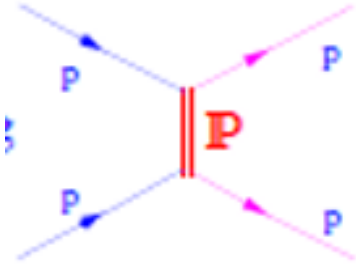
Studies of elastic and diffractive pp scatterings with SPD detector at NICA collider

David Maksimov (MSU)
Leonid Gladilin (SINP MSU / DLNP JINR)

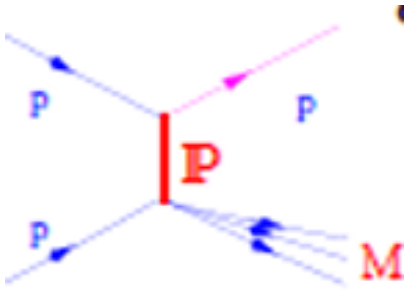
2nd SPD Phase-I workshop, March 31, 2026

Outline:

Modelling with Pythia 8



Modelling with SPDroot



Current work and Goals

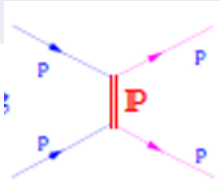
Summary and Requirements at Phase-I

Modelling with Pythia 8

Pythia 8.312

pp at √s = 4 GeV and 10 GeV, SoftQCD:all = on

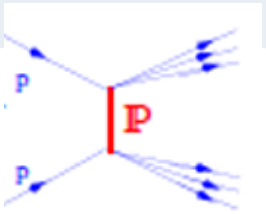
√s	Total x-section	Elastic	Inelastic
4 GeV	43.1 mb	22%	88%
10 GeV	38.5 mb	18%	82%



Fractions of inelastic events:

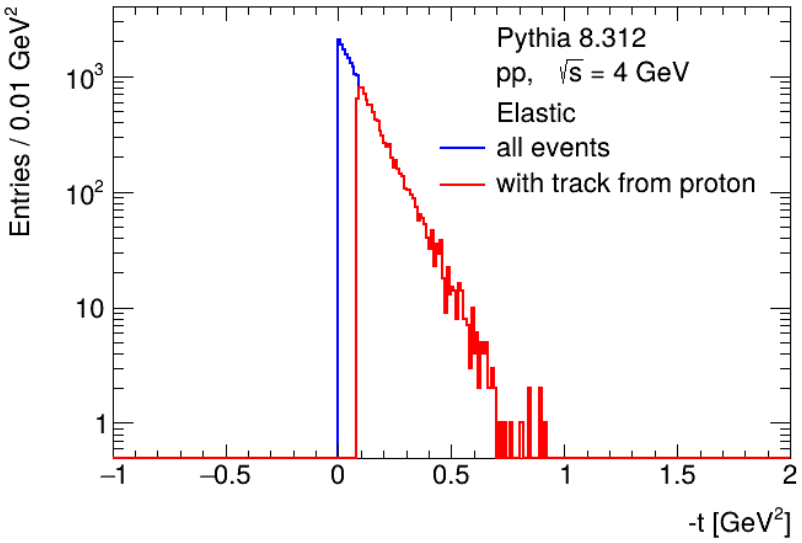
√s	Non-diffraction	Single diffraction	Double diffraction
4 GeV	90.8%	8.8%	0.4%
10 GeV	80.8%	16.5%	2.7%

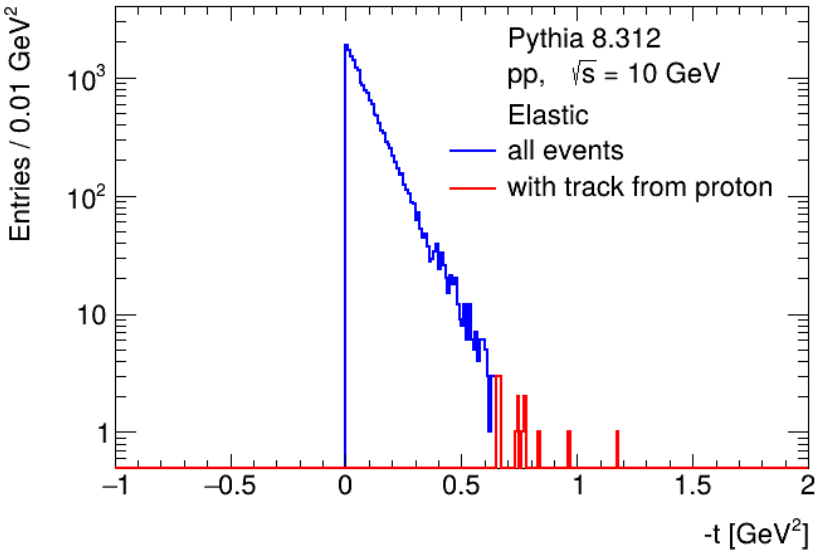


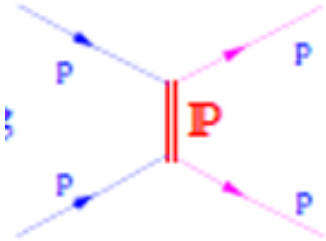


Modelling with Pythia 8

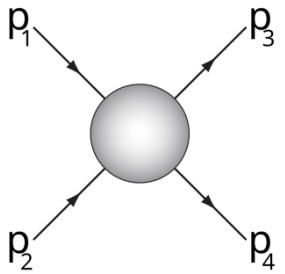
pp at √s = 4 GeV and 10 GeV, Elastic







~43% of elastic events ($-t > 0.08$ GeV^2) have the scattered proton(s) in the main detector (p_T>150 MeV, $|\eta|$<2.5)



$\mathbf{t = (p_1 - p_3)^2}$

only 0.1% of elastic events ($-t > 0.08$ GeV^2) havevthe scattered proton(s) in the main detector (p_T>150 MeV, $|\eta|$<2.5)

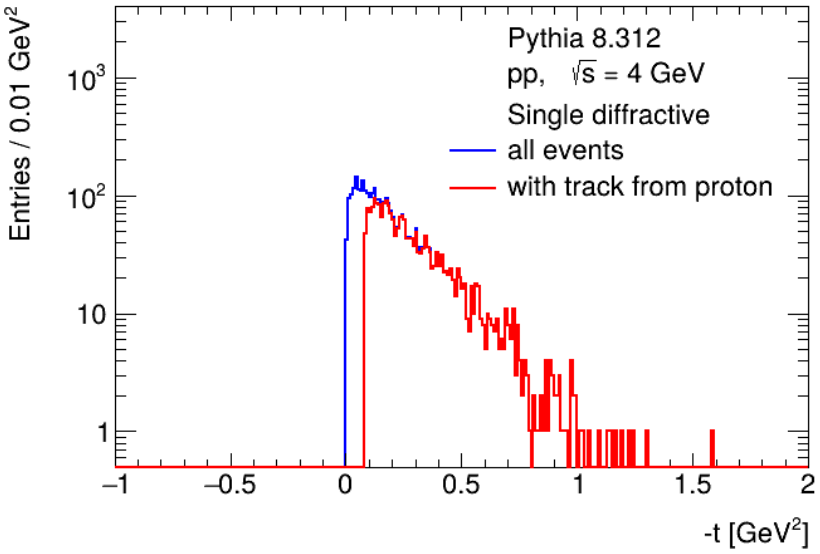
Forward detectors are needed for √s >= 10 GeV

For detailed discussion see report from Adel Terkulov (LPI) on 29.10.24
https://indico.jinr.ru/event/4985/

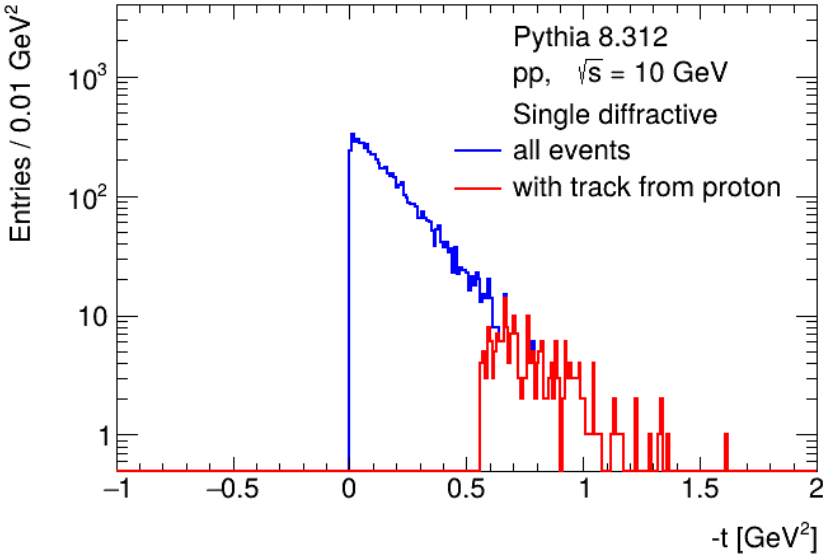
Modelling with Pythia 8



pp at √s = 4 GeV and 10 GeV, Single Diffractive



~68% of single-diffractive events ($-t > 0.08$ GeV^2) have the scattered proton in the main detector (p_T>150 MeV, $|\eta|$<2.5)



~3.4% of single-diffractive events ($-t > 0.55$ GeV^2) have the scattered proton in the main detector (p_T>150 MeV, $|\eta|$<2.5)

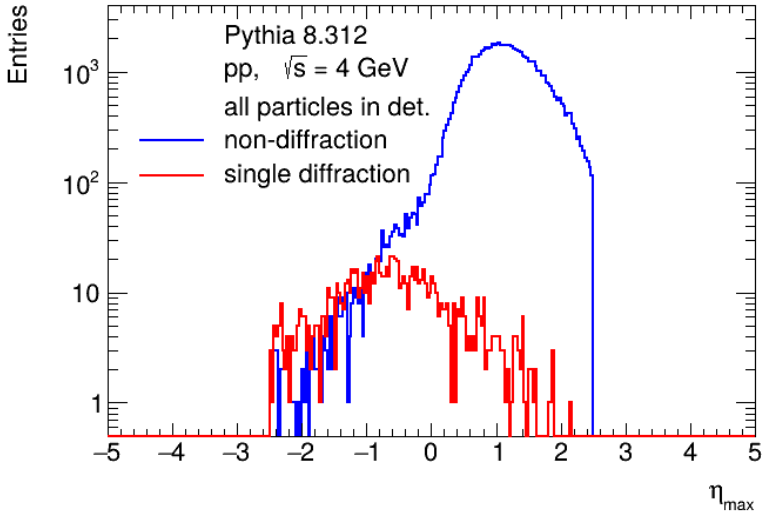
Large Rapidity Gap (LRG) method should be used in addition

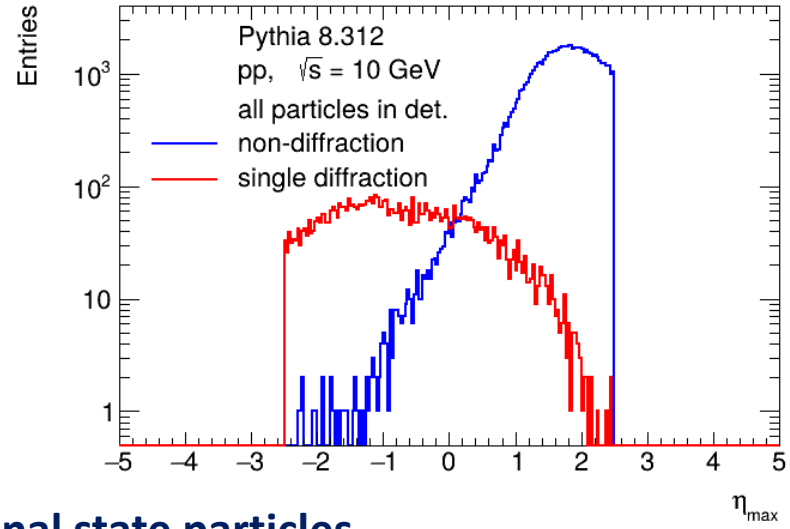
Modelling with Pythia 8, LRG metod



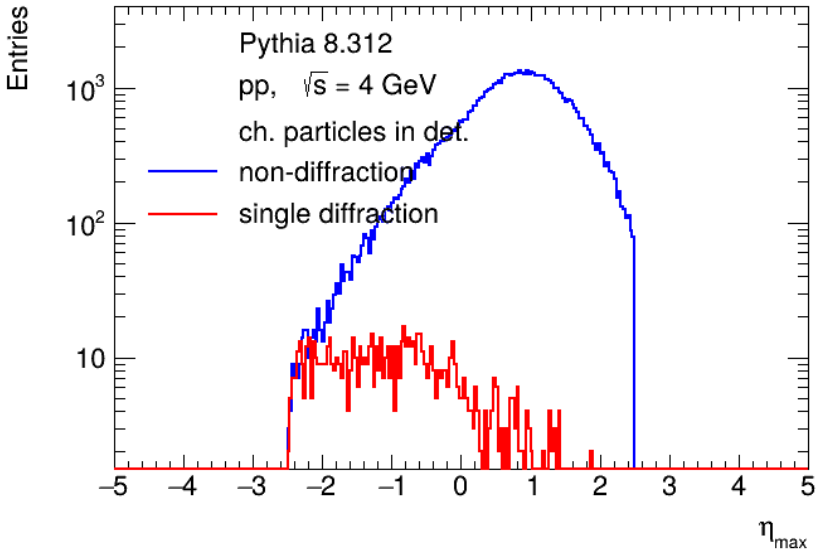
η_{max} using particles with p_T>150 MeV and $|\eta|$<2.5

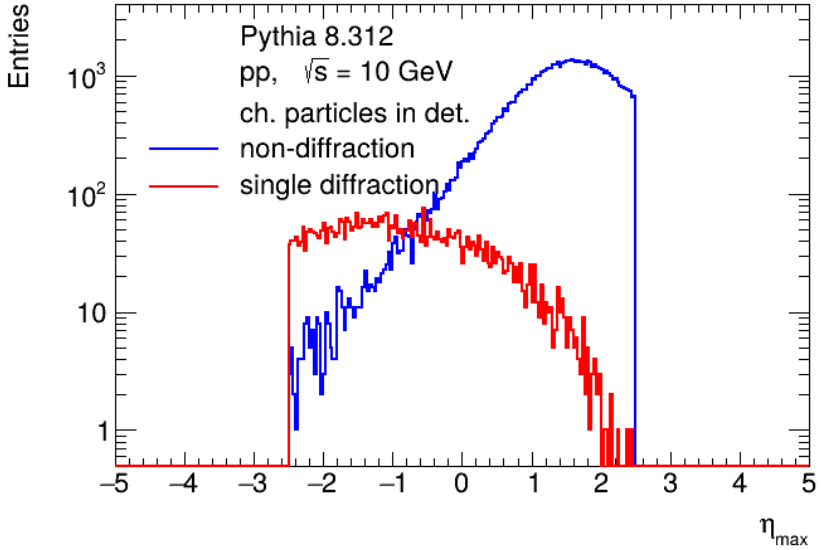
all final state particles





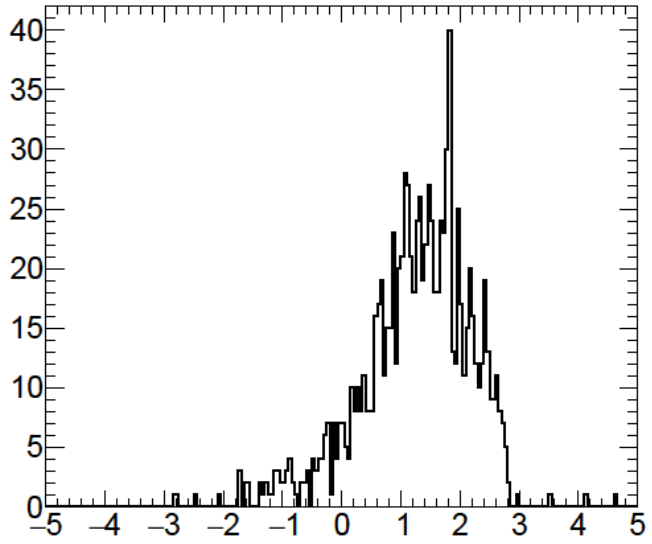
charged final state particles



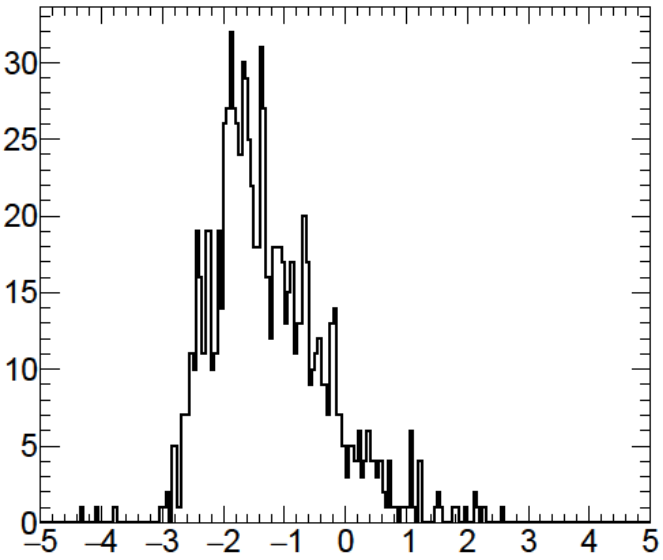


Modelling with SPDroot, LRG method, 10 GeV

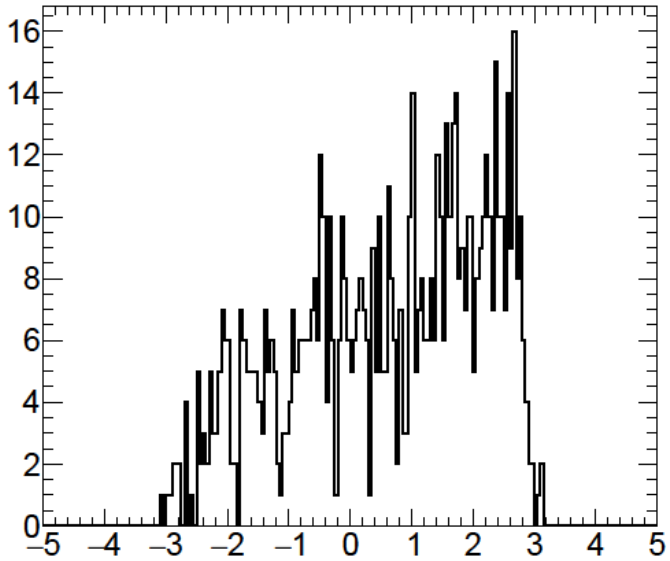
η_{max} using tracks with p_T>150 MeV

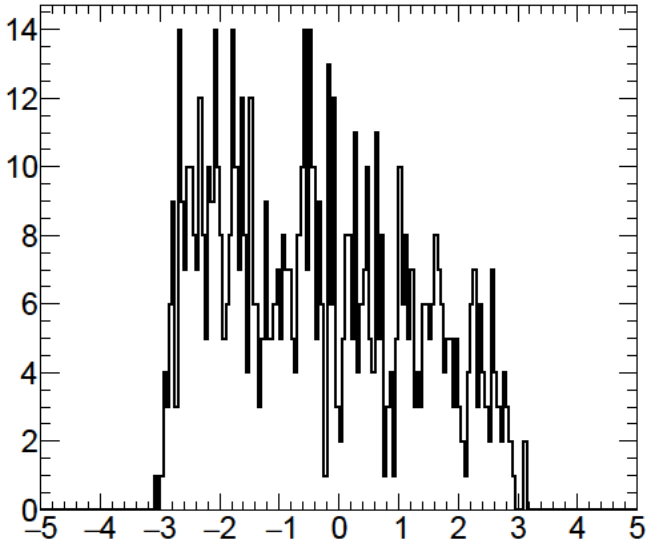


η_{min} using tracks with p_T>150 MeV



Non-diffr.





Single diffr.



Current work

Removing intact protons for LRG method

Switch to lhe files (“Code” for subprocesses separation is not available at rec. level of SPDroot)

Goals:

Add non-tracking information to the LRG calculation

Try to combine LRG and proton tagging methods

Ultimate goal:

Prepare a tool for separation of non-diffractive, single diffractive and doubly diffractive components

Summary

Phase-I of SPD@NICA offers an unique opportunity to measure the elastic and diffractive events with the scattered protons in the main detector

LRG method can/should be used in addition

Requirements at Phase-I:

Beam species: pp (pd)
Collision energy: 3,5 -13 GeV (a few values would be beneficial)
Luminosity: $10^{30\text{-}31}$ cm^{-2} s^{-1}
Polarization: interesting but not necessarily
Involved SPD subsystems: MCT, Straw tracker, (Range system?)
Optimal duration of data taking: 2 months
Minimal duration of data taking: ~1 week

Simulation information used: Pythia8 MC, SPDroot

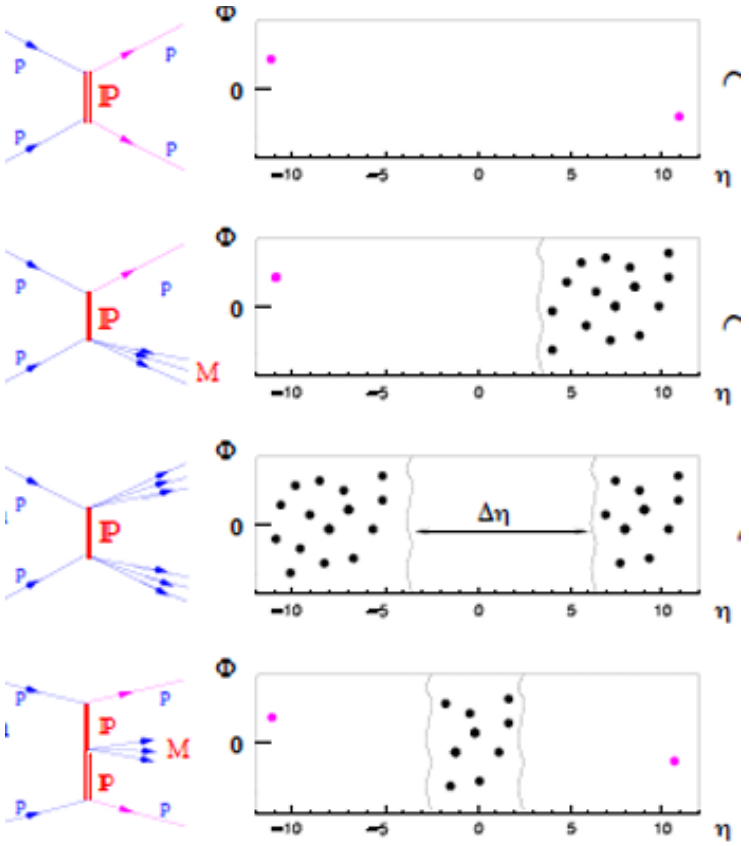
Backup

How identify the elastic and diffractive scatterings?

1. Measuring the scattered proton(s)

At high-energy colliders the scattered protons are very forward and can be measured only with Roman pots.

2. Selecting events with Large Rapidity Gap (LRG) between the expected direction of one proton (system) and another proton (system)



Can we identify the elastic and diffractive events with SPD@NICA by measuring the scattered proton(s) in the main detector?

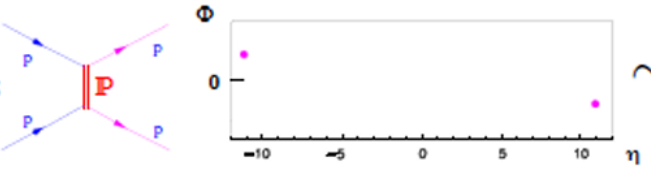
Introduction

99.9999% of LHC events are QCD

$$\sigma_{\text{tot}} = \sigma_{\text{el}} + \sigma_{\text{sd}} + \sigma_{\text{dd}} + \sigma_{\text{cd}} + \sigma_{\text{nd}}$$

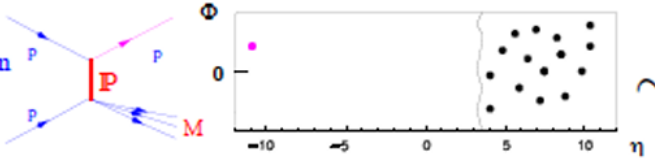
~ 100 mb (note: $\sim 1/\Lambda_{QCD}^2$)

Elastic Scattering
el



~ 20 mb

Single Diffraction
(SD)
sd



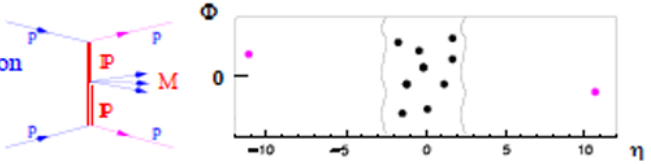
~ 15 mb

Double Diffraction
(DD)
dd



~ 10 mb

Central Diffraction
(CD)
cd

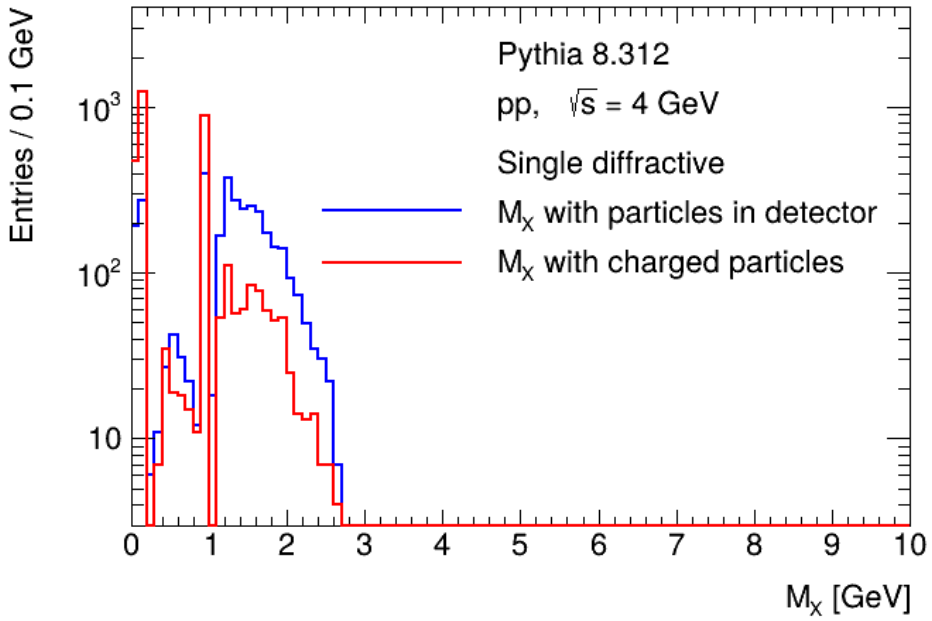


~ 1 mb

Pomeron – colorless object with quantum numbers of vacuum

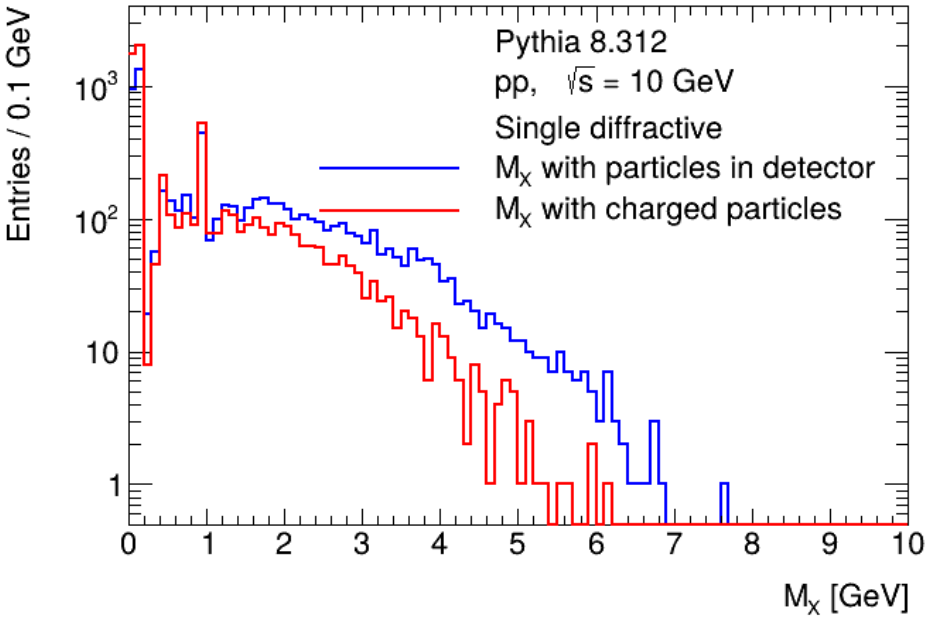
Modelling with Pythia 8, Single Diffraction





M_X reconstructed using particles of the M_X system in the main detector (p_T>150 MeV, |η|<2.5)

Calo/RS information should be helpful

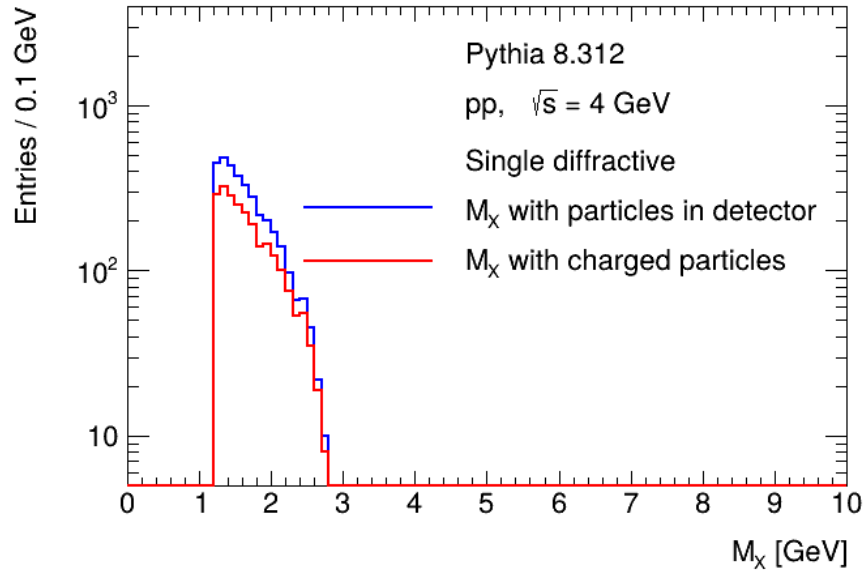


Better statistics w.r.t. the scattered proton method

LRG method using both tracking and Calo/RS information should be helpful

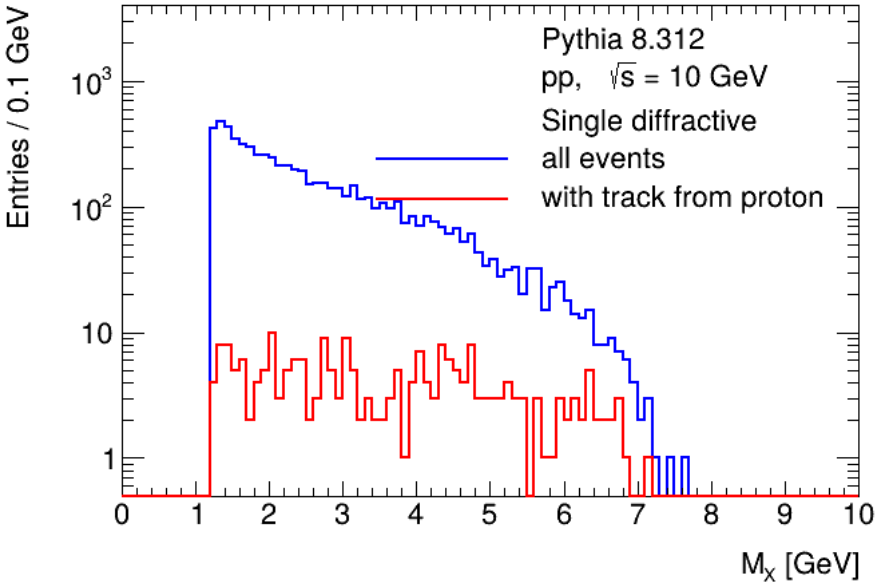
Modelling with Pythia 8, Single Diffraction





M_X reconstructed using the scattered proton

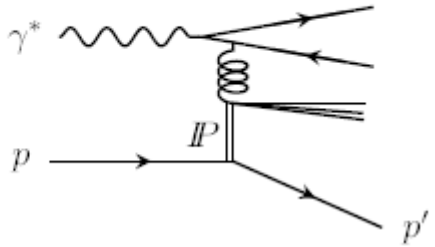
Large acceptance for all M_X values



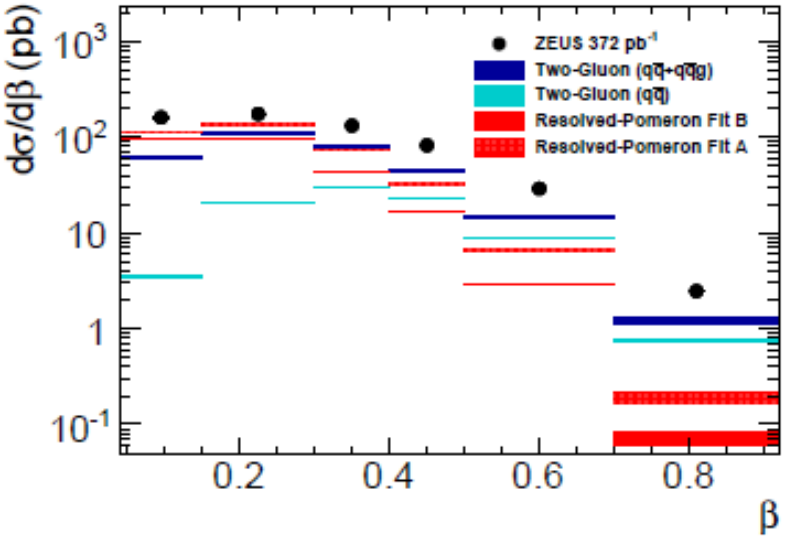
Sensitivity to all M_X values

Exclusive Dijets in Diffractive DIS

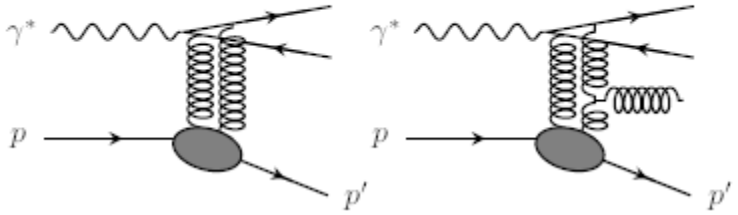
Resolved-Pomeron model



Prediction based on diffractive gluon density obtained from fits (H1 2006 fits A and B) to H1 data



Two-Gluon-Exchange model



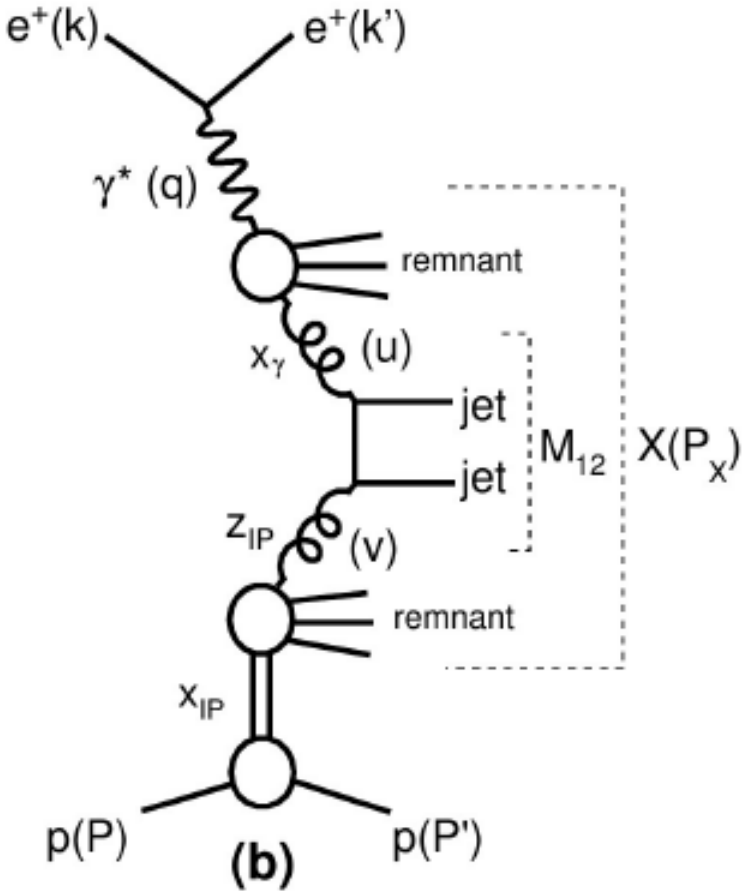
Prediction based on GRV parameterisation of the gluon density

The $q\bar{q}g$ final state is sensitive to the parton-level cut $p_{T,cut}$

$\beta = x/x_{I\!P}$ - fraction of Pomeron momentum "seen" by the photon

Diffractive Dijets in DIS and Photoproduction

JHEP 05 (2015) 056
arXiv:1502.01683



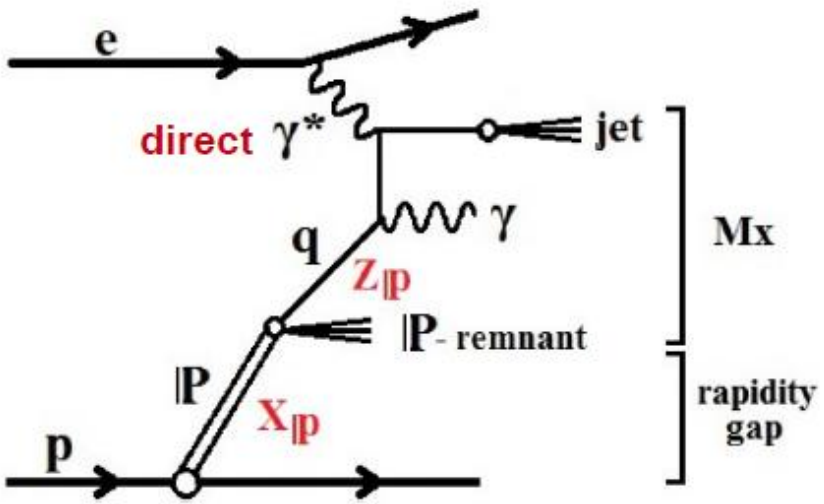
Measure scattered proton in VFPS (Very Forward Spectrometer)

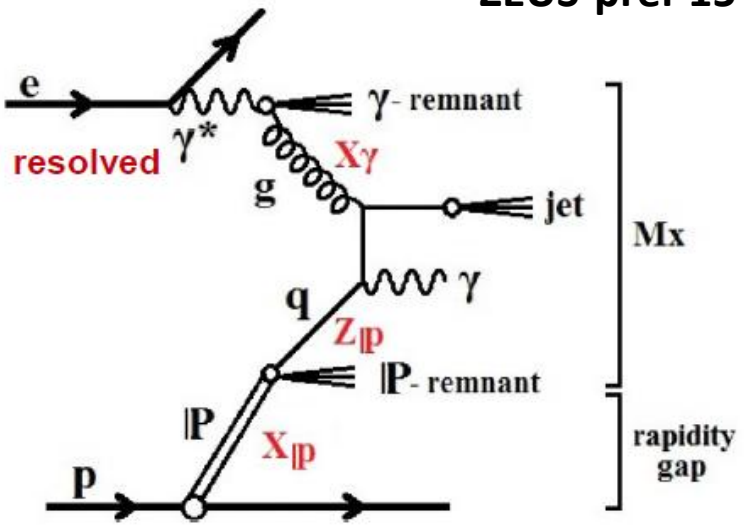
- VFPS is 220m from interatction point
- Complementary method to LRG method

PHP	DIS
$Q^2 < 2\,\mathrm{GeV}^2$	$4\,\mathrm{GeV}^2 < Q^2 < 80\,\mathrm{GeV}^2$
Common Cuts	
$0.2 < y < 0.7$	
$E_T^{*\mathrm{jet1}} > 5.5\,\mathrm{GeV}$	$E_T^{*\mathrm{jet2}} > 4.0\,\mathrm{GeV}$
$-1 < \eta^{\mathrm{jet1}} < 2.5$	$-1 < \eta^{\mathrm{jet2}} < 2.5$
$\lvert t\rvert < 0.6\,\mathrm{GeV}^2$	$0.010 < x_{I\!P} < 0.024$
$z_{I\!P} < 0.8$	

Prompt photons in diffractive photoproduction

ZEUS-prel-15-001





$x_{IP} = \Sigma(E + p_z)_{\text{all EFOs}} / 2 E_p$

x_{IP} = fraction of proton energy taken by pomeron.

z_{IP} = fraction of pomeron energy taken in scatter.

η_{max} = maximum value of pseudorapidity of outgoing particles in scatter (Ignore forward proton.)

