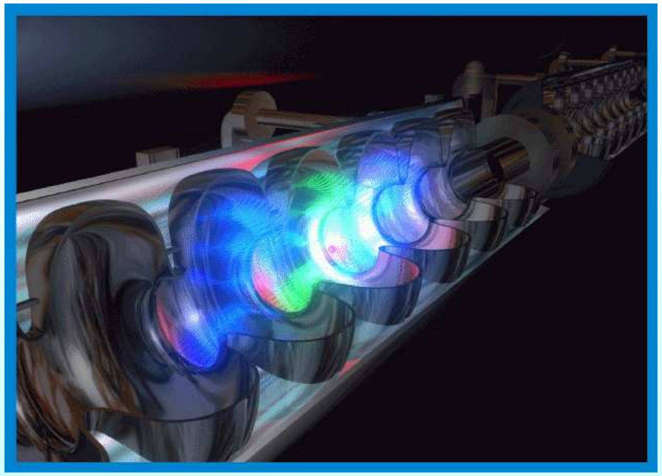
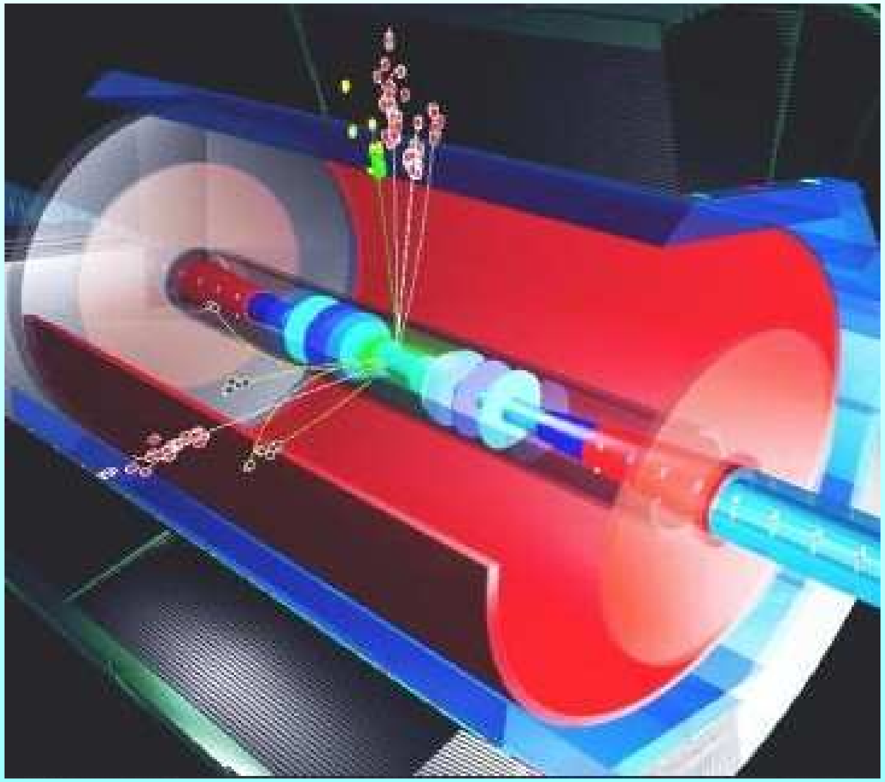


MSSM Higgs Bosons at Future Linear Collider

Heavy Quarks at H1

Tatsiana Klimkovich
DESY Hamburg

Future Linear Collider



e^+e^- **Linear Collider**

Luminosity: 500 fb^{-1}

$\sqrt{s}$ **= 500 GeV, 1 TeV**

Content:

- **Higgs-Boson and Supersymmetry**
- **MSSM Higgs-Pairproduction**

  $e^+e^- \longrightarrow HA \longrightarrow b\bar{b}b\bar{b}$
- **5σ discovery potential**
- **Trilinear coupling**
- **Charm and Beauty at H1**
- **Inclusive method**
- **Summary and Outlook**

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

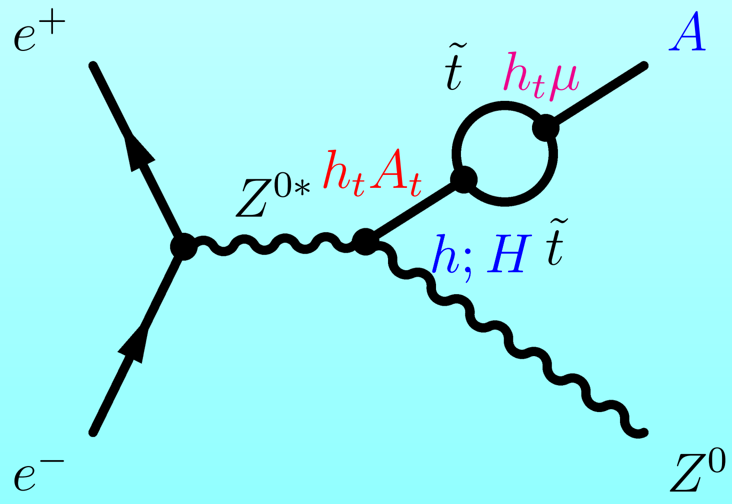
CP-Violation:

$\boxed{A_{t,b}}$ **- Complex** $\boxed{m_{\tilde{g}}}$ **- 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** $tan\beta = \frac{v_2}{v_1}$

Motivation

Questions:

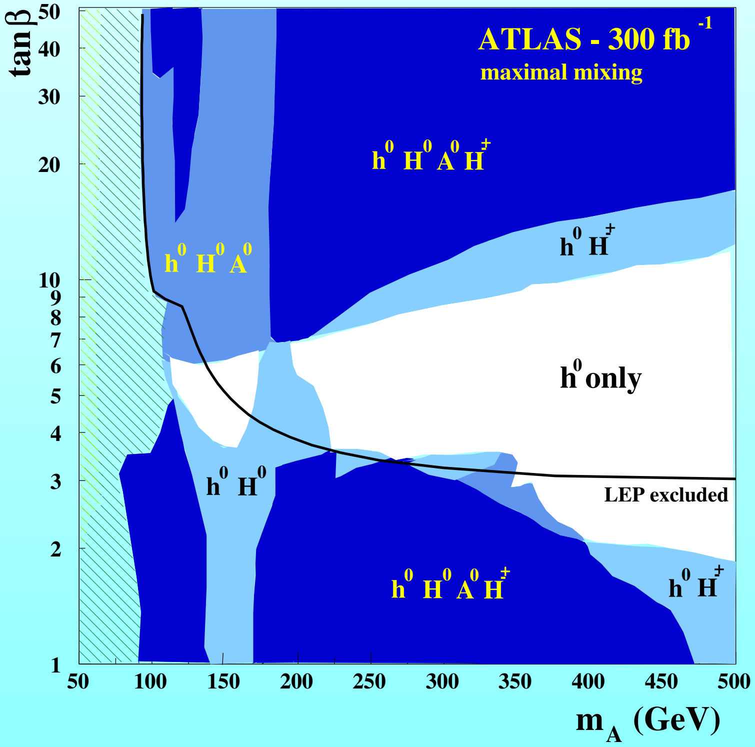
- Discovery mass range?
- Mass measurement precision – ?

  Cross section – ?

  Branching ratios – ?
- Width?

- LHC "wedge" region

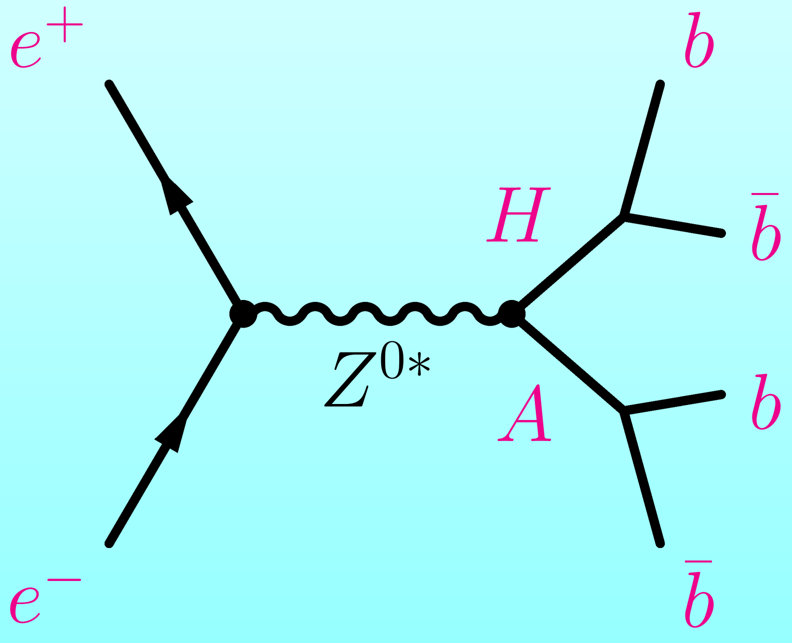
  $\Longrightarrow$ can be "discovery channel"!



MSSM Higgs Pair Production

Model independent analysis:

$$\boxed{\mathbf{e^+e^- \to HA \to b\bar{b}b\bar{b}}}$$



$\sqrt{s}$ = 500 GeV, 800 GeV

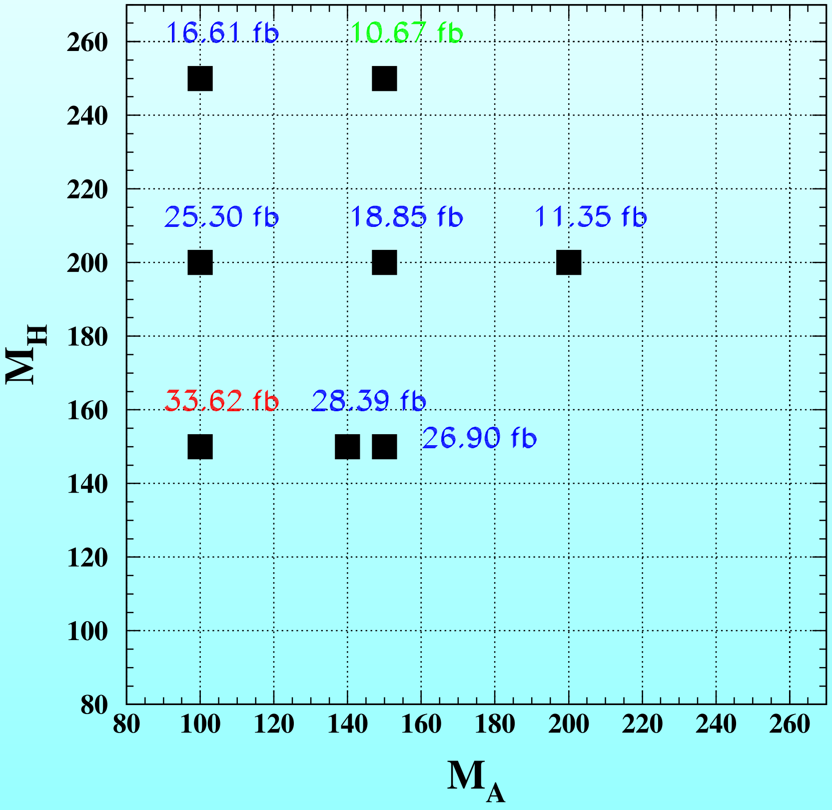
L = 500 fb^{-1}

TOOLS:

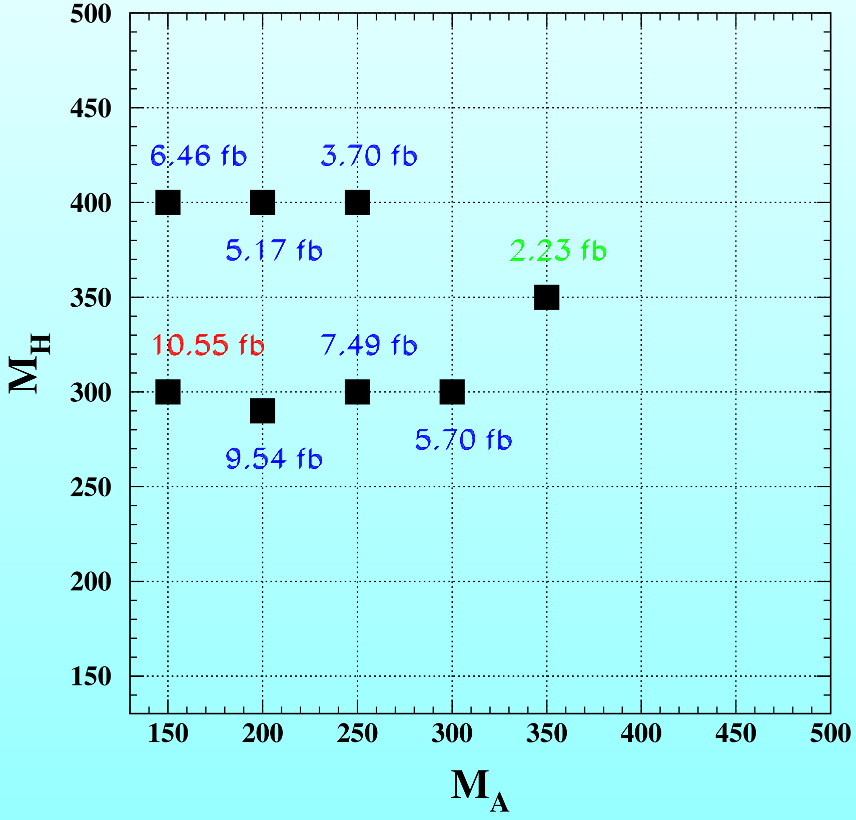
- **PYTHIA: Event generation (Signal and Background)**
- **CIRCE: Beamstrahlung**
- **SIMDET 4.01: Fast parametric detector simulation**
- **ZV-TOP (from SLD): b-tagging**
- **Kinematic Fit (from DELPHI)**

Investigated Mass Combinations

500 GeV



800 GeV



Assumptions:

$\sin^2(\beta - \alpha)$ = 1

BR($H, A \to b\bar{b}$) = 0.90

Several thousands Higgs Bosons

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

Background Processes:

Process	σ [fb]	
	500 GeV	800 GeV
$Z^0Z^0 \rightarrow 4q$	311	174
$W^+W^- \rightarrow 4q$	4130	2340
$Z^0/\gamma^* \rightarrow 2q$	12900	5450
$t\bar{t} \rightarrow W^+W^-b\bar{b}$	669	165

Typical Signal: 10 – 30 fb

Cuts

Against 2-fermion Background:

- Hadronic 4-jet events with full energy

Against 4-fermion background:

- Central and spherical events

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

- Number of tracks and cluster cut (for 500 GeV)
- Jet resolution parameter cut (y_{56})

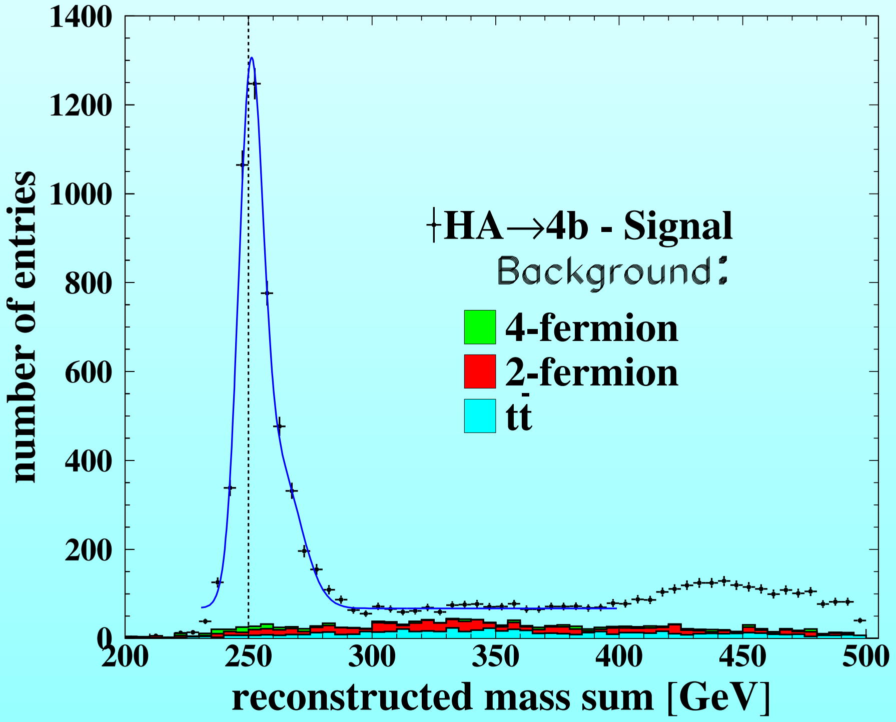
Against light flavour quarks:

- b-Tag

Mass Spectra

$\mathrm{M_A}$ = 100 GeV, $\mathrm{M_H}$ = 150 GeV

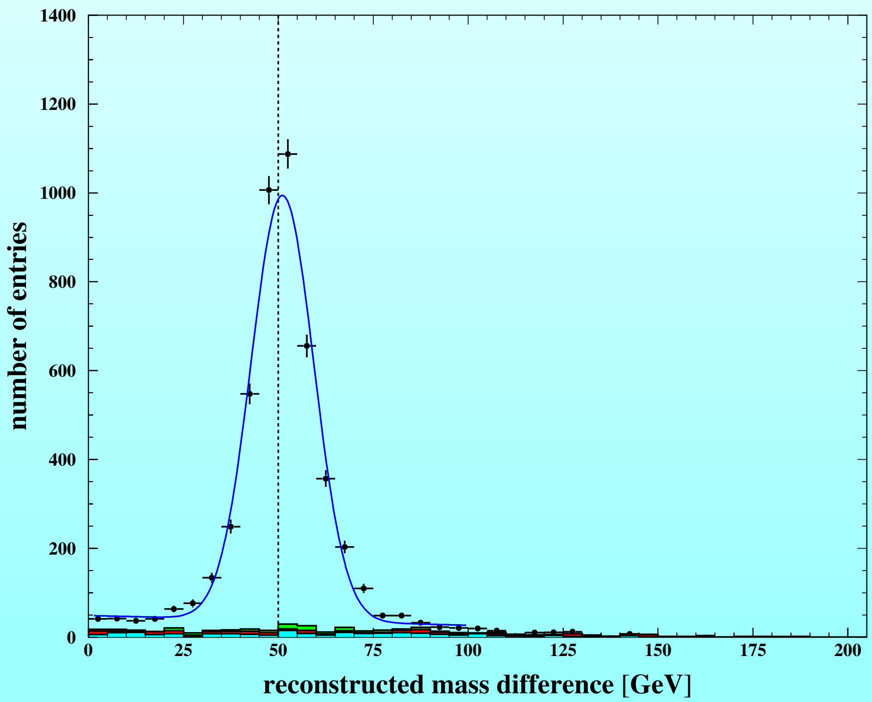
Reconstructed Mass Sum



ΣM = (250.79 $\pm$ 0.20) GeV

Resolution = (4.90 $\pm$ 0.19) GeV

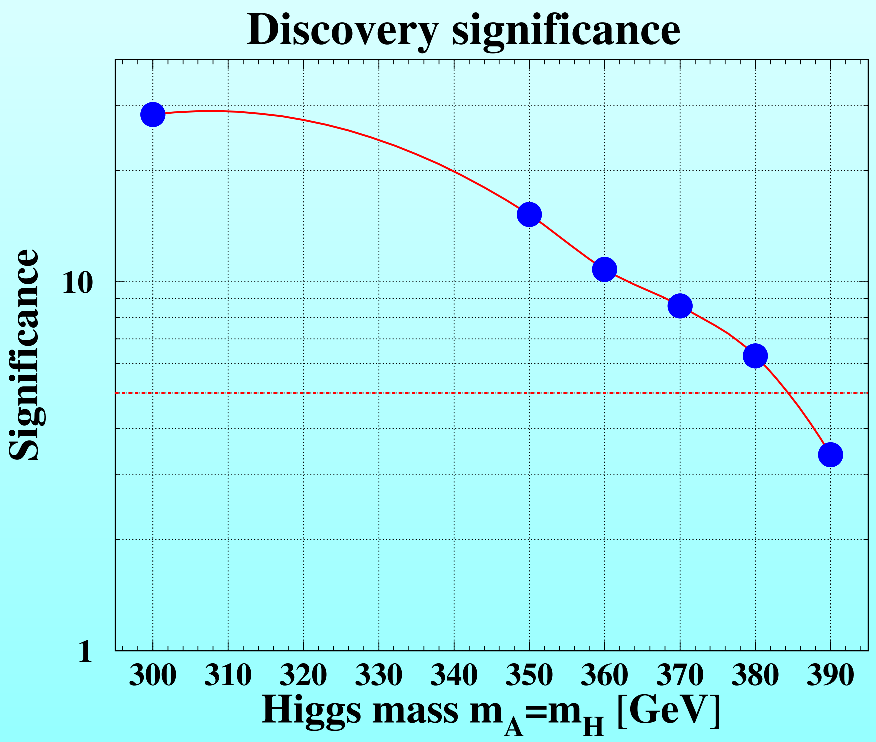
Reconstructed Mass Difference



ΔM = (51.11 $\pm$ 0.15) GeV

Resolution = (8.25 $\pm$ 0.16) GeV

5σ Discovery Potential



$$\mathrm{e^+e^- \rightarrow HA \rightarrow b\bar{b}b\bar{b}}$$

$\sqrt{s}$ = 800 GeV

For 6 mass combinations

$(\mathrm{m_A}, \mathrm{m_H})$ **with** $\mathrm{m_A} = \mathrm{m_H}$

Significance = $\frac{\text{cross section}}{\delta(\text{cross section})}$

Benchmark point SPS 1a

Parameters:

$\tan\beta$	10
m_0	100 GeV
$m_{1/2}$	250 GeV
A_0	-100 GeV
μ	> 0

M_{h^0} = 113.70 GeV

M_{A^0} = 394.65 GeV

M_{H^0} = 394.90 GeV

$M_{H^\pm}$ = 403.60 GeV

At Linear Collider:

$\sqrt{s}$ = 1 TeV, $\mathcal{L}$ = 1000 fb^{-1}

$\sigma(e^+e^- \to HA)$ = 2.5 fb

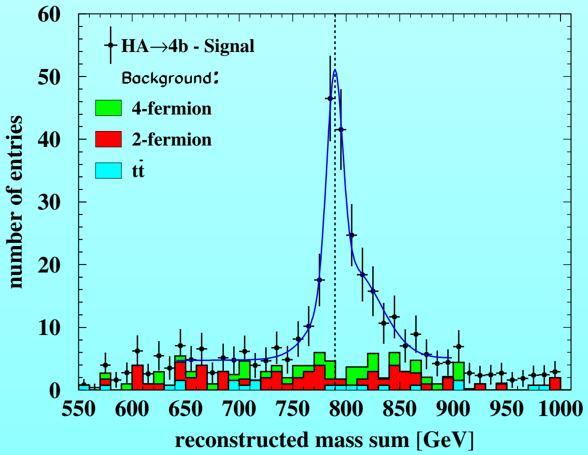
BR($H \to b\bar{b}$) = 0.64

BR($A \to b\bar{b}$) = 0.40

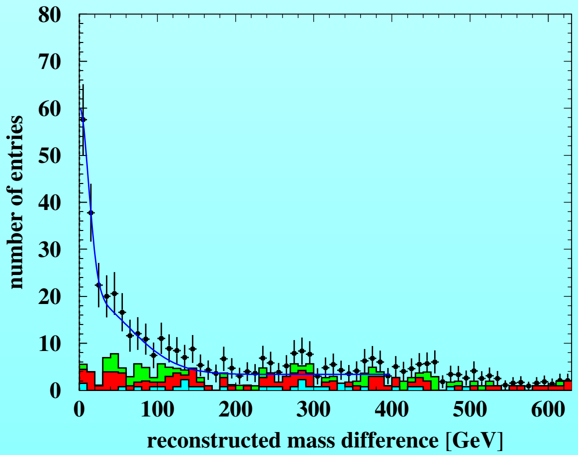
$\delta(M_{H,A})$ = 1.3 GeV

$\delta\sigma/\sigma$ = 9 %

Reconstructed Mass Sum



Mass Difference

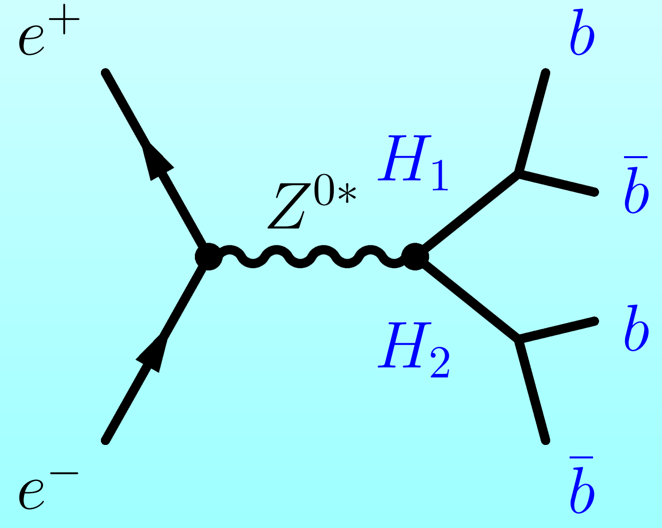


Measurement of parameters of CP-violating MSSM scenario

CP-Violating Scenario:

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

$\arg(A_{t,b})$ - ?



Suppose we know:

$\sigma * BR$: 10 %

M_{H_1}, M_{H_2}: 1 GeV

2-Parameter Scan:

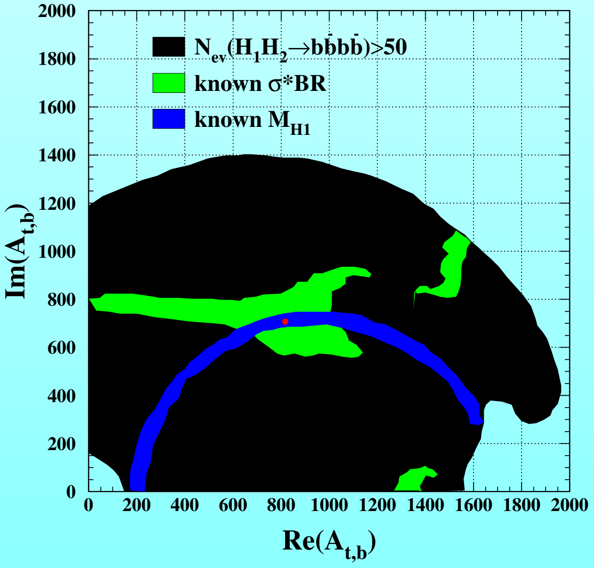
$\sqrt{s}$ = 500 GeV

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

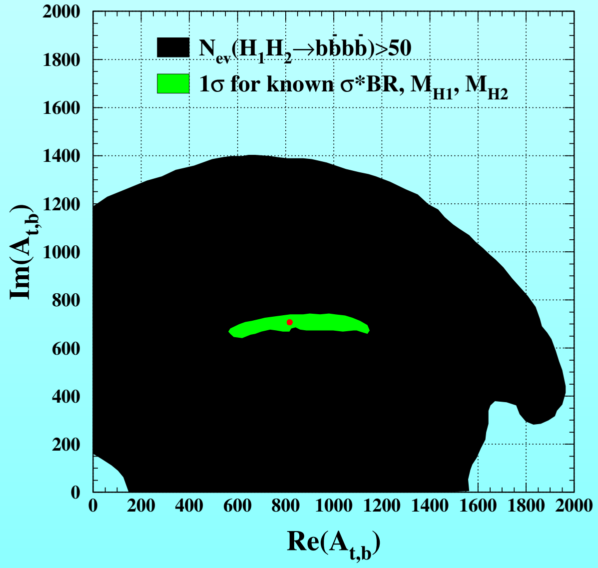
$\tan\beta$ = 3

M_{H^+} = 200 GeV

Known $\sigma * BR$, M_{H_1}



Known $\sigma * BR$, M_{H_1,H_2}



Charm and Beauty at H1 experiment

ep Collisions at HERA

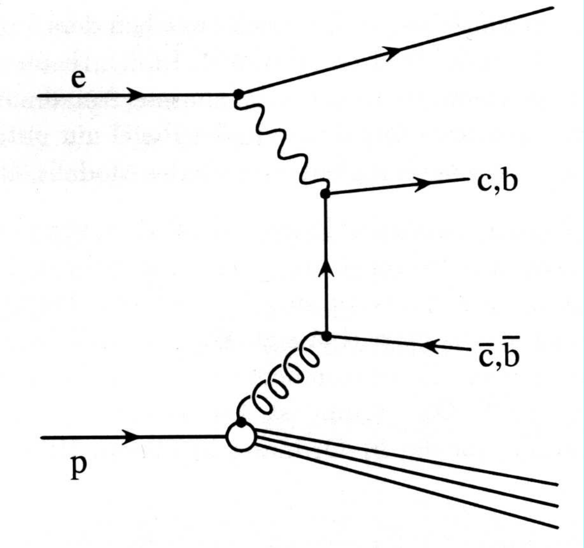
E_e = **27.5 GeV**

E_p = **920 GeV**

$\sqrt{s}$ = **318 GeV**

Low Q^2 DIS

Boson Gluon Fusion:



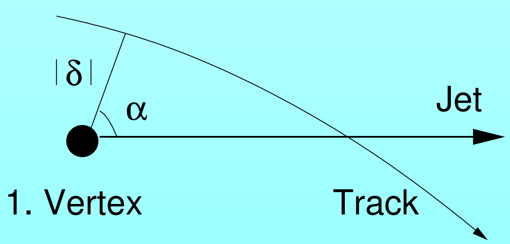
- **Statistical limitation of exclusive methods**
- **$\Longrightarrow$ Inclusive measurement using lifetime information of heavy flavours, model independent**

Method:

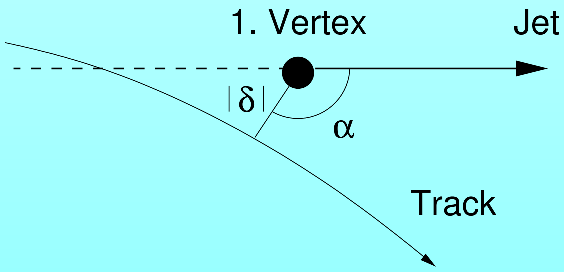
Use of signed DCA for all tracks from CST

(distance of closest approach $\equiv$ impact parameter)

$\alpha < \pi/2 \rightarrow \delta = +|\delta|$



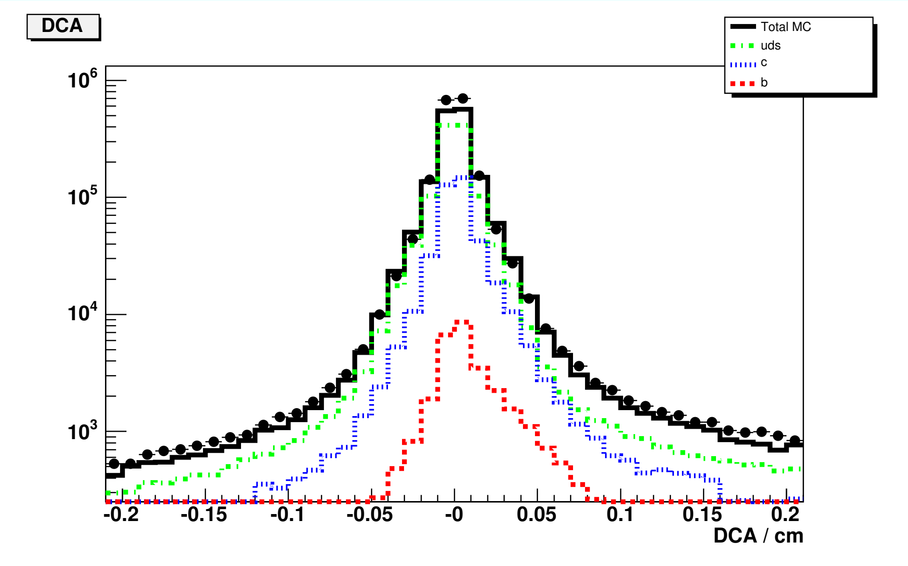
$\alpha > \pi/2 \rightarrow \delta = -|\delta|$



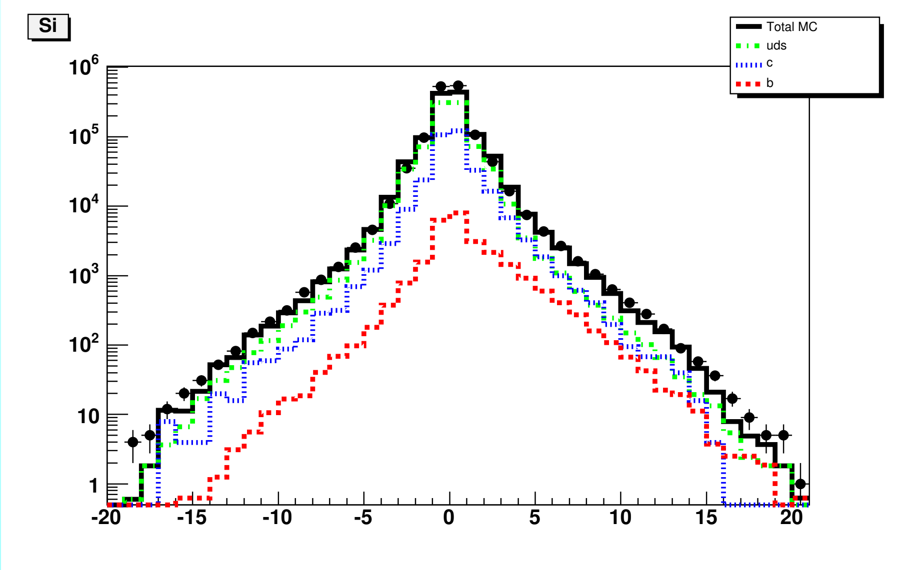
- **Heavy Flavours $\Longrightarrow$ large positive DCA**
- **Light Flavours $\Longrightarrow$ small negative and positive DCA**

Charm and Beauty at H1 experiment

DCA



Significance of each track

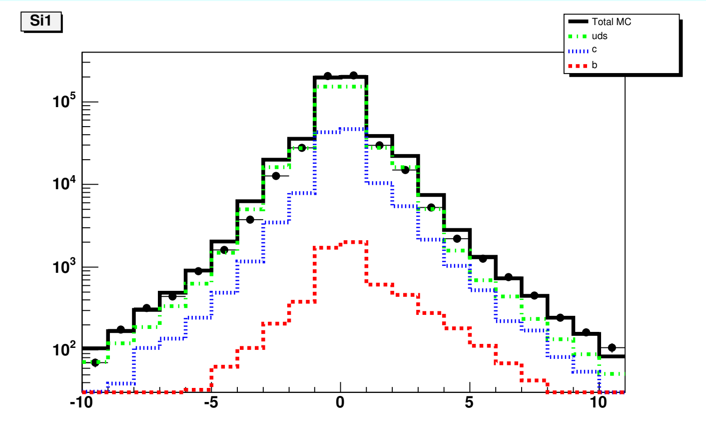


- **Tracks mached to jet axis**
- **For each track within each jet, plot DCA to primary vertex in $r\phi$ plane (δ)**

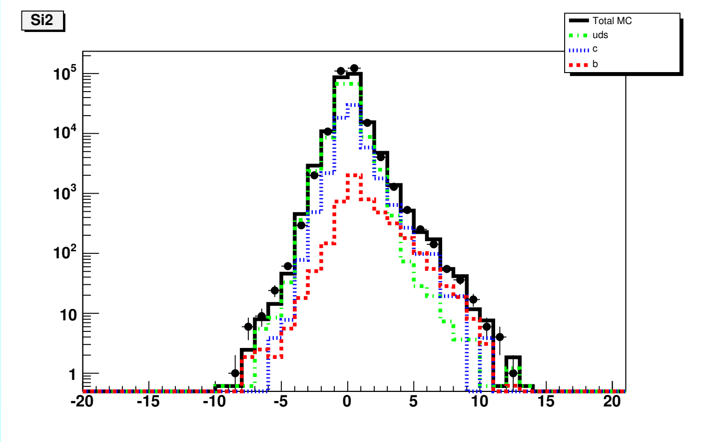
$$S_i = \frac{\delta}{\sigma(\delta)}$$

Fit of Subtracted Significance

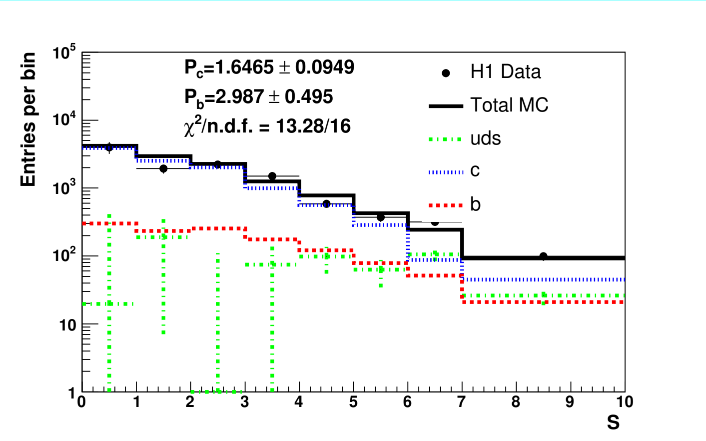
S_1: Highest track significance for 1 CST track events



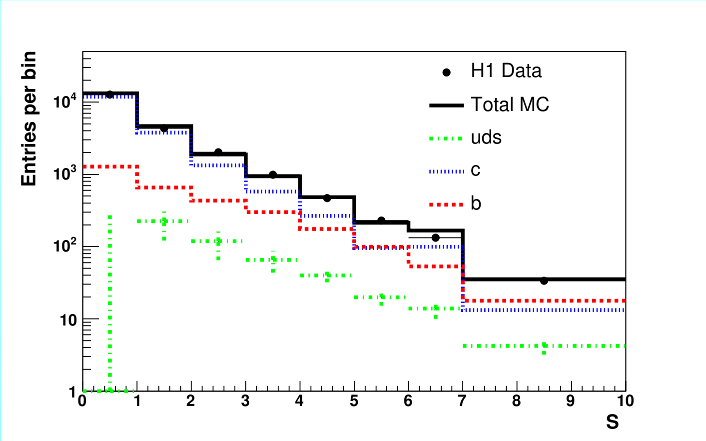
S_2: Second highest track significance for $>$ 1 track events



Subtracted S_1



Subtracted S_2



Summary and Outlook

- Study of MSSM Higgs pair production analysis $\mathrm{e^+e^- \to HA \to b\bar{b}b\bar{b}}$ for both 500 and 800 GeV
- Higgs discovery till $\mathrm{M_{H,A} \sim (\frac{\sqrt{s}}{2} - 15)}$ GeV
- Typical precision:

	500 GeV	800 GeV
δ(Mass) [GeV]	0.12-0.48	0.33-0.99
$\delta\sigma/\sigma$ [%]	1.6 - 3.5	2.7 - 6.6

- 5σ Discovery potential for $\mathrm{b\bar{b}b\bar{b}}$ channel at $\sqrt{\mathrm{s}}$ = 800 GeV

▷ Interpretation of results for CP-conserving and CP-violating scenarios

- The prospects for CP-violating MSSM parameters measuremets are good

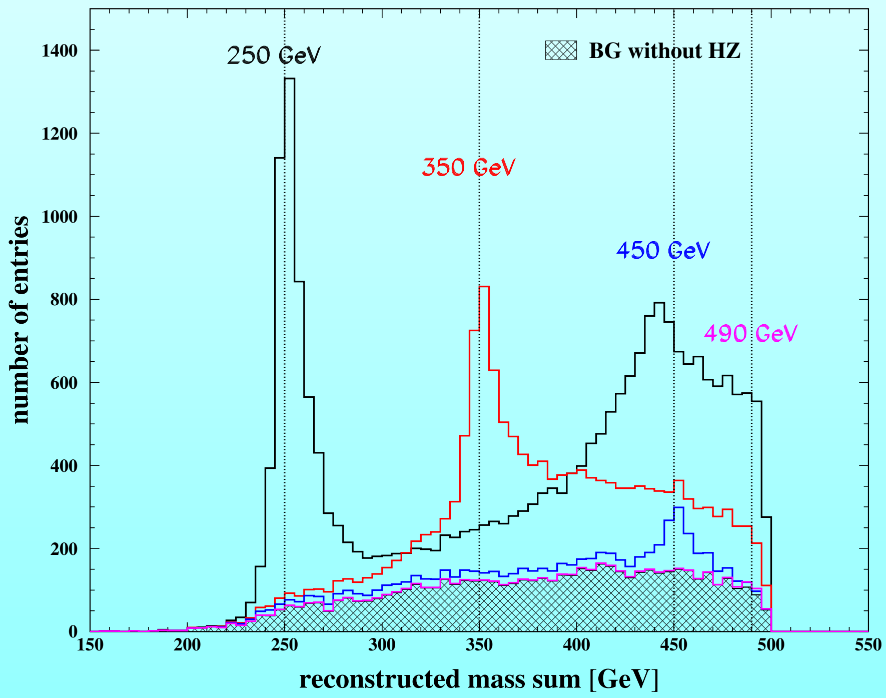
▷ Need more systematic study

- The method for Charm and Beauty measurements at H1 is established
- The results look promising

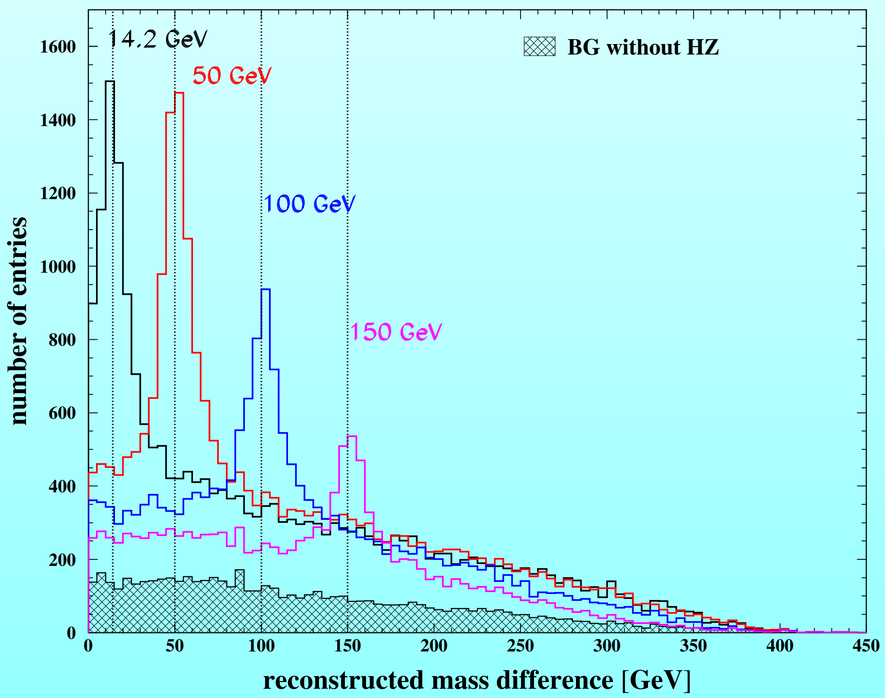
▷ Need full statistics and systematic study

Different Mass Combinations for 500 GeV

Reconstructed Mass Sum



Reconstructed Mass Difference



Results ($b\bar{b}b\bar{b}$ Channel) for 500 GeV

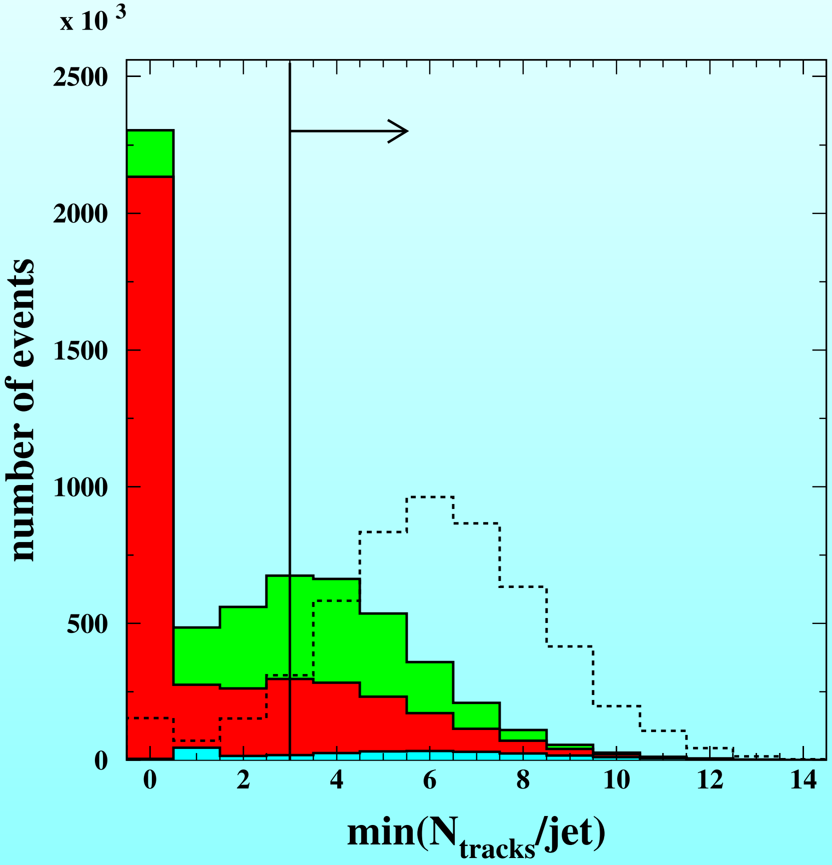
(M_A, M_H) [GeV]	Eff. [%]	$\delta\sigma/\sigma$ [%]	$\delta M_{A,H}$[GeV]
(100,150)	43	1.6	0.12
(100,200)	41	2.0	0.15
(100,250)	36	2.4	0.27
(140,150)	48	1.5	0.13
(150,150)	45	1.5	0.12
(150,200)	42	2.3	0.26
(150,250)	36	3.5	0.48
(200,200)	37	2.7	0.31

Results ($b\bar{b}b\bar{b}$ Channel) for 800 GeV

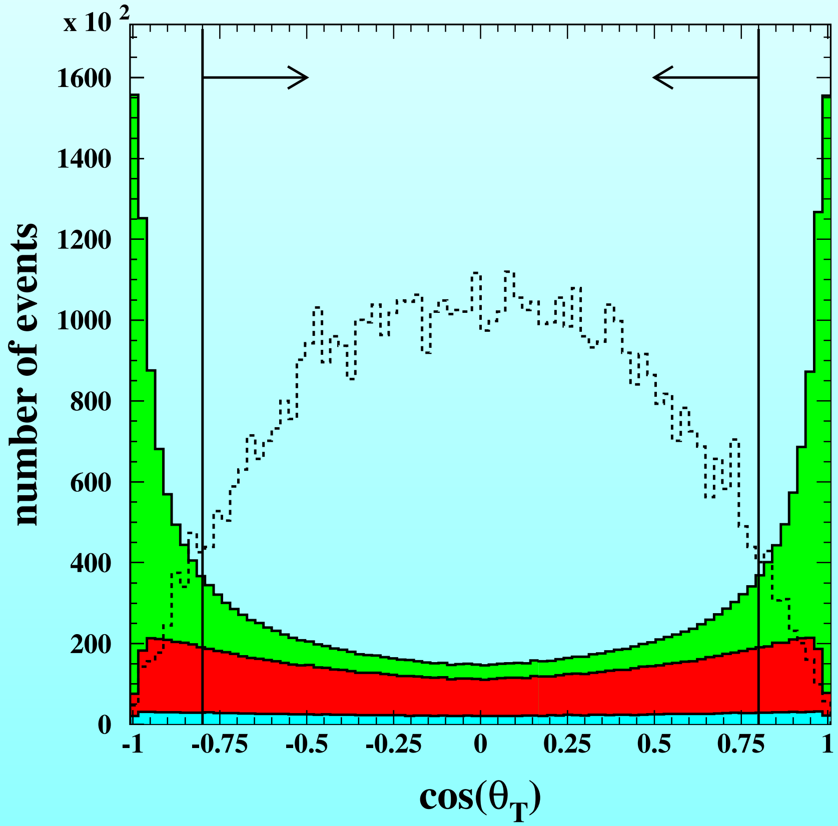
(M_A, M_H) [GeV]	Eff. [%]	$\delta\sigma/\sigma$ [%]	$\delta M_{A,H}$[GeV]
(150,300)	43	2.7	0.33
(200,290)	46	2.7	0.33
(250,300)	45	3.0	0.45
(300,300)	44	3.5	0.48
(350,350)	37	6.6	0.97
(150,400)	37	3.9	0.47
(200,400)	40	4.3	0.74
(250,400)	40	5.2	0.99

Cuts

$min(N_{tracks}/jet)$

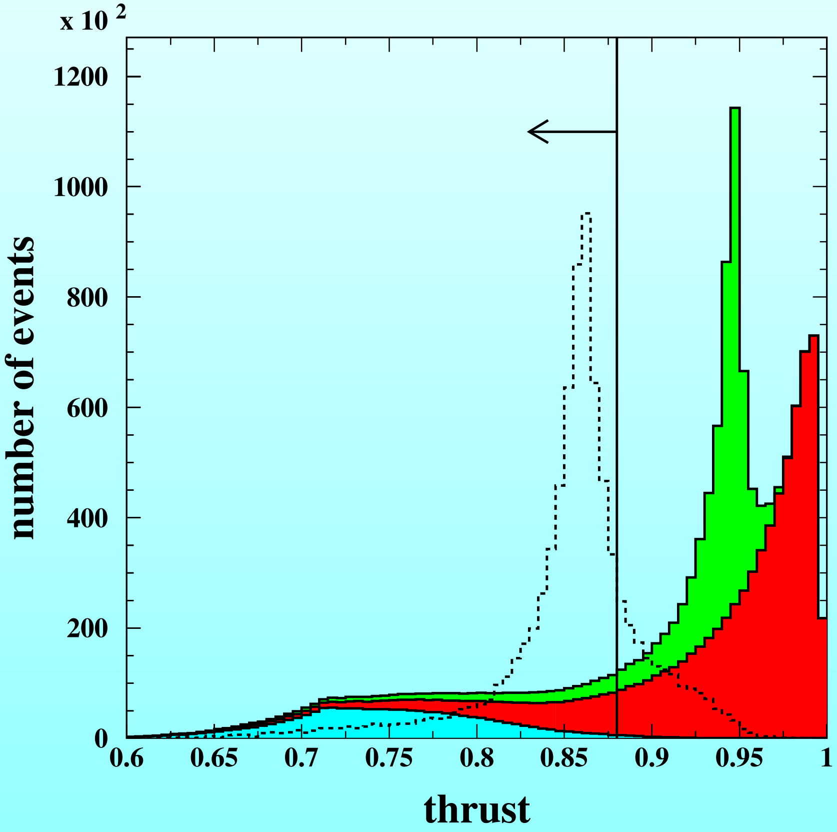


$cos(thrust)$

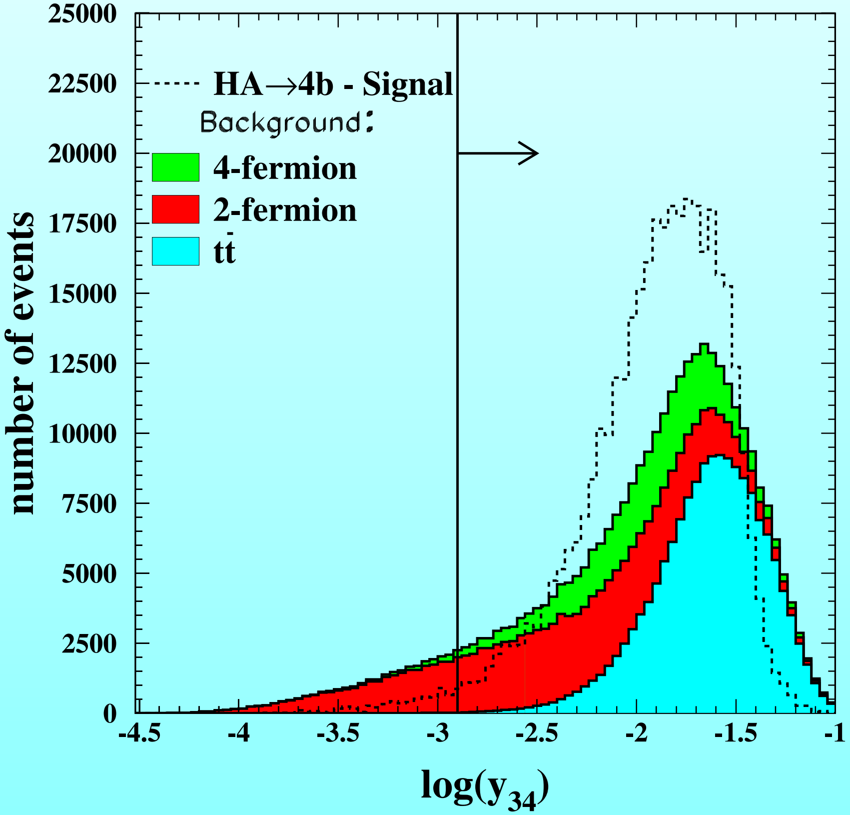


Cuts

thrust value



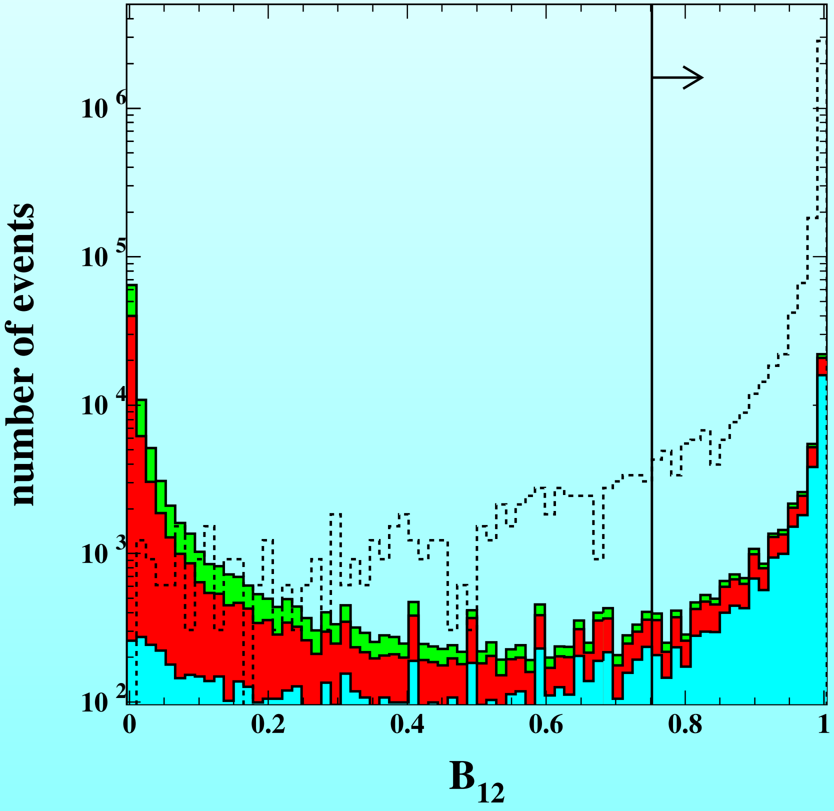
$log(y_{34})$

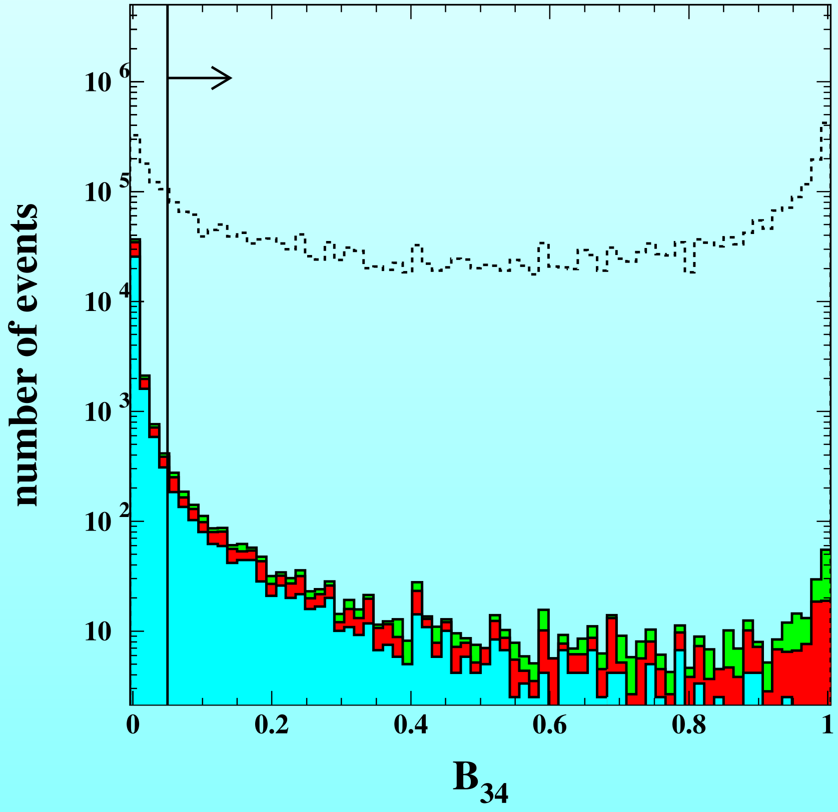


Cuts

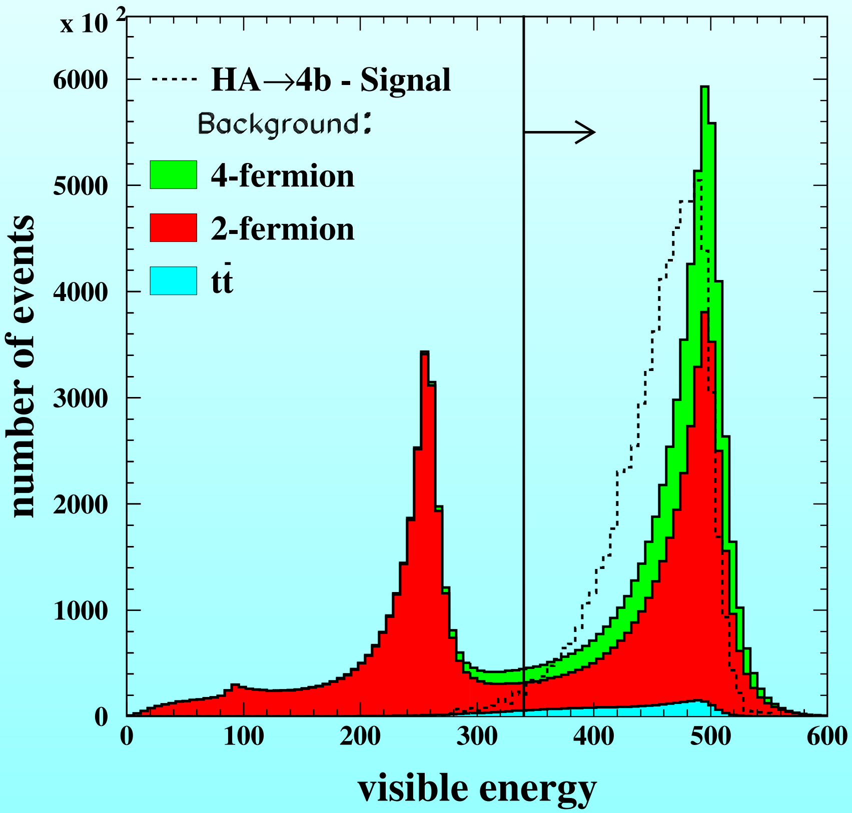
$$B_{12} = \frac{B_1 B_2}{B_1 B_2 + (1 - B_1)(1 - B_2)}$$

$$B_{34} = \frac{B_3 B_4}{B_3 B_4 + (1 - B_3)(1 - B_4)}$$





Cuts

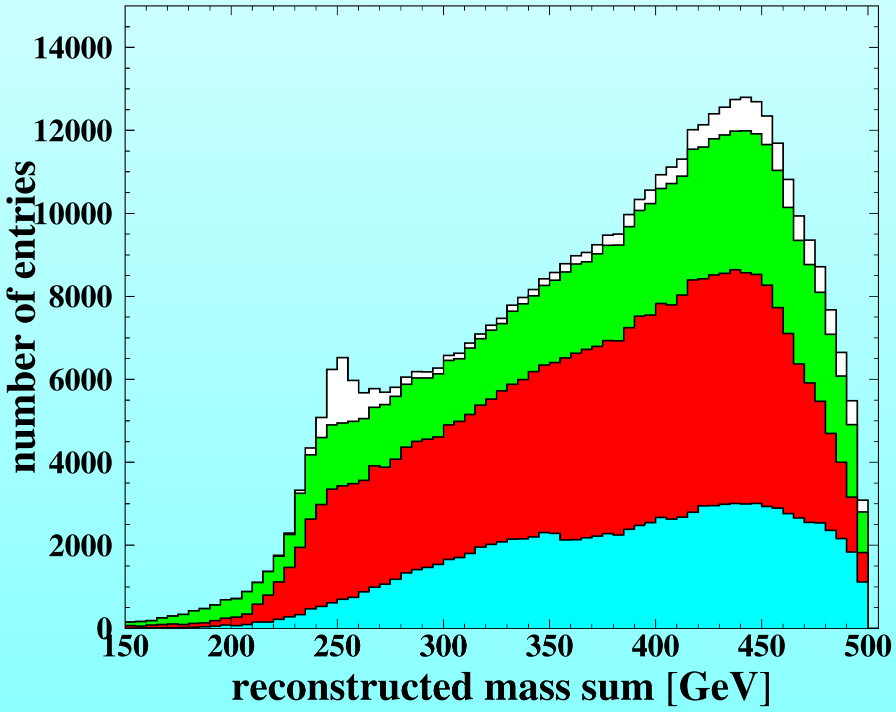

x 10 2
6000
5000
4000
3000
2000
1000
0
0
100
200
300
400
500
600
number of events
visible energy
HA→4b - Signal
Background:
4-fermion
2-fermion
tt̄

Mass reconstruction before and after b-tag cuts for 500 GeV

3 combinations of 4 jets for 2 masses

M_A = 100 GeV, M_H = 150 GeV

Mass sum before b-tag cuts



Mass sum after b-tag cuts