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

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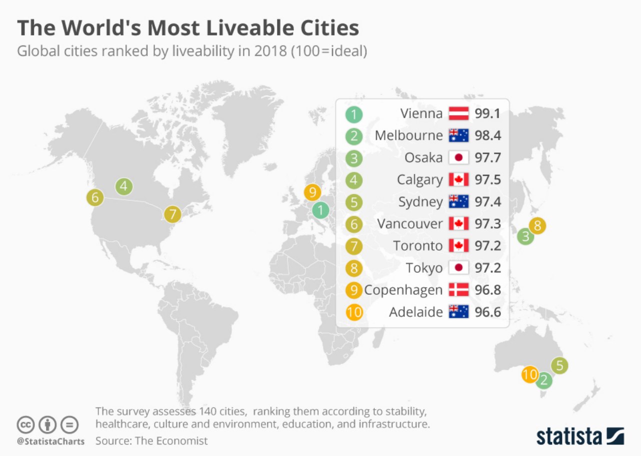
Overview

1. Introduction
2. Benchmark Selection
3. Monte Carlo Modelling
4. Parton Level Results
5. Detector Level Results
6. Conclusion

Adelaide, Australia

Adelaide, Australia



- January 24th 2019: Adelaide reached 46.6°C (116°F) (nearby town reached 49°C [120°F]!)

Introduction

- Collider studies generally model Signal and Background seperately.
- Define: $\mathrm{I} = (\mathrm{S}+\mathrm{B}) - \mathrm{S} - \mathrm{B}$
- This assumption that interference is small may not hold for some areas of parameter space.

Signal to background interference in $pp \to tH^- \to tW^- b\bar{b}$ at the LHC Run-II

Abdesslam Arhrib[1], Rachid Benbrik[2,3,4], Stefano Moretti[5], Rui Santos[6,7,8] and Pankaj Sharma[9]

Figure: arxiv:1712.05018

- Interference can be of same order as signal, and sometimes negative.
- Interference large when width-mass ratio large.
- We look at $pp \to tbH^{\pm} \to tb\bar{t}\bar{b}$ in this study.

Current Exclusion

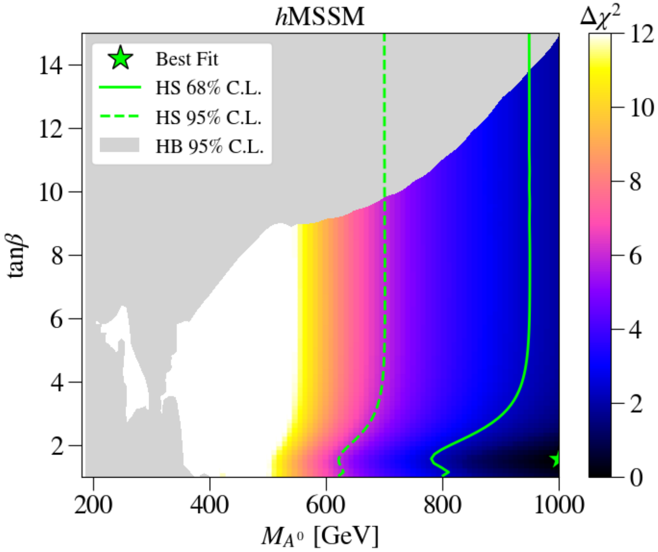


Figure: χ^2 fit sliced in the $\tan\beta$ and M_A plane.

Parameter Space

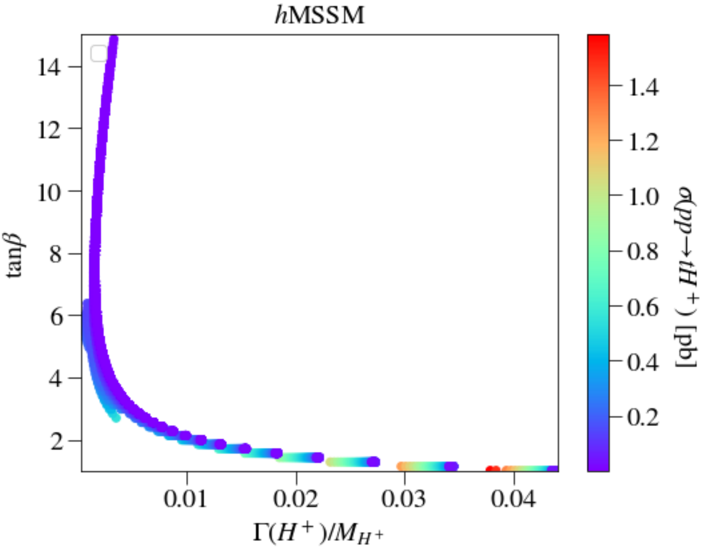


Figure: Cross section as a function of $\tan\beta$ and $H^{\pm}$ width-mass ratio.

Parameter Space

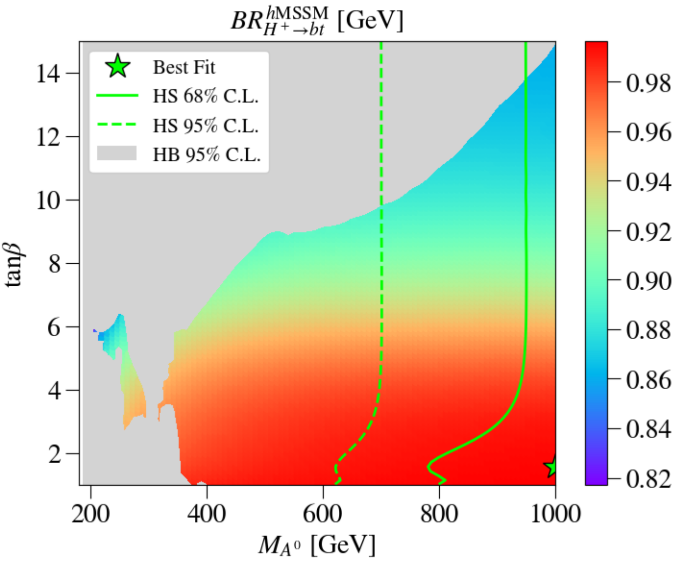


Figure: Br($H^{\pm} \to tb$) as a function of $\tan\beta$ and M_A.

Parameter Space

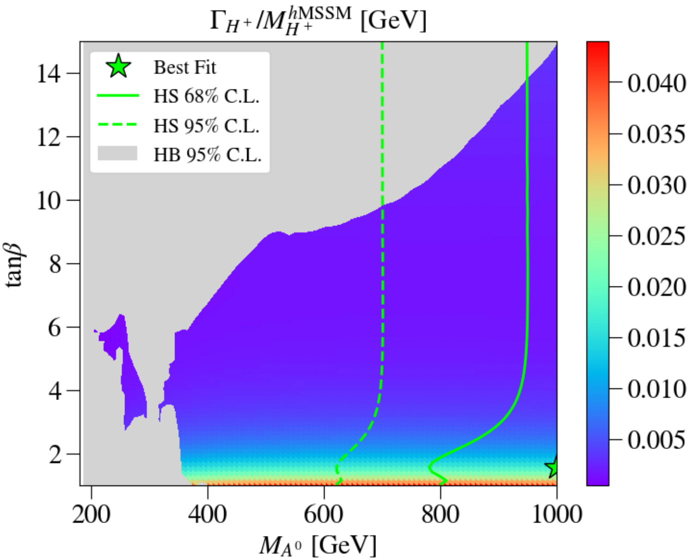


Figure: $H^{\pm}$ mass-width ratio as a function of $\tan\beta$ and M_A.

Process and Key Parameters

- 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: $pp \to tbH^\pm \to tb\bar{t}\bar{b}$

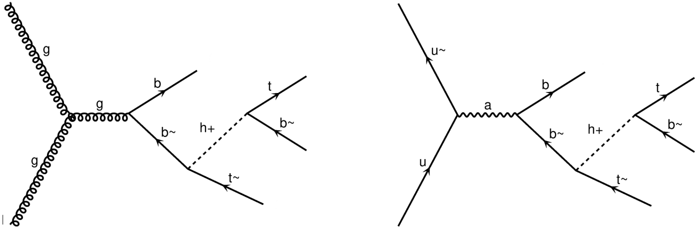


Figure: Examples of Production Diagrams for *tbtb*.

Monte Carlo

- `MadGraph5` used to generate 1,000,000 parton level events.
- `PYTHIA8` used on 500,000 of these events for fragmentation/hadronization.
- `Delphes` used on (the same) 500,000 events for detector effects.

Event Reconstruction

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

$$p_\nu^z = \frac{1}{2p_{\ell T}^2}\left(A_W p_\ell^z \pm E_\ell \sqrt{A_W^2 \pm 4p_{\ell T}^2 E_{\nu T}^2}\right)$$

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

- Reconstruction performed via simultaneous minimization of:

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

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

Event Reconstruction

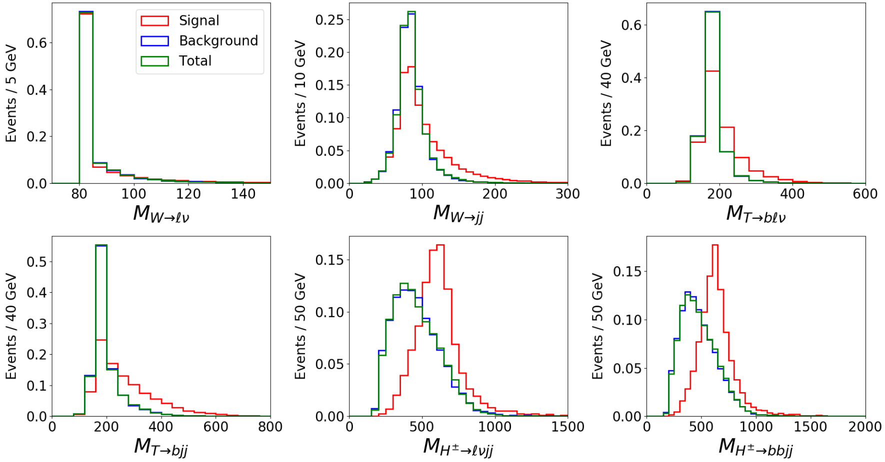


Figure: Invariant Mass distributions for reconstructed particles.

Parton Level Results

- The full 1,000,000 events used to achieve required statistics.

Model		**S**	**B**	**S+B**	**I**
hMSSM	σ	0.032402	13.092	13.143	0.019
	$\Delta\sigma$	1.4×10^{-5}	0.004	0.004	0.008
$\mathbf{m_h^{125}}$	σ	0.088502	13.103	13.20	0.009
	$\Delta\sigma$	3.3×10^{-5}	0.004	0.004	0.008
$\mathbf{m_h^{mod+}}$	σ	0.016802	13.177	13.197	0.003
	$\Delta\sigma$	5.8×10^{-6}	0.004	0.004	0.008

Table: Parton level results for three MSSM benchmarks.

Detector Level 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
$\not{E} + m_T^W > 60$:	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
$\not{E} + m_T^W > 60$:	0.0008	0.1491	0.1502	0.0003

Table: Cut flow results presented in cross sections for the hMSSM benchmark.

Interference Shape

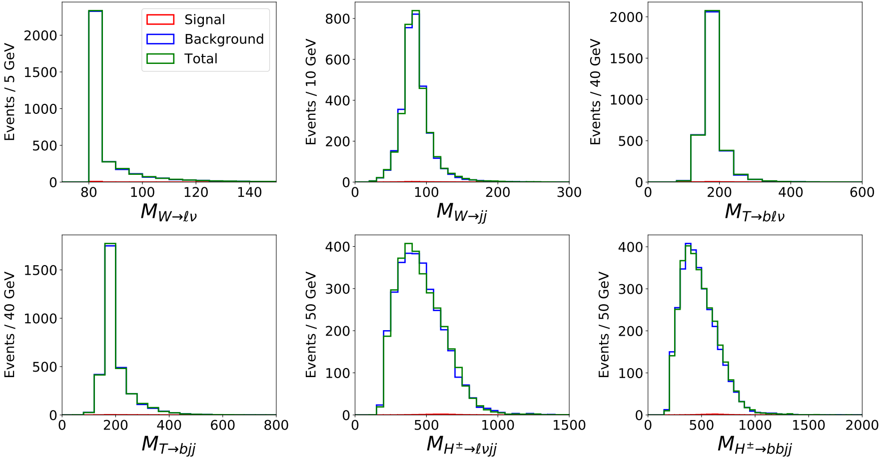


Figure: Invariant Mass distributions for reconstructed particles normalized to cross section.

Interference Shape

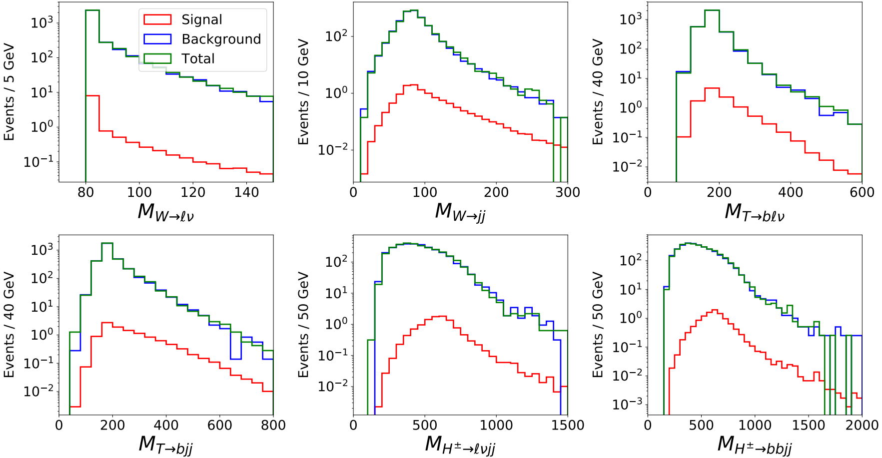


Figure: Invariant Mass distributions for reconstructed particles normalized to cross section with log y-axis.

Interference Shape

- Interference an overall normalization factor? Or are there shape differences?

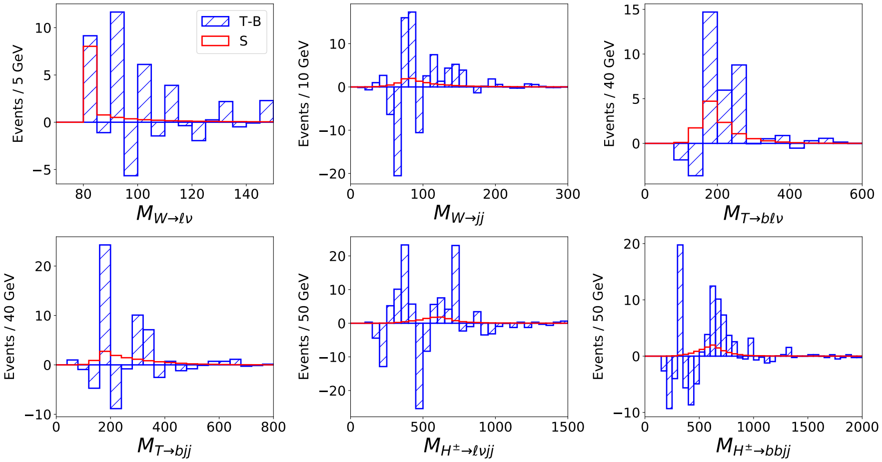


Figure: Signal vs Total - Background.

Summary and Conclusion

- Interference effects non-negligible in some high width-mass ratio scenarios.
- To account for this we must model Signal, Background and Signal+Background seperately.
- hMSSM presents significant interference in reasonable circumstance.
- Parton and Detector level results of inclusive cross section presented.
- Preliminary results on detector level interference shapes presented.
- How does one design a machine learning framework that includes interference effects?
- How does interference effect the machine learning discriminant?

Thank You