Lepton ID in the SiD LOI benchmarking

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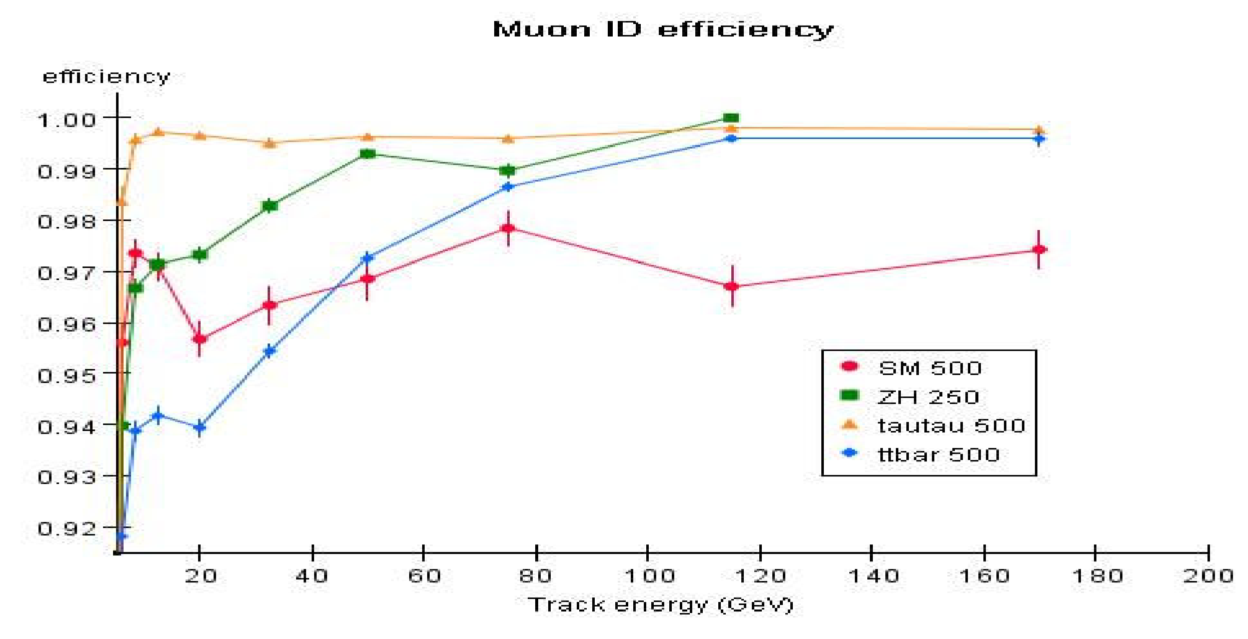
LCWA09

Outline

- Standard Reconstruction
  - Muons:
  - Electrons:
- High P extension
  - Electrons in ZH events:
  - Full energy taus:

Muon identification: algorithm

- Find mip stubs in the Muon calorimeter
  Require 5 hits -> improves overall purity,
  at expense of loss of efficiency for 5-15 GeV
  muons.
- Extrapolate reconstructed Tracks to end of hadron calorimeter.
- Match using tangent of extrapolated track with direction of innermost 2 muon hits.
- Efficiency/purity depends on event type (μ/π ratio, confusion)



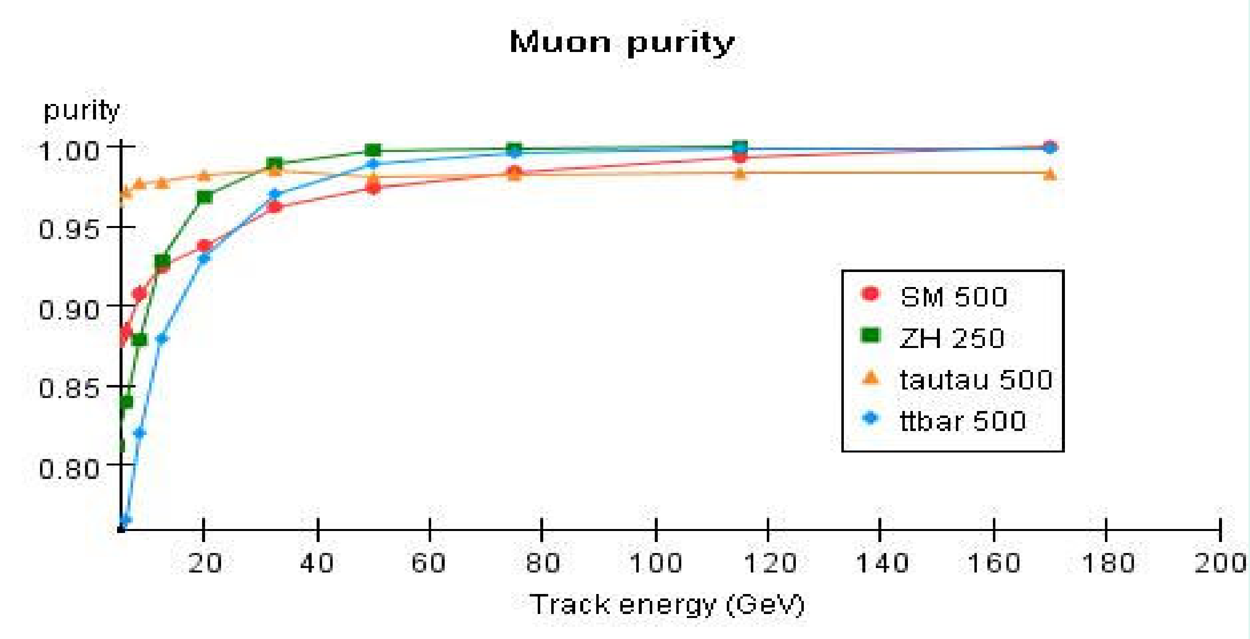
For E > 15 GeV:

SM = 96.9%

ZH = 98.3%

tautau = 99.7%

ttbar = 96.6%



For E > 15 GeV:

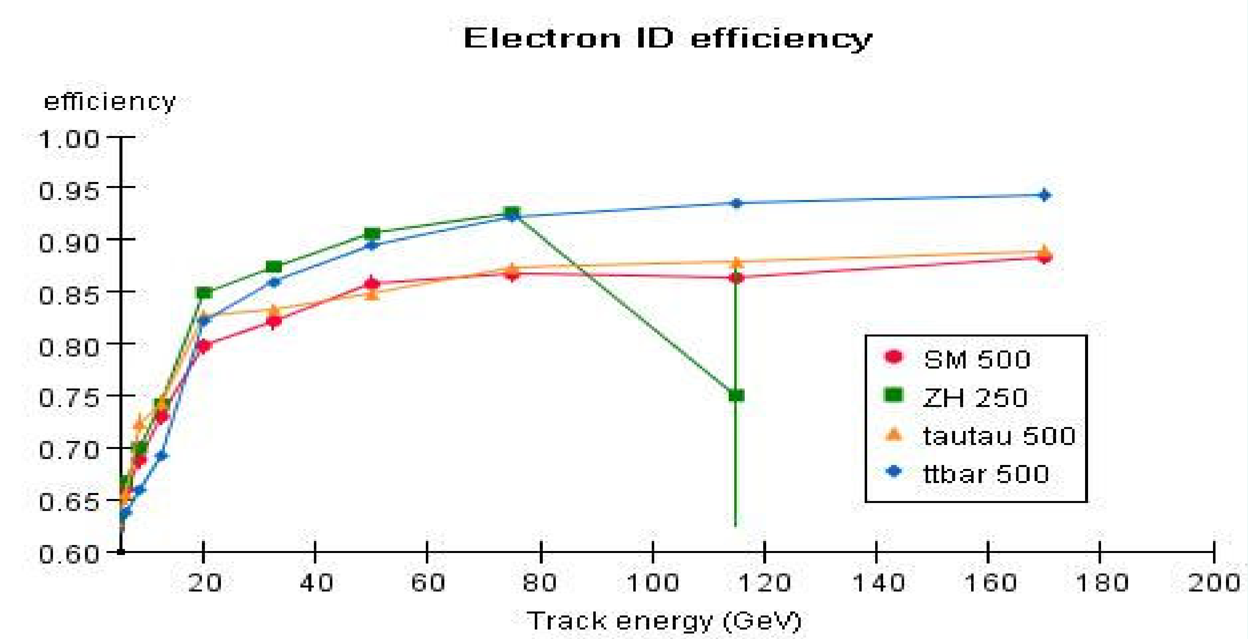
SM = 97.3%
ZH = 98.5%
tautau = 98.3%
ttbar = 97.2%

Muon ID: results

- Above 15 GeV, ~ 97% eff and purity for SM events.
- Better for events with larger μ/π ratio.
- Could be improved for lower momentum, but no critical use case in benchmark analyses.
- Used as is for all benchmark analyses.

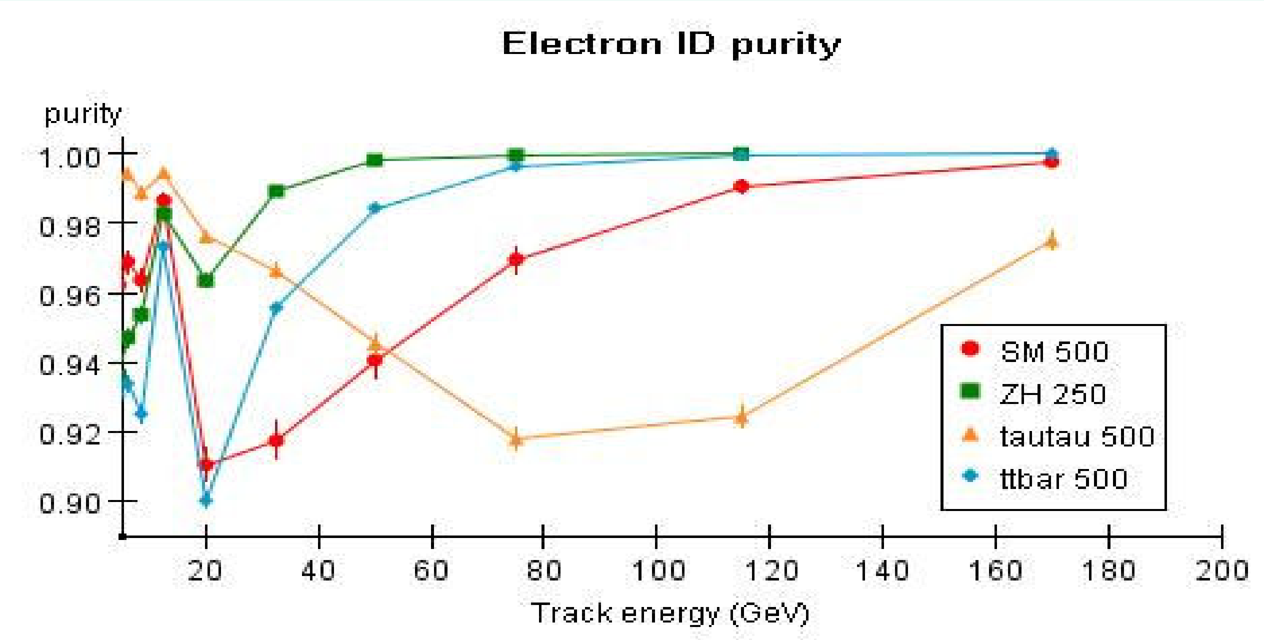
Electron identification: algorithm

- PFA: Extrapolate Track to EM calorimeter.
  Match Track with EM cluster.
  If EM cluster IDed as photon and E/P match, ID as electron.
- High P (P > 15 GeV) extension:
  Relax cluster-track match criteria.
  Relax photonID requirement: Use shape parameters of cluster.



For E > 15 GeV:

SM = 84.7%
ZH = 88.0%
tautau = 85.6%
ttbar = 87.8%



For E > 15 GeV:

SM = 95.4%
ZH = 98.4%
tautau = 94.9%
ttbar = 96.1%

Electron ID: results

- Above 15 GeV, ~85% efficiency and 95% purity for SM events.
- Used in standard reconstruction for benchmark analyses.
- Most of inefficiency arises from separation problems with hadron fragments.

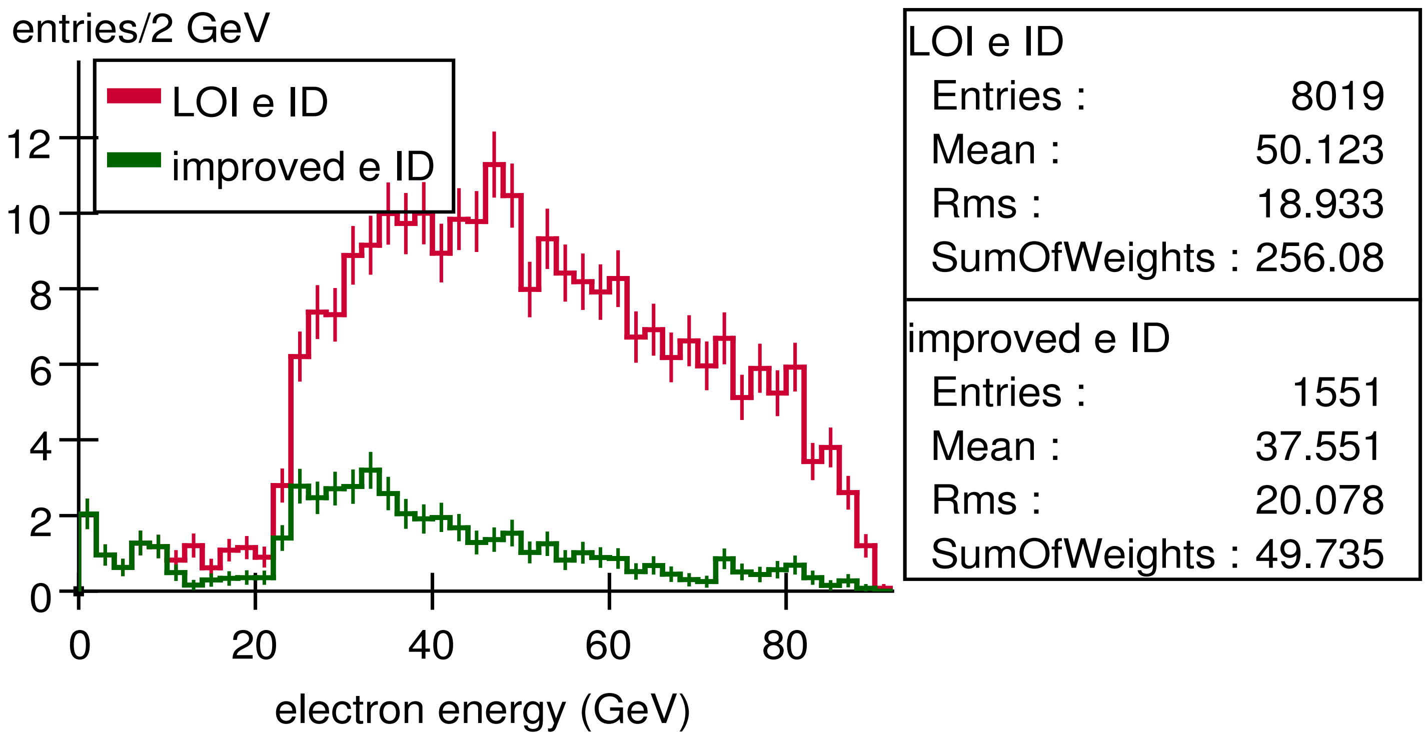
Isolated high P electron ID

- Some processes depend critically on high P lepton ID.
- *$e+e-$ -> $e+e-H$; $\mu+\mu-H$* , $\sqrt{s}$=250 GeV
  Leptons mostly isolated
- *$e+e-$ -> $\tau+\tau-$* , $\sqrt{s}$=500 GeV
  Leptons completely isolated
- ttbar -> bWbW, W->qq, $\sqrt{s}$=500 GeV
  Isolation a problem, no improvement attempted in rejecting leptonic background

Isolated electron ID

- Basic algorithm: For tracks not IDed as e:
  - P > 10GeV.
  - Find all HCal hits within 25d cone.
  - Sum the energy of those hits.
  - If Sum < .04*P -> call it an electron.
- Check with eeH events.

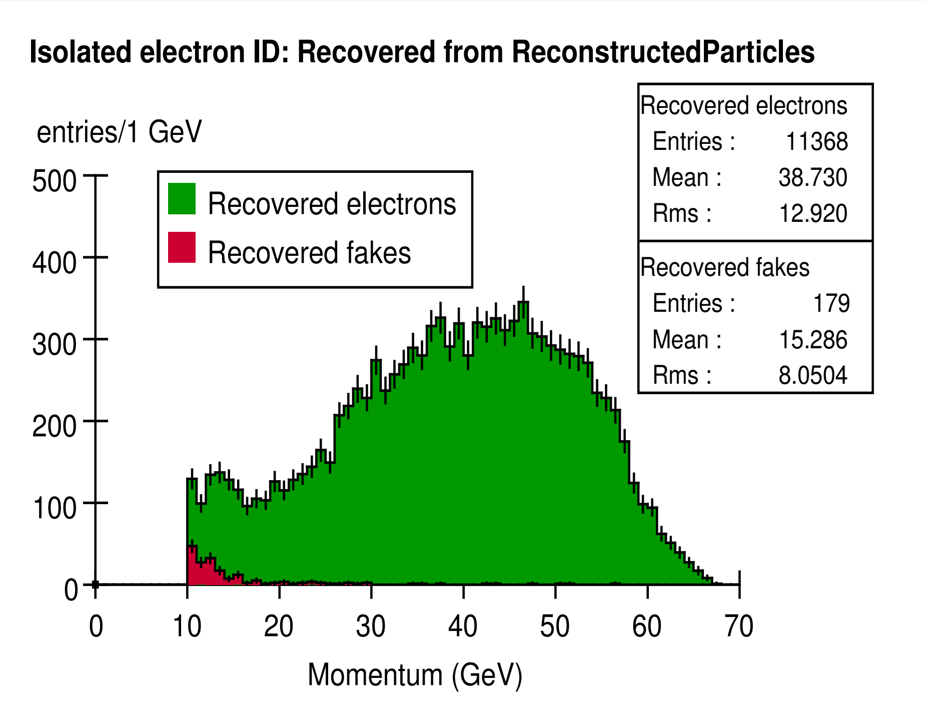
Failed electron ID: electron energy



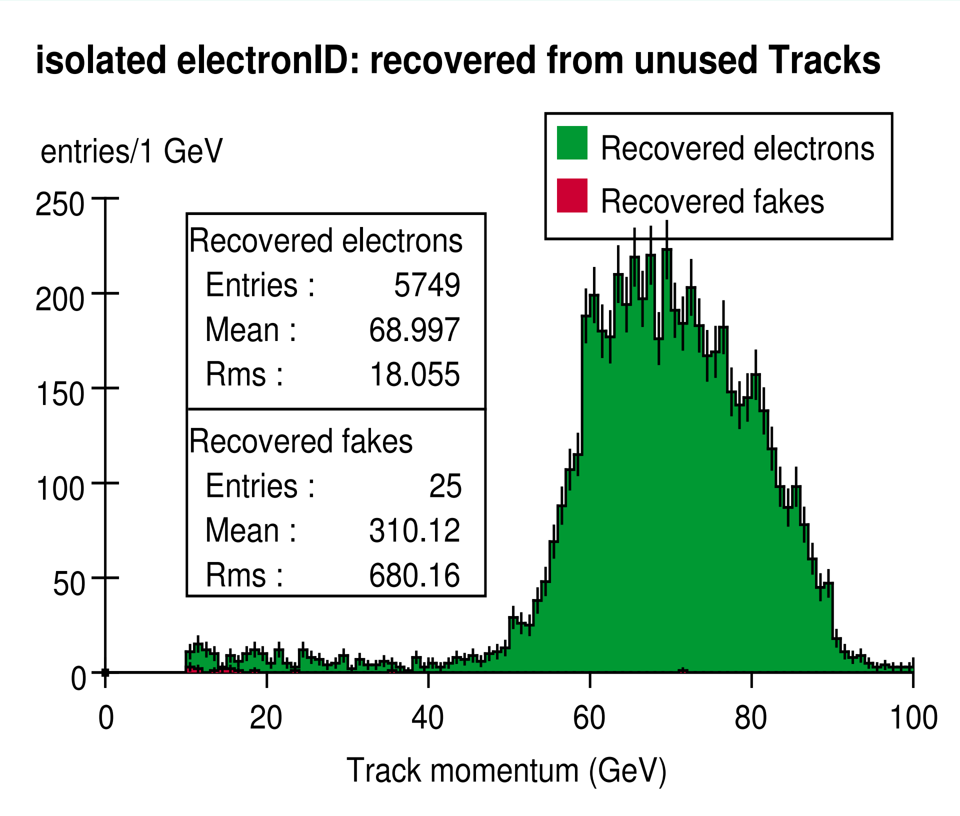
Plotted in red is the energy distribution of missed electrons from the LOI reconstruction. Overlayed in green is the improved e ID. The separation of the 2 curves is the gain from the improved ID algorithm.

Electron ID efficiency:

Old = 89.6%, New = 98.0%



Purity of recovered electrons = 98.8%

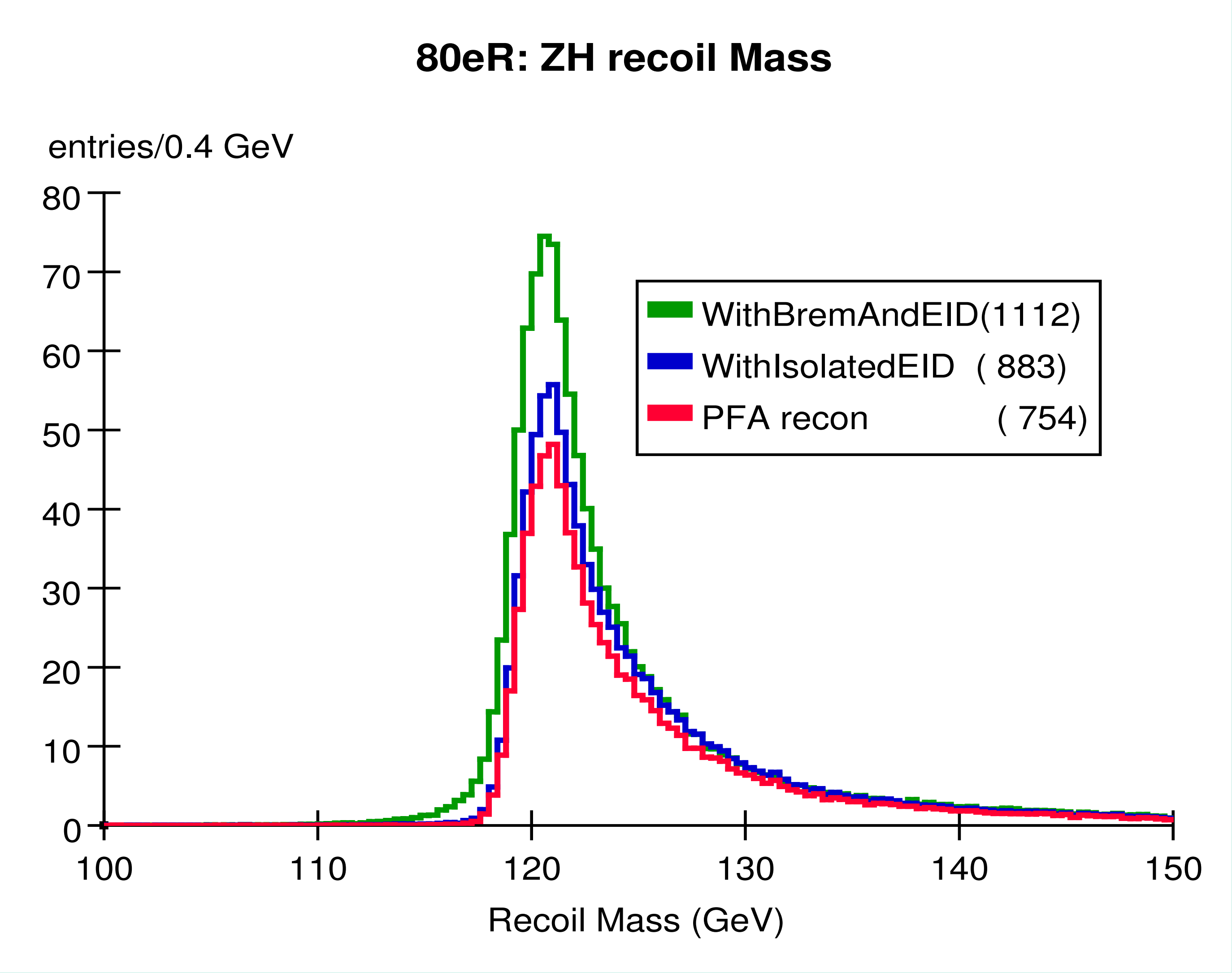


Isolated electron ID

- eeH events:
- Significant improvement in efficiency.
- No loss in purity.
- For analysis, set minE for adding electron to 15 GeV. Gain in purity, virtually no loss in efficiency.
- Checked SM sample and ttbar events:
  purity of added electrons >=
  purity of existing IDed electrons.

Brem recovery in eeH analysis

- Simple algorithm: Add photons to electron if $M(e\gamma) < M_{cut}$.
- For these events, Mcut set to .7 GeV to maximize # events passing Zmass cut.



80eR: ZH recoil Mass
entries/0.4 GeV
80
70
60
50
40
30
20
10
0
100
110
120
130
140
150
Recoil Mass (GeV)
WithBremAndEID(1112)
WithIsolatedEID (883)
PFA recon (754)

$e^+e^- \to \tau^+\tau^-$, $\sqrt{s}$=500 GeV

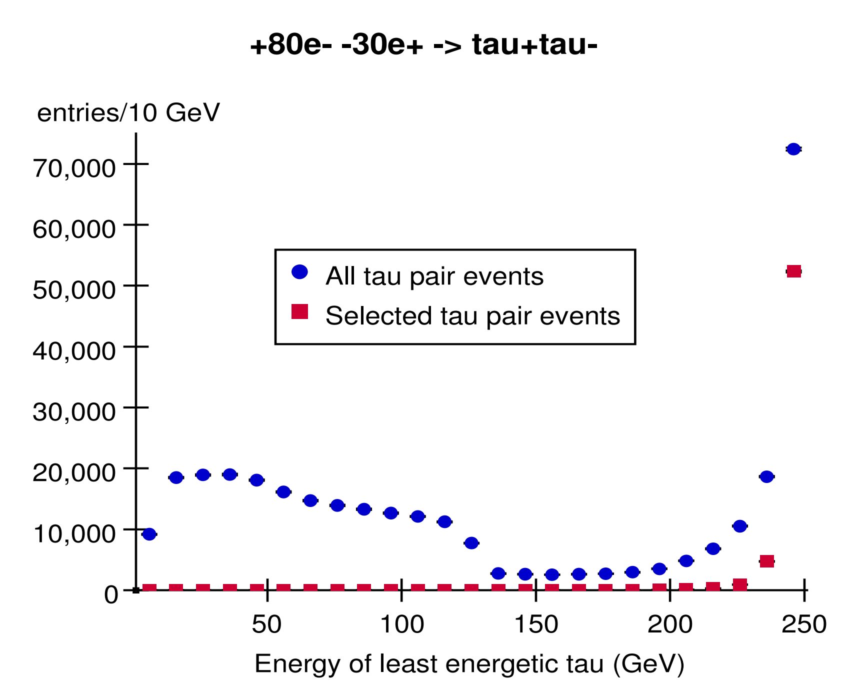
- Selection
- Improved electron ID
- Decay mode identification

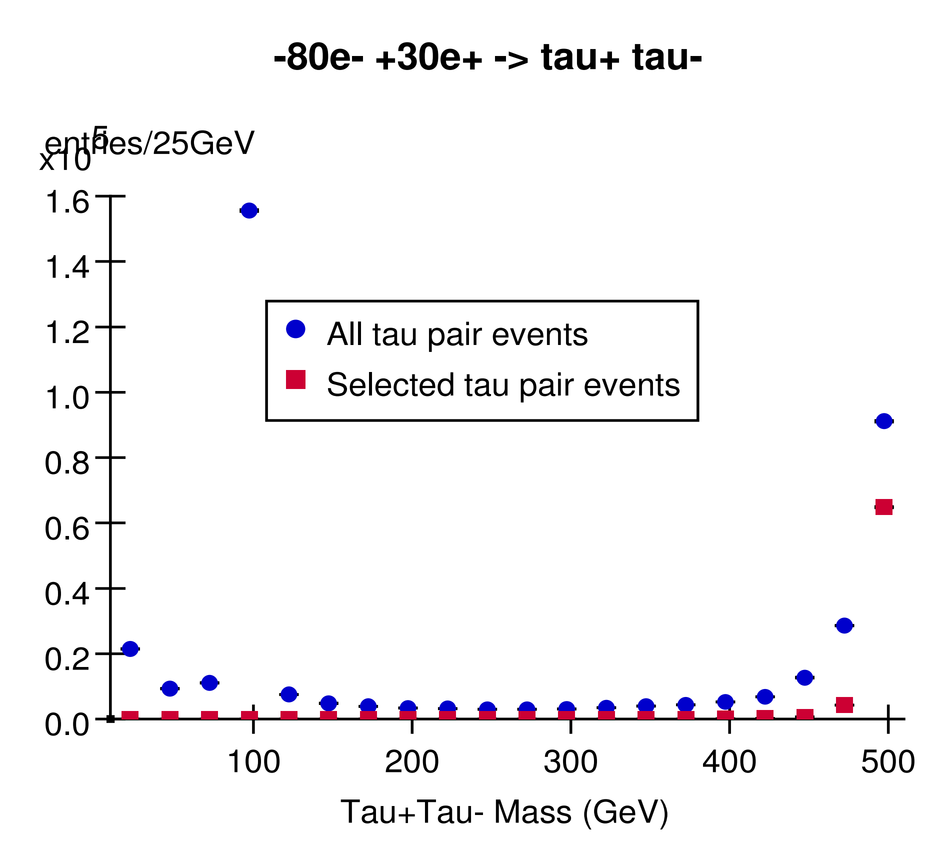
Selection of full energy tau pair events

- Event cuts include: 1 < #Tracks < 7, 40GeV<Evis<450GeV
- Use standard PFA reconstruction, form tau jets.
- Require opening angle between jets > 178°
- Could improve on PFA reconstruction for these low multiplicity events, but would require running on full SM sample, not feasible on LOI time scale.

Tau pair selection (cont)

- Use isolated electron ID, with hemisphere cut on HCal hits.
- Remove 2-prong events where both are IDed as electrons(Bhabha background) or both IDed as muons.
- ~18% of all tau pair events selected.


+80e- -30e+ -> tau+tau-
entries/10 GeV
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
50
100
150
200
250
Energy of least energetic tau (GeV)
All tau pair events
Selected tau pair events


-80e- +30e+ -> tau+ tau-
entries/25GeV
x10^5
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
100
200
300
400
500
Tau+Tau- Mass (GeV)
All tau pair events
Selected tau pair events

Tau decay mode identification

$e^- \bar{\nu}_e \nu_\tau$
$\mu^- \bar{\nu}_\mu \nu_\tau$
$\pi^- \nu_\tau$
$\rho^- \nu_\tau \rightarrow \pi^- \pi^0 \nu_\tau$
$a_1^- \nu_\tau \rightarrow \pi^- \pi^0 \pi^0 \nu_\tau$
$a_1^- \nu_\tau \rightarrow \pi^- \pi^+ \pi^- \nu_\tau$

- Decay modes of interest:
- All π± or πº
- Alternate reconstruction.
- Cluster all calorimeter hits
- Assign to nearest tau jet
- ID photons, assign non-photon clusters to charge tracks.
- Check E/P, if inconsistent look for missed photons.
- Have only π's and photons as ReconstructedParticles.

Decay mode ID criteria

- a π^0 is a pair of photons satisfying 0.06 GeV < $M_{2\gamma}$ < 0.18 GeV
- If criteria not met, alternate photon reconstructions tried. They include combining 2 nearest photons, changing the photon ID of clusters to add or remove photons.
- E/P checked at each iteration.

decay mode	$\#\gamma$	$\#\pi^0$	EPcut	other criteria
$e^-\bar{\nu}_e\nu_\tau$	0	0	-	HCAL energy < 4% of track energy.
$\mu^-\bar{\nu}_\mu\nu_\tau$	0	0	-	identified as μ by PFA
$\pi^-\nu_\tau$	0	0	2.5	-
$\rho^-\nu_\tau \rightarrow \pi^-\pi^0\nu_\tau$	1	0	2.2	$0.6\ \text{GeV} < M_\rho < 0.937\ \text{GeV}$, $E_\gamma > 10\ \text{GeV}$
$\rho^-\nu_\tau \rightarrow \pi^-\pi^0\nu_\tau$	2	1	2.2	$0.4\ \text{GeV} < M_\rho < 0.93\ \text{GeV}$
$a_1^-\nu_\tau \rightarrow \pi^-\pi^0\pi^0\nu_\tau$	3	1	2.2	$0.8\ \text{GeV} < M_{a_1} < 1.5\ \text{GeV}$, $E_\gamma > 10\ \text{GeV}$
$a_1^-\nu_\tau \rightarrow \pi^-\pi^0\pi^0\nu_\tau$	4	2	2.2	$0.8\ \text{GeV} < M_{a_1} < 1.5\ \text{GeV}$
$a_1^-\nu_\tau \rightarrow \pi^-\pi^+\pi^-\nu_\tau$	0	0	2.5	$0.8\ \text{GeV} < M_{a_1} < 1.7\ \text{GeV}$

Table 4.6: Decay mode identification criteria.

Tau decay mode ID results

decay mode	Correct ID	Wrong ID	ID eff	ID purity	SM bgnd
$e^- \bar{\nu}_e \nu_\tau$	39602	920	0.991	0.977	1703
$\mu^- \bar{\nu}_\mu \nu_\tau$	39561	439	0.993	0.989	1436
$\pi^- \nu_\tau$	28876	2612	0.933	0.917	516
$\rho^- \nu_\tau \to \pi^- \pi^0 \nu_\tau$	55931	8094	0.790	0.874	1054
$a_1^- \nu_\tau \to \pi^- \pi^0 \pi^0 \nu_\tau$	18259	11140	0.732	0.621	847
$a_1^- \nu_\tau \to \pi^- \pi^+ \pi^- \nu_\tau$	21579	2275	0.914	0.905	141

Table 4.7: Tau decay mode reconstruction for all events.

Summary

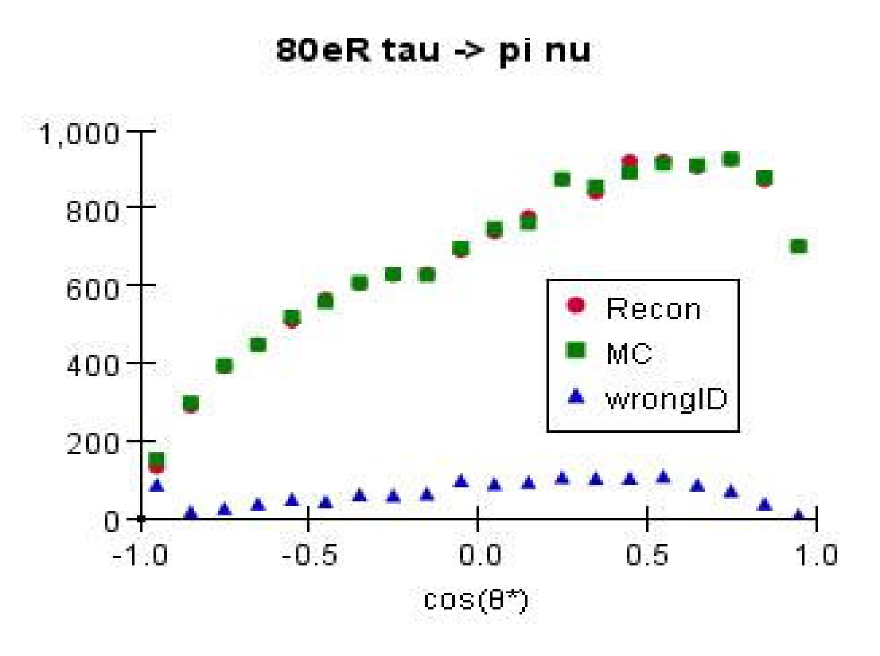
- E > 15 GeV:

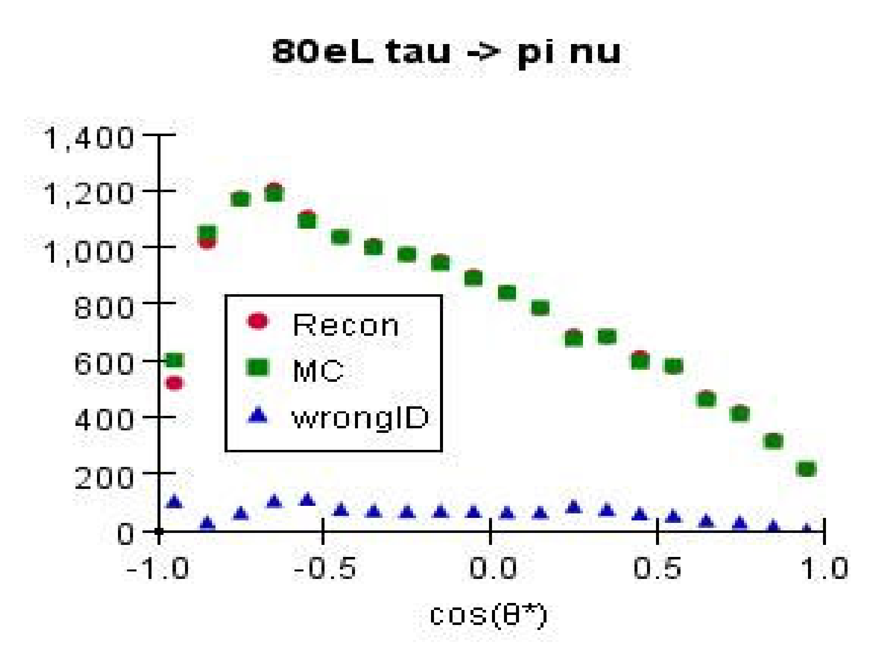
	efficiency	purity
SM events:		
muons:	.97	.97
electrons:	.85	.95
ZH events:		
muons:	.983	.985
electrons:	.896 -> .980	.984
tau pair evts:		
muons:	.993	.989
electrons:	.87 -> .991	.95 -> .977

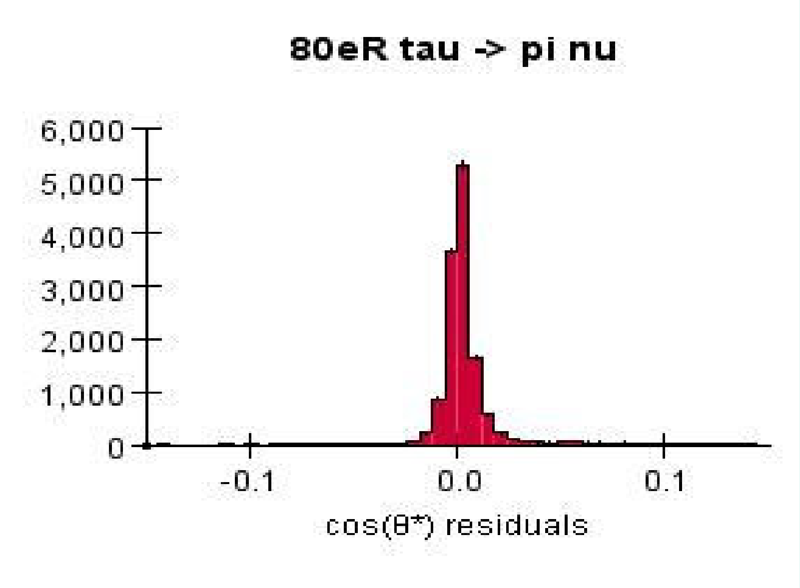
- Full energy tau pairs: ~75% of events IDed
  decay mode identification sufficient for a 1% polarization measurement.

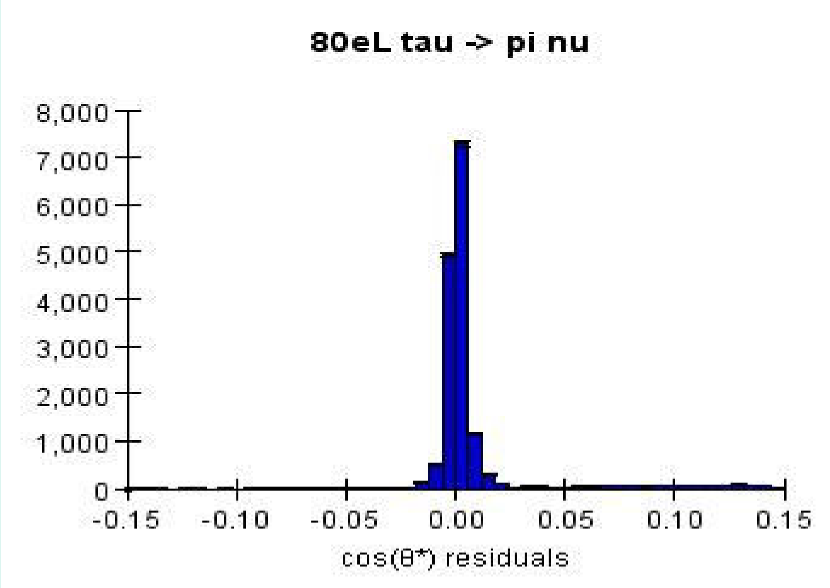
Extras

Θ* = angle between pi and tau in tau rest frame

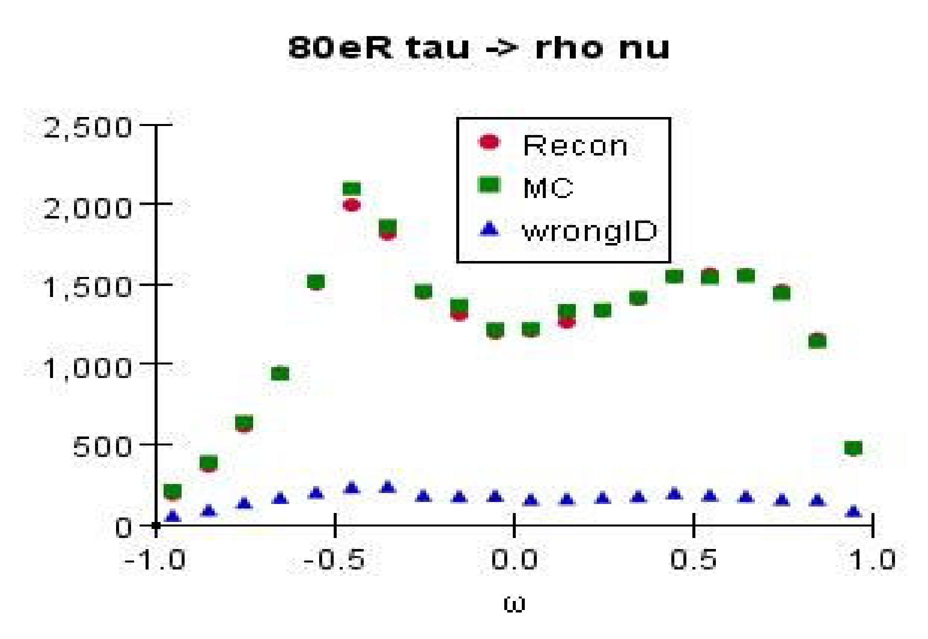


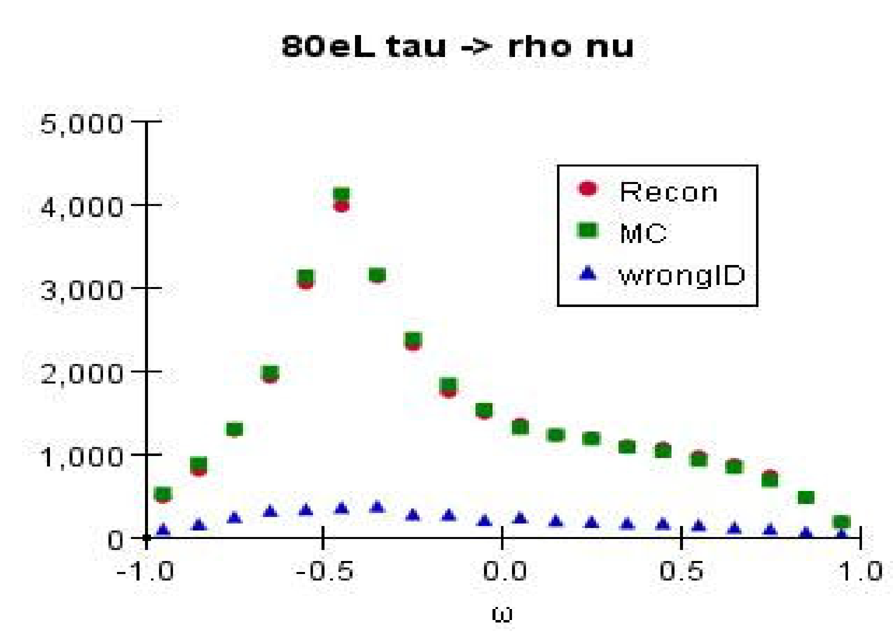


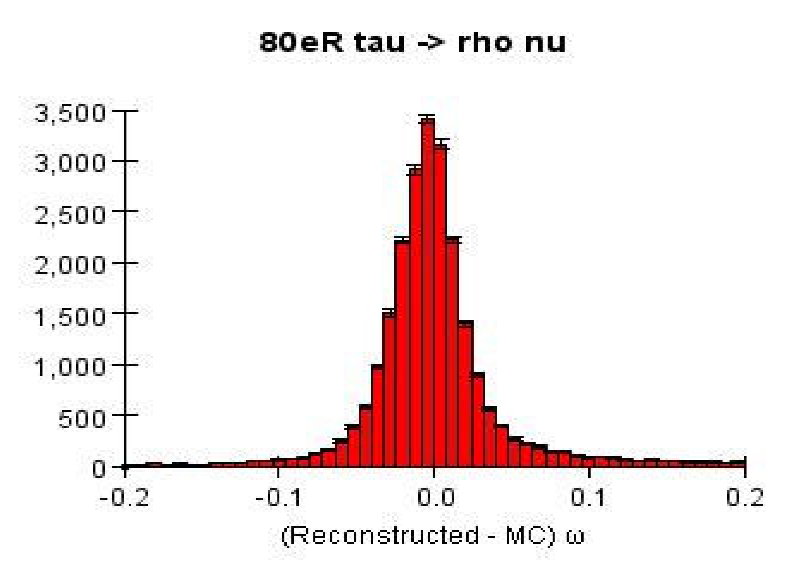


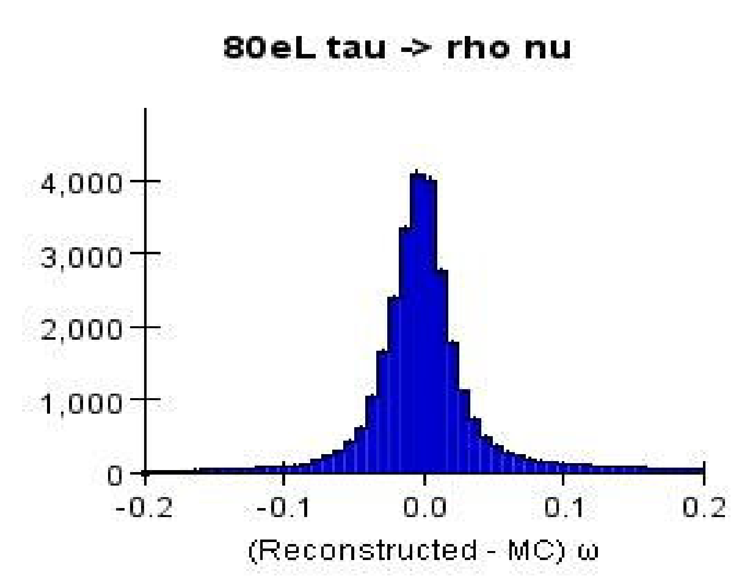


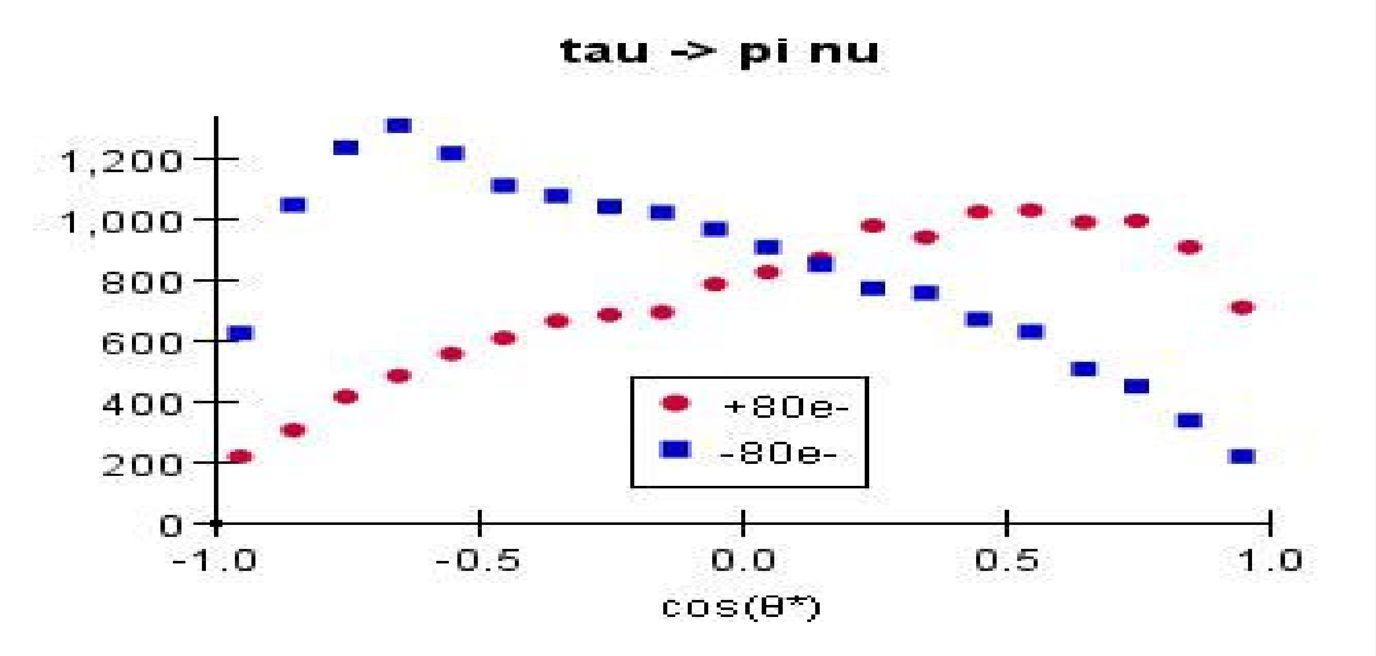
ω = optimal observable

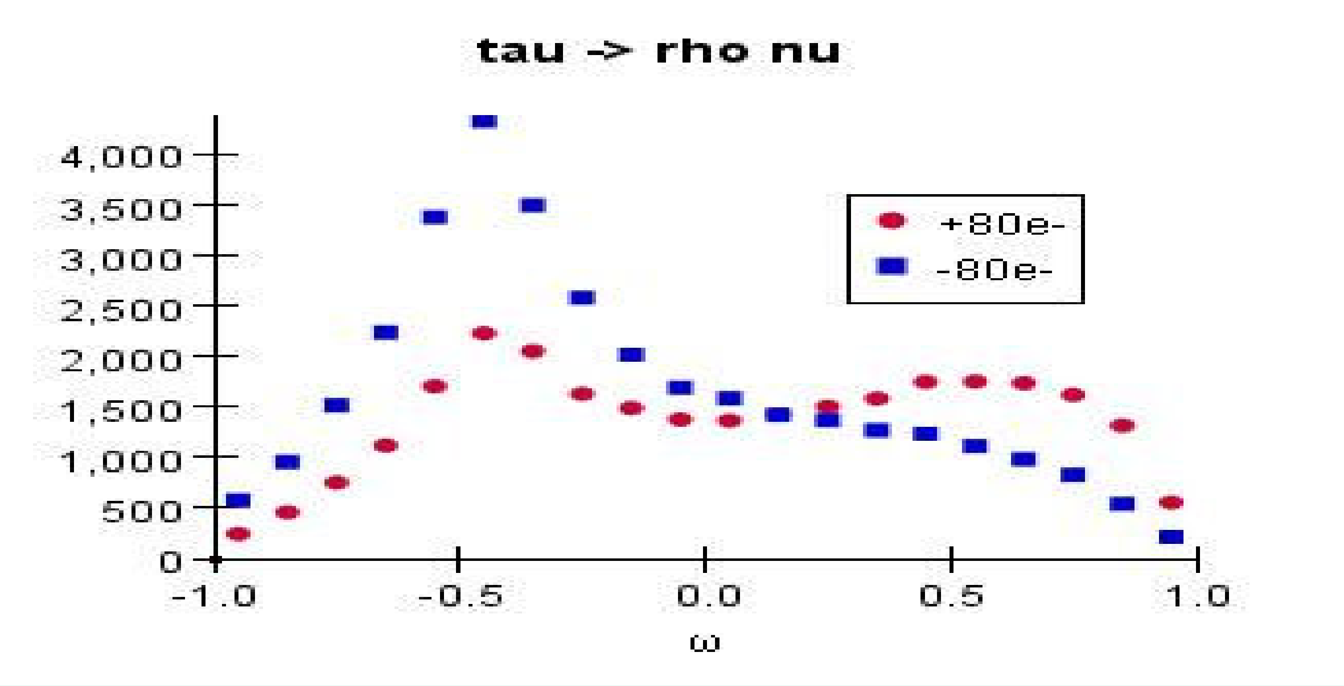









tau -> pi nu
1,200
1,000
800
600
400
200
0
-1.0
-0.5
0.0
0.5
1.0
cos(θ*)
+80e-
-80e-


tau -> rho nu
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
-1.0
-0.5
0.0
0.5
1.0
ω
+80e-
-80e-