Feasibility Study of Measuring the Higgs Self-coupling Using the Muon Collider

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Jun 16th, 2022

Reconstruction of hadronically decaying di-τ

- For highly boosted Higgs to $\tau^+\tau^-$ pairs, we reconstruct two anti-k_t jet with cone size $R = 0.2$, and requiring the following criteria:
  - charge product Q of the two leading di-τ jets = -1;
  - ΣTauTag = 2 for the tau-tagged jets pair;
  - In order to avoid selecting b jet fake tau, require Σ Btag = 0;

- Then for reconstructing the $b\bar{b}$ jets pair, we require:
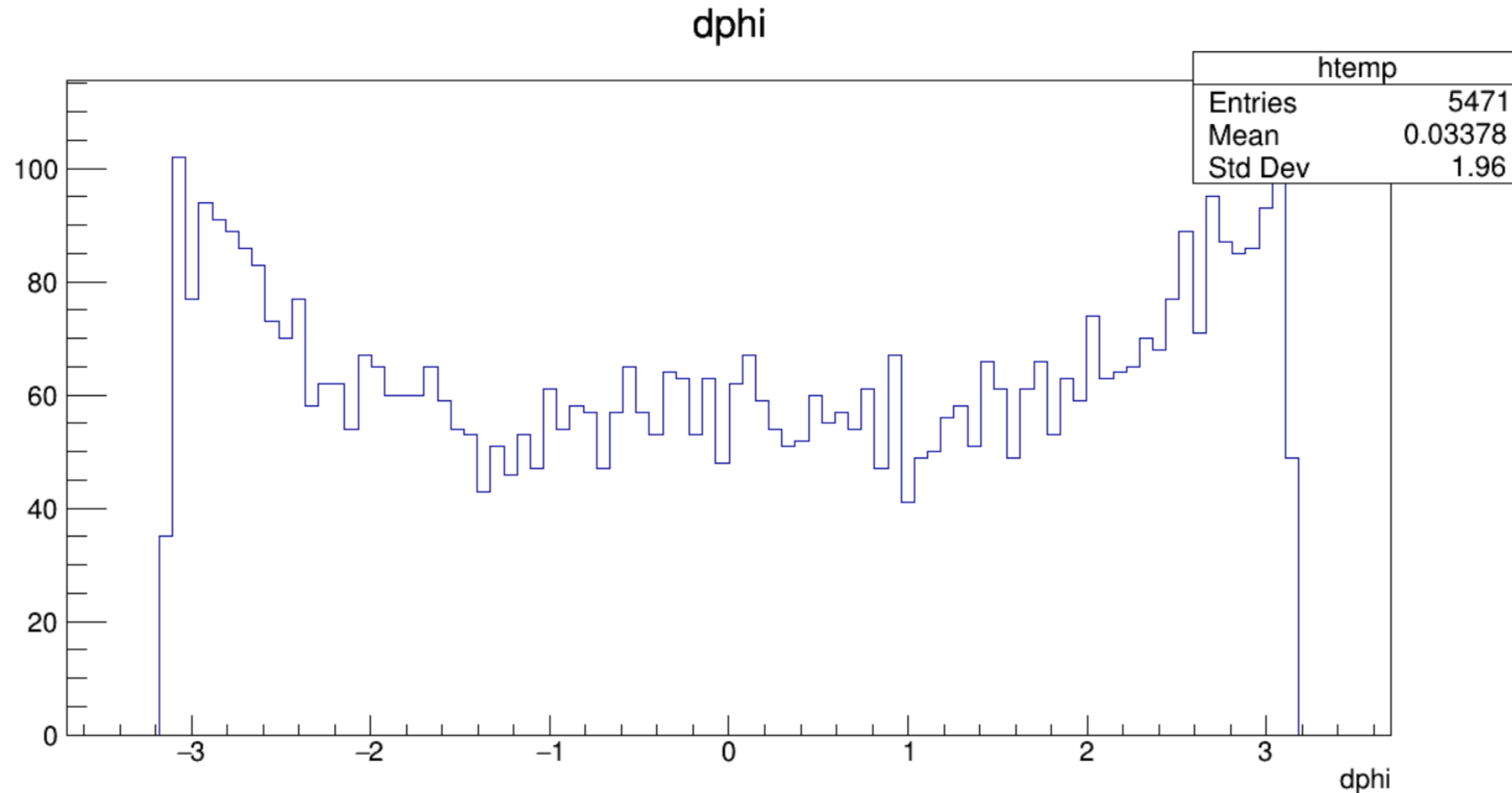 - ΣBTag =2 for the $b\bar{b}$ jets pair;
  - Require ΣTauTag =0;

DeltaR between Higgs1 and MET
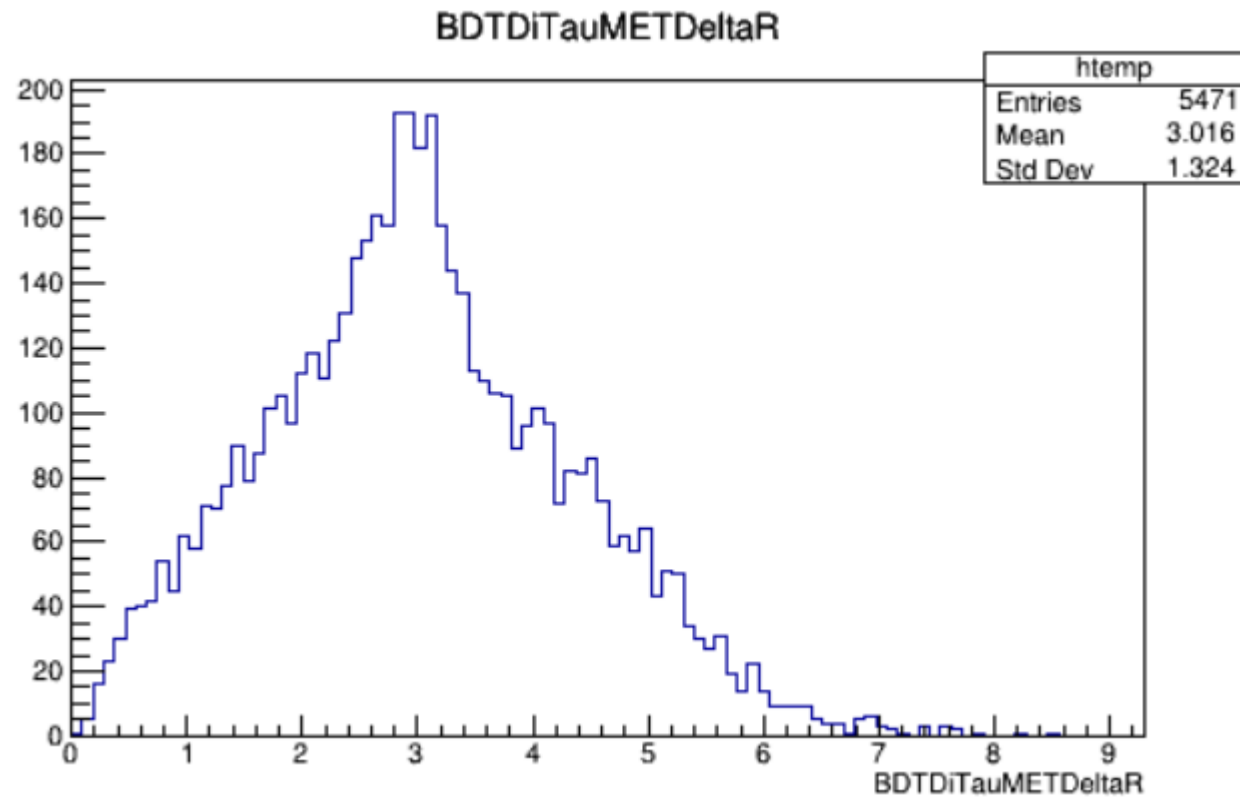
DeltaPhi between Higgs1 and MET

Reconstruct di-tau mass by collinear method (showed in paper)

- Assume MissingET component in the direction of the di-tau system are entirely contribute by the neutrinos in di-tau decay. Thus, the neutrino momentum is given by

$$\vec{p}_T^{\nu\nu} = (\vec{E}_T^{\text{miss}} \cdot \hat{p}_T^{h_{vis}}) \, \hat{p}_T^{h_{vis}}.$$

- The fraction of the tau momentum carried by the visible tau decay products, $x_{\tau_{vis}}$, is then

$$x_{\tau_{vis}} = \frac{|\vec{p}_T^{h_{vis}}|}{|\vec{p}_T^{h_{vis}}| + |\vec{p}_T^{\nu\nu}|}.$$

- Since $M_H \gg m_\tau^2, m_l^2$

$$M_H = M_{collinear} = \frac{M_{vis}}{\sqrt{x_{\tau_{vis}}}}.$$

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- Then we could simply make it a four momentum p_T^{invis} with mass 0.

- Then the collinear mass is the magnitude of the TLorentzVector of

  - jet1+jet2+ p_T^{invis}.

Result of selection w/o collinear

	vvHH	vvZH	vvqqH
Has three R02 jet and three R05 jet	37197	38615	49819
Two tau with opposite charge	12535	1141	979
Has two B jet	6342	206	143
Two b two tau (expect 21.3%)	5471 14.7%	166	111

Result of selection w/ collinear (add four momentum)

	vvHH	vvZH	vvqqH
Has three R02 jet and three R05 jet	37197	38615	49819
Two tau with opposite charge	9033	894	768
Has two B jet	4427	150	103
Two b two tau (expect 21.3%)	3925 (10.6%)	126	181

Result of selection w/ collinear (fraction)

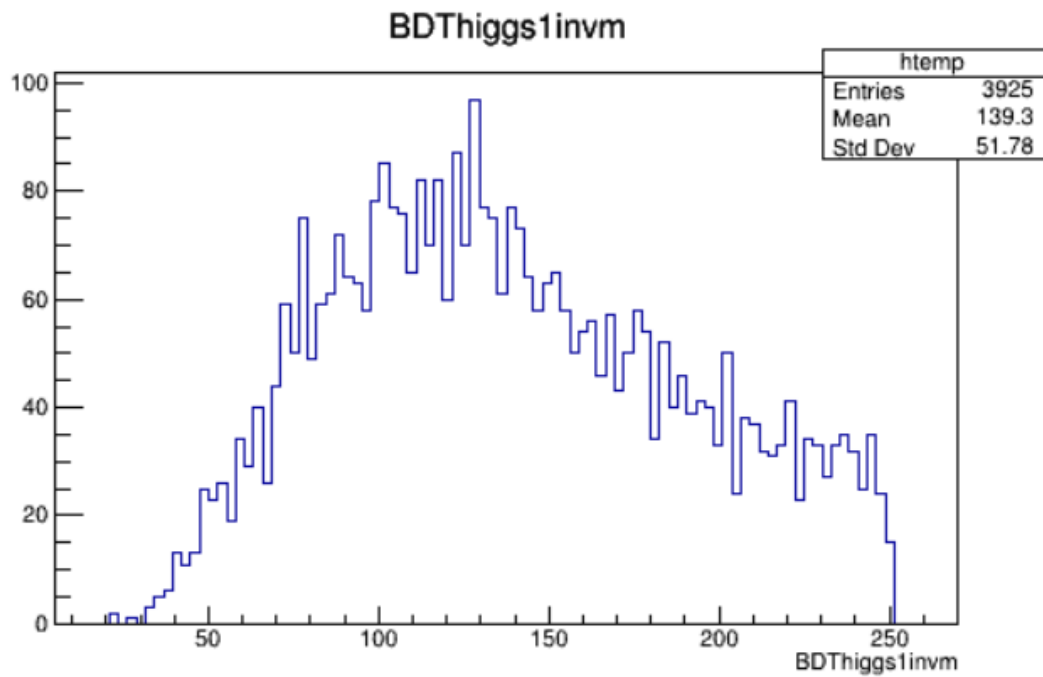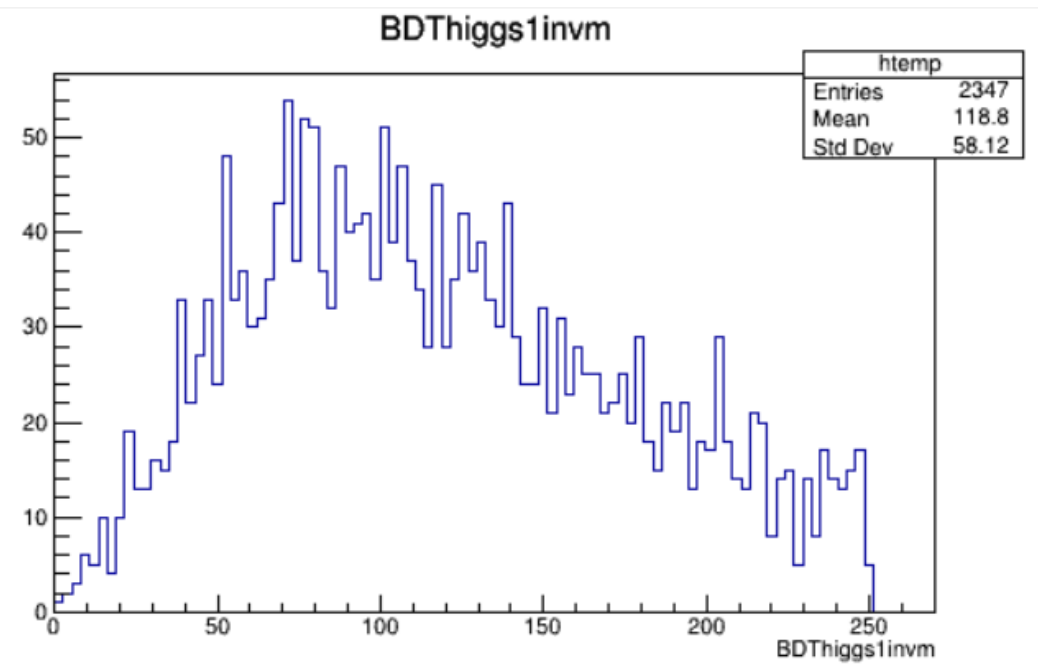|	vvHH	vvZH	vvqqH
Has three R02 jet and three R05 jet	37197	38615	49819
Two tau with opposite charge	5865	460	393
Has two B jet	2914	77	59
Two b two tau (expect 21.3%)	2621 (7.0%)	70	49

Result of vvHH w/0 collinear
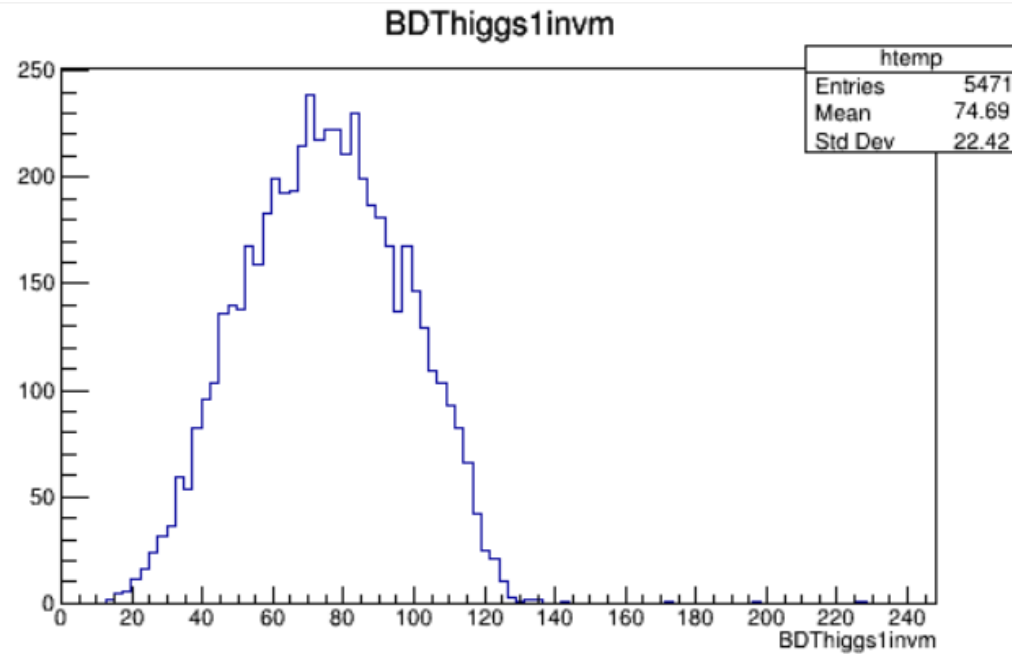
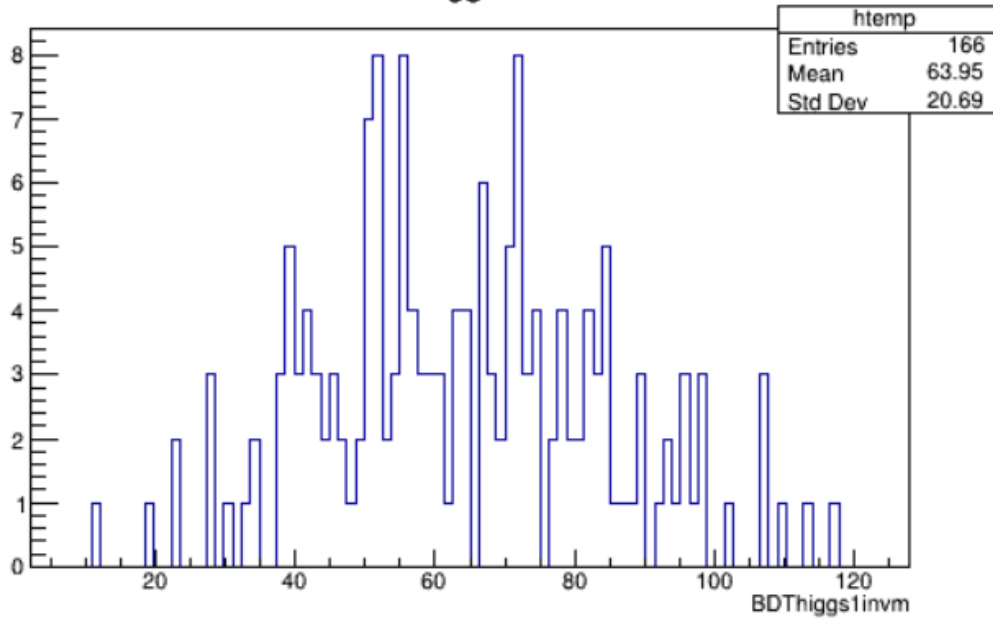# Result of vvHH w/ collinear

Add four momentum

Fraction

Where to access my code and result

- Pairing algorithm for both hadronic decay:
https://github.com/cvuosalo/MuonCollider/blob/main/Delphes/src/Pairing_tau_had.C

- Script for event generation:
  - https://github.com/cvuosalo/MuonCollider/blob/main/runMGjobs/runMG_job/delphes_card_MuonColliderDet_HHstudy.tcl
  - Other sub-script are in:
  https://github.com/cvuosalo/MuonCollider/tree/main/runMGjobs/runMG_job/MuonCollider

- Result are accessible at:
  - root -l
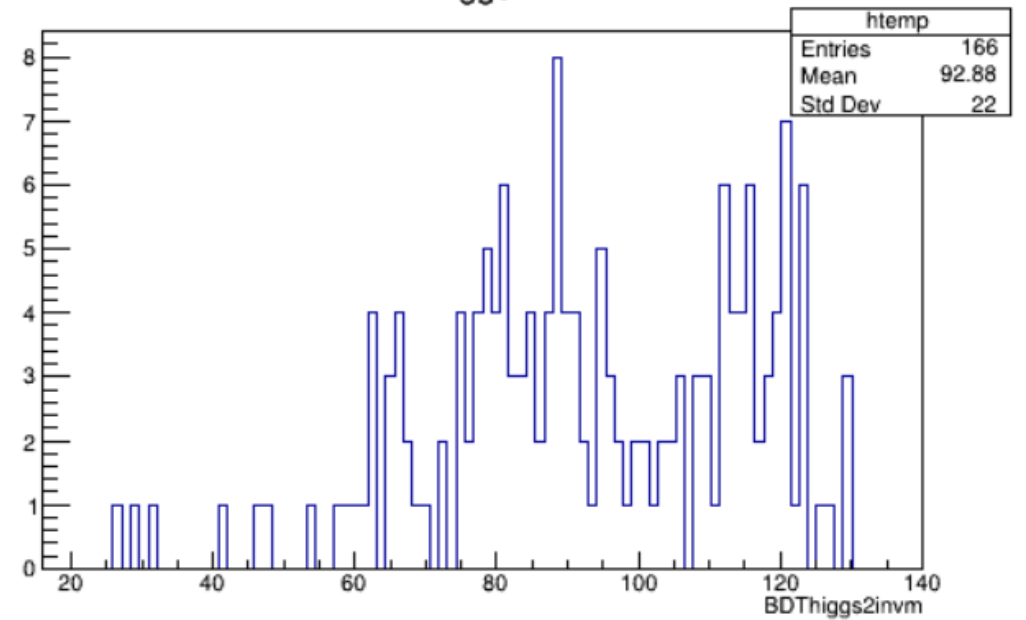 /afs/hep.wisc.edu/home/hjia38/Delphes/delphes_dhiggs_sig+bkg_pairmass_tau_had_10TeV.root

Result of vvZH

Result of vvqqH