UNIVERSITÄT HEIDELBERG
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Impact of α_s on Higgs production and decay uncertainties

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Motivation

Precise predictions for Higgs production and decays essential for

- Higgs Coupling Measurements
- Determination of the Higgs potential
- Search for the New Physics

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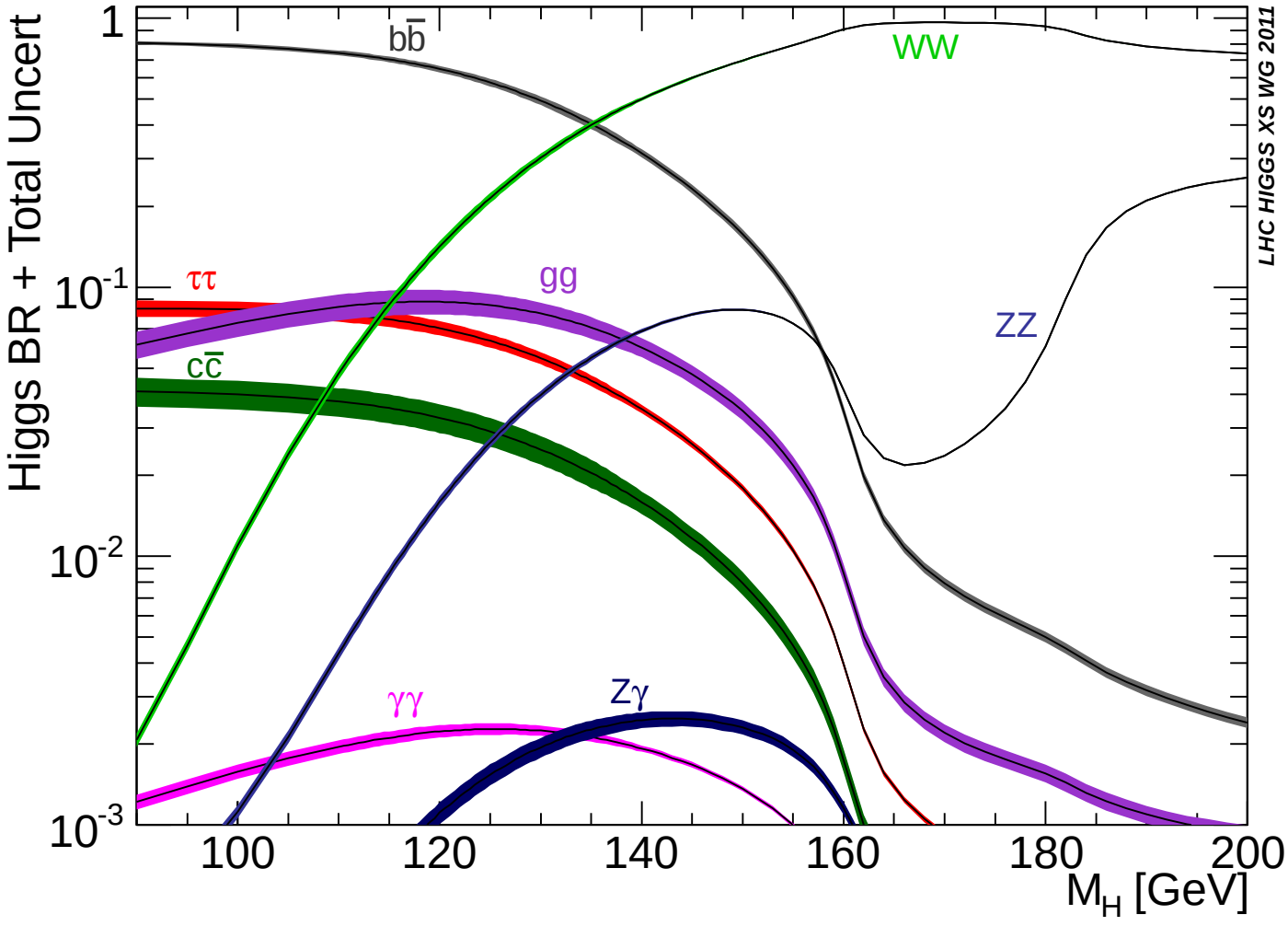
Goal:

reduce **theoretical** and **parametric** uncertainties below the experimental ones.

Higgs decays

Theoretical uncertainties



Theoretical uncertainties

Theoretical Uncertainties (update of [LHC HXSWG 2011])

Partial Width	**QCD**	**Electroweak**	**Total**
$\mathrm{H} \to \mathrm{b\bar{b}}/\mathrm{c\bar{c}}$	$\sim 0.1\%$	$\sim 0.3\%$ for $M_{\mathrm{H}} \lesssim 135\,\mathrm{GeV}$	$\sim 0.3\%$
$\mathrm{H} \to \tau^+\tau^-/\mu^+\mu^-$		$\sim$ 1–2% for $M_{\mathrm{H}} \lesssim 135\,\mathrm{GeV}$	$\sim 2\%$
$\mathrm{H} \to \mathrm{gg}$	$\sim 3\%$	$\sim 1\%$	$\sim 3\%$
$\mathrm{H} \to \gamma\gamma$	$< 1\%$	$< 1\%$	$\sim 1\%$
$\mathrm{H} \to \mathrm{Z}\gamma$	$< 1\%$	$\sim 5\%$	$\sim 5\%$
$\mathrm{H} \to \mathrm{WW/ZZ} \to 4\mathrm{f}$	$< 0.5\%$	$\sim 0.5\%$ for $M_{\mathrm{H}} < 500\,\mathrm{GeV}$	$\sim 0.5\%$

SM Results for $\Gamma(H \to b\bar{b})$

$$\Gamma(H \to b\bar{b}) \;=\; \Gamma^{(0)} \left(1 + \Delta^{(\alpha_s)} + \Delta^{(\alpha)} + \Delta^{(\alpha\alpha_s)} + \ldots\right)$$

	$\Delta^{(\alpha_s)}$	$\Delta^{(\alpha_s^2)}$	$\Delta^{(\alpha_s^3)}$	$\Delta^{(\alpha_s^4)}$
QCD	0.2040	0.0378	0.0020	-0.0014
	$\Delta^{(\mathrm{QED})}$	$\Delta^{(\mathrm{QED},\alpha_s)}$		
QED/QCD	0.0011	0.0001		
	$\Delta^{(\mathrm{weak})}$	$\Delta^{(\mathrm{weak},\alpha_s)}$	$\Delta^{(\mathrm{weak,Z})}$	$\Delta^{(\mathrm{weak},\alpha_s,\mathrm{Z})}$
weak/QCD	-0.0100	-0.0029	-0.0097	-0.0020

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- M_t^2-Approximation provides less than 20 % of $\Delta^{(\mathrm{weak},\alpha_s)}$
- Non-factorisable effects ($\approx 30\%$)

Parametric uncertainties

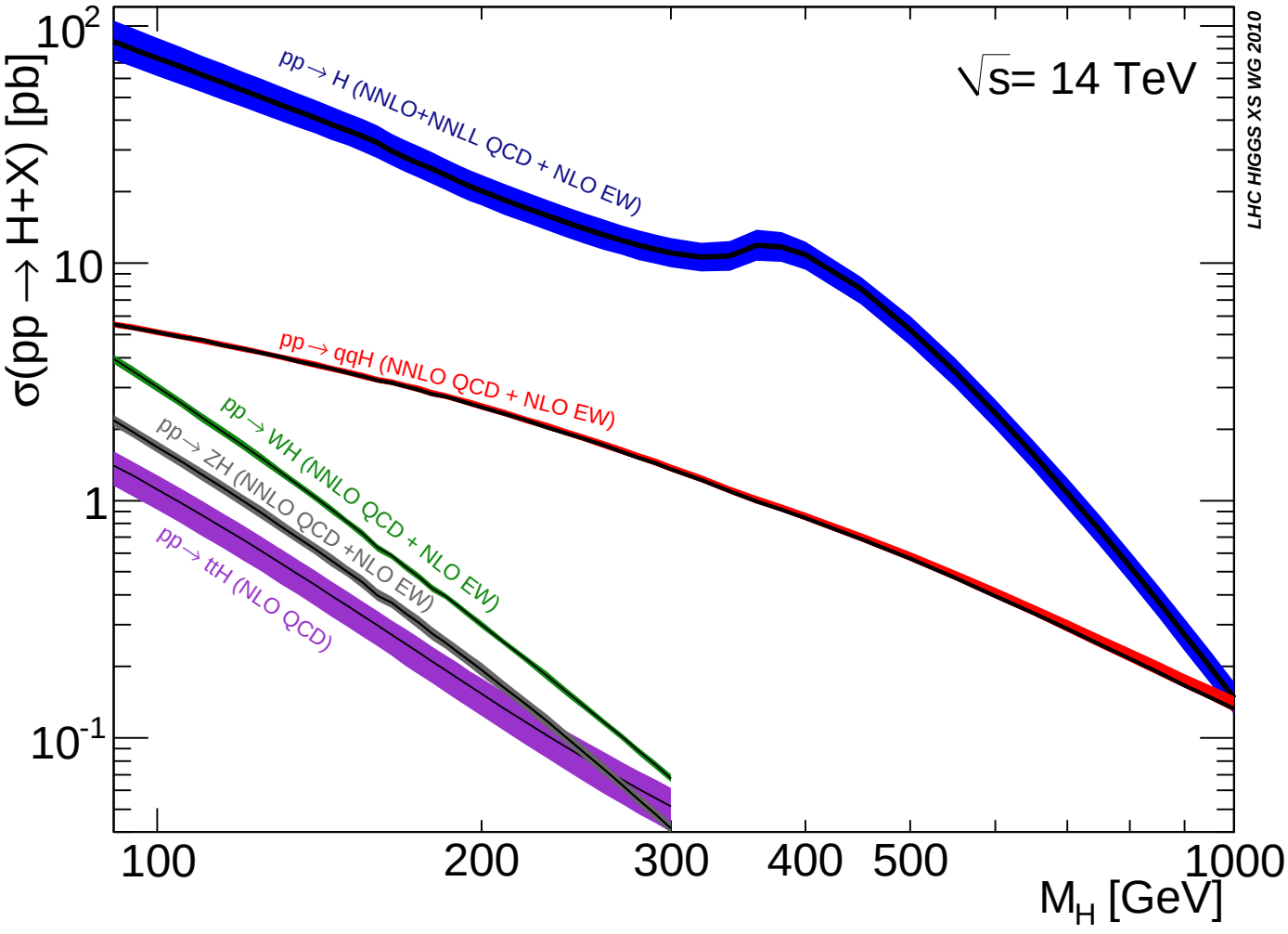
Parametric Uncertainties (from [LHC HXSWG 2013])

Channel	$M_{\mathrm{H}}[\mathrm{GeV}]$	$\Delta\alpha_s$	Δm_b	Δm_c
$\mathrm{H} \to \mathrm{b\bar{b}}$	126	$\pm$ 0.4 %	$\pm$ 0.8%	$\pm$ 0 %
$\mathrm{H} \to \mathrm{c\bar{c}}$	126	$\pm$ 7.1 %	$\pm$ 0.1%	$\pm$ 2.3 %
$\mathrm{H} \to \mathrm{gg}$	126	$\pm$ 4.1 %	$\pm$ 0.1%	$\pm$ 0 %

Parameter	Central Value	Uncertainty
$\alpha_s(M_Z)$	0.1184	$\pm$0.002
$m_c(m_c)$	1.279 GeV	$\pm$0.013 GeV
$m_b(m_b)$	4.163 GeV	$\pm$0.016 GeV

Higgs Production

Higgs Production @ LHC

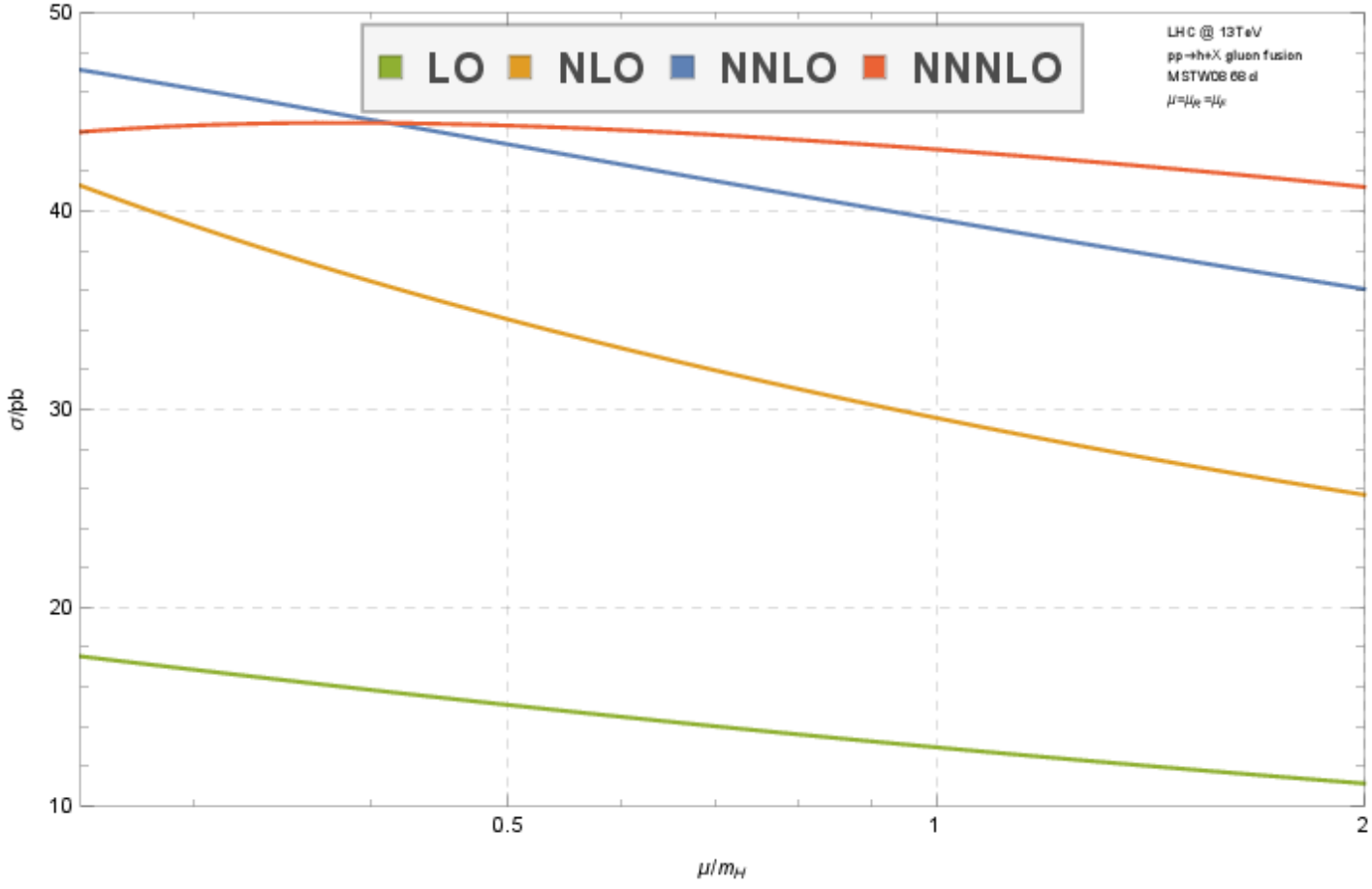


Higgs Production @ LHC

Uncertainties (update of [LHC HXSWG 2013] for $\sqrt{s} = 14$ TeV)

Process	**Cross section(pb)**	**Scale**(%)		**PDF** $+\alpha_s$
ggH	49.87	-2.61	+ 0.32	-6.2 +7.4
VBF	4.15	-0.4	+ 0.8	$\pm$ 2.5
WH	1.474	-0.6	+ 0.3	$\pm$ 3.8
ZH	0.863	-1.8	+ 2.7	$\pm$ 3.7
ttH	0.611	-9.3	+ 5.9	$\pm$ 8.9

Higgs Production @ LHC



Anastasiou, Duhr, Dulat, Mistlberger '15

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Higgs Production @ LHC

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$\sigma(ggH)$ @ NNLO

- NNLOPDF
- $\sqrt{s} = 14$ TeV; $\mu_R = \mu_F = M_H/2$; $M_H = 125.09$ GeV

$\sigma(\mathbf{ggH})$ (pb):

PDF	**CT10**	**MSTW2008**	**NNPDF23**	**HERAPDF15**
$\alpha_s(M_Z) = 0.114$				48.41 ± 0.58
$\alpha_s(M_Z) = 0.117$	50.07 ± 0.58	51.13 ± 0.59	52.42 ± 0.61	
$\alpha_s(M_Z) = 0.119$	52.00 ± 0.59	52.84 ± 0.60	54.38 ± 0.62	

with **SUSHI** [Harlander, Liebler and Mantel'15]

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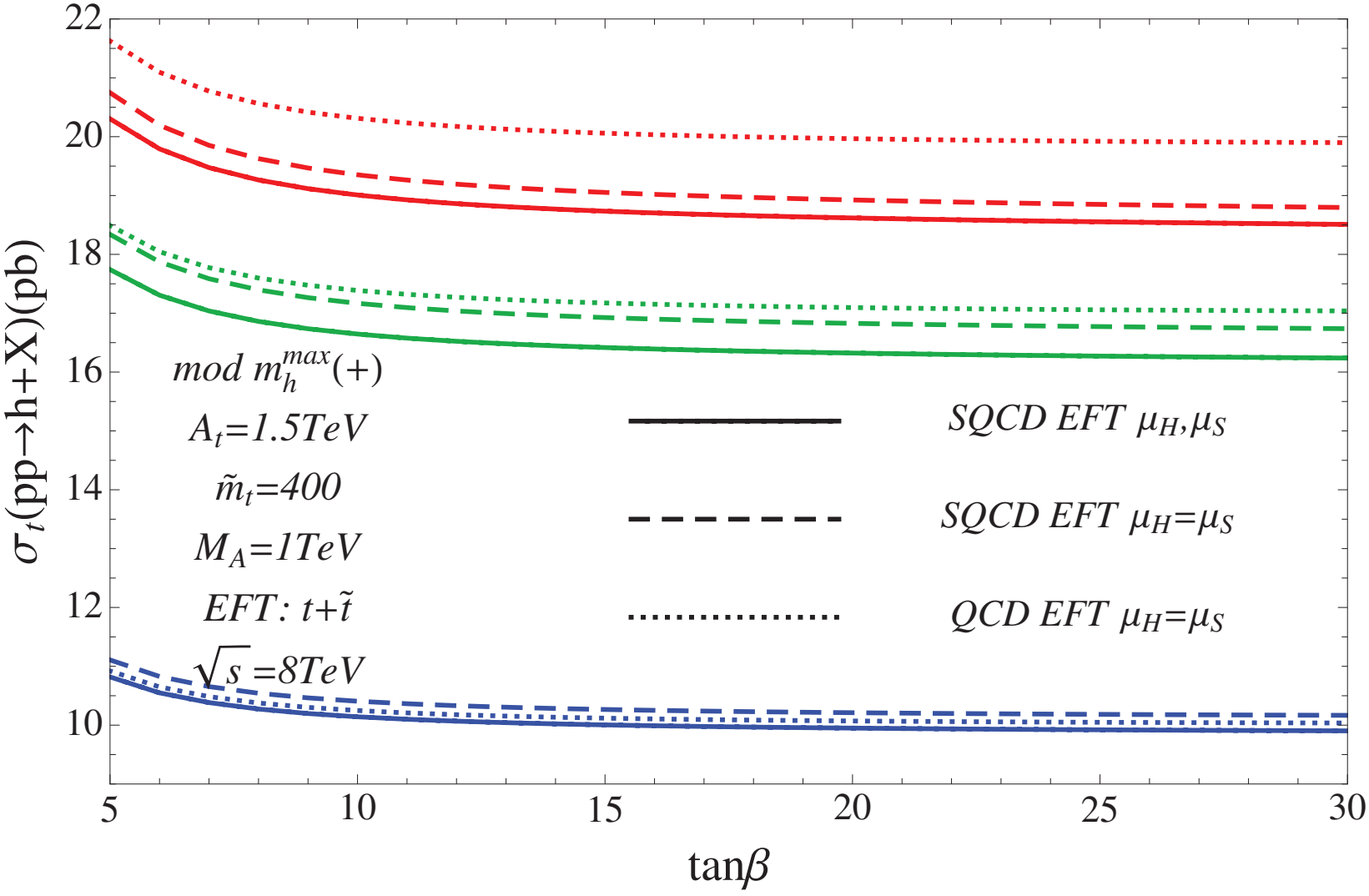
- similar results with **HIGLU** [M. Spira]
- $\delta\alpha_s = 0.002 \Rightarrow \delta\sigma/\sigma = 3 - 4\%$

$\sigma(ggH)$ @ NNLO in the MSSM



[Pak, Steinhauser and Zerf'12]

Higgs Production @ e^+e^- FC

- $e^+e^- \to t\bar{t}H$
  - QCD corrections especially large near $t\bar{t}$-threshold
  - Theory uncertainty $\approx 5\%$
  - Parametric uncertainty induced by $\delta\alpha_s$ at $\mathcal{O}(\%)$

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- see talk by H. Kühn

Summary

Precise α_s knowledge essential for

- hadronic Higgs decay rates
- Higgs production cross section in **ggh**
- Higgs production cross section in $e^+e^- \to t\bar{t}H$