Diffraction in Pythia

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Outline

- Motivation for the project
  - ALICE first physics programme and detectors
  - Minimum Bias trigger efficiencies and corrections
  - Pythia vs Phojet
- Diffraction
  - pp collisions, process types
  - Physics of diffraction
  - As seen by the ALICE detectors
- Diffraction in Pythia
  - Before
  - Current
  - Future
- Summary

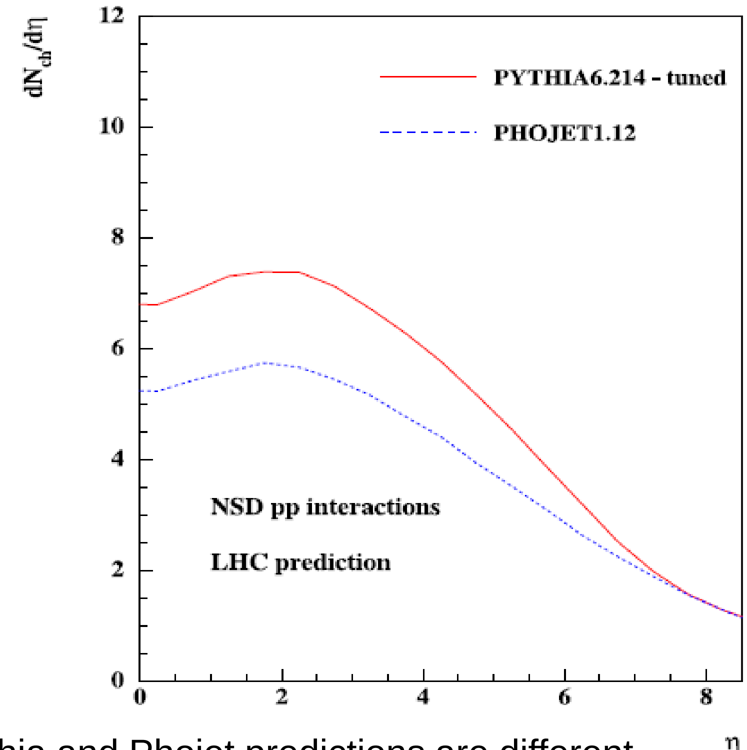
First pp Physics measurements

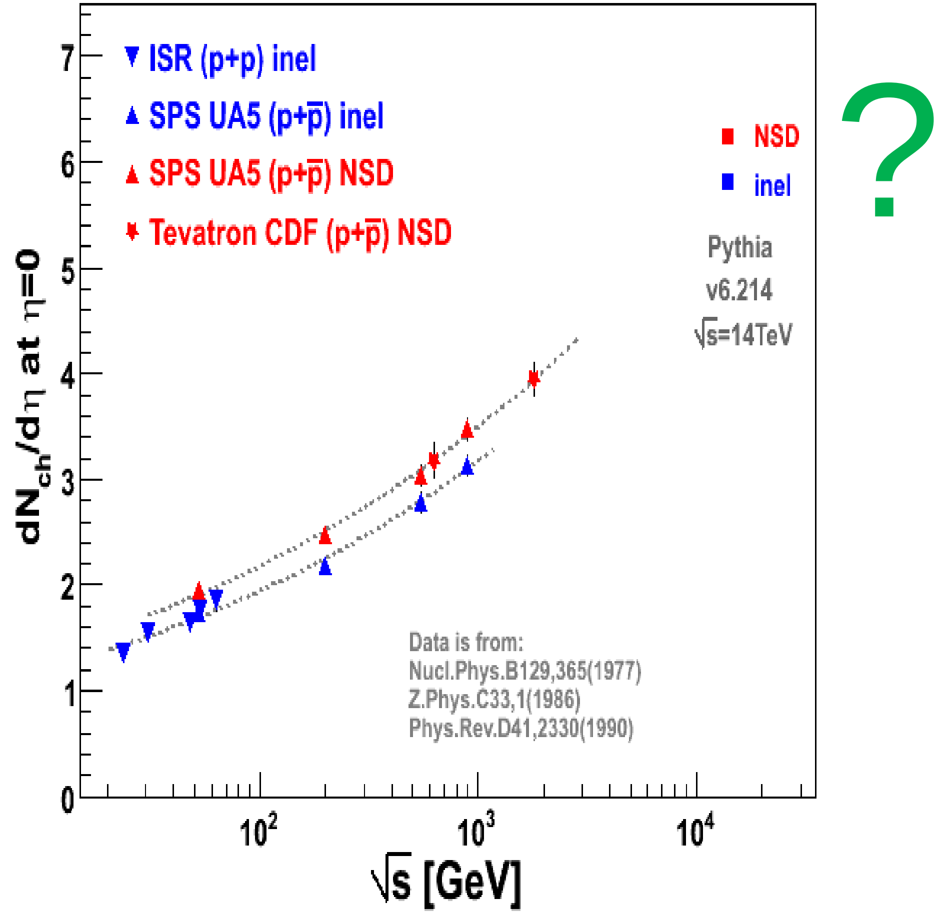
few minutes of data taking :

Pseudorapidity η

Multiplicity N_{CH}

Transverse momentum p_T

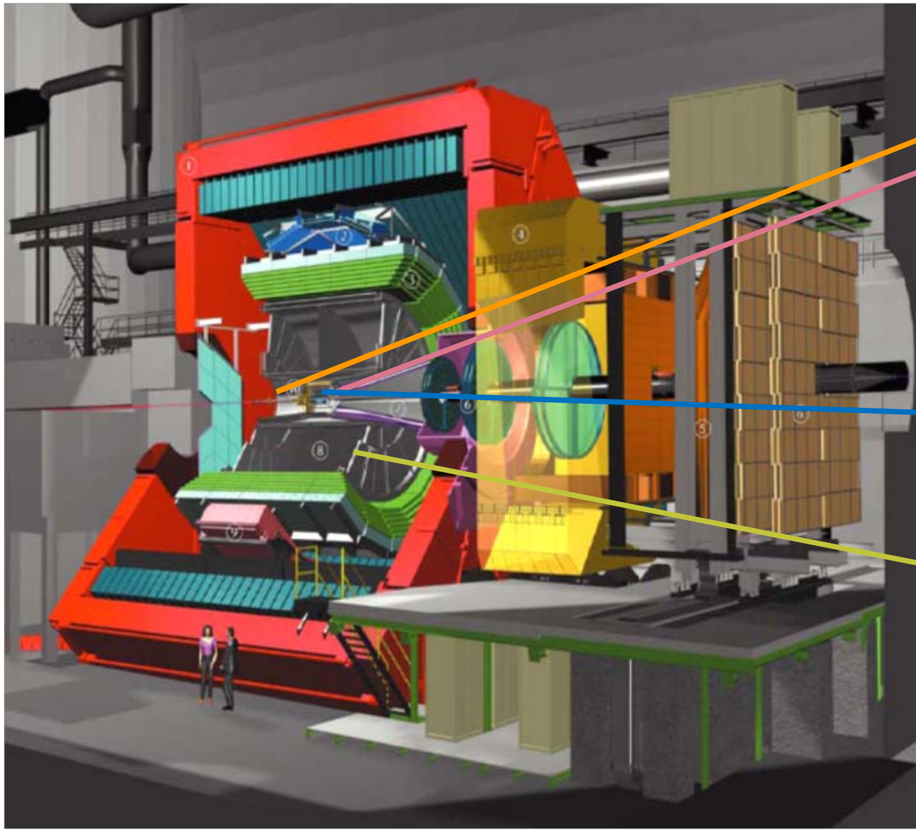




LHC energy predictions from models

Pythia and Phojet predictions are different
=> First measurements will be able to distinguish between them
Eur. Phys. J. C 50, 435–466 (2007)

A Large Ion Collider Experiment



V0A
V0C

- Two discs of scintillators either side of interaction point.
- Provide the V0A and V0C trigger signals

ITS
(Inner Tracking System)

- 6 concentric silicon cylinders surrounding the interaction point
- Used for tracking
- Inner 2 layers provide the SPD trigger signal

TPC
(Time Projection Chamber)

- Main gas-filled tracking detector

52 m underground

16 m high

26 m long

10,000 tonnes

0.5 T magnetic field

Primary purpose – heavy ion detector for Pb-Pb collisions at 5.5 TeV
First physics programme is pp at 900 GeV, 2 TeV, 10 TeV, 14 TeV collision energy

- Time and space alignments
- Physics cross checks with previous results
- pp bench mark to study genuine Pb-Pb effects

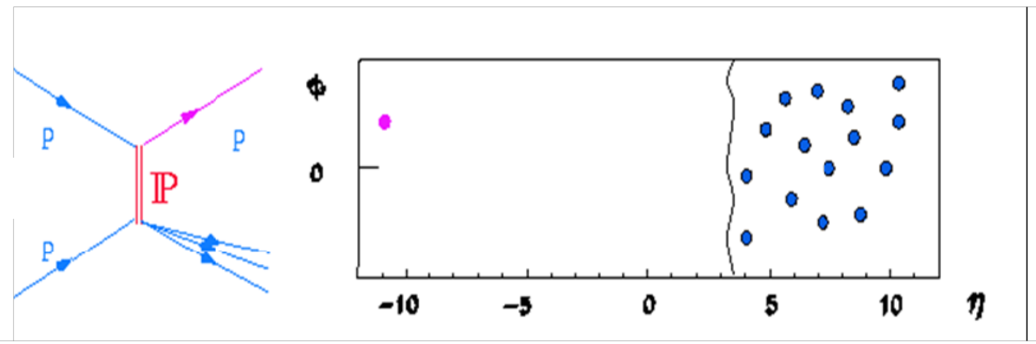
Process Types

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

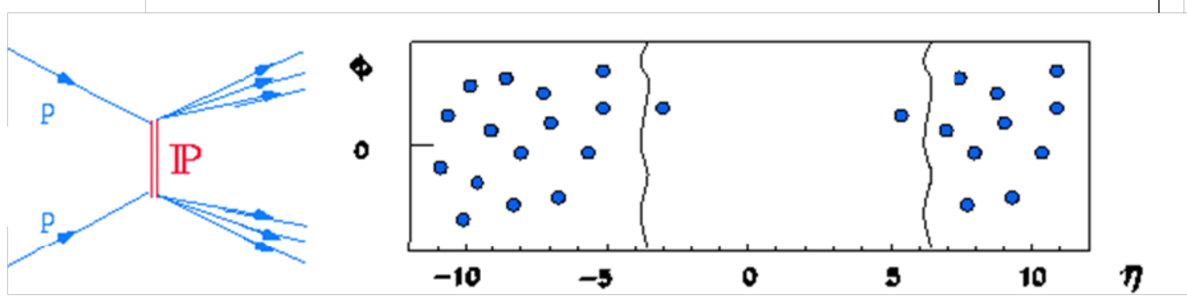
$$\sigma_{SD} + \sigma_{DD} + \sigma_{ND} + \ldots$$

- True cross sections at LHC energies are not known
- Scaling of cross sections with energy is model dependent

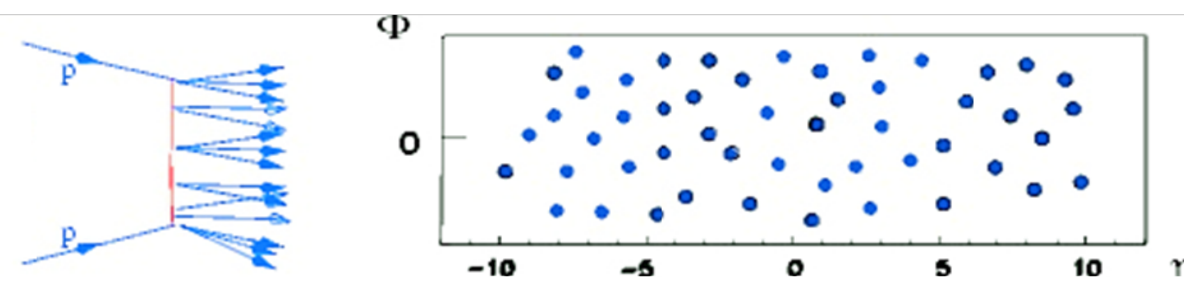
Single Diffraction - SD



Double Diffraction - DD



Non Diffractive - ND



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

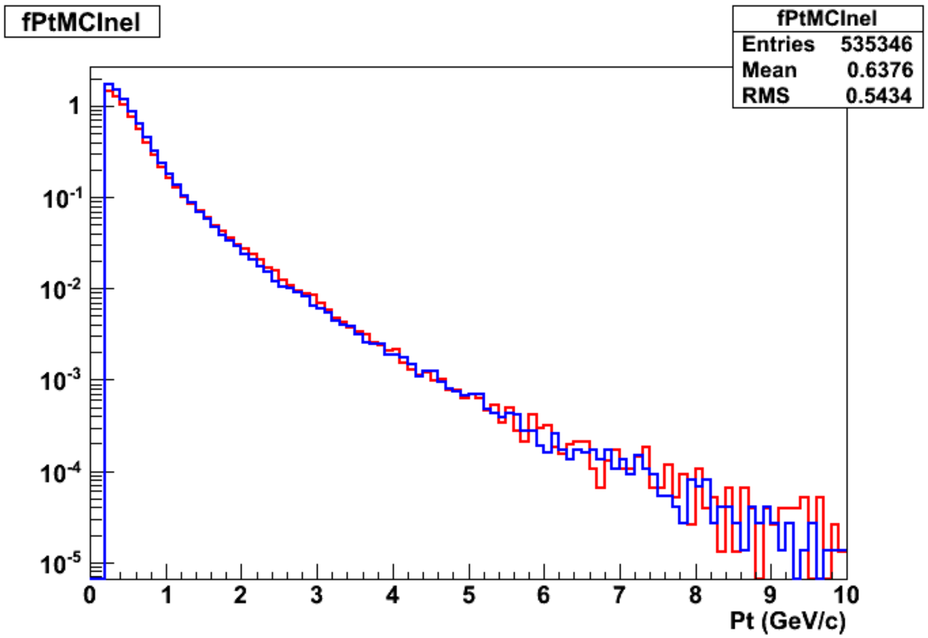
Phojet: 96.4%

Major difference is in diffractive events

Reason for difference:
f – uncertainty in cross sections
e – uncertainty in kinematics

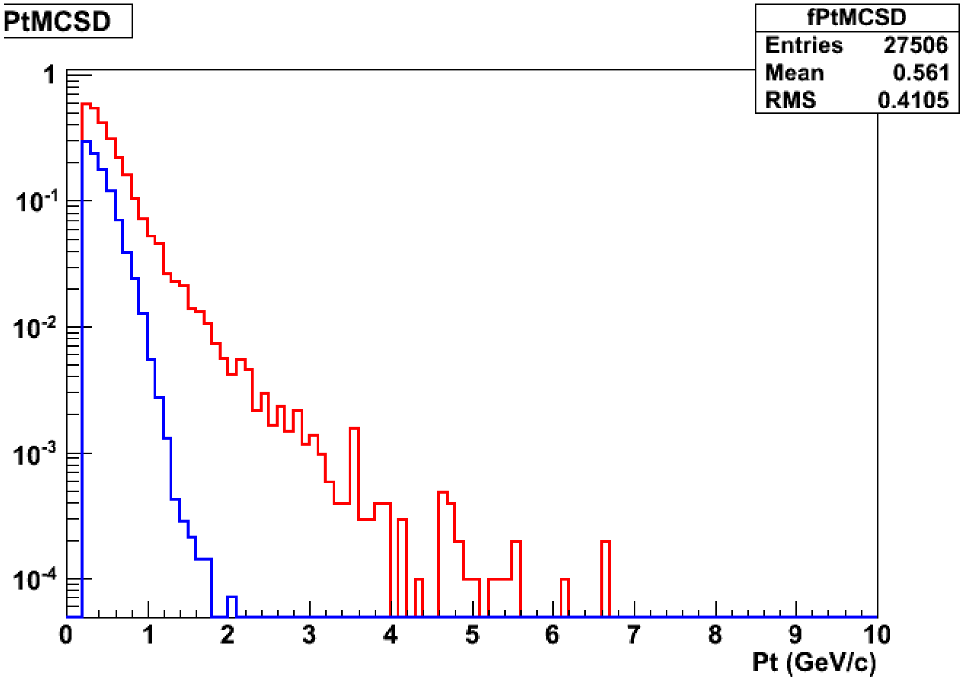
~2-4% effect each

Pythia vs Phojet - p_T



Pythia
Phojet

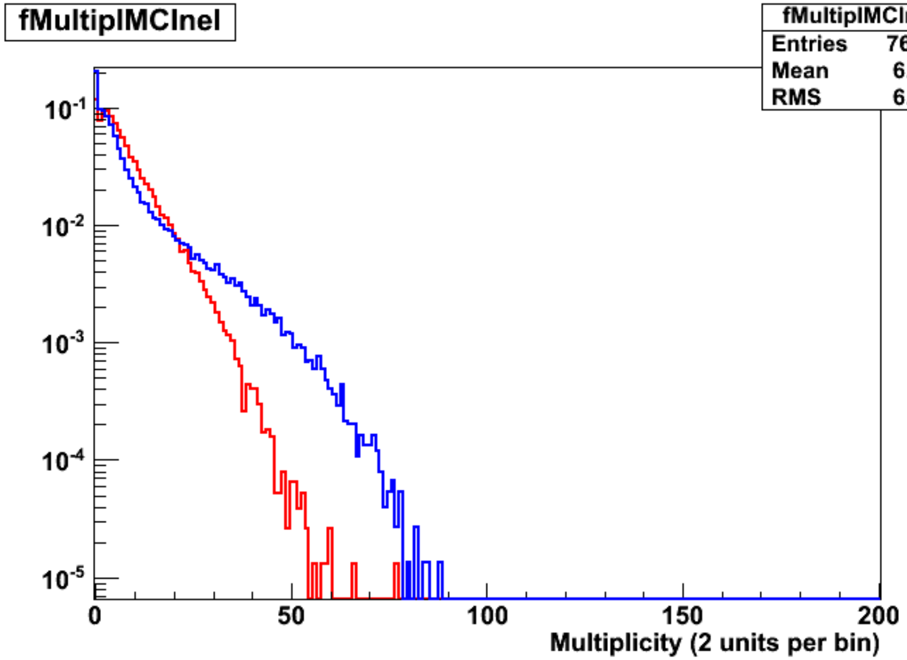
SD



Inelastic = SD + DD + ND

Normalised to number of events

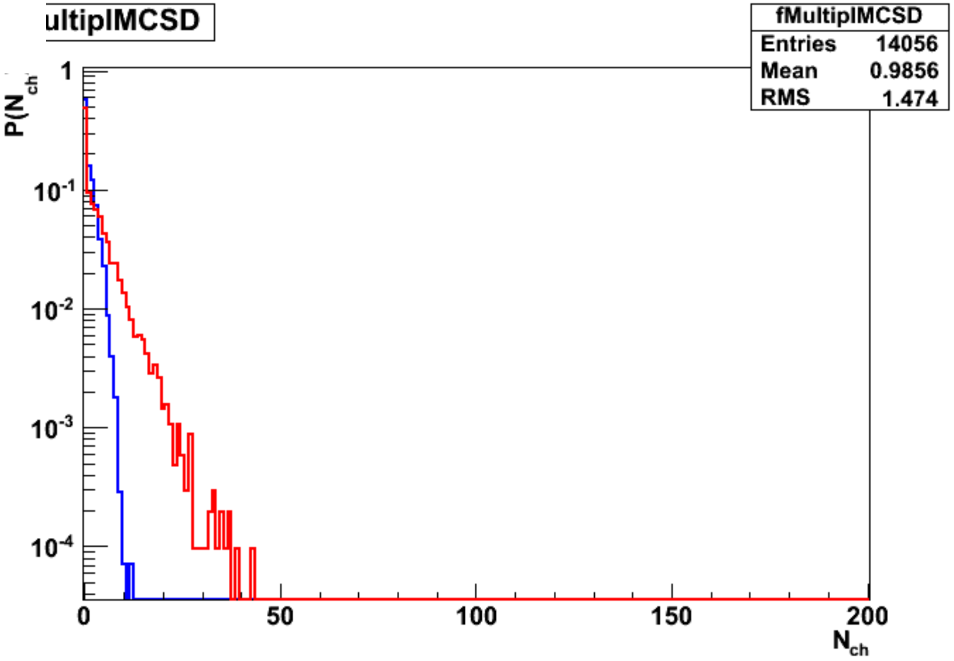
Pythia vs Phojet - multiplicity



Pythia

Phojet

SD



Inelastic = SD + DD + ND

Normalised to one

Diffraction

- Very brief introduction

Diffraction and the Pomeron

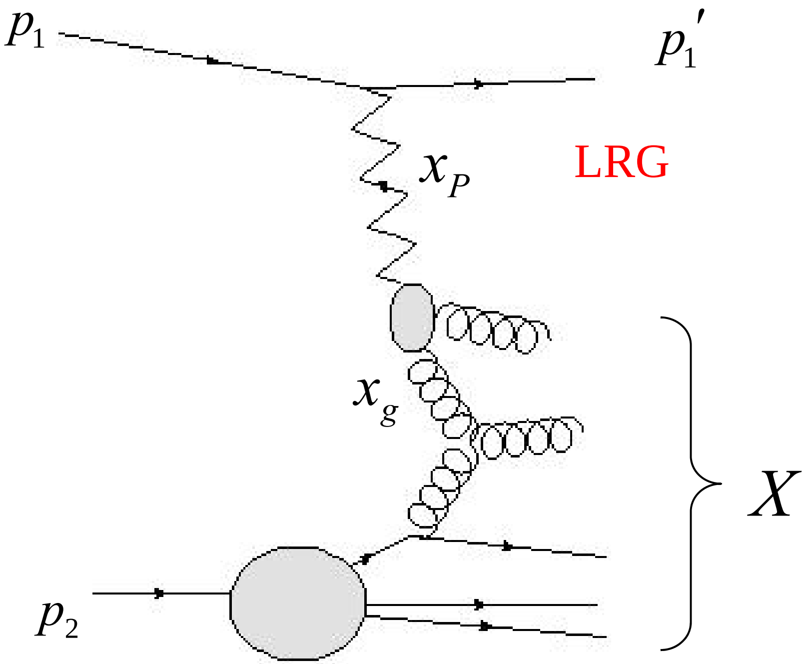
• Small energy transfer between the two interacting hadrons

• One (SD) or both (DD) of the hadrons dissociate into multi-particle final states with mass (much) less than the total energy

• Quantum numbers of initial hadron preserved

• In Regge theory, diffraction is a result of the exchange of a Pomeron
  - Pomeron lies on the Regge trajectory
  - Is the effective summation of particles on the trajectory
  - Has quantum numbers of vacuum – "glueball" exchange
  - Has parton distribution functions (PDF)

Diffraction – kinematic variables



In the massless limit

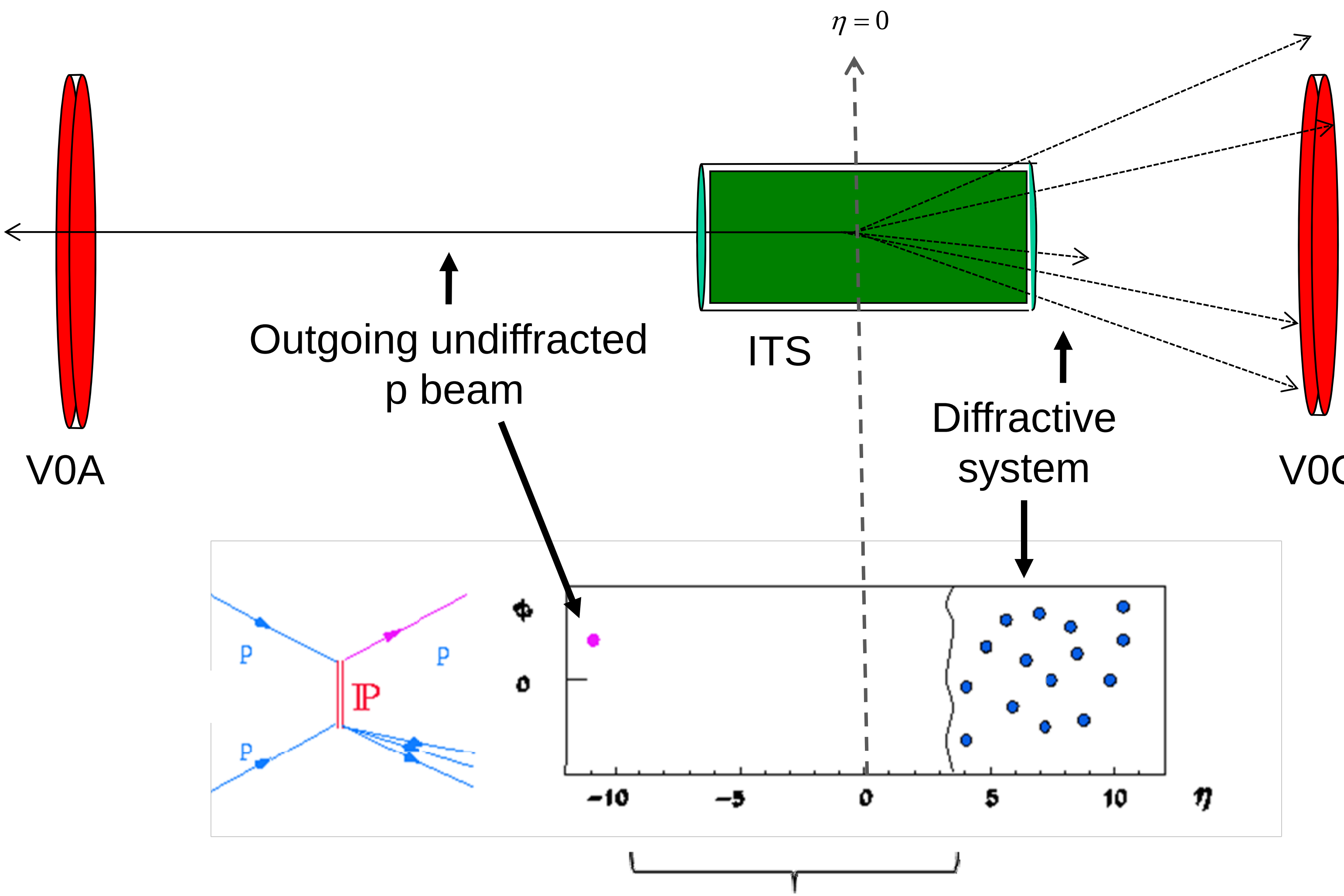
$$x_P \approx \frac{E_P}{E_p} \qquad x_g \approx \frac{E_g}{E_P}$$

$$M_X^2 \approx x_P s$$

Diffractive hard scattering cross section:

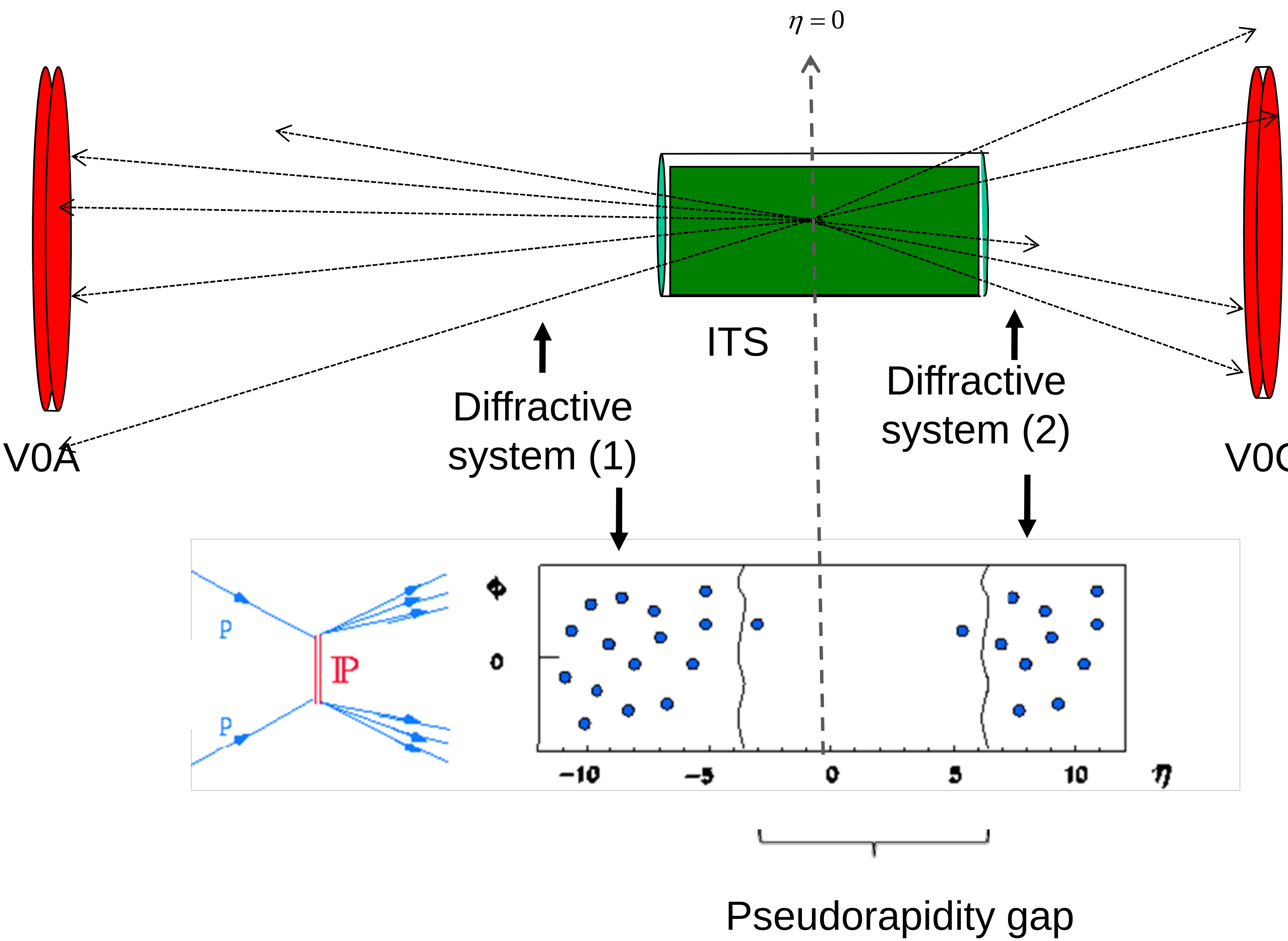
$$\frac{d\sigma}{dQ^2} \propto \underbrace{f_{P/p}(x_P)}_{\text{Pomeron flux}} \; \underbrace{f_{q(g)/P}(x_{q(g)}, Q^2)}_{\text{Pomeron PDF}} \; \frac{d\hat{\sigma}}{dQ^2}$$

Single Diffraction (SD) in ALICE

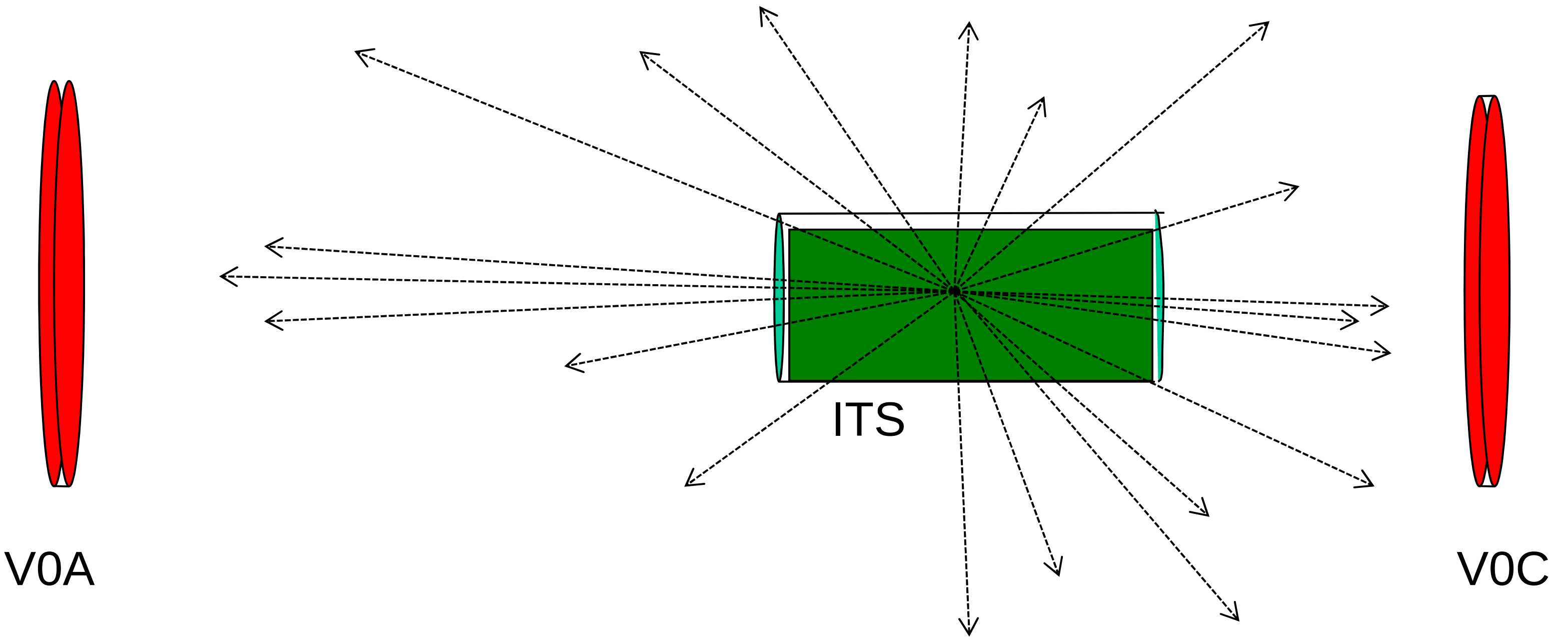


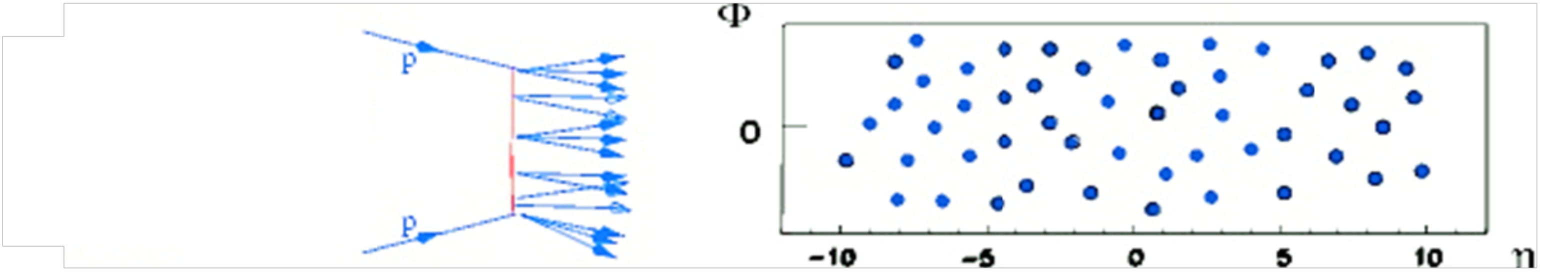
Pseudorapidity gap

Double Diffraction (DD) in ALICE



Non Diffractive (ND) events





No pseudorapidity gap

Diffraction in Pythia

- Current and future

Diffraction: Pythia vs Phojet

Event generation

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

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

– M.Bombara ALICE first physics 23/01/09

b - slope parameter of t distribution (different in Pythia and Phojet)

Particle production

Pythia

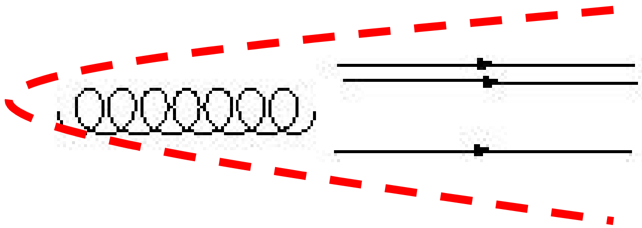
- For $M_X < 1\ GeVc^{-2}$ above mass of incoming particles - isotropical decay into 2-body state
- More massive system is treated as a string with quantum numbers of the original hadron

Phojet

- Pomeron+p interactions
- Contributions from hard scattering and from multiple soft interactions
- Central diffraction

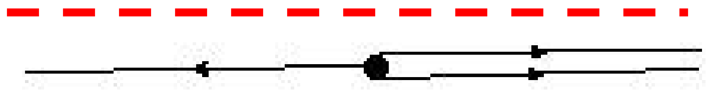
Diffraction in Pythia

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



Pomeron (P) exchange

Dominates in large M_X systems



Reggeon (R) exchange

Dominates in small M_X systems

Version 6.4 (Fortran)

- q and g contributions are set by a fixed ratio

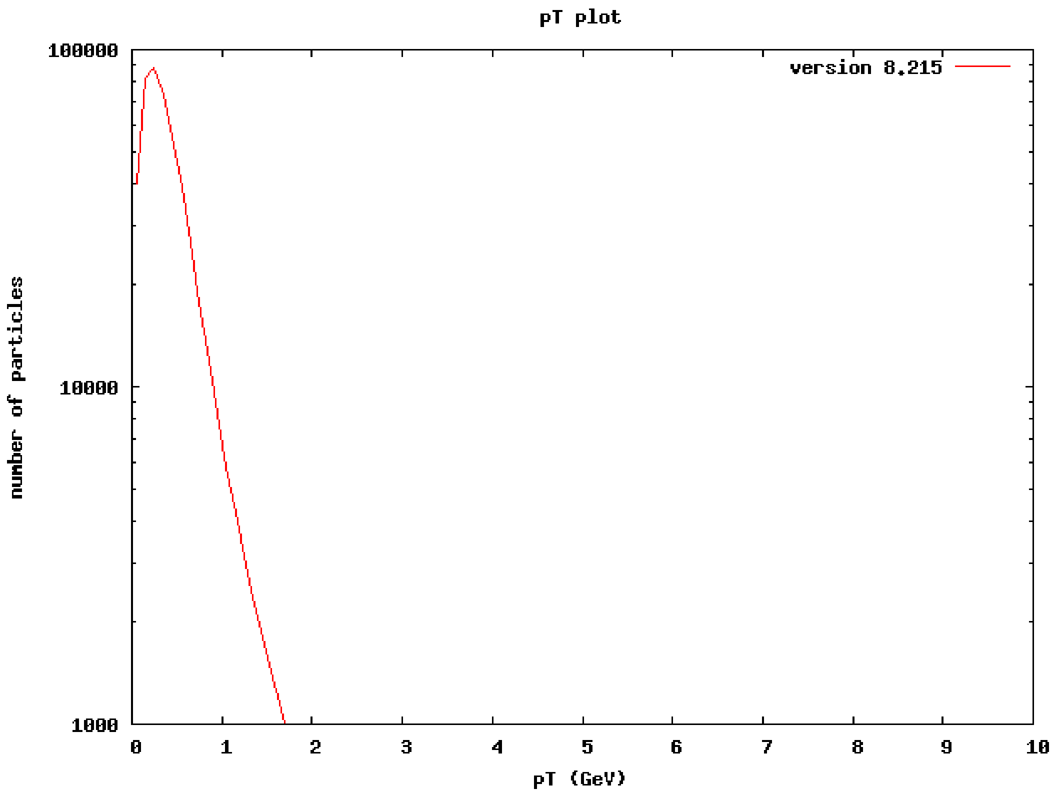
Version 8.1 (C++)

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

- Slopes (value of p) in P and R case are different
- Now there is a mass (M_X) dependence

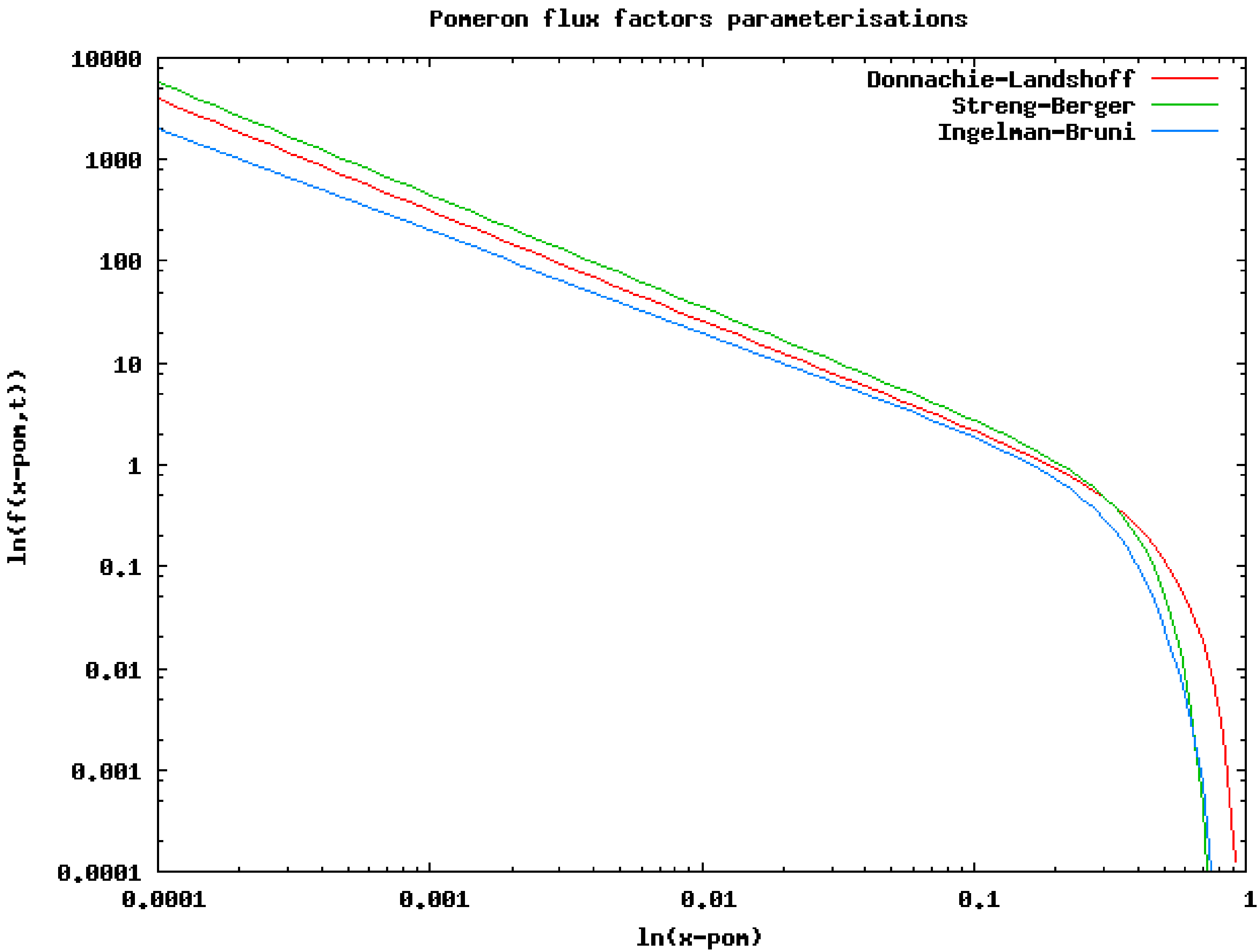
Current Work

- Diffraction being modelled as Pomeron-p collisions
- Pomeron PDF with Q^2 dependence from H1 data (H1 2007 DPDF Fit Jets) introduced
  - user sets quark and gluon contributions
  - H1 cannot measure gluons – DGLAP
- Pion PDF also available



Pomeron Flux factor

- Introduce Pomeron flux – energy dependent

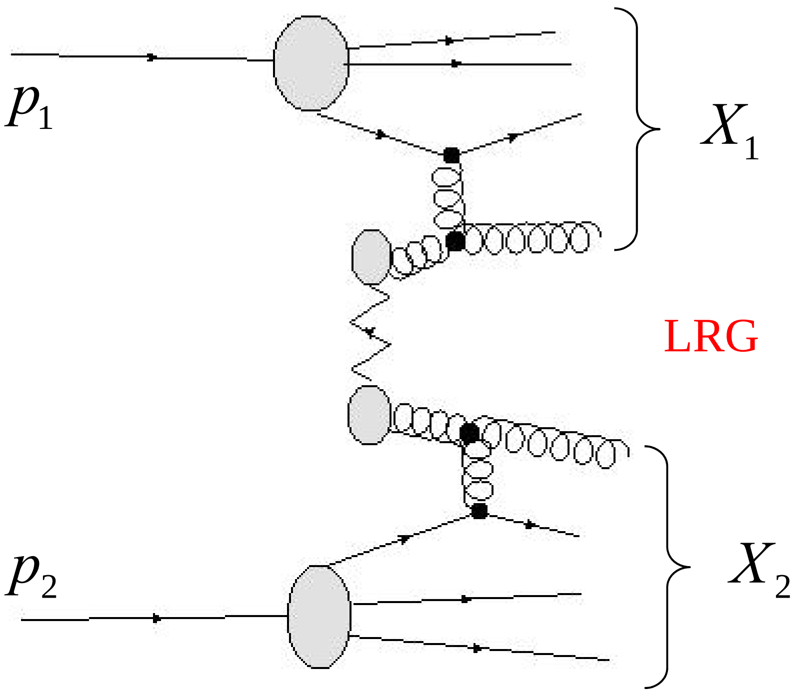


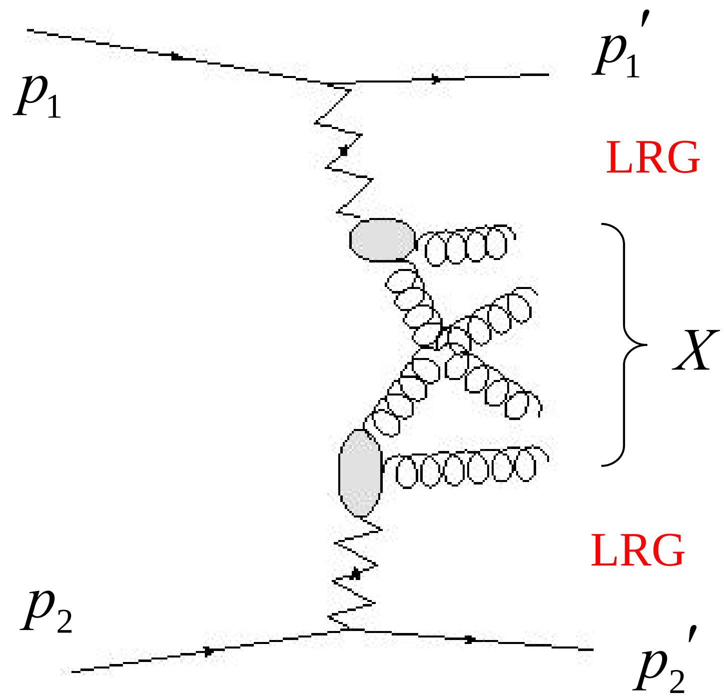
Future Plans

Include

Double Diffraction (DD)

Central Diffraction (CD)





- Does p_{T0} cut off depend on the diffractive mass?
- Introduce a screening factor to go from ep to pp collisions (colour screening in pP collisions)

Summary

- Major difference in efficiencies for ALICE triggers seen in diffractive events
- Pythia has a more primitive description of diffraction
- Diffraction modelled as Pomeron proton collisions using latest Q^2 - dependent PDF – work in progress
- Improvement of diffraction in Pythia => reduction of systematics in ALICE

Back up slides

- Why is it called diffraction
- Diffraction in Phojet
- More pythia vs phojet kinematics plots
- Trigger efficiencies
- 2d plot on the effect of systematics on multiplicity with ALICE triggers
- Extraction of fractions from data
- LHC incident and schedule

Why the name diffraction?

- Analogy with optics – single slit diffraction of white light
- Large forward peak for scattering angle $\theta = 0$ (elastic scattering)
- Series of symmetric minima and maxima
- Diffraction pattern related to size of target and wavelength of light beam

$$a \sin\theta = k\lambda$$

- If instead there is an obstacle at the slit
- Some of the wave energy absorbed by obstacle depending on how opaque it is
- Peripheral collision leads to diffraction -> more complex wave state (many particle diffractive state)

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

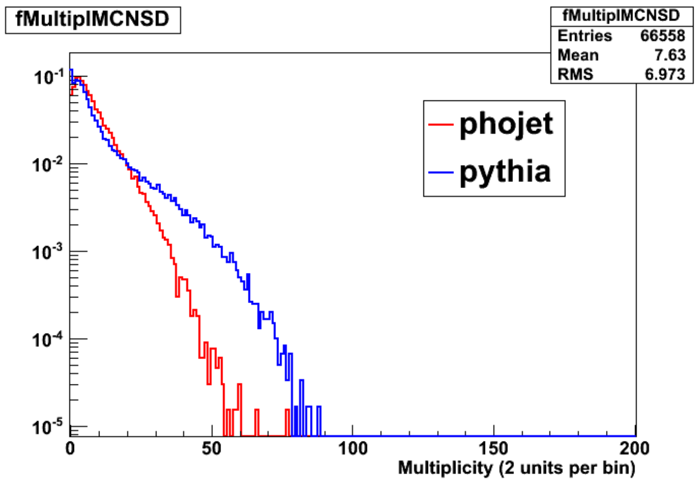
Topological identification of different terms (Dual parton model)

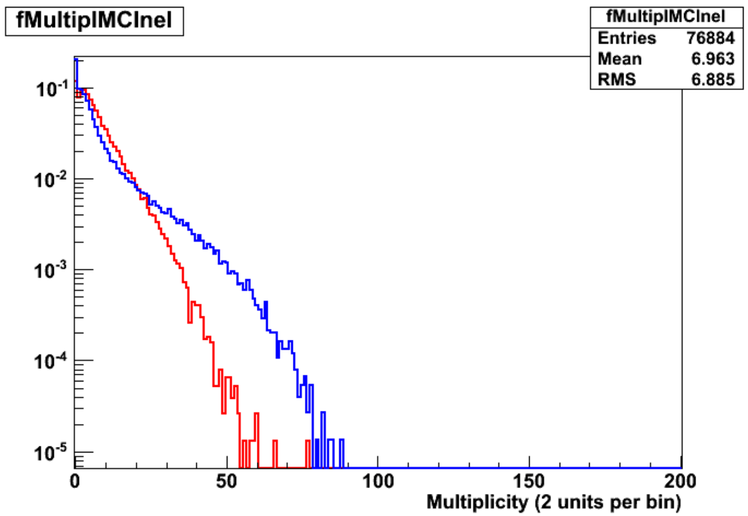
Soft and hard partons differ in impact parameter distribution

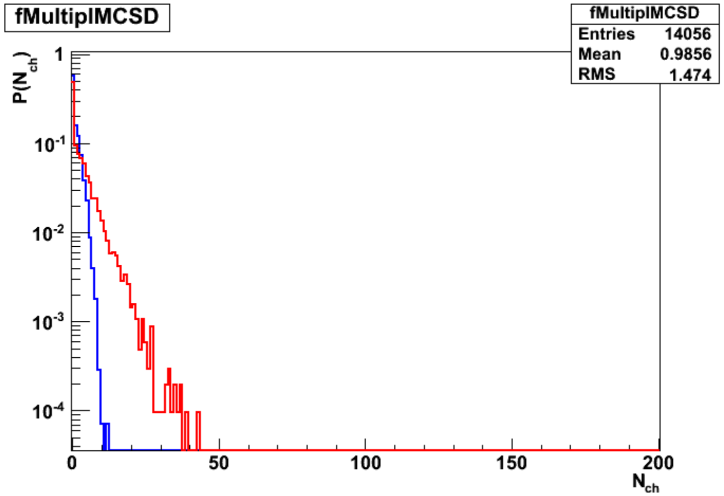
Application of existing parton density parametrisation

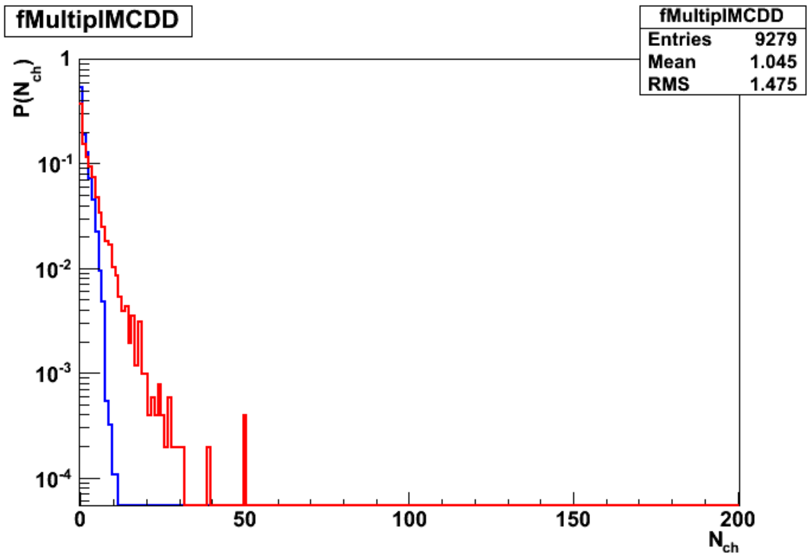
Initial and final state radiation (leading logQ^2 parton showers)

Kinematic comparison of generators



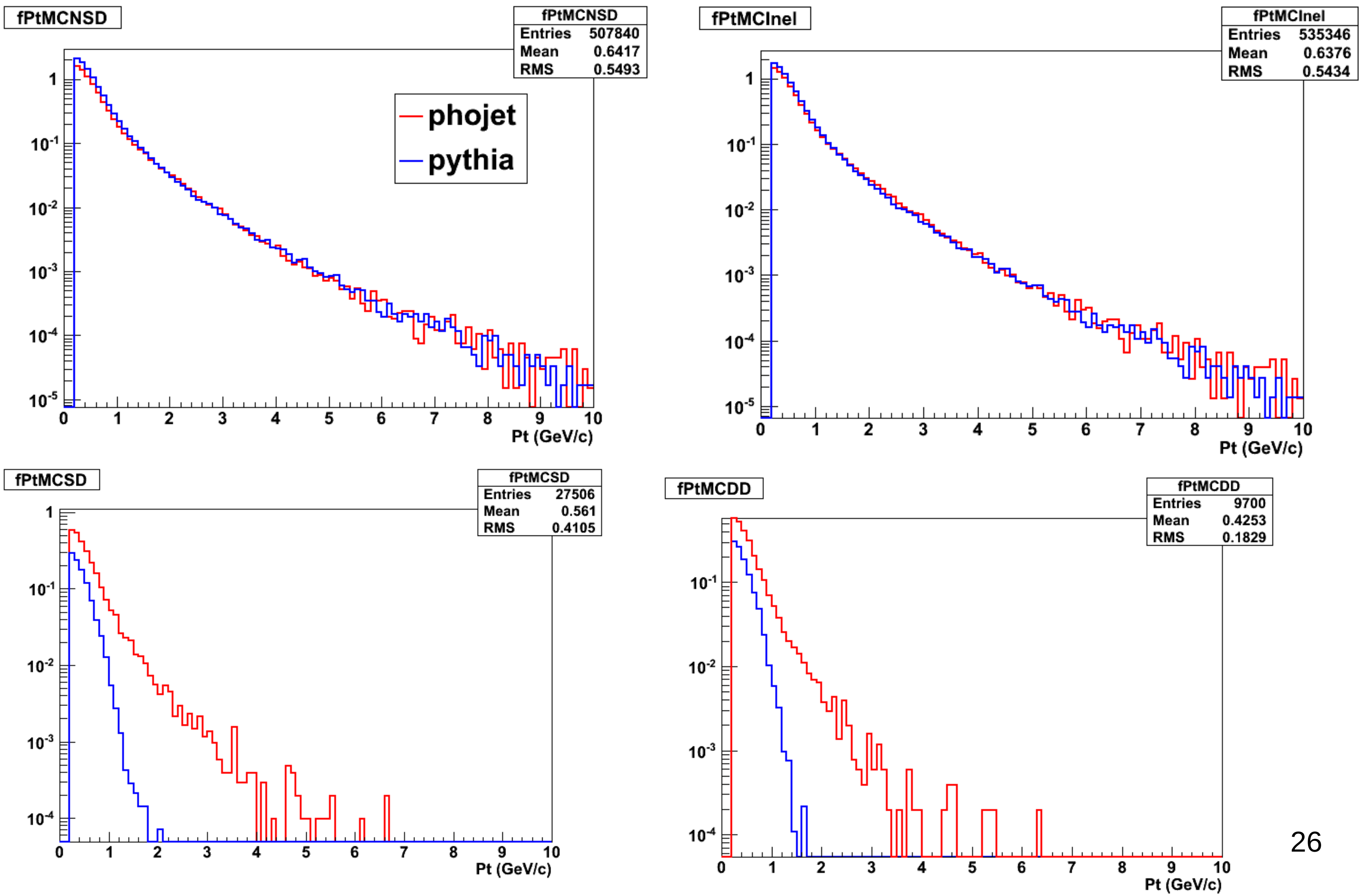


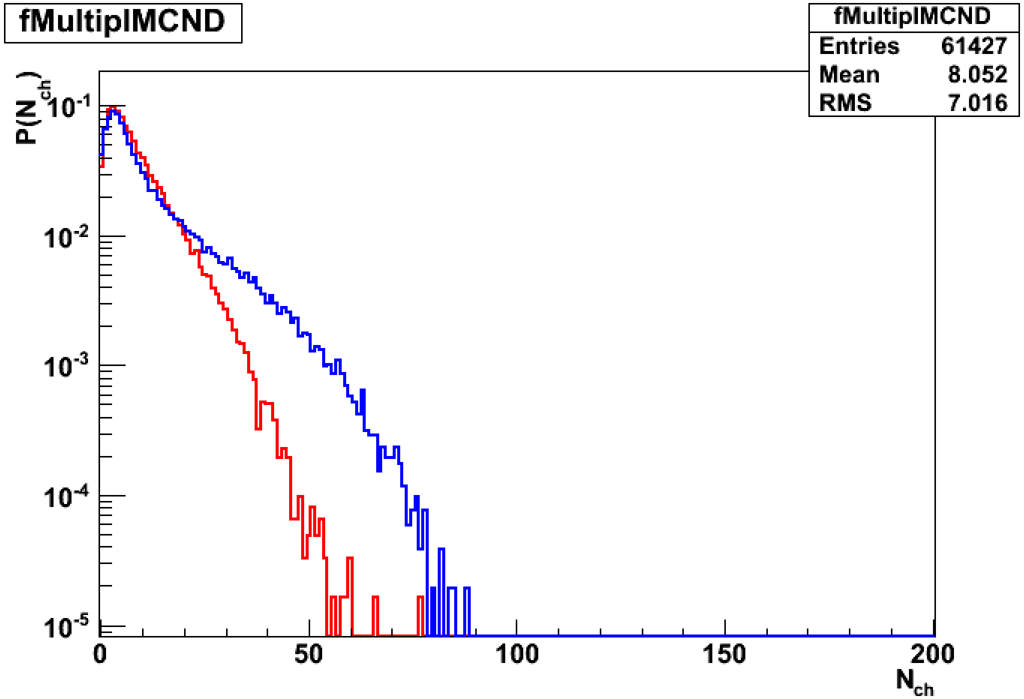


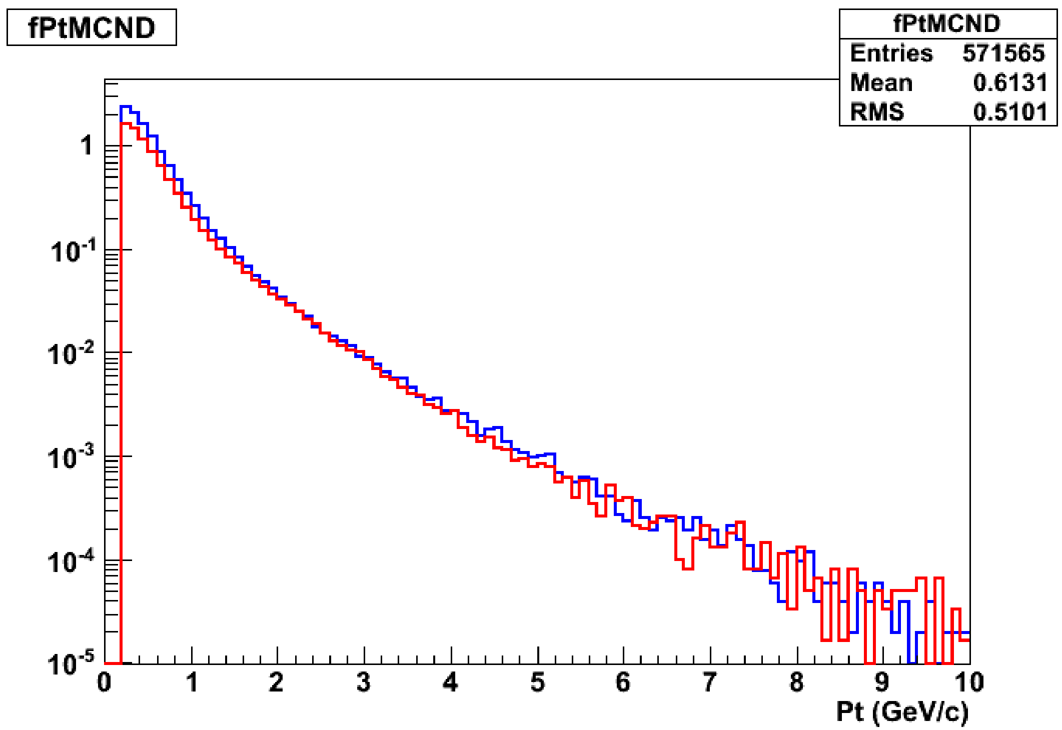


75,000 events of PYTHIA6.214 vs PHOJET1.12 at 10TeV collision energy

Kinematic comparison of generators




fMultiplMCND
fMultiplMCND
Entries 61427
Mean 8.052
RMS 7.016
P(N_ch)
N_ch


fPtMCND
fPtMCND
Entries 571565
Mean 0.6131
RMS 0.5101
Pt (GeV/c)

Single Diffractive Efficiencies

TRIGGER	PYTHIA	PHOJET	MEAN	SPREAD
MB1	0.71429	0.76680	0.73562	0.02626
MB2	0.56830	0.60343	0.58266	0.01757
MB3	0.36639	0.38553	0.37426	0.00957
MB4	0.57961	0.60604	0.59052	0.01322
SPD	0.51501	0.56024	0.53324	0.02261
TPC	0.28209	0.38321	0.31758	0.05056
PIX	0.57534	0.60507	0.58757	0.01487

Systematics: 1%-5%

Double Diffractive Efficiencies

TRIGGER	PYTHIA	PHOJET	MEAN	SPREAD
MB1	0.86399	0.93841	0.88910	0.03721
MB2	0.65600	0.76496	0.69105	0.05448
MB3	0.40058	0.52758	0.43814	0.06350
MB4	0.70805	0.81310	0.74219	0.05252
SPD	0.57172	0.70103	0.61191	0.06466
TPC	0.30186	0.44455	0.34082	0.07134
PIX	0.66354	0.77841	0.70034	0.05743

Systematics: 3.7%-7.1%

Non Diffractive Efficiencies

TRIGGER	PYTHIA	PHOJET	MEAN	SPREAD
MB1	0.99928	0.99938	0.99934	0.00005
MB2	0.99212	0.99676	0.99464	0.00232
MB3	0.97608	0.98584	0.98135	0.00488
MB4	0.99654	0.99819	0.99744	0.00083
SPD	0.98192	0.99026	0.98644	0.00417
TPC	0.79557	0.79094	0.79305	0.00231
PIX	0.99276	0.99731	0.99523	0.00228

Systematics: 0.005%-0.5%

Non-Single Diffractive Efficiencies

TRIGGER	PYTHIA	PHOJET	MEAN	SPREAD
MB1	0.97869	0.99468	0.98697	0.00800
MB2	0.94095	0.97889	0.96038	0.01897
MB3	0.88845	0.95051	0.91980	0.03103
MB4	0.95261	0.98392	0.96870	0.01566
SPD	0.91947	0.96797	0.94416	0.02425
TPC	0.72040	0.76424	0.74264	0.02192
PIX	0.94264	0.98044	0.96200	0.01890

Systematics: 0.8%-3.1%

Inelastic Efficiencies

TRIGGER	PYTHIA	PHOJET	MEAN	SPREAD
MB1	0.92913	0.96408	0.94650	0.01747
MB2	0.87111	0.92846	0.89923	0.02868
MB3	0.79061	0.87463	0.83102	0.04201
MB4	0.88271	0.93317	0.90755	0.02523
SPD	0.84367	0.91321	0.87749	0.03477
TPC	0.63825	0.71306	0.67405	0.03740
PIX	0.87380	0.93002	0.90138	0.02811

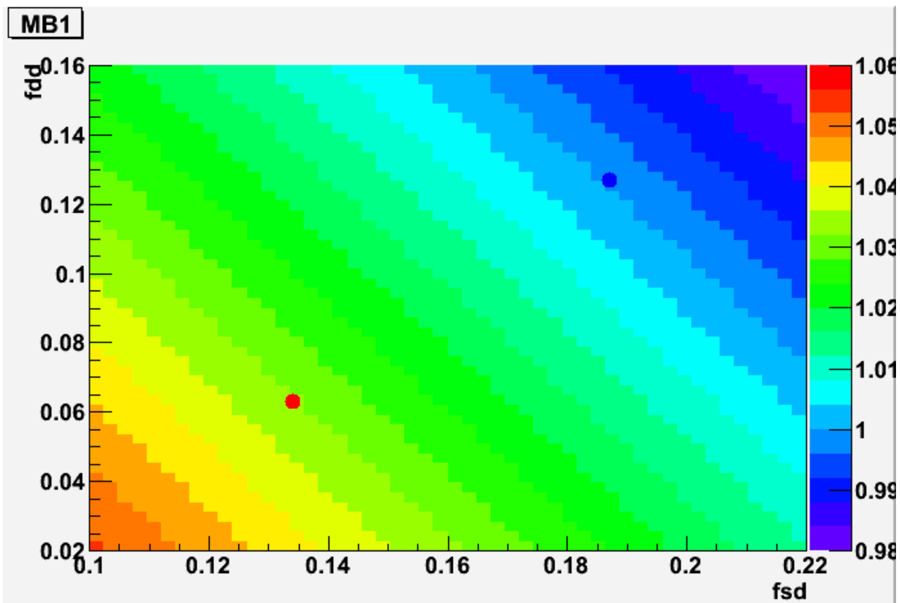
Systematics: 1.7%-4.2%

Multiplicity correction

- Multiplicity is a measure of the number of charged tracks per event
- Kinematic differences between Pythia and Phojet affect our efficiency of multiplicity measurements

MB1 trigger with Pythia as default

fdd

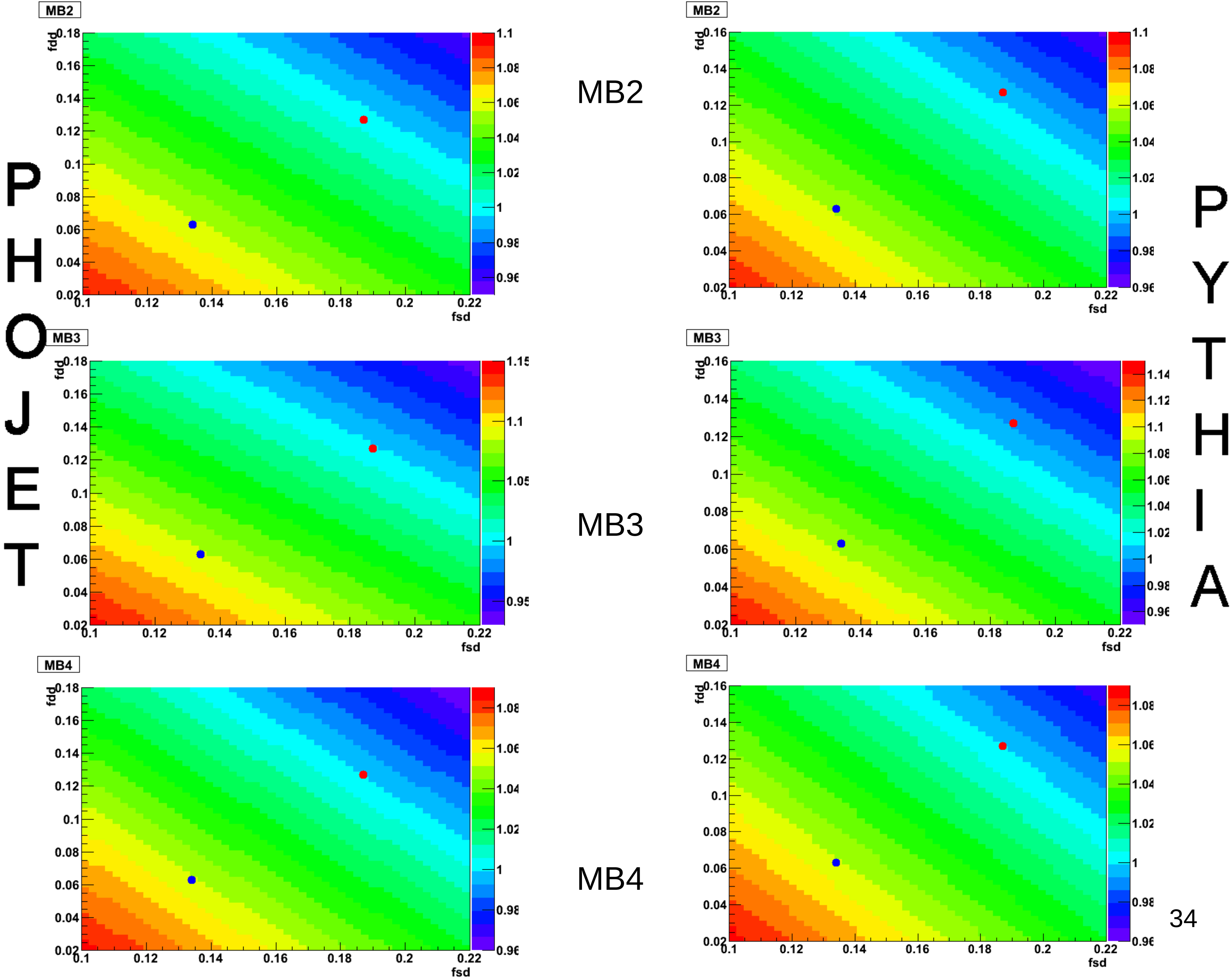


fsd

Varying fractions to view effect of multiplicity change with respect to Pythia's default multiplicities

Phojet and Pythia default fractions

Systematics error = 4%


PHOJET
PYTHIA
MB2
MB3
MB4
fsd
fdd

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}

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

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

$$\underbrace{N_{trig}}_{\text{measured}} = \underbrace{N_{gen}\left(f_{SD}e_{SD} + f_{DD}e_{DD} + f_{ND}e_{ND} + f_{NI}e_{NI}\right)}_{\text{calc}}$$

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

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

LHC incident and schedule

- 19th September 2008 – during powering tests of the main dipole circuit in sector 3-4 (near ALICE), fault in connection between dipole and quadrupole

- Mechanical damage and helium leak into the tunnel ~2.4 km of beam pipes were spoilt

- 5 quadrupoles and 24 dipoles needed to be repaired
- 14 quadrupoles and 39 dipoles reinstalled

- Everything under control and more safety checks in place

New Schedule:

Latest News! ~3 week delay

- First beam – end of September

- First collisions – late October