ECFA LC2013

European Linear Collider Workshop

27 – 31 May 2013

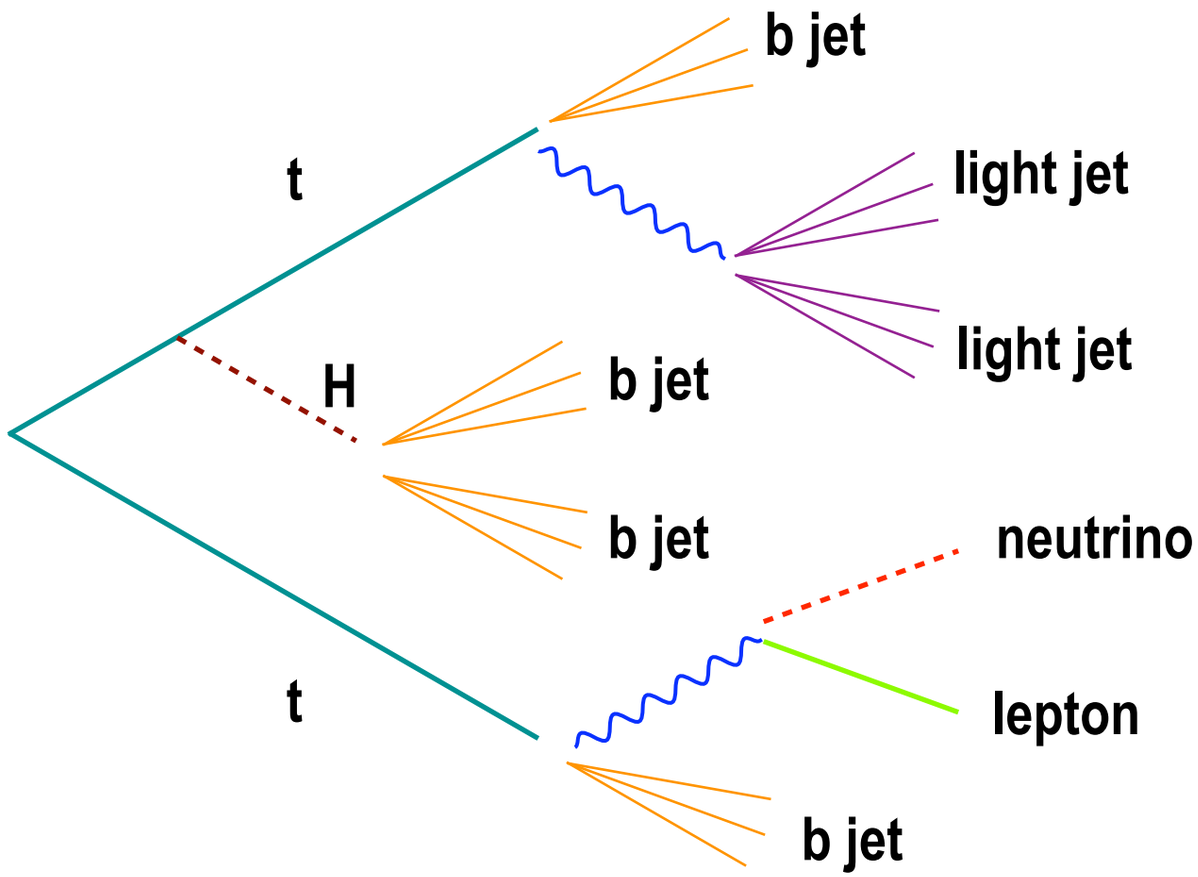
DESY, Hamburg

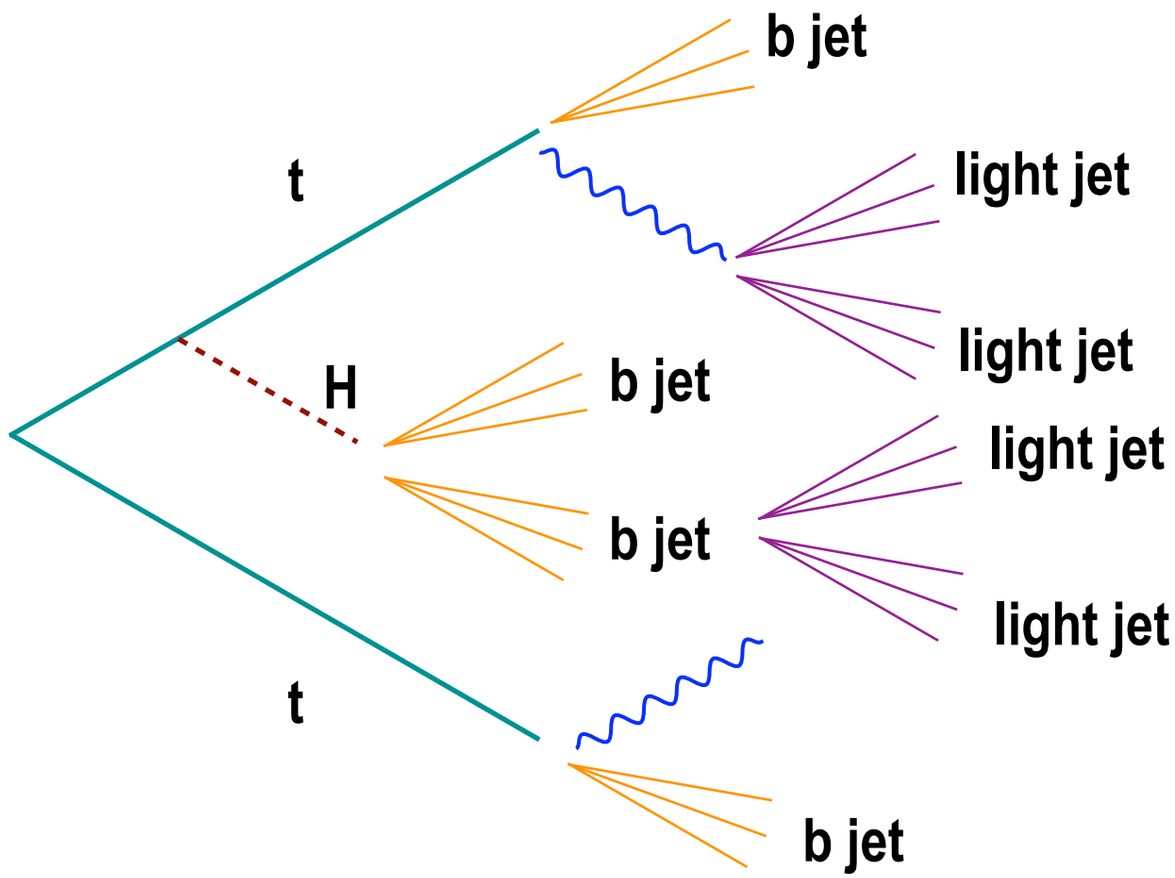
$t\bar{t}h$ at 1.4 TeV

Sophie Redford (CERN)
Philipp Roloff (CERN)
Marcelo Vogel (Pontificia Universidad Catolica de Chile)
on behalf of the CLIC Detector and Physics Study

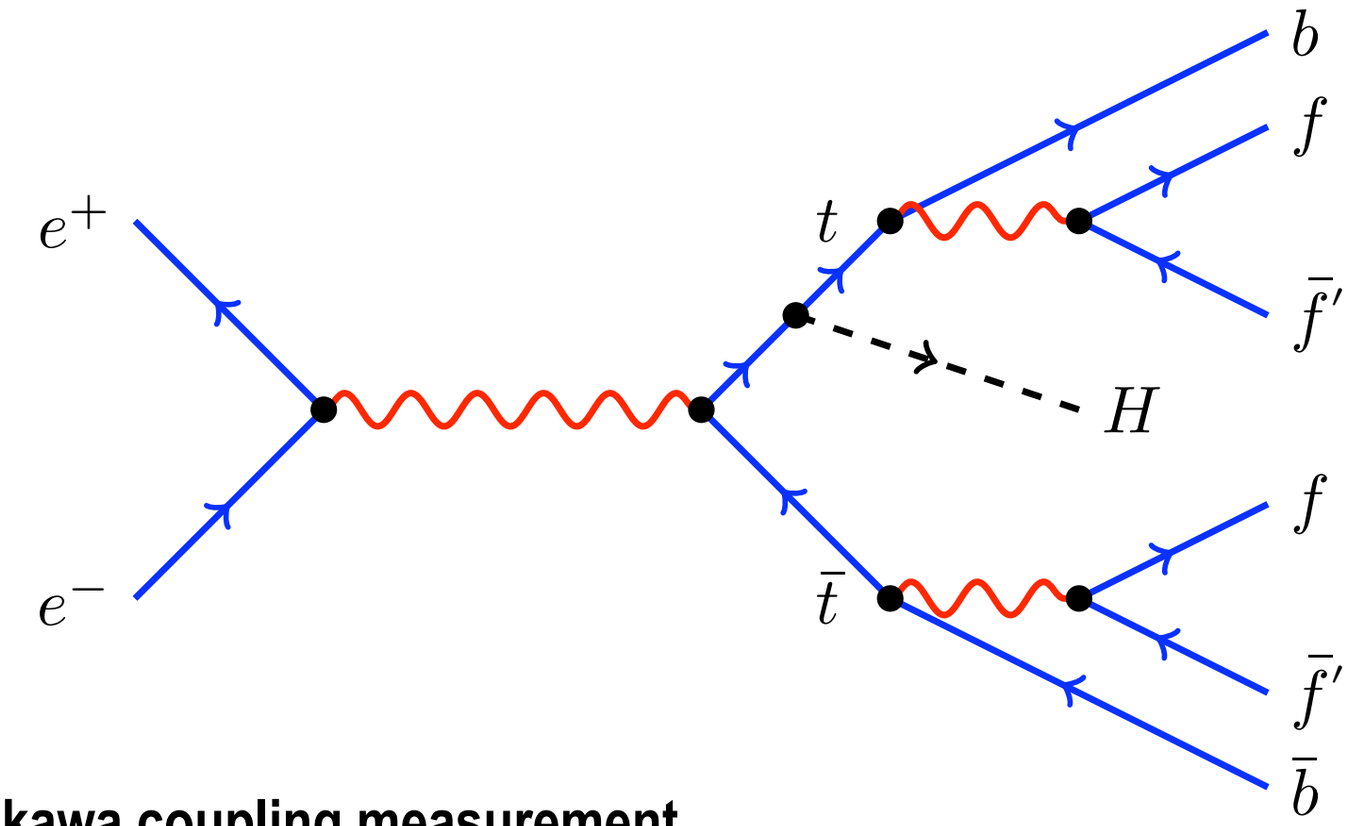
Introduction

- Consider $e^+e^- \rightarrow t\bar{t}H$
- 1.4 TeV centre of mass energy, no beam polarisation used, luminosity 1.5 ab^{-1}
- Two final states: 6 jets and 8 jets





Motivation



- Top Yukawa coupling measurement
- SM: linear dependence between Higgs-fermion coupling and fermion mass
- Top: heaviest SM particle, couples most strongly to the Higgs field
- NP: could induce sizeable deviation from SM expectation

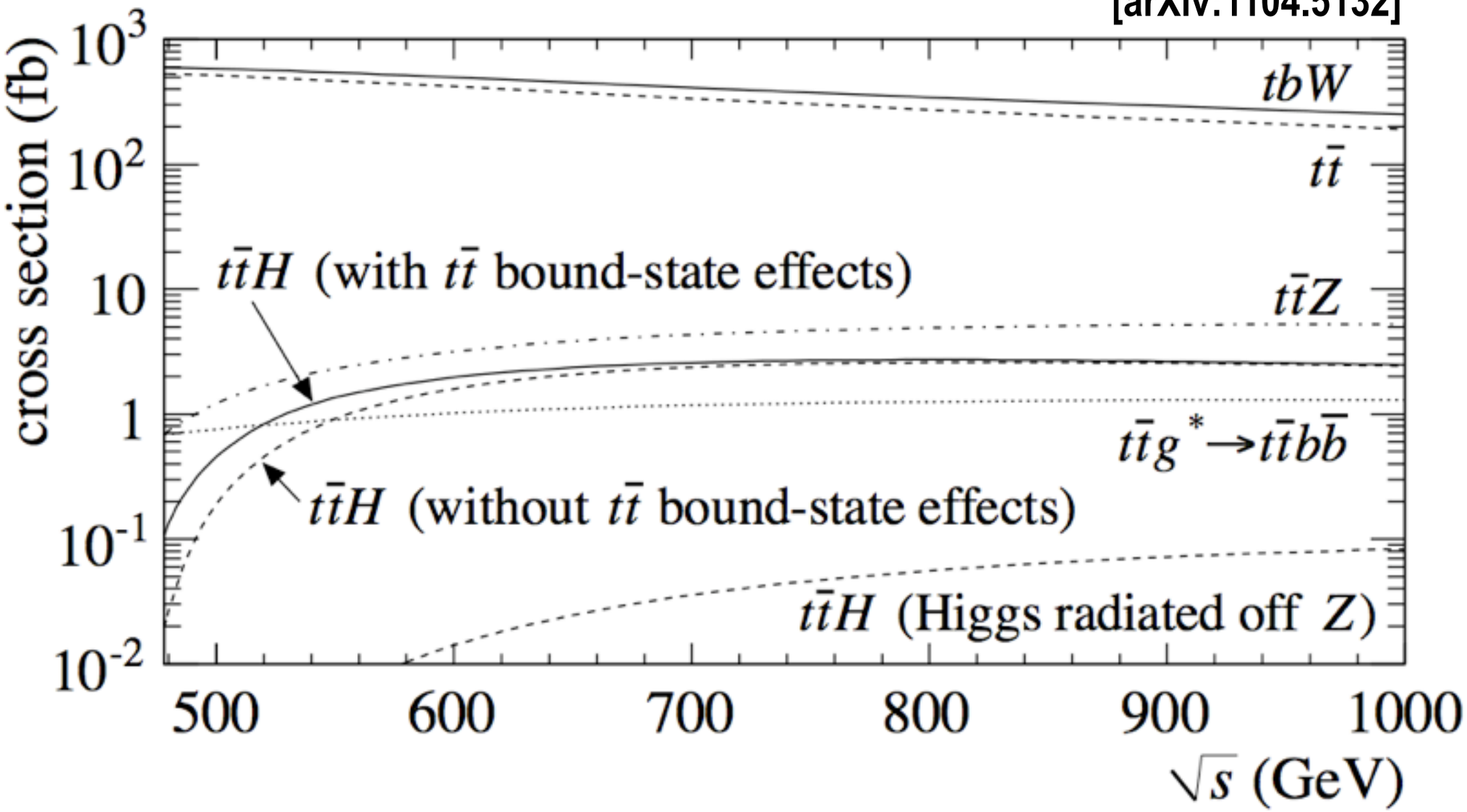
- Benchmark analysis: final state requires many reconstruction tools, hence comprehensive check of analysis chain and detector performance

Event Samples

8 fermion final state:	Cross section (fb)	N events in 1.5 ab^{-1}
Signal		
ee → tth, tt → lvbbqq, h → bb	0.415	620
ee → tth, tt → bbqqqq, h → bb	0.431	650
Signal / background?		
ee → tth, tt → lvbbqq, h → not bb	0.303	450
ee → tth, tt → bbqqqq, h → not bb	0.315	470
Background		
ee → tth, tt → llvvbb, h → bb	0.100	150
ee → tth, tt → llvvbb, h → not bb	0.073	110
ee → ttZ, tt → llvvbb	0.439	660
ee → ttZ, tt → lvbbqq	1.825	2,700
ee → ttZ, tt → bbqqqq	1.895	2,800
ee → ttbb, tt → llvvbb	0.127	190
ee → ttbb, tt → lvbbqq	0.529	790
ee → ttbb, tt → bbqqqq	0.549	820
6 fermion final state:		
ee → ttbar	135.8	200,000

Cross Sections vs. Energy

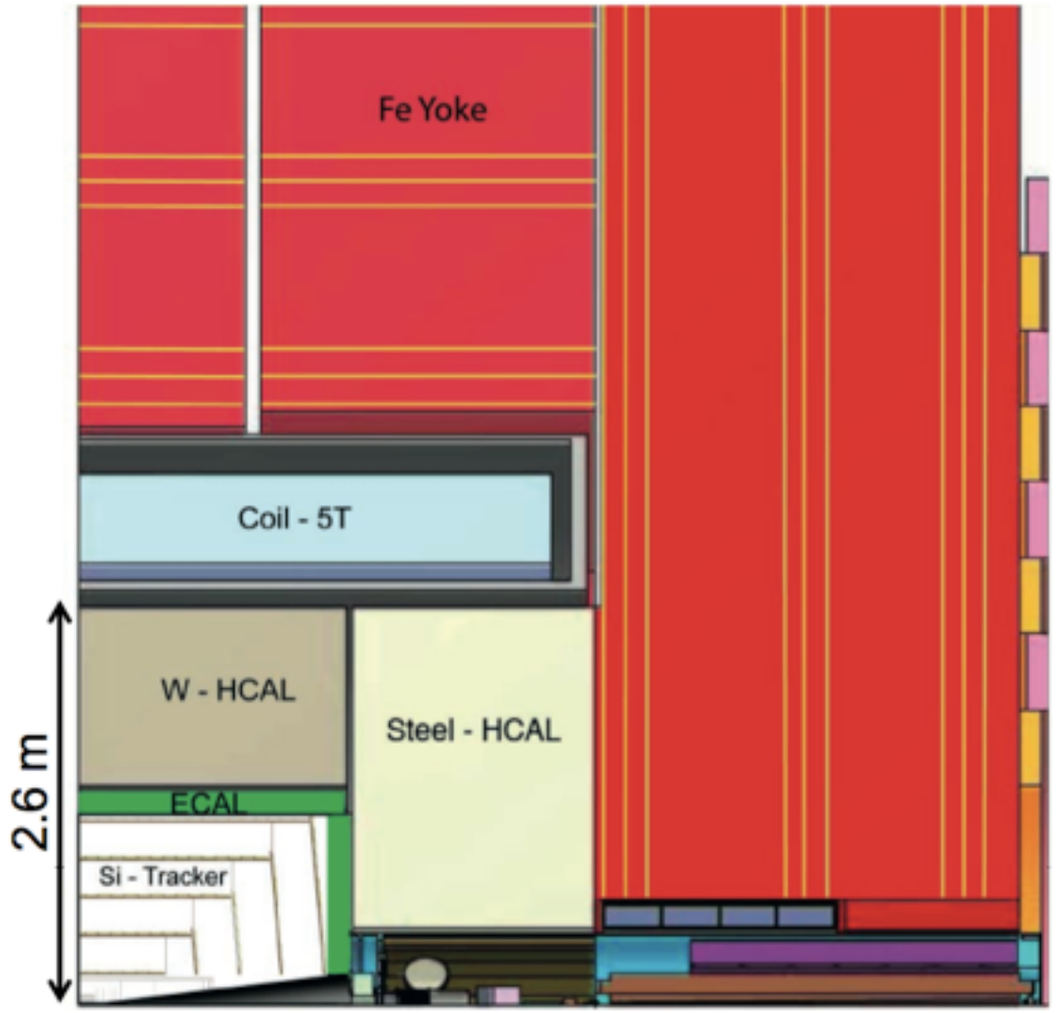
[arXiv:1104.5132]



- At higher energy, same number of signal events, less background
- Expect better precision at higher energy, if similar reconstruction performance can be achieved

Signal Simulation

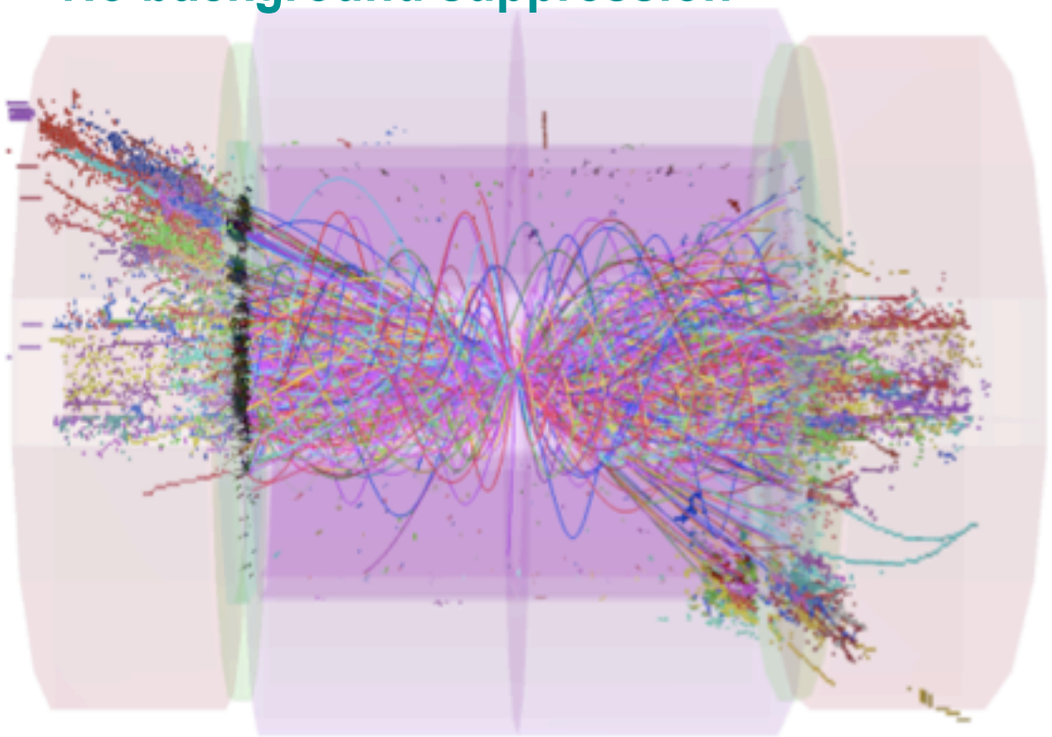
- Physsim generates ttH events
- Pythia for hadronisation
- Pile up from beam induced backgrounds (gamma gamma to hadrons) overlaid
- Full CLIC_SiD detector simulation in GEANT4



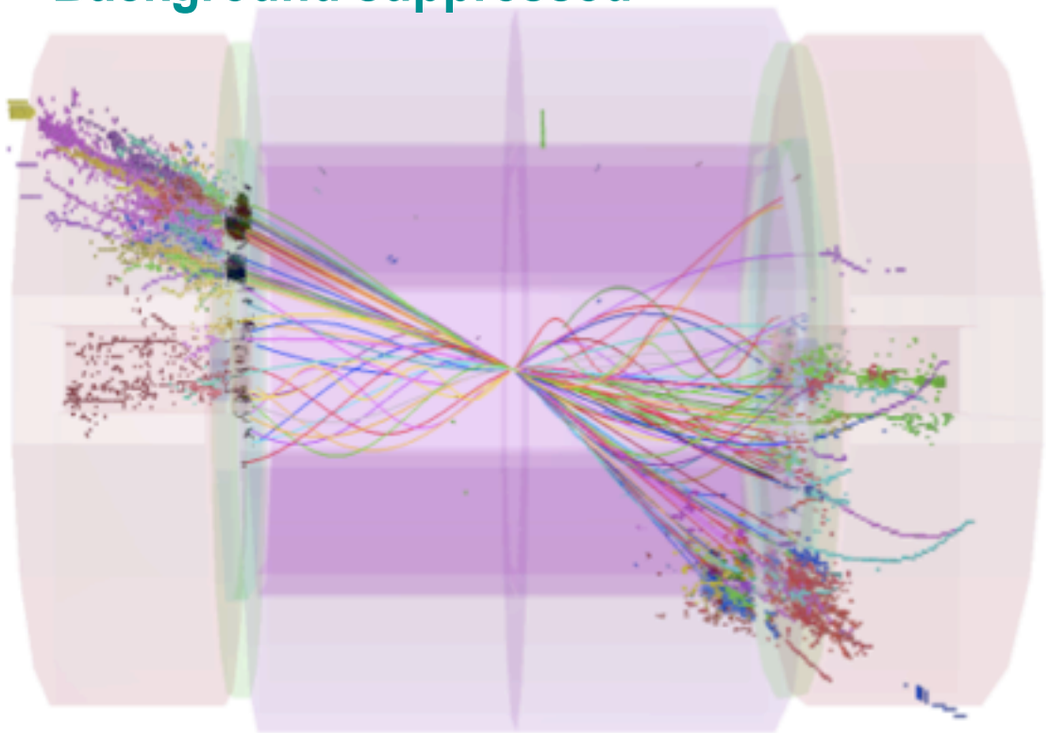
Reconstruction

- Reconstruct particles using Particle Flow technique
  - Particle Flow Objects (PFOs)
- Beam induced background suppressed by timing and momentum cuts
- Identify isolated lepton
- Cluster jets using FastJet hadron collider kT algorithm, in exclusive mode
- LCFIPlus for vertexing and flavour tagging

No background suppression

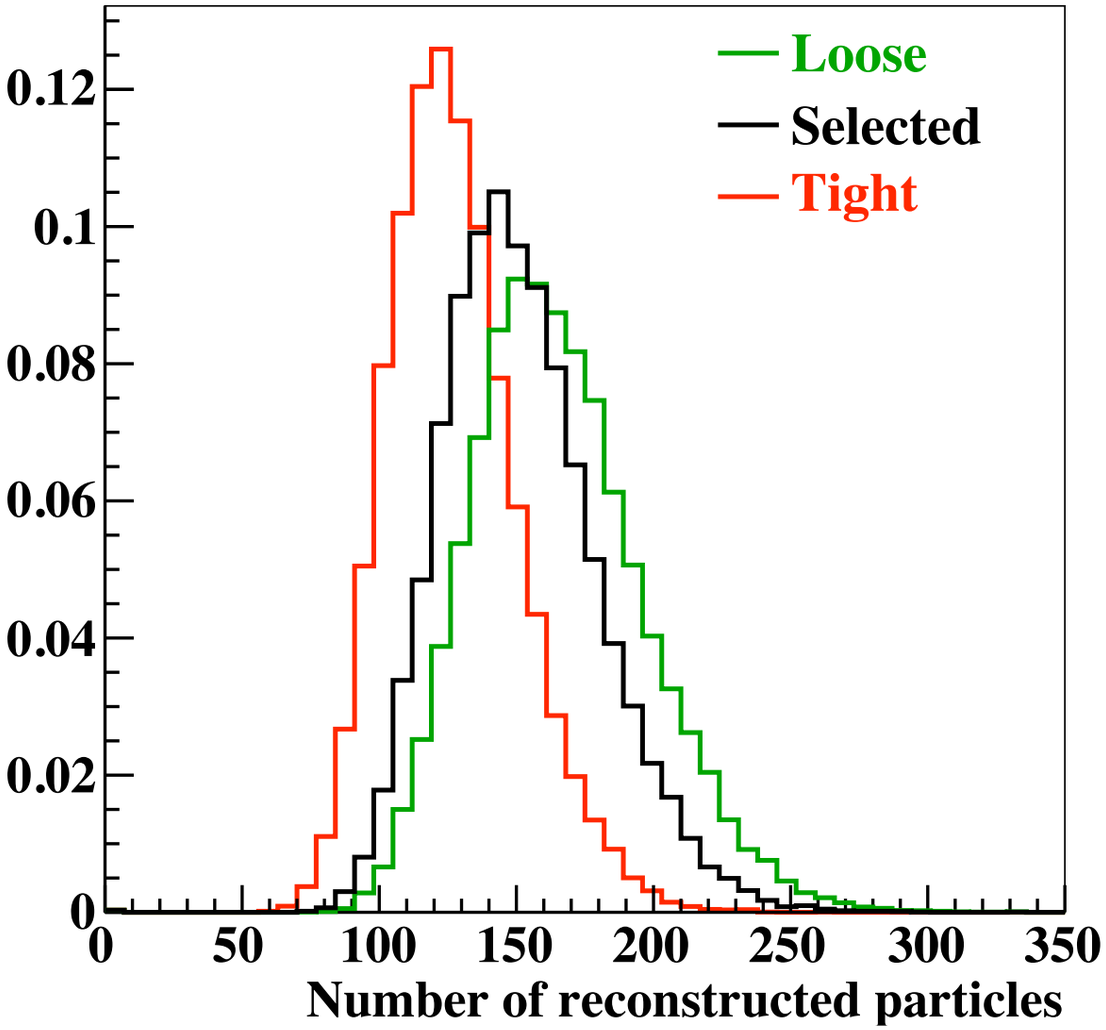


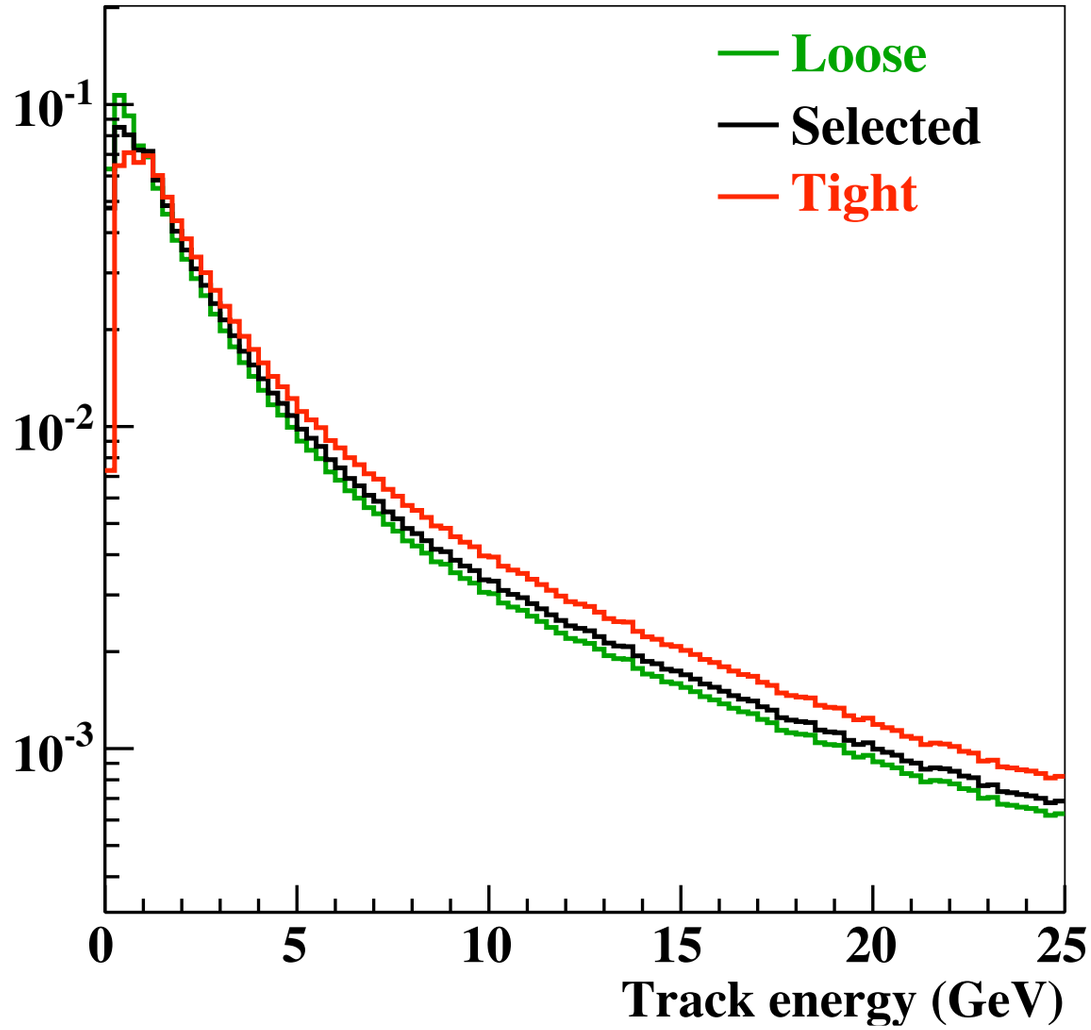
Background suppressed



Background Suppression Cuts

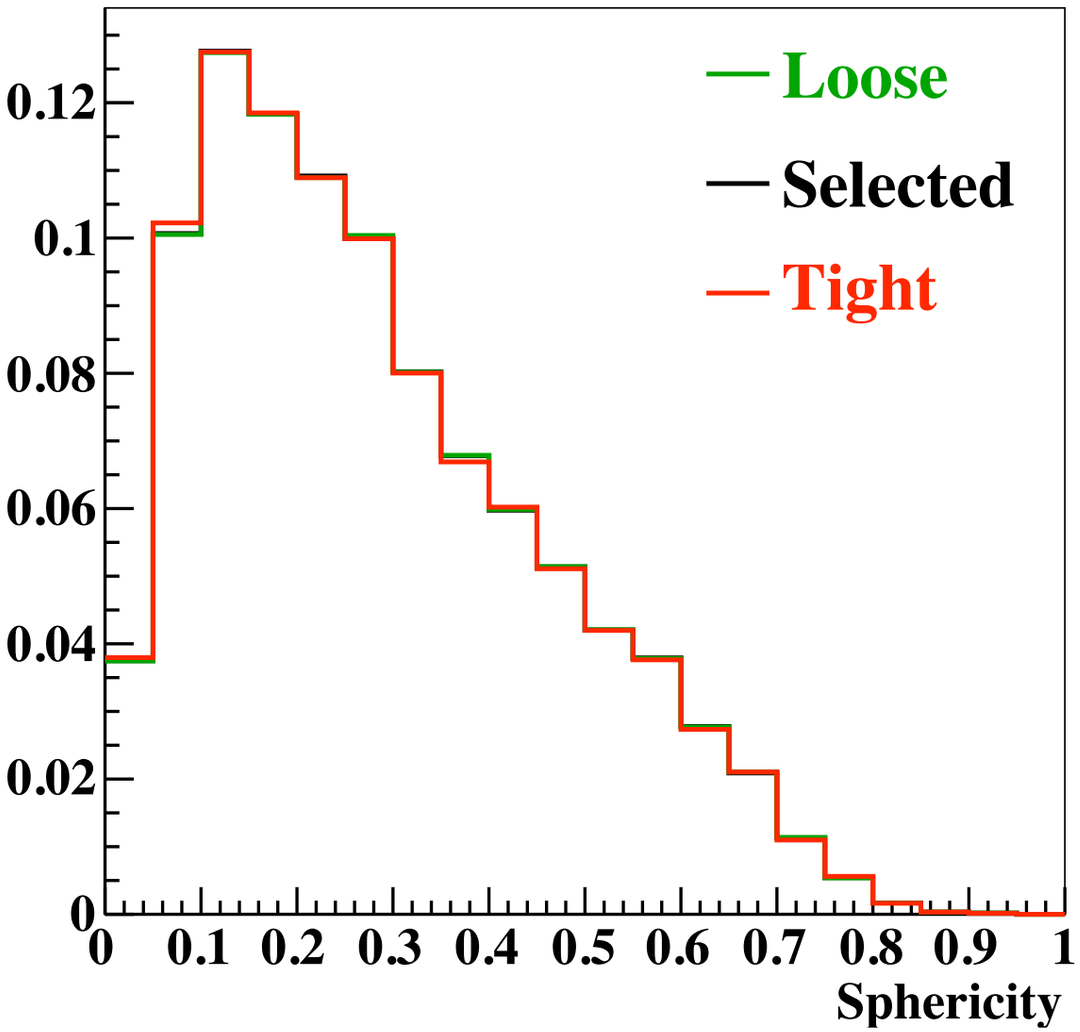
- Three sets of reconstructed particles available
- Different levels of background suppression applied (time, momentum cuts)
- Reconstructed particles typically have very low track energy

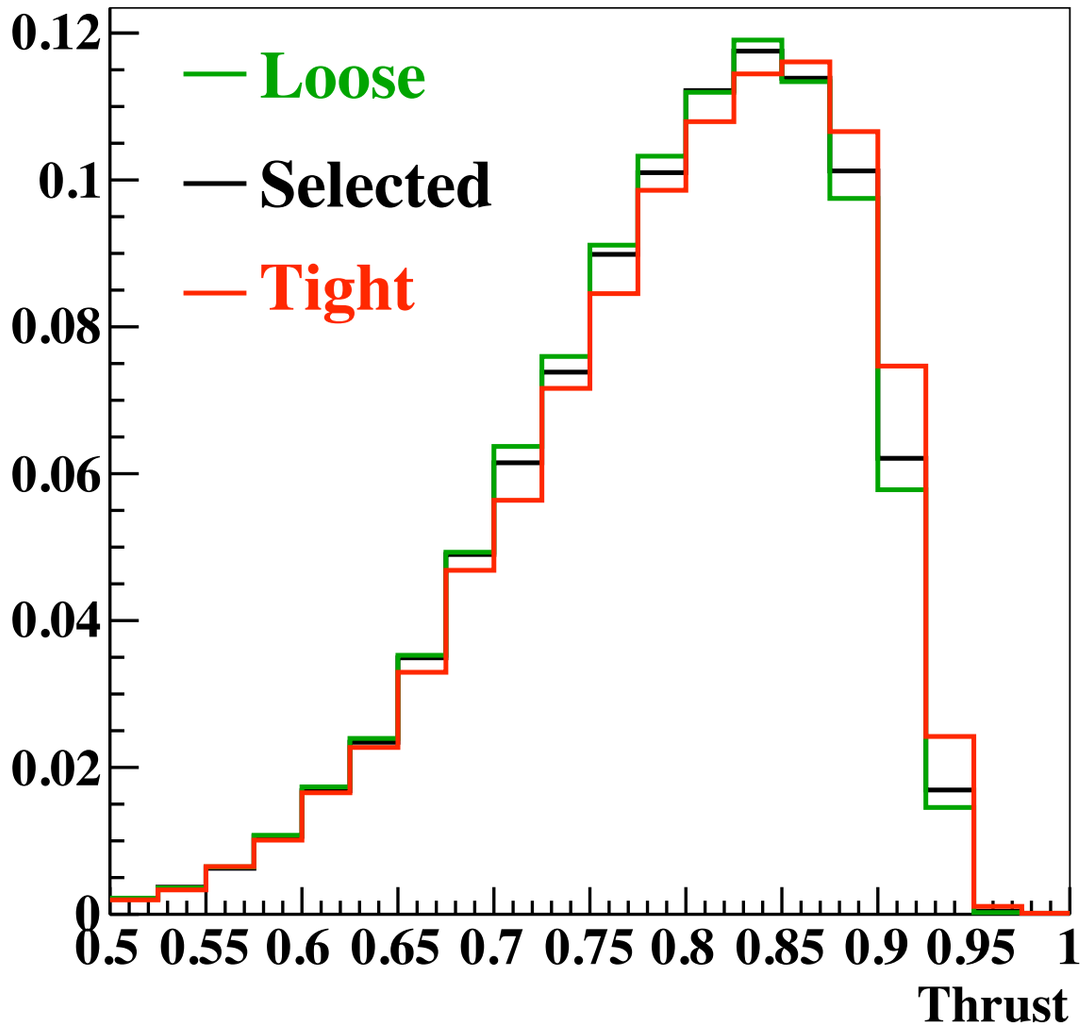




Event Shapes

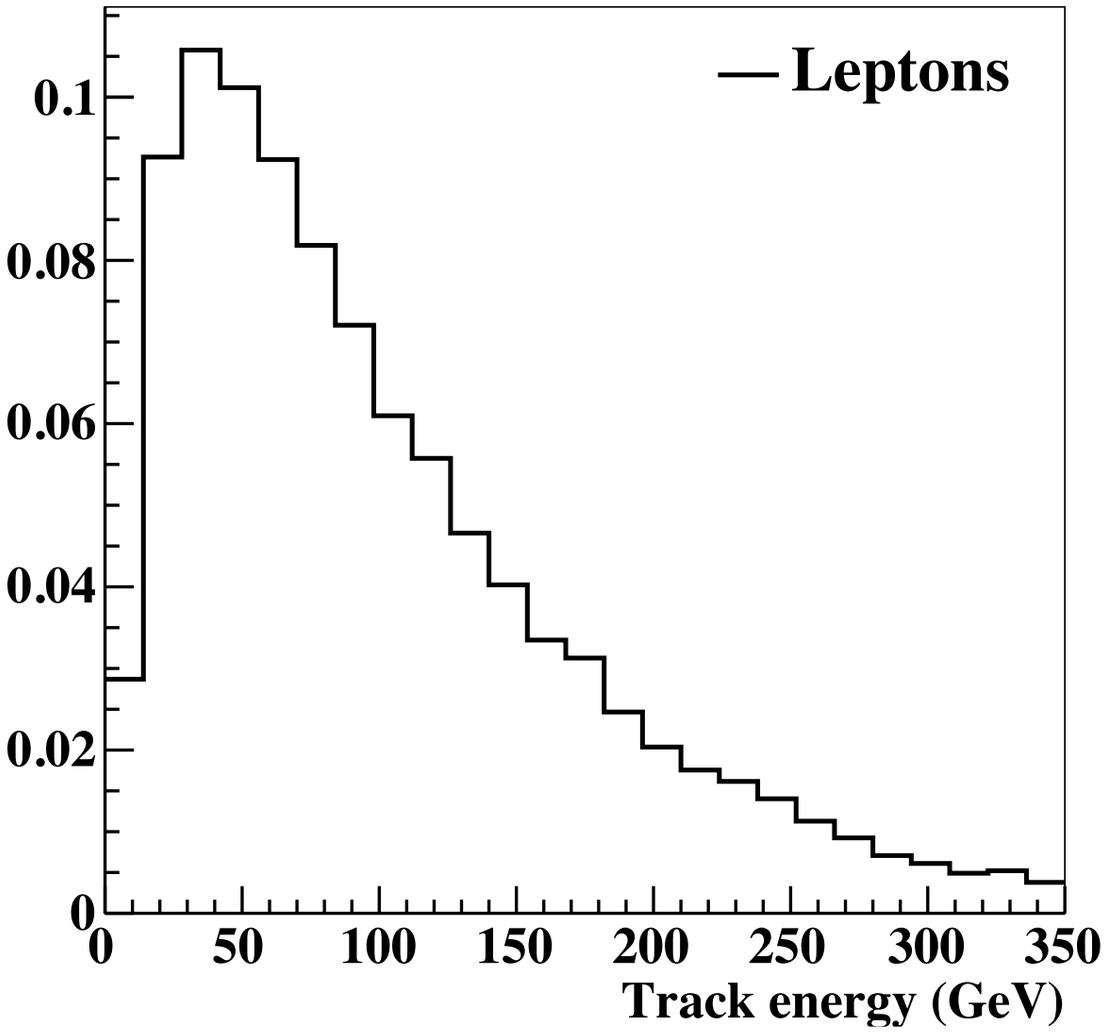
- Describe the shape or balance of the event
- Often used to discriminate from background
- Tight selection removes most background, so higher event thrust

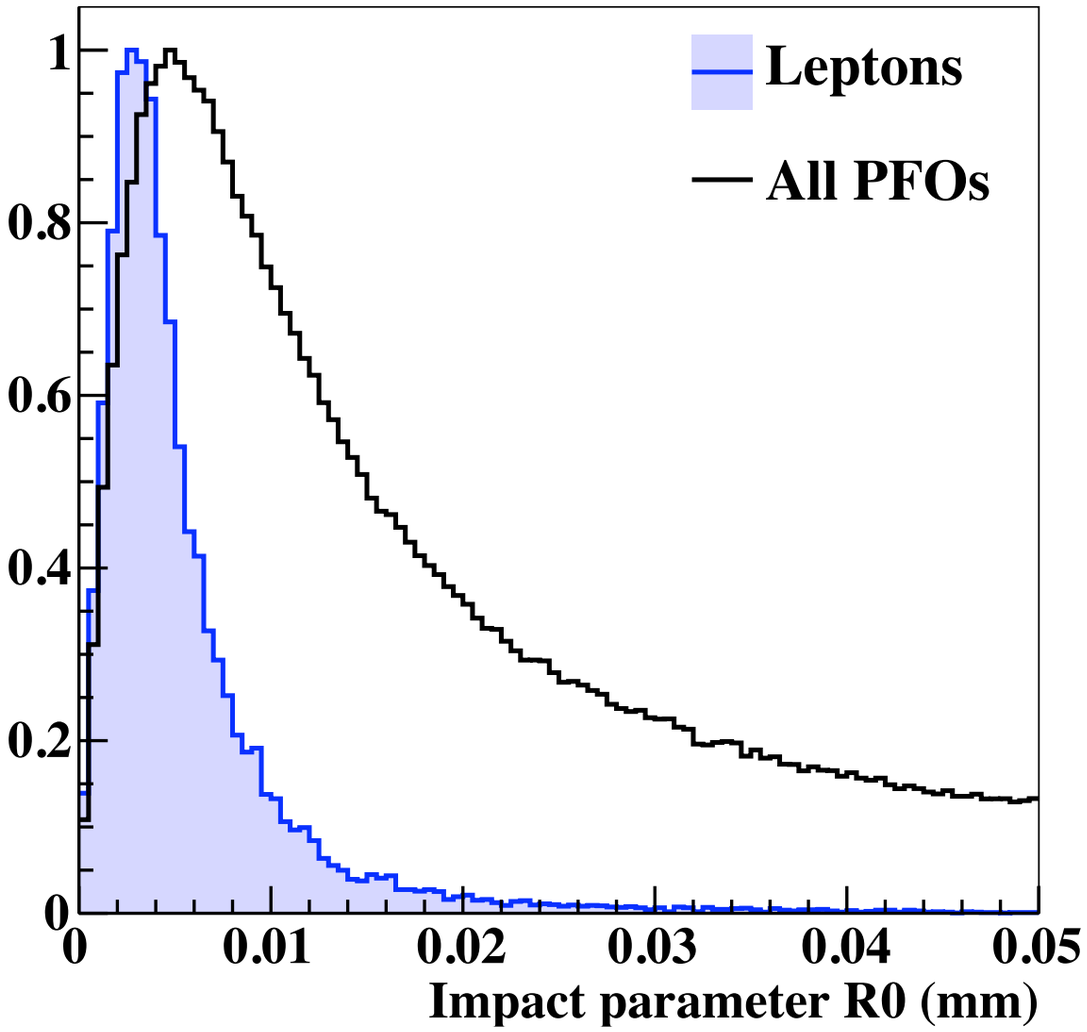




Lepton Identification

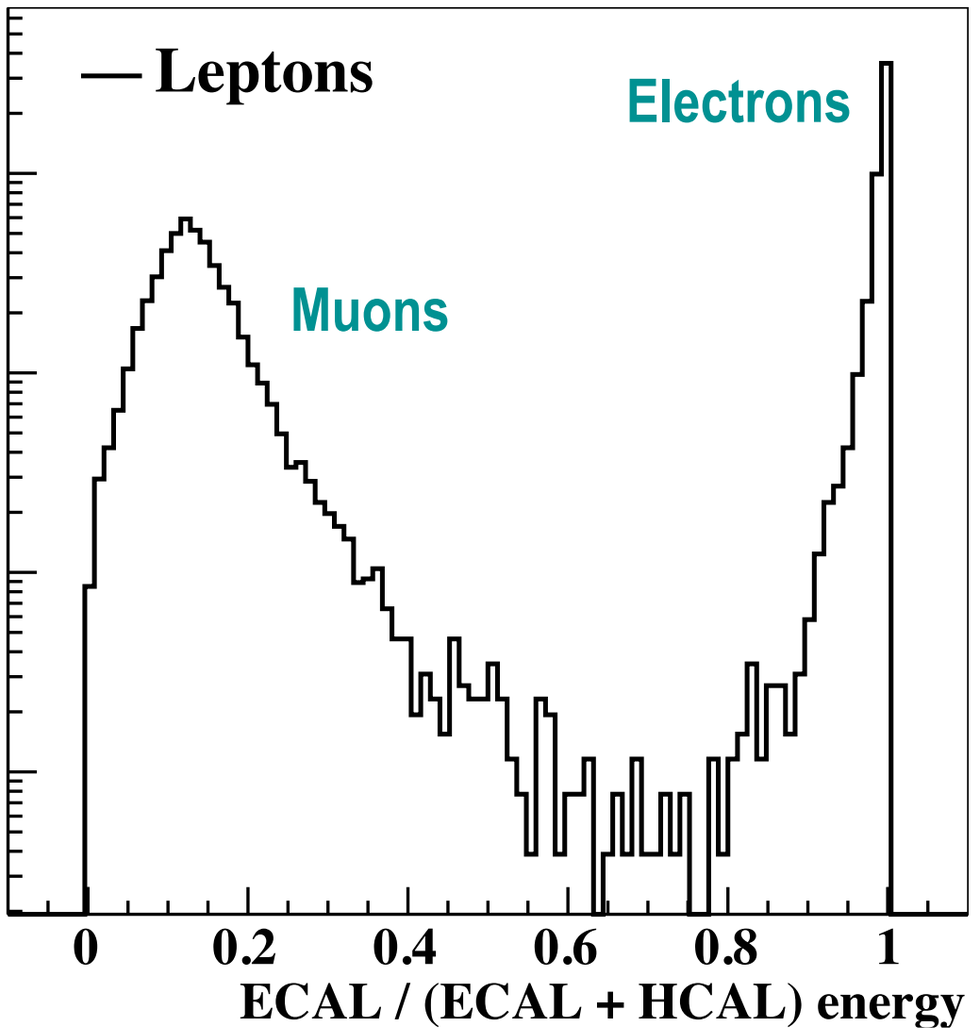
- Truth-matched, reconstructed electrons and muons from W decays
- Lepton track energy much higher than average particle track energy
- Leptons have smaller 3D impact parameter

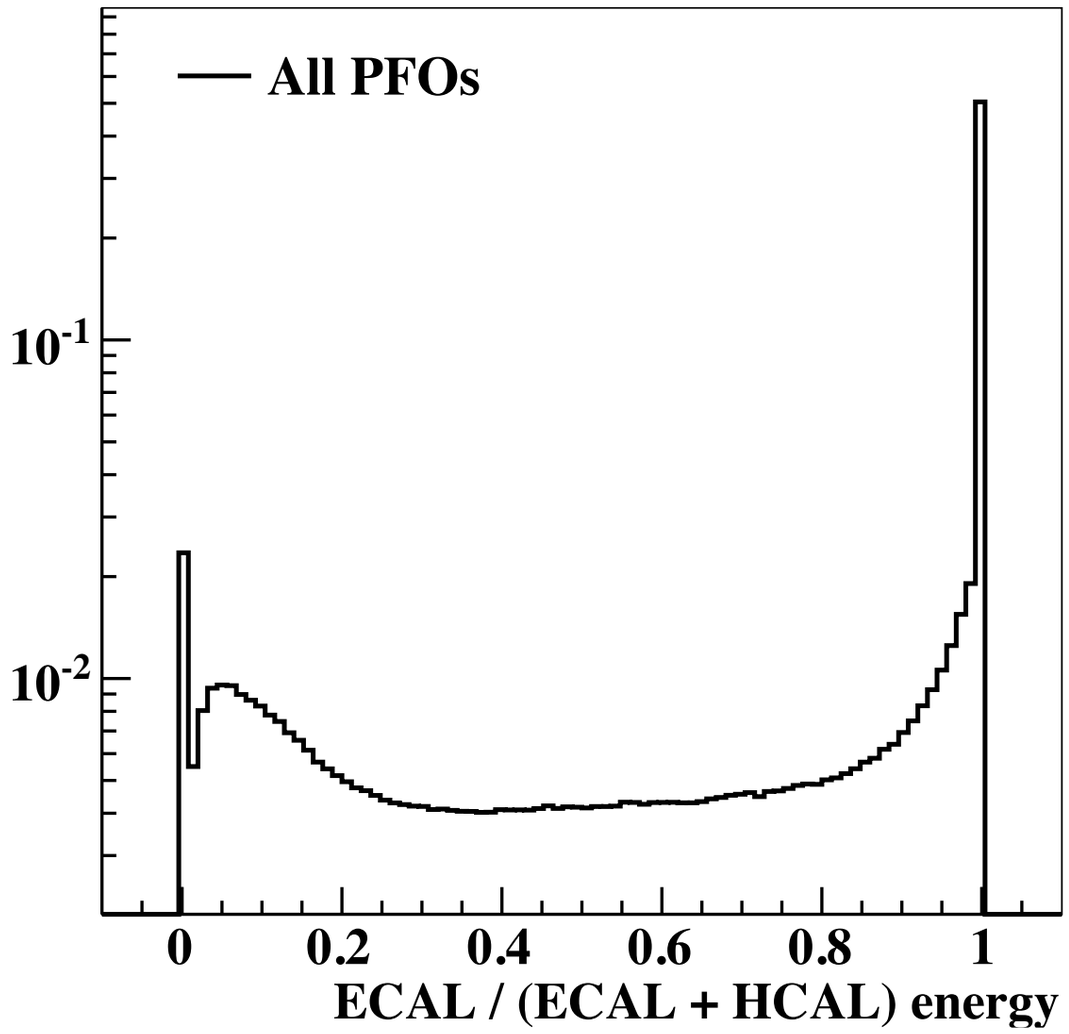




Lepton Identification

- Consider the track energy deposited in ECAL and HCAL
- Gives information on penetration depth and shower size

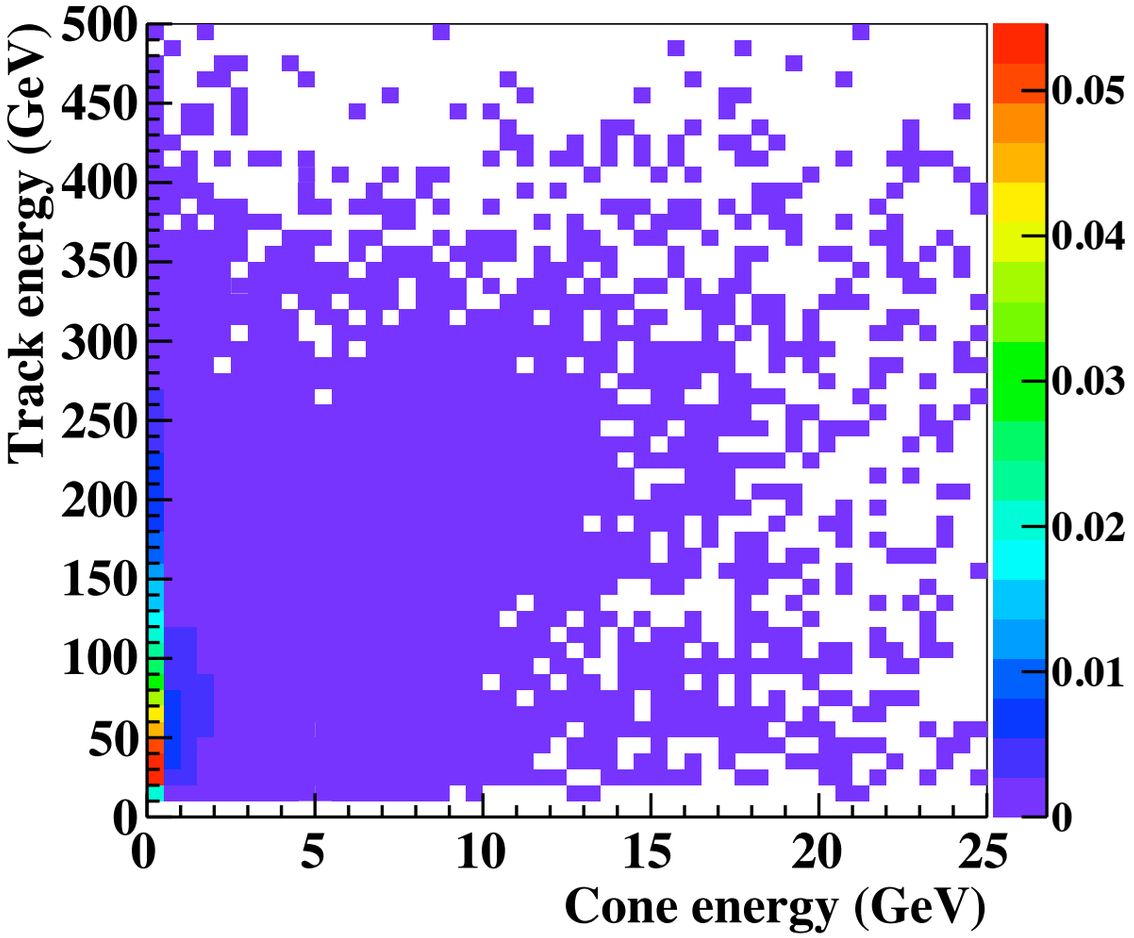




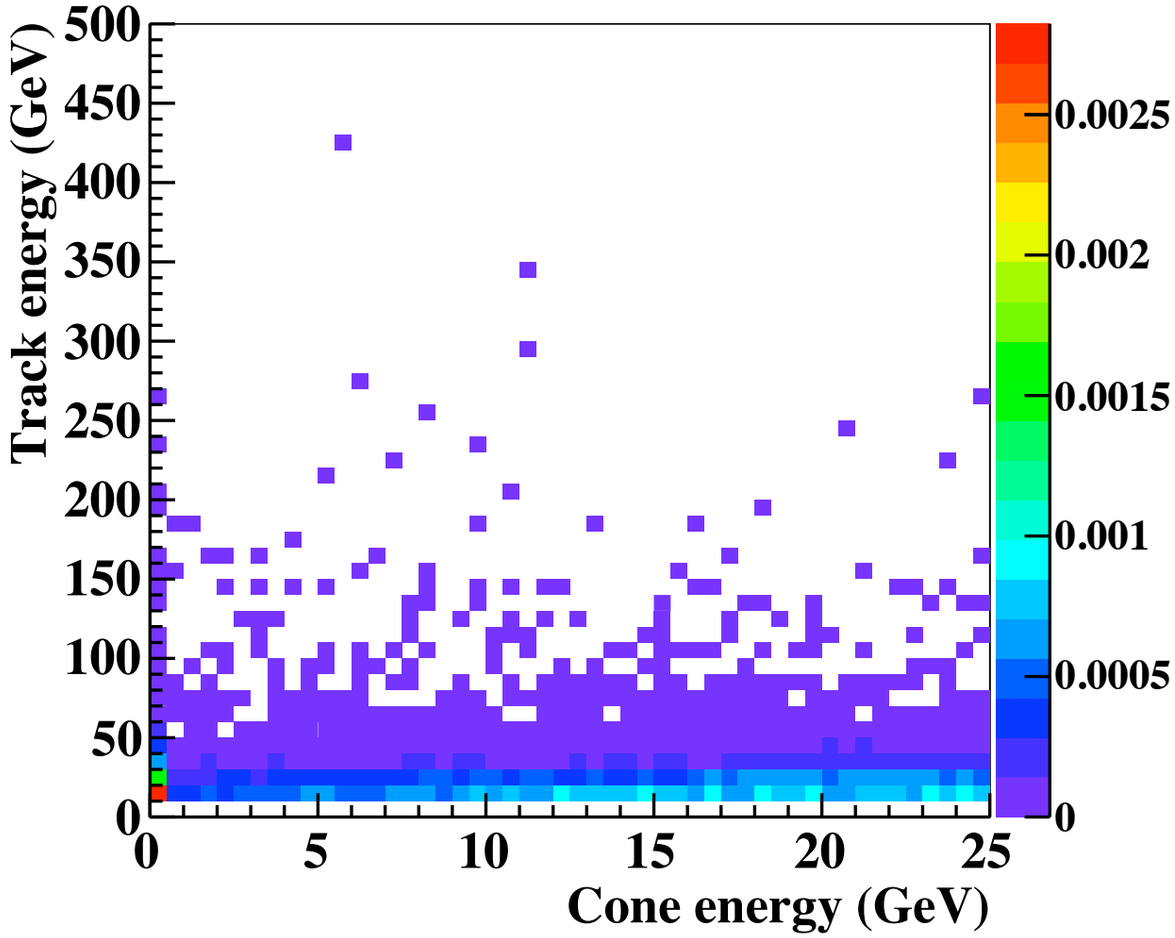
Lepton Isolation

- Calorimeter activity within a cone of size 0.995 around particle track
- With cuts to track energy, PID and IP applied:

Leptons



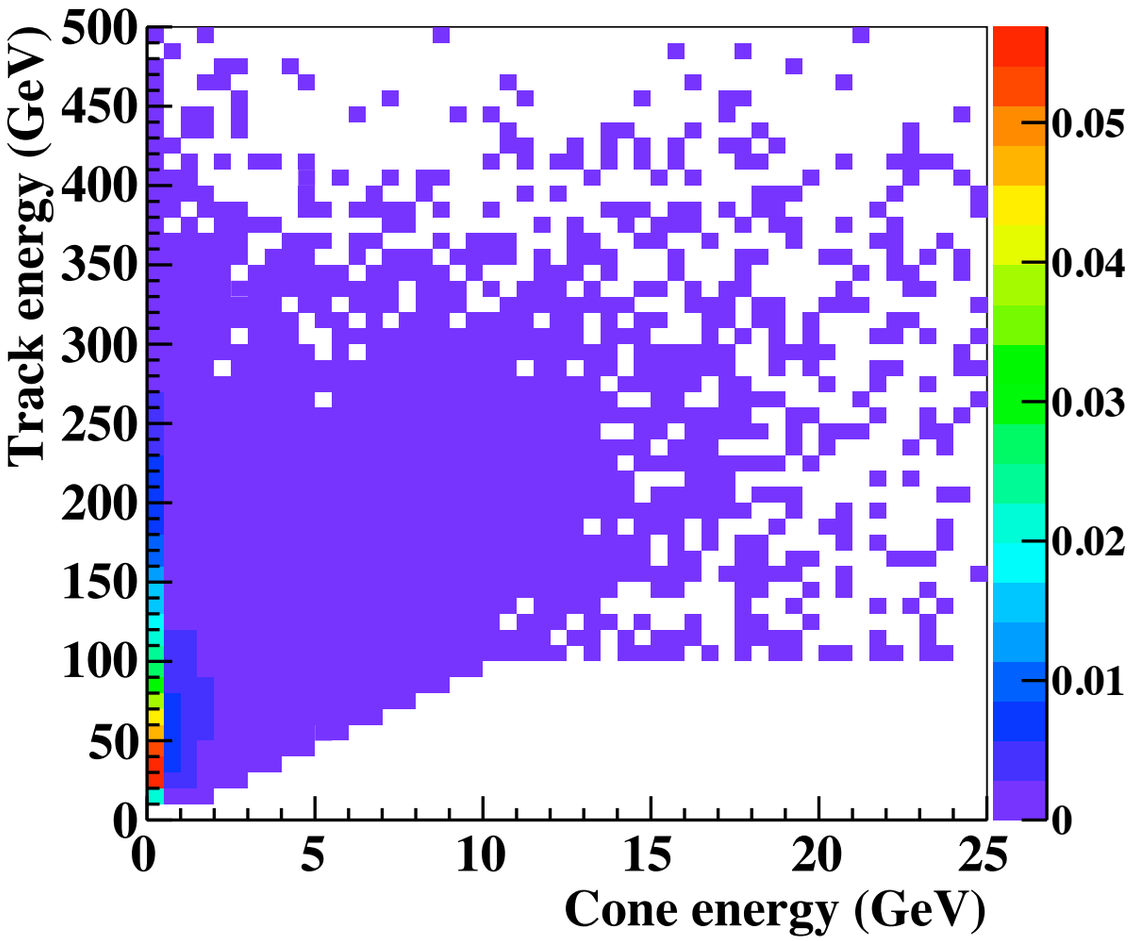
All reconstructed particles



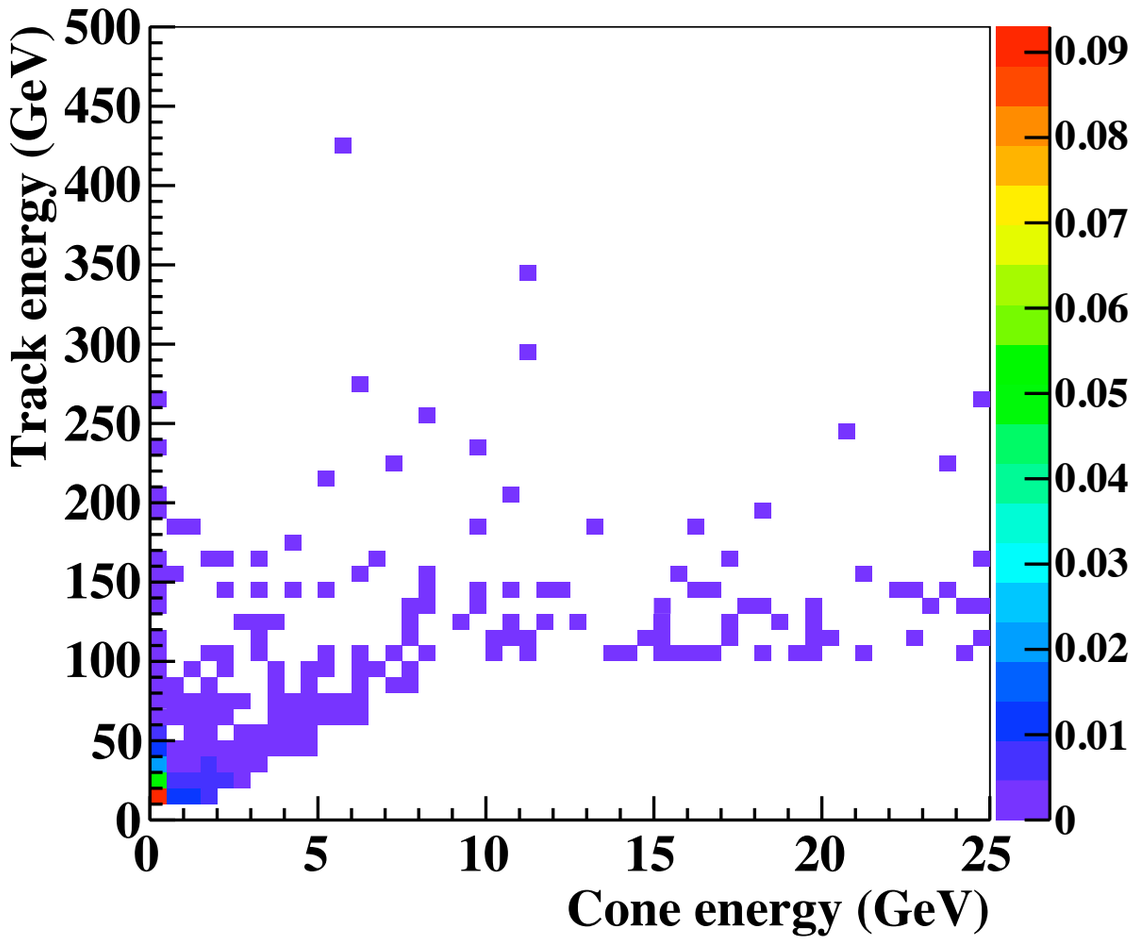
Lepton Isolation

- Calorimeter activity within a cone of size 0.995 around particle track
- Non linear selection chosen

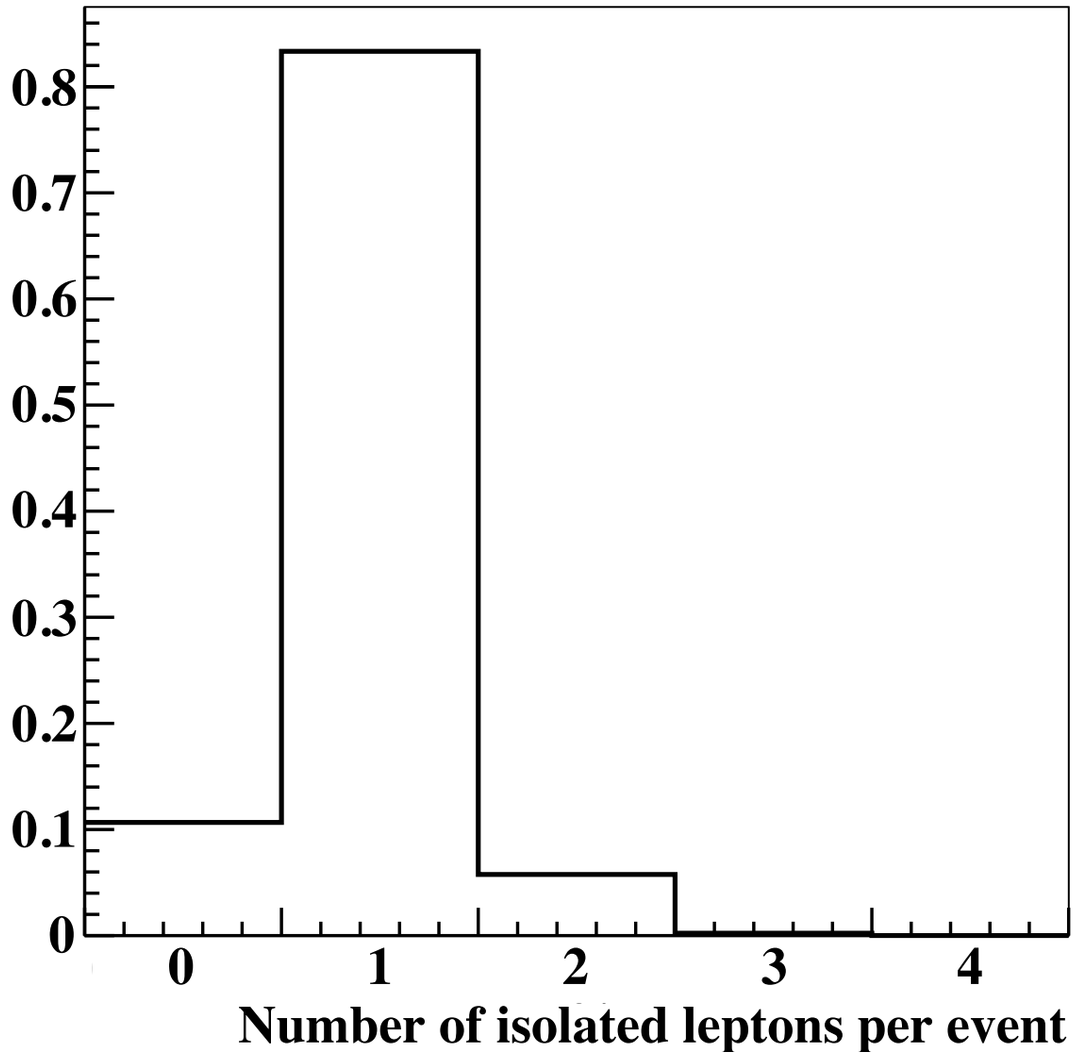
Leptons



All reconstructed particles



Isolated Lepton Finding

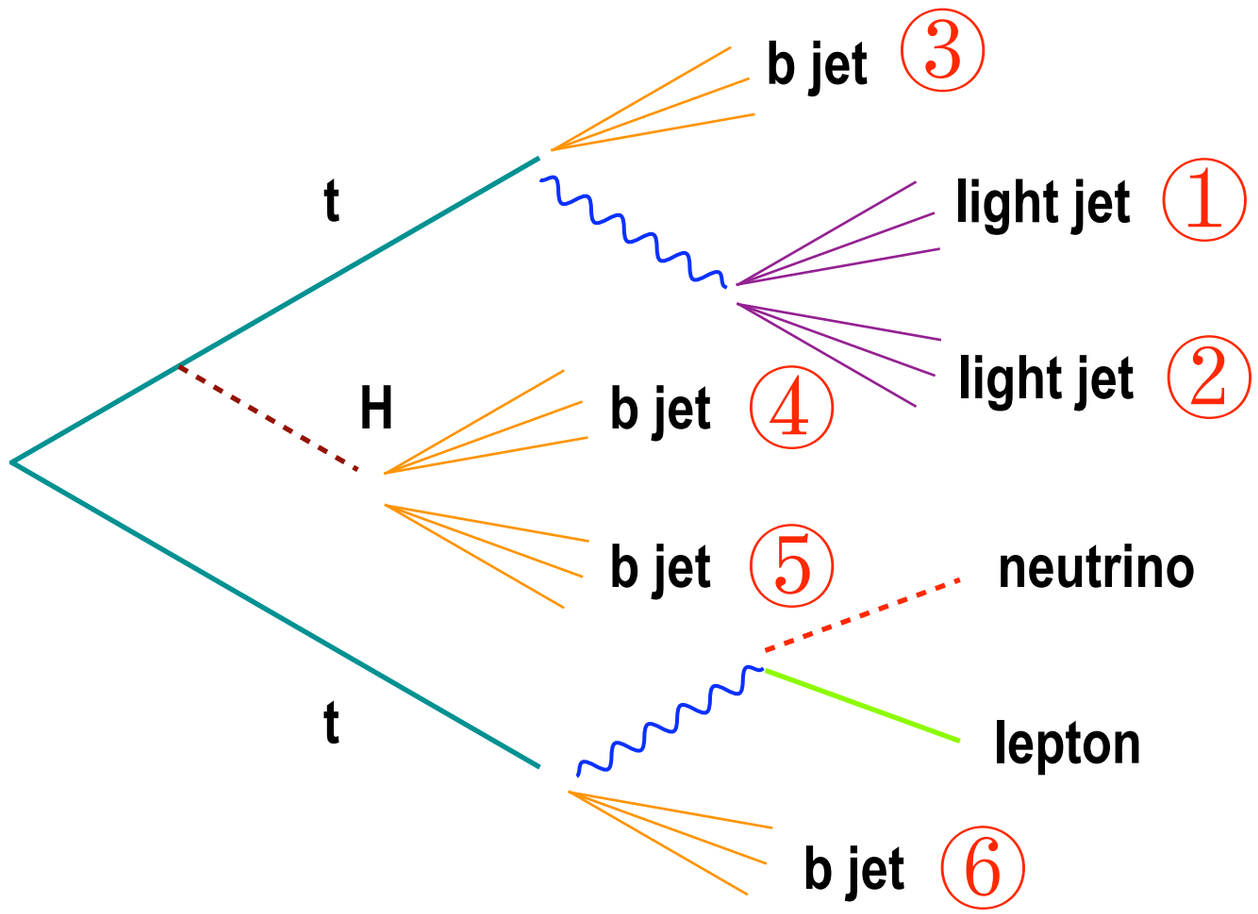


- High efficiency finding the electron or muon from W decay
- If 1 isolated lepton found, > 99% efficiency of finding the right one
- Includes detector acceptance effects (sometimes lepton not reconstructible)

Jet Matching

- Need to group jets together to give W, t, H
- Done by trying every permutation and choosing the smallest chi^2:

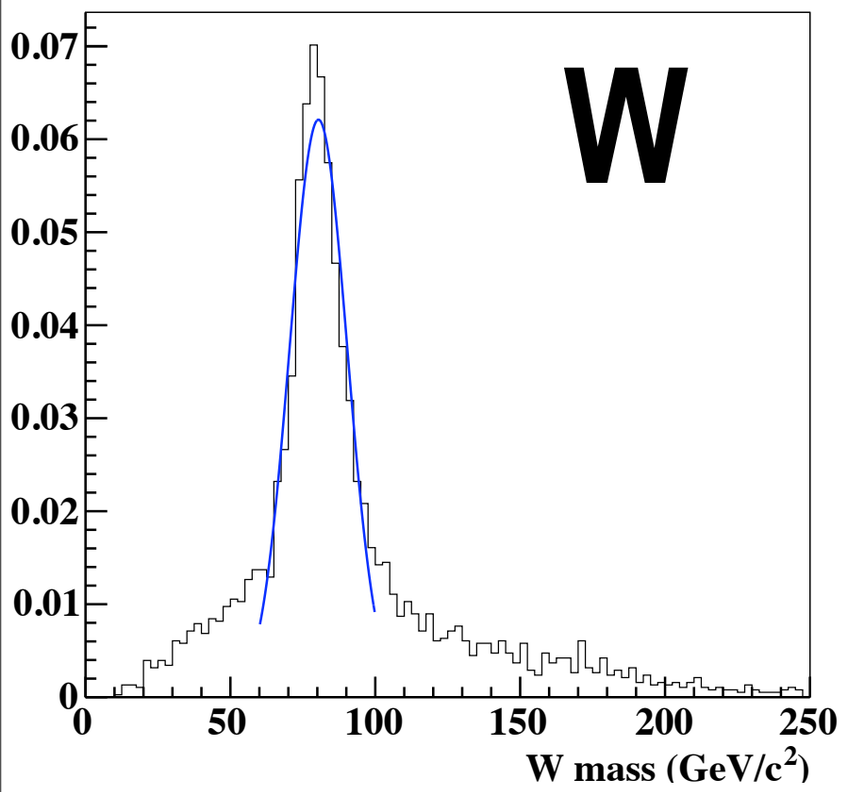
$$\chi^2 = \frac{(M_{12} - M_W)^2}{\sigma_W^2} + \frac{(M_{123} - M_t)^2}{\sigma_t^2} + \frac{(M_{45} - M_h)^2}{\sigma_h^2}$$

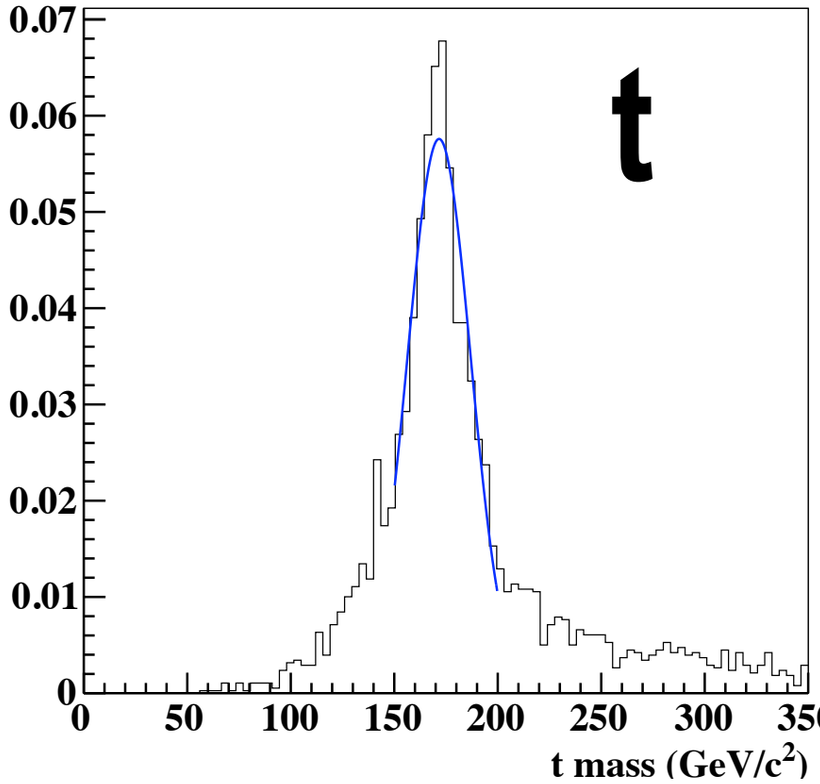


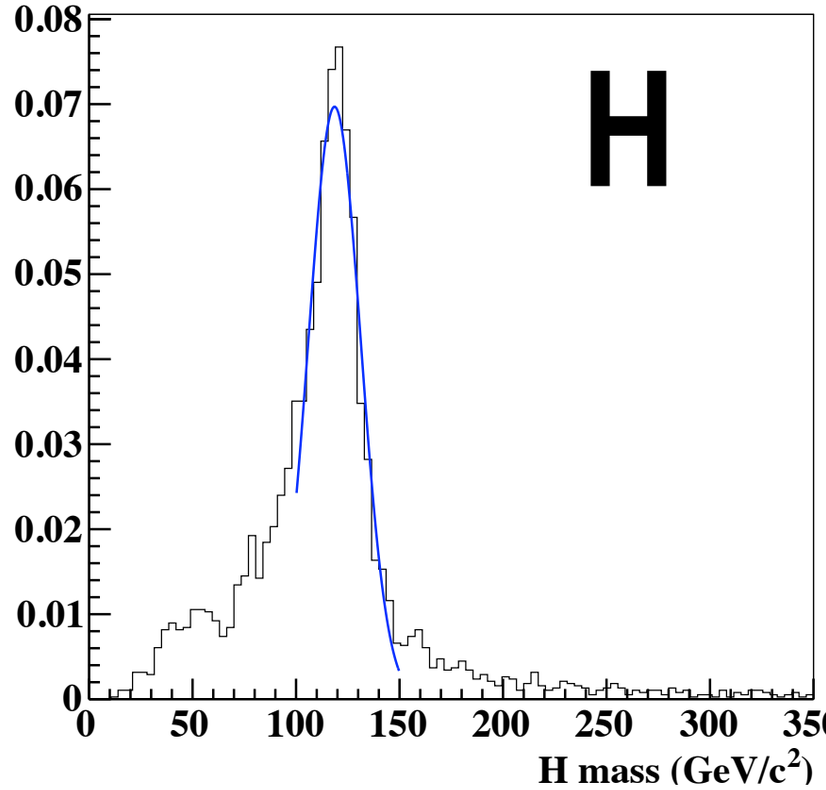
- In order to know the chi^2, need to know di/tri-jet resolutions....

Di and Tri-Jet Resolutions

- Calculated by truth matching particles in the jets to MC quarks

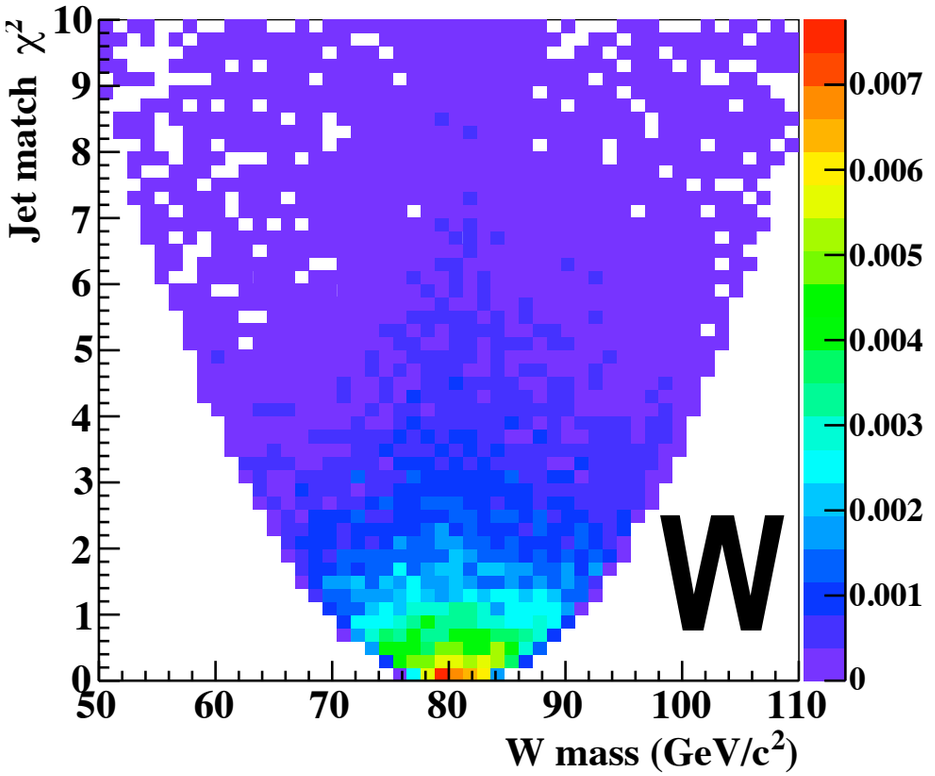


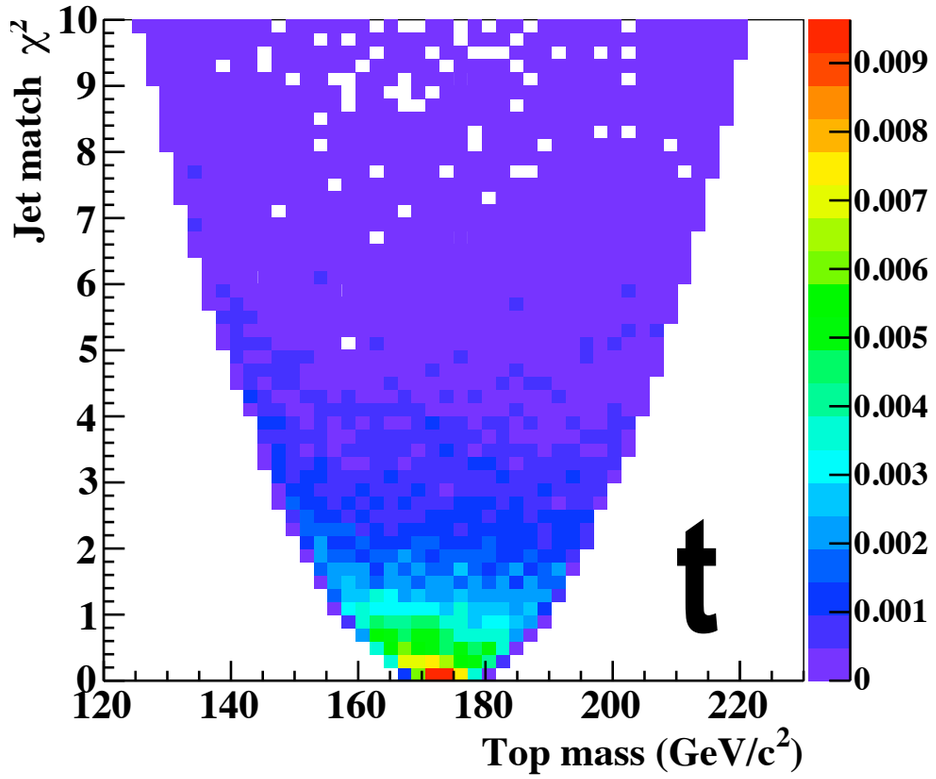




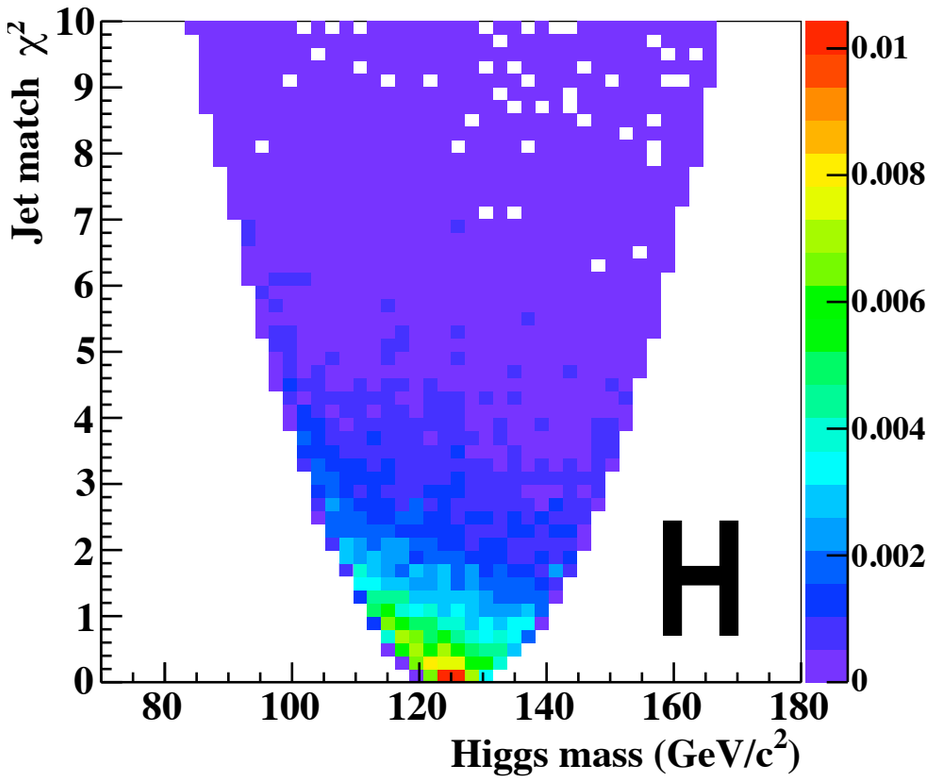
- Resolutions: W ~ 10 GeV/c^2, t ~ 15 GeV/c^2, H ~ 13 GeV/c^2

Jet Matching





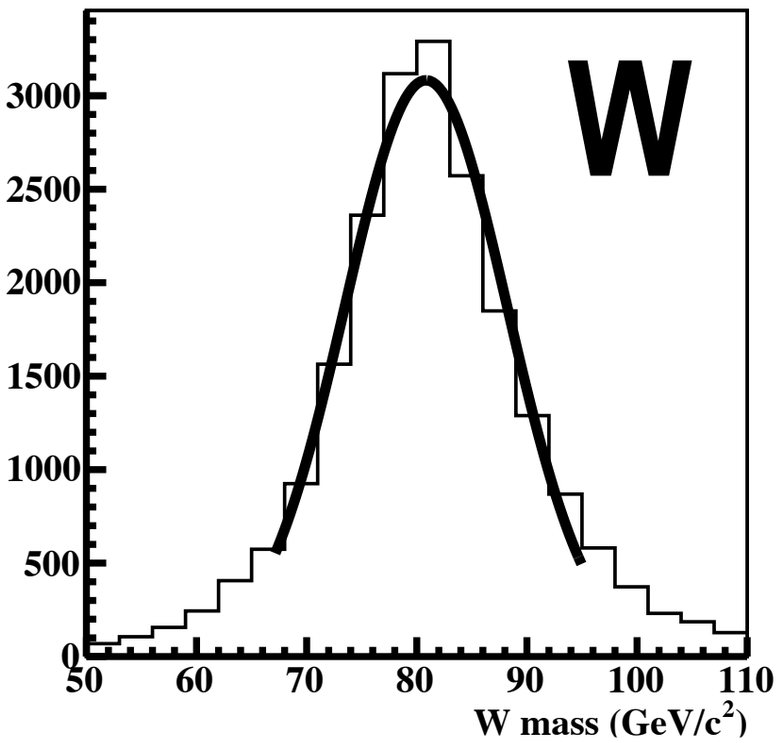
- Jet match chi^2 possible input to selection
- Asymmetry due to energy loss in b-jets

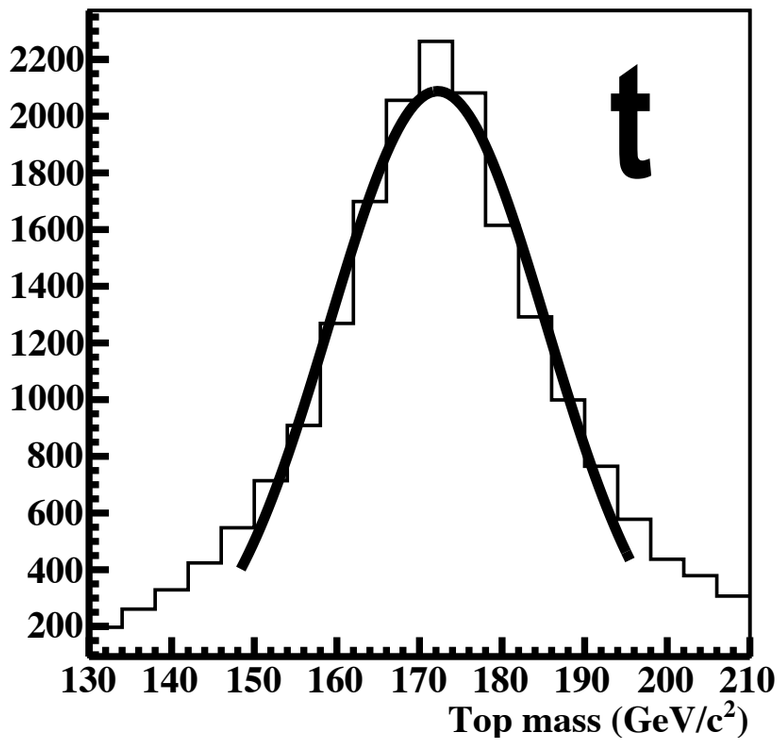


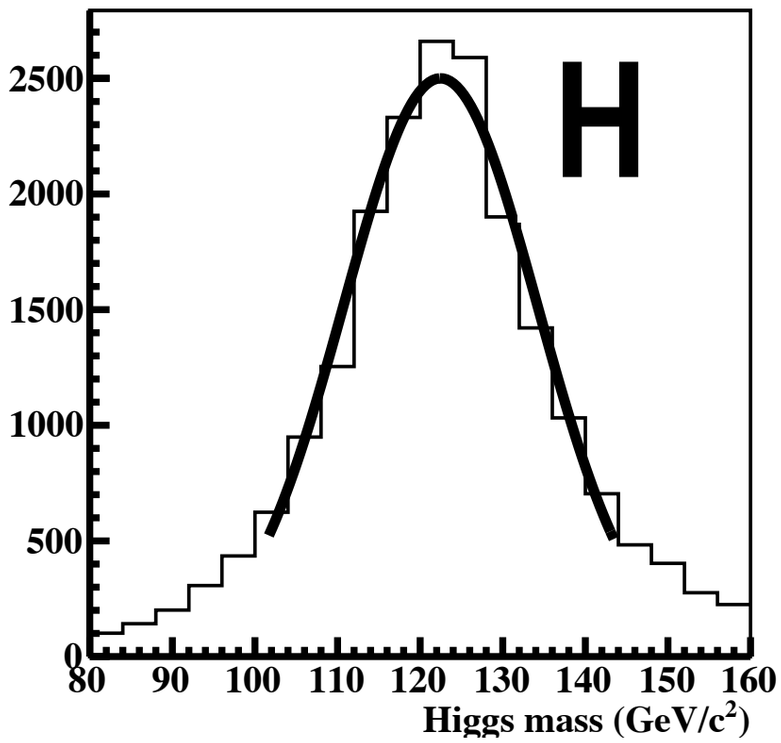
Resolution as a Function of Jet Radius

- Measure the width of W, t, H as a result of the chi^2 minimisation
- Repeat for all timing cut variations, and jet radii between 0.5 and 1.5

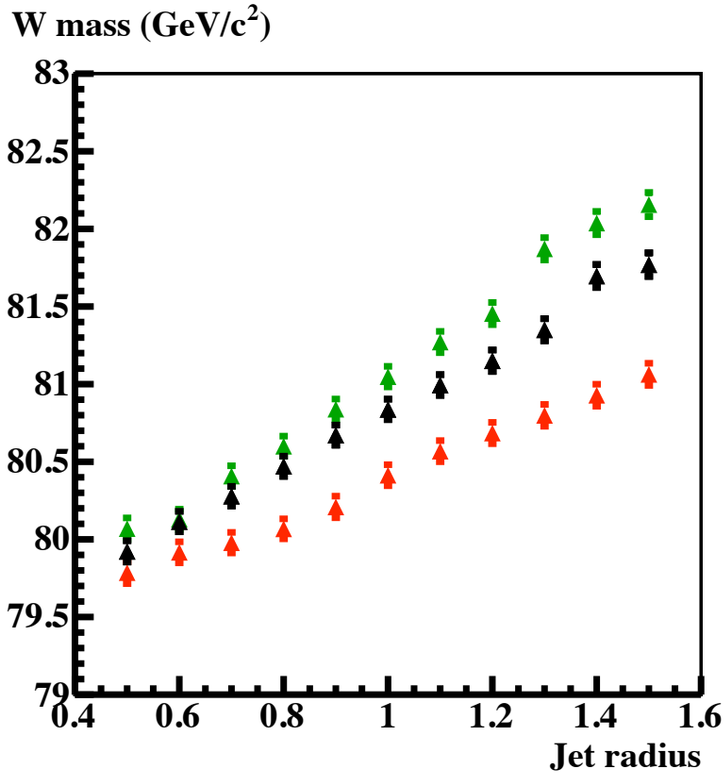
Example resolutions for default timing cuts, jet radius = 1.0

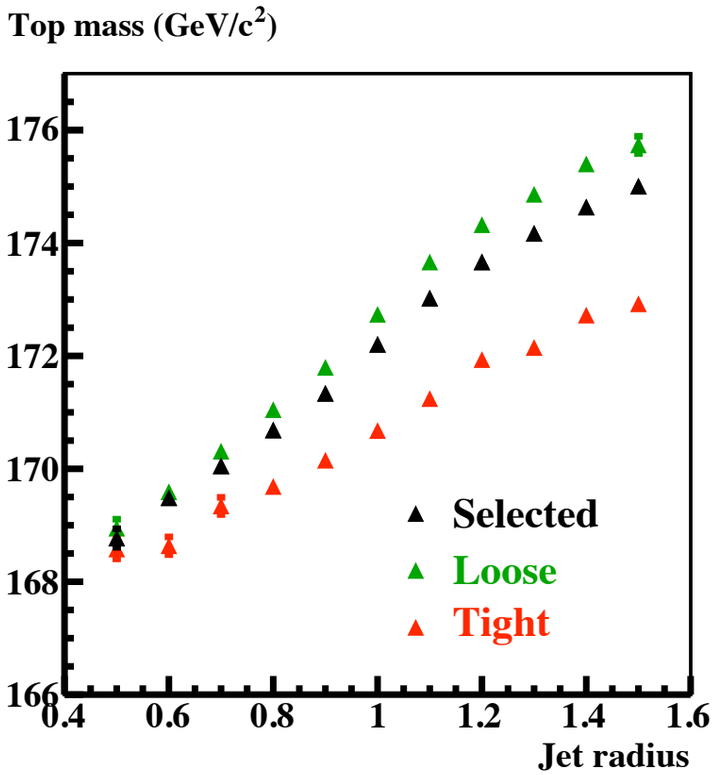


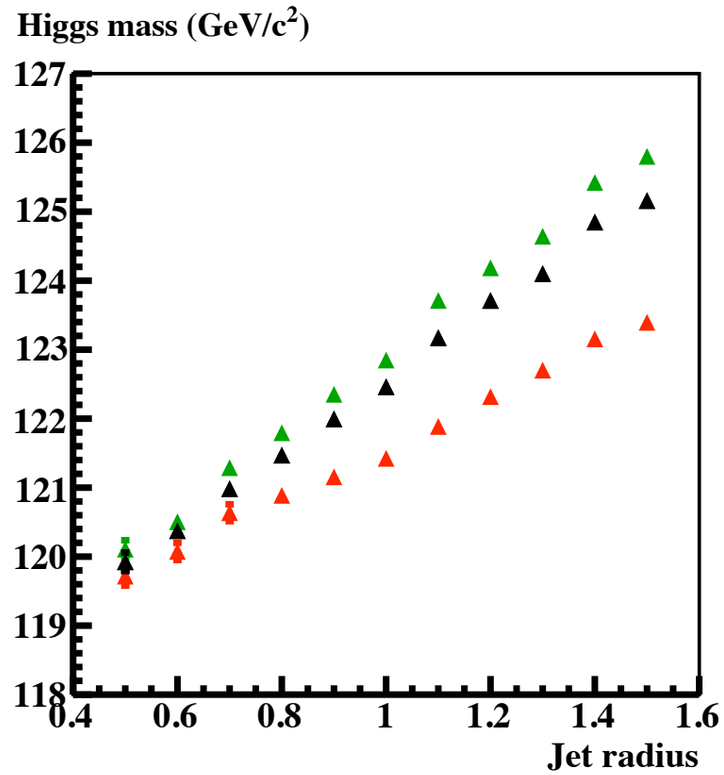


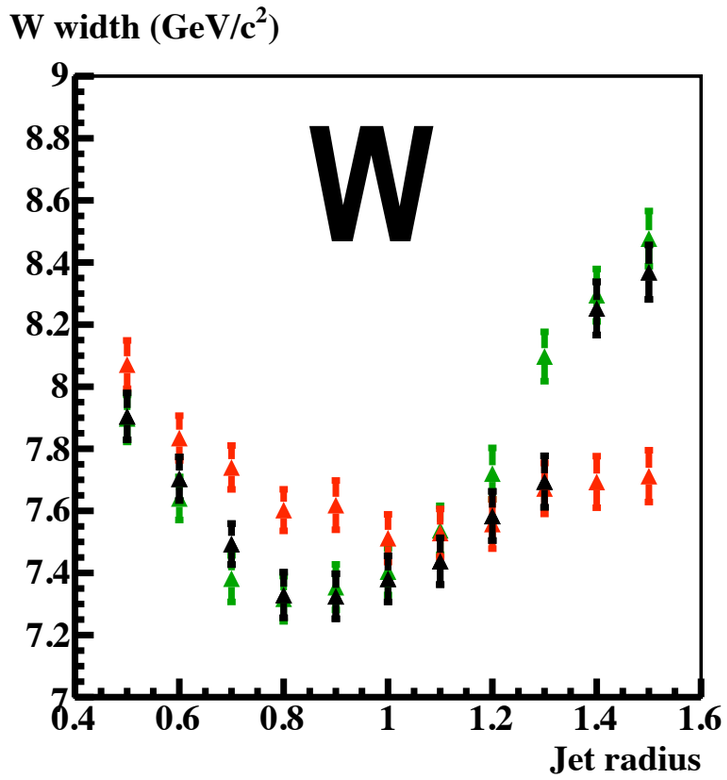


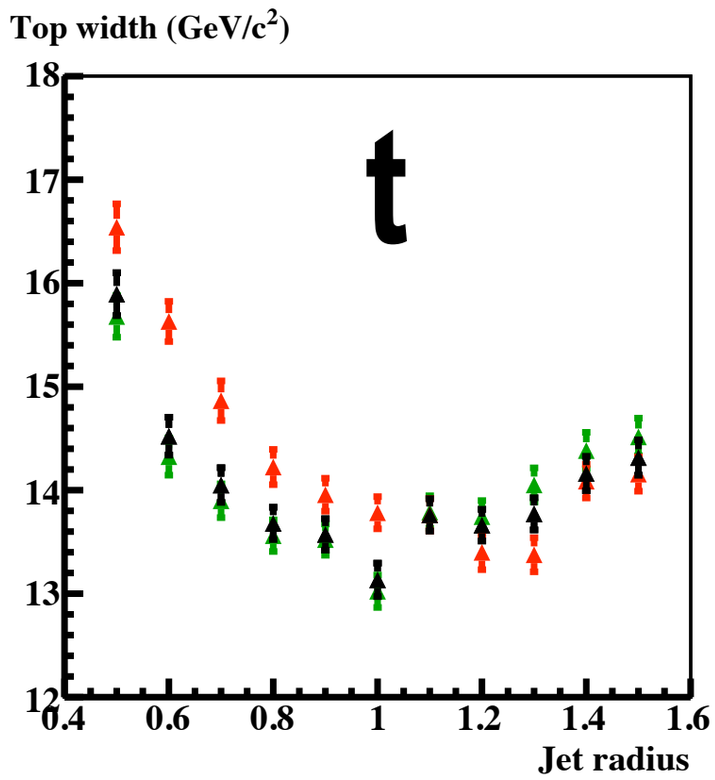
Choice of Jet Radius

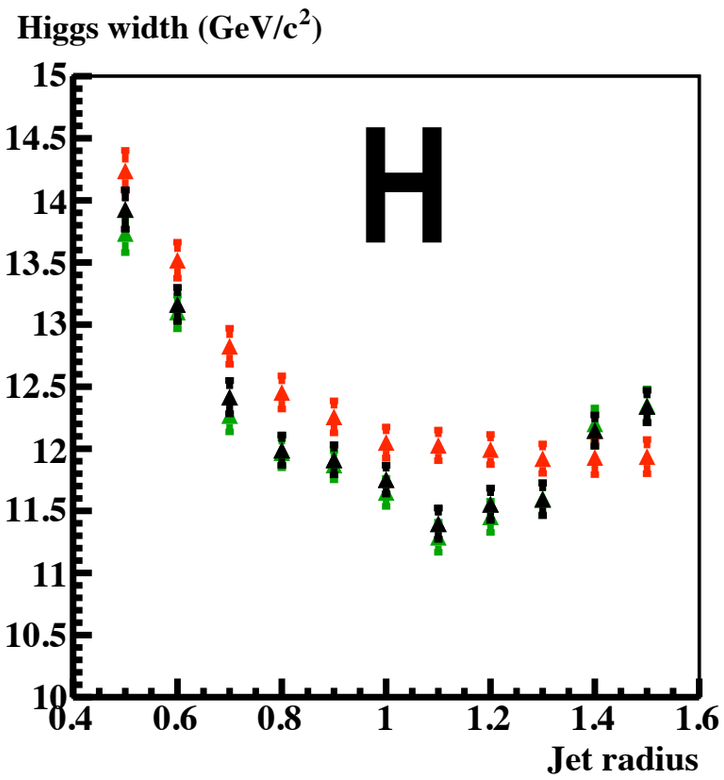








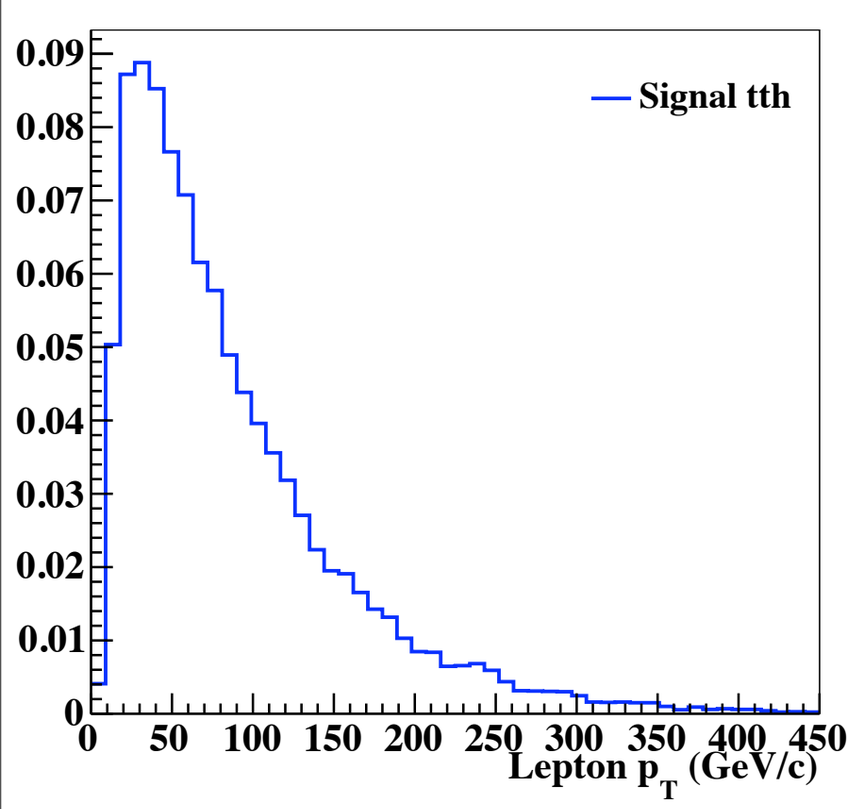


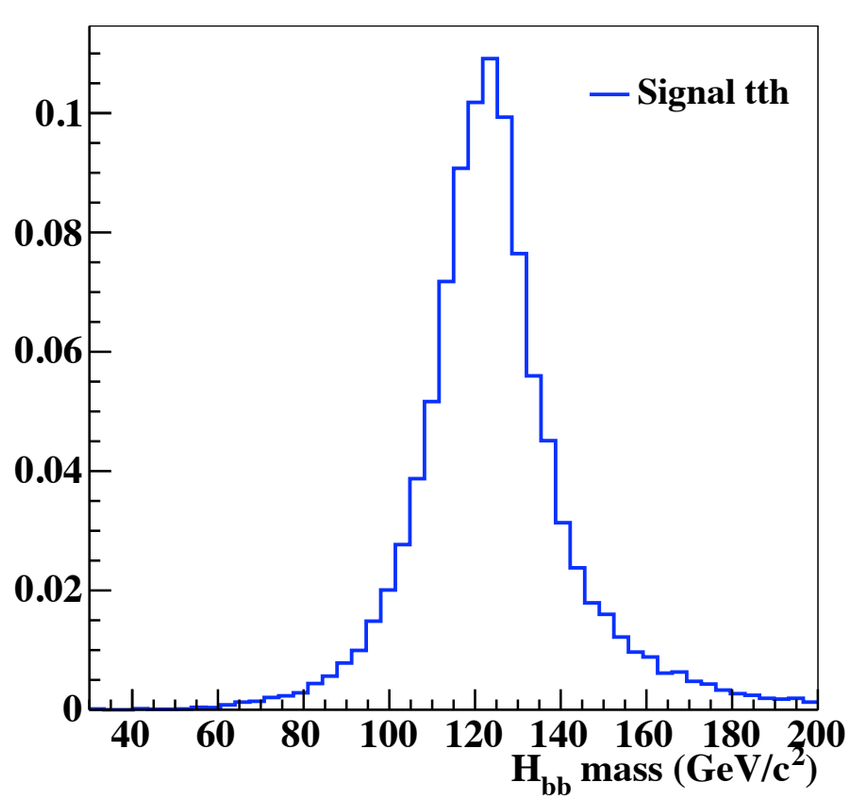


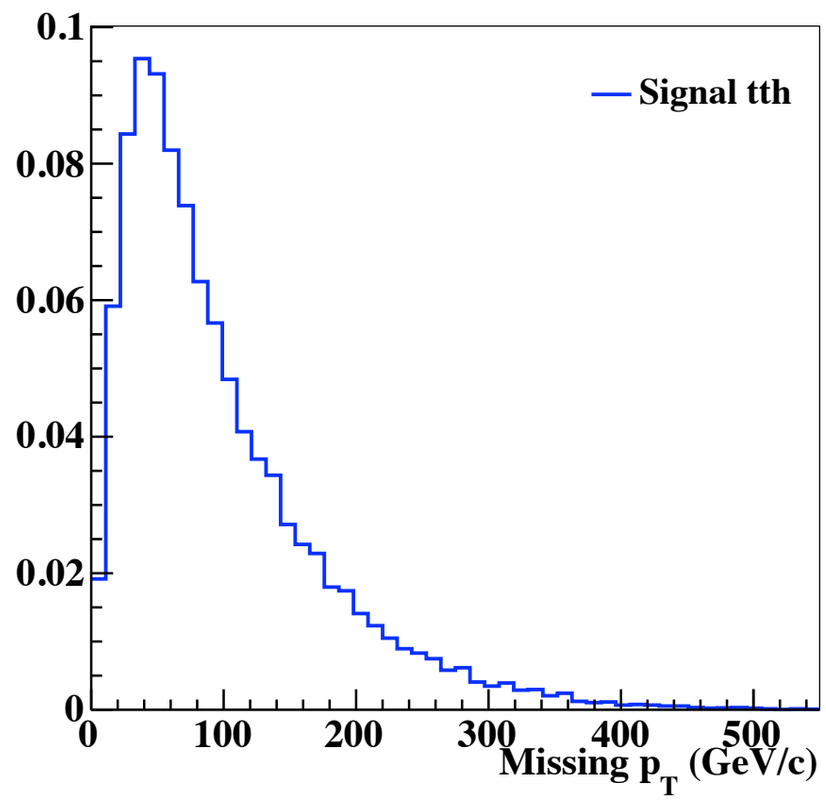
Implies an optimal choice of default background suppression cuts, jet radius = 1.0

Towards a Selection

- Kinematic distributions
- Compare between signal and background



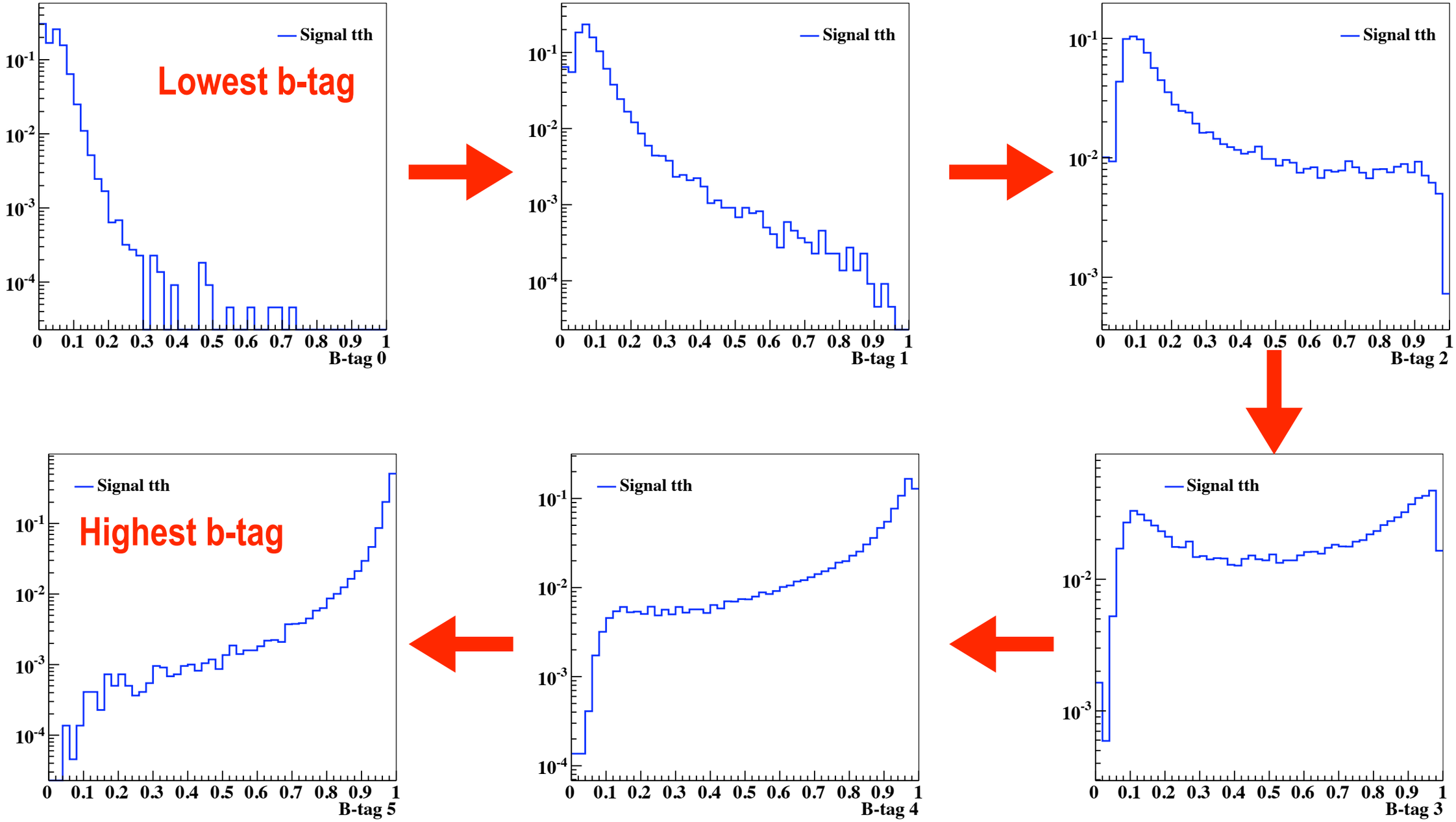




Flavour Tagging

- Flavour tag each jet with a b-tag probability
- Should discriminate signal from background

Six jet analysis b-tag values



Summary and Outlook

- Analysis of tth at 1.4 TeV CLIC, with integrated luminosity of 1.5 ab^{-1}
- Top Yukawa coupling measurement and detector benchmark analysis
- Signal reconstruction possible in challenging detector environment
- Initial conclusions drawn - beam background suppression cuts and jet radius chosen
- Ready to analyse physics background samples and choose a selection