CT14 update
…plus a few other things

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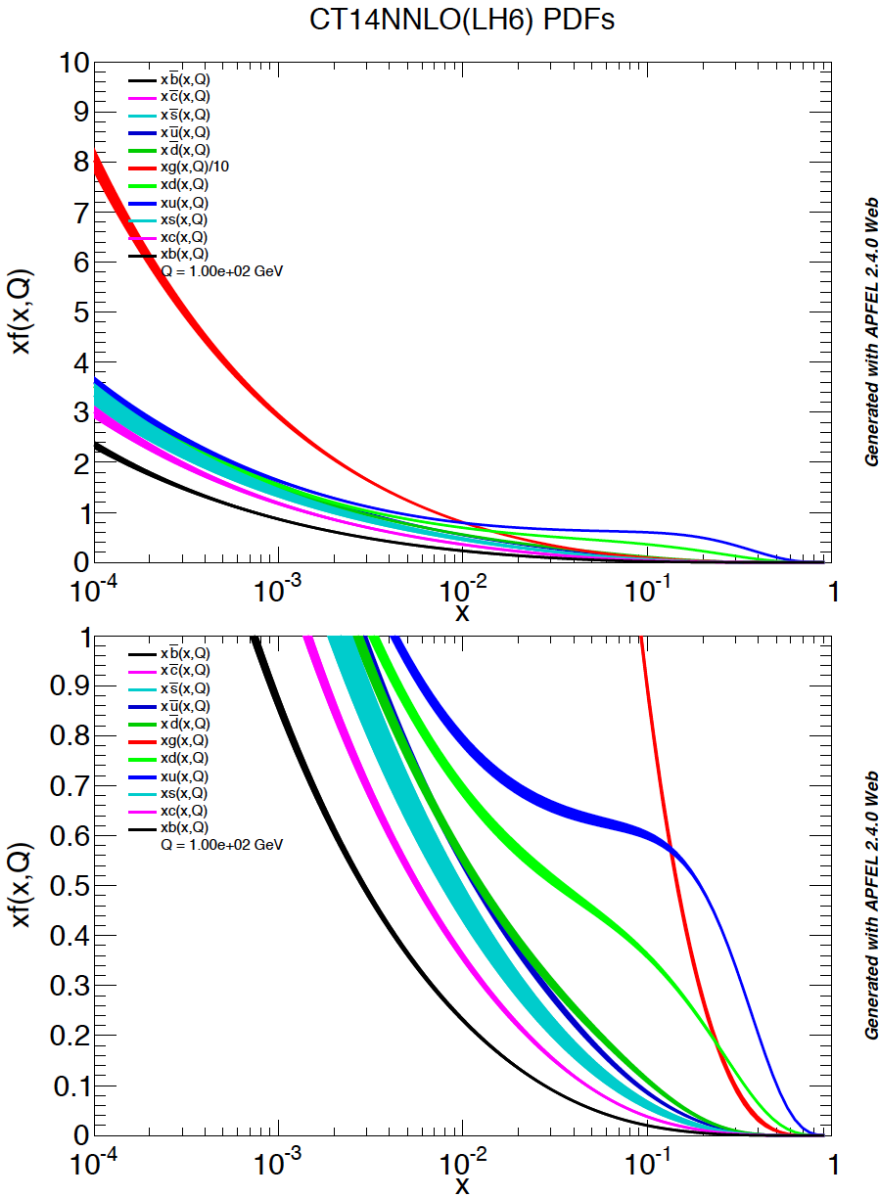
…for the CTEQ-TEA PDF fitting group

CT14++

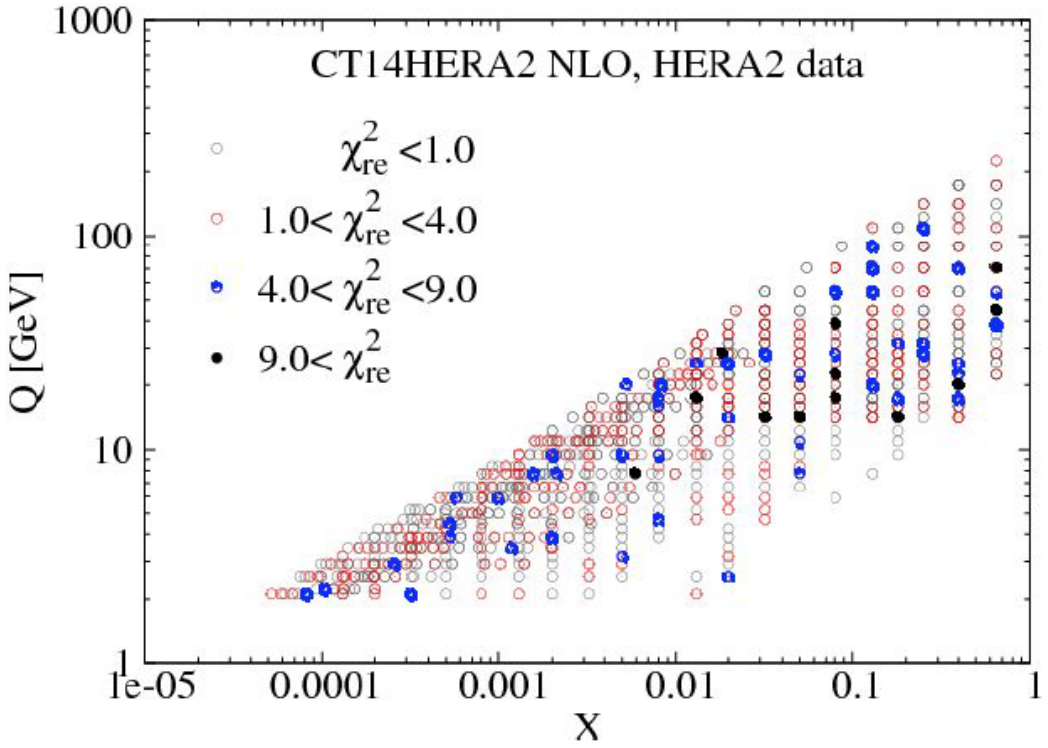
- Since the publication of CT14, paper on replicas
  - arXiv:1607.06066
  - see Pavel Nadolsky's presentation on Monte Carlo replicas and intrinsic charm in post-CT14 fits
- …and on photon PDFs
  - arXiv:1509.02905
  - arXiv:1603.04874
  - see CP's presentation on photon PDFs
- …and investigations of the HERA2 data
  - arXiv:1609.XXXX
- …and work on inclusion of new LHC data in CT fits
  - paper in progress



HERA2 data

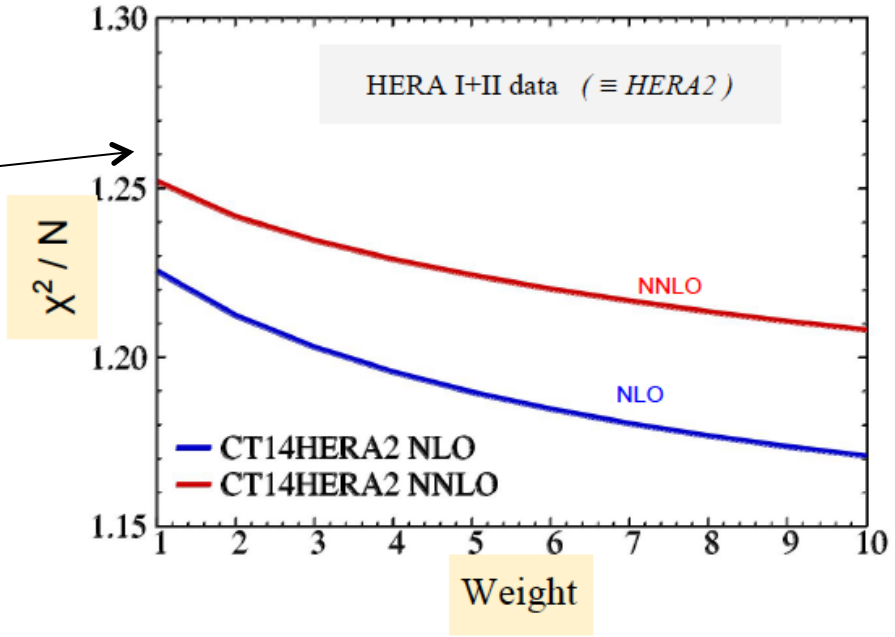
- Make the following changes with regards to CT14
  - replace HERA1 (N=579) by HERA1+2 (N=1120)
  - remove NMC F2p (N=201)
  - add 1 more parameter to strange quark PDF
- As others have seen, χ^2 for HERA1+2 is large, even with HERA1 data included
  - bad χ^2 is distributed in x,Q

PDFs	χ^2_{HERA1} /N_1	χ^2_{HERA2} /N_2	χ^2_{HERA2} /N_2
CT14 (NNLO)	591 /579 (fit)	1469 /1120 (not fit)	= 1.31
$CT14_{HERA2}$(NNLO)	610 /579 (not fit)	1402 /1120 (fit)	= 1.25



HERA2 data

- e-p data hardest to fit
- increasing the weight of the HERA1+2 data improves the χ^2, but not tremendously



Separate the four HERA2 DIS processes;
($Q_{cut} = 2$ GeV)

	N_{pts}	$\chi^2_{red.} / N_{pts}$
NC e^+p	880	1.11
CC e^+p	39	1.10
NC e^-p	159	1.45
CC e^-p	42	1.52
totals		
[reduced χ^2] /N	1120	1.17
χ^2 / N	1120	1.25
R^2 / N	1120	0.08

reduced χ^2 values

χ^2 = [reduced χ^2] + R^2

The quadratic penalty for 162 systematic errors = 87.5

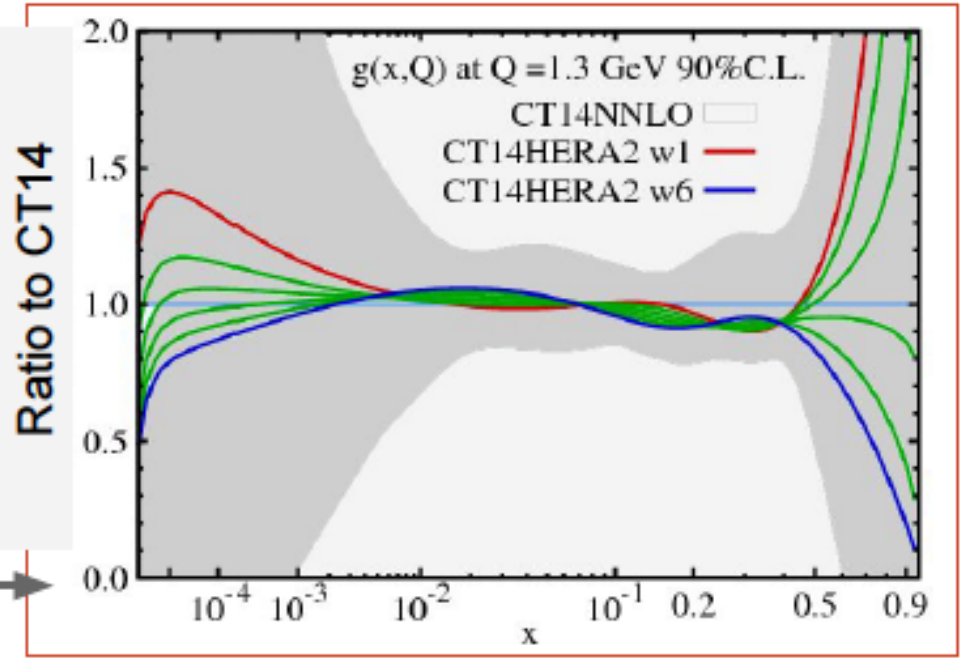
CT14HERA2

- Ratio to the standard CT14 PDF;
- six choices of **weight** applied to the HERA2 data set in the global fit (*nominal=1* to *heaviest=6*)
- CT14 Hessian error band (shaded)

Comparing PDFs

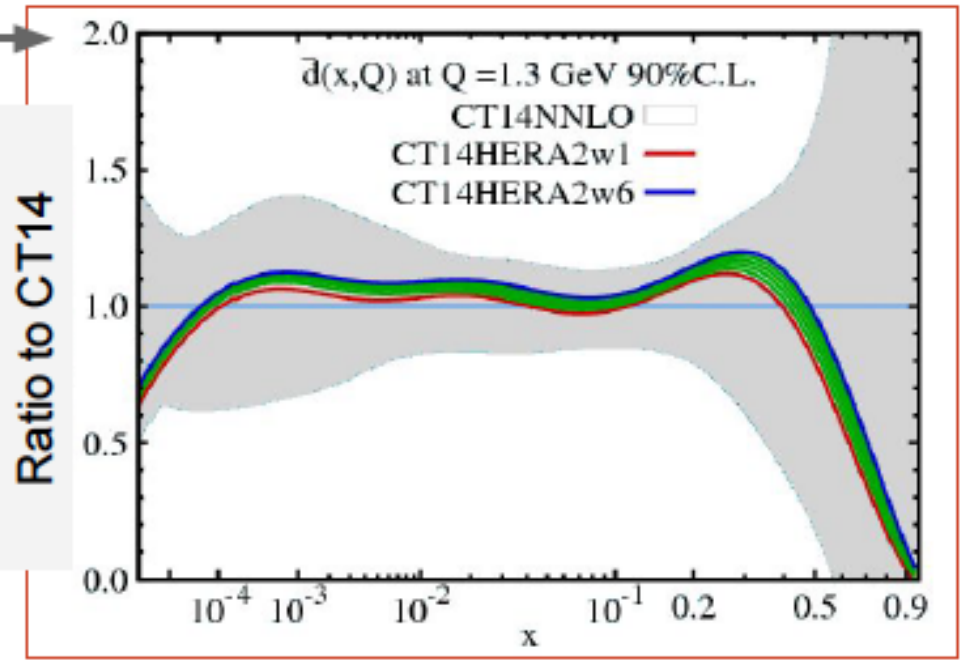
description of LHC W/Z data using CT14HERA2 very similar to that using CT14.

gluon



d antiquark

CT14HERA2 is slightly larger but always in the error band



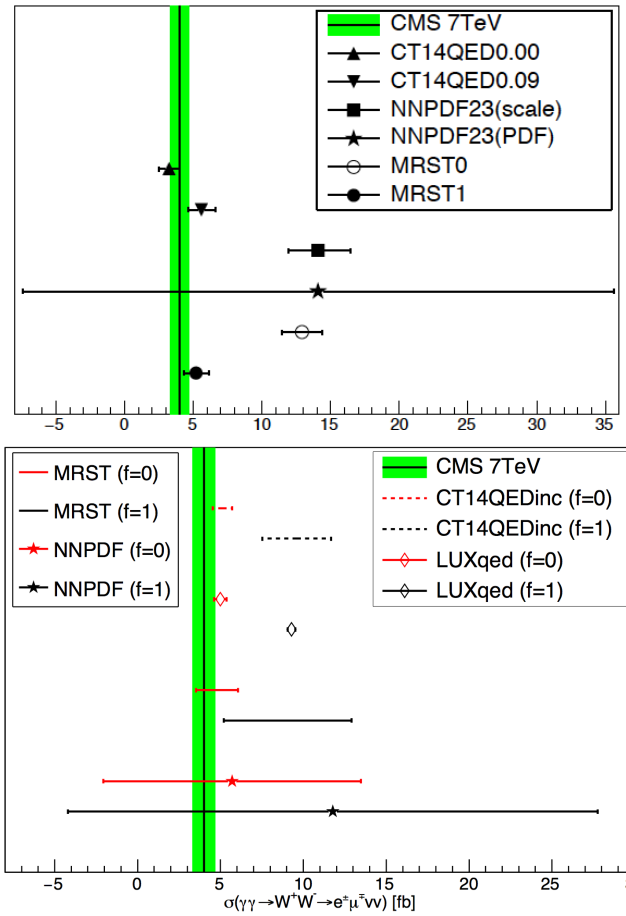
Impact of the *HERA2* data:

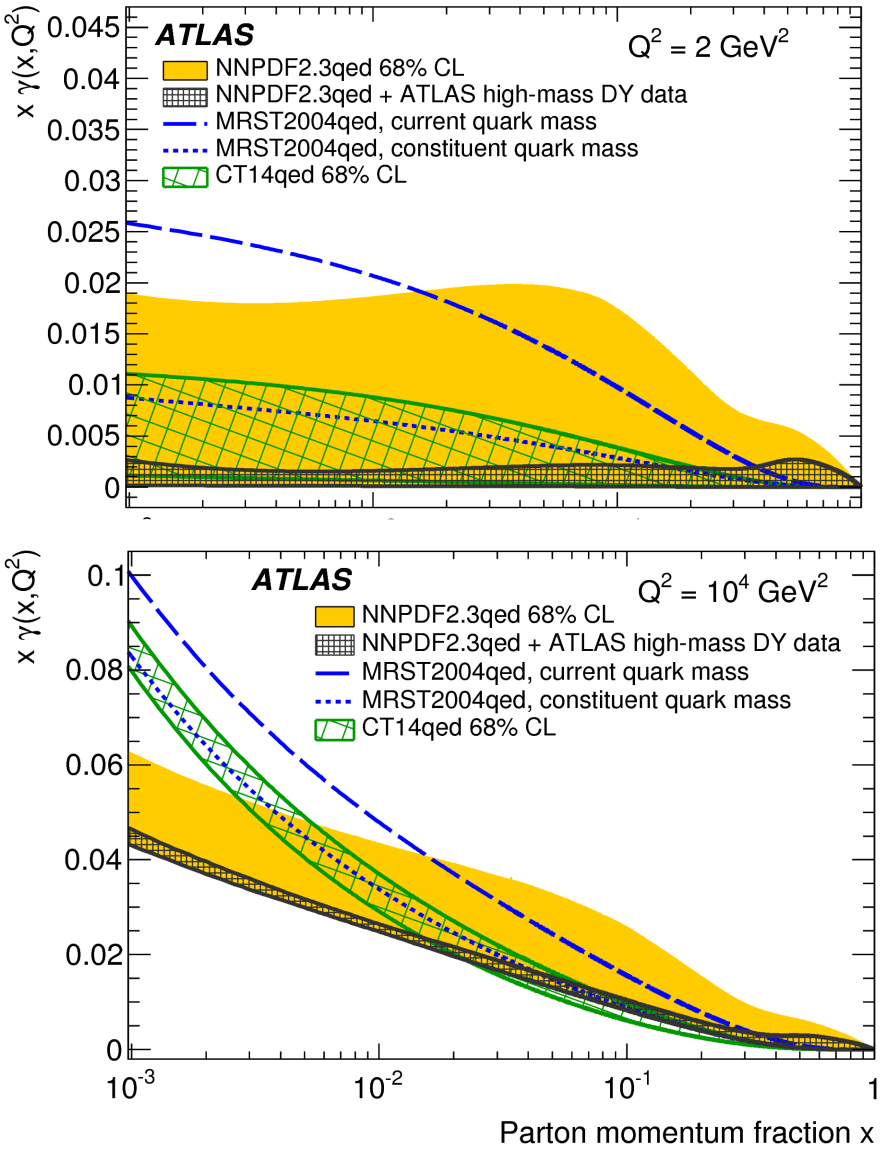
- ➢ skews the gluon pdf *vs.* x;
- ➢ pushes the d-antiquark up *vs.* x

Just a few words about photon PDFs

- ATLAS fit to Drell-Yan data prefers photon distribution at lower end of NNPDF2.3qed uncertainty band, closer to MRST, CT14qed, LUX

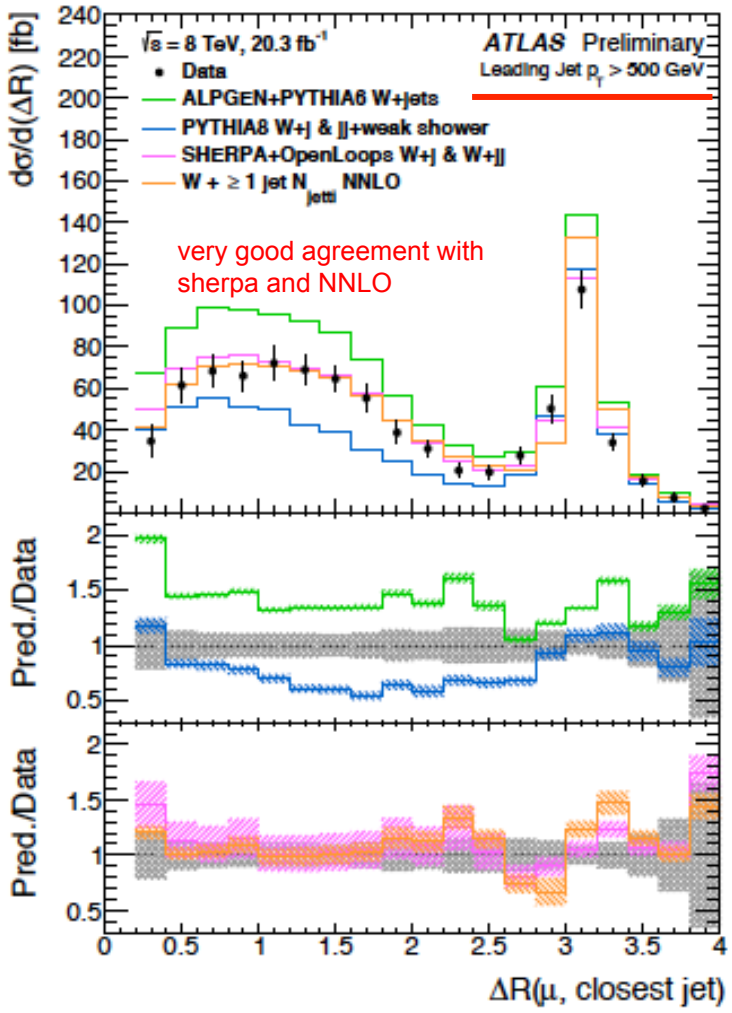
CP's talk





NLO EW predictions for $\Delta R(\mu, j_1)$

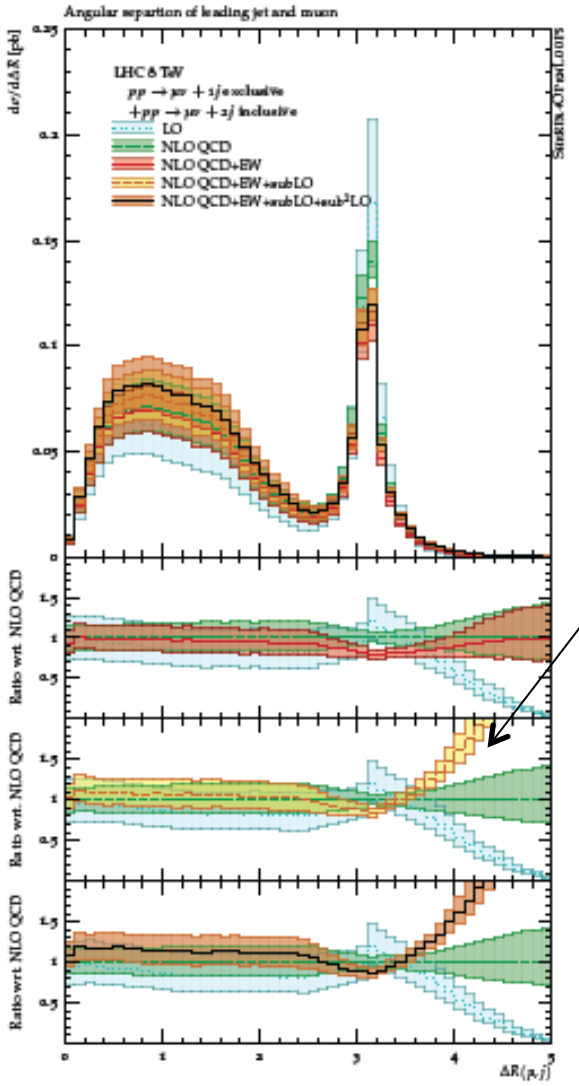
LoopFest in August



Data comparison M. Wu ICHEP'16

- ALPGEN+PYTHIA
  $pp \to W +$ jets MLM merged
  Mangano et.al. JHEP07(2003)001
- PYTHIA 8
  $pp \to Wj$ + QCD shower
  $pp \to jj$ + QCD+EW shower
  Christiansen, Prestel EPJC76(2016)39
- SHERPA+OPENLOOPS
  NLO QCD+EW+subLO
  $pp \to Wj/Wjj$ excl. sum
  Kallweit, Lindert, Maierhöfer, Pozzorini, MS JHEP04(2016)021
- NNLO QCD $pp \to Wj$
  Boughezal, Liu, Petriello arXiv:1602.06965

NLO EW predictions for $\Delta R(\mu, j_1)$



Measure coll. W emissions, simplified from
Krauss, Petrov, MS, Spannowsky PRD89(2014)114006

LHC@8TeV, $p_\perp^{j_1} > 500\,\text{GeV}$, central μ and jet

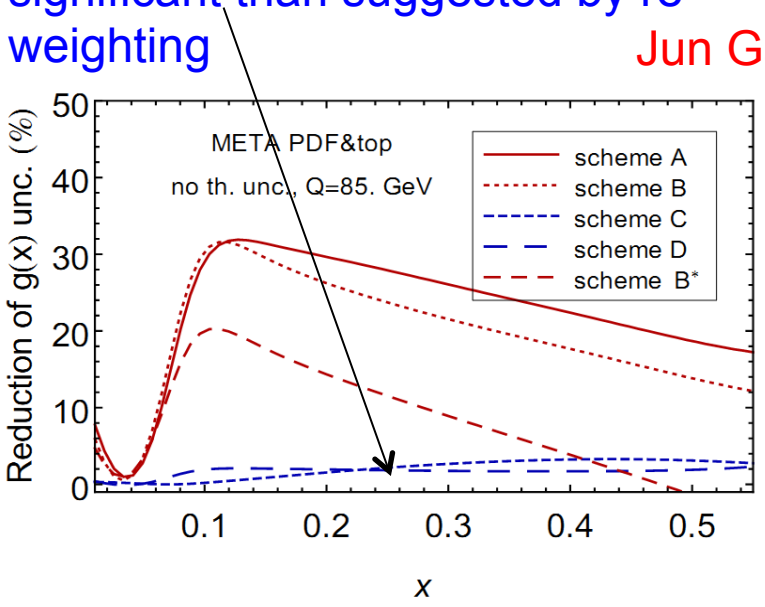
- LO $pp \to Wj$ with $\Delta\phi(\mu, j) \approx \pi$
- NLO corrections neg. in peak
  large $pp \to Wjj$ component opening PS
- subleading Born (γPDF) imp. at large ΔR
- restrict to exactly $1j$, no $p_\perp^{j_2} > 100\,\text{GeV}$
- describe $pp \to Wjj$ @ NLO,
  use $p_\perp^{j_2} > 100\,\text{GeV}$
- pos. NLO QCD, neg. NLO EW, $\sim$ flat
- subleading Born contribs positive
- sub^{2}leading Born (diboson etc) conts. pos.
  $\to$ possible double counting with BG
- merge using exclusive sums

Plans/inclusion of new LHC data

- Inclusive jets
  - will continue to use NLO and fastNLO/applgrid to include 8 and 13 TeV ATLAS/CMS jet data sets
  - NNLO corrections have been shown to be reasonably small when correct scale is used; no need for rapidity cuts
  - will adapt to NNLO format when available
- tT inclusive and differential
  - applgrid at NLO with NNLO/NLO K-factors
- Photon/W/Z+charm
  - some theoretical work ongoing before inclusion in global PDF fit
  - framework for charm will continue to be perturbative charm, without an intrinsic component
    - see Pavel's talk

- In general,we are working on improving the speeds of NLO and NNLO fits
- PDF re-weighting is being explored, but has to take into account tolerance issues
- For example, for global PDF fits like MMHT or CT, reduction in χ^2 for tT total cross section (1303.7215) less significant than suggested by re-weighting

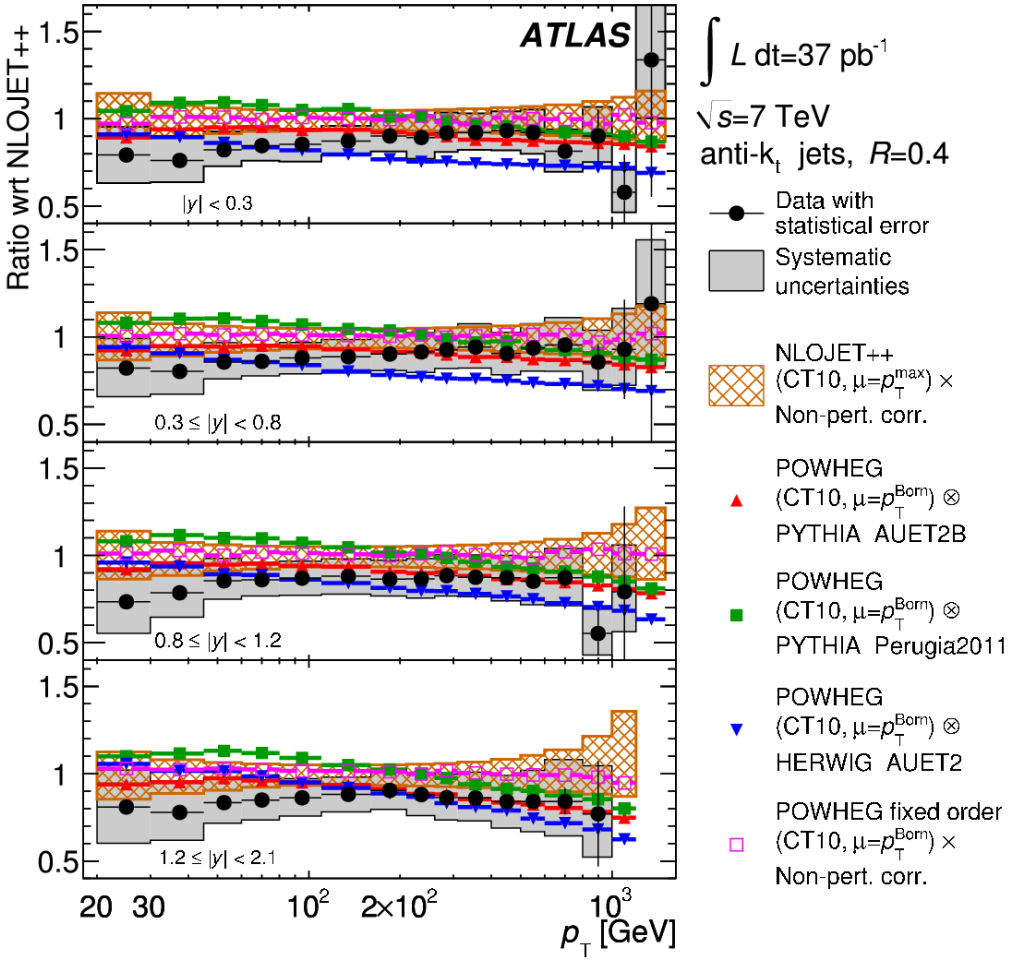
Jun Gao



…and now a few questions

LHC jet data

- In global PDF fits, we assume that fixed order (with non-perturbative predictions) is sufficient to describe the data, as long as the cross sections are sufficiently inclusive, such as the inclusive jet cross section
- There seems to be some difference between Powheg+parton shower and Powheg+fixed order
- This is not seen with Sherpa
- …and needs to be better understood
- In Les Houches 2015 study for Higgs +jets observables, all ME+PS programs *devolve* to underlying fixed order predictions in non-Sudakov regions, **i.e. the parton showers have little effect on either the normalization or shape of these cross sections**



There is an ongoing investigation on the possible influence of parton showers on inclusive jet cross sections. PSR17->Les Houches

NB

- Modern technology for ME+PS programs allows the underlying event to be calculated (and tuned) using one PDF and the matrix element evaluation and parton showering to be done with another
  - can think of it as an effective factorization
- That UE PDF can even be LO…in fact usually better/easier if it's LO
- Thus, a lot of work that is carried out by LHC experiments on creating tunes for new versions of PDFs can be avoided

- ATLAS has interpreted the PDF4LHC15 document as stating that the PDF4LHC15 PDFs should never be used for Monte Carlo generation
  - this was not my interpretation and is not the sense of the PDF4LHC group (I believe)
  - it might be useful to issue a clarification

8 is enough

- PDF4LHC15_30 is a general purpose LHC set
- Can re-diagonalize eigenvector set to look for directions most sensitive to a particular class of physics, for example Higgs physics
- In that case, 8 PDFs are sufficient

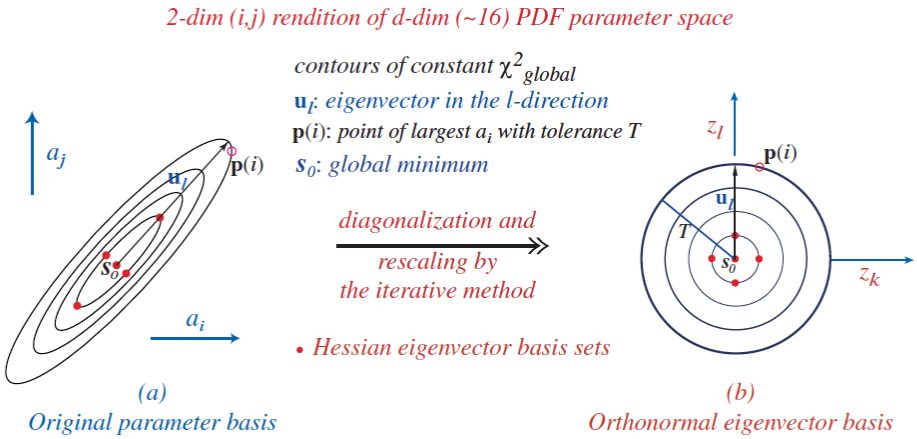


Fig. 6.13 A schematic representation of the transformation from the pdf parameter basis to the orthonormal eigenvector basis.

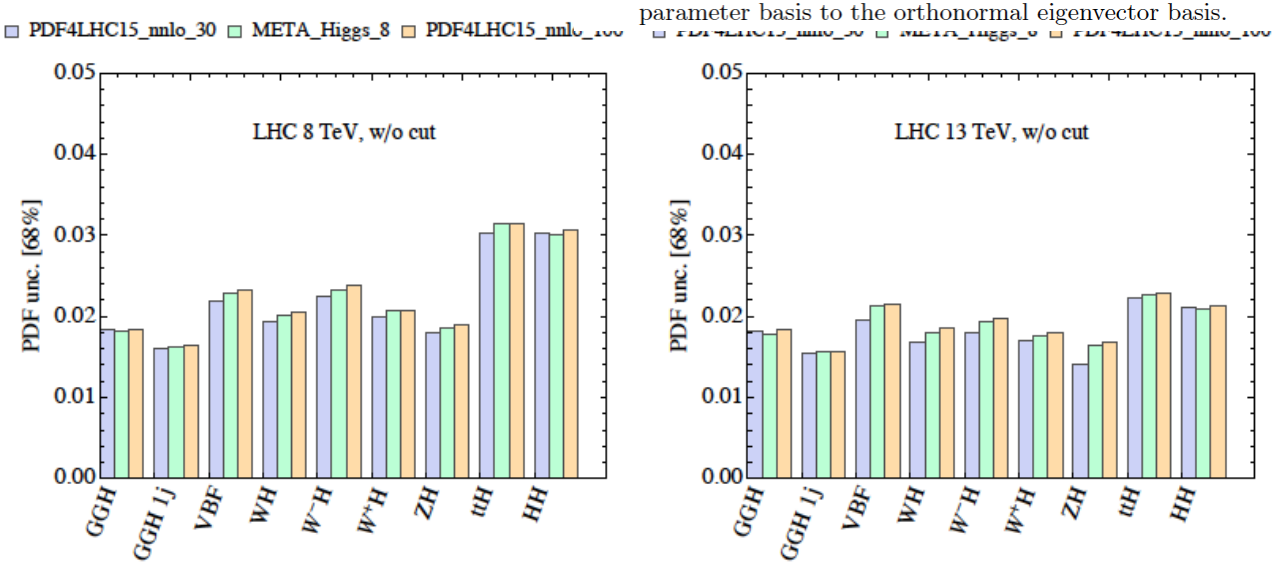
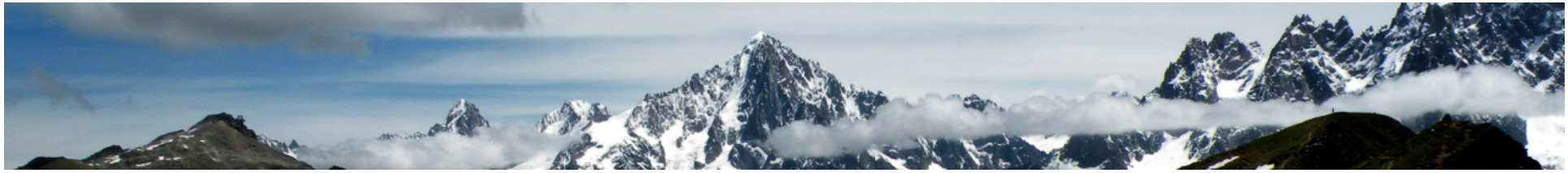


FIG. 1: Predictions on the total PDF uncertainties comparing NNLO PDFs of PDF4LHC15 30 set, reduced set (with 8 eigenvectors), and PDF4LHC15 100 set.

~~Winter~~ Les Houches is coming



Les Houches 2017 June 5-23

The topics in this talk, and many others, will be investigated.

PDF4LHC goal

Making PDFs Great Again