Diffraction in PYTHIA

Sparsh Navin – University of Birmingham

MCnet studentship at University of Lund

Supervisor - Torbjörn Sjöstrand

Outline:

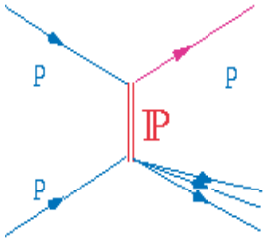
- Diffraction in PYTHIA – old description
- PYTHIA vs PHOJET
- Diffraction in PYTHIA – new description and distributions
- Outlook

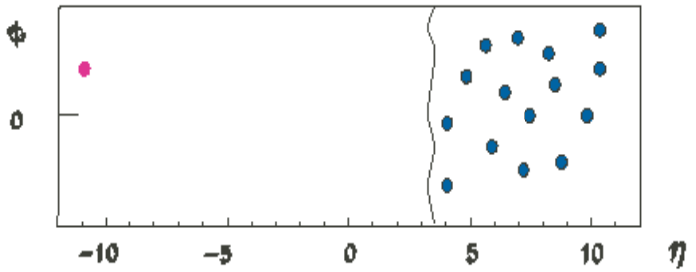
Process Types

$$\sigma_{total} = \sigma_{elastic} + \sigma_{inelastic}$$

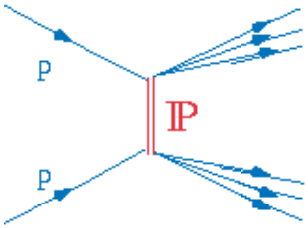
$$\sigma_{SD} + \sigma_{DD} + \sigma_{ND} + \ldots$$

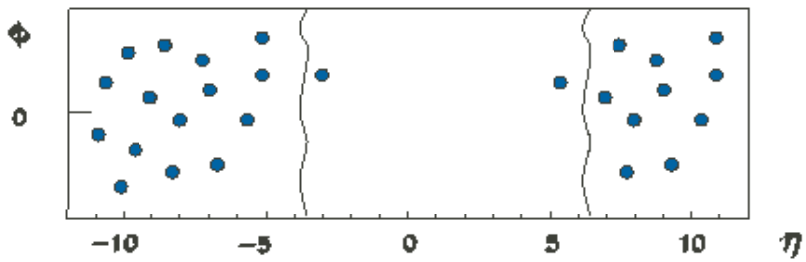
Single Diffraction - SD



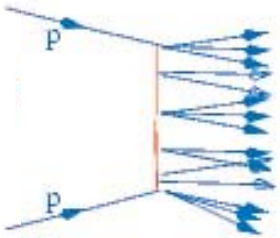


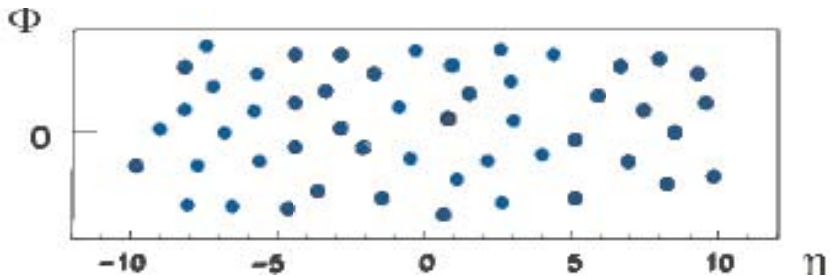
Double Diffraction - DD





Non Diffractive - ND





Diffraction in PYTHIA – “old”

Event Generation:

• Diffractive cross sections given by model by Schuler and Sjöstrand (Phys. Rev. D 49, 2257 (1994))

• Diffractive mass (M_X) and momentum transfer (t) generated according to:

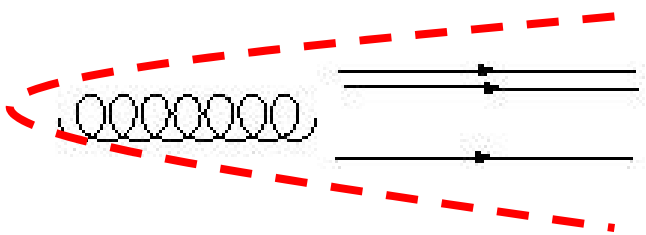
$$\frac{d^2s}{dtdM_X{}^2} \sim \frac{1}{M_X{}^2} e^{-b|t|}$$

Particle Production:

- $M_X < 1\ GeVc^{-2}$ above mass of incoming particles => isotropical decay into 2-body state
- More massive system treated as a string with quantum numbers of the original hadron

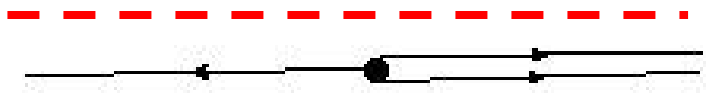
Diffraction in “old” PYTHIA – stretching the string

Has a gluon (g) and quark (q) contribution



Pomeron couples to gluon

Dominates at large M_X



Pomeron couples to valence quarks

Dominates at small M_X

Version 6.214 (Fortran)

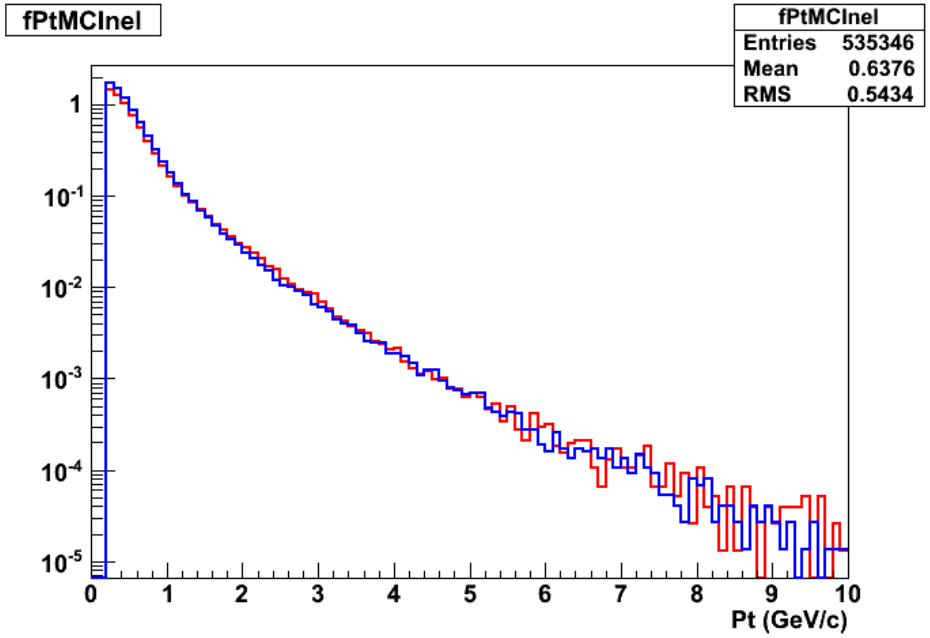
- q and g contributions are set by a user-defined fixed ratio

Version 8.1 (C++)

$$\frac{\mathrm{P}(q)}{\mathrm{P}(g)} = \frac{N}{M_X^p}$$

- Slopes (value of p) in q and g case are different
- mass (M_X) dependence

PYTHIA “old” vs PHOJET - p_T

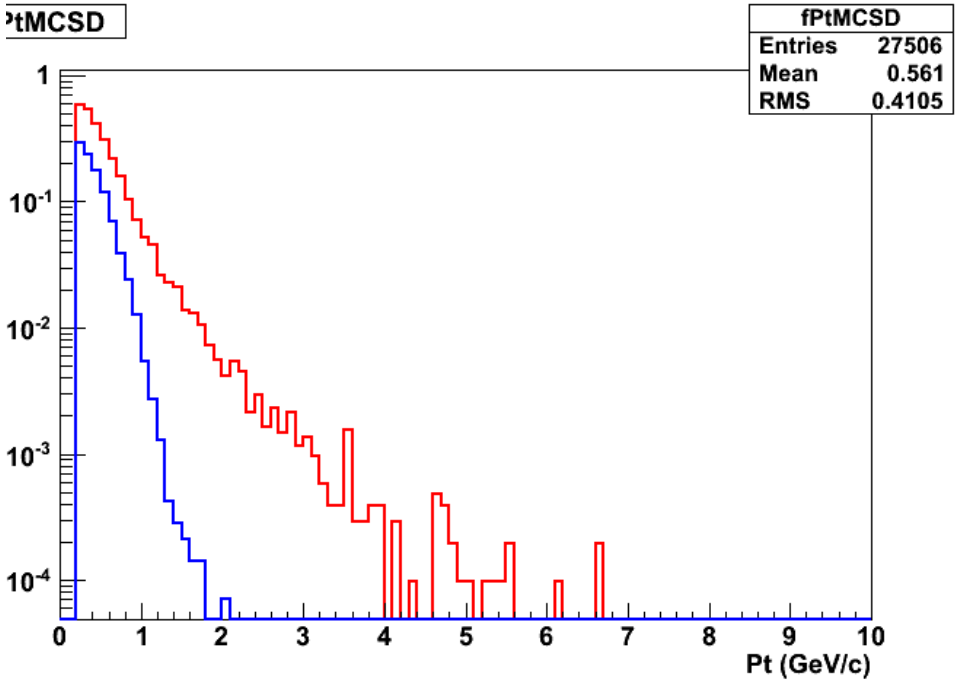


Inelastic = SD + DD + ND

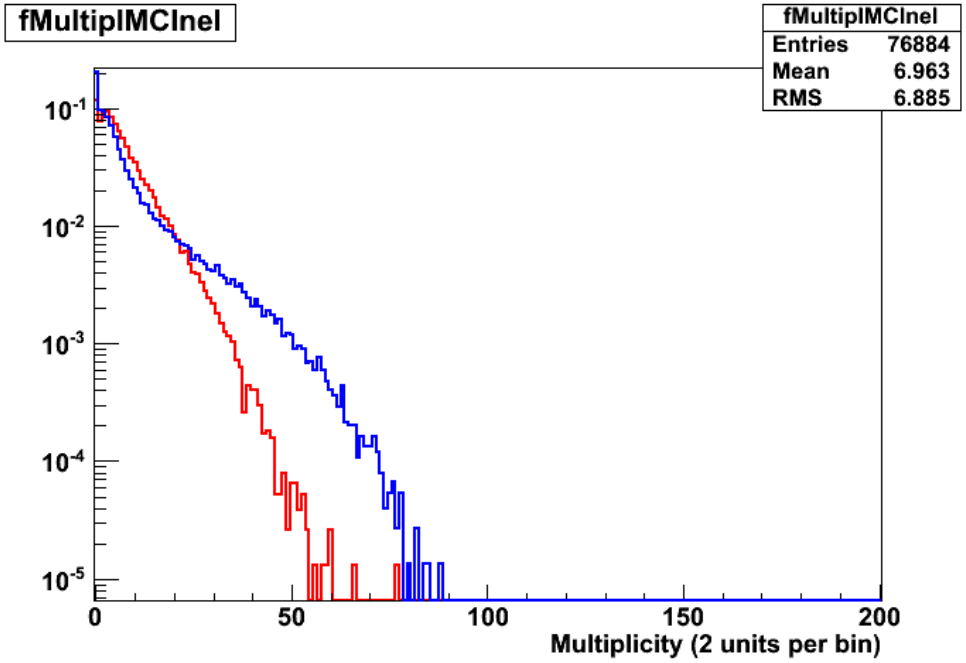
Pythia

Phojet

SD



PYTHIA “old” vs PHOJET - N_{ch}

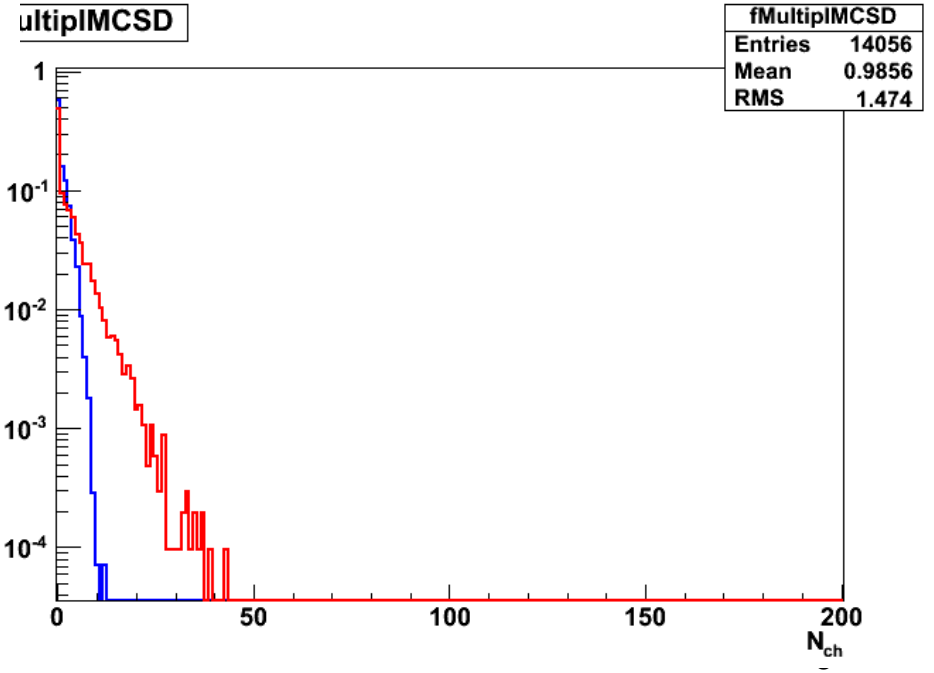


Inelastic = SD + DD + ND

Pythia

Phojet

SD



Diffraction in PYTHIA – “new”

Event Generation:

- Cross sections - same way as before
- Diffractive mass (M_X) and momentum transfer (t) picked by Pomeron flux model

Particle Production:

- Pomeron-p collisions
- Pomeron PDF with Q^2- dependence from H1 data

  - H1 2007 DPDF Fit Jets and H1 2006 Fits A and B

  - Pion PDF also available
- Standard PYTHIA machinery for multiple interactions, parton showers, hadronization

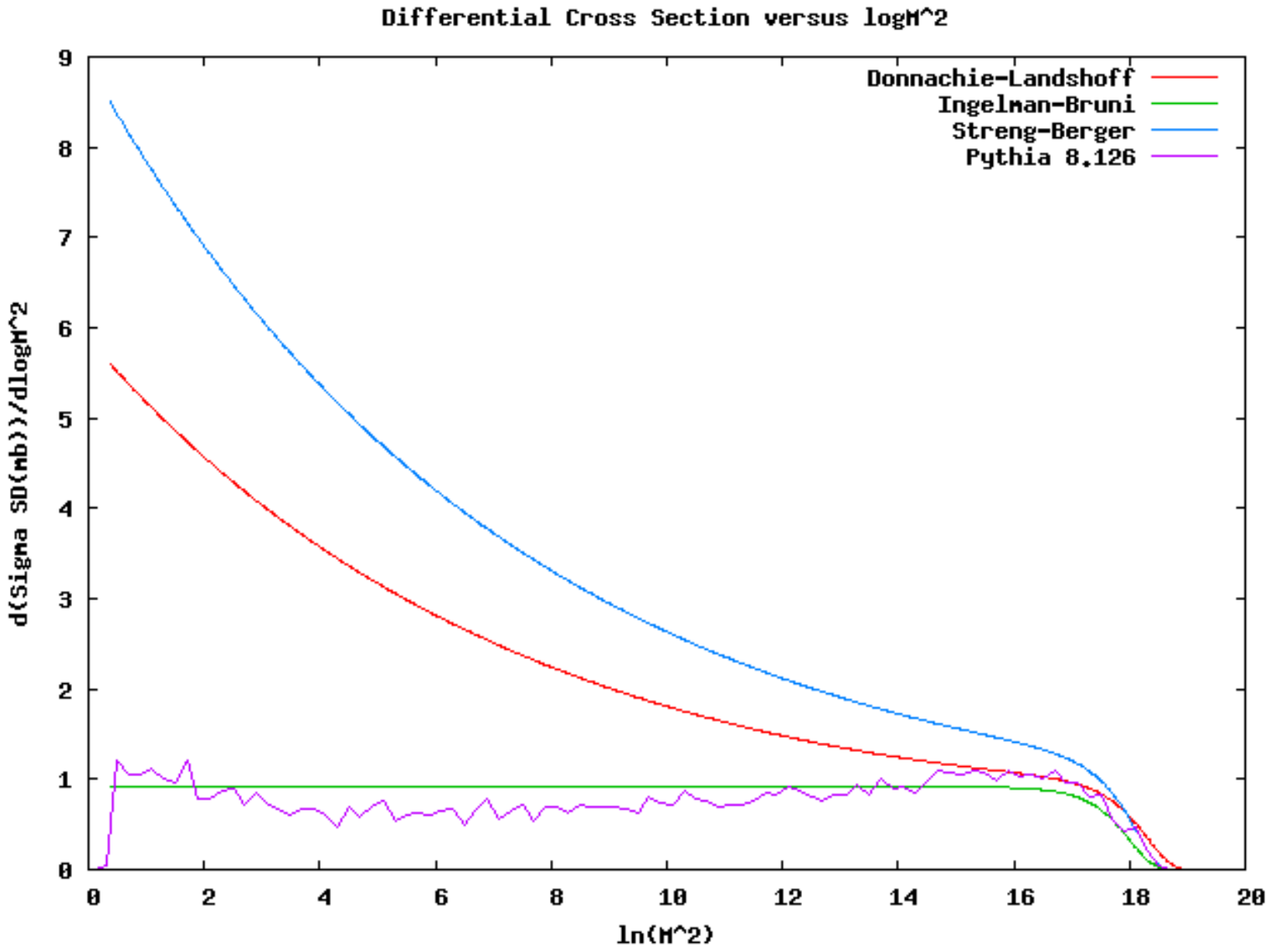
Mass separation:

- For $1.2\ GeV < \mathrm{M}_X < 10\ GeV$ non-perturbative description (as before)

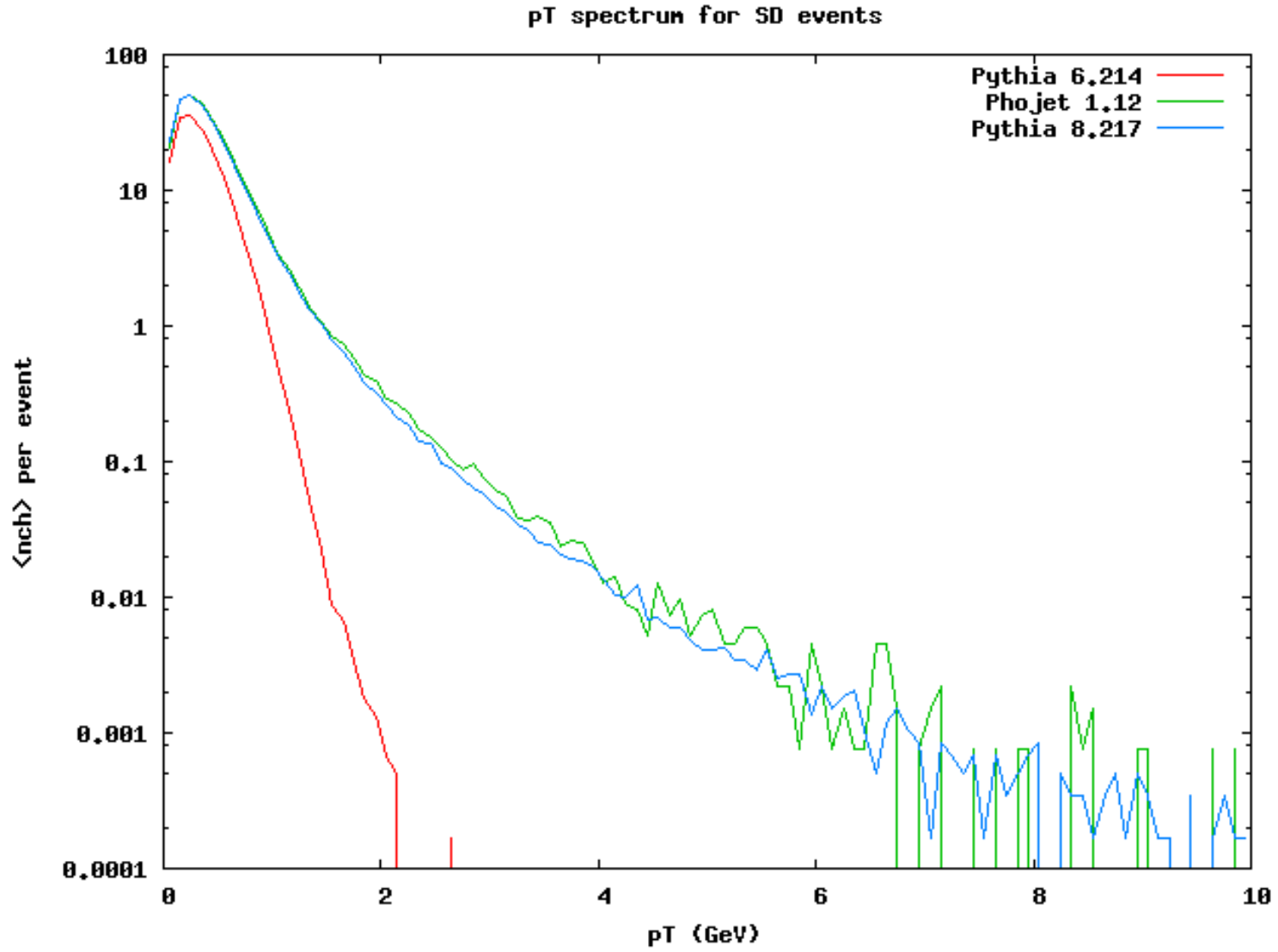
  - longitudinally stretched strings
- For $\mathrm{M}_X > 10\ GeV$ perturbative

Pomeron Flux factor

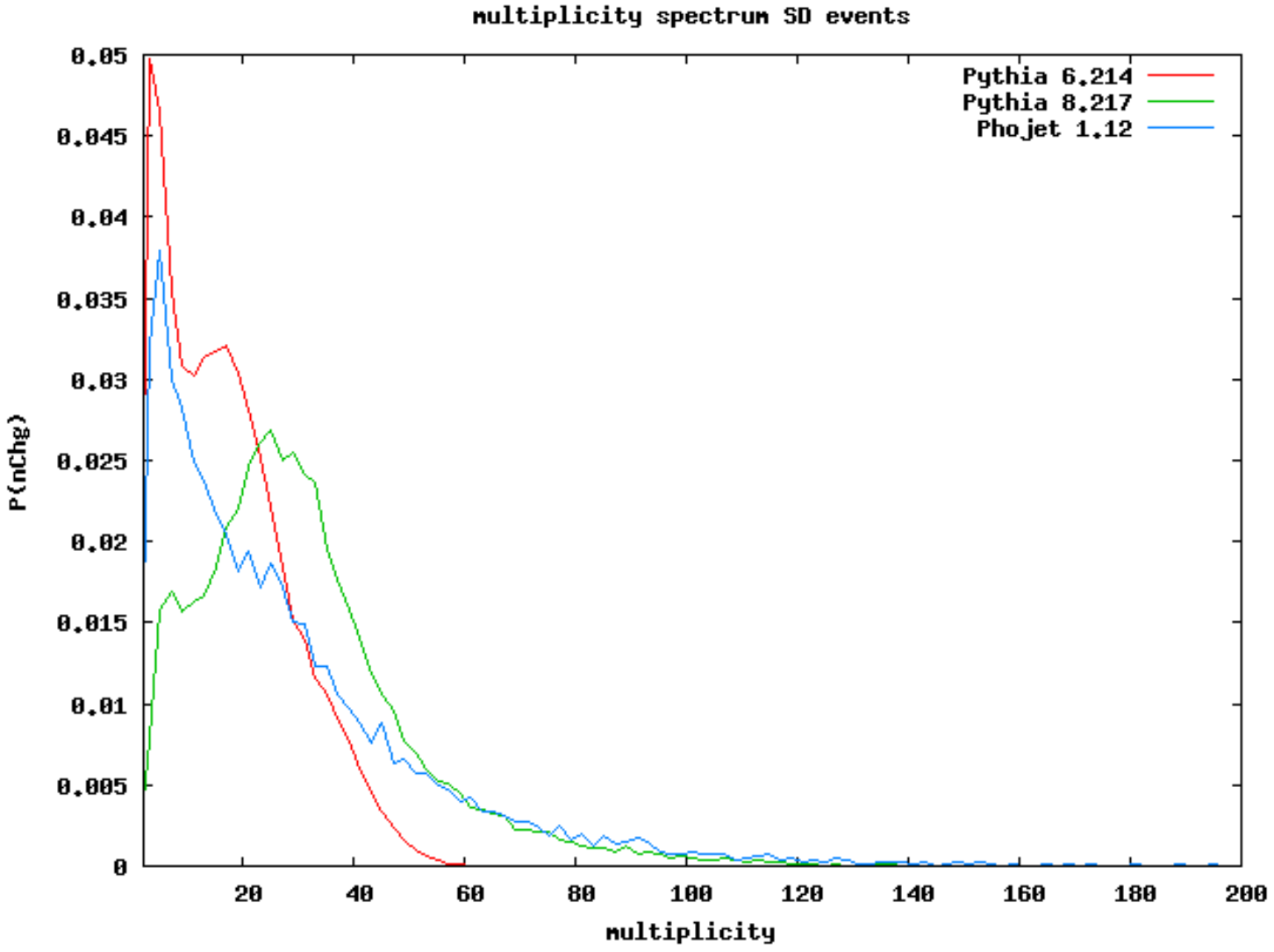
- Energy dependent



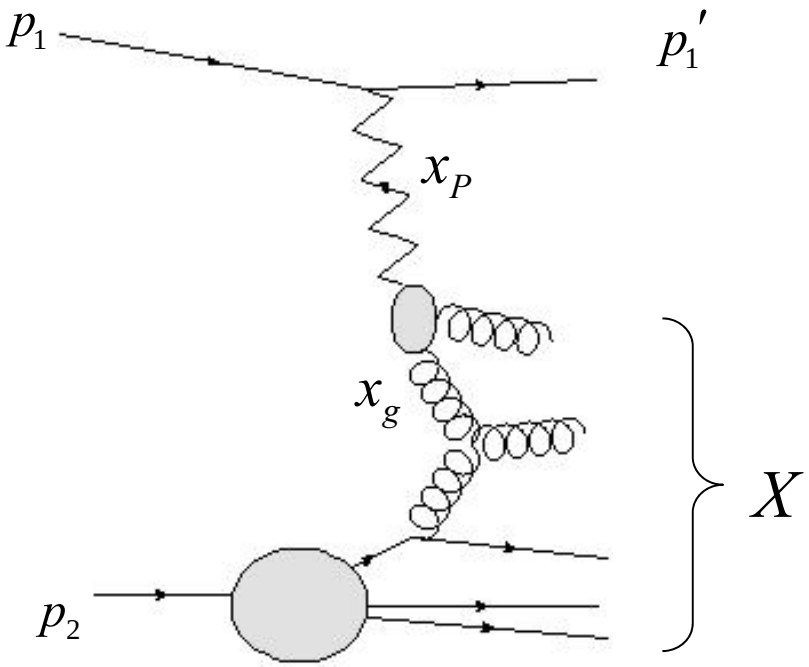
PYTHIA “old” vs “new” - pT



PYTHIA “old” vs “new” - Nch



Comments



In the massless limit

$$x_P \approx \frac{E_P}{E_{proton}} \qquad x_g \approx \frac{E_g}{E_P}$$

$$M_X^2 \approx x_P s$$

Diffractive hard scattering cross section:

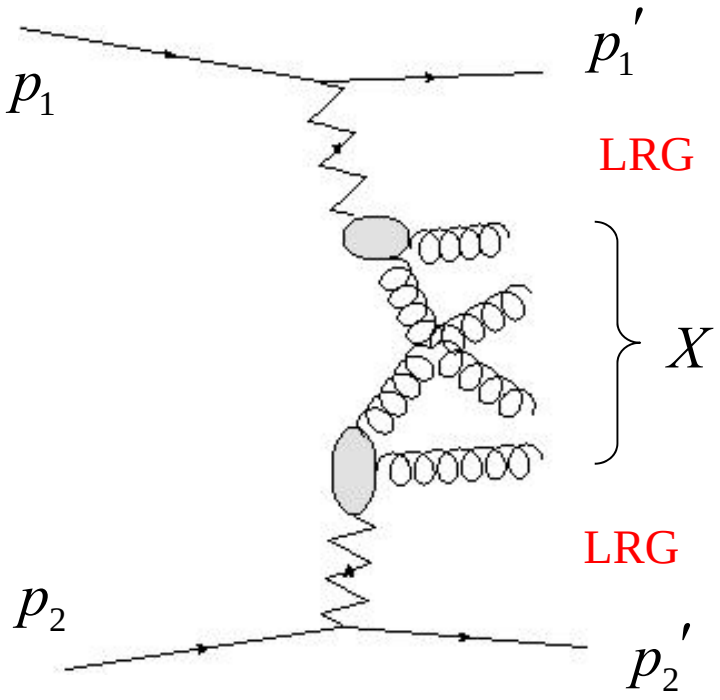
$$\frac{d\sigma}{dQ^2} \propto \underbrace{f_{P/proton}(x_P)}_{\text{Pomeron flux}} \underbrace{f_{q(g)/P}(x_{q(g)}, Q^2)}_{\text{Pomeron PDF}} \frac{d\hat{\sigma}}{dQ^2}$$

Not known from first principles

Multiple interactions => screening of diffractive rates

Future Plans

- Include Central Diffraction



- Does p_{T0} cut-off depend on the diffractive mass?
- Introduce a screening factor to go from ep to pp collisions
- Momentum sum of PDFs

Summary

- Earlier versions of PYTHIA had a primitive description of diffraction
- No hard diffraction – caused the difference in pT and multiplicity tails compared to PHOJET
- New version has Pomeron description of diffraction
- Hard collisions can be simulated
- Better agreement with PHOJET

Back up slides

- Trigger efficiencies – ALICE
- SD, DD, ND events in ALICE detectors
- Diffraction in Phojet
- Extraction of fractions from data - ALICE

Trigger Efficiencies and corrections

$$\text{Efficiency} = N_{triggered} / N_{total} = \sum f_{process} e_{process}$$
$$= f_{SD} e_{SD} + f_{DD} e_{DD} + f_{ND} e_{ND}$$

- Need to know the fraction (f) and the efficiency (e) for each process.
- Efficiency is process, trigger and generator dependent

MB1 = SPD or V0A or V0C

MB1 efficiencies:

Process	SD	DD	ND
Fraction (f)	0.187	0.127	0.686
Efficiency (e)	0.714	0.864	0.999

Pythia: 92.9%

Process	SD	DD	ND
Fraction (f)	0.134	0.063	0.803
Efficiency (e)	0.767	0.938	0.999

Phojet: 96.4%

Major difference is in diffractive events

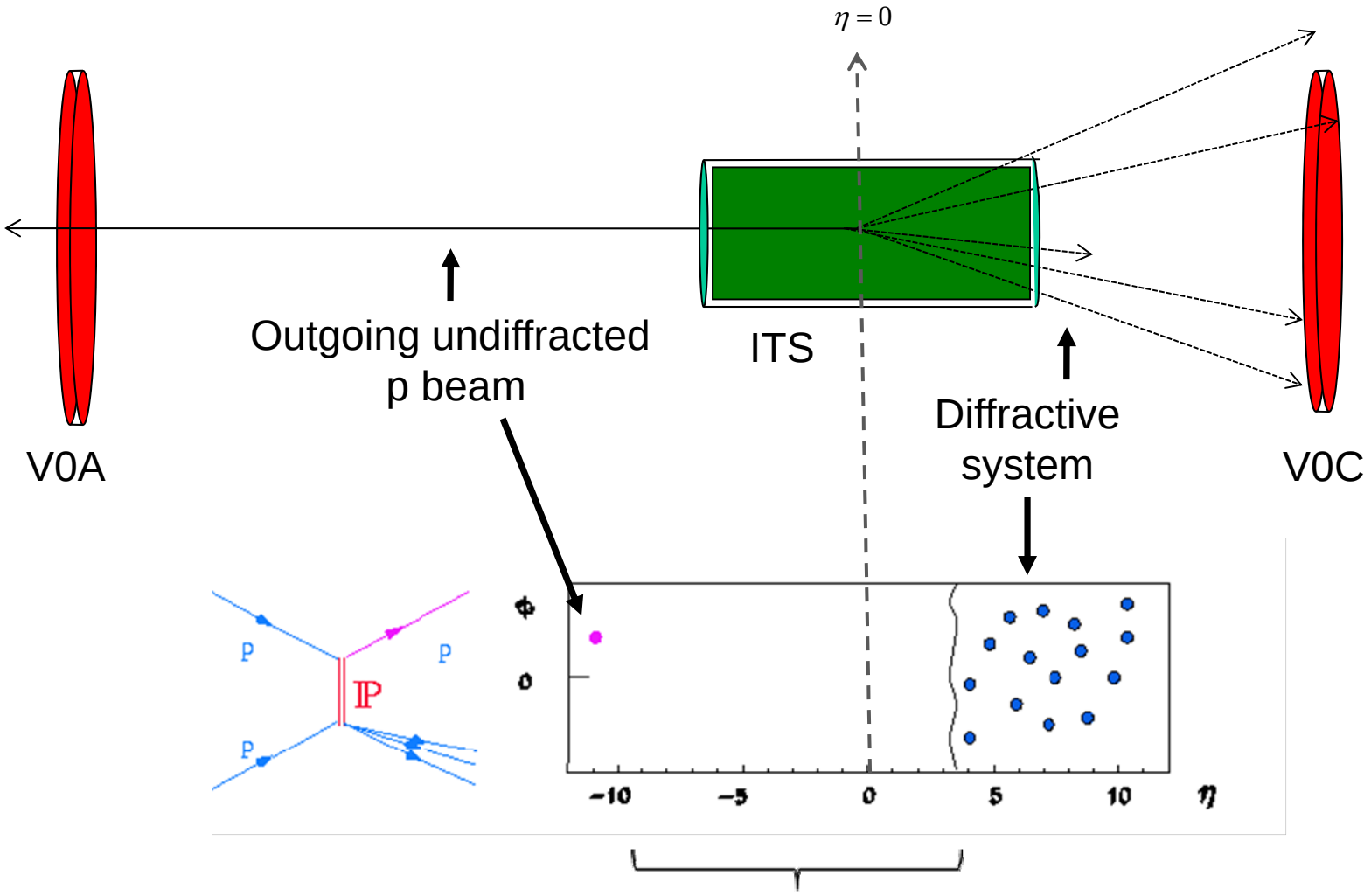
Reason for difference:

f – uncertainty in cross sections

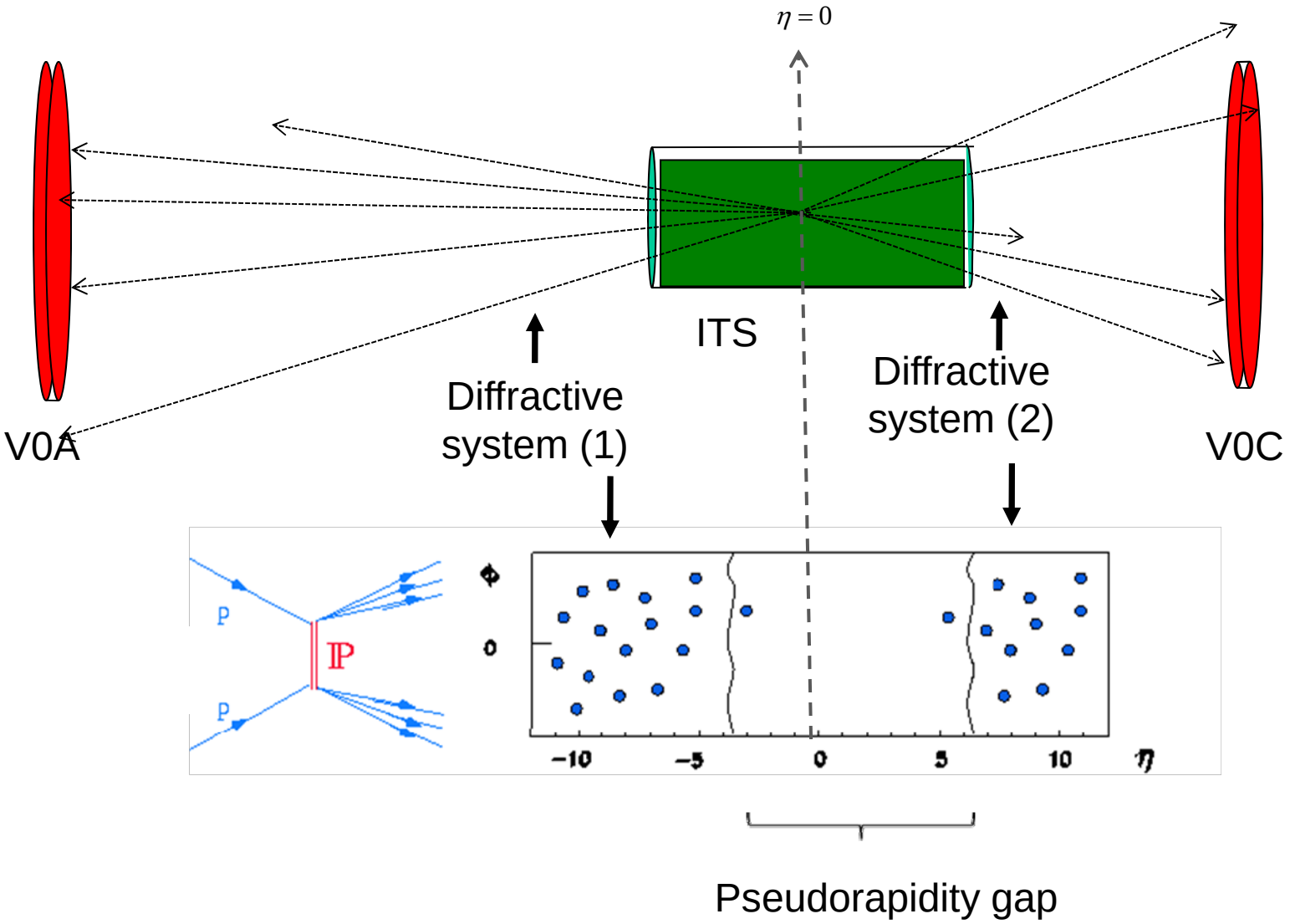
e – uncertainty in kinematics

~2-4% effect each

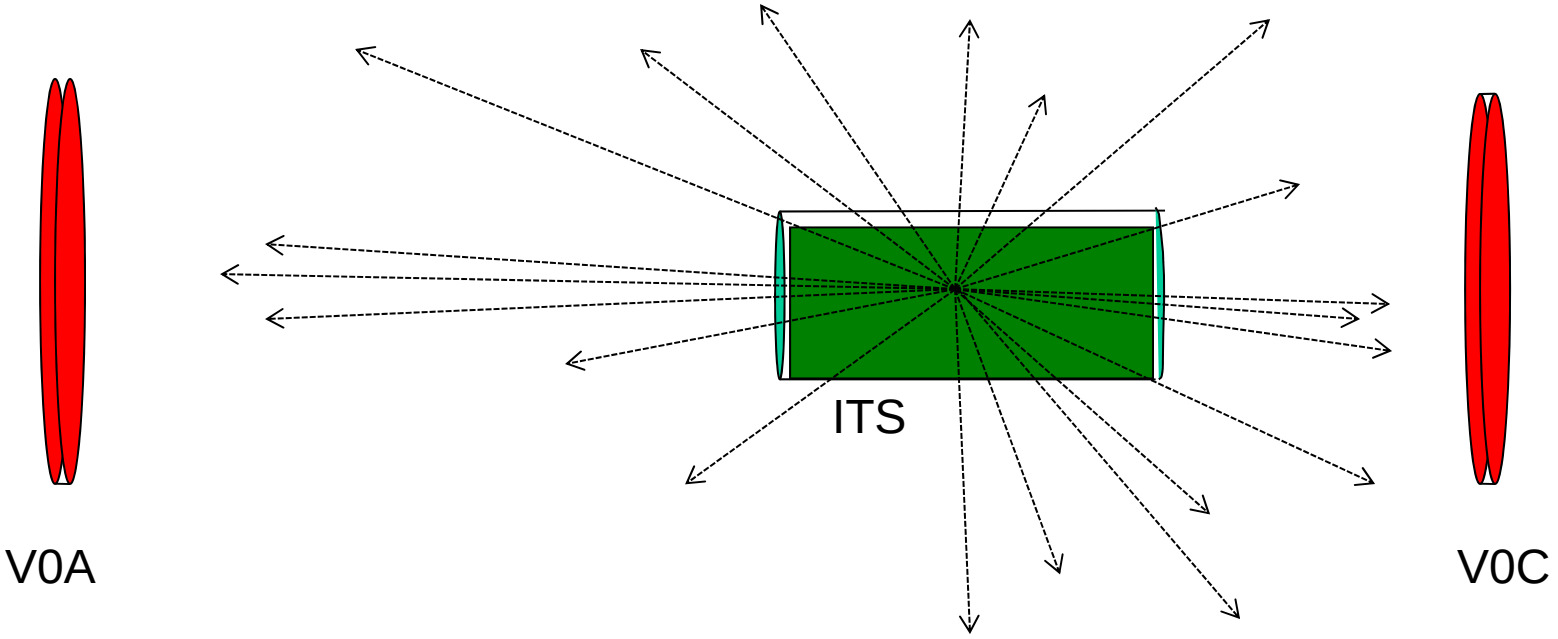
Single Diffraction (SD) in ALICE

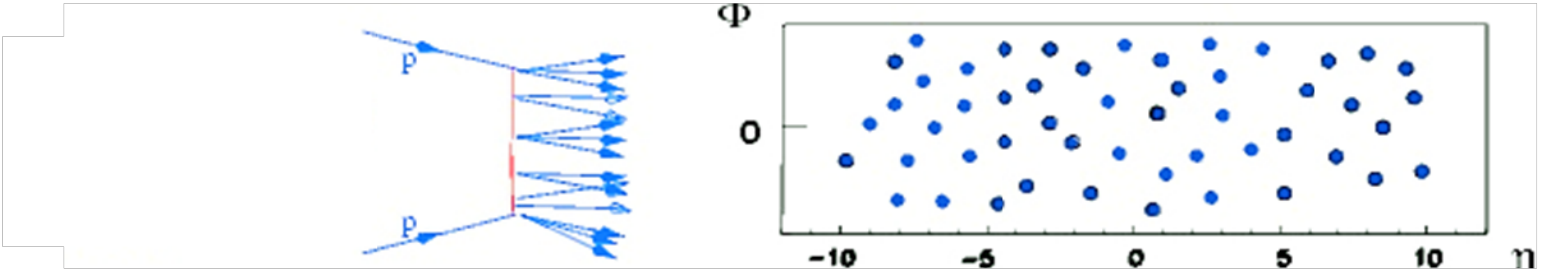


Double Diffraction (DD) in ALICE



Non Diffractive (ND) events





No pseudorapidity gap

Central elements of Phojet

- R. Engel workshop on soft diffraction at LHC 26/6/09

Two component Pomeron

Only one pomeron with soft and hard contributions

Topological identification of different terms (Dual parton model)

Soft and hard partons differ in impact parameter distribution

Application of existing parton density parametrisation

Initial and final state radiation (leading logQ^2 parton showers)

Extraction of fractions

- Z.Matthews 20/03/09, ALICE first physics meeting

- Trigger on bunch crossing
- Define 8 uncorrelated trigger types using SPD, V0A and V0C
- Meausre N_{trig}

$$N_{trig} = N_{trig}^{SD} + N_{trig}^{DD} + N_{trig}^{ND} + N_{trig}^{NI}$$

$$N_{trig} = N_{gen}\left(\frac{N_{trig}^{SD}}{N_{gen}^{SD}} \frac{N_{gen}^{SD}}{N_{gen}} + \frac{N_{trig}^{DD}}{N_{gen}^{DD}} \frac{N_{gen}^{DD}}{N_{gen}} + \frac{N_{trig}^{ND}}{N_{gen}^{ND}} \frac{N_{gen}^{ND}}{N_{gen}} + \frac{N_{trig}^{NI}}{N_{gen}^{NI}} \frac{N_{gen}^{NI}}{N_{gen}} \right)$$

$$N_{trig} = N_{gen}\left(f_{SD} e_{SD} + f_{DD} e_{DD} + f_{ND} e_{ND} + f_{NI} e_{NI} \right)$$

measured

calc

$$\chi^2 = \sum_{trig} \left[\frac{N_{trig-calc}(i) - N_{trig-measured}(i)}{\text{Error}(N_{trig-measured}(i))} \right]^2$$

- Program works out combinations of fractions to generate $N_{trig-calc}$ so as to minimise χ^2