Simulation of diffractive jet production processes in pp collisions at the LHC

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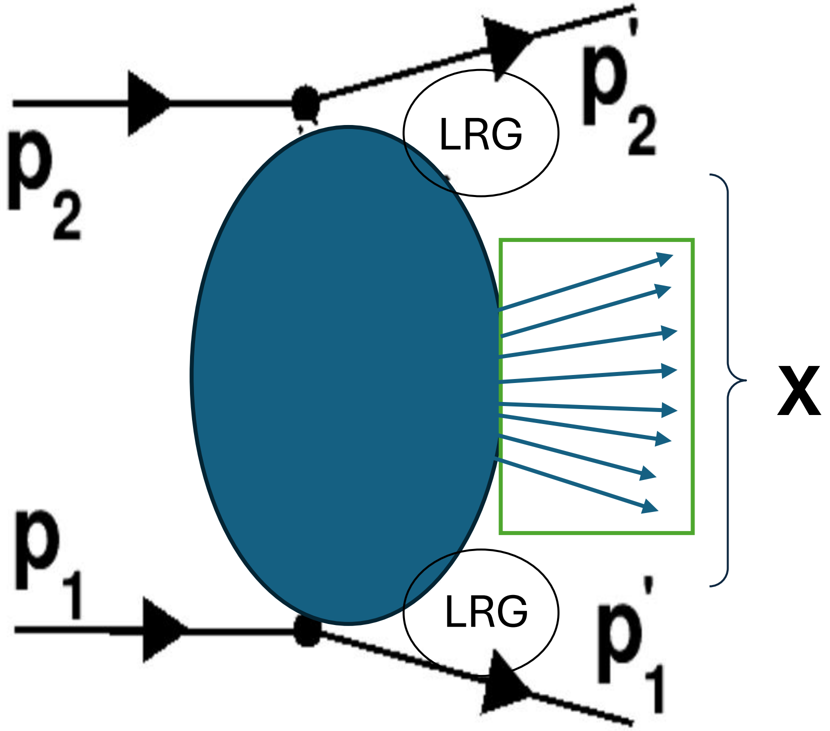
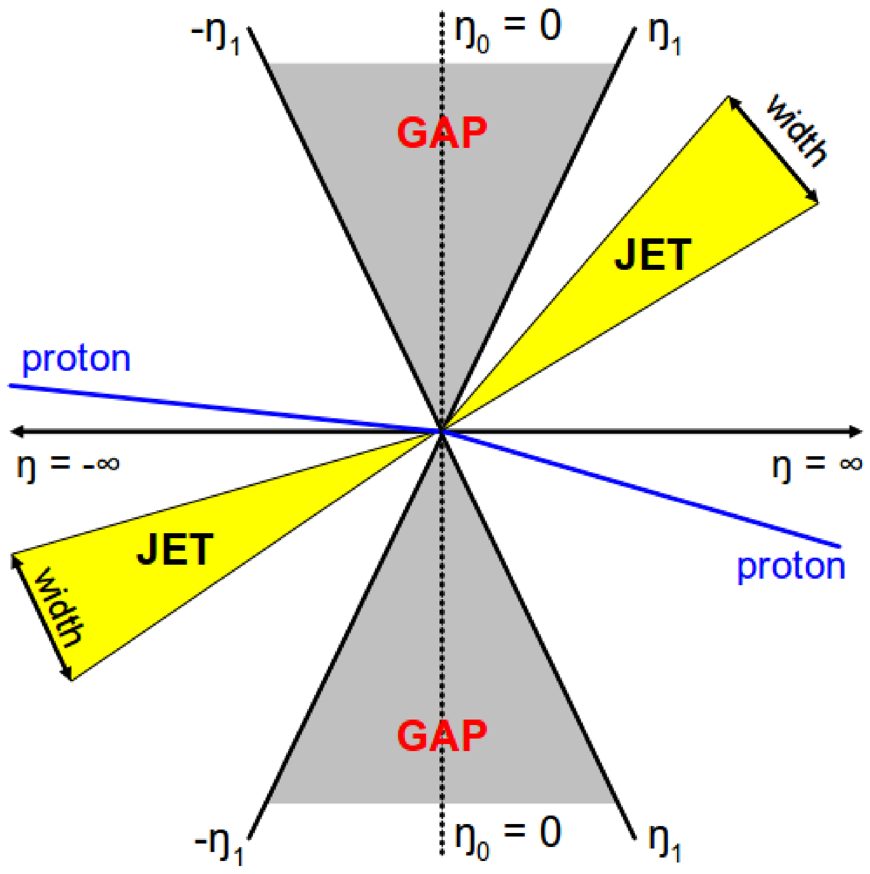
Diffractive processes



Feynam diagram of general diffractive process

- pp events with hard scale and intact leading proton in final state: pp -> pXp
- forward proton carries large fraction of init. momentum
- typical large rapidity gap (LRG) between proton and X system
- measured in fwd. detectors (now AFP) the only viable option at LHC energies to tag diffraction
- preferably at low pile-up, unless ToF is utilised

Diffractive processes



LRG in pseudorapidity plane

- pp events with hard scale and intact leading proton in final state: pp -> pXp
- proton carries large fraction of init. momentum and stays intact
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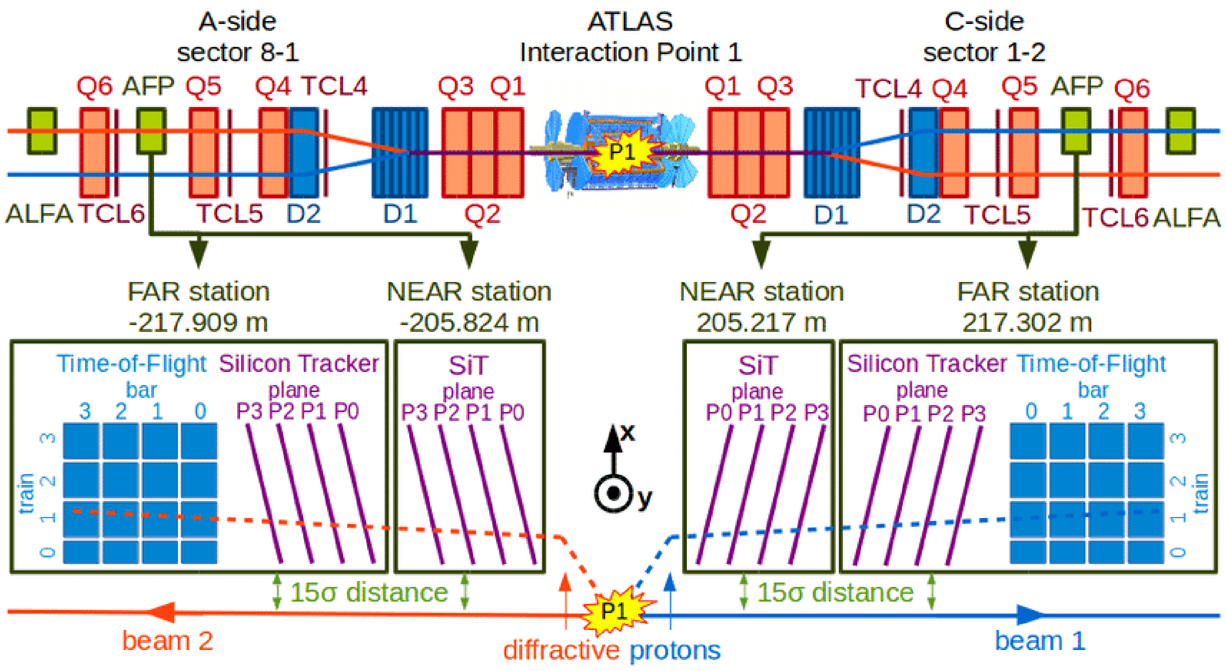
Diffractive processes



Layout of the ATLAS and AFP detectors

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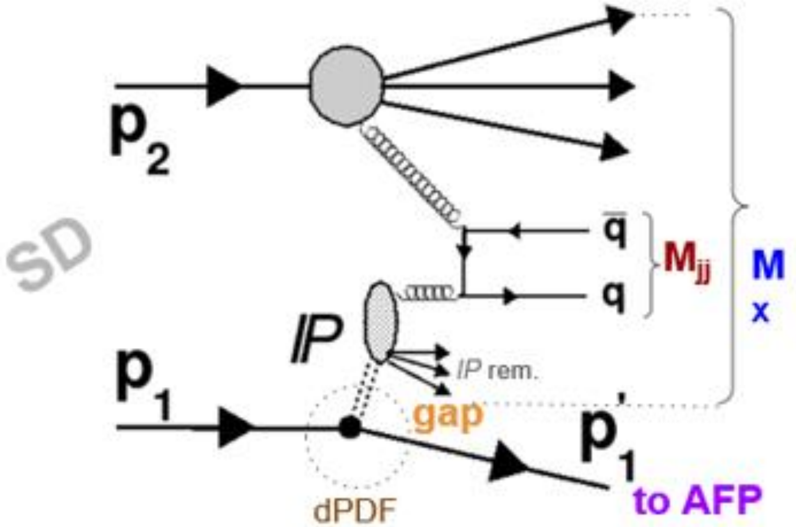
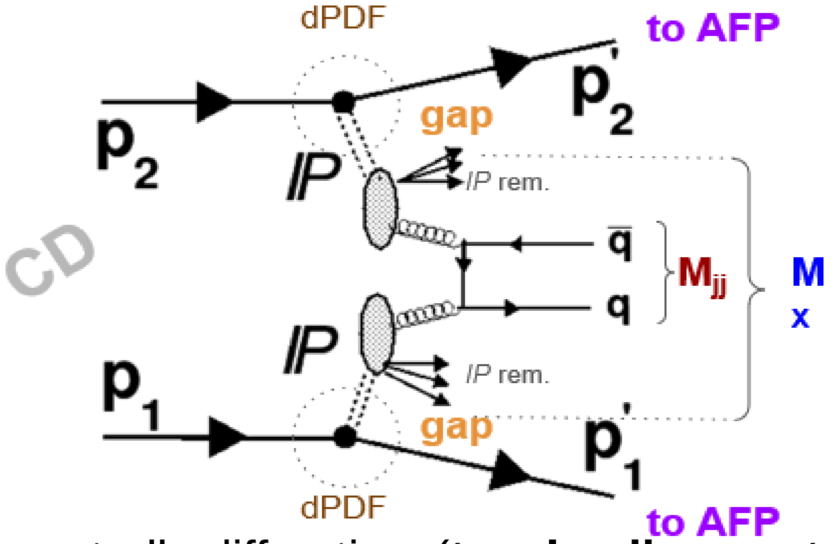
Topologies of interest



SD: single diffractive (**one leading proton**)



CD: centrally diffractivec(**two leading protons)**

- described by colourless exchange: Pomeron (IP) -> partonic object (Ingelman-Schlein) proton PDFs under diffractive constraint
- exclusive production, CD with all pomeron energy transfer in to the hard process (no remnants)
- hard factorization employed

$$\sigma_{(p_1 p_2 \to p_1{'} + X + p_2{'})} = \int \mathrm{d}\xi_1 \mathrm{d}\xi_2 \int \mathrm{d}\beta_1\, d\beta_2\; \mathrm{f}_{\mathrm{P}/p}(\xi_1)\, \mathrm{f}_{\mathrm{P}/p}(\xi_2)\, \mathrm{f}_{\mathrm{a}/P}(\beta_1)\, \mathrm{f}_{\mathrm{a}/P}(\beta_2)\, \hat{\sigma}_{(\mathrm{ab}\to\mathrm{X})}$$

Progress in simulations

Event generation

- Mad Graph -> hard processes of CD (custom modification for reaching higher energies)
- Pythia -> hadronization of CD + SD + ND as background
- Delphes -> detector response simulation

Analysis

- jet cuts (Pt, eta ,...), single tag or double tag
- possible approaches:

different beam energies (5.1TeV, 13.6 TeV)

different pileups (0, 1, 5, 10, 50)

Summary

What is finished

- MG modification
- event generation (CD, SD, ND) via MC and Pythia
- detector response simulations using Delphes

To be done and explored

- different approaches in analysis
- measurent of cross sections
- discusion about other possible factors influencing the cross section

Thank you for your attention

Back up slides

Factorization formula

$$\sigma_{(p_1 p_2 \rightarrow p_1{}' + X + p_2{}')} = \int d\xi_1 d\xi_2 \int d\beta_1\, d\beta_2\ f_{P/p}(\xi_1)\, f_{P/p}(\xi_2)\, f_{a/P}(\beta_1)\, f_{a/P}(\beta_2)\, \hat{\sigma}_{(ab\rightarrow X)}$$

- where ξ_1 and ξ_2 are the momentum fractions of the protons carried by the Pomerons.
- β_1 and β_2 are the momentum fractions of the Pomerons carried by their constituent partons.
- $f_{P/p}(\xi_1)\, f_{P/p}(\xi_2)$ is the Pomeron flux factor, describing the probability of emitting a Pomeron with momentum fraction ξ_i from a proton.
- $f_{a/P}(\beta_1)\, f_{a/P}(\beta_2)$ is the parton distribution function within the Pomeron, describing the probability of finding a parton aaa inside a Pomeron with momentum fraction β_i.
- $\hat{\sigma}_{(ab\rightarrow X)}$ is the hard scattering cross-section for the parton-level process $p_1 p_2 \rightarrow p_1{}' + X + p_2{}'$
- https://arxiv.org/pdf/hep-ph/0305186

$$\left(\frac{d\sigma_{DPE}}{d\eta_{boost}}\right)_{jj} = \sum_{a,b,c,d} \int 2d\eta^* \int dE_T^2 \int \beta_a f_{\mathbb{P}}(\beta_a, \mu^2)\ g_N(\xi_p)\ d\xi_p \int \beta_b f_{\mathbb{P}}(\beta_b, \mu^2)\ g_N(\xi_{\bar{p}})\ d\xi_{\bar{p}}\ \left(\frac{d\hat{\sigma}_{ab\rightarrow cd}}{d\hat{t}}\right)_{jj}$$

Possible effects influencing cross section

1. Probability of Gap Survival

- The probability of gap survival is the likelihood that the rapidity gaps remain intact without being filled by secondary particles from additional interactions. Several factors influence this probability:
- **Multiple Parton Interactions (MPI):** In high-energy collisions, multiple parton interactions can occur, which may fill the rapidity gaps with particles. The higher the energy, the higher the probability of MPI, which can reduce the gap survival probability.
- **Impact Parameter:** The distance between the centers of the colliding hadrons affects the likelihood of additional interactions. Collisions with smaller impact parameters (head-on collisions) are more likely to have multiple interactions, thus lowering the gap survival probability.
- **Underlying Event Activity:** The general activity in the event, which includes everything besides the hard scatter, can influence the survival of the gaps. A higher underlying event activity can decrease the gap survival probability.

2. Energy Dependence

- **Higher Energies:** At higher collision energies, the cross section for DPE processes generally increases due to the higher probability of Pomeron exchanges.
- **Pomeron Trajectory:** The energy dependence of the Pomeron exchange is described by the Pomeron trajectory, which affects the growth of the cross section with energy.

3. Diffractive Parton Distribution Functions (DPDFs)

- **DPDFs:** These functions describe the probability of finding a parton within a Pomeron, which in turn influences the cross section of the diffractive process.
- **Factorization:** The factorization of the cross section into a partonic cross section and DPDFs can be affected by the dynamics of the Pomeron and its interaction with the proton.

4. Pomeron Flux

- **Pomeron Flux Factor:** This factor describes the distribution of Pomerons in the proton and is dependent on the momentum fraction carried by the Pomeron.
- **Normalization and Shape:** The normalization and shape of the Pomeron flux factor influence the overall cross section for DPE processes.

Benefits of increasing the energy

Understanding Energy Dependence

- **Validation of Theoretical Models:** By comparing simulation results with experimental data, researchers can validate or refine theoretical models of Pomeron exchange and diffractive processes.
- **Energy Scaling:** Simulations can provide insights into how the probability of Pomeron exchange and other relevant parameters scale with energy, improving our understanding of the underlying physics.

Gap Survival Probability

- At higher energies, multiple parton interactions (MPI) become more significant, potentially affecting the probability of rapidity gap survival.
- **Impact of MPI:** Simulations can help quantify the effect of MPI on gap survival probability and provide strategies to mitigate these effects.
- **Better Predictions:** Accurate simulations can improve predictions of gap survival probability, which is essential for interpreting experimental results.

Detector Performance and Design

- **Detector Requirements:** Higher energy collisions produce more particles and higher multiplicities, which require advanced detector capabilities to efficiently identify and measure DPE events.
- **Trigger Strategies:** Simulations can help develop effective trigger strategies to identify diffractive events amidst high-background conditions.

Exploration of New Physics

- **Search for New Phenomena:** Simulations can help identify signatures of new particles or interactions that may manifest in DPE events at higher energies.
- **Sensitivity Studies:** By exploring different energy scenarios, simulations can assess the sensitivity of current and future experiments to new physics.

Ingelman Schein model of Pomeron

- model of the Pomeron provides a framework to describe diffractive processes by treating the Pomeron as a particle with its own parton structure
- The Pomeron flux factor, describing the emission of a Pomeron from a proton
- Diffractive parton distribution functions, describing the internal structure of the Pomeron
- The hard scattering cross section, describing the interaction between partons from the Pomeron and the other hadron.