PWG-UD Diffraction

Diffractive and inelastic proton–proton cross sections measurement at 13 TeV

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The pomeron trajectory

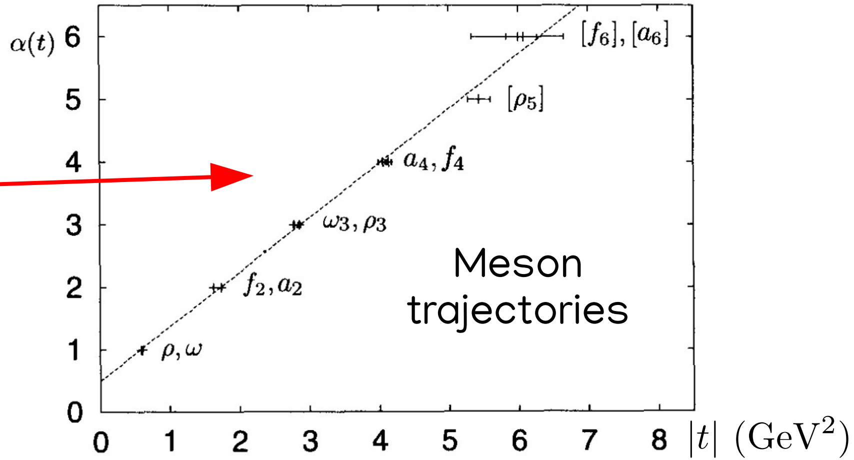
- Hadronic cross sections are a hard problem within QCD.
- But within the framework of Regge theory they are described by the exchange of trajectories.
- These trajectories, at low t values, can be approximated as linear functions of *t*.

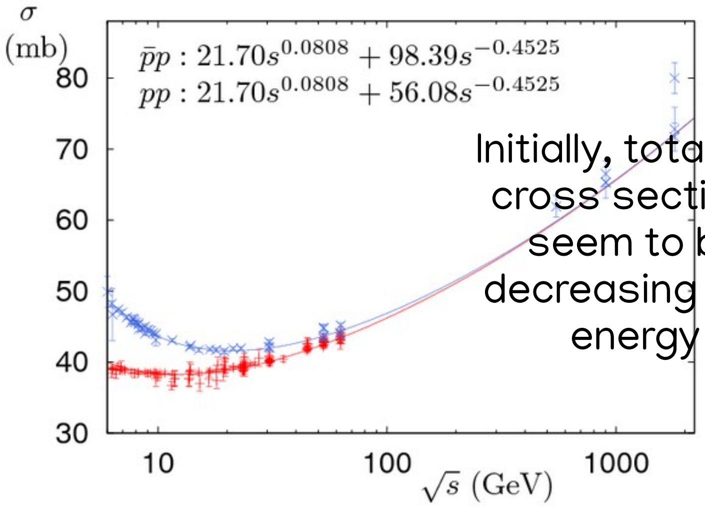
$$\alpha(t) = \alpha(0) + \alpha' t$$

- And their contribution to the total cross section is:

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

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



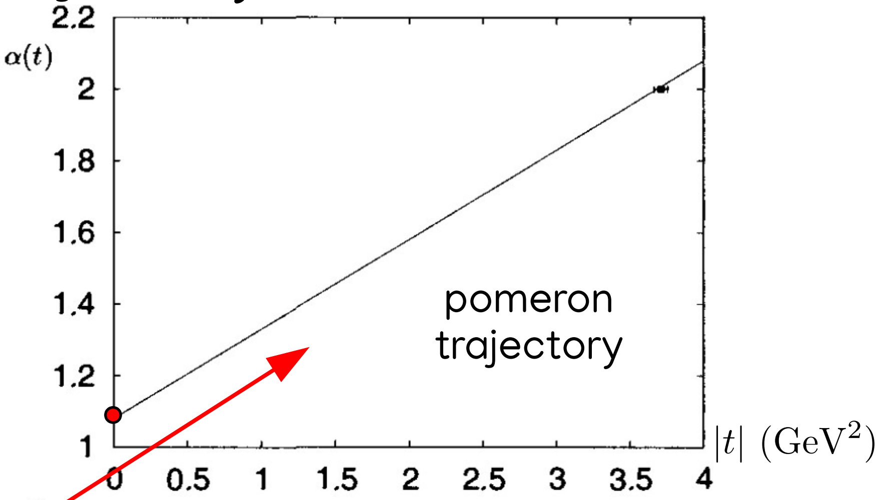


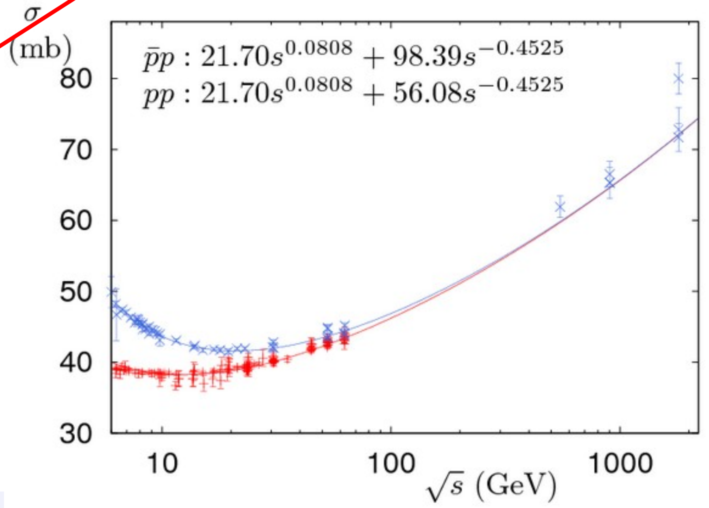
The pomeron trajectory

- Contribution of regge trajectories to the total cross section is:

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

- The explanation in term of Regge teory is a new trajectory with intercept greater than unity.
- This trajectory was named the **pomeron** after the Ukrainian Soviet physicist Isaak Pomeranchuk.



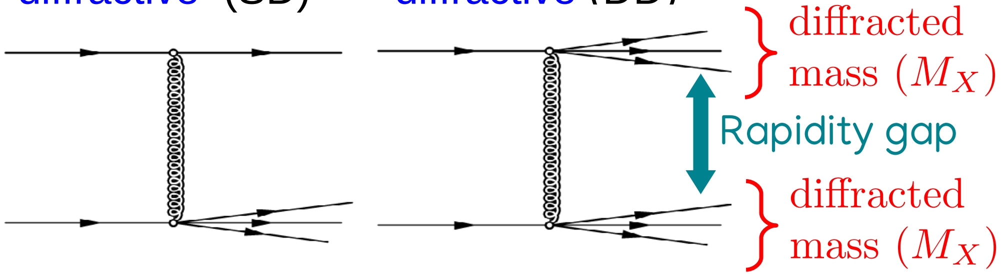


$$\sigma_{inel} = \sigma_{SD} + \sigma_{DD} + \sigma_{CD} + \sigma_{Non\text{-}Diff}$$

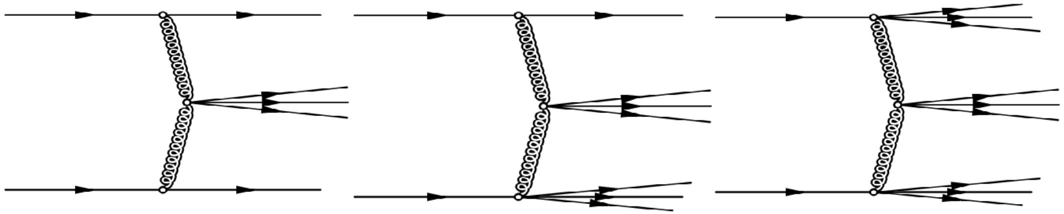
- Diffractive events, exchange of pomerons

Single diffractive (SD)

Double diffractive (DD)

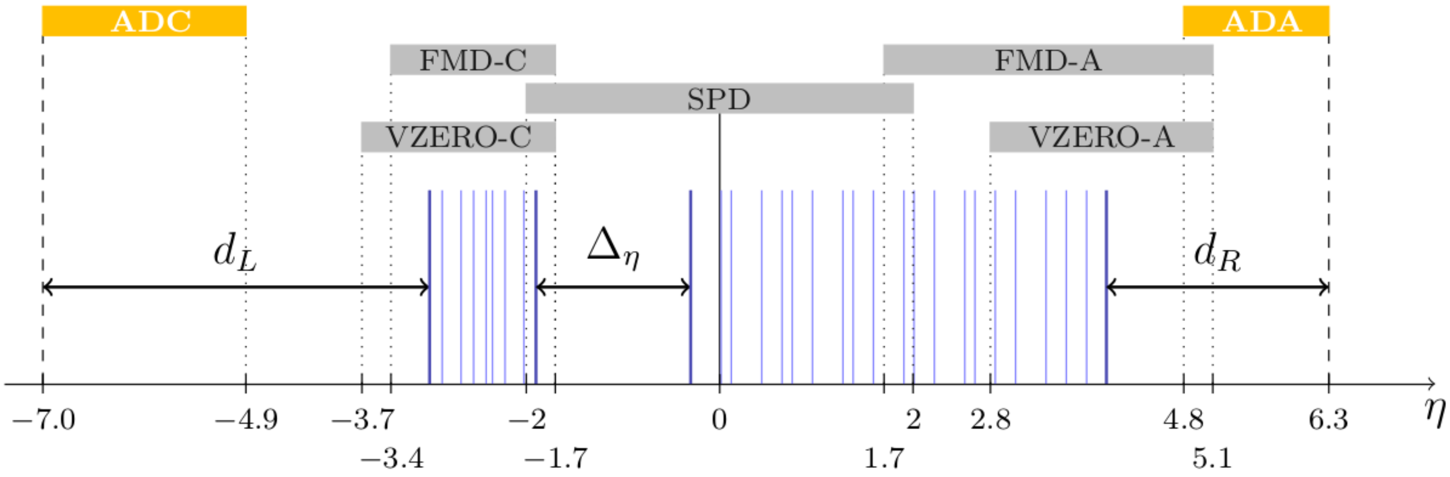


Central diffractive (CD)

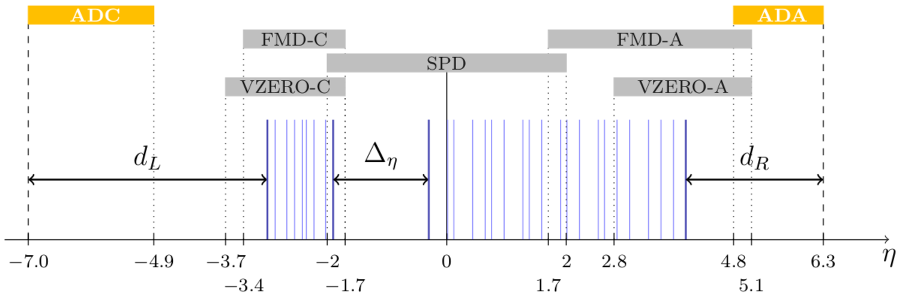


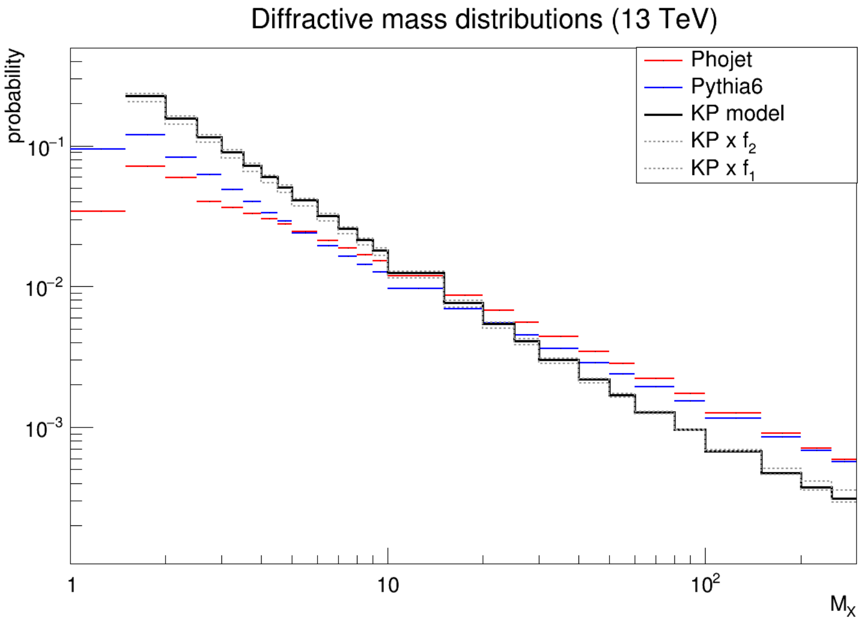
- Non diffractive events (ND).
  No gap, no pomeron exchange

ALICE pseudo-rapidity coverage

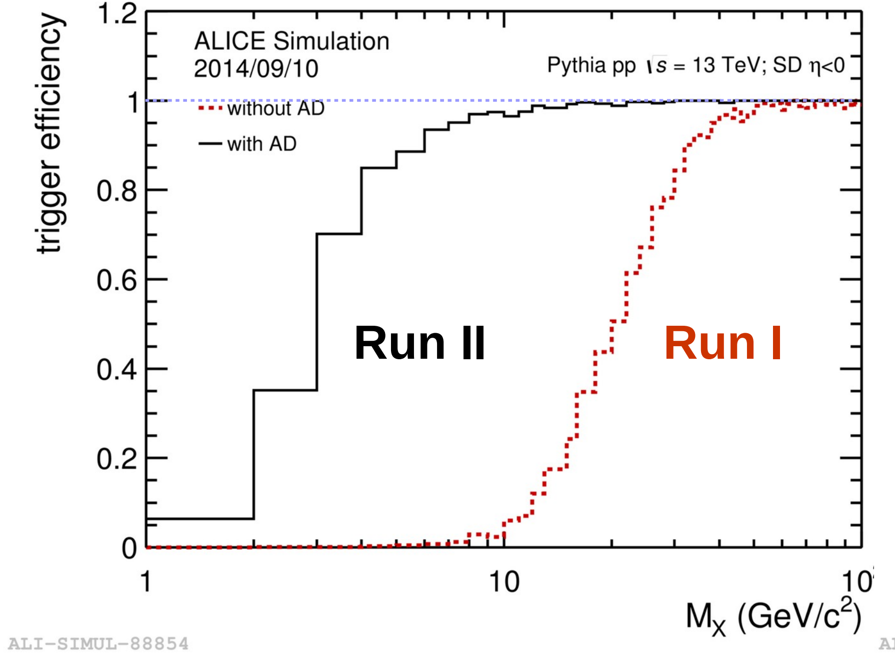


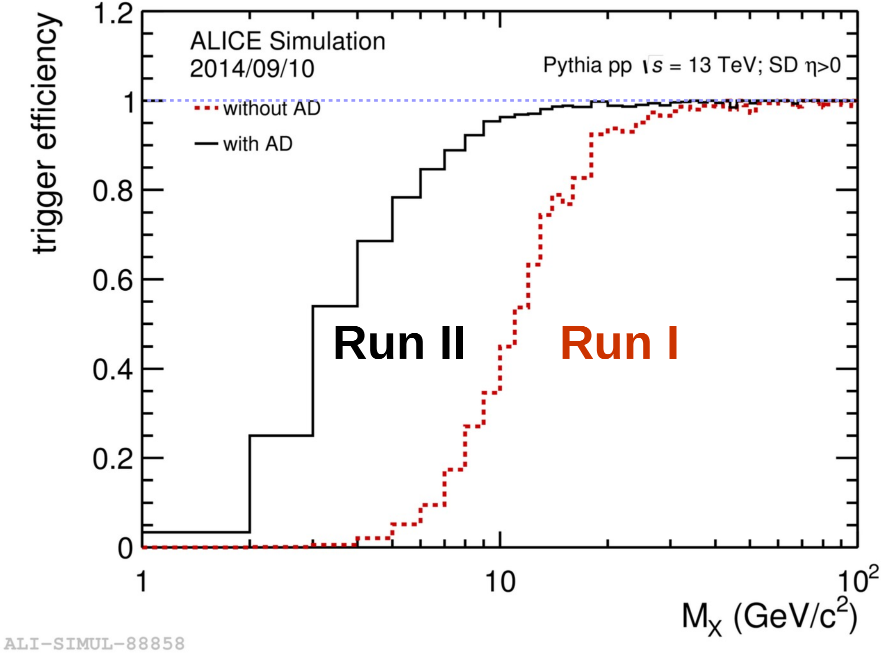
Single diffraction





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



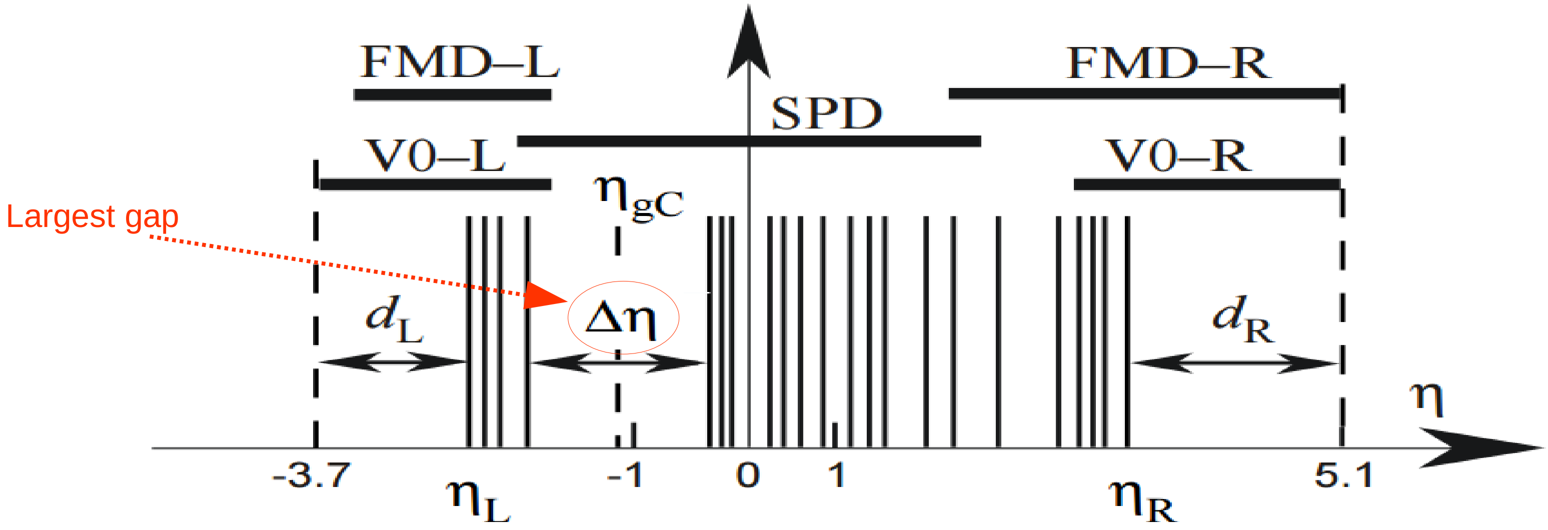


Event categories

There are 3 event categories:

1-arm-L → **SD-L** (left or $\eta<0$)
1-arm-R → **SD-R** (right or $\eta>0$)
2-arm → **ND** and **DD** events

DD: 2-Arm and $\Delta\eta>3$

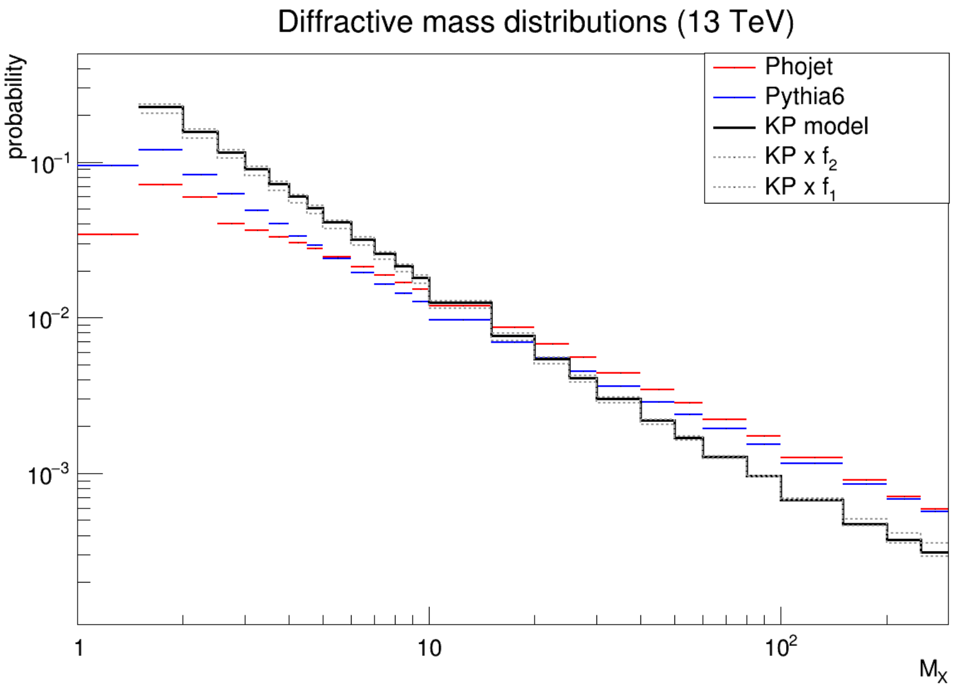


Simulation of single diffraction

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.



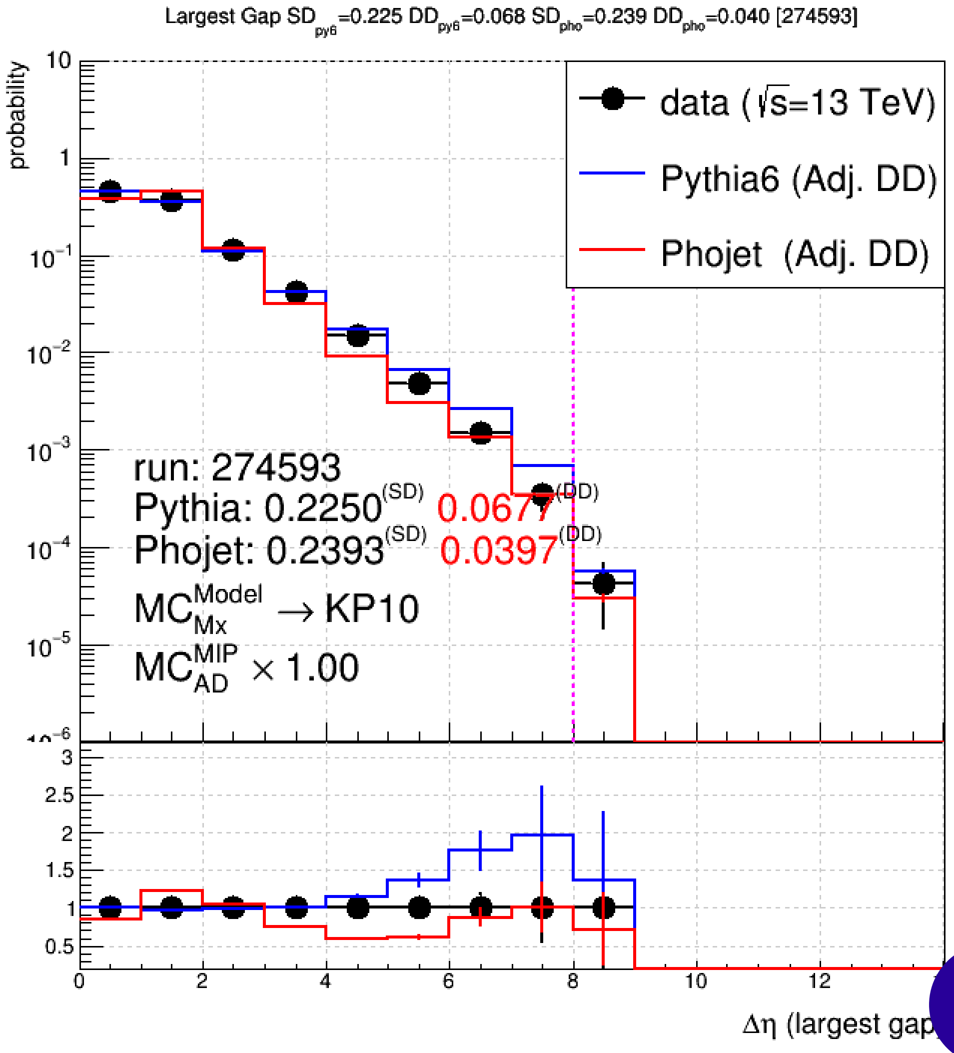
Example of double diffractive content adjustment (without AD)

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 excluded due to low data count



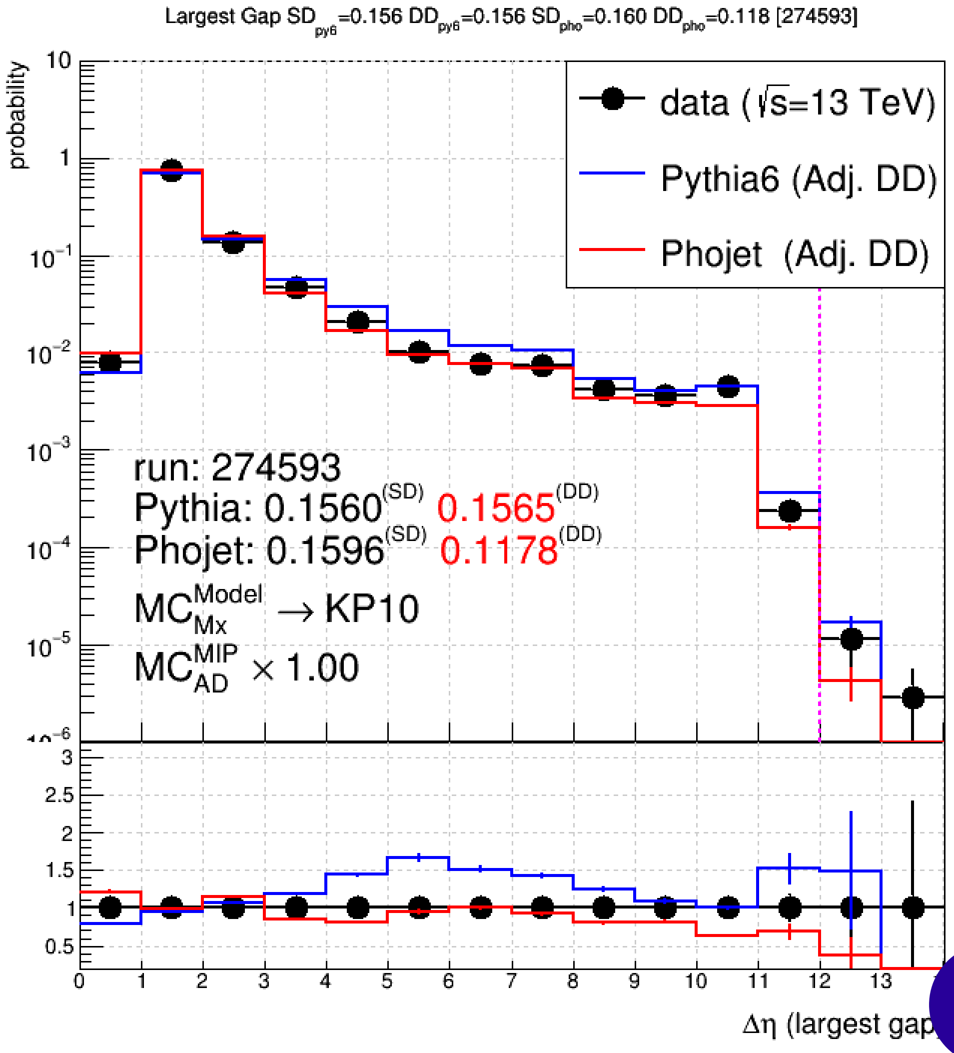
Example of double diffractive content adjustment (using AD)

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).

The last two bins are excluded due to large data uncertainty



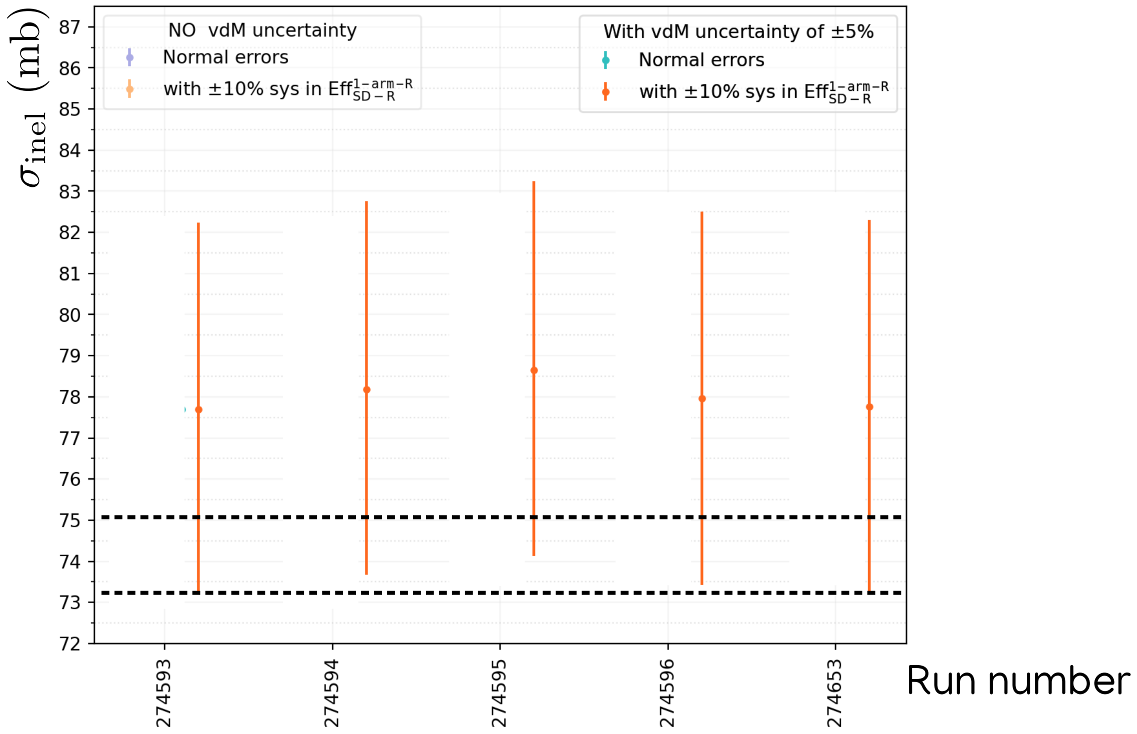
The visible cross sections of the $\sigma_{\text{arm-L}}$, $\sigma_{\text{arm-R}}$ and $\sigma_{\text{2-arm}}$ event classes are a linear combination of the physical cross sections and the trigger efficiencies: σ_{SDL}, σ_{SDR}, σ_{DD}, σ_{CD} and σ_{ND}.

$$\underbrace{\begin{pmatrix} \sigma_{\text{arm-L}} \\ \sigma_{\text{arm-R}} \\ \sigma_{\text{2-arm}} \end{pmatrix}}_{\text{observable cross sections}} = \underbrace{\begin{pmatrix} \epsilon^{\text{SDL}}_{\text{arm-L}} & \epsilon^{\text{SDR}}_{\text{arm-L}} & \epsilon^{\text{DD}}_{\text{arm-L}} & \epsilon^{\text{CD}}_{\text{arm-L}} & \epsilon^{\text{ND}}_{\text{arm-L}} \\ \epsilon^{\text{SDL}}_{\text{arm-R}} & \epsilon^{\text{SDR}}_{\text{arm-R}} & \epsilon^{\text{DD}}_{\text{arm-R}} & \epsilon^{\text{CD}}_{\text{arm-R}} & \epsilon^{\text{ND}}_{\text{arm-R}} \\ \epsilon^{\text{SDL}}_{\text{2-arm}} & \epsilon^{\text{SDR}}_{\text{2-arm}} & \epsilon^{\text{DD}}_{\text{2-arm}} & \epsilon^{\text{CD}}_{\text{2-arm}} & \epsilon^{\text{ND}}_{\text{2-arm}} \end{pmatrix}}_{\text{detector and trigger efficiency}} \underbrace{\begin{pmatrix} \sigma_{\text{SDL}} \\ \sigma_{\text{SDR}} \\ \sigma_{\text{DD}} \\ \sigma_{\text{CD}} \\ \sigma_{\text{ND}} \end{pmatrix}}_{\text{physical cross sections}}$$

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

$$\sigma_{\text{INEL}} = \underbrace{\frac{\sigma_{\text{INEL}}}{\sigma_{\text{MB-OR}}}}_{\text{from MC}} \times \underbrace{\frac{\sigma_{\text{MB-OR}}}{\sigma_{\text{ref trigger}}}}_{\text{2017's data}} \times \underbrace{\sigma_{\text{ref trigger}}}_{\text{2015's vdM scan}}$$

Results



σ_{inel} (mb)
NO vdM uncertainty
Normal errors
with ±10% sys in $\mathrm{Eff}^{\mathrm{1-arm-R}}_{\mathrm{SD-R}}$
With vdM uncertainty of ±5%
Normal errors
with ±10% sys in $\mathrm{Eff}^{\mathrm{1-arm-R}}_{\mathrm{SD-R}}$
87
86
85
84
83
82
81
80
79
78
77
76
75
74
73
72
274593
274594
274595
274596
274653
Run number

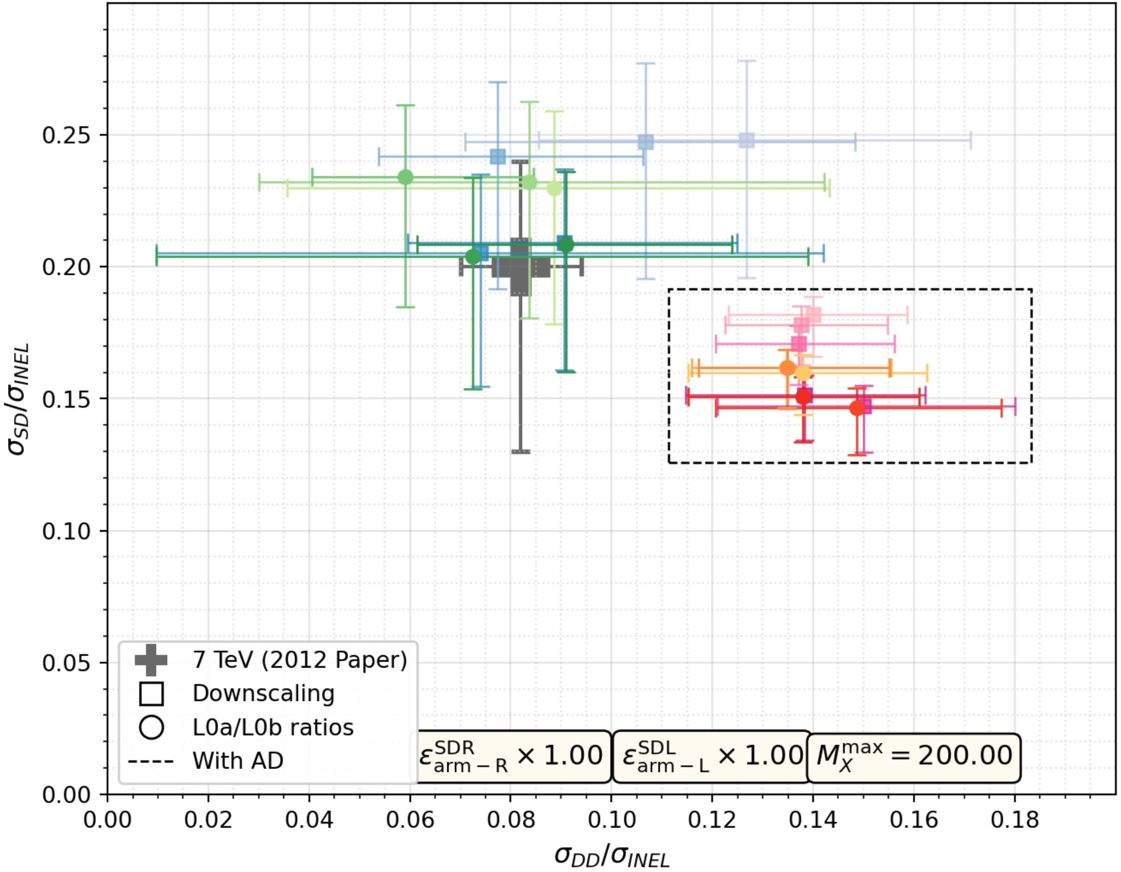
Summary and outlook

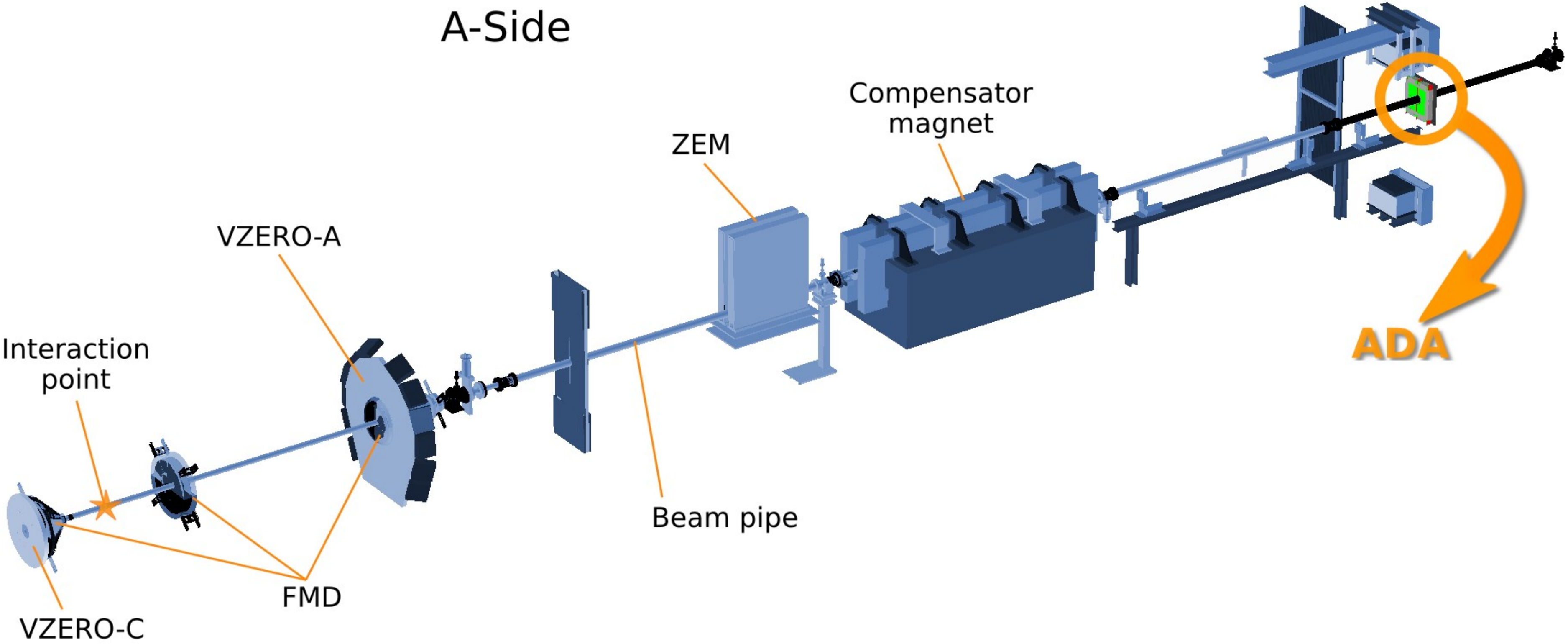
- Inelastic and diffractive measurement are well advenced.
- Pile-up corrections are negligible due to low mu values.
- Things to be considered:
  - Donnachie-Landshoff model was not included.
  - Pythia8

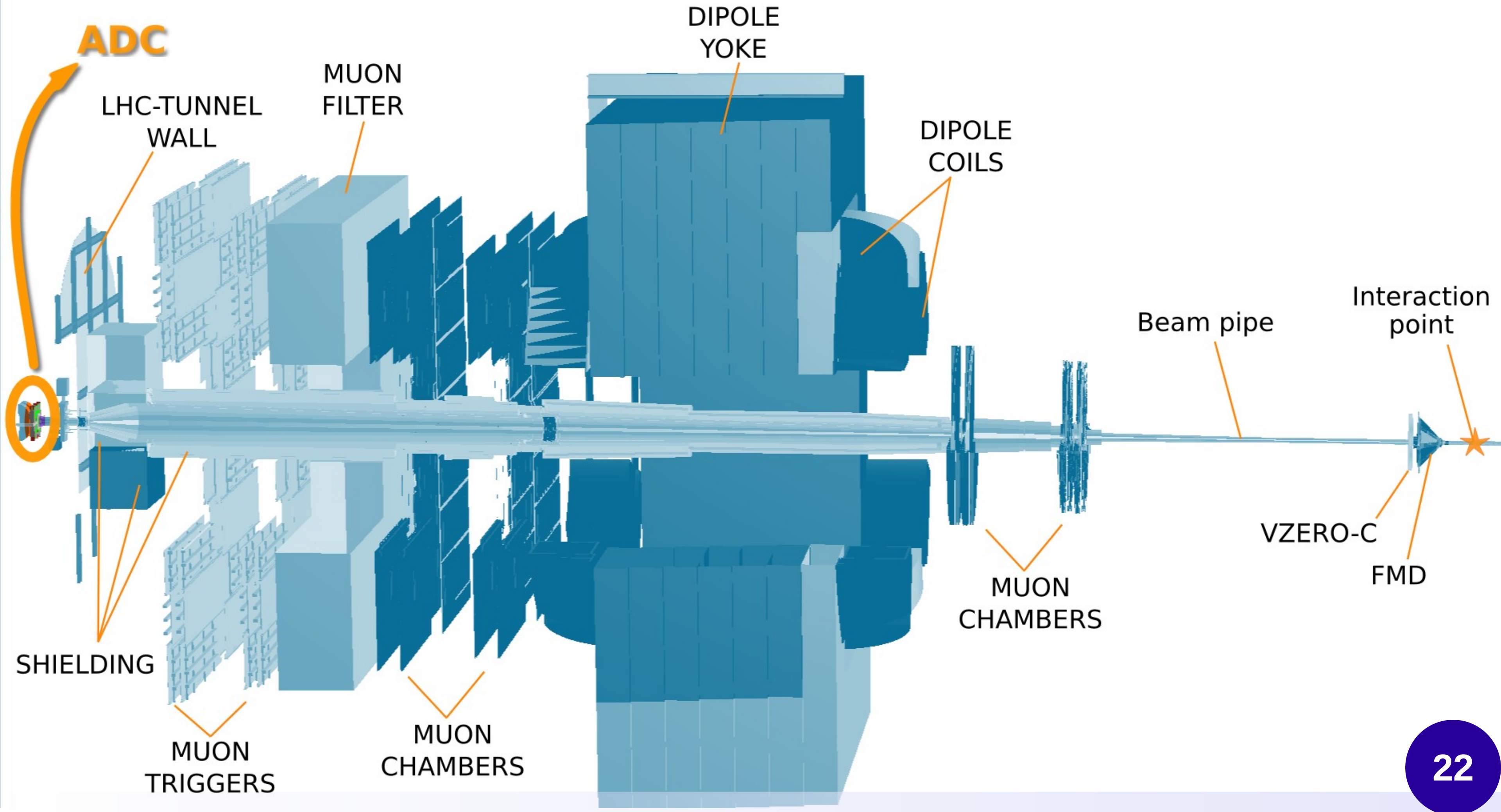
Back-up slides

Results

SD vs DD




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


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

Classification procedure

There are 3 event categories:

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

DD: 2-Arm and Δη>3
```

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

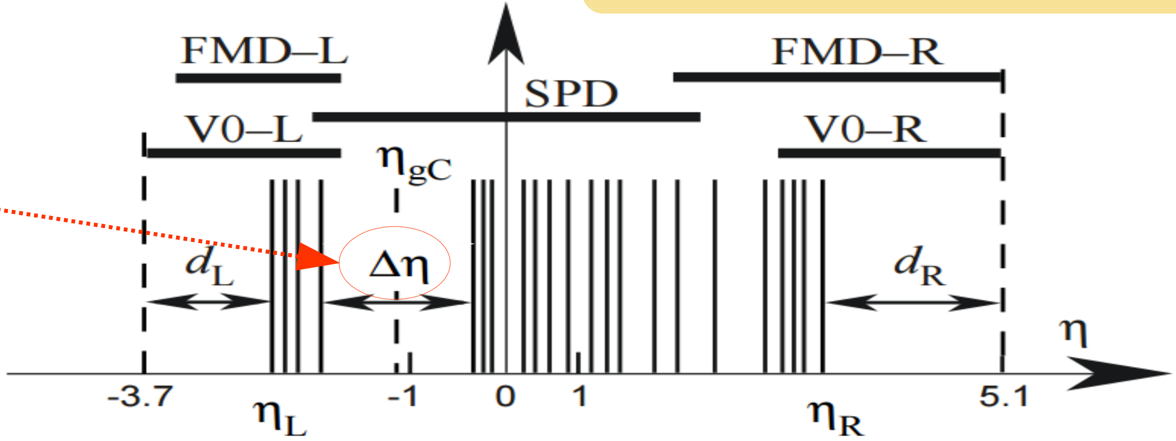
For them we use:

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

If $\eta_C < 0$: → 1-arm-L

If $\eta_C > 0$: → 1-arm-R

Largest gap



Classification procedure

There are 3 event categories:

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

DD: 2-Arm and Δη>3
```

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

If $\Delta\eta$ is larger than d_R and d_L → 2-arm

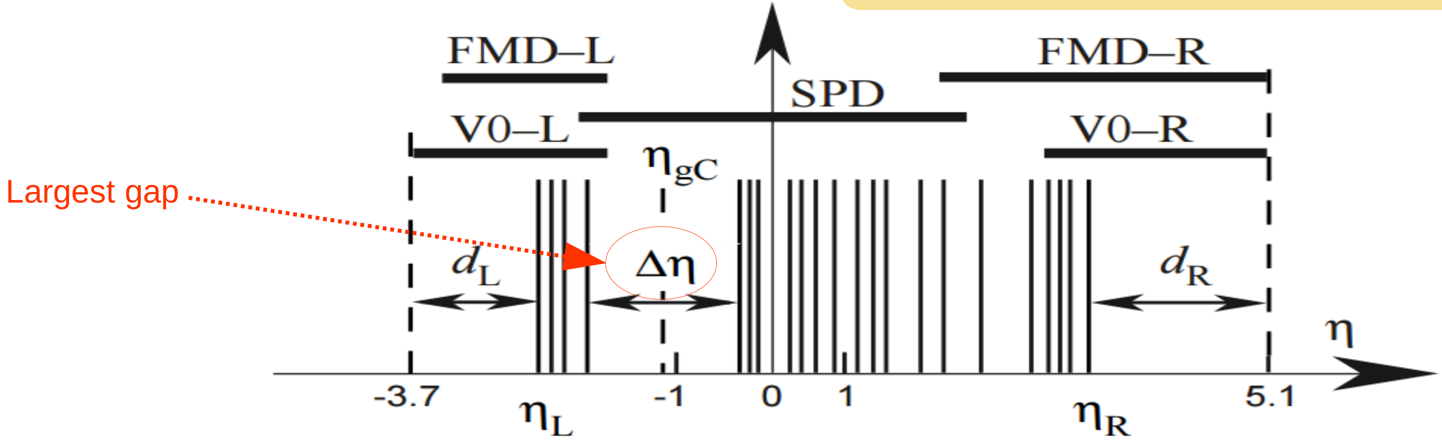
If $-1<\eta<1$ → 2-arm

else,

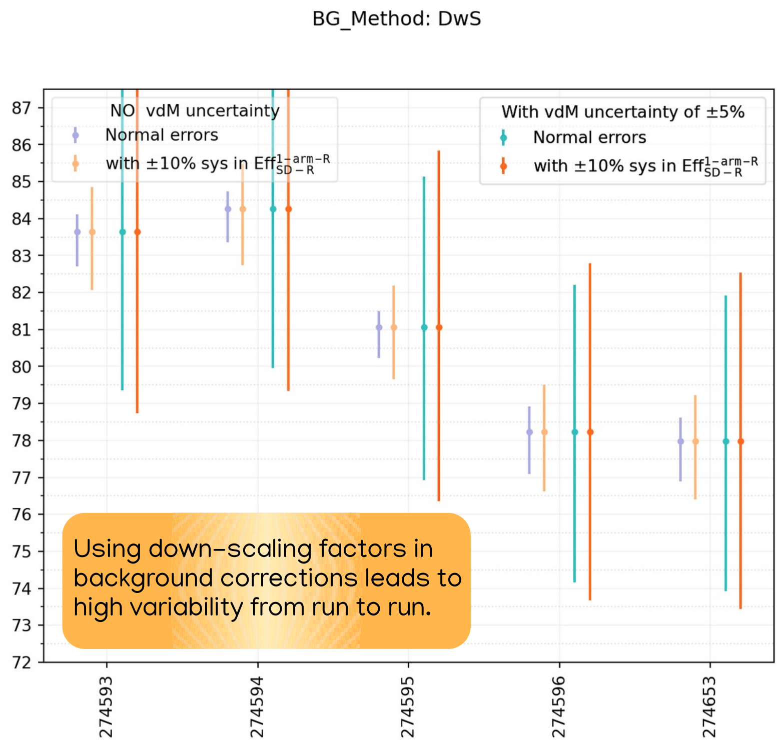
If $\eta_R<1$ → 1-arm-L

If $\eta_L>-1$ → 1-arm-R

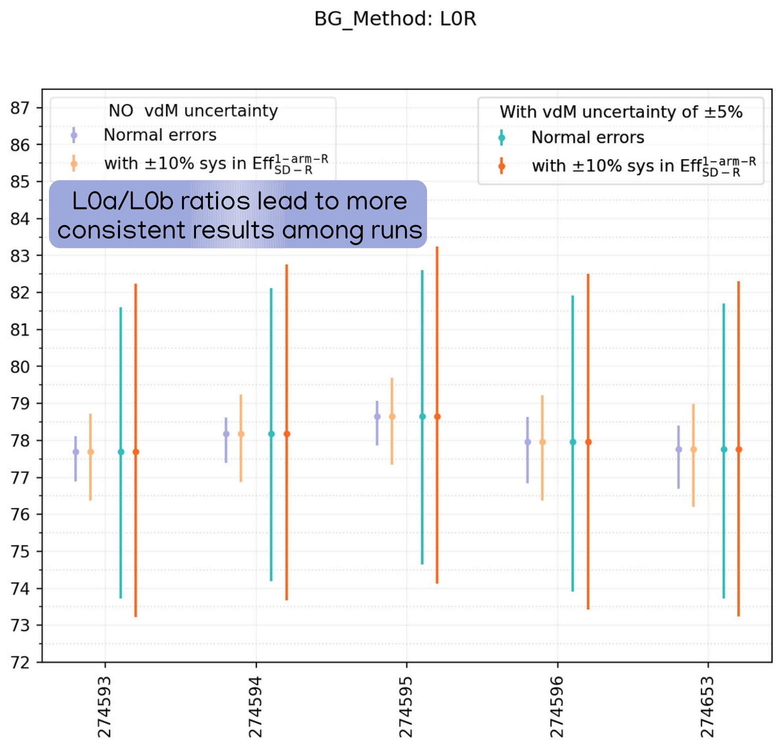
Any remaining events → 2-arm



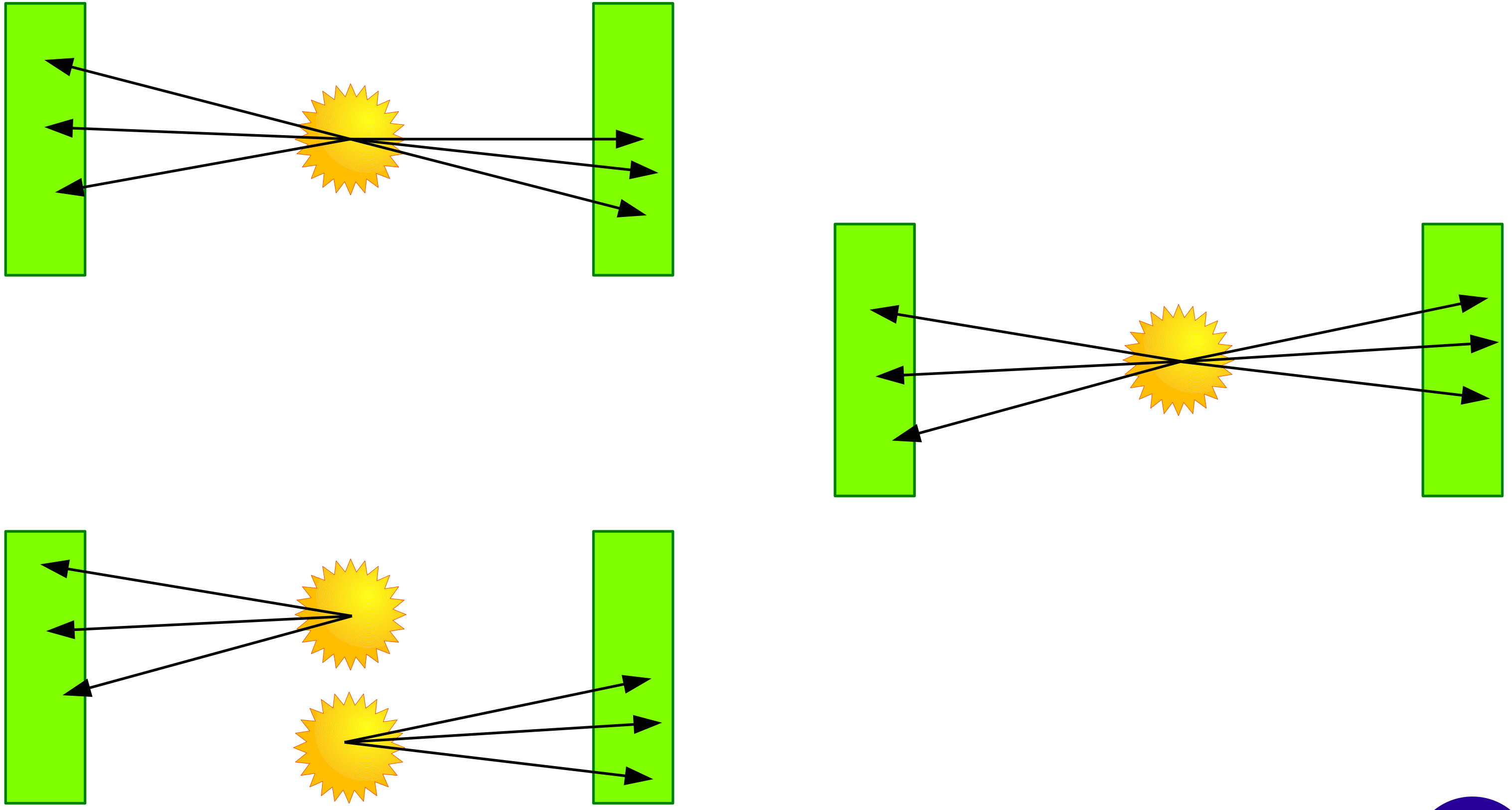
Results



BG_Method: DwS
NO vdM uncertainty
Normal errors
with ±10% sys in $Eff^{1-arm-R}_{SD-R}$
With vdM uncertainty of ±5%
Normal errors
with ±10% sys in $Eff^{1-arm-R}_{SD-R}$
Using down-scaling factors in background corrections leads to high variability from run to run.
274593
274594
274595
274596
274653



BG_Method: L0R
NO vdM uncertainty
Normal errors
with ±10% sys in $Eff^{1-arm-R}_{SD-R}$
With vdM uncertainty of ±5%
Normal errors
with ±10% sys in $Eff^{1-arm-R}_{SD-R}$
L0a/L0b ratios lead to more consistent results among runs
274593
274594
274595
274596
274653



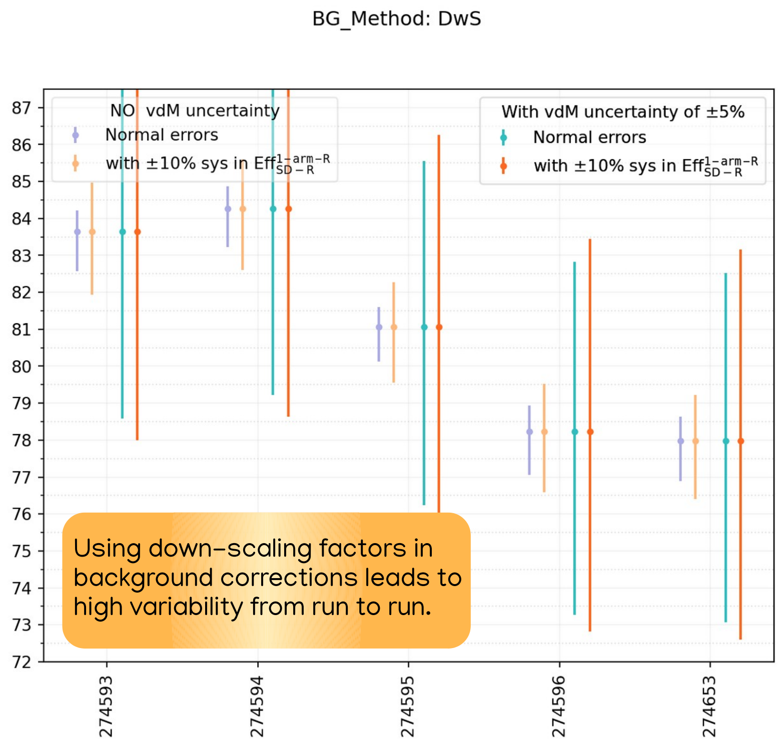
$$\epsilon^{\mathrm{NSD}}_{\text{arm-L}} = \frac{\left(f_{\mathrm{DD}}\epsilon^{\mathrm{DD}}_{\text{arm-L}} + f_{\mathrm{CD}}\epsilon^{\mathrm{CD}}_{\text{arm-L}} + f_{\mathrm{ND}}\epsilon^{\mathrm{ND}}_{\text{arm-L}}\right)}{f_{\mathrm{DD}} + f_{\mathrm{CD}} + f_{\mathrm{ND}}}$$

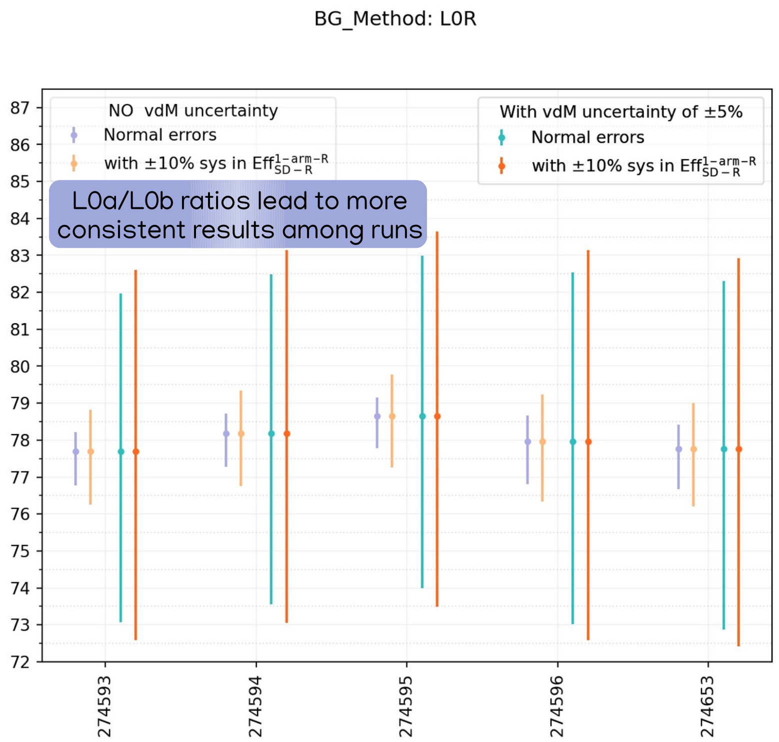
$$\epsilon^{\mathrm{NSD}}_{\text{arm-R}} = \frac{\left(f_{\mathrm{DD}}\epsilon^{\mathrm{DD}}_{\text{arm-R}} + f_{\mathrm{CD}}\epsilon^{\mathrm{CD}}_{\text{arm-R}} + f_{\mathrm{ND}}\epsilon^{\mathrm{ND}}_{\text{arm-R}}\right)}{f_{\mathrm{DD}} + f_{\mathrm{CD}} + f_{\mathrm{ND}}}$$

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

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

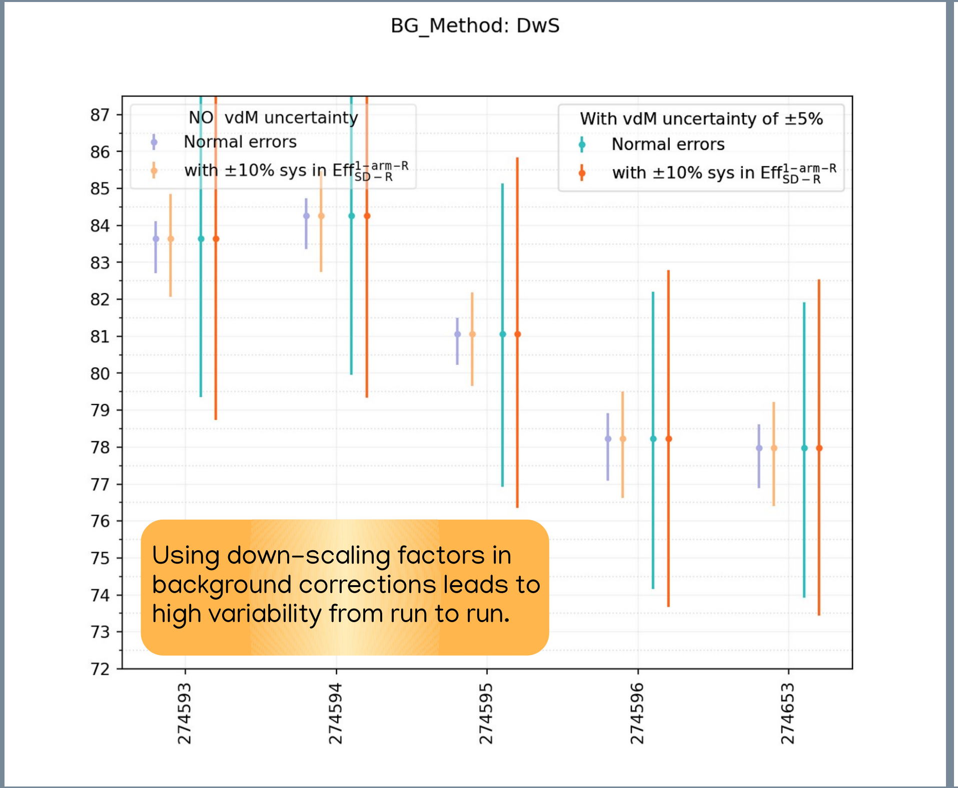
Effect of BG corrections on INEL cs

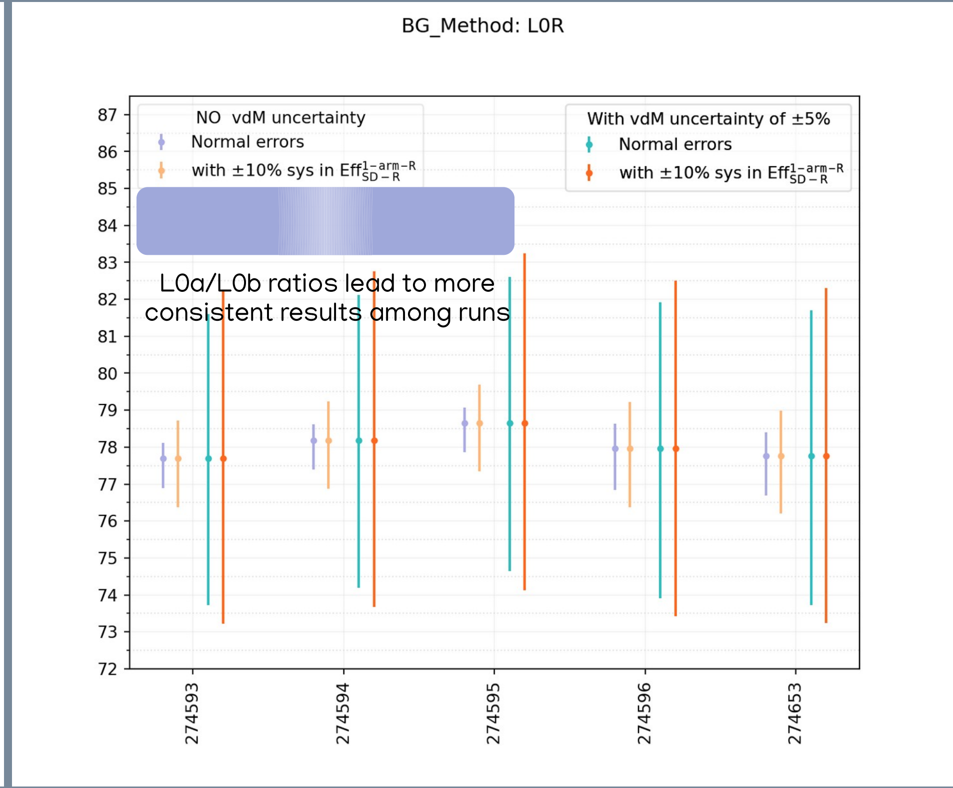




Errors were added linearly, causing small over estimation of systematic errors.

Effect of BG corrections on INEL cs

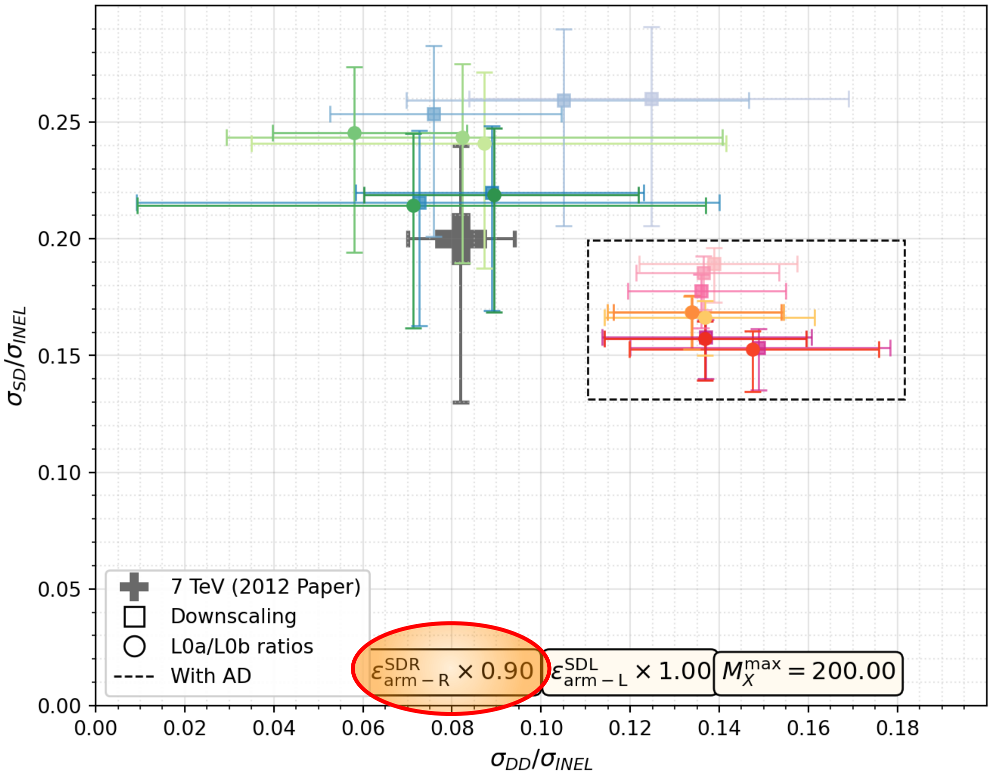




Now errors are added in “quadrature”. Small reduction in systematic errors.

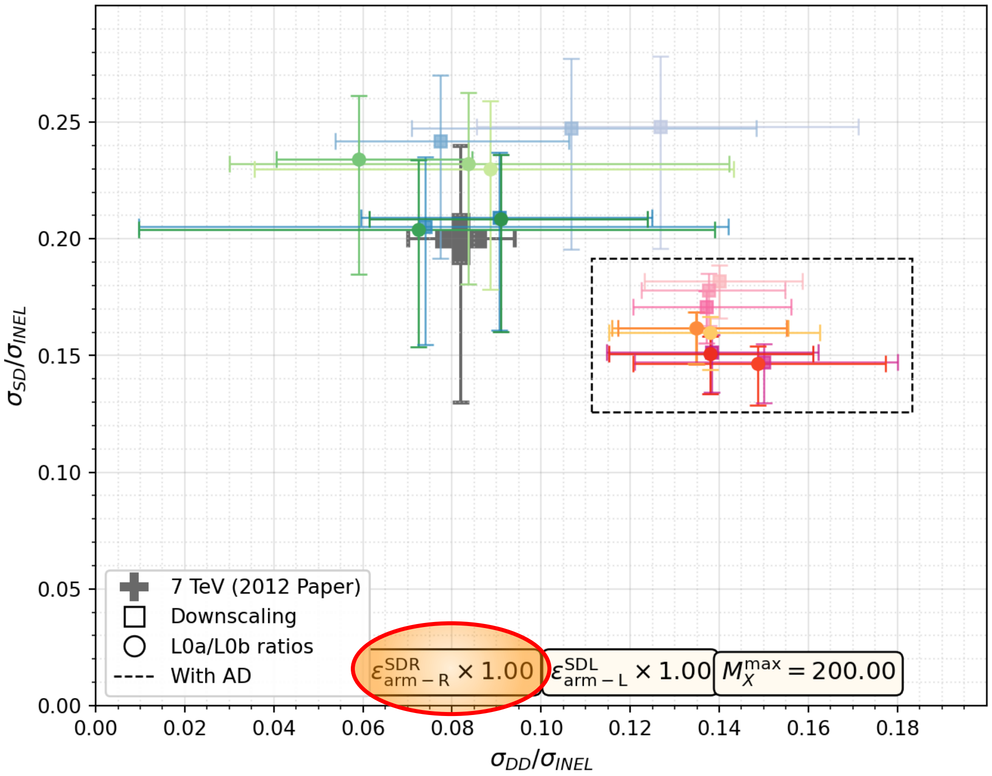
Effect of efficiency variation on INEL cs

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



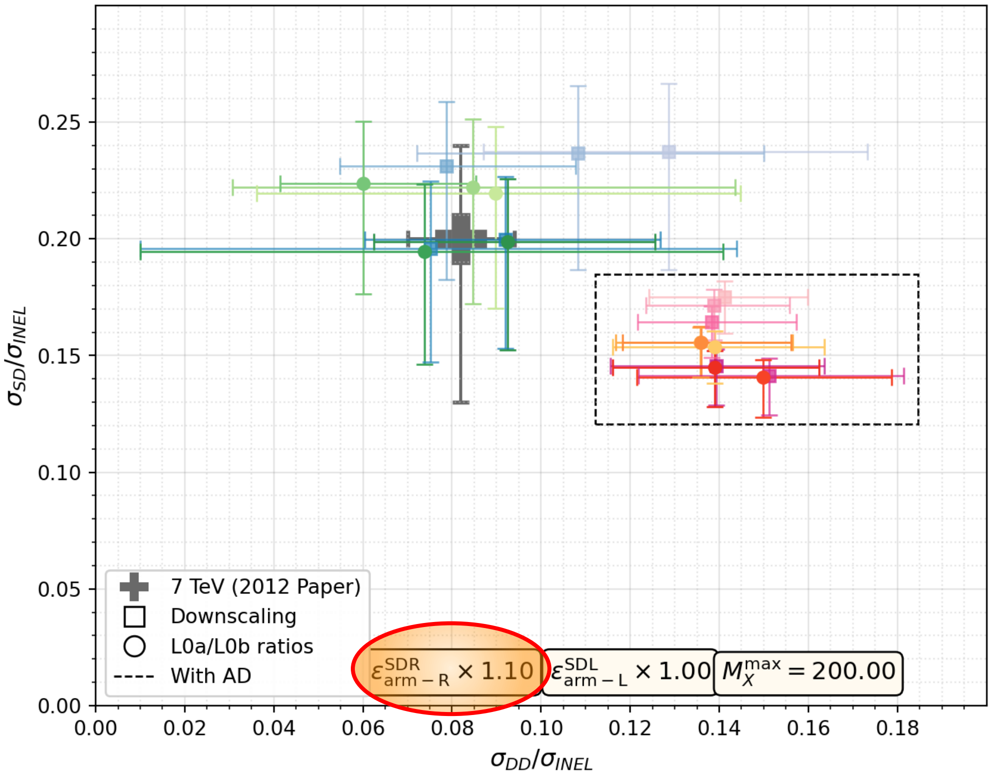
Effect of efficiency variation on INEL cs

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

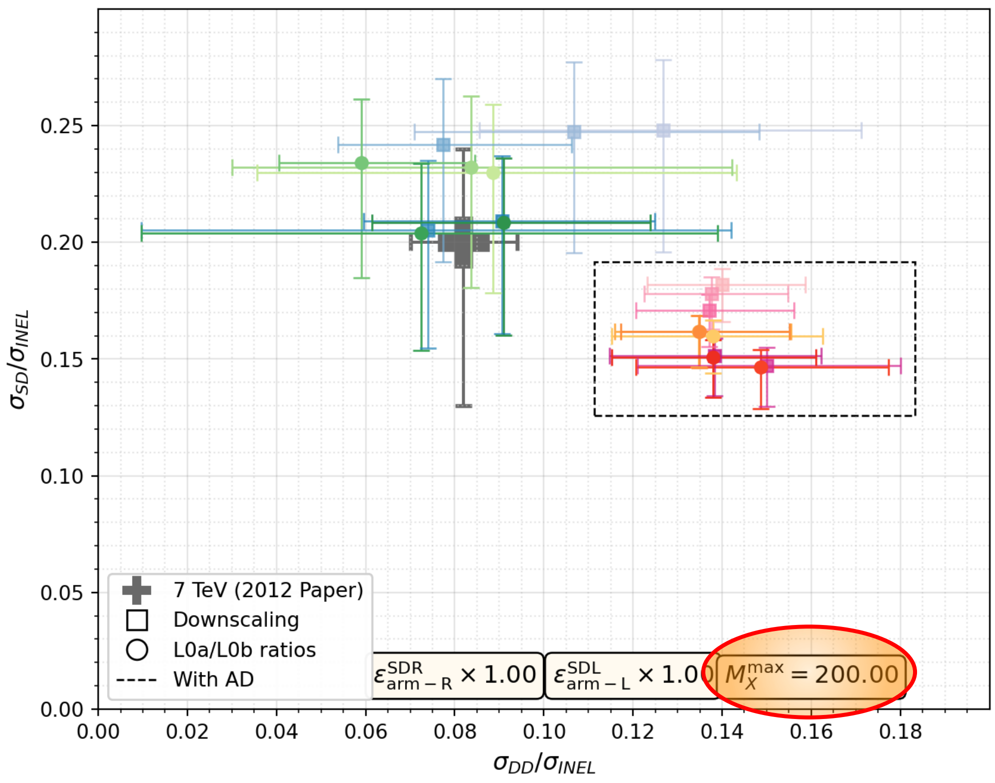


Effect of efficiency variation on INEL cs

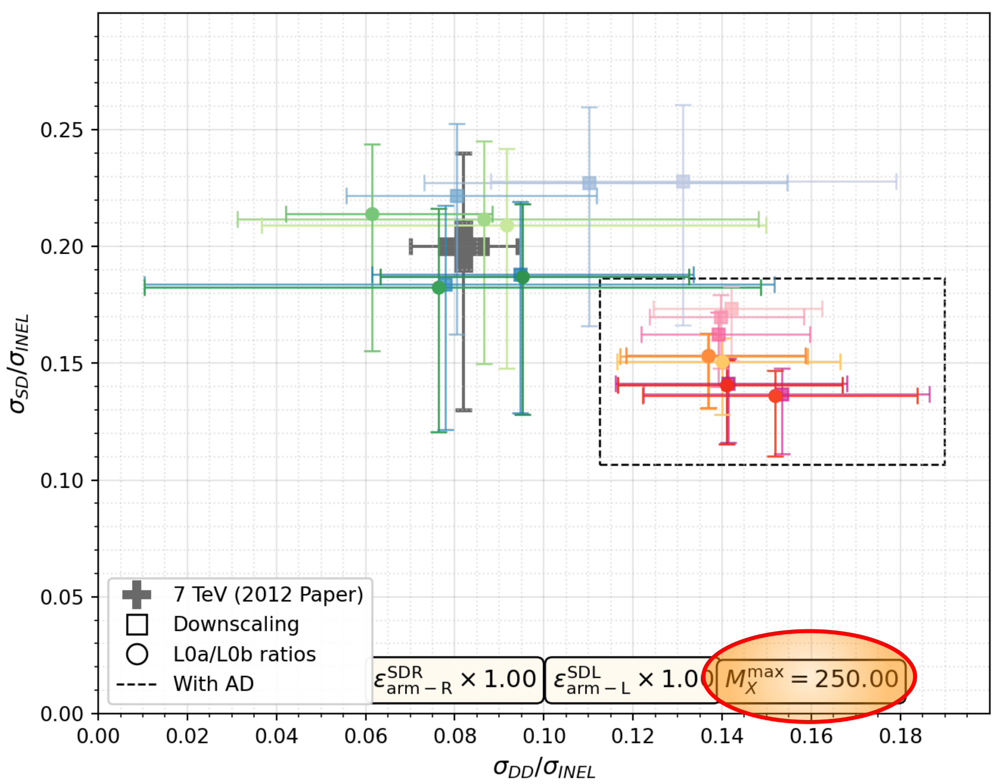
Change in CS due to variation of right arm efficiency (1-arm-R)



Effect of SD mass limit on INEL cs



Effect of SD mass limit on INEL cs



Effect of SD mass limit on INEL cs