
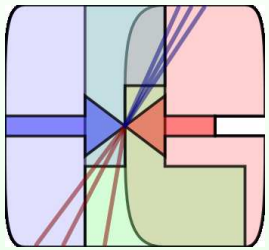

# Experimental Study of Higgs Bosons in Minimal Supersymmeric Extension of Standard Model at TESLA

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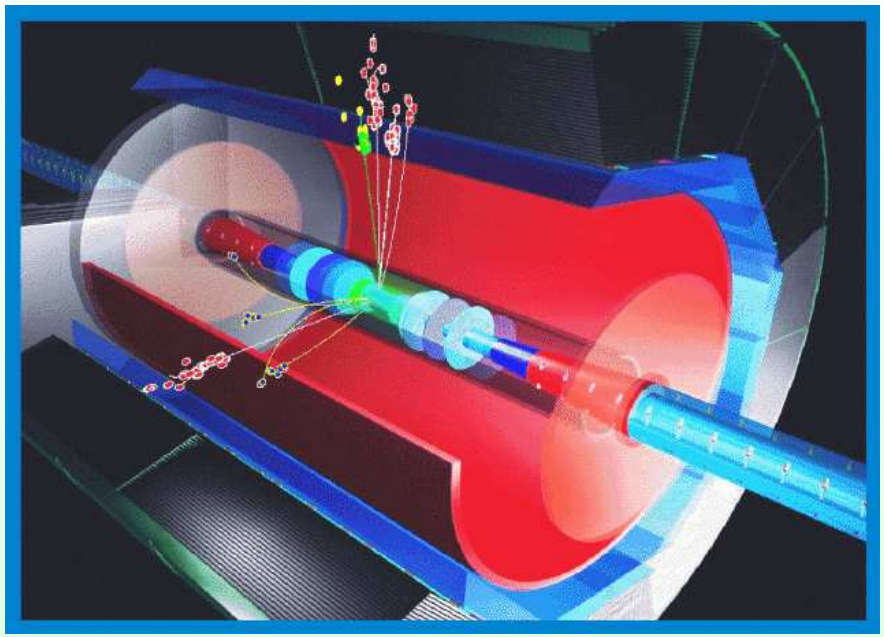
## TESLA



**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**

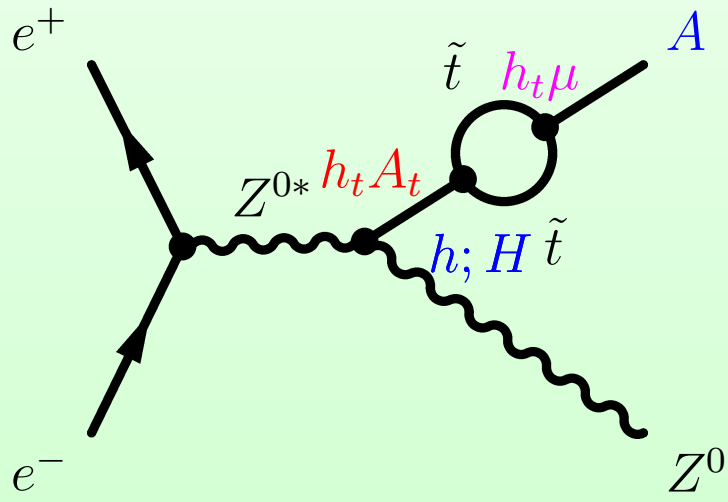
## CP-Violation:

$A_{t,b}$ **- 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:**

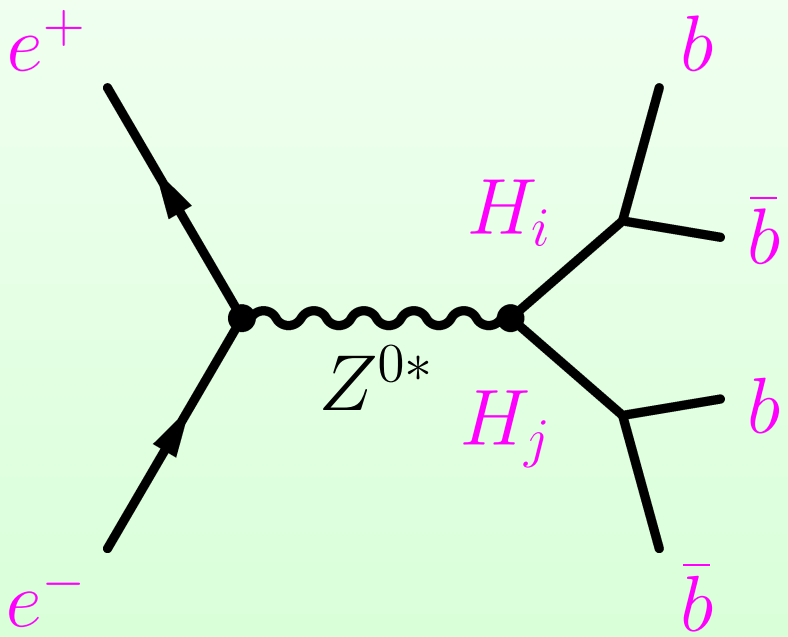



**Parametrization of the Higgs sector:**

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

# TESLA

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




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

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

## 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 $e^+e^- \longrightarrow H_2H_3 \longrightarrow b\bar{b}b\bar{b}$ 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

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

## Signal and BG samples:

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

# Cuts

**Against 2-fermion background:**

- Hadronic 4-jet events with full energy

**Against 4-fermion background:**

- Nonforward peaked and spherical events

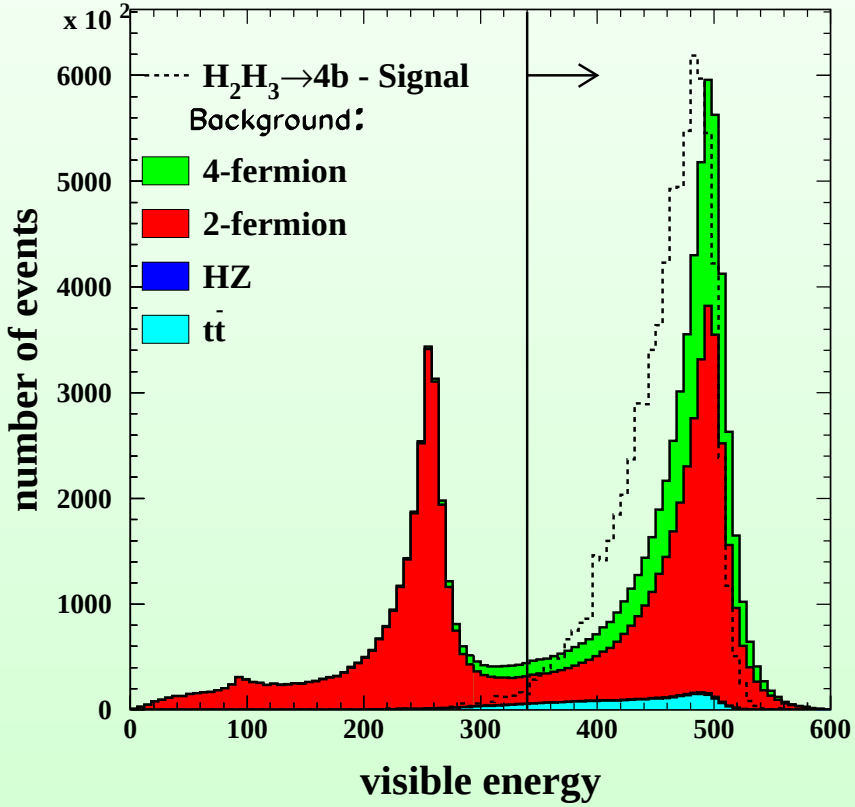
**For $t\bar{t}$ background reduction:**

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

**Against light flavour quarks:**

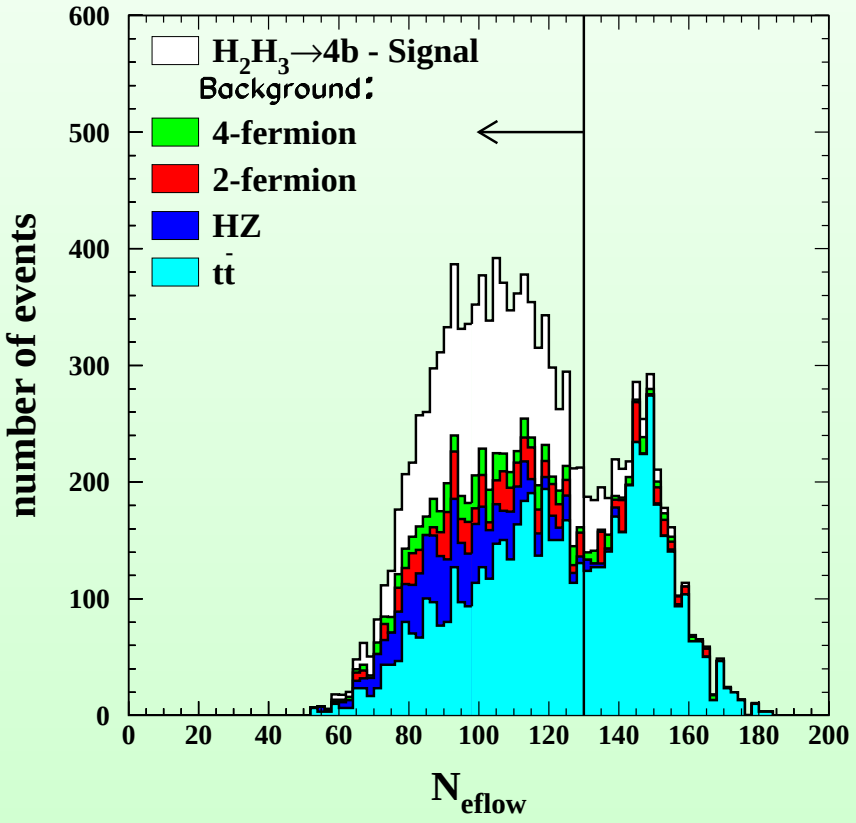
- b-Tag

## Visible energy cut

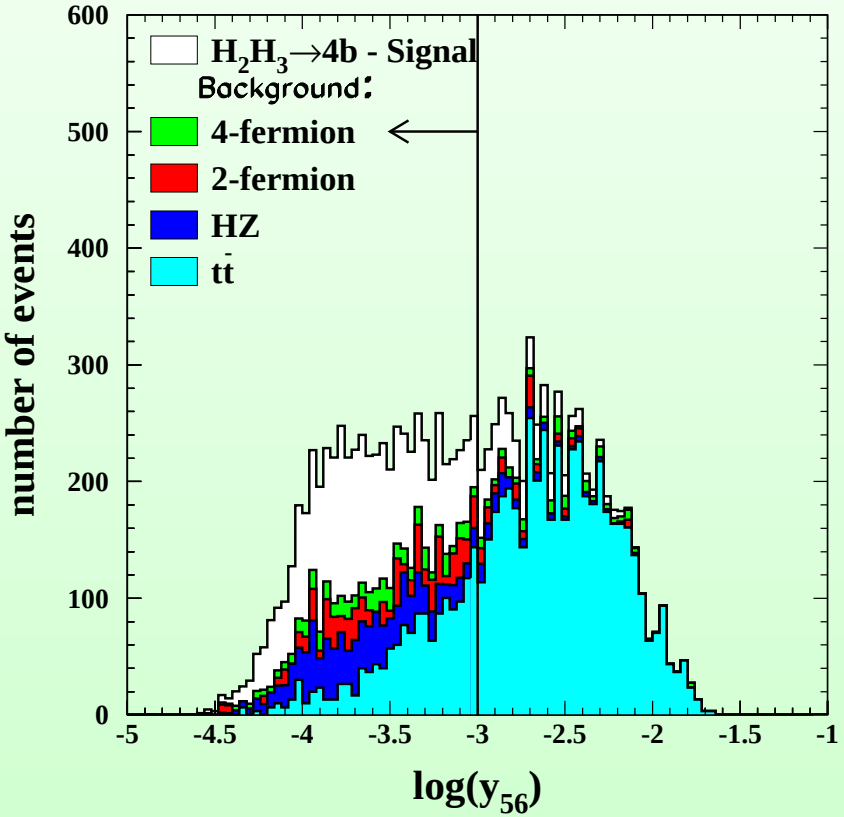


# Cuts against $t\bar{t}$ background

## Number of tracks and clusters cut

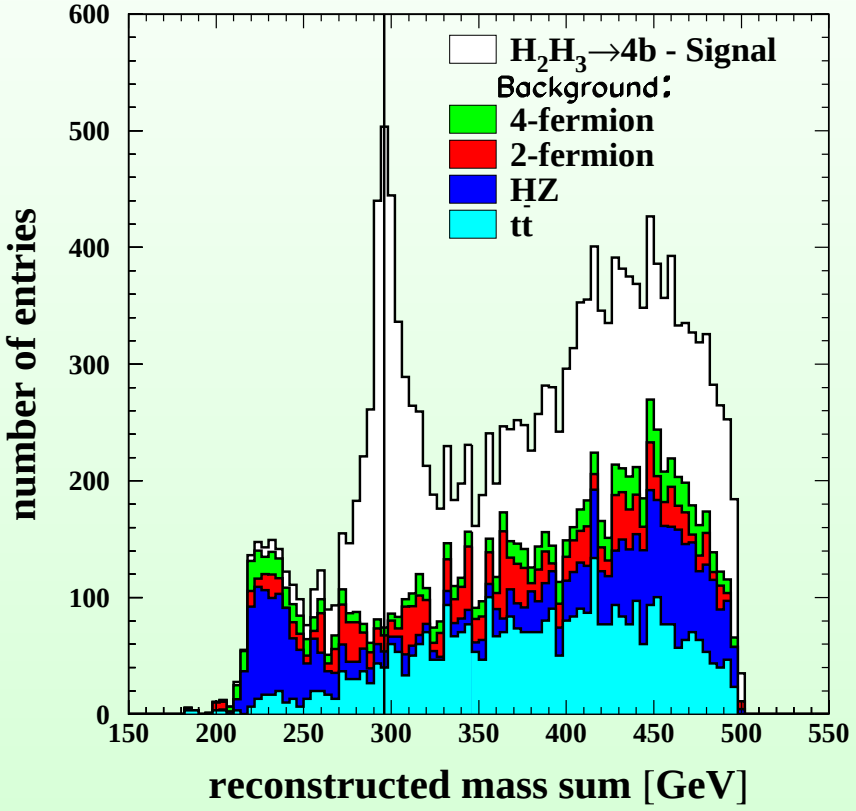



## Jet resolution parameter cut



# Reconstructed Mass Sum

**3 combinations of 4 jets for 2 masses**




$\Sigma M$ = (296.8 $\pm$ 0.6) GeV

# Cutflow

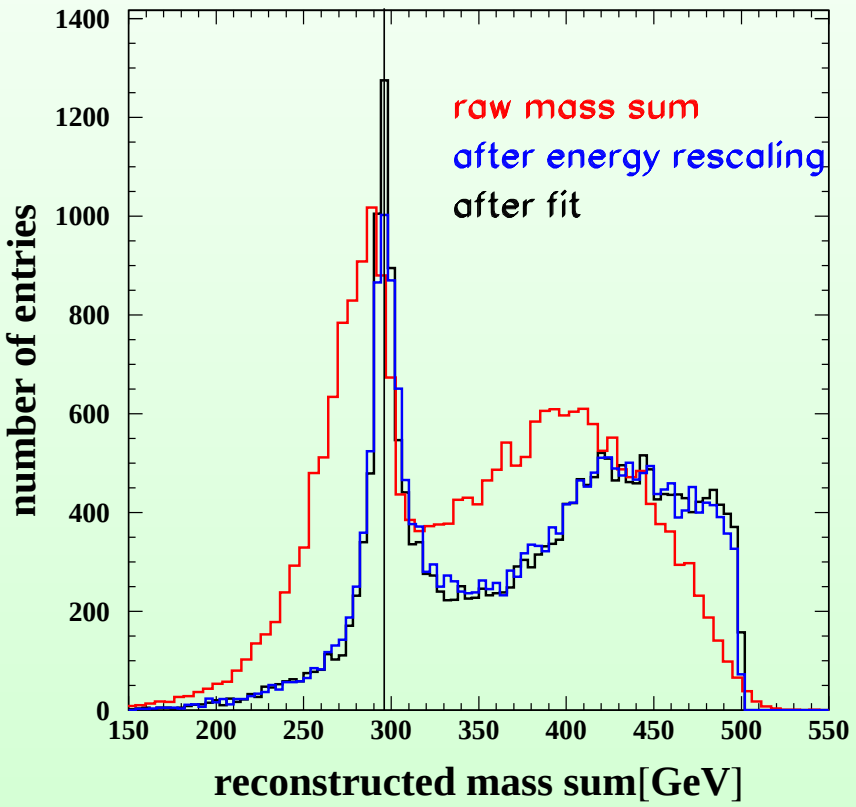
| Cut | Signal | Eff. | Total BG |
|---|---|---|---|
| no cuts | 6305 | 100.0 | 9428007 |
| $N_{jets}$ | 6305 | 100.0 | 9355106 |
| $P_{vis}$ | 6217 | 98.6 | 6020137 |
| $N_{tr}/jet$ | 5706 | 90.5 | 2669602 |
| $\cos(thrust)$ | 5253 | 83.3 | 1383264 |
| $thrust$ | 5126 | 81.3 | 399239 |
| $\log(y_{34})$ | 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:** $E_{jet}, \vec{p}_{jet} * \frac{\sqrt{s}}{E_{vis}}$

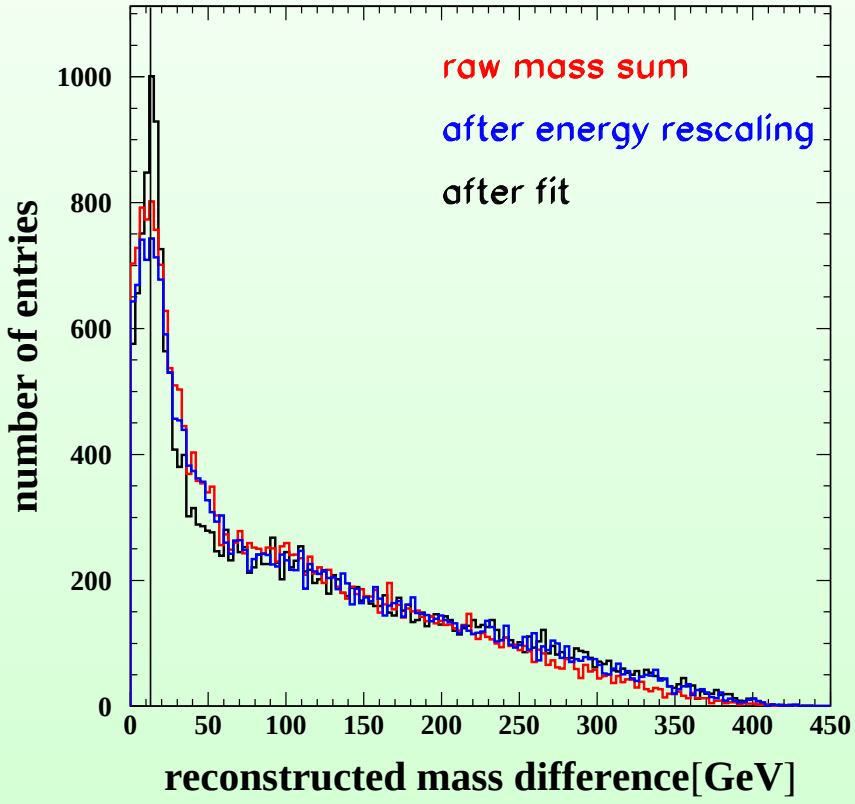
**4c fit:** $\vec{p}$, **E constraints**

## Mass Sum




$\Sigma M$ = (296.2 $\pm$ 0.2) GeV

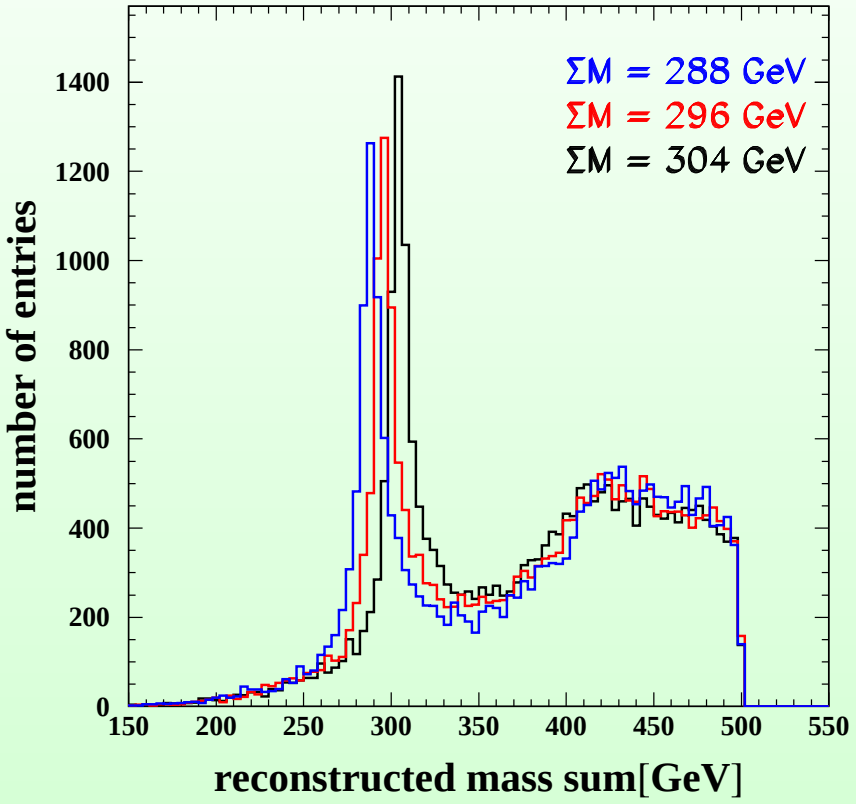
## Mass Difference




$\Delta M$ = (13.3 $\pm$ 0.3) GeV

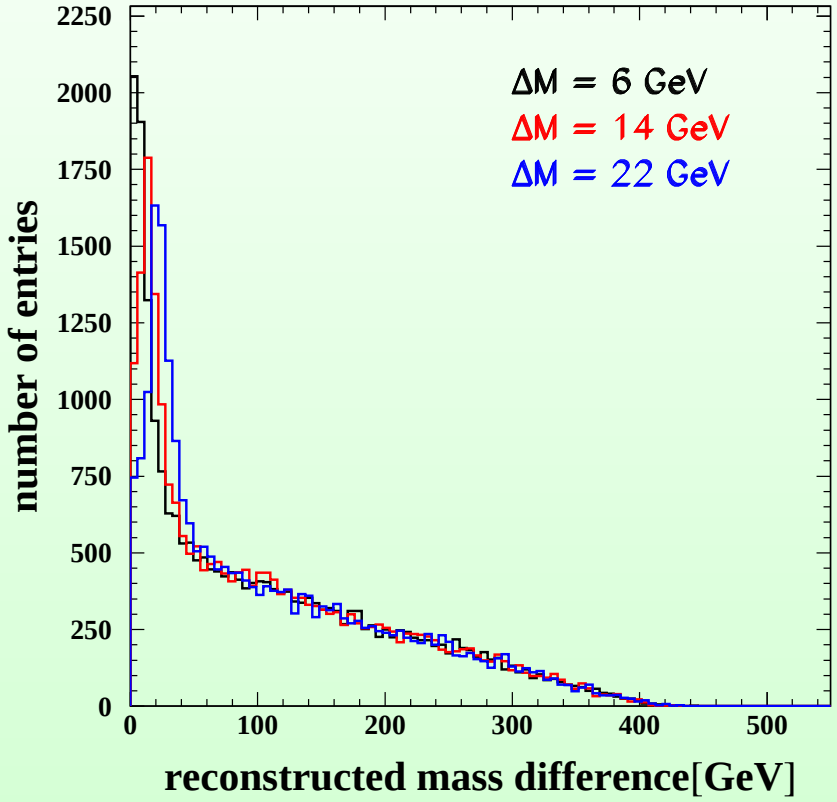
# Improved Mass Reconstruction

## Mass Sum

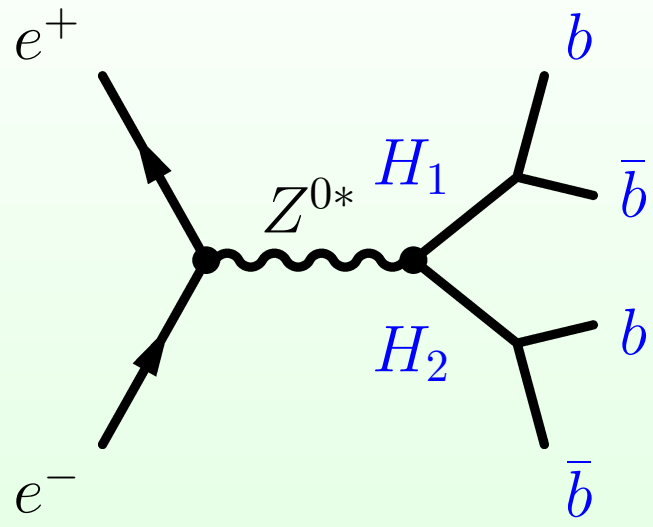


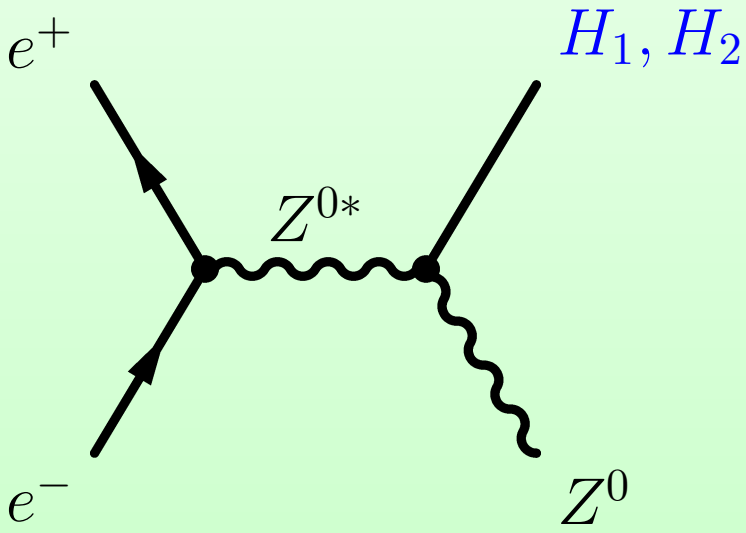

Distinguishable mass sum: 4 GeV

## 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:**

$$\sigma(e^+e^- \rightarrow H_1H_2)*$$

$$BR(H_1 \rightarrow b\bar{b}) * BR(H_2 \rightarrow b\bar{b})$$

**with precision 10 %**

**Input from Higgsstrahlung:**

$M_{H_1}, M_{H_2}$

**with precision 1 GeV**

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**It is found: we can measure**

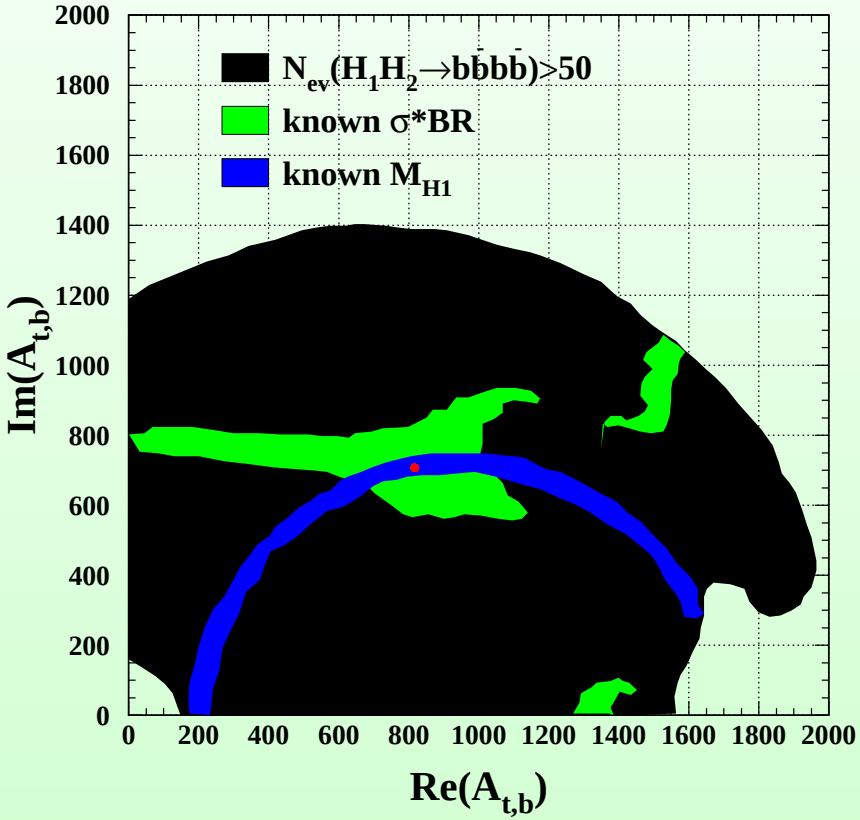
$\arg(A_{t,b})$ **(indirect)**

# 2-Parameter Scan

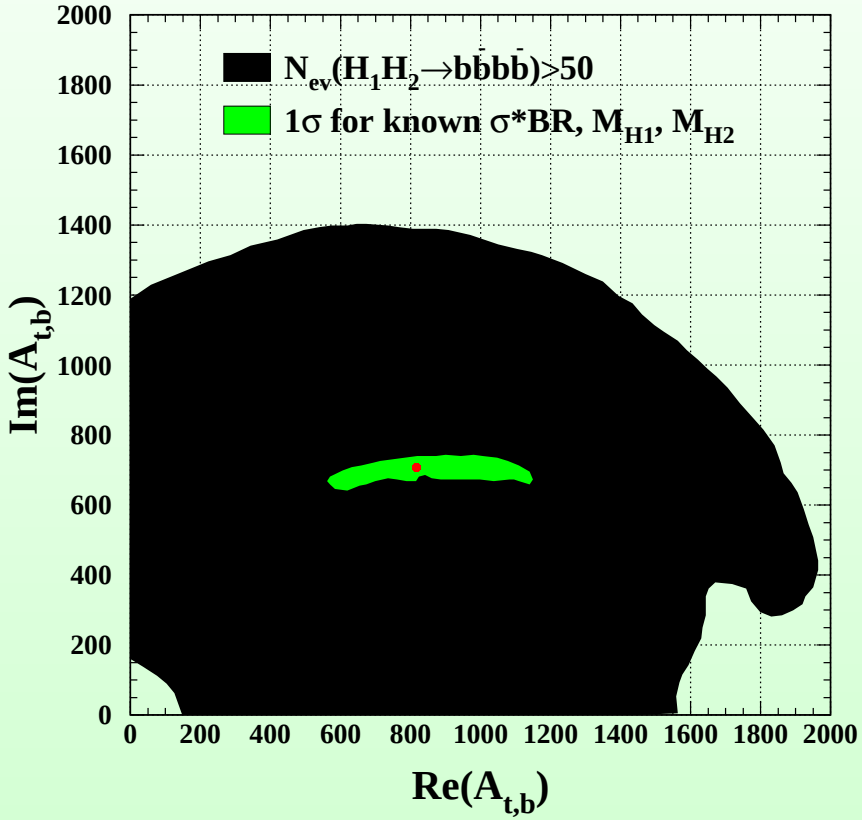
$\sqrt{s} = 500GeV \quad L = 500fb^{-1}$

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

**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.**