Effect of Scattering Interference Terms On the Search for a Charged Higgs Boson

A. Arhrib, D. Azevedo, R. Benbrik, H. Harouiz, S. Moretti, **R. Patrick**, R. Santos

Motivation

- A typical collider analysis involves modelling signal and background scattering amplitudes seperately.
- This fails to take into account interference between signal and background diagrams as interference is assumed to be negligible.
- For particles with high widths relative to mass, i.e. potential heavy BSM scalars, this interference can be significant.
- This poster presents such an example in the hMSSM with the process $pp \to tbH^{\pm}$.
- Both a parton level inclusive cross section calculation and full detector analysis are presented.

Parameter Space

- `HiggsBounds` and `HiggsSignals` employed to generate Fig. 1.

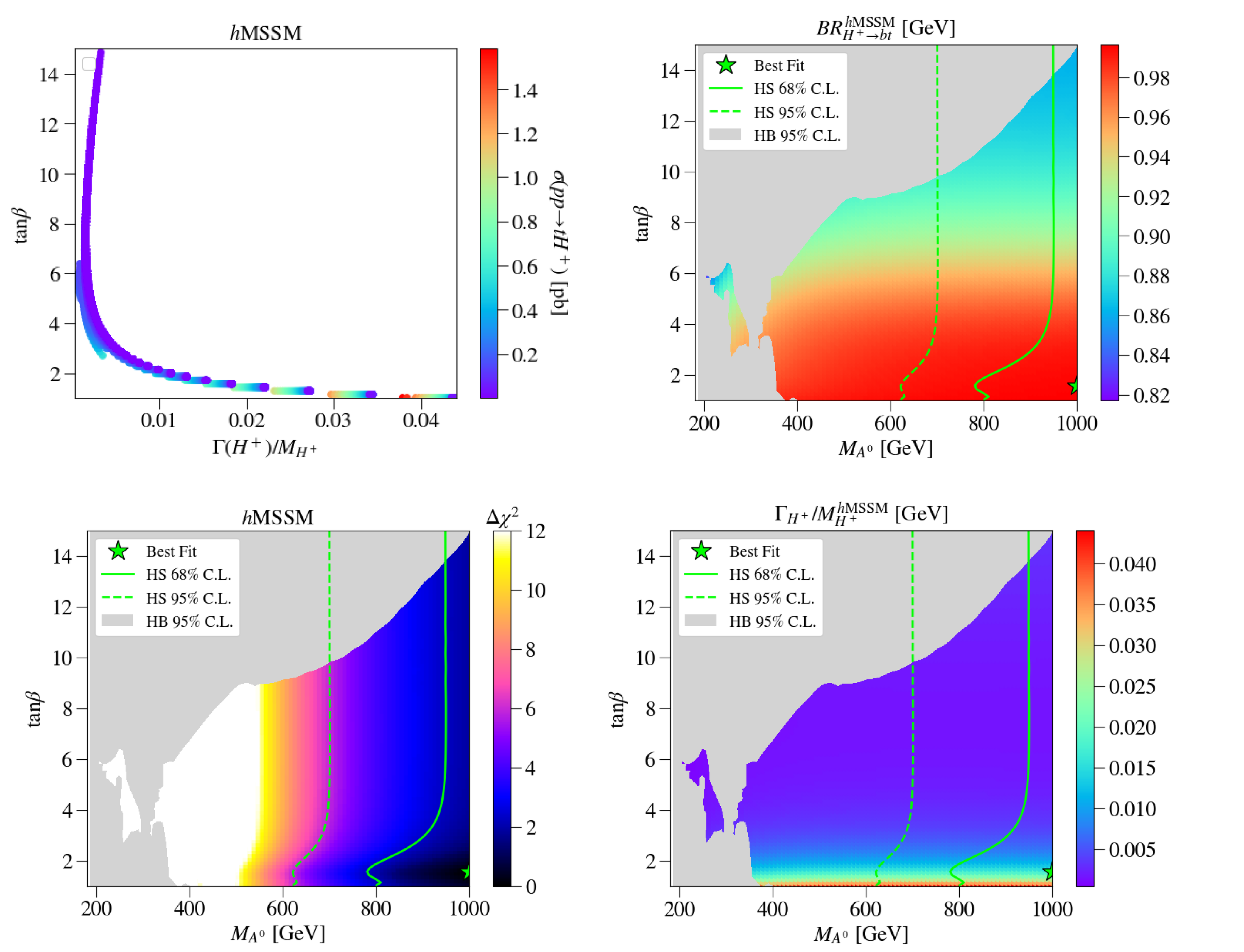

Fig. 1: Slices of hMSSM parameter space fits in terms of cross section, $\mathrm{Br}(H^{\pm} \to tb)$, masses and widths.

- Non-excluded areas containing high width to mass ratio, cross section and $\mathrm{Br}(H^{\pm} \to tb)$ can be seen.

Benchmark and Process

- Model: hMSSM
- Key Parameters:
  - $\tan\beta = 1.01$
  - $M_{H^{\pm}} \approx M_A \approx M_H \approx 635$ GeV
  - $\Gamma_{H^{\pm}} \approx \Gamma_A \approx \Gamma_H \approx 27$ GeV
- Process: $pp \to tbH^{\pm} \to tbt\bar{b}$

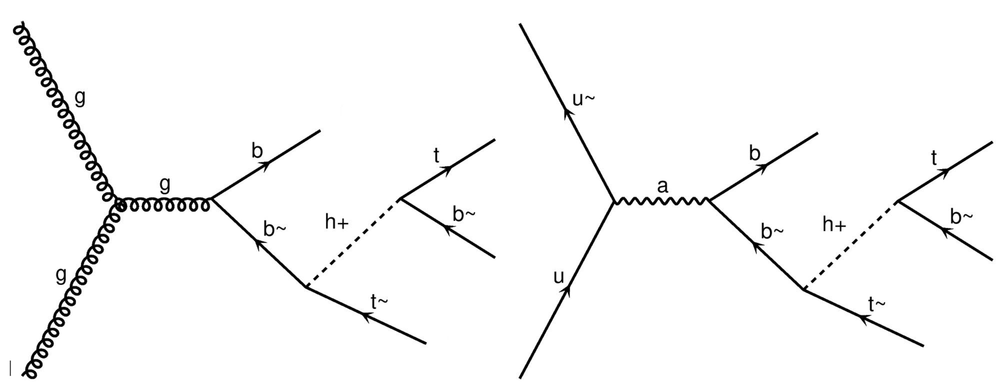

Fig. 2: Examples of signal diagrams.

Data Generation and Parton Level Results

- `MadGraph5` - 1,000,000 events at parton level to achieve required systematics.
- `PYTHIA8` for hadronization/fragmentation - applied to 500,000 events.
- `Delphes` for detector effects.

Model		S	B	S+B	I
hMSSM	σ	0.032402	13.092	13.143	0.019
	$\Delta\sigma$	1.4e−5	0.004	0.004	0.008
$\mathbf{m_h^{125}}$	σ	0.088502	13.103	13.20	0.009
	$\Delta\sigma$	3.3e−5	0.004	0.004	0.008
$\mathbf{m_h^{mod+}}$	σ	0.016802	13.177	13.197	0.003
	$\Delta\sigma$	5.8e−6	0.004	0.004	0.008

Tab. 1: Parton level results for three MSSM benchmarks.

- hMSSM provides very high levels of interference relative to signal cross section.
- $\mathrm{m_h^{mod+}}$ and $\mathrm{m_h^{125}}$ benchmarks with higher interference likely exist.

Vetoes and Reconstruction

- The following vetoes are applied:
  $-N_\ell = 1,\ N_j \geq 5,\ N_b \geq 3$
- Longitudinal momentum of missing energy solved using:

$$p^z_\nu = \frac{1}{2p^2_{\ell T}}\left(A_W p^z_\ell \pm E_\ell\sqrt{A^2_W \pm 4p^2_{\ell T}E^2_{\nu T}}\right)$$

where, $A_W = M_{W^{\pm}} + 2p_{\ell T} \cdot E_{\nu T}$

- Reconstruction performed via simultaneous minimization of:

$$\chi^2_{\text{had}} = \frac{(M_{\ell\nu} - M_W)^2}{\Gamma^2_W} + \frac{(M_{jj} - M_W)^2}{\Gamma^2_W} + \frac{(M_{\ell\nu j} - M_T)^2}{\Gamma^2_T} + \frac{(M_{jjj} - M_T)^2}{\Gamma^2_T} + \frac{(M_{jjjj} - M_{H^{\pm}})^2}{\Gamma^2_{H^{\pm}}}$$

- and the equivalent term for a leptonically decaying $H^{\pm}$.

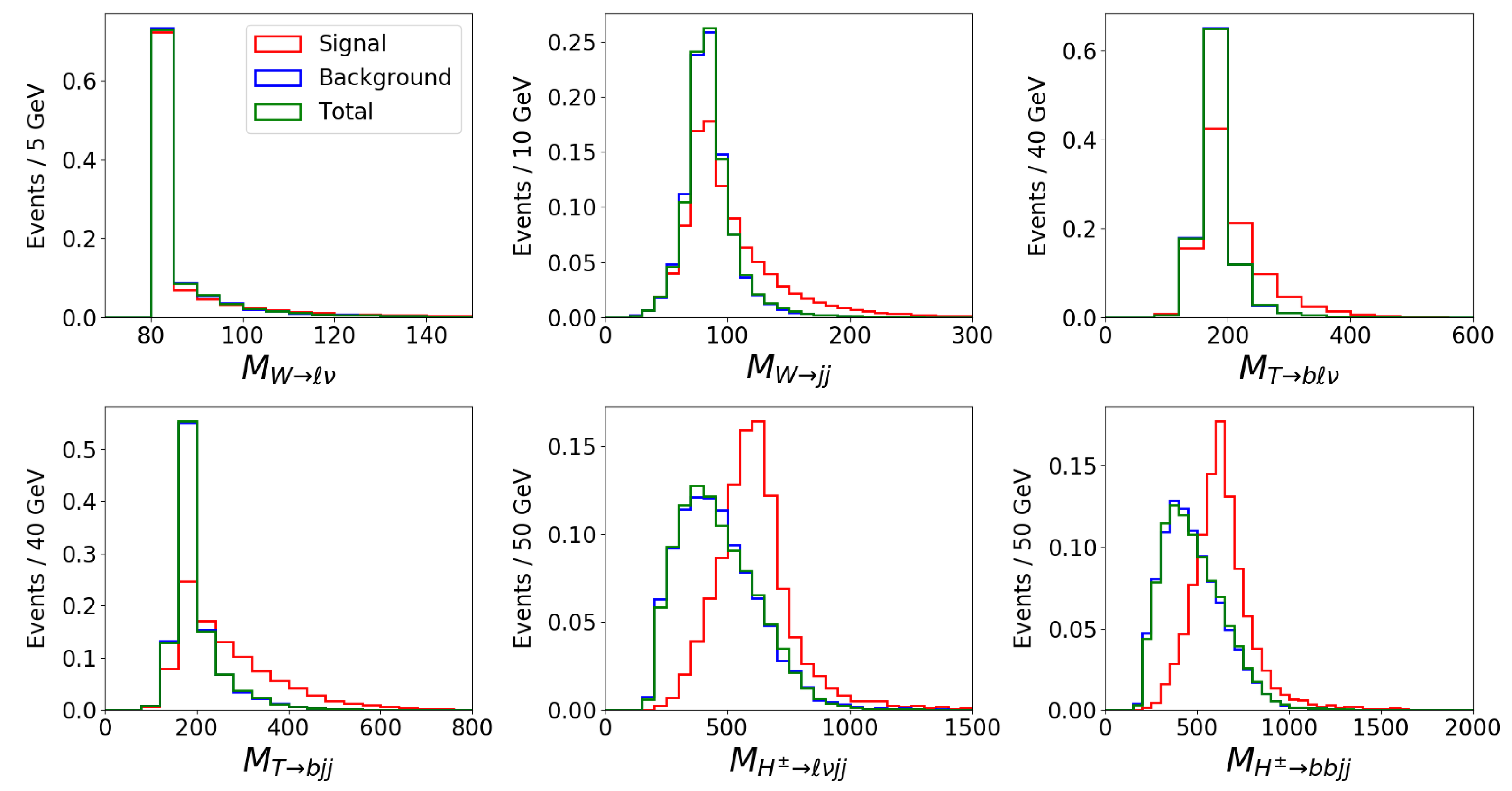

Fig. 3: Normalized distributions of the invariant masses of reconstructed particles.

Cut Flow Results

Cut	S	B	S+B	I
No cuts:	0.0324	13.0920	13.1430	0.0186
$N_\ell = 1$:	0.0045	1.8634	1.8798	0.0186
$N_J \geq 5$:	0.0037	1.0576	1.0662	0.0049
$N_{BJ} \geq 2$:	0.0022	0.5143	0.5142	-0.0023
$\not{E} > 20$:	0.0021	0.4763	0.4754	-0.0030
$\not{E} + m^W_T > 60$:	0.0020	0.4637	0.4634	-0.0023
Cut	**S**	**B**	**S+B**	**I**
$N_{BJ} \geq 3$:	0.0009	0.1651	0.1670	0.0011
$\not{E} > 20$:	0.0008	0.1530	0.1539	0.0000
$\not{E} + m^W_T > 60$:	0.0008	0.1491	0.1502	0.0003

Tab. 2: Cut flow results for the hMSSM benchmark.

- Two b-tag region results in interference of same magnitude as signal but negative.
- Three b-tag region has much lower interference, but signal cross section suffers greatly.

Future Work

- Detector level results for $\mathrm{m_h^{mod+}}$ and $\mathrm{m_h^{125}}$.
- Is the effect of interference simply an overall scaling factor, or are shape changes significant? This must be quantified.
- How can one incorporate interference effects into an MVA analysis (i.e. BDT, SVM, ANN)?
- How are MVA discriminants effected?