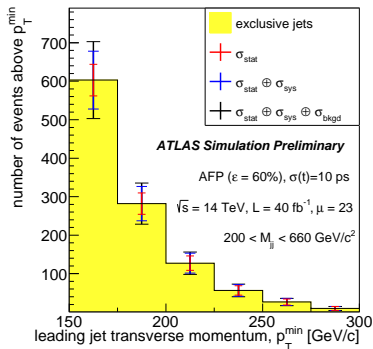
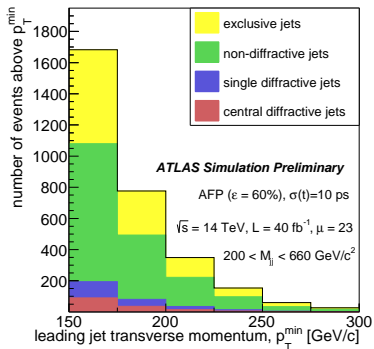
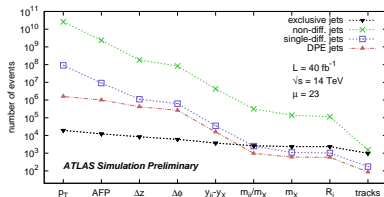


Published in: Phys.Rev. D 87 (2013) 3, 034010



Motivation:

- cross section measurement,
- constrain other exclusive productions (e.g. $pp \rightarrow p \text{ Higgs } p$).



Public ATLAS note: ATL-PHYS-PUB-2015-003

- Intact protons → natural diffractive signature → usually scattered at very small angles (μrad) → detectors must be located far from the IP.
- Two forward detectors systems in ATLAS (similar situation in CMS):
 - ALFA – existing vertical RPs located 240 m from IP1,
 - AFP – planned horizontal RPs located 210 m from IP1.
- AFP TDR was published: CERN-LHCC-2015-009, ATLAS-TDR-024,
- AFP during Run 2:
 - debug the detector; explore the environment close to the LHC beam,
 - special runs at low- μ , focusing on high-rate diffractive physics processes,
 - staged installation:
 - Winter 2015-2016 shutdown – installation of a single AFP arm with two Roman pot stations (AFP0+2),
 - Winter 2016-2017 shutdown – installation of the second detector arm (AFP2+2).
- Possible measurements:

Analysis	$\int L dt$ [pb^{-1}]	Optimal μ	β^* [m]	Trigger
Particle spectra	1	< 0.05	90, 0.55	AFP-ST, AFP-DT
Gap spectra	1	< 0.05	90, 0.55	AFP-ST, AFP-DT
SD jj	1–100	0.01–1.0	90, 0.55	AFP-ST & Jet15
DPE jj	10–100	0.5–5.0	90, 0.55	AFP-DT & Jet15
SD W	> 100	0.1–1.0	90, 0.55	AFP-ST & Lep15 & MET15
DPE $\gamma + j/jj$	> 200	1.0–2.0	0.55	AFP-DT & Jet/Photon
DPE $j - gap - j$	> 100	0.1–2.0	0.55	AFP-DT & Jet
EXC jj (single tag)	10–100	0.5–3.0	90, 0.55	AFP-ST & Jet15
EXC jj (double tag)	$10^3 - 10^5$	23–46	0.55	AFP-DT & Jet150

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