Study of a heavy charged Higgs boson in ATLAS

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Content

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Charged Higgs in the Minimal Supersymmetric Standard Model (MSSM)

- Minimal extension: adds smallest possible number of parameters
- 2 doublets of complex scalar fields
  - 5 physical Higgs bosons after symmetry breaking: h, H, A and $H^{\pm}$
  - 2 additional parameters in electroweak sector: $m_{H^{\pm}}$ (or m_A) and $\tan\beta$, the ratio of vacuum expectation values of the two doublets
- $H^{\pm}$ production and decay ($m_{H^{\pm}} > m_t$)
  - $gb \to tH^{\pm}$, $gg \to tH^{\pm}b$
  - the cross section is a function of $\tan\beta$ and $m_{H^{\pm}}$
  - decays: almost exclusively $H^{\pm} \to tb$ and $H^{\pm} \to \tau\nu$

Hadronic τ decay of heavy H$^{\pm}$

- published in ATL-PHYS-2000-031
- signal:

$$\begin{aligned} gb &\rightarrow tH^{\pm} \\ H^{\pm} &\rightarrow \tau\nu_{\tau} \\ t &\rightarrow Wb \rightarrow jjb \end{aligned}$$

- backgrounds:

$$t\bar{t} \rightarrow WWb\bar{b}, \quad W^{+} \rightarrow \tau\nu, \quad W^{-} \rightarrow \mathrm{jets}$$

$$Wtb \quad (p_T > 30 \text{ GeV})$$

$$\mathrm{QCD}(p_T > 10 \text{ GeV}) \qquad W + \mathrm{jets}(p_T > 30 \text{ GeV})$$

- rates (integrated luminosity 30 fb^{-1}):

Process	$\tan\beta$	$m_{H^{\pm}}$ (GeV)	$\sigma \times$ BR (pb)
Signal	45	300	0.54
$t\bar{t}$			84.11
Wtb			56.9
W+jet			$1.64\,10^{4}$
QCD			$6.04\,10^{9}$

Event jet selection

- 1 hadronic τ jet:

$$\frac{p_T^{\text{had}}}{p_T^{\tau\ \text{jet}}} > 80\%$$

$$\Delta R_{(\tau\ \text{jet},\ \text{had})} < 0.1$$

$$p_T^{\tau} > 30\ \text{GeV}$$

$$|\eta^{\tau}| \leq 2.5$$

- at least 3 other jets with $p_T > 30$ GeV
- 1 of these is a b-tagged jet with $|\eta^b| < 2.5$
- b-jet veto: only 1 b jet with $|\eta^b| \leq 2$ and $p_T^b > 50$ GeV
- ATLFAST efficiencies:

$$\varepsilon_{b\ \text{tag}} = 60\% \quad (50\%\ \text{at high luminosity})$$

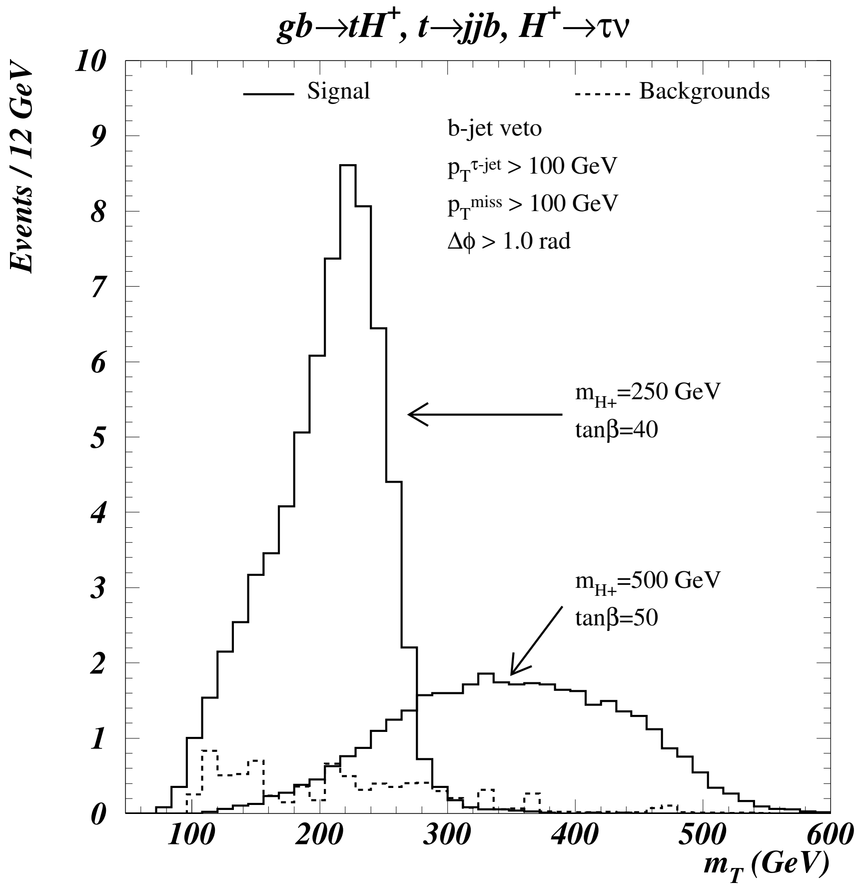
$$\varepsilon_{\tau\ \text{tag}} = 30\% \quad (\text{rejection} \sim 500)$$

Analysis procedure

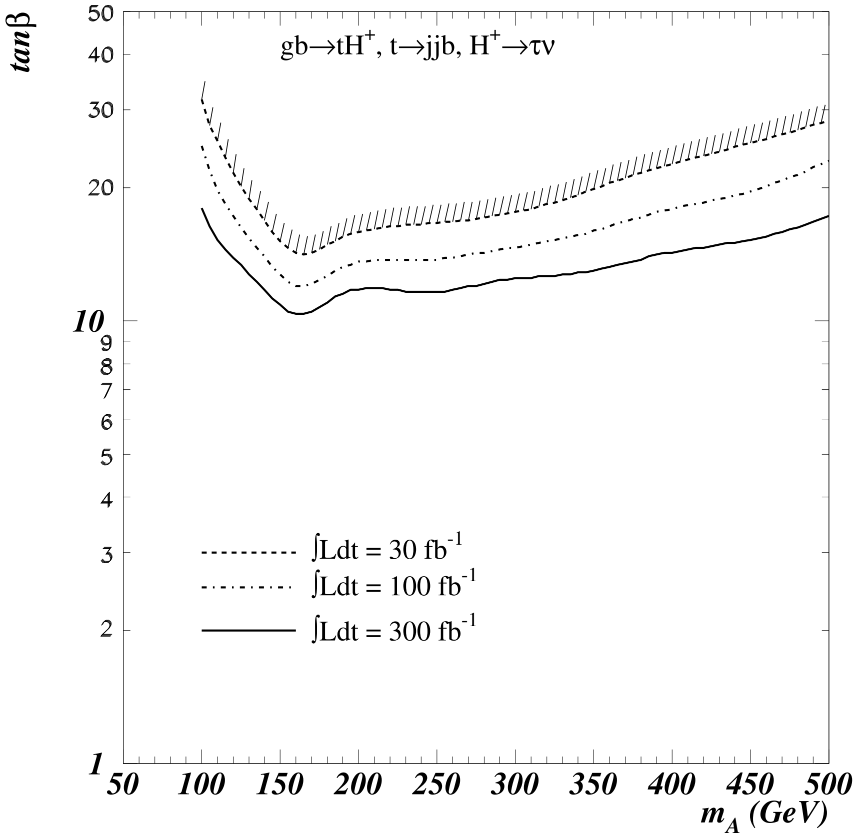
- W reconstructed from paired non-b and non-τ jets, $|m_{jj} - m_W| \leq 25$ GeV
- W candidates combined with b jet. Top candidate has minimum $\chi^2 = (m_{jjb} - m_t)^2$
- Keep only events with $|m_{jjb} - m_t| < 25$ GeV
- $p_T^\tau > 100$ GeV
- $\not{p}_T > 100$ GeV
- $\Delta\phi > 1$

transverse mass: $m_T = \sqrt{2 p_T^\tau \not{p}_T (1 - \cos\Delta\phi)}$

Transverse mass

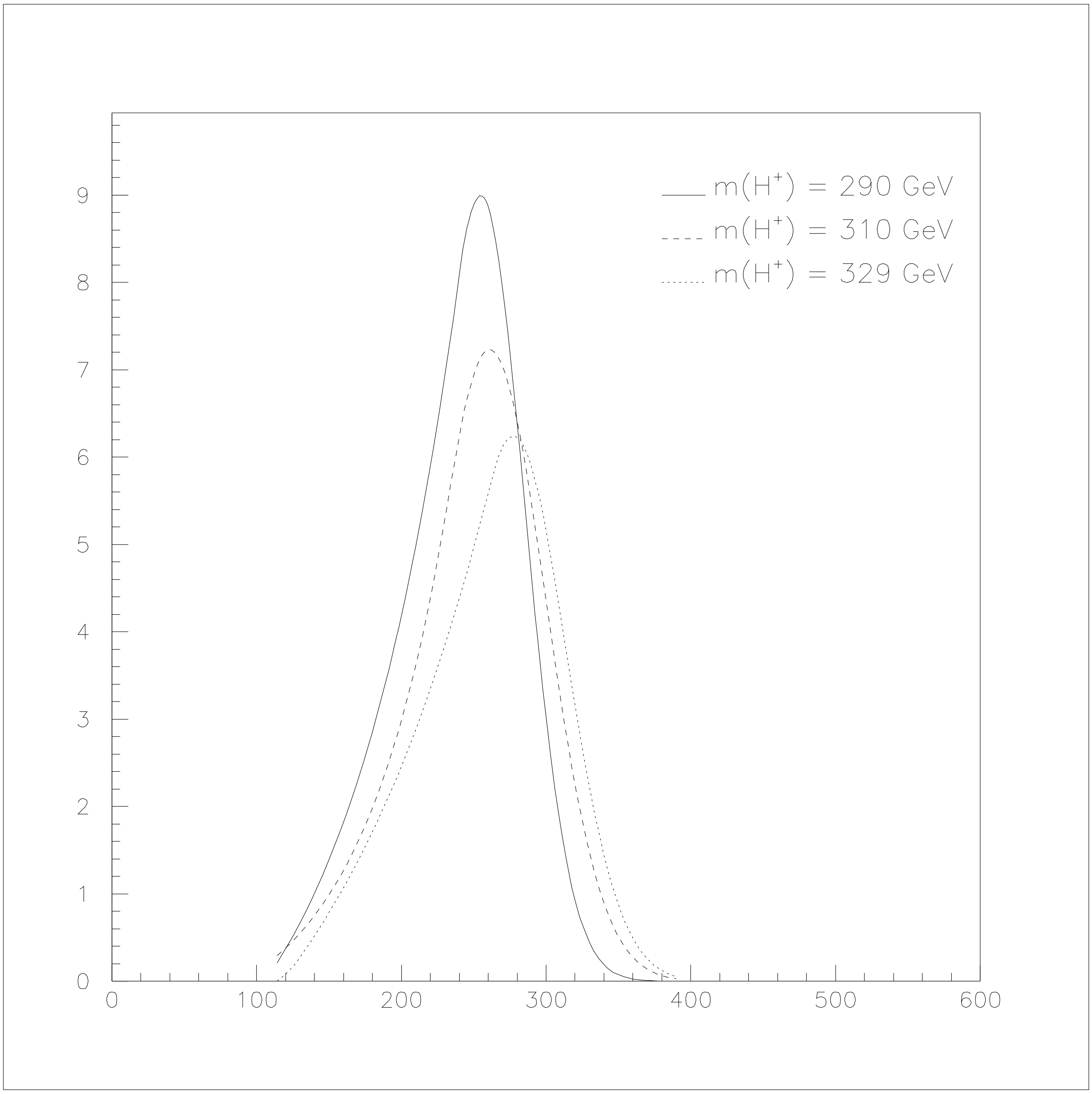


5-σ discovery contour



integrated luminosity: 30 fb^{-1}

Transverse mass distributions



Maximum Likelihood method

- Choose one reference Higgs mass m_H^{ref}
- Get expected number of events N from transverse mass distribution
- For each generated mass m_k compute the Likelihood function for a set $\{m_{T_i}\}$ of random transverse masses

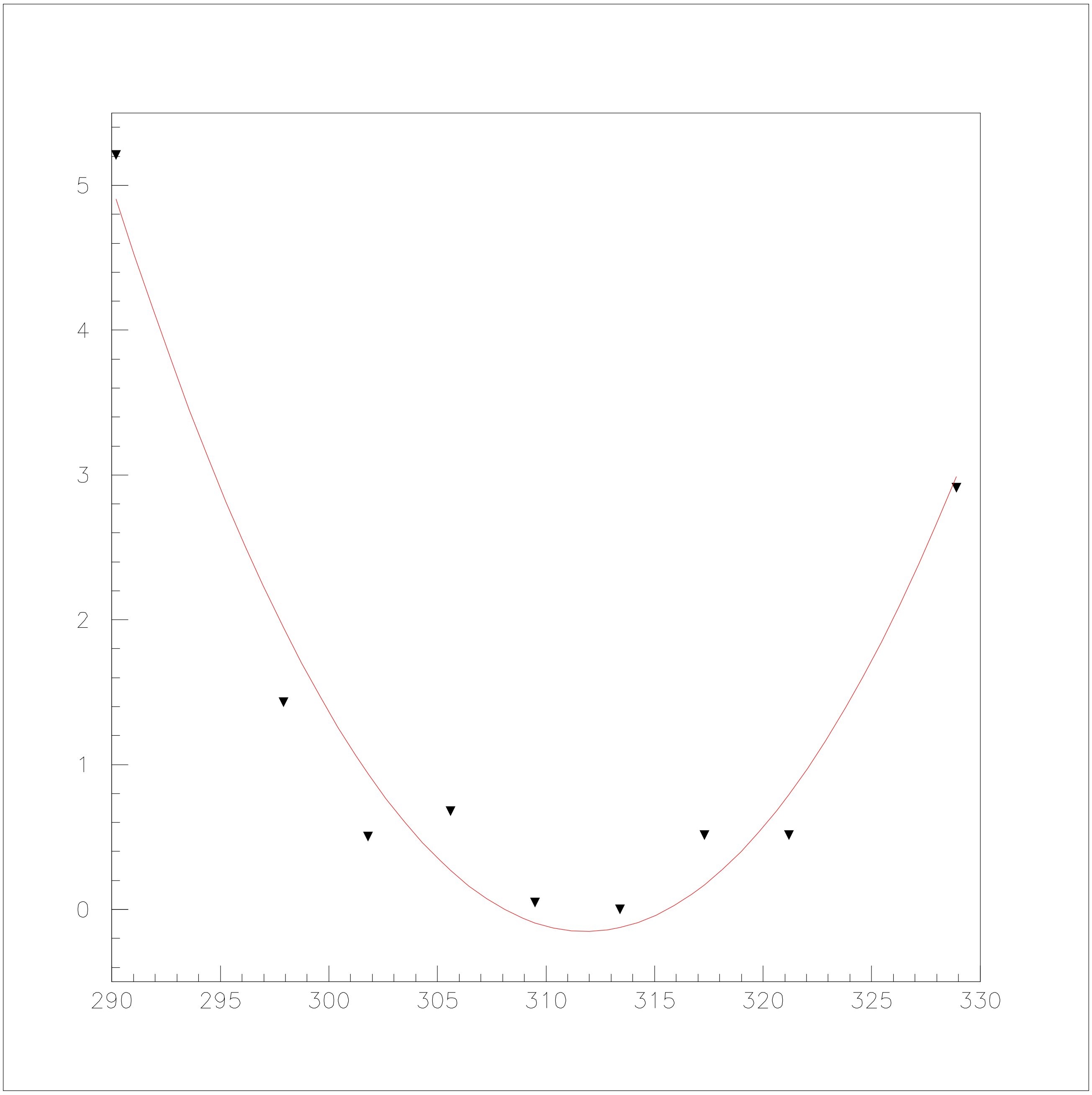
$$\ln \mathcal{L}_k = \sum_{i=1}^{N} \ln P(m_{T_i})$$

- Compute the differences

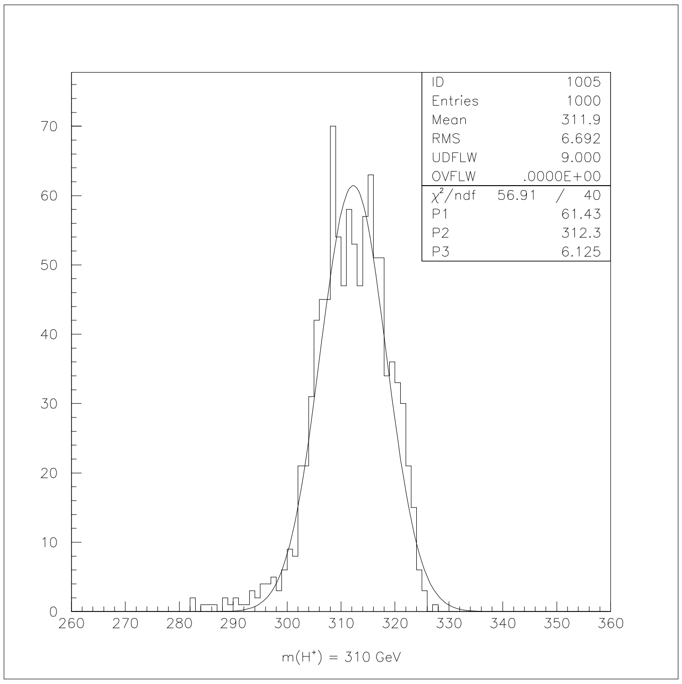
$$\Delta(\ln \mathcal{L}_k) = \ln \mathcal{L}^{ref} - \ln \mathcal{L}_k$$

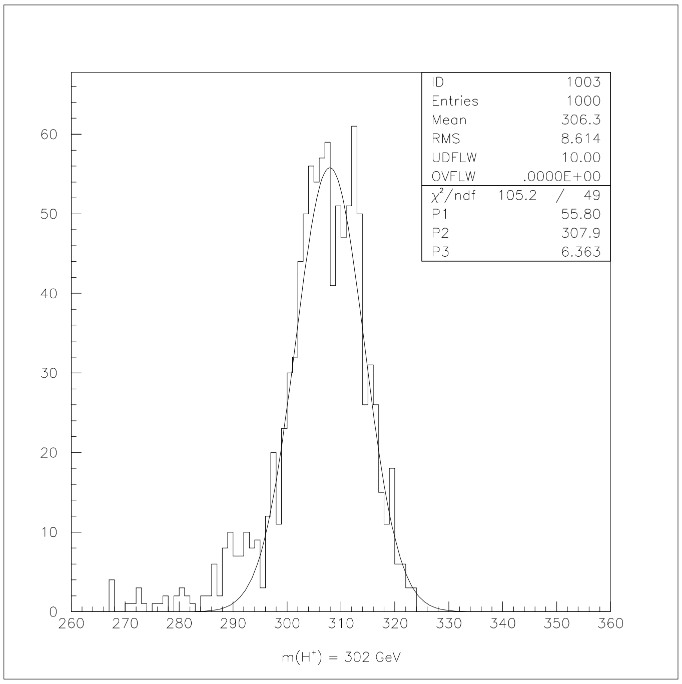
- Parabolic fit to $\Delta(\ln \mathcal{L})$. The minimum should be at the reference mass.
- Repeat the procedure many times

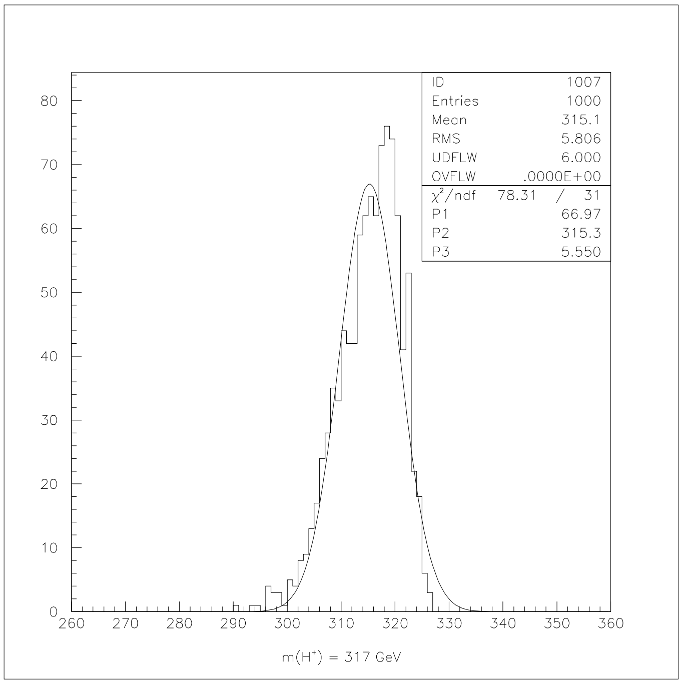
Parabolic fit



Mass distributions



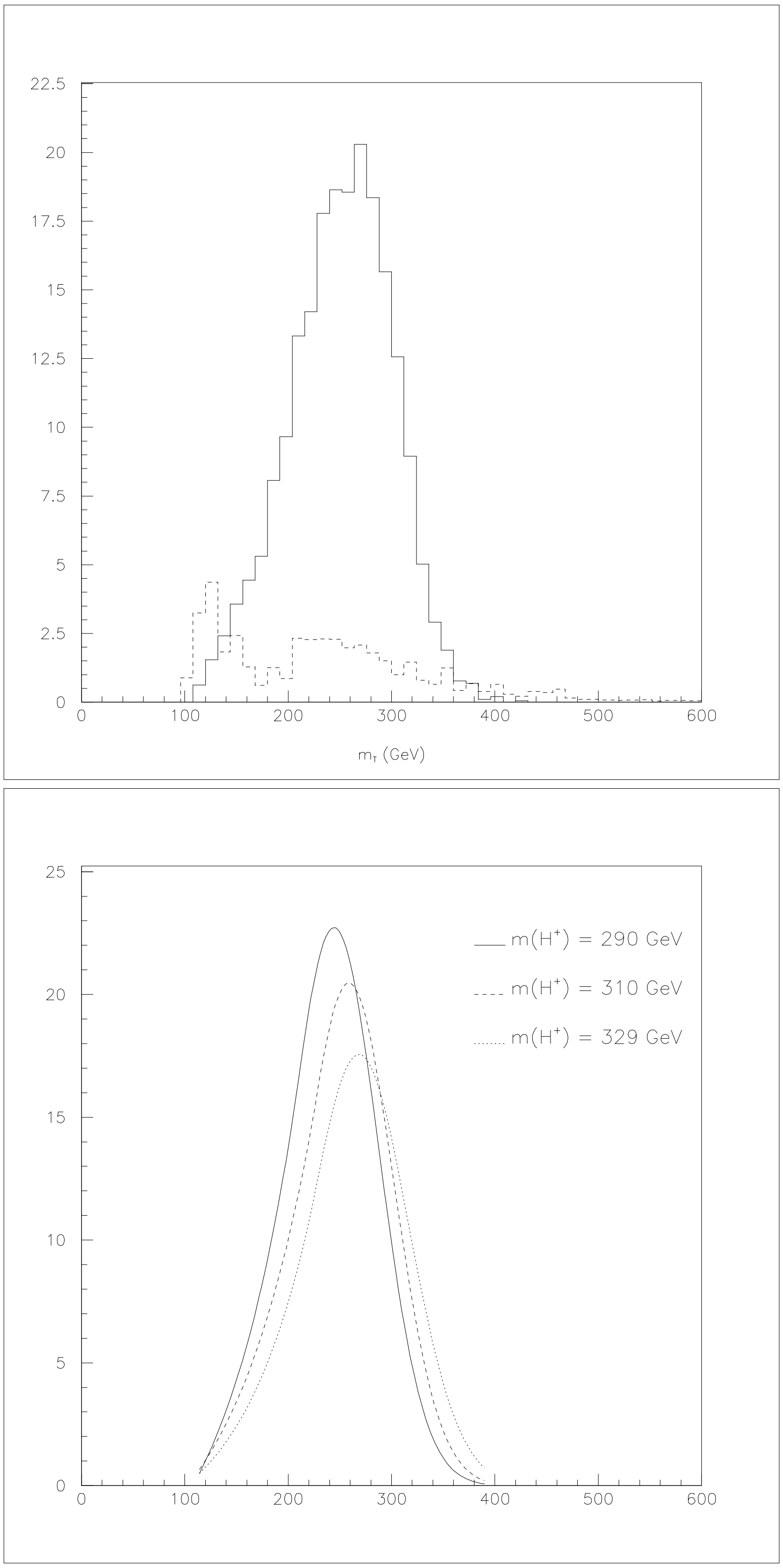




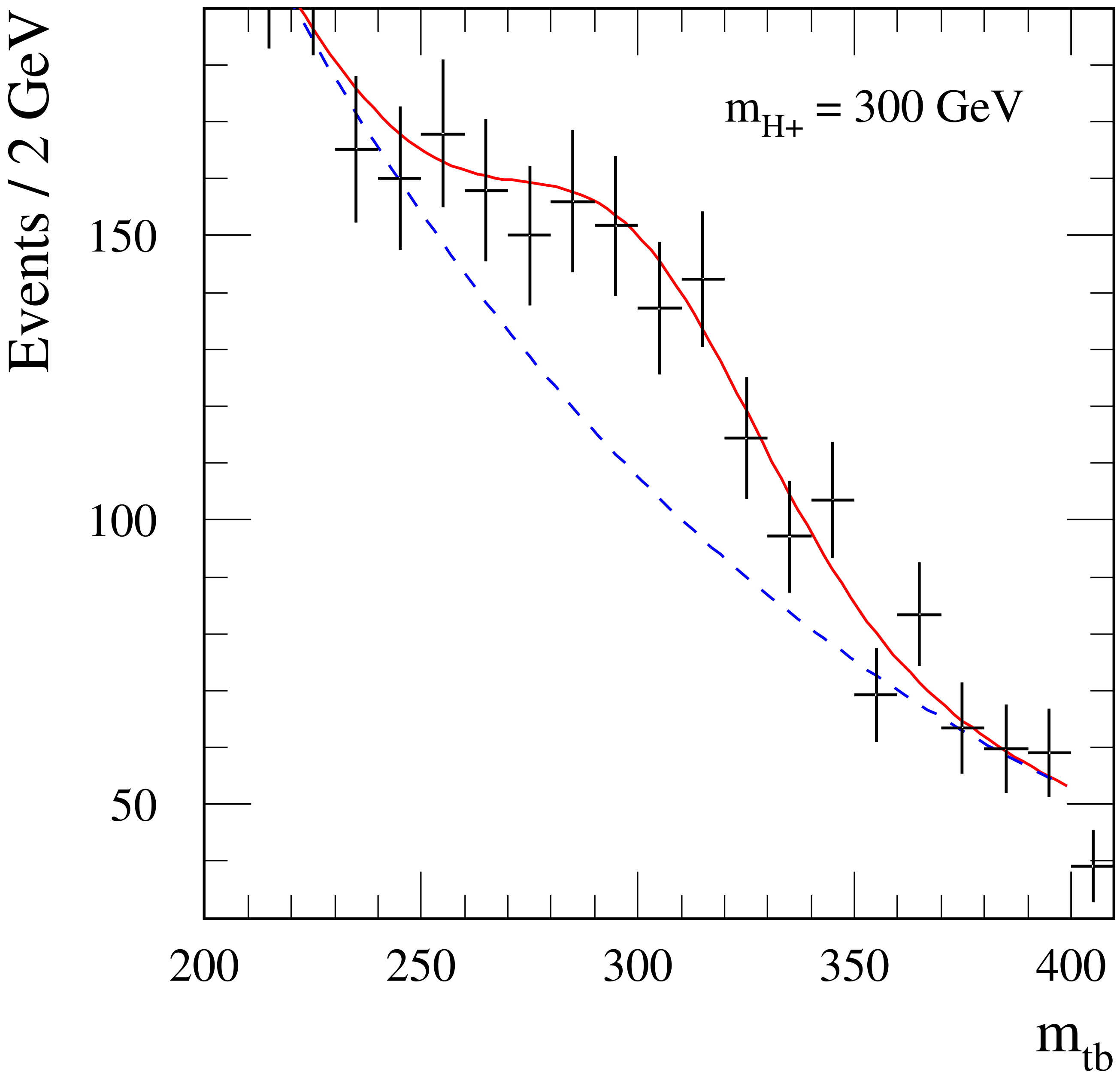
Outlook

- investigate mass and cross-section calculations (systematics, ongoing)
- Include background (basically done)
- Use more masses to scan the parameter space, from 180 GeV to 500 GeV (almost ready)
- Go at high luminosity (almost done)
- Apply the same method to $H^{\pm} \to tb$
- Derive $\tan\beta$ from the ratio of the two channels.

High luminosity



The $H^{\pm} \to tb$ channel



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