A Study of Diffraction with the ATLAS Experiment

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Introduction and Objective

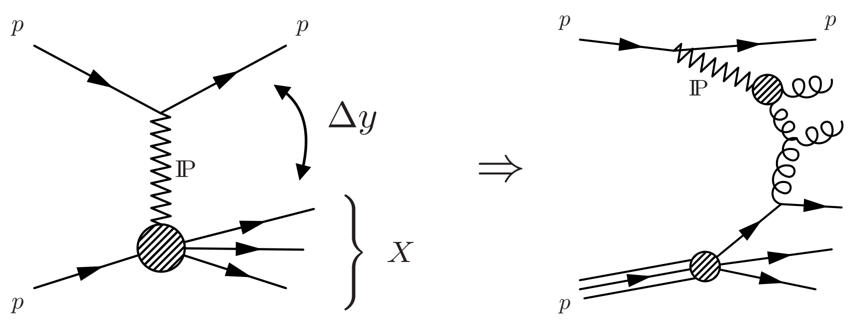
About 25% of all proton-proton collisions at the LHC are classified as diffractive. Diffraction is not well understood and phenomenological models are therefore used in simulations.

The aim of this work is to:

- Study diffractive scattering of high-energy protons, and understand how model parameters affect distributions
- Establish experimental observables which show good sensitivity to model parameters

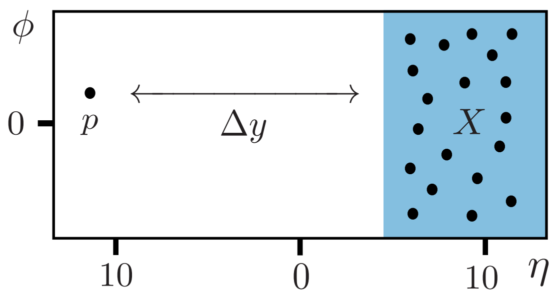
Theory

A diffractive reaction is where no internal quantum numbers are exchanged between the colliding high-energy particles. A definition with more experimental utility is that a diffractive reaction is characterized by one or more large rapidity gap(s) Δy in the final state.



Single diffraction is when one of the colliding protons will be elastically scattered while the other proton will be diffractively dissociated into a system of particles, denoted X. This is illustrated above.

The experimental signature of single diffraction is a large **rapidity gap** between the scattered proton and the system X:



From Regge theory, diffraction happens when the two protons exchange one or more Pomeron(s). A **Pomeron** $\mathbb{P}$ is a mathematical construct and must be a 0^+ color singlet, i.e. have the quantum numbers of vacuum. The Pomeron is considered as having a partonic substructure, as per Ingelman-Schlein (1984), as well as having a parton distribution function, in the form of a **Pomeron Flux factor**:

$$f_{\mathbb{P}/p}(\xi,t) = \frac{\mathrm{d}\sigma^{\mathrm{SD}}/\mathrm{d}\xi\mathrm{d}t}{\sigma_{\mathbb{P}/p}(M_X^2)}$$

t : momentum transfer $\quad\quad$ ξ : relative energy loss of proton

The Pomeron is parameterized in Regge theory by a Pomeron trajectory:

$$\alpha(t) = 1 + \varepsilon + \alpha' t$$

Where an $\varepsilon > 0$ results in a rising total cross-section: $\sigma_{\mathrm{tot}} \sim s^{\alpha(0)-1}$

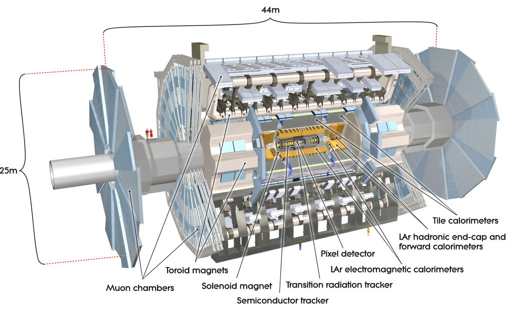
The Pomeron flux factor cannot be calculated from first principles, but it can be modelled to first approximation as:

$$f_{\mathbb{P}/p}(\xi,t) \approx \frac{1}{\xi}\exp(Bt)$$

B : energy-dependent parameter which will include $\alpha(t)$

Pythia 8 will be used to generate proton-proton events. In Pythia 8 we can vary the form of $f_{\mathbb{P}/p}$ as well as the values of ε and α'

The ATLAS and ALFA Detector

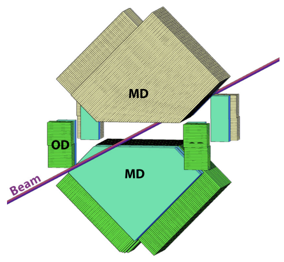


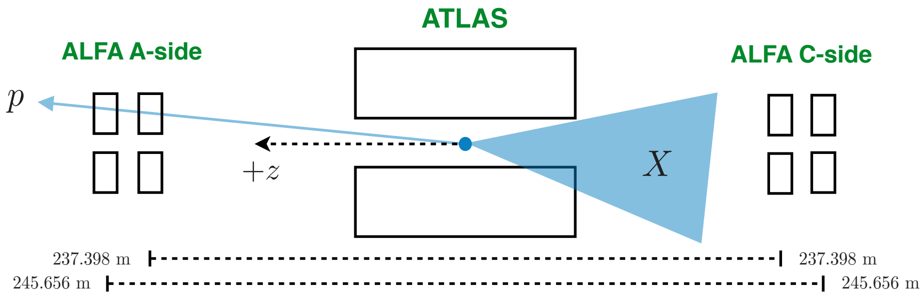
The ATLAS detector is used to measure the particles from the dissociated system X.

This means that ATLAS can be used to find the invariant mass M_X and the rapidity gap Δy

The ALFA detector stations are located about 240 m away from ATLAS down the beam pipe.

The ALFA detector can measure elastically scattered protons with a small momentum transfer t, i.e. a small scattering angle.

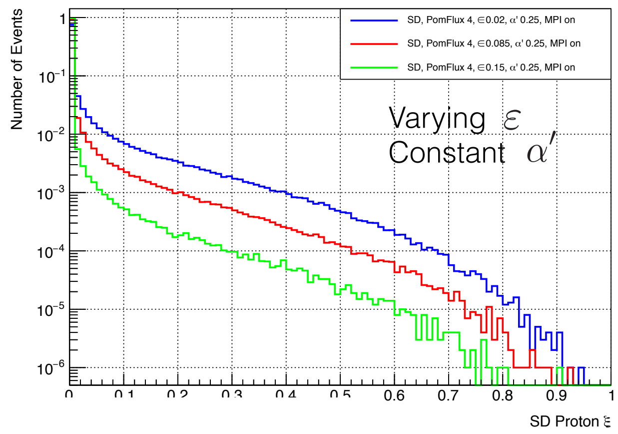


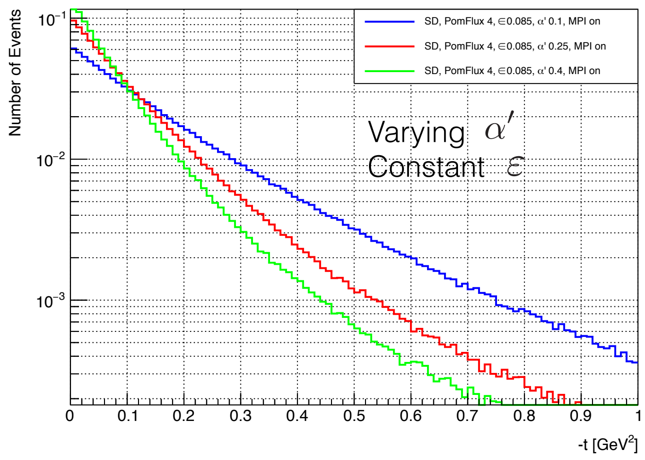


Results from Simulations

The following observables was found to be sensitive to ε:

- Relative energy loss ξ (See right plot)
- Invariant mass M_X
- Multiplicity
- Rapidity gap Δy





The following observables was found to be sensitive to α':

- Low values of -t (See left plot)
- Rapidity and polar angle of elastically scattered proton

Plots done for Monte Carlo truth

Outlook

- Following the simulation study, the next step is to analyse the new data from 2015 at a center-of-mass energy of $\sqrt{s} = 13$ TeV at ATLAS and ALFA at the LHC accelerator
- Investigate the validity of the phenomenological models and their parameters

Done in collaboration with Jørgen Beck Hansen, Torbjörn Sjöstrand, Christine Rasmussen, Simon Stark Mortensen, and Sune Jakobsen

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