HH→bbττ

And use of MVA

Carl Gwilliam

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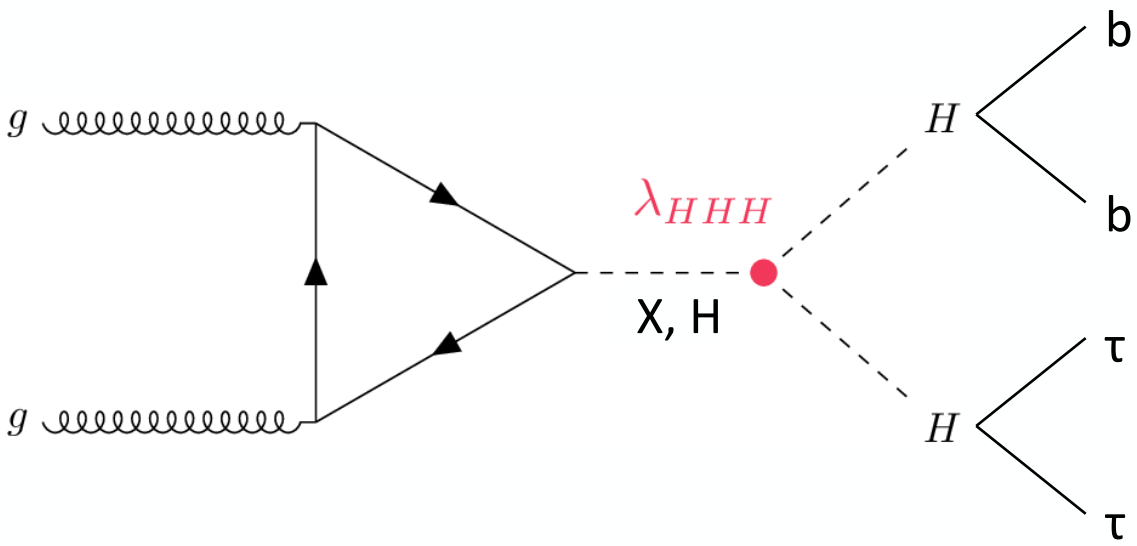
From Graph NN to Explainable AI

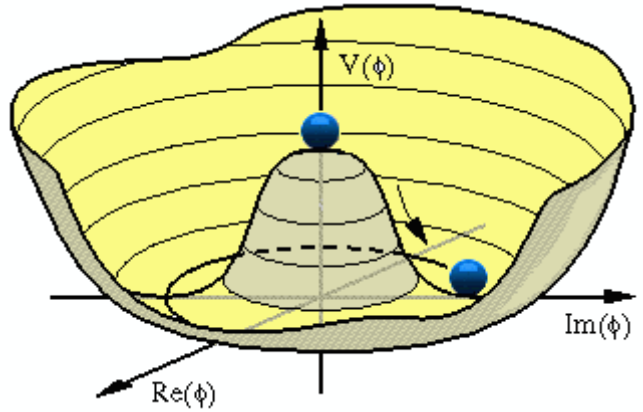
ATLAS EXPERIMENT

UNIVERSITY OF LIVERPOOL

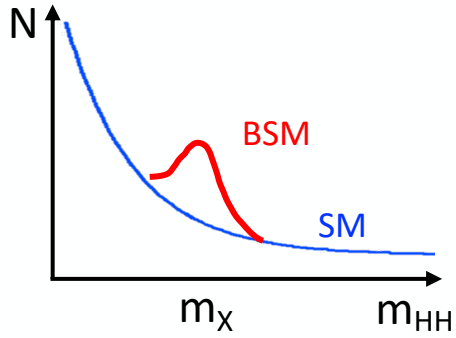
Introduction

- Search for non-resonant Higgs-pair (HH) production to measure Higgs self-coupling (λ_{HHH})
  - In addition, search for Beyond-the-SM (BSM) resonant di-Higgs production giving a peak in the HH mass





Higgs Potential

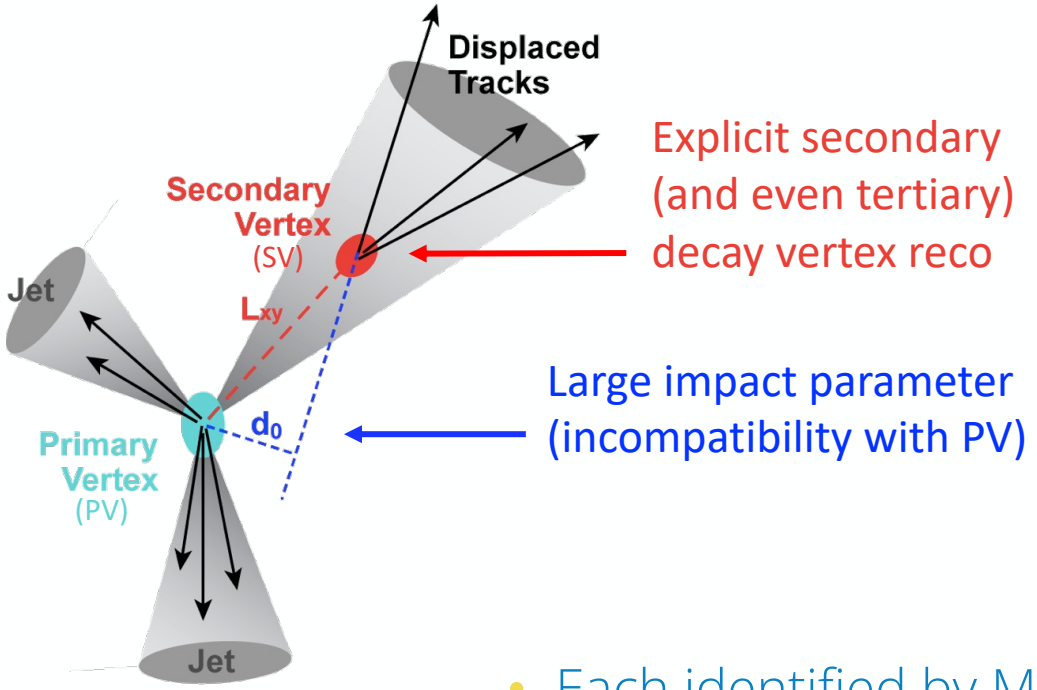


Resonant

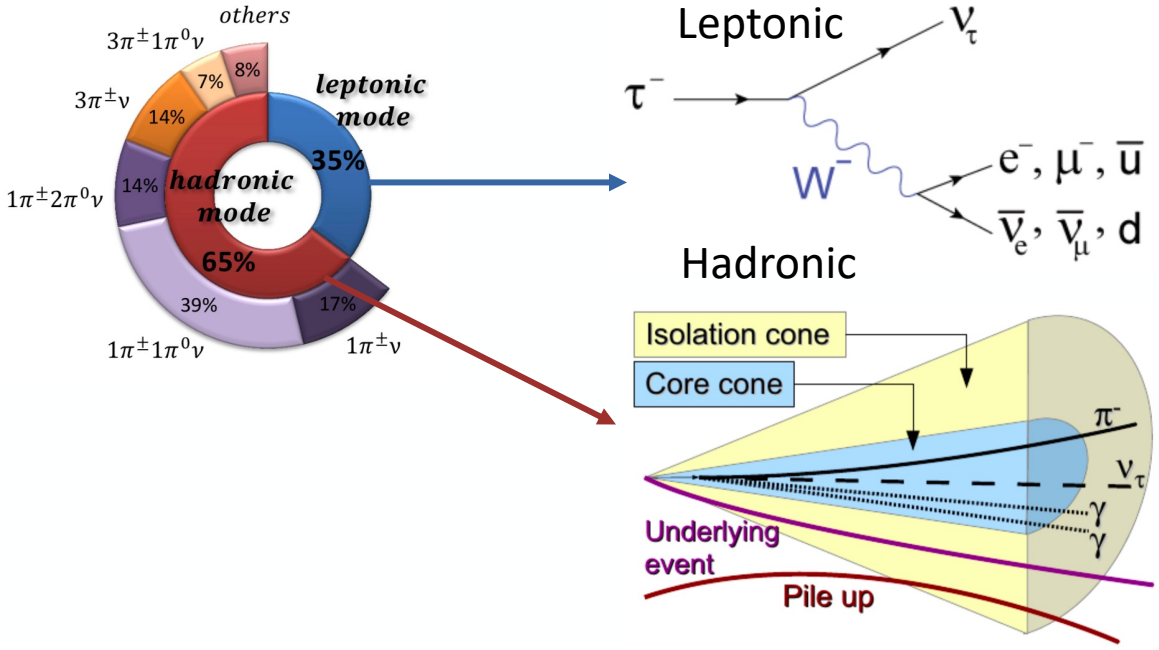
- Complex final state consisting of two b-quarks, two τ-leptons and missing transverse energy (MET)
  - Two separate channels depending on decay of taus: both hadronic or one leptonic + one hadronic

Signature: compnents

- B-quarks
  - Clusters of E in calorimeter (jets)
  - Tracks with displace vertex due to lifetime



- τ-leptons
  - Leptonic (1 track) or hadronic (1 or 3 tracks)
  - Narrow E deposit in calorimeter

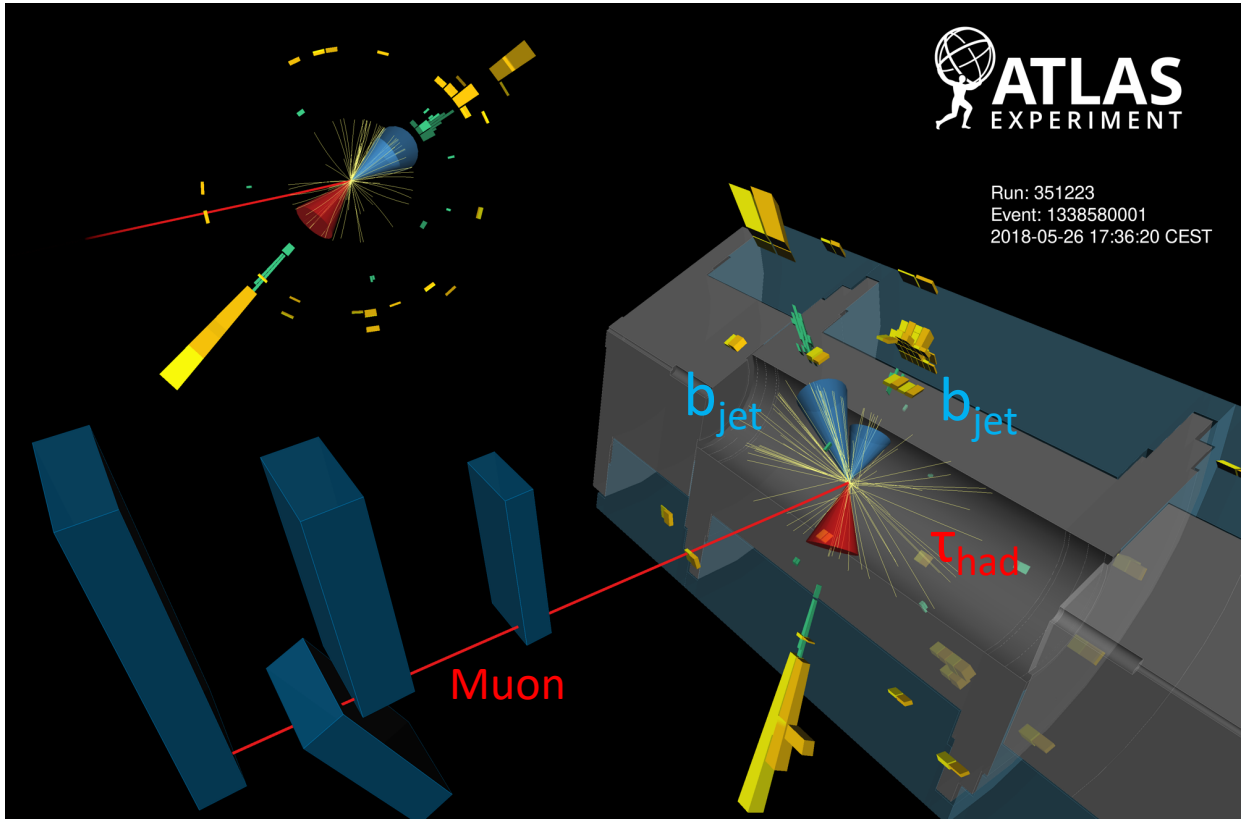


- Each identified by MVA algorithms: RNN, GNN

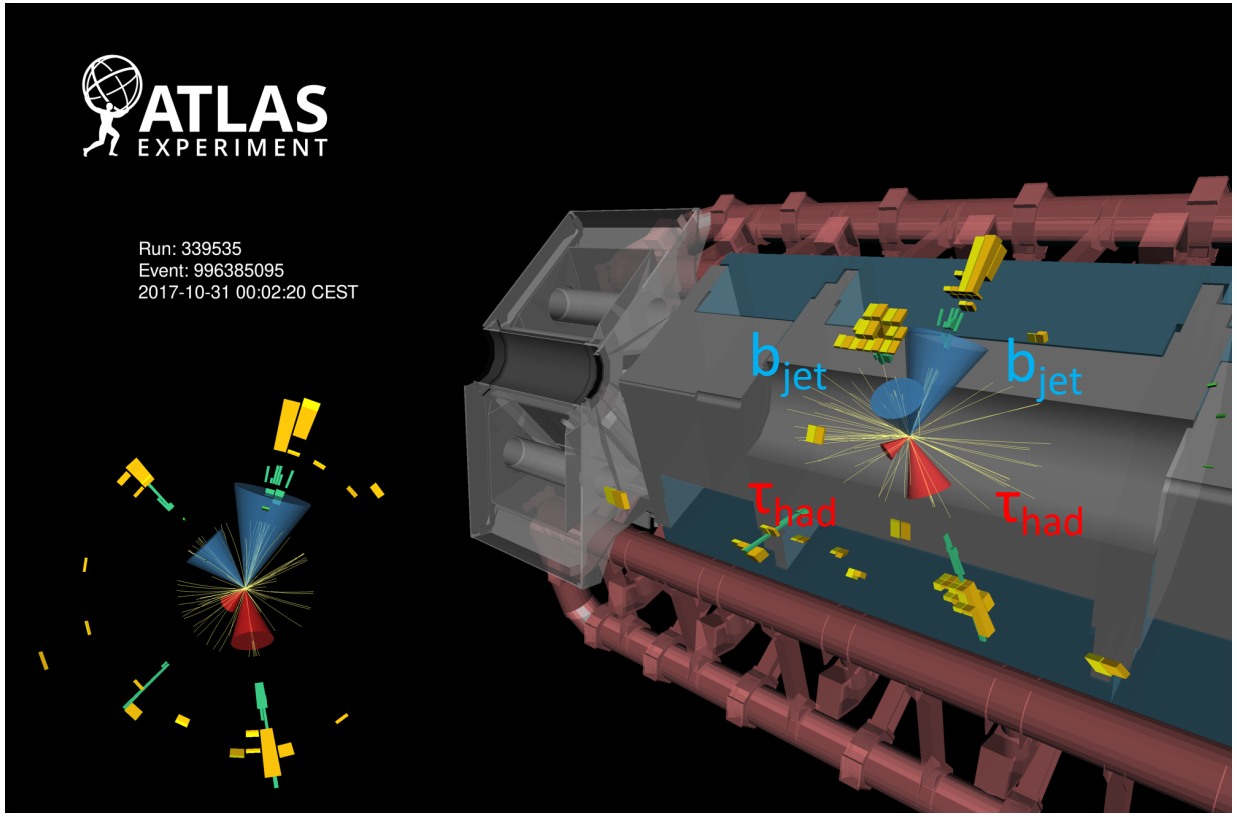
- Missing transverse energy (MET):
  - Imbalance in energy in transverse plane due to neutrinos from τ- (and b-) decays

Signature: putting it together

- Example LepHad event



- Example HadHad event



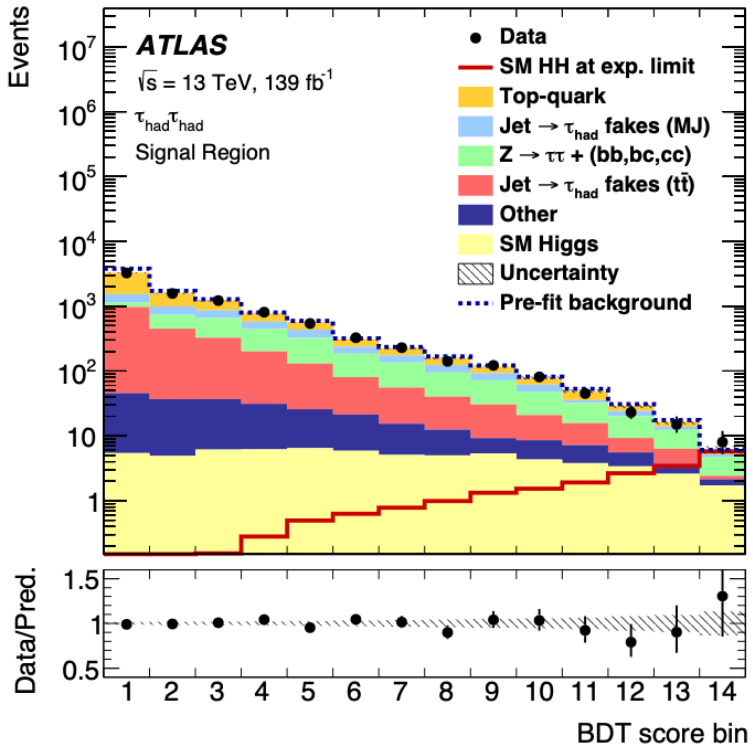
- Yellow lines are tracks while green (yellow) boxes are EM (hadronic) calorimeter energy clusters

Previous approach

- Construct $m_{\tau\tau}$ using system of unconstrained equations using Missing Mass Calculator
  - https://arxiv.org/abs/1012.4686

- BDT or DNN classifier (parametrised in terms of mass for the resonance case)
  - Based on high-level variables: kinematics, angular separations, invariant masses

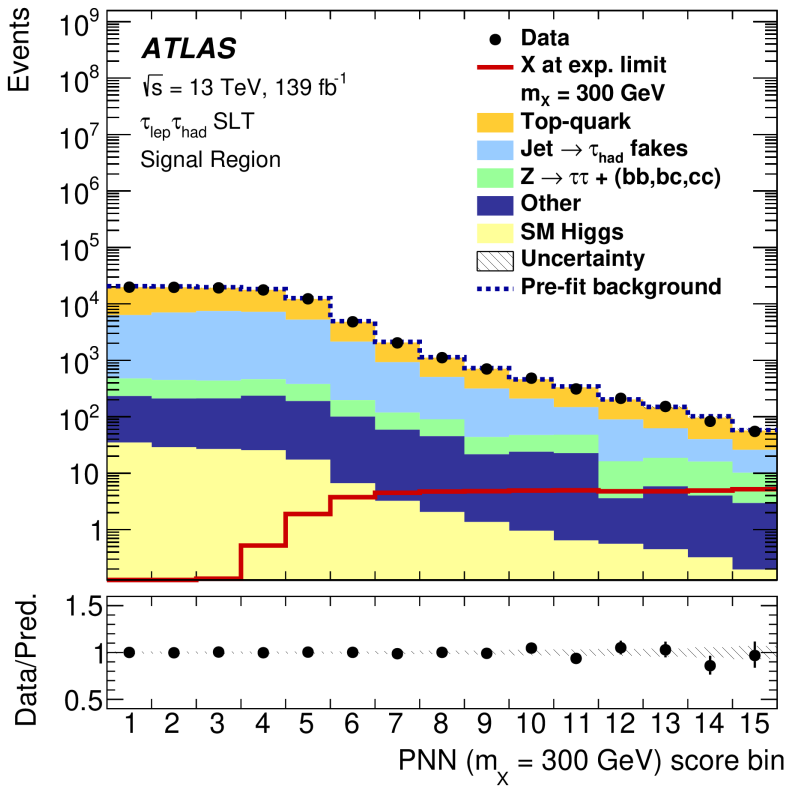
HadHad



Inputs

Variable	$\tau_{\text{had}}\tau_{\text{had}}$	$\tau_{\text{lep}}\tau_{\text{had}}$ SLT
m_{HH}	✓	✓
$m_{\tau\tau}^{\text{MMC}}$	✓	✓
m_{bb}	✓	✓
$\Delta R(\tau,\tau)$	✓	✓
$\Delta R(b,b)$	✓	✓
$\Delta p_{\text{T}}(\ell,\tau)$		✓
Sub-leading b-tagged jet p_{T}		✓
m_{T}^{W}		✓
$E_{\text{T}}^{\text{miss}}$		✓
$\mathbf{p}_{\text{T}}^{\text{miss}}$ ϕ centrality		✓
$\Delta\phi(\ell\tau, bb)$		✓

LepHad



- Significant level of background from a range of processes

Questions

- Is this signal-background discrimination suited for a GNN approach?
  - How would we approach that?
- Would we gain by using low-level variables directly (or a mix of low- and high-level)?
  - Rather than e.g. reconstructing b-jets and τ-leptons first and using those
  - How best to present those to the MVA?
- Additionally, can we use an MVA regression for the $m_{\tau\tau}$ mass reconstruction?
  - Which type is best suited for this?