Diffractive and inelastic cross-sections in proton-proton collisions at $\sqrt{s}$ = 0.9 TeV, 2.76 TeV and 7 TeV with ALICE at the LHC.

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CERN
ALICE Collaboration

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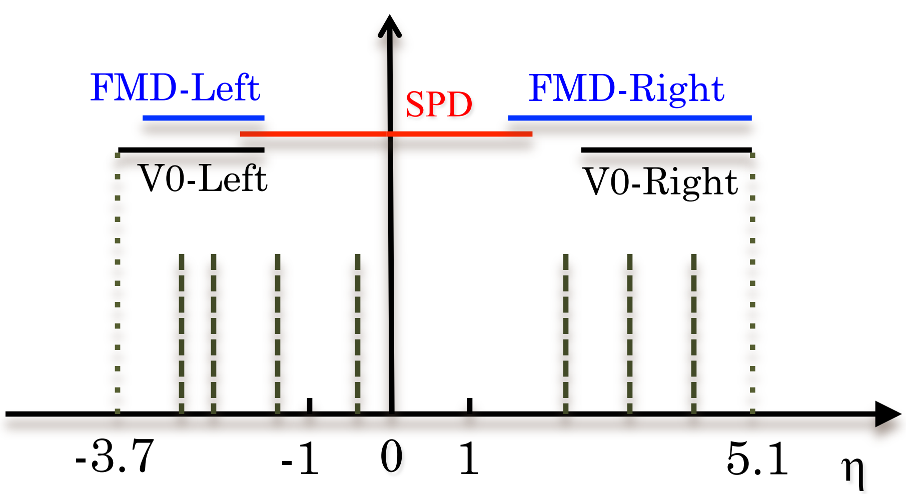
Detectors used to measure pseudorapidity gaps

- Silicon Pixel Detector **(SPD)** corresponds to the two innermost layers of the ALICE Inner Tracking System and covers pseudorapidity range **$|\eta| < 2$**.
- **V0** scintillator hodoscopes are placed on both sides of the interaction point covering the pseudorapidity ranges **$-3.7 < \eta < -1.7$** and **$2.8 < \eta < 5.1$**.
- Forward Multiplicity Detector **(FMD)** is made of silicon strip sensors placed on either side of the interaction point covering the pseudo-rapidity range **$-3.4 < \eta < -1.7$** and **$1.7 < \eta < 5.1$**.



MC generators: PYTHIA(-perugia0 tune) and PHOJET

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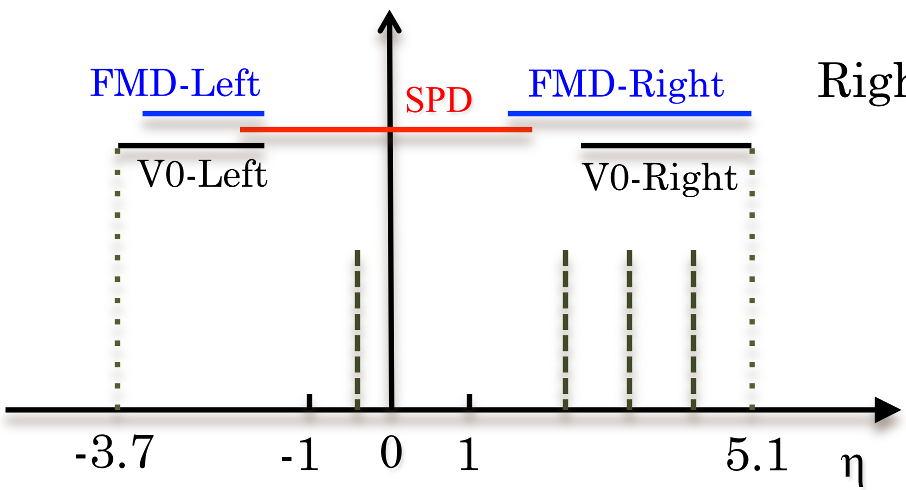

Right-side 1-arm trigger: no signal with $\eta < -1$

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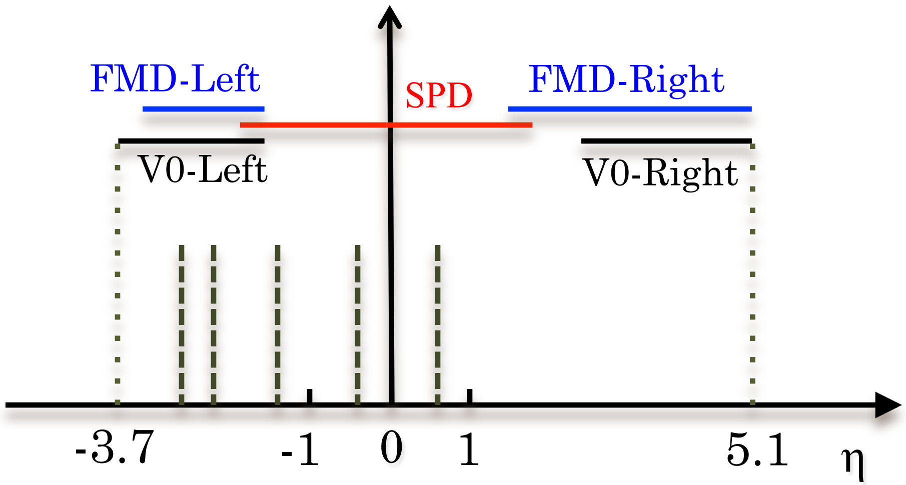

Left-side 1-arm trigger : no signal with $\eta > 1$

Detectors used to measure pseudorapidity gaps

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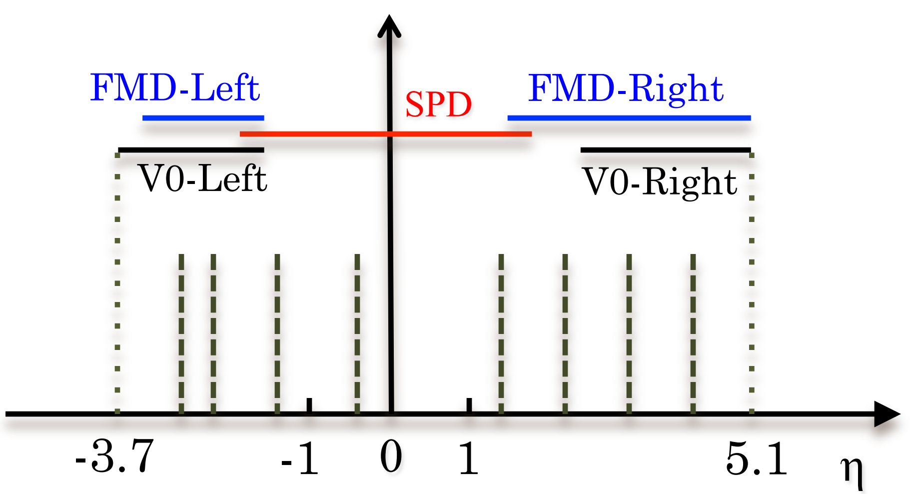
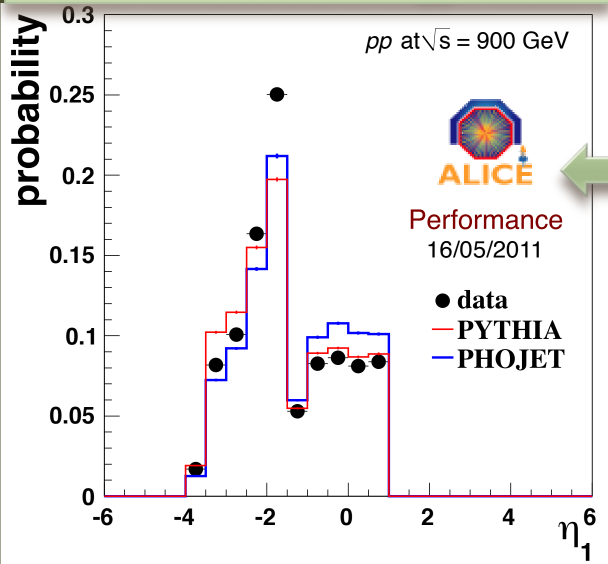
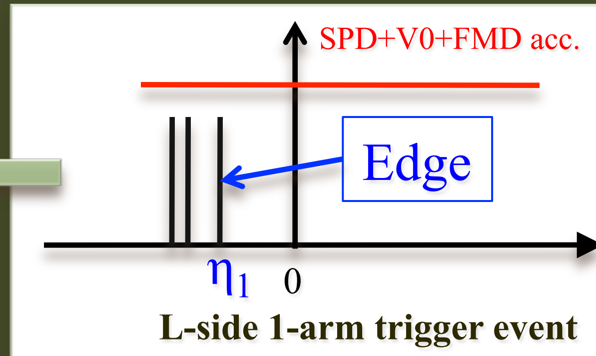


2-arm trigger

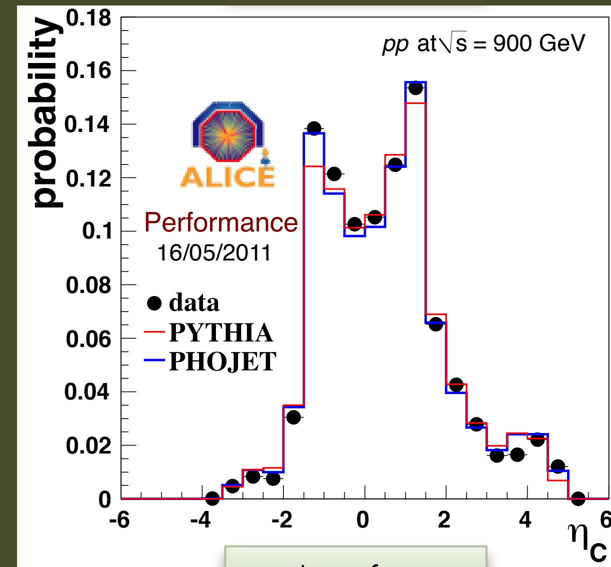
Uncorrected data vs Simulation (900 GeV)

edge of left-side 1-arm trigger event



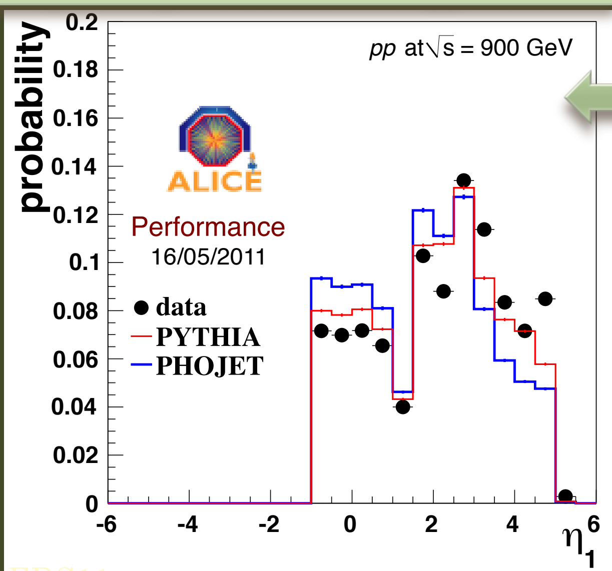


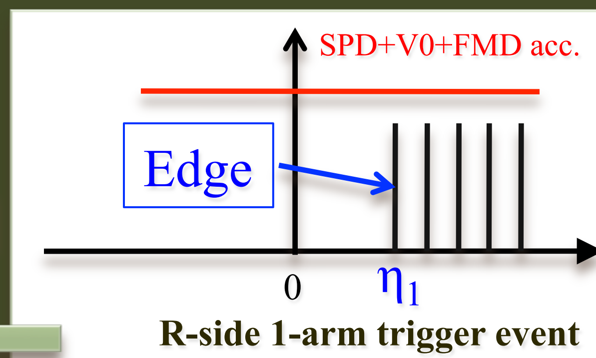
2-arm trigger

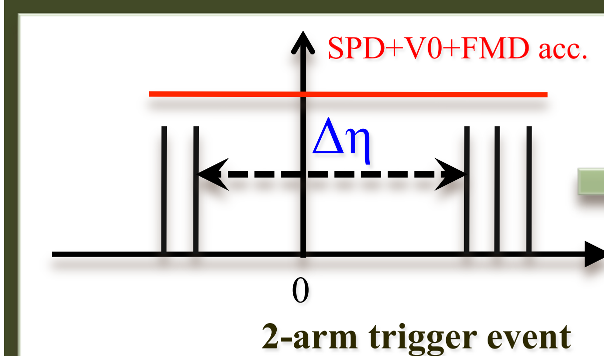


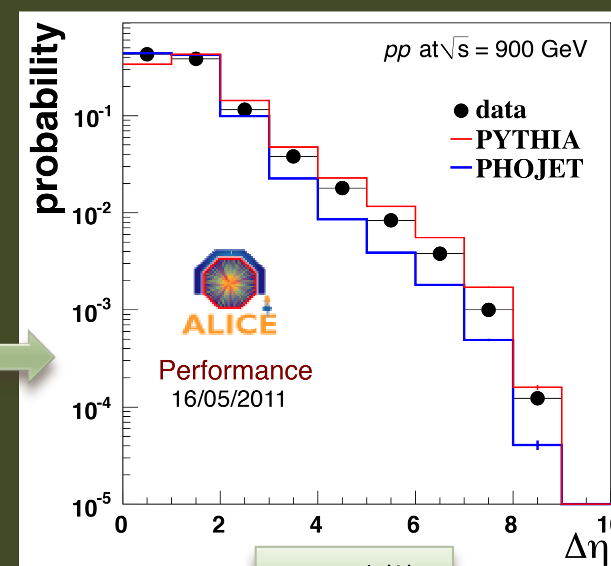
center of gap

edge of right-side 1-arm trigger event







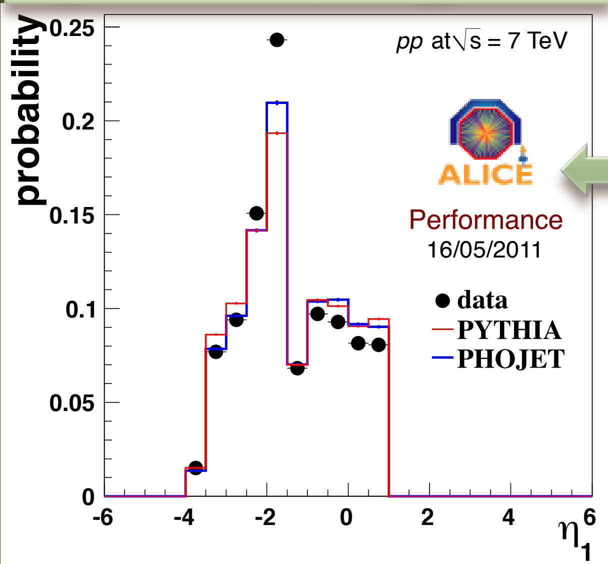


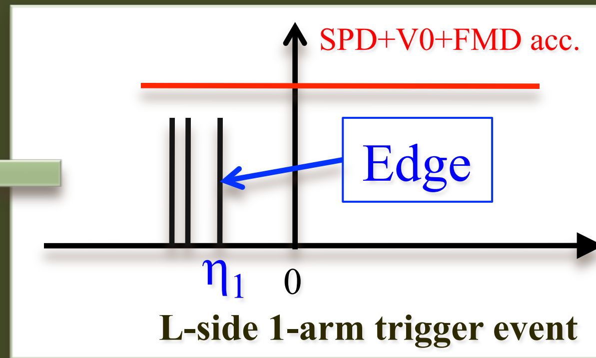
gap width

M.Poghosyan

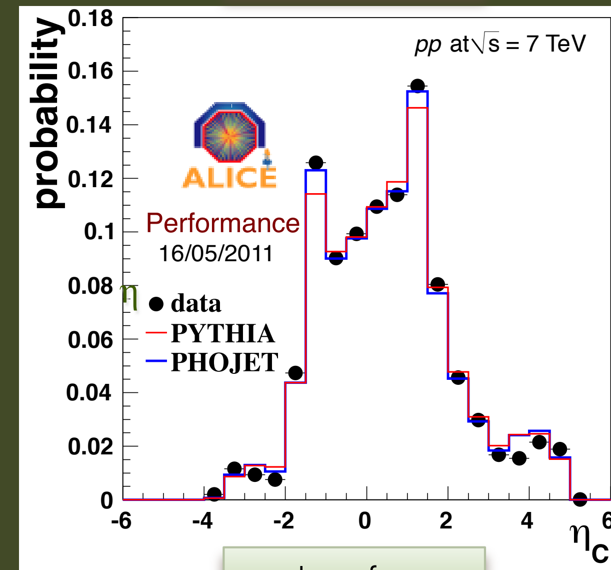
Uncorrected data vs Simulation (7 TeV)

edge of left-side 1-arm trigger event



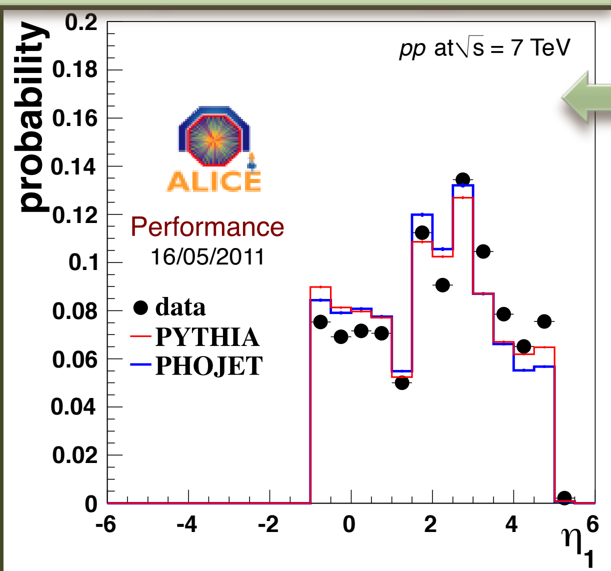


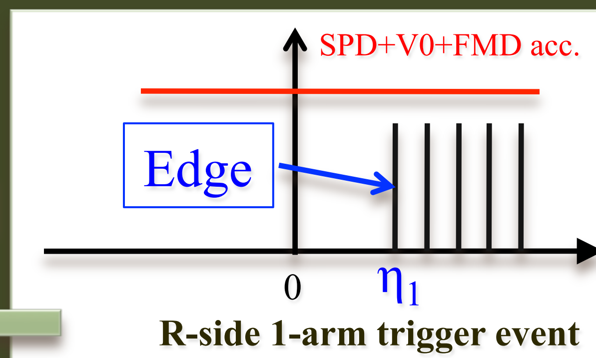
2-arm trigger

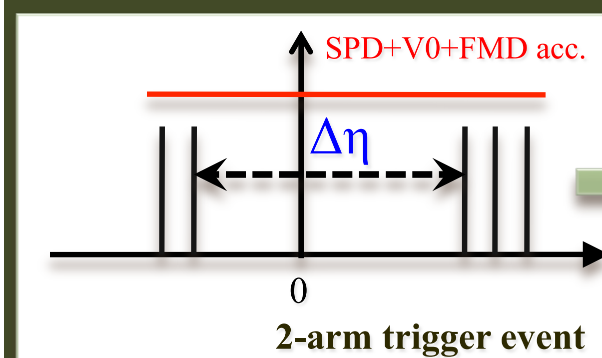


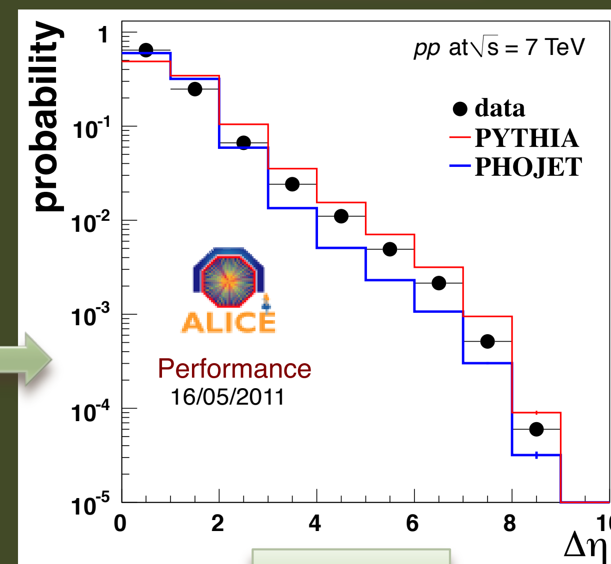
center of gap

edge of right-side 1-arm trigger event







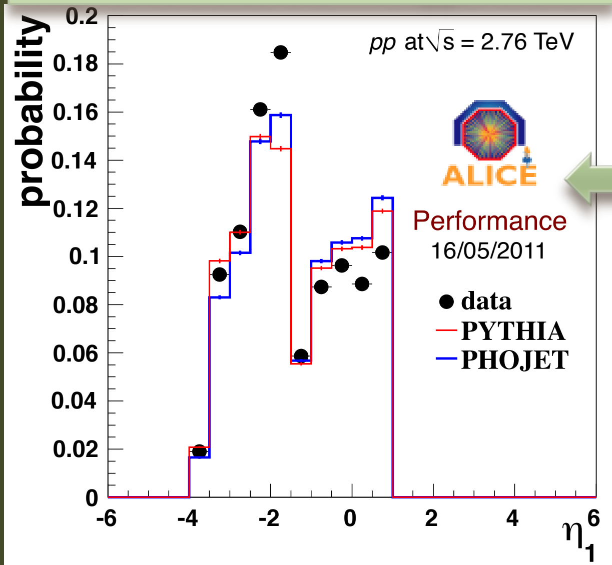


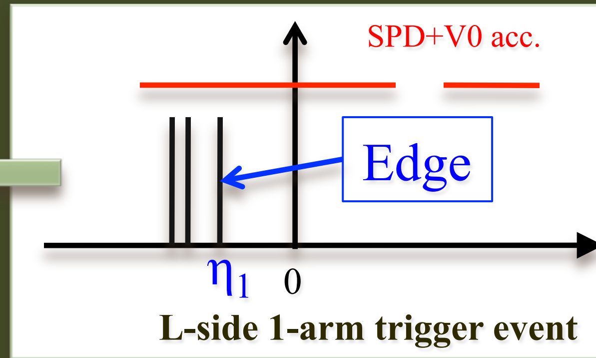
gap width

Uncorrected data vs Simulation (2.76 TeV)

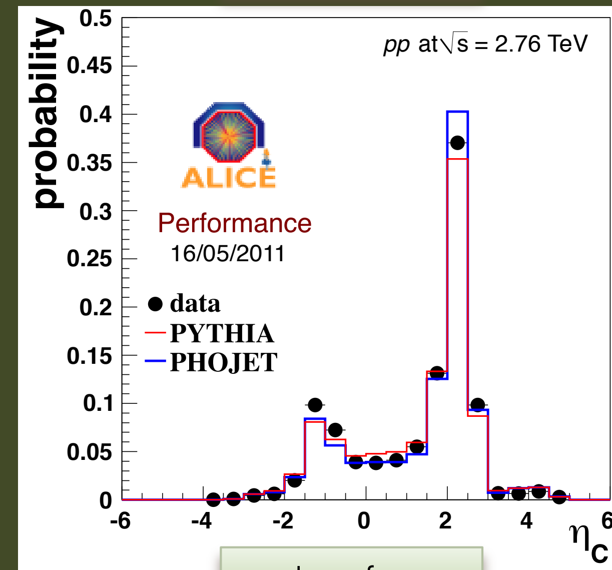
SPD+V0

edge of left-side 1-arm trigger event



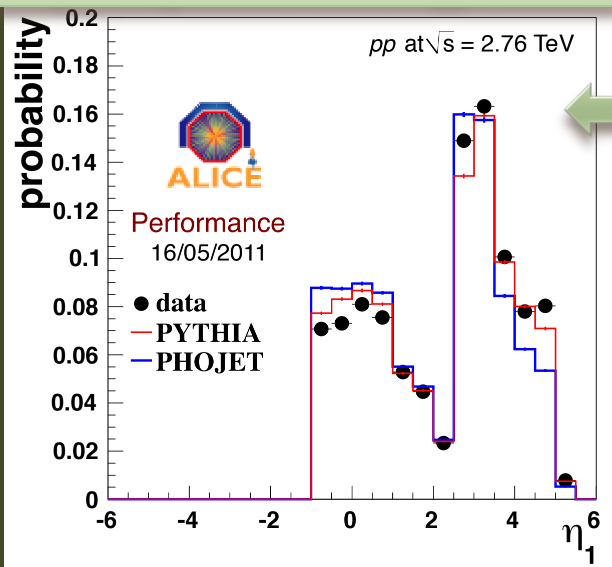


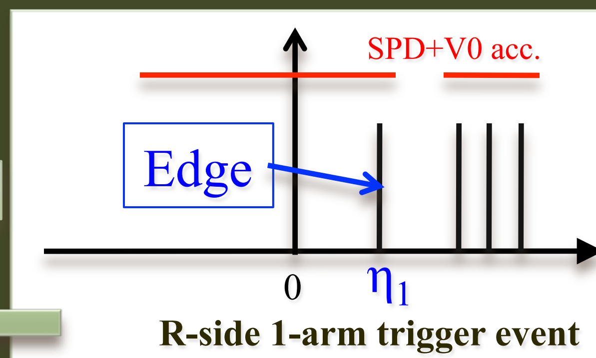
2-arm trigger

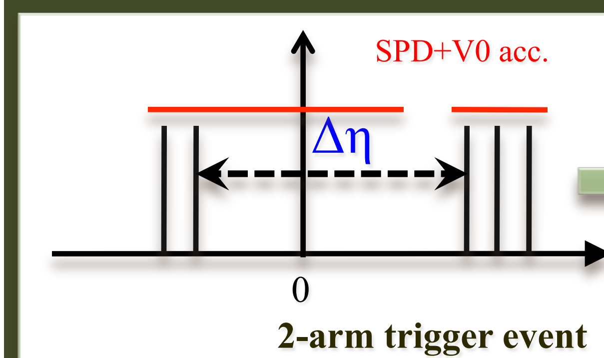


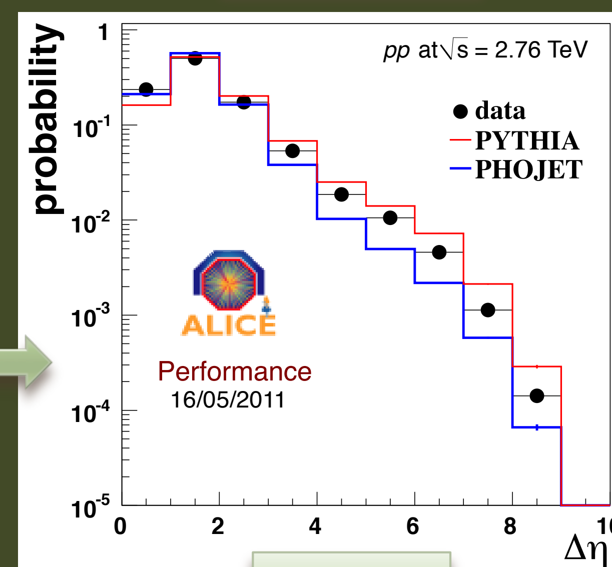
center of gap

edge of right-side 1-arm trigger event







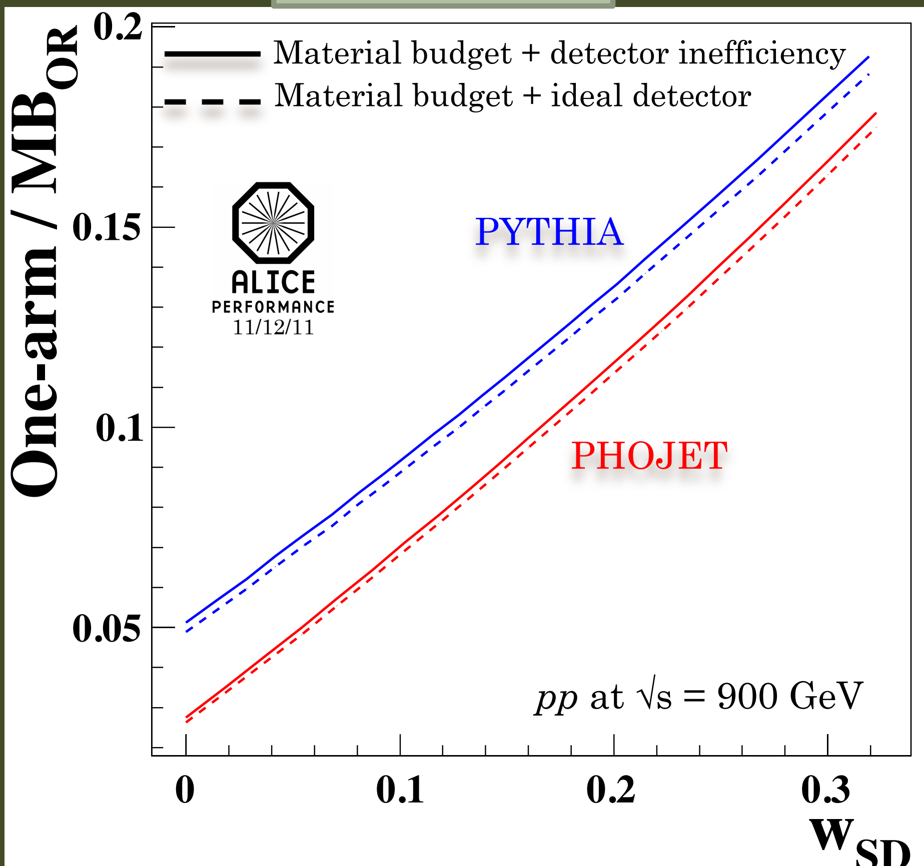


gap width

Varying the fraction of single- and double-diffractions in MC generator

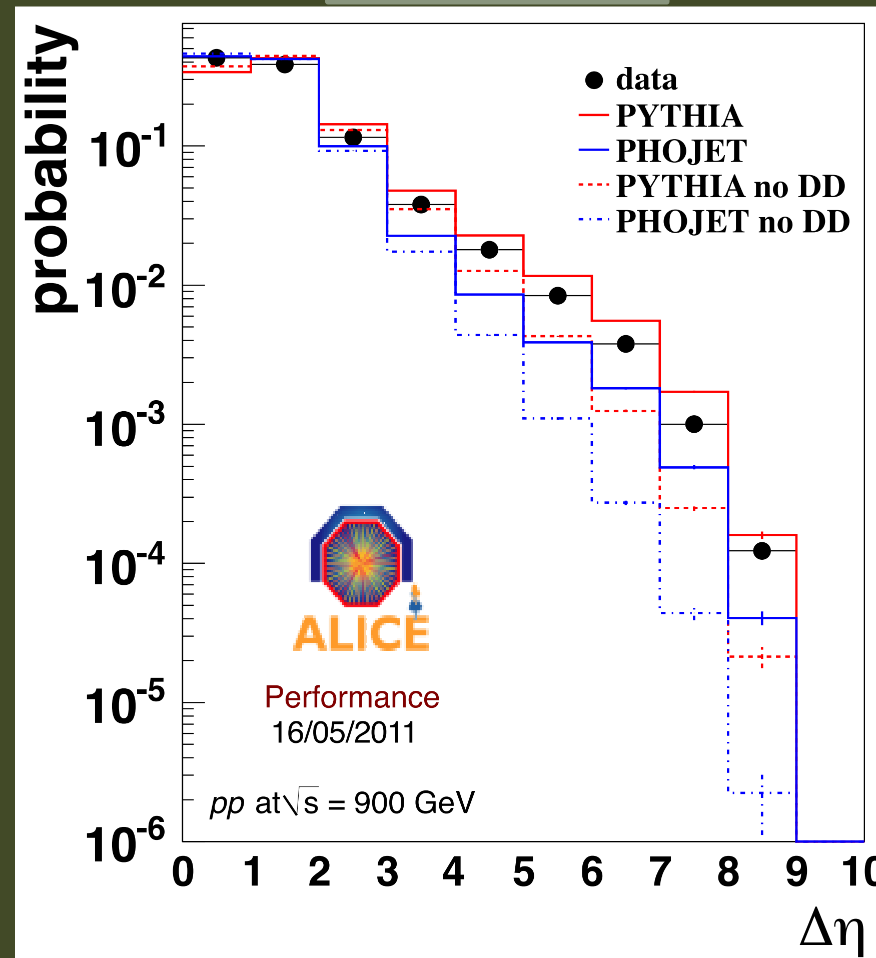
900 GeV

1-arm triggers



Material budget + simulation of detector response do not spoil the sensitivity to SD

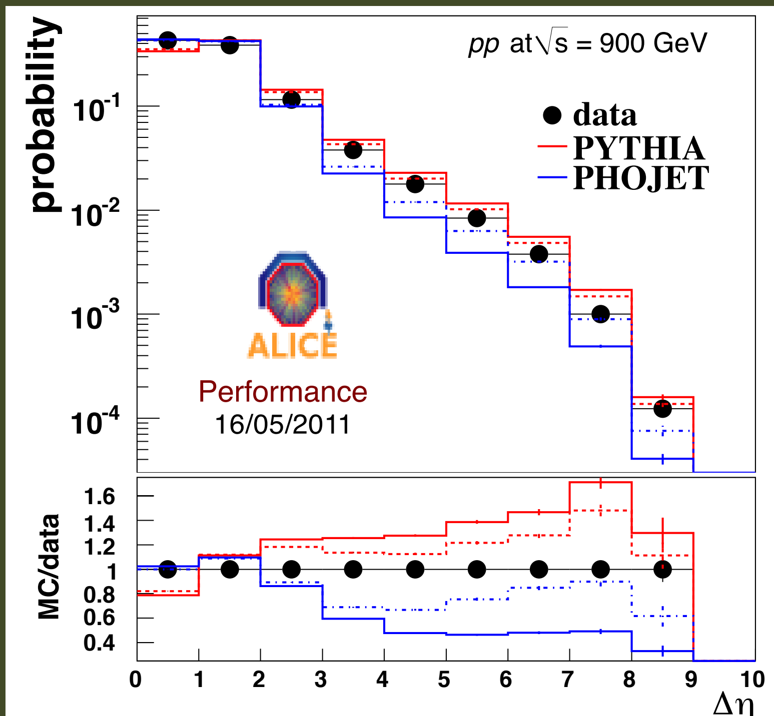
2-arm triggers

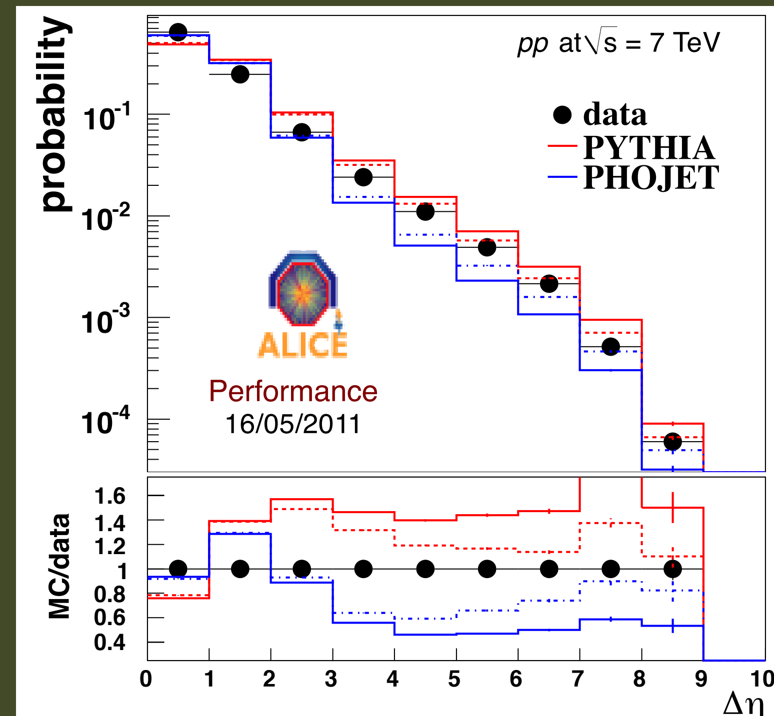


gap width distribution is sensitive to DD

Fixing the fraction of DD in Monte Carlo

Use the measured width distribution from two-arm triggers to constrain the contribution of double-diffraction.





PYTHIA: $w_{DD} = 0.12 \rightarrow 0.1$
PHOJET: $w_{DD} = 0.06 \rightarrow 0.1$

PYTHIA: $w_{DD} = 0.13 \rightarrow 0.09$
PHOJET: $w_{DD} = 0.05 \rightarrow 0.07$

Fractions of DD events converging to same value in the two MC

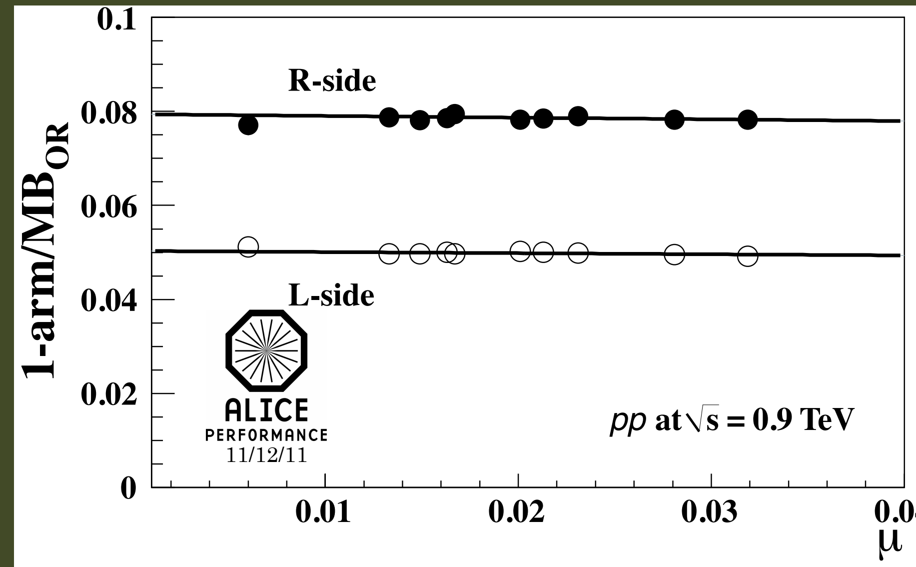
For 2.76 TeV the FMD is not used and the fraction of DD is not changed.

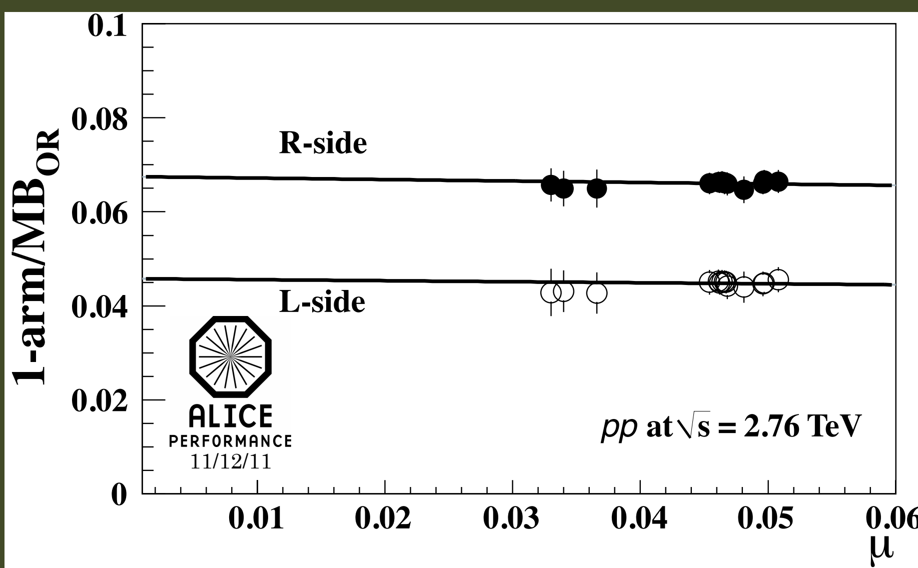
Pileup correction

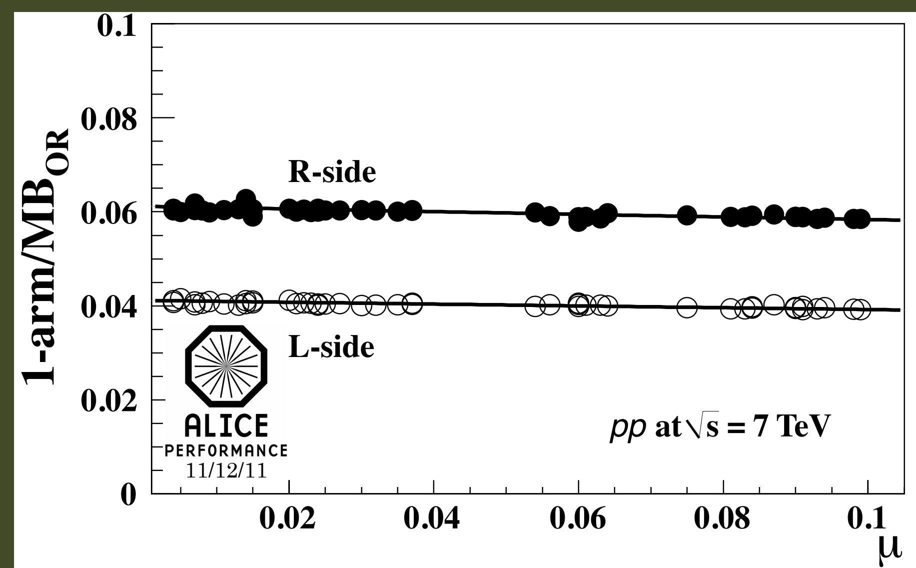
Higher luminosity
➔ higher pileup
➔ smaller rate of one-arm triggers
➔ underestimation of σ_{SD} and σ_{Inel}

$$A(\mu) = \frac{\exp\{A_0\mu\} - 1}{\exp\{\mu\} - 1}$$

μ – fraction of interactions per bunch crossing
A_0 – trigger rate in case of single interactions



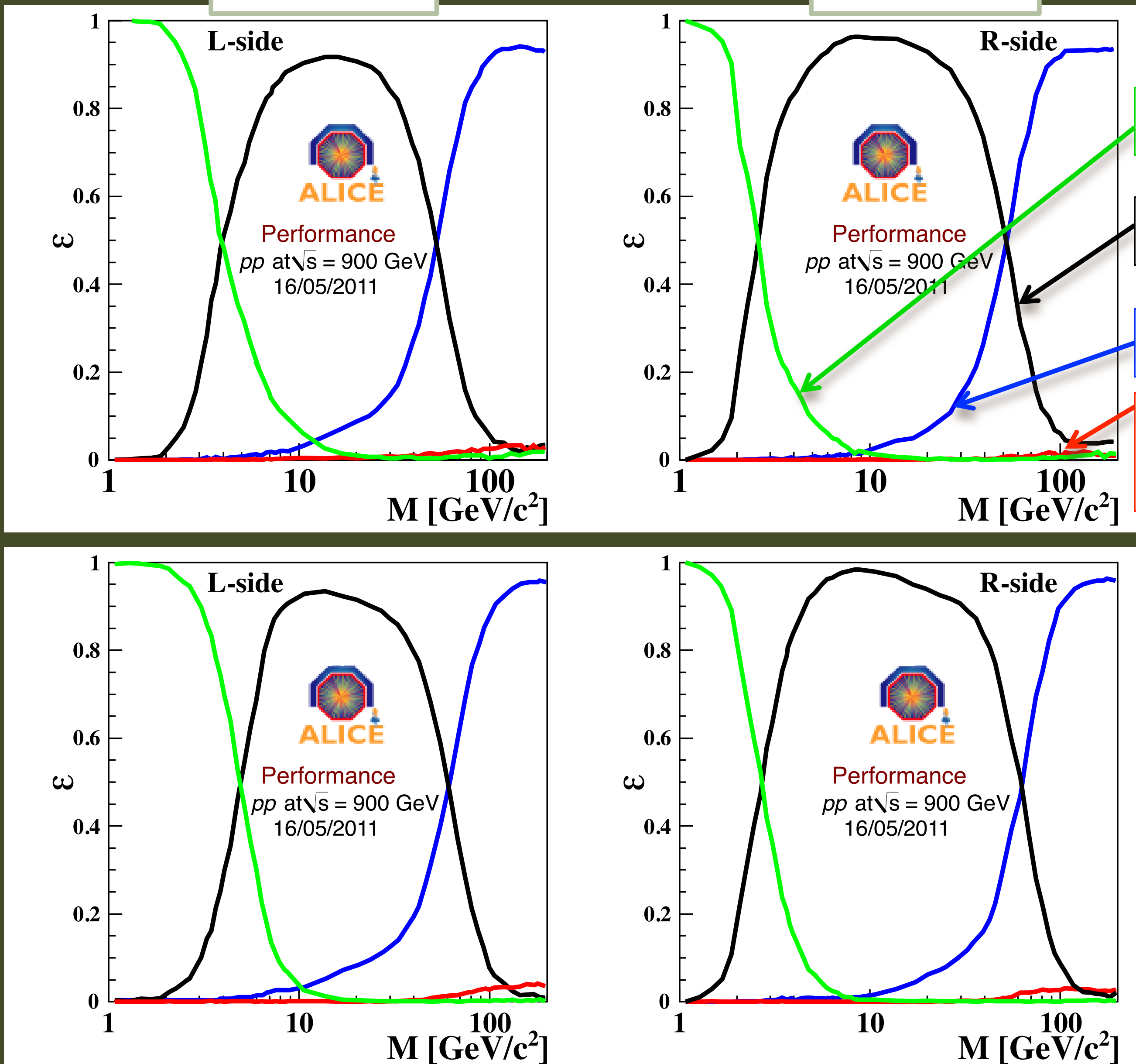




Efficiency/Inefficiency vs mass for SD (900 GeV)

L-side SD | R-side SD

PYTHIA / PHOJET



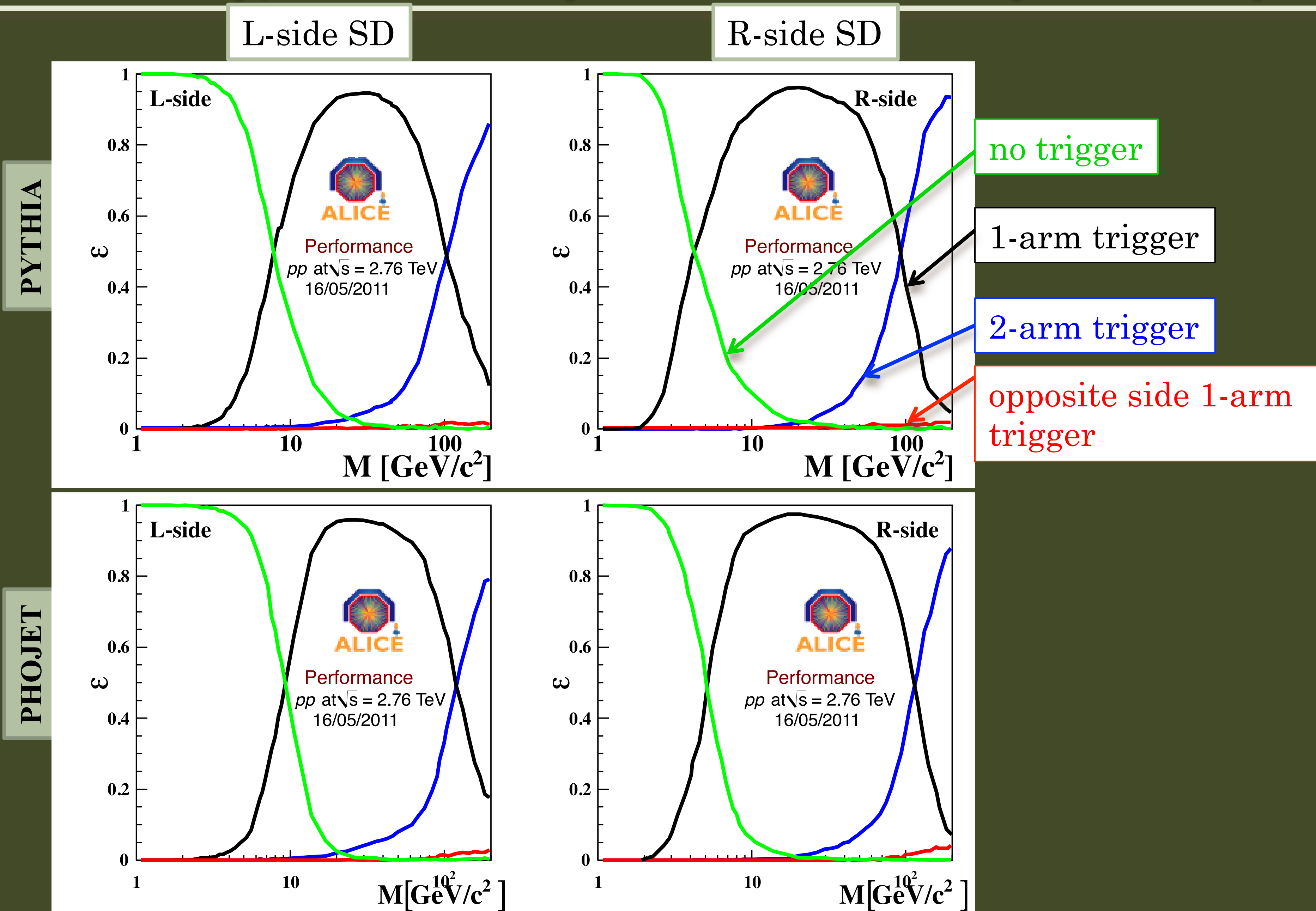
no trigger

1-arm trigger

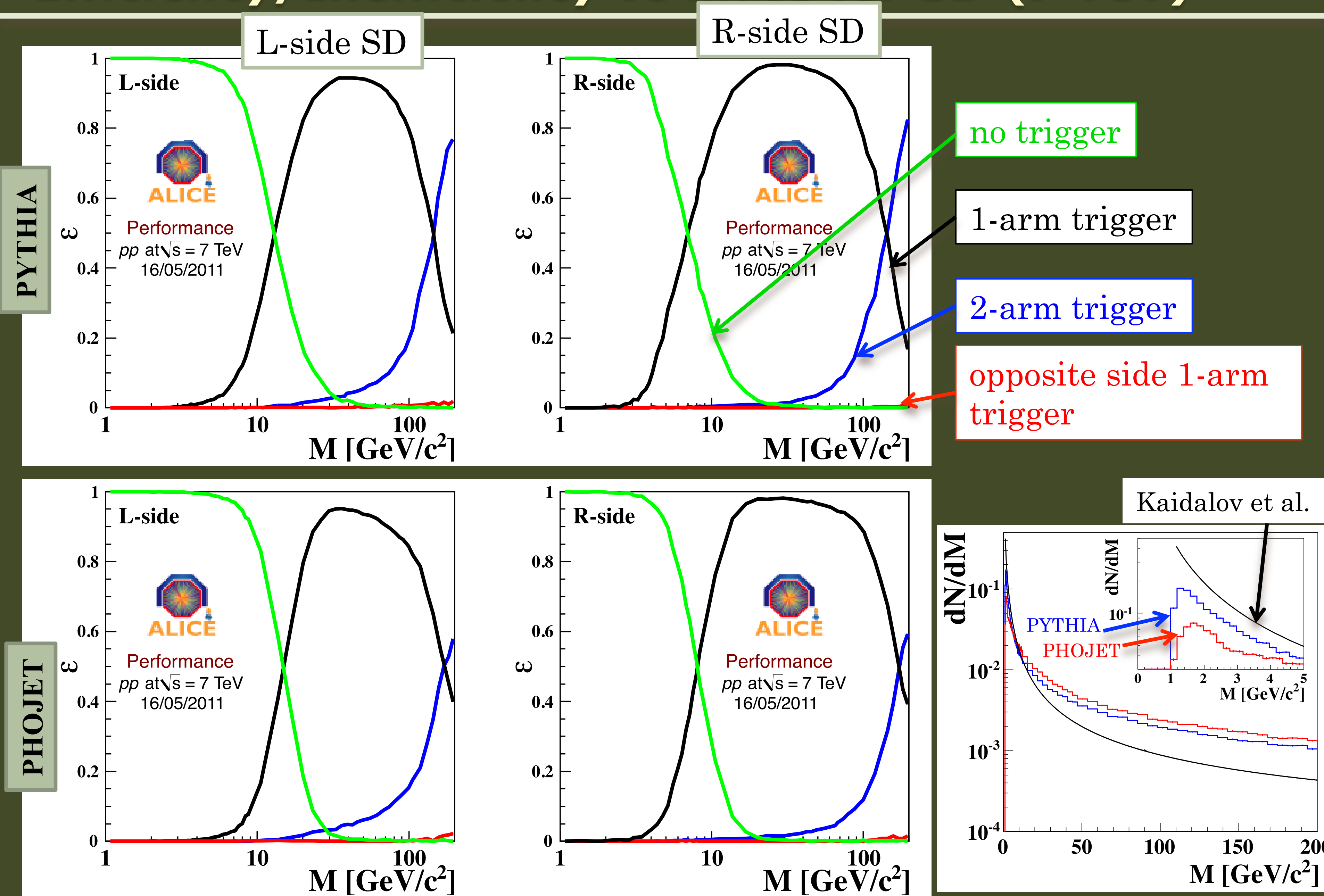
2-arm trigger

opposite side 1-arm trigger

Efficiency/Inefficiency vs mass for SD (2.76 TeV)

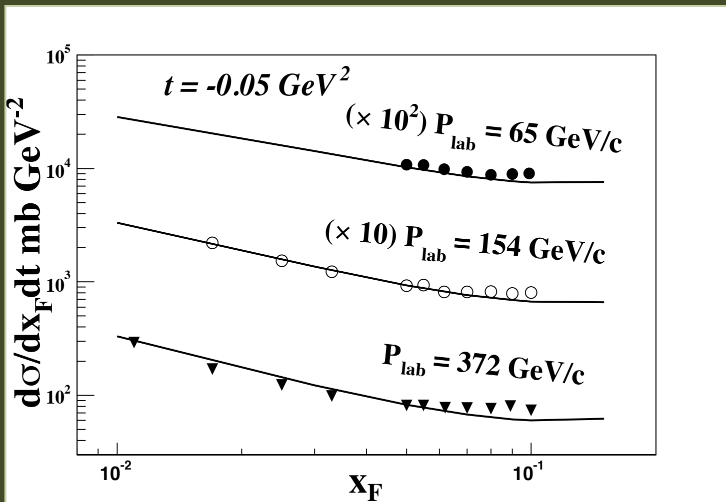


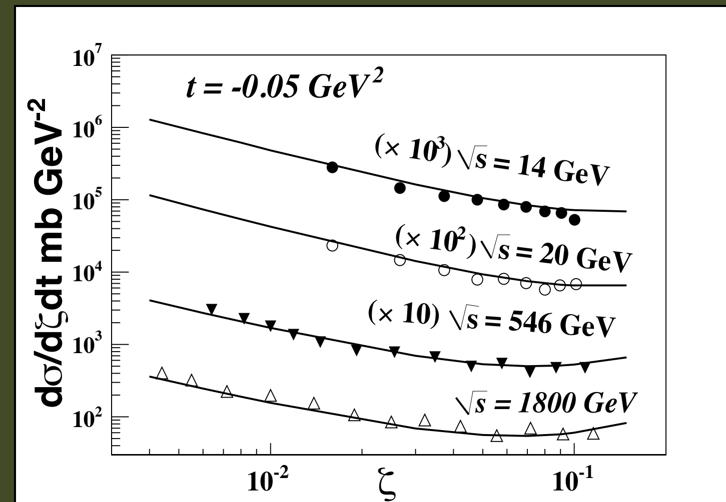
Efficiency/Inefficiency vs mass for SD (7 TeV)



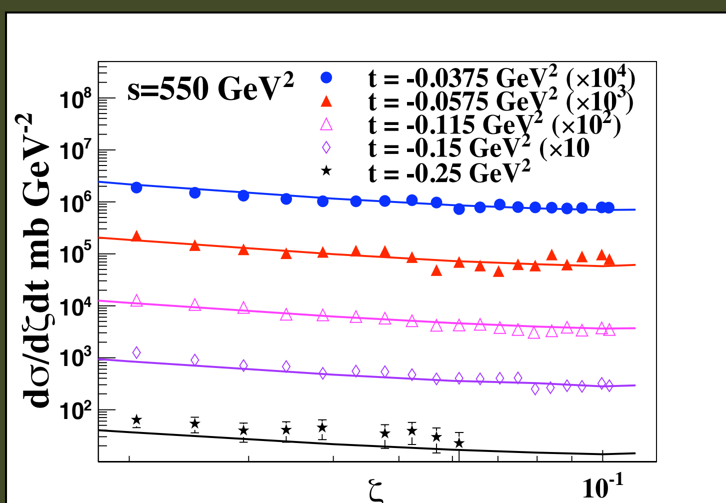
Performance of the model used to parameterise SD

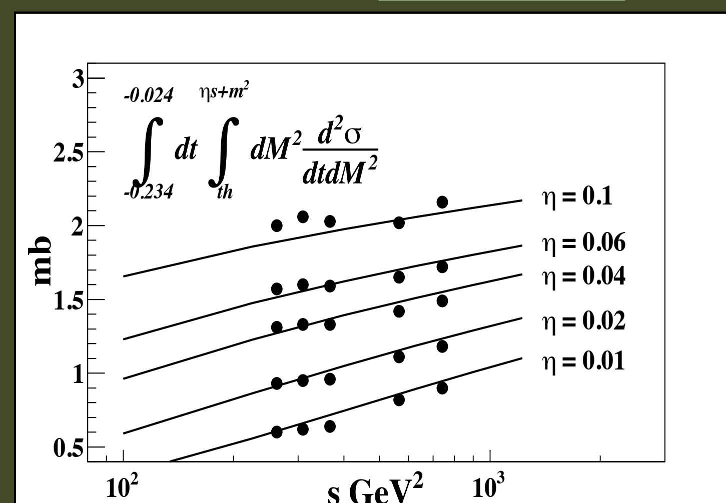
A.Kaidalov et al. [arxiv:0909.5156, EPJ. C67]





$\xi = M^2/s$





$\xi = M^2/s$

Resulting mean efficiencies

900 GeV

process \ trigger (input \ output)	R-side 1-arm trig.	L-side 1-arm trig.	2-arm trig.
R-side SD	0.465 ± 0.031	0.002 ± 0.001	0.198 ± 0.054
L-side SD	0.004 ± 0.003	0.352 ± 0.014	0.201 ± 0.050
NSD	0.025 ± 0.007	0.012 ± 0.004	0.956 ± 0.014

2.76 TeV

process \ trigger (input \ output)	R-side 1-arm trig.	L-side 1-arm trig.	2-arm trig.
R-side SD	0.395 ± 0.011	0.002 ± 0.001	0.087 ± 0.036
L-side SD	0.002 ± 0.001	0.301 ± 0.021	0.073 ± 0.027
NSD	0.026 ± 0.007	0.017 ± 0.009	0.946 ± 0.028

7 TeV

process \ trigger (input \ output)	R-side 1-arm trig.	L-side 1-arm trig.	2-arm trig.
R-arm SD	0.333 ± 0.027	0.0002 ± 0.0002	0.038 ± 0.019
L-arm SD	0.0007 ± 0.0006	0.243 ± 0.029	0.041 ± 0.017
NSD	0.022 ± 0.006	0.013 ± 0.003	0.952 ± 0.014

syst. error comes from:

- adjustment of DD in Pythia and Phojet
- Changing $d\sigma/dM$ by ±50% at the threshold
- SD kinematic in PYTHIA and PHOJET

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

Raw trigger ratios

900 GeV

L-side/2-arm= 0.0578 ± 0.0001(syst.)
R-side/2-arm= 0.0912 ± 0.0001(syst.)

2.76 TeV

L-side/2-arm= 0.0518 ± 00.001(syst.)
R-side/2-arm= 0.0763 ± 0.0001(syst.)

7 TeV

L-side/2-arm= 0.0458 ± 0.0001(syst.)
R-side/2-arm= 0.0680 ± 0.0001(syst.)

Corrected ratios

900 GeV:

$$\frac{\sigma_{SD}}{\sigma_{Inel}} = \mathbf{0.215} \quad \pm \mathbf{0.030}(\mathbf{syst.})$$

$$\frac{\sigma_{SD}^{left}}{\sigma_{Inel}} = 0.103 \quad \pm 0.015(syst.)$$

$$\frac{\sigma_{SD}^{right}}{\sigma_{Inel}} = 0.112 \quad \pm 0.015(syst.)$$

2.76 TeV:

$$\frac{\sigma_{SD}}{\sigma_{Inel}} = \mathbf{0.187} \quad \pm \mathbf{0.055}(\mathbf{syst.})$$

$$\frac{\sigma_{SD}^{left}}{\sigma_{Inel}} = 0.097 \quad \pm 0.026(syst.)$$

$$\frac{\sigma_{SD}^{right}}{\sigma_{Inel}} = 0.090 \quad \pm 0.028(syst.)$$

7 TeV:

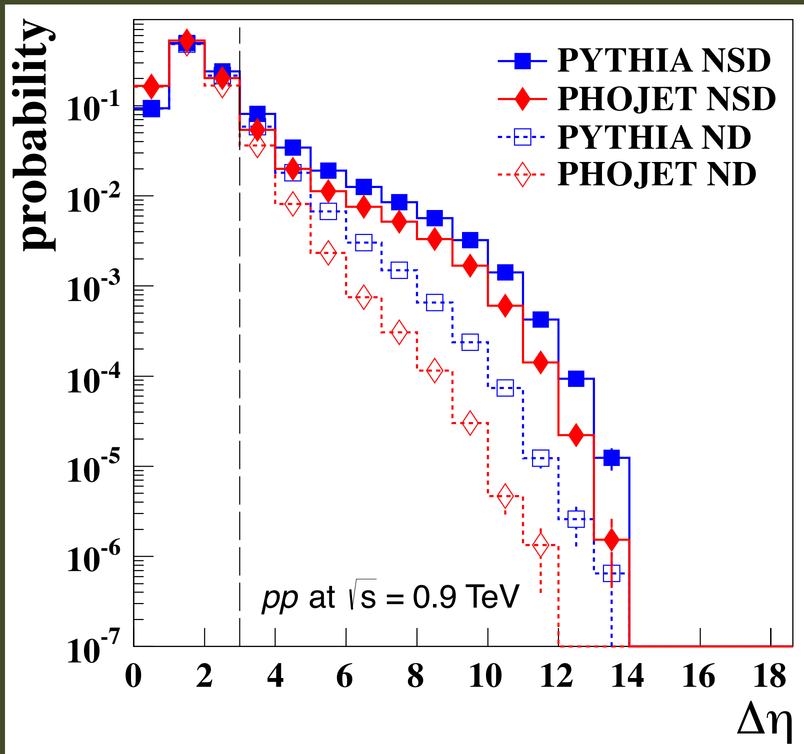
$$\frac{\sigma_{SD}}{\sigma_{Inel}} = \mathbf{0.207} \quad \pm \mathbf{0.04}(\mathbf{syst.})$$

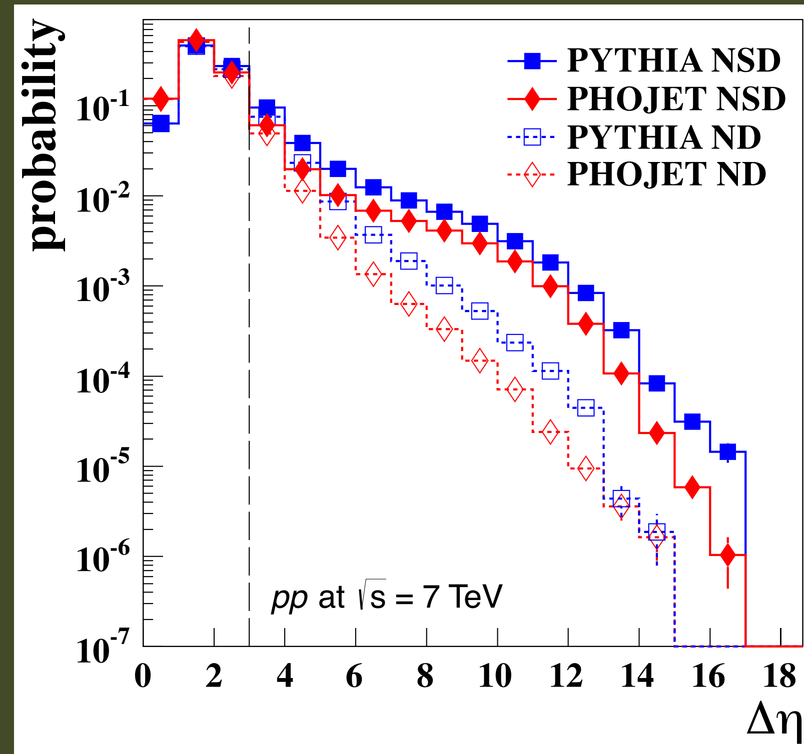
$$\frac{\sigma_{SD}^{left}}{\sigma_{Inel}} = 0.104 \quad \pm 0.019(syst.)$$

$$\frac{\sigma_{SD}^{right}}{\sigma_{Inel}} = 0.103 \quad \pm 0.020(syst.)$$

Despite different acceptances of the two ALICE sides, the results are symmetrical as expected from the symmetry of the physics process

$\sigma_{DD}/\sigma_{Inel}$



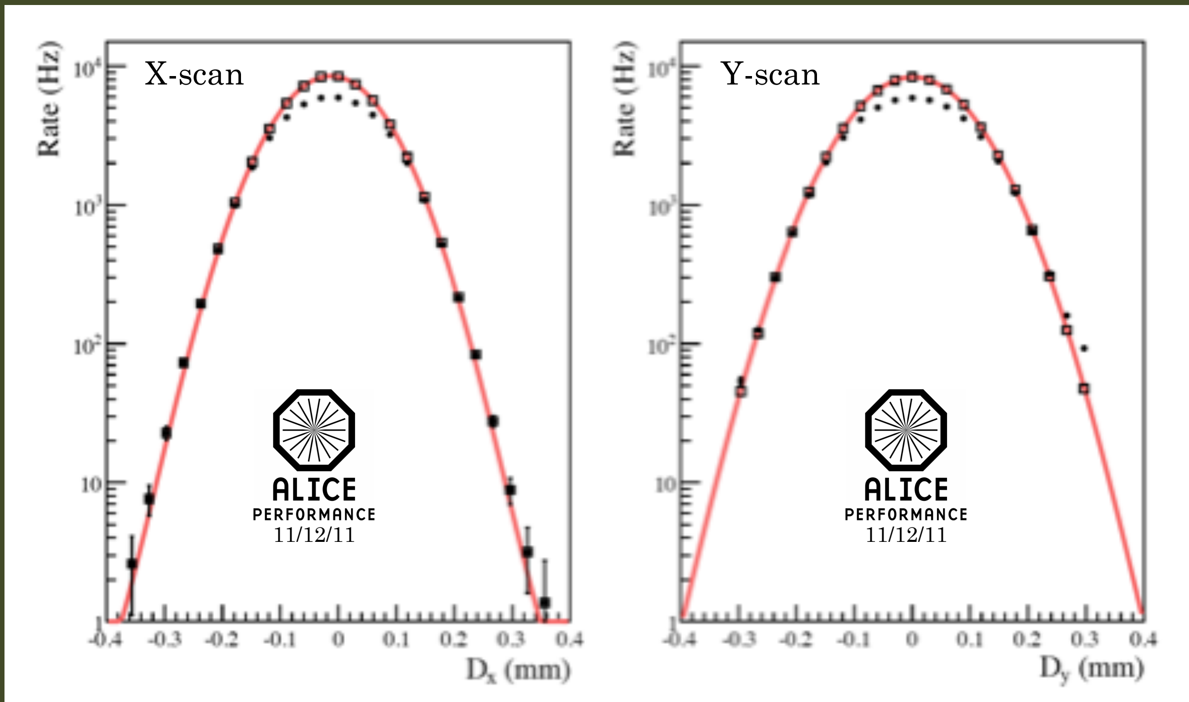


Definition of DD : all events with a gap $\Delta\eta > 3$:

900 GeV	2.76 TeV	7 TeV
$\frac{\sigma_{DD}}{\sigma_{Inel}} = 0.108 \pm 0.028$	$\frac{\sigma_{DD}}{\sigma_{Inel}} = 0.125 \pm 0.052$	$\frac{\sigma_{DD}}{\sigma_{Inel}} = 0.124 \pm 0.035$

Van der Meer scans

A part of Inelastic cross-section is measured by requiring coincidence of V0-Left and V0-Right



$$L = f\,\frac{N_1 N_2}{h_1 h_2}$$

f = 11245.5 Hz - accelerator frequency
$N_{1,2}$ – numbers of protons per bunch
h_x and h_y – effective width and height of the collision region

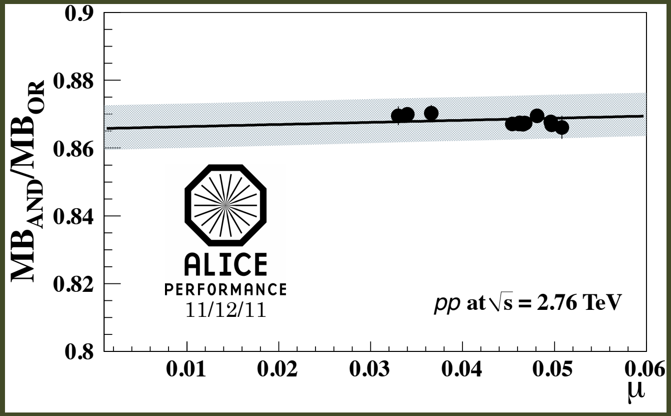
$$R^{trigger} = \sigma^{visible} L$$

vdM scan	√s TeV	Colliding bunches	Crossing angle (rad)	β^* (m)	Max μ	$h_x/2\sqrt{\pi}$ (μm)	$h_y/2\sqrt{\pi}$ (μm)	$\sigma^{visible}$
a	7	1	280	2	0.086	43.8	46.7	54.21 ± 2.9
b	7	1	500	3.5	0.74	57.3	65.1	54.34 ± 1.9
c	2.76	48	710	10	0.12	164	166	47.67 ± 1.5

Triggering efficiencies

From the MC tuned with our SD and DD measurements, we can calculate the ALICE triggering efficiencies:

MB_{OR} = V0-Left or SPD or V0-Right
MB_{AND} = V0-Left and V0-Right

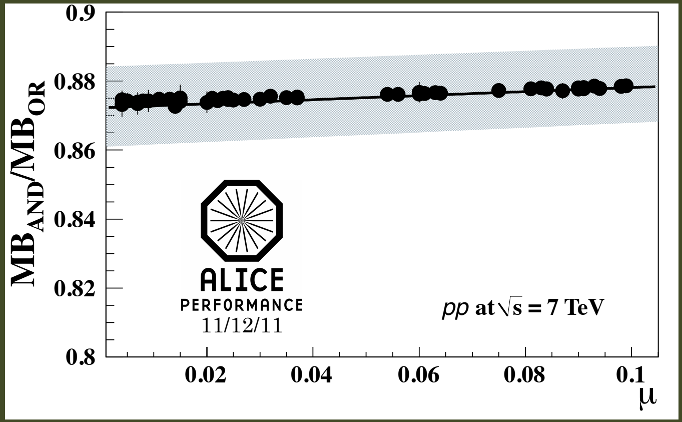


900 GeV

MB_{AND} = (76.3 ± 1.0)%
MB_{OR} = (91.0 ± 1.3)%
MB_{AND}/MB_{OR} = 0.838 ± 0.005

2.76 TeV

MB_{AND} = (76.7 ± 2)%
MB_{OR} = (88.6 ± 3)%
MB_{AND}/MB_{OR} = 0.866 ± 0.007



7 TeV

MB_{AND} = (74.2 ± 1.1)%
MB_{OR} = (85.1 ± 2.2)%
MB_{AND}/MB_{OR} = 0.872 ± 0.012

σ_{Inel} ($\sqrt{s}$ = 2.76 TeV) = 62.2 ± 1.7(model) ± 2.0(lumi) mb
σ_{Inel} ($\sqrt{s}$ = 7 TeV) = 73.2 ± 1.1(model) ± 2.6(lumi) mb

Comparison with other experiments and models

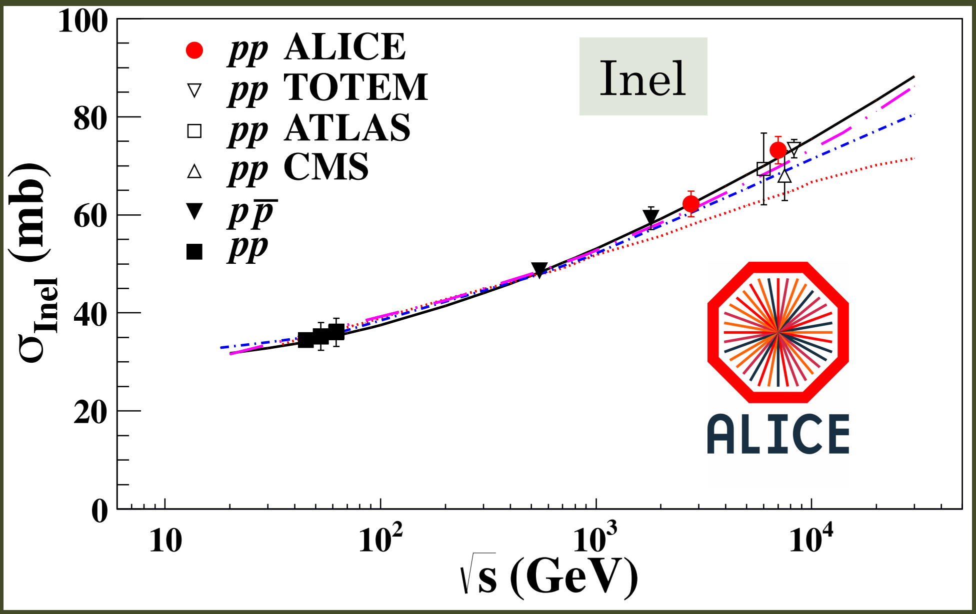
σ_{Inel} at $\sqrt{s}$ = 7 TeV

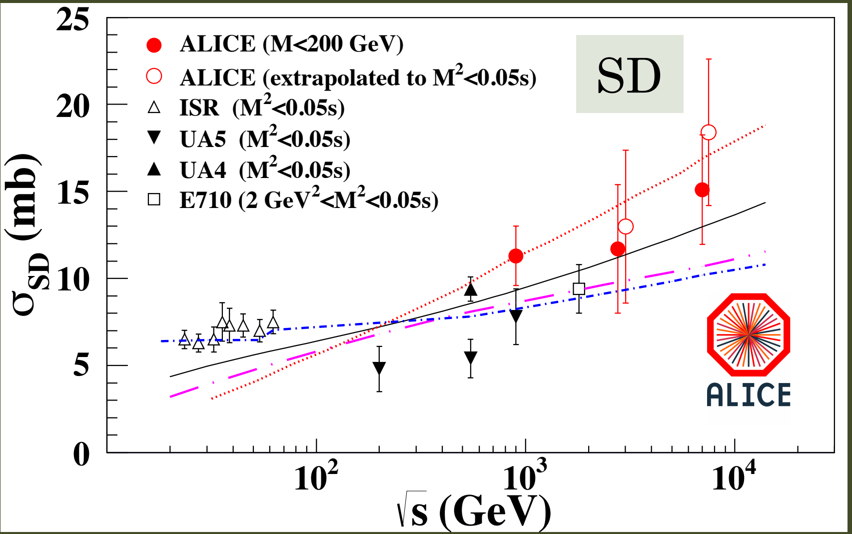
ALICE : $73.2 \pm 1.1^{model} \pm 2.6^{lumi}$

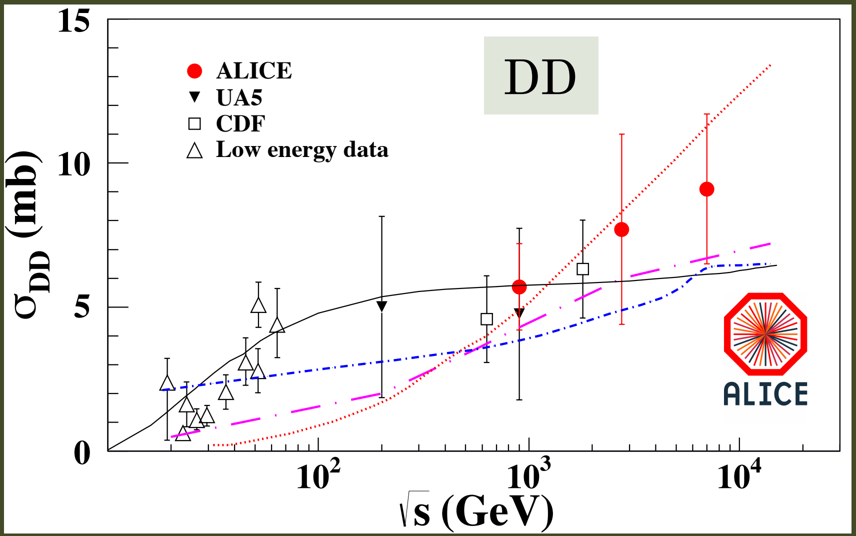
ATLAS : $69.4 \pm 2.4^{exp.} \pm 6.9^{extrap.}$

CMS : $68.0 \pm 2.0^{syst.} \pm 2.4^{lumi} \pm 4^{extrap.}$

TOTEM: $73.5 \pm 0.6^{stat.}\,{}^{+1.8}_{-1.3}$ syst.







Gotsman et al., arXiv:1010.5323, EPJ. C74, 1553 (2011)

Kaidalov et al., arXiv:0909.5156, EPJ. C67, 397 (2010)

Ostapchenko, arXiv:1010.1869, PR D83 114018 (2011)

Khoze et al., EPJ. C60 249 (2009), C71 1617 (2011)

Model predictions:

SD ➔ $M^2 < 0.05s$

DD ➔ $\Delta \eta > 3$

Summary

Ratios of single-diffraction dissociation (M < 200 GeV/c^2) to inelastic cross-sections were measured at $\sqrt{s}$ = 0.9, 2.76 and 7 TeV. Within our accuracy, we do not observe variations of these ratios with energy ($\sigma_{SD}/\sigma_{Inel} \approx 0.2$).

From a determination of the inelastic cross-section (van der Meer scan) single-diffraction and double-diffraction cross-sections were obtained at $\sqrt{s}$ = 2.76 and 7 TeV.

$\sqrt{s}$ (TeV)	σ_{Inel} (mb)	$\sigma_{SD}(M < 200\ \mathrm{GeV})/\sigma_{Inel}$	$\sigma_{DD}(\Delta\eta>3)/\sigma_{Inel}$
0.9		0.215 ± 0.030	0.108 ± 0.028
2.76	62.2 ± 1.7 ± 2.0	0.187 ± 0.055	0.125 ± 0.052
7	73.2 ± 1.1 ± 2.6	0.207 ± 0.040	0.124 ± 0.035