

Generator Validation

W+012j inclusive sample validation (MG5 v3.5.2 vs v2.9.18)

Yilin ZHOU

Fudan University

June 28, 2024

Cross section of MGv2 LO

Table 1: cross section information of MGv2 LO

progress	xsec_before[pb]	xsec_match[pb]	accepted[%]
0	30990.00 ± 136.80	26778.66 ± 119.99	86.41
1	21430.00 ± 438.30	3999.97 ± 84.13	18.67
2	14430.00 ± 245.50	1701.84 ± 31.75	11.79
3	23120.00 ± 123.20	20034.48 ± 108.21	86.65
4	15190.00 ± 361.20	2844.86 ± 69.55	18.73
5	11580.00 ± 275.90	1322.58 ± 33.74	11.42
total	116700.00 ± 702.00	56681.07 ± 345.91	48.57

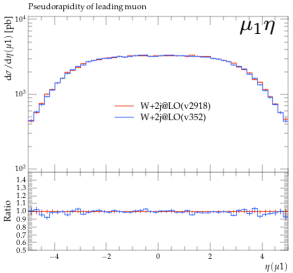
Cross section of MGv3 LO

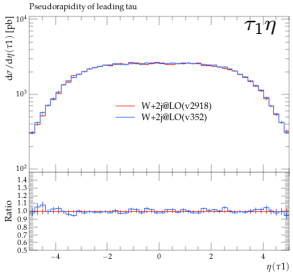
Table 2: cross section information of MGv3 LO

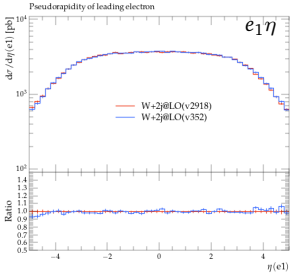
progress	xsec_before[pb]	xsec_match[pb]	accepted[%]
0	31200.00 ± 135.30	26978.47 ± 118.80	86.47
1	21240.00 ± 451.50	4000.84 ± 87.26	18.84
2	14970.00 ± 258.60	1759.90 ± 33.26	11.76
3	23090.00 ± 126.00	20018.65 ± 110.65	86.70
4	15460.00 ± 374.30	2867.06 ± 71.33	18.55
5	10970.00 ± 240.70	1249.12 ± 29.69	11.39
total	116900.00 ± 709.20	56861.21 ± 349.87	48.64

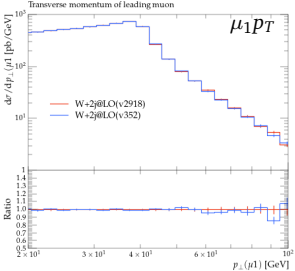
- The cross-section values of LO are consistent between MGv2 and MGv3.

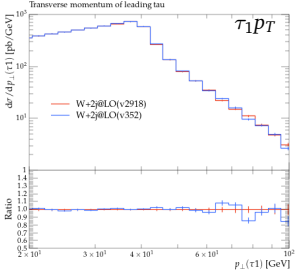
Kinetic Distribution of Leptons [LO]

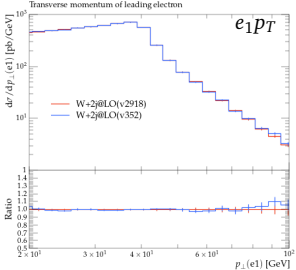




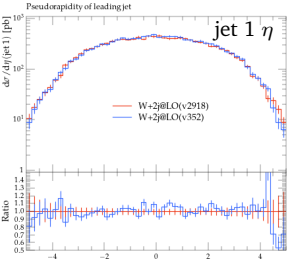


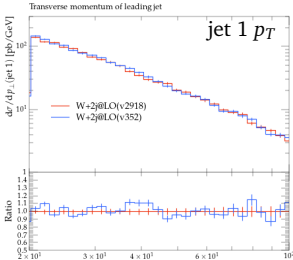


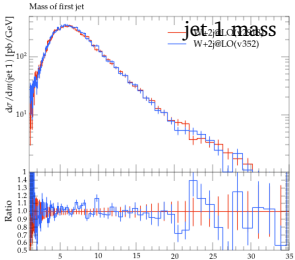


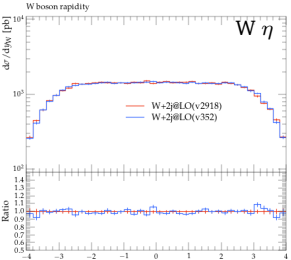


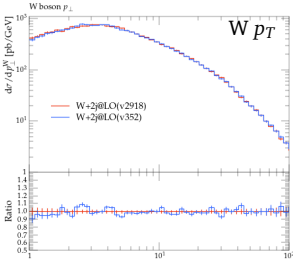
Kinetic Distribution of W and jet [LO]

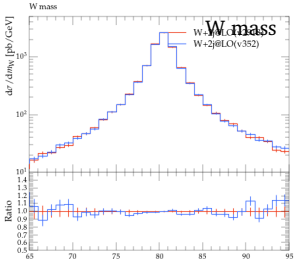












NLO process card

```
set low_mem_multicore_nlo_generation True

#import model loop_sm-ckm_no_b_mass
#switch to diagonal ckm matrix if needed for speed
import model loop_sm-no_b_mass

define ell+ = mu+ ta+
define ell- = mu- ta-

generate p p > ell+ vl $$ t t~ h [QCD] @0
add process p p > ell+ vl j $$ t t~ h [QCD] @1
add process p p > ell+ vl j j $$ t t~ h [QCD] @2

add process p p > ell- vl~ $$ t t~ h [QCD] @3
add process p p > ell- vl~ j $$ t t~ h [QCD] @4
add process p p > ell- vl~ j j $$ t t~ h [QCD] @5

output wellnu012j_5f_NLO_FXFX -nojpeg
```

- Use loop_sm-no_b_mass model;
- Remove e from ell.

Cross section of MGv2 NLO

Table 3: cross section information of MGv2 NLO

progress	xsec_before[pb]	xsec_match[pb]	accepted[%]
0	22400.00 ± 70.14	19515.33 ± 64.43	87.12
1	12910.00 ± 54.09	3359.81 ± 33.15	26.02
2	5711.00 ± 49.29	1259.48 ± 25.81	22.05
3	16760.00 ± 50.63	14602.43 ± 47.52	87.13
4	9589.00 ± 46.55	2539.68 ± 28.52	26.49
5	4239.00 ± 40.32	908.59 ± 21.40	21.43
total	71610.00 ± 129.00	42034.34 ± 107.46	58.70

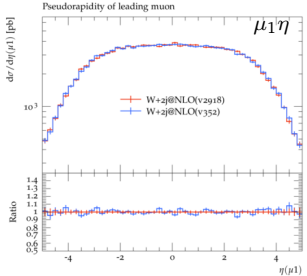
Cross section of MGv3 NLO

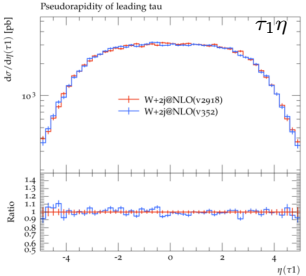
Table 4: cross section information of MGv3 NLO

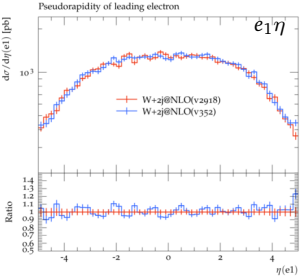
progress	xsec_before[pb]	xsec_match[pb]	accepted[%]
0	22470.00 ± 71.02	19629.92 ± 65.38	87.36
1	11730.00 ± 50.67	3212.91 ± 32.33	27.39
2	6697.00 ± 87.37	1309.96 ± 31.06	19.56
3	16680.00 ± 56.39	14562.34 ± 52.36	87.30
4	8806.00 ± 47.53	2406.76 ± 28.30	27.33
5	4963.00 ± 45.04	998.46 ± 23.00	20.12
total	71350.00 ± 150.70	41956.50 ± 118.33	58.80

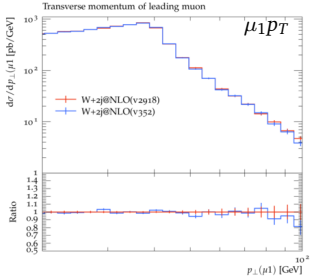
- The cross-section values of NLO are consistent between MGv2 and MGv3.

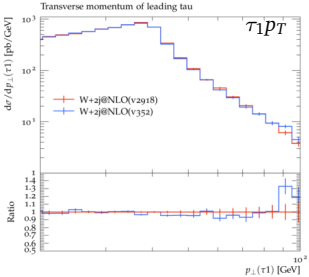
Kinetic Distribution of Leptons [NLO]

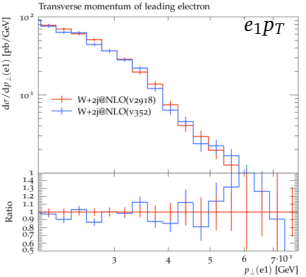




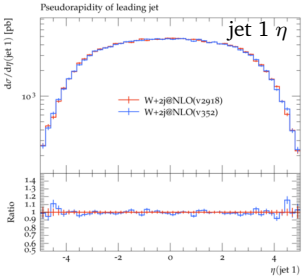


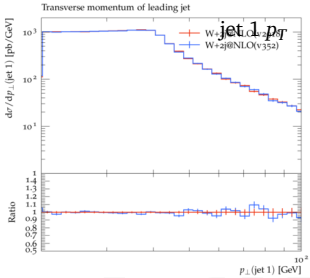


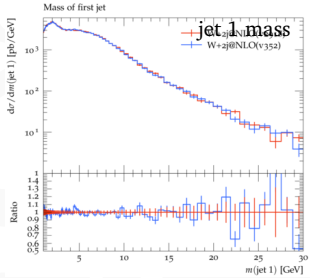




Kinetic Distribution of jet [NLO]







Issue about W [NLO]

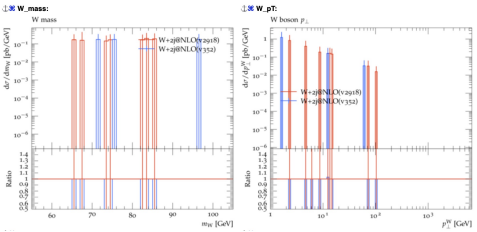


Figure 1: example

# xlow	xhigh	val	errminus	errplus	
1.000000e+00	1.092258e+00	0.000000e+00	0.000000e+00	0.000000e+00	
1.092258e+00	1.193027e+00	0.000000e+00	0.000000e+00	0.000000e+00	
1.193027e+00	1.303093e+00	0.000000e+00	0.000000e+00	0.000000e+00	
1.303093e+00	1.423313e+00	0.000000e+00	0.000000e+00	0.000000e+00	
1.423313e+00	1.554624e+00	0.000000e+00	0.000000e+00	0.000000e+00	
1.554624e+00	1.698050e+00	0.000000e+00	0.000000e+00	0.000000e+00	
1.698050e+00	1.854708e+00	0.000000e+00	0.000000e+00	0.000000e+00	
1.854708e+00	2.025819e+00	0.000000e+00	0.000000e+00	0.000000e+00	
2.025819e+00	2.212717e+00	0.000000e+00	0.000000e+00	0.000000e+00	
2.212717e+00	2.416857e+00	8.302758e-01	8.302760e-01	8.302760e-01	
2.416857e+00	2.639830e+00	0.000000e+00	0.000000e+00	0.000000e+00	
2.639830e+00	2.883375e+00	0.000000e+00	0.000000e+00	0.000000e+00	
2.883375e+00	3.149388e+00	0.000000e+00	0.000000e+00	0.000000e+00	
3.149388e+00	3.439943e+00	0.000000e+00	0.000000e+00	0.000000e+00	
3.439943e+00	3.757304e+00	0.000000e+00	0.000000e+00	0.000000e+00	
3.757304e+00	4.103944e+00	0.000000e+00	0.000000e+00	0.000000e+00	
4.103944e+00	4.482564e+00	0.000000e+00	0.000000e+00	0.000000e+00	
4.482564e+00	4.896115e+00	4.003156e-01	4.003157e-01	4.003157e-01	
4.896115e+00	5.347819e+00	0.000000e+00	0.000000e+00	0.000000e+00	
5.347819e+00	5.841196e+00	0.000000e+00	0.000000e+00	0.000000e+00	
5.841196e+00	6.380091e+00	-3.286091e-01	3.286091e-01	3.286091e-01	
6.380091e+00	6.968703e+00	0.000000e+00	0.000000e+00	0.000000e+00	
6.968703e+00	7.611619e+00	0.000000e+00	0.000000e+00	0.000000e+00	
7.611619e+00	8.313849e+00	0.000000e+00	0.000000e+00	0.000000e+00	
8.313849e+00	9.080865e+00	1.890490e-01	1.890489e-01	1.890489e-01	
9.080865e+00	9.918644e+00	0.000000e+00	0.000000e+00	0.000000e+00	
9.918644e+00	1.083371e+01	0.000000e+00	0.000000e+00	0.000000e+00	
1.083371e+01	1.183321e+01	0.000000e+00	0.000000e+00	0.000000e+00	
1.183321e+01	1.292491e+01	1.569668e-01	1.569669e-01	1.569669e-01	
1.292491e+01	1.411733e+01	1.639682e-01	1.639682e-01	1.639682e-01	
1.411733e+01	1.541977e+01	1.471947e-01	1.471946e-01	1.471946e-01	
1.541977e+01	1.684236e+01	0.000000e+00	0.000000e+00	0.000000e+00	
1.684236e+01	1.839619e+01	0.000000e+00	0.000000e+00	0.000000e+00	
1.839619e+01	2.009338e+01	0.000000e+00	0.000000e+00	0.000000e+00	

Figure 2: W_pt.dat

- Check the *.dat of W
- Very few non-zero values
- Another question: Why still have electrons even though we have removed them from ell definition?

Summary

- For LO:
  - xsec are consistent between MGv2 and MGv3.
  - Kinetic distributions are consistent between MGv2 and MGv3.
- For NLO:
  - xsec are consistent between MGv2 and MGv3.
  - Leptons and jets' distributions are consistent.
  - Some issues when generating kinetic distributions of W.

Thanks!

Source code: MC_WINC.cc

Two verisons of MC_WINC.cc:

```
/// Do the analysis
void analyze(const Event & e) {
  const double weight = e.weight();

  const WFinder& wfinder = applyProjection<WFinder>(e, "WFinder");
  if (wfinder.bosons().size() != 1) {
    vetoEvent;
  }

  double charge3_x_eta = 0;
  int charge3 = 0;
  FourMomentum emom;
  FourMomentum wmom(wfinder.bosons().front().momentum());
  _h_W_mass->fill(wmom.mass(), weight);
```

Figure 3: version one

```
/// Do the analysis
void analyze(const Event & event) {

  // MET cut
  const P4& pmiss = apply<MissingMom>(event, "MET").missingMom();
  if (pmiss.pT() < 25*GeV) vetoEvent;

  // Identify the closest-matching l+MET to m == mW
  const Particles& ls = apply<LeptonFinder>(event, "Leptons").particles();
  const int ifound = closestMatchIndex(ls, pmiss, Kin::mass, 80.4*GeV, 60*GeV, 100*GeV);
  if (ifound < 0) vetoEvent;
  const Particle& l = ls[ifound];

  double charge3_x_eta = 0;
  int charge3 = 0;
  FourMomentum wmom = l.mom() + pmiss;
  _h_W_mass->fill(wmom.mass()/GeV);
```

Figure 4: version one

Links of source code: Version 1 and Version 2.

- Ver.1 use ”WFinder” to reconstruct W
- Ver.2 add FourMomentum of lepton and MET as W

WFinder

```
/// Book histograms
void init() {
  FinalState fs;
  WFinder wfinder(fs, -3.5, 3.5, 25.0*GeV, PID::ELECTRON, 60.0*GeV, 100.0*GeV, 25.0*GeV, 0.2);
  addProjection(wfinder, "WFinder");
```

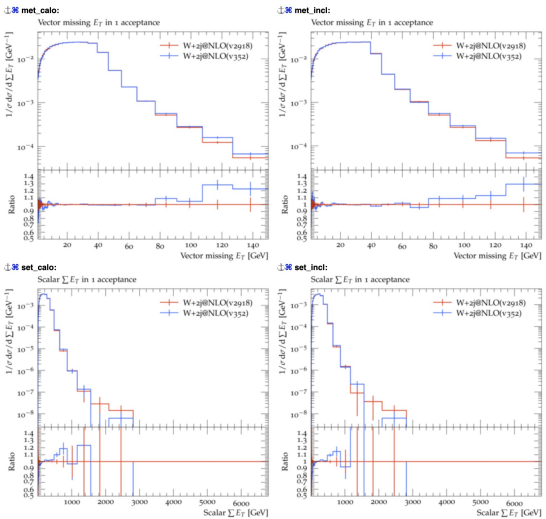
in MC_WINC.cc

```
WFinder(const FinalState& inputfs,
        double etaMin, double etaMax,
        double pTmin,
        PdgId pid,
        double minmass, double maxmass,
        double missingET,
        double dRmax=0.1, ClusterPhotons clusterPhotons=CLUSTERNODECAY, PhotonTracking trackPhotons=NOTRACK,
        MassWindow masstype=MASS, double masstarget=80.4*GeV) {
  vector<pair<double, double> > etaRanges;
  etaRanges += std::make_pair(etaMin, etaMax);
  _init(inputfs, etaRanges, pTmin, pid, minmass, maxmass, missingET,
        dRmax, clusterPhotons, trackPhotons, masstype, masstarget);
}
```

in WFinder.hh

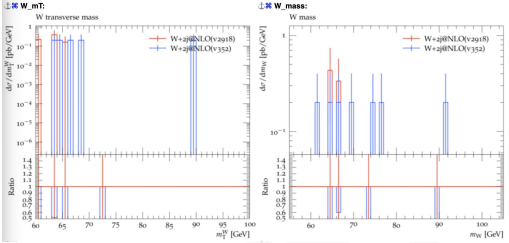
- WFinder also use MET imformation.

MC_MET



- Add MC_MET class into `/config/analysis/W/MC.dat`.
- Re-generate 10k events.

The same issue on W



- Still has the same issue due to few non-value in merged.yoda file.
- Maybe it's gridpack problem?
  - The same thing happens in the yoda files for both MGv2 and MGv3.
  - LO results are normal and MET plots are normal.
  - The only difference is process card.

Next step: re-generate NLO gridpack with previous settings

All W inclusive validation information on Gitlab: Validation_WINC_Gitlab

W issue solved

- In process card, if we remove electron from lepton definition, we will get some weird W related plots.
- This is likely due to rivet analysis code using electron to reconstruct W boson.
- Therefore, in this case, we will get very few W boson events.
- It can be resolved by adding e instead of μ in process card.

What happen in events generation via GS code

```
xz: (stdin): Unexpected end of input
tar: Unexpected EOF in archive
tar: Unexpected EOF in archive
tar: Error is not recoverable: exiting now
----- Begin Fatal Exception 19-Jun-2024 11:32:19 CEST-----------------------
An exception of category 'ExternalLHEProducer' occurred while
   [0] Processing global begin Run run: 1
   [1] Calling method for module ExternalLHEProducer/'externalLHEProducer'
Exception Message:
Child failed with exit code 2.
----- End Fatal Exception -------------------------------------------------
Another exception was caught while trying to clean up runs after the primary fatal exception.
```

Figure 5: MGv3_genval_run_result.log

```
**** Following environment variables are going to be unset.
     MAKEFLAGS
     MAKEFILES
     MAKELEVEL
     MAKEOVERRIDES
     MFLAGS
     PERL5LIB
     PERL_LOCAL_LIB_ROOT
     PERL_MB_OPT
     PERL_MM_OPT
     PYTHON3PATH
     PYTHONPATH

stty: standard input: Inappropriate ioctl for device
stty: standard input: Inappropriate ioctl for device
stty: standard input: Inappropriate ioctl for device
stty: standard input: Inappropriate ioctl for device
19-Jun-2024 12:54:48 CEST  Initiating request to open LHE file cmsgrid_final.lhe
19-Jun-2024 12:54:48 CEST  Successfully opened LHE file cmsgrid_final.lhe
19-Jun-2024 12:54:49 CEST  Initiating request to open LHE file cmsgrid_final.lhe
19-Jun-2024 12:54:49 CEST  Successfully opened LHE file cmsgrid_final.lhe
%MSG-w LogicError:  RivetAnalyzer:rivetAnalyzer@beginRun  19-Jun-2024 12:54:49 CEST Run: 1
::getByLabel: An attempt was made to read a Run product before endRun() was called.
The product is of type 'LHERunInfoProduct'.
The specified ModuleLabel was 'externalLHEProducer'.
The specified productInstanceName was ''.
```

Figure 6: MGv2_genval_run_result.log

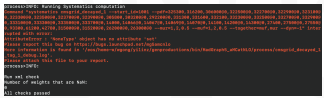


Figure 7: MGv3 runcmsgrid error

Links of log file: from MGv3 and from MGv2.

- Can not generate MGv3 events using `./genval-run` (MGv2 is fine).
- Also tried to generate MGv3 events locally using `./runcmsgrid.sh` in the corresponding gridpack file, got error like fig.7.

What happen in gridpack generation

From MGv3_genval_run_result.log, the error looks like can not read the gridpack tar ball successfully. So I checked the log file when generating them.

I found two diffs in MGv2 and v3 logs:

- Line 3740 in MGv2 and Line 4403 in MGv3, the total num is diff.
- Line 4680 in MGv2 and Line 5427 in MGv3
  - I checked the corresponding file like ”extended_cmd.py” or ”master_interface.py” in the error, they are truly diff in v2 and v3.

I don’t know if they will have an impact. Maybe there are some differences I didn’t find out. The gridpack generation log can be found in MGv3 and MGv2. BTW, MGv3 always needs more time than MGv2 when generating gridpack.

I have uploaded all relevant gridpacks and log files to GitLab: MGv3 NLO issue.

Two diffs in gridpack generation log

```
3731 INFO: Generating born process: b~ b > ta~ vt~ c s~ [ all = QCD ] $$ t t~ h @5
3732 INFO: Generating born process: b b~ > e~ ve~ c s~ [ all = QCD ] $$ t t~ h @6
3733 INFO: Generating born process: s~ u~ > e~ ve~ s~ d~ [ all = QCD ] $$ t t~ h @5
3734 INFO: Generating born process: c~ c~ > ta~ vt~ c~ s~ [ all = QCD ] $$ t t~ h @5
3735 INFO: Generating born process: b b~ > ta~ vt~ u d~ [ all = QCD ] $$ t t~ h @5
3736 INFO: Generating born process: s~ u~ > ta~ vt~ s~ d~ [ all = QCD ] $$ t t~ h @5
3737 INFO: Collecting infos and finalizing matrix elements...
3738 INFO: ... Done
3739 Writing directories...
3740 INFO: Writing files in P2_uu_tapvtud (26 / 164)
3741 INFO: Writing files in P2_ud_epvedd (31 / 164)
3742 INFO: Writing files in P0_udx_epve (1 / 164)
3743 INFO: Writing files in P1_udx_epveg (11 / 164)
3744 INFO: Writing files in P1_dxu_tapvtg (16 / 164)
3745 INFO: Writing files in P2_udx_tapvtddx (46 / 164)
3746 INFO: Writing files in P1_gu_tapvtd (6 / 164)
```

Figure 8: MGv2 diff 1

```
4395 INFO: Generating born process: s~ u~ > ta~ s~ d~ vt~ [ all = QCD QED ] QCD^2=6 QED^2=4 $$ t t~ h @6
4396 INFO: Generating born process: b~ b > ta~ u d~ vt~ [ all = QCD QED ] QCD^2=6 QED^2=4 $$ t t~ h @5
4397 INFO: Generating born process: c~ u > ta~ u s~ vt~ [ all = QCD QED ] QCD^2=6 QED^2=4 $$ t t~ h @5
4398 INFO: Generating born process: b~ b > ta~ c s~ vt~ [ all = QCD QED ] QCD^2=6 QED^2=4 $$ t t~ h @5
4399 INFO: Collecting infos and finalizing matrix elements, 520 left...
4400 INFO: Collecting infos and finalizing matrix elements, 28 left...
4401 INFO: ... Done
4402 Writing directories...
4403 INFO: Writing files in P2_udx_tapddxvt (46 / 192)
4404 INFO: Writing files in P2_uu_tapuvtd (26 / 192)
4405 INFO: Writing files in P0_udx_veep (1 / 192)
4406 INFO: Writing files in P2_ud_ddveep (31 / 192)
4407 INFO: Writing files in P1_dxu_tapvtg (16 / 192)
4408 INFO: Writing files in P1_udx_veepg (11 / 192)
4409 INFO: Writing files in P2_gdx_vxuaepg (21 / 192)
4410 INFO: Writing files in P2_uux_tapvtscx (36 / 192)
4411 INFO: Writing files in P1_gu_tapvtd (6 / 192)
```

Figure 9: MGv3 diff 1

```
4677 ell+ =|e+ ta+
4678 ell- = e- ta-
4679 quit
4680 copying generated process to working directory
4681
4682         WARNING: You've chosen not to use the PDF sets recommended for run3 production!
4683         If this isn't intentional, and you prefer to use the recommended sets,
4684         insert the following lines into your process_name_run_card.dat:
4685
4686             '$DEFAULT_PDF_SETS = lhaid'
4687             '$DEFAULT_PDF_MEMBERS = reweight_PDF'
4688
4689         or for nuclear PDF sets insert:
4690
4691             '$DEFAULT_nPDF_SETS = lhaid'
4692             '$DEFAULT_nPDF_MEMBERS = reweight_PDF'
4693
4694 copying run_card.dat file
4695 starting NLO mode
4696 No module named 'madgraph'
4697   No hepmc reader since No module named 'madgraph' ^[[1;30m[lhe_parser.py at line 60]^[[0m
4698 INFO: ********************************************************************
4699 *                                                                  *
4700 *           W E L C O M E  to  M A D G R A P H 5                    *
4701 *                       a M C @ N L O                              *
```

Figure 10: MGv2 diff 2

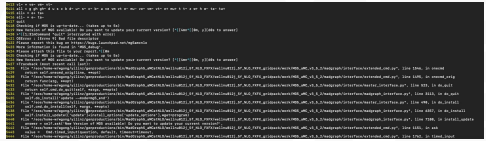


Figure 11: MGv3 diff 2

W012j gridpack issue solved

- The W012j NLO MGv3 issue has been solved by re-generating a new gridpack. (Don't know why)

NLO process card

```
set low_mem_multicore_nlo_generation True

#import model loop_sm-ckm_no_b_mass
#switch to diagonal ckm matrix if needed for speed
import model loop_sm-no_b_mass

define ell+ = e+ ta+
define ell- = e- ta-

generate p p > ell+ vl $$ t t~ h [QCD] @0
add process p p > ell+ vl j $$ t t~ h [QCD] @1
add process p p > ell+ vl j j $$ t t~ h [QCD] @2

add process p p > ell- vl~ $$ t t~ h [QCD] @3
add process p p > ell- vl~ j $$ t t~ h [QCD] @4
add process p p > ell- vl~ j j $$ t t~ h [QCD] @5

output wellnu012j_5f_NLO_FXFX -nojpeg
```

- Use loop_sm-no_b_mass model;
- Remove μ from ell.

Cross section comparison v2 and v3

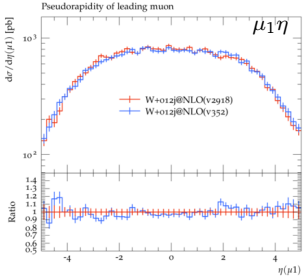
Table 5: cross section information of W012j NLO

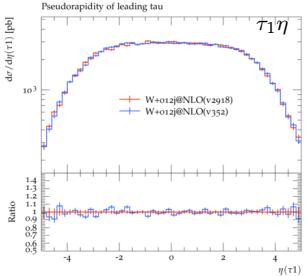
progress	xsec_before[pb]	xsec_match[pb]	accepted[%]
W^++0j	22400.00 ± 70.14	19515.33 ± 64.43	87.12
	22470.00 ± 71.02	19629.92 ± 65.38	87.36
W^++1j	12910.00 ± 54.09	3359.81 ± 33.15	26.02
	11730.00 ± 50.67	3212.91 ± 32.33	27.39
W^++2j	5711.00 ± 49.29	1259.48 ± 25.81	22.05
	6697.00 ± 87.37	1309.96 ± 31.06	19.56
W^-+0j	16760.00 ± 50.63	14602.43 ± 47.52	87.13
	16680.00 ± 56.39	14562.34 ± 52.36	87.30
W^-+1j	9589.00 ± 46.55	2539.68 ± 28.52	26.49
	8806.00 ± 47.53	2406.76 ± 28.30	27.33
W^-+2j	4239.00 ± 40.32	908.59 ± 21.40	21.43
	4963.00 ± 45.04	998.46 ± 23.00	20.12
total	71610.00 ± 129.00	42034.34 ± 107.46	58.70
	71350.00 ± 150.70	41956.50 ± 118.33	58.80

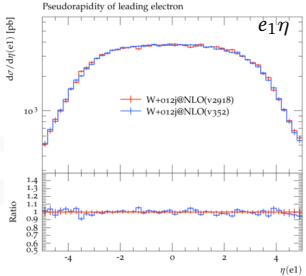
The first line is MGv2, second line is MGv3.

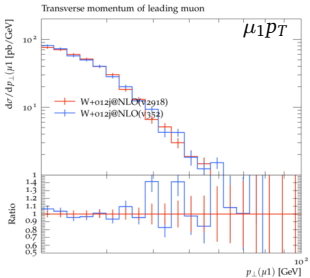
Discrepancy in some progress.
Total xsec is consistent.

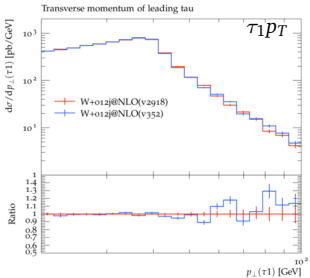
Kinetic Distribution of Leptons [NLO]

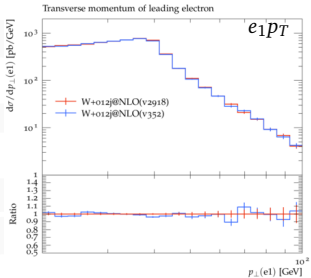




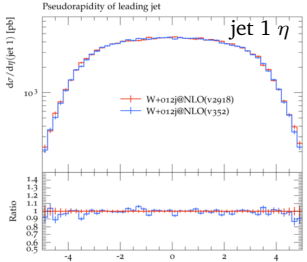


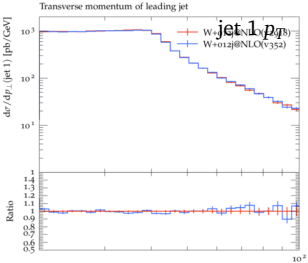


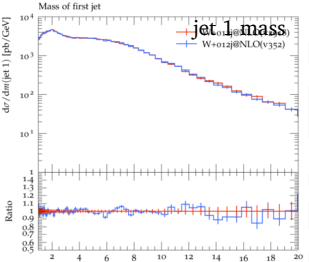


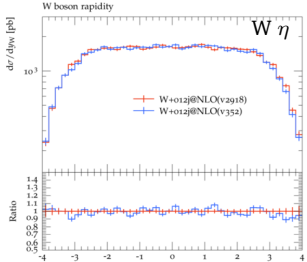


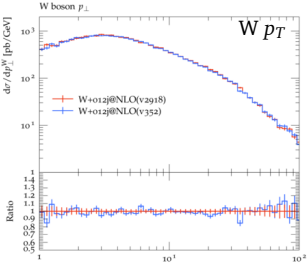
Kinetic Distribution of W and jet [NLO]

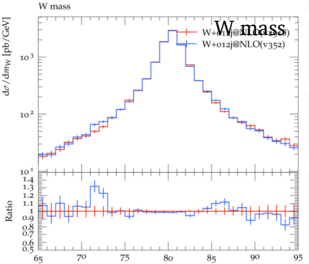












Summary

- For W up to 2jet NLO:
  - Totoal xsec are consistent between MGv2 and MGv3.
  - There are discrepancies of xsec in some progress.
  - Kinetic distributions are consistent.
- Until now, the results of MGv2 vs. MGv3 of W+01j and W+012j (LO and NLO) have been obtained.
- All codes and results have been uploaded on GitLab:Validation_WINC.

Thanks!