

# Preparation for a measurement of diffraction processes in the ATLAS experiment

## Research task

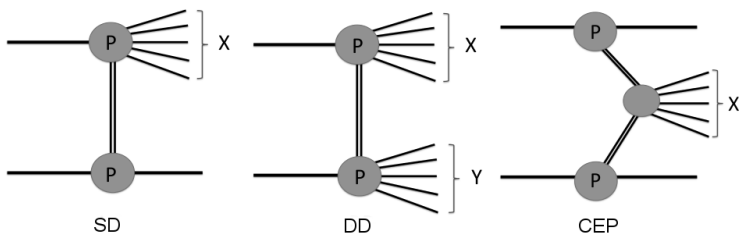
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# Diffraction

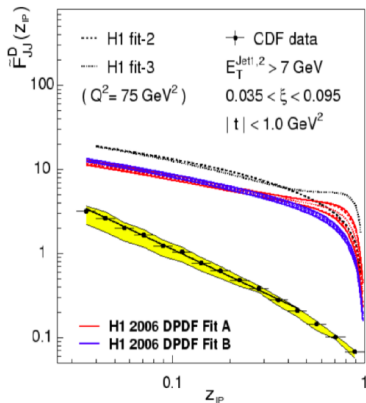


- **Single diffraction** - most frequent, one of the  $p$  rescattered, other one dissociates into the system X, LRG present
- **Double diffraction** - both protons are dissociated into hadronic systems
- **Central diffraction** - double pomeron exchange and central exclusive production

- Pomeron - object carrying quantum numbers of vacuum, colorless
- Processes with small transferred momenta - **soft scale**
  - ▶ Phenomenological models based on Regge theory
- Processes with large momentum transfer - **hard scale**
  - ▶ pQCD can be used
  - ▶ Pomeron = composed object with an inner structure
  - ▶ Diffractive parton distribution functions (DPDF)
  - ▶ Cross-section of a certain process:

$$d\sigma = \sum_i f_i^D(x, Q^2, \xi, t) * d\sigma_i(x, Q^2)$$

$$f_i^D(x, Q^2, \xi, t) = f_{\mathbb{P}}(\xi, t) \cdot f_i^{\mathbb{P}}(x, Q^2)$$



- Factorization breaking  $\rightarrow$  DPDFs are not process independent
- Soft survival probability factor  $S^2$
- $S^2 \approx 0.1$  for SD processes with 2 jets at Tevatron, same estimation for the LHC
- CMS measurements -  $S^2(\text{LO}) \approx 0.12 \pm 0.04$  and  $S^2(\text{NLO}) \approx 0.08 \pm 0.04$
- ATLAS measurements -  $S^2 \approx 0.16 \pm 0.04(\text{stat.}) \pm 0.08(\text{exp.sys.})$

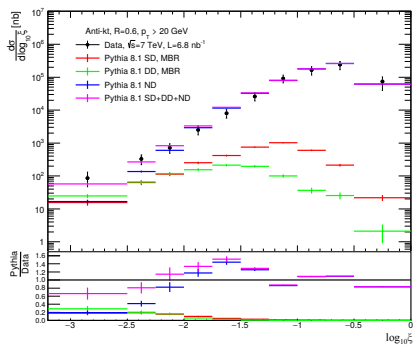
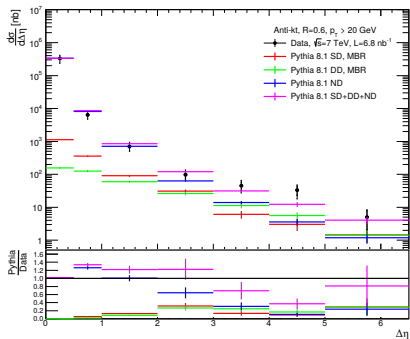
## Comparison of PYTHIA 8 results and the ATLAS data

- Pythia 8.186 and Pythia 8.219, MBR pomeron flux
- At least two jets with  $p_T > 20$  GeV, jet radius  $R = 0.6$ , anti- $k_t$  algorithm
- Inelastic differential cross-section in  $\Delta\eta_F$ 
  - ▶ RG = region in  $\eta$  devoid of:
    - Neutral particles with  $p > 200$  MeV
    - Charged particles with  $p > 500$  MeV or  $p_T > 200$  MeV
- Inelastic differential cross-section in  $\xi$

$$\xi_{det} = \frac{1}{\sqrt{s}} \sum_i p_T^i \exp(\pm\eta_i)$$

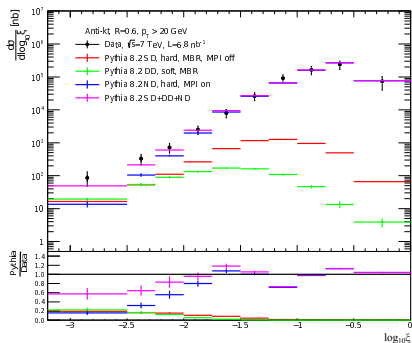
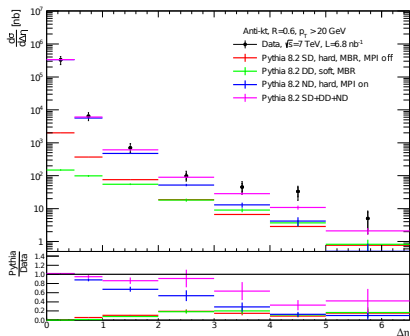
$$\Delta\eta \approx -\ln \xi$$

# Comparison of PYTHIA 8.1 results and the ATLAS data



- Normalization factor 0.75 in ND first bin,  $\sigma_{ND} = (1.3260 \pm 0.0003)$  mb
- Pythia 8.1 results in accordance with the ATLAS data [4]

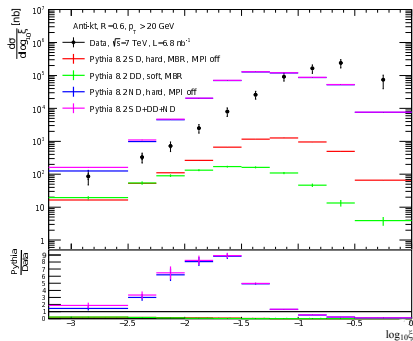
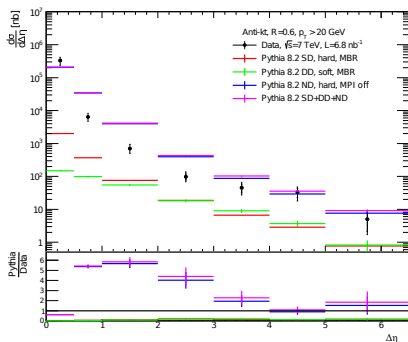
# Comparison of PYTHIA 8.2 results and the ATLAS data



- Normalization factor 0.87 in ND first bin,  $\sigma_{ND} = (1.0950 \pm 0.0004)$  mb
- Exclusive hard SD process with MPI switched off



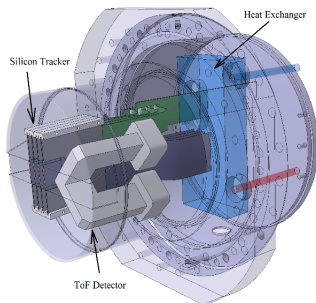
# Comparison of PYTHIA 8.2 results and the ATLAS data



- MPIs for ND component switched off
- Exclusive hard SD process with MPI switched off
- Increased presence of large gaps in ND  $\rightarrow$  MPIs are necessary to provide satisfactory description of the data

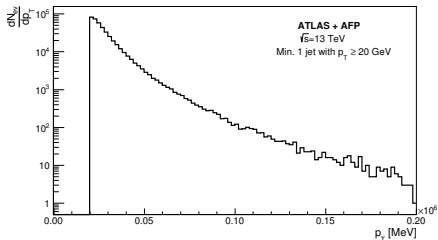
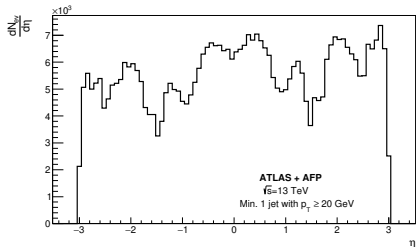
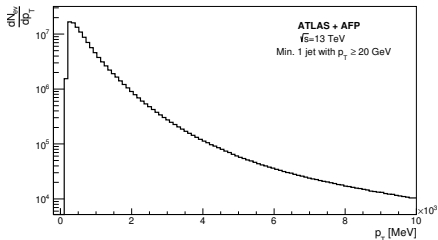
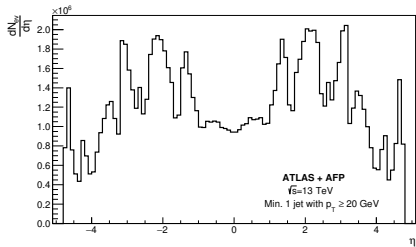
# ATLAS Forward Proton (AFP) detector

- Studies of diffractive processes
- 2 arms, 4 stations in total,  $\pm 206$  m &  $\pm 214$  m from the ATLAS IP
- **Roman pot**
  - ▶ horizontal movement of the detector
  - ▶ 4 Si pixel tracking planes tilted by  $14^\circ$  from y axis
  - ▶ ToF counters in far stations (trigger signal)
- Installed in two stages:
  - ▶ AFP 0+2 (2016) - 2 stations in negative-z, SD processes in low pile-up runs
  - ▶ AFP 2+2 (2017) - other 2 stations + ToF detectors



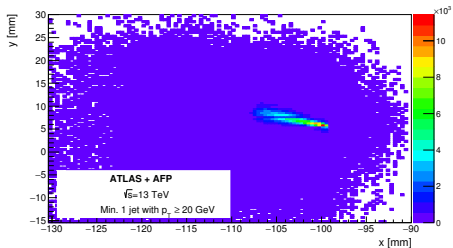
- Run 310216 (October 2016),  $\sqrt{s} = 13$  TeV,
- Low pile-up,  $\langle \mu \rangle \approx 0.3$
- AFP detector at C side ( $z < 0$ ) of the ATLAS
- Data skimmed with HLT\_noalg\_L1AFP\_C\_J12 trigger
- Cuts on event selection:
  - ▶ At least 2 hits per one AFP station & at least 5 hits per AFP arm
  - ▶ Single reconstructed primary vertex
  - ▶ Two associated tracks with  $p_T > 100$  MeV
  - ▶ At least one jet with  $p_T > 20$  GeV and  $|\eta| < 3.0$
  - ▶ Particles reconstructed in calorimeter with  $p_T > 200$  MeV
  - ▶ Anti- $k_t$  clustering algorithm, jet radius  $R = 0.4$
- Final sample contains 328 832 events

# Particle and jet properties

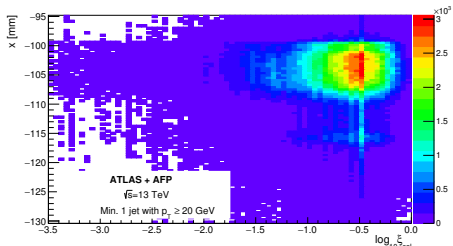


# Tracks in AFP detector

- $(x,y)$ -track position
- Near station ( $z = -206$  m)
- Visible structure with higher multiplicity
- Background contamination

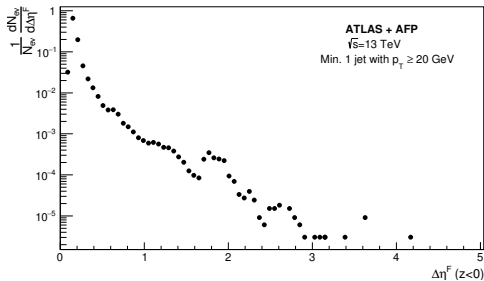


- $\xi$  vs  $x$ -position correlation
- No diffractive structure
- Large ND background and pile-up contribution



## Diffractive characteristics - rapidity gaps

- Uncorrected forward rapidity gap size  $\Delta\eta_{z<0}^F$  distribution
- Edge of the calorimeter acceptance  $\eta < 4.9$
- Exponential tendency towards large  $\Delta\eta_{z<0}^F$
- Visible peak at  $\Delta\eta_{z<0}^F \approx 2$
- No clear tail towards large  $\Delta\eta_{z<0}^F$

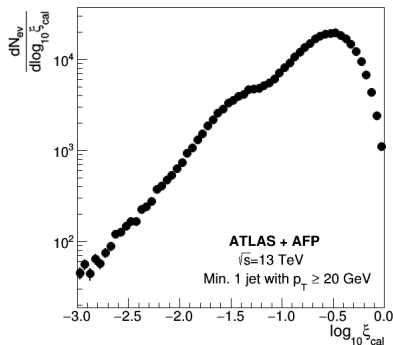
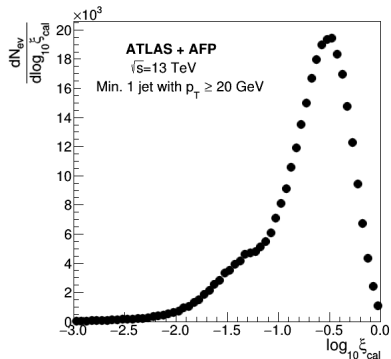


## Diffractive characteristics - $\xi$

- Uncorrected distribution of the detector level  $\xi_{cal}$







$$\xi_{cal} = \frac{1}{\sqrt{s}} \sum_i p_T^i \exp(-\eta_i)$$

- Peak at  $\log_{10} \xi_{cal} \approx -0.5$  from ND contribution
- Evidence of SD peak at large  $\log_{10} \xi_{cal}$
- Sample is still contaminated with ND background and pile-up



- Comparison of the two PYTHIA 8 models with the ATLAS data
  - ▶ Both Pythia 8.1 and Pythia 8.2 satisfactorily describe the data
  - ▶ Generation of exclusive hard single diffractive process
  - ▶ multiparton interactions are essential to provide the correct description of the data
- AFP as the proton tagger at ATLAS detector
  - ▶ Detector level distributions of the events with jets in the final state
  - ▶ Slightly asymmetric  $\eta$  distribution of the jets
  - ▶ Evidence of SD peak in  $\xi_{cal}$  distribution, clear ND peak
  - ▶ No visible correlation of  $\xi_{cal}$  and  $x$ -track position in AFP Near station for SD process
  - ▶ Slight evidence of SD processes identified using the tagged proton in AFP, yet still with large ND background



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