(Preliminary) Studies on Top Quark Pair Production in Association With Higgs and Z Bosons

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In Collaboration With S. Frixione, V. Hirschi, M. Mangano, D. Pagani and M. Zaro

2014.11.05

SELF-INTRODUCTION

- I am coming from China. I received my Ph.D. from Peking University, Beijing, China in June 2014.

- During 2012-2013, I spent one year at CERN as a visitor supported by ERC grant LHCtheory (hosted by Michelangelo, Stefano, Fabio and Roberto) and started to join in MadGraph5_aMC@NLO collaboration.

- My main interests rely on two fields:

- QCD and heavy quarkonium production (my main field during my Ph.D.). The aim is to understand heavy quarkonium production mechanism and probe the dynamics in the QCD non-perturbative regime.

- Automatic NLO (e.g. QCD and/or EW corrections) computations in SM and BSM (my main stuff at CERN, one BSM example see Benjamin's talk). The aim is realizing any quantum corrections in any QFT (include EFT).

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Numerical values

The best-fit results for independent signal strengths corresponding to the four main production processes, ggH, VBF, VH, and ttH; the expected sensitivities and observed significances with respect to background-only hypothesis ($\mu = 0$), and the pull of the observation with respect to the SM hypothesis ($\mu = 1$). These results assume that the relative values of the branching fractions are those predicted by the SM.

Parameter	Best fit result (68% CL) for full combination	Observed significance (σ)	Expected sensitivity (σ)	Pull to SM hypothesis (σ)
μ_{ggH}	$0.85^{+0.19}_{-0.17}$	6.5	7.5	-0.8
μ_{VBF}	$1.15^{+0.37}_{-0.35}$	3.6	3.3	0.4
μ_{VH}	$1.00^{+0.40}_{-0.40}$	2.7	2.7	0.0
μ_{ttH}	$2.93^{+1.04}_{-0.97}$	3.5	1.2	2.1

CMS twiki: https://twiki.cern.ch/twiki/bin/view/CMSPublic/Hig14009TWiki

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$$\sigma_{t\bar{t}Z} = 200^{+80}_{-70}(stat)^{+40}_{-30}(syst)fb$$

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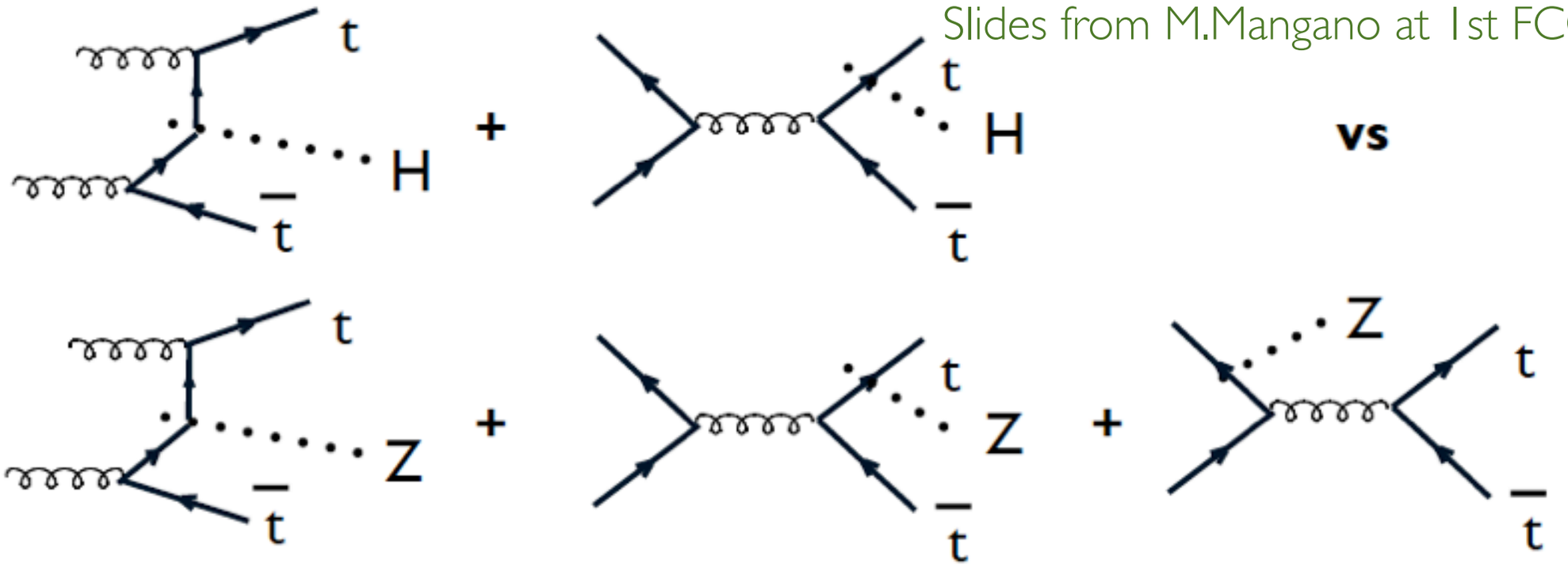
It is time to harvest on those 'rare' processes at the LHC Run II phase

pp→tt H vs pp→tt Z

Slides from M.Mangano at 1st FCC-hh Workshop



To the extent that the qqbar → tt Z/H contributions are subdominant:

- **Identical production dynamics:**

  - **o correlated QCD corrections, correlated scale dependence**
  - **o correlated α_S systematics**

- **$m_Z \sim m_H \Rightarrow$ almost identical kinematic boundaries:**

  - **o correlated PDF systematics**
  - **o correlated m_{top} systematics**

For a given y_{top}, we expect σ(ttH)/σ(ttZ) to be predicted with great precision

At 100 TeV, gg→tt X is indeed dominant ....

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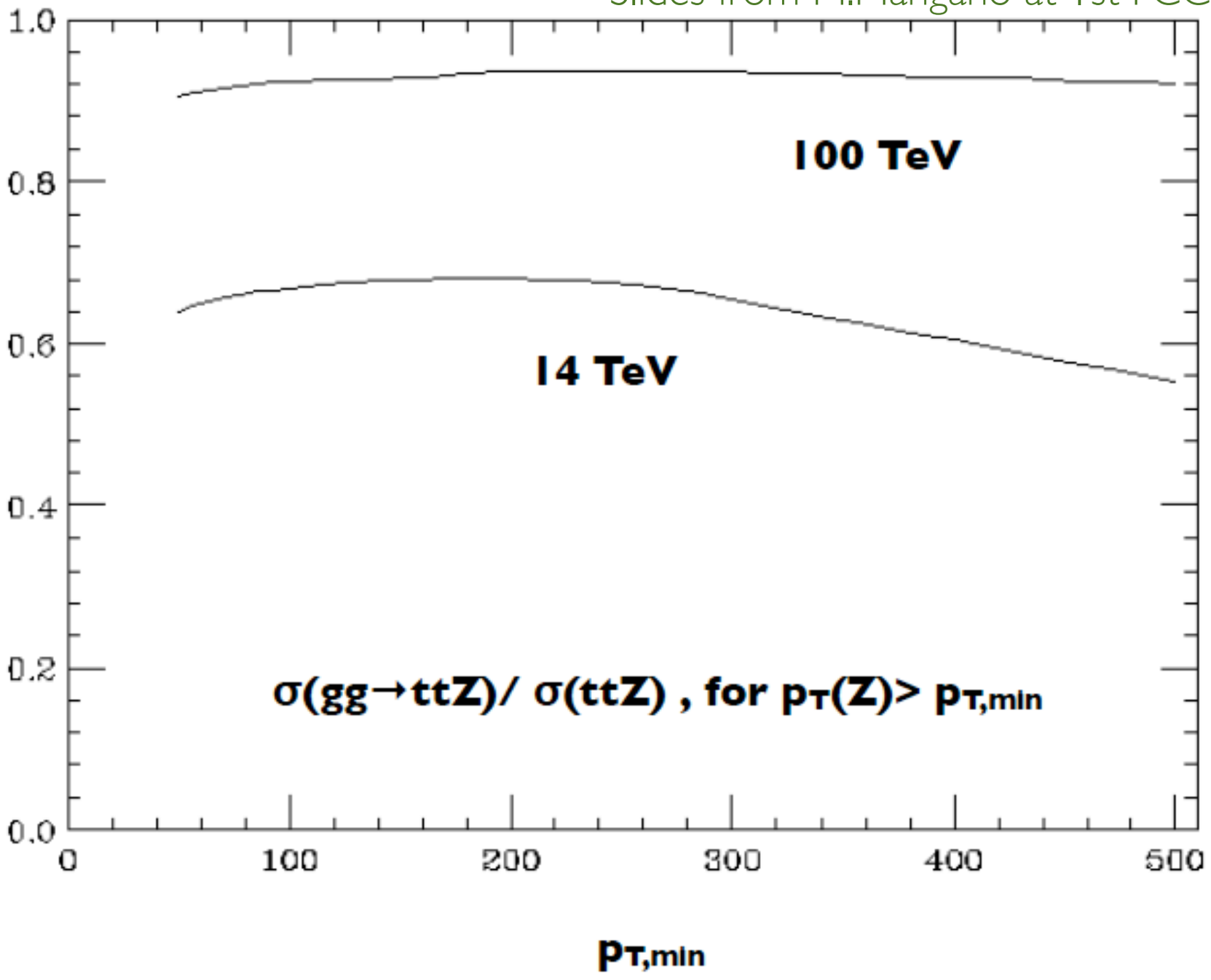

NB: At lower p_T values, gg fraction is slightly larger for ttZ than for ttH, since $m_Z < m_H$

MSTW2008NLO, $\mu_0 = H_T/2$*, LHC13*

	ttH (pb)	ttZ (pb)	ttH/ttZ
LO	0.367 $[^{+30.0\%}_{-21.5\%}]$Scale $[^{+1.78\%}_{-2.18\%}]$PDF	0.540 $[^{+30.5\%}_{-21.8\%}]$Scale $[^{+1.83\%}_{-2.25\%}]$PDF	0.682 $[^{+0.361\%}_{-0.446\%}]$Scale +PDF
NLO QCD	0.475 $[^{+5.79\%}_{-9.04\%}]$Scale $[^{+2.02\%}_{-2.50\%}]$PDF	0.785 $[^{+9.81\%}_{-11.2\%}]$Scale $[^{+1.93\%}_{-2.39\%}]$PDF	0.606 $[^{+2.46\%}_{-3.66\%}]$Scale +PDF
Weak	-0.00659	-0.0252	0.263

NLO QCD , $\mu_0 = H_T/2$, LHC13

	ttH (pb)	ttZ (pb)	ttH/ttZ
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CT10	0.450 $[^{+5.70\%}_{-8.80\%}]_{\text{Scale}}$ $[^{+6.00\%}_{-5.34\%}]_{\text{PDF}}$	0.741 $[^{+9.50\%}_{-10.9\%}]_{\text{Scale}}$ $[^{+5.91\%}_{-5.29\%}]_{\text{PDF}}$	0.607 $[^{+2.34\%}_{-3.47\%}]_{\text{Scale}}$ $[^{+0.672\%}_{-0.675\%}]_{\text{PDF}}$
NNPDF	0.470 $[^{+5.26\%}_{-8.58\%}]_{\text{Scale}}$ $[^{+2.22\%}_{-2.22\%}]_{\text{PDF}}$	0.771 $[^{+8.97\%}_{-10.6\%}]_{\text{Scale}}$ $[^{+2.16\%}_{-2.16\%}]_{\text{PDF}}$	0.609 $[^{+2.23\%}_{-3.41\%}]_{\text{Scale}}$ $[^{+0.205\%}_{-0.205\%}]_{\text{PDF}}$

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5%-6%

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0.5%

MSTW2008NLO, $\mu_0 = H_T/2$ *, NLO QCD*

	ttH (pb)	ttZ (pb)	ttH/ttZ
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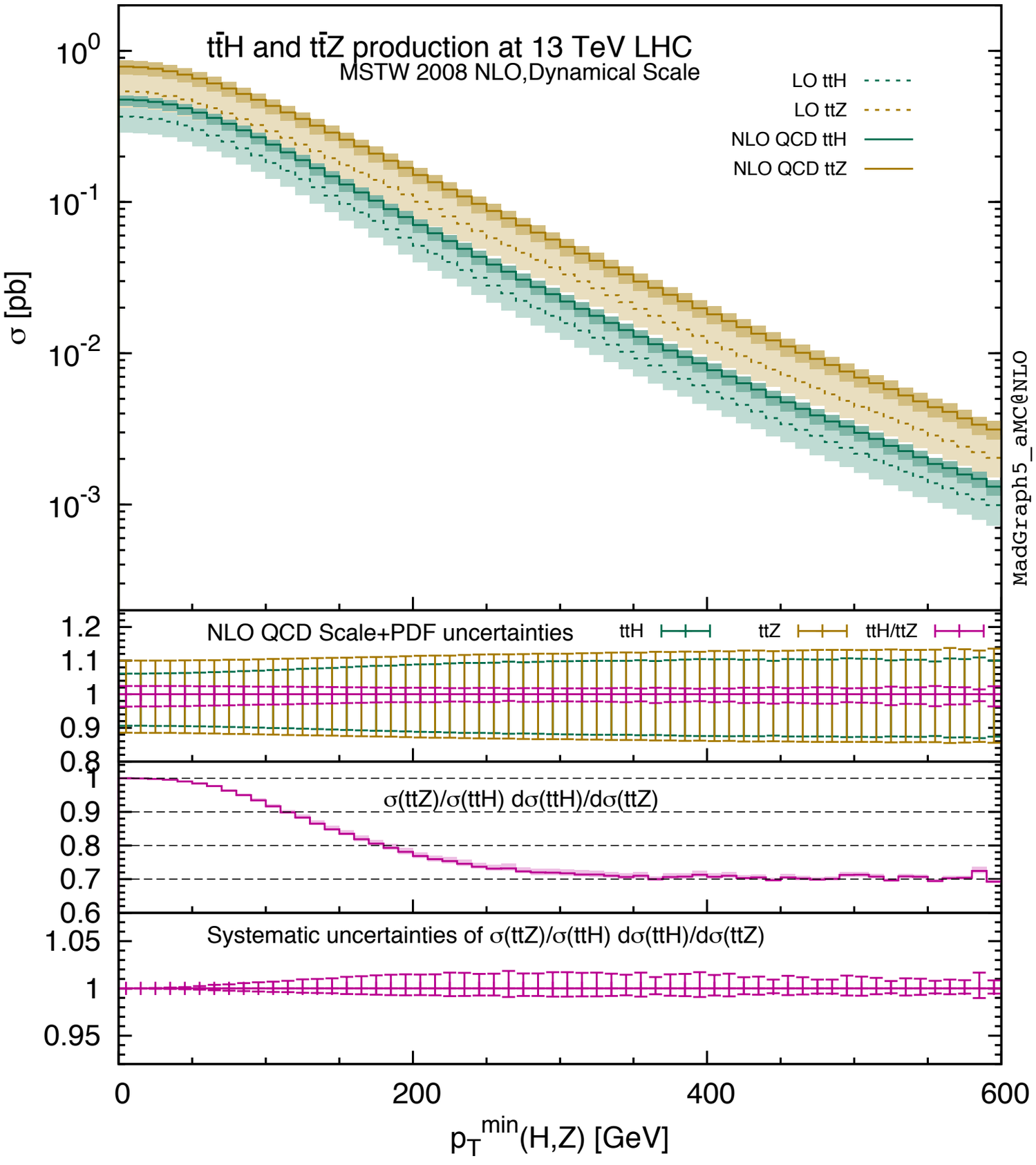
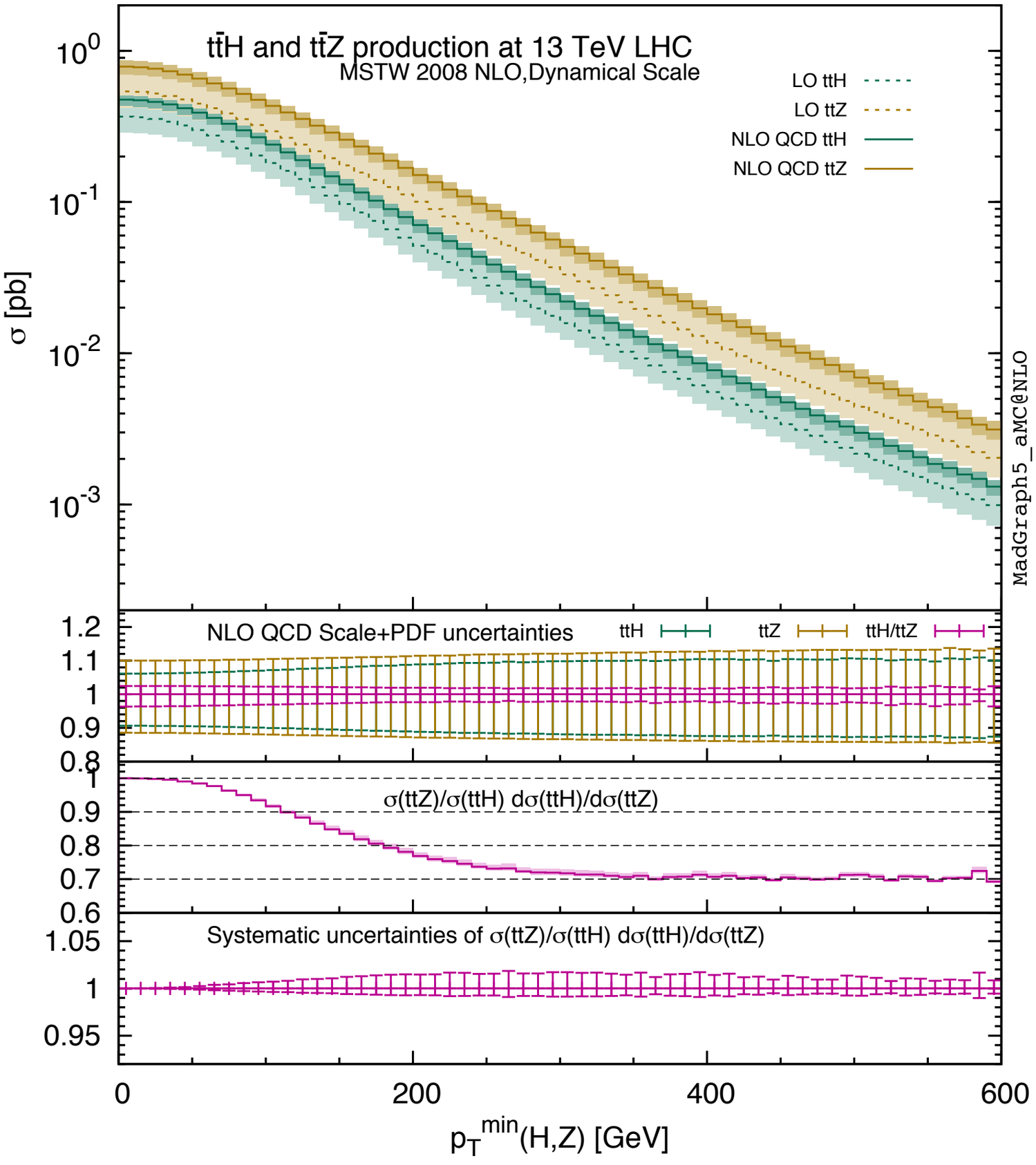
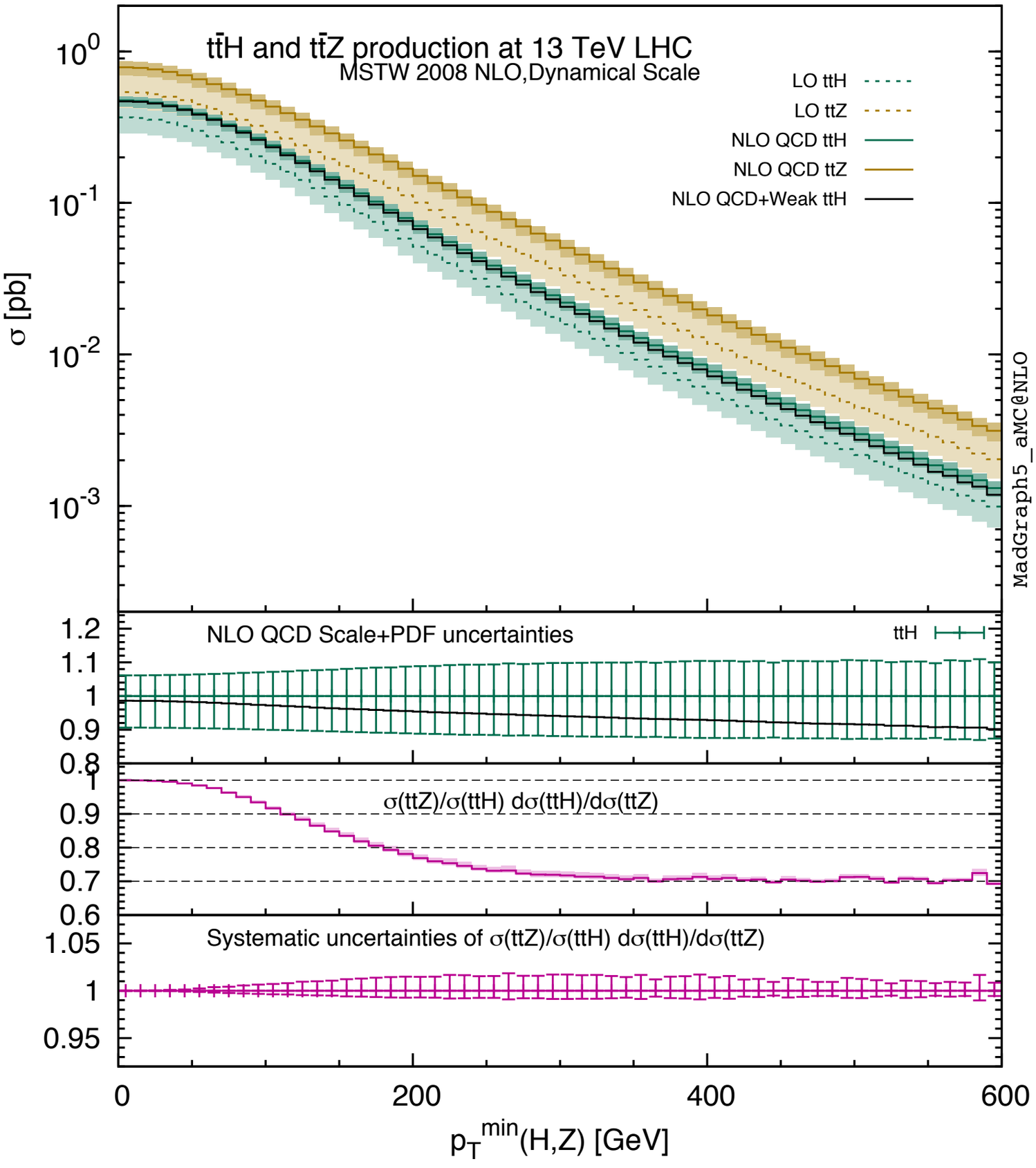
100 TeV	33.9 $[^{+7.06\%}_{-8.29\%}]$Scale $[^{+0.941\%}_{-1.26\%}]$PDF	57.9 $[^{+8.93\%}_{-9.46\%}]$Scale $[^{+0.901\%}_{-1.20\%}]$PDF	0.585 $[^{+1.29\%}_{-2.02\%}]$Scale $[^{+0.0526\%}_{-0.0758\%}]$PDF


tt̄H and tt̄Z production at 13 TeV LHC
MSTW 2008 NLO,Dynamical Scale
LO ttH
LO ttZ
NLO QCD ttH
NLO QCD ttZ
σ [pb]
MadGraph5_aMC@NLO
NLO QCD Scale+PDF uncertainties
ttH
ttZ
ttH/ttZ
σ(ttZ)/σ(ttH) dσ(ttH)/dσ(ttZ)
Systematic uncertainties of σ(ttZ)/σ(ttH) dσ(ttH)/dσ(ttZ)
p_T^min(H,Z) [GeV]



- QCD corrections reduce theoretical uncer. a lot, while systematical uncer. reduce further by taking the ratio.



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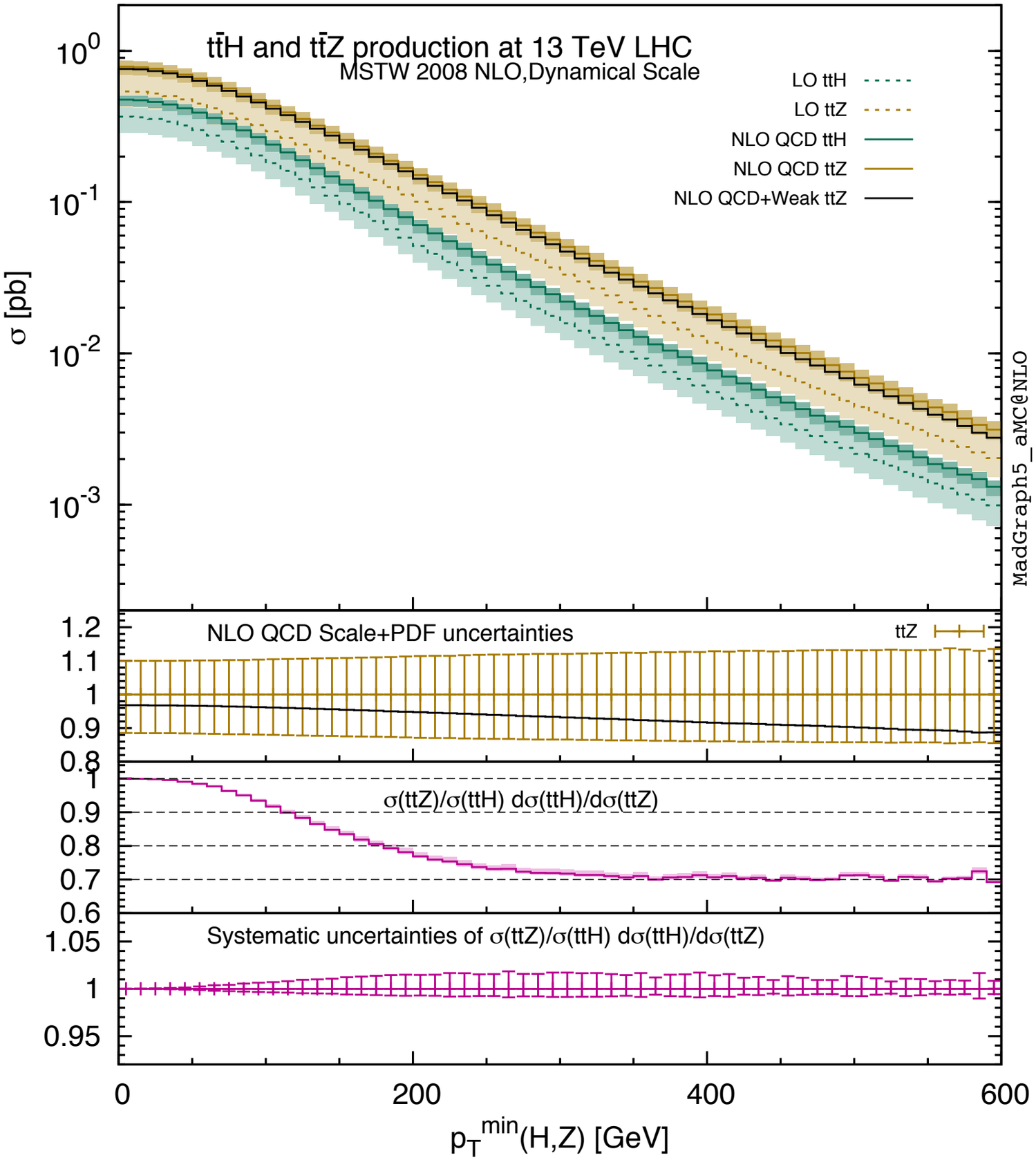

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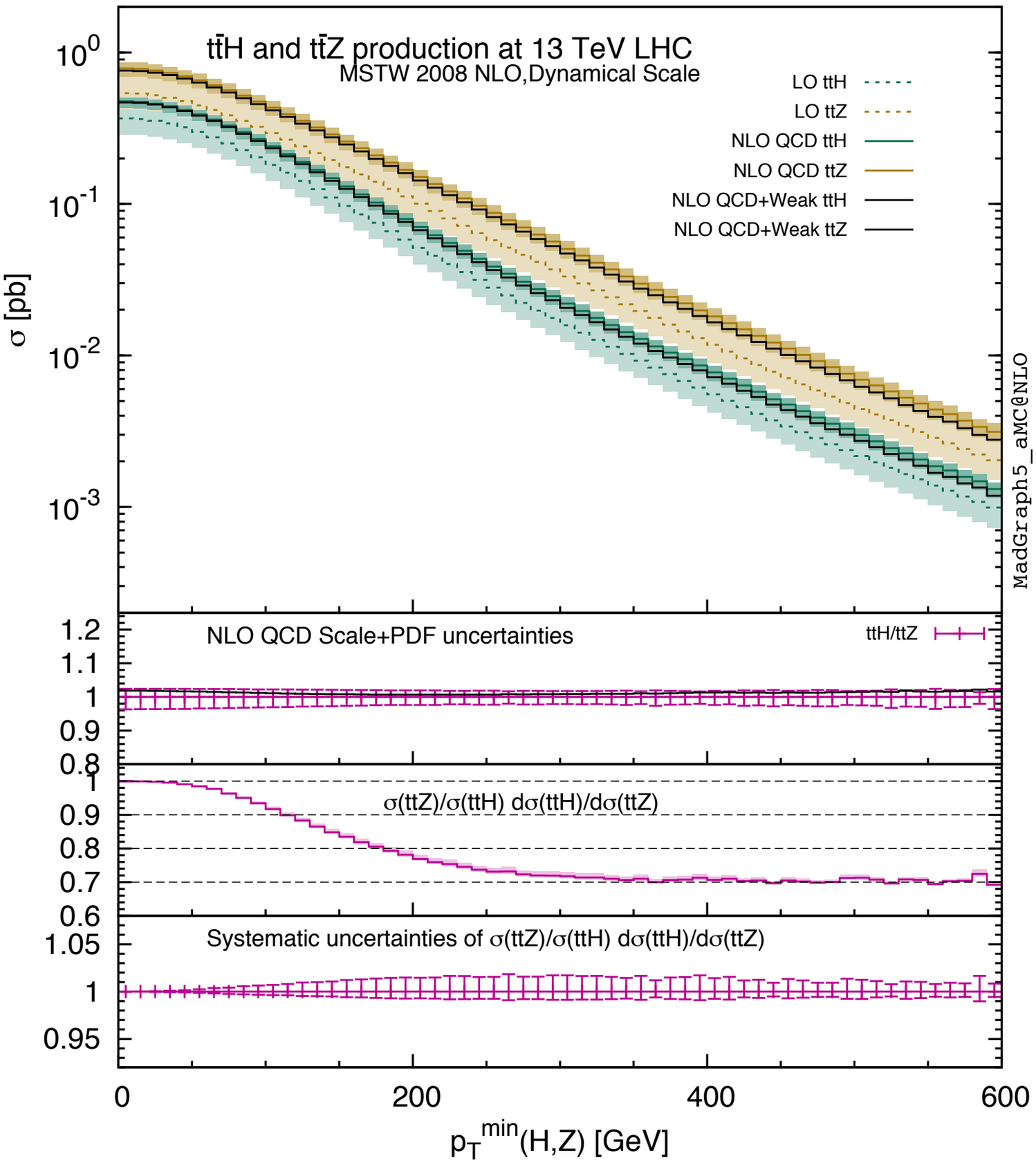
- Weak corrections are only important (~system. uncer.) in the boost region for ttH as well as ttZ.



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TO DO ...

- Two EW schemes: alpha(MZ), Gmu
- Other scale choice: e.g. fixed scale m(t)+m(H,Z)/2 (in Higgs XS WG arXiv: 1101.0593)
- Systematic dependence on parameters: m(H), m(t), alphas(MZ) ...

- Repeat for 100 TeV, where the systematics should be smaller
- Introduce some BR's, some reasonable cuts, and estimate event rates and statistical precision vs luminosity
- In the future: parton shower ?