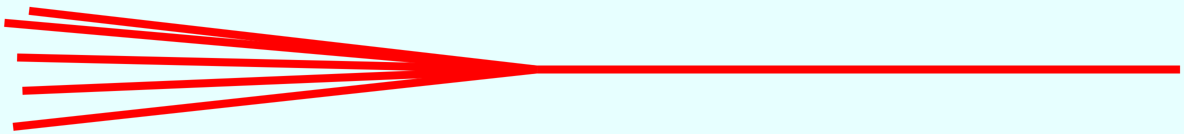
Study of Inelastic and Diffractive Production in ALICE



O. Villalobos Baillie for the ALICE Collaboration

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Plan of Talk

- Introduction
- The ALICE Detector
- Data samples
- Classification procedure
- Results - Fractions and cross-sections
- Summary

Diffractive Measurements

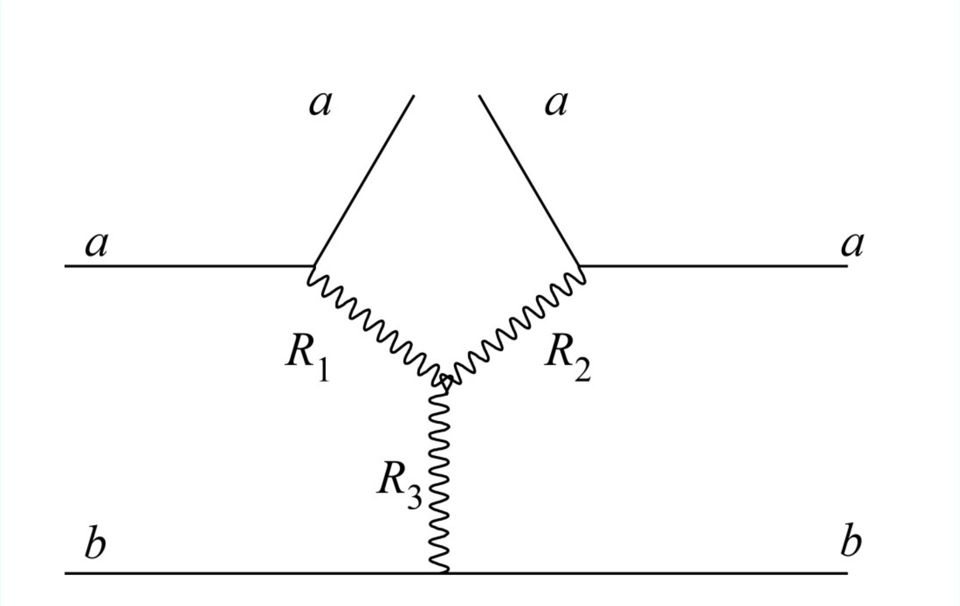
- As part of the pp interaction analysis programme, the ALICE collaboration is studying the behaviour of the inelastic cross-section as a function of energy.
- The inelastic cross section can be separated into three main components

$$\sigma_{\mathrm{inel}} = \sigma_{\mathrm{SD}} + \sigma_{DD} + \sigma_{ND} (+\sigma_{\mathrm{CD}})$$

  - Central Diffraction (CD not discussed here – see separate talk by Felix Reidt)
- In order to determine the inelastic cross-section, each of these processes must be studied separately
- Study involves the use of a *model* for diffractive processes, essential since the detector does not see the full inelastic cross-section.

Diffractive Model

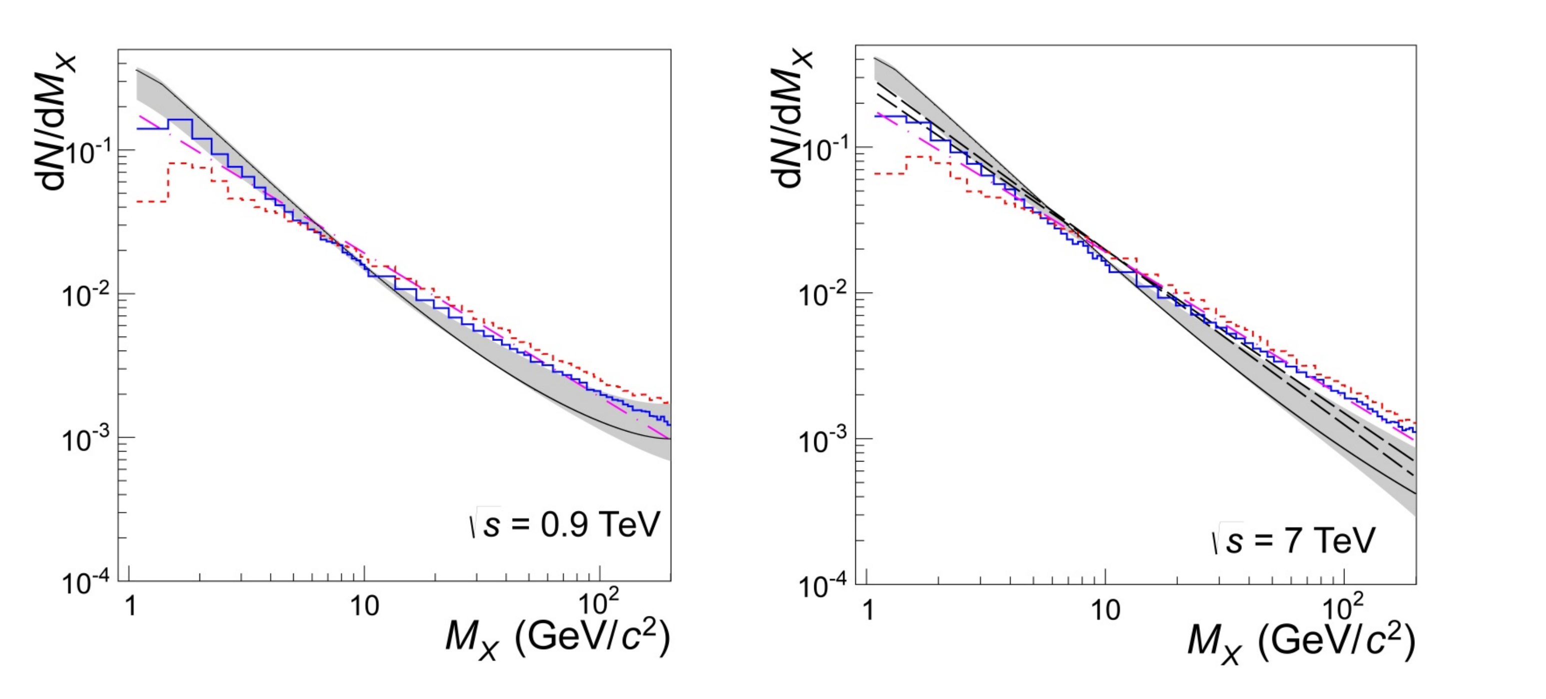
- The ALICE choice is to use the Kaidalov and Poghosyan model, based on a Regge analysis of diffraction.



- Each of the legs R_1, R_2, R_3 can be a Pomeron or a Reggeon
- Couplings determined by a fit to data over a wide energy range.
- At high energies, PPP and PPR terms dominate.
- For PPP $dN/dM_X \sim 1/M_X^{1+2\Delta}$
- For PPR $dN/dM_X \sim 1/M_X^{2+4\Delta}$
  $\Delta = \alpha_P - 1$
- At low M_X, PPR dominates overall

A.B. Kaidalov and M.G. Poghosyan, *Proc. Conf. on Elastic and Diffractive Scattering, ("Blois Workshop", CERN, June 2009: ArXiv:0909.5156)*

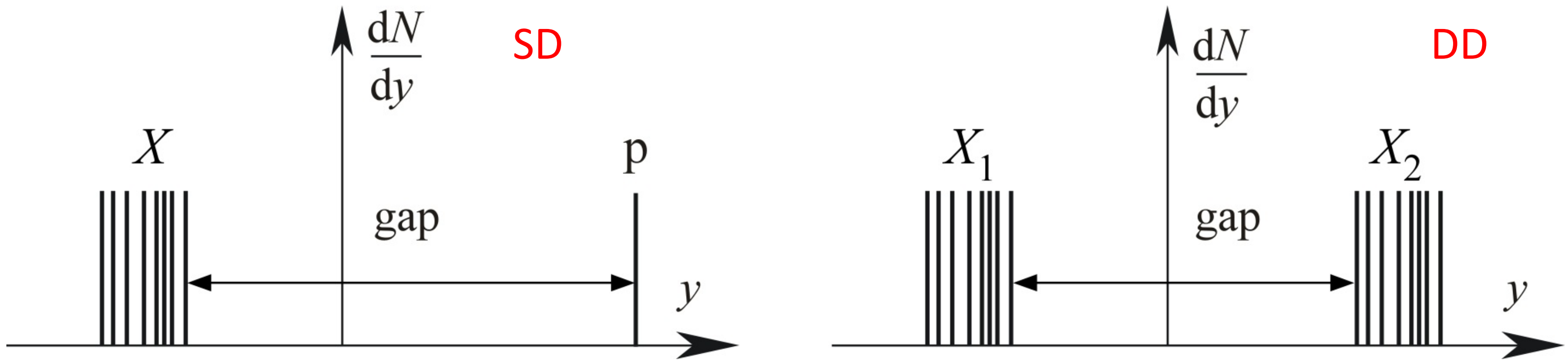
Diffractive Mass Distributions



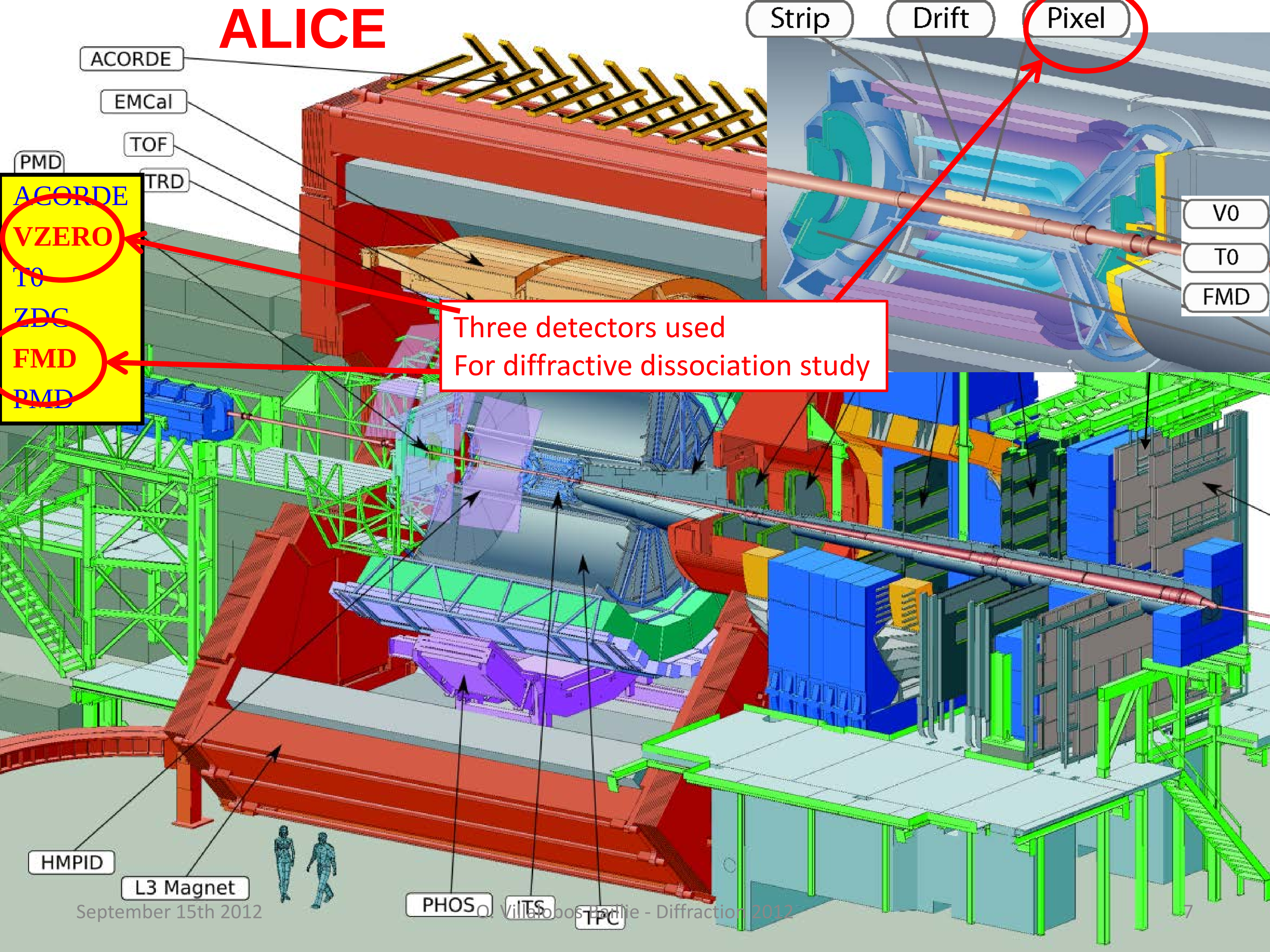
- Black line – Kaidalov-Poghosyan model
- Red dashed-line histogram - PHOJET
- Blue histogram - PYTHIA 6
- Magenta dotted-dashed line – $1/M_X$
- (7 TeV only) black dashed lines, $1/M_X^{1+2\Delta}$, $\Delta = 0.085, 0.12$ (PYTHIA 8)

Classification of Processes

- Diffractive and non-diffractive processes are classified using pseudorapidity gaps.
  - Single Diffraction (SD) Large gap after leading proton on either left or right hand side (Leading proton *not measured* in this experiment.)
  - Double Diffraction (DD) Large central gap, tracks on both sides.



ALICE

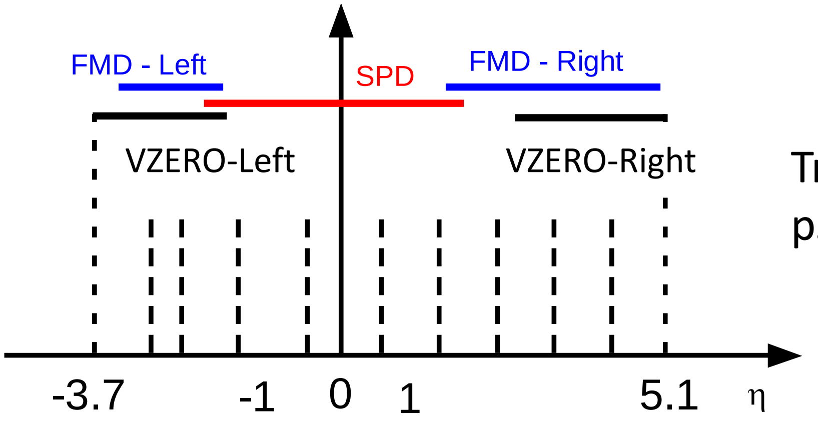


ACORDE
VZERO
T0
ZDC
FMD
PMD

Three detectors used
For diffractive dissociation study

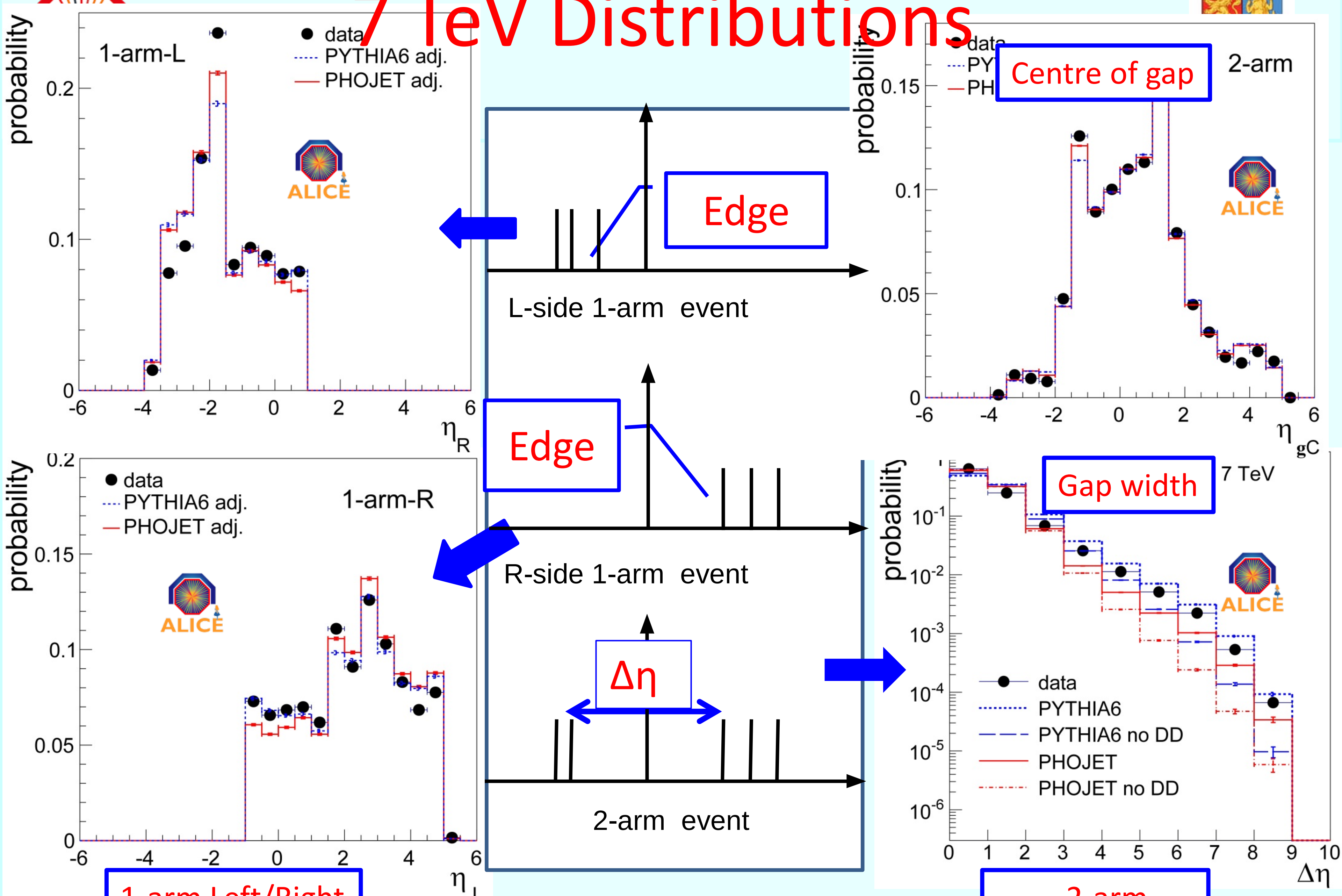
Detectors used in Study

- Diffractive and non-diffractive processes are classified using pseudorapidity gaps.
  - *Silicon Pixel Detector (SPD):* Innermost two layers of the ALICE Inner Tracking System (ITS). $|\eta|<2$ (~ 10^7 elements).
  - *VZERO*: Scintillator hodoscopes on either side of the interaction region. $-3.7<\eta<-1.7$ (L) and $2.8<\eta<5.1$ (R) (64 elements) .
  - *Forward Multiplicity Detector (FMD):* silicon pad sensors on either side of the interaction region. $-3.4<\eta<-1.7$ and $1.7<\eta<5.1$ (5×10^4 elements).
- Trigger- (Minimum Bias): MB_{OR} defined as (SPD_{OR} VOL_{OR} VOR)



Tracks detected over an interval of 8.8 units in pseudorapidity.

7 TeV Distributions

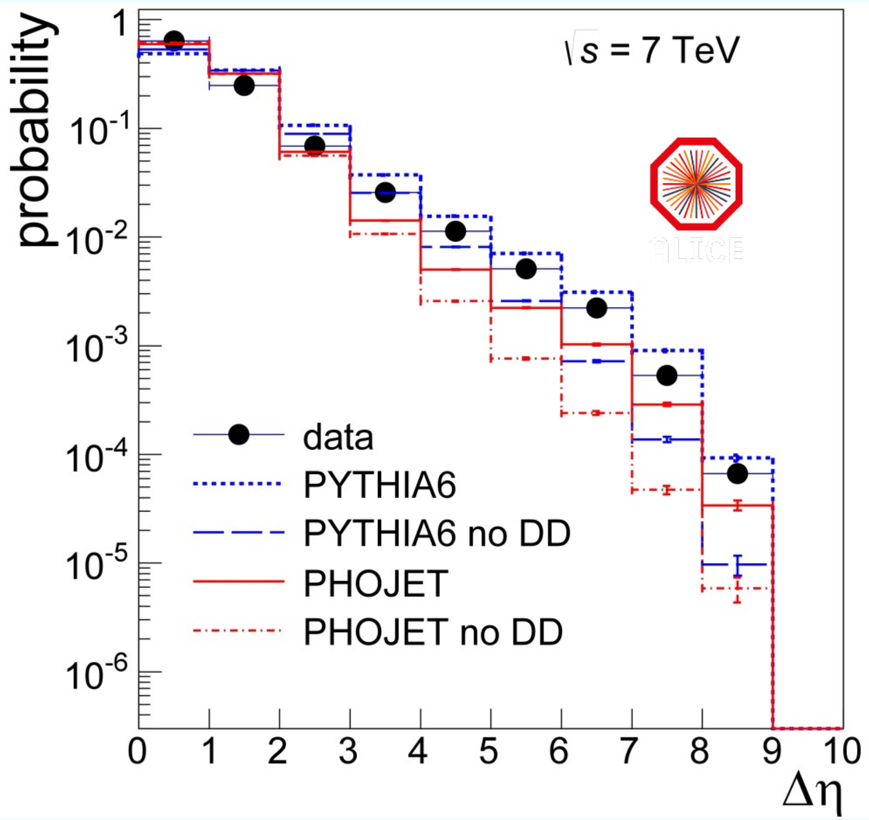


Data Samples

- pp data have been collected at three energies for these studies, using a Minimum Bias trigger:-
  - 900 GeV 7×10^6 events
  - 2.76 TeV (heavy ion "reference" run) 23×10^6 events
  - 7 TeV 75×10^6 events
- Two Monte Carlo generators have been employed:-
  - PYTHIA 6.421 ("Perugia-0" tune)
  - PHOJET 1.12

Modified to follow Kaidalov-Poghosyan diffractive mass distribution

Largest gap Distribution

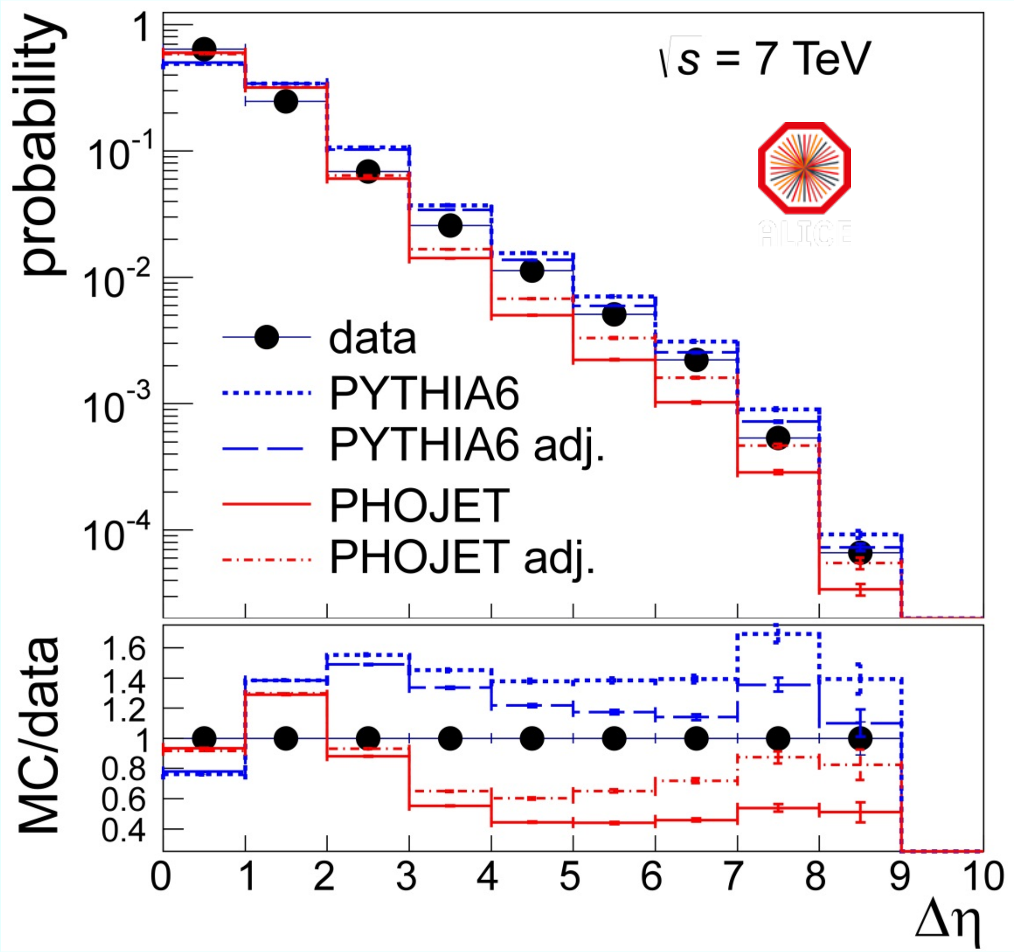


- For 2-arm events, the distribution of Δη, the largest pseudorapidity gap in the event, allows us to determine the DD contribution
- Distribution cannot be reproduced with either PHOJET or PYTHIA 6 unless the DD fraction is non-zero.
- DD major contribution for Δη>3.

STRATEGY

- MODIFY the diffractive mass distributions, weighting events so as to reproduce the Kaidalov-Poghosyan distribution
- ADJUST the DD (and SD) fractions so as to
  - *approach* the measured Δη distribution
  - *exactly reproduce* the observed 1-arm/2-arm ratio

Result of Adjustment



- For Δη>3, Δη distribution bracketed by PYTHIA and PHOJET.
- Mid-point closely follows experimental points
- Error limits given by the two generators.

DEFINITION OF DOUBLE DIFFRACTION

- After adjustment, use generators to predict shape of largest central gap distribution in full phase space
- Define DD events to be all those with Δη>3.

Measurement of $\sigma_{SD}/\sigma_{INEL}$

Raw Trigger ratios

	0.9 TeV	2.76 TeV	7 TeV
$N^{left}_{1\text{-}arm}/N_{2\text{-}arm}$	0.0576±0.0002	0.0543±0.0004	0.0458±0.0001
$N^{right}_{1\text{-}arm}/N_{2\text{-}arm}$	0.0906±0.0003	0.0791±0.0004	0.0680±0.0001

Corrected ratios

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	0.9 TeV	**2.76 TeV**	**7 TeV**
$\sigma^{left}_{SD} / \sigma_{INEL}$	0.1 ± 0.02	0.09 ± 0.03	$0.10^{+0.02}_{-0.04}$
$\sigma^{right}_{SD} / \sigma_{INEL}$	0.11 ± 0.02	$0.11^{+0.04}_{-0.05}$	$0.10^{+0.02}_{-0.03}$
$\boldsymbol{\sigma_{SD} / \sigma_{INEL}}$	$\mathbf{0.21 \pm 0.03}$	$\mathbf{0.20^{+0.07}_{0.08}}$	$\mathbf{0.20^{+0.04}_{-0.07}}$

Errors shown are *systematic*, statistical errors are negligible

$\sigma_{DD}/\sigma_{INEL}$

Definition of DD: *all* events with a gap $\Delta\eta > 3$

	900 GeV	2.76 TeV	7 TeV
$\sigma_{DD}/\sigma_{INEL}$	0.11 ± 0.03	0.12 ± 0.05	0.12 +0.05-0.04

Errors shown are *systematic*, statistical errors are negligible

REMINDER

- Result of adjustment procedure is to obtain generator fractions for PYTHIA and PHOJET needed to bracket the experimental results (and corresponding SD fraction values)
- This is used to extrapolate to the full kinematically allowed pseudorapidity range.
- Double diffractive events defined to be those 2-arm events for which $\Delta\eta>3$, *irrespective* of generator classification

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van der Meer Scans

Scan	$\sqrt{s}$ (TeV)	Colliding bunches	Crossing Angle (μrad)	β^* (m)	μ	σ_x (μm)	σ_y (μm)	$A \times \sigma_{inel}$ (mb)
I	7	1	280	2	0.086	44	47	54.2 ± 2.9
II	7	1	500	3.5	0.74	58	65	54.3 ± 1.9
III	2.76	48	710	10	0.12	158	164	47.7 ± 0.9

- Scans were performed at 2.76 TeV and 7 TeV (twice)
  - For the two 7 TeV scans, conditions were significantly different, so as to check the systematics of the scan.
- Trigger condition was MB_{AND} (hits in both VZERO arrays)

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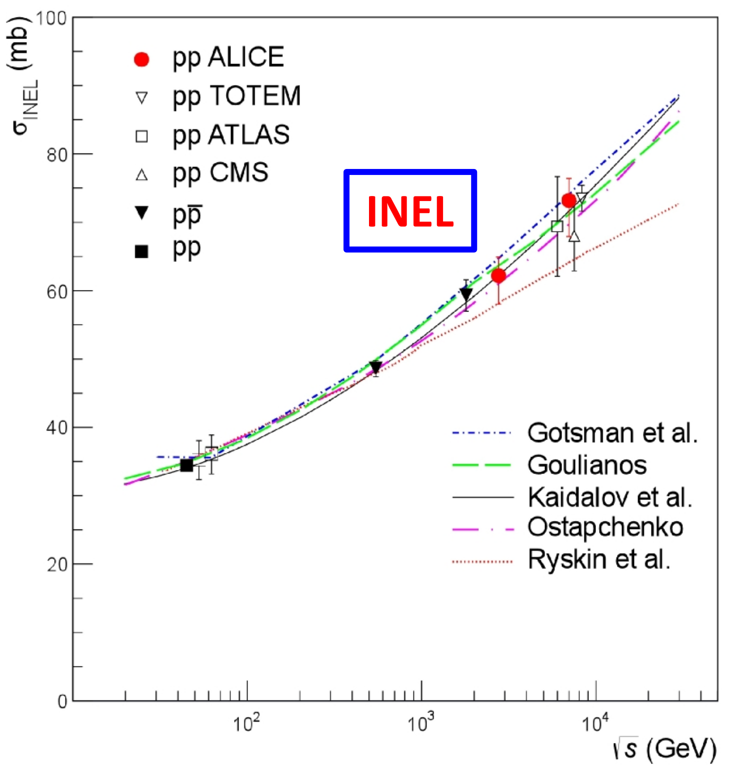
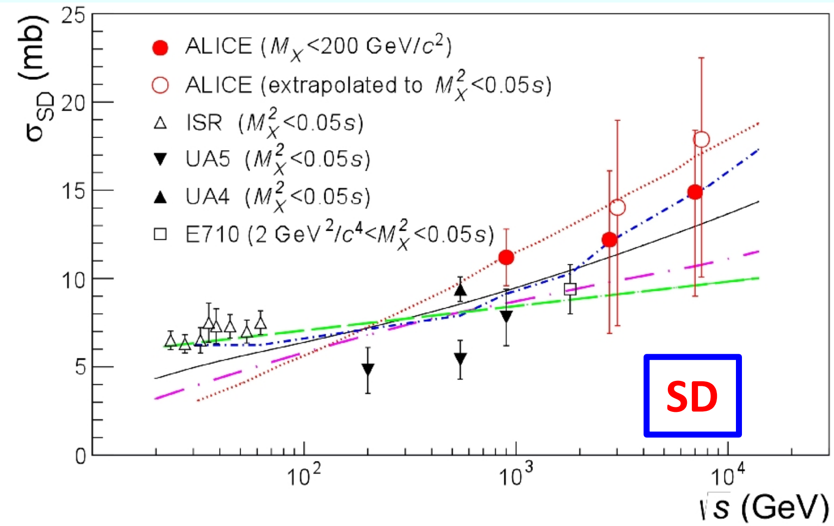
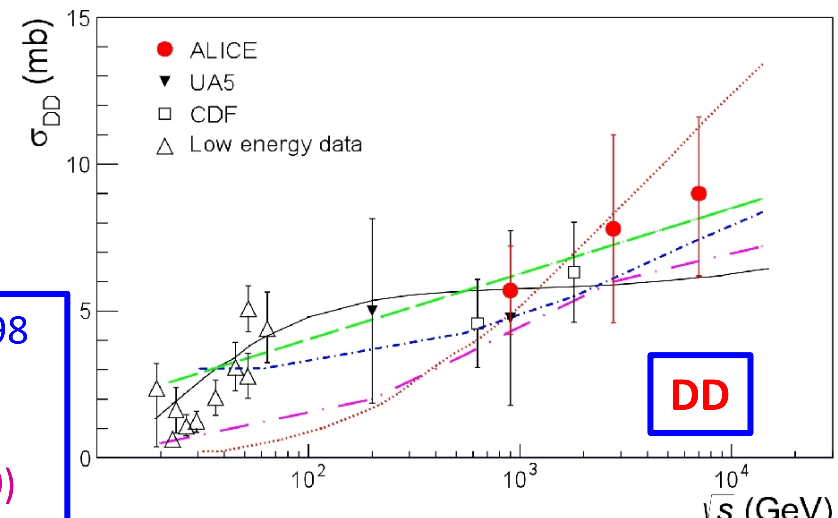
Comparison with other experiments and models

From van-der-Meer scan







Gotsman et al. Phys. Rev. **D85** (2012), arXiv:1208:0898
Goulianos Phys. Rev. D80 (2009) 111901
Kaidalov et al., arXiv:0909.5156, EPJ **C67** 397 (2010)
Ostapchenko, arXiv:1010.1869, PR **D81** 114028 (2010)
Ryskin et al., EPJ **C60** 249 (2009), **C71** 1617 (2011)

ALICE

Summary

- A technique based on classification of pseudorapidity gaps has been used to determine the fractions of diffractive events in inelastic pp interactions at 900 GeV, 2.76 TeV and 7 TeV.
- From these fractions, the diffractive and inelastic cross sections at these energies have been determined.
  - At 2.76 TeV and 7 TeV the inelastic cross-section data comes from recent van-der-Meer scans.

Experiment	σ_{INEL} (mb)	$\sigma_{INEL}^{\xi>5\times10^{-6}}$ (mb)
ALICE	$73.2^{+2.0}_{-4.6}$ (model) ± 2.6 (lumi)	$62.1^{+1.0}_{-0.9}$ (model) ± 2.2 (lumi)
ATLAS	69.4±6.9 (model) ±2.4 (exp)	60.3±0.5 (syst) ±2.1 (lumi)
CMS	68.0±4.0 (model) ±2.0 (syst) ±2.4 (lumi)	
TOTEM	$73.5^{+1.8}_{-1.3}$ (syst) $\pm$ 0.6 (stat)	

7 TeV Inelastic cross-sections

- Extrapolation to (unmeasured) low diffractive masses uses the Kaidalov-Poghosyan model
- The diffractive fractions $\sigma_{SD}/\sigma_{INEL}$ and $\sigma_{DD}/\sigma_{INEL}$ are found to be almost constant over the energy range $0.9<\sqrt{s}<7$ TeV
- The cross-sections obtained are compatible with those from other LHC experiments, and also with available current model predictions.

$\sqrt{s}$ (TeV)	σ_{SD} (mb)	σ_{DD} (mb)
0.9	$11.2^{+1.6}_{-2.1}$	5.6 ± 2.0
2.76	$12.2^{+3.9}_{-5.3}$	7.8 ± 3.2
7	$14.9^{+3.4}_{-5.9}$	9.0 ± 2.6

Diffractive cross-sections

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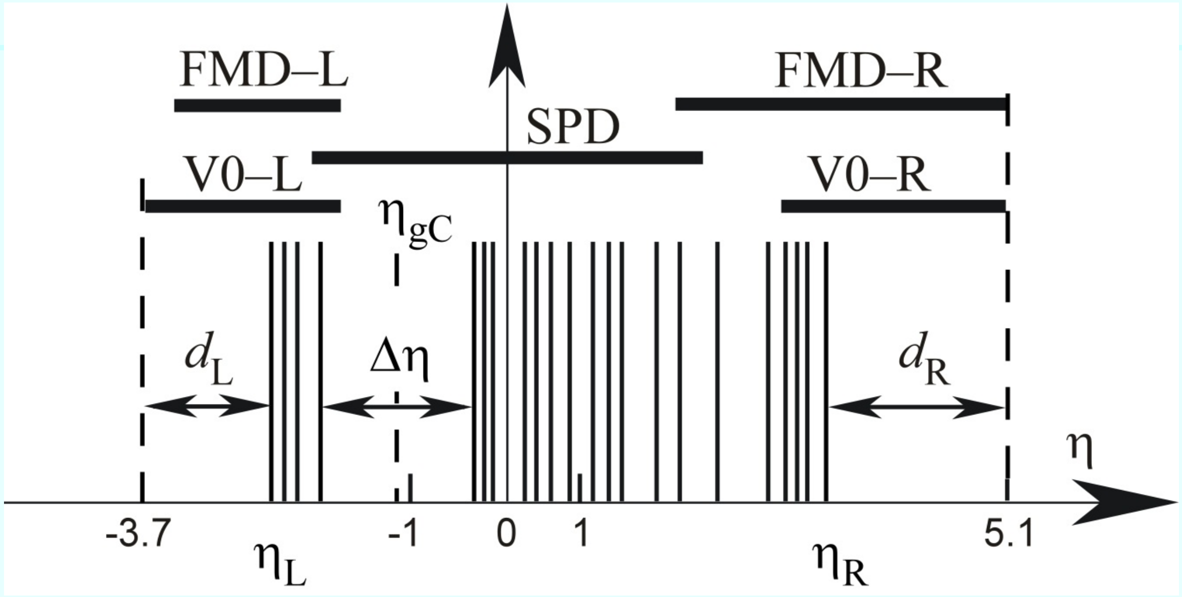
Back-Up

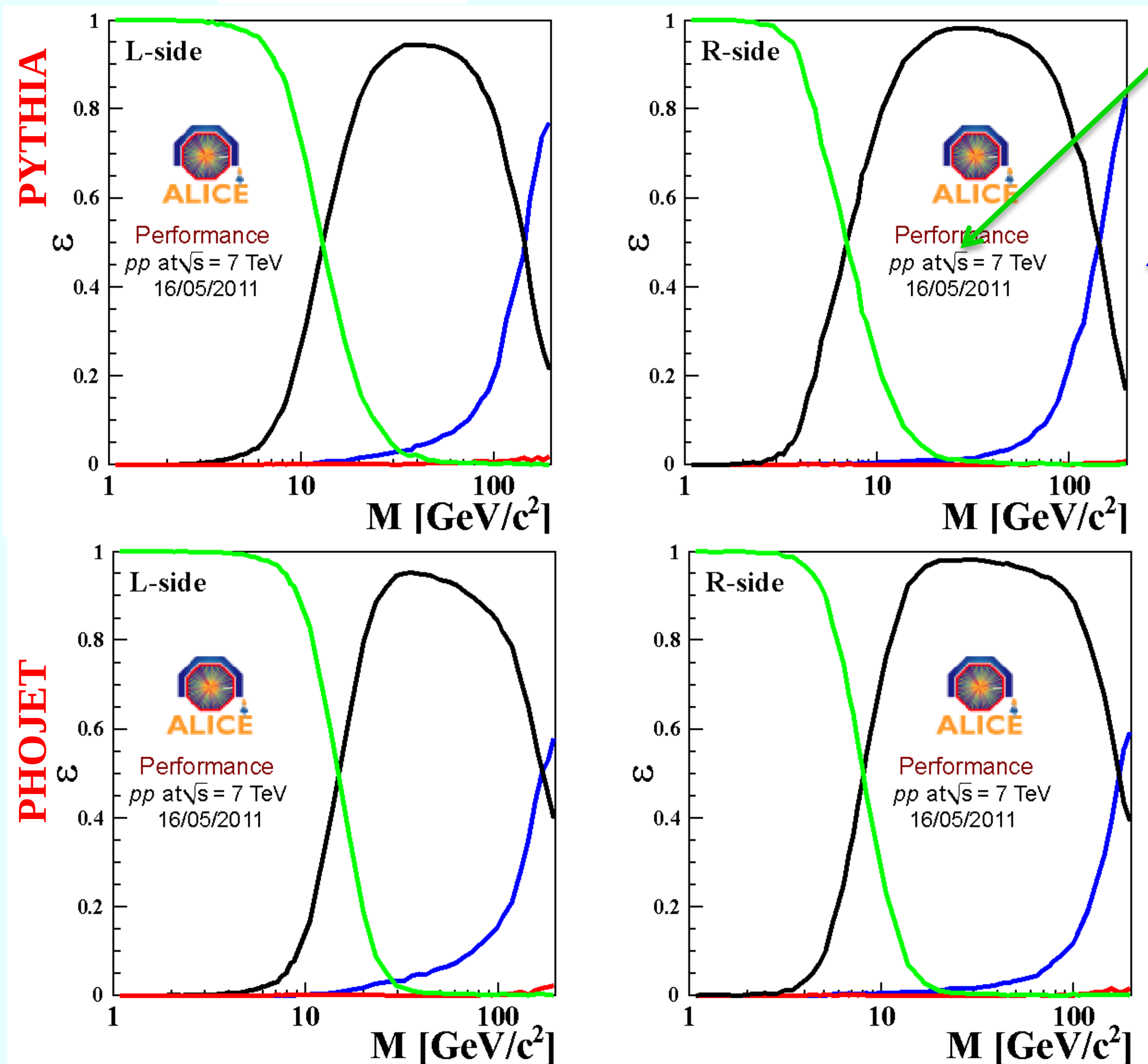
Classification in Practice



- 3 Categories: 1-arm-Left, 1-arm-Right and 2-arm events
- For events with *more than one track*
  - $\Delta\eta > d_L, d_R$ — 2-arm event
  - If η_L in $-1 \leq \eta \leq 1$ AND η_R in $-1 < \eta < 1$ — 2-arm event
  - *otherwise,* $\eta_R < 1$ — 1-arm-Left event
    $\eta_L > -1$ — 1-arm-Right event
  - any remaining events — 2-arm event

Acceptance versus Diffractive Mass

L-side SD 7 TeV R-side SD



not selected

1-arm event

2-arm event

opposite side 1-arm event

R-side sensitive to smaller masses because of asymmetric detector acceptance

Efficiencies used in the analysis: mean between PYTHIA and PHOJET post adjustment