

CDF $H \rightarrow WW$ Analysis: (N)NLO Cross Section Studies

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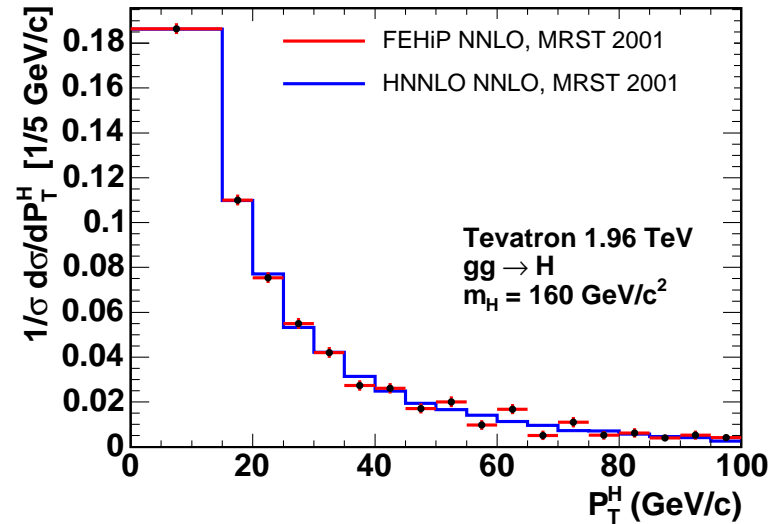
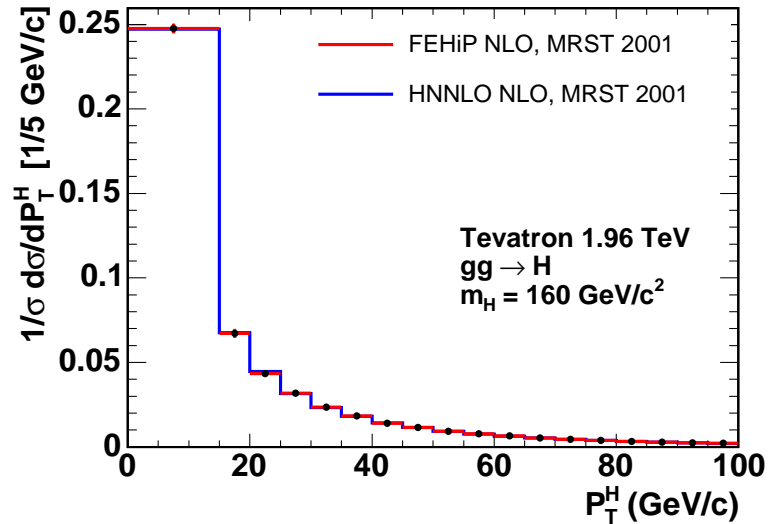
Higgs (N)NLO cross section

- Relates to two systematic uncertainties:
 - Higgs acceptance
 - Higgs cross section
- (N)NLO corrections are large...
 - but since Higgs is pseudo-scalar, effects on kinematic variables limited mostly to p_T and η
- Previously studied effect of p_T on acceptance by reweighting Pythia to NLO p_T from FEHiP
 - Shifts on the order of 5%
- NB: CDF uses events with $N_{jets} \leq 1$

FEHiP vs. HNNLO

- FEHiP program:
 - Only decays $H \rightarrow \gamma\gamma$
 - To make a histogram, must run program once for each bin
 - Only includes MRST 2001 PDF
- Last time M. Grazzini introduced HNNLO program:
 - Includes decay $H \rightarrow WW \rightarrow l\nu l\nu$ ($l = e, \mu$)
 - Produces user defined histograms
 - User also able to implement selection cuts (**not used in most of these studies**)
 - Large selection of PDFs available

FEHiP-HNNLO comparison

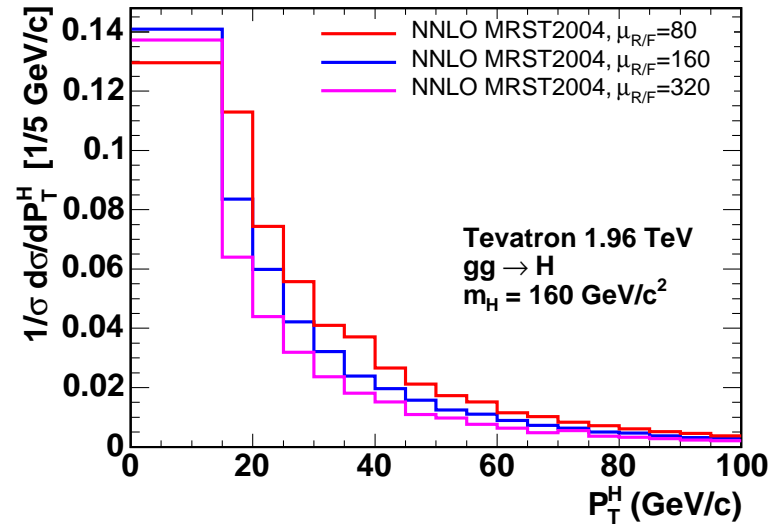
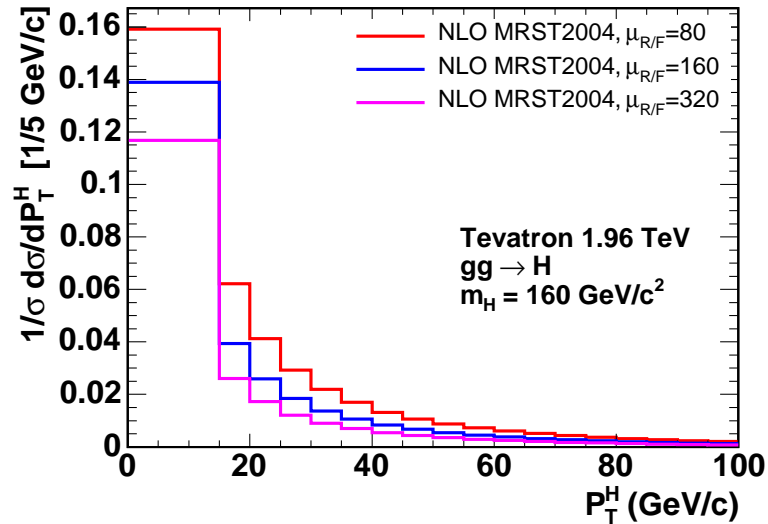


- Both methods less reliable as $p_T \rightarrow 0$; first bin from 0 to 15 GeV, divided by three
 - Good agreement overall:
 - NNLO agrees within uncertainties
- Use HNNLO for Higgs cross section studies

Theoretical uncertainties on Higgs cross section

- See discussion in [hep-ph/0306211](#) and Grazzini's talk
- Largest uncertainty due to uncalculated higher order QCD radiative corrections
 - Renormalization and factorization scales μ_R and μ_F set to hard scale M_H ($M_H = 160$ in all studies)
 - Method used in perturbative QCD:
Evaluate with $\mu_{R/F} = m_H/2, 2m_H$
 - In general, procedure gives lower limit on uncertainty; trust it more if NLO & NNLO bands overlap
- Impact supposedly reduced by making selection cuts (shown in Grazzini's talk, not studied yet)
- Use HNNLO with MRST2004 to check uncertainty estimate

HNNLO renormalization and factorization plots



- Total cross sections consistent with uncertainty in hep-ph/0306211: $\sim 25\%$ for NLO, $\sim 13\%$ for NNLO

$\mu_R = \mu_F =$	80	160	320
NLO	3.666 ± 0.008	2.884 ± 0.005	2.277 ± 0.003
NNLO	4.385 ± 0.058	3.936 ± 0.035	3.403 ± 0.020

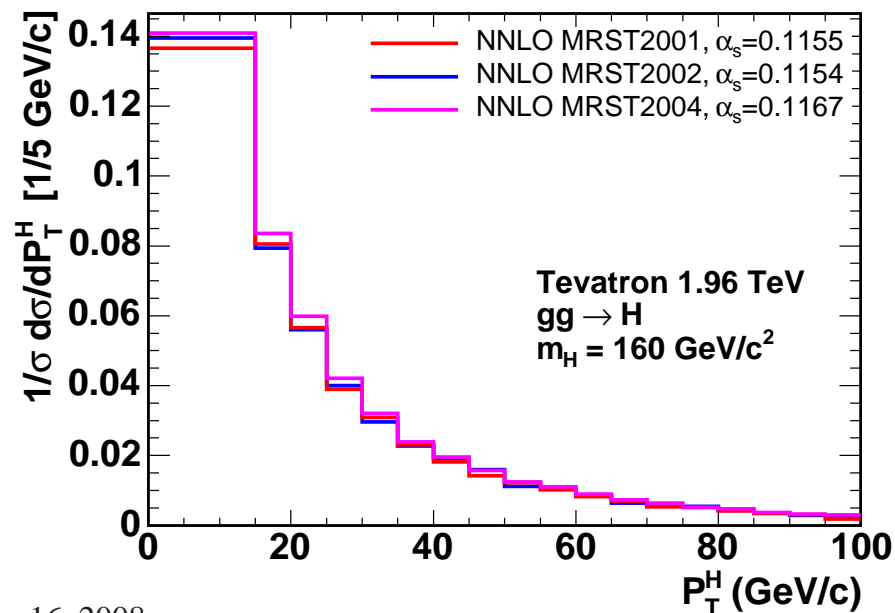
Theoretical uncertainties cont.

- Only other appreciable uncertainty due to limited knowledge of parton distributions
 - Compare different PDFs
 - For NLO, compare CTEQ and MRST PDFs
 - For NNLO, only have MRST PDFs in HNNLO
- NLO cross section difference ranges from $\sim 6\%$ ($M_H = 100$) to $\sim 10\%$ ($M_H = 200$)
 - Consistent w/in experimental uncertainty on gg luminosity
- In paper NNLO compared to [hep-ph/0211096](https://arxiv.org/abs/hep-ph/0211096)
 - Difference ranges from 7% ($M_H = 100$) to 14% ($M_H = 200$)
 - Not fully explained w/in experimental uncertainties

NNLO MRST cross sections

NNLO PDF ($\mu_{R/F} = 160 \text{ GeV}$)	Total cross section (fb)
MRST2001, $\alpha_s = 0.1155$	3.770 ± 0.034
MRST2002, $\alpha_s = 0.1154$	3.780 ± 0.033
MRST2004, $\alpha_s = 0.1167$	3.936 ± 0.035

- $\sim 4\%$ rate change, small shape variation:

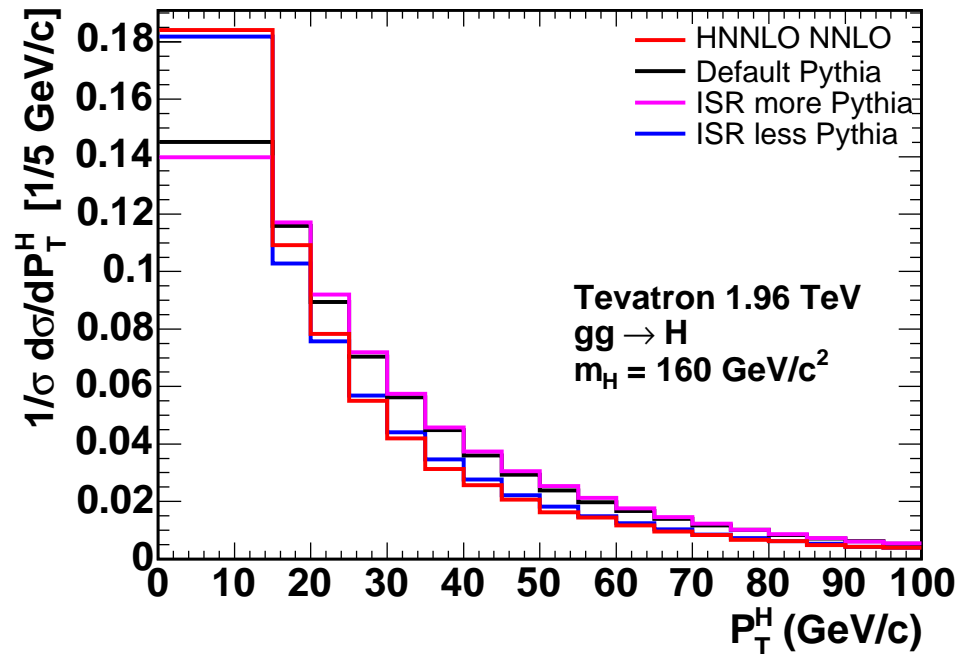


Compare HNNLO to Pythia (generator level)

- Compare to $gg \rightarrow H$ Pythia Tune A with CTEQ5L PDF and $\mu_R = \mu_F = M_H$
- Also have Pythia samples with more or less ISR:
 - PARP(61): Λ value used in space-like parton shower
 - PARP(64): multiplies transverse momentum evolution scale in space-like parton shower

Pythia Sample	PARP(61)	PARP(64)
Tune A	0.146	1.0
ISR less	0.073	2.0
ISR more	0.292	0.5

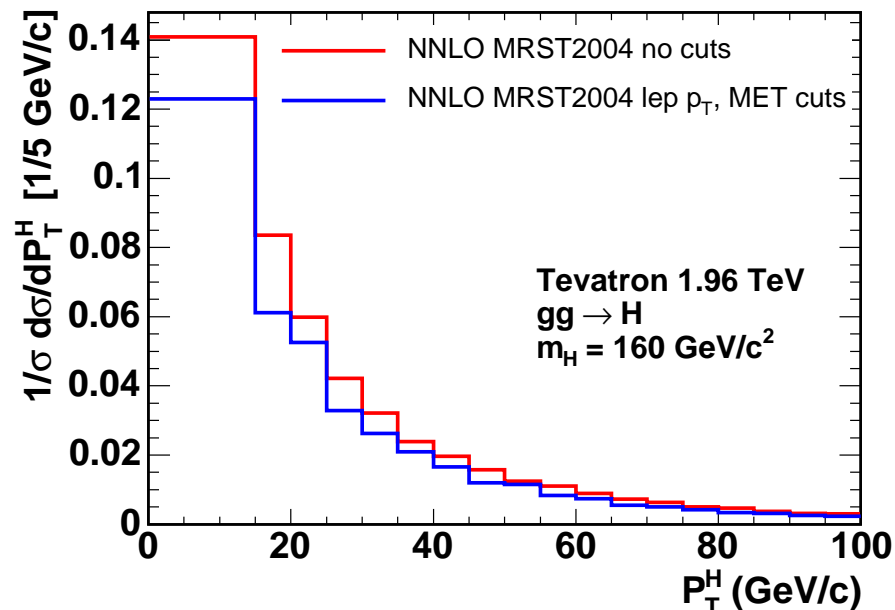
Compare HNNLO to Pythia (generator level plots)



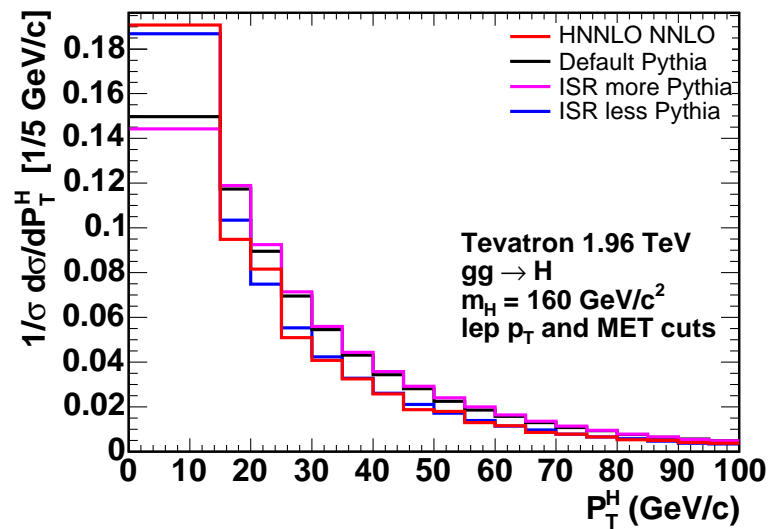
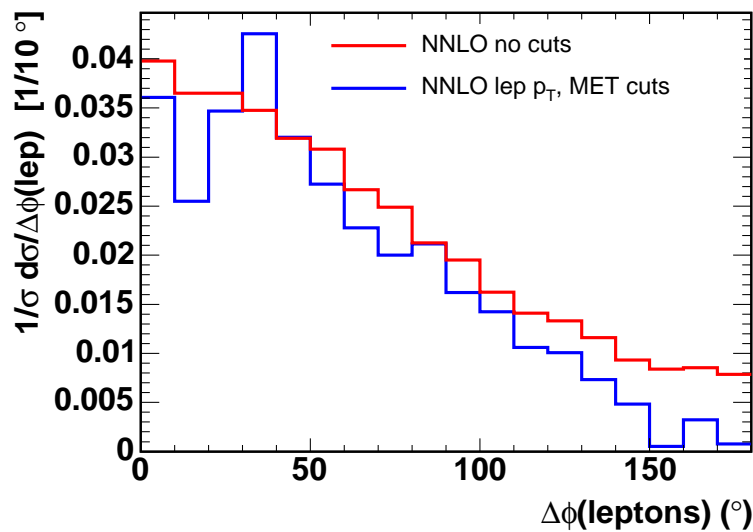
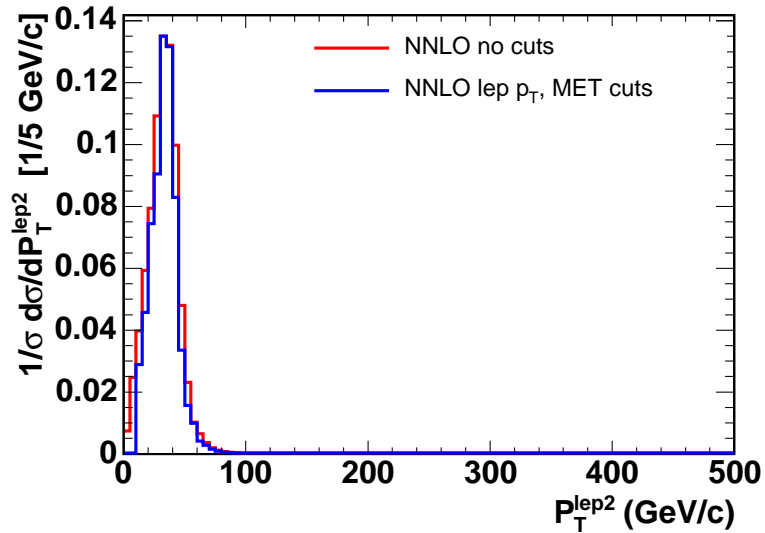
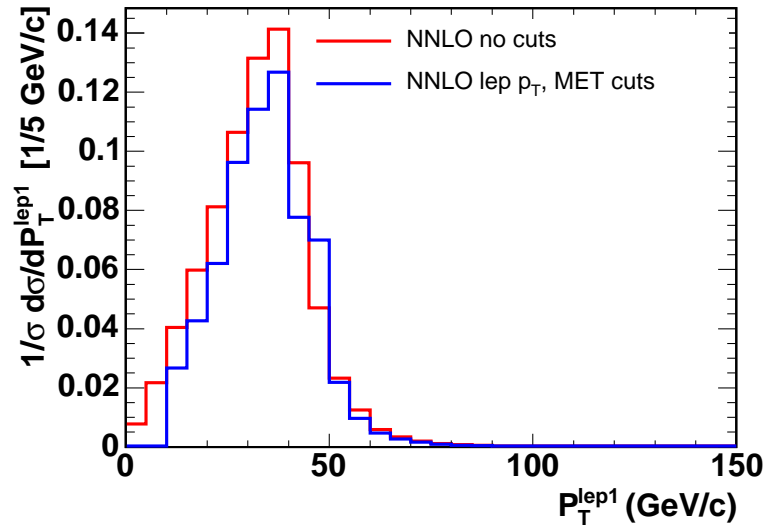
- Compare Pythia to NNLO at $M_H = 160$:
 - Pythia with less ISR agrees well
- Acceptance rate systematic from reweighting default Pythia to NNLO: $\sim 4.5\%$ at $M_H = 160$

Simple selection on HNNLO

- Ran HNNLO with a few selection cuts:
 - $p_T^{\text{lep}} > 10 \text{ GeV}$
 - One $p_T^{\text{lep}} > 20 \text{ GeV}$
 - $E_T > 25 \text{ GeV}$
- NNLO cross section reduced from $3.94 \rightarrow 3.34 \pm 0.04 \text{ fb}$:



Preliminary kinematic plots



Summary

- HNNLO program agrees with FEHiP
 - Switch to using HNNLO for cross section studies
- Higgs acceptance systematic
 - Reweight Pythia Higgs p_T to estimate rate systematic
 - Check as a shape systematic
- Higgs cross section systematic
 - Total theoretical uncertainty on NNLO cross section estimated to be $\sim 10\%$ in [hep-ph/0306211](#)
 - Our studies consistent with theirs
- Beginning studies with selection cuts

Backup slides...

Higgs cross section prediction

- Evaluated Higgs cross section for NLO PDFs available in HNNLO, see $\sim 10\%$ variation:

NLO PDF ($\mu_{R/F} = 160$ GeV)	Total cross section (fb)
MRST99, $\alpha_s = 0.1175$	2.542 ± 0.004
MRST2001, $\alpha_s = 0.119$	2.751 ± 0.005
MRST2001, $\alpha_s = 0.117$	2.549 ± 0.004
MRST2001, $\alpha_s = 0.121$	2.984 ± 0.005
MRST2002, $\alpha_s = 0.1197$	2.854 ± 0.005
MRST2004, $\alpha_s = 0.1205$	2.884 ± 0.005
CTEQ6M, $\alpha_s = 0.118$	2.584 ± 0.004
CTEQ5M, $\alpha_s = 0.118$	2.726 ± 0.005

Compare HNNLO to Pythia (plots)

