Impacts on H→WW→llνν Analysis from H.O. QCD Corrections to gg→H

- How good is MCatNLO (NLO+PS) MC in simulating higher-order effects in kinematic distributions?
- What are reasonable estimates of theoretical uncertainties of jet multiplicity distributions?

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On behalf of many people in ATLAS

Issues

- Most of our gg→H signal samples are produced using MCatNLO, a MC generator based on NLO calculations interfaced to HERWIG for parton shower and fragmentation;
- The total inclusive cross section of gg→H has been calculated up to NNLO in fixed order and to NNLL in soft-gluon resummation. These higher-order corrections significantly increase the Higgs production cross sections. These cross sections will be used for our first Higgs results.
- Is our MC simulation up to task? How can we assess theoretical uncertainties on acceptances, in particular jet fractions? We use HNNLO* program to study these issues. HNNLO calculates
  - differential gg→H cross sections in LO, NLO and NNLO (in the large m_t limit for the NNLO case)

*Grazzini et al: http://theory.fi.infn.it/grazzini/codes.html

Event Selection

- Higher-order corrections can alter the distributions of kinematic variables used in the event selection, therefore potentially impact on the selection efficiency ;

- Study effects for two sets of basic event selection cuts at parton level:

  - Selections for ATLAS/CMS/Theory study

    Two leptons with pT>20 GeV and $|\eta|<2.5$;

    MissingEt > 30 GeV (pT of the two neutrino system);

    Event veto if jets with pT>30 GeV and $|\eta|<3.0$

  - ATLAS selection (CONF note analysis):

    Two leptons with pT>20, 15 GeV and $|\eta|<2.5$;

    MissingEt > 30 GeV;

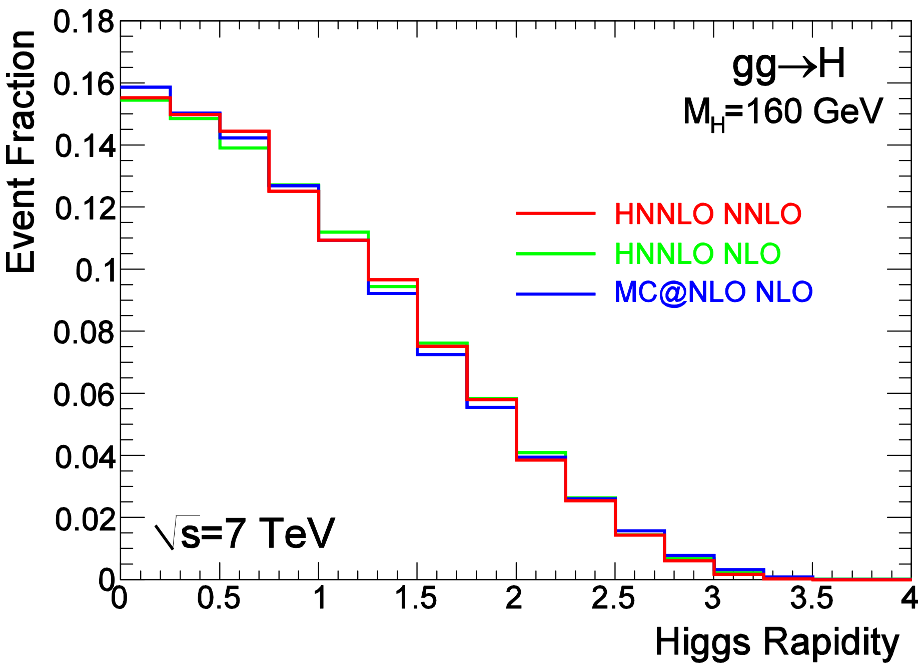
    Separate analyses for different jet bins: pT>20 GeV and $|\eta|<4.5$

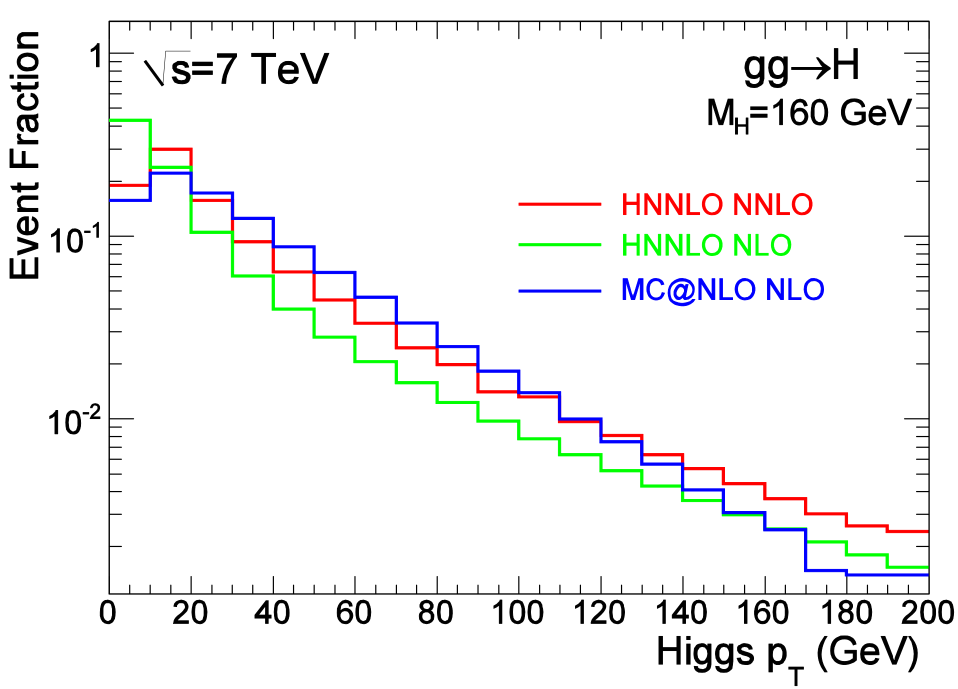
Though most of the plots/numbers are done for the former, the conclusions are similar in most cases

Higgs Kinematics

- **NLO, NNLO and NLO+PS all predict similar Higgs rapidity distributions;**

- **pT distributions are different**
  - **NLO and NNLO differ at low pT and are the same at high pT;**
  - **MCatNLO prediction is higher in intermediate pT region,**



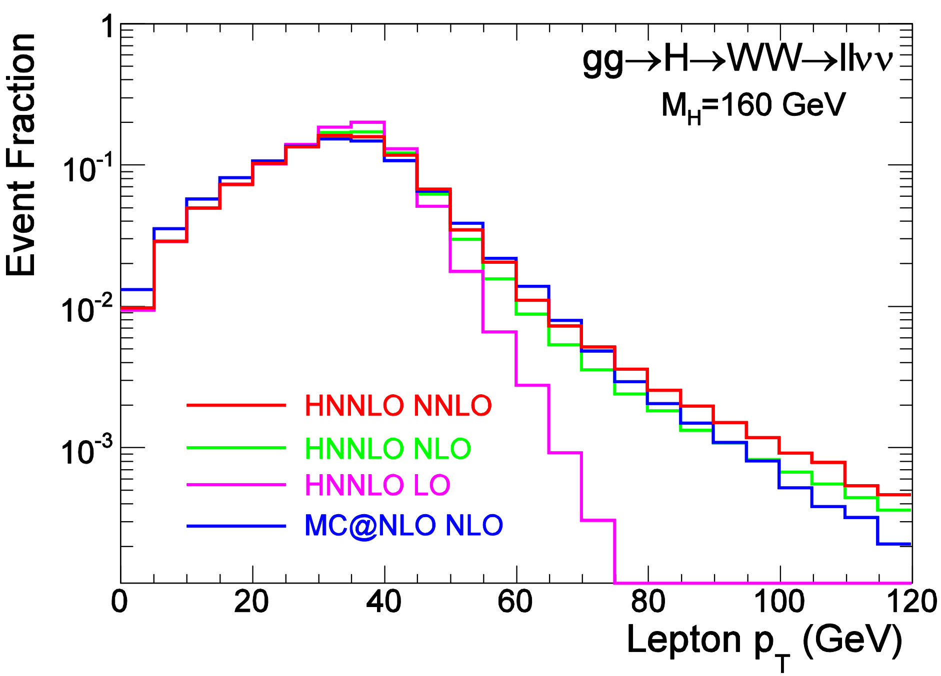


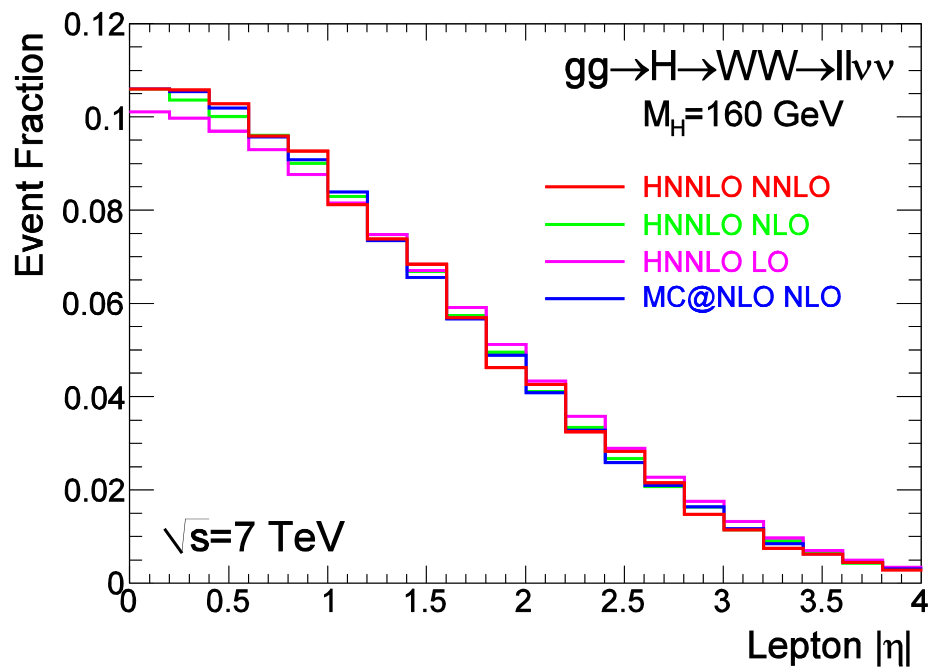
Lepton Kinematics

- **Lepton pT distribution: the W*-boson mass largely determines low pT distribution while h.o. corrections affect high pT region**
  - distributions at small pT values are similar at LO, NLO and NNLO
  - MCatNLO predicts more leptons with soft pT, perhaps FS radiation?

- **Lepton eta distributions are much less sensitive to h.o. corrections**

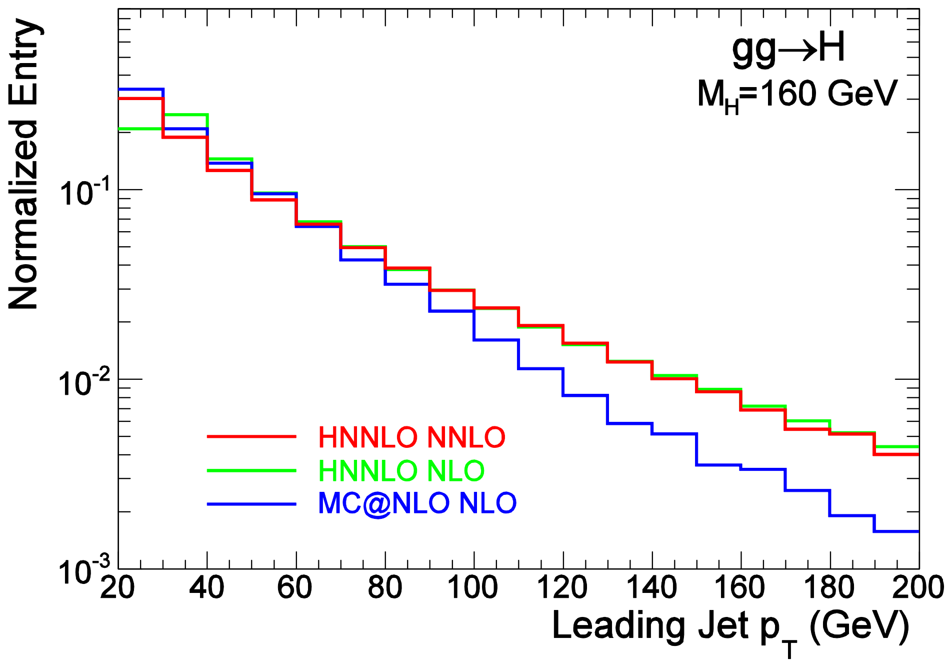
⇒ No major issues for our cuts.





Jet Kinematics

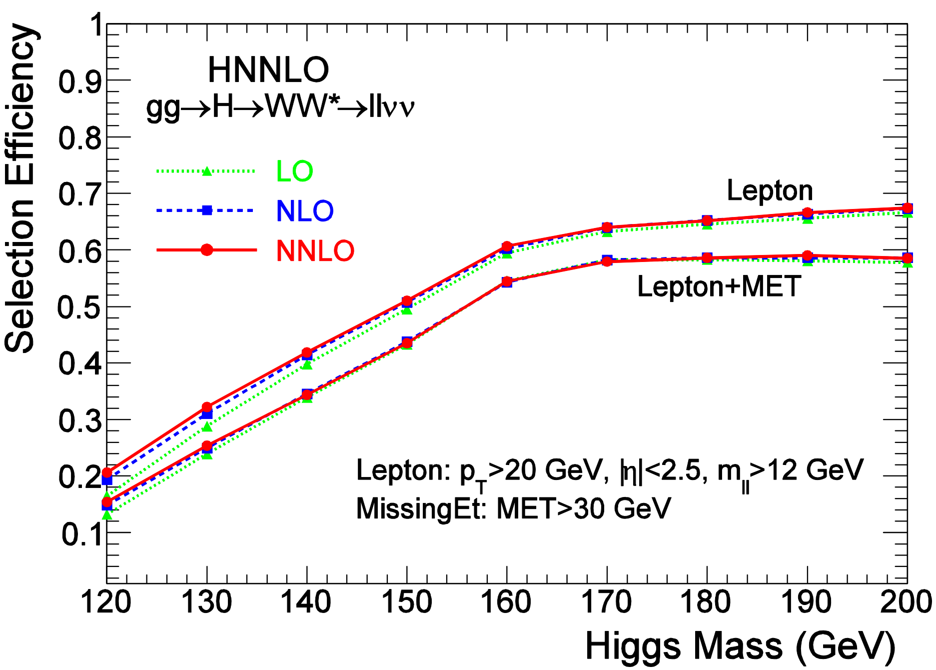
- **NLO and NNLO have very similar jet pT distributions above 40 GeV;**
- **MCatNLO has notably different jet pT spectrum**
  - **More soft radiation, consistent with the Higgs pT spectrum;**
  - **need to look at the rate, not just the shape…**

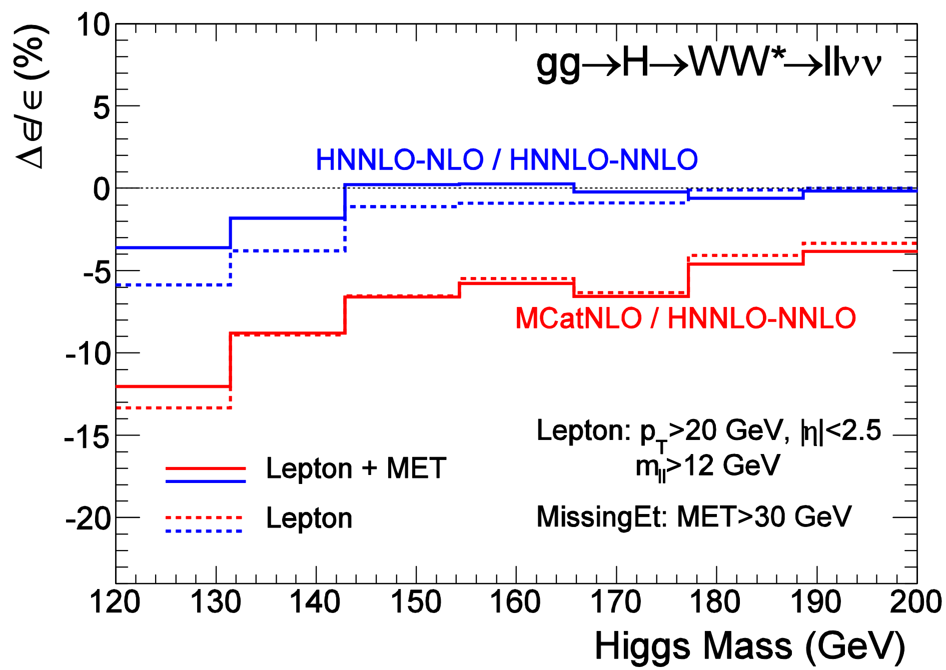


Selection Efficiencies

- For Higgs mass above 160 GeV, the lepton and MET selection efficiencies are essentially the same at LO, NLO and NNLO;
- For low masses, the efficiencies increase slightly at higher orders likely due to additional boost in lepton/MET pT from Higgs pT;
- Smaller MCatNLO efficiency can be attributed to FS QED radiation

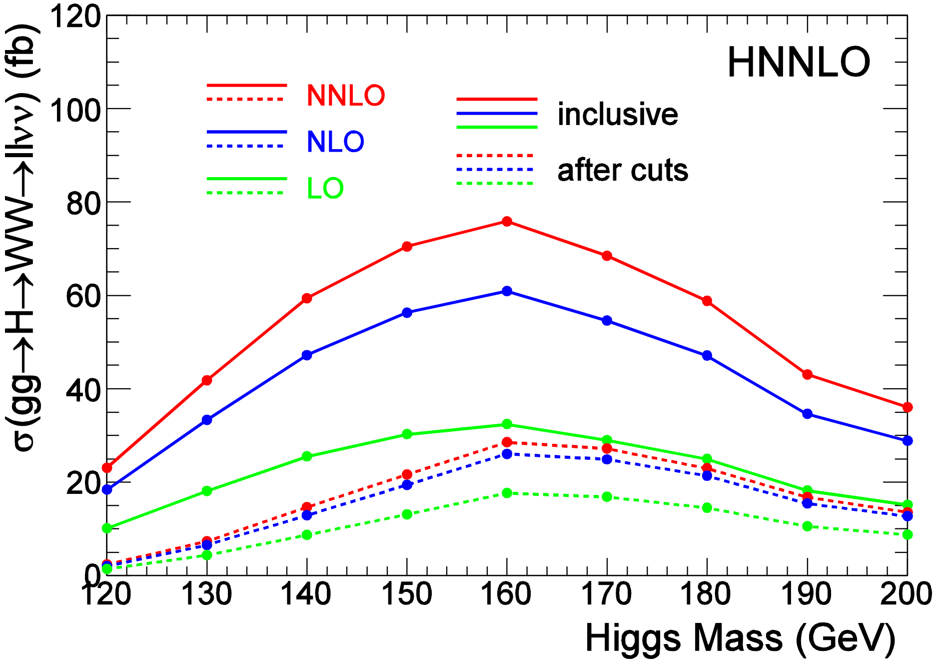
⇒ MCatNLO should be sufficient to simulate lepton/MET kinematics

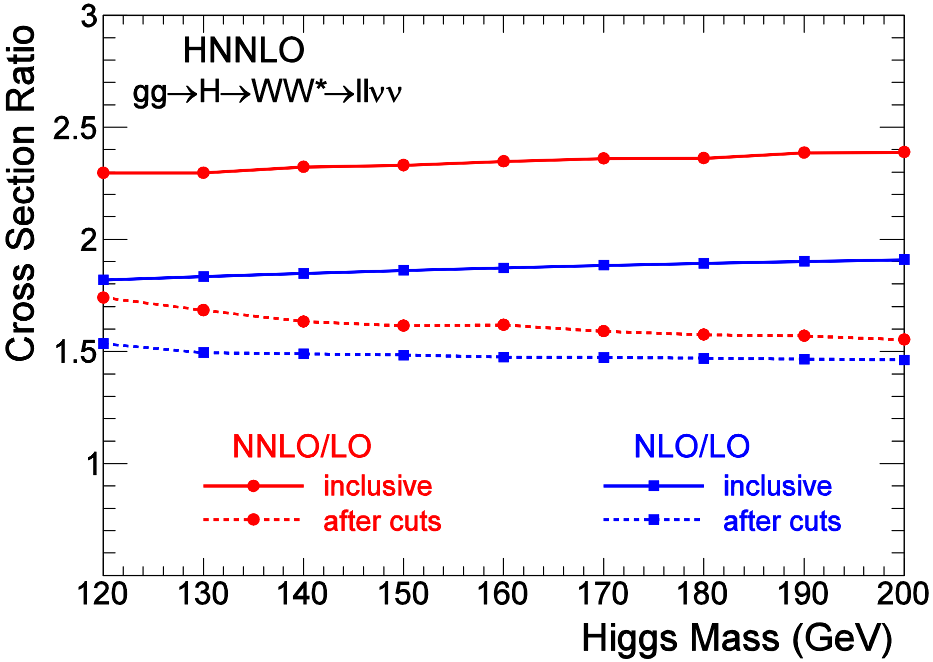




Cross Sections

- A significant fraction of the cross section gain from NLO and NNLO corrections is from real radiations ⇒ increase event jet activity;
- Significantly change the jet multiplicity distribution or worse effectively reduce the signal in the case of jet veto
  - Most of the NNLO cross section increase disappears after jet veto



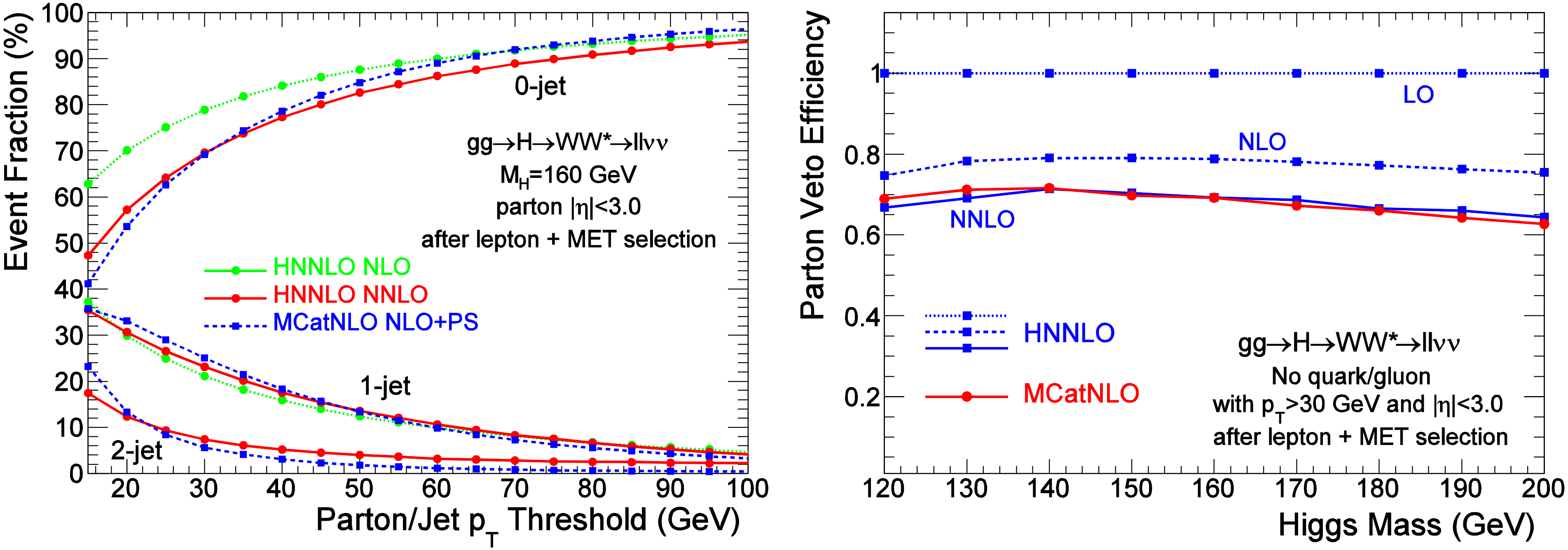


Parton/Jet Multiplicities

- **Jet multiplicity distributions of MCatNLO (NLO+PS) follows reasonable well with those of fixed order NNLO calculation**
  - **a bit jettier at low pT and approaches NLO calculation at high pT**
- **Good agreement in jet veto efficiencies between MCatNLO MC and NNLO calculation over a wide Higgs mass range, *i.e.***

NLO+PS ≈ NNLO

for our basic selections, i.e. PS simulates NNLO effect reasonably well



Scale and PDF Uncertainties

Relative change in the 0-jet fraction:

- **QCD scale: ~5% (pT>30 GeV)**

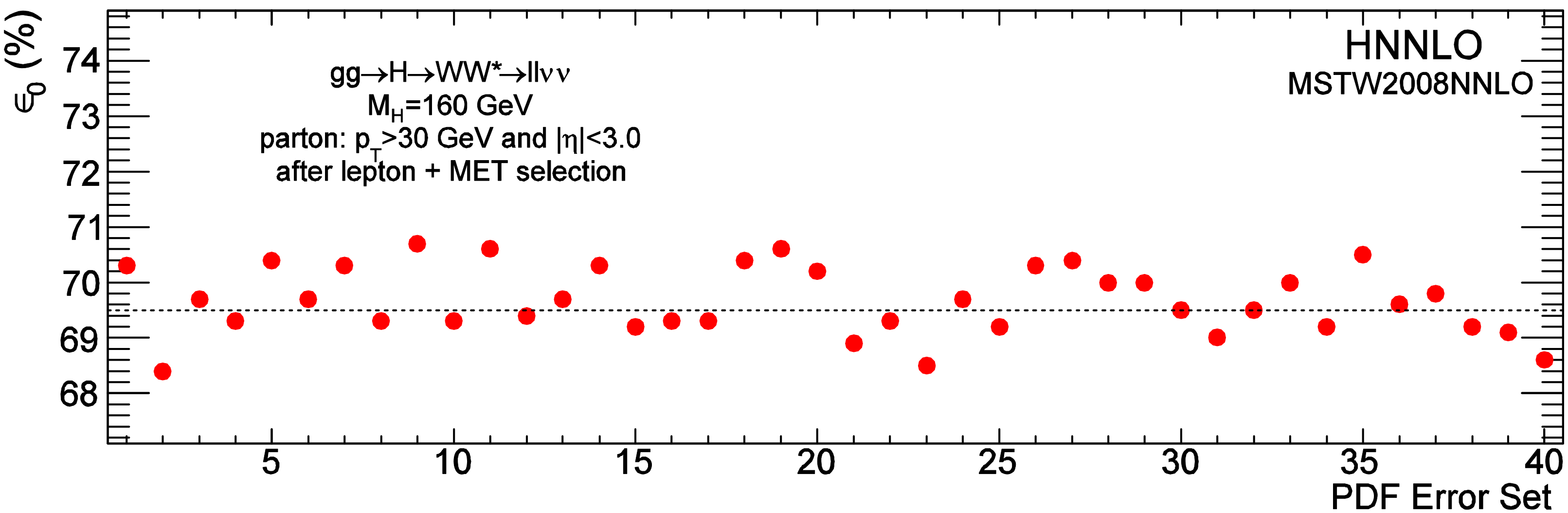
  from μ_F and μ_R variations by x2 around their central value M_H

- **PDF: ~3%**

  from 40 MSTW2008 90%CL error sets following $\Delta\varepsilon = \frac{1}{2}\sqrt{\sum_{i=1}^{20}\left(\varepsilon_i^+ - \varepsilon_i^-\right)^2}$

Scale variations

μ_F/M_H	μ_R/M_H	ϵ_0 (%)
0.5	0.5	66.2
0.5	1.0	68.2
0.5	2.0	70.9
1.0	0.5	66.8
1.0	1.0	69.5
1.0	2.0	72.1
2.0	0.5	67.2
2.0	1.0	69.4
2.0	2.0	72.6



Uncertainties Continued…

- α_s: ~2% variation

  from ±90% CL α_s MSTW2008 fits

- For the joint ATLAS/CMS selection, the combined scale, PDF and as uncertainties are:

  0-jet fraction: ~6%
  1-jet fraction: ~7%
  2-jet fraction: ~35%

- For ATLAS selection (pT>20 GeV and $|\eta|<4.5$), the combined uncertainties are

  0-jet fraction: ~10%
  1-jet fraction: ~6%
  2-jet fraction: ~35%

Strong anti-correlations between 0- and 2-jet fractions

Summary

- **MCatNLO NLO+PS MC are not bad!**
  - adequate simulation of lepton/MET/jet kinematics of fixed order QCD NNLO calculations;
  - suitable model of basic event selection efficiency provided that the selection is not too aggressive.

- **Modeling of jet fractions…**
  - For pT threshold around 20-30 GeV, MCatNLO NLO+PS models the NNLO effect well;
  - Residual theoretical uncertainties remain, theoretical uncertainty gets larger at lower jet pT threshold.
  - ATLAS took the jet fractions from MCatNLO MC, but assigned theoretical uncertainties of 10%, 6% and 35% to the 0-, 1- and 2-jet fractions…. for now.