FERMILAB-CONF-06-148-E

Search for Standard Model Higgs Boson Production in Association with W Boson at CDF

Y. Ishizawa[a], S. Kim[a], K. Kondo[b], **Y. Kusakabe**[b], T. Masubuchi[a], M. McFarlane[c], J. Nielsen[c], A. Taffard[d], W. Yao[c]

(a): University of Tsukuba, (b): Waseda University, (c): Lawrence Barkley National Laboratory, (d): University of Illinois at Urbana-Champaign

The Standard Model (SM)

- Quarks and Leptons are the fundamental particles
- Gauge bosons mediate forces between fundamental fermions
- Higgs Mechanism gives masses to elementary particles without breaking SU(2)×U(1) symmetry

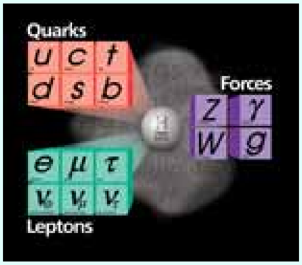


Figure.1 Elementary particles in the standard model.

Motivation

- Standard Model needs higgs boson as a fundamental particle
- Constraint from W and Top mass $m_H < 207$ GeV/c^2 @95%C.L.
- LEP2 Direct search $m_H > 114.4$ GeV/c^2 @95%C.L.
- TEVATRON is the only active collider with a potential to find higgs

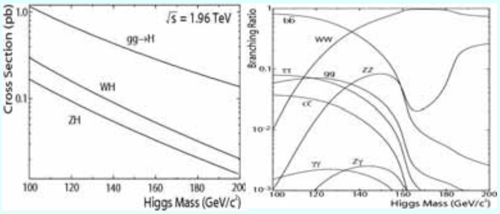


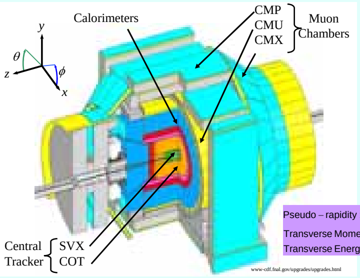
Figure.2 SM Higgs production cross section (left) and branching ratio (right) as a function of higgs mass at the TEVATRON.

One of the most sensitive processes at TEVATRON for m_H<135GeV/c^2

$$p\bar{p} \rightarrow W^{\pm}H \rightarrow \ell\nu b\bar{b}$$

The CDF II Detector

- Central Tracker – Measures momentum, *p*, of charged particles.
- Calorimeters – Measure energy, *E*, of particles.
- Muon Chambers – Used to identify muons.



Pseudo – rapidity : $\eta = -\ln(\tan\frac{\theta}{2})$

Transverse Momentum : $P_T = P\sin\theta$

Transverse Energy : $E_T = E\sin\theta$

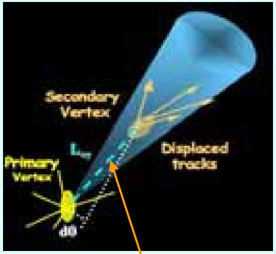
Figure.3 Isometric view of the CDF Detector.

---

b-tagging

Crucial to reduce large W + light flavor background

Displaced Secondary Vertex tagging (SECVTX)



Long decay length of B decay

Figure4. Displaced Secondary Vertex b-tagging.

Contamination in SECVTX b-tagged jet (major background)

- Finite tracking resolution → false tag
- Long decay length of D-meson → c-jet identified as b

Neural Network(NN) b-tagging

- Separate b-jet from light-jet(mistag) and c-jet in SECVTX tagged jet
- Utilize impact parameter and SECVTX tagging information

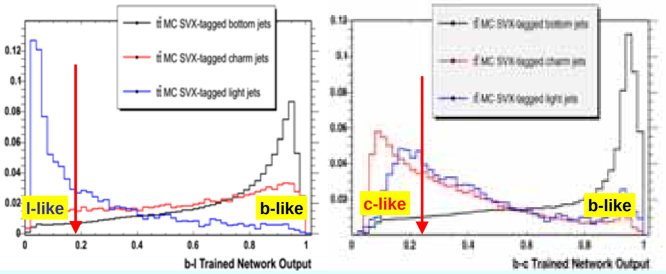


Figure.5 Neural network output for l-jet, c-jet and b-jet.

Keeping 90% of b-jet, reject 65% of light-jet and 50% of c-jet

Data Sample and Event Selection

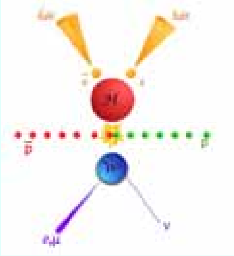


Figure.6 WH production and decay.

- **Luminosity: 695pb^{-1}** (March 2002 - September 2005)
- 2 jet (E_T>15GeV)
- At least 1 SECVTX tagged jet
  - 1 SECVTX tagged jet → require NN b-tagging
  - ≥2 SECVTX tagged jets → no NN b-tagging
- 1 primary high p_T isolated lepton (e/μ, p_T>20GeV/c)
- Large missing E_T (>20GeV)

Result

Background and Observed Data

b-tagging strategy	=1 tag with NN tag	≥ 2jet
Mistag	39.2 ± 8.6	2.6 ± 0.4
$Wb\bar{b}$	105.4 ± 36.0	14.8 ± 5.1
$Wc\bar{c}$	31.3 ± 10.7	2.4 ± 0.8
Wc	25.0 ± 6.5	0.0 ± 0.0
$t\bar{t}$(6.7pb)	30.4 ± 4.7	7.5 ± 1.6
Single Top	17.1 ± 1.7	3.0 ± 0.5
Diboson/$Z^0 \rightarrow \tau\tau$	9.8 ± 1.6	0.8 ± 0.2
non-W QCD	28.5 ± 4.9	1.0 ± 0.2
Total Background	286.6 ± 48.7	32.2 ± 6.2
Observed Events	306	29

Table.1 Background estimate and observed data for b-tagging strategies in W+2jets sample.

Acceptance and Systematics

NN b-tagging keeps ~90% of signal (~35% of total background is rejected)

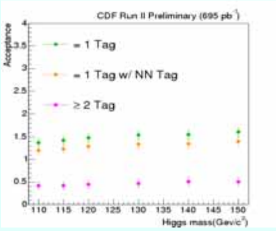


Figure.7 Signal acceptance as a function of higgs mass.

Source	Systematic Uncertainty(%)	
b-tagging strategy	=1 tag with NN tag	≥ 2jet
Lepton ID	2	2
Trigger	<1	<1
b-tagging	5.3	16
Luminosity	6	6
Monte Calro Modeling	4.7	10.3
Total	9.4	20.0

Table.2 Systematic uncertainties.

Dijet Mass Distribution

Single Tag with NN Tag

Double Tag

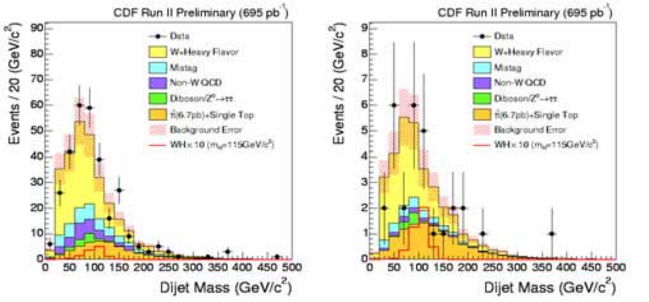


Figure.8 Dijet mass distributions for each b-tagging strategy.

No significant excess over the SM background prediction

Set an upper limit on the production cross section times branching ratio by fitting the dijet mass distributions using binned likelihood technique

$$L(\sigma\times \mathrm{BR}) = \prod_{i=\mathrm{bin}} \frac{\mu_i^{N_i} e^{-\mu_i}}{N_i!}$$

μ_i : Expected events in i-th bin(Signal+Background)

N_i : Observed events in i-th bin

Combine single and double tag likelihood

$$L(\text{combined}) = L(1\text{tag w/ NN tag}) \times L(\geq 2\text{tag})$$

95% C.L. Upper Limit

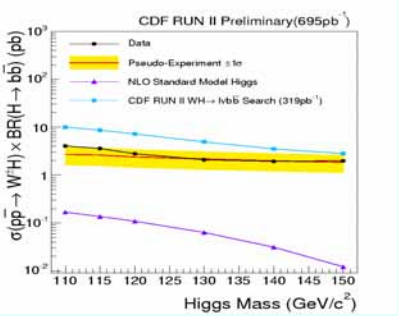


Figure.9 Limit on WH production cross section times branching ratio as a function of higgs mass.

Conclusions

- **Analysis technique improved significantly compared to the previous WH search with 319pb^{-1} at CDF.**
- **Dijet mass distributions are consistent with SM background prediction**
- **Set an upper limit on the production cross section as**

$\sigma(p\bar{p}\rightarrow WH)BR(H\rightarrow b\bar{b})$<2.0- 4.0pb

m_H = 110-150GeV/c^2 at 95% C.L.

Best limit from single higgs production process

For more information,

Public web-site http://www-cdf.fnal.gov/physics/exotic/r2a/20060420.lmetbj_wh