PDF Session Summary

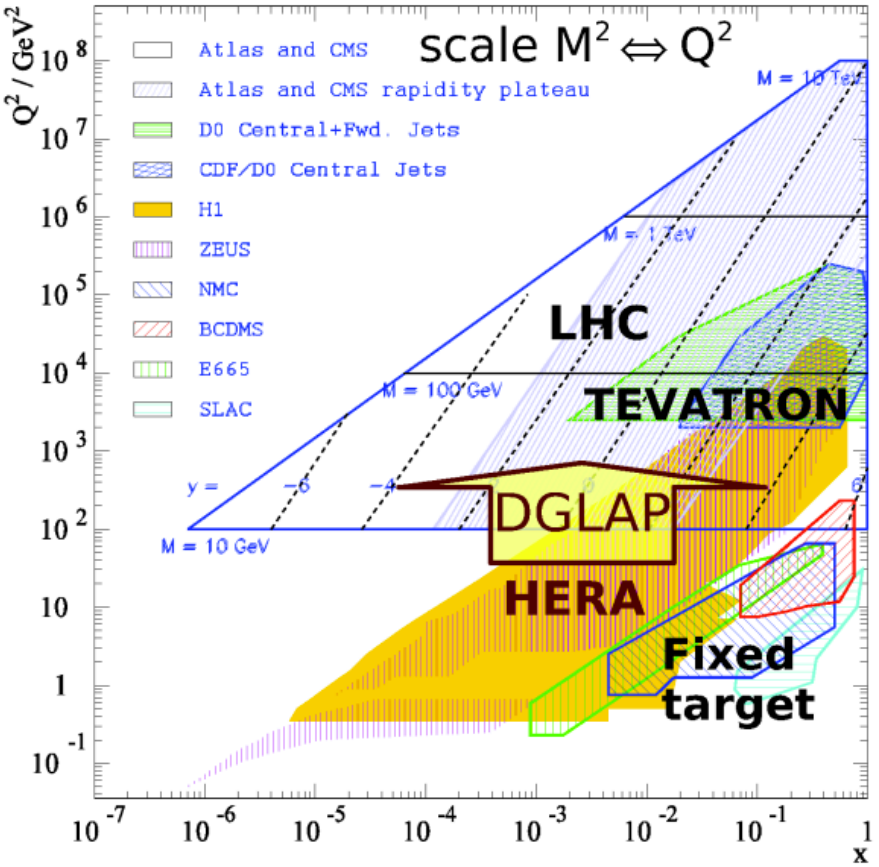
Pedro Jimenez-Delgado (JLAB)
Voica Radescu (DESY)

3 sessions with 22 presentations

- a joined session with Hard Scattering
- a joined session with PDF4LHC
- a stand alone session for PDF

New Results important for PDFs from:

- DIS and DY experiments
- theory: global fits and HO calculations



Many thanks to all participants for a handful of new results and interesting discussions!

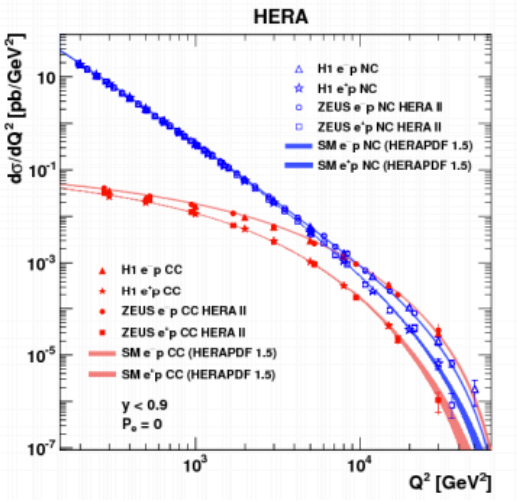
News from HERA

F. Januschek

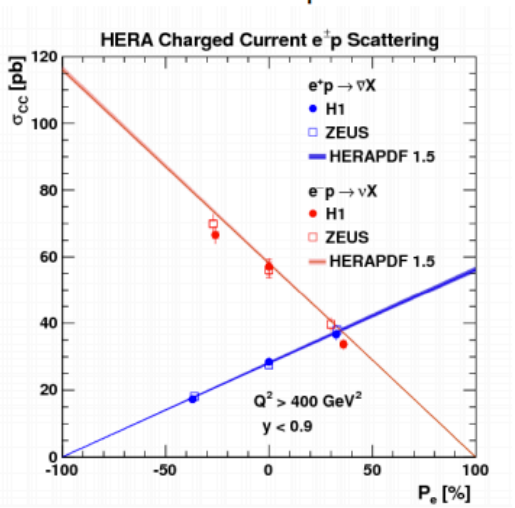
- HERA Combined F2 charm data provides constraints for heavy flavour quark treatment
- H1 JHEP 09 (2012) 061 and ZEUS EPJ C 70, (2010) 945-963 published the final pieces of HERA-II NC and CC inclusive data.

Inclusive NC and CC: HERA Textbook Plots

Electroweak Unification

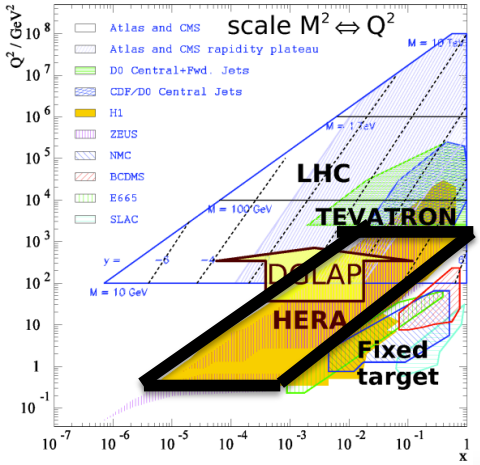


Linear Polarisation Dependence



Good agreement with SM (HERAPDF 1.5) prediction.

Friederike Januschek DESY — On Behalf of the ZEUS and H1 Collaborations



HERAPDF Version	Included data	Order
HERAPDF 1.0	HERA-I NC,CC data	NLO, NNLO
HERAPDF 1.5	HERA-I NC,CC data partial HERA-II data	LO, NLO, NNLO recommended
HERAPDF 1.6	HERA-I NC,CC data partial HERA-II data, jets	NLO
HERAPDF 1.0 +charm	HERA-I NC,CC data charm	NLO
HERAPDF 1.7	HERA-I NC,CC data partial HERA-II data, jets, charm	NLO
HERAPDF 2.0	HERA-I NC,CC data HERA-II data	LO, NLO, NNLO planned

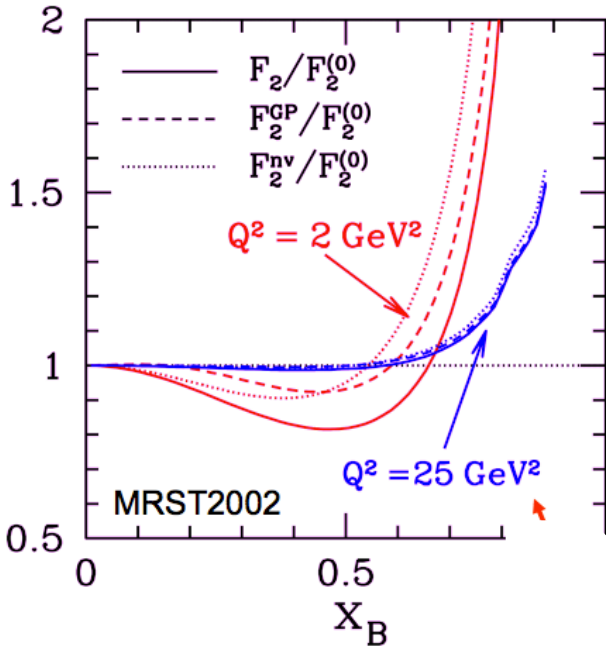
Ongoing efforts towards final inclusive HERA I+II data combination and realising of corresponding HERAPDF2.0 – very much awaited!

News from JLAB and CTEQ-JLAB

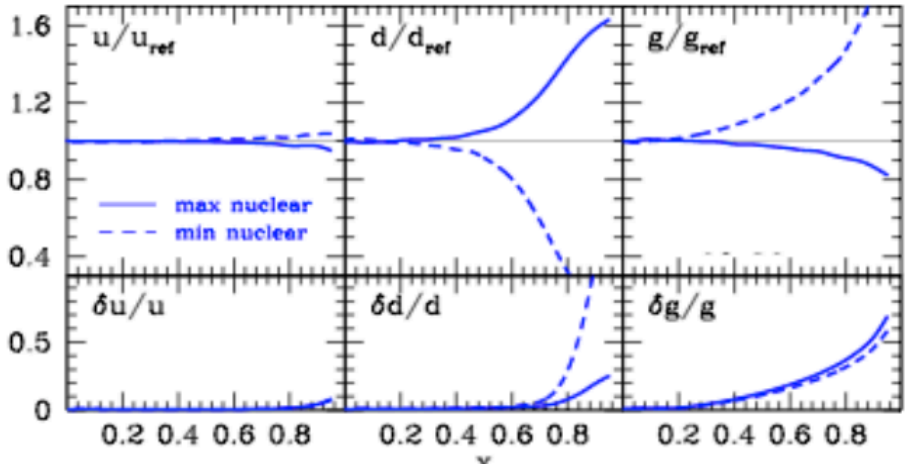
C. Keppel

- JLAB: active program to provide PDF information at high x ➔ useful for LHC
- CAVEATS: To extract PDF information from nuclear targets, corrections must be applied:
  - CTEQ-JLAB collaboration addresses the theoretical issues at high x data to reduce the PDF uncertainties

Size of Target mass correction



- Target Mass Corrections: crucial at low Q2, large x
  (HERA data not affected due to the kinematic acceptance)
  - Higher Twist contribution (parametrised by ~c(x)/Q2))
- Nucleon corrections for deuteron targets:
  - affects d, which is anti-correlated with g



BONUS experiment at JLAB extracts F2n in a model independent way using tagging spectator proton approach ➔ this measurement is encouraged to be used for global PDF fits PRL108 (2012) 199902

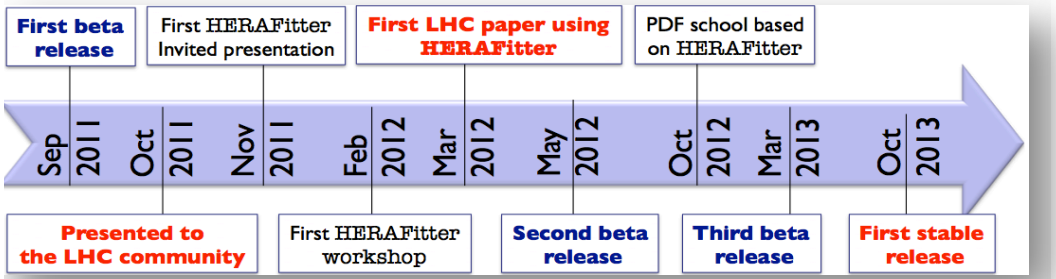
A lot of new experiment to come to assess d/u: first scheduled experiment in 2015 at JLAB Hall A

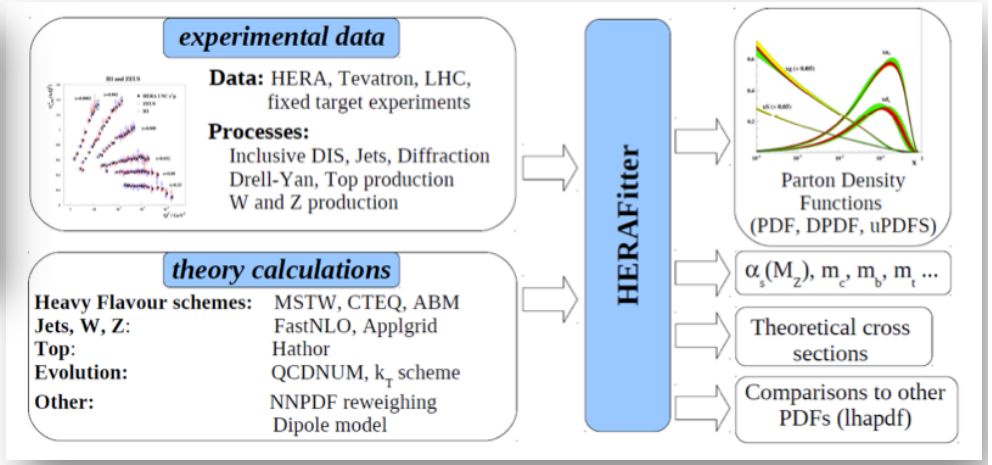
HERAFitter QCD platform

R. Sadykov

Heritage of HERA transferred to LHC:

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





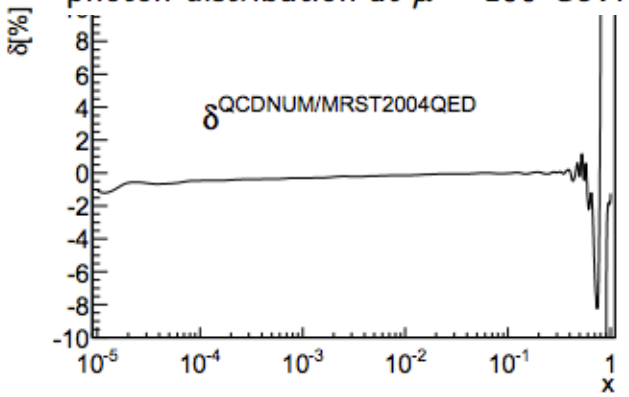
Towards stable release:

New:

- Implementation of QED effects in PDF evolution of importance to measurements at LHC

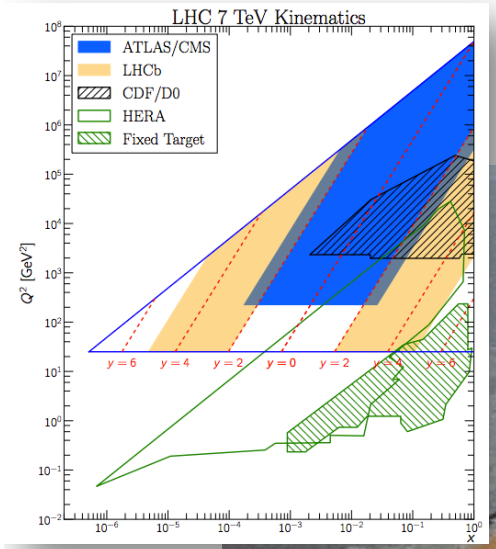
$$\delta = \frac{xf(QCDNUM+QED) - xf(MRST2004qed)}{xf(MRST2004qed)}$$

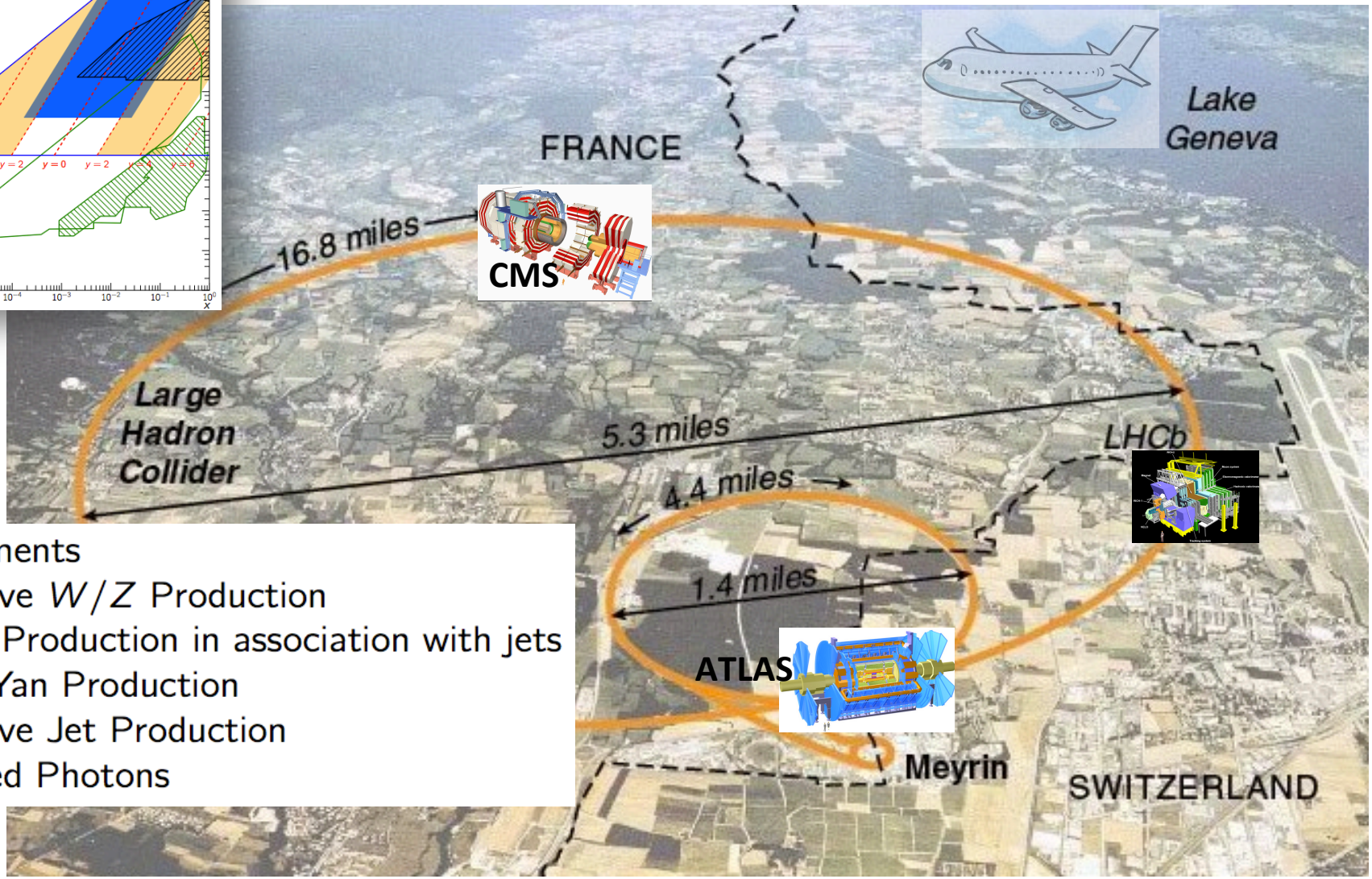
photon distribution at $\mu = 100$ GeV:



Implementation cross checked against MRST2004qed and very good agreement is found.

Precision Measurements from the LHC sensitive to PDFs





Measurements

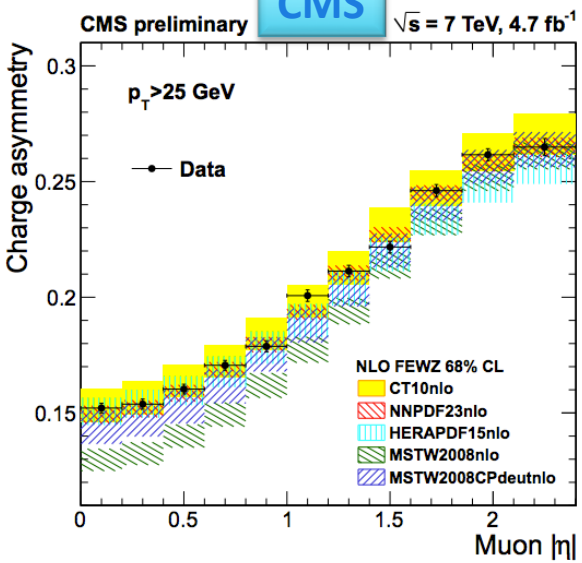
- Inclusive W/Z Production
- W/Z Production in association with jets
- Drell-Yan Production
- Inclusive Jet Production
- Isolated Photons

W Charge Asymmetry

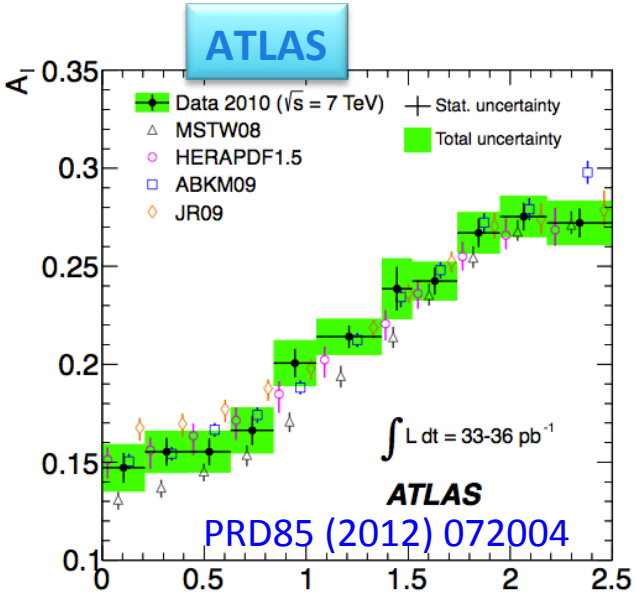
S. Farry
S.Wollstadt
E. Gallo

- 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

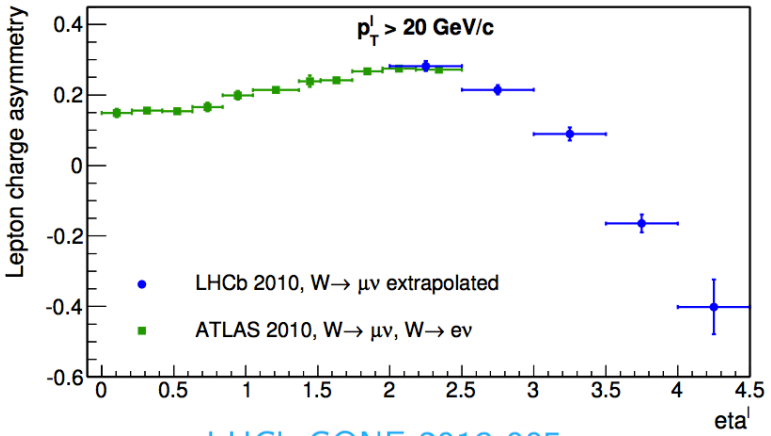
CMS



ATLAS



LHCb



- CMS measures directly the lepton asymmetry – updated result with 4.7/fb of 2011 data
- 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 ATLAS measurement in the overlapping region, after LHCb was extrapolated from its fiducial volume.

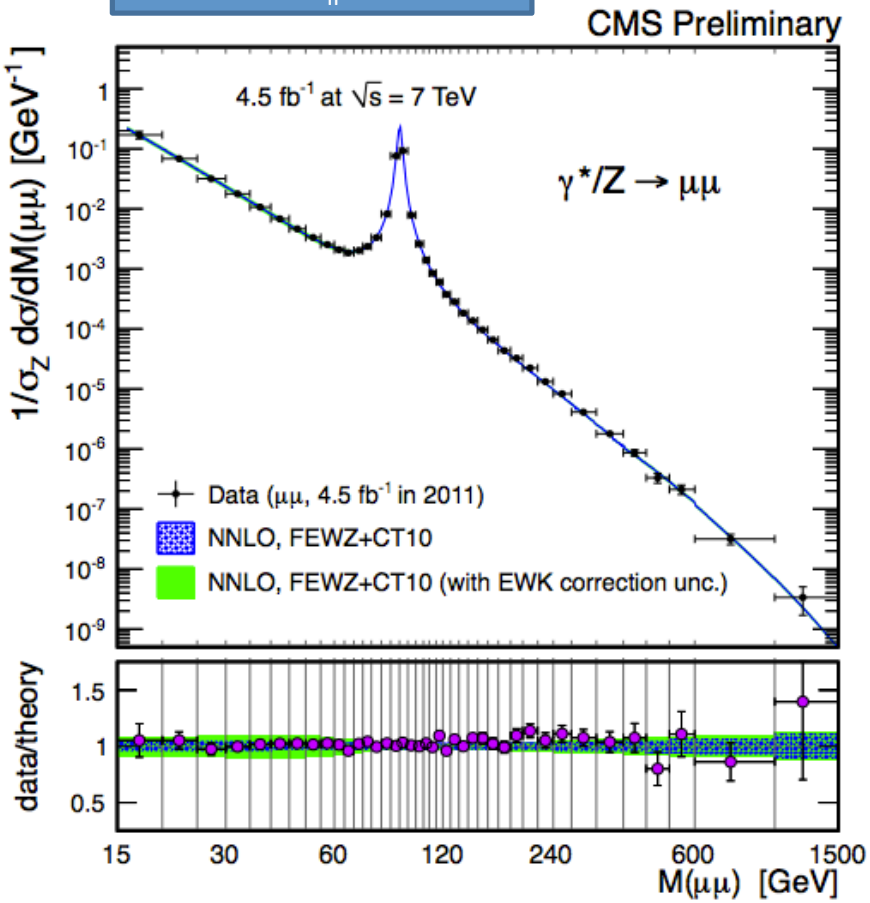
NOTE: Selection criteria are optimized for each experiment

Neutral Current Drell Yan di-lepton measurements

S. Farry
E. Gallo

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

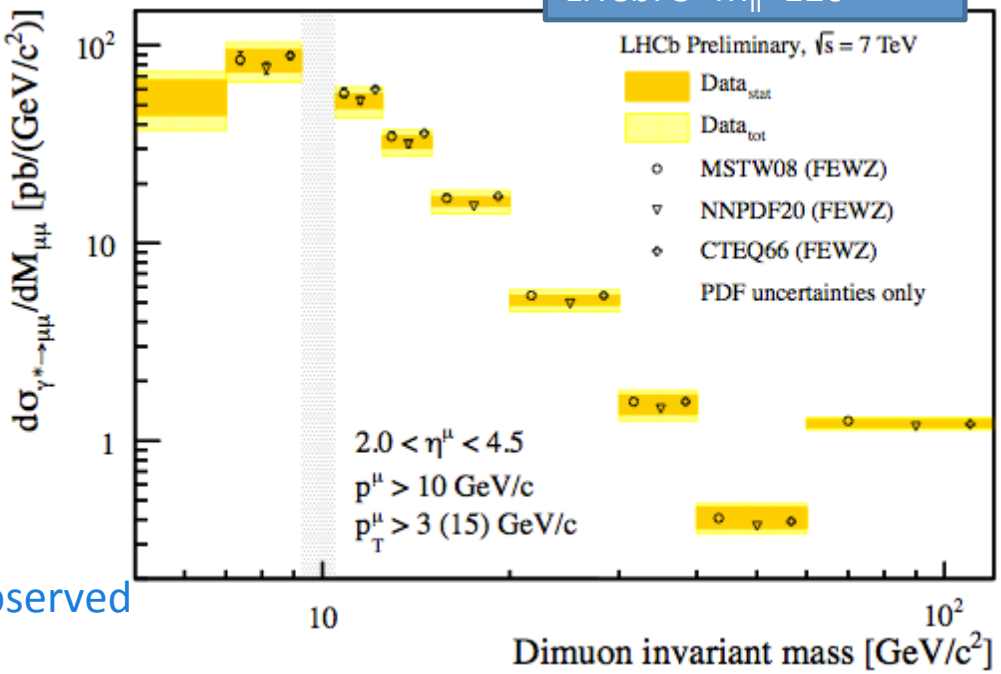
CMS: 20<M_{ll}<1500



The Drell Yan invariant mass spectrum in the dimuon (electron) channel, normalized to the Z resonance region for CMS in the 20 < *Mμμ* < 1500 GeV region [CMS-SMP-13-003]

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

LHCb: 5<M_{ll}<120

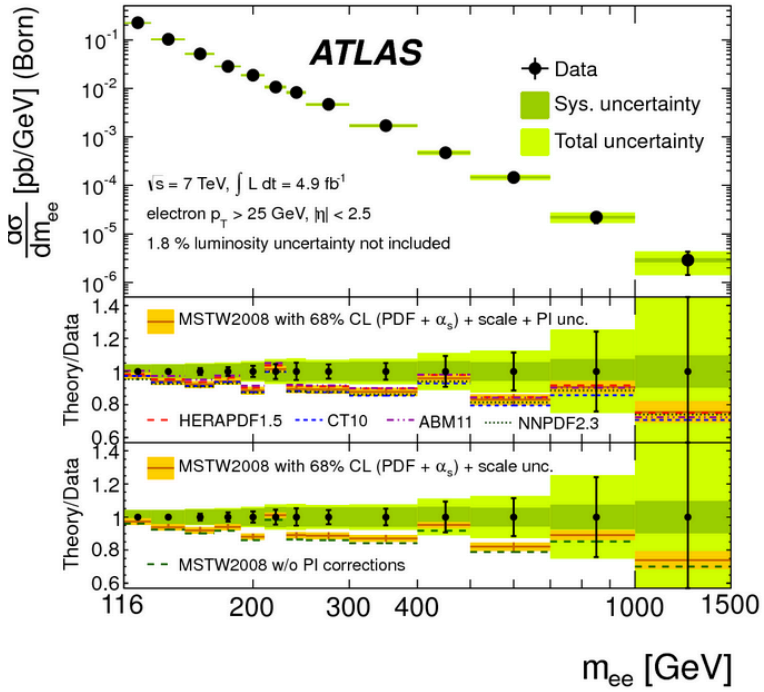


Good agreement with SM predictions is observed

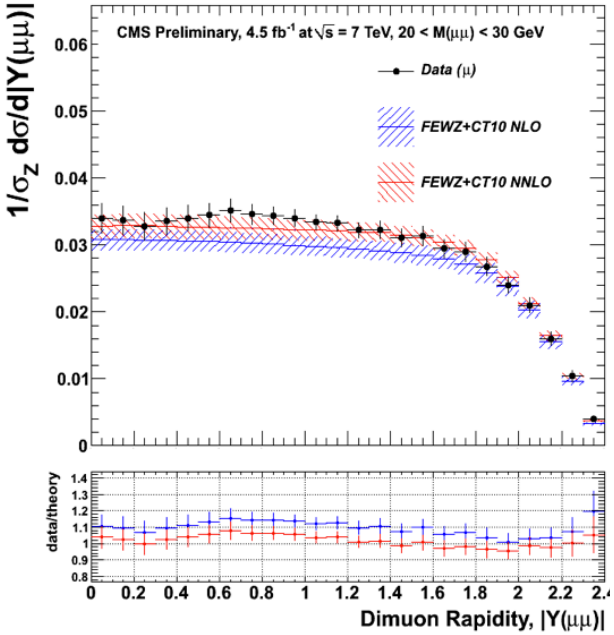
Z Differential Cross Section (off peak region)

S. Farry
S.Wollstadt
E.Gallo

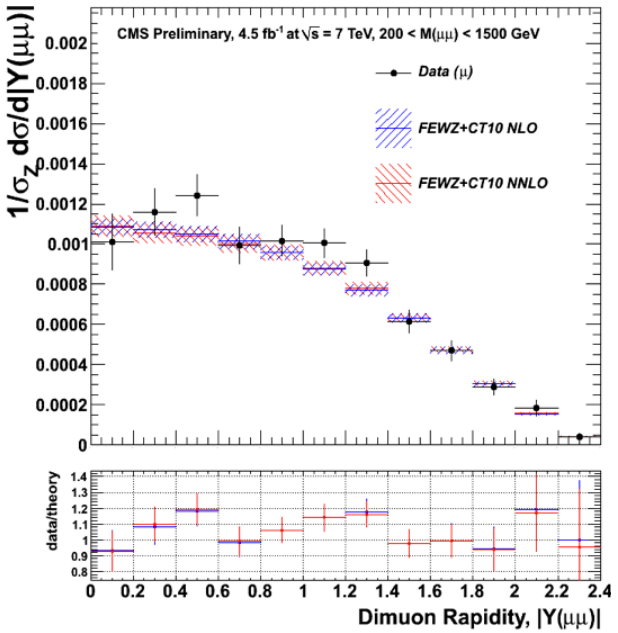
ATLAS: 116<M_{ee}<1500



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
- CMS: normalized to the Z resonance region, function of dimuon rapidity for CMS in selected $M_{\mu\mu}$ bins

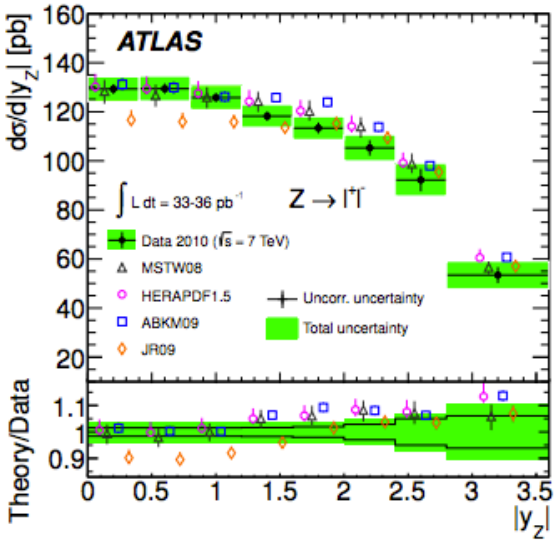
Data is confronted with NNLO predictions (corrected for NLO EW effects)

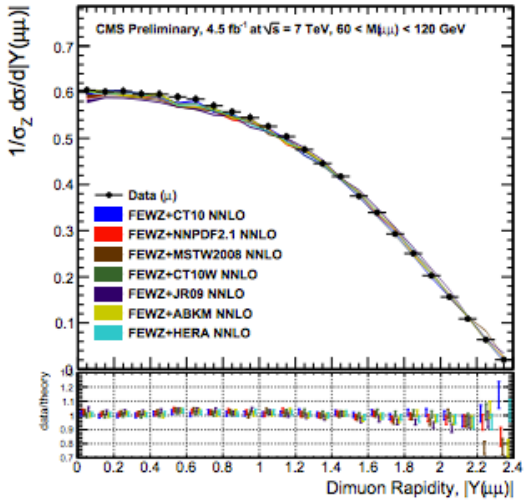
- NNLO is relevant, especially at low mass.
- Currently all PDFs shown give a reasonable description

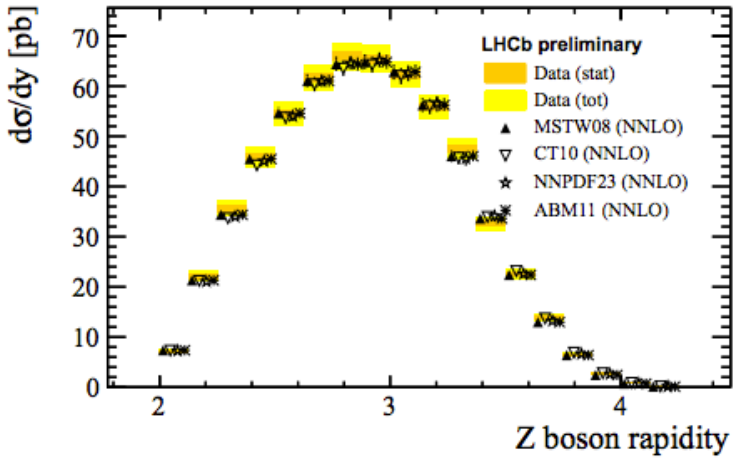
Z Differential Cross Section (peak region)

S. Farry
E. Gallo
S. Wollstadt

Measurements of differential cross sections are compared to NNLO predictions:





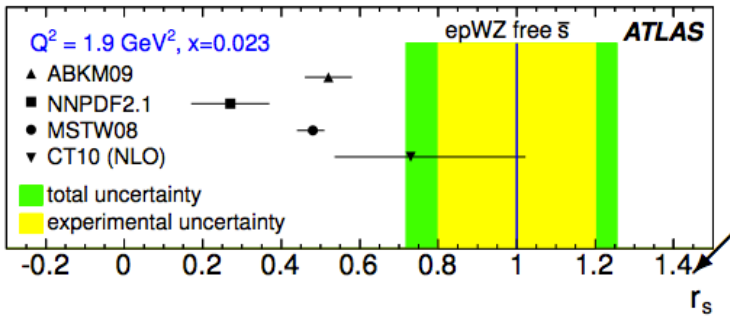


ATLAS

CMS

LHCb

Differences in predictions arises for different treatment of strange PDF



$$r_s = \frac{s+\bar{s}}{2\bar{d}}$$

$$r_s(0.023, 1.9\ \mathrm{GeV}^2) = 1.00^{+0.25}_{-0.28}$$

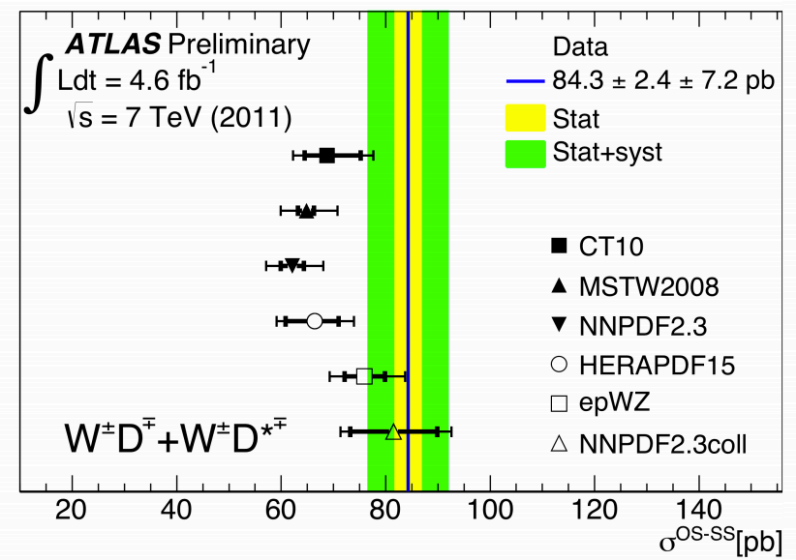
$$r_s(0.013, M_Z^2) = 1.00^{+0.09}_{-0.10}$$

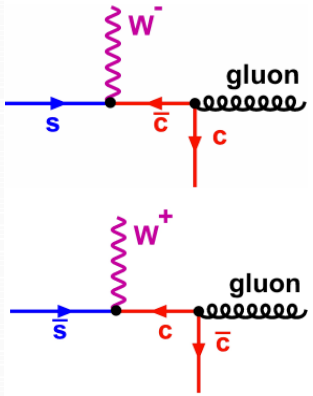
W+c from ATLAS and CMS

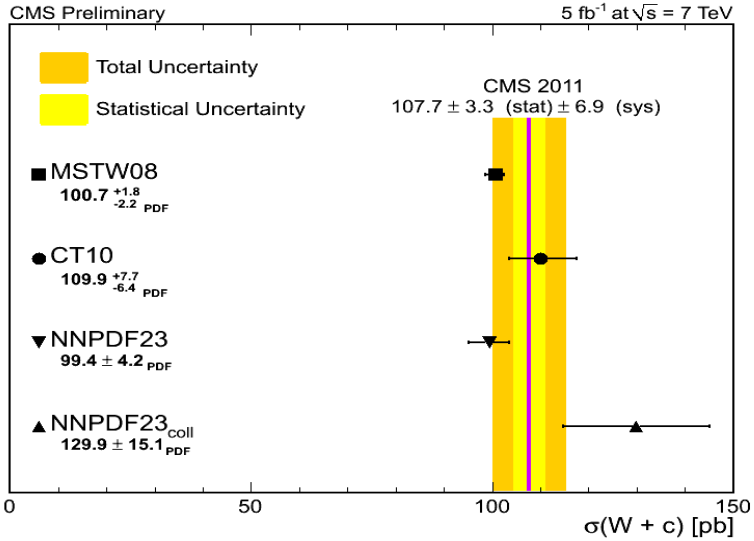
A. Vargas
S. Farry

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

- 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 for ATLAS, parton level for CMS using world values for BR







Theoretical predictions are based on aMC@NLO:

- measurement suggest a non-suppressed strange
- better agreement with predictions based on enhanced strange s ~d

Theoretical predictions are based on MCFM:

- Best agreement with CT10 (s~3/4 d)

Suggestions to release both type of measurements: at particle level and partonic level

Other interesting measurements involving W, Z

- Measurement of Z angular correlation dependence from ATLAS (e and mu, 2011 data)

  [Phys. Lett. B 720 (2013) 32-51]

  S. Wollstadt

  - Probes the same physics as measurements in Z pT, but provides better experimental precision
  - An important input in comparison to predictions of different MC generators and is a stringent test to resummation calculations
- Measurement of Z pt dependence from CMS (8 TeV data of low pile up)

  E. Gallo
- Measurement of Forward-backward Z asymmetry from ATLAS: [ATLAS-CONF-2013-043]
  - Used to determine the $\sin^2 \Theta_W^{eff}$ which is already as precise as measurements from Tevatron.

  S. Wollstadt
- Measurement of W/Z + b results compared to range of theoretical predictions from Madgraph, MCFM(4FNS + 5FNS), Alpgen, Powheg, Sherpa:
  - Large experimental uncertainties - dominated by Jet Energy Scale and purity determinations

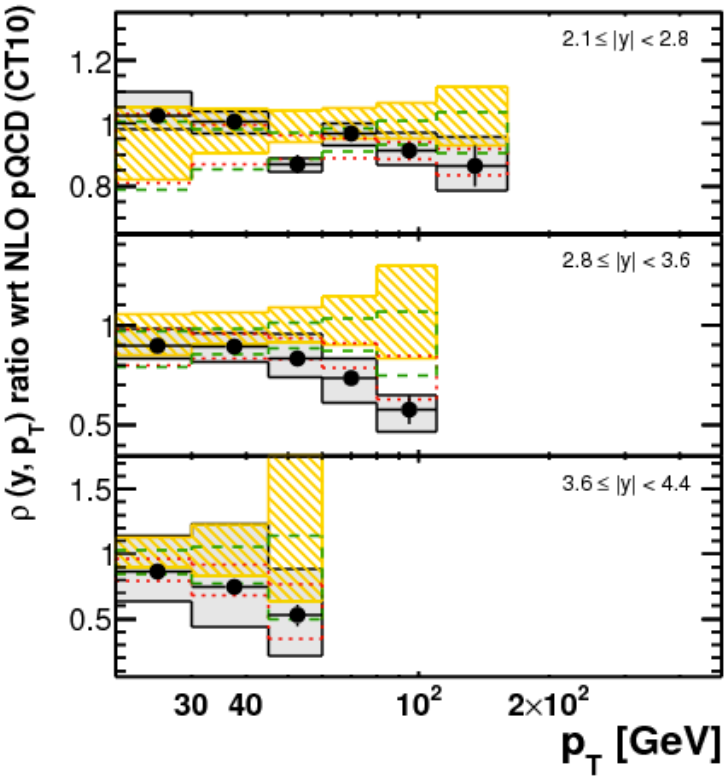
  S. Farry
- Measurements of diboson production in Wγ, Zγ, WW, WZ, ZZ at ATLAS (7 TeV) and CMS (7 and 8 TeV) in remarkable agreement with the SM predictions.

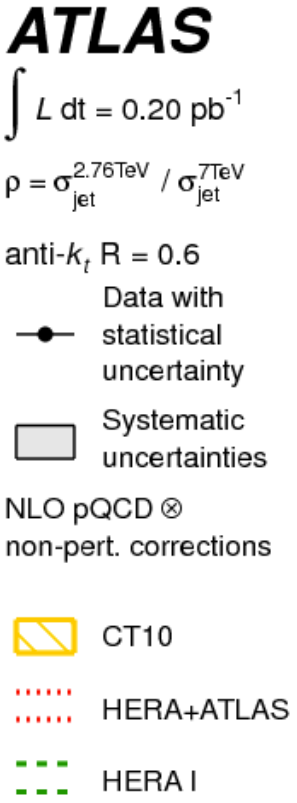
  A. Mengarelli
  D. Bourilkov

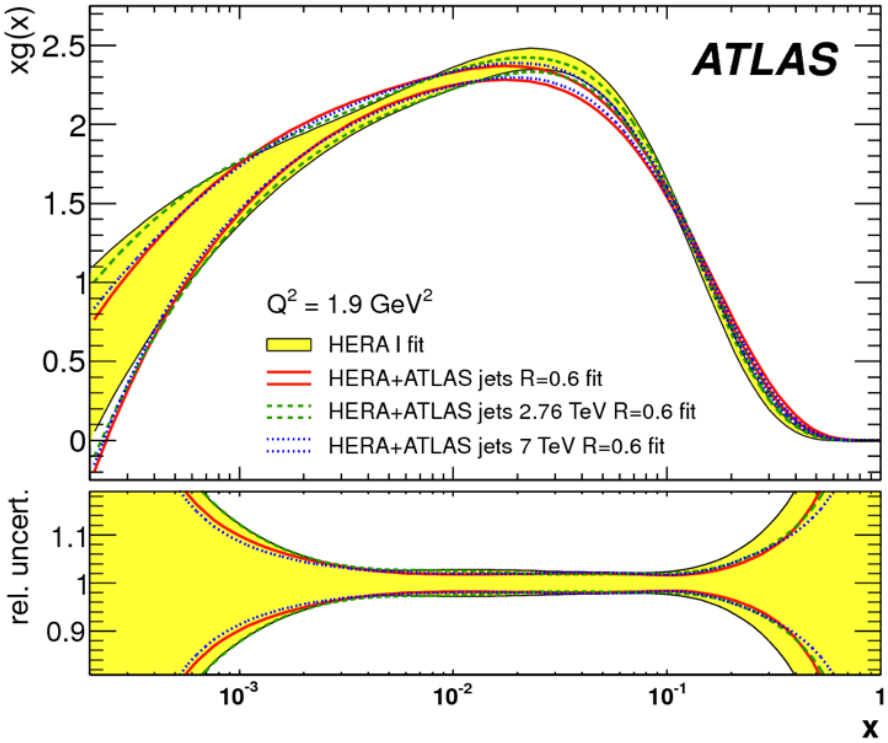
Impact of Inclusive jet measurements on gluon

F. Corriveau
G. Flouris

- LHC provided different beam energies of 2.76, 7 and 8 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 (for all y bins) used in a NLO QCD fit







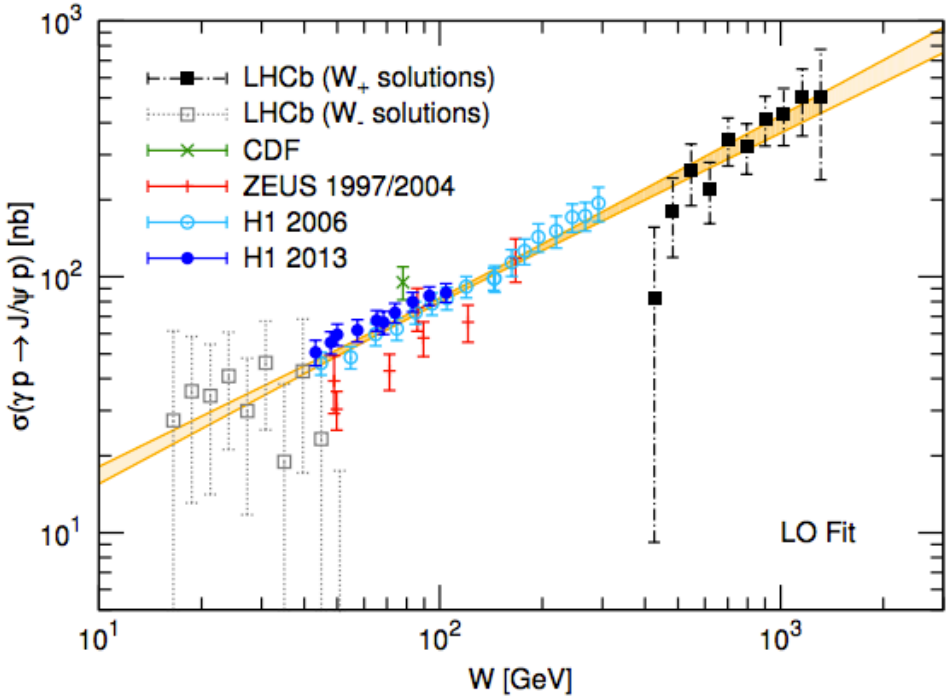
arXiv:1304.4739

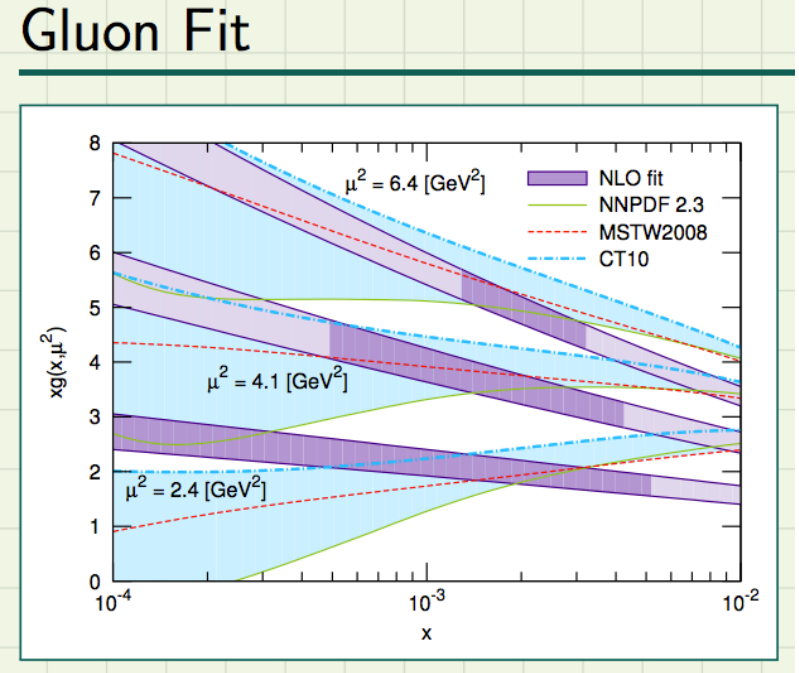
More on Jet measurements (and alphas) in the next talk

Potential of elastic J/psi data on low x gluon

S. Jones

- A fit to HERA and LHCb elastic photon(electron)-production accesses gluon at low x





J/psi data diminish the huge uncertainty on global gluons at low scale & small-x

Issues

- Considerable scale uncertainty remains
- Not a complete NLO analysis (but main kinematic effects included)
- Can not directly identify extracted gluon with e.g. $\overline{\text{MS}}$ partons

Future

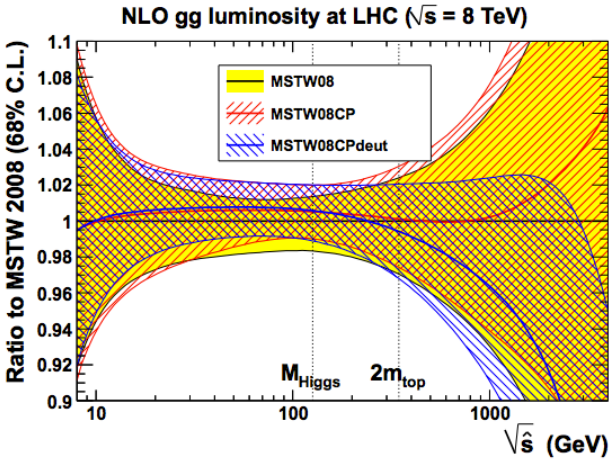
- Work under way to include NLO gluon diagrams and quark coupling [Ivanov et al. 2004]

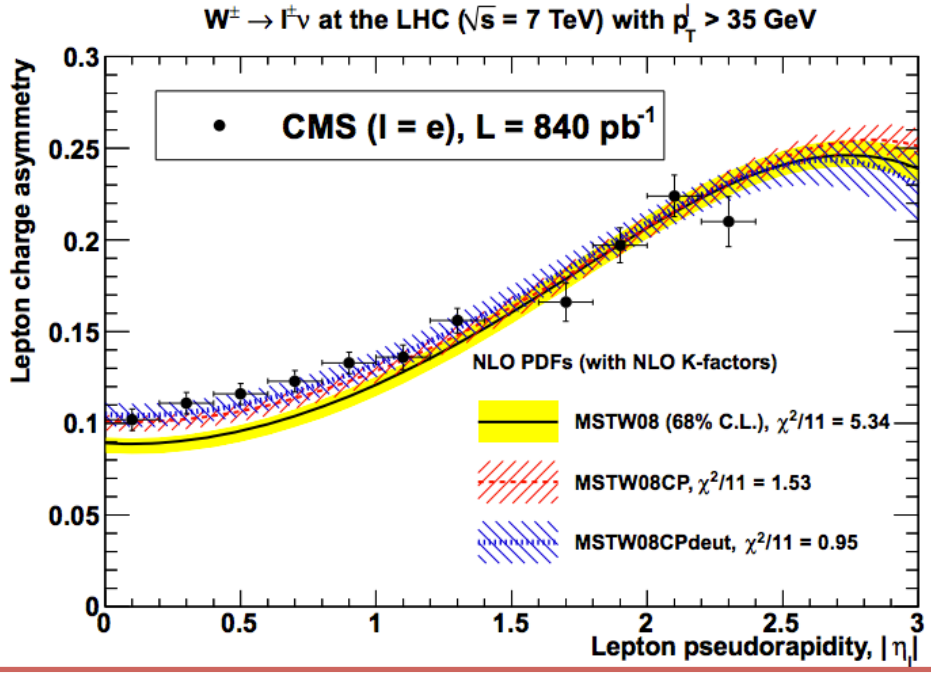
News from MSTW PDF group

R. Thorne

- MSTWCPdeut PDFs now available on LHAPDF [Eur.Phys.J. C73 (2013)2318]
  - similar with MSTW08 but with param. extension and change in deuterium corrections

A not totally insignificant change in the high-x gluon luminosity for the MSTWCPdeut set . Due to softer d_V





Ongoing further updates in MSTW framework (reweighing method tested against real fit for impact)

inclusion of combined HERA I data, HERA F2 charm data

inclusion of newer Tevatron DO electron asymmetry, CDF W asymmetry

inclusion of most relevant LHC data:

=> observe the enhanced strange with WZ inclusive data

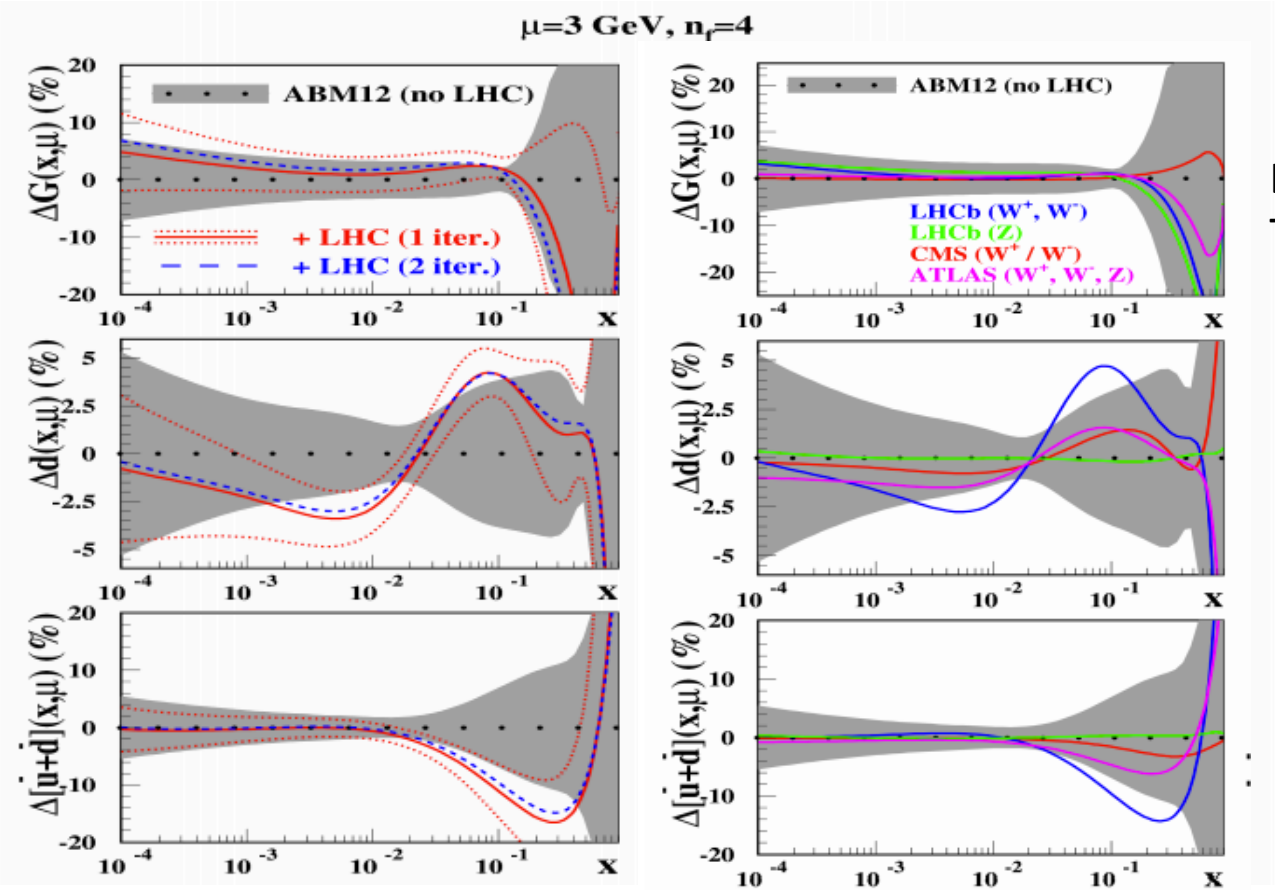
*change in BR=0.099 -> 0.080 can yield a good fit to both NuTeV dimuon data and LHC WZ

=> inclusive and dijet data is well fit, confirm the impact on gluon PDF

News from ABM PDF group

S. Alekhin

- ABM groups has included more data as well, and studied the impact of the LHC data:



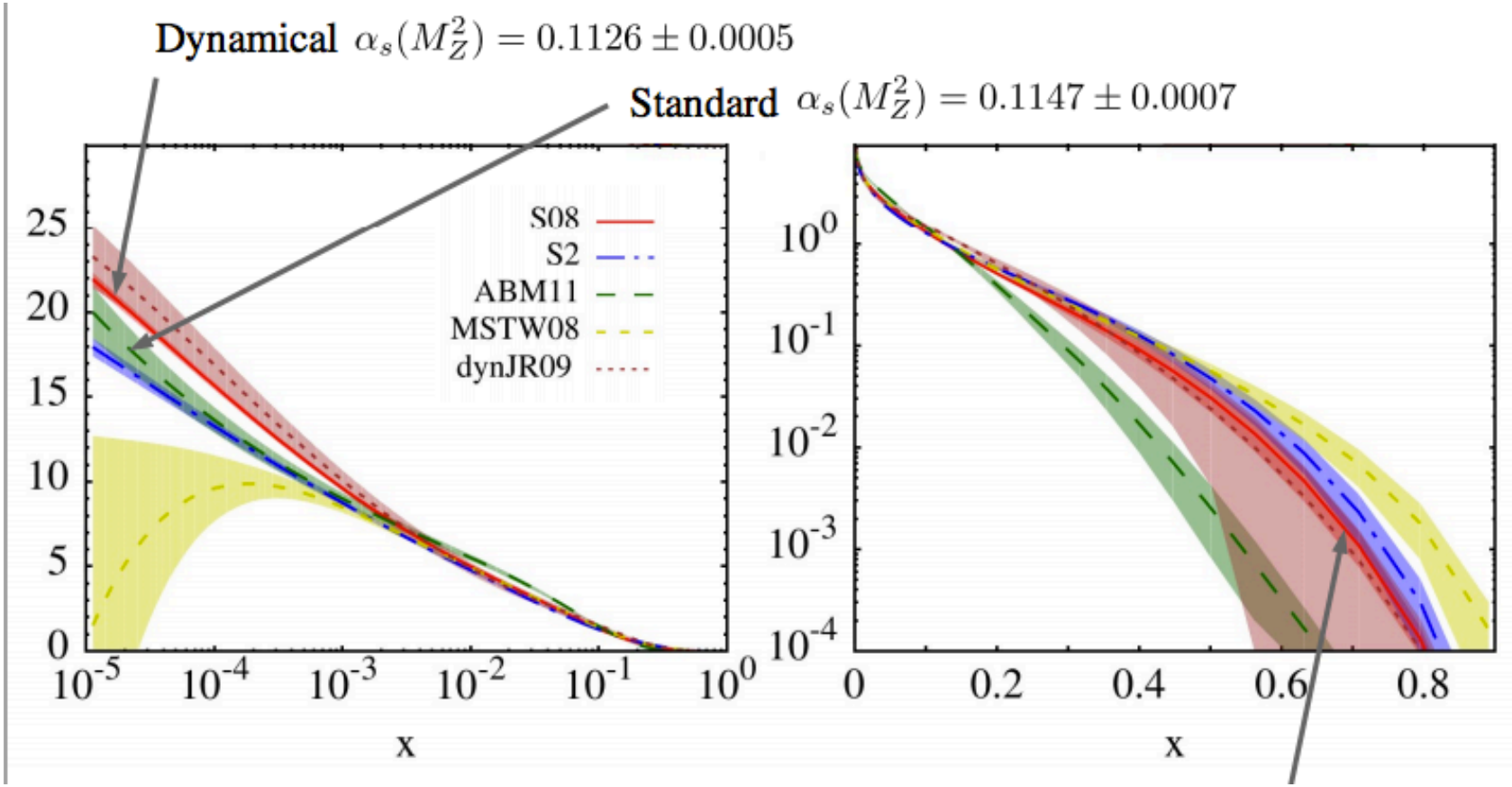
Largest impact is attributed
To LHCb data on the d quarks

- t-pair production has been analysed and – the running-mass definition provides better description of data as compared to the pole mass case
  - The change in gluon is ~1sigma

News from JR group

P. Jimenez-Delgado

- Strategy is to get the most from all pre-LHC data, inclusion of LHC data foreseen next year.
  - Inclusion of HERA I combined data, and the all available low Q2 data (requires then corrections)
  - extended parametrisation to 44 free parameters
  - Choice of input scale (dynamic vs standard) affects alphas value, but gluon at high x is stable.



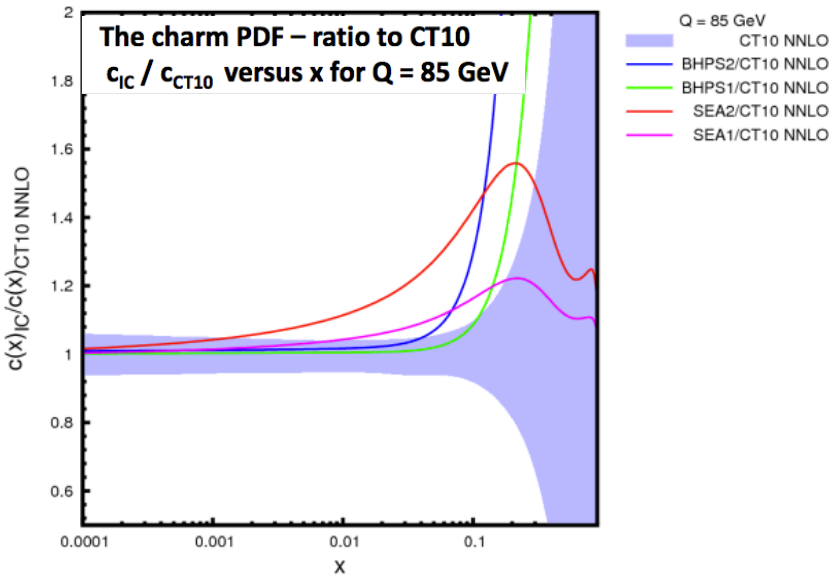
  - Preliminary results mostly consistent with JR09

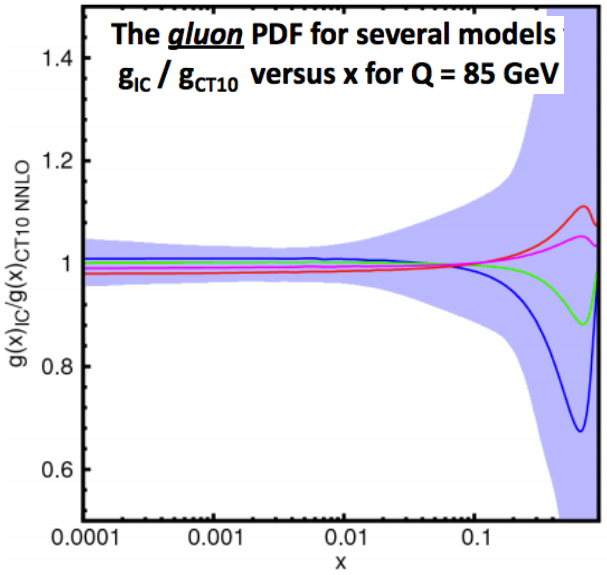
News from CT PDF group

D. Stump

- New studies on intrinsic charm (IC) with various model being investigated:

/1/ CT10 NNLO = no intrinsic charm
/2/ The BHPS Model = "valence-like" intrinsic charm
/3/ The Sea Model – "sea-like" intrinsic charm





Remarks:
IC is not necessary to fit global data, but data does not rule out the IC model. There is dependence on the choice of mc:

- 1.6 GeV enhances the effect

- CT addresses the issues related to PDF uncertainty of the Higgs Production Cross Section at the LHC:
  - Preferred method is the Lagrange Multiplier method, but Hessian method provides similar results.

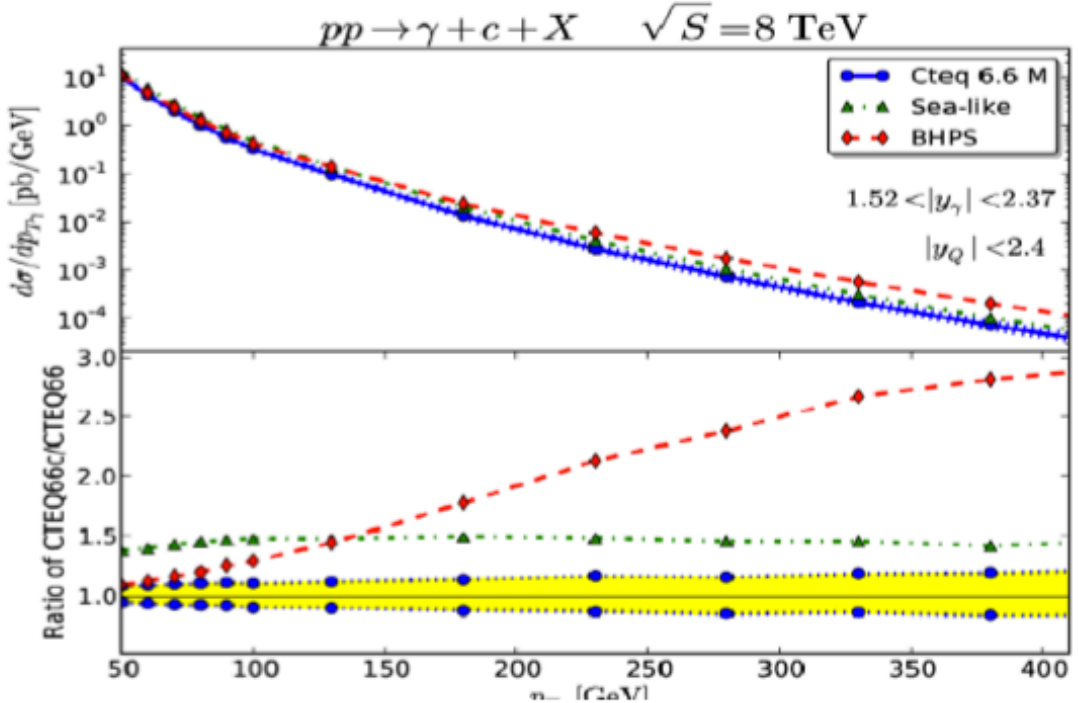
Searching for intrinsic charm and strangeness at LHC

[Gennady Lykasov]

Intrinsic charm and strangeness contributions would be enhanced at high-x

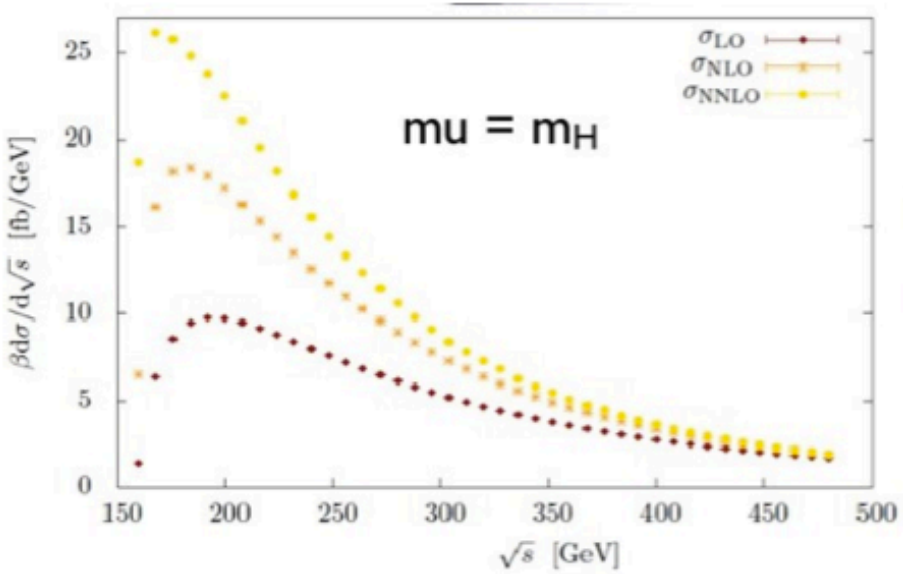
Can be studied at LHC:

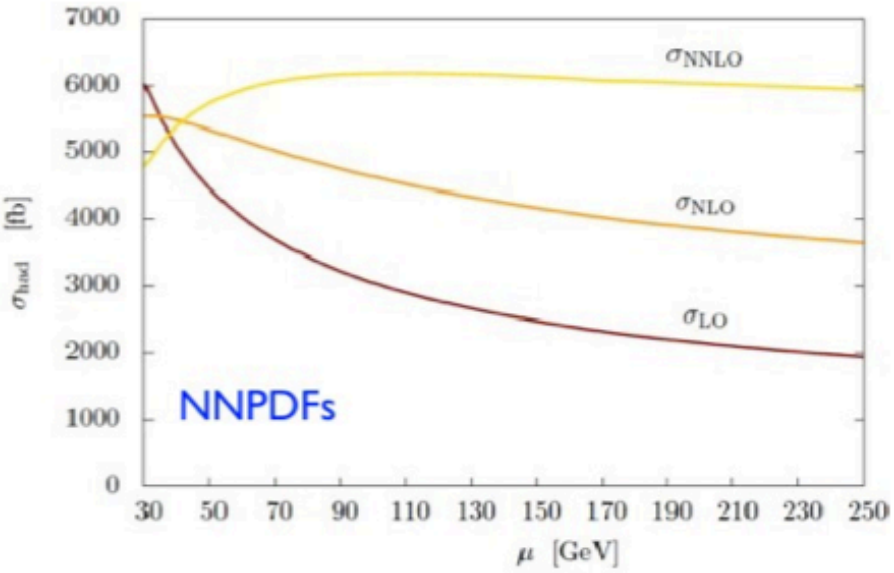
- open charm and strangeness production at high p_T
- $\gamma, W/Z$ production in association with c and b jet
- rapidity and p_T distributions of photons and vector bosons



Higgs production in association with a jet [Radja Boughezal]

New results for Higgs+jet at NNLO (gg-chanel, quark channels in progress)





R.B., Caola, Melnikov, Petriello, Schulze (2013)

$$\sigma_{\rm LO}(pp \to Hj) = 2713^{+1216}_{-776}\ {\rm fb},$$
$$\sigma_{\rm NLO}(pp \to Hj) = 4377^{+760}_{-738}\ {\rm fb},$$
$$\sigma_{\rm NNLO}(pp \to Hj) = 6177^{-204}_{+242}\ {\rm fb}.$$

σ_{NLO}/σ_{LO} = 1.6

$\sigma_{NNLO}/\sigma_{NLO}$ = 1.3

- Significant reduction of scale dependence from 50% at LO to 20% at NLO to less than 5% at NNLO.

Higgs production in gluon fusion at approximate N3LO

[Marco Bonvini]

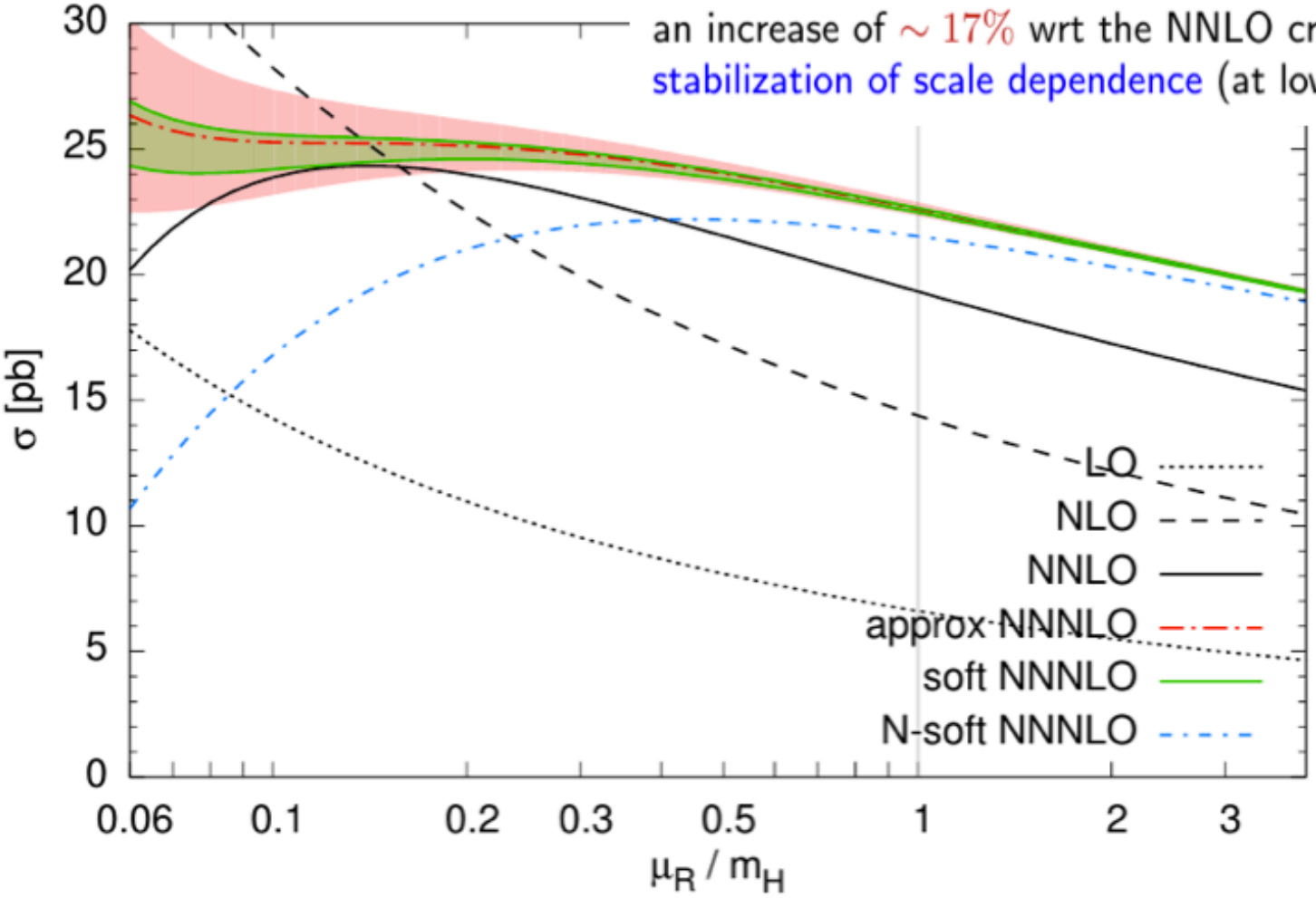
predicting the inclusive Higgs N^{3}LO cross section using

$$C_{gg}^{(3)}(z) \simeq C_{\text{soft}}^{(3)}(z) + C_{\text{high-energy}}^{(3)}(z)$$

find ($m_H = 125$ GeV, LHC at 8 TeV)

an increase of $\sim 17\%$ wrt the NNLO cross section

stabilization of scale dependence (at low scales)



Summary and outlook

- A plenty of new precision measurements from DIS and DY experiments:
  - Awaiting for final HERA combined measurements
  - JLAB addresses the high x physics with a series of new measurements
  - 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 and most of PDF groups
    - 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.
  - J/psi data shows potential in constraining gluon at very low x
- PDF groups are active and eager to include new avalanche of data and address remaining theoretical differences.
- Even Higher order calculations (NNLO and N3L0) are becoming available for the Higgs Cross section
- 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, …

MANY THANKS TO ALL SPEAKERS AND PARTICIPANTS FOR LIVELY SESSISONS
(apologies for uncovered topics)

Back up slides

Not necessarily
useful

Impact of jet measurements on alphas

C. Belanger-Champagne

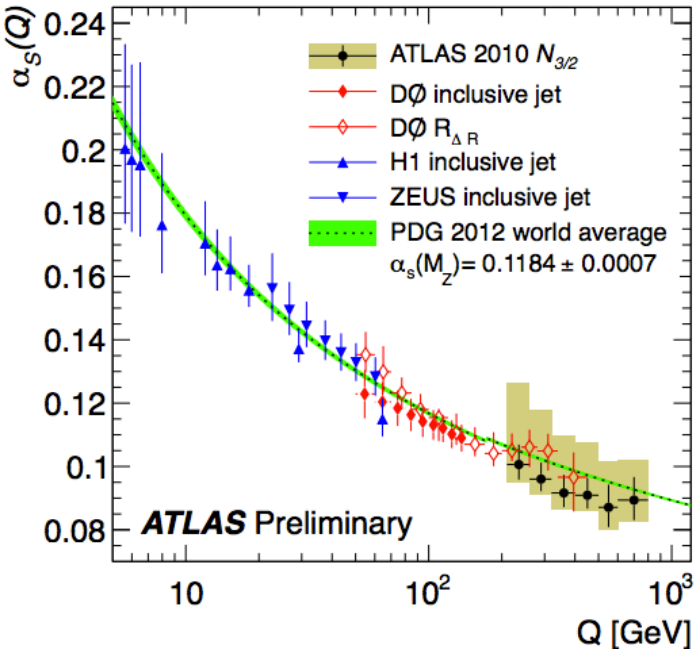
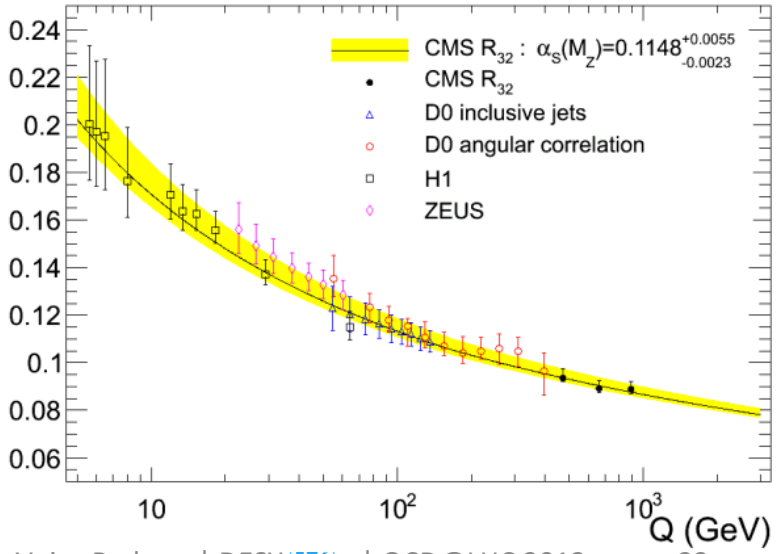
- Determination of alphas from ratio of events with ≥3 jets to ≥2 jets ratio of 2010 data: [ATLAS-CONF-2013-041]
  - Two observables were used: $R_{3/2}$ (in lead pt), $N_{3/2}$ (all pt)

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

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

- From CMS:

$$\alpha_S(M_Z) = 0.1148 \pm 0.0014\,(\text{exp.}) \pm 0.0018\,(\text{PDF})^{+0.0050}_{-0.0000}\,(\text{scale})$$

- All LHC-era results are consistent with the current world average from the Particle Data Group, $\alpha_s(M_Z)=0.1184\pm0.0007$

	$\alpha_s(M_Z)$		
ATLAS $N_{3/2}$, 2010	0.111	+0.017	-0.007
CMS R_{32}, 2011	0.1148	+0.0055	-0.0023
CMS top quark, 2011	0.1151	+0.0033	-0.0032
CMS 3-jet mass, 2011	0.1160	+0.0072	-0.0031