

$$WH \rightarrow WWW \rightarrow l\nu l\nu l\nu$$

Modelling The P_T , η , and ϕ of the Primary Trilepton Signal

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Stntuple File

- Stntuple dataset *fhgs6f* contains $WH \rightarrow WWW$ events for a 160 GeV Higgs boson, where one W decays leptonically.
- For the trilepton study, all three W 's decay leptonically ($WWW \rightarrow l\nu l\nu l\nu$)
- Filter: Require $WWW \rightarrow l\nu l\nu l\nu$ and if the lepton is tau, require tau also to decay leptonically. Hence, signature given by electrons and muons.
- 100,000 events $\rightarrow$ 2358 events

Leading Lepton - Generator Level (no cuts)

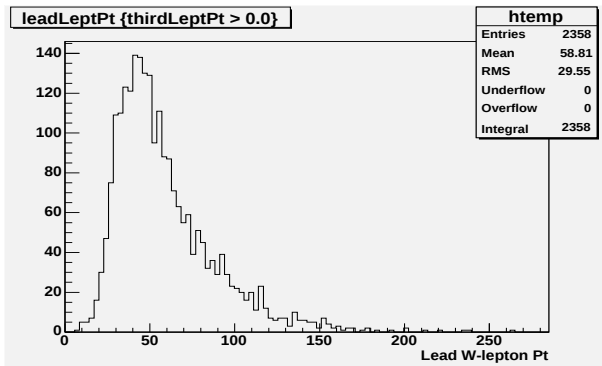


Figure: Lead Generator-level Lepton Pt (GeV)

2nd Lepton - Generator Level (no cuts)

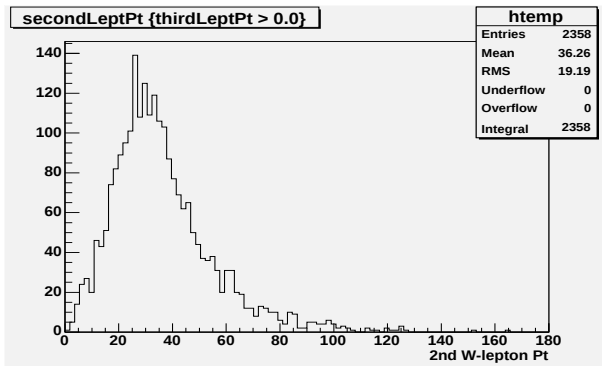
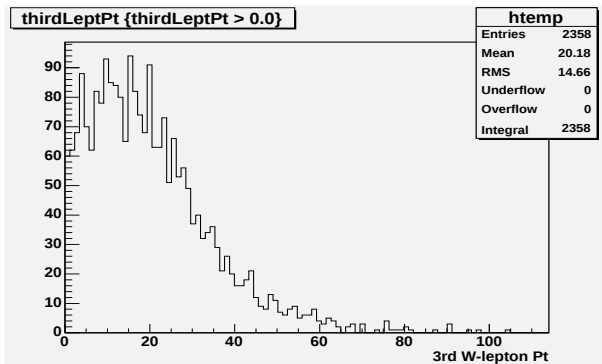


Figure: Second Generator-level Lepton Pt (GeV)

Third Lepton - Generator Level (no cuts)

Third lepton P_T substantial at low values. Note: If an events has $W \rightarrow \tau \nu_\tau \rightarrow l_{e,\mu} \nu_{e,\mu}$, then two neutrinos carry away energy.



Gen.-Level P_T and η Cuts

Now make basic cuts to exclude electrons, muons the detector could never find.

- Leading lepton $P_T > 16$ GeV
- 2nd lepton $P_T > 8$ GeV
- 3rd lepton $P_T > 2$ GeV
- $-1.7 < \eta < 1.7$ for muons
- $-2.9 < \eta < 2.9$ for electrons

2358 events $\rightarrow$ 1902 events.

Leading Lepton - Generator Level P_T and η Cuts

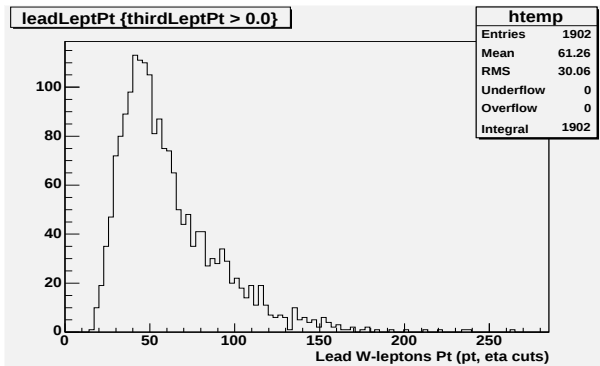


Figure: Lead Generator-level Lepton Pt (GeV). Basic P_T and η cuts at generator-level.

2nd Lepton - Generator Level P_T and η Cuts

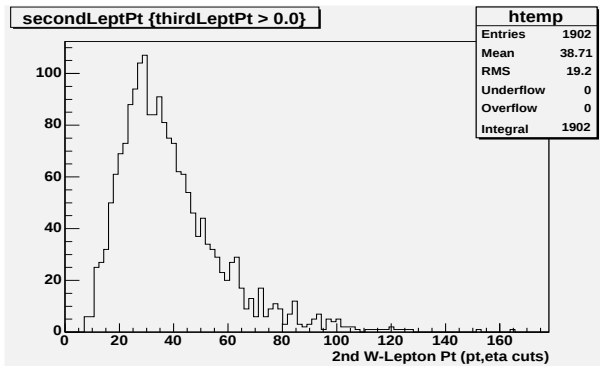


Figure: 2nd Generator-level Lepton Pt (GeV). Basic P_T and η cuts at generator-level.

Third Lepton - Generator Level P_T and η Cuts

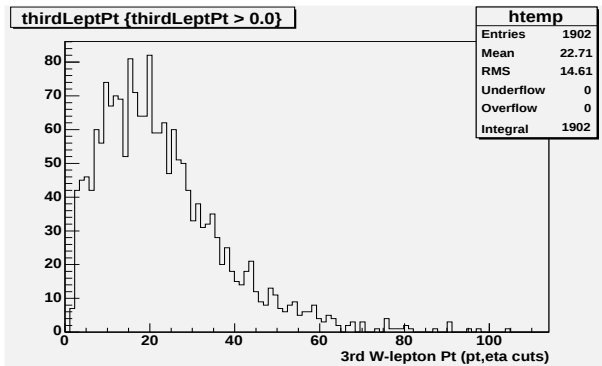


Figure: 3rd Generator-level Lepton Pt (GeV). Basic P_T and η cuts at generator-level.

Three Reconstructed Leptons

Among these 1902 events, let's find the first three leptons (electrons or muons) at reconstruction-level. No additional cuts have been made here. Because a few of these events will not find three reconstructed leptons, 1902 events whittles down to 1845 events.

Lead Recon. Lepton

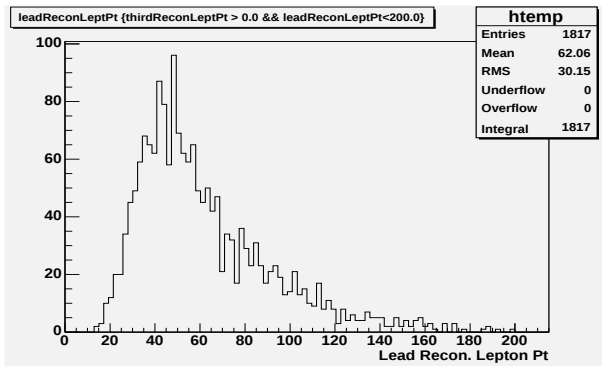


Figure: Lead Reconstructed-level Lepton Pt (GeV). Basic P_T and η cuts at generator-level. The count is 1845; events above 200.0 GeV

2nd Recon. Lepton

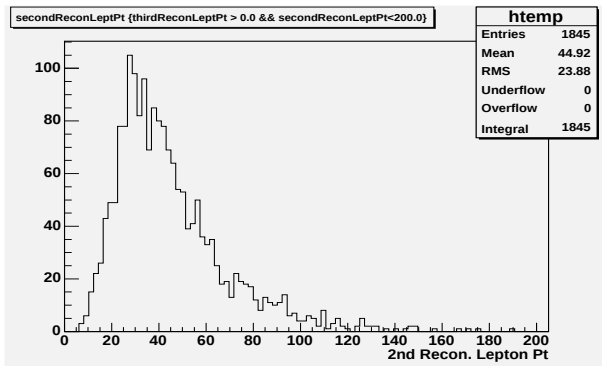


Figure: 2nd Reconstructed-level Lepton Pt (GeV). Basic P_T and η cuts at generator-level.

3rd Recon. Lepton

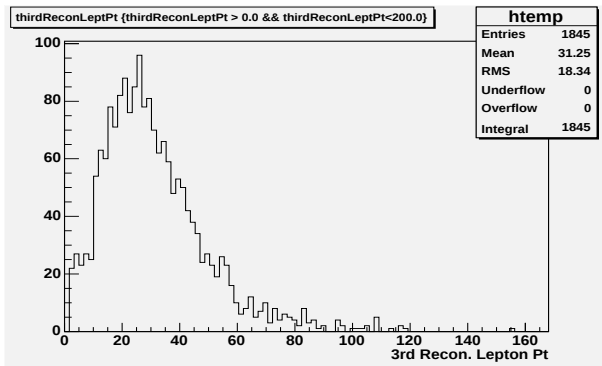
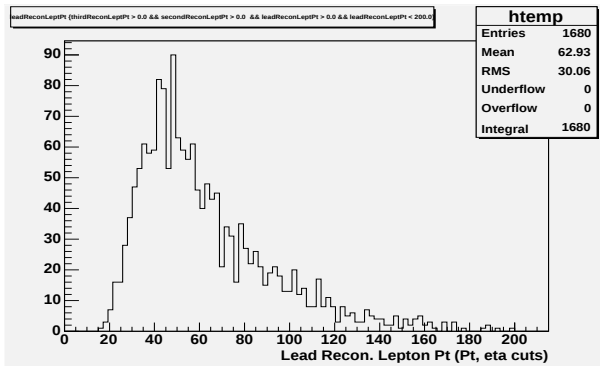


Figure: 3rd Reconstructed-level Lepton Pt (GeV). Basic P_T and η cuts at generator-level.

Lead Recon. Lepton

Make the same P_T and η on the reconstructed electrons and muons. 1845 events becomes 1702 events.



2nd Recon. Lepton

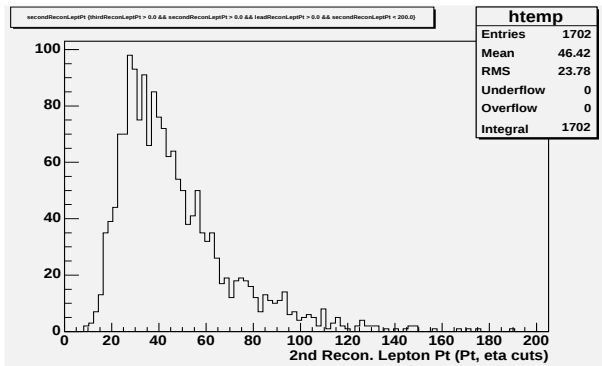


Figure: 2nd Reconstructed-level Lepton Pt (GeV). Basic P_T and η cuts at generator-level, as well as at reconstruction-level.

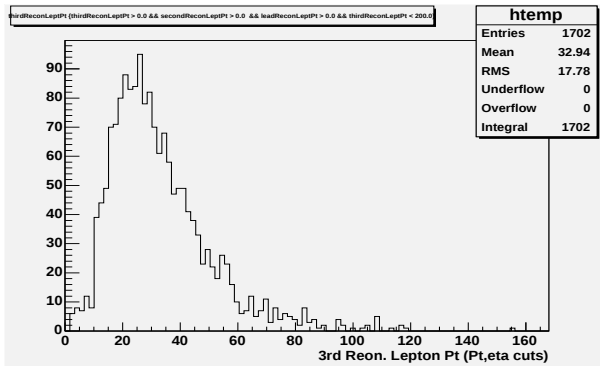


Figure: 3rd Reconstructed-level Lepton Pt (GeV). Basic P_T and η cuts at generator-level, as well as at reconstruction-level.

Matching Definition

The matching criterion is:

$$\text{Matching Factor} \equiv \frac{|P_{T,\text{recon}} - P_{T,\text{gen}}|}{\delta_{P_T}} + \frac{|\eta_{\text{recon}} - \eta_{\text{gen}}|}{\sigma_\eta} + \frac{|\phi_{\text{recon}} - \phi_{\text{gen}}|}{\sigma_\phi} < 40.0$$

$P_{T,\text{recon}}$ = Reconstructed particle P_T

$P_{T,\text{gen}}$ = Generator-level particle P_T

$\delta_{P_T} = 0.0015 \cdot P_{T,\text{recon}}$

η_{recon} = Pseudorapidity of reconstructed particle

η_{gen} = Psuedorapidity of generator-level particle

ϕ_{recon} = Azimuthal Angle of reconstructed particle

ϕ_{gen} = Azimuthal Angle of generator-level particle

σ_η = Standard Deviation of a Gaussian fit to $\eta_{\text{recon}} - \eta_{\text{gen}}$

σ_ϕ = Standard Deviation of a Gaussian fit to $\phi_{\text{recon}} - \phi_{\text{gen}}$

Lead Recon. Lepton

1702 events cut down to 1129.

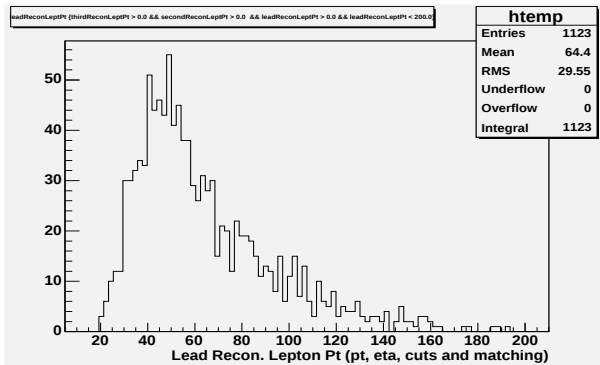


Figure: Lead Reconstructed-level Lepton Pt (GeV). Basic P_T and η

2nd Recon. Lepton

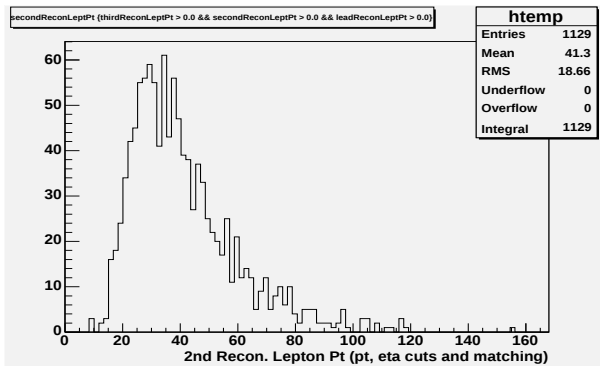


Figure: 2nd Reconstructed-level Lepton Pt (GeV). Basic P_T and η cuts at generator-level, as well as at reconstruction-level, and matched.

3rd Recon. Lepton

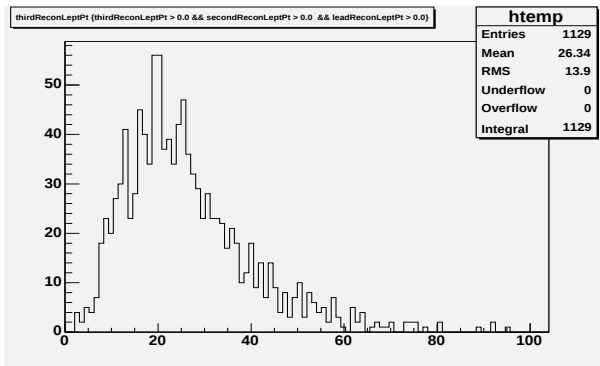


Figure: 3rd Reconstructed-level Lepton Pt (GeV). Basic P_T and η cuts at generator-level, as well as at reconstruction-level, and matched.

Electron Cuts

- Central Electrons

- $\frac{\text{TrackIso()}}{E_T} < 0.1$
- $\frac{\text{Had. Energy}}{\text{Em. Energy}} < 0.055 + 0.00045 \cdot E$
- $\frac{E}{p} < 2.5 + 0.015 \cdot E_T$

- Plug Electrons

- $\frac{\text{TrackIso()}}{E_T} < 0.1$
- $\frac{\text{Had. Energy}}{\text{Em. Energy}} < 0.05$

- No Forward Electrons found, no PHX electrons found that aren't already central or Plug(Under Investigation). Precedence is given to central and plug electrons.

Muon Cuts

- Em. Energy < 2.0 GeV
- Had. Energy < 6.0 GeV
- $\frac{\text{TrackIso()}}{P_T} < 0.1$

1129 events cut down to 771.

Lead Leptons

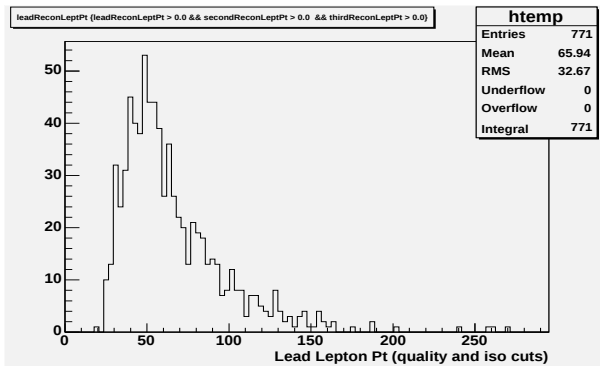


Figure: Lead Reconstructed-level Lepton Pt (GeV). Basic P_T and η cuts at generator-level, as well as at reconstruction-level, matched,

2nd Leptons

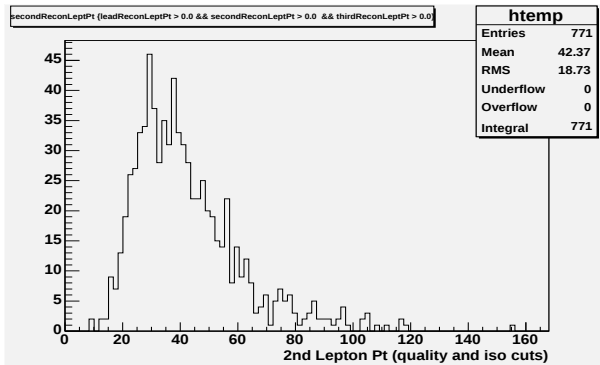


Figure: 2nd Reconstructed-level Lepton Pt (GeV). Basic P_T and η cuts at generator-level, as well as at reconstruction-level, matched, and

3rd Leptons

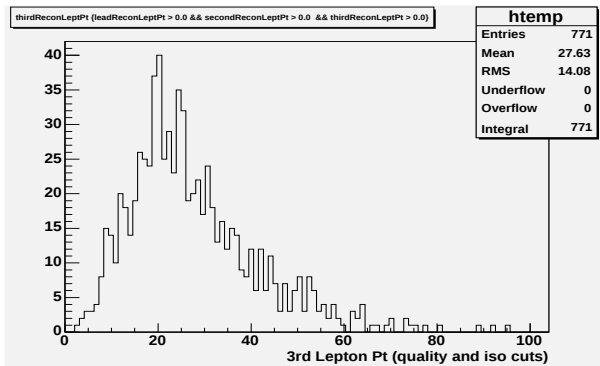


Figure: 3rd Reconstructed-level Lepton Pt (GeV). Basic P_T and η cuts at generator-level, as well as at reconstruction-level, matched, and

Table

Cuts	Number (out of 100,000)	%(from previous step)
Pass $HW \rightarrow WWW \rightarrow l\nu l\nu l\nu$ filter	2358	2.36
P_T , η cuts at generator-level	1902	80.6
Lead, 2nd, 3rd Reconstructed leptons found	1845	97.0
Same P_T , η cuts at reconstruction-level	1702	92.2
Pass Matching Criterion	1129	66.3
Pass Quality/Isolation Cuts	771	68.3

Table: Event Summary

Tripleton File/Filter
 Gen. P_T , η Cuts
 3 Recon. Leptons
 Recon. P_T , η Cuts
 Matching
 Quality/Isolation Cuts
 Summary

Overall Summary Table
 Quality Cuts Table
 Quality Cuts Table

Quality Cuts Table

Cuts	Number (out of 1129)	%(from previous step)
Central Electron $\frac{\text{TrackIso()}}{E_T} < 0.1$	1083	95.9
Central Electron $\frac{\text{Had.E}}{\text{Em.E}} < 0.055 + 0.00045 \cdot E$	1059	97.8
Central Electron $\frac{E}{p} < 2.5 + 0.015 \cdot E_T$	1006	95.0
Plug Electron $\frac{\text{TrackIso()}}{E_T} < 0.1$	882	87.7
Plug Electron $\frac{\text{Had.E}}{\text{Em.E}} < 0.05$	873	99.0
Forward Electron $\frac{\text{TrackIso()}}{E_T} < 0.1$	-	0
Forward Electron $\frac{\text{Had.E}}{\text{Em.E}} < 0.05$	-	0
PHX Electron $\frac{\text{TrackIso()}}{E_T} < 0.1$	-	0
PHX Electron $\frac{\text{Had.E}}{\text{Em.E}} < 0.05$	-	0
Muons Em. Energy < 2.0	803	92.0
Muons Had. Energy < 6.0	784	97.6
Muons $\frac{\text{TrackIso()}}{E_T} < 0.1$	771	98.2

Quality Cuts detailed by 1st, 2nd, 3rd electrons and muons. Each of the leptons in this table are required to pass P_T and η cuts at both generator-level and reconstruction-level, and pass the matching criterion. Note that there are 1409 events with leading electrons that meet these requirements (and 1513 events with leading muons that meet these requirements), but the table lists only 1129 events passing the same requirements. The latter count is lower because it corresponds to finding three leading leptons meetings these requirements.

Quality Cuts Table (electrons)

Cuts	Number	%
Lead Electron $\frac{\text{TrackIso}()}{E_T} < 0.1$	1276/1409	90.6
Lead Electron $\frac{\text{Had.E}}{\text{Em.E}} < 0.055 + 0.00045 \cdot E$	1348/1409	95.7
Lead Electron $\frac{E}{p} < 2.5 + 0.015 \cdot E_T$	1152/1409	81.8
2nd Electron $\frac{\text{TrackIso}()}{E_T} < 0.1$	632/781	80.9
2nd Electron $\frac{\text{Had.E}}{\text{Em.E}} < 0.055 + 0.00045 \cdot E$	726/781	93.0
2nd Electron $\frac{E}{p} < 2.5 + 0.015 \cdot E_T$	585/781	74.9
3rd Electron $\frac{\text{TrackIso}()}{E_T} < 0.1$	159/215	74.0
3rd Electron $\frac{\text{Had.E}}{\text{Em.E}} < 0.055 + 0.00045 \cdot E$	200/215	93.0
3rd Electron $\frac{E}{p} < 2.5 + 0.015 \cdot E_T$	136/215	63.3

Table:

Quality Cuts Table (muons)

Cuts	Number	%
Lead Muon Em. Energy < 2.0	1427/1513	94.3
Lead Muon Had. Energy < 6.0	1476/1513	97.6
Lead Muon $\frac{\text{TrackIso}()}{P_T} < 0.1$	1511/1513	99.9
2nd Muon Em. Energy < 2.0	837/876	95.5
2nd Muon Had. Energy < 6.0	858/876	97.9
2nd Muon $\frac{\text{TrackIso}()}{P_T} < 0.1$	865/876	98.7
3rd Muon Em. Energy < 2.0	234/241	97.1
3rd Muon Had. Energy < 6.0	240/241	99.6
3rd Muon $\frac{\text{TrackIso}()}{P_T} < 0.1$	220/241	91.3

Table: