International Summer school on TeV Experimental Physics (iSTEP)

MC Tutorial

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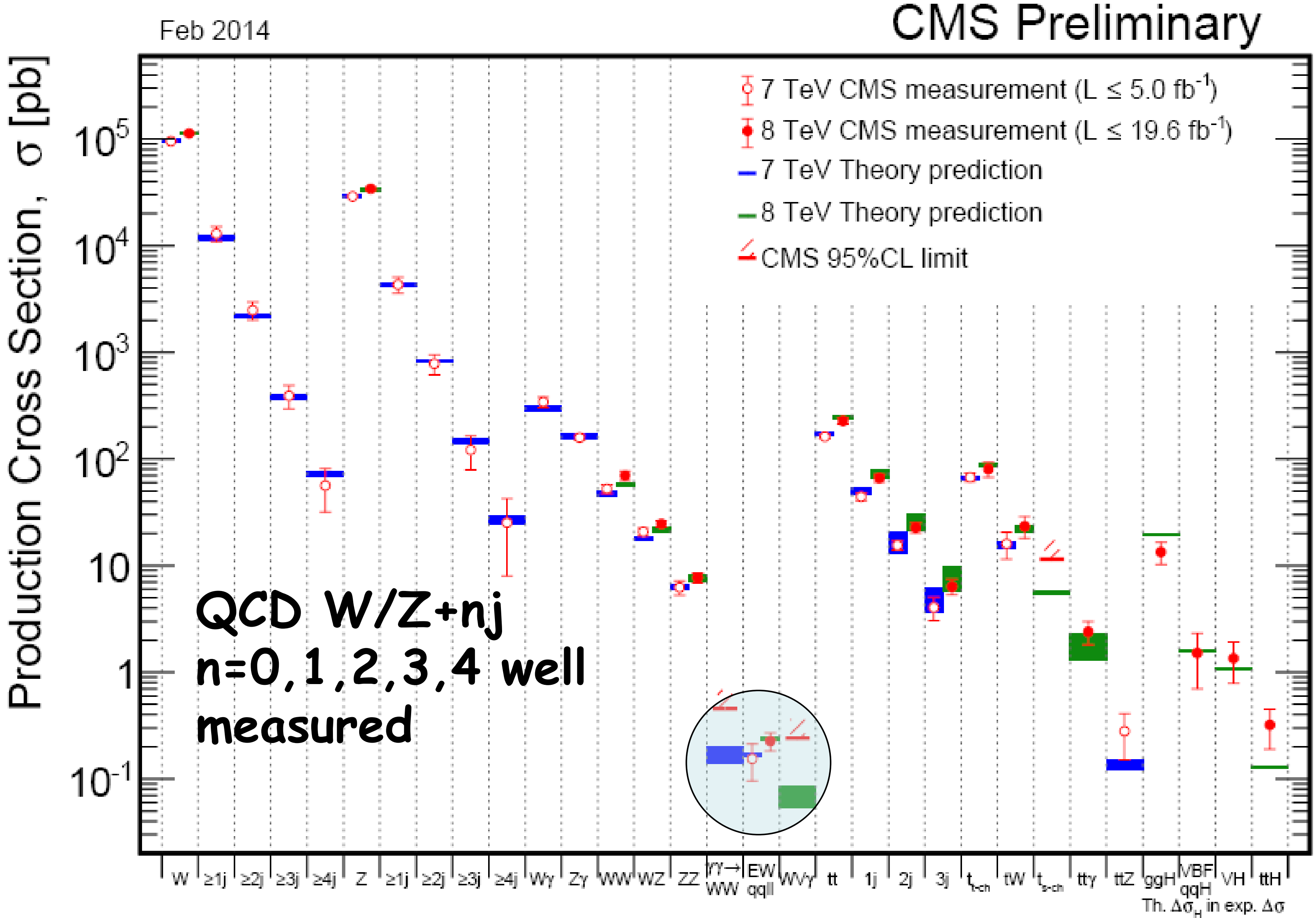
内容提要

- VBF W+2J: Physics Motivation
- MadGraph/MadEvent:

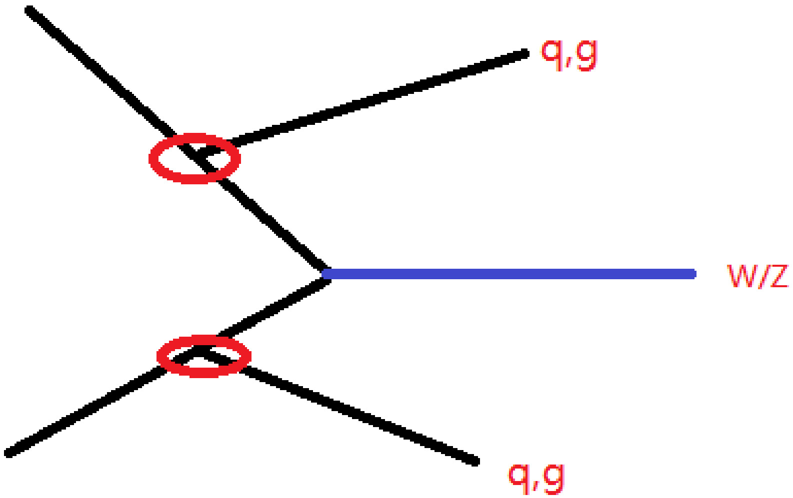
  Basic Instructions
  Les Houches Event (LHE) format
  Root Analysis
- VBFNLO: Basic Instructions
- Comparison Between MG and VBFNLO
- Signal/Bkg discrimination
- Raw Significance



EWK Z+2J recently measured by CMS/ATLAS

EWK W+2J@CMS is being analyzed by PKU

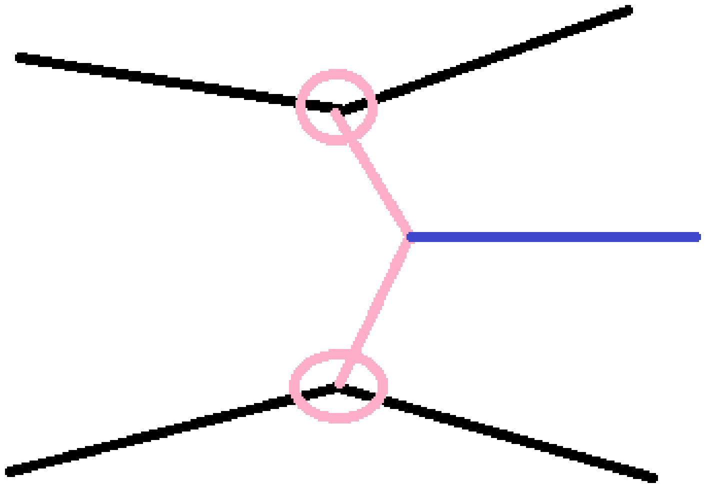
Background



QCD W+nj

alphas=gs^2~0.12

Signal



EWK W+2J

alpha~/128~0.0078

Xsec ratio: (alphas/aplha)^2~10000

However, the two favor different Phase space

Lumi 20fb-1
Xsec 100fb
Nevents: 10000

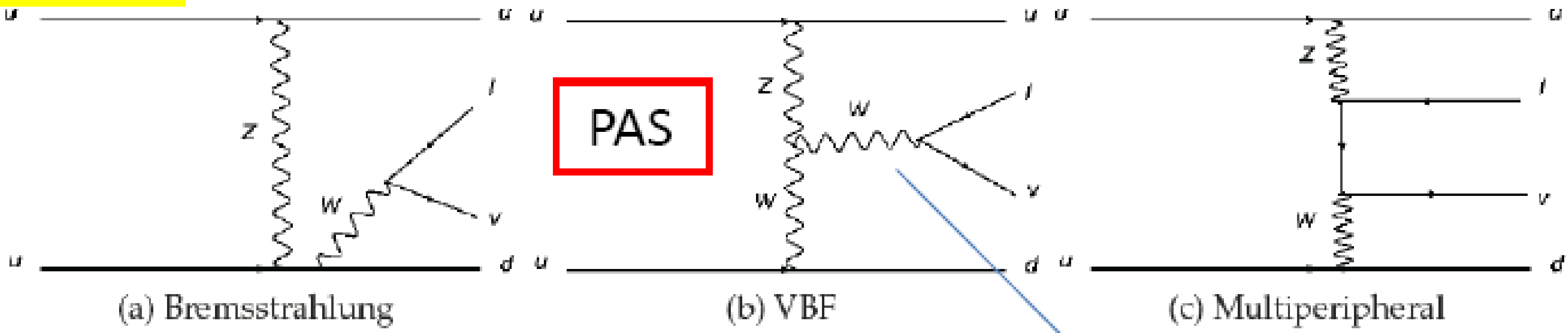
Xsec*Lumi=2000 events

Generated Lumi = 1000/100fb = 100fb-1

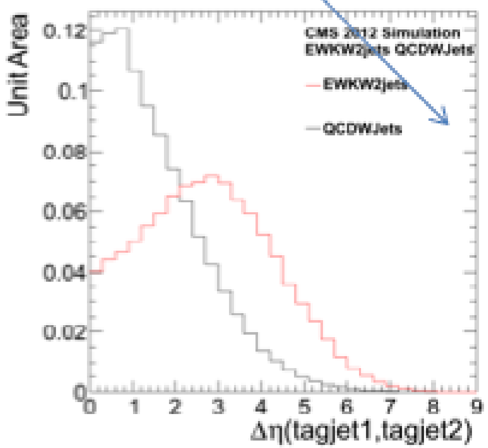
Lumi Weight (applied per event)
= 20fb-1/(10000/100fb)
=0.2

Pure EWK couplings, no QCD ones
Contains VBF diagrams, leading to VBF topology

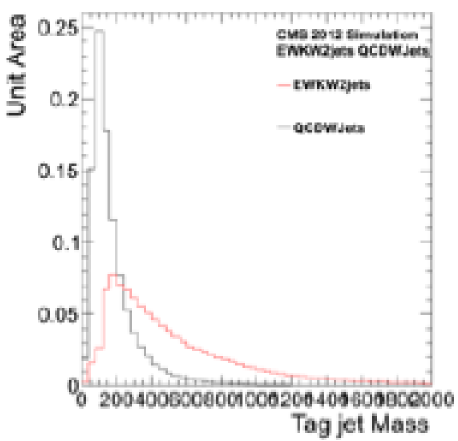
Signature



- SM process: first cross section measurement for EWK W+2jets
- Simplest VBF-like process with large cross section
- Background for SM Higgs in the VBF channel and in searching the invisible Higgs



Large Δη separation



Large dijet mass

Taking leading jets as VBF tagged ones
$\Delta\eta_{jj}$, and M_{jj} are good discriminants

$M_{jj} = \sqrt{(P_{j1} + P_{j2})^{\ 2}} = \sqrt{(E_{j1} + E_{j2})^2 - (Px1 + Px2)^2 - \cdots}$

$\Delta\eta_{jj} = |\boldsymbol{\eta}_{j1} - \boldsymbol{\eta}_{j2}|$

Zeppenfeld= $|\boldsymbol{\eta}_{\mathrm{W}} - (\boldsymbol{\eta}_{j1} + \boldsymbol{\eta}_{j2})/2|$

Tutorial Caveat:

A toy experiment

Parton level (no Parton shower, detector effects)
Parton=Jets: Always only 2 jets

Only main background considered (no Top, di-boson, Jet fake lepton…)

No MVA technique applied

No Systematics
Simple statistic analysis (S/sqrt(B))

Tutorial:

(a) You can either work on your own PC or

(b) Try our cluster

ATLAS 账户：atlas02, 密码： tutorial

CMS 账户：cms02, 密码： tutorial

CEPC 账户：cepc02, 密码： tutorial

After login:

(1) Setup root:

source /home/cms01/bin/setroot.sh

(2) cd /home/cms01/tutorial/qiang

have a look

[cms01@sl62-vm qiang]$ ls

example refs softwares

3 root macros under example

Tutorial: MadGraph/MadEvent

download from http://madgraph.phys.ucl.ac.be/
or
[cms02@sl62-vm ~]$ cp /home/cms01/tutorial/qiang/softwares/MG5_aMC_v2.1.2.tar.gz .

```
tar xzvf MG5_aMC_v2.1.2.tar.gz
cd MG5_aMC_v2_1_2/
./bin/mg5
MG5_aMC>tutorial
MG5_aMC>install ExRootAnalysis
```

Tutorial: MadGraph/MadEvent

generate p p > l- vl~ j j QCD=0 @1
add process p p > l+ vl j j QCD=0 @2
output EWKW2J

have a look at EWKW2J directories

launch EWKW2J
modify cards

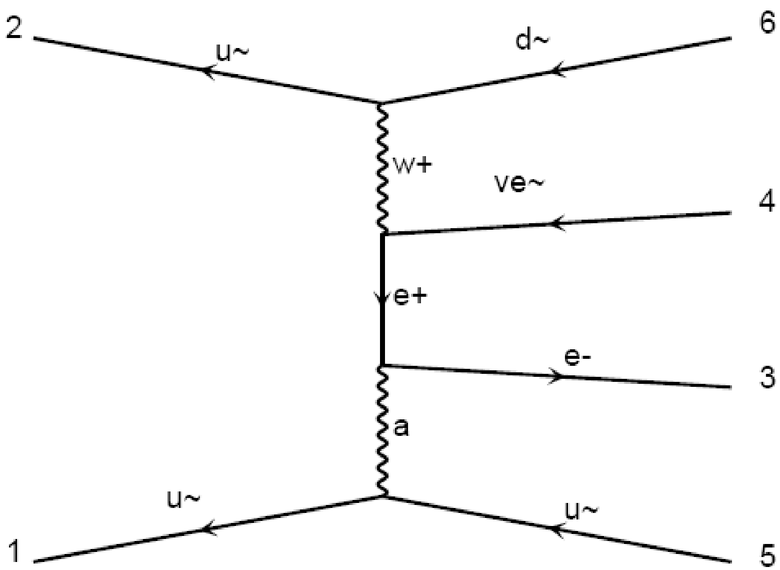


diagram 1 QCD=0, QED=4

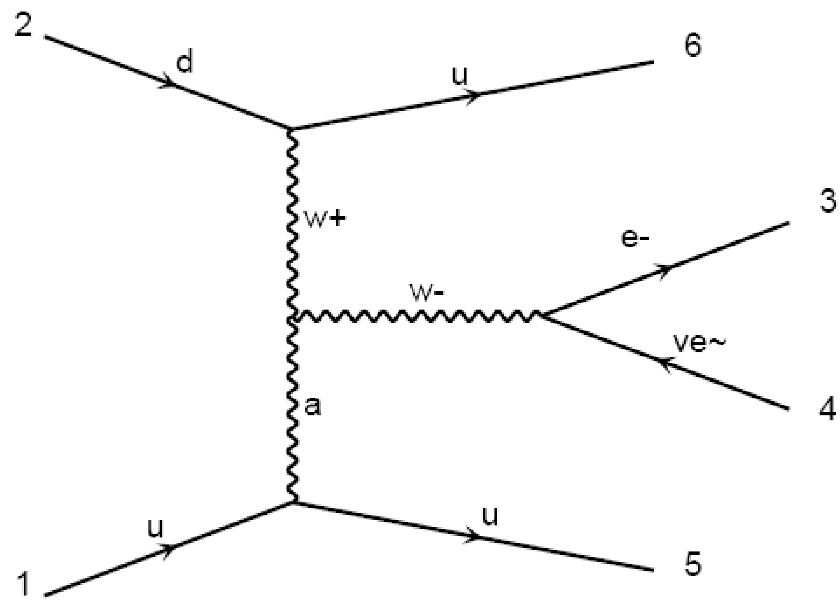


diagram 4 QCD=0, QED=4

/home/cms01/tutorial/qiang/example/MG5_aMC_v2_1_2/EWKW2J-QiangLi/Cards/run_card.dat

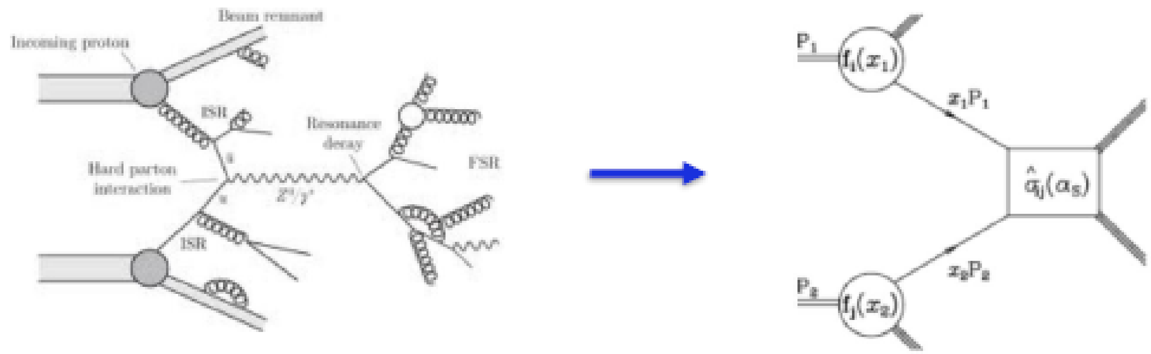
```
10000 = nevents ! Number of unweighted events requested
'cteq6l1'    = pdlabel     ! PDF set

F        = fixed_ren_scale  ! if .true. use fixed ren scale
F        = fixed_fac_scale  ! if .true. use fixed fac scale

91.1880  = scale            ! fixed ren scale
91.1880  = dsqrt_q2fact1    ! fixed fact scale for pdf1
91.1880  = dsqrt_q2fact2    ! fixed fact scale for pdf2
1        = scalefact        ! scale factor for event-by-event scales

1.0      = lhe_version      ! Change the way clustering information pass
to shower.
```

Theoretical Calculation



From Prof. JianBei Liu's slides

Physical cross section

Parton distribution function

Renormalization scale μ_R

$$\sigma(P_1, P_2) = \sum_{i,j} \int dx_1 dx_2\, f_i(x_1, \mu_F) f_j(x_2, \mu_F)\, \hat{\sigma}_{ij}(p_1, p_2, \alpha_S(\mu_R), Q^2, \mu_R, \mu_F).$$

Factorization scale μ_F

Short distance cross section, calculated as a perturbation series in α_S

- Factorization theorem makes theoretical calculations possible
  - by separating long-distance effects from short-distance behavior

Long-distance : universal PDFs (derived from data directly)
Short-distance: perturbative QCD (theoretically calculable)

/home/cms01/tutorial/qiang/example/MG5_aMC_v2_1_2/EWKW2J-QiangLi/Cards/run_card.dat

```
15  = bwcutoff      ! (M+/-bwcutoff*Gamma)

 10  = ptj       ! minimum pt for the jets
 10  = ptl       ! minimum pt for the charged leptons
  0  = misset    ! minimum missing Et (sum of neutrino's momenta)
   7  = etaj    ! max rap for the jets
 2.5  = etal    ! max rap for the charged leptons
 0.3 = drjj    ! min distance between jets
 0.4 = drjl    ! min distance between jet and lepton
 120   = mmjj    ! min invariant mass of a jet pair
```

/home/cms01/tutorial/qiang/example/MG5_aMC_v2_1_2/EWKW2J-QiangLi/Events/run_01

You will get unweighted LHE and root files

```
<event>
 7   0  0.5856700E-03  0.5518792E+02  0.7546771E-02  0.1474310E+00
       -2   -1    0    0    0  501  0.00000000000E+00  0.00000000000E+00
0.12767428260E+02  0.12767428260E+02  0.00000000000E+00 0.  1.
        2   -1    0    0  502    0  0.00000000000E+00  0.00000000000E+00 -
0.11863296737E+04  0.11863296737E+04  0.00000000000E+00 0. -1.
       24    2    1    2    0    0  0.44134326638E+02 -0.31296668413E+02 -
0.58882925980E+03  0.59667476739E+03  0.79834582770E+02 0.  0.
      -13    1    3    3    0    0  0.30023411440E+02  0.45120124514E+01 -
0.68533409604E+02  0.74957265978E+02  0.00000000000E+00 0.  1.
       14    1    3    3    0    0  0.14110915198E+02 -0.35808680864E+02 -
0.52029585019E+03  0.52171750141E+03  0.00000000000E+00 0. -1.
        1    1    1    2  502    0  0.12681548653E+02  0.31474390135E+02 -
0.49534499291E+03  0.49650591226E+03  0.00000000000E+00 0. -1.
       -2    1    1    2    0  501 -0.56815875291E+02 -0.17772172235E+00 -
0.89387992757E+02  0.10591642233E+03  0.00000000000E+00 0.  1.
</event>
```

Read arXiv:0609017 for more info

Cross-section :   5.857 +- 0.01803 pb

Check more the output under /Event/run_01

Rename unweighted_events.root as EWKWJJ.root

Try

/home/cms01/tutorial/qiang/example/plot/test1.C

root -b -q test1.C\(\"EWKWJJ\"\)

You will get Mjj histogram

Please try to get other distributions like $\Delta\eta_{jj}$

/home/cms01/tutorial/qiang/example/plot/test1.C

```
void test1(char* dataFileName)

// Load shared library
 gSystem-
>Load("/home/qliphy/Desktop/Tutorial/MG/MG5_aMC_v2_1_2/ExRootAnalysis/li
b/libExRootAnalysis.so");
 gSystem->Load("/home/qliphy/Desktop/common/root/lib/root/libPhysics.so");


 TString buffer = dataFileName;
     cout<<buffer<<endl;
     TString IFile = buffer + ".root";
     TString OFile ="test" + buffer+".root";

     float xsec;
     if(buffer=="EWKWJJ") {xsec=5.857;}
     if(buffer=="QCDWJJ") {xsec=723.8;}
     if(buffer=="V130") {xsec=1.743*2.0;}
     if(buffer=="V140") {xsec=1.104*2.0;}
```

/home/cms01/tutorial/qiang/example/plot/test1.C

```
// Create object of class ExRootTreeReader
 ExRootTreeReader *treeReader = new ExRootTreeReader(&chain);
 Long64_t numberOfEntries = treeReader->GetEntries();
// Get pointers to branches used in this analysis
 TClonesArray *branchEvent = treeReader->UseBranch("Event");
 TClonesArray *branchParticle = treeReader->UseBranch("Particle");

 float inix= 200.0;
 float finx= 2000.0;
 float nbin= 18.0;
 TH1F *h1= new TH1F(buffer+"_Mjj","test histogram",nbin,inix,finx);
 h1->Sumw2();

TLorentzVector J1, J2, JJ;
```

```
for(int i=0; i<=numberOfEntries-1; i++)
{
   J1.SetPtEtaPhiE(0.,0.,0.,0.);
   J2.SetPtEtaPhiE(0.,0.,0.,0.);

   treeReader->ReadEntry(i);
   TRootLHEFEvent *event=(TRootLHEFEvent*) branchEvent->At(0);

   int np=event->Nparticles;
   for(int j=2; j<np; j++) {
    TRootLHEFParticle *particle1=(TRootLHEFParticle*) branchParticle->At(j);
     if((abs(particle1->PID)<6 || (particle1->PID)==21) ) {
       if(J1.E()>0){
       J2.SetPtEtaPhiE(particle1->PT,particle1->Eta,particle1->Phi,particle1->E);
         }
       else{
       J1.SetPtEtaPhiE(particle1->PT,particle1->Eta,particle1->Phi,particle1->E);
         }
      }
    }
   JJ=J1+J2;
   h1->Fill(JJ.M(),xsec/float(numberOfEntries)/(finx-inix)*nbin);
```

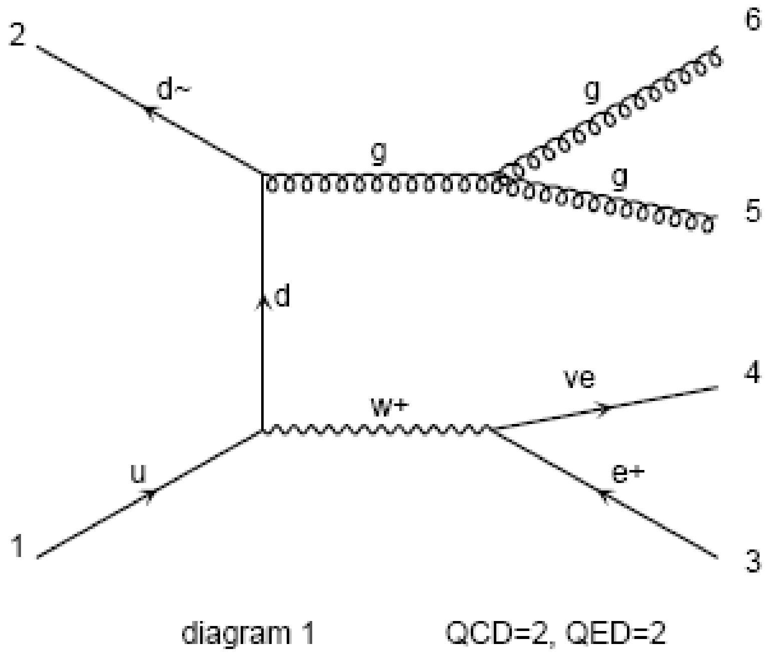
Now let's generate the QCD Bkg

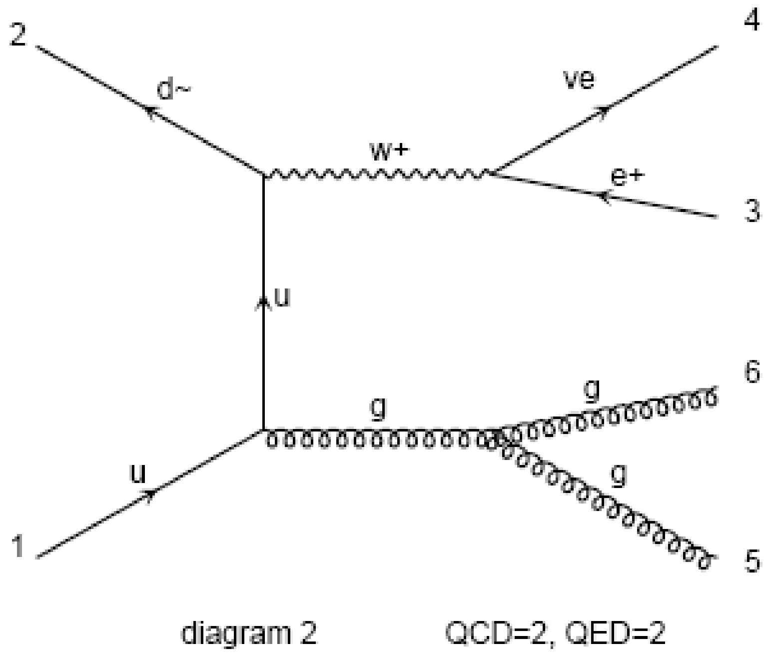
generate p p > l- vl~ j j QED=2 @1
add process p p > l+ vl j j QED=2 @2
output QCDW2J

have a look at QCDW2J directories

launch QCDW2J
modify cards (same as before)
Rename unweighted_events.root as
QCDWJJ.root
root -b -q test1.C\(\“QCDWJJ\"\)

Cross-section :   722.8 +- 0.9378 pb





Tutorial: VBFNLO

https://www.itp.kit.edu/~vbfnloweb/wiki/doku.php?id=overview

mkdir YourVBFNLO

/home/cms01/tutorial/qiang/example/VBFNLO/testrun/bin/vbfnlo **--** input=/home/cms01/tutorial/qiang/example/VBFNLO/testrun/share/LO 130

(Cards have been tuned to match previous MG runs)

Do twice:

PROCESS = 130 (W+) ! Identifier for process

or

PROCESS = 140 (W-) ! Identifier for process

130 LO: 1742.6962044343247 +-
1.4567136144307047 fb
140 LO: 1103.6925492789890 +-
0.92133563254564066 fb
Note: only ele channel

Note: 2846.4*2 fb=5.693 pb

The difference from MG is about 2%, and may be due to scale and other parameter settings

/home/cms01/tutorial/qiang/example/MG5_aMC_v2_1_2/ExRootAnalysis/ExRootLHEFConverter events.lhe V130.root

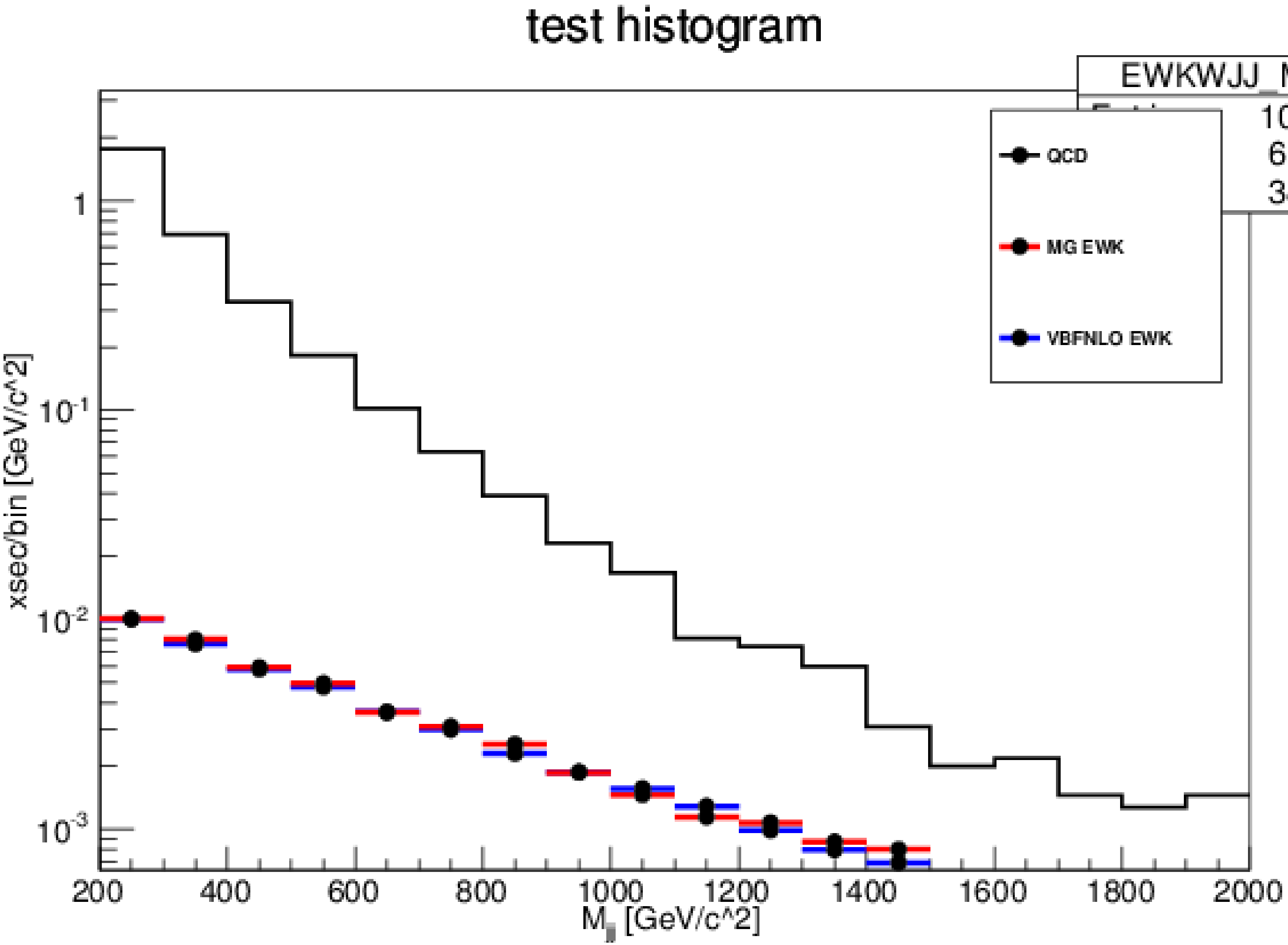
So for V140.root

root -b -q test1.C\(\“V130\"\)
root -b -q test1.C\(\“V140\"\)

/home/cms01/tutorial/qiang/example/plot/Compare.C

root –b

.x Compare.C


test histogram
EWKWJJ_Mjj
10000
612.5
382.6
QCD
MG EWK
VBFNLO EWK
xsec/bin [GeV/c^2]
1
10^{-1}
10^{-2}
10^{-3}
200
400
600
800
1000
1200
1400
1600
1800
2000
M_{jj} [GeV/c^2]

Tutorial: Simple Analysis

/home/cms01/tutorial/qiang/example/plot/test2.C

Do twice

TString buffer = "EWKWJJ“ **->S**

Or

TString buffer = “QCDWJJ“ **->B**

What is S/sqrt(B)?

Notice the cuts applied inside. Try to optimizing the results

/home/cms01/tutorial/qiang/example/plot/test2.C

```
if(L1.Pt()>30 && V1.Pt()>30 &&
W1.Mt()>30 && J1.Pt()>50 && J2.Pt()>50
&& abs(J1.Eta())<5. && abs(J2.Eta())<5. &&
JJ.M()>1000 && abs(J1.Eta()-J2.Eta())>2.0)
```

More to do:

Verify the top output file from VBFNLO

Using VBFNLO to get the NLO results and the K factors