tHq signal modelling

LHCHXSWG meeting – ttH/tH subgroup

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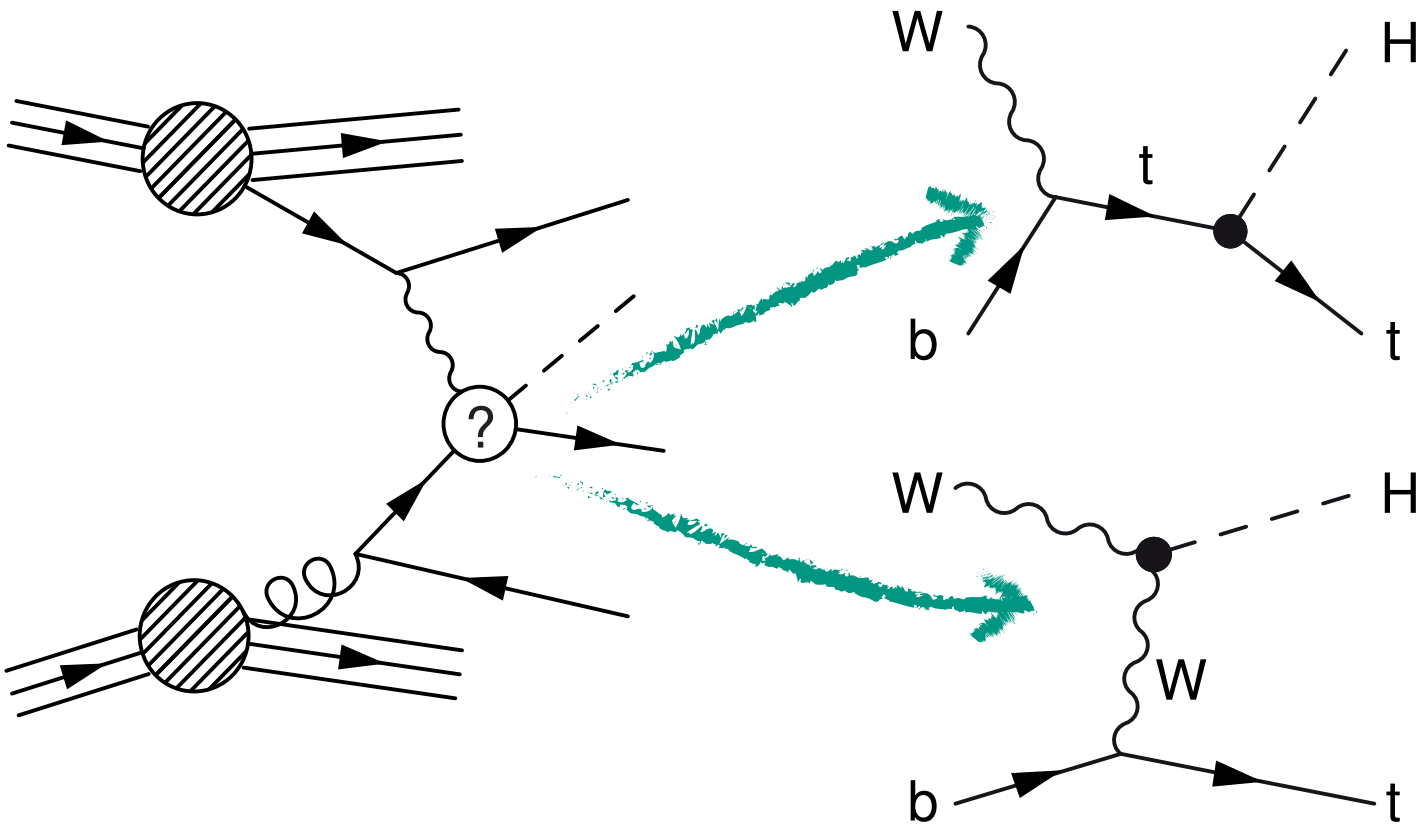
Guideline

1. Introduction to single top + Higgs
   - ➤ Process
   - ➤ Modelling aspects

2. Modelling in Run-II
   - ➤ Strategy
   - ➤ Going NLO

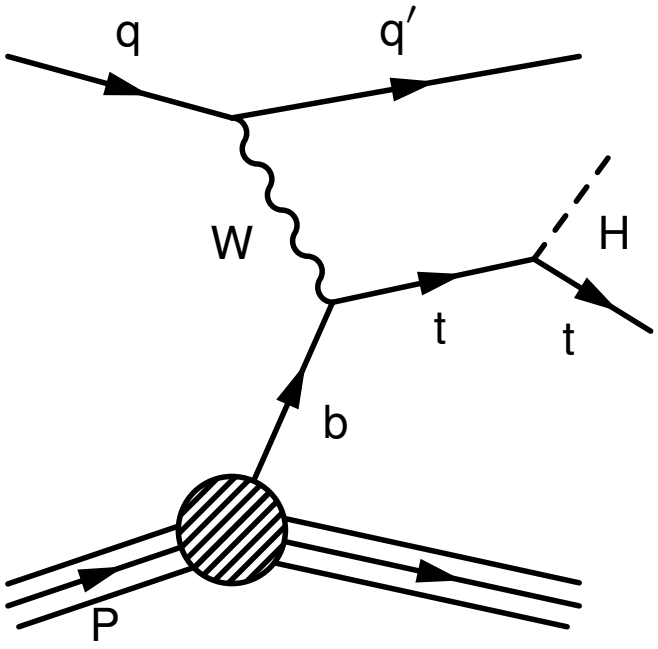
The process: tHq at LO



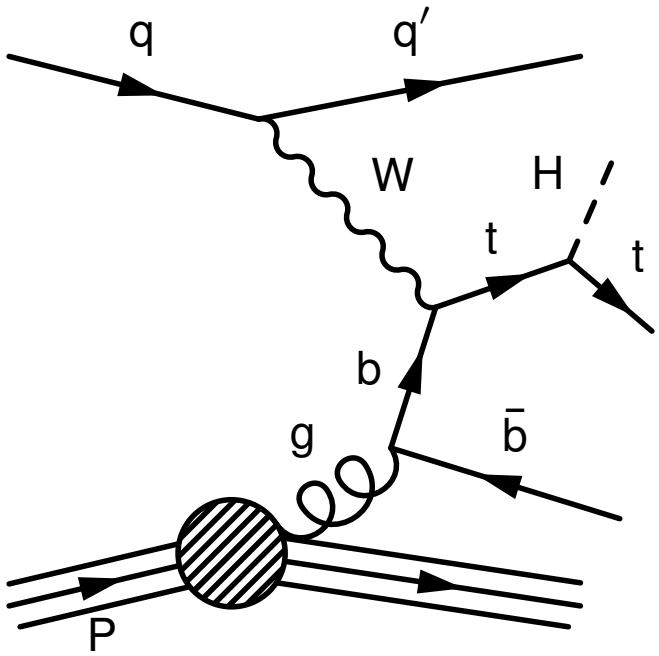
- Destructive interference for SM, constructive for flipped top-Yukawa coupling
- Case of $y_t = -1$ searched for in CMS analyses

tHq modelling

Five-flavor scheme ($2 \to 2$)



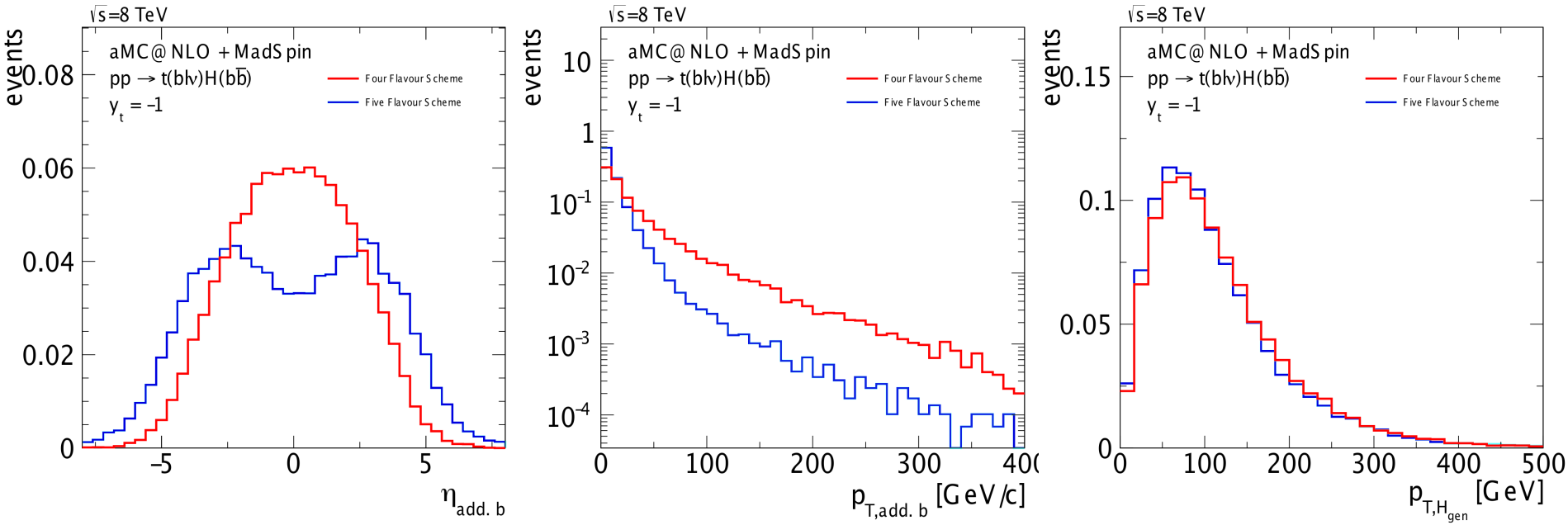
Four-flavor scheme ($2 \to 3$)



- Five-flavour scheme: slightly more accurate in kinematics of top, Higgs (and more accurate in incl. observables like cross-section)
- Four-flavour scheme gives ME accuracy in additional b quark $\to$ important for analyses (like $H \to b\bar{b}$) sensitive to b tagging

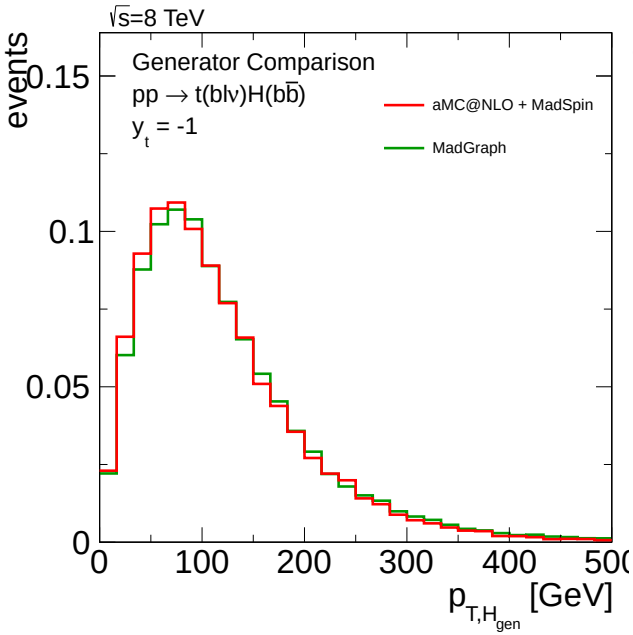
Flavour-scheme comparison

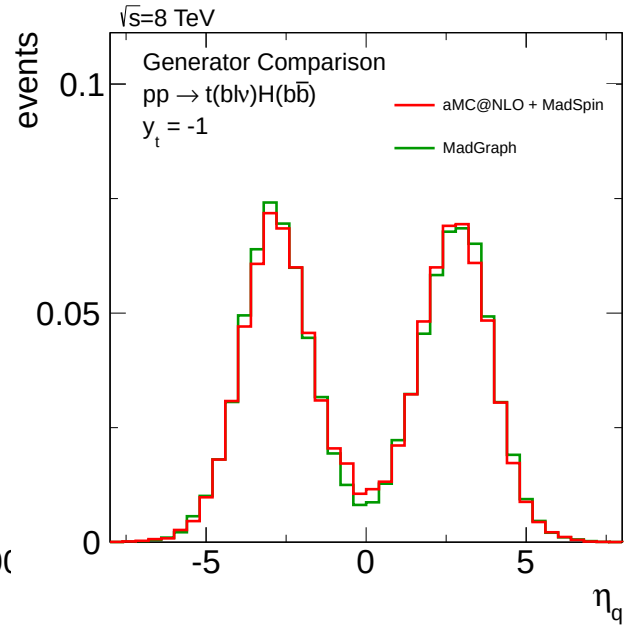
- We choose the Four Flavour Scheme (4FS) to derive kinematics of the single top + Higgs process in $H \rightarrow b\bar{b}$
- Five Flavour Scheme cross section is used for normalization
- Choices above are intentional. See e.g. Campbell et al. in `arXiv:0907.3933 [hep-ph]` and R. Frederix `here`
- Following strategy of other similar processes like “pure” single top

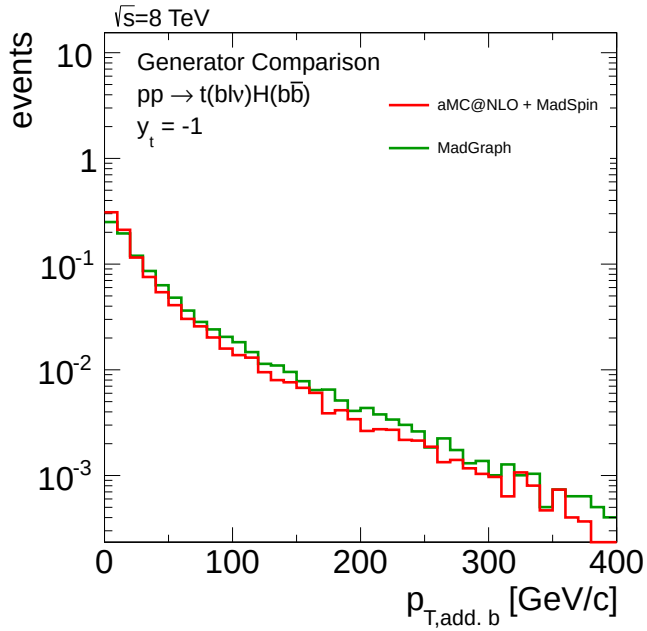


LO vs. NLO at 8 TeV

- Comparing MadGraph to aMCatNLO (both showered with Pythia6)
- LO yields slightly harder spectra

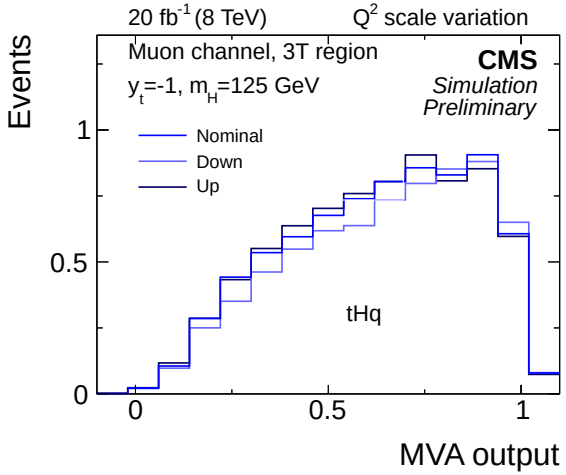


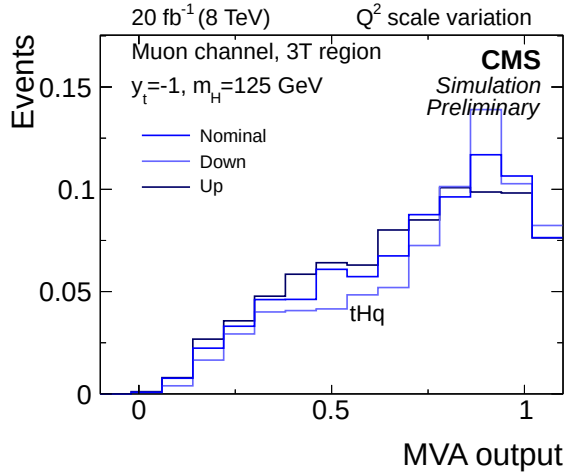




CMS Run-I strategy

- Using LO MadGraph + Pythia6 TuneZ2star for tHq generation
  - 4-and 5-flavour-scheme (depending on channel)
    - 4fs for H $\rightarrow b\bar{b}$
    - 5fs for H $\rightarrow W\bar{W},\tau\tau,\gamma\gamma$ (historical reasons) ... 4fs taken into account as syst. unc. ($\mathcal{O}(5.5\,\%)$)
  - cteq6l1 PDF
  - Fixed fact./ren. scale: $\mu = 100\,\text{GeV}$
  - $y_t = -1$
- $\mathcal{Q}^2$ uncertainty via rate/shape uncertainties $\rightarrow$ dedicated samples





- Did not consider tHW in Run-I

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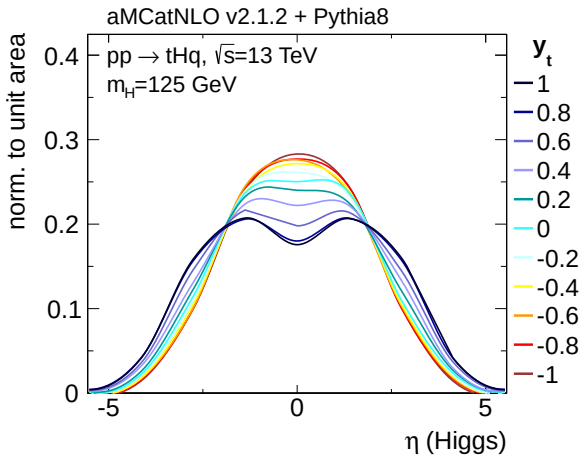
Strategy

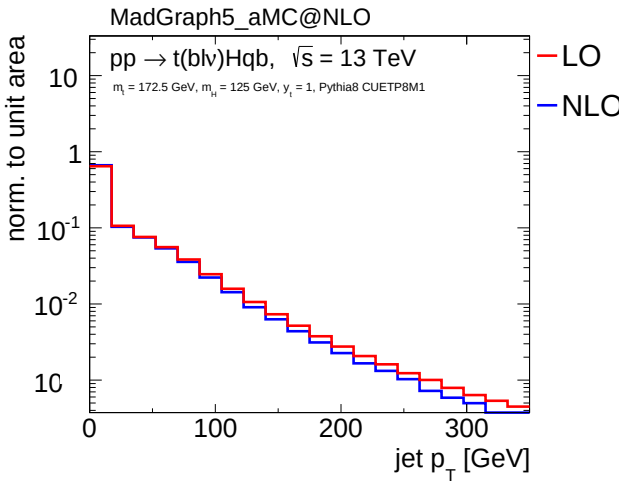
- Model tHq (and tHW) with MadGraph5_aMCatNLO
  - LO mode for Run-II startup
  - In the mid-term: switch to NLO mode
- Switch from Pythia6 to Pythia8
- Not only focus on $y_t = -1$

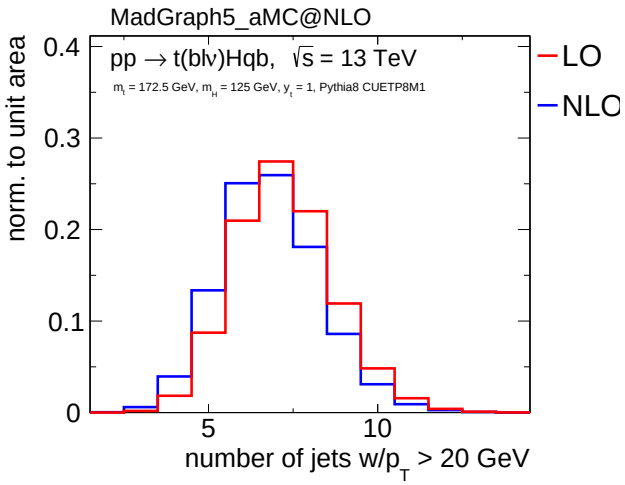


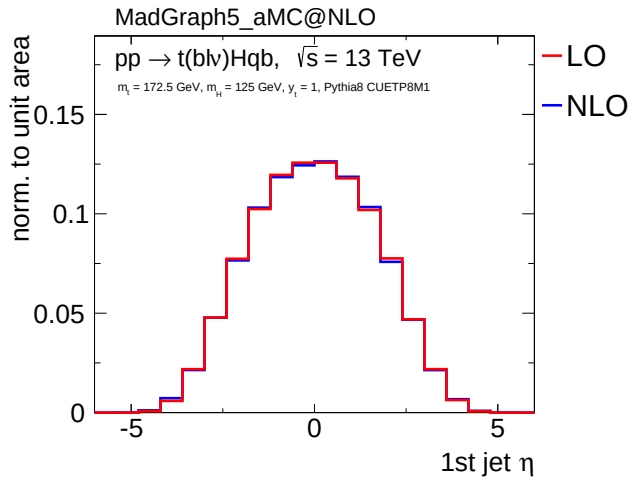
- Systematics:
  - Access Q^2 uncertainty via event weights in LHE_v2 format (same holds for PDF uncertainty)
  - Include parton shower uncertainty: e.g. Pythia8 vs. Herwig++

Madgraph5_aMCatNLO

- For Run-I searches, LO accuracy in the ME calculation was sufficient
- As more and more data arrives in Run-II, an increasing precision becomes important
- In general: If available, there is no reason not to use NLO generators for a process





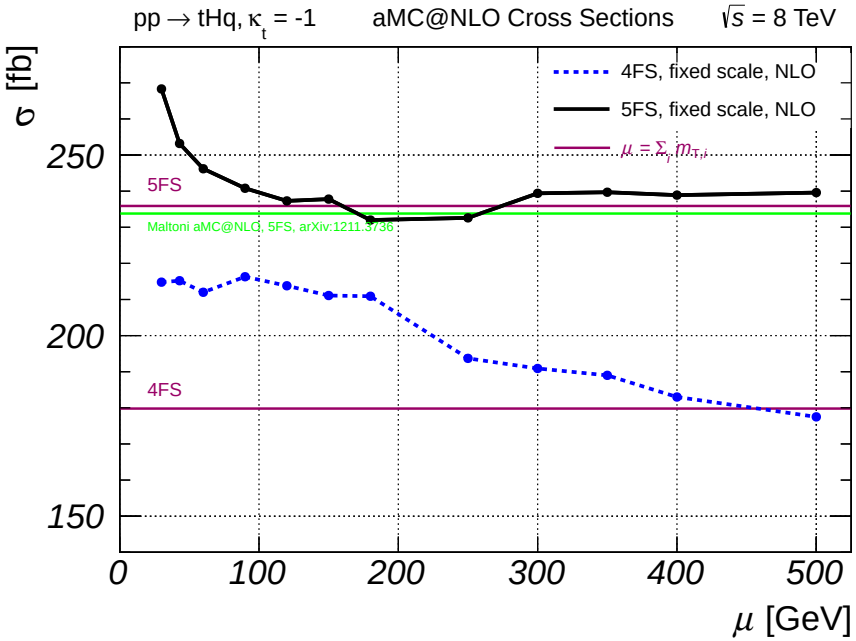


Conclusion

- The single top + Higgs process brings some subtleties due to its t-(or tW-)channel-like nature: flavour scheme, choice of scale, etc.
  - Therefore, deliberate choices have to be made for MC generation
- CMS is and will be using the MadGraph5_aMCatNLO package, interfaced to Pythia, for signal simulation
- Have not spoken about background modelling here, but CMS puts heavy efforts in studying and improving modelling of ttbar + jets and single top + jets backgrounds!

Backup

Cross sections



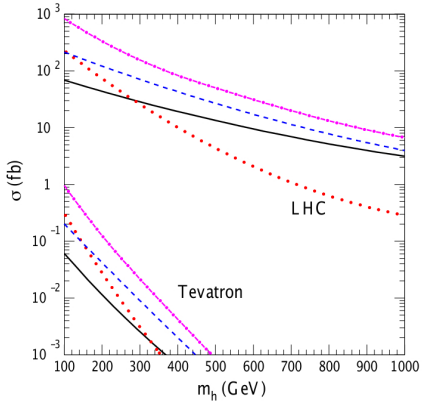


Figure 13: The cross section for production of Higgs in association with a single top quark, as a function of the Higgs mass at the Tevatron Run II (lower family of curves) and the LHC (upper family of curves). The cross sections are shown for models in which the Higgs couplings are completely SM-like (solid curves), the coupling to the $W^{\pm}$ boson is zero and the coupling to top is SM-like (dotted curves), the coupling to top is zero and the coupling to $W^{\pm}$ is SM-like (dashed curves), and the coupling to $W^{\pm}$ is SM-like and the coupling to top is -1 times the SM coupling (dash-dotted curves).

- Comparing 4FS vs. 5FS cross sections with aMC@NLO
- See Tim et al., arXiv:hep-ph/0007298