Kansas State University
College of Arts & Sciences
Department of Physics

Phenomenology of the Semi-Leptonic Double Higgs Channel

Curtis McLennan, Dr. Andrew Ivanov

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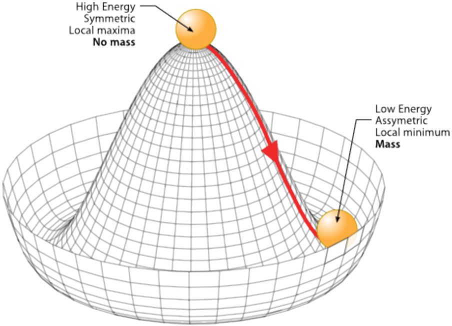
Introduction

Introduction

The Higgs

- Higgs was experimentally discovered in 2012
- Confirmation of Standard Model predictions
- Parameterized Higgs self coupling term in the Higgs potential important to electroweak symmetry breaking, but weakly bound experimentally



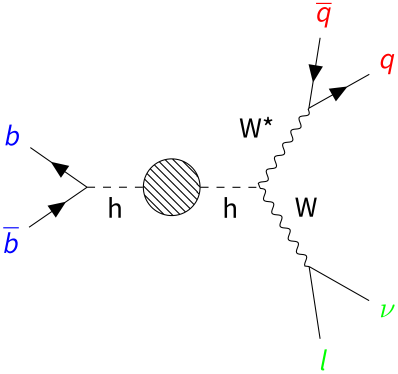
Source

Introduction

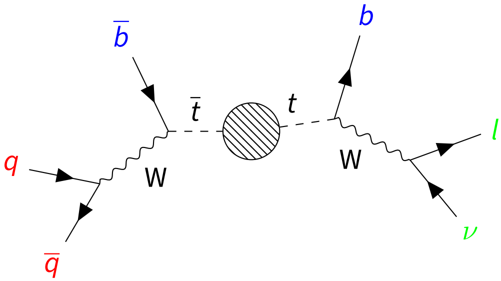
Background Process

Bottom Quarks
Light Quarks
Leptons

- Singular background process 100,000x larger than signal [4]



(a) Double Higgs decay

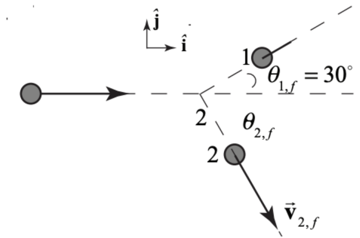


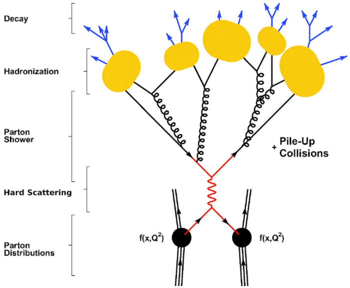
(b) $t\bar{t}$ Decay

Introduction

Separating the sheep from the goats

- How do we differentiate between the signal and the background?
- Kinematic variables!
- Based off work on the di-leptonic channel [3] which is considered much better





Source

Source

Methods

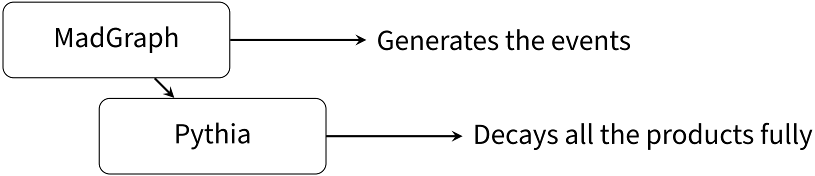
Methods

Procedure

MadGraph → Generates the events

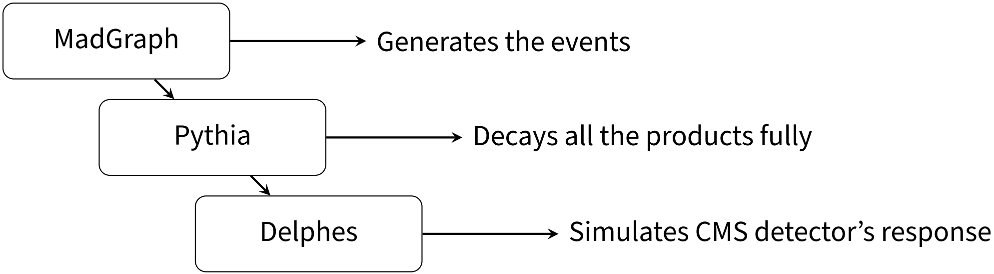
Methods

Procedure



Methods

Procedure



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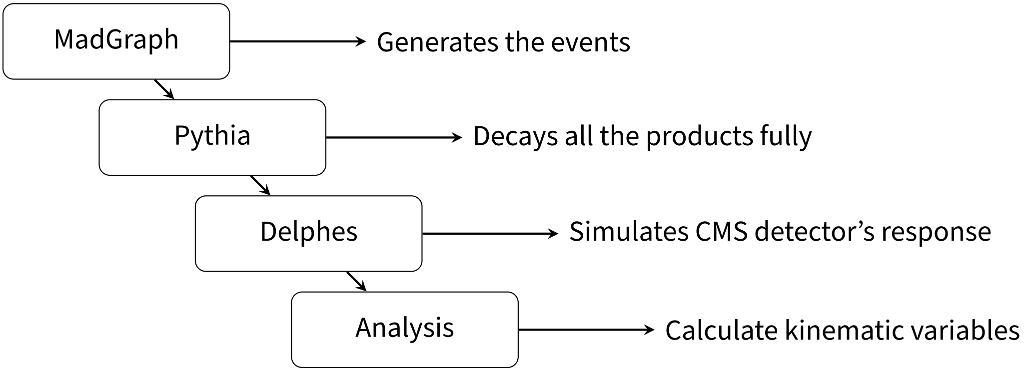

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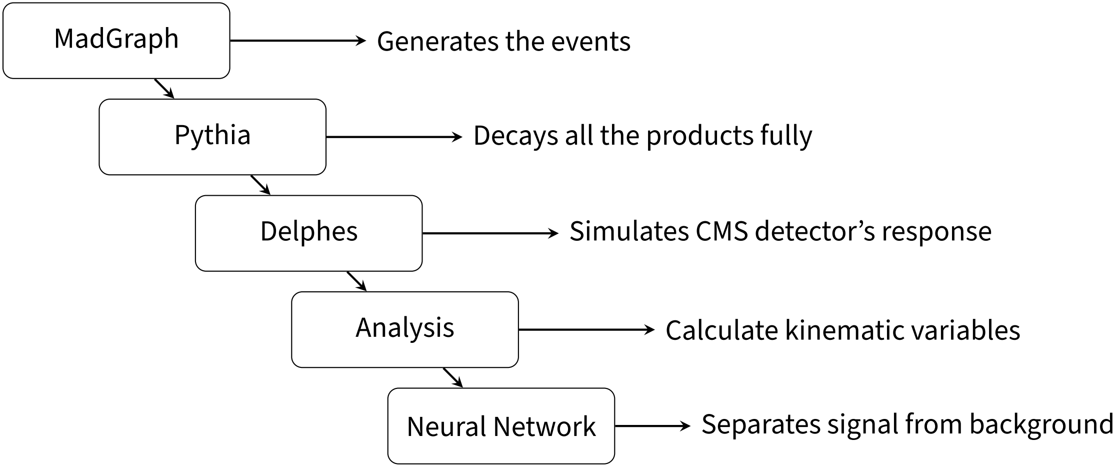


Methods

Significance (How well are they differentiated?)

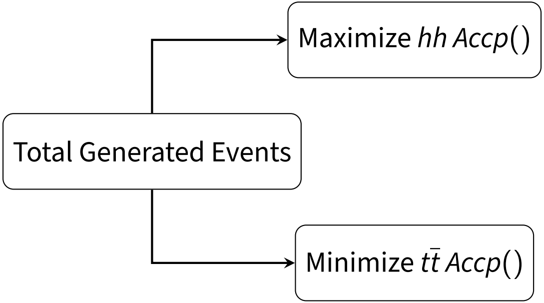
Total Generated Events

$$\text{Significance} = \frac{S_{exp}}{\sqrt{B_{exp}}}$$

$$N_{exp} = Acc() \cdot \underbrace{\sigma \cdot \int L\, dt \cdot BR()}_{\text{Fixed}}$$

Methods

Significance (How well are they differentiated?)



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Methods

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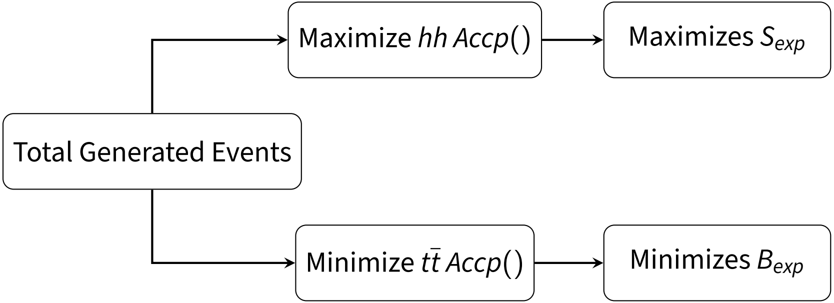

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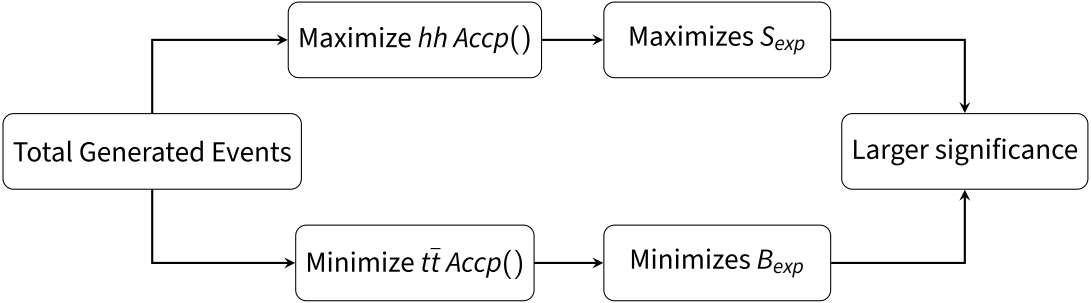


$$\text{Significance} = \frac{S_{exp}}{\sqrt{B_{exp}}} \qquad N_{exp} = Acc() \cdot \underbrace{\sigma \cdot \int L\, dt \cdot BR()}_{\text{Fixed}} \tag{1}$$

Results

Results

New Kinematic Variables

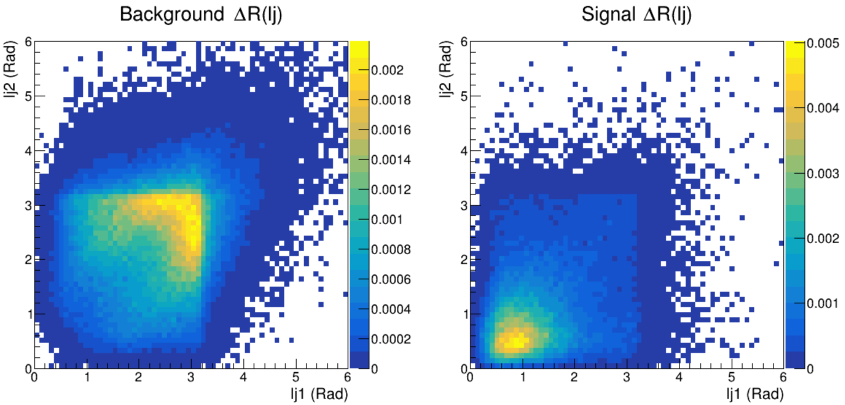


Figure 3: Parton Level ΔR_{lj}: angular separation between the lepton and one of the light jets

Results

New Kinematic Variables

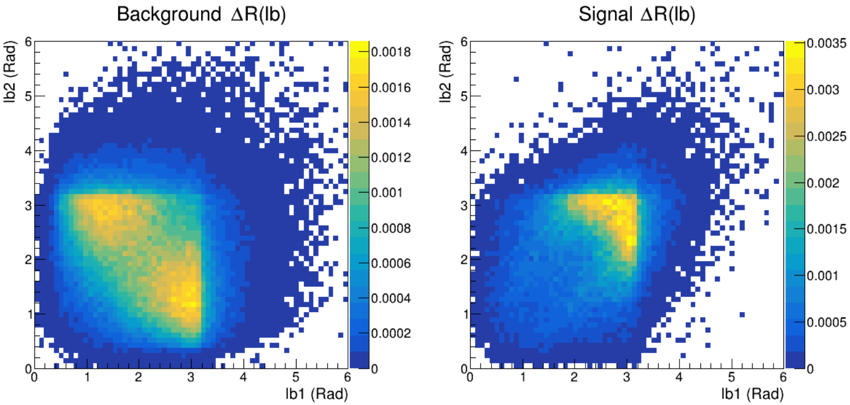


Figure 4: Parton Level ΔR_{lb}: angular separation of the lepton and one of the b-jets

Results

New Kinematic Variables

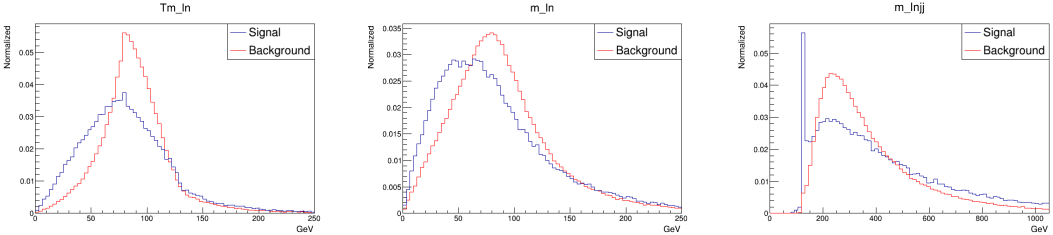


Figure 5: Reconstructed invarient masses based off high level variables Higgsness and Topness

Results

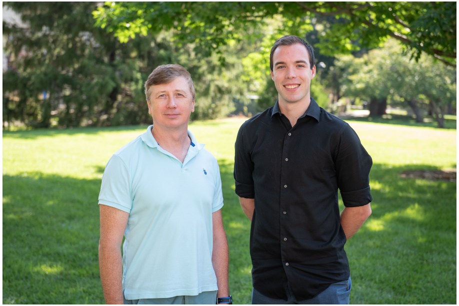
Significance

	N_{sig}	N_{bknd}	σ
Low Level (10) BDT from [2]	134.34	866,990.56	0.13
Low Level (10) NN	73.29	90,111.28	0.24
High Level (14) NN	54.63	31,897.80	0.31
Extra Variables (21) NN	78.87	40,669.67	0.39

Table 1: Comparison of Neural Networks with different inputs. N_{sig} and N_{bknd} calcuated using Eq. (1). We follow [1] and [3] for applying the high level variables to semi-leptonic channel.

Thank You!

Thank you Dr. Ivanov!



NSF Research Experiences For Undergraduates

Thank you NSF for the opportunity!

Thanks to Dr. Jeong Han Kim and collaborators for sharing their code

Low Level Kinematic Variables			
m_{jj}	Invariant mass of jets	m_{bb}	Invariant mass of the b-jets
P_{T_l}	Transverse momentum of lepton	$\not{E}_T$	Missing transverse momentum
ΔR_{jj}	Angular separation between jets	$P_{T,ljj}$	Transverse momentum of ljj
$P_{T,bb}$	Transverse momentum of b-jets	$\Delta\phi_{bb\ ljj}$	Angle between bb and ljj system
ΔR_{bb}	Angle between b-jets	ΔR_{ljj}	Angle between l and ljj system
ΔR_{bb}	Angular separation between b-jets	$\Delta R_{l\ jj}$	Angular separation of l and bb
ΔR_{lj}	Angular separation of l and one j	ΔR_{lb}	Angular separation of l and one b
Mid Level Kinematic Variables			
$m^H_{l\nu}$	Hness reconstructed $l\nu$ system	$m^T_{l\nu}$	Tness reconstructed $l\nu$ system
$m^H_{l\nu jj}$	Hness reconstructed $l\nu jj$ system		
High Level Kinematic Variables			
Tness	Consistent with $t\bar{t}$ production?	Hness	Consistent with hh production?
$\sqrt{\hat{s}^{(ljjbb)}_{min}}$	Minimum COM energy for $lbbjj$	$\sqrt{\hat{s}^{(ljj)}_{min}}$	Minimum COM energy for ljj
Tness_T	Top Hypothesis Tness		

$$\chi_{ij} \equiv \min_{\vec{P}_z^{\nu}} \left[\frac{\left(m_{b_i l\nu}^2 - m_t^2\right)^2}{\sigma_t^4} + \frac{\left(m_{l\nu}^2 - m_W^2\right)^2}{\sigma_W^4} + \frac{\left(m_{b_j qq}^2 - m_t^2\right)^2}{\sigma_t^2} + \frac{\left(m_{qq}^2 - m_W^2\right)^2}{\sigma_W^2} \right]$$

$$T \equiv \min(\chi_{12}^2, \chi_{21}^2)$$

$$H \equiv \min_{\vec{P}_z^{\nu}} \left[\frac{\left(m_{l\nu qq}^2 - m_2\right)^2}{\sigma_{hl}^4} + \min\left(\frac{\left(m_{l+\nu}^2 - m_W^2\right)^2}{\sigma_W^4} + \frac{\left(m_{l-\overline{\nu}} - (m_{W^*}^{peak})^2\right)^2}{\sigma_{W^*}^4}, \right.\right.$$
$$\left.\left. \frac{\left(m_{l-\nu}^2 - m_W^2\right)^2}{\sigma_W^4} + \frac{\left(m_{l+\overline{\nu}} - (m_{W^*}^{peak})^2\right)^2}{\sigma_{W^*}^4} \right) \right]$$

References I

- Higgsness and Topness plots for non-resonant *HH* production in the single lepton *bbWW* decay channel.
  Technical report, CERN, Geneva, Oct 2019.
  All figures including auxiliary figures are available at https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2019-040.
- A. Adhikary, S. Banerjee, R. K. Barman, B. Bhattacherjee, and S. Niyogi.
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  Journal of High Energy Physics, 2018(7), jul 2018.

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Higgs boson pair production at the lhc in the bb w+w- channel.
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