Search for compressed mass Higgsino production at the CMS experiment in events with a reconstructed lepton and an isolated track

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Where is SUSY?

- Absence of SUSY signals - SUSY particles have very large mass?
- Many searches that yield the most stringent limits on the masses of the SUSY particles are based on events with large MET and energetic final-state objects such as leptons and jets.
- Maybe SUSY particles are in a part of the parameter space that is not easily accessible?

Why Compressed Higgsinos?

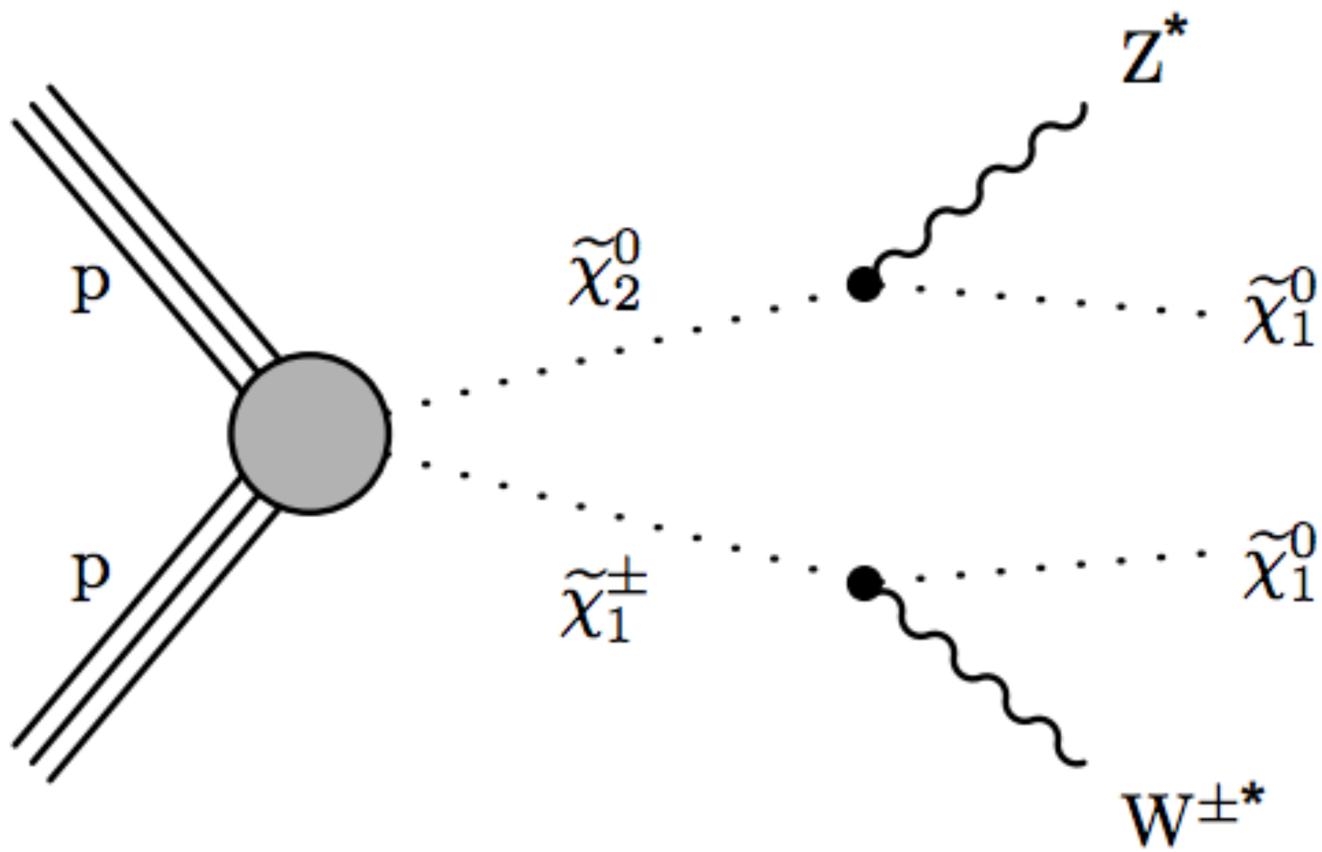
- One scenario, where previously mentioned searches would not be sensitive, is where the mass spectrum is compressed, i.e. the mass splitting between the produced SUSY particles and the LSP is small.

- Almost degenerate bino-higgsino neutralinos with masses in the range between 100 and 300 GeV are acceptable dark matter candidates if the relative mass splittings are less than about 10% – 20%, depending on the specific case (degenerate in mass at the level of 10–20 GeV or less).

arxiv:1004.4902

Decay of an Electroweakino Pair

- Typical Process:

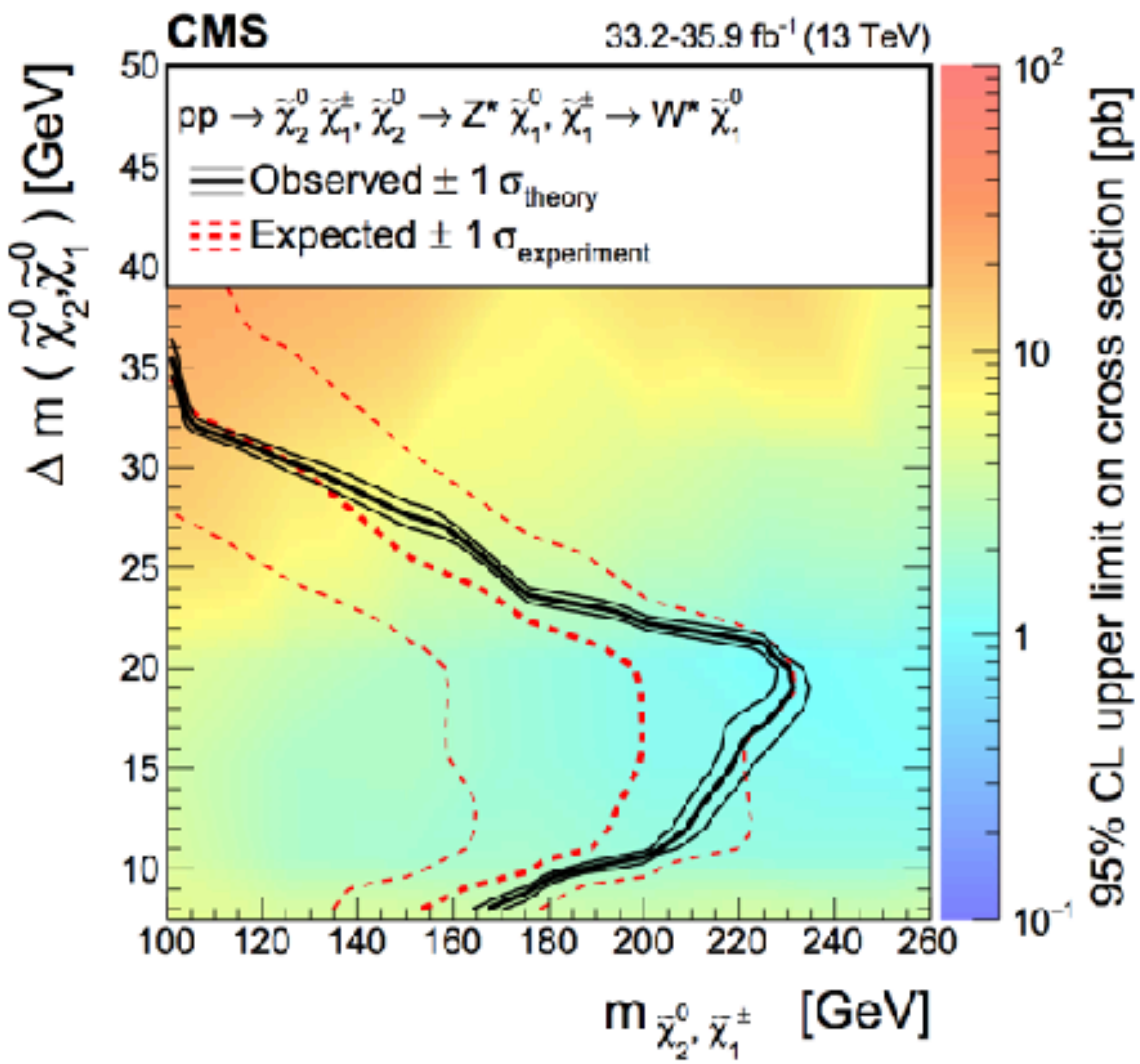


General Features

- Signatures that include moderate missing transverse momentum.
- Most momentum/energy is carried away by Neturolinos.
- Very soft leptons (2 same-flavour leptons from Z*, W decays hadronically).
- Monojets (ISR) usually boost sensitivity.

Previous Work

- Previous analysis on this process has been done by **arXiv: 1801.01846** at CMS using two reconstructed leptons.



arXiv:1801.01846

Figure 5: The observed 95% CL exclusion contours (black curves) assuming the NLO+NLL cross sections, with the variations corresponding to the uncertainty in the cross section for electroweakino. The dashed (red) curves present the 95% CL expected limits with the band covering 68% of the limits in the absence of signal. Results are based on a simplified model of $\tilde{\chi}_2^0\tilde{\chi}_1^\pm \to Z^*W^*\tilde{\chi}_1^0\tilde{\chi}_1^0$ process with a pure wino production cross section.

Can we go lower?

- Previous work is based on traditional event selection rectangular cuts. Cuts has been “eyeballed”.
- MVA techniques hopefully will boost the sensitivity.
- We hope to be able to probe lower mass splitting using track information when leptons are too soft to reconstruct.

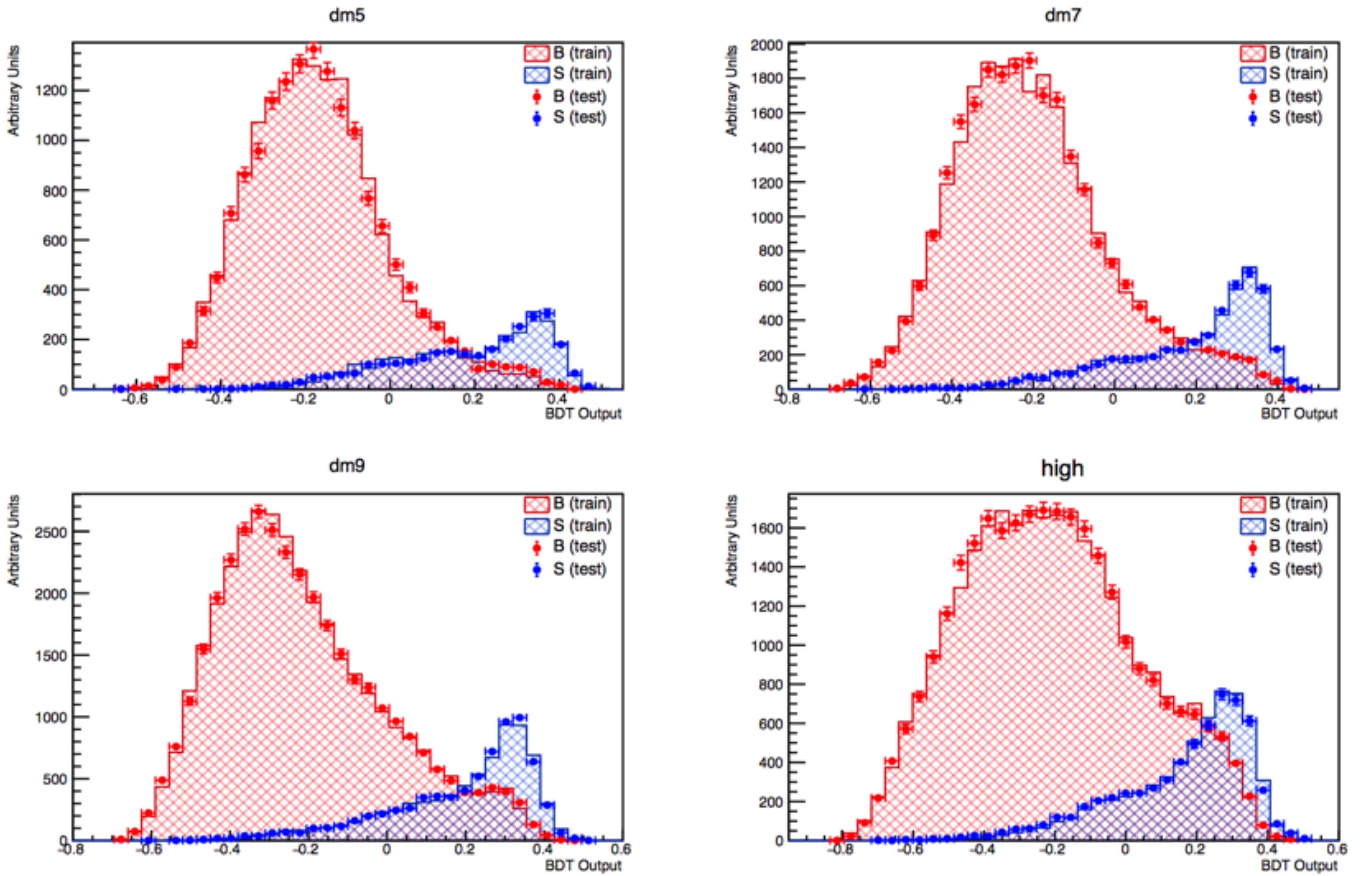
Strategy

- For events with one reconstructed lepton try to match an opposite charged track (using a BDT).
- Once a pair has been matched - theoretically can follow the path of the usual dilepton previous searches.
- Here we use MVA techniques to try and gain some more sensitivity.
- Hopefully we will see a bump (shoulder) on top of a smoothly falling background (similar to the Higgs to photons search).
- If tracks were correctly matched to the partner lepton - an edge should be seen at the mass difference of the neutrolinos.

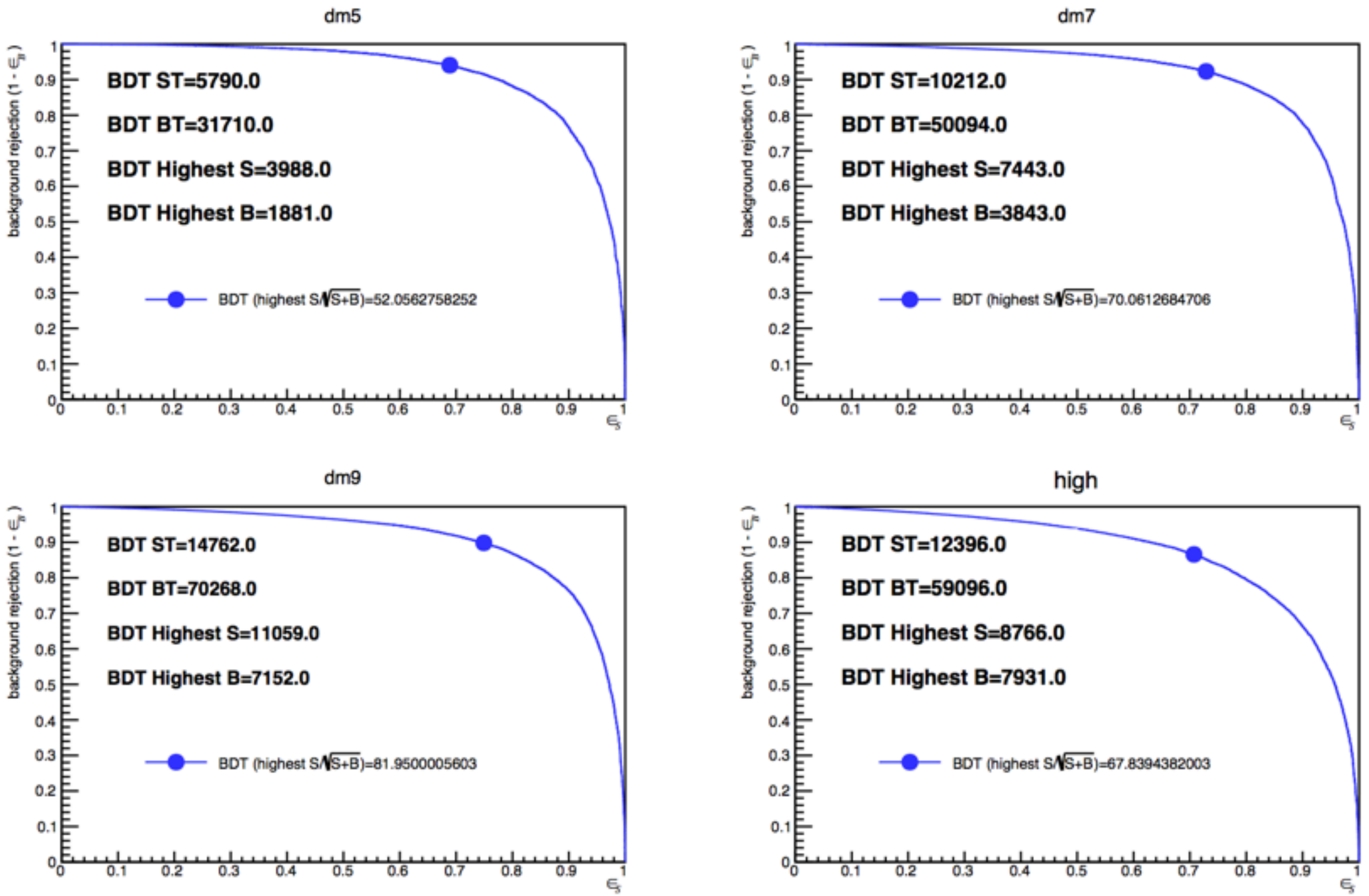
Matching a track
"Track BDT"

- The goal is to train a BDT that will successfully identify non-reconstructed leptons which are the decay product of the Z*.
- The signals are split into "Z tracks" and non-Z tracks, which we call the "Background". This training uses only the signal points and no SM background events.
- Model-points are grouped in similar mass splittings for extra statistics in order to avoid overtraining.
- Observable: Track's Eta, Phi, Pt, dxyVtx, dzVtx (impact parameters), delta eta track-lepton, delta eta track-leading jet, delta R track-lepton, delta R track-leading jet.

Track BDT Output



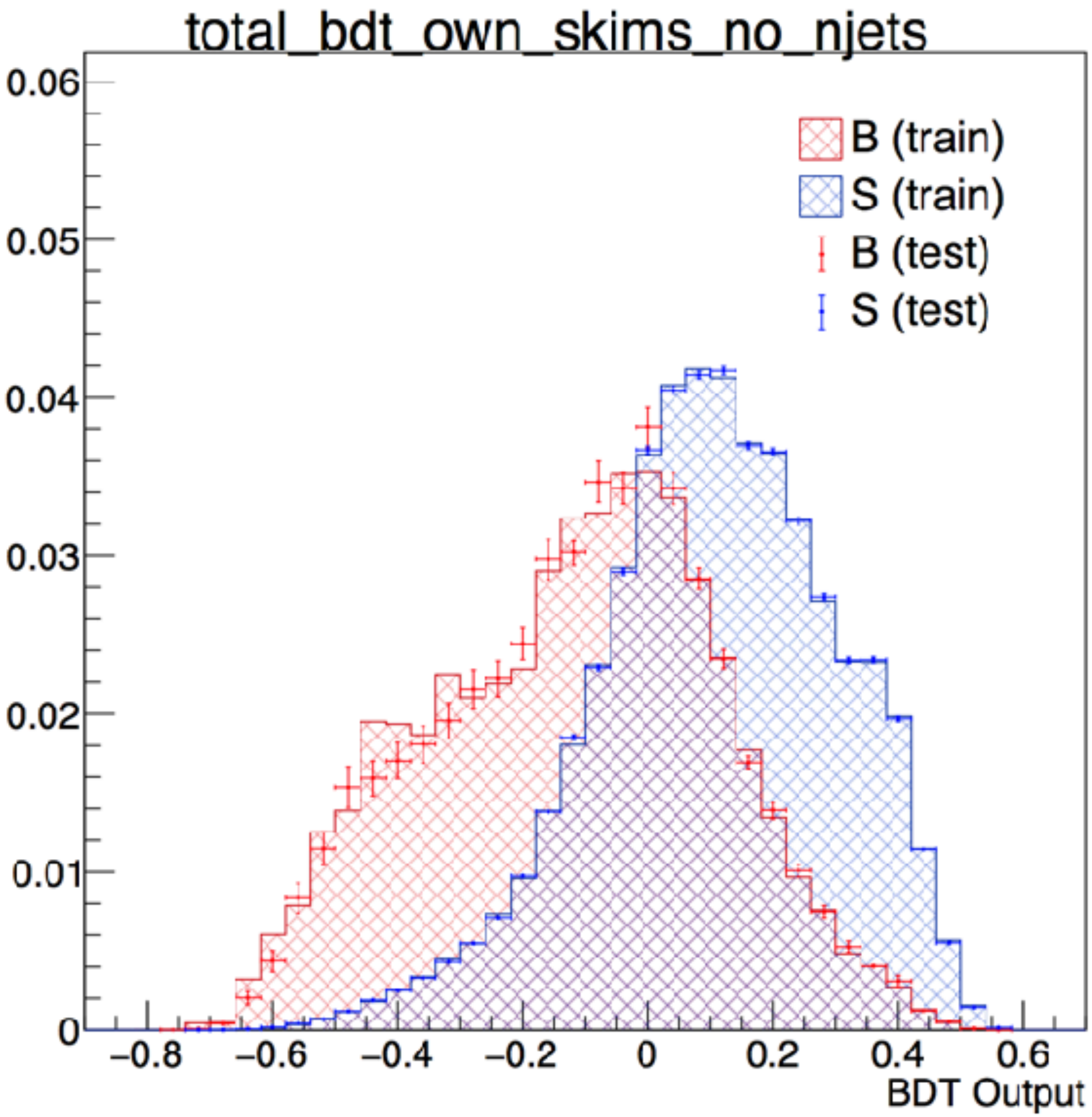
Track BDT ROC

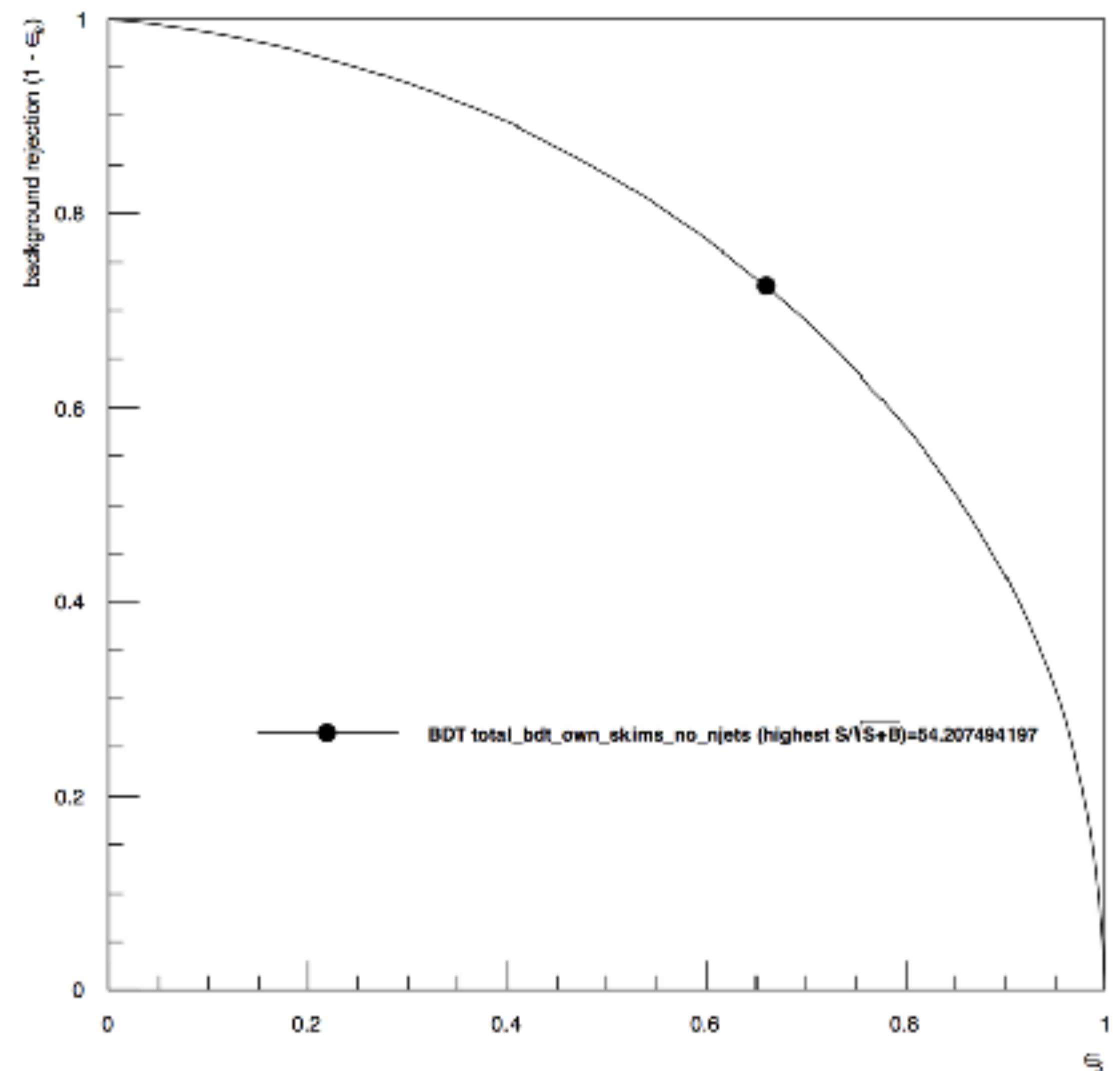


Universal BDT

- We train a BDT independent of the leptons' kinematics.
- Will not depend on the mass spitting, and will mostly control overall signal-background ration, and not their shapes.
- Will help "tuning" our working point without disturbing the edge shape of the signal.
- Observable: Ht, LeadingJetQgLikelihood, MinDeltaPhiMhtJets, Mht, LeadingJetPt, LeadingJetEta.

Universal BDT Overtraining and ROC





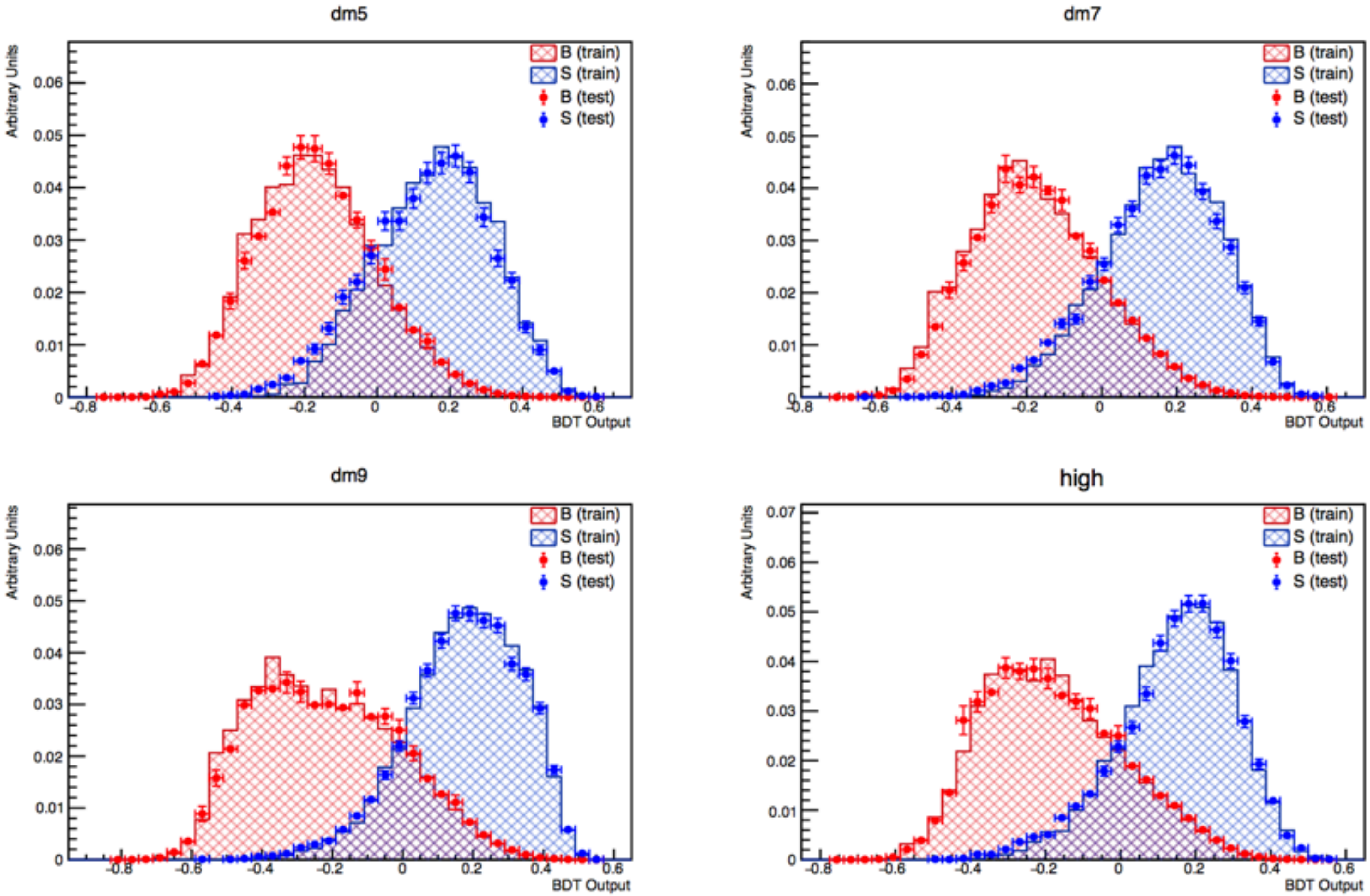
Intermediate Selection Process

- The universal and track BDT's are evaluated independently of each other.
- For each event with one reconstructed lepton an opposite charged track with the highest track BDT score is chosen as the second lepton.
- Both BDT scores are then written to event and skimmed to new trees.

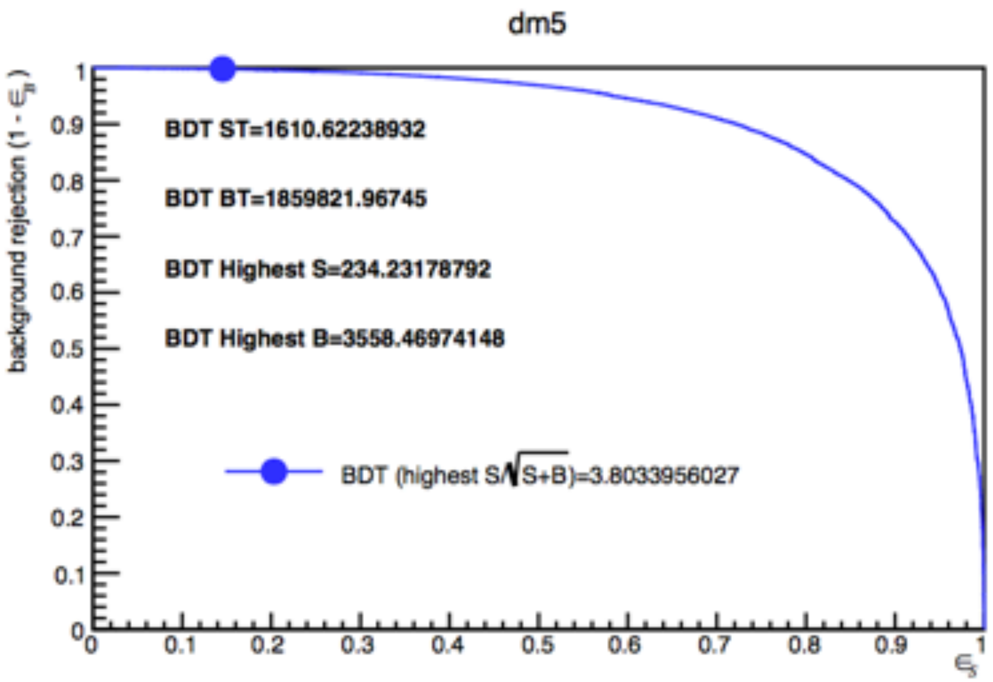
Dilepton BDT

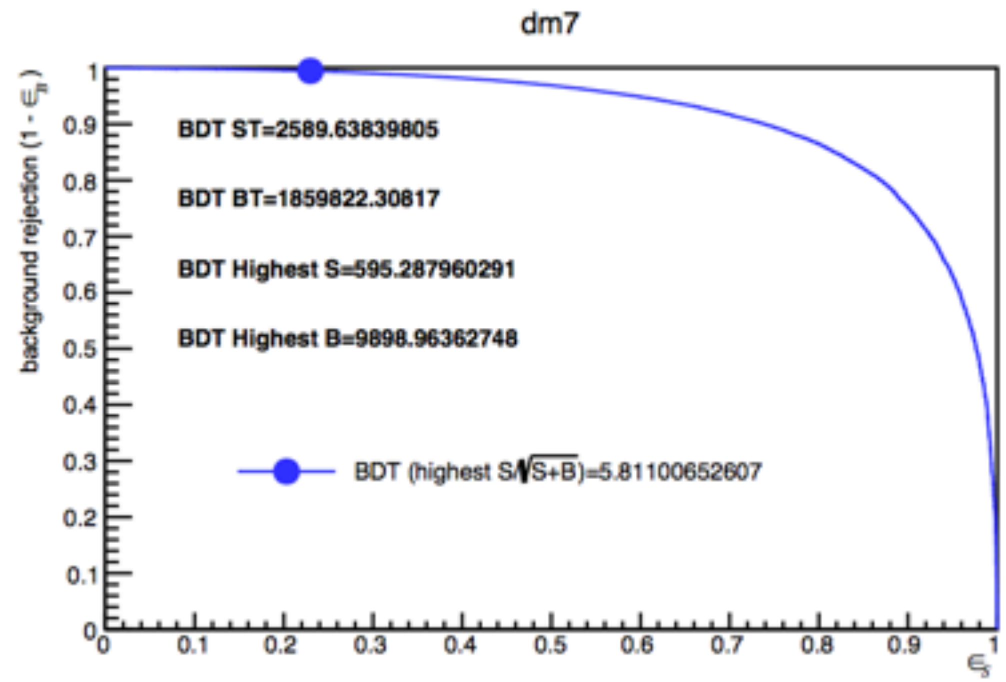
- Finally, a third BDT is trained to include all the kinematics of the leptons.
- The scores of the first BDT's are included and are also the most significant to the dilpton BDT.
- Extra observables: delta Phi, delta Eta, delta R, transverse mass of the softer lepton, Delta Eta between the dilepton system and the leading jet, and the lepton's eta, phi, pt.

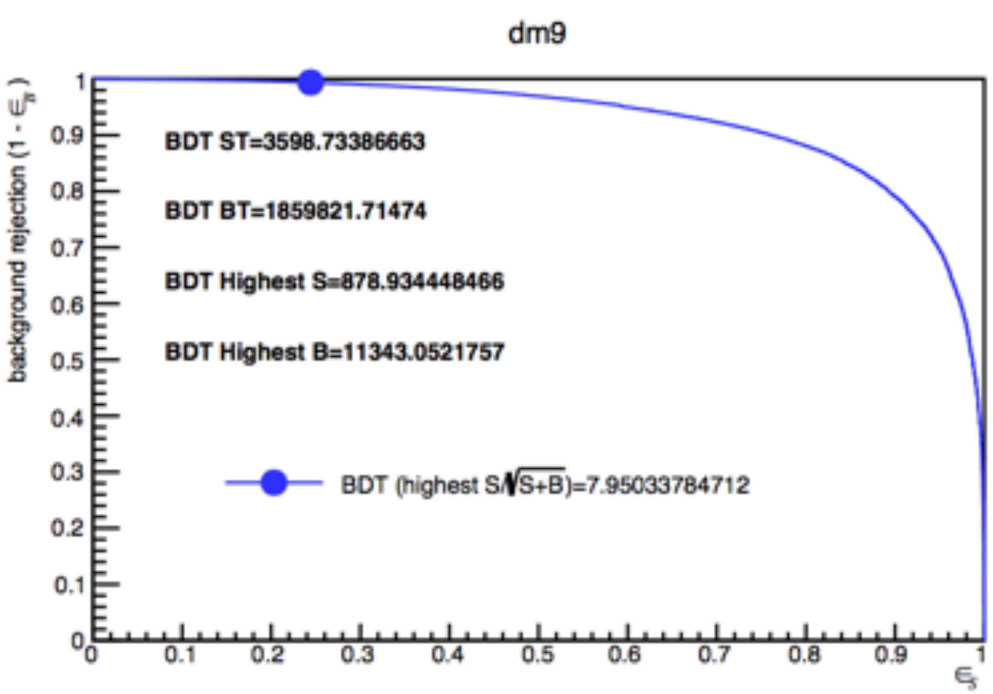
Dilepton BDT output

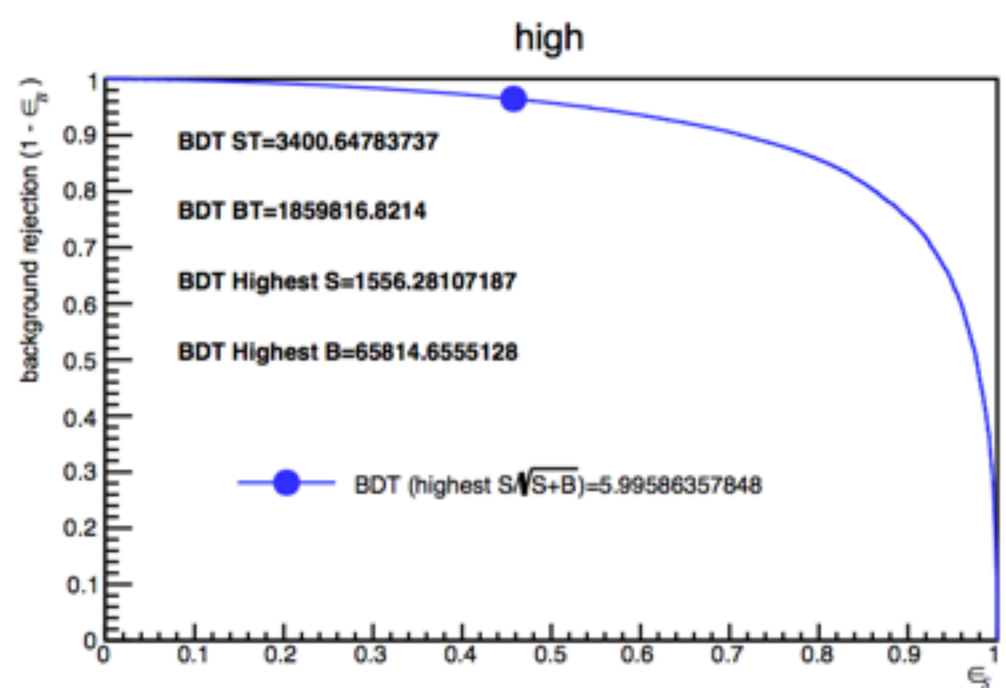


Dilepton BDT ROC





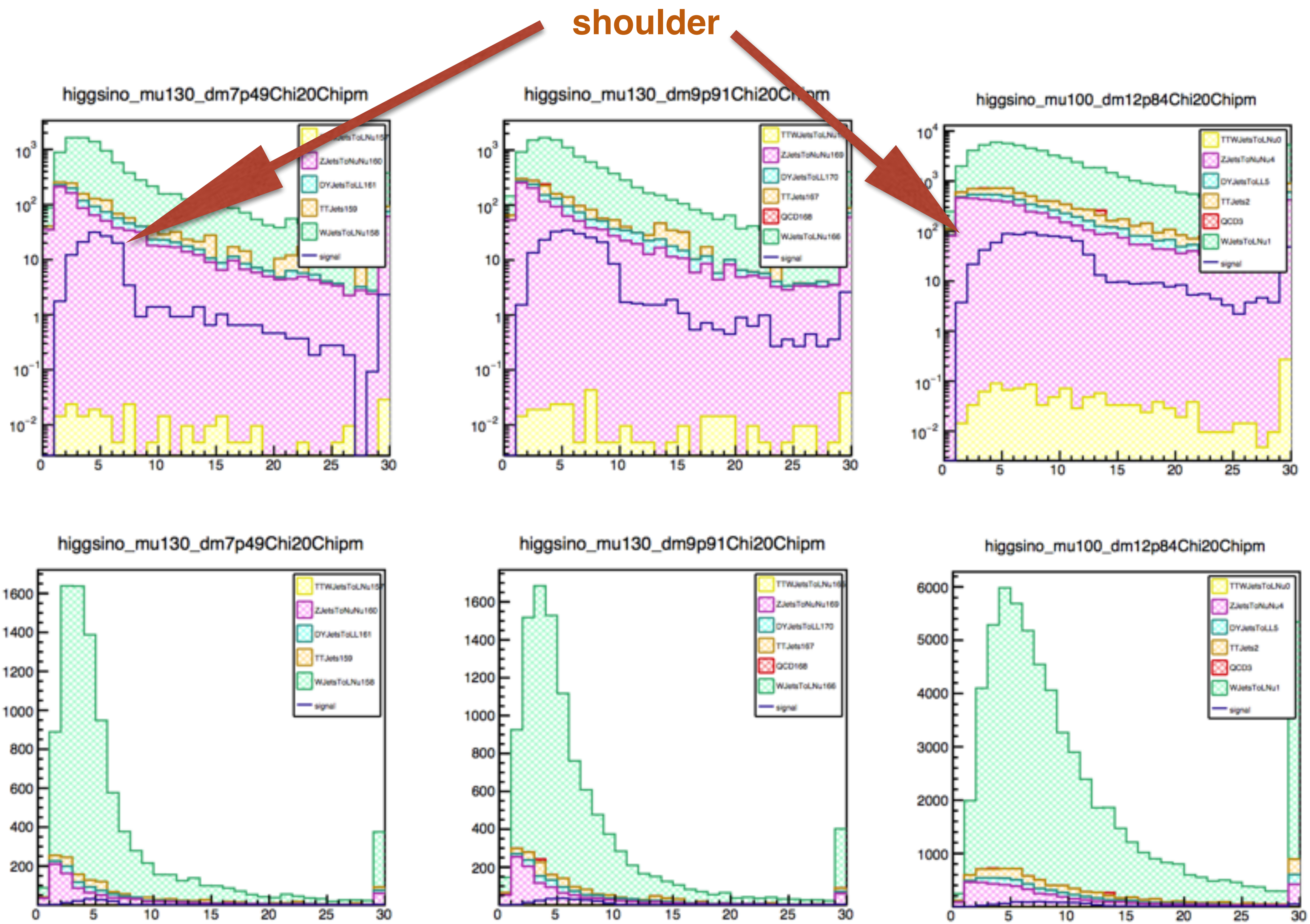




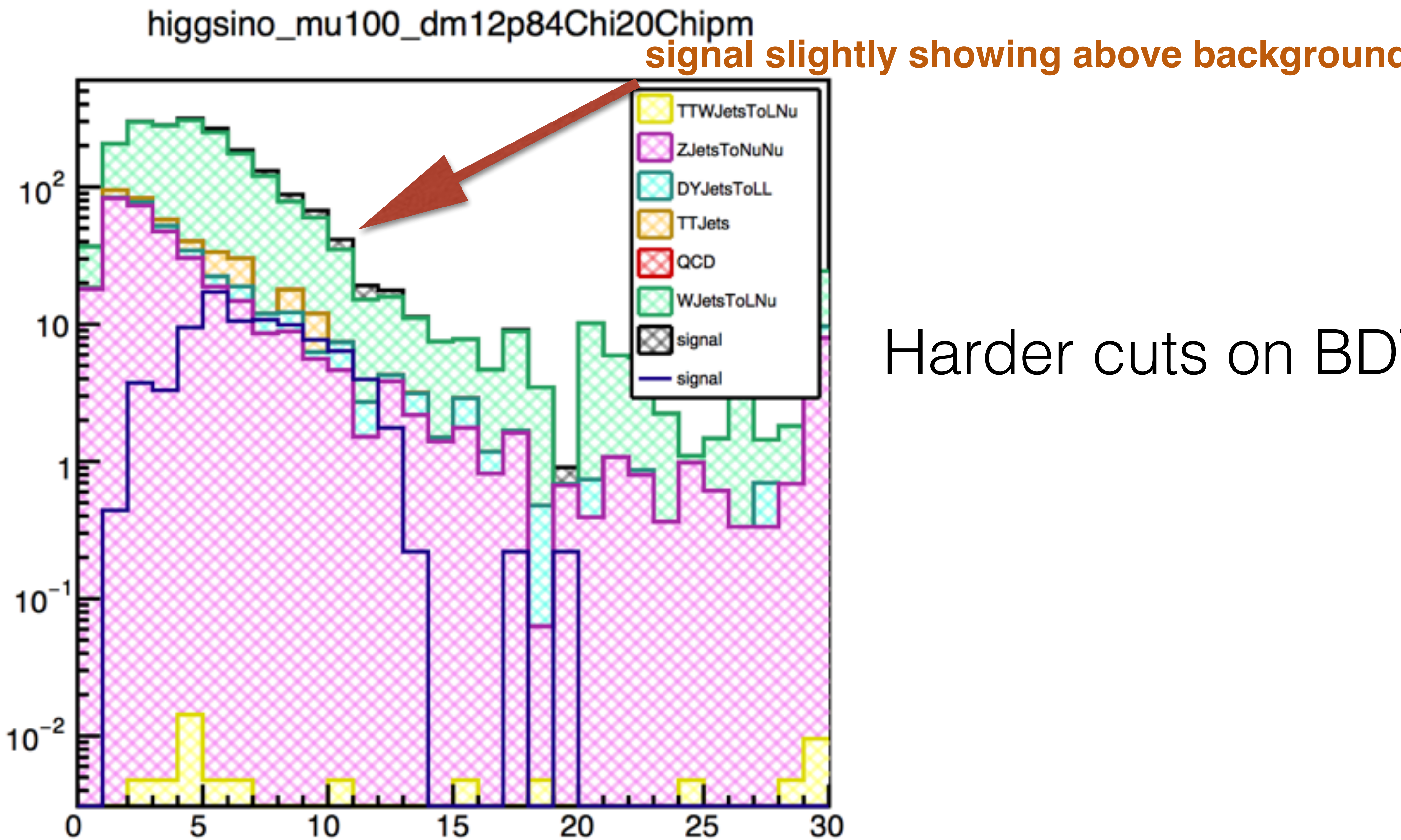
Invariant Mass

- End goal is to observe a bump over the background.
- Need to decide on cut-point for the BDT's or even apply further cuts.

Naive cuts - Invariant Mass



Extra Cuts Applied
Very early results



Harder cuts on BDT's

To Do

- Improve cuts and research how to shape the background better for more difficult model points.

Backup

Cross Section Calculation

- In order to get a more precise evaluation of signal to BG ration, we need to have the cross section of the signal points.
- Cross sections have been calculated and given in this twiki: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections13TeVn2x1hino
- However, that calculation assumes completely degenerate Higgsinos.

Cross Section Calculation

- To get a better estimation for the cross section, the CS has been calculated using the SLHA files that were used to simulate the signal.
- CS has been calculated using resummino (ARXIV:1304.0790)
- PDF fit is done via LhaPdf (arXiv:1412.7420v2)
- Calculation been done for 13TeV for NLO-NLL using MSTW2008nlo90cl PDF set.
- After discussion with Basil he suggested moving to the more recent PDF4LHC15_nlo_mc - but that is a very minor correction - will be done in the future.
- Calculation is for total cross section for both positive and negative chargino production (taking the sum).
- Since we don't have two neutrolino production in our data - this calculation has not been done.