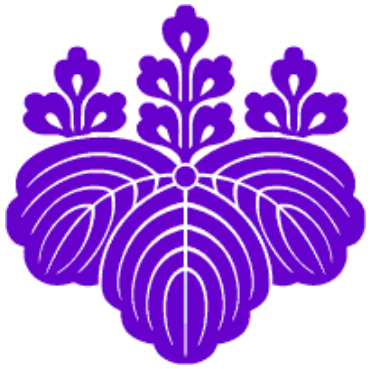


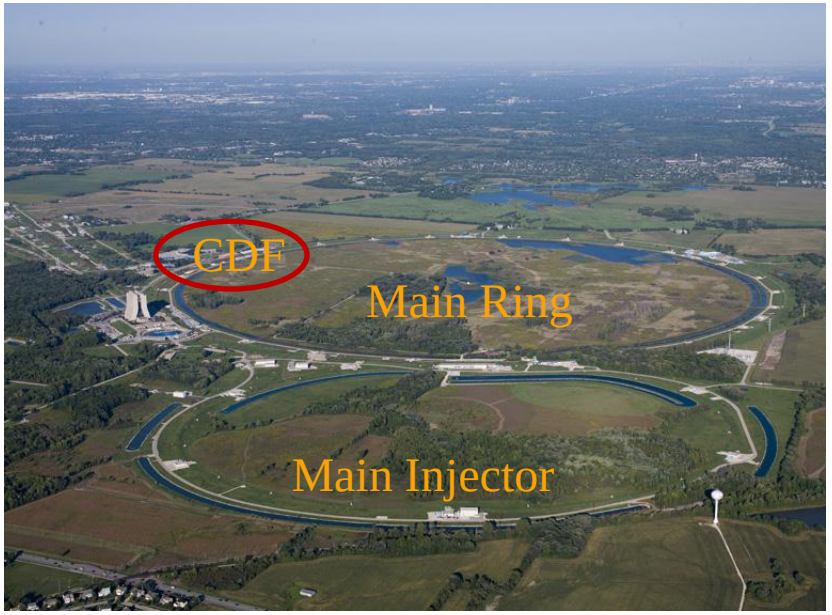
Search for Standard Model Higgs Boson in the $H \rightarrow WW \rightarrow lvjj$ final state at CDF

New Perspectives 2011
@FNAL, 5/31
Yuji Sudo, University of Tsukuba
On behalf of the CDF Collaboration

CDF Experiment

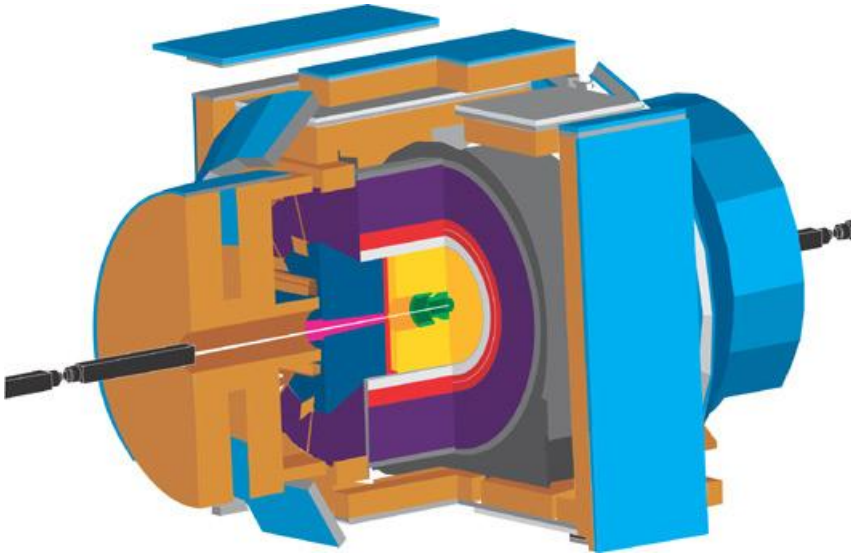
Tevatron: p-pbar collision at 1.96 TeV

CDF is a multipurpose detector.
- Detects electrons, muons, jets, missing energy, precision tracking to detect to long life time particles.

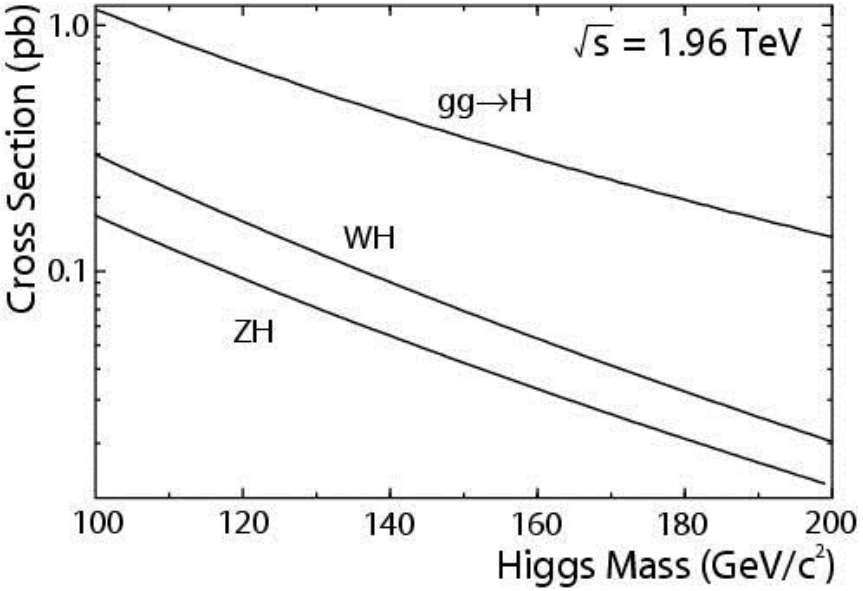


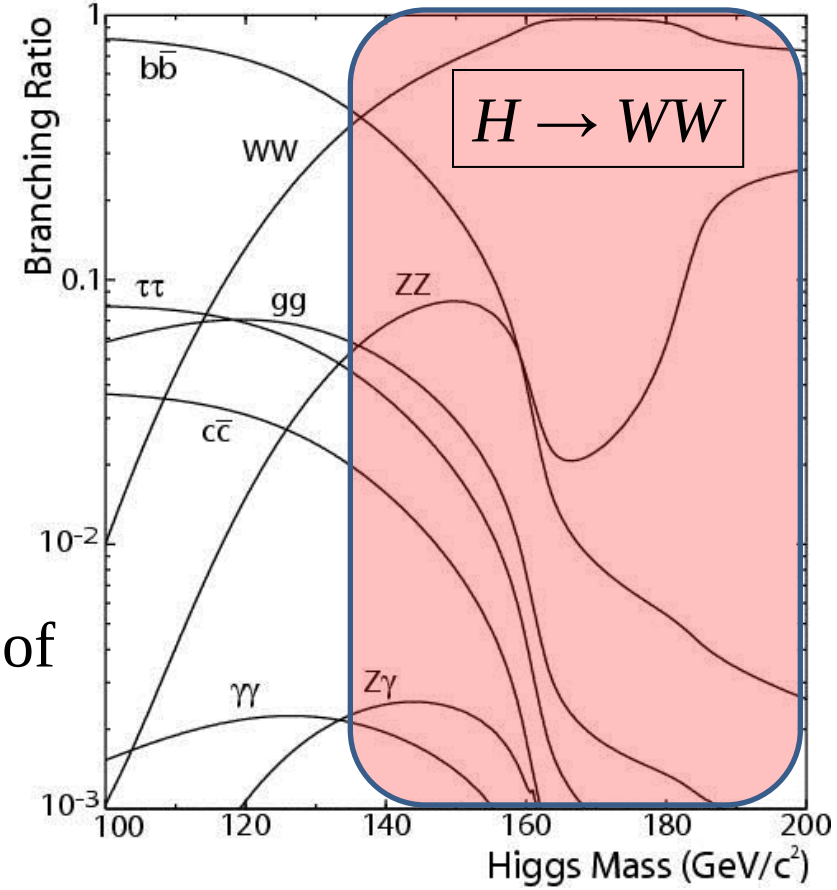
CDF Detector Components

- Silicon inner tracker $|\eta| < 2.0$
- Central outer tracker $|\eta| < 1.0$
- Solenoid 1.4 Tesla
- Central calorimeter
  - Electromagnetic calorimeter (CEM) $|\eta| < 1.1$
  - Hadronic calorimeter $|\eta| < 1.2$
- End plug calorimeter
  - EM $1.1 < |\eta| < 3.6$
  - Had $1.2 < |\eta| < 3.6$
- Muon chambers
  - Central muon chambers (CMUP) $|\eta| < 0.6$
  - Central muon extension (CMX) $0.6 < |\eta| < 1.0$



Higgs Boson Production Cross section and Branching Ratio



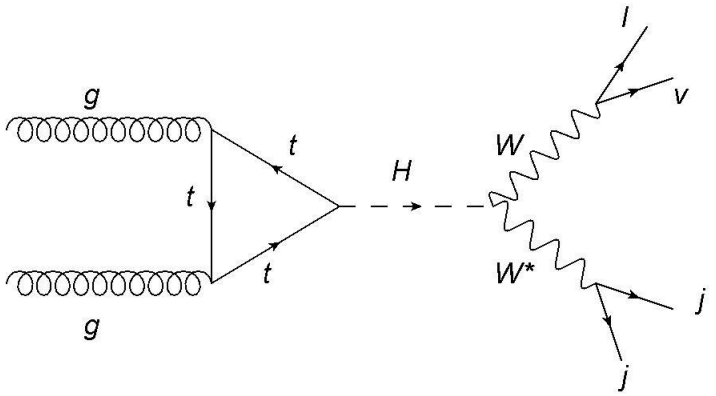


gg → *H* is the main production mode of standard model Higgs Boson.

SM Higgs decays mainly into *WW* for $m_H > 135$ GeV.

High Mass Search

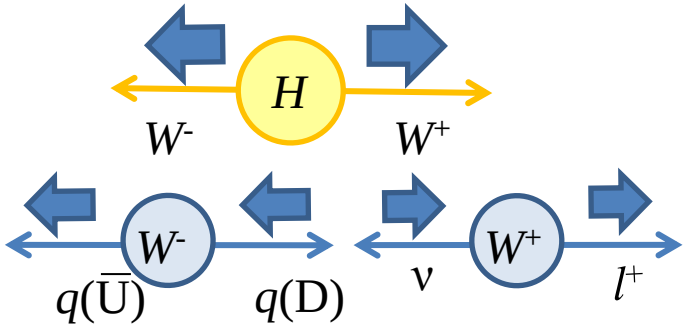
- $gg \rightarrow H \rightarrow WW \rightarrow l\nu l\nu$
  - ✓ Dominant search mode
  - ✓ Analysis considers WH, ZH, VBF modes.
  - ✓ Backgrounds
    dibosons (WW, WZ, ZZ) , Z/γ^*, $t\bar{t}$, $W\gamma$, W+jets
- $gg \rightarrow H \rightarrow WW \rightarrow l\nu jj$
  - ✓ Addition of this mode will enhance CDF sensitivity
  - ✓ Backgrounds
    W+jets , dibosons, single top, $t\bar{t}$, non-W



Motivation and Analysis Idea
$H \rightarrow WW \rightarrow lvjj$

- $H \rightarrow WW$ is a promising decay mode for SM Higgs search for $m_H \geq 135$ GeV.
- $WW \rightarrow lvjj$ has a branching ratio 6 times larger than $WW \rightarrow lvlv$, though it will have a huge QCD W + jets background.
- We assumed m(lep,ν) = 80.419 GeV and reconstructed P_z^{ν}. We can fully reconstruct Higgs mass.
- We can take advantage of the decay kinematics of the Higgs (spin=0). There is strong angular correlation between leptons and jets.
- Finally compose Likelihood discriminant for S/B separation.
  - Angular distribution between lepton and down type jet.
  - Dijet mass, reconstructed higgs mass, ...

W Decay Mode
lv ~ 10 %
cs, ud ~ 30 %



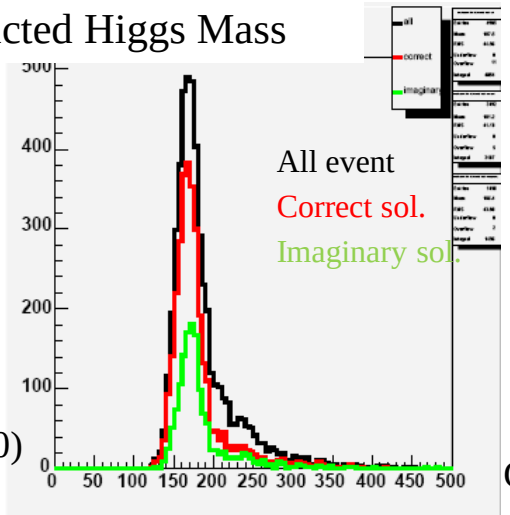
p_z^{ν} Reconstruction

- Solve equation:
  m(l,ν) = 80.419 GeV.
- Pick up the solution with smaller absolute value $|p_z^{\nu}|$.
- Take the real part if imaginary solution.
- Some results of the reconstruction method:

input m_H	imaginary solution	correct fraction	mass resolution(GeV)
150	16%	62%	14.9
170	30%	49%	14.4
200	31%	48%	21.9

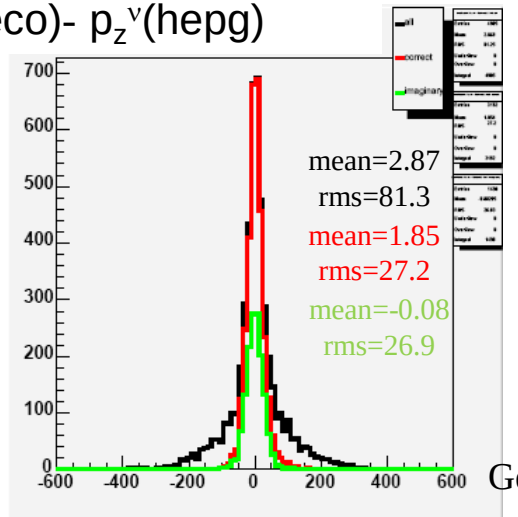
Correct : the picked solution is closer than another one to HEPG P_z value.

Reconstructed Higgs Mass



(Input m_H=170) GeV

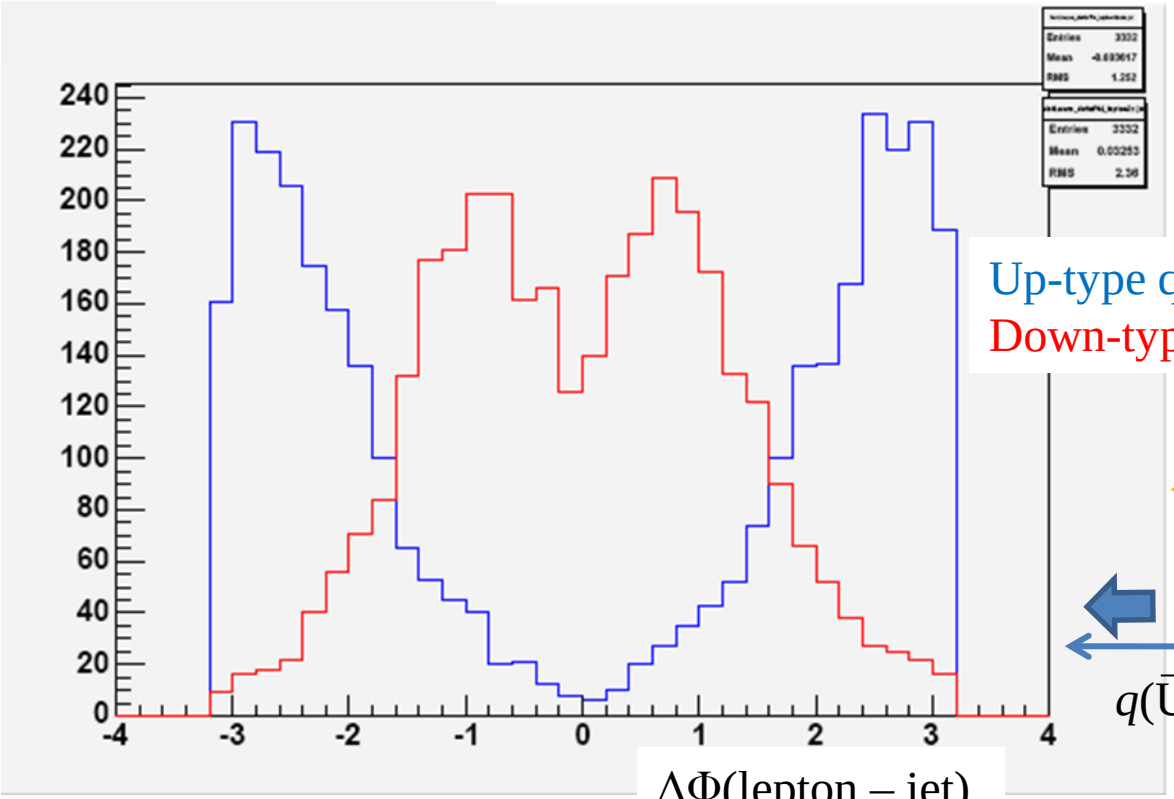
p_z^{ν} (reco)- p_z^{ν}(hepg)

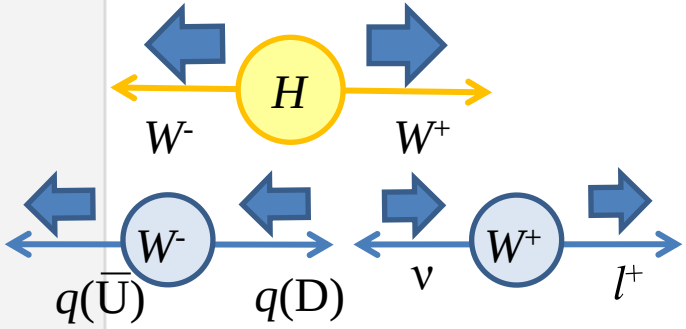


GeV

Up/Down-type Jet Distinction

- We assume the jet with smaller |ΔΦ(lepton,jet)| as down-type.





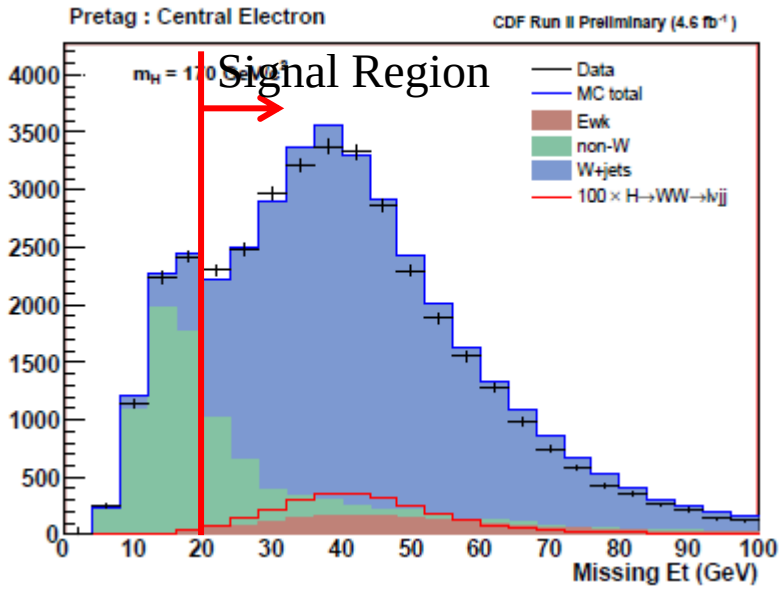
Analysis Overview

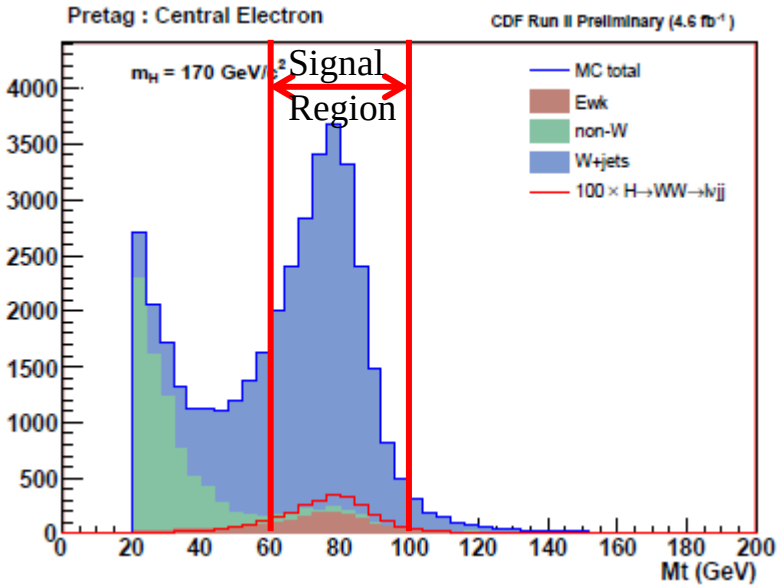
- We used 4.6 fb^{-1} of data collected by CDF.

- Signal topology : $H \rightarrow WW \rightarrow lvjj$
- One Central Lepton
  - Et > 20 GeV, |η| < 1.1
- Missing Et (MET) > 20 GeV
- Exact 2 Jets
  - Et > 20 GeV, |η| < 2.0
- We applied angular and transvers mass (Mt) cuts to reduce non-W QCD events.
- We can Fully reconstruct the event.

- Signal Region 60 < Mt <100 GeV
- Control Region Mt ≤ 60, Mt ≥100 GeV

(MET > 20 GeV cut didn't apply to control region.)





Background Estimation

In the control region , we fitted missing Et distribution of data with expected background shapes to obtain non-W and W+Jets normalization.

Fraction of Background Components

- Control Region
  - Ewk ~5 %
  - non-W ~45 %
  - W+Jets ~50 %
- Signal Region
  - Ewk ~6 %
  - non-W ~2 %
  - W+Jets ~92 %

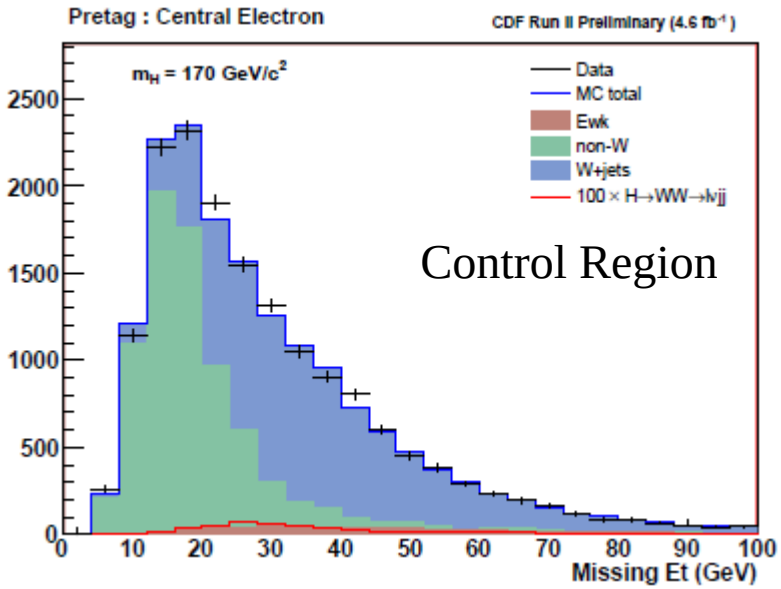
(Ewk : *WW*, *WZ*, *ZZ*, single top, *tt*bar)

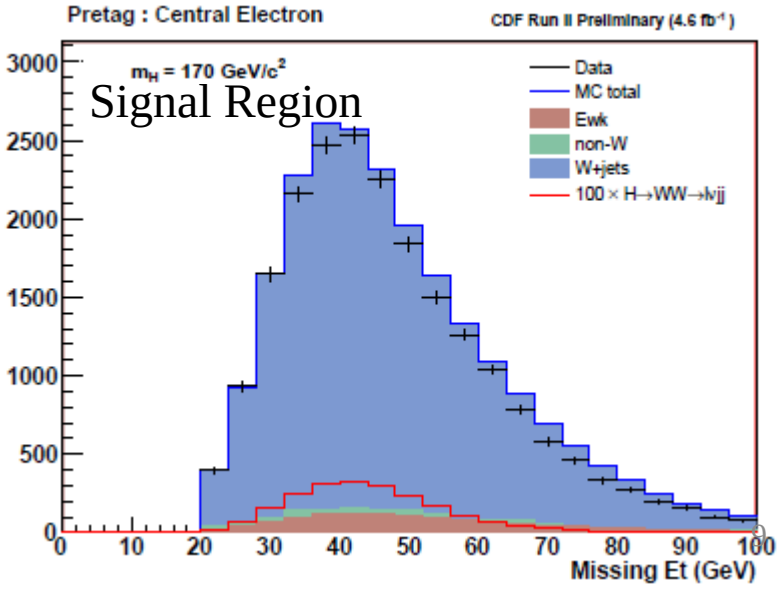
- We estimated rate systematic uncertainties.

	signal	Electroweak	W+LF	non-W
Luminosity	6%	6%		
Trig. Eff., Lepton ID	2%	2%		
ISR/FSR, PDFs	6.6%			
Jet energy scale	3%	2%	15%	
W+jets normalization			3%	
non-W normalization				40%

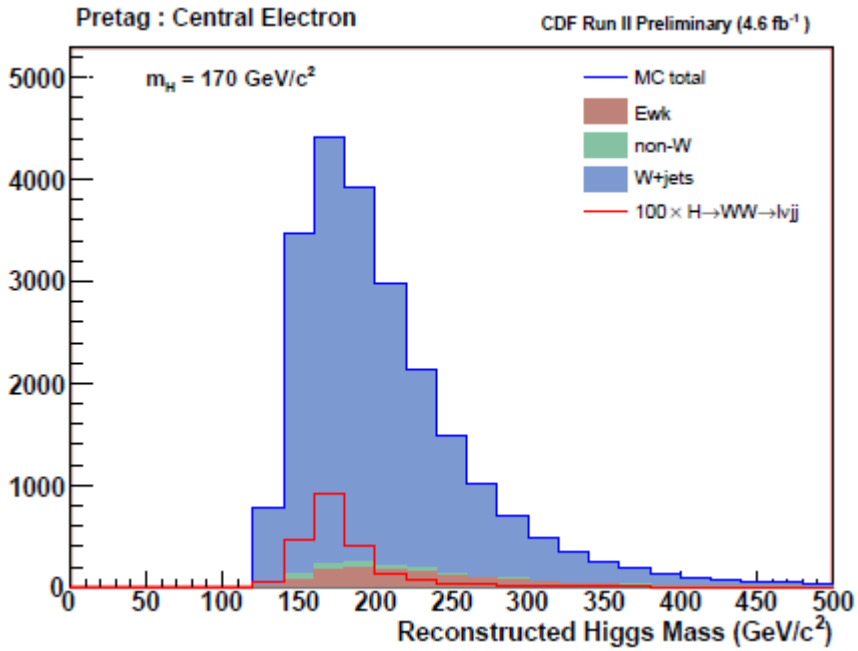
- Study of shape systematic uncertainties is ongoing.

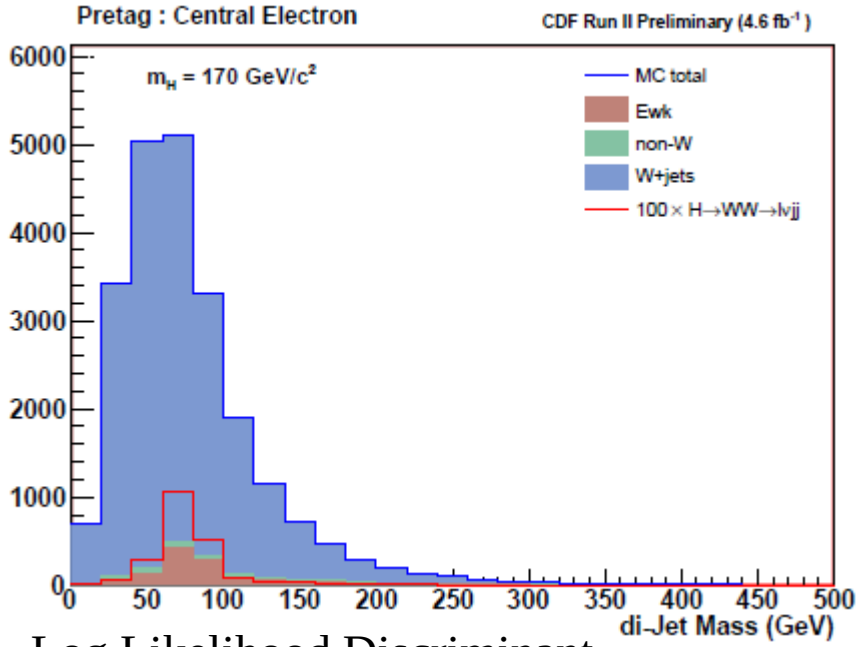
Missing Et Distribution



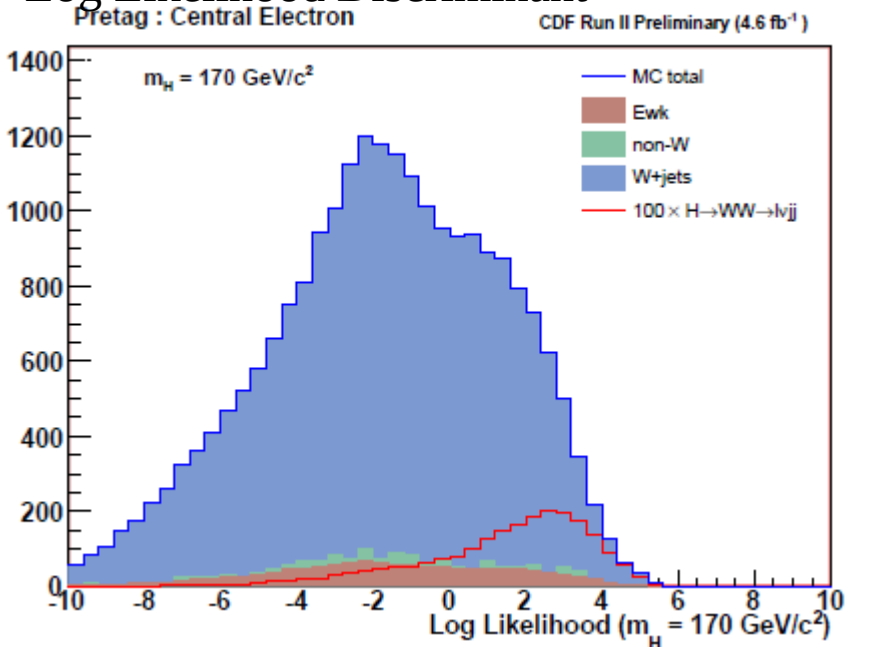


Components of Log Likelihood





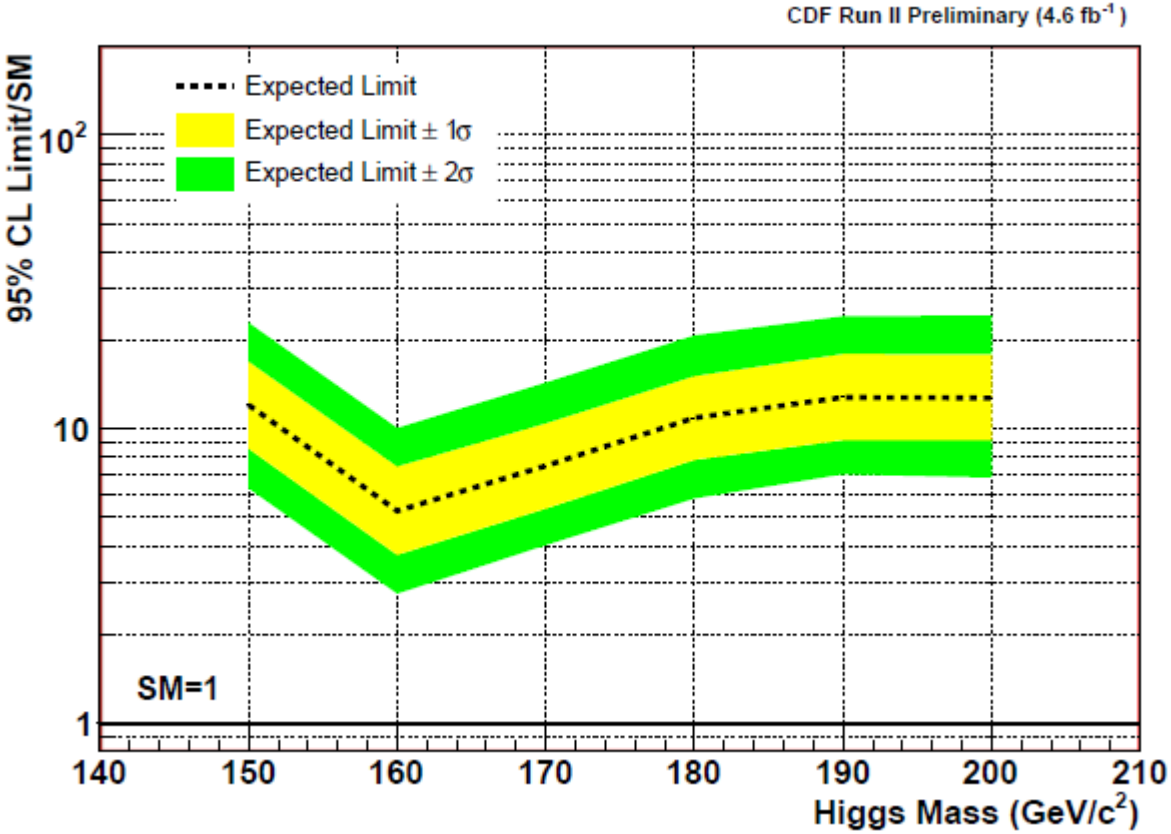
Log Likelihood Discriminant



- We compose a likelihood discriminant with nine kinematics, which are m_H, Mjj, ΔR(j1,j2), ΔR(lep,j1), ΔΦ(LepW,HadW), Δ Φ(lep,HadW), Pt(lep), Pt(J1) and Pt(J2).

- Log Likelihood = $\sum_{i=1}^{Nval} \log\left(\frac{P_i^{sig}}{P_i^{bkg}}\right)$

Expected Limit of Higgs Boson Production Cross-section in $H \rightarrow WW \rightarrow lvjj$



Higgs Mass (GeV/c^2)	150	160	170	180	190	200
$-2\sigma/\sigma_{SM}$	6.28	2.75	4.03	5.80	7.01	6.83
$-1\sigma/\sigma_{SM}$	8.59	3.74	5.37	7.86	9.18	9.18
median/σ_{SM}	12.0	5.26	7.49	10.9	12.7	12.7
$+1\sigma/\sigma_{SM}$	16.9	7.46	10.4	15.1	18.0	17.9
$+2\sigma/\sigma_{SM}$	22.9	10.0	14.3	20.7	24.1	24.2

We estimated upper limit on cross-section using 4.6 fb^{-1} data with rate systematic uncertainties.

We combined results of central lepton categories.

Shape systematic uncertainties are not included yet.

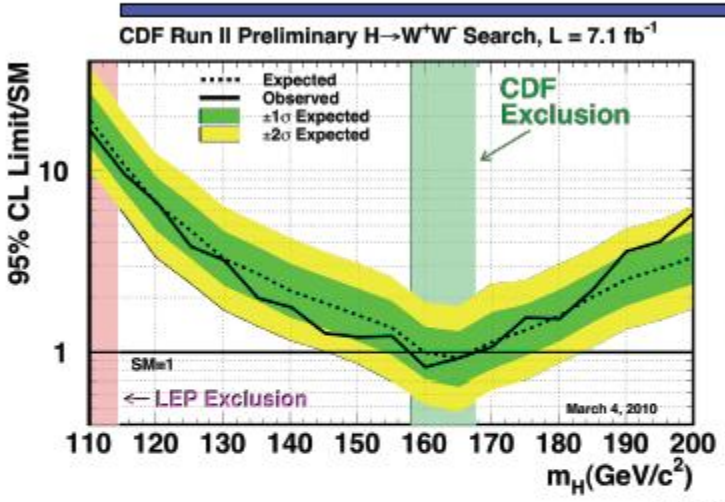
Summary

- We are working on a search for SM Higgs boson decaying to $H \rightarrow WW \rightarrow lvjj$ at CDF.
- We compose a likelihood discriminant with 9 kinematic variables as input.
- Our Expected upper limit on cross section is $7.49 \times \sigma_{SM}$ at $m_H = 170$ GeV with rate systematic uncertainties.
- We are studying shape systematic uncertainties.

Backup

$H \rightarrow WW \rightarrow lvlv$

SM Result



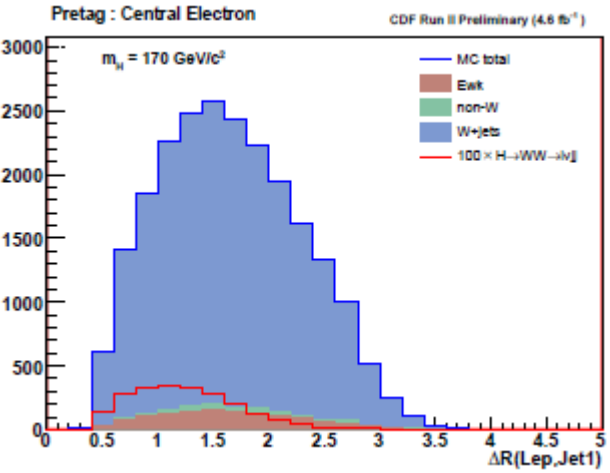
CDF-only exclusion between 157-168 GeV

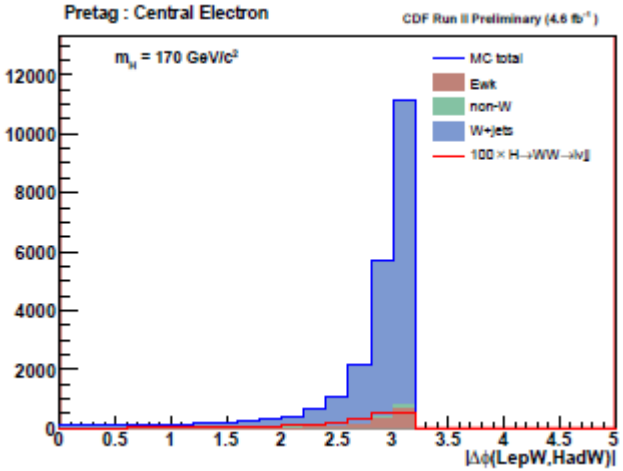
Expected exclusion range: 159-167 GeV

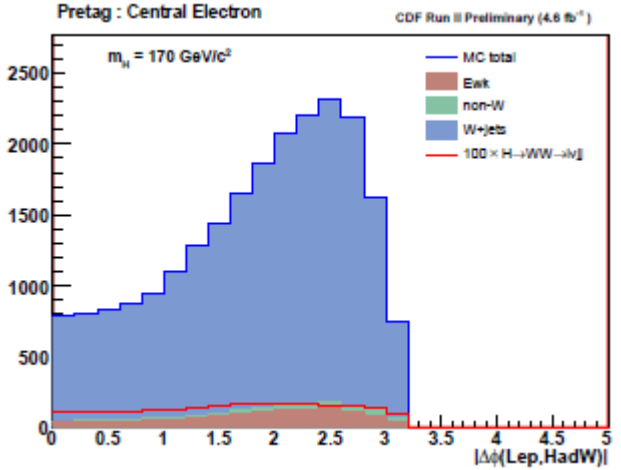
- Obtained using Markov Chain integration
- Consistent with scattershot
- Consistent results by Tom and Sergo

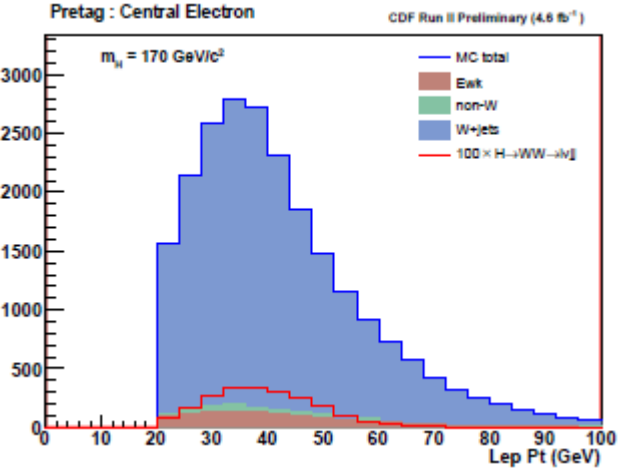
m_H (GeV/c2) (GeV/c2)	obs (Limit/SM)	-2σ exp (Limit/SM)	-1σ exp (Limit/SM)	Median exp (Limit/SM)	$+1\sigma$exp (Limit/SM)	$+2\sigma$exp (Limit/SM)
110	16.61	9.87	13.43	18.94	26.77	37.33
115	9.62	5.85	7.73	10.75	15.17	21.25
120	6.60	3.32	4.61	6.49	9.06	12.43
125	3.81	2.40	3.29	4.66	6.59	9.19
130	3.20	1.71	2.32	3.26	4.60	6.42
135	1.98	1.39	1.92	2.69	3.78	5.21
140	1.76	1.16	1.54	2.16	3.05	4.28
145	1.27	1.02	1.35	1.87	2.60	3.59
150	1.21	0.86	1.14	1.59	2.23	3.12
155	1.22	0.69	0.96	1.36	1.90	2.61
160	0.83	0.53	0.71	0.99	1.37	1.88
165	0.92	0.48	0.66	0.93	1.30	1.79
170	1.07	0.62	0.81	1.14	1.66	2.39
175	1.55	0.70	0.95	1.32	1.83	2.50
180	1.52	0.87	1.15	1.58	2.20	3.05
185	2.21	1.07	1.46	2.02	2.76	3.72
190	3.58	1.34	1.81	2.51	3.49	4.79
195	4.06	1.50	2.07	2.88	3.96	5.35
200	5.77	1.74	2.38	3.33	4.64	6.39

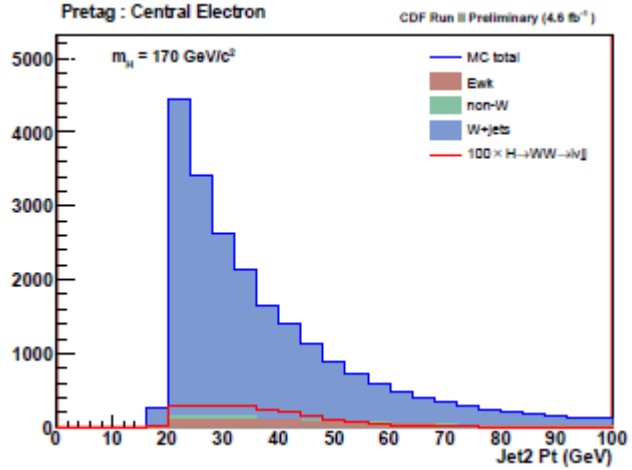
CEM : Likelihood Inputs

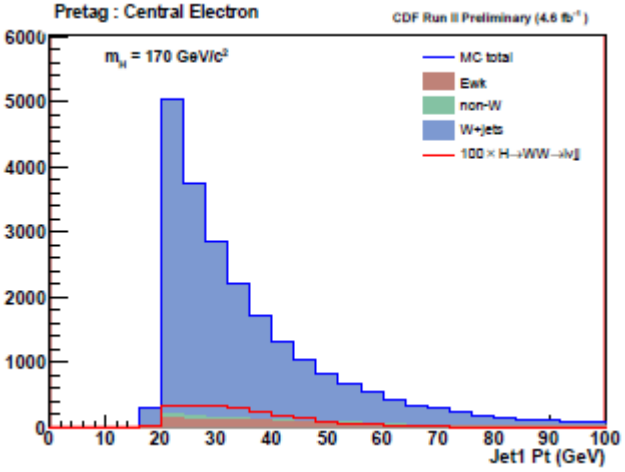






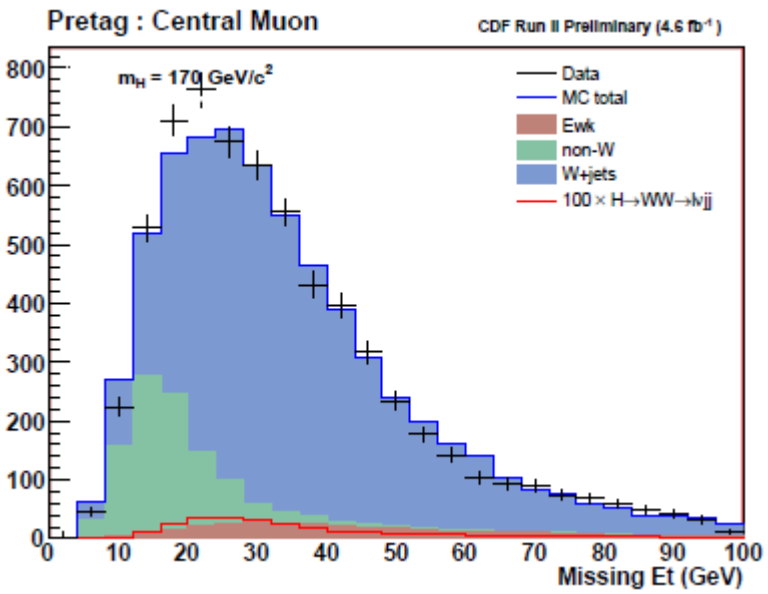




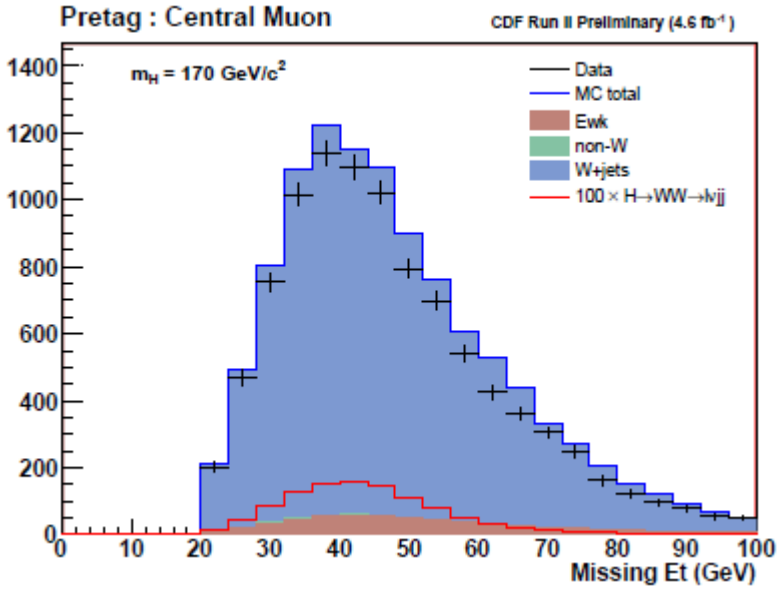


CMUP : MET

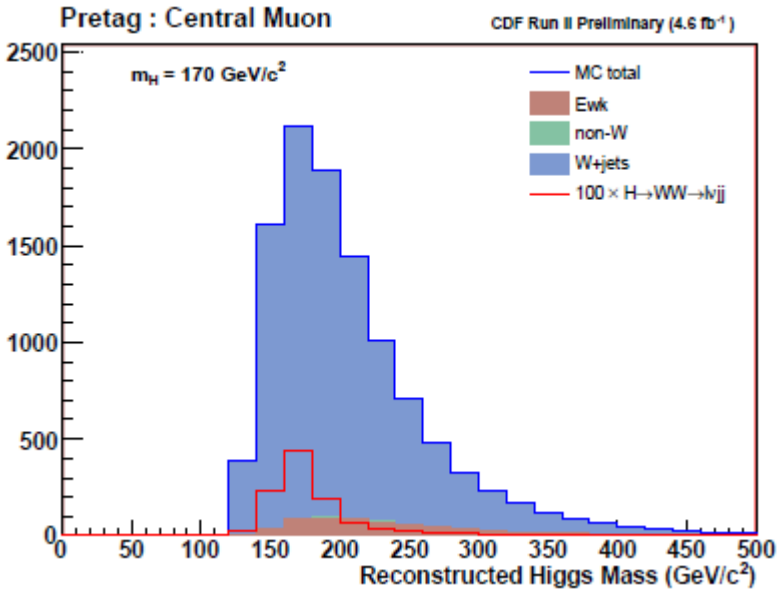
Control Region

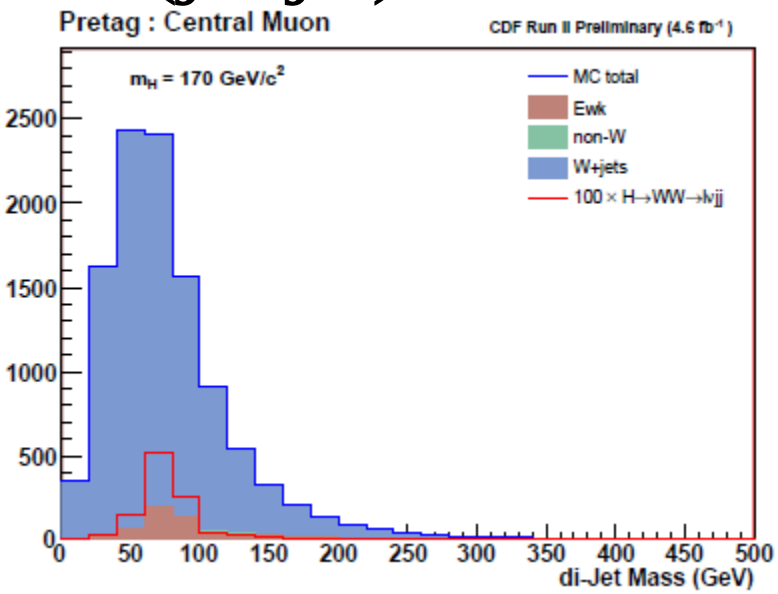


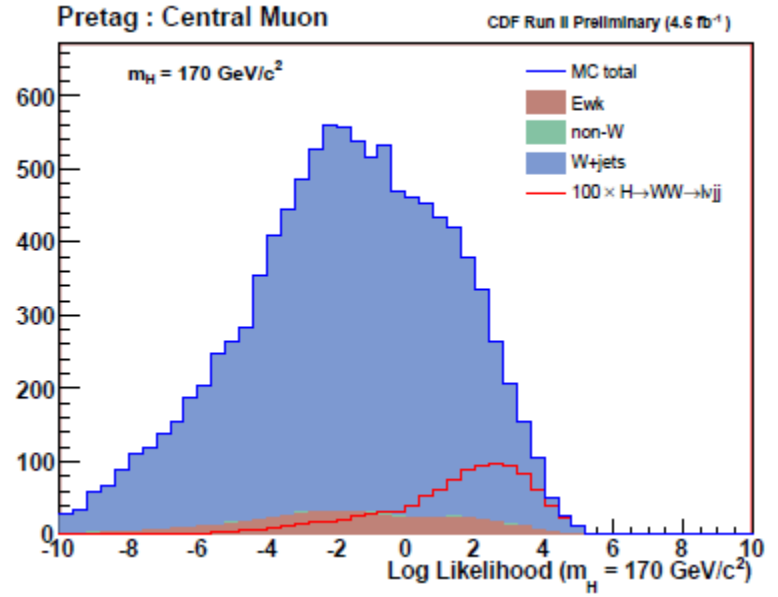
Signal Region



CMUP : Likelihood Inputs
m_H, Mjj, $\Delta R(j1,j2)$

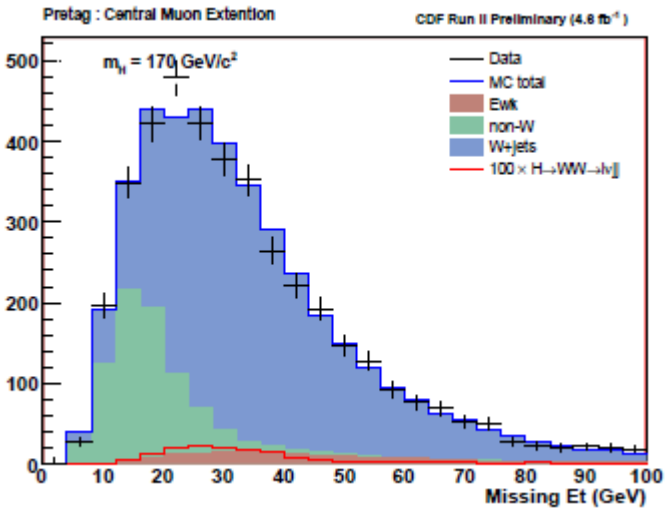




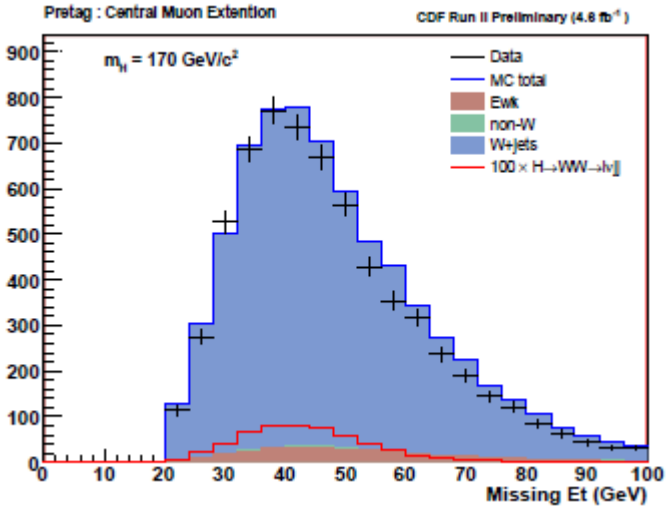


CMX : MET

Control Region



Signal Region



CMX : Likelihood Inputs
m_H, Mjj, ΔR(j1,j2)