Flavor Tagging with a CCD Vertex Detector: Higgs BRs as a Benchmark

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Outline

Review of Snowmass Study
of Higgs Branching Ratio Measurement

Investigation of Improved "Jet-level" NN tag

Improved Event-level tags and new estimate
of $H \rightarrow cc$ precision

Review of Snowmass Study

Higgs branching ratio measurement study:

500 GeV, 500 fb^{-1}

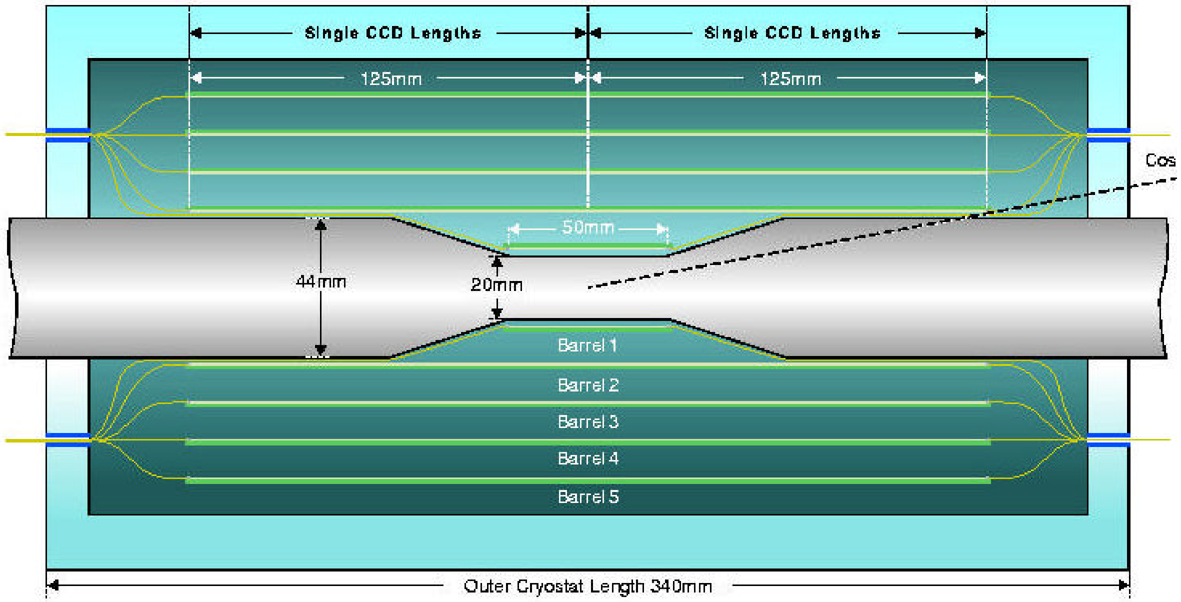
M_H = 115, 120, 140, 160, 180, and 200 GeV

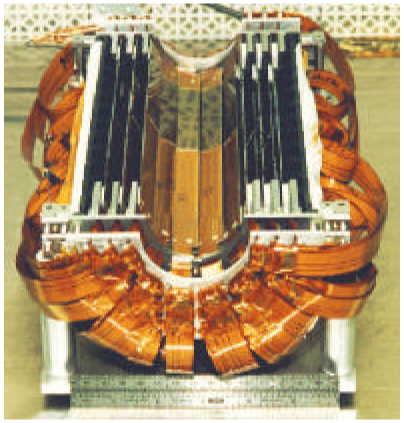
Pandora generator with ISR and beamstrahlung

NLD Large detector w/ Fast Sim (LCD Root Tools)

ZVTOP with neural net (LCD Root Tools)

CCD Vertex Detector for the Future Linear Collider





~700,000,000 pixels
standalone tracking
w/ 5 barrels

Event simulation

- Pandora-pythia and Pythia v5.7
  - beamstrahlung included and important
- Detector model : NLC L

$e^+ e^- \to ZH$

$H \to bb,\ \tau\tau,\ cc,$

$gg,\ WW,\ ZZ$

$e^+ e^- \to WW$

$e^+ e^- \to ZZ$

$e^+ e^- \to qq$

$e^+ e^- \to tt$

$\sqrt{s} = 500$ GeV

$\int L = 500\ \mathrm{fb}^{-1}$

Analysis with $Z \to l^+ l^-$ evts, scaled to $Z \to qq$ (x 4)

Previous studies:

Hildreth, Barklow, Burke, PRD49, 3441 (1994)

I. Nakamura, K. Kawagoe, LCWS (1996)

M. Battaglia, HU-P-264 (1999)

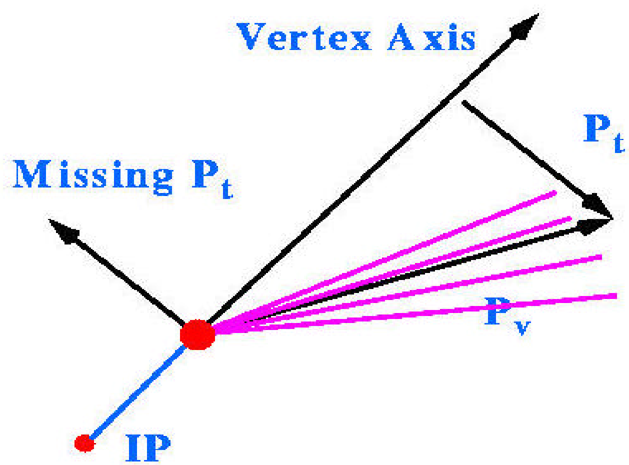
G. Borisov, F. Richard, LAL-99-26 (1999)

ZVTOP

- Vertex reconstruction is based on the SLD algorithm ZVTOP
  - D. Jackson, NIM A388, 247 (1997)

- Implemented in the ROOT based NLC software by T. Abe

- Provides secondary vertex reconstruction, and pt-corrected mass



$$M = p_T + \sqrt{M_V^2 + p_T^2}$$

Event Selection

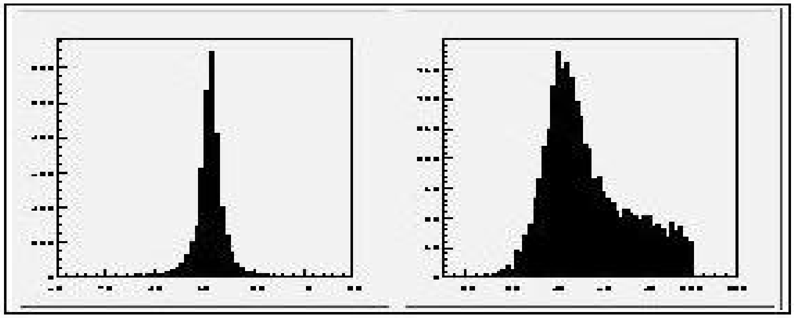
We select for $e^+e^- \to HZ \to l^+l^-$ $(l = e, \mu)$

- Reconstruct all lepton pair masses in an event
- Select pair with mass closest to m_Z
- Calculate recoil mass
- Apply cuts on masses:

$$|m_Z - m_{l^+l^-}| < 10 \text{ GeV}$$

$$m_H - 10 \text{ GeV} < m_{recoil} < m_H + 20 \text{ GeV}$$

- Include hadronic Z decays by scaling signal up by a factor of 4 (D. Strom, LEP experience)



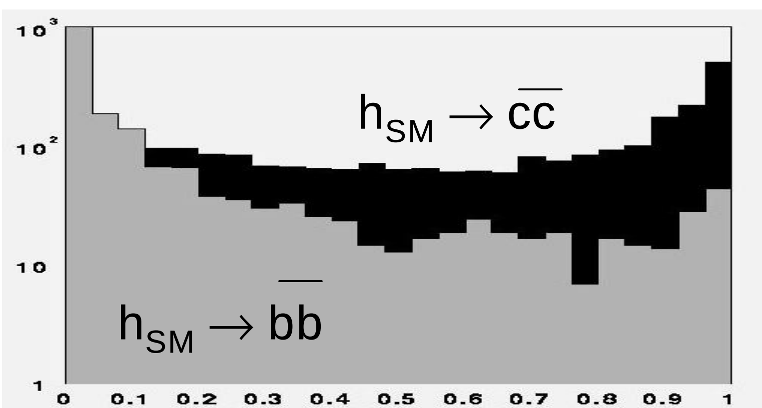
Signal event reconstructed Z and recoil mass distributions.

Neural Net Analysis

14 parameters have been defined to distinguish decay modes of the Higgs Boson, and the backgrounds.

A neural net with 15 hidden units and 6 output units (one for each decay mode) was trained.

Cuts on each of the 6 output units were determined for each decay mode to maximize $S/\sqrt{S+B}$.

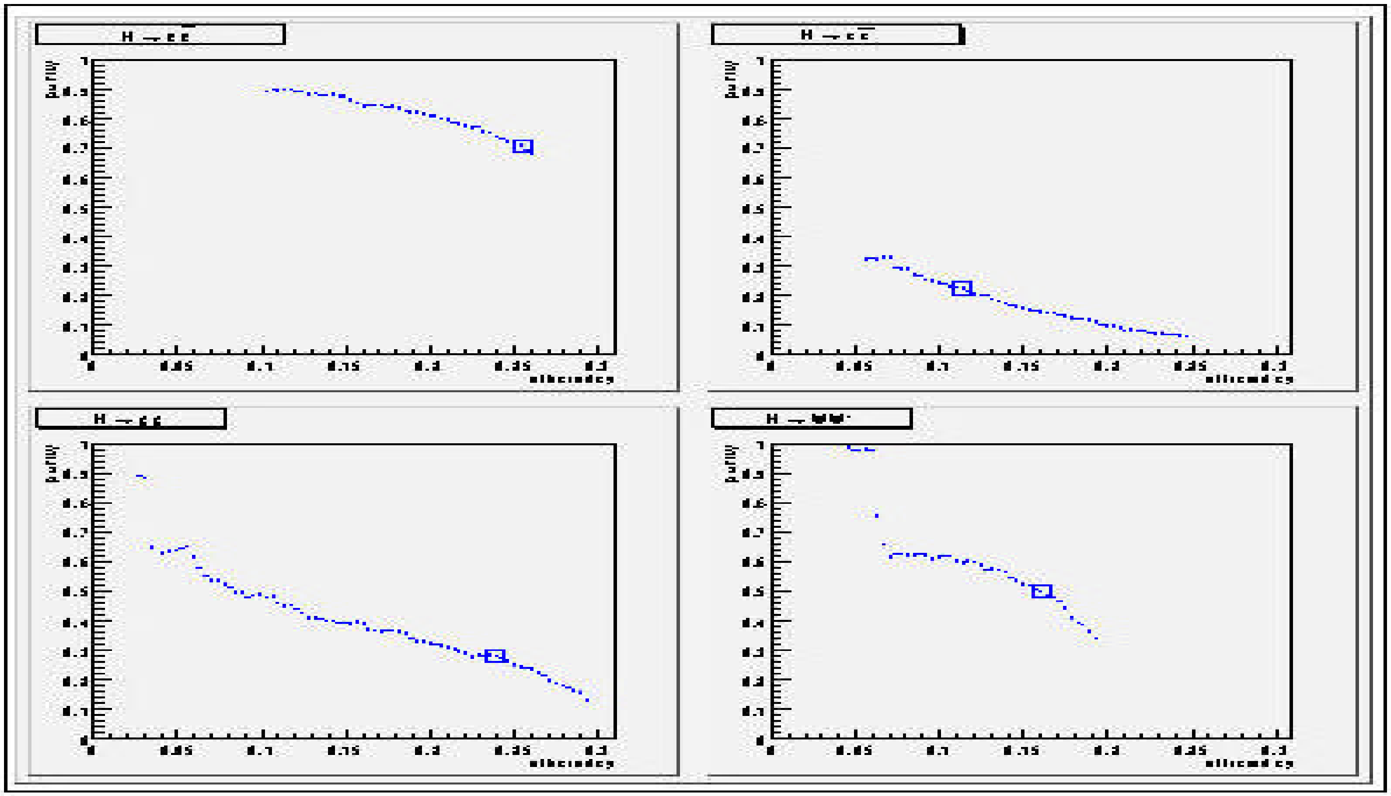


$h_{SM} \to c\bar{c}$ output

__Parameters__

p_l^{max}
E_{cone}
m_W(recon)
$thrust_{Higgs}$
y_{32}
n_{tracks}
m_h(recon)
N_{sig}
n_{vert}(jet 1)
n_{vert}(jet 2)
m_{pt}(jet 1)
m_{pt}(jet 2)
p_{jet}/p_{kin}(jet 1)
p_{jet}/p_{kin}(jet 2)

Efficiency/Purity Curves from Neural Net



Purity vs. efficiency for the case $m_H = 120$ GeV. The maximum possible efficiency is 0.31 due to mass cuts.

Branching Ratio Errors (σ_{BR}/BR)

$\sqrt{s}$ = 500 GeV, $\int L$ = 500 fb^{-1}

Mode	115 GeV	120 GeV	140 GeV	160 GeV	180 GeV	200 GeV
h->WW*	0.16	0.1	0.03	0.02	0.03	0.04
h->bb	0.03	0.03	0.04	0.13	0.59	-
h->tau+tau-	0.07	0.08	0.1	0.36	-	-
h->cc	0.31	0.39	0.44	-	-	-
h->gg	0.16	0.18	0.23	-	-	-
h->cc+gg	0.15	0.16	0.2		-	-

Impact of Detector Parameters on BR Errors

$M_H = 140$ GeV/c^2 , $\sqrt{s} = 500$ GeV, $\int L = 500$ fb^{-1}

R_{INNER}(cm)	**1.2**	**2.4**	**1.2**	**2.4**	**1.2**
hit res (μm)	**5.0**	**5.0**	**3.0**	**3.0**	**4.0**
$H \to bb$	**3.8%**	**3.8%**	**3.8%**	**3,8%**	**3.8%**
$H \to \tau\tau$	**10%**	**10%**	**10%**	**10%**	**10%**
$H \to cc$	**46%**	**47%**	**42%**	**46%**	**42%**
$H \to gg$	**23%**	**22%**	**22%**	**22%**	**22%**
$H \to WW^*$	**3.5%**	**3.5%**	**3.5%**	**3.5%**	**3.5%**

Mild dependence of charm to r_{INNER} and hit resolution.

In this analysis, we are essentially tagging on one of the two possible jets. In an analysis in which one needs to tag multiple jets, the dependence should be stronger.

Charm Backgrounds

There are two principal backgrounds to the charm measurement:

the much larger bottom BR

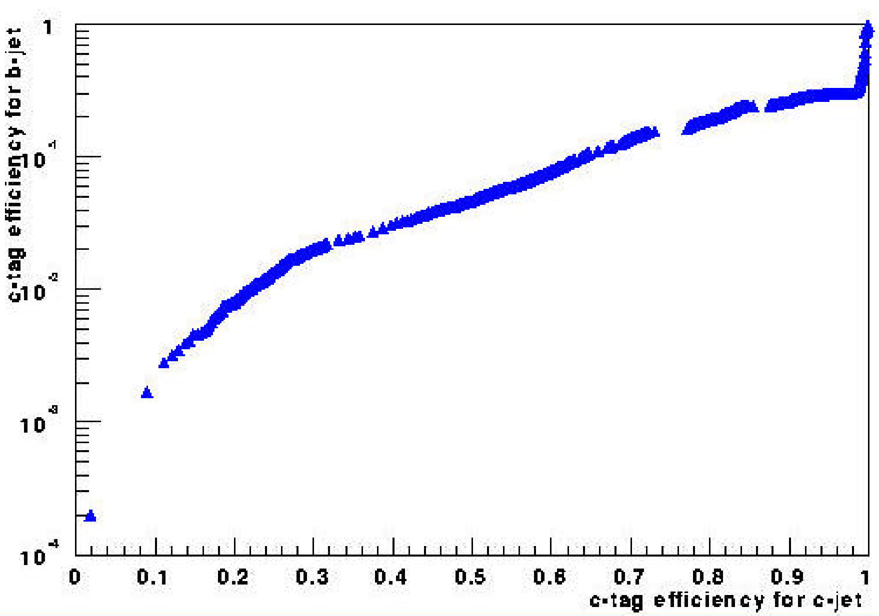
the ZZ^* background

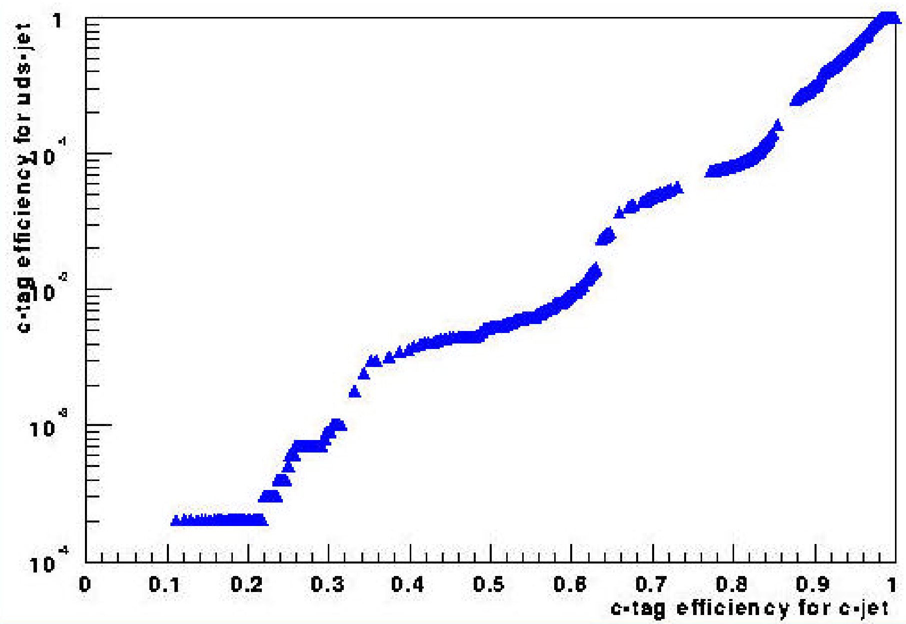
Mode	Charm Tag
h->WW*	3
h->bb	60
h->cc	30
h->gg	3
e+e-->ZZ(*)	39

Investigation of Jet Level Tags

- Five parameters to discriminate b and c
  - Largest 3D impact parameter sig in jet
  - Number of tracks with 3D-ip $> 3\sigma$
    - these two jet-level parameters motivated by their effectiveness in TESLA study (R. Hawkings, LC-PHSIM-2000-021)
  - Number of vertices in jet
  - Pt corrected mass
  - P(jet)

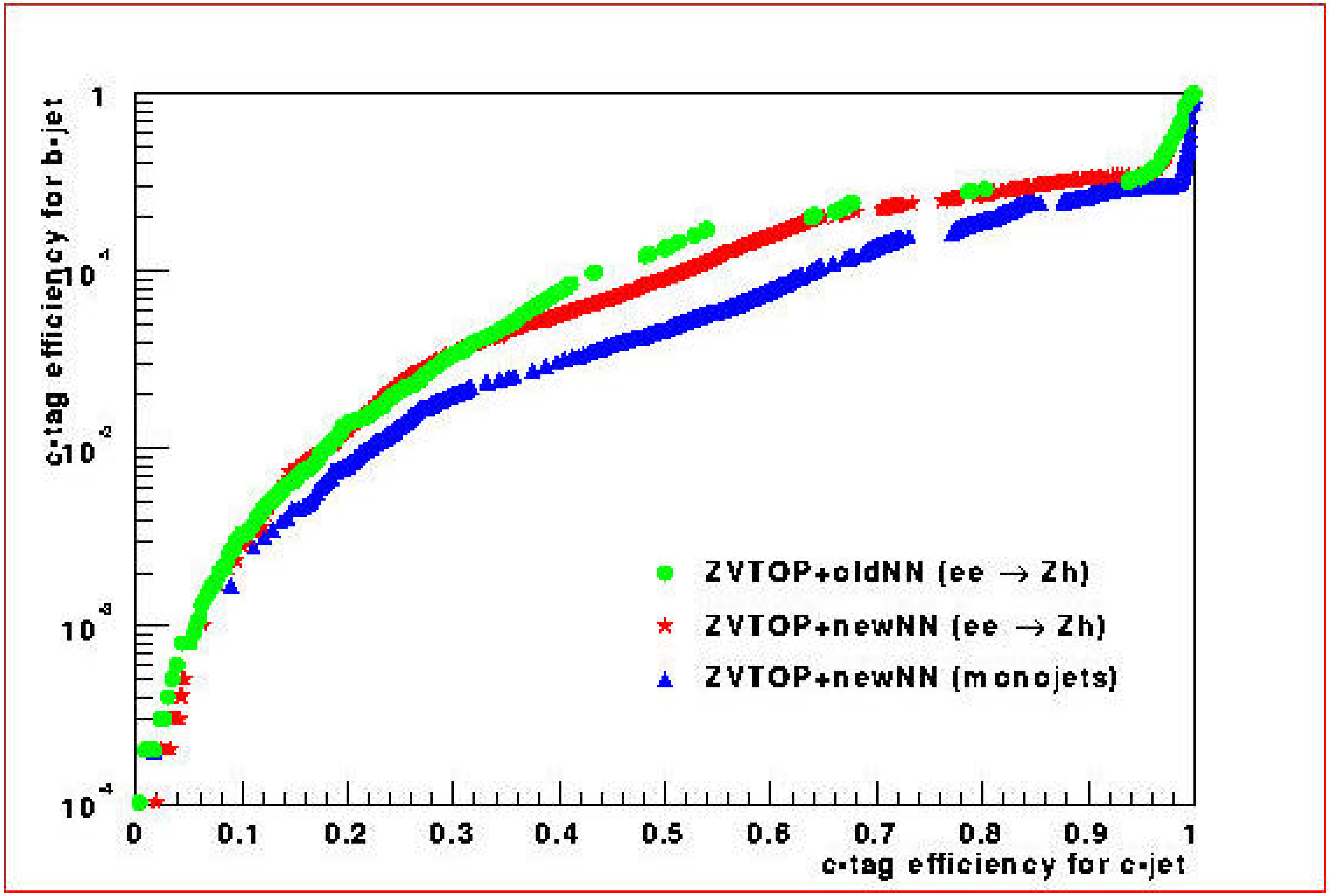
Investigation of Jet Level Tags: Monojets (45 GeV)





Compares very well with results in TESLA study
(R. Hawkings, LC-PHSIM-2000-021)

Investigation of Jet Level Tags: Comparison



New Jet Level Tag added to Event Level Tag

We have added the jet level tag described above
to the event level tag:

If an event tags as b or c,
tag as $H \rightarrow bb$ if at least 1 jet tags b
tag as $H \rightarrow cc$ if at no jet tags as b,
and at least 1 tags as c

Charm BR precision improves from 39% to 32%
(at 500 GeV, 500 fb^{-1}, Higgstrahlung only)

Conclusions

$H \rightarrow bb$ and $e^+e^- \rightarrow ZZ^*$
are significant backgrounds to $H \rightarrow cc$

Improved $H \rightarrow cc$ precision is obtained by adding
the jet level maximum impact parameter,
and jet level Nsig

(39% -> 32%)