PDF & nPDF Fits

What happens ÄFTER the Higgs

Fred Olness

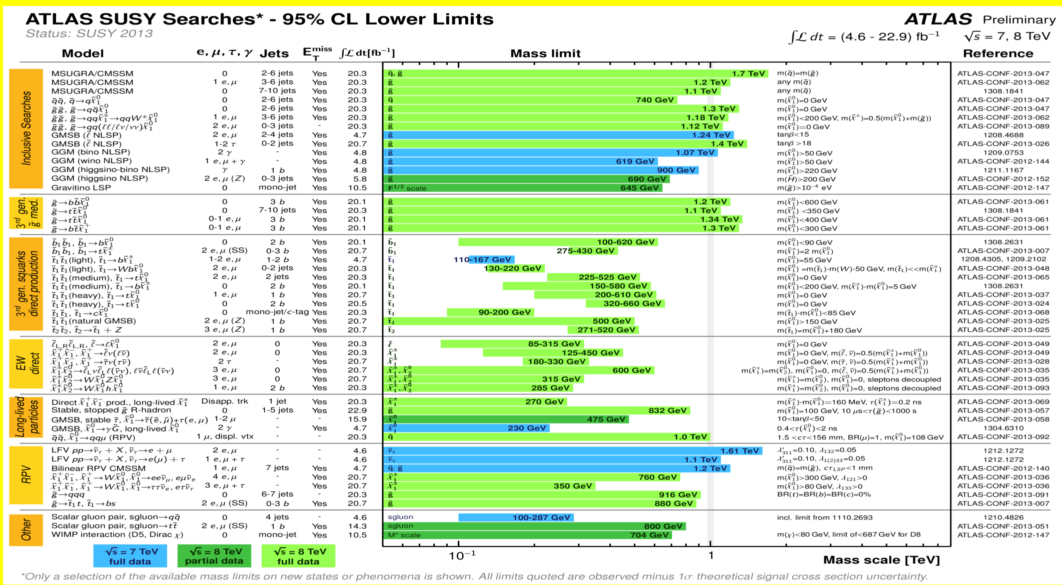
SMU

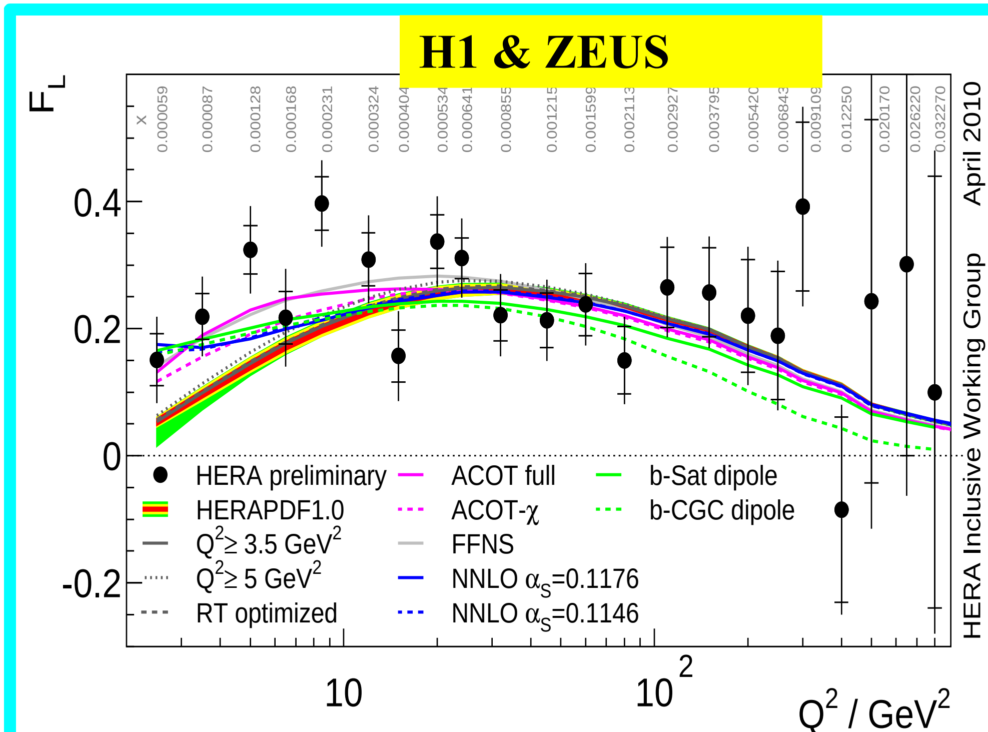
Conspirators:

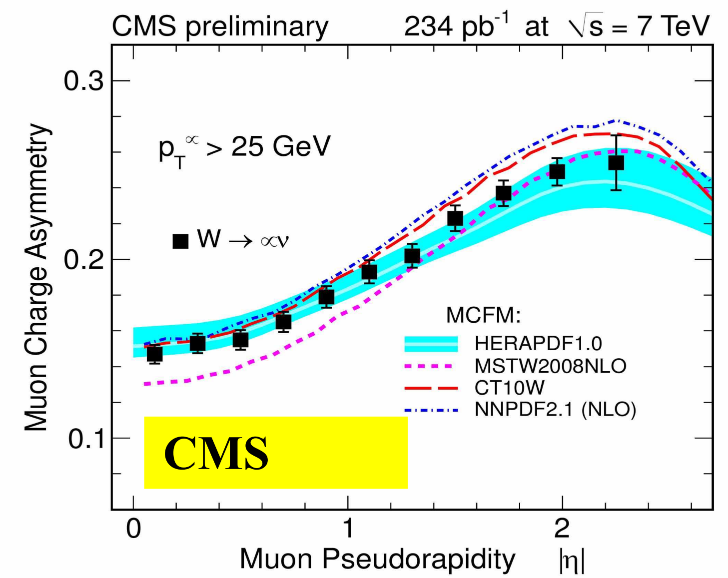
A. Kusina,, I. Schienbein, K. Kovarik, J.Y. Yu, T. Stavreva, T. Jezo,
J.G. Morfin, J.F. Owens P. Nadolsky, M. Guzzi, C. Keppel, B. Clark

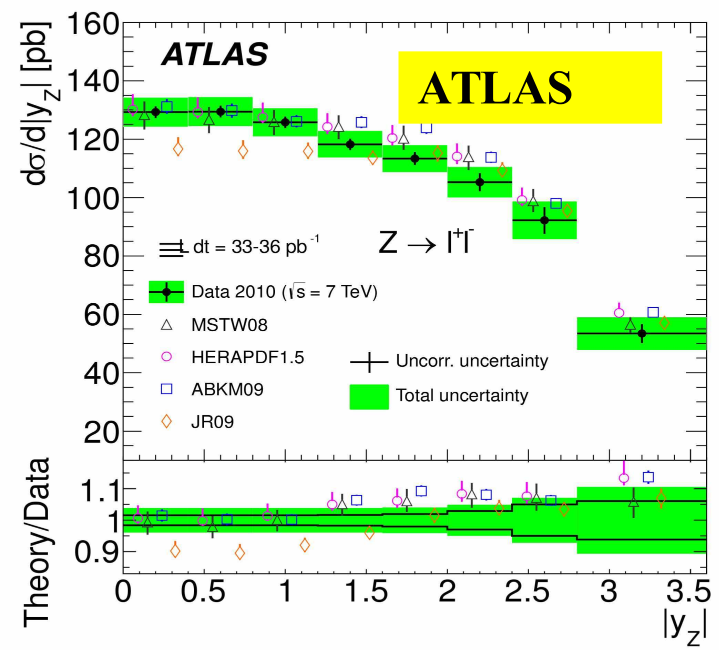
Les Houches
14 January 2014

Recent Measurements Spectacular:



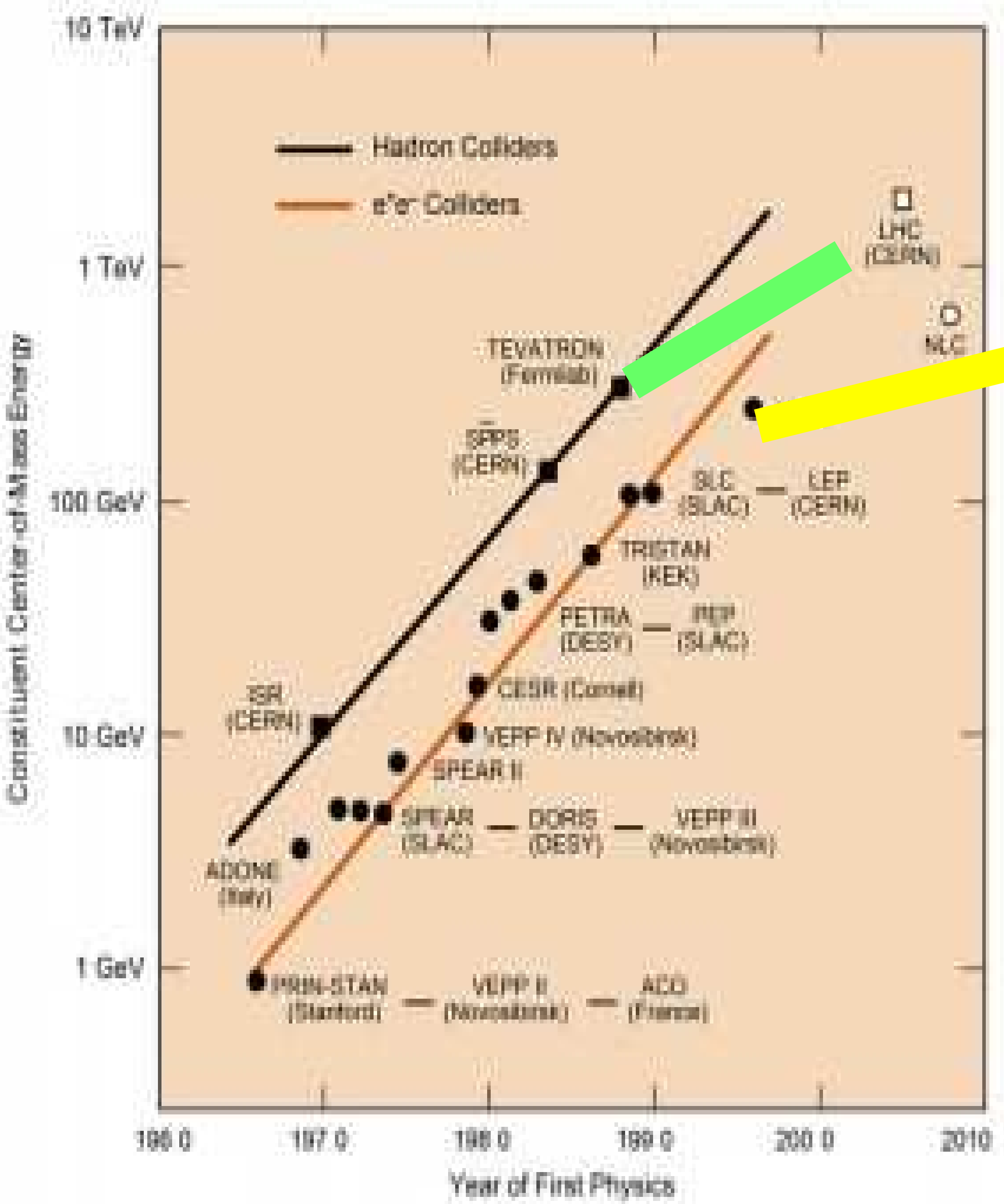






Jan Kretzschmar, 7.3.2012 – p.5

What Physics is AFTER the Higgs Discovery???



Hadron colliders

Intersecting Storage Rings	CERN, 1971–1984
Super Proton Synchrotron	CERN, 1981–1984
ISABELLE	BNL, cancelled in 1983
Tevatron	Fermilab, 1987–2011
Relativistic Heavy Ion Collider	BNL, 2000–present
Superconducting Super Collider	Cancelled in 1993
Large Hadron Collider	CERN, 2009–present
High Luminosity Large Hadron Collider	Proposed, CERN, 2020–
Very Large Hadron Collider	Theoretical

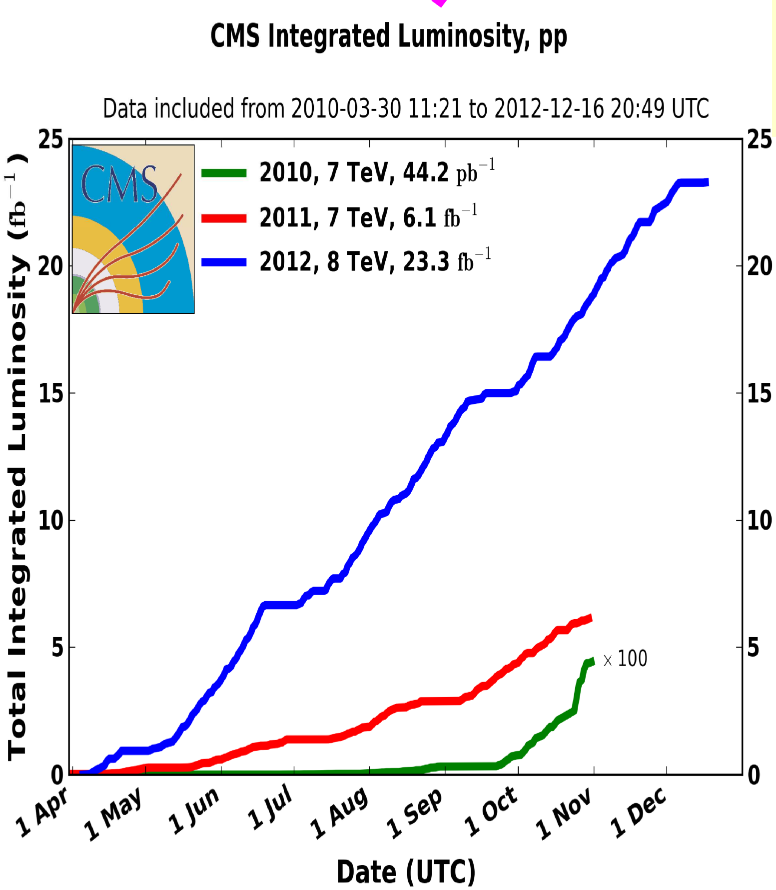
The Parton Model and Factorization

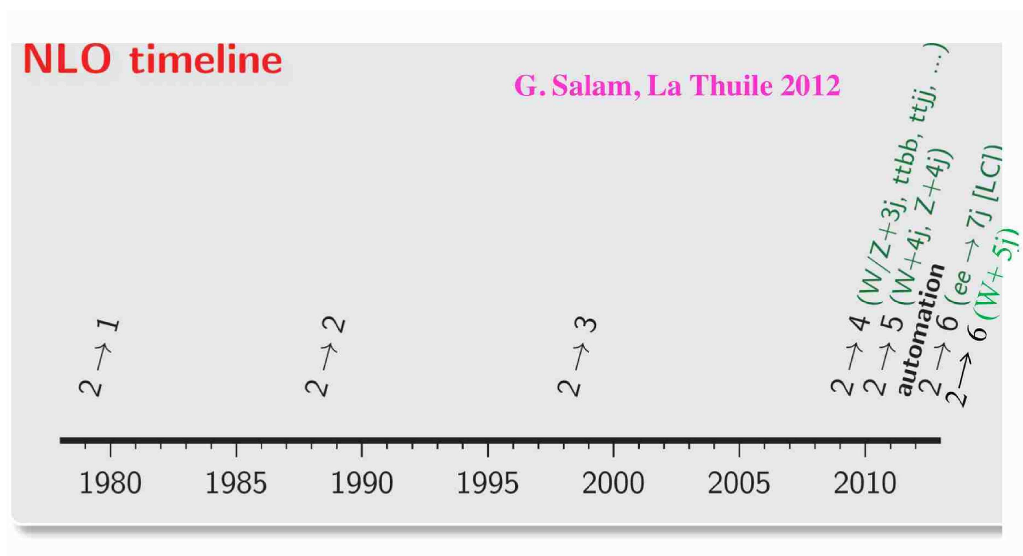
$$\sigma_{P\gamma\to c} = f_{P\to a} \otimes \hat{\sigma}_{a\gamma\to c}$$

Experimental Observables

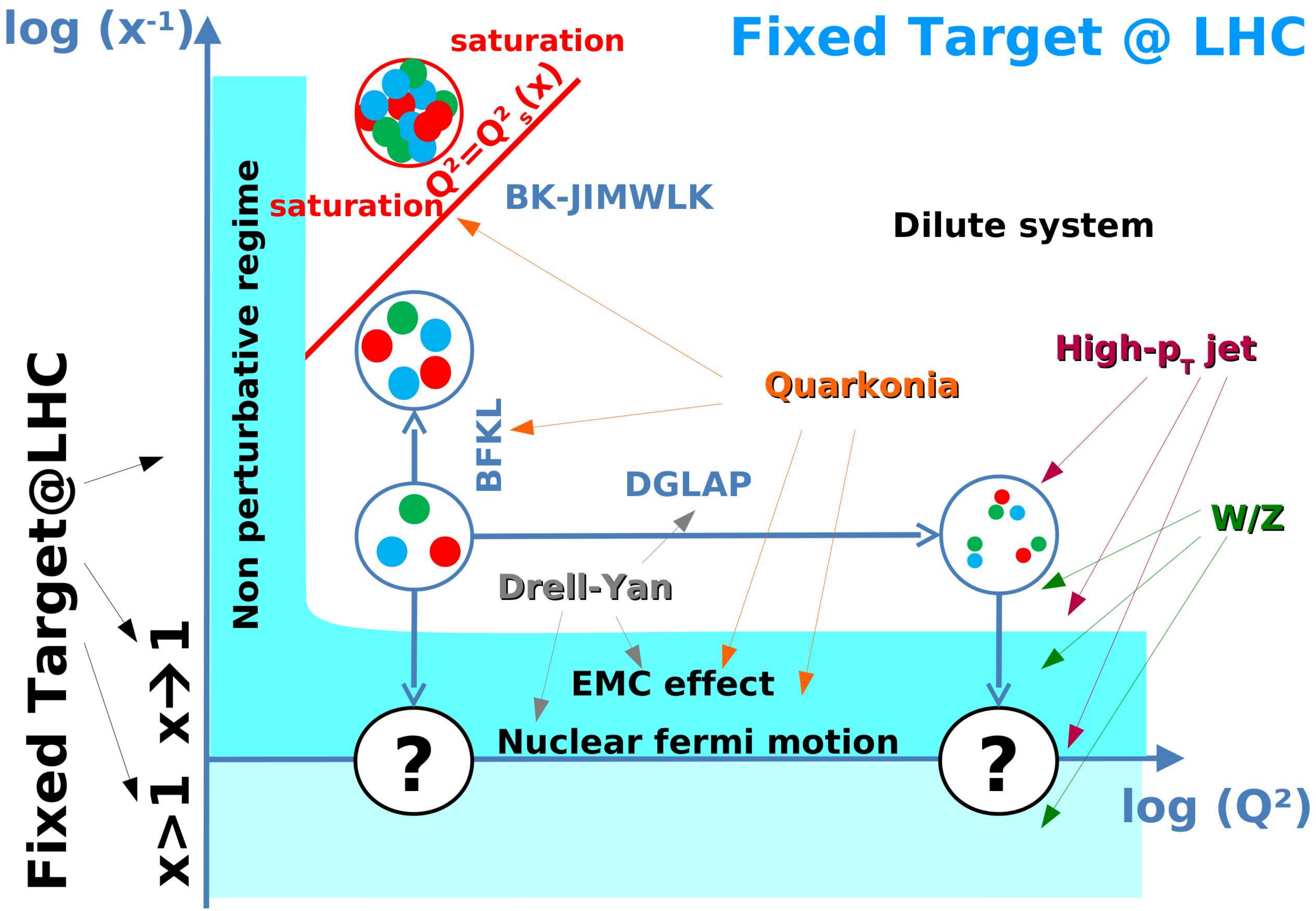
WHAT ABOUT PDF'S ???

Theoretical Calculations



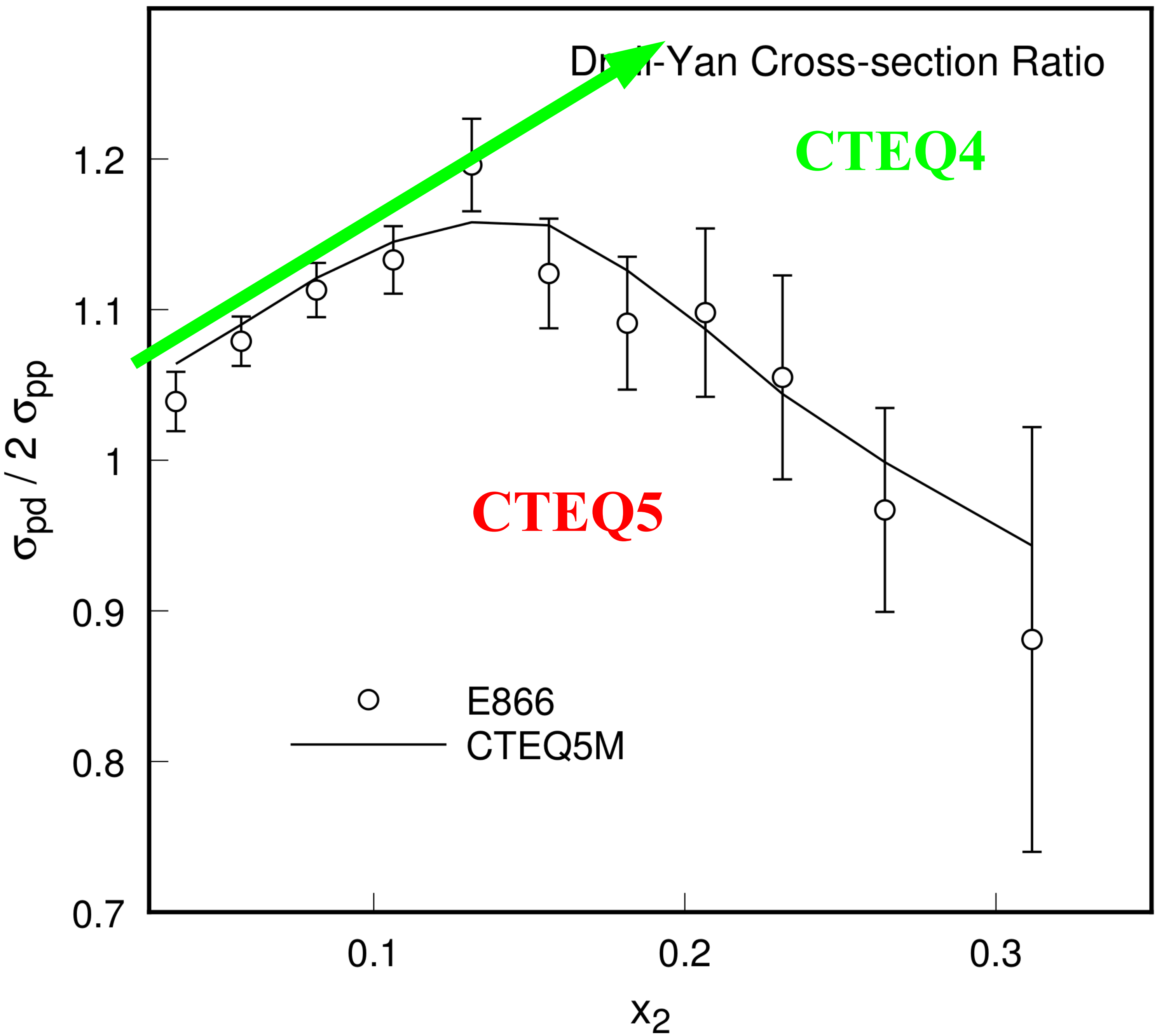


The PDF f(x,Q) and the {x,Q} plane



Challenging, but large kinematic regime is essential

How one experiment can make a difference



Some issues we encounter:

1) Nuclear Corrections

2) Heavy Quarks &
Intrinsic Components

3) High X

4) Isospin Symmetry

Without a good foundation ...

W/Z Production

"Benchmark Calculations"

...influence of Fixed-Targets at LHC

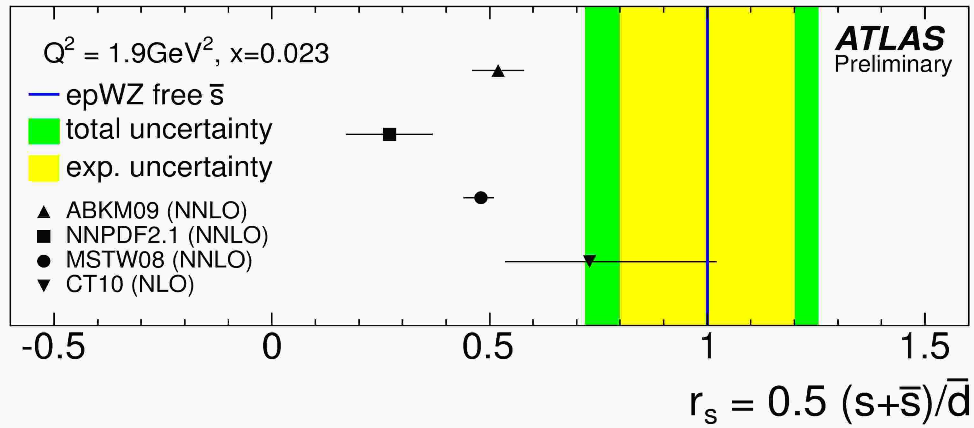
An example

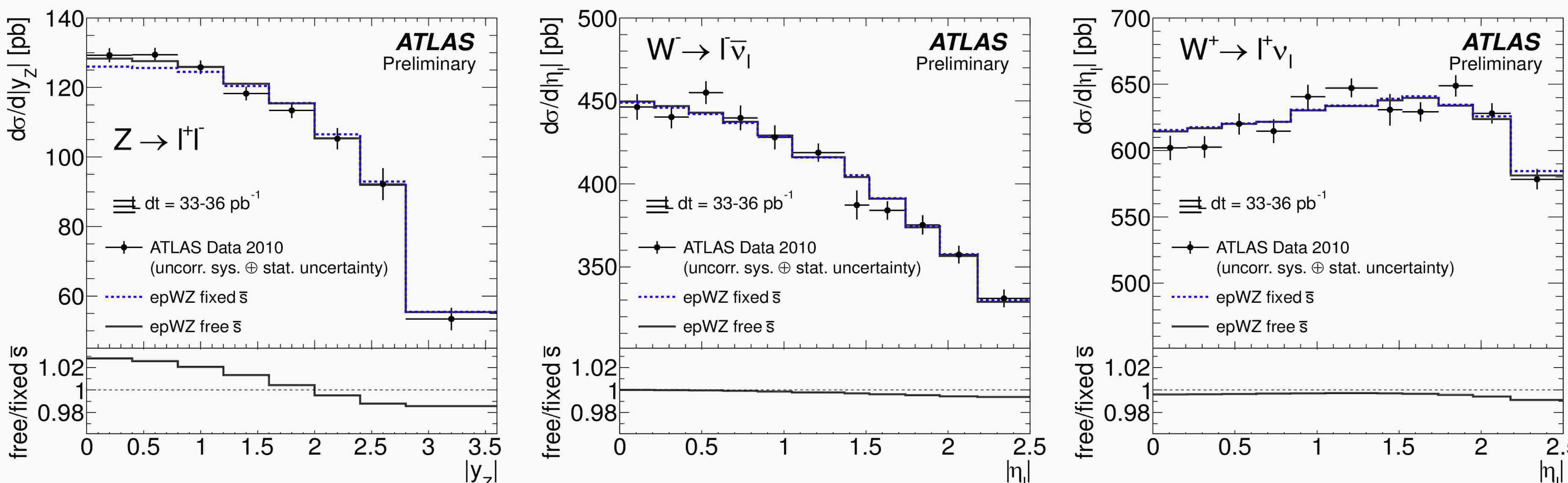
W, Z data sensitivity to strange sea

- 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

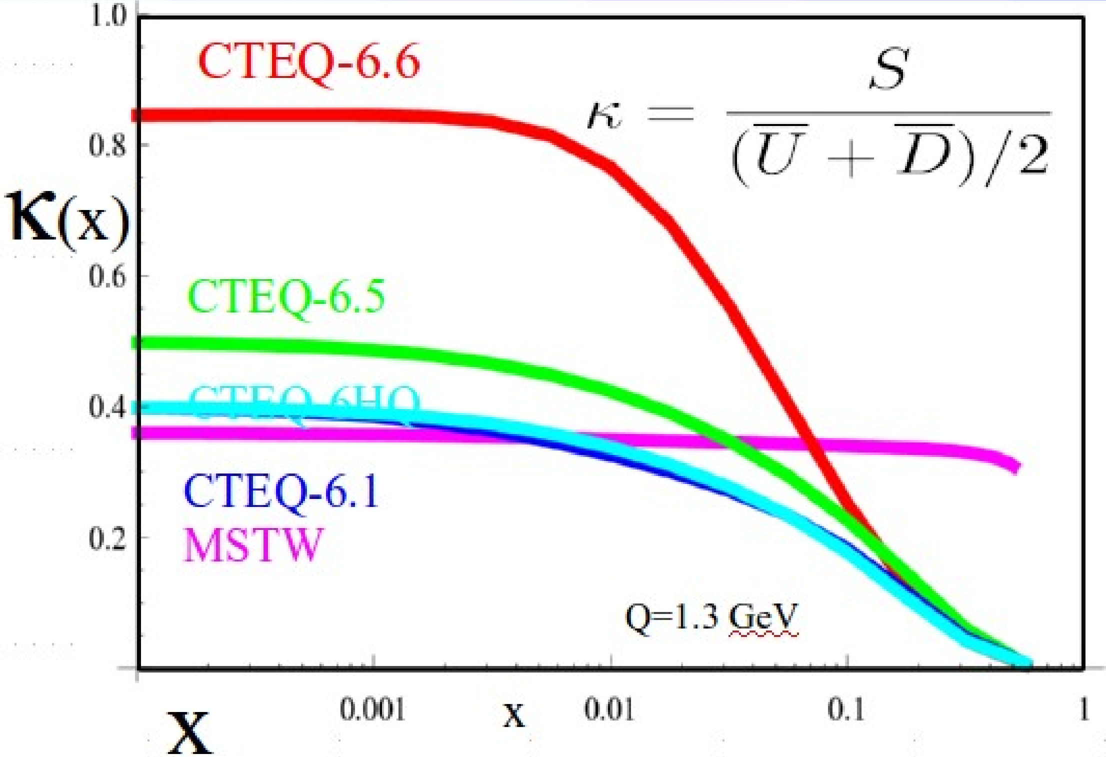
$$r_s = 1.00 \pm 0.20_{\mathrm{exp}}\ {}^{+0.16}_{-0.20\ \mathrm{sys}}$$

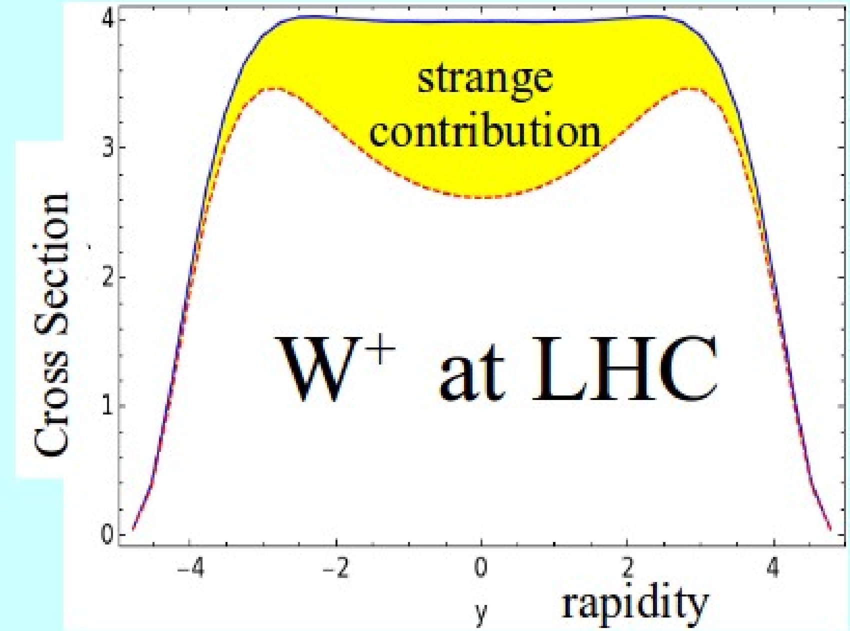


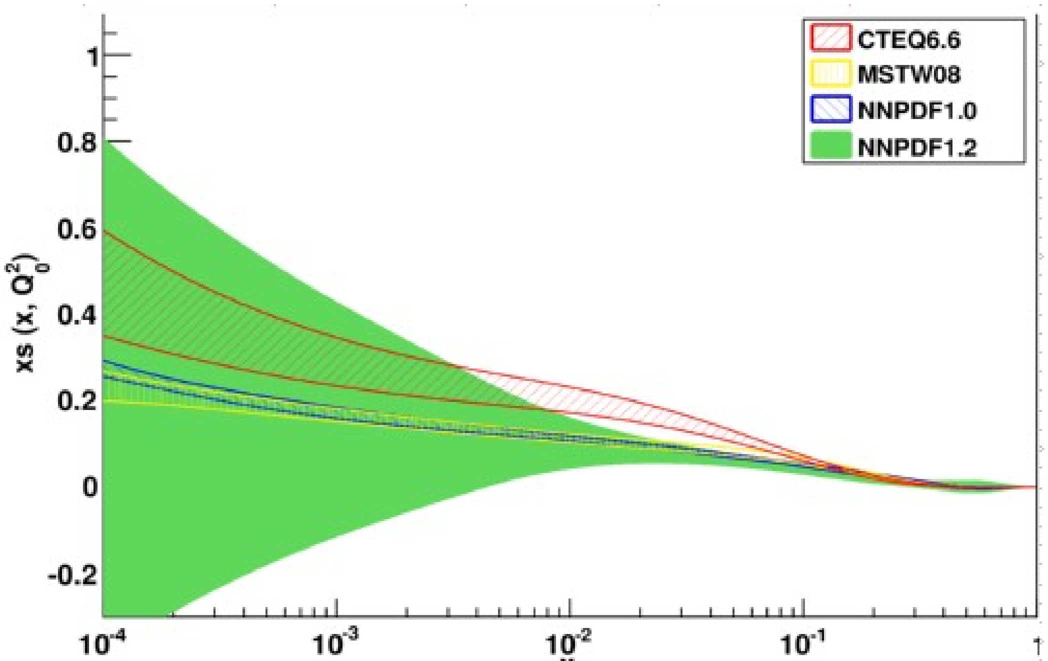


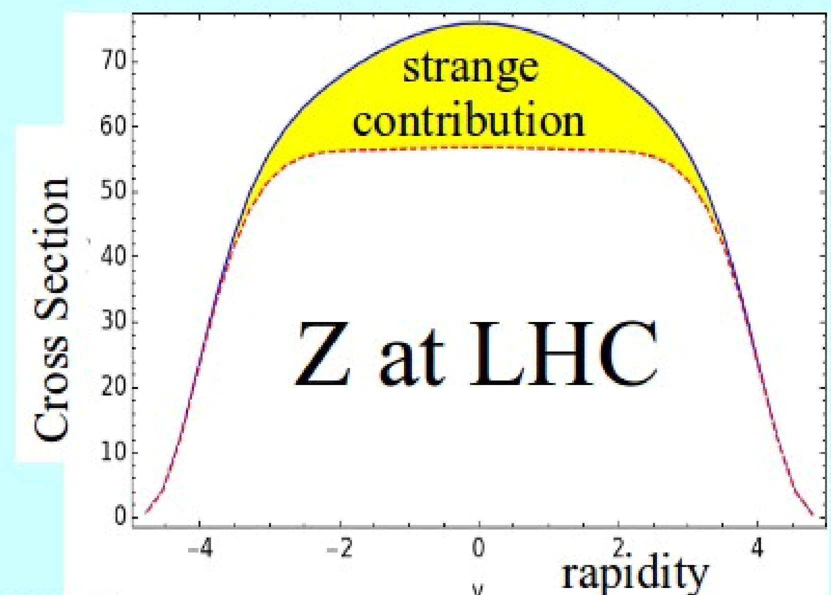
ATLAS-STDM-2011-43 → PRL

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







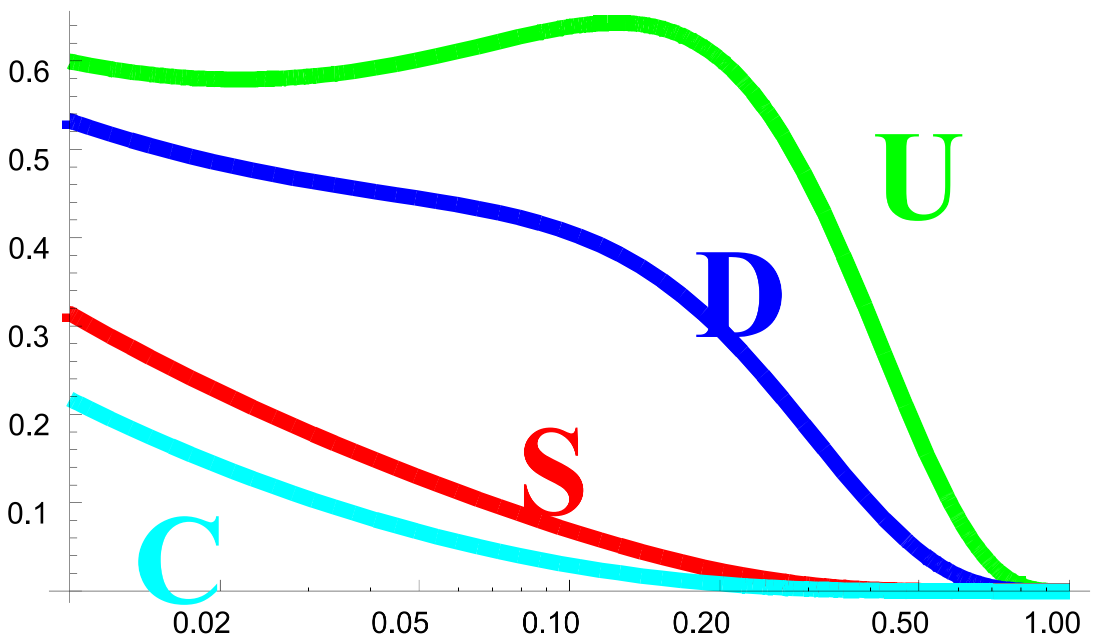


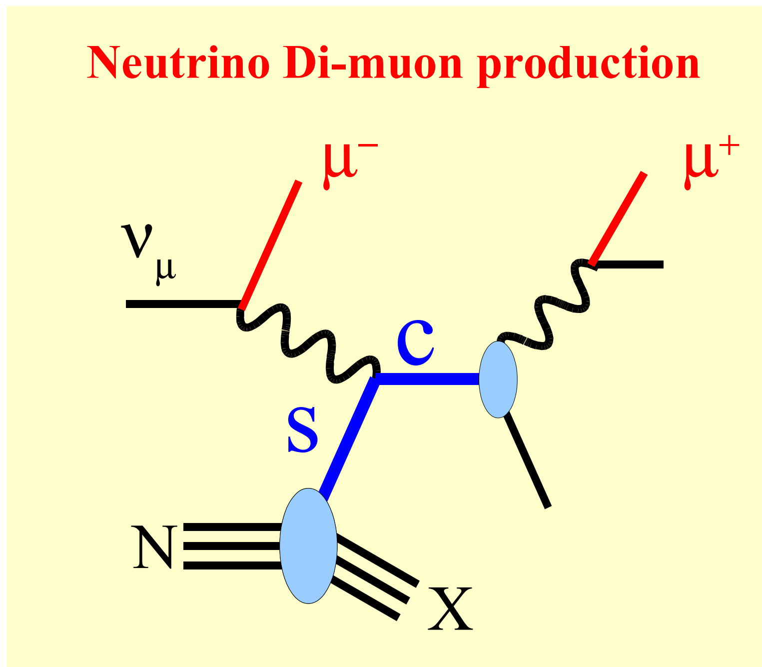
VRAP Code

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

What constrains the Strange???

Not much





Depends on nuclear corrections

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...

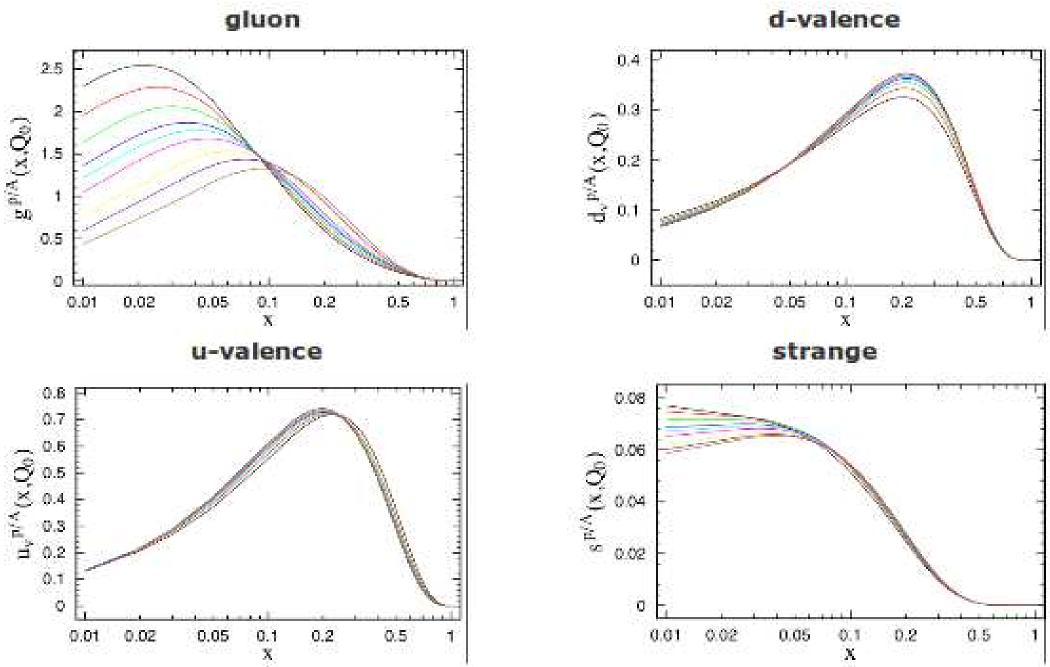
nCTEQ Go! hosted by **CEDAR HepForge**

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

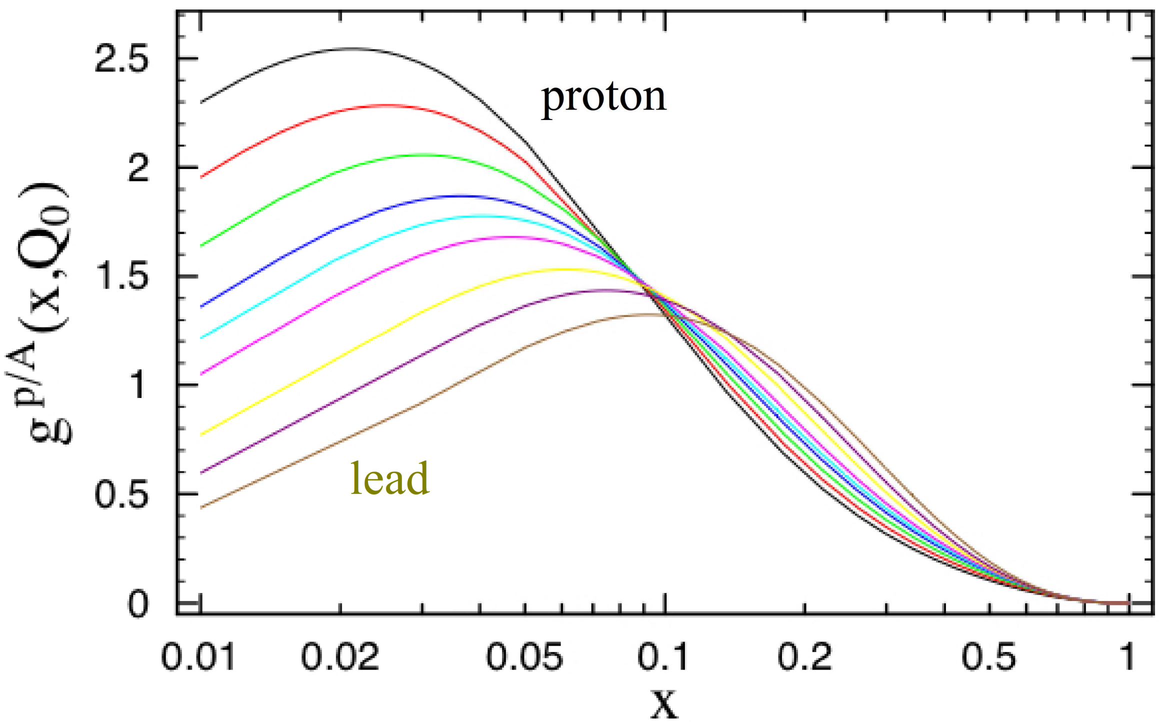
- ✔ CTEQ style global fit extended
  handle various nuclear targets
- ✔ CTEQ Data + nuclear DIS & DY
  [~15 targets; ~2000+ data]
- ✔ A-dependence modeled;
  NLO fits work well

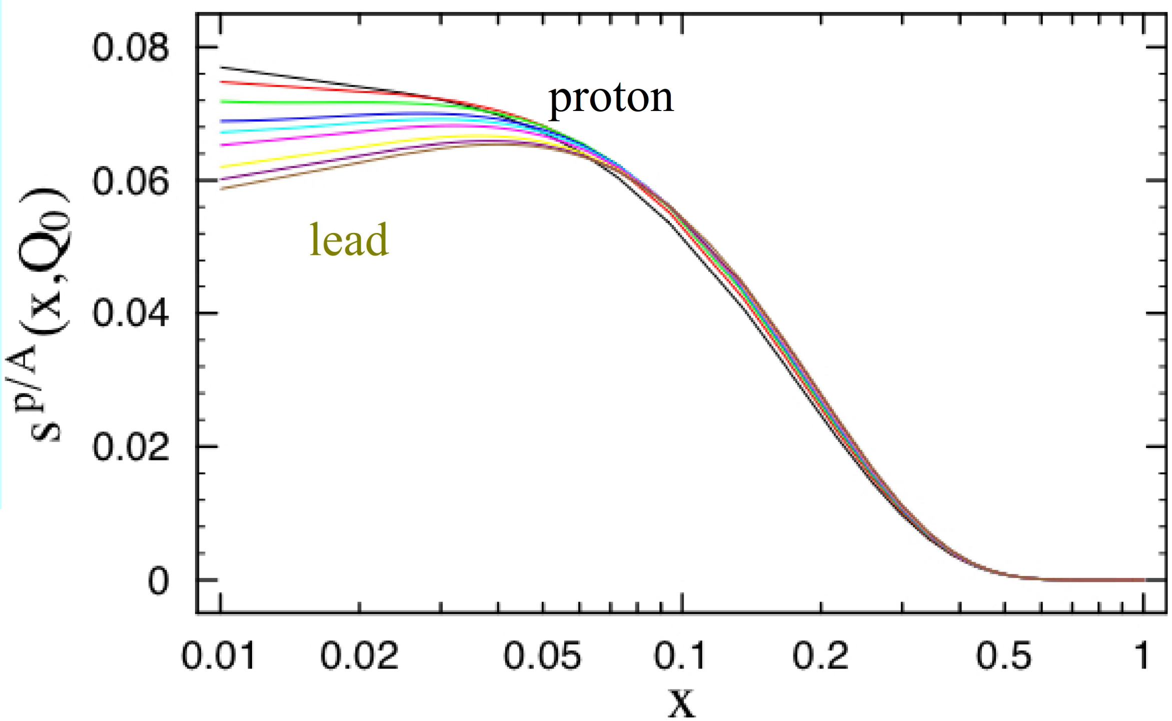
A-Dependent PDFs

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

$$a_i \rightarrow a_i(A)$$

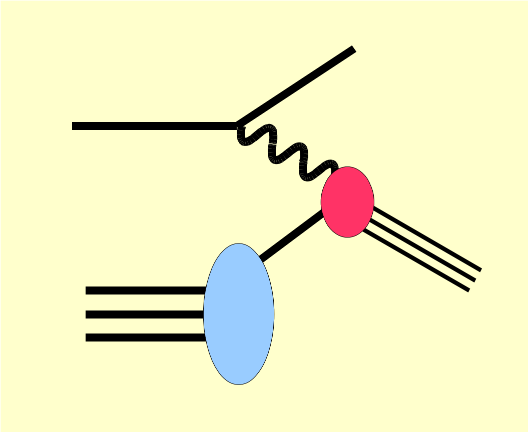
$$a_k = a_{k,0} + a_{k,1}\left(1 - A^{-a_{k,2}}\right)$$

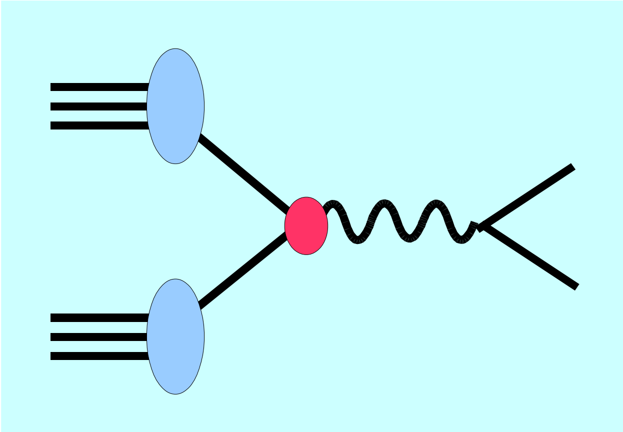


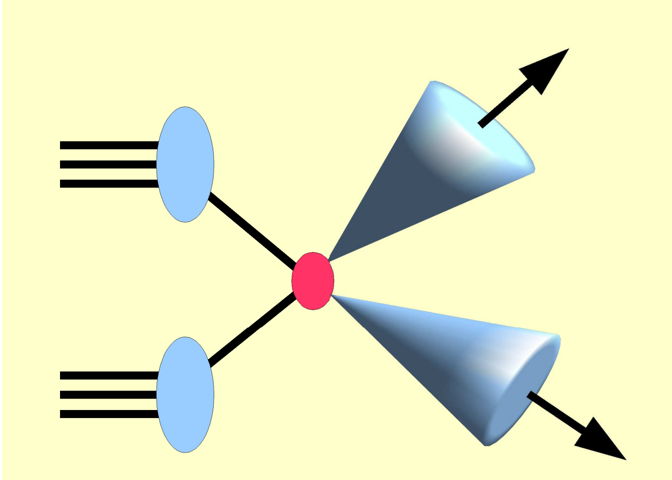


Nuclear PDFs from neutrino deep inelastic scattering.
I. Schienbein, J.Y. Yu, C. Keppel, J.G. Morfin,
F. Olness, J.F. Owens. Phys.Rev.D77:054013,2008.

Why Do We Need Nuclear Corrections????







$$F_2^{\nu} \sim [d + s + \bar{u} + \bar{c}]$$

$$F_2^{\bar{\nu}} \sim [\bar{d} + \bar{s} + u + c]$$

$$F_3^{\nu} = 2[d + s - \bar{u} - \bar{c}]$$

$$F_3^{\bar{\nu}} = 2[u + c - \bar{d} - \bar{s}]$$

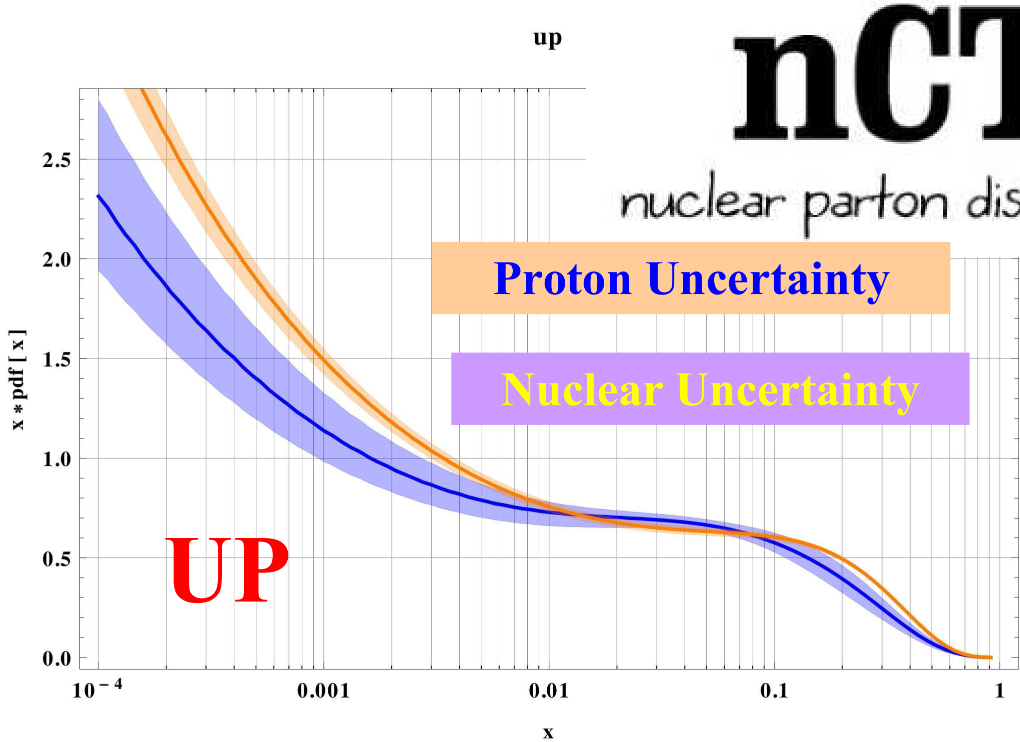
$$F_2^{\ell^\pm} \sim \left(\frac{1}{3}\right)^2 [d + s] + \left(\frac{2}{3}\right)^2 [u + c]$$

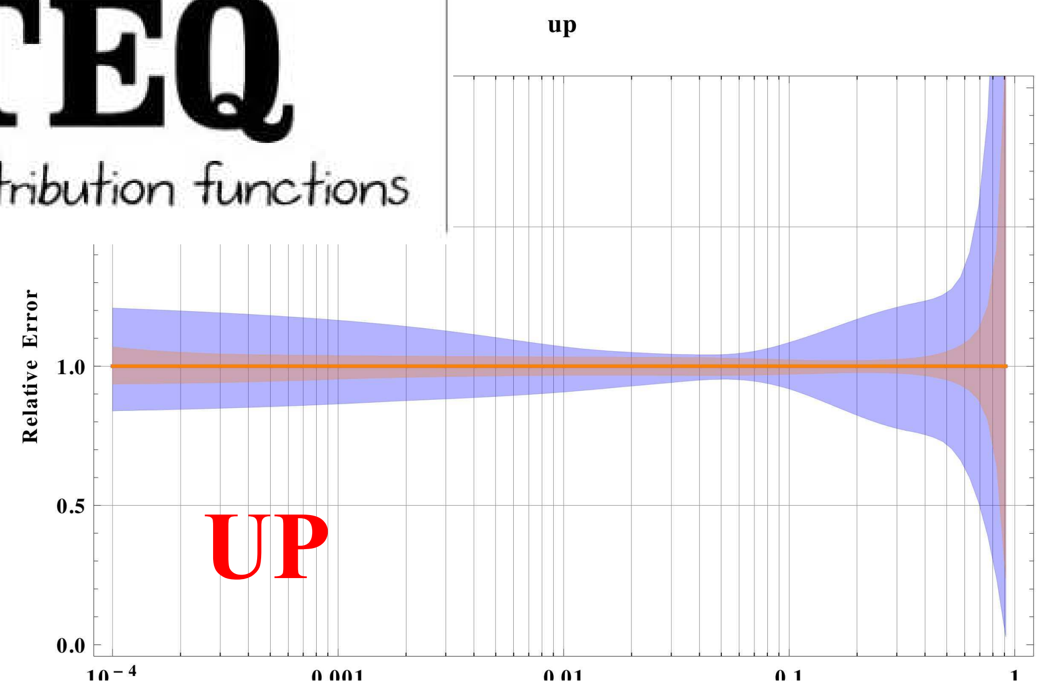
<u>Different</u> linear combinations – key for flavor differentiation

The ν-DIS data typically use heavy targets, and this requires the application of ***<u>nuclear corrections</u>***

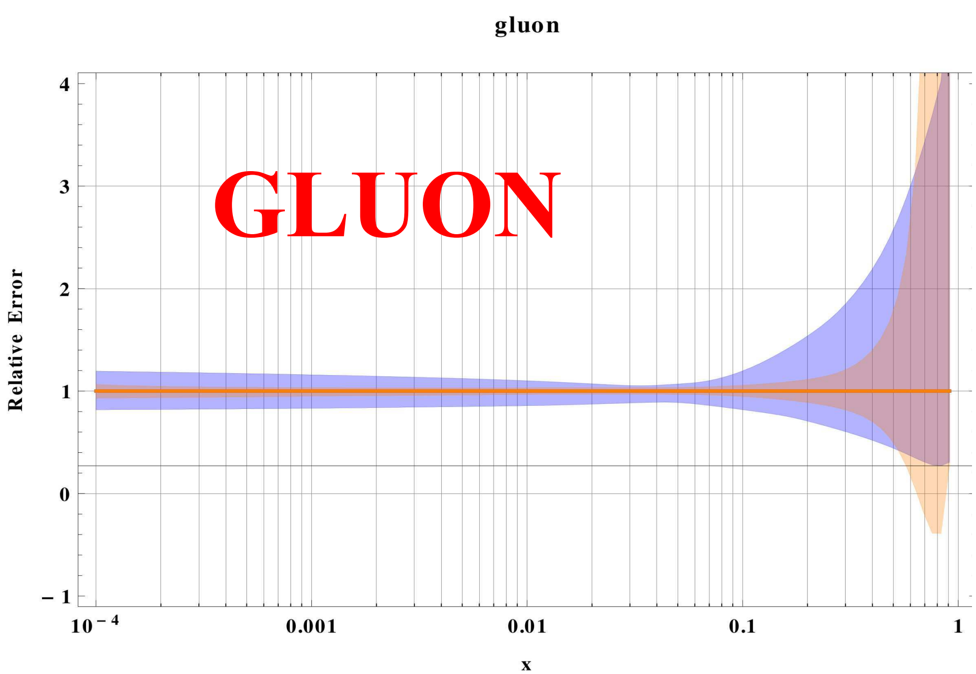
Nuclear Corrections: Nuclear PDF Uncertainties

nCTEQ
nuclear parton distribution functions





up – ubar + down – dbar Luminosity @ 14 TeV



Target	ρ (g.cm^{-3})	A	$\mathcal{L}$ (μb^{-1}.s^{-1})	$\int\mathcal{L}$ (pb^{-1}.yr^{-1})
Sol. H_2	0.09	1	26	260
Liq. H_2	0.07	1	20	200
Liq. D_2	0.16	2	24	240
Be	1.85	9	62	620
Cu	8.96	64	42	420
W	19.1	185	31	310
Pb	11.35	207	16	160

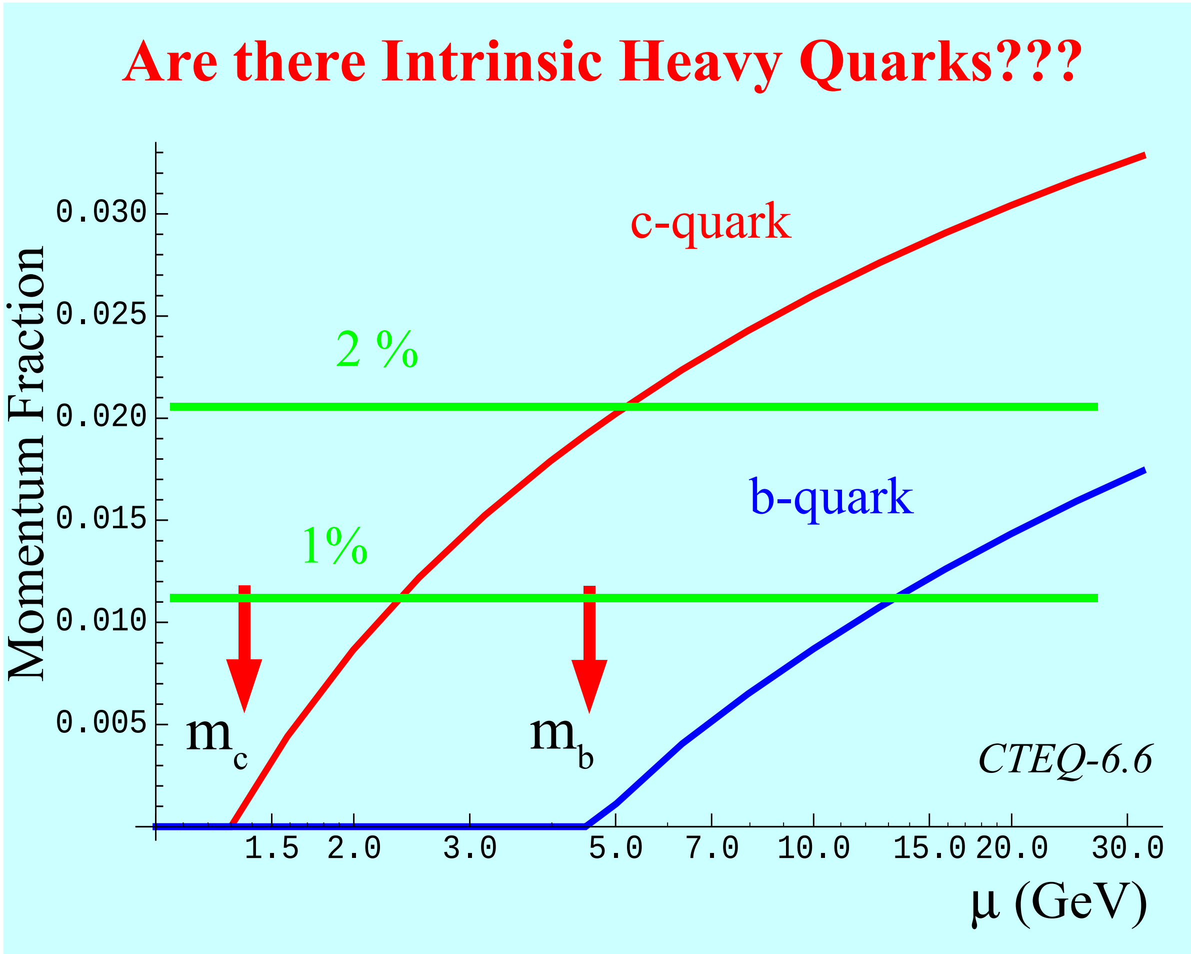
... what about the

Heavy Quarks

c & *b*

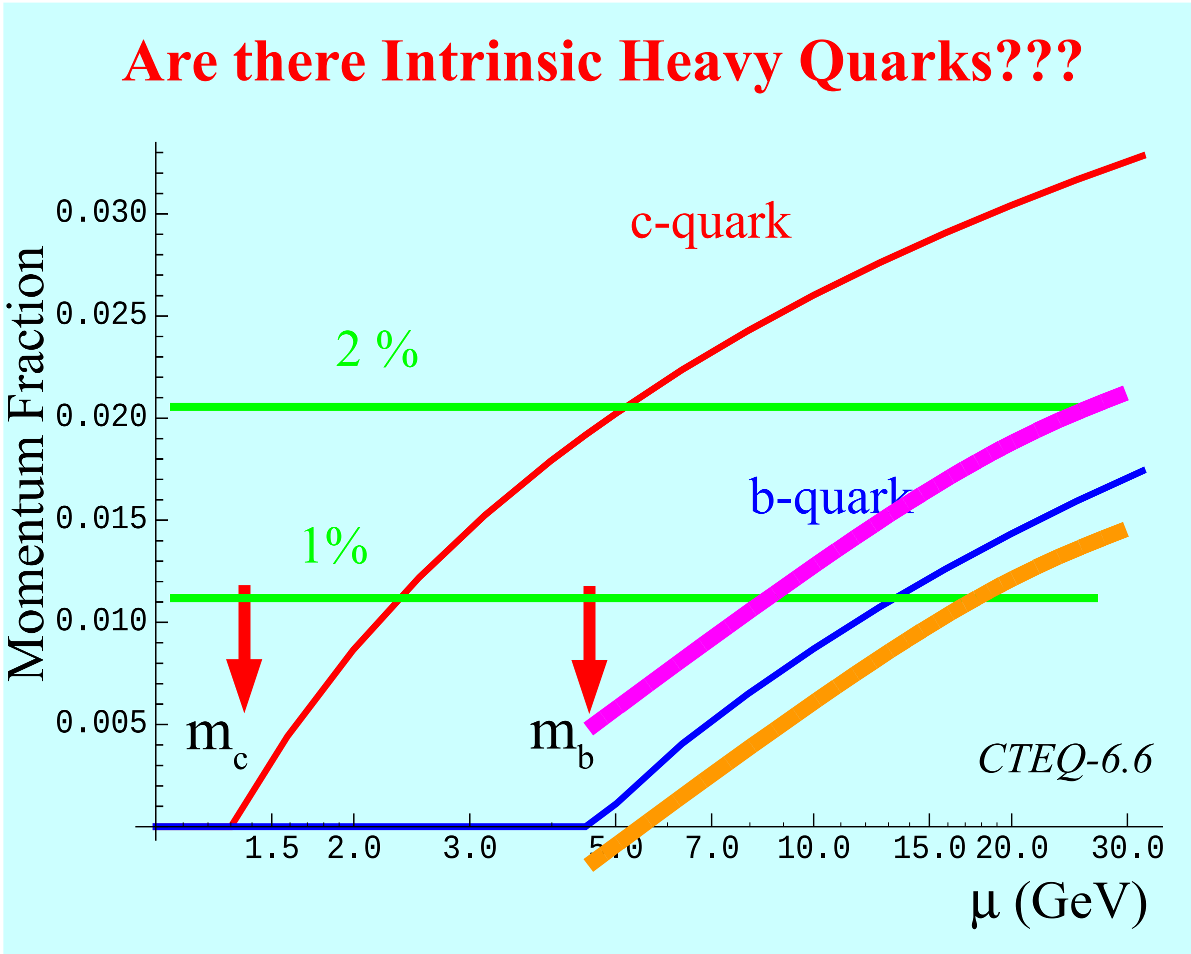
Extrinsic & Intrinsic

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



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

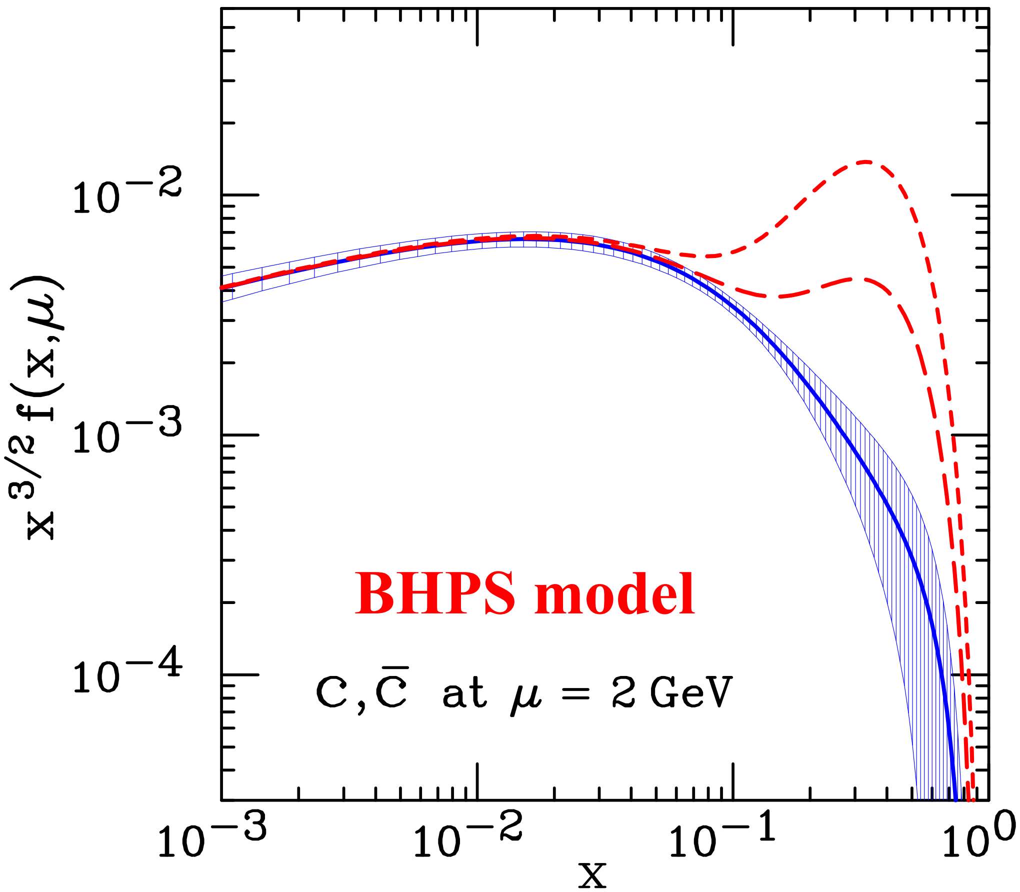
Are there Intrinsic Heavy Quarks??? Do they matter???

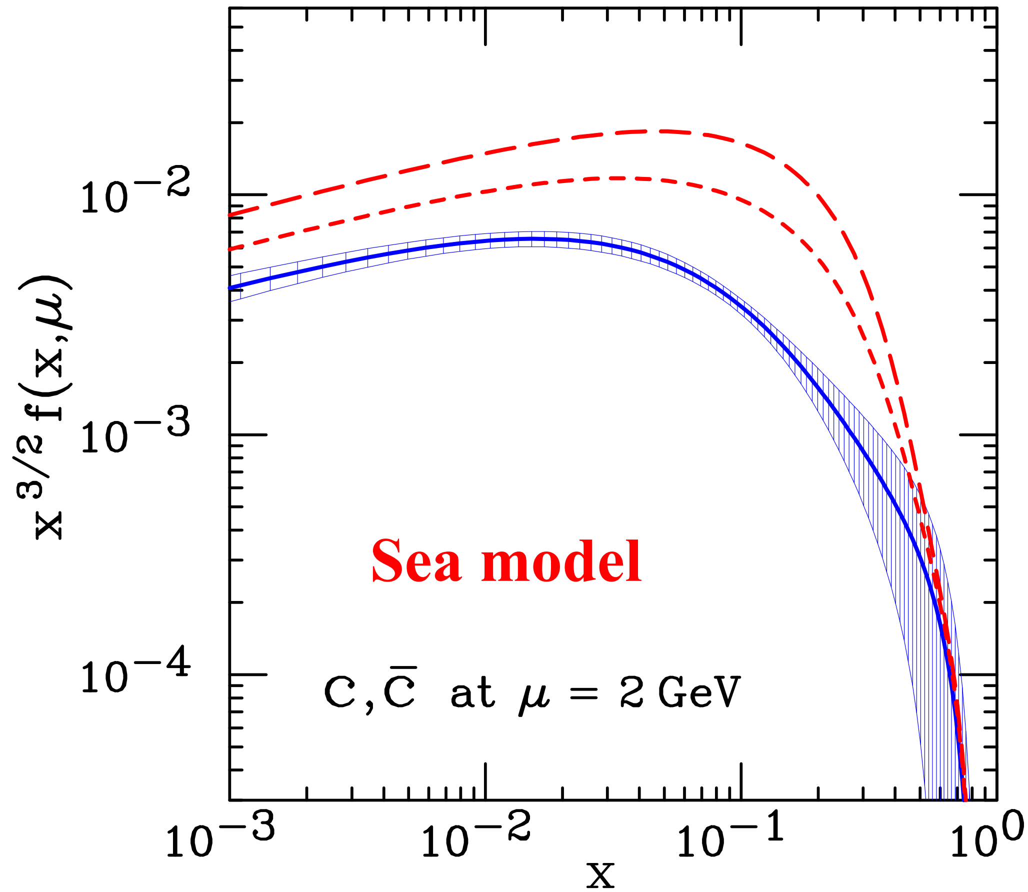


- * Most sensitive near threshold
- * What happens if we allow the evolution to determine charm?

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

What might intrinsic charm look like???





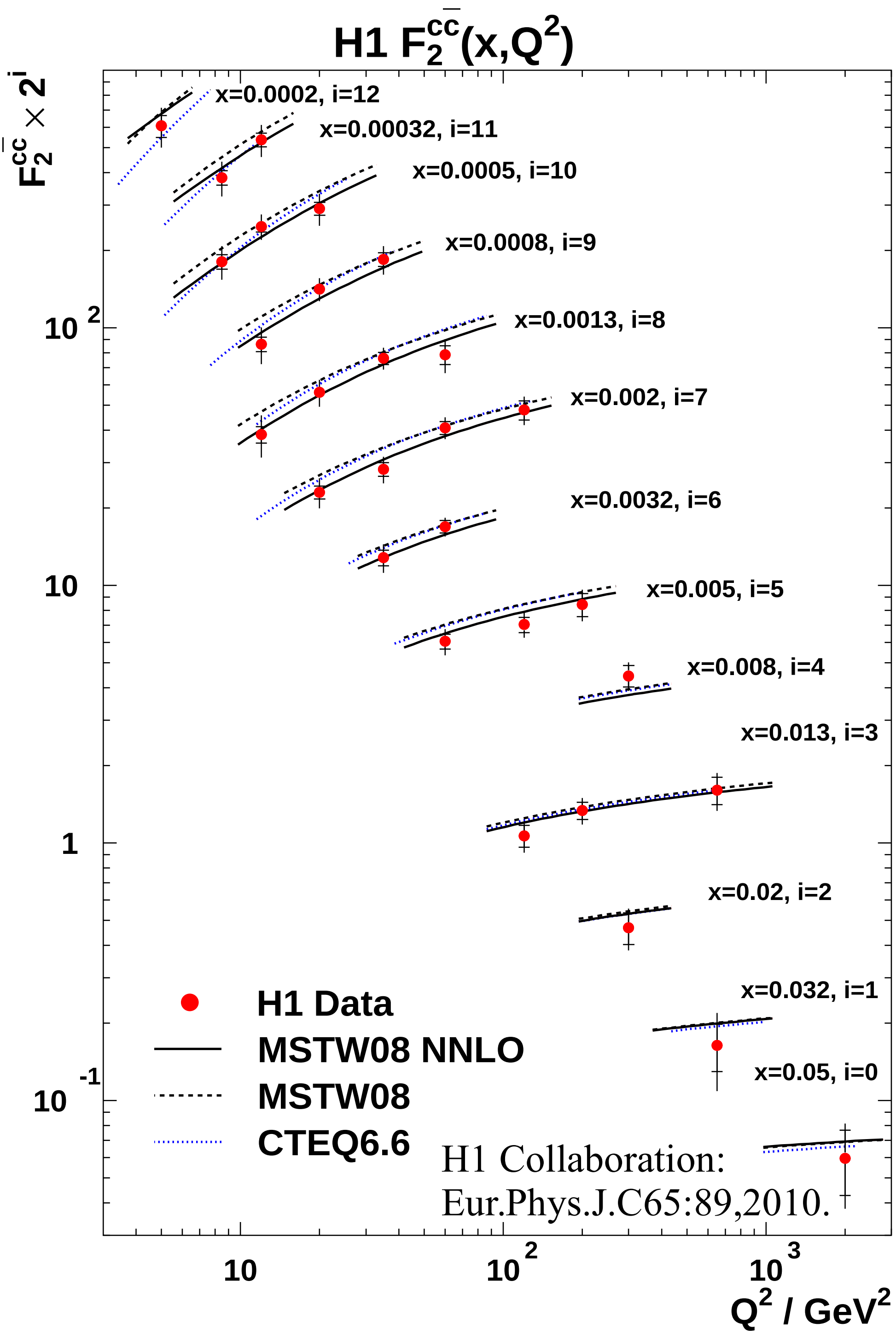
Add 1% or 2% momentum fraction
in intrinsic component

Note, structure persists to higher
(e.g., Q~100 GeV) scales

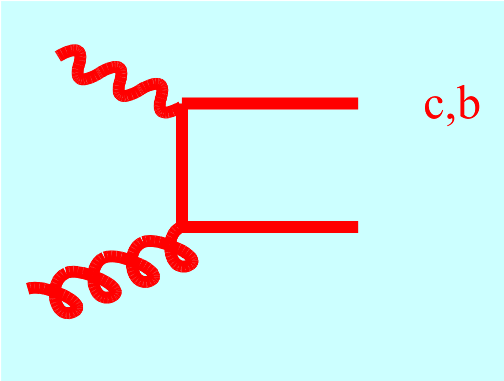
BHPS MODEL:
The Intrinsic Charm of the Proton.
Brodsky, Hoyer, Peterson, Sakai,
Phys.Lett.B93:451-455,1980.

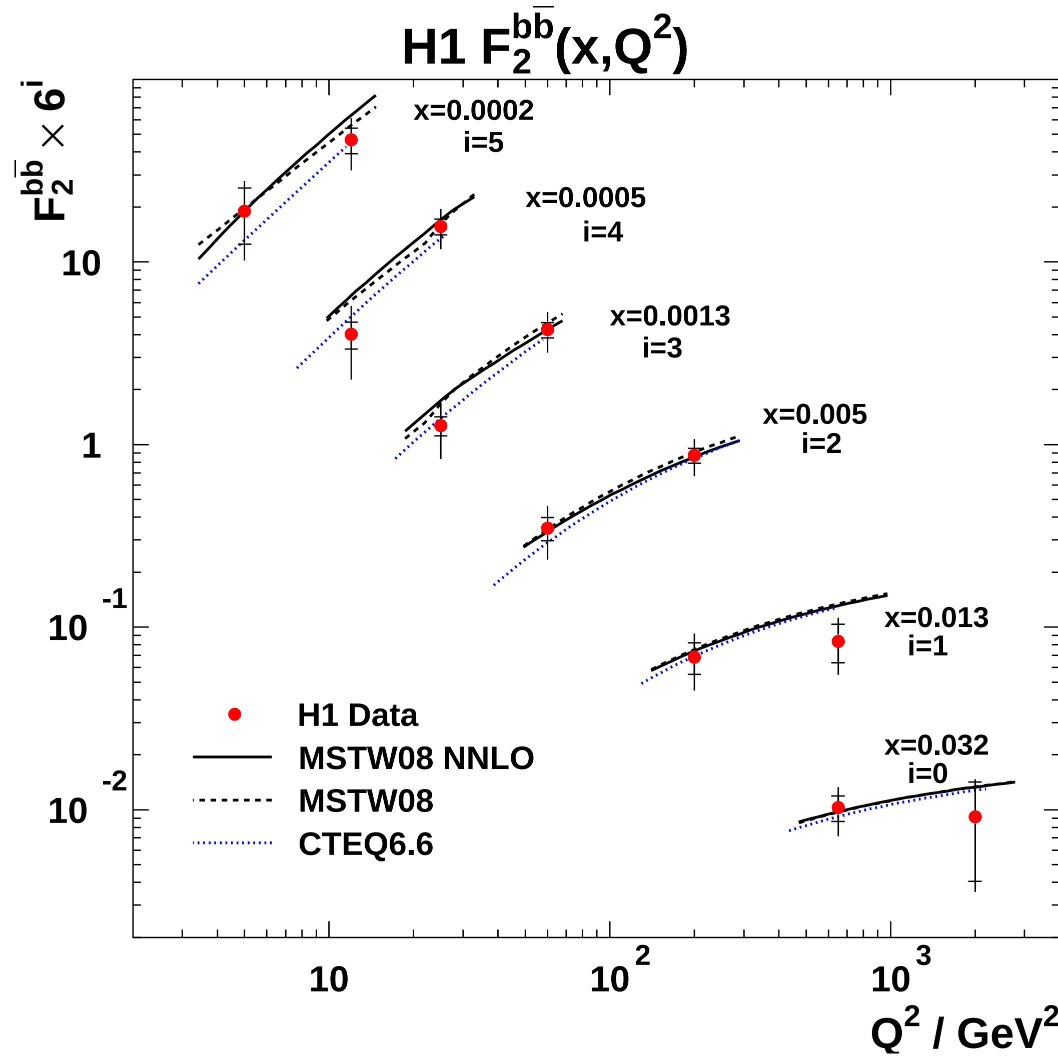
The Charm Parton Content of the Nucleon.
J. Pumplin, et al., Phys.Rev.D75:054029,2007.

Heavy Flavor Components play prominent role at LHC

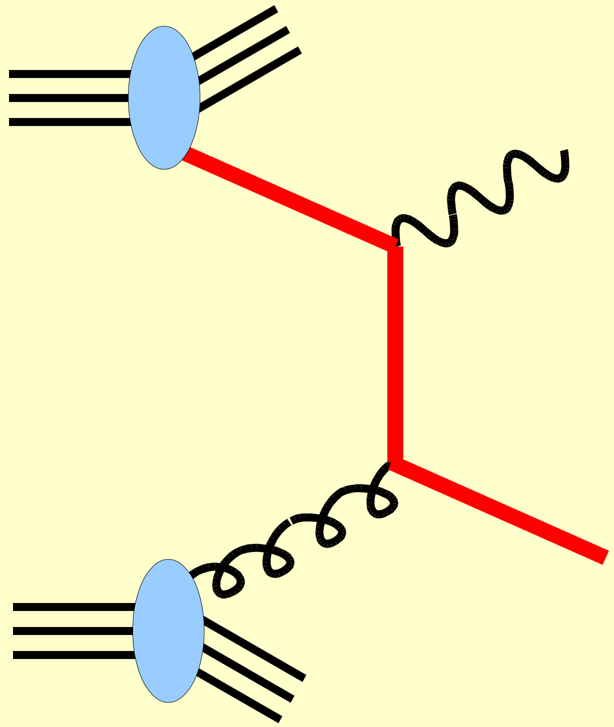


c & b tied to gluon PDFs





How to Access Heavy Flavor Components Directly???



$$c\ g \to c\ \gamma$$

$$b\ g \to b\ \gamma$$

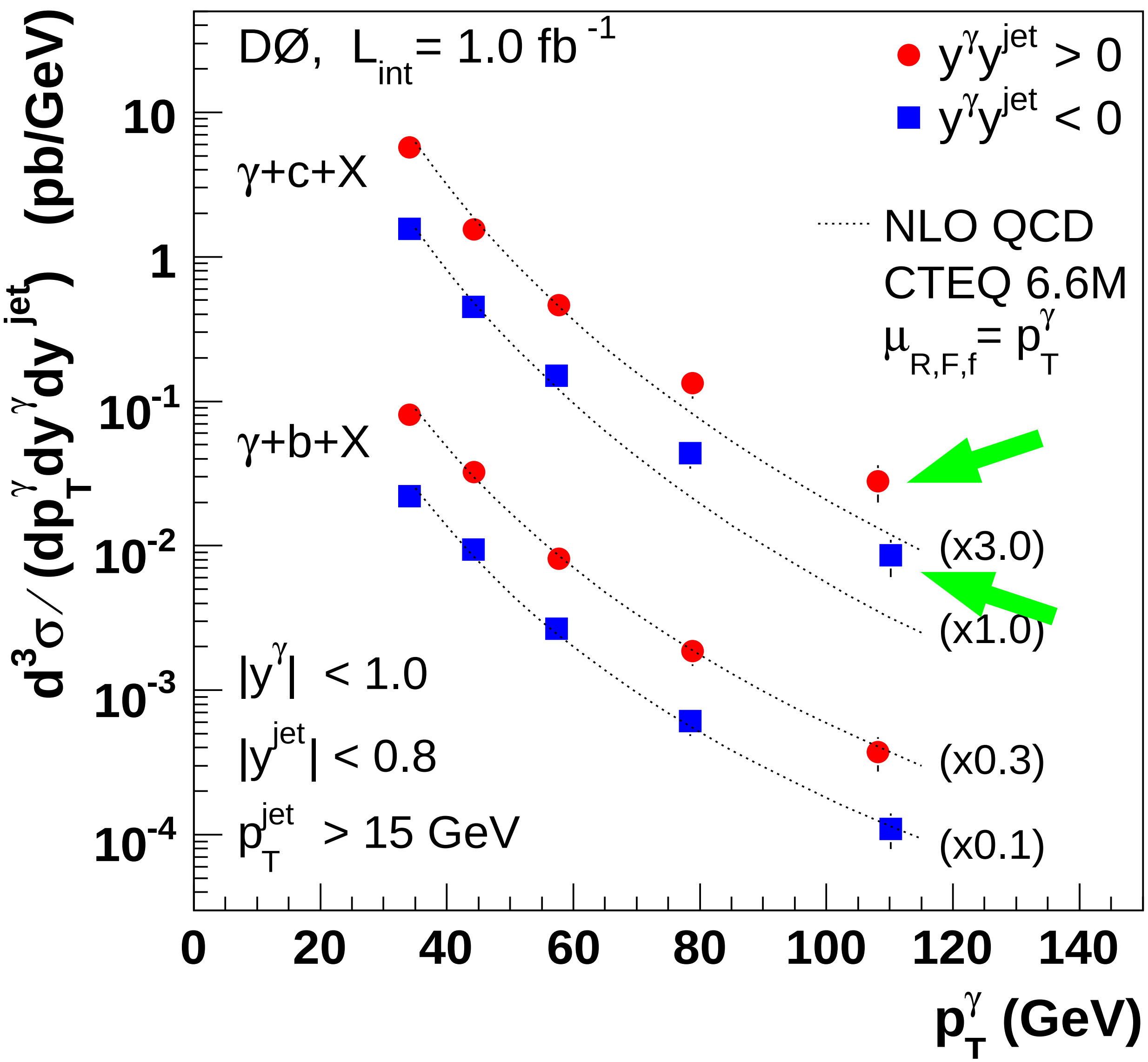
$$s\ g \to c\ W$$

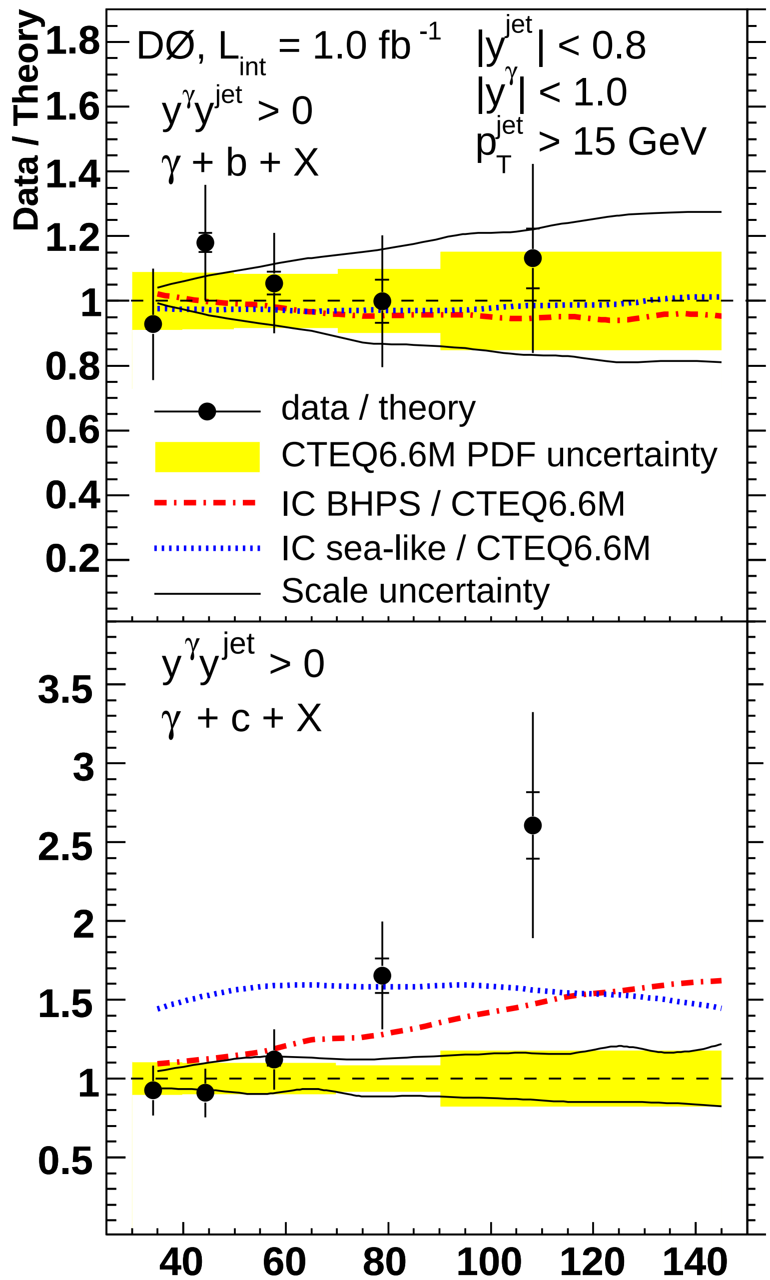
$$c\ g \to b\ W$$

Direct Photon: Can it constrain the gluon???

Test Heavy Quark PDF resummation

Heavy Quarks at the Tevatron

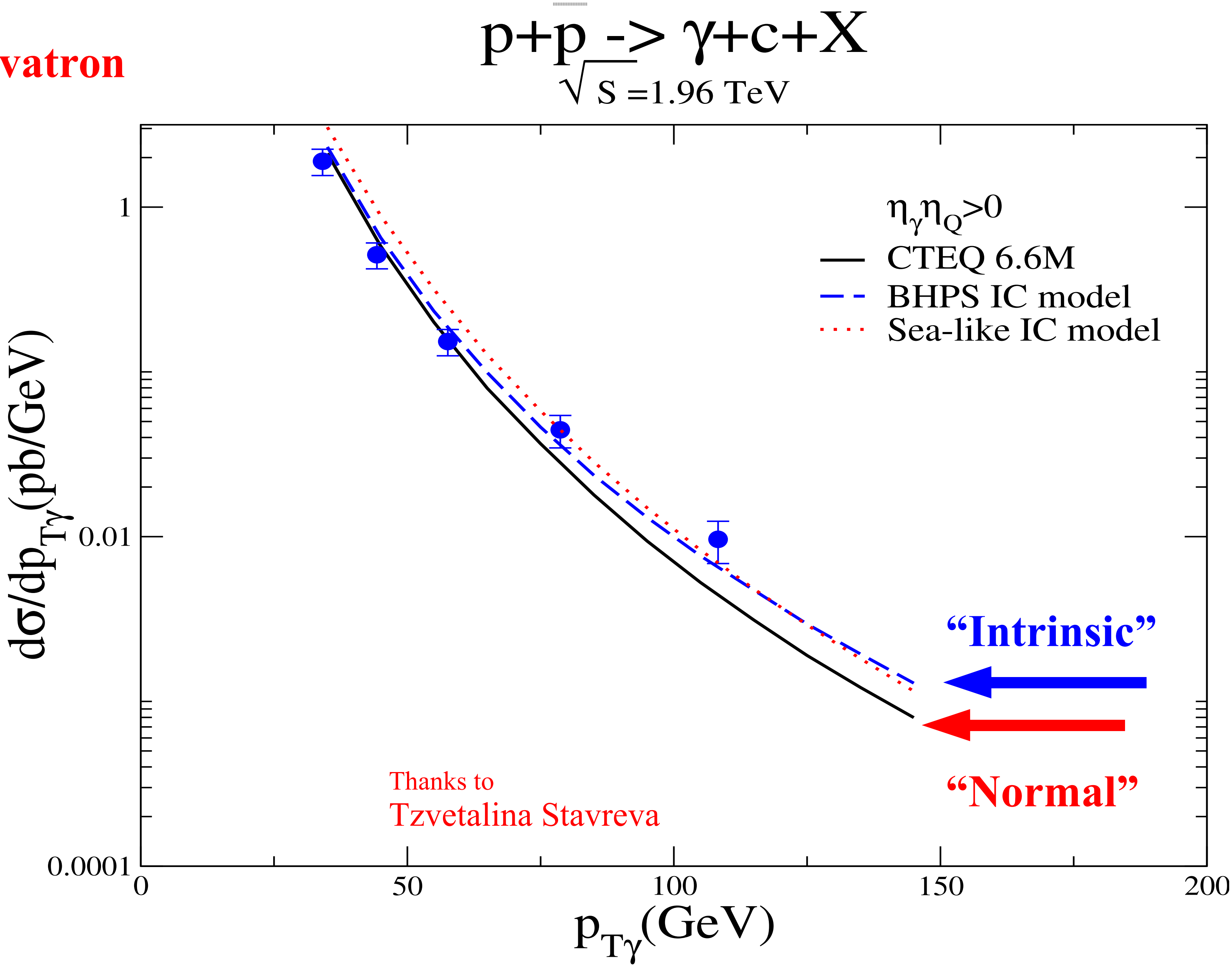




D. Duggan (D0) arXiv:0906.0136

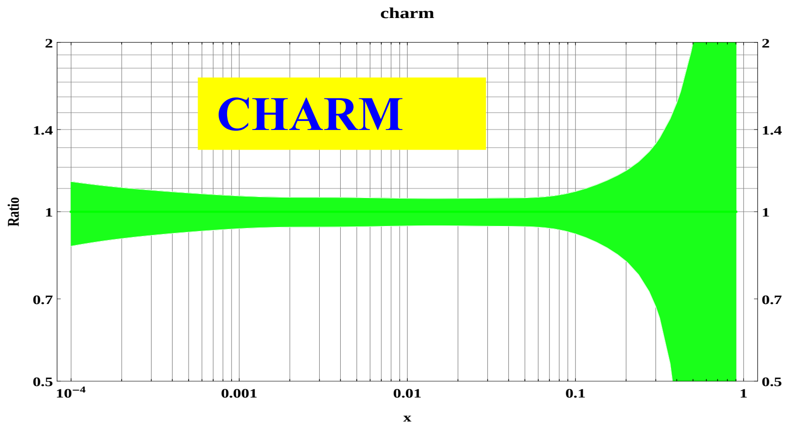
Including "Intrinsic Heavy Quark" Component

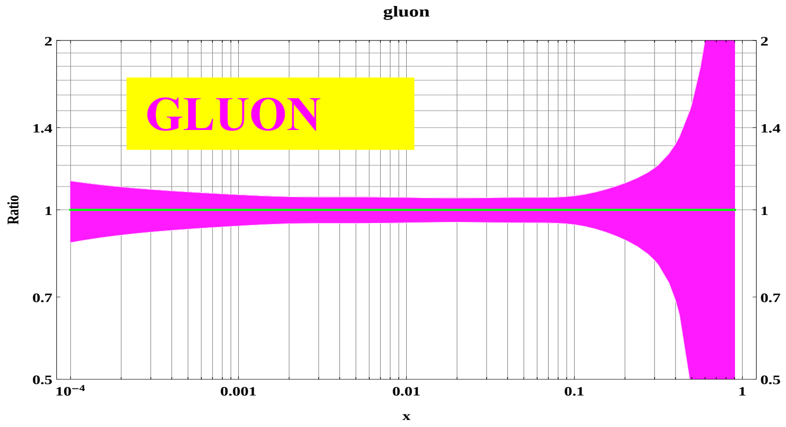
Tevatron

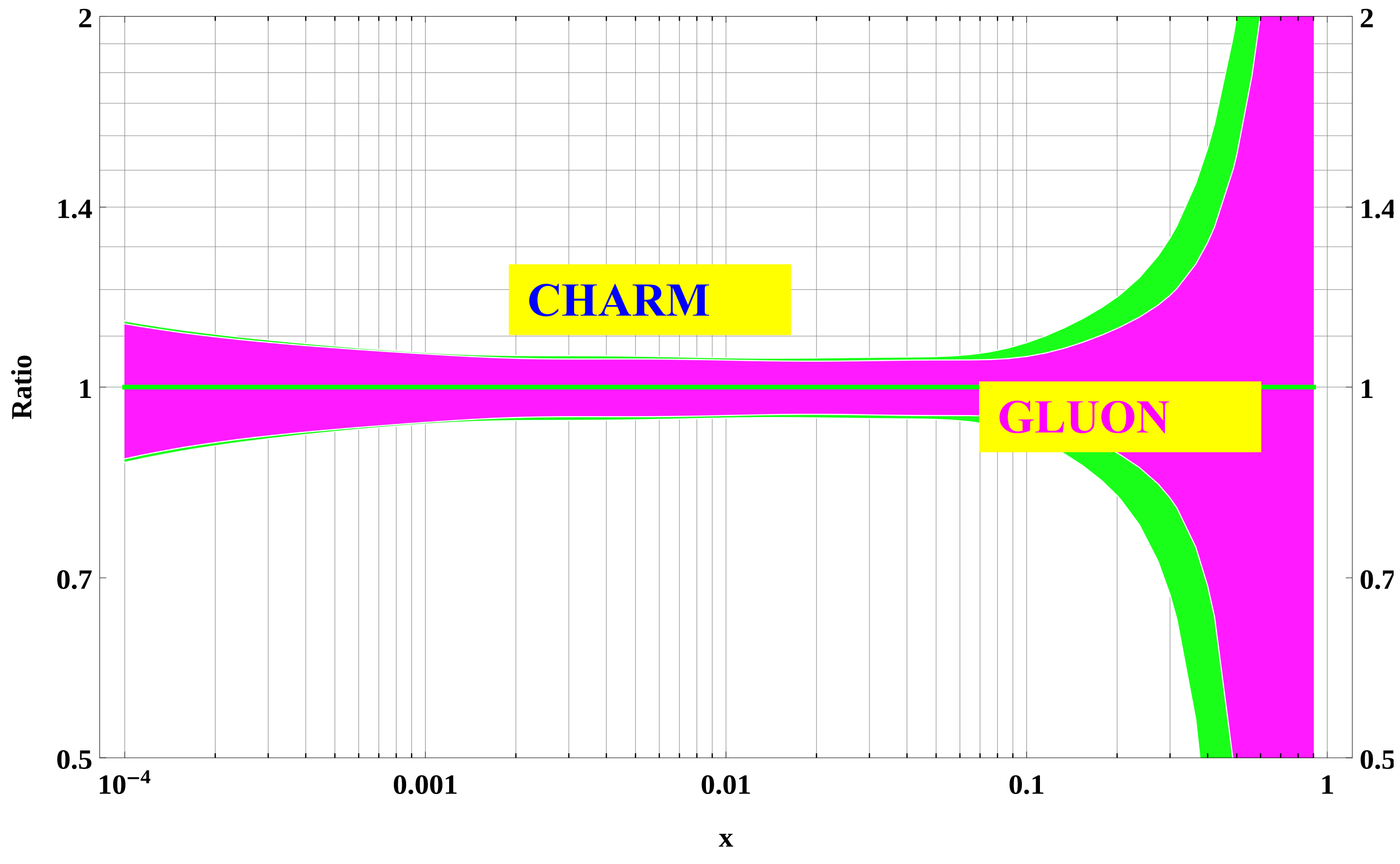


T. Stavreva, K. Kovarik, F. Olness, arXiv:1206.2175
T. Stavreva, I. Schienbein, F. Arleo, K. Kovarik, F. Olness, J.Y. Yu, J.F. Owens, JHEP 1101 (2011) 152

Charm PDF Uncertainty & Relation to Gluon

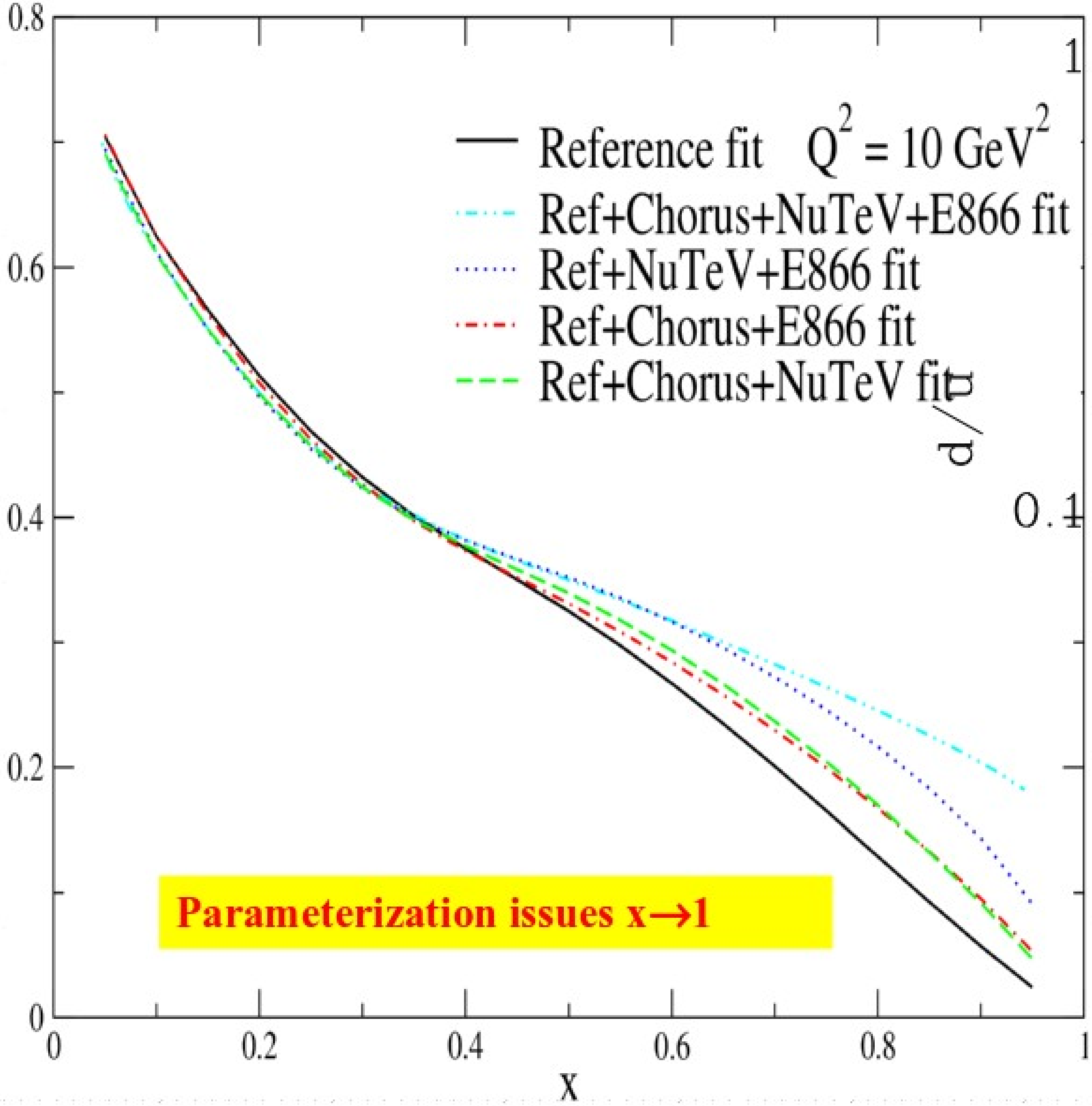




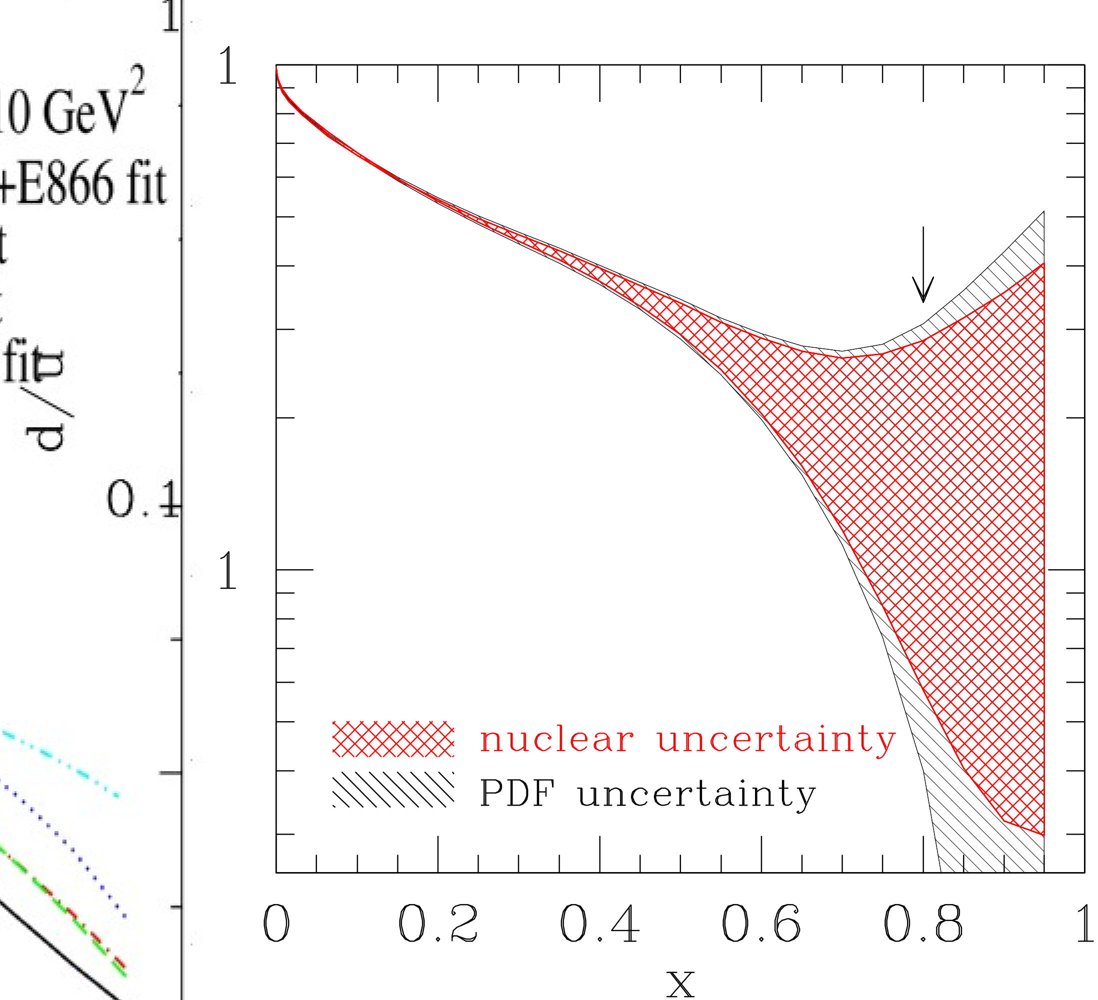


HI-X

Tension between data sets: Example: d/u ratio at high x

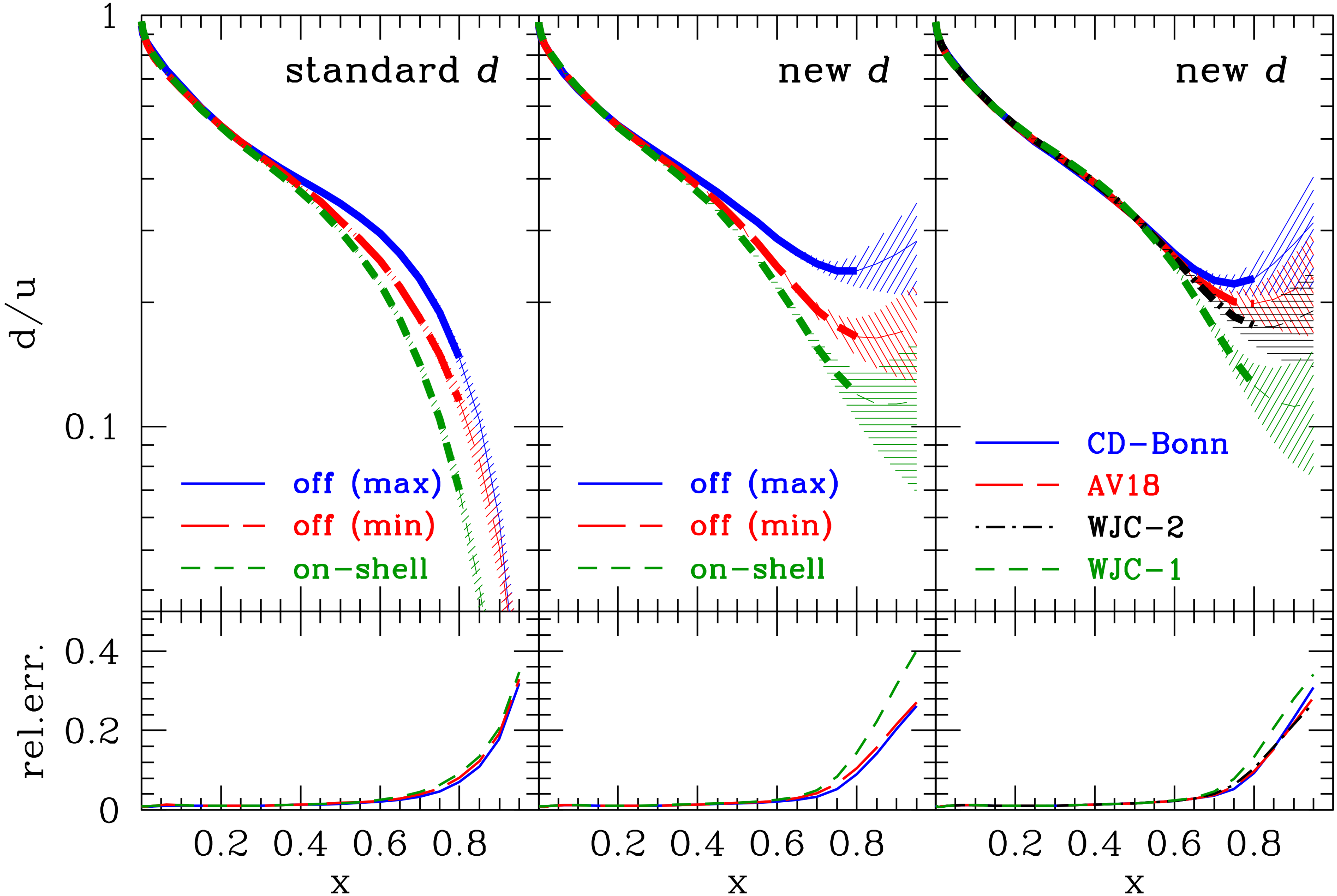


Parameterization issues x→1



What about x>1 for nuclear PDF?

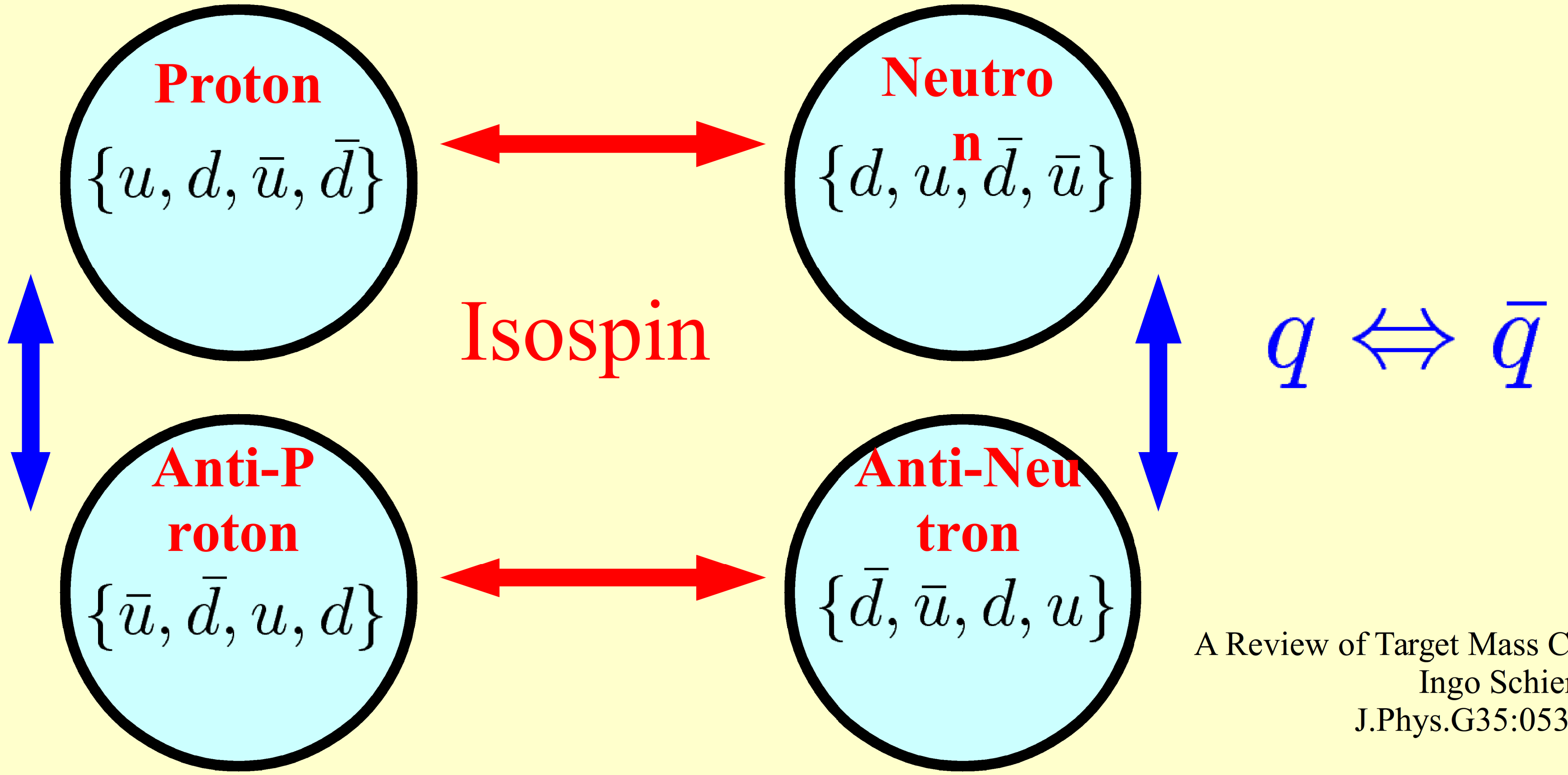
d/u at Hi-X: Lots to choose from



Isospin Symmetry

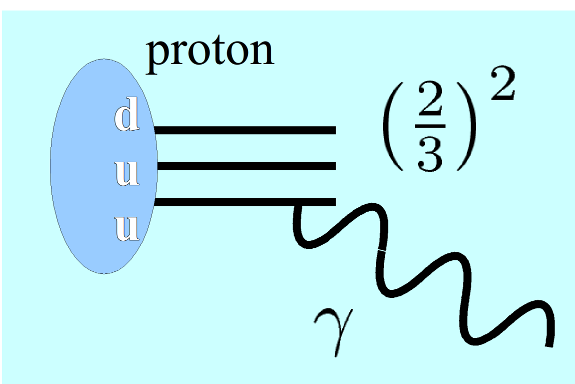
... *taken for granted*

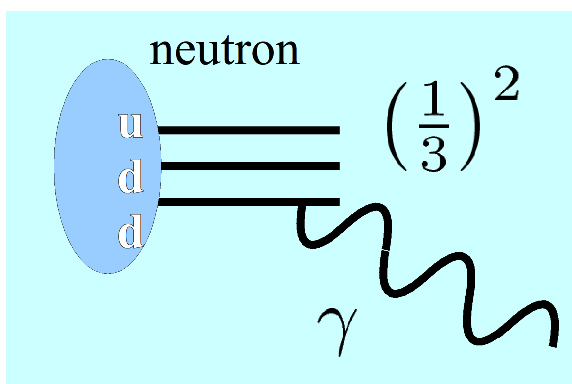
Isospin Symmetry used to relate PDFs



A Review of Target Mass Corrections.
Ingo Schienbein et al,
J.Phys.G35:053101,2008.

MRST, Eur.Phys.J.C39:155-161,2005.



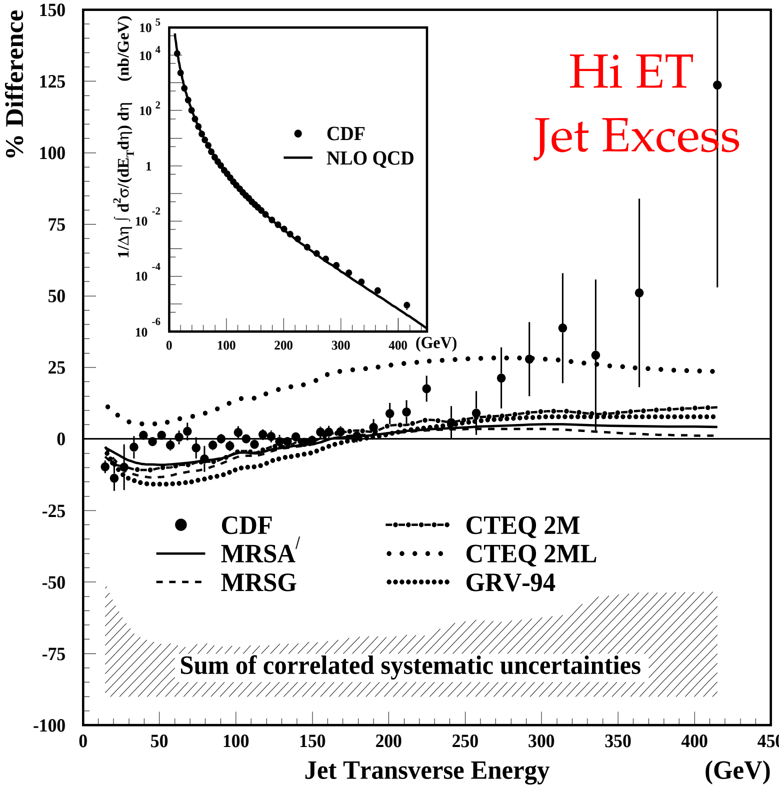


Isospin terms are comparable to NNLO QCD

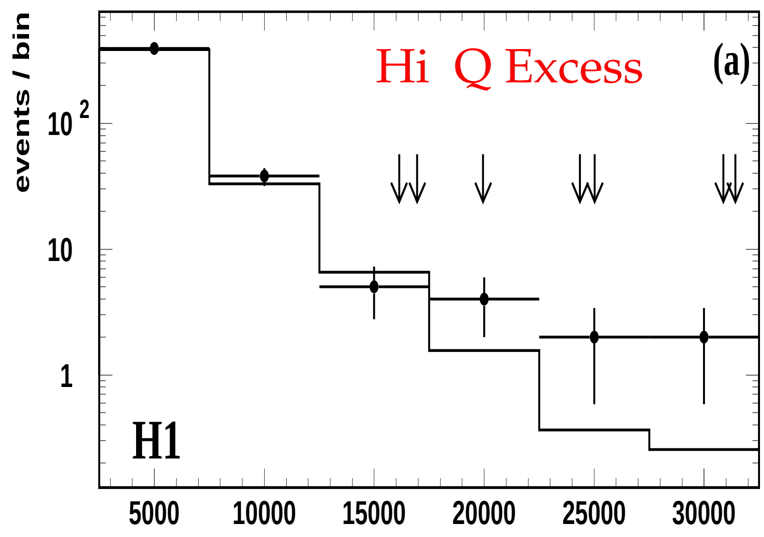
Fast evolution of parton distributions
Stefan Weinzierlar, Xiv:hep-ph/0203112

Why Do We Need Independent Experiments

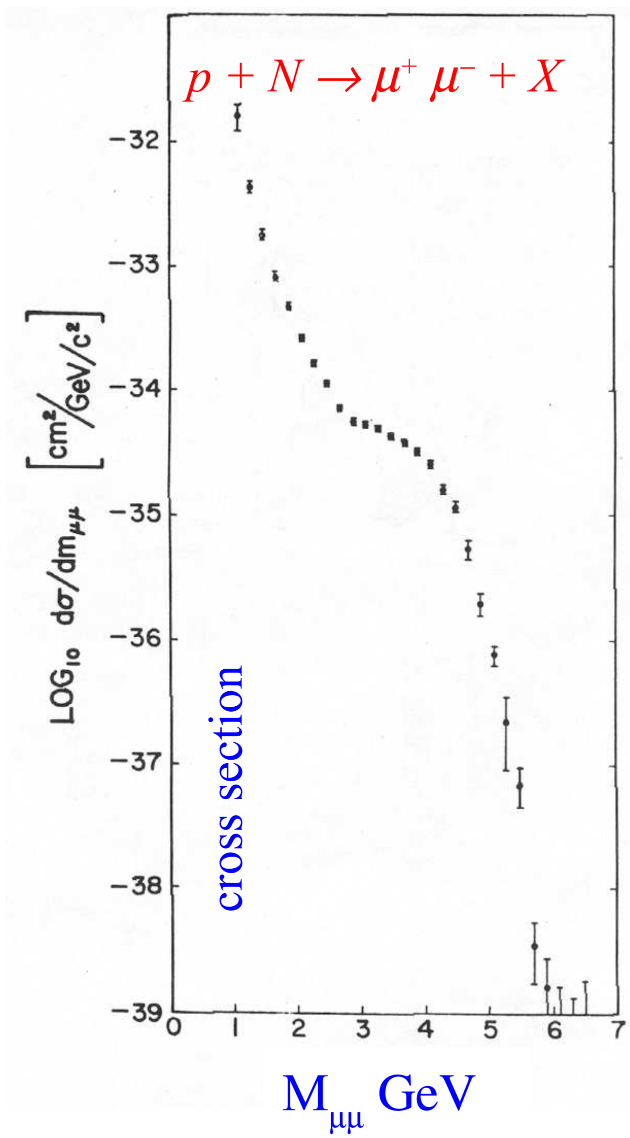
Can you find the Nobel Prize???



CDF Collaboration, PRL 77, 438 (1996)



H1 Collaboration, ZPC74, 191 (1997) Q_e^2 (GeV^2)
ZEUS Collaboration, ZPC74, 207 (1997)



Conclusion

Combination of high statistics, variety of nuclear targets, and large kinematic range allow …

PDF Precision:

Flavor Differentiation
TMD PDFs, Generalized PDFs

Nuclear Effects:

Corrections (EMC Effect)
Phenomena (Saturation, Recombination)
Isospin Symmetry & Deuteron corrections

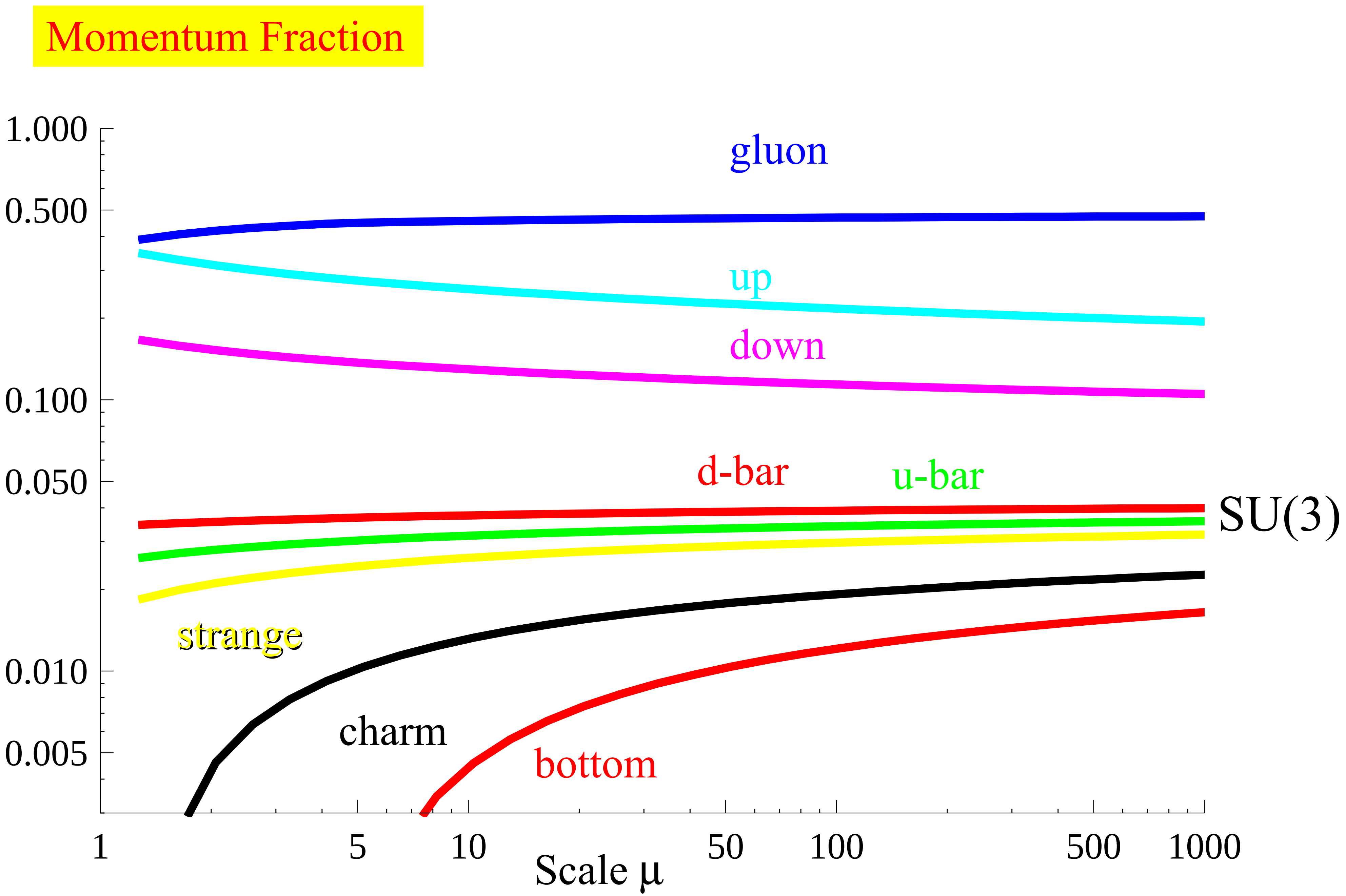
Heavy Quarks:

Log(m/Q) resummation & Intrinsic HQs

High X

Higher Twist, Fermi Motion, x>1

PDF Momentum Fractions vs. scale μ



Scaling violations are essential feature of PDFs