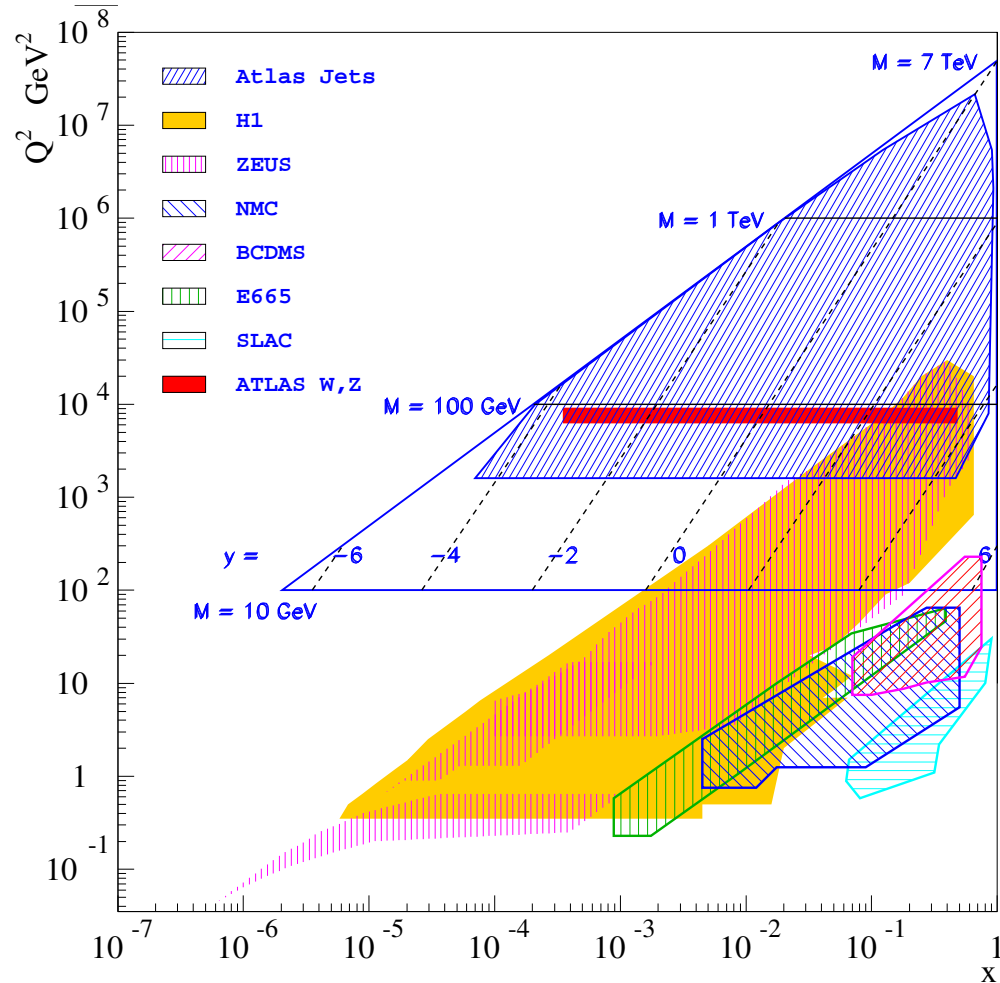


LHC and HERA common analyses

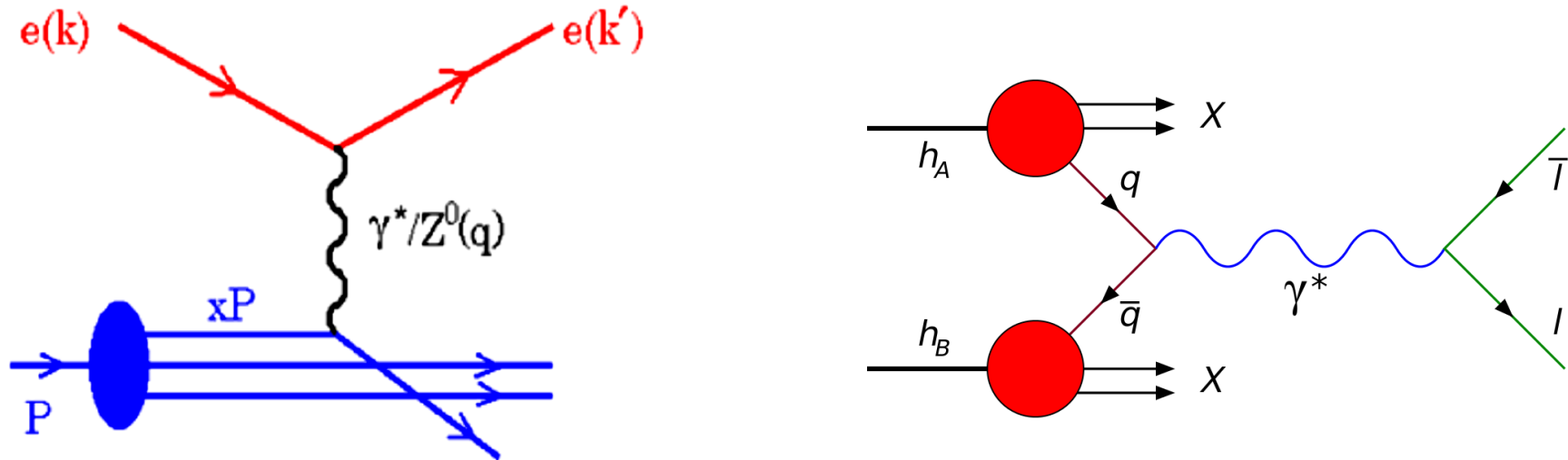
S.Glazov, 12/11/14, DESY

Kinematic coverage of ep and pp colliders



- HERA-LHC workshop: HERA is essential for physics at the LHC
- First LHC results: LHC can complement HERA measurements
- Future: Common HERA+LHC measurements (?)

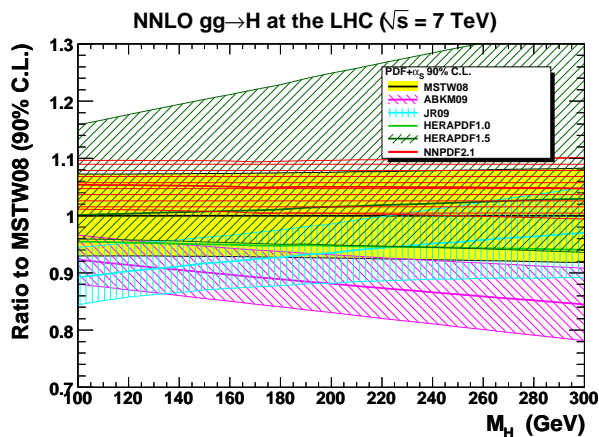
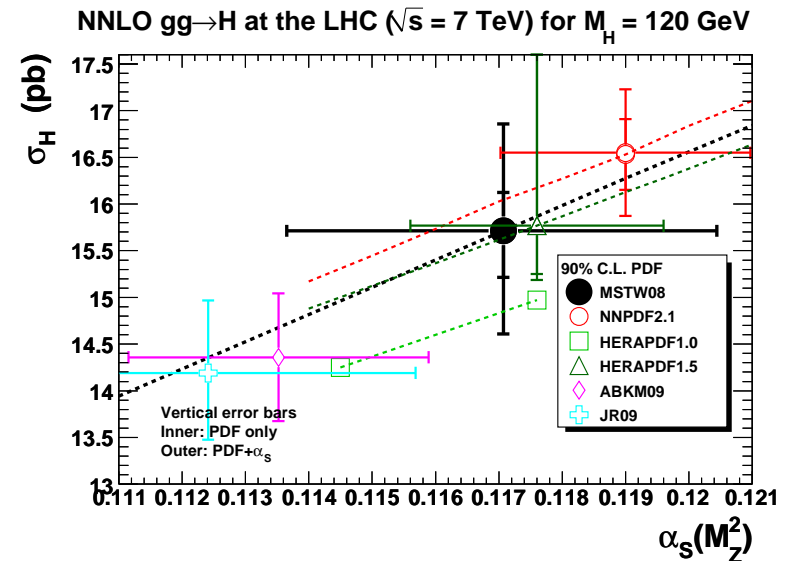
DIS vs DY



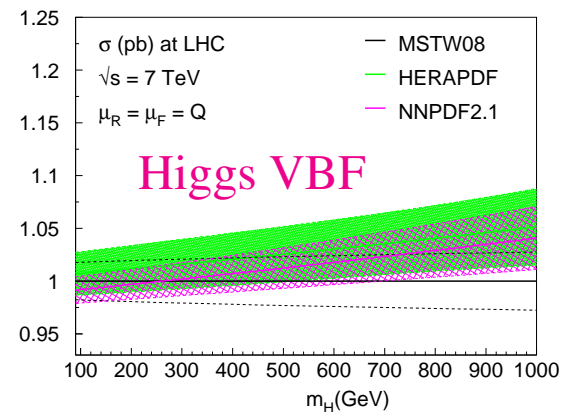
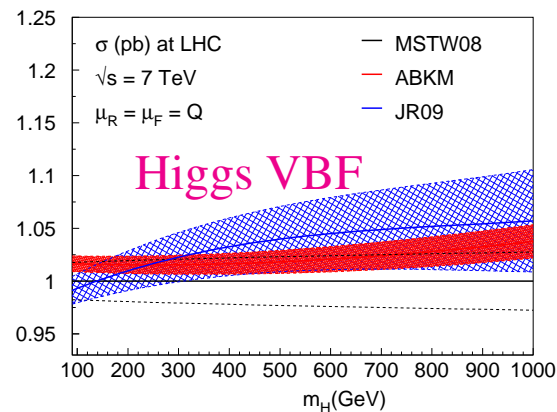
- Virtuality of the exchange γ^*/Z and invariant mass of the lepton pair provide the hard scale to study QCD/EWK effects.
- Large samples of DY events at the W, Z pole already collected at LHC run-I, several analyses of QCD-properties of events. A few theory developments how to study them better.
- DIS and DY have very different structure of MPI, UE – comparison of the two can help to disentangle different effects.

Cross-section predictions at the LHC: Higgs

- Uncertainties for the dominant $gg \rightarrow H$ process are mostly from gluon density and α_S . VBF process given at LO by $qq \rightarrow Hqq$ has smaller uncertainties.
- Overall $\sim 10\%$ agreement for the same α_S . Somewhat larger uncertainty for HERAPDF since no jet data are included.



G. Watt (September 2011)

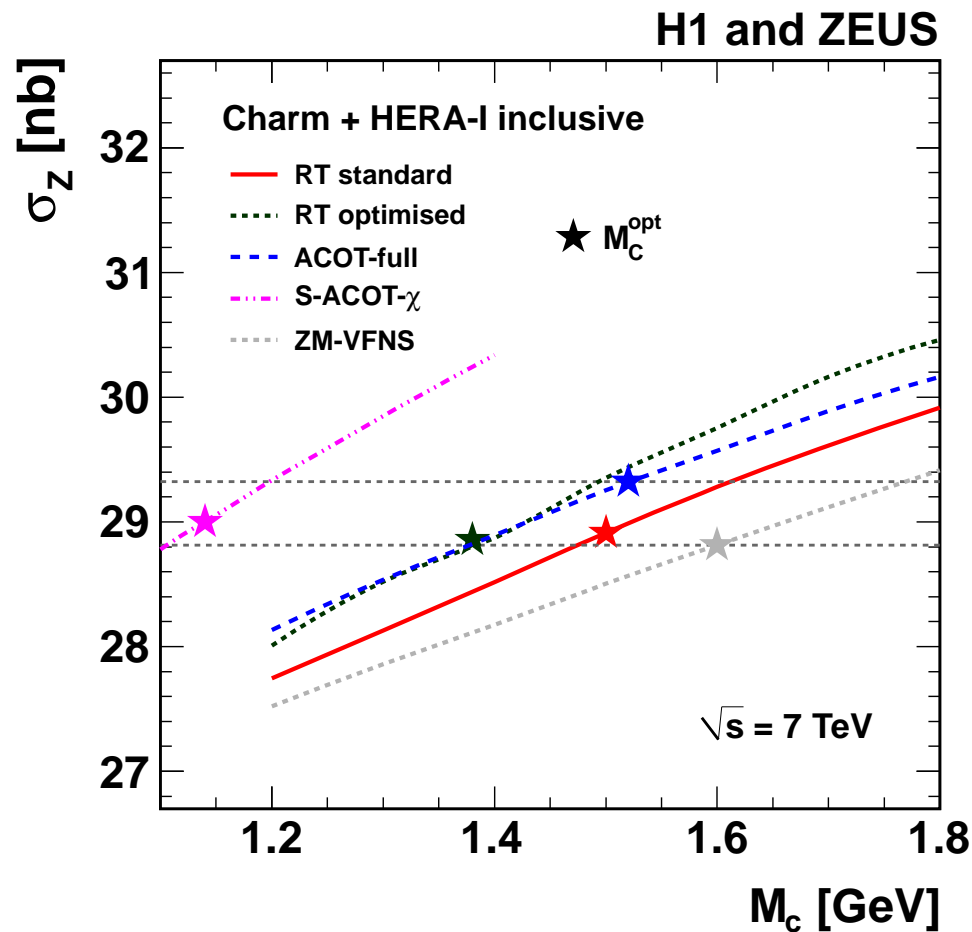


G. Watt, <http://mstwpdf.hepforge.org/pdf4lhc/ringberg>

P. Bolzoni, *et. al.* Phys. Rev. D 85, 035002 (2012), Anastasiou, *et. al.* arXiv:1202.3638.

G. Watt (September 2011)

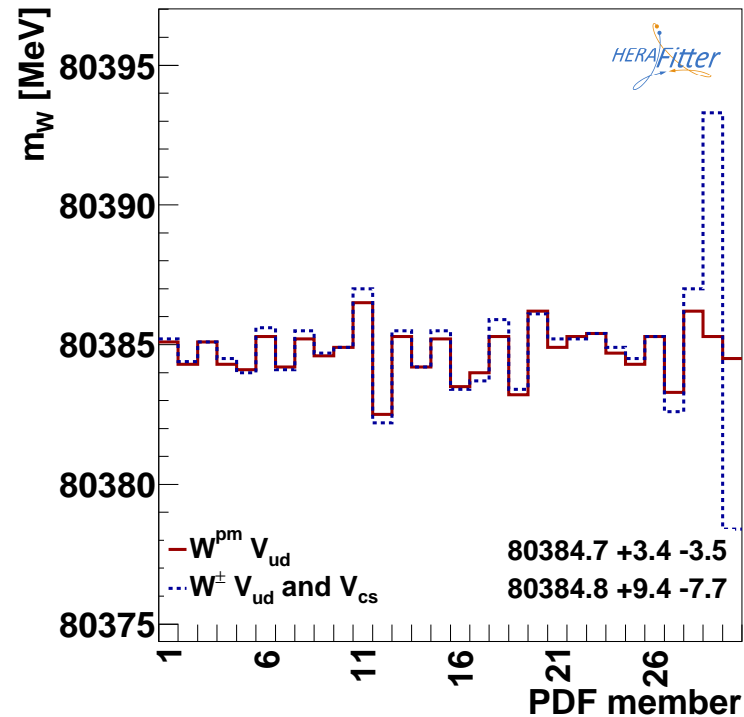
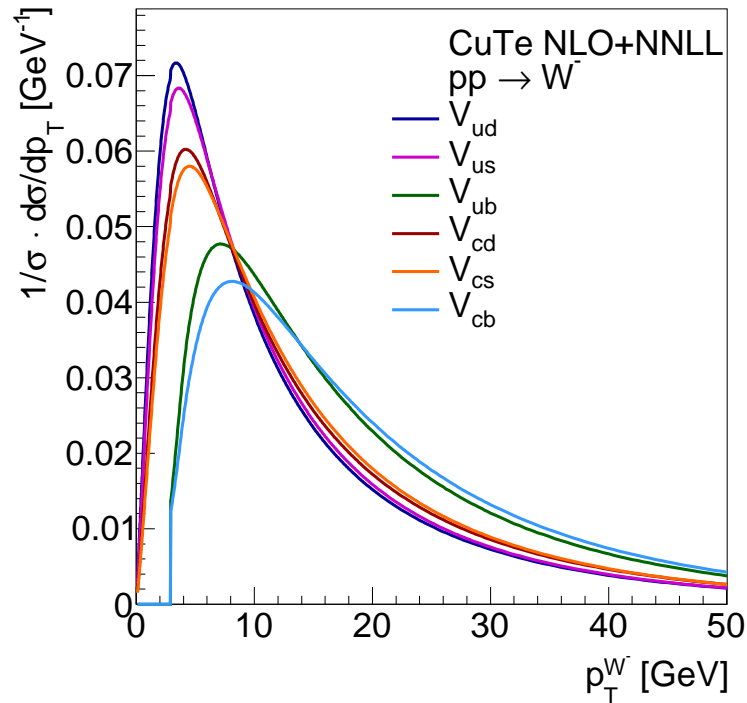
Sensitivity of LHC predictions to the charm



Eur. Phys. J. C73 (2013) 2311

Large $\sim 7\%$ spread of the total cross section prediction for m_c^{model} scan between $1.2 - 1.8 \text{ GeV}$ and also for a fixed m_c^{model} when considering different models. However, the spread is reduced when predictions are evaluated at the $m_c^{\text{model}}(\text{opt})$ values.

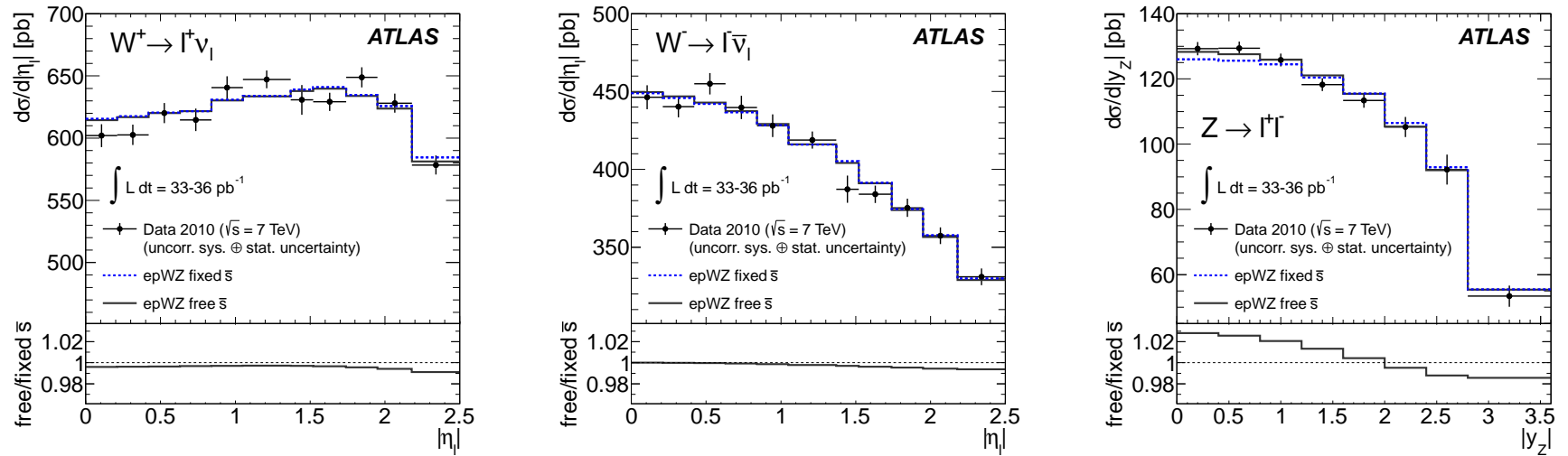
W-mass measurement at the LHC and charm



- Most sensitive determination of M_W at the LHC uses the lepton p_T^ℓ . p_T^ℓ is sensitive to p_T^W modeling, which is different for cs vs uv production.
- Dedicated PDF set, produced using HERAFitter and HERAPDF1.0 data with charm-mass (**PDF members 27-28**) and strange-fraction variations (**29-30**), affecting cs fraction, have large impact on the uncertainty. Impact of m_C variation would be larger without HERA results.

ATL-PHYS-PUB-2014-15

Determination of the strange-sea density



Perform two NNLO fits to HERA+ATLAS data: with fixed strangeness fraction $r_s = 0.5(s + \bar{s})/\bar{d}$, $r_s = 0.5$ and free strange density parametrized as

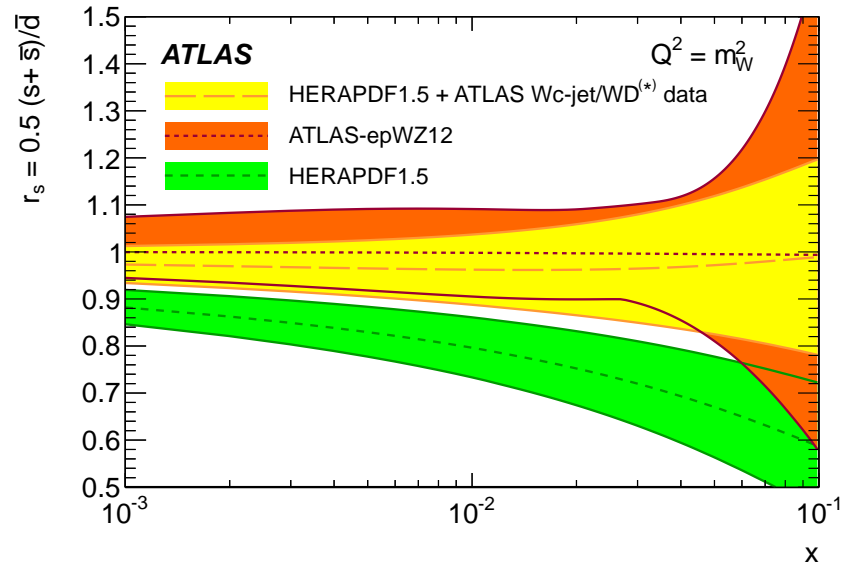
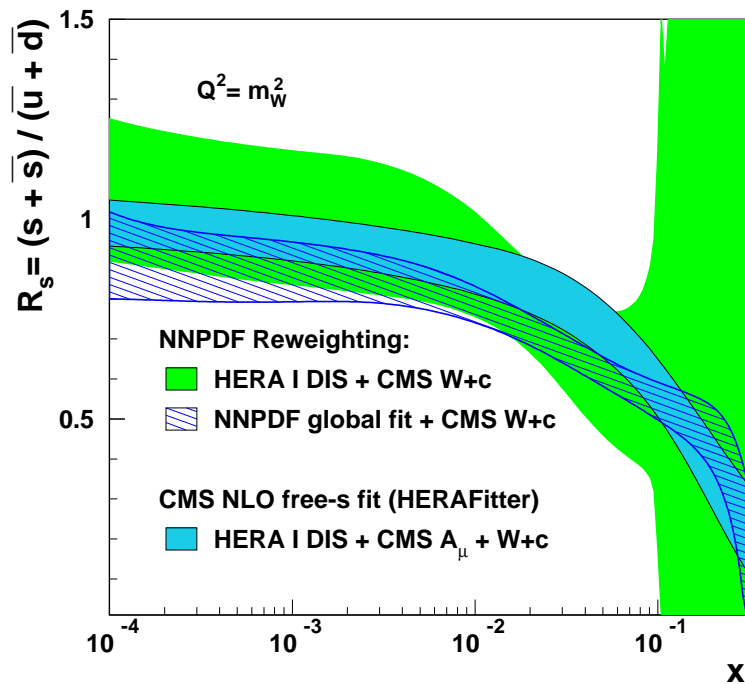
$$x\bar{s}(x) = A_s x^{B_{\bar{d}}}(1-x)^{C_s}$$

For $x = 0.023$ and $Q^2 = 1.9 \text{ GeV}^2$, corresponding to the maximum of ATLAS data sensitivity extrapolated to low Q^2

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

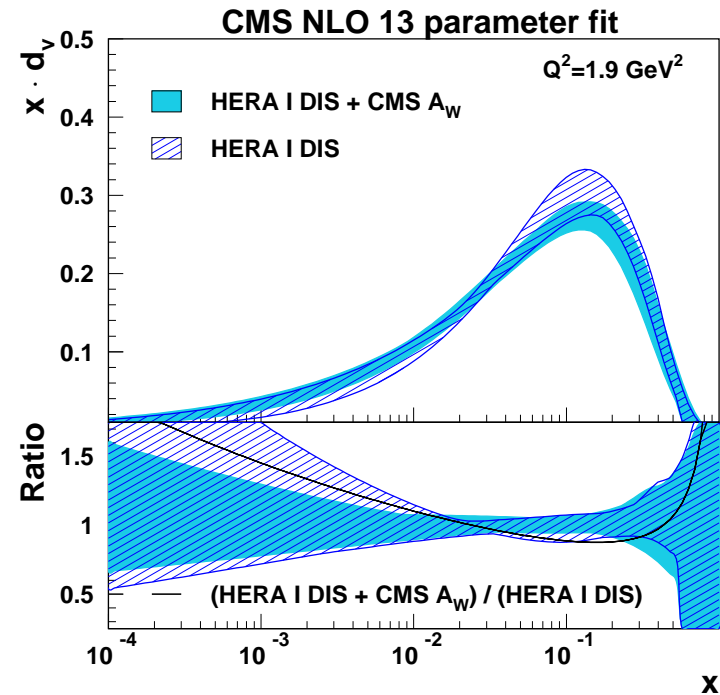
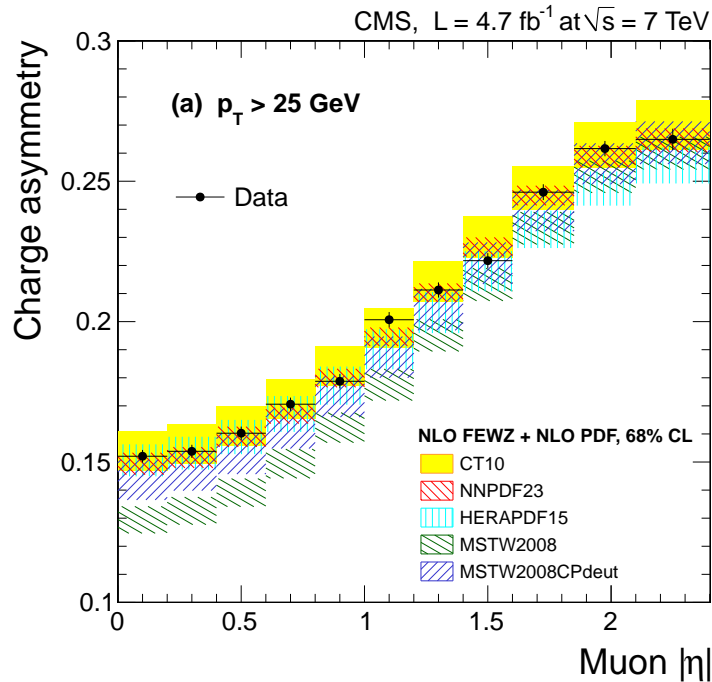
consistent with sea quark flavour democracy at low x .

Strange-sea PDF comparison



- CMS performs QCD analysis using HERA and CMS W asymmetry and $W + c$ data, reports $\bar{s}/(\bar{u} + \bar{d})$.
- ATLAS profiles HERAPDF1.5 which separates \bar{s}/\bar{d} ratio as an uncertainty sources. The x -independent result $\bar{s}/\bar{d} = 0.96^{+0.26}_{-0.30}$ is consistent with no suppression.

CMS muon asymmetry measurement



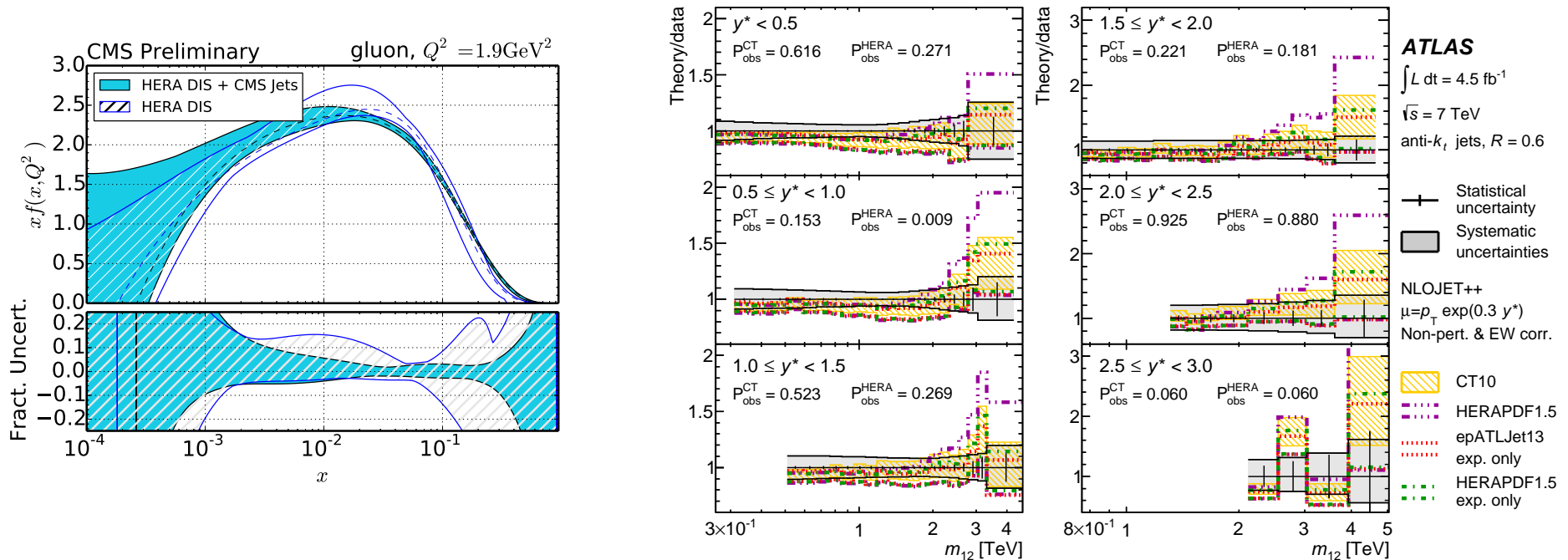
- CMS performs muon charge asymmetry measurement for $W^\pm \rightarrow \mu^\pm \nu$ decays. MSTW08 PDF is disfavoured, NNPDF2.3 which includes ATLAS W, Z data, describes data well.
- QCD analysis of the HERA+CMS asymmetry data illustrates reduction of the d_v uncertainty in the range where data contributes.

[arXiv:1312.6283](https://arxiv.org/abs/1312.6283)

HERA data in future LHC analyses

- HERA data are essential for PDF determination at the LHC. HERA-II inclusive cross-section data, jets and heavy flavour results will be used in future LHC fits.
- A few more results are expected from run-I LHC data, many more expected from 13 TeV data. Shift to lower x for the EWK scale data (from ~ 0.01 to ~ 0.005) will highlight importance of the low x HERA data.
- Analysis of the LHC data may potentially reveal tensions with HERA, which may need expert input from HERA analysers. Some “tensions” may be resolved by future theory developments, which are to be included in the common analyses.
- **Expected results from these analyses:** improved flavour decomposition at low x , valence-sea separation at low x , improved gluon density at medium-high x , improved PDFs at high x , accurate determination of EWK parameters.

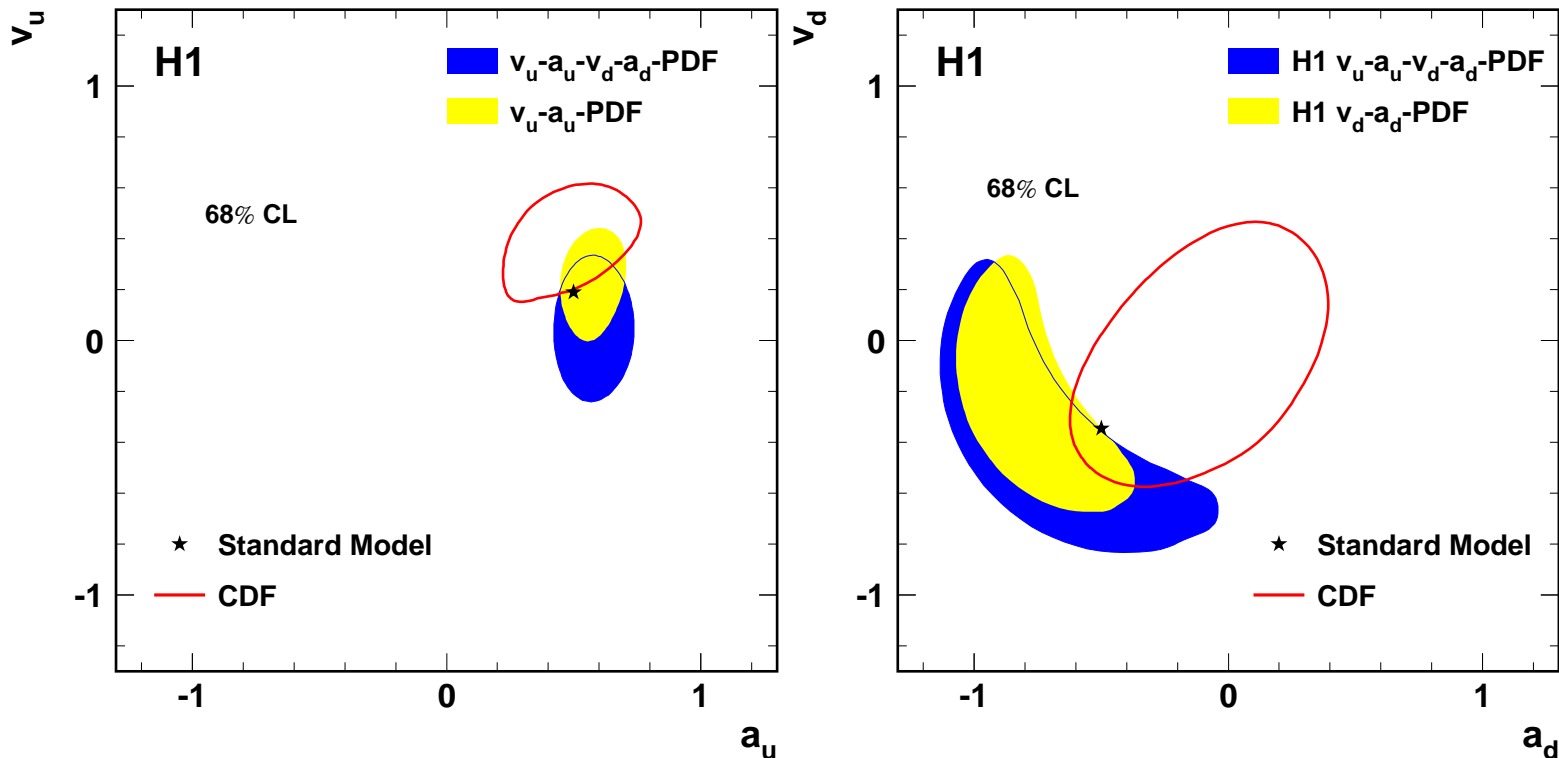
PDF sensitivity of the jet data



- CMS performed NLO QCD analysis of the inclusive jet plus HERA data, finds that data prefers harder gluon, reduces uncertainty at high x .
- ATLAS compared dijet data to NLO QCD+EWK predictions based on various PDFs, using frequentist approach. Good agreement with CT10, MSTW08 and NNPDF2.3 while ABM11 is disfavored.

CMS-PAS-SMP-12-028, arXiv:1312.3524

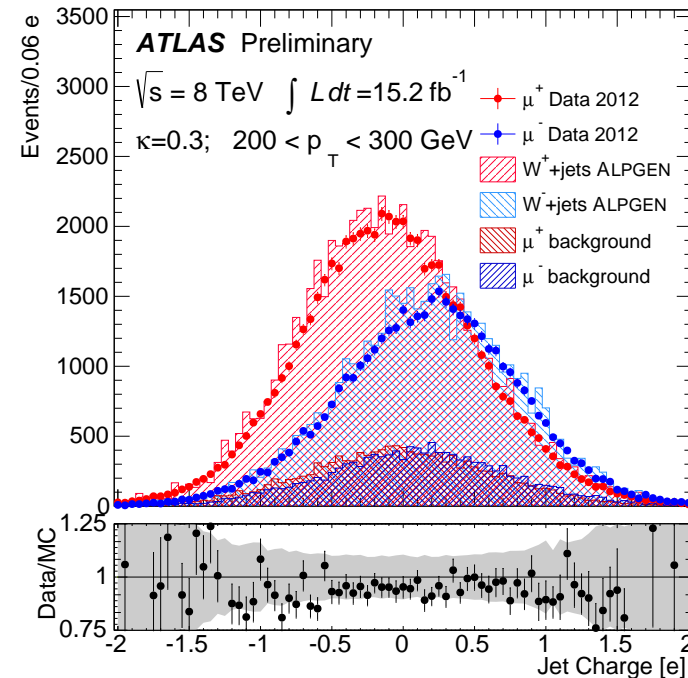
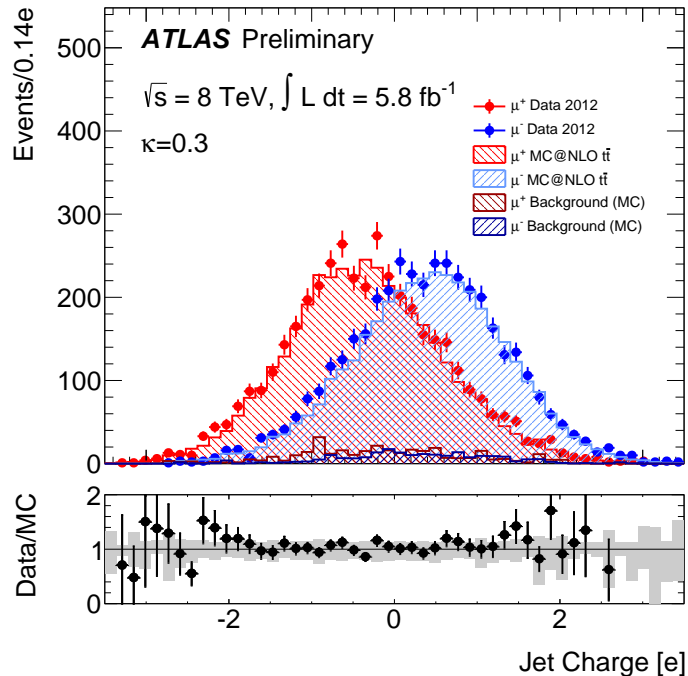
Example: common QCD+EWK fit



- HERA data can be used to determine u and d -type quark couplings in a QCD-EWK fit
- Large samples of Z samples collected at the LHC.
- Consistent treatment of EWK effects: common fit to HERA and LHC data.

PLB632 (2006).

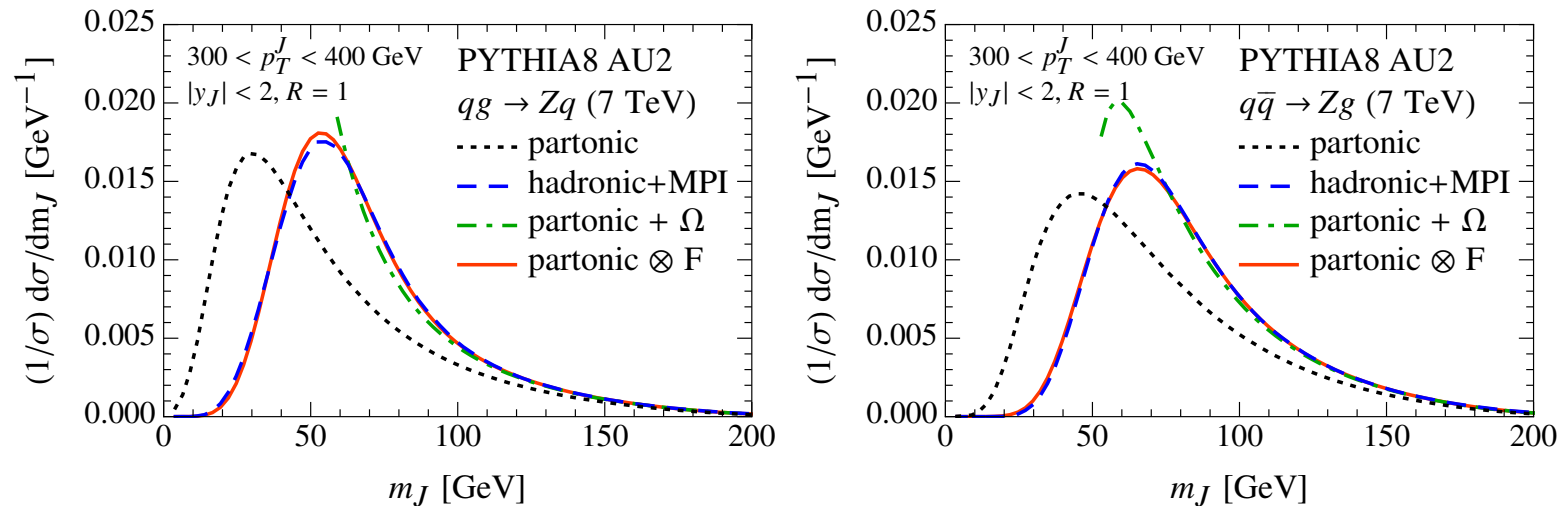
Recent QCD developments for LHC \rightarrow HERA



- Many recent developments in QCD area, related in particular to HFS, (fat)jets.
- E.g. jet charge seems to be an interesting way to distinguish u and d -quark jets. Can this method be applied to HERA data to constrain d/u quark density ?

ATLAS-CONF-2013-086

Example: separation of MPI, UE and hard radiation effects



- New idea to separate MPI/UE and hard radiation effects using jet mass for Z +jet and H +jet events
- Study first momentum of m_J as a function of jet radius: different components have different dependence.
- DIS jets would help a lot for the separation.

arXiv 1405.6722

Possible models of common HERA-LHC analyses

- Published HERA data included in PDF fits:
 - papers by the LHC collaborations, HERAFitter developers, PDF groups, ...
 - Essential: detailed correlation model on HepData/HERAFitter, as for combined inclusive paper.
- HERA data used for MC tunes:
 - Papers and pub-notes by the LHC collaborations, MC authors,
 - Essential: Rivet analysis.
 - Some MC developers are willing to include unpublished data (from PhD theses).
- Genuine new analyses of the HERA data (e.g. jet mass of anti-Kt $R = 1.5$ jets)
 - Analysis performed within HERA collaborations.
 - Open access to the HERA data.
 - Essential: expert knowledge of the HERA analyses, tools to perform calibration, determine systematic uncertainties.

Summary

- HERA data plays essential role for understanding of the LHC physics.
- A few LHC analyses use HERA directly. HERA-II combined inclusive cross section measurements, charm and jet measurements will be included in future QCD/EWK analyses.
- Driven by the need of LHC experiments, there is a number of new QCD developments. Checking them for DIS environment could help to separate various effects: another room for common HERA-LHC analyses.