W / Z / Higgs Production at LHC & PDF Uncertainties

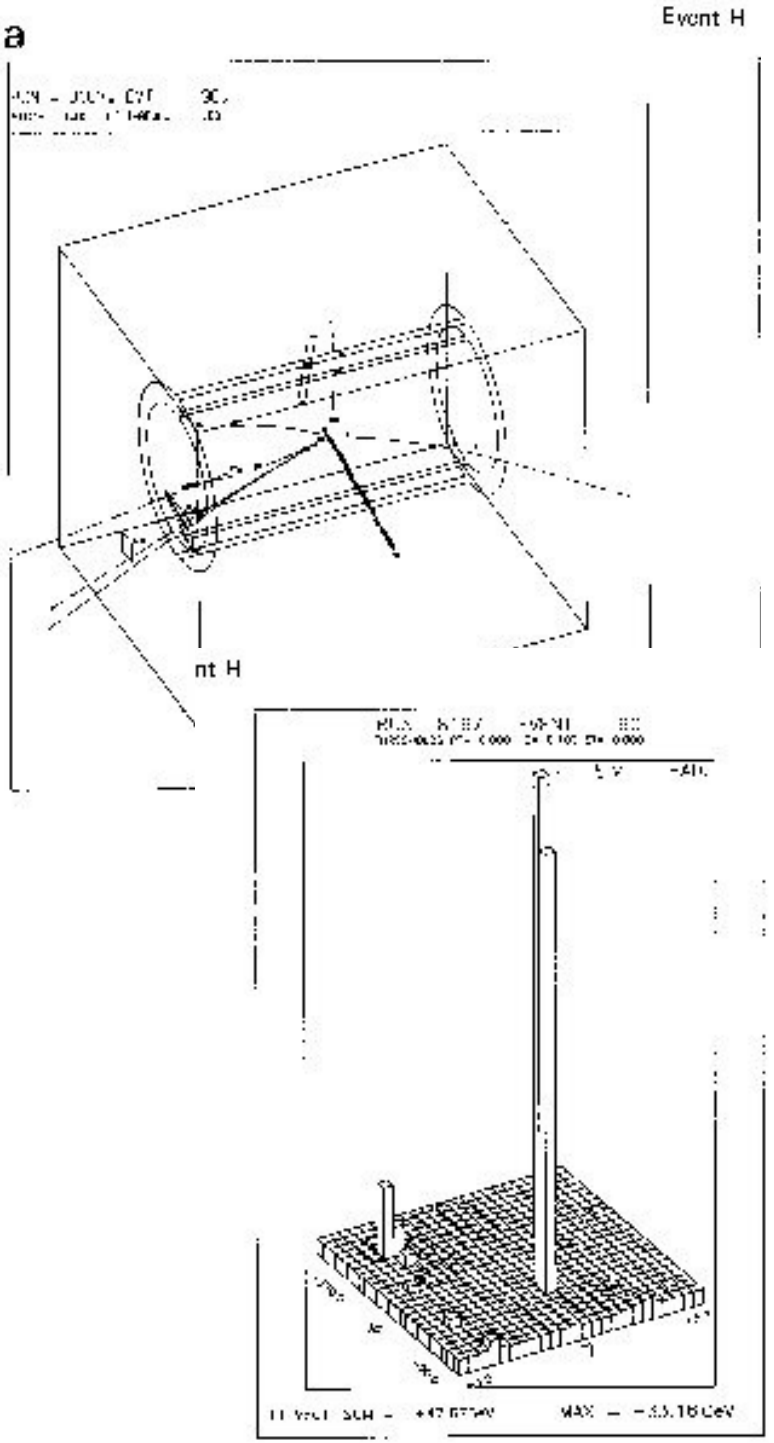
... or

are we ready to make discoveries at the LHC

Fred Olness
SMU/CERN

Conspirators:
P. Nadolsky, S. Berge, I Schienbein,
J.-Y. Yu, J. Owens, J. Morfin, C. Keppel, ...

HERA and the LHC
28 May 2008

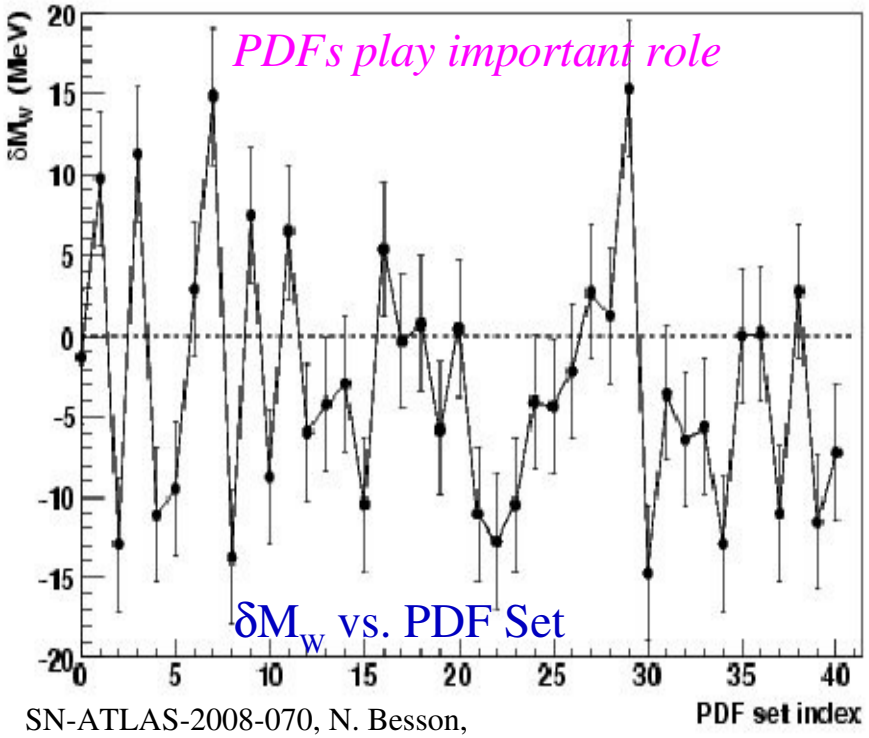


UA1 Physics Letters 139B, 1984

W, Z, Higgs Production:

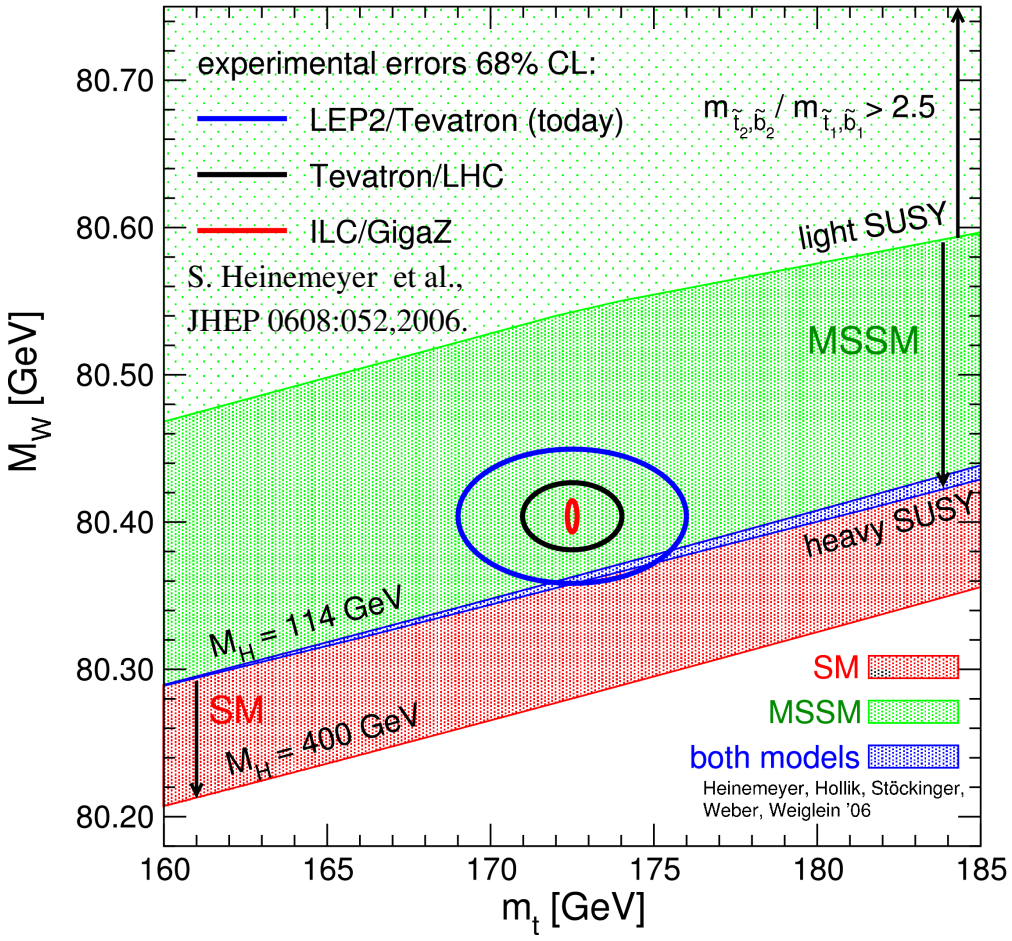
W,Z will be used to calibrate both SM and New Physics

see Maarten's talk



SN-ATLAS-2008-070, N. Besson,
M. Boonekamp, E. Klinkby, . Mehlhase, T. Petersen

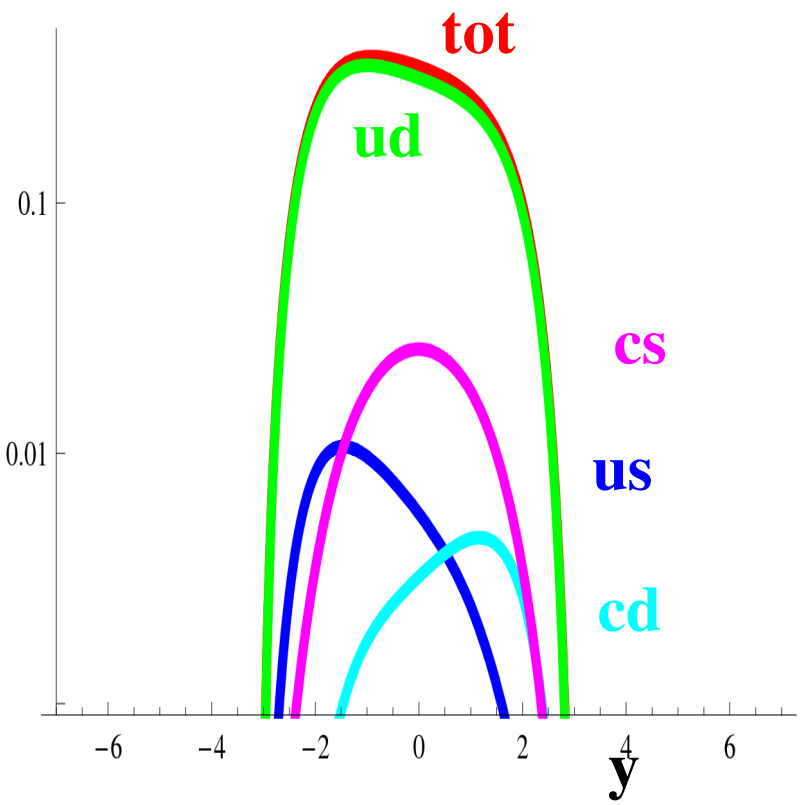
Precision M_W provides clues of Higgs and Beyond



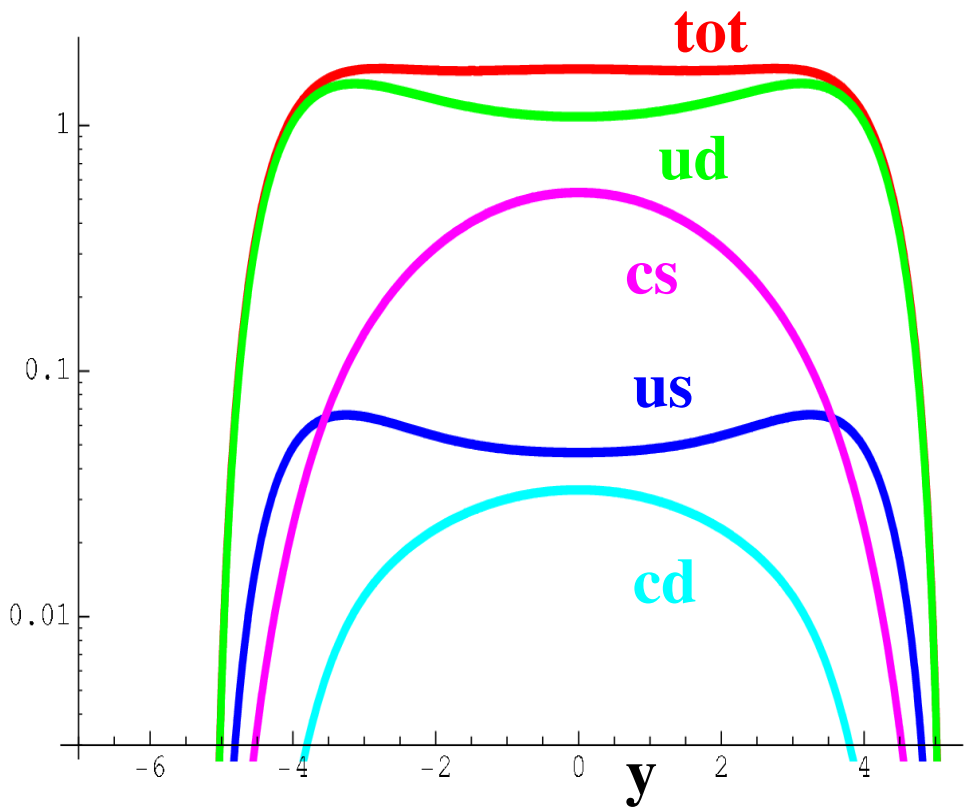
W & Z Production are "Benchmark" processes at LHC

"Old" is "New" --- Re-discovering W & Z

dσ/dy(W^+) at Tevatron

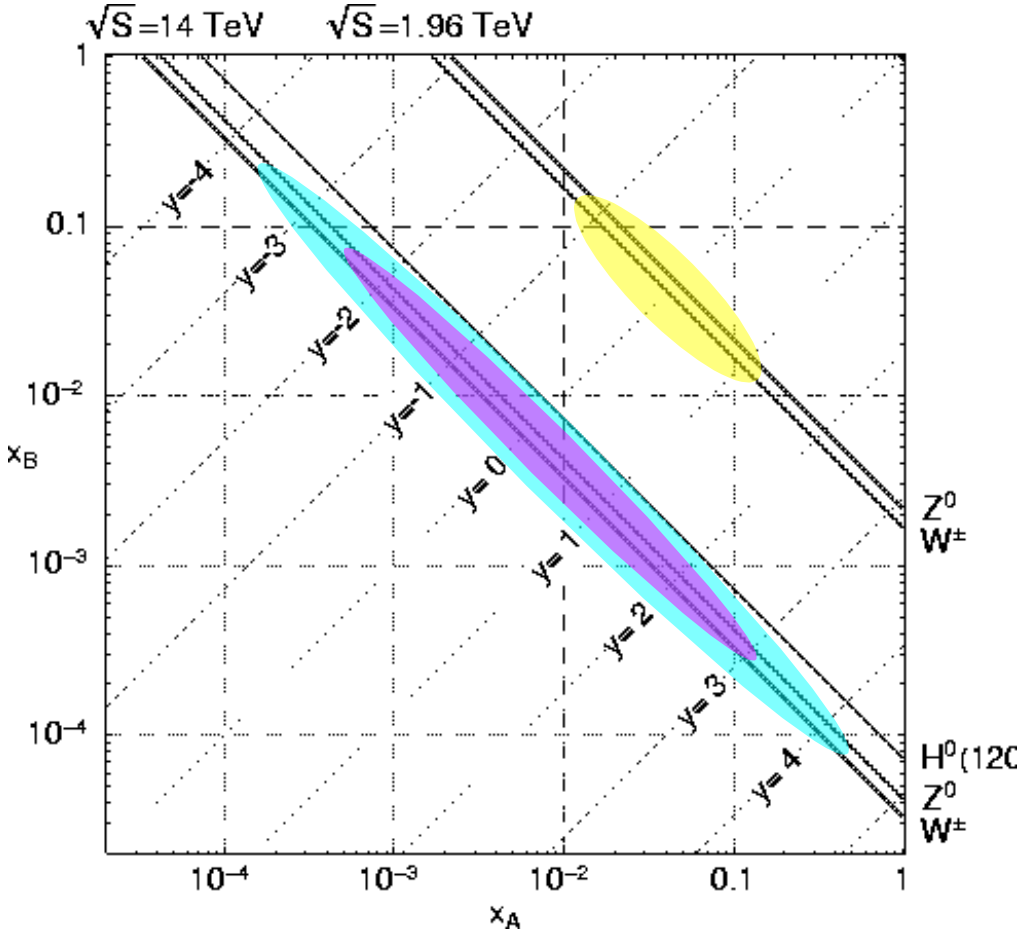


dσ/dy(W^+) at LHC

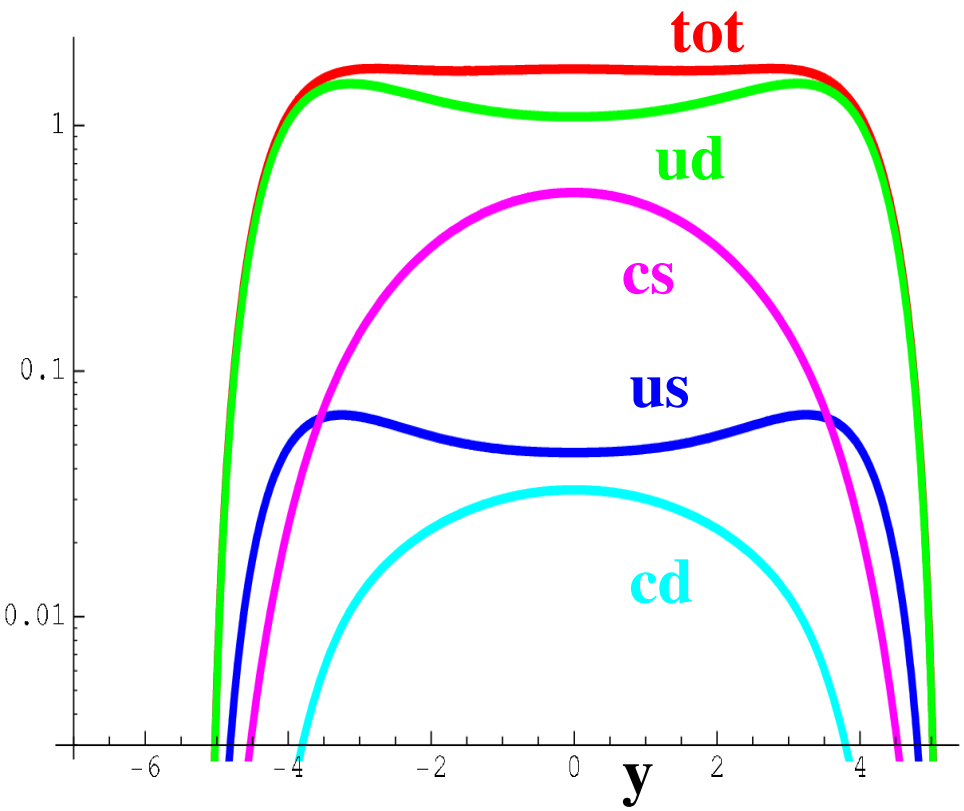


- Larger E ⇒ probes PDFs to small x
- Larger Rapidity ⇒ probes PDFs to really small x
- Larger fraction of heavy quarks

"Old" is "New" --- Re-discovering W & Z



dσ/dy(W⁺) at LHC

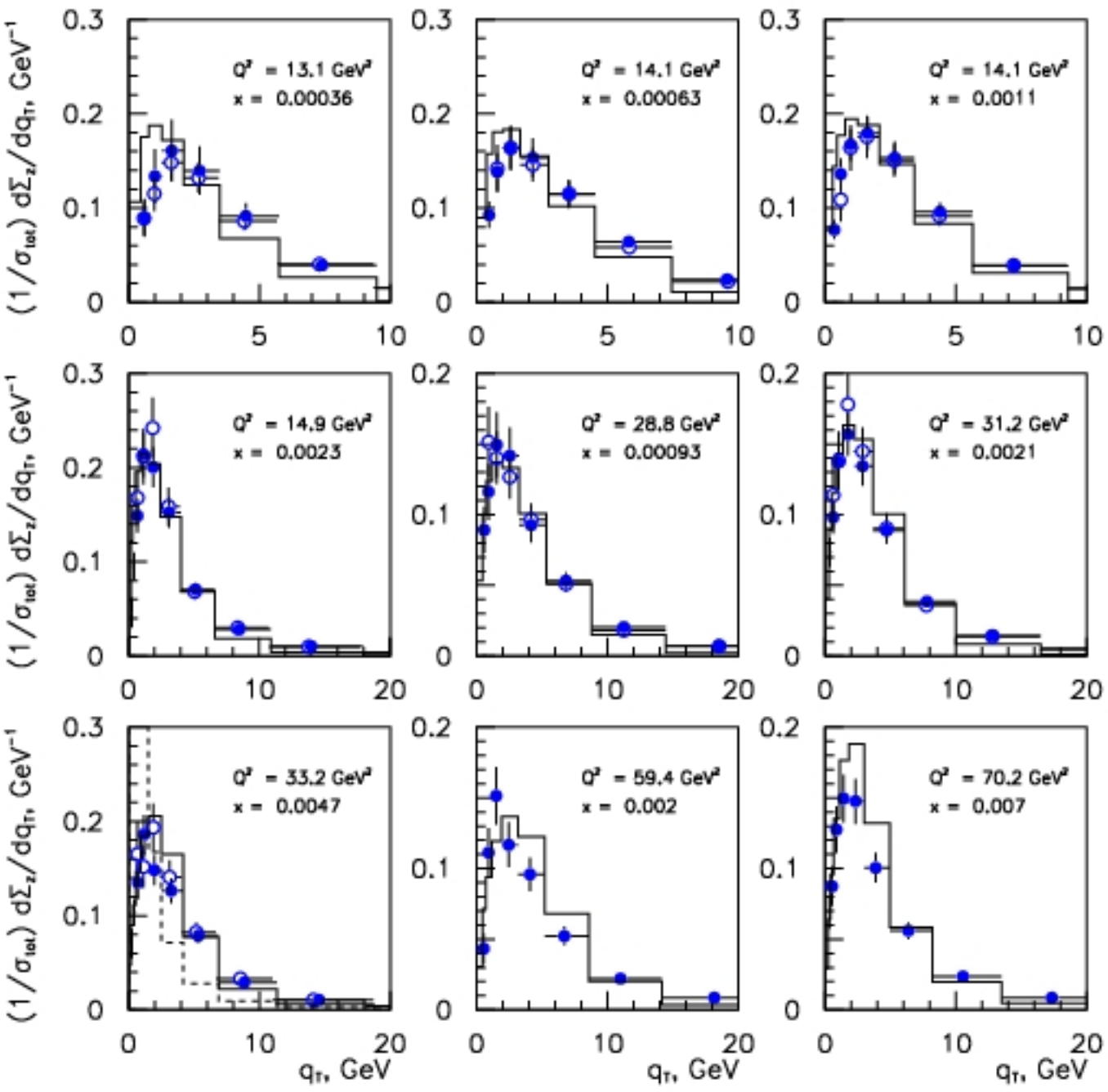


x range for LHC

x range for Tevatron

What can go wrong at small x???

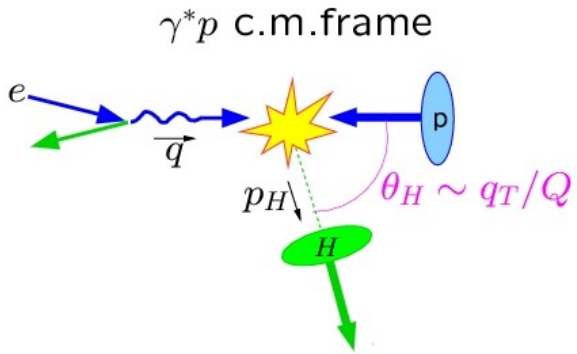
Differential energy flow at small-x???



... this data is not yet included in global fit

$$\frac{d\Sigma_z}{dx\,dQ^2\,dq_T}$$

$$d\Sigma_z = \int z\,\frac{d\sigma}{dz}$$



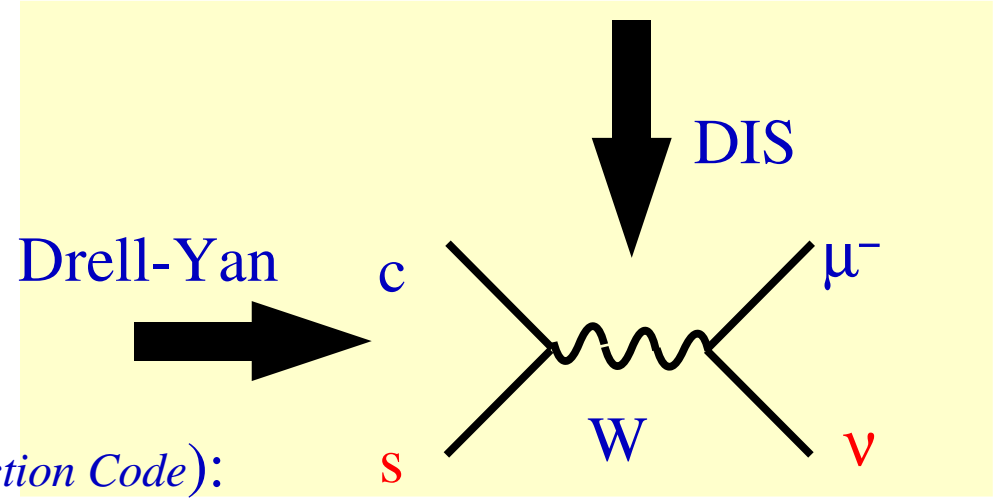
Extra q_T broadening for $x<10^{-2}$

H1 Collaboration,
PL B356, 118 (1995)
EPJ C12,595 (2000)

What are the implications for LHC???

Drell-Yan ($qq \rightarrow W/Z/\gamma/H \rightarrow ee$) at

LHC is simply crossed DIS process



Apply to LHC:

Use ResBos (*Resummed Boson Production Code*):

Implements Sudakov soft gluon resummation via CSS

Collins, Soper Sterman

Include small-x broadening in Sudakov exponent

$$e^{-S(q_T,Q)} \rightarrow e^{-S(q_t,Q)-\rho(x)q_T^2}$$

Additional small-x broadening term

Form taken from HERA data

Crossing is valid. See Collins & Metz

Only turns on at small-x

Possible Sources: *BFLK, Log(1/x), Higher Orders, Non-Perturbative ...*

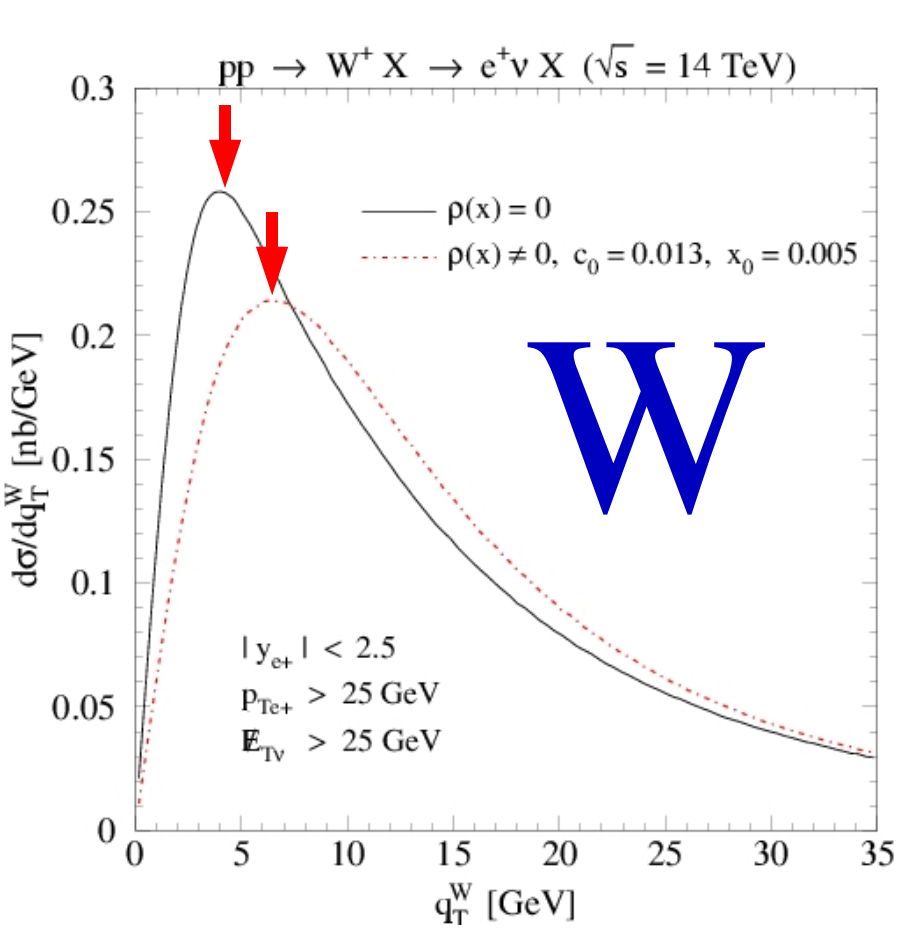
Method: simply parameterize the effects

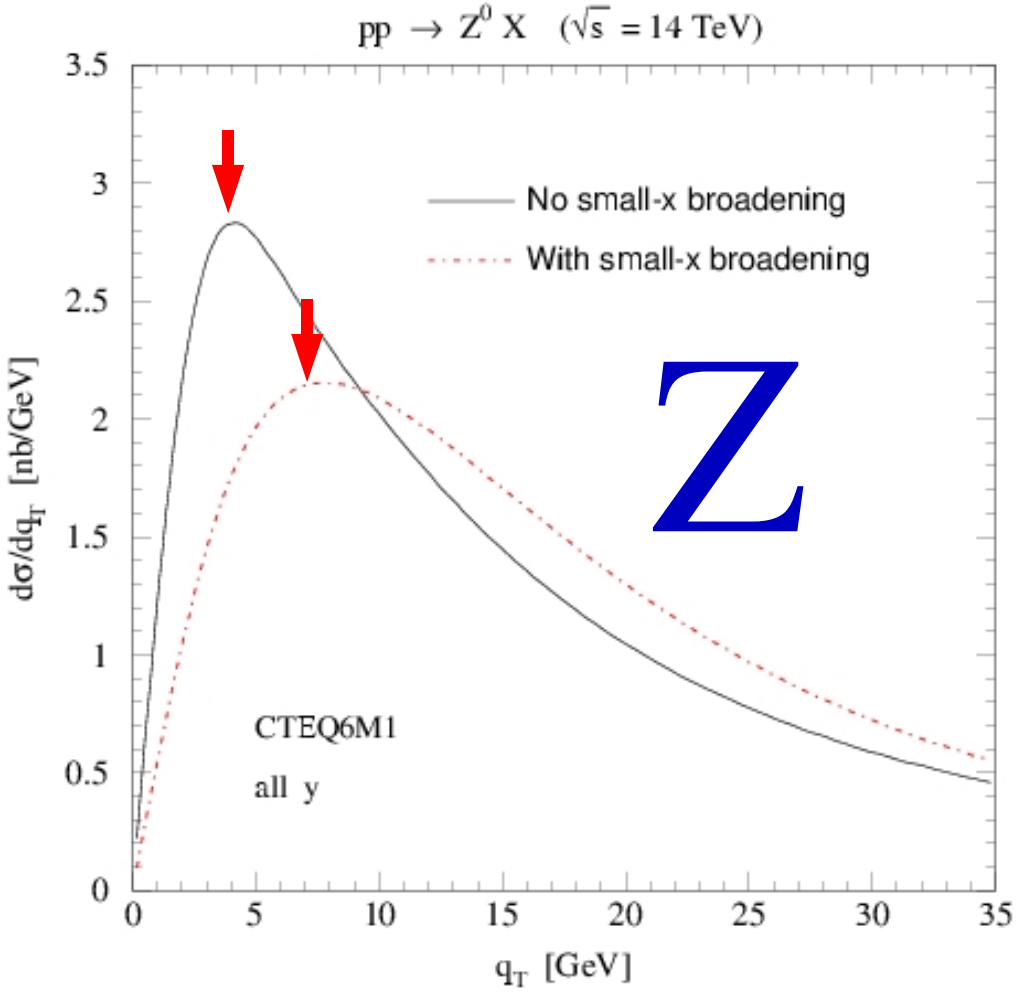
J. C. Collins and A. Metz, hep-ph/0408249.

J. C. Collins, D. E. Soper and G. Sterman, Nuc.Phys. B250, 199 (1985).

W/Z Production at LHC

These effects are note part of the "know unknowns"





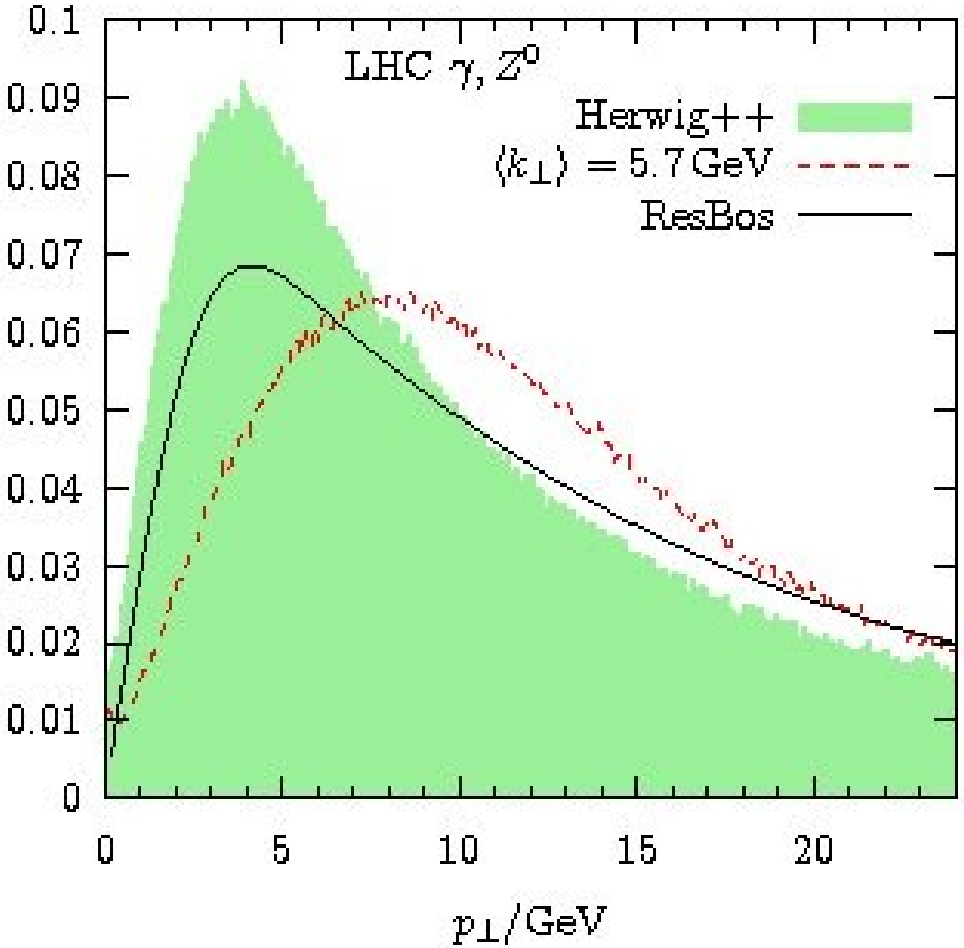
These uncertainties are not acceptable for "benchmark" processes

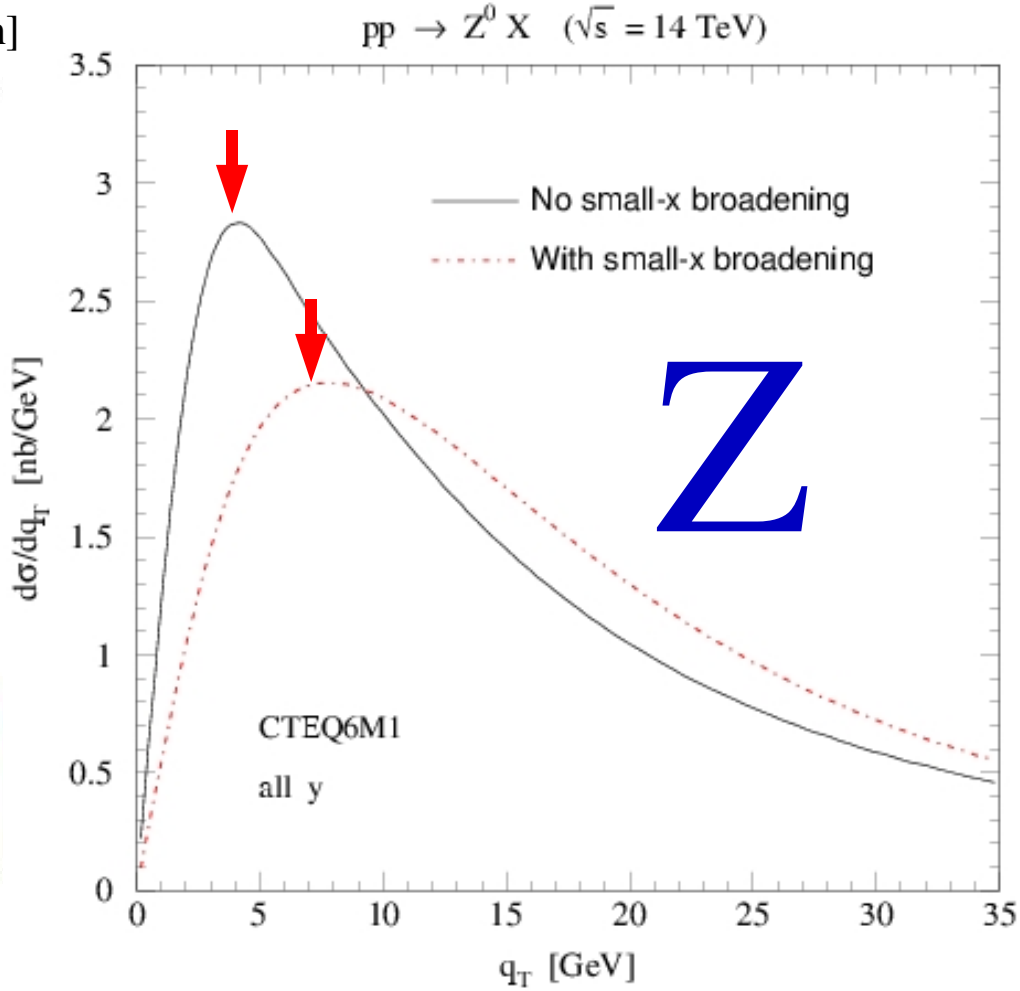
Berge, Nadolsky, Olness PRD72:033015,2005.

W/Z Production at LHC

These effects are note part of the "know unknowns"

Gieseke, Seymour, Siodmok, arXiv:0712.1199 [hep-ph]





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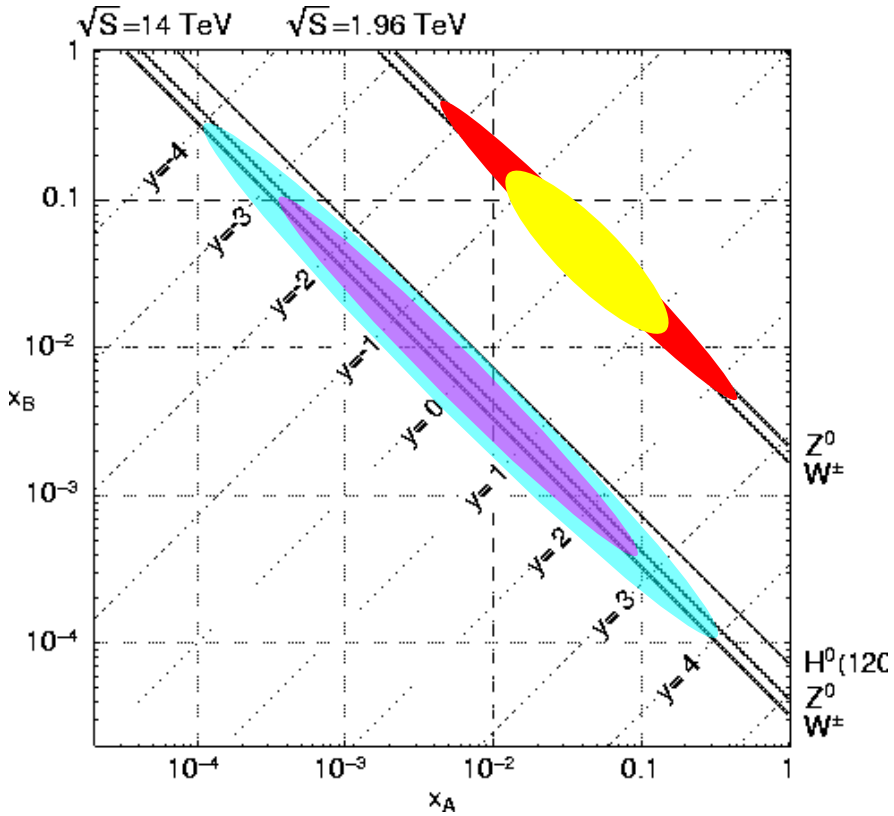
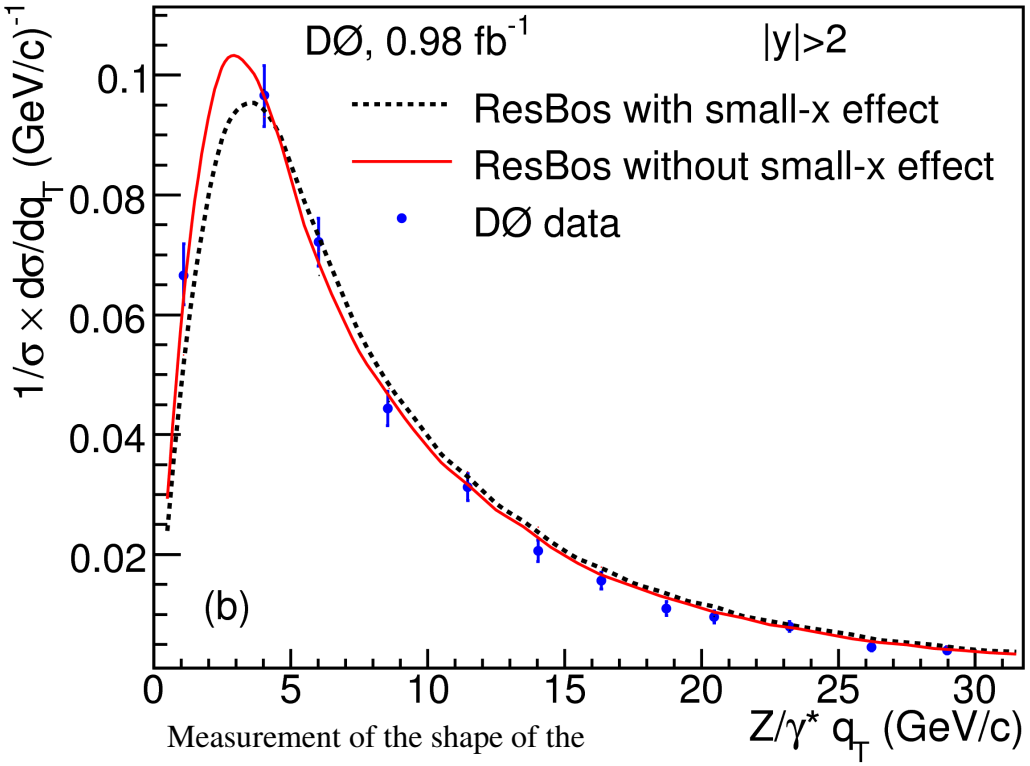
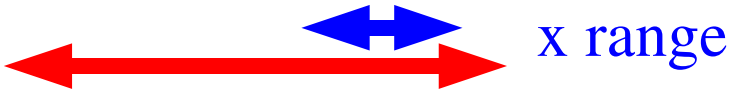
Berge, Nadolsky, Olness PRD72:033015,2005.

Tevatron $Z \rightarrow ee$ Measurements



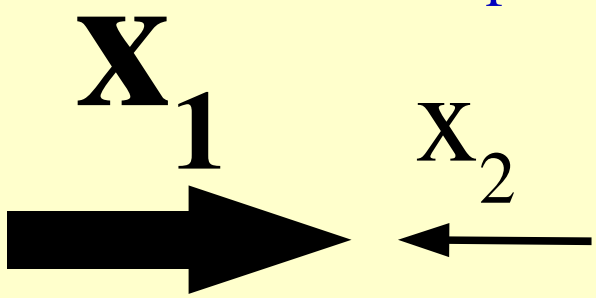


Measurement of the shape of the boson transverse momentum distribution ....
D0 Collaboration FERMILAB-PUB-07-642-E, Dec 2007.



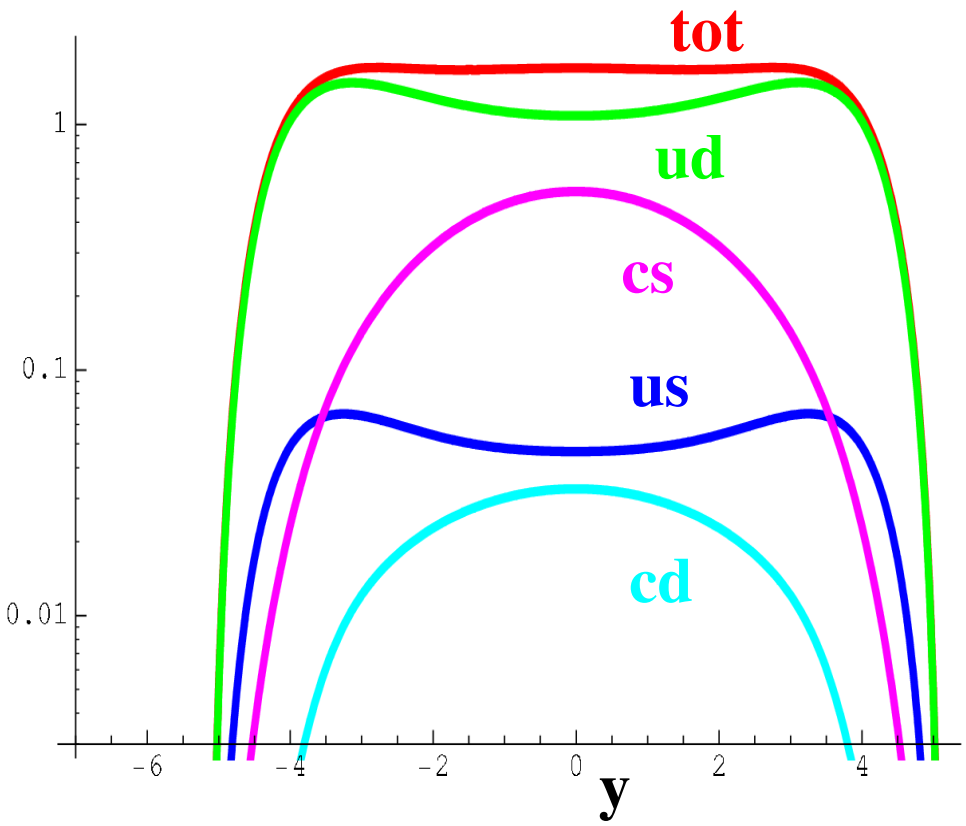
x range for LHC

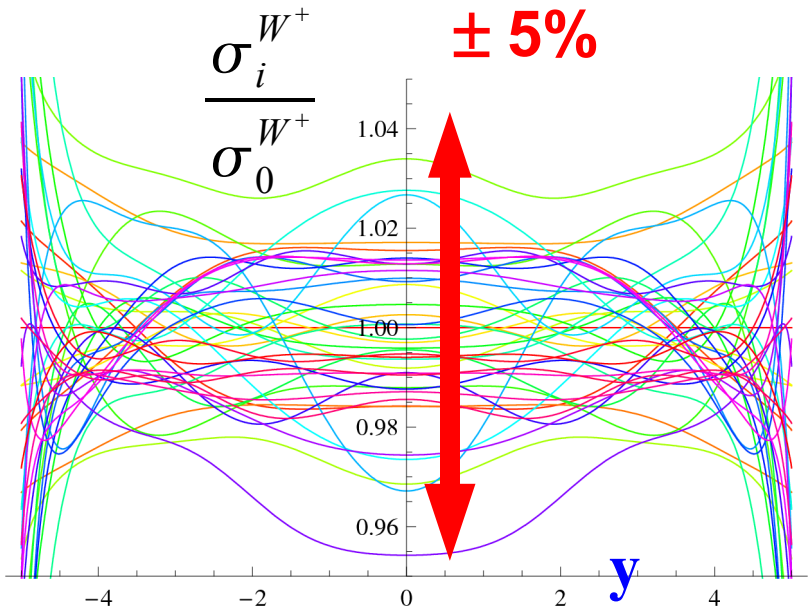
x range for Tevatron

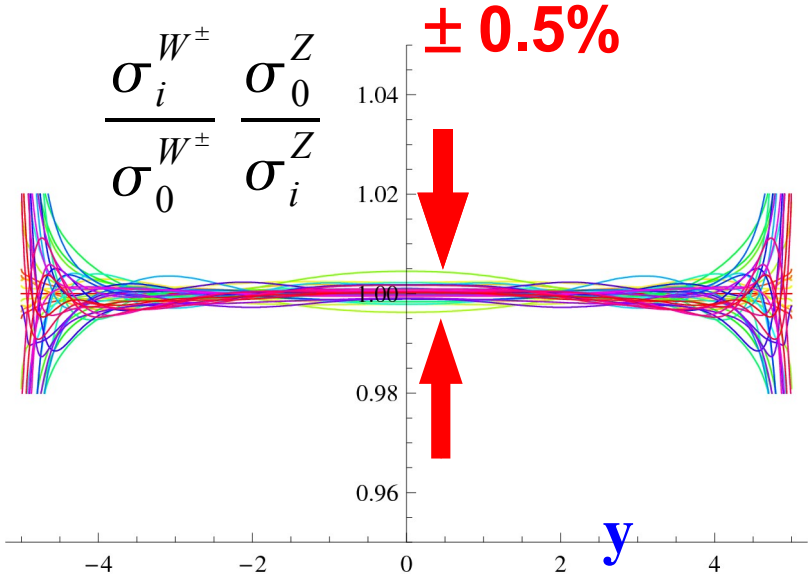


PDF Uncertainties

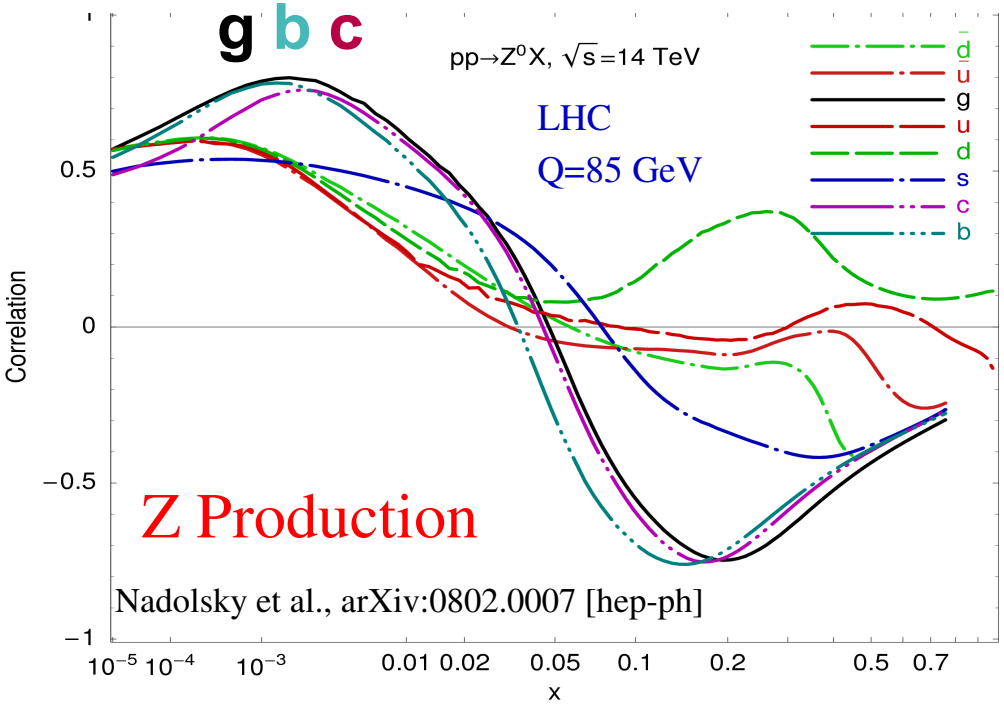
Can we use Z to "Calibrate" W ???

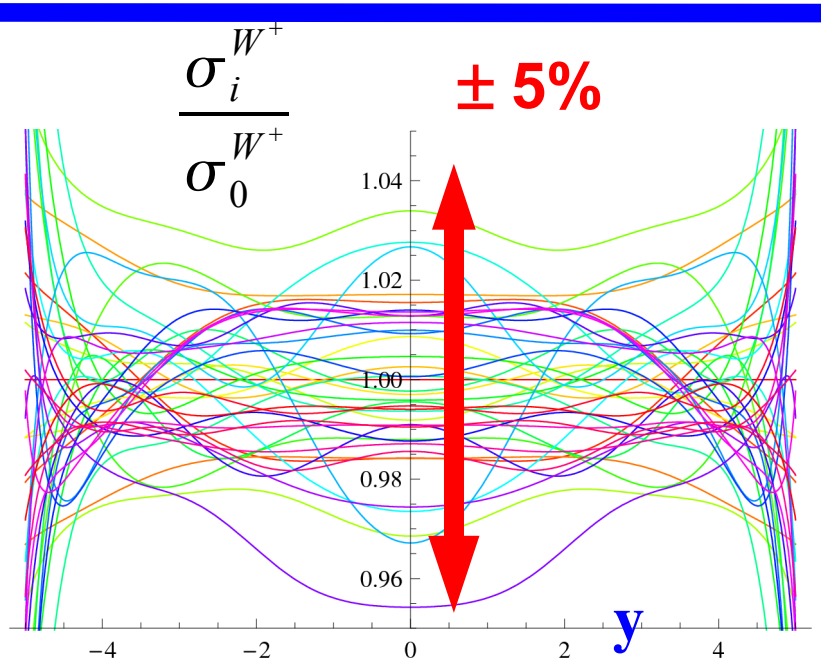


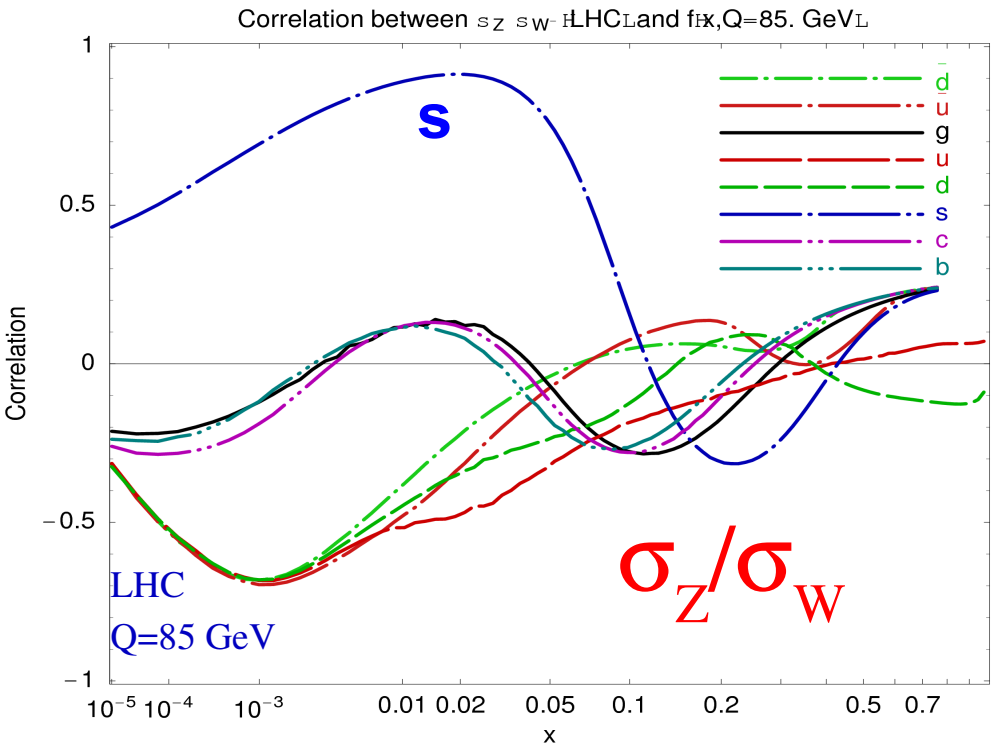


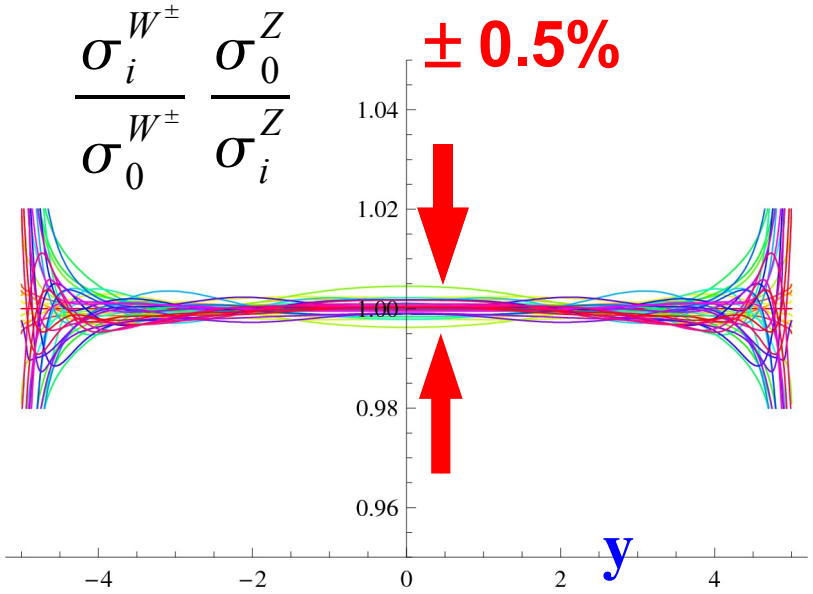


W, Z Correlations



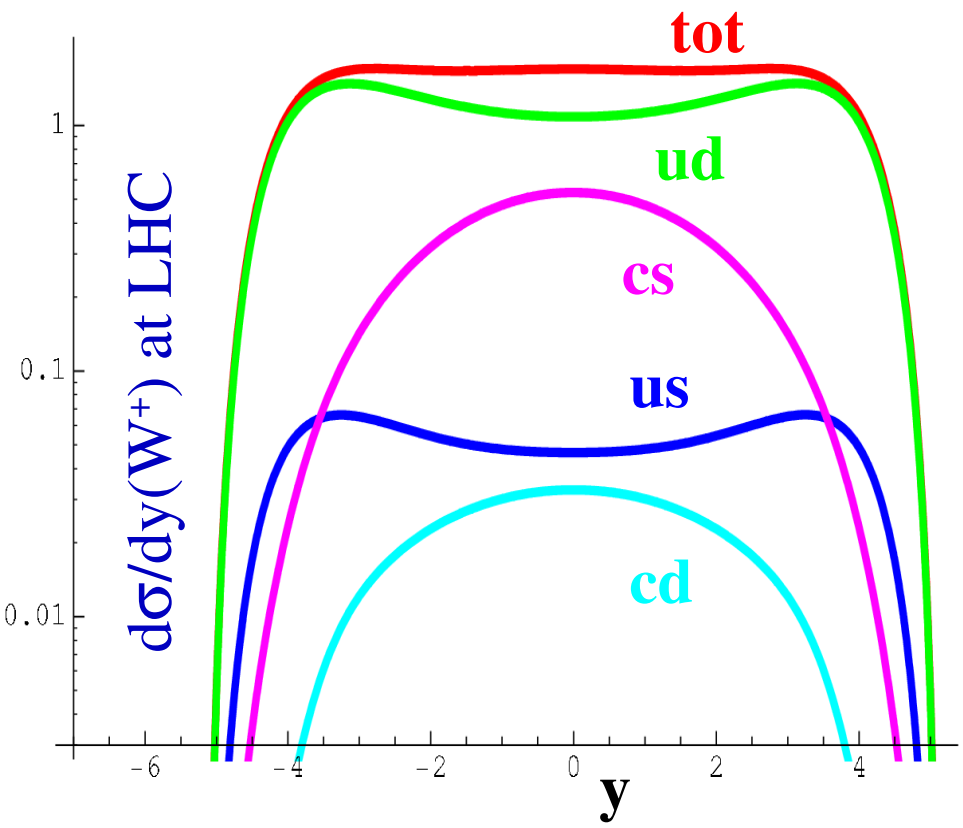


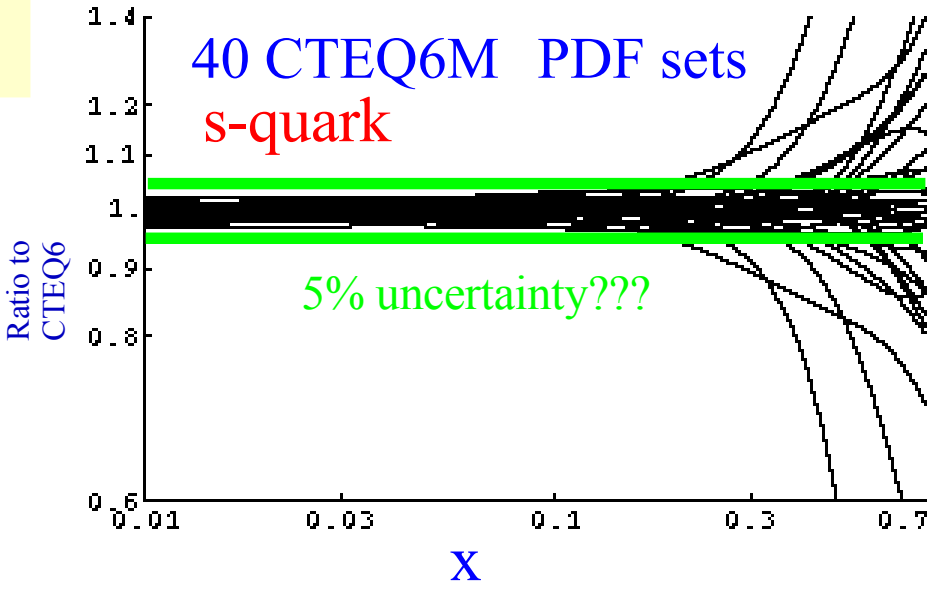


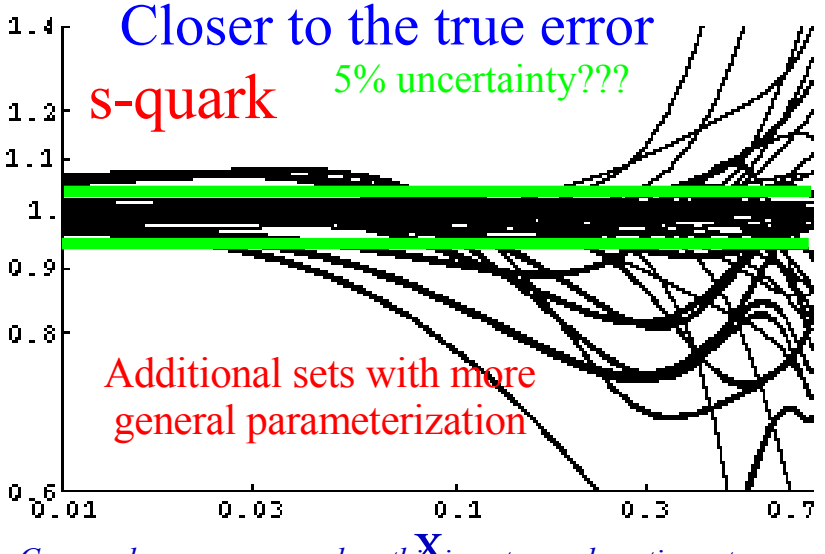


How well do we know the Strange PDF???

Heavy quark PDFs essential ingredient





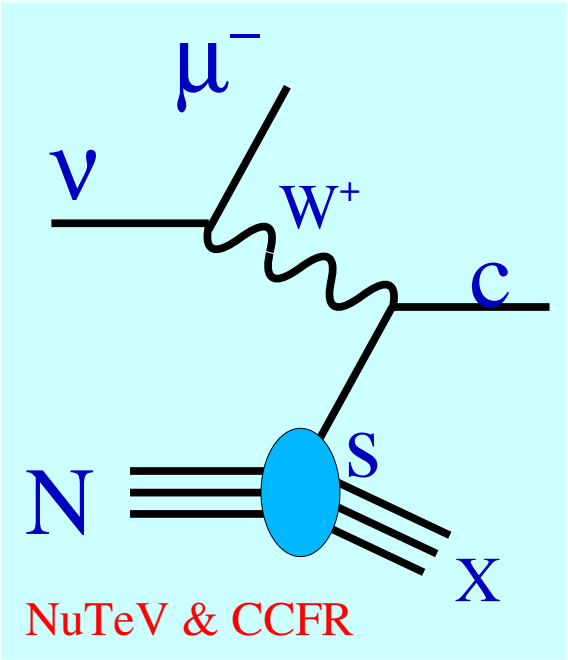


Curves shown are examples; this is not an exhaustive set

Warning: The Director General has determined the band of PDFs can greatly underestimate the true uncertainty

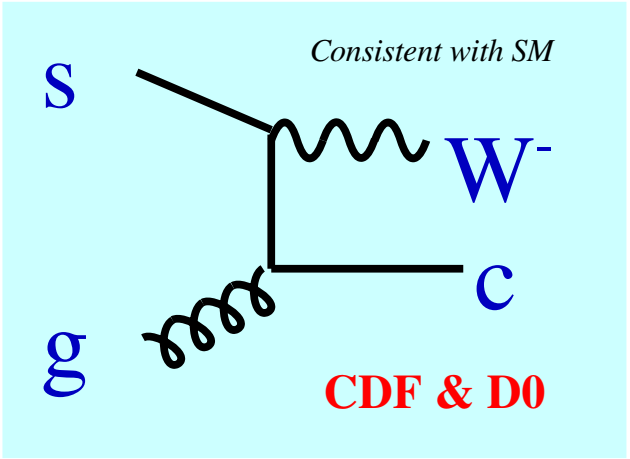
What constrains the Strange PDF

Neutrino DIS Charm Production



NuTeV & CCFR

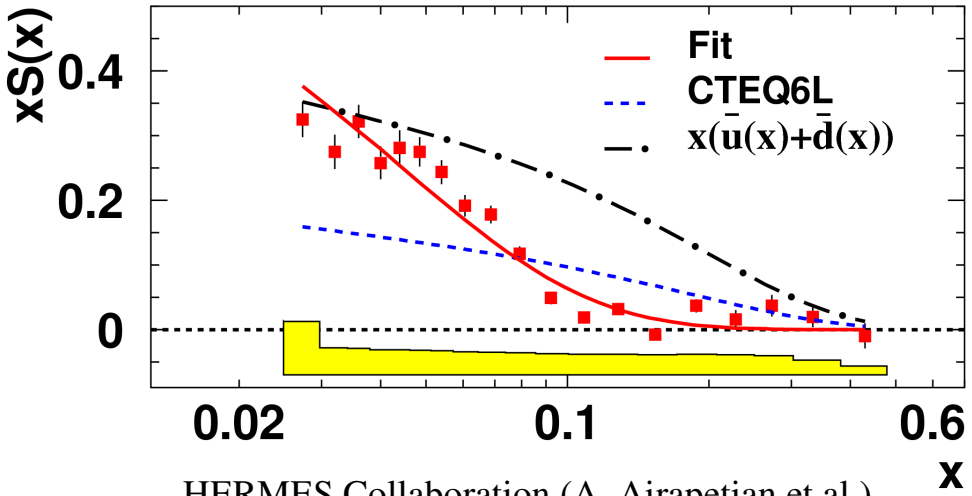
s g→Wc at the Tevatron



CDF ArXiv:0711.2901 [hep-ex]
D0 Note 5415-CONF (July 2007)

- ν-DIS: Hi Stats, Nuc. Corr.
- TeV: Consistent, need stats
- LHC: s g→Wc difficult?

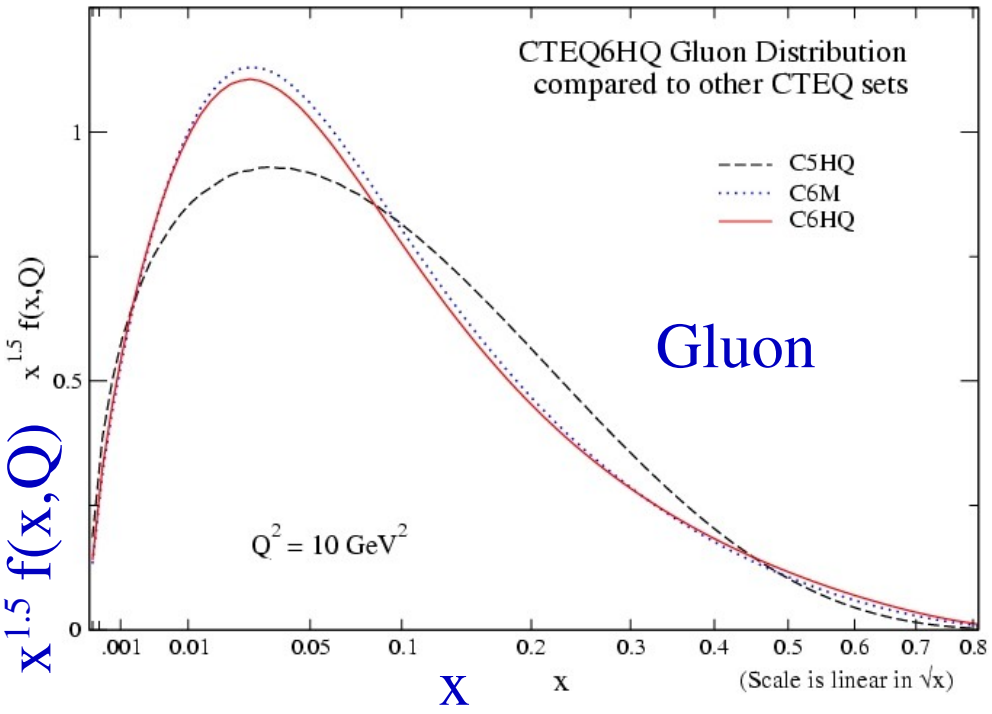
HERMES: DIS $K^{\pm}$ Production

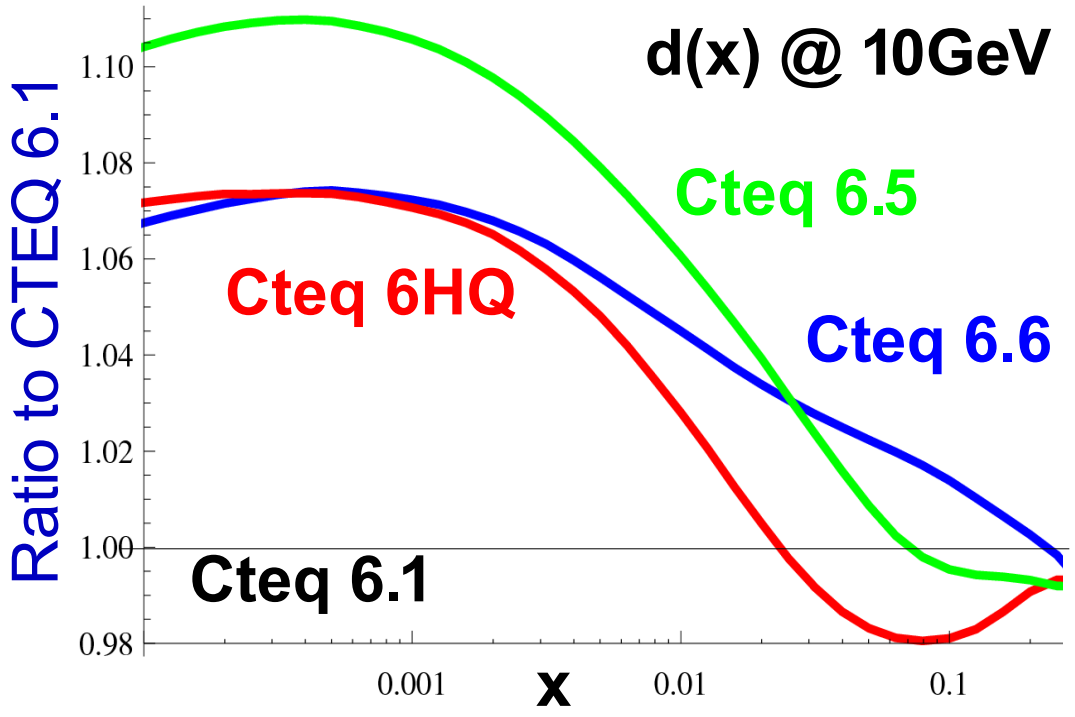


HERMES Collaboration (A. Airapetian et al.)
arXiv:0803.2993 [hep-ex]

Heavy Quarks & PDF's

Heavy Quark Schemes: CTEQ6M, CTEQ6HQ, CTEQ5M





- Large shift C5M⇒C6M
  - *(New DIS & Jet data)*
- Charm PDF tied to gluon *(g →cc)*
- Small visual difference but ...

Shift due to both scheme and uncertainty

χ^2/DOF

Set	# pts	6HQ	6M	6M⊗GM	6HQ⊗ZM
ZEUS	104	0.91	0.98	2.84	3.72
H1	484	1.02	1.04	1.50	1.22
TOTAL	1925	1.04	1.06	1.26	1.30

Mixed Schemes

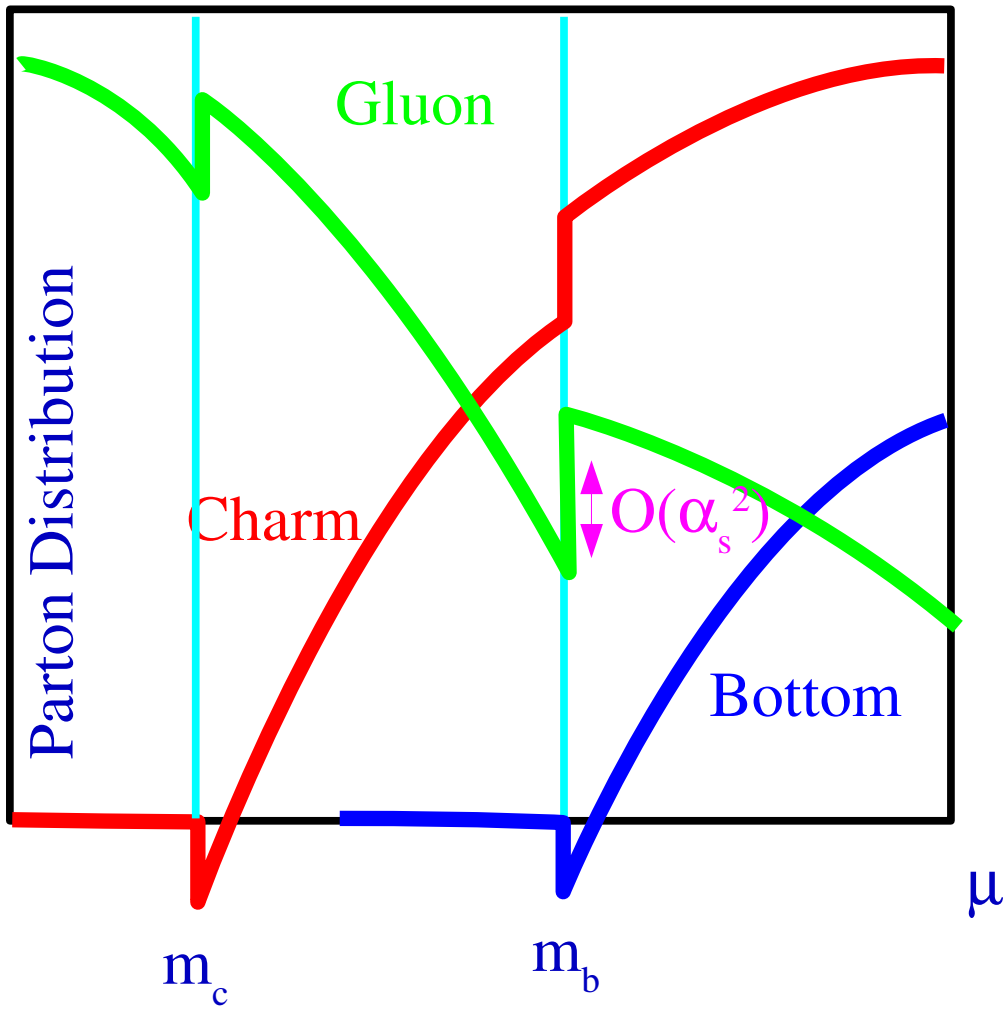
S. Kretzer, H.L. Lai, F. I. Olness and W.K. Tung. Phys.Rev.D69:114005,2004

NNLO

A proposal for NNLO PDF implementation

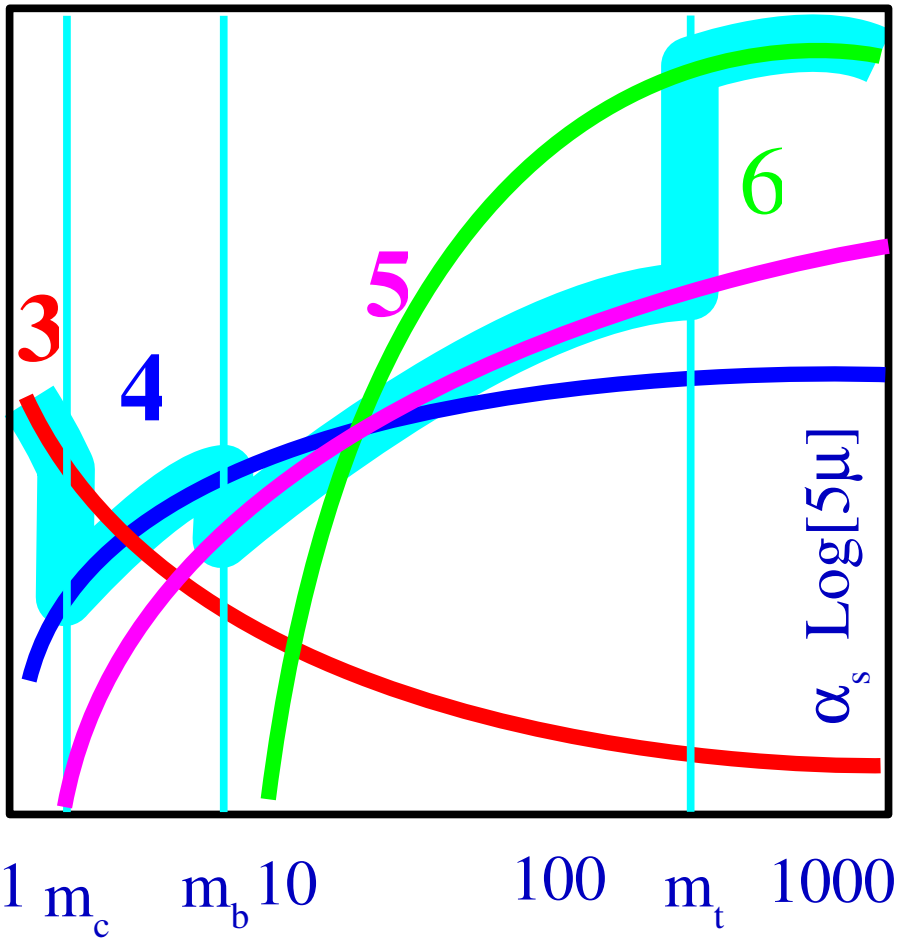
A Proposal for PDFs at NNLO

PDFs as a function of μ



Not continuous at $O(\alpha_s^2)$

α_s as a function of μ

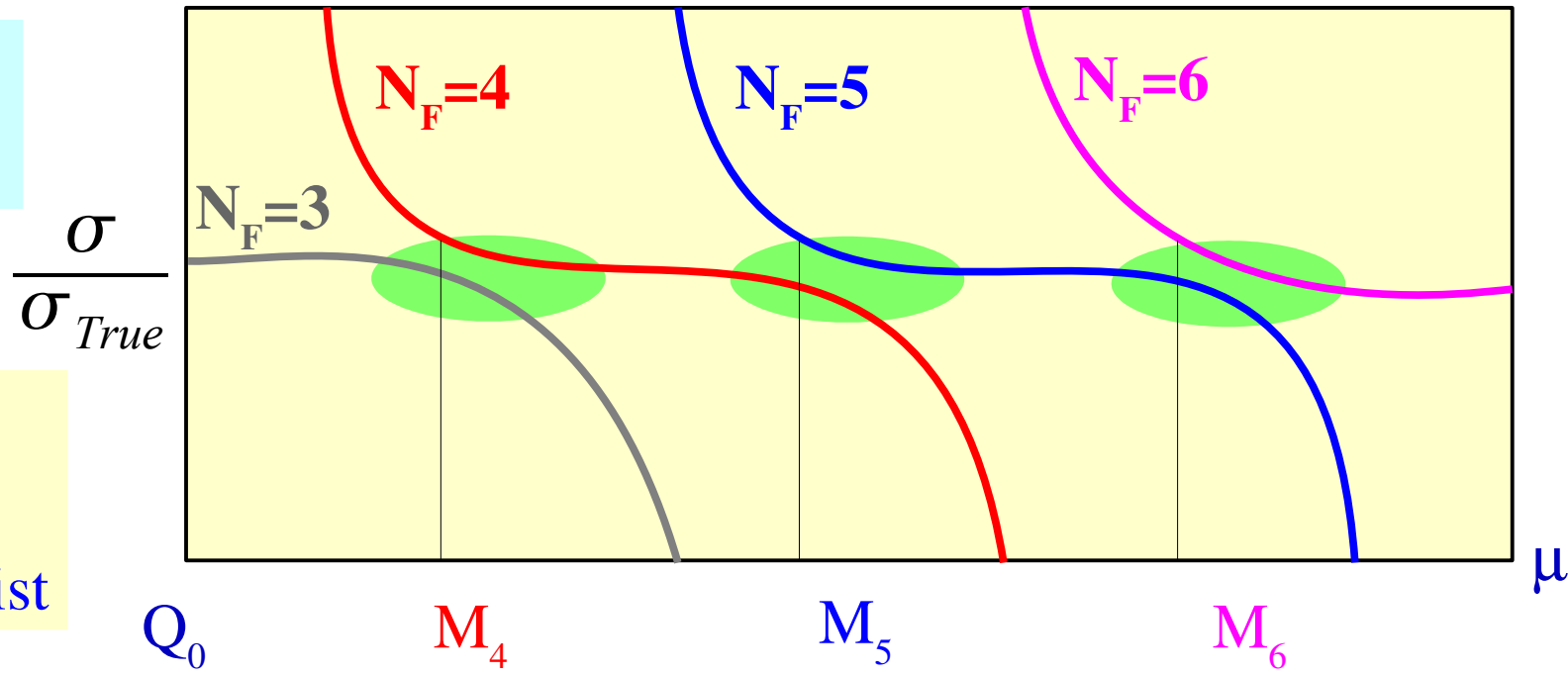


Not continuous at $O(\alpha_s^3)$

A Proposal for PDFs at NNLO

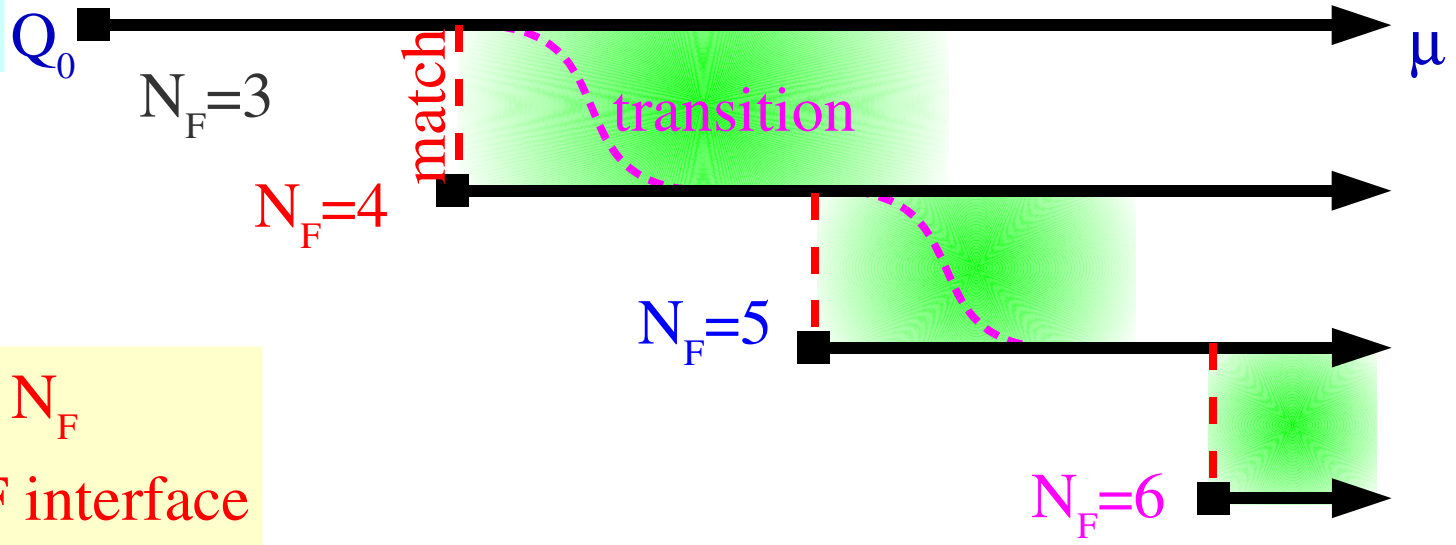
Match at μ=m
Transition at ...

For μ~m,
N and N+1
Schemes Co-exist



$f_{a/p}(x, Q, N_F)$

new



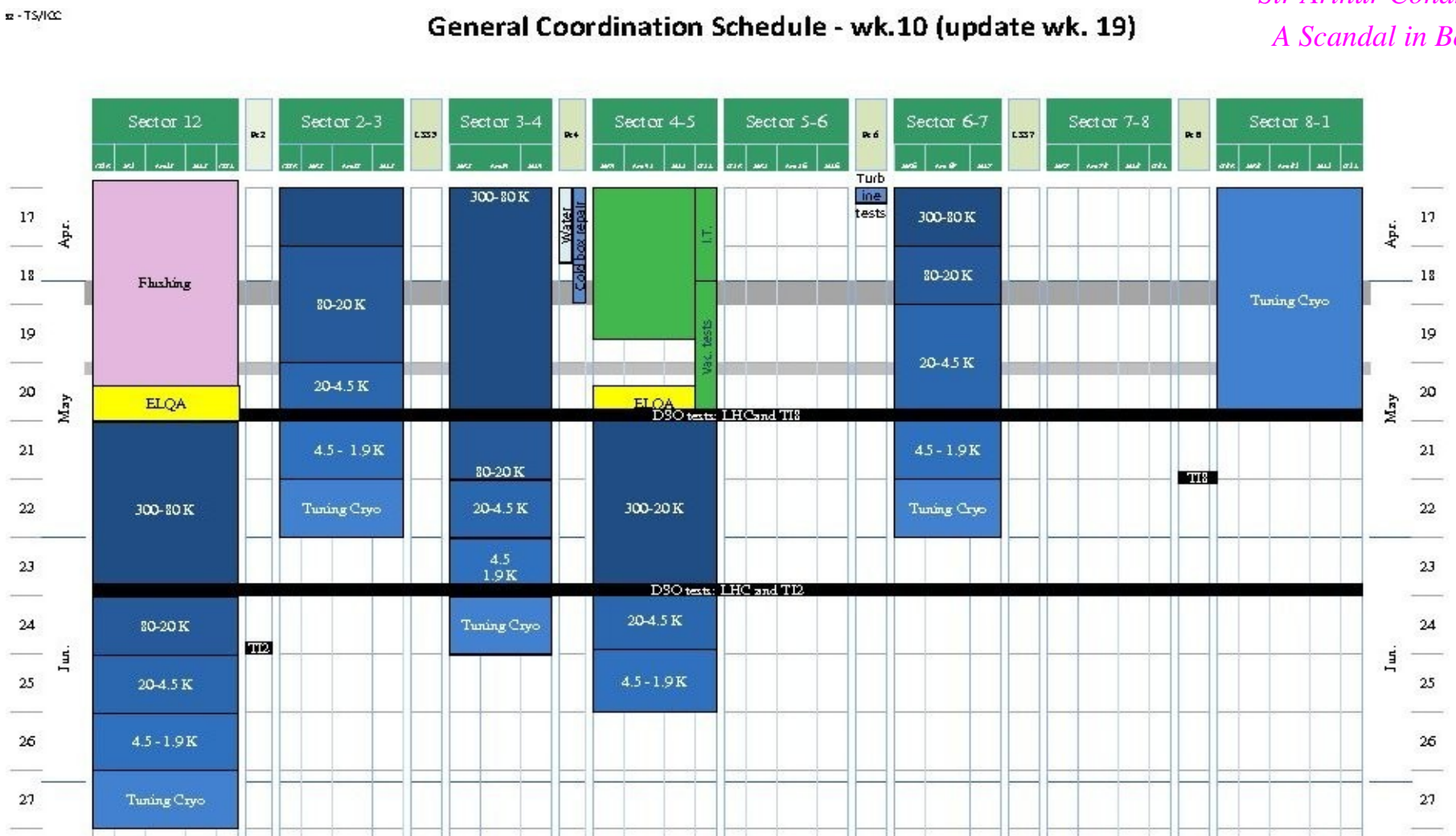
- Freedom to specify N_F
- Requires N_F in PDF interface
- Simplified Numerics

Conclusion

“I have no data yet.

It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts.”

The Adventures of Sherlock Holmes
Sir Arthur Conan Doyle
A Scandal in Bohemia



Conclusions

* W/Z Production:

  LHC probes smaller x values where PDF's are undetermined

  Essential for "calibration"

  We will need to "re-discover" W & Z Physics

* Heavy Quarks & PDFs

  Massive treatment matters--this is real progress!!!

  Heavy DOF impact light DOF

* NNLO Issues:

  Matching conditions have $O(\alpha_s^2)$ gap

  Proposal: Allow N_F and N_F+1 Schemes to Co-Exist

Thanks to: P. Nadolsky, S. Berge, I Schienbein, J.-Y. Yu, J. Owens, J. Morfin, C. Keppel, M. Boonekamp, ...