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Physics and Detectors for a
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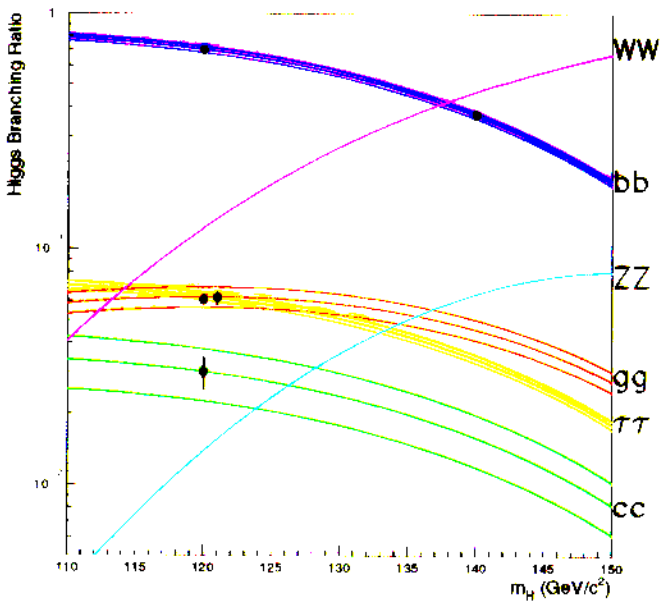
A Study of Higgs Decay Branching Ratios at the e^+e^- Linear Collider

Marco Battaglia

Dept. of Physics

University of Helsinki (Finland)



Event Simulation and Data Analysis

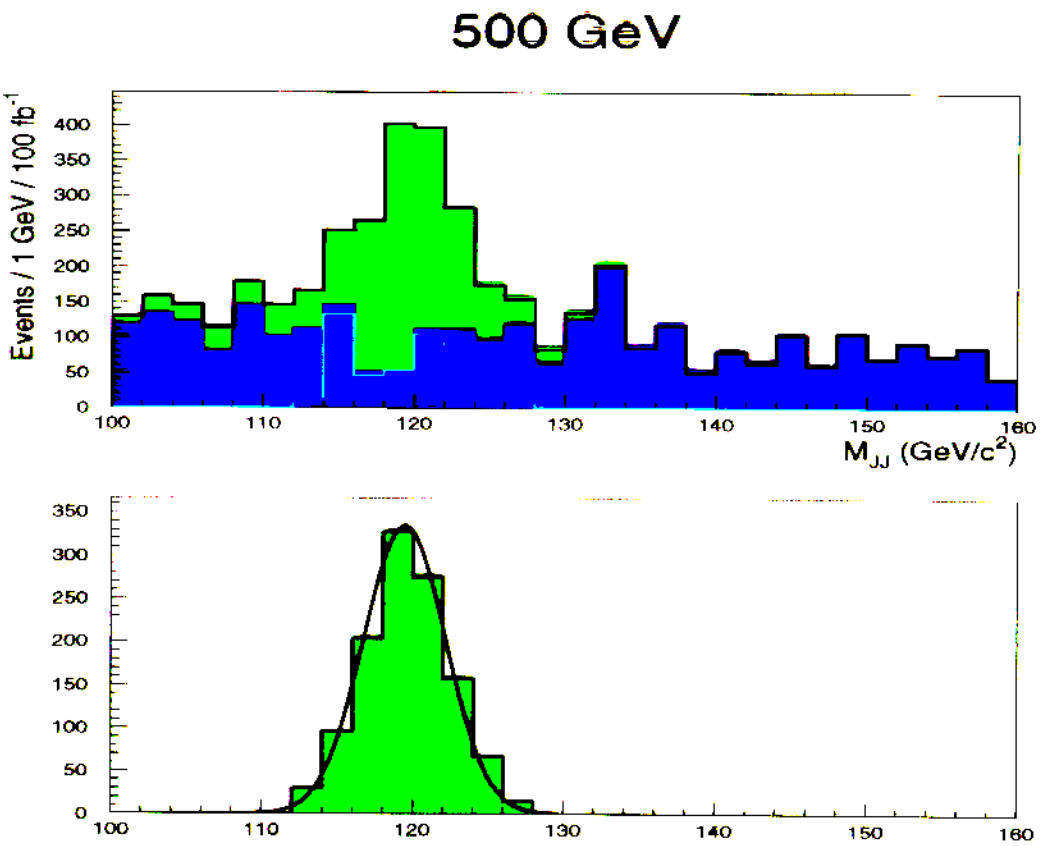
- Signal $e^+e^- \rightarrow Z^0H^0$, $H^0\nu\bar{\nu}$ events and backgrounds:
  - $e^+e^- \rightarrow q\bar{q}(\gamma)$
  - $e^+e^- \rightarrow t\bar{t}$
  - $e^+e^- \rightarrow Z^0Z^0$
  - $e^+e^- \rightarrow W^+W^-$
  - $e^+e^- \rightarrow e^-\nu W^+$

  generated with PYTHIA 5.02 and JETSET 7.405
- generators tuned on LEP data for EW and QCD variables and CLEO+LEP data for heavy flavour decays.
- include $\sqrt{s}$ smearing due to beamstrahlung
- simulation at $\sqrt{s} = 350$ and 500 GeV
  for $M_H = 120$ and 140 GeV/c^2
- Assume $\int L = 100\ fb^{-1}$ for analysis and extrapolate to 500 fb^{-1}

Detector Simulation

- Parametric smearing (SIMDET Program),
- Full GEANT simulation and track fit
  (BRAHMS+DELFIT Programs),
- Dedicated event Reconstruction and jet flavour tagging.

Higgs Selection

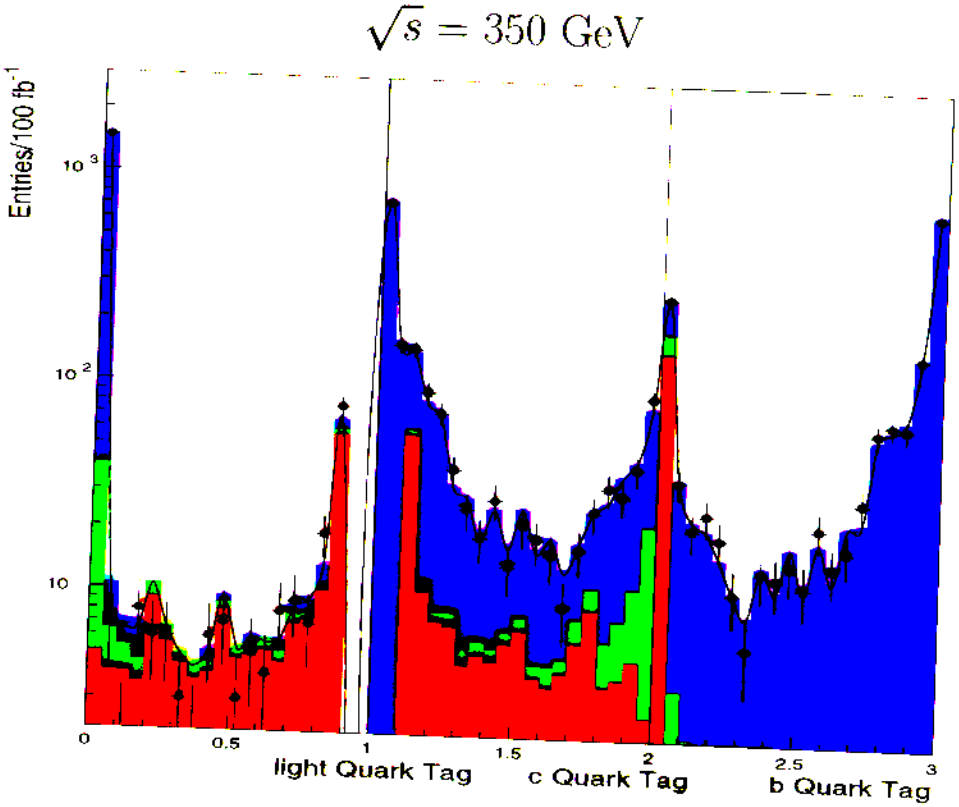


EFFICIENCY FOR $e^+e^- \to Z^0H^0$, $H^0\nu\nu$;
$Z^0 \to$ ANYTHING, $H \to$ HADRONS.

$\sqrt{s}$ (GeV)	350	500
$m(H)$ (GeV/c^2)	120	120
H^0Z^0, $H^0\nu\bar{\nu}$ Efficiency	15 %	20 %
H^0Z^0, $H^0\nu\bar{\nu}$ Purity	68 %	68 %
$S/\sqrt{B}$	59	52

Higgs Branching Ratio Determination

- For each candidate hadronic Higgs decay compute uds, cc and bb di-jet flavour tagging probabilities;
- obtain background composition from H^0 peak sidebands;
- Fit:
  - $\mathrm{BR}(H \to b\bar{b})/\mathrm{BR}(H \to \mathrm{hadrons})$,
  - $\mathrm{BR}(H \to c\bar{c})/\mathrm{BR}(H \to \mathrm{hadrons})$ and
  - $\mathrm{BR}(H \to gg)/\mathrm{BR}(H \to \mathrm{hadrons})$ fractions
- use a binned likelihood fit to the background subtracted di-jet flavour tagging response (3 entries/evt).



BR($H^0 \to q\bar{q}$) Determination

FIT RESULTS FOR $m(H) = 120$ GEV/C^2 AND 500 fb^{-1}

Channel	Input BR	Fit $\sqrt{s} = 350$	Fit $\sqrt{s} = 500$
$\frac{BR(H\to b\bar{b})}{BR(H\to hadrons)}$	0.87	0.87 ± 0.01	0.88 ± 0.01
$\frac{BR(H\to c\bar{c})}{BR(H\to hadrons)}$	0.03	0.031 ± 0.005	0.025 ± 0.006
$\frac{BR(H\to gg)}{BR(H\to hadrons)}$	0.09	0.093 ± 0.004	0.095 ± 0.005

BR($H^0 \to \tau^+\tau^-$) Determination

- $\tau\tau$ Higgs decays rejected by hadronic Higgs decay selection,
- Define global $H \to \tau\tau$ probability using six discriminating variables:

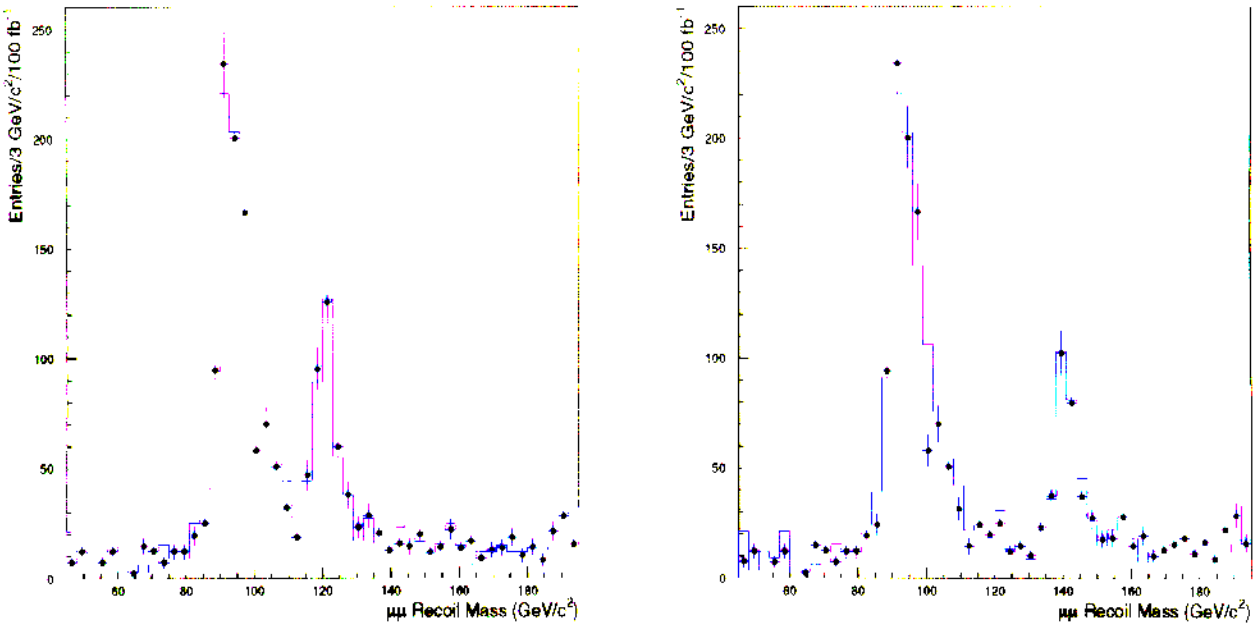
RESULTS FOR $m(H) = 120$ GEV/C^2 AND 500 fb^{-1}

Channel	Selected Evts. / 500 fb^{-1}
$H \to \tau\tau$	810
$H \to b\bar{b}$	2
$H \to gg, c\bar{c}$	9
Non Higgs Bkg.	1390

Accuracy on $\sigma_{ZH} \times BR(H \to \tau\tau) = 5.7\%$

$\ell\ell$ Recoil Mass for $e^+e^- \to Z^0H^0 \to \ell^+\ell^- X$

$M_H = 120$ GeV/c^2 $M_H = 140$ GeV/c^2



- Good agreement between full GEANT and SIMDET simulations.

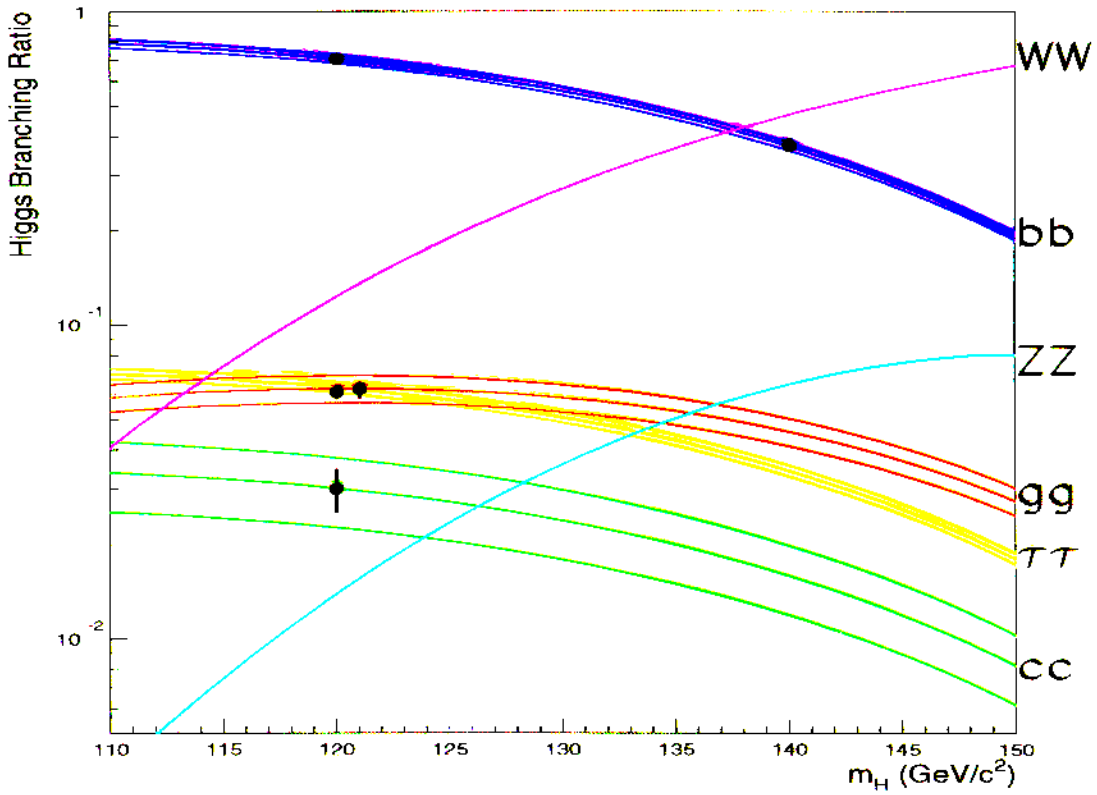
M_H	Signal $(\mu\mu)$ /100 fb^{-1}	Bkg / 100 fb^{-1}	Eff.	$S/\sqrt{B}$
120 GeV/c^2	250	78	57%	27
140 GeV/c^2	216	38	55%	35

Statistical Accuracy on σ_{ZH}

M_H GeV/c^2	$\frac{\delta(\sigma_{ZH})}{\sigma_{ZH}}$ (ee + $\mu\mu$) for 500 fb^{-1}
120	$\pm$ 2.1 %
140	$\pm$ 2.2 %

Higgs Branching Ratio Determination for $m_H = 120$ GeV/c^2 and 500 fb^{-1}

Channel	$\delta(BR)/BR$
$H^0/h^0 \to b\bar{b}$	$\pm$ 0.024
$H^0/h^0 \to c\bar{c}$	$\pm$ 0.160
$H^0/h^0 \to gg$	$\pm$ 0.047
$H^0/h^0 \to \tau^+\tau^-$	$\pm$ 0.060



- SM BR's and uncertainties estimated from HDECAY with:
  - $m_b = 4.82 \pm 0.10$ GeV/c^2, $m_b - m_c = 3.40 \pm 0.04$ GeV/c^2
  - $\alpha_s(m_Z) = 0.1164 \pm 0.0025$, $m_{top} = 174 \pm 0.3$ GeV/c^2

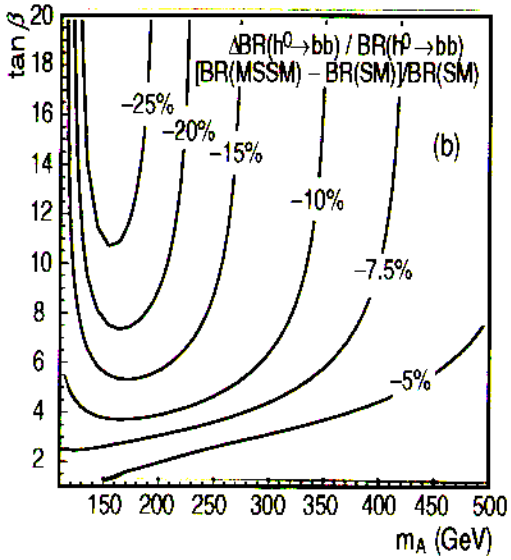
- in MSSM:

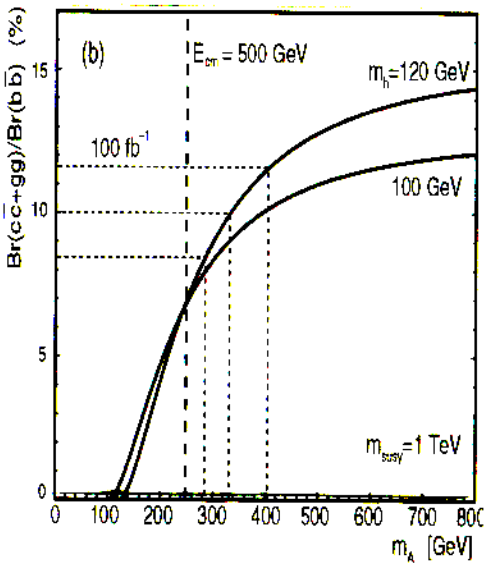
$$\mathrm{BR}(h^0 \to b\bar{b}) \propto \frac{\sin^2\alpha}{\cos^2\beta} \quad \mathrm{BR}(h^0 \to c\bar{c}) \propto \frac{\cos^2\alpha}{\sin^2\beta}$$

$$\text{with: } \tan\alpha = \frac{(M_Z^2+M_A^2)\sin\beta\cos\beta}{M_h^2-(M_Z^2\cos^2\beta+M_A^2\sin^2\beta)} \quad \text{and} \quad \tan\beta = \frac{v_2}{v_1}$$

$$\frac{BR(h\to c\bar{c})}{BR(h\to b\bar{b})} \propto \frac{1}{tan^2\alpha\tan^2\beta} \simeq \frac{(M_h^2-M_A^2)^2}{(M_Z^2+M_A^2)^2}$$

- $\to$ Higgs $b\bar{b}$ branching ratio sensitive to SM or MSSM nature of the Higgs boson but not to the mass of the CP-odd scalar A due to dependence on $m_{SUSY} = \sqrt{M_{\tilde{t}_1} M_{\tilde{t}_2}}$ from radiative corrections;

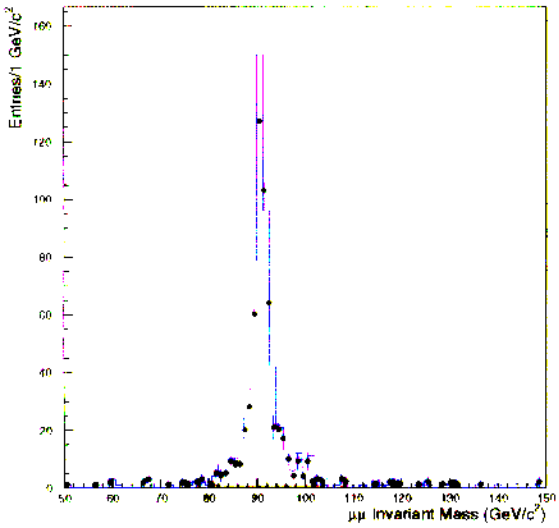




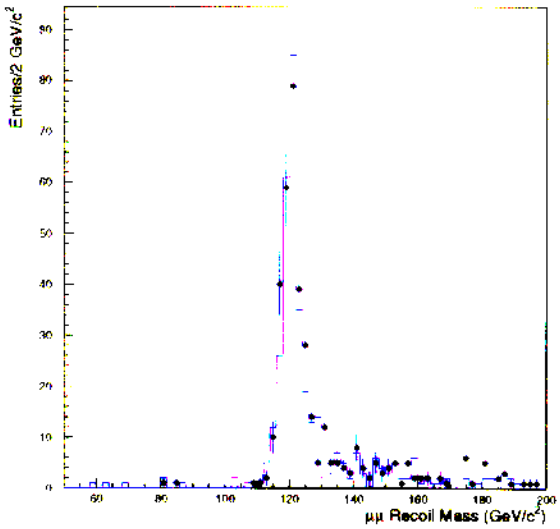
- $\to$ Ratio of h^0 branching ratios to up and down type quark sensitive to A mass M_A almost independently on the stop mass scale m_{SUSY}:

- $h \to gg$ decay has similar features to $c\bar{c}$ since it proceeds mainly via a top loop diagram.

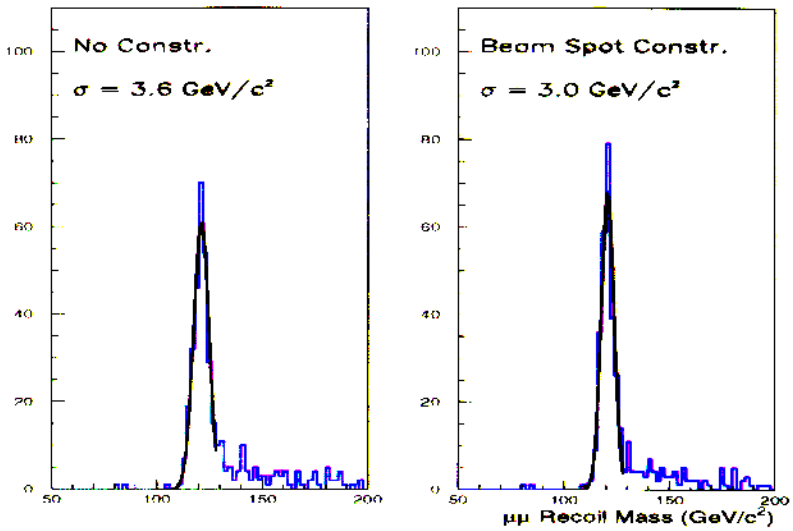
$M_{\mu\mu}$



$\mu\mu$ Recoil Mass



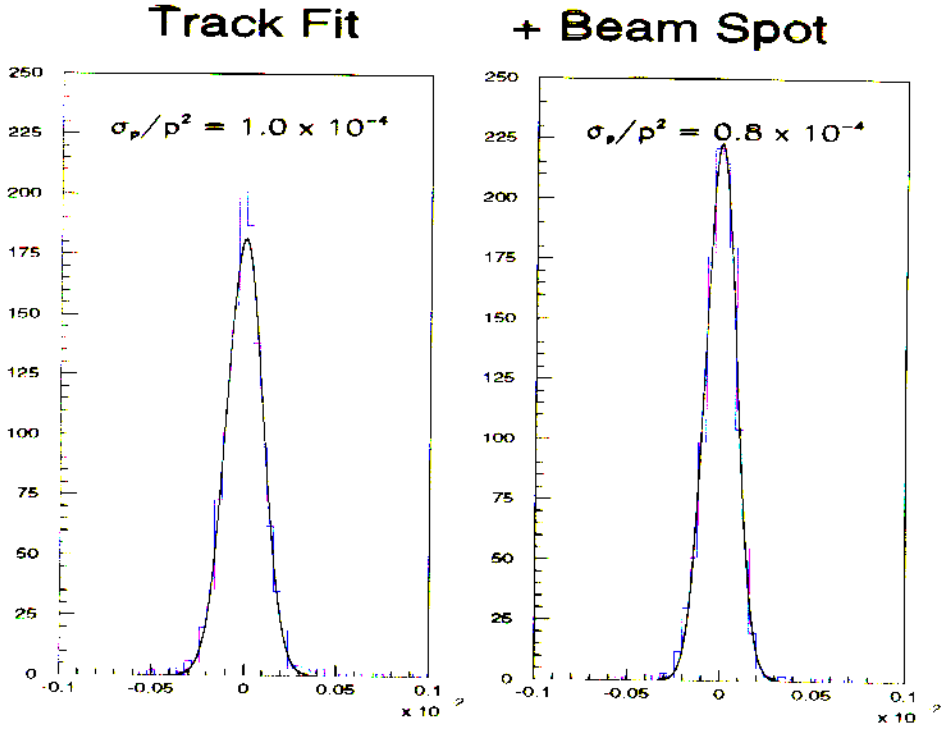
Recoil Mass Resolution at $\sqrt{s} = 350$ GeV/c^2



Mass GeV/c^2	$\sigma_{Recoil\,Mass}$ GeV/c^2
91.2	3.9
120	3.0
140	2.5

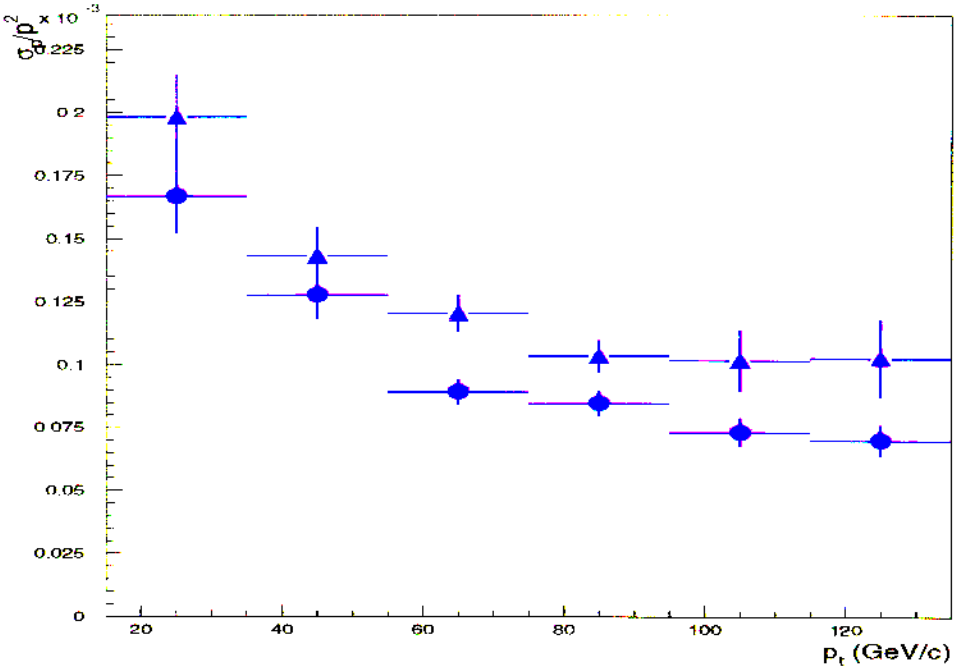
σ_{ZH} Determination

- The determination of the Higgstrahlung cross-section is a key ingredient in the extraction of the absolute Higgs decay branching ratios.
- Higgs tagging independant on the Higgs decay mode is important in the study of rare and exotic Higgs decays (e.g. $H^0 \rightarrow$ *invisible*).
- Use dilepton recoil mass from $Z^0 \rightarrow \ell^+\ell^-$ decay.
- This reaction sets stringent constraints on the momentum resolution from the main tracker.
- Study σ_p/p^2 using BRAHMS simulation and full track fit:



- Impose beam-spot constraint to improve momentum resolution of energetic leptons.

Momentum Resolution



Event Selection

- Select events with at least 2 isolated oppositely charged particles:
  - no explicit lepton identification
  - p > 20 GeV/c
  - Define cone $\pm 10°$ around the particle and require $E_{cone} < 7$ GeV.
- $\cos\theta_{Thrust} < 0.85$
- $\frac{|M_{\ell\ell} - M_Z|}{\sigma_M} < 2.5$
- $\cos\theta_{Pmiss} < 0.90$ if $Pmiss > E_{beam}$