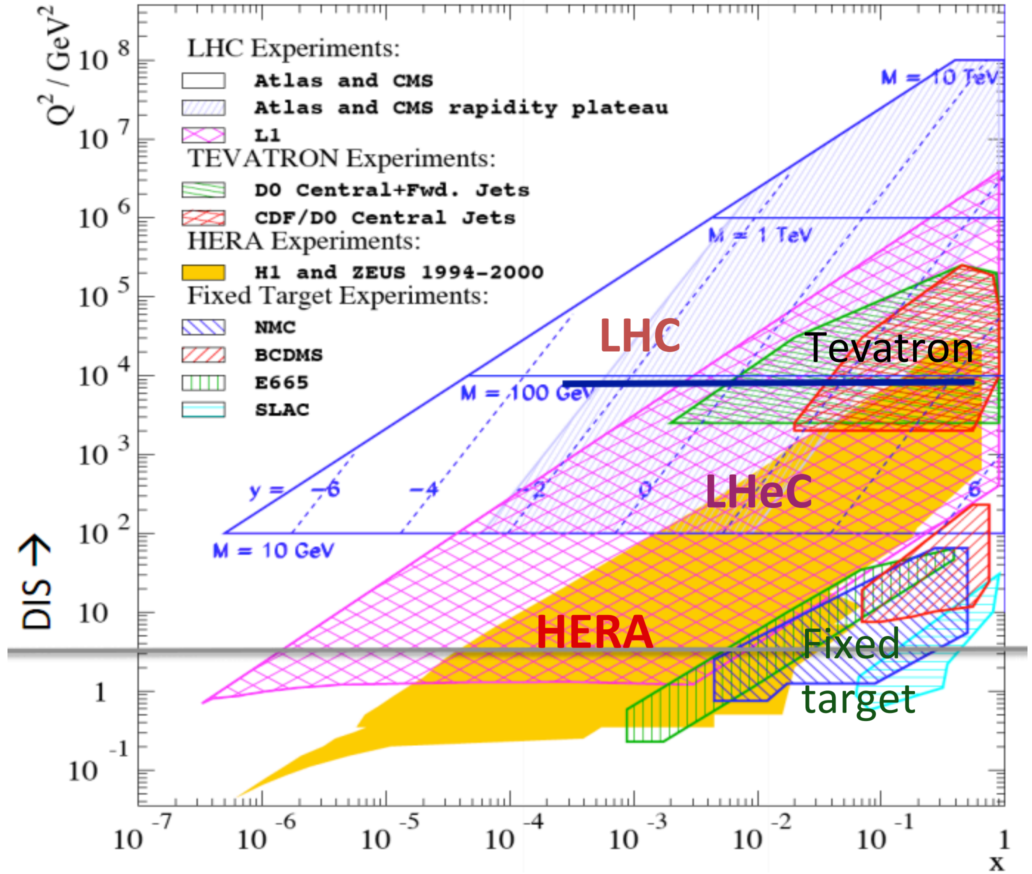
# Recent experimental constraints on proton structure


Voica Radescu (DESY)


DIS 2013, Marseille




This talk is a guided tour on recent results sensitive to proton structure from:

- Past
- Present
- Future

experiments


essential to permit further discoveries

# Recent experimental constraints on proton structure

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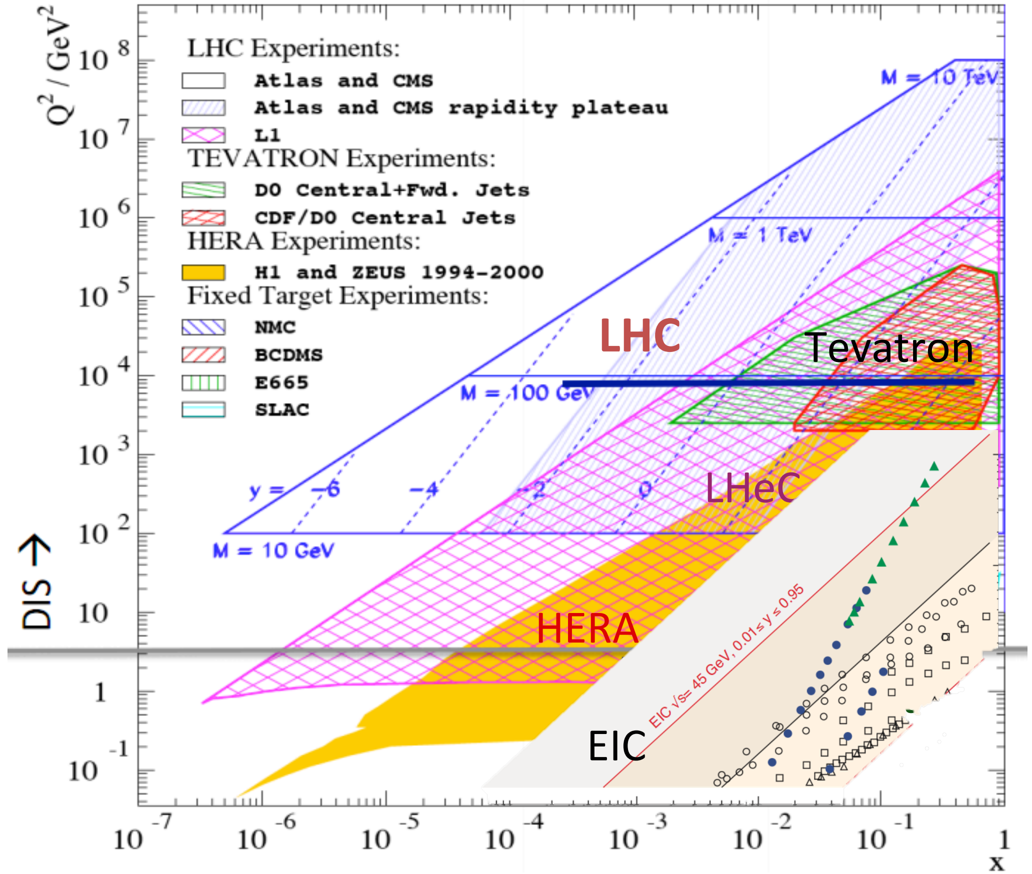
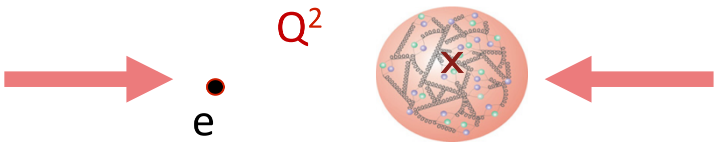


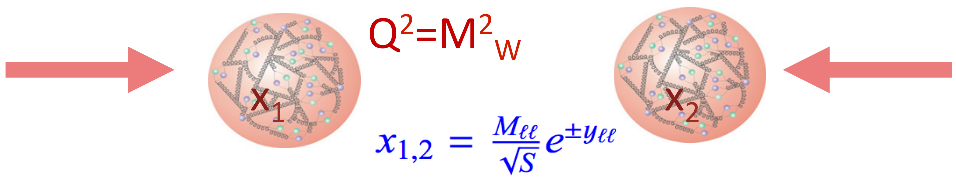
# Proton Structure

- Factorization theorem:
  - cross section can be calculated by convoluting short distance calculable partonic reaction with universal parton distributions (PDFs)

- Probing Proton Structure via Deep Inelastic Scattering using elementary particles such as:
  - Neutrinos, muons (fixed target experiments)
  - Electrons (fixed target and collider experiments)



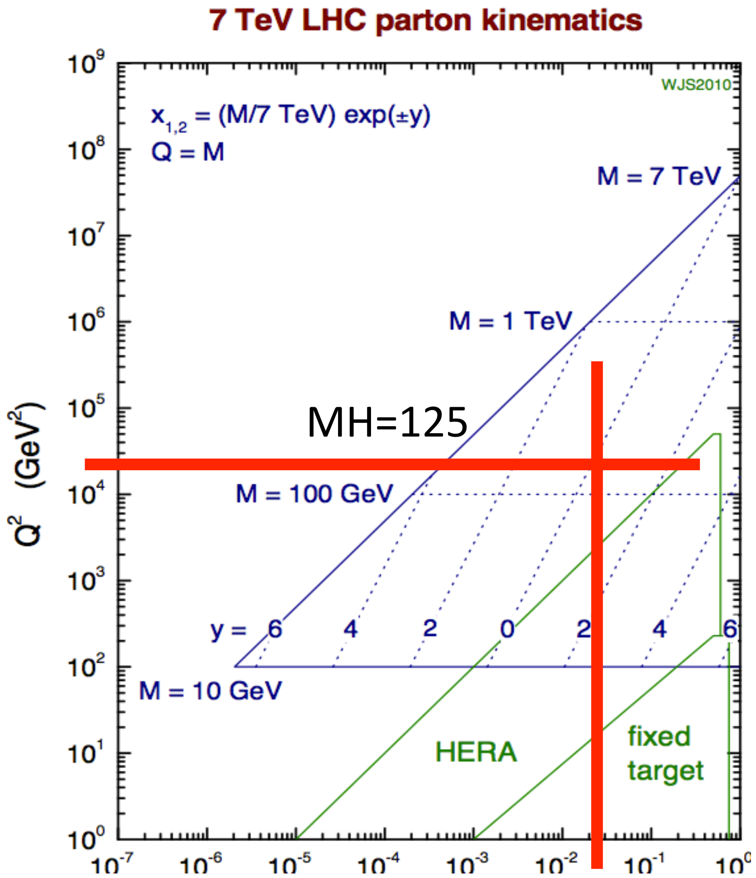

- Knowledge on proton structure can be complemented by the collider experiments at Tevatron and LHC




Persistent experimental effort over the last 40 years both by fixed-target and collider experiments around the world supported by the theoretical developments

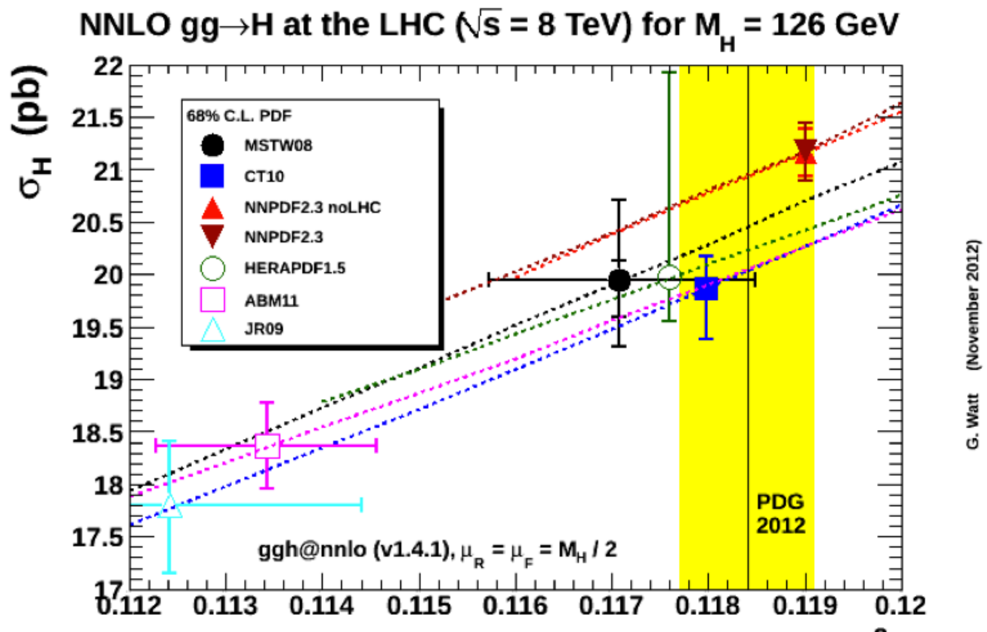
# Why do we need precise PDFs?

- It is just fundamental to understand the hadron structure and q(g)-g dynamics.
- Discovery of new exciting physics relies on precise knowledge of proton structure.
  - Various PDF groups using different approaches reach a level of overall agreement of ~10%




Courtesy of J. Stirling

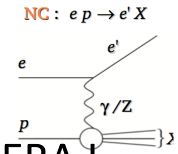
X~0.02




Courtesy of G. Watt

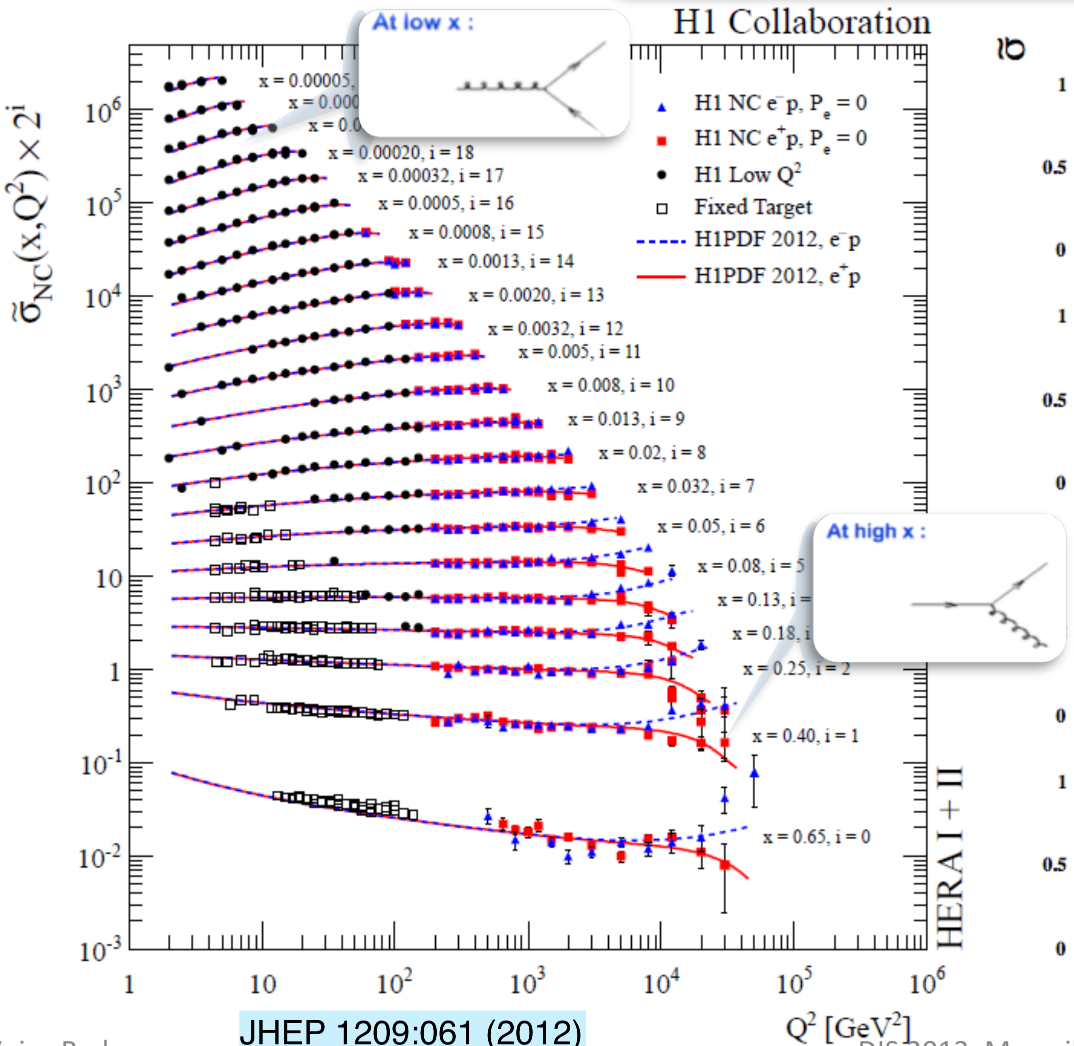
Although at x-0.02 there is precise data from HERA, PDFs are one of main TH uncertainties in Higgs production.

# Towards HERAPDF2.0: final Neutral Current

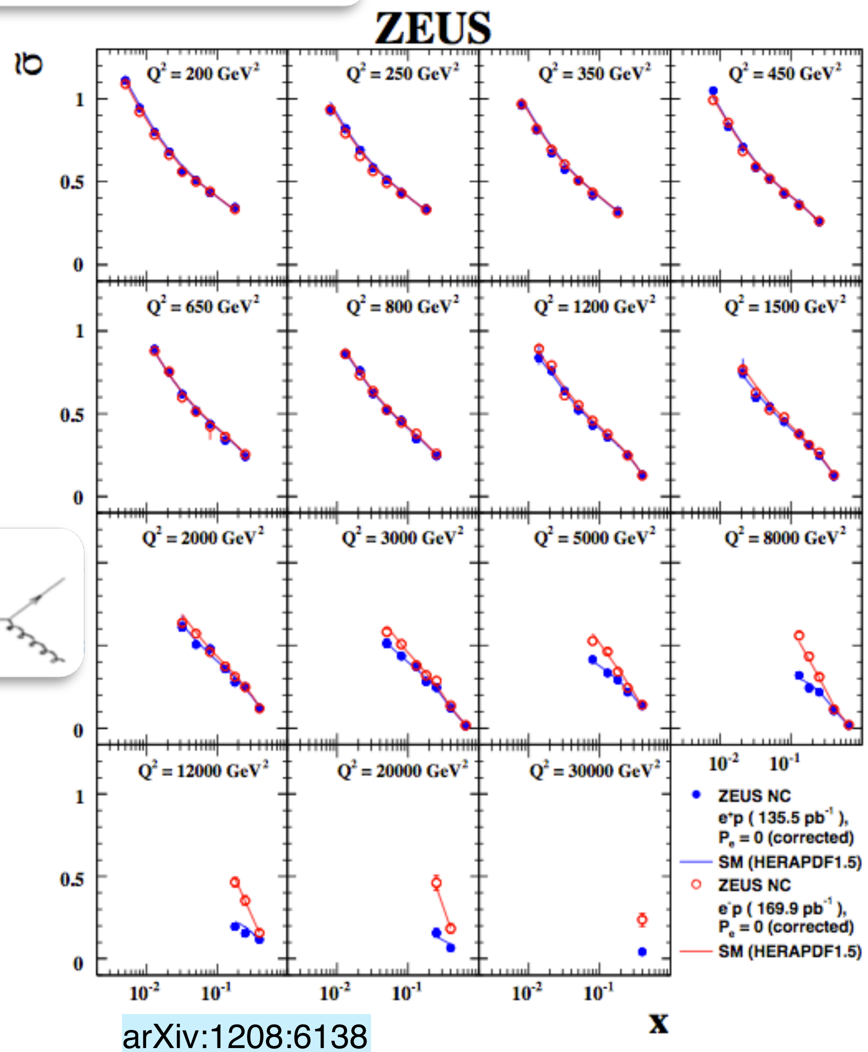



- Final NC (and CC) differential measurements from HERA II are ready to be combined with HERA I

$$\sigma_r^{\pm} = \tilde{F}_2^{\pm} \mp \frac{1-(1-y)^2}{1+(1+y)^2} x\tilde{F}_3 - \frac{y^2}{1+(1-y)^2}\tilde{F}_L$$

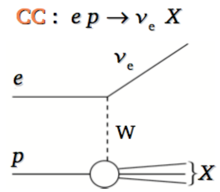



JHEP 1209:061 (2012)



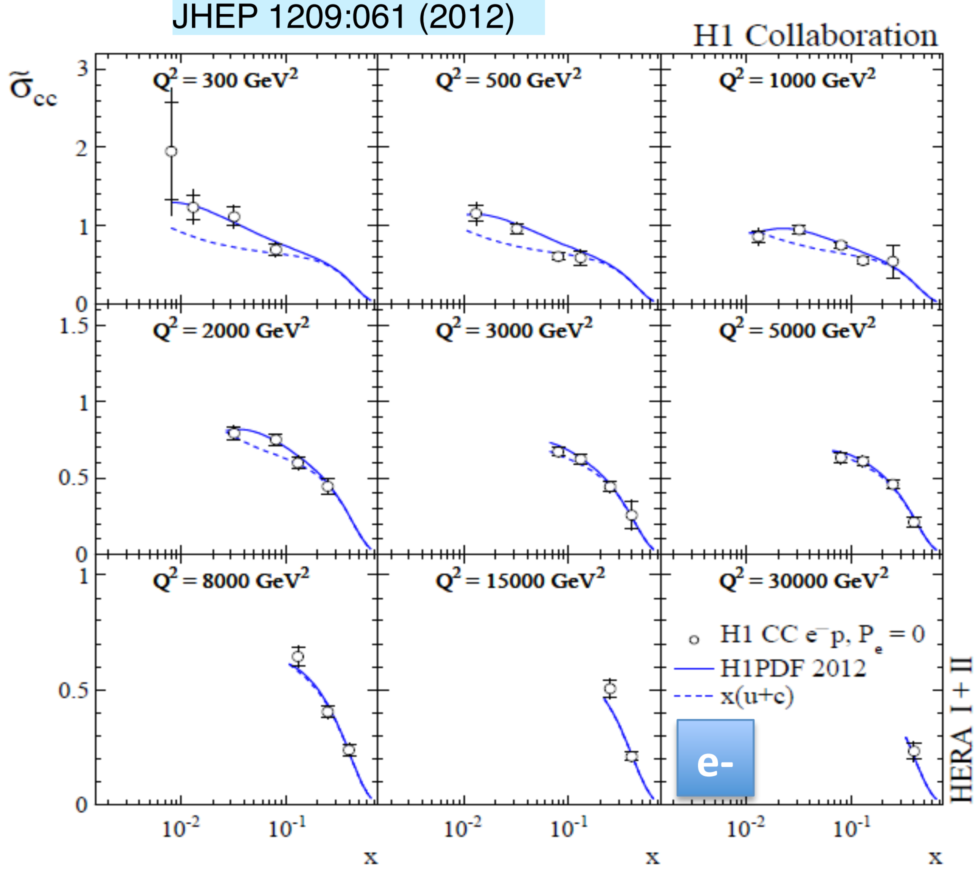

arXiv:1208:6138

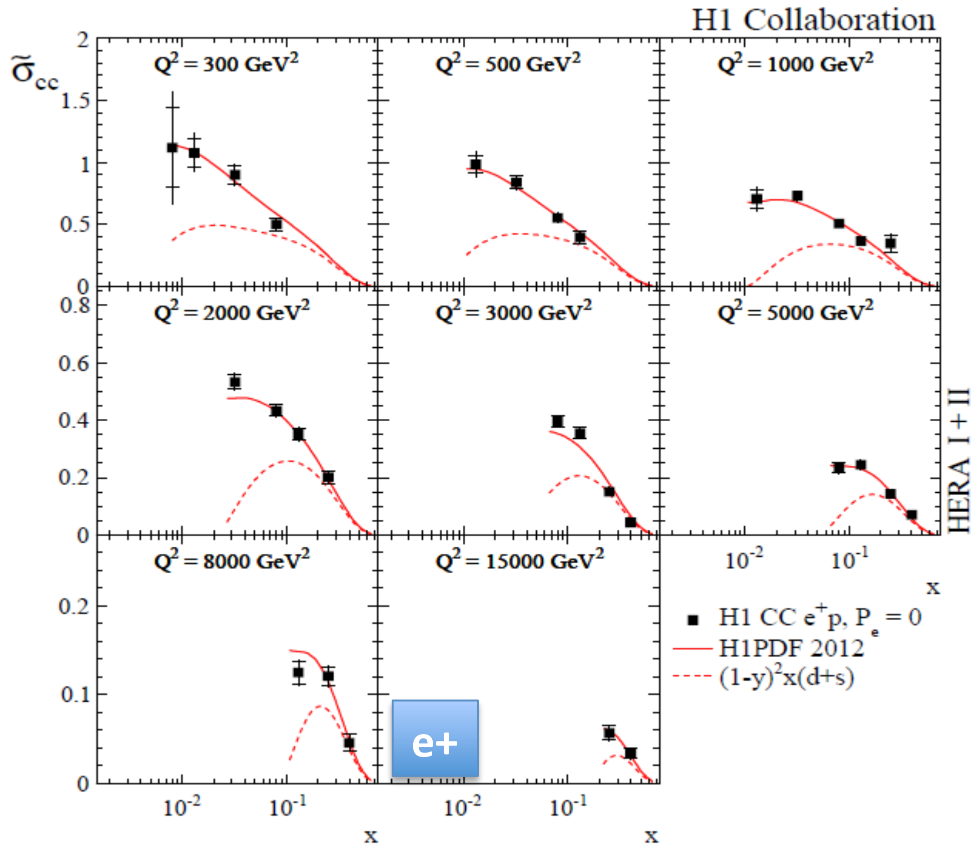
# Towards HERAPDF2.0: final Charged Current




HERA II CC improvement in precision: $e$+ ($e$-) $p$ by a factor of 3 (10) in luminosity compared to HERA I

JHEP 1209:061 (2012)



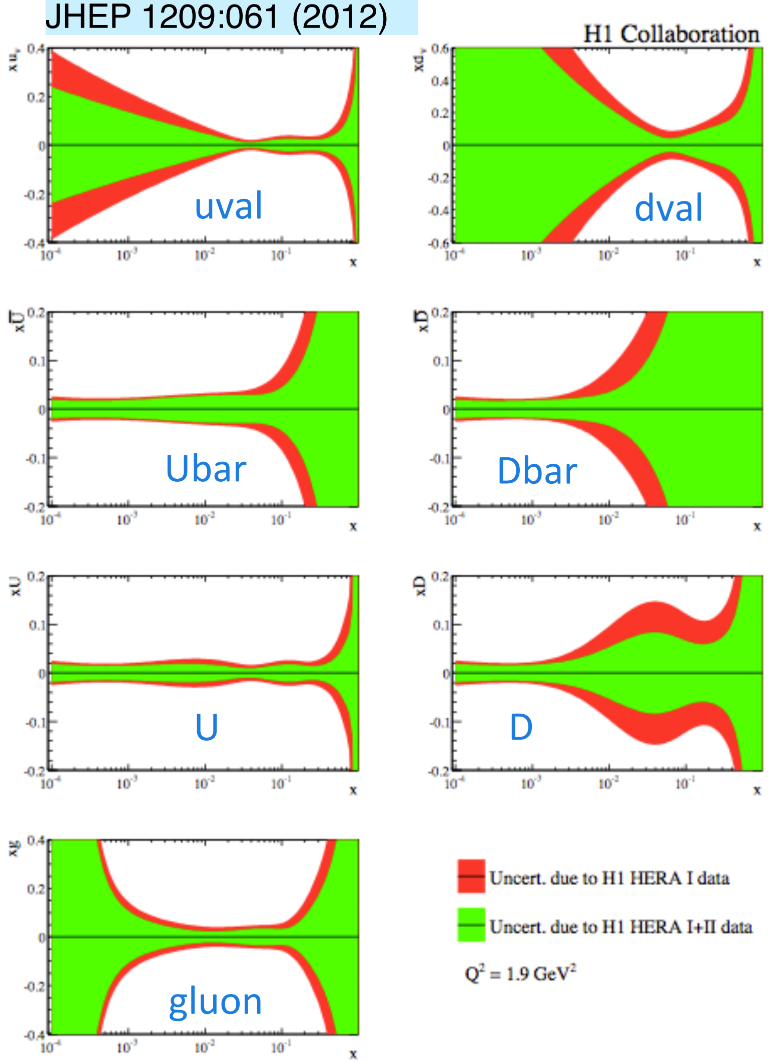



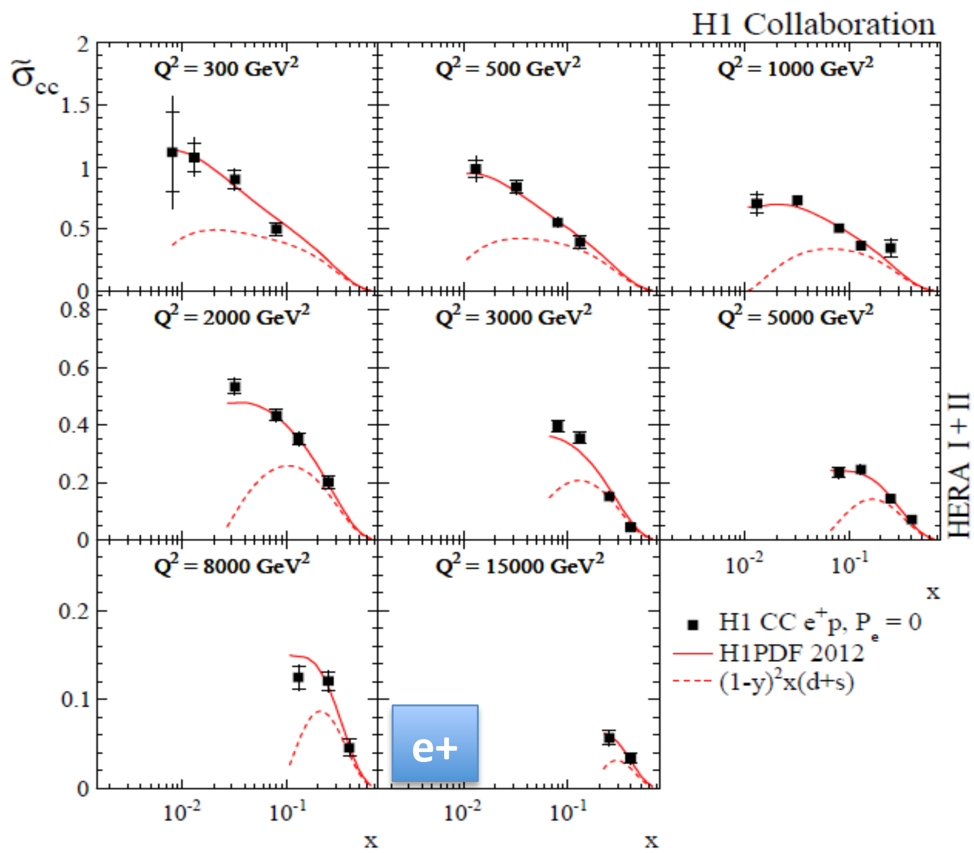

important step towards combination of complete H1 and ZEUS data samples.

# Towards HERAPDF2.0: impact of HERA II

HERA II CC improvement in precision: $e+$ ($e-$) $p$ by a factor of 3 (10) in luminosity compared to HERA I

JHEP 1209:061 (2012)




New measurements improve the PDF uncertainties at high x, in particular D=d+s

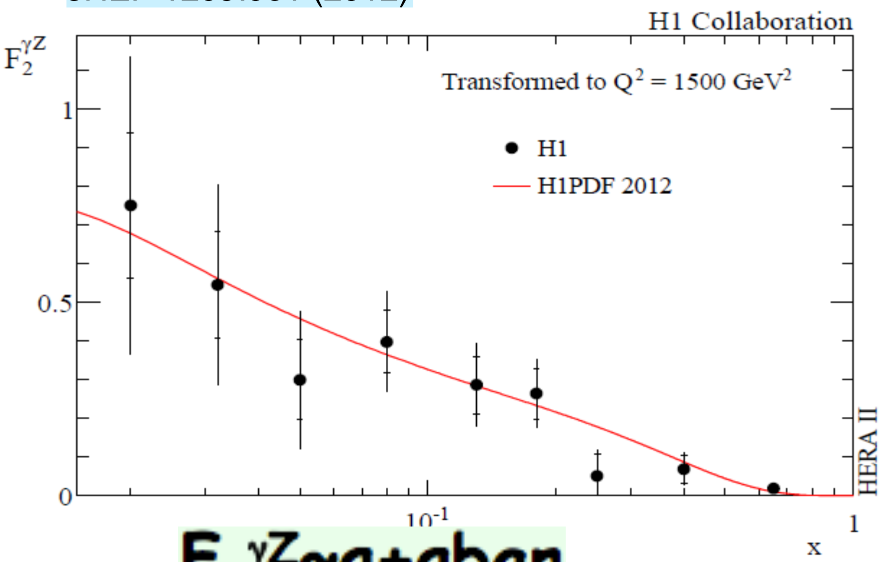
# Measurements of Asymmetries from HERA

- Explore charge asymmetry to extract $xF_3^{\gamma Z}$ (improved measurement from HERA I+II)
- Explore polarisation asymmetry to extract $F_2^{\gamma Z}$

$$\tilde{F}_2^{\pm} \approx F_2 - (v_e \pm P_e a_e)\kappa \frac{Q^2}{Q^2 + M_Z^2} F_2^{\gamma Z}$$

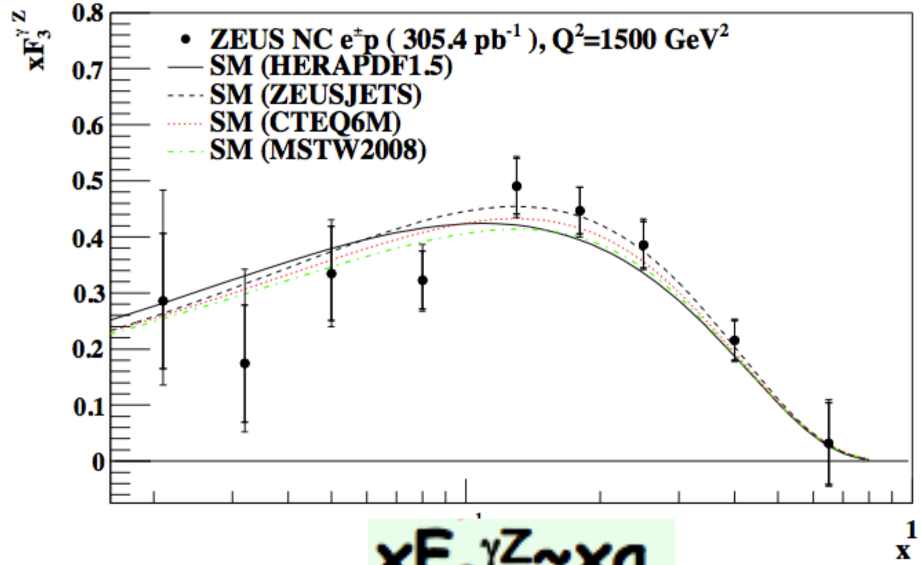
$$\sigma_r^{\pm} = \tilde{F}_2^{\pm} \mp \frac{1-(1-y)^2}{1+(1+y)^2} x\tilde{F}_3 - \frac{y^2}{1+(1-y)^2}\tilde{F}_L$$

JHEP 1209:061 (2012)




$F_2^{\gamma Z} \sim q + \bar{q}$

arXiv:1208:6138



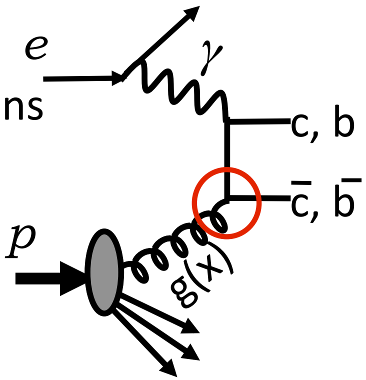

$xF_3^{\gamma Z} \sim xq_v$

The shape of the distribution reflects their parton sensitivity

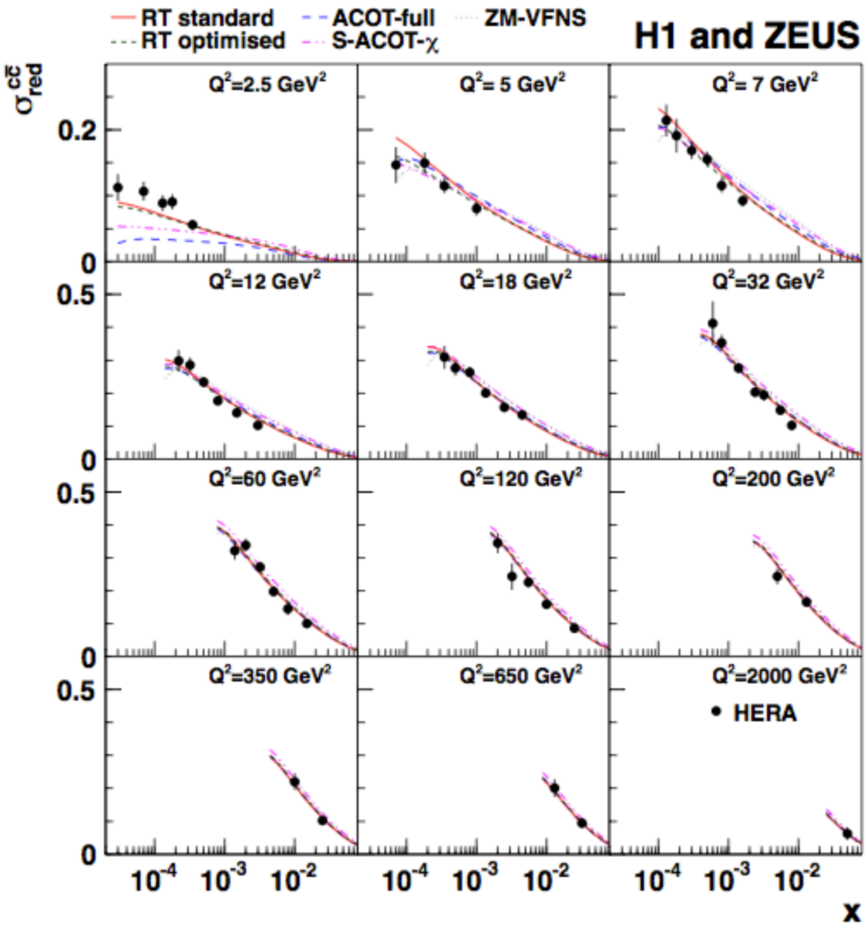
# Additional Constraints on PDFs: Charm at HERA

$F_2$ charm data provides a complementary way to impact gluon:

- precise measurements combined into one taking full account of correlations



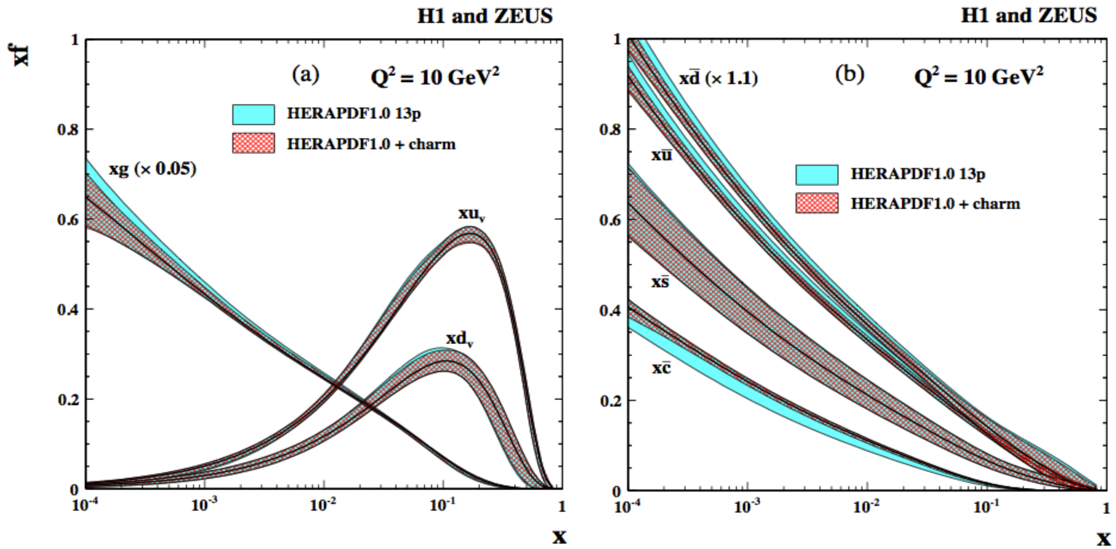

[more in O. Behnke's talk]




Eur. Phys. J. C 73:2311 (2013), [arXiv:1211.1182]

Inclusion of charm has impact on:

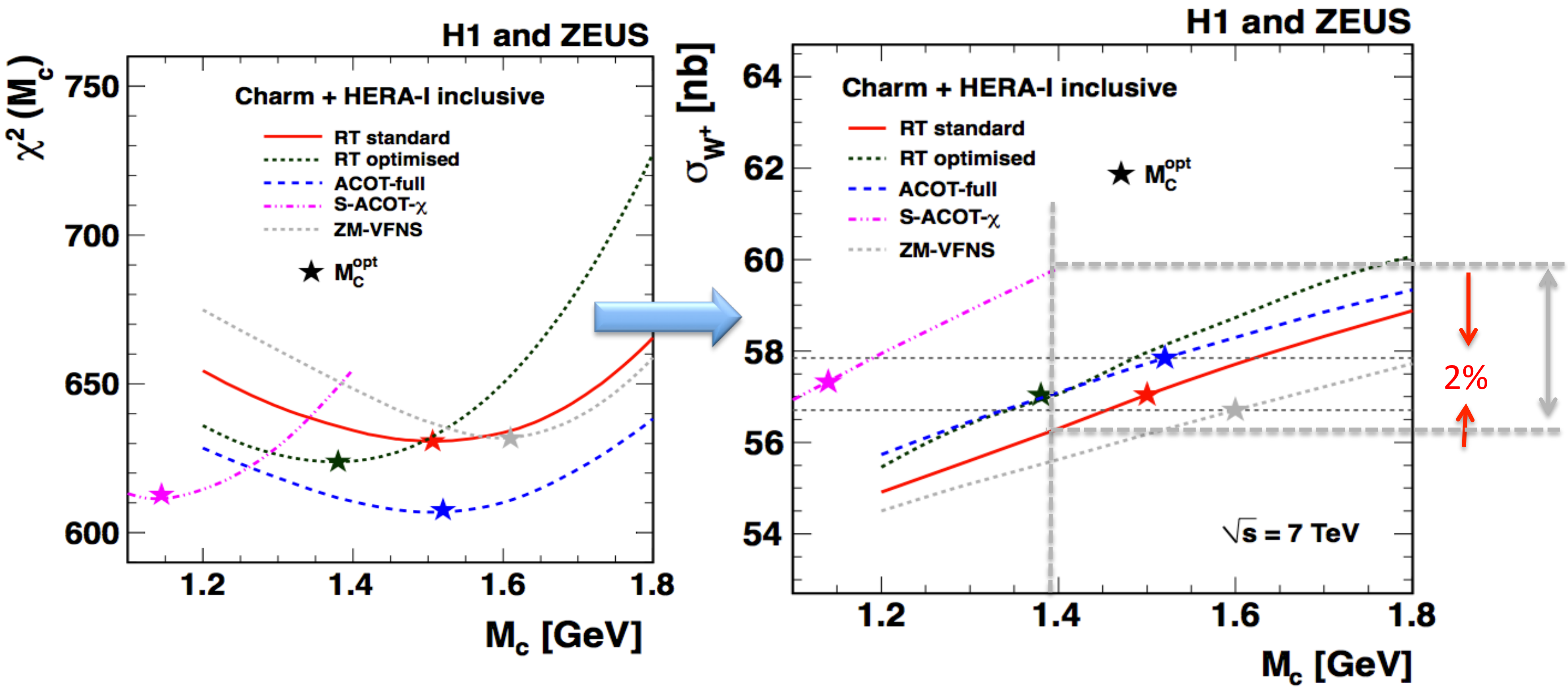
- gluon, charm and light sea:



# Impact of F2 charm on W,Z cross sections

- $F_2$ charm data helps constrain charm-quark by studying $m_c$ -choice in variable flavor number schemes

Eur. Phys. J. C 73:2311 (2013), [arXiv:1211.1182]

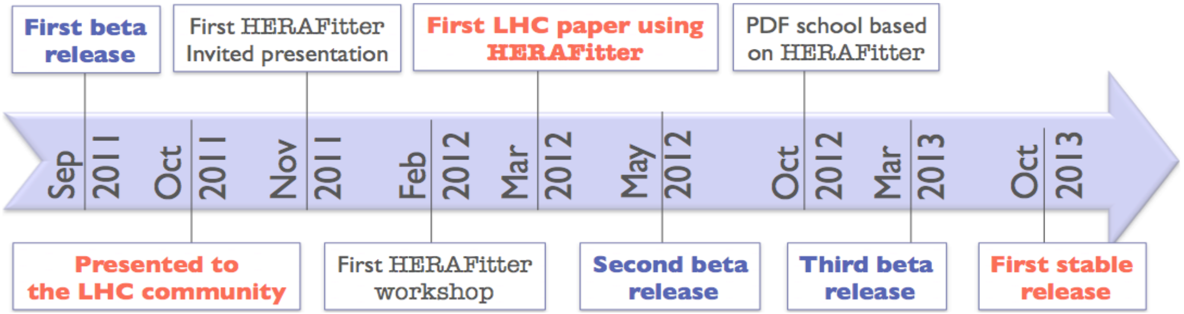


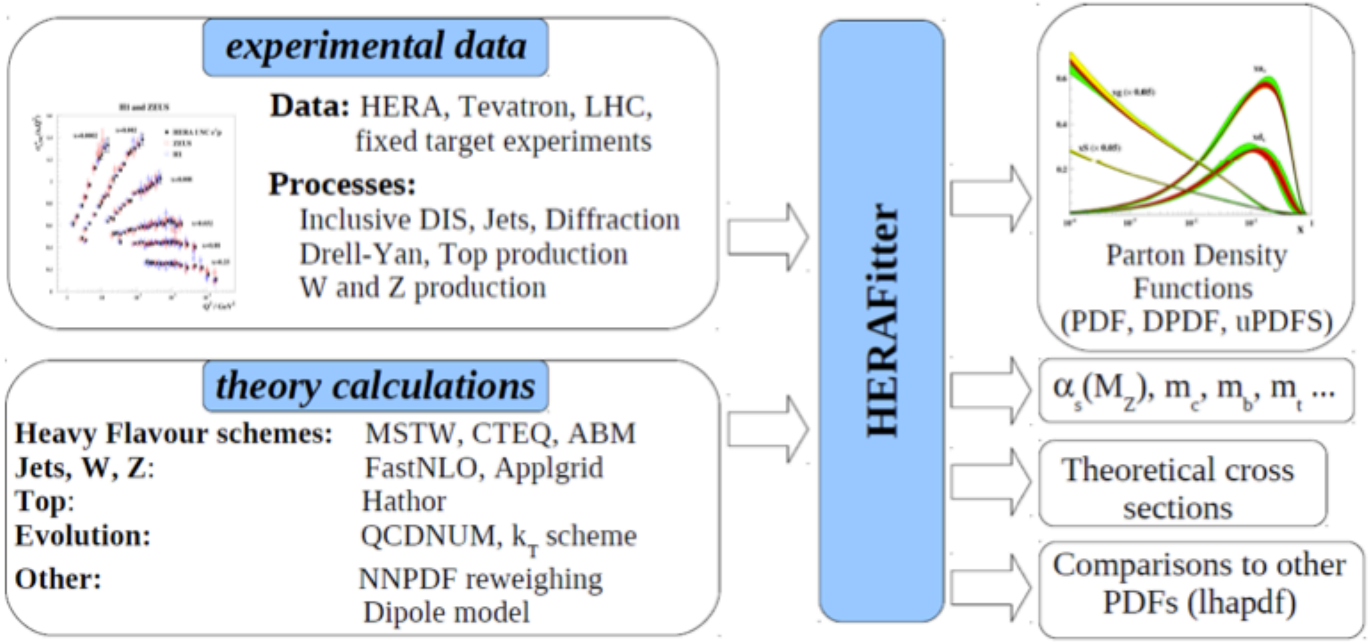

- Large spread of the total cross section predictions at the LHC for W+, W-, Z:
  - The spread is reduced significantly when predictions are evaluated at the $m_c$ determined from $F_2$ charm

# HERAFitter QCD platform

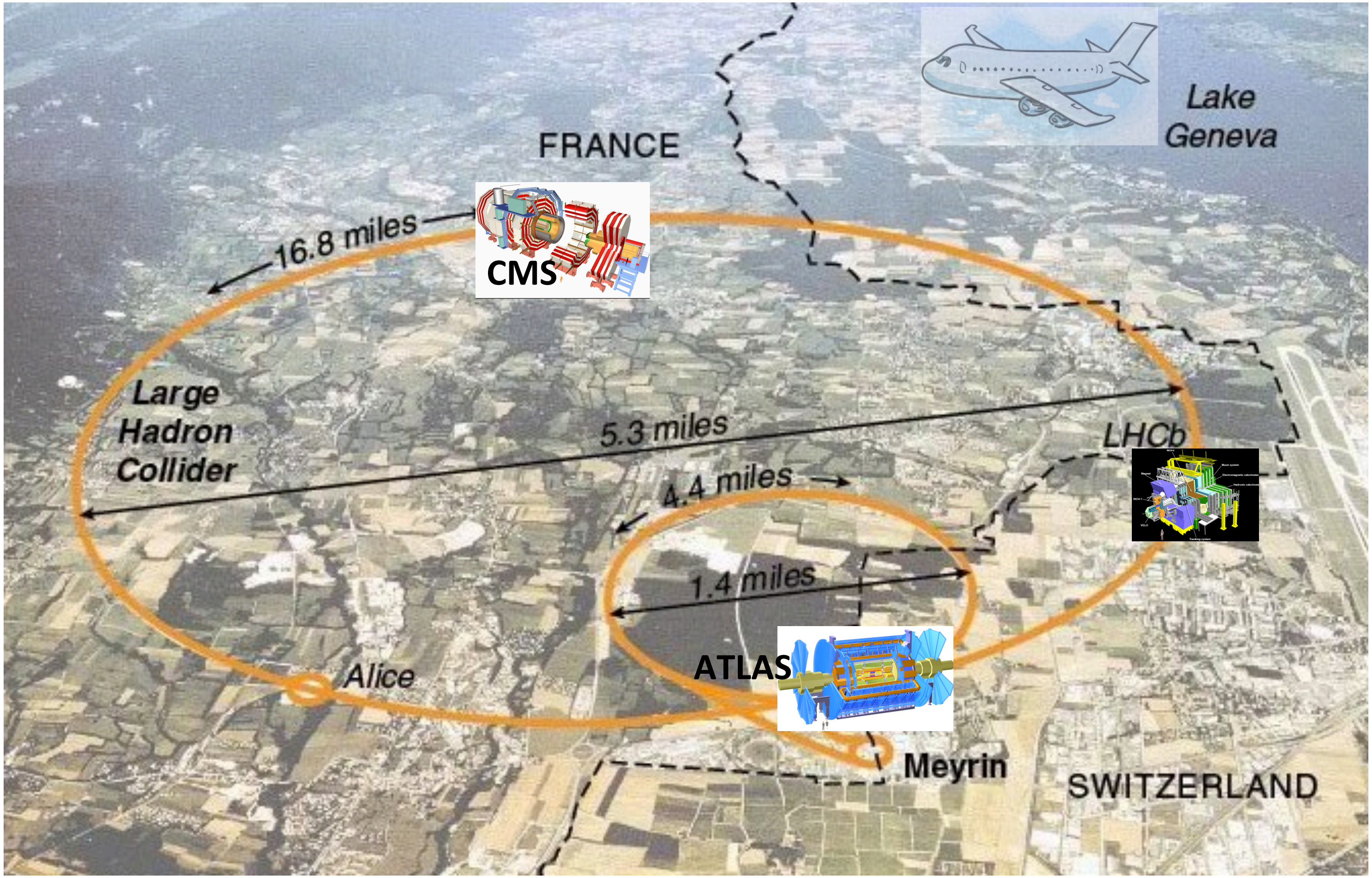
## Heritage of HERA transferred to LHC:

Open Source QCD Framework freely available at **https://www.herafitter.org**



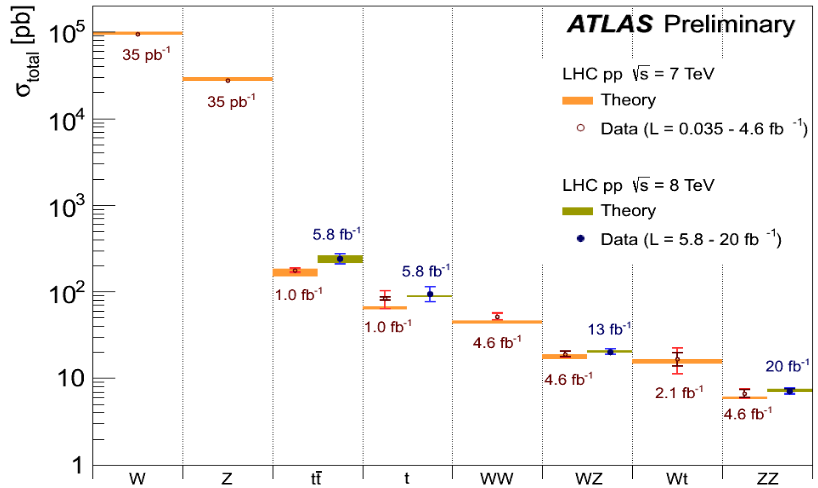



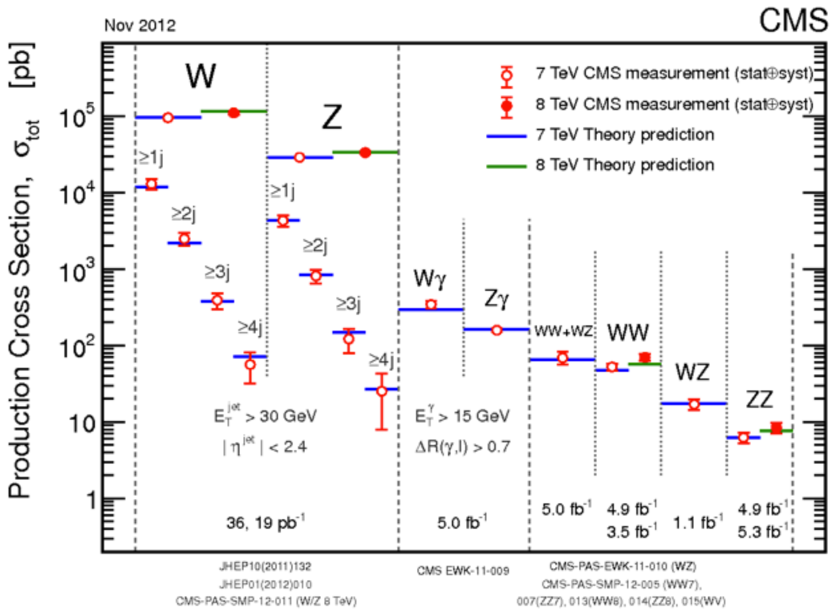
# From HERA to LHC



# 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

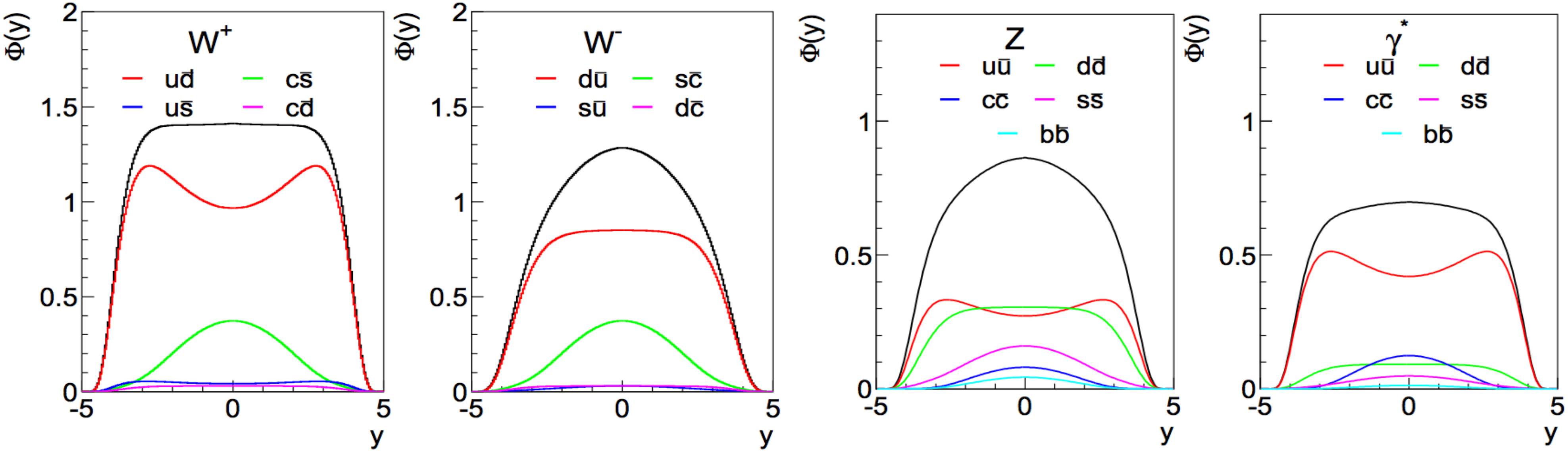
1. W and Z production
2. W+c production
3. Inclusive Jet and Di-Jet production
4. Drell-Yan: low and high invariant mass
5. Top, ttbar
6. Prompt Photon, + Jets [see P. Lenzi's talk]
7. W,Z+b

[See J. Rojo's talk for a theoretical perspective]

# Flavour decomposition of W and Z and the LHC

- Additional constraints on PDFs come from DY and jet data at the LHC
  probe a bi-linear combination of quarks

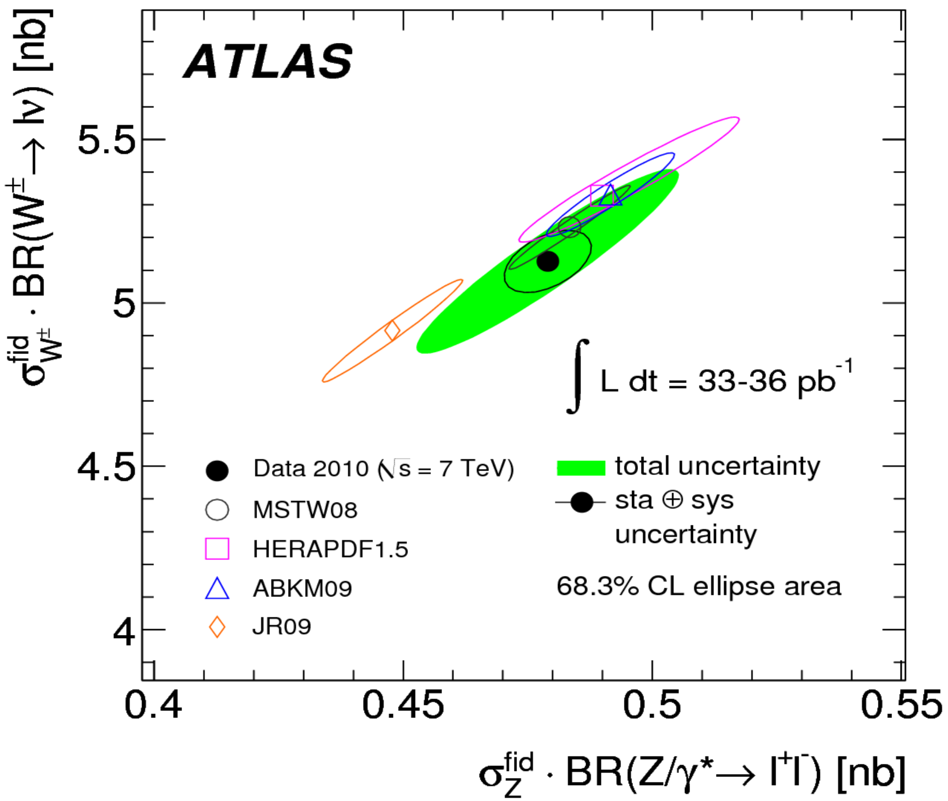

$$W^+ \quad \sim 0.95(u\bar{d} + c\bar{s}) + 0.05(u\bar{s} + c\bar{d})$$
$$W^- \quad \sim 0.95(d\bar{u} + s\bar{c}) + 0.05(d\bar{c} + s\bar{u})$$
$$Z \quad \sim 0.29(u\bar{u} + c\bar{c}) + 0.37(d\bar{d} + s\bar{s} + b\bar{b})$$
$$\gamma^* \quad \sim 0.44(u\bar{u} + c\bar{c}) + 0.11(d\bar{d} + s\bar{s} + b\bar{b})$$

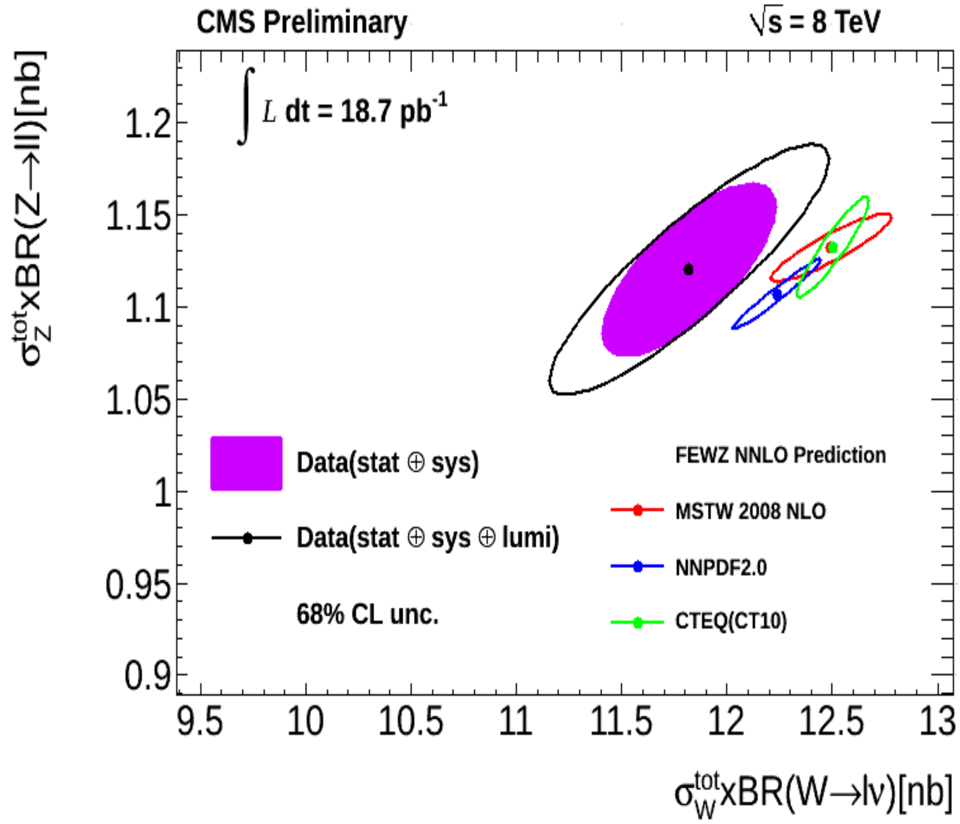



Measurements of W, Z production differentially in $y_Z$ and $\eta_\ell$ provide information on light sea decomposition

# Total W,Z Cross Sections Results

- Cross Section measurements of W+, W-, Z  for ll decay channels in the corresponding fiducial volume [ATLAS at 7 TeV Phys Rev D85(2012)072004] and total volume [CMS at 8 TeV prel. CMS-SMP-12011]
  - combined muon and electron channels

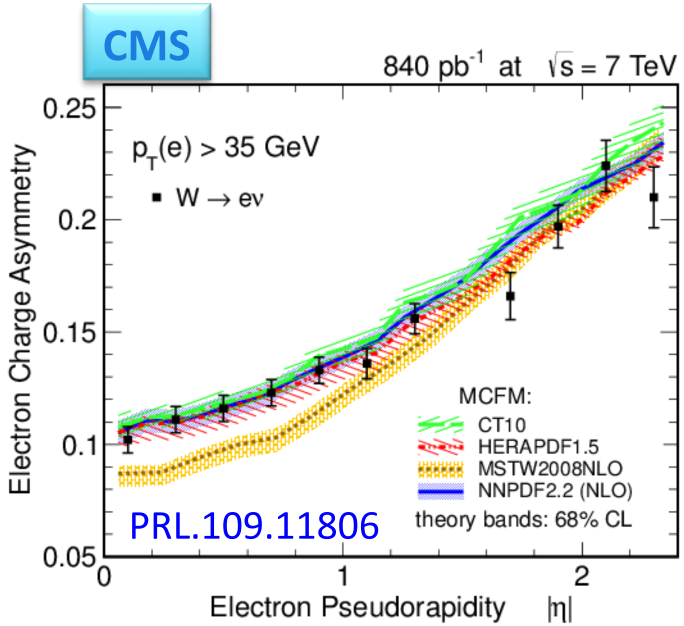


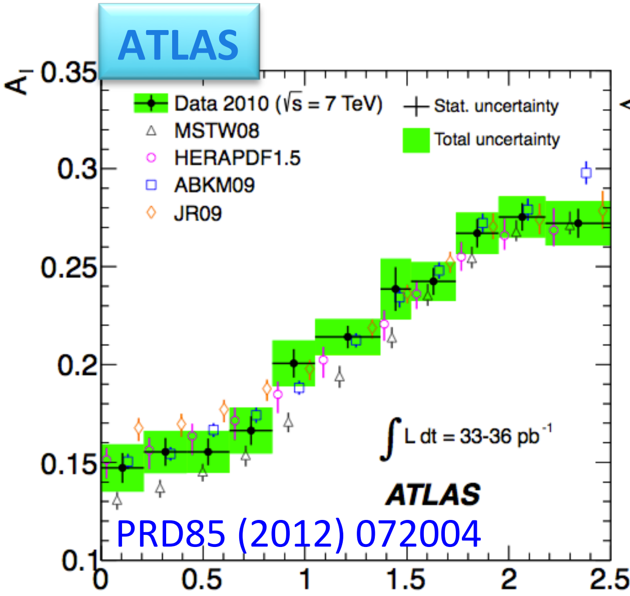



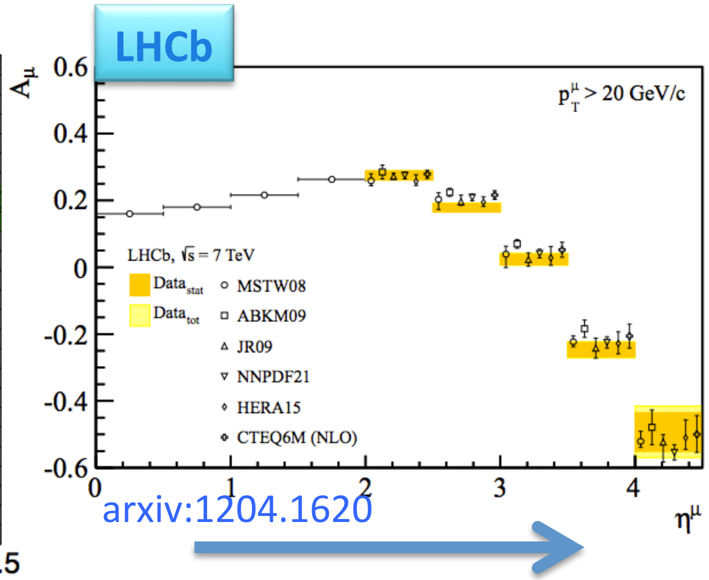

- Precision data of ~1% uncertainty enables more interesting comparison to PDFs;
- More information for PDFs is provided in the differential distributions.

# W Charge Asymmetry

- The interplay between the flavour asymmetries can be enhanced via ratio measurements:
  - W-asymmetry $\mathbf{A_W = [\sigma(W^+) - \sigma(W^-)] / [\sigma(W^+) + \sigma(W^-)] = (u_v - d_v) / (u_v + d_v + 2\ qbar)}$ at x1=x2




- CMS measures directly the electron asymmetry data from 2011 and clearly disfavour MSTW2008:
  - MSTW have addressed this in more recent versions of their PDFs [see J. Rojo's talk].

- ATLAS differential measurements of $W^+$ and $W^-$ (combined muon and electron) based on 2010 data translated into charge asymmetry *Al* as long as proper treatment of correlations are accounted for.

- LHCb extends the measurement (muon channel) to forward region and provides a comparison with various predictions (interesting region where distribution changes sign due to V-A structure)

*NOTE: Selection criteria are optimized for each experiment*

# W Charge Asymmetry

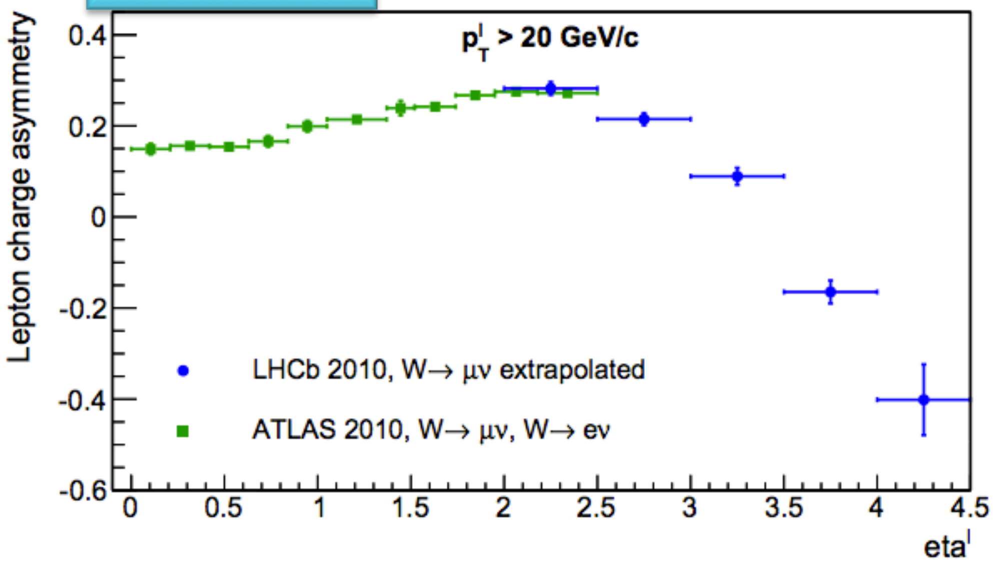
- The interplay between the flavour asymmetries can be enhanced via ratio measurements:
  - W-asymmetry $\mathbf{A_W = [\sigma(W^+) - \sigma(W^-)]/ [\sigma(W^+) + \sigma(W^-)]=(u_v - d_v) /(u_v + d_v + 2\ qbar)}$ at x1=x2

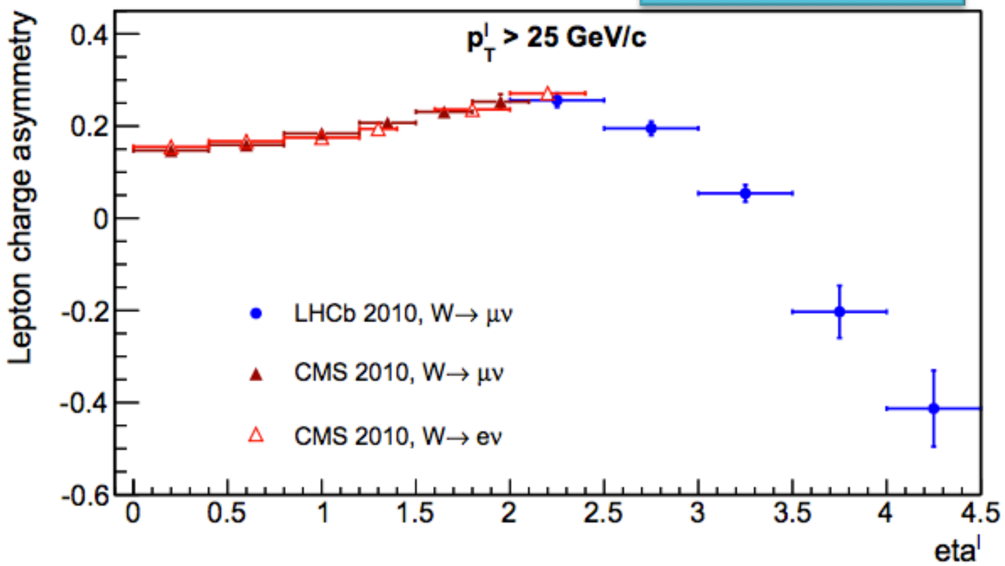
| Measurement | | $p_T^\ell$ GeV/c | $\eta^\ell$ or $y_Z$ | $M_{\ell\ell}$ GeV/$c^2$ | $M_T$ GeV/$c^2$ | $p_T^\nu$ GeV/c |
|---|---|---|---|---|---|---|
| $A_\ell(\eta)$ | LHCb | $> 20, 25, 30$ | $2 < \eta^\ell < 4.5$ | | | |
| $A_\ell(\eta)$ | ATLAS | $> 20$ | $\lvert\eta^\ell\rvert < 2.5$ | | $> 40$ | $> 25$ |
| $A_\ell(\eta)$ | CMS | $> 25, 30, 35$ | $\lvert\eta^\ell\rvert < 2.4$ | | | |

**CMS vs LHCb**

LHCb-CONF-2013-005

**ATLAS vs LHCb**



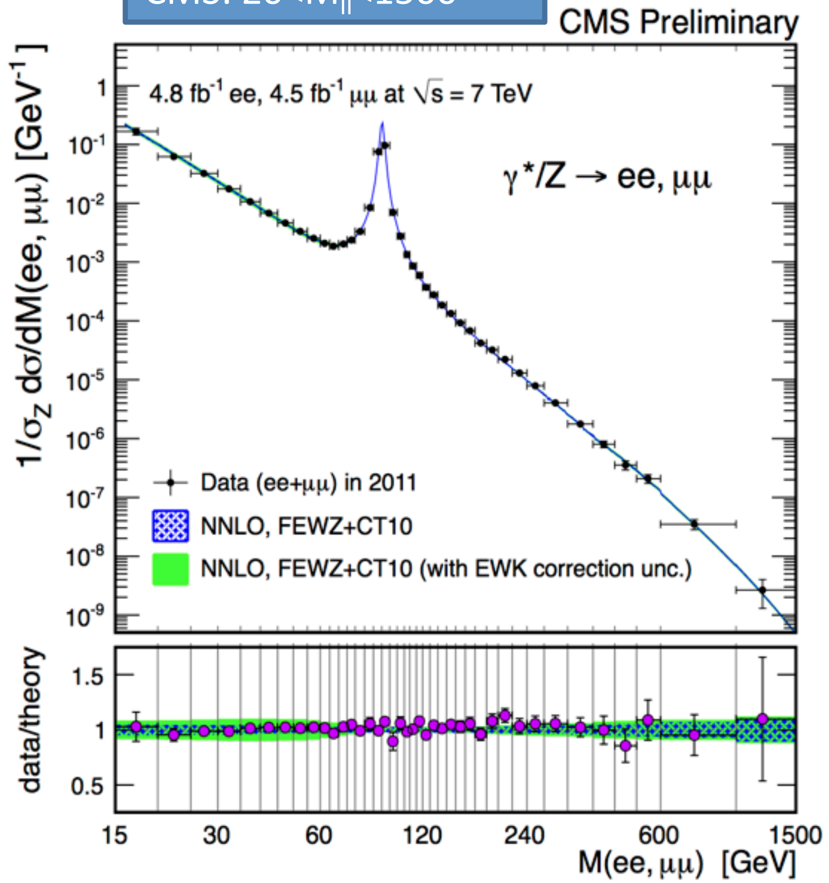




  - A good agreement is observed between ATLAS and LHCb results as well as the CMS and LHCb results in the overlapping region, after LHCb was extrapolated from its fiducial volume.

# Neutral Current Drell Yan di-lepton measurements

- Drell Yan data can give information on sea quark PDFs.

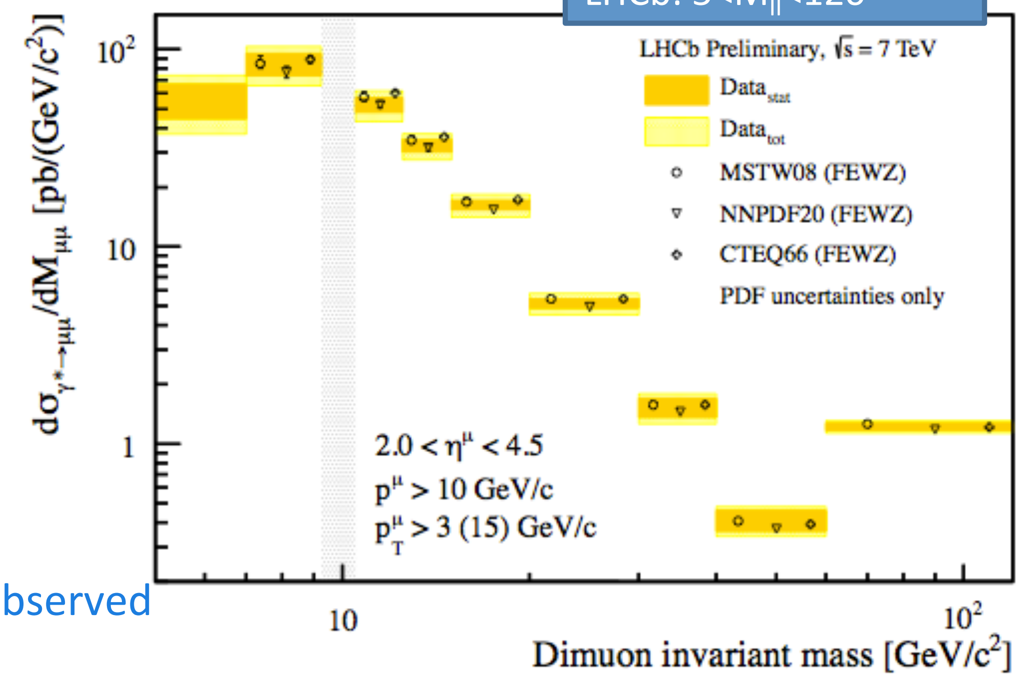
CMS: $20<M_{ll}<1500$




The Drell Yan invariant mass spectrum in the combined dimuon with dielectron channel, normalized to the Z resonance region for CMS in the $20 < M\mu\mu < 1500$ GeV region [CMS-SMP-13-003]

Measurement complemented by LHCb down to 5 GeV [LHCb-CONF-2012-013 ]

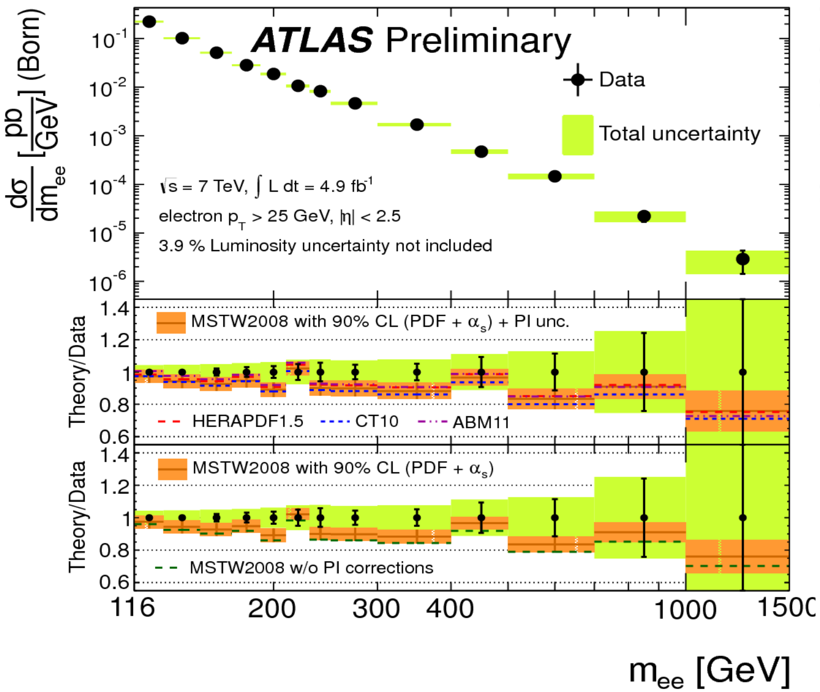
LHCb: $5<M_{ll}<120$



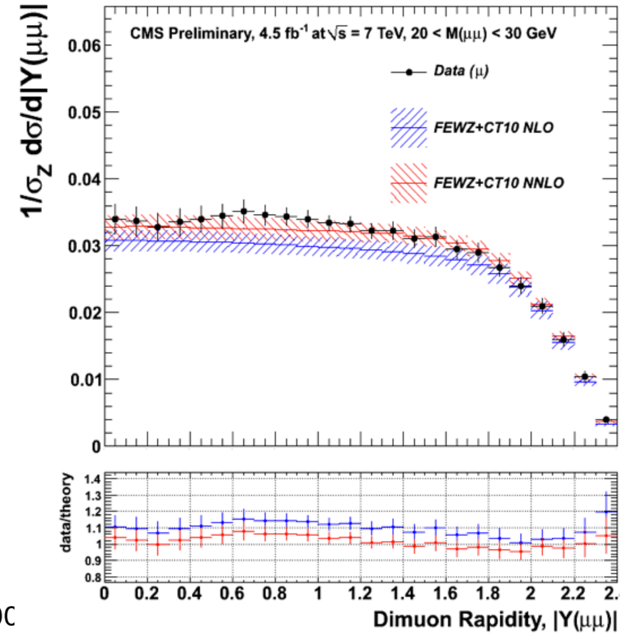

Good agreement with SM predictions is observed

# Z Differential Cross Section (off resonance region)

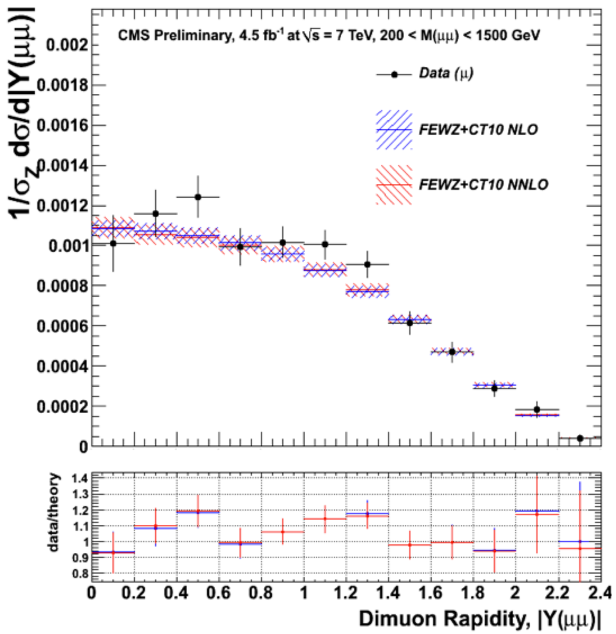
ATLAS: $116<M_{ee}<1500$




CMS: $20<M_{\mu\mu}<30$




CMS: $200<M_{\mu\mu}<1500$




The Drell Yan invariant mass spectrum in the off resonance region:

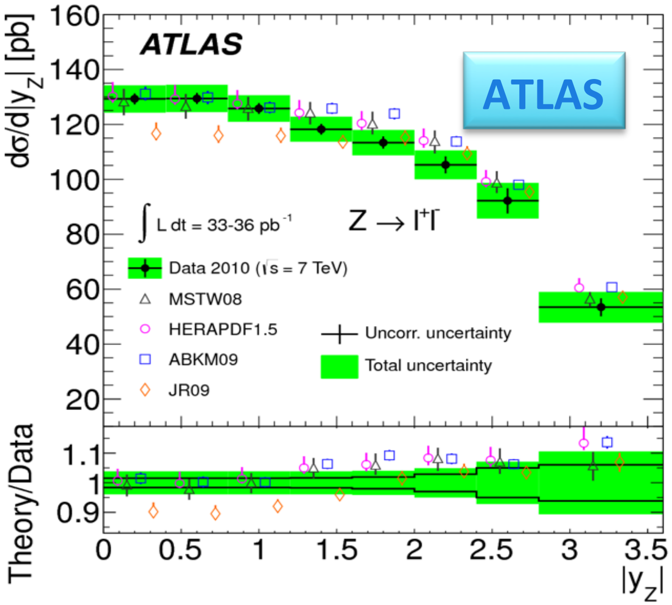
- ATLAS In the dilectron channel [ATLAS-CONF-2012-159]
- normalized to the Z resonance region, function of dimuon rapidity for CMS in selected $M_{\mu\mu}$ bins [CMS-SMP-13-003]

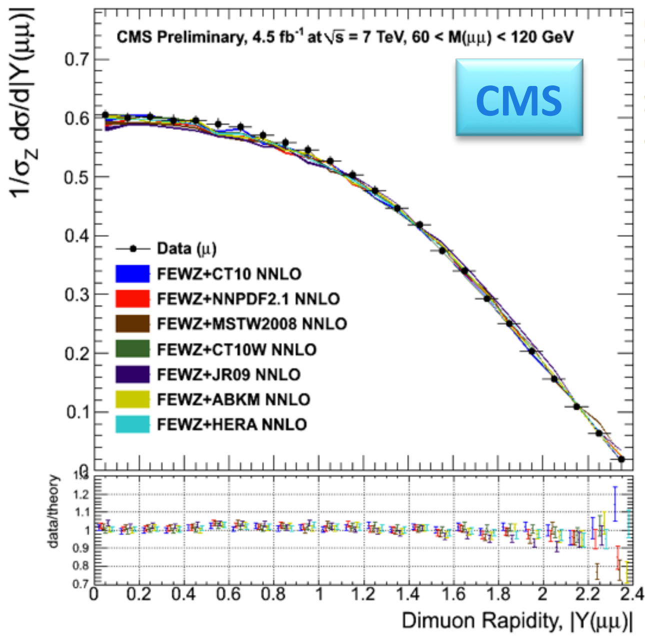
Data is confronted with NNLO predictions corrected for NLO EW effects

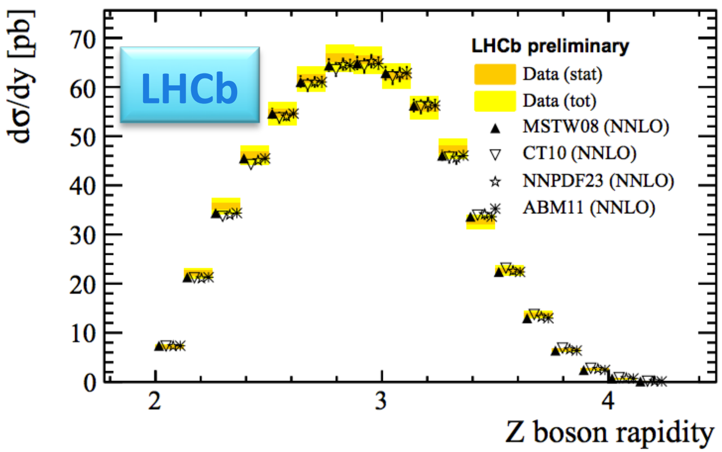
- Currently all PDFs shown give a good description

# Z Differential Cross Section (resonance region)

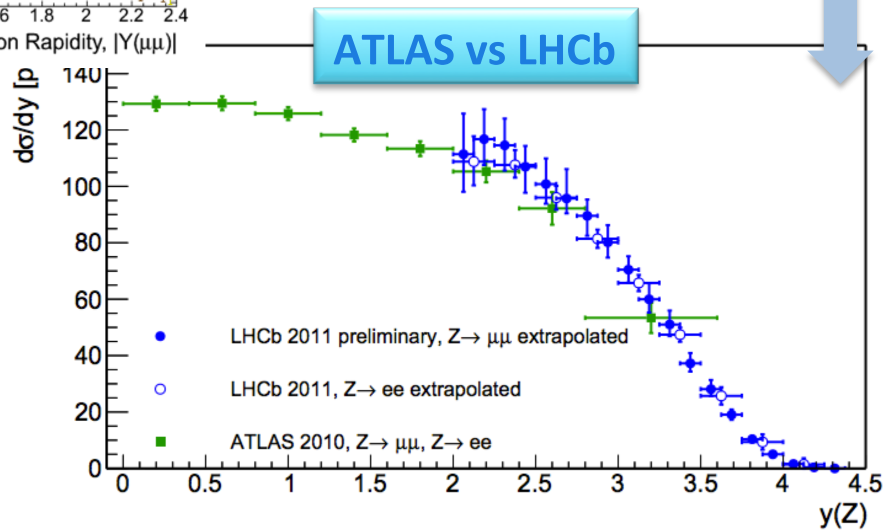
- Measurements of differential cross sections are compared to NNLO predictions:




After acceptance corrections:



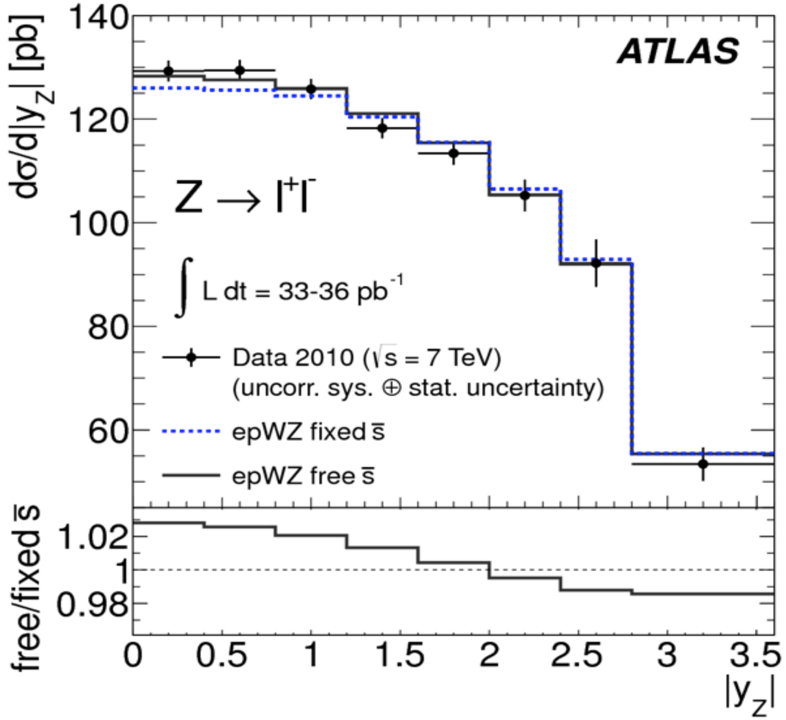

- Good agreement in the overlap region with LHCb after extrapolating to common region.

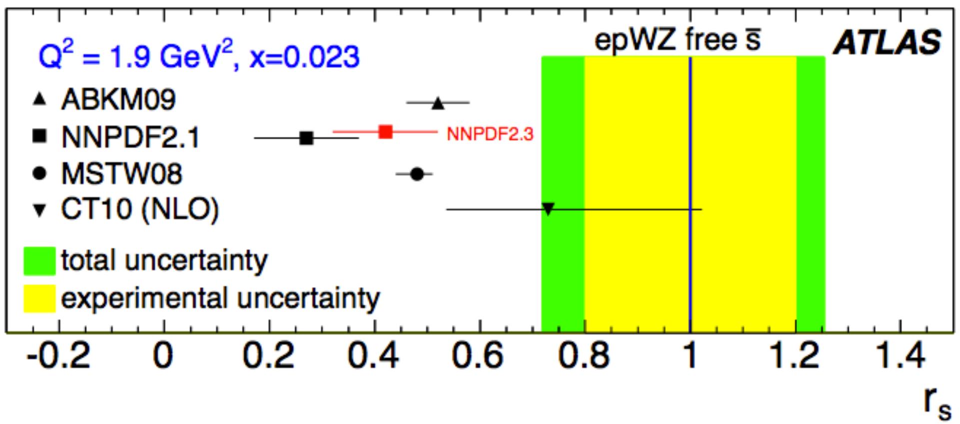
  [LHCb-CONF-2013-007]

- Measurements are confronted with high order predictions based on different PDFs
  - Indicate some tensions with ABM, JR

# Strange quark from W, Z measurements at ATLAS

- Strange quark is not so well constrained:
  - Neutrino dimuon data favours suppressed strange
- At LHC, Z cross sections together with $y_Z$ shape may provide a constraint on **s**-quark density and it can be cross checked by W+charm data.
  - The results for NNLO fits to inclusive W, Z differential data with free and fixed **s:**
    - For W+ and W- there is little difference, helps to fix the normalisation.
    - For Z, the cross section is increased and the shape is modified.




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

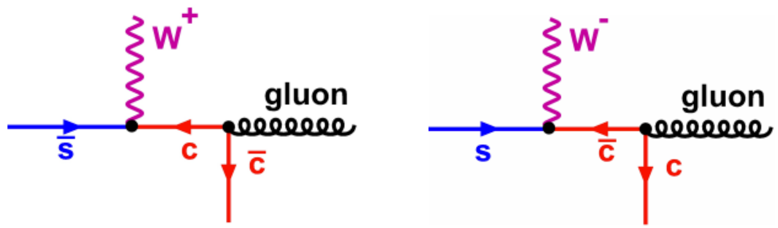
ATLAS result is the kinematic region probed by LHC data at x~0.01 and indicates a flavour symmetric sea with an enhanced strangeness, in agreement with the CT10 (s/d~0.75)

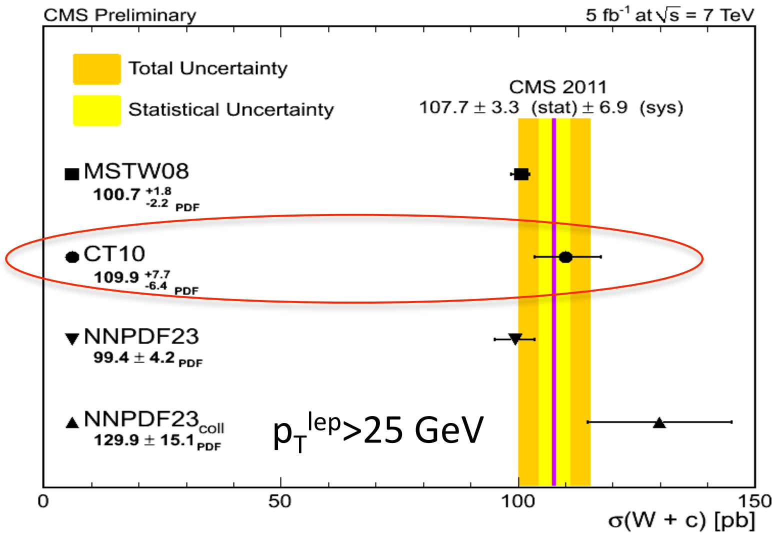
- It is above of MSTW08, ABKM09, NNPDF2.3 (s/d~0.5)

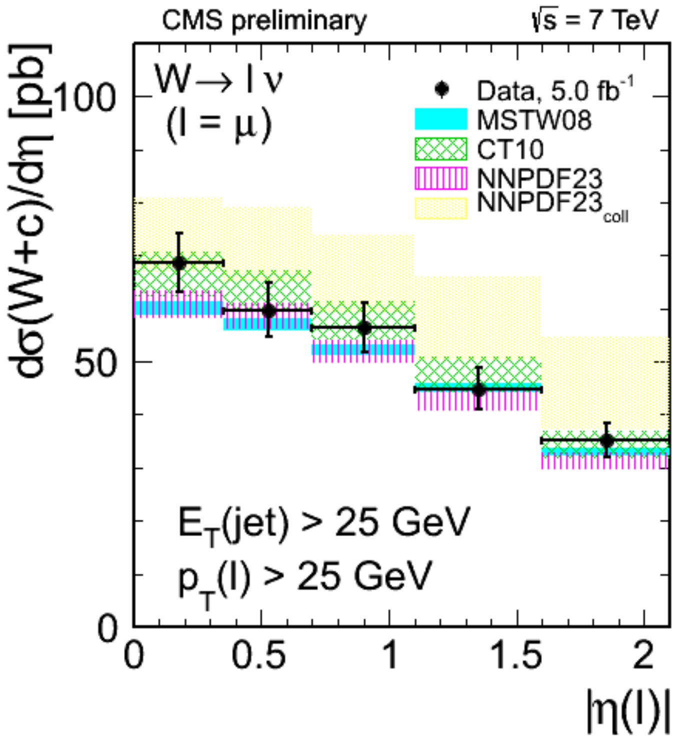
# W+c sensitivity to Strange from CMS

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

- CMS has released a preliminary W+c measurement directly sensitive to strange:



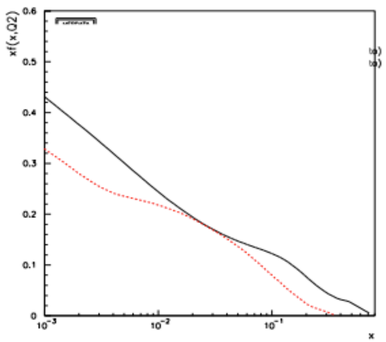




[CMS-SMP-12-002]

Very good agreement with CT10 and not in such good agreement with NNPDF2.3 (Coll):

- has large strangeness

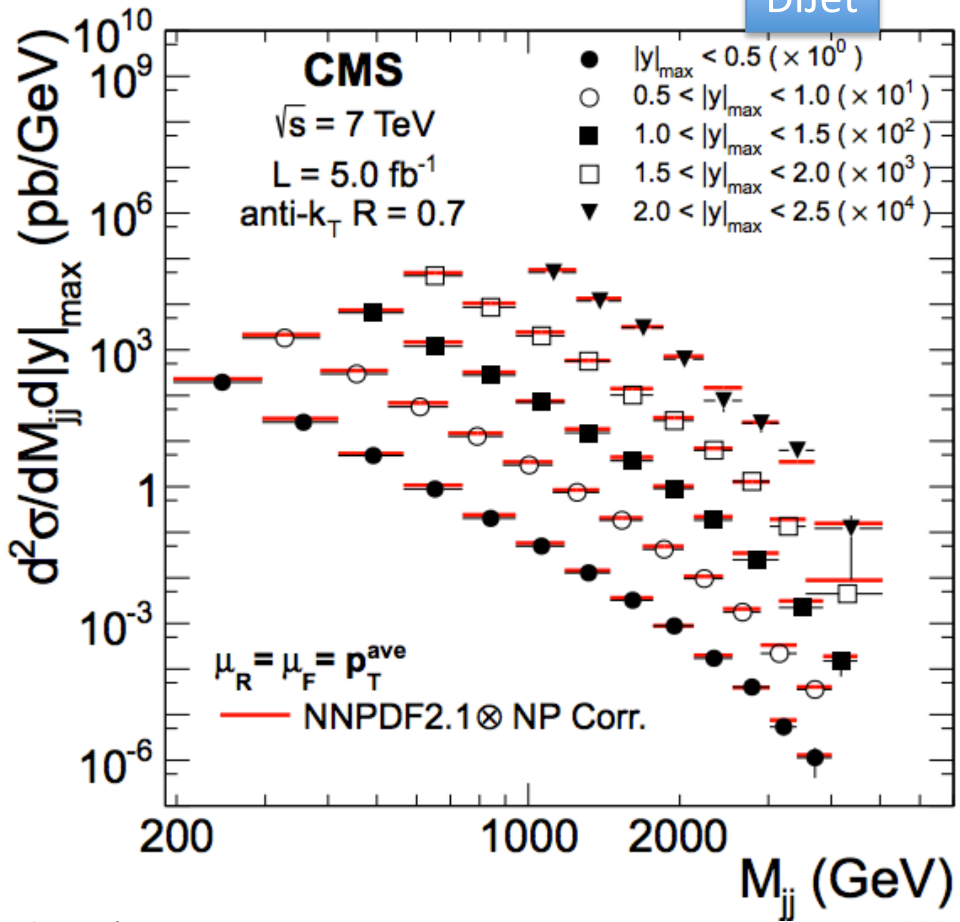


$Q^2$=2 GeV$^2$
NNPDF23(Coll)
Strange
Downsea

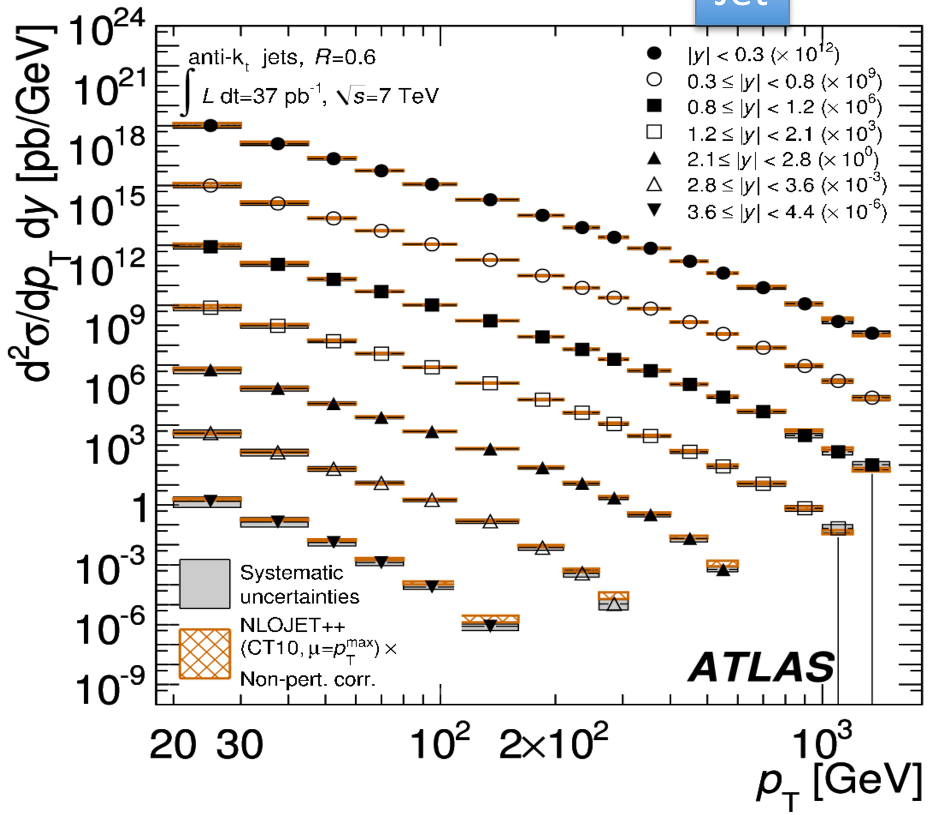
# Inclusive Jet production

- Measurements of ATLAS and CMS inclusive jet and di-jet cross-sections differential in $p_T$ or in invariant mass and y
  [ATLAS: Phys ReV D86(2012)014022]
  [CMS-QCD-11-004 arXiv:1212.6660]
  - sensitive to gluon at high x

DiJet




Jet




- Measurements are provided with full information on correlations
- Measurements can be used in alphas determination

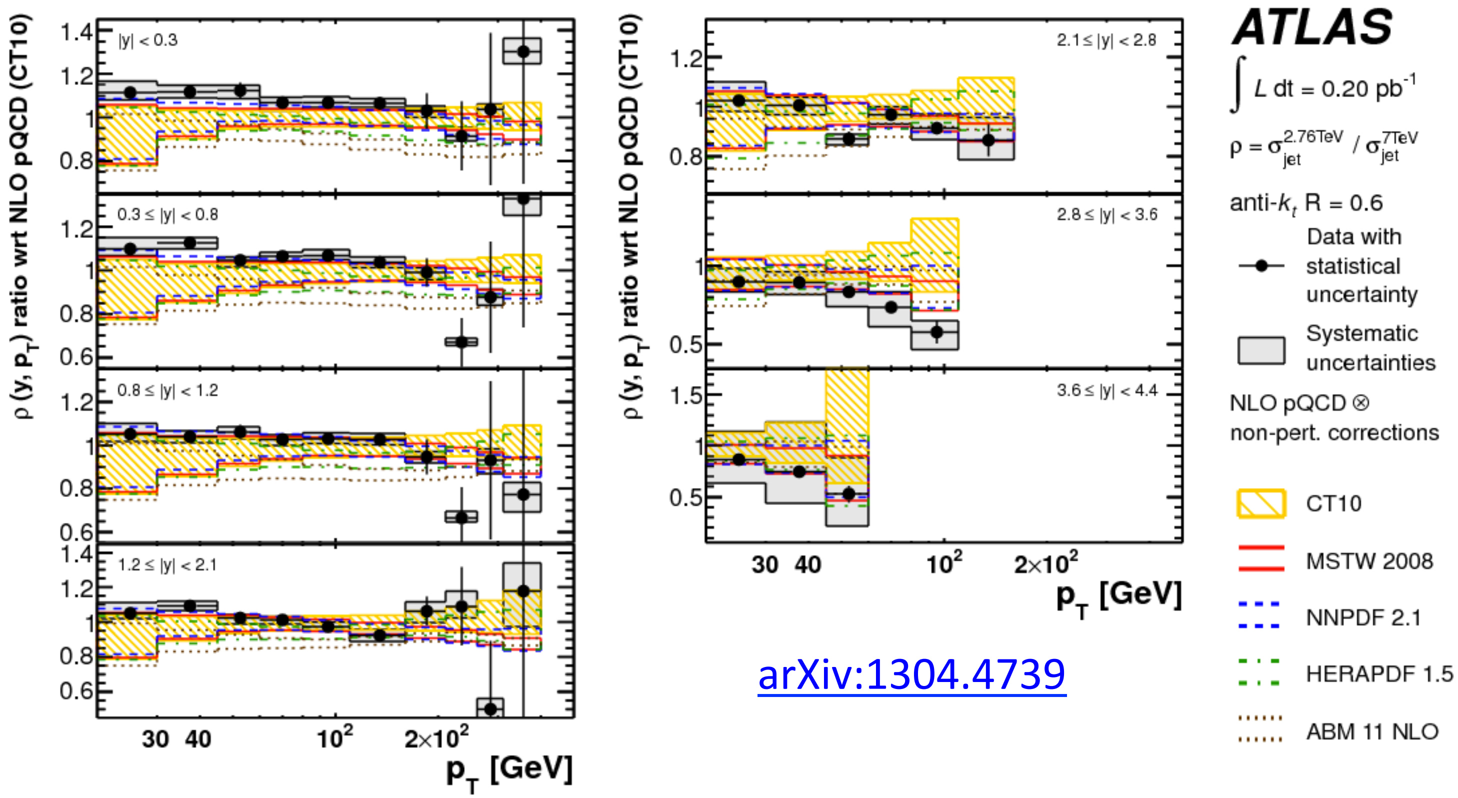
  [see P.Lenzi's talk]

# Ratio of Jets at different beam energies

- Advantage of the ratio measurements: common systematic uncertainties cancel out
  - 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

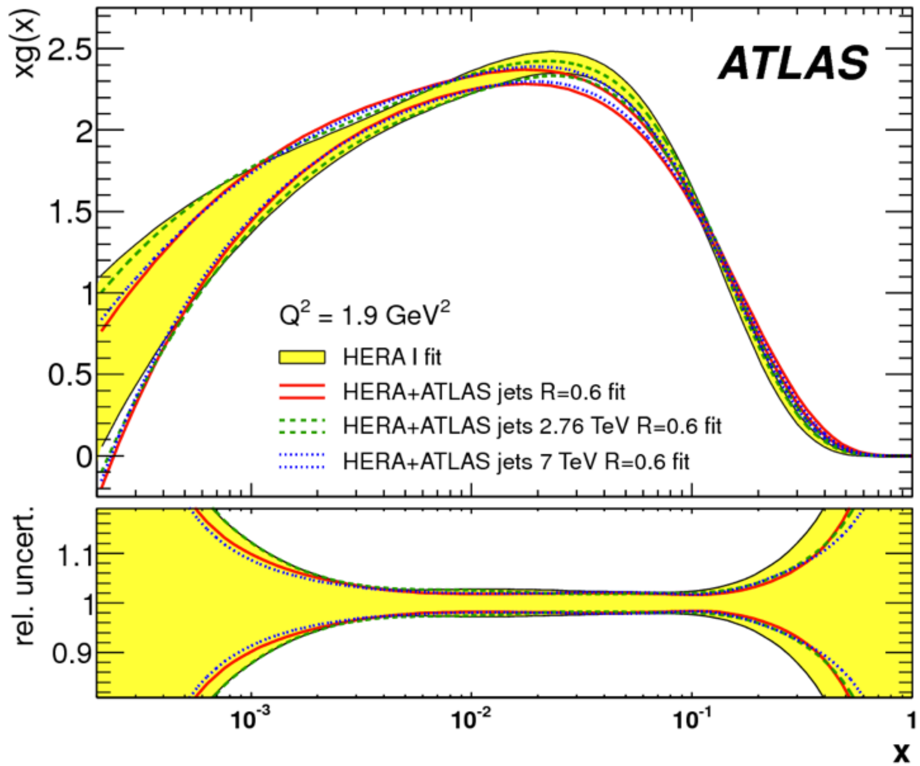
  - ATLAS provides ratio of 2.76 TeV to the 7 TeV jet cross sections in ratio to the CT10 predictions, compared to the predictions of MSTW2008, NNPDF2.1, HERAPDF1.5, ABM11:

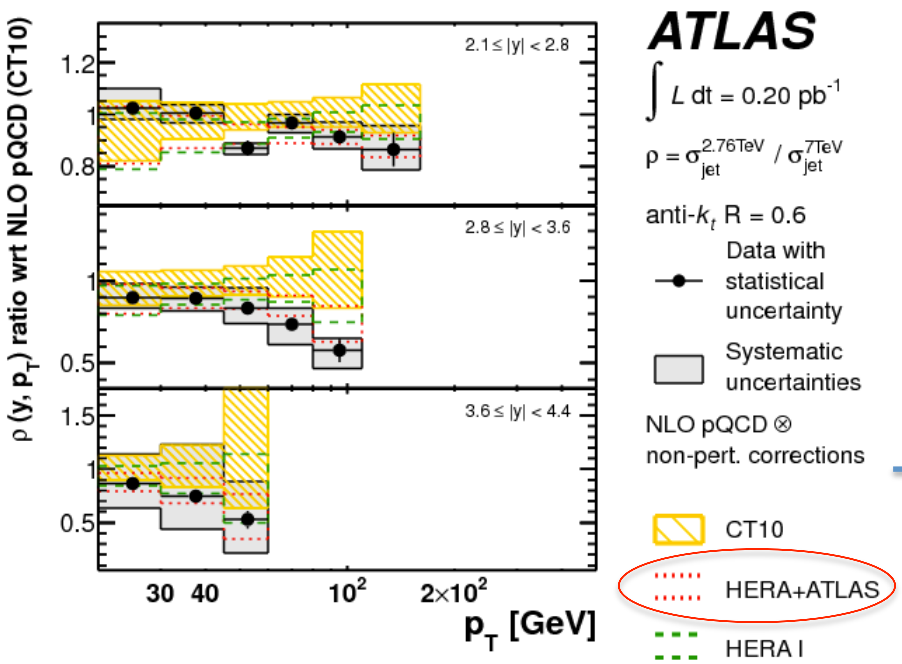



arXiv:1304.4739

# Impact of ratio of jets at different beam energies

- Employing HERAFitter framework an NLO fit is performed to study the sensitivity to the 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.

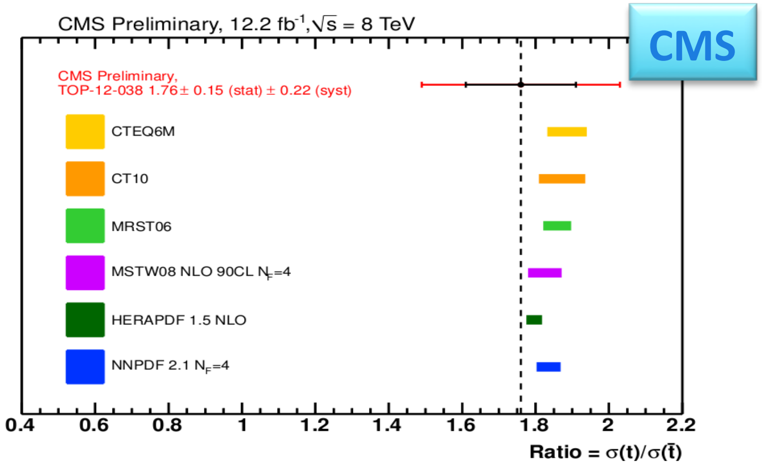


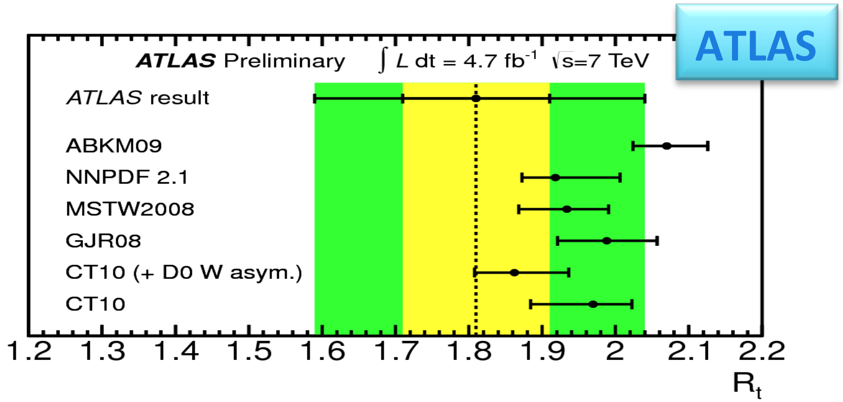



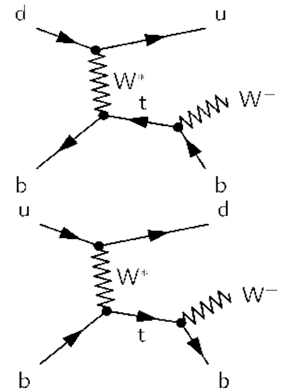

Comparing Fit result including this measurement there is improvement in high y region

# Sensitivity to PDFs from top production

- Single top t/tbar ratio has the potential to provide u/d [ATLAS-CONF-2012-056, CMS-TOP-12-038]



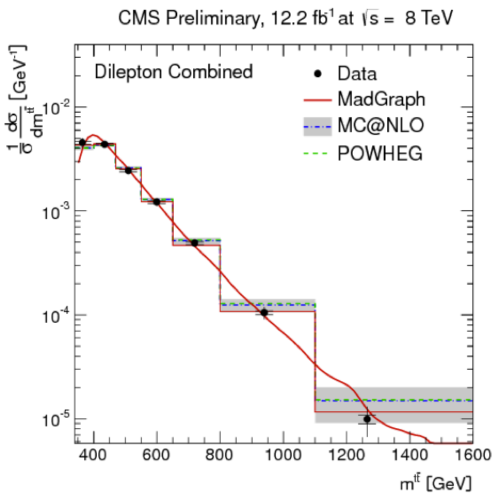



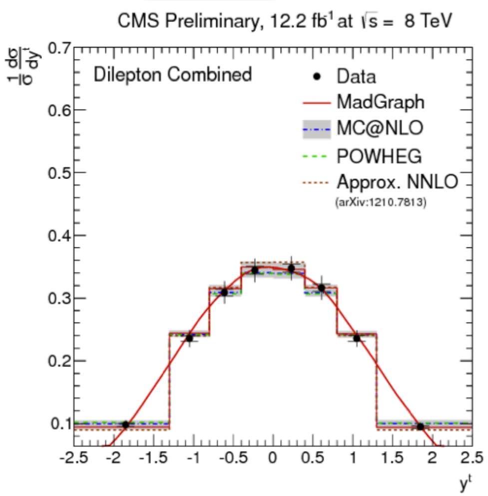




- t-tbar production could improve the gluon PDF [CMS-TOP-12-028 (di-lepton)]

8 TeV preliminary data :

CMS



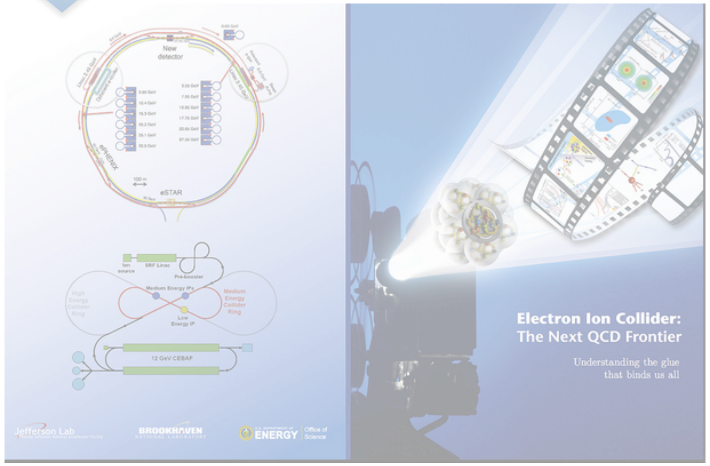

Normalised differential ttbar production cross section as a function of invariant mass and rapidity of the top quarks:

- Good agreement with NLO predictions and when available with ~NNLO

# Future prospects

LHeC (ep collider to complement LHC at CERN), EIC [see M. Stratmann's talk], ILC

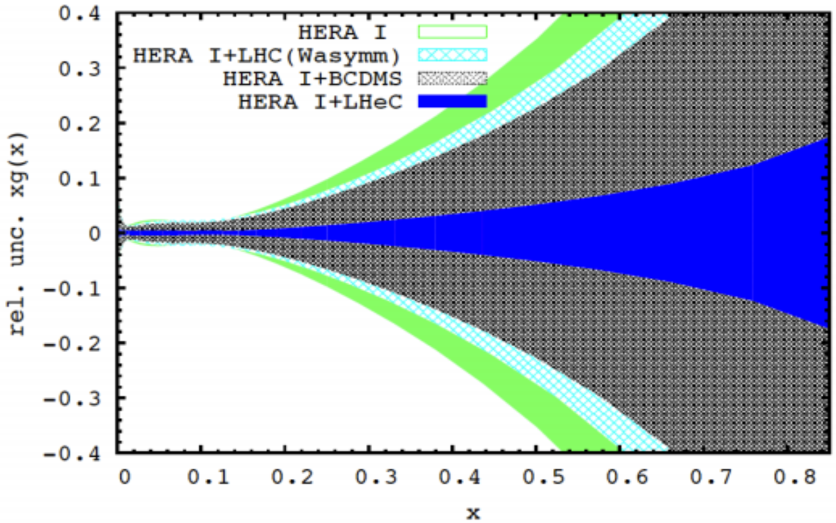

arXiv:1206.2913




# PDFs and Higgs at the LHeC

- PDFs are essential for precision physics at the LHC :
  - one of the main theory uncertainties in Higgs production and measurements at high Pt, masses
- LHeC could provide a complete PDF set with precise gluon, valence at high x, as well as $\alpha_S$ coupling

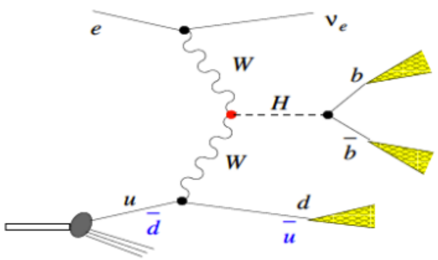
**LHeC Gluon at high X**




LHeC promises per mille accuracy on alphas!

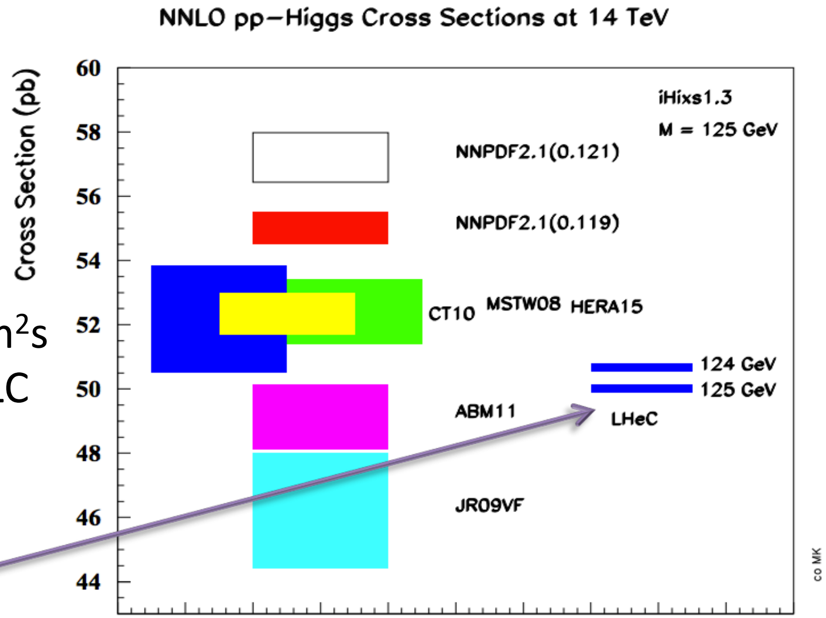
| case | cut [$Q^2$ in GeV$^2$] | relative precision in % |
|---|---|---|
| HERA only (14p) | $Q^2 > 3.5$ | 1.94 |
| HERA+jets (14p) | $Q^2 > 3.5$ | 0.82 |
| LHeC only (14p) | $Q^2 > 3.5$ | 0.15 |
| LHeC only (10p) | $Q^2 > 3.5$ | 0.17 |
| LHeC only (14p) | $Q^2 > 20.$ | 0.25 |
| LHeC+HERA (10p) | $Q^2 > 3.5$ | 0.11 |
| LHeC+HERA (10p) | $Q^2 > 7.0$ | 0.20 |
| LHeC+HERA (10p) | $Q^2 > 10.$ | 0.26 |

- At the LHeC , Higgs is cleanly produced via **ZZ** or **WW** fusion, complementary to the dominant **gg** fusion at pp




With an *ep* luminosity near to $10^{34}$ /cm$^2$s LHeC can generate as many Higgs as ILC

- precision trom LHeC can add a significant constraint on MH



# Summary

PDFs still limit our knowledge of cross sections whether SM or BSM.

- HERA has finalised its separate measurements relevant to PDFs and currently ongoing efforts are on combining final measurements to reach its ultimate precision.

- Standard Model LHC measurements can themselves contribute to PDF discrimination and PDF improvement:
  - LHC data suggest that the light quark sea is flavour symmetric:
    - W,Z inclusive cross check against W+c
  - Exploiting different energy beams for inclusive jets brings forward sensitivity to the gluon PDFs.
    - gluon PDF can also be improved through Photon-jet measurements [see P. Lenzi]
  - Top measurement is becoming a valuable players in the impact on PDFs (and alphas)

**… Many more valuable measurements are already available, but not covered in this talk …**

- More precision measurements from LHC to come from Run I and in future from Run 2

- LHeC can represent a natural extension to LHC by providing an accurate and complete PDF set and access to a clean channel in Higgs production.

# List of covered topics

- HERA:
  1. Combination and QCD Analysis of Charm Production Cross Section Measurements in Deep-Inelastic ep Scattering at HERA [EPJ C73 (2013) 2311] – H1 and ZEUS combined
  2. Inclusive Deep Inelastic Scattering at High Q2 with Longitudinally Polarised Lepton Beams at HERA [JHEP 09 (2012) 061] – H1
  3. Measurement of high-Q2 neutral current deep inelastic e+p scattering cross sections with a longitudinally polarised positron beam at HERA, arXiv:1208.6138 - ZEUS
- LHC:
  1. Measurement of the inclusive W+- and Z/gamma cross sections in the electron and muon decay channels in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector, (ATLAS) Phys Rev D85(2012)072004
  2. Measurement of inclusive W and Z boson cross section in pp collisions at sqrt{s} =8 TeV, (CMS) CMS-SMP-12011
  3. Measurement of the electron charge asymmetry in inclusive W production in pp collisions at 7TeV (CMS), PRL109.11806
  4. Inclusive W and Z production in the forward region (LHCb), arXiv:1204.1620
  5. LHCb-CONF-2013-005 (extrapolated)
  6. LHCb-CONF-2012-007 (extrapolated)
  7. CMS-SMP-13-003 (W,Z inclusive)
  8. LHCb-CONF-2012-013 (Z low mass)
  9. ATLAS-CONF-2012-159 (High mass)
  10. CMS SMP-12002 (W+charm)
  11. ATLAS: Phys ReV D86(2012)014022 inclusive jets
  12. CMS: QCD-11004 arXiv:1212.6660 inclusive jets
  13. arXiv:1304.473 2.76 jets
  14. ATLAS-CONF-2012-056 single top anti top
  15. CMS-TOP-12-038 single top
  16. CMS-TOP -12-028 (di-lepton 8TeV)
- LHeC:
  1. CDR

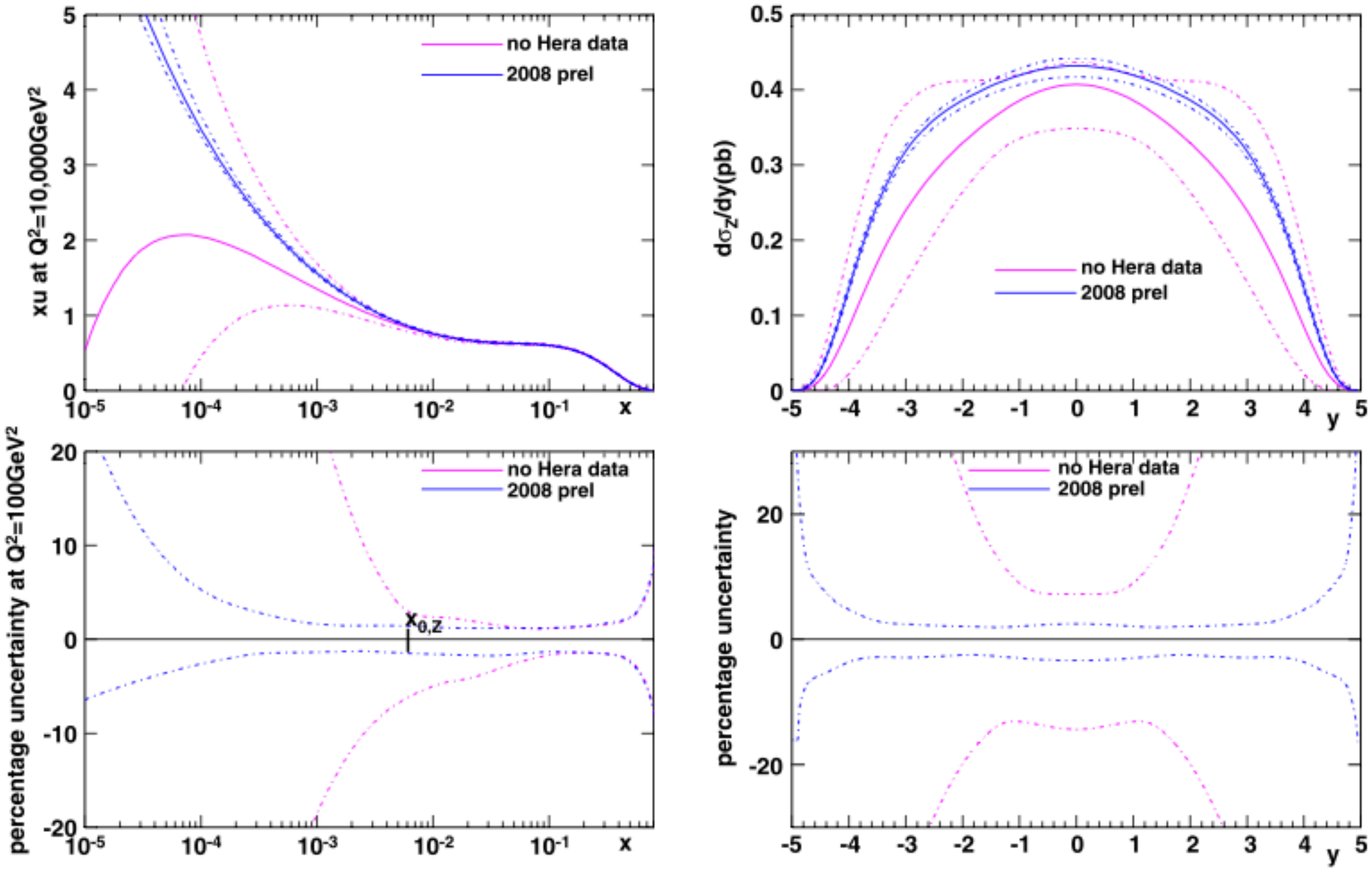

Back up slides


Not necessarily
useful

# HERA Legacy

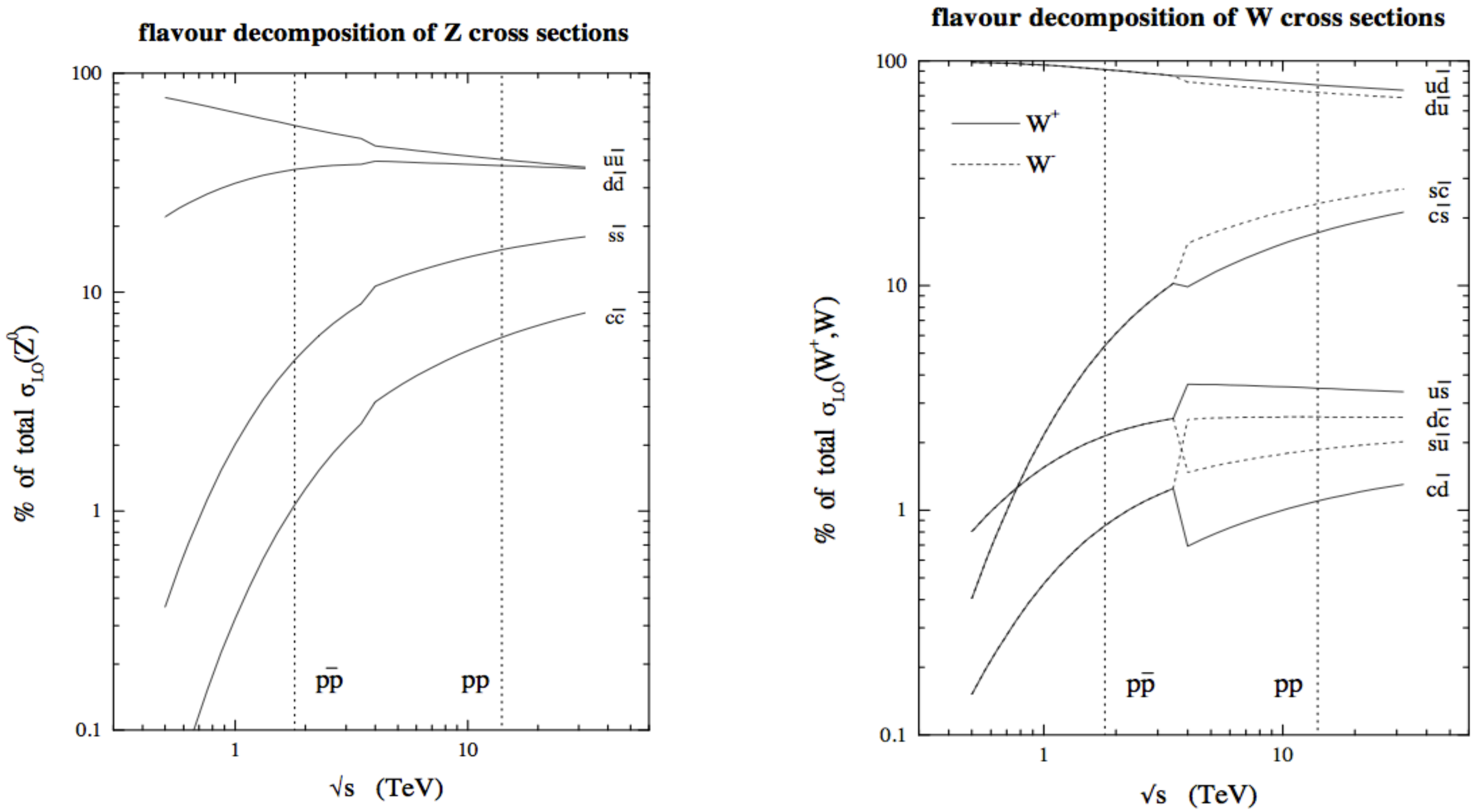
- The results provided by HERA are essential for the interpretation of the LHC data
  - An accurate knowledge of these distributions is vital:

*A. De Roeck, R.S. Thorne / Progress in Particle and Nuclear Physics 66 (2011) 727–781*



# Flavour decomposition

- At different energies (Tevatron vs LHC, split at 4TeV between ppbar and pp)



# ATLAS determination of the strange sea density

- To assess the impact of ATLAS data:
  - HERA I combined data [JHEP 01, 109, 2010] used as a ground
    - 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] is added on top

- 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

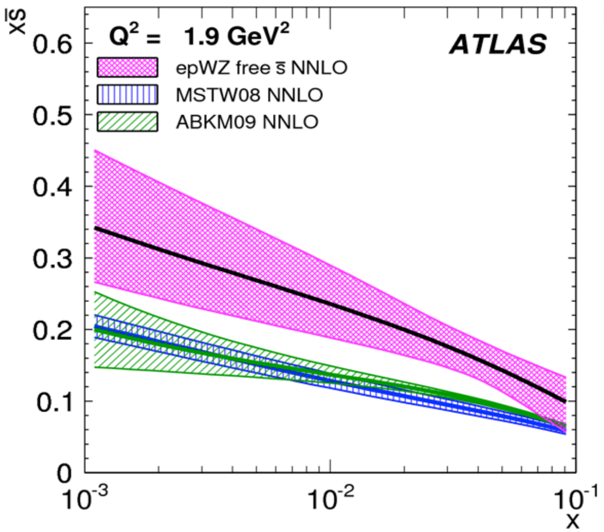
$$r_s = 0.5(s + \bar{s})/\bar{d},\ r_s = 0.5$$

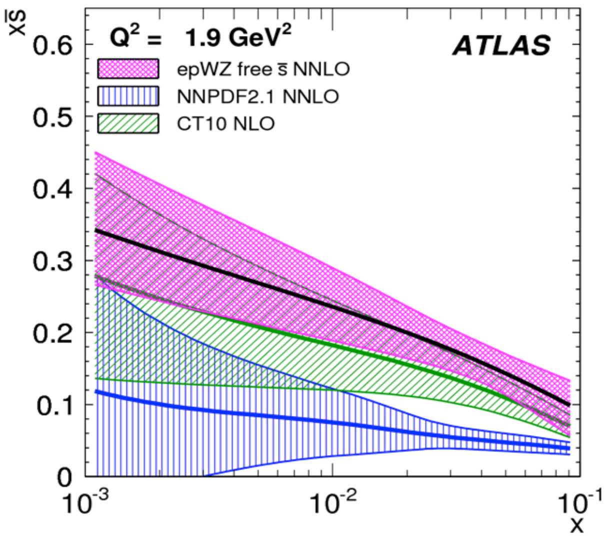
  - Free Strange fit: parametrise strange distribution as done with other individual PDFs

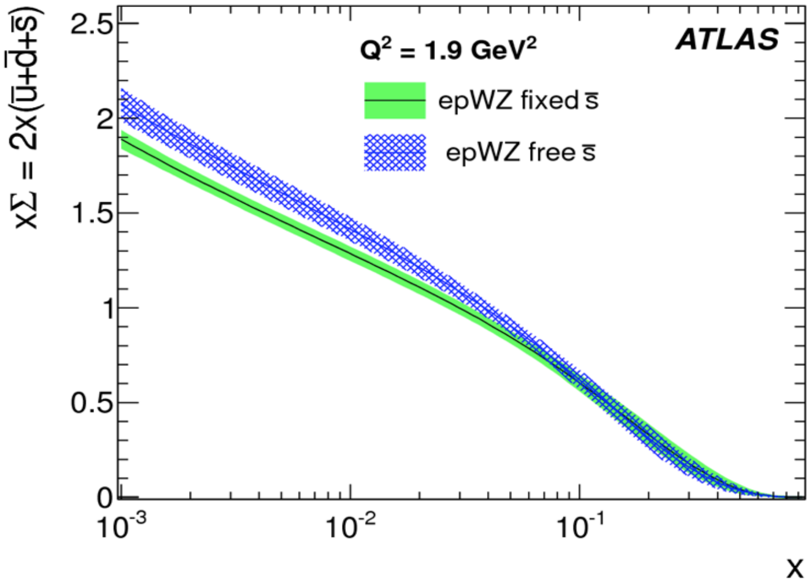
$$x\bar{s} = xs = r_s A_{\bar{d}} x^{B_{\bar{d}}} (1 - x)^{C_s}$$

**Fits are performed using HERAFitter framework**

# Strange distribution



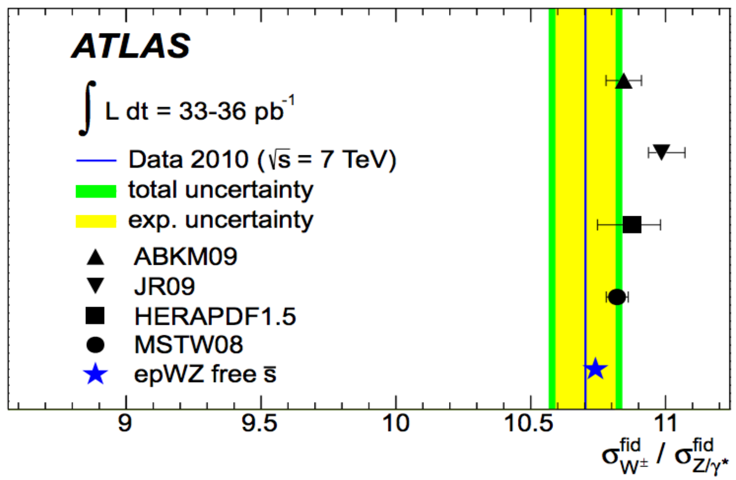




- Comparisons of the strange quark density resulting from th free strangeness epWZ fit with the predictions of different PDF sets.

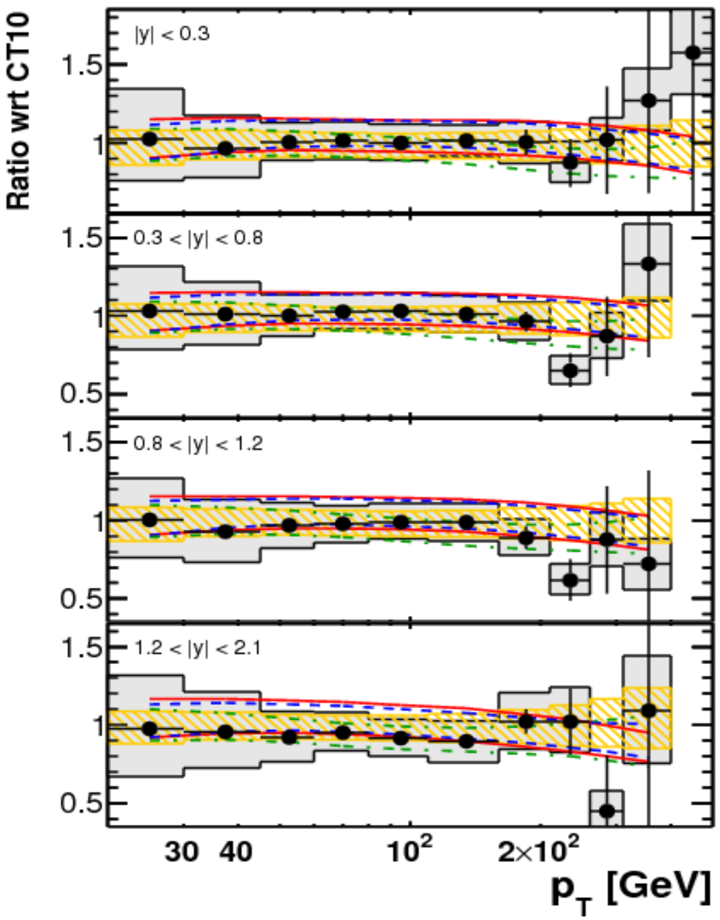
- A change of the strange density with fixed F2 measured by HERA must affect the light sea $x\Sigma$.
  - Enhancement by about 8% at the starting scale

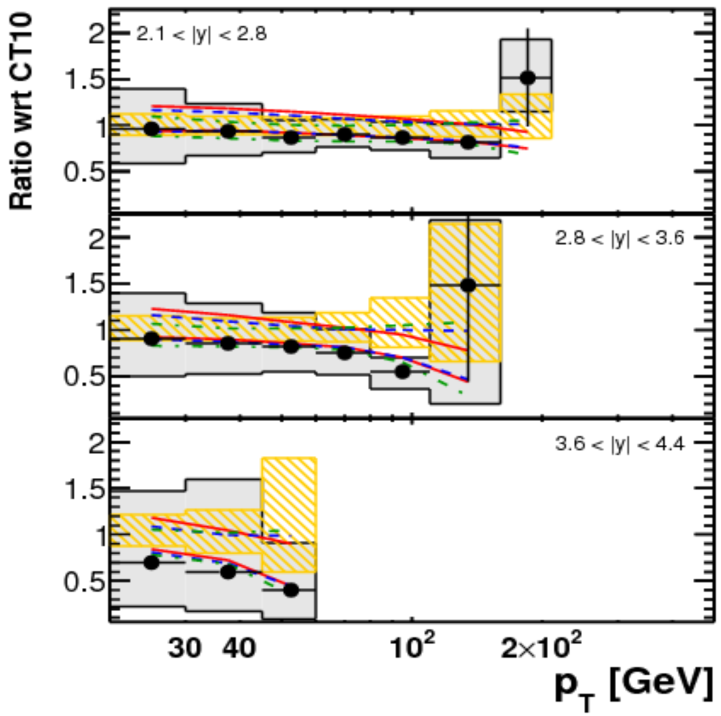
- The free strange fit provides the best description of the measured W/Z cross sections ratio.

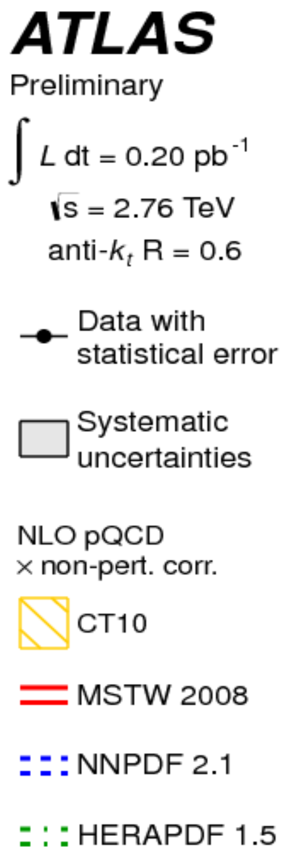


# Inclusive Jet production vs predictions

- 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.



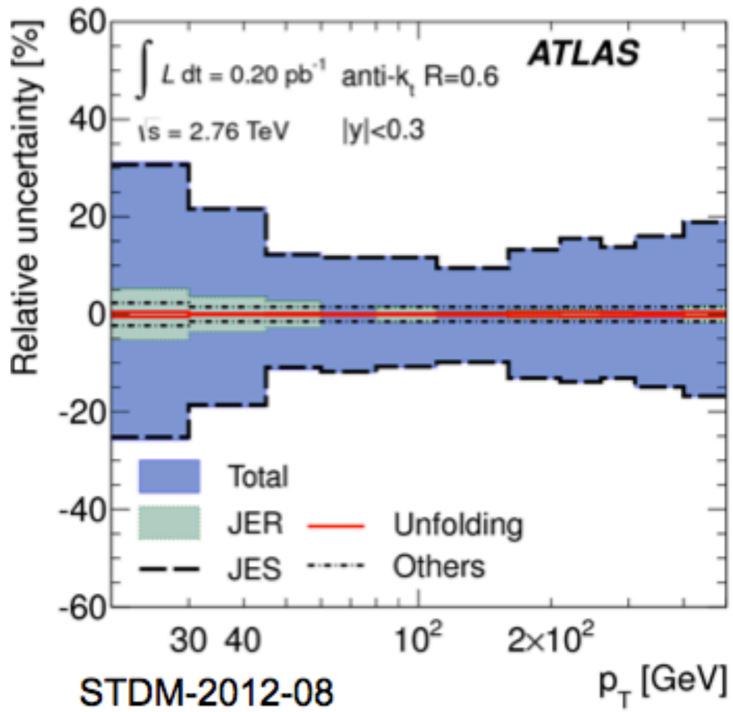



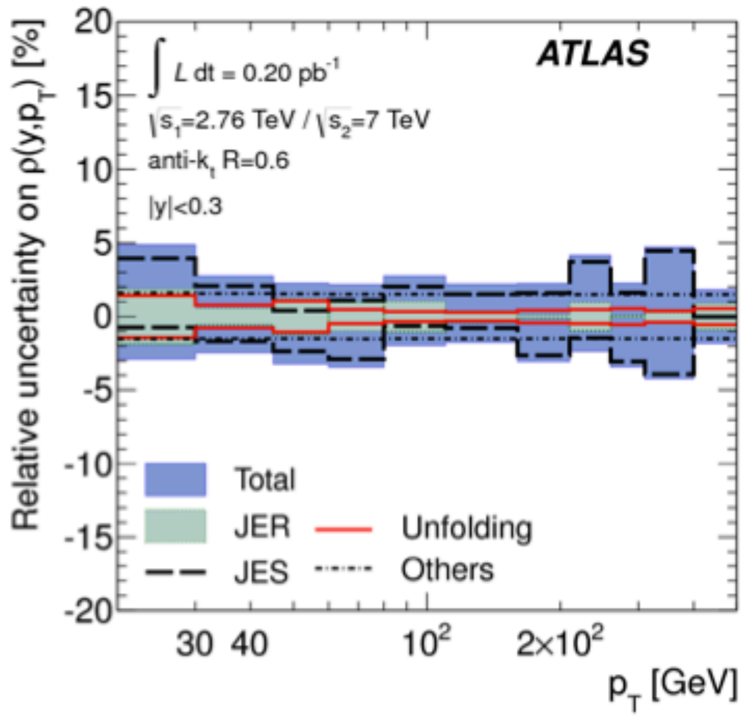




Measurement is consistent with all theory predictions using diffe-rent PDF sets.

# Jet Ratios: cancelation of exp. uncertainties

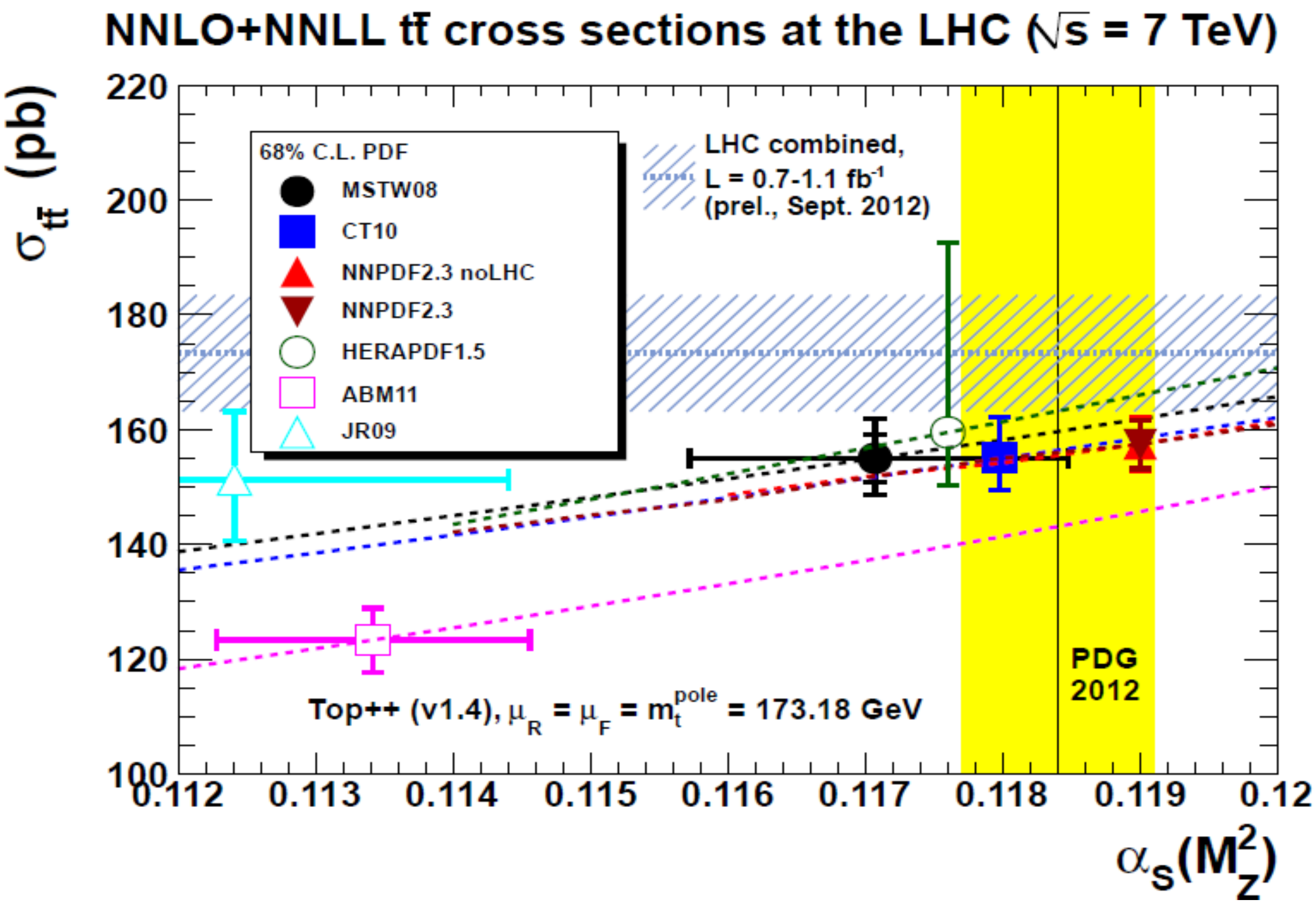
- From 2.76 TeV to 2.76/7 TeV effect on JES, JER:

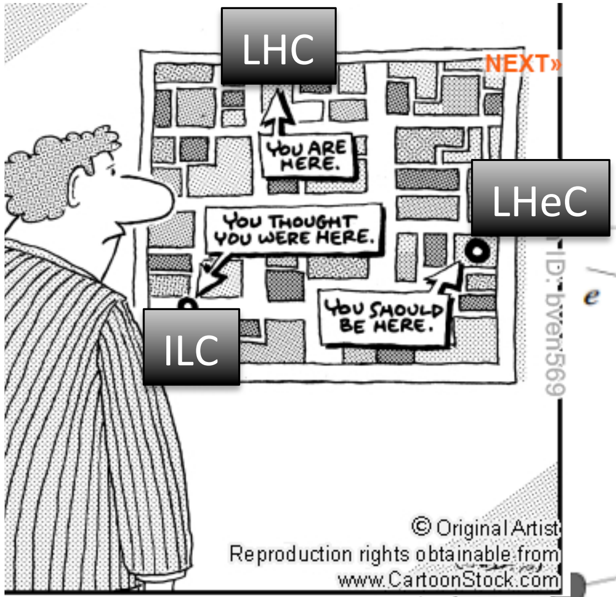


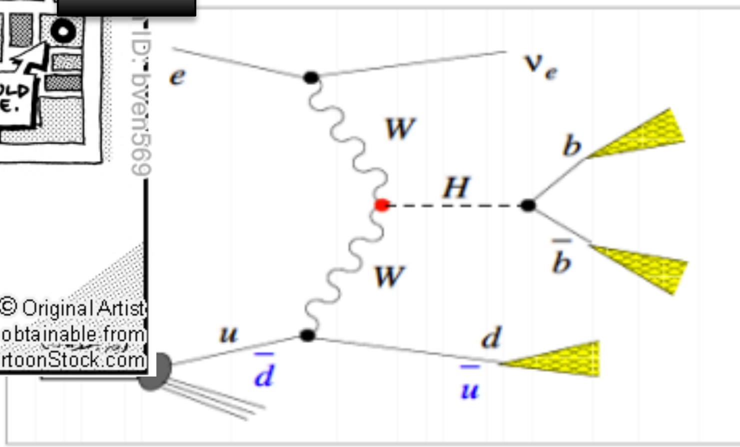
# Sensitivity to PDFs from ATLAS top production

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






# Higgs at the LHeC




In ep the Higgs is radiated from a W or Z exchanged in the t channel. This is a unique production mode. The theoretical uncertainties are very small: J.Blümlein et al, NP B395(1993)35
At the LHC ~90% is gg → H, while VBF is an admixture of WW and ZZ fusion. The ep final state is cleaner than in pp. A first study of the dominant H → bb decay shows the WW-H-bb coupling can be measured to 3% with an S/B=1.
(cf CDR and U.Klein Talk at ICHEP2012)

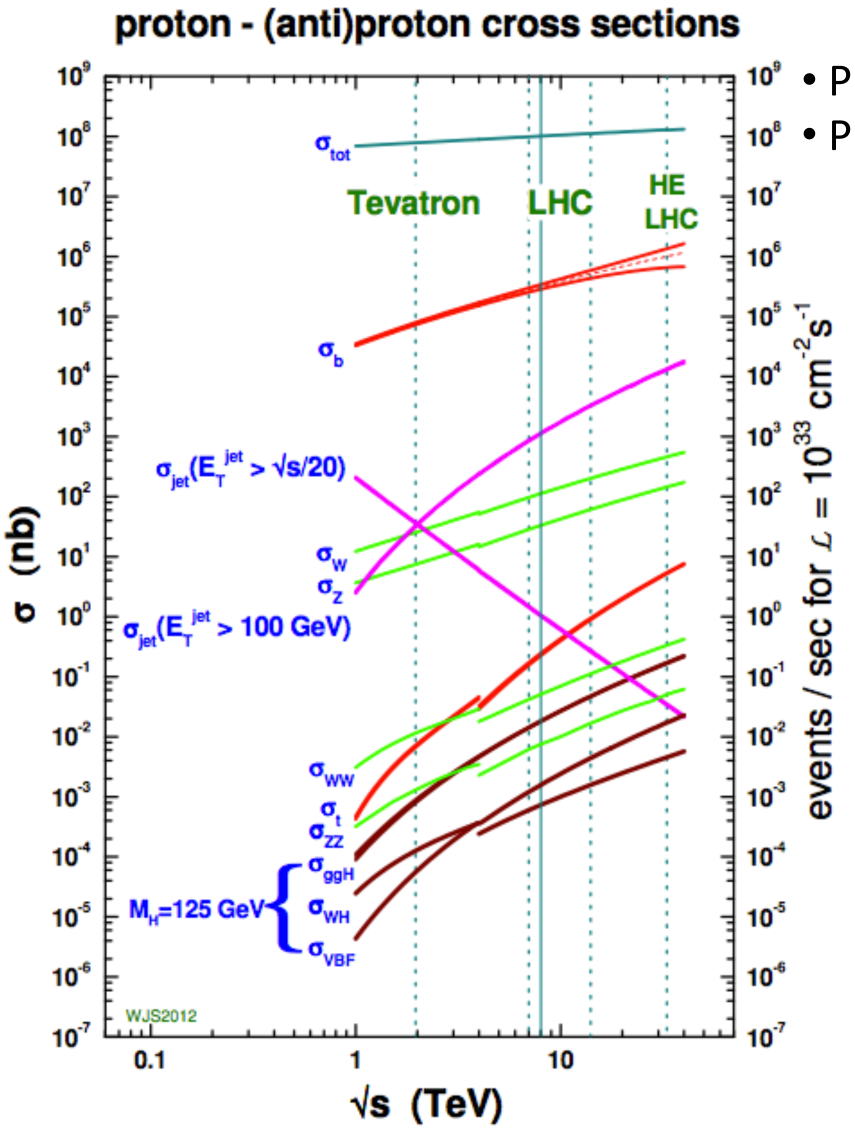
The rates are high and with a simpler final state and dedicated detector also difficult channels may be accessed (as the charm 2nd generation one). This needs to be studied. With an ep luminosity near to $10^{34}$, the LHeC generates as many Higgses as the ILC at that L.

| kinematic requirements | CC $e^-p$ | CC $e^+p$ | NC $e^\pm p$ |
|---|---|---|---|
| cross section | 109 fb | 58 fb | 20 fb |
| acceptance | 0.92 | 0.94 | 0.93 |
| H→ $bb$ | 6500 | 3500 | 1200 |
| H→ $c\bar{c}$ | 330 | 180 | 60 |
| H→ $gg$ | 900 | 480 | 160 |
| H→ $WW$ | 1400 | 760 | 260 |
| H→ $ZZ$ | 160 | 190 | 30 |
| H→ $\tau\tau$ | 570 | 310 | 100 |
| H→ $\gamma\gamma$ | 20 | 12 | 4 |

$E_e$=60Ge

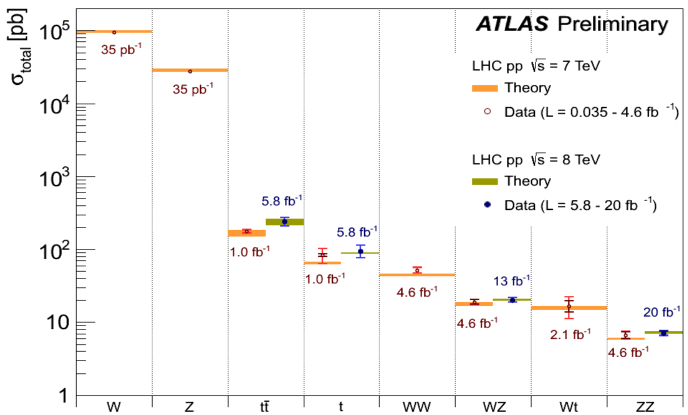
Table 2: Cross sections and events, for an integrated luminosity of 100 fb-1, calculated with MADGRAPH5 (v1.5.4) using the transverse momentum of the scattered quark as scale, the CTEQ6L1 partons and a mas of 125 GeV for a Standard Model Higgs boson and decays as indicated in the left column. A kinematic acceptance is calculated of above 90 % with the following cuts: $|\eta_{jet}| < 5$, $|\eta_{e,\gamma}| < 4.74$, $p_{T,jet} > 1$ GeV, $E_{jet} > 15$ GeV, $E_e > 10$ GeV, $E_\gamma > 5$ GeV. For charm and beauty, tagging is assumed up to $\eta = 3$, the HFL acceptance.

# Pushing Energy Frontier




LHC can provide with its multitude of new measurements

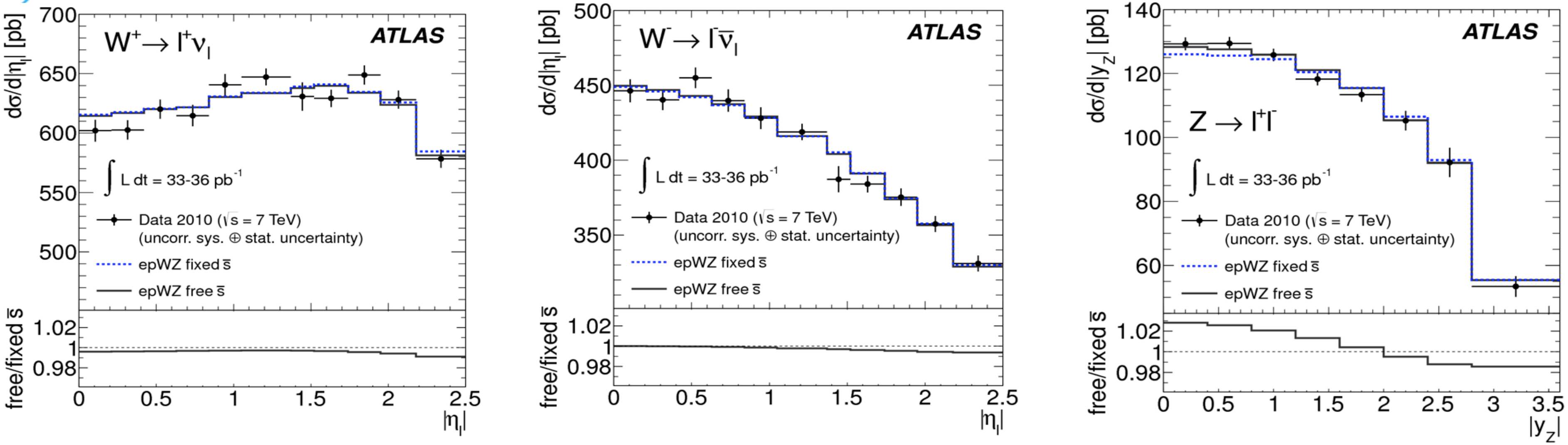
- PDF discrimination by confronting theory with data
- PDF improvement by using LHC data for more accurate



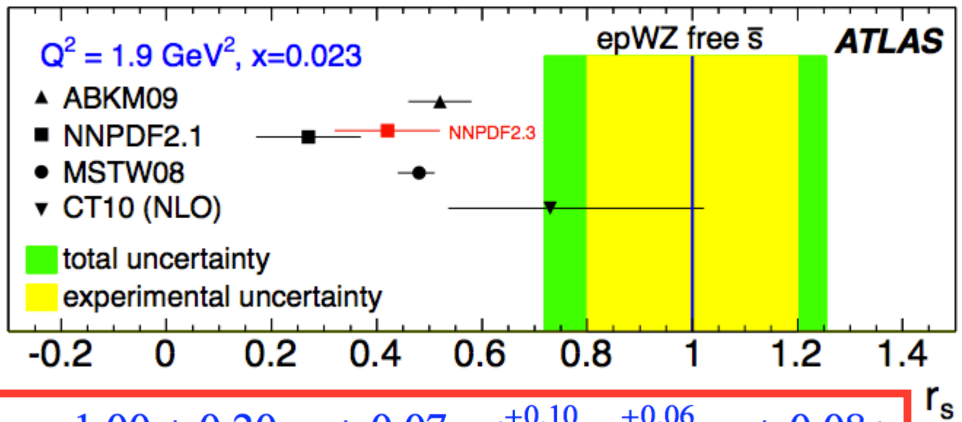

1. W and Z production
2. W+c production
3. Inclusive Jet and Di-Jet production
4. Drell-Yan: low and high invariant mass
5. Top, ttbar
6. Prompt Photon, + Jets [see P. Lenzi]
7. W,Z+b

[See J. Rojo's talk for a theoretical perspective]

# Results of QCD Fit to W, Z measurements




- The results for NNLO fits with free and fixed strangeness
  - For W+ and W- there is little difference however they help to fix the normalisation.
  - For Z instead, the cross section is increased and the shape is modified.



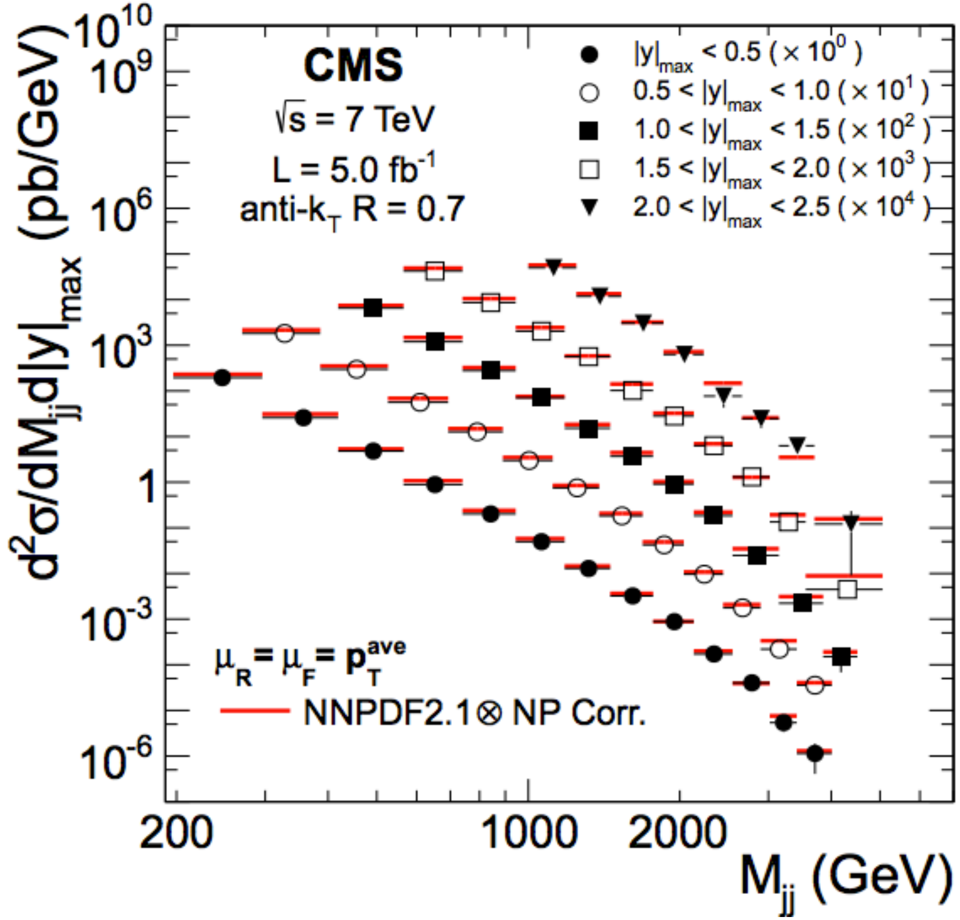

$$r_s = 1.00 \pm 0.20_{\text{exp}} \pm 0.07_{\text{mod}}{}^{+0.10}_{-0.15}{}_{\text{par}}{}^{+0.06}_{-0.07}{}_{\alpha_S} \pm 0.08_{\text{th.}}$$

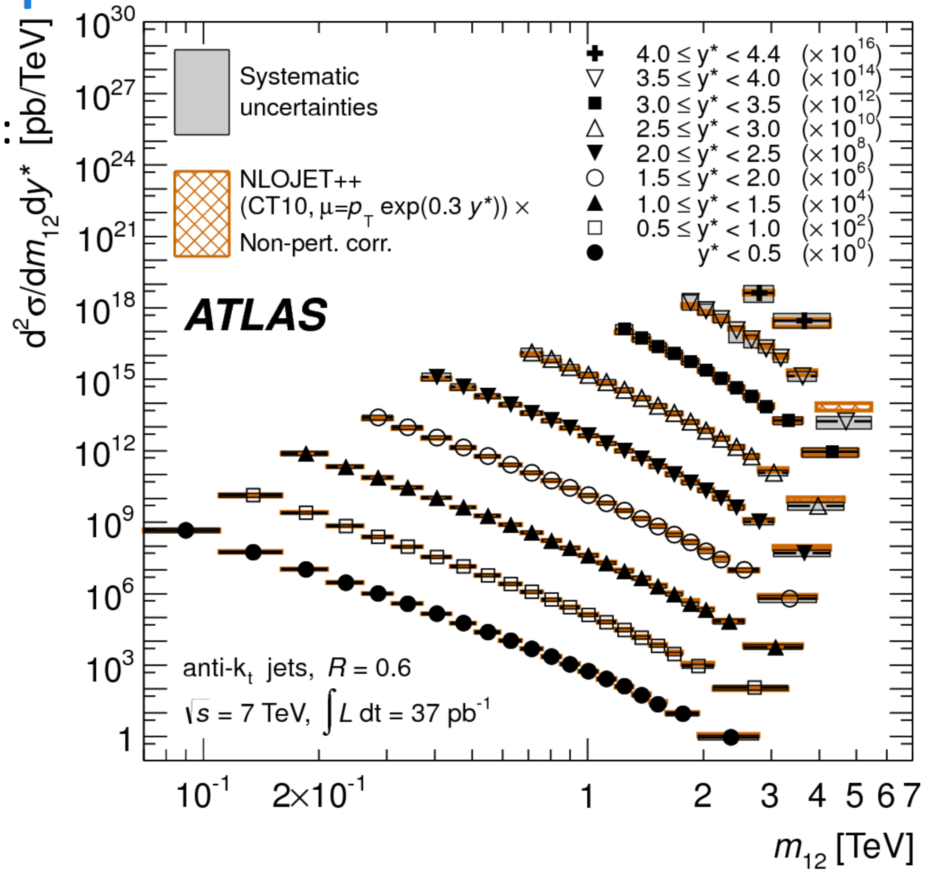
**ATLAS Result:** is the kinematic region probed by LHC data at x~0.01 and indicates enhanced strangeness in agreement with the CT10

- It is consistent with CT10 (NLO) which has an enhanced strangeness (s/d~0.75)
- It is above of MSTW08, ABKM09, NNPDF2.3 (s/d~0.5)

# Inclusive DiJet production

- Measurements of ATLAS and CMS inclusive di-jet cross-sections differential in invariant mass and y:
  - [ATLAS: Phys ReV D86(2012)014022]
  - [CMS-QCD-11-004 arXiv:1212.6660]
  - sensitive to gluon at high x



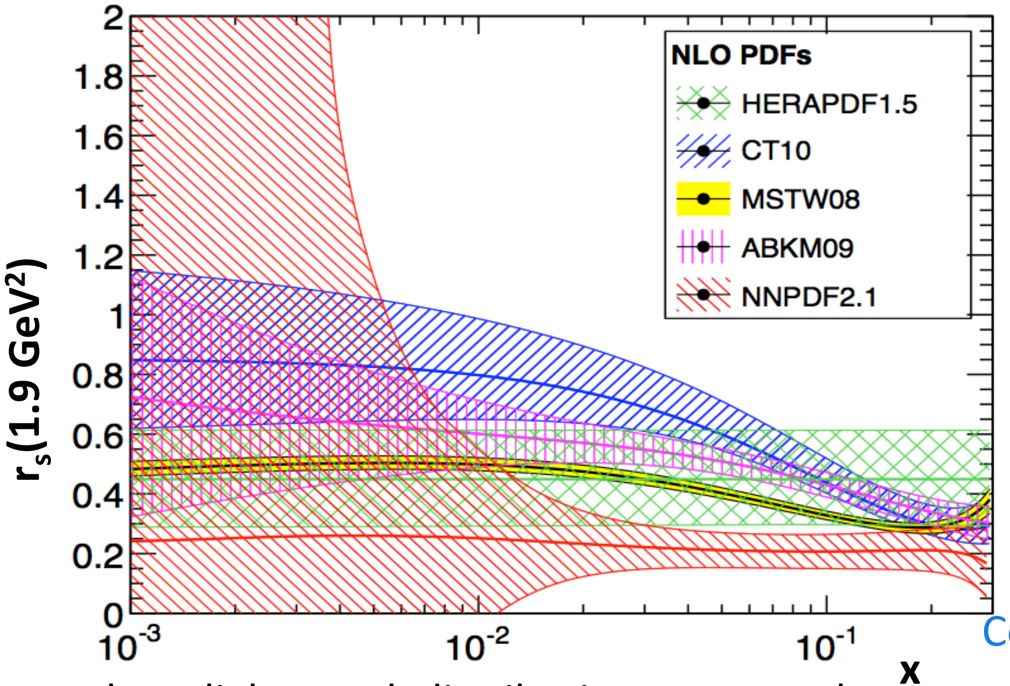




- Measurements are provided with full information on correlations
- Measurements can be used in alphas determination

  [see P.Lenzi's talk]

# Strange quark content of the proton

Strange quark is not so well constrained:




Courtesy of G. Watt

- Flavour SU(3) symmetry: three light quark distributions are equal:
  - Strange quark density may be suppressed due to their larger mass as favored by Neutrino dimuon data.
  - Often it is assumed that s=sbar and rs=0.5 $r_s(x) = 0.5(s(x) + \bar{s}(x))/\bar{d}(x)$

- At LHC, Z cross sections together with $y_Z$ shape may provide a constraint on **s**-quark density and cross checked against its W+charm data.