H→WW→ lvlv Final State Differential Cross-section: Generators, Agreements, Plans and Few Results

Tiesheng Dai, Javier Cuevas Maestro, Jianming Qian

Third LHC Higgs Cross Section Workshop
Nov. 4-5, 2010 at Bari, Italy

Generators for MC Productions

ATLAS (Both NLO and LO generators are used)

- **Signals : MC@NLO (GGF), PYTHIA, HERWIG and SHERPA. Plan to include POWHEG for 2010 MC productions**
- **Backgrounds : MC@NLO, gg2WW, PYTHIA, HERWIG, ALPGEN, POWHEG …**

CMS:

- **Signals and qq→WW (NLO only): POWHEG and MC@NLO**
- **Other Backgrounds (NLO and LO): ALPGEN, PYTHIA, MADGRAPH, POWHEG/PYTHIA, POWHEG/HERWIG and gg2WW**

gg2WW LO only with published cross-section at 14GeV, any possibility goes to NLO and published/official cross-section at 7TeV?

Generators for H→WW→lvlv XS

GGF:

- **HNNLO (Massimiliano Grazzini, Daniel de Florian, ... http://theory.fi.infn.it/grazzini/codes.html) Major program for cross-section and K-factor studies of NNLO, NLO and LO**
- **FEHIPro (C. Anastasiou, F. Petriello, K. Melnikov, S. Bucherer, ... http://www.phys.ethz.ch/~pheno), MCFM, HIGLU, MC@NLO and POWHEG for cross checks, and MC production related studies.**

VBF:

- **HAWK (A. Mueck, A. Denner, S. Dittmaier http://heptools.inp.demokritos.gr/node/2920) Major program for cross-section and K-factor studies of NLO and LO**
- **VV2H (M. Spira http://people.web.psi.ch/spira/vv2h/), MCFM and POWHEG for cross checks, and MC production related studies.**

Basic Parameters

Parameter	ATLAS	CMS
Top mass/width (GeV)	**172.5/1.320**	**172.5/1.454**
W mass/width (GeV)	**80.403/2.141**	**80.419/2.048**
Z mass/width (GeV)	**91.1876/2.4952**	**91.188/2.441**

ATLAS NLO generator (MC@NLO parameters)

Parameter	Value	Parameter	Value
sin2thW_eff	0.23113	1/alphaem (at Z pole mass)	127.934
CKM_Vud	0.9748	CKM_Vus	0.2225
CKM_Vub	0.0036	CKM_Vcd	0.2225
CKM_Vcs	0.9740	CKM_Vcb	0.041
CKM_Vtd	0.009	CKM_Vts	0.0405
CKM_Vtb	0.9992	u mass	0.32GeV
d mass	0.32GeV	s mass	0.50GeV
c mass	1.55GeV	b mass	4.95GeV
g mass	0.75GeV		

Agreed to use the proposal for common parameters for cross-sections to for ATLAS and CMS:
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SMInputParameter

Cuts

CMS and ATLAS agreed to use a set of simple cuts to start the differential cross-section studies:

1) Pt_l1/l2 > 20 GeV, |eta_l1/l2|<2.5
2) MET > 30 GeV
3) mass(ll) >12 GeV
4) pt_jet_max < 30 GeV for |eta|<3.

Also agreed that future common interested cuts could be introduced, and will scan cuts to study the K-factor dependences on cuts.

Work Plans

1. **Good understanding of GGF H→WW→lvlv differential cross-sections and K-factors, where scan of K-factors on different cuts will be done to see any K-factor dependence on cuts;**
2. **Next move to studies on VBF H→WW→lvlv**
3. **Background studies of qq→WW (how to deal with gg→WW, only LO generator is available?)**
4. **Theoretical uncertainty studies**
5. **- What is a cut on the jet veto for WW and H→WW?**
   - What kind systematic uncertainties must be included and how to combine them in a proper way?
   - Can the theoretical and experimental uncertainties be considered as uncorrelated?

Aims

- **Tools to reweight MC events for acceptance calculations**
- **Tools to provide K-factors**
- **Tools to obtain differential cross-sections**
- **Tools to get theoretical uncertainties**

Above tools will be function of PDF, generator and certain cuts

Results on gluon-gluon fusion qq→ H → WW → lvlv

HNNLO

1. **Easy to use, where user manual only 4 pages.**
2. **Basic cuts have been implemented on lepton Pt, eta, missing Pt, jet (KT algorithm) veto and isolations. Also it is pretty easy to add addition cuts such as mass of two leptons.**
3. **CPU times: 20 minutes for LO, few hours for NLO, few days for NNLO, where CPU time could be issue during scans on cuts and systematic and theoretical uncertainty studies.**

Note: HNNLO calculates the cross sections in the large mtop limit. So it's cross sections may not be unreliable for Higgs mass above ~150 GeV, cross-checks are necessary.

Comparing LO Cross-section (No Cuts)

PDF : HNNLO MSTW2008LO,
PYTHIA HWLHAPDF 20650 (mLO pdf)

ggF qq → H → WW → evev

HMass (GeV),	PYTHIA (fb),	HNNLO (fb),	ratio (PYTHIA/HNNLO)								
110	4.39	4.175	1.05	120	11.614	10.226	1.14	130	21.631	18.400	1.18
140	31.013	25.876	1.20	150	37.159	30.683	1.21	160	42.22	32.903	1.28
165	42.079	31.112	1.35	170	39.507	29.893	1.32	180	33.974	25.703	1.32
190	25.568	18.763	1.36	200	21.551	15.596	1.38	220	17.207	11.740	1.47
240	14.064	9.142	1.54	260	11.957	7.243	1.65	280	10.333	5.813	1.78
300	9.187	4.716	1.95	400	6.17	1.617	3.82	500	2.426	0.690	3.52
600	1.006	0.353	2.85								

Two set cross-sections have large difference : Is HNNLO calculation reliable on cross-sections and K-factor? What's the right way to use K-factor (for instance, a lot of cases, people directly apply K-factor to LO cross-sections from PYTHIA)?

Comparing NLO Cross-section (No Cuts)

PDF : HNNLO MSTW2008NLO,
MC@NLO LHAPDF 10550 CTEQ66,

ggF qq → H → WW → evev

HMass (GeV),	MC@NLO (fb),	HNNLO (fb),	ratio (MC@NLO/HNNLO)				
110	7.835	7.444	1.05	120	19.275	18.377	1.05
130	34.085	33.318	1.02	140	46.945	47.179	1.00
150	54.935	56.383	0.97	160	61.028	60.780	1.00
170	56.485	54.651	1.03	180	47.845	47.170	1.01
190	35.488	34.588	1.02	200	29.68	28.867	1.03
220	23.035	21.889	1.05	240	18.433	17.147	1.08
260	15.28	13.667	1.12	280	12.983	11.019	1.19
300	11.39	8.974	1.27				

Reasonable agreement are observed for most Higgs mass up to 220GeV within 5%, does it mean that HNNLO NLO cross-sections are reliable? Will cross check with other available NLO MC generators.

Comparing NNLO, NLO XS (No Cuts)

PDF : HNNLO MSTW2008NNLO, MSTW2008NLO,

ggF qq → H → WW → evev

HMass (GeV),	NNLO (fb),	NLO (fb),	ratio (NNLO/NLO)								
110	9.359	7.444	1.26	120	23.189	18.377	1.26	130	41.715	33.318	1.25
140	59.312	47.179	1.26	150	70.597	56.383	1.25	160	76.271	60.780	1.25
170	68.493	54.651	1.25	180	58.867	47.170	1.25	190	43.414	34.588	1.26
200	36.117	28.867	1.25	220	27.130	21.889	1.24	240	21.358	17.147	1.25
250	19.000	15.285	1.24	260	17.117	13.667	1.25	280	13.649	11.019	1.24
300	11.161	8.974	1.24	320	9.132	7.375	1.24	340	7.543	6.118	1.23
350	6.882	5.567	1.24	360	6.094	4.940	1.23	380	4.793	3.878	1.24
400	3.895	3.123	1.25	450	2.440	1.977	1.23	500	1.663	1.345	1.24
550	1.174	0.952	1.23	600	0.859	0.691	1.24				

K-factor of NNLO to NLO almost constants vs Higgs Mass

0 jet bin, μμ Comparison

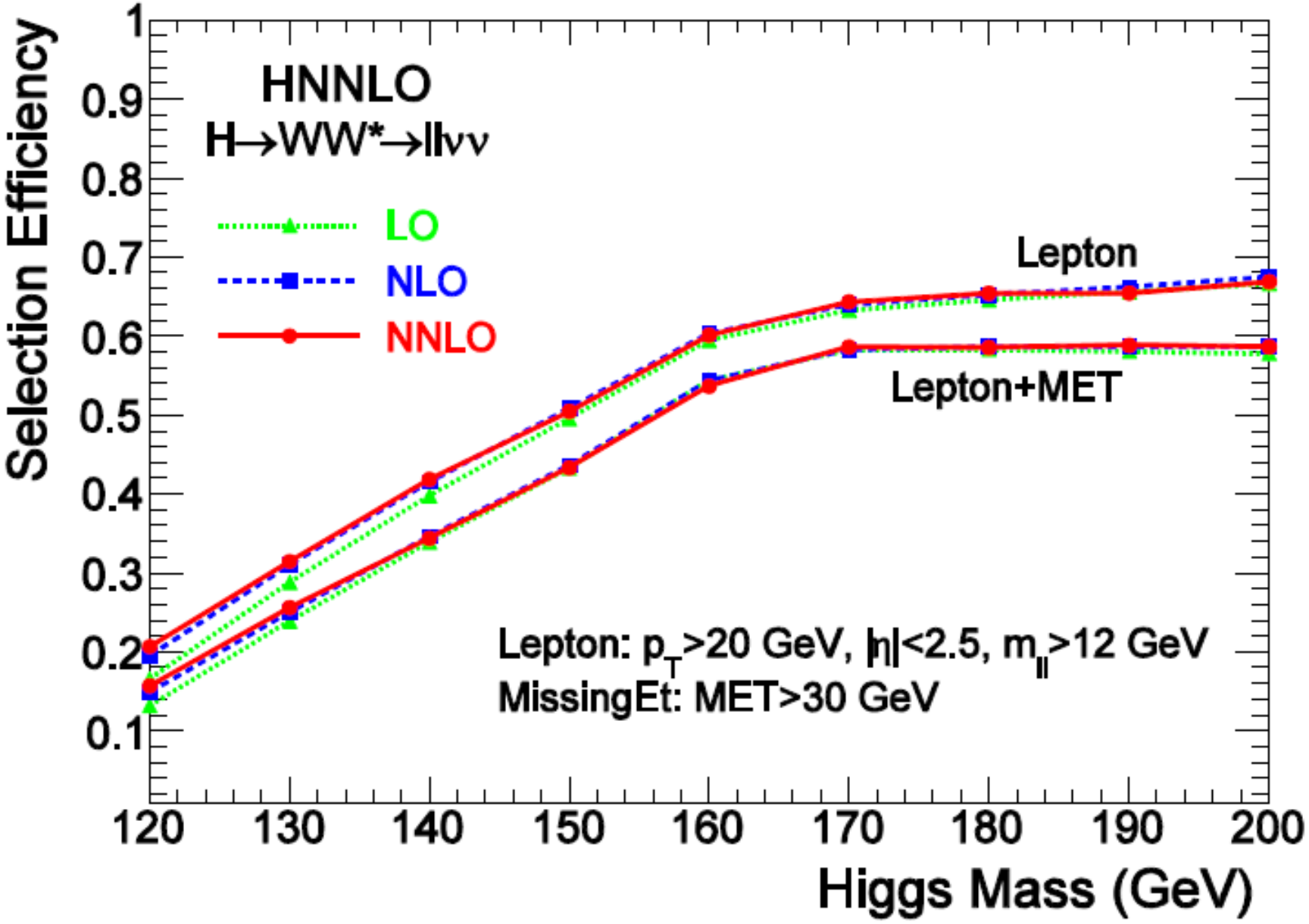
1fb-1	HWW160	WW	tt	WZ	ZZ	S/Sqrt(B)
CMS	10.78	3.83	0.52	0.15	0.08	**5.04**
ATLAS	19.75	19.18	2.87	0.77	0.49	**4.09**

1fb-1	HWW130	WW	tt	WZ	ZZ	S/Sqrt(B)
CMS	5.64	14.65	2.34	0.46	0.40	**1.33**
ATLAS	5.13	19.18	2.87	0.77	0.49	**1.06**

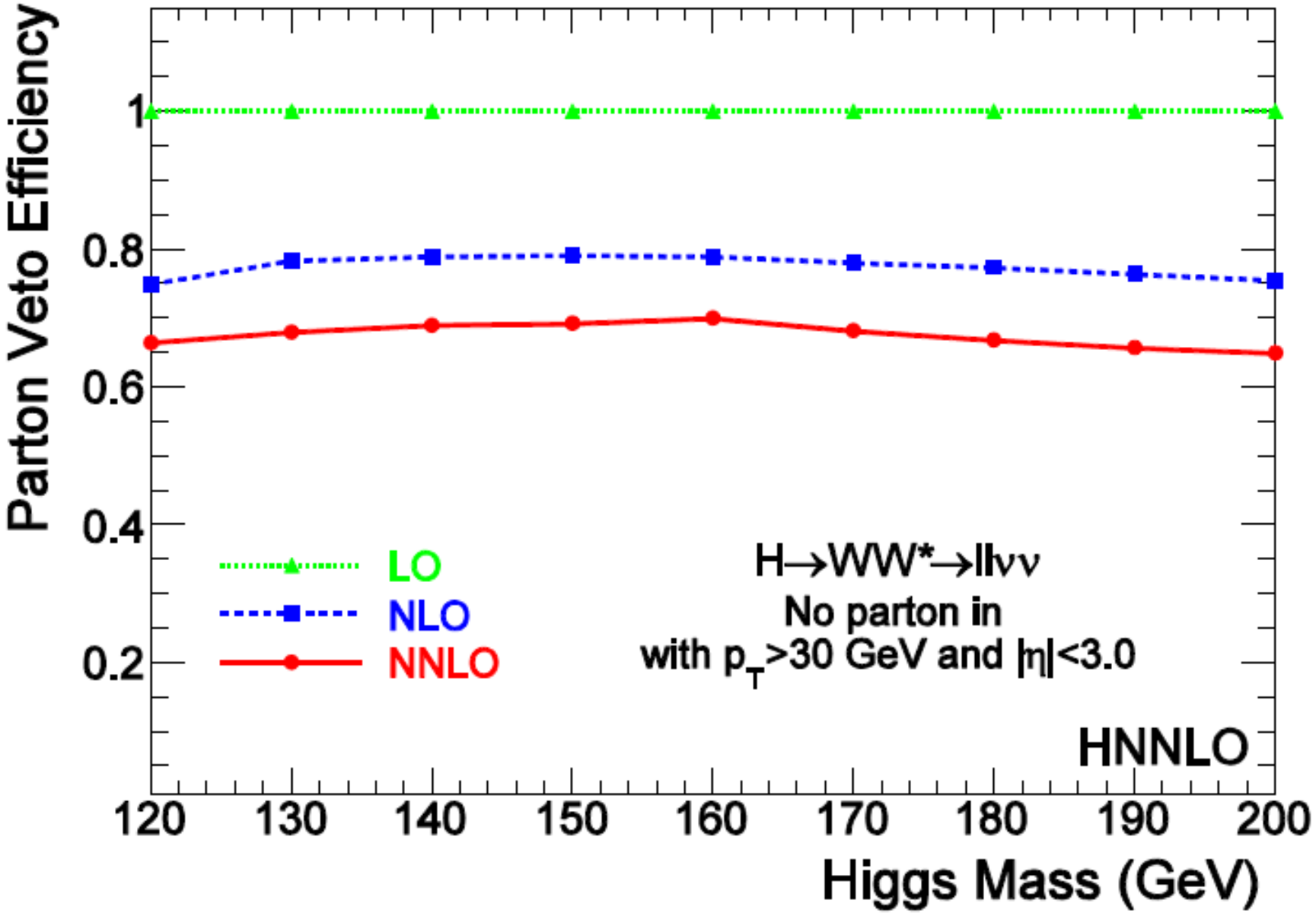
1fb-1	HWW190	WW	tt	WZ	ZZ	S/Sqrt(B)
CMS	2.55	1.74	1.30	0.31	0.20	**1.35**
ATLAS	6.92	19.18	2.87	0.77	0.49	**1.43**

*W+jets, Z+jets no events remain after all the cuts

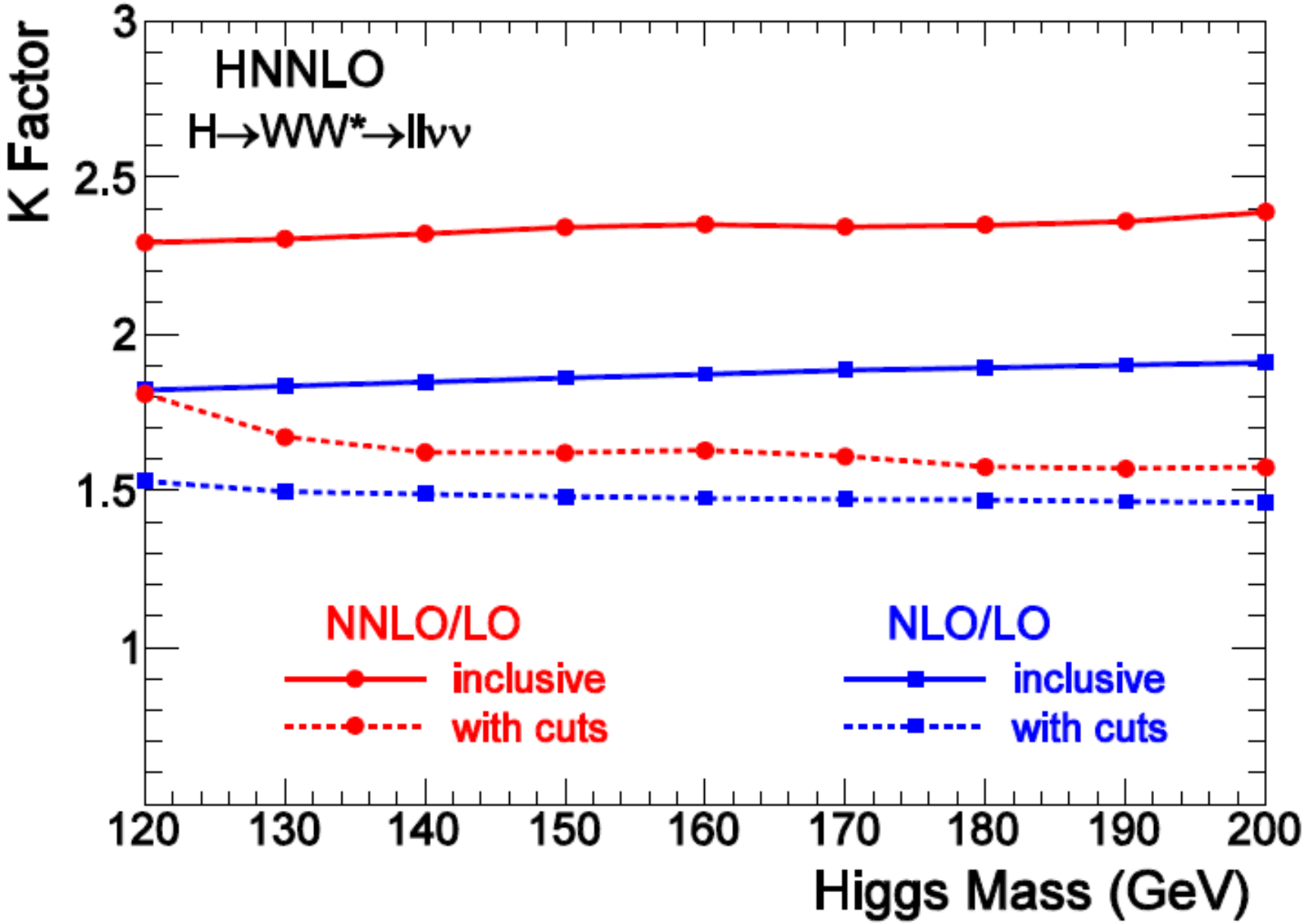
Lepton + MET Selection



Jet (Parton) Veto



K-Factor


HNNLO
H→WW*→lνlν
K Factor
3
2.5
2
1.5
1
120
130
140
150
160
170
180
190
200
Higgs Mass (GeV)
NNLO/LO
inclusive
with cuts
NLO/LO
inclusive
with cuts