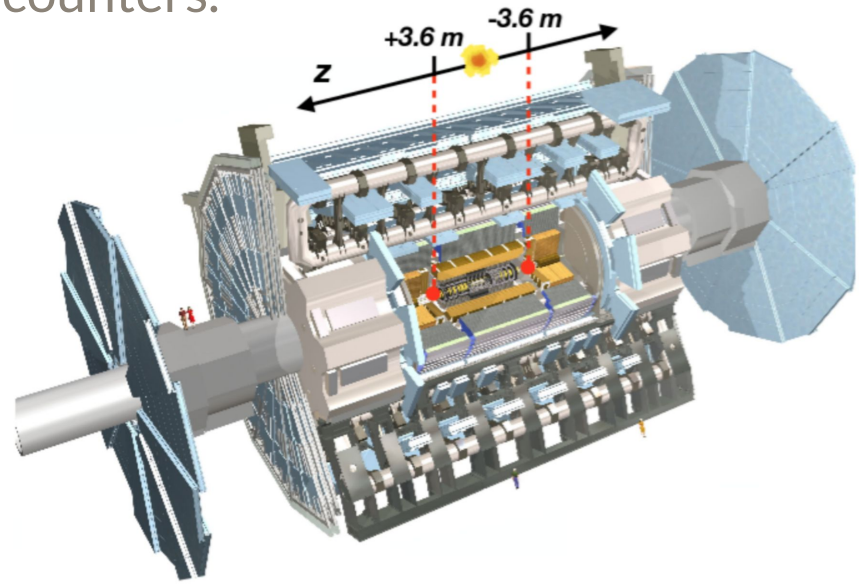
INELASTIC CROSS SECTION

Measurement of the inelastic cross section
using the MBTS detector in the ATLAS experiment at 13 TeV.

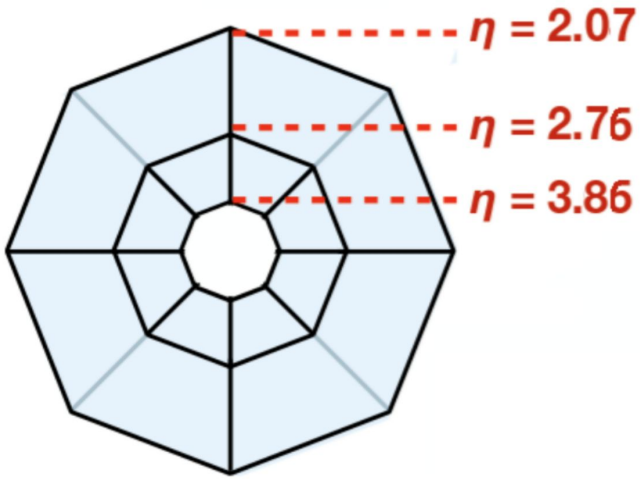
MBTS DETECTOR GEOMETRY AND ACCEPTANCE

Completely replaced for Run 2: Scintillating disk with 12 individual counters.



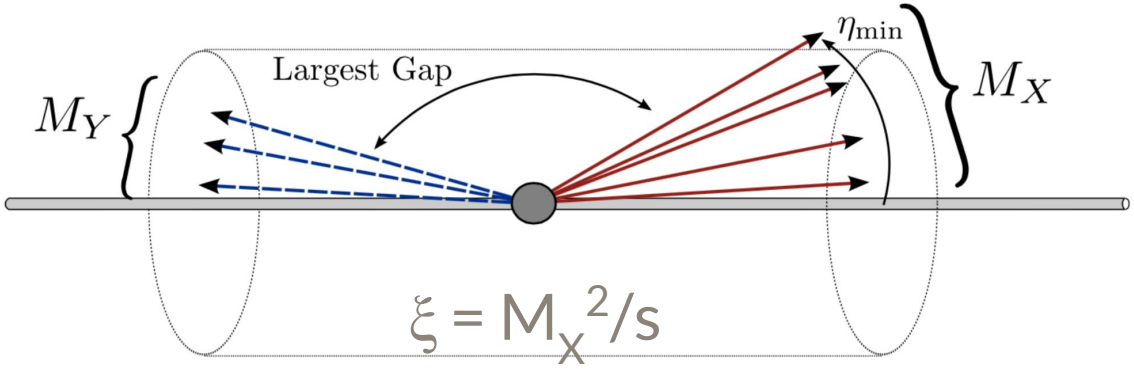
- Acceptance for $2.07 < |\eta| < 3.86$
  - Outer layer overlaps with the inner detector
  - Both layers overlap with the calorimeter

- Placed on both sides of the detector (A and C)



MBTS ACCEPTANCE DEFINITION OF ξ

Fiducial region defined by the MBTS acceptance.



- M_X and M_Y: Invariant mass of dissociated protons, $M_X > M_Y$
- ξ is closely correlated with largest η of dissociated system
  - Choose ξ to be where MBTS becomes 50% efficient
  - $\xi = 1\text{x}10^{-6}$ corresponds to $|\eta| \lesssim 3.86$

This measurement: $\sigma(\xi > 1\text{x}10^{-6})$

MEASUREMENT OVERVIEW

Number of events with at least two MBTS counter hits

Background from non-collision processes

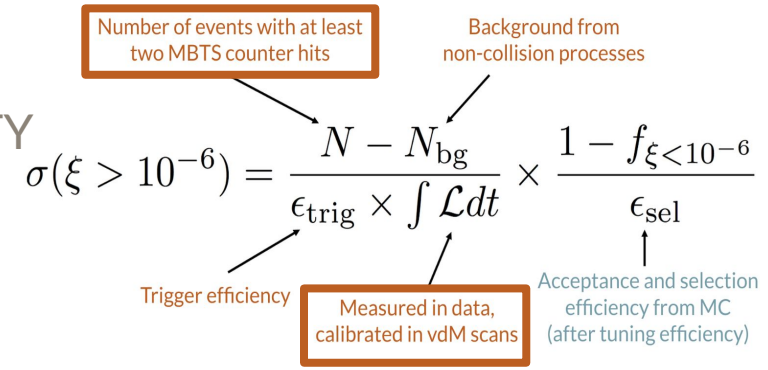
$$\sigma(\xi > 10^{-6}) = \frac{N - N_{\mathrm{bg}}}{\epsilon_{\mathrm{trig}} \times \int \mathcal{L} dt} \times \frac{1 - f_{\xi<10^{-6}}}{\epsilon_{\mathrm{sel}}}$$

Trigger efficiency

Measured in data, calibrated in mini VdM scans

Acceptance and selection efficiency from MC (after tuning efficiency)

COUNT IN DATA AND LUMINOSITY



Measurement performed in early run of 63±6 μb^{-1} collected in June

- Triggered by requiring 1 hit in the MBTS
- Very low pileup: no need to correct for multiple interactions
  - 2.3 x 10^{-3} collisions per bunch crossing
- No full VdM scans available at the time
  - Dominant uncertainty from the luminosity (±9%)

4 million events with at least two MBTS hits.

BACKGROUND ESTIMATION

$$\sigma(\xi > 10^{-6}) = \frac{N - N_{\mathrm{bg}}}{\epsilon_{\mathrm{trig}} \times \int \mathcal{L} dt} \times \frac{1 - f_{\xi<10^{-6}}}{\epsilon_{\mathrm{sel}}}$$

Number of events with at least two MBTS counter hits

Background from non-collision processes

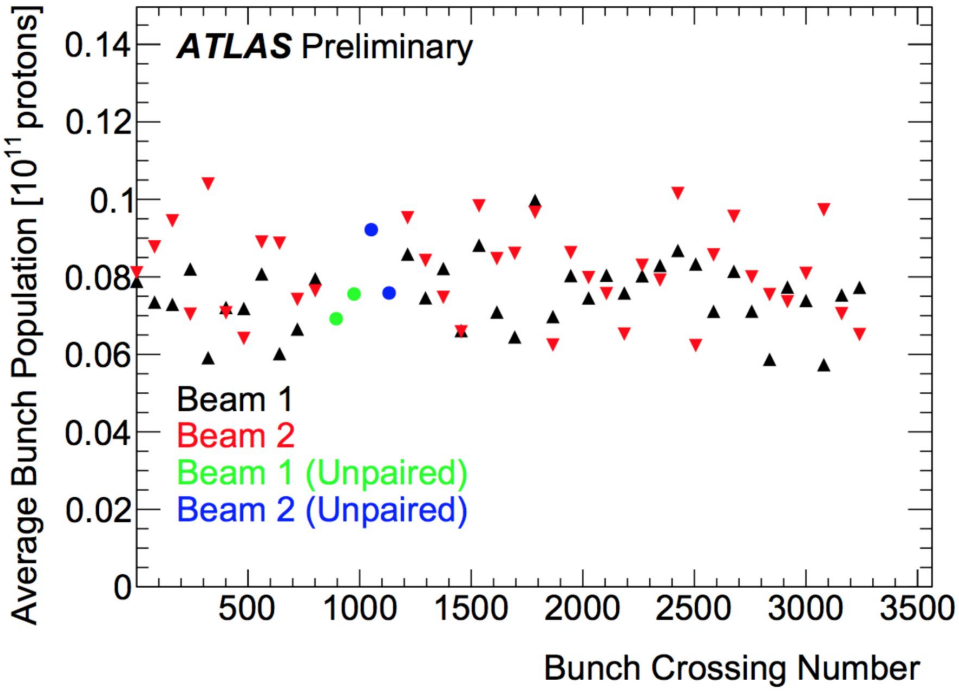
Trigger efficiency

Measured in data, calibrated in vdM scans

Acceptance and selection efficiency from MC (after tuning efficiency)

Several possible sources of backgrounds

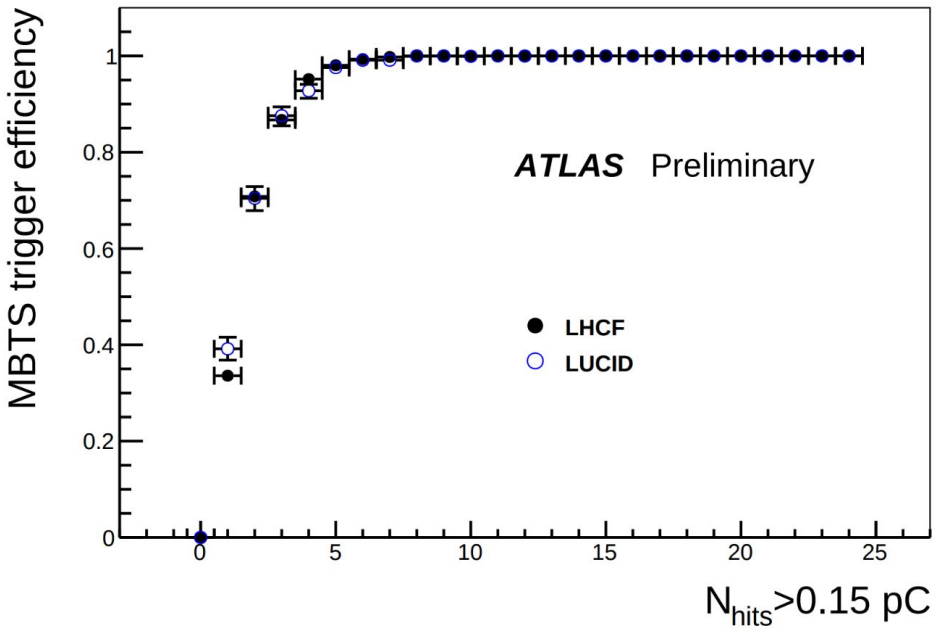
- Beam-Gas Interactions
- Beam Halo
- Collision Induced Radiation
- Detector Noise



Measure by triggering on unpaired bunches (no collisions):

- Found to be ~1% of inclusive sample
- Compatible with mostly beam-gas
- 100% taken as uncertainty to allow for all possible compositions

TRIGGER EFFICIENCY



Number of events with at least two MBTS counter hits

Background from non-collision processes

$$\sigma(\xi > 10^{-6}) = \frac{N - N_{\mathrm{bg}}}{\epsilon_{\mathrm{trig}} \times \int \mathcal{L} dt} \times \frac{1 - f_{\xi<10^{-6}}}{\epsilon_{\mathrm{sel}}}$$

Trigger efficiency

Measured in data, calibrated in vdM scans

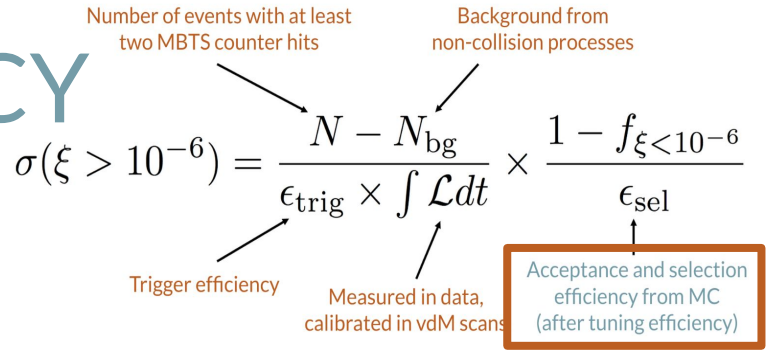
Acceptance and selection efficiency from MC (after tuning efficiency)

Estimated with alternative forward triggers: LUCID and LHCf

- LUCID: $5.6 < |\eta| < 5.9$
- LHCf: $|\eta| > 8.4$

99.7 ± 0.1 % efficient in the inclusive sample

ACCEPTANCE/EFFICIENCY



$$C_{MC} \equiv \frac{1-f_{\tilde{\xi}<10^{-6}}}{\epsilon_{\mathrm{sel}}} \approx 1$$

- Acceptance for the fiducial region
  - Sensitive to relative contribution of inelastic processes
  - Taken from MC samples after tuning contributions
- Selection efficiency for two hit requirement
  - Efficiency of MBTS measured in data
  - Event level efficiency taken from tuned MC

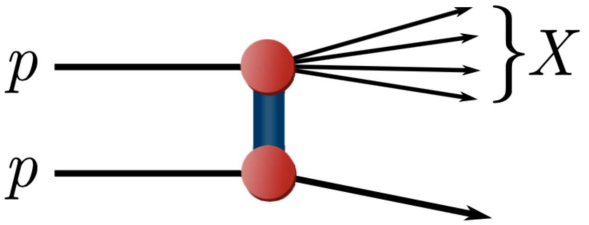
MC SAMPLES

MC required to measure the fiducial region acceptance, but many models available for inelastic processes:

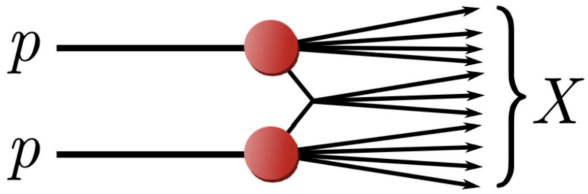
Name	Generator	Tune	Model
Pythia8 A2	Pythia8	A2	Schuler and Sjöstrand Pomeron
Pythia8 DL	Pythia8	Monash	Donnachie and Landshoff Pomeron
MBR	Pythia8	Monash	Minimum Bias Rockefeller
EPOS	EPOS LHC	-	Cut Pomeron
QGSJET	QGSJET-II	-	Reggeon Field Theory

Pythia8 DL found to do the best job describing data and used as nominal MC

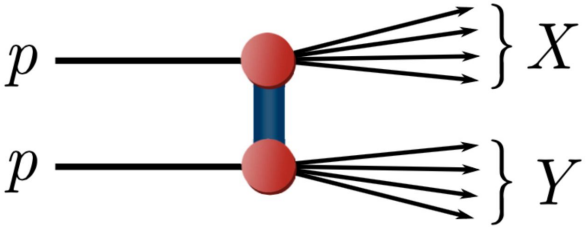
MC MODELING PROCESSES



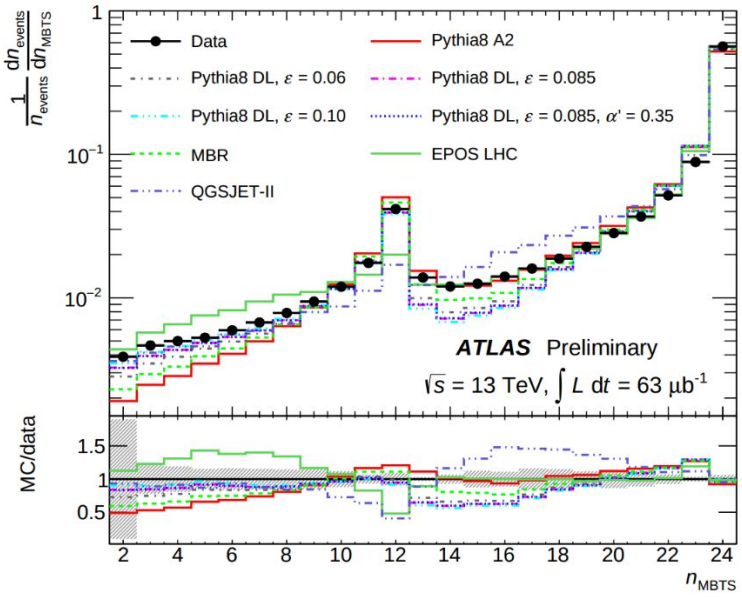
Single-Dissociation (SD)

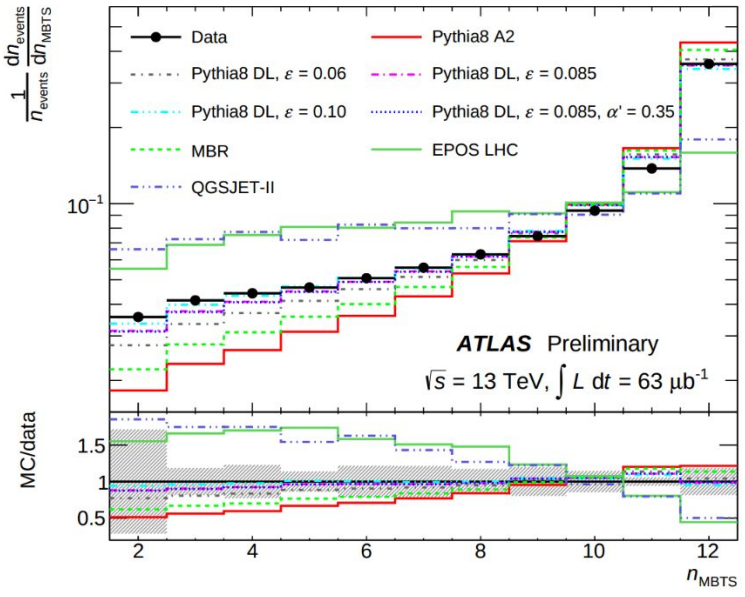


Non-Diffractive (ND)
(color-exchange)



Double-Dissociation (DD)





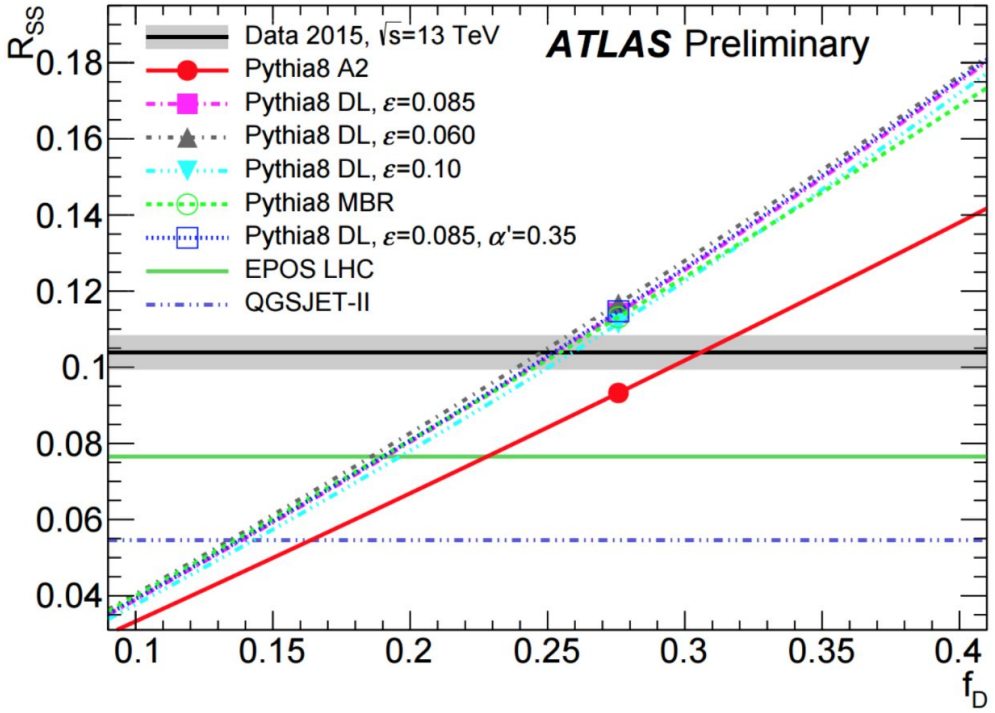
Non-Diffractive events make up majority of inelastic collisions, but the single dissociation events drive uncertainties (MBTS has lower efficiency for them)

DIFFRACTIVE FRACTION

Constrain $f_D = (\sigma_{SD}+\sigma_{DD})/\sigma_{TOT}$ by measuring fraction of single sided events

R_{SS} = Fraction of events with 2 MBTS hits which have hits on only A or C side

- Adjust f_D in MC to match R_{SS} where possible
- Sets the relative contribution of dissociative for acceptance measurement in MC



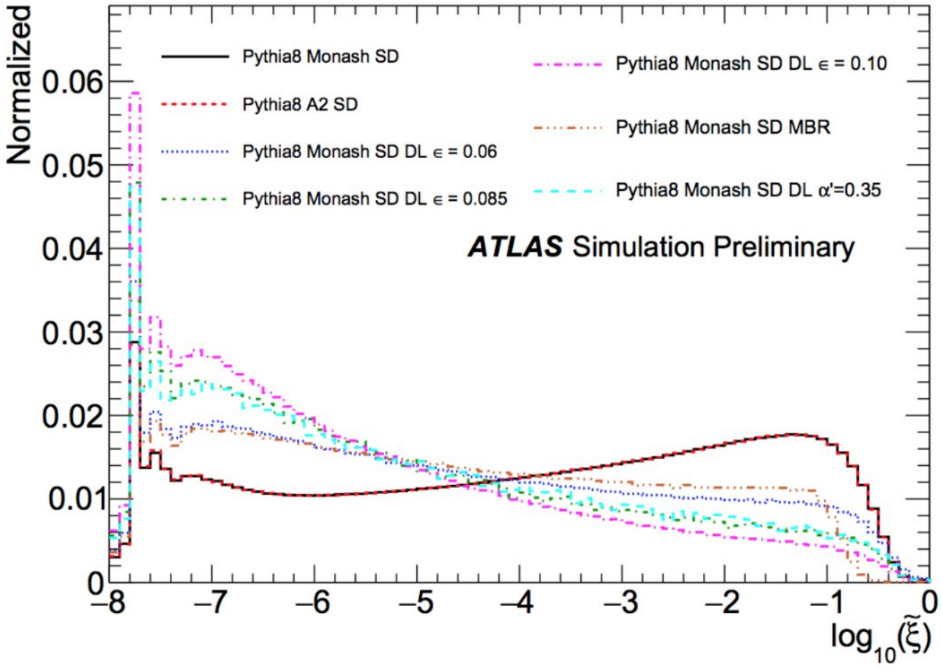
R_{SS} = 10.4 ± 0.5 % in Data

Corresponds to f_D = 25% in Pythia

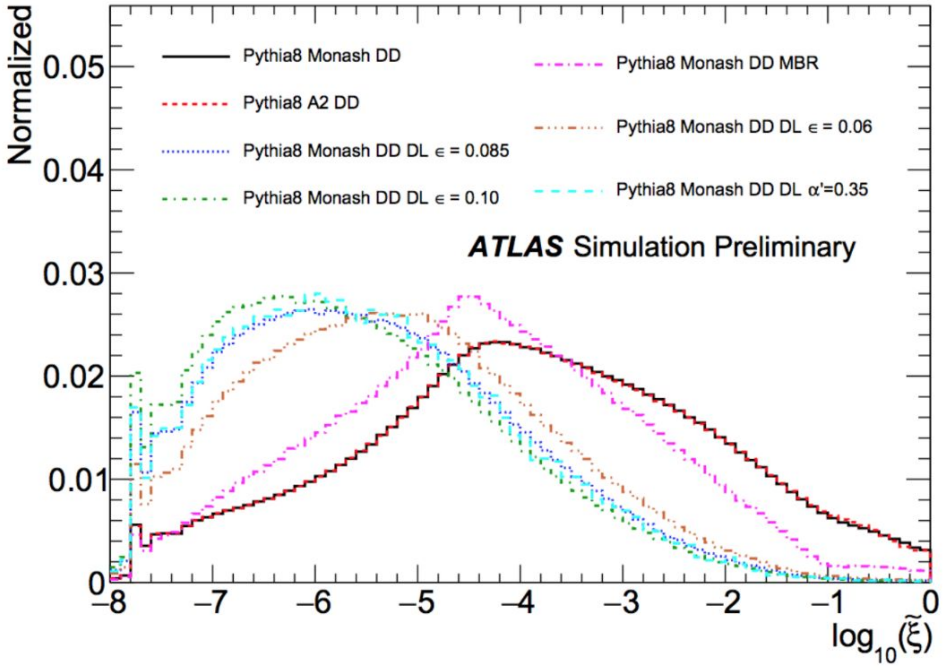
MC MODELING ξ DEPENDENCE

The distributions of each contribution are significantly different between samples, and so they still have different acceptances.

Single Diffractive



Double Diffractive



These differences are accounted for in the uncertainty for C_{MC}.

EFFICIENCY MEASUREMENT

Number of events with at least two MBTS counter hits

Background from non-collision processes

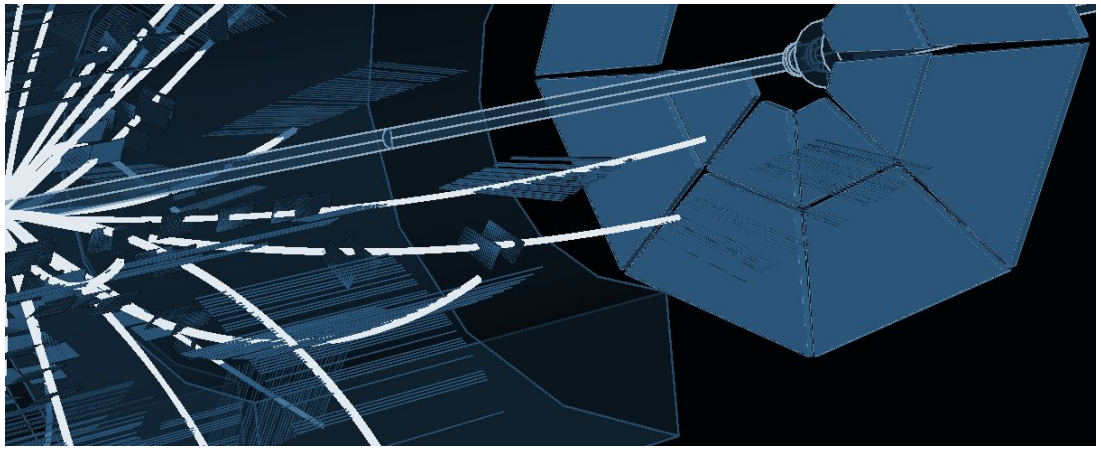
$$\sigma(\xi > 10^{-6}) = \frac{N - N_{\mathrm{bg}}}{\epsilon_{\mathrm{trig}} \times \int \mathcal{L} dt} \times \frac{1 - f_{\xi<10^{-6}}}{\epsilon_{\mathrm{sel}}}$$

Trigger efficiency

Measured in data, calibrated in vdM scans

Acceptance and selection efficiency from MC (after tuning efficiency)

Event level efficiency taken from MC after tuning the per particle efficiency



Per particle efficiency based on extrapolation to MBTS from the inner detector or calorimeters:

- Tag cells which extrapolate from a track or calorimeter cluster
- Measure the fraction of these cells which have a deposited charge above threshold (0.15 pC in data)

MBTS EFFICIENCY WITH TRACKS

Number of events with at least two MBTS counter hits

Background from non-collision processes

$$\sigma(\xi > 10^{-6}) = \frac{N - N_{\mathrm{bg}}}{\epsilon_{\mathrm{trig}} \times \int \mathcal{L} dt} \times \frac{1 - f_{\xi<10^{-6}}}{\epsilon_{\mathrm{sel}}}$$

Trigger efficiency

Measured in data, calibrated in vdM scans

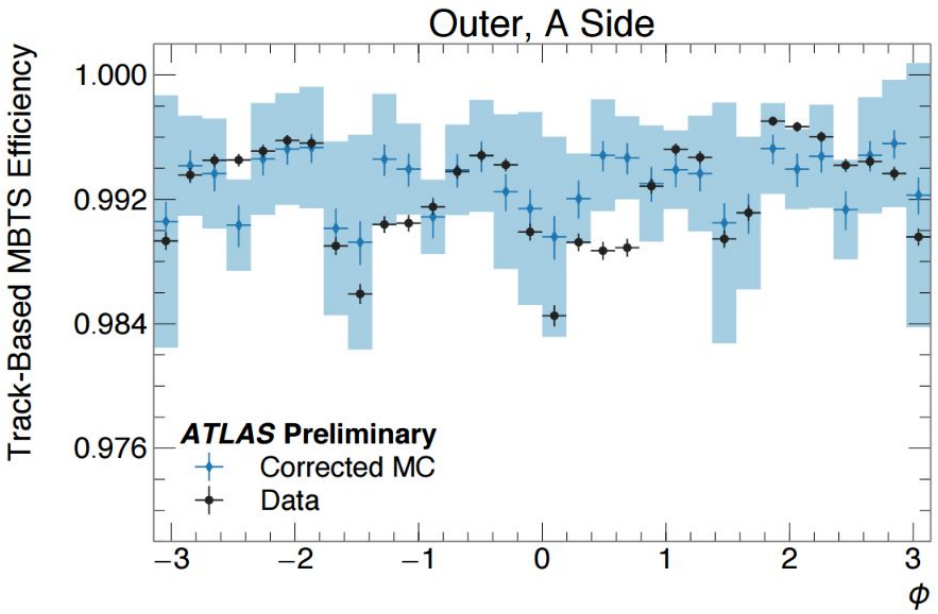
Acceptance and selection efficiency from MC (after tuning efficiency)

CELLS ABOVE THRESHOLD

$$\epsilon = \frac{N_{Q>0.15}}{N_{tot} - 2.0 \cdot N_{Q<0.0}}$$

TRACK-TAGGED CELLS

NOISE CORRECTION



MBTS cells are tagged if tracks extrapolates to MBTS within acceptance ($2.07 < |\eta| < 2.5$)

Efficiency measured in data used to set the threshold in MC. Systematic taken as range of thresholds for MC to match every cell in data.

MBTS EFFICIENCY WITH CALO

Number of events with at least two MBTS counter hits

Background from non-collision processes

$$\sigma(\xi > 10^{-6}) = \frac{N - N_{\mathrm{bg}}}{\epsilon_{\mathrm{trig}} \times \int \mathcal{L} dt} \times \frac{1 - f_{\xi<10^{-6}}}{\epsilon_{\mathrm{sel}}}$$

Trigger efficiency

Measured in data, calibrated in vdM scans

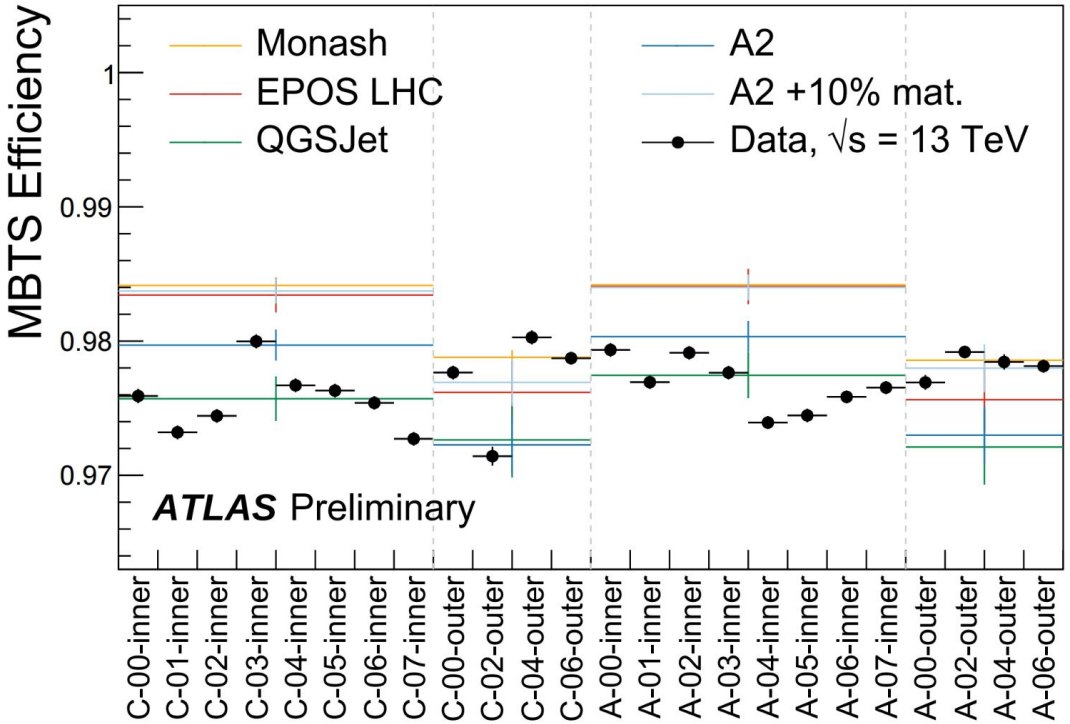
Acceptance and selection efficiency from MC (after tuning efficiency)

CELLS ABOVE THRESHOLD

$$\epsilon = \frac{N_{Q>0.15}}{N_{tot} - 2.0 \cdot N_{Q<0.0}}$$

CALO-TAGGED CELLS

NEUTRAL CORRECTION

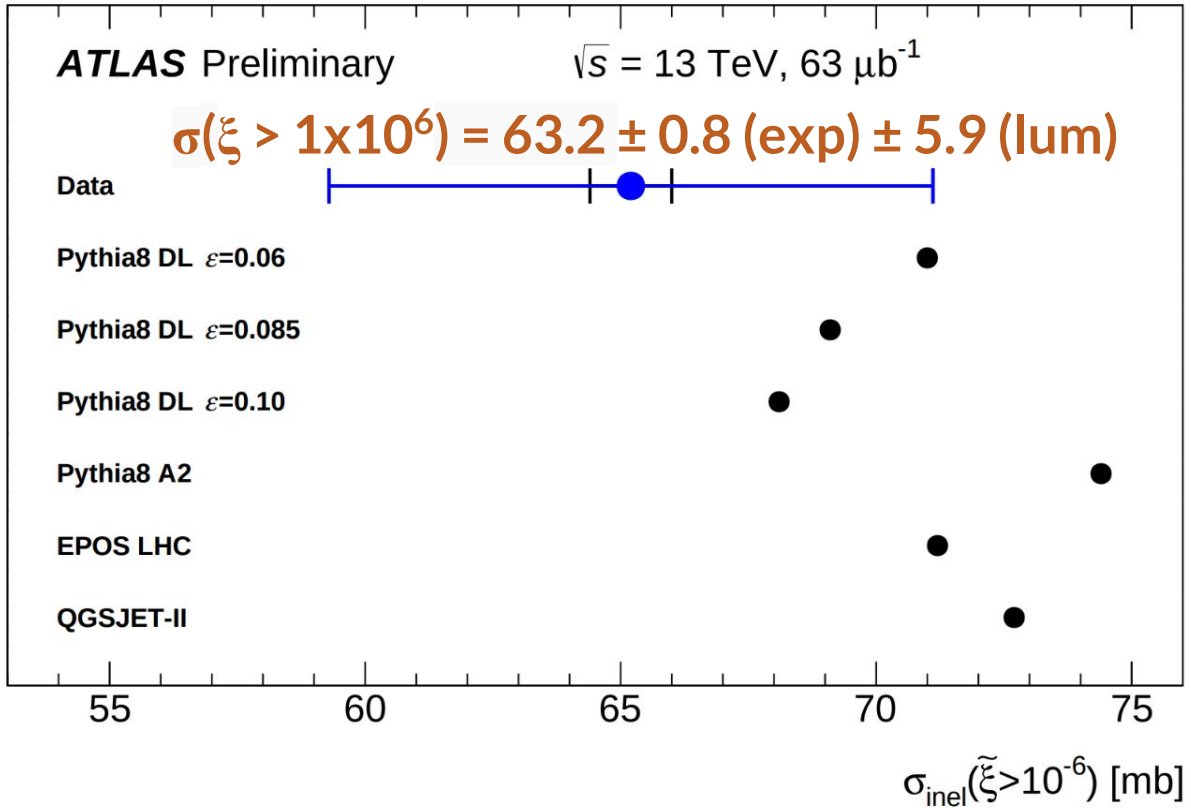


MBTS cells are tagged if calo cluster within acceptance

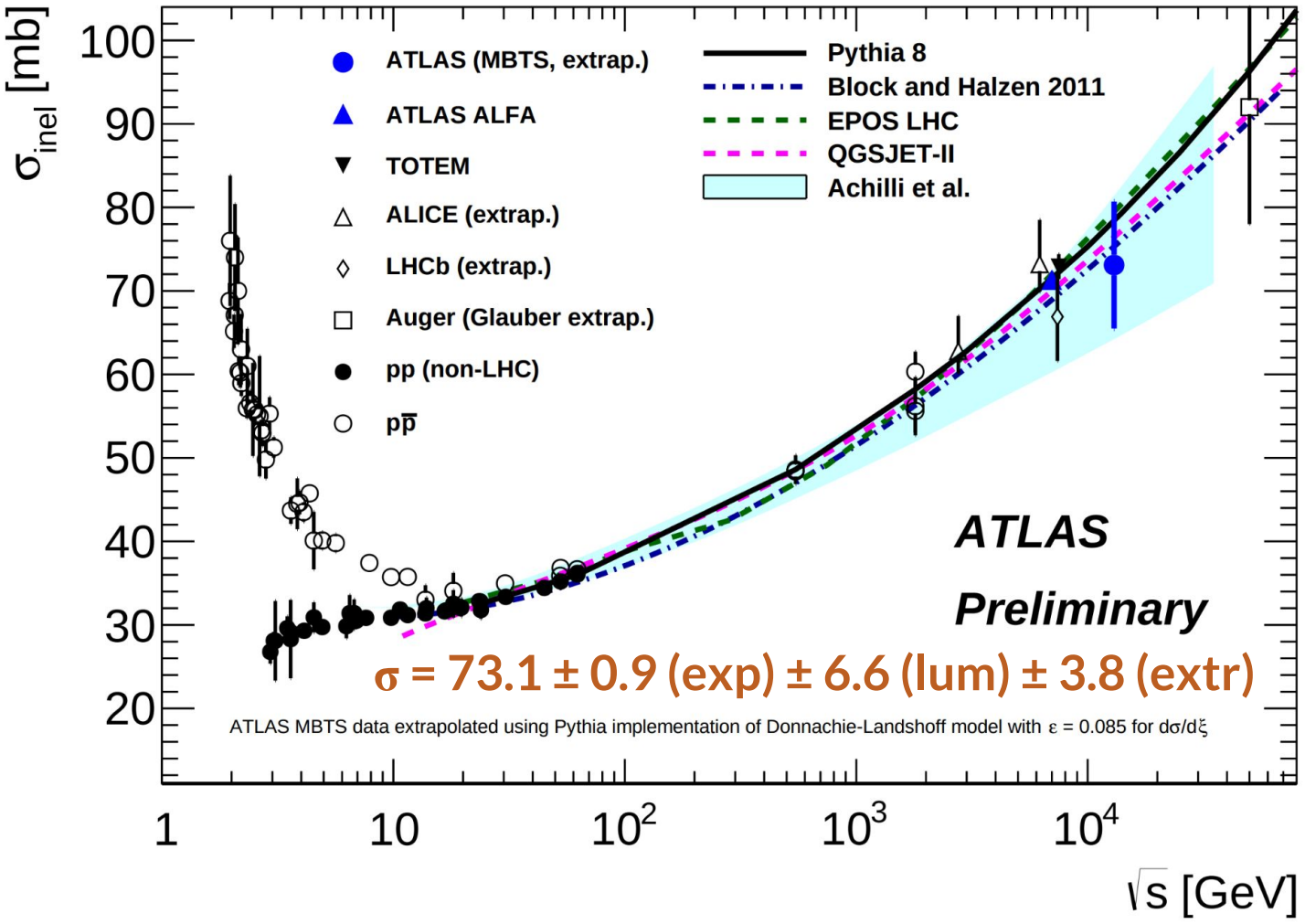
- Calorimeter also includes neutral particles (corrected for)
- Used to cross check the track measurement: covers both inner and outer counters

FIDUCIAL RESULT

Factor	Value	Rel. unc.
Number of selected events (N)	4159074	–
Number of background events (N_{BG})	43512	±100 %
Luminosity [μb^{-1}] (L)	62.9	±9 %
Trigger efficiency (ϵ_{trig})	99.7%	±0.1 %
MC Correction factor ($(1 - f_{\tilde{\xi}<10^{-6}})/\epsilon_{\mathrm{sel}}$)	0.993	±0.5 %



EXTRAPOLATED RESULT



Extrapolation factor obtained from MC (Pythia 8 D-L 0.085), with uncertainty as the envelope of the extrapolation factors from the different models

CONCLUSION

In ATLAS-CONF-2015-038, we measure a fiducial cross section of

$$\sigma(\xi > 1\text{x}10^{6}) = 63.2 \pm 0.8\ (\text{exp}) \pm 5.9\ (\text{lum})\ \text{mb}$$

and an extrapolated cross section of

$$\sigma = 73.1 \pm 0.9\ (\text{exp}) \pm 6.6\ (\text{lum}) \pm 3.8\ (\text{extr})\ \text{mb}$$

which falls a bit below, but consistent with, most theoretical predictions.

The dominant uncertainty comes from the luminosity, which is expected to improve significantly with analysis of the full VdM scans from August