First AFP results

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on behalf of the AFP collaboration

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LHC Working Group on Forward Physics and Diffraction

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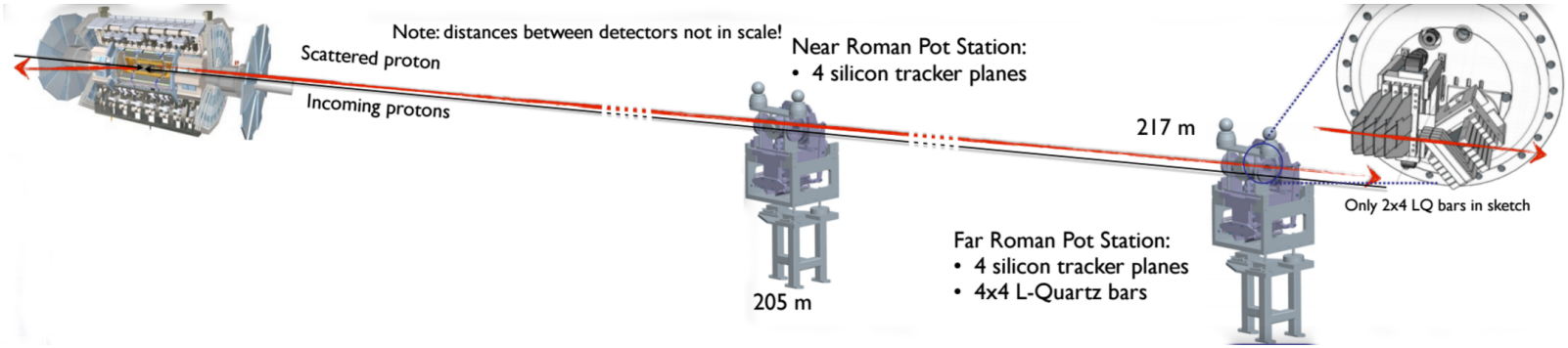
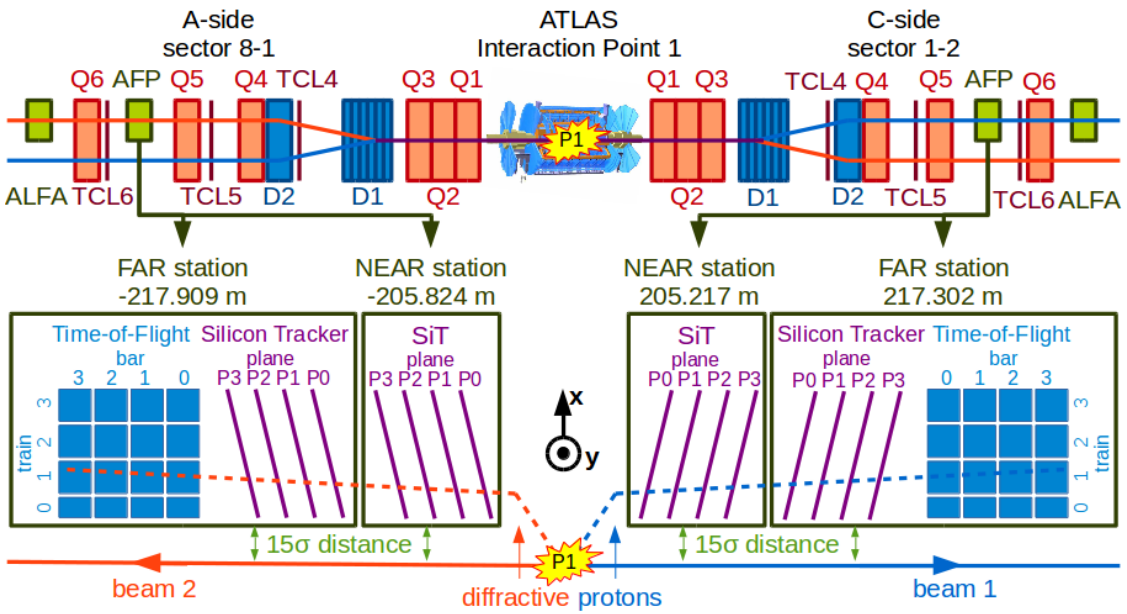
ATLAS Forward Proton detectors





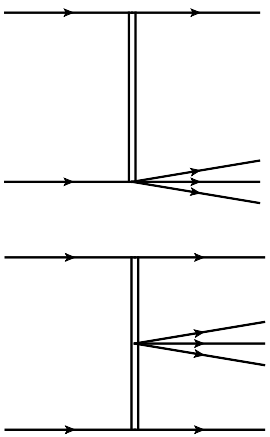
AFP delivers single (one side) and double (both sides) proton tags for ATLAS

AFP programme

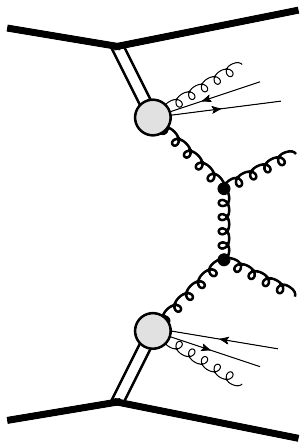
Physics motivation:

- general properties of diffractive events
- structure and universality of the pomeron
- testing QCD description of diffraction
- proton structure (GPD)
- rescattering effects (gap survival probability)
- searches for new physics

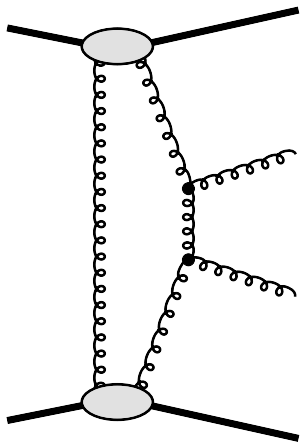
Classes of processes to be studied:



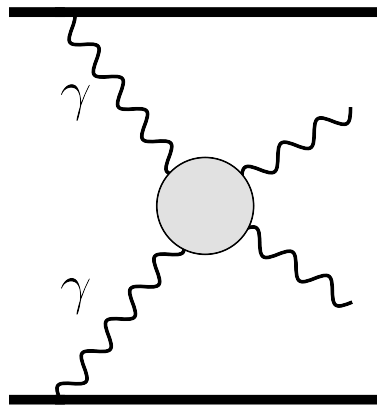
inclusive (soft) diffraction



hard diffraction



exclusive diffraction



two-photon processes

Programme for special runs

Possible measurements

Properties of diffractive events:

- proton kinematics
- central tracks
- rapidity gaps
- energy flow
- studies of non-intact protons

Hard diffraction:

- jets, jet–gap–jet, γ + jet
- heavy quarks
- Drell-Yan, W
- pomeron structure
- gap survival probability

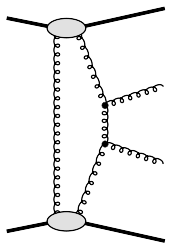
Running conditions

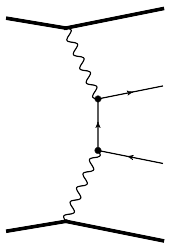
- nominal LHC optics (low β^*)
- reduced pile-up (e.g. by beam separation)
- L1 AFP trigger crucial for all measurements

Programme for standard LHC runs

Standard-Model physics

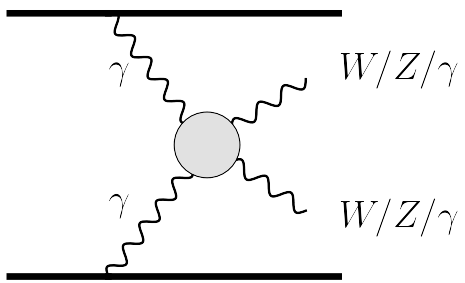
- exclusive jets
- $\gamma\gamma \to ll$ (single tag)





Searches for new physics

- virtual BSM particles in $\gamma\gamma \to \gamma\gamma$
- virtual BSM particles in $\gamma\gamma \to WW$
- virtual BSM particles in $\gamma\gamma \to ZZ$
- resonances in exclusive jets
  (not yet studied in detail)



Running conditions

- standard high-luminosity runs
- AFP L1 trigger needed for exclusive jet measurement
  (allows using lower p_T threshold $\to$ increase triggering efficiency)
- HLT triggers exploiting exclusivity

AFP triggering strategy

AFP Trigger

- high $\mu \rightarrow$ ToF detector (low dead time, only in far stations)
- low $\mu \rightarrow$ tracking detector (dead time of $\sim$ 10 BX, allows triggering on coincidence between near and far stations)
- different topologies: near (only low μ), far, near+far (only low μ), left, right, left+right

Physics data stream

- Event = AFP $\oplus$ ATLAS
- Rates limited by large size of information from ATLAS
- Triggered by AFP or ATLAS

AFP callibration data stream

- Event = AFP
- Possible to store higher rates (tens of kHz)

Data

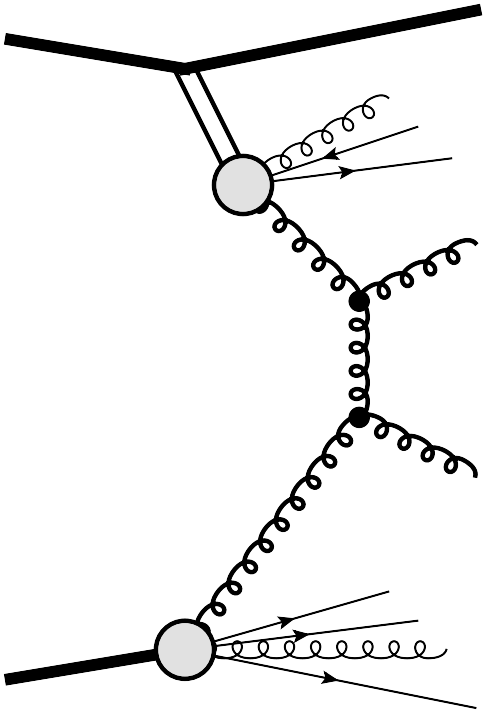
2016

- $\sqrt{s} = 13$ TeV, $\beta^* = 0.4$ m
- Only two stations installed (one side)
- Only single tagged events
- Data taken during BBA:
  - two runs
  - closer to the beam than during standard running
  - very useful for alignment and optics studies
- Data taken during special runs:
  - $\mu \sim 0.03$:
    - int. lumi.:$\sim$40 nb^{-1}
    - main goal: soft diffraction
  - $\mu \sim 0.3$:
    - int. lumi.:$\sim$500 nb^{-1}
    - main goal: low-p_T jets
- Data taken during standard runs:
  AFP was inserted only when the number of bunches was not greater than 600 (ramp-up)

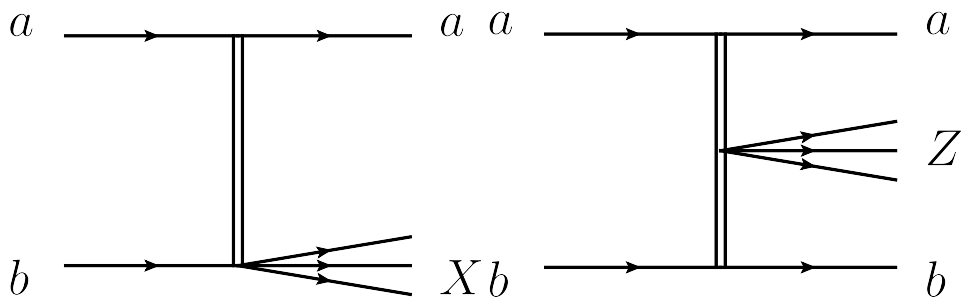
2017

- $\sqrt{s} = 13$ TeV, $\beta^* = 0.3$ and 0.4 m
- Full system ready
- Single and double tagged events
- Data taken during BBA:
  - two runs
- Data taken during special runs:
  - $\mu \sim 0.05$:
    - int. lumi.:$\sim$65 nb^{-1}
    - main goal: soft diffraction
  - $\mu \sim 1$:
    - int. lumi.:$\sim$640 nb^{-1}
    - main goal: low-p_T jets
  - $\mu \sim 2$:
    - int. lumi.:$\sim$150 pb^{-1}
    - goals: hard diffraction
- Data taken during standard runs:
  AFP was inserted on regular basis, usually few minutes after stable beams were declared

Kinematics of diffractive event



- ξ – momentum fraction lost by proton (carried by pomeron)
- t – squared four-momentum transferred from proton
- β – fraction of pomeron momentum carried by the interacting parton
- M_X – diffractive mass

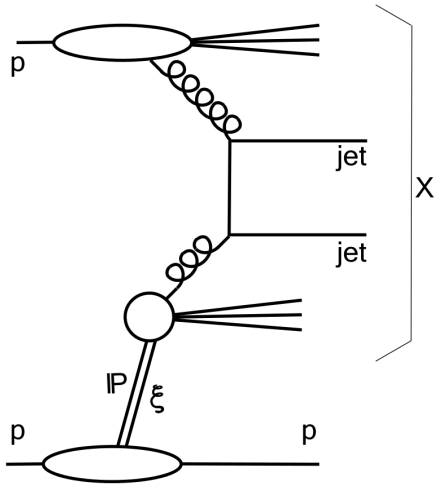


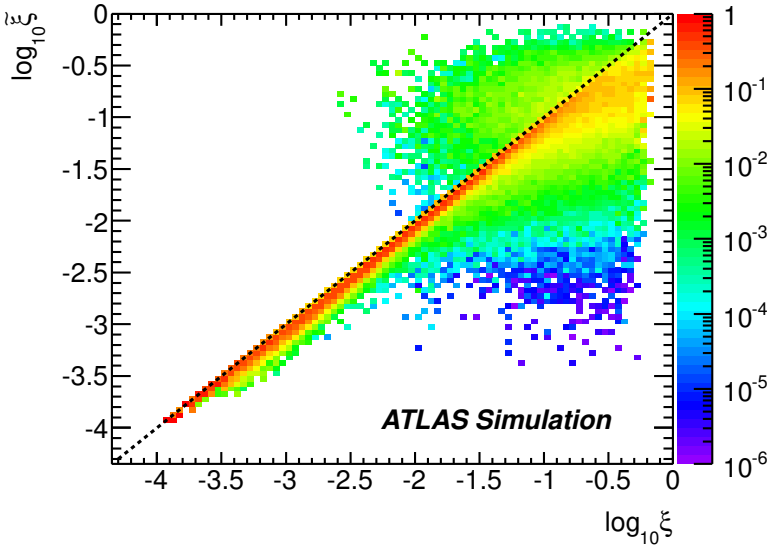
$M_X^2 = s\xi$ $\qquad$ $M_X^2 = s\xi_1\xi_2$

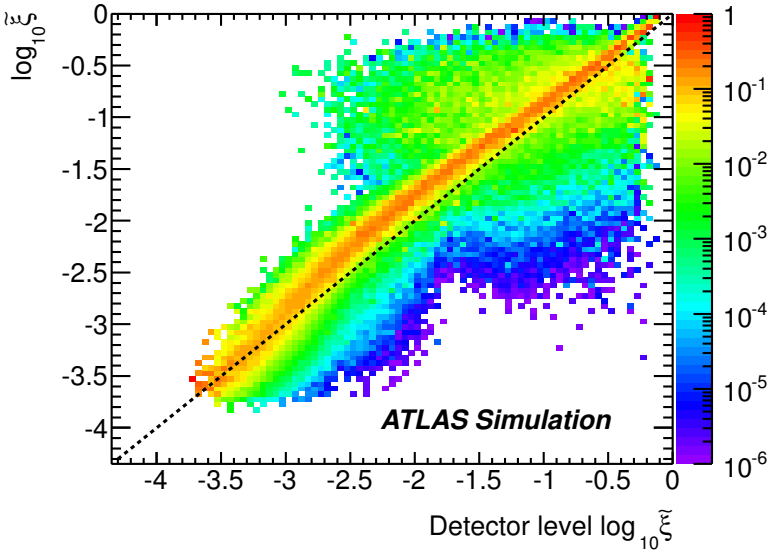
ξ_{cal}

- Proton energy loss and diffractive mass

$$\xi = M_X^2/s \qquad \xi_{\text{cal}} = \tilde{\xi} = \frac{\sum p_T e^{\pm\eta}}{\sqrt{s}}$$

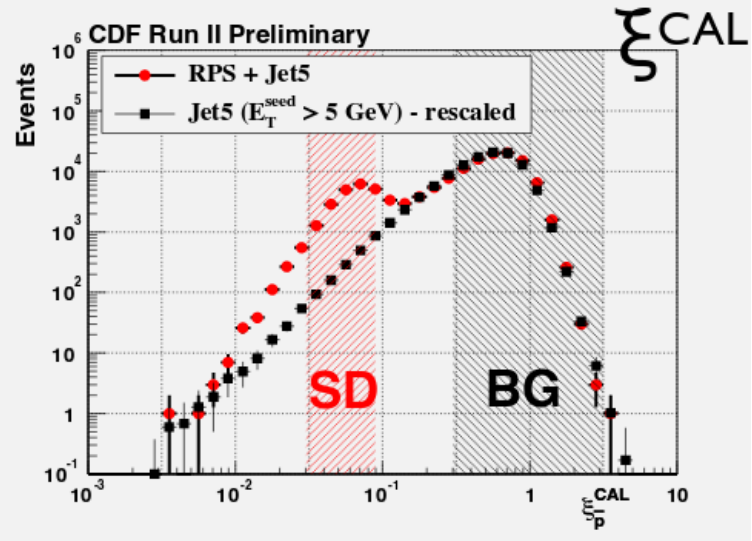


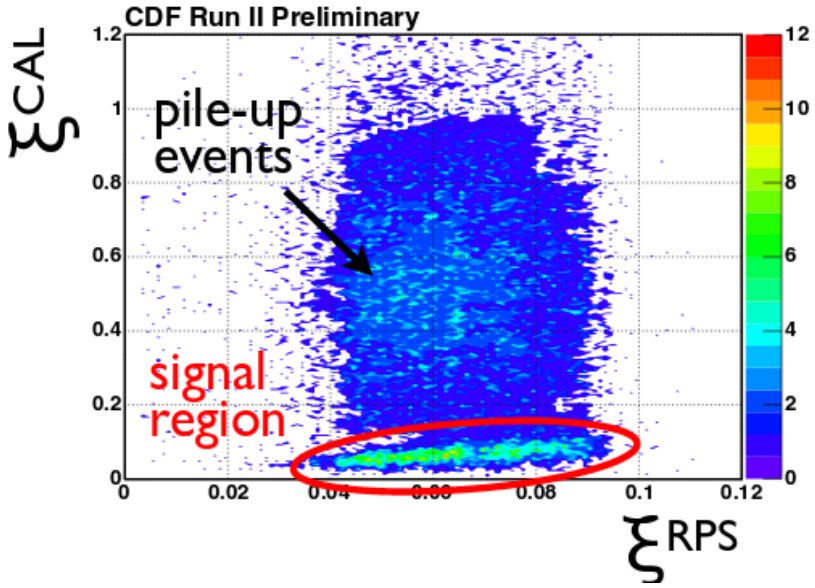




(simulations for $\sqrt{s} = 7$ TeV, Phys. Lett. B 754 (2016) 214)

Diffractive jets in CDF





PRD 86, 032009 (2012)

Sample triggered by forward proton detectors was dominated by pile-up related backgrounds already at the Tevatron!

Data sample used in AFP analysis

Special run taken in October 2016, μ ∼ 0.3, $\beta^* = 0.4$ m

Trigger:

- signal sample – triggered with AFP (SiT, near and far)
- background sample – triggered with minimum bias trigger

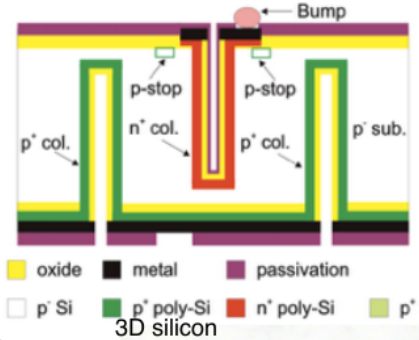
Event selection:

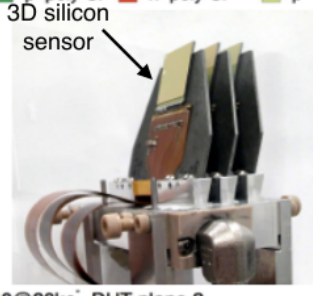
- at least one jet with $p_T > 20$ GeV and $|\eta| < 3$
- exactly one reconstructed primary vertex
- at least two tracks associated with vertex
- for signal sample – clean signal in AFP (no more than one cluster in each plane, at least 5 planes with a cluster)

AFP Silicon Tracker

Silicon tracker technology: 3D pixel sensors

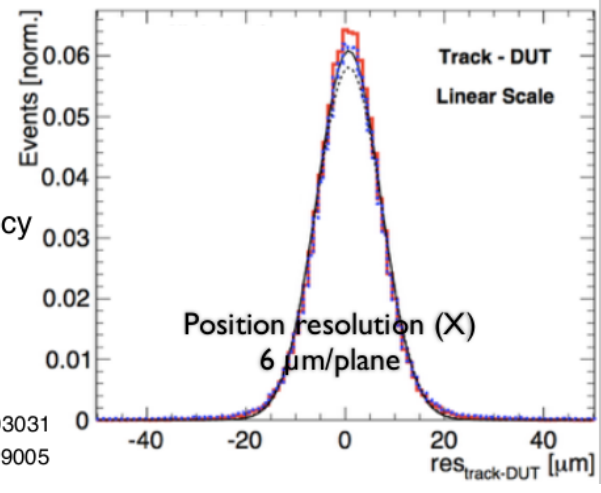
- **Column-like electrodes:** Inter-electrode distance (~67 μm) de-coupled from detector thickness (230 μm)
  - ➡ **Low voltage** for full depletion (~10 V) before irradiation
  - ➡ Shorter drift distance -> Lower trapping probability -> **Radiation hard**
- Use its trigger signal in AFP0+2
- 336x80 pixels with 50x250 μm^2 area each





Tracker qualification: Performance evaluated in various test-beams

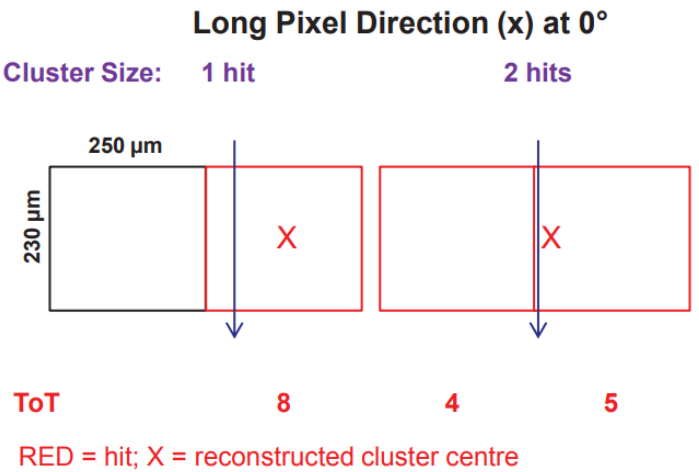
- Measured ~6 μm/plane resolution in short pixel direction
- Able to sustain non-uniform radiation of up to 5x10^{15} n_{eq}/cm^2 (expected in AFP life-span)
- Dead area can be cut down to <150 μm without losing efficiency
  - ➡ Active area as close as possible to the Roman Pot wall

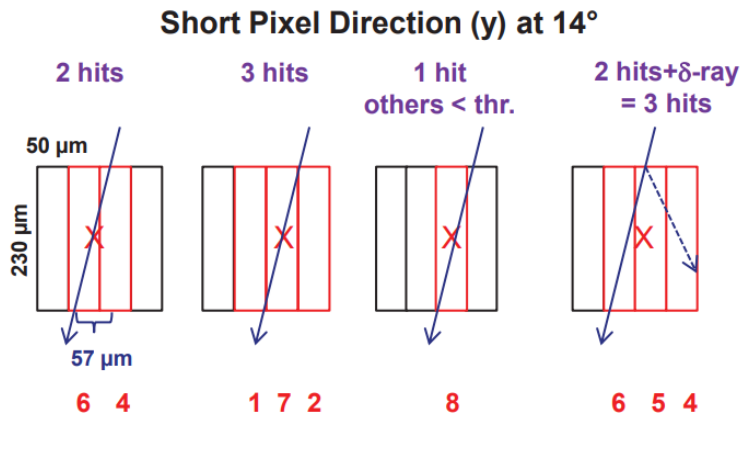


JINST 10 (2015) C03031
JINST 11 (2016) P09005

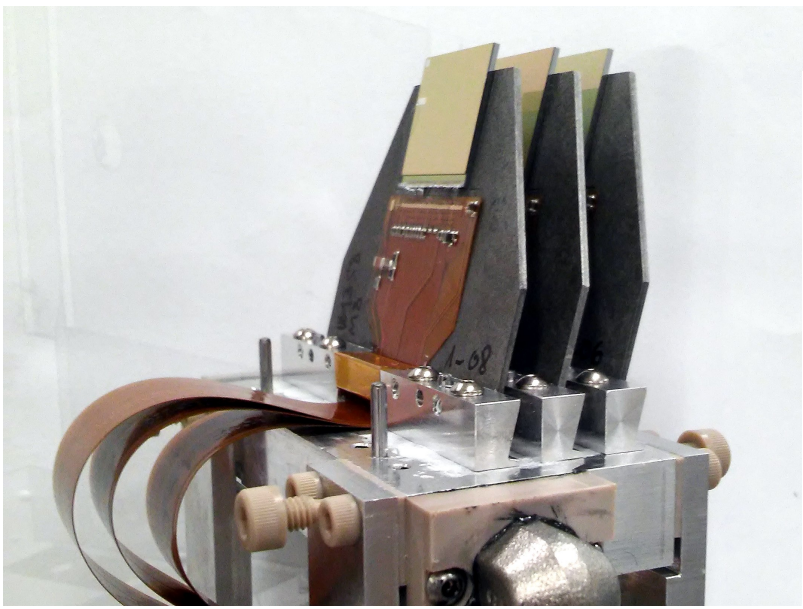
(slide taken from Ivan Lopez Paz)

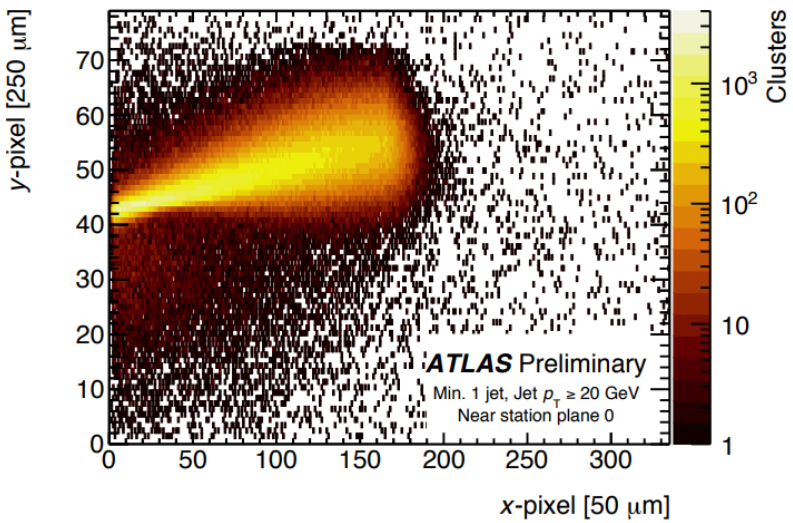
Pixel clusters





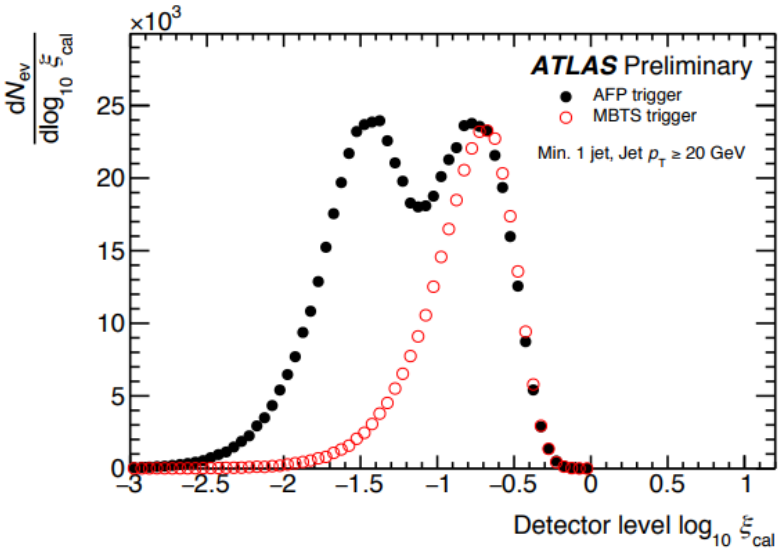
RED = hit; X = reconstructed cluster centre

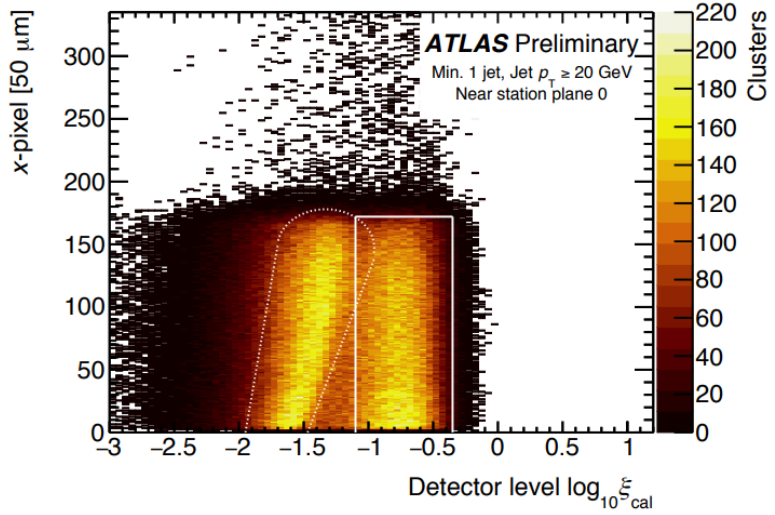




Diffractive events seen in AFP

$$\xi_{\text{cal}} = \frac{\sum p_T e^{\pm\eta}}{\sqrt{s}}$$





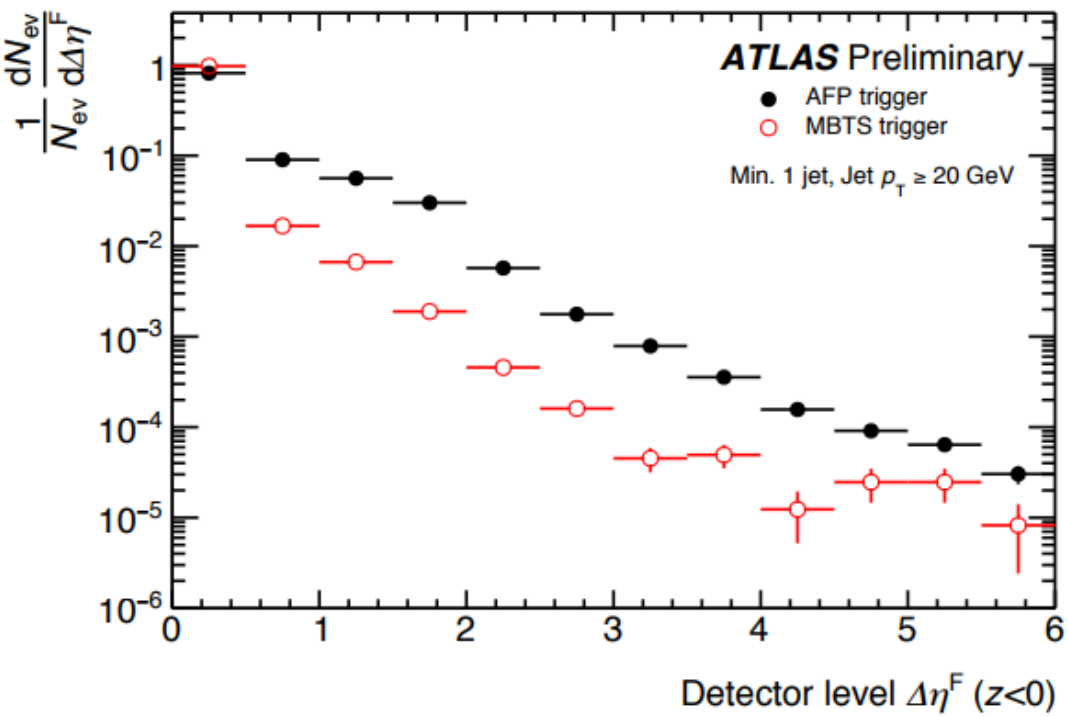
ATL-PHYS-PUB-2017-012

- Presence of diffractive events clearly seen
- Enhancement in the AFP acceptance region
- Overall sample is dominated by pile-up related background

Size of rapidity gap

Rapidity gap based on

- tracks ($|\eta| < 2.5$, $p_T > 200$ MeV)
- calorimeter cells ($|\eta| < 4.8$)



Signal sample enriched with events with rapidity gaps

Summany and conclusions

- Large amount of data taken with AFP
- Standard runs – exclusive processes, new physics
- Special runs – diffraction (non-exclusive)
- First results – diffractive jets with proton tagged by AFP
- Even at small μ, jet+AFP sample dominated by pile-up background
- Present activities:
  - Improving understanding of background
  - Proton kinematic reconstruction