The search for Di-Higgs production in bbWW

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Overview

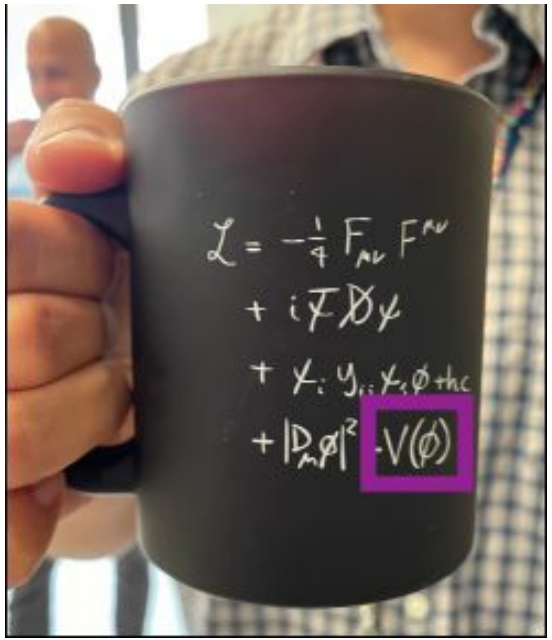
- Theory and experimental overview
- Event structure
- Event extraction
- Results

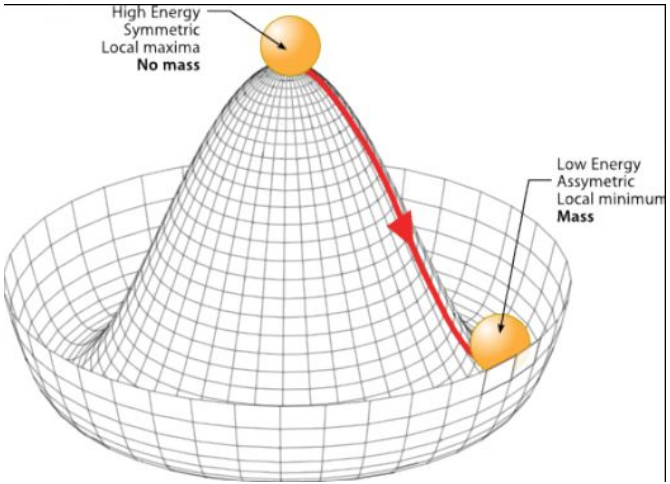
Theory - Intro

Electroweak spontaneous symmetry breaking

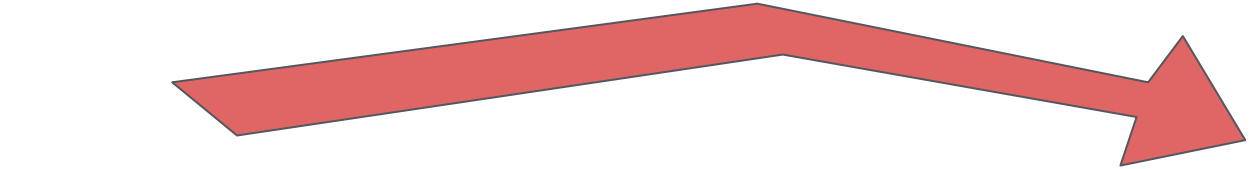
$$\phi_0(x) \rightarrow v + h(x)$$

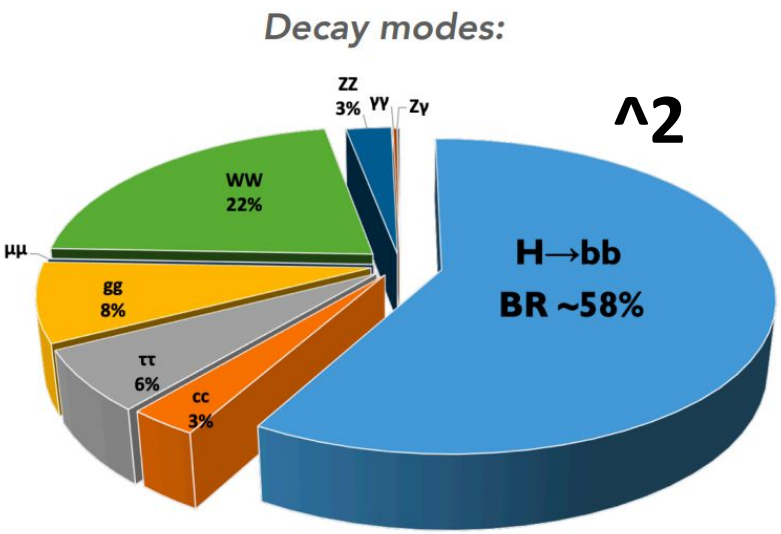
$$V_{SM}(h) = \ldots + \lambda v h^3 + \frac{\lambda}{4} h^4$$

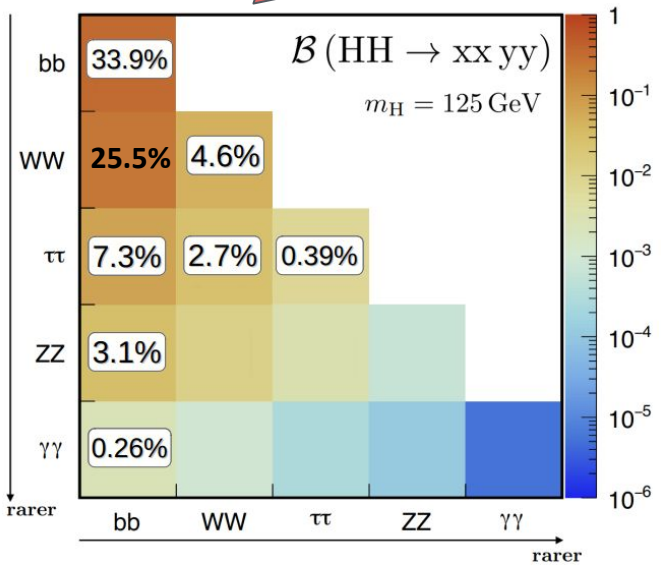




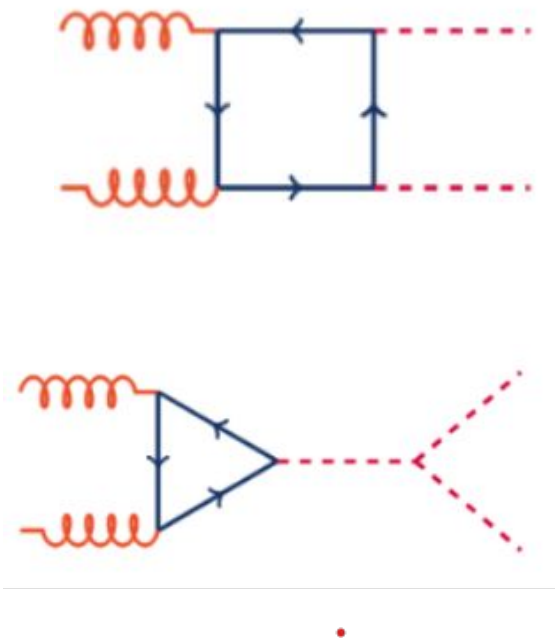
Theory - branching ratio

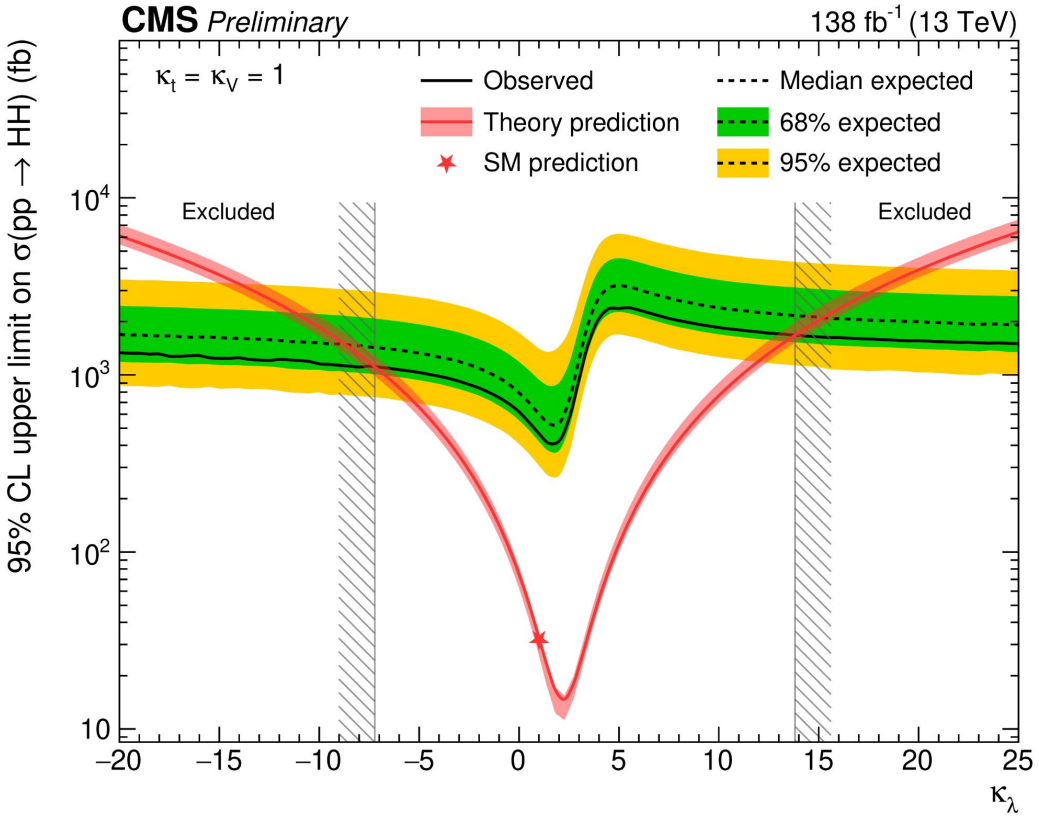




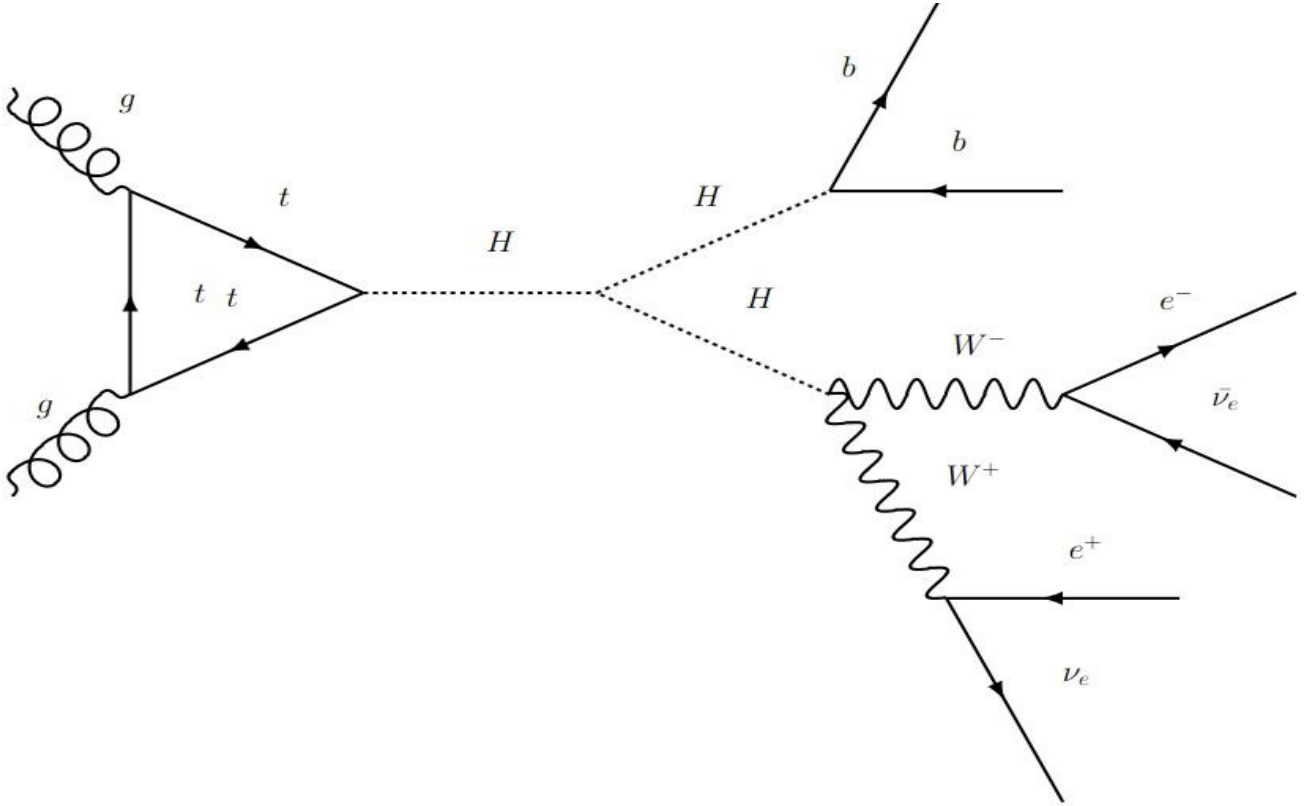


Experimental - Goal



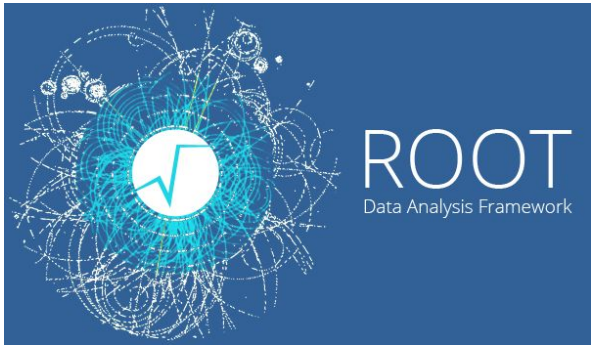


Signal topology



Methods

- **ROOT data analysis framework**
  - TLorentz Vector
  - Four vector
  - 3 space like and 1 time like component
  - 3 momentum and Energy or Mass
    - <Pt, Eta, Phi, E>
    - <Pt, Eta, Phi, M>
  - Lorentz invariant under dot product with each other
- **Invariant Mass:**



$$m = \frac{1}{c^2}\sqrt{E^2 - p^2c^2}$$

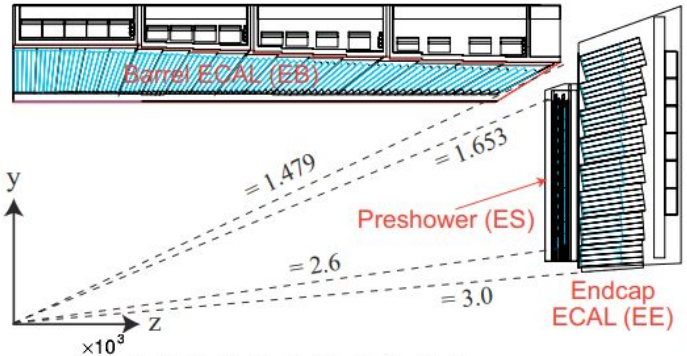
$$\sqrt{P \cdot P} = \sqrt{E^2 - p^2c^2} = mc^2$$

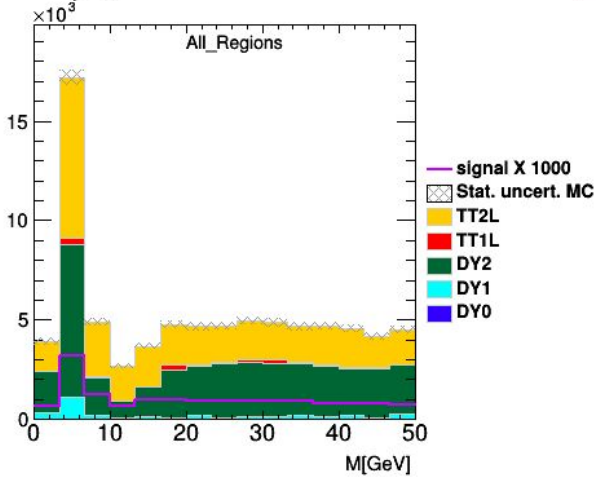
Event Selection(DiLeptonChannel)

Good Lepton Selection

Observable	Electron	Muon
p_T	> 15 GeV	> 15 GeV
$\|\eta\|$	< 2.5	< 2.4
Identification WP[1]	loose	medium
PF relative isolation (Particle Flow)	Included in ID	≤ 0.15 (at ΔR = 0.4)

1:The identification of electrons (muons) is developed by the EGamma (Muon) POG and follows an MVA based (cut-based) strategy for the electrons (muons). The respective WPs for electrons (muons) are also defined by the EGamma (Muon) POG.





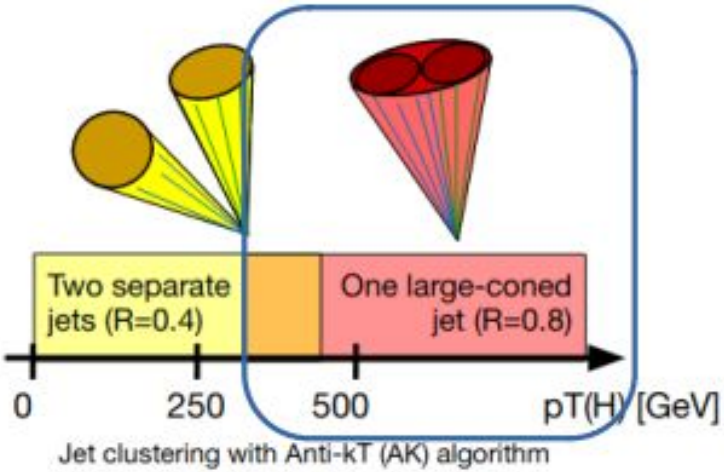
Event Requirement

- Event need to have exactly one good lepton pairs(two electrons, two muons, or one electron and one muon). The “leading” (higher p_T) lepton is required to satisfy the condition $p_T > 25$ GeV and the “sub-leading” (lower p_T) lepton the condition $p_T > 15$ GeV. The two leptons are required to be of opposite charge.

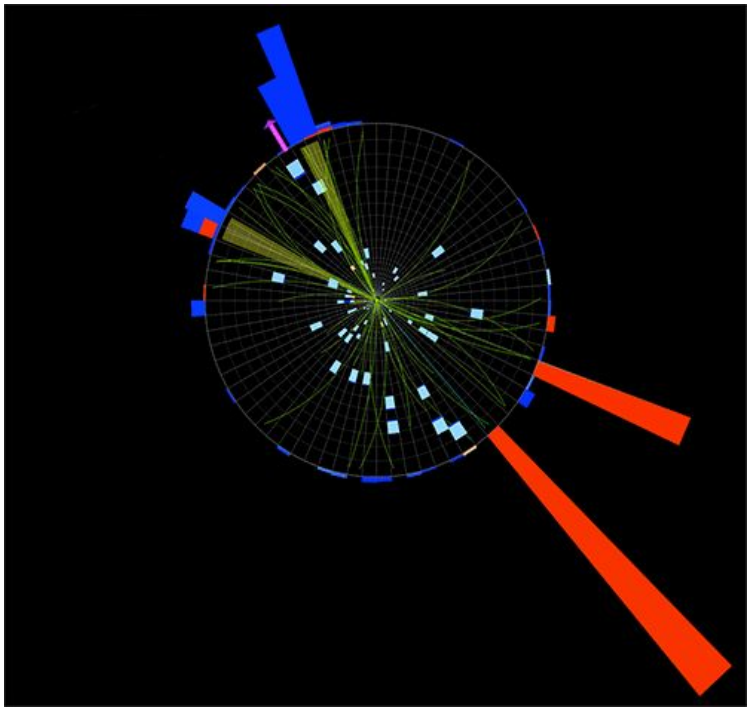
Leading Lepton	Subleading Lepton
$p_T > 25$ GeV	$p_T > 15$ GeV
$\sum q_\ell = 0$	

Event Selection(DiLeptonChannel)

Cleaning



Jet clustering with Anti-kT (AK) algorithm



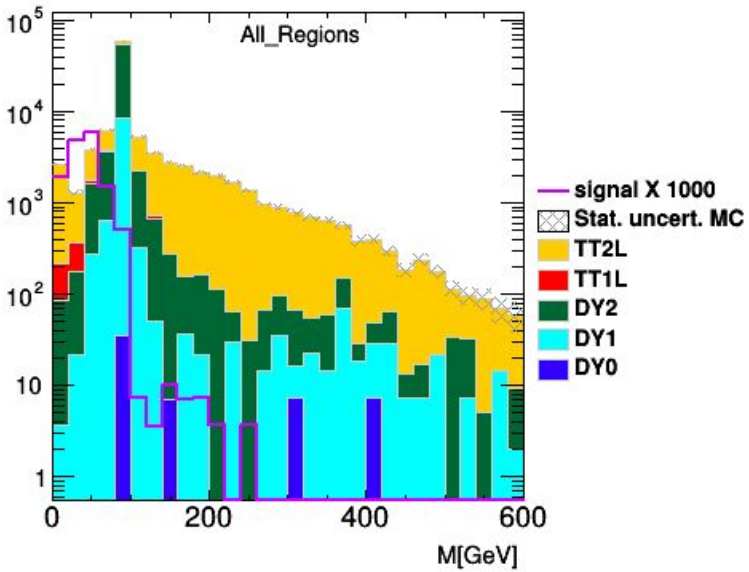
Event Selection(DiLepton Channel)

Event Requirement

Must contain\Must Pass	p_T	$\|\eta\|$	Other condition (working point)
≥AK8-Jet	> 200 GeV	< 2.4	Medium WP
≥AK4-Jet	> 25 Gev	< 2.4	Medium WP of the Deep Jet b-tagging algorithm

Event Selection(DiLeptonChannel)

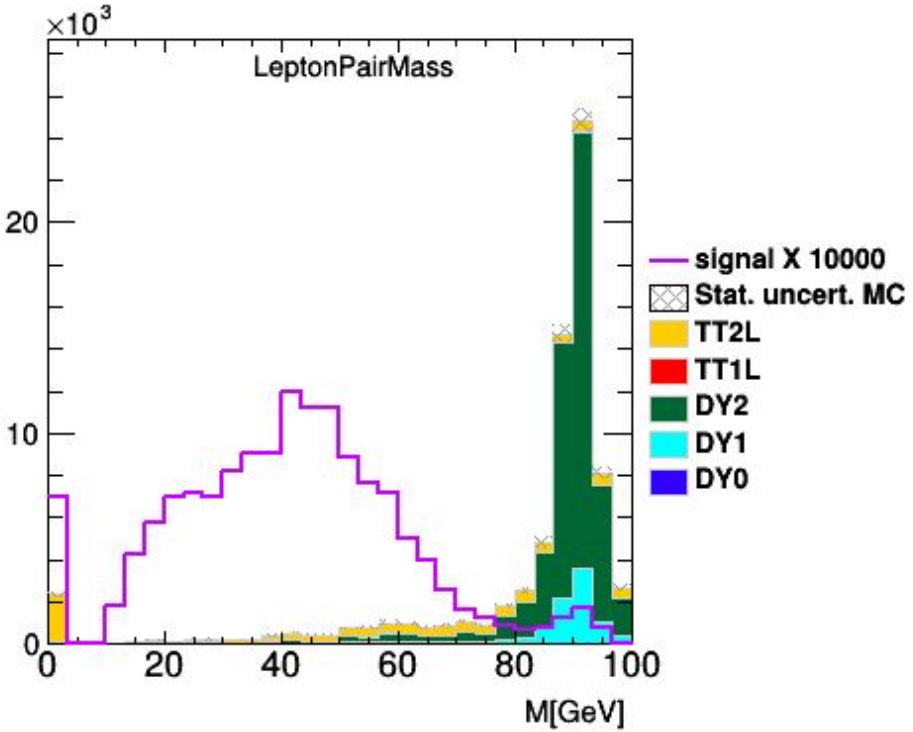
Event Requirement



Lepton Pair(unclean)	Cleaning	Lepton Pair
Rejected if Same favor & ($m\ell\ell$ < 12 GeV)	Electrons cleaned with respect to muons	**Rejected if** Same favor & ($\lvert m\ell\ell - mZ \rvert$ > 10 GeV)

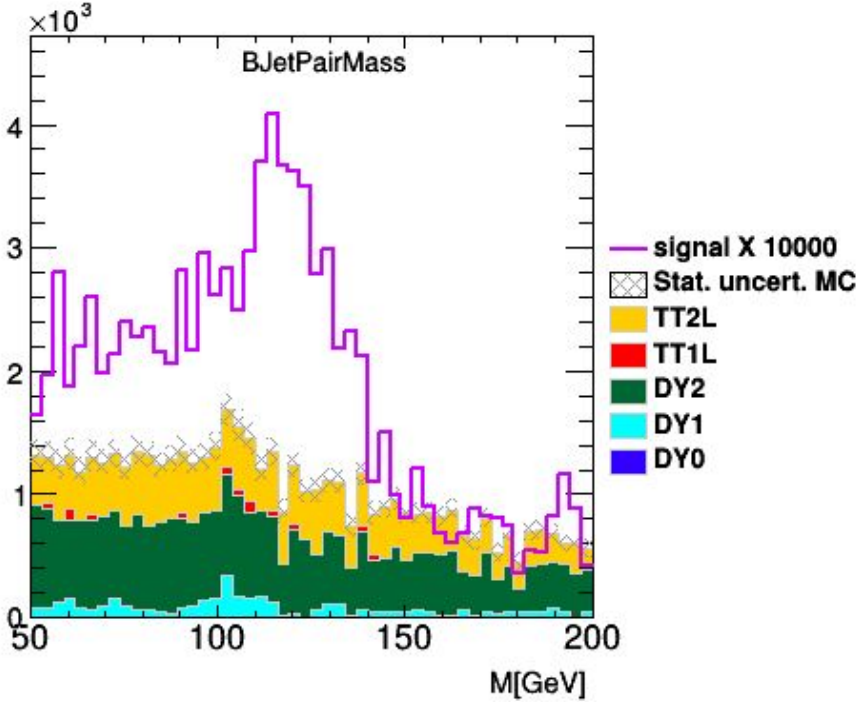
Interesting kinematics

- **Signal Main Peak: ~50GeV**
- **Signal Sub Peak: ~90GeV**
- **Background Peak at ~90Gev: Z boson**
- **~30GeV offset**
  - **Limited energy**
  - **W mass wide spectrum**
  - **Neutrinos**



Interesting kinematics

- **Peak around Higgs Mass (~125GeV)**
- **SM cross sections are small but large enhancements can occur with BSM-sized couplings (** If trilinear Higgs self coupling is larger than the standard model prediction**)**



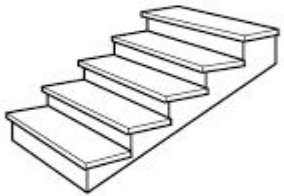
Future work

- Complete reproduction of public result
- Optimize Selection
  - Catagorize selection for different processes, background and control region.
- Improve bJet resolution
- Use differential way to give arbitrary weight of kappa lambda(higgs self-coupling strength) and produce different signal weights
- Conduct statistical analysis
  - HH inference tool
    - https://gitlab.cern.ch/hh/tools/inference
  - Asimov significance

Some Funny Code

```
std::vector<std::pair<TLorentzVector, TLorentzVector>> LeptonPairs;
```

```
lepPairPt = (LeptonPairs[pairs].first + LeptonPairs[pairs].second).Pt();
```



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https://physics.aps.org/articles/v11/91

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