Studies of elastic and diffractive scatterings at Phase-I SPD

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Outline:

Introduction

Modelling with Pythia 8

Summary and Requirements at Phase-I

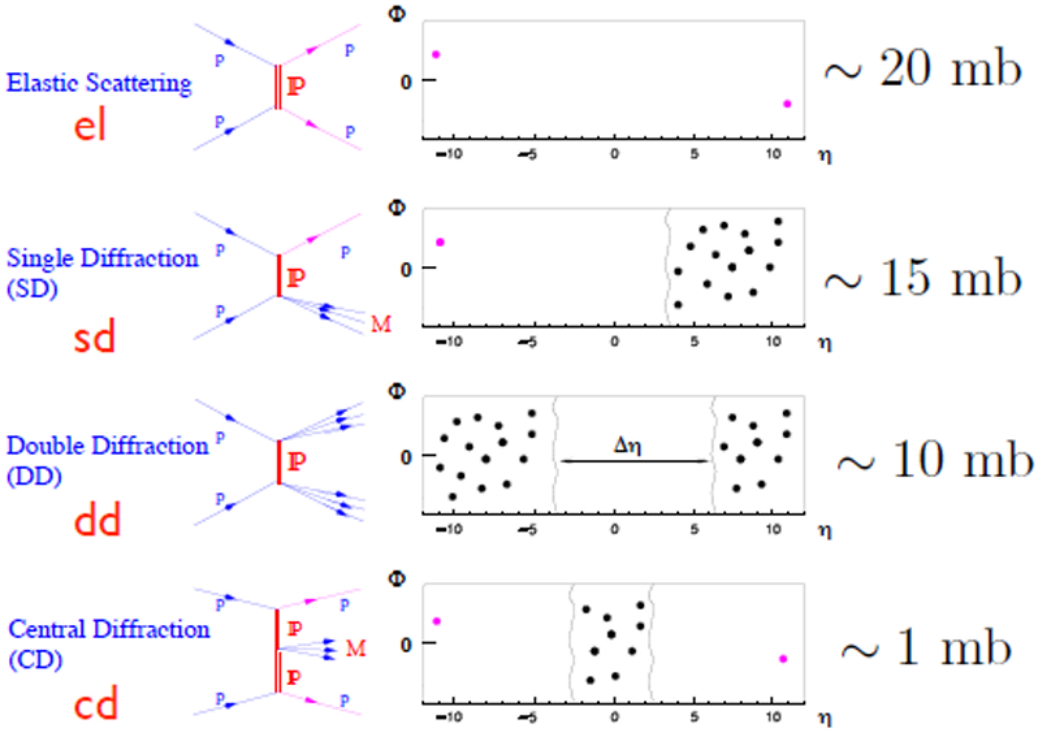
Introduction

99.9999% of LHC events are QCD

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

$$\sim 100 \text{ mb}$$

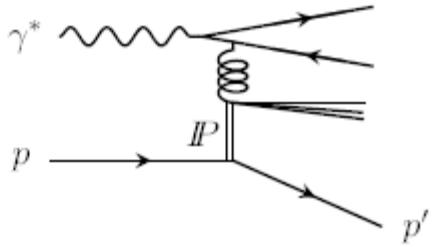
(note: ~ $1/\Lambda_{QCD}^2$)



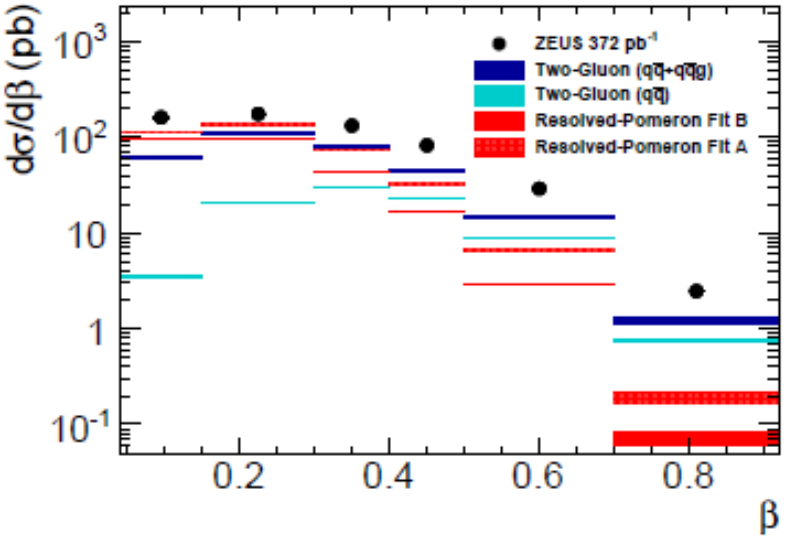
Pomeron – colorless object with quantum numbers of vacuum

Exclusive Dijets in Diffractive DIS

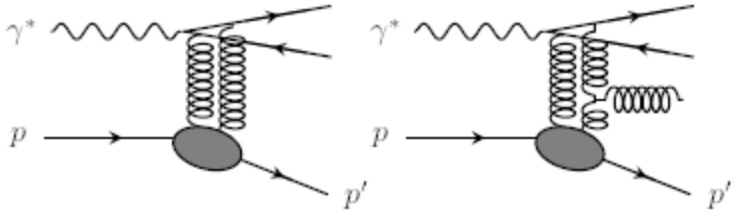
Resolved-Pomeron model



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 $p_{T,cut}$

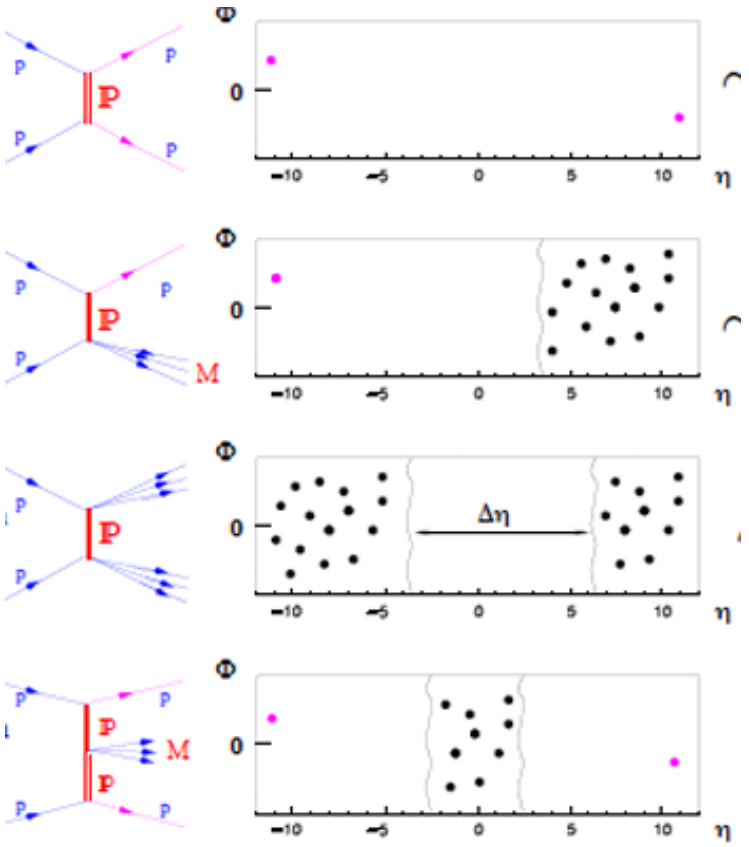
$\beta = x/x_{I\!P}$ - fraction of Pomeron momentum "seen" by the photon

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)



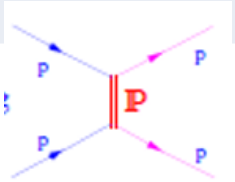
Can we identify the elastic and diffractive events with SPD@NICA by measuring the scattered proton(s) in the main detector?

Modelling with Pythia 8

Pythia 8.312

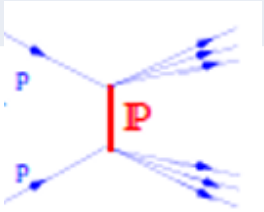
pp at √s = 4 GeV and 10 GeV, SoftQCD:all = on

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



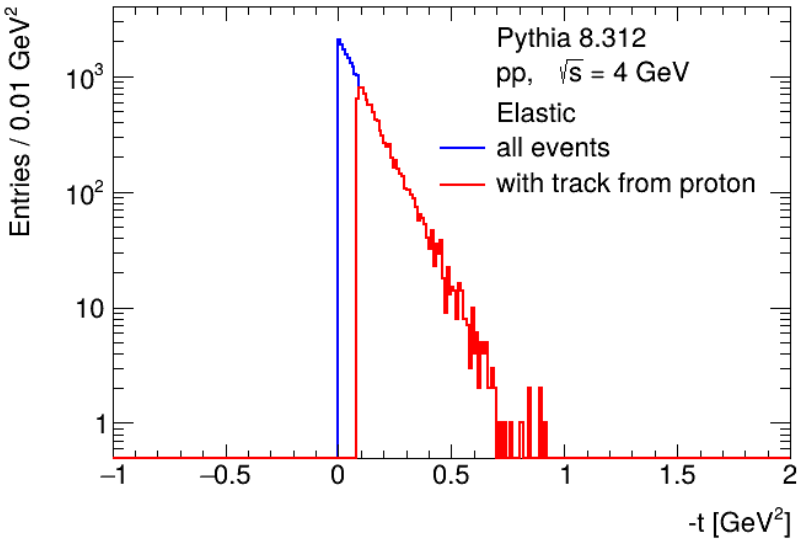
Fractions of inelastic events:

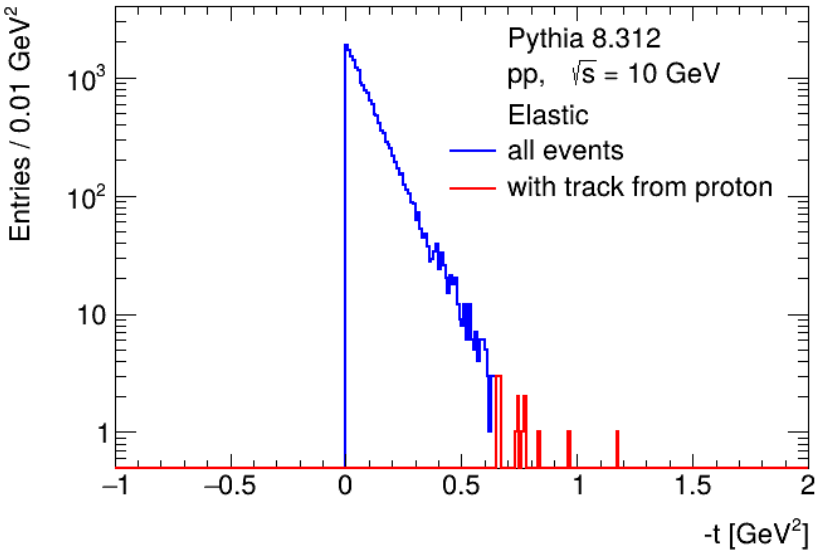
√s	Non-diffraction	Single diffraction	Double diffraction
4 GeV	90.8%	8.8%	0.4%
10 GeV	80.8%	16.5%	2.7%

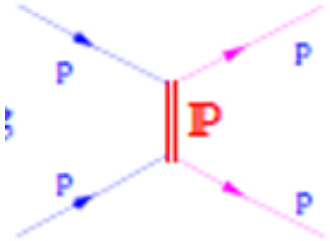


Modelling with Pythia 8

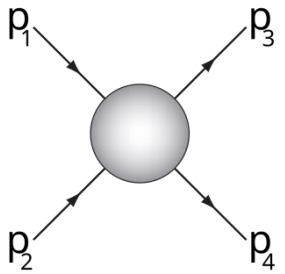
pp at √s = 4 GeV and 10 GeV, Elastic







~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)



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

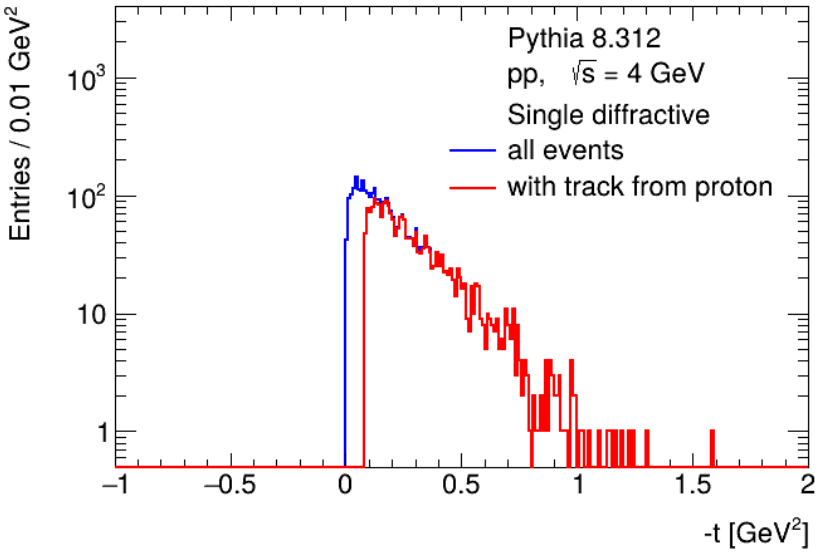
only 0.1% of elastic events ($-t > 0.08$ GeV^2) havevthe scattered proton(s) in the main detector (p_T>150 MeV, $|\eta|$<2.5)

Forward detectors are needed for √s >= 10 GeV

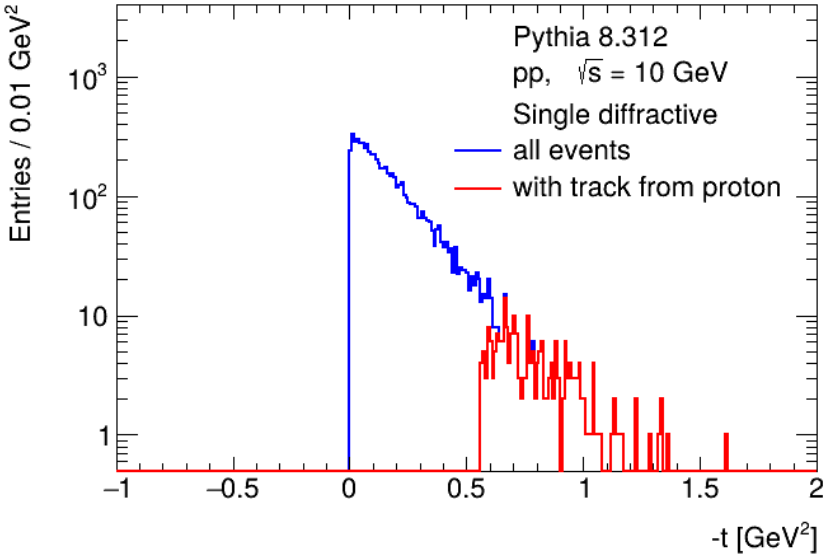
For detailed discussion see report from Adel Terkulov (LPI) on 29.10.24
https://indico.jinr.ru/event/4985/

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)

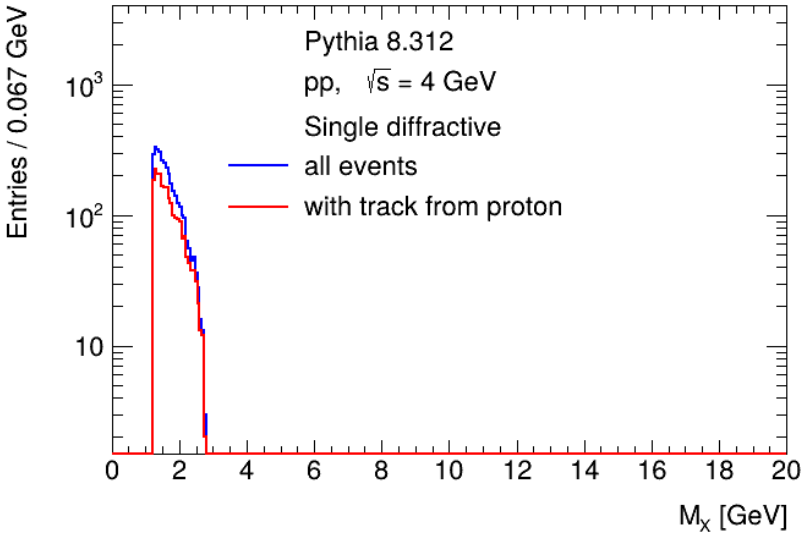


~3.4% of single-diffractive events ($-t > 0.55$ GeV^2) have the scattered proton in the main detector (p_T>150 MeV, $|\eta|$<2.5)

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

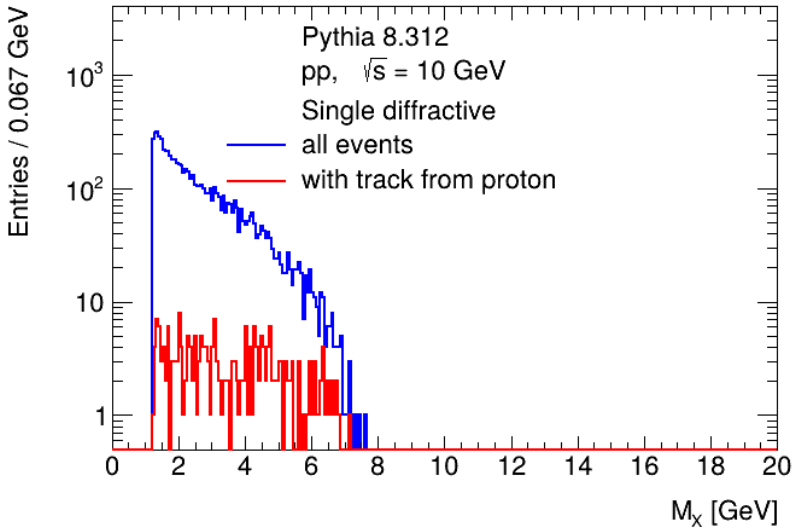
Modelling with Pythia 8

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



M_X reconstructed using the scattered proton

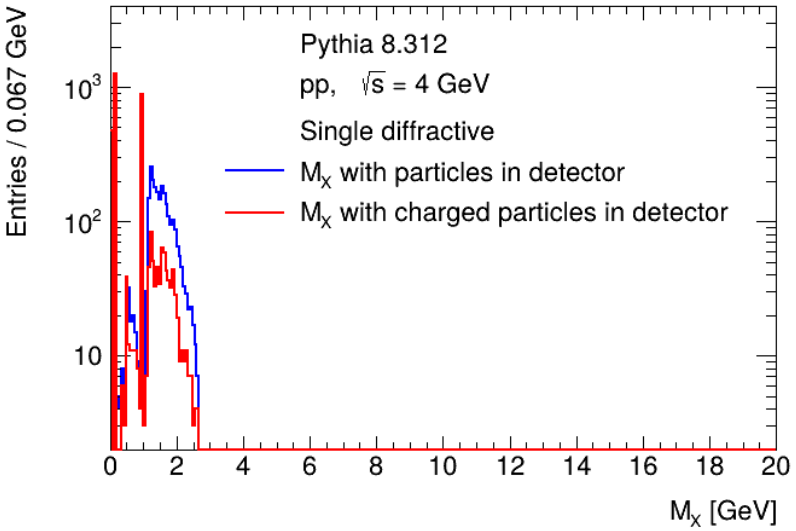
Large acceptance for all M_X values

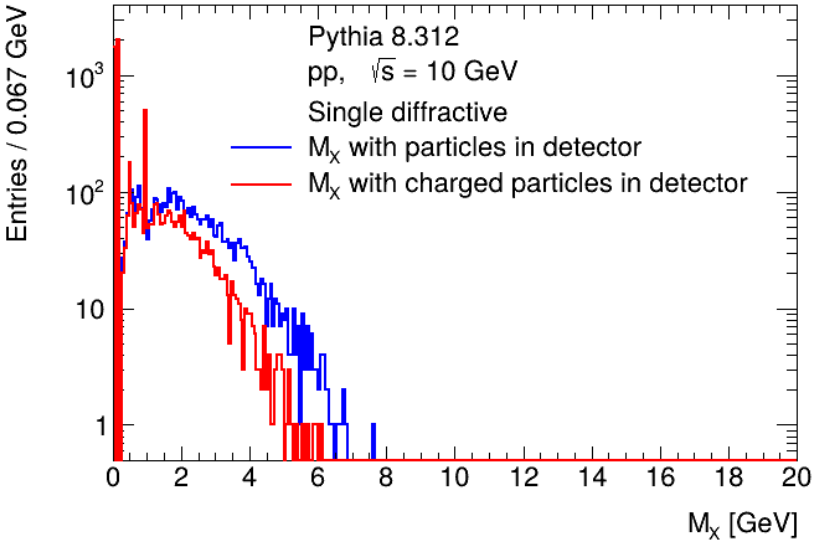


Sensitivity to all M_X values

Modelling with Pythia 8

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





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

Calorimeter information should be helpful

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

LRG method using both tracking and calorimeter information should be helpful

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

Combining the tracking and calorimeter information is helpful for the LRG selection of diffractive events

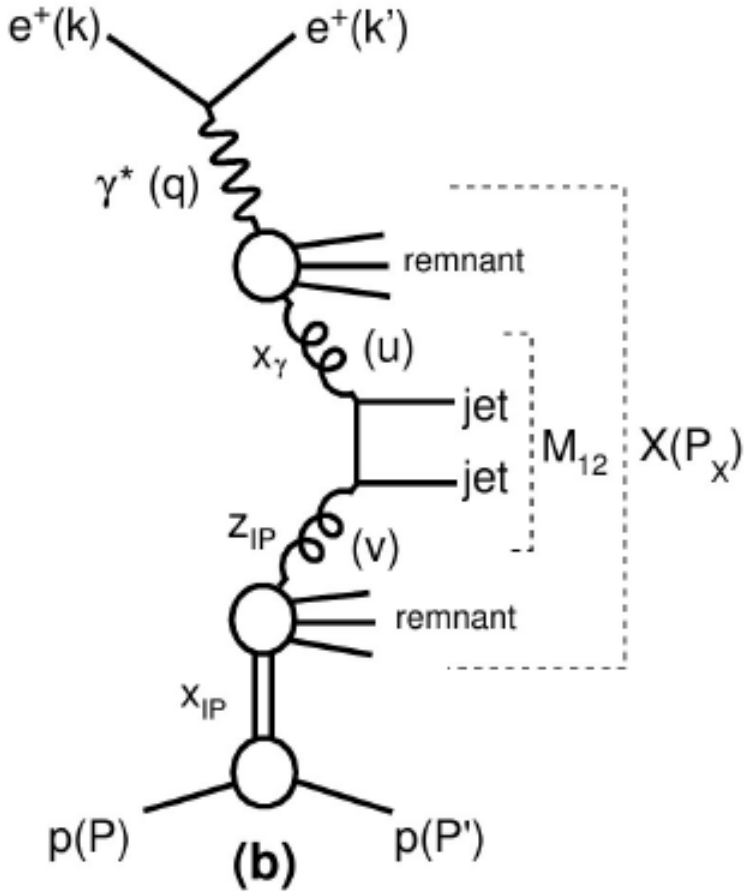
Requirements at Phase-I:

Beam species: pp
Collision Energy: 3.5 – 10 GeV (2-3 energies better than one)
Polarization: interesting but not necessarily
Involved subsystems: tracking (mandatory), proton identification (important), calorimetry (helpful)
Statistics: 10-100 Mevts unpreselected events at each energies

Backup

Diffractive Dijets in DIS and Photoproduction

JHEP 05 (2015) 056
arXiv:1502.01683



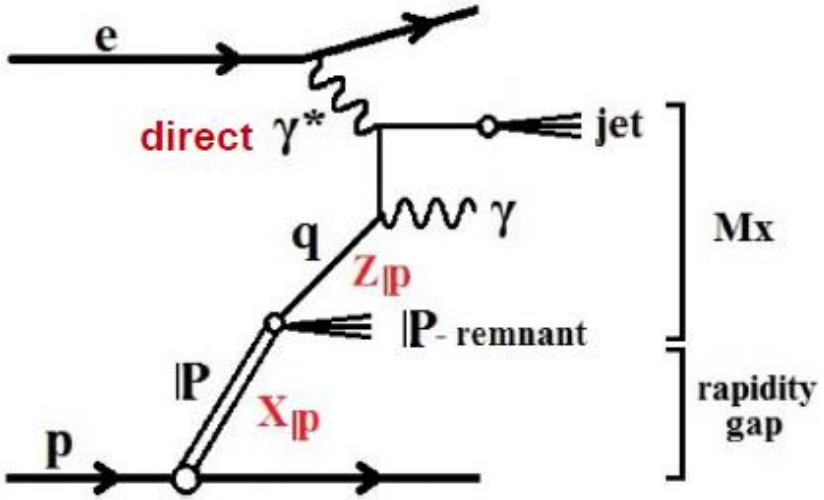
Measure scattered proton in VFPS (Very Forward Spectrometer)

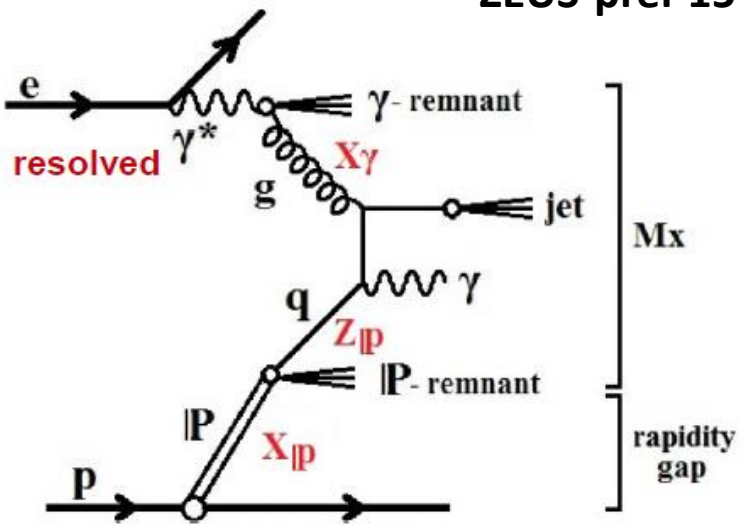
- VFPS is 220m from interatction point
- Complementary method to LRG method

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.)