Impact of ATLAS data on PDFs

Voica Radescu (DESY)

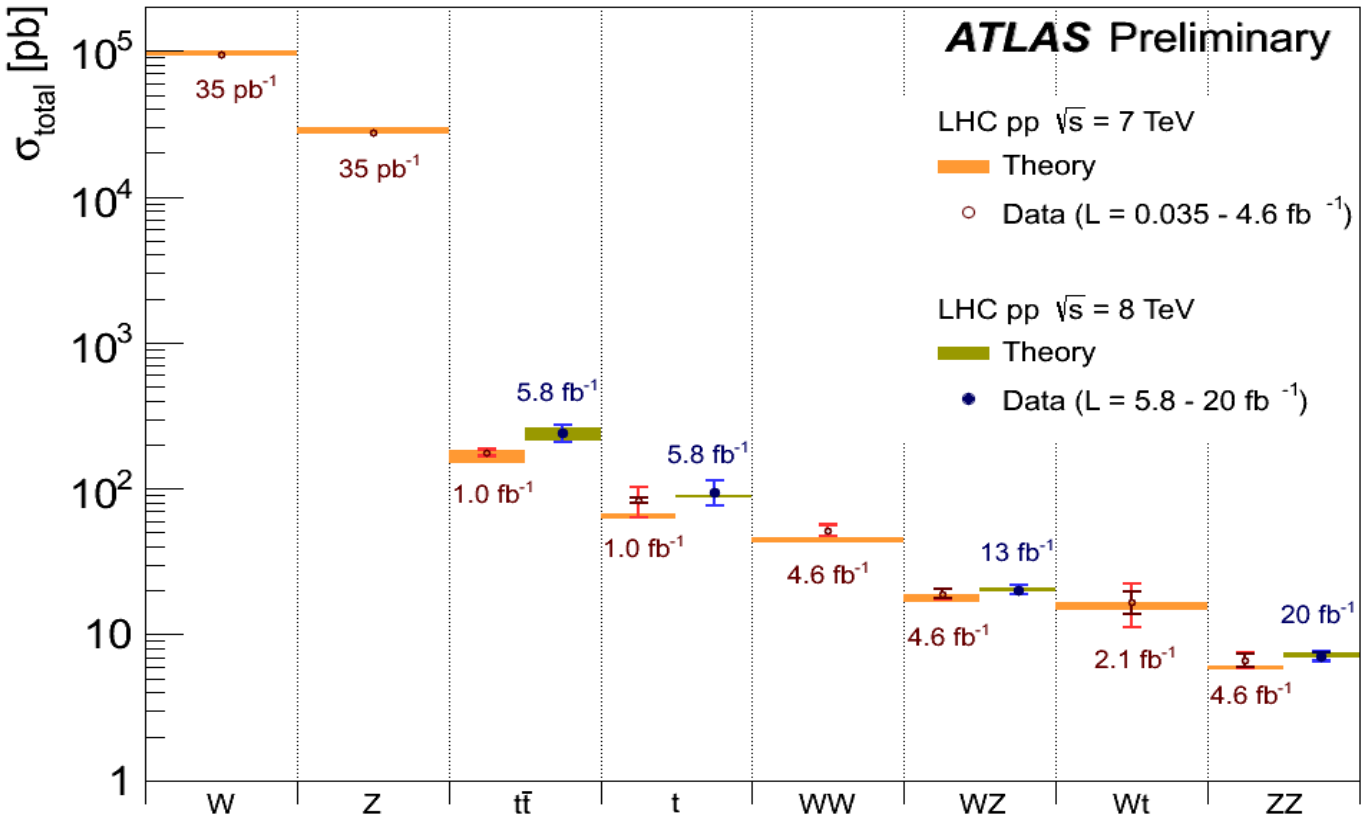
on behalf of the ATLAS Collaboration

Outline

- W and Z production
  - sensitivity to the strange PDF and anti-quark PDFs
- Inclusive Jet production
  - sensitivity to the gluon PDF
- Top Production

LHC performance

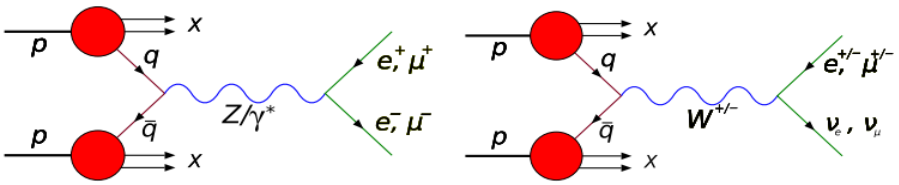
- Successful run in 2010 - 2012 at the LHC confirmed and tested SM!



- LHC can provide with its multitude of new measurements:
  - PDF discrimination by confronting theory with data
  - PDF improvement by using LHC data in QCD fit

W and Z production at LHC

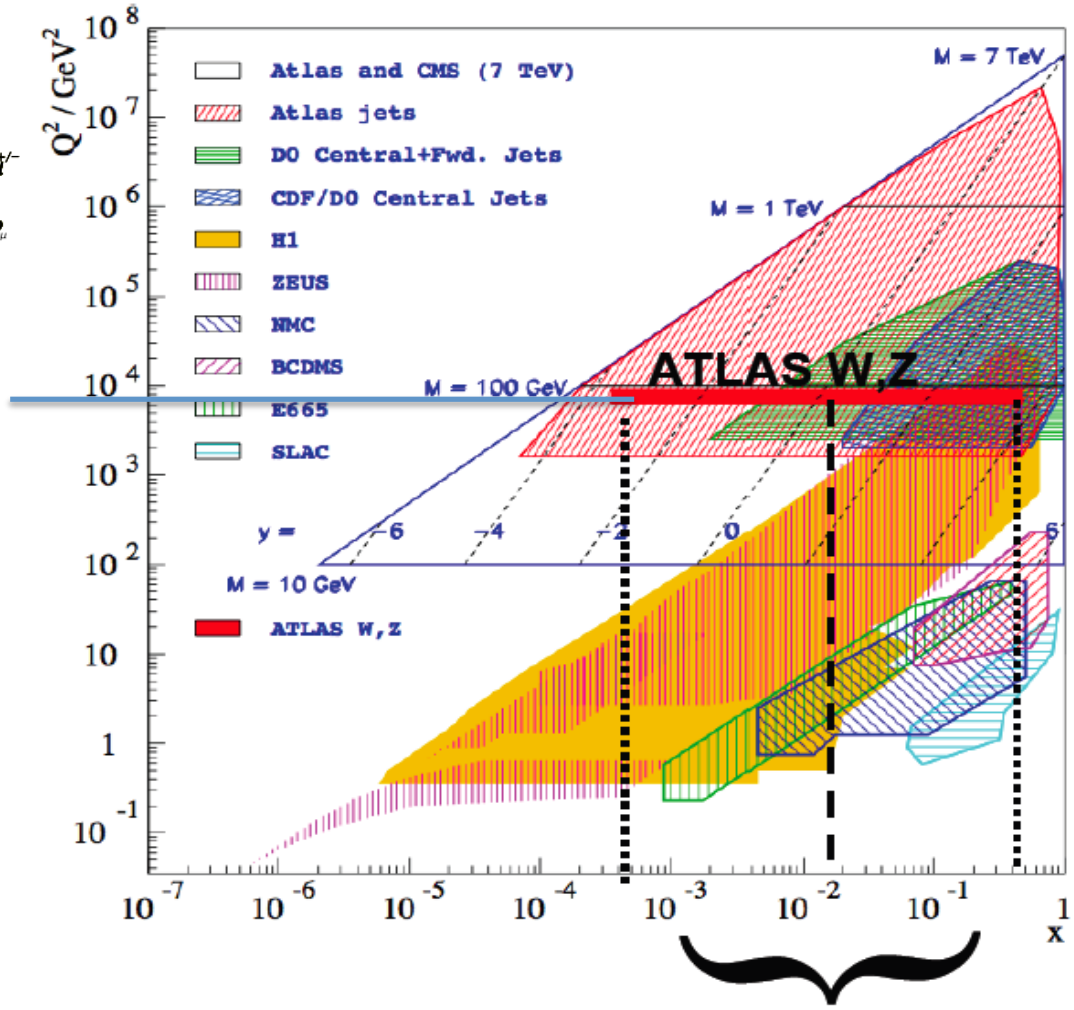
- Drell-Yan production of W and Z bosons is calculable to high orders in pQCD (NNLO)



- Interpretation of EW physics results at the LHC requires an accurate theory predictions to match experimental precision
  - An interesting testing ground of PDFs .

- ATLAS data is in kinematic range given by boson masses W, Z and the Ep=3.5 TeV
  - Kinematic variables are related via:

$$x_{1,2} = \frac{M_{\ell\ell}}{\sqrt{S}} e^{\pm y_{\ell\ell}}$$

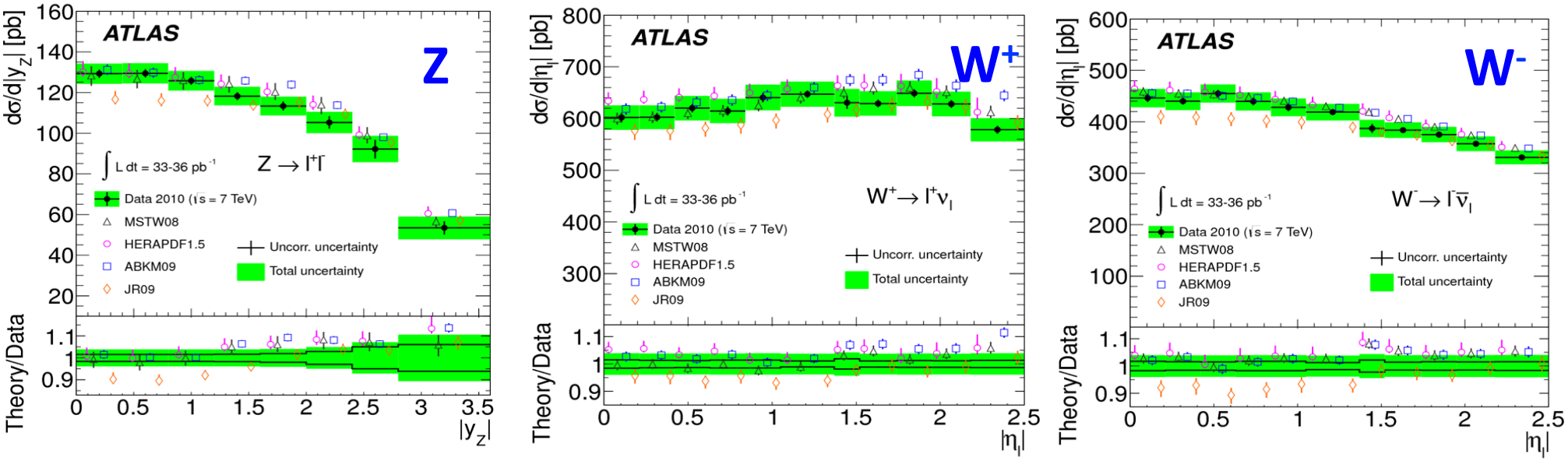


ATLAS W,Z sensitivity region: 0.001<x <0.1

W,Z Differential Cross Section

[Phys. Rev. D85 (2012) 072004]

- Measurements of WZ differential cross sections are compared to NNLO predictions
  - The electron and muon data have been combined accounting for the correlated systematic uncertainties using the HERAverager programme
  - The results are given with 30 sources of correlated uncertainties



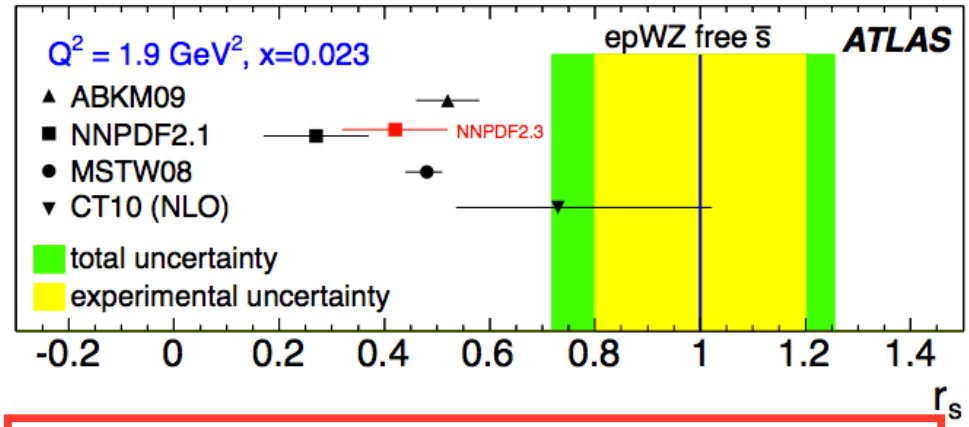
→ Measurements have the potential to bring impact on PDFs:

- Tension between data and predictions for the Z cross sections where all PDF considered have a suppressed strange quark density.

Strange quark from W, Z measurements at ATLAS

- Strange quark is not so well constrained:
  - Neutrino dimuon data favours suppressed strange
- Z differential cross sections in y_Z provide a constraint on **s**-quark density through NNLO QCD Fit

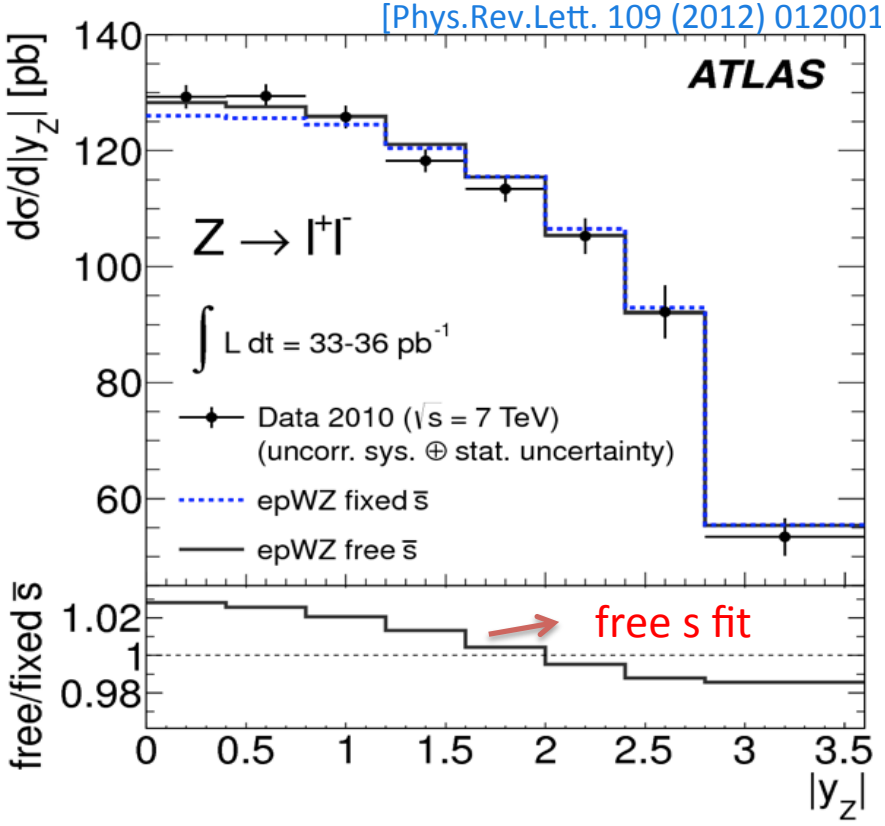
  (W helps to constrain common normalisation):
  - NNLO QCD fit results with free and fixed **s:**



$$r_s = 1.00 \pm 0.20_{\text{exp}} \pm 0.07_{\text{mod}}{}^{+0.10}_{-0.15\,\text{par}}{}^{+0.06}_{-0.07}\alpha_S \pm 0.08_{\text{th.}}$$

(kinematic region probed is at x~0.01)

[Phys.Rev.Lett. 109 (2012) 012001]



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- It is above MSTW08, ABKM09, NNPDF2.3 (s/d~0.5)

- WZ 2011 data with far more statistics would provide a more stringent constraints
- Sensitivity to strange can be complemented by independent measurement of W+c

W+c sensitivity to Strange from ATLAS

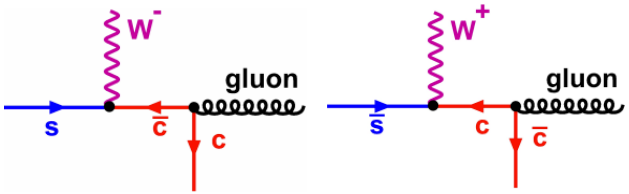
[ATLAS-CONF-2013-045]

Question: would other measurements confirm ATLAS favour of sbar=dbar?

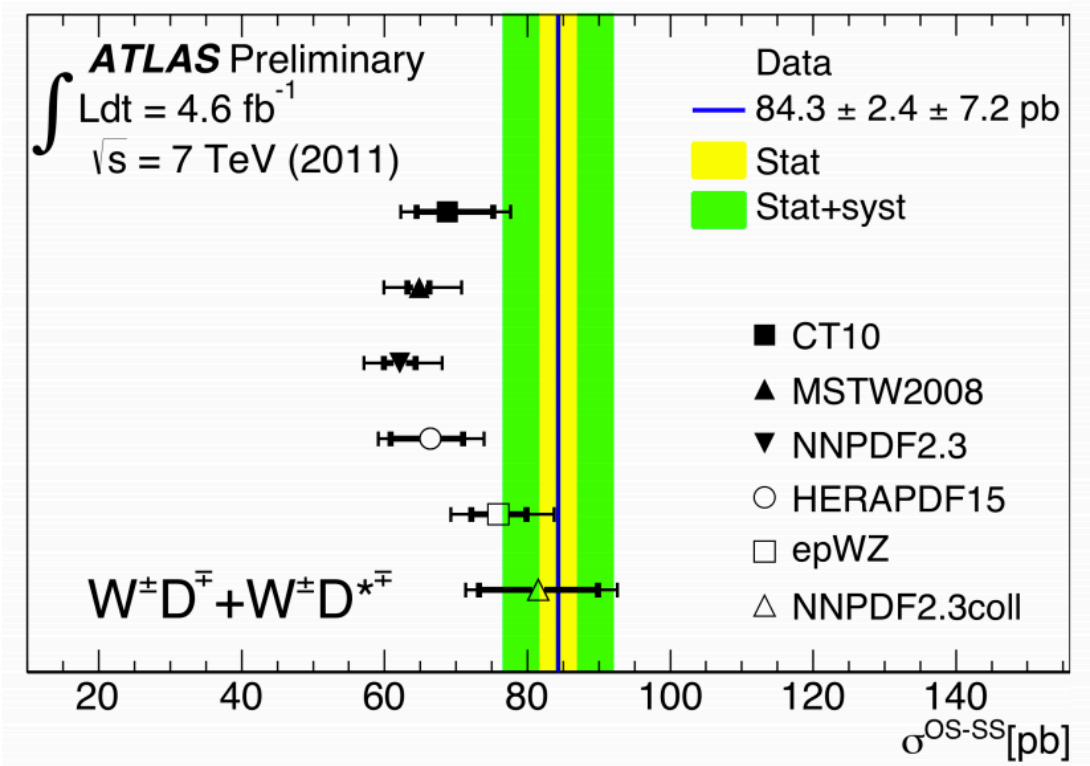
NEW Preliminary W+c measurement sensitive to strange , with charm hadrons reconstructed in four D^+/D^* decay modes based on 4.6/fb data (7TeV)

- presented at particle level in fiducial phase space:

$p_T^l > 20$ GeV, $|\eta^l| < 2.5$, $p_T^\nu > 25$ GeV, $m_T^W > 40$ GeV, $p_T^D > 8$ GeV, $|\eta^D| < 2.2$



- presented in integrated and differential modes (pt or eta):



Theoretical predictions are based on aMC@NLO:

- Inner error bar is PDF uncertainty
- Outer error bar is total:
  - quadratic sum of PDF+scale+fragm

Good agreement with epWZ (ATLAS PDF based on WZ 2010) and NNPDF2.3 (Coll) sets

Results suggest a non-suppressed strange

Differential measurements in lepton rapidity provide shape information important for a PDF extraction.

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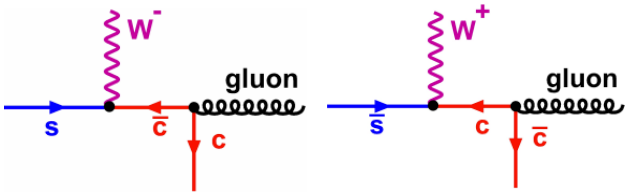

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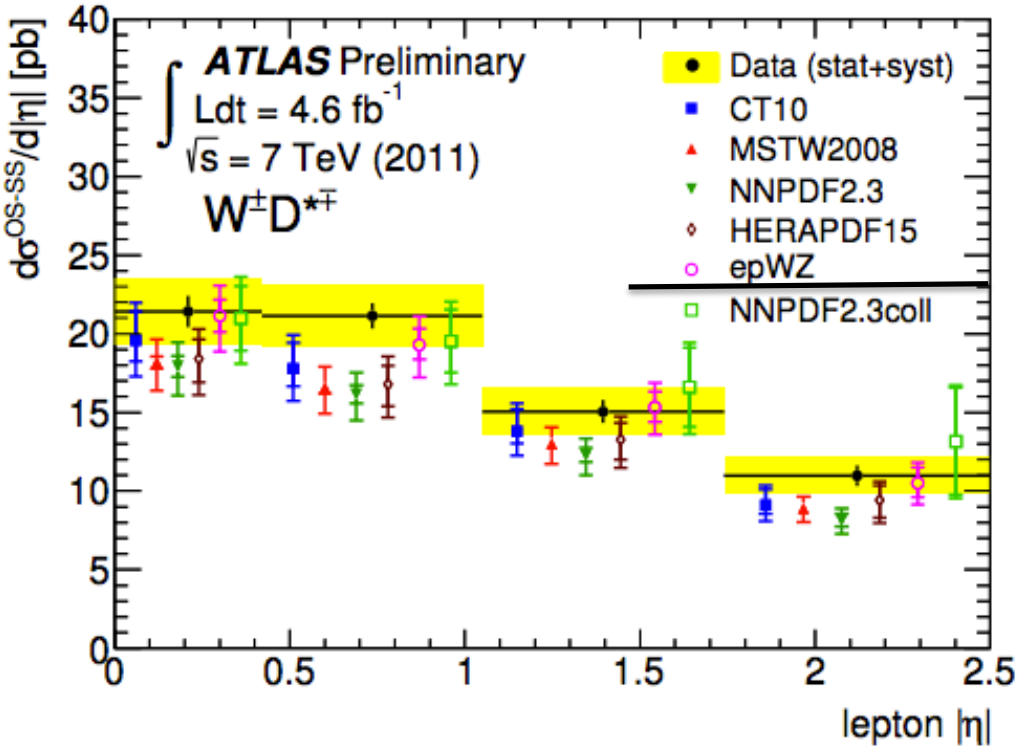

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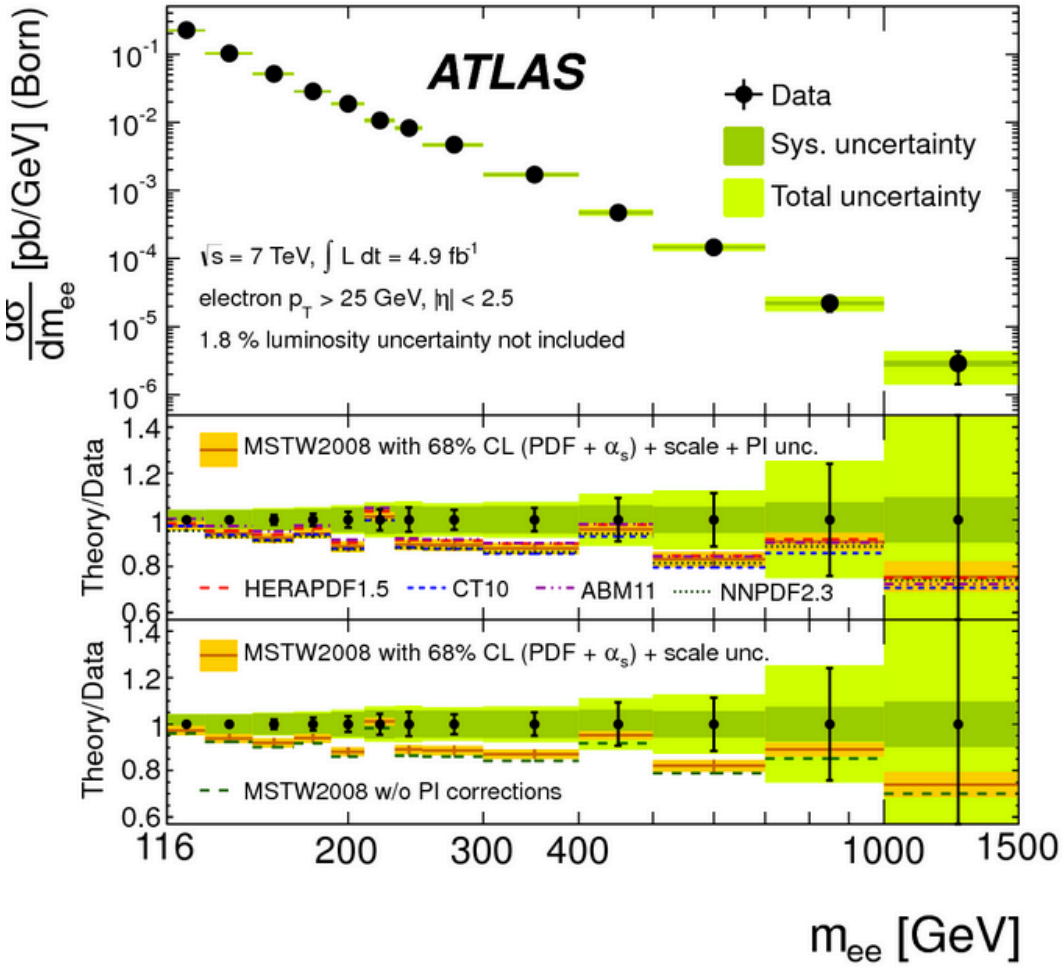
High Mass Drell-Yan at ATLAS

[arXiv:1305.4192]

- ATLAS High Mass Drell-Yan data In Z → e^+e^- channel



Data is confronted with NNLO predictions corrected for NLO EW effects (FEWZ3.1 framework)

- Currently all PDFs shown give a good description

Theoretical issue:

The electroweak corrections include a positive contribution from photon-induced background

- 3% effect in the highest bin mass

(estimated using MRST2004qed PDF set and verified by SANC group)

and a real W,Z boson emission in single-boson production

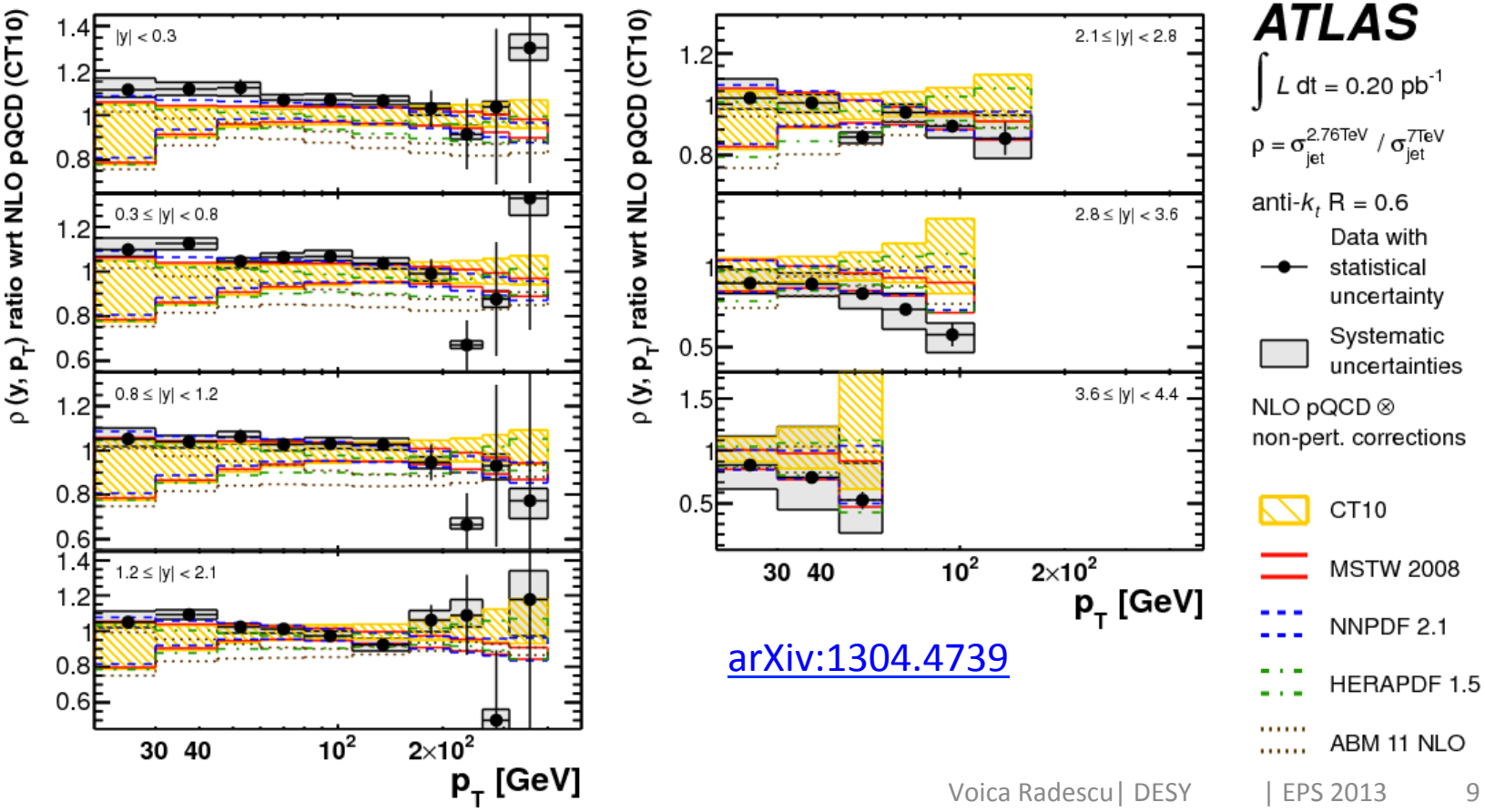
- < 2% effect in the highest mass bin

(estimated using MADGRAPH)

The size of the photon-induced contribution is similar to the sum of the PDF, αs and scale uncertainties

Ratio of Jets at different beam energies

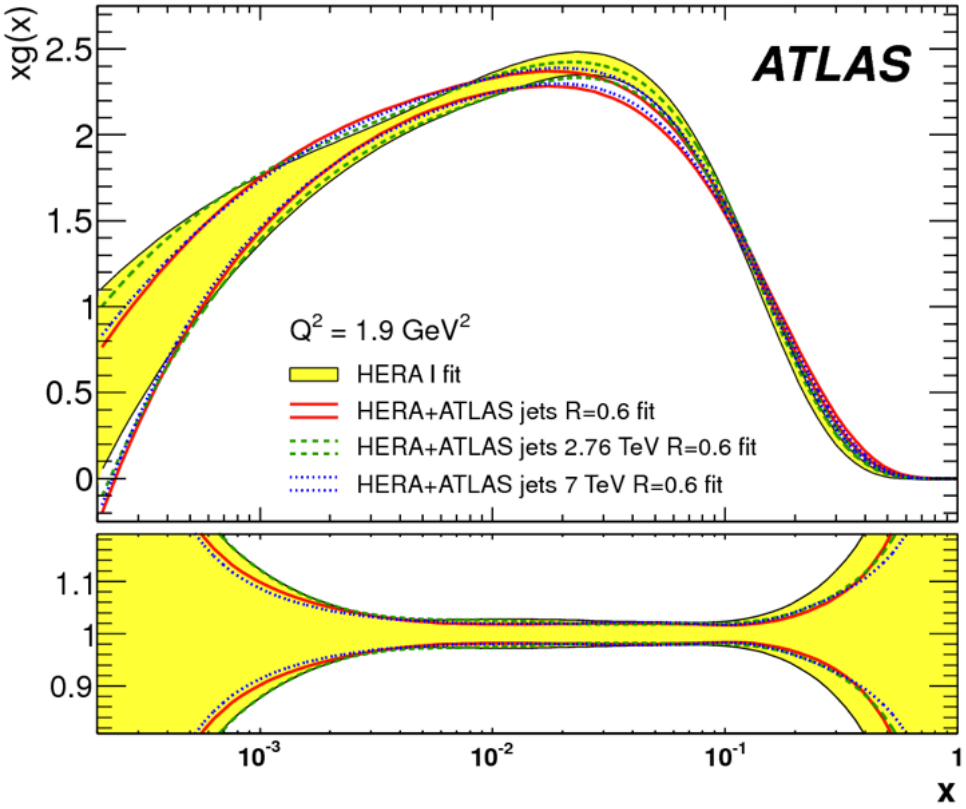
- ATLAS provides inclusive jet and di-jet cross-sections for anti-kt algorithm differential in p_T (for dijet in m_{12}) and y
- LHC provided two different beam energies of 2.76 and 7 TeV which probe different x and Q^2 values for the same p_T and y ranges so that theoretical uncertainties due to PDFs do not cancel in the ratio:
  - ➔ these ratio data have more impact on PDF determination than the separate data sets
  - ATLAS provides ratio of 2.76 TeV to the 7 TeV jet cross sections in ratio to the CT10 predictions, compared to the predictions of MSTW2008, NNPDF2.1, HERAPDF1.5, ABM11:

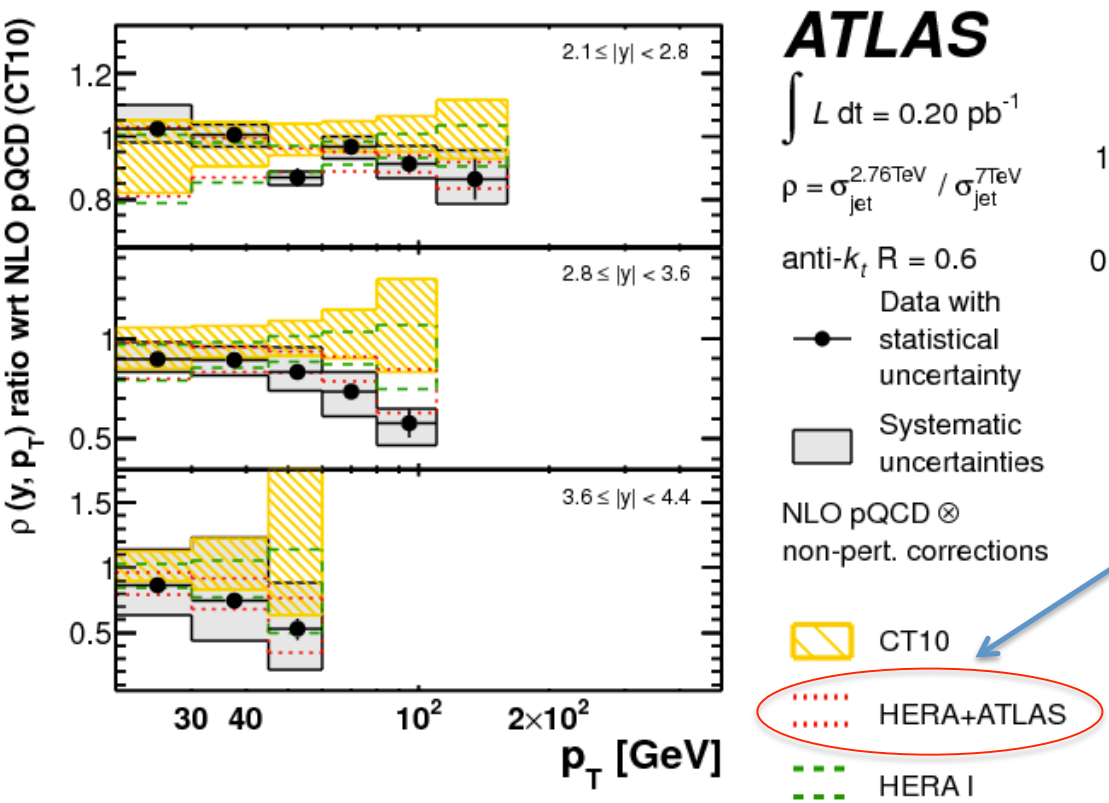


arXiv:1304.4739

Impact of ratio of jets at different beam energies

- Employing HERAFitter framework an NLO fit is performed to study sensitivity to gluon PDFs.
  - Compare the gluon for PDF fit using just HERA data and a fit using HERA+ ATLAS 2.76 and 7 TeV jet data.
  - The gluon becomes harder and the uncertainties on the gluon are reduced.





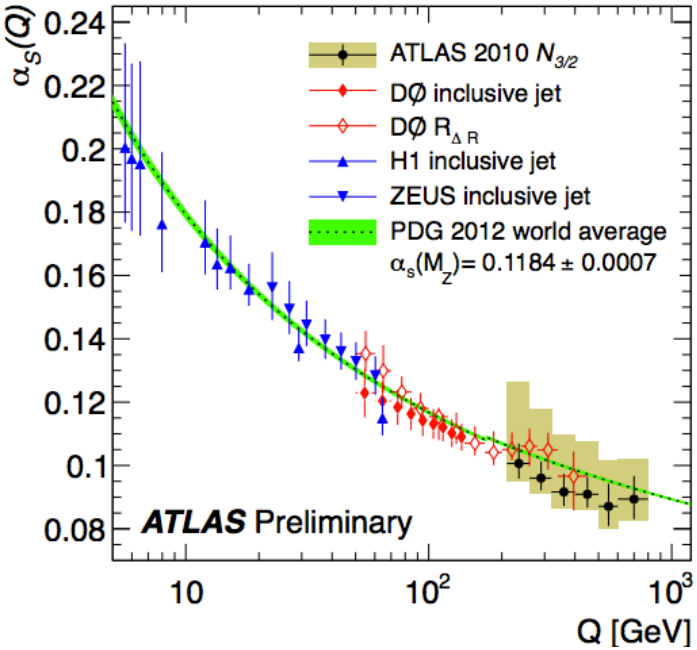
Comparing Fit result including this measurement there is improvement in high y region

Other jet measurements at ATLAS

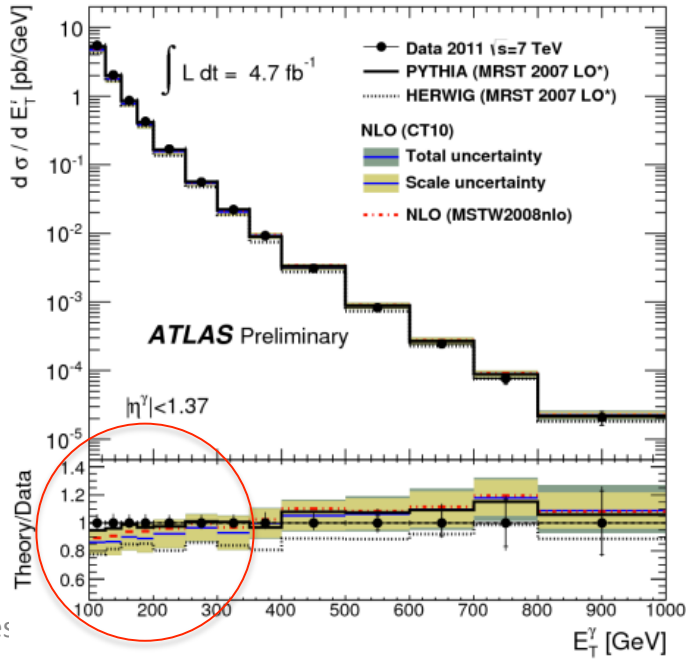
- Determination of alphas from ratio of events with ≥3 jets to ≥2 jets ratio of 2010 data: [ATLAS-CONF-2013-041]
  - Two observables were used: $R_{3/2}$ (in lead pt), $N_{3/2}$ (all pt)

$$\alpha_S(M_Z) = 0.111 \pm 0.006(\text{exp.})^{+0.016}_{-0.003}(\text{theory})$$

Improvements are possible on experimental aspects of the determination of αs:
→ Results using a different physical observable and the full 2012 dataset are coming soon
→ NNLO predictions for jets are needed



- Photon Production has potential to add constraint to gluon PDF:
  - New ATLAS result from 2011 data for the region 100-1000GeV [ATLAS-CONF-2013-022]
  - NLO preditions are calculated using Jetphox:
    - At low ET 5% difference between CT10 and MSTW2008



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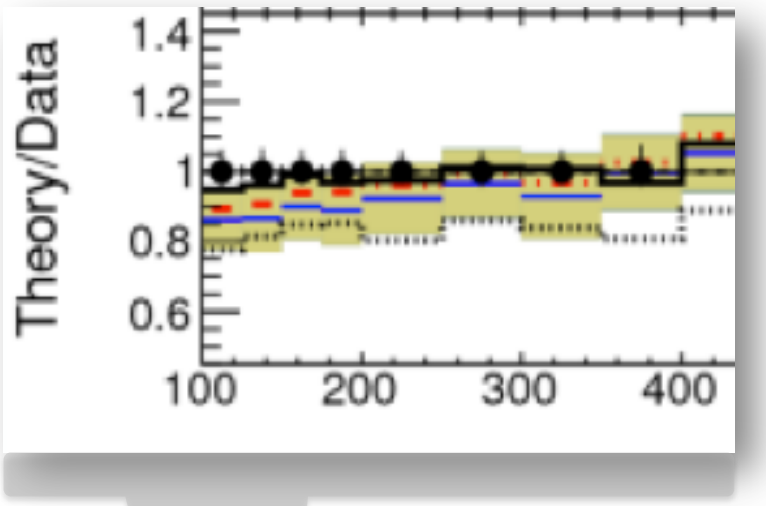

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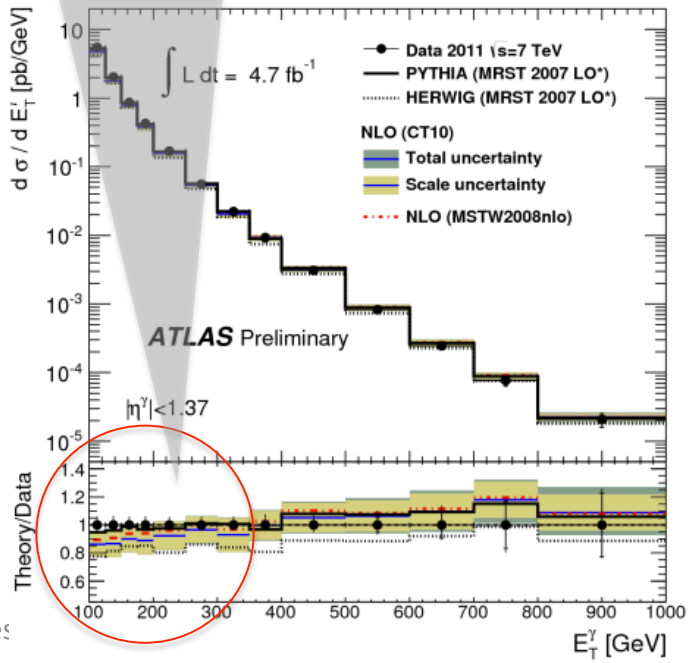
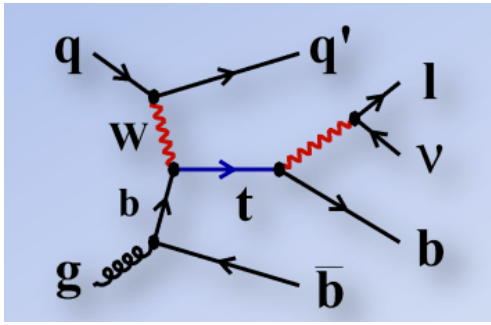
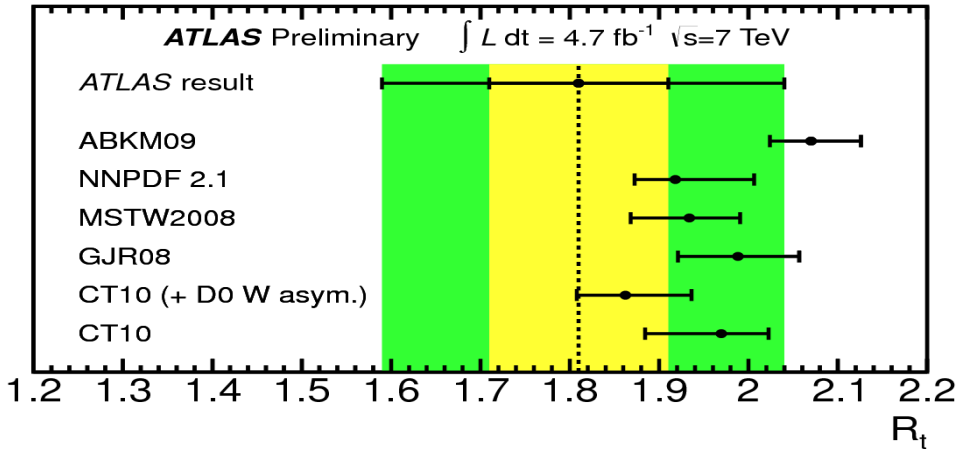


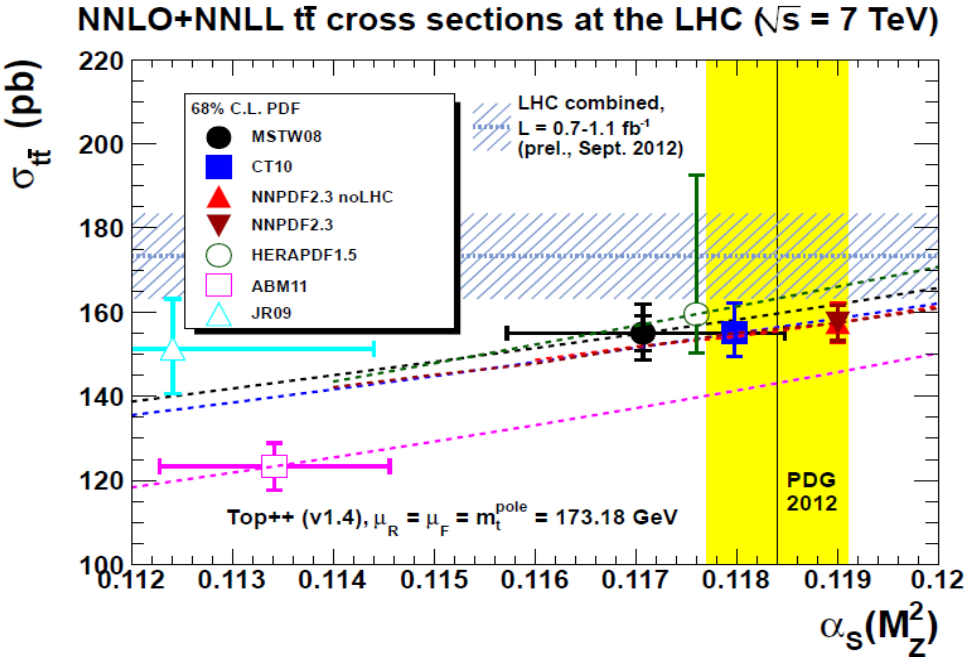
Sensitivity to PDFs from ATLAS top production

- Single t/tbar ratio has the potential to provide u/d [ATLAS-CONF-2012-056]





- The ATLAS and CMS combined ttbar cross section is 173 ± 2.3 ± 9.8pb [ATLAS-CONF-2012-134/ CMS-TOP-12003]
  - The predictions for this cross section have a strong $\alpha_S(M_Z)$ dependence



Summary and outlook

- Standard Model LHC measurements can add PDF discrimination and PDF improvement:
  - W, Z inclusive:light quark sea is flavour symmetric:
    - Confirmed by preliminary W+c
    - High mass DY: potential feedback on dbar-ubar, importance of EW corrections
  - Exploiting different energy beams for inclusive jets brings forward sensitivity to the gluon PDFs.
    - Photon-jet measurements → gluon PDF
    - First alphas from ATLAS from 3/2 jets 2010 → consistent with world average
  - Top measurement is becoming a valuable player in the impact on PDFs (and alphas)

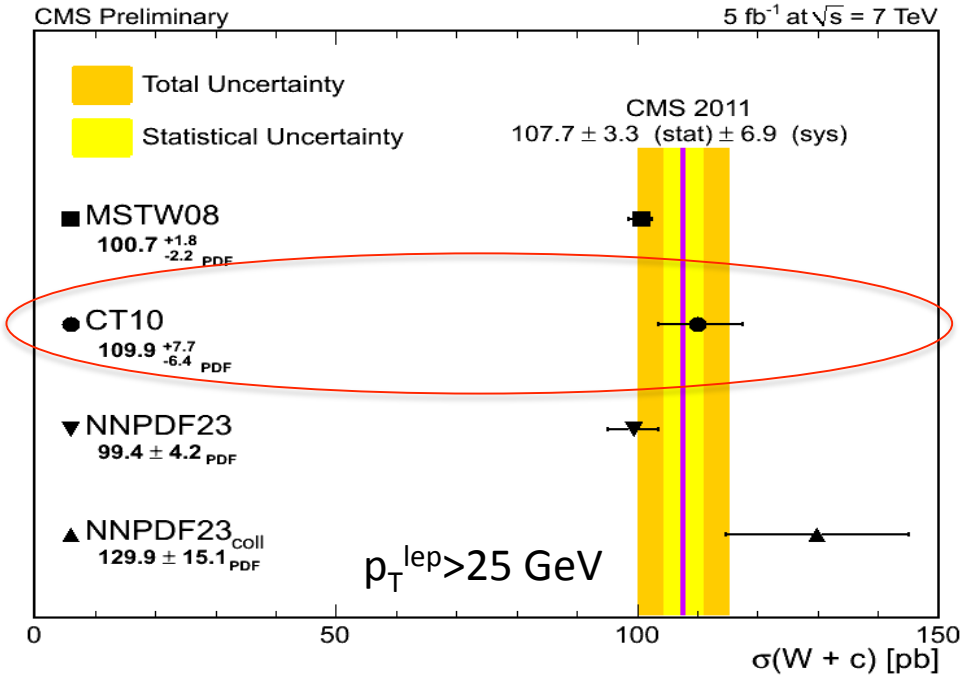
- More precision measurements from LHC are to come also with 2012 data:
  - W, Z, W+c production, low invariant mass, top, W,Z+ c,b, W,Z+jets, …

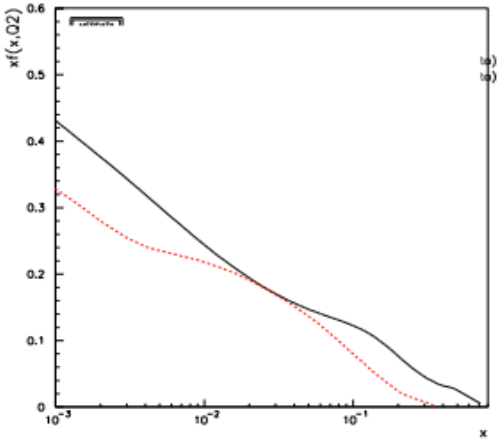
W+c sensitivity to strange from CMS

[CMS SMP-12002]

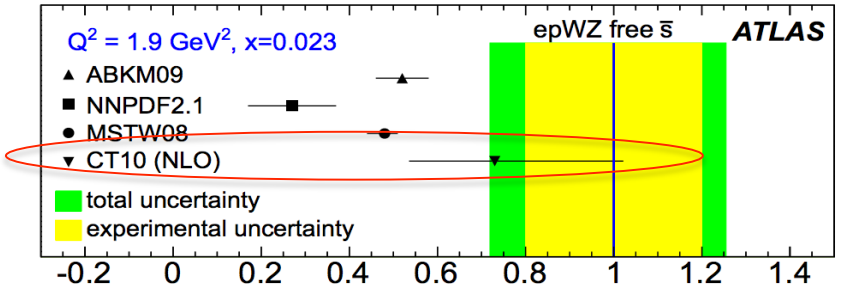
Question: would other measurements confirm ATLAS favour of sbar=dbar?

- CMS has release a preliminary W+c measurement directly sensitive to strange:
- Very good agreement with CT10 and not in such good agreement with NNPDF2.3 (Coll) but this has VERY large strangeness





Q^2=2 GeV^2
NNPDF23(Coll)
Strange
Downsea



ATLAS determination of the strange sea density

- To assess the impact of ATLAS data, a minimum set of input data are used to allow PDF determination:
  - HERA I combined data [JHEP 01, 109, 2010]
    - NC, CC e+p and e-p $7.5 < Q^2 < 10000$ and $0.0001 < x < 0.65$
  - ATLAS 2010 W,Z data [CERN-PH-EP-2011-06]

- Two types of fits are performed with different treatments of strangeness:
  - Fixed Strange fit: At the starting scale, strange is fully coupled to down sea
    - Information from di-muon production in neutrino induced deep inelastic scattering data

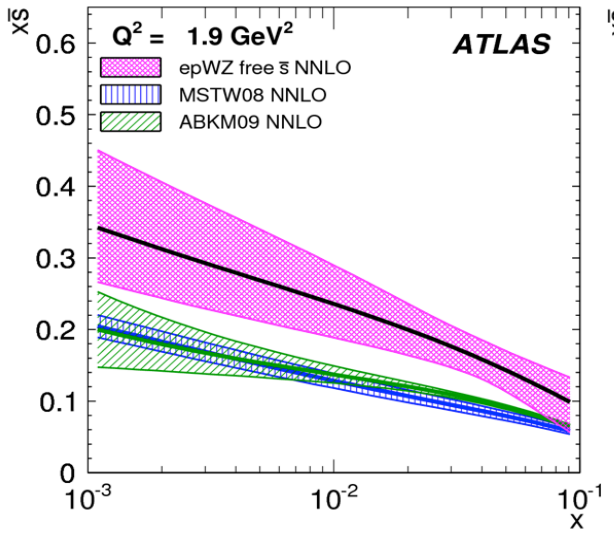
$$r_s = 0.5(s + \bar{s})/\bar{d},\ r_s = 0.5$$

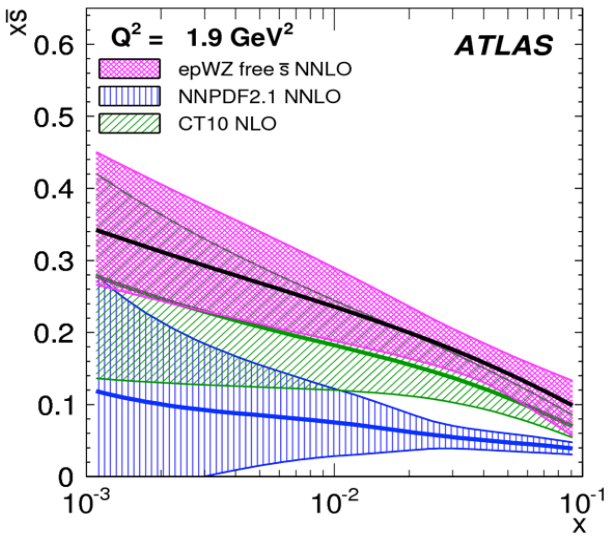
  - Free Strange fit: parametrise strange distribution as done with other individual PDFs

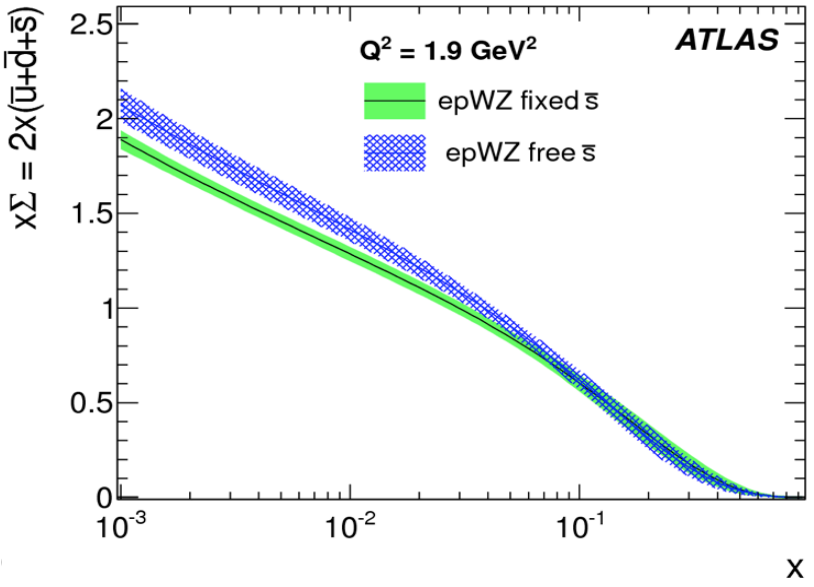
$$x\bar{s} = xs = r_s A_{\bar{d}} x^{B_{\bar{d}}} (1 - x)^{C_s}$$

Fits are performed using HERAFitter framework

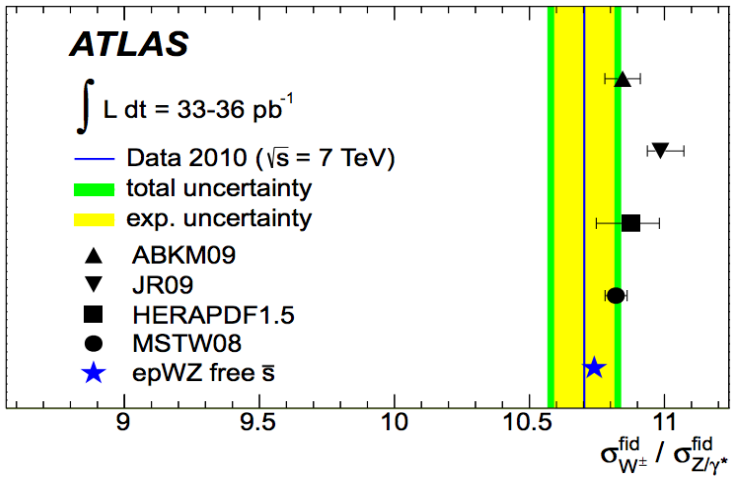
Strange distribution







- Comparisons of the strange quark density resulting from th free strangeness epWZ fit with the predictions of different PDF sets.
- A change of the strange density with fixed F2 measured by HERA must affect the light sea xΣ.
  - Enhancement by about 8% at the starting scale
- The free strange fit provides the best description of the measured W/Z cross sections ratio.



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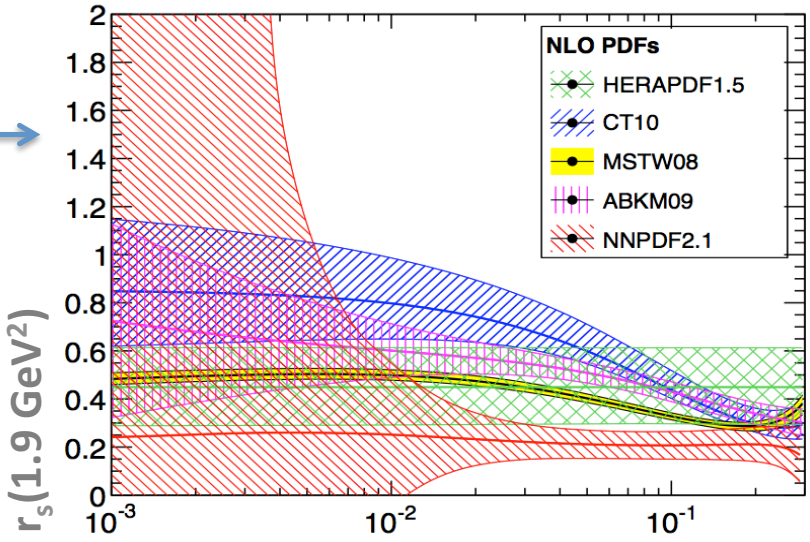
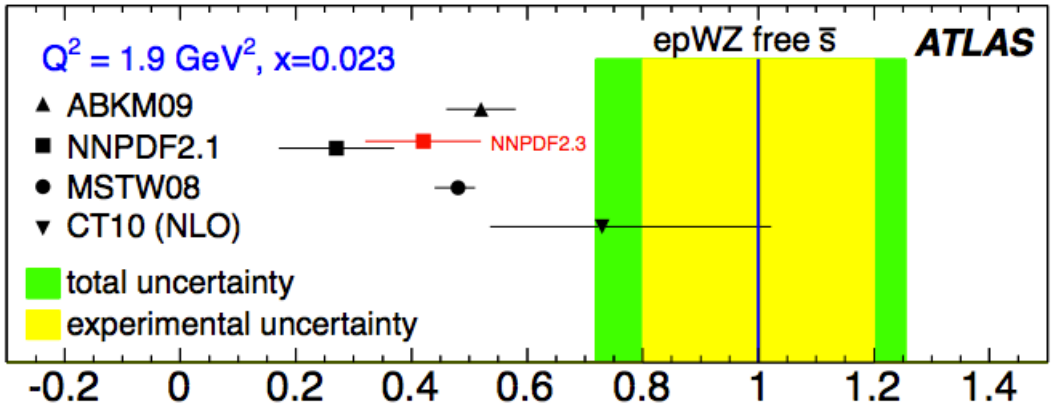


Courtesy of G. Watts



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ATLAS Inclusive Jet production

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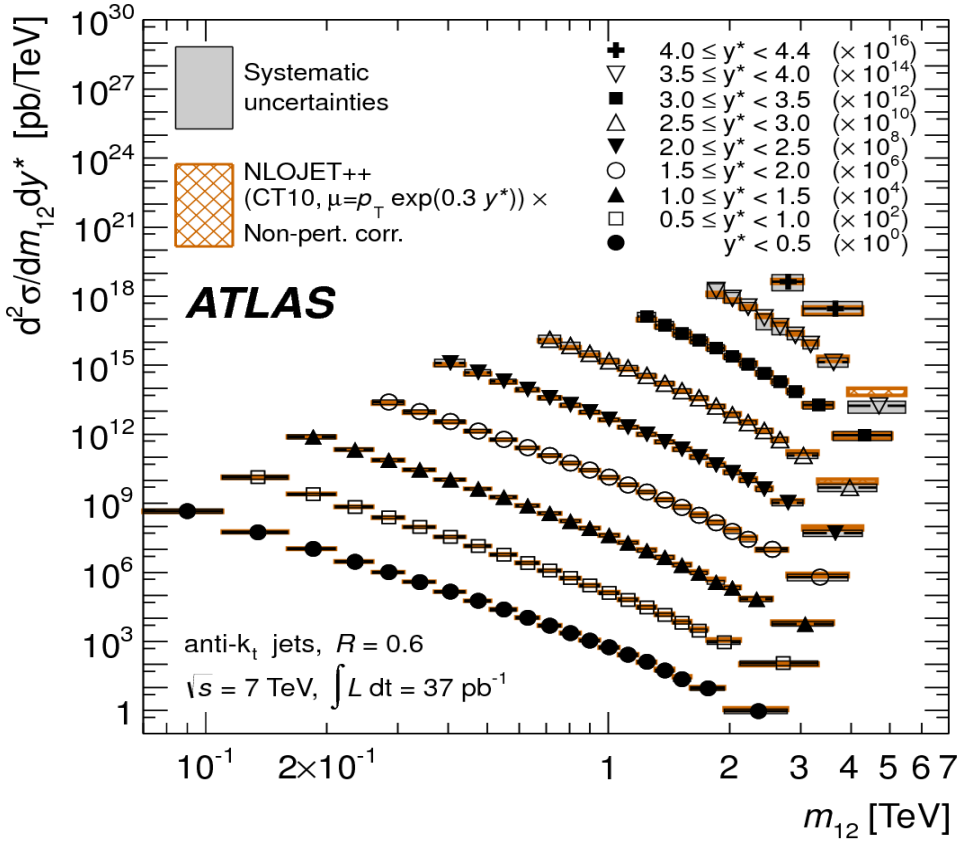
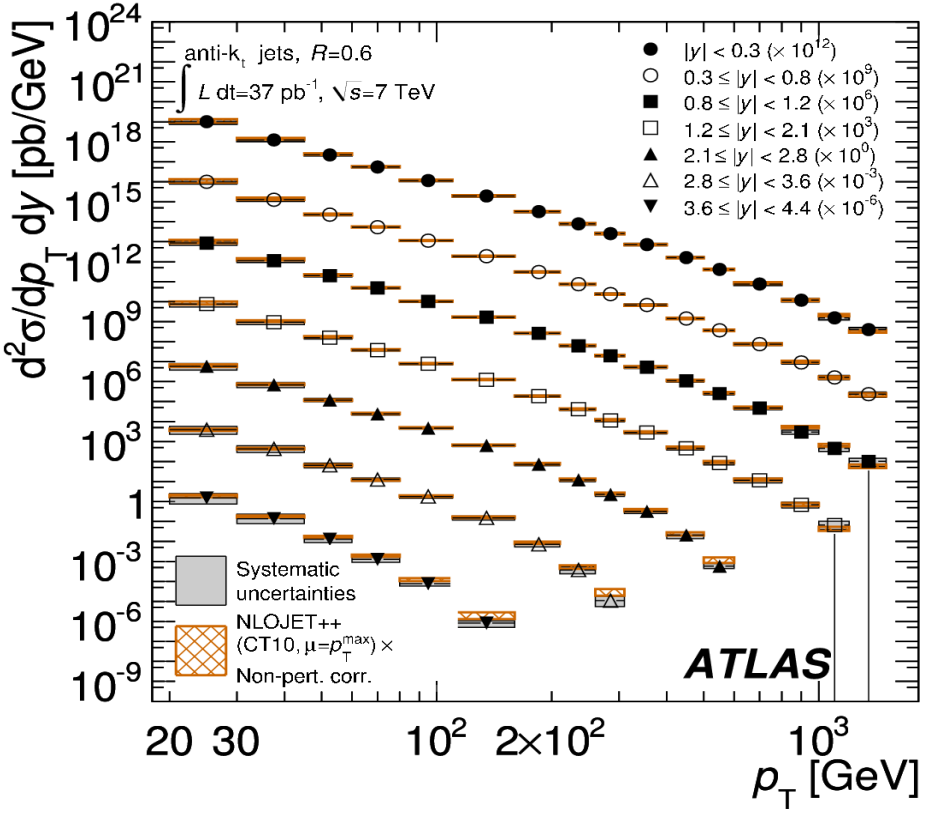
  (Shown here for R=0.6, R=0.4 also available)

  [Phys ReV D86(2012)014022]

  - sensitive to gluon at high x

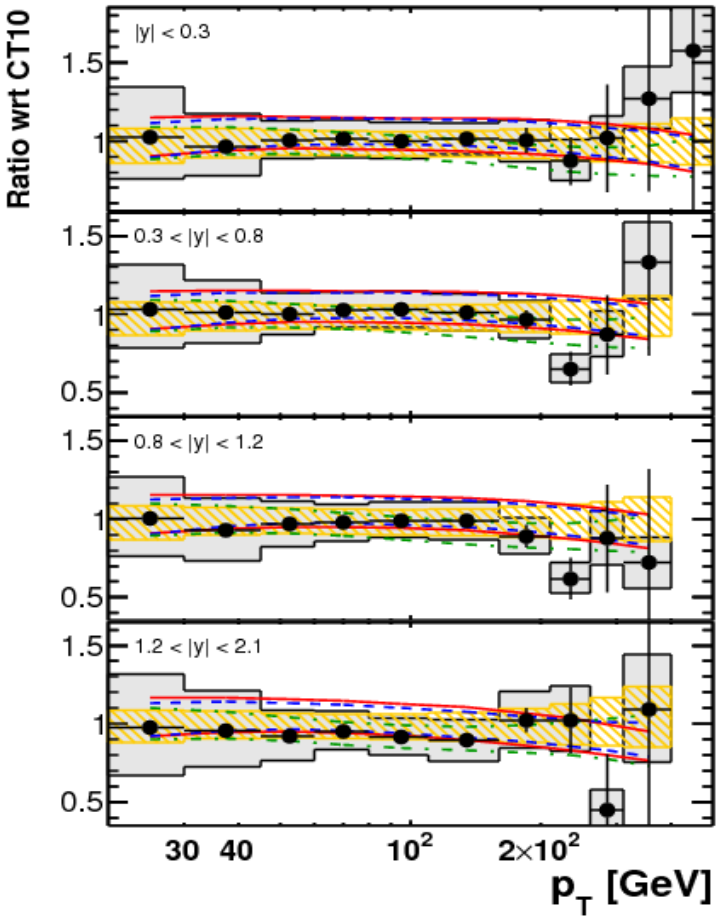


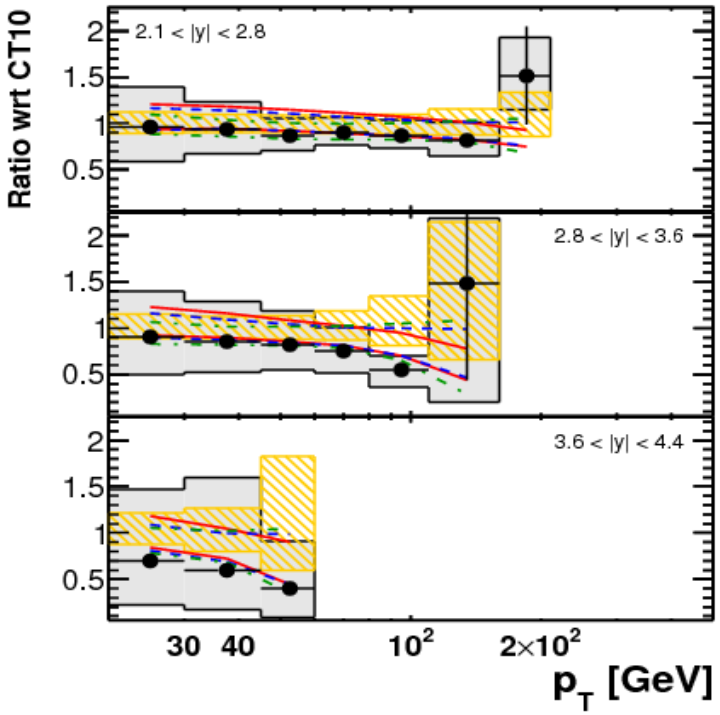


- Measurements are provided with full information on correlations
  - 90 sources of uncertainties

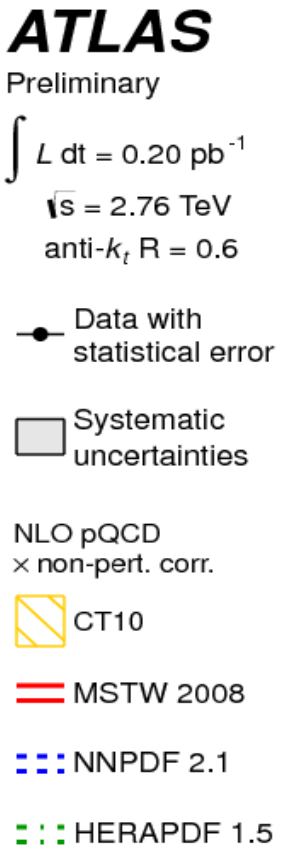
Inclusive Jet production vs predictions

- In 2011, data of 0.2 pb^{-1} was collected for 2.76 TeV [ATLAS-CONF-2012-128]
  - The inclusive jet cross sections are shown in ratio to the predictions of CT10, with the predictions of other PDFs also illustrated.





Measurement is consistent with all theory predictions using different PDF sets.



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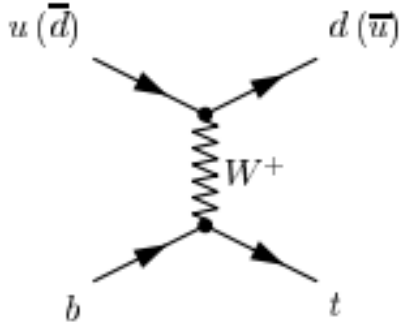
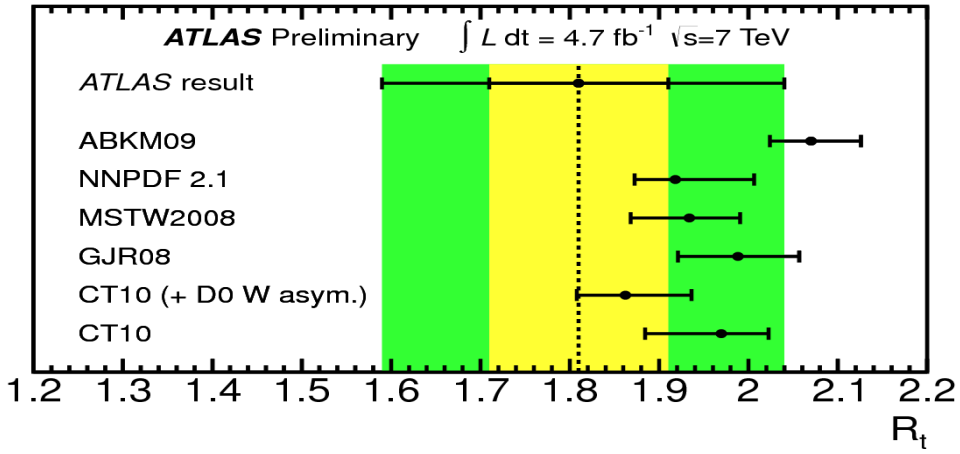
- Single t/tbar ratio has the potential to provide u/d [ATLAS-CONF-2012-056]





- The ATLAS and CMS combined ttbar cross section is 173 ± 2.3 ± 9.8pb [ATLAS-CONF-2012-134/ CMS-TOP-12003]
  - The predictions for this cross section have a strong $\alpha_S(M_Z)$ dependence