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LCWS2000
Parallel Session P1a:
Higgs / SUSY Higgs

H+H- production at the LC

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Outline

Introduction and background

Heavy $H^{\pm}$ at LC:

- $H^+H^- \longrightarrow t\bar{b}\bar{t}b$
- $H^+H^- \longrightarrow W^+h^0W^-h^0$

Background processes

Full mass reconstruction of 8 jets final states

Kinematical fits

Results: mass, cross-section, branching ratio

Conclusions

Introduction

H^+H^- searches:

- Direct search of $e^+e^- \longrightarrow H^+H^-$ at LEP
- Indirect measurements such as CLEO $b \longrightarrow s\gamma$
- $t \longrightarrow bH^+$, $H^+ \longrightarrow \tau\nu$ at Tevatron

Feasibility studies for H^+H^- in different energies and mass ranges at future LC's

Recent studies have shown that the radiative corrections of the H^+H^- cross-section are large and model dependent $\longrightarrow$ measurement of the mass and the cross-section provides information about the model

Measurement of the branching fractions of H^+H^- provide additional information about the Higgs sector

Now present a complete mass reconstruction method for eight jet final states and some first estimates of its performance

Assumed TESLA LC with 500 fb^{-1} of data at 800 GeV. H^+H^- of 300 GeV$/c^2$ signal simulated with PYTHIA and processed with SIMDET detector simulation (ISR and beamstrahlung included).

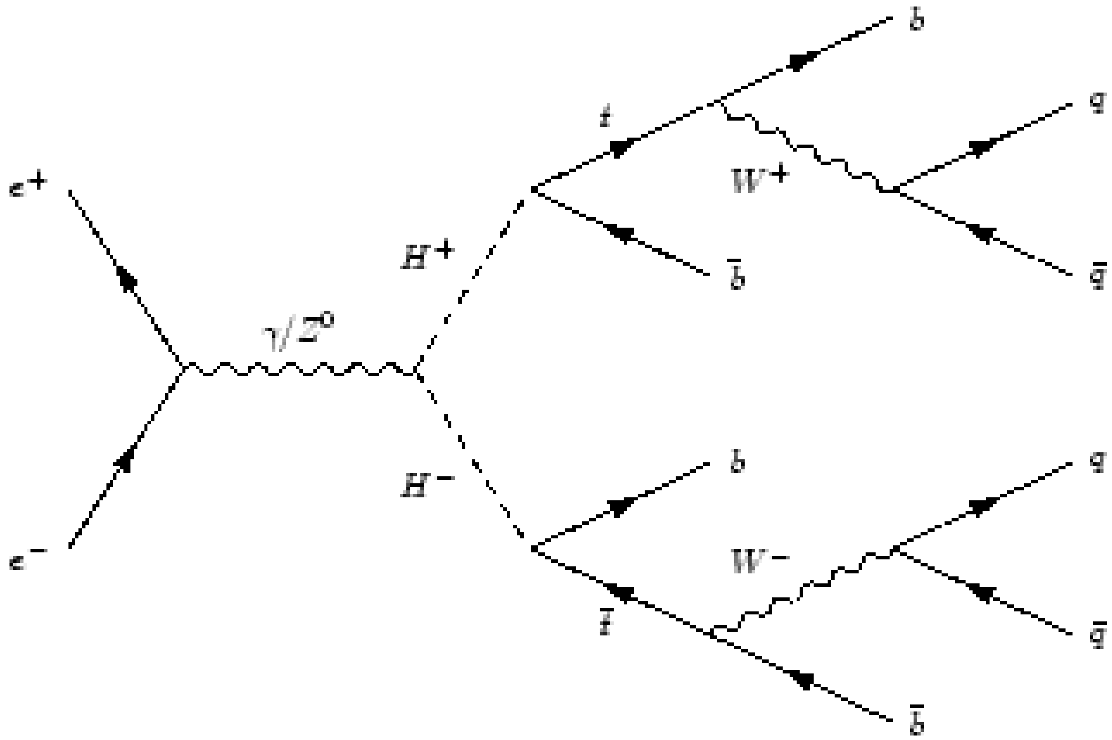
Heavy $H^{\pm}$

Dominant decays of a heavy $H^{\pm}$:

- $H^+H^- \longrightarrow t\bar{b}\bar{t}b$
- $H^+H^- \longrightarrow W^+h^0W^-h^0$

Same final state: $W^+W^-b\bar{b}b\bar{b}$.

Select fully hadronic W decays for full mass reconstruction.



Background processes

Background analysis not complete yet. Numbers not precise but give the order of magnitude.

Main backgrounds are the Standard Model Yukawa Higgs production and its backgrounds:

Process	σ (fb)
$\mathrm{H^+H^-}$ (250 GeV/c^2)	23
$\mathrm{H^+H^-}$ (300 GeV/c^2)	13
$\mathrm{H^+H^-}$ (350 GeV/c^2)	4
$q\bar{q}(g)$	1500
$\mathrm{W^+W^-}$	4400
ZZ	300
HZ	25
$t\bar{t}$	300
$t\bar{t}\mathrm{Z}$	5
$t\bar{t}\mathrm{H}$	3
$tb\bar{t}b$	< 5

$\mathrm{H^+H^-} \longrightarrow \mathrm{t\bar{b}\bar{t}b}$ and $\mathrm{H^+H^-} \longrightarrow \mathrm{W^+h^0W^-h^0}$ have the same final states and are potential backgrounds for each other.

Additional backgrounds possibly from SUSY.

b tagging

Essential for the analysis.

Background has to be reduced by orders of magnitude with reasonable signal efficiency.

Jet-by-jet tagging requiring four jets to have a good tag (not an event tag).

Assumed 95% b-jet efficiency with 5% c-jet miss-tag probability.

Gluon splitting not yet taken into account but the effect to the final results is small as the background rejection at the mass recontruction phase is very efficient.

Background rejection

Preselection of $4b4q$ events:

- $E_{vis} > 600$ GeV
- $p_{miss} < 100$ GeV$/c$
- $E_{lepton} < 50$ GeV
- Eight jets (CAMJET with sliding $y_{cut} = 0.00026 - 0.00057$)
- Four b-tagged jets

Four-fermion processes like W^+W^-, ZZ and HZ reduced by three orders of magnitude already with 8-jet requirement.

Final states with less than 4 b-quarks reduced by additional orders of magnitude with b-tagging.

$t\bar{t}$ rejection:

- Eight jets + other hadronic preselections: 10% pass
- Two c quarks (25%) and both miss-tagged (5%*5%): 0.06% pass
- Total rejection factor of more than 10^4

Significant backgrounds come from true $4b4q$ final states (mainly $t\bar{t}$H and $t\bar{t}$Z).

Mass reconstruction

After preselection: events with four b-tagged jets and four light quark jets, complete mass reconstruction with alternative signal hypotheses.

Reconstruction of $\mathrm{H^+H^-} \longrightarrow \mathrm{t\bar{b}\bar{t}b}$

- Find the two qq pairs that make the best W's (and cut)
- Find the two bW pairs that make the best t-quarks (and cut)
- Find the two bt pairs that make the best equal mass charged Higgses (and cut)

Reconstruction of $\mathrm{H^+H^-} \longrightarrow \mathrm{W^+h^0W^-h^0}$:

- Find the two qq pairs that make the best W's (and cut)
- Find the two bb pairs that make the best $\mathrm{h^0}$'s (and cut)
- Find the two $\mathrm{Wh^0}$ pairs that make the best equal mass charged Higgses (and cut)

Additional hypotheses can be used for background rejection:

- If compatible with $t + t + \mathrm{H}$ reject as Standard Model like Yukawa Higgs production
- If compatible with $t + t + \mathrm{Z}$ reject as Standard Model $t\bar{t}\mathrm{Z}$ process

Kinematical fits

Mass resolution and background rejection can be improved by using kinematical fits to compensate the detector inefficiencies

Use all possible constraints:

- Energy and momentum conservation (beamstrahlung and ISR effect a bit)
- Known W masses
- Known h^0 masses or known t-quark masses
- H^+ and H^- masses equal

Cut on the χ^2 of the fit to reject events that do not match the used hypothesis $\rightarrow$ improves the mass resolution and reduces backgrounds

Results: mass measurement

Cuts optimised to get the best sensitivity for the mean value of the mass peak.

Very efficient background rejection with tight cut on the fit χ^2 $\longrightarrow$ high purity.

Signal efficiencies of few per cent depending on the decay channel and on the cuts.

Mass measurement:

- Gaussian fit to the peak to estimate the mass
- Width of the mass peak from 5 to 10 GeV/c^2
- Need precision in the measurement of the effective beam energy spectrum and good understanding of jet energy resolution in the detector
- Statistical error of the mean value of the mass peak at 300 GeV/c^2 mass from 1 to 2 GeV/c^2

Results: cross-section and branching ratio

Cuts optimised to get the best sensitivity for the number of correctly reconstructed signal events.

Very efficient background rejection with tight cut on the fit χ^2 $\longrightarrow$ high purity.

Signal efficiencies of few per cent depending on the decay channel and on the cuts.

Cross-section and branching ratio measurements:

- Gaussian fit to the peak to estimate the number of events in the real signal peak $\longrightarrow$ remove the effect of possible remaining backgrounds
- Measure the partial cross-sections for both (all) decay channels
- Branching ratio from the ratio of the partial cross-sections
- Total cross-section from the combination of the partial ones
- Statistical error of the cross-section measurement at 300 GeV/c^2 mass assuming one decay channel to be dominant is of the order of 10–15 %

Conclusions

Studied heavy charged Higgs (order of 300 GeV/c^2) at a future LC with TESLA parameters.

Full reconstruction possible in $H^+H^- \rightarrow t\bar{b}\bar{t}b$ and $H^+H^- \rightarrow W^+h^0W^-h^0$ decay channels.

Kinematical fits improve results significantly

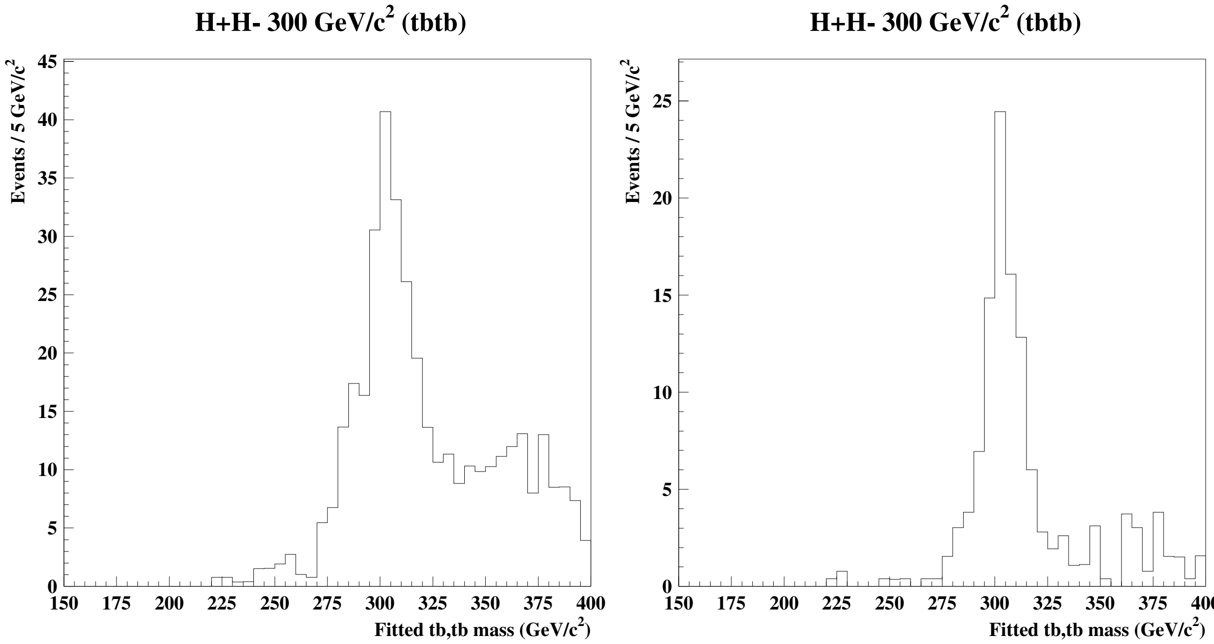
High purity with signal efficiencies of few per cent

Estimated measurement precisions at 300 GeV/c^2 mass:

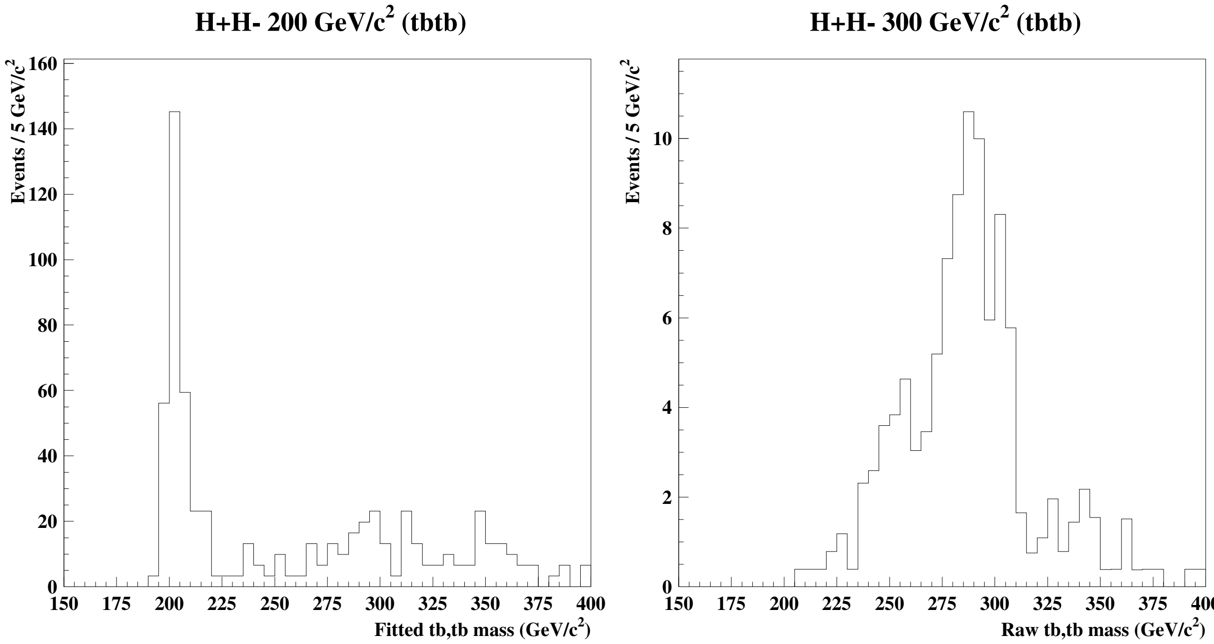
- Mass measurement: 1–2 GeV/c^2
- Cross-section and branching fraction measurements: 10-15 %

As the H^+H^- cross-section is strongly mass dependent the results are better at lower masses and deteriorate with increasing mass.

$H^+H^- \rightarrow t\bar{b}\bar{t}b$ mass plots

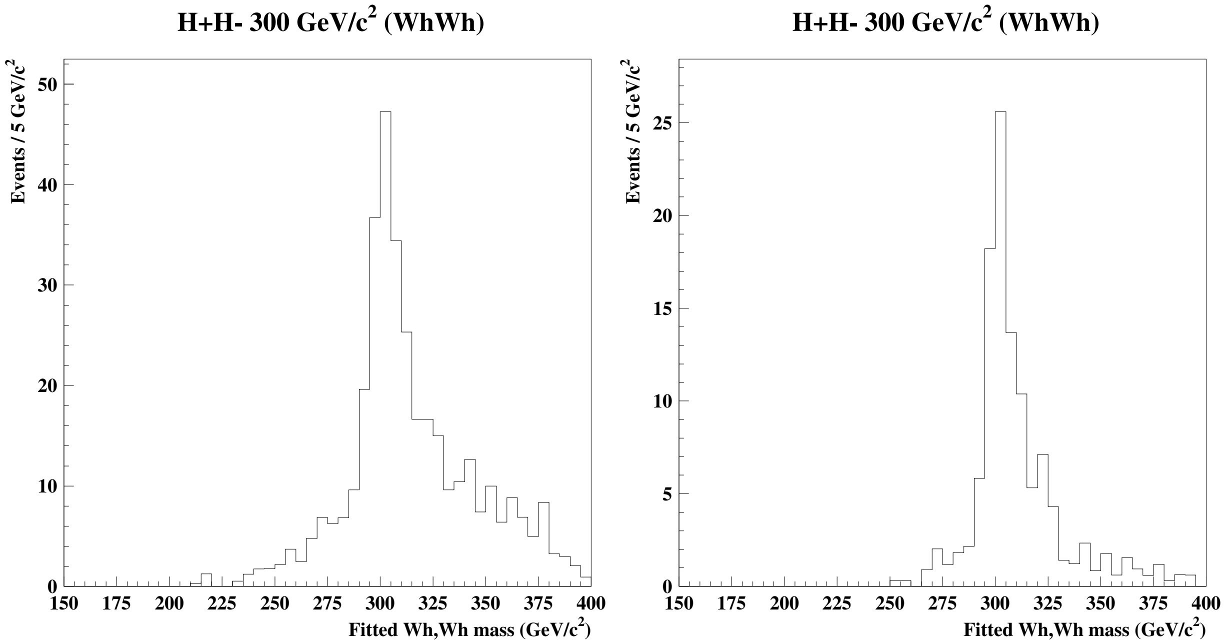


Figures 1,2: Fitted mass of 300 GeV/c^2 H^+H^- with 6% and 2% efficiency.

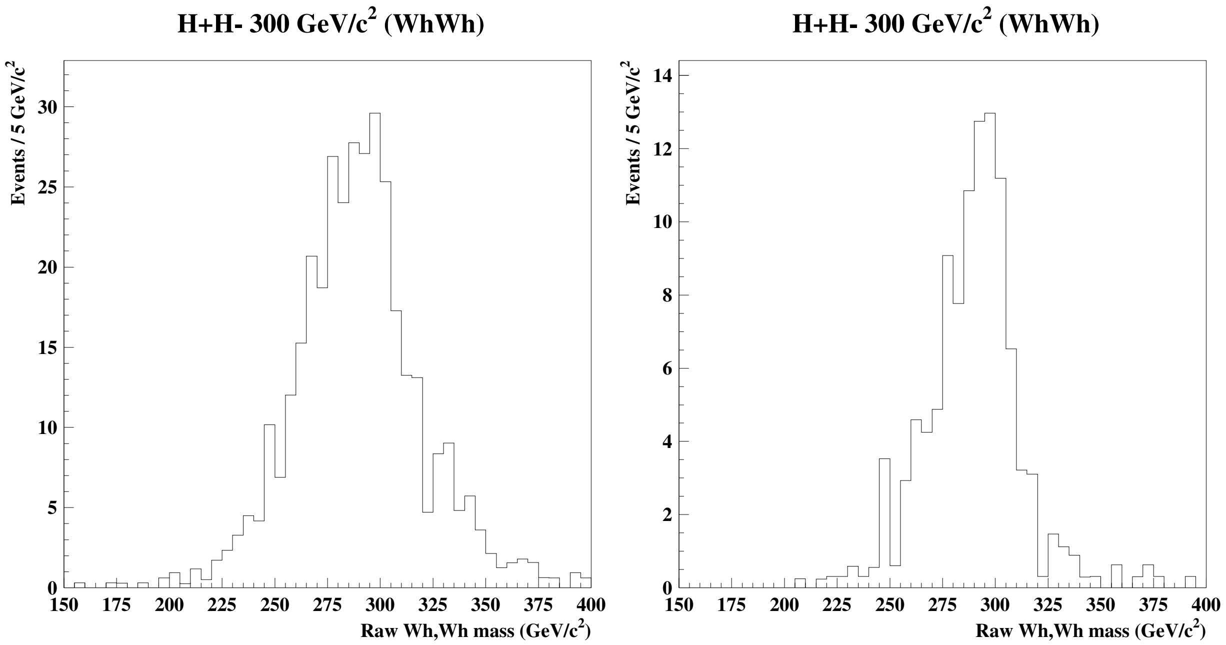


Figures 3,4: Fitted mass of 200 GeV/c^2 H^+H^- with 4% efficiency and raw mass of 300 GeV/c^2 H^+H^- with 2% efficiency.

$H^+H^- \rightarrow W^+h^0W^-h^0$ mass plots



Figures 1,2: Fitted mass of 300 GeV/c^2 H^+H^- with 6.5% and 2% efficiency.

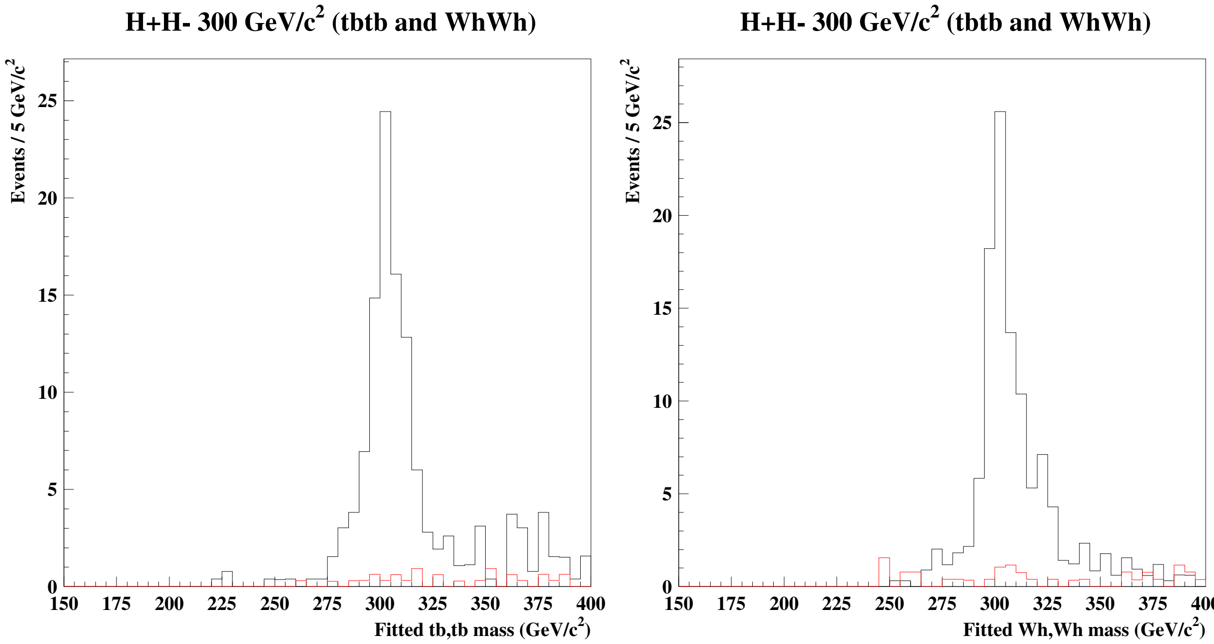


Figures 3,4: Raw mass of 300 GeV/c^2 H^+H^- with 6% and 2% efficiency.

Overlap of the two decay channels

Branching ratio measurement requires a powerful separation between the two decay channels which have the same final state parton configuration.

This can be obtained by comparing the χ^2 of the fit with the $t\bar{b}\bar{t}b$ hypothesis to the χ^2 of the fit with the $\mathrm{W^+h^0W^-h^0}$ hypothesis.



Figures 5,6: Fitted masses with $t\bar{b}\bar{t}b$ and $\mathrm{W^+h^0W^-h^0}$ hypotheses. Red histograms show the number of events of the other decay channel passing cuts.

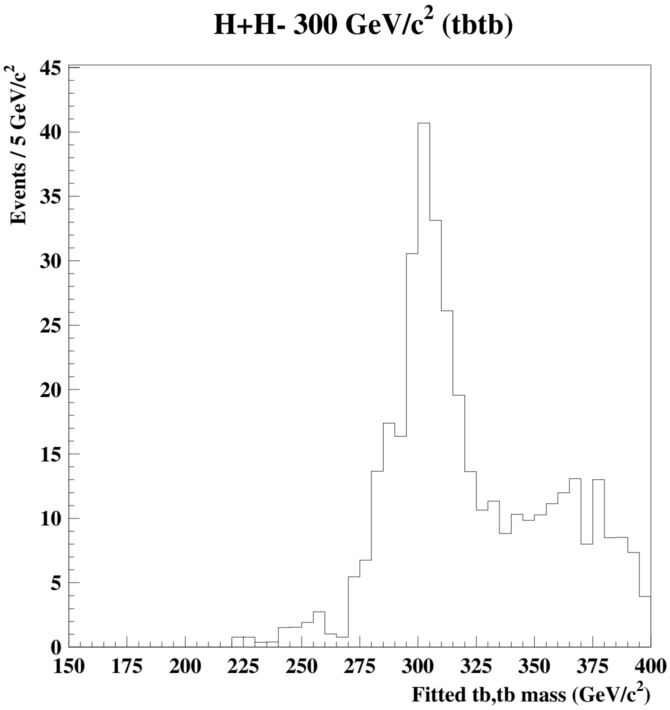
H^+H^- summary

Full reconstruction of eight jet events possible in $H^+H^- \longrightarrow t\bar{b}\bar{t}b$ and $H^+H^- \longrightarrow W^+h^0W^-h^0$ decay channels.

High purity with few per cent signal efficiency with b-tagging and kinematical fits.

Estimated measurement precisions for 300 GeV/c^2 H^+H^- (500 pb^{-1} at 800 GeV at TESLA):

- Mass measurement: 1–2 GeV/c^2
- Cross-section measurement: 10-15 %



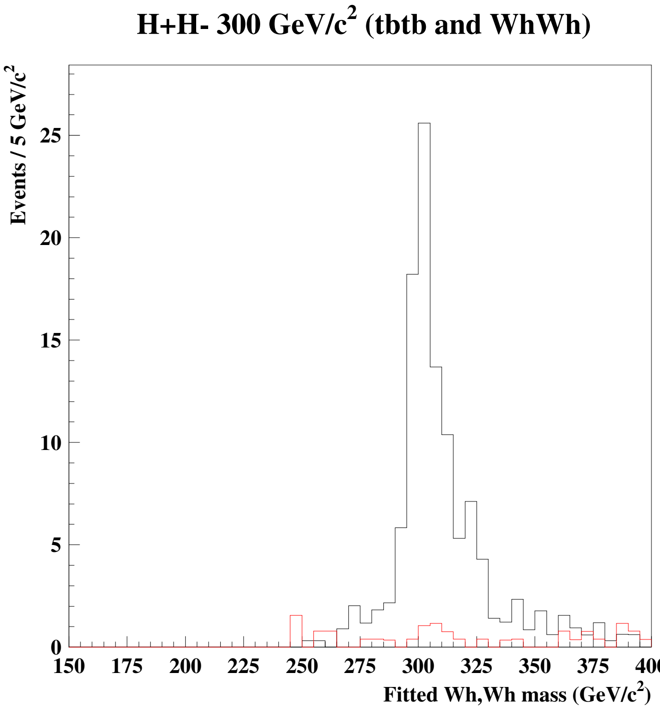


Fig. 1: Fitted mass of 300 in $t\bar{b}\bar{t}b$ decay channel. Fig. 2: Fitted mass in $W^+h^0W^-h^0$ channel. Red histogram shows the fraction of $t\bar{b}\bar{t}b$ events passing the $W^+h^0W^-h^0$ cuts.