Experimental Study of Higgs Bosons in Minimal Supersymmeric Extension of Standard Model at TESLA

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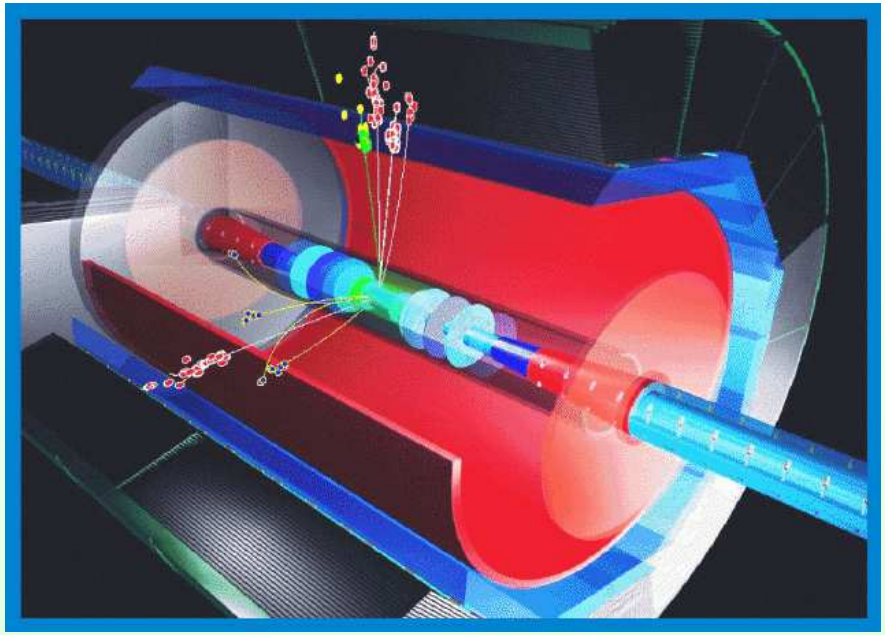
TESLA



Future e^+e^- Linear Collider

Energies: 90 - 800+ GeV

Integrated Luminosity:

350 $fb^{-1}/year$ at 500 GeV

500 $fb^{-1}/year$ at 800 GeV

Contents:

- **MSSM scenario**
- **Analysis of the process** $e^+e^- \to H_iH_j \to b\bar{b}b\bar{b}$
- **Indirect measurement of parameters of CP-violating MSSM scenario**

MSSM

CP-Conserving Scenario:

5 physical Higgs Bosons:

2 neutral CP-even: H^0, h^0

1 neutral CP-odd: A^0

2 charged: H^+, H^-

mass eigenstates = CP eigenstates

CP-Violating Scenario:

3 neutral Higgs Bosons:

$$H_1, H_2, H_3$$

$$M_{H_1} \leq M_{H_2} \leq M_{H_3}$$

have mixed CP parities

mass eigenstates $\neq$ CP eigenstates

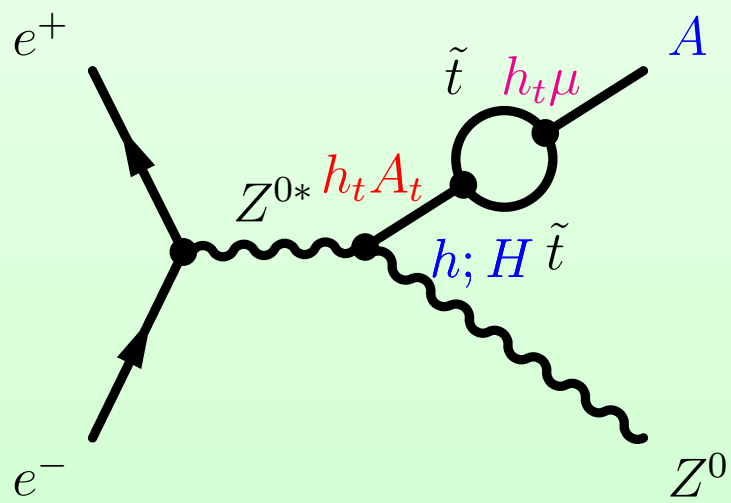
CP-Violation:

$A_{t,b}$ **- Complex** $m_{\tilde{g}}$ **- Complex**

$A_{t,b}$ **- soft SUSY-breaking trilinear coupling of the Higgs boson to top (bottom) squarks.**

$h_{t,b}$ **- Yukawa couplings.**

Higgsstrahlung:

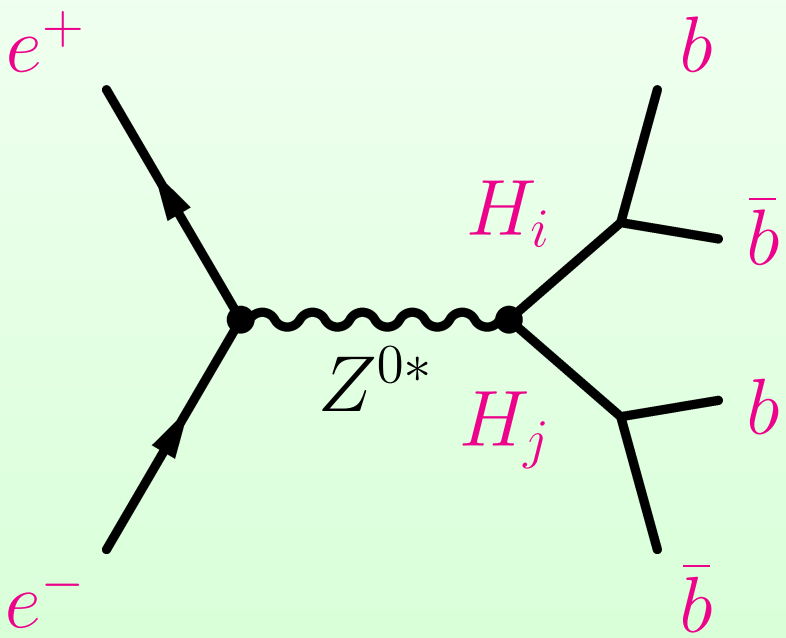


Parametrization of the Higgs sector:

M_{H^+} **and** $tan\beta = \frac{v_2}{v_1}$

TESLA

$$e^+e^- \longrightarrow H_iH_j \longrightarrow b\bar{b}b\bar{b}$$



$$\sqrt{s} = 500GeV$$

$$L = 500fb^{-1}$$

Using:

- HZHA (from ALEPH): generation
- SIMDET 4.01: fast simulation
- ZV-TOP (from SLD): b-tagging
- Kinematical Fit (from DELPHI)

($\sigma * BR$) - ?

M_{H_i} **- ?** M_{H_j} **- ?**

Analysis of $e^+e^- \to H_2H_3 \to b\bar{b}b\bar{b}$ at TESLA.

Signal (example point):

Parameter	Value
$\tan\beta$	19
M_{H^+}	164 GeV
$Re(A_t)$	285 GeV
$Im(A_t)$	771 GeV

M_{H_1} = 112 GeV

M_{H_2} = 141 GeV

M_{H_3} = 155 GeV

$N_{events}(H_2H_3 \to b\bar{b}b\bar{b})$ = 7000

Signal and BG samples:

Process	σ [fb]
$H_1H_2 \to b\bar{b}b\bar{b}$	0.4196
$H_2H_3 \to b\bar{b}b\bar{b}$	12.61
$H_1H_3 \to b\bar{b}b\bar{b}$	3.428
$Z^0\gamma^* \to 2q$	13580
$W^+W^- \to 4q$	4134
$Z^0Z^0 \to 4q$	314.3
$H_1Z^0 \to b\bar{b}q\bar{q}$	34.63
$H_2Z^0 \to b\bar{b}q\bar{q}$	6.043
$t\bar{t} \to W^+W^-b\bar{b}$	669.3

Cuts

Against 2-fermion background:

- Hadronic 4-jet events with full energy

Against 4-fermion background:

- Nonforward peaked and spherical events

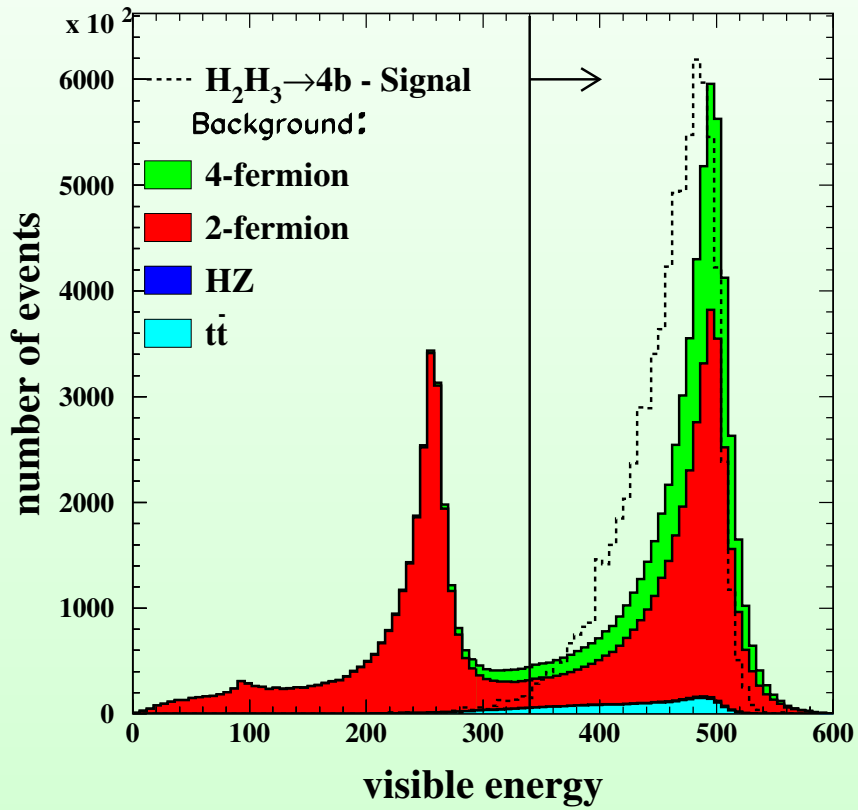
For $t\bar{t}$ background reduction:

- Number of tracks and clusters cut
- Jet resolution parameter cut

Against light flavour quarks:

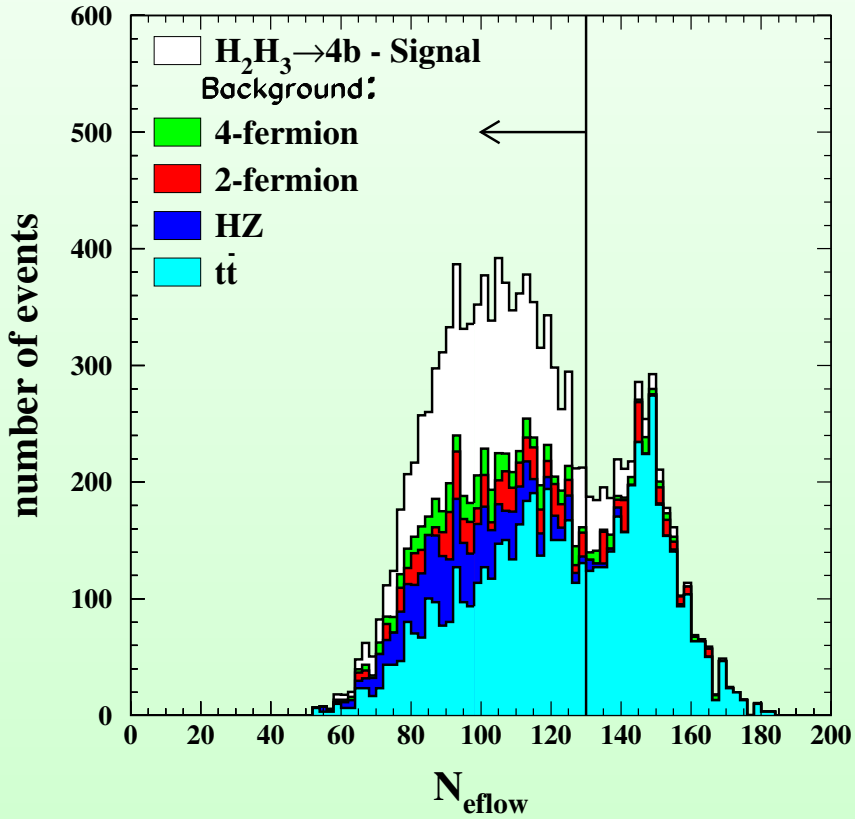
- b-Tag

Visible energy cut

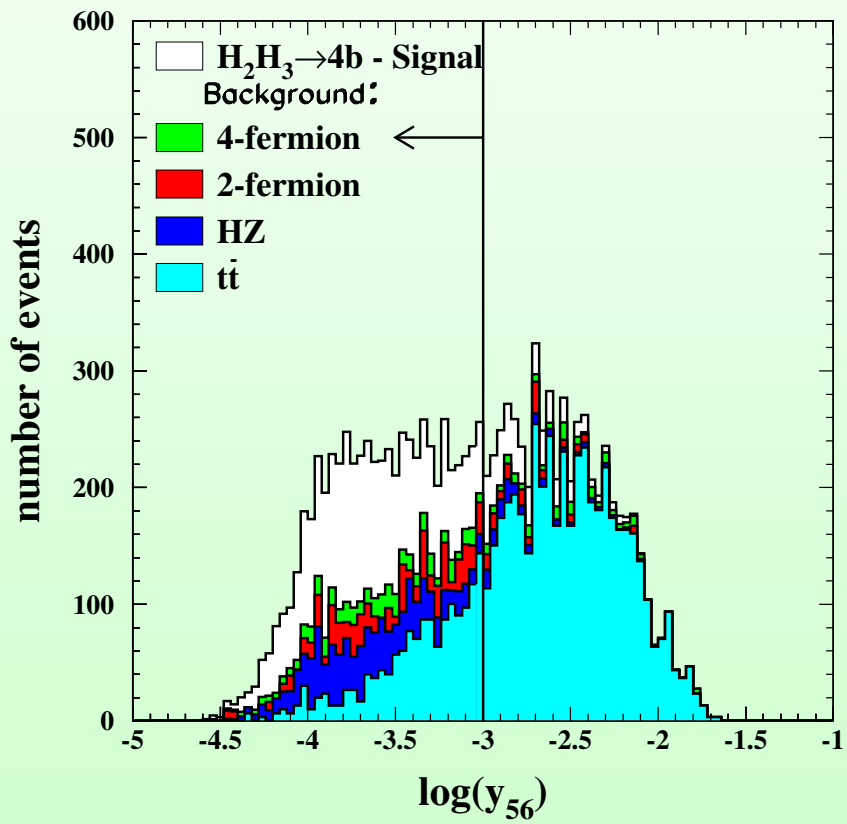


Cuts against $t\bar{t}$ background

Number of tracks and clusters cut

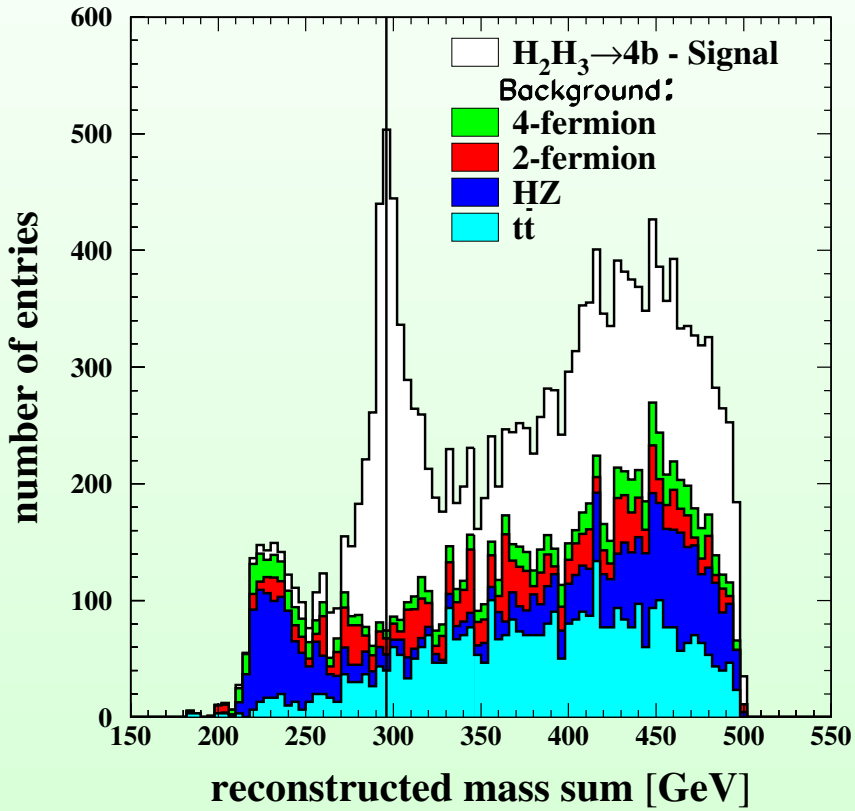


Jet resolution parameter cut



Reconstructed Mass Sum

3 combinations of 4 jets for 2 masses



ΣM = (296.8 $\pm$ 0.6) GeV

Cutflow

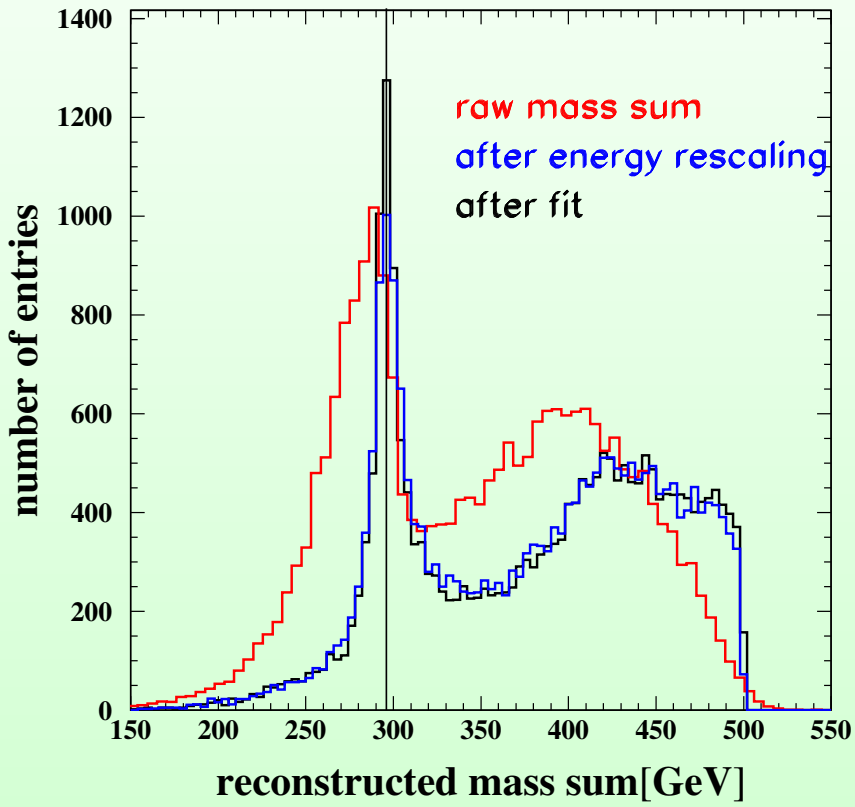
Cut	Signal	Eff.	Total BG
no cuts	6305	100.0	9428007
N_{jets}	6305	100.0	9355106
P_{vis}	6217	98.6	6020137
N_{tr}/jet	5706	90.5	2669602
$\cos(thrust)$	5253	83.3	1383264
$thrust$	5126	81.3	399239
$\log(y_{34})$	4979	79.0	356903
N_{eflow}	4554	72.2	314351
$\log(y_{56})$	3930	62.3	207202
B_{12}	3719	59.0	48611
B_{34}	2845	45.1	3159

Improved Mass Reconstruction

Energy rescaling: $E_{jet}, \vec{p}_{jet} * \frac{\sqrt{s}}{E_{vis}}$

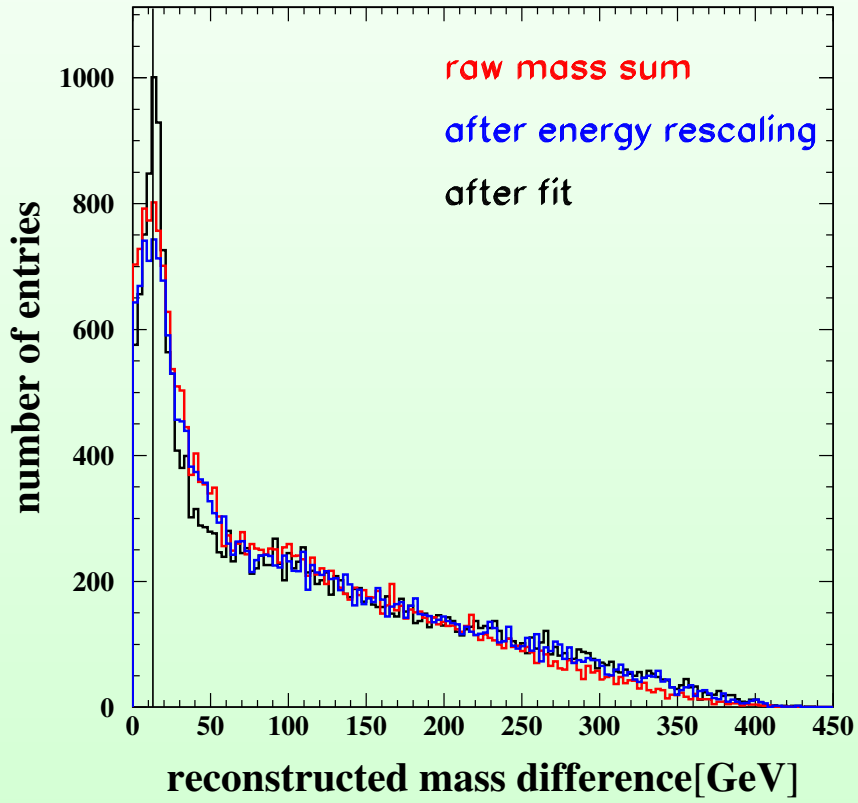
4c fit: $\vec{p}$, **E constraints**

Mass Sum



ΣM = (296.2 $\pm$ 0.2) GeV

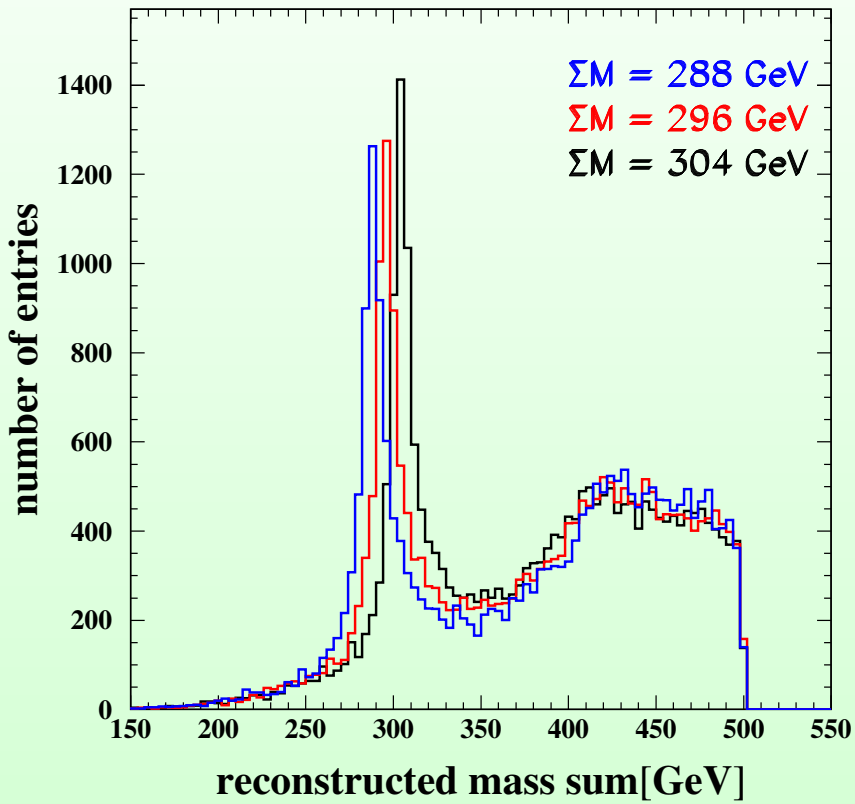
Mass Difference



ΔM = (13.3 $\pm$ 0.3) GeV

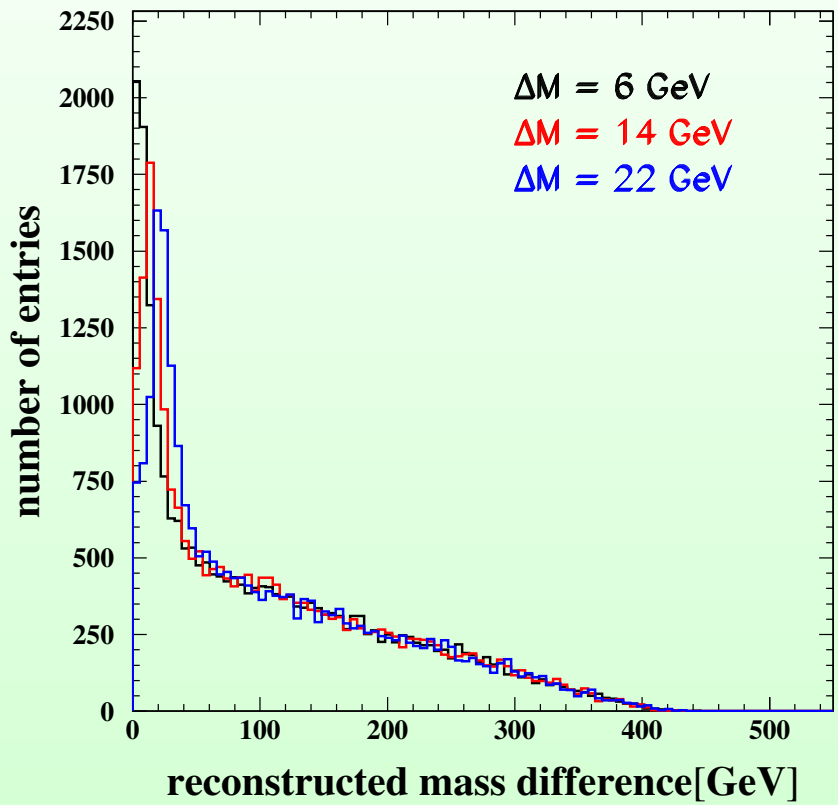
Improved Mass Reconstruction

Mass Sum

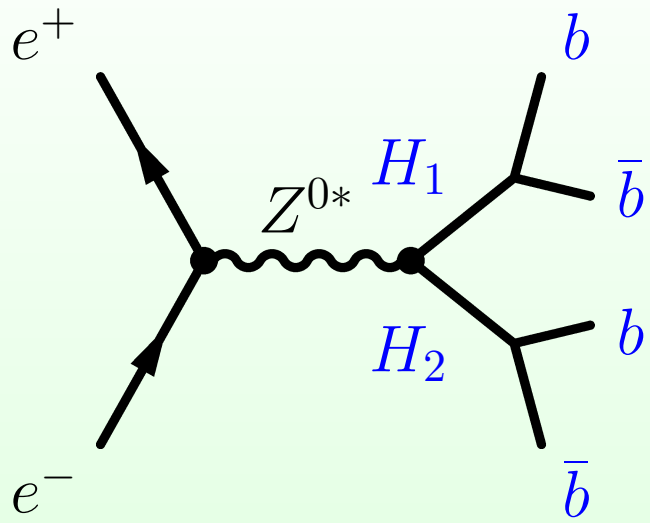


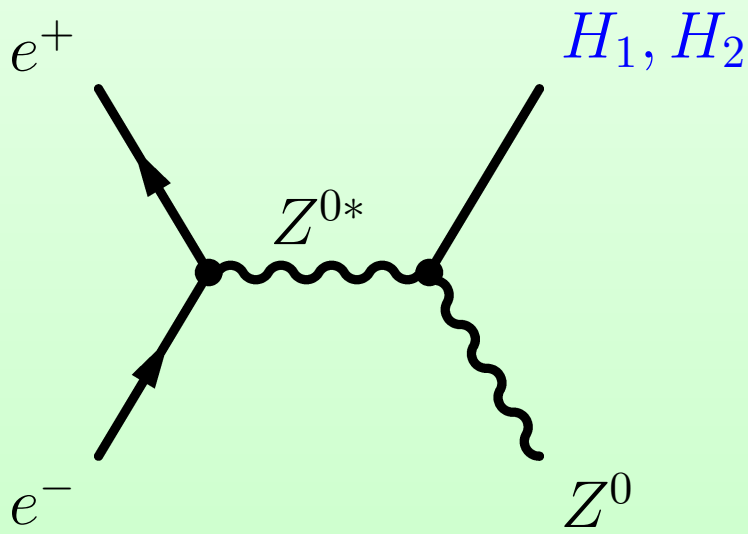
Distinguishable mass sum: 4 GeV

Mass Difference



Distinguishable mass difference: 8 GeV





We measured: $\sigma * BR, \Sigma M, \Delta M$

$\Rightarrow$**We know:** $\boxed{\sigma * BR}$ $\boxed{M_{H_i}}$ $\boxed{M_{H_j}}$

Example:

We measured:

$$\sigma(e^+e^- \to H_1 H_2) *$$
$$BR(H_1 \to b\bar{b}) * BR(H_2 \to b\bar{b})$$

with precision 10 %

Input from Higgsstrahlung:

$$M_{H_1}, M_{H_2}$$

with precision 1 GeV

It is found: we can measure

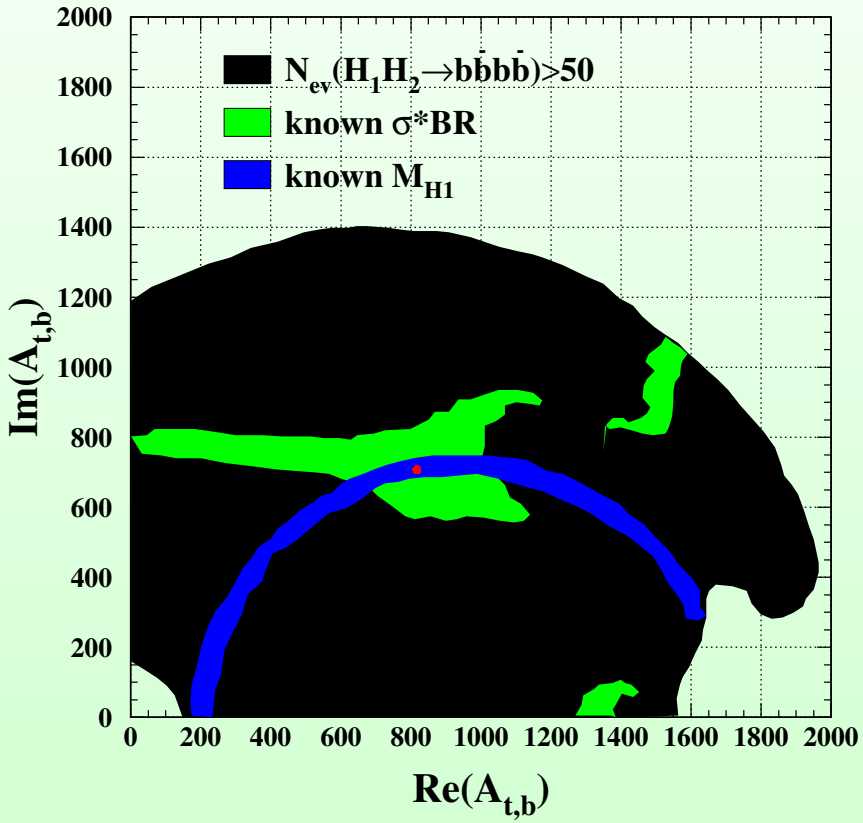
$\arg(A_{t,b})$ **(indirect)**

2-Parameter Scan

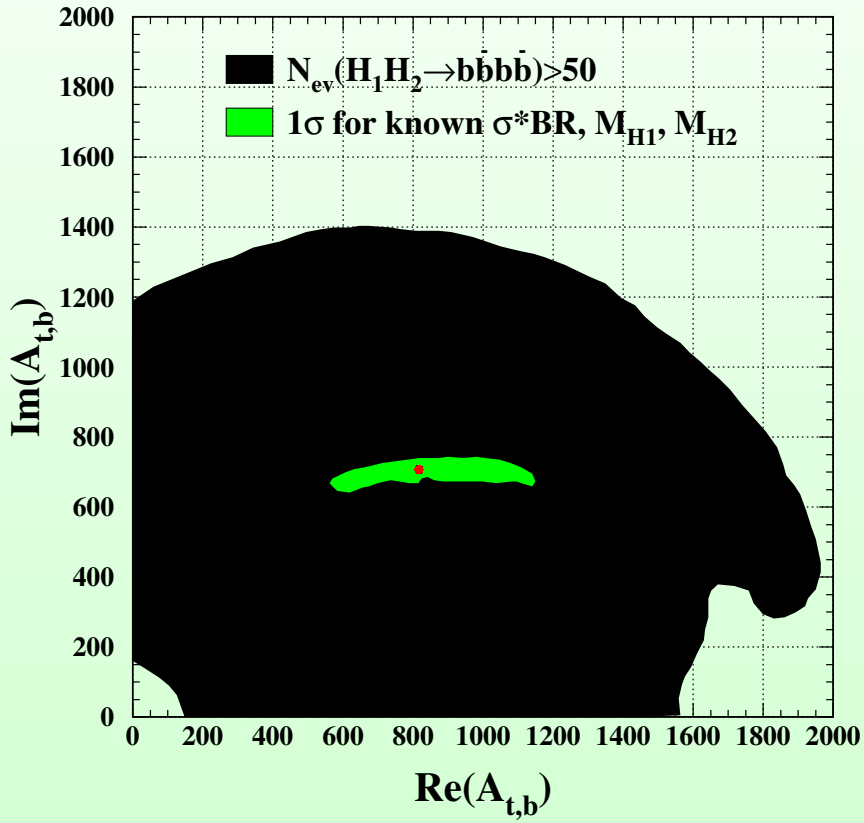
$\sqrt{s} = 500GeV \qquad L = 500fb^{-1}$

$\tan\beta = 3 \qquad M_{H^+} = 200GeV$

We know: $\sigma * BR$, M_{H_1}



We know: $\sigma * BR$, M_{H_1}, M_{H_2}



Sensitivity:

$$Re(A_{t,b}) = (800 \pm 300)GeV$$

$$Im(A_{t,b}) = (700 \pm 50)GeV$$

Summary

- **Cut analysis for the process $e^+e^- \to H_iH_j \to b\bar{b}b\bar{b}$ at TESLA is made.**
- **Kinematical fit for the mass spectra is promising. Accuracies for the Higgs mass determination without background are:**

$$\sigma(\Sigma M) = 200 \text{ MeV}$$
$$\sigma(\Delta M) = 300 \text{ MeV}$$

- **The prospects for CP-violating MSSM parameters measurements at TESLA are good.**

Outlook

- **Kinematical fit: to include background.**
- **Scan over the Higgs mass grid.**
- **Full CP-violating MSSM parameters scan.**