ttH/ttZ as a precision probe of the top Yukawa coupling

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with input from R.Frederix

At 14 TeV σ(ttH) = 0.6113 pb [$^{+5.9\%}_{-9.3}$] Scale ± 8.9% PDF+αS

At 100 TeV σ(ttH) = 37.9 pb ~ 60 x σ(14 TeV)

Higgs XS WG, arXiv:1101.0593 and twiki page

L(fb^{-1})	Exp.	$\kappa_g \cdot \kappa_Z / \kappa_H$	κ_γ/κ_Z	κ_W/κ_Z	κ_b/κ_Z	κ_τ/κ_Z	κ_Z/κ_g	κ_t/κ_g	κ_μ/κ_Z	$\kappa_{Z\gamma}/\kappa_Z$
300	ATLAS	[3,6]	[5,11]	[4,5]	N/a	[11,13]	[11,12]	[17,18]	[20,22]	[78,78]
	CMS	[4,6]	[5,8]	[4,7]	[8,11]	[6,9]	[6,9]	[13,14]	[22,23]	[40,42]
3000	ATLAS	[2,5]	[2,7]	[2,3]	N/a	[7,10]	[5,6]	[6,7]	[6,9]	[29,30]
	CMS	[2,5]	[2,5]	[2,3]	[3,5]	[2,4]	[3,5]	[6,8]	[7,8]	[12,12]

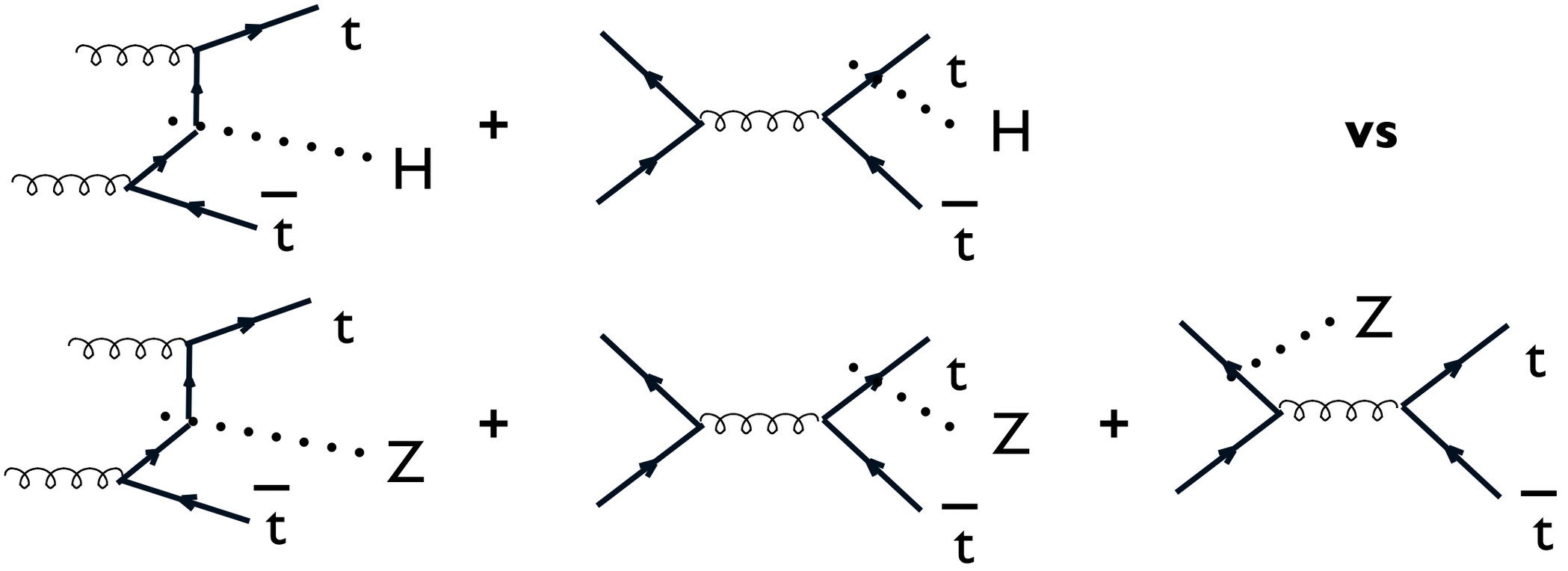
Table 1. Estimated precision on the measurements of ratios of Higgs boson couplings. These values are obtained at √s = 14 TeV using an integrated dataset of 300 fb^{-1} at LHC, and 3000 fb^{-1} at HL-LHC. Numbers in brackets are % uncertainties on couplings for [no theory uncertainty, current theory uncertainty] in the case of ATLAS and for [Scenario2, Scenario1] in the case of CMS.

Note: assume no invisible Higgs decay contributing to the Higgs width

CMS Scenario 2: same systematics as 2012 (TH and EXP)
CMS Scenario 1: half the TH syst, and scale with 1/sqrt(L) the EXP syst

ATLAS Scenario 2: same TH systematics as 2012, EXP syst driven by stats scaled accordingly
ATLAS Scenario 1: same as 2, but TH syst →0

pp→tt H vs pp→tt Z



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

- Identical production dynamics:

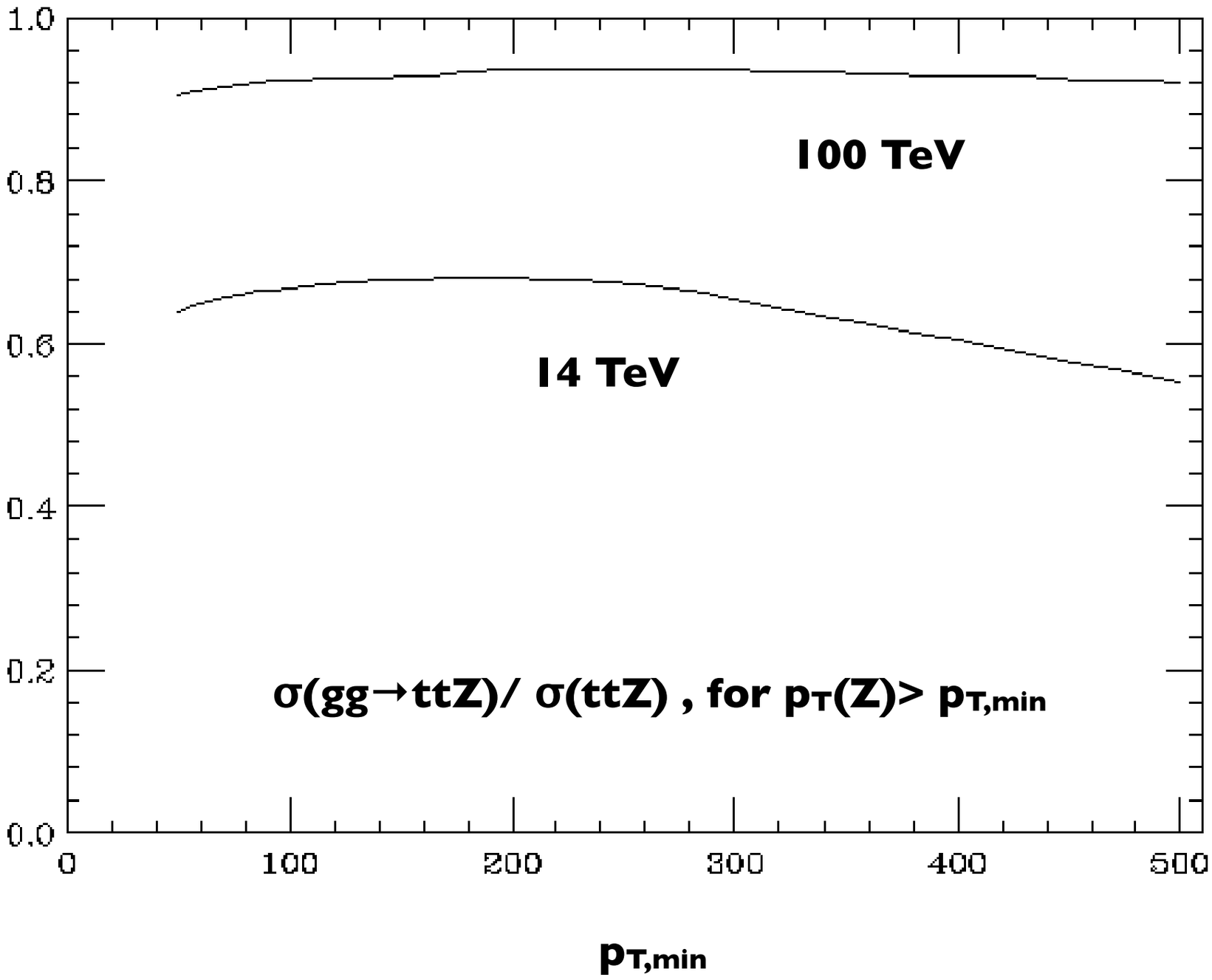
o correlated QCD corrections, correlated scale dependence
o correlated α_S systematics

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

o correlated PDF systematics
o correlated m_{top} systematics

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

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

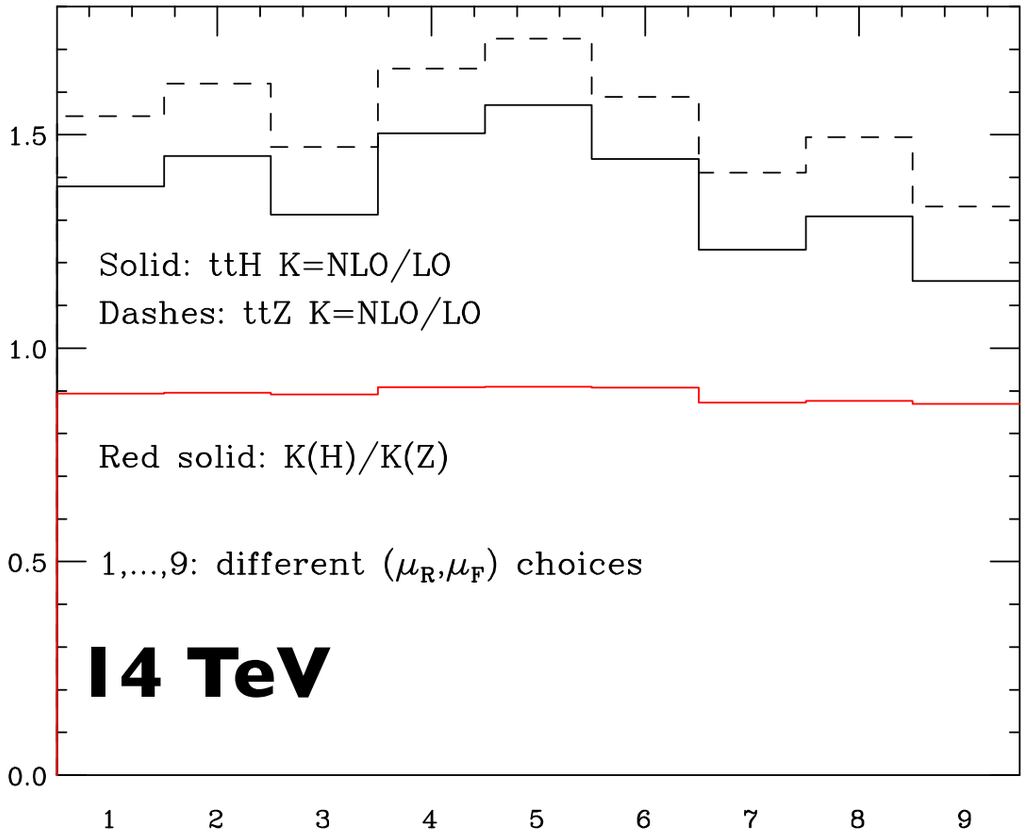


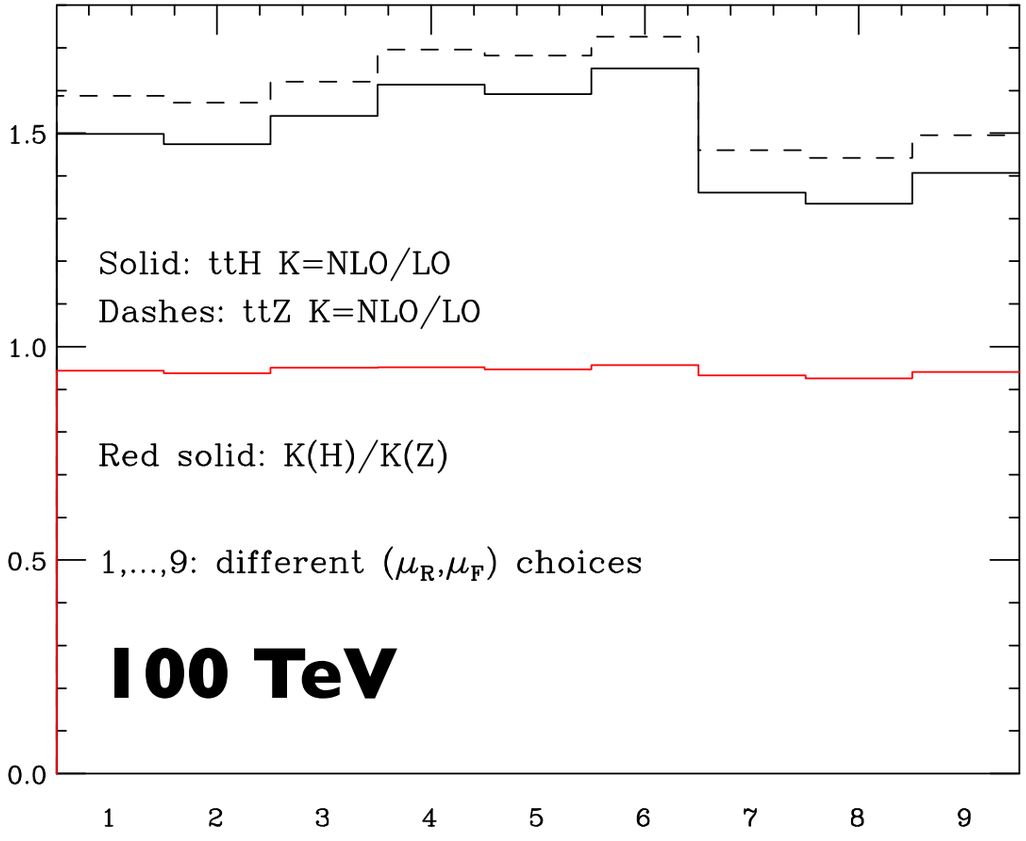
NB: At lower p_T values, gg fraction is slightly larger for ttZ than for ttH, since $m_Z < m_H$

LO scale dependence:

	δσ(ttH)	δσ(ttZ)	**σ(ttH)/σ(ttZ)**	**δ[σ(ttH)/σ(ttZ)]**
14 TeV	± 30%	± 30%	**0.683**	**±0.3%**
100 TeV	± 20%	± 19.5%	**0.626**	**±0.5%**

.... this is misleading, since at LO both σ's go like $\alpha_s^2(\mu)$, which ~cancels in teh ratios. No other explicit μ dependence except PDF. At NLO qg processes appear, with different weight, as well as μ dependence at $O[\alpha_s^3(\mu)]$





NLO scale dependence:

data from R.Frederix

Scan μ_R and μ_F independently, at $\mu_{R,F} = [0.5, 1, 2]\ \mu_0$, with $\mu_0 = m_H+2m_t$

	δσ(ttH)	δσ(ttZ)	**σ(ttH)/σ(ttZ)**	**δ[σ(ttH)/σ(ttZ)]**
14 TeV	± 9.8%	± 12.3%	**0.608**	**±2.6%**
100 TeV	± 9.6%	± 10.8%	**0.589**	**±1.2%**

PDF dependence (CTEQ6.6. only)

data from R.Frederix

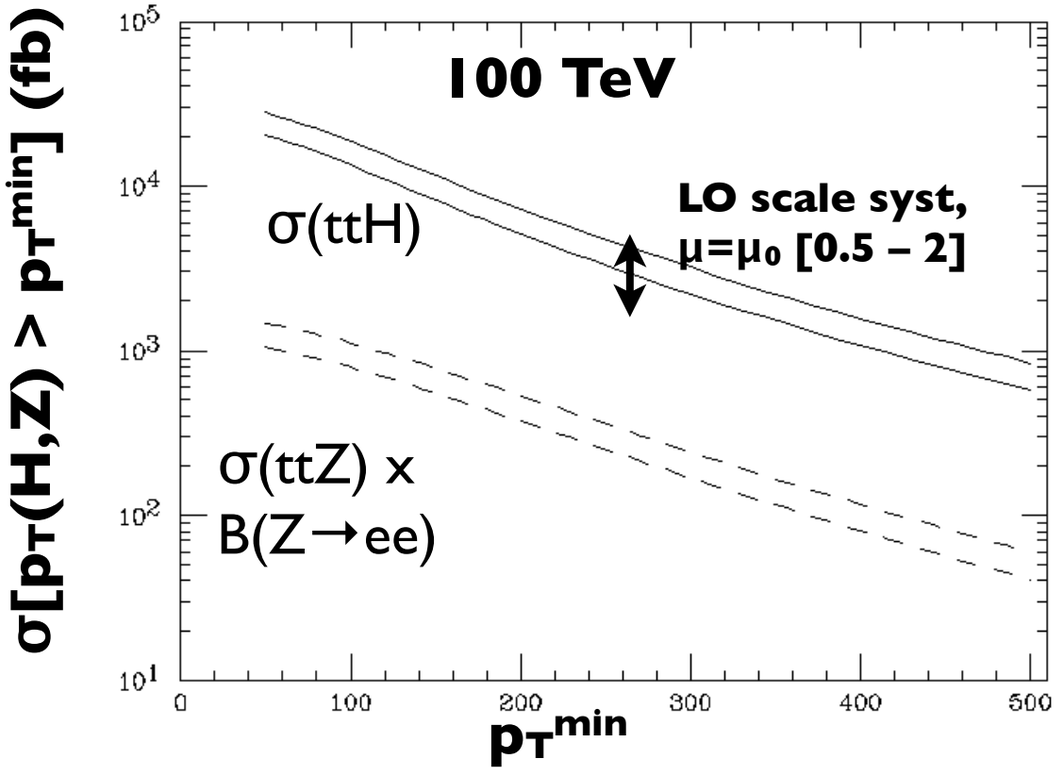
	δσ(ttH)	δσ(ttZ)	**δ[σ(ttH)/σ(ttZ)]**
14 TeV	± 4.8%	± 5.3%	**±0.75%**
100 TeV	± 2.7%	± 2.3%	**±0.48%**

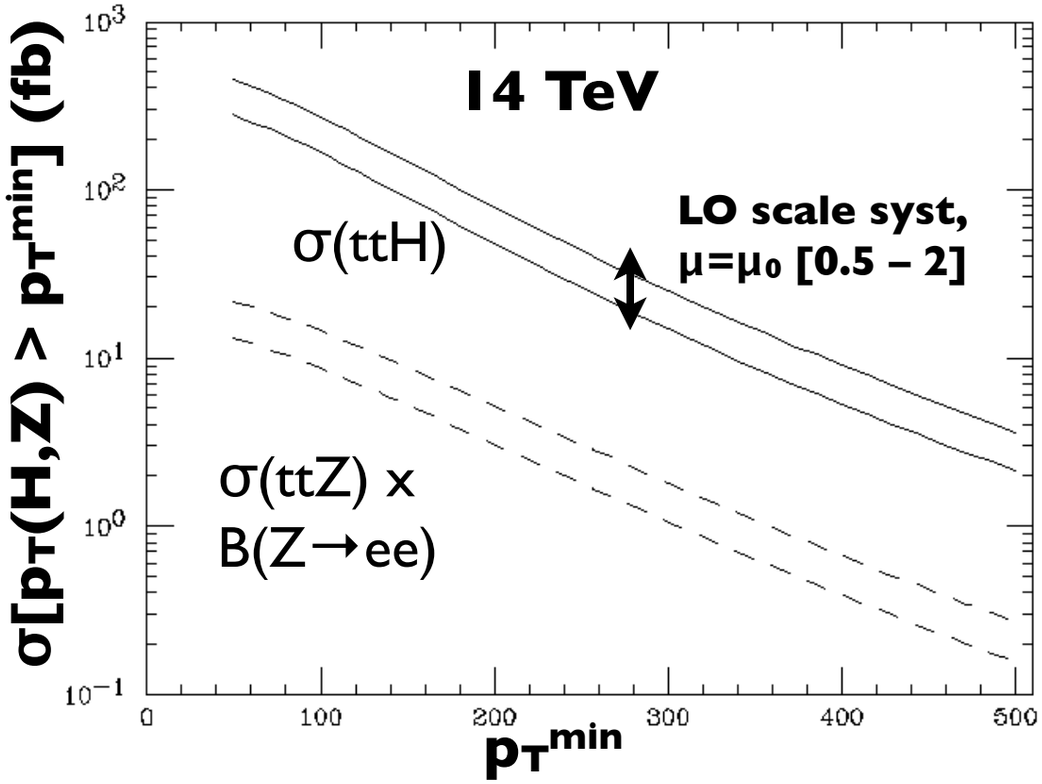
NB Uncertainty bands for x symmetrized around $(x_{min}+x_{max})/2$

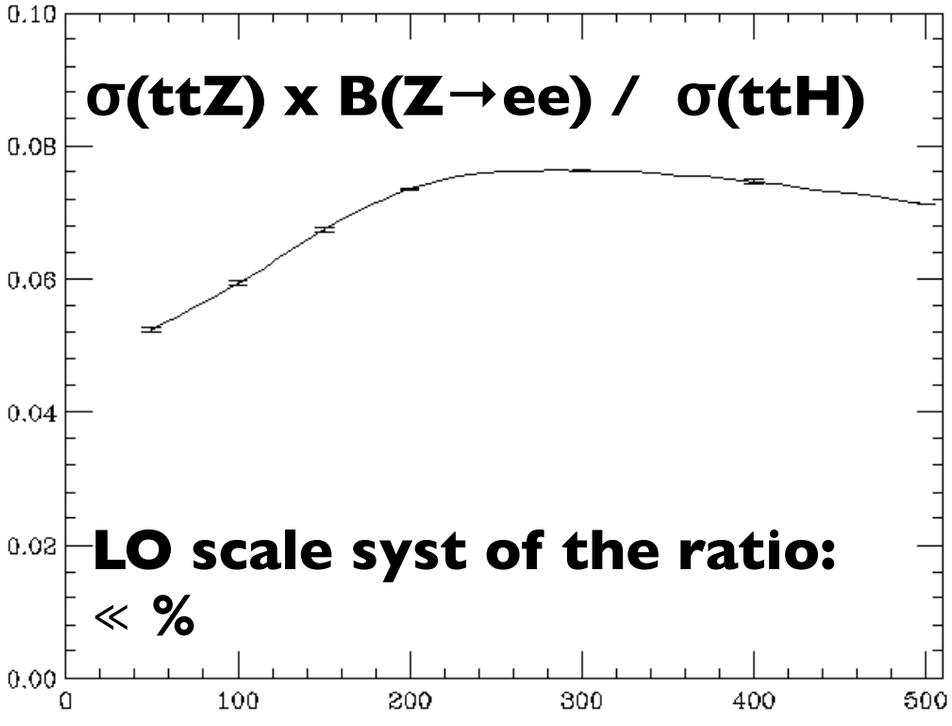
Very mild kinematical bias in the ratio => reduced exptl systematics from analysis cuts

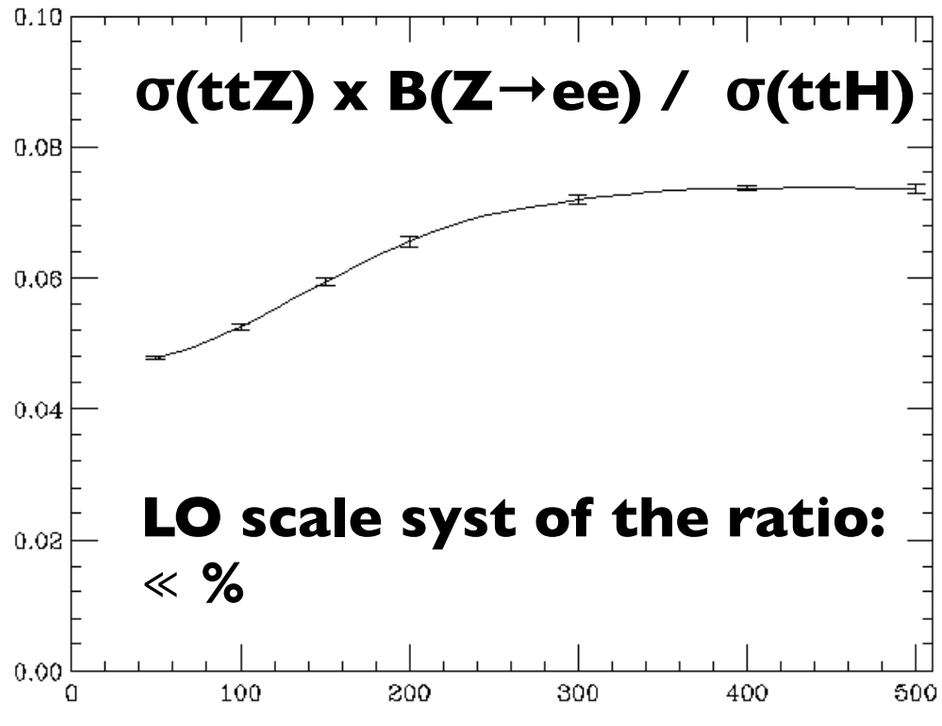
$\mu_0^2 = m_H^2 + \sum_{t,tbar} (m_t^2 + p_{T,t}^2)$

Alpgen









To be done

- Complete scale and PDF systematics study
  - broader range of kinematic choices for the scale
  - full set of recent PDF sets
  - PDF and NLO scale dependence of distributions ($p_{T,H}$, $p_{T,top}$, ...)
- m_H and m_{top} systematics
- Inclusion and impact of EW effects
- A realistic study of experimental prospects (statistics and systematics)