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

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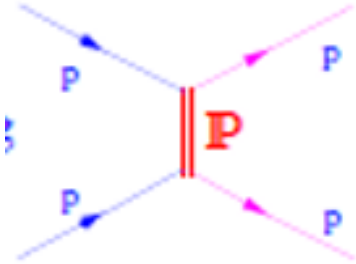
SPD Phase-I workshop, April 23, 2025

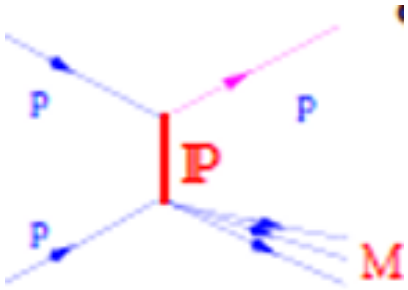
Outline:

Introduction

Modelling with Pythia 8

Summary and Requirements at Phase-I



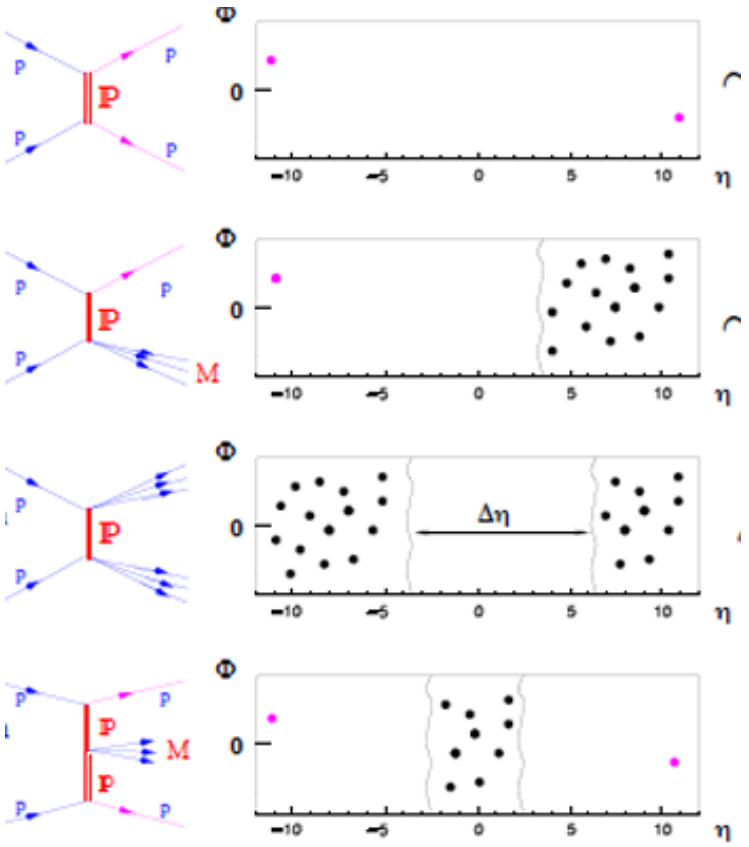


How identify the elastic and diffractive scatterings?

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)



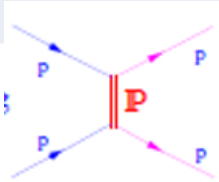
Can we identify the elastic and diffractive events with SPD@NICA by measuring the scattered proton(s) in the main detector?

Modelling with Pythia 8

Pythia 8.312

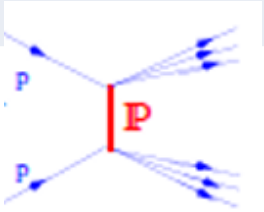
pp at √s = 4 GeV and 10 GeV, SoftQCD:all = on

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



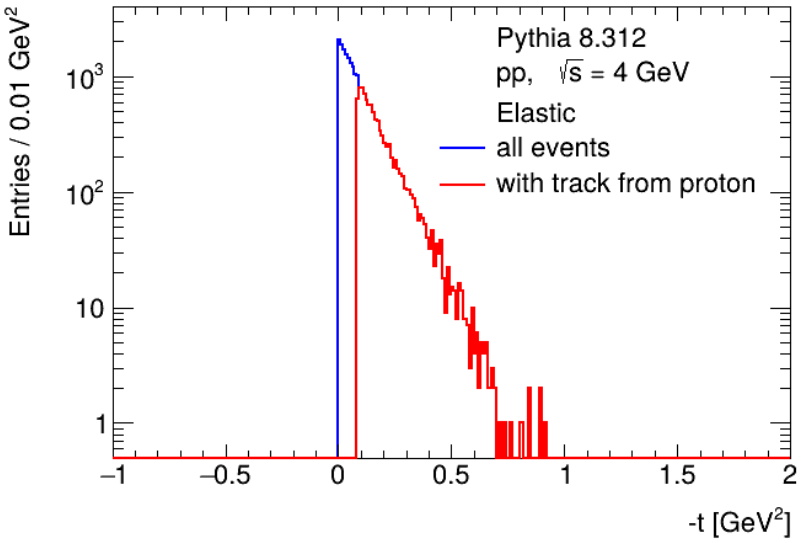
Fractions of inelastic events:

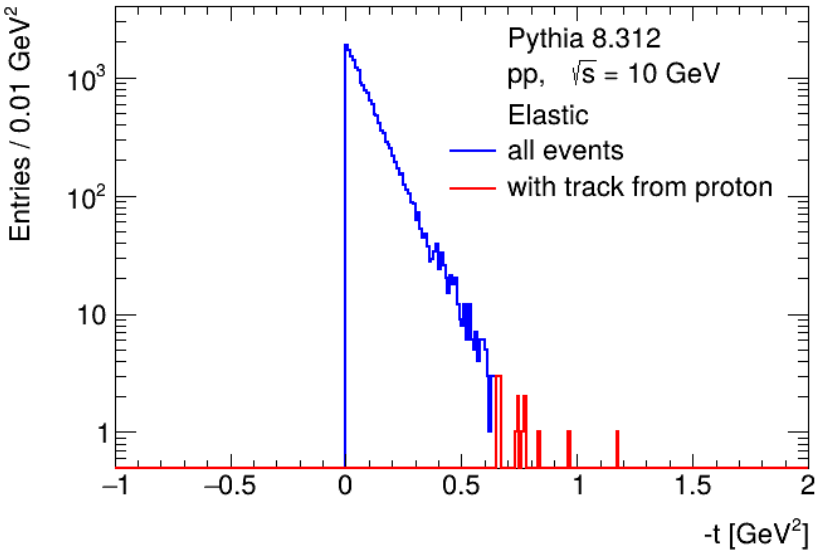
√s	Non-diffraction	Single diffraction	Double diffraction
4 GeV	90.8%	8.8%	0.4%
10 GeV	80.8%	16.5%	2.7%

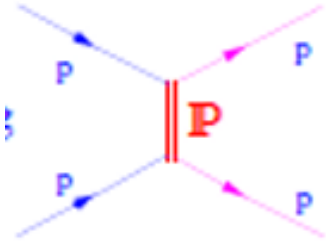


Modelling with Pythia 8

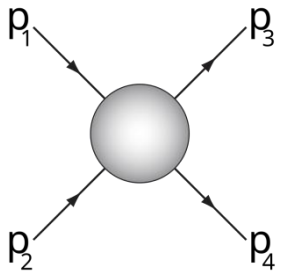
pp at √s = 4 GeV and 10 GeV, Elastic







~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)



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

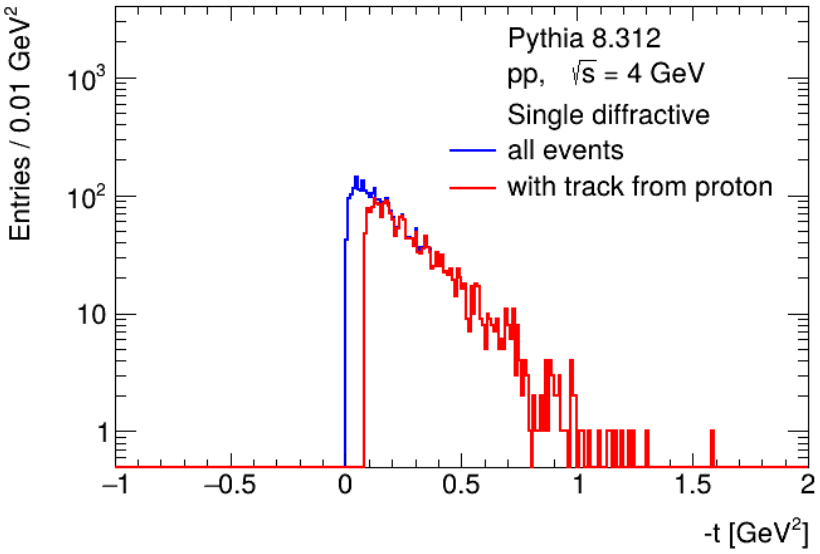
only 0.1% of elastic events ($-t > 0.08$ GeV^2) havevthe scattered proton(s) in the main detector (p_T>150 MeV, $|\eta|$<2.5)

Forward detectors are needed for √s >= 10 GeV

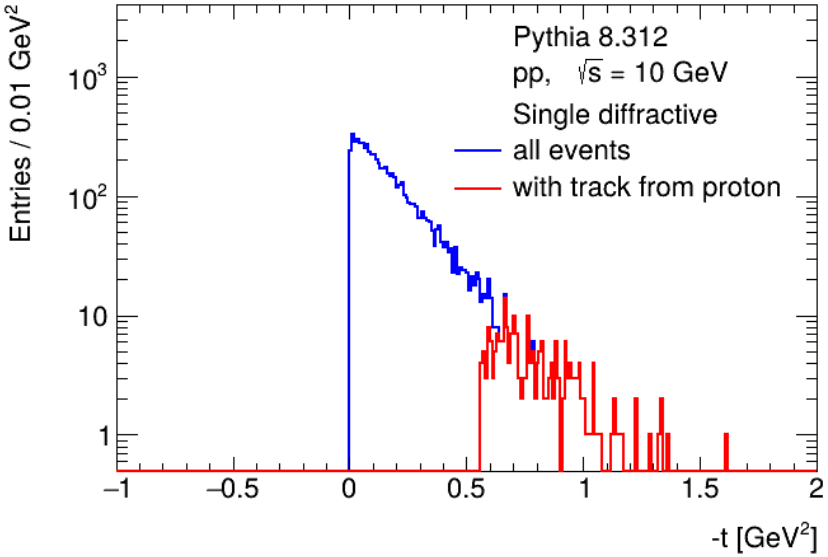
For detailed discussion see report from Adel Terkulov (LPI) on 29.10.24
https://indico.jinr.ru/event/4985/

Modelling with Pythia 8

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



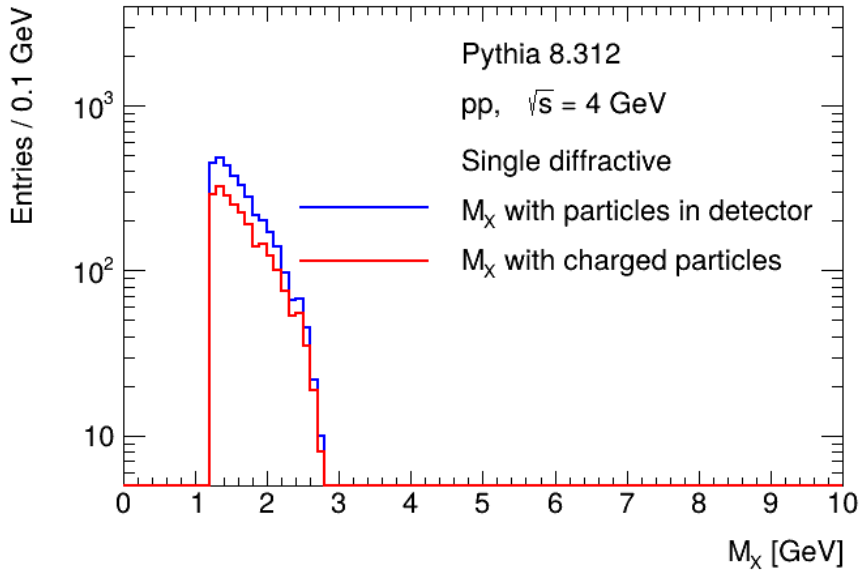
~68% of single-diffractive events ($-t > 0.08$ GeV^2) have the scattered proton in the main detector (p_T>150 MeV, $|\eta|$<2.5)



~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)

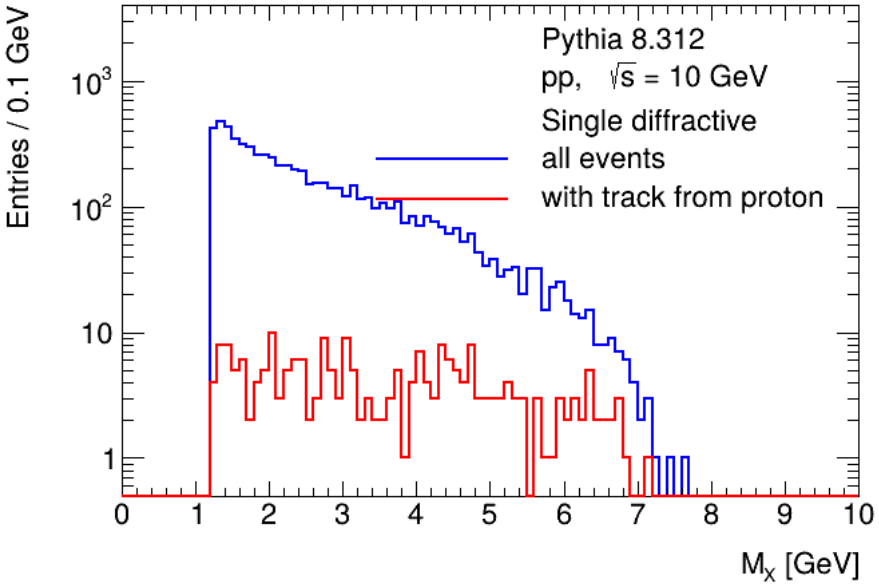
Large Rapidity Gap (LRG) method should be used in addition

Modelling with Pythia 8, Single Diffraction



M_X reconstructed using the scattered proton

Large acceptance for all M_X values

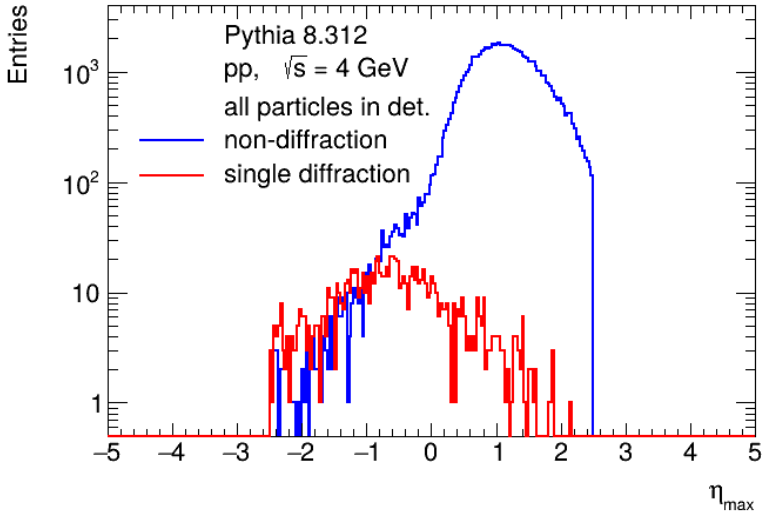


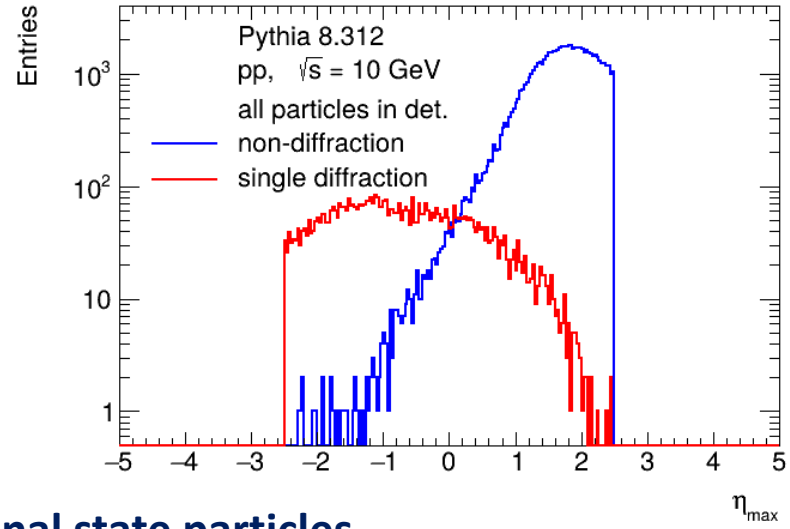
Sensitivity to all M_X values

Modelling with Pythia 8, LRG metod

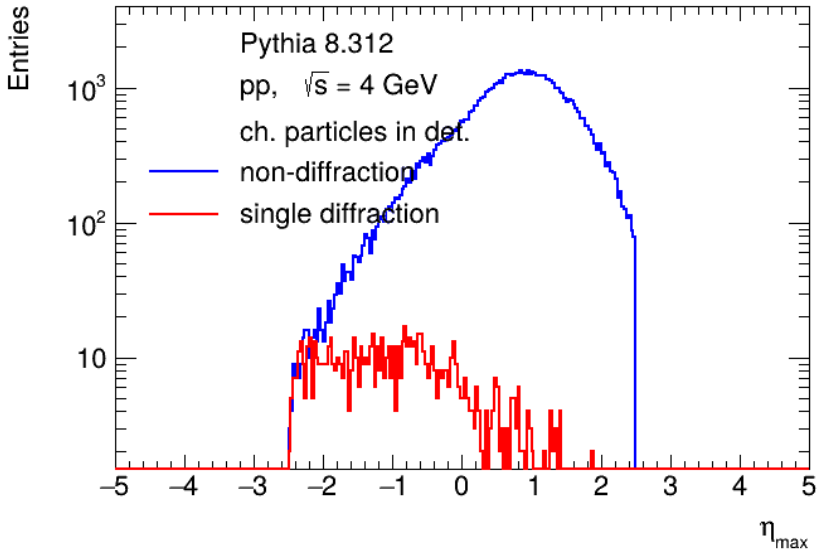
η_{max} using particles with p_T>150 MeV and $|\eta|$<2.5

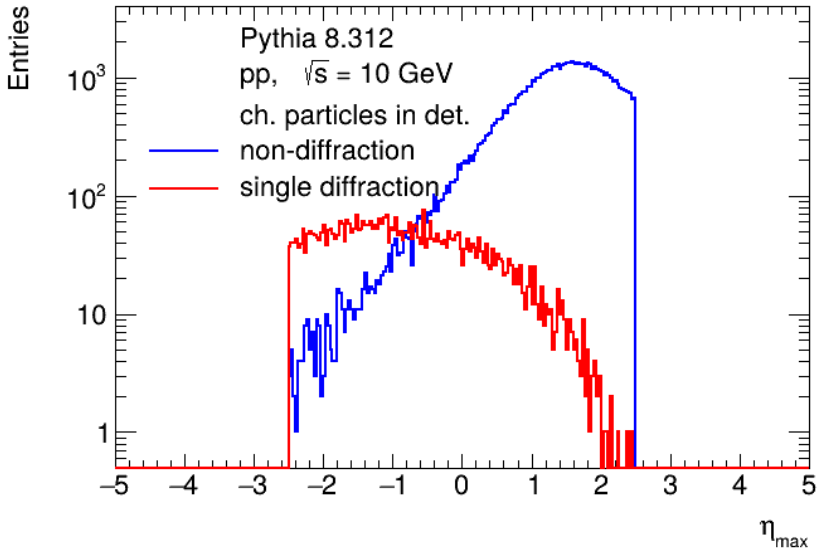
all final state particles





charged final state particles





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: 3 weeks

Simulation information used: Pythia8 MC

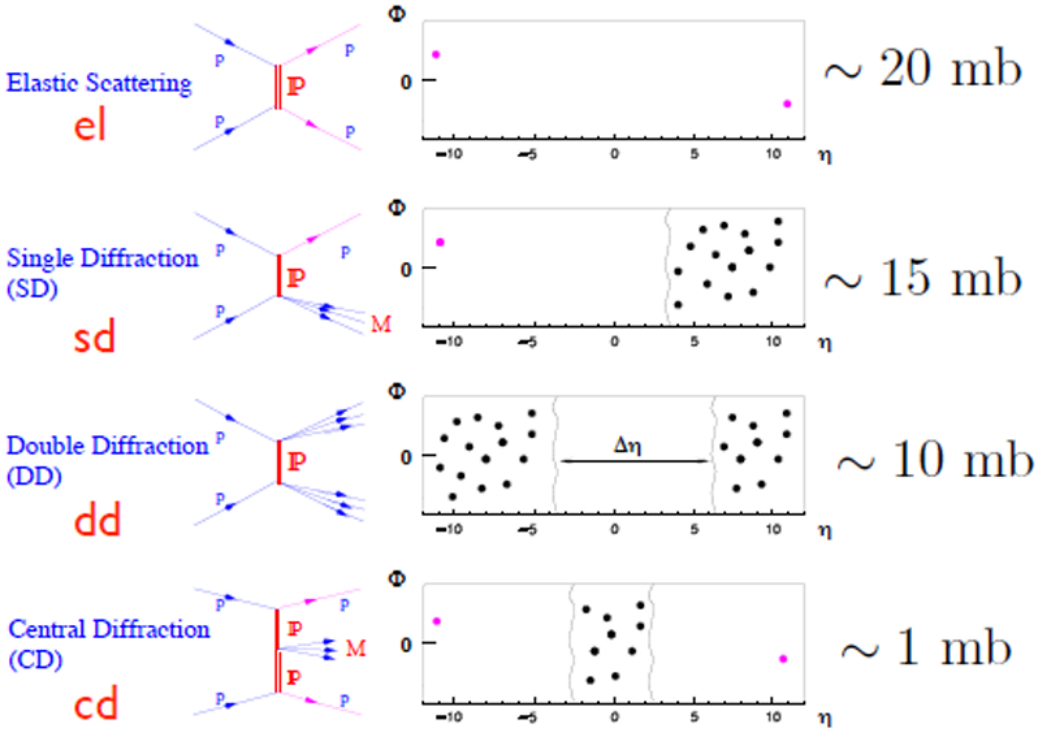
Backup

Introduction

99.9999% of LHC events are QCD

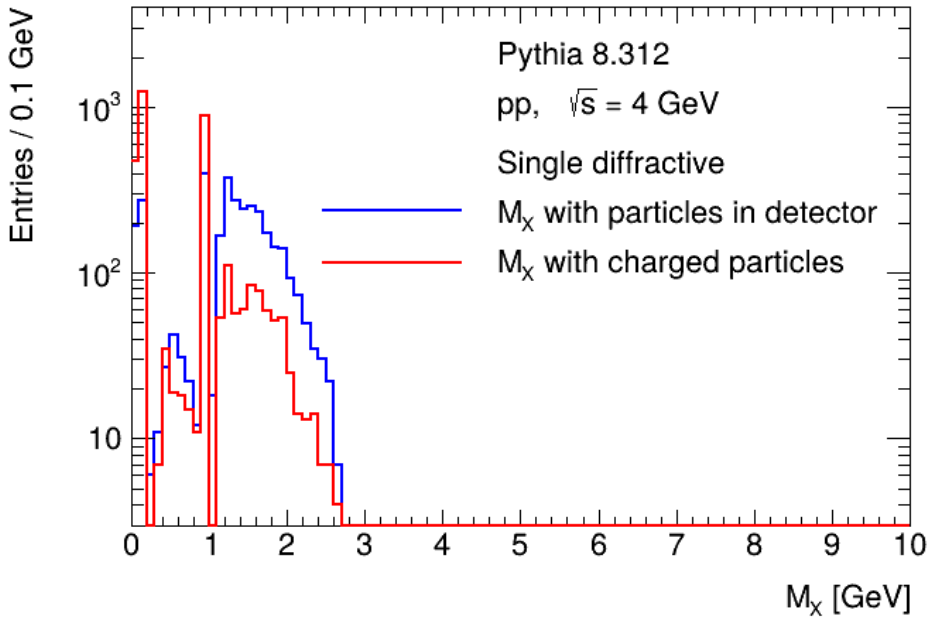
$$\sigma_{\text{tot}} = \sigma_{\text{el}} + \sigma_{\text{sd}} + \sigma_{\text{dd}} + \sigma_{\text{cd}} + \sigma_{\text{nd}}$$

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



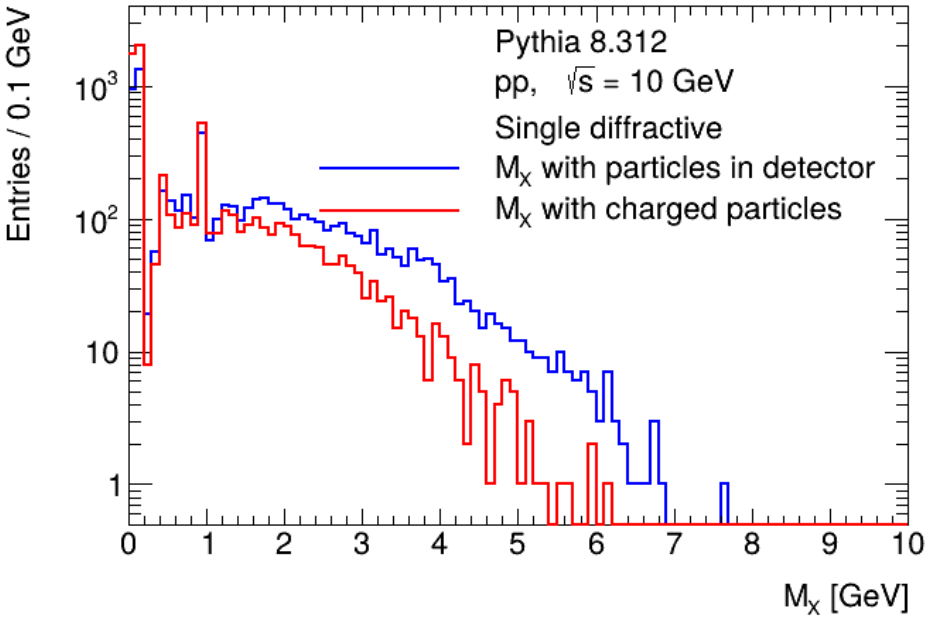
Pomeron – colorless object with quantum numbers of vacuum

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

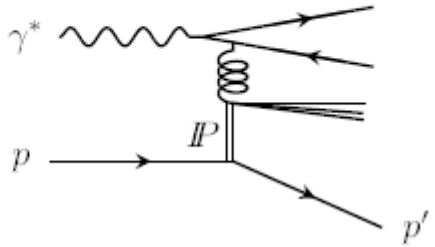


Better statistics w.r.t. the scattered proton method

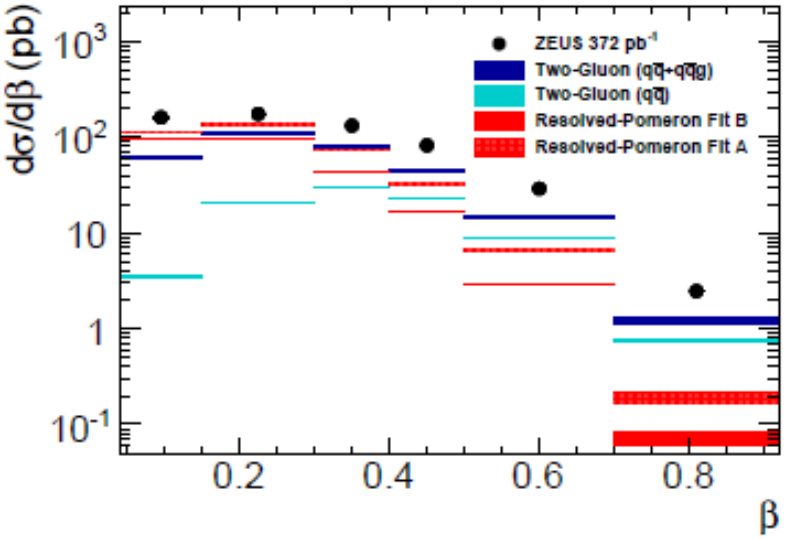
LRG method using both tracking and Calo/RS information should be helpful

Exclusive Dijets in Diffractive DIS

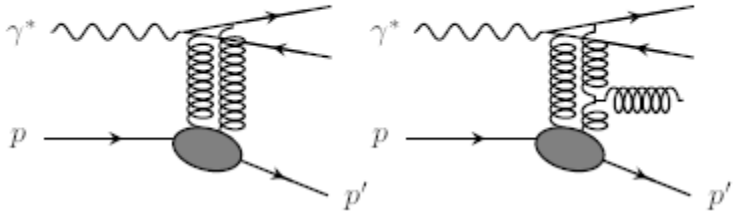
Resolved-Pomeron model



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



Two-Gluon-Exchange model



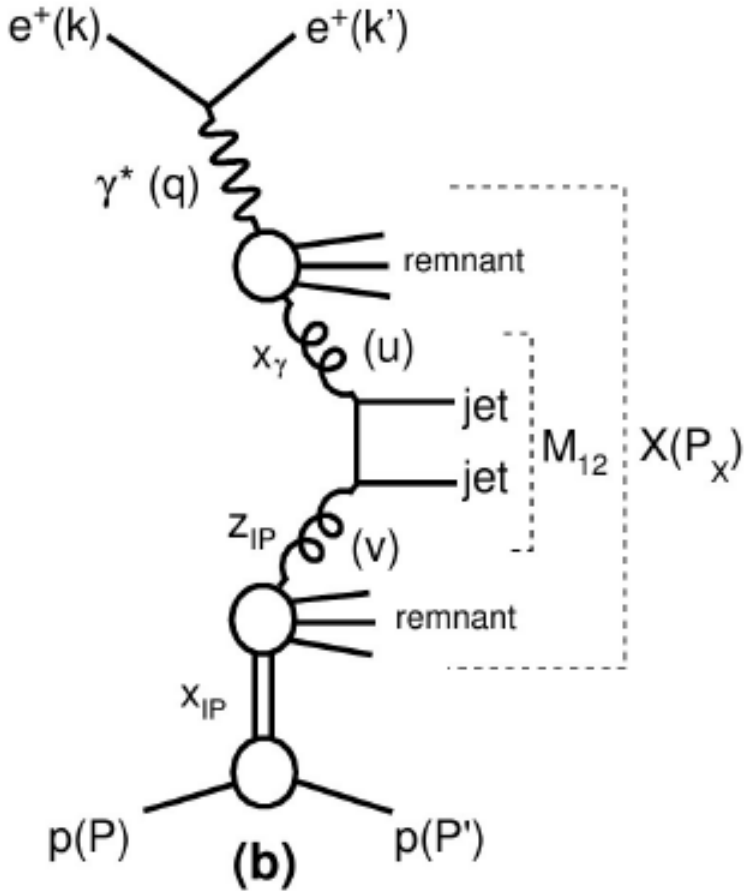
Prediction based on GRV parameterisation of the gluon density

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



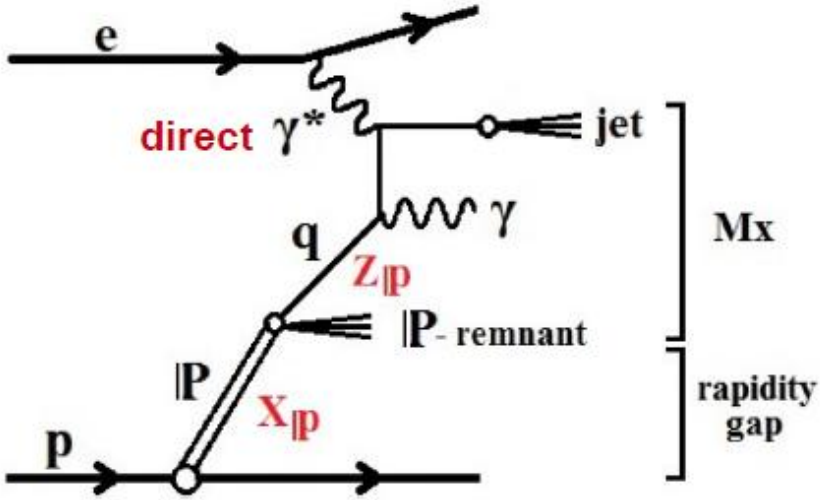
Measure scattered proton in VFPS (Very Forward Spectrometer)

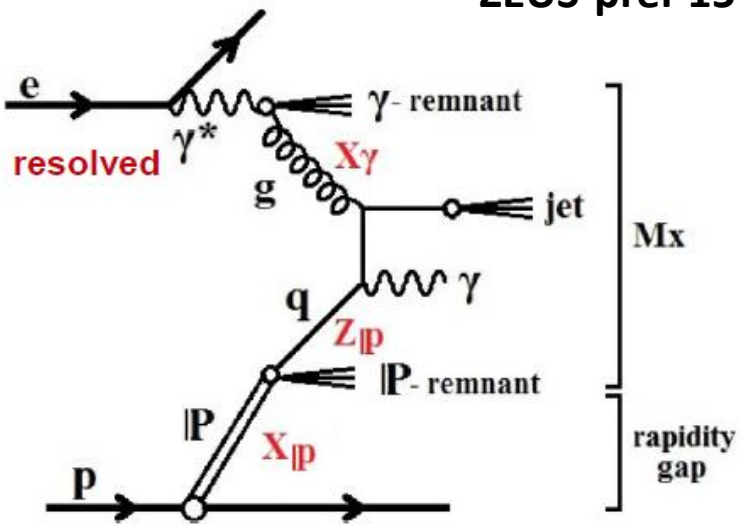
- VFPS is 220m from interatction point
- Complementary method to LRG method

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.)