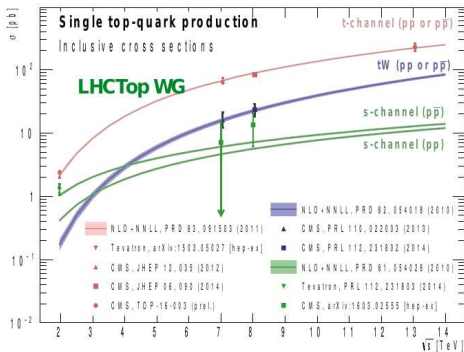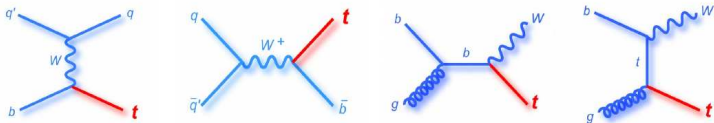# CTEQ-TEA:
updates and relevance for single top

Tie-Jiun Hou
for the CTEQ-TEA collaboration

November 29, 2018 at Oviedo.
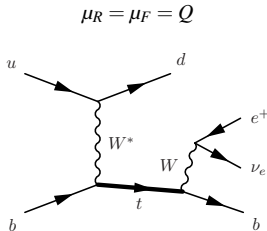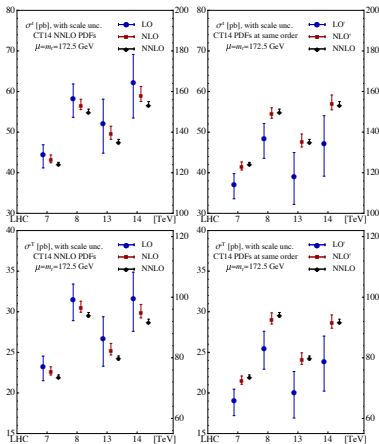5th CMS Single Top Workshop

Single top-quark production

Top quark can be produced singly at LHC via electroweak interactions, including t-channel, s-channel, and associated production

- ⭐ probing EW coupling (Vtb)
- ⭐ polarized top-quark production
- ⭐ test of heavy-quark scheme
- ⭐ constraining parton distributions
- ⭐ measuring top-quark mass
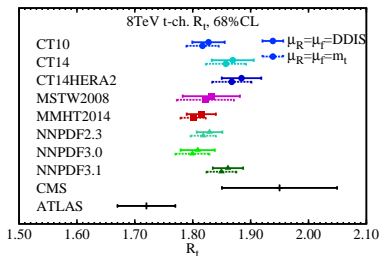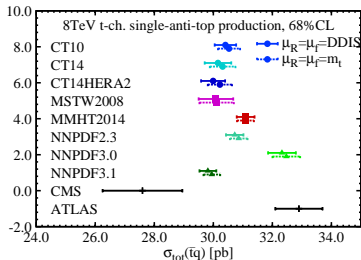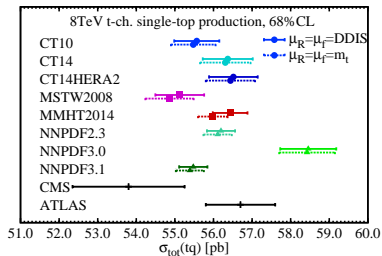- ⭐ sensitive to various new physics

QCD correction for T-ch. single top(anti-top)

$$\mu_R = \mu_F = Q$$

$$\mu_R = \mu_F = \sqrt{Q^2 + m_t^2}$$

• Double DIS scale.

$$\sigma(t) = \int [f(x_1, \mu_F) \times f(x_2, \mu_F)]_{NNLO} \times \hat{\sigma}(t)_{NNLO}$$

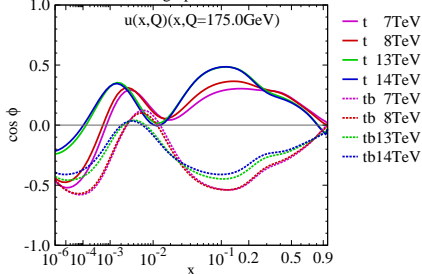$$\cong \int [f(x_1, \mu_F) \times f(x_2, \mu_F)]_{NLO} \times \hat{\sigma}(t)_{NLO}$$

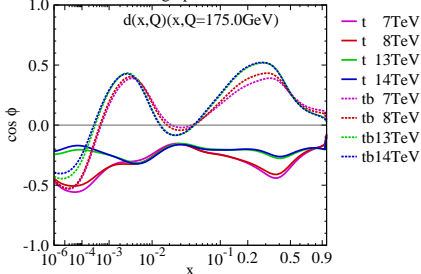- ALTAS and CMS uncertainty in the figures are statistic uncertainty.

CMS : 1403.7366, ATLAS: 1702.02859
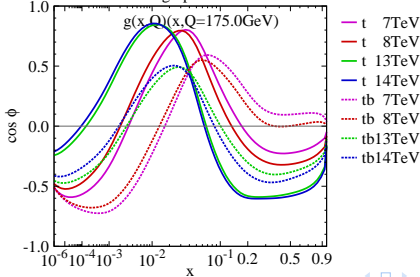
Correlation between t-ch. single top(anti-top) and PDFs
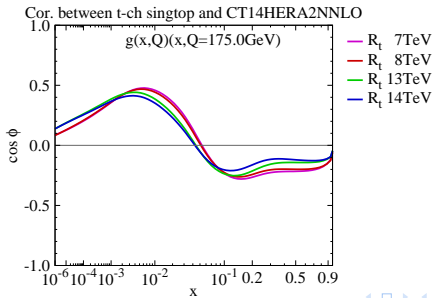
Correlation between R_t and PDFs

ePump - Error PDF Updating Method Package
Hessian Updating

- Updated Chi-square function :

$$\Delta\chi^2(Z) = \Delta\chi^2_{old}(Z) + (X_i^E - X_i(Z))C_{ij}^{-1}(X_j^E - X_j(Z))$$

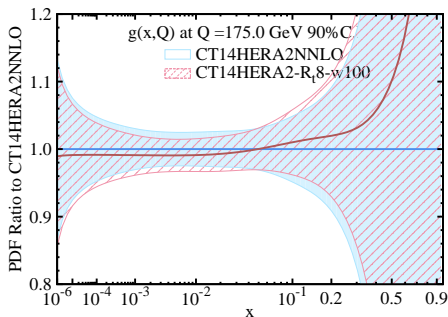Where $\Delta\chi^2_{old}(Z) = T^2 Z^2$.

- Minimize to find new best fit:

$$Z_{new}^2 = (1+M)^{-1}A \text{ with } A^\alpha = \frac{1}{T^2}(X_i^E - X_i(0))C_{ij}^{-1}\Delta X_j^\alpha, \ M^{\alpha\beta} = \frac{1}{T^2}\Delta X_i^\alpha C_{ij}^{-1}\Delta X_j^\beta$$

- New best-fit PDF and new error PDF.

$$f_{new}^0 = f^0 + \Delta f \cdot Z, \ f^{\pm(r)} = f_{new}^0 \pm \frac{1}{\sqrt{1+\lambda^{(r)}}}\Delta f \cdot U^{(r)}$$

where $\lambda^{(r)}$ and $U^{(r)}$ are the eigenvalues and eigenvectors of matrix M.

[Carl Schmidt et al., arXiv:1806.07950]

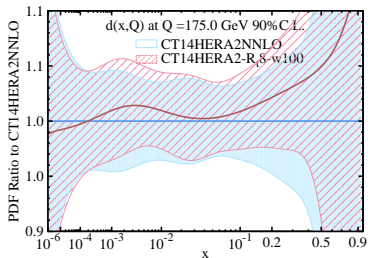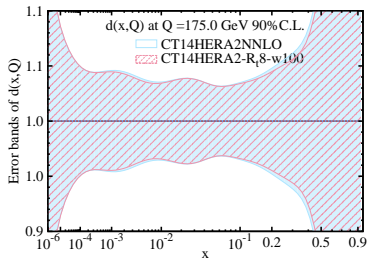- QCD scale uncertainty is not concerned in the PDF update.
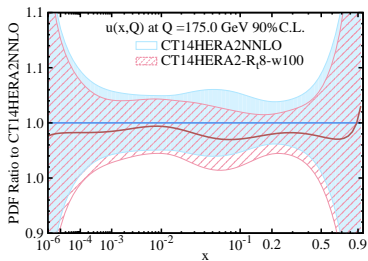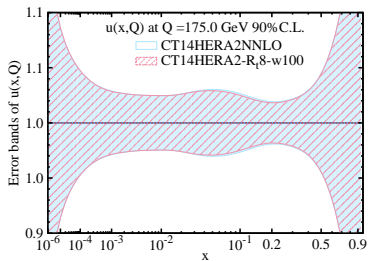
- Larger luminosity for R_t measurement is needed to compete with 3000 data points in the pool.

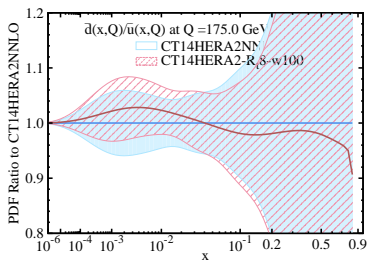- Hight luminosity measurement is estimated by increasing weight with the assumption of the same central measurements.

$$\chi^2 = W \frac{(D-T)^2}{\varepsilon^2} \cong WL\sigma(D-T)^2$$

- T-ch. single top(anti-top) total cross section gives similar impact to PDFs as R_t.

Figure showing u(x,Q) and d(x,Q) at Q = 175.0 GeV 90% C.L., comparing CT14HERA2NNLO and CT14HERA2-R$_t$8-w100 error bands and PDF ratios to CT14HERA2NNLO.

- With weight 100.0, little reduction in uncertainty on u-quark and d-quark respect to the most correlated Bjorken-x region.
- Central PDF is relatively sensitive to t-ch. single top(anti-top) production with weight 100.0.

Top-left plot: d(x,Q)/u(x,Q) at Q =175.0 GeV 90%C.I.
- CT14HERA2NNLO
- CT14HERA2-R_t8-w100

y-axis: Error bands of d(x,Q)/u(x,Q)
x-axis: x

Top-right plot: d(x,Q)/u(x,Q) at Q =175.0 GeV 90%C.I.
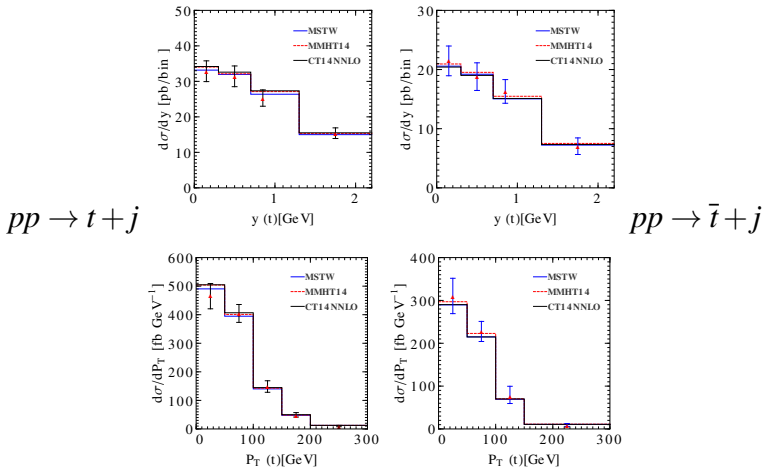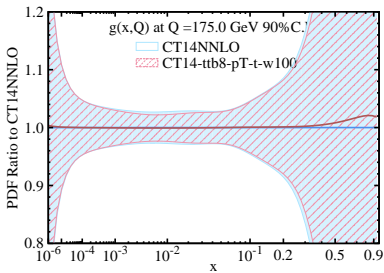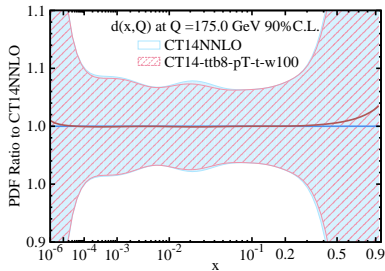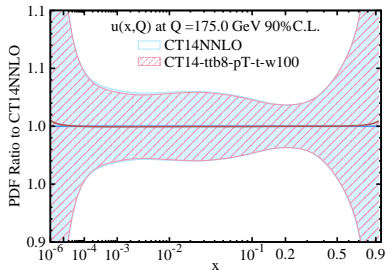- CT14HERA2NNLO
- CT14HERA2-R_t8-w100

y-axis: PDF Ratio to CT14HERA2NNLO
x-axis: x

Bottom-left plot: $\bar{d}$(x,Q)/$\bar{u}$(x,Q) at Q =175.0 GeV
- CT14HERA2NN
- CT14HERA2-R_t8-w100

y-axis: Error bands of $\bar{d}$(x,Q)/$\bar{u}$(x,Q)
x-axis: x

Bottom-right plot: $\bar{d}$(x,Q)/$\bar{u}$(x,Q) at Q =175.0 GeV
- CT14HERA2NN
- CT14HERA2-R_t8-w100

y-axis: PDF Ratio to CT14HERA2NNLO
x-axis: x

- The d/u and $\bar{d}/\bar{u}$ is relative sensitive to the t-ch. single top and anti-top or R_t.
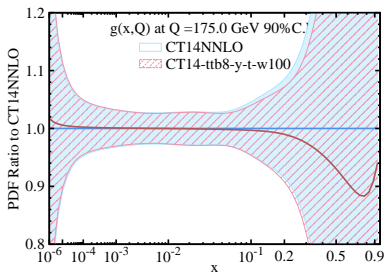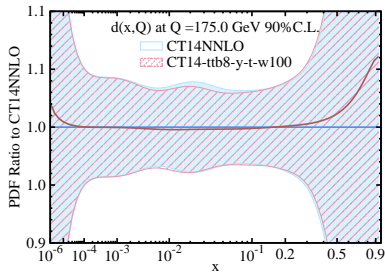
T-ch. Differential Xsec in pT(t) and y(t)
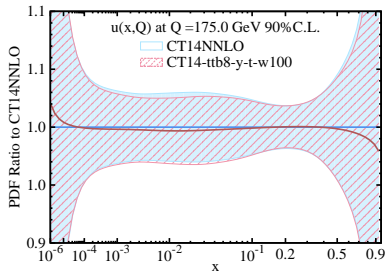

$pp \to t+j$

$pp \to \bar{t}+j$

- MSTW give a better prediction for the p_T distribution. While the uncertainty is large ($\sim 10\%$)

pT(t) Distribution

y(t) Distribution

- Compare to

Summary

- ATLAS and CMS 8TeV t-ch. single top (anti-top) and R_t data are included for updating PDFs by using ePump with NNLO calculation.

- With the estimation of large luminosity and assumption of the same ceter value of single top measurement, R_t has potential to have impact on central PDFs and mild impact to PDF uncertainty.

- Further studies are on going....