Displacement of Thresholds in xFitter¶

V. Bertone, R. Placakyte, V. Radescu, E. Godat, F. Lyonnet, F. Olness …. & xFitter collaborators

What is the idea???

xFitter

Impact of heavy quark matching scale dependence in global PDF fits

APFEL has a new feature

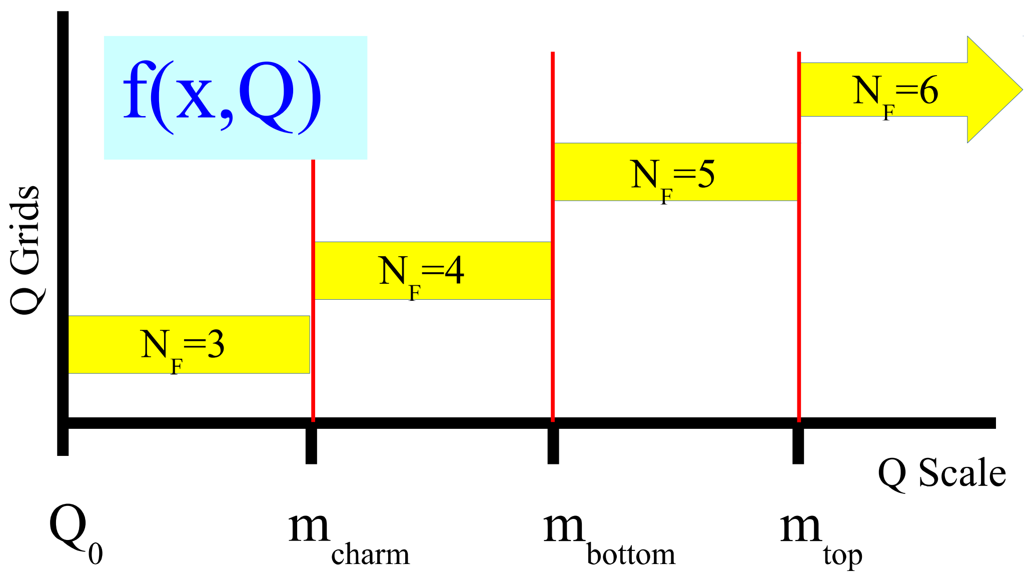
We can adjust the matching scale for the heavy quark PDF transition

What are the benefits?

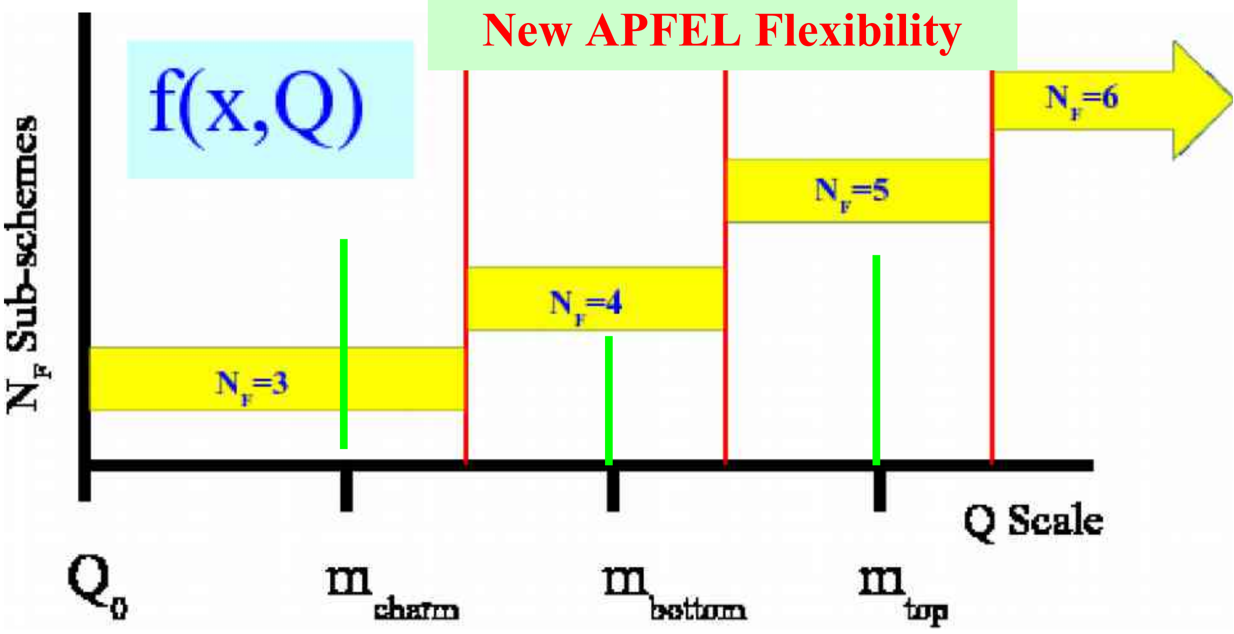
1) avoid discontinuities in the middle of data sets

2) avoid delicate matching in region $\mu \sim m_{c,b}$

Traditional VFNS



New APFEL Flexibility



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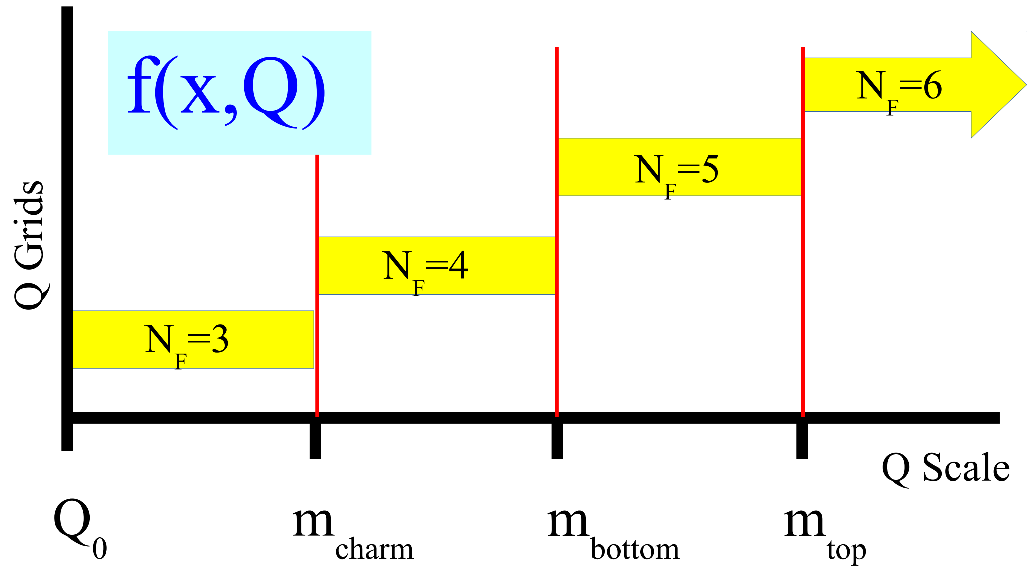
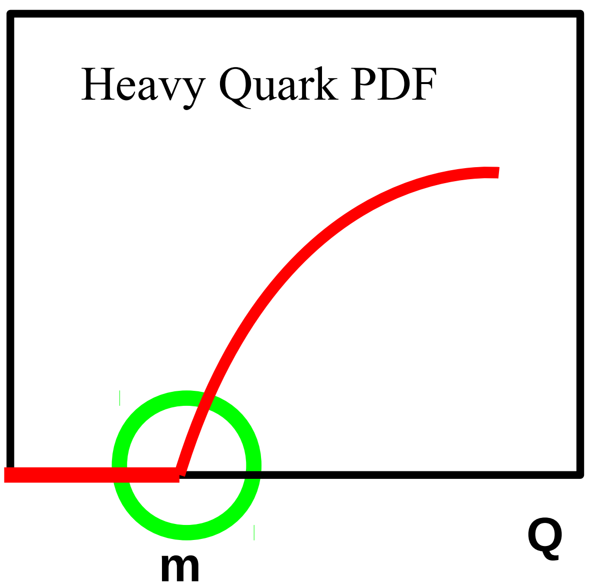


NLO Matching Condition

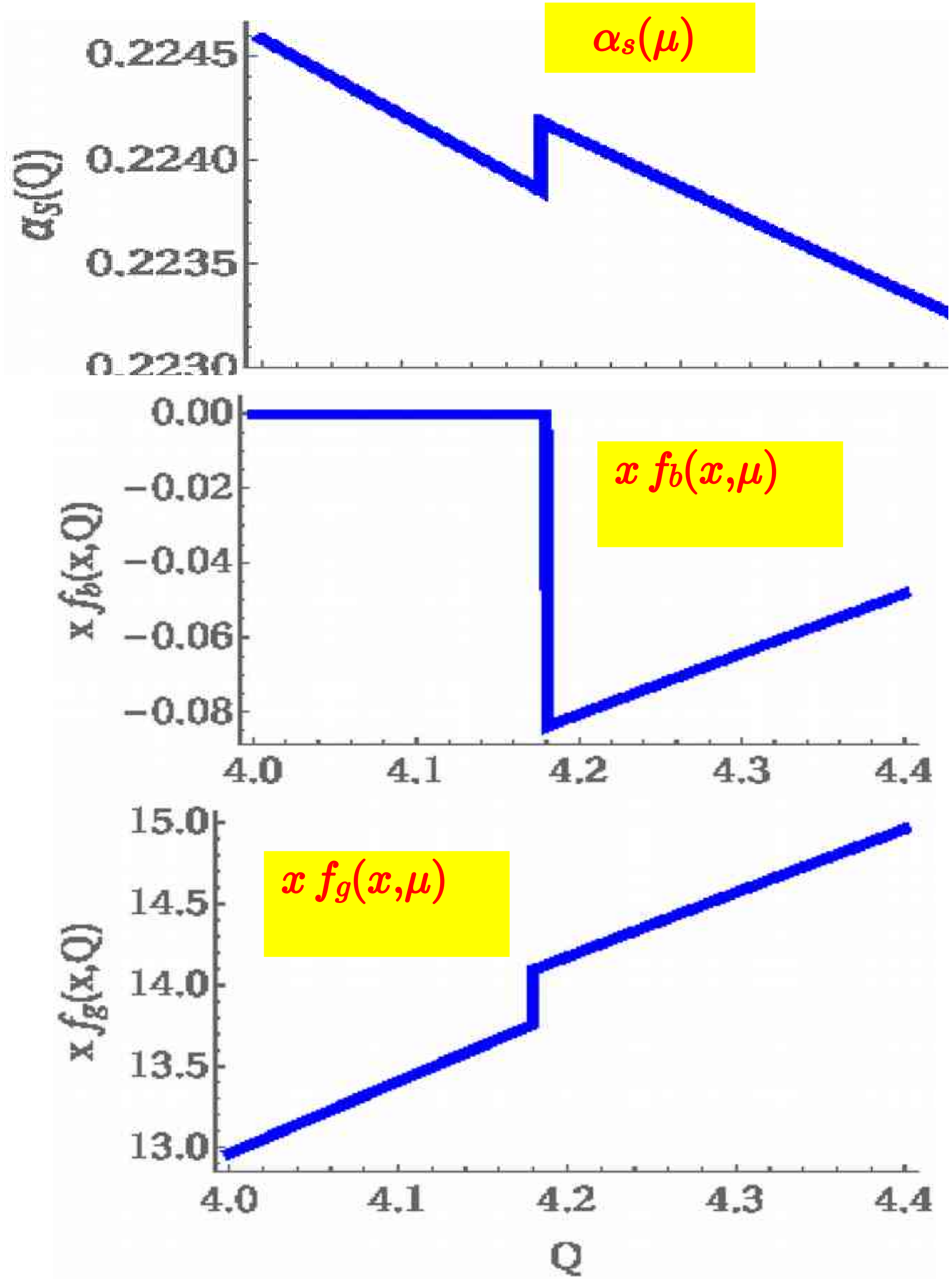
$$f_b^5(x,\mu) = \left(\frac{\alpha_S}{2\pi}\right)\left[P_{1,0} + P_{1,1}\log\left(\frac{\mu^2}{m_b^2}\right)\right] \otimes f_g^4(x,\mu)$$

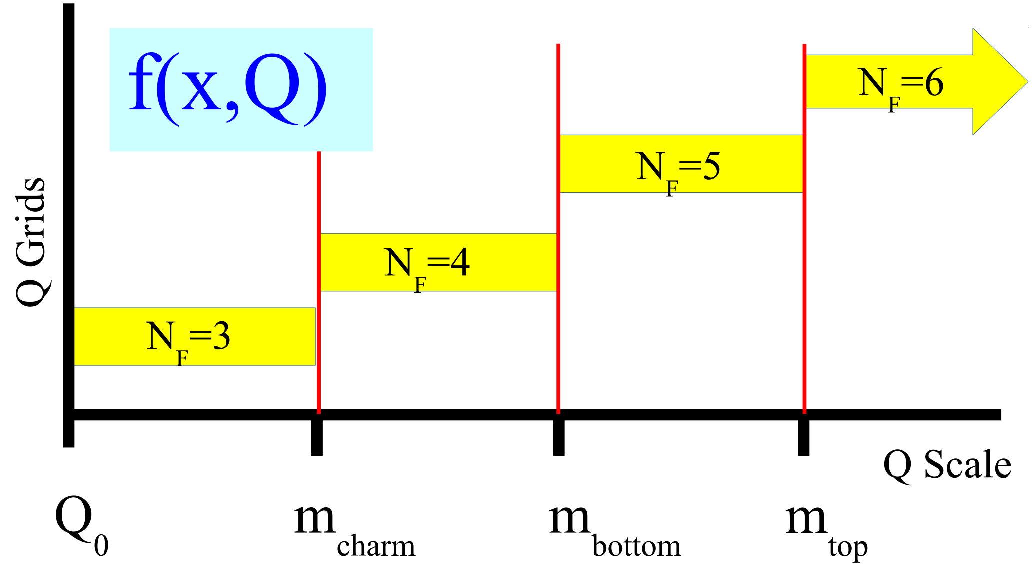
Zero at Leading Order

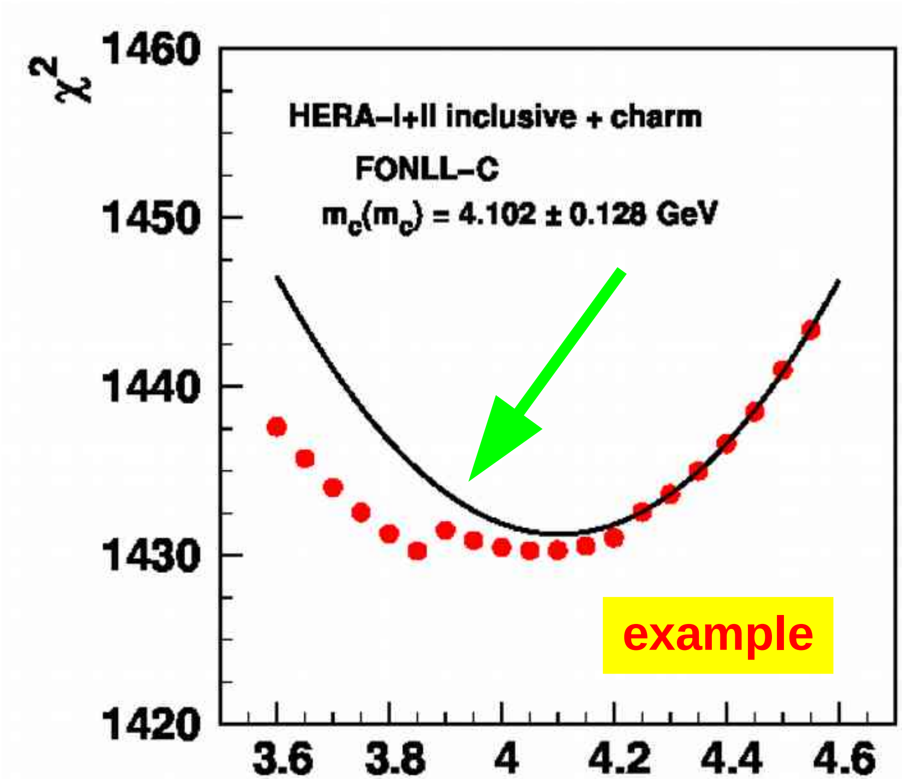
Leading DGLAP contribution



At NNLO we cannot avoid discontinuities







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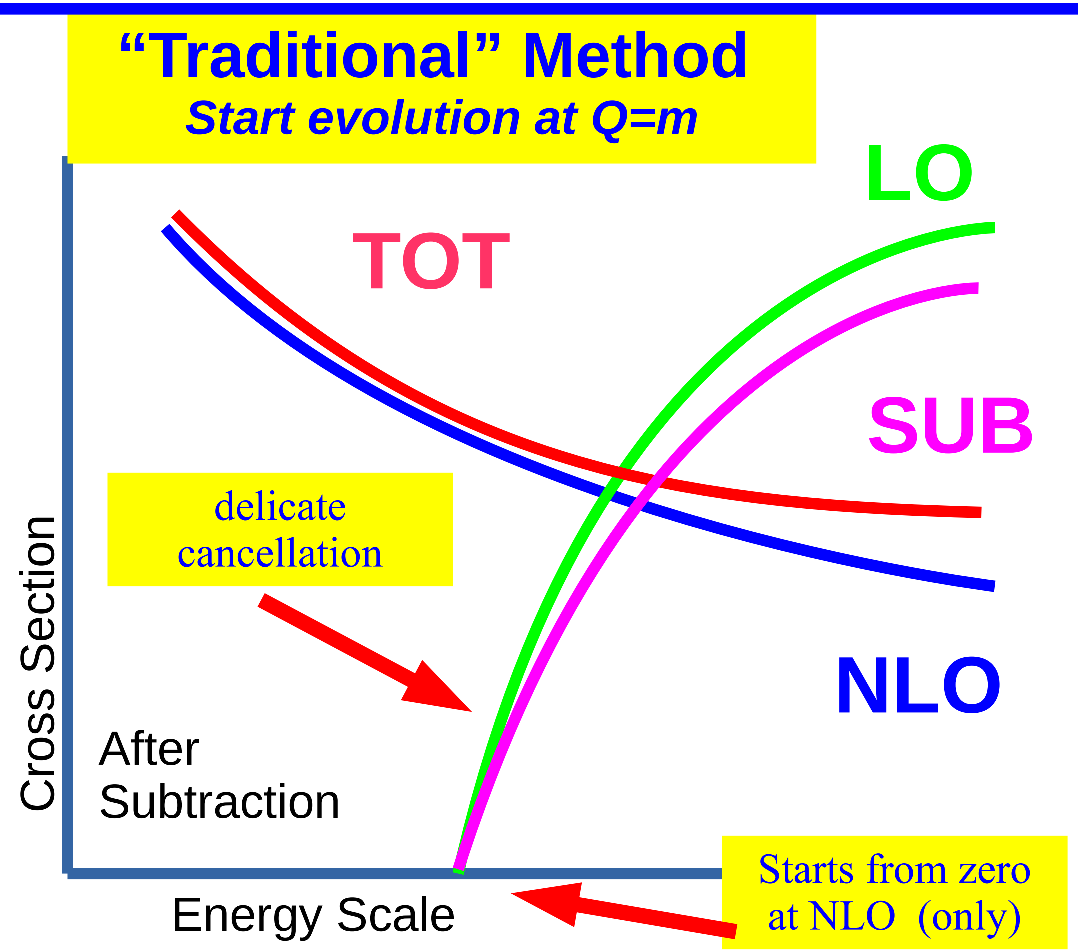
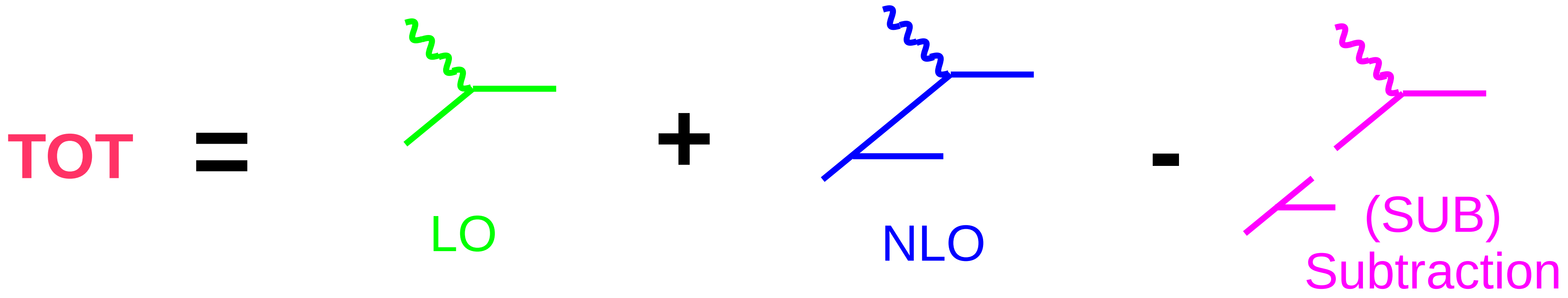
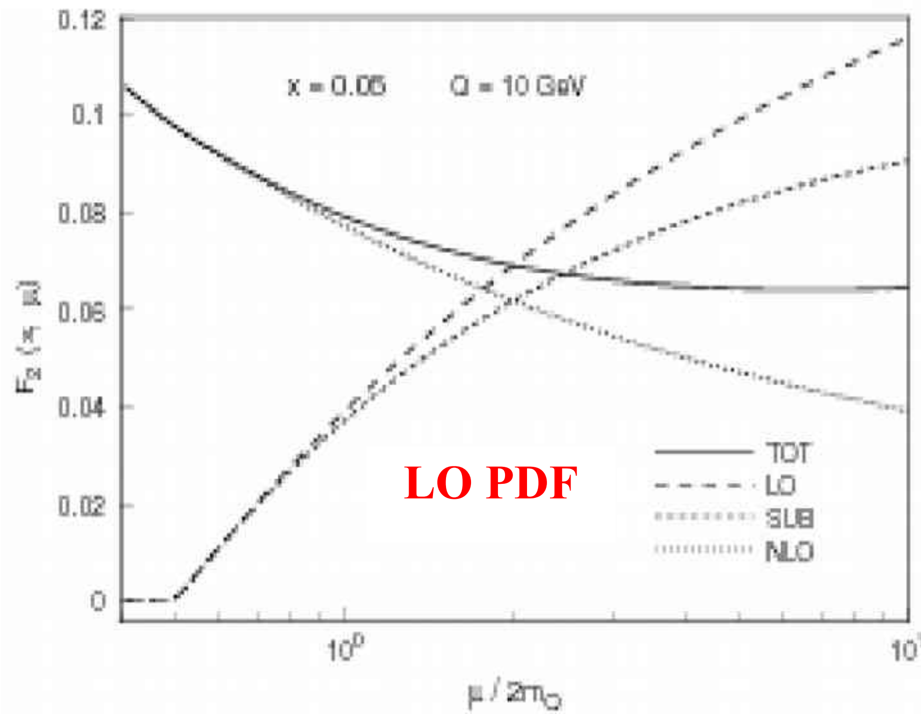
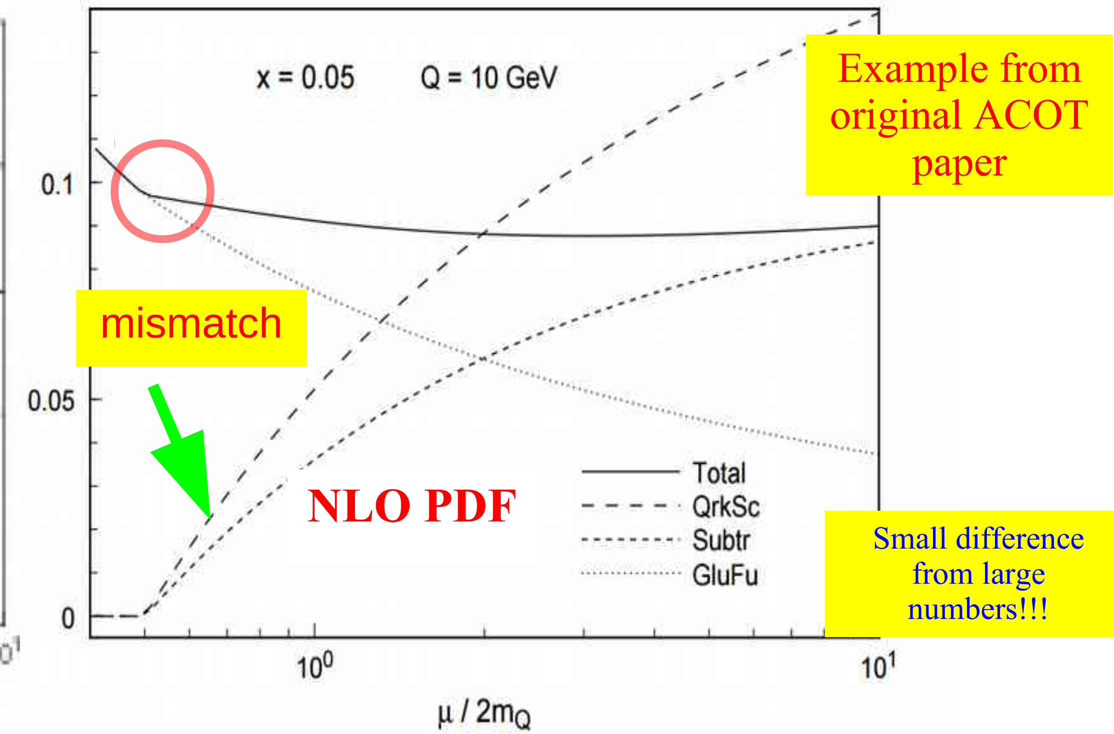
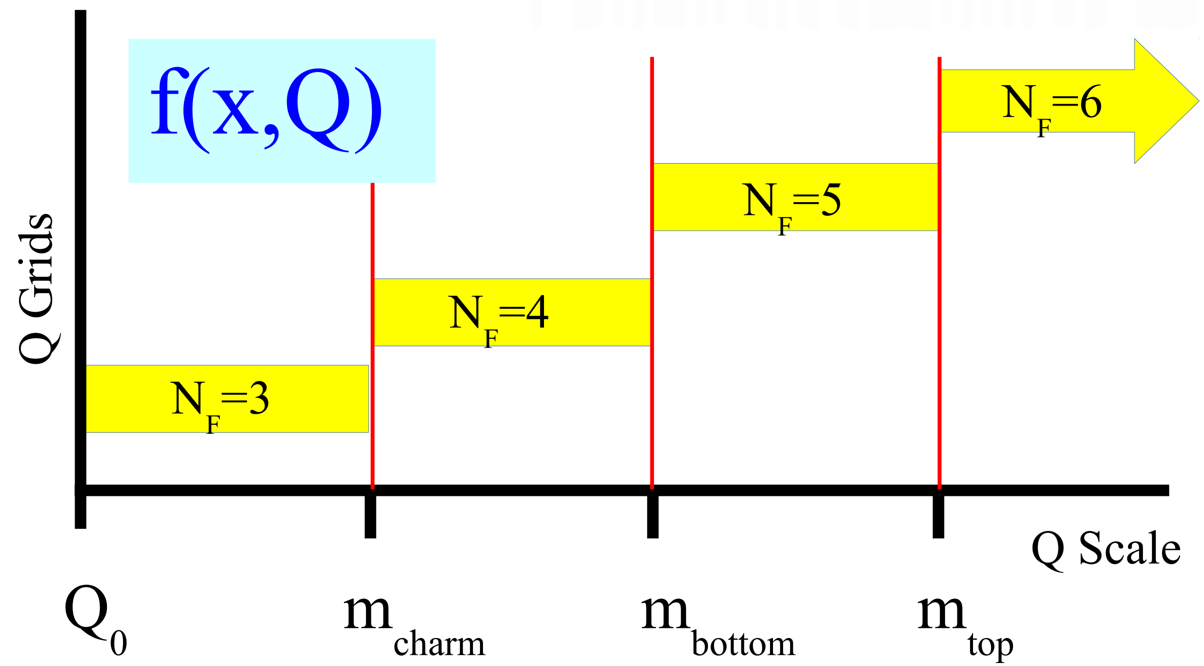




Delicate cancellation in $\mu \sim m_{c,b}$ region for VFNS







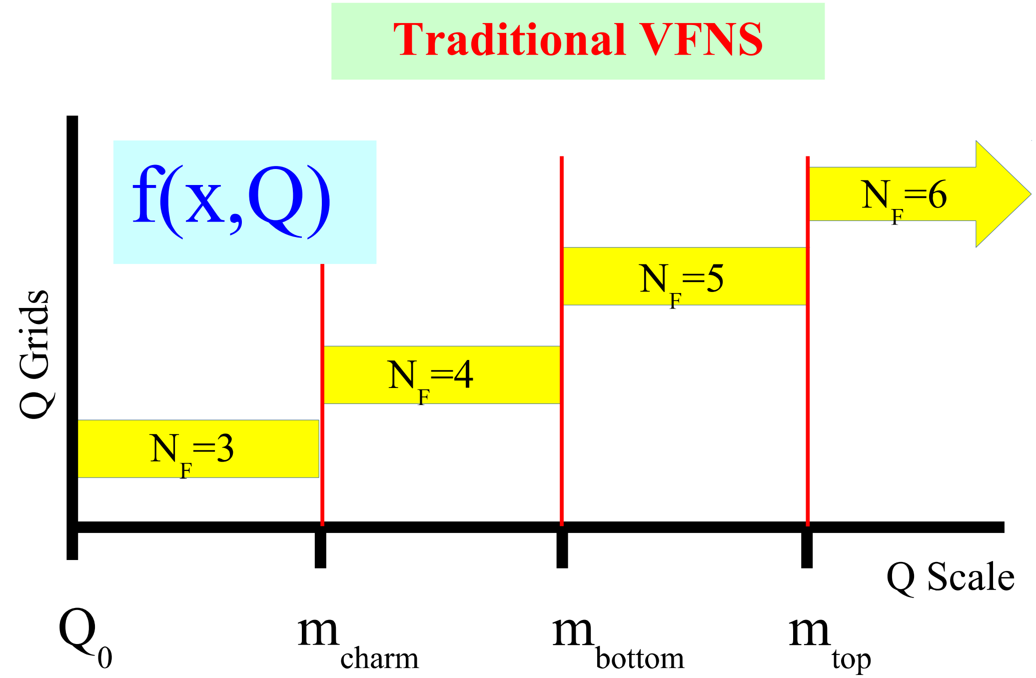
SOLUTION: shift heavy quark matching scale

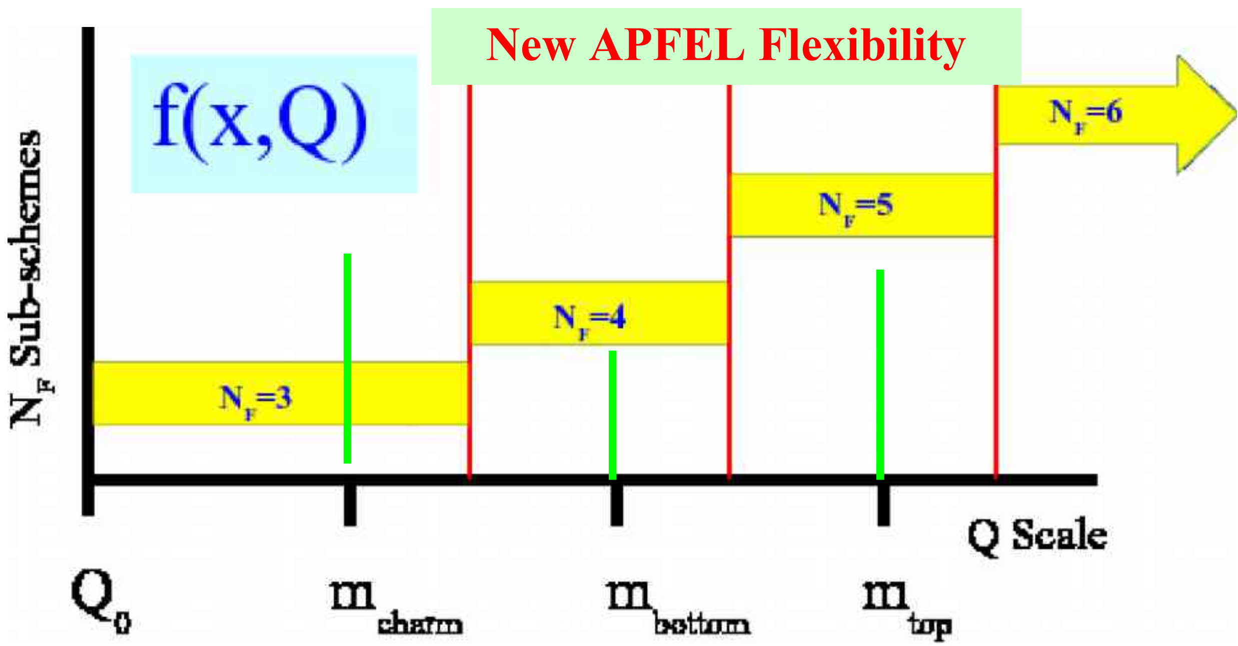
We can adjust the matching scale for the heavy quark PDF transition

APFEL Features

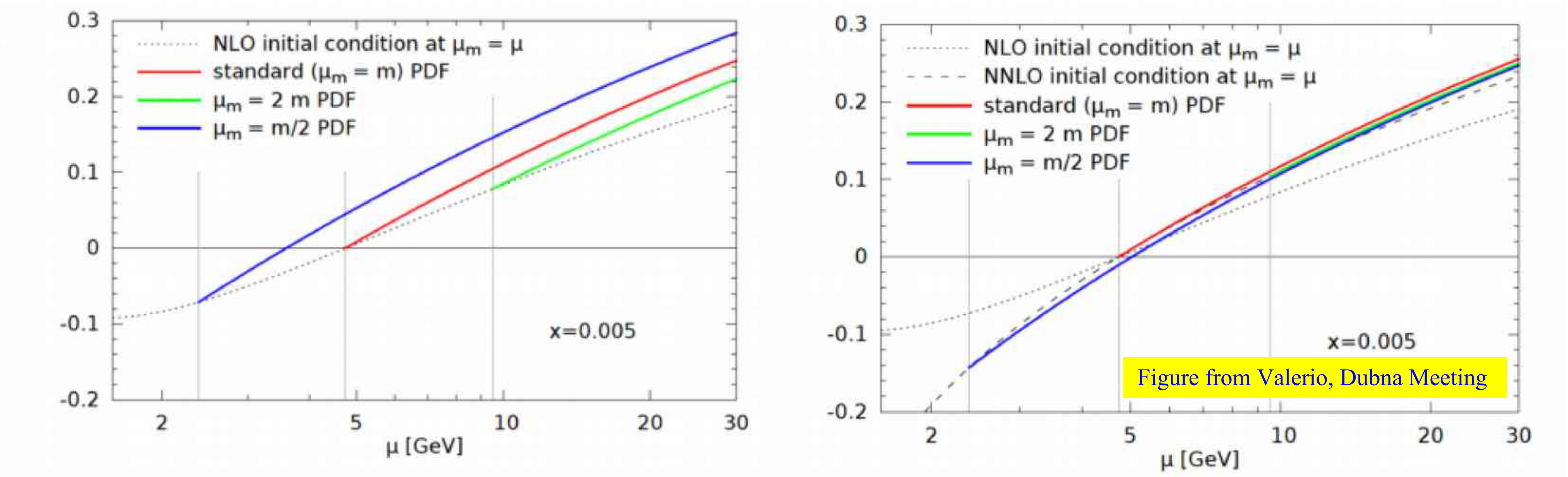
Ability to adjust matching scale $\mu_{c,b}$

Need to compute proper boundary conditions at NLO/NNLO





The matching conditions are non-trivial



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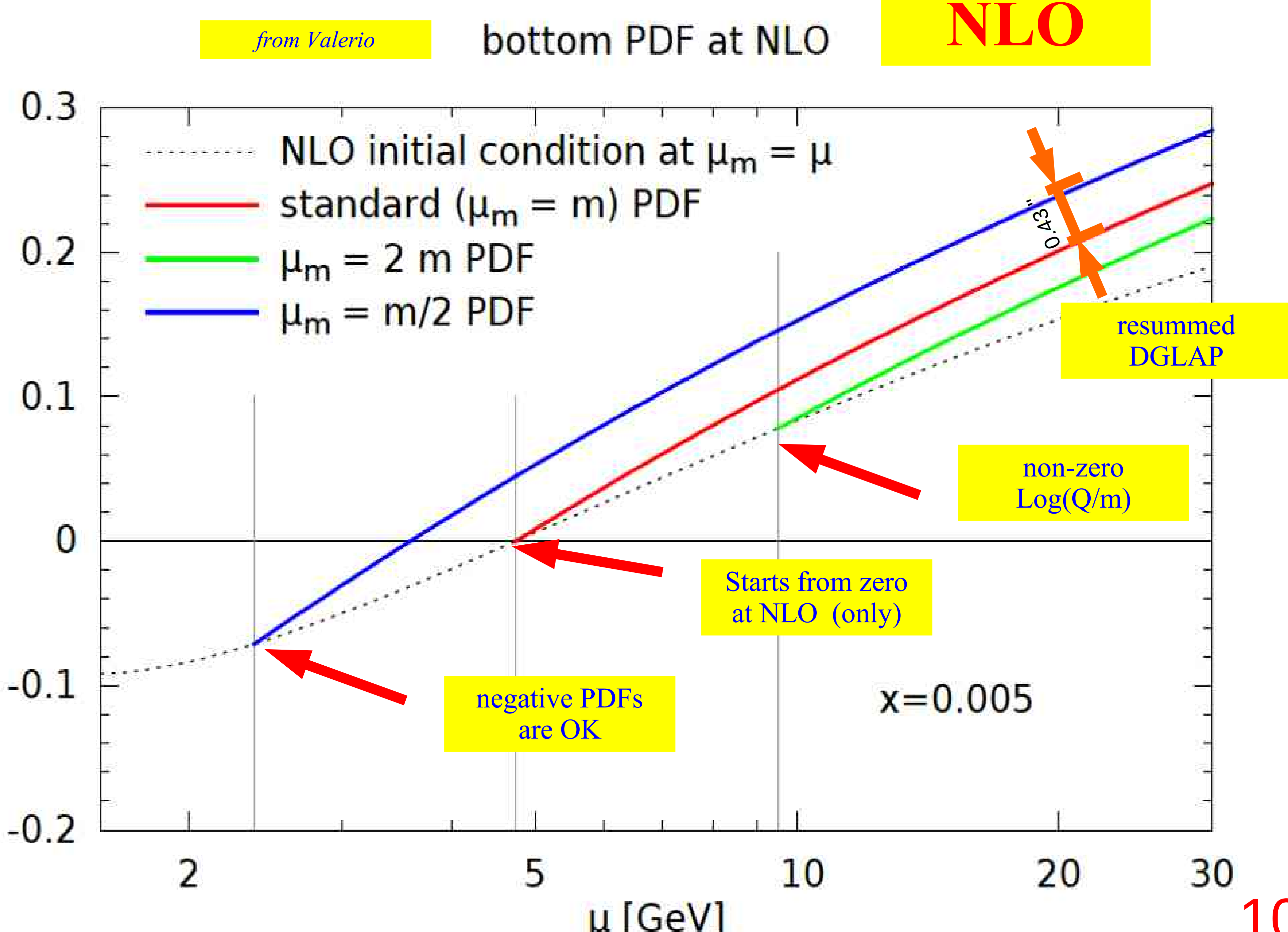
Zero at Leading Order

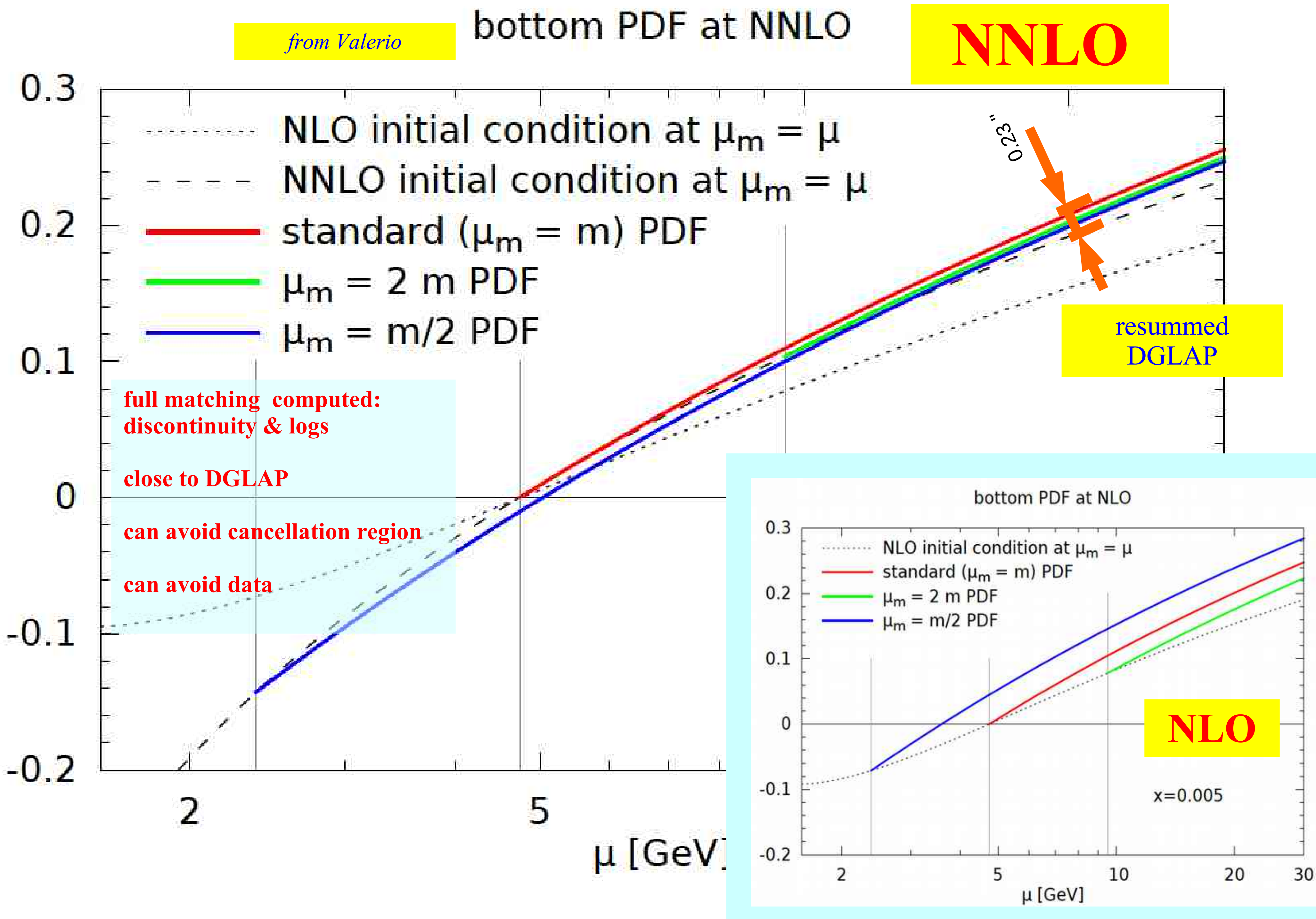
Leading DGLAP contribution

The matching conditions are non-trivial

NLO



The matching conditions are non-trivial, especially at NNLO



Bottom m_b × 1, 1.4, 1.8, 2.2, 2.6

Dataset	output01	output02	output03	output04	output05
Beauty cross section ZEUS Vertex	12 / 17	14 / 17	13 / 17	12 / 17	12 / 17
Charm cross section H1-ZEUS combined	49 / 47	49 / 47	50 / 47	50 / 47	50 / 47
HERA1+2 CCep	48 / 39	48 / 39	48 / 39	48 / 39	48 / 39
HERA1+2 CCem	55 / 42	55 / 42	56 / 42	56 / 42	57 / 42
HERA1+2 NCem	223 / 159	223 / 159	222 / 159	222 / 159	222 / 159
HERA1+2 NCep 820	71 / 70	69 / 70	69 / 70	70 / 70	70 / 70
HERA1+2 NCep 920	439 / 377	439 / 377	436 / 377	433 / 377	432 / 377
HERA1+2 NCep 460	222 / 204	222 / 204	222 / 204	222 / 204	222 / 204
HERA1+2 NCep 575	219 / 254	218 / 254	218 / 254	218 / 254	218 / 254
CMS W- cross section 8 TeV	0 / 11	0 / 11	0 / 11	0 / 11	0 / 11
CMS W+ cross section 8 TeV	0 / 11	0 / 11	0 / 11	0 / 11	0 / 11
H1 F2 Beauty Vertex	3.2 / 12	3.9 / 12	3.5 / 12	3.4 / 12	3.3 / 12
ATLAS low mass Z rapidity 2011	30 / 6	30 / 6	31 / 6	31 / 6	32 / 6
ATLAS peak CC Z rapidity 2011	19 / 12	20 / 12	21 / 12	22 / 12	23 / 12
ATLAS peak CF Z rapidity 2011	10 / 9	10 / 9	10 / 9	10 / 9	10 / 9
ATLAS high mass CC Z rapidity 2011	6.2 / 6	6.3 / 6	6.3 / 6	6.4 / 6	6.4 / 6
ATLAS high mass CF Z rapidity 2011	3.8 / 6	3.9 / 6	3.9 / 6	3.9 / 6	3.9 / 6
ATLAS W- lepton rapidity 2011	16 / 11	17 / 11	17 / 11	18 / 11	18 / 11
ATLAS W+ lepton rapidity 2011	13 / 11	13 / 11	13 / 11	13 / 11	13 / 11
Correlated χ^2	140	145	148	150	
Log penalty χ^2	-4.98	-5.75	-5.62	-5.20	
Total χ^2 / dof	1579 / 1290	1588 / 1290	1588 / 1290	1589 / 1290	1593 / 1290
χ^2 p-value	0.00	0.00	0.00	0.00	0.00

NLO

$\Delta\ \chi^2 \sim 14$

ATLAS high mass CC Z rapidity 2011	6.6 / 6	6.6 / 6	6.6 / 6	6.6 / 6	6.6 / 6
ATLAS high mass CF Z rapidity 2011	4.3 / 6	4.3 / 6	4.3 / 6	4.3 / 6	4.3 / 6
ATLAS W- lepton rapidity 2011	13 / 11	14 / 11	14 / 11	14 / 11	14 / 11
ATLAS W+ lepton rapidity 2011	13 / 11	13 / 11	13 / 11	13 / 11	
Correlated χ^2	164	166	167	167	
Log penalty χ^2	-2.96	-3.34	-3.67	-3.94	
Total χ^2 / dof	1639 / 1290	1644 / 1290	1645 / 1290	1644 / 1290	1644 / 1290
χ^2 p-value	0.00	0.00	0.00	0.00	0.00

NNLO

$\Delta\ \chi^2 \sim 5$

Round 8

Bottom m_b × 1, 1.4, 1.8, 2.2, 2.6

Dataset	output01	output02	output03	output04	output05
Beauty cross section ZEUS Vertex	12 / 17	14 / 17	13 / 17	12 / 17	12 / 17
ATLAS high mass CF Z rapidity 2011	5.8 / 6	5.9 / 6	5.9 / 6	5.9 / 6	5.9 / 6
ATLAS W- lepton rapidity 2011	16 / 11	17 / 11	17 / 11	18 / 11	18 / 11
ATLAS W+ lepton rapidity 2011	13 / 11	13 / 11	13 / 11	13 / 11	13 / 11
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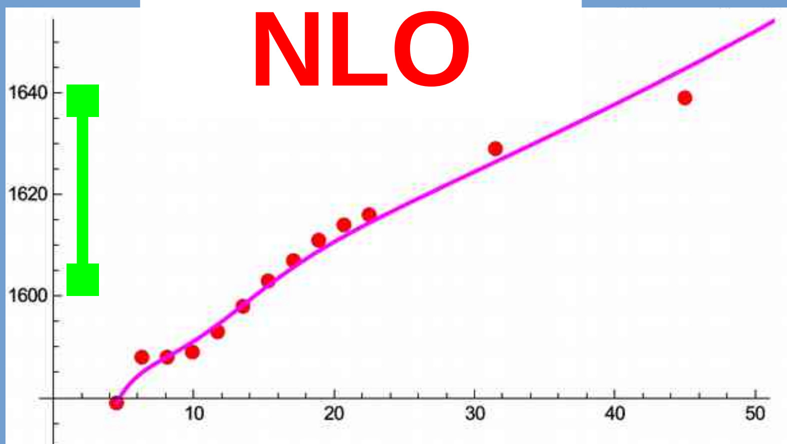
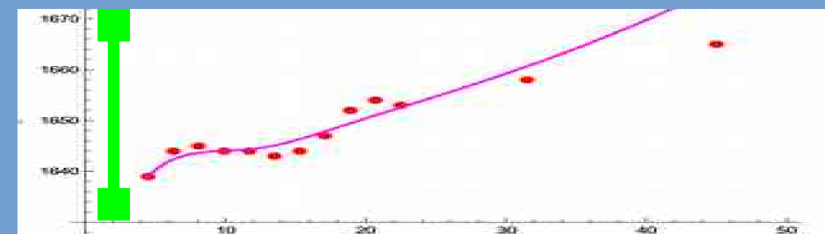
χ^2 p-value	0.00	0.00	0.00	0.00	0.00

NLO



NNLO



$\Delta\ \chi^2 \sim 14$

NLO

ATLAS high mass CC Z rapidity 2011	6.6 / 6	6.6 / 6	6.6 / 6	6.6 / 6	6.6 / 6
ATLAS high mass CF Z rapidity 2011	4.3 / 6	4.3 / 6	4.3 / 6	4.3 / 6	4.3 / 6
ATLAS W- lepton rapidity 2011	13 / 11	14 / 11	14 / 11	14 / 11	14 / 11
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χ^2 p-value	0.00	0.00	0.00	0.00	0.00

NNLO

$\Delta\ \chi^2 \sim 5$

Round 8

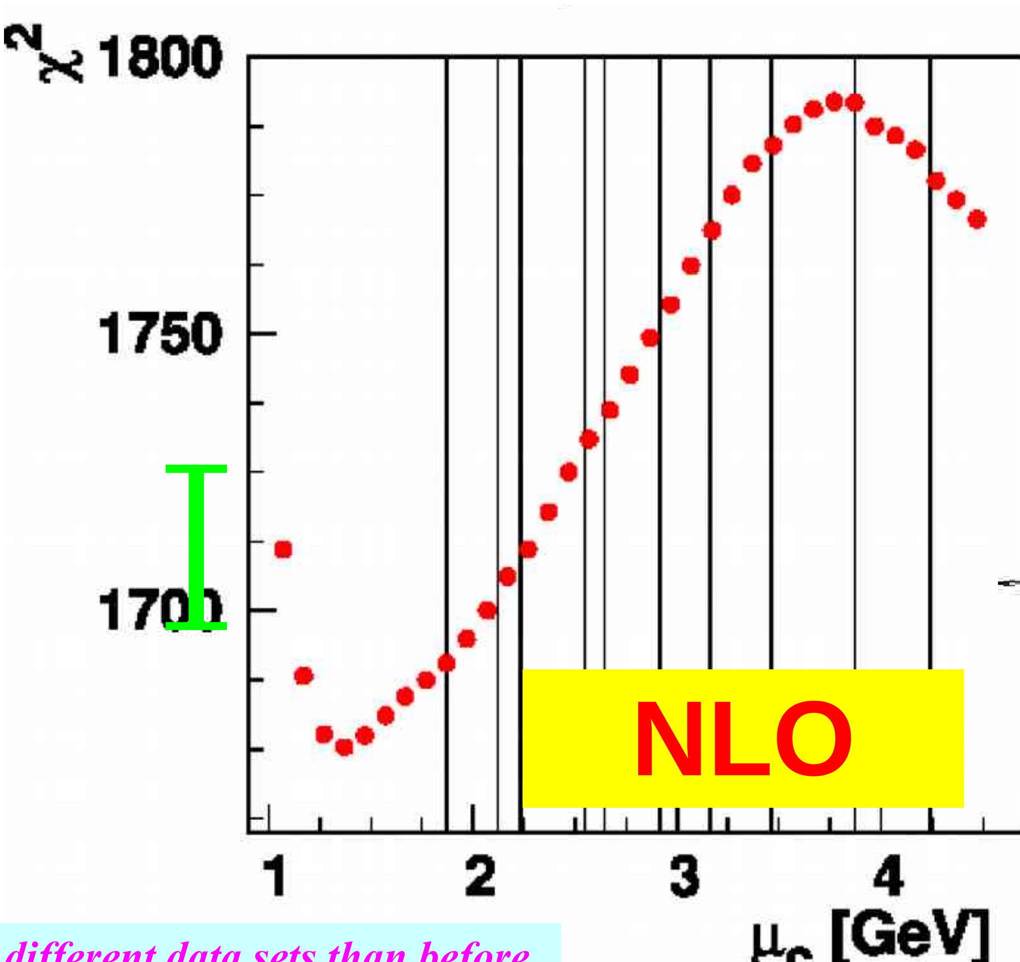
Impact of heavy quark matching scale dependence in global PDF fits

NLO Fit prefers matching in the region $\mu_c \sim m_c$

Suggests that higher order logs (resumed by DGLAP) are important

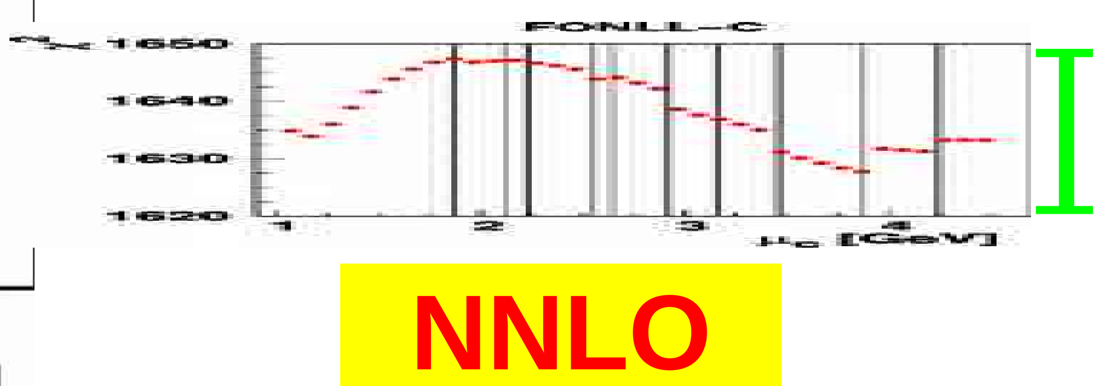
Experiments: Hi Precision HERA920 & H1-ZEUS Charm

Charm



NNLO greatly reduced χ^2 dependence

vertical lines show bin boundaries



different data sets than before

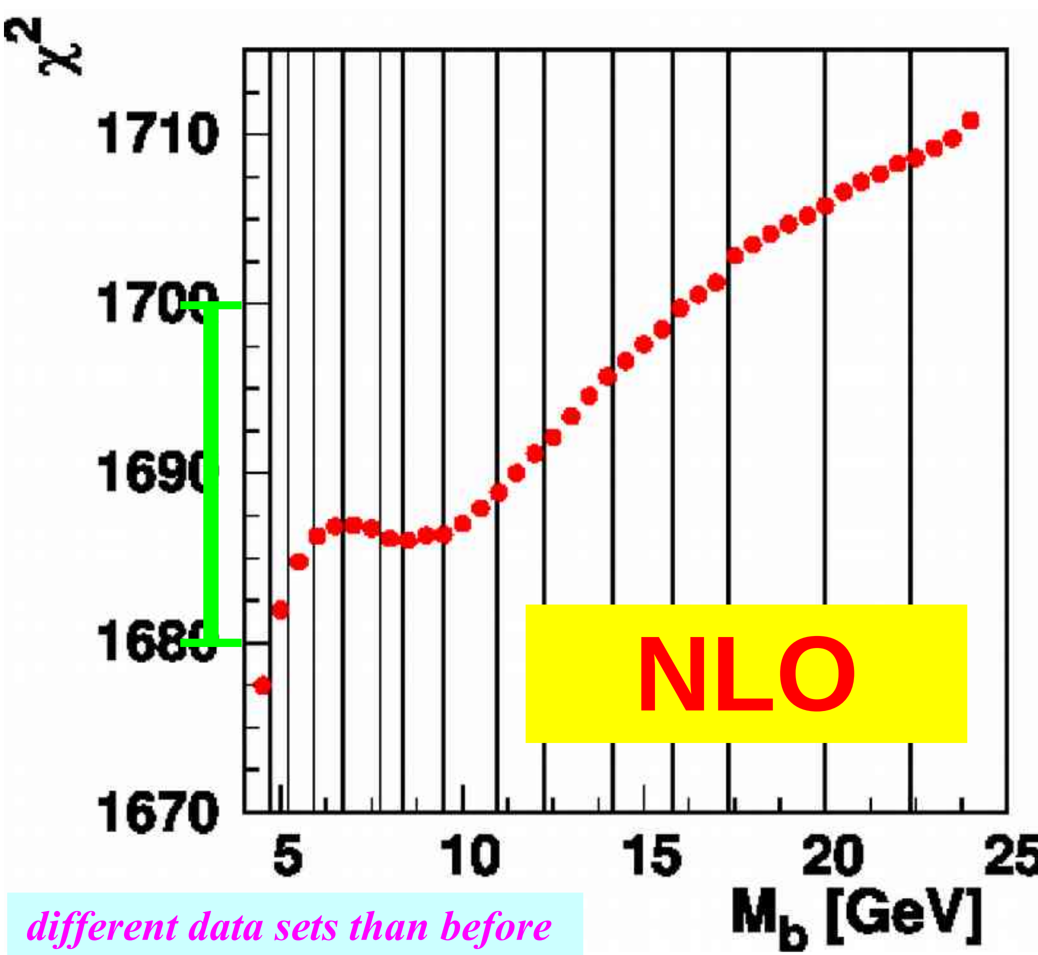
Impact of heavy quark matching scale dependence in global PDF fits

NLO Fit prefers matching in the region $\mu_b \sim m_b$

Suggests that higher order logs (resumed by DGLAP) are important

Experiments: Hi Precision HERA920 & H1-ZEUS Beauty

Bottom



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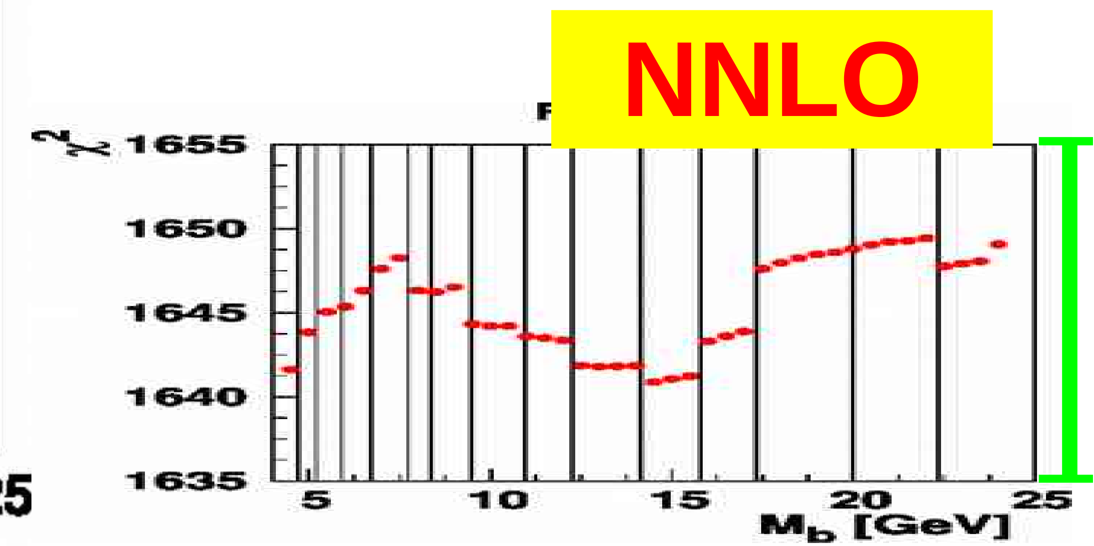
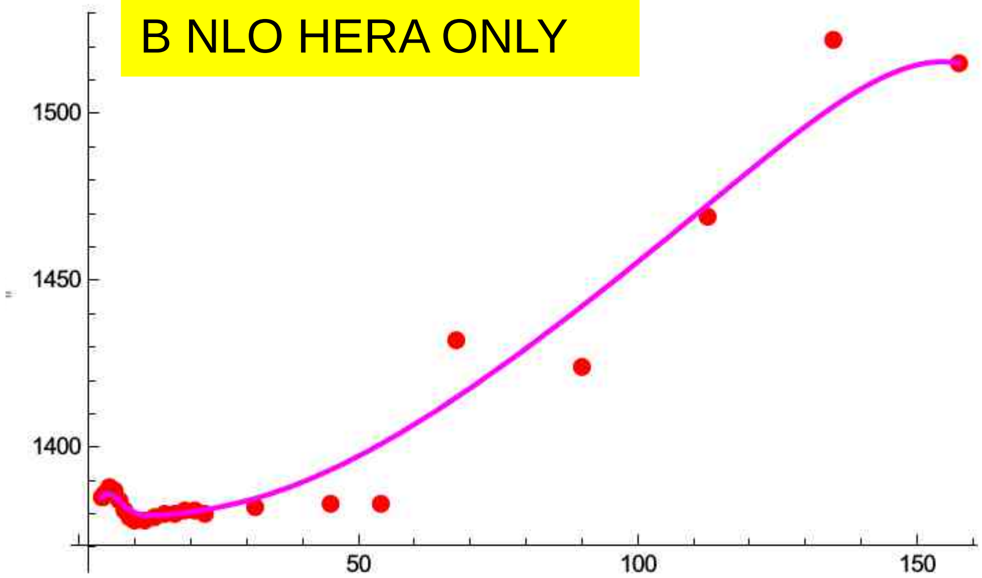
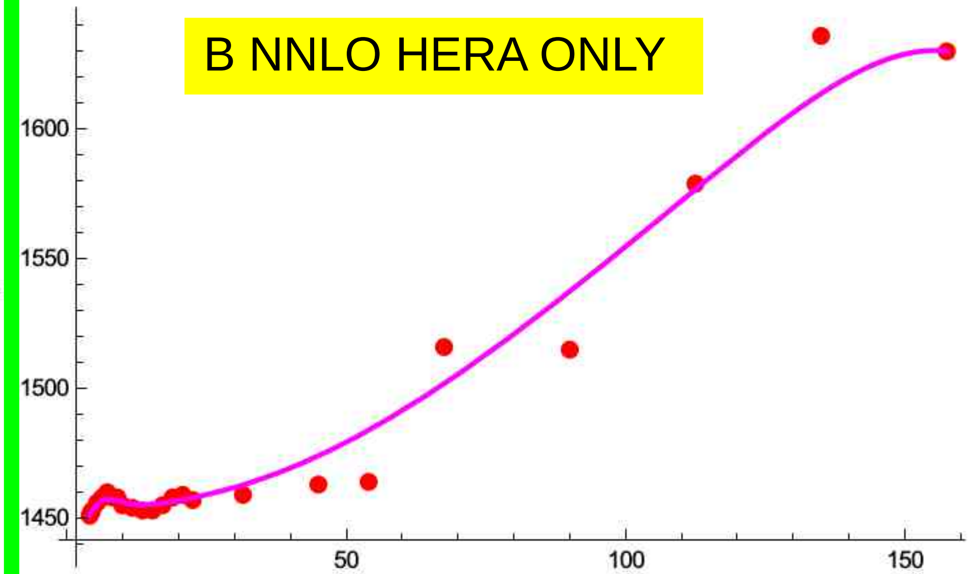


Try HERA only

Minimal χ^2 Variation



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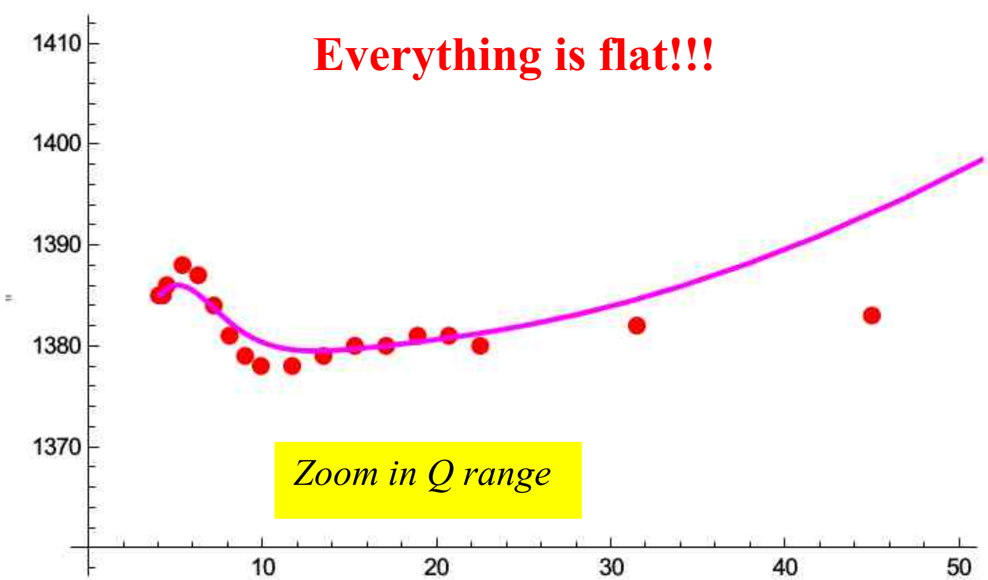
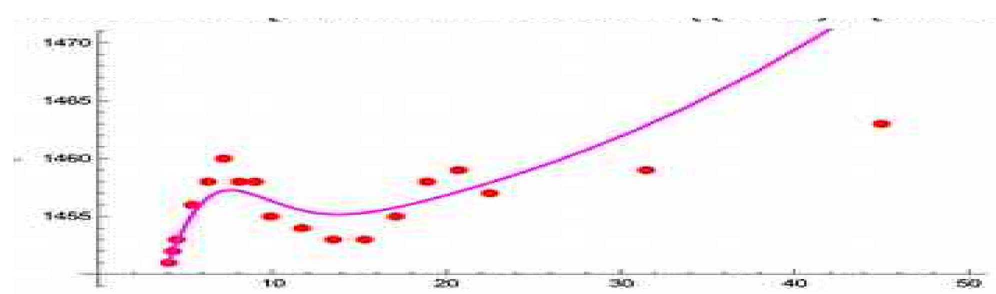
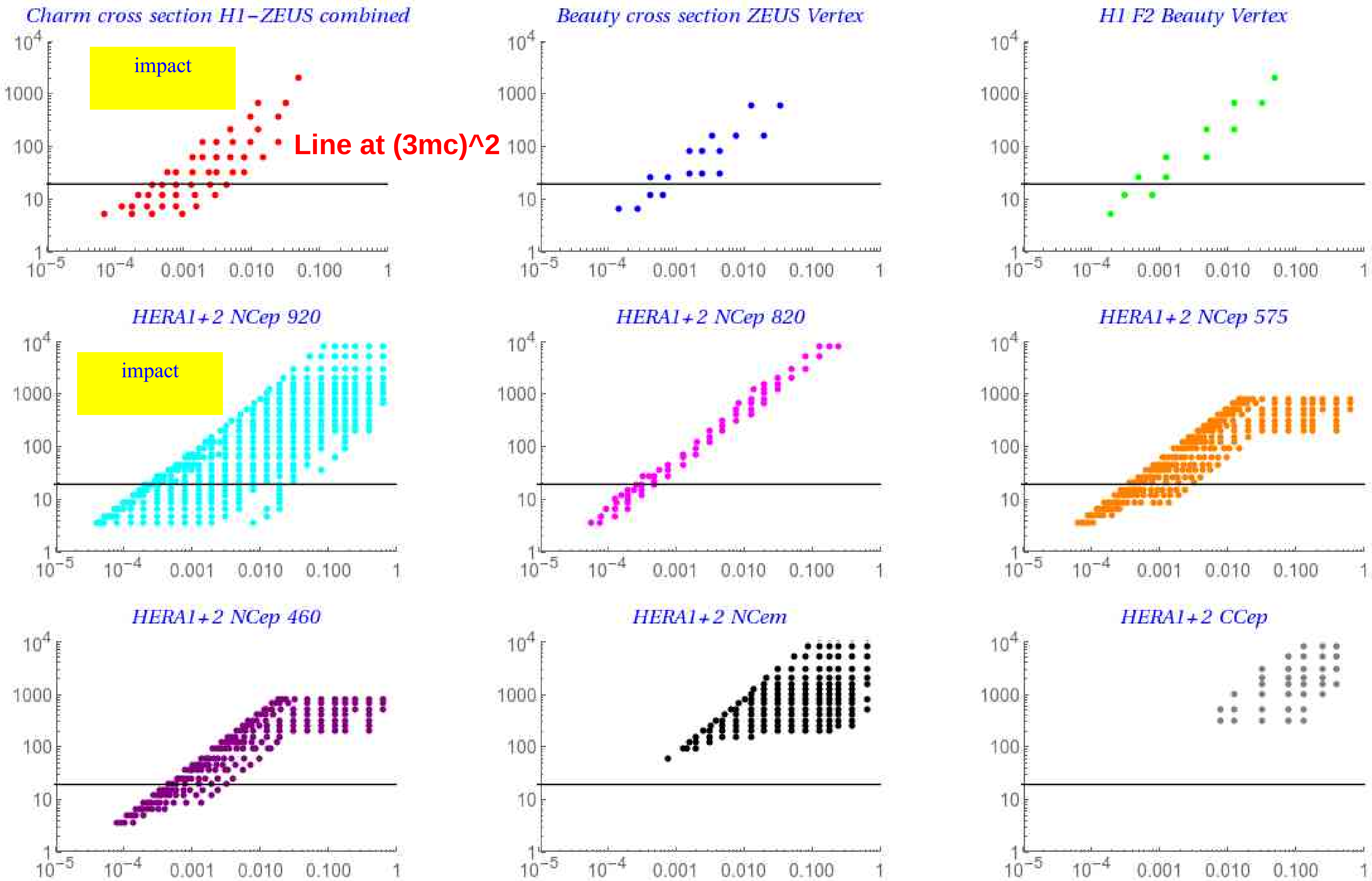


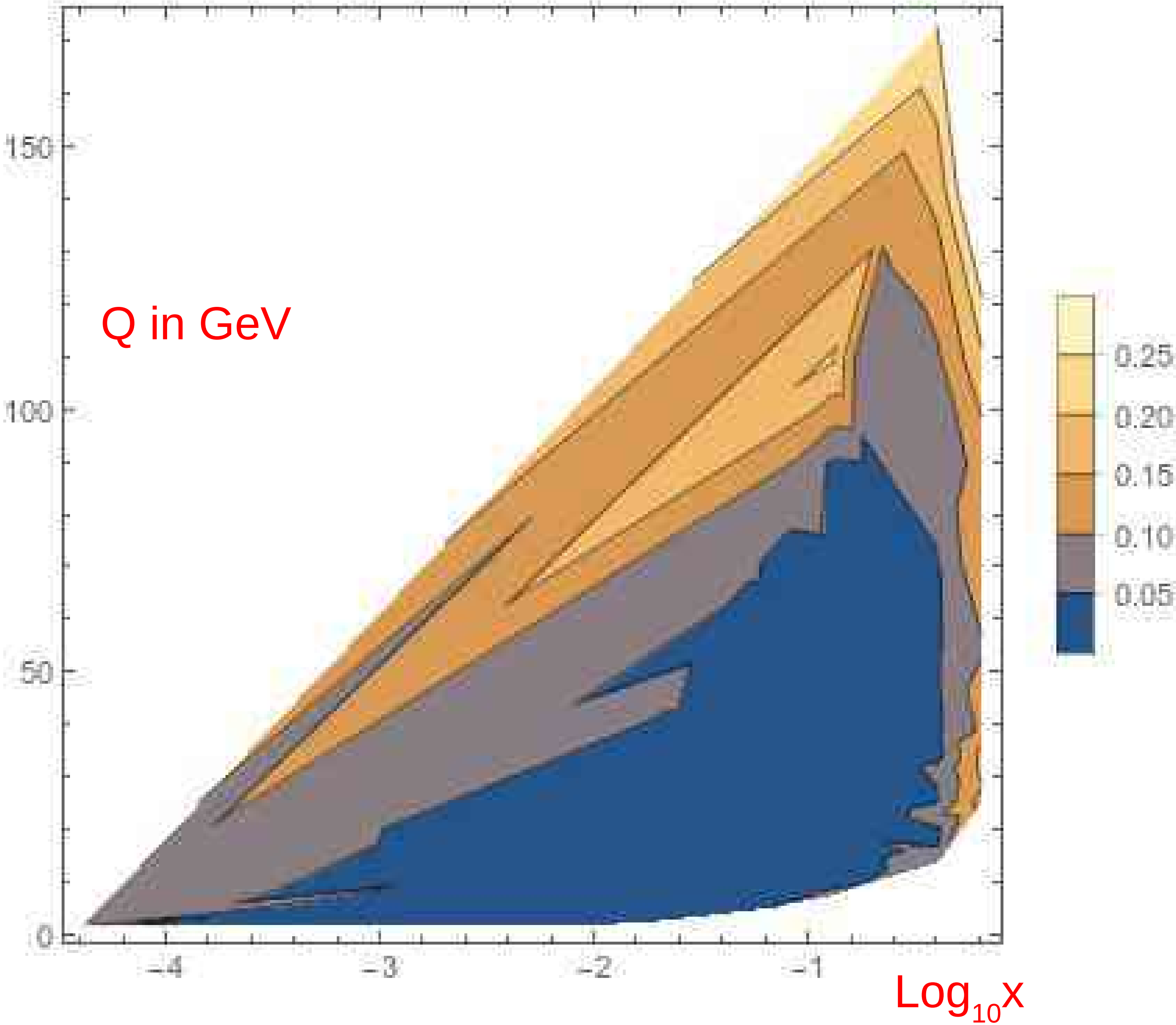


Zoom in Q range

HERA Kinematic coverage



Fractional Uncertainty in {x, Q} Plot



Lessons so far ….

If we have constraints across a wide Q range:

At NLO, need to match near $\mu_{c,b} \sim m_{c,b}$

VFNS w/ DGLAP resums higher logs; these are important

At NNLO, we have greater freedom where to match $\mu_{c,b}$

We can use this freedom to avoid

i) discontinuities in the middle of data sets

ii) delicate cancellations near $\mu_{c,b} \sim m_{c,b}$

If we DON'T have constraints across a wide Q range:

We have greater freedom where to match $\mu_{c,b}$

But, we DO have to transition eventually

One more idea

A proposal: Consider N_F dependent PDF

Provides some of the benefits & flexibility of displaced matching, but with a compromise.

Disadvantages:

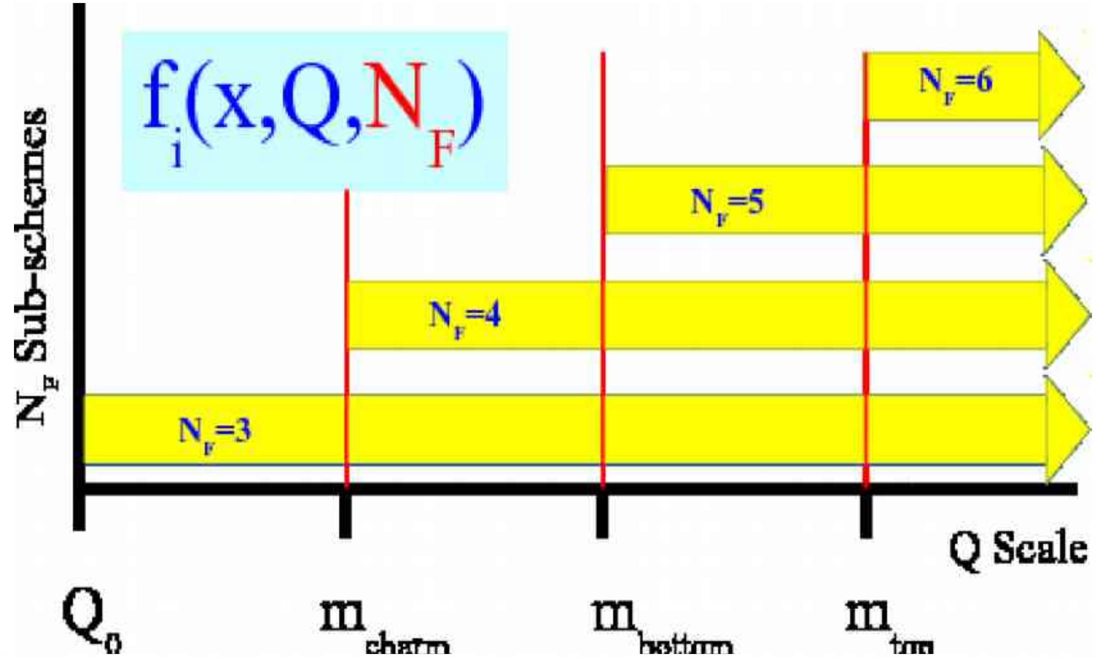
Match at $\mu_{c,b} \sim m_{c,b}$,

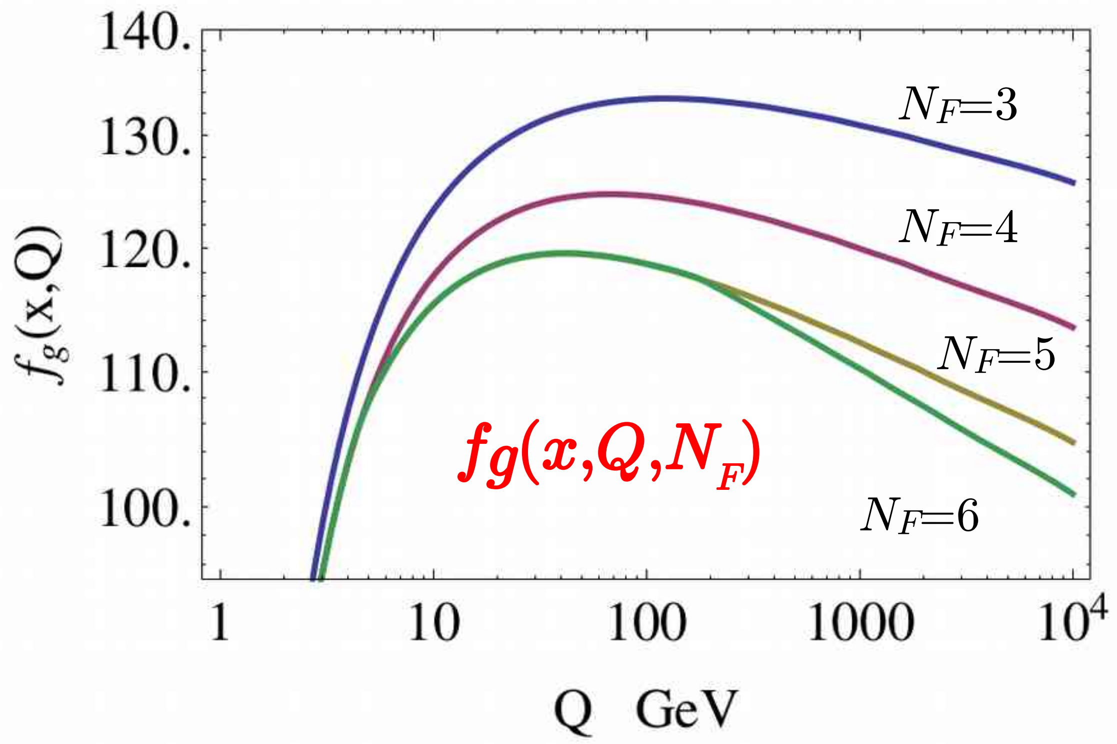
but switch at higher scale

How much do we "lose" in χ^2 ???

Advantages:

* avoid discontinuities in data
* avoid delicate cancellations and
* minimal set of PDF grids





The End

xFitter

is near

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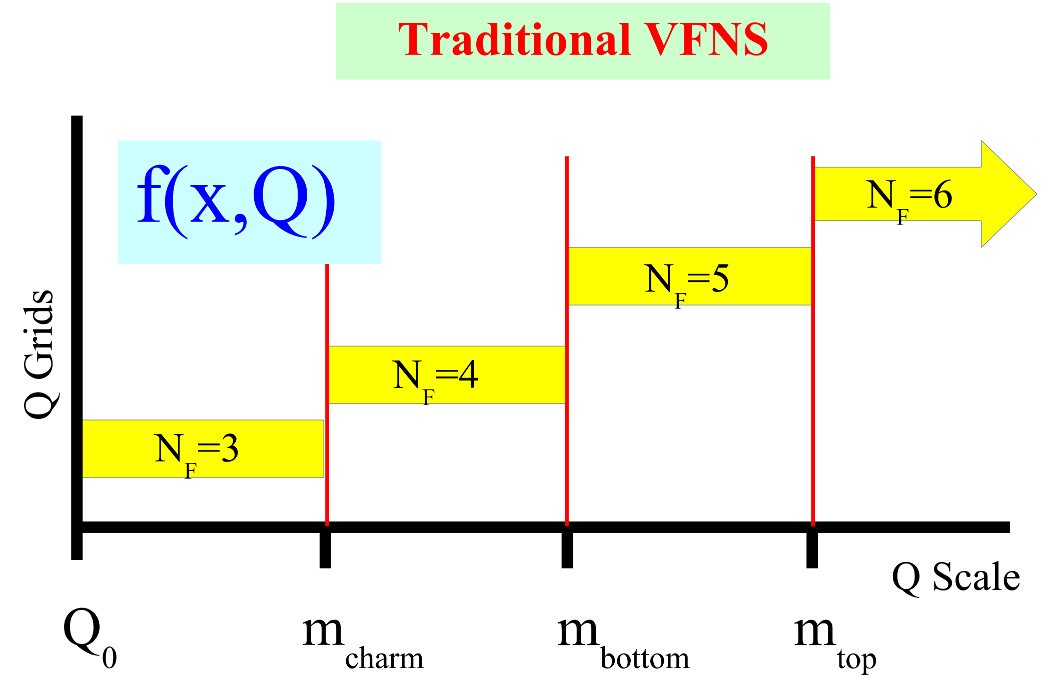
2) **avoid delicate matching in region $\mu \sim m_{c,b}$**



In a broader sense ...

1) **flexibly interpolate between VFNS and FFNS**
2) **answer many outstanding theoretical debates with numerical results!!!**