

Present and Future ATLAS Forward Detectors: ALFA and AFP

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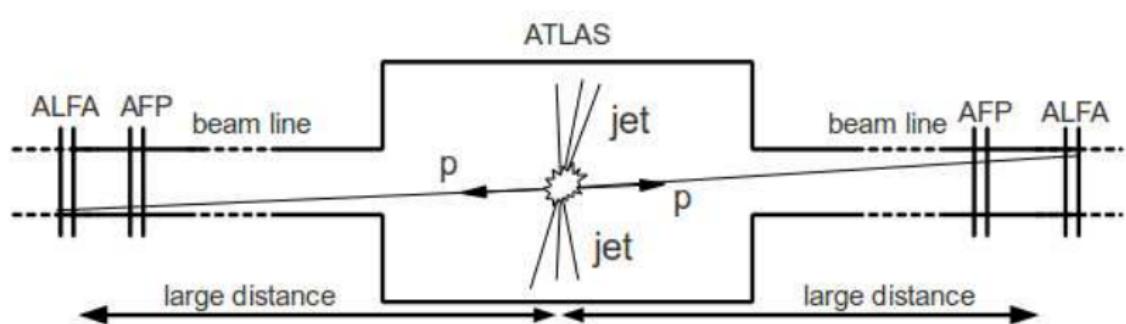
Service de Physique des Particules
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CEA Saclay



2nd Workshop on QCD and Diffraction at the LHC

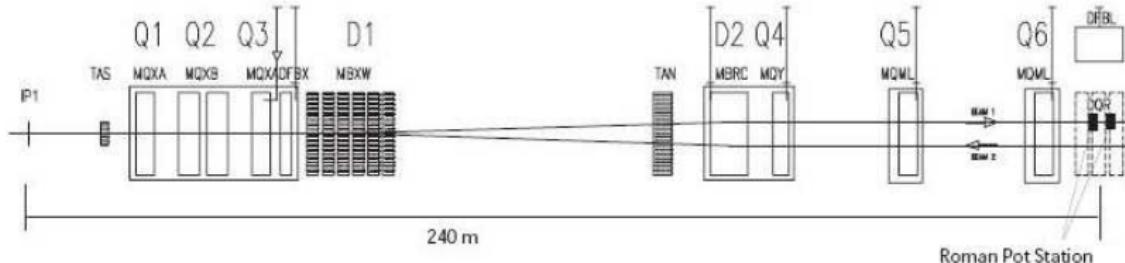
**27th November 2012
Cracow, Poland**

Introduction

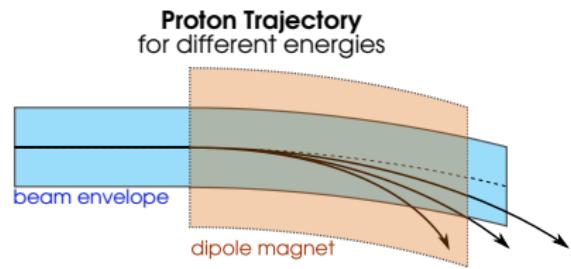
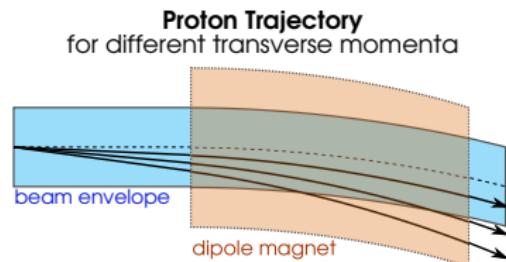


- Protons are interacting in the ATLAS Interaction Point (IP1).
- At least one them stays intact and is propagating along LHC beam pipe.
- If the proton transverse momentum or/and relative energy loss is large enough it could be measured in forward detectors.

LHC Magnets



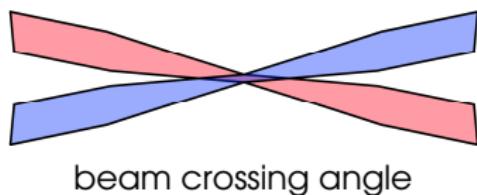
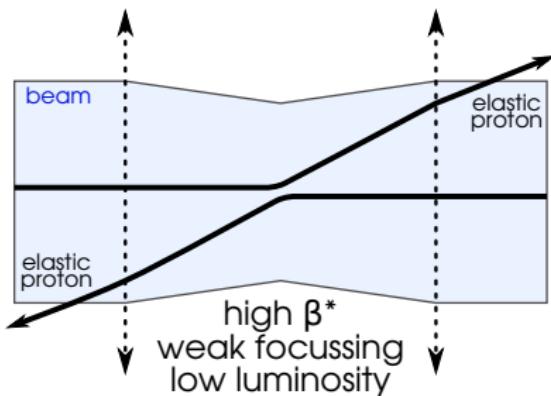
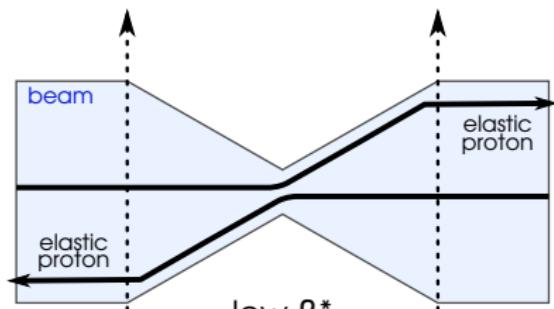
There are several LHC magnets between ATLAS IP and forward detectors: dipole and quadrupole type.



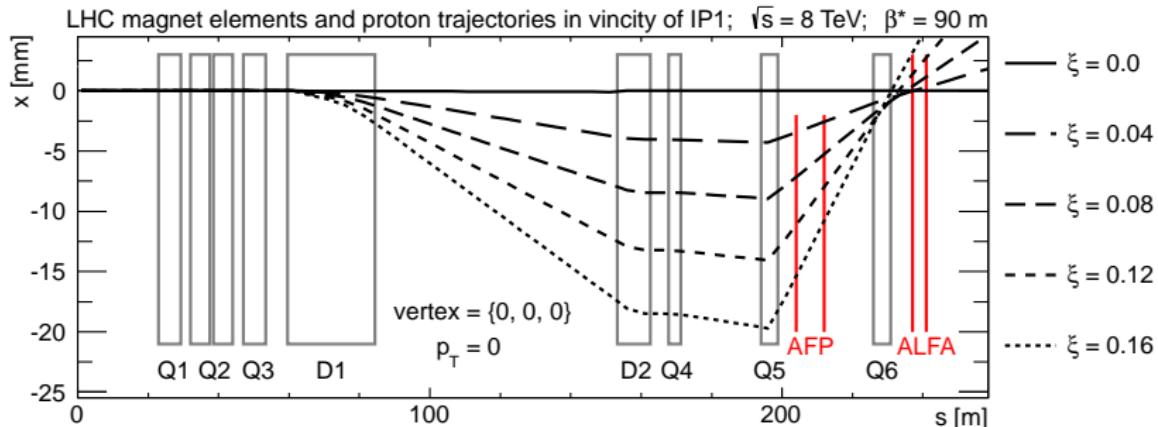
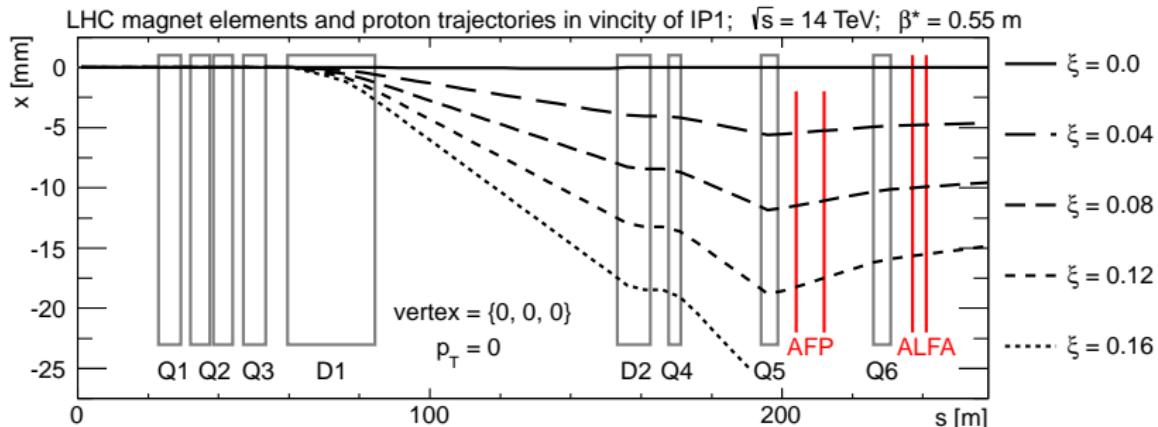
LHC Optic Modes

For the simplicity runs in which the forward detectors collect data can be classified using two parameters:

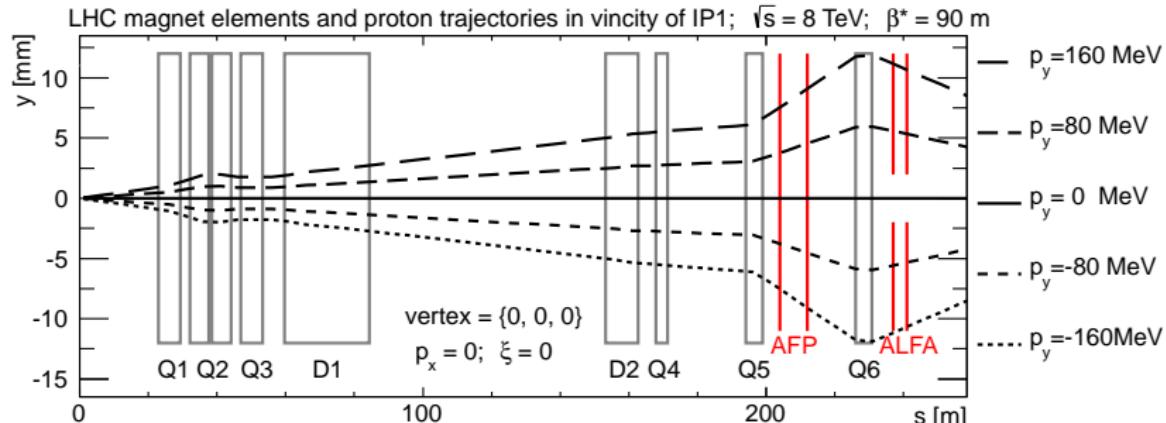
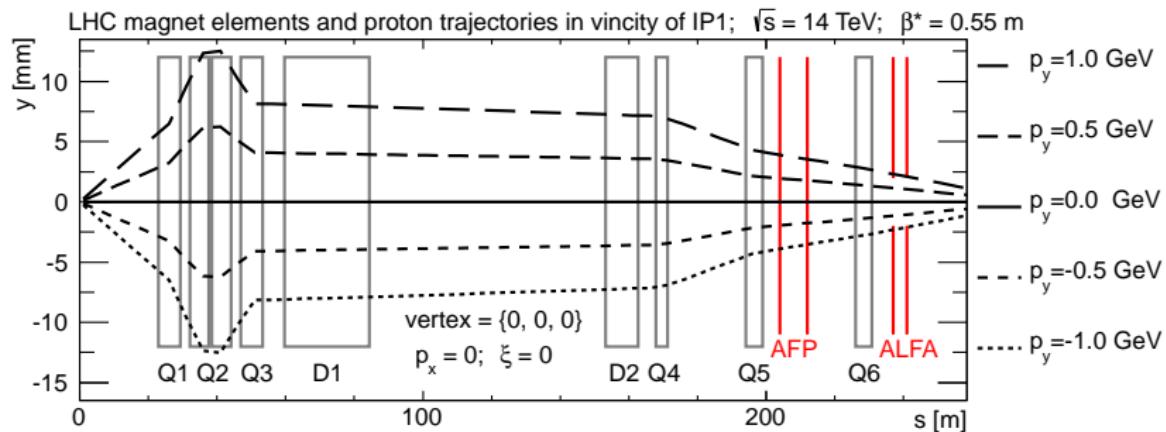
- centre of mass energy: \sqrt{s} ,
- betatron function at the IP1: β^* .



Forward Proton Trajectories – ξ Dependence



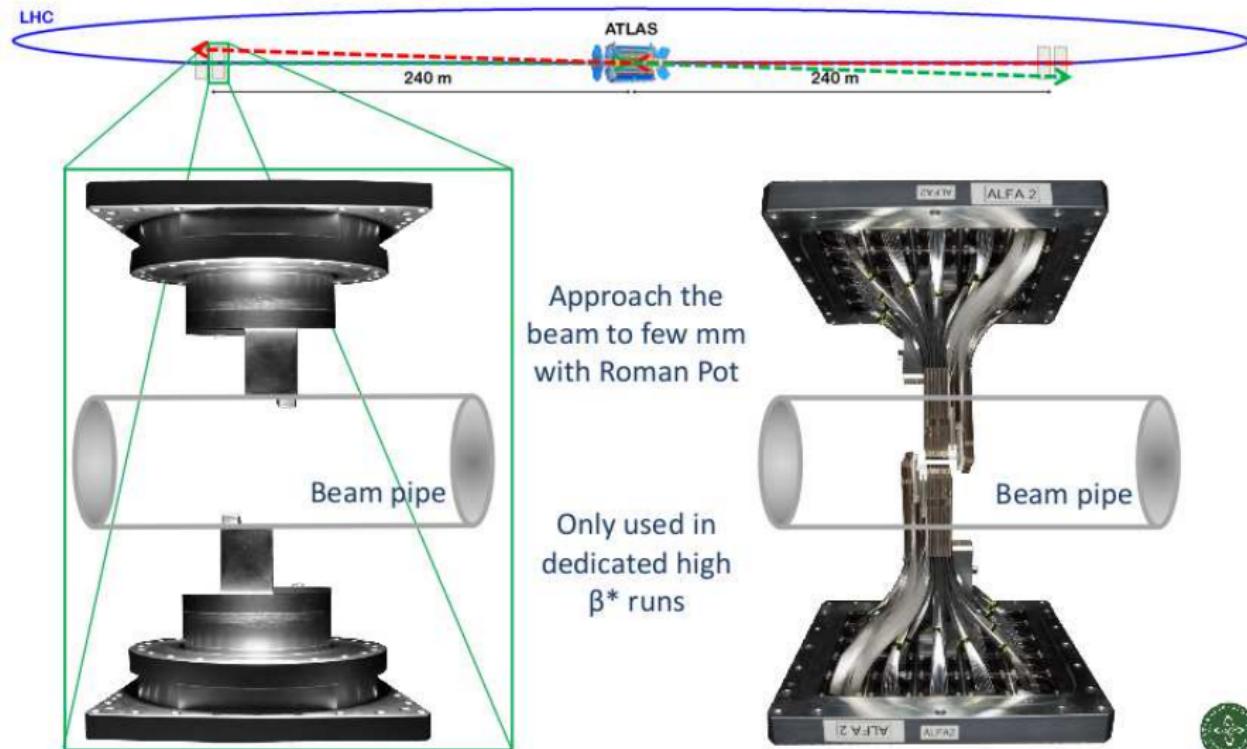
Forward Proton Trajectories – p_y Dependence



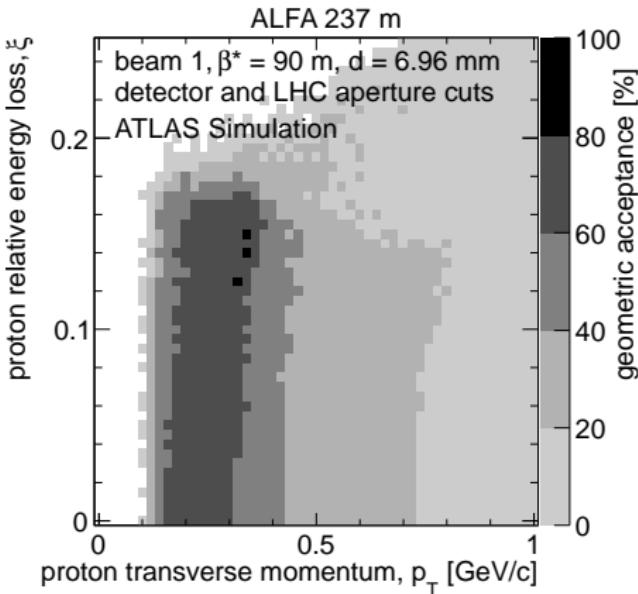
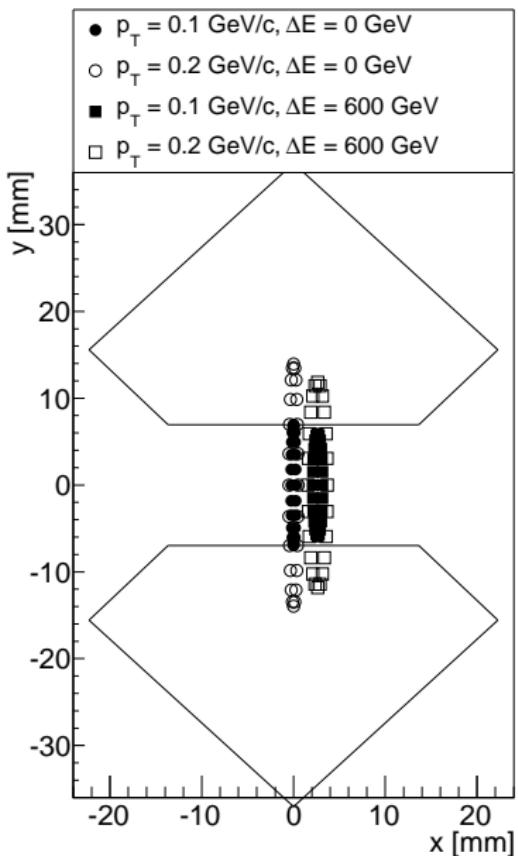
ALFA Detectors

(Absolute Luminosity For ATLAS)

Introduction



ALFA Acceptance



High acceptance for:

- $0 < \xi < 0.18,$
- $0.15 \text{ GeV} < p_T < 0.3 \text{ GeV}.$

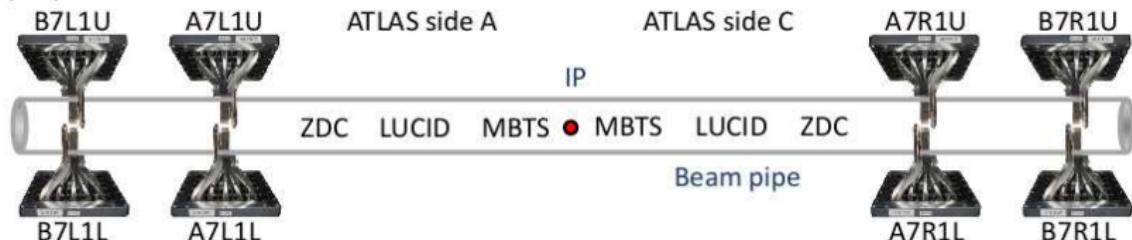
$$\xi = (E_{\text{beam}} - E_{\text{proton}})/E_{\text{beam}}$$

Collected Data

Collected data:

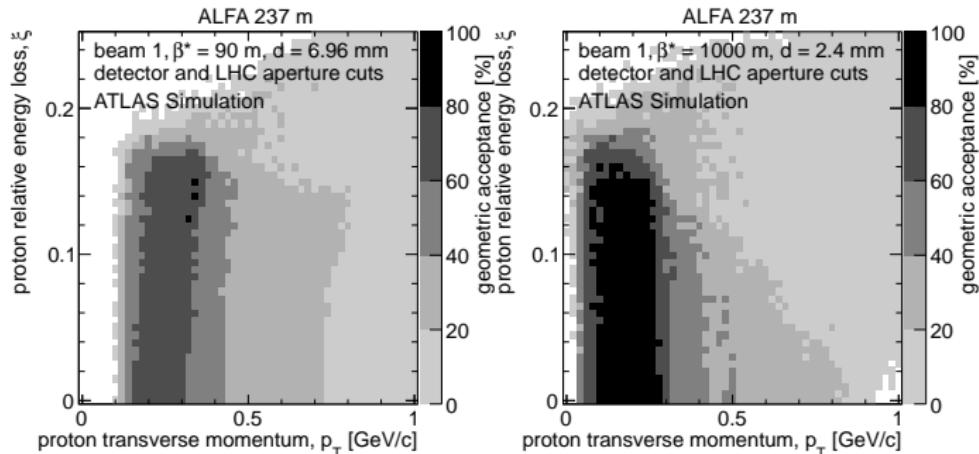
- 2011, $\sqrt{s} = 7 \text{ TeV}$, $\beta^* = 90 \text{ m}$, $\int L \sim 0.1 \text{ nb}^{-1}$, $\langle \mu \rangle \sim 0.003$,
- 2012, $\sqrt{s} = 8 \text{ TeV}$, $\beta^* = 90 \text{ m}$, $\int L \sim 25 \text{ nb}^{-1}$, $\langle \mu \rangle \sim 0.07$,
- 2012, $\sqrt{s} = 8 \text{ TeV}$, $\beta^* = 1000 \text{ m}$, $\int L \sim 0.1 \text{ nb}^{-1}$, $\langle \mu \rangle \sim 0.003$.

Triggers:



Summary

- High acceptance:
 - $0 < \xi < 0.18$,
 - $0.15(0.05) \text{ GeV} < p_T < 0.3 \text{ GeV}$ for $\beta^* = 90(1000) \text{ m}$.



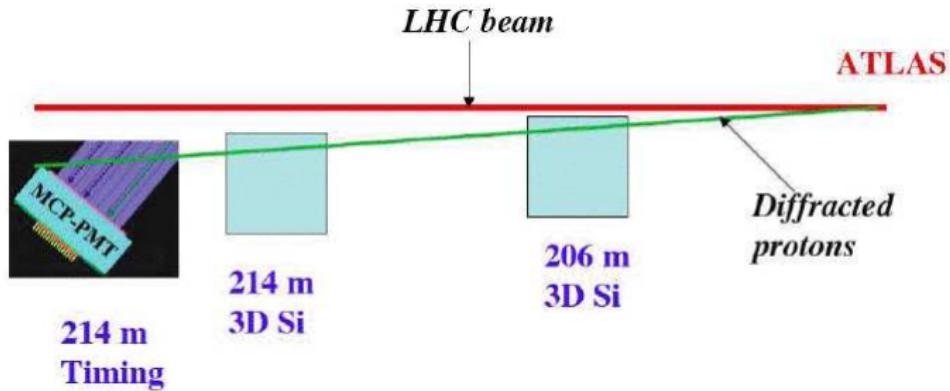
- Collected data:
 - 2011, $\sqrt{s} = 7 \text{ TeV}$, $\beta^* = 90 \text{ m}$, $\int L dt \sim 0.1 \text{ nb}^{-1}$, $\langle \mu \rangle \sim 0.003$,
 - 2012, $\sqrt{s} = 8 \text{ TeV}$, $\beta^* = 90 \text{ m}$, $\int L dt \sim 25 \text{ nb}^{-1}$, $\langle \mu \rangle \sim 0.07$,
 - 2012, $\sqrt{s} = 8 \text{ TeV}$, $\beta^* = 1000 \text{ m}$, $\int L dt \sim 0.1 \text{ nb}^{-1}$, $\langle \mu \rangle \sim 0.003$.
- Possible to study eg.: elastic scattering, single diffraction, soft central production, central exclusive production (eg. pions), low- p_T single diffractive jets.

AFP Detectors

(ATLAS Forward Proton)

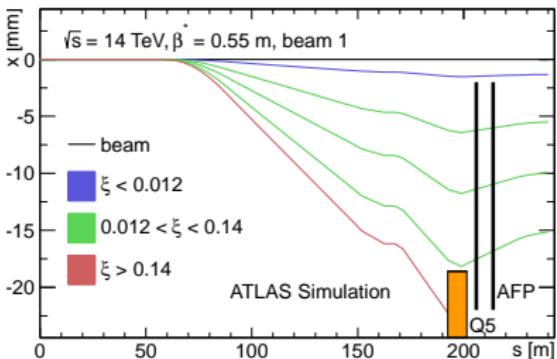
Introduction

- **Motivation:** detect intact protons from hard interaction scattered at very small angles during normal (high pile-up) LHC runs (+ dedicated programme for special low pile-up runs).
- Detector located close to the beam – Movable Beam Pipe.



- Proton position measurement (3-D Pixel detectors).
- Precise time of flight measurement (QUARTIC timing detector).

AFP Acceptance

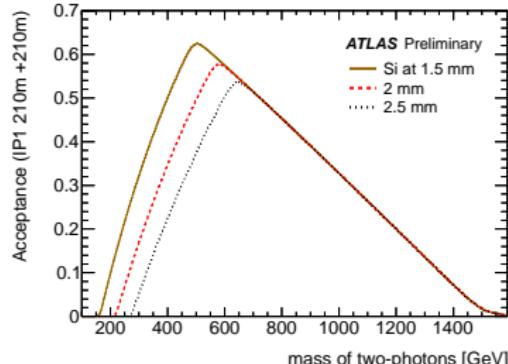
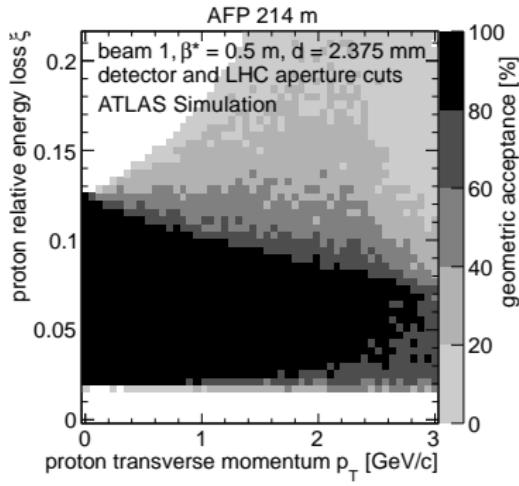


$$M_X = \sqrt{s \cdot \xi_1 \cdot \xi_2}$$

ξ_1, ξ_2 – proton relative energy loss

$200 \text{ GeV} < M_X < 2000 \text{ GeV}$

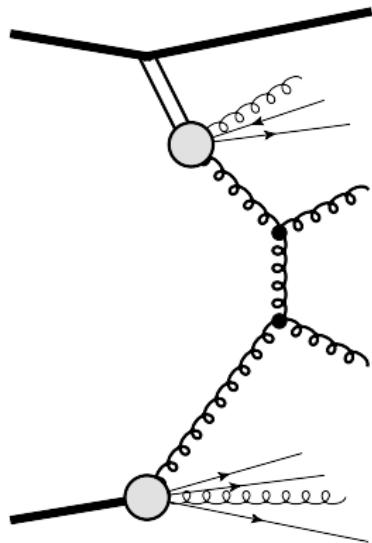
$0 < p_T < 3 \text{ GeV}$



AFP Low Pile-up Programme

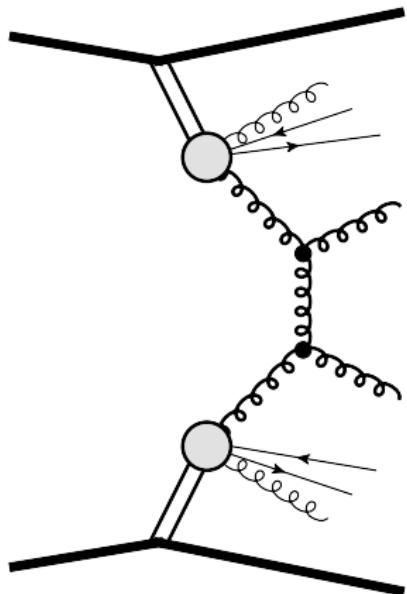
$$\begin{aligned} & \langle \mu \rangle \sim 1 \\ & \int L dt \sim 100 \text{ pb}^{-1} \end{aligned}$$

SD Production



- Measure jet cross section for wide range of p_T .
- Measure gap survival probability.
- Tag SD $W, Z, \text{jet}+\gamma, \text{jets}$ (b -jets).

DPE Jet Production

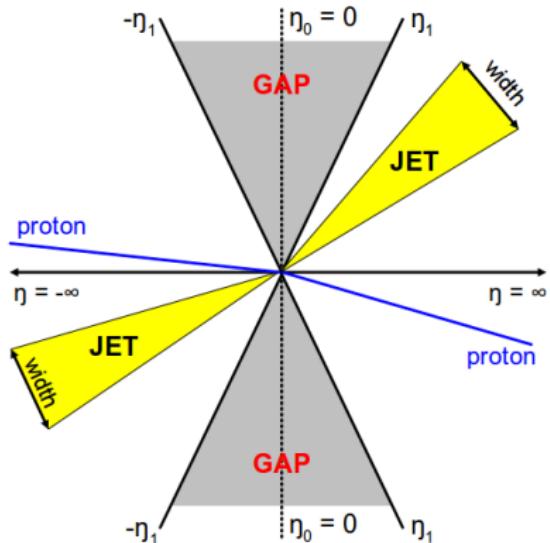
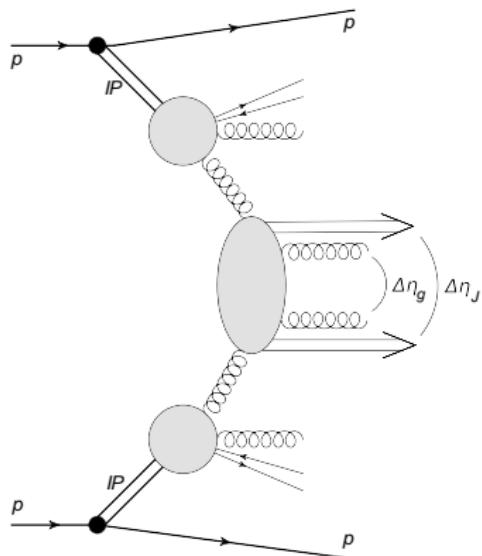


- Measure cross section.
- Probe QCD and diffraction in a new kinematic domain.
- Measure gap survival probability.
- Jet production in Double Pomeron Exchange events: sensitivity to gluon density in Pomeron (especially at high β) in double tagged events.

$$B_g = B_g(1 - \beta)^\nu$$

- Tag DPE jet+ γ , jets (b -jets).

Diffractive jet-gap-jet event



Event signature:

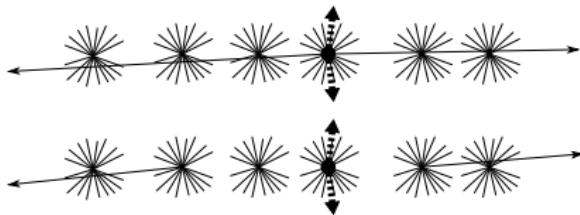
- Measure cross section.
- Measure gap survival probability – Triple Pomeron Exchange process!
- Test BFKL model – see C. Royon talk.

AFP High Pile-up Programme

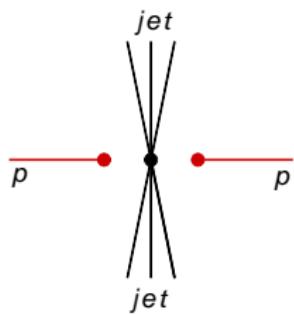
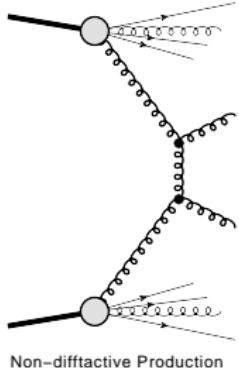
$$\begin{aligned} <\mu> &\sim 50 \\ \int L dt &\sim 100 \text{ fb}^{-1} \end{aligned}$$

New Types of Background

Minimum bias pile-up protons may fake hard diffractive signature.

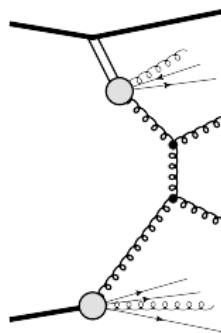


Non-diffractive background +
pile-up.

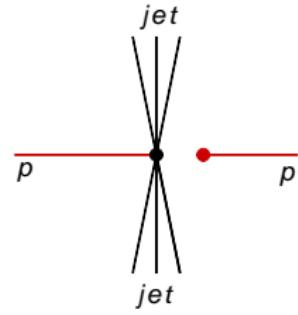


Non-diffractive Production

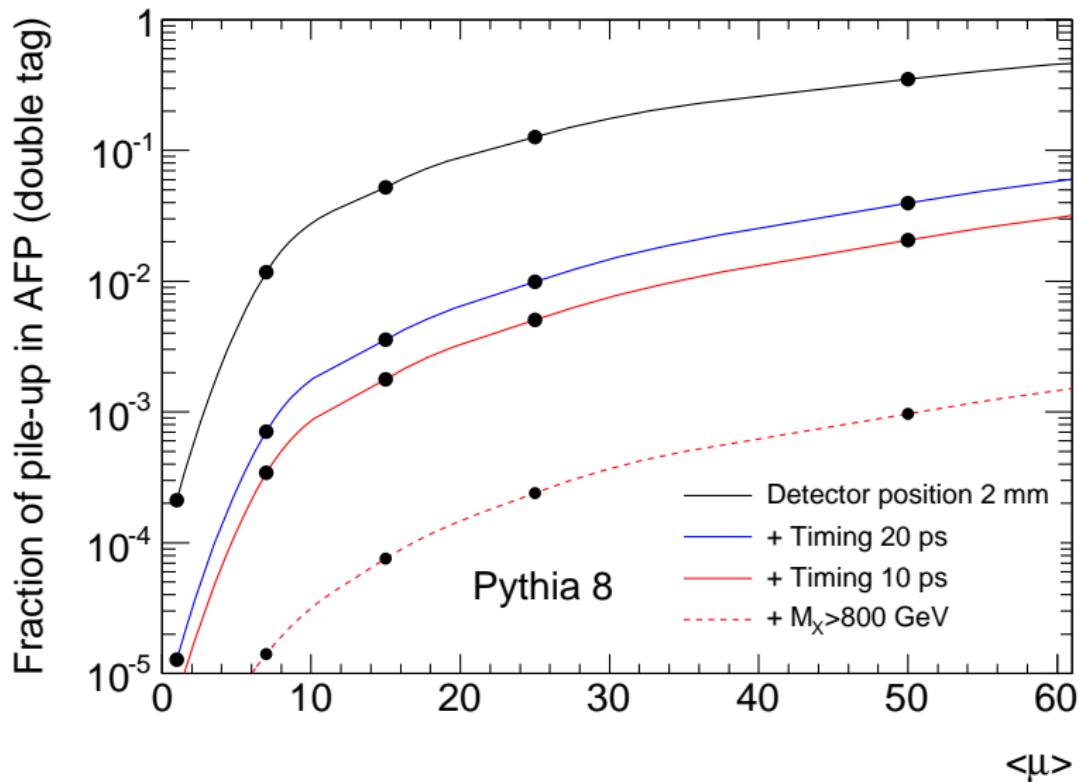
Single-diffractive background +
pile-up.



Single Diffractive Production

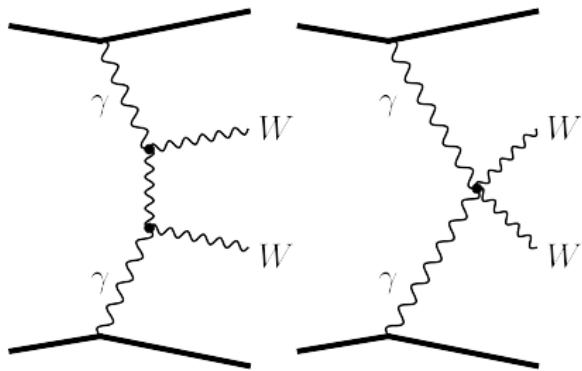


AFP Tag and Timing Cuts



Anomalous Couplings

Motivation: provide stringent test of the electroweak symmetry breaking mechanism.



Additional contribution from BSM Largangian:

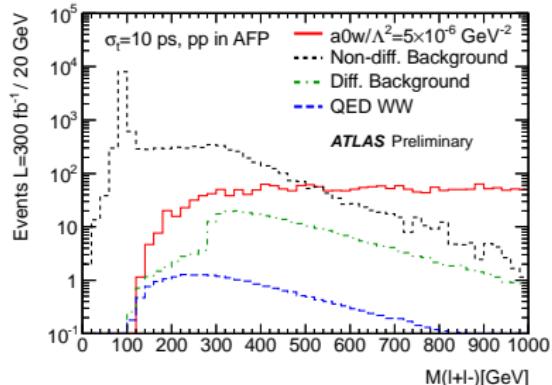
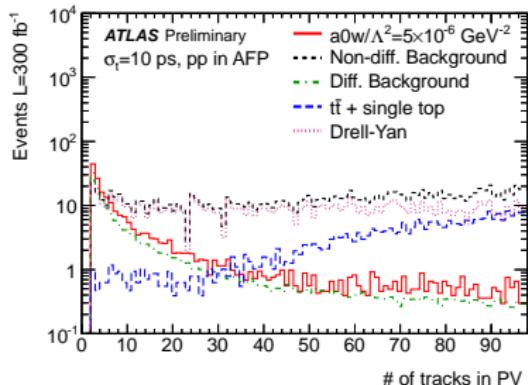
$$\begin{aligned}\mathcal{L}_{\text{eff}}^{\text{BSM}} = & - \frac{e^2}{8} \frac{a_0^W}{\Lambda^2} F_{\mu\nu} F^{\mu\nu} W^{+\alpha} W^{-\alpha} - \frac{e^2}{16} \frac{a_C^W}{\Lambda^2} F_{\mu\alpha} F^{\mu\beta} (W^{+\alpha} W^{-\beta} + W^{-\alpha} W^{+\beta}) \\ & - \frac{e^2}{16 \cos^2 \theta_W} \frac{a_0^Z}{\Lambda^2} F_{\mu\nu} F^{\mu\nu} Z^\alpha Z_\alpha - \frac{e^2}{16 \cos^2 \theta_W} \frac{a_C^Z}{\Lambda^2} F_{\mu\alpha} F^{\mu\beta} Z^\alpha Z_\beta\end{aligned}$$

QGC – Backgrounds and Selection Cuts

Backgrounds:

- non-diffractive (+ pile-up): WW , WZ , ZZ , Drell-Yan, $W/Z + \text{jet}$, $t\bar{t}$, single top,
- diffractive: QED \parallel , SD WW , DPE WW , DPE \parallel .

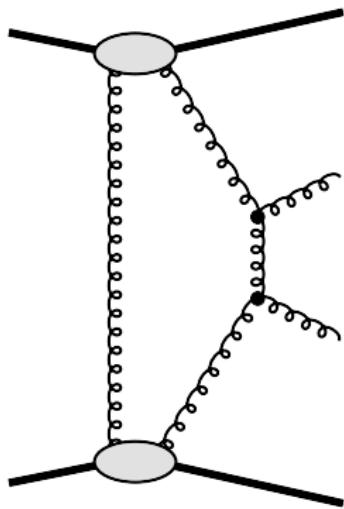
Due to AFP tag and timing + ATLAS selection cuts are enough to significantly suppress background.



	a_0^W/Λ^2 Sensitivity	
	5σ	95% C.L.
$\mathcal{L} = 40 \text{ fb}^{-1}, \mu = 23$	$5.5 \cdot 10^{-6}$	$2.4 \cdot 10^{-6}$
$\mathcal{L} = 300 \text{ fb}^{-1}, \mu = 46$	$3.2 \cdot 10^{-6}$	$1.3 \cdot 10^{-6}$

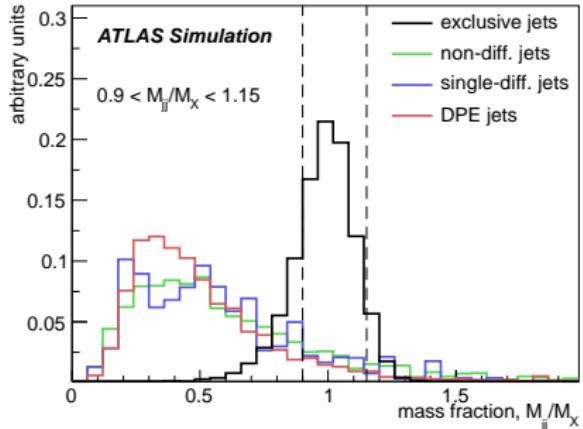
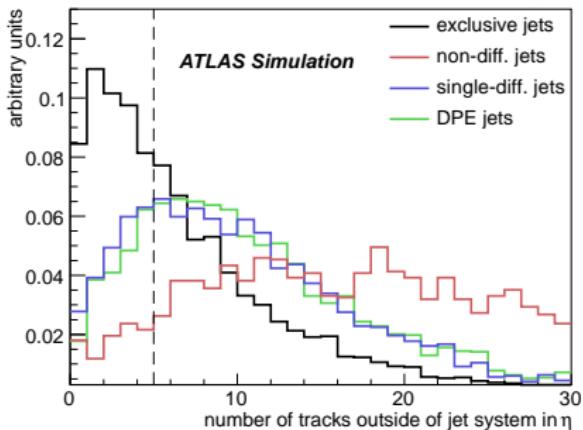
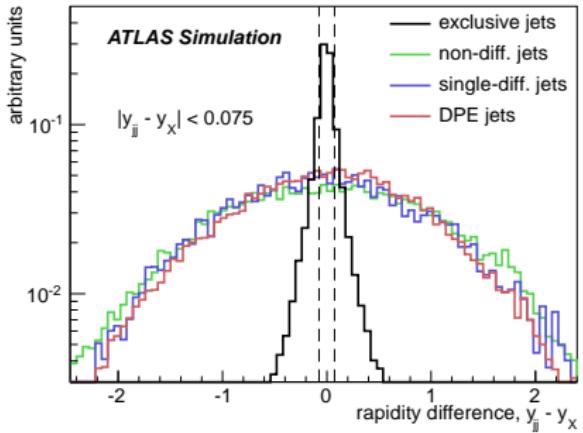
Exclusive Jet Production

Signature: two jets in central region + two intact protons
+ gap in rapidity between jet and proton (no remnants).



- Theoretical description – KMR model.
- No Pomeron remnants.
- Measure cross-section.
- Constrain theoretical models.

Exclusivity Cuts



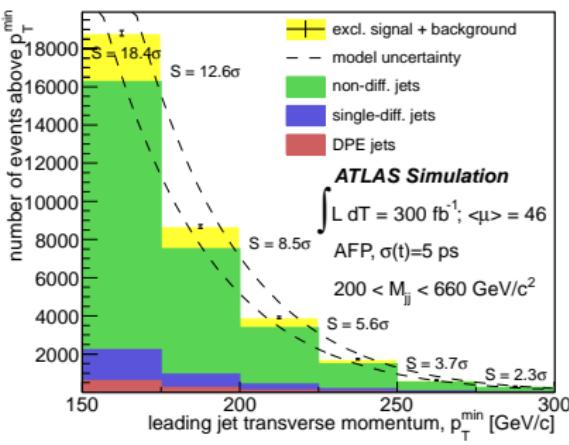
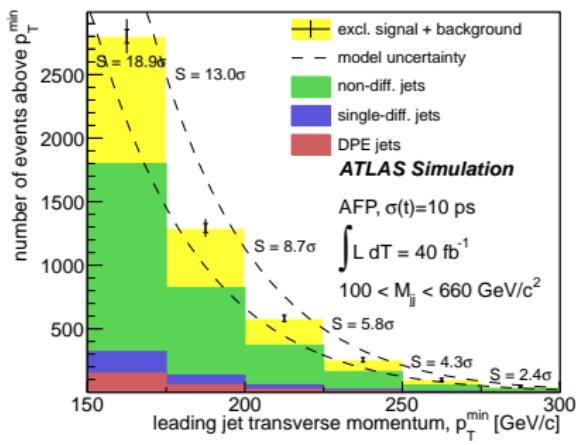
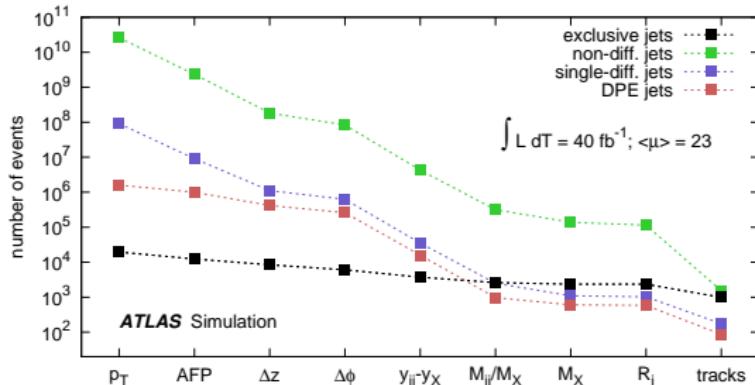
Correlations between central state and protons in:

- rapidity,
- mass.

Number of tracks outside the jet system.

Results

All exclusivity cuts
needed.



Summary

① ALFA:

- very low luminosity runs ($\int Ldt \sim 1 \text{ nb}^{-1}$),
- very small pile-up ($\langle \mu \rangle \sim 0.01$),
- only process with high cross-section ($\sim \text{mb}$).

② AFP:

- low pile-up programme:
 - moderate luminosity runs ($\int Ldt \sim 100 \text{ pb}^{-1}$),
 - small pile-up ($\langle \mu \rangle \sim 1$),
 - hard Single Diffraction and Double Pomeron Exchange,
- high pile-up programme:
 - high luminosity runs ($\int Ldt \sim 100 \text{ fb}^{-1}$),
 - large pile-up ($\langle \mu \rangle \sim 50$),
 - exclusive production, two-photon physics, BSM.