Topics for discussion

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Rencontres Vietnam Sep 2016

Extension of tools to

- NNLO and beyond N3LO- but we don't have NNLO for everything yet
- AND OR NNLO+parton showers (often with LO PDF from different family)
- Resummation at low-pt, low-x, high-x
- Fragmentation/hadronisation corrections
- Scale variations

Is any process really OK at fixed order? (apart from inclusive DIS)
Even W and Z inclusive production is done under pt-cuts – fiducial volume.
So our inability to describe the pt spectrum affects it at the ~0.5% level, data accurate to 0.5% are now available
FEWZ vs DYNNLO differences

- QED – is LuxQED the be-all and end-all?

- What happens if we cut out low Q2 data and fit Q2>10

Ie cut out much of higher twist region
AFTER we evolve back up to LHC scales?

- ABM vs the rest

Some remarks on ABM vs the rest (JR is defunct)

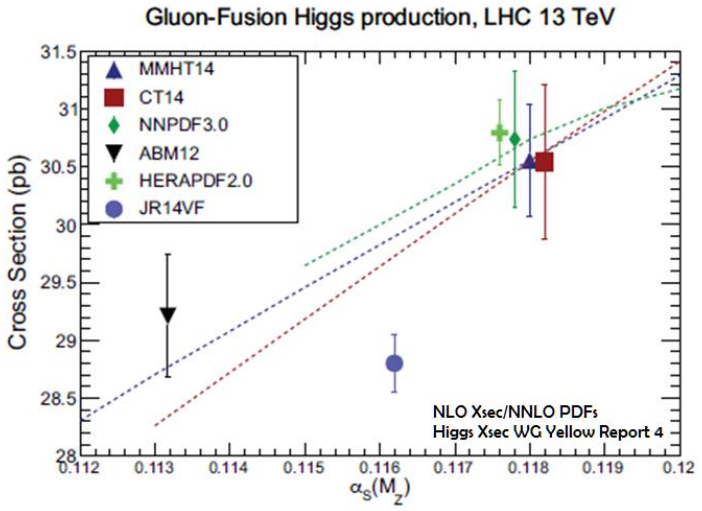
It is processes which depend on the gluon PDF where ABM differs most- such as jet production and t-tbar profuction AND Higgs
It is fine for q-qbar Drell-Yan sort of processes
Apart from direct –photon which may not be theoretically so well understood-- only NLO

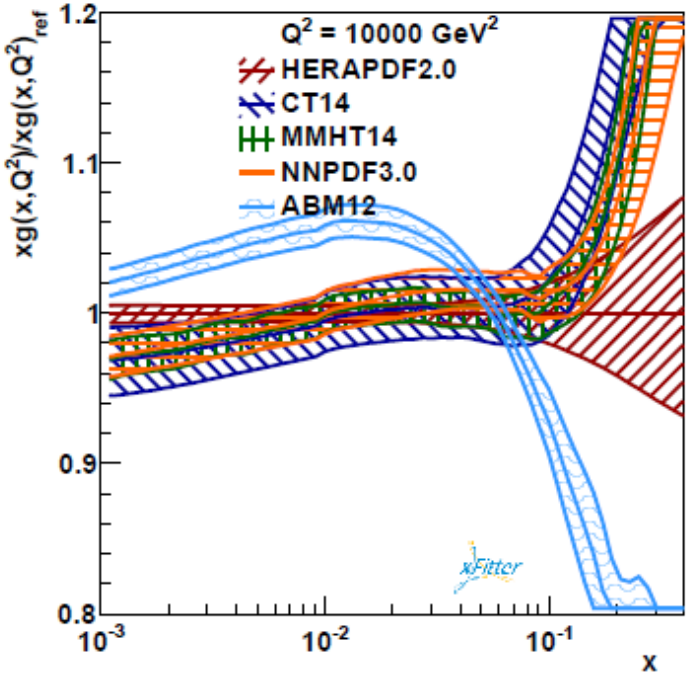
This is because of its soft high-x gluon AND Lower preferred value of alpha_s(M_Z)

And those are because of the use of the FFN VS a GMVFN heavy quark scheme
This has been established by studies by both Thorne (MMHT) and Rojo(NNPDF) who Re-do their fits changing ONLY the heavy quark scheme and obtain similar softer Gluons and lower vaues of alpha_s(M_Z)

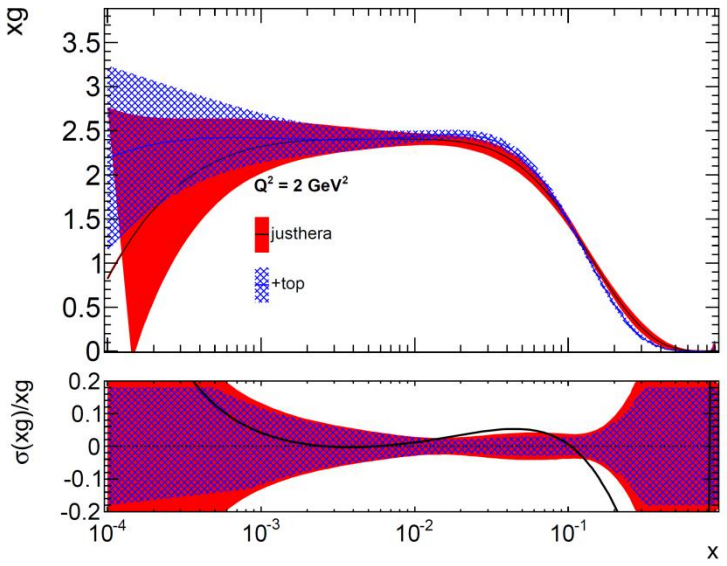
So now we can focus the argument on what Is the right heavy quark scheme

- FFN does not resum ln(Q2/mc2) terms
- GMVFN involve matching between massive calcuations at threshold and zero mass treatment at high scale

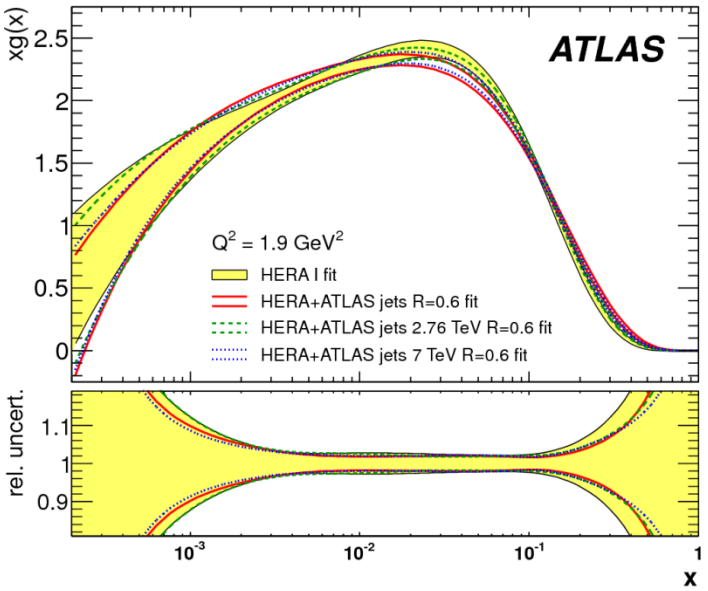




Need for NNLO



Adding NLO top (pt-top, mass t-tbar, y t-tbar)
Pulls to a softer high-x gluon



But adding NLO jets (2.76/7 Tev ratios)
Pulls to a harder high-x gluon

This is probably not new physics but differing NNLO corrections, we don't have full NNLO jets QUITE yet
We have full NNLO top but so far only k-factor technology can be used- no fast grids
Also need statistical correlations between different distributions for top– or double differential

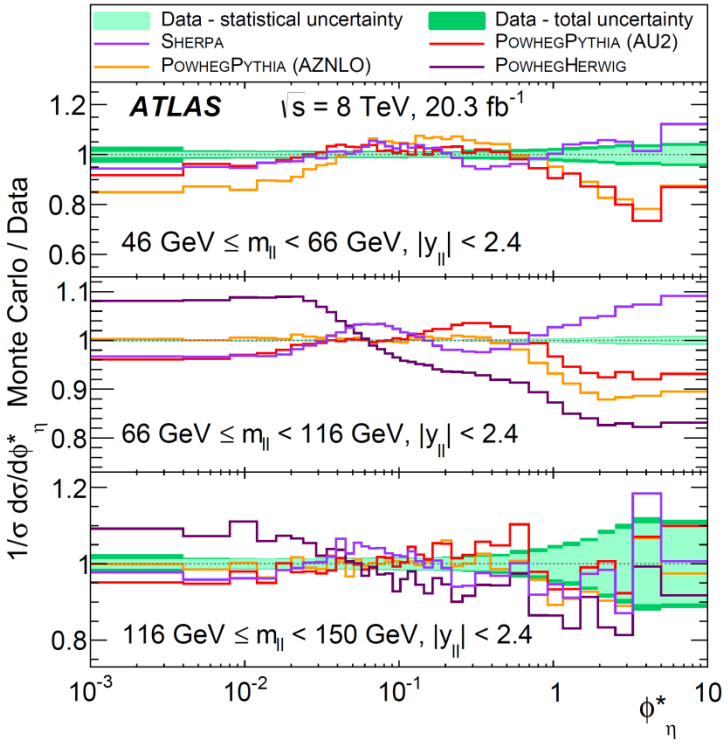
Are the fixed order calculations always adequate?

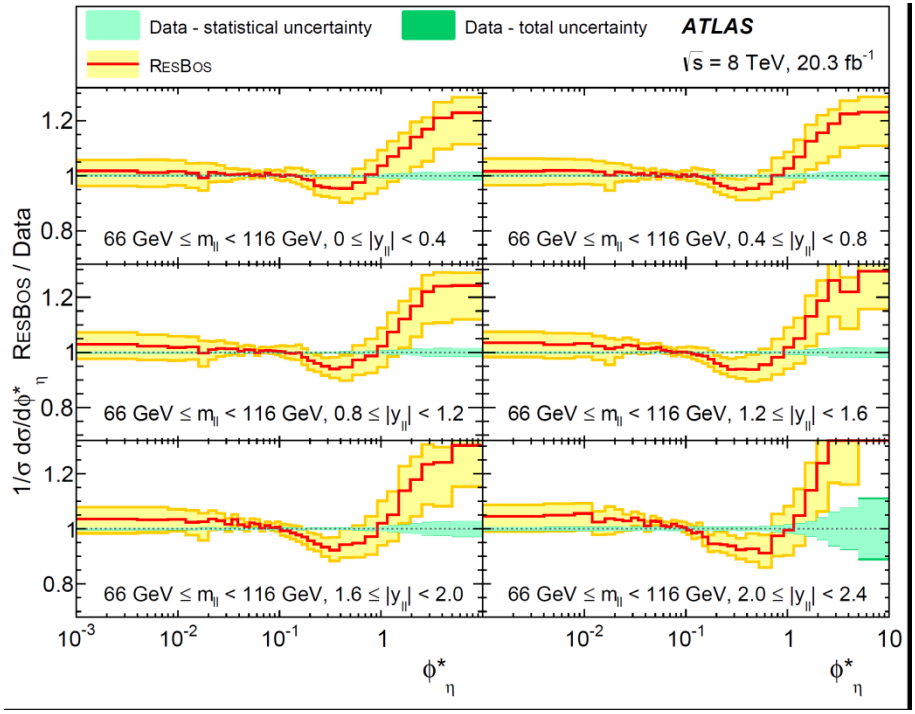
e.g. Zpt, W+jets, Z+jets, also W+b,c, Z+b,c

- Can one use re-summed calculations-

NNLO calculations for Z+jets have improved a previously poor description?

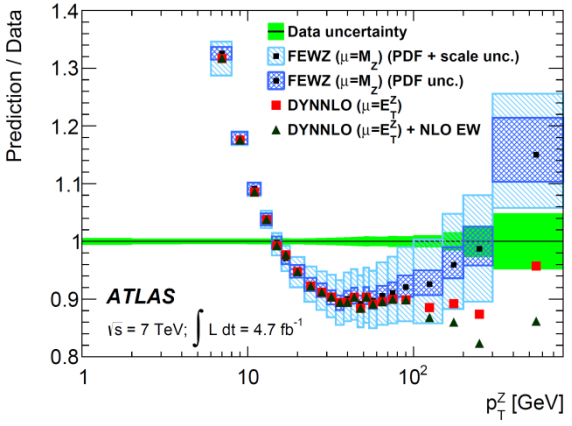
Are fixed order calculations even adequate for W, Z inclusive production when we have to apply pT cuts? FEWZ/DYNNLO differ by ~.5%
Experimental precision of < 0.5% challenges the predictions





ATLAS 8 TeV: Z pt and Z φ* ArXIV:1512.02912

And the same question can be asked for Zpt
Are present calculations really adequate ?



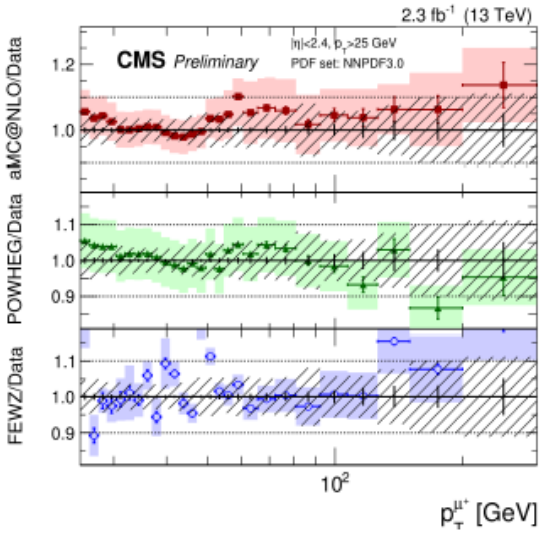
ATLAS 7 TeV Z pt

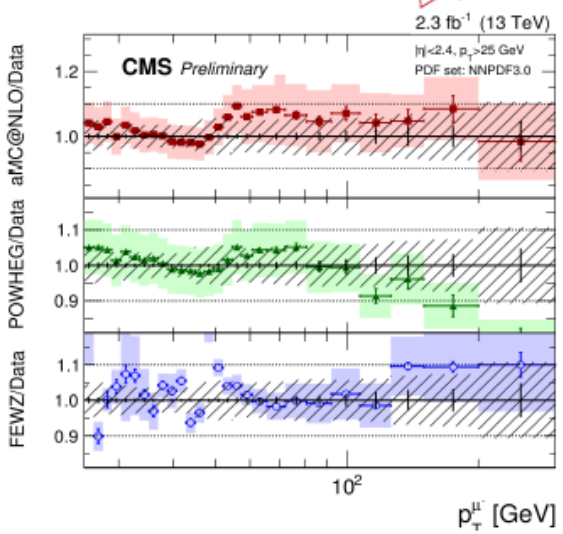
Z production at 13 TeV (cont.)

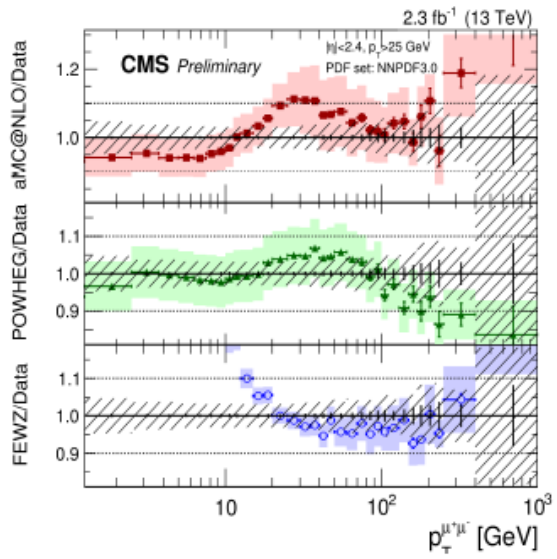
CMS-PAS-SMP-15-011

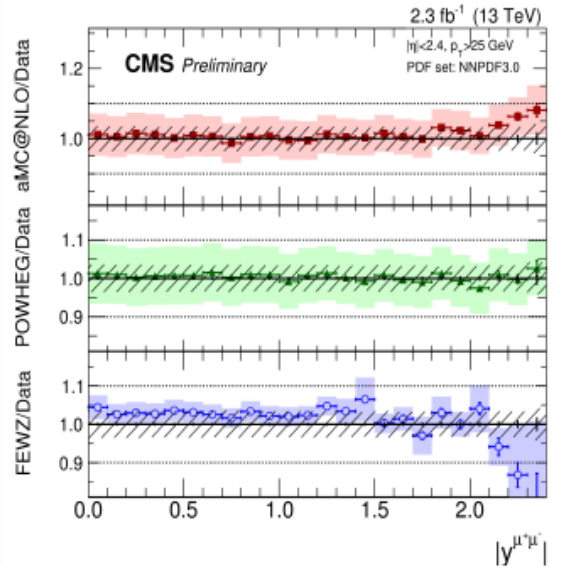
NEW

- Generator: aMC@NLO, POWHEG, FEWZ using NNPDF3.0
- Discrepencies are observed in some regions (within errors)



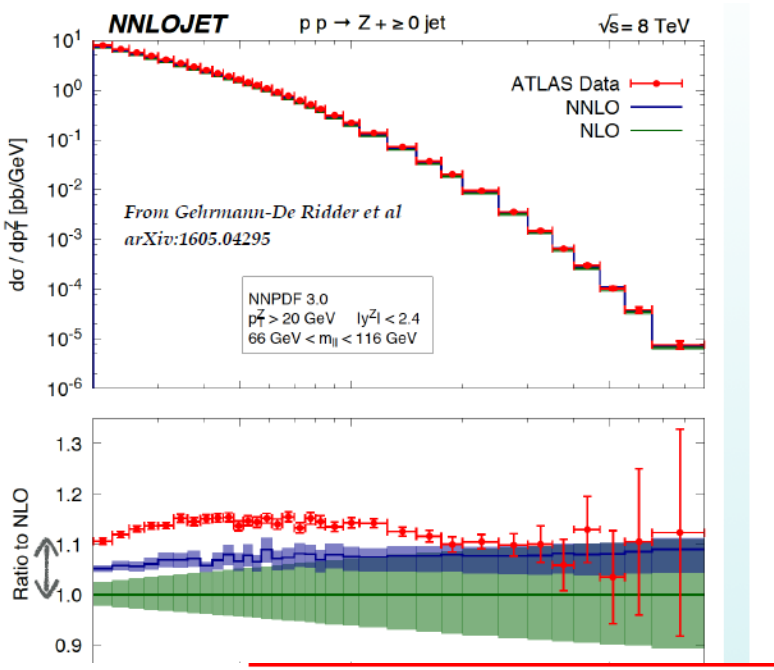


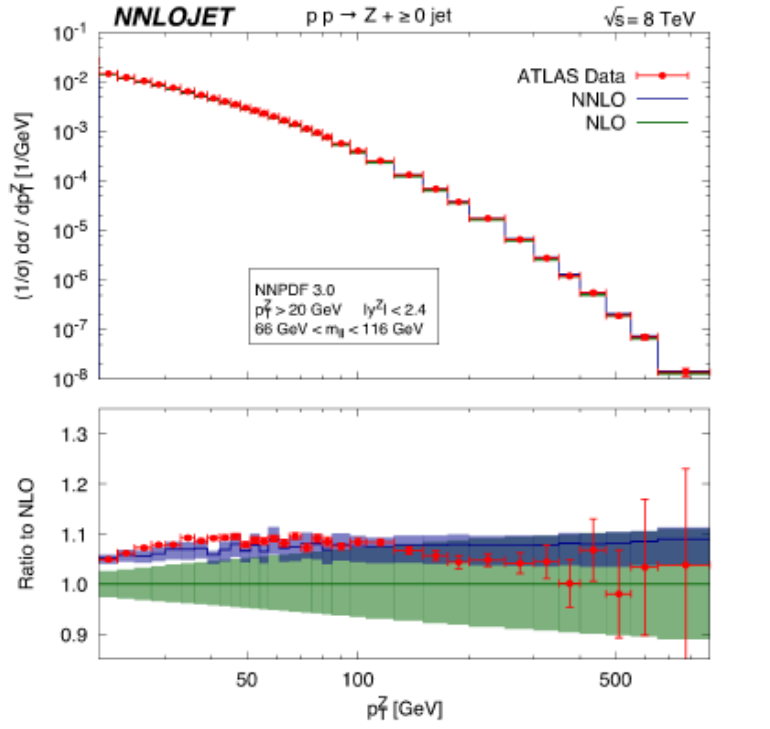




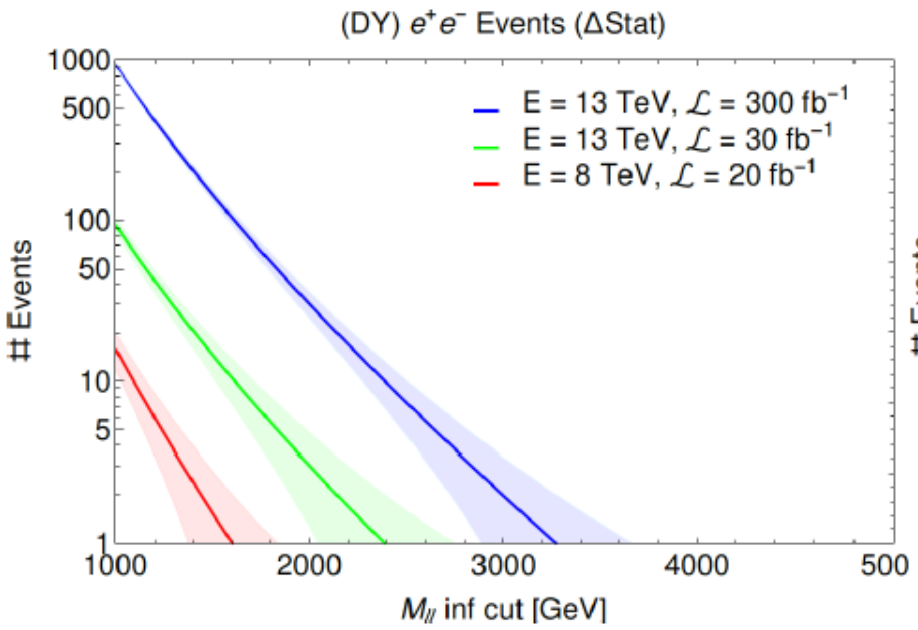
Z p_T as an input to PDFs ?
It is not clear to me that this is very clean theoretically

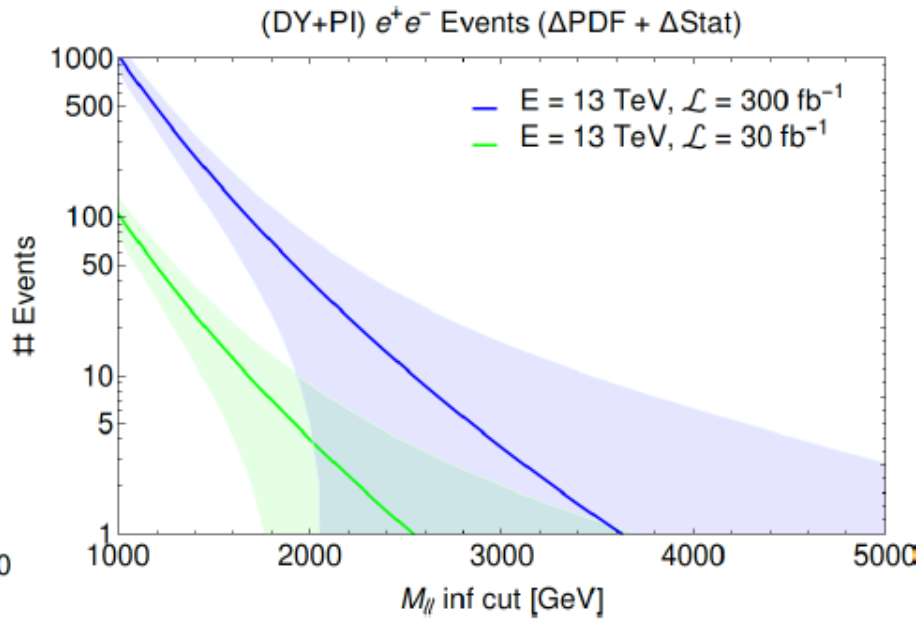
- Needs low-pt resummation
- Is even NNLO good enough?
- Do we understand the normalisation of the data in this plot of Z+jets to NNLO





Including the QED part in the proton is now becoming essential

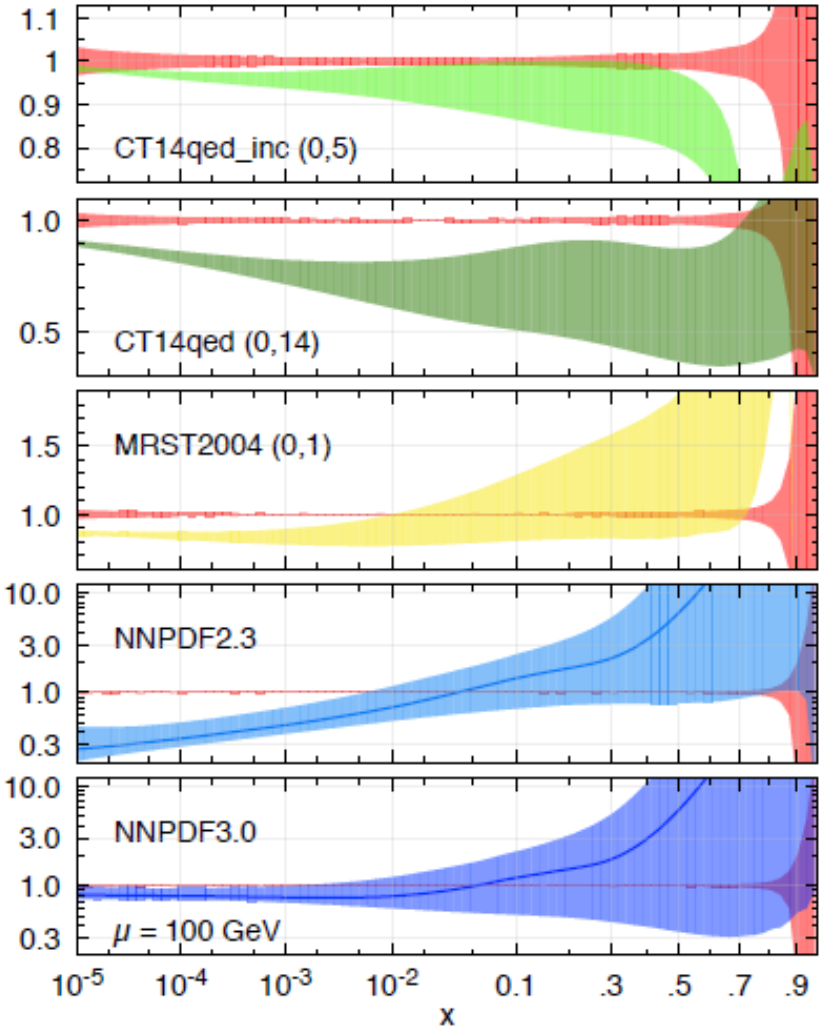


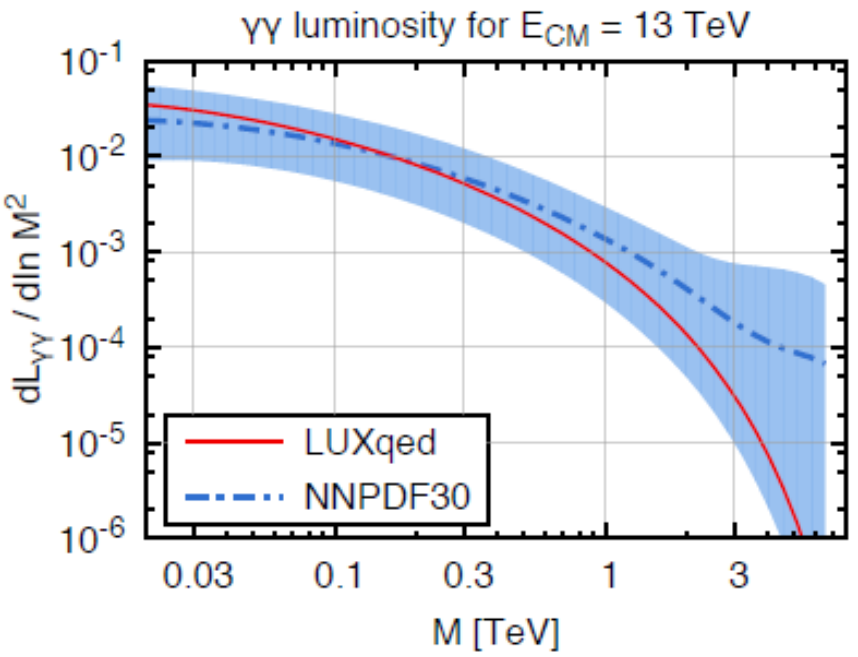


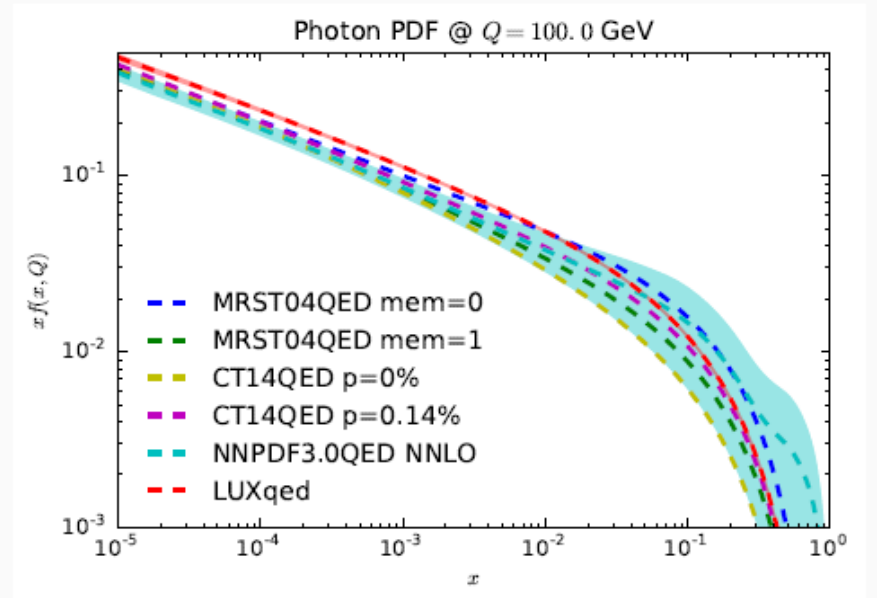
These plots are amusing but the uncertainties on PI come from the NNPDF
Not even NNPDF themselves think things are so bad now because of the new photon PDF calculations.

LuxQED and HKR

Compare LUXqed with other approaches

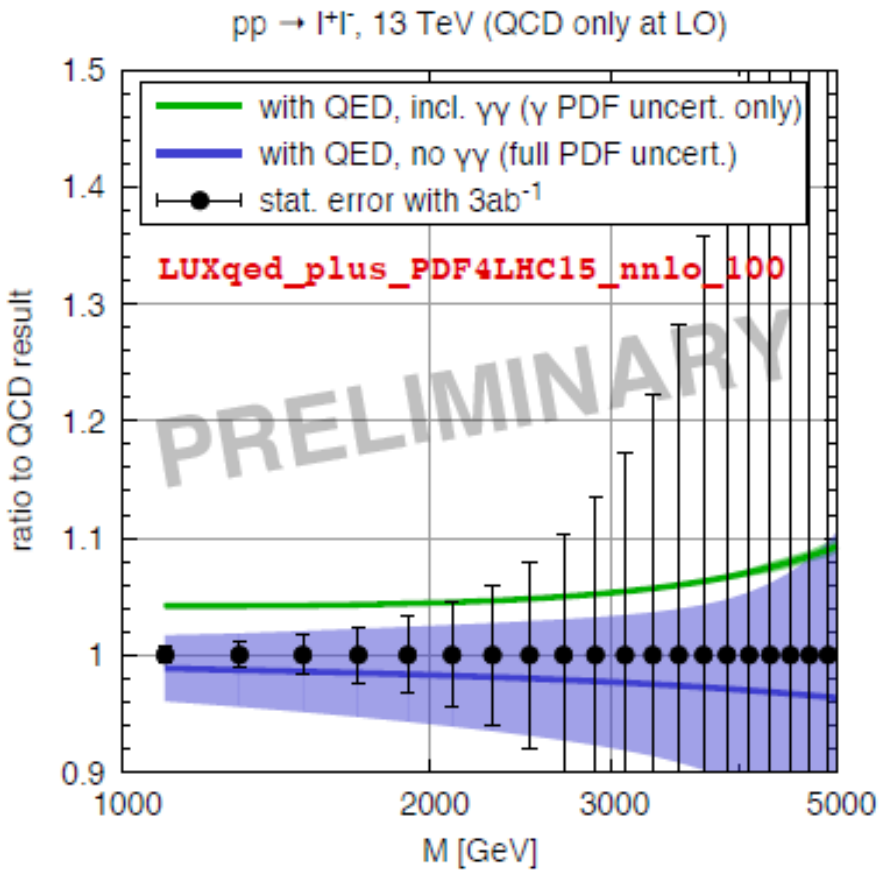


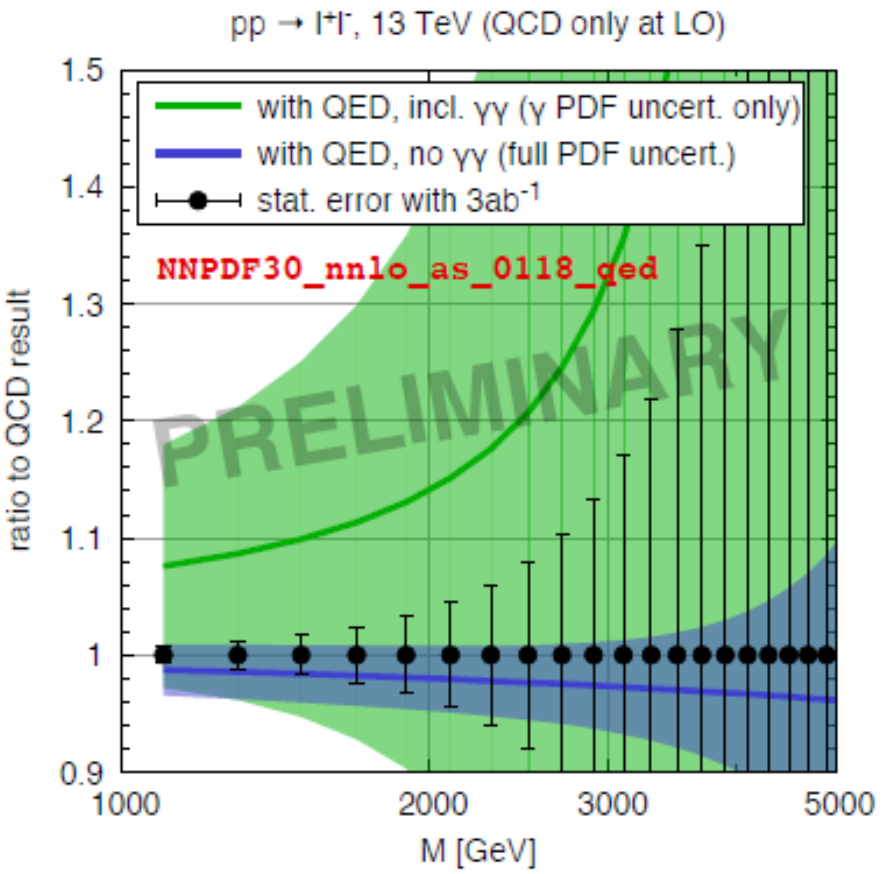




LUXqed is the pink one which is normalised to unity

Since it only relies on knowledge of the quark distributions it has far better precision



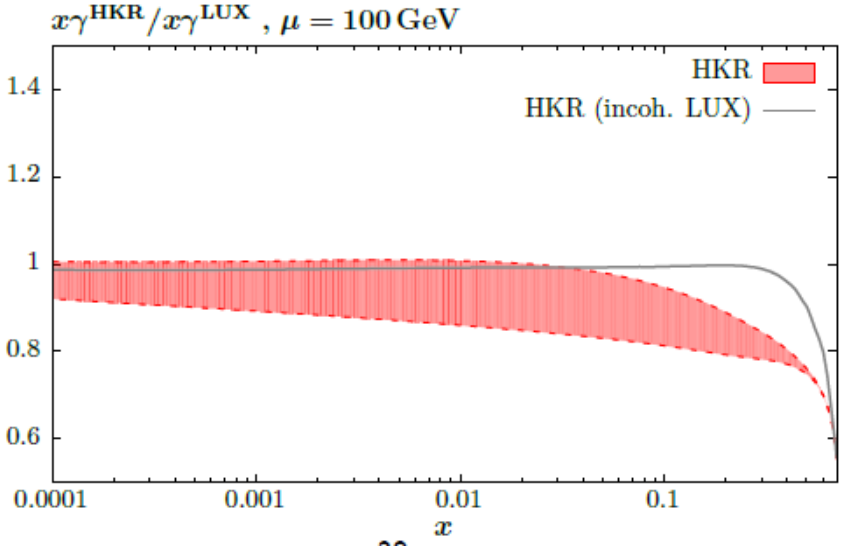


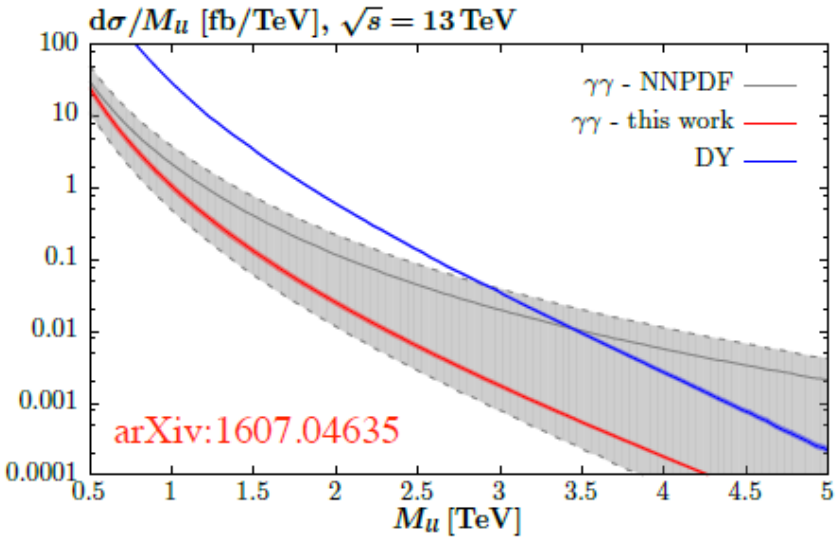
LUXQED photon has few % effect on di-lepton spectrum and negligible uncertainties

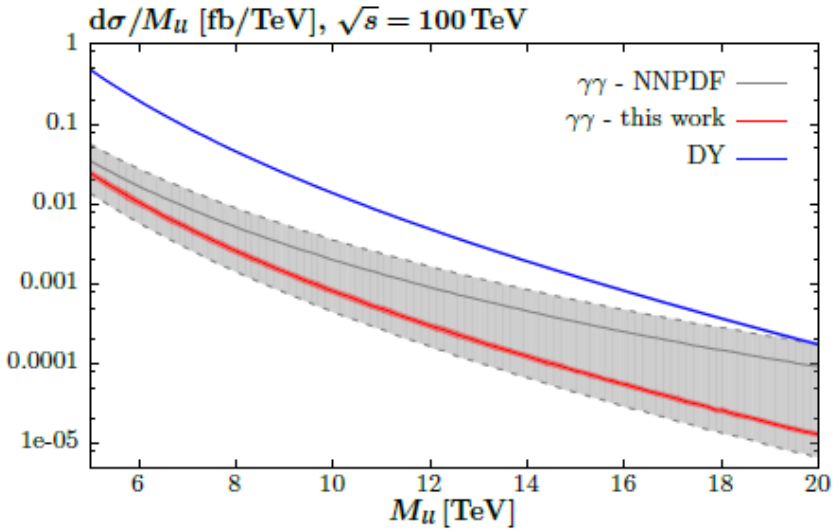
HKR also compare to LUX qed

- Have demonstrated that standard PDF approach very close to LUXqed when taking same data input for $\gamma(x, Q_0^2)$.

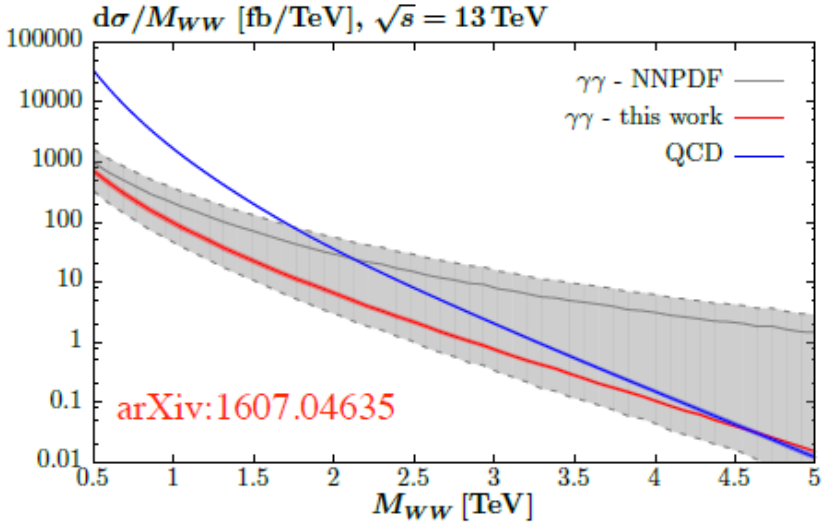
$\longrightarrow$ Possible to unify approaches. Consider constraints from both LHC and low Q^2 structure function data. Full treatment of uncertainties and coupled DGLAP evolution.

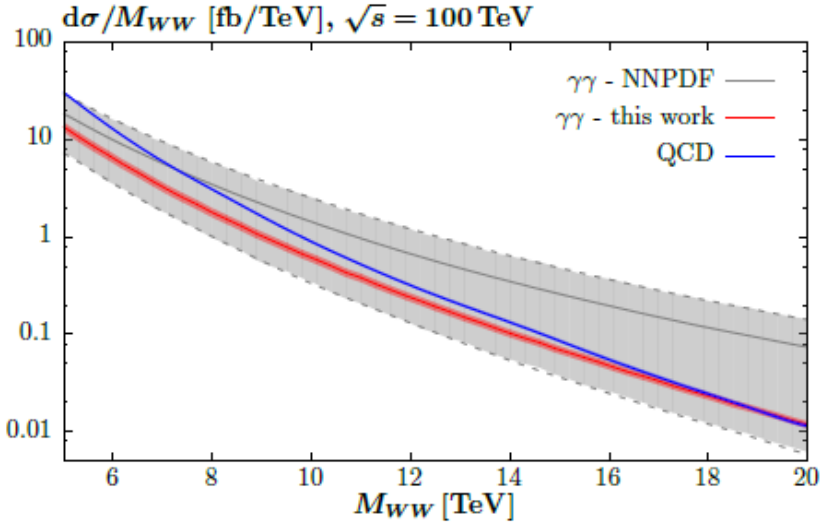




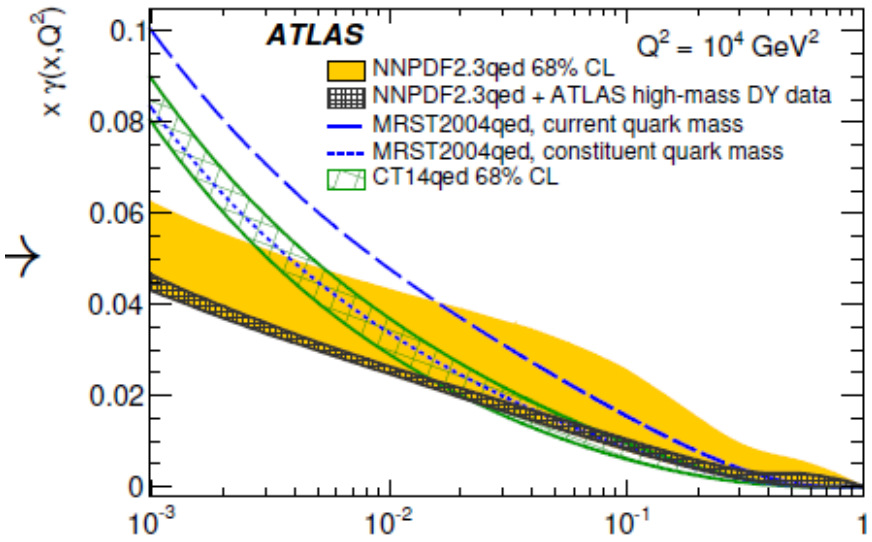


Compare dilepton mass and WW mass spectra at high scale, maybe life is not so bad

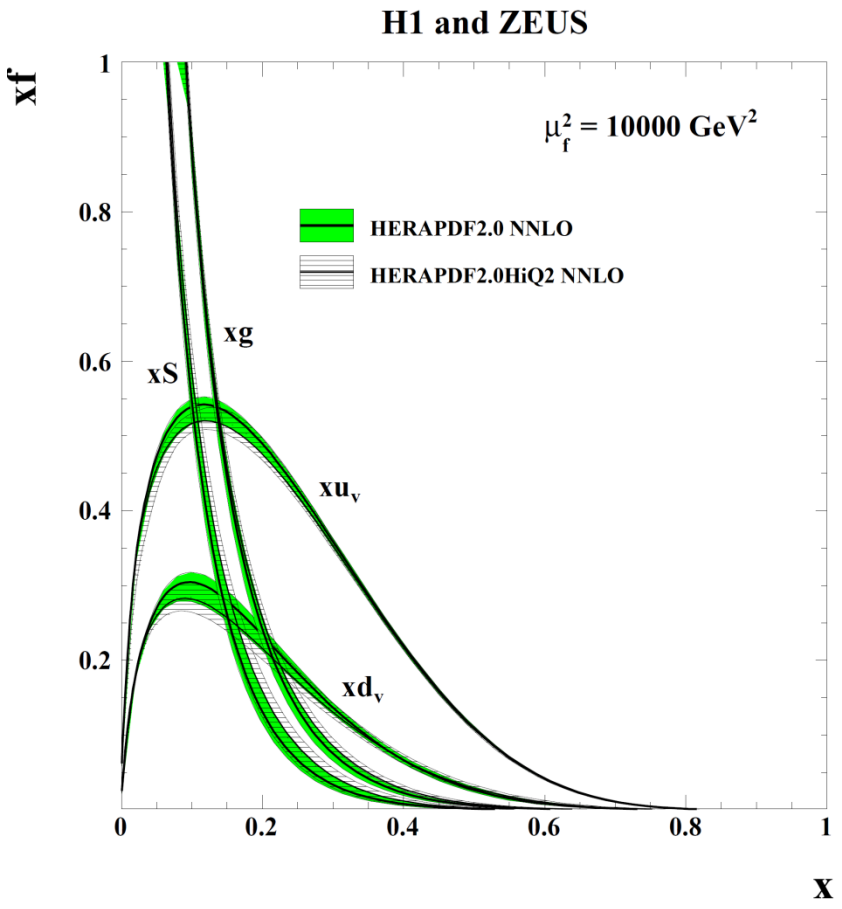




This is consistent with what we have found with ATLAS 8 TeV HMDY data using NNPDF-style reweighting



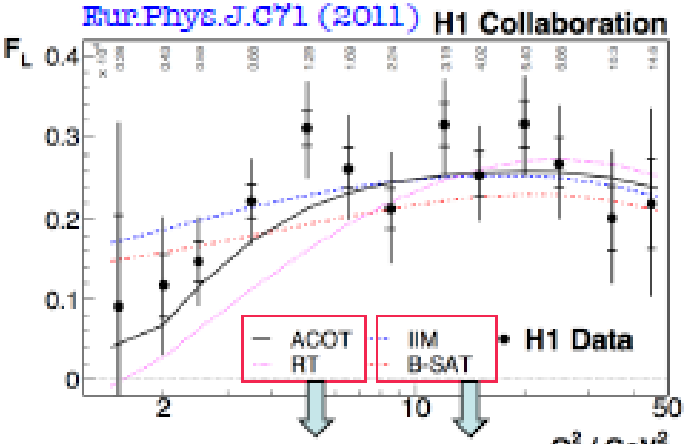
What happens if we cut out low Q2 data and fit Q2>10
Ie cut out much of higher twist region
And much of very low-x region
AFTER we evolve back up to LHC scales?



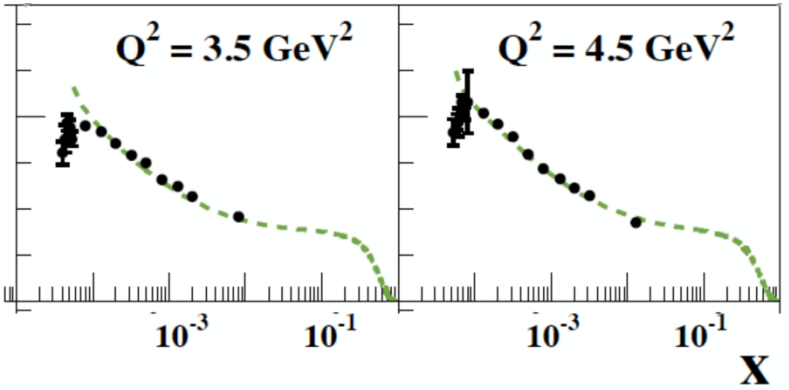
Going beyond DGLAP at low-x

As an alternative to DGLAP, HERAFitter includes also Dipole models:

- Studied by the H1 collaboration in comparing different models on FL:
  - Dipole Models implemented in HERAFitter:
    - GBW model: first model
    - IIM (based on BK-equation)
    - BGK (based on GBW, but gluon evolved using DLGAP)
  - DGLAP Models:
    - RT as used by MSTW group
    - ACOT as used by CTEQ group



- Some **tension** between fixed-order predictions and data in the low-*x* region reached by HERA:



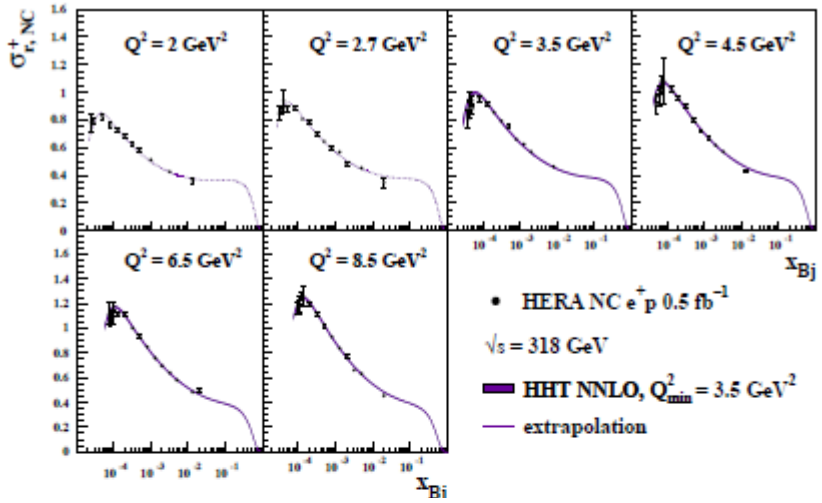
From Eram Rizvi talk at QCD@LHC14

- A similar effect was observed some time ago in the NNPDF framework by F. Caola *et al.* [arXiv:1007.5405].

- Strong suggestion of the need for **small-*x* resummation**.

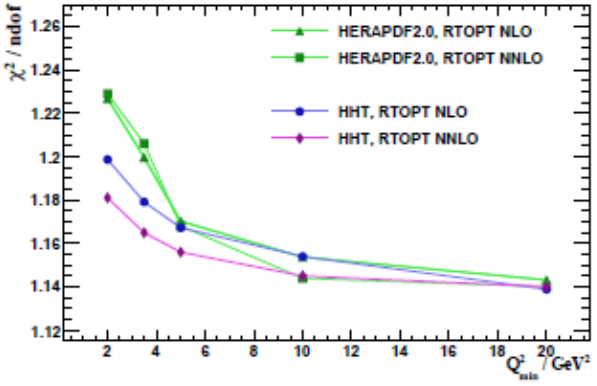
The χ2 of the HERAPDF fit decreases with increasing Q^2 cut. It helps to add higher twist terms to F_L. Note Low Q^2 at HERA is low x – maybe this could also be addressed with low-x resummation

$$\sigma^{\pm}_{r,NC} = F_2 - \frac{y^2}{Y_+} F_L$$

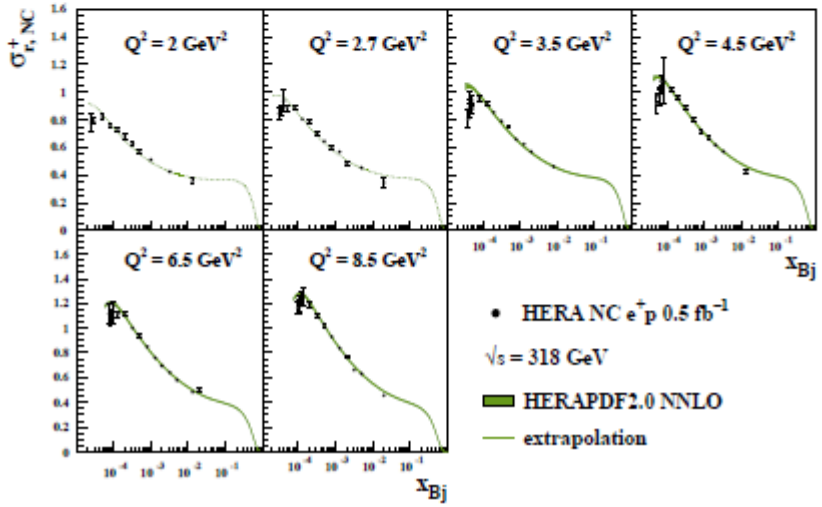


$$F_L^{HT} = F_L^{DGLAP}\,(1 + A_L^{HT}/Q^2)$$

The higher twist terms are only significant in F_L. A larger F_L is predicted which fits the high-y turn over of the reduced cross section much better. This reduces the χ2 of the NNLO fit by 47.

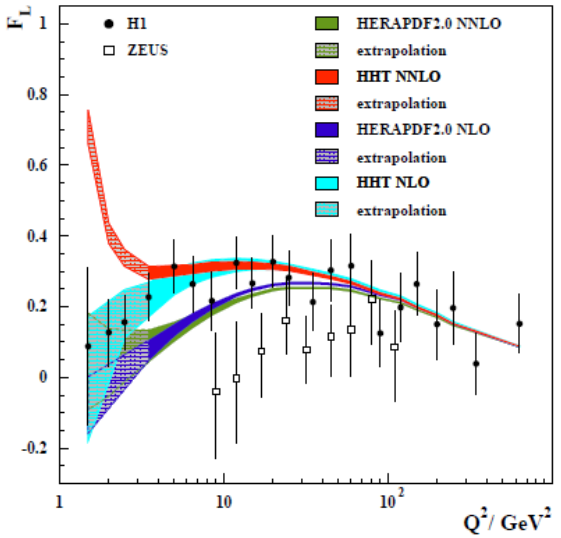


NNLO is now better than NLO



The PDFs from these HHT fits are similar to HERAPDf2.0 at LHC scales

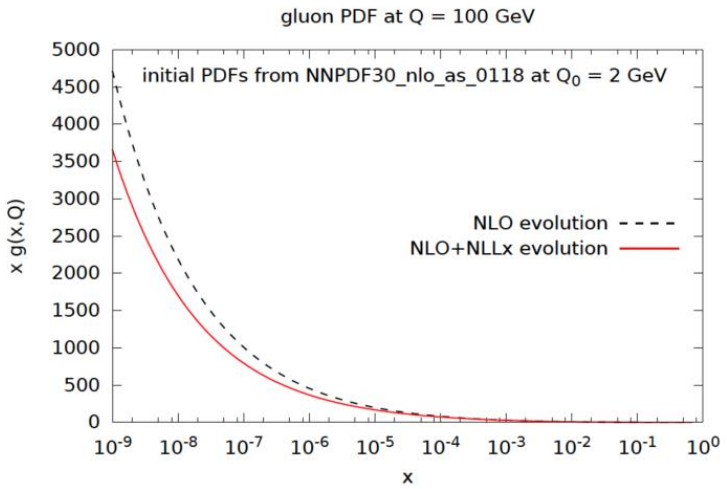
Data can be fitted down to $Q^2 = 2\text{GeV}^2$ - but lower Q^2 cannot be described in such a simple picture

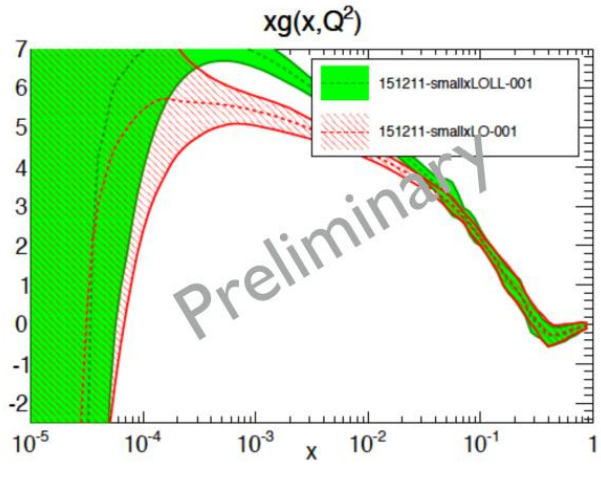


- In collaboration with Marco Bonvini, quite some work has been done to interface to interface the **HELL** code to APFEL:
  - HELL implements small-x resummed splitting functions up to **NLL** accuracy based on the ABF approach [arXiv:0802.0032].
  - it will soon implement also small-x resummed DIS coefficient functions (Marco Bonvini, Luca Rottoli and Tiziano Peraro are presently working on that).
- The actual interface is **already in place** and fully operative.
- As a proof of concept, we have already run PDF fits with small-x resummed evolution obtaining encouraging results.
- A fully consistent PDF fit would require resummed coefficient functions which should be available in HELL within a few weeks.

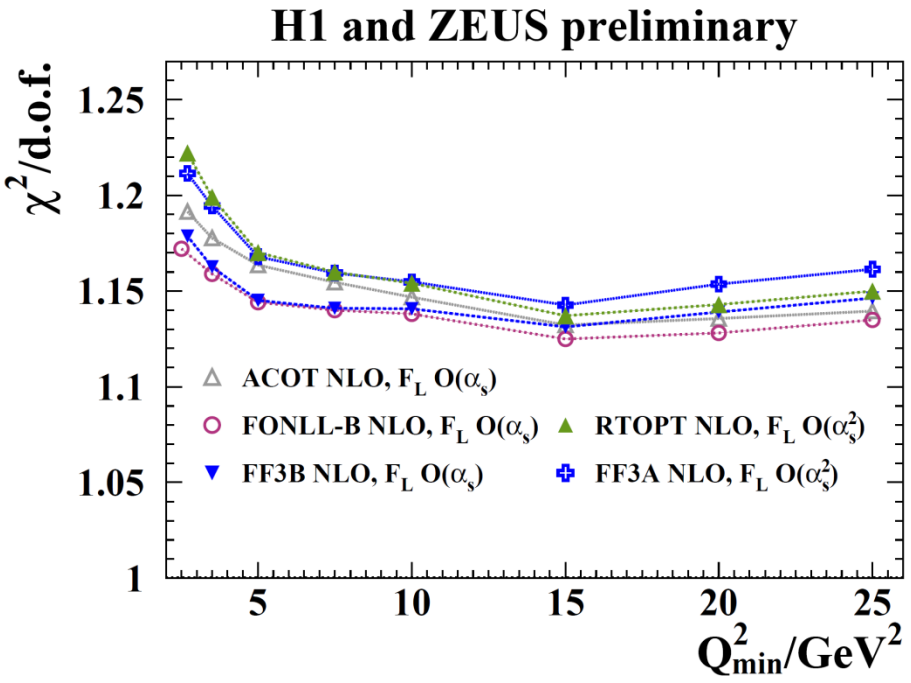
And don't completely forget high-x threshold resummation TROLL for ln(1-x)

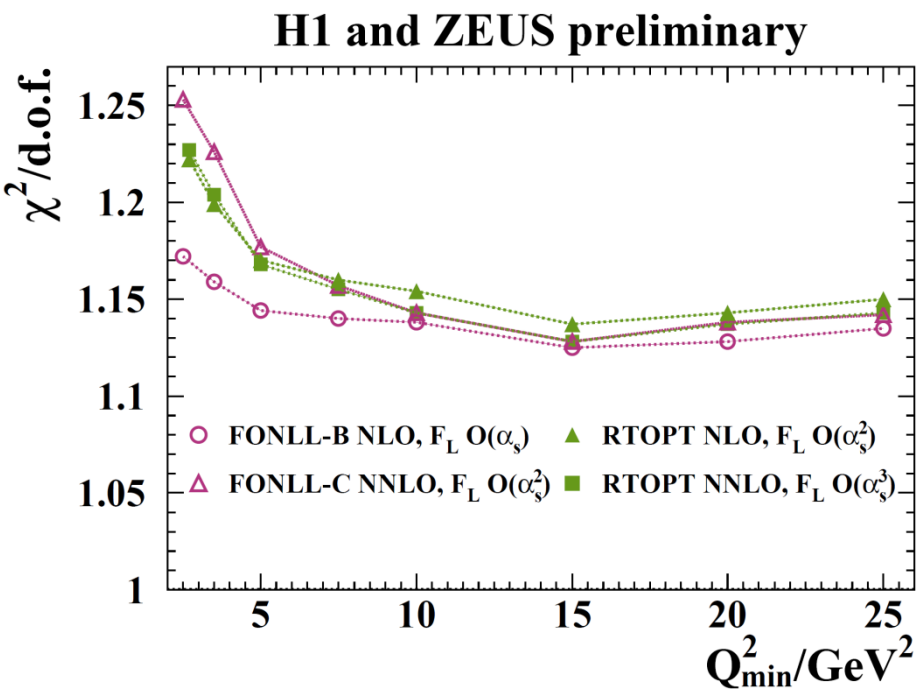
- Enhancement of the fitted gluon PDF at small values of x due to the relative suppression of the resummed evolution.
- Compensation expected when also resummed coefficient functions will be introduced.





Further remarks on dependence on Q^2_{min}
Compare heavy flavour schemes at NLO and compare NLO to NNLO





Treating F_L to O(α_S) – the same order as F_2 yields better χ2 than treating FL to O(α_S^2) almost independent of heavy flavour scheme

RTOPT NNLO is marginally worse than NLO
FONLL NNLO is a lot worse than NLO