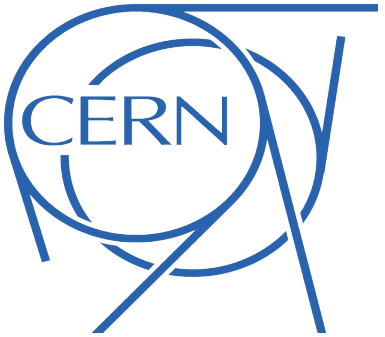
Measurement of the inelastic pp Cross Section with the ATLAS detector



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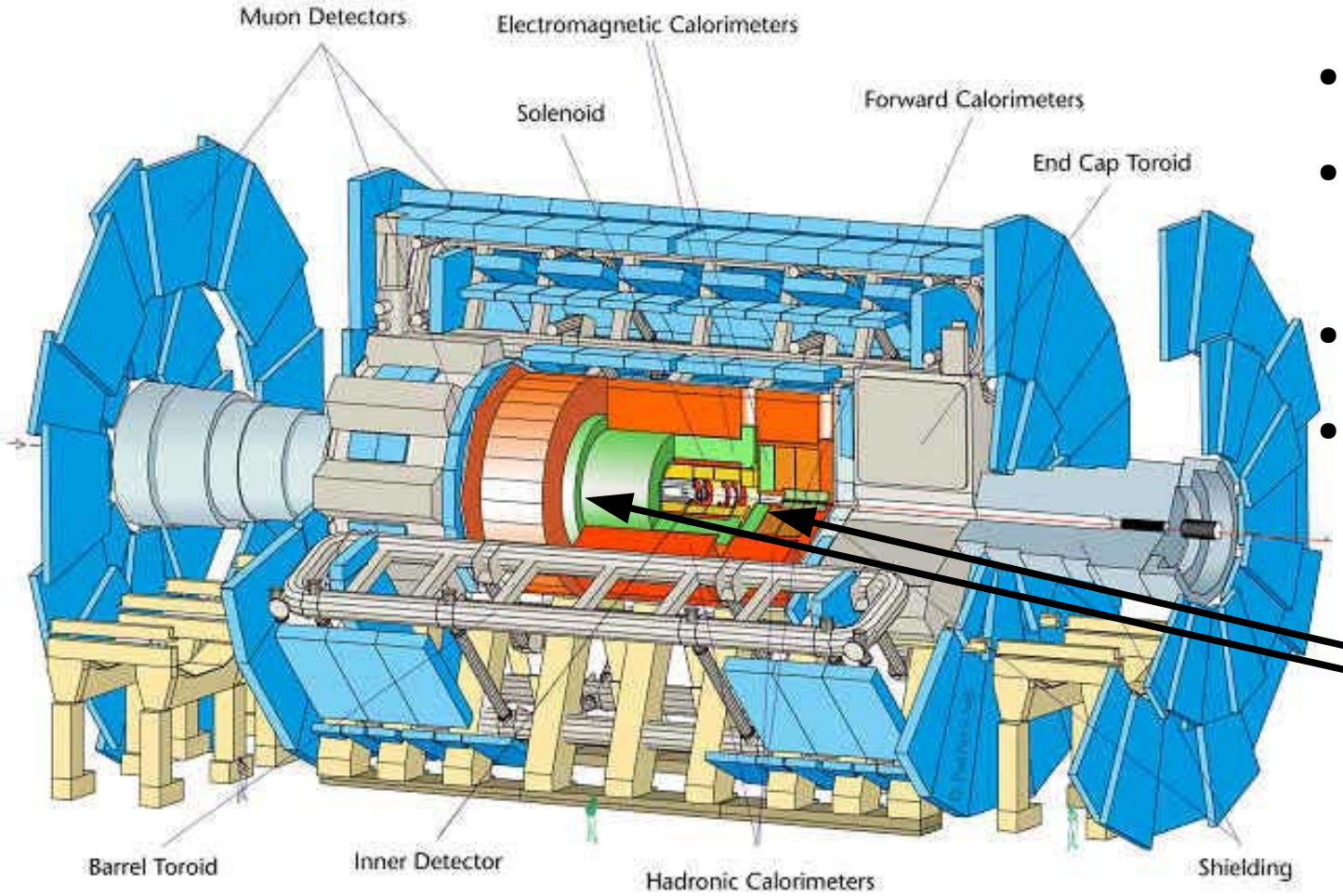
On behalf of the ATLAS collaboration

Overview

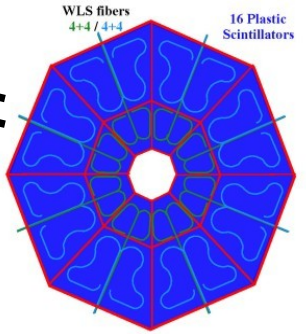
- Experiment ATLAS: Brief Description
- Properties of used data
- Event selection
- Monte-Carlo simulations
- Contribution of the Diffractive events
- Calculation of the Inelastic cross-section
- Results
- Cross-section from rapidity gap
- Conclusion

The ATLAS Detector



- Tracking detector
- Electromagnetic and hadronic calorimeters
- Muon system
- Magnets

MBTS



- The key component of the ATLAS for inelastic cross section measurement is the Minimum Bias Trigger Scintillator (MBTS)
  - is located in front of the Endcap calorimeters
  - consists from two rings of 8 counters on each side of detector
  - covers pseudorapidity $|\eta|$ 2.09 – 2.82, 2.82 – 3.84

Data properties

Total inelastic cross-section

- $\sqrt{s}$ = 7 TeV
- 8 hour fill at LHC, March 31st, 2010
- Integrated luminosity:

  $20.3 \pm 0.7\ \mu b^{-1}$
- Peak luminosity:

  $1.2 \times 10^{27}\ cm^{-2}s^{-1}$
- Mean number of interactions per crossing: 0.01
- Acceptance region:

  $\xi = M^2_X / s > 5 \times 10^{-6}$,
  $M_X > 15.7$ GeV

Rapidity gaps study

- $\sqrt{s}$ = 7 TeV
- LHC, March 2010
- Integrated luminosity:

  $7.1 \pm 0.2\ \mu b^{-1}$
- Peak luminosity:

  $1.1 \times 10^{27}\ cm^{-2}s^{-1}$
- Mean number of interactions per crossing: 0.005
- Acceptance region:

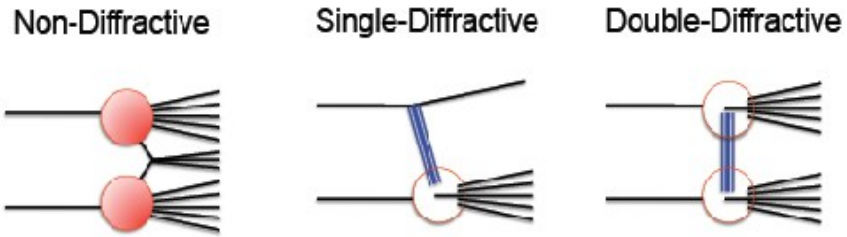
  $|\eta| < 4.9$,
  $\Delta\eta < 8$

Event selection

- The MBTS functions as a trigger by determining the number of scintillation counters with a signal passing threshold
- The MBTS signals are fit offline to obtain the total charge and timing of the signal
- The event selection required at least two counters with a charge larger than 0.15 pC
  - The noise is described by a Gaussian centered at zero with width 0.02 pC
  - **Total cross-section**
    - Total 1 220 743 data events are selected for the inclusive sample
    - A diffractive sub-sample of 122 490 events is selected requiring at least two hits on one side of the MBTS detector and no hits on the opposite side in z
  - **Rapidity gap**
    - 422 776 recorded events, approximately 400 events with pile-up

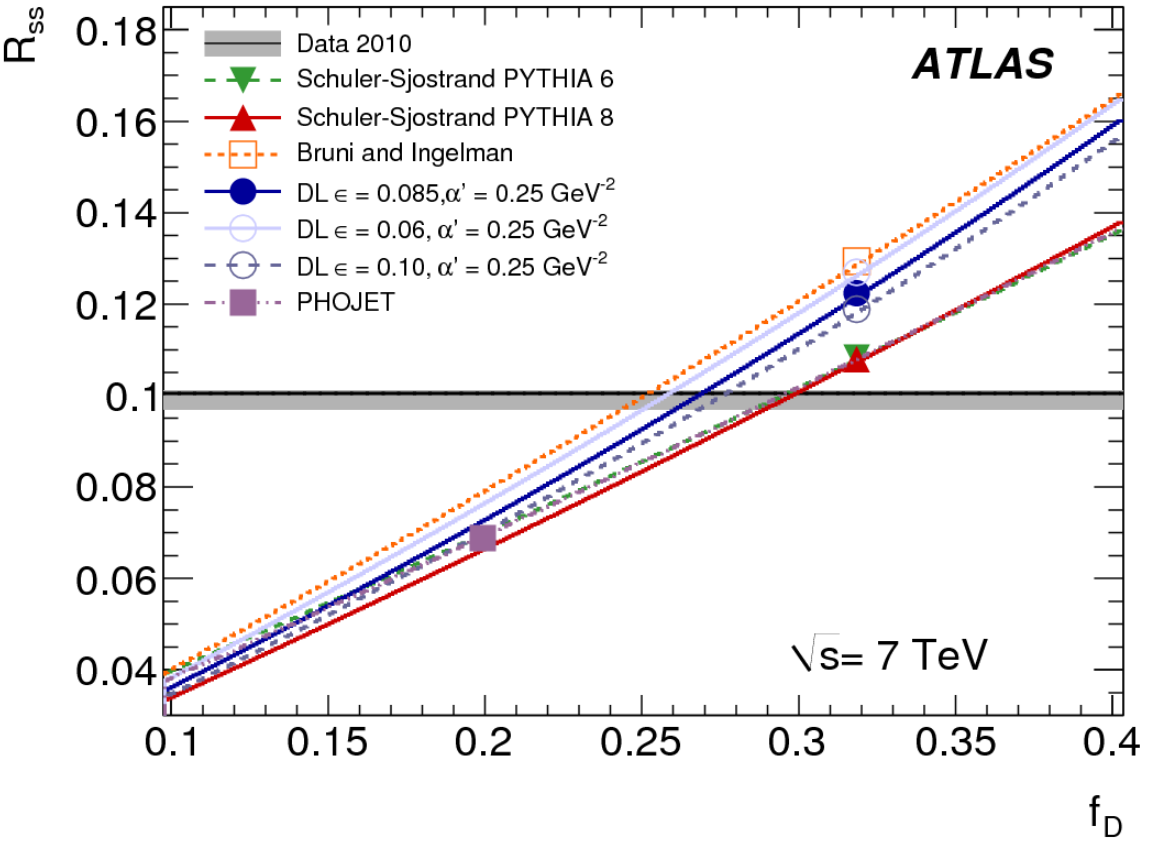
Monte Carlo simulations

- Determination of the event selection acceptance and of estimation systematic uncertainties
- Detector response to generated events:
  - GEANT4 based ATLAS simulation
- MC generators:
  - PYTHIA6, PYTHIA8, PHOJET
    - single dissociative (SD) processes
      - pp → pX, one proton dissociates
    - double dissociative (DD) processes
      - pp → XY, both proton dissociate, with no net color flow between X, Y
    - non-diffractive (ND) processes
      - a color flow is present between two initial-state protons
    - central diffractive (CD) processes (PHOJET only)
      - pp → ppX, no one of protons dissociates



Contribution of diffractive events

- The ND and SD/DD events contribute differently to the single-sided (SS) events
- MC predicts
  - 1% of ND passes SS
  - 27–41% of SD/DD pass SS
- The measured ratio of SS events (R_{SS}) is used to set fraction of diffractive events to inelastic cross section (f_D) for each MC generator
  - The value of R_{SS} extracted from data requires the f_D to be 25–30% for MC models



Prediction of ratio of the single-sided events as a function of fraction of diffractive events for the MC models

More results about the diffractive processes:
M. Tasevsky, *Results on diffraction from the ATLAS experiment*

Cross-section calculation

$$\sigma_{\text{inel}}\left(\xi>5\times10^{-6}\right)=\frac{N-N_{\text{BG}}}{\varepsilon_{\text{trig}}\times\int L\,\mathrm{d}t}\times\frac{1-f_{\xi<5\times10^{-6}}}{\varepsilon_{\text{sel}}}$$

- N number of selected events
- N_{BG} number of background events
- $f_{\xi<5\times10^{-6}}$ fraction of events pass selections but $\xi<5\times10^{-6}$
- $\int L\mathrm{d}t$ integrated luminosity
- $\varepsilon_{\text{trig}}$, ε_{sel} trigger and offline event selection efficiencies

Results

- The inelastic cross-section of pp collisions at 7 TeV

  $\sigma_{inel}(\xi>5\times10^{-6}) = 60.3 \pm 0.05(stat) \pm 0.5(syst) \pm 2.1(lumi)$ **mb**

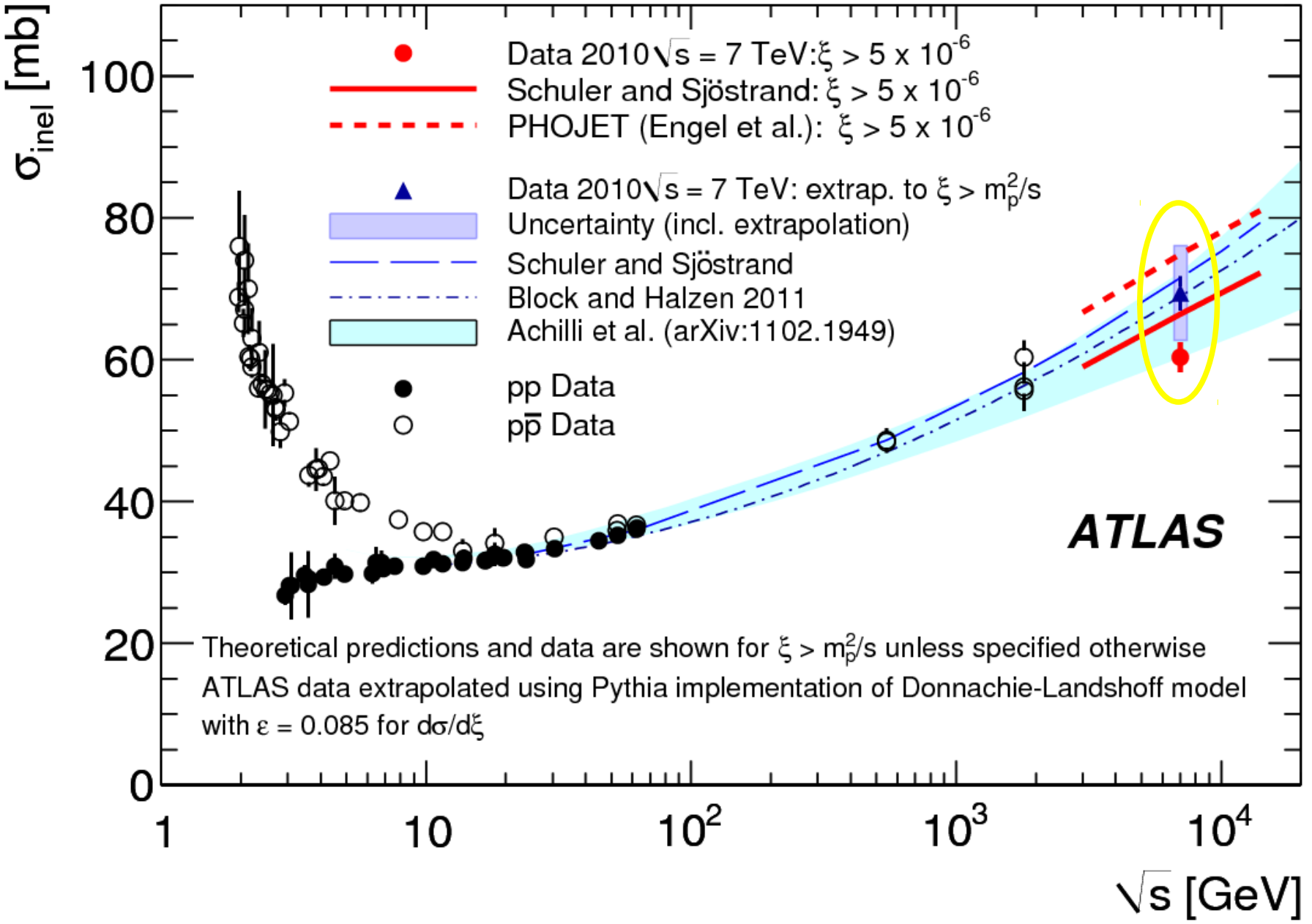
- Sources of systematic uncertainties:
  - Trigger Efficiency: 0.1%
  - MBTS Response: 0.1%
  - Beam Background: 0.4%
  - f_D: 0.3%
  - MC Multiplicity: 0.4%
  - ξ-Distribution: 0.4%
  - Material: 0.2%
  - Luminosity: 3.4%
  - **Total: 3.5%**

Results (2)

- Extrapolation to the full inelastic cross-section:
  - The fractional contribution to the inelastic cross-section of events passing the $\xi > 5\times10^{-6}$ cut is determined from the models and used to extrapolate the measurement to the full inelastic cross-section:
    - 87.6% for default DL model (PYTHIA)
    - 86% to 96% for other models / tunes
    - 79% to 84% for recent calculations
  - The used fraction is 87% with 10% uncertainty
- The total inelastic cross-section:

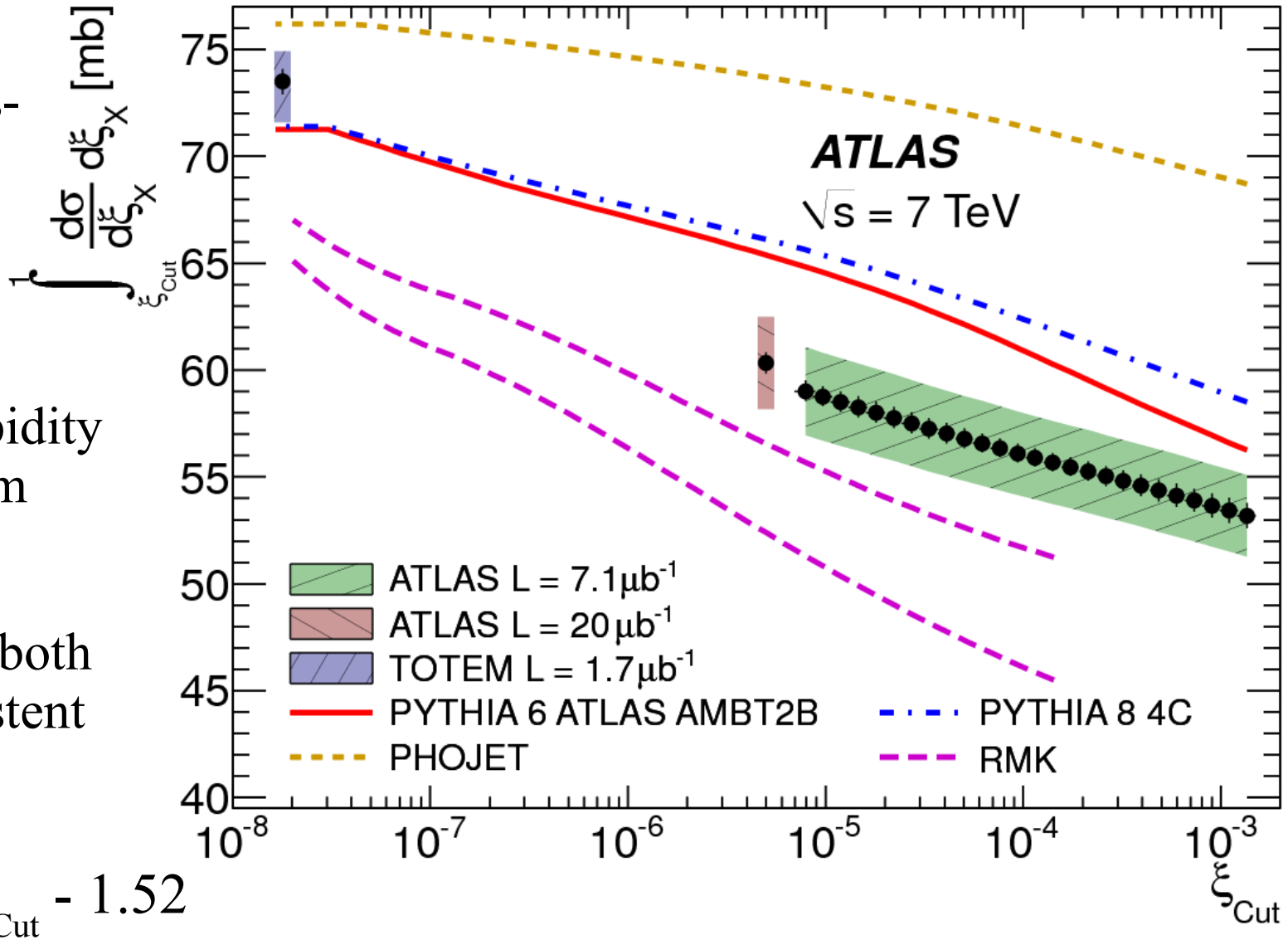
$$\sigma_{\mathrm{inel}} = 69.4 \pm 2.4(\mathrm{exp}) \pm 6.9(\mathrm{extr})\ \mathrm{mb}$$

Results (3)


σ_{inel} [mb]
100
80
60
40
20
0
1
10
10^2
10^3
10^4
$\sqrt{s}$ [GeV]
Data 2010 $\sqrt{s}$ = 7 TeV: $\xi > 5 \times 10^{-6}$
Schuler and Sjöstrand: $\xi > 5 \times 10^{-6}$
PHOJET (Engel et al.): $\xi > 5 \times 10^{-6}$
Data 2010 $\sqrt{s}$ = 7 TeV: extrap. to $\xi > m_p^2/s$
Uncertainty (incl. extrapolation)
Schuler and Sjöstrand
Block and Halzen 2011
Achilli et al. (arXiv:1102.1949)
pp Data
$p\bar{p}$ Data
ATLAS
Theoretical predictions and data are shown for $\xi > m_p^2/s$ unless specified otherwise
ATLAS data extrapolated using Pythia implementation of Donnachie-Landshoff model
with $\varepsilon = 0.085$ for $d\sigma/d\xi$

Inelastic cross section from the rapidity gap

- Differential cross-section for gap size $\Delta\eta$ used to calculate total cross section
- Integration of rapidity cross-section from 0 to $\Delta\eta_{Cut}$
- The results from both studies are consistent

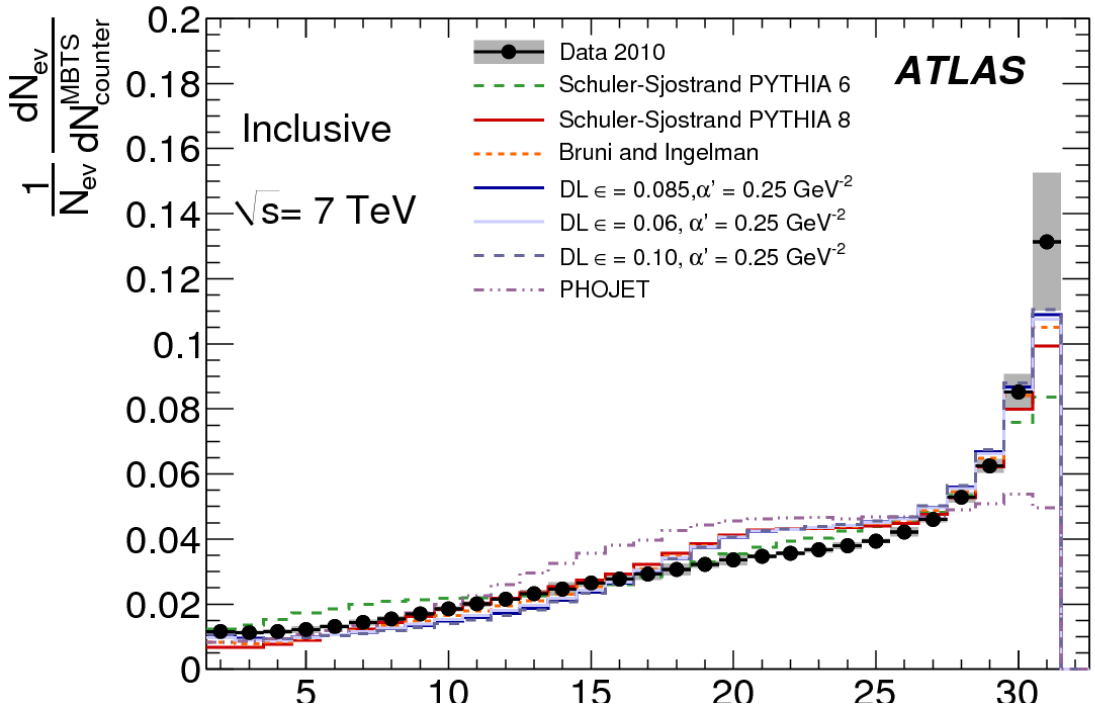
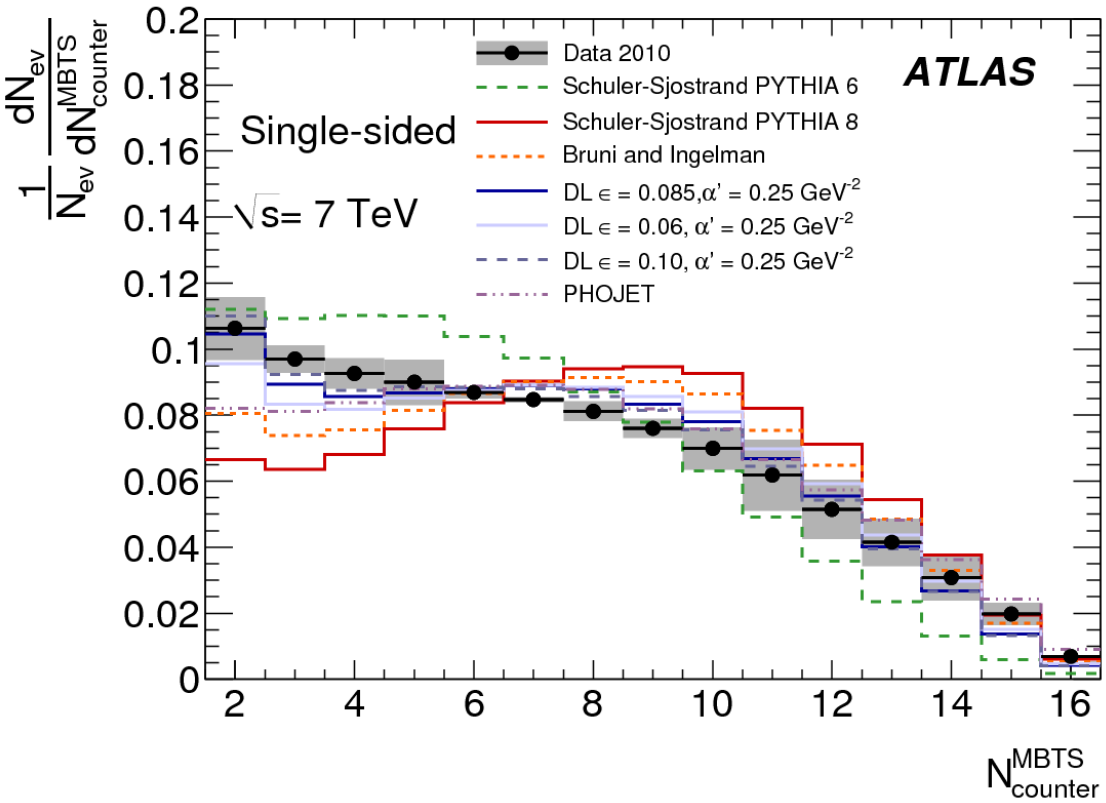


$$\log_{10}\xi_{Cut} = -0.45\Delta\eta_{Cut} - 1.52$$

Conclusion

- Measurement of the inelastic cross-section has been presented for pp collisions at $\sqrt{s}$ = 7 TeV with a precision of 3.5%
- The measurement is limited to the kinematic range corresponding to the detector acceptance:
- Phenomenological predictions for both a power law dependence and a logarithmic rise of the cross-section with energy are consistent with the measurement
- More info:
  - **arXiv:1104.0326**: Measurement of the Inelastic Proton-Proton Cross-Section at sqrt(s) = 7 TeV with the ATLAS Detector
  - **arXiv:1201.2808**: Rapidity Gap Cross Sections in pp Interactions at sqrt(s) = 7 TeV measured with the ATLAS detector

Backup slides

MBTS multiplicity

Comparison of MBTS multiplicity for inclusive (top) and single-sided (bottom) events for data and several MC models