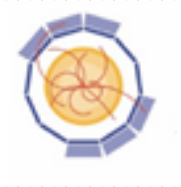

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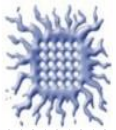

# Higgs to ZZ* at 1.4 TeV

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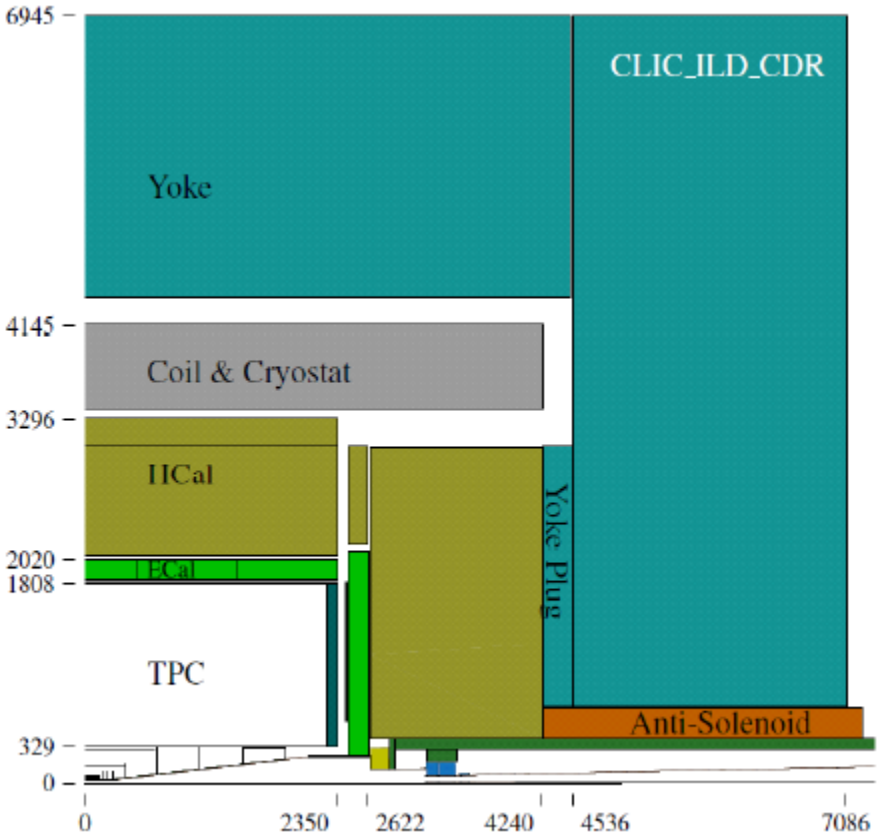
*CLIC Workshop 2015, 26-31 January, CERN*

# Overview

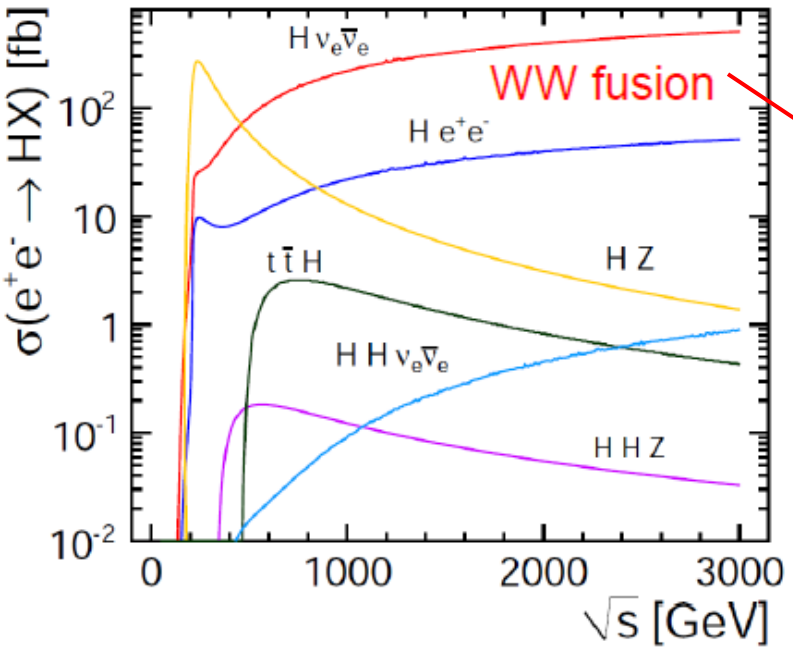
- Simulation and reconstruction
- Signal and background x-sec
- Analysis strategy
- MVA results
- Conclusions

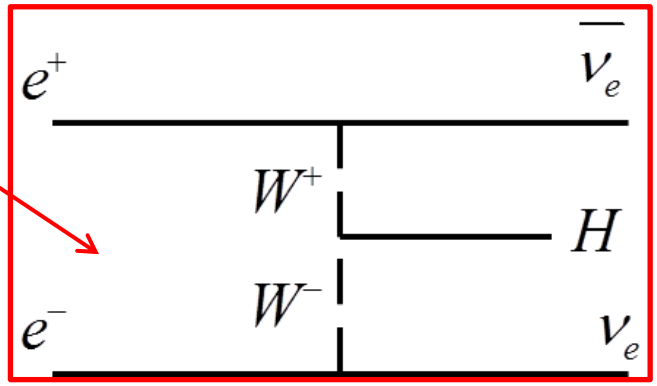
# Detector simulation and reconstruction

- Full CLIC ILD CDR detector simulation of signal and background events
- Same software chain as used for the CLIC CDR
- Full Geant4 detector simulation
- Overlay of $\gamma\gamma \rightarrow$ hadrons background
- Full event reconstruction



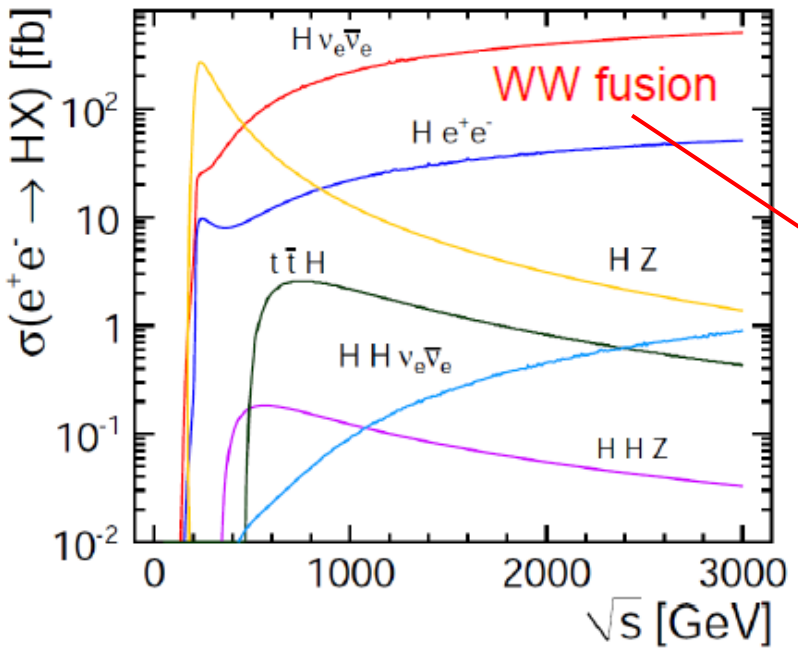
# Higgs production at 1.4 TeV



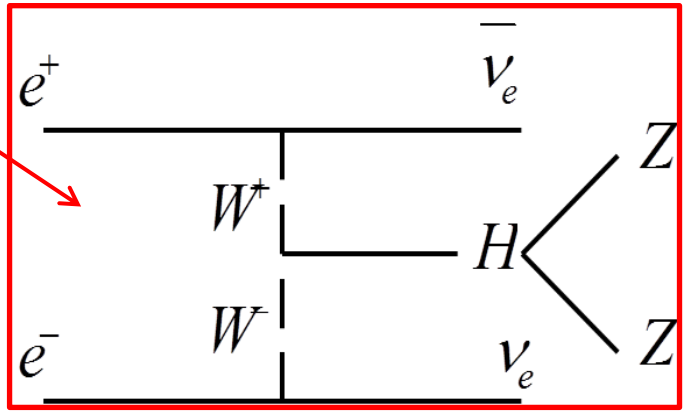




- Assuming mH = 126 GeV
- Using WHIZARD v.1.95, including ISR and CLIC BS
- WW fusion dominant H production process
- $\sigma(e^+e \rightarrow H\nu\nu) \approx 244$ fb (with unpolarized beams)
- Hνν events: 370000/1.5 $ab^{-1}$

# Signal process




Signal : 2 jets + 2 leptons (muons, electrons or taus) + missing energy

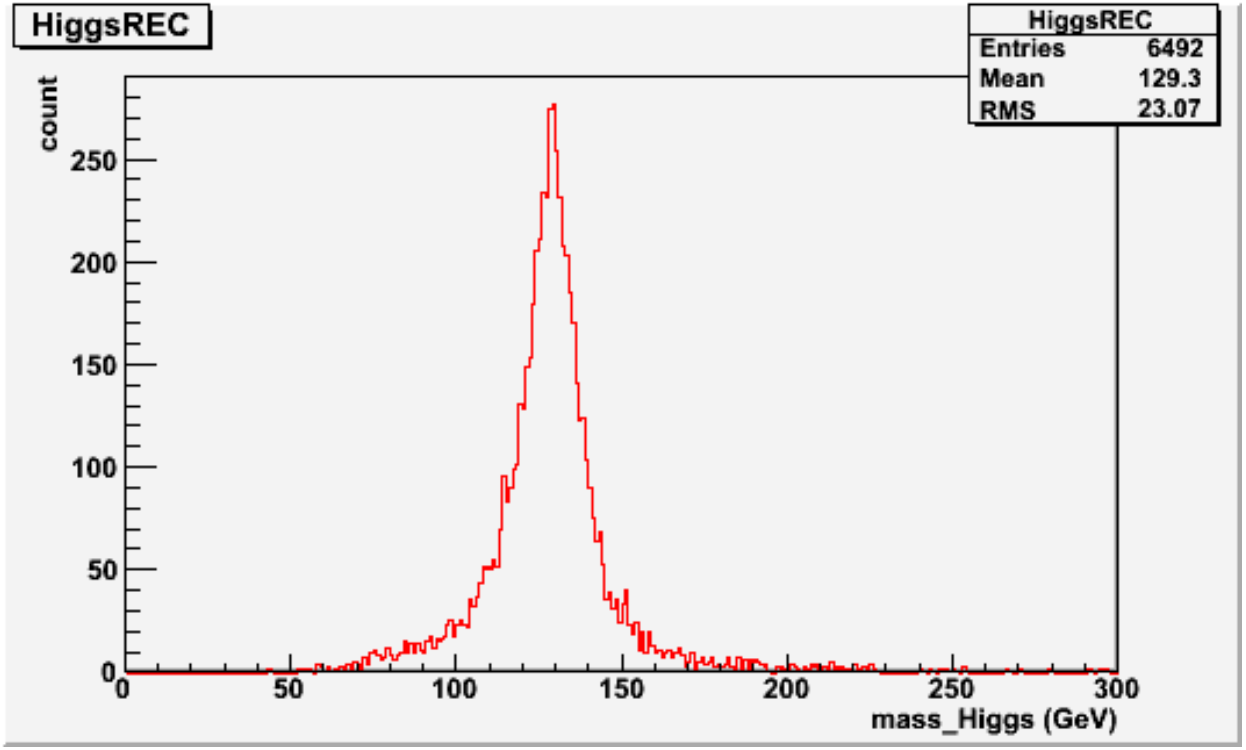



Higgs coupling: $\frac{g^2_{HWW} \cdot g^2_{HZZ}}{\Gamma_H}$

- BR(H→ZZ*) ≈ 2.89% ⇒ $\sigma_{HWW}$ × BR ≈ 7.05 fb
- BR(Z→e+e−, Z→μ+μ−, Z →ττ) ≈ 10%
- $N_s$(ZZ*→qqe+e−, ZZ*→qqμ+μ−, ZZ*→ qq ττ ) ≈ 1500/1.5 ab$^{-1}$

# Signal

The reconstruction is based on the pair of jets or leptons (muons, electrons or taus) with the mass closest to the mass of real Z.

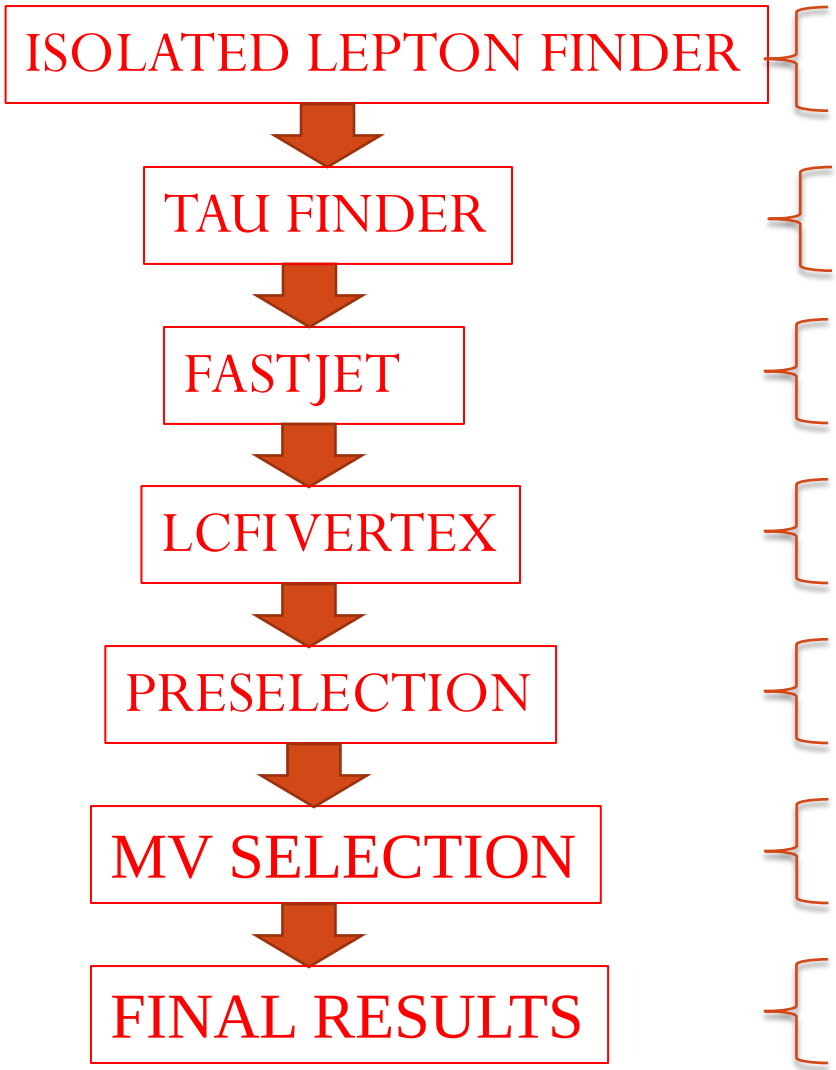



Higgs mass

# Signal and bck x-sec

| Process | $\sigma[fb]$ |
|---|---|
| $e^+e^- \to H\nu_e\overline{\nu}_e, H \to ZZ- > qqll$ | 0.995 |
| $e^+e^- \to qq\nu_e\overline{\nu}_e$ | 788 |
| $e^+e^- \to qqqq\nu_e\overline{\nu}_e$ | 24.7 |
| $e^+e^- \to H\nu_e\overline{\nu}_e, H \to WW$ | 56.4 |
| $e^+e^- \to qq$ | 4009 |
| $e^+e^- \to qqqq$ | 1245 |
| $e^+e^- \to qqqqll$ | 71.7 |
| $e^+e^- \to qqqql\nu$ | 115 |
| $e^+e^- \to H\nu_e\overline{\nu}_e, H \to bb$ | 137 |
| $e^+e^- \to qqll$ | 2726 |
| $e^+e^- \to H\nu_e\overline{\nu}_e, H \to ZZ- > qqqq/llll$ | 3.51 |
| $e\gamma \to qq\nu$ | 29873 |
| $e\gamma \to qqe$ | 16898 |
| $\gamma\gamma \to qq$ | 76782 |

# Analysis strategy




Find 2 isolated electrons or muons

Find 2 isolated taus

Force events into 2 jets, $k_T$ exclusive, SELECTEDPFOs, R=1.0

helps to reduce $e^+e^- \to H\nu_e\overline{\nu}_e, H \to bb$

helps to reduce large x-sec background

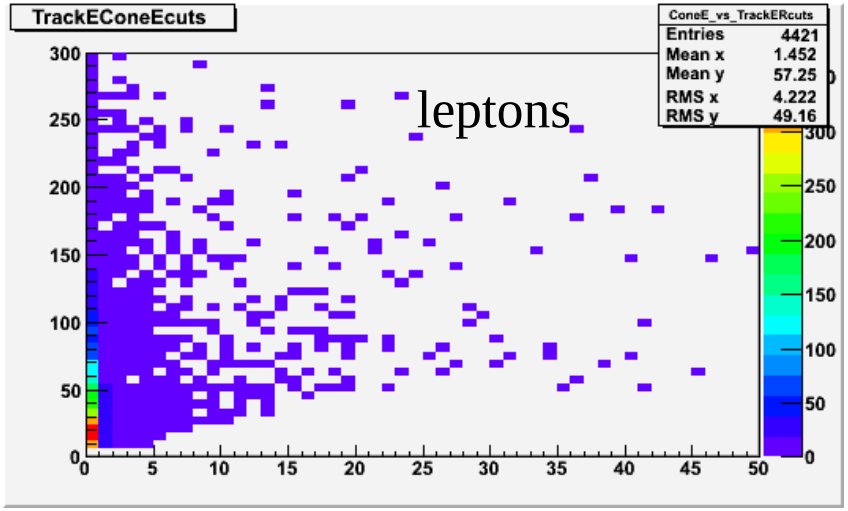
Multivariate BDT analysis

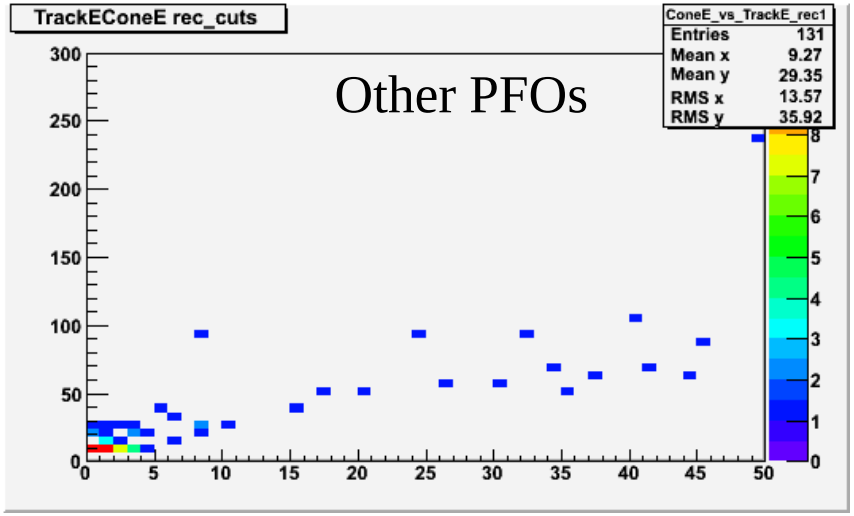
$\frac{\sqrt{S+B}}{S} * 100\%$

# Step by step: Isolated Lepton Finder

Lepton identification:

- Remove all tracks with E < 6 GeV
- Energy contained in a cone around the track (cos θ <0.995)
- Cut at Impact Parameter < 0.02mm
- Ratio of track energy deposition in ECAL and HCAL:
  - 0.02< μ $E_{ECAL}$ to $E_{HCAL}$ fraction<0.3
  - $e^-$ $E_{ECAL}$ to $E_{HCAL}$ fraction>0.94



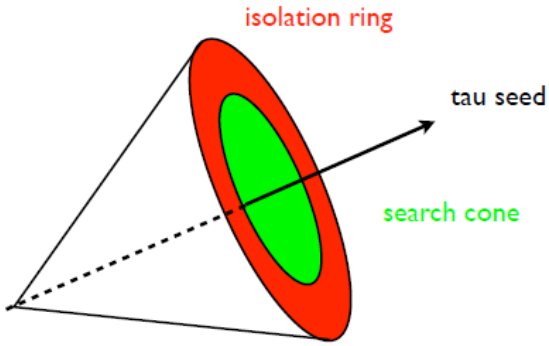

87% efficiency in reconstruction of the lepton pair

# Step by step: Tau Finder

Steps to reconstruct a tau:

- 1. Look for tau 'seed' (a high energy, charged track)
- 2. Add all particles within search cone to seed
- 3. Check number of charged tracks, isolation, tau mass

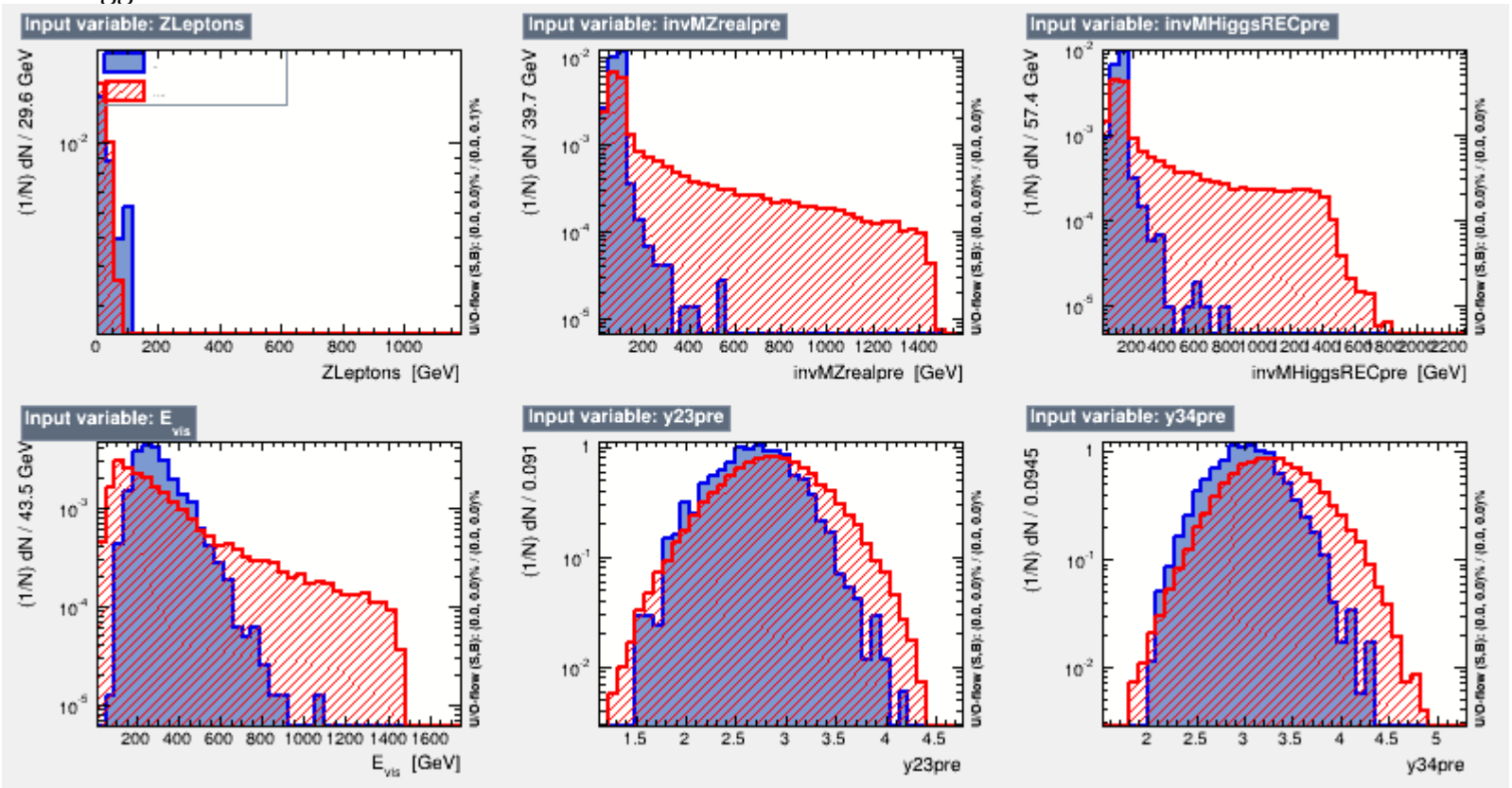
Initial pT cut for all tracks > 4 GeV
pT cut for seed > 10 GeV
Impact parameter $R_0$: 0.01 - 0.5
Search cone angle < 0.15 rad
Isolation energy < 3 GeV
Ring particles < 5
Invariant mass < 2. GeV/$c^2$



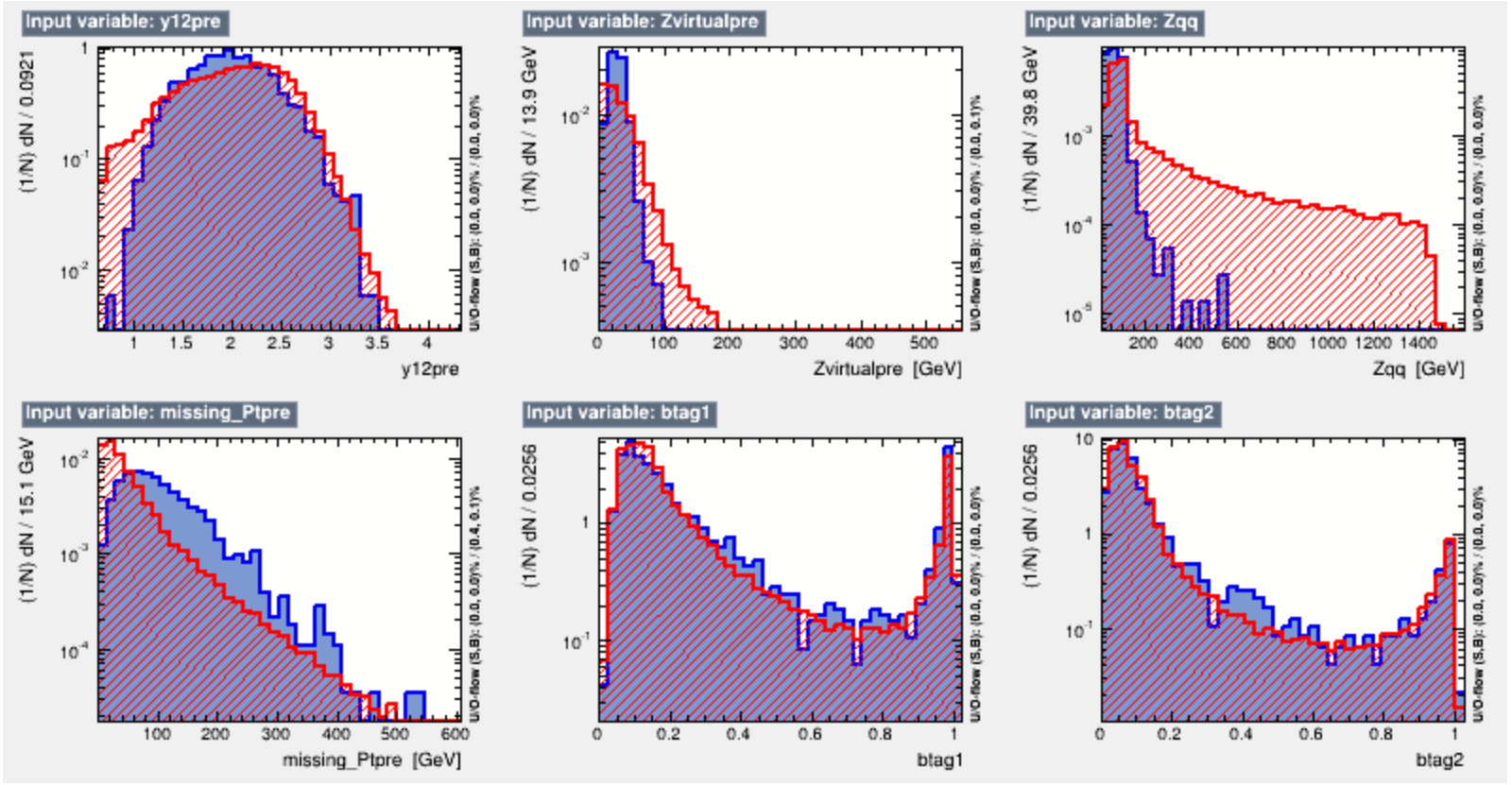

37% efficiency in reconstruction of tau pair

# Step by step: MVA analysis

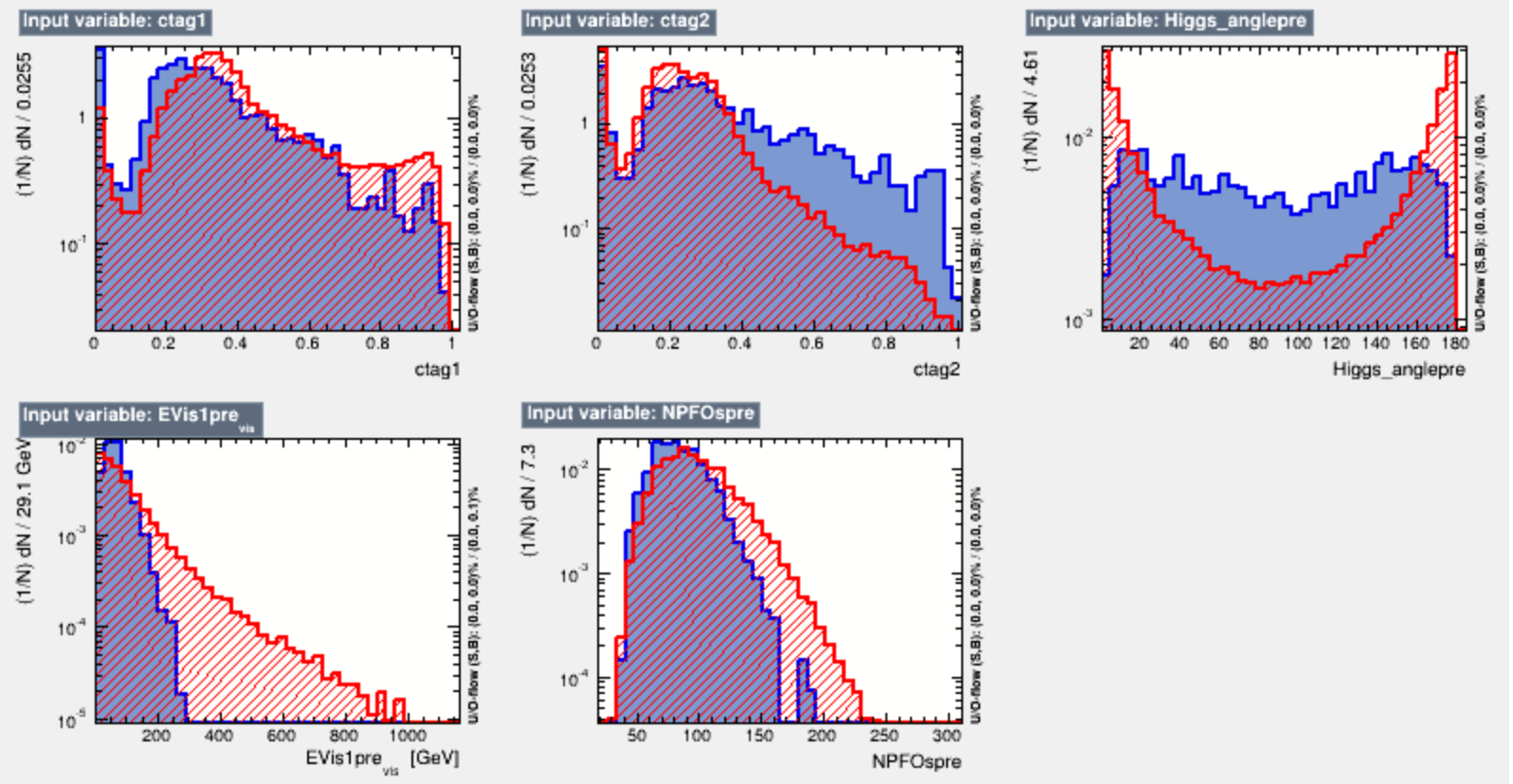
- TMVA trained with 17 variables ($m_{Z1,}$ $m_{Z2,}$ -log ($y_{34}$), -log($y_{23}$), -log($y_{12}$), $P(b)^{jet1}$, $P(b)^{jet2}$, $P(c)^{jet1}$, $P(c)^{jet2}$, $E_{vis}$, $Pt_{missing}$, $\theta_{Higgs}$, $m_H$, $m_{ll}$, $m_{qq}$, $E_{vis1}$($E_{vis}$-$E_{Higgs}$), $N_{PFOs}$) on total background



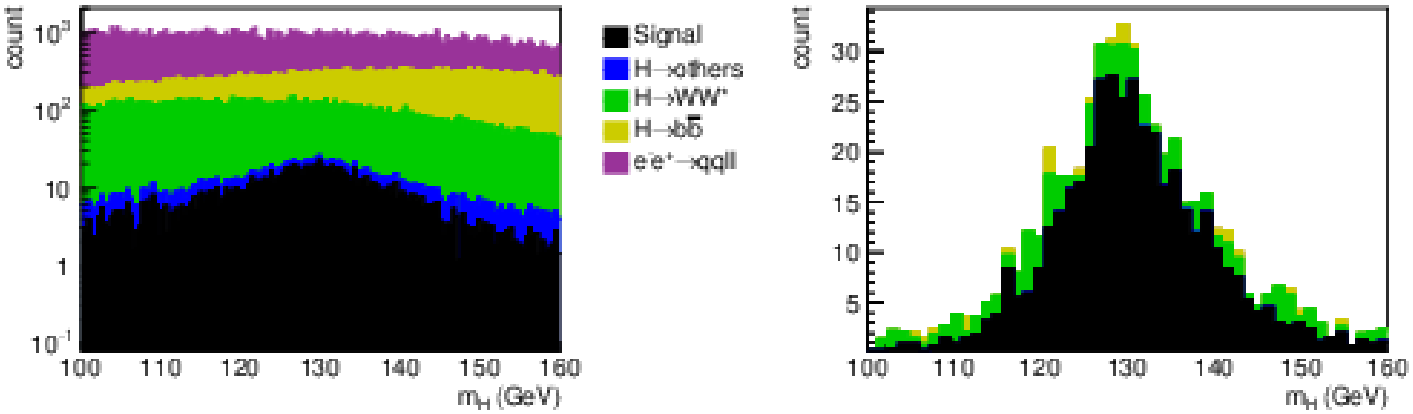
# MVA analysis



# MVA analysis



# Step by step: Result after the MVA




Overall signal efficiency 30.4%

$$\frac{\Delta\sigma}{\sigma} \sim 5.6\%$$

# Step by step: Result

| | |
|---|---|
| Signal efficiency | 30% |
| Signal cross section | 0.995 fb |
| Statistical uncertainty | 5.6% |

- Uncertainty of the measurement is dominated by the backgrounds with large x-sections and limited efficiency in tau pair reconstruction which reduces the overall gain in statistics.
- One should note that no polarization is included. Polarization can boost statistics by a factor 2.

# Conclusion

- The status of the H→ZZ*→qqll analysis is being presented
- All relevant SM background processes are considered, and beam-induced background from gamma gamma->hadrons interactions is overlaid to the physics events.
- It has been shown that BR(H→ ZZ) can be measured with a statistical accuracy of 5.6%.
- Limited efficiency in tau pair reconstruction reduces the overall gain in statistics.
- Result will be included in global Higgs fit to contribute to $g_{HZZ}$ determination.

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# THANK YOU

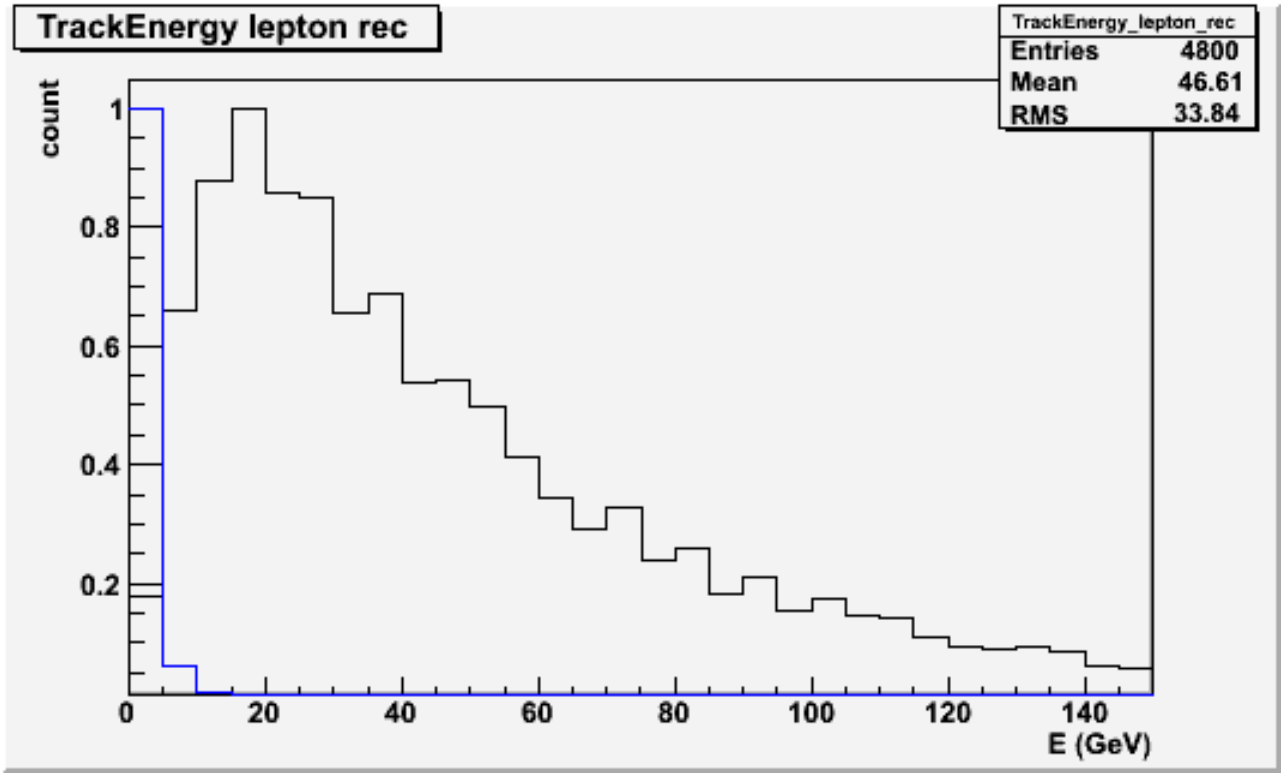
# BACK UP

# Isolated Lepton Finder

## Lepton track energy

- Remove all tracks with E < 6 GeV

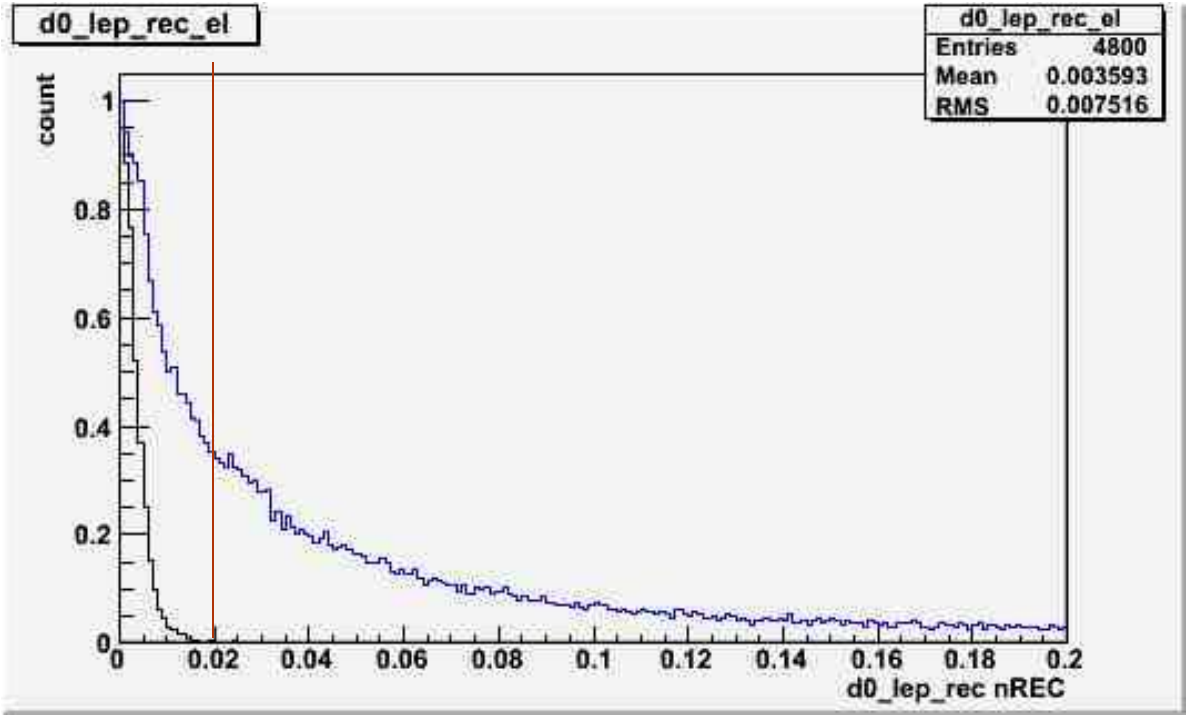
PFOs
leptons



# Isolated Lepton Finder

## Impact parameters

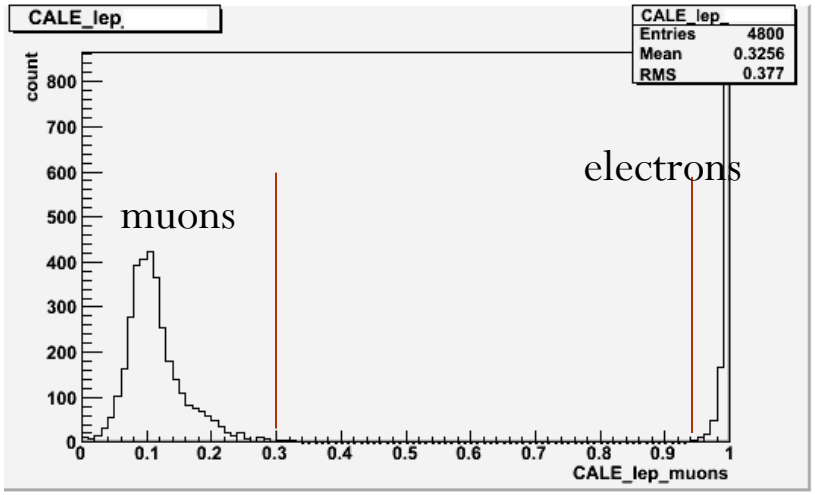
- Cut at IP < 0.02

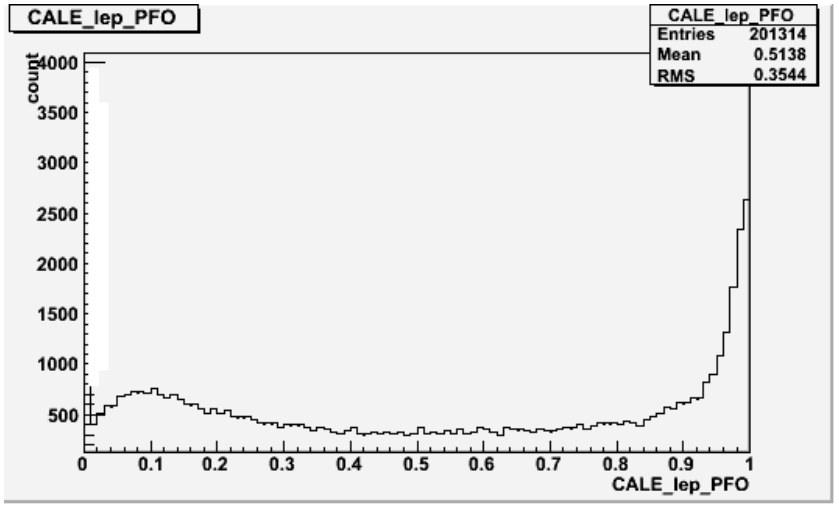


# Isolated Lepton Finder

## Lepton PID information

- Ratio of track energy deposition in ECAL and HCAL



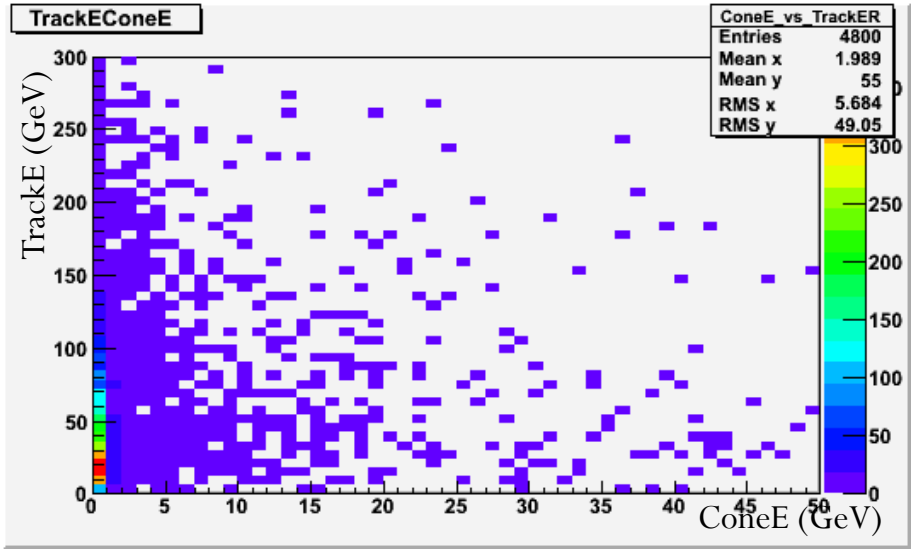

0.02< μ ECAL to HCAL fraction<0.3

$e^-$ ECAL to HCAL fraction>0.94

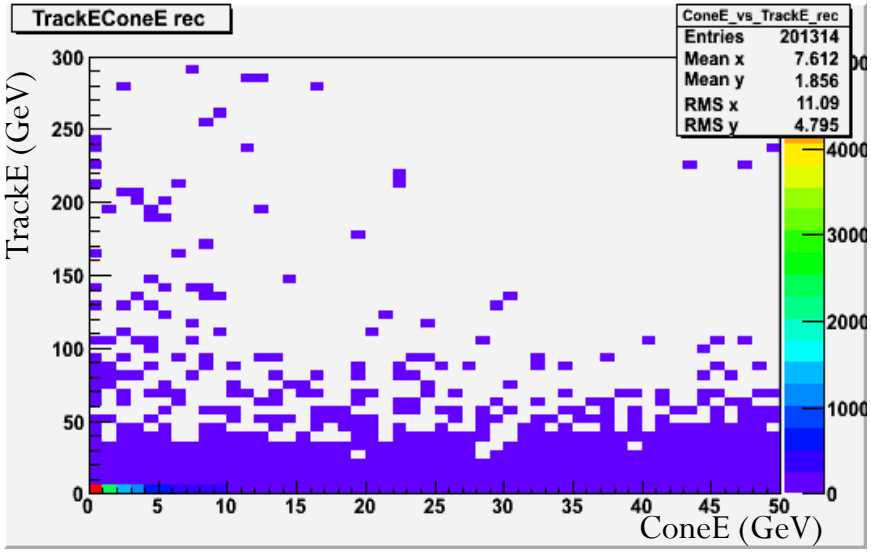
# Isolated Lepton Finder

## Isolation criteria

- Use cone energy to find isolated leptons
- Consider cone energy as a function of track energy




leptons




Other PFOs