

Bhabha Tracking Efficiencies

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Motivation

- I am performing an analysis to estimate the tracking efficiency on phase 2 data
- The process I am considering is Bhabha events $e^+ + e^- \rightarrow e^+ + e^-$
- The definition of efficiency I am going to use is:

$$\epsilon = \frac{\text{Number of Bhabha events with exactly 2 tracks}}{\text{Number of Bhabha events with 1 or more tracks}}$$

- After selecting Bhabha events where at least one of the tracks was detected, one can look how many times the second one is found
- This idea comes from some plots presented by Sam Cunliffe in previous [tracking and ECL](#) meetings.

Best Candidate Selection

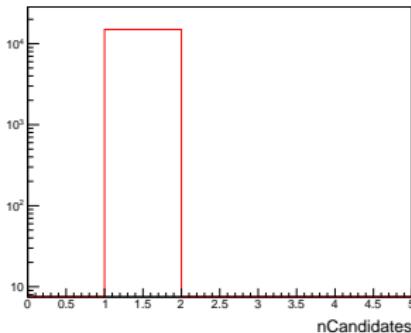
$v\text{pho} \rightarrow \text{ECL-Object(HcLE)} + \text{ECL-Object(LcLE)}$

HcLE: particle with the higher cluster Energy; LcLE: particle with the lower cluster Energy

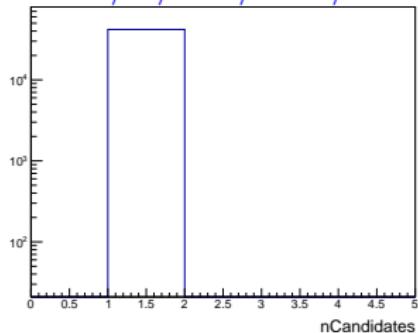
- $0.296706 < \theta_{\text{ECL Object}} < 2.61799 \rightarrow$ It has to hit the ECL
- Exactly two clusters with at least 3.5 GeV per event
- $8 \text{ GeV} < M_{v\text{pho}} < 12 \text{ GeV}$
- nTracks < 7
- Total Energy in the ECL $< 15 \text{ GeV}$

Phase 2 data

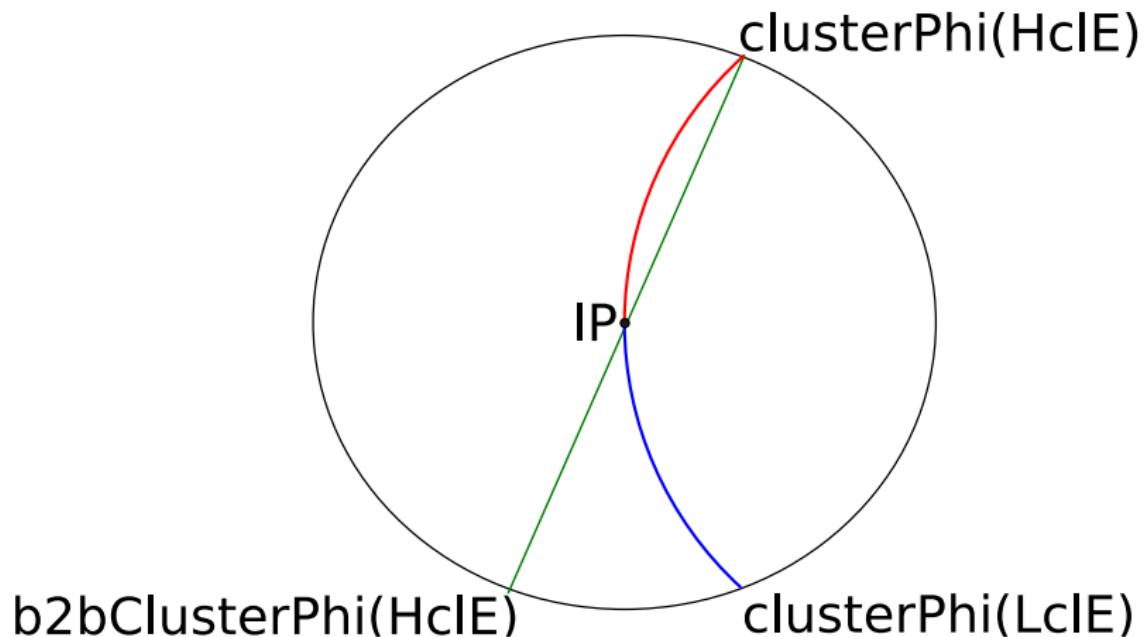
1 MC ee → ee File



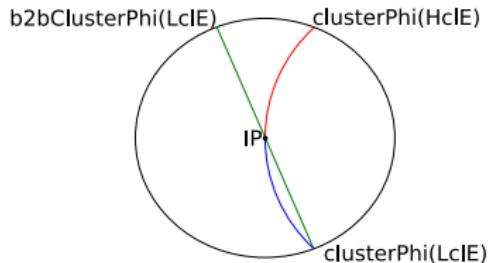
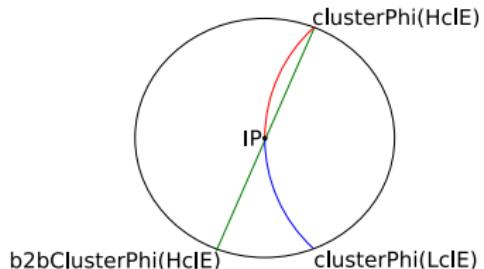
r02608/all/mdst/sub00/*.root



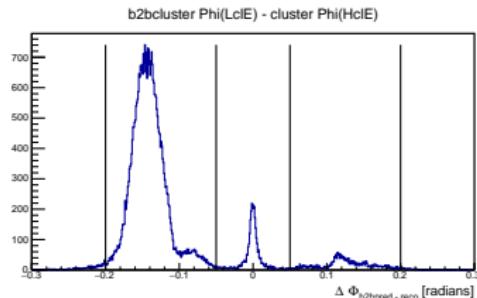
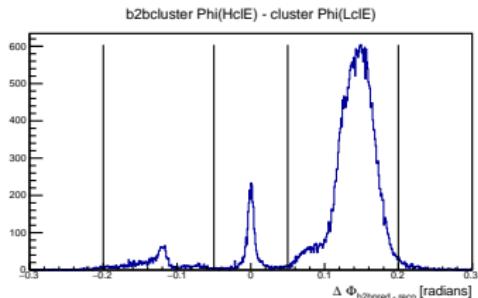
Bhabha Event Selection



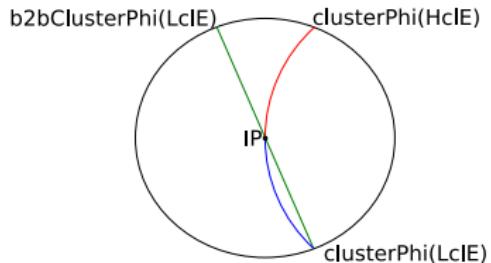
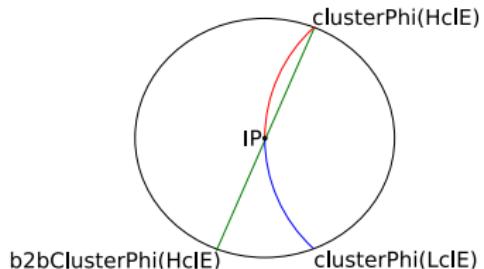
Bhabha Event Selection (Phase 2 data)



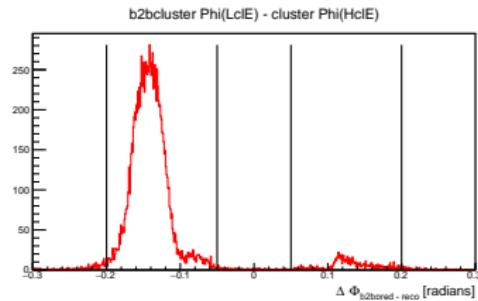
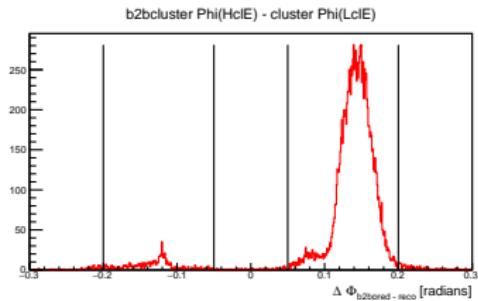
Phase 2 data r02608



Bhabha Event Selection (MC)



MC: ee → ee



More Events

MC:

- /belle/MC/release-02-00-01/DB00000411/MC11/prod00006731/
s00/e1002/4S/r00000/3600520000/mdst/sub00
- 5272146 candidates selected

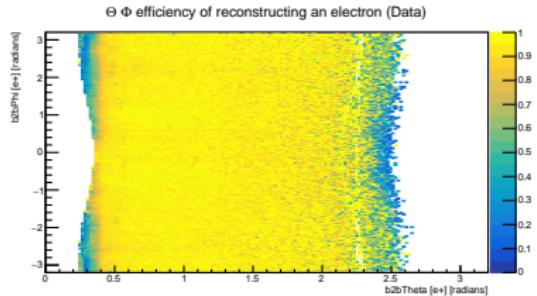
Phase 2 data:

- /ghi/fs01/belle2/bdata//Data/release-03-00-03/
DB00000528/proc00000008/e0003/4S/r02*/all/mdst/sub00/*.root
- proc8
- 3669759 candidates selected

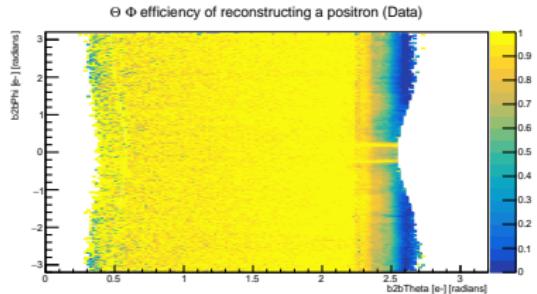
Compare MC And Phase 2 data Efficiency

e^-

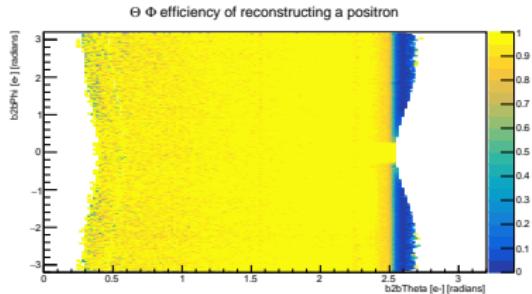
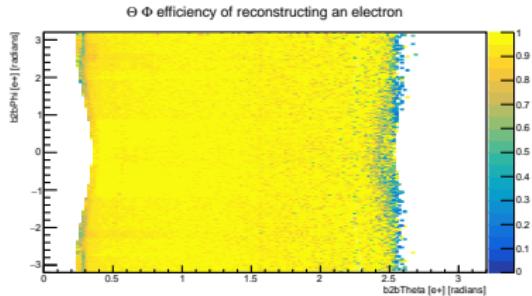
Phase 2 data



e^+



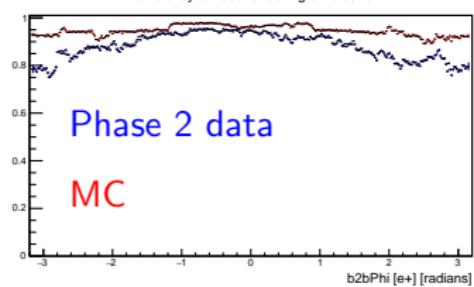
MC



Theta And Phi Projection

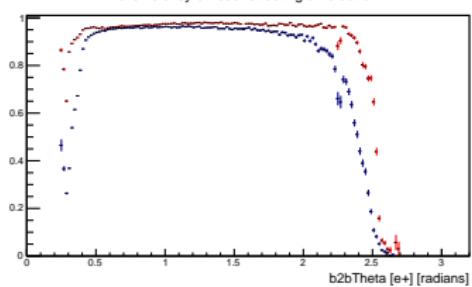
Φ

e^-

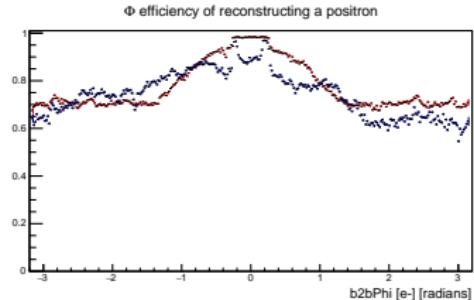


Phase 2 data
MC

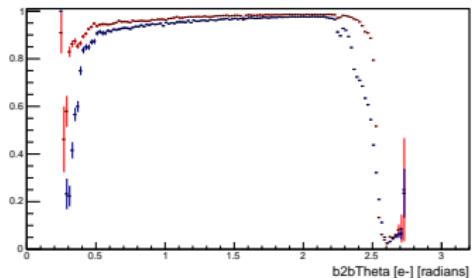
Θ



e^+



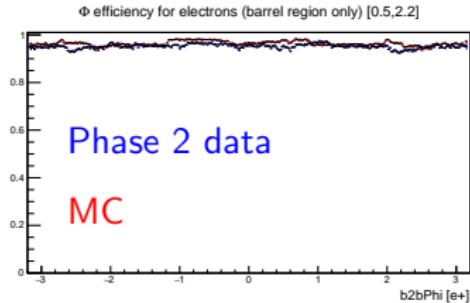
Θ efficiency of reconstructing a positron



Theta And Phi Projection (Barrel Region Only)

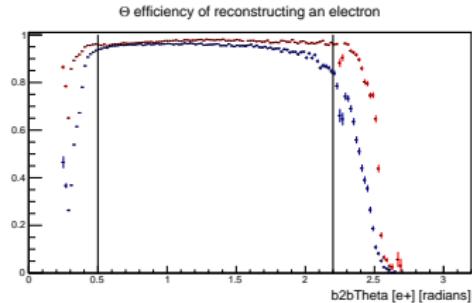
e⁻

Φ

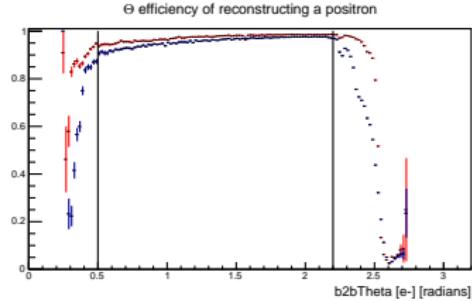
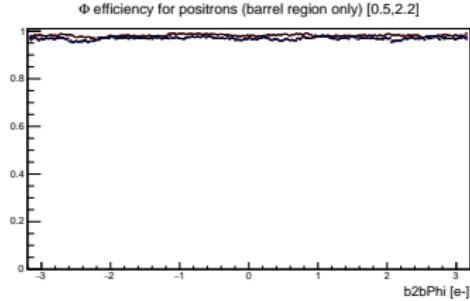


Phase 2 data
MC

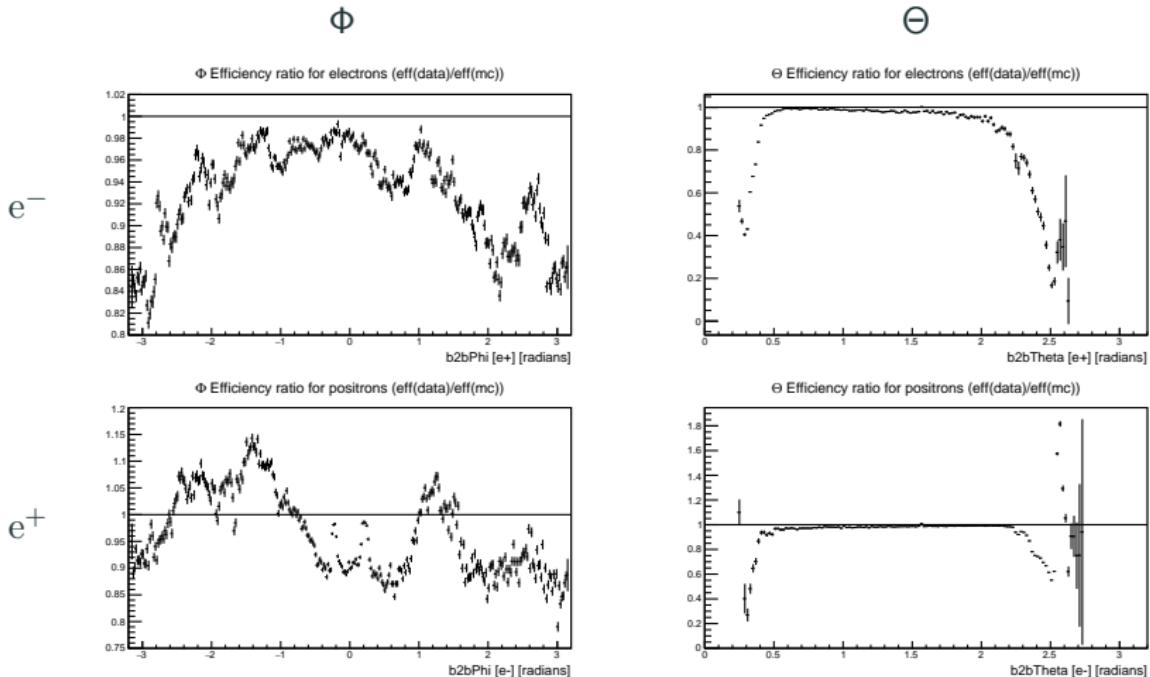
Θ



e⁺



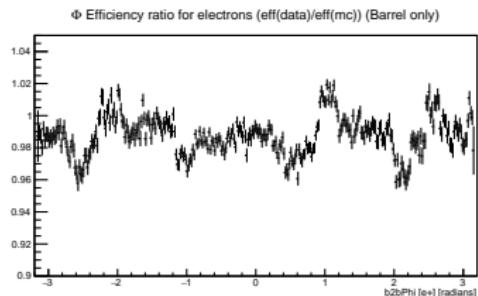
Ratio Between MC And Phase 2 Data



Ratio Between MC And Phase 2 Data (Barrel Region Only)

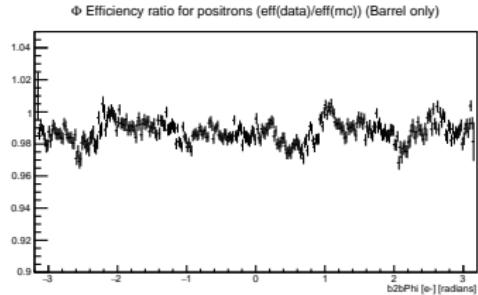
e^-

Φ



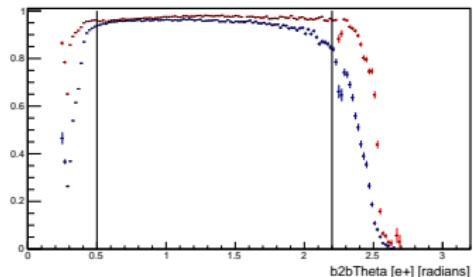
e^+

Φ

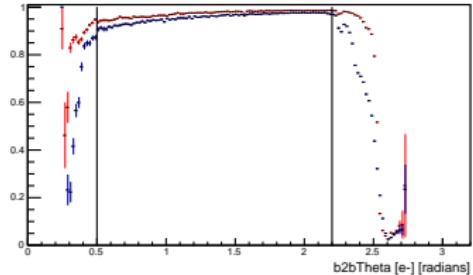


Θ

Θ efficiency of reconstructing an electron



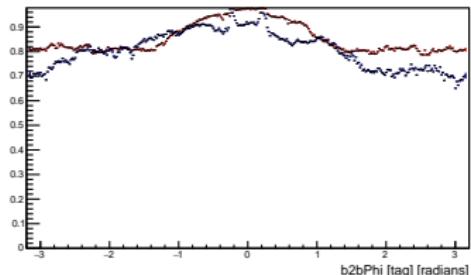
Θ efficiency of reconstructing a positron



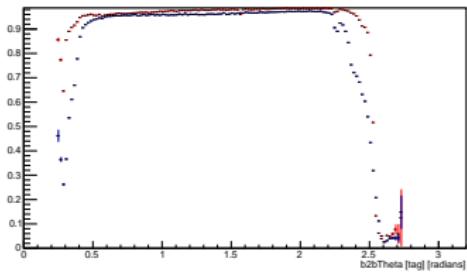
Random

Random means that in an event, I take a particle with a charge and check if the other particle has a track. (No a priori requirement on the charge of the tag particle)

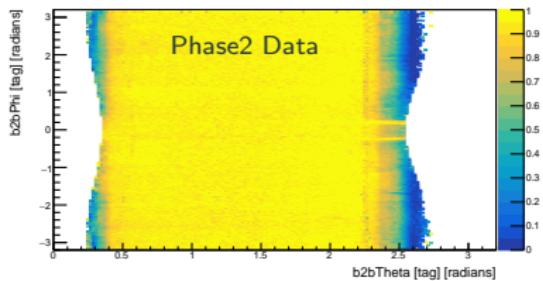
Φ efficiency of reconstructing probe as a charge particle



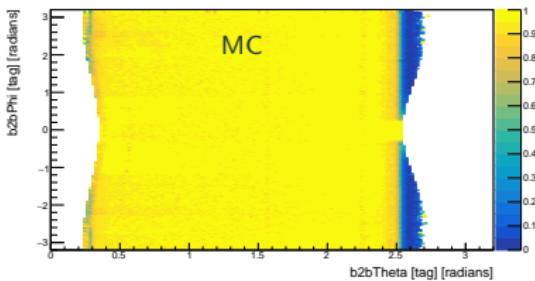
Θ efficiency of reconstructing probe as a charged particle



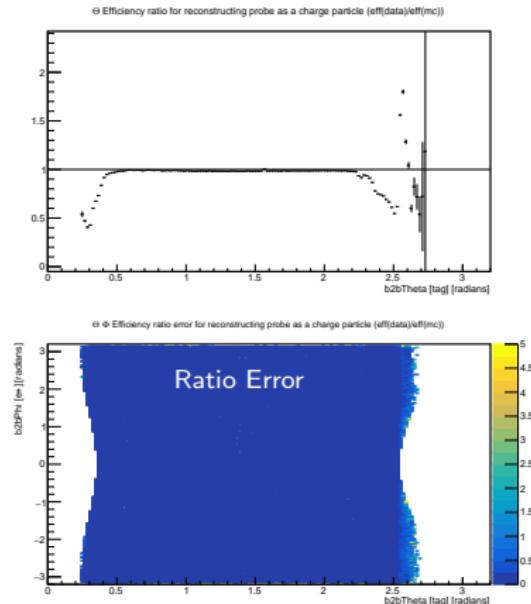
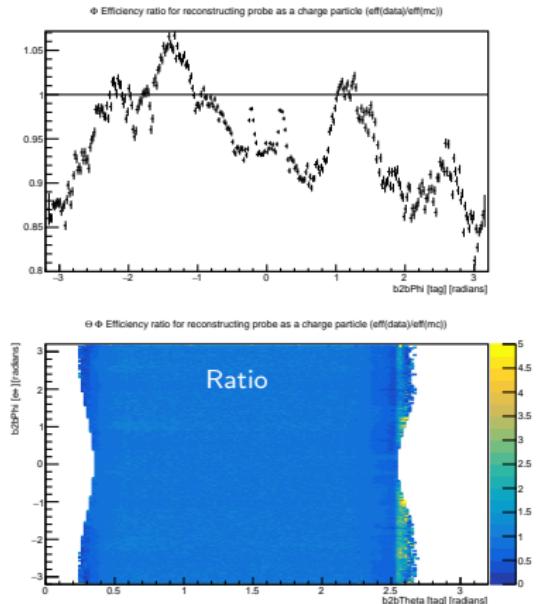
$\Theta \Phi$ efficiency of reconstructing probe as a charged particle



$\Theta \Phi$ efficiency of reconstructing probe as a charged particle

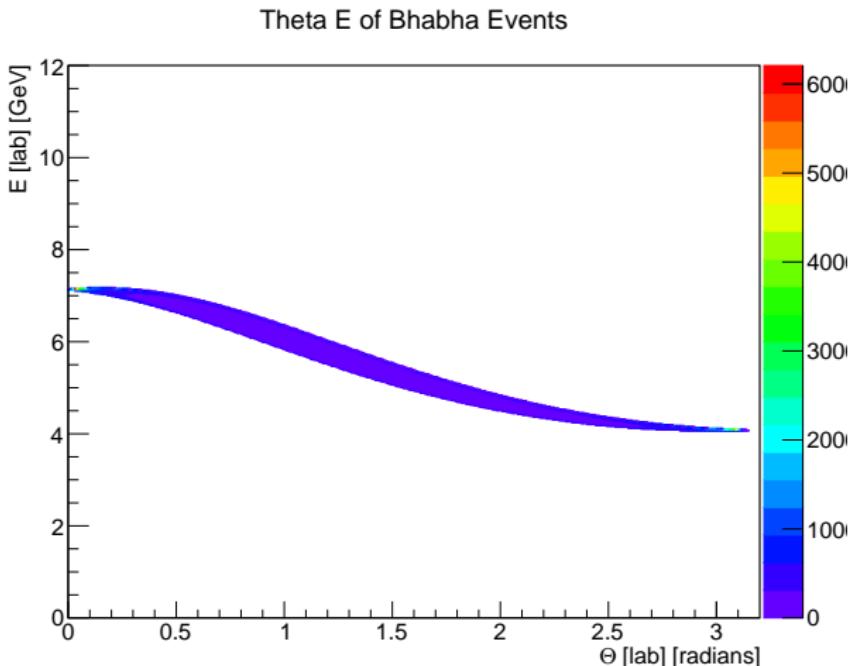


Random Ratio



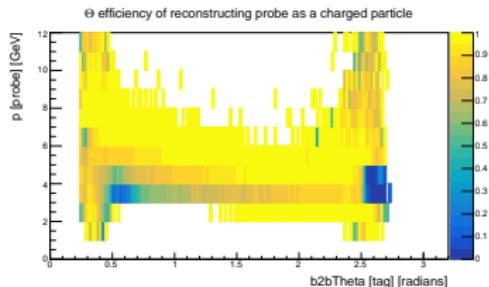
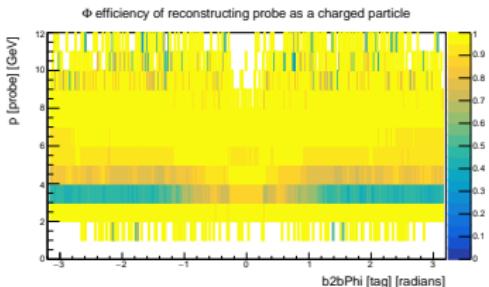
Energy

This plot was created with a random event generator I wrote myself. It's just supposed to visualize the energy angle dependence of the Bhabha particles.

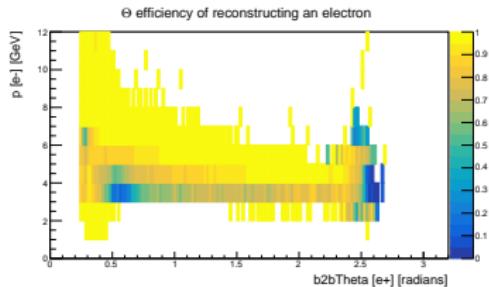
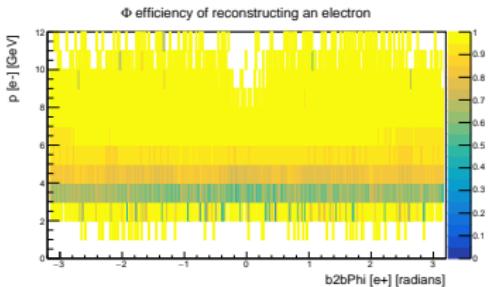


Momentum (MC)

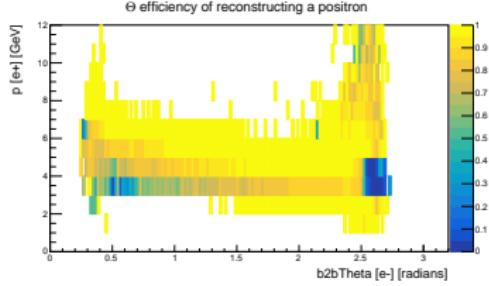
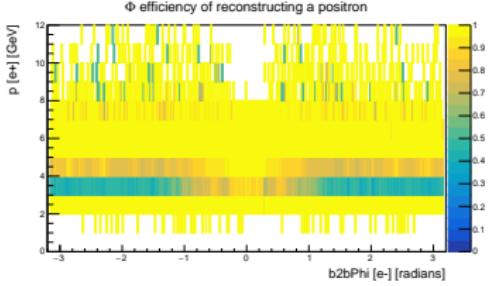
Random



e^-

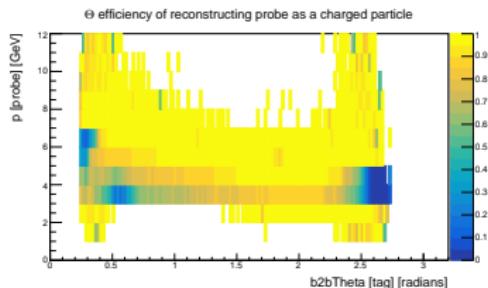
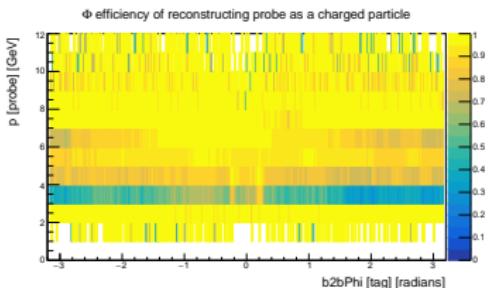


e^+

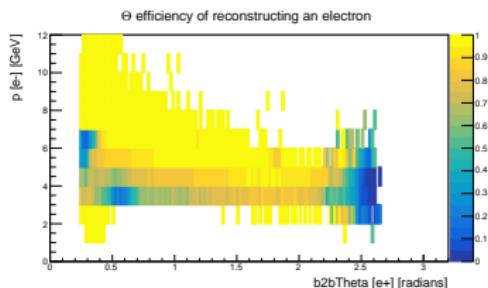
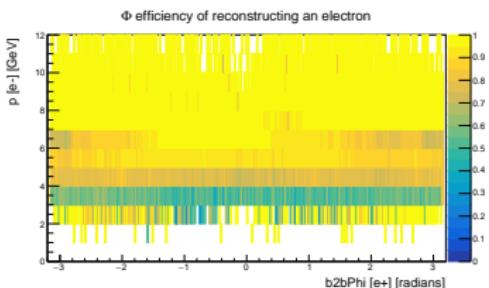


Momentum (Phase 2 Data)

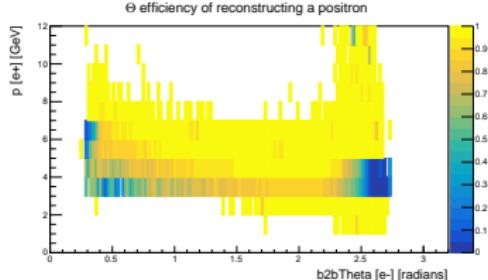
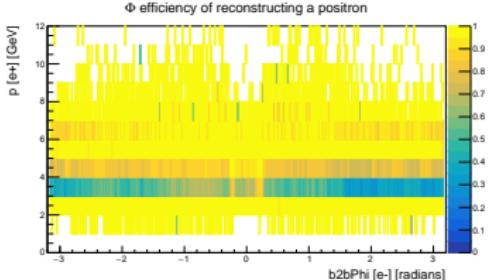
Random



e^-



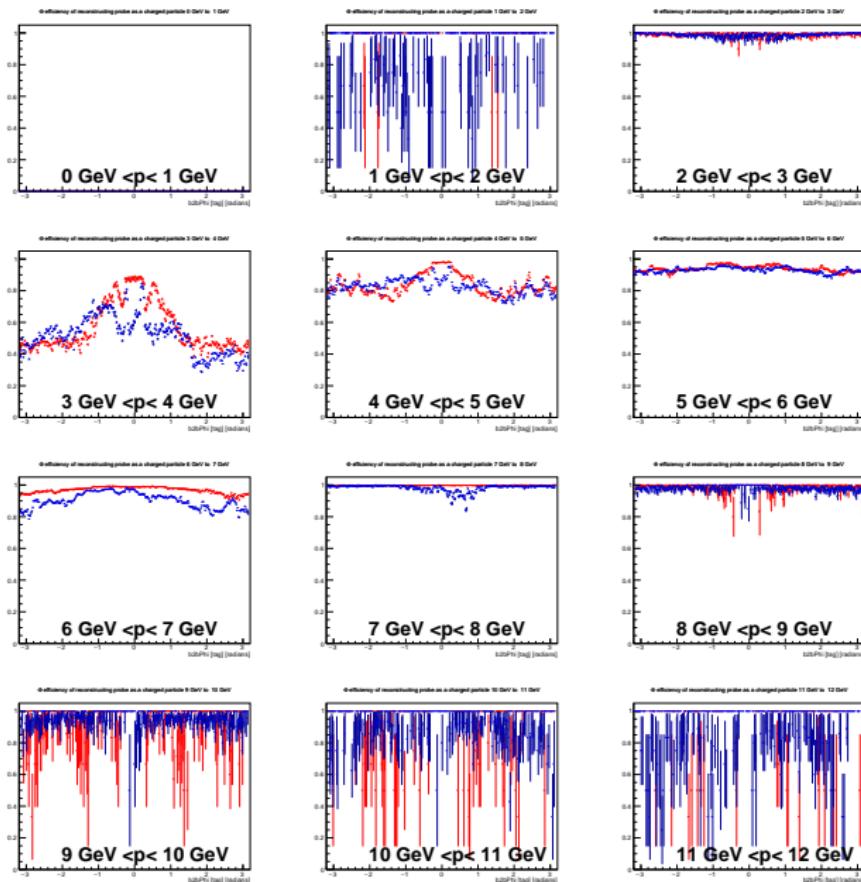
e^+



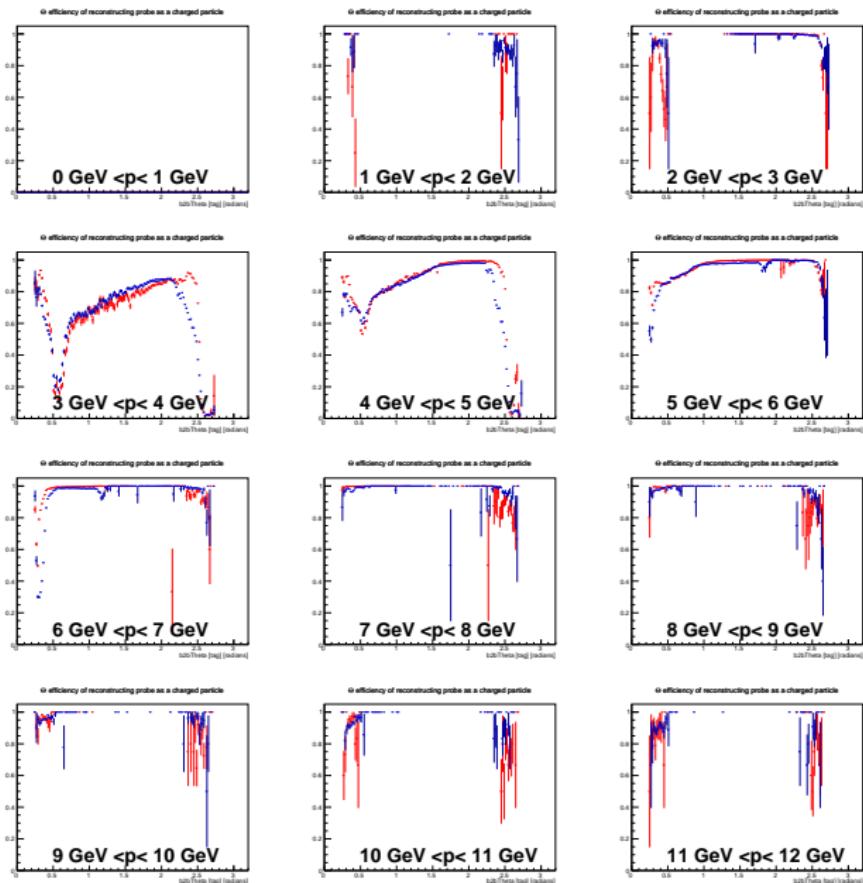
Momentum Random ϕ Projection

Phase 2 data

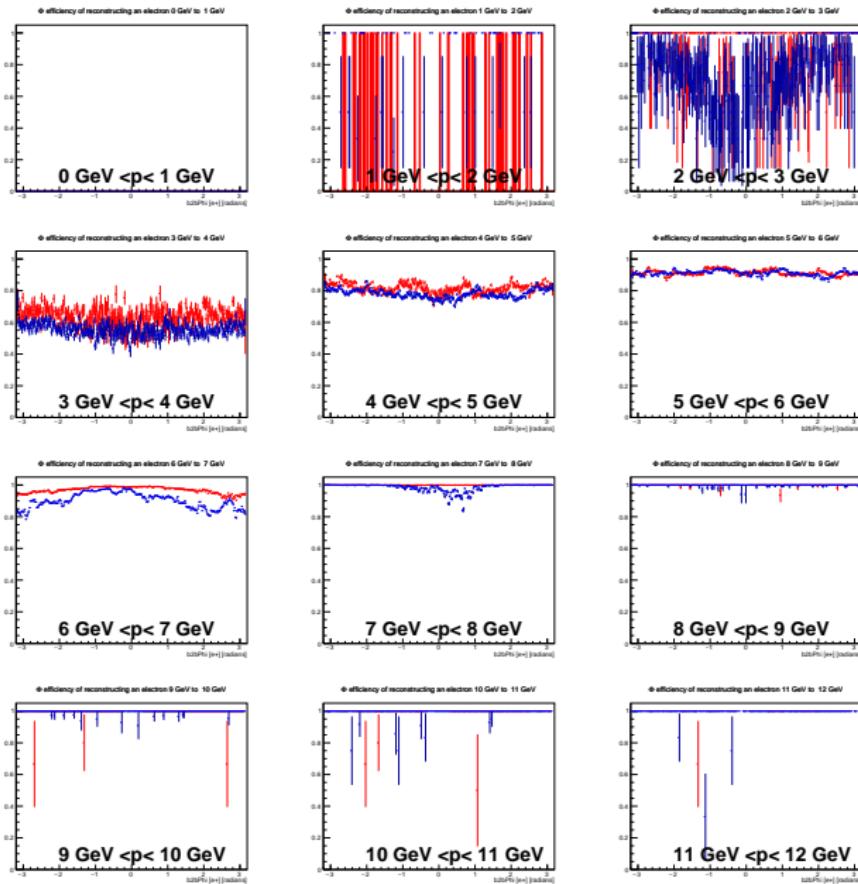
MC



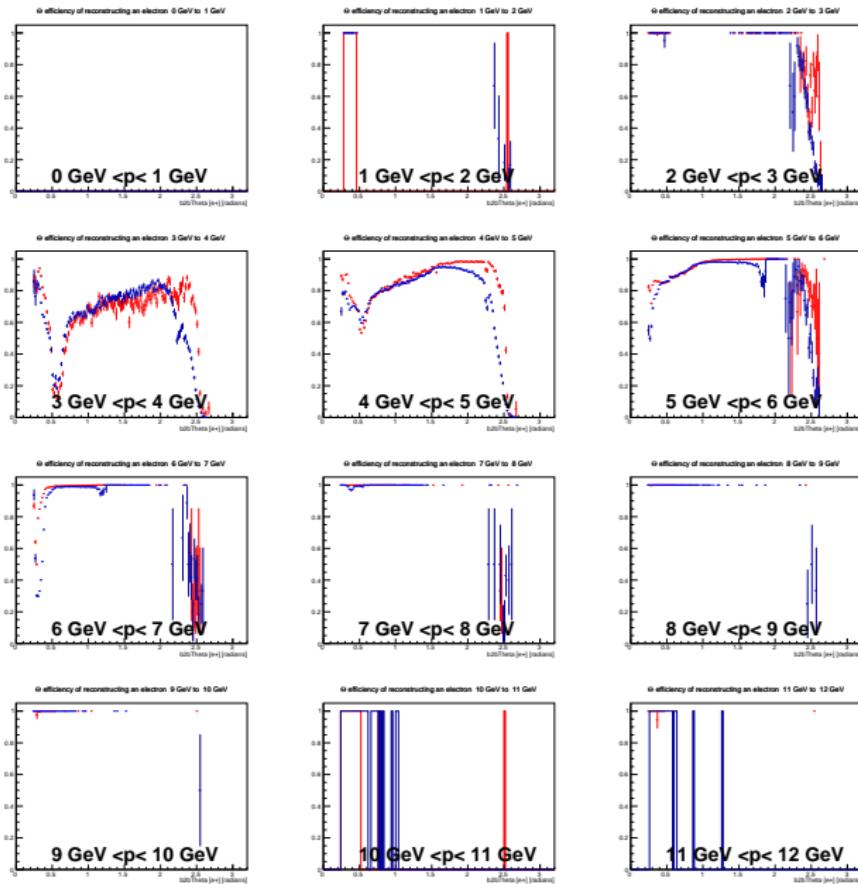
Momentum Random Θ Projection



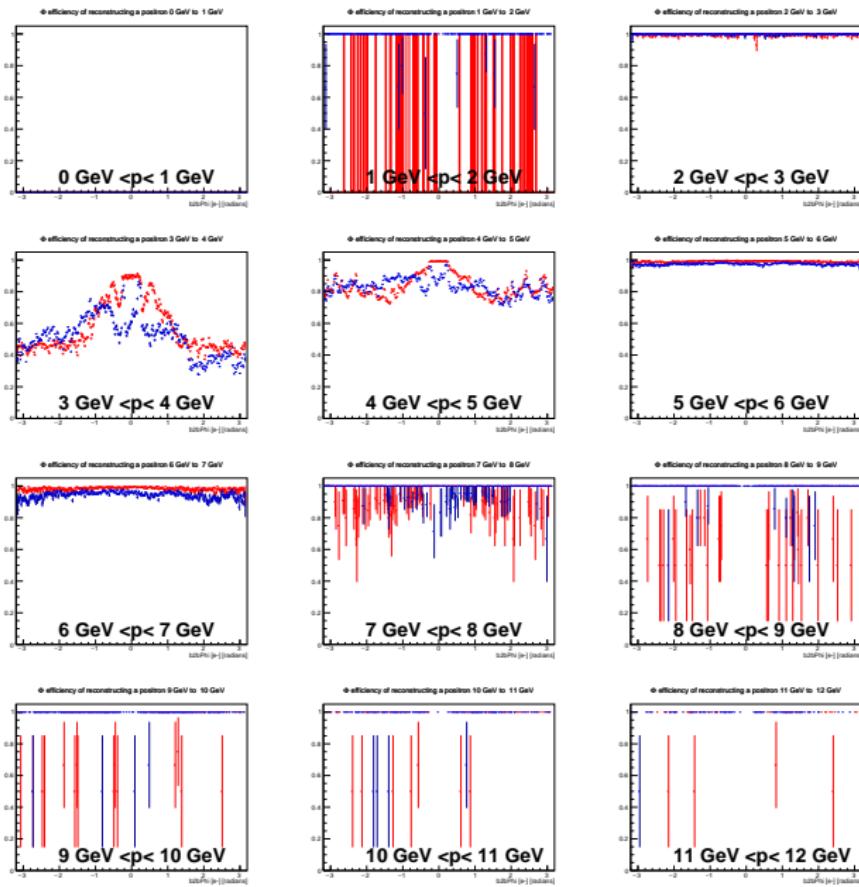
Momentum $e^- \phi$ Projection



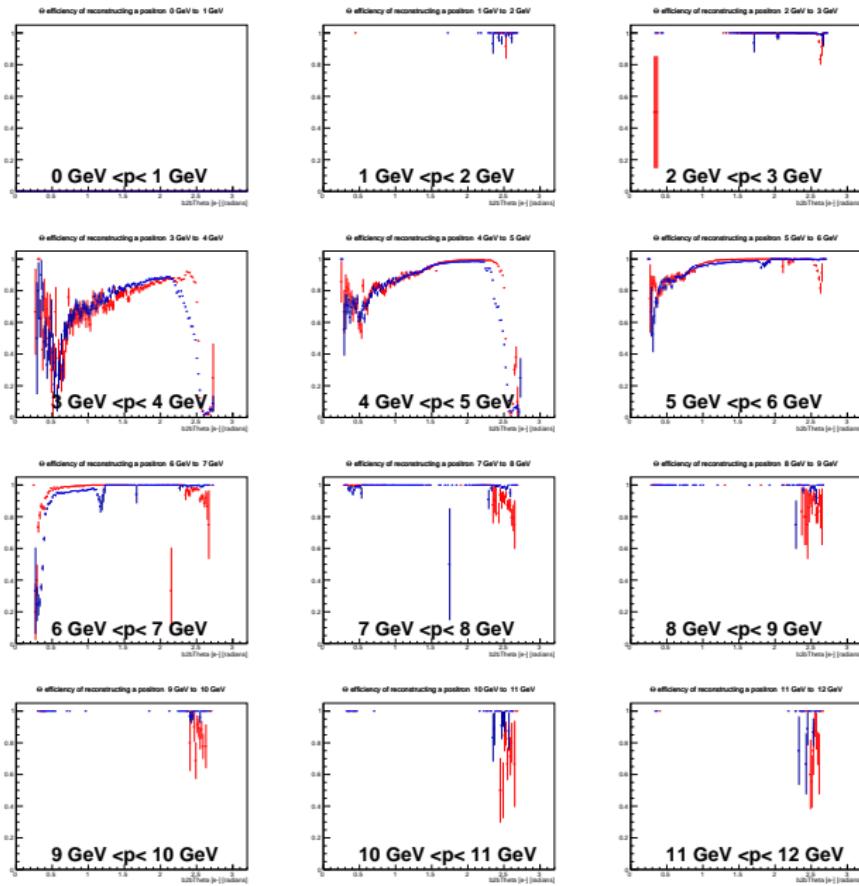
Momentum $e^- \Theta$ Projection



Momentum $e^+ \phi$ Projection

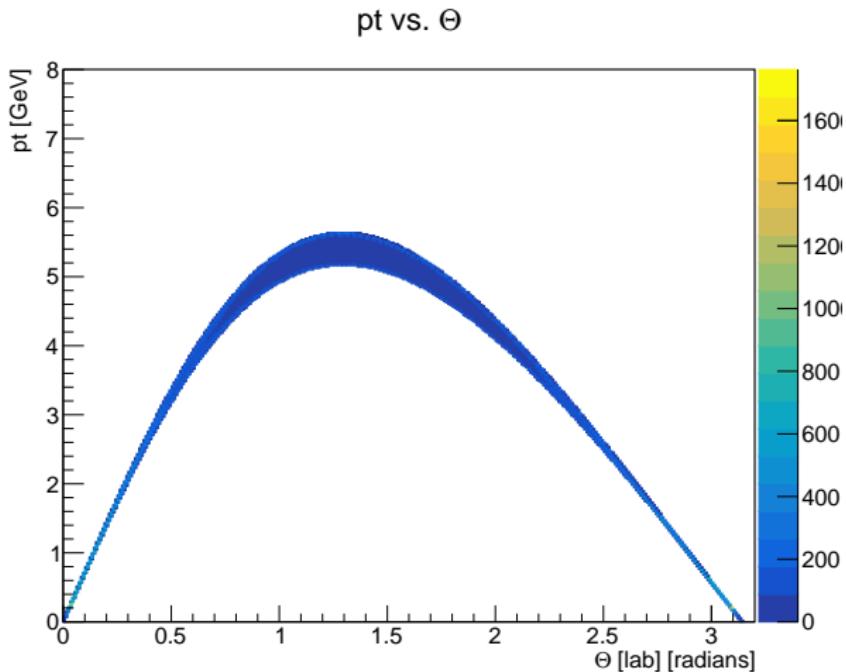


Momentum e^+ Θ Projection



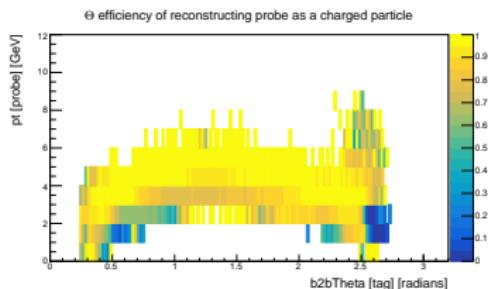
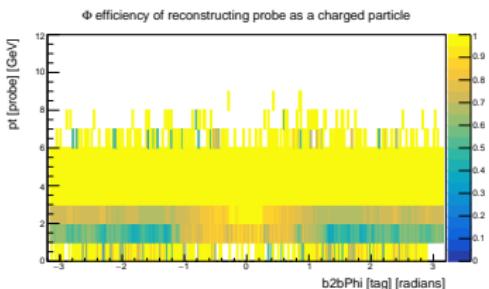
Kinematic Transverse Momentum

This plot was also created with a random event generator I wrote myself. Again, this only visualizes the transverse momentum of the Bhabha particles as a function of the θ angle.

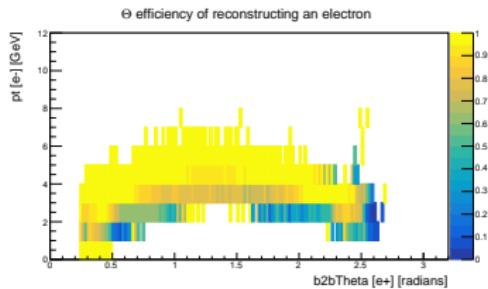
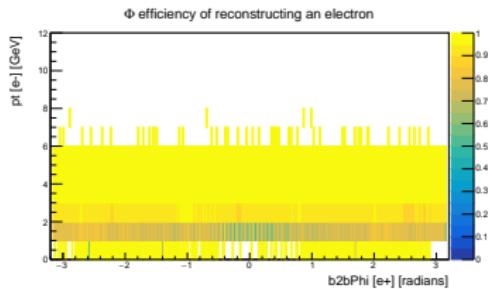


Transverse Momentum (MC)

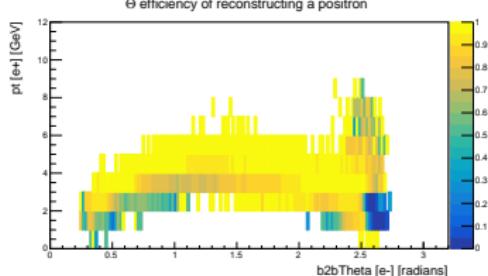
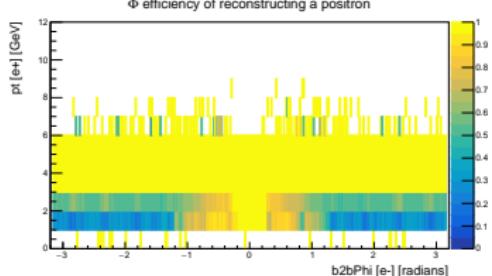
Random



e^-

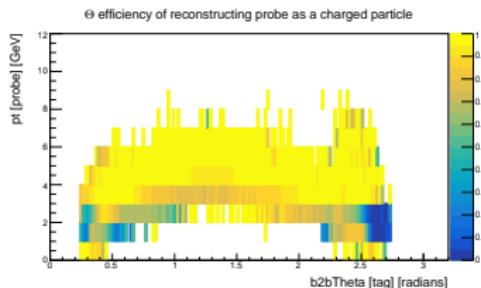
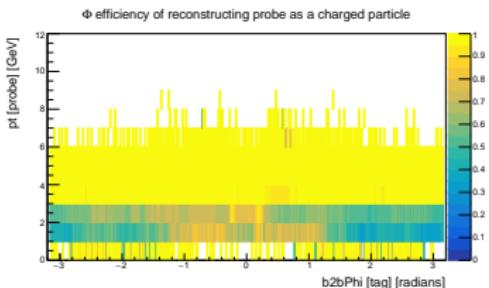


e^+

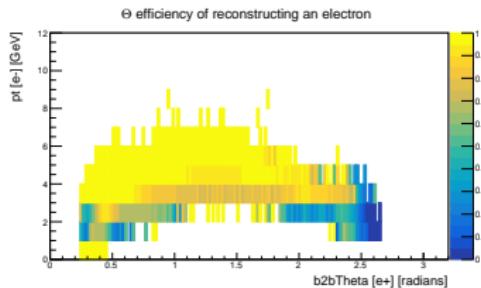
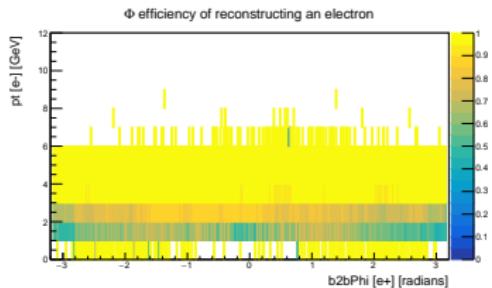


Transverse Momentum (Phase 2 Data)

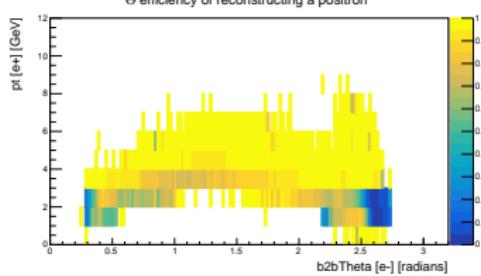
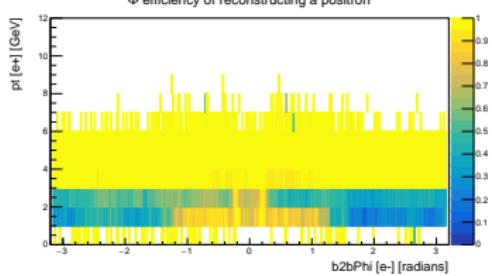
Random



e^-



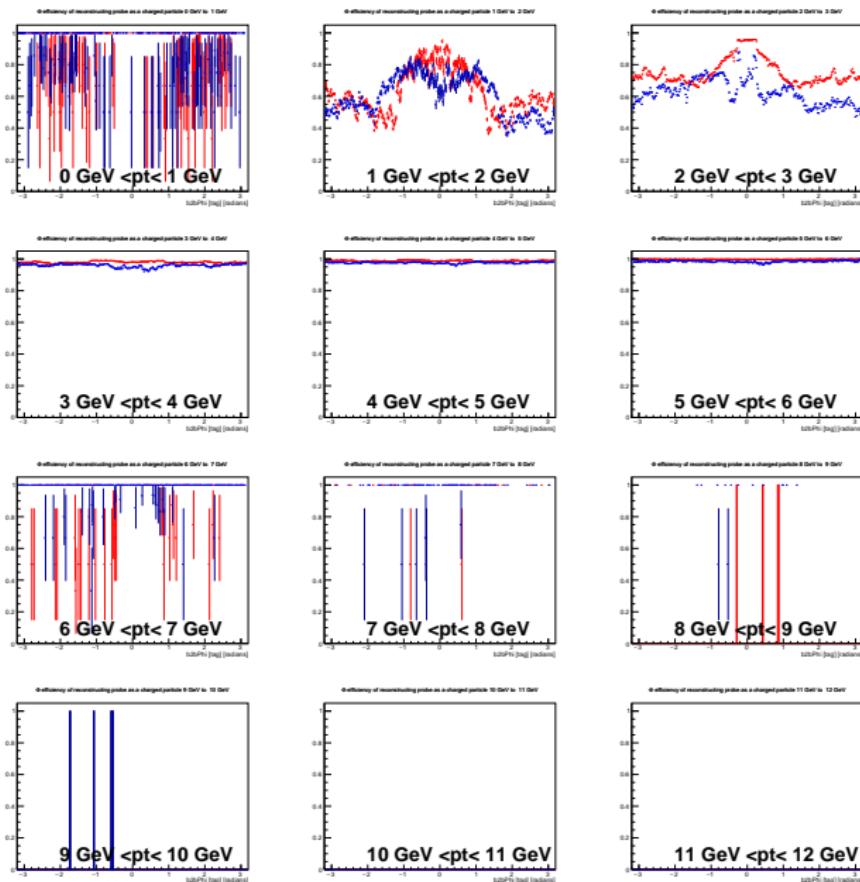
e^+



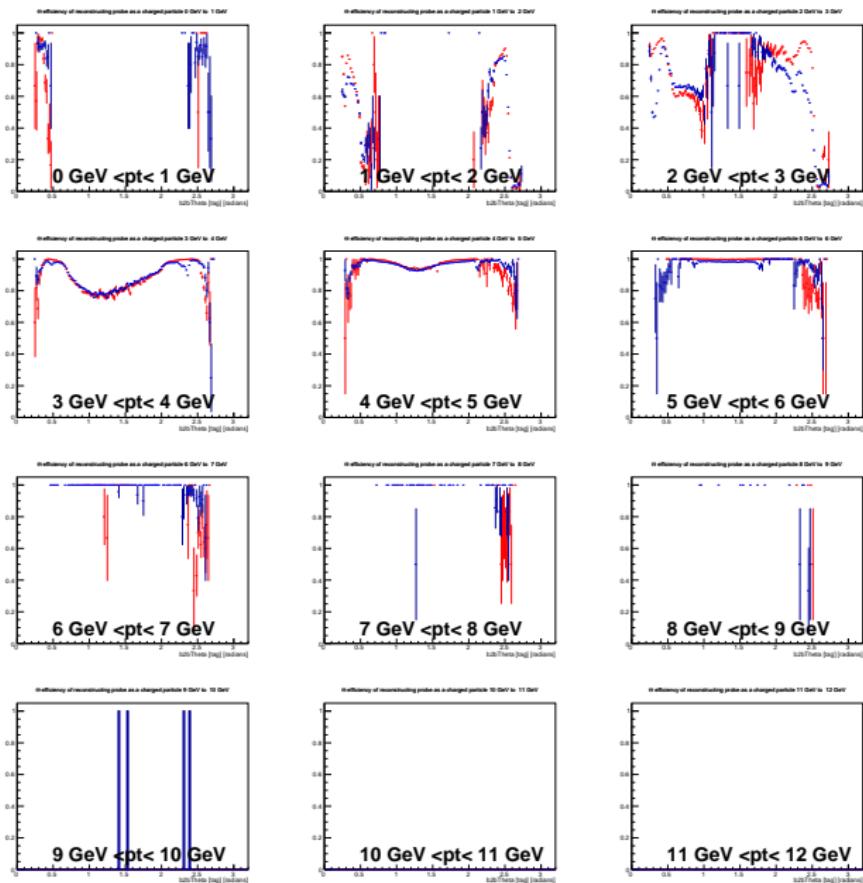
Transverse Momentum Random ϕ Projection

Phase 2 data

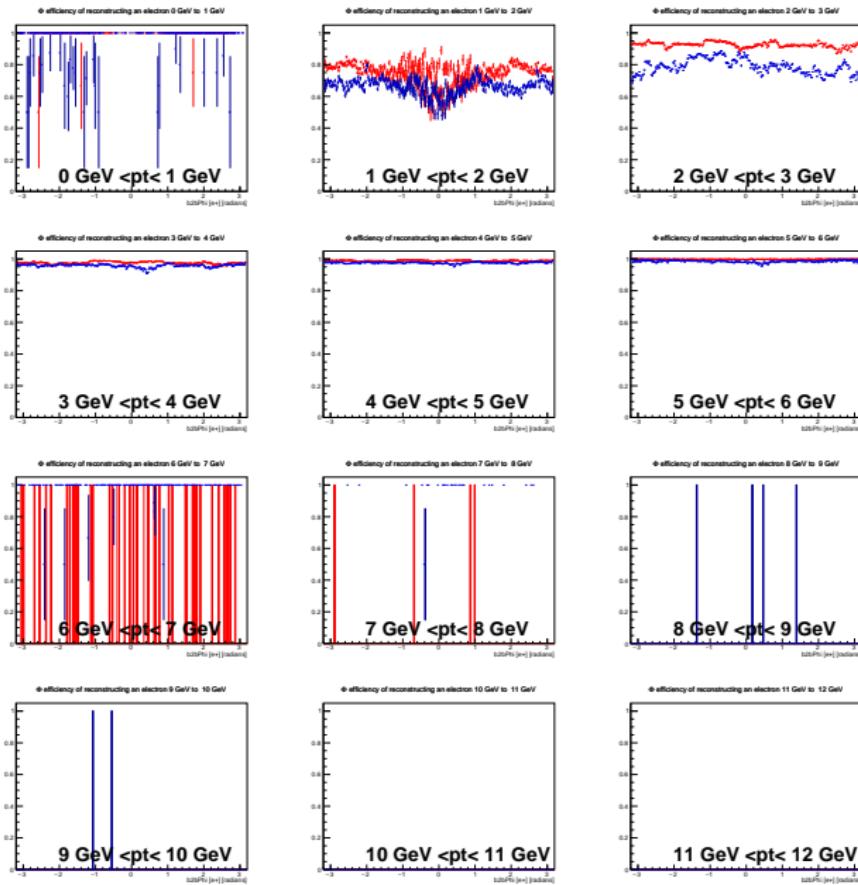
MC



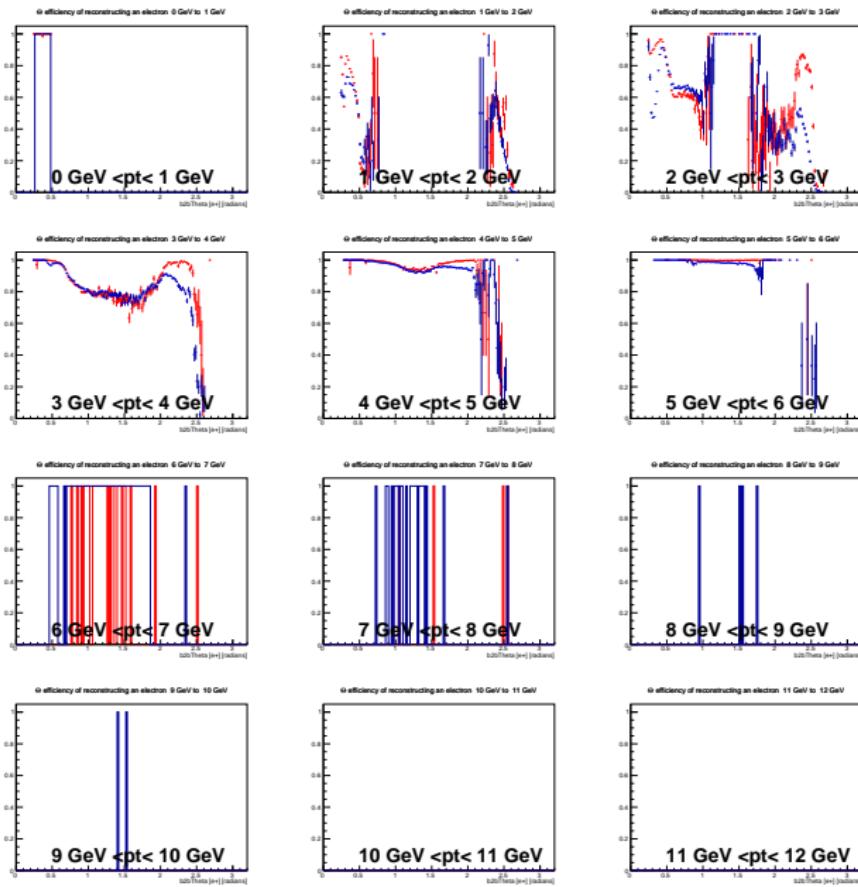
Transverse Momentum Random Θ Projection



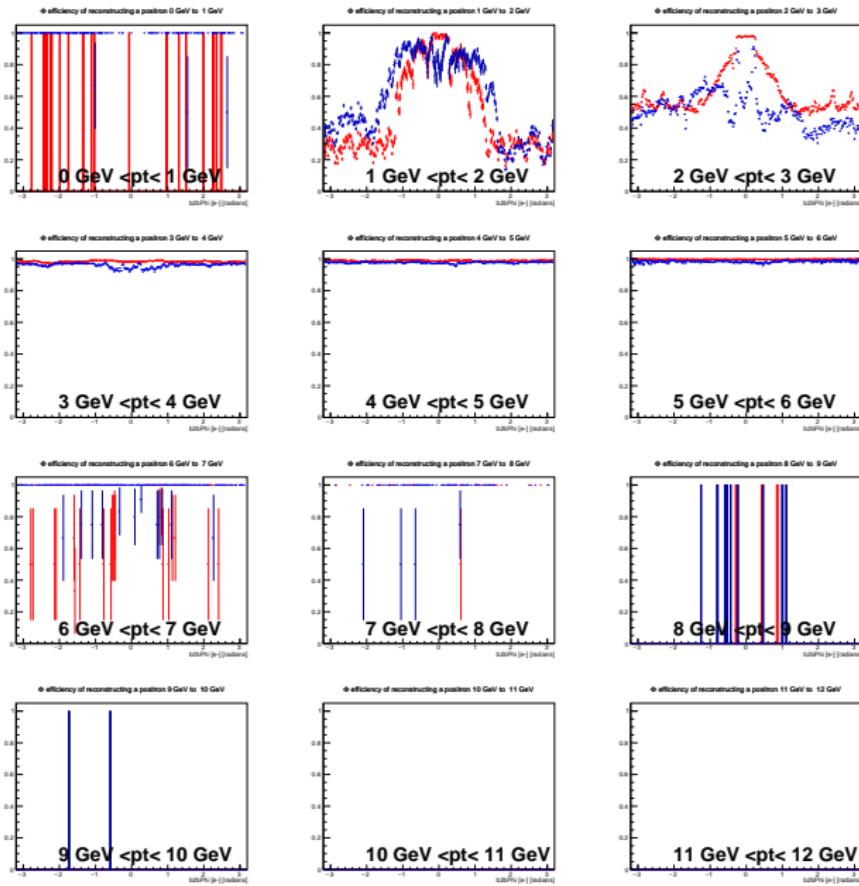
Transverse Momentum $e^- \phi$ Projection



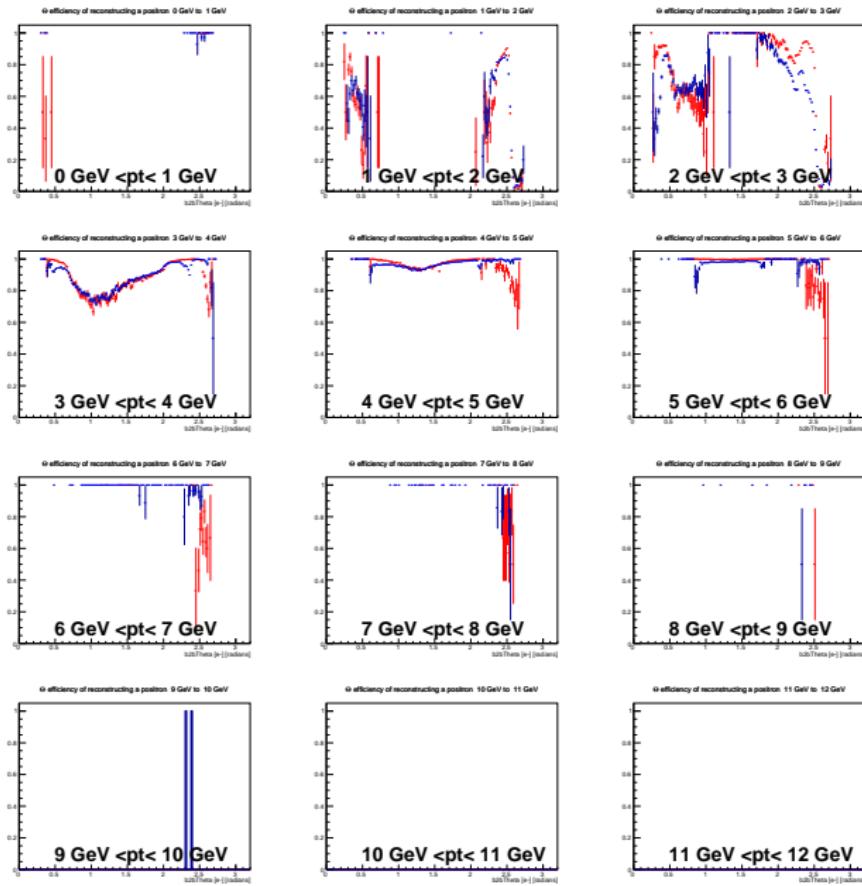
Transverse Momentum $e^- \Theta$ Projection



Transverse Momentum e^+ ϕ Projection

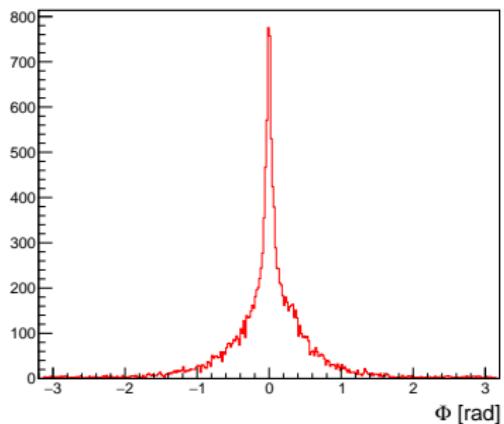
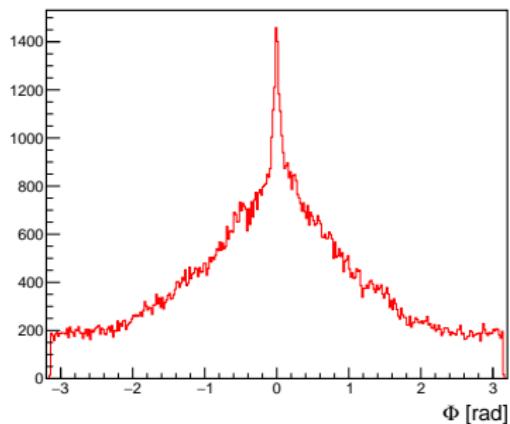


Transverse Momentum e^+ Θ Projection



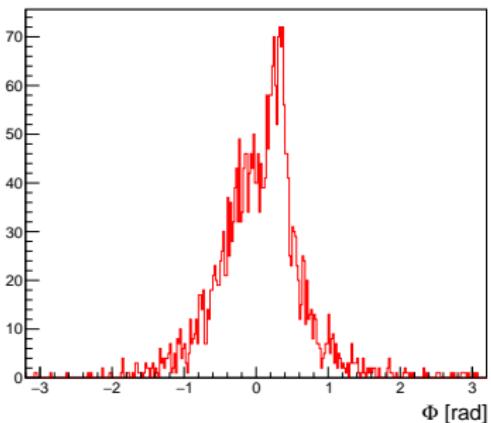
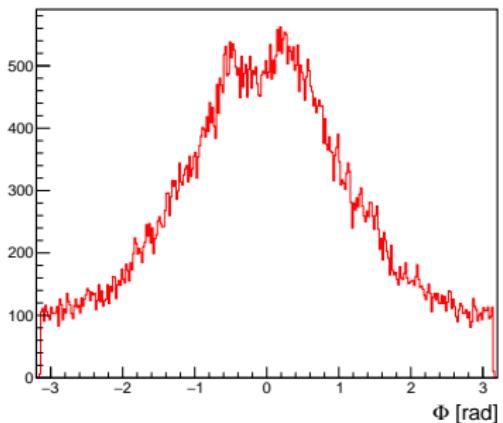
Virtual Photon Φ (Single MC File)

Φ angle of the virtual photon in a single MC file. Left before selection, right after selection.



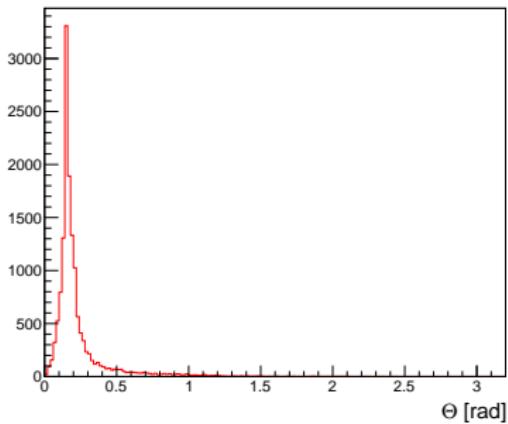
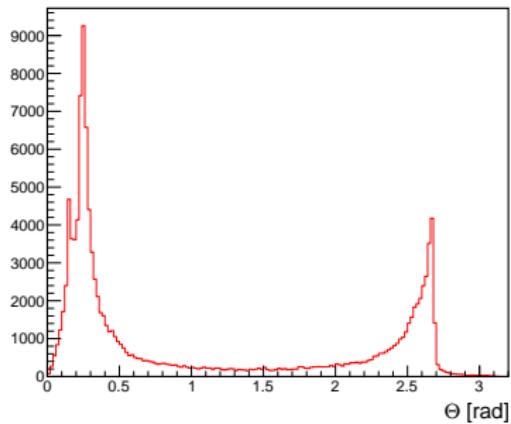
Virtual Photon Φ And nTracks ≤ 1 (Single MC File)

Φ angle of the virtual photon in a single MC file. The number of tracks in each event has to be smaller than 2. Left before selection, right after selection.



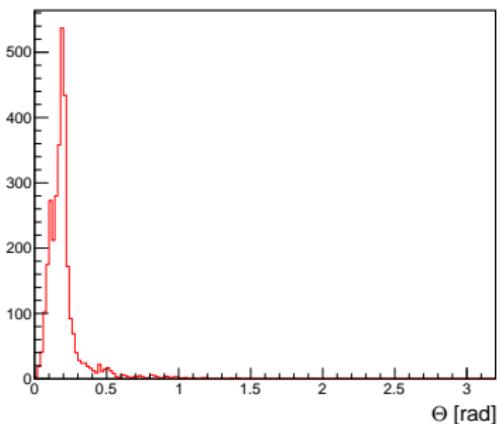
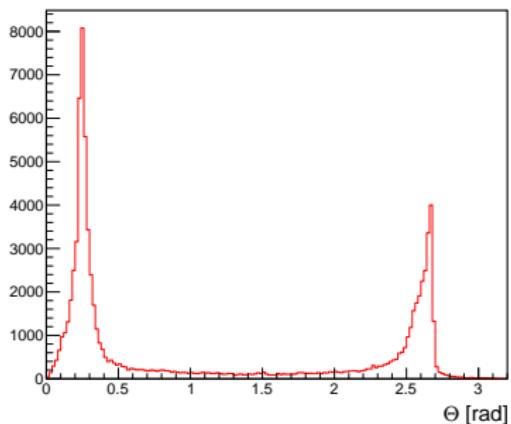
Virtual Photon Θ (Single MC File)

Θ angle of the virtual photon in a single MC file. Left before selection, right after selection.



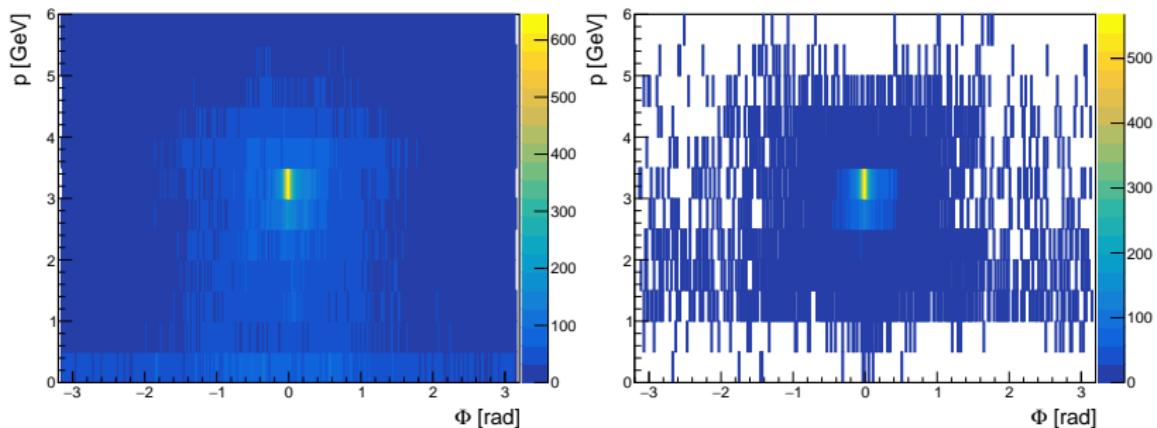
Virtual Photon Θ And nTracks ≤ 1 (Single MC File)

Θ angle of the virtual photon in a single MC file. The number of tracks in each event has to be smaller than 2. Left before selection, right after selection.



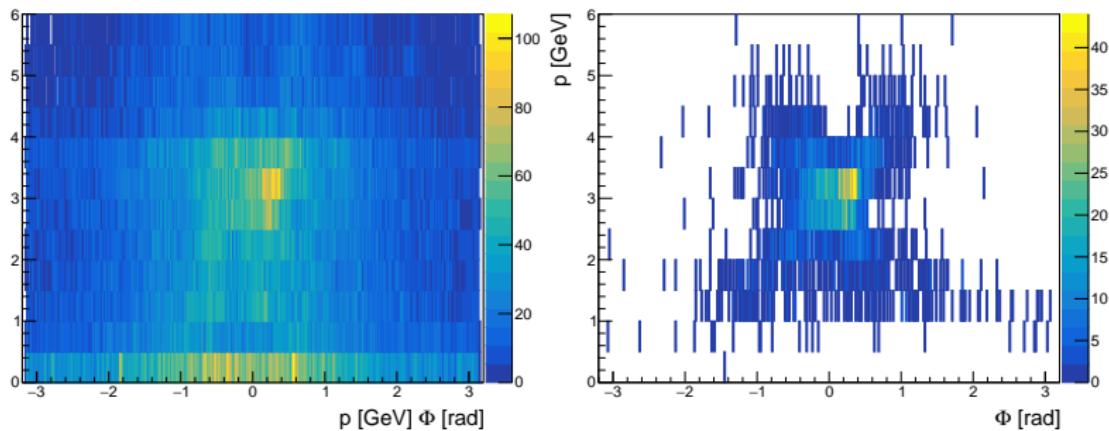
Virtual Photon Φ vs. p (Single MC File)

Φ angle vs. the momentum of the virtual photon in a single MC file. Left before selection, right after selection.



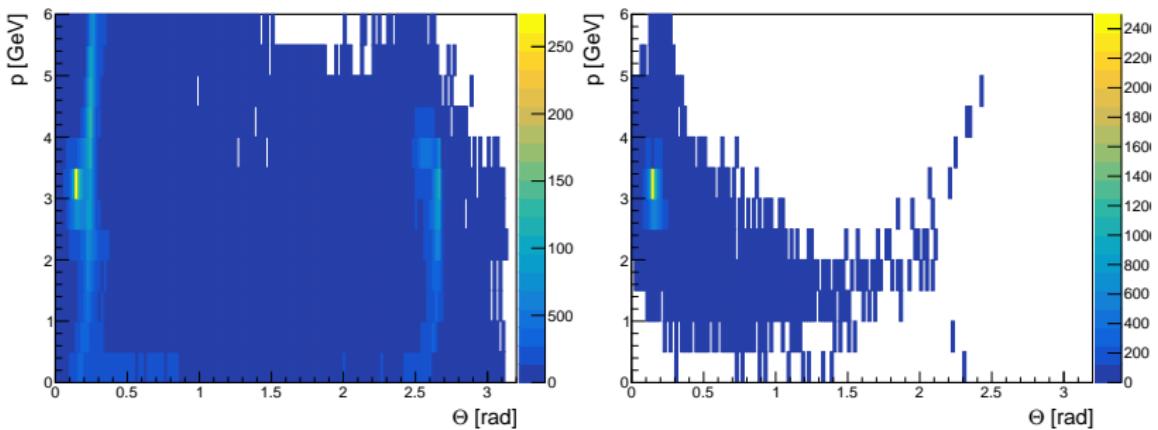
Virtual Photon Φ vs. p And nTracks ≤ 1 (Single MC File)

Φ angle vs. the momentum of the virtual photon in a single MC file. The number of tracks in each event has to be smaller than 2. Left before selection, right after selection.



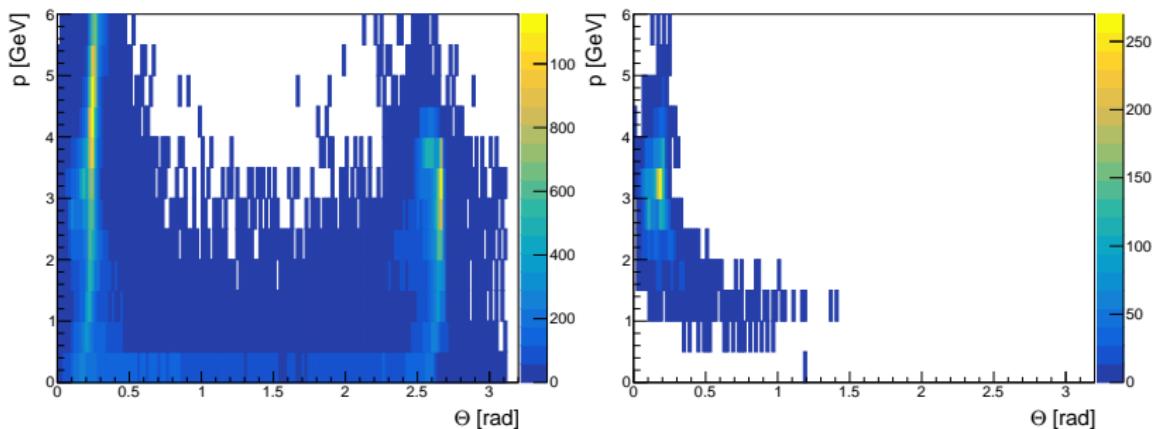
Virtual Photon Θ vs. p (Single MC File)

Θ angle vs. the momentum of the virtual photon in a single MC file. Left before selection, right after selection.



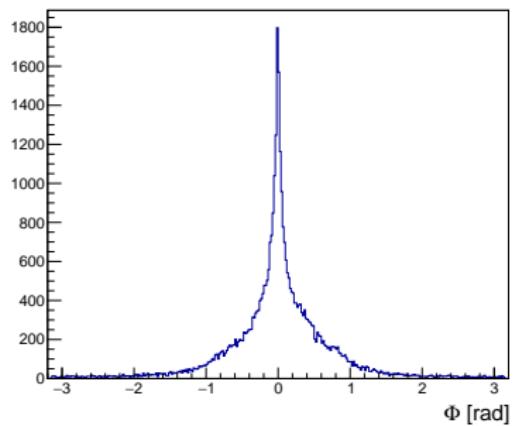
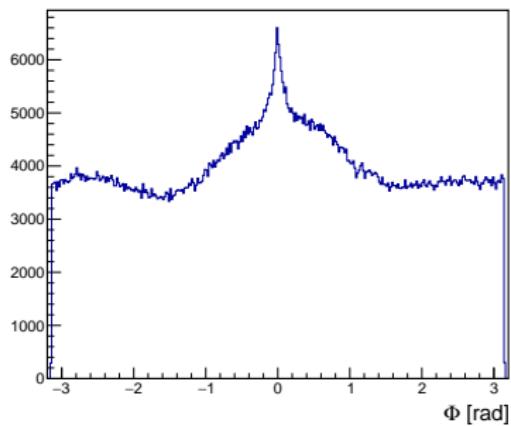
Virtual Photon Θ vs. p And nTracks ≤ 1 (Single MC File)

Θ angle vs. the momentum of the virtual photon in a single MC file. The number of tracks in each event has to be smaller than 2. Left before selection, right after selection.



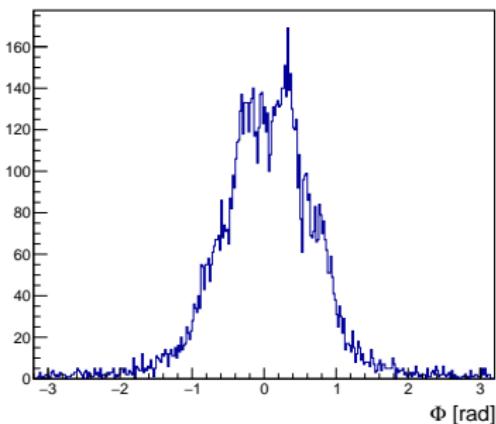
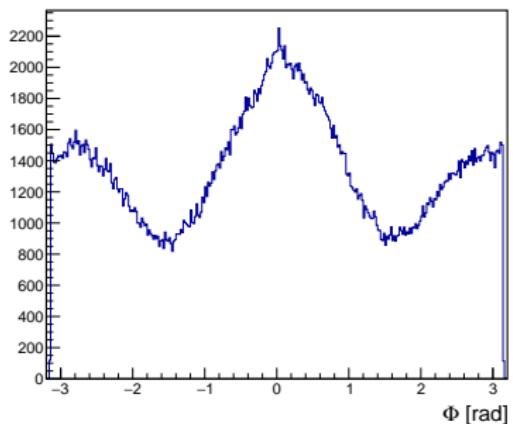
Virtual Photon Φ (Single Phase 2 File)

Φ angle of the virtual photon in a single Phase 2 file. Left before selection, right after selection.



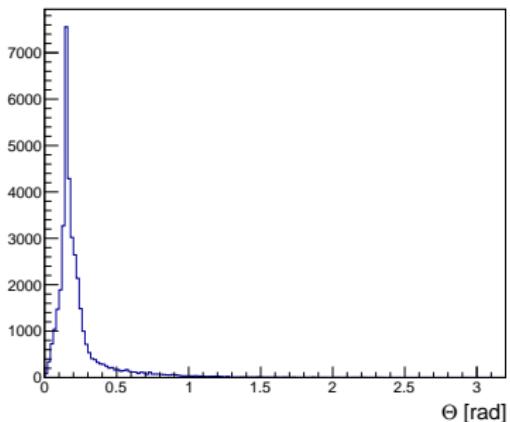
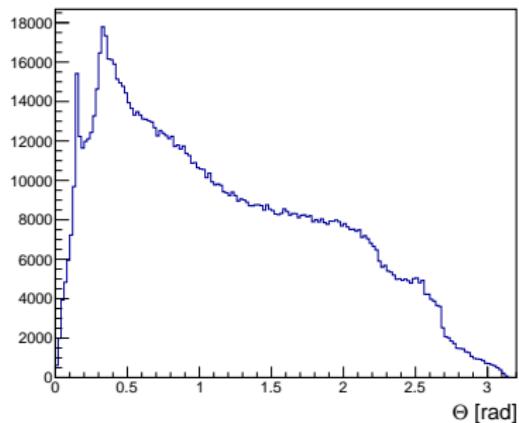
Virtual Photon Φ And nTracks ≤ 1 (Single Phase 2 File)

Φ angle of the virtual photon in a single Phase 2 file. The number of tracks in each event has to be smaller than 2. Left before selection, right after selection.



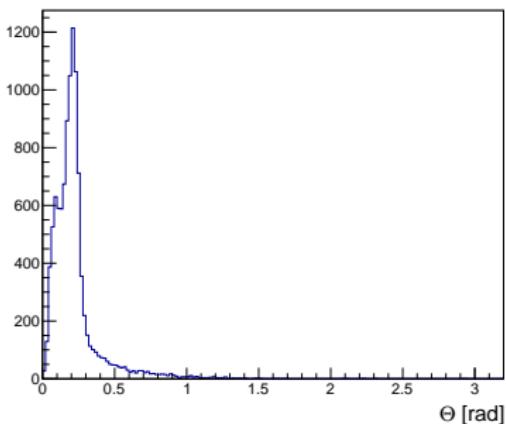
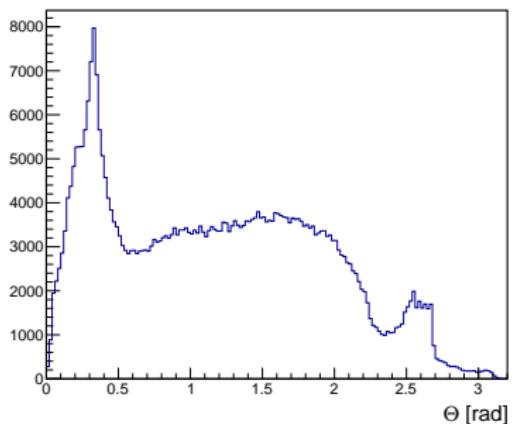
Virtual Photon Θ (Single Phase 2 File)

Θ angle of the virtual photon in a single Phase 2 file. Left before selection, right after selection.



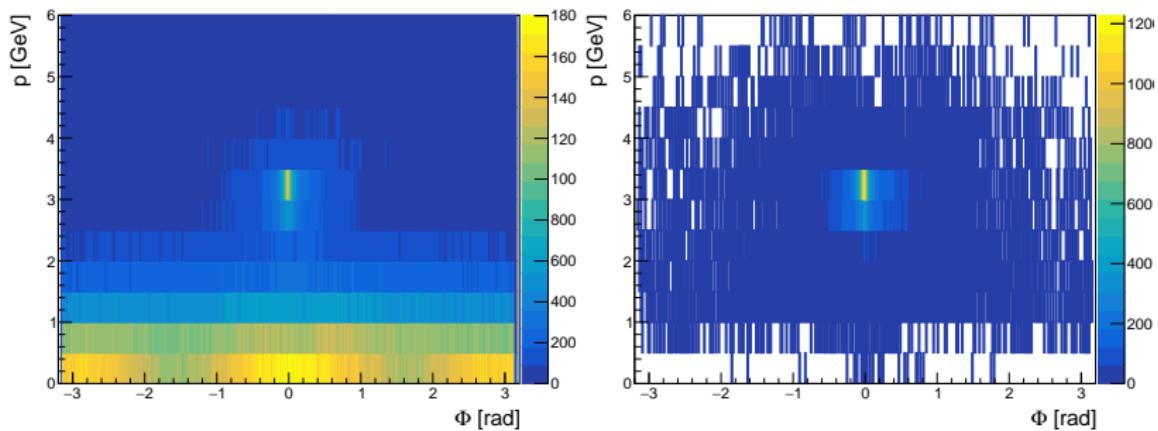
Virtual Photon Θ And nTracks ≤ 1 (Single Phase 2 File)

Θ angle of the virtual photon in a single MC file. The number of tracks in each event has to be smaller than 2. Left before selection, right after selection.



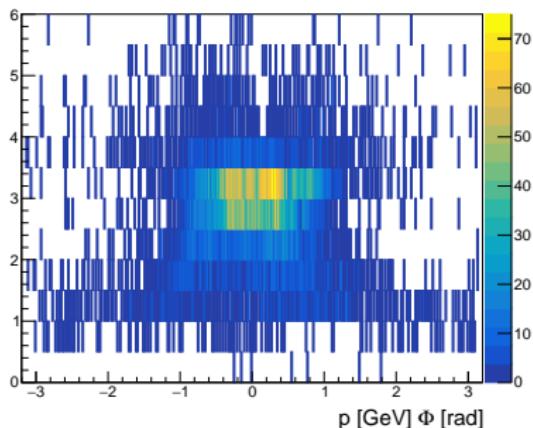
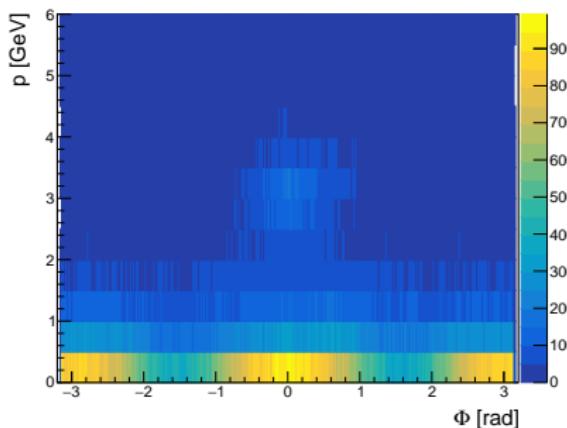
Virtual Photon Φ vs. p (Single Phase 2 File)

Φ angle vs. the momentum of the virtual photon in a single Phase 2 file.
Left before selection, right after selection.



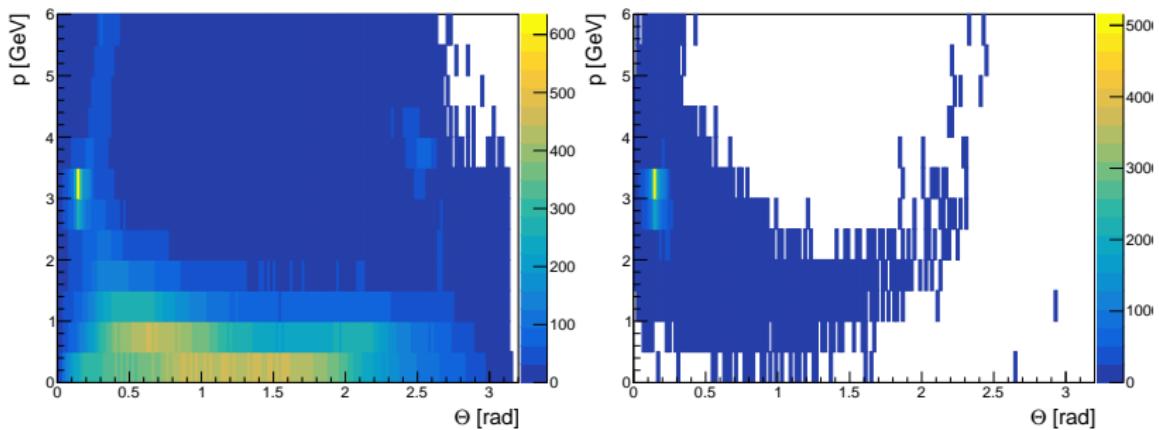
Virtual Photon Φ vs. p And nTracks ≤ 1 (Single Phase 2 File)

Φ angle vs. the momentum of the virtual photon in a single Phase 2 file.
The number of tracks in each event has to be smaller than 2. Left before selection, right after selection.



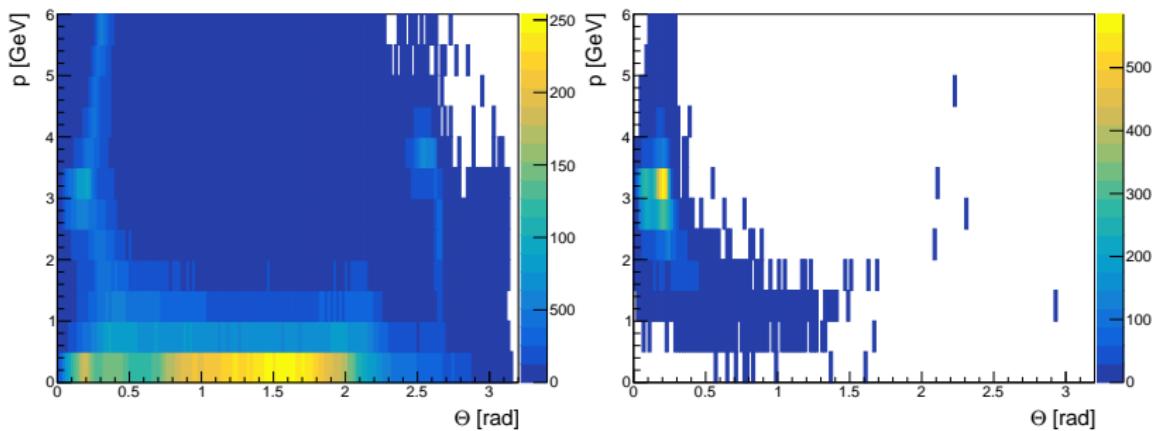
Virtual Photon Θ vs. p (Single Phase 2 File)

Θ angle vs. the momentum of the virtual photon in a single Phase 2 file.
Left before selection, right after selection.



Virtual Photon Θ vs. p And nTracks ≤ 1 (Single Phase 2 File)

Θ angle vs. the momentum of the virtual photon in a single Phase 2 file.
The number of tracks in each event has to be smaller than 2. Left before selection, right after selection.



Backup

ECL-Object

- To have a complete list of objects with an ECL cluster associated, one needs to "mix" two different lists, one of gammas and one of electrons

```
fillParticleList('gamma:all','E > 0.01 ',path=mypath)
fillParticleList('e+:all','clusterE > 0.01 ', path=mypath)

reconstructDecay('vpho:elec -> e+:all','','path=mypath')
reconstructDecay('vpho:gamma -> gamma:all','',' path=mypath')

copyLists(outputListName='vpho:ECLobject_unranked',inputListNames=['vpho:elec','vpho:gamma'],path=mypath)
rankByHighest('vpho:ECLobject_unranked','daughter(0,clusterE)',path=mypath)
cutAndCopyList('vpho:ECLobject','vpho:ECLobject_unranked','','path=mypath')

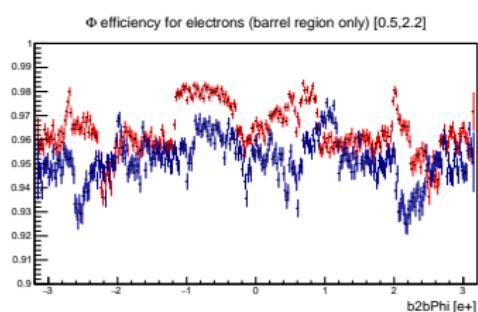
reconstructDecay('vpho:bhabha -> vpho:ECLobject vpho:ECLobject','M > 8.0',path=mypath)
```

- The electron list does not require a ECL cluster → problem solved with the cut on clusterE
- The framework does not allow to mix lists of different types → problem solved with the "trick" of two intermediate virtual photons
- The ranking is a way for me to have the order of the daughters' under control
- The Bhabha candidates are finally reconstructed starting from 2 ECLobjects

Theta And Phi Projection (Barrel Region Only)

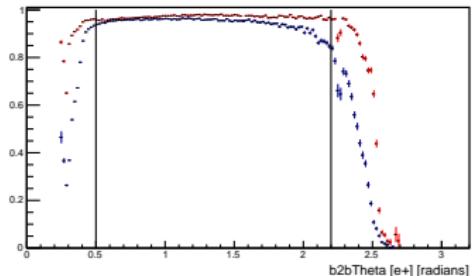
Φ

e^-

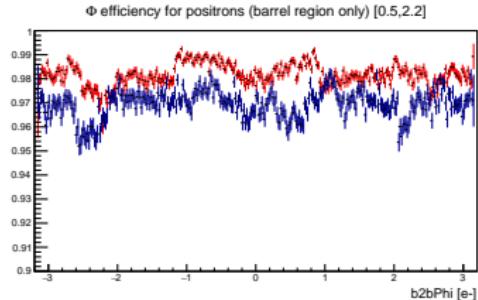


Θ

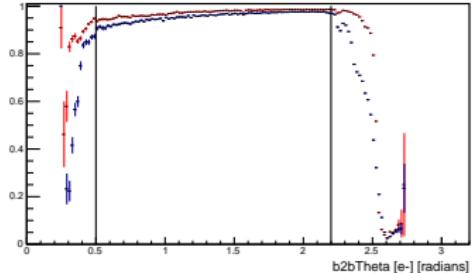
Θ efficiency of reconstructing an electron



e^+



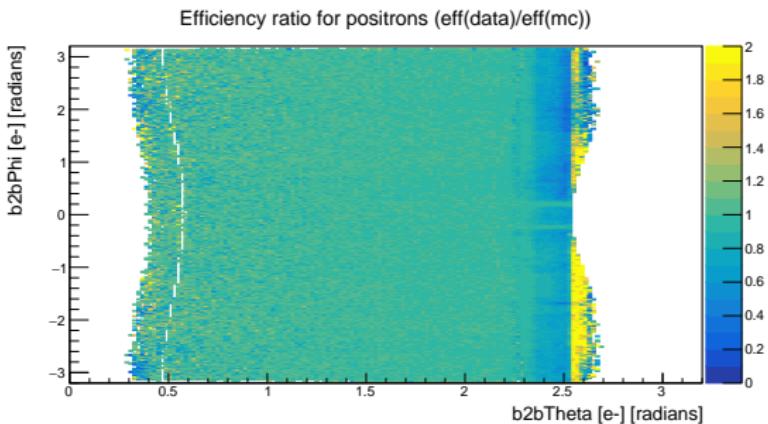
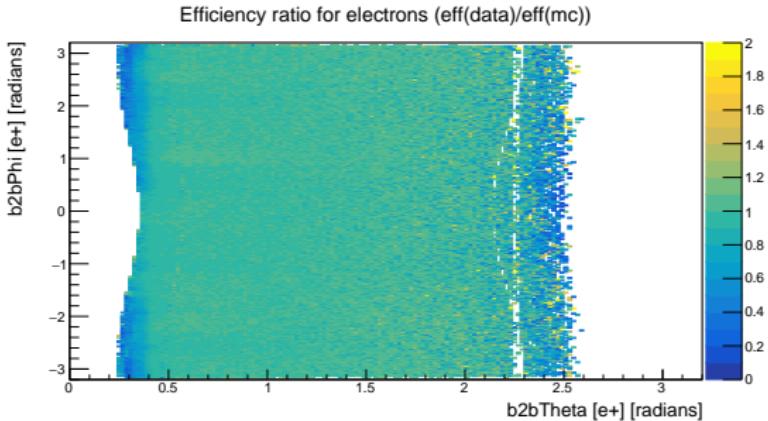
Θ efficiency of reconstructing a positron



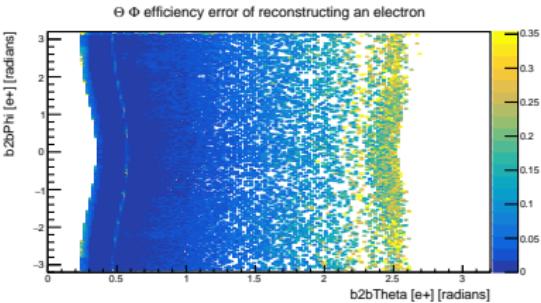
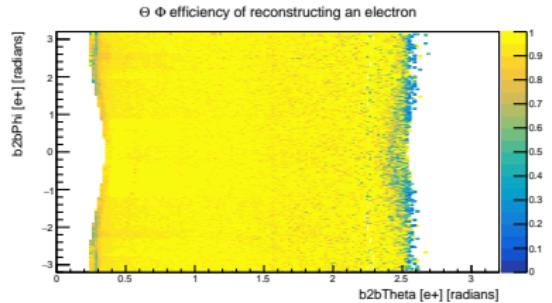
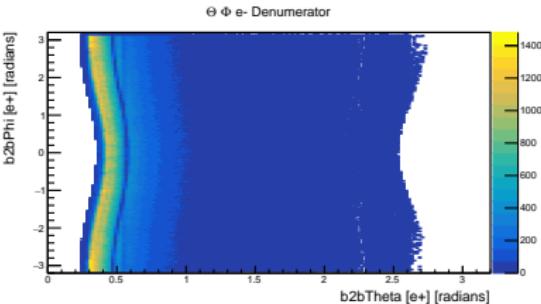
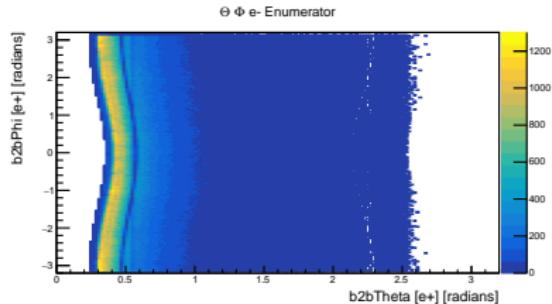
Phase 2 data

MC

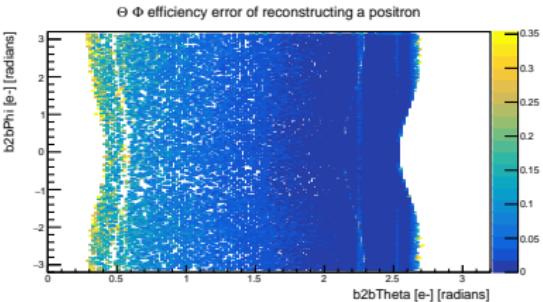
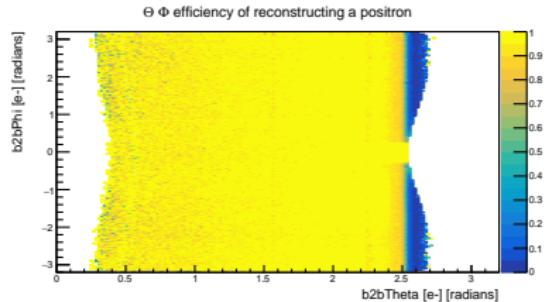
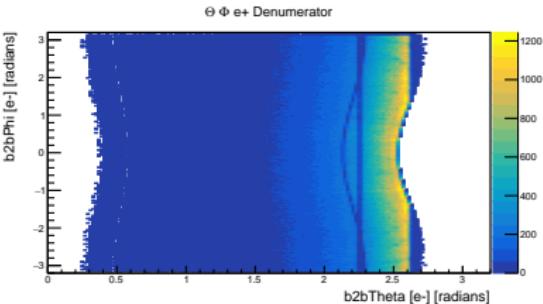
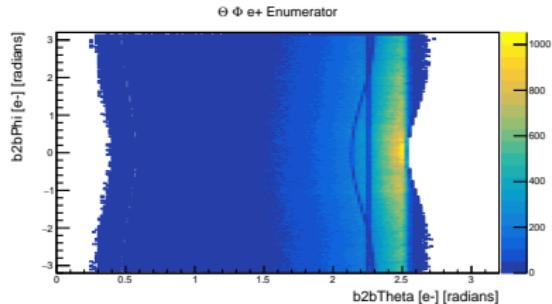
Ratio between MC And Phase 2 data (Barrel Region Only)



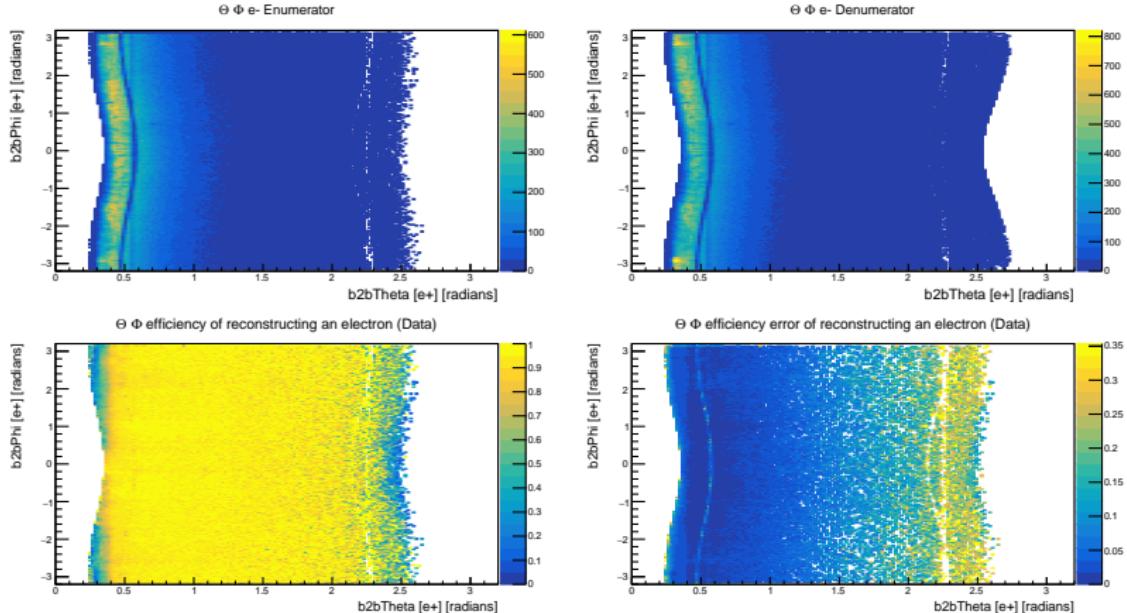
Electron Efficiency (MC)



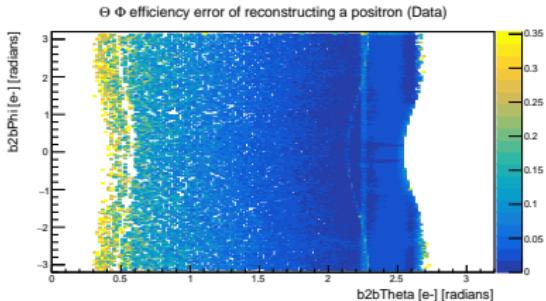
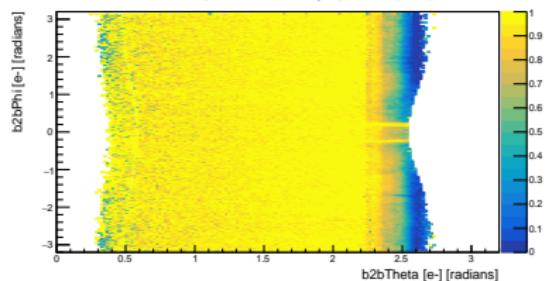
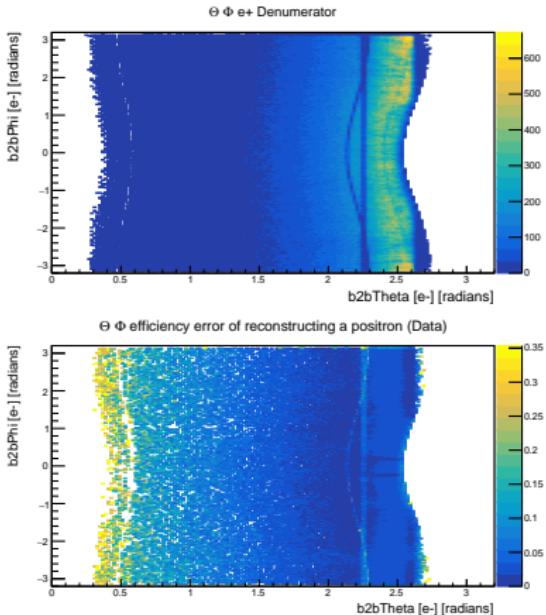
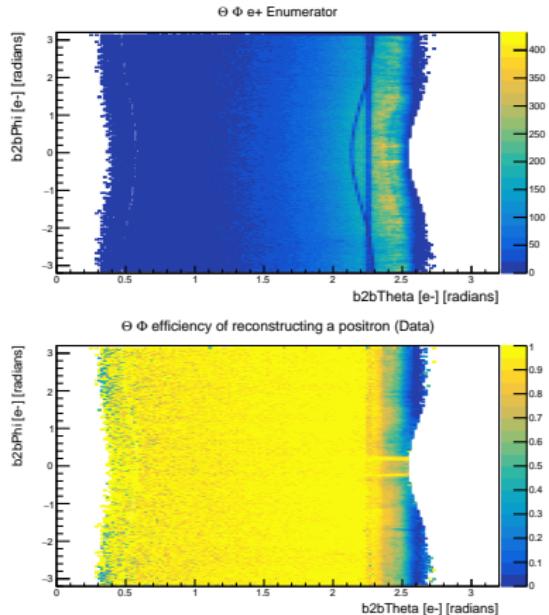
Positron Efficiency (MC)



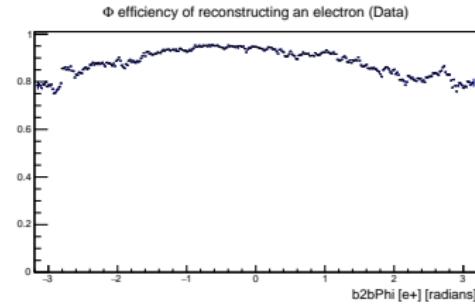
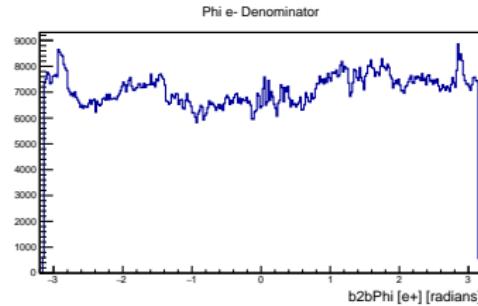
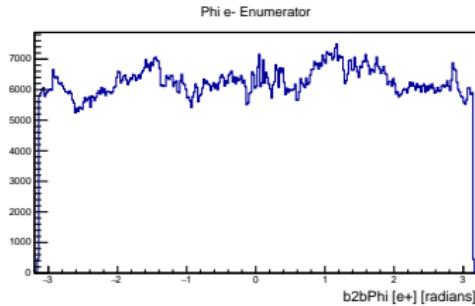
Electron Efficiency (Phase 2 data)



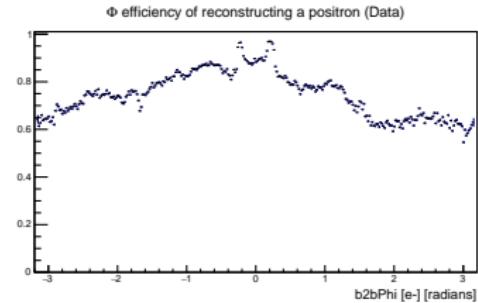
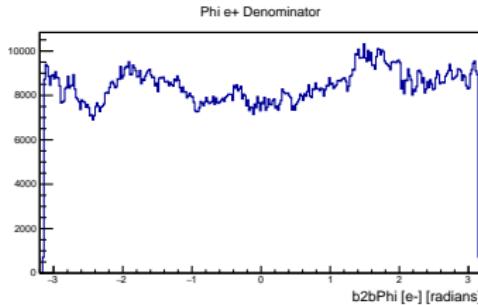
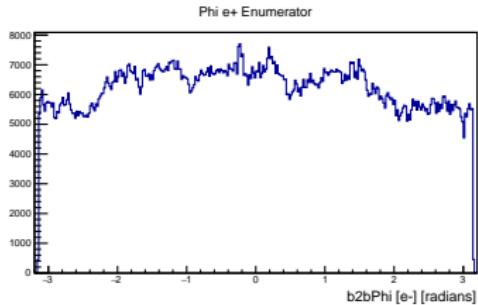
Positron Efficiency (Phase 2 data)



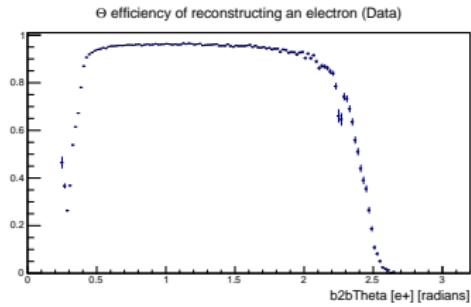
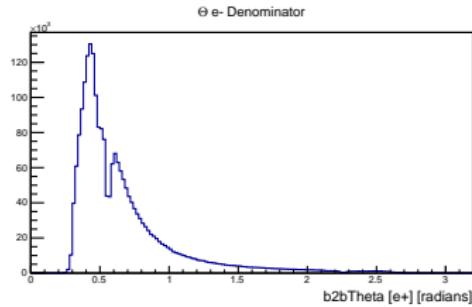
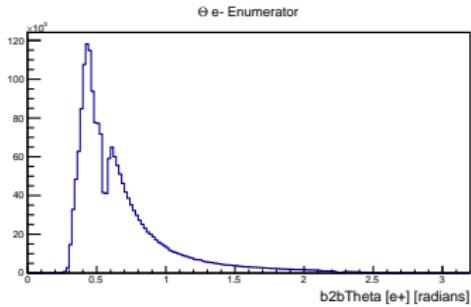
Electron ϕ Projection (Phase 2 data)



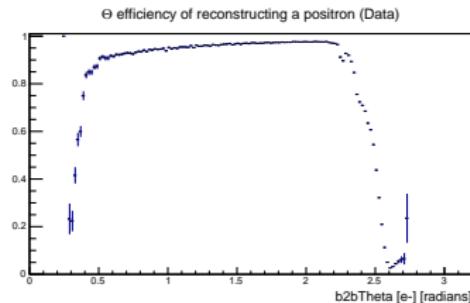
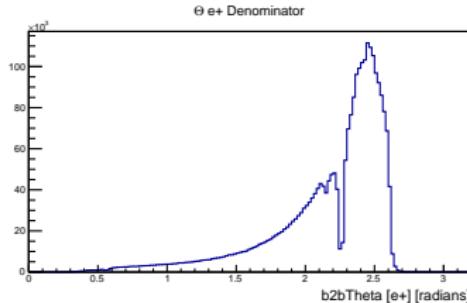
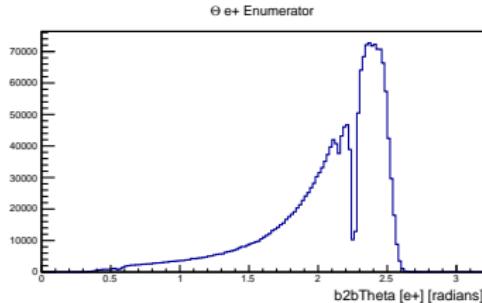
Positron Φ Projection (Phase 2 data)



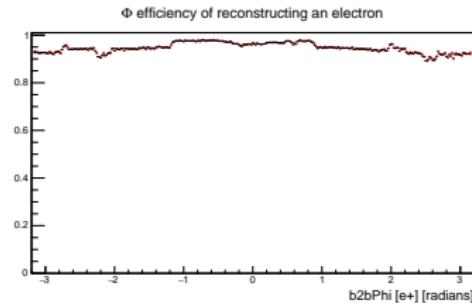
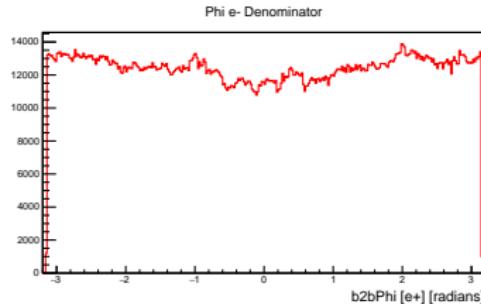
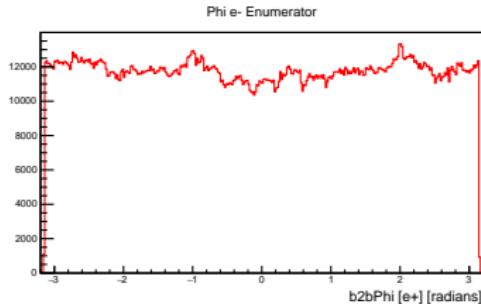
Electron Θ Projection (Phase 2 data)



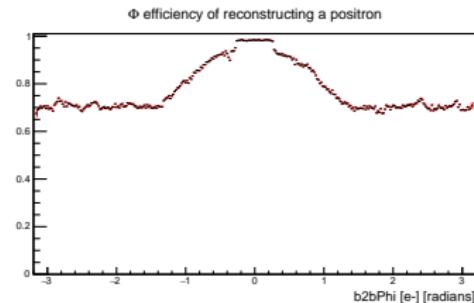
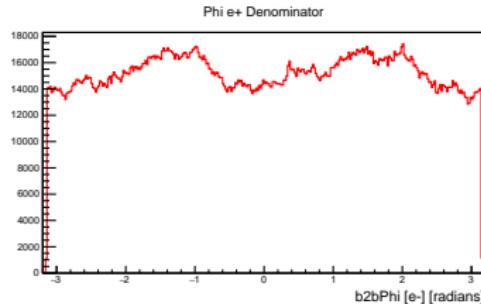
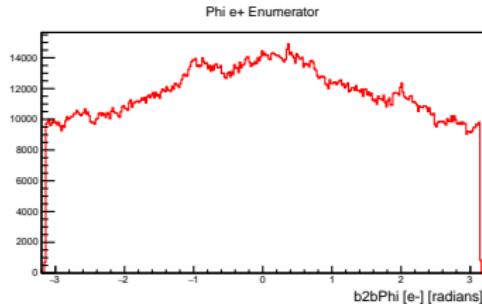
Positron Θ Projection (Phase 2 data)



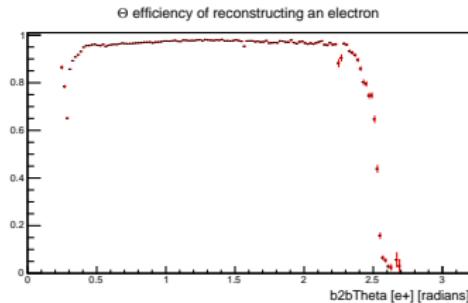
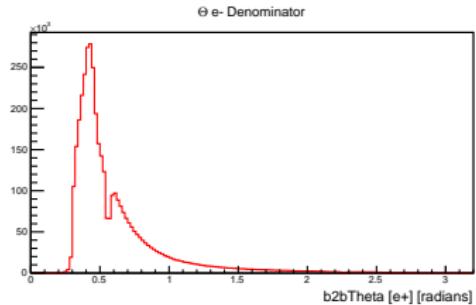
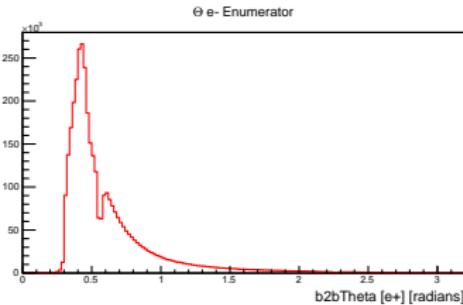
Electron ϕ Projection (MC)



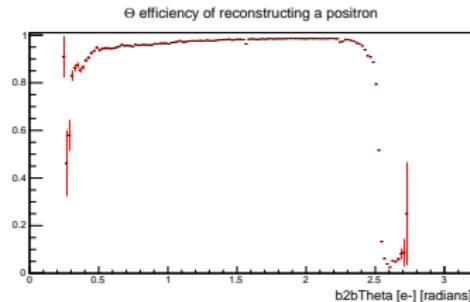
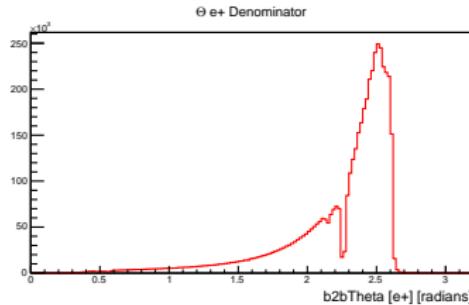
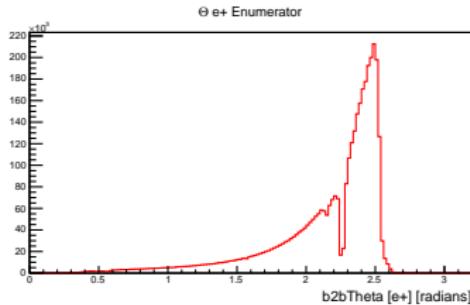
Positron Φ Projection (MC)



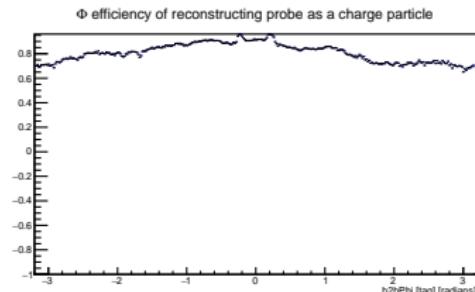
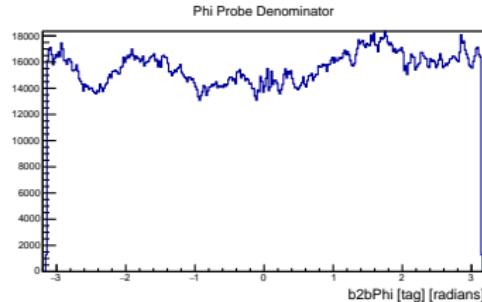
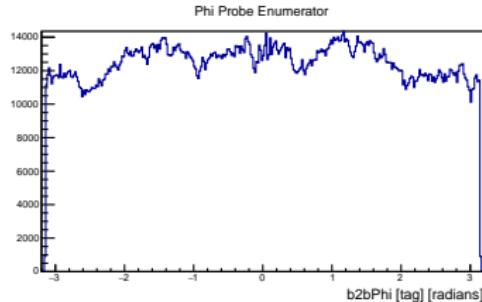
Electron Θ Projection (MC)



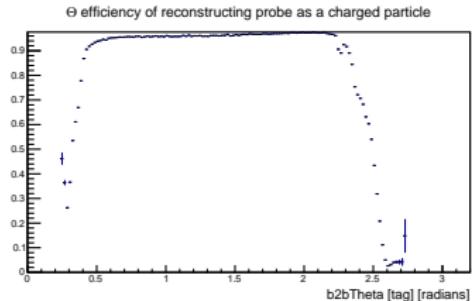
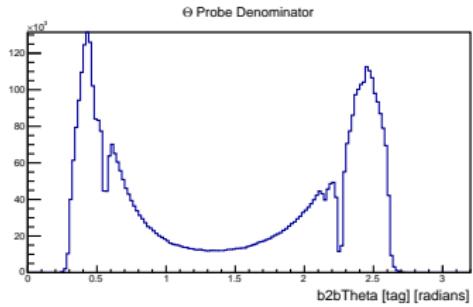
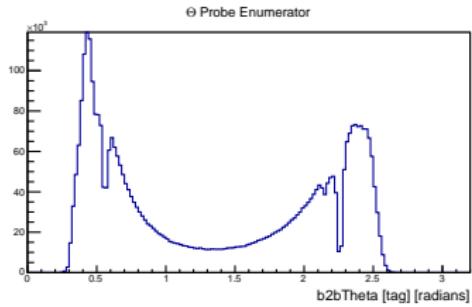
Positron Θ Projection (MC)



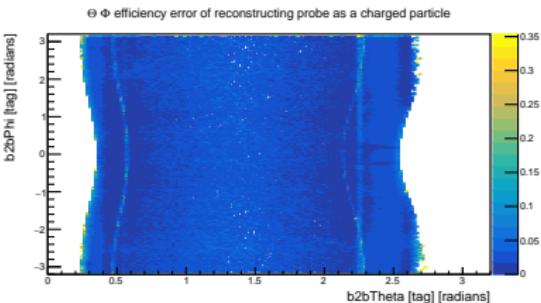
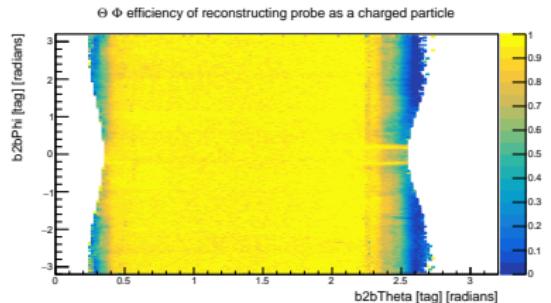
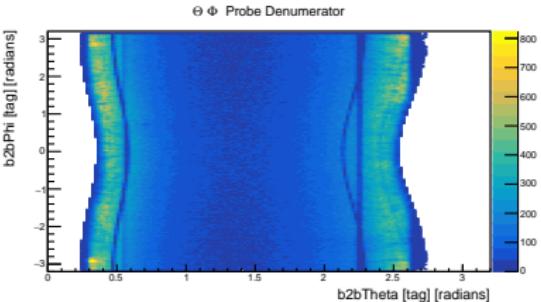
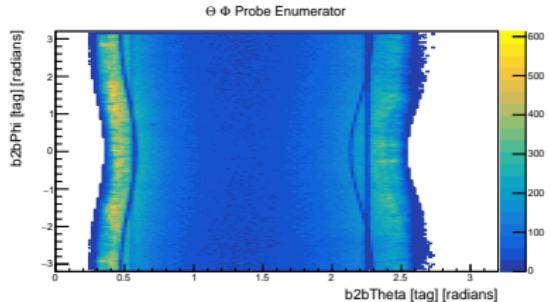
Random Φ (Data)



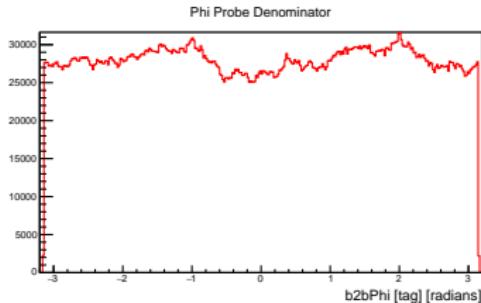
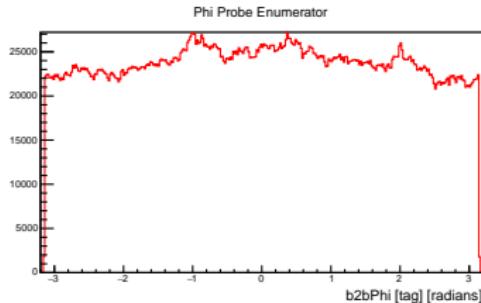
Random Θ (Data)



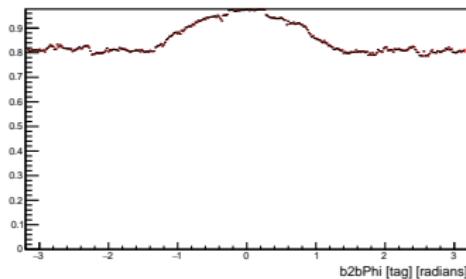
Random $\Theta\Phi$ (Data)



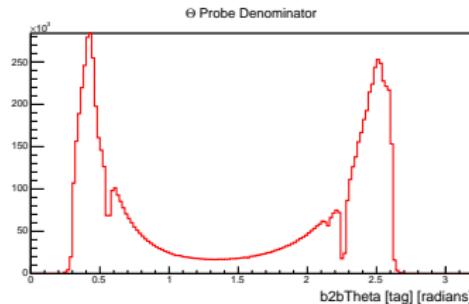
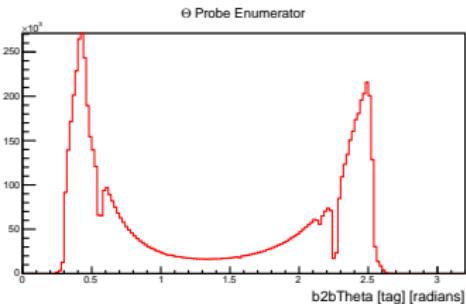
Random Φ (MC)



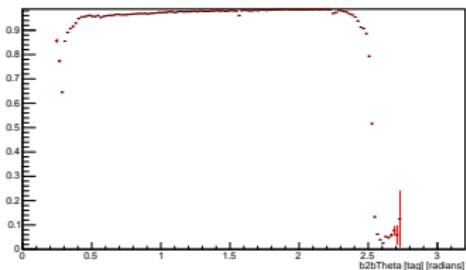
Φ efficiency of reconstructing probe as a charge particle



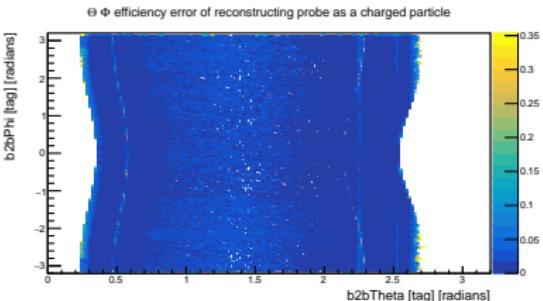
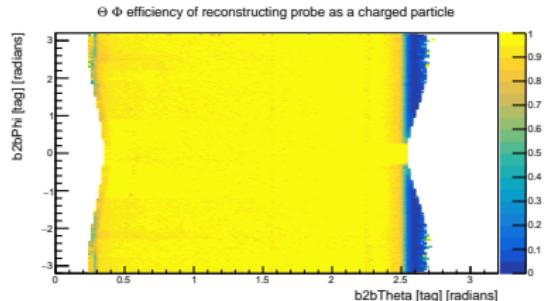
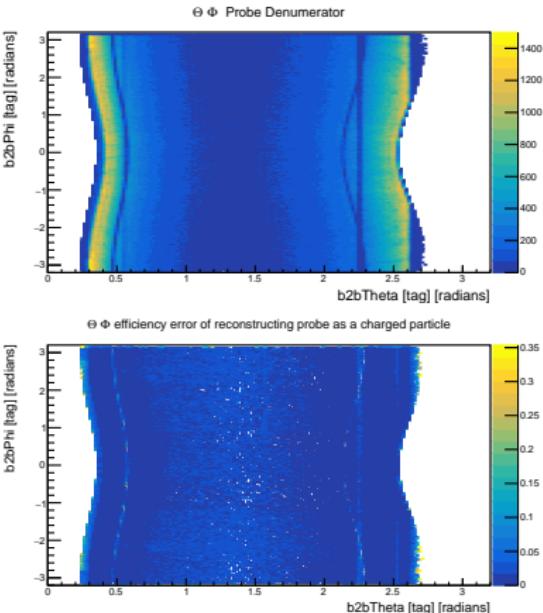
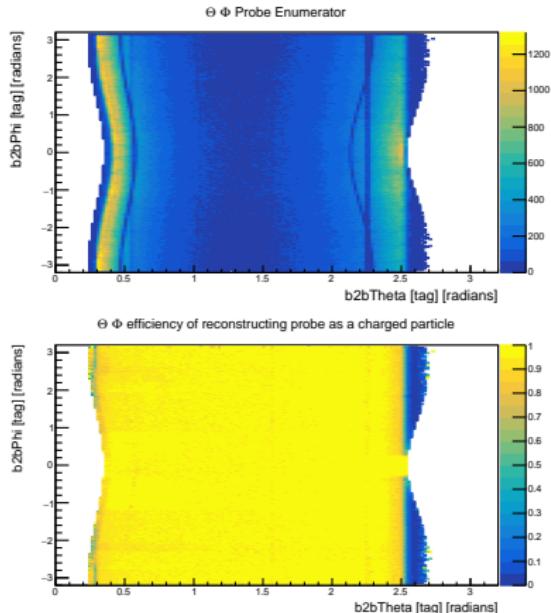
Random Θ (MC)



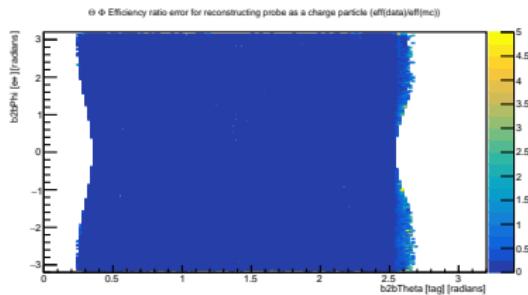
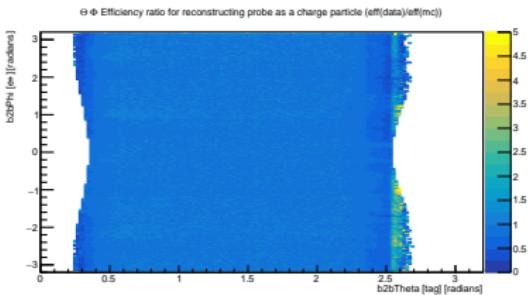
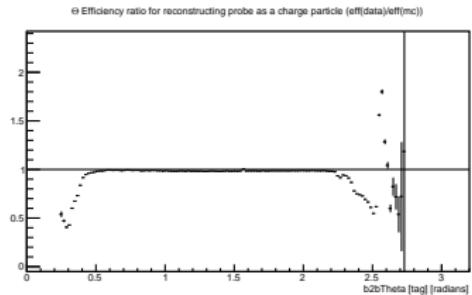
Θ efficiency of reconstructing probe as a charged particle



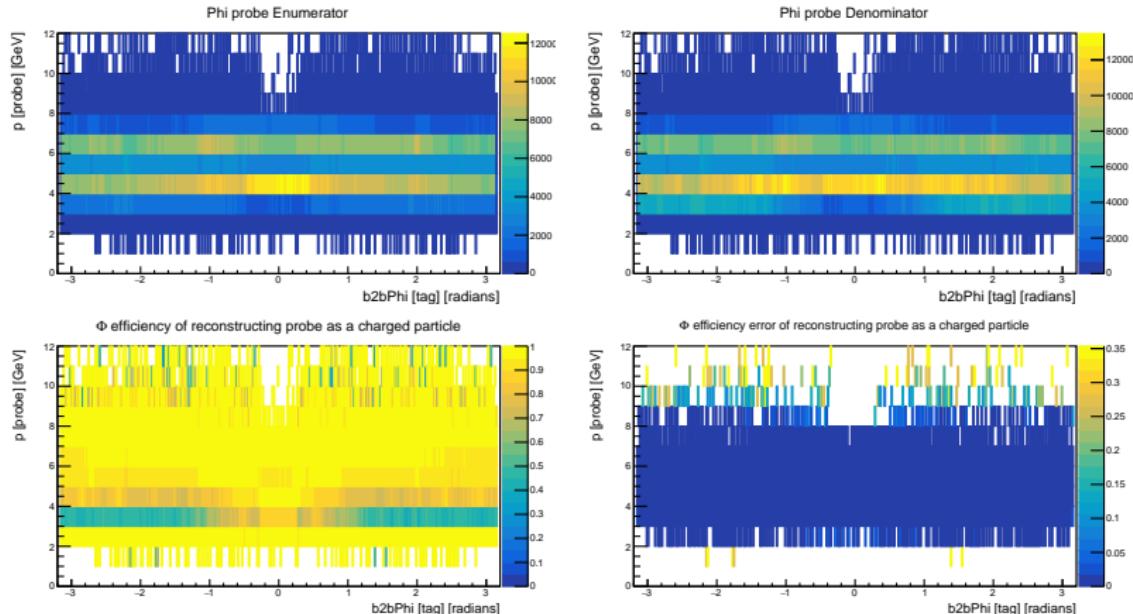
Random $\Theta\Phi$ (MC)



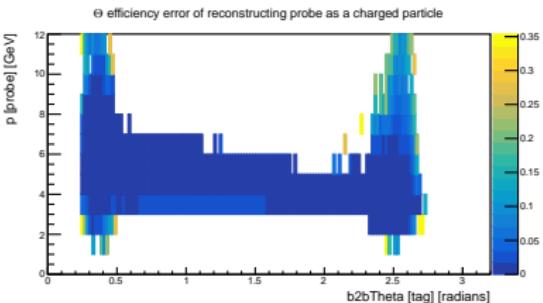
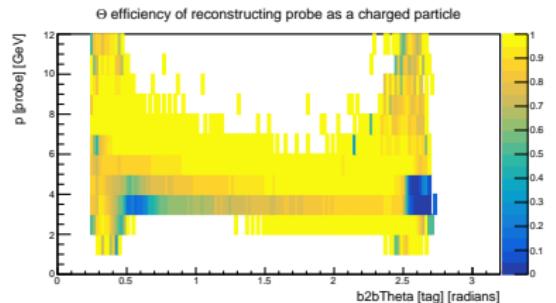
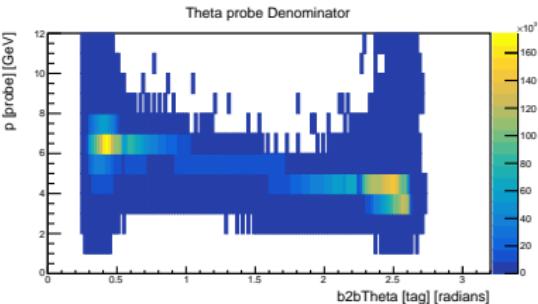
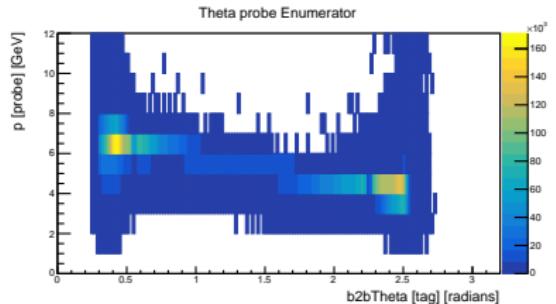
Random Ratio



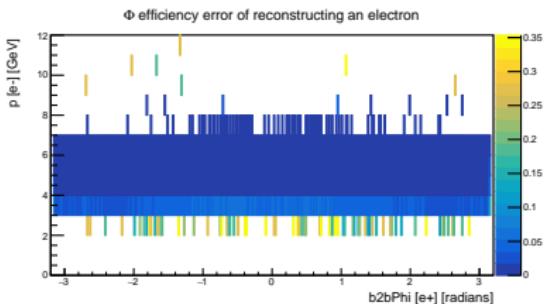
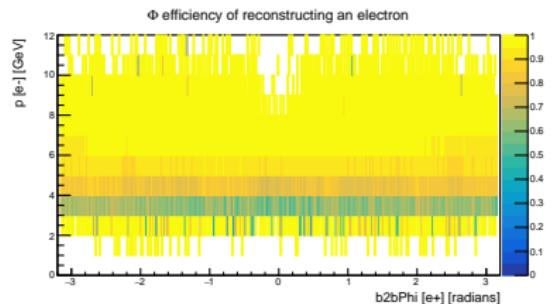
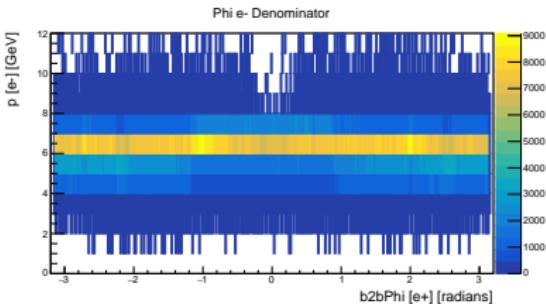
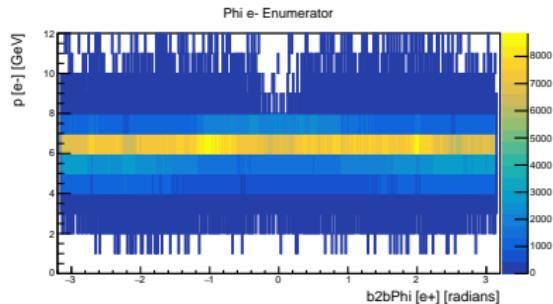
Momentum Random ϕ (MC)



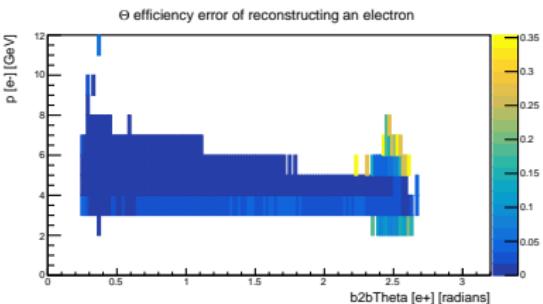
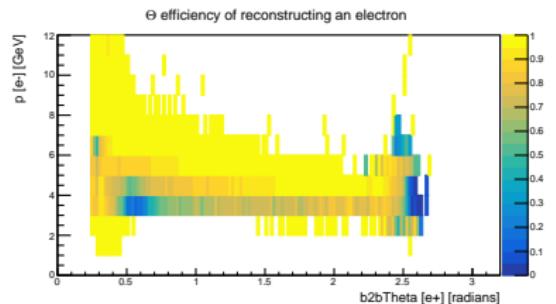
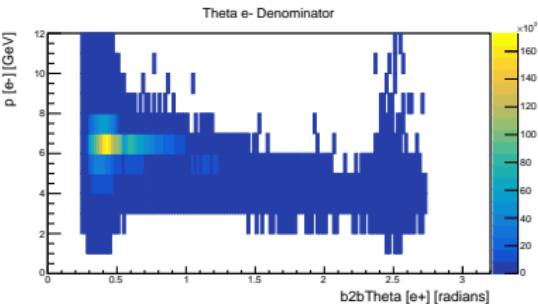
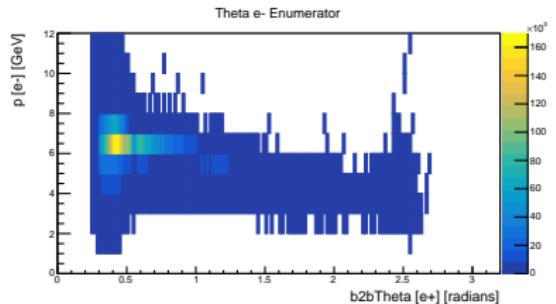
Momentum Random Θ (MC)



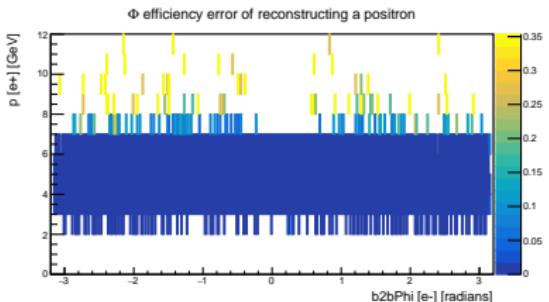
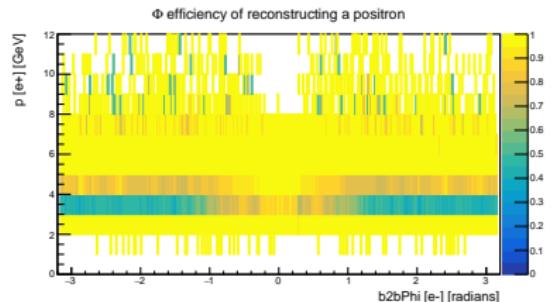
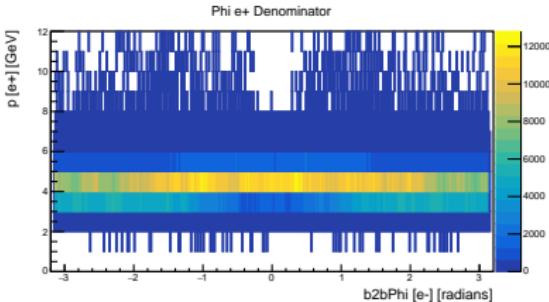
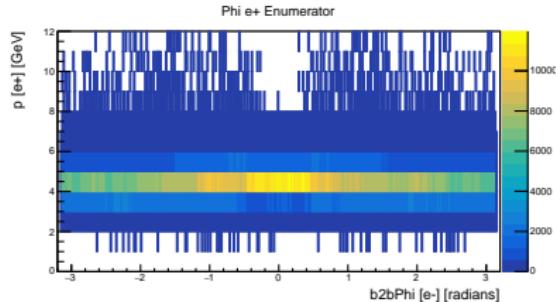
Momentum $e^- \phi$ (MC)



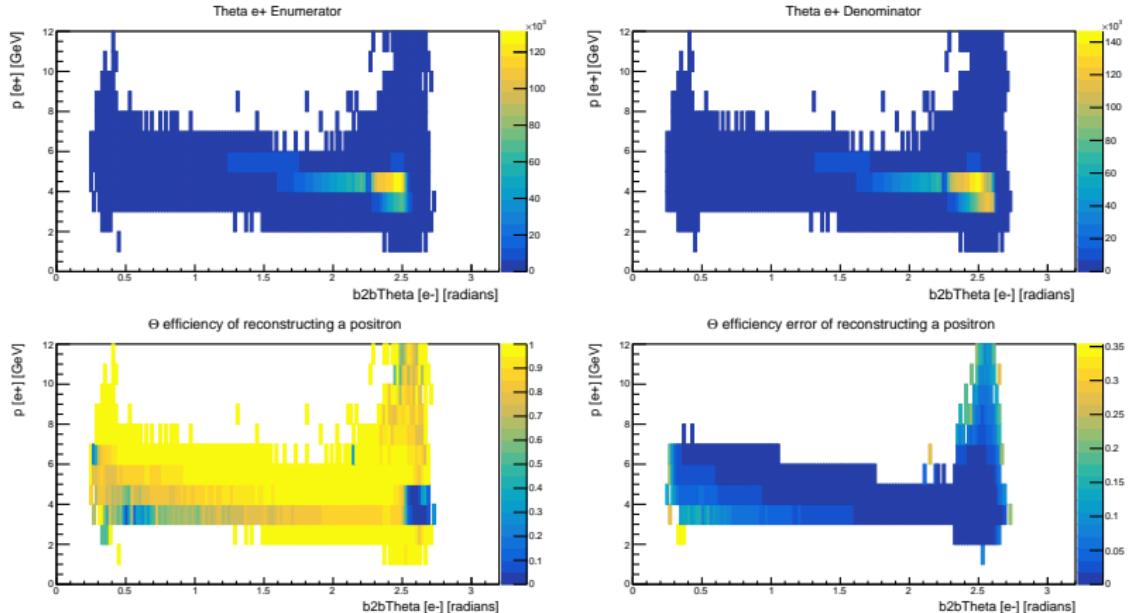
Momentum $e^- \Theta$ (MC)



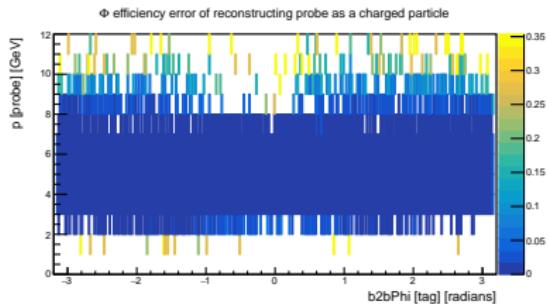
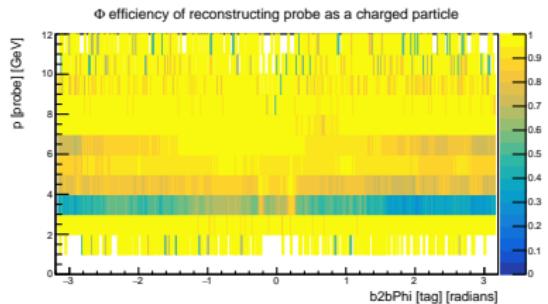
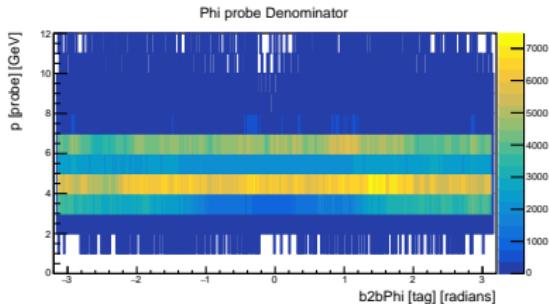
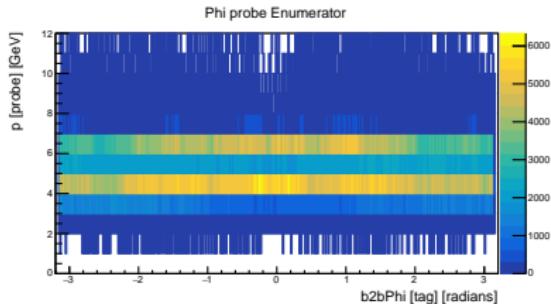
Momentum $e^+ \phi$ (MC)



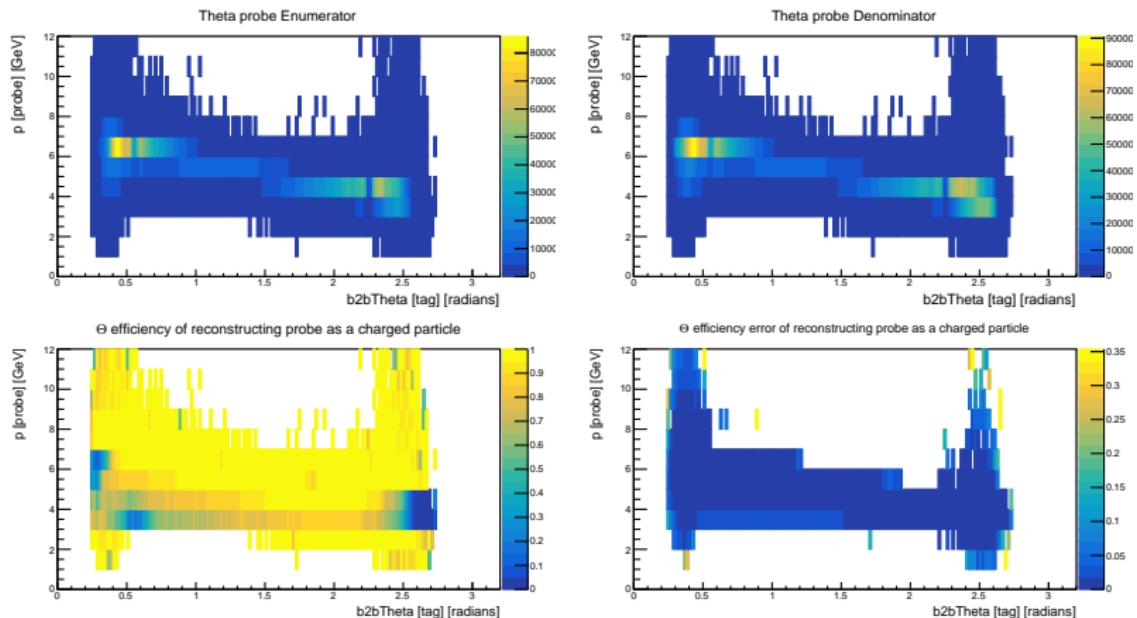
Momentum $e^+ \Theta$ (MC)



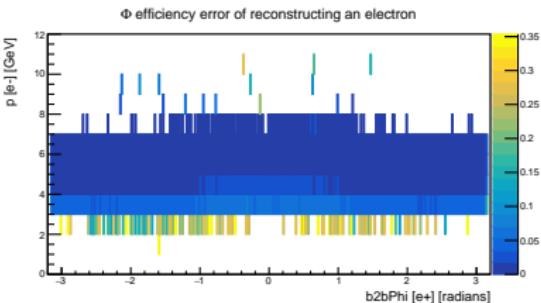
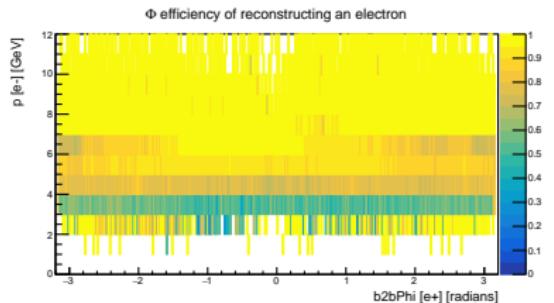
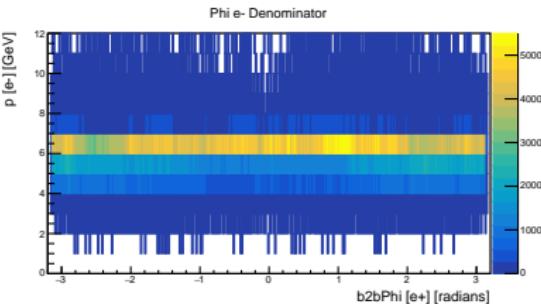
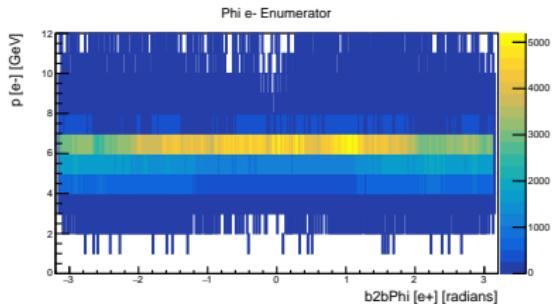
Momentum Random ϕ (Data)



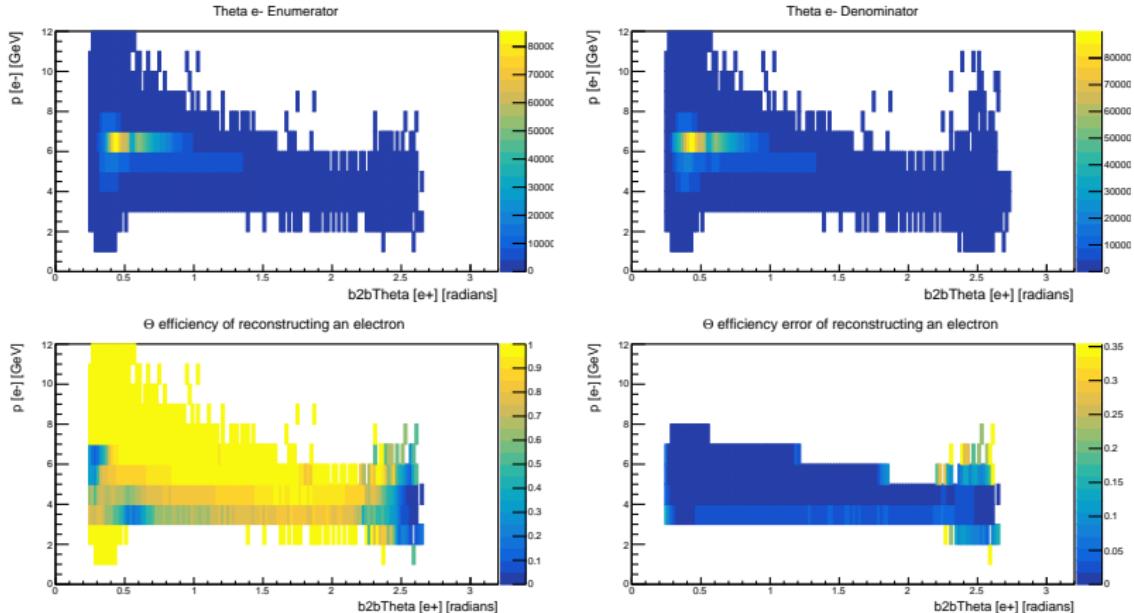
Momentum Random Θ (Data)



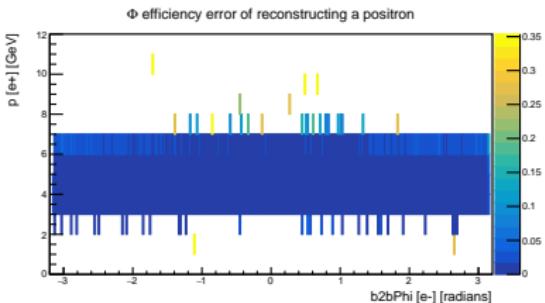
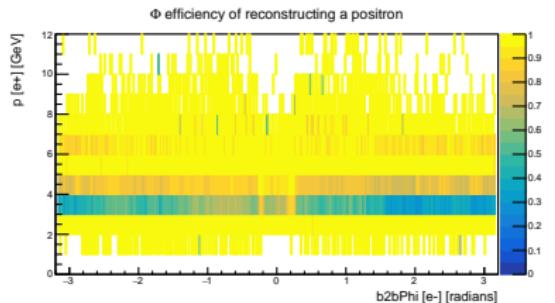
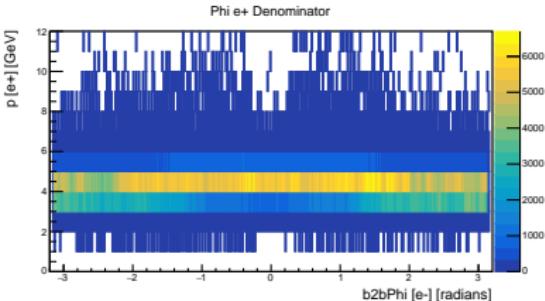
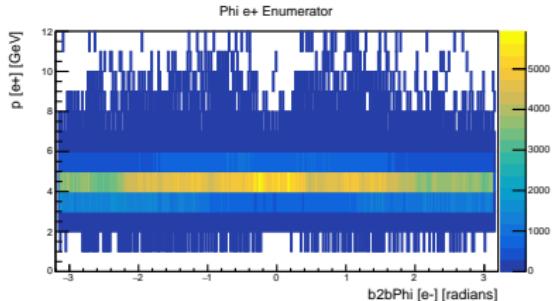
Momentum $e^- \Phi$ (Data)



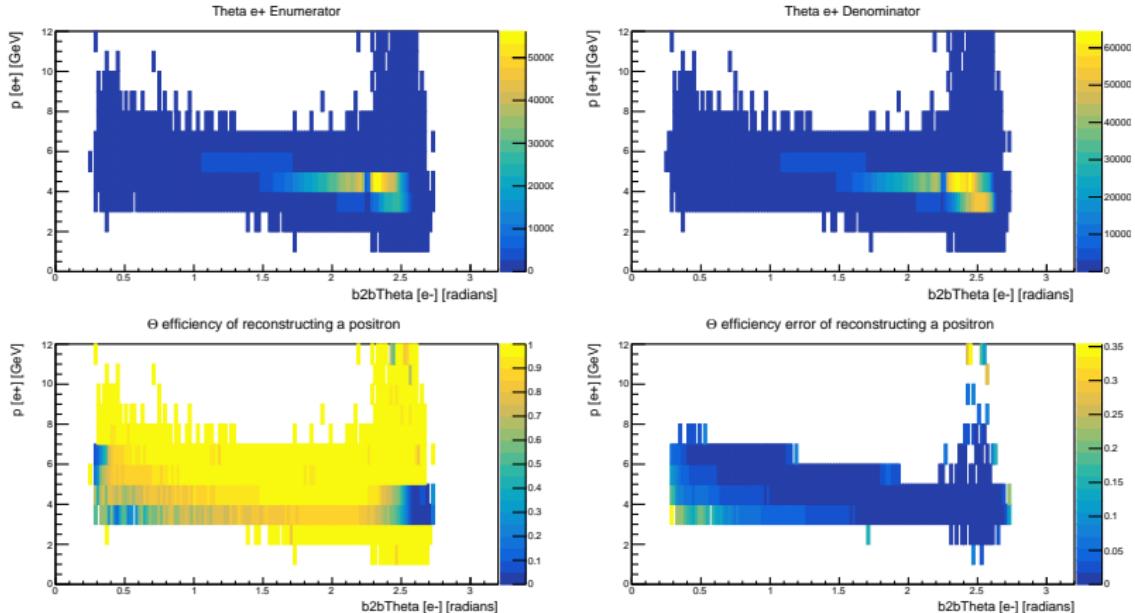
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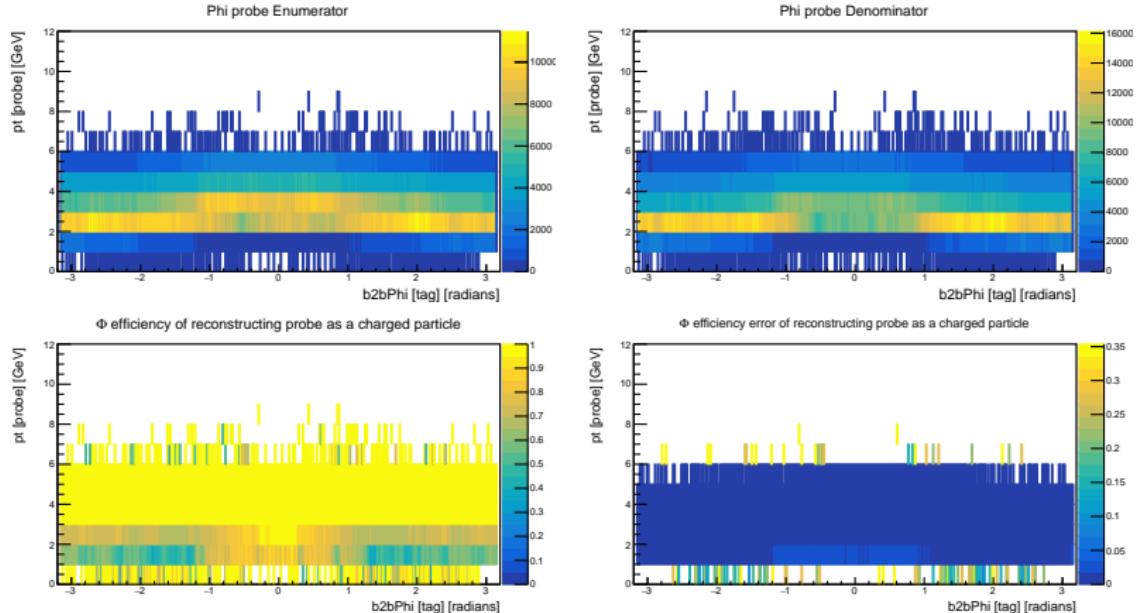
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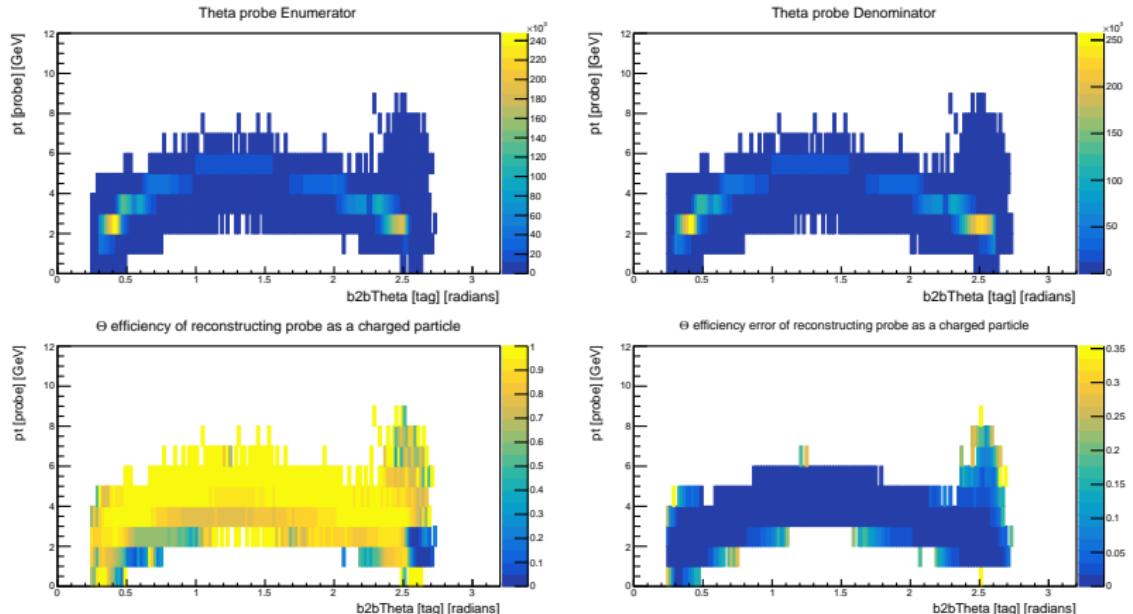
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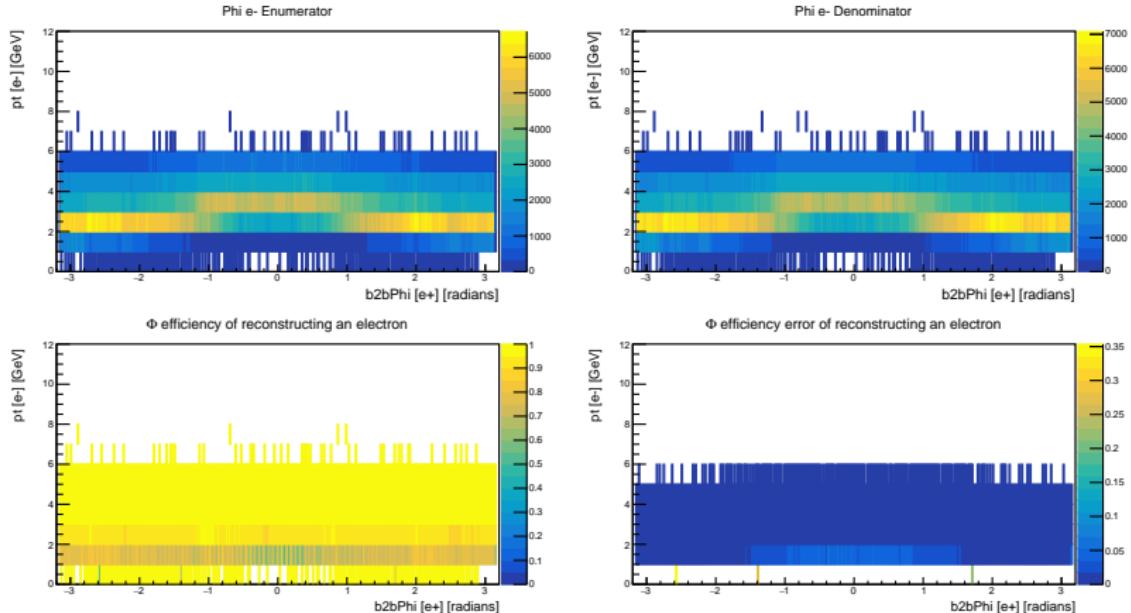
Transverse Momentum Random Φ (MC)



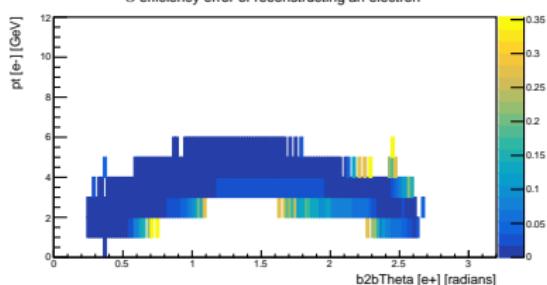
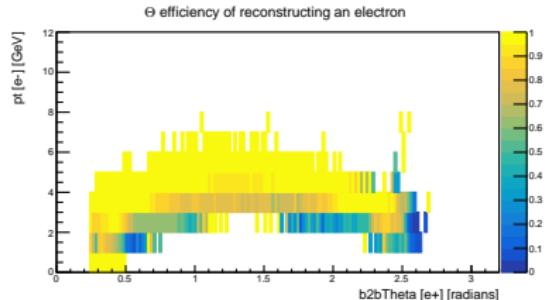
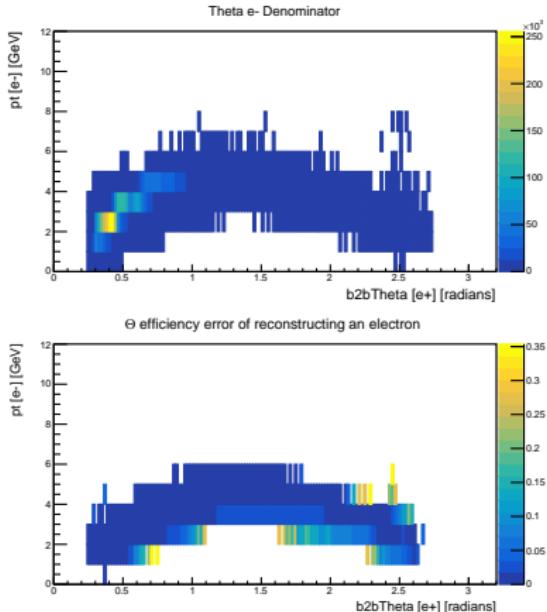
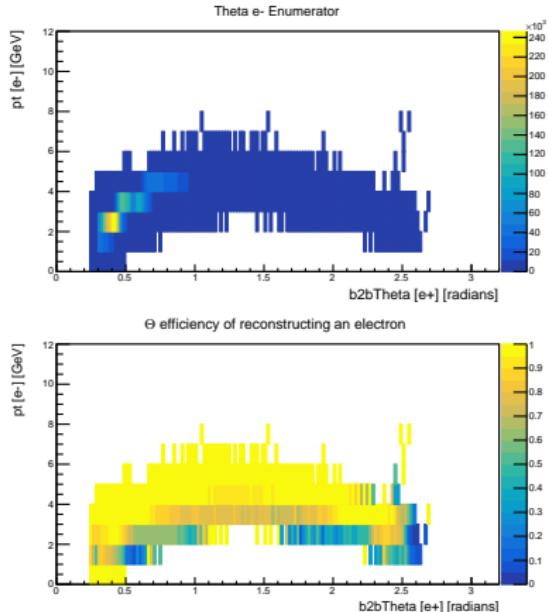
Transverse Momentum Random Θ (MC)



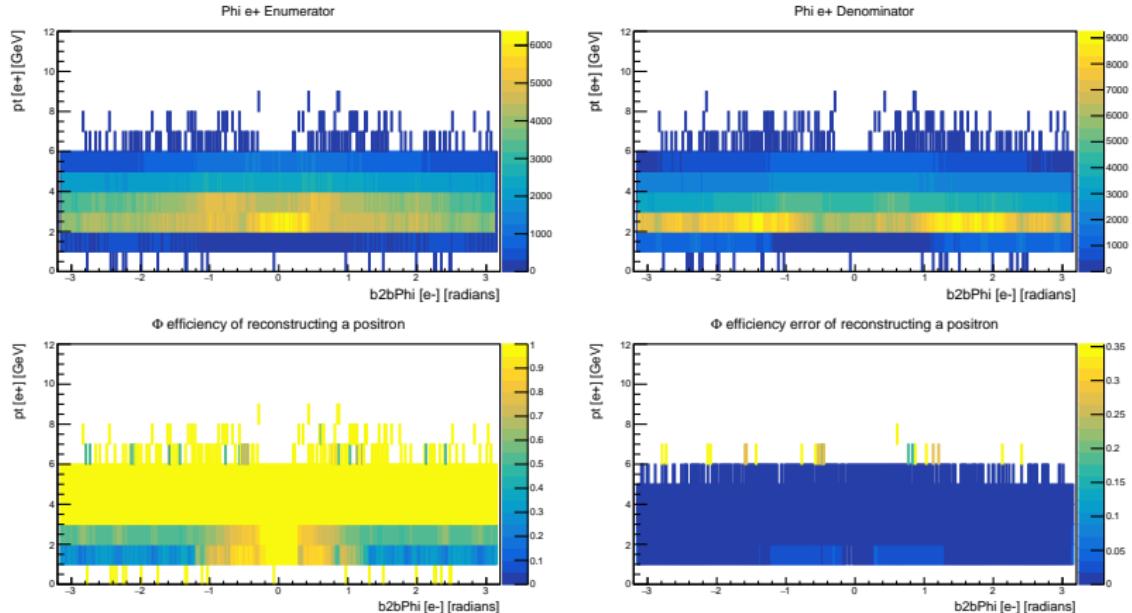
Transverse Momentum $e^- \phi$ (MC)



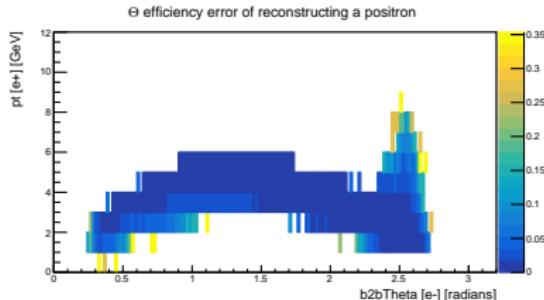
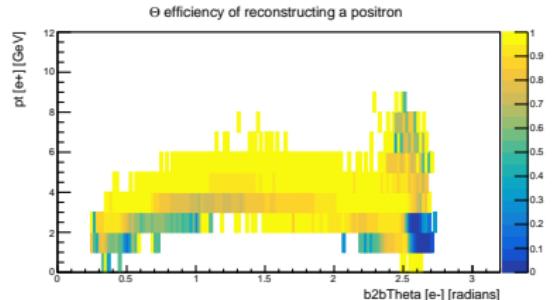
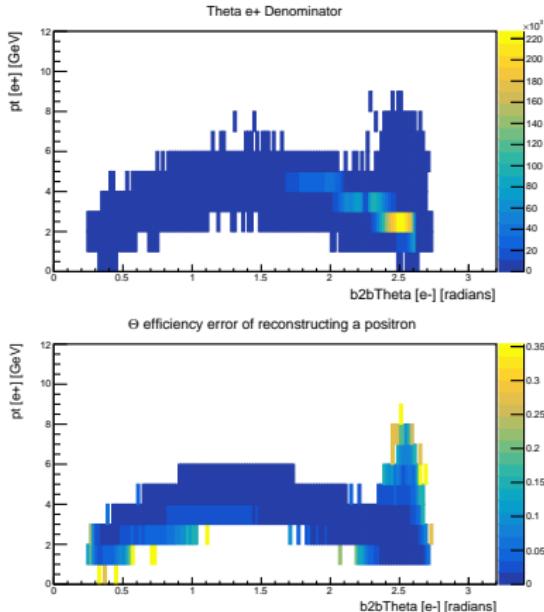
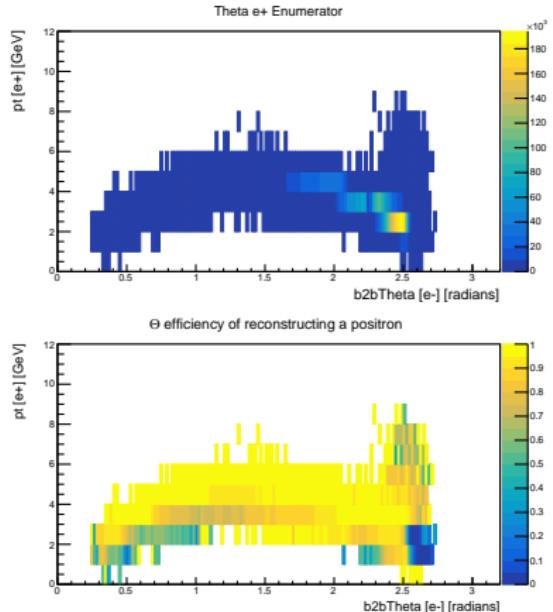
Transverse Momentum $e^- \Theta$ (MC)



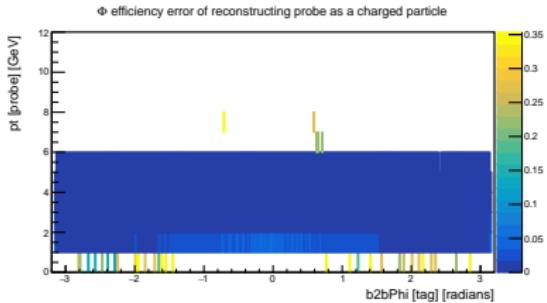
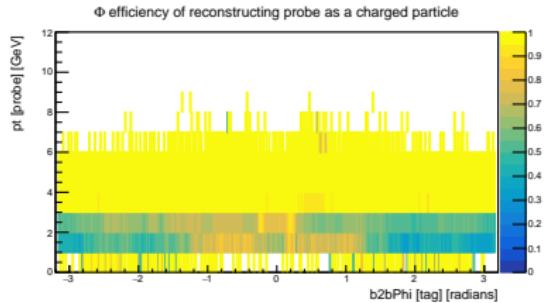
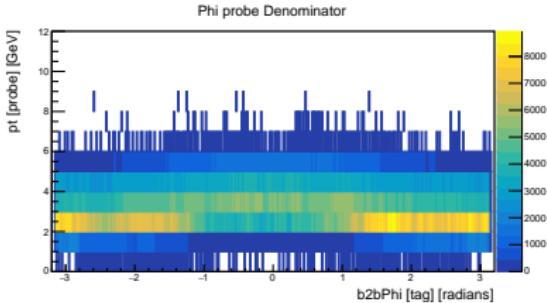
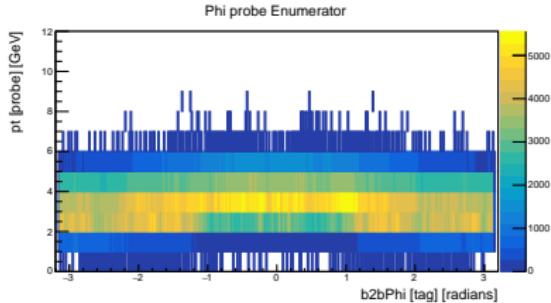
Transverse Momentum $e^+ \phi$ (MC)



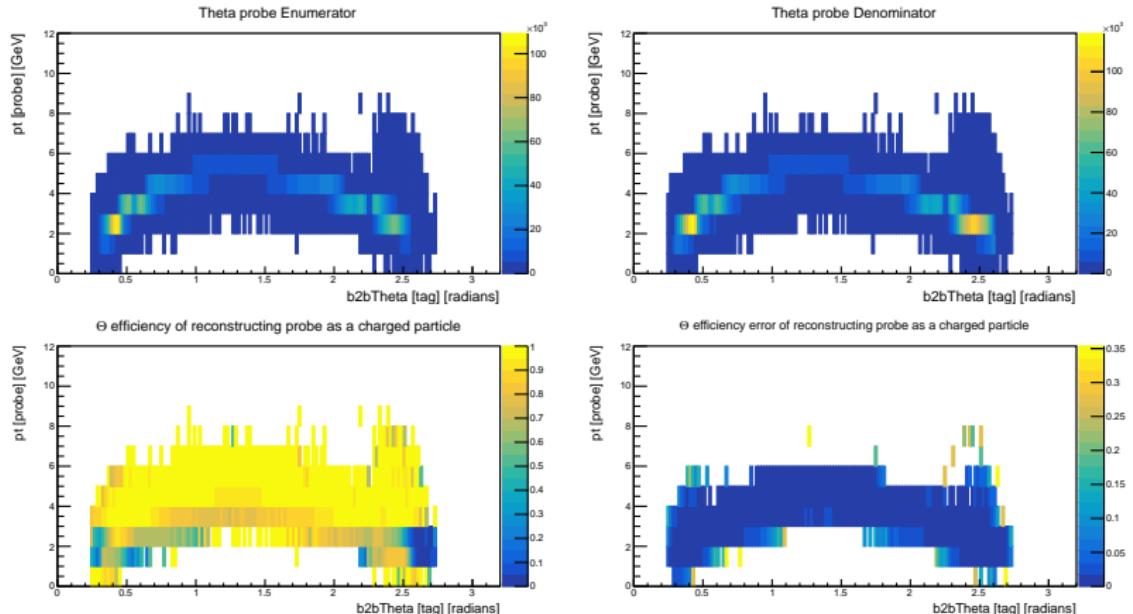
Transverse Momentum $e^+ \Theta$ (MC)



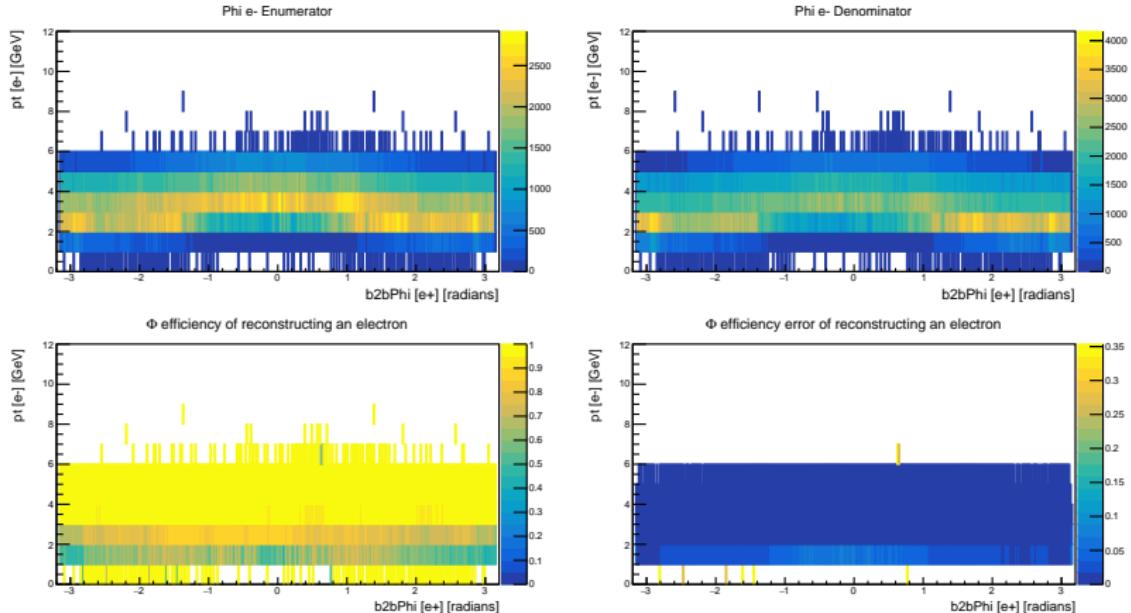
Transverse Momentum Random Φ (Data)



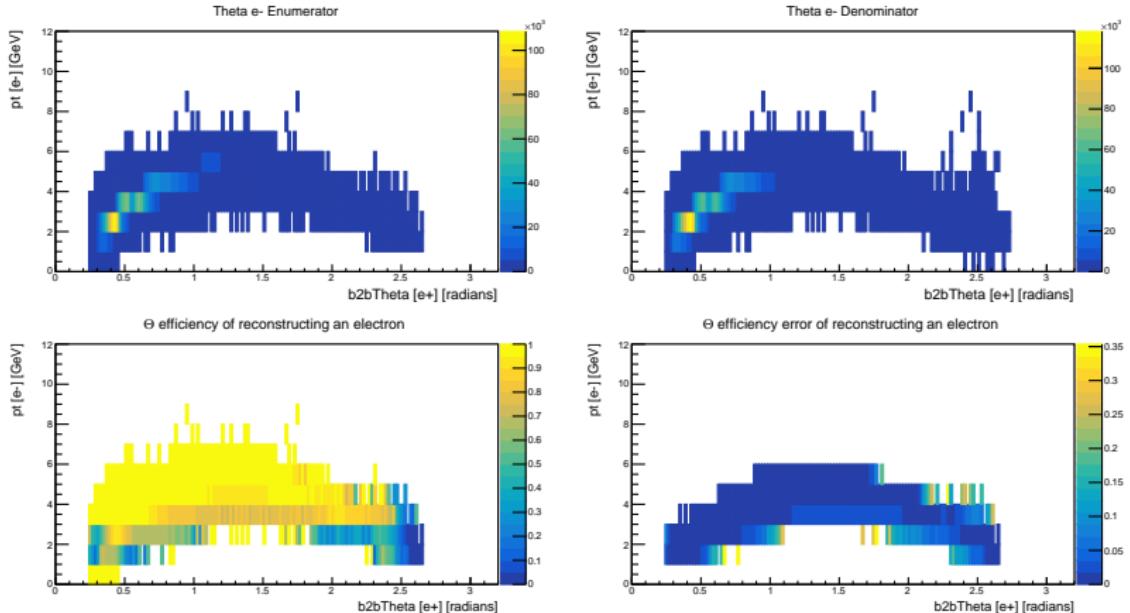
Transverse Momentum Random Θ (Data)



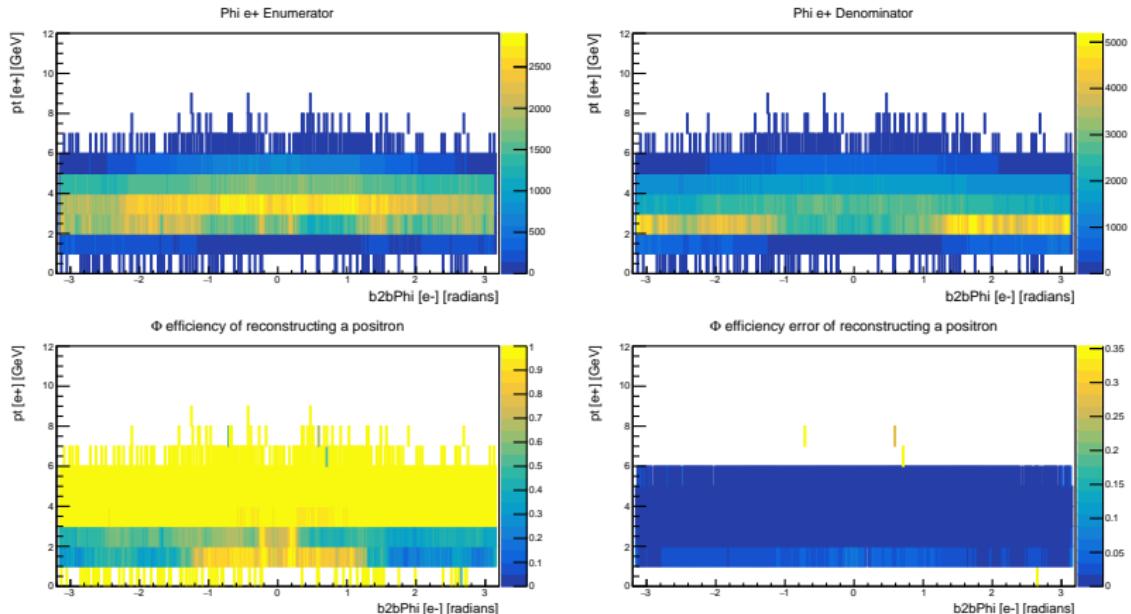
Transverse Momentum $e^- \phi$ (Data)



Transverse Momentum $e^- \Theta$ (Data)



Transverse Momentum $e^+ \phi$ (Data)



Transverse Momentum $e^+ \Theta$ (Data)

