Modified LO PDF's for Monte Carlo discussion: CTEQ update

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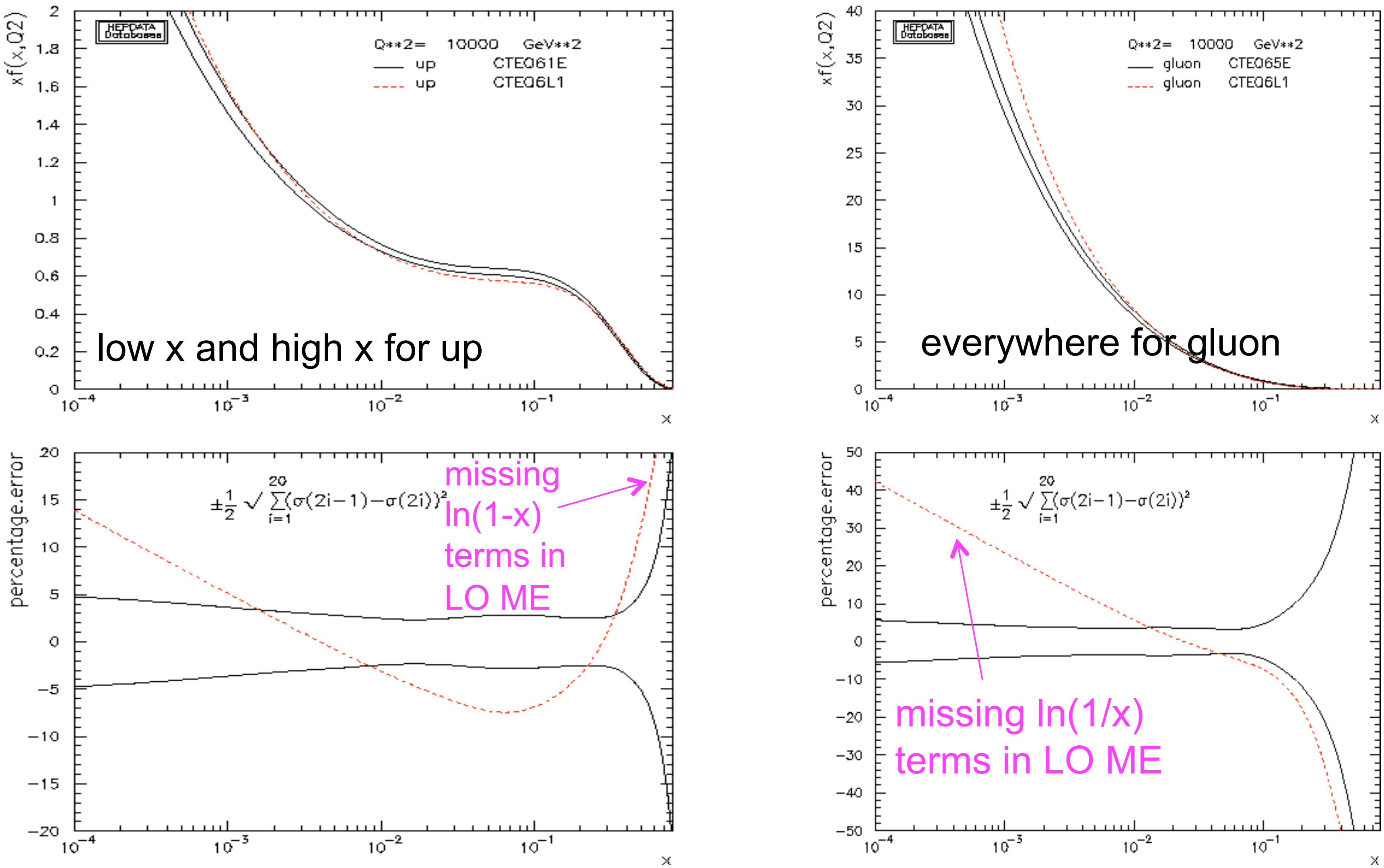
group

Motivation

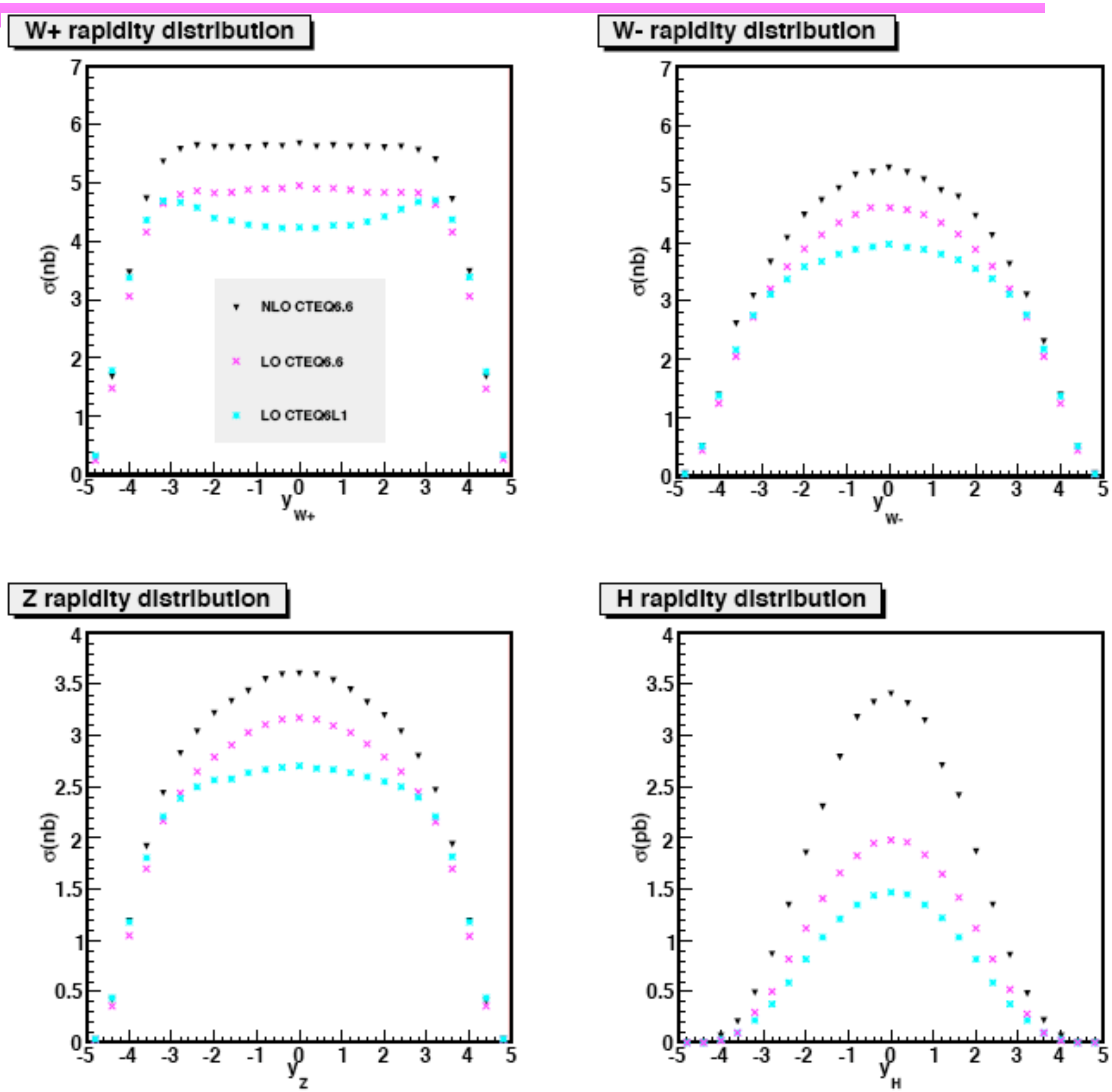
- Skip the detailed motivation since we've all seen it before…
- Basically,we want the LO* pdf's to behave as LO as x->0; as close to NLO as possible as x->1
- In this way, we can
  - maintain the connection to the underlying event tunes already in use (dependent on the low x behavior of the gluon)
  - better describe the shapes (and normalizations) of hard cross sections at the LHC (dependent on the high x behavior of the PDFs)

Where are the differences between LO and NLO partons?



LO and NLO distributions

- The shapes for the cross sections shown to the right are well-described by LO matrix elements using NLO PDFs, but there are distortions that are evident when LO PDFs are used
- Normalizations are not fully described using LO matrix elements (K-factor)



CTEQ mod LO PDFs

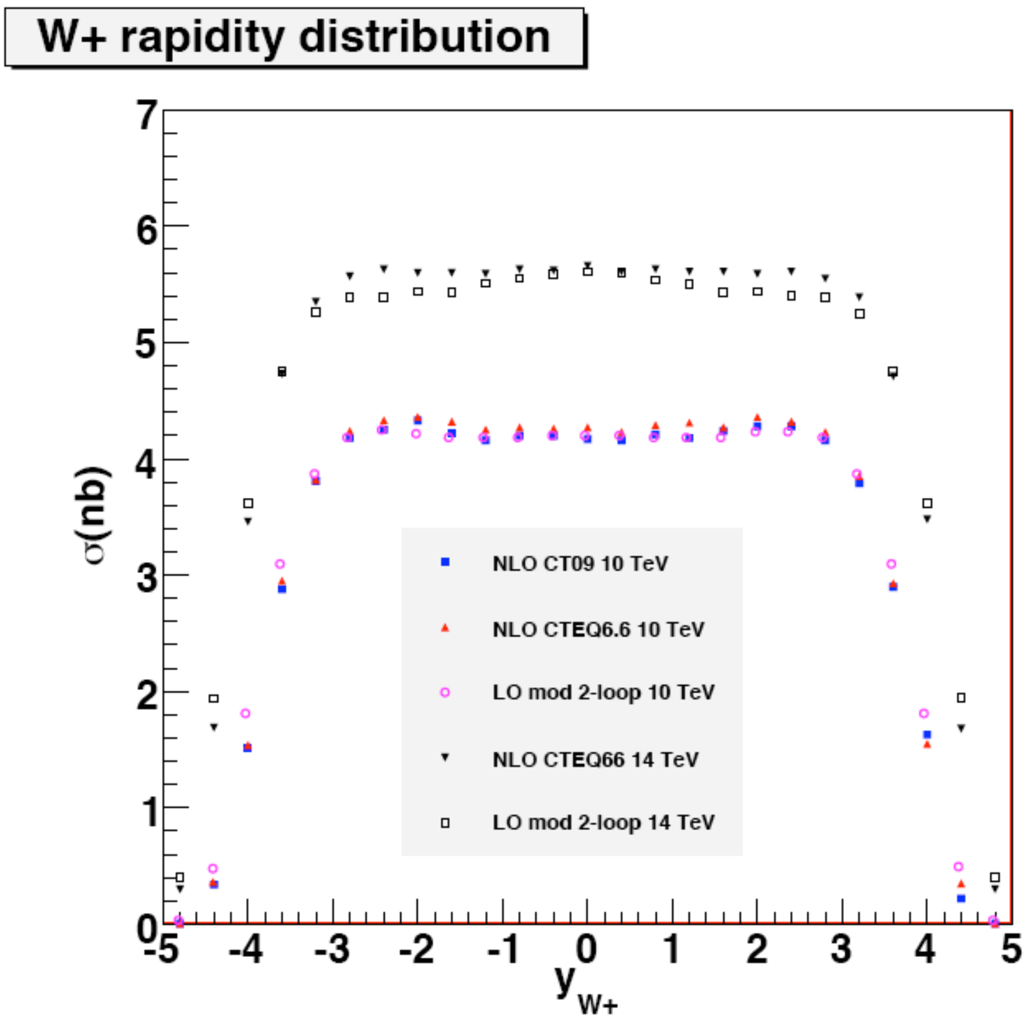
- Include in LO* fit (weighted) pseudo-data for characteristic LHC processes produced using CTEQ6.6 NLO pdf's with NLO matrix elements (using MCFM), along with full CTEQ6.6 dataset (2885 points)
  - low mass bB
    - fix low x gluon for UE
  - tT over full mass range
    - higher x gluon
  - W^+, W^-, Z^0 rapidity distributions
    - quark distributions
  - gg->H (120 GeV) rapidity distribution
- Allow total momentum in proton to exceed 1.00 if needed to fit the real and pseudo-data
  - other sum rules intact
- Use 1-loop or 2-loop α_s
  - two different fits and thus 2 different PDFs
  - will concentrate on 2-loop results here
  - keep $\alpha_s(m_Z)$ fixed on 1-loop (2-loop) world averages, for better connection to other CTEQ PDFs
- Also, another technique involving use of scales

Some observations

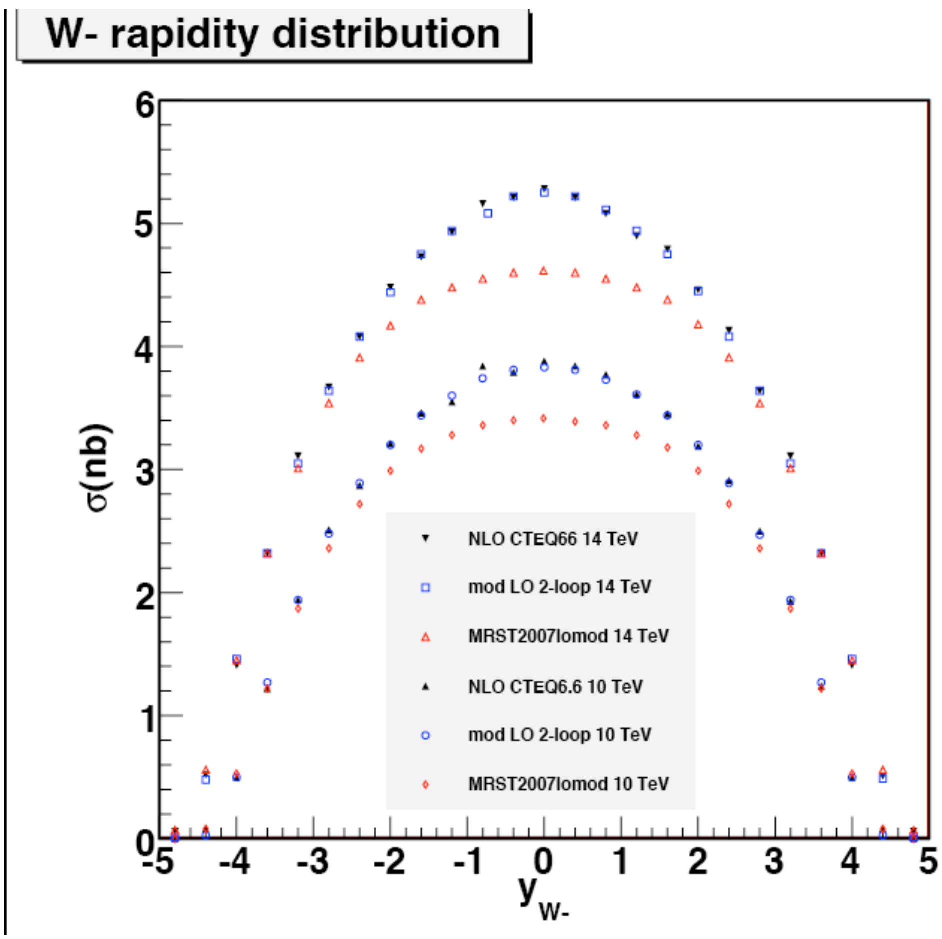
- χ^2 improves with momentum sum rule free
  - without pseudo-data in fit, the momentum sum increases by ~3-4%
- Pseudo-data has conflicts with global data set
  - that's the motivation of the modified pdf's
- Requiring better fit to pseudo-data increases chisquare of LO fit to global data set by about 10-20% (although this is not the primary concern; the fit to the pseudo-data is)
  - prefers more momentum (1.10 for 1-loop and 1.14 for 2-loop); mostly goes into the gluon distribution
- No strong preference for 1-loop or 2-loop α_s that I can see, with fits containing weighted pseudo-data; without pseudo-data, prefers 2-loop
- Normalization of pseudo-data (needed K-factor) gets closer to 1
  - 1.00 for W production (instead of 1.15)
  - ~1.1 for tT production (instead of 1.4)
  - ~1.4 for Higgs (120 GeV) (instead of 1.7)

Results

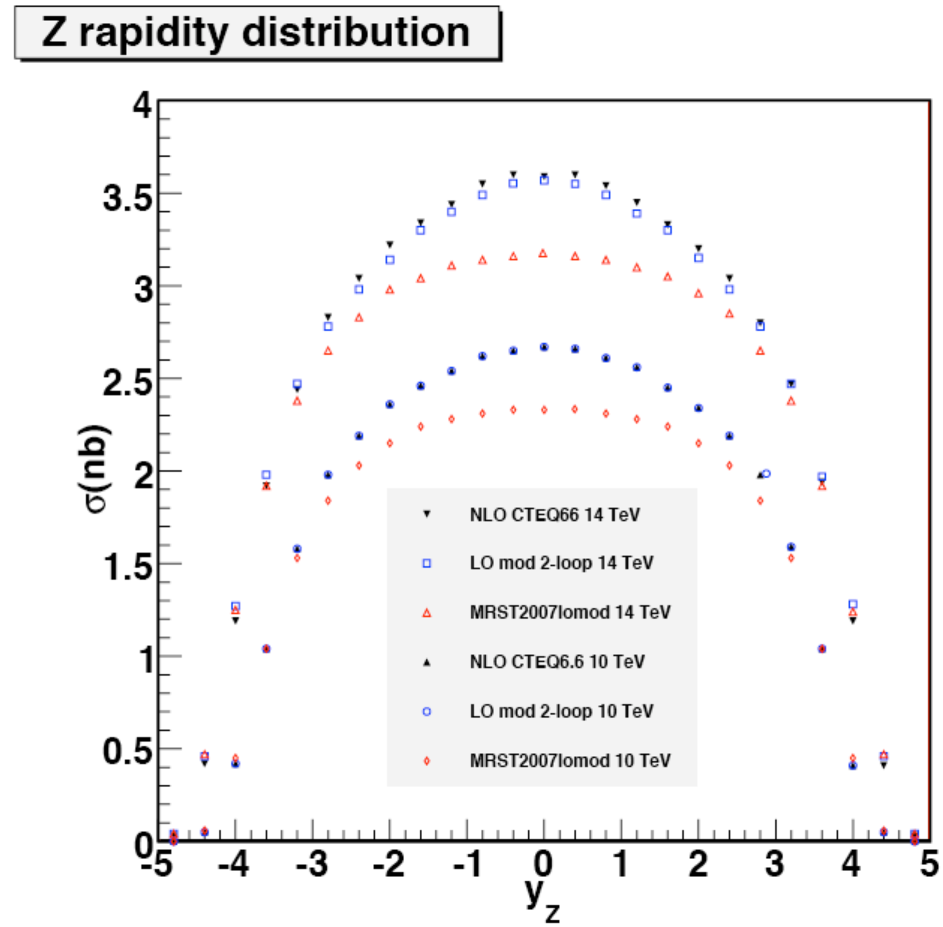
- Mod LO W^+ rapidity distribution agrees better with NLO prediction in both magnitude and shape
- Agreement at 10 TeV (not in fit) even better



Results



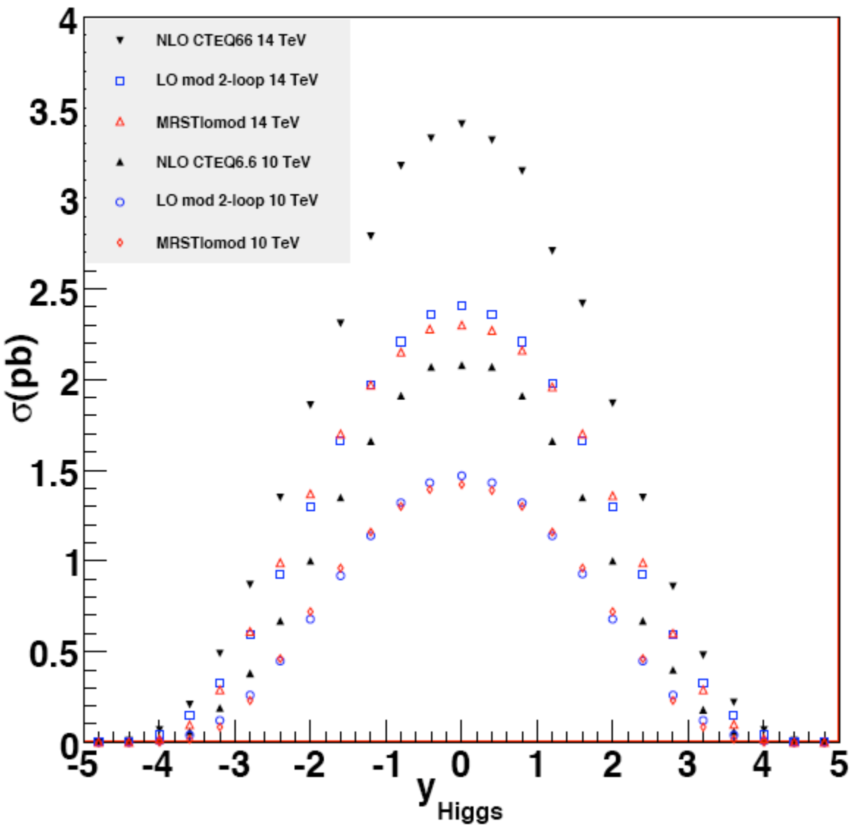
W- rapidity distribution
σ(nb)
y_{W-}
NLO CTEQ66 14 TeV
mod LO 2-loop 14 TeV
MRST2007lomod 14 TeV
NLO CTEQ6.6 10 TeV
mod LO 2-loop 10 TeV
MRST2007lomod 10 TeV



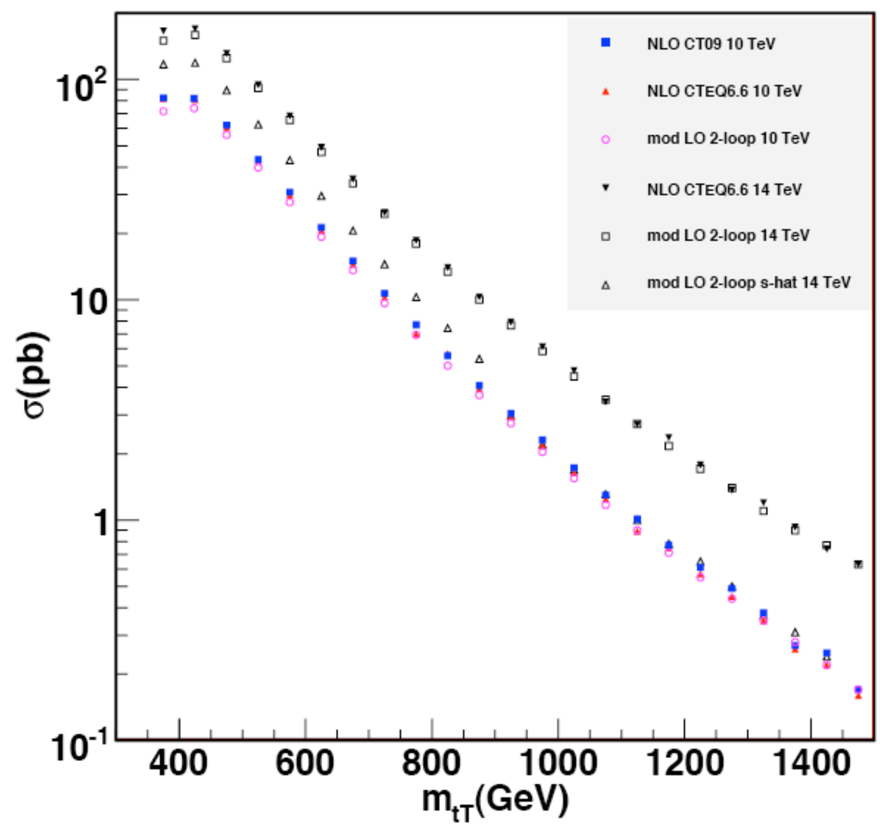
Z rapidity distribution
σ(nb)
y_Z
NLO CTEQ66 14 TeV
LO mod 2-loop 14 TeV
MRST2007lomod 14 TeV
NLO CTEQ6.6 10 TeV
LO mod 2-loop 10 TeV
MRST2007lomod 10 TeV

Results

Higgs(120 GeV) rapidity distribution



tT mass distribution



K-factor table from CHS paper

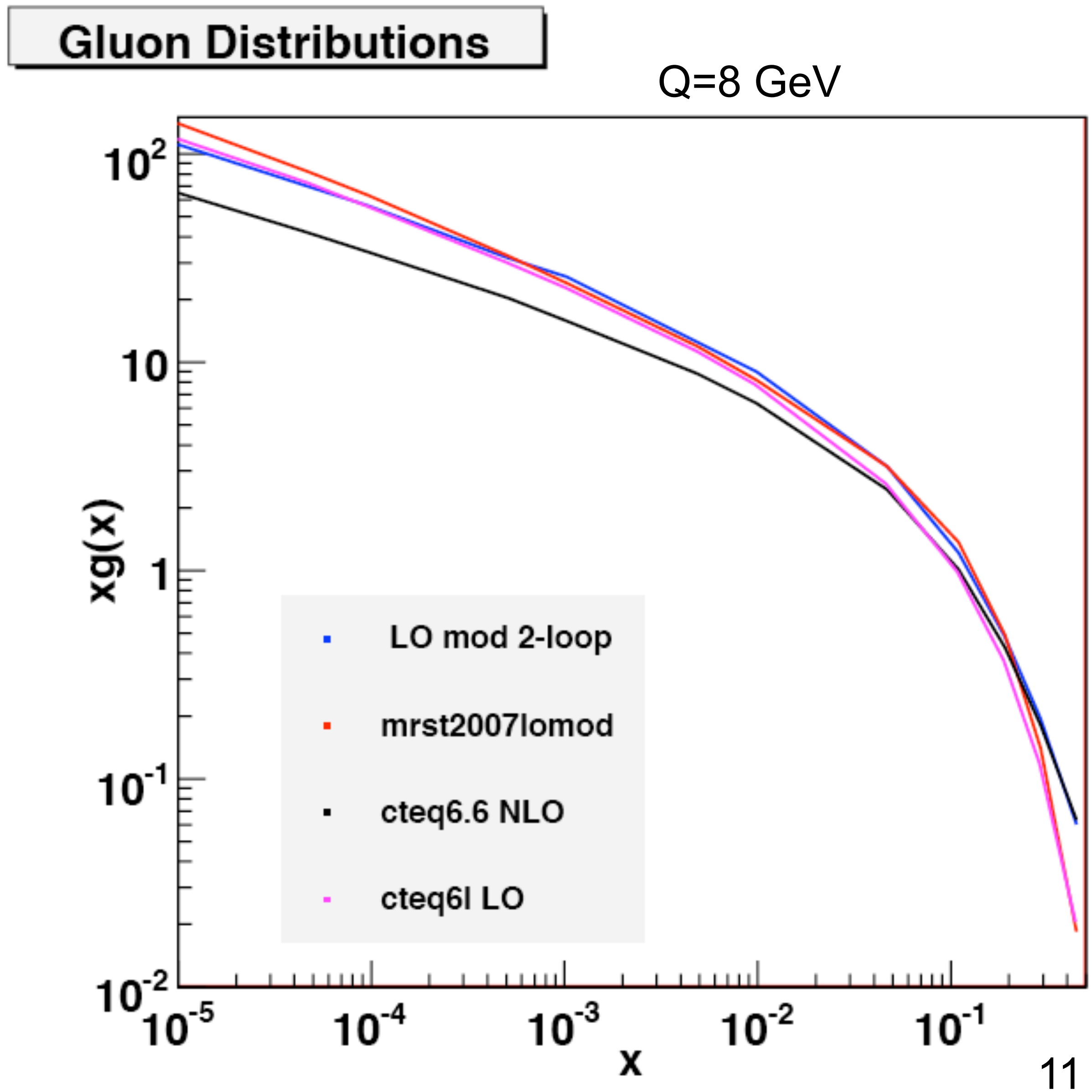
Process	Typical scales μ_0	μ_1	Tevatron K-factor $\mathcal{K}(\mu_0)$	$\mathcal{K}(\mu_1)$	$\mathcal{K}'(\mu_0)$	LHC K-factor $\mathcal{K}(\mu_0)$	$\mathcal{K}(\mu_1)$	$\mathcal{K}'(\mu_0)$	$\mathcal{K}''(\mu_0)$
W	m_W	$2m_W$	1.33	1.31	1.21	1.15	1.05	1.15	0.95
W+1jet	m_W	$p_T^{\rm jet}$	1.42	1.20	1.43	1.21	1.32	1.42	0.99
W+2jets	m_W	$p_T^{\rm jet}$	1.16	0.91	1.29	0.89	0.88	1.10	–
WW+jet	m_W	$2m_W$	1.19	1.37	1.26	1.33	1.40	1.42	–
$t\bar{t}$	m_t	$2m_t$	1.08	1.31	1.24	1.40	1.59	1.19	1.09
$t\bar{t}$+1jet	m_t	$2m_t$	1.13	1.43	1.37	0.97	1.29	1.10	
$b\bar{b}$	m_b	$2m_b$	1.20	1.21	2.10	0.98	0.84	2.51	–
Higgs	m_H	$p_T^{\rm jet}$	2.33	–	2.33	1.72	–	2.32	1.43
Higgs via VBF	m_H	$p_T^{\rm jet}$	1.07	0.97	1.07	1.23	1.34	0.85	0.75
Higgs+1jet	m_H	$p_T^{\rm jet}$	2.02	–	2.13	1.47	–	1.90	1.33
Higgs+2jets	m_H	$p_T^{\rm jet}$	–	–	–	1.15	–	–	1.13

Table 3: K-factors for various processes at the LHC calculated using a selection of input parameters. Have to fix this table. In all cases, the CTEQ6M PDF set is used at NLO. $\mathcal{K}$ uses the CTEQ6L1 set at leading order, whilst $\mathcal{K}'$ uses the same set, CTEQ6M, as at NLO and $\mathcal{K}''$ uses the modified LO (2-loop) PDF set. For Higgs+1,2jets, a jet cut of 40 GeV/c and $|\eta| < 4.5$ has been applied. A cut of $p_T^{\rm jet} > 20$ GeV/c has been applied for the $t\bar{t}$+jet process, and a cut of $p_T^{\rm jet} > 50$ GeV/c for WW+jet. In the W(Higgs)+2jets process the jets are separated by $\Delta R > 0.52$, whilst the VBF calculations are performed for a Higgs boson of mass 120 GeV. In each case the value of the K-factor is compared at two often-used scale choices, where the scale indicated is used for both renormalization and factorization scales.

Note K-factor for W < 1.0, since for this table the comparison is to CTEQ6.1 and not to CTEQ6.6, i.e. corrections to low x PDFs due to treatment of heavy quarks in CTEQ6.6 "built-in" to mod LO PDFs

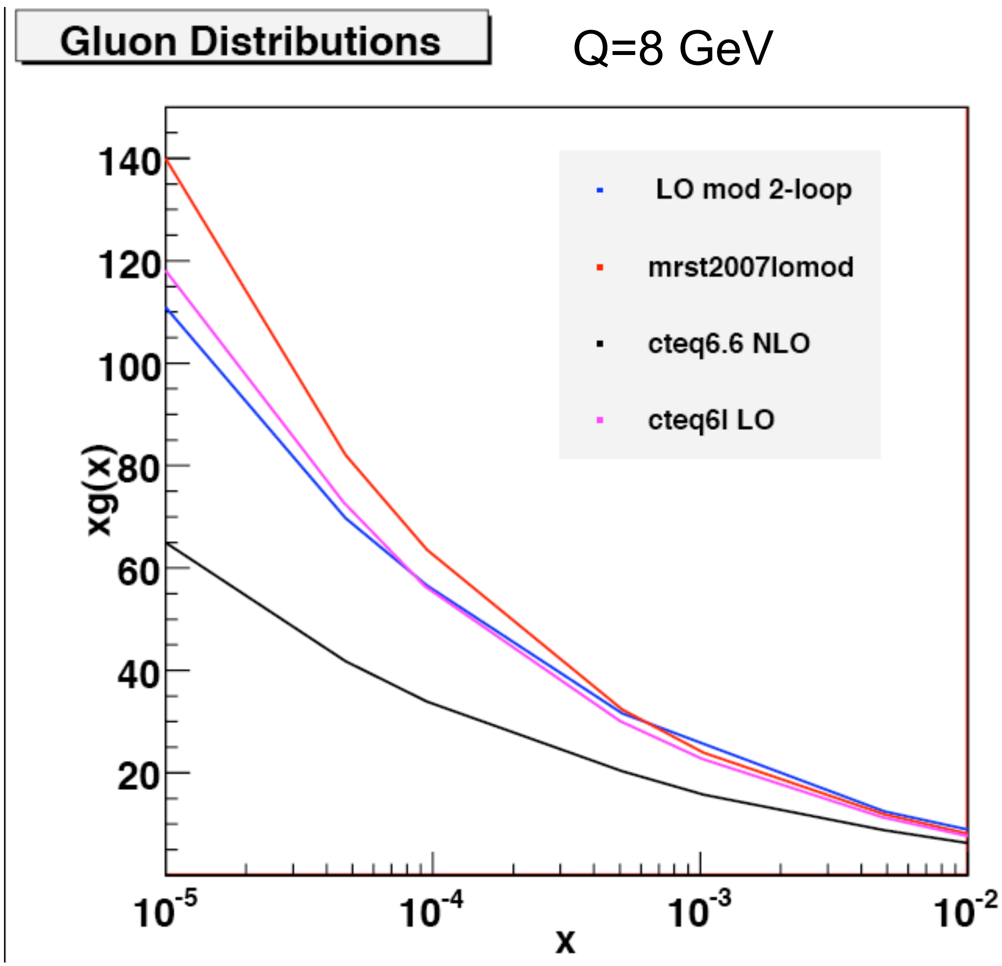
Some PDF comparisons

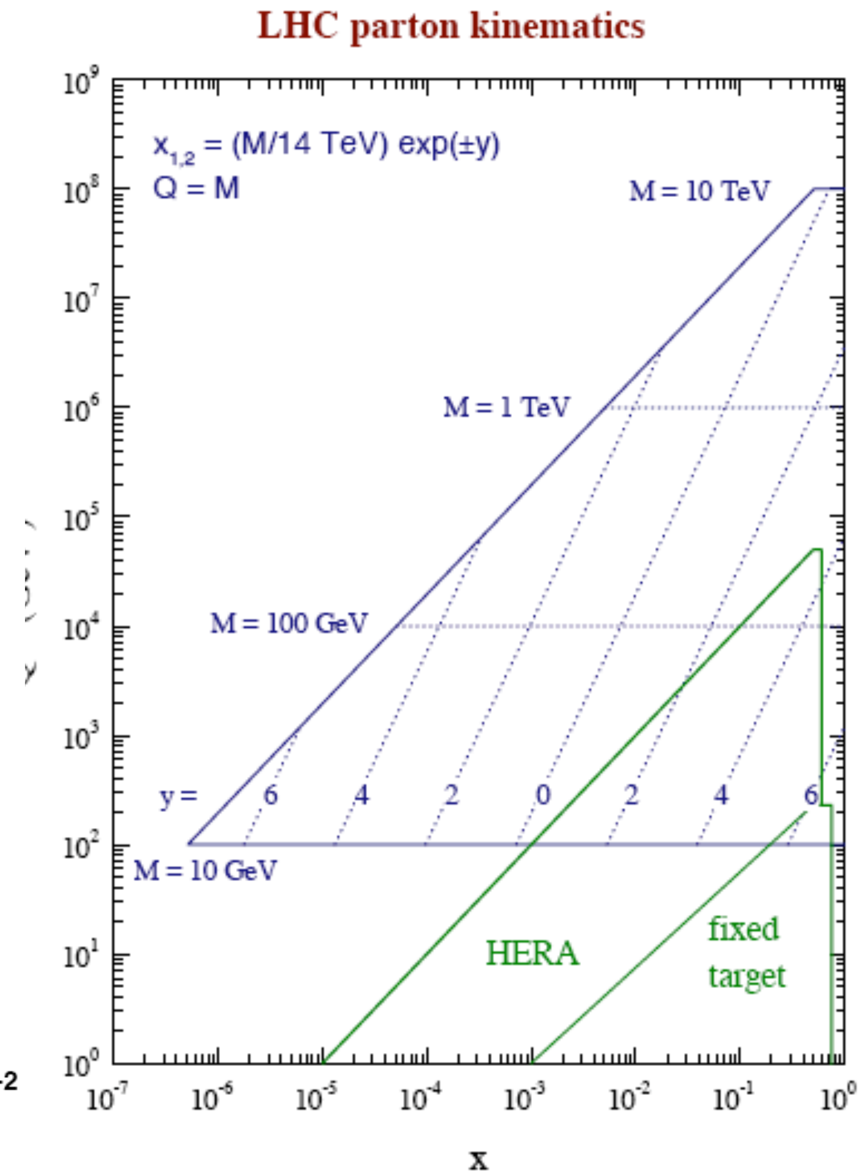
- The 2-loop modified LO PDF is similar to CTEQ6L at low x and to CTEQ6.6 at high x, as designed
- Also shown for comparison is the mrst2007lomod gluon PDF



Mini-jet production

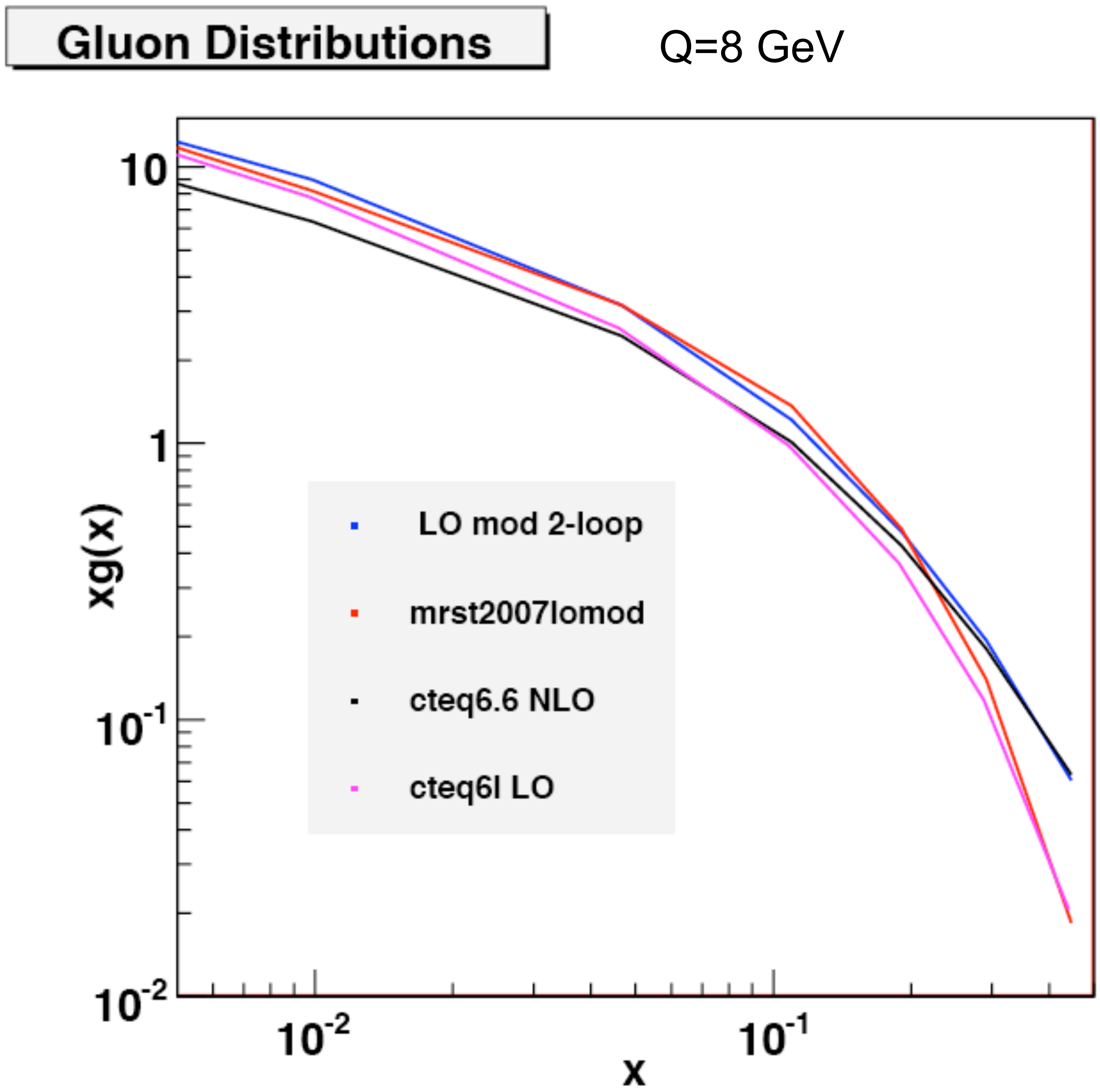
- …will be especially sensitive to gluons in x range of 1E-05 to 1E-02





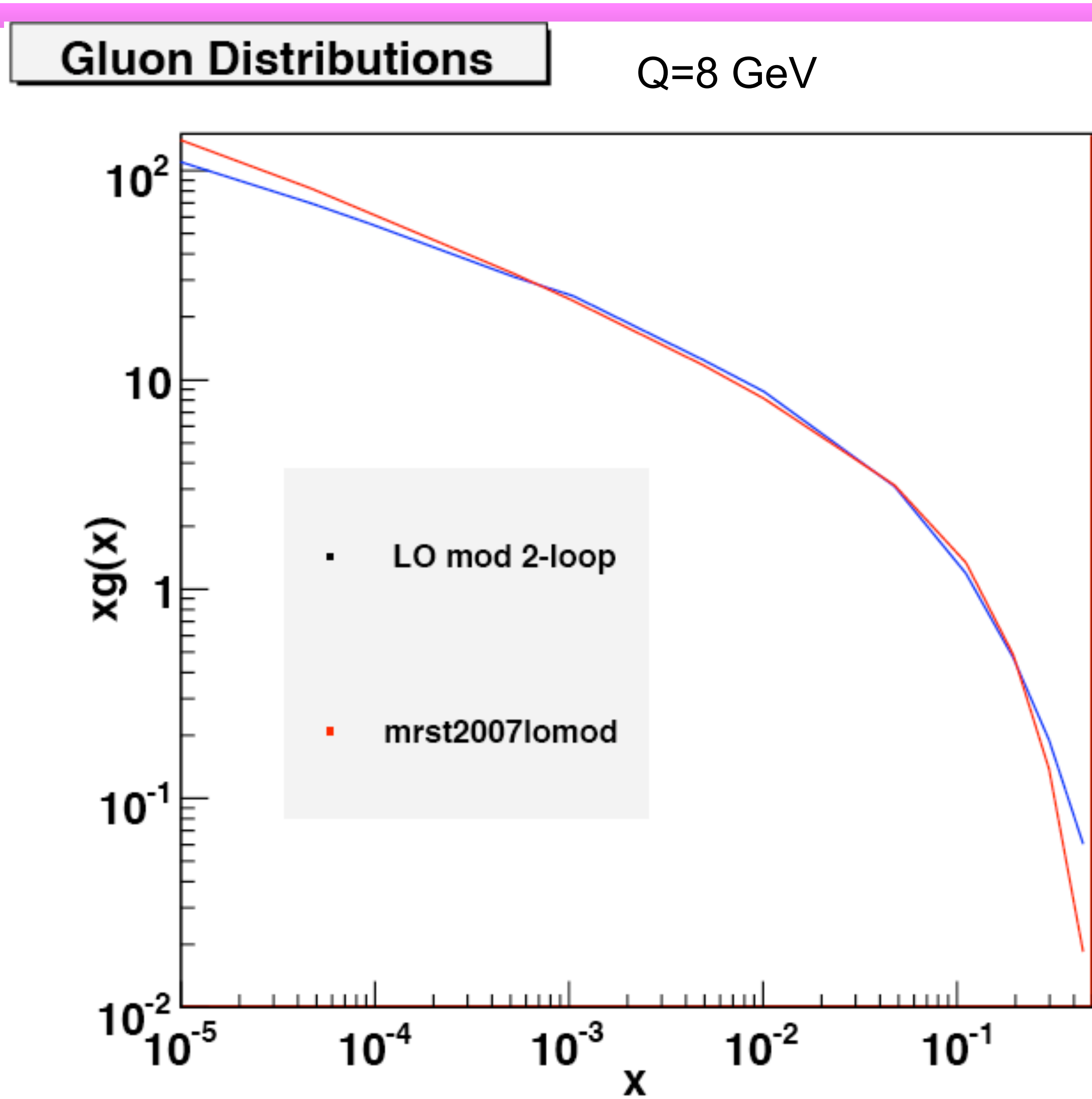
Some PDF comparisons

- high x region



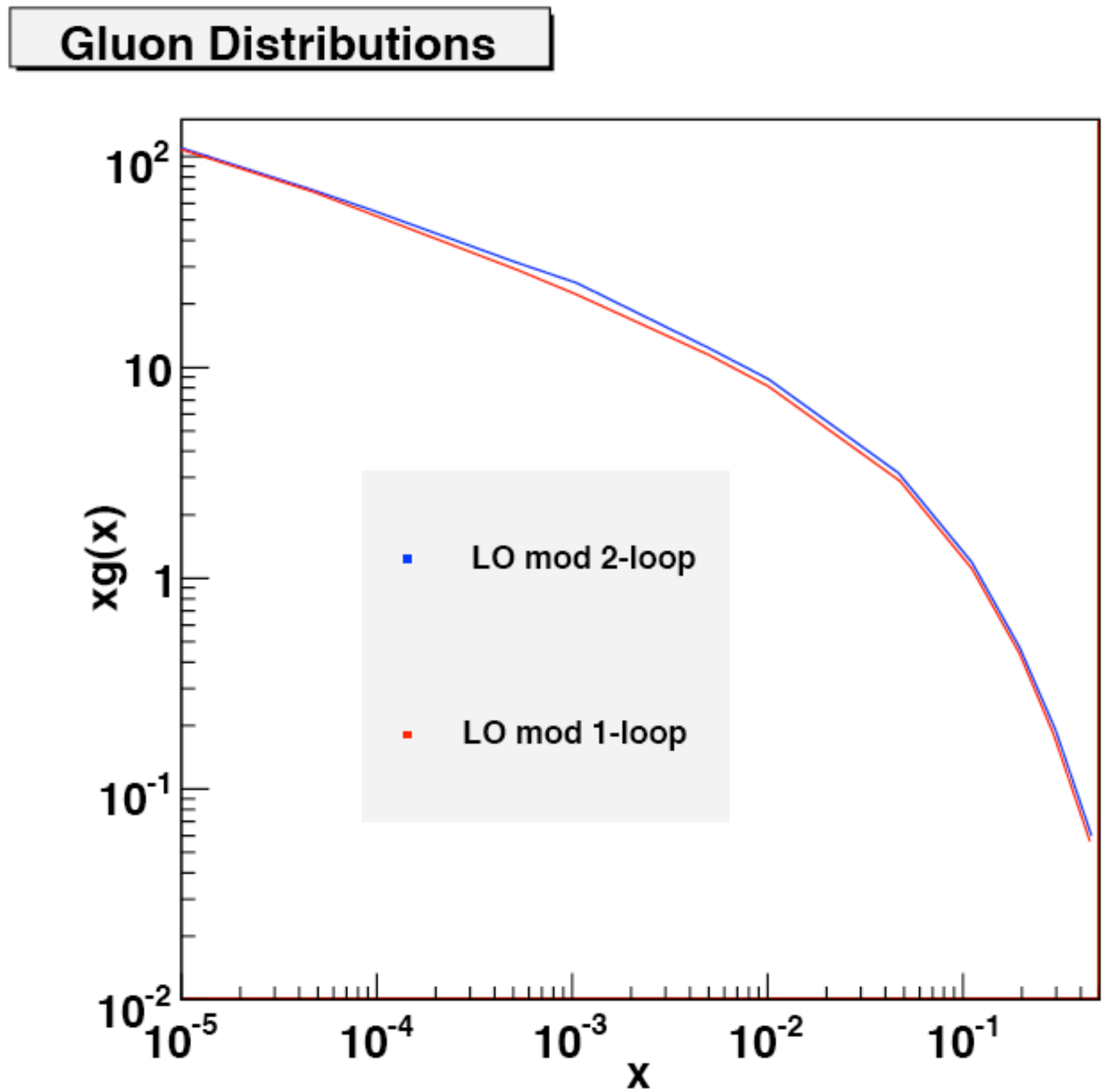
Only mod 2-loop and mrst

- similar over a wide x range
- mrst is larger at small x; CTEQ at high x



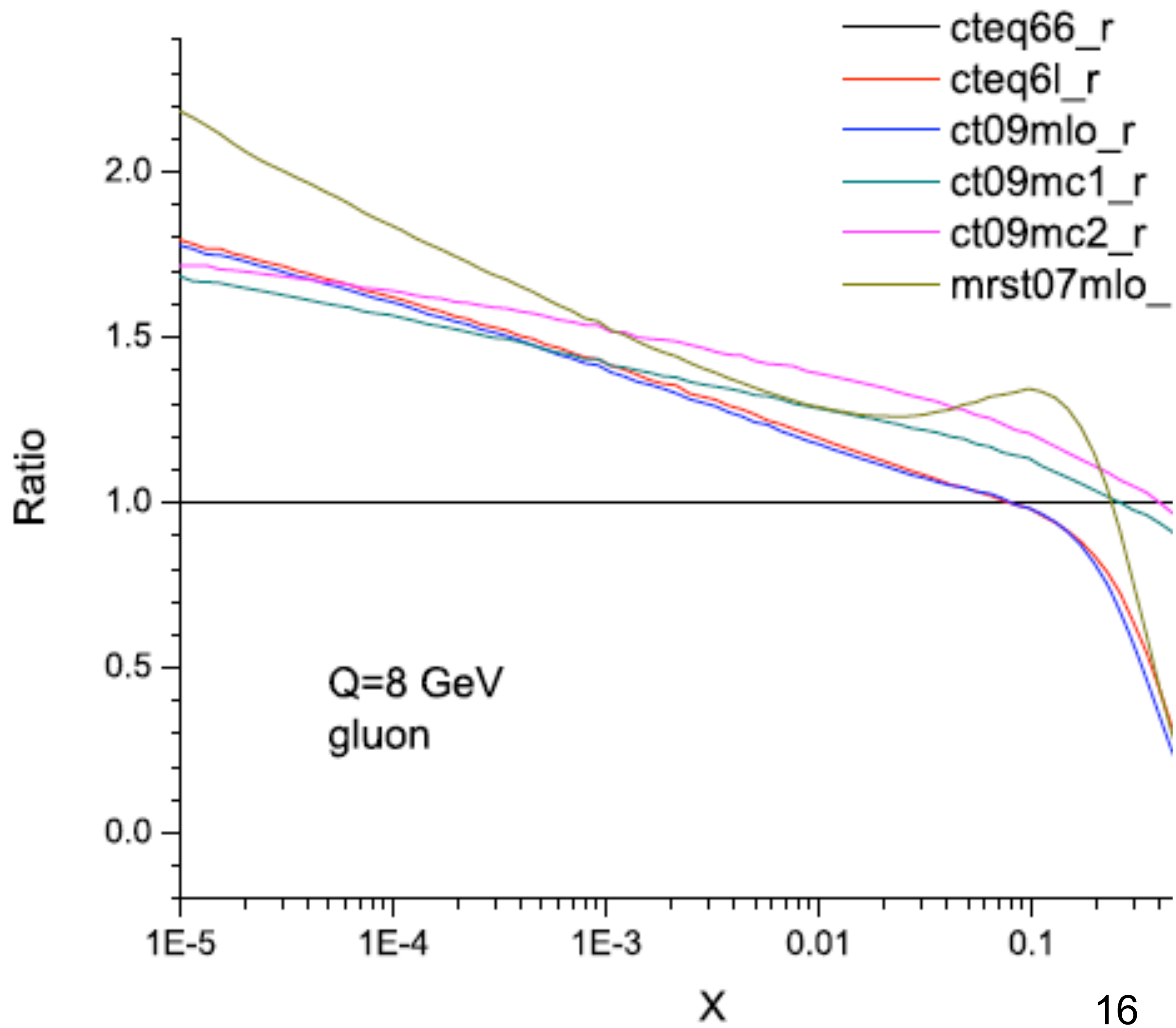
Compare 1-loop and 2-loop mod LO PDFs

- 2-loop slightly higher than 1-loop over most of x range
  - larger α_s for 1-loop version enables easier normalization for pseudo-data
- That's why the violation of the momentum sum rule is larger for the 2-loop



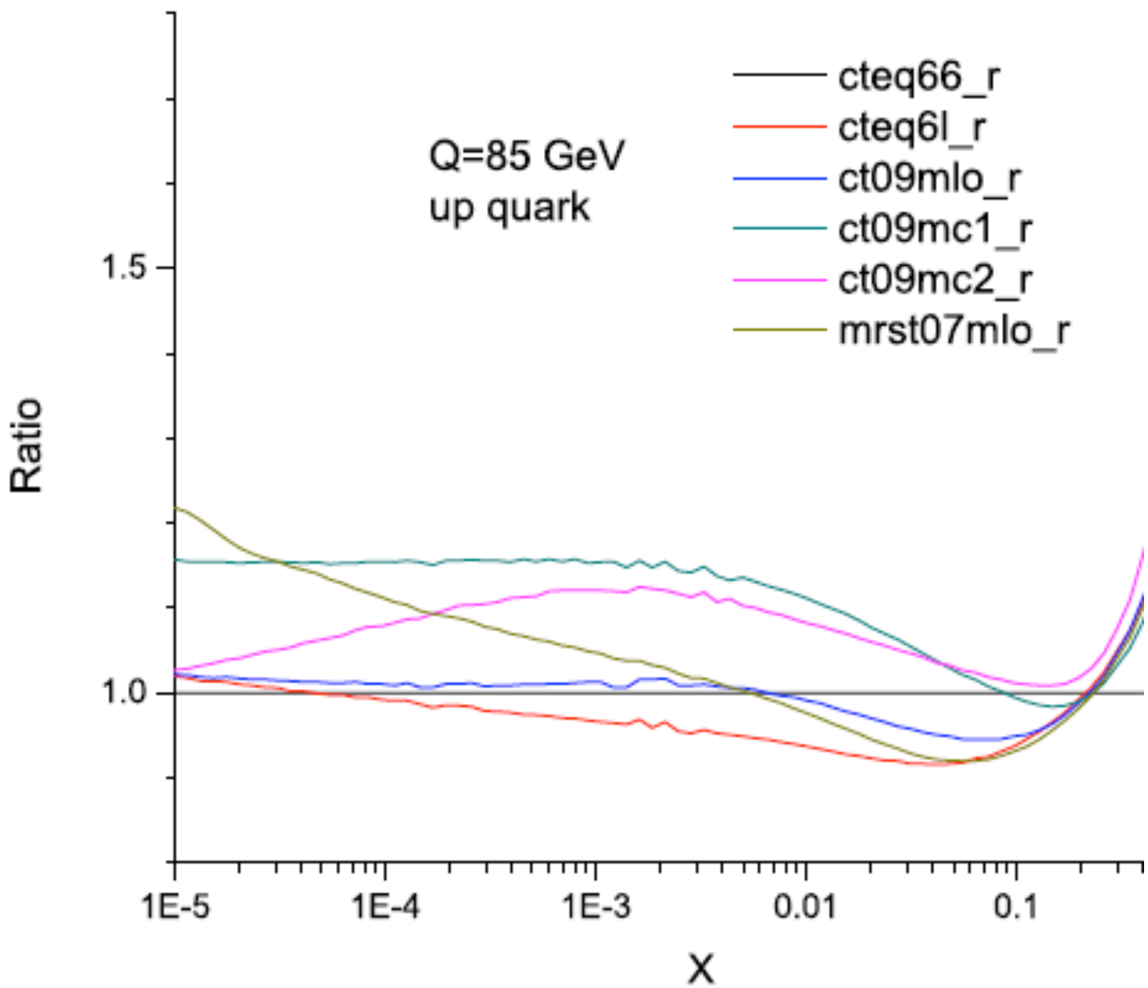
Ratio plot:comparison to CTEQ6.6

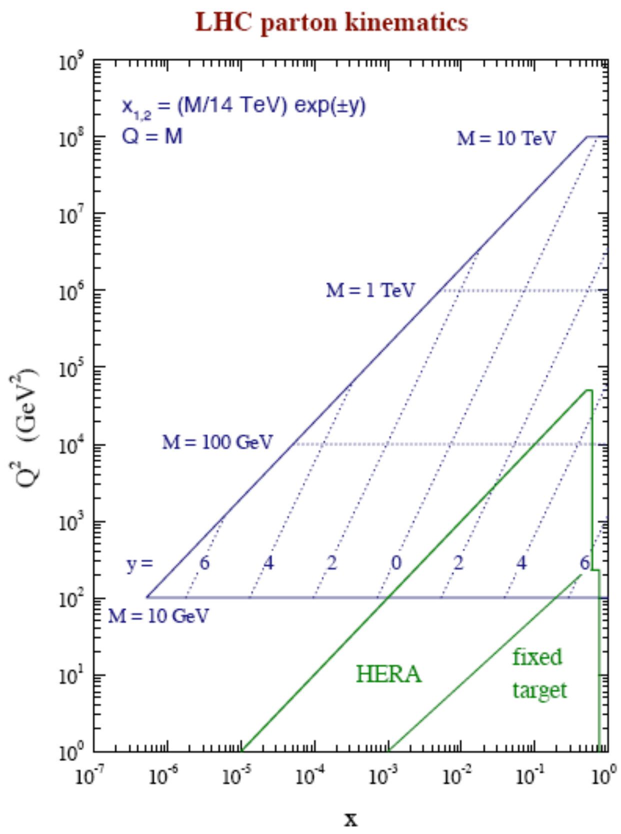
- CTEQ mod LO PDFs higher than CTEQ6.6 up to x ~0.3-0.4



Up quarks at Q=85 GeV

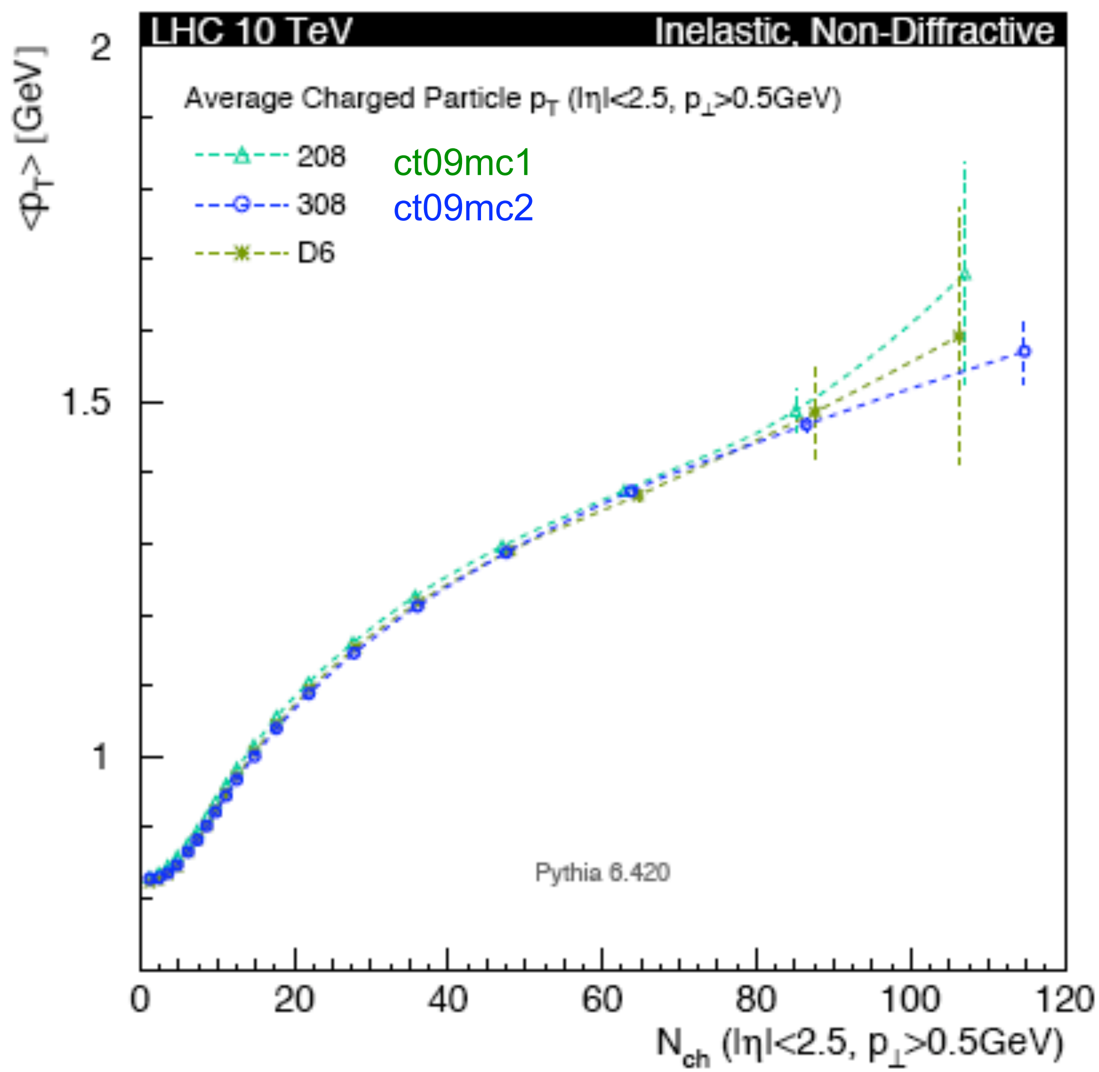
- Larger quark distributions in 1E-04 to 1E-01 lead to higher W/Z cross sections





UE tuning for the LHC

- Working on UE tunes for the new PDFs (S. Mrenna)
- To the right is a comparison to Pythia reference tune D6



Summary

- Conventional ways of generating events with LO parton shower Monte Carlos have drawbacks from the point of view of parton distribution functions
- CTEQ mod LO PDFs reduce some of those drawbacks and can be considered as an additional tool for the LHC, leading to better shapes and normalizations with some LHC benchmark cross sections
  - I still also like the option in Pythia8 to be able to use a LO PDF for the UE and parton showering and a NLO PDF for the matrix element evaluation
- Paper almost complete; the two PDFs discussed here will be called
  - ct09mc1: 1-loop
  - ct09mc2: 2-loop
  - working on UE tune(s) and mini-jet implications for the LHC for these two PDFs

In memoriam

- This work was made possible by the insight and inspiration of our late colleague Wu Ki Tung