

# QCD Backgrounds for VBF $H \rightarrow \tau\tau \rightarrow eh$

Rachid Mazini  
Jaspreet Sidhu & Saminder Dhaliwal

University of Toronto

Higgs WG meeting  
CERN

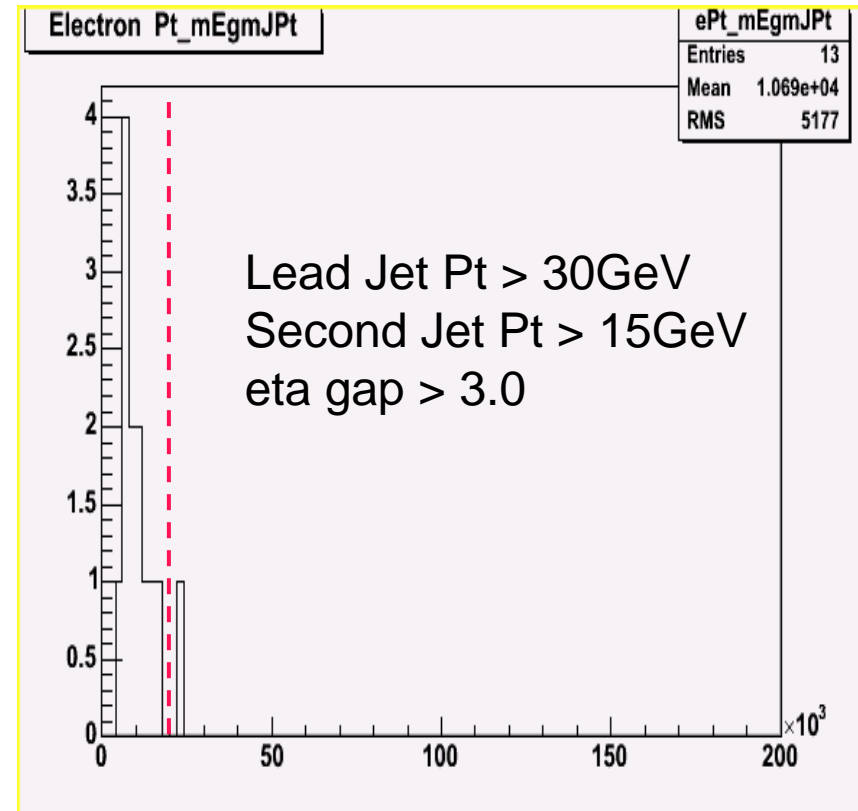
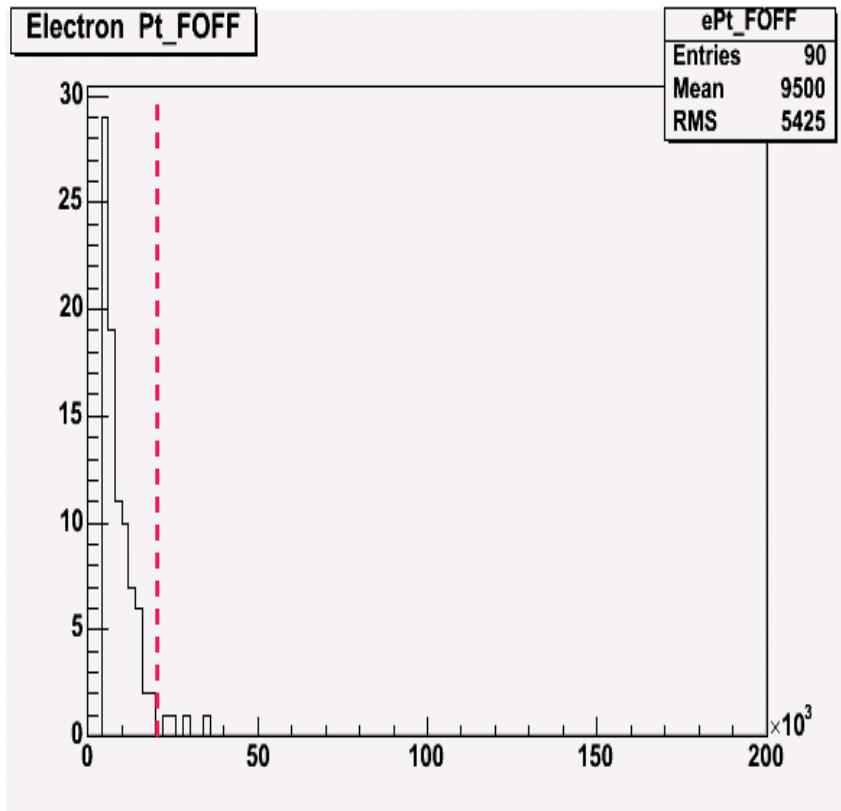
# Introduction

- VBF  $qqH \rightarrow qq \tau\tau$ ,  $\tau \rightarrow e \nu \nu$ ,  $\tau \rightarrow h\nu$ , may suffer from the huge QCD backgrounds at LHC
  - Misidentified jets could fake electron and  $\tau$ -jet signals
  - Mis-measured jet energy could produce  $E_{\text{miss}}$  signal
- Cross sections:
  - QCD dijets  $\sigma \sim 1\text{mb}$
  - Higgs Signal  $\sigma \sim 400\text{fb}$
  - A large rejection is needed at the electron/  $\tau$ -jet identification level to reject this background

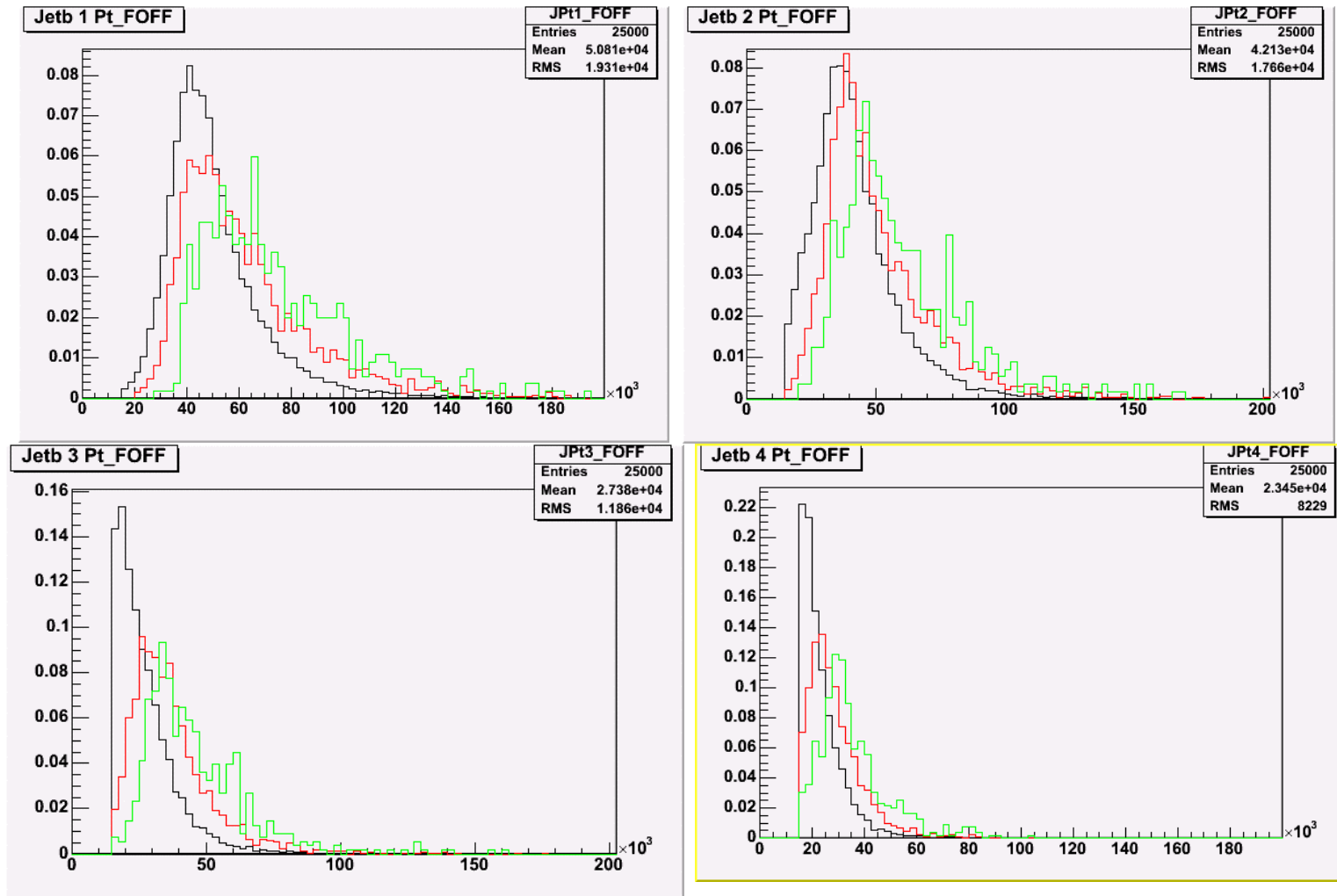
# Event Generation

- Pythia QCD dijets
  - $p_T > 40$  GeV
  - $\sigma = 0.8$  mb
  - A small fraction, 0.02% has real electrons, from c,b-Mesons
- Filter
  - At least 4 jets
  - 1<sup>st</sup> tagging jet  $p_T > 30$  GeV
  - 2<sup>nd</sup> tagging jet  $p_T > 15$  GeV
  - 1 central jet  $p_T > 30$  GeV (tau-jet candidate)
  - 1 central jet  $p_T > 15$  GeV (fake electron candidate)
  - $\eta$  separation:  $|\eta_1 - \eta_2| > 3$
  - Filter efficiency  $\varepsilon = 5\%$

# Event Filter effects (electrons)



# Event Filter effects (jets)



Black = Filter OFF    Green = Hard Filter (ON)    Red = Soft Filter (ON)

# Monte Carlo Production

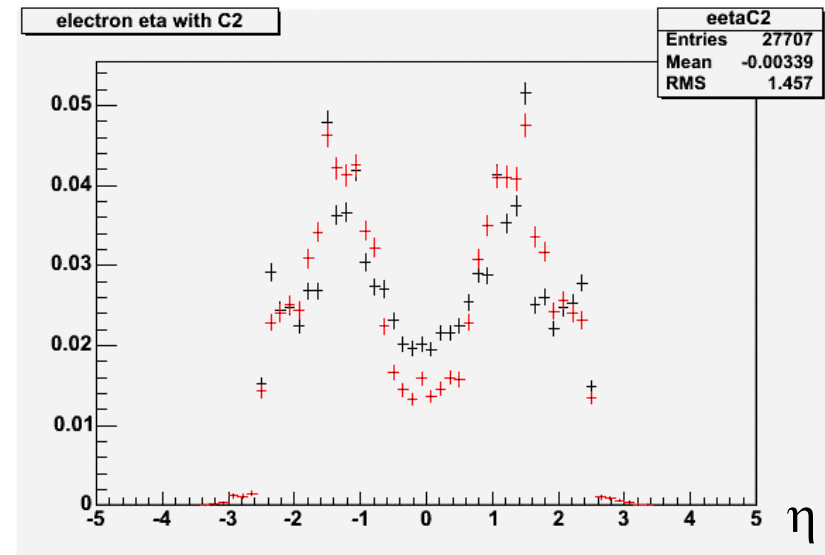
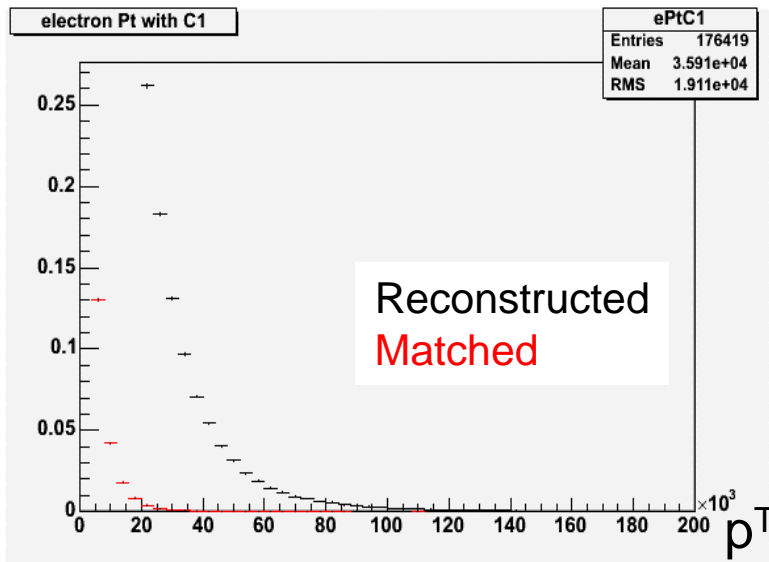
- Simulation + digitization
  - Release 10.0.1
  - Rome Layout
- Reconstruction
  - Release 10.0.4
  - Default reconstruction parameters
    - Electrons,  $\tau$ 's , jets...
  - ESD/AOD production
- Statistics
  - About 10000 QCD events/day @ Toronto
  - Expecting 52 real electrons, in witch ~5 have  $p_T > 20$  GeV

# Event Reconstruction

- Starting with Electrons Container in AOD's
- Candidates selection:
  - HasTrack,  $p_T > 20$  GeV
  - Egamma object
  - isEM, including TRT flag
  - $epiNN > 0.8$
  - Likelihood:  $emWeight / (emWeight + pionWeight) > 0.8$
- Optimizing Electron ID parameters for a better QCD background rejection
  - Isolation, tracks association...
- Available statistics (for now)
  - 3.4M QCD events filtered down to 170K fully simulated
  - The sample should have 85 electrons with  $p_T > 20$  GeV and  $|\eta| < 2.5$
  - 20000 Higgs signal with 1 electron  $p_T > 15$  GeV and  $|\eta| < 2.7$

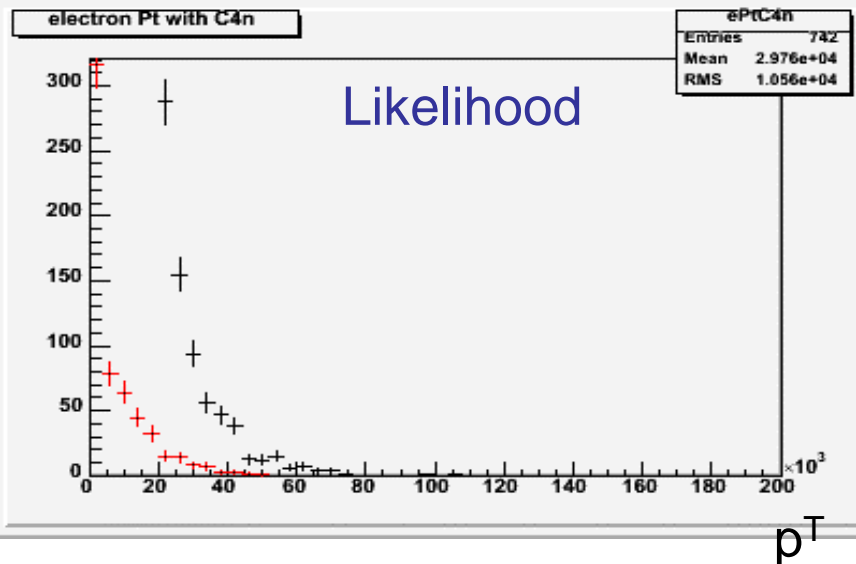
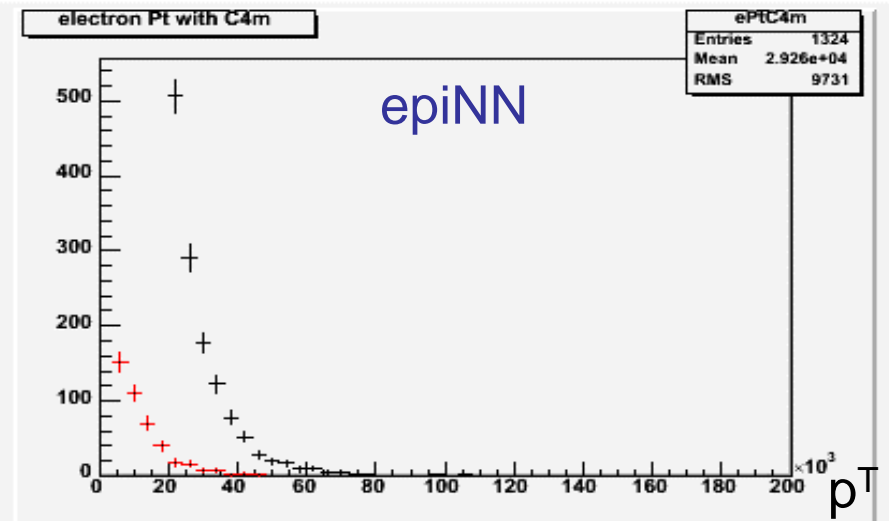
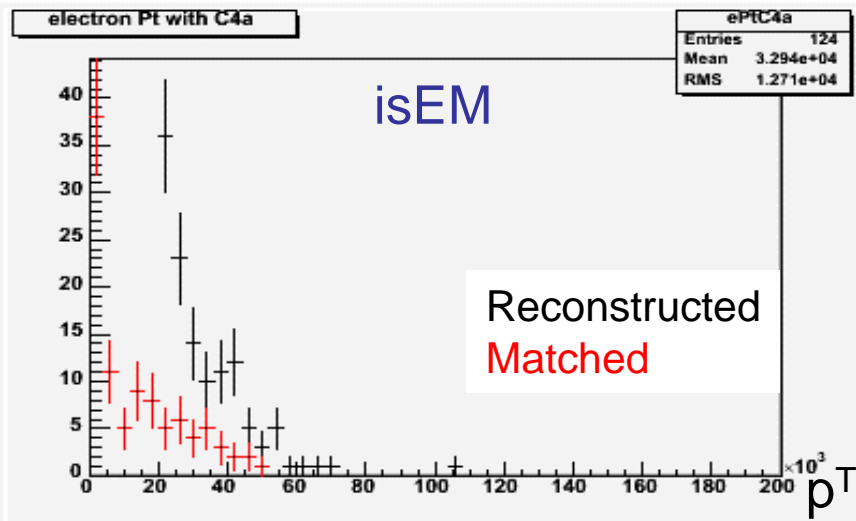
# Electron Identification (QCD dijets)

	No Cuts	hasTrack & Pt > 20 GeV	Egamma
# of electrons Candidates	$2.64 \times 10^6$	$1.76 \times 10^5$	27707
% of original candidates		6.7%	1.05%
# of electrons matched to Truth	$1.72 \times 10^6$	$1.49 \times 10^5$	23104
Fake Rate	54%	17.8%	19.9%



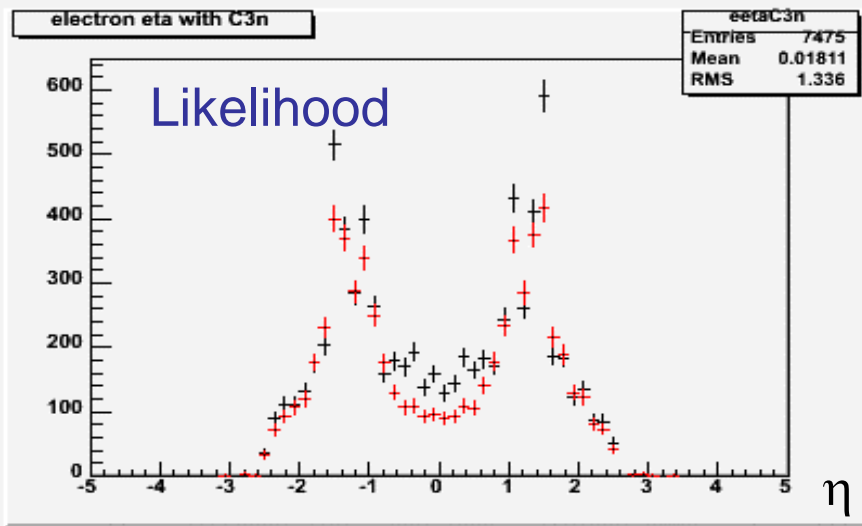
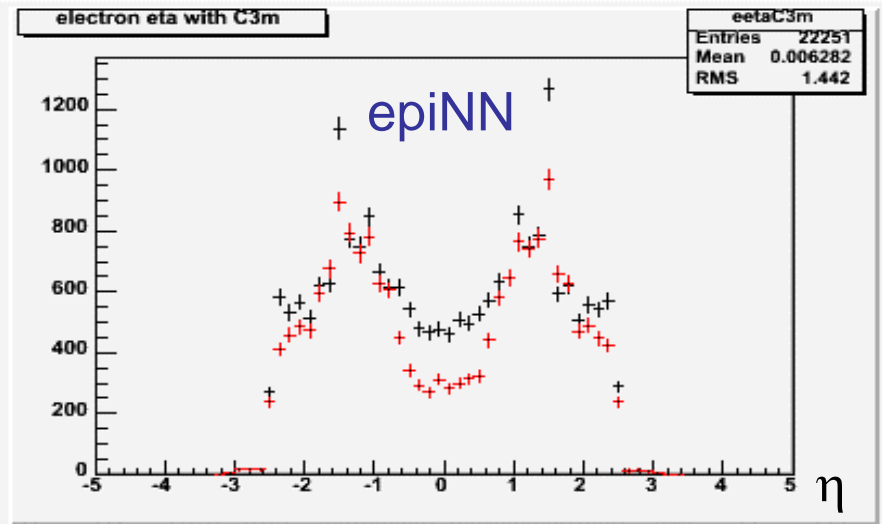
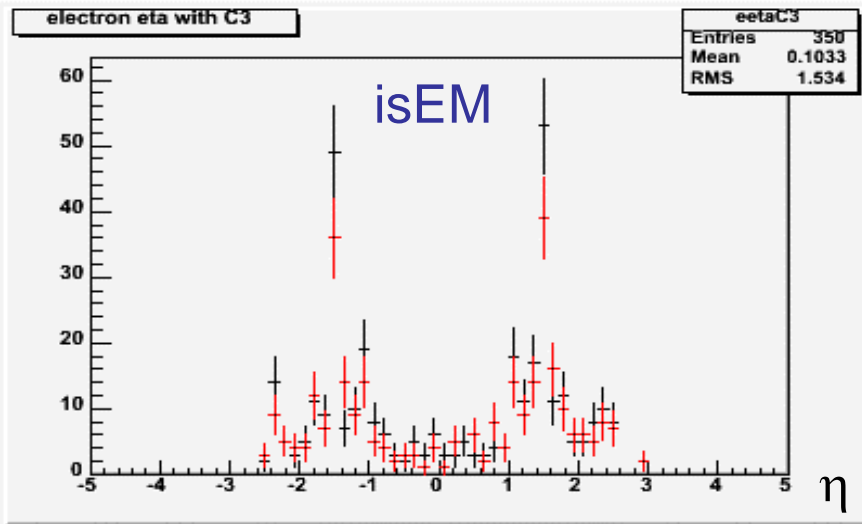


# Identification Algorithms



	IsEM	epiNN	Likelihood
# of electrons Candidates	350	19018	7475
% of original candidates	0.013%	0.84%	0.28%
# of electrons matched to Truth	301	$1.49 \times 10^5$	6449
Fake Rate	16%	17%	16%

# Electron Identification (QCD dijets)



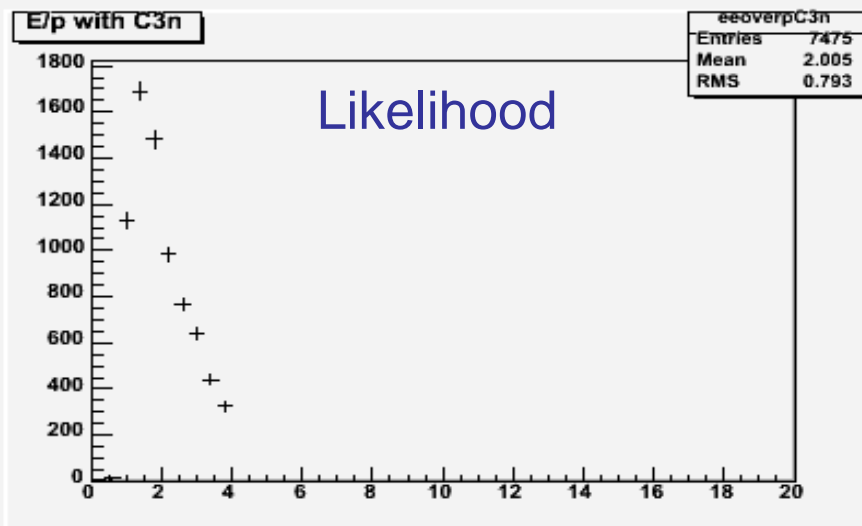
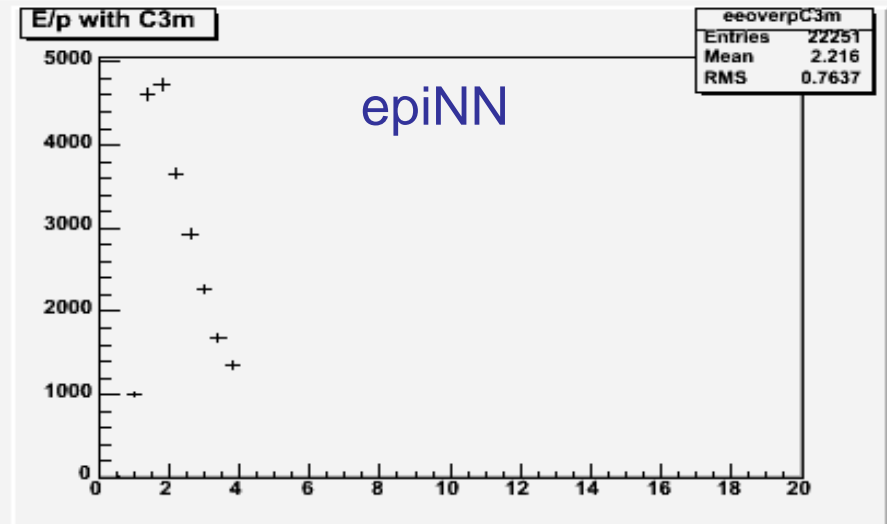
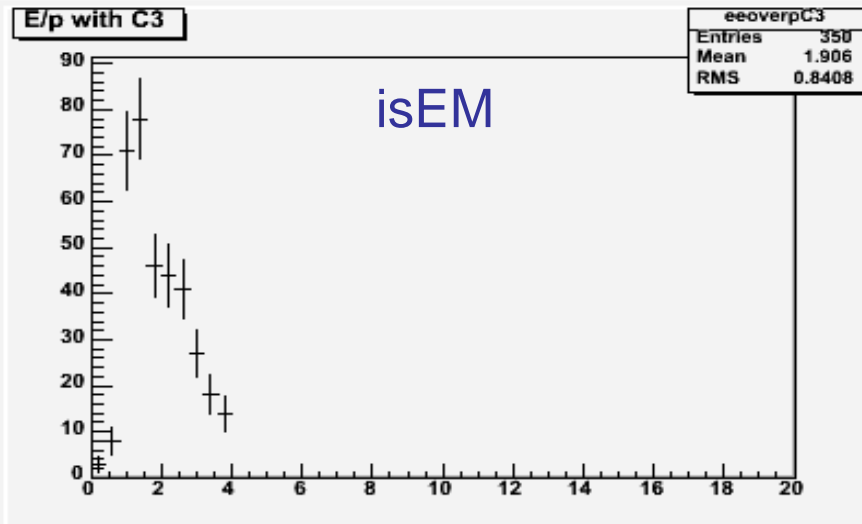
epiNN seems to reconstruct more events in  $-1 < \eta < +1$

# Isolation cuts

	Reconstructed	Matched	FakeRate	% of original Candidates
isEM	350	301	16%	0.013%
Etcone < 10GeV	124	99	25%	0.010%
$0.8 < E/P < 1.4$	47	39	20%	0.0017%
epiNN	22251	19018	17%	0.84%
Etcone < 10GeV	1324	1035	28%	0.05%
$0.8 < E/P < 1.4$	229	171	34%	0.0086%
likelihood	7475	6449	16%	0.28%
Etcone < 10GeV	742	591	26%	0.028%
$0.8 < E/P < 1.4$	196	149	31%	0.0074%

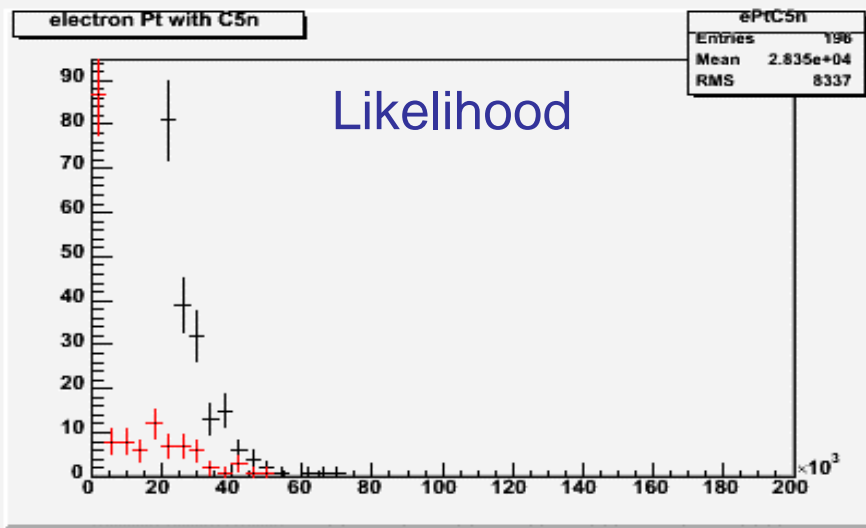
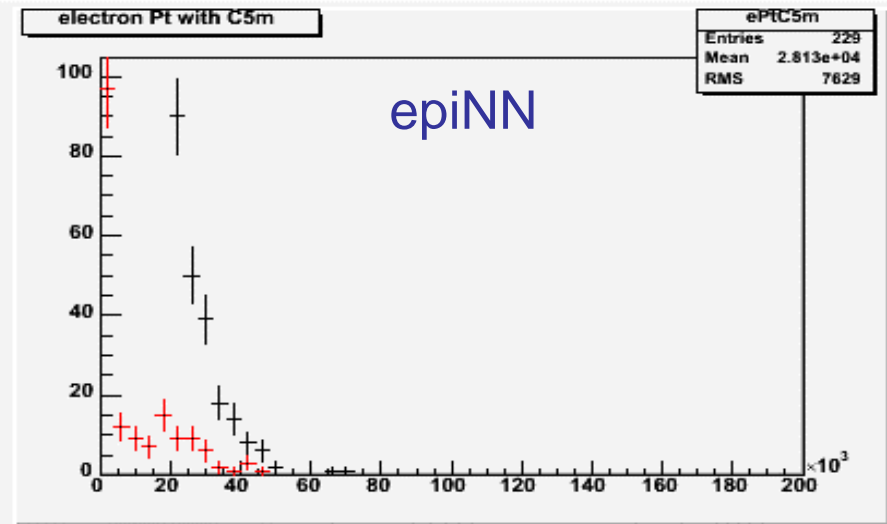
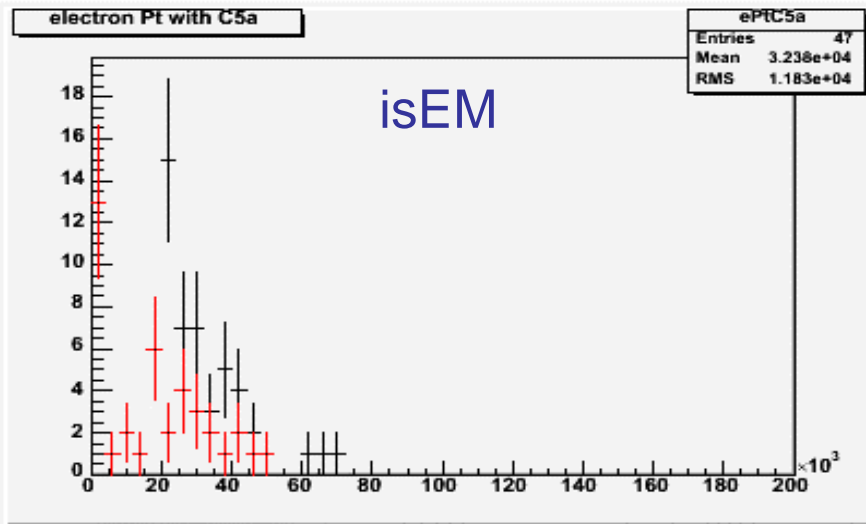
85 real electrons in this sample. IsEM has the best rejection rate

# EoverP



Same distribution shape  
for all algorithm

# $p_T$ distributions



$p_T$  after all reconstruction cuts

- EtCone < 10GeV
- $0.8 < E_{\text{overP}} < 1.$

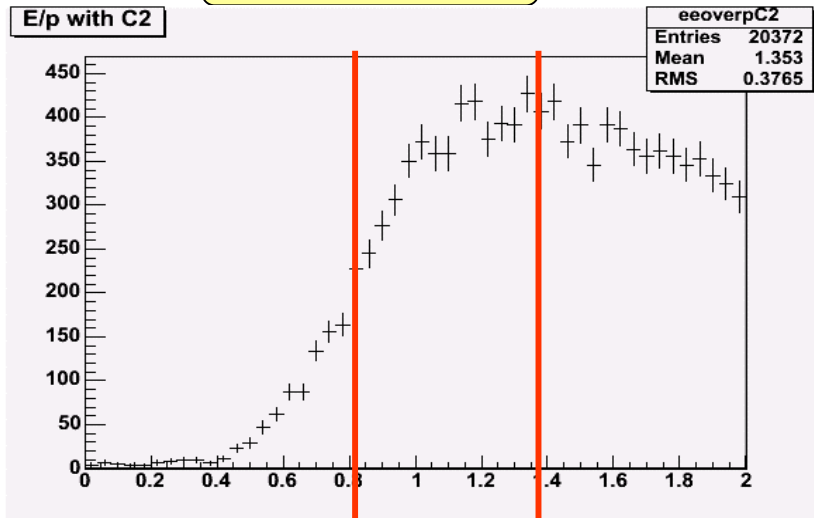
# Electron Identification (Higgs signal)

	# elec	$\epsilon$ (%)
Truth	20 000	
Reco. No Cuts	193 146	
Cut 1 (HasTrack...)	46 761	
Cut 2 (egamma)	21 877	
isEM (all flags)	13 891	69.5%
epiNN	18 312	91.6%
Likelihood	16 313	81.6%

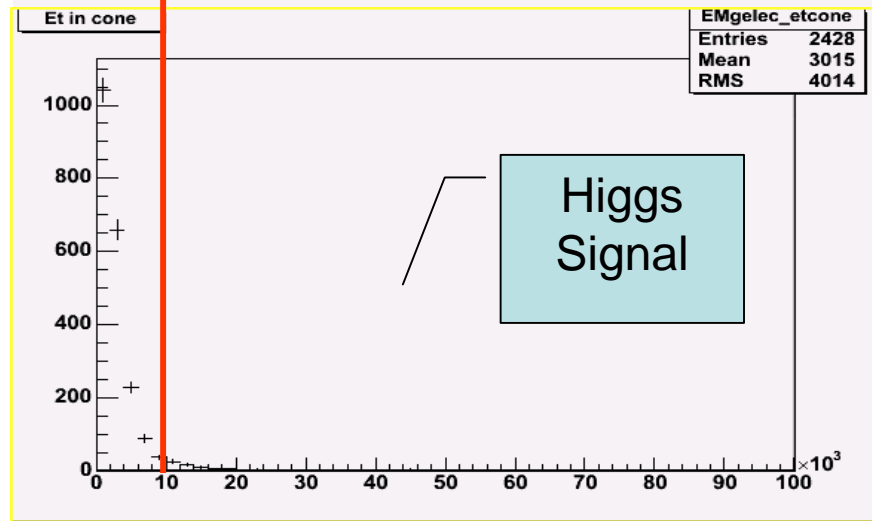
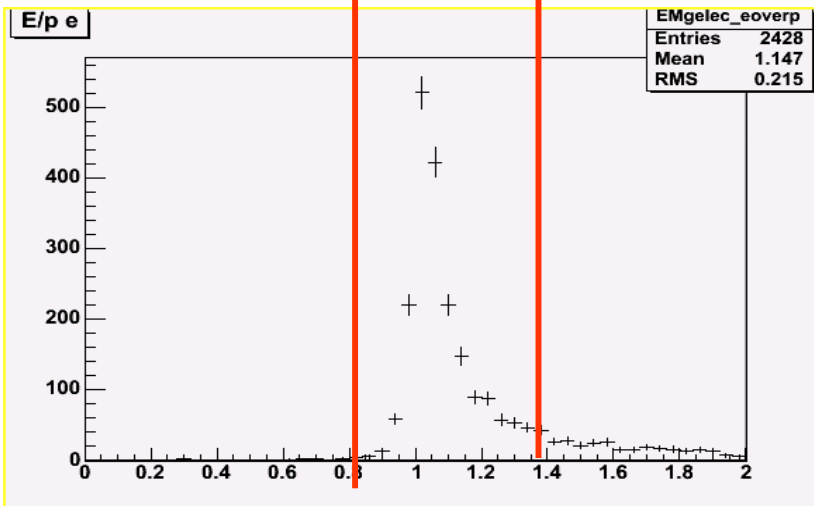
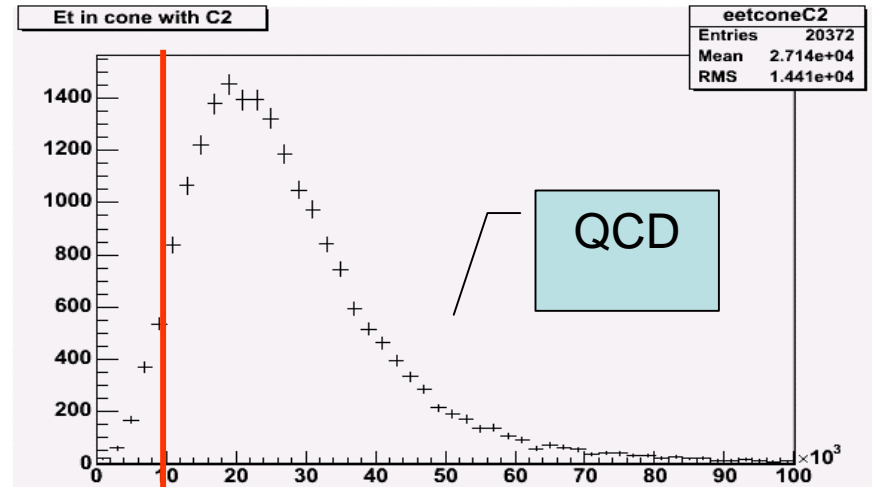
isEM has lowest reconstruction efficiency but the best QCD background rejection

# Isolation Cuts (Higgs signal)

**EoverP**



**EtCone**



# Isolation Cuts (Higgs signal)

	# elec	$\epsilon$ (%)
isEM	13,891	69.5%
Isolation (EtCone<10GeV)	13,049	65.2%
E/p (0.8< E/P <1.4)	11,163	<b>55.8%</b>
epiNN	18,312	91.6%
Isolation	13,096	65.5%
EoverP	10,554	<b>52.3%</b>
likelihood	16,313	81.6%
Isolation	14,700	73.5%
E/p	11,812	<b>59.1%</b>

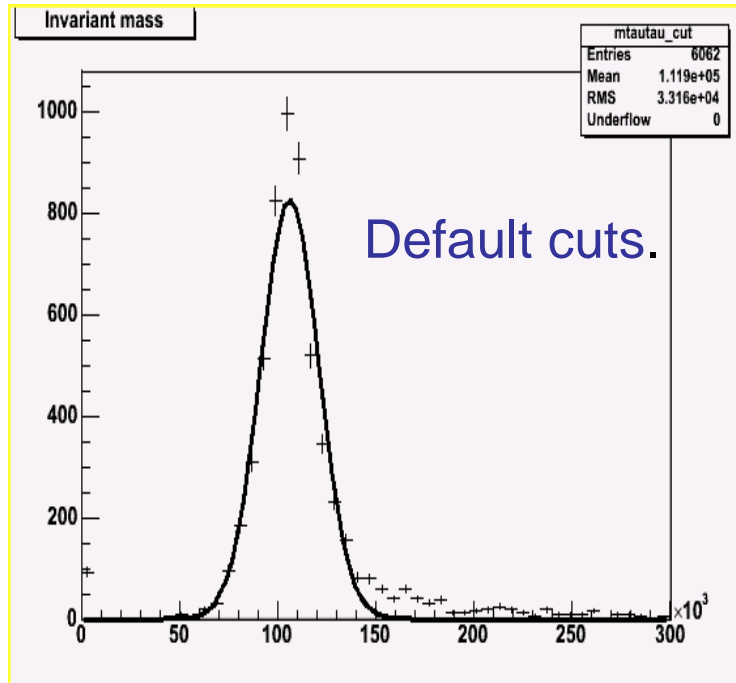


# Higgs signal Reconstruction

- Aim: estimate signal efficiency loss with harder Electron ID requirement
- $\tau$ -jet reconstruction
  - From  $\tau$ -jets container
  - cut 1:  $\text{abs}(\text{charge})==1$
  - cut 2:  $\text{NumTrack}==1$  or 3
  - cut 3:  $\text{likelihood} > 4$
  - cut 4:  $\text{pt} > 40 \text{ GeV}$
- Select identified Electrons and  $\tau$ 's
- Use Collinear approximation
- Use  $E_{\text{miss}} > 20 \text{ GeV}$

	# $\tau$ -jets
Truth	2000
No Cuts	57316
Cut 1	42452
Cut 2	41178
Cut 3	17951
Cut 4	6106 ( $\epsilon = 30.5 \%$ )

# Higgs signal Reconstruction

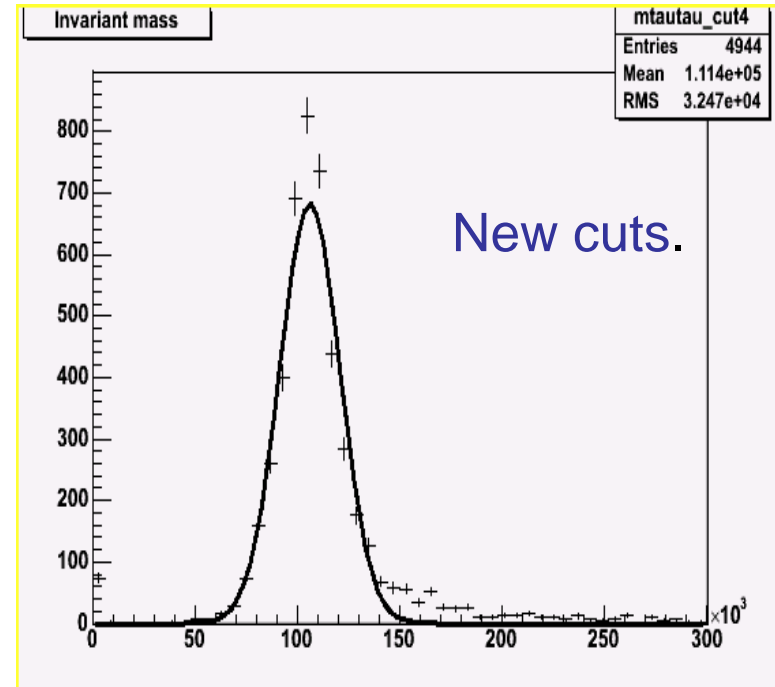


Reconstruct 6062 events  
Efficiency of Reconstruction

$$\varepsilon = 30.31\%$$

Mean = 106.2 GeV

$\sigma = 14.9$  GeV



Reconstructed 4944 events  
Efficiency of Reconstruction

$$\varepsilon = 24.7\%$$

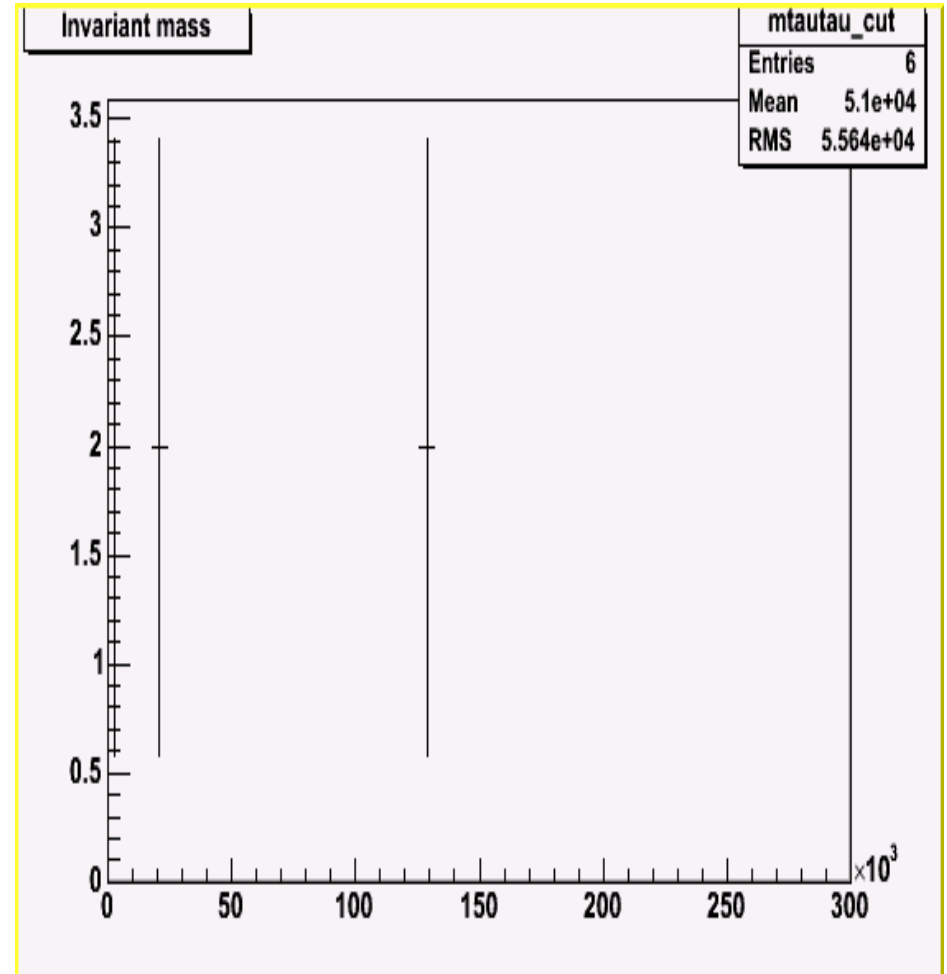
Efficiency drop = 5.6%

Mean = 106.2 GeV

$\sigma = 14.7$  GeV

# QCD Backgrounds for $H \rightarrow \tau\tau \rightarrow eh$

- Apply electron and  $\tau$  reconstruction Algorithms and selection cuts to QCD dijets events
- Reconstruct  $M_{\tau\tau}$  using same procedure as Higgs signal events
- **1 Event** left in the Higgs mass region
  - Out of 3.4M total events
  - Less than  $1\text{pb}^{-1}$
  - More statistics on the way
  - few cuts in VBF analysis have yet to be applied
    - $m_T$  , jet Veto

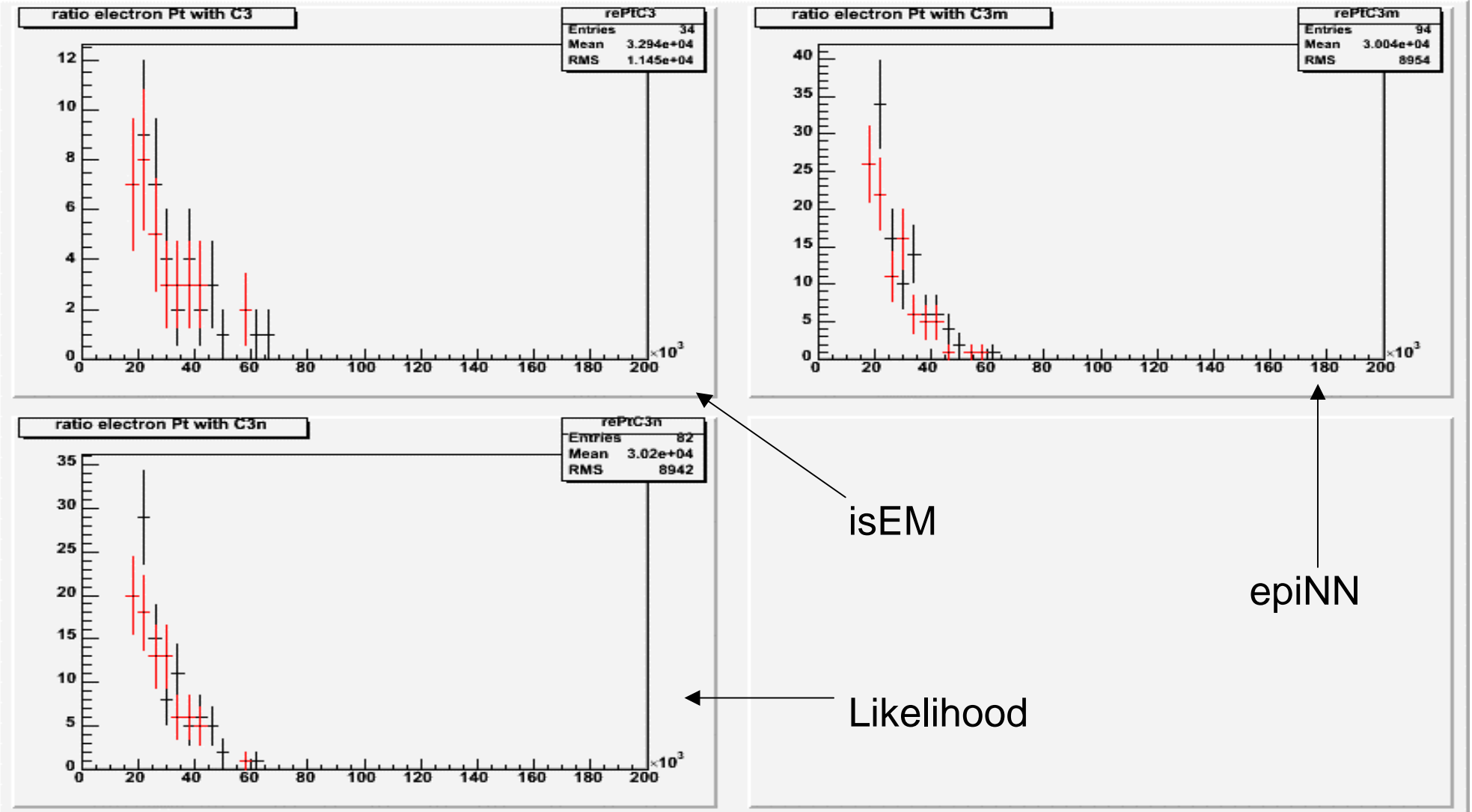


# Summary

- Initial Results show that we can expect a strong rejection factor against QCD jets
  - 47 events out of 3.4M survived electrons ID and some kinematical cuts
  - 1 event in the Higgs mass region, with less than  $1\text{pb}^{-1}$
  - Would new features in release 11 make things better?
- Only ~6% loss in Signal reconstruction efficiency
- More statistics to confirm these results and possibly extract shape of distributions if we need to scale-up to the needed luminosity
- Pile-up being added to the available events. Result for the next meeting
- Trigger requirements as well, for signal and background

# Back-ups

# Electron Pt (with EtTruth/EtRec > 0.8) after egamma cut



# Statistics with EtTruth/EtRec > 0.8)

	Reconstructed	Matched	% of original Candidates
hasTrack and Pt > 20GeV	316	316	0.081%
egamma	105	105	0.027%
isEM	34	34	0.0087%
Etcone < 10GeV	16	16	0.0041%
0.8 < E/P < 1.4	12	12	0.0031%
epiNN	94	94	0.24%
Etcone < 10GeV	28	28	0.007%
0.8 < E/P < 1.4	24	24	0.006%
likelihood	82	82	0.021%
Etcone < 10GeV	27	27	0.007%
0.8 < E/P < 1.4	22	22	0.005%