PDFs in the LHC Era
… a new perspective

Fred Olness

SMU

… for the nCTEQ group

K Kovarik, I. Schienbein, J.Y. Yu,
T. Stavreva, T Jezo, C. Keppel,
A. Kusina J.G. Morfin, F. Olness,
J.F. Owens.

QCD @ LHC

22 August 2012

LHC results

We now have a wealth of new data
in an entirely new energy regime

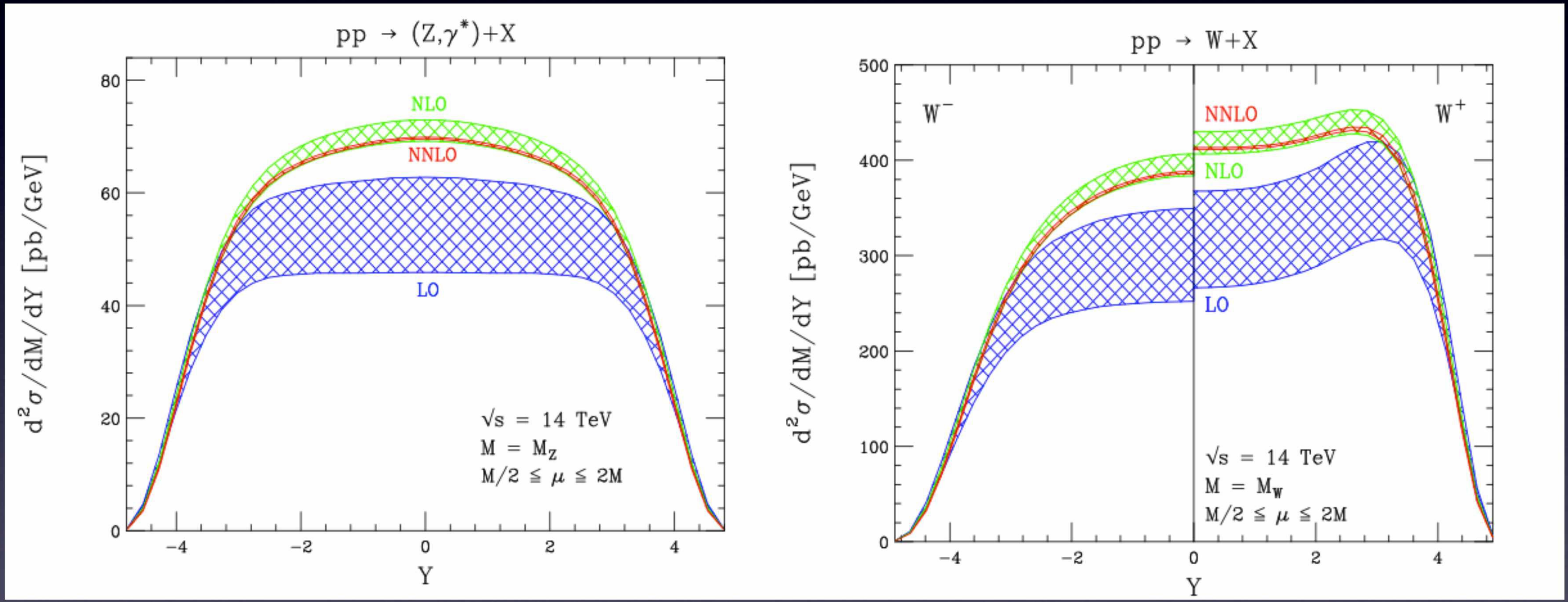
Combine these new measurements
with existing results to expand the foundation we use
to calibrate the search for “new physics”

I will look at some select examples

W/Z Production

“Benchmark Calculations”

Rapidity distributions

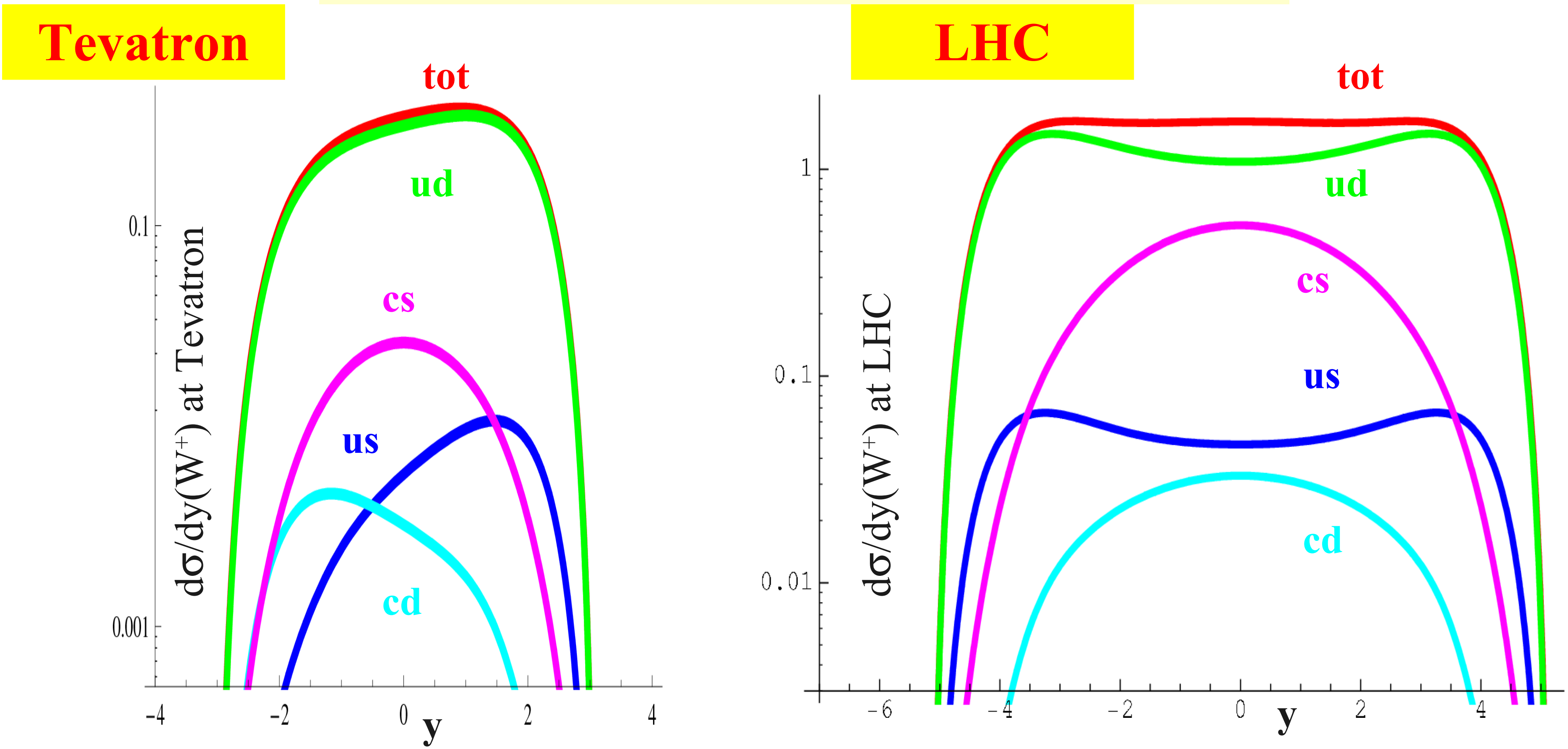


Anastasiou, Dixon, Melnikov, Petriello ’03, ’05; Melnikov, Petriello ’06

☛ *LHC: perturbative accuracy of the order of 1%. This is absolutely unique.*

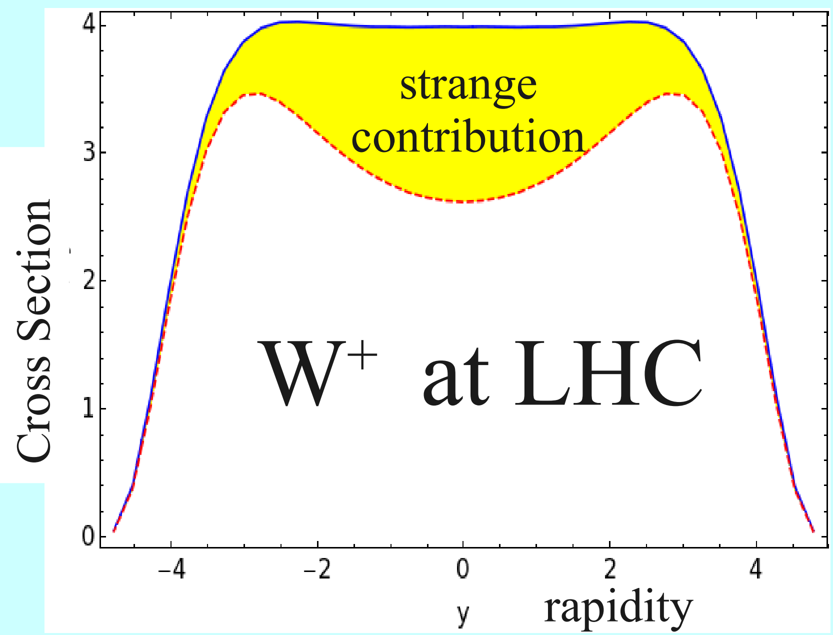
W Production at LHC: A Benchmark Cross Section

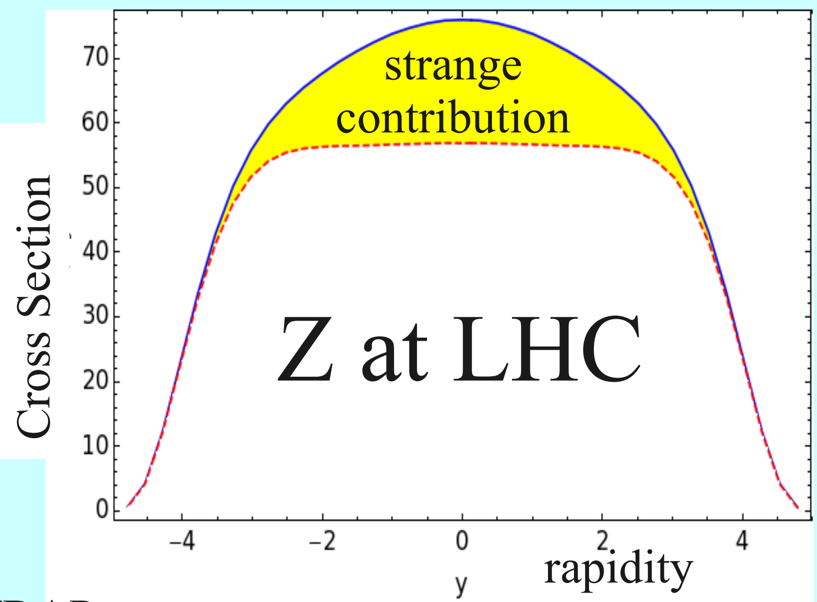
Heavy quark PDFs are essential ingredient



Heavy Quark components play an increasingly important role at the LHC

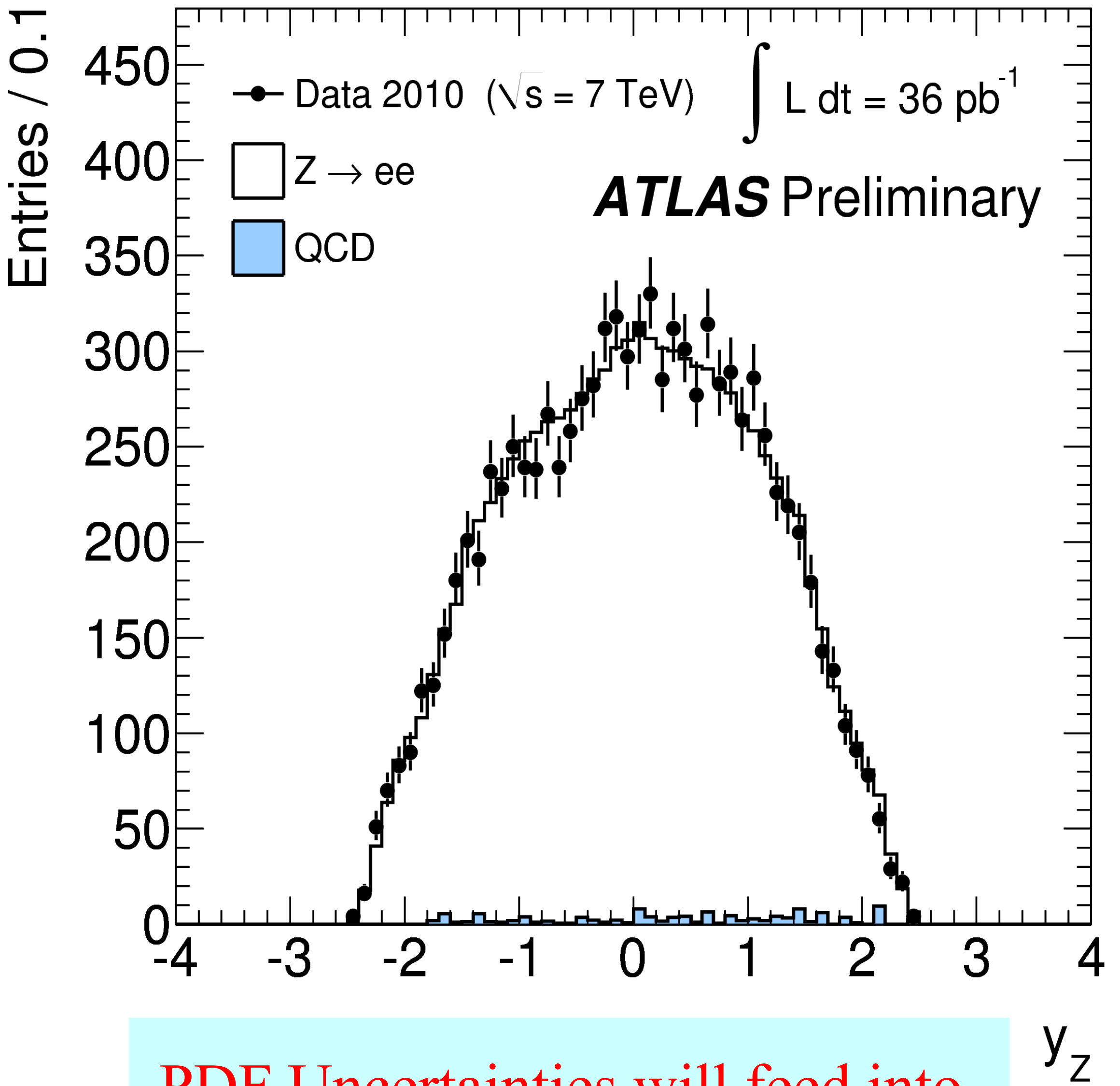
PDF Uncertainties ⇒ S(x) PDF ⇒ W/Z at LHC





VRAP Code

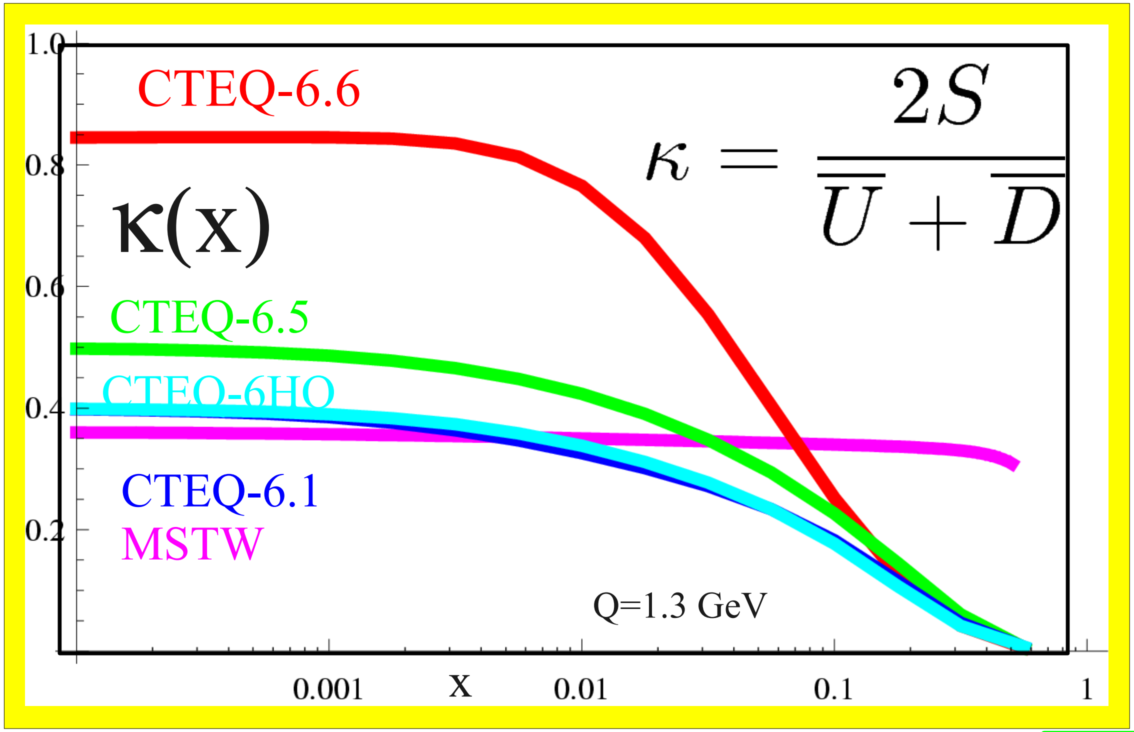
Anastasiou, Dixon, Melnikov, Petriello, Phys.Rev.D69:094008,2004.



PDF Uncertainties will feed into LHC "Benchmark" processes

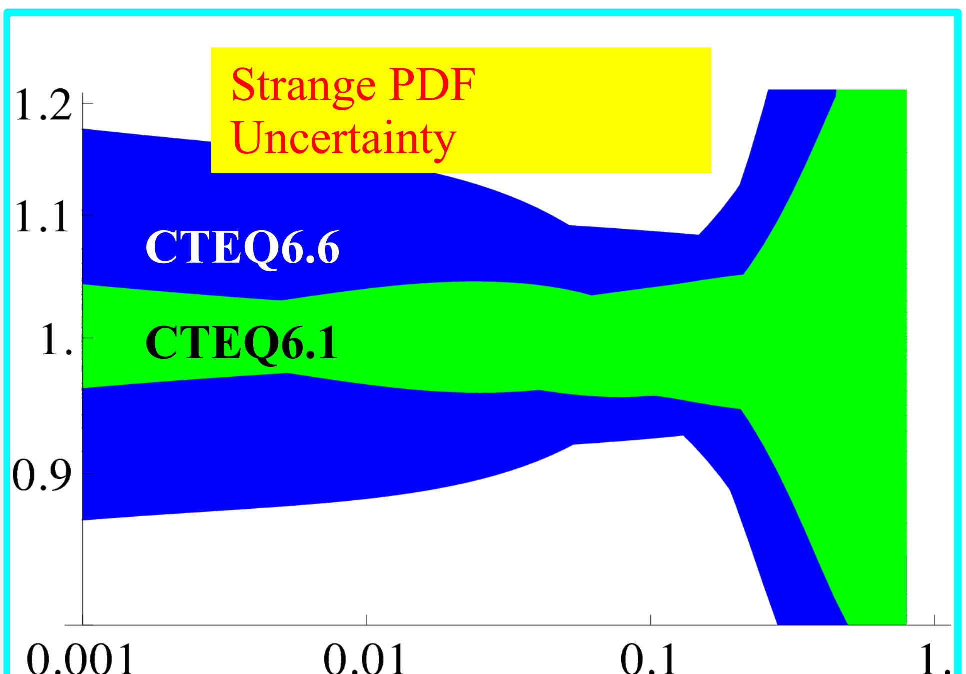
Comparison with new NNPDF sets: Les Houches 2009

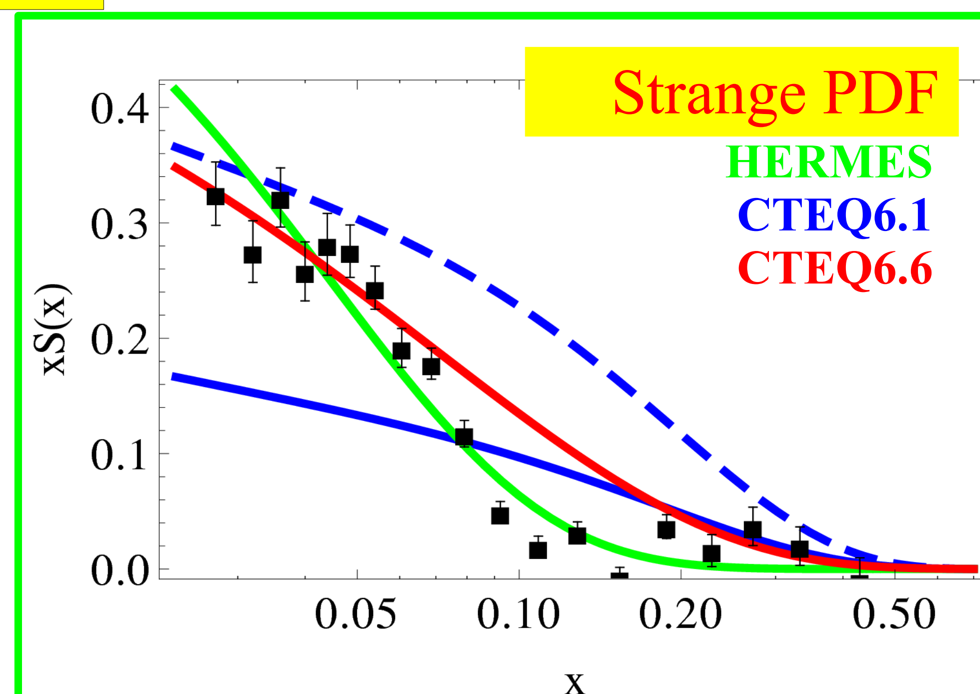
How well do we know the Strange PDF???



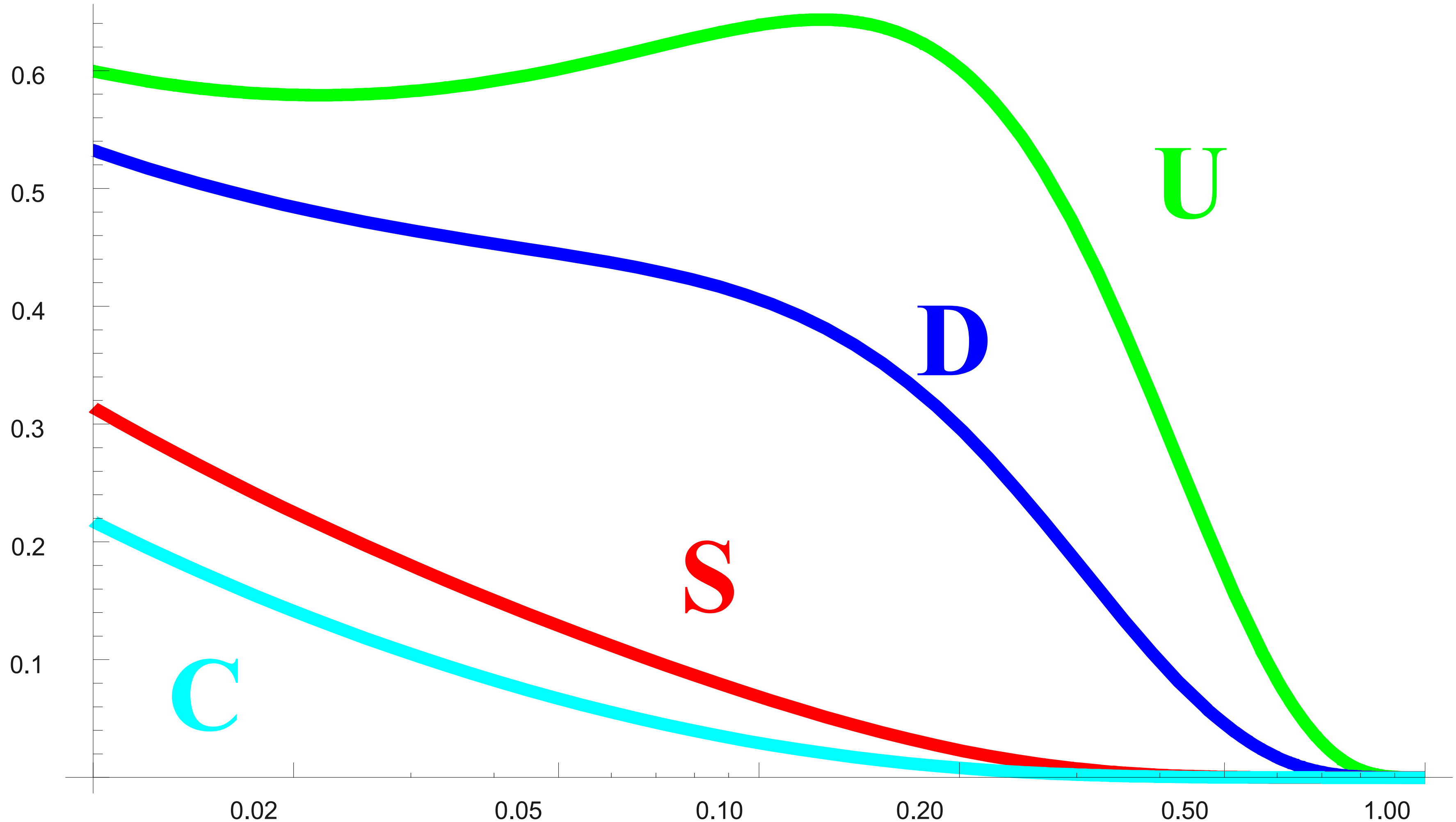
Not so well

... even after 20 years of PDFs

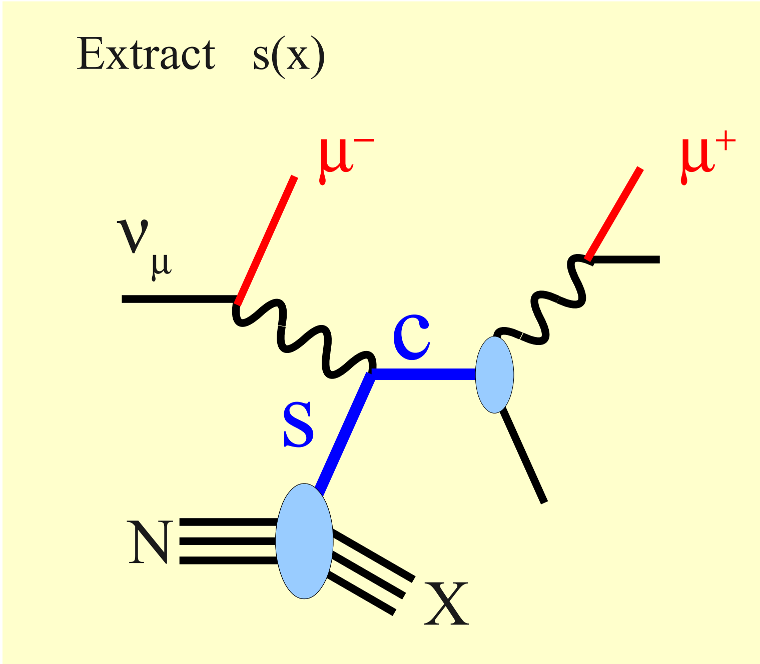


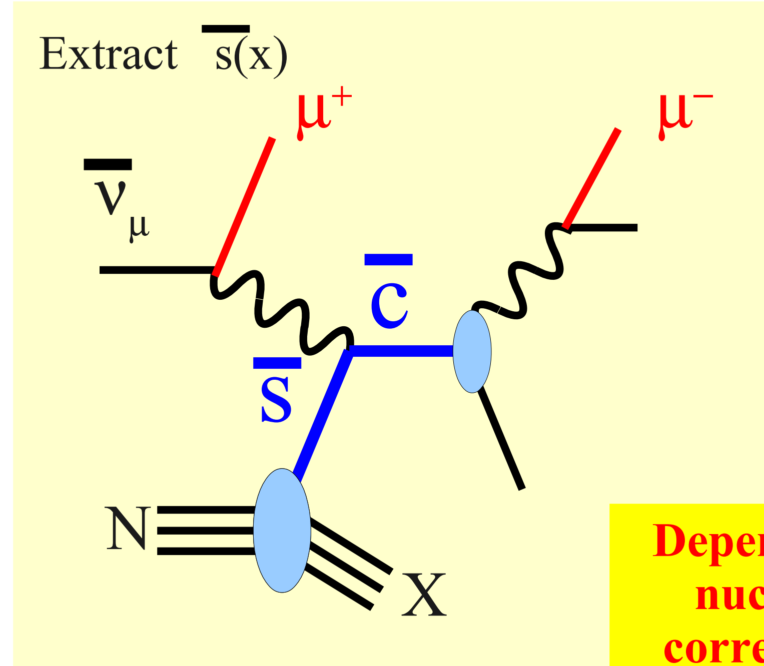


What constrains the Strange???



Di-muon production ⇒ Extract s(x) Parton Distribution



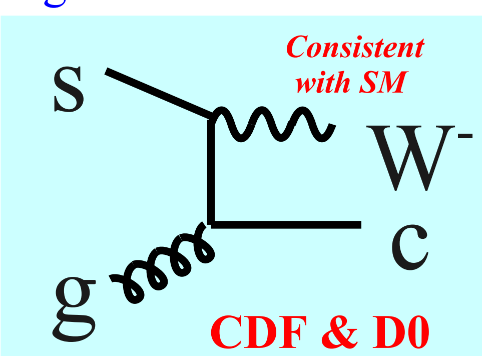


Depends on nuclear corrections

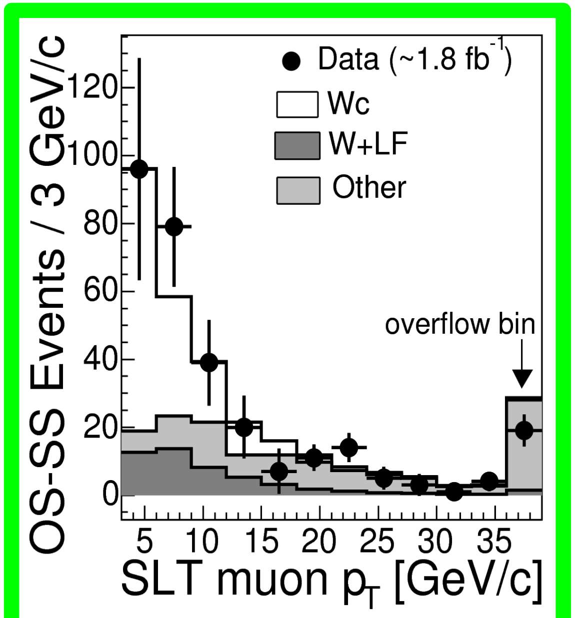
s(x) and $\bar{s}(x)$ are essential in extraction of $\sin\theta_W$

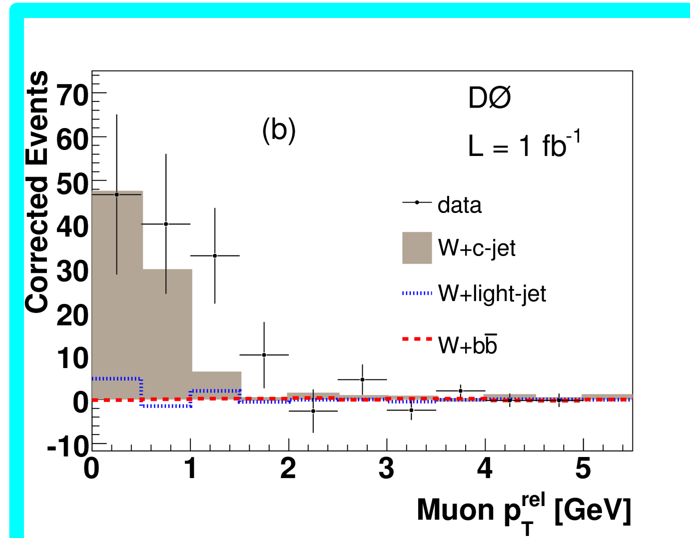
Used in CTEQ6 Fits

s g→Wc at the Tevatron



CDF: PRL 100:091803,2008.
D0: PLB666:23,2008.



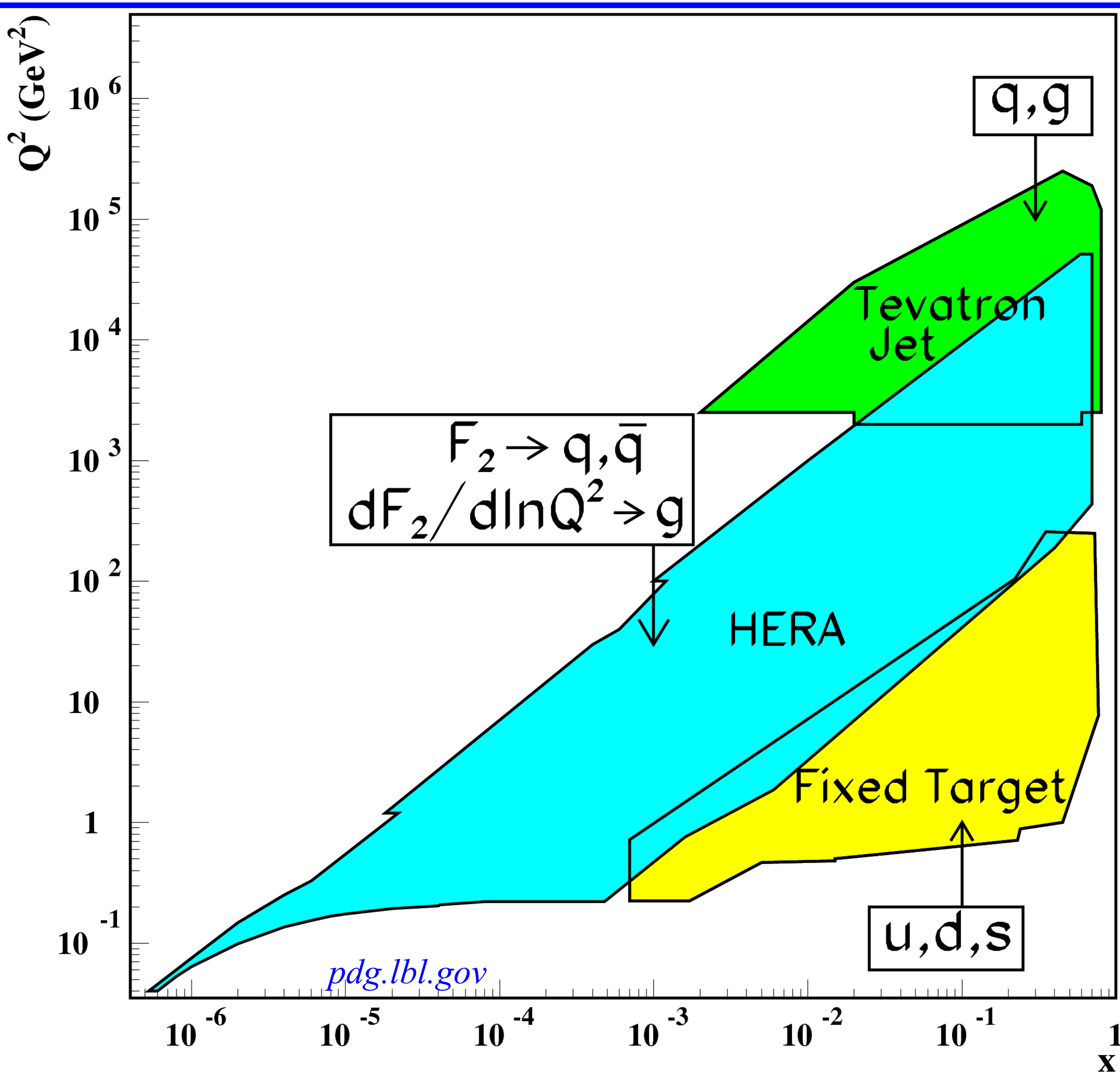


Also a challenge at LHC

Nuclear Corrections

???

Global PDF analyses combine Hadron-Hadron w/ other sets



Fixed Target:
DIS charged lepton
DIS neutrino
DY
Direct Photon

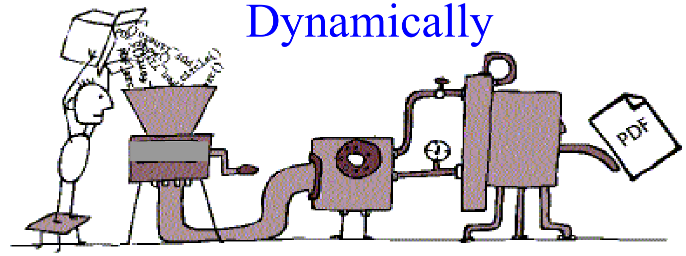
HERA (ep)

Tevatron:
Jets
W Asymmetry

LHC DATA
just now being included

Traditional Input to Global PDF Fit

Include Nuclear Dimension Dynamically



Start with Neutrino data on heavy targets (Fe, Pb, ...)

Nuclear Correction

"Corrected" data for isoscalar

Isospin Symmetry

"Corrected" data for proton

Nuclear Correction "Frozen"

Global PDF Fit

No Feedback!!!

Nuclear CTEQ parton distribution functions - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://projects.hepforge.org/ncteq/

The CTEQ Meta-Page | Nuclear CTEQ parton distri...

nCTEQ Go!

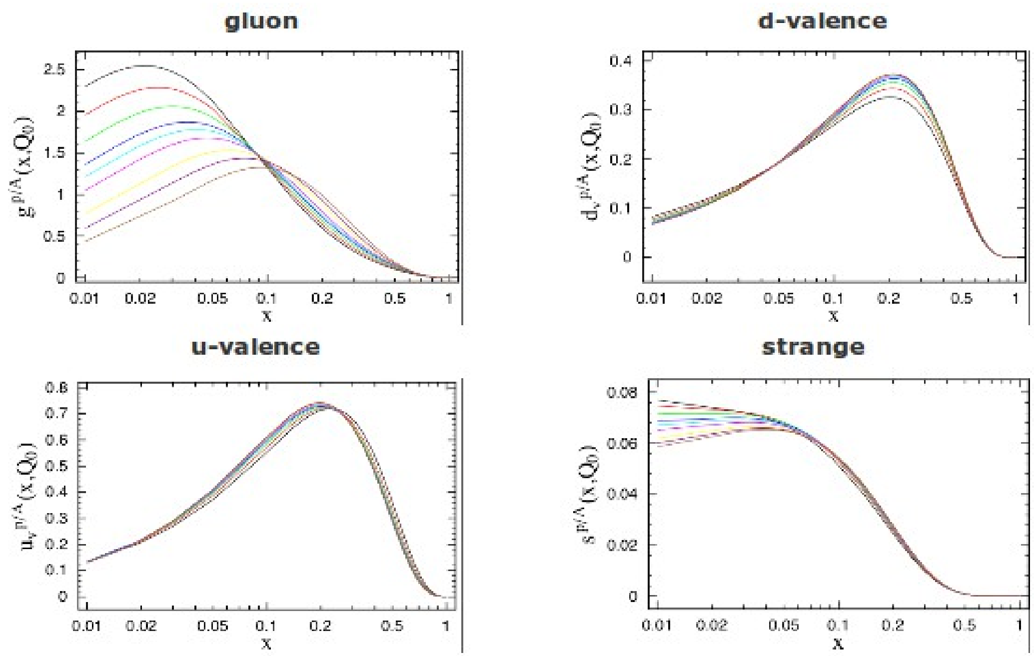
hosted by **CEDAR HepForge**

nCTEQ

nuclear parton distribution functions

- Home
- PDF grids & code
- Papers & Talks
- Subversion
- Tracker
- Wiki

nCTEQ project is an extension of the CTEQ collaborative effort to determine parton distribution functions inside of a free proton. It generalizes the free-proton PDF framework to determine densities of partons in bound protons (hence nCTEQ which stands for nuclear CTEQ). More details on the framework and the first results can be found in arXiv:09072357 [hep-ph].
The effects of the nuclear environement on the parton densities can be shown as modified parton densities



where all black curves stand for free proton PDF and red, green, blue, cyan, pink, yellow, magenta and brown curves show PDF in protons bound in nuclei - from deuterium (red) to lead (brown).

K Kovarik,
I. Schienbein,
J.Y. Yu,
T. Stavreva,
T Jezo,
C. Keppel,
J.G. Morfin,
F. Olness,
J.F. Owens.

Done

nCTEQ Nuclear PDF's

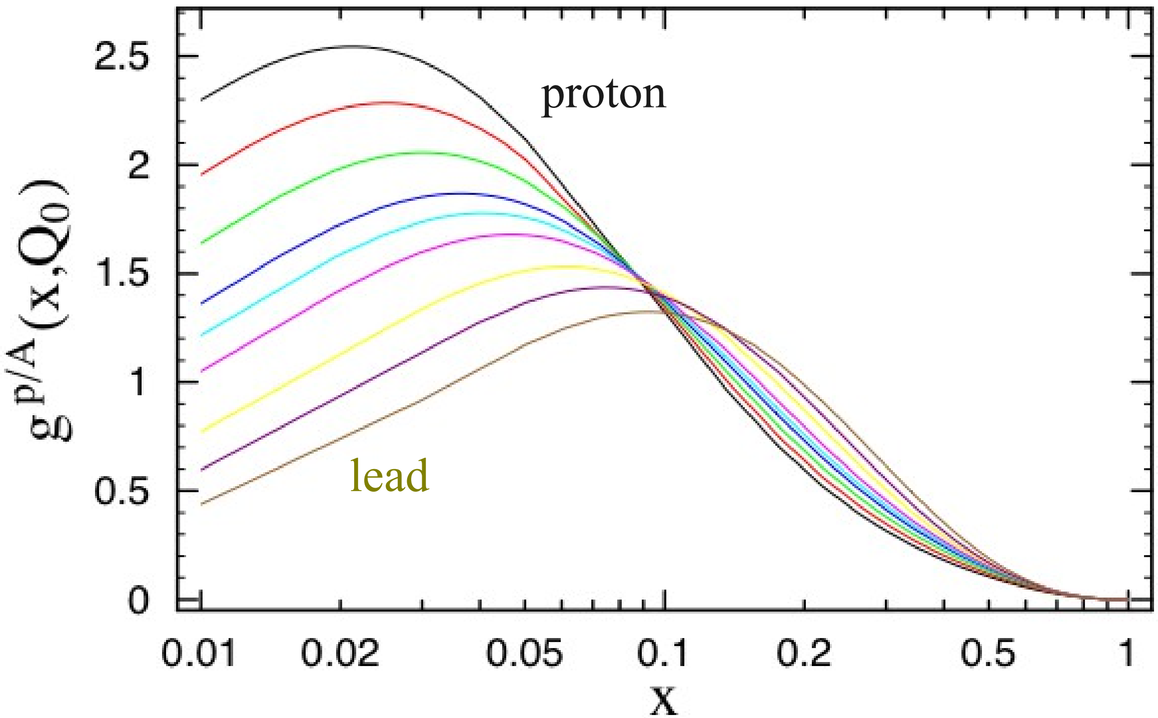
- ✔ CTEQ style global fit extended
  handle various nuclear targets
- ✔ CTEQ Data + nuclear DIS & DY
  [~15 targets; ~2000+ data]
- ✔ A-dependence modeled;
  NLO fits work well

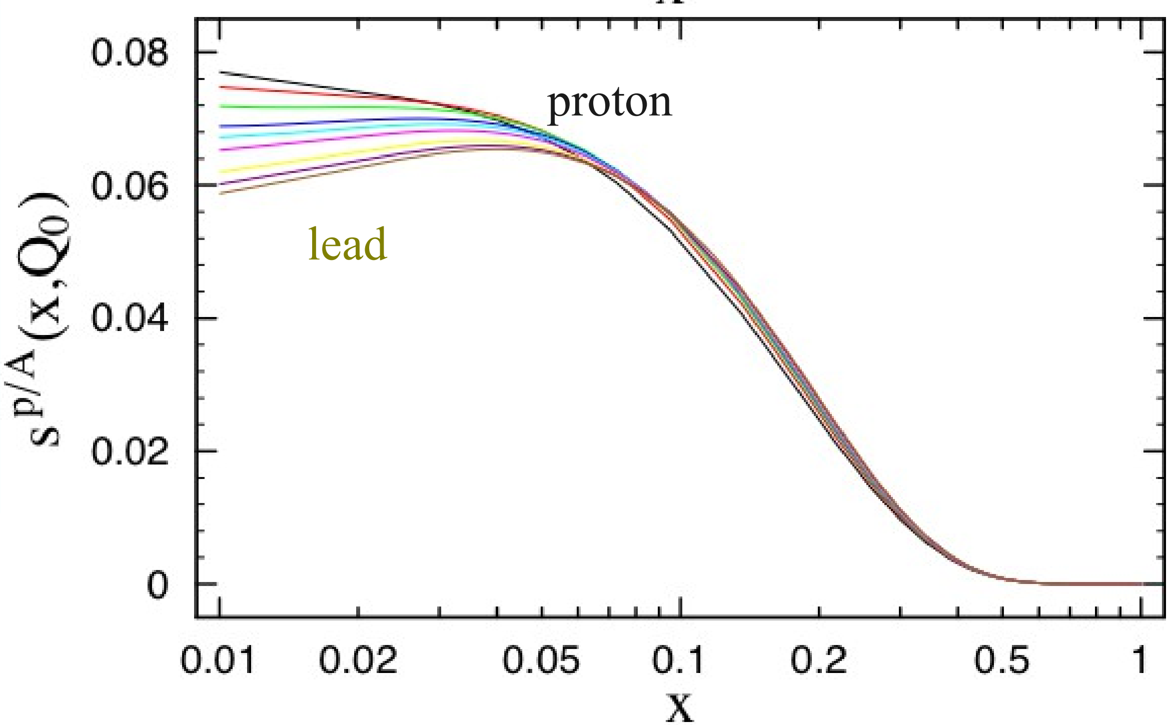
A-Dependent PDFs

$$xf(x) = x^{a_1}(1-x)^{a_2} e^{a_3 x}(1+e^{a_4}x)^{a_5}$$

$$a_i \to a_i(A)$$

$$a_k = a_{k,0} + a_{k,1}\left(1 - A^{-a_{k,2}}\right)$$



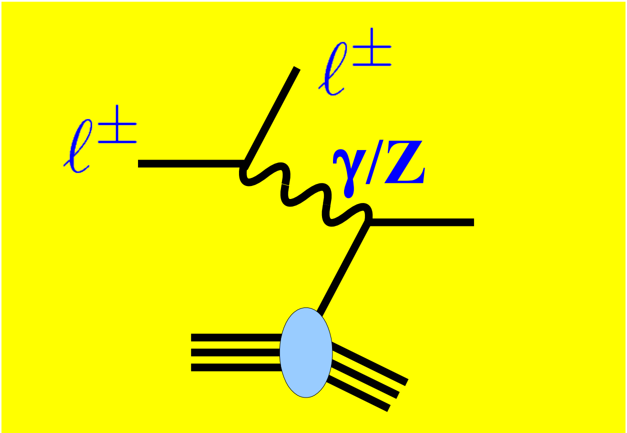


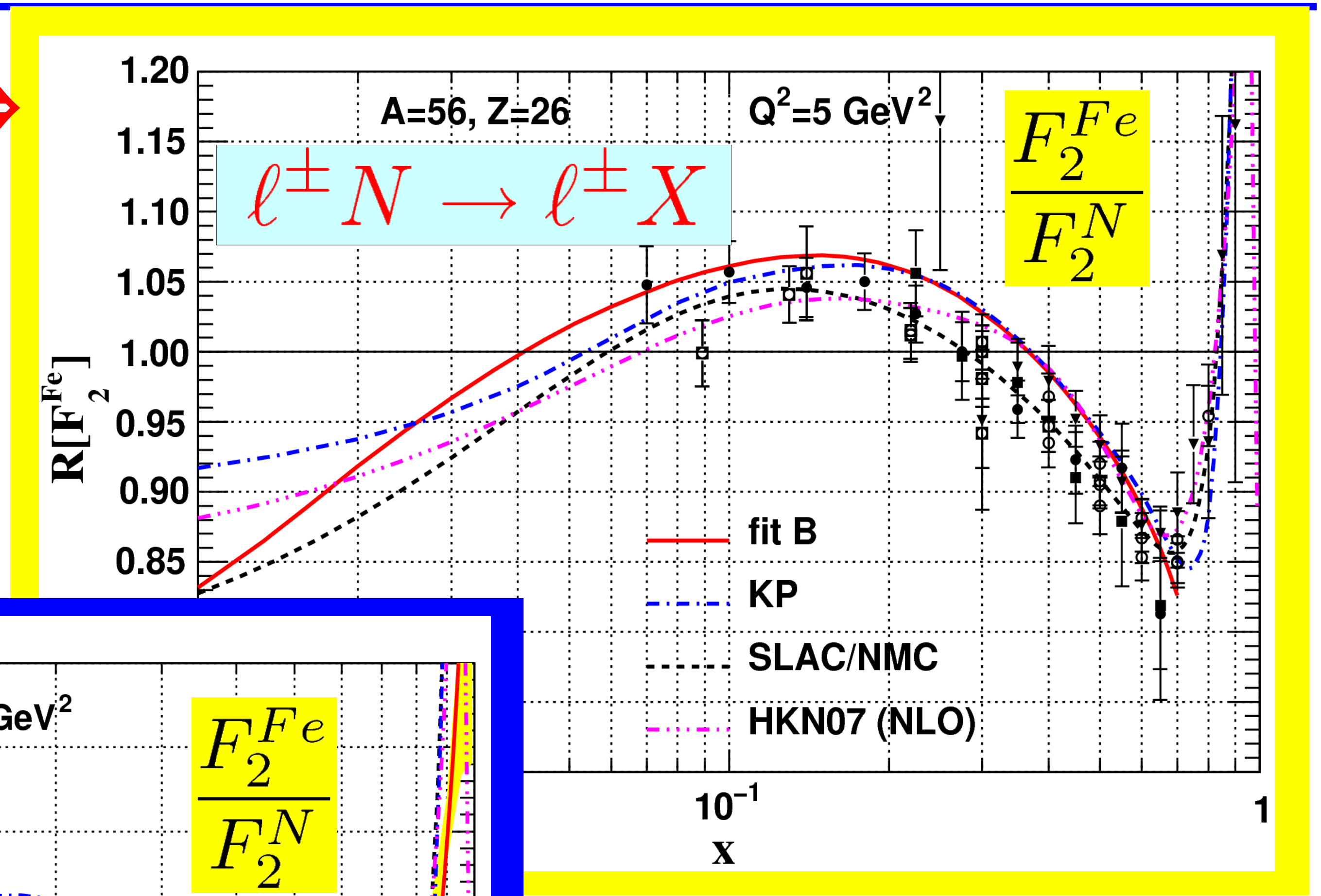
Nuclear PDFs from neutrino deep inelastic scattering.
I. Schienbein, J.Y. Yu, C. Keppel, J.G. Morfin,
F. Olness, J.F. Owens. Phys.Rev.D77:054013,2008.

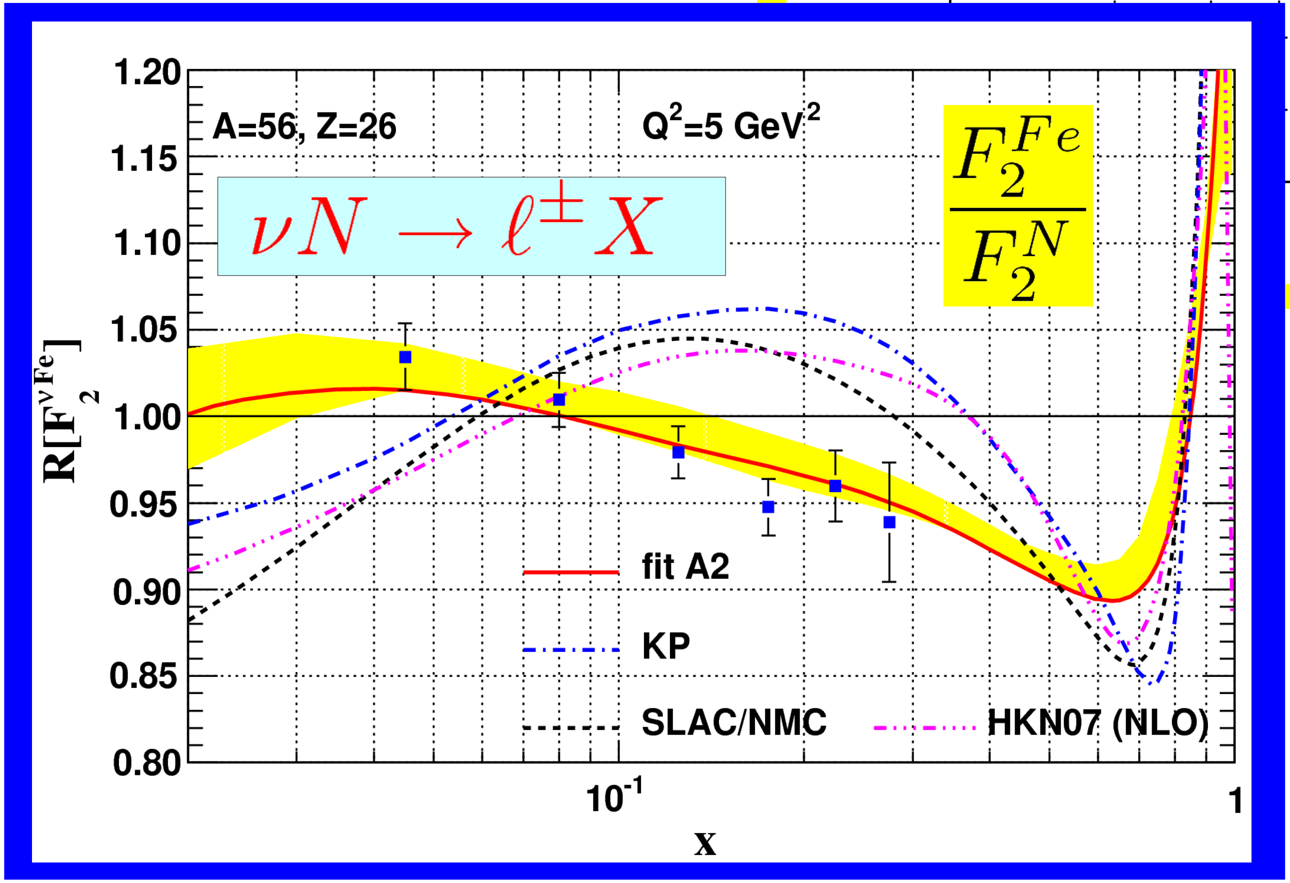
What Nuclear Correction do the data prefer?

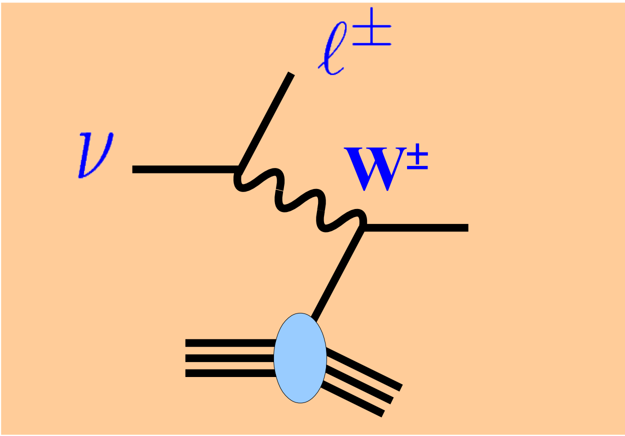
Nuclear Corrections: Compare Neutrino and Charged Lepton DIS

Charged Lepton DIS ⇒









⇐ Neutrino DIS

Could there be a "compromise" fit

... some recent results by led by Karol Kovarik

How to reconcile with literature???

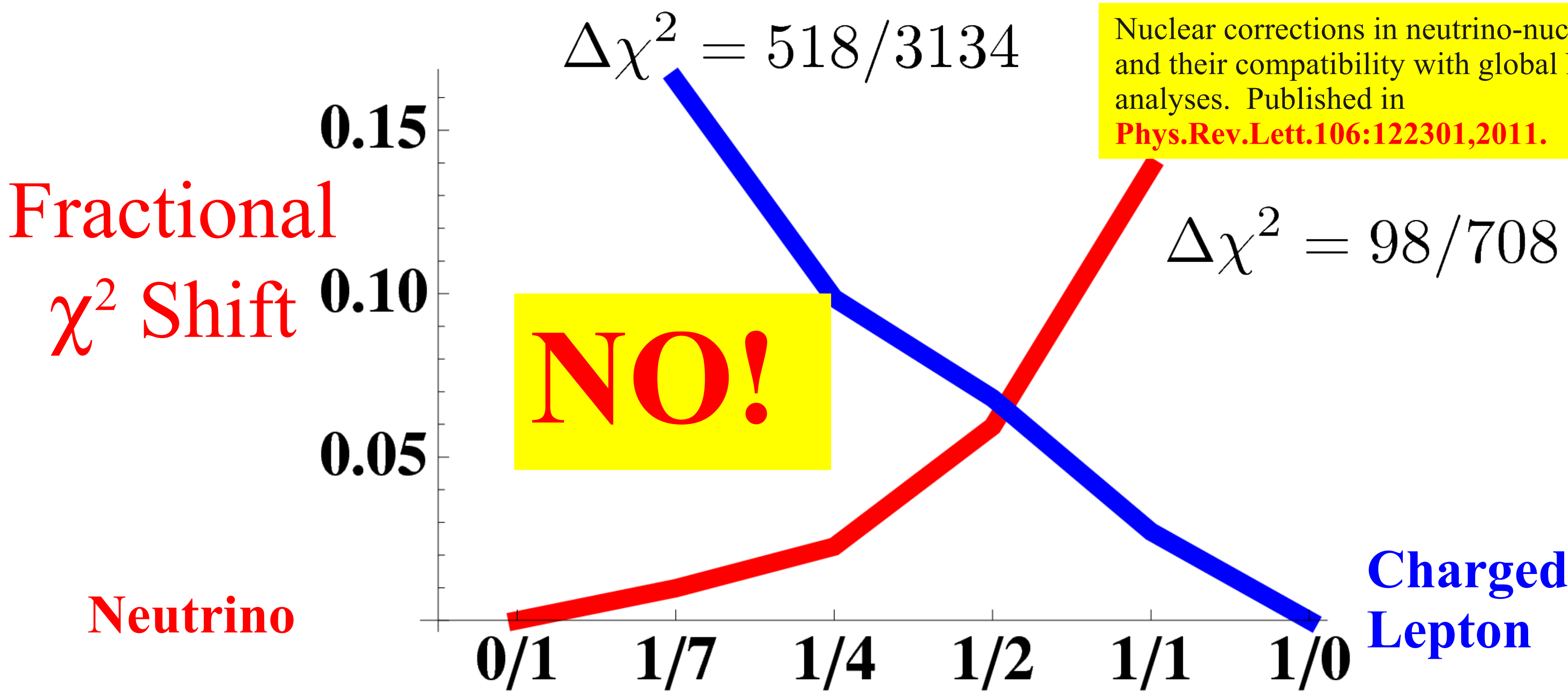
"Thus, nuclear effects in νA DIS are in line with those extracted from charged lepton DIS and Drell-Yan dilepton production."

Hannu Paukkunen, DIS'10

Comparison: Charged Lepton and Neutrino DIS

Weight	Name of fit	$l^{\pm}A$ data	χ^2 (/pt)	νA data	χ^2 (/pt)	total χ^2 (/pt)
$w = 0$	decut3	708 √	638 (0.90)	- X	-	638 (0.90)
$w = 1/7$	glofac1a	708 √	645 (0.91)	3134 X	4710 (1.50)	5355 (1.39)
$w = 1/4$	glofac1c	708 √	654 (0.92)	3134 X	4501 (1.43)	5155 (1.34)
$w = 1/2$	glofac1b	708 √	680 (0.96)	3134 X	4405 (1.40)	5085 (1.32)
$w = 1$	global2b	708 X	736 (1.04)	3134 √	4277 (1.36)	5014 (1.30)
$w = \infty$	nuanua1	- X	-	3134 √	4192 (1.33)	4192 (1.33)

Nuclear corrections in neutrino-nucleus DIS and their compatibility with global NPDF analyses. Published in **Phys.Rev.Lett.106:122301,2011.**

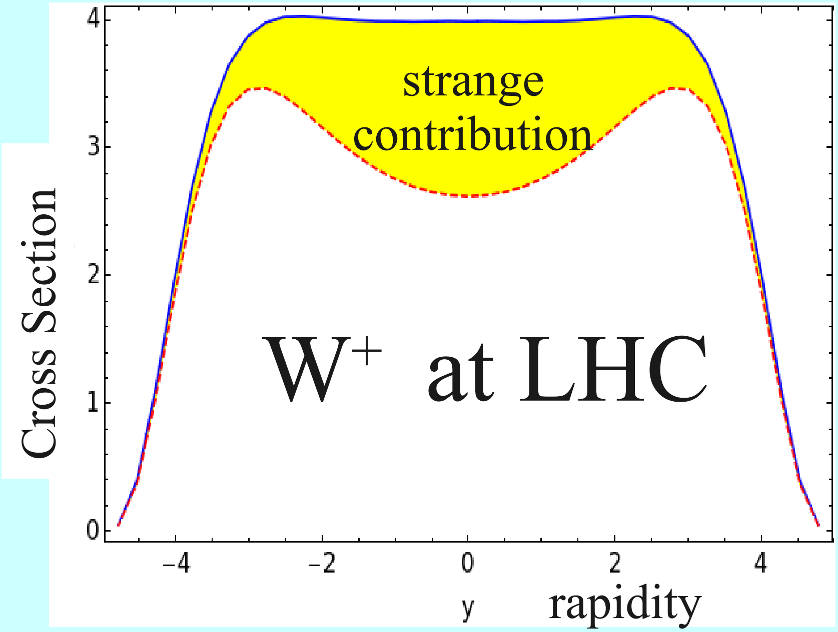


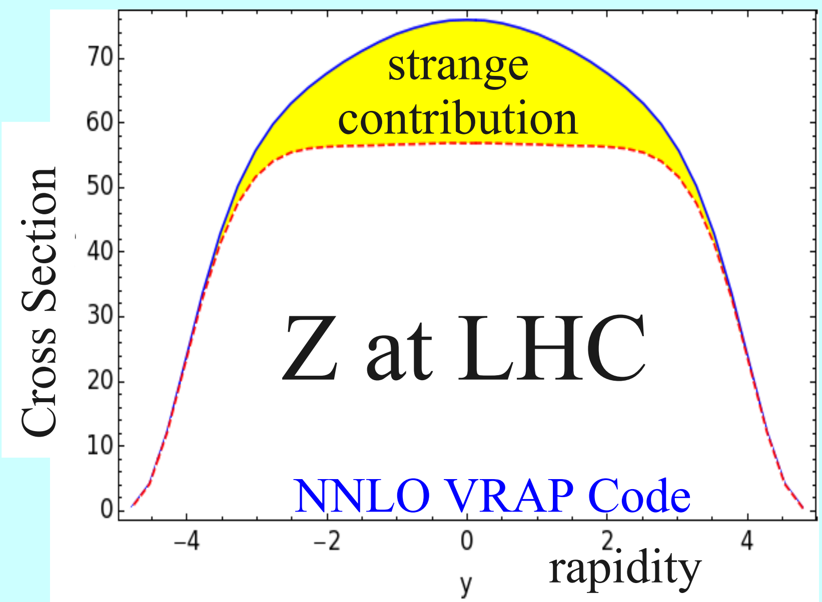
Could there be a “compromise” fit

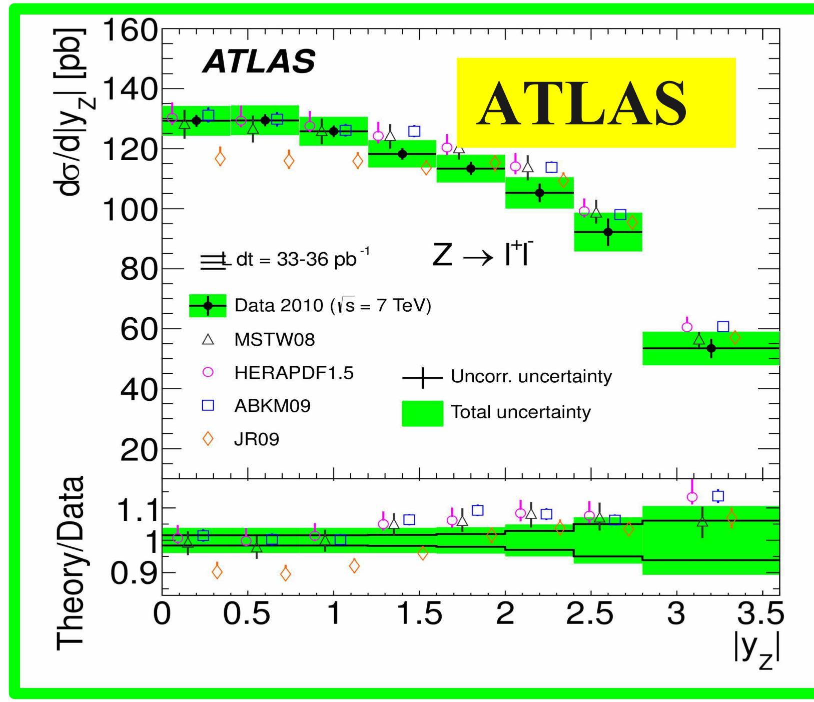
NO!
Correlated errors are essential to consider!!!

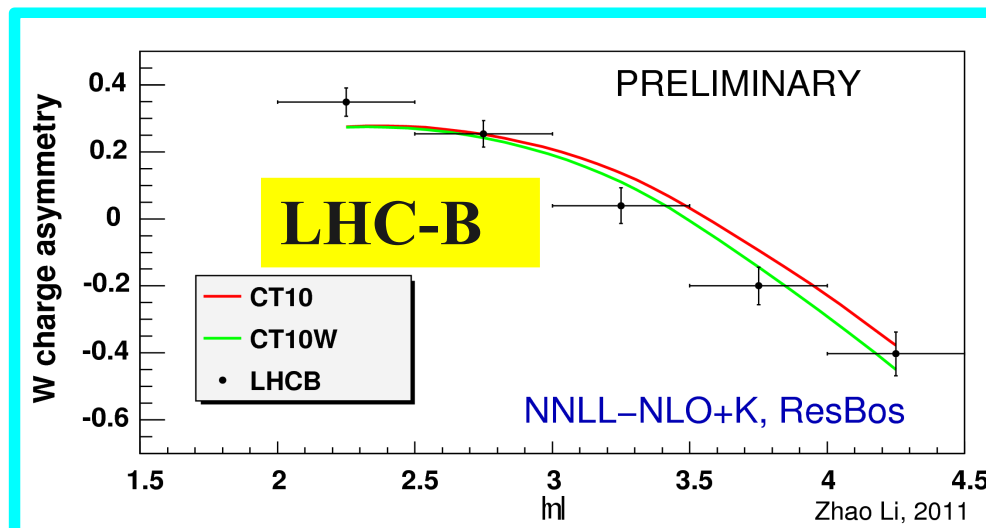
LHC DATA

PDF Uncertainties ⇒ S(x) PDF ⇔ W/Z at LHC









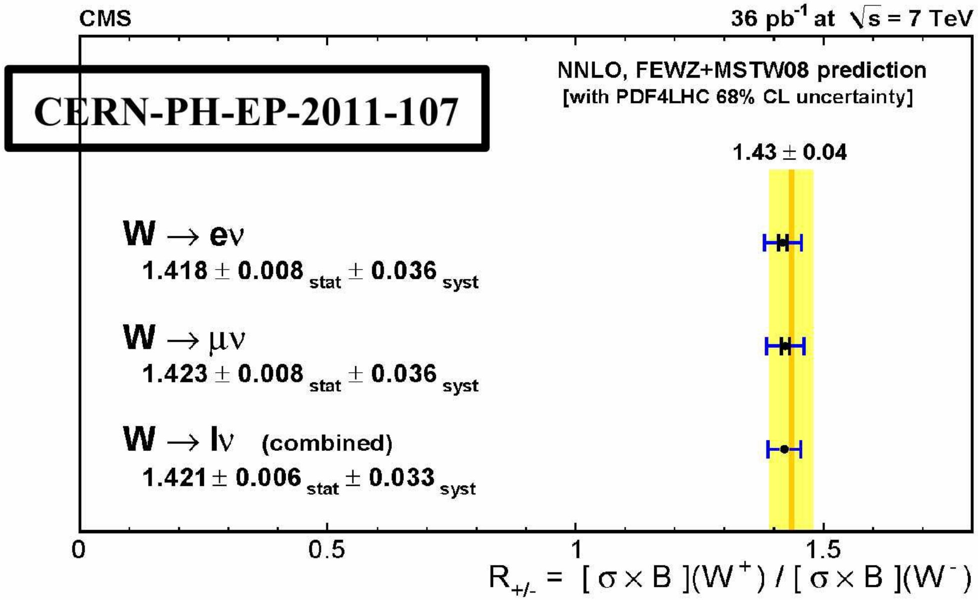
NNLO VRAP Code
Anastasiou, Dixon, Melnikov, Petriello,
Phys.Rev.D69:094008,2004.

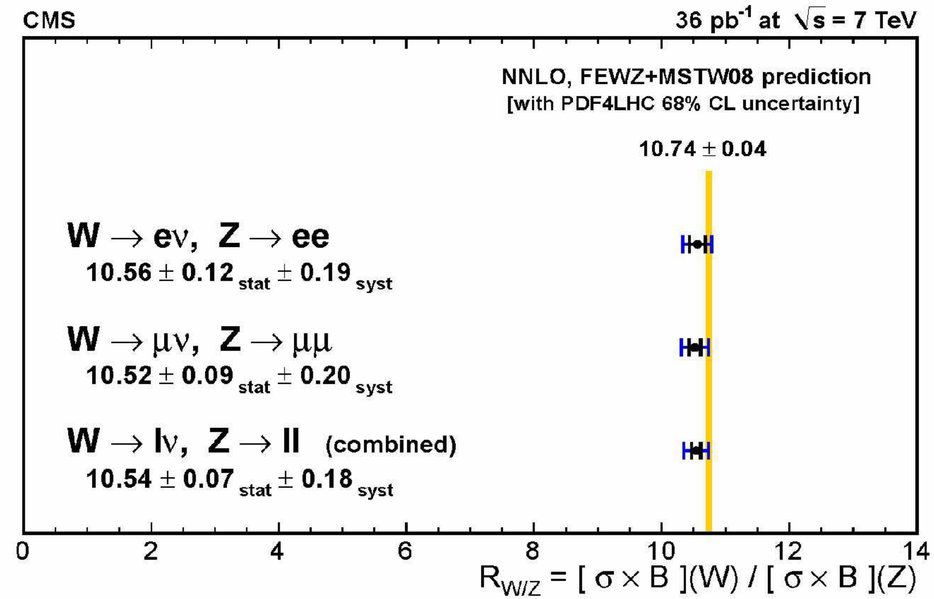
Kusina, Stavreva, Berge, Olness,
Schienbein, Kovarik, Jezo, Yu, Park
arXiv:1203:1290

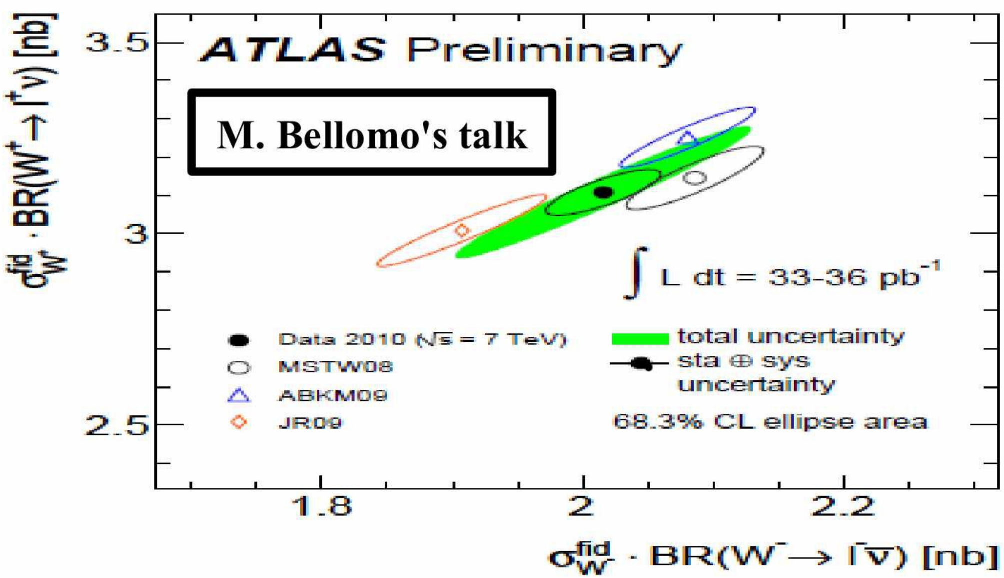
y distribution shape can constrain s(x) PDF

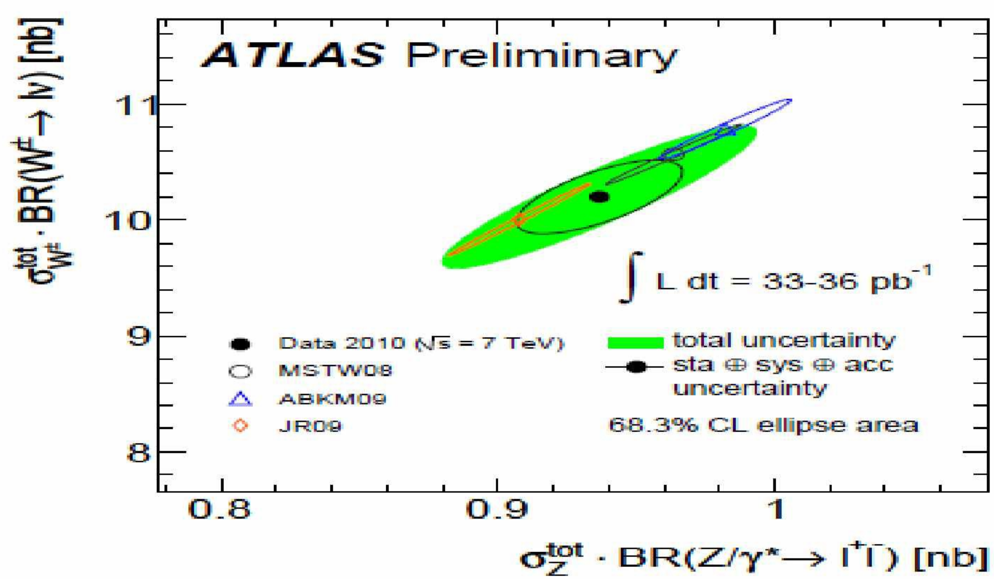
W/Z
Ratios

LHC W+/W- and W/Z ratios





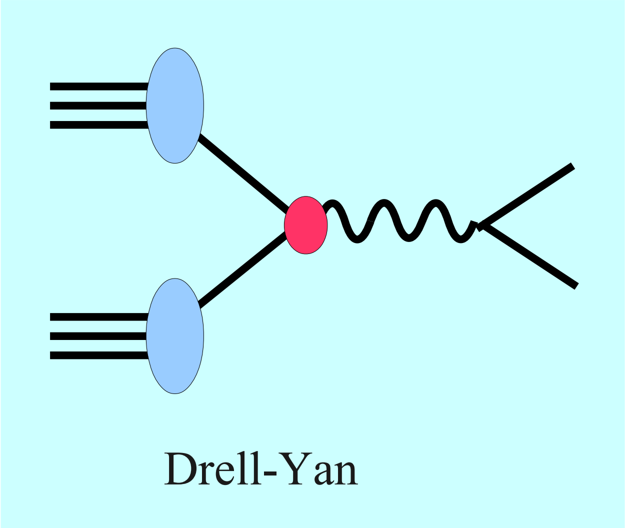


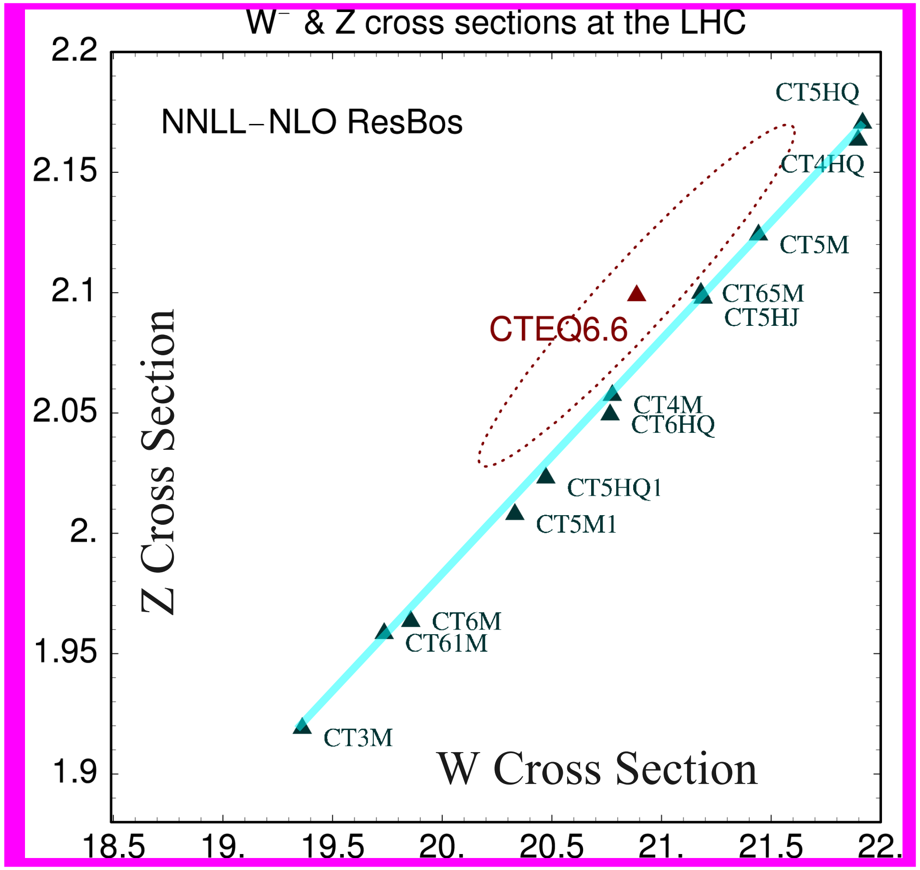


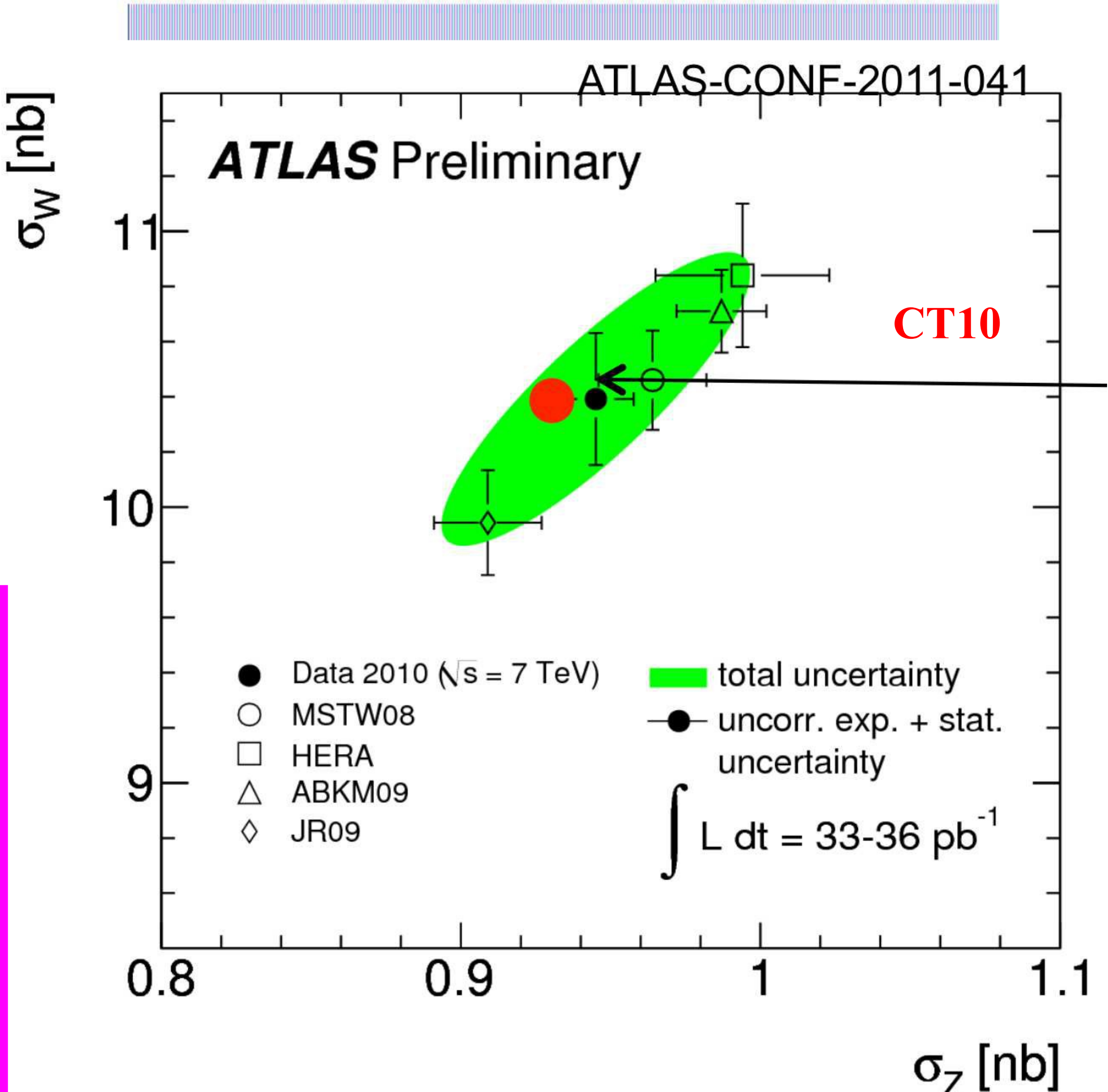
W+/W-: potential to constrain PDF uncertainties

W/Z: stringent test of theoretical expectations

W/Z PRODUCTION







ATLAS W/Z cross section ratio in good agreement with NNLO predictions from the PDF groups shown

LHC Constraints on $s(x)$

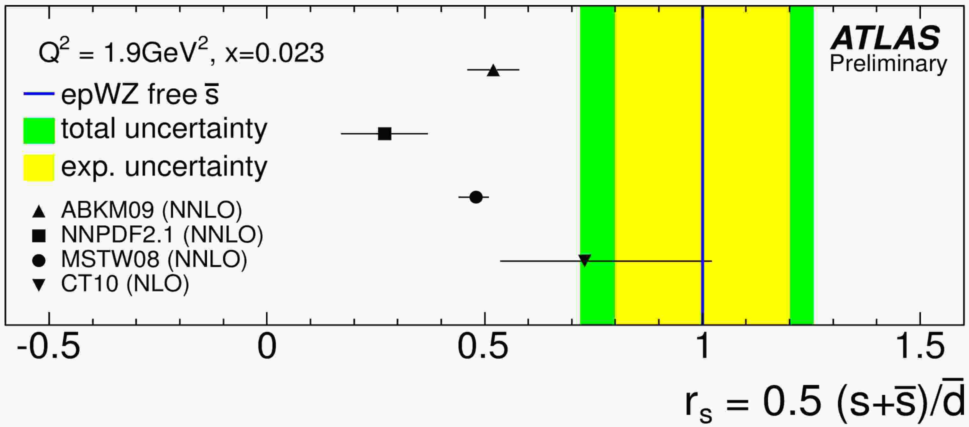
Recent Results from EW Moriond 2012

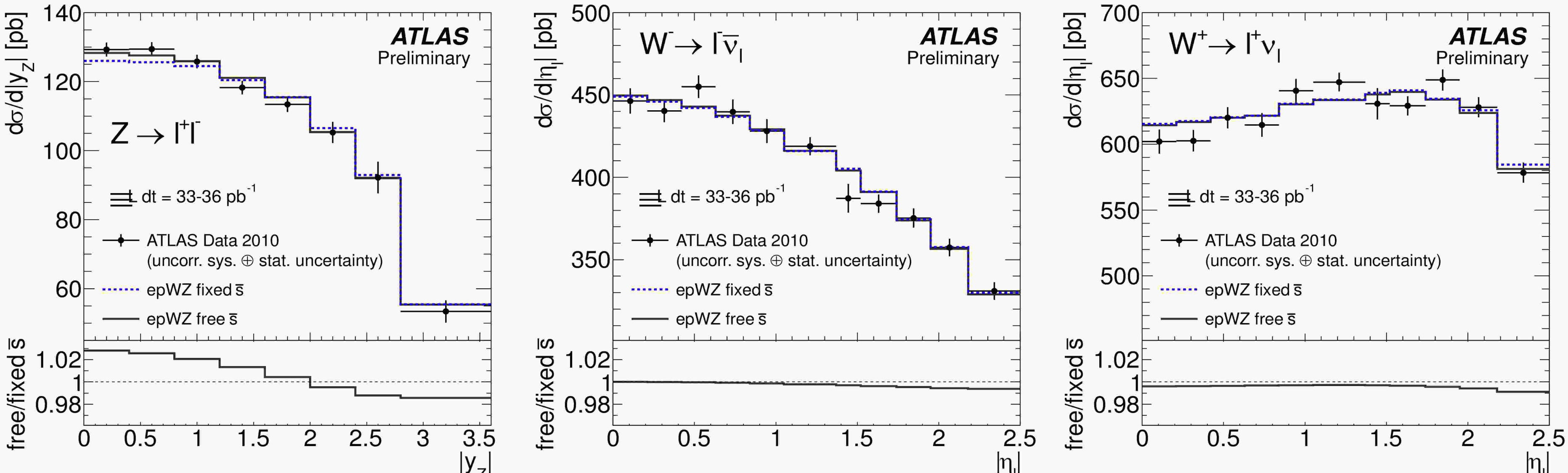
W, Z data sensitivity to strange sea

- ATLAS performed NNLO QCD fit to Z, W^+, W^- + HERA ep DIS cross sections: significant tension for Z observed when suppressing strange by 50% at low scale $1.9\,\mathrm{GeV}^2$

- Fit with free strange sea gives no supression

$$r_s = 1.00 \pm 0.20_{\mathrm{exp}} \, {}^{+0.16}_{-0.20}\,\mathrm{sys}$$





ATLAS-STDM-2011-43 → PRL

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HERAFitter

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- More Actions:

HERAFitter

Welcome to HERAFitter Project

HERAFitter is a QCD Fit Package used to determine HERAPDFs and it is part of the HERAPDF project https://www.desy.de/h1zeus.

Downloads of HERAFItter software package

New HERAFitter release is available! The HERAFitter releases can be accessed HERE upon registration. Everyone is free to register.

Registration

To register, please log in (upper right corner) by creating an account (firstnamelastname, example: JohnSmith) and send your request and login name to `<herafitter-help AT SPAMFREE desy DOT de>`.

HERAFitter Meetings

- User's Meetings: monthly meetings to enhance communication between users and developers (open access)

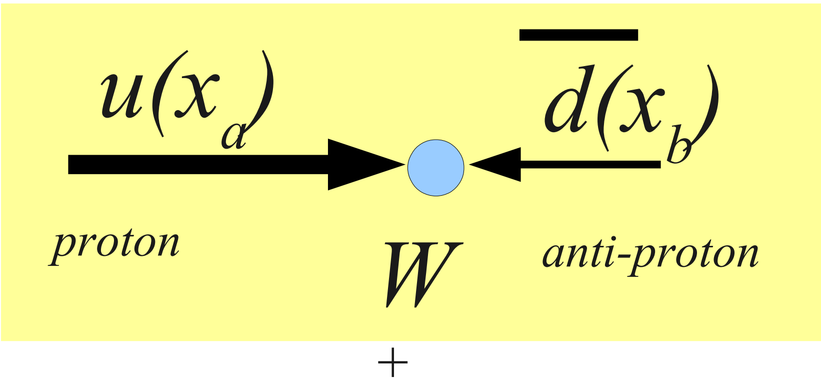
W

Asymmetry

@ LHC

W Asymmetry

A bit of calculation



$$A(y) = \frac{\frac{d\sigma}{dy}(W^+) - \frac{d\sigma}{dy}(W^-)}{\frac{d\sigma}{dy}(W^+) + \frac{d\sigma}{dy}(W^-)}$$

With the previous approximation,

$$A \approx \frac{u(x_a)d(x_b) - d(x_a)u(x_b)}{u(x_a)d(x_b) + d(x_a)u(x_b)} = \frac{R_{du}(x_b) - R_{du}(x_a)}{R_{du}(x_b) + R_{du}(x_a)}$$

where $$R_{du}(x) = \frac{d(x)}{u(x)}$$

$$x_{1,2} = x_0 e^{\pm y} \simeq x_0(1 \pm y)$$

We can make Taylor expansions:

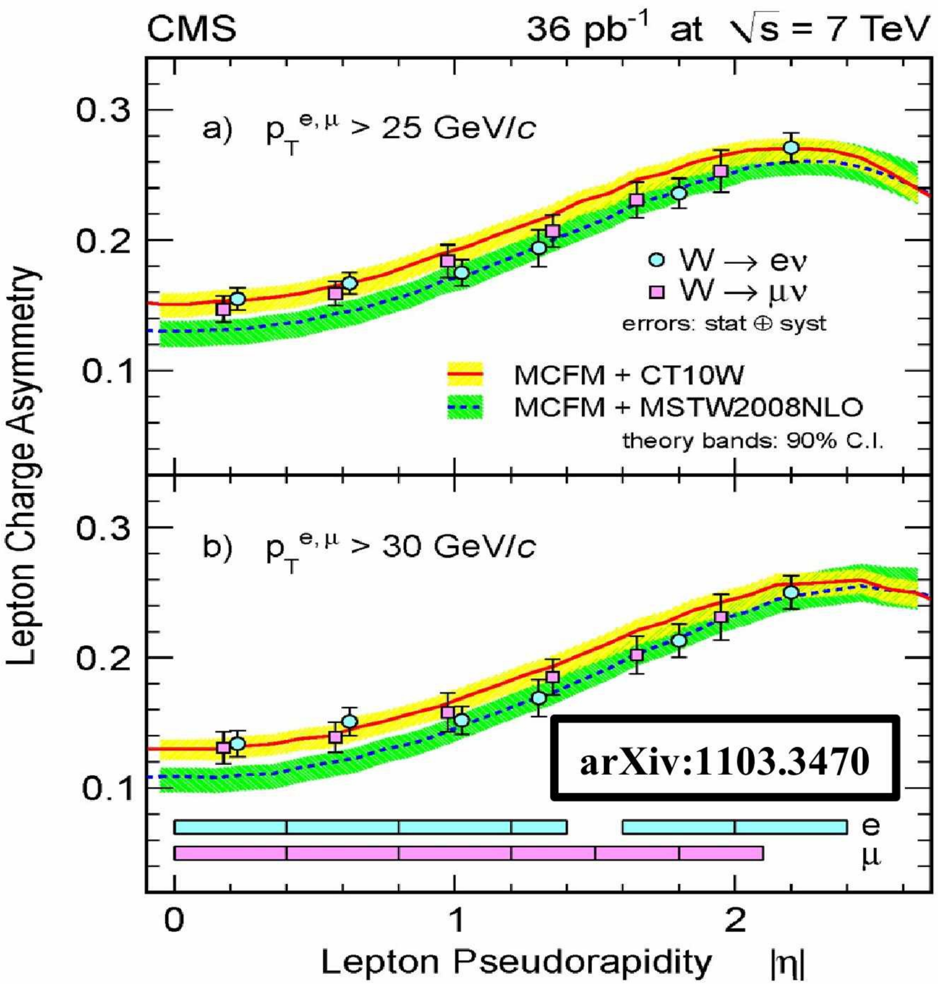
$$R_{du}(x_{1,2}) \approx R_{du}(x_0) \pm y\, x_0\, R'_{du}(\sqrt{\tau})$$

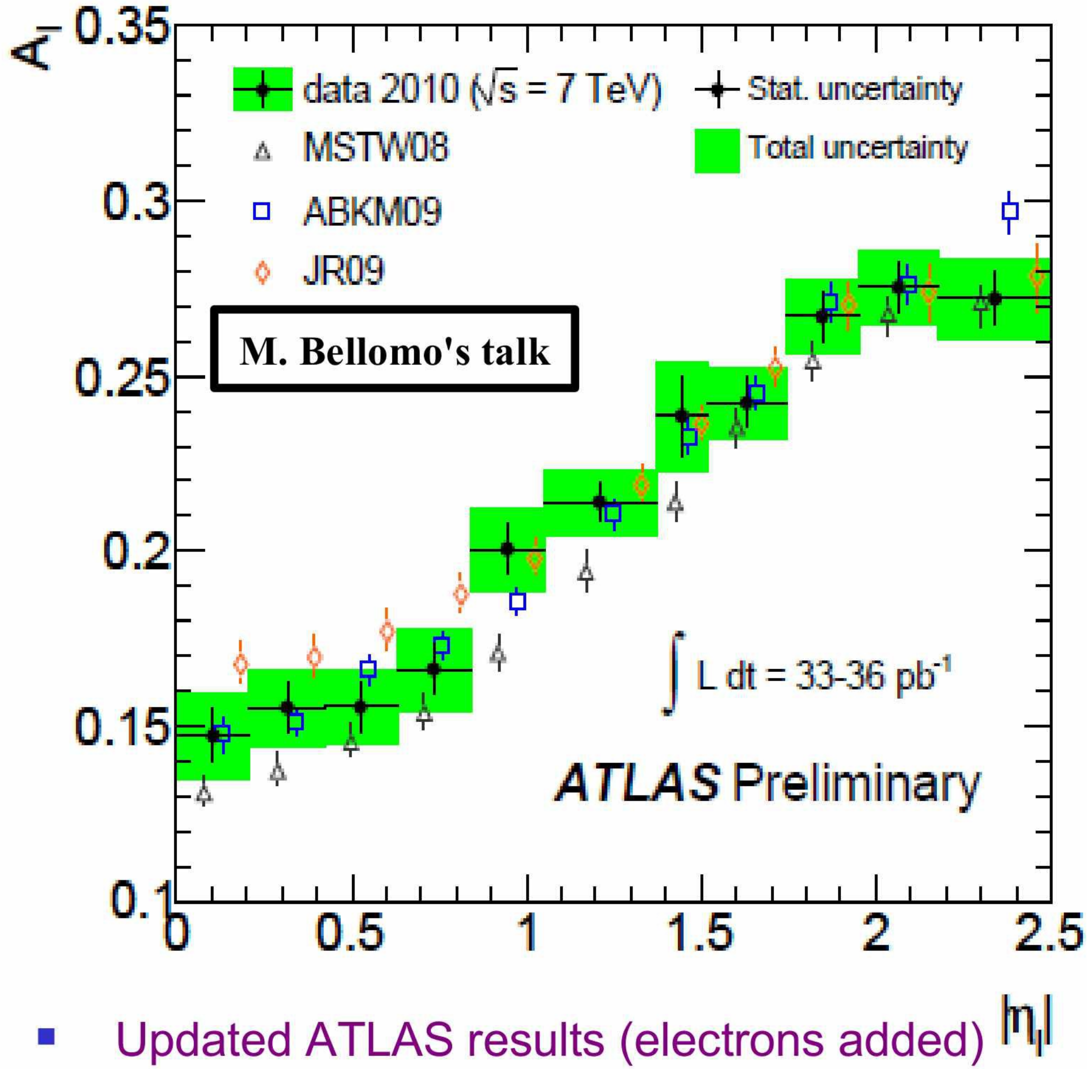
Thus, the asymmetry is:

$$A(y) = -y\, x_0 \frac{R'_{du}(x_0)}{R_{du}(x_0)}$$

EXERCISE: Verify the above.

W lepton charge asymmetry





- CMS published results
- Updated ATLAS results (electrons added)

In reasonable agreement with different PDF predictions, but extremely sensitive to shape details

W Asymmetry

@ Tevatron

The puzzle of the CDF/D0 W lepton asymmetry

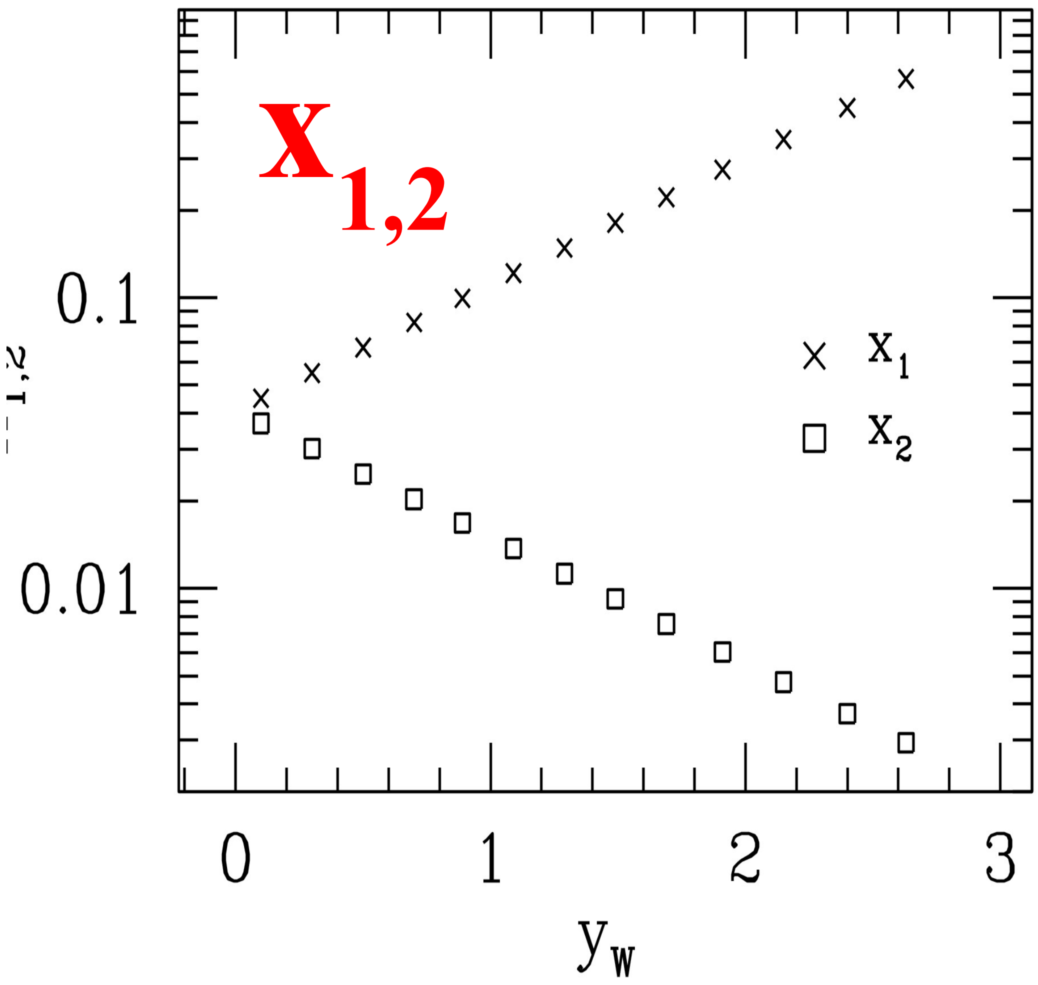
- CT10W set reasonably agrees with 3 $p_{T\ell}$ bins of $A_e(y_e)$ and one bin of $A_\mu(y_\mu)$ from D0 Run-2 (2008).
- NNPDF 2.0 *(arXiv:1012.0836)* agrees with $A_\mu(y_\mu)$, disagrees with two p_{Te} bins of $A_e(y_e)$.
- CT10, many other PDFs fail.

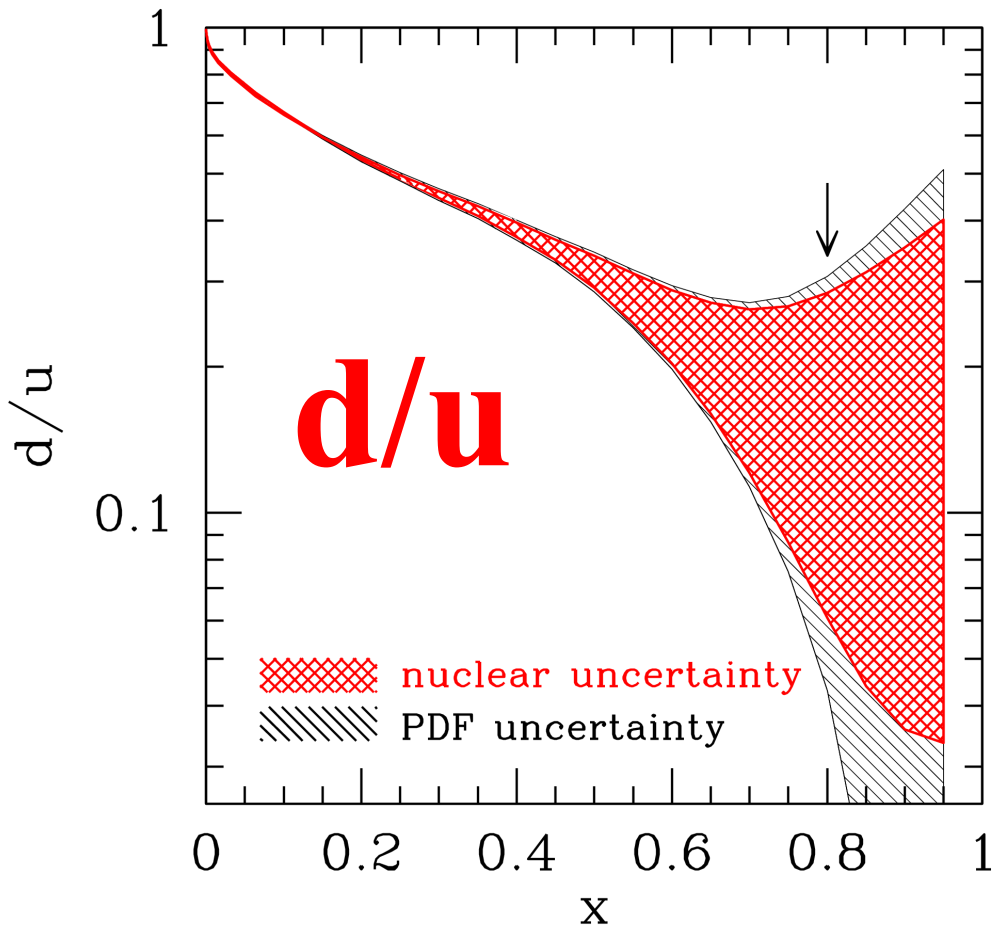
Agreement of PQCD with D0 $A_e(y_e)$	χ^2/npt	Source or comments
CTEQ6.6, NLO	191/36=5.5	*Our study;* *Resbos, NNLL-NLO*
CT10W, NLO	**78/36=2.2** **With $A_\mu(y_\mu)$: 88/47=1.9**	
ABKM'09, NNLO	540/24=22.5	*Catani, Ferrera, Grazzini, JHEP 05, 006 (2010)*
MSTW'08, NNLO	205/24=8.6	
JR09VF, NNLO	113/24=4.7	

What is happening with d/u

This combination rather unique

$$A_\ell = \frac{d\sigma(W^+ \to \ell^+) - d\sigma(W^- \to \ell^-)}{d\sigma(W^+ \to \ell^+) + d\sigma(W^- \to \ell^-)}$$





Determined from DIS and DY on p and d

$$x_{1,2} \sim \frac{M}{\sqrt{s}} e^{\pm y}$$

LHC values scaled appropriately

Uncertainties in determining parton distributions at large x.
A.Accardi, W.Melnitchouk, J.F.Owens, M.E.Christy, C.E.Keppel, L.Zhu, J.G.Morfin
arXiv:1102.3686 [hep-ph]

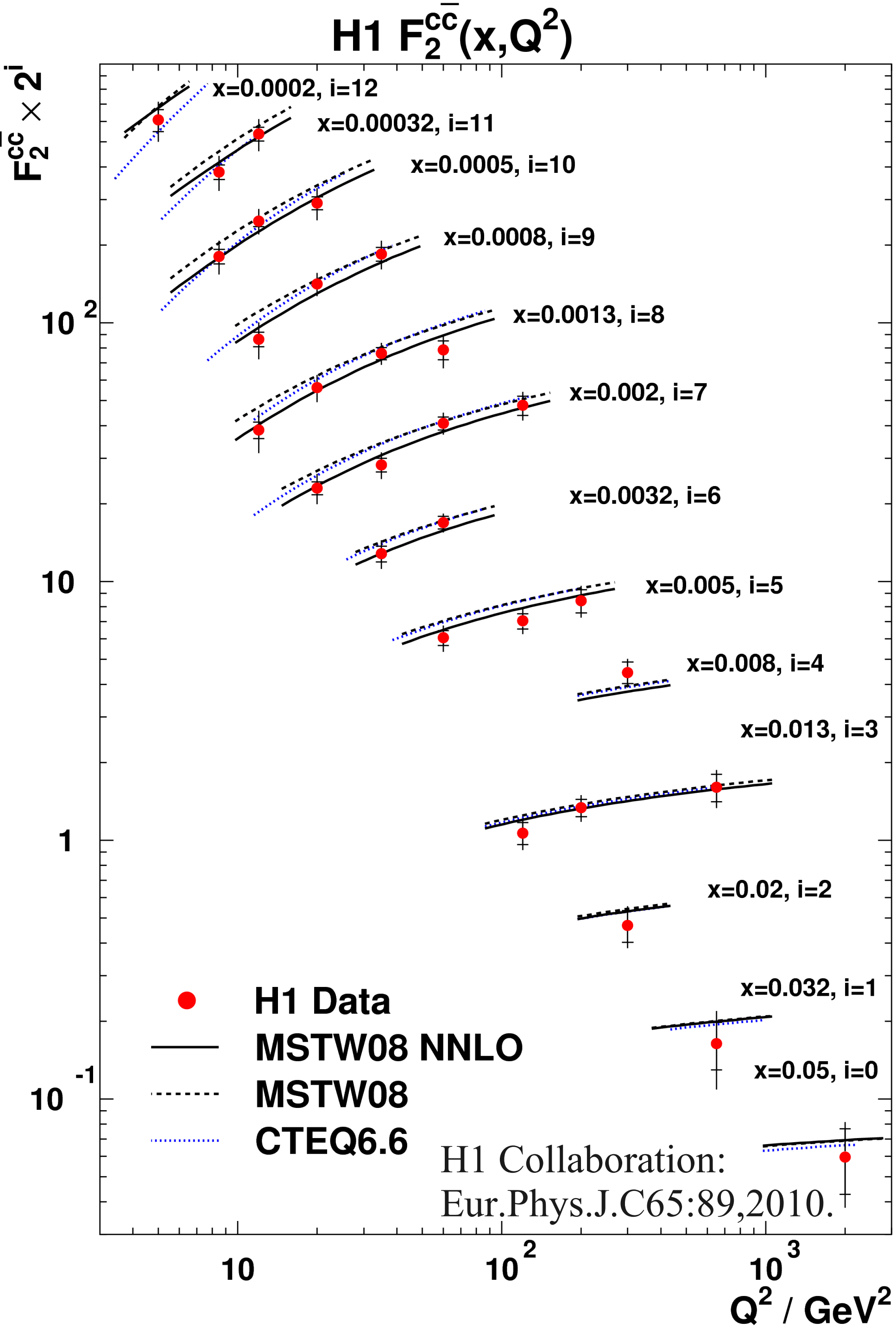
... what about the

Heavy Quarks

c & *b*

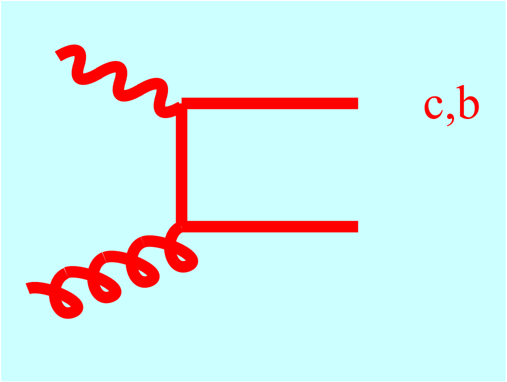
Extrinsic & Intrinsic

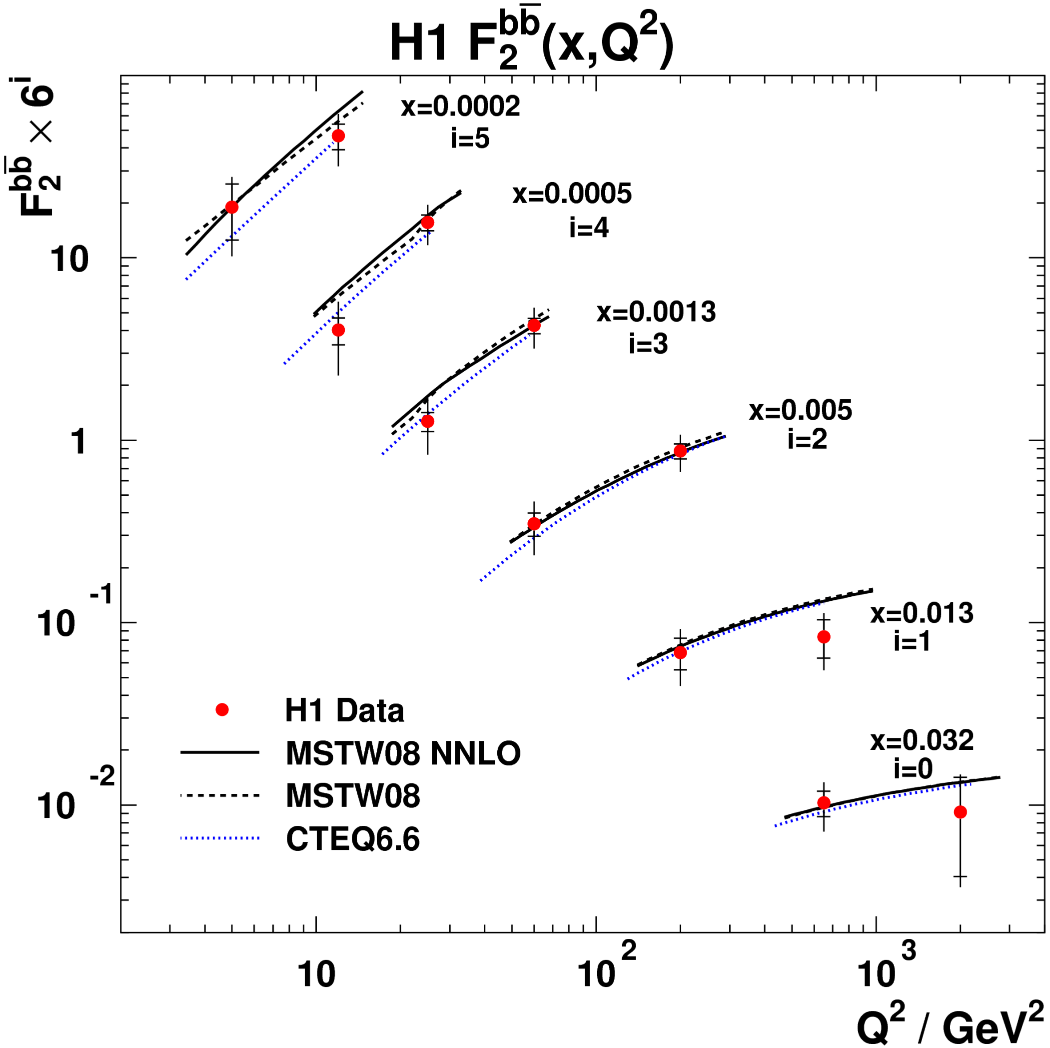
Heavy Flavor Components will play prominent role at LHC



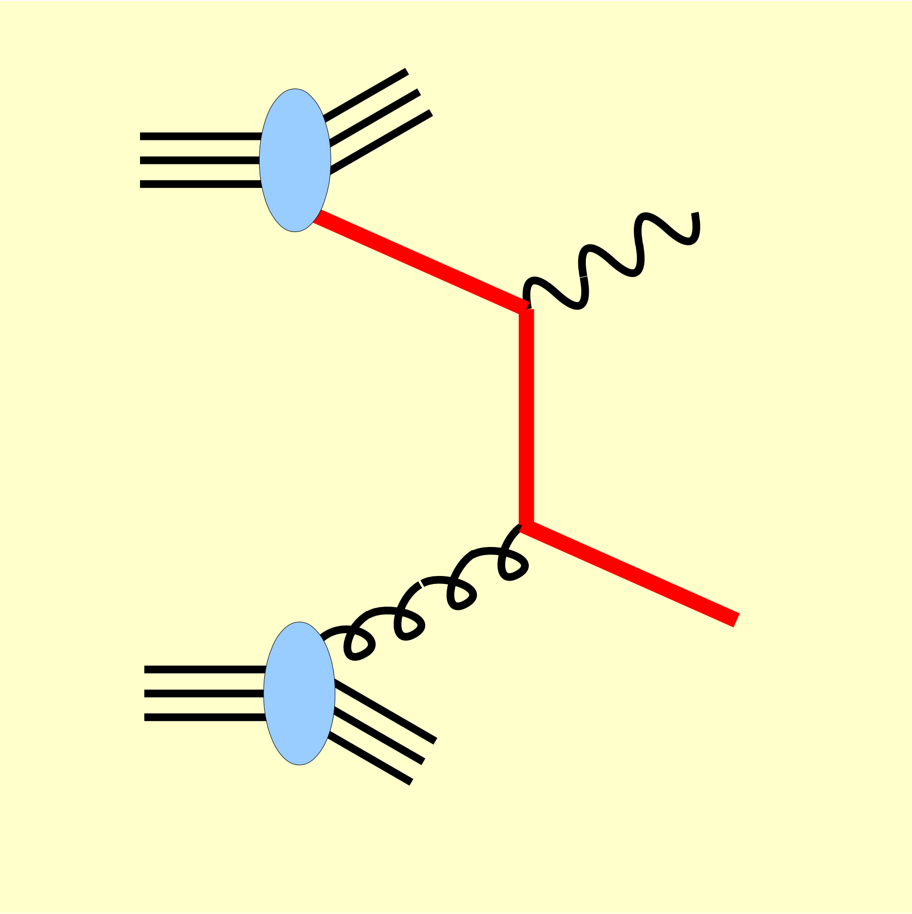
H1 Collaboration:
Eur.Phys.J.C65:89,2010.

c & b tied to gluon PDFs





How to Access Heavy Flavor Components Directly???



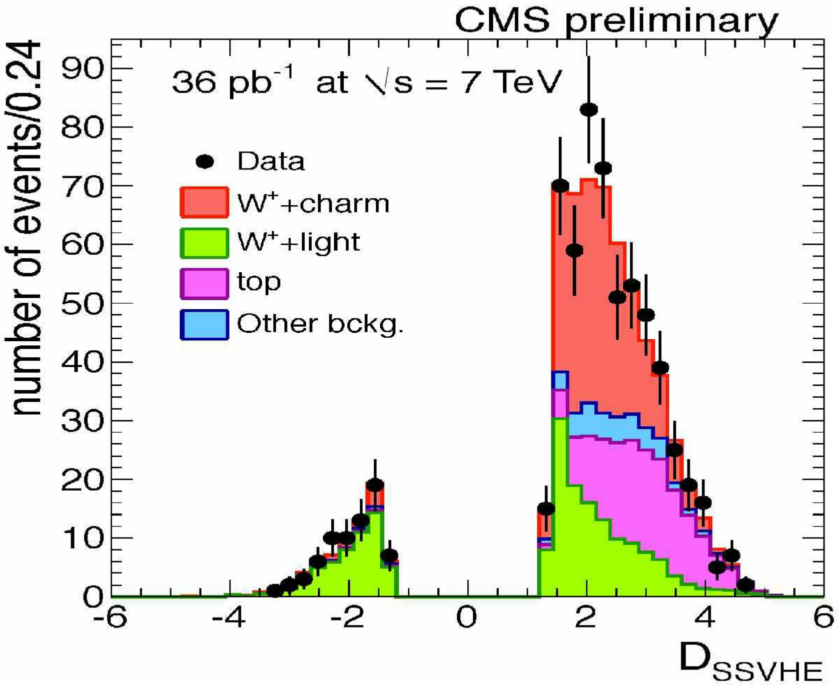
$c\ g \rightarrow c\ \gamma$

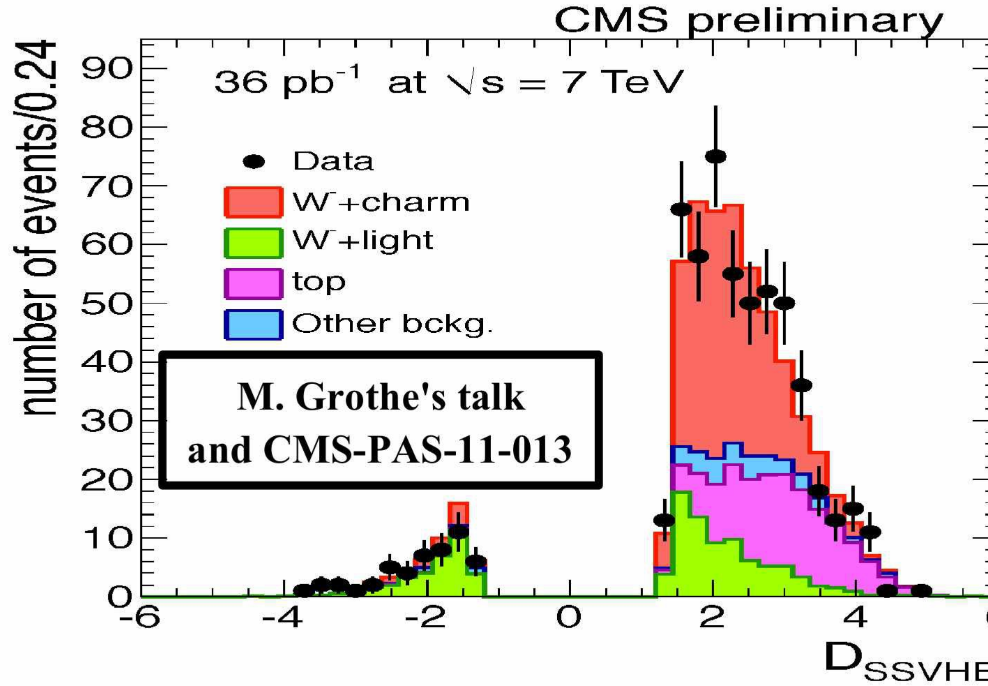
$b\ g \rightarrow b\ \gamma$

$s\ g \rightarrow c\ W$

$c\ g \rightarrow b\ W$

First LHC results on W+charm (CMS)





- Sensitive to strange quark PDFs (process dominated by s+g → W + charm):
  - PDF uncertainties from the second quark generation are a potential source of uncertainty for the W mass measurement at the LHC
  - Data-driven control of light-quark and top backgrounds
  - Enormous margin for improvement (only 2010 statistics used), new method (secondary vertex tagging), complementary to the one employed until now at Tevatron (semileptonic charm decay tagging):

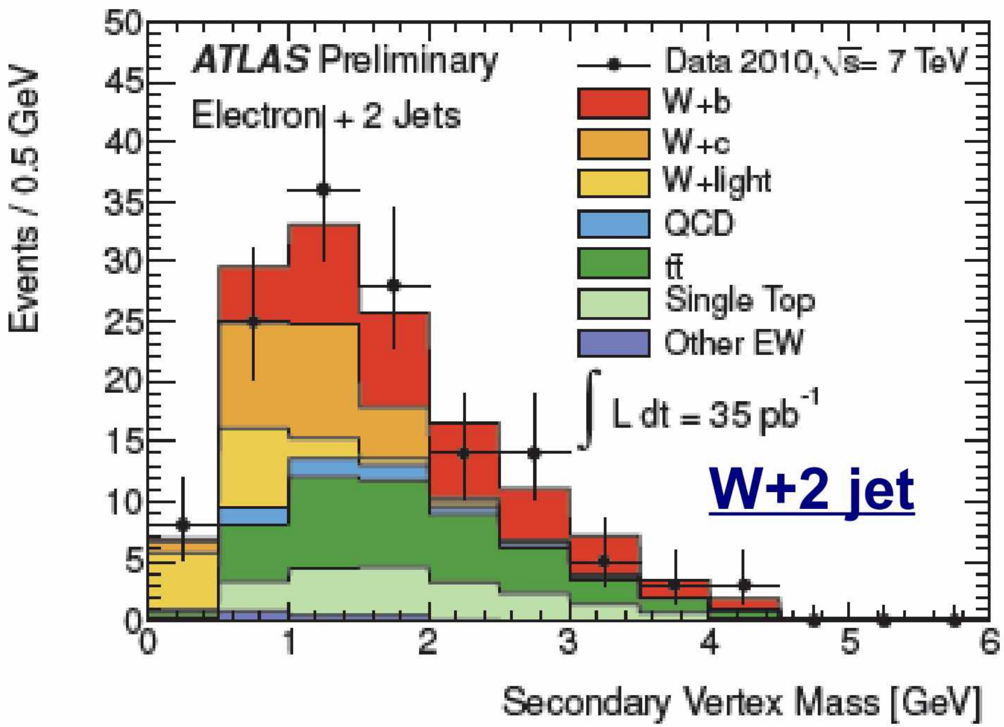
$$\underline{For\quad p_T^{jet} > 20\ \ GeV, |\eta^{jet}| < 2.1}:$$

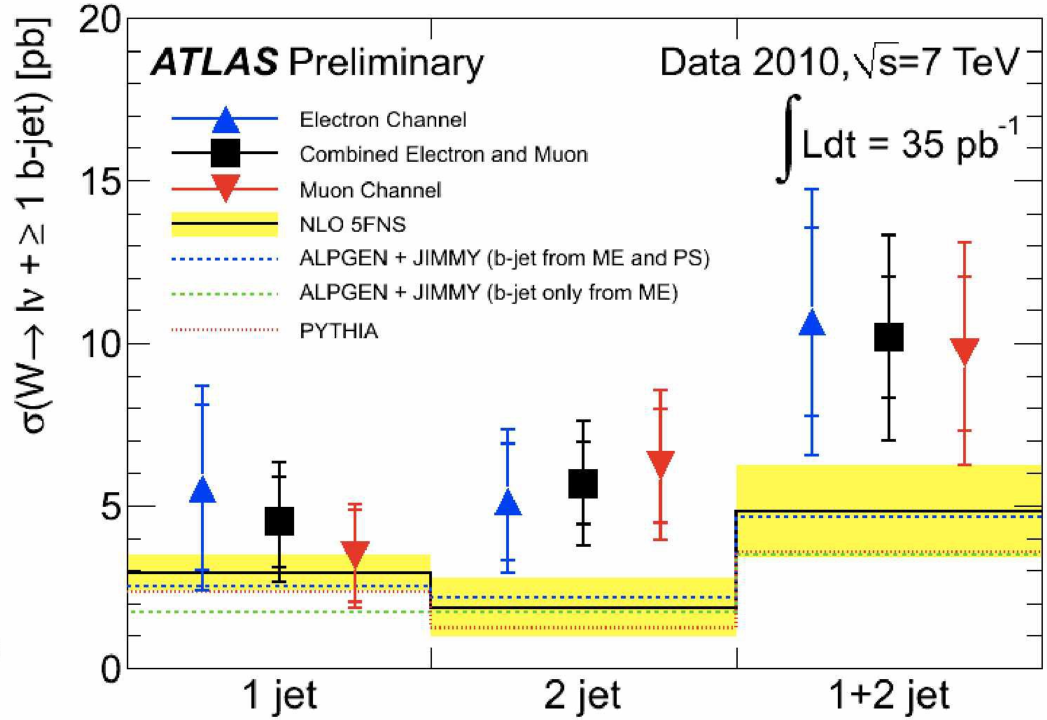
$$\frac{\sigma(W^+ + charm)}{\sigma(W^- + charm)} = 0.92 \pm 0.19(stat.) \pm 0.04(syst.); \quad \frac{\sigma(W + charm)}{\sigma(W + jets)} = 0.142 \pm 0.015(stat.) \pm 0.024(syst.)$$

First LHC W+b results (ATLAS)

- Important background for Higgs searches: W+H (H → $b\bar{b}$) at low Higgs masses. Also a background for $t\bar{t}$ and single-top measurements
- W+b excess over expectations published by CDF

A. Messina's talk

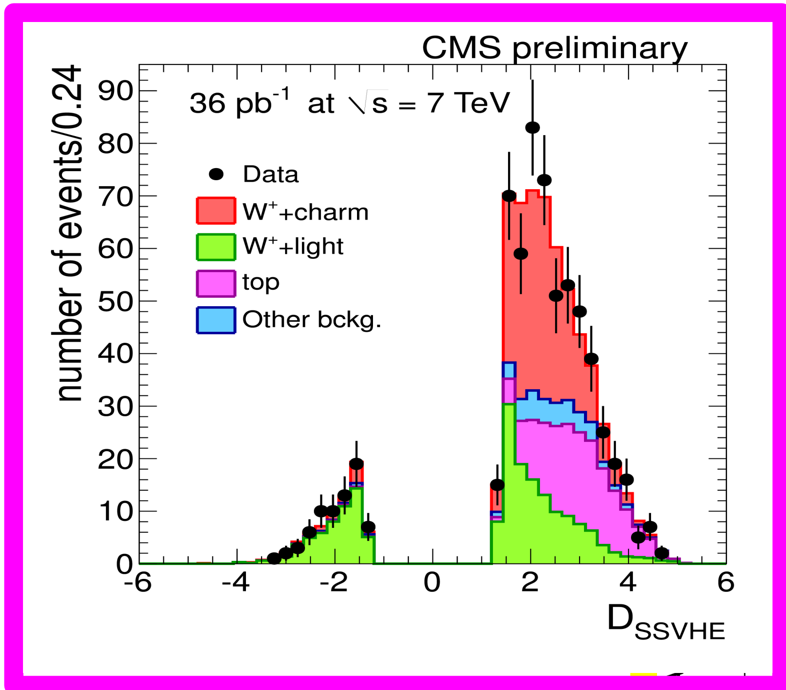




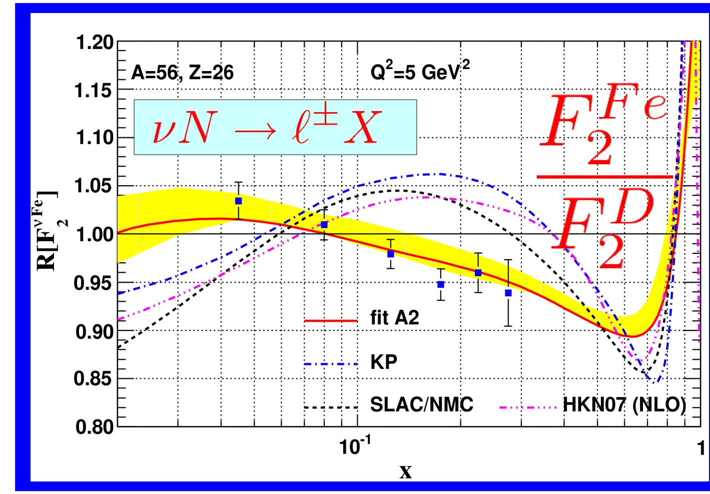
- Significant decay length (>5.85 σ), fit to the reconstructed mass at secondary vertex
- Challenging analysis: it requires significant reduction and control of top backgrounds and W+charm. Analysis performed independently for 1 and 2 b-tags in the event

Agreement with theoretical predictions at the 1.5 σ level

The Challenges

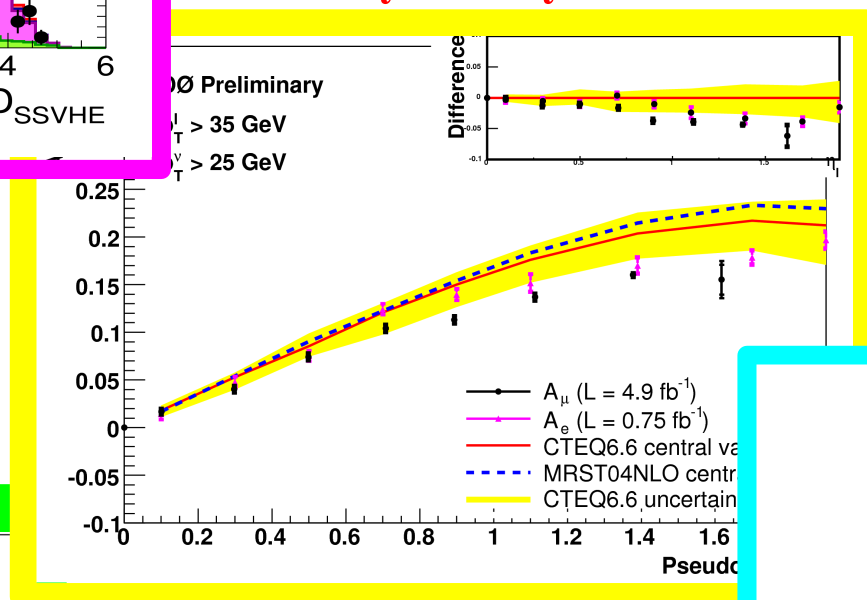


Charm+Bottom



Nuclear Modifications

W Asymmetry



s(x) uncertainty