Diffractive and inelastic proton–proton cross sections at 13 TeV with ALICE

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Regge Theory

Relativistic scattering amplitud is analytically continued so that angular momentum can take complex values:

$$A_\ell(t) \to A(\ell, t)$$

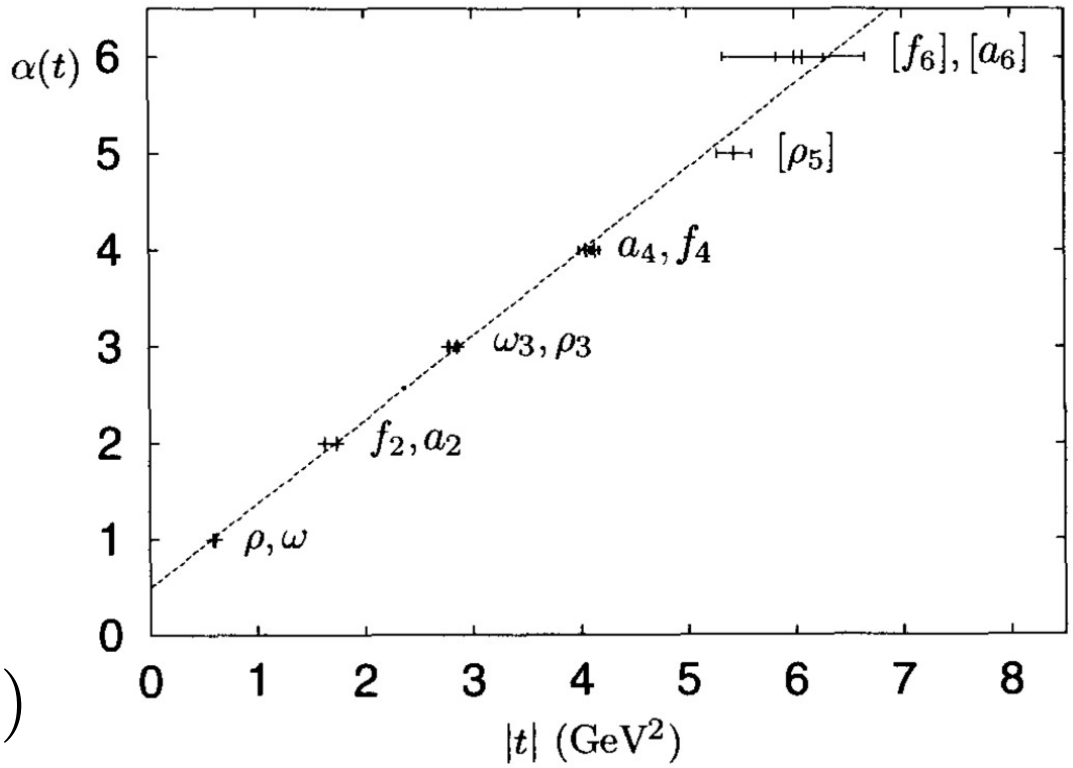
This lead to a function with singularities or poles that lie in trajectories in the complex plane described by:

$$\ell = \alpha(t)$$

These poles are known as Regge poles, or reggeons. Interestingly, when:

$$t = m^2 \qquad \alpha(t = m^2)$$

Becomes an integer equal to the spin of the particle of mass m.



Regge Theory

According to the Regge theory, the contribution of each pole to the total proton-proton scattering amplitude is given by a term which behaves asymptotically ($s \to \infty$ and t fixed) as:

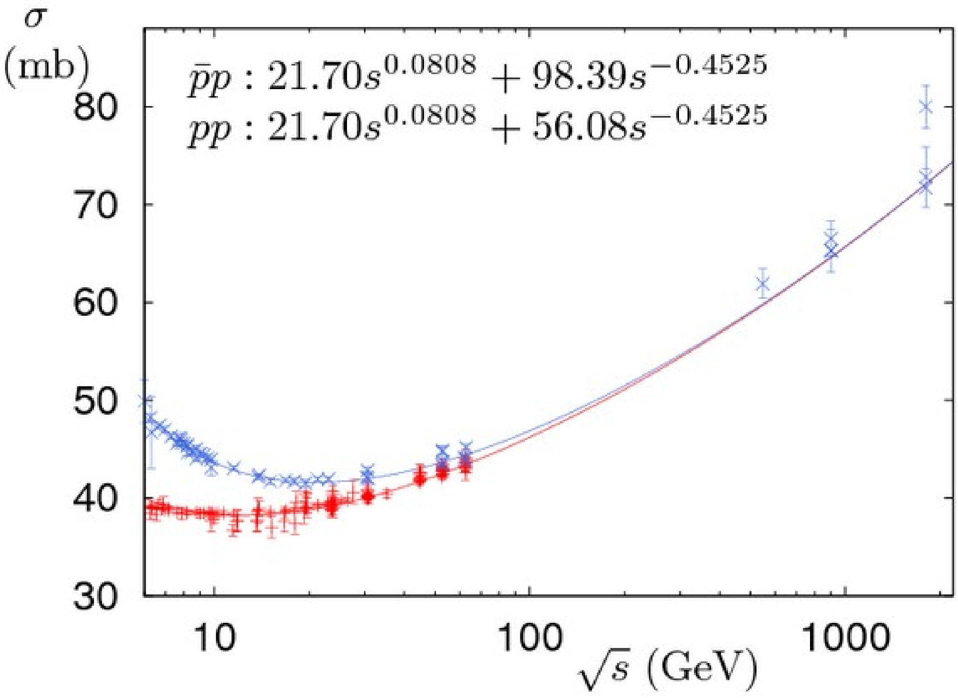
$$A(s,t)_{s\to\infty} \sim s^{\alpha(t)}$$

For low t values this trajectories can be approximated as:

$$\alpha(t) = \alpha(0) + \alpha' t$$

where $\alpha(0)$ is called the intercept and α' the slope of the trajectory. This contributes to the total cross section:

$$\sigma_{s\to\infty} \sim \frac{1}{s}\mathrm{Im}A(s,t=0)_{s\to\infty} \sim s^{\alpha(0)-1}$$



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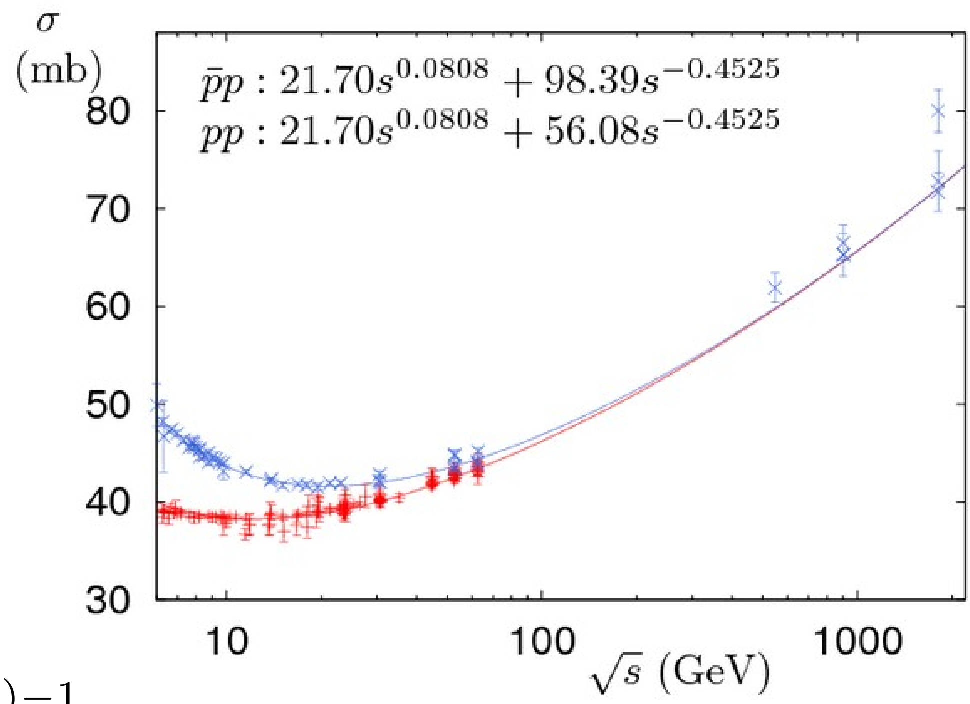

If the intercept is lower than one, the contribution of a trajectory to the total cross section is decreasing with the energy

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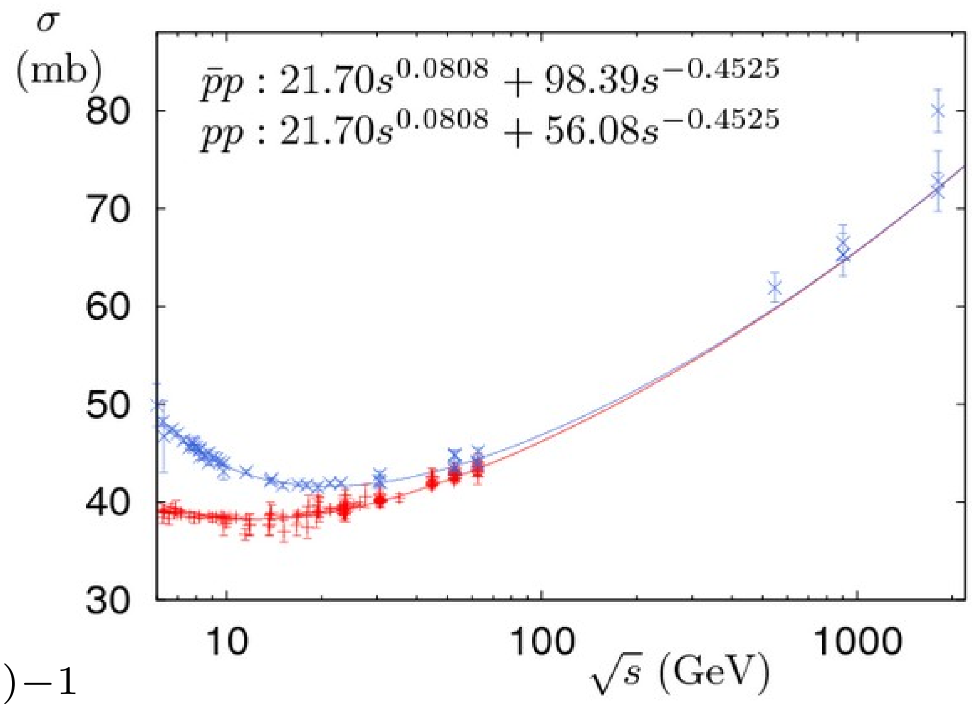


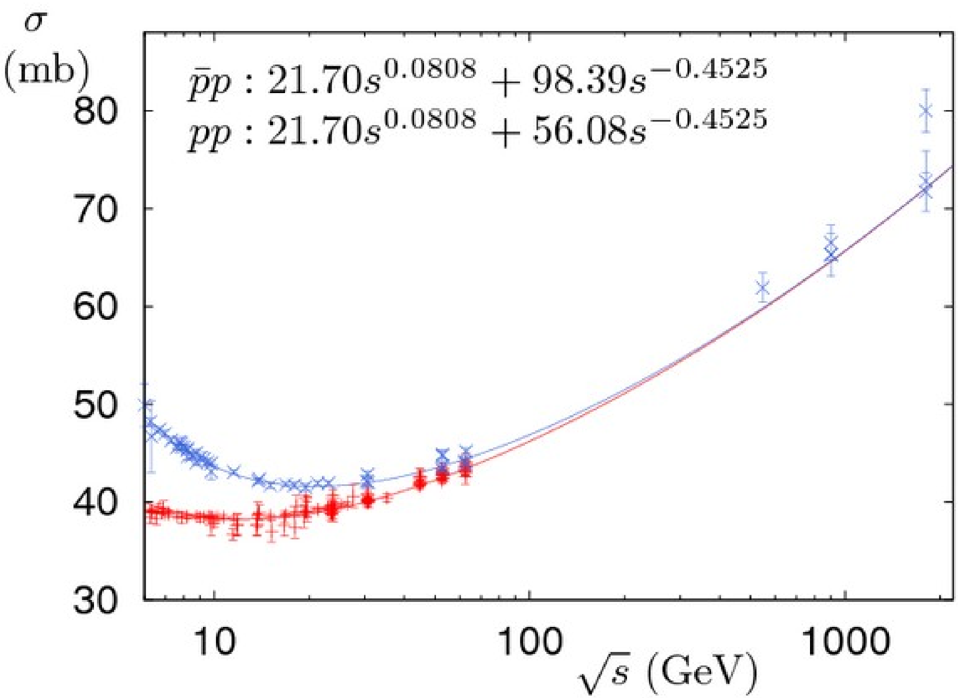
It turns out that all known mesons have intercepts that are smaller than unity. This leads to the expectation that the total cross section for hadron scattering should decrease with energy.

Regge Theory

Although initially experiments seemed to confirm that behavior at low energies it was soon found that at higher energies the total cross sections begin to level and seemed to be constant around $\sqrt{s} = 20$ GeV.

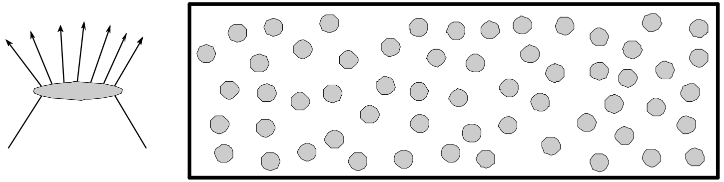
The explanation to this on terms of Regge theory was the existence of a trajectory with an intercept $\alpha(0) = 1$. This trajectory was named the **pomeron** after the Ukrainian Soviet physicist Isaak Pomeranchuk, who show that the total cross section of proton-proton and antiproton-proton scattering should be asymptotically equal at high energies.

Later with higher energies available it was clear that the total cross section rise with energy. and the Pomeron intercept was fitted to $= 1.08$

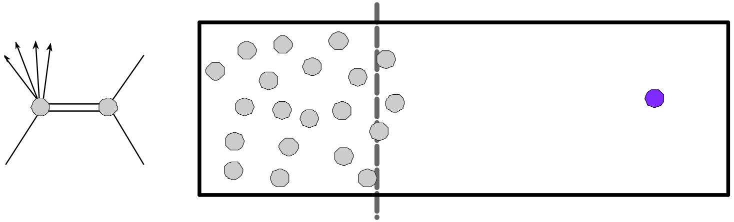


$$\sigma_{total} = \sigma_{elastic} + \sigma_{SD} + \sigma_{DD} + \sigma_{CD} + \sigma_{Non\text{-}Diff}$$

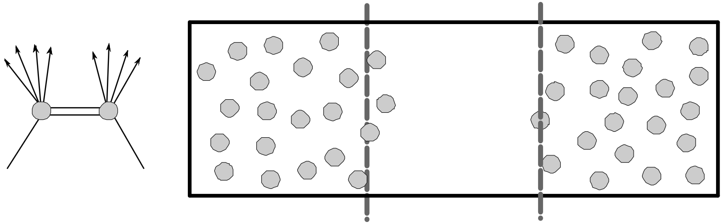
Non diffractive event (ND). No gap



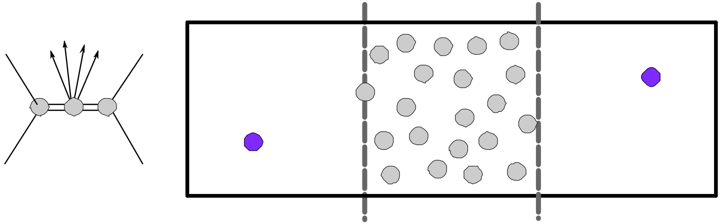
Single diffractive event (SD)



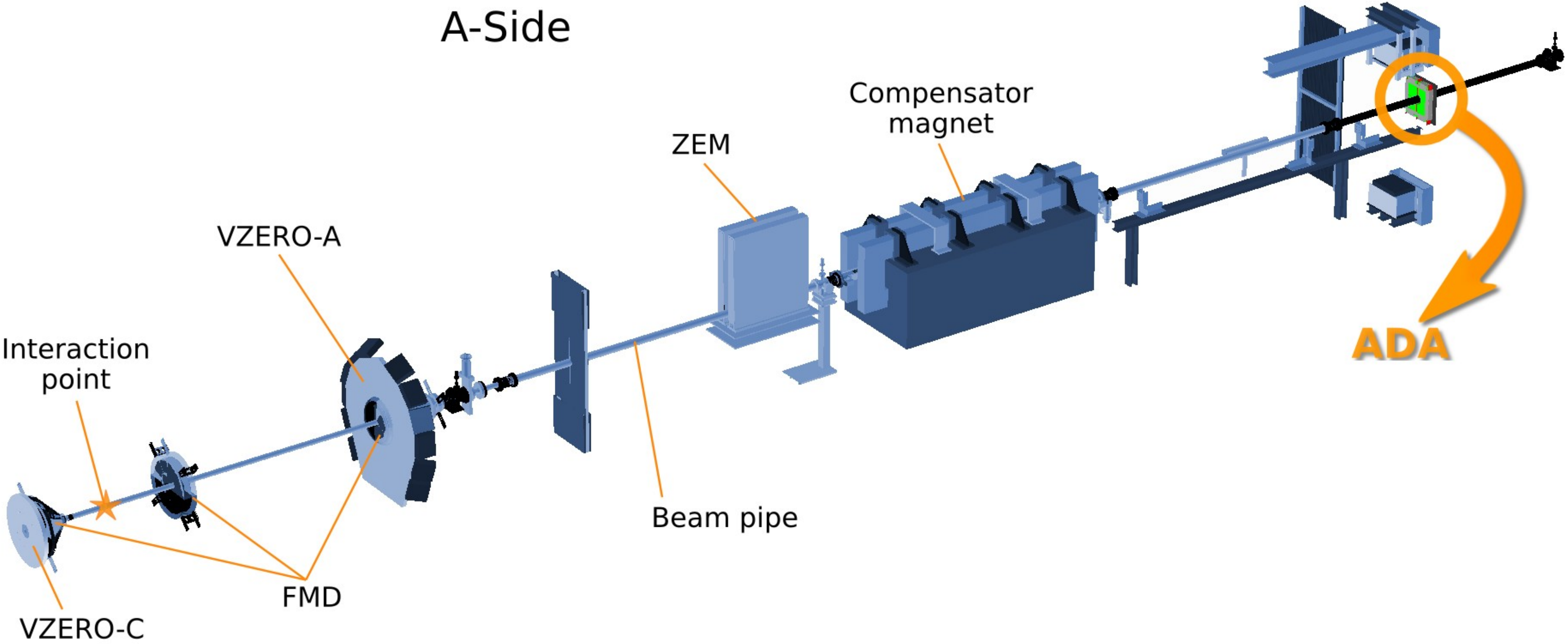
Double diffractive event (DD)

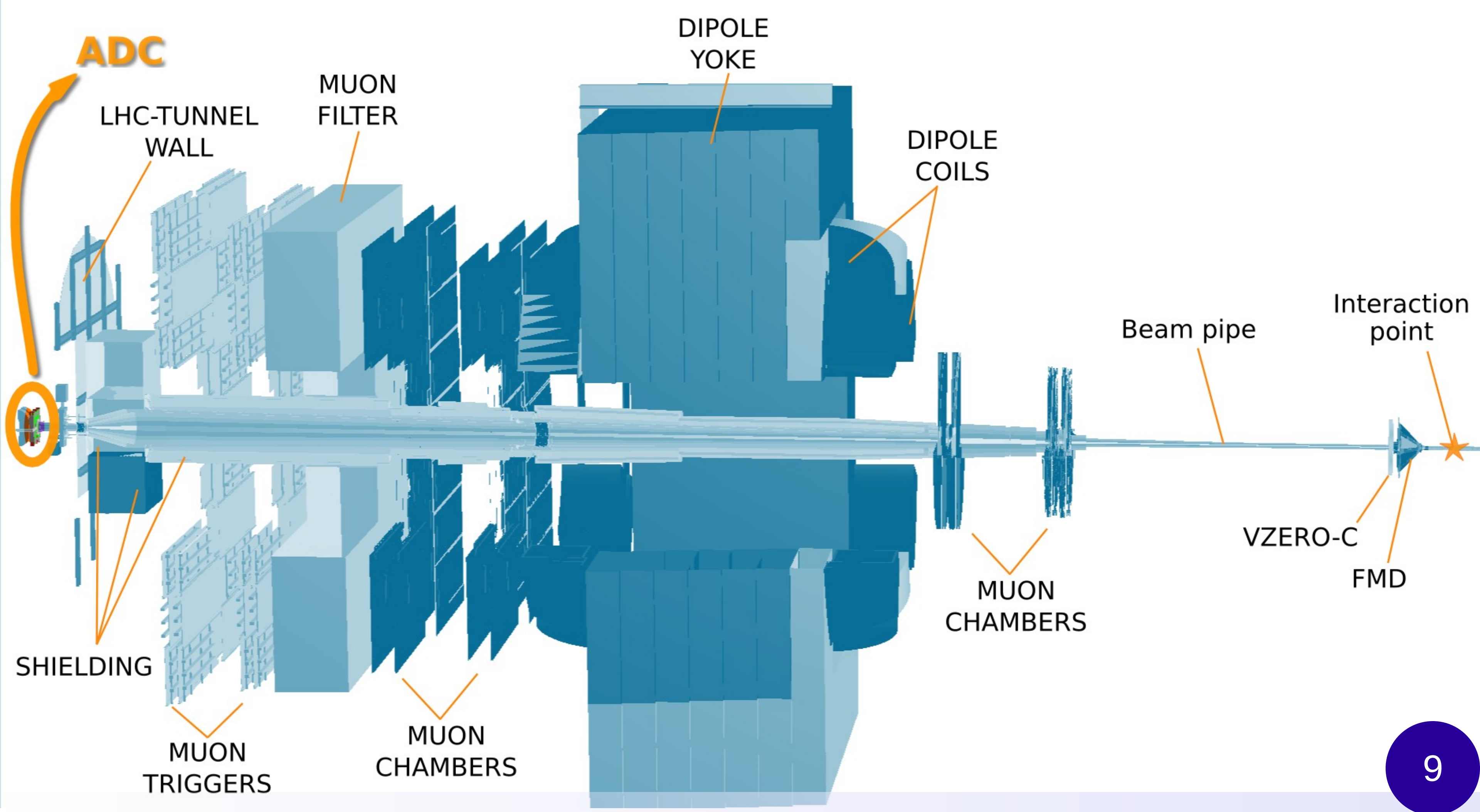


Central diffractive event (CD)

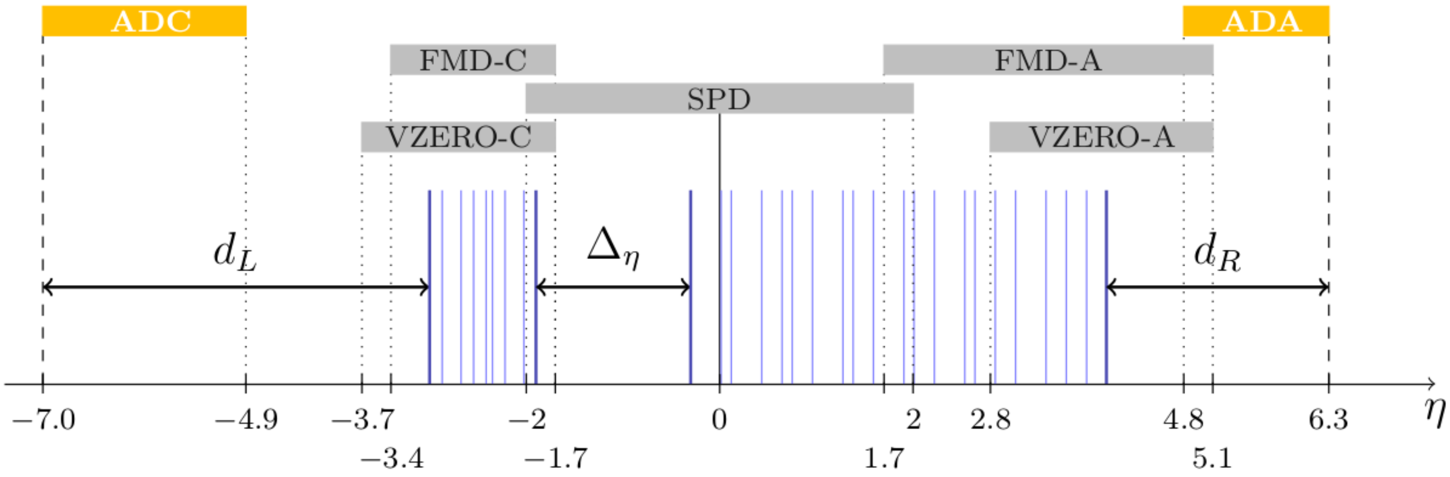


A-Side

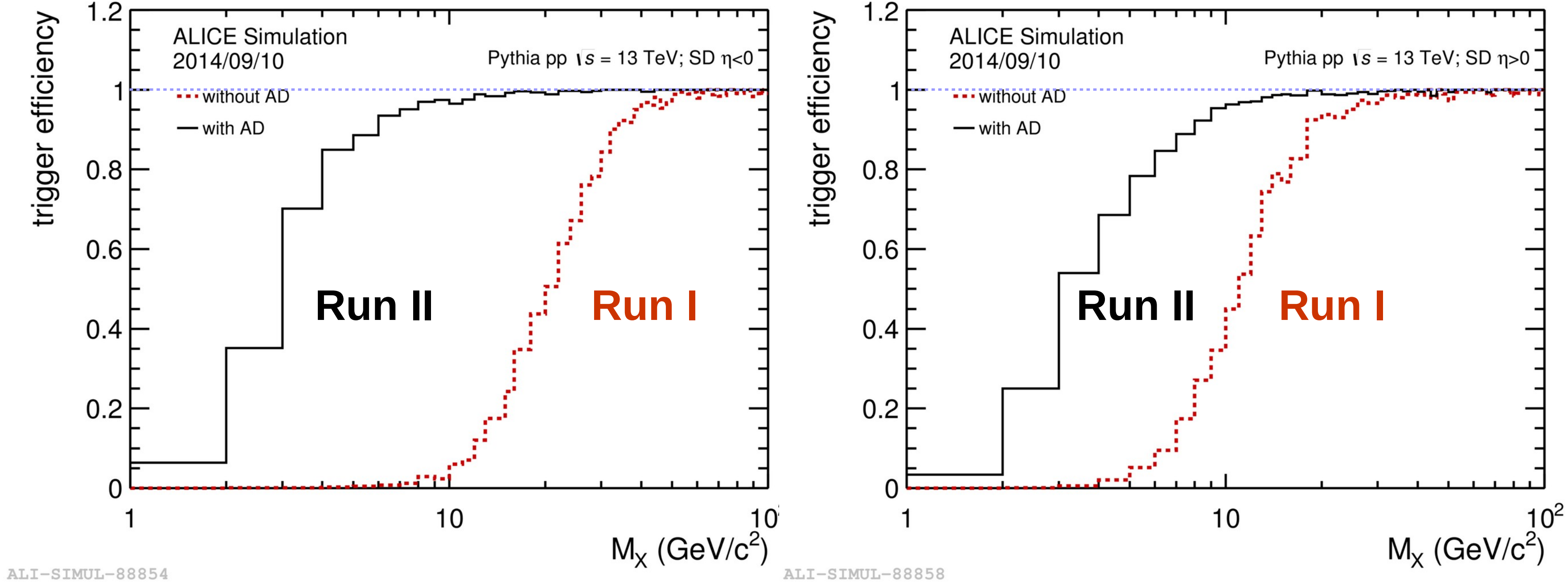

Compensator magnet
ZEM
VZERO-A
ADA
Interaction point
Beam pipe
FMD
VZERO-C


ADC
LHC-TUNNEL WALL
MUON FILTER
DIPOLE YOKE
DIPOLE COILS
Interaction point
Beam pipe
VZERO-C
FMD
MUON CHAMBERS
SHIELDING
MUON TRIGGERS
MUON CHAMBERS

ALICE pseudo-rapidity coverage



Improved trigger efficiency at low diffracted mass: MB_{OR} = ADC || V0C || SPD || V0A || ADA

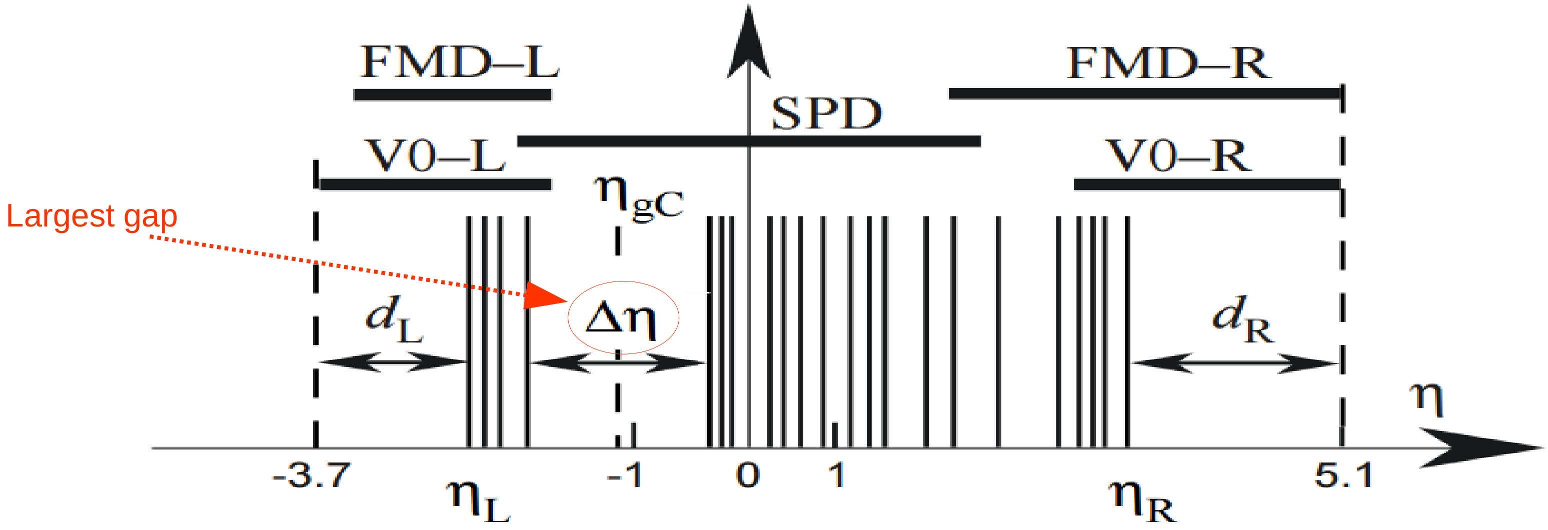


Event categories

There are 3 event categories:

```
1-arm-L →  SD-L (left  or η<0)
1-arm-R →  SD-R (right or η>0)
2-arm   →  ND and DD events

DD: 2-Arm and Δη>3
```



Classification procedure

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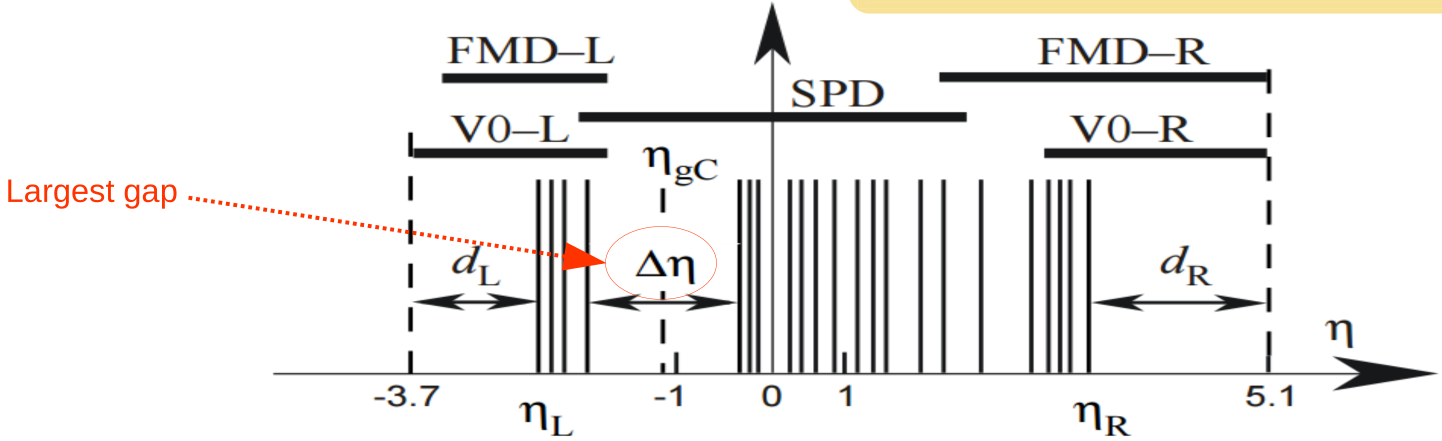
one-track event: all events satisfying the condition $(\eta_R - \eta_L) < 0.5$ and having all pseudo-tracks within 45◦ in ϕ,

For them we use:

$\eta_C = 1/2(\eta_L + \eta_R)$

If $\eta_C < 0$: → 1-arm-L

If $\eta_C > 0$: → 1-arm-R



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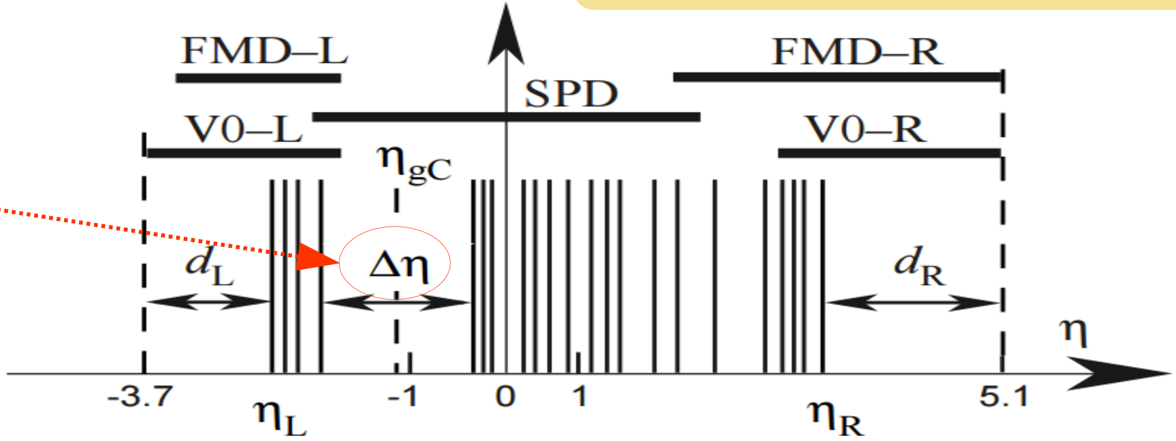
Otherwise, is a **multi**-track event,

If $\Delta\eta$ is larger than d_R and d_L → 2-arm
If $-1<\eta<1$ → 2-arm
else,
If $\eta_R<1$ → 1-arm-L
If $\eta_L>-1$ → 1-arm-R
Any remaining events → 2-arm

Largest gap

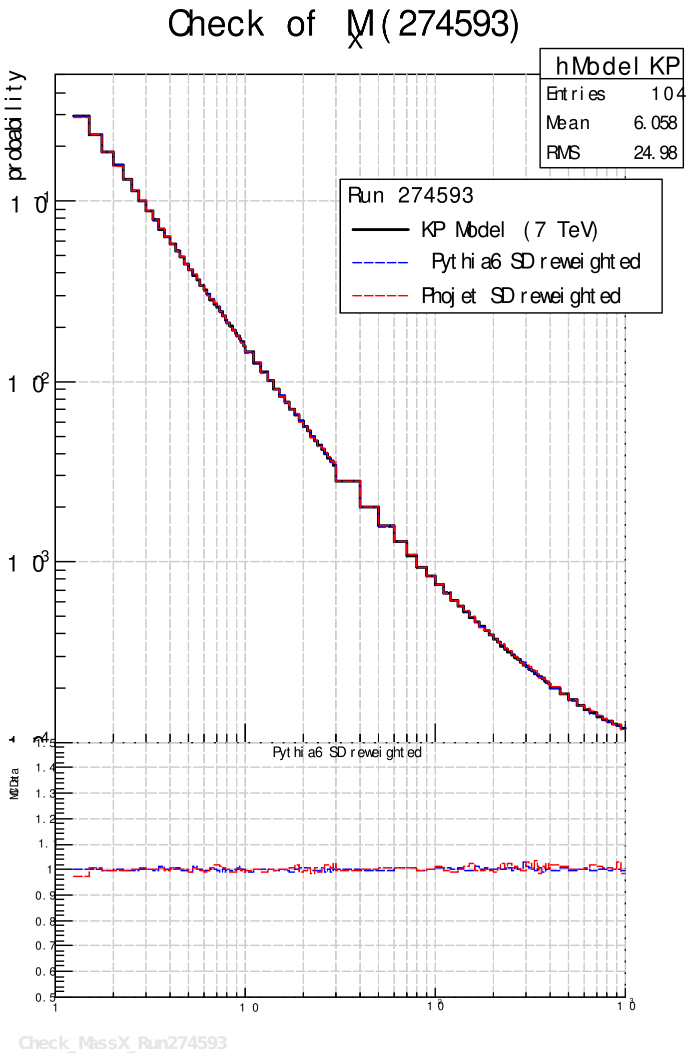


Simulation of single difraction

The main uncertainty in the simulation of diffraction is the shape of the single diffractive mass distribution.

Here, weights are applied to the single diffractive (SD) events in the Monte Carlo with the purpose of reproducing the diffractive mass distributions from the Kaidalov-Poghsyan model.

If the diffracted mass is larger than the upper mass cut then the events are relabeled as non-diffractive.



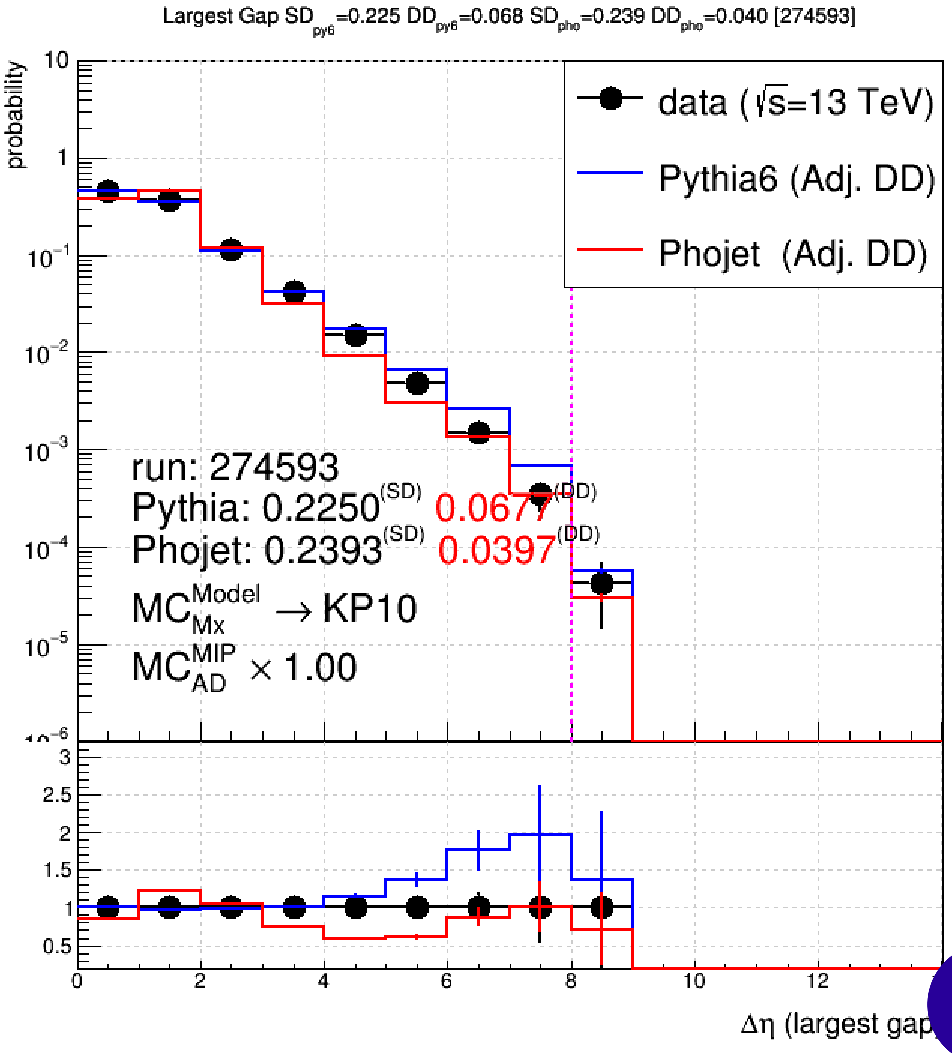
Example of double diffractive content adjustment (without AD)

Here, events selected by the 2-arm condition (mostly non diffractive and double diffractive).

The distribution of the largest gap per event is plotted for data and MC.

The double-diffractive content of Pythia 6 (Phojet)is tuned in order to better follow the data distribution from above (below).

Bins corresponding to a pseudo-rapidity gap larger than 8 are discarded due to low data count



Example of double diffractive content adjustment (using AD)

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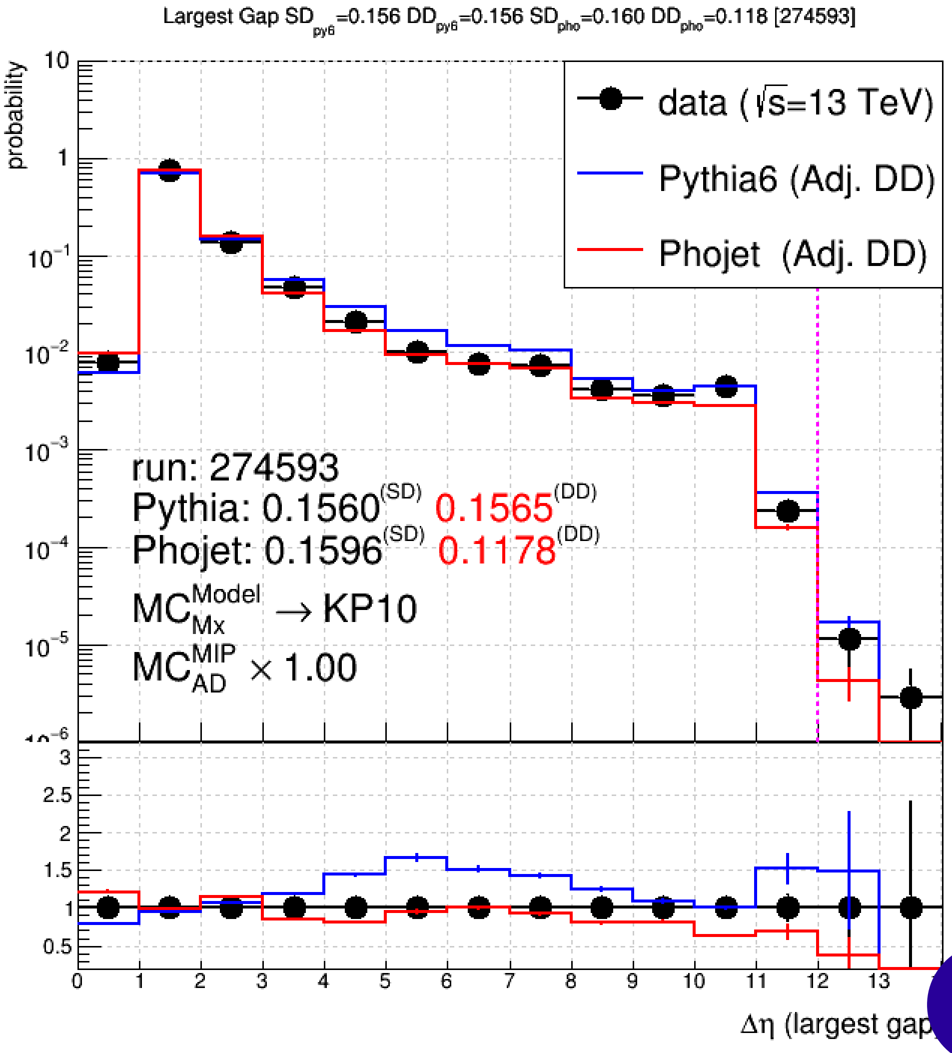
The distribution of the largest gap per event is plotted for data and MC.

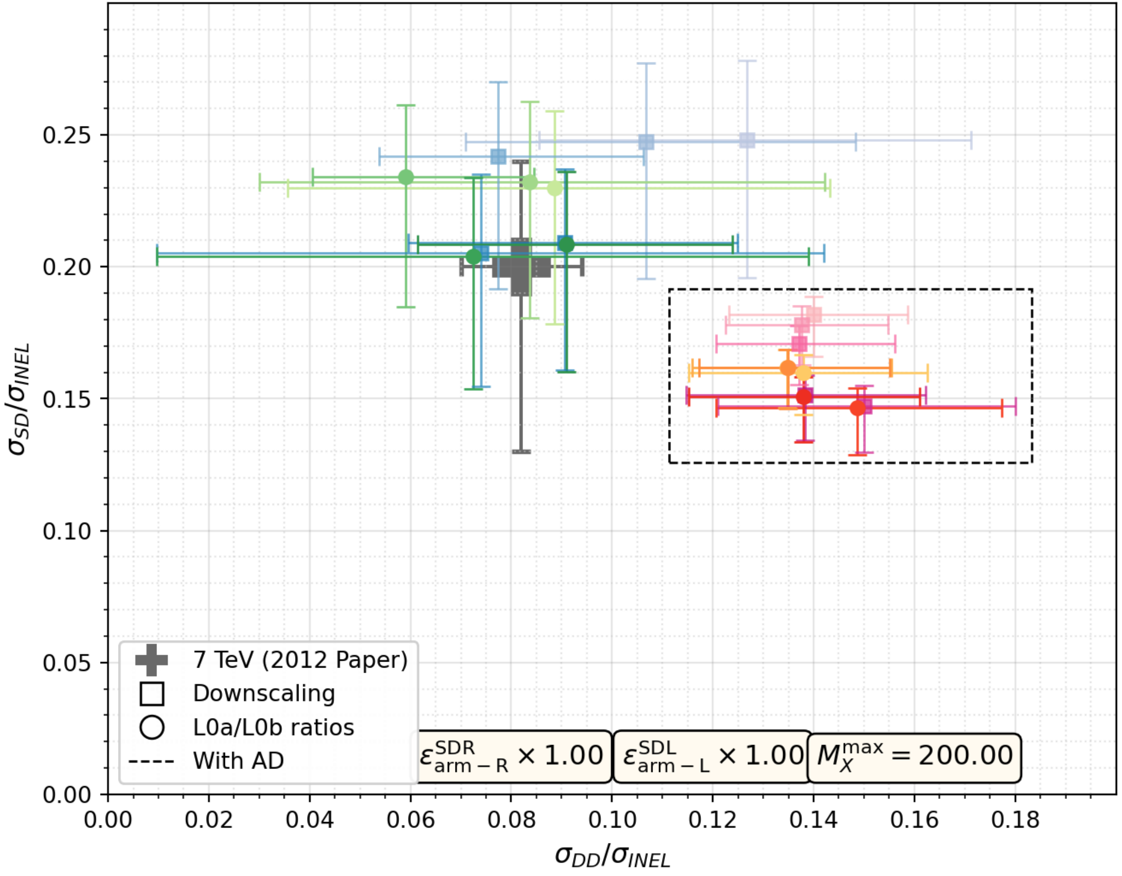
The double-diffractive content of Pythia 6 (Phojet)is tuned in order to better follow the data distribution from above (below).

The last two bins are neglected due to large data uncertainty



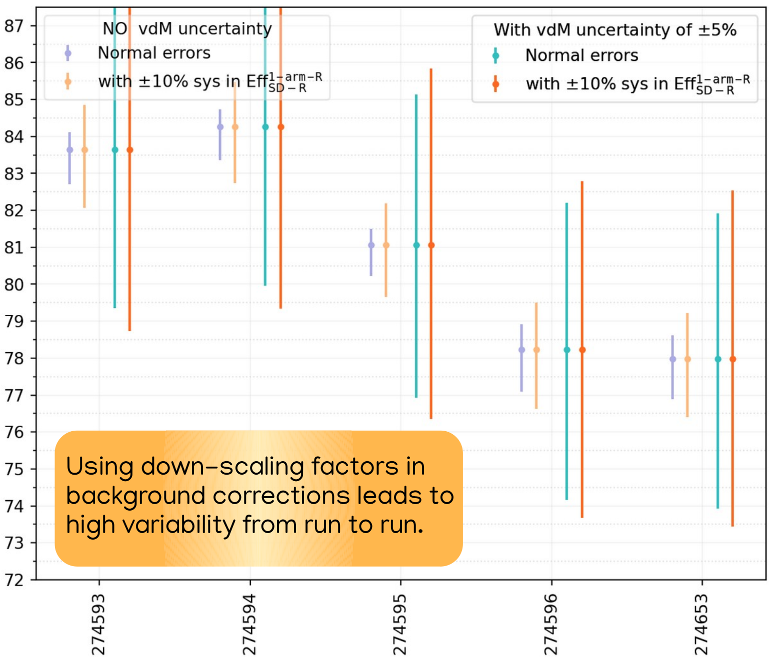
Results

SD vs DD

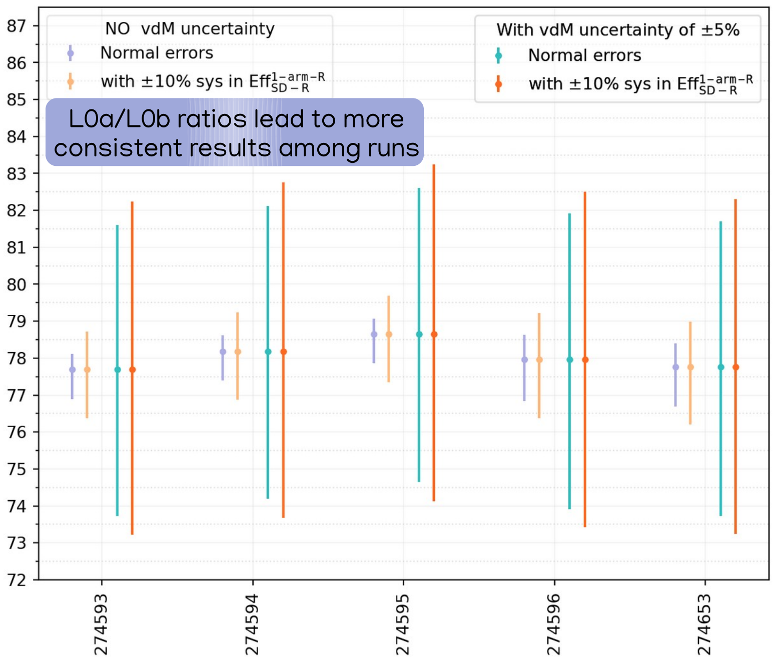


Results

BG_Method: DwS



BG_Method: L0R



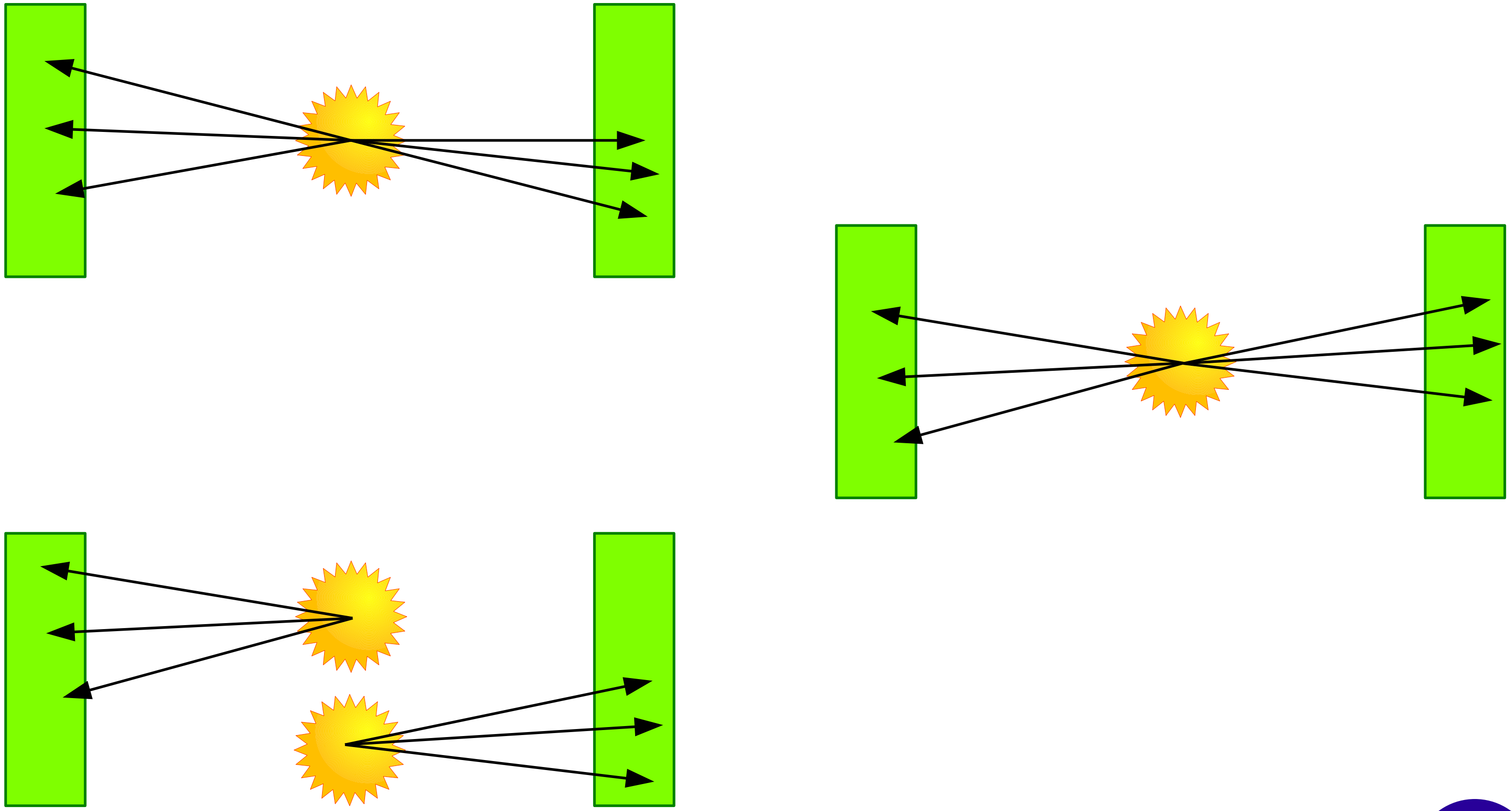
Back-up slides

$$\epsilon^{\mathrm{NSD}}_{\text{arm-L}} = \frac{\left(f_{\mathrm{DD}}\epsilon^{\mathrm{DD}}_{\text{arm-L}} + f_{\mathrm{CD}}\epsilon^{\mathrm{CD}}_{\text{arm-L}} + f_{\mathrm{ND}}\epsilon^{\mathrm{ND}}_{\text{arm-L}}\right)}{f_{\mathrm{DD}} + f_{\mathrm{CD}} + f_{\mathrm{ND}}}$$

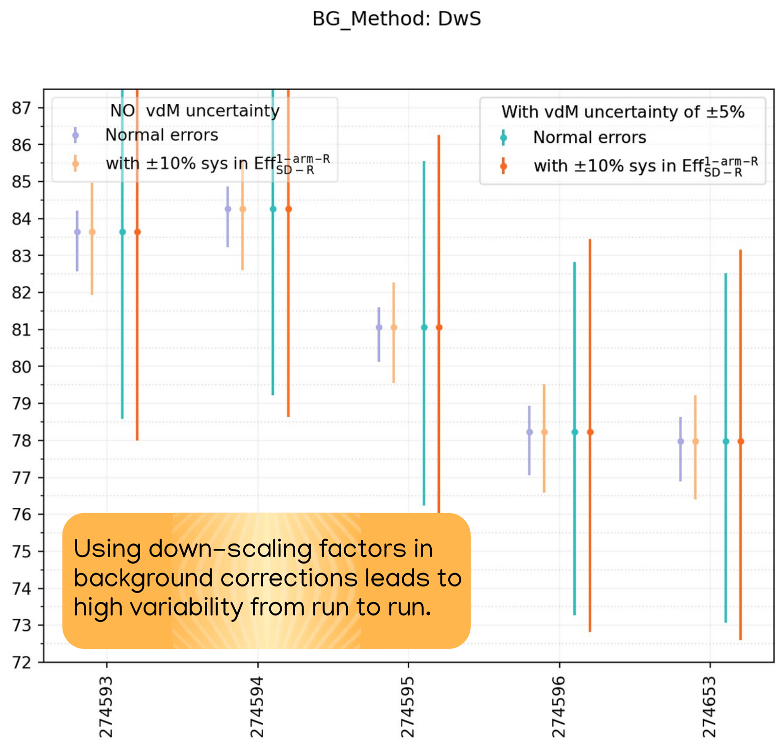
$$\epsilon^{\mathrm{NSD}}_{\text{arm-R}} = \frac{\left(f_{\mathrm{DD}}\epsilon^{\mathrm{DD}}_{\text{arm-R}} + f_{\mathrm{CD}}\epsilon^{\mathrm{CD}}_{\text{arm-R}} + f_{\mathrm{ND}}\epsilon^{\mathrm{ND}}_{\text{arm-R}}\right)}{f_{\mathrm{DD}} + f_{\mathrm{CD}} + f_{\mathrm{ND}}}$$

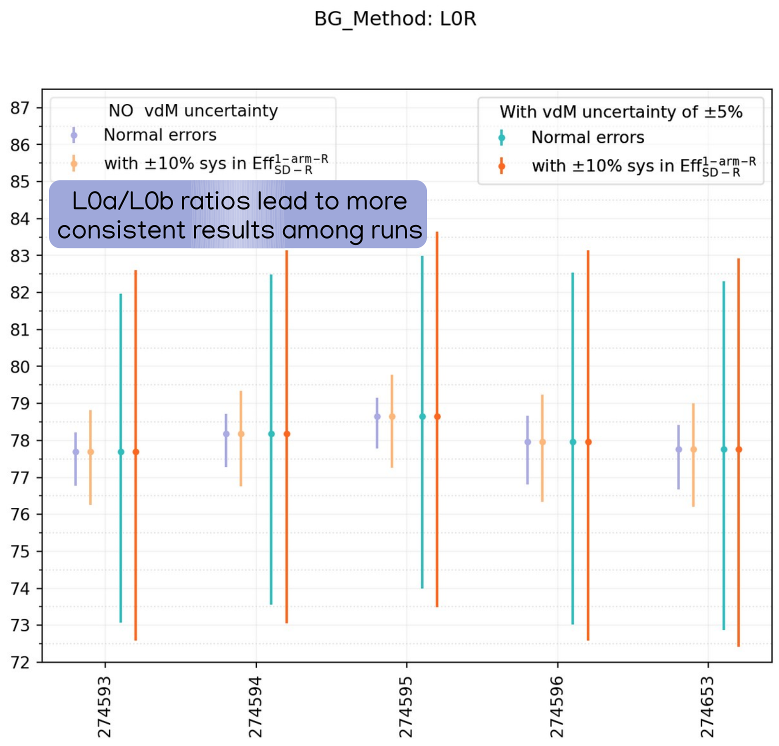
$$\epsilon^{\mathrm{NSD}}_{\text{2-arm}} = \frac{\left(f_{\mathrm{DD}}\epsilon^{\mathrm{DD}}_{\text{2-arm}} + f_{\mathrm{CD}}\epsilon^{\mathrm{CD}}_{\text{2-arm}} + f_{\mathrm{ND}}\epsilon^{\mathrm{ND}}_{\text{2-arm}}\right)}{f_{\mathrm{DD}} + f_{\mathrm{CD}} + f_{\mathrm{ND}}}$$

$$\begin{pmatrix} \sigma_{\text{arm-L}} \\ \sigma_{\text{arm-R}} \\ \sigma_{\text{2-arm}} \end{pmatrix} = \begin{pmatrix} \epsilon^{\mathrm{SDL}}_{\text{arm-L}} & \epsilon^{\mathrm{SDR}}_{\text{arm-L}} & \epsilon^{\mathrm{NSD}}_{\text{arm-L}} \\ \epsilon^{\mathrm{SDL}}_{\text{arm-R}} & \epsilon^{\mathrm{SDR}}_{\text{arm-R}} & \epsilon^{\mathrm{NSD}}_{\text{arm-R}} \\ \epsilon^{\mathrm{SDL}}_{\text{2-arm}} & \epsilon^{\mathrm{SDR}}_{\text{2-arm}} & \epsilon^{\mathrm{NSD}}_{\text{2-arm}} \end{pmatrix} \begin{pmatrix} \sigma_{\mathrm{SDL}} \\ \sigma_{\mathrm{SDR}} \\ \sigma_{\mathrm{NSD}} \end{pmatrix}$$



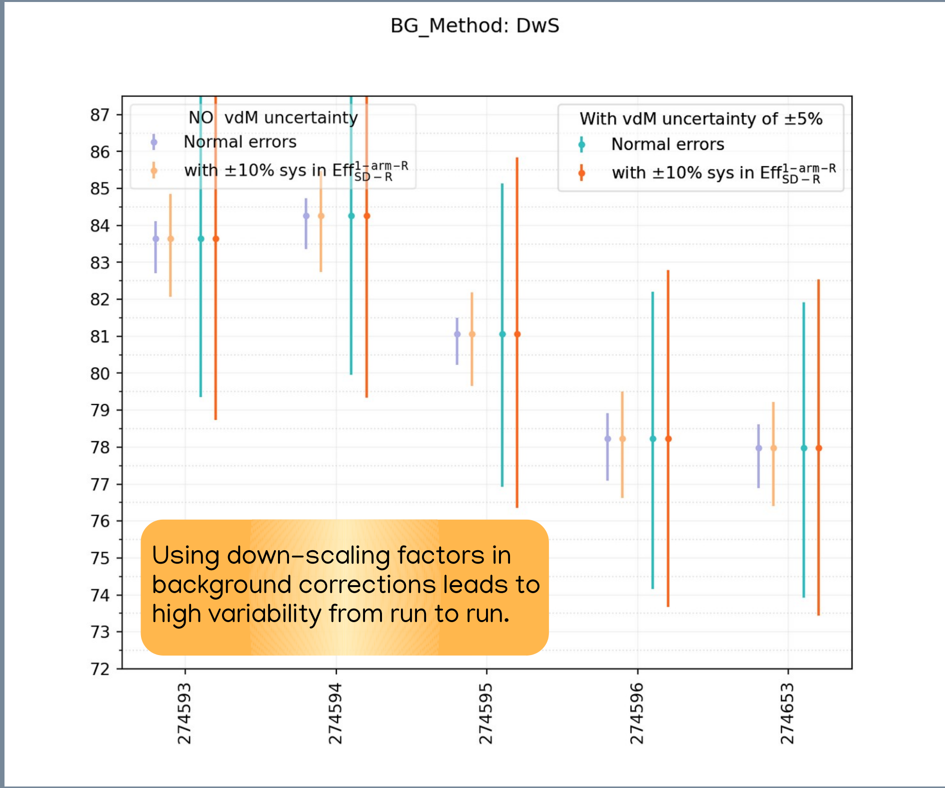
Effect of BG corrections on INEL cs

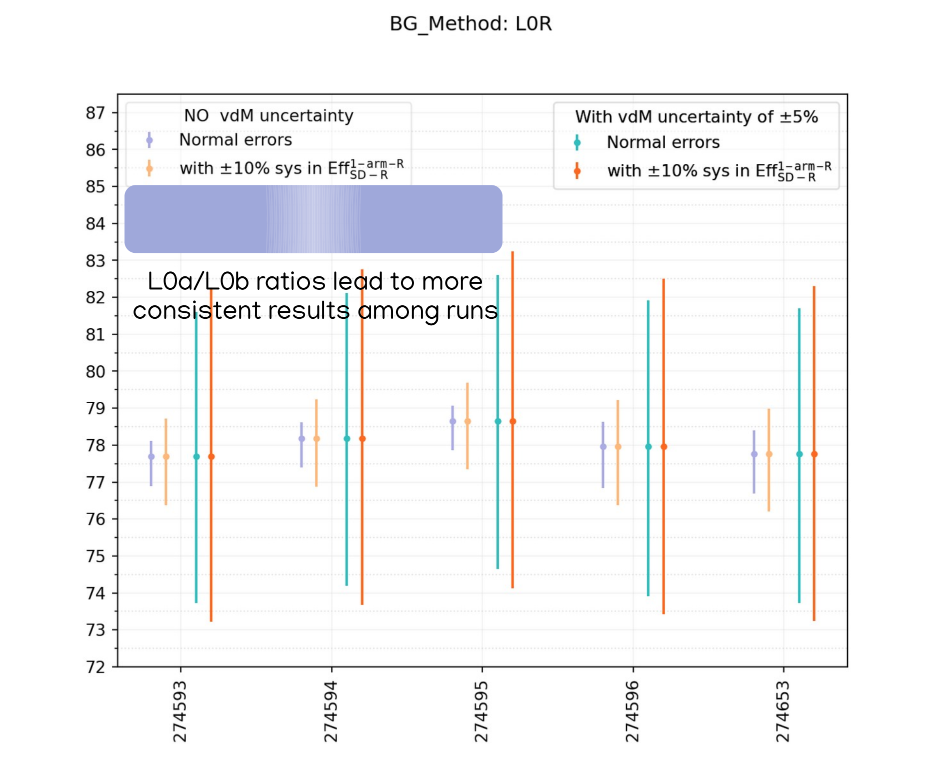




Errors were added linearly, causing small over estimation of systematic errors.

Effect of BG corrections on INEL cs

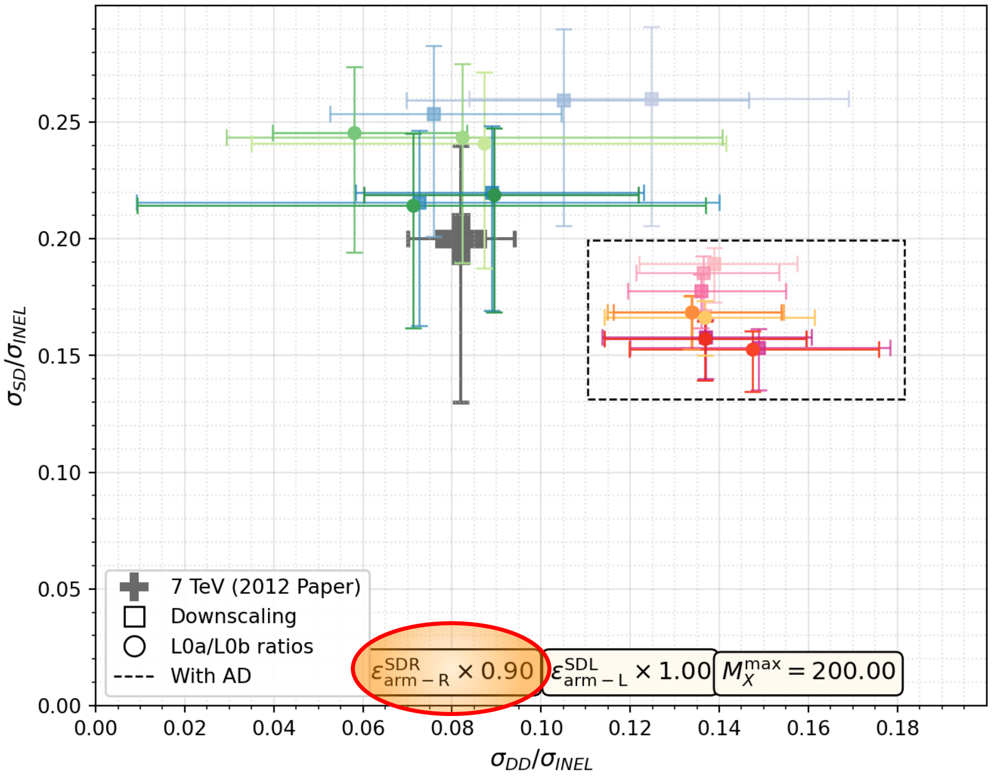




Now errors are added in “quadrature”. Small reduction in systematic errors.

Effect of efficiency variation on INEL cs

Change in CS due to variation of right arm efficiency (1-arm-R)



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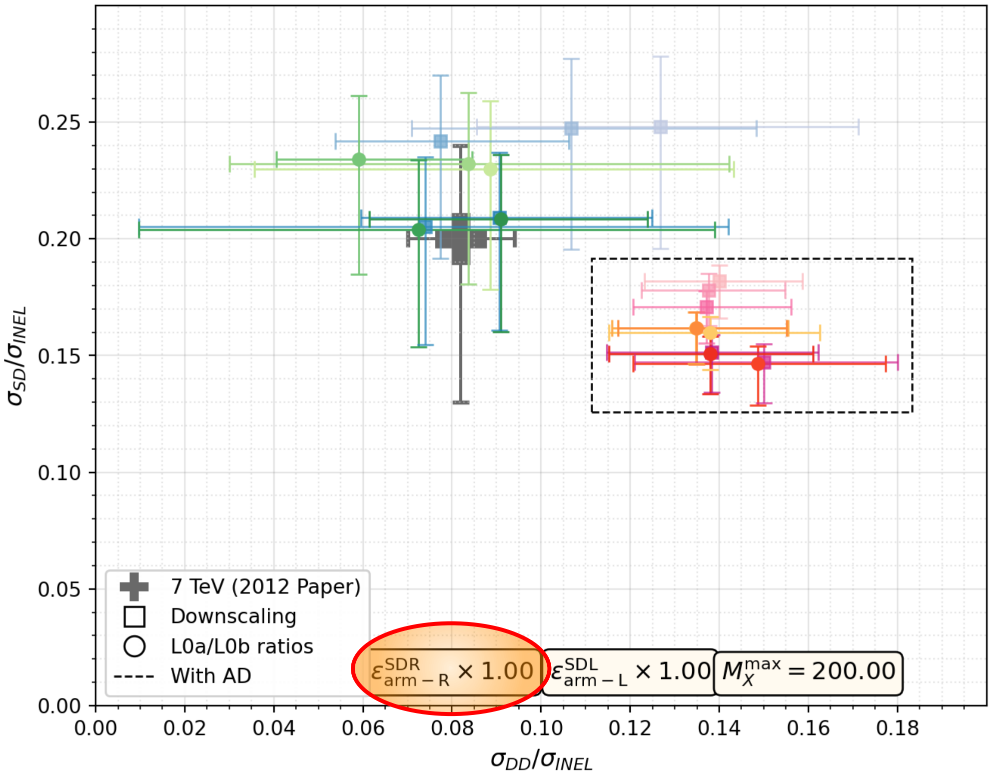

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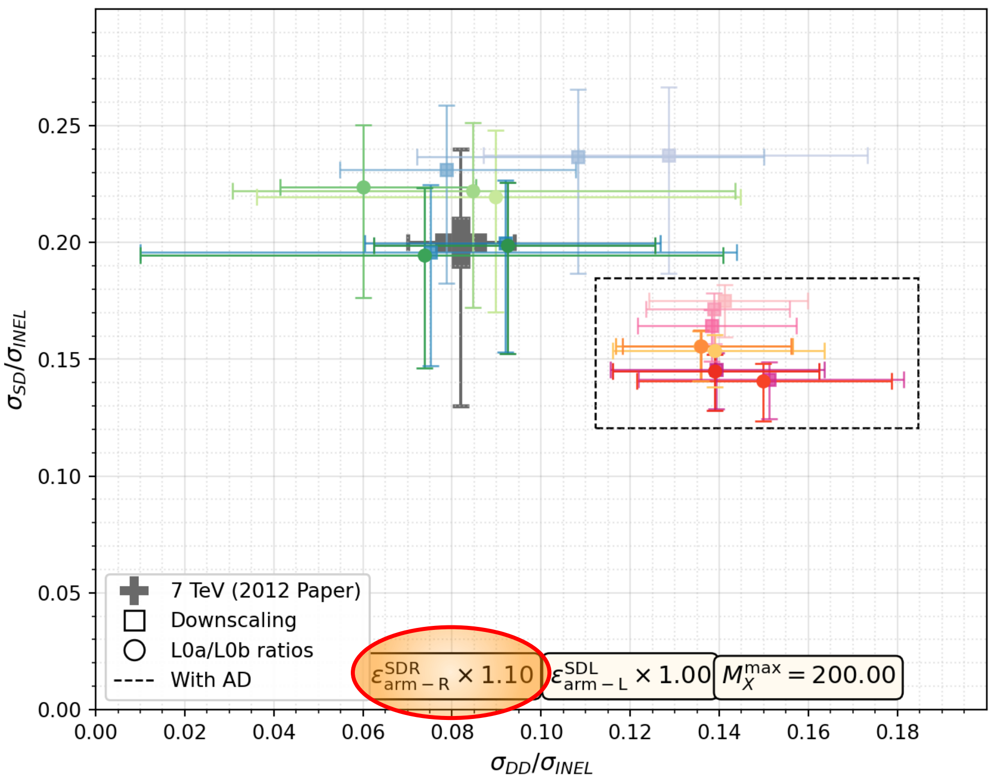
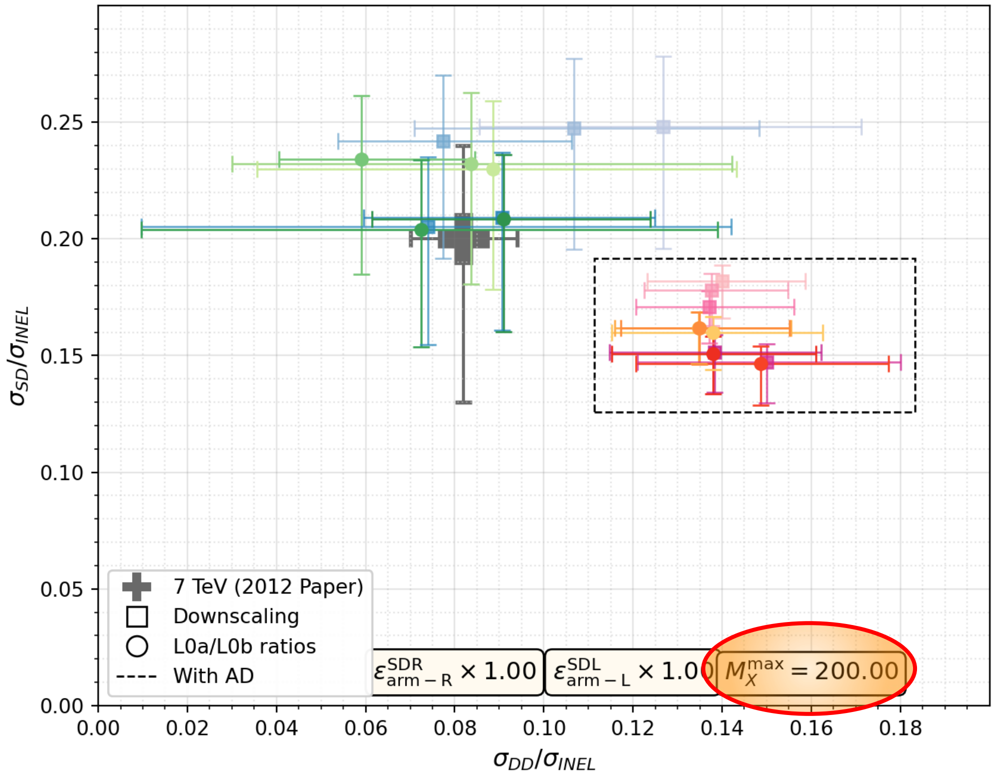


Effect of SD mass limit on INEL cs



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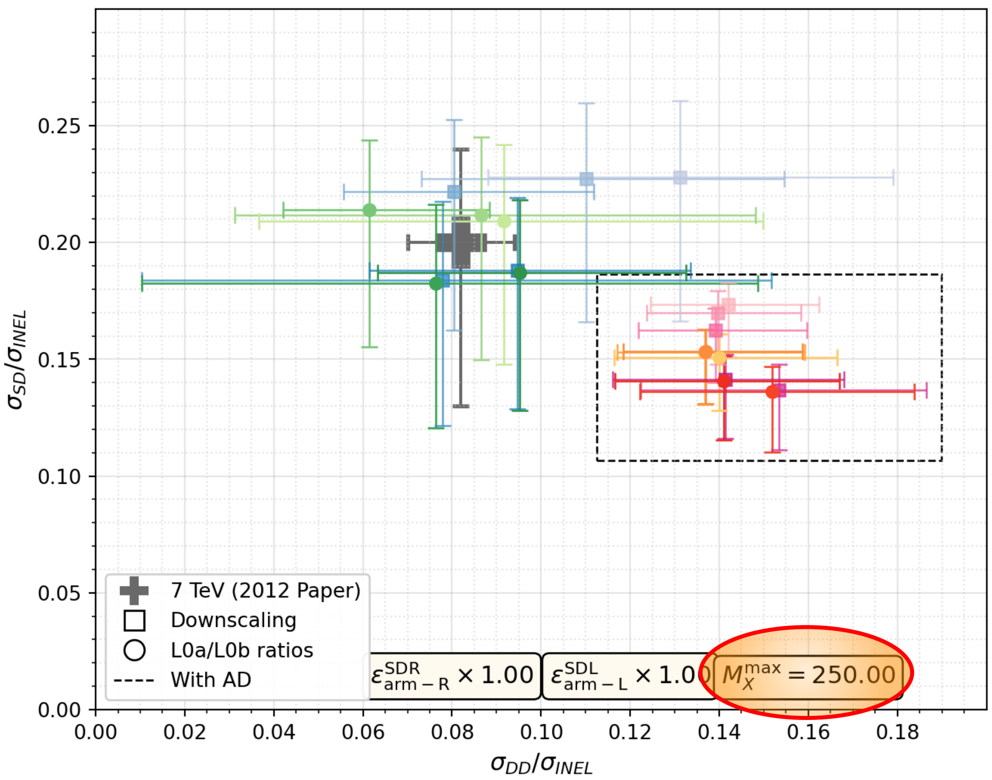

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