

International Summer school on TeV Experimental Physics (iSTEP)

MC Tutorial

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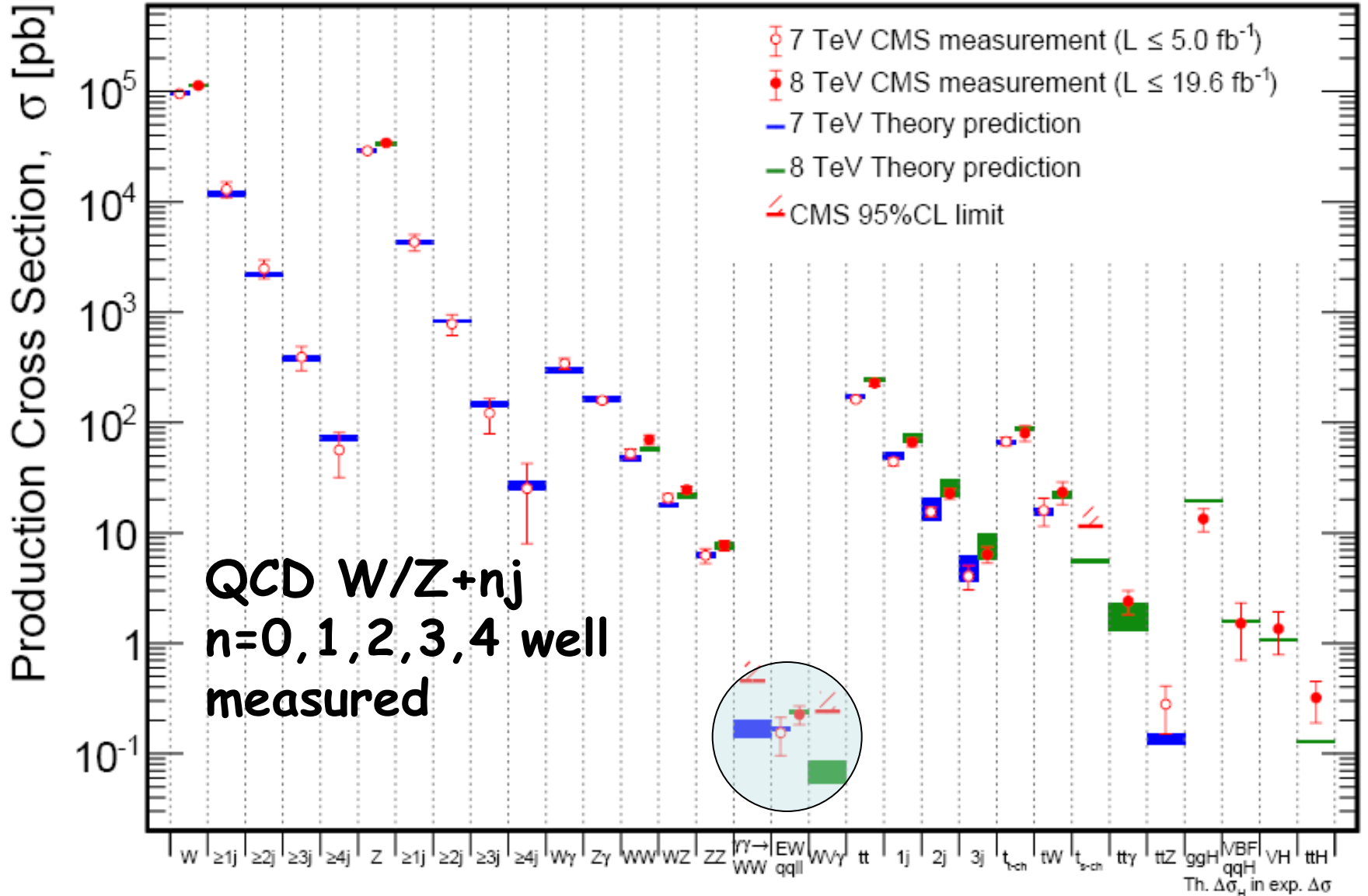


麻雀虽小五脏俱全



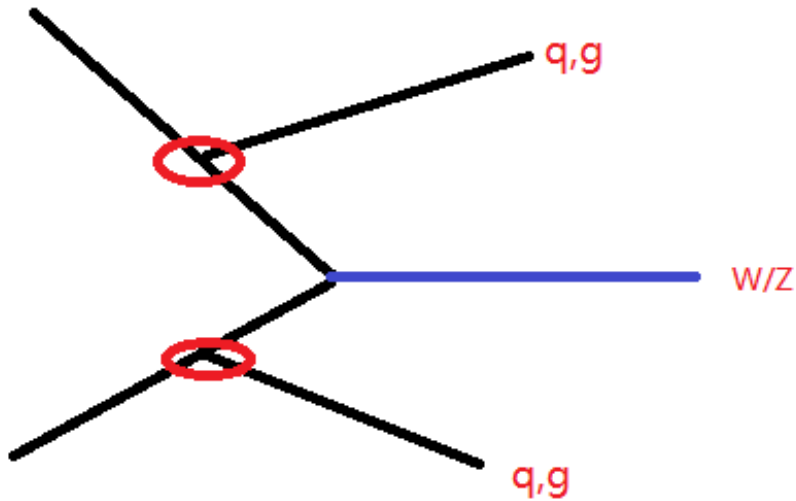
内容提要

- 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

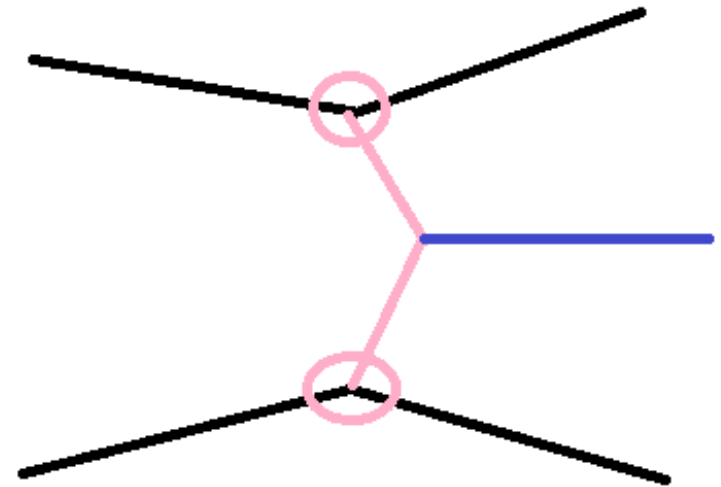
Background



QCD W+nj

$\alpha_s = g_s^2 \sim 0.12$

Signal



EWK W+2J

$\alpha \sim 1/128 \sim 0.0078$

Xsec ratio: $(\alpha_s/\alpha)^2 \sim 10000$

However, the two favor different Phase space

Lumi 20fb-1

Xsec 100fb

Nevents: 10000

$Xsec * Lumi = 2000 \text{ events}$

$Generated \text{ Lumi} = 1000 / 100fb = 100fb^{-1}$

Lumi Weight (applied per event)

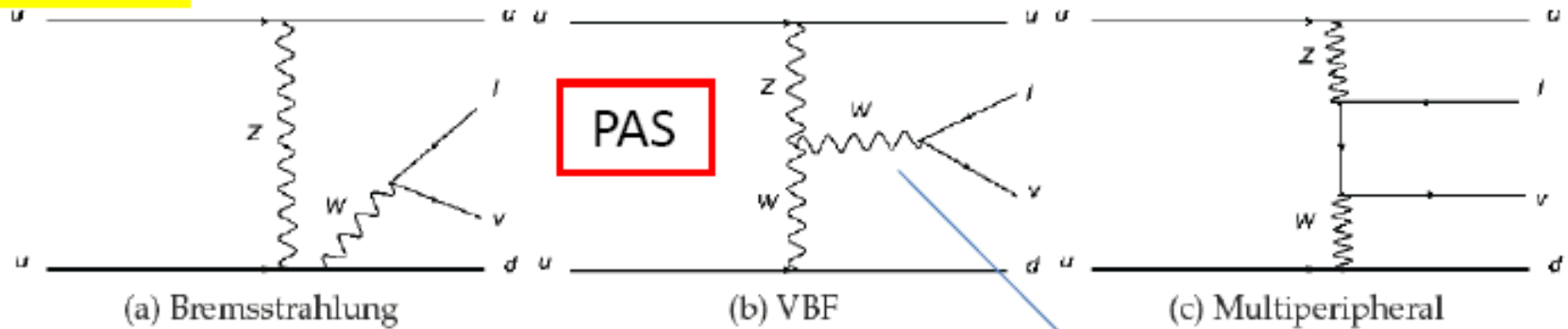
$= 20fb^{-1} / (10000 / 100fb)$

$= 0.2$

Pure EWK couplings, no QCD ones

Contains VBF diagrams, leading to VBF topology

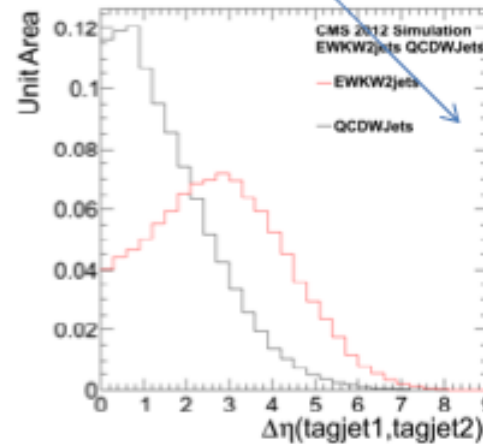
Signature



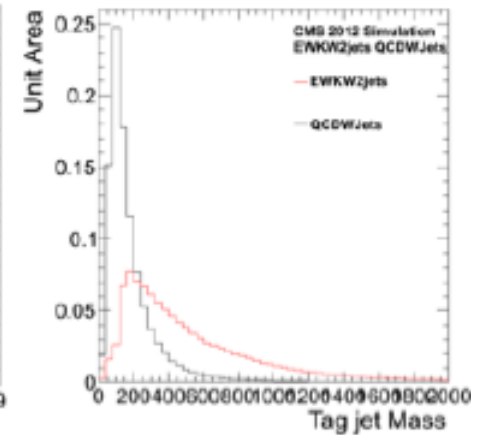
SM process: first cross section measurement for EWK W+2jets

Simplest VBF-like process with large cross section

Background for SM Higgs in the VBF channel and in searching the invisible Higgs



Large $\Delta\eta$ separation



Large dijet mass

Taking leading jets as VBF tagged ones

$\Delta\eta_{jj}$, and M_{jj} are good discriminants

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

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

$$\text{Zeppenfeld} = |\eta_w - (\eta_{j1} + \eta_{j2})/2|$$

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: cepec02, 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/software/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
```

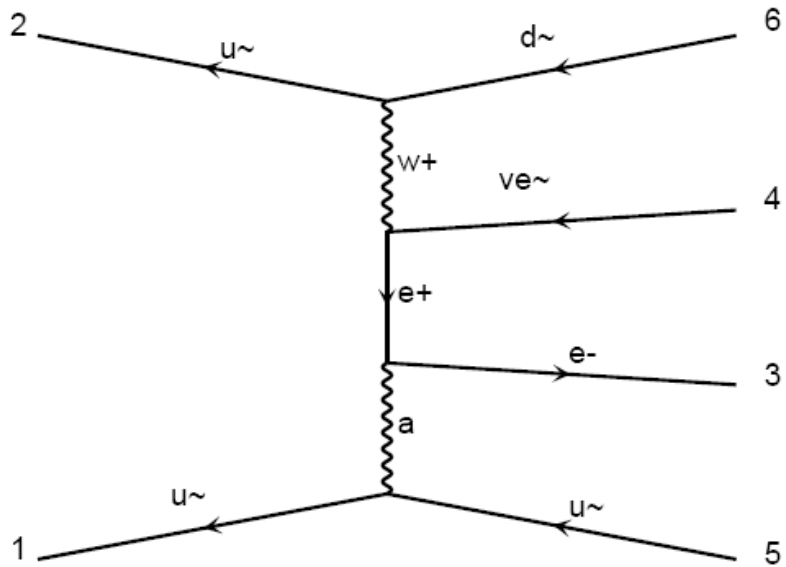


diagram 1

QCD=0, QED=4

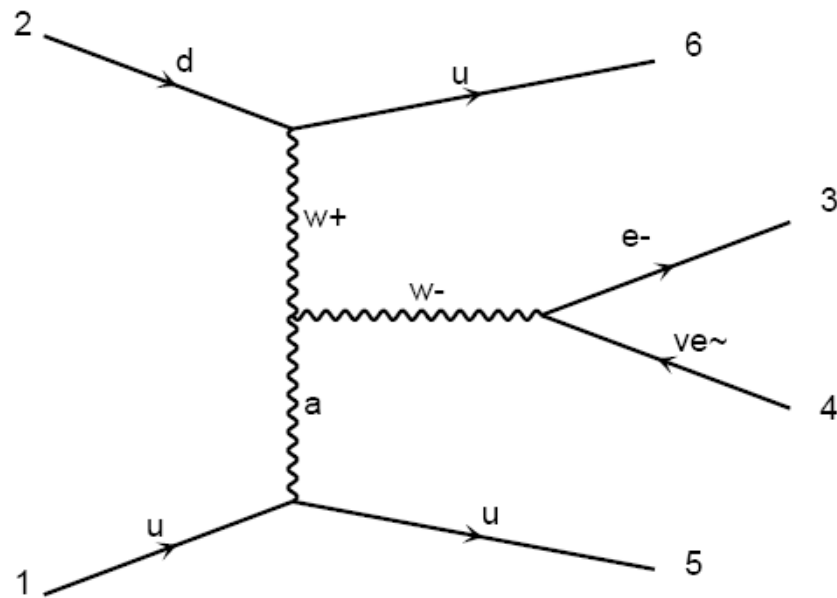


diagram 4

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

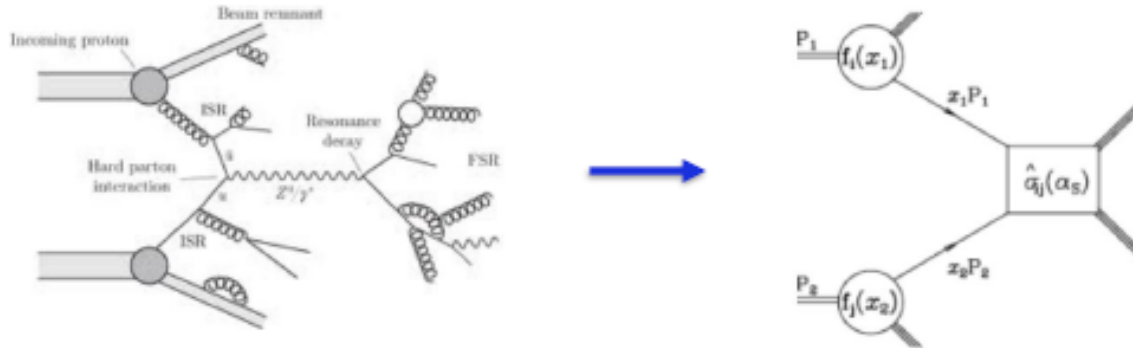
91.1880 = dsqrt_q2fact1 ! fixed fact scale for pdf1

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

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  0.000000000000E+00  0.000000000000E+00
0.12767428260E+02  0.12767428260E+02  0.000000000000E+00  0.  1.
    2  -1  0  0  502  0  0.000000000000E+00  0.000000000000E+00 -
0.11863296737E+04  0.11863296737E+04  0.000000000000E+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  0.000000000000E+00  0.  1.
    14  1  3  3  0  0  0.14110915198E+02 -0.35808680864E+02 -
0.52029585019E+03  0.52171750141E+03  0.000000000000E+00  0. -1.
    1  1  1  2  502  0  0.12681548653E+02  0.31474390135E+02 -
0.49534499291E+03  0.49650591226E+03  0.000000000000E+00  0. -1.
    -2  1  1  2  0  501 -0.56815875291E+02 -0.17772172235E+00 -
0.89387992757E+02  0.10591642233E+03  0.000000000000E+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/lib/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 : $722.8 \pm 0.9378 \text{ pb}$

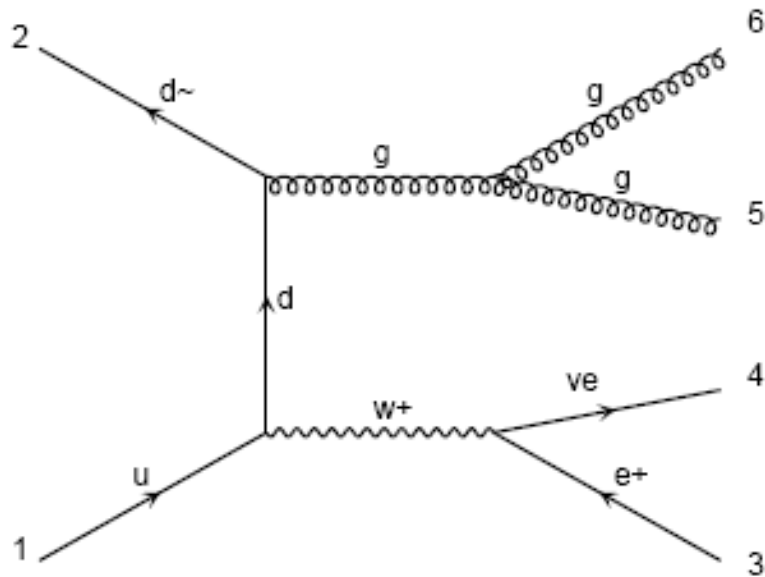


diagram 1

QCD=2, QED=2

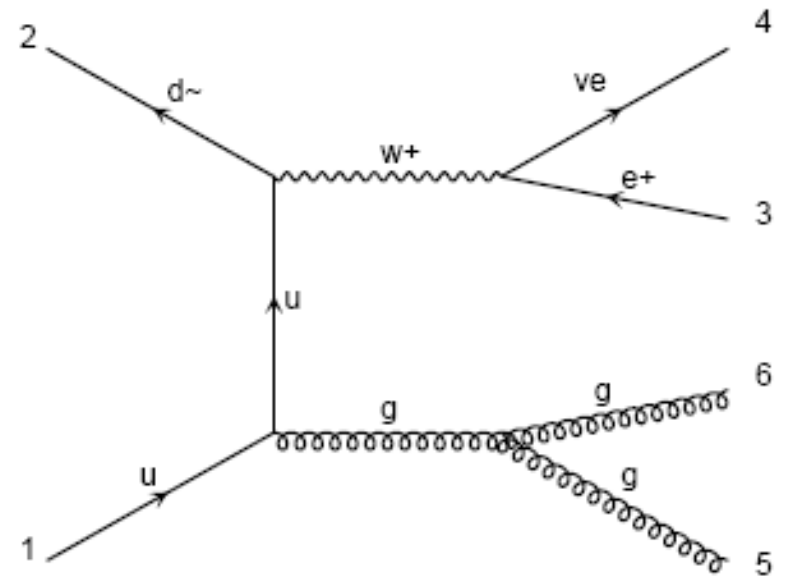


diagram 2

QCD=2, QED=2

Tutorial: VBFNLO

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

```
mkdir YourVBFNLO
```

```
/home/cms01/tutorial/qiang/example/VBFNLO/testrun/bin/vbfno --  
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: $2846.4 * 2 \text{ fb} = 5.693 \text{ pb}$

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\(\“V130\”\)
```

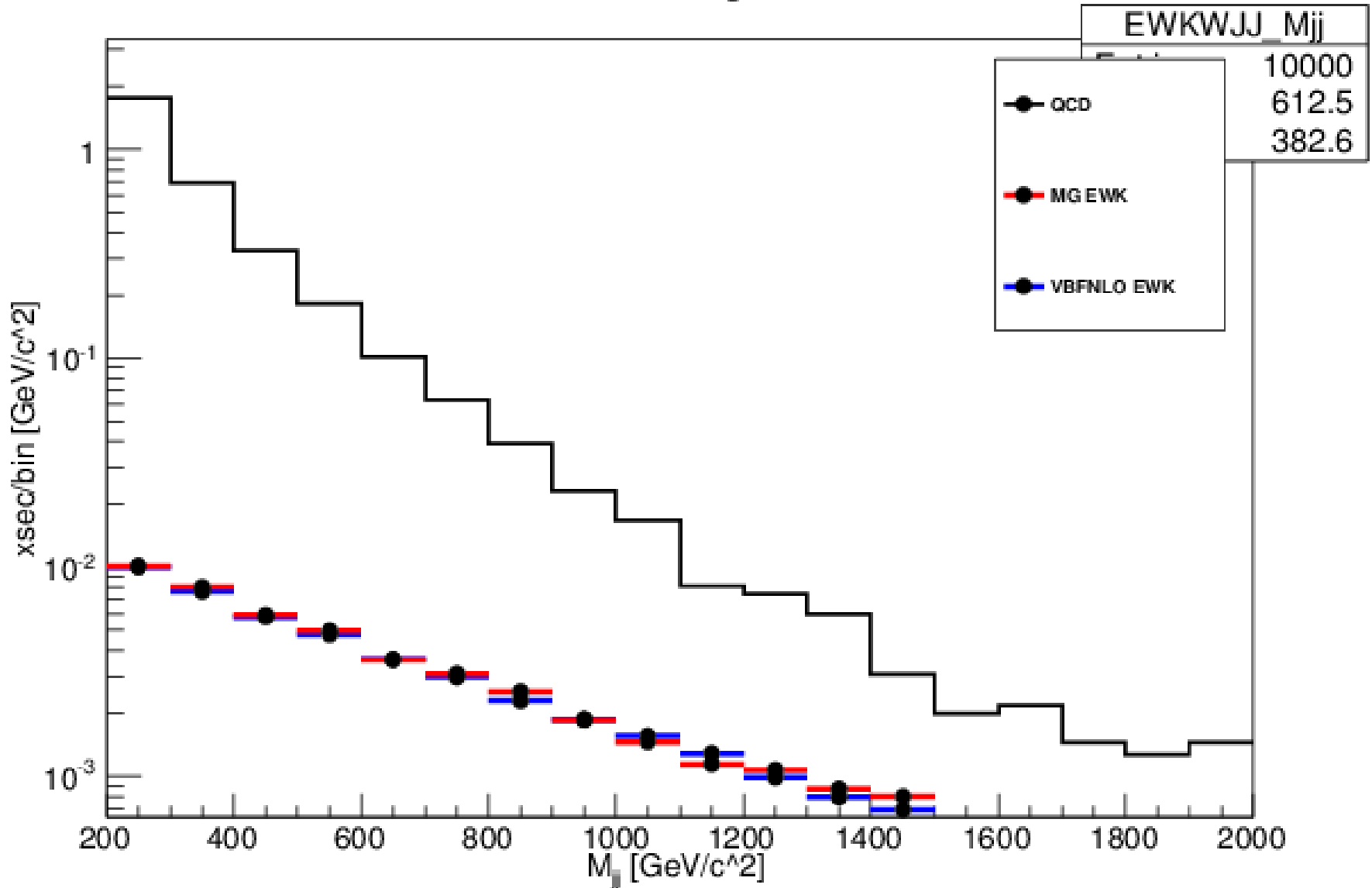
```
root -b -q test1.C\(\“V140\”\)
```

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

```
root -b
```

```
.x Compare.C
```

test histogram



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