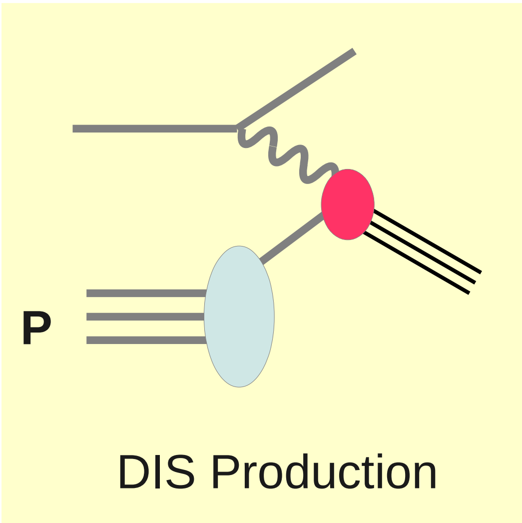
Anti-Proton Drell-Yan Issues and Opportunities

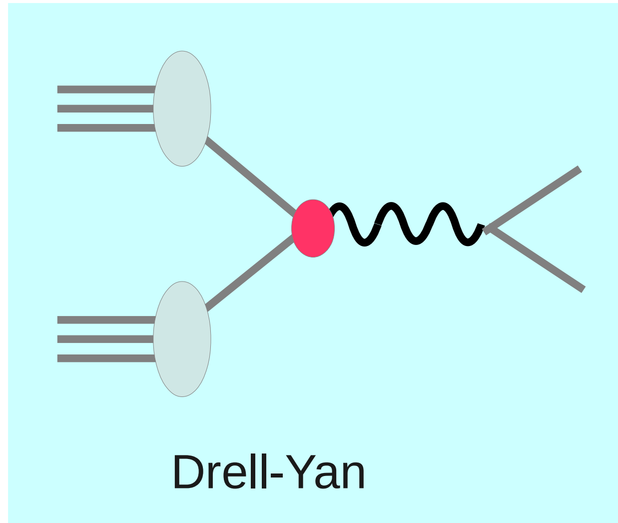
Fred Olness
SMU/CTEQ

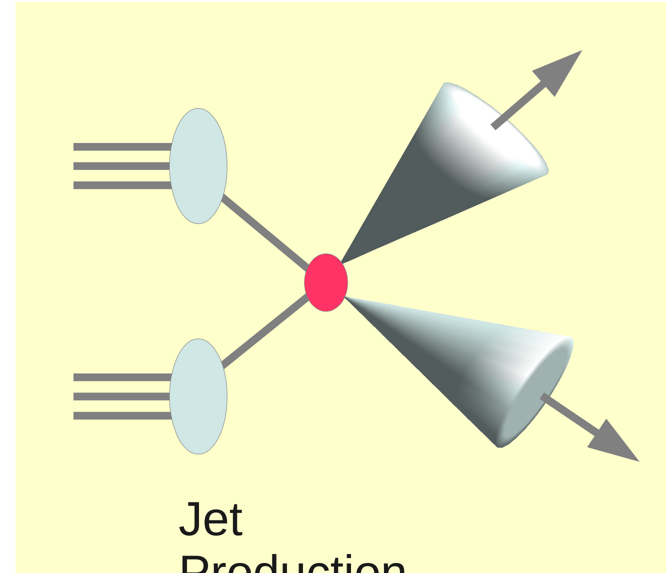
Thanks to Jeff Owens, Pavel Nadolsky, Zack Sullivan ...

18 November 2011
Fermilab

PDF extraction requires a variety of measurements







Different linear combinations – key for flavor differentiation

$$\sigma(\gamma, Z) \sim \left[u\,\bar{u} + d\,\bar{d} + s\,\bar{s} + c\,\bar{c} + \ldots\right]$$

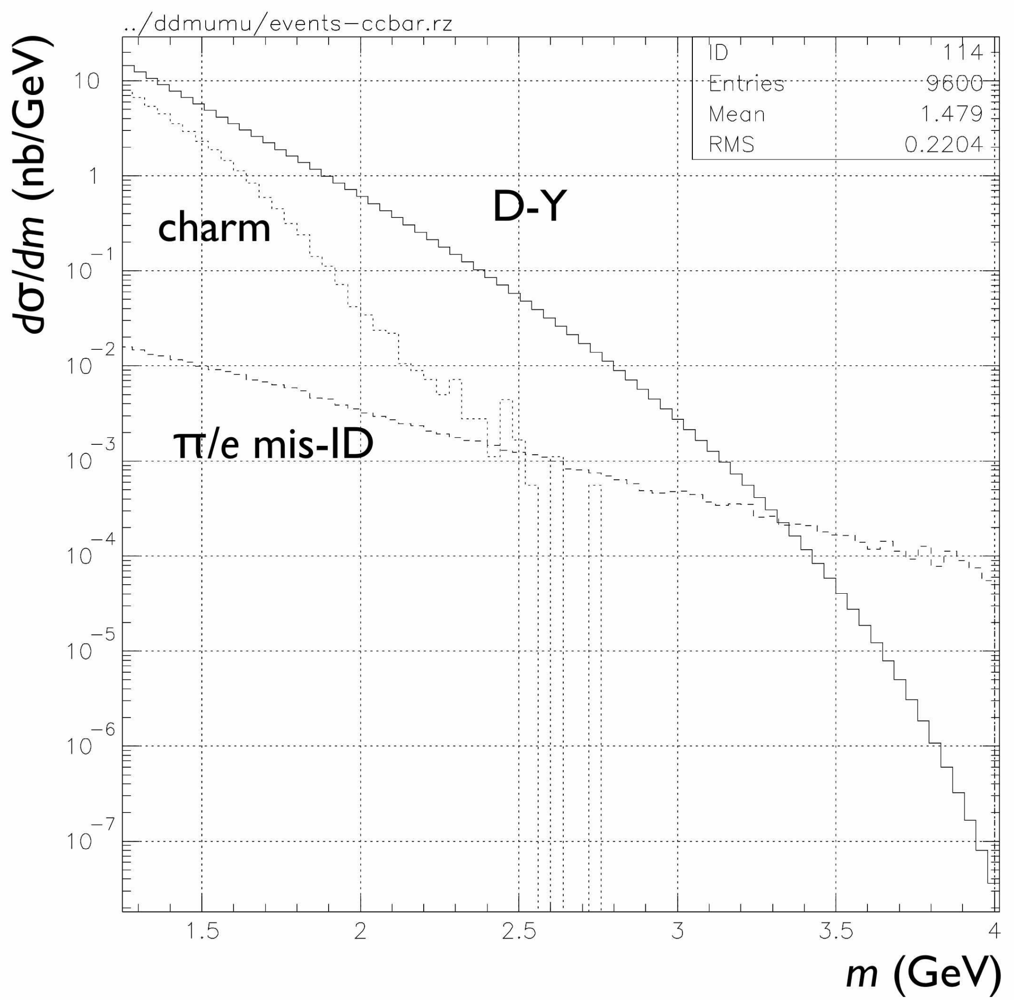
$$\sigma(W) \sim \left[u\,\bar{d} + d\,\bar{u} + s\,\bar{c} + c\,\bar{s} + \ldots\right]$$

DY combinations have interesting history

As we've already seen from Dan Kaplan:

At low Q and large x

$\bar{p}p$ Drell-Yan

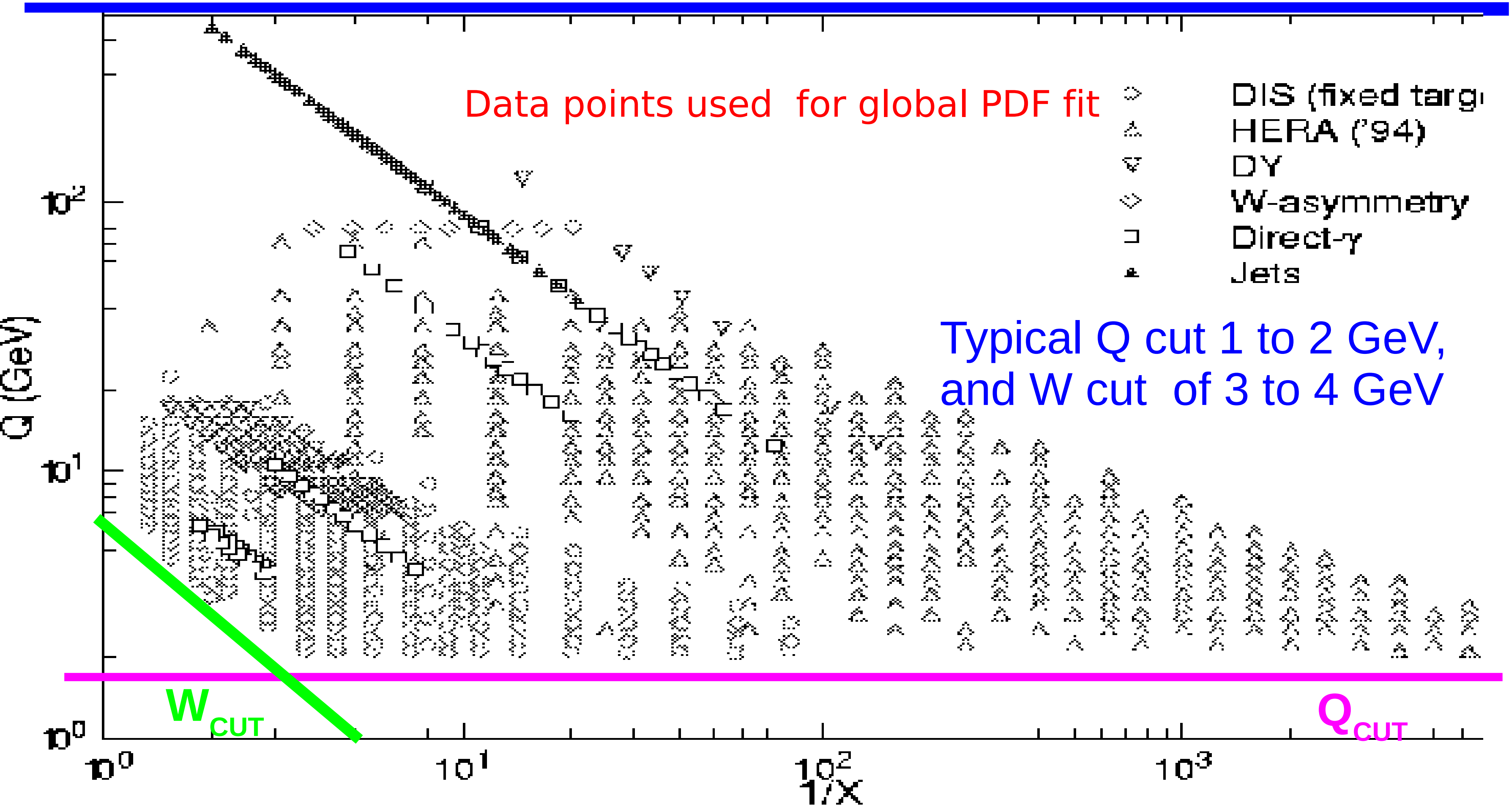


Compare signal with main backgrounds

- Low energy is advantageous:
  - ➡ less charm background
  - ➡ fewer pions to confuse
  - ➡ allows measurement in new kinematic region

What are the issues in the kinematic region of interest???

What is the kinematic region we will work in???



Low Q: DGLAP can evolve to Hi-Q. Provides BC:
Possibly describe Particle/Resonance Overlap region???

Hi x: Will "feed-down" to lower x with DGLAP evolution
Possibly investigate TMC & Higher Twist regions???

IOP Publishing — Journal of Physics G: Nuclear and Particle Physics

J. Phys. G: Nucl. Part. Phys. **35** (2008) 053101 (32pp) doi:10.1088/0954-3899/35/5/053101

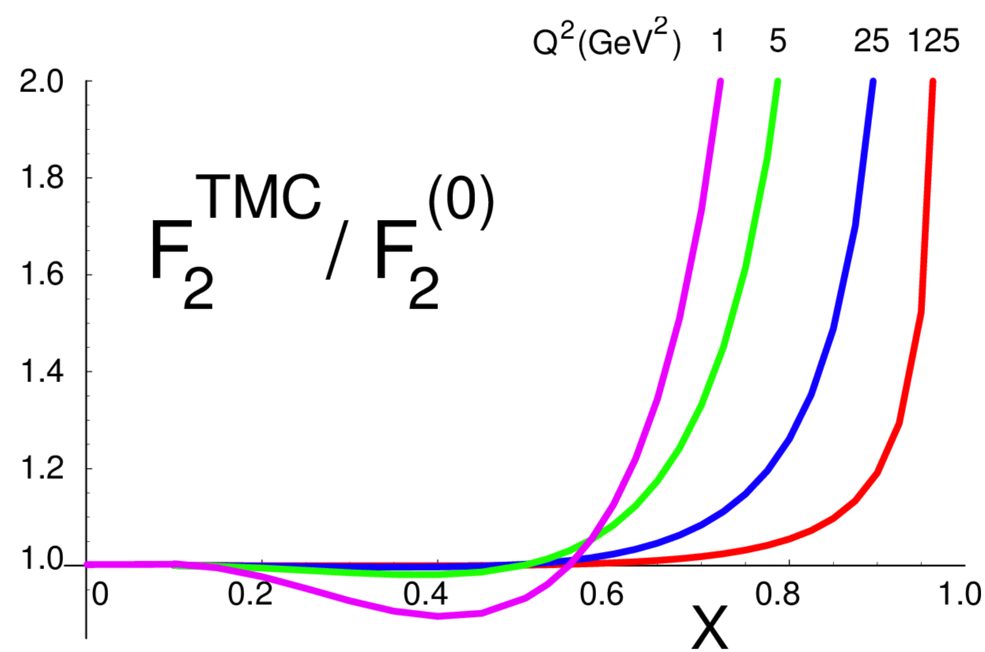
TOPICAL REVIEW

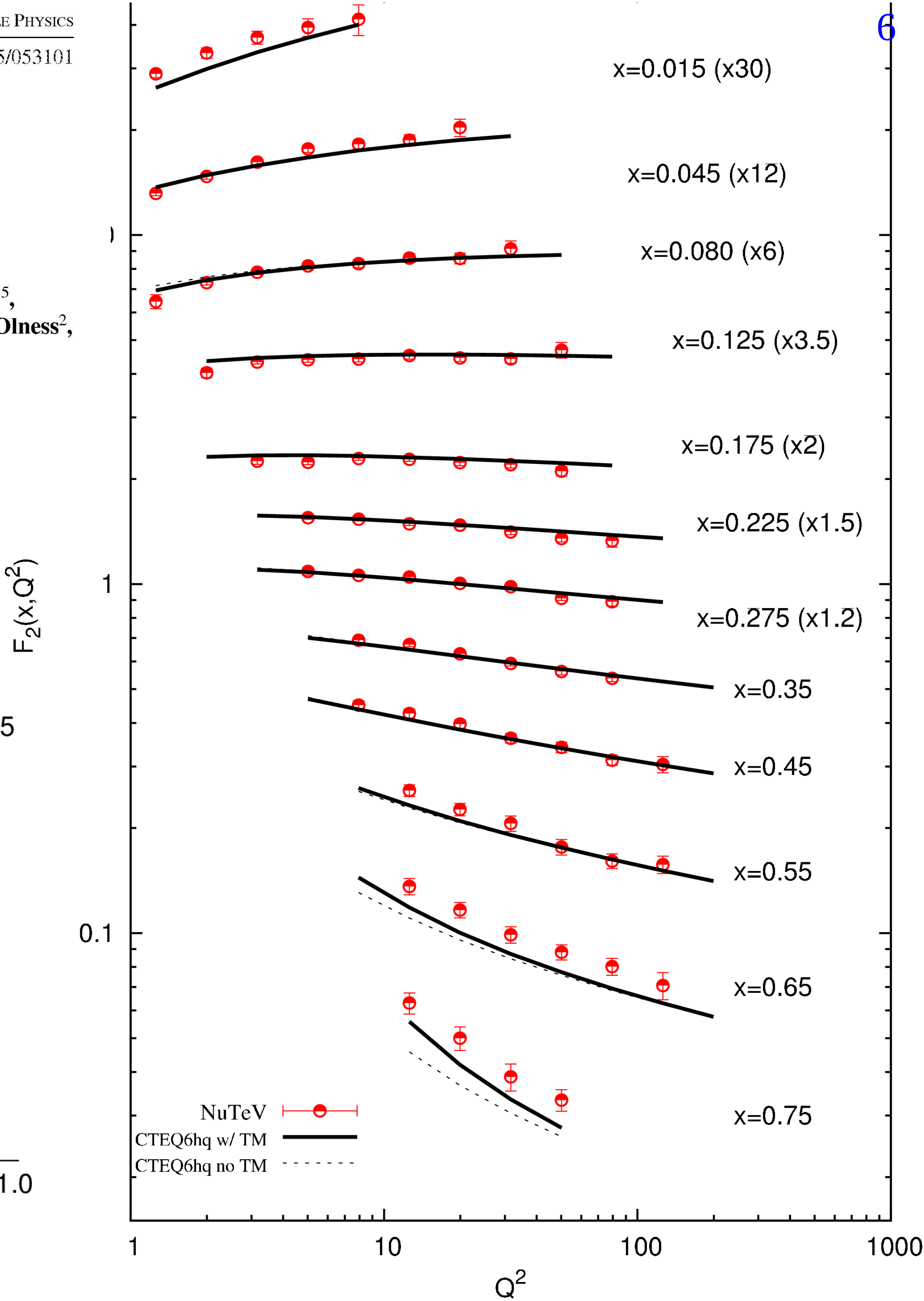
Target mass corrections

Ingo Schienbein[1,2], Voica A Radescu[3], G P Zeller[4], M Eric Christy[5], C E Keppel[5,6], Kevin S McFarland[7], W Melnitchouk[6], Fredrick I Olness[2], Mary Hall Reno[8], Fernando Steffens[9] and Ji-Young Yu[2]

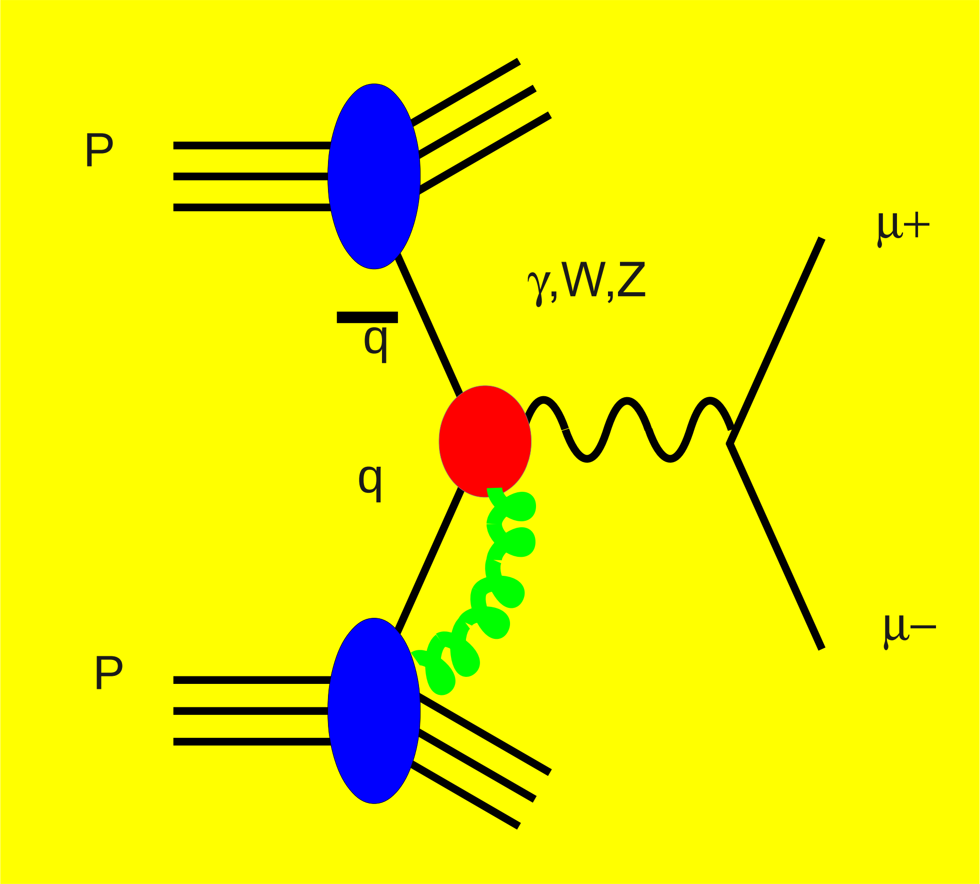
[1] Laboratoire de Physique Subatomique & Cosmologie, F-38026 Grenoble, France
[2] Southern Methodist University, Department of Physics, Dallas, TX 75275, USA
[3] Deutsches Elektronen-Synchrotron, Notkestrasse 85, D-22603 Hamburg, Germany

Target Mass Corrections





What about Higher Twist???



- Factorization breaks down
- Lose Universality
- No "First Principles" model
- ... sometimes parameterized as a Λ^2/Q^2 correction

Q: hard interaction scale
Λ: characteristic hadron scale

$(Q/\Lambda)^2$ Quality of factorization approximation

$$\sigma_{DY} = f_{P\rightarrow q} \otimes f_{P\rightarrow \bar{q}} \otimes \hat{\sigma}_{q\bar{q}\rightarrow \mu^+\mu^-}$$

Standard Wall Street Disclaimer:

Past performance
is not necessarily a guide
to future returns.

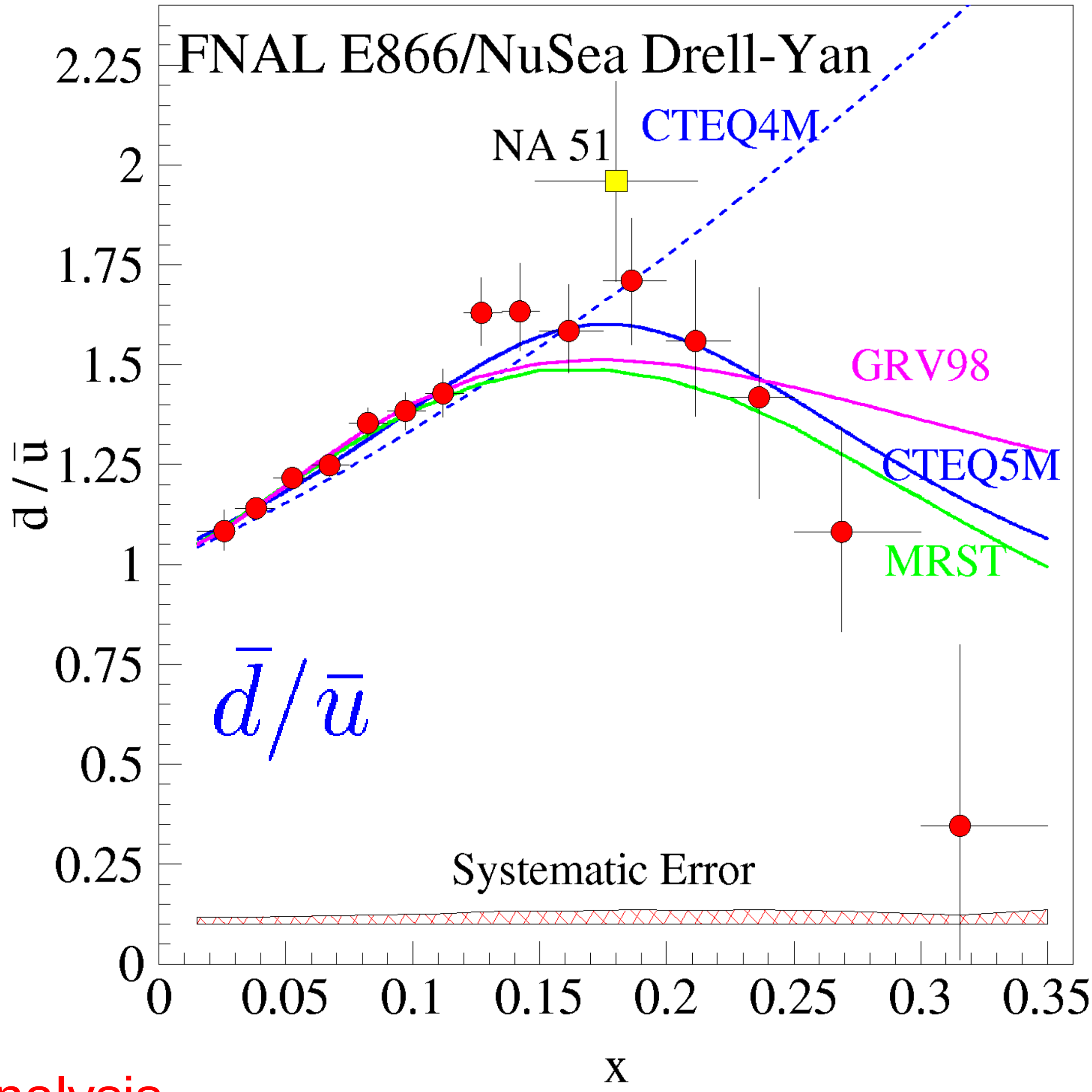
Nevertheless, lets' look at some recent history ...

E866 quark sea distributions:

Examine ratio of deuterium to hydrogen

$$\left.\frac{\sigma^{pd}}{2\sigma^{pp}}\right|_{x_b \gg x_t} \approx$$

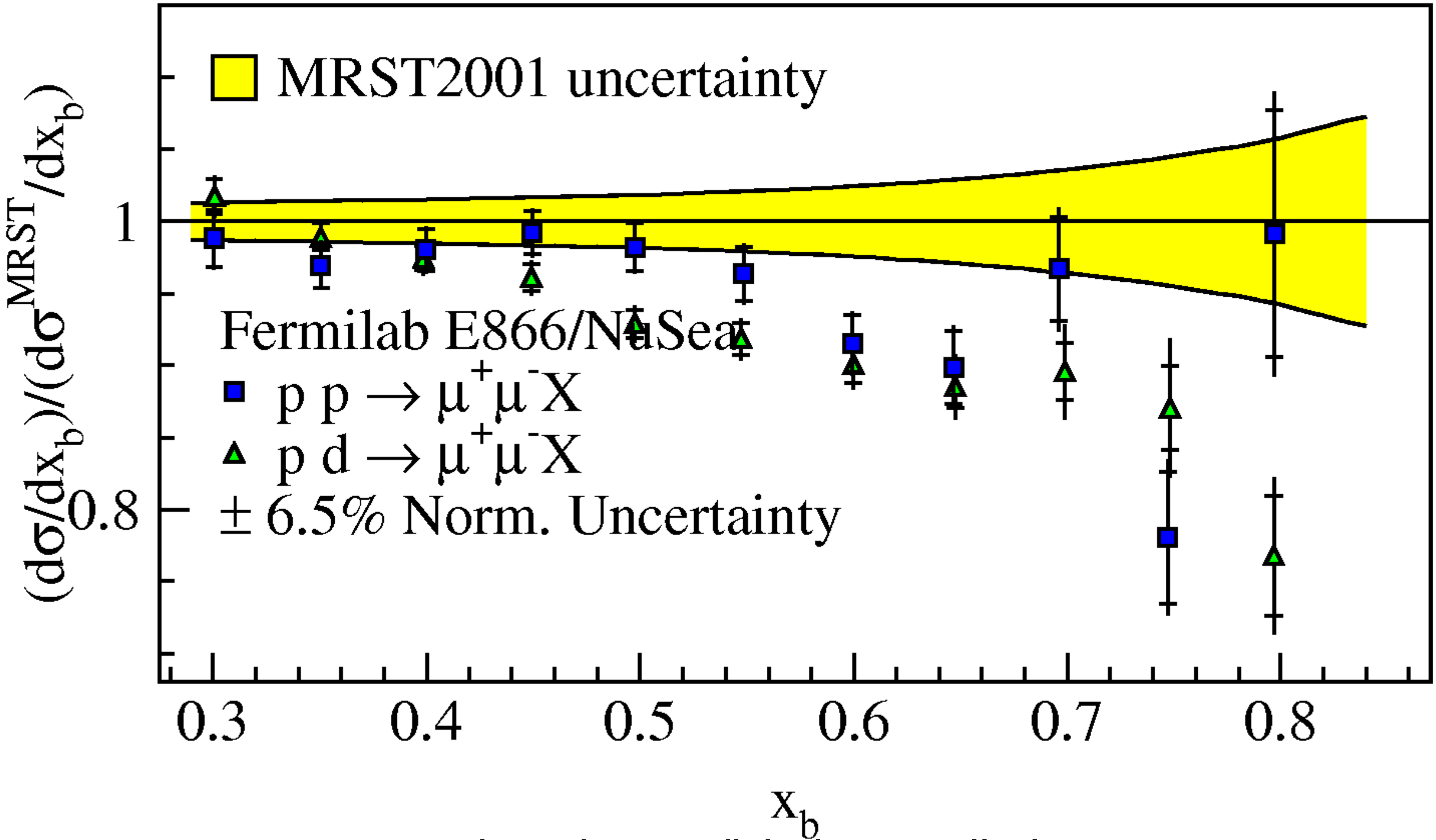
$$\approx \frac{1}{2}\left[1 + \frac{\bar{d}(x_t)}{\bar{u}(x_t)}\right]$$



Even for a “mature” analysis, new data can have a large impact

Let's look at large x

Drell-Yan Cross Section in large x limit

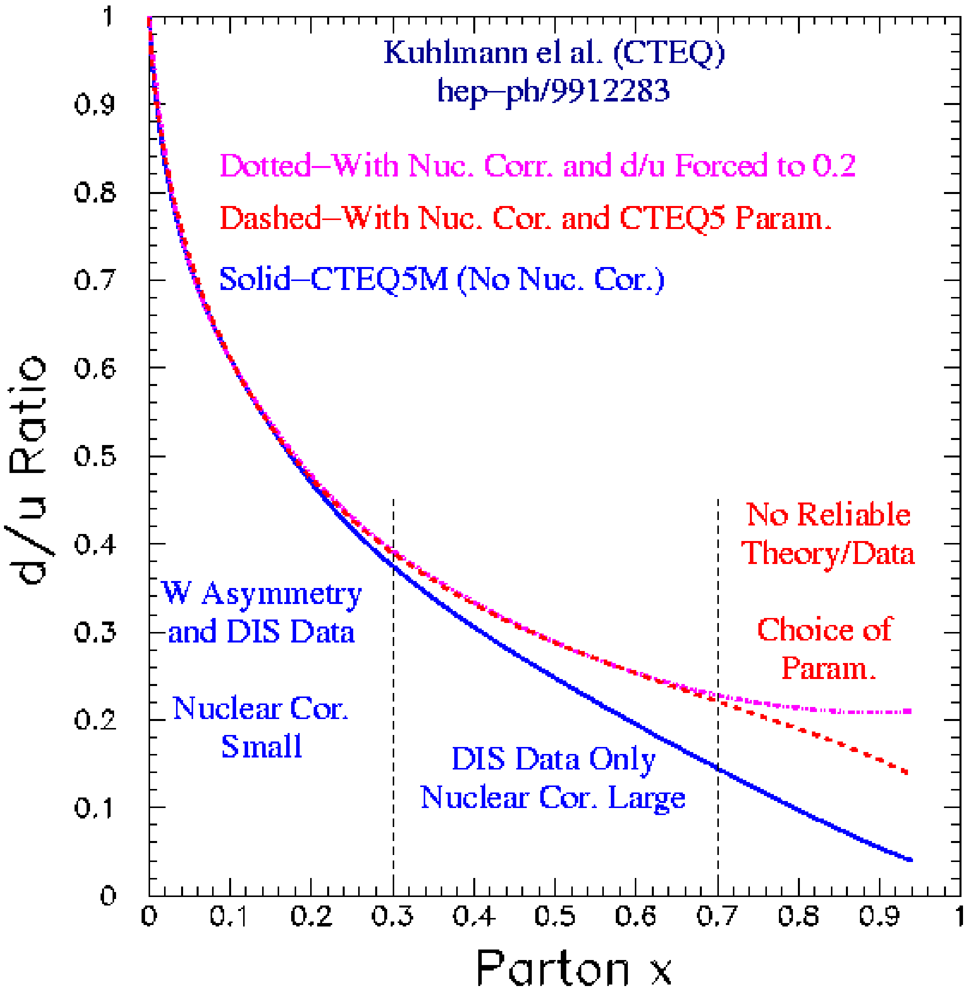


dσ ~ (4 u + d) in large x limit

Theory over estimates data in this limit

J. C. Webb, et al. [NuSea Collaboration], hep-ex/0302019

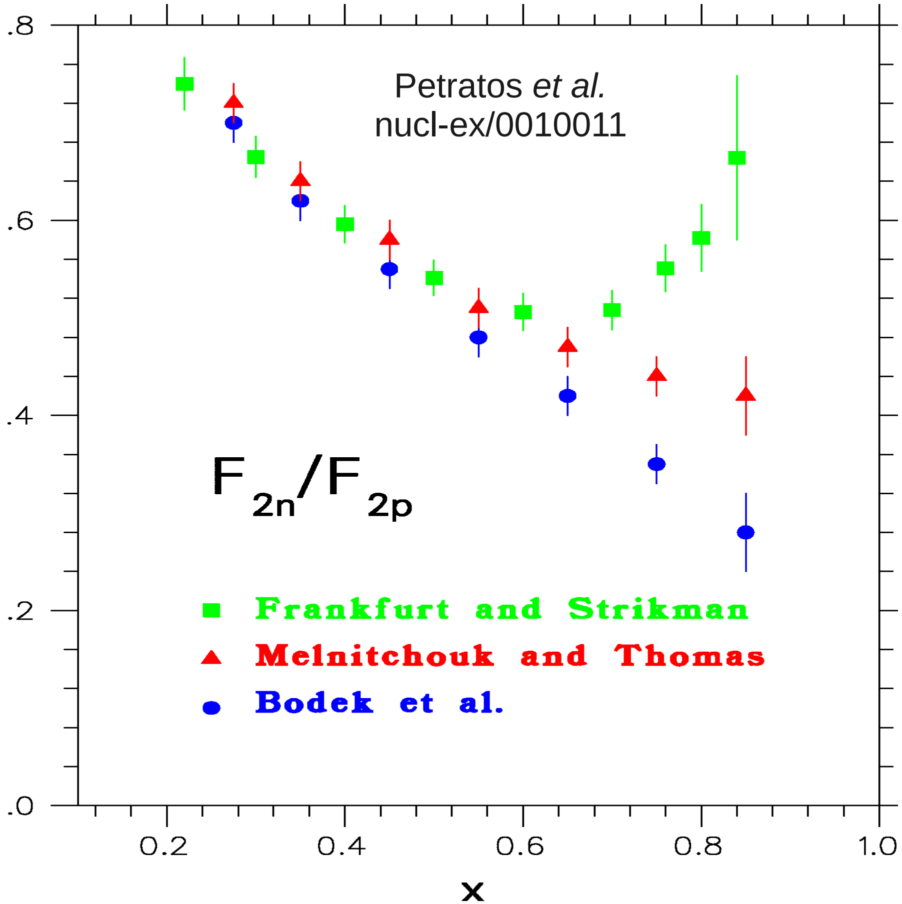
Proton Valence Structure: d/u for large x



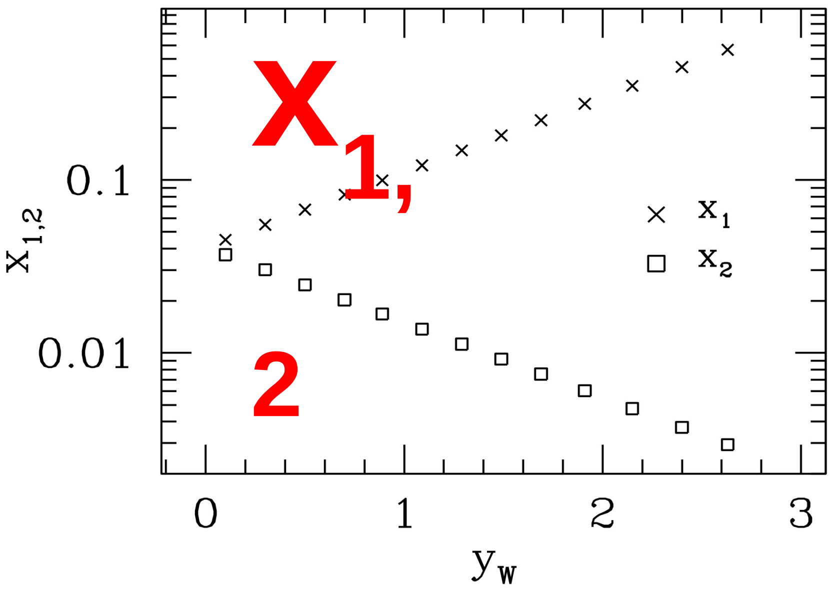
For large x, nuclear binding/Fermi motion corrections are important

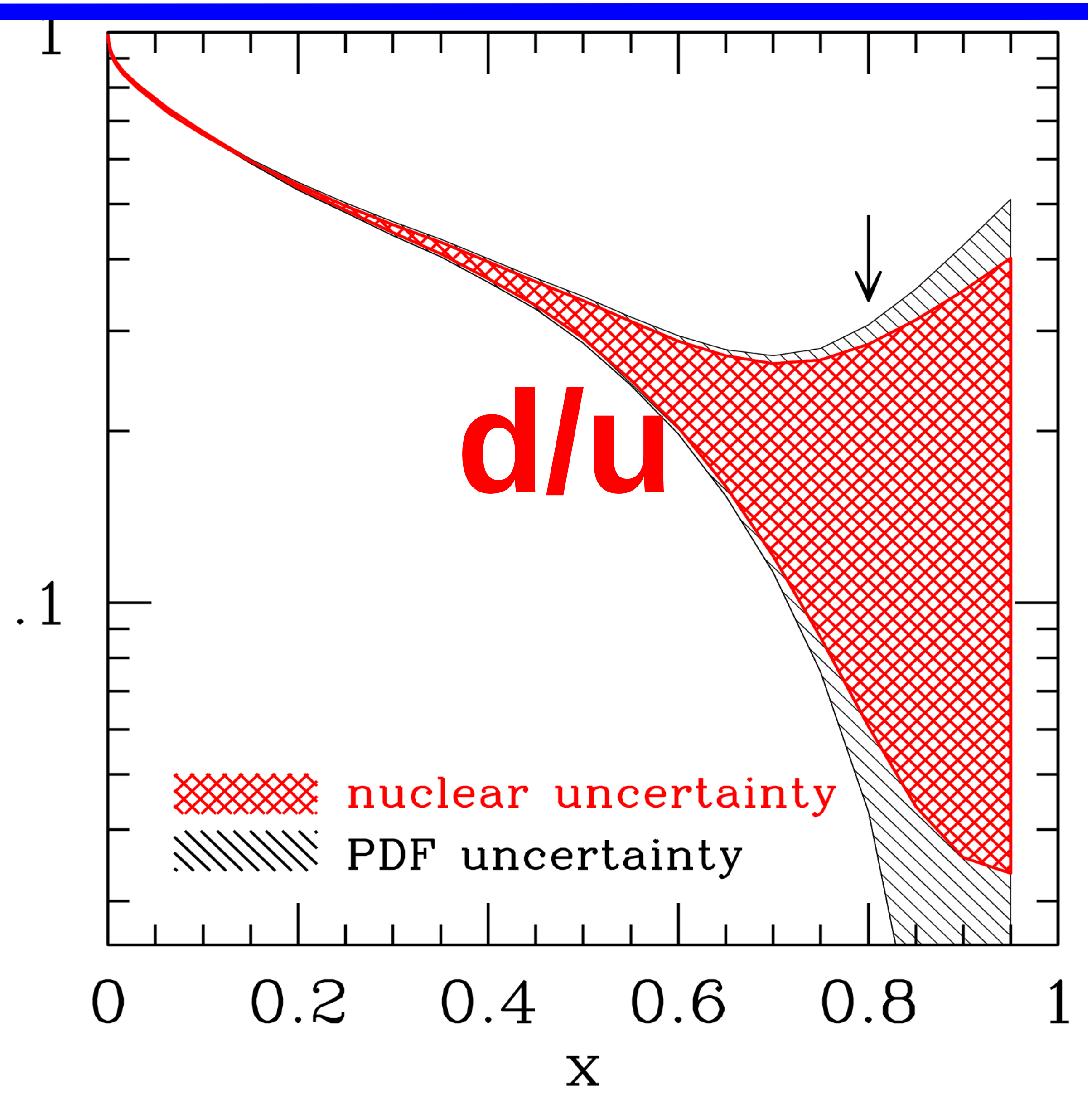
Even Deuterion has large effects

Lots of models to choose from



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





Determined from DIS and DY on p and d

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

LHC values scaled appropriately

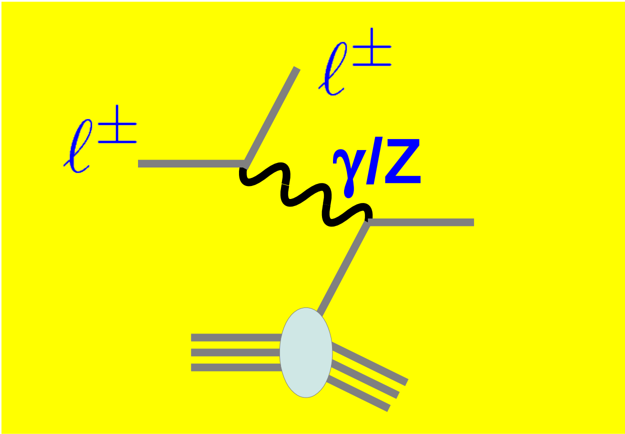
Uncertainties in determining parton distributions at large x.
A.Accardi, W.Melnitchouk, J.F.Owens, M.E.Christy, C.E.Keppel, L.Zhu, J.G.Morfin
arXiv:1102.3686 [hep-ph]

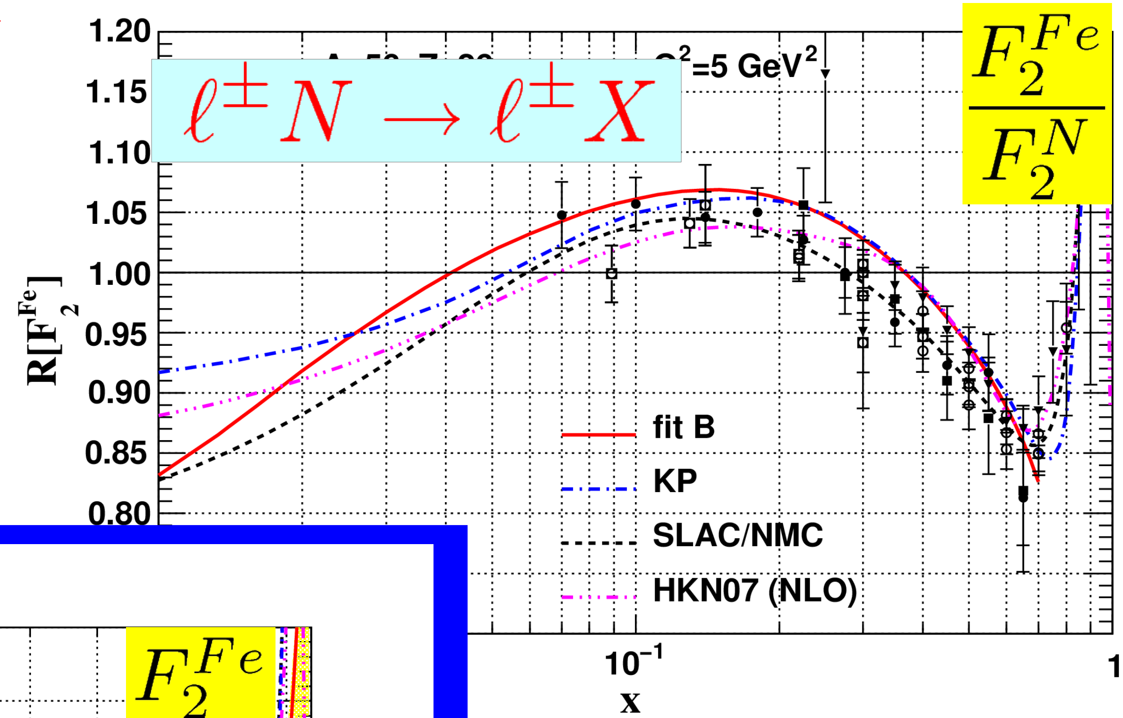
… plenty of puzzles to ponder

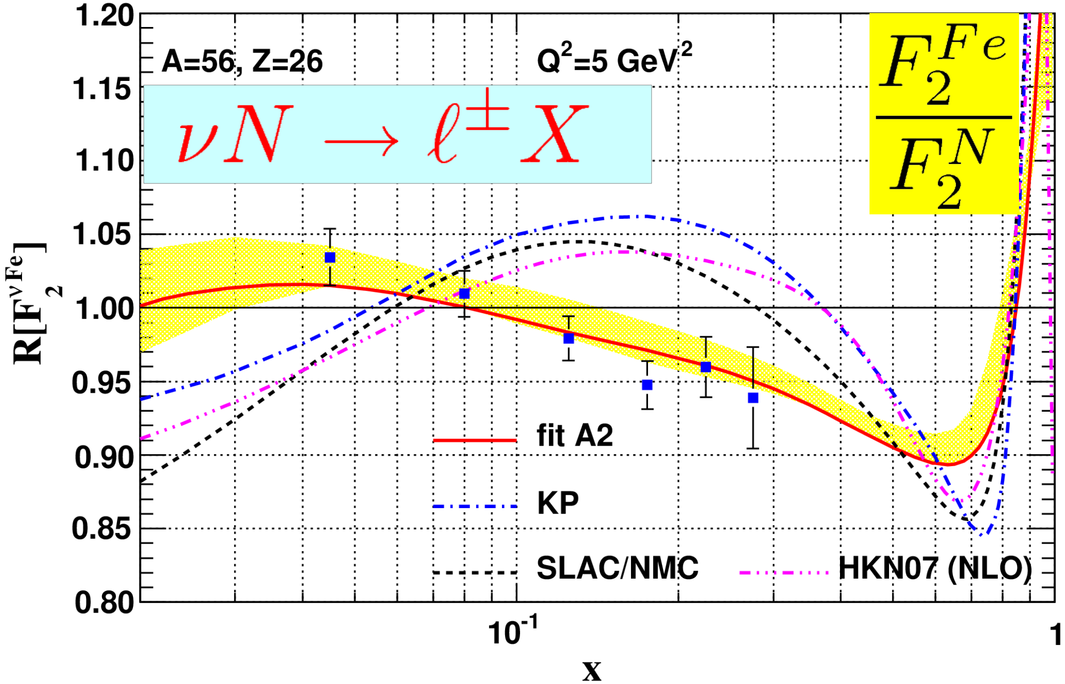
Nuclear A Dependence

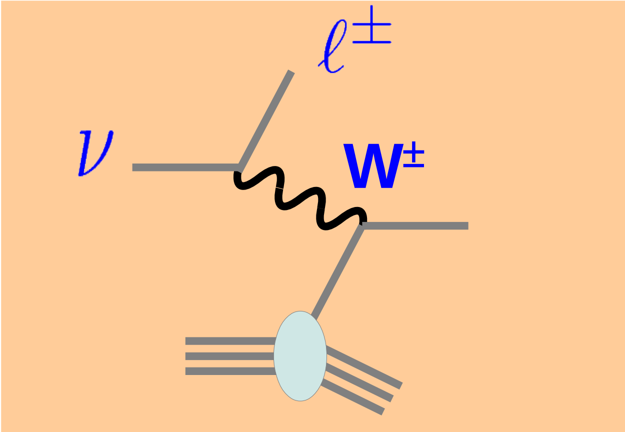
Nuclear Corrections: Compare Neutrino and Charged Lepton

Charged Lepton DIS ⇒









⇐ Neutrino DIS

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...

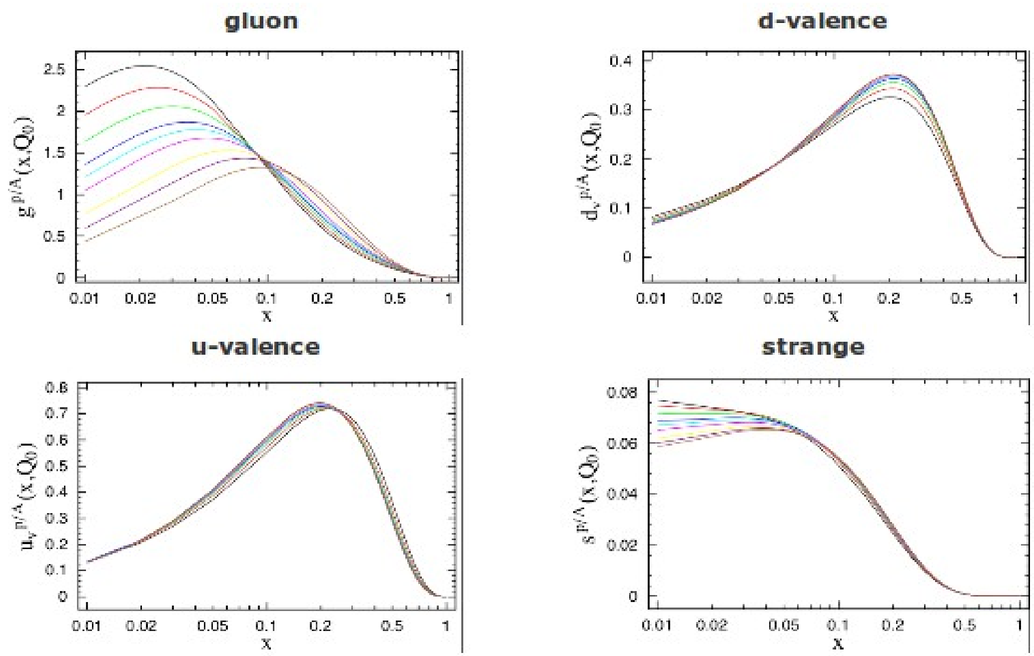
nCTEQ Go! hosted by CEDAR HepForge

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;

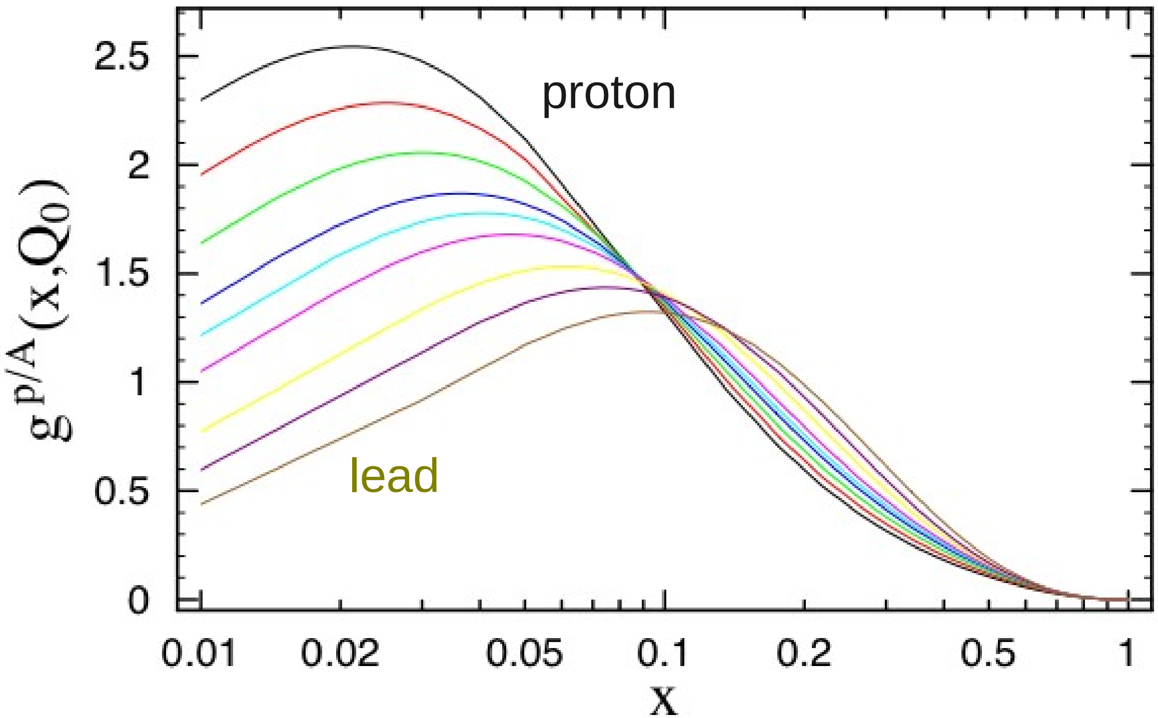
NLO fits work well

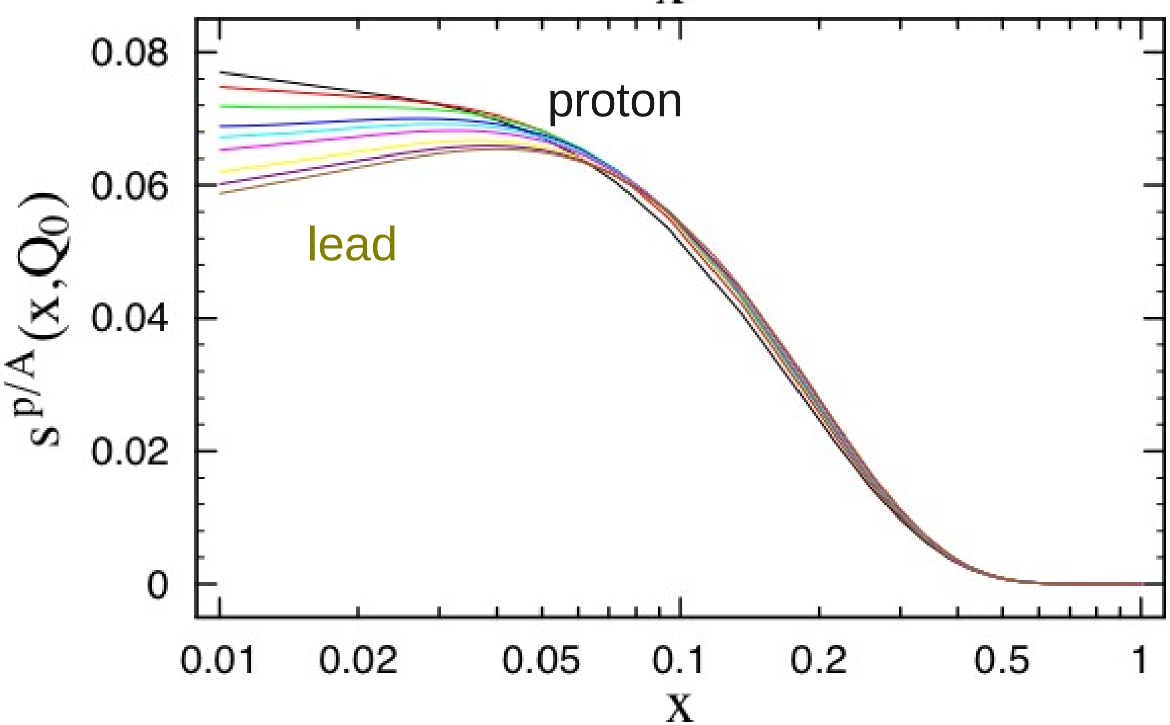
A-Dependent PDFs

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

$$a_i \to a_i(A)$$

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





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.

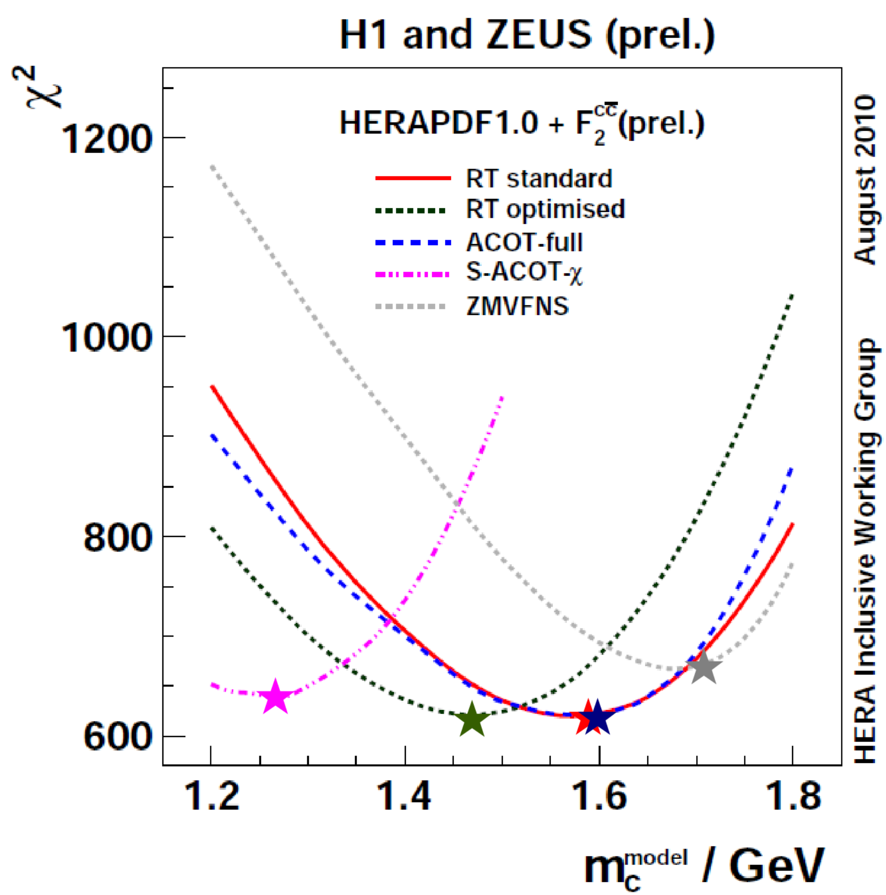
Heavy Quark Topics

What is the proper treatment of masses???

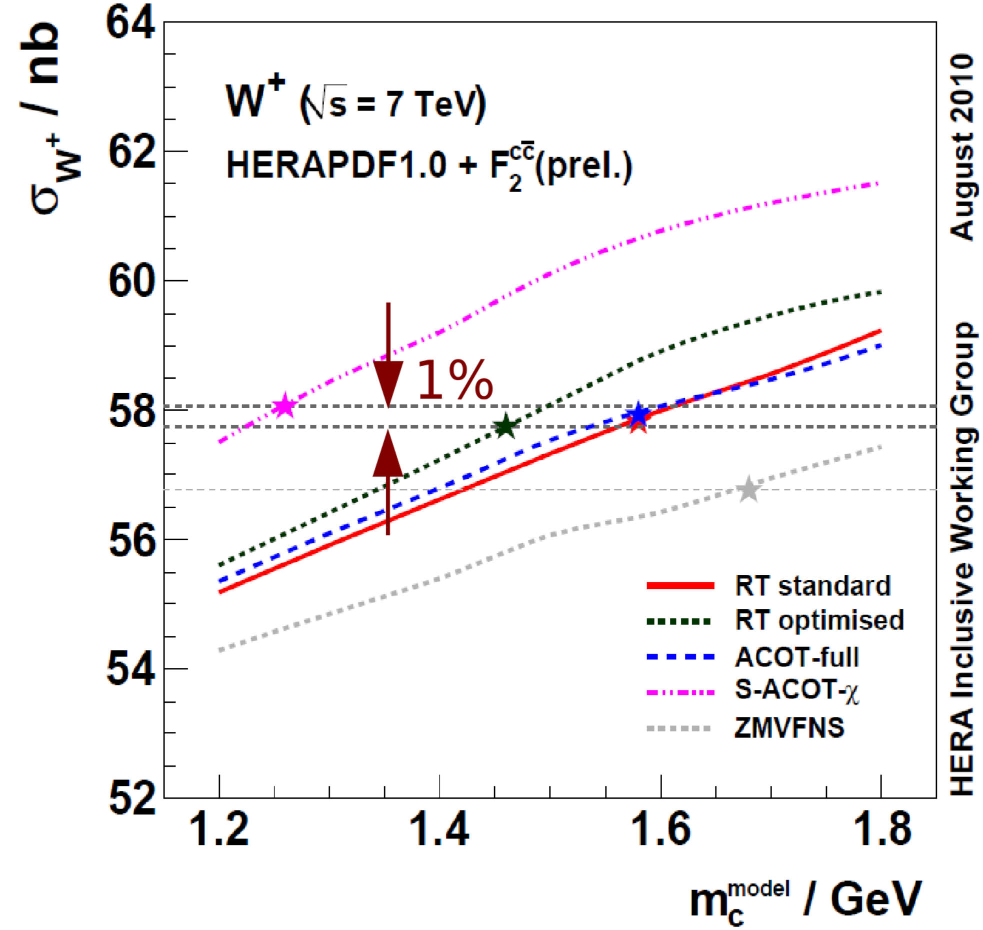
Constraints on PDFs from HERA Charm Data

Ringaile Placakyte

Inclusive ep data + F_2^{cc}
for different HQ schemes

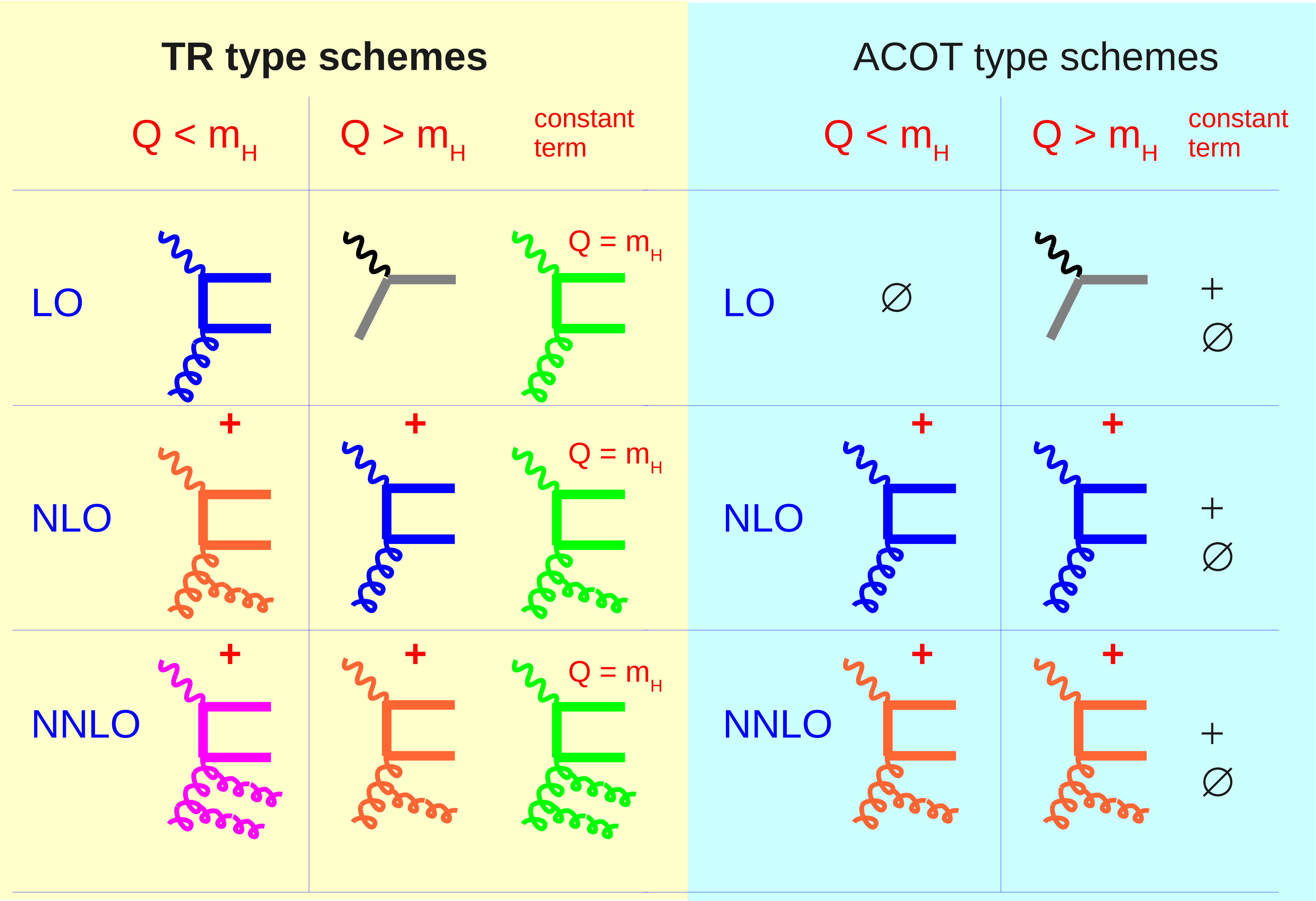


Impact of mc on W σ at LHC



Different HQ schemes have different optimal m_c^{model}

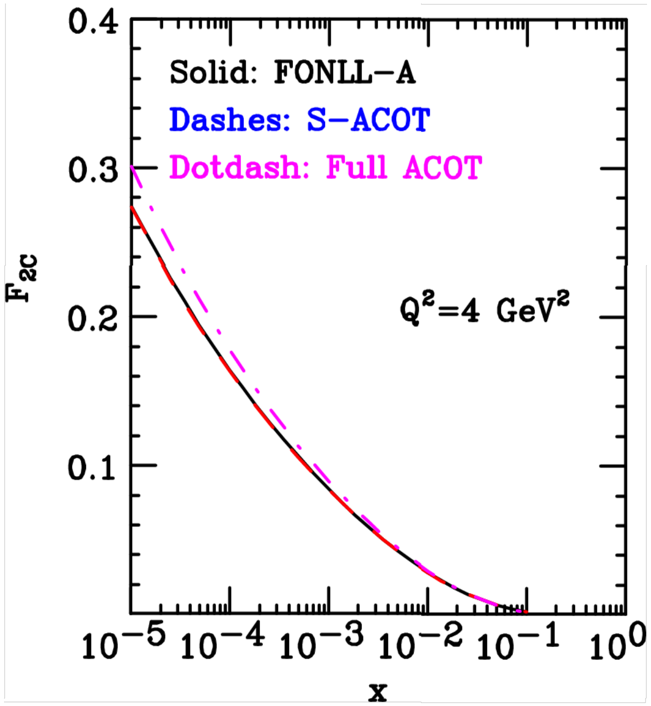
Schematic Summary of ACOT & TR Schemes

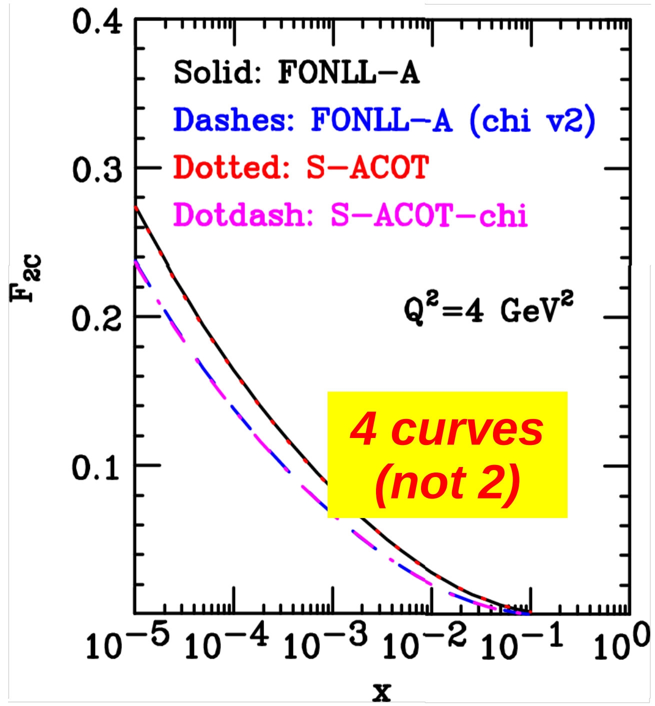


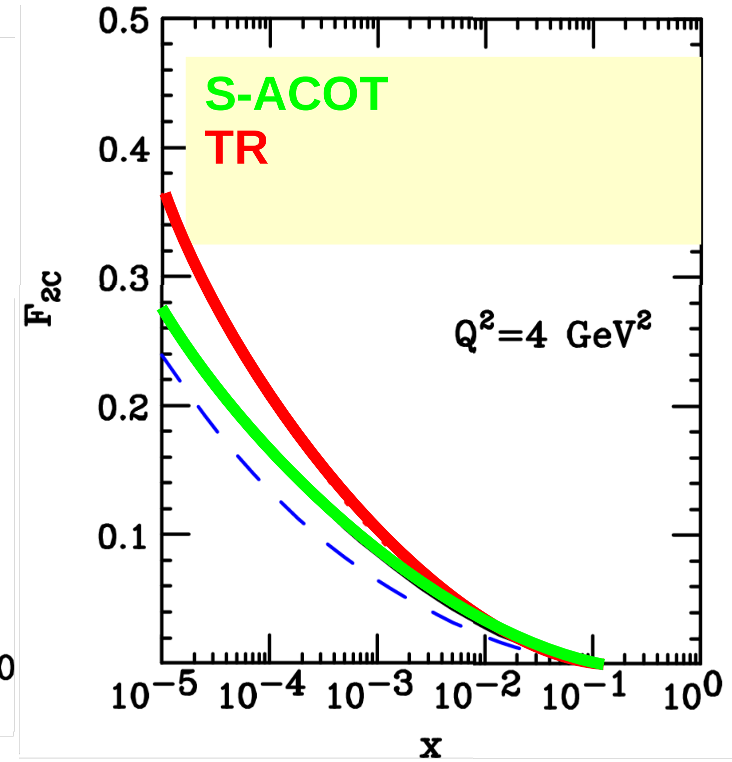
2009 Les Houches Comparative Studies

The SM and NLO Multileg Working Group: Summary report.
e-Print: arXiv:1003.1241 [hep-ph]

Les Houches Comparative Study







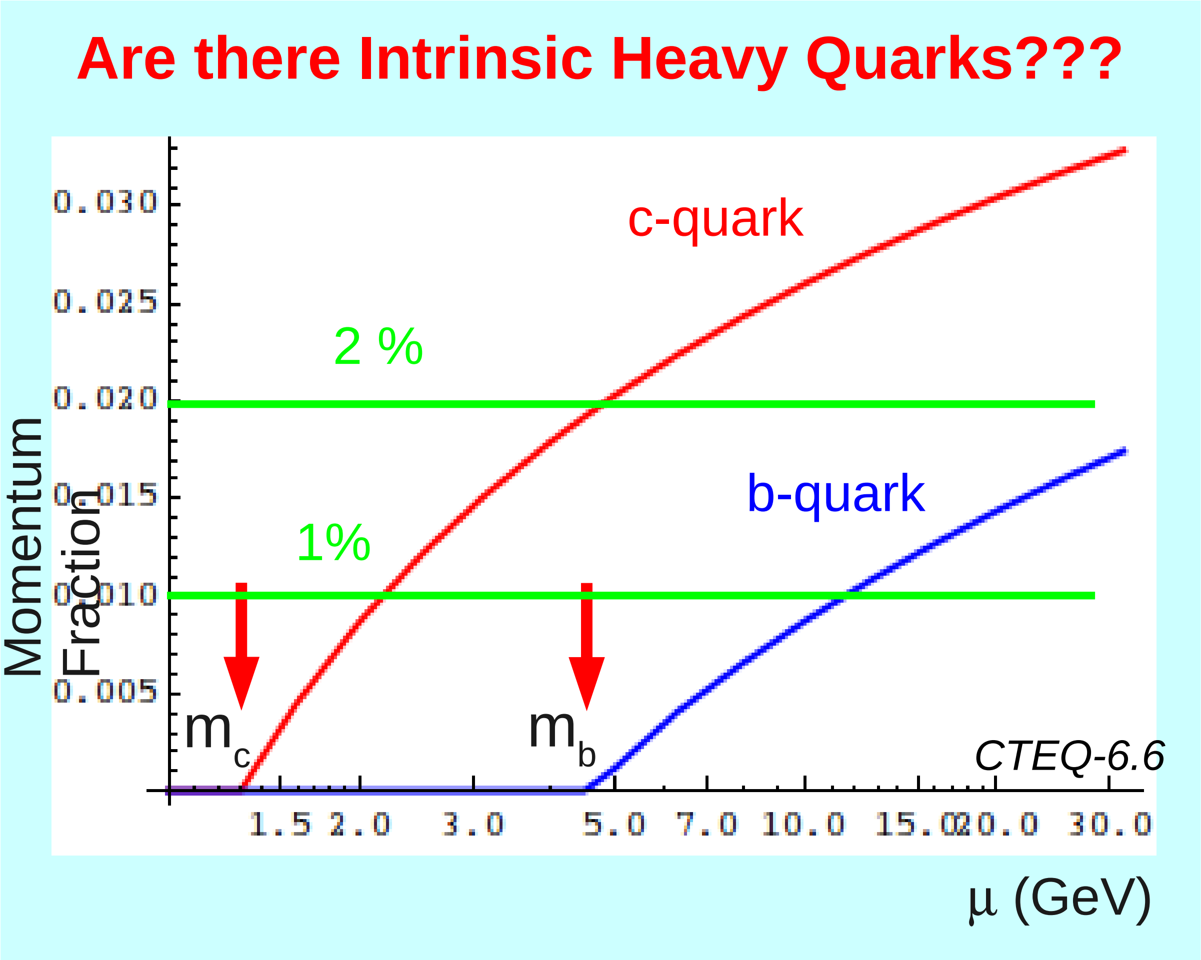
ACOT & S-ACOT essentially identical
... scheme differences are higher order

FONNL & S-ACOT
Numerically similar

MSTW09
We can quantify <u>theoretical</u> scheme diffferences

The SM and NLO Multileg Working Group: Summary report.
J. Rojo, et al., e-Print: arXiv:1003.1241 [hep-ph]

Are there Intrinsic Heavy Quarks??? Do they matter???



- ∗ Most sensitive near threshold
- * What happens if we allow the evolution to determine charm?

Zero: No intrinsic charm
Positive: Intrinsic charm
Negative: Inconsistent

Also, the 2-scale problem: {m,Q}

Final thoughts

Anti-Proton Drell-Yan Issues and Opportunities

Precision measurements in a new kinematic regime reinforce our Standard Model foundation

As experimental precision has increased, we need to be concerned about the details

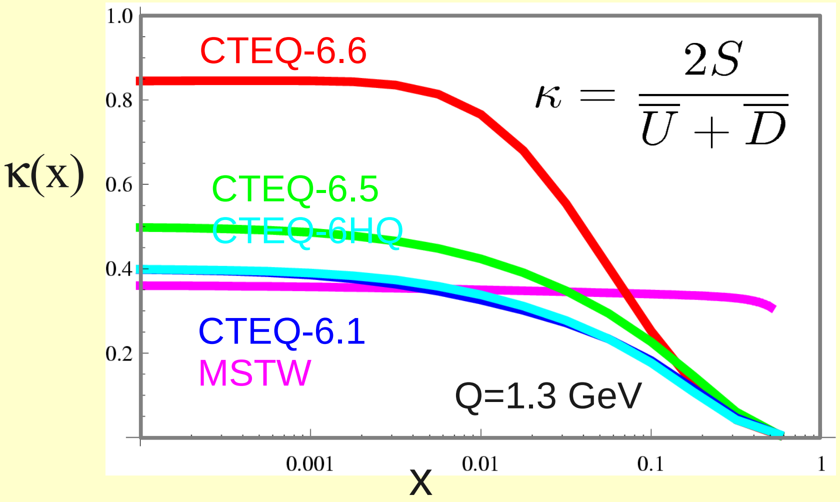
- TMC & Higher Twist
- PDFs at Large X
- Nuclear A dependence
- Proper treatment of quark mass
- Resolution of outstanding puzzles

… ideas for further study

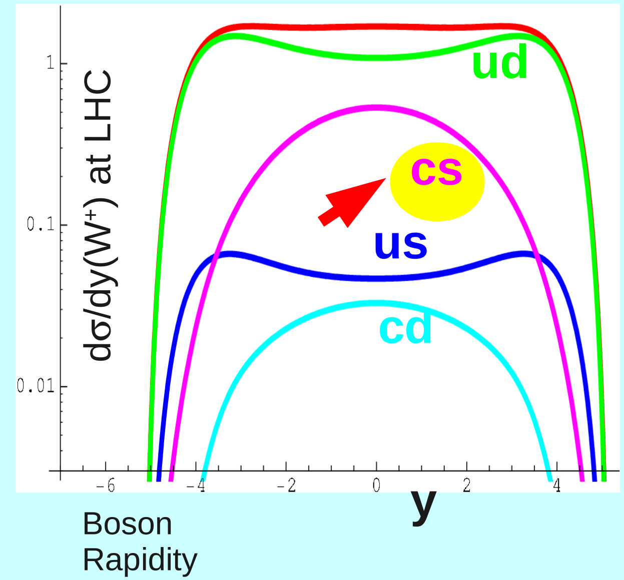
BACKUP

Heavy Quark Topics

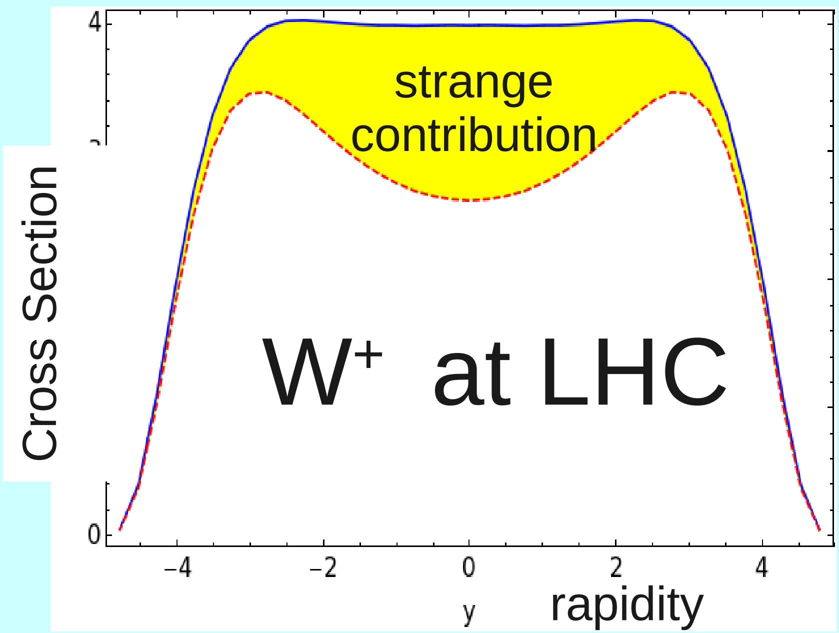
strange



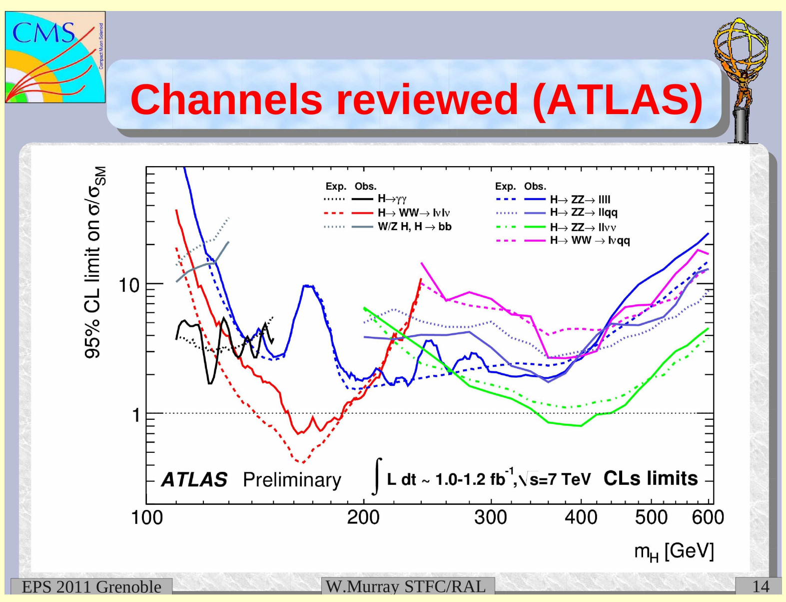
We're not sure how strange is the proton



Uncertainty in W/Z



Uncertainty in Benchmark process



Limited Discovery Potential