WGI: PARTON DISTRIBUTIONS
SUMMARY

Stefano Forte
Università di Milano

HERA-LHC Workshop

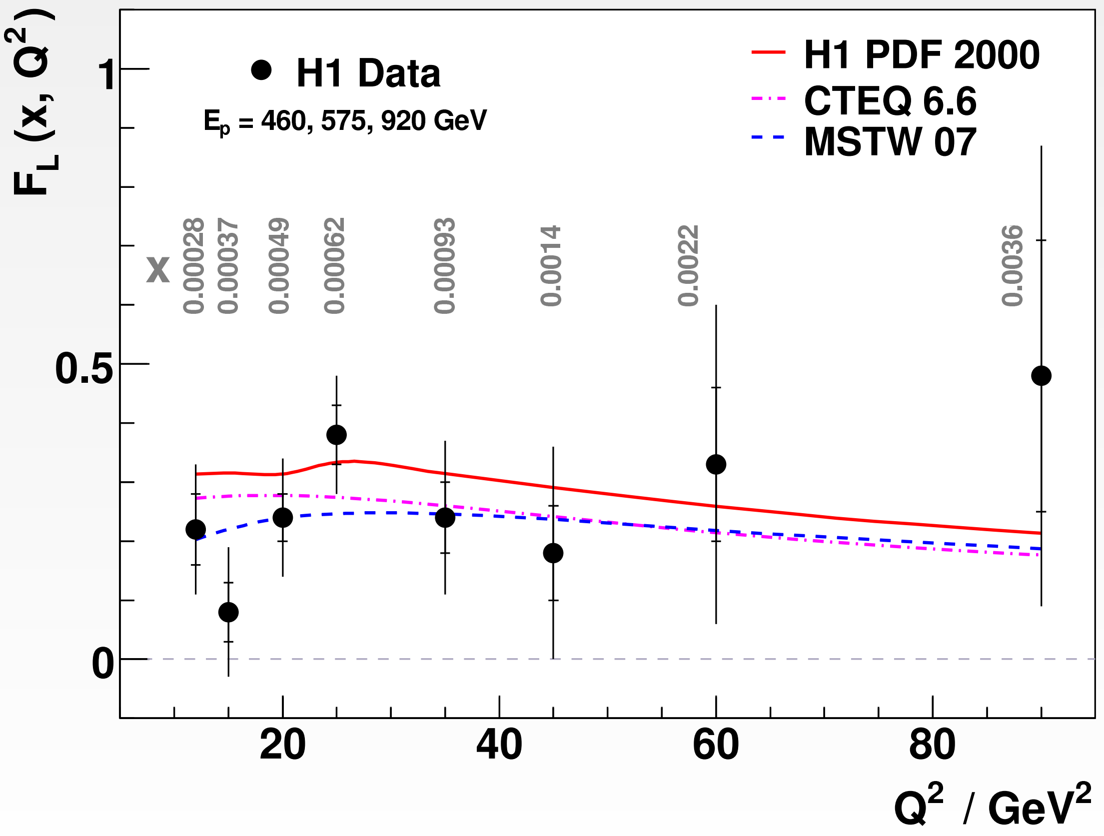
CERN, May 30, 2008

THE LATEST NEWS FROM HERA

F_L ! (POSTED ON ARXIV MAY 19, 2008)

Averaged $F_L(x, Q^2)$ at Medium Q^2

Central values are obtained taking stat. and uncorr. syst. uncertainties into account
Syst. errors are determined from corr. syst. by offset method

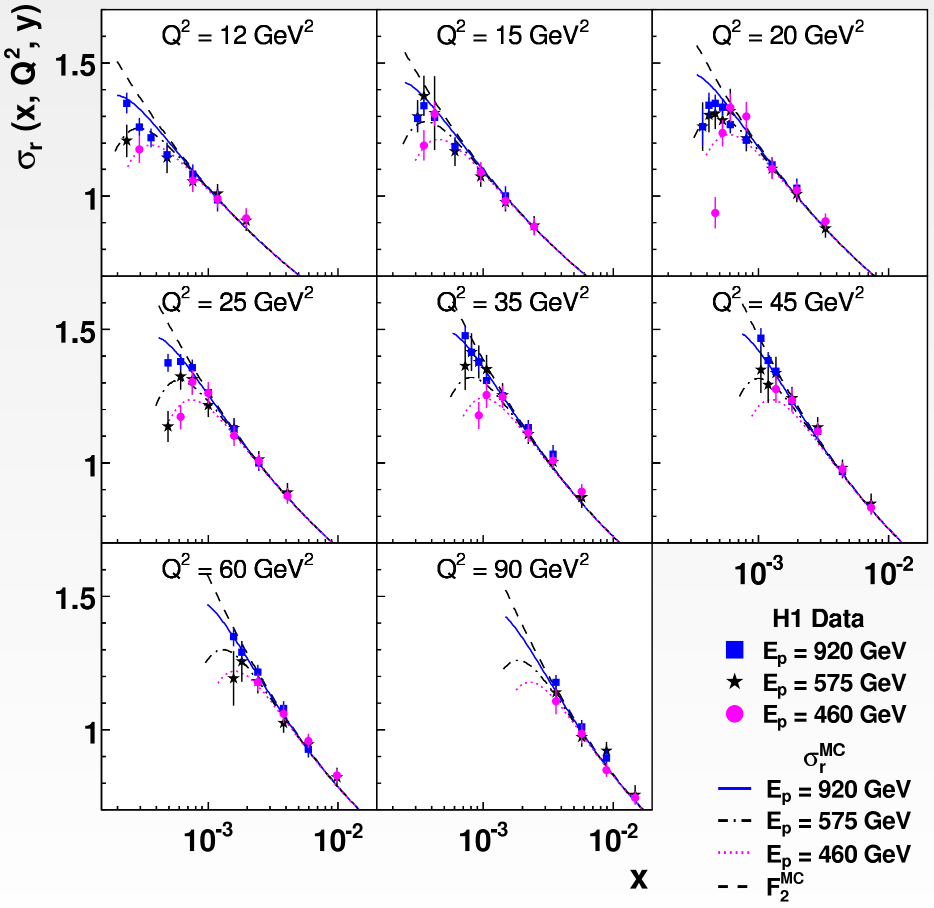


Data are consistent with NLO and NNLO QCD predictions

V. LENDERMANN (H1)

A VIRTUOSO PERFORMANCE

Reduced Cross Section



Flattening and turn over at high y
for different samples due to F_L

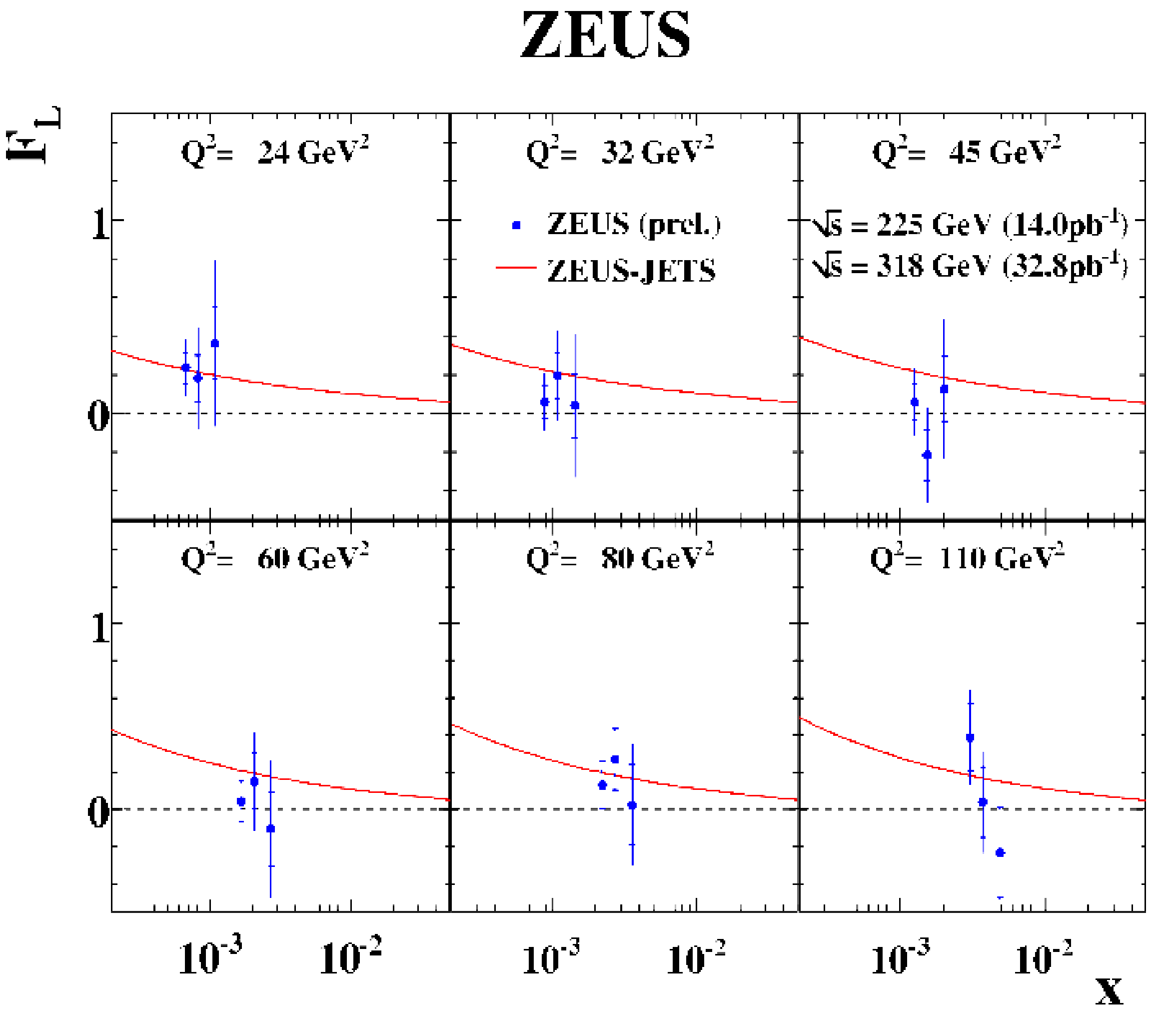
- Currently 5% luminosity uncertainty
  correlated for all samples
  Uncertainty of F_L includes this value
- Samples were normalised
  to each other using F_2 at low y:
  920, 575, 460 GeV : –2%, –0.5%, +1%
- Relative normalisation error: 1.6%

V. LENDERMANN (H1)

WIDE SCALE RANGE $10 \lesssim Q^2 \lesssim 100\ GeV^2$, SMALL x

ZEUS F_L

- Extracted values of F_L are consistent with ZEUS-JETS predictions and with 0 as well
  (due to large uncertainties)



→ Room for improvements:

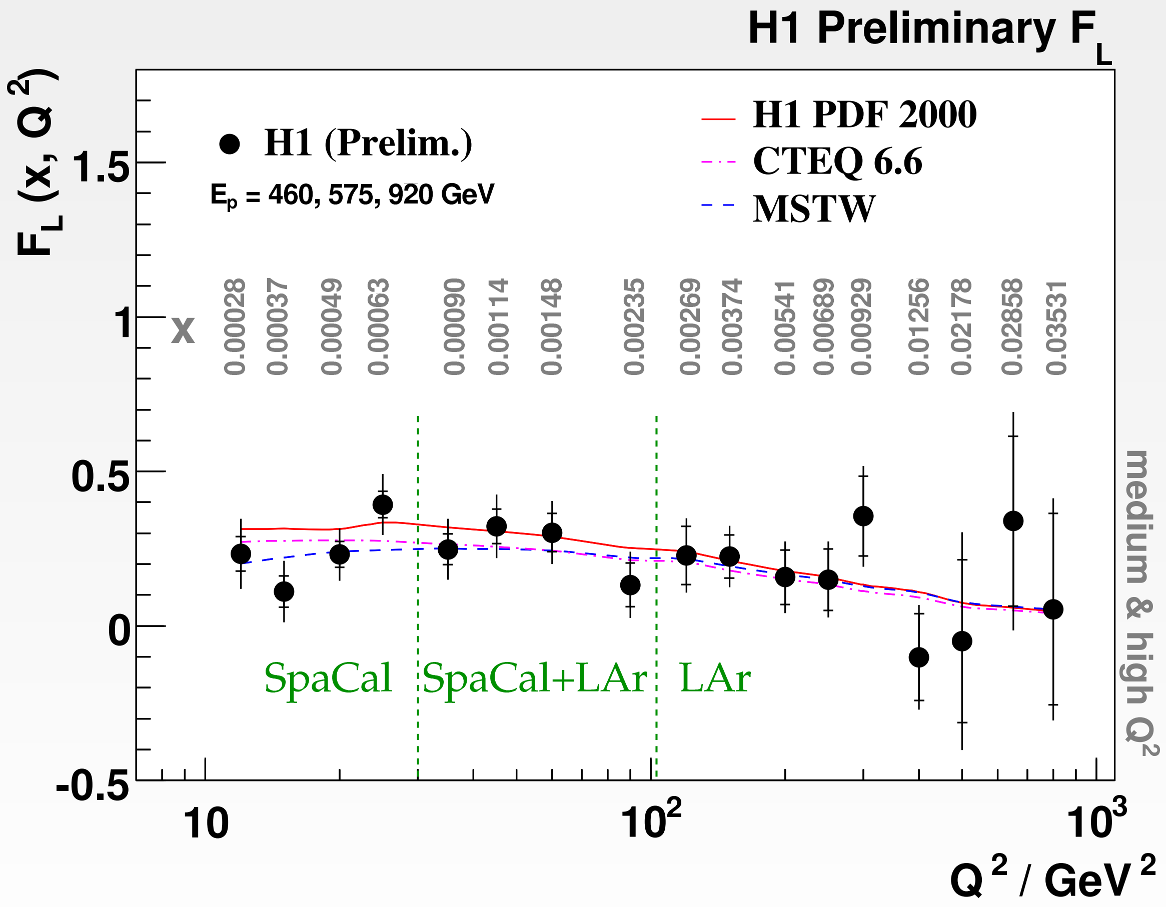
- Lower energies of scattered electron
- Reduction of systematics
- Third beam energy data set

- Analysis in progress

J. GREBENYUK (ZEUS)

PERFECT AGREEMENT WITH NLO/NNLO QCD PREDICTION

Preliminary F_L *in Full Medium–High* Q^2 *Range*



Data are consistent with NLO and NNLO QCD predictions

V. LENDERMANN (H1)

RECENT PROGRESS

EXPERIMENT

- F_L MEASUREMENT, soon in extended range down to $Q^2 = 5$ GeV^2
- AVERAGED ZEUS/H1 F_2 AND REDUCED XSECT. MEASUREMENTS already in use by experiments for pdf fits

THEORY

- HEAVY QUARKS: towards NNLO matched results
- SMALL x RESUMMATION: towards resummed fits
- SATURATION AND HIGHER TWISTS: isolating dangerous regions
- LARGE x RESUMMATION: precision physics

CTEQ6.5 and CTEQ6.6: advanced treatment of heavy quarks

1. full implementation of the **general-mass "SACOT-χ" scheme**
   - differences in predictions for c, b scattering ($F_2^{c,b}(x,Q^2)$, etc.), EW precision cross sections, as compared to the zero-mass CTEQ6.1

Tung et al., JHEP 0702, 053 (2007); ***CTEQ6.5***

2. exploration of **free strange PDF's** and/or asymmetric strange sea

$$s_+(x) \neq r\left(\bar{u}(x)+\bar{d}(x)\right), \quad s_-(x) \neq 0,$$

where $s_\pm(x) \equiv s(x) \pm \bar{s}(x)$

Lai et al., JHEP 0704, 089 (2007); ***CTEQ6.5S***

3. PDF's with **nonperturbative charm**
   - $c(x,\mu_0 = m_c) \neq 0$ due to low-energy charm excitations (as opposed to $g \to c\bar{c}$ radiative production)

Pumplin et al., PRD 75, 054029 (2007); ***CTEQ6.5C***

PREVIOUS DISCREPANCIES RESOLVED!

Predictions for W and Z cross-sections for LHC and Tevatron (in brackets) with common fixed order QCD and vector boson width effects, and common branching ratios.

	$B_{l\nu} \cdot \sigma_W$ (nb)	$B_{l^+l^-} \cdot \sigma_Z$ (nb)
MSTW 2008 NLO (prel.)	20.45 (2.650)	1.965 (0.2425)
MSTW 2008 NNLO (prel.)	21.44 (2.739)	2.043 (0.2512)

Ratio to MSTW 2008 (prel.)	σ_W	σ_Z
MRST 2006 NLO (unpublished)	1.002 (0.995)	1.009 (1.001)
MRST 2006 NNLO	0.995 (1.004)	1.001 (1.010)
MRST 2004 NLO	0.974 (0.990)	0.982 (1.000)
MRST 2004 NNLO	0.936 (0.991)	0.940 (1.003)
CTEQ6.6 NLO	1.019 (0.978)	1.022 (0.987)

Increases from MRST2006 compared to MRST2004 due to changes due to improved (NLO) or completed (NNLO) heavy flavour prescription.

Virtually no change from MRST2006 → MRST2008. Not guaranteed to be true for all quantities.

Consistent with CTEQ6.6, but systematic differences mirror shape of gluon/quarks.

5. Towards the calculation of $A_{ij,Q}^{(3)}$

Contributing OMEs:

$$\begin{array}{lcccc} \text{Singlet} & A_{Qg} & A_{qg,Q} & A_{gg,Q} & A_{gq,Q} \\ \text{Pure–Singlet} & & A_{Qq}^{\rm PS} & A_{qq,Q}^{\rm PS} & \\ \text{Non–Singlet} & A_{qq,Q}^{\rm NS,+} & A_{qq,Q}^{\rm NS,-} & A_{qq,Q}^{\rm NS,v} & \end{array} \left.\vphantom{\begin{array}{c} A \\ A \end{array}}\right\} \text{mixing}$$

- All 2–loop $O(\varepsilon)$–terms in the unpolarized case are known:

$$\overline{a}_{Qg}^{(2)}, \quad \overline{a}_{Qq}^{(2),\mathbf{PS}}, \quad \overline{a}_{gg,Q}^{(2)}, \quad \overline{a}_{gq,Q}^{(2)}, \quad \overline{a}_{qq,Q}^{(2),\mathbf{NS}}.$$

- Unpolarized anomalous dimensions are known up to $O(a_s^3)$ [Moch, Vermaseren, Vogt, 2004.]

  $\Longrightarrow$ All terms needed for the renormalization of unpolarized 3–Loop heavy OMEs are present.

  $\Longrightarrow$ Calculation will provide first independent checks on $\gamma_{qg}^{(2)}$, $\gamma_{qq}^{(2),\rm PS}$ and on respective color projections of $\gamma_{qq}^{(2),\rm NS\pm,v}$, $\gamma_{gg}^{(2)}$ and $\gamma_{gq}^{(2)}$.

- Calculation proceeds in the same way in the polarized case. Known so far :

$$\Delta\overline{a}_{Qg}^{(2)}, \quad \Delta\overline{a}_{Qq}^{(2),\mathbf{PS}}, \quad \Delta\overline{a}_{qq,Q}^{(2),\mathbf{NS}} = \overline{a}_{qq,Q}^{(2),\mathbf{NS}} \; .$$

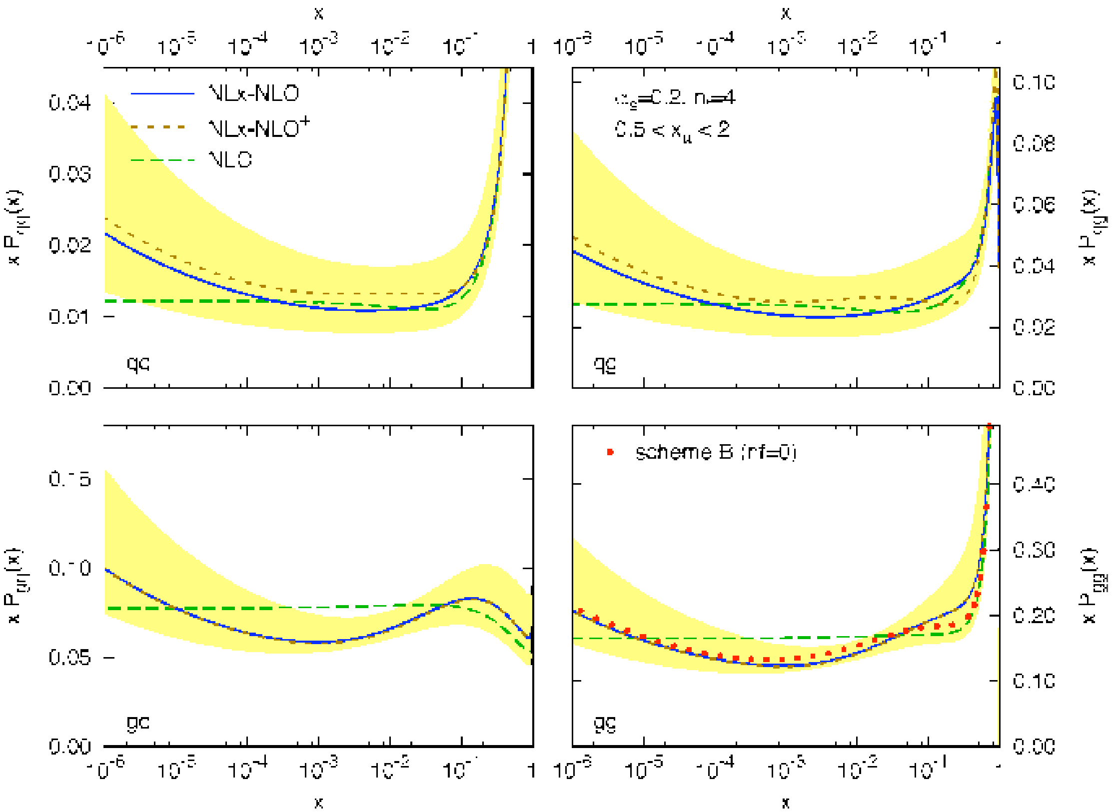
- Calculation of first moments using MATAD will soon be possible.

SMALL x RESUMMATION:

RESUMMED SPLITTING FUNCTION MATRIX COMPUTED BY THREE GROUPS

Splitting functions

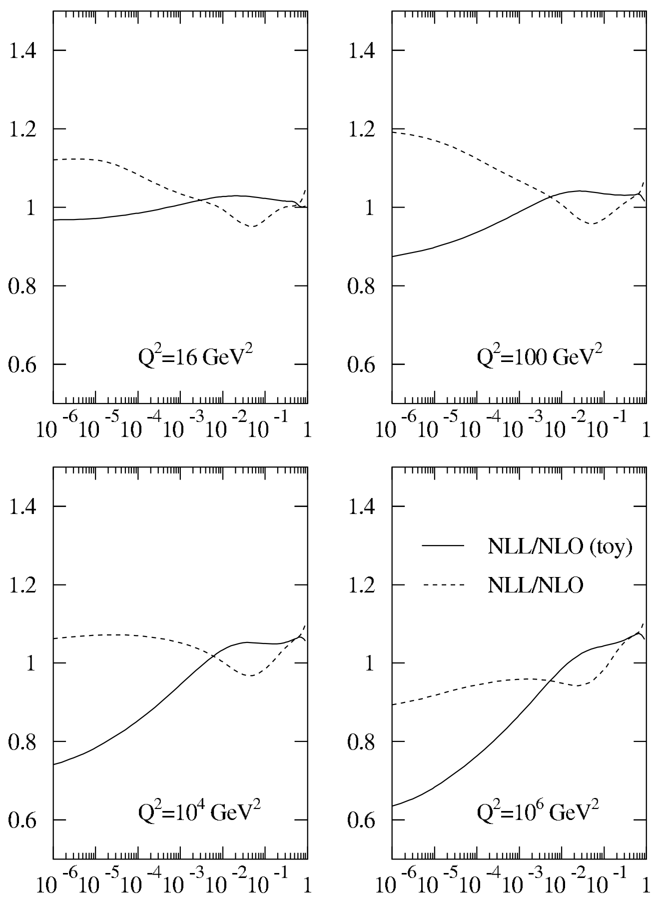
- gg channel results similar to the older (2003) calculations
- gq channel close to gg
- characteristic dip at $x \simeq 10^{-3}$ still present (in both channels)
- onset of rise at $x \simeq 10^{-1}$
- scale dependence grows with decreasing x, but not larger than at plain NLO
- qg,qq splitting functions: larger scale uncertainty, but closer to NLO
- dip structure in qg,qq channels is much milder

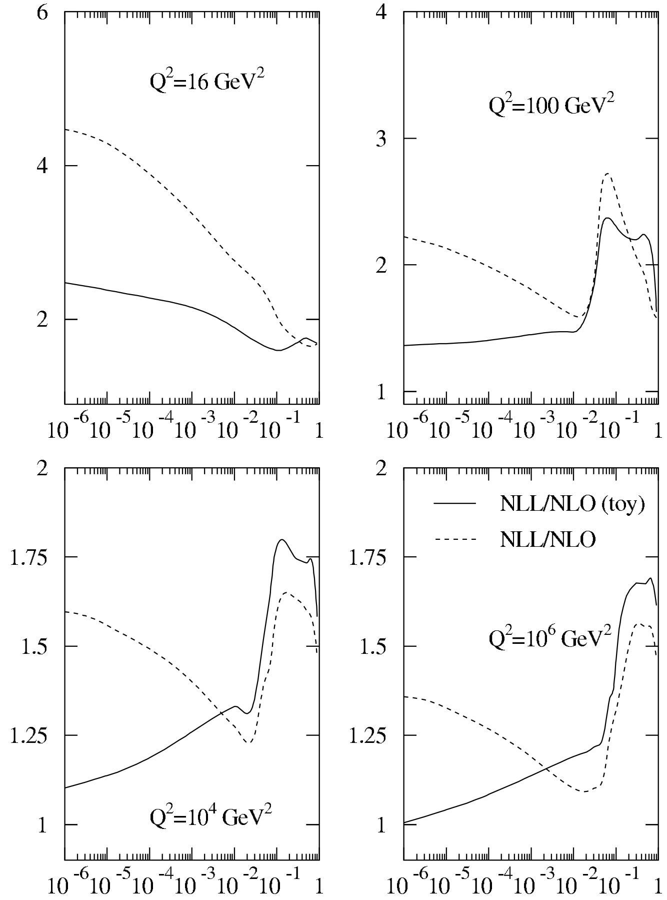


A. STAŚTO (CCSS)

Global CAN DETERMINE K-FACTORS FOR OBSERVABLES

Ratios: NLL/NLO


F_2 - Ratio of Resummed and Fixed Order Results


F_L - Ratio of Resummed and Fixed Order Results

C. WHITE (TW)

CONTROL OF SCHEME DEPENDENCE: COMBINE WITH DGLAP

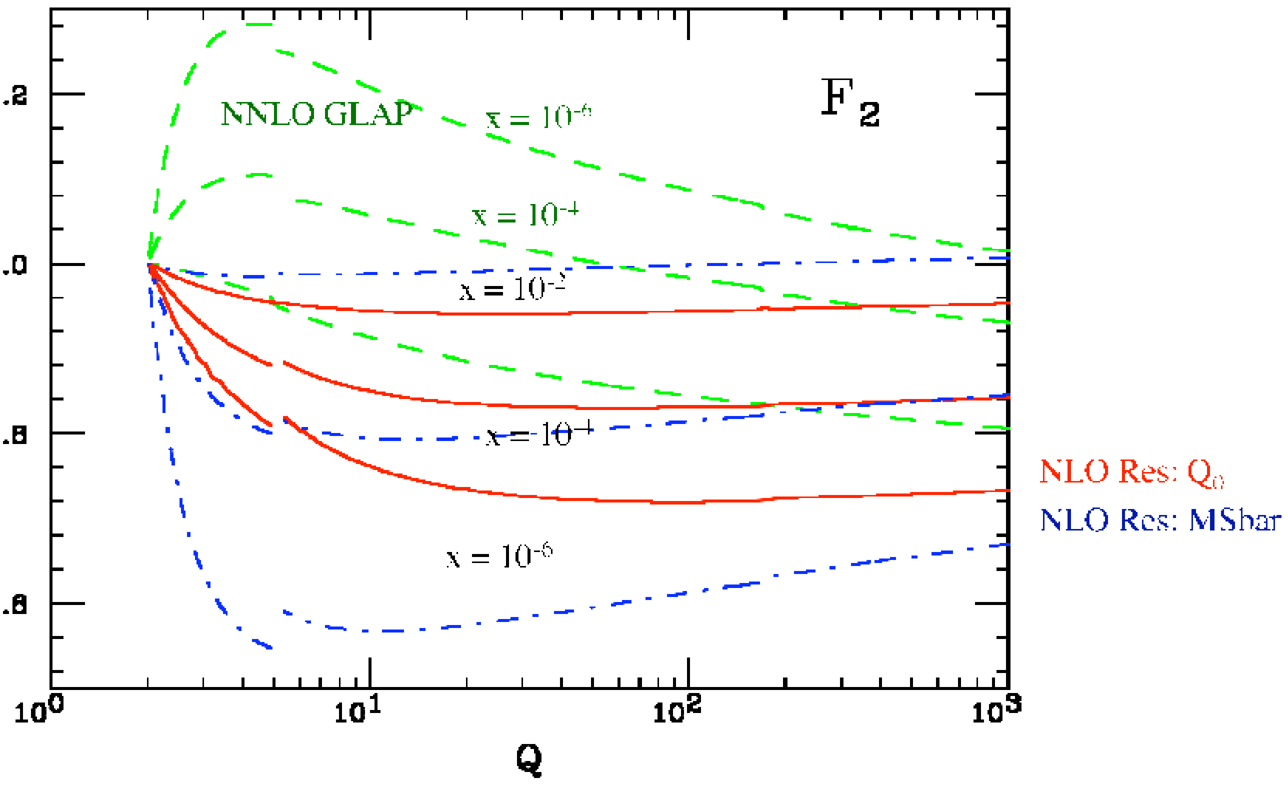
GENERAL FEATURE: RESUMMATION ⇒ SUPPRESSION OF SMALL x RISE

Structure Function F_2

Initial pdfs at Q_0 = 2GeV adjusted so that $F_2^{Res} = F_2^{NLO}$ etc.

$$K \equiv \frac{F_2^{Res}}{F_2^{NLO}}$$

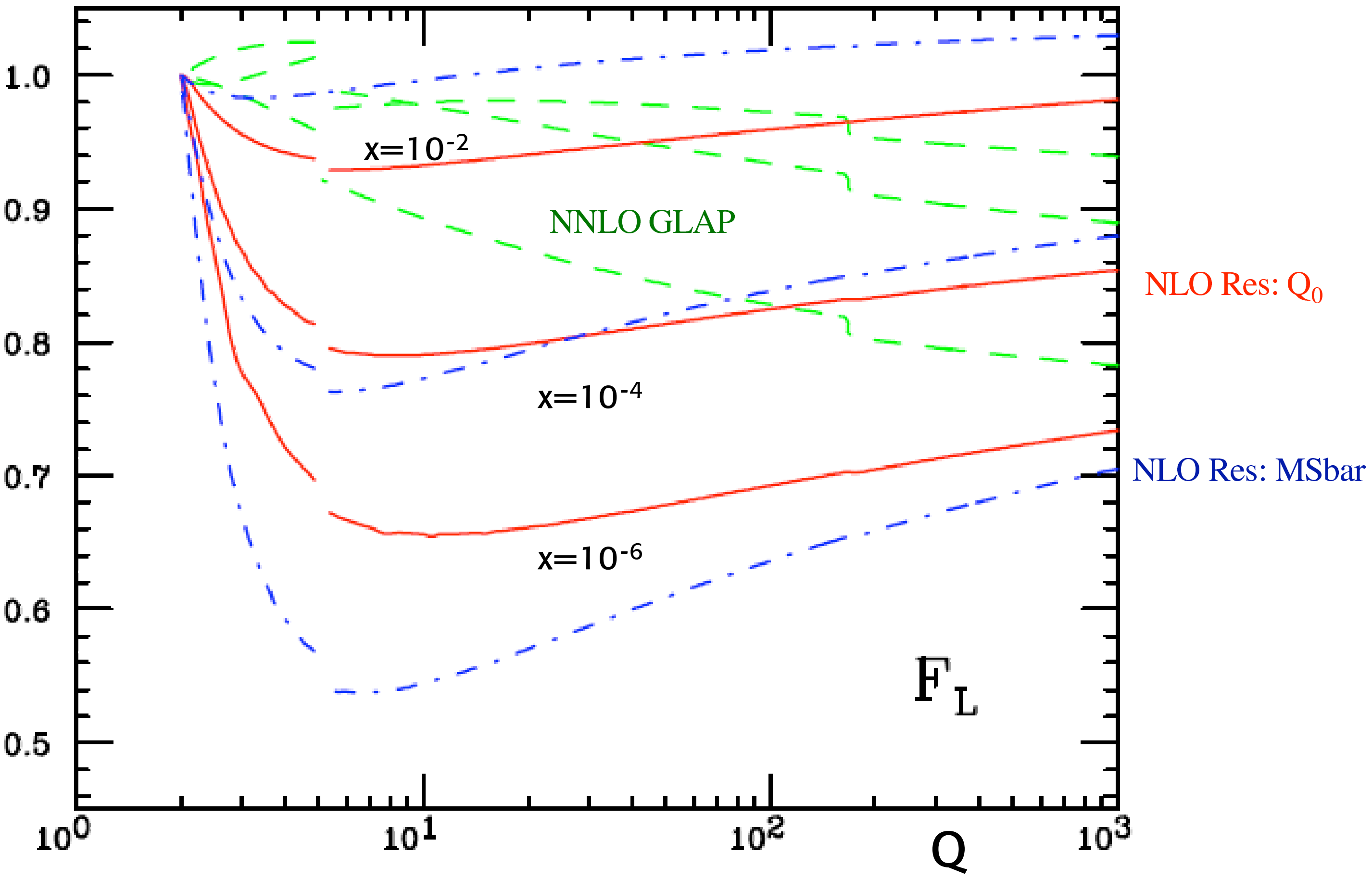
Effect of
resummation
opposite
to NNLO



G. ALTARELLI (ABF)

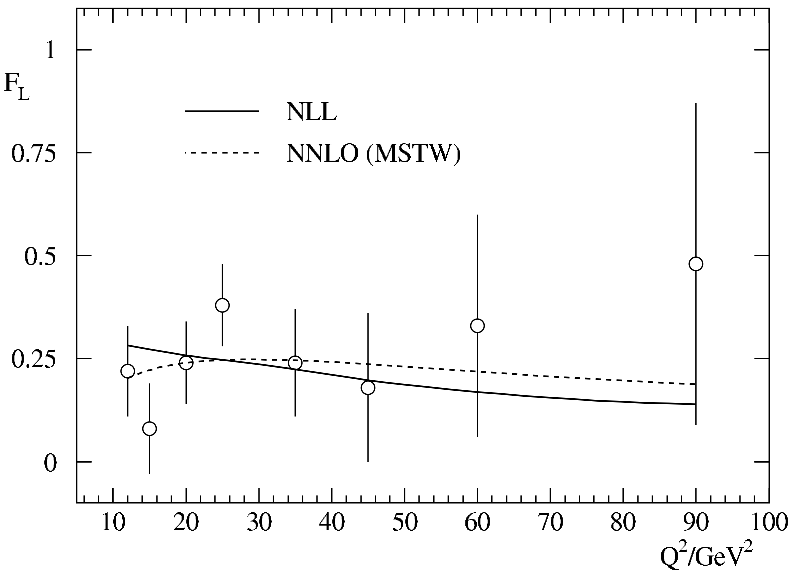
CORRECTIONS TO F_L MODERATE BUT NOT NEGLIGIBLE

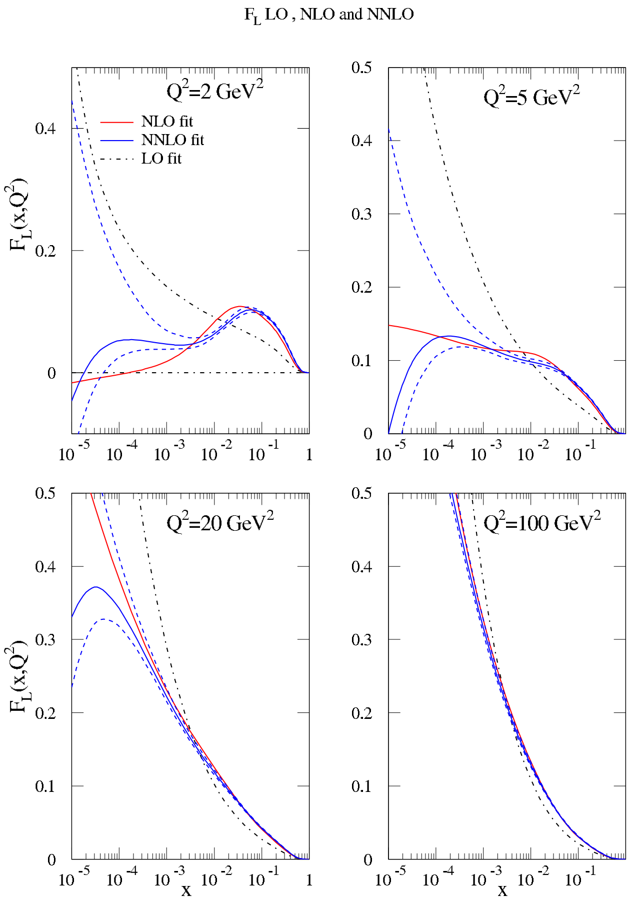
The longitudinal structure function F_L



G. ALTARELLI (ABF)

Results - F_L



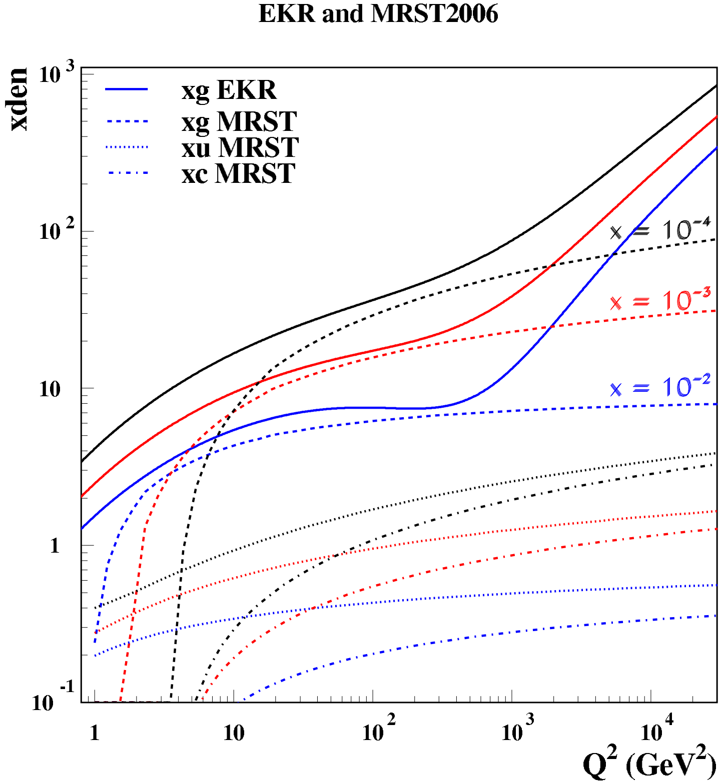


- Data currently unable to distinguish between predictions.
- But fixed order looks unstable.

C. WHITE (TW)

CAN CALCULATE THE STARTING GLUON AT SMALL x?

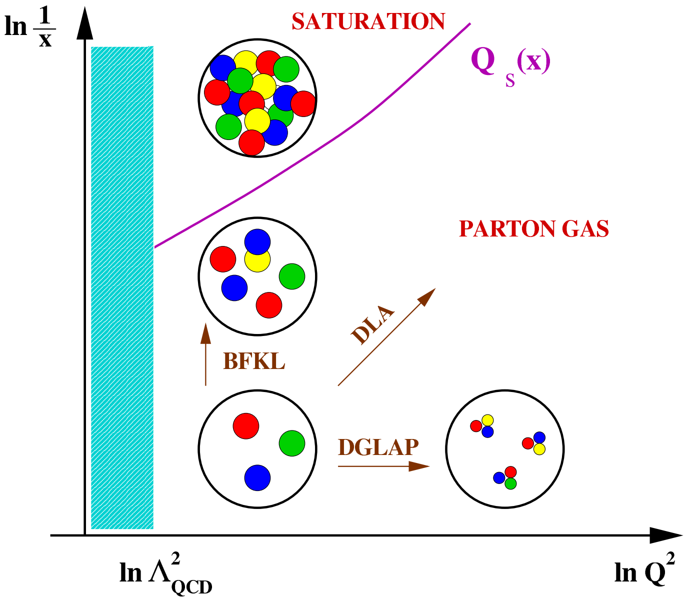
Although we do not use the integrated gluon density this can be constructed and we find remarkable agreement with MRST gluon distribution for $10 < Q^2 < 10^3 \ (GeV^2)$



Preliminary: (Factorization scheme to be sorted out)

D. Ross (EKR)

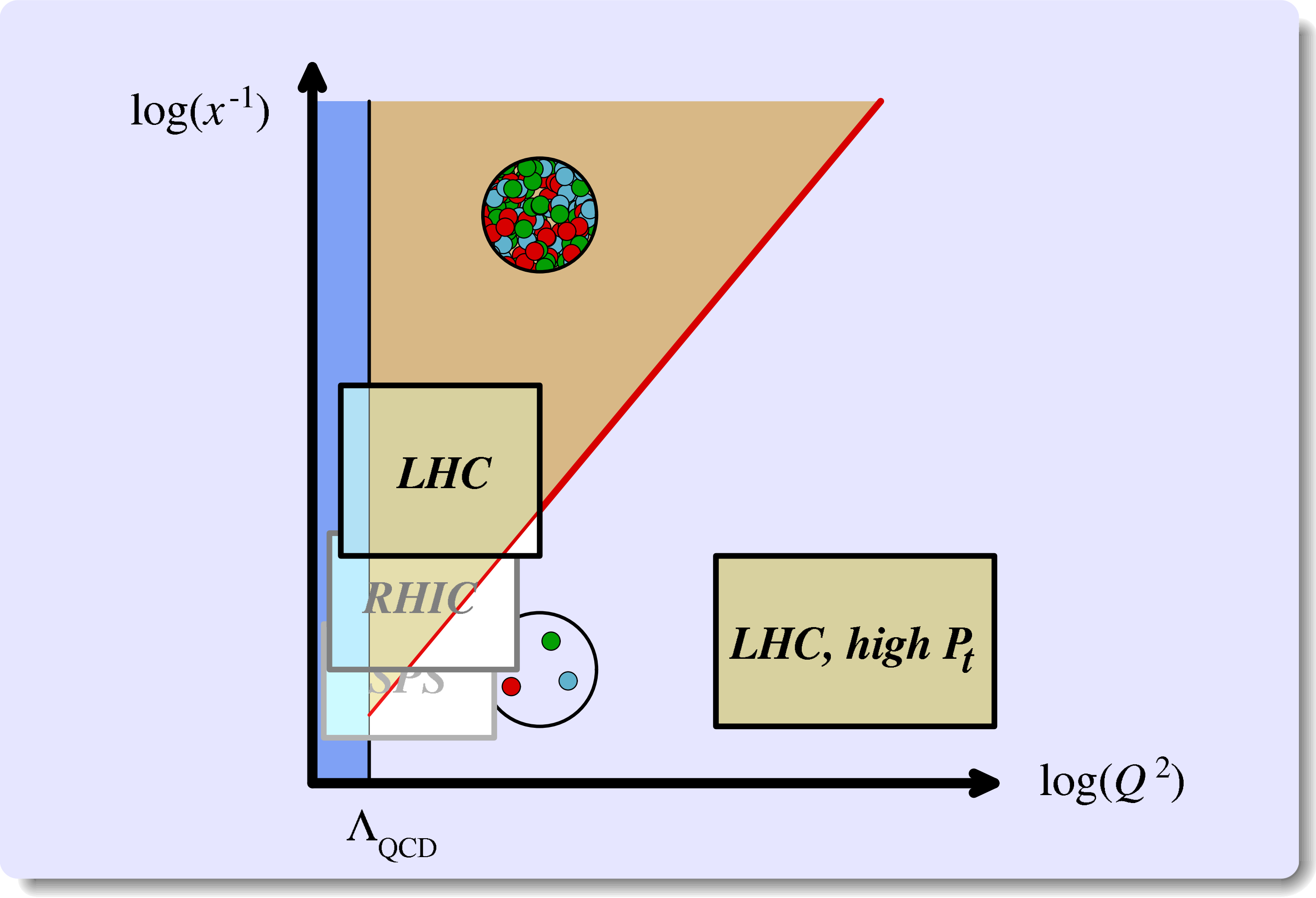
Free partons *vs.* Saturation



However, the very existence of saturation constrains the dynamics in the linear regime!

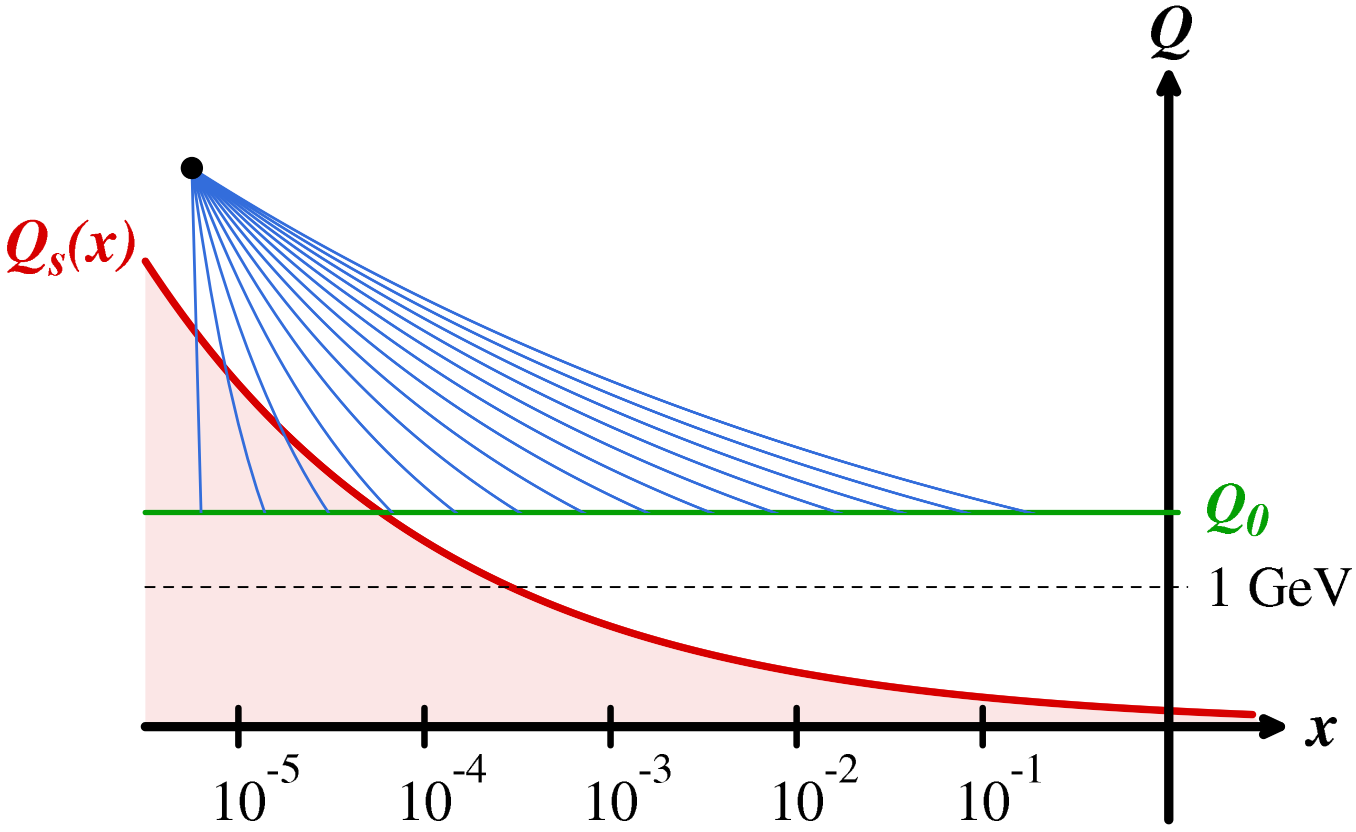
Saturation domain

IMPORTANT AT SMALL x...



…COULD CONTAMINATE PARTON DETERMINATION

- Even if the observable under consideration involves parton distributions only outside of the saturation domain, the DGLAP evolution may have been contaminated by saturation physics :



GEOMETRIC SCALING

In each bin of scaling variable are data points with different x and Q values

Region where scaling is nontrivial (outside this region data are close in x and Q)

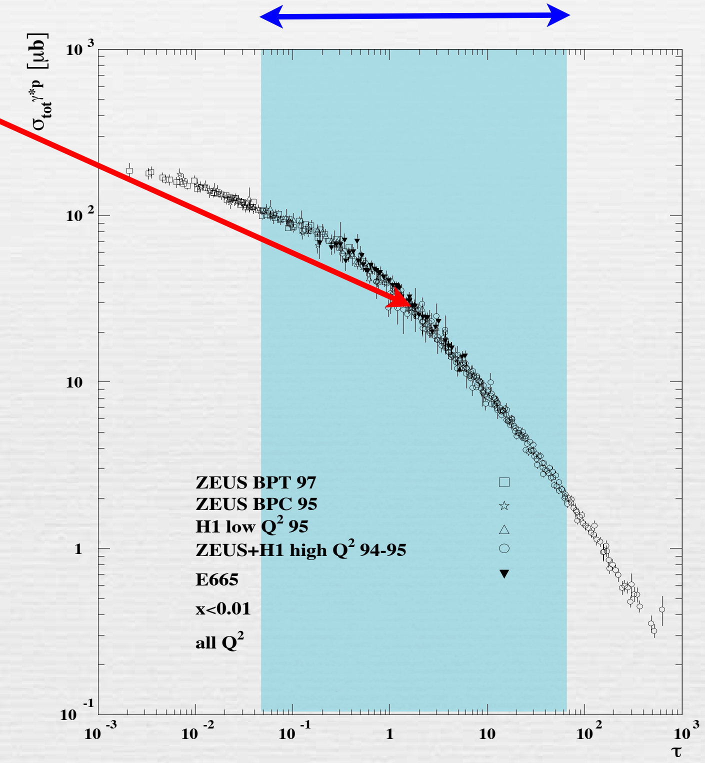


Figure 1: Experimental data on $\sigma_{\gamma^* p}$ from the region $x < 0.01$ plotted versus the scaling variable $\tau = Q^2 R_0^2(x)$.

Scaling motivated by the GBW model + dipole picture. Regularity observed in the data independently of the model.

A. Staśto

Summary

If you have to remember one thing:

Even if the geometric scaling properties of the HERA data are due to saturation, it does not mean that the non-linear saturated regime has been probed at HERA and that the pdf determination at low-x suffers from saturation uncertainties.

MAYBE NOT: FEATURE OF BOUNDARY CONDITION?

Solution for the gluon density

Solution at small x:

$$\frac{\alpha_s}{2\pi}\frac{xg(x,Q^2)}{Q^2} \simeq \frac{r^0}{\tilde{Q}_0^2}\left(\frac{\alpha_s}{2\pi}\right)\left(\frac{Q^2}{Q_s^2(x)}\right)^{(\alpha_s/2\pi)\gamma_{gg}(\omega_0)-1}$$

Solution exhibits approximate scaling.
Power controlled by the anomalous dimension.

Critical value of the saturation exponent:
determines the existence of scaling.

Example:in the DLLA approximation

$$\gamma_{gg}^{DL}(\omega) = \frac{2N_c}{\omega}$$

$\lambda \geqslant 4\bar{\alpha}_s$ scaling

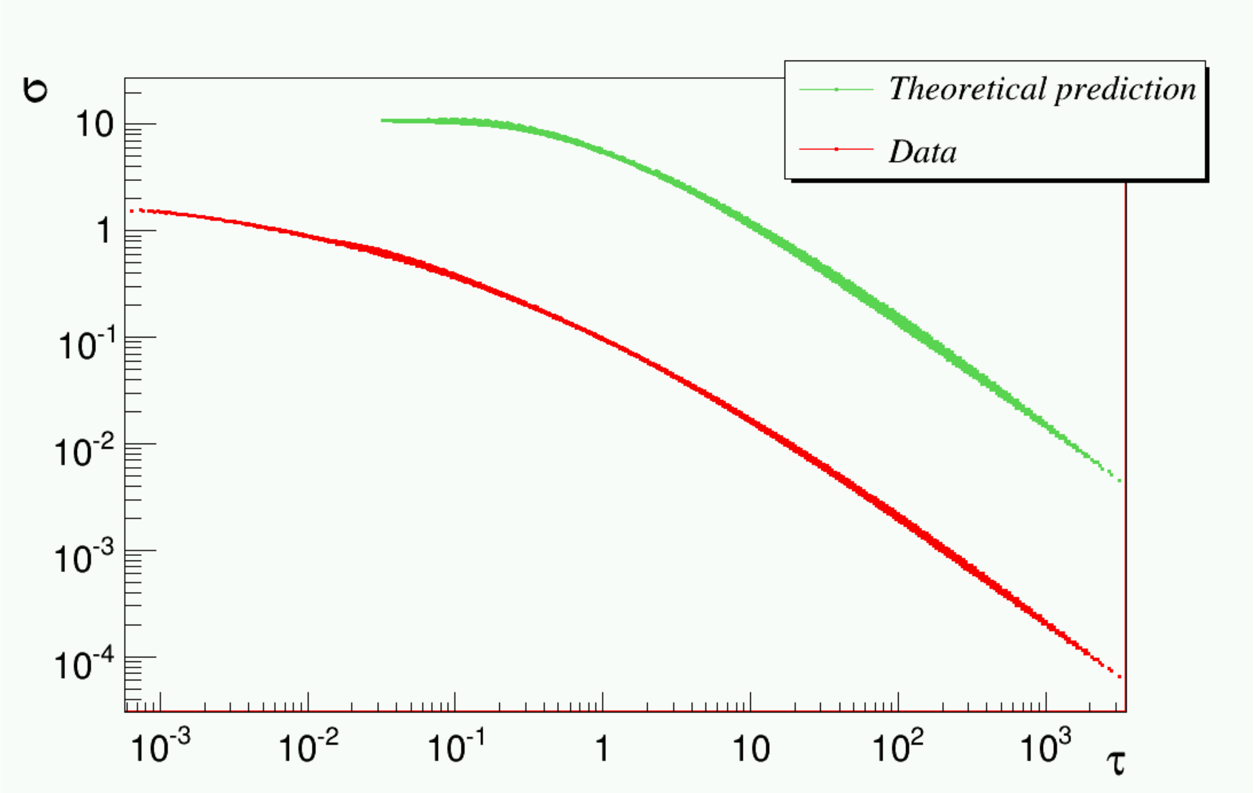
$\lambda < 4\bar{\alpha}_s$ no scaling

A. Staśto

Our final results:

Fixed–coupling scaling

$\lambda = \lambda_{fix} = 0.32$, $x < 0.1$, $Q^2 > 1$ GeV^2 for the theoretical curve



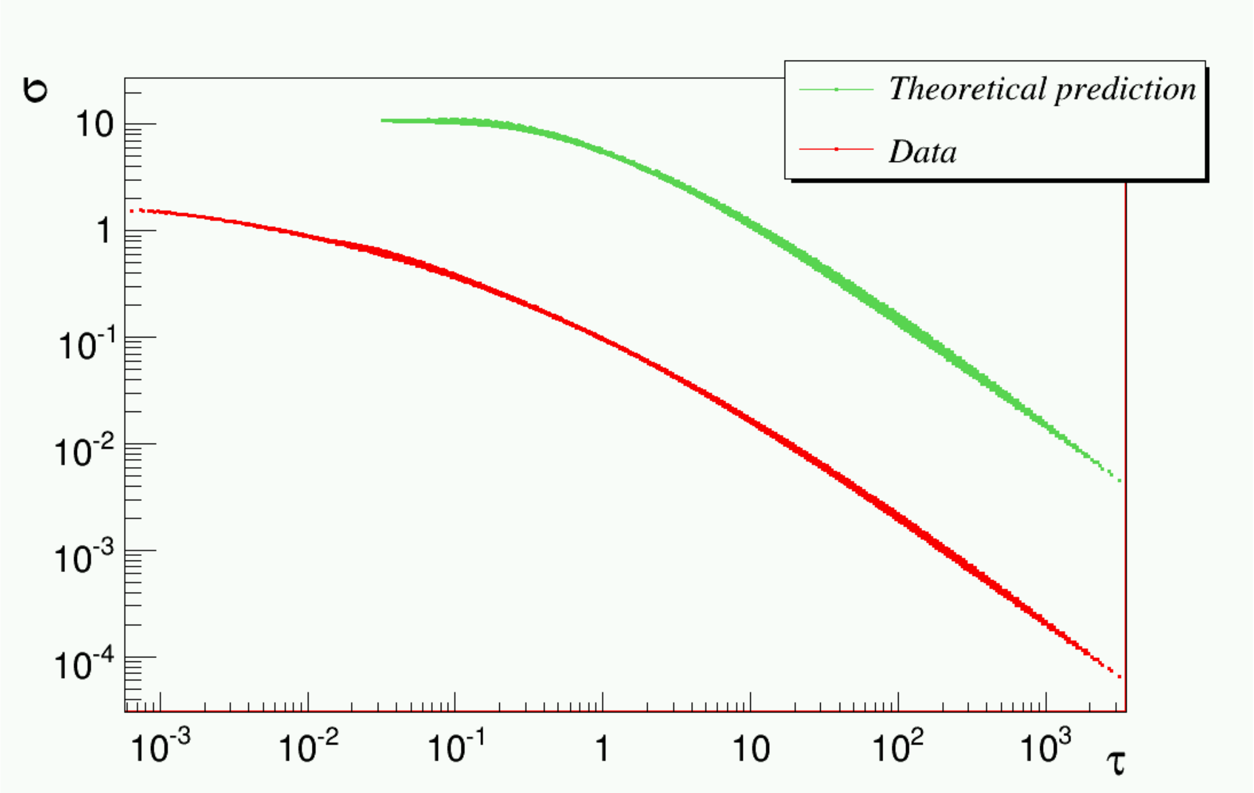
Our final

OBSERVED SCALING FOR $Q^2 > 10$ GEV^2

IN AGREEMENT WITH DGLAP PREDICTION

Fixed–coupling scaling

$\lambda = \lambda_{fix} = 0.32$, $x < 0.1$, $Q^2 > 1$ GeV^2 for the theoretical curve

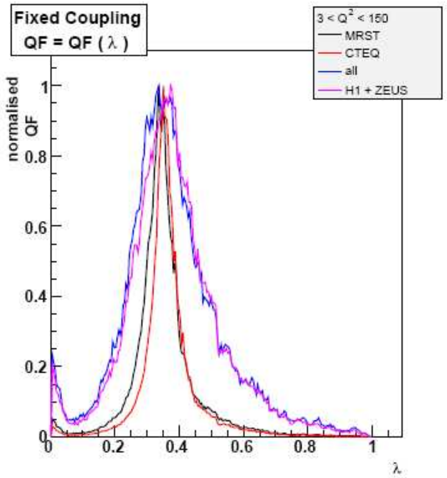


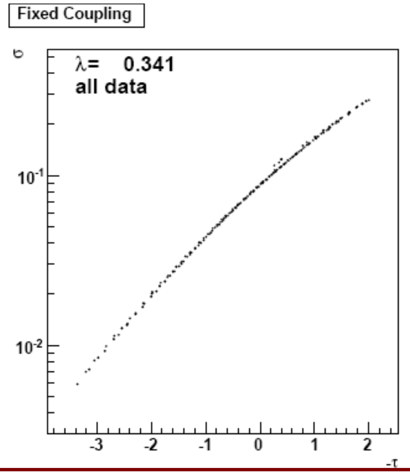
F. CAOLA

AS CONFIRMED BY DETAILED FITS!

MRST and CTEQ Parametrisation

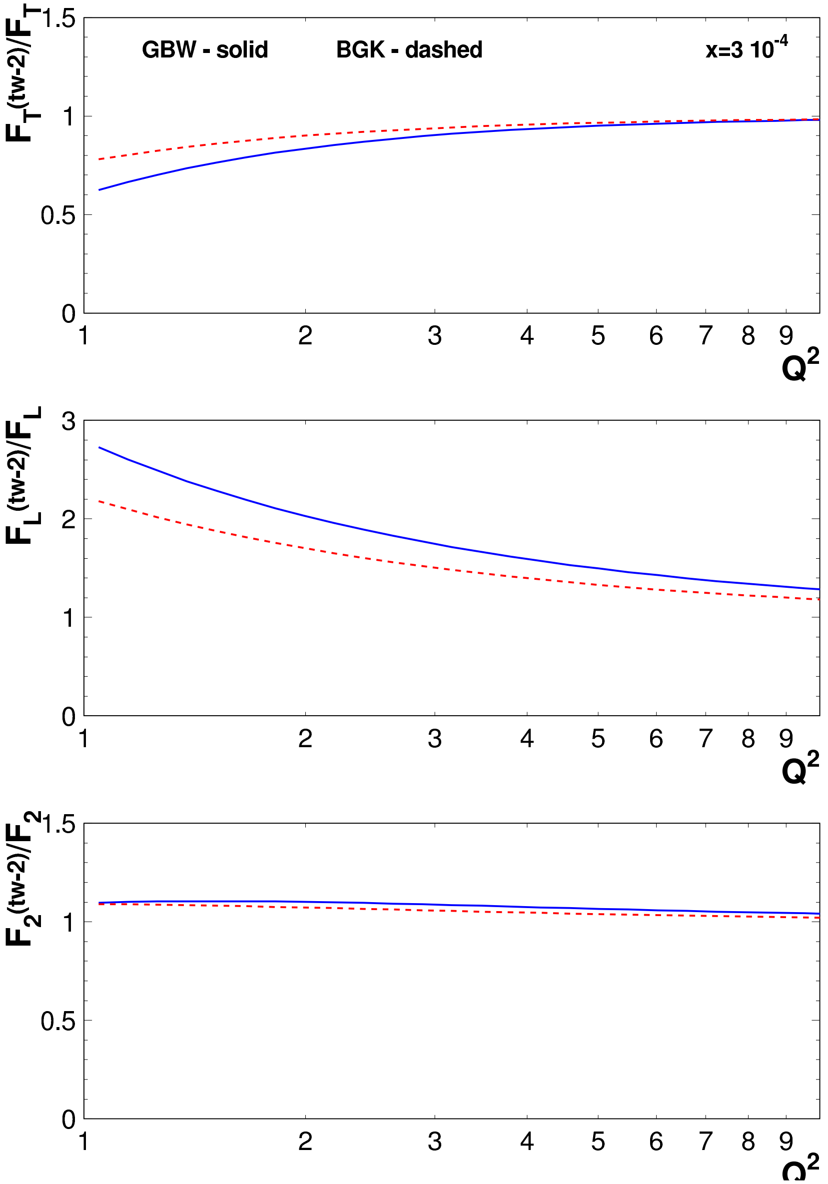
- F_2 from MRST and CTEQ parametrisation tested
- the same x, Q^2 values as $Q^2 > 3$ data (217 points)
- smooth scaling curves
- similar values of λ as in the data
- DGLAP shows scaling but it's not naturally explained (saturation explains the scaling naturally)





D. ŠÁLEK

EXPLANATION: SATURATION $\Rightarrow$ HIGHER TWISTS



Higher twist contribution at $x = 3 \cdot 10^{-4}$ and $Q^2 = 10$ GeV^2:

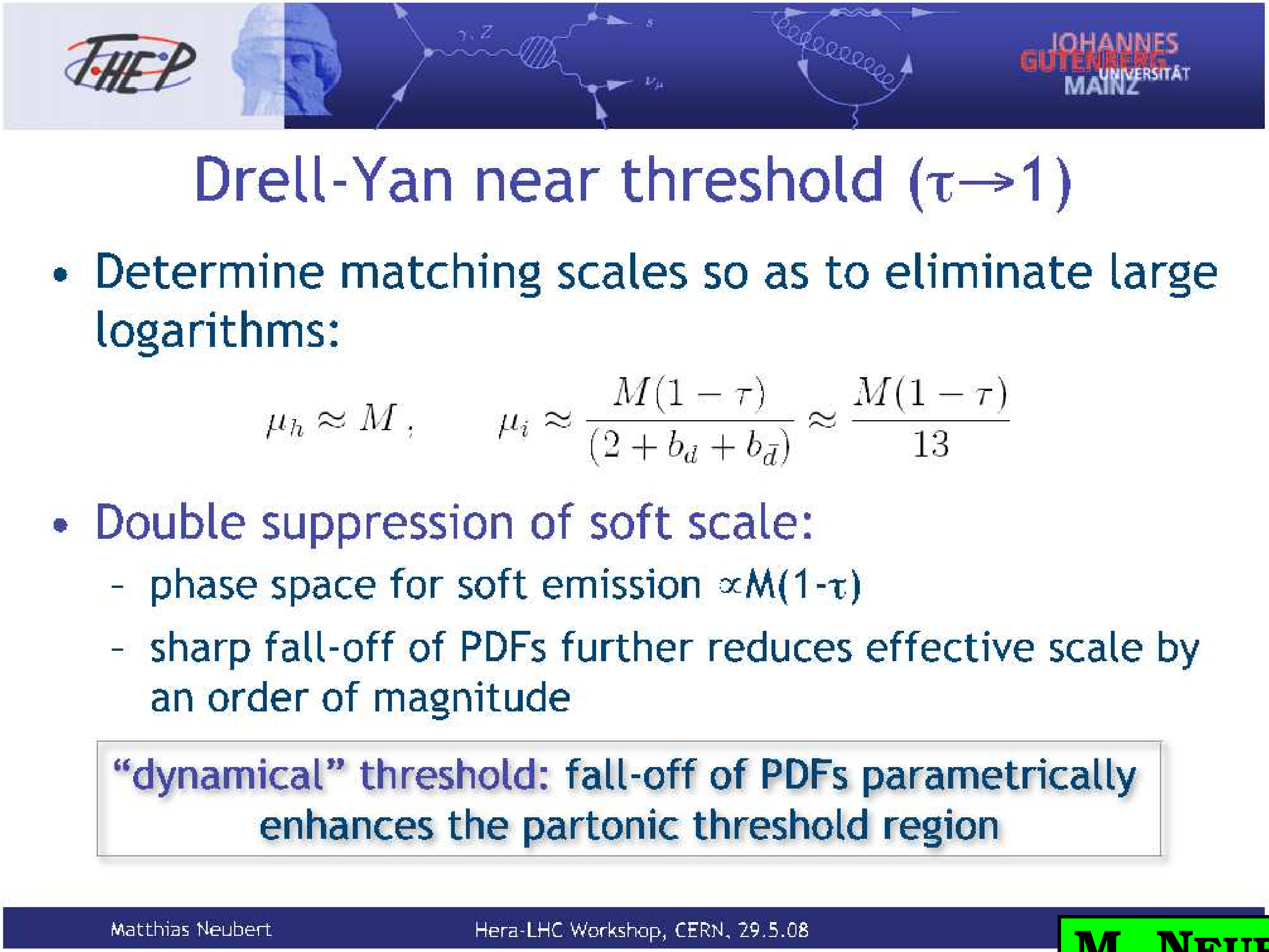
F_T: $\sim 1\%$

F_L: $\sim 20\%$

F_2: $\sim 1\%$

VERY SUPPRESSED IN F_2, LESS SO IN F_L

SOFT RESUMMATION: PARTONIC ENERGY << HADRONIC ENERGY



Drell-Yan near threshold (τ→1)

- Determine matching scales so as to eliminate large logarithms:

$$\mu_h \approx M\,, \qquad \mu_i \approx \frac{M(1-\tau)}{(2+b_d+b_{\bar d})} \approx \frac{M(1-\tau)}{13}$$

- Double suppression of soft scale:
  - phase space for soft emission ∝M(1-τ)
  - sharp fall-off of PDFs further reduces effective scale by an order of magnitude

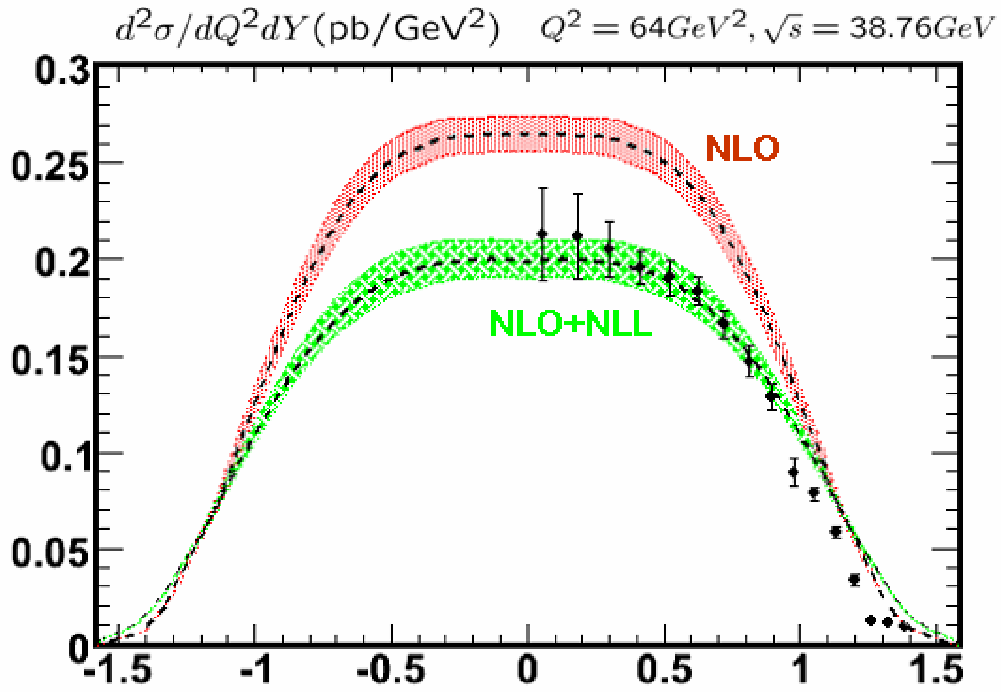
"dynamical" threshold: fall-off of PDFs parametrically enhances the partonic threshold region

Matthias Neubert   Hera-LHC Workshop, CERN, 29.5.08

M. NEUBERT

A LARGE CORRECTION TO DY RAPIDITY DISTRIBUTIONS?

NLL RESUMMATION AND E866 DATA



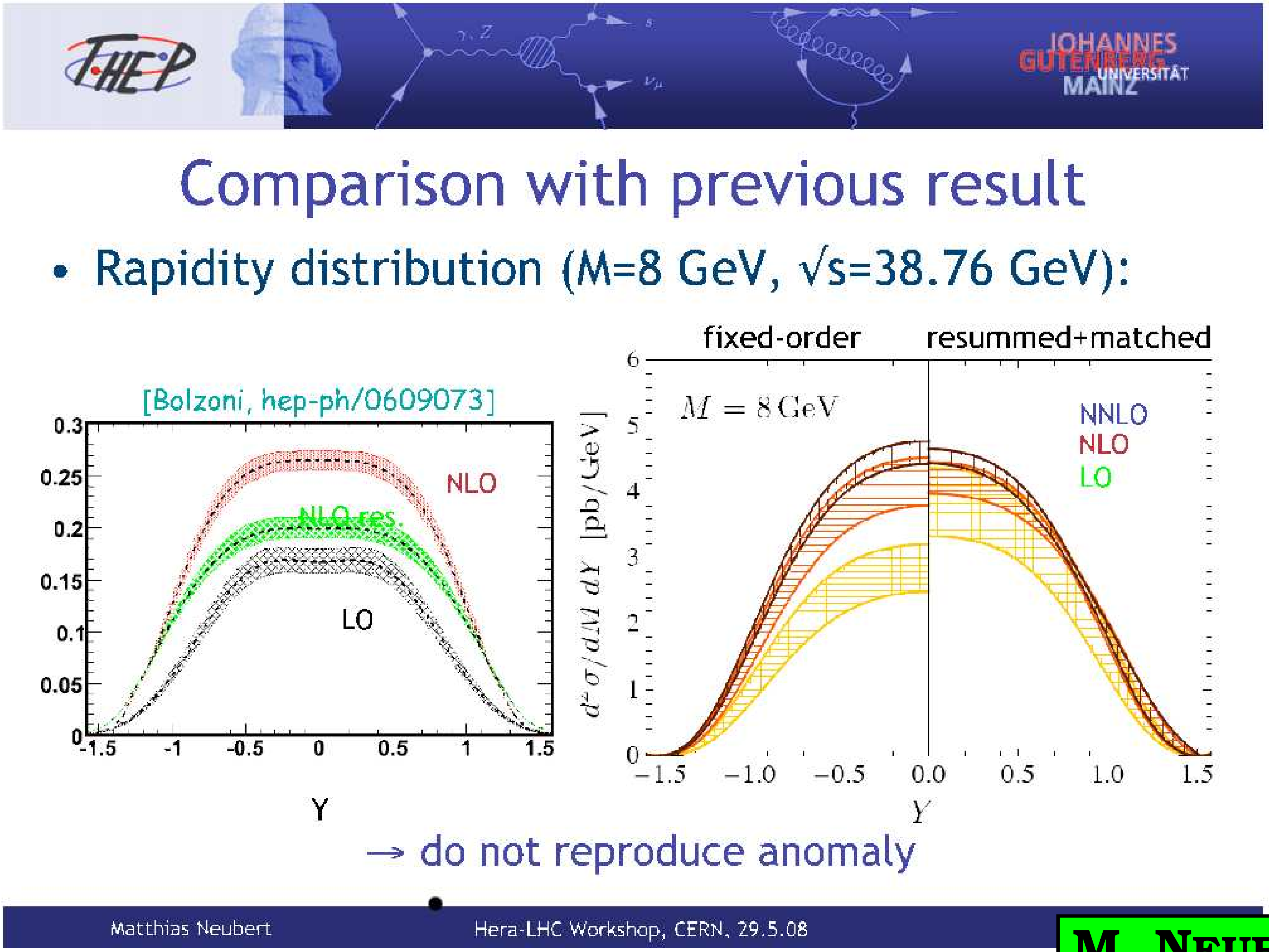
RAPIDITY DISTRIBUTION
IN pp COLLISIONS AT NLO
AND NLO+NLL WITH
THE PARAMETER CHOICES
AND DATA OF
Anastasiou et al.
(hep-ph/0306192)

NLL RESUMMATION REDUCES THE CROSS SECTION INSTEAD OF ENHANCING IT FOR NOT LARGE VALUES OF RAPIDITY

THE AGREEMENT WITH THE DATA IS GOOD

A GREAT IMPROVEMENT FOR NOT LARGE RAPIDITY IS OBTAINED WITH RESPECT TO THE NLO CALCULATION

…OR PERHAPS NOT



Comparison with previous result

- Rapidity distribution (M=8 GeV, $\sqrt{s}$=38.76 GeV):

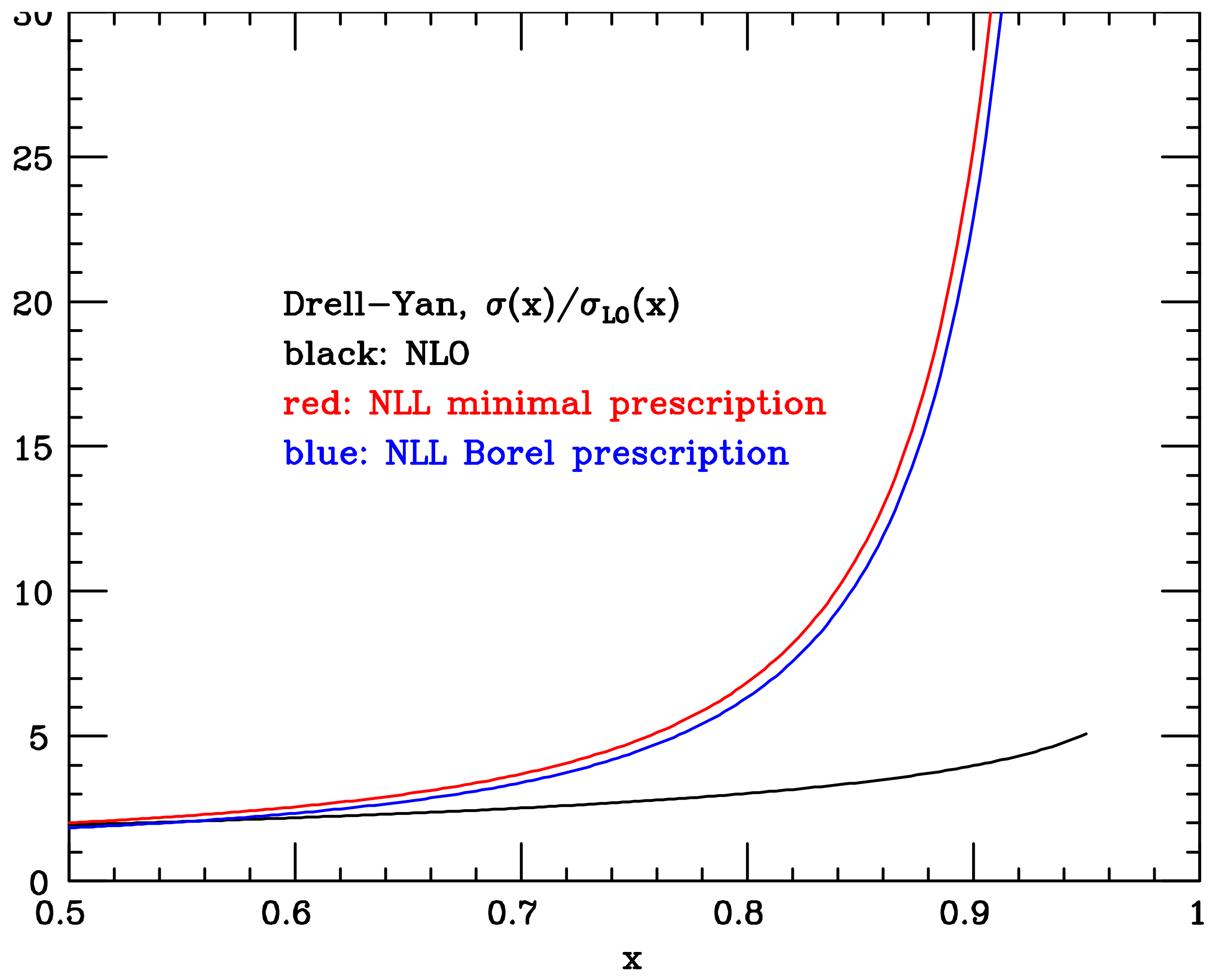
→ do not reproduce anomaly

Matthias Neubert

Hera-LHC Workshop, CERN, 29.5.08

M. NEUBERT

RESUMMATION AFFECTED BY NON-PERTURBATIVE AMBIGUITIES



DY

S. Forte, GR, in preparation

PDFS: WHERE DO WE STAND?

PARTON FITS:

PROGRESS AND PROBLEMS

PROGRESS: NEW DATA

- FINAL HERA COMBINED DATA ⇒ CONSISTENT FITS
- NEUTRINO DATA AND STRANGE DISTRIBUTION
- PARTON CORRELATION STUDIES
- NEW TOOLS

PROBLEMS: PDF UNCERTAINTIES

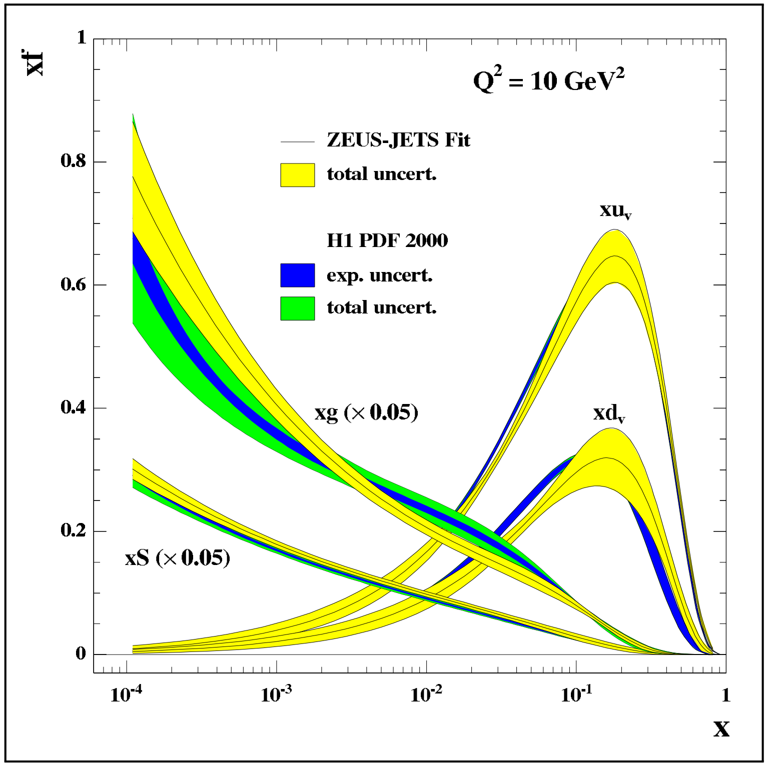
- NONGAUSSIAN ERRORS?
- INCONSISTENT DATA?
- UNCERTAINTY DETERMINATION

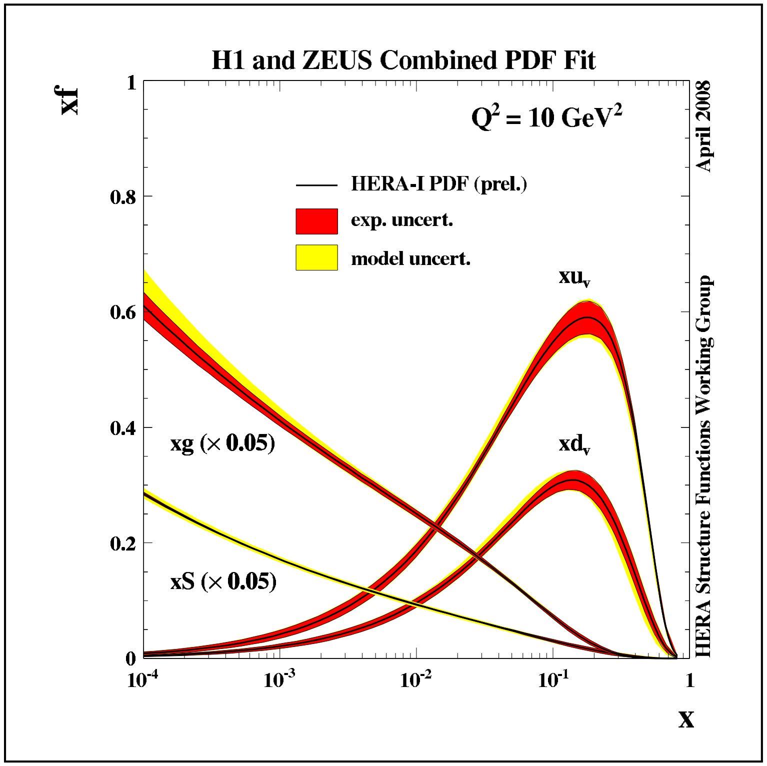
COHERENT DATA ⇒ REDUCED UNCERTAINTIES

also used

only HERA data

Note in published PDFs H1 has α_s variation included in model error, ZEUS does not.





Resolution of previous discrepancies, improvement in level of uncertainty

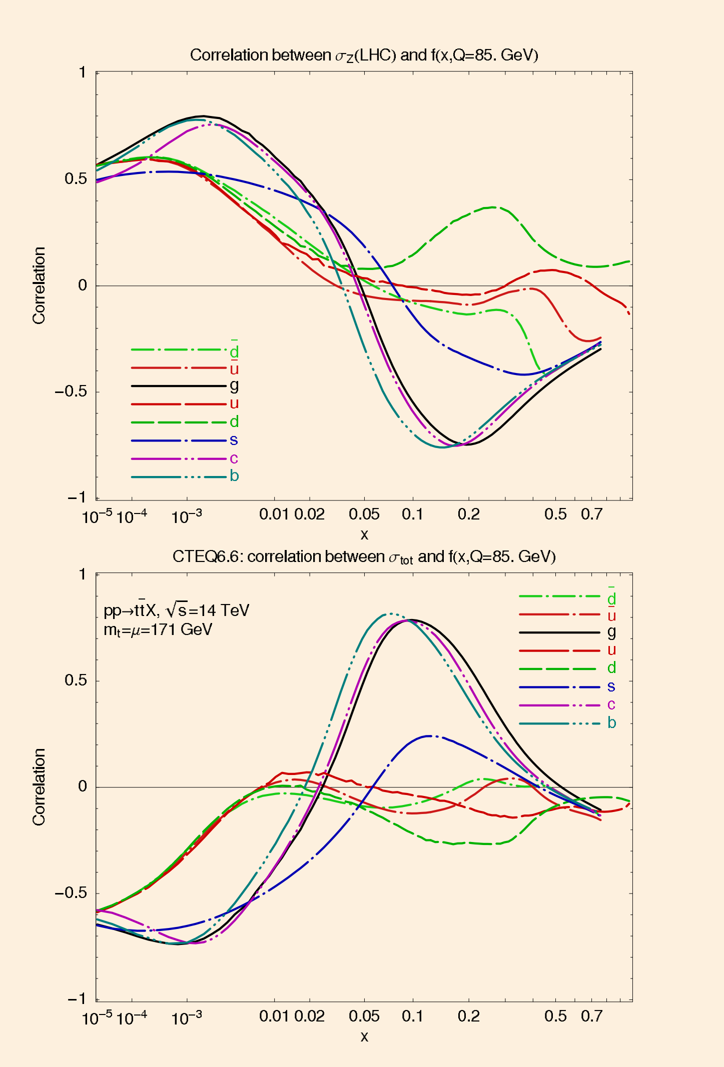
GANG LI (ZEUS/H1)

CAN PERFORM PARTON CORRELATION STUDIES

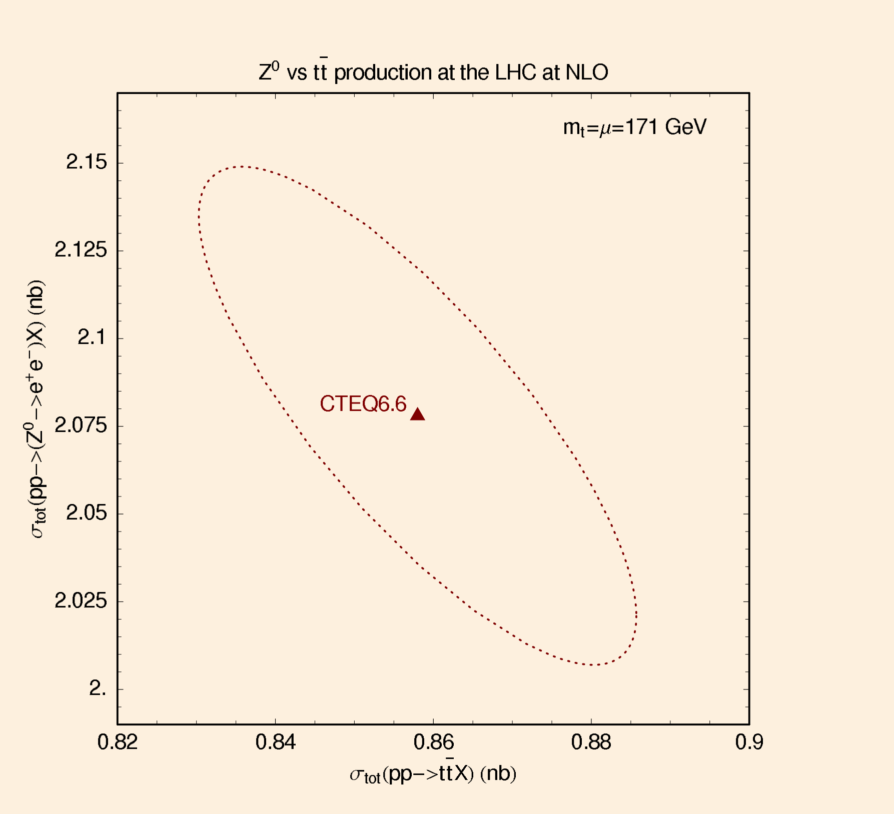
Correlations of Z and $t\bar{t}$ cross sections with PDF's

LHC Z, W cross sections are strongly correlated with $g(x)$, $c(x)$, $b(x)$ at $x \sim 0.005$

$\therefore$ they are strongly anticorrelated with processes sensitive to $g(x)$ at $x \sim 0.1$ ($t\bar{t}$, $gg \to H$ for $M_H > 300$ GeV) as a consequence of momentum sum rule



$t\bar{t}$ vs Z cross sections at the LHC

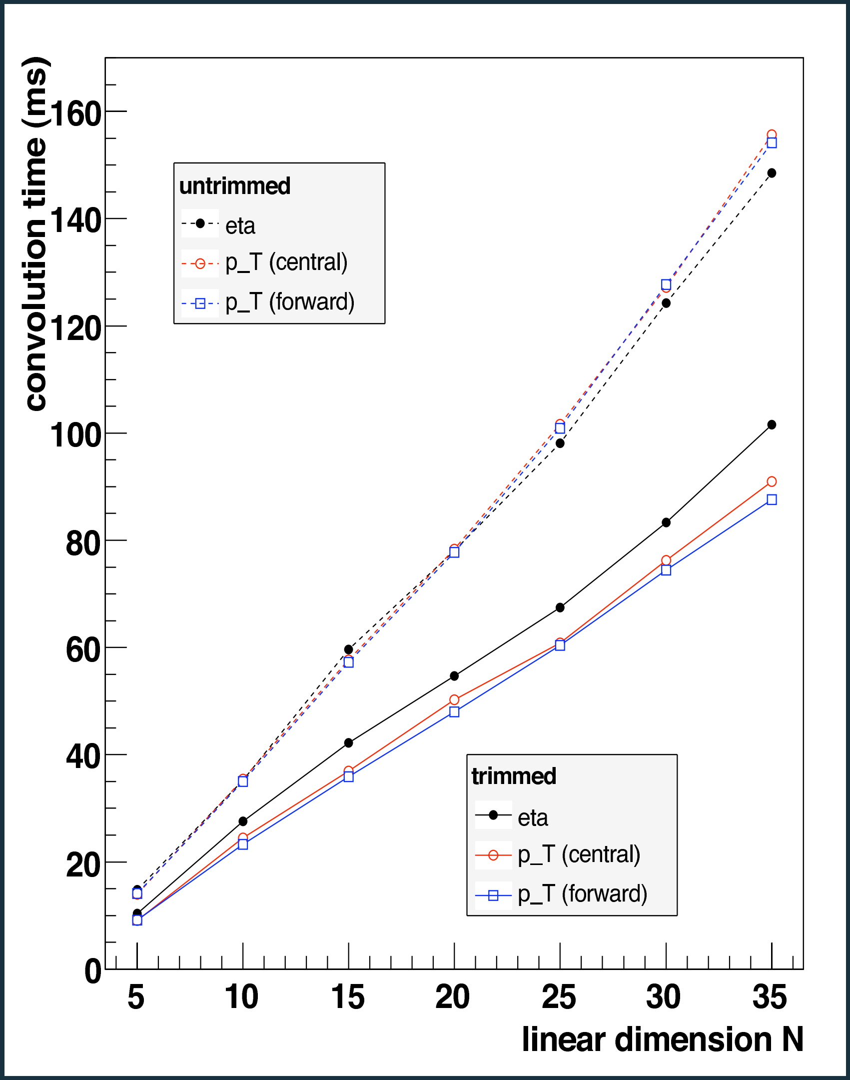


Measurements of $\sigma_{t\bar{t}}$ and σ_Z probe the same (gluon) PDF degrees of freedom at different x values

P. NADOLSKY

Convolution time

- Old grid around 5 seconds.
- Constant $N(Q^2)$, expect quadratic dependence on grid $N(x)$ size.
- Why does convolution time not scale with $N(x)^2$?
- Convolution itself is fast, the time consuming part is the calculation of the pdfs on the grid nodes.
- If the x_1 and x_2 nodes have the same values, only need to calculate 1 set of pdfs at each x_1 node, time goes as $N(x_1)$.
- If x_1 and x_2 nodes have independent values, scales with $N(x_1) + N(x_2)$.
- Trimmed grid is 40% faster.



M. Sutton

BUT NEW DATA ⇒ MORE PARAMETERS ⇒ INCREASED UNCERTAINTIES

Direct determination of strange affects uncertainties on partons other than strange.

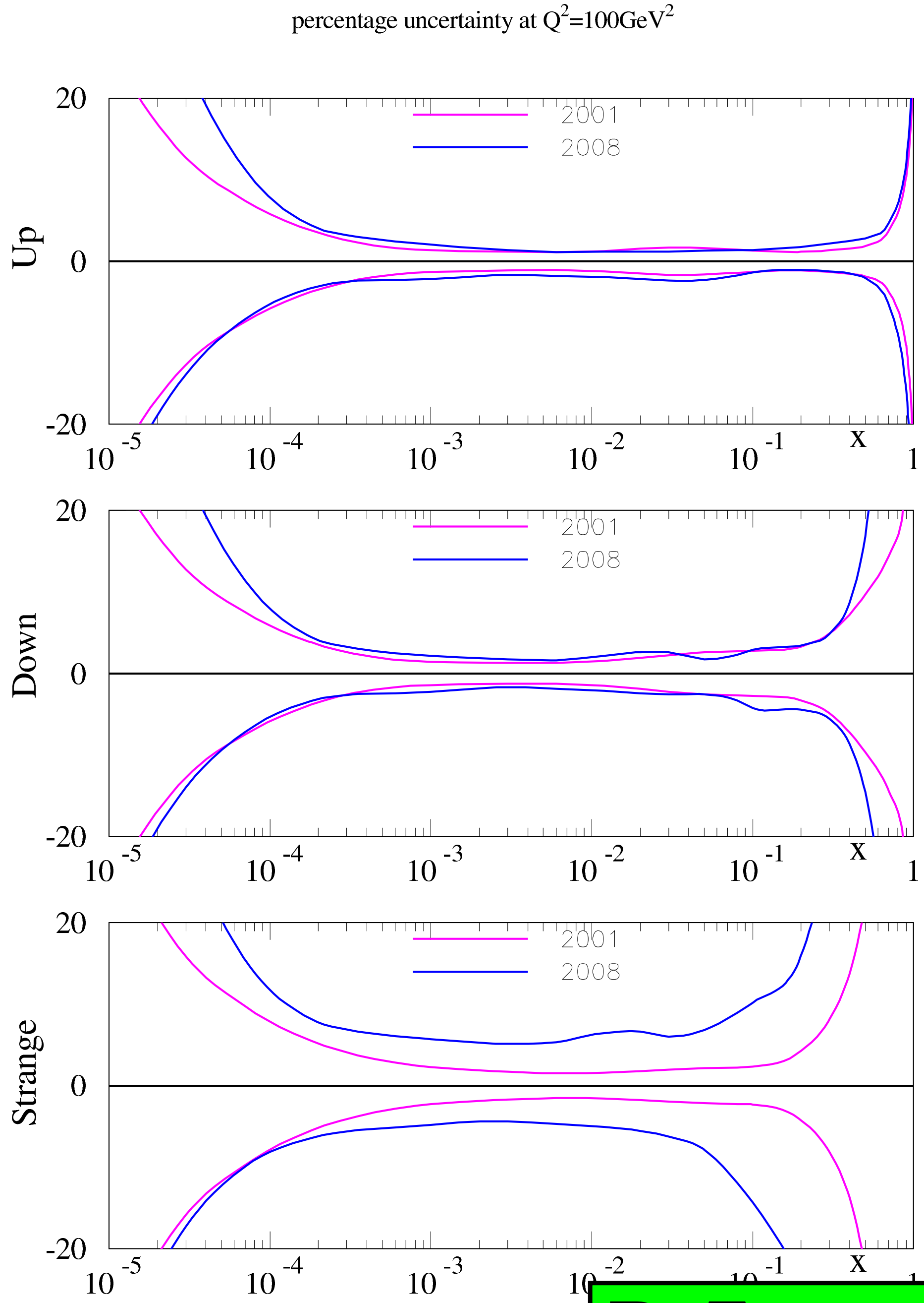
Previously for us (and everyone else) strange a fixed proportion of total sea in global fit.

Genuine *larger* uncertainty on $s(x)$– feeds into that on $\bar{u}$ and $\bar{d}$ quarks.

Low x data on $F_2(x,Q^2)$ constrains sum $4/9(u+\bar{u})+1/9(d+\bar{d}+s+\bar{s})$.

Changes in fraction of $s+\bar{s}$ affects size of $\bar{u}$ and $\bar{d}$ at input.

The size of the uncertainty on the small x anti-quarks increases – $\sim 1.5\% \rightarrow \sim 2-2.5\%$, despite additional constraints on quarks in new fit.



PDF4LHCMSTW

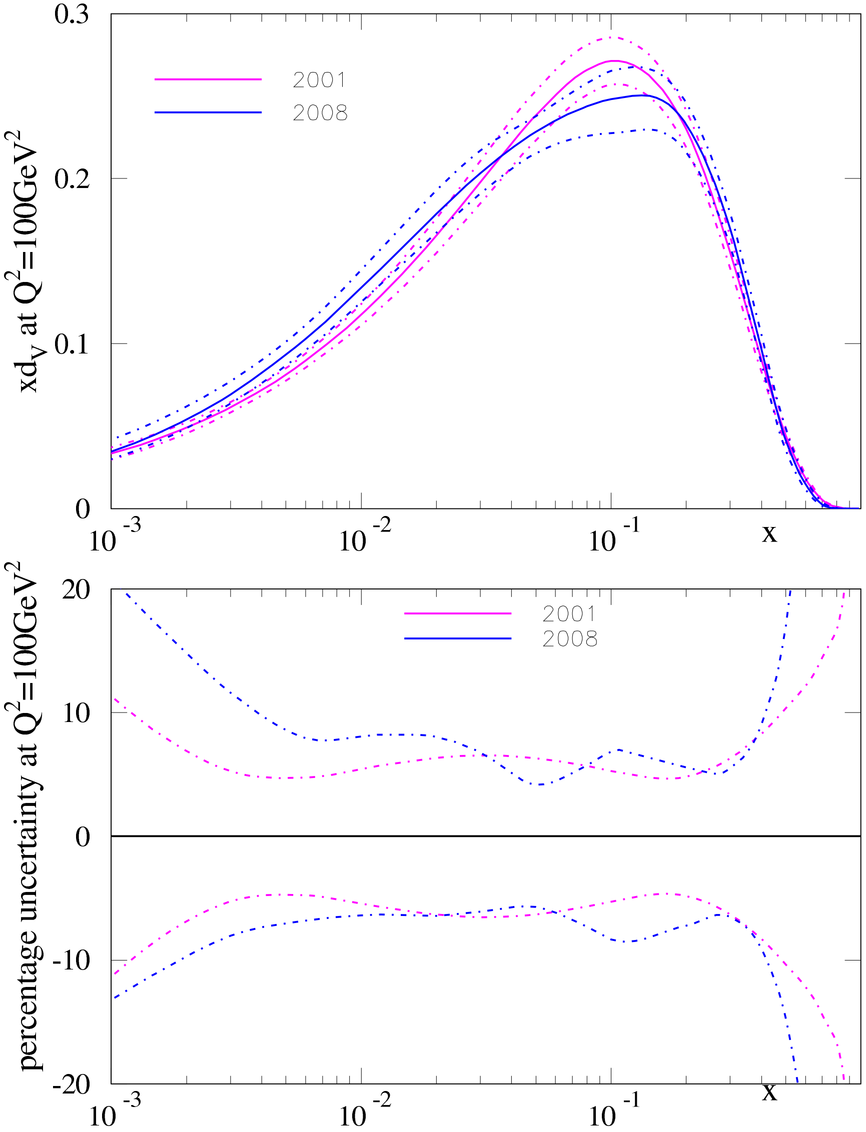
R. THORNE

DITTO WITH BETTER DATA...

Overall $d_V(x,Q^2)$ now chooses a different type of shape.

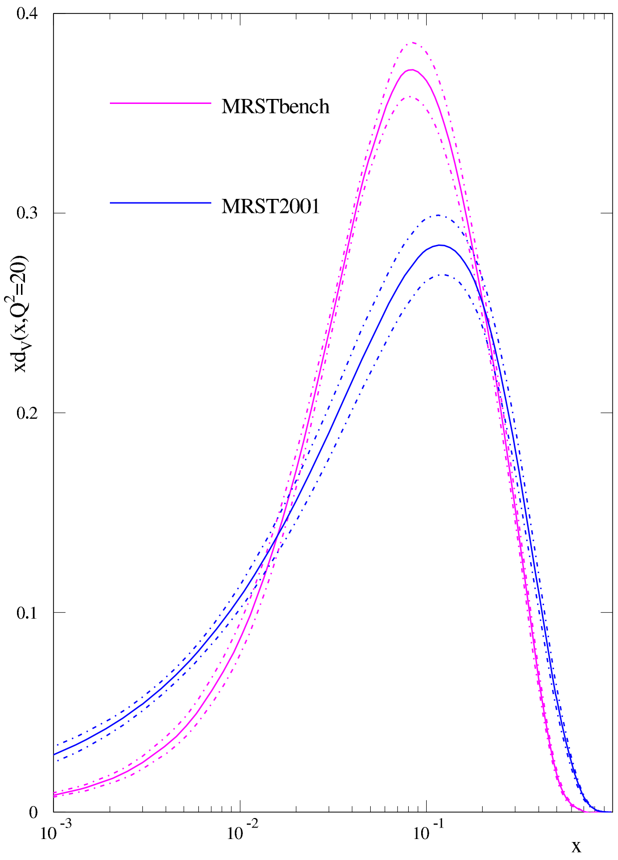
Mainly changed by new *Tevatron* W-asymmetry data and new neutrino structure function data.

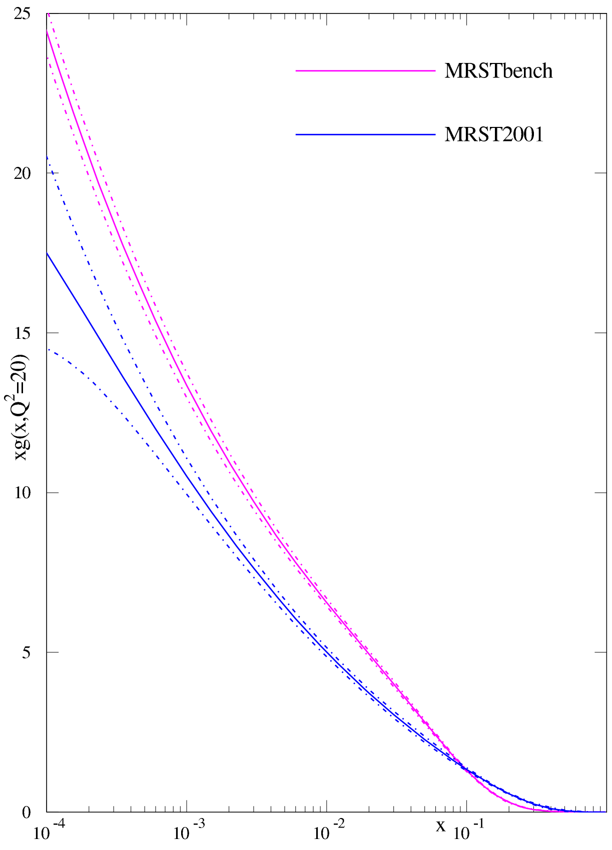
Uncertainty growing more quickly as $x \rightarrow 0$ and $x \rightarrow 1$ than before due to better parameterisation in determining uncertainty eigenvectors.



THE HERALHC BENCHMARK

However, how do partons from very conservative, structure function only data compare to global partons? Compare to MRST01 partons with uncertainty from $\Delta\chi^2 = 50$. Enormous difference in central values. Errors similar. Moreover $\alpha_S(M_Z^2) = 0.1110 \pm 0.0015$ compared to $\alpha_S(M_Z^2) = 0.119 \pm 0.002$.

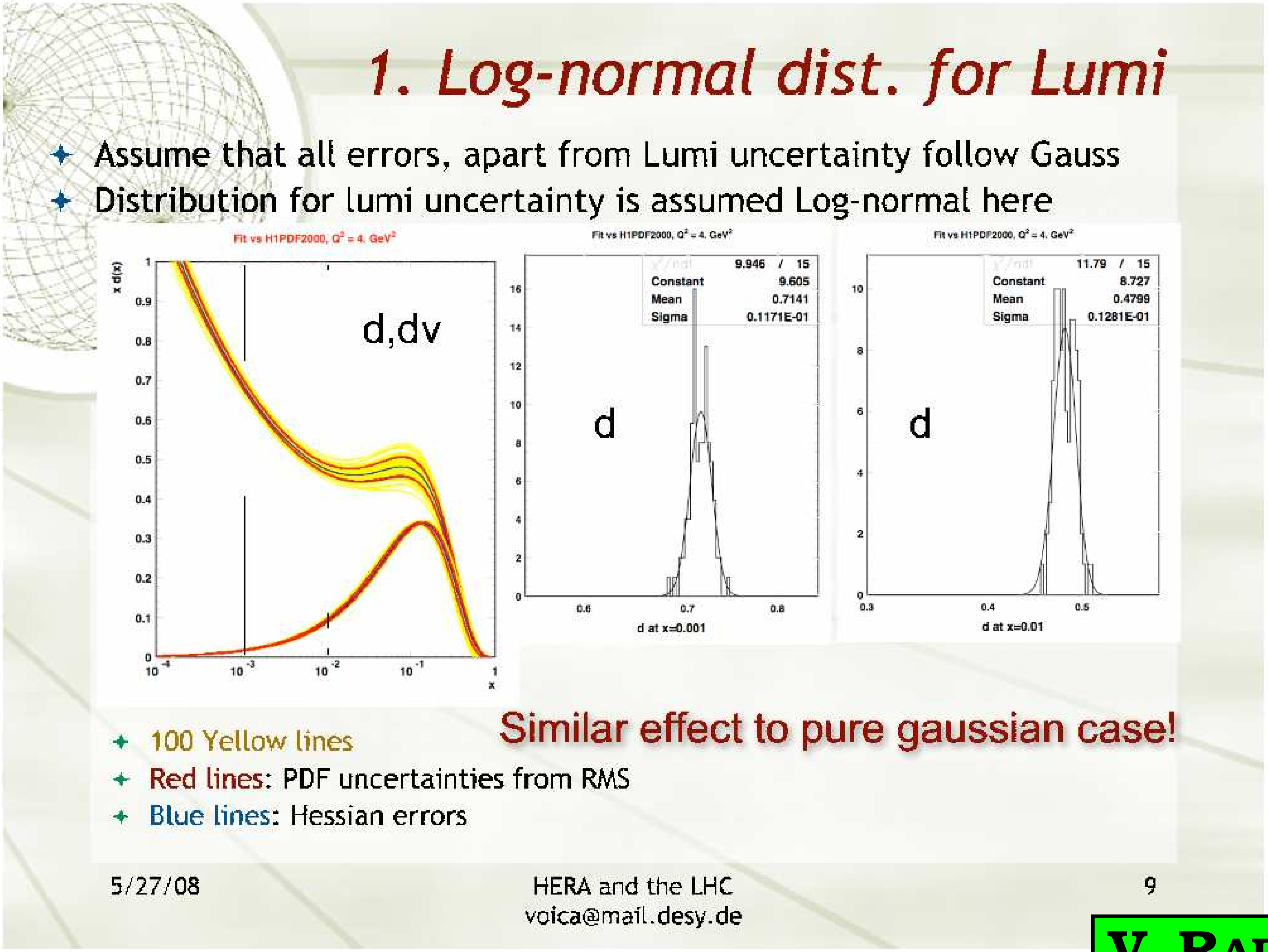




Conclude that fit using small sample of data sets and standard $\Delta\chi^2 = 1$ not a good way of proceeding. (Monte Carlo approach different alternative).

⇒ EITHER DATA INCOMPATIBLE, OR PARM. BIAS, OR BOTH!

NON-GAUSSIAN EXPT. UNCERTAINTIES: A RED HERRING



1. Log-normal dist. for Lumi

- Assume that all errors, apart from Lumi uncertainty follow Gauss
- Distribution for lumi uncertainty is assumed Log-normal here

Similar effect to pure gaussian case!

- 100 Yellow lines
- Red lines: PDF uncertainties from RMS
- Blue lines: Hessian errors

5/27/08

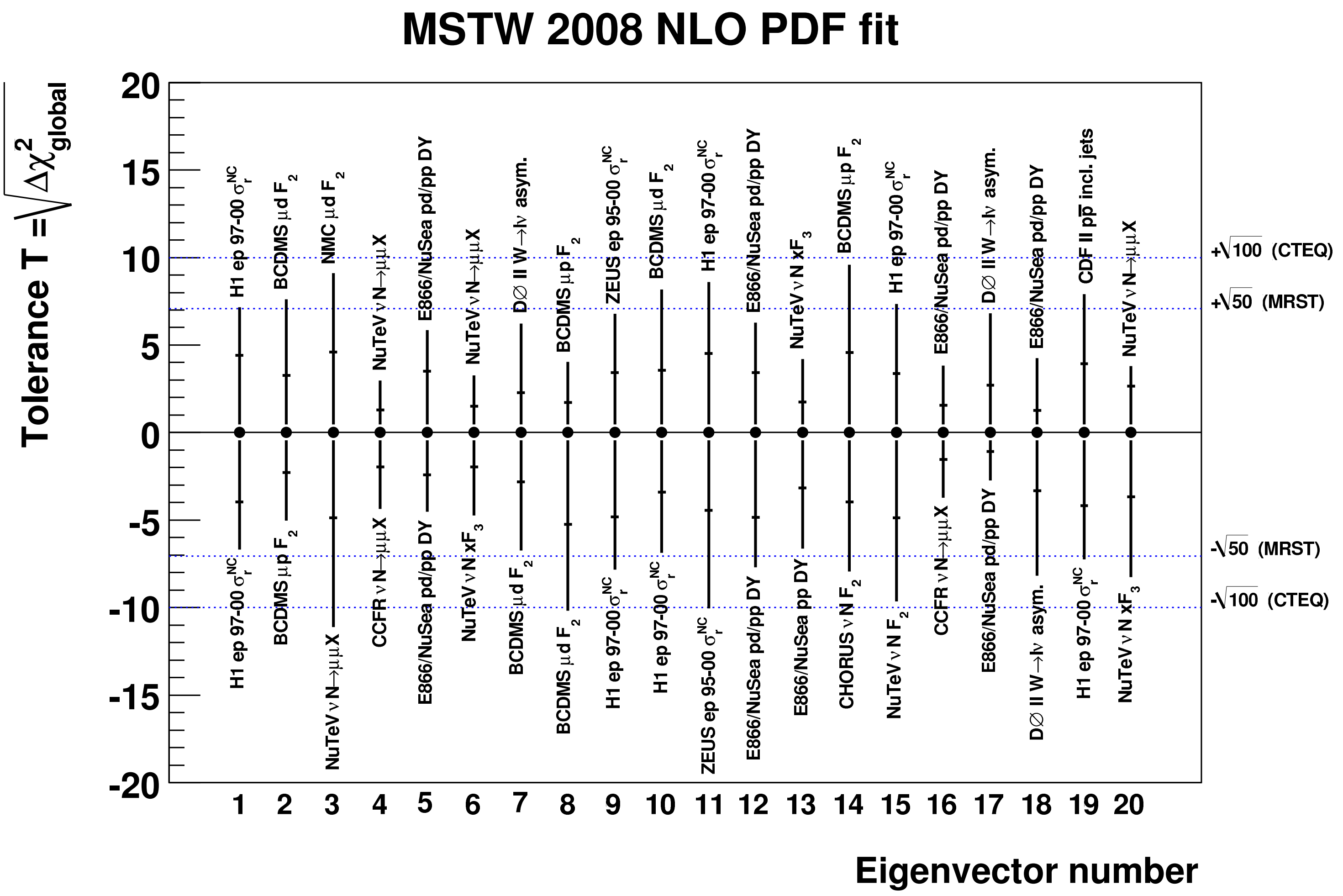
HERA and the LHC
voica@mail.desy.de

9

V. RADESCU

INCOMPATIBLE DATA/THEORY: THE TOLERANCE APPROACH

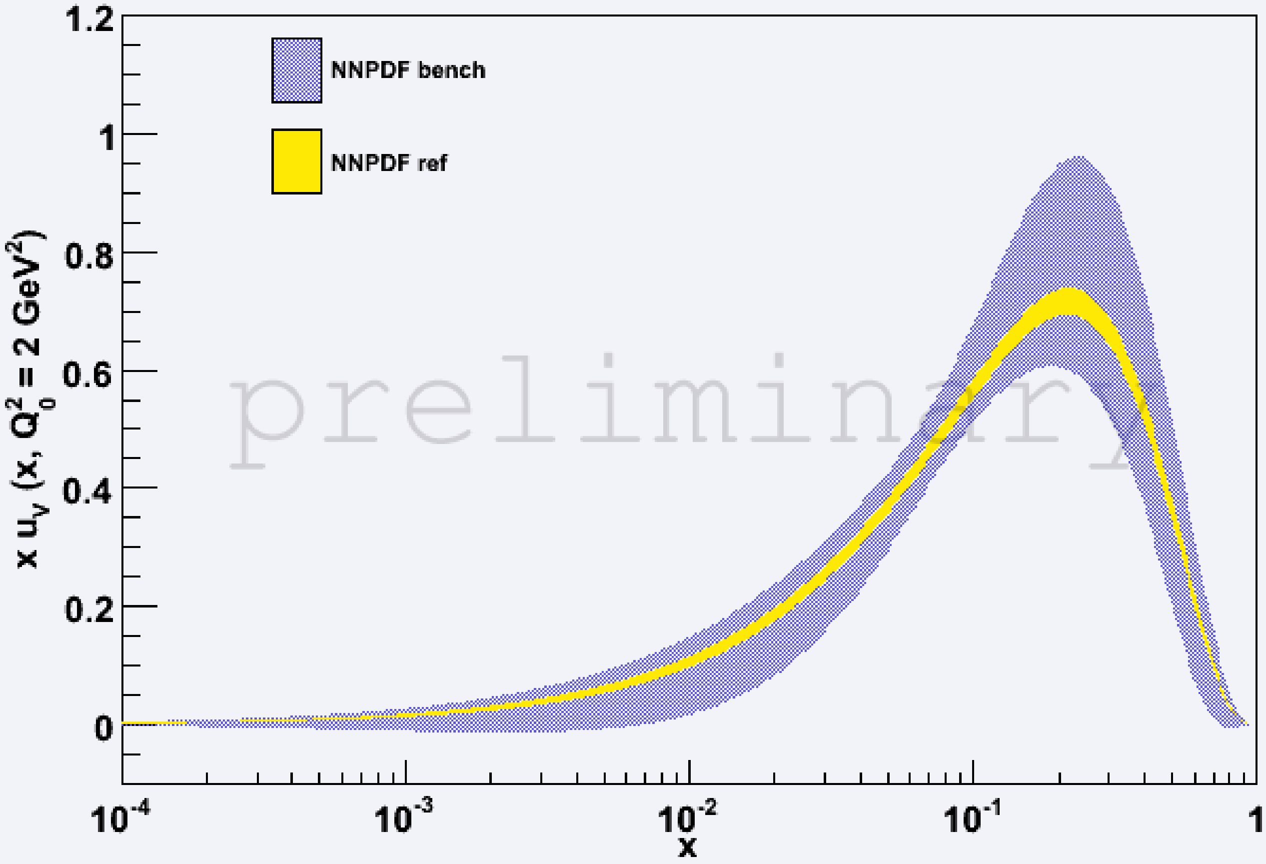
Approach repeated for all 20 eigenvectors to determine uncertainty on each. On average $\Delta\chi^2 = 40$, but large variations, and asymmetries.



THE NEURAL MC APPROACH

results

LESS DATA ⇒ LARGER UNCERTAINTY

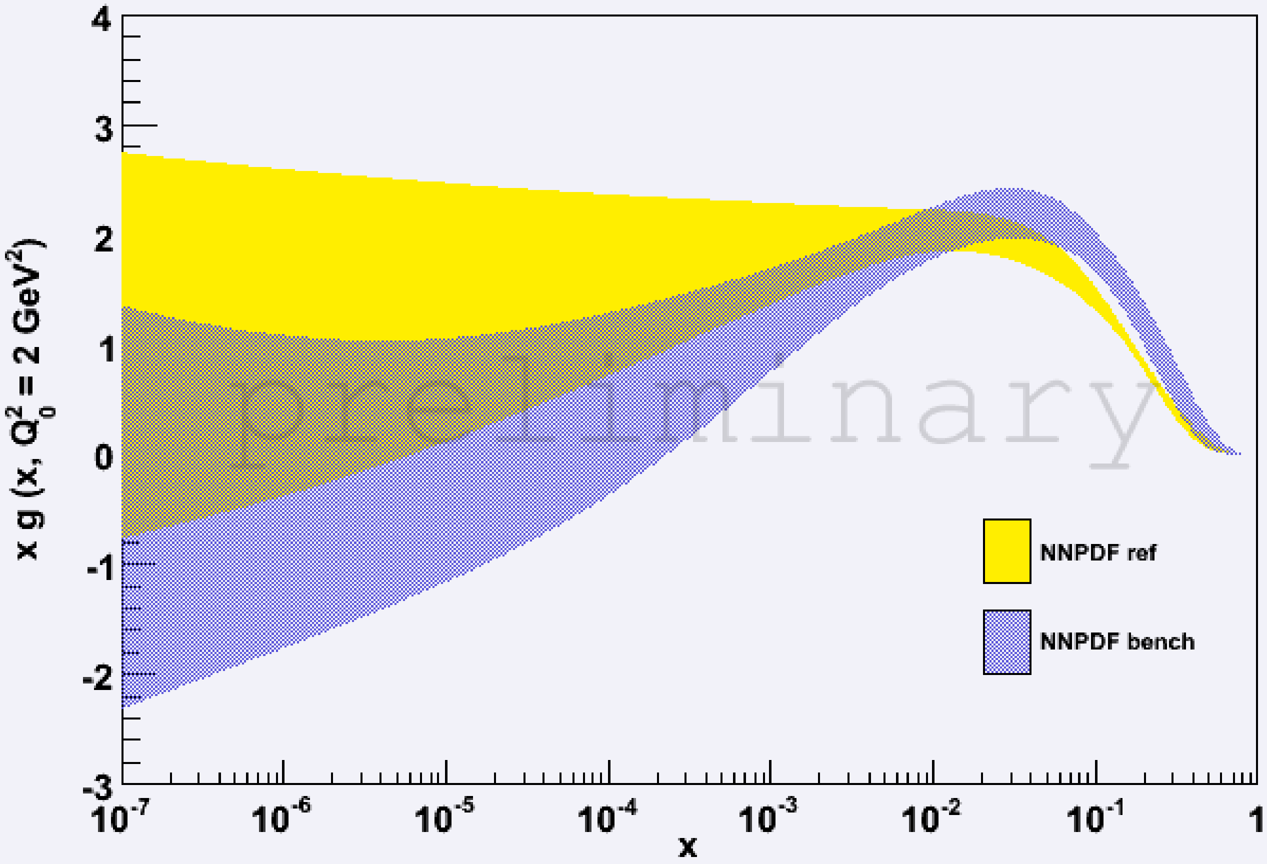


u-valence

A. PICCIONE (NNPDF)

THE NEURAL MC APPROACH

results EXTRAPOLATION ⇒ GROWING UNCERTAINTY



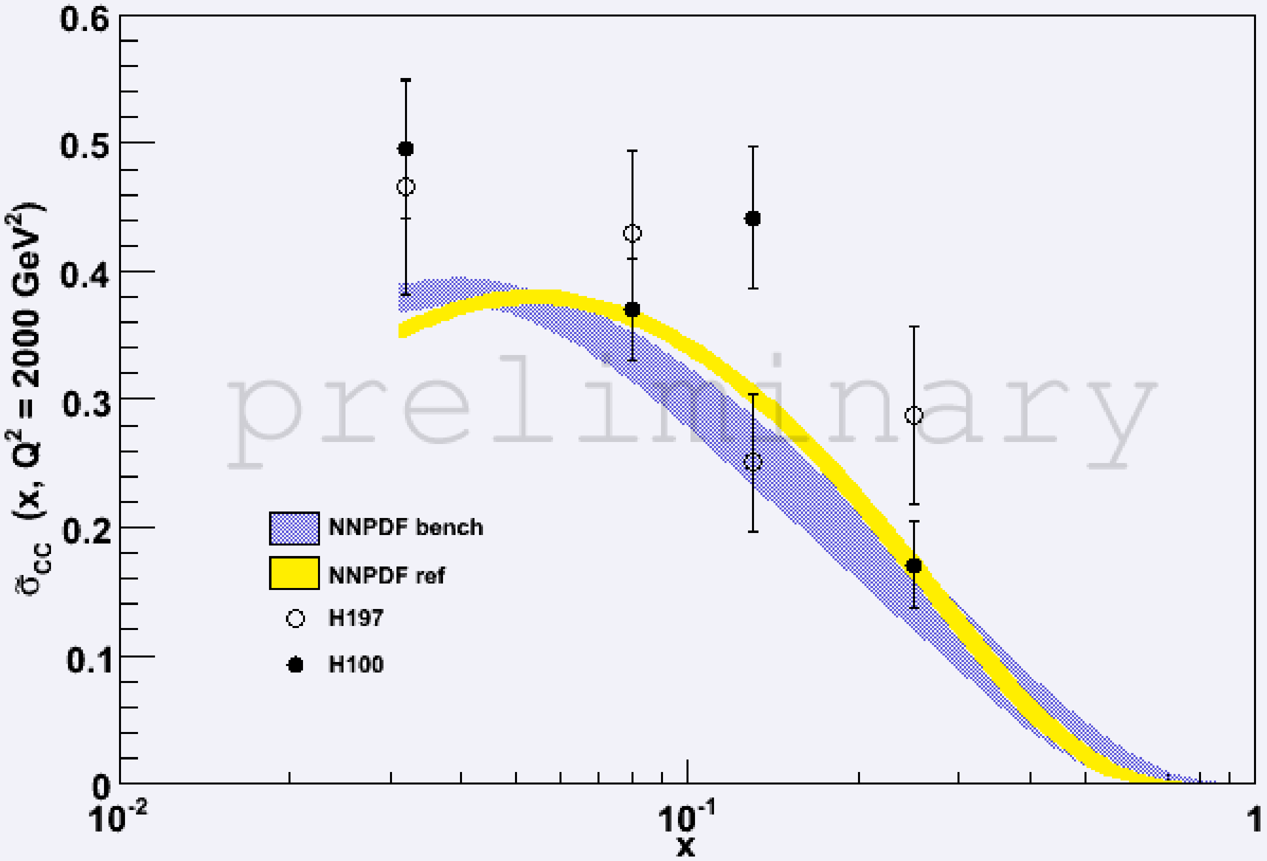
gluon

A. PICCIONE (NNPDF)

THE NEURAL MC APPROACH

INCONSISTENT DATA ⇒ INTERPOLATION

details: C

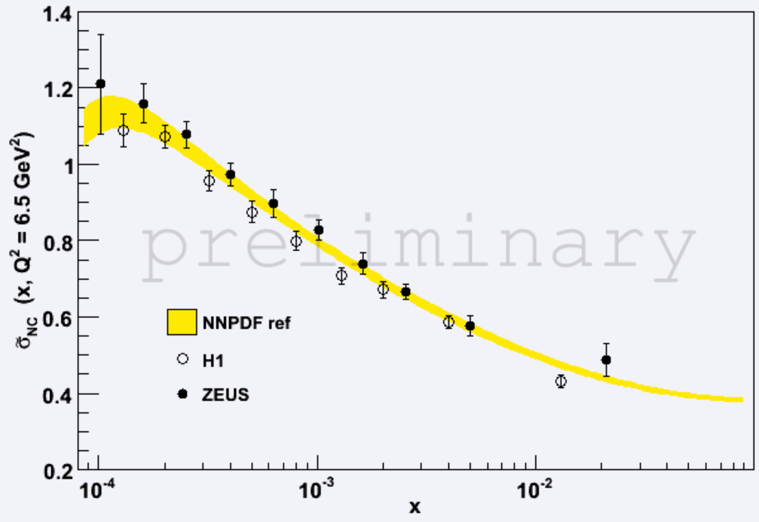


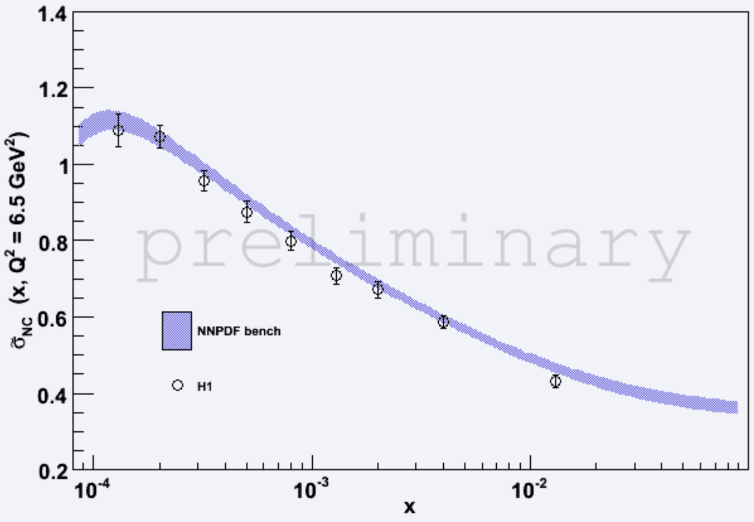
A. PICCIONE (NNPDF)

THE NEURAL MC APPROACH

detail

INCONSISTENT DATA ⇒ NO ERROR REDUCTION





A. PICCIONE (NNPDF)

TOWARDS LHC

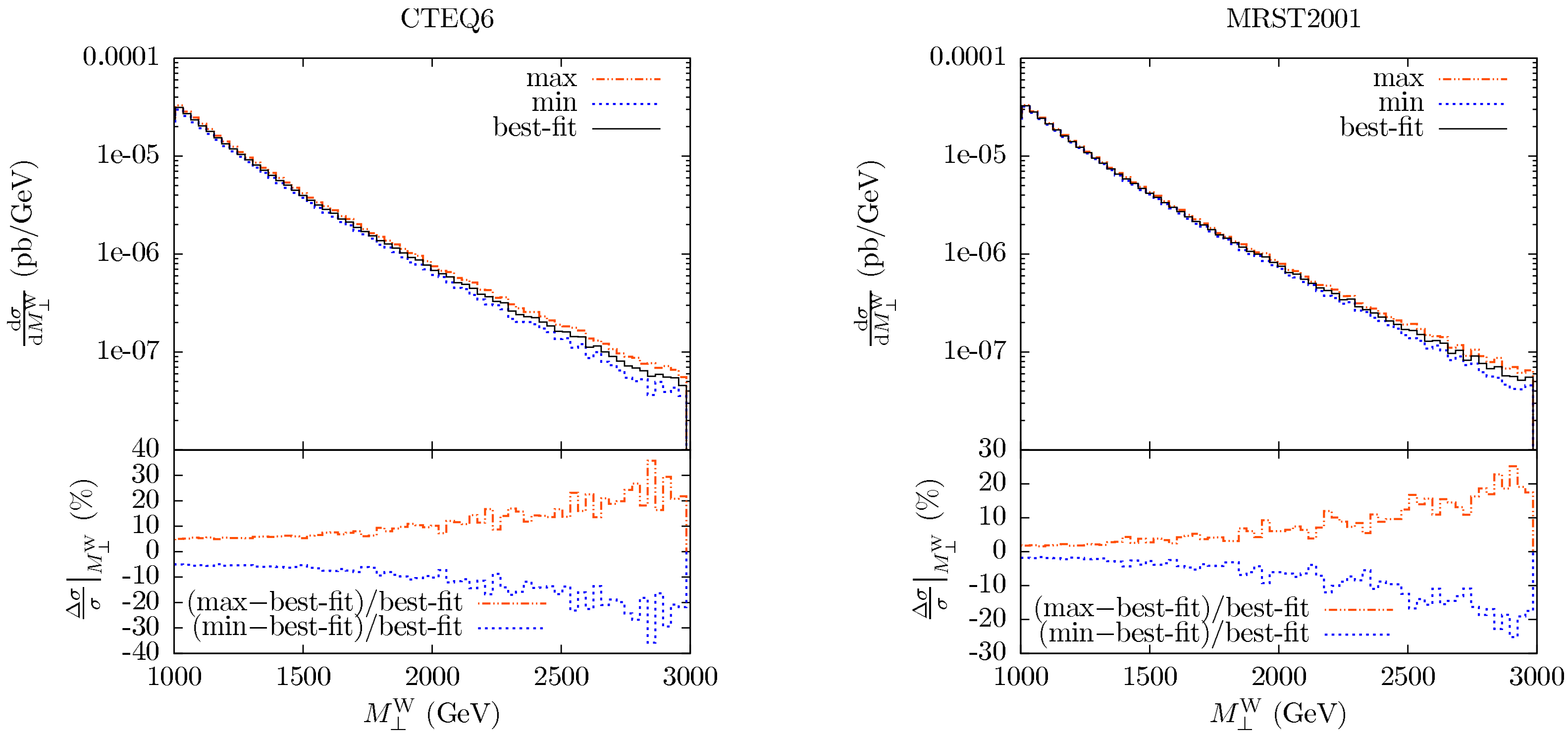
PROCESSES

- Drell-Yan, w and Z production: the standard candle
- Higgs production: a future standard candle?
- top production: unexpected precision

MEASUREMENTS

- using the data to calibrate PDFs
- using standard candles to calibrate experiments

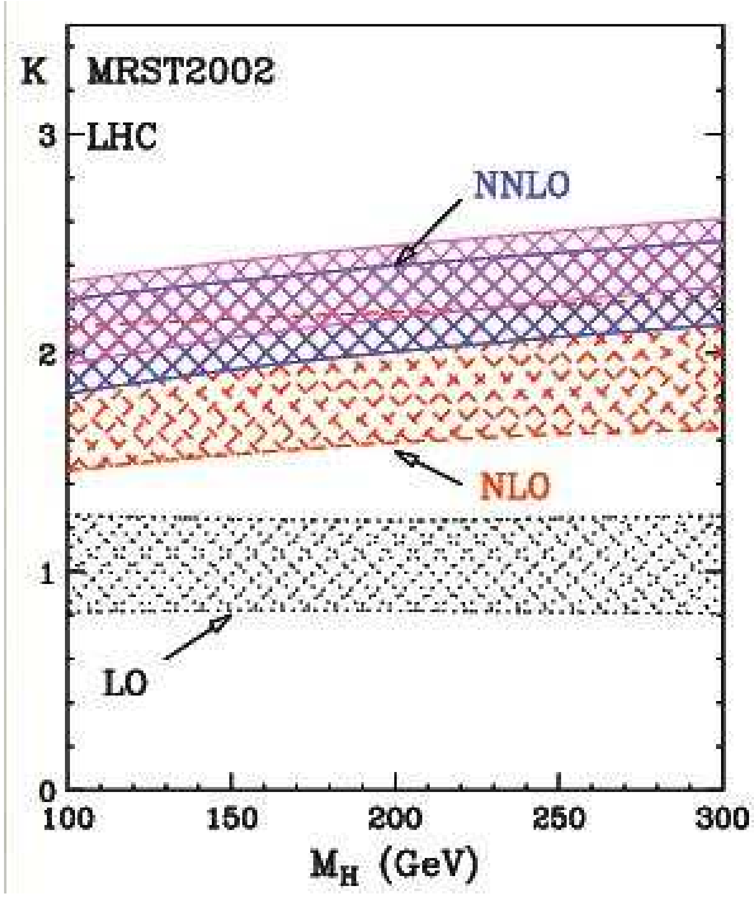
HIGH-MASS DRELL-YAN: PDF DOMINANT UNCERTAINTY



- large uncertainty from the sea at large x

F. PICCININI

Higgs total cross section



[Catani,deFlorian,Grazzini,Nason(2003)]

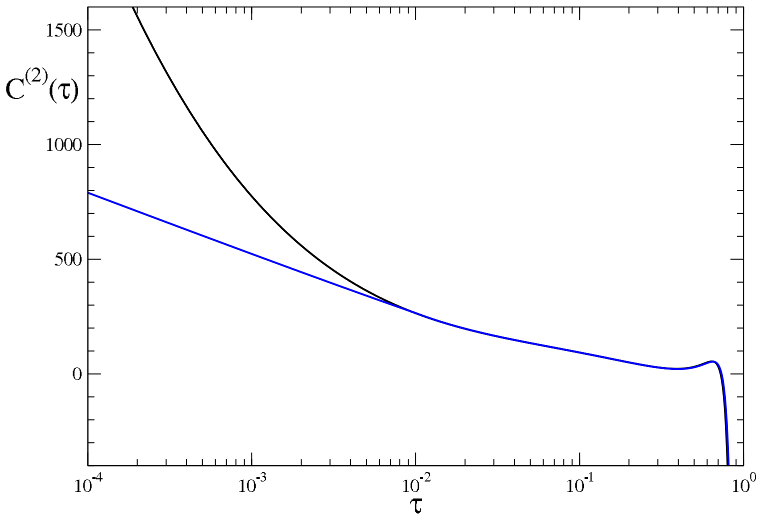
- NNLO: 10-20% increase wrt NLO
- Threshold resummation further improves stability (6% wrt NNLO)
- 10% uncertainty due to scale variation
- 2-loop EW also available: 5-8% effect below WW threshold

[Aglietti,Bonciani,Degrassi,Vicini(2004)]

G. Bozzi

NNLO FINITE MASS CORRECTIONS NEGLIGIBLE

NNLO with $m_H = 130 GeV$ (II)



- Two procedures to determine τ_0: same as NLO or matching the slopes
- The two methods give similar curves
- In both cases the constant is adjusted requiring continuity

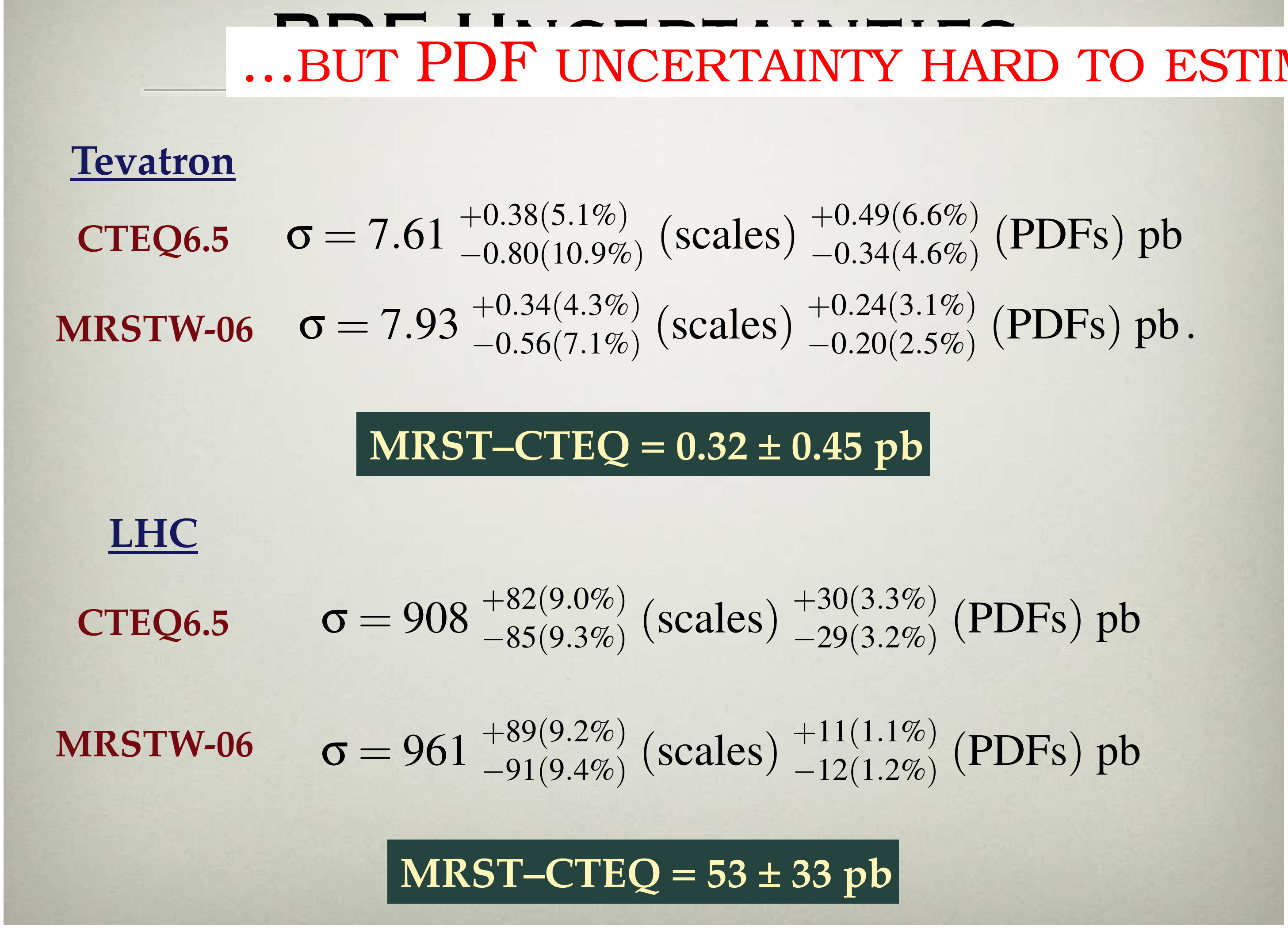
S. MARZANI

$t\bar{t}$ production as a standard candle process

- Measurements of $\sigma_{t\bar{t}}$ with accuracy $\sim 5\%$ may be within reach
- would provide additional constraints on the large-x gluon PDF
- will be useful for monitoring of $\mathcal{L}_{LHC}$ luminosity in the first years and normalization of LHC event rates

See also the talk by M. Csakon; Moch, Uwer, arXiv:0804.1476; Cacciari et al., arXiv:0804.2800; Kidonakis, Vogt, arXiv:0805.3844

…BUT PDF UNCERTAINTY HARD TO ESTIMATE!



Tevatron

CTEQ6.5 $$\sigma = 7.61\ {}^{+0.38(5.1\%)}_{-0.80(10.9\%)}\ (\text{scales})\ {}^{+0.49(6.6\%)}_{-0.34(4.6\%)}\ (\text{PDFs})\ \text{pb}$$

MRSTW-06 $$\sigma = 7.93\ {}^{+0.34(4.3\%)}_{-0.56(7.1\%)}\ (\text{scales})\ {}^{+0.24(3.1\%)}_{-0.20(2.5\%)}\ (\text{PDFs})\ \text{pb}\,.$$

MRST–CTEQ = 0.32 ± 0.45 pb

LHC

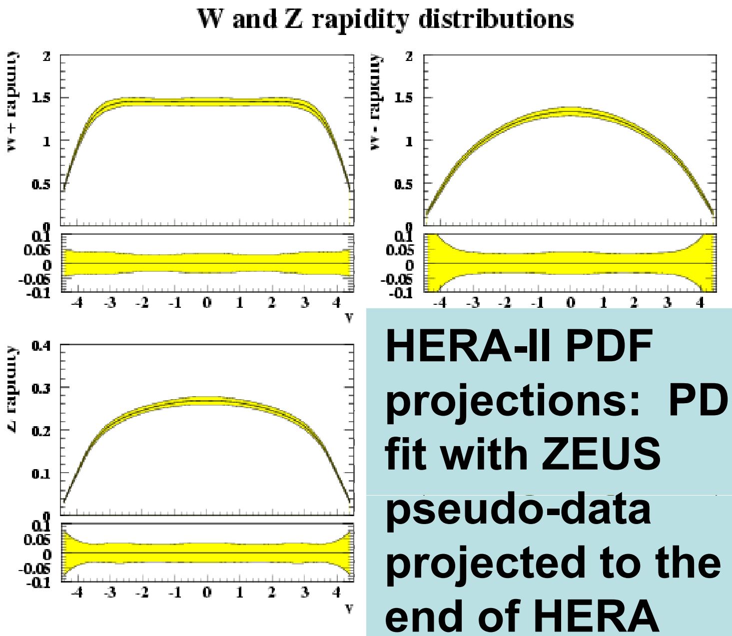
CTEQ6.5 $$\sigma = 908\ {}^{+82(9.0\%)}_{-85(9.3\%)}\ (\text{scales})\ {}^{+30(3.3\%)}_{-29(3.2\%)}\ (\text{PDFs})\ \text{pb}$$

MRSTW-06 $$\sigma = 961\ {}^{+89(9.2\%)}_{-91(9.4\%)}\ (\text{scales})\ {}^{+11(1.1\%)}_{-12(1.2\%)}\ (\text{PDFs})\ \text{pb}$$

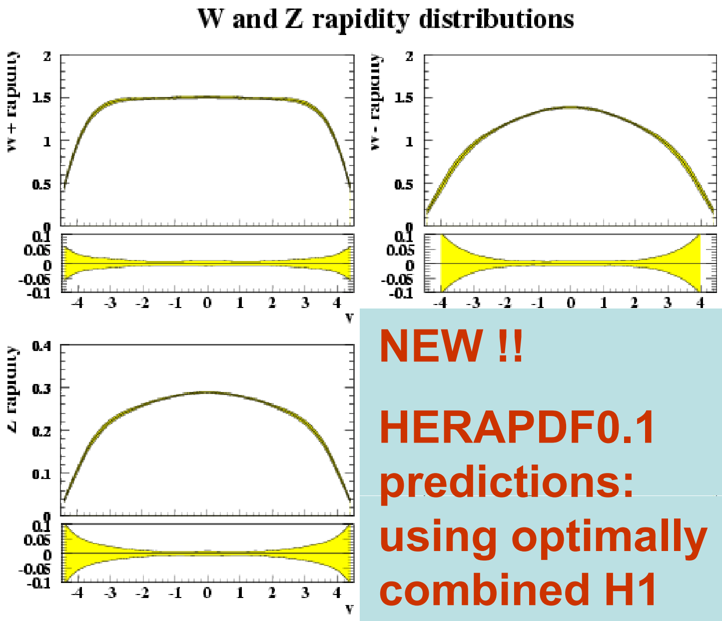
MRST–CTEQ = 53 ± 33 pb

M. MANGANO

W PRODUCTION: EXPLOIT THE EXPERIMENTAL ACCURACY



HERA-II PDF projections: PDF fit with ZEUS pseudo-data projected to the end of HERA



NEW !!

HERAPDF0.1 predictions: using optimally combined H1 and ZEUS data

For previous HERALHC workshops we even made a projections of how good it could get with final HERA-II data.

But we were pessimistic

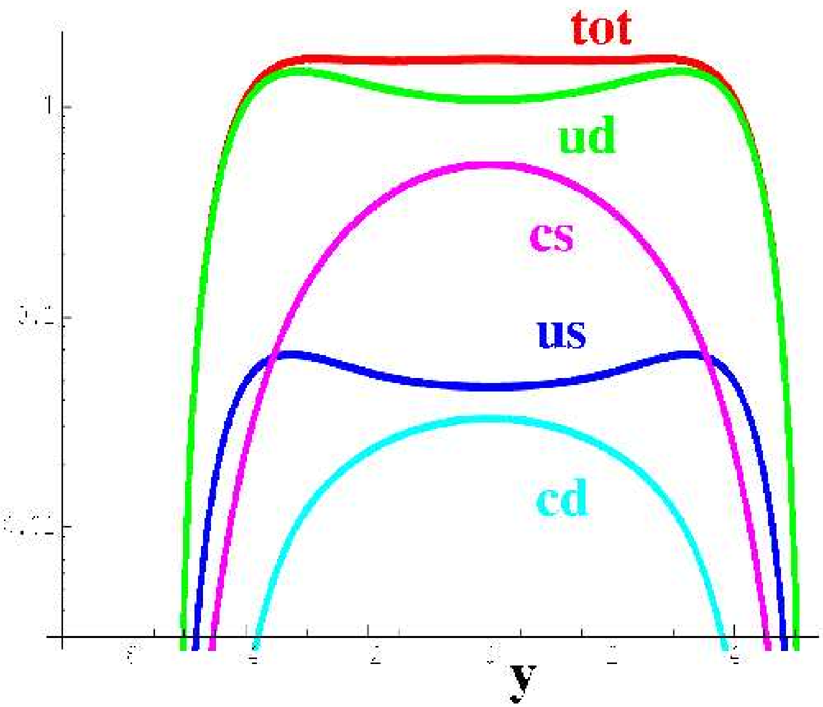
We were not expecting the improvement in systematic error that the 2008 H1/ZEUS combination has made.

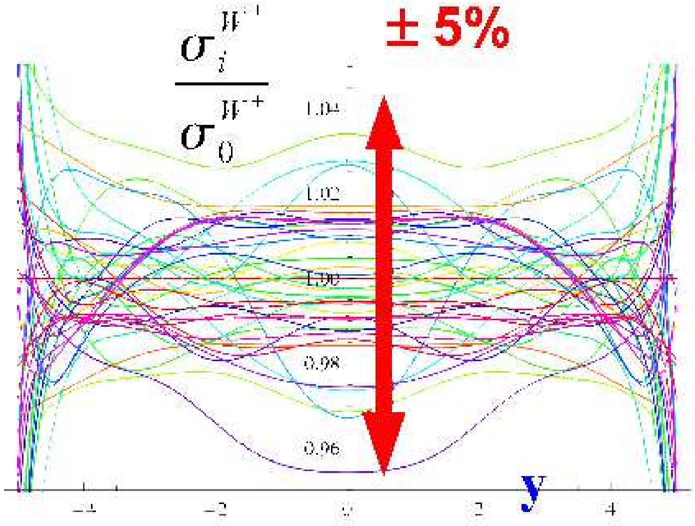
The new predictions are very precise ~1.5% error in the central region

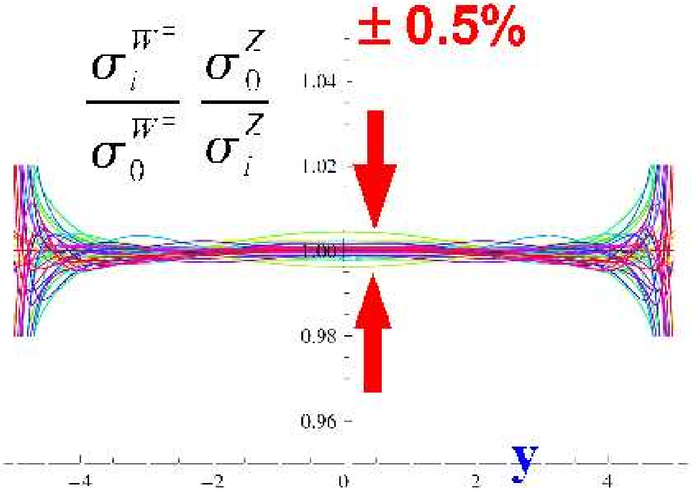
A. COOPER-SARKAR

USE DATA TO CALIBRATE THEORY

dσ/dy(W^+) at LHC

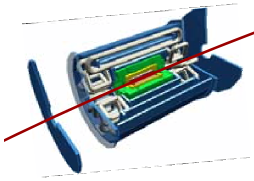






F. OLNESS

A MORE SOPHISTICATED EXAMPLE…



High-mass Drell-Yan

- ☐ Current LHC uncertainty : ~6-7% for 100 GeV < M < 1 TeV and y~0
- ☐ → Gain a factor ~5. To do this, relate:
  - $\sigma(m,y=0) \sim f^2(x,m)$ (at m [low-mass], **measure**)
  - $\sigma(m_Z,y\neq0) \sim f(X,m_Z) \times f(x,m_Z)$ (at M_Z, **measure**)
  - $\sigma(M,y=0) \sim f^2(X,M)$ (at M [high-mass], **predict**)
- ☐ Specifically, write:

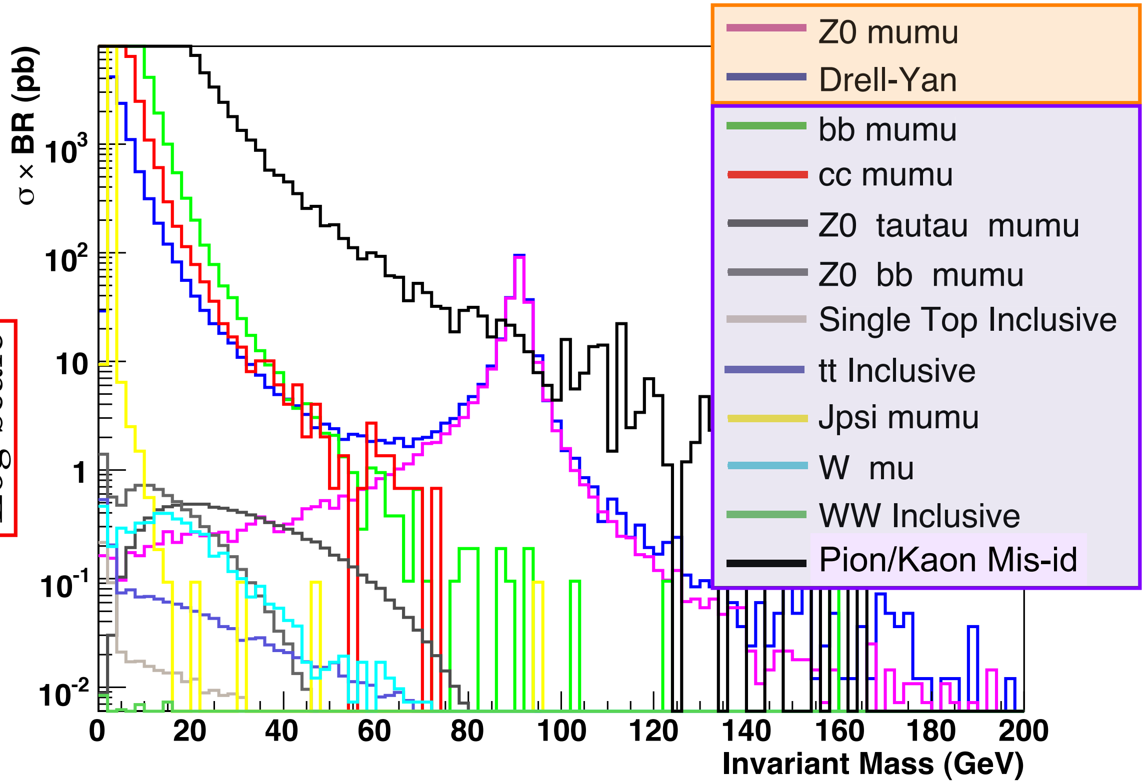
$$\underbrace{\sigma(M,y=0)}_{\text{Raw prediction}} \rightarrow \underbrace{\frac{\sigma(M,y=0)\times\sigma(m,y=0)}{\sigma^2(M_Z,y\neq0)}}_{\text{Smaller PDF dependence?}} \times \underbrace{\frac{\sigma^2(M_Z,y\neq0)}{\sigma(m,y=0)}}_{\text{Measured}}$$

chosing m, M and y such that $m = M_Z\, e^{-y}$; $M = M_Z\, e^{+y}$

- ☐ Work by Maarten Boonekamp and Florent chevallier, in preparation.

Z AS A LUMINOSITY MONITOR:

Raw mass distributions (signal & background)



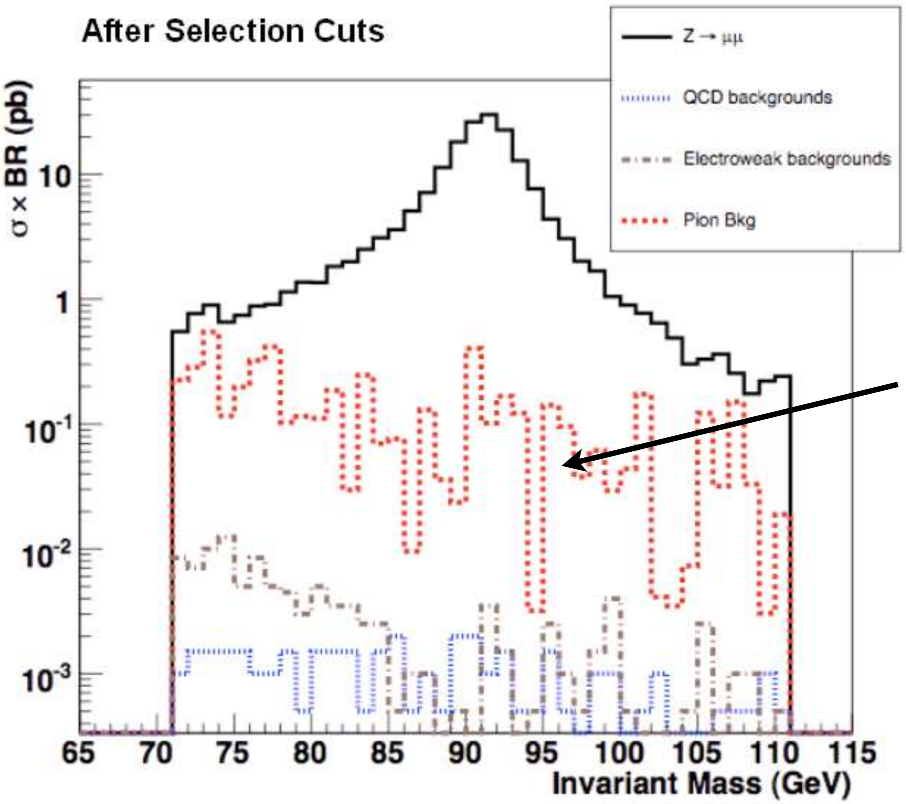
Log scale

J. ANDERSON (LHCB)

Z AS A LUMINOSITY MONITOR: A CLEAN SIGNAL

Mass after selection cuts

71GeV < $M_{\mu\mu}$< 111GeV



Efficiency = 91%

Purity = (97 ± 3)%

Bkg dominated by hadron mis-id

Determine with data or eliminate using cone cuts

~180 events per pb^{-1}

5% luminosity measurement in 2008!

J. ANDERSON (LHCB)

WITH SMALL UNCERTAINTIES

Summary:

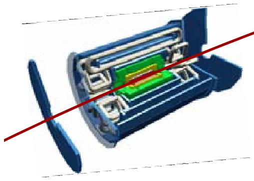
	Invariant Mass (GeV/c^2)	Pseudorapidity	Transverse Momentum (GeV/c)
Cut 1	$M_{\ell\ell} > 40$	$\|\eta_\ell\| < 2.0$	$p_T^\ell > 20$

Total Theoretical Uncertainty (%)

Uncertainty	Cross-section $\Delta\sigma$	Acceptance ΔA
Missing $O(\alpha)$ EWK	0.38 ± 0.26	0.96 ± 0.21
Total QCD Uncertainty	1.51 ± 0.75	2.55 ± 0.79
PDF Uncertainty	3.79	1.32
Total Uncertainty	4.1 ± 0.3	3.0 ± 0.7

Total theoretical uncertainty on the Z production cross-section σ, and acceptances A.

OR NOT?

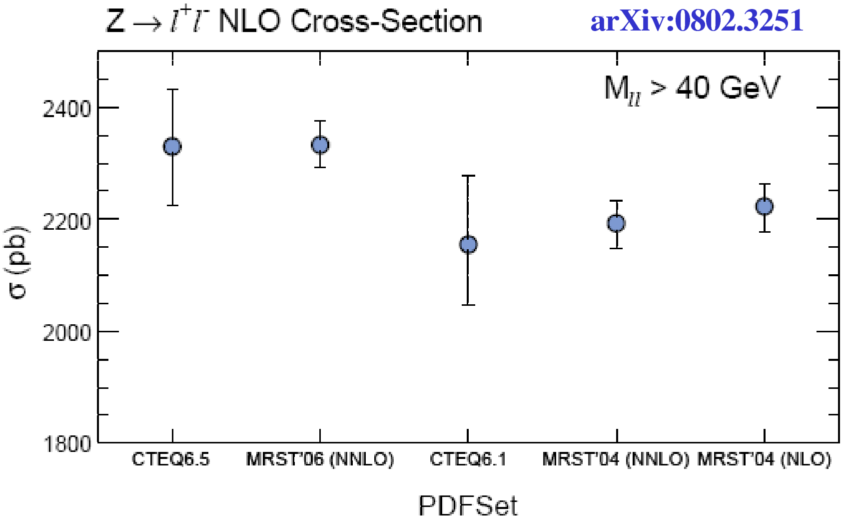


Summary, so far

- ☐ Z total cross-section:
  - ☐ dL/L ~ 10% → <3%
  - ☐ dε/ε ~ 3% → <1%
  - ☐ dA/A ~ 3% irreducible at this stage
- ☐ Acceptance uncertainties will play a dominant role, especially when measuring cross-section ratios where L cancels.
- ☐ Z as luminosity monitor?

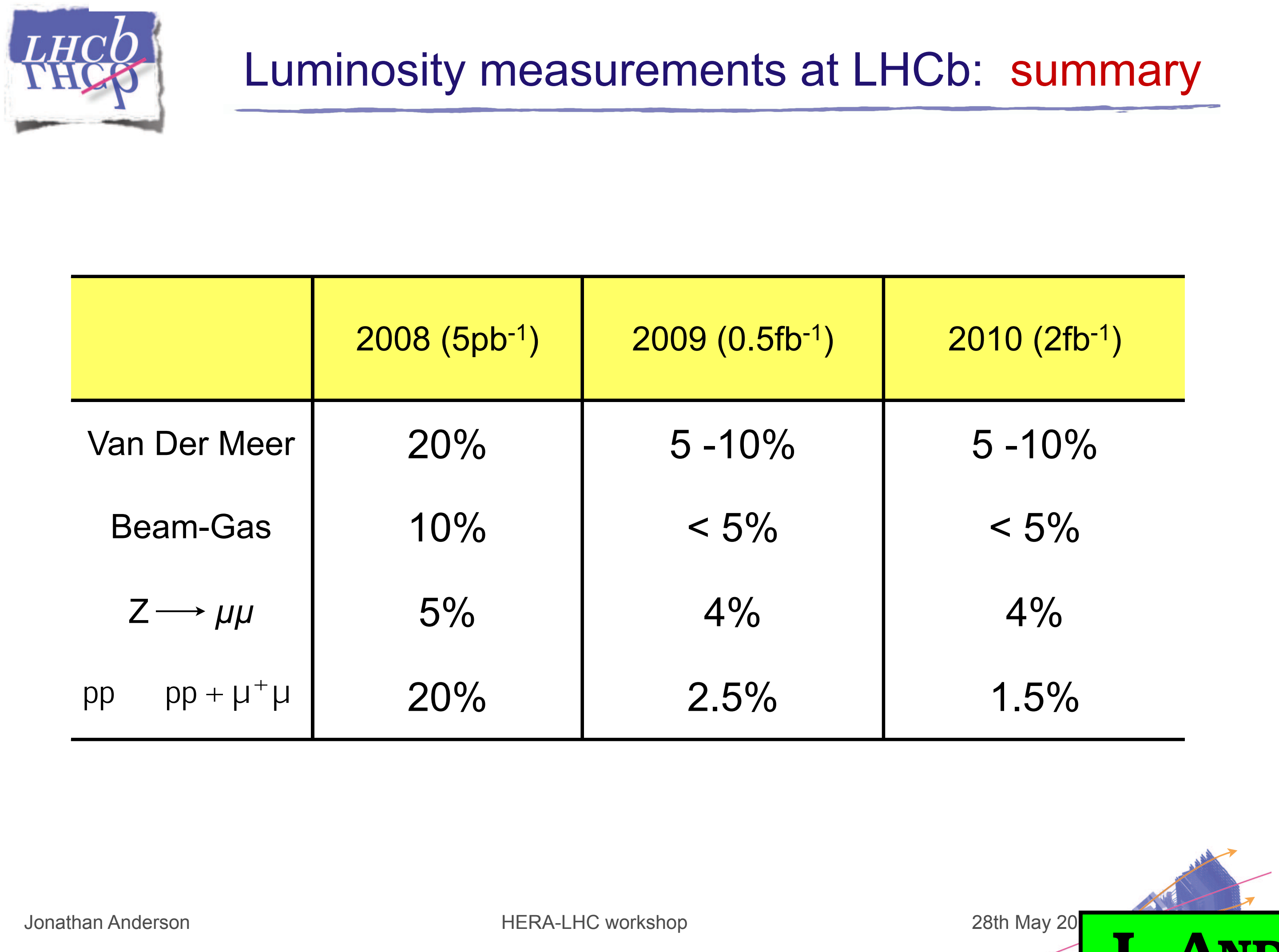
  Account for overall normalization uncertainty ~5% :

  This is, at best, a temporary hack.



T. PETERSEN (ATLAS)

LUMINOSITY MEASUREMENTS: A COMPARISON



Luminosity measurements at LHCb: summary

	2008 ($5pb^{-1}$)	2009 ($0.5fb^{-1}$)	2010 ($2fb^{-1}$)
Van Der Meer	20%	5 -10%	5 -10%
Beam-Gas	10%	< 5%	< 5%
$Z \longrightarrow \mu\mu$	5%	4%	4%
pp pp + $\mu^+\mu$	20%	2.5%	1.5%

Jonathan Anderson HERA-LHC workshop 28th May 20

J. ANDERSON (LHCB)

ATLAS/CMS: QUALITATIVELY SIMILAR CONCLUSIONS

BUT AFTER 1ST YEAR, DIRECT MEASUREMENT: TOTEM (3%), ALFA (5%)

CONCLUSION

IF ALL THIS LOOKED LIKE A LOT OF INFORMATION…

…wait and see until the LHC turns on!