Search for the Higgs boson in the ZH → ννbb decay channel with the ATLAS detector

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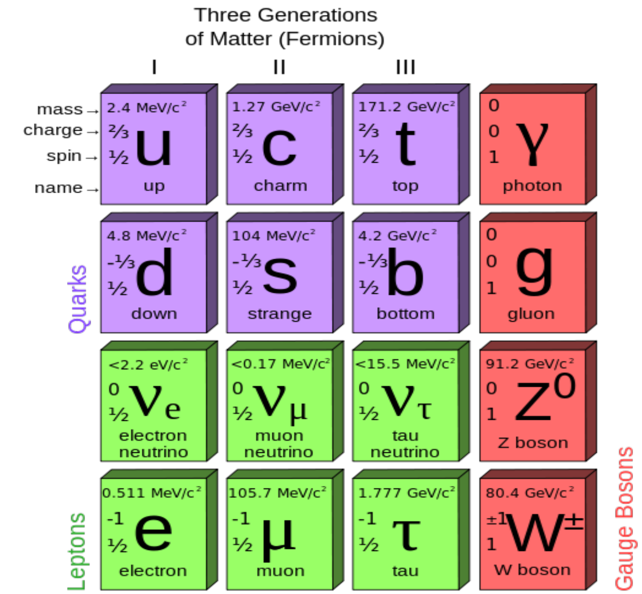
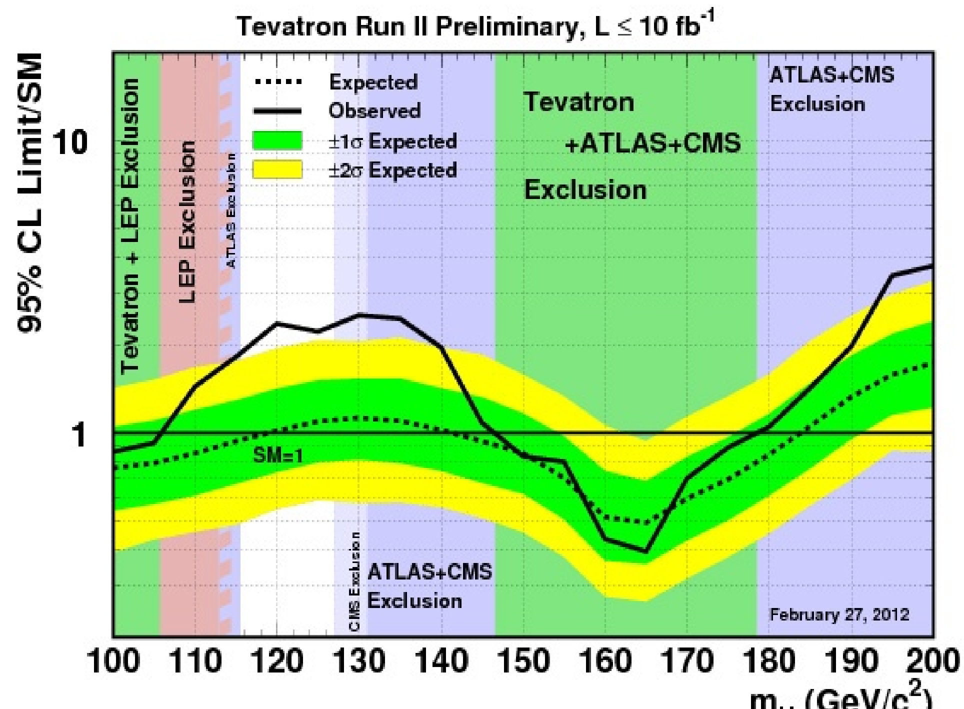
Introduction

- In Standard Model, 3 generations of particles are predicted and observed.
- 3 types of interactions in SM:
  - Electromagnetic with mediator photon
  - Weak interaction with mediators W and Z
  - Strong interaction with mediator gluons
- SM is perfect if:
  - Particles are massless (in fact, all particles are proven to have masses)
  - All mediator bosons are massless (in fact, weak bosons have heavy masses)
- Need some mechanism to complete Standard Model → Higgs mechanism
- The Higgs search has been pursued by many experiments in the world at LEP, Tevatron, and now LHC.

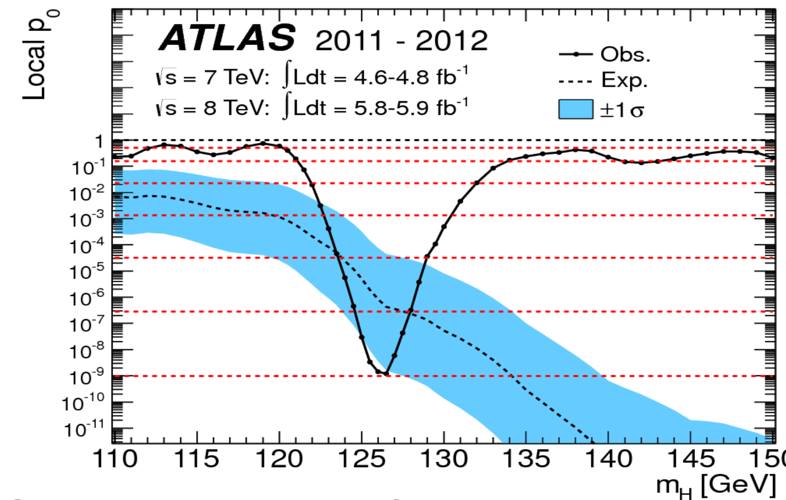




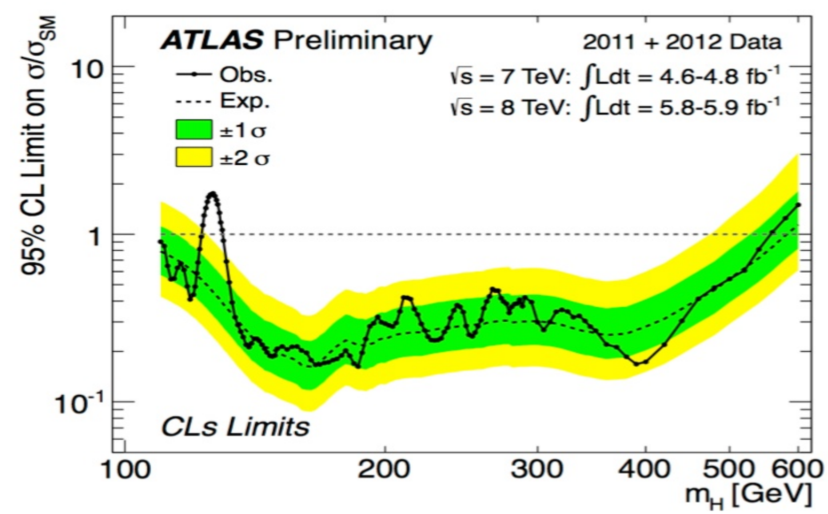
Moriond 2012 Combined limits on Higgs mass for Tevatron. LEP, ATLAS and CMS

Recent results of Higgs search at LHC in 2012

- In the recent Higgs search at LHC: for the decay channels of Higgs to 4 leptons and 2 photons, ATLAS and CMS discovered a Higgs-like particle at about 126 GeV
- New particle? Yes! But is this the Standard Model Higgs boson? Still under investigation!
- Need to be confirmed more with the other Higgs decay channels. In this case, the Higgs→2 b quarks is very important: discovery shows only coupling to bosons, so H → bb and H → ττ are needed to establish Higgs coupling to fermions



Combined results for Higgs→4l and Higgs→ 2 photons

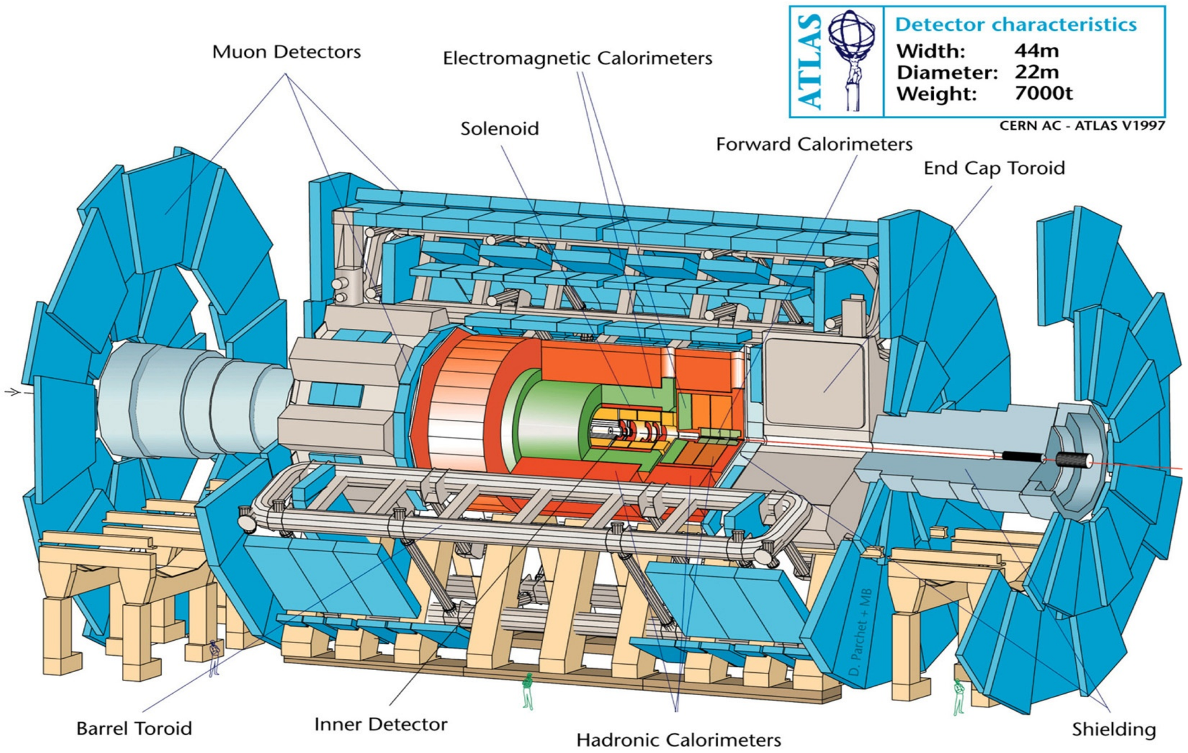


Observed a particle arount 126 GeV

Large Hadron Collider

- Large Hadron Collider is the project created for general particle physics research
- Mainly use proton-proton collisions, but also work on the heavy-ion collisions
- Four main detectors: ALICE, ATLAS, CMS, LHCb
- Currently in 2012 LHC works at $\sqrt{s}$ = 8 TeV, with luminosity in ATLAS detector about 22 fb^{-1} so far. ATLAS Data taking period began from 4th April and will keep running till the end of December with 25 fb^{-1} of luminosity expected
- In the end of 2015, LHC will be expected to have the collisions at $\sqrt{s}$ = 13 TeV and deliver about 30 fb^{-1}

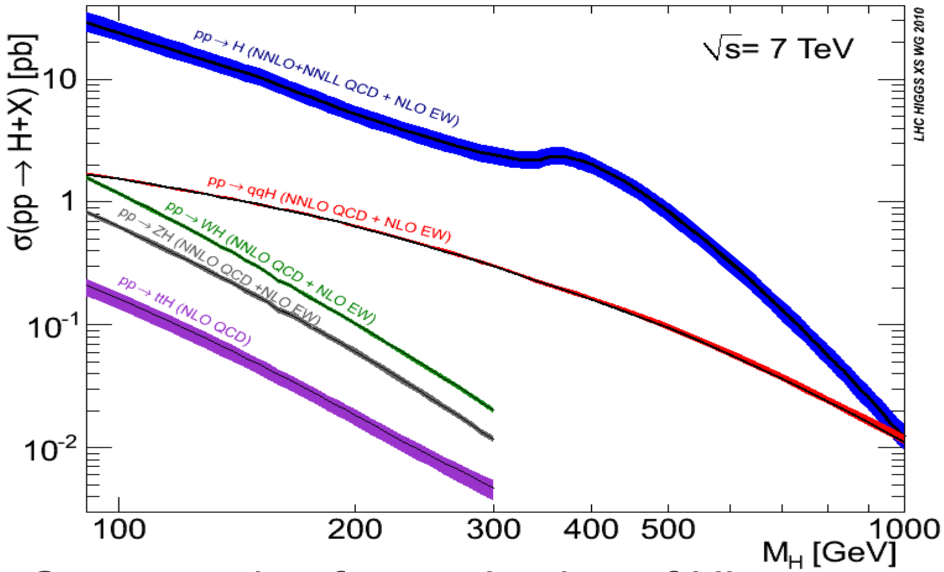
ATLAS detector



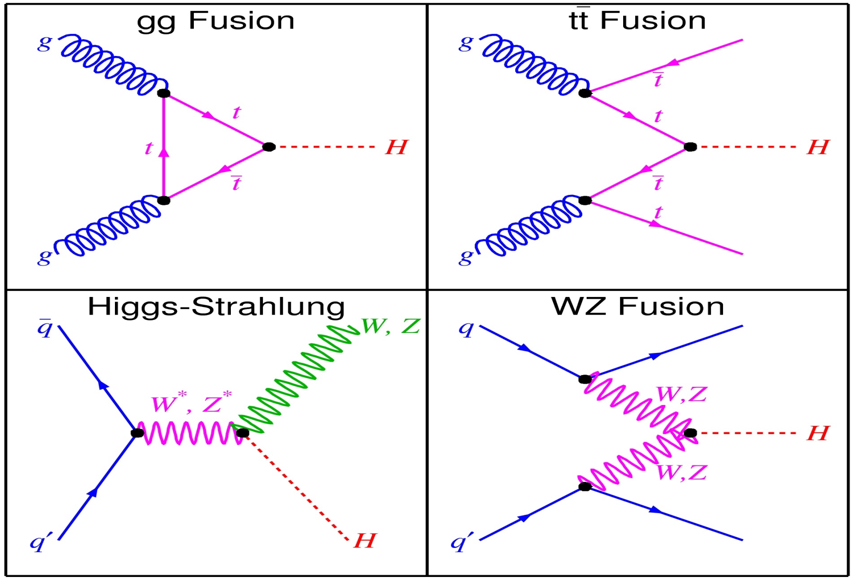
- In our study, we use the following parts:
  - Inner detector for reconstructing tracks, vertexes. It also plays a role for measuring the momenta of particles, jet reconstruction and measuring impact parameters
  - Calorimeter: used for measuring particle's and jet's energy, and jet reconstruction
  - For measuring MET: we use the calorimeter, whose coverage extends to large pseudorapidity

Production of Higgs boson at LHC

- In LHC, Higgs is created in proton-proton collision
- In our study, we are interested in the channel of Higgs-strahlung, where the Z boson decays to neutrinos because of the high branching ratio (Z can decay to each of 3 types of neutrinos: ν_e, ν_μ, ν_τ)



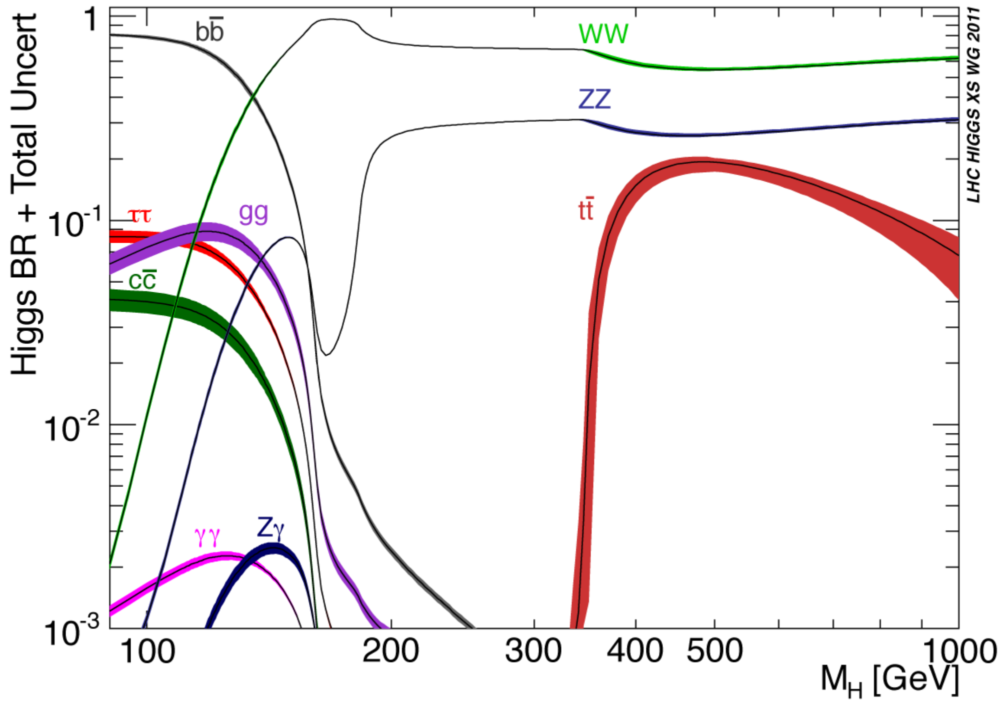
Cross section for production of Higgs at LHC for energy = 7 TeV at center-of-mass



Feynman diagram for Higgs production

Production of Higgs boson at LHC

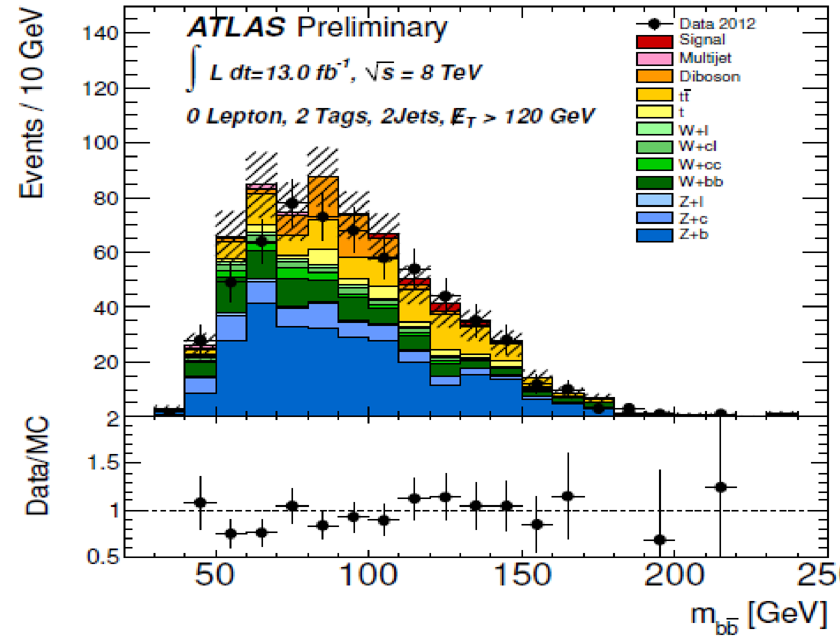
- To detect the Higgs, we find the outputs of Higgs decay channels in detectors.
- In our study, we search for the Higgs decay to 2 b quarks, because this is the most dominant decay channel at the low mass.



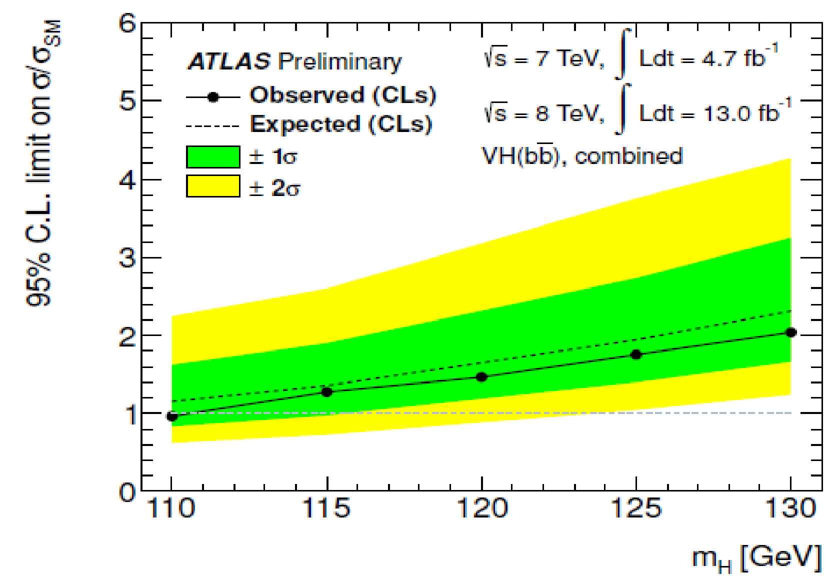
Higgs decay channel as the function of mass

Event selection for ZH → vvbb channel

- Object selection:
  - Use the lowest threshold unprescaled trigger for missing transverse energy
  - Lepton veto
  - 2 or 3 jets, 2 jets identified as b-jet using b-tagging algorithm MV1 (70% efficiency) with leading b-jet pt > 45 GeV
  - Large missing transverse energy (>120 GeV) and missing transverse momentum > 30 GeV
  - Extra cuts on ΔR(b1, b2) and Δφ(MET, Higgs)
- Main backgrounds:
  - Diboson events: WW, WZ, ZZ
  - QCD background (multijets)
  - Weak bosons (W or Z) + multijets
- The results of 2011+2012 study show good agreement between data and Monte Carlo, but the signal of Higgs (red blocks) is still lying in the uncertainties → need more work to extract the clear signal of Higgs



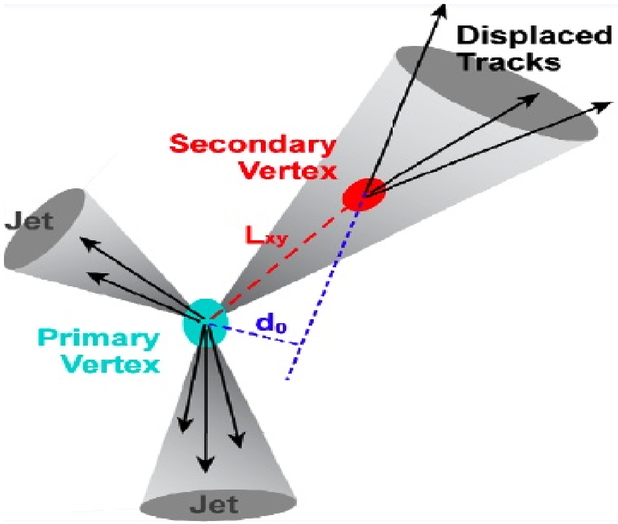
Mass invariant of 2 b-jets in ATLAS CONF Note HCP 2012

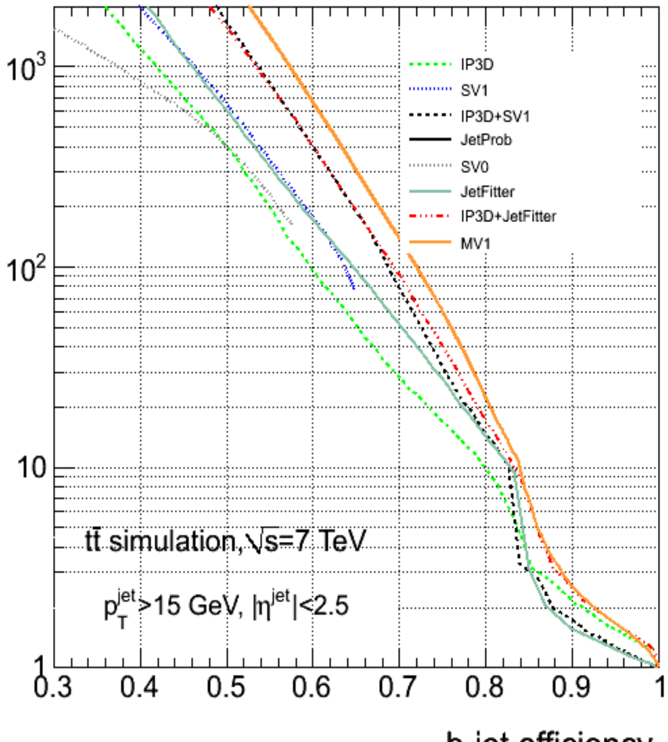


Limit of Higgs mass for the combination of 2011 and 2012 data from HCP

More about b-tagging

- In the study of the H → bb analysis, b-jet identification is important.
- In the detector, due to the relatively long lifetime, b-quarks can travel a significantly long path before decaying. This displacement can be identified by measuring the impact parameter of the displaced tracks and secondary vertices from the b-decay products
- The b-tagging algorithm is constructed on these constituents. Currently using the multivariate tagger (MV1) for its advantage in performance
- Example of the performance of b-tagging: at 70% efficiency, the rejection of light jet (inverse of mis-tag rate) for the MV1 tagger can be read at 150

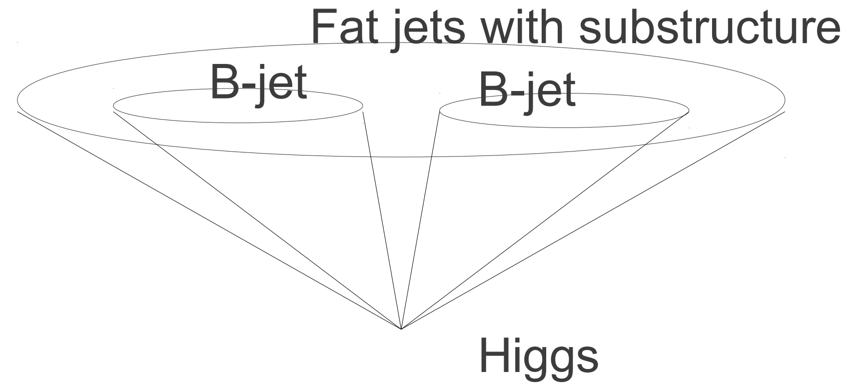


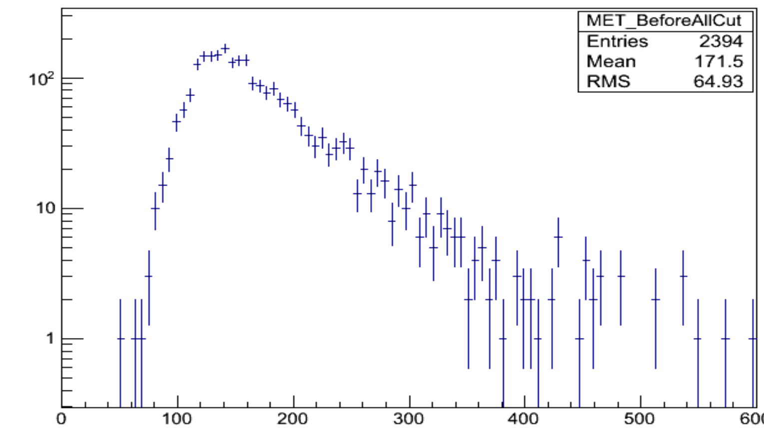


B-tagging performance for ttbar sample

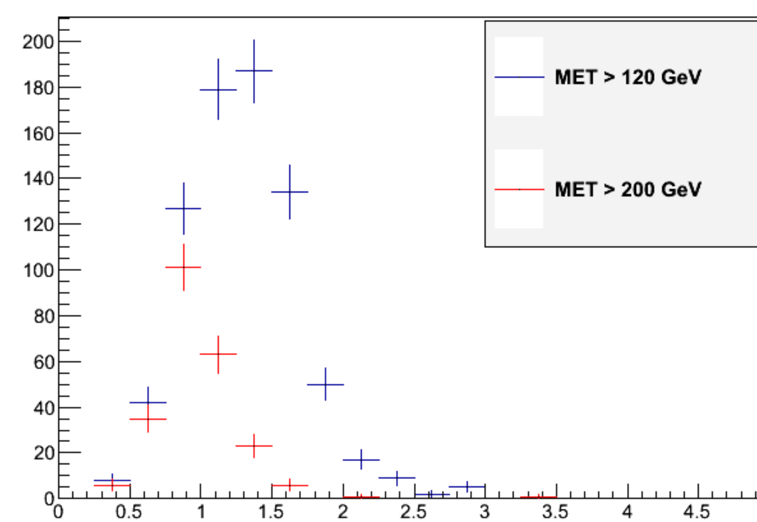
Higgs → bb situation

- In H→bb analysis, energy is high (for ex.: $\sqrt{s}$ = 13 TeV), consequently Higgs can be in boost regime: 2 b-jets maybe no longer separated, they can be superimposed → need a new method to associate tracks to jets with substructure (jet contains subjets)
- Non-standard cone algorithm should be applied
- B-tagging should rely on these jets and their substructures





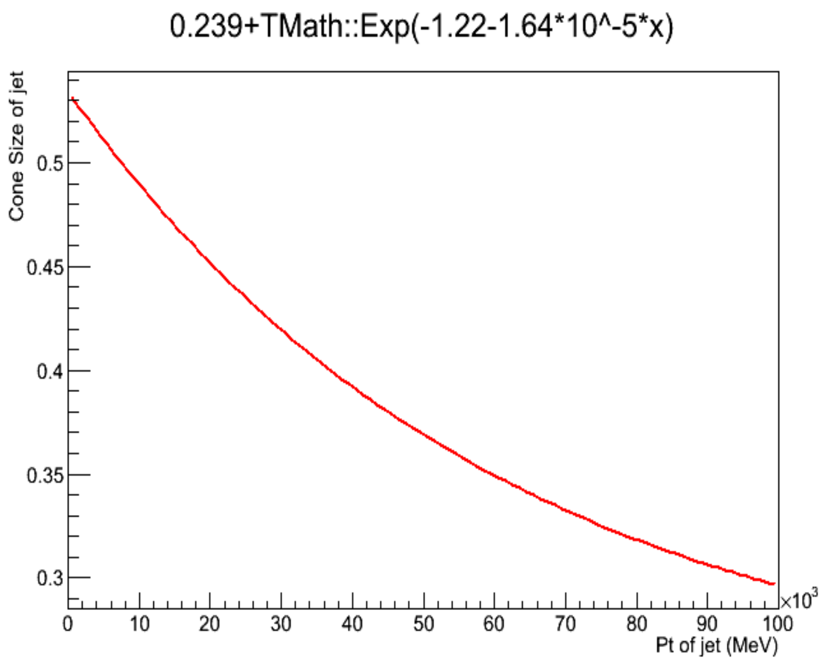
Distribution of missing transverse energy



Distribution of deltaR(b,b)

Ghost association of tracks to jets: principles

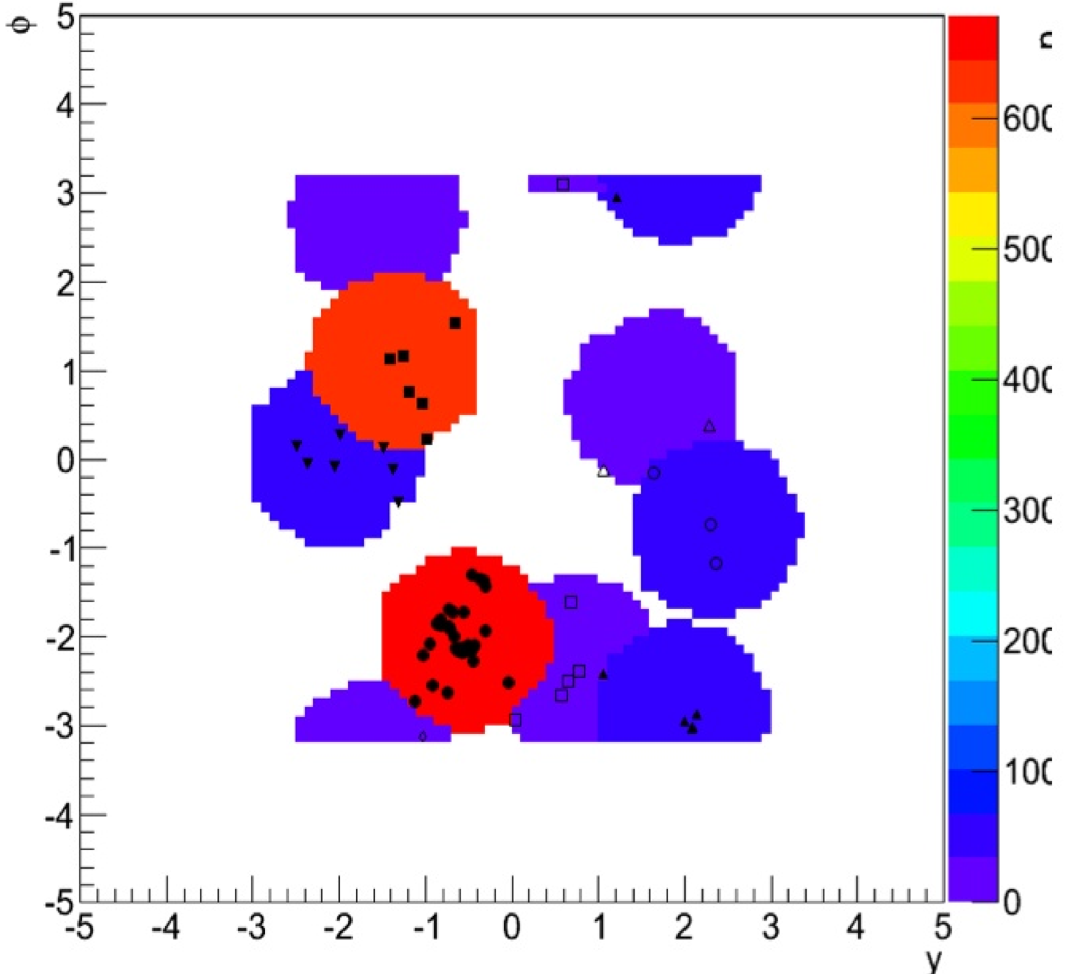
- In standard cone track association to jet: using a geometrical distance (conical form), then associate every track within
- In general, to find which area of calorimeter can be associated with jet, we use concept of active area
- To find this active area:
  - Generate a distribution of low energy particles (ghost particles)
  - Cluster these particle into jets
  - These ghost particles tell us the shape of the jet: If parts of calorimeter where these ghosts are found, they could be associated to that jet
- Ghost tracks association of jets use the same principles of active area



Cone of the jet as function of pt in our ghost association of tracks to jet study

Ghost association of tracks to jets

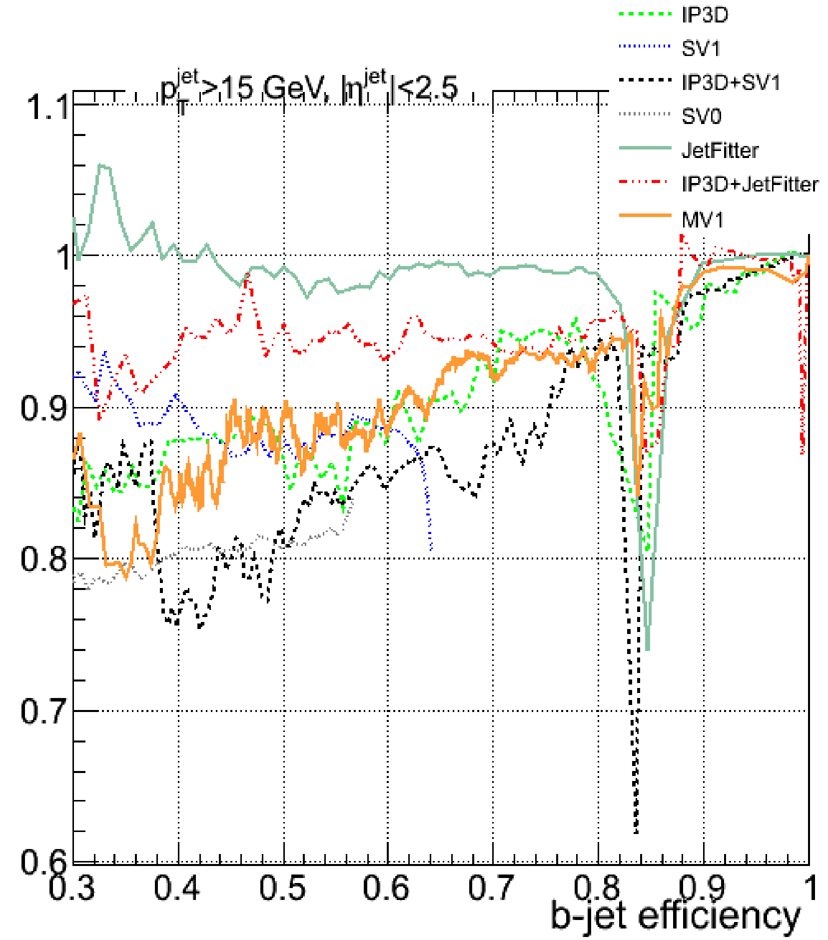
- Create ghost tracks with the same direction of tracks but at low energy, these ghost tracks refer to some real tracks (B-hadron, muon, electron, etc...)
- Add these ghost tracks to the constituents of clustering procedures of jet
- Use the clustering algorithm to find which regions of the ghost tracks in calorimeter belong to which jet
- The ghosts can tell the precise shape of the jet



Horizontal axis: eta of tracks in detector coordinate
Vertical axis: phi of tracks in detector coordinate
Color: the value of jet pt

B-tagging performance using ghost association of tracks to jet

- Run ghost track association algorithm and create the collection of jet with ghost-association
- Run the b-tagging algorithm on these ghost-association jets and see its performance
- In this work, the b-tagging performance for ghost-association jet is lower than the normal jet → trying to understand
- The ghost association looks promising in studying jets with substructure and boosted jets. Will understand more the problem in the future work on this subject



Ratio between the b-tagging performance of ghost-association of tracks to jets and normal jets

Conclusion

- First discovery of Higgs-like particle is a great motivation to continue on Standard Model Higgs studies.
- Got acquainted with the Higgs studies on the channel ZH → vvbb for the 2011 analysis. Will continue this Higgs study for 2012 analysis.
- Will work more on the studies of b-tagging for ghost-association jet and implement it in the Higgs → bb studies