Higgs Branching Ratio Measurements at the Linear Collider and Vertex Detection

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Higgs Branching Ratio measurements

Vertex Detector Parameter dependences

Neutron Radiation Damage Studies
IEEE Trans. Nuclear Science (2000)

Higgs Branching Ratio Measurements at the Linear Collider and Vertex Detection

The physics opportunities of a future Linear Collider motivates a detector with the best possible vertex detector:

- Higgs branching ratios
- Higgs self coupling
- SUSY physics, eg. staus
- Top physics
- W/Z reconstruction
- Z pole physics

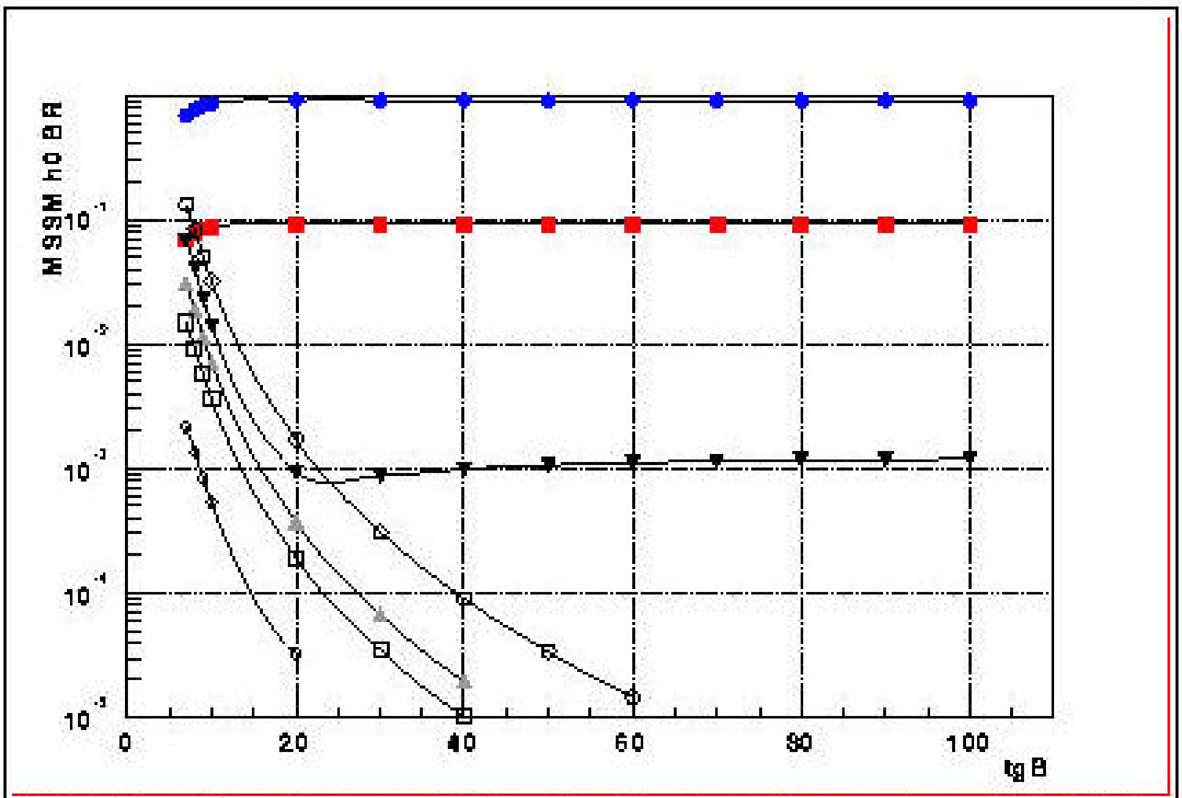
…..and the event rates will be small.

So we really want to optimize performance

The measurement of Higgs decay modes it a particularly good benchmark physics process for the vertex detector design:

- Significant physics goal
- Rich in secondary vertexing
- Contains mixture of strong and weak channels

MSSM h^0 Branching Ratios (Maximal Mixing)



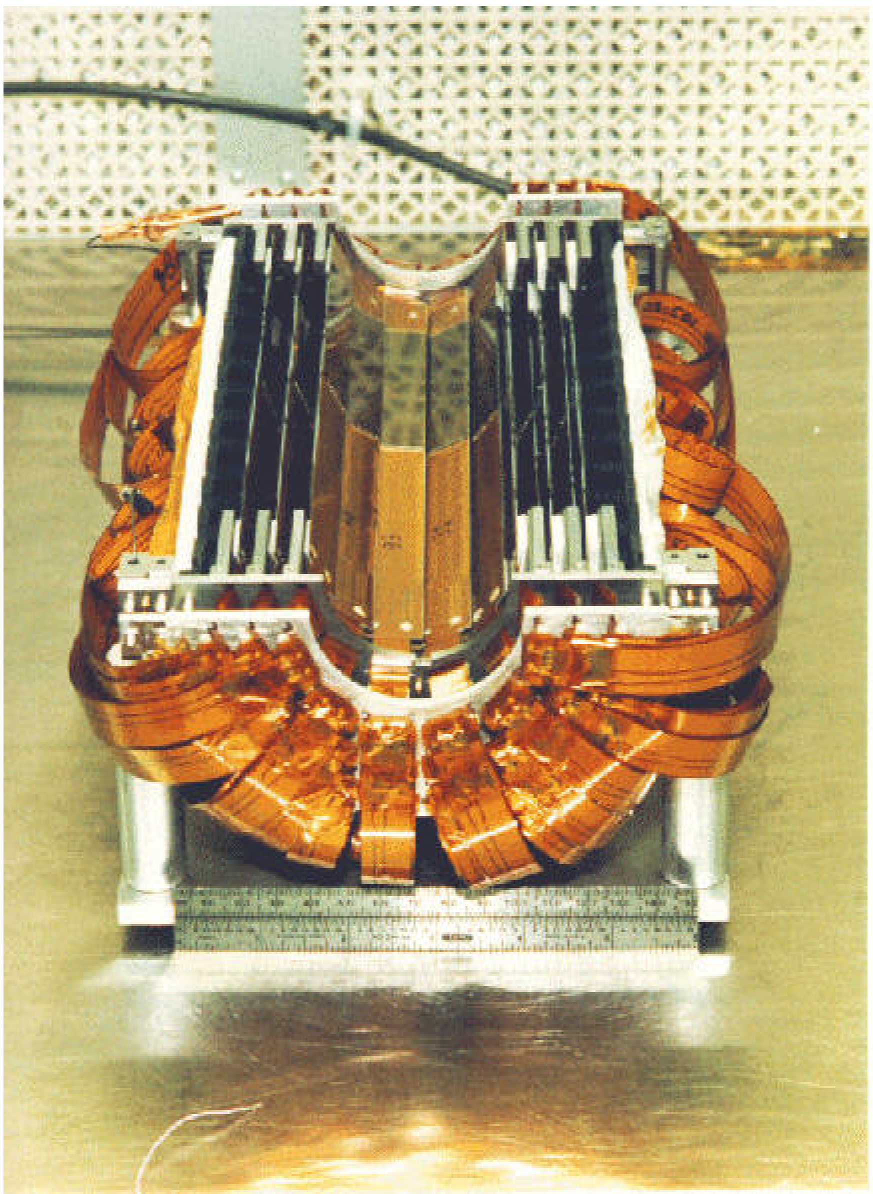
MSSM h^0 Branching Ratios vs $tg\beta$ Assuming Maximal Mixing and m_{h^0}=120 GeV (solid ◯=bb, solid square=$\tau\tau$, solid Δ=cc, solid ▽=gg, ◯=ww, square=ss, Δ=tt ◇=$\gamma\gamma$)

HDECAY, Djouadi, Kalinowki, Spira,
DESY 97-079 (1997)

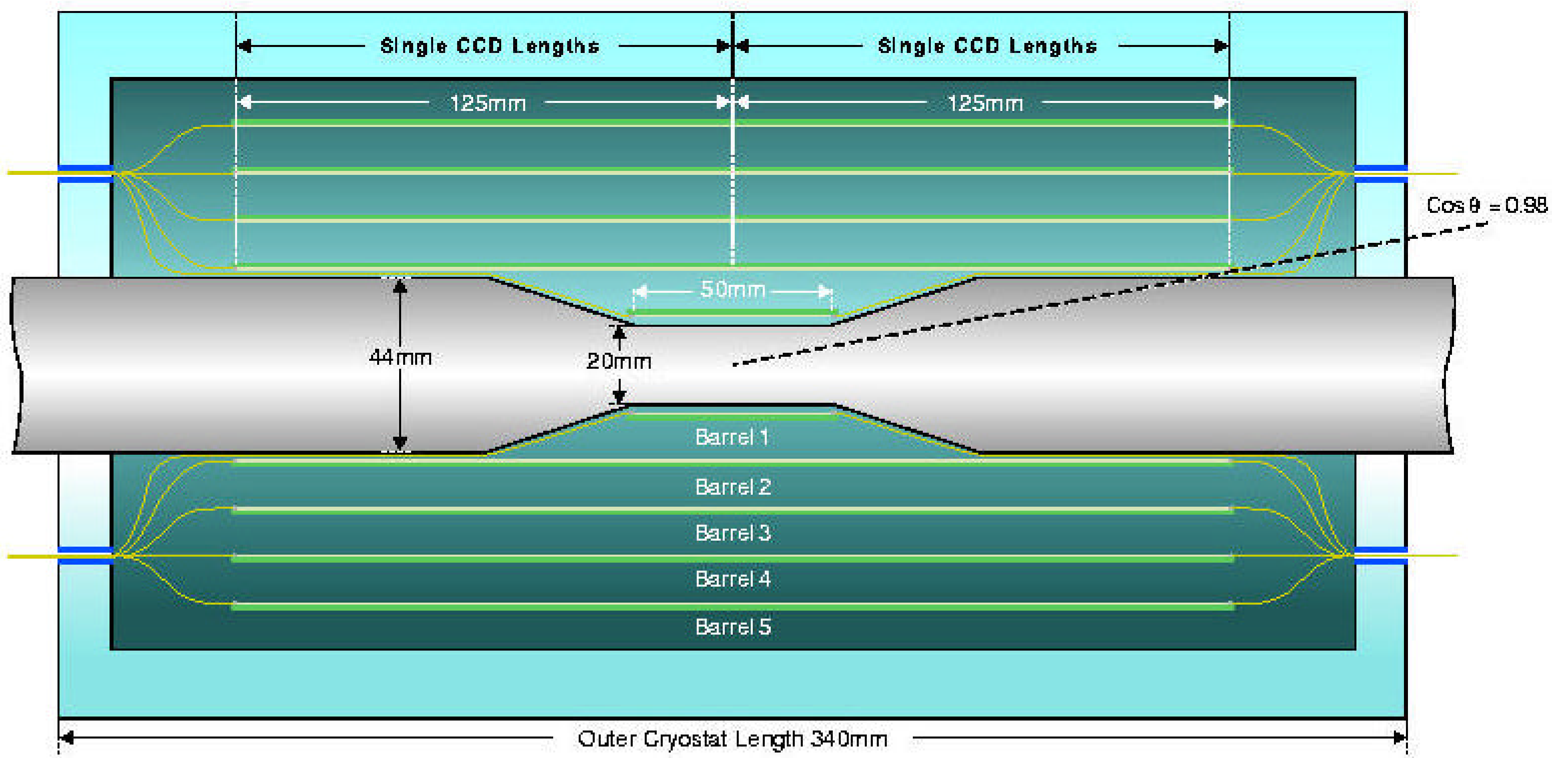
SLD's VXD3

307,000,000 pixels
3.8 μm point resolution
Excellent b/c tagging

} We can do even better



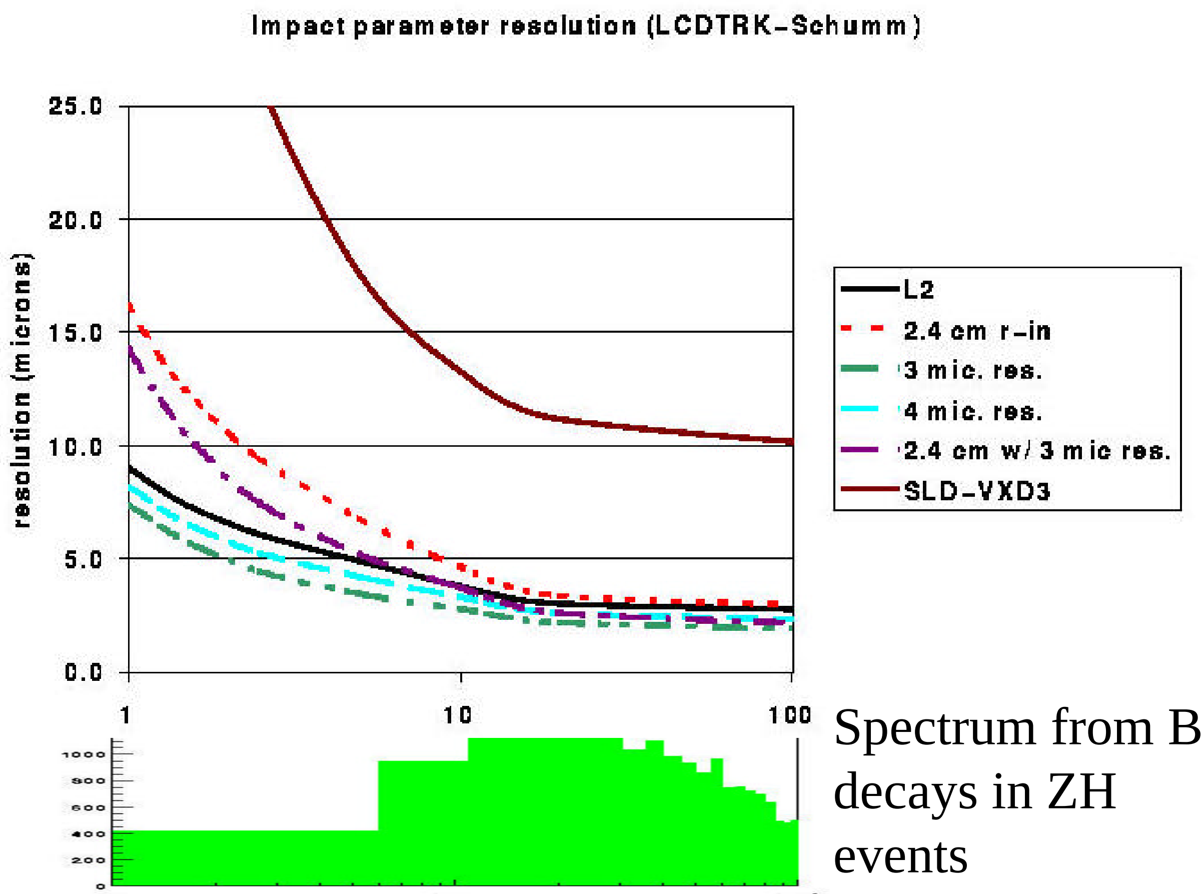
Suggested layout of Vertex Detector for future e^+e^- Linear Collider (Updated November 1998)



799,000,000 pixels
standalone tracking
w/ 5 barrels

Vertex Detector Parameters

Hit resolution
Number of barrels
Thickness of barrels (rad. lengths)
Angular coverage
Readout speed
Material inside vertex detector (beampipe, etc.)
Radiation hardness



Spectrum from B decays in ZH events

J. Brau, LCWS 2000, October 25, 2000

Radiation Hardness Tests of CCDs

Nick Sinev

(http://blueox.uoregon.edu/~jimbrau/talks/IEEE-99/ieee99.pdf,
to be published in IEEE Trans. Nucl. Science (2000))

Background estimates have varied from 10^7 n/cm^2/year
to 10^{11} n/cm^2/year
- 2.3 x 10^9 n/cm^2/year (Maruyama-Berkeley2000)

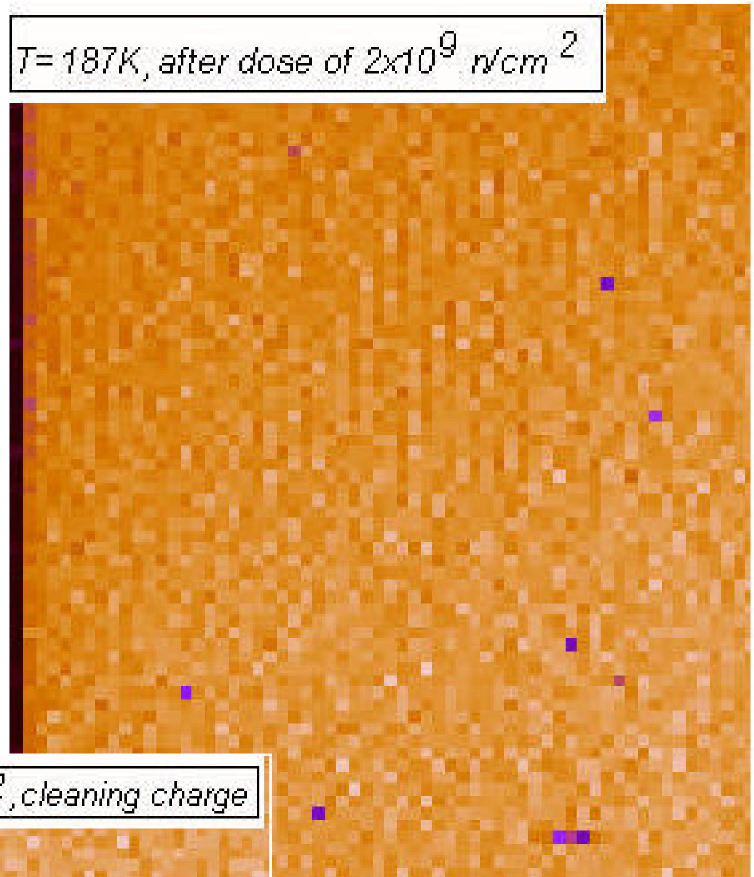
Expected tolerance for CCDs in the range of 10^{9-10}

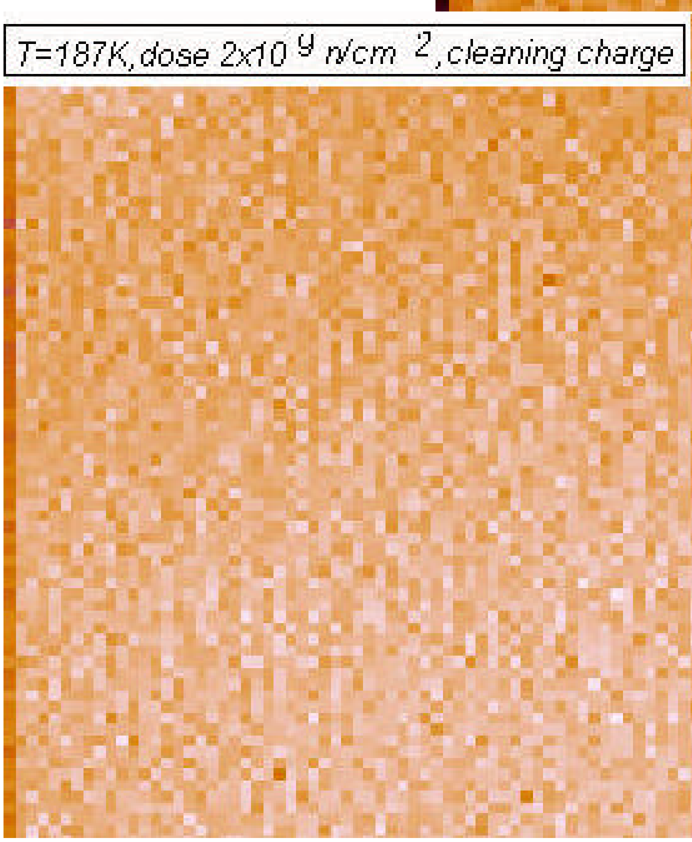
Increase tolerance to neutrons can be achieved through
- improve understanding of issues and sensitivity
- engineering advances
  - flushing techniques
  - supplementary channels
  - bunch compression & clock signal optimization

This study investigated flushing techniques on spare VXD3 CCD

@SLAC ~ 2×10^9 n/cm^2, T_{room}, Pu(Be), ≈ 4 MeV
@SLAC Annealing study 100° C for 35 days
@Reactor (I) ~ 2×10^9 n/cm^2, T_{room}, reactor*, ≈ 1 MeV
@Reactor (II) ~ 1.2×10^9 n/cm^2 , T~190K, reactor* , ≈ 1 MeV
Total exposure ~ 5.2×10^9 n/cm^2

Image of damaged sites ⇒





⇐ Image of damaged sites after flushing

Signal Loss Results from Exposures

	$\sim 2 \times 10^9$ n/cm^2	$\sim 5.2 \times 10^9$ n/cm^2
T = 185K, cluster sum no flushing light	4.05%	29.1%
T = 185K, cluster sum with flushing light	1.5%	18.0% *
T = 178K		11.0% *

Note (*) - flush is only partially effective in test set-up due to required delay between flush and readout (1 second)

In LC detector – much reduced loss with flushing

Vertex Detector Design for the future Linear Collider

- Maximum Precision (< 4 μm)
- Minimal Layer Thickness
  (1.2% $X_0 \rightarrow$ 0.4% $X_0 \rightarrow$ 0.12% $X_0 \rightarrow$ 0.06% X_0)
  SLD-VXD2 SLD-VXD3 Linear Collider stretched
- Minimal Layer 1 Radius (28 $\rightarrow$ 12 mm $\rightarrow$ 5mm)
  SLD-VXD3 LC Schumm challenge
- Polar Angle Coverage (cos θ~ 0.9)
- Standalone Track Finding (perfect linking)
- Layer 1 Readout Between Bunch Trains

Event simulation

- Pandora-pythia and Pythia v5.7
  - beamstrahlung included and important
- Detector model : L2

$e^+ e^- \rightarrow ZH$
$H \rightarrow bb$
$H \rightarrow \tau\tau$
$H \rightarrow cc$
$H \rightarrow gg$
$H \rightarrow WW$
$e^+ e^- \rightarrow WW$
$e^+ e^- \rightarrow ZZ$
$e^+ e^- \rightarrow qq$
$e^+ e^- \rightarrow tt$

$\sqrt{s} = 500$ GeV
$M_H = 140$ GeV/c^2
$\int L = 500$ fb^{-1}
Analysis with $Z \rightarrow l^+ l^-$ evts, scaled to $Z \rightarrow qq$
(OPAL, D. Strom)

Very Preliminary Results Presented in this Talk

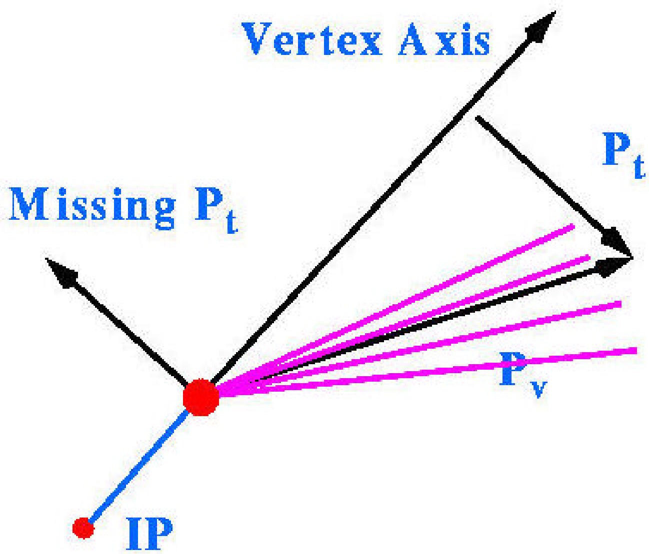
Previous studies:
Hildreth, Barklow, Burke, PRD49, 3441 (1994)
M. Battaglia, HU-P-264 (1999)
G. Borisov, F. Richard, LAL-99-26 (1999)

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 (see last talk)

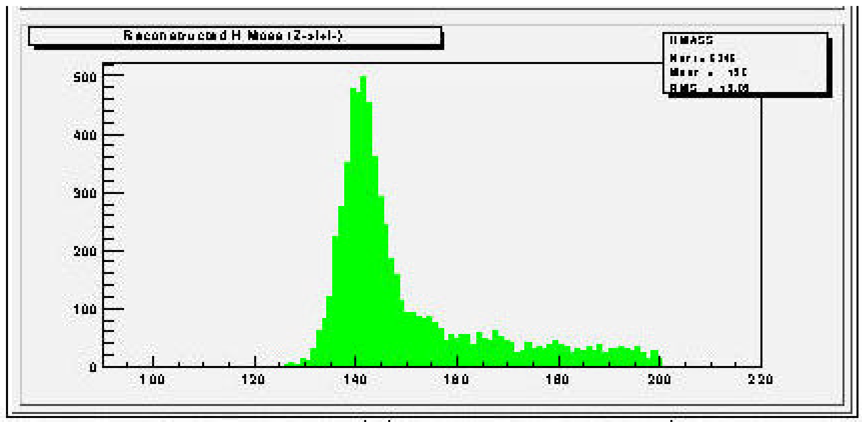
- Provides secondary vertex reconstruction, and pt-corrected mass



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

Higgs decay tags

Z -> leptons ($M_Z \pm 10$ GeV/c^2)
recoiling Higgs mass calculated



Higgs mass 130-150 GeV/c^2

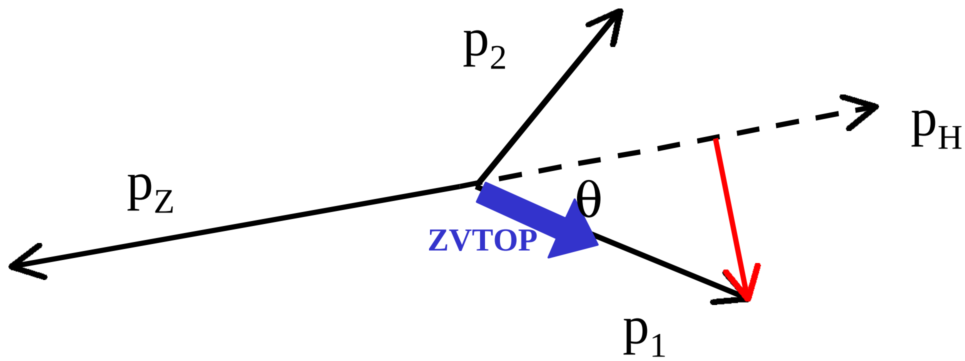
B tag

$M_{sec\text{-}vtx}$(pt-corrected) > 2.0 GeV/ c^2

c tag

$M_{sec\text{-}vtx}$(pt-corrected) < 2.0 GeV/ c^2
Only 1 ZVTOP secondary vertex
p(jet)/p(expected) > 0.45

p(vertex)/p(expected)



$p_H = p_1 + p_2 = - p_Z$

$p_1^T = f\,(M_H, m_1, \sin\theta)$

$p_1 = p_1^T / \sin\theta$, (p-expected)

where $\sin\theta$ is determined by VXD analysis by ZVTOP

W, tau, glue tags

- W tag (l νq q)
  - 3 leptons, non-Z p > 10 GeV
  - $E_{cone}(\cos\theta_l < 0.95) < 10$ GeV
  - track mult >6
- tau tag
  - track mult 2-8
  - anti W tag
  - max bnorm > 4
- glue-glue tag
  - analyze as two jet event
  - no sec. Vtx, no non-Z lepton w/ p>1 GeV/c,
  - not tagged as tau-tau, bb, cc, or WW

Efficiencies and Purities

(M_H = 140 GeV/c^2 , $\sqrt{s}$ = 500 GeV,

Model L2)

	Eff.	Signal/Backg.
$H \rightarrow bb$	0.30	5.3
$H \rightarrow \tau\tau$	0.30	1.6
$H \rightarrow cc$	0.19	0.2
$H \rightarrow gg$	0.21	0.06
$H \rightarrow WW^*$	0.09	3.6

Preliminary (not optimized)

Branching Ratio Errors

(M_H = 140 GeV/c^2 , $\sqrt{s}$ = 500 GeV,

$\int L$ = 500 fb^{-1}, Model L2)

$H \rightarrow bb$	0.390 ± 0.014
$H \rightarrow \tau\tau$	0.034 ± 0.005
$H \rightarrow cc$	0.024 ± 0.011
$H \rightarrow gg$	0.034 ± 0.020
$H \rightarrow WW^*$	0.458 ± 0.031

Preliminary (not optimized)

Detector Parameter Dependence

Branching Ratio Errors

(M_H = 140 GeV/c^2 , $\sqrt{s}$ = 500 GeV,

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

	L2	2.4 cm radius*	L2 3.0 μm res.
$H \rightarrow bb$	± .014	± .017	
$H \rightarrow \tau\tau$	± .005	± .006	
$H \rightarrow cc$	± .011(46%)	± .014 (60%)	
$H \rightarrow gg$	± .020(59%)	± .026 (78%)	
$H \rightarrow WW^*$	± .031	± .035	

*(optimistic-primary vtx)

Preliminary (not optimized)

Conclusions

- We have reported first results of a study of the sensitivity of the Higgs branching ratio measurements to the vertex detector parameters

- Future plans
  - add neural net analysis of selection parameters
  - ZVTOP studies
  - expand base of vertex detector variations
  - add $Z \rightarrow q\bar{q}$ selection