

Systematic Studies On Track Reconstruction Efficiency At Belle II

Martin Sobotzik (msobotzi@students.uni-mainz.de)

22.01.2020

Johannes Gutenberg-Universität Mainz

Outline

- Overview on the Belle II experiment
- Bhabha kinematics at Belle II
- Preparation for calculating the tracking efficiency
- Phase3 tracking efficiency
- Comparing the phase2 with phase3 tracking efficiency
- Conclusion

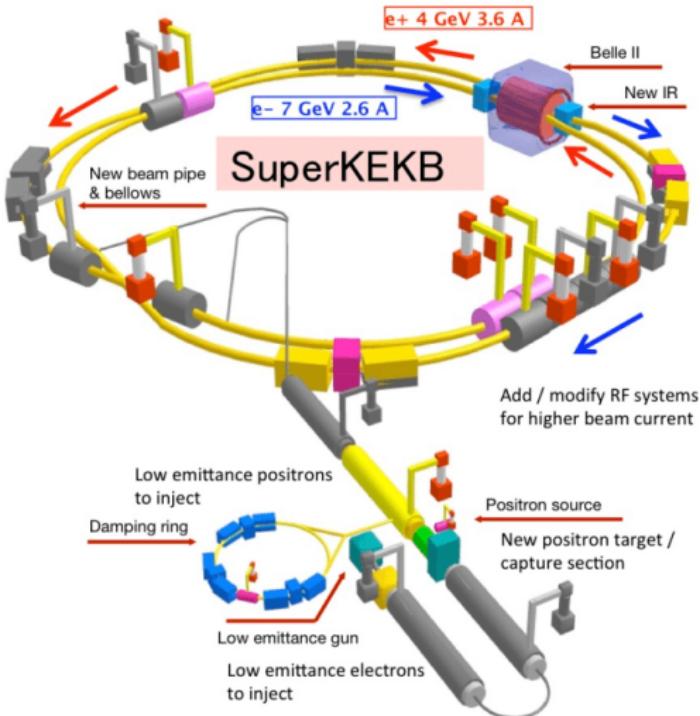
Motivation

- At an electron-positron accelerator most outgoing particles are again electrons and positrons (these events are called Bhabha events)
- These events can be used to estimate the performance of the tracking detectors
- If the *tag* particle in a Bhabha event has a track than the *probe* particle also should have a track associated
→ a tracking efficiency can be calculated

Overview Of The Belle II Experiment

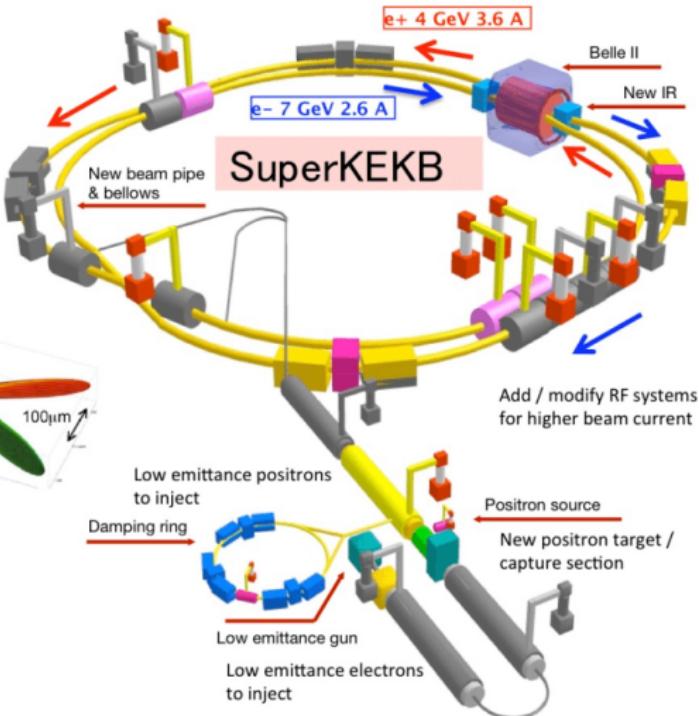
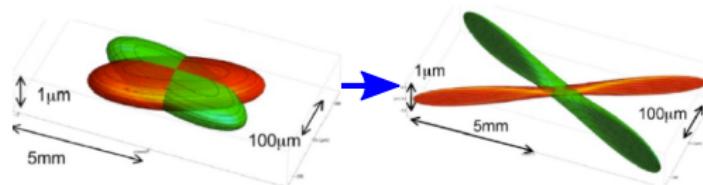
The SuperKEKB e^+e^- Collider And Luminosity Goals

- Asymmetric B -factory
- Center-of-mass close to $\Upsilon(4S)$
 $\sim 10.58 \text{ GeV}$
- Upgrade of the KEKB collider:
 - Larger beam currents
 - Reduced beam size



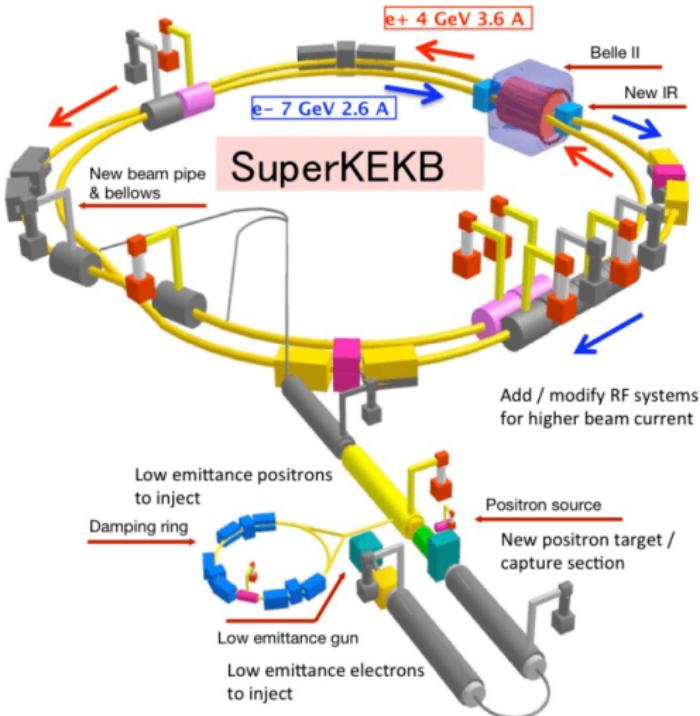
The SuperKEKB e^+e^- Collider And Luminosity Goals

- Asymmetric B -factory
- Center-of-mass close to $\Upsilon(4S)$
 ~ 10.58 GeV
- Upgrade of the KEKB collider:
 - Larger beam currents
 - Reduced beam size



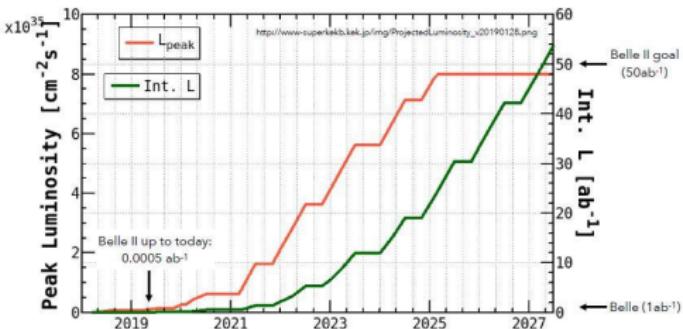
The SuperKEKB e^+e^- Collider And Luminosity Goals

- Asymmetric B -factory
- Center-of-mass close to $\Upsilon(4S)$
 $\sim 10.58 \text{ GeV}$
- Upgrade of the KEKB collider:
 - Larger beam currents
 - Reduced beam size
- \rightarrow Luminosity increase $\times 40$



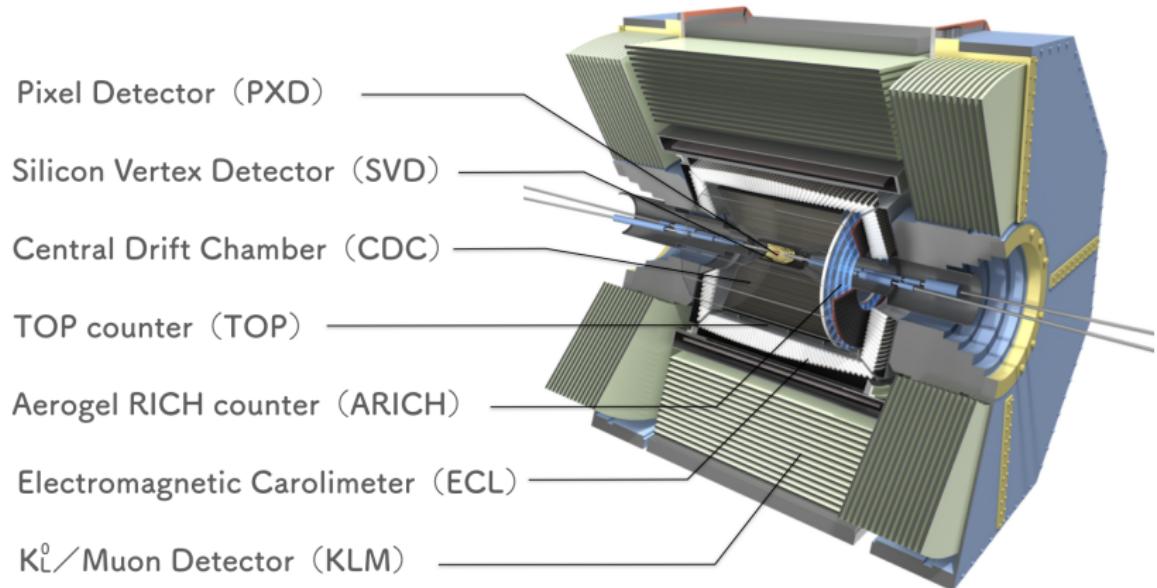
The SuperKEKB e^+e^- Collider And Luminosity Goals

- Asymmetric B -factory
- Center-of-mass close to $\Upsilon(4S)$
 $\sim 10.58 \text{ GeV}$
- Upgrade of the KEKB collider:
 - Larger beam currents
 - Reduced beam size
- \rightarrow Luminosity increase $\times 40$
- Designed peak luminosity of
 $8 \cdot 10^{35} \text{ cm}^{-2}\text{s}^{-1}$
- Planned data sample corresponding to a recorded integrated luminosity of
 $\sim 50 \text{ ab}^{-1}$



- Phase1: accelerator commissioning and background estimation (completed in 2016)
- Phase2: collision runs and background studies with partially installed detector (completed in 2018)
- Phase3: data taking with the whole detector (started in April 2019)

The Belle II Detector



Vertex Detectors

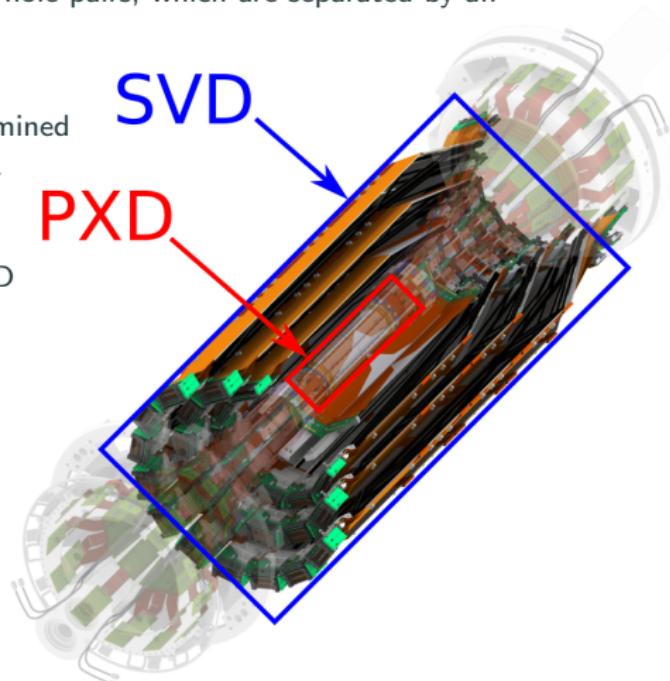
Vertex Detectors (VXD):

- Consist of Pixel Detector (PXD) and Silicon Vertex Detector (SVD)
- Both detectors consist of multiple ladders of strip detectors
- Charged particles create electron-hole pairs, which are separated by an electric field

The signal is then read out

→ particle position can be determined

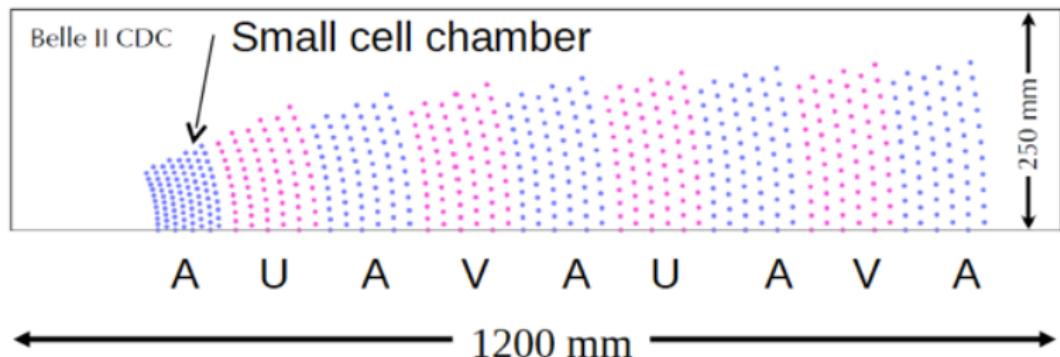
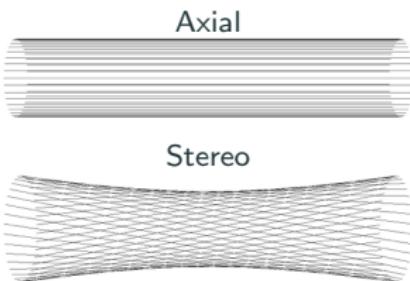
- During phase2, only a fraction of the VXD detectors were installed
- During phase3, the complete SVD and roughly half of the PXD are installed
- Acceptance: $17.0^\circ < \theta < 150.0^\circ$



Central Drift Chamber

Central Drift Chamber:

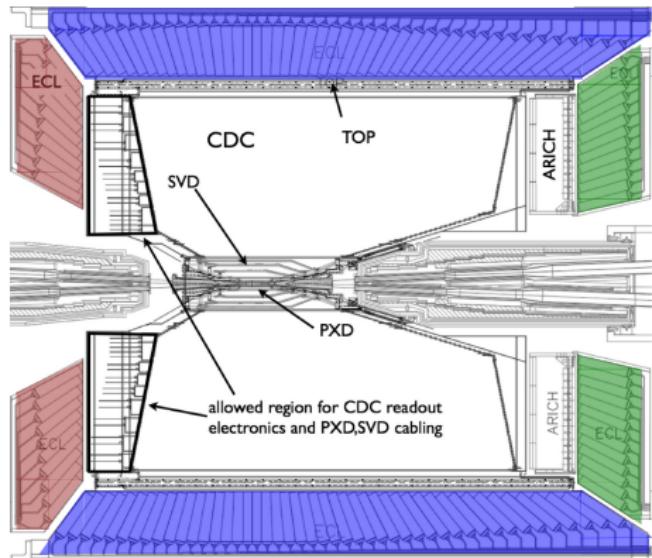
- Consists of 14336 sense wires arranged in 5 axial and 4 stereo superlayers (each superlayer consists of 6 layers; with an exception to the innermost superlayer)
- Charged particles ionize the gas
The signal is then read out by the sense wires
→ Determination of momenta and tracks of charged particles
- Acceptance: $17.0^\circ < \theta < 150.0^\circ$



Electromagnetic Calorimeter

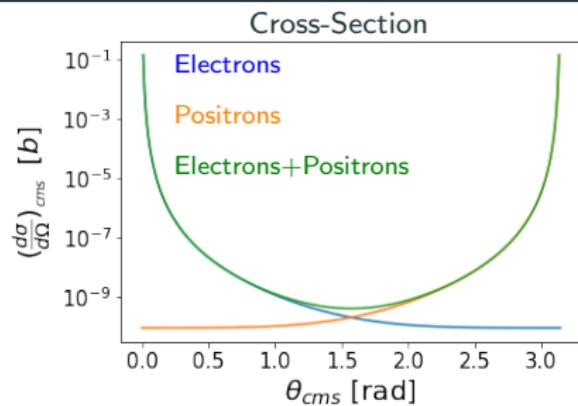
Electromagnetic Calorimeter:

- Consists of 8936 CsI(Tl) crystals
- Electromagnetically interacting particles are creating electromagnetic cascades when they pass through the crystals
 - clusters are created
 - The position and the energy of the particles can be determined
- Separation in **barrel**, **forward end-cap** and **backward end-cap**
- There are two $\sim 1^\circ$ wide gaps at transition between the sections
- Acceptance: $12.4^\circ < \theta < 155.1^\circ$

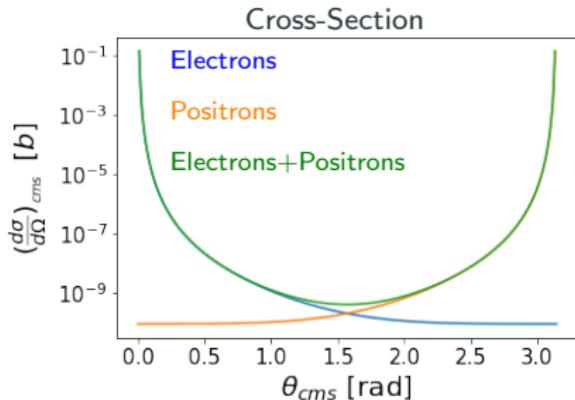


Bhabha Kinematics At Belle II

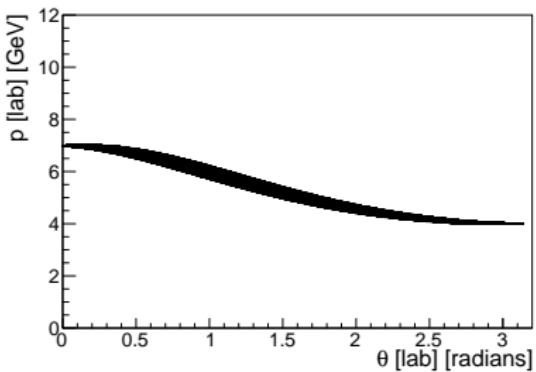
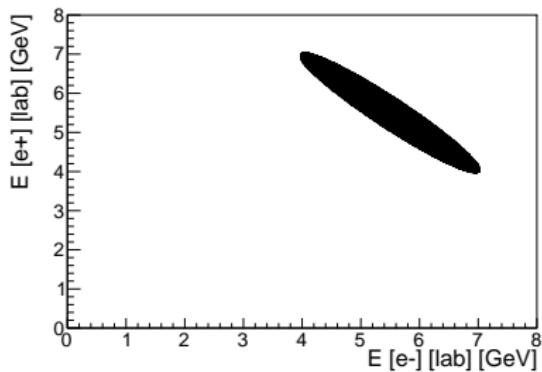
Bhabha Kinematics At Belle II



Bhabha Kinematics At Belle II



- The beams have asymmetric energies
- The beams are hitting each other under an angle of 1.26°
→ Boost the particles from CMS to lab frame



Preparation For Calculating The Tracking Efficiency

Introducing Cuts

Goal: Reconstruct Bhabha events using only ECL information

$$vpho \rightarrow \text{ECL-Object(HcIE)} + \text{ECL-Object(LcIE)}$$

HcIE: particle with higher cluster Energy; LcIE: particle with lower cluster Energy

Introducing Cuts

Goal: Reconstruct Bhabha events using only ECL information

$$\text{vpho} \rightarrow \text{ECL-Object(HcIE)} + \text{ECL-Object(LcIE)}$$

HcIE: particle with higher cluster Energy; LcIE: particle with lower cluster Energy

- The particles have to pass the tracking detectors

$$\rightarrow 17.0^\circ < \theta_{\text{ECL-Object}} < 150.0^\circ$$

Introducing Cuts

Goal: Reconstruct Bhabha events using only ECL information

$$vpho \rightarrow \text{ECL-Object(HcIE)} + \text{ECL-Object(LcIE)}$$

HcIE: particle with higher cluster Energy; LcIE: particle with lower cluster Energy

- The particles have to pass the tracking detectors
 $\rightarrow 17.0^\circ < \theta_{\text{ECL-Object}} < 150.0^\circ$
- $8 \text{ GeV} < M_{vpho} < 12 \text{ GeV}$
- 2 clusters with at least 3.5 GeV per event; One cluster has to have at least 4.5 GeV
- Number of reconstructed tracks per event < 7
- Total energy in the ECL $< 15 \text{ GeV}$

Introducing Cuts

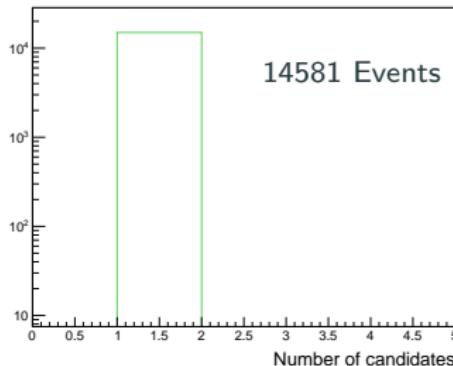
Goal: Reconstruct Bhabha events using only ECL information

$$vpho \rightarrow \text{ECL-Object(HcIE)} + \text{ECL-Object(LcIE)}$$

HcIE: particle with higher cluster Energy; LcIE: particle with lower cluster Energy

- The particles have to pass the tracking detectors
 $\rightarrow 17.0^\circ < \theta_{\text{ECL-Object}} < 150.0^\circ$
- $8 \text{ GeV} < M_{vpho} < 12 \text{ GeV}$
- 2 clusters with at least 3.5 GeV per event; One cluster has to have at least 4.5 GeV
- Number of reconstructed tracks per event < 7
- Total energy in the ECL $< 15 \text{ GeV}$

Single phase2 MC10 Bhabha file



Introducing Cuts

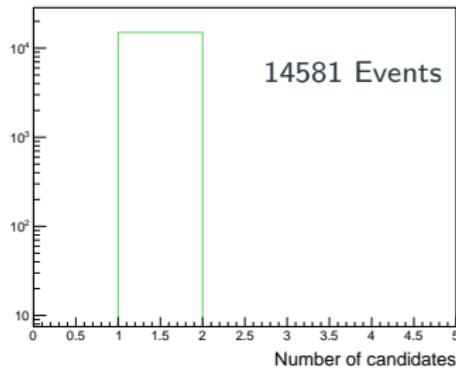
Goal: Reconstruct Bhabha events using only ECL information

$$\text{vpho} \rightarrow \text{ECL-Object(HcIE)} + \text{ECL-Object(LcIE)}$$

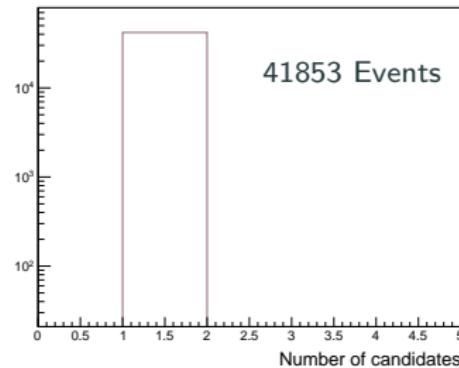
HcIE: particle with higher cluster Energy; LcIE: particle with lower cluster Energy

- The particles have to pass the tracking detectors
 $\rightarrow 17.0^\circ < \theta_{\text{ECL-Object}} < 150.0^\circ$
- $8 \text{ GeV} < M_{\text{vpho}} < 12 \text{ GeV}$
- 2 clusters with at least 3.5 GeV per event; One cluster has to have at least 4.5 GeV
- Number of reconstructed tracks per event < 7
- Total energy in the ECL $< 15 \text{ GeV}$

Single phase2 MC10 Bhabha file



Single phase2 data file



Introducing Cuts

Goal: Reconstruct Bhabha events using only ECL information

$$\text{vpho} \rightarrow \text{ECL-Object(HcIE)} + \text{ECL-Object(LcIE)}$$

HcIE: particle with higher cluster Energy; LcIE: particle with lower cluster Energy

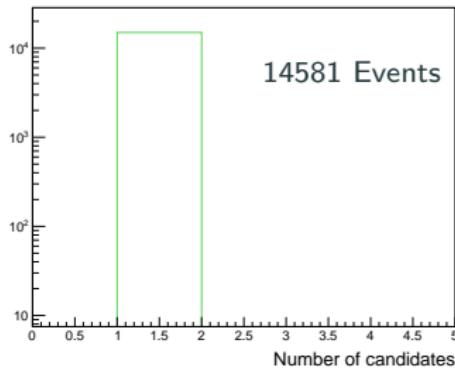
- The particles have to pass the tracking detectors

$$\rightarrow 17.0^\circ < \theta_{\text{ECL-Object}} < 150.0^\circ$$

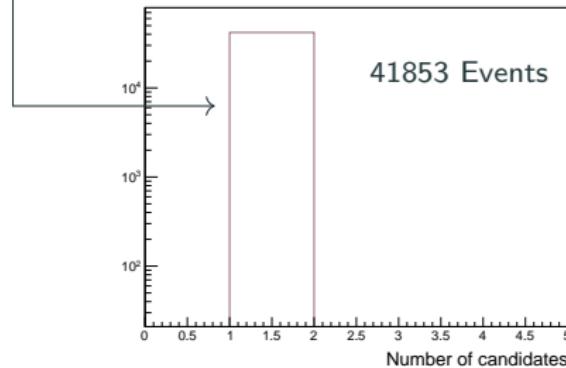
- $8 \text{ GeV} < M_{\text{vpho}} < 12 \text{ GeV}$
- 2 clusters with at least 3.5 GeV per event; One cluster has to have at least 4.5 GeV
- Number of reconstructed candidates
- Total energy in the ECL objects

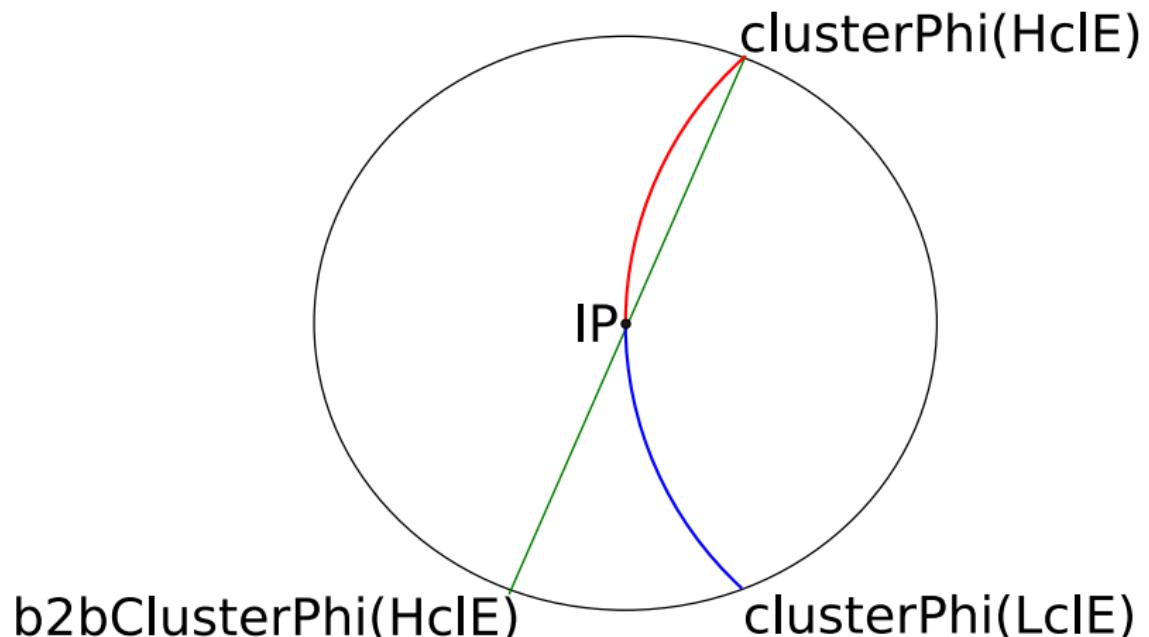
Also contains $e^+e^- \rightarrow \gamma\gamma$ events

Single phase2 MC10 Bhabha file

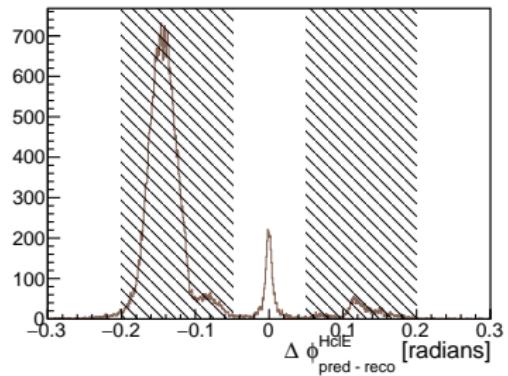
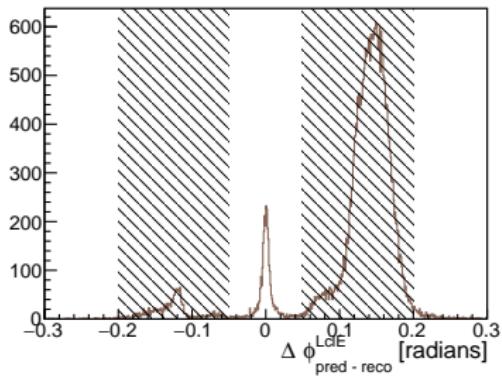
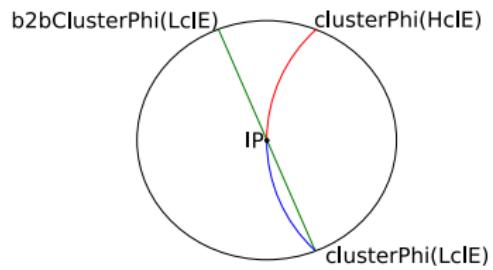
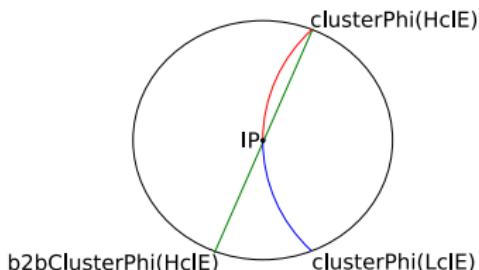


Single phase2 data file

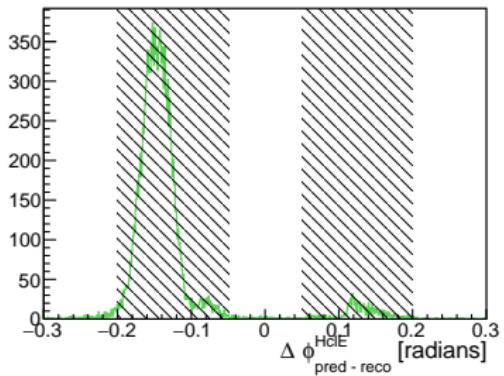
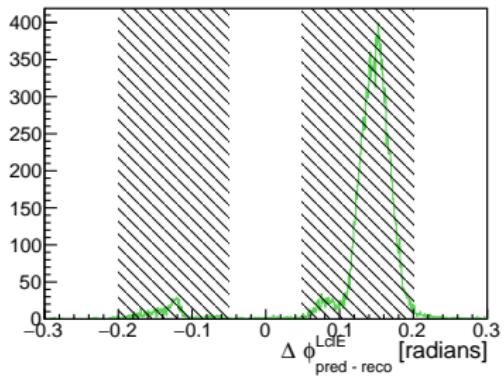
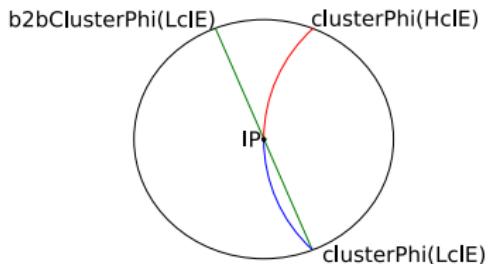
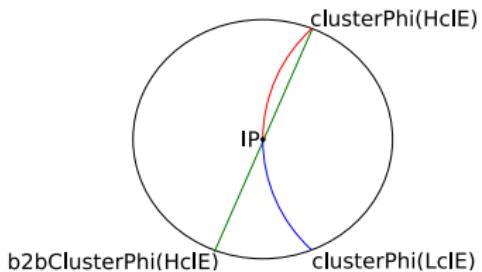




Bhabha Event Selection



Bhabha Event Selection



Trigger

We need to be sure that a trigger signal is coming from the ECL

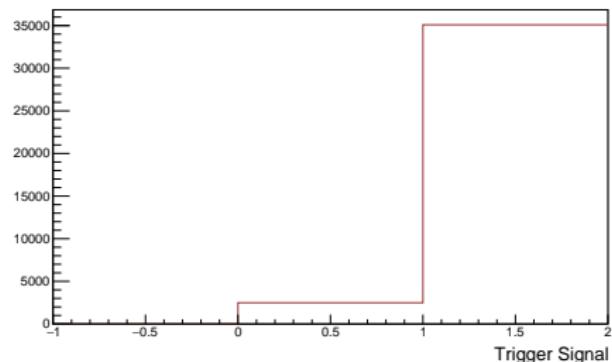
Otherwise there could be a bias

→ The bhabha trigger bit is used

This trigger requires several conditions:

- Trigger signal coming from the ECL
- Both reconstructed particles have to have a cluster energy of at least 2.5 GeV each and one has to have at least 4 GeV
- $160^\circ < \sum \theta_{cms} < 200^\circ$
- $140^\circ < \Delta\phi_{cms} < 220^\circ$

The trigger cut will not be applied to MC since the trigger simulation does not work reliably on MC



Dividing The ECL In Areas Of Interest

As function of azimuthal angle

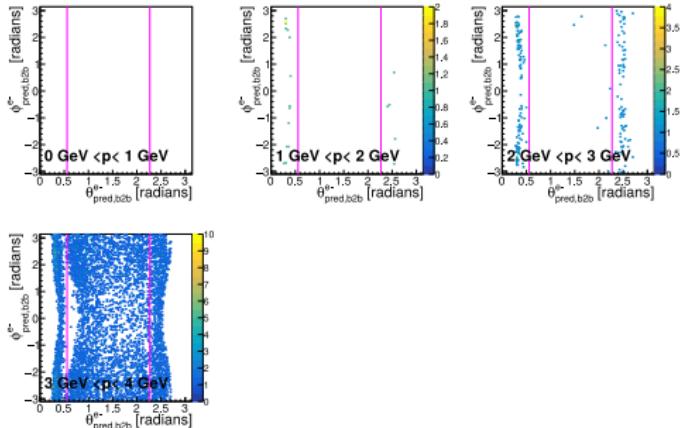
$\phi_{\text{pred},\text{b2b}}$

$p(e^-)$

Forward End-Cap

Barrel

Backward End-Cap



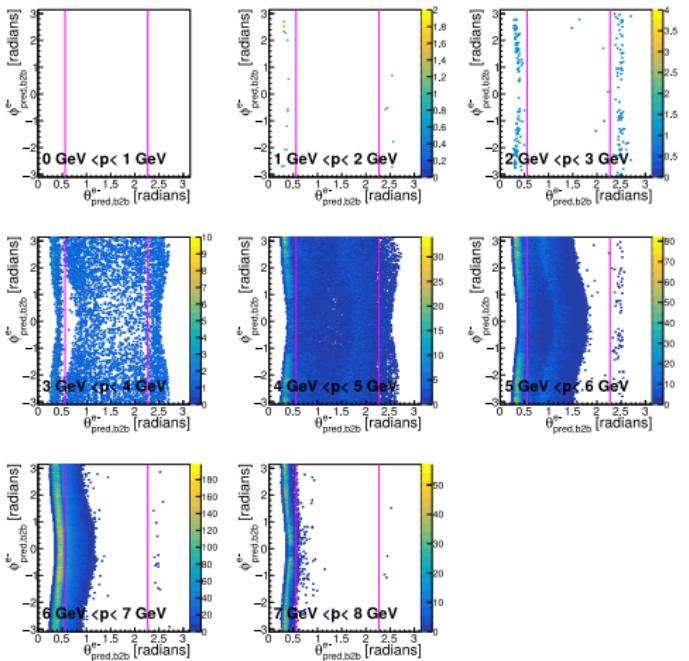
Dividing The ECL In Areas Of Interest

As function of azimuthal angle

$\phi_{\text{pred,b2b}}$

$$p(e^-)$$

Forward End-Cap	4 GeV – 8 GeV
Barrel	4 GeV – 7 GeV
Backward End-Cap	/



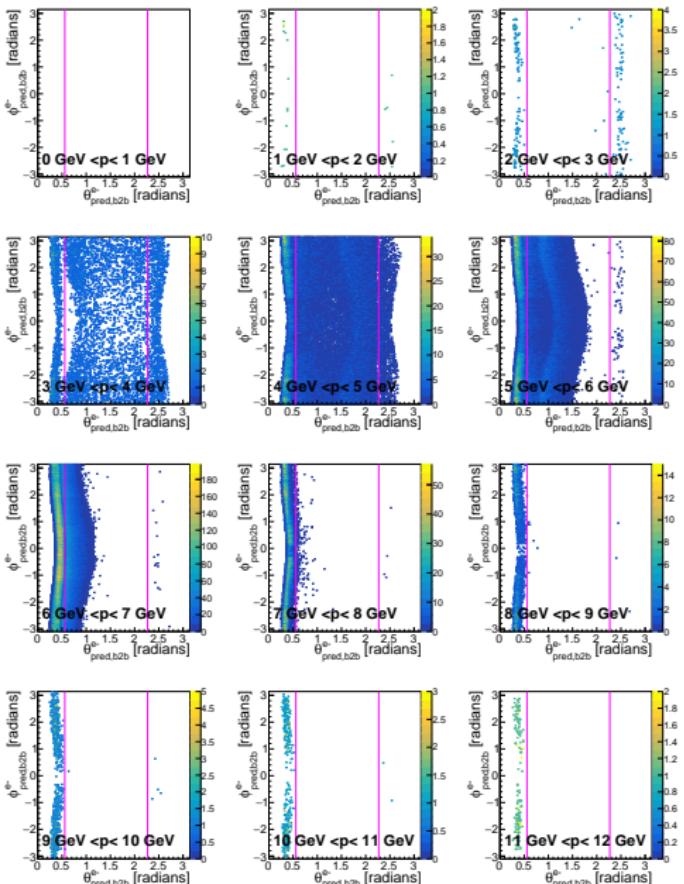
Dividing The ECL In Areas Of Interest

As function of azimuthal angle

$\phi_{\text{pred,b2b}}$

$p(e^-)$

Forward End-Cap	4 GeV – 8 GeV
Barrel	4 GeV – 7 GeV
Backward End-Cap	/

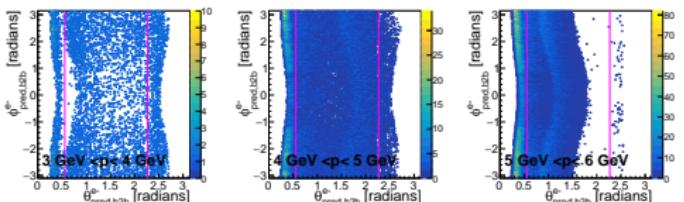
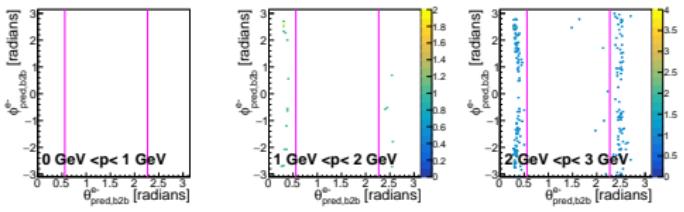


Dividing The ECL In Areas Of Interest

As function of azimuthal angle

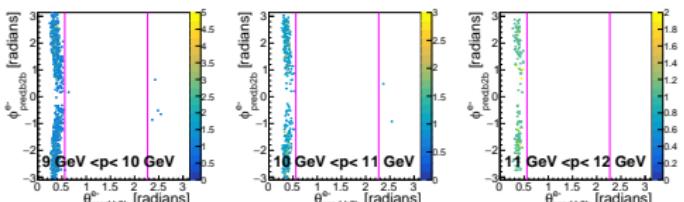
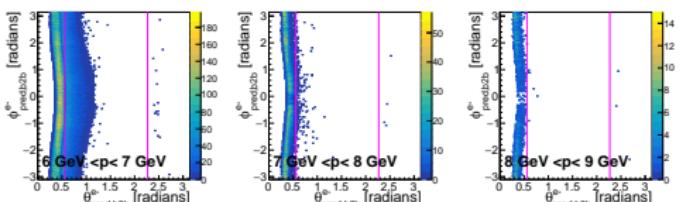
$$\phi_{\text{pred},\text{b2b}}$$

	$p(e^-)$
Forward End-Cap	4 GeV – 8 GeV
Barrel	4 GeV – 7 GeV
Backward End-Cap	/



As function of polar angle $\theta_{\text{pred},\text{b2b}}$

$$p \quad e^- \quad 4 \text{ GeV} - 9 \text{ GeV}$$



Dividing The ECL In Areas Of Interest

As function of azimuthal angle

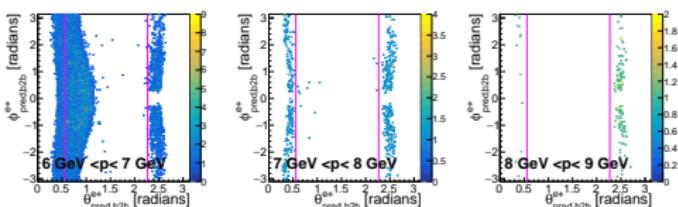
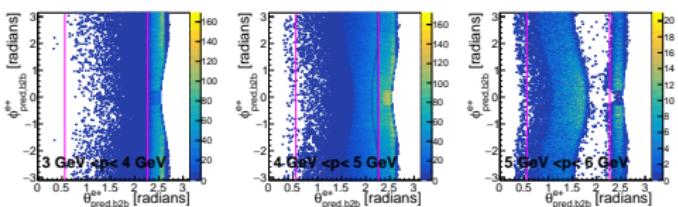
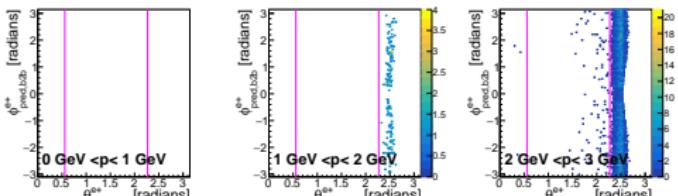
$$\phi_{\text{pred},\text{b2b}}$$

$$p(e^-)$$

Forward End-Cap	4 GeV – 8 GeV
Barrel	4 GeV – 7 GeV
Backward End-Cap	/

$$p(e^+)$$

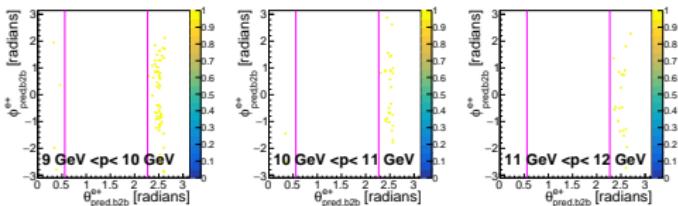
Forward End-Cap	/
Barrel	3 GeV – 7 GeV
Backward End-Cap	2 GeV – 6 GeV



As function of polar angle $\theta_{\text{pred},\text{b2b}}$

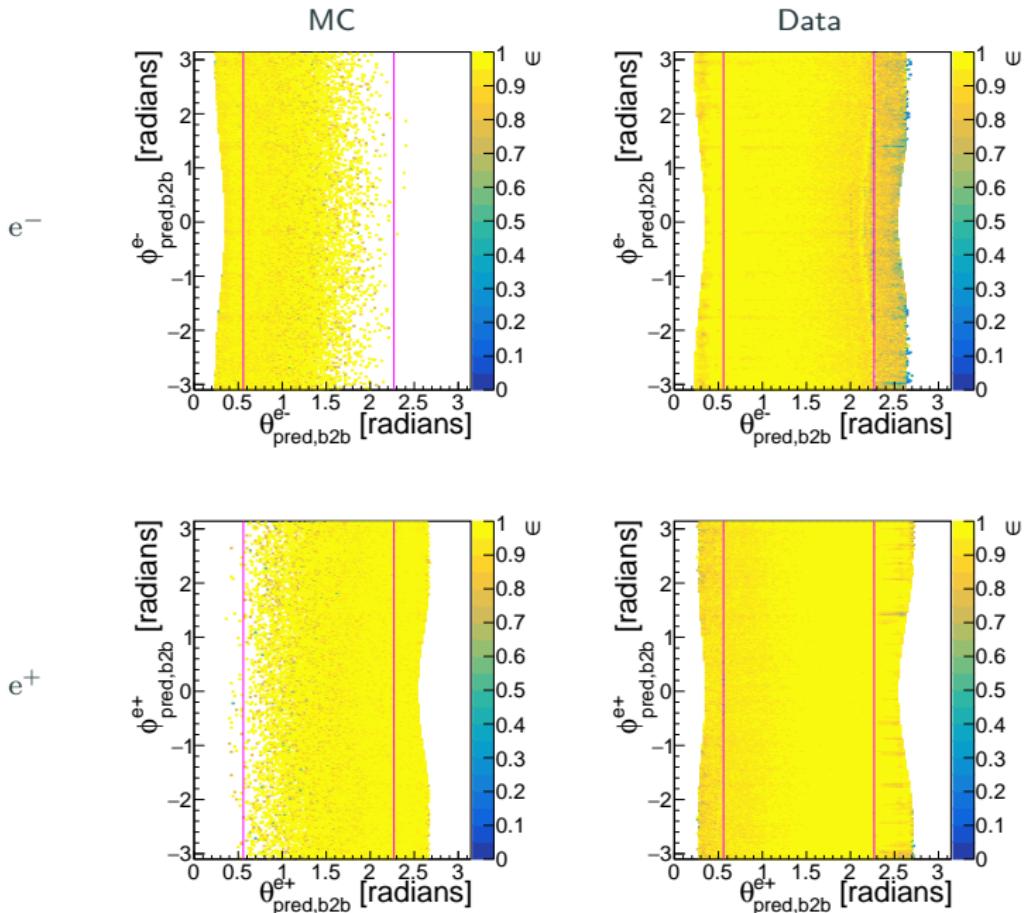
$$p$$

$$\begin{aligned} e^- & \quad 4 \text{ GeV} - 9 \text{ GeV} \\ e^+ & \quad 2 \text{ GeV} - 7 \text{ GeV} \end{aligned}$$

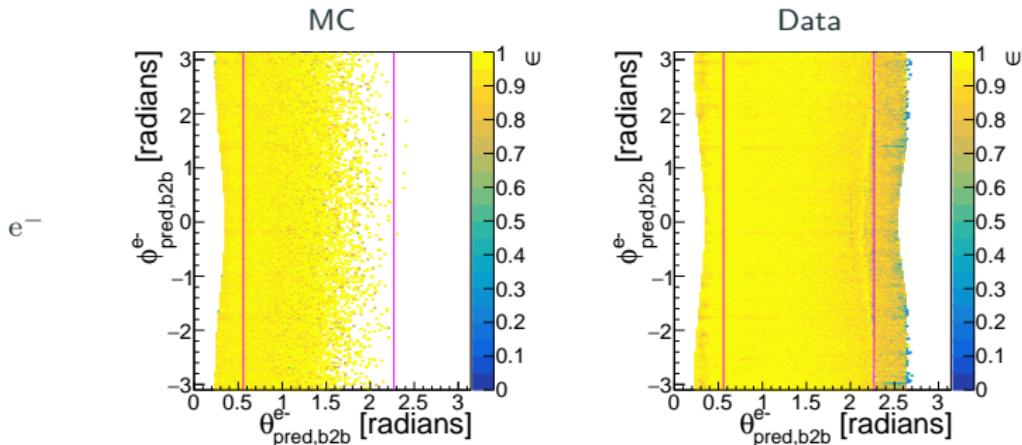


Phase3 Tracking Efficiencies

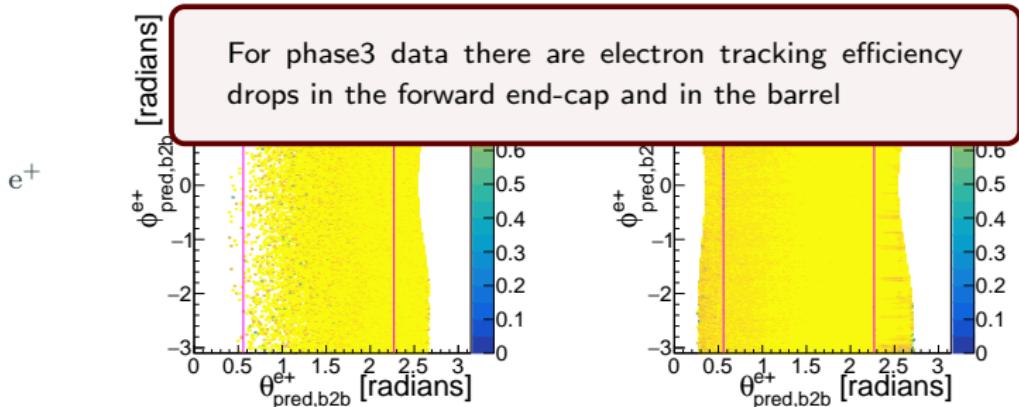
Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}} - \phi_{\text{pred,b2b}}$



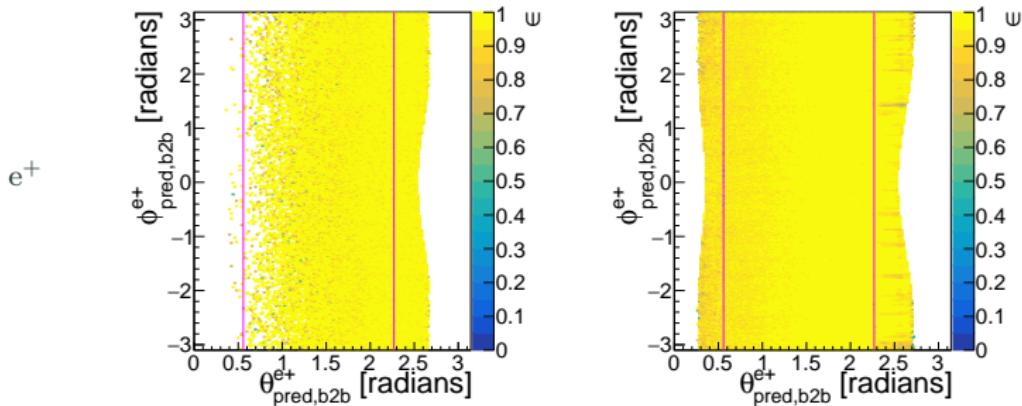
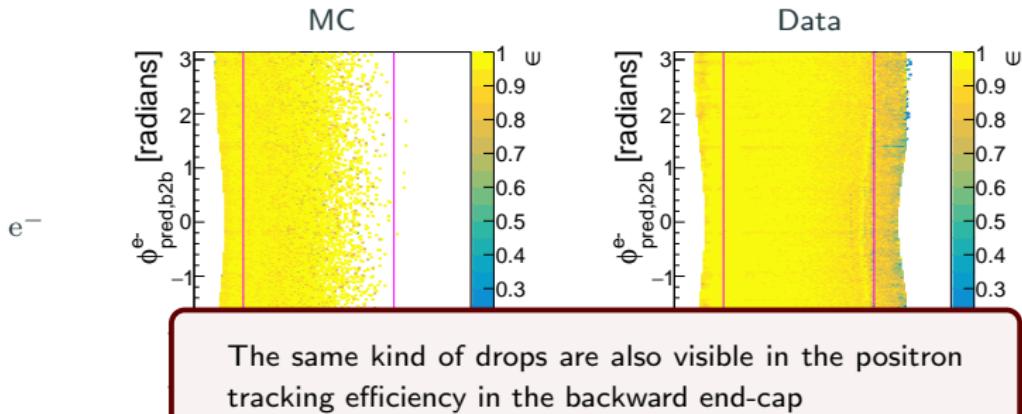
Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}} - \phi_{\text{pred,b2b}}$



For phase3 data there are electron tracking efficiency drops in the forward end-cap and in the barrel



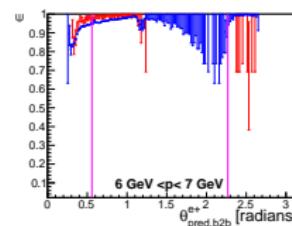
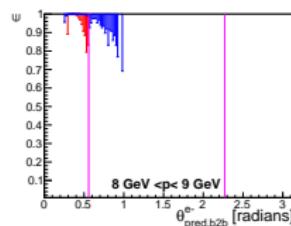
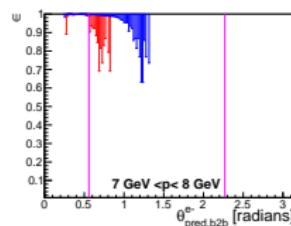
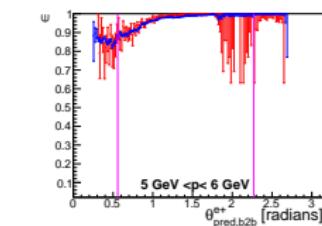
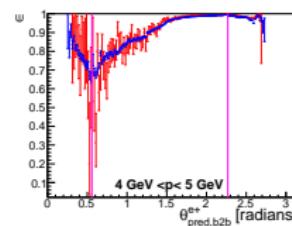
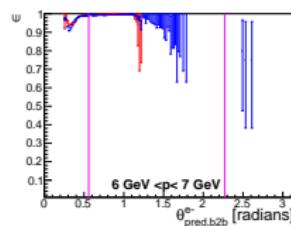
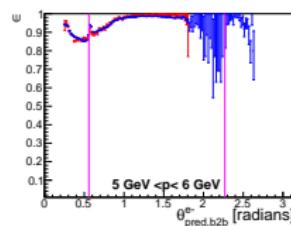
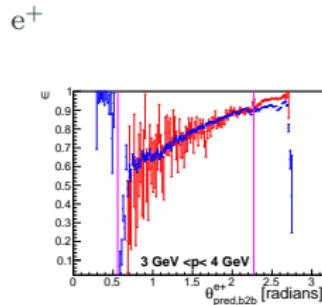
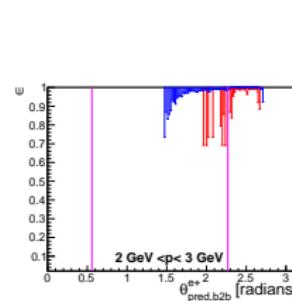
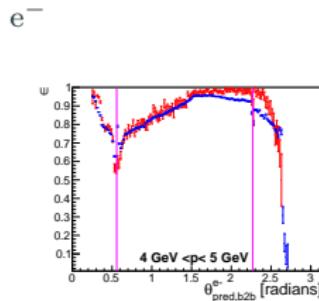
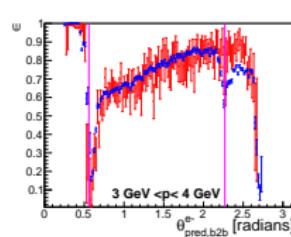
Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}} - \phi_{\text{pred,b2b}}$



Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase3 MC10

Phase3 Data

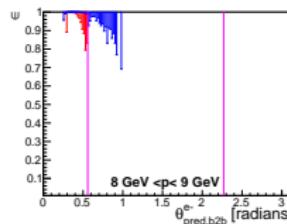
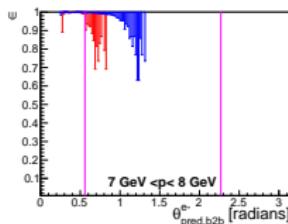
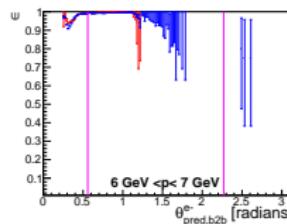
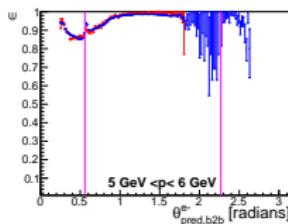
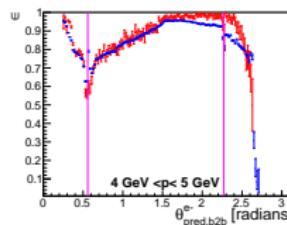
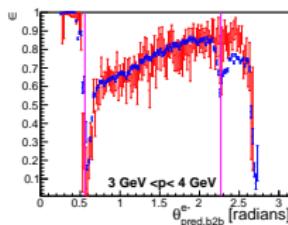


Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase3 MC10

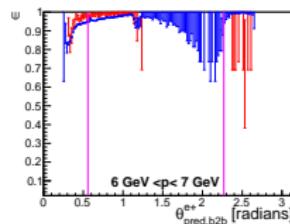
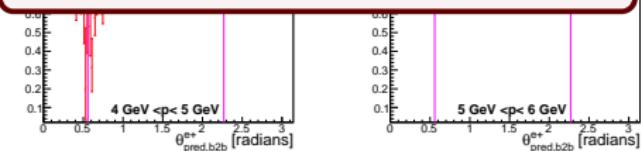
Phase3 Data

e^-



Electron Tracking Efficiency:

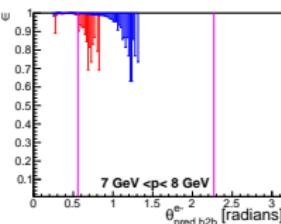
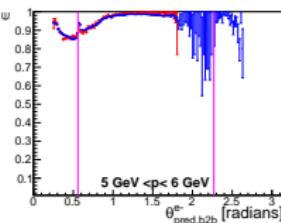
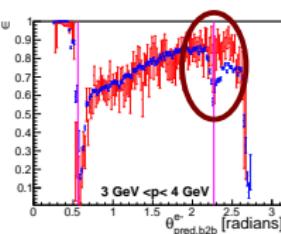
- Phase3 MC and phase3 data are very close to each other (exception occurs for momenta between 4 GeV and 5 GeV)



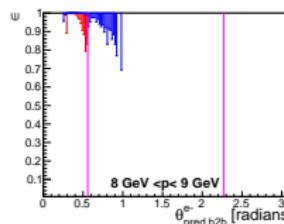
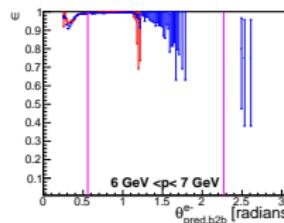
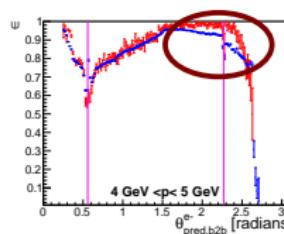
Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase3 MC10

Phase3 Data

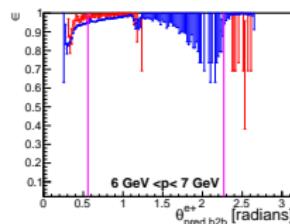
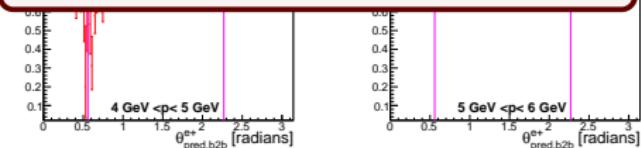


e⁻



Electron Tracking Efficiency:

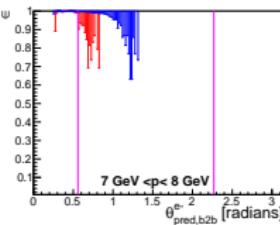
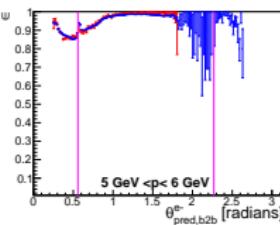
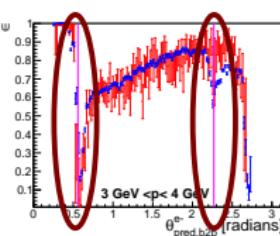
- Phase3 MC and phase3 data are very close to each other (exception occurs for momenta between 4 GeV and 5 GeV)



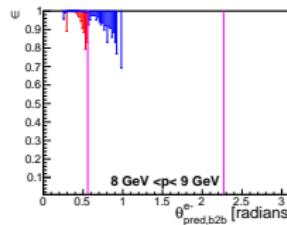
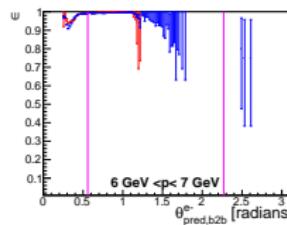
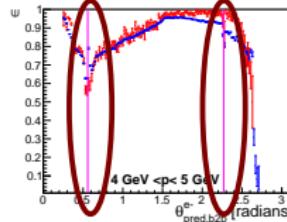
Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase3 MC10

Phase3 Data

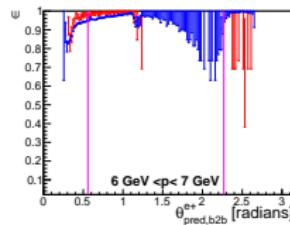
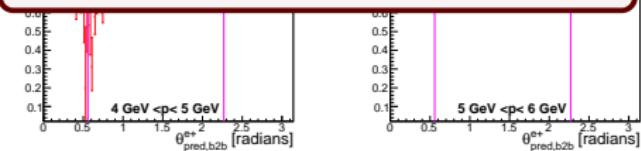


e^-



Electron Tracking Efficiency:

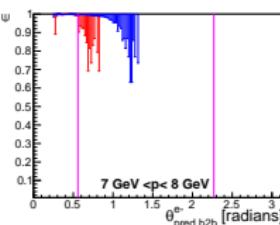
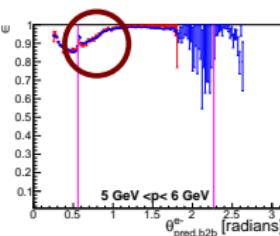
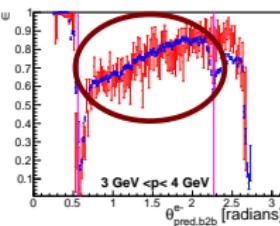
- Phase3 MC and phase3 data are very close to each other (exception occurs for momenta between 4 GeV and 5 GeV)
- Efficiency drops at transition between barrel and end-caps



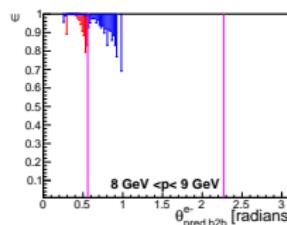
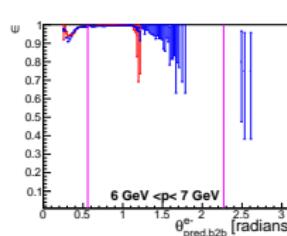
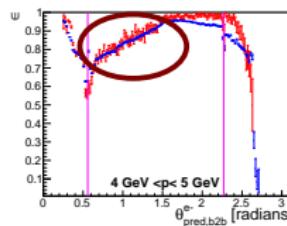
Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase3 MC10

Phase3 Data

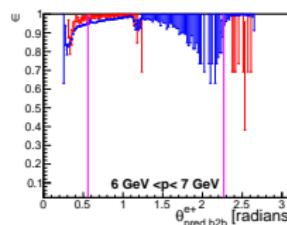
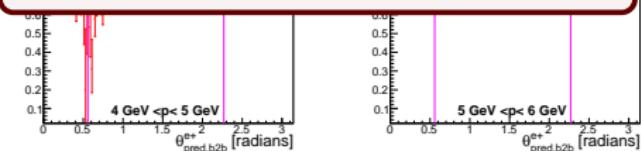


e^-



Electron Tracking Efficiency:

- Phase3 MC and phase3 data are very close to each other (exception occurs for momenta between 4 GeV and 5 GeV)
- Efficiency drops at transition between barrel and end-caps
- There is a slope in the barrel

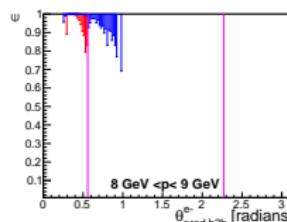
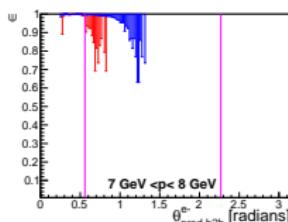
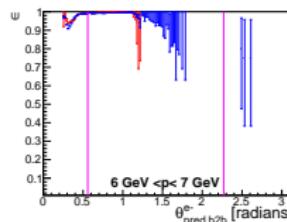
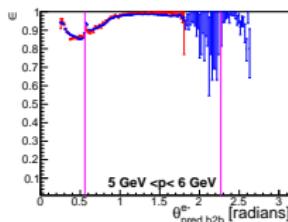
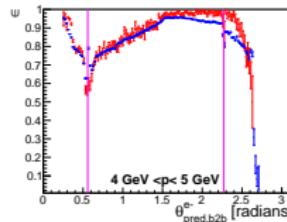
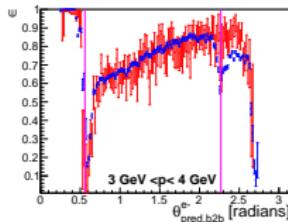


Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase3 MC10

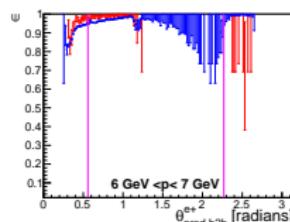
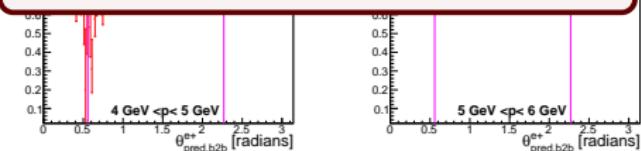
Phase3 Data

e^-



Electron Tracking Efficiency:

- Phase3 MC and phase3 data are very close to each other (exception occurs for momenta between 4 GeV and 5 GeV)
- Efficiency drops at transition between barrel and end-caps
- There is a slope in the barrel



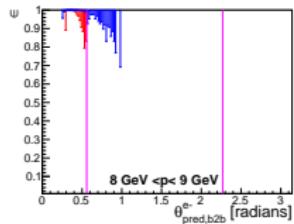
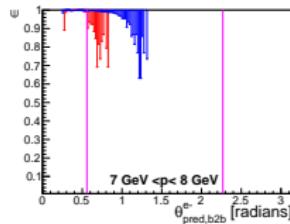
Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Positron Tracking Efficiency:

- The tracking efficiency pf phase3 MC and phase3 data are close to each other (exception occurs in the backward end-cap for momenta between 2 GeV and 4 GeV and between 6 GeV and 7 GeV)

$\theta_{\text{pred,b2b}}$ [radians]

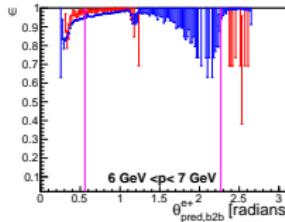
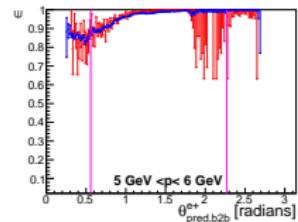
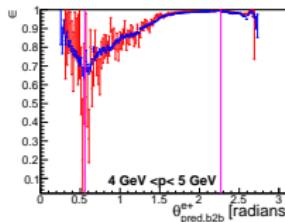
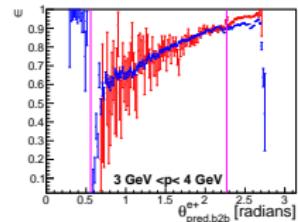
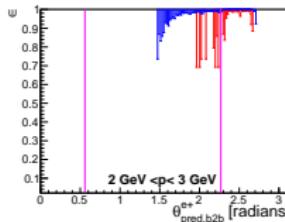
$\theta_{\text{pred,b2b}}$ [radians]



Phase3 MC10

Phase3 Data

e⁺



Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

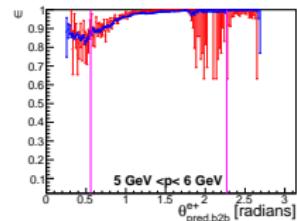
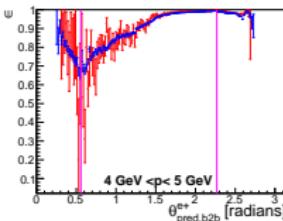
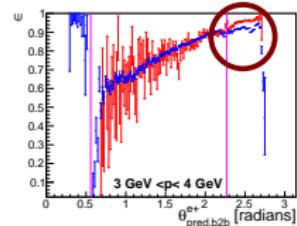
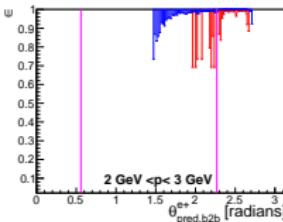
Positron Tracking Efficiency:

- The tracking efficiency pf phase3 MC and phase3 data are close to each other (exception occurs in the backward end-cap for momenta between 2 GeV and 4 GeV and between 6 GeV and 7 GeV)

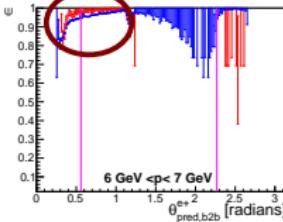
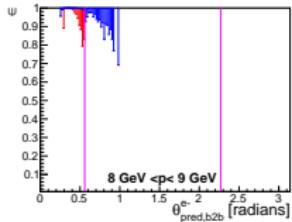
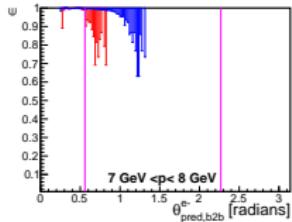
Phase3 MC10

Phase3 Data

e⁺



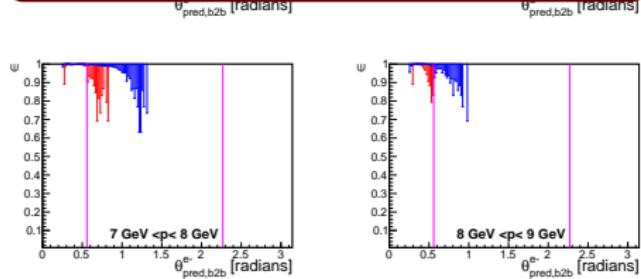
$\theta_{\text{pred,b2b}}$ [radians] $\theta_{\text{pred,b2b}}$ [radians]



Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

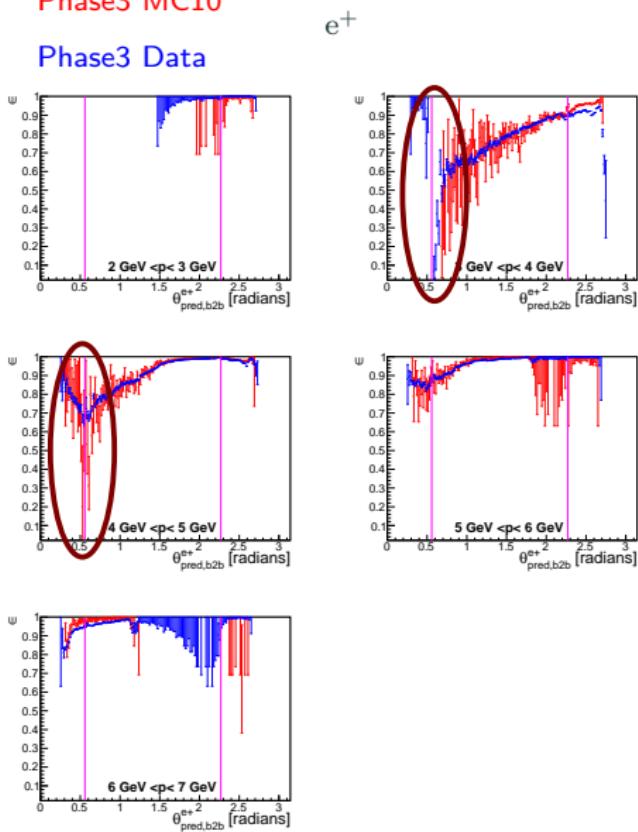
Positron Tracking Efficiency:

- The tracking efficiency pf phase3 MC and phase3 data are close to each other (exception occurs in the backward end-cap for momenta between 2 GeV and 4 GeV and between 6 GeV and 7 GeV)
- Efficiency drops at transition between barrel and end-caps



Phase3 MC10

Phase3 Data



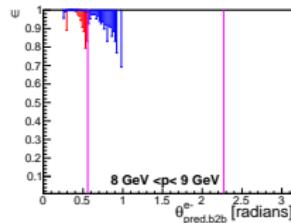
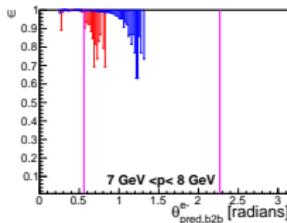
Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Positron Tracking Efficiency:

- The tracking efficiency pf phase3 MC and phase3 data are close to each other (exception occurs in the backward end-cap for momenta between 2 GeV and 4 GeV and between 6 GeV and 7 GeV)
- Efficiency drops at transition between barrel and end-caps
- There is a slope in the barrel

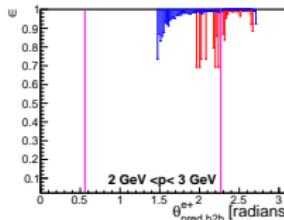
$\theta_{\text{pred,b2b}}$ [radians]

$\theta_{\text{pred,b2b}}$ [radians]

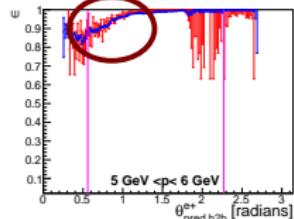
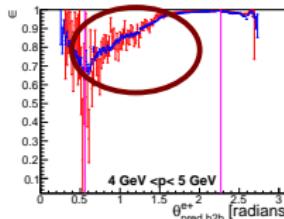
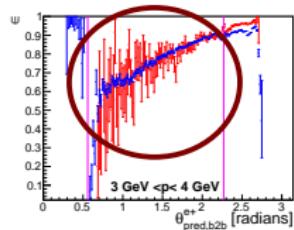


Phase3 MC10

Phase3 Data



e^+



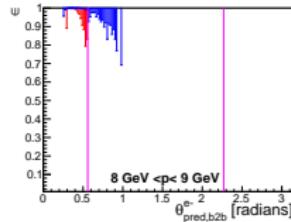
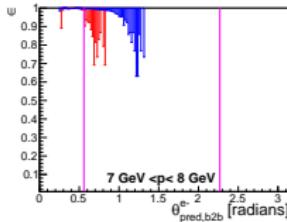
Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Positron Tracking Efficiency:

- The tracking efficiency pf phase3 MC and phase3 data are close to each other (exception occurs in the backward end-cap for momenta between 2 GeV and 4 GeV and between 6 GeV and 7 GeV)
- Efficiency drops at transition between barrel and end-caps
- There is a slope in the barrel

$\theta_{\text{pred,b2b}}$ [radians]

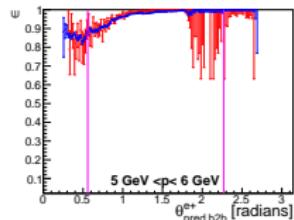
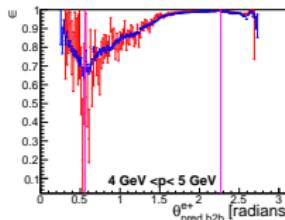
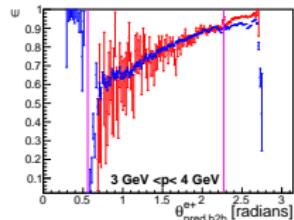
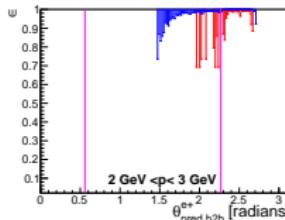
$\theta_{\text{pred,b2b}}$ [radians]



Phase3 MC10

Phase3 Data

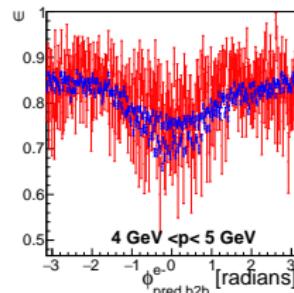
e⁺



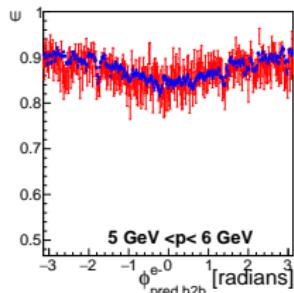
Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

Phase3 MC10

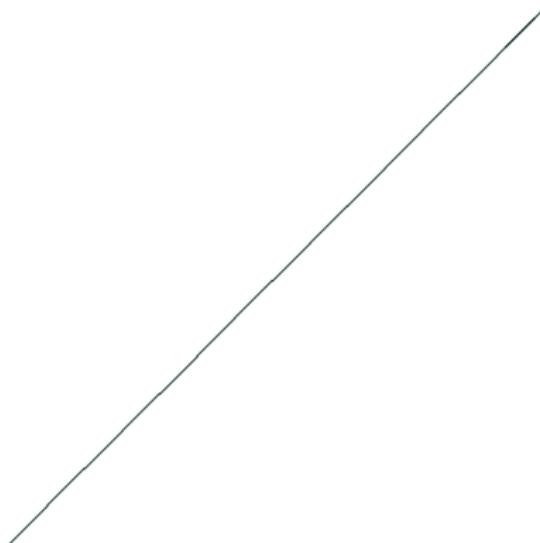
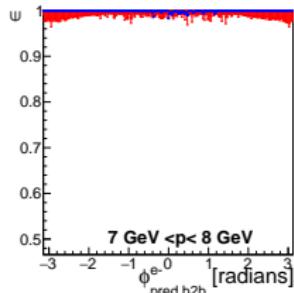
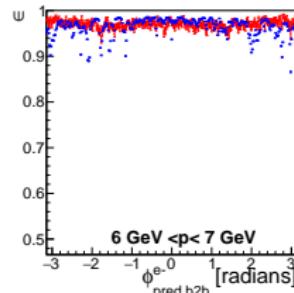
Phase3 Data



e^-



e^+

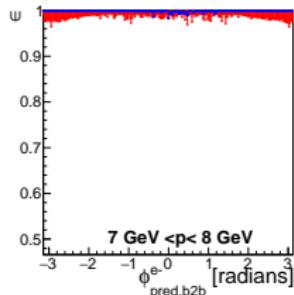
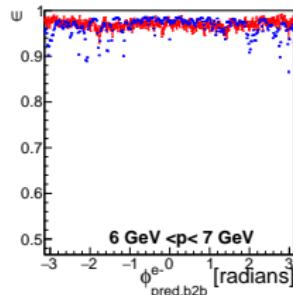
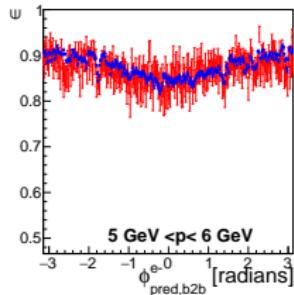
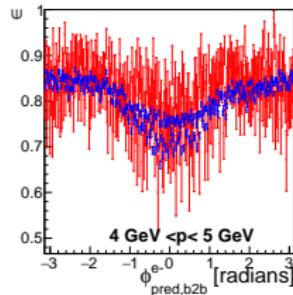


Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

Phase3 MC10

Phase3 Data

e⁻



Electron Tracking Efficiency:

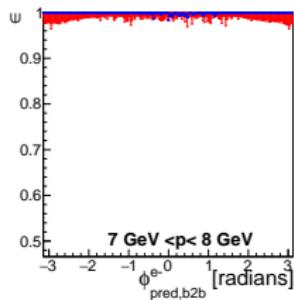
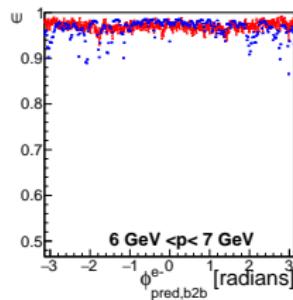
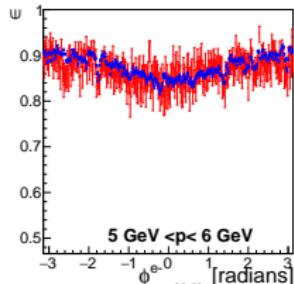
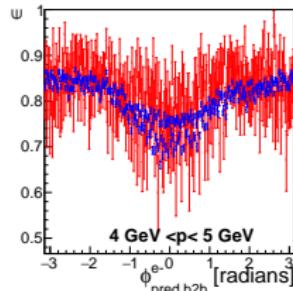
- Highest tracking efficiency for momenta between 7 GeV and 8 GeV

Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

Phase3 MC10

Phase3 Data

e⁻



Electron Tracking Efficiency:

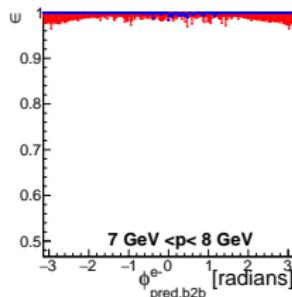
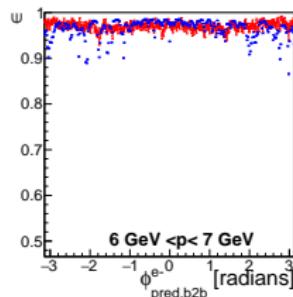
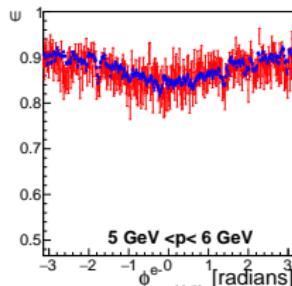
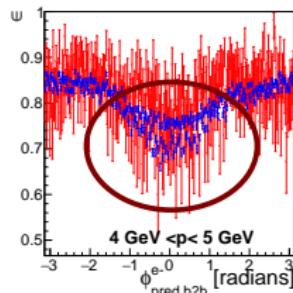
- Highest tracking efficiency for momenta between 7 GeV and 8 GeV
- Minimum at $\phi_{\text{pred,b2b}} \approx 0$ for momenta between 4 GeV and 6 GeV

Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

Phase3 MC10

Phase3 Data

e⁻



Electron Tracking Efficiency:

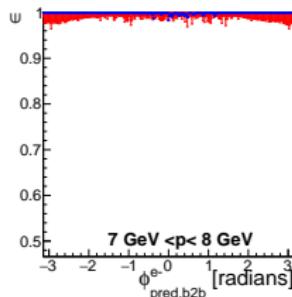
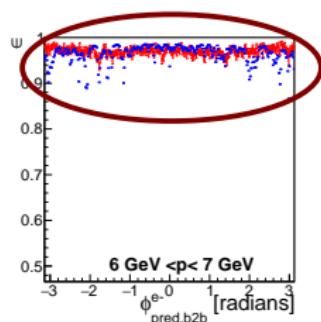
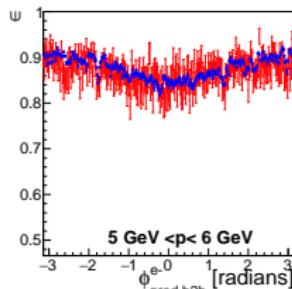
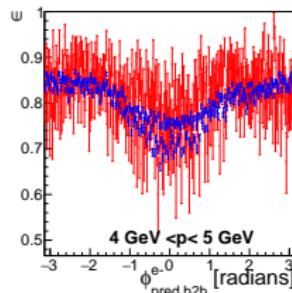
- Highest tracking efficiency for momenta between 7 GeV and 8 GeV
- Minimum at $\phi_{\text{pred,b2b}} \approx 0$ for momenta between 4 GeV and 6 GeV
- Weird *ribbon* structure in the phase3 data tracking efficiency at $\phi_{\text{pred,b2b}} \approx 0$ for momenta between 4 GeV and 5 GeV

Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

Phase3 MC10

e⁻

Phase3 Data



Electron Tracking Efficiency:

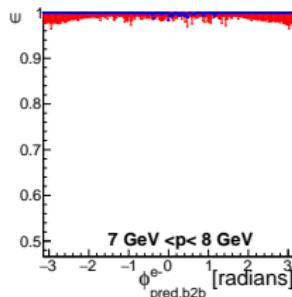
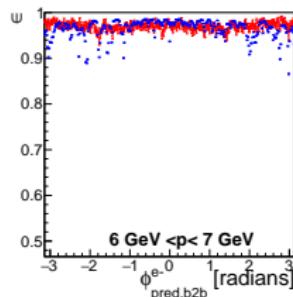
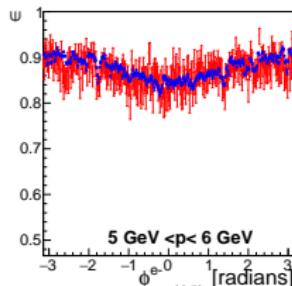
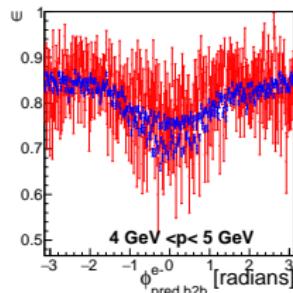
- Highest tracking efficiency for momenta between 7 GeV and 8 GeV
- Minimum at $\phi_{\text{pred,b2b}} \approx 0$ for momenta between 4 GeV and 6 GeV
- Weird *ribbon* structure in the phase3 data tracking efficiency at $\phi_{\text{pred,b2b}} \approx 0$ for momenta between 4 GeV and 5 GeV
- Weird efficiency drops in phase3 data for momenta between 6 GeV and 7 GeV

Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

Phase3 MC10

e⁻

Phase3 Data



Electron Tracking Efficiency:

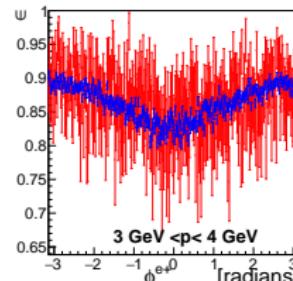
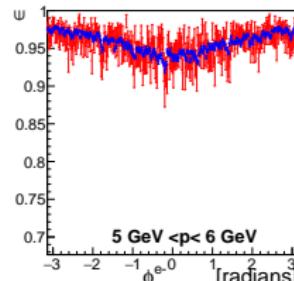
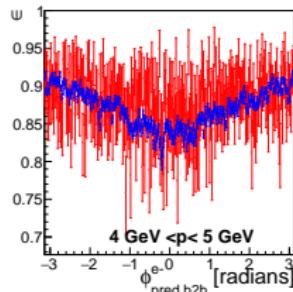
- Highest tracking efficiency for momenta between 7 GeV and 8 GeV
- Minimum at $\phi_{\text{pred,b2b}} \approx 0$ for momenta between 4 GeV and 6 GeV
- Weird *ribbon* structure in the phase3 data tracking efficiency at $\phi_{\text{pred,b2b}} \approx 0$ for momenta between 4 GeV and 5 GeV
- Weird efficiency drops in phase3 data for momenta between 6 GeV and 7 GeV

Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Barrel

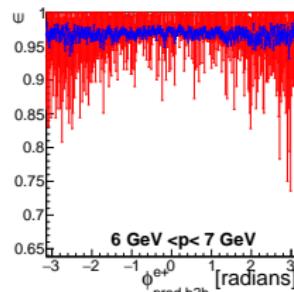
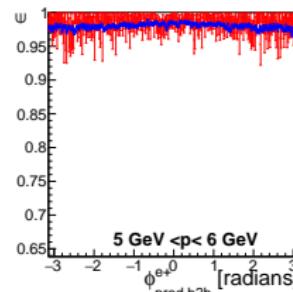
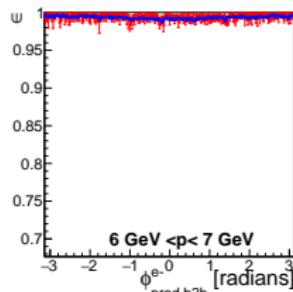
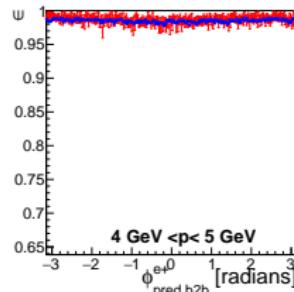
Phase3 MC10

e⁻

Phase3 Data



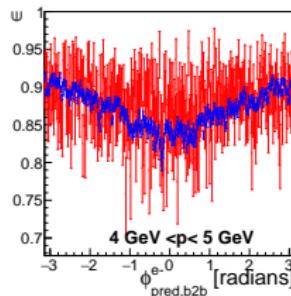
e⁺



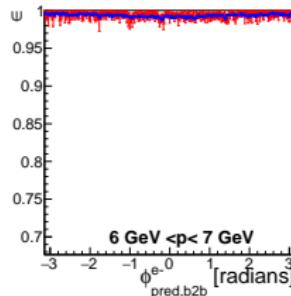
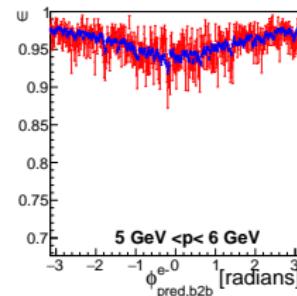
Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Barrel

Phase3 MC10

Phase3 Data

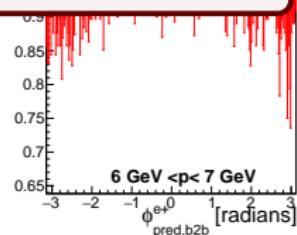
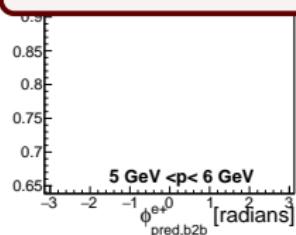


e^-



Electron Tracking Efficiency:

- Highest tracking efficiency for momenta between 6 GeV and 7 GeV
- Lowest tracking efficiency for momenta between 4 GeV and 5 GeV

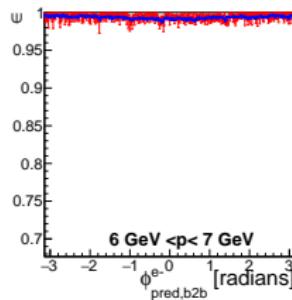
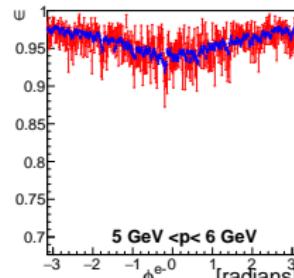
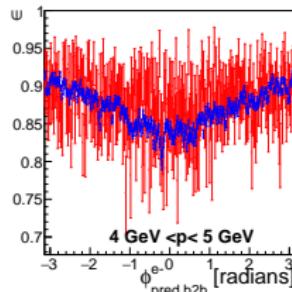


Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Barrel

Phase3 MC10

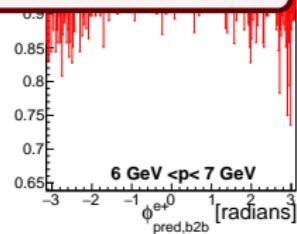
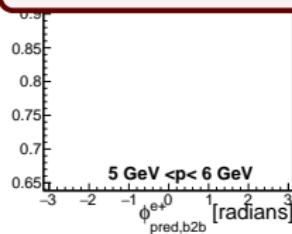
Phase3 Data

e⁻



Electron Tracking Efficiency:

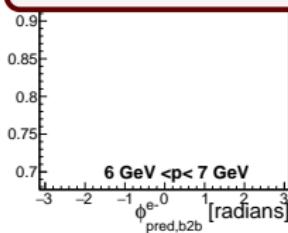
- Highest tracking efficiency for momenta between 6 GeV and 7 GeV
- Lowest tracking efficiency for momenta between 4 GeV and 5 GeV
- Minimum at $\phi_{\text{pred,b2b}} \approx 0$ for momenta between 4 GeV and 6 GeV



Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Barrel

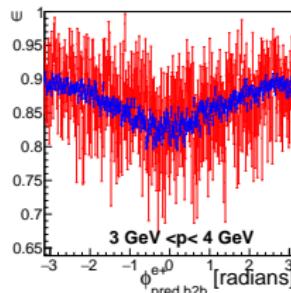
Positron Tracking Efficiency:

- Highest tracking efficiency for momenta between 4 GeV and 6 GeV
- Lowest tracking efficiency for momenta between 3 GeV and 4 GeV

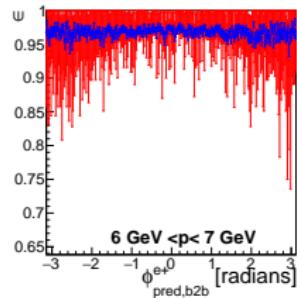
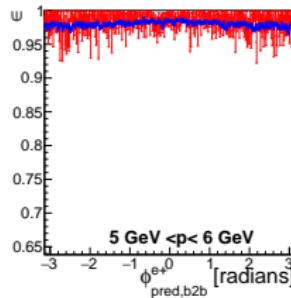
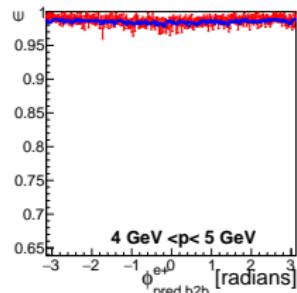


Phase3 MC10

Phase3 Data



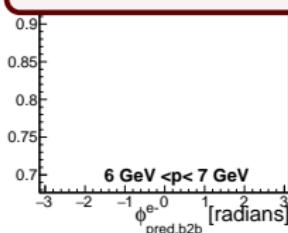
e^+



Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Barrel

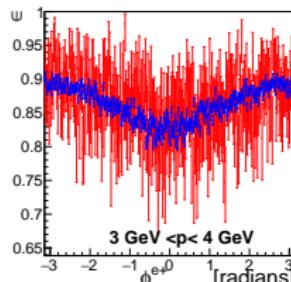
Positron Tracking Efficiency:

- Highest tracking efficiency for momenta between 4 GeV and 6 GeV
- Lowest tracking efficiency for momenta between 3 GeV and 4 GeV
- Minimum at $\phi_{\text{pred,b2b}} \approx 0$ for momenta between 3 GeV and 4 GeV

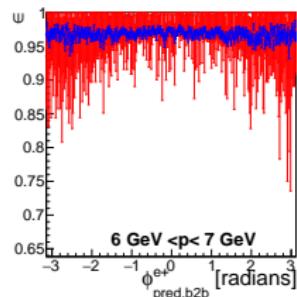
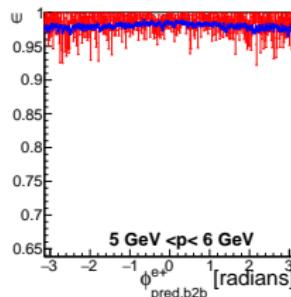
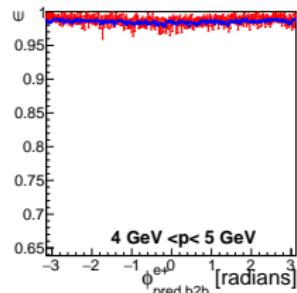


Phase3 MC10

Phase3 Data



e⁺

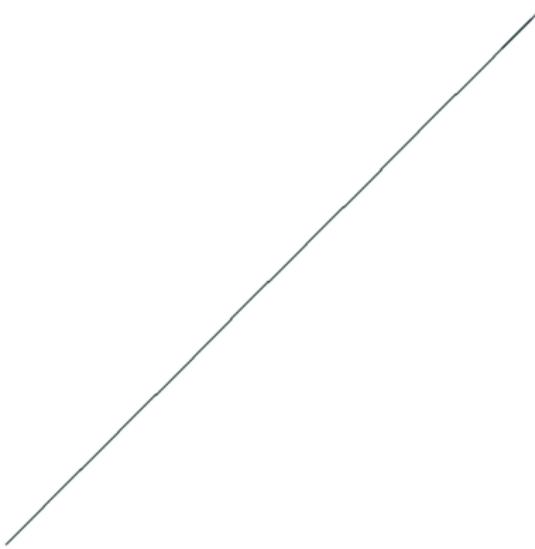


Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Backward End-Cap

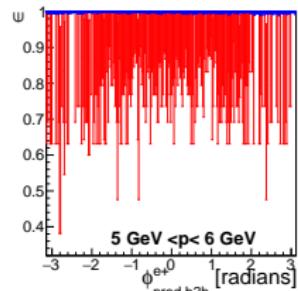
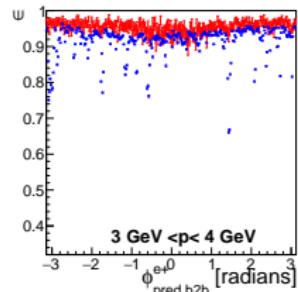
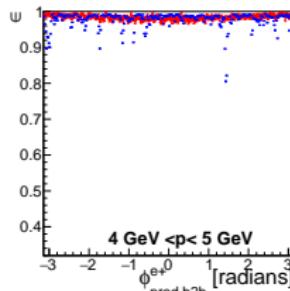
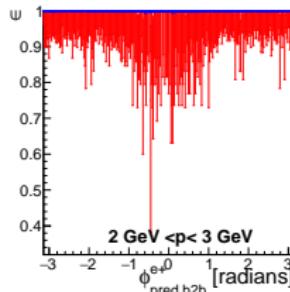
Phase3 MC10

Phase3 Data

e^-



e^+



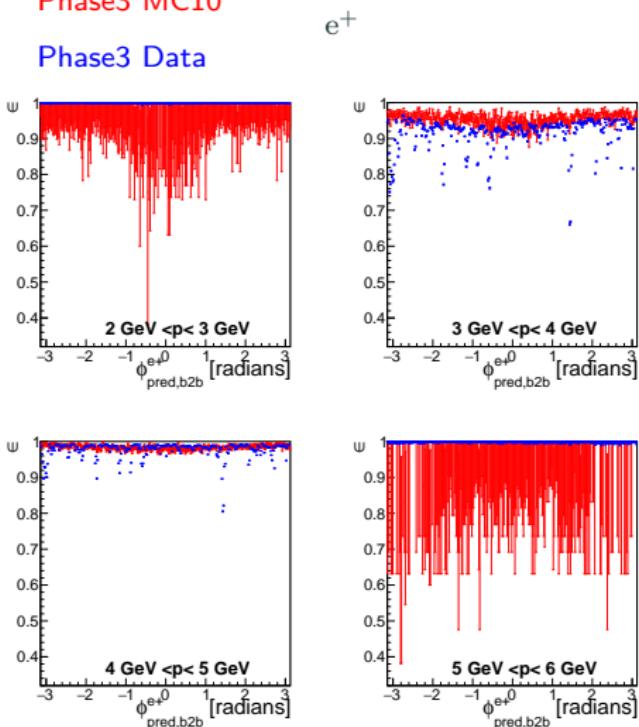
Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Backward End-Cap

Positron Tracking Efficiency:

- The highest phase3 data tracking efficiency occurs for momenta between 2 GeV and 3 GeV and 5 GeV and 6 GeV

Phase3 MC10

Phase3 Data



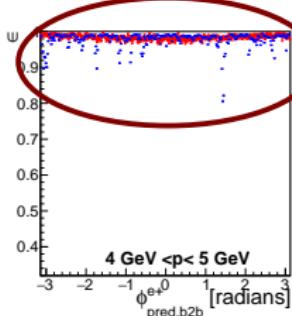
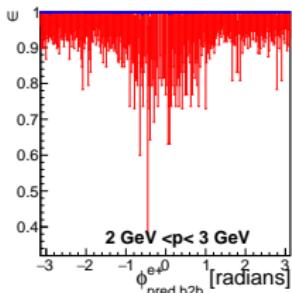
Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Backward End-Cap

Positron Tracking Efficiency:

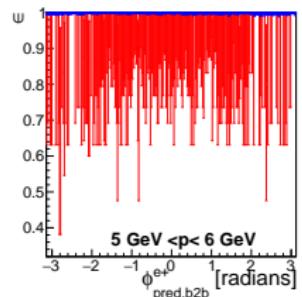
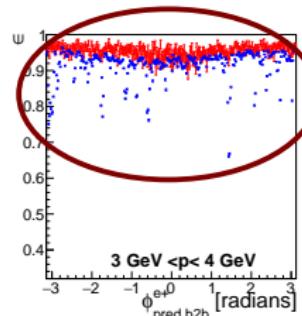
- The highest phase3 data tracking efficiency occurs for momenta between 2 GeV and 3 GeV and 5 GeV and 6 GeV
- Weird efficiency drops in the phase3 data tracking efficiency for momenta between 3 GeV and 5 GeV

Phase3 MC10

Phase3 Data



e^+



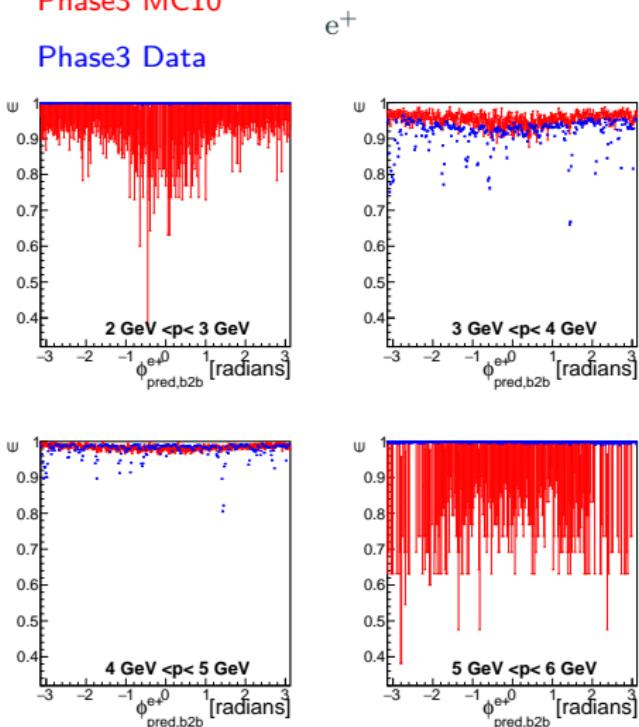
Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Backward End-Cap

Positron Tracking Efficiency:

- The highest phase3 data tracking efficiency occurs for momenta between 2 GeV and 3 GeV and 5 GeV and 6 GeV
- Weird efficiency drops in the phase3 data tracking efficiency for momenta between 3 GeV and 5 GeV

Phase3 MC10

Phase3 Data



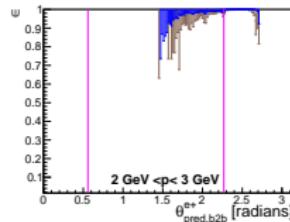
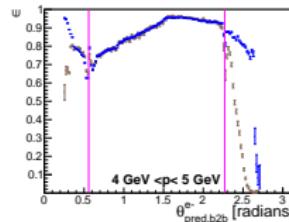
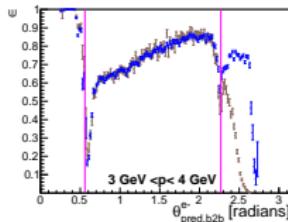
Comparing The Tracking Efficiency Of Phase2 Data with Phase3 Data

Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

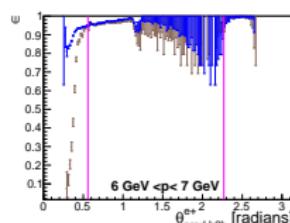
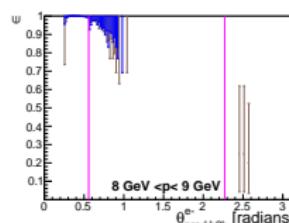
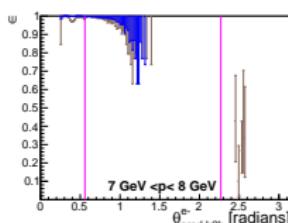
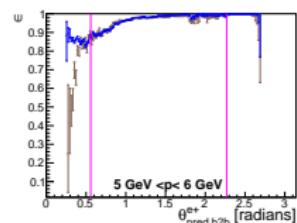
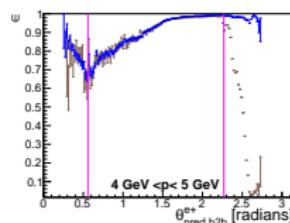
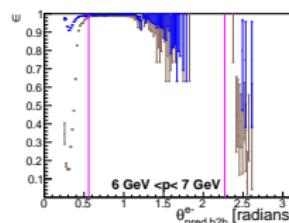
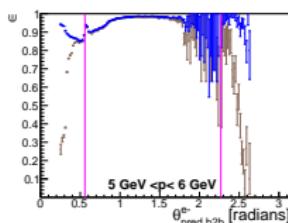
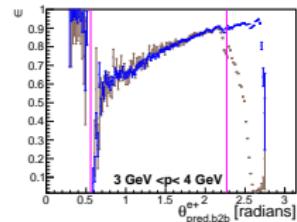
Phase2 Data

e^-

Phase3 Data



e^+

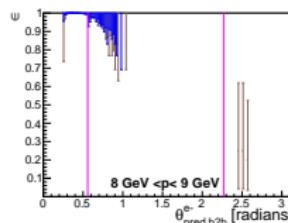
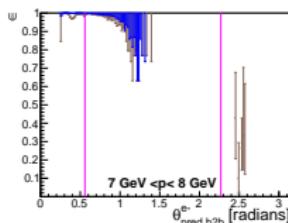
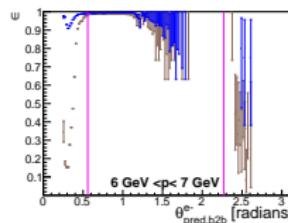
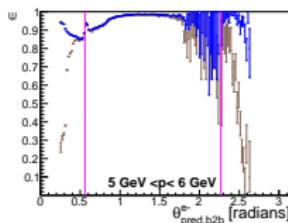
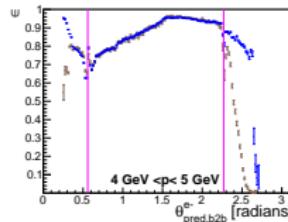
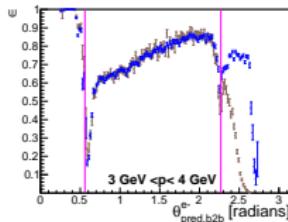


Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 Data

e^-

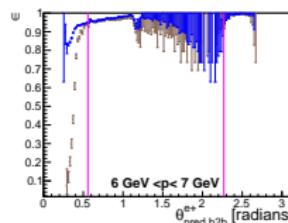
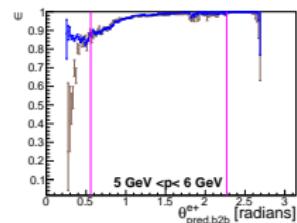
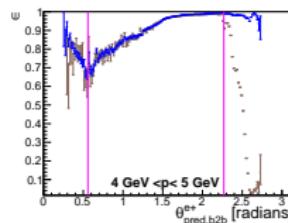
Phase3 Data



Electron Tracking Efficiency:

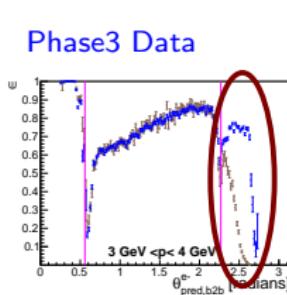
- Drastic improvement in the end-caps

$\theta_{\text{pred,b2b}}$ [radians] $\theta_{\text{pred,b2b}}$ [radians]



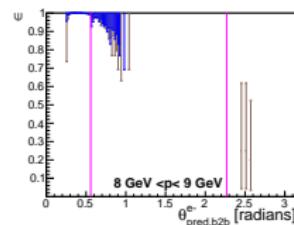
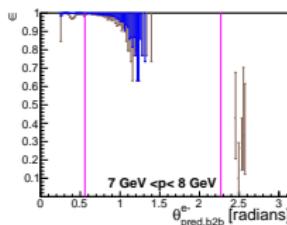
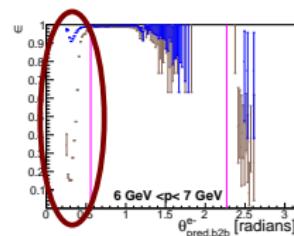
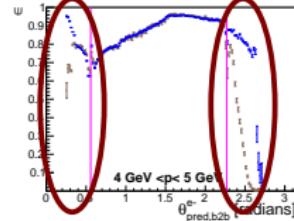
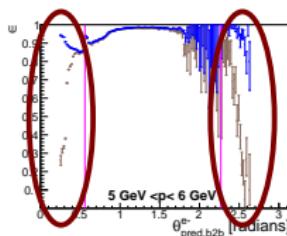
Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 Data



e^-

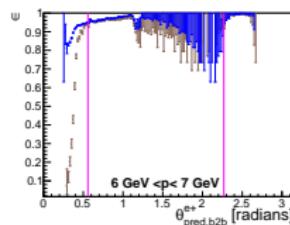
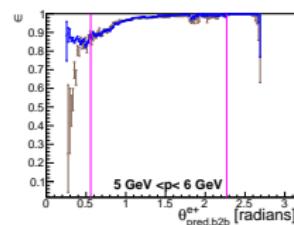
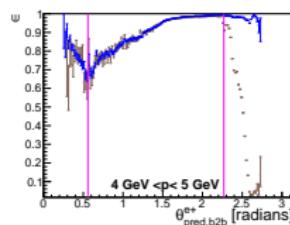
Phase3 Data



Electron Tracking Efficiency:

- Drastic improvement in the end-caps

$\theta_{\text{pred,b2b}}$ [radians]

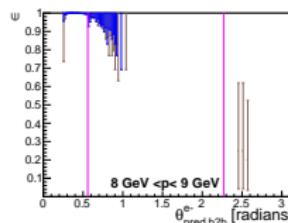
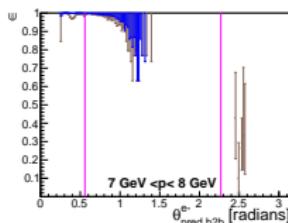
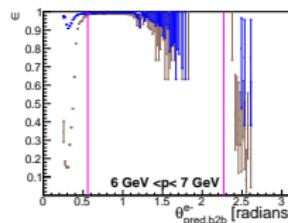
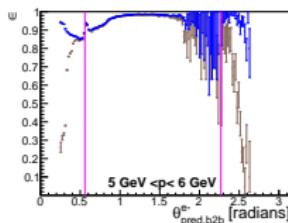
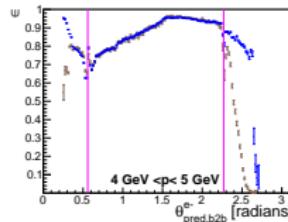
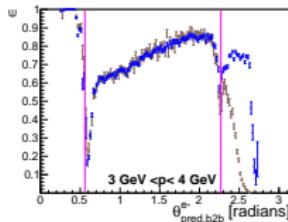


Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 Data

e⁻

Phase3 Data

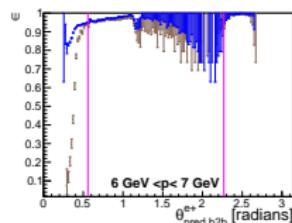
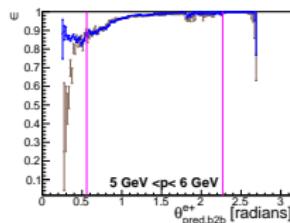
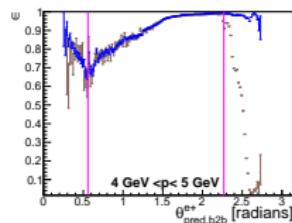


Electron Tracking Efficiency:

- Drastic improvement in the end-caps
- Tracking efficiency in the barrel stayed more or less the same

$\theta_{\text{pred,b2b}}$ [radians]

$\theta_{\text{pred,b2b}}$ [radians]

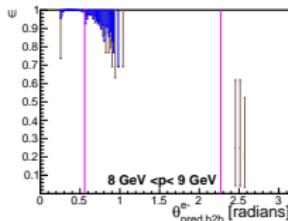
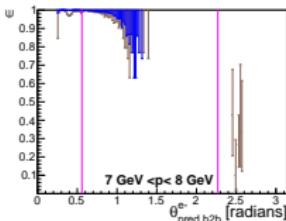
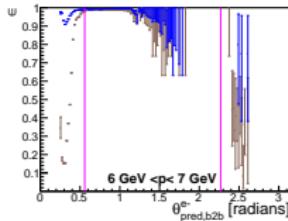
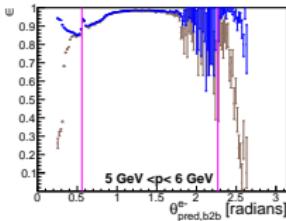


Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Positron Tracking Efficiency:

- Drastic improvement in the end-caps

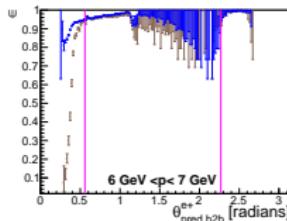
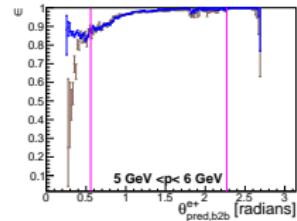
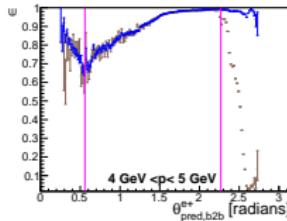
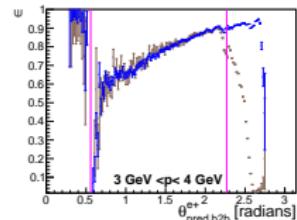
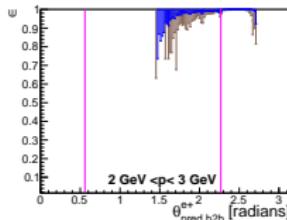
$\theta_{\text{pred,b2b}}$ [radians]



Phase2 Data

Phase3 Data

e⁺

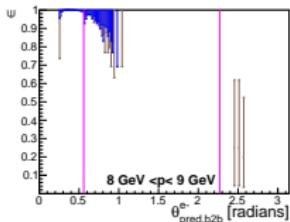
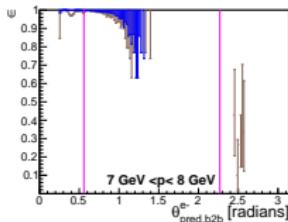
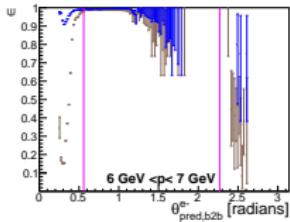
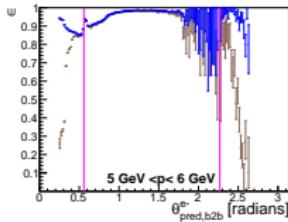


Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Positron Tracking Efficiency:

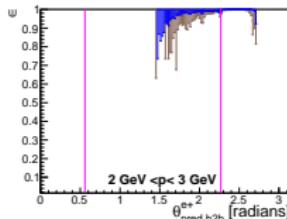
- Drastic improvement in the end-caps

ψ vs $\theta_{\text{pred,b2b}}$ [radians]

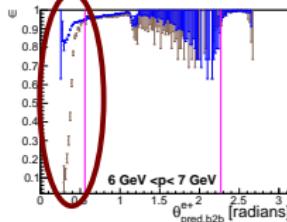
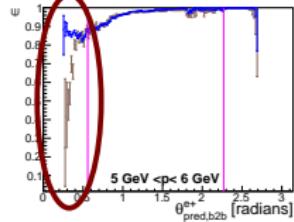
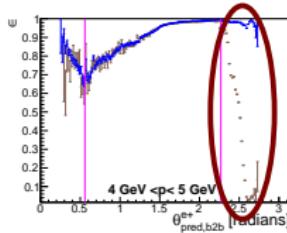
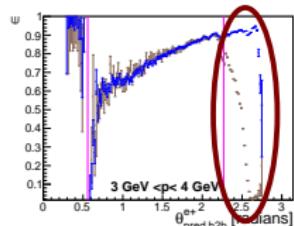


Phase2 Data

Phase3 Data



e^+

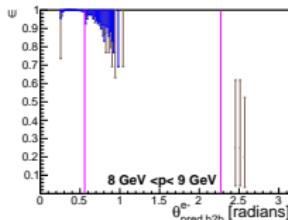
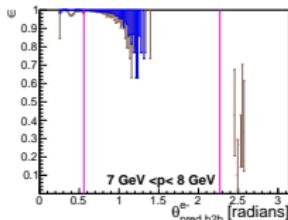
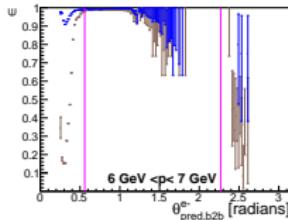
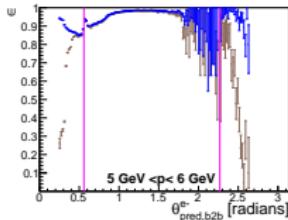


Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Positron Tracking Efficiency:

- Drastic improvement in the end-caps
- Tracking efficiency in the barrel stayed more or less the same

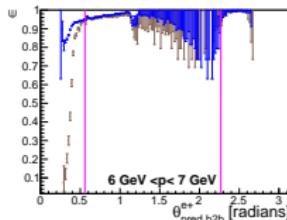
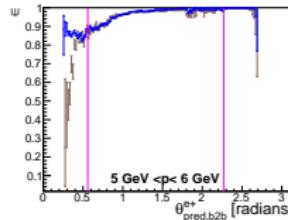
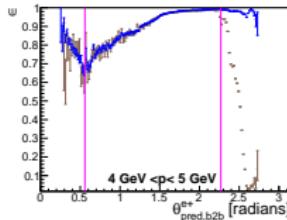
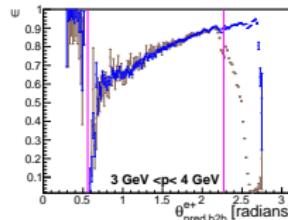
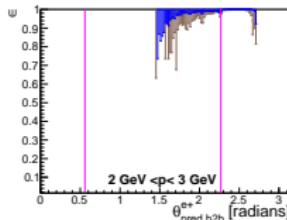
$\theta_{\text{pred,b2b}}$ [radians]



Phase2 Data

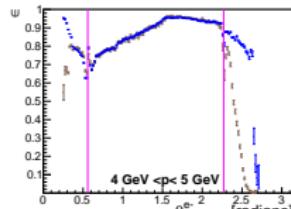
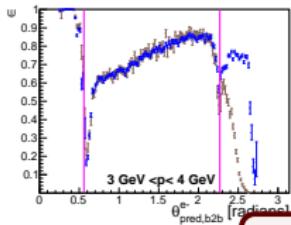
Phase3 Data

e⁺



Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

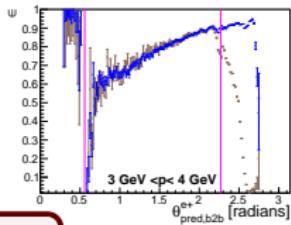
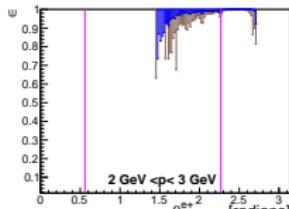
e^-



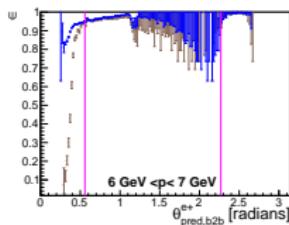
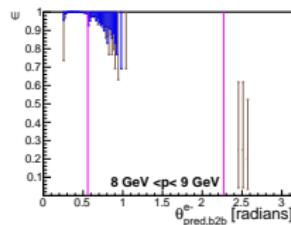
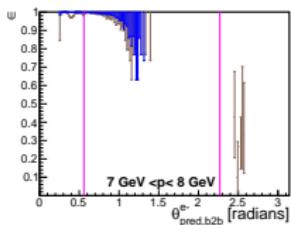
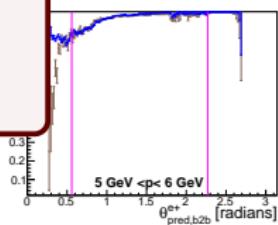
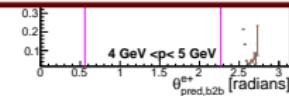
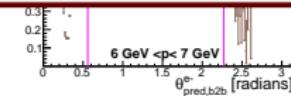
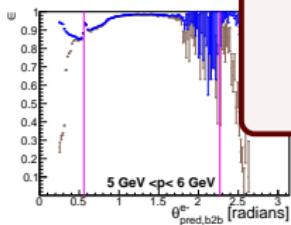
Phase2 Data

Phase3 Data

e^+



We will only compare the tracking efficiencies for electrons in the forward end-cap and the tracking efficiencies for positrons in the backward end-cap

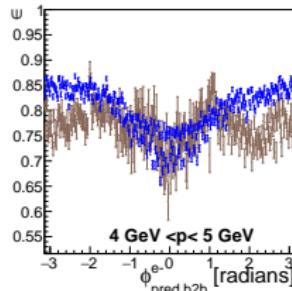


Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

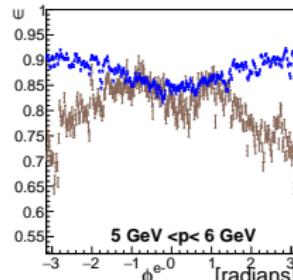
Phase2 Data

e⁻

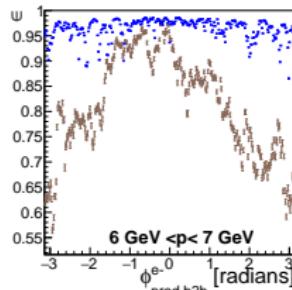
Phase3 Data



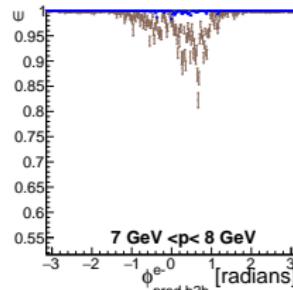
4 GeV $< p <$ 5 GeV



5 GeV $< p <$ 6 GeV



6 GeV $< p <$ 7 GeV

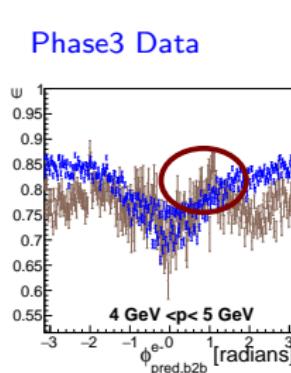


Electron Tracking Efficiency:

- The tracking efficiency improved over almost all $\phi_{\text{pred,b2b}}$ (exception occurs for $\phi_{\text{pred,b2b}} \approx 1$ for momenta between 4 GeV and 5 GeV)

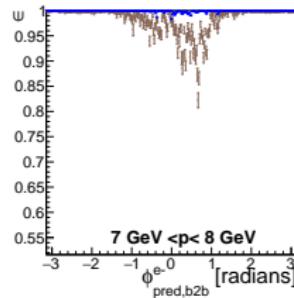
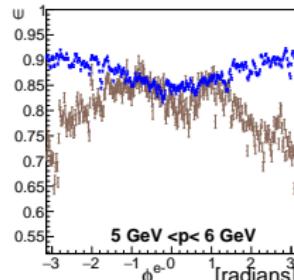
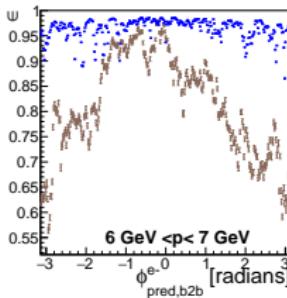
Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

Phase2 Data



e^-

Phase3 Data

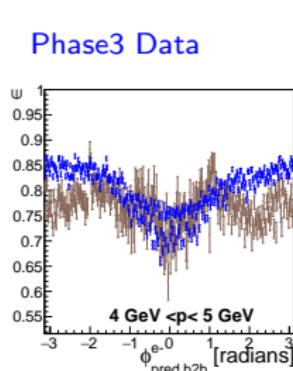


Electron Tracking Efficiency:

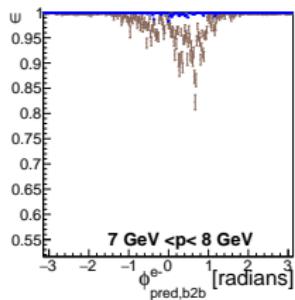
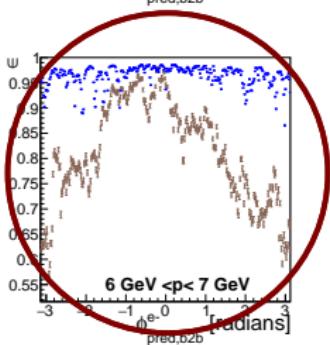
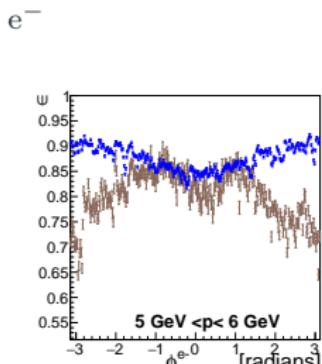
- The tracking efficiency improved over almost all $\phi_{\text{pred,b2b}}$ (exception occurs for $\phi_{\text{pred,b2b}} \approx 1$ for momenta between 4 GeV and 5 GeV)

Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

Phase2 Data



Phase3 Data

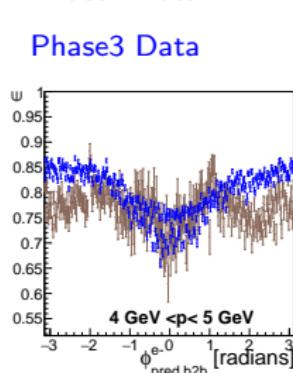


Electron Tracking Efficiency:

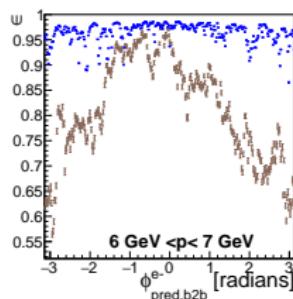
- The tracking efficiency improved over almost all $\phi_{\text{pred,b2b}}$ (exception occurs for $\phi_{\text{pred,b2b}} \approx 1$ for momenta between 4 GeV and 5 GeV)
- The tracking efficiency improved drastically for momenta between 6 GeV and 7 GeV

Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

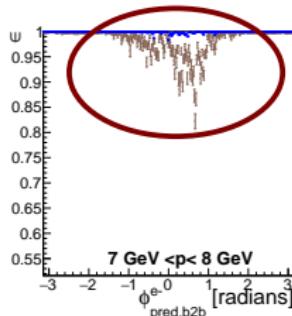
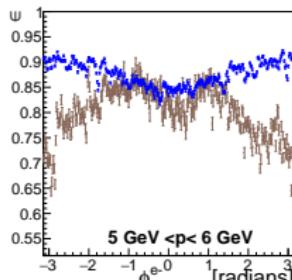
Phase2 Data



Phase3 Data



e^-

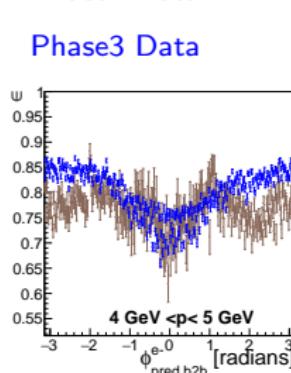


Electron Tracking Efficiency:

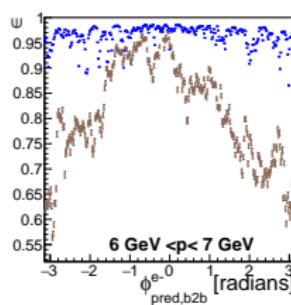
- The tracking efficiency improved over almost all $\phi_{\text{pred,b2b}}$ (exception occurs for $\phi_{\text{pred,b2b}} \approx 1$ for momenta between 4 GeV and 5 GeV)
- The tracking efficiency improved drastically for momenta between 6 GeV and 7 GeV
- No efficiency drops for momenta between 7 GeV and 8 GeV in the phase3 data tracking efficiency

Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

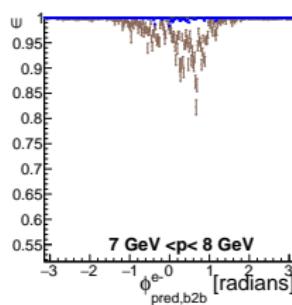
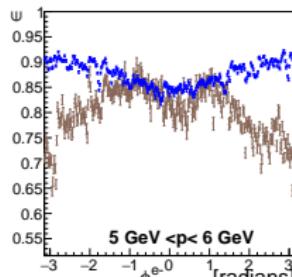
Phase2 Data



Phase3 Data



e^-



Electron Tracking Efficiency:

- The tracking efficiency improved over almost all $\phi_{\text{pred,b2b}}$ (exception occurs for $\phi_{\text{pred,b2b}} \approx 1$ for momenta between 4 GeV and 5 GeV)
- The tracking efficiency improved drastically for momenta between 6 GeV and 7 GeV
- No efficiency drops for momenta between 7 GeV and 8 GeV in the phase3 data tracking efficiency

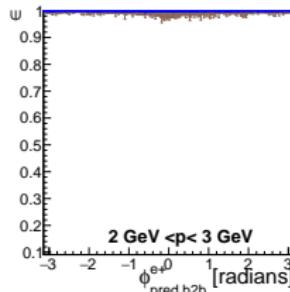
Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Backward End-Cap

Positron Tracking Efficiency:

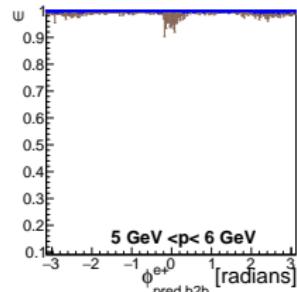
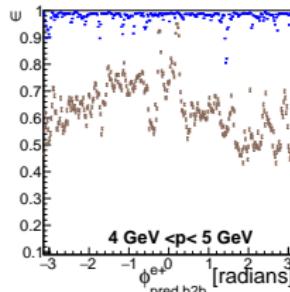
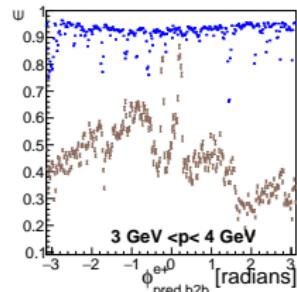
- The tracking efficiencies for momenta between 2 GeV and 3 GeV and between 5 GeV and 6 GeV look very similar

Phase2 Data

Phase3 Data



e^+



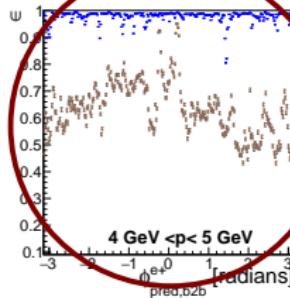
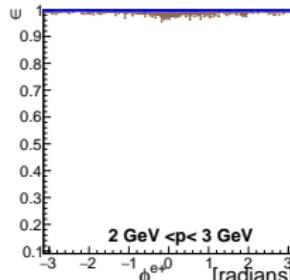
Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Backward End-Cap

Positron Tracking Efficiency:

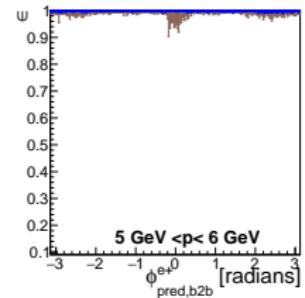
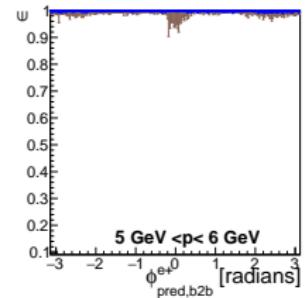
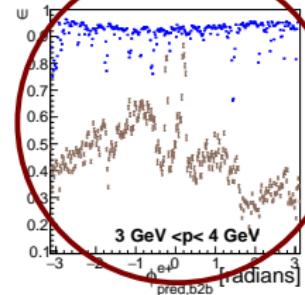
- The tracking efficiencies for momenta between 2 GeV and 3 GeV and between 5 GeV and 6 GeV look very similar
- The tracking efficiency for momenta between 3 GeV and 5 GeV improved drastically

Phase2 Data

Phase3 Data



e^+



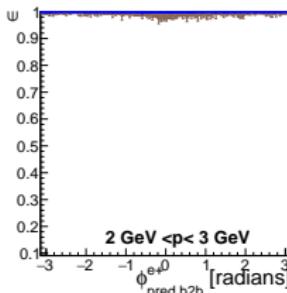
Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Backward End-Cap

Positron Tracking Efficiency:

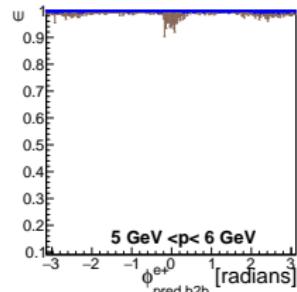
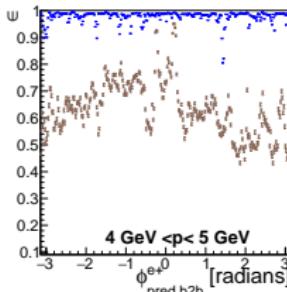
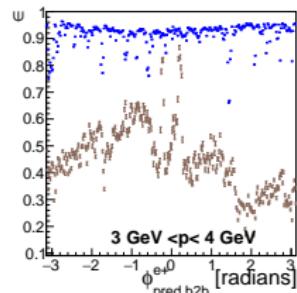
- The tracking efficiencies for momenta between 2 GeV and 3 GeV and between 5 GeV and 6 GeV look very similar
- The tracking efficiency for momenta between 3 GeV and 5 GeV improved drastically

Phase2 Data

Phase3 Data



e⁺



Conclusion

Conclusion

- It is possible to select Bhabha events using only information coming from the ECL
- The phase3 MC tracking efficiency is very close to the phase3 data tracking efficiency
- On phase3 data *random* efficiency drops appear for some momenta in the end-caps
- Drastic improvement in the tracking efficiency in the end-caps for phase3 compared to phase2

Appendix

Code

```
1 fillParticleList('gamma:all', 'clusterE > 0.01 and 0.296706 < theta < 2.61799', path  
    ↪ =mypath)  
fillParticleList('e+:all', 'clusterE > 0.01 and 0.296706 < theta < 2.61799', path=  
    ↪ mypath)  
3  
reconstructDecay('vpho:gamma -> gamma:all', '', path=mypath)  
5 reconstructDecay('vpho:elec -> e+:all', '', path=mypath)  
7 copyLists(outputListName = 'vpho:ECLObjectUnranked', inputListNames=['vpho:elec  
    ↪ ', 'vpho:gamma'], path=mypath)  
9 rankByHighest('vpho:ECLObjectUnranked', 'daughter(0,clusterE)', path=mypath)  
cutAndCopyList('vpho:ECLObject', 'vpho:ECLObjectUnranked', '', path=mypath)  
11 reconstructDecay('vpho:bhabha -> vpho:ECLObject vpho:ECLObject', '', path=  
    ↪ mypath)  
13 variablesToNtuple('vpho:bhabha', variables, treename = 'vpho_bhabha', filename =  
    ↪ output.root, path=mypath)
```

More Events

Phase2 data:

- /ghi/fs01/belle2/bdata//Data/release-03-00-03/
DB00000528/proc00000008/e0003/4S/r0*/all/mdst/sub00/*.root
- proc9

Phase2 MC:

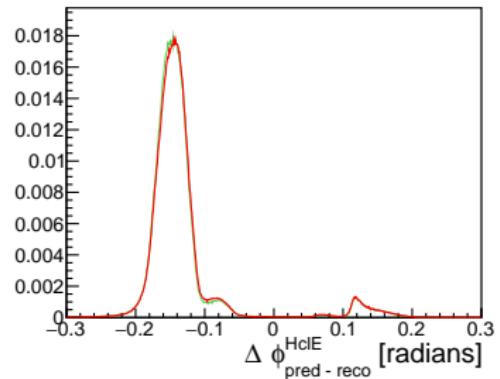
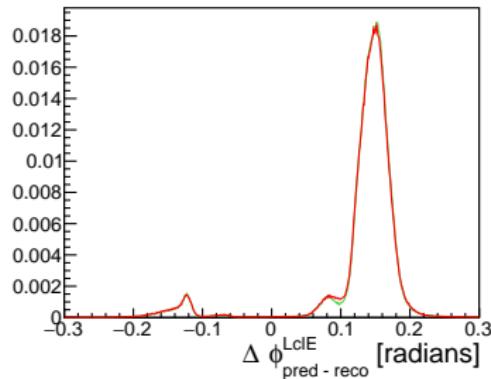
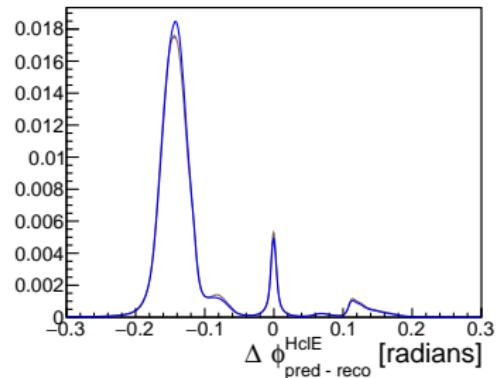
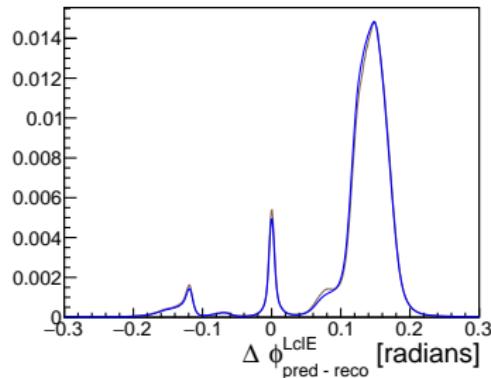
- /belle/MC/release-01-00-02/DB00000294/MC10/
prod00004668/s00/e1002/4S/r00000/3600520000/mdst/sub00

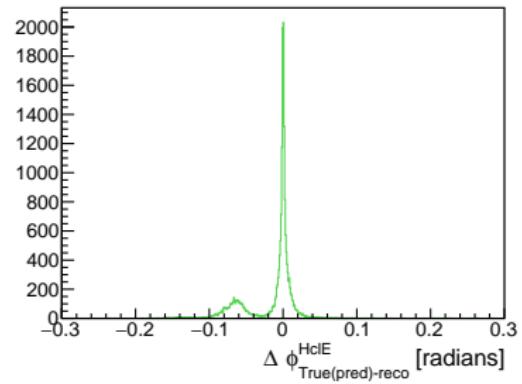
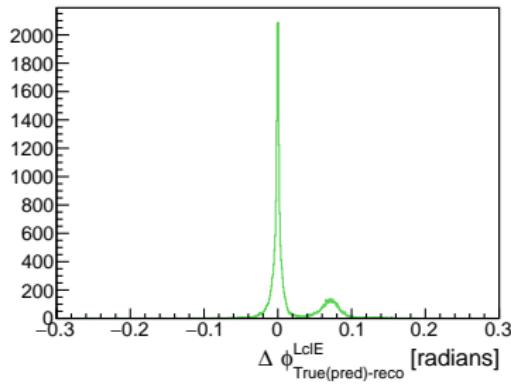
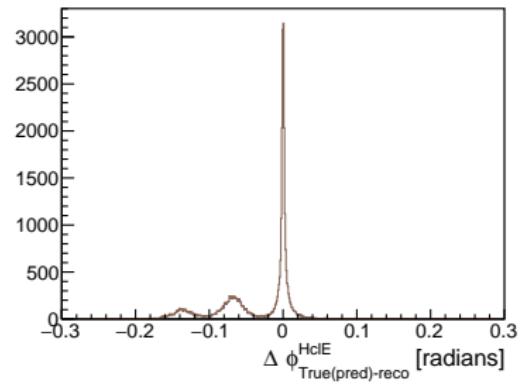
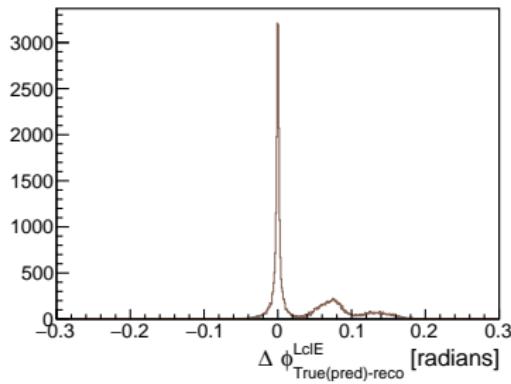
Phase3 data:

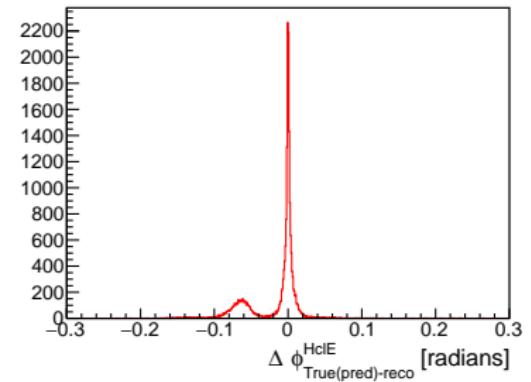
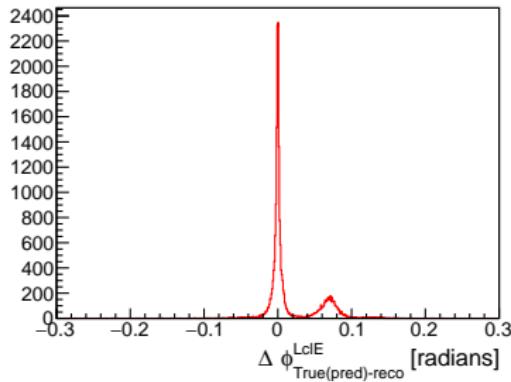
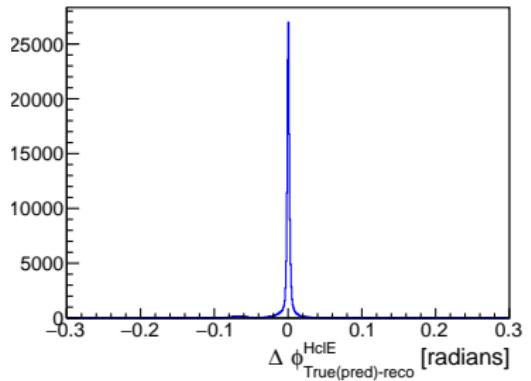
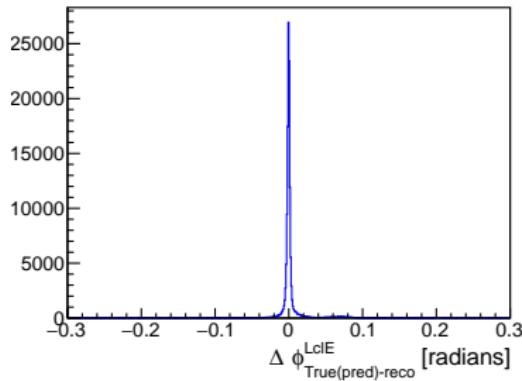
- Exp7: /group/belle2/dataprod/Data/release-03-02-
02/DB00000654/proc9/e0007/4S/r0*/all/mdst/sub00/*.root
- Exp8: /group/belle2/dataprod/Data/release-03-02-
02/DB00000654/proc9/e0008/4S/r0*/all/mdst/sub00/*.root
- proc9

Phase3 MC:

- /belle/MC/release-01-00-02/DB00000294/MC10/
prod00004664/s00/e0000/4S/r00000/3600520000/mdst/sub00

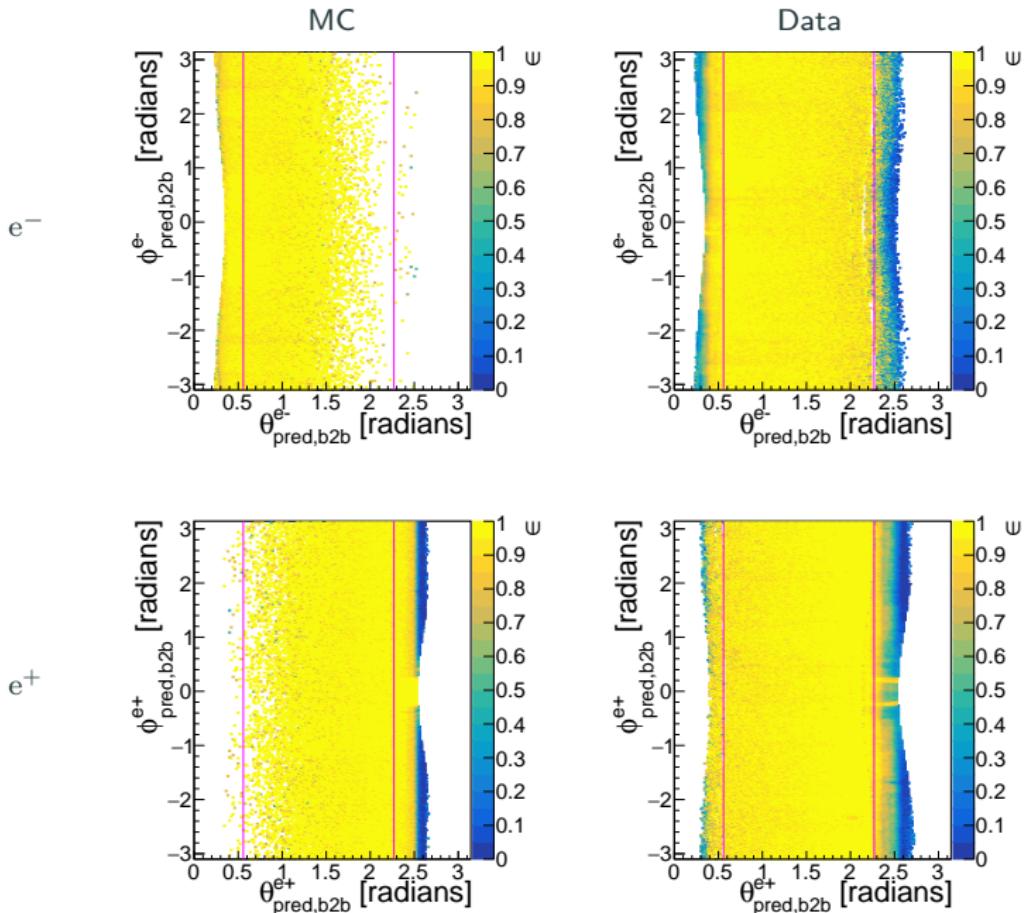




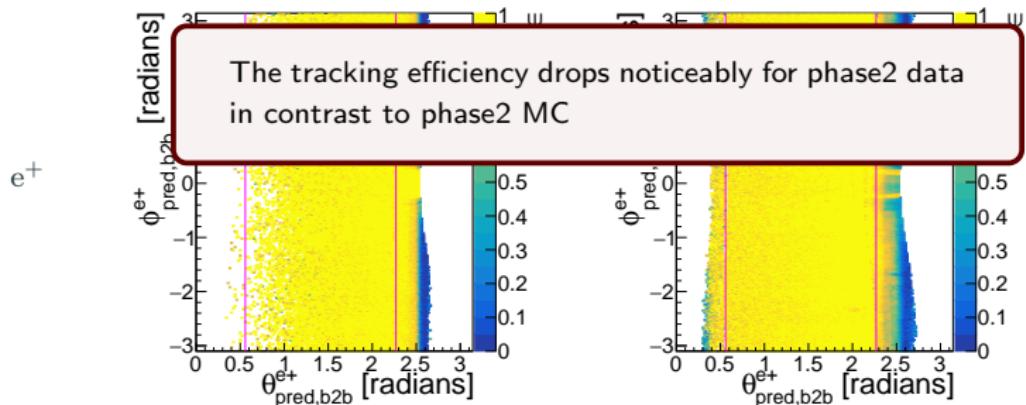
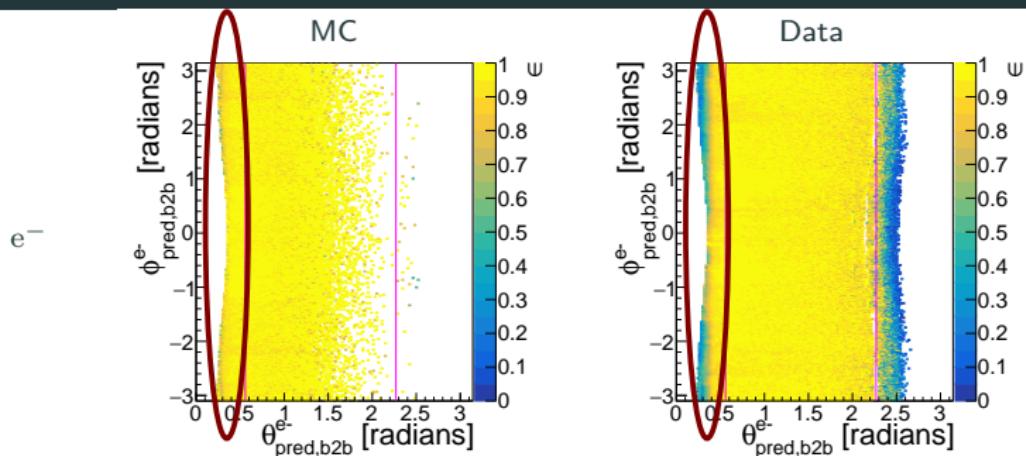


Phase2 Tracking Efficiencies

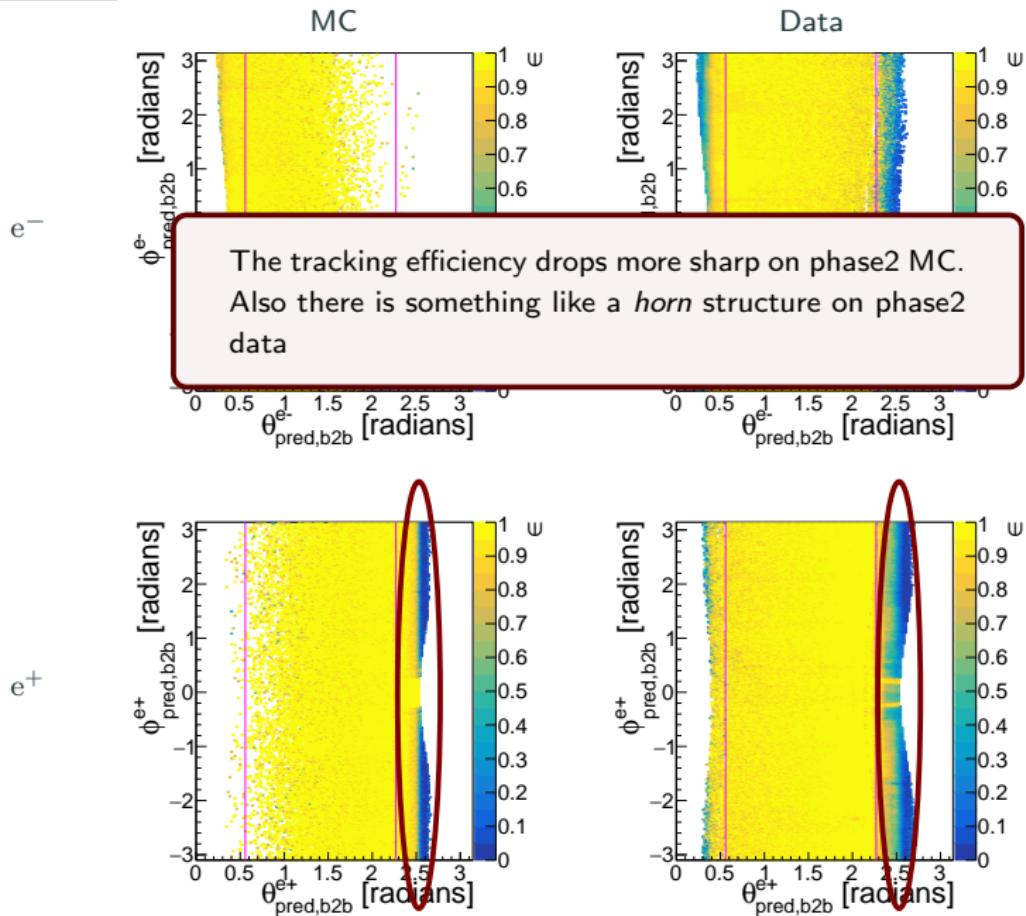
Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}} - \phi_{\text{pred,b2b}}$



Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}} - \phi_{\text{pred,b2b}}$



Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}} - \phi_{\text{pred,b2b}}$

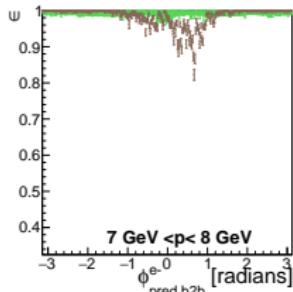
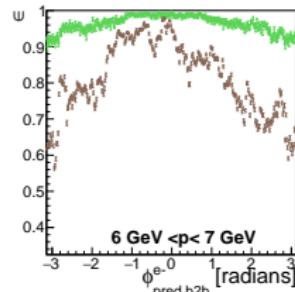
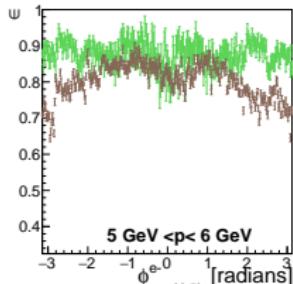
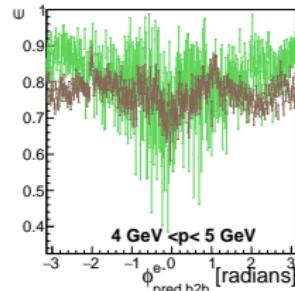


Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

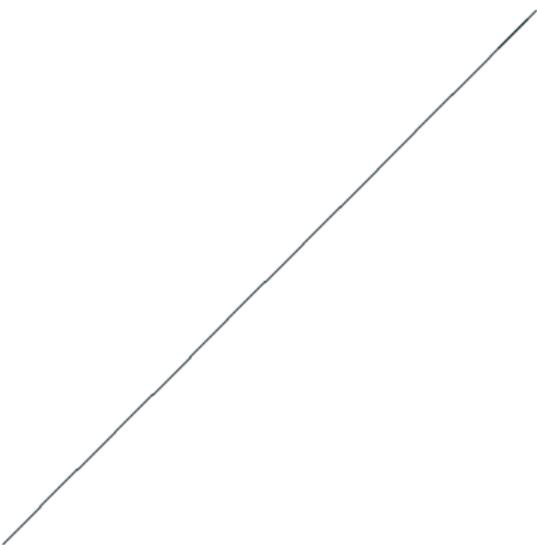
Phase2 MC10

Phase2 Data

e⁻



e⁺

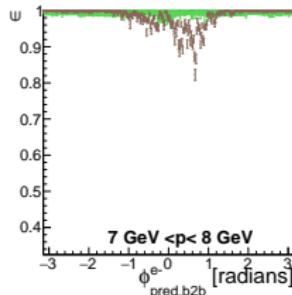
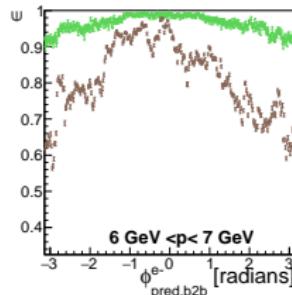
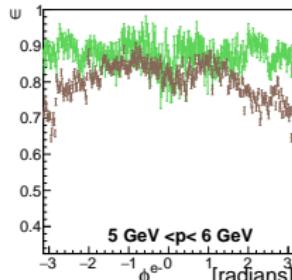
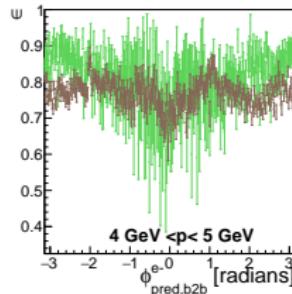


Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

Phase2 MC10

Phase2 Data

e⁻



Electron Tracking Efficiency:

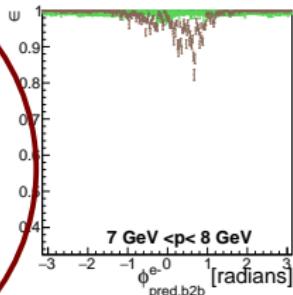
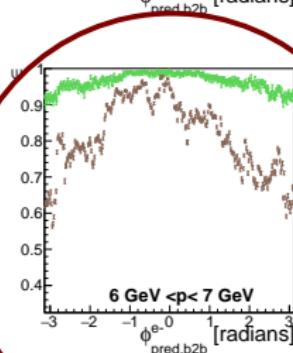
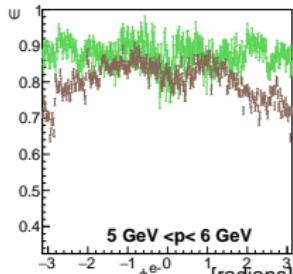
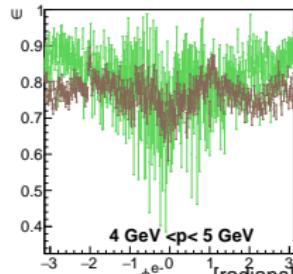
- Phase2 MC has almost always a higher tracking efficiency compared to phase2 data
- For most momenta the biggest difference between phase2 MC and phase2 data occurs for $|\phi_{\text{pred,b2b}}| \gtrsim 2$

Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

Phase2 MC10

Phase2 Data

e⁻



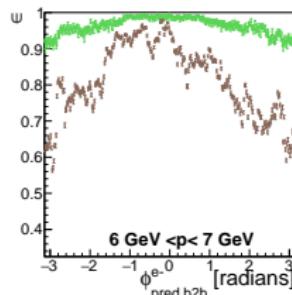
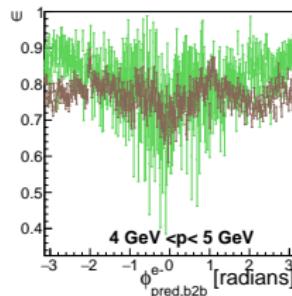
Electron Tracking Efficiency:

- Phase2 MC has almost always a higher tracking efficiency compared to phase2 data
- For most momenta the biggest difference between phase2 MC and phase2 data occurs for $|\phi_{\text{pred,b2b}}| \gtrsim 2$
- There is no similarity in the structure for momenta between 6 GeV and 7 GeV

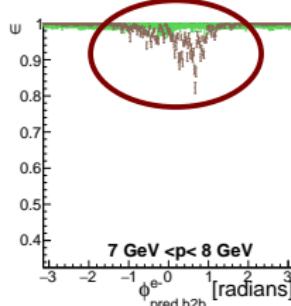
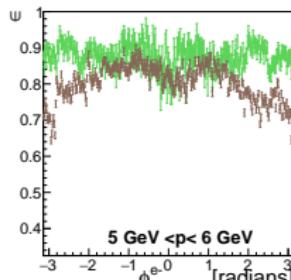
Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

Phase2 MC10

Phase2 Data



e^-



Electron Tracking Efficiency:

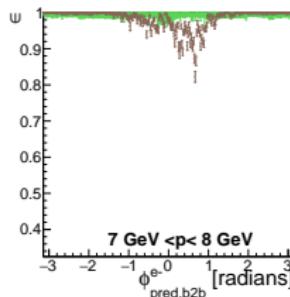
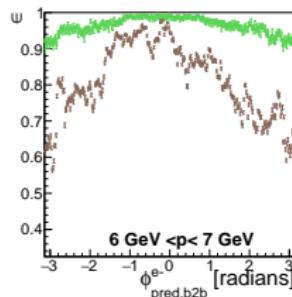
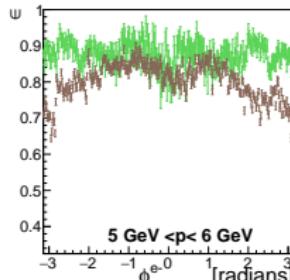
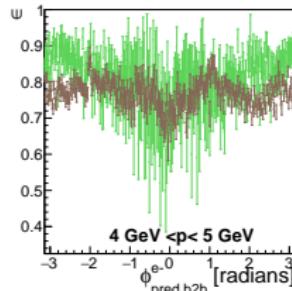
- Phase2 MC has almost always a higher tracking efficiency compared to phase2 data
- For most momenta the biggest difference between phase2 MC and phase2 data occurs for $|\phi_{\text{pred,b2b}}| \gtrsim 2$
- There is no similarity in the structure for momenta between 6 GeV and 7 GeV
- Highest tracking efficiency occurs for momenta between 7 GeV and 8 GeV. But there is also an efficiency drop at $\phi_{\text{pred,b2b}} \gtrsim 0$

Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

Phase2 MC10

Phase2 Data

e⁻



Electron Tracking Efficiency:

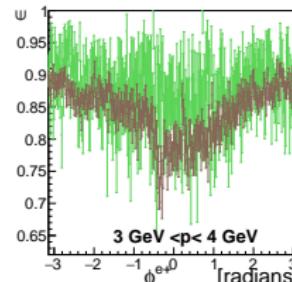
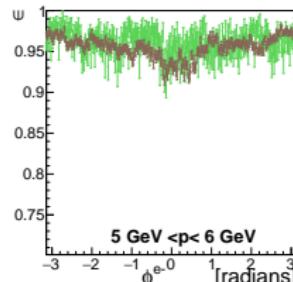
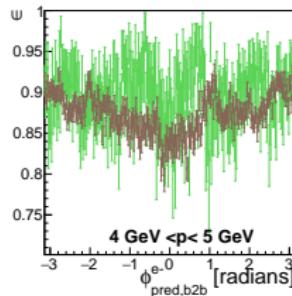
- Phase2 MC has almost always a higher tracking efficiency compared to phase2 data
- For most momenta the biggest difference between phase2 MC and phase2 data occurs for $|\phi_{\text{pred,b2b}}| \gtrsim 2$
- There is no similarity in the structure for momenta between 6 GeV and 7 GeV
- Highest tracking efficiency occurs for momenta between 7 GeV and 8 GeV. But there is also an efficiency drop at $\phi_{\text{pred,b2b}} \gtrsim 0$

Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Barrel

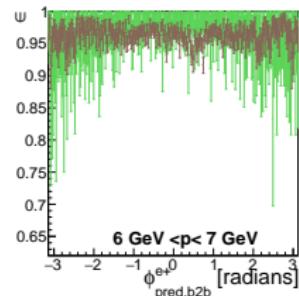
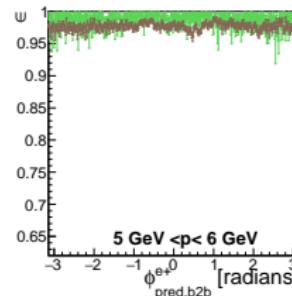
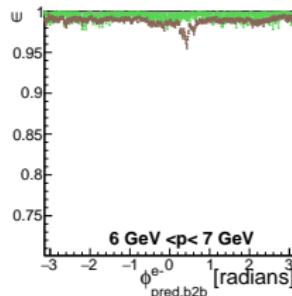
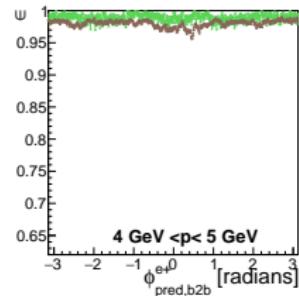
Phase2 MC10

e⁻

Phase2 Data



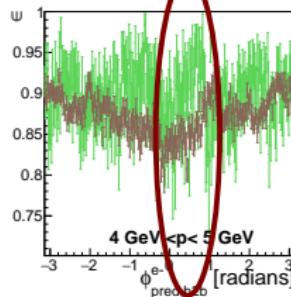
e⁺



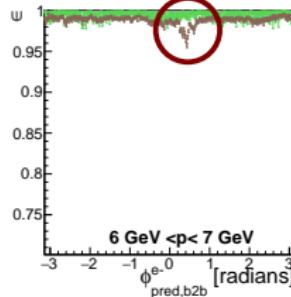
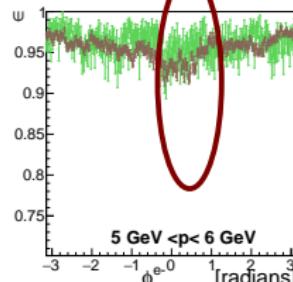
Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Barrel

Phase2 MC10

Phase2 Data

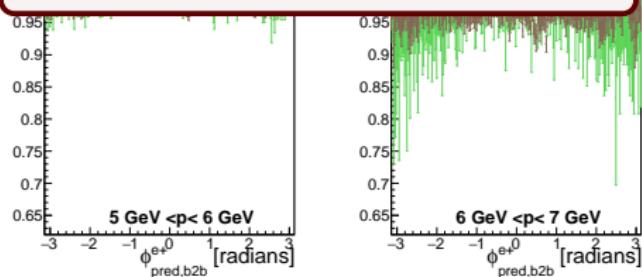


e^-



Electron Tracking Efficiency:

- The highest tracking efficiency occurs for momenta between 6 GeV and 7 GeV
- There is a slope at $\phi_{\text{pred,b2b}} \gtrsim 0$ for phase2 MC and phase2 data

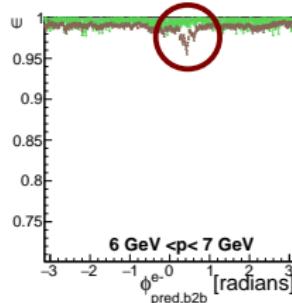
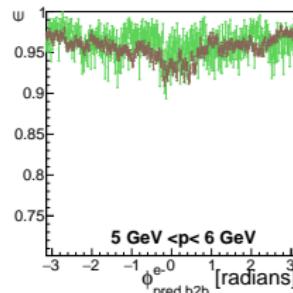
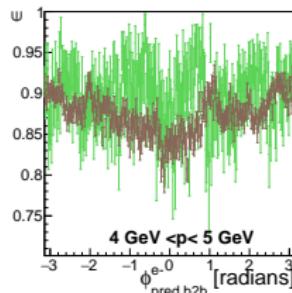


Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Barrel

Phase2 MC10

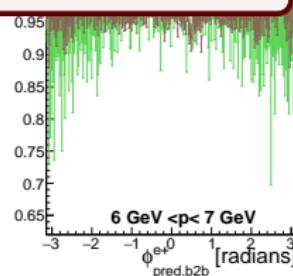
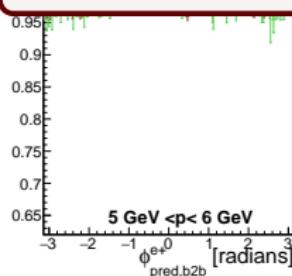
e⁻

Phase2 Data



Electron Tracking Efficiency:

- The highest tracking efficiency occurs for momenta between 6 GeV and 7 GeV
- There is a slope at $\phi_{\text{pred,b2b}} \gtrsim 0$ for phase2 MC and phase2 data
- This kind of drop we also saw in the forward end-cap for momenta between 7 GeV and 8 GeV

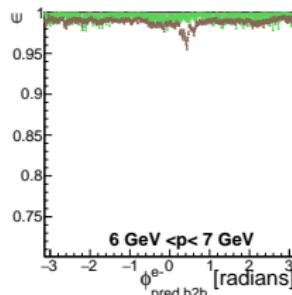
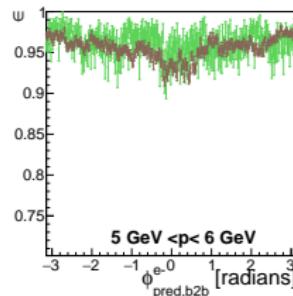
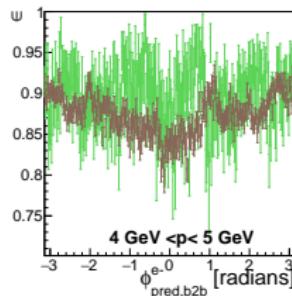


Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Barrel

Phase2 MC10

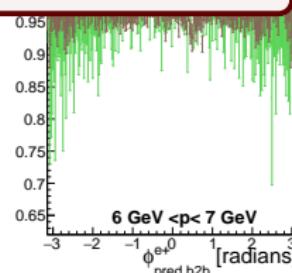
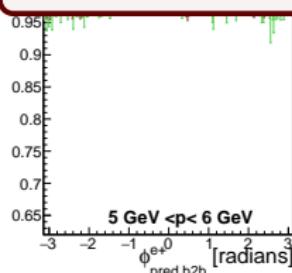
e⁻

Phase2 Data



Electron Tracking Efficiency:

- The highest tracking efficiency occurs for momenta between 6 GeV and 7 GeV
- There is a slope at $\phi_{\text{pred,b2b}} \gtrsim 0$ for phase2 MC and phase2 data
- This kind of drop we also saw in the forward end-cap for momenta between 7 GeV and 8 GeV

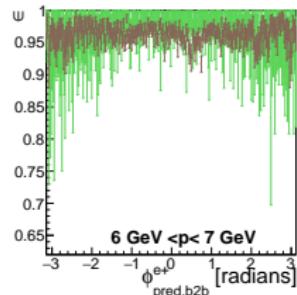
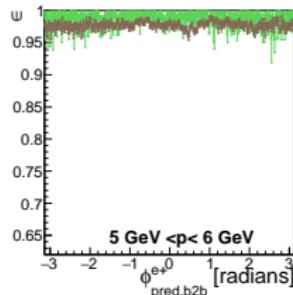
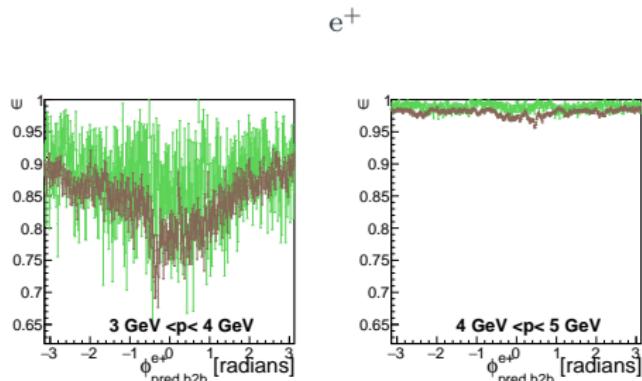
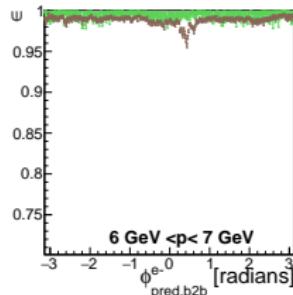


Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Barrel

Phase2 MC10

Positron Tracking Efficiency:

- The highest tracking efficiency occurs for momenta between 4 GeV and 5 GeV
- The lowest tracking efficiency occurs for momenta between 3 GeV and 4 GeV with a minima at $\phi_{\text{pred,b2b}} \approx 0$

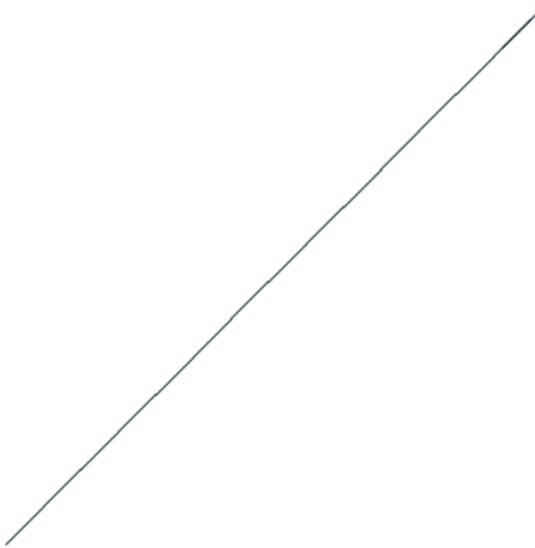


Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Backward End-Cap

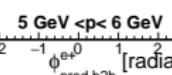
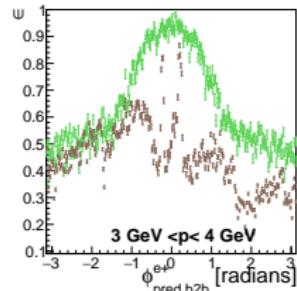
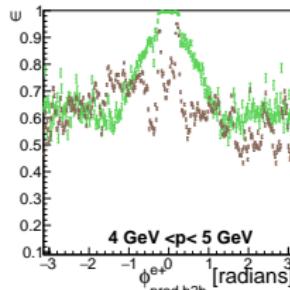
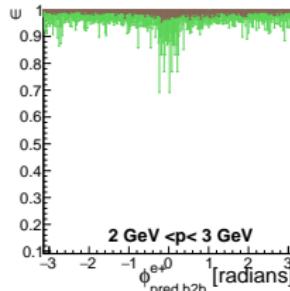
Phase2 MC10

Phase2 Data

e^-



e^+



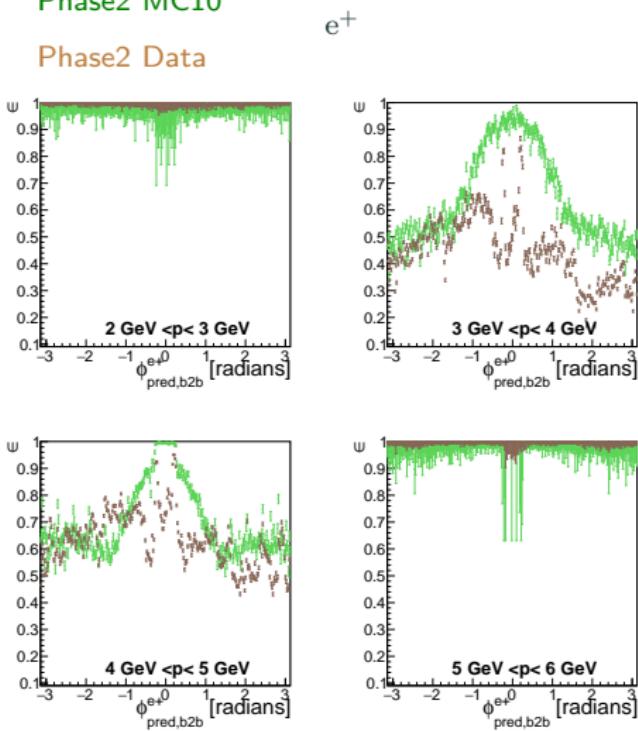
Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Backward End-Cap

Positron Tracking Efficiency:

- The highest tracking efficiency occurs for momenta between 2 GeV and 3 GeV and 5 GeV and 6 GeV

Phase2 MC10

Phase2 Data



e^+

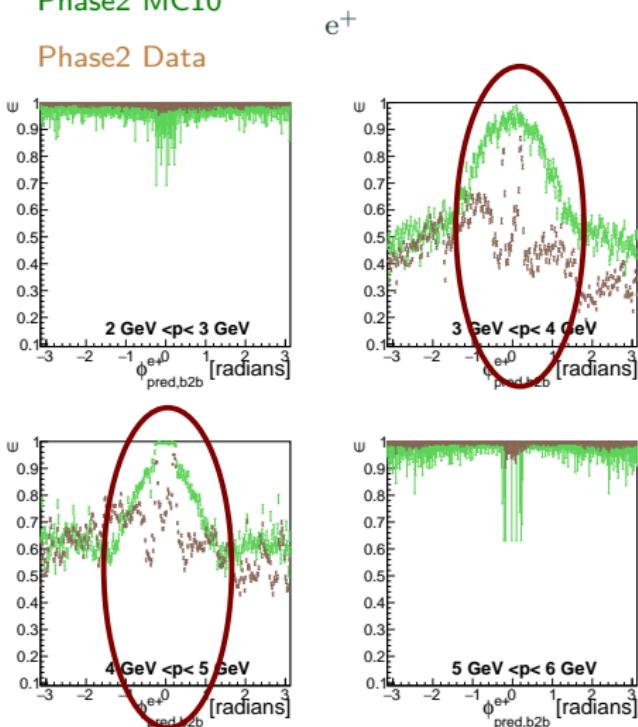
Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Backward End-Cap

Positron Tracking Efficiency:

- The highest tracking efficiency occurs for momenta between 2 GeV and 3 GeV and 5 GeV and 6 GeV
- Weird *horn* structure we saw earlier
- Phase2 MC tracking efficiency peaks at $\phi_{\text{pred,b2b}} \approx 0$

Phase2 MC10

Phase2 Data



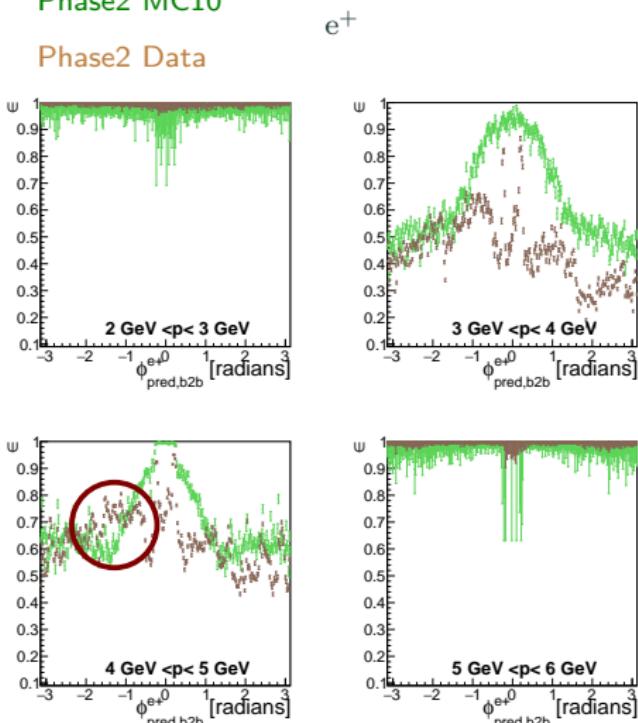
Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Backward End-Cap

Positron Tracking Efficiency:

- The highest tracking efficiency occurs for momenta between 2 GeV and 3 GeV and 5 GeV and 6 GeV
- Weird *horn* structure we saw earlier
- Phase2 MC tracking efficiency peaks at $\phi_{\text{pred,b2b}} \approx 0$
- For momenta between 4 GeV and 5 GeV phase2 data appears to have a higher tracking efficiency compared to phase2 MC at $\phi_{\text{pred,b2b}} \approx -1$

Phase2 MC10

Phase2 Data

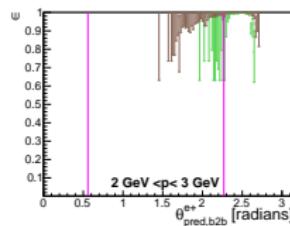
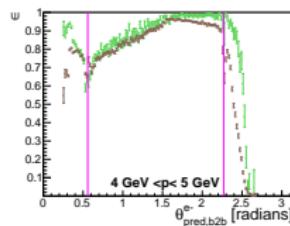
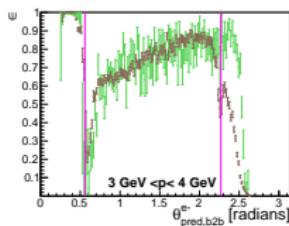


Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

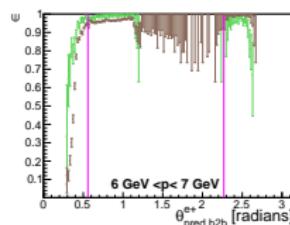
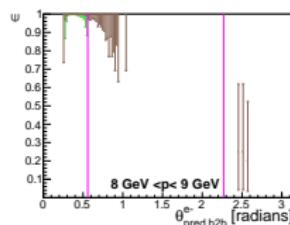
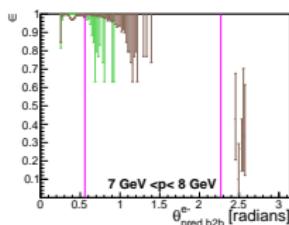
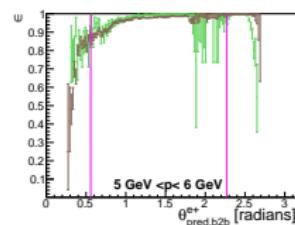
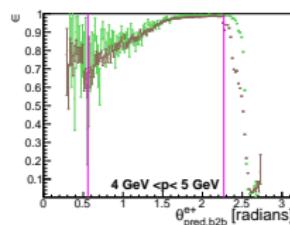
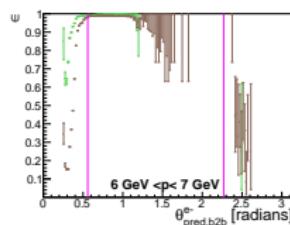
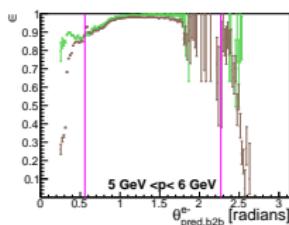
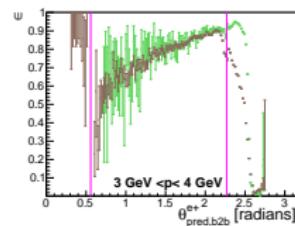
Phase2 MC10

e^-

Phase2 Data



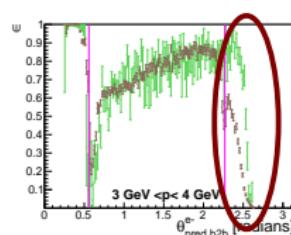
e^+



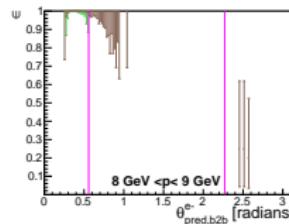
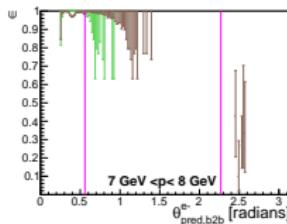
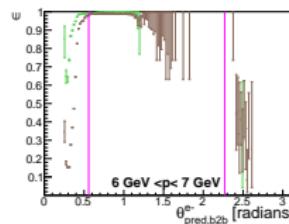
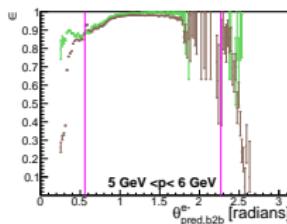
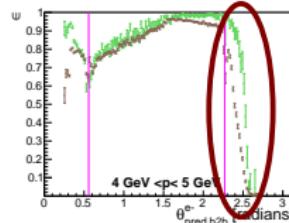
Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 MC10

Phase2 Data



e^-



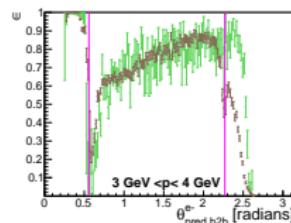
Electron Tracking Efficiency:

- For momenta between 3 GeV and 5 GeV the tracking efficiency in the backward end-cap is worse for phase2 data compared to phase2 MC

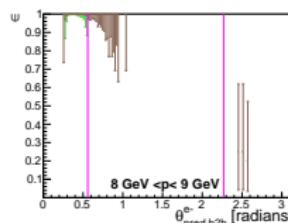
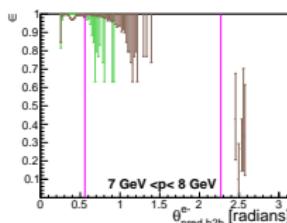
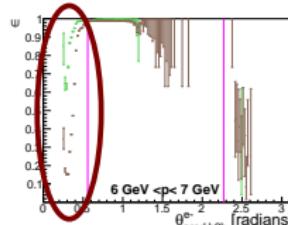
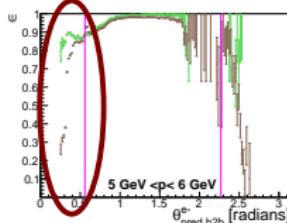
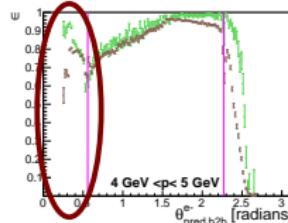
Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 MC10

Phase2 Data



e^-



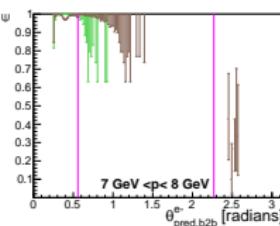
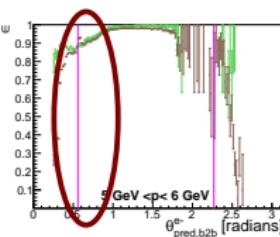
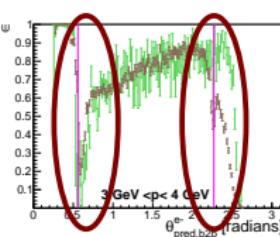
Electron Tracking Efficiency:

- For momenta between 3 GeV and 5 GeV the tracking efficiency in the backward end-cap is worse for phase2 data compared to phase2 MC
- For momenta between 4 GeV and 6 GeV the tracking efficiency in the forward end-cap is worse for phase2 data compared to phase2 MC

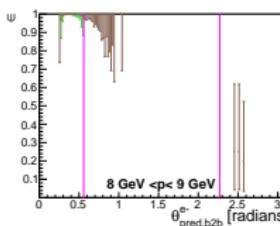
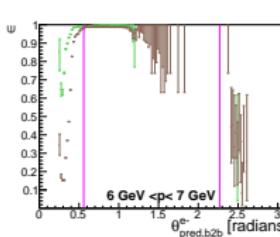
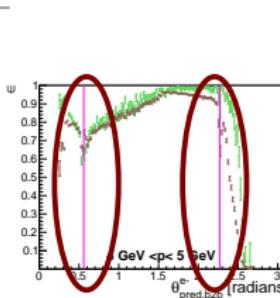
Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 MC10

Phase2 Data



e^-



Electron Tracking Efficiency:

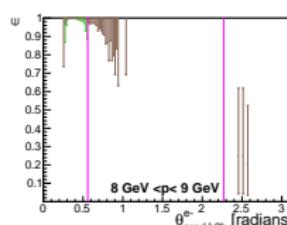
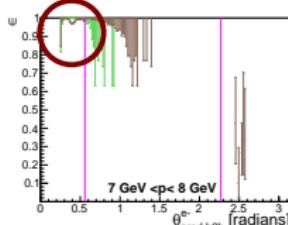
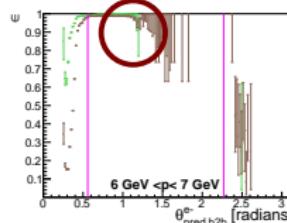
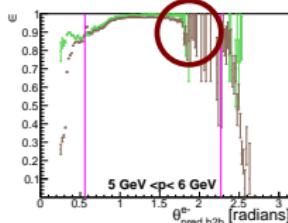
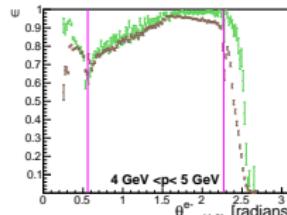
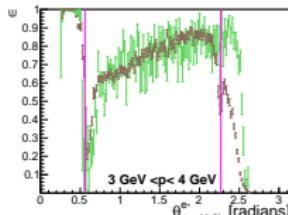
- For momenta between 3 GeV and 5 GeV the tracking efficiency in the backward end-cap is worse for phase2 data compared to phase2 MC
- For momenta between 4 GeV and 6 GeV the tracking efficiency in the forward end-cap is worse for phase2 data compared to phase2 MC
- Drops in efficiency at transition between barrel and end-caps

Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 MC10

Phase2 Data

e⁻



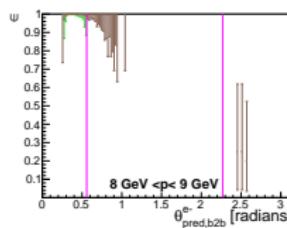
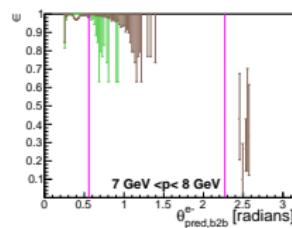
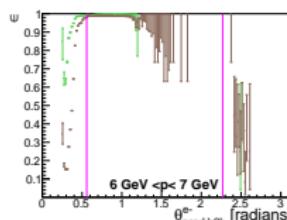
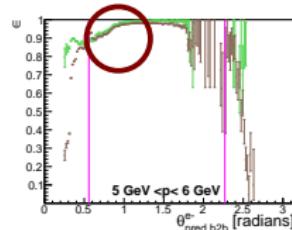
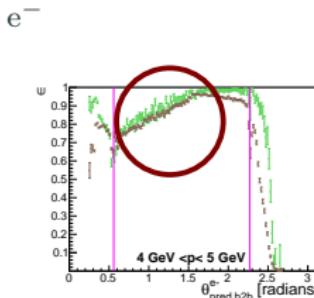
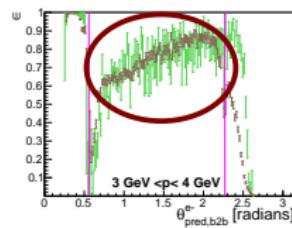
Electron Tracking Efficiency:

- For momenta between 3 GeV and 5 GeV the tracking efficiency in the backward end-cap is worse for phase2 data compared to phase2 MC
- For momenta between 4 GeV and 6 GeV the tracking efficiency in the forward end-cap is worse for phase2 data compared to phase2 MC
- Drops in efficiency at transition between barrel and end-caps
- A efficiency drop appears to propagate for momenta between 5 GeV and 7 GeV for phase2 data

Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 MC10

Phase2 Data



Electron Tracking Efficiency:

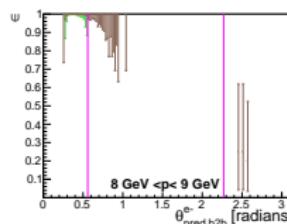
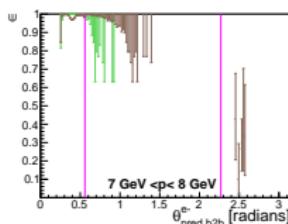
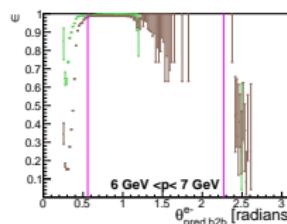
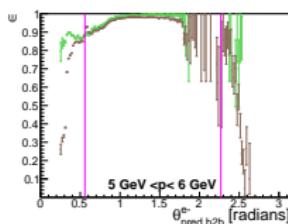
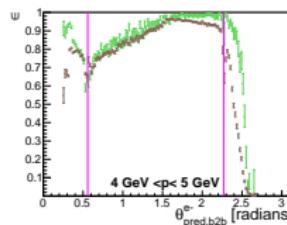
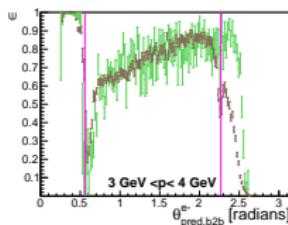
- For momenta between 3 GeV and 5 GeV the tracking efficiency in the backward end-cap is worse for phase2 data compared to phase2 MC
- For momenta between 4 GeV and 6 GeV the tracking efficiency in the forward end-cap is worse for phase2 data compared to phase2 MC
- Drops in efficiency at transition between barrel and end-caps
- A efficiency drop appears to propagate for momenta between 5 GeV and 7 GeV for phase2 data
- There is a slope in the barrel

Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 MC10

Phase2 Data

e⁻



Electron Tracking Efficiency:

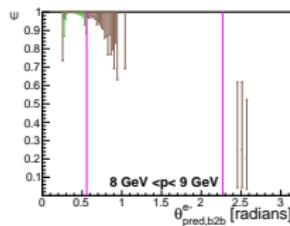
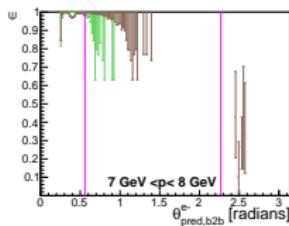
Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Positron Tracking Efficiency:

Phase2 MC10

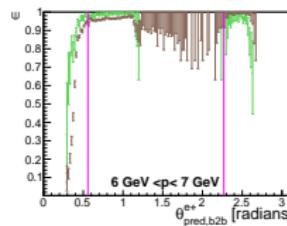
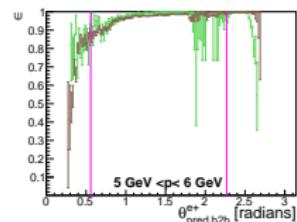
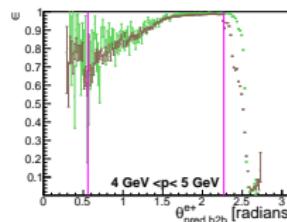
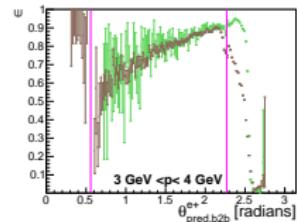
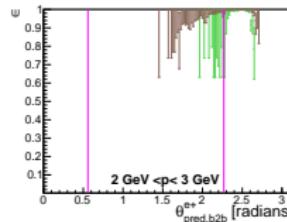
Phase2 Data

e⁺



Phase2 MC10

Phase2 Data



Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Positron Tracking Efficiency:

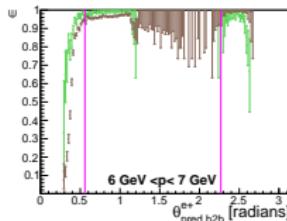
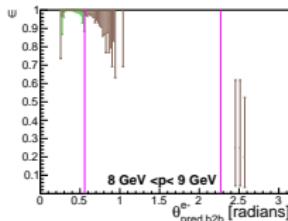
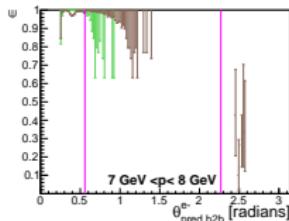
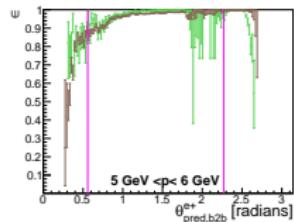
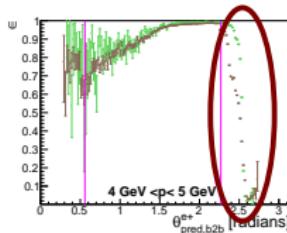
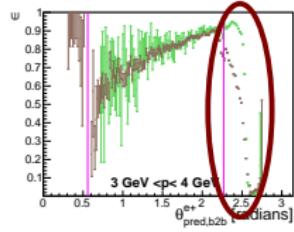
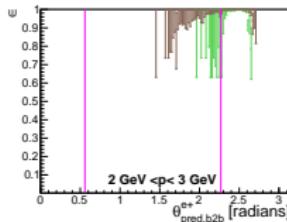
- For momenta between 3 GeV and 5 GeV the phase2 data tracking efficiency is lower compared to phase2 MC in the backward end-cap

Phase2 MC10 Phase2 Data

Phase2 MC10

Phase2 Data

e⁺



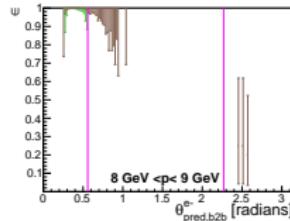
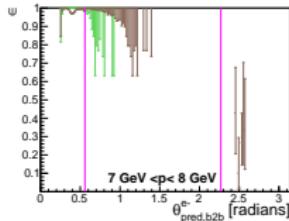
Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Positron Tracking Efficiency:

- For momenta between 3 GeV and 5 GeV the phase2 data tracking efficiency is lower compared to phase2 MC in the backward end-cap
- For momenta between 5 GeV and 7 GeV it is vice versa

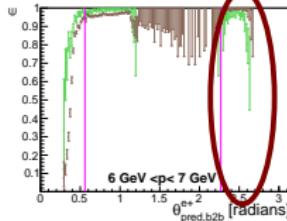
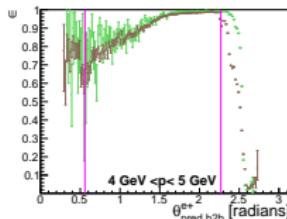
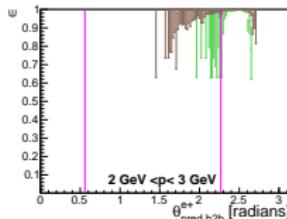
phase2MC10

phase2Data

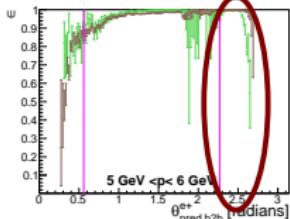
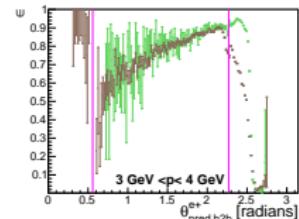


Phase2 MC10

Phase2 Data



e⁺



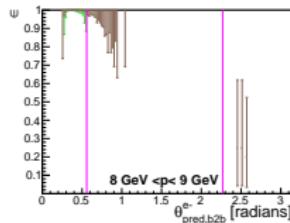
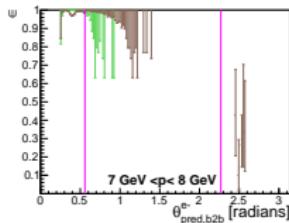
Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Positron Tracking Efficiency:

- For momenta between 3 GeV and 5 GeV the phase2 data tracking efficiency is lower compared to phase2 MC in the backward end-cap
- For momenta between 5 GeV and 7 GeV it is vice versa
- Efficiency drop at transition between barrel and end-caps

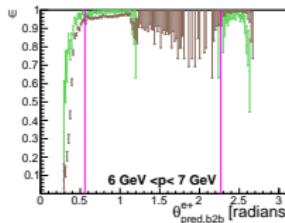
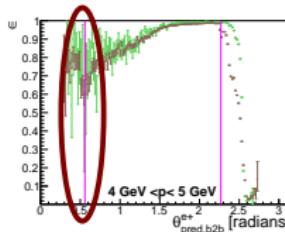
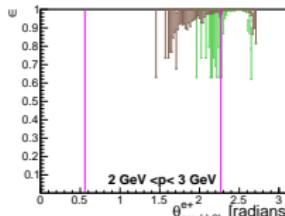
phase2MC

phase2Data

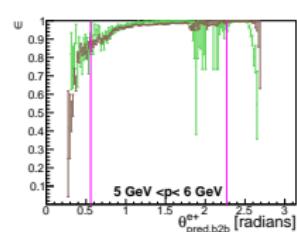
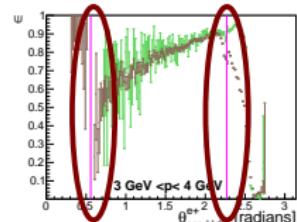


Phase2 MC10

Phase2 Data



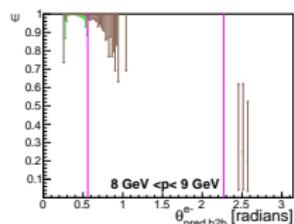
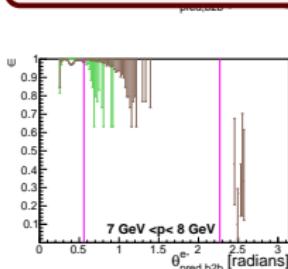
e⁺



Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

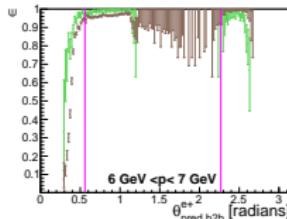
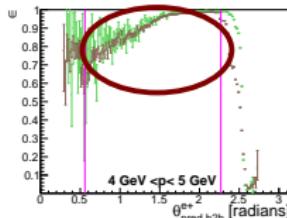
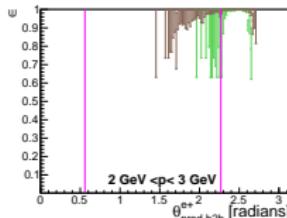
Positron Tracking Efficiency:

- For momenta between 3 GeV and 5 GeV the phase2 data tracking efficiency is lower compared to phase2 MC in the backward end-cap
- For momenta between 5 GeV and 7 GeV it is vice versa
- Efficiency drop at transition between barrel and end-caps
- There is a slope in the barrel again

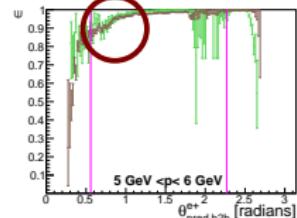
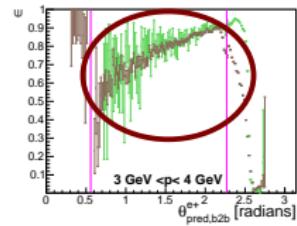


Phase2 MC10

Phase2 Data



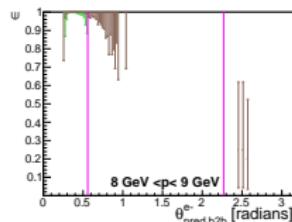
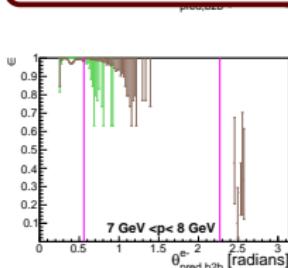
e⁺



Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred},\text{b}2\text{b}}$

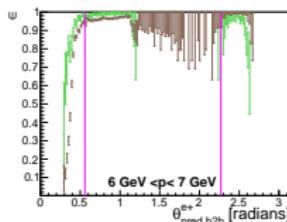
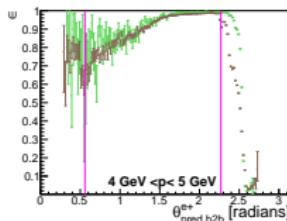
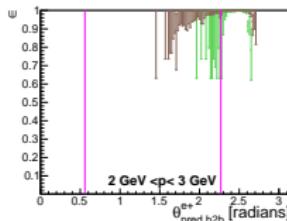
Positron Tracking Efficiency:

- For momenta between 3 GeV and 5 GeV the phase2 data tracking efficiency is lower compared to phase2 MC in the backward end-cap
 - For momenta between 5 GeV and 7 GeV it is vice versa
 - Efficiency drop at transition between barrel and end-caps
 - There is a slope in the barrel again

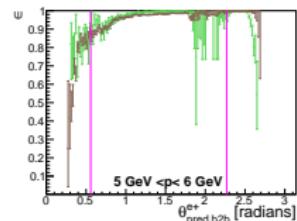
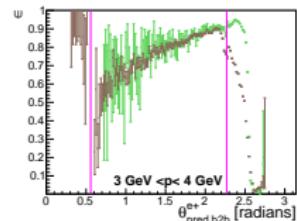


Phase2 MC10

Phase2 Data



e⁺



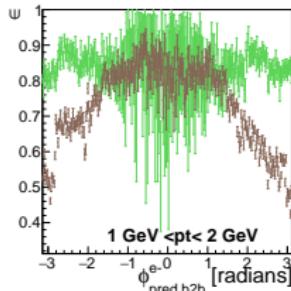
Transverse Momentum

Phase2 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

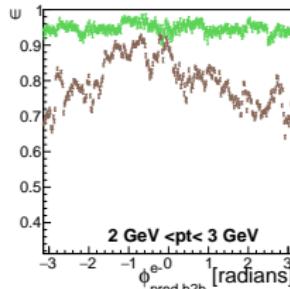
Phase2 MC10

Phase2 Data

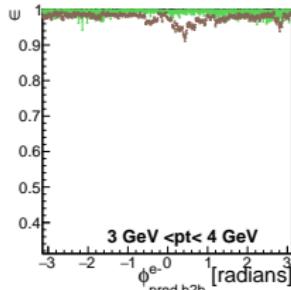
e^-



$1 \text{ GeV} < p_t < 2 \text{ GeV}$

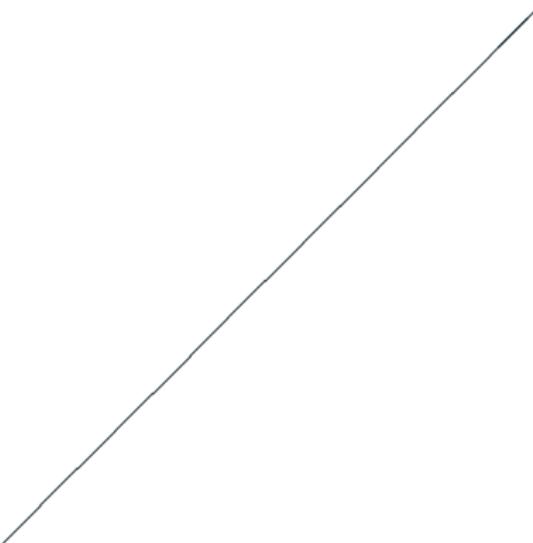


$2 \text{ GeV} < p_t < 3 \text{ GeV}$



$3 \text{ GeV} < p_t < 4 \text{ GeV}$

e^+

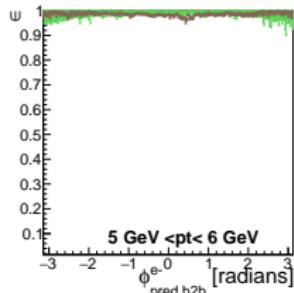
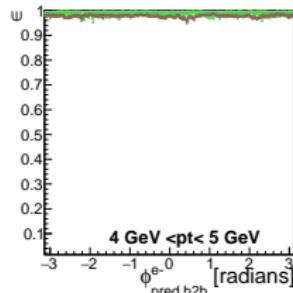
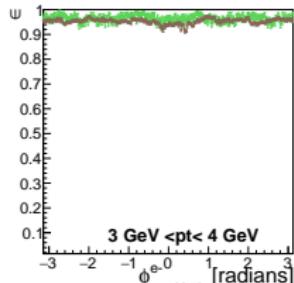
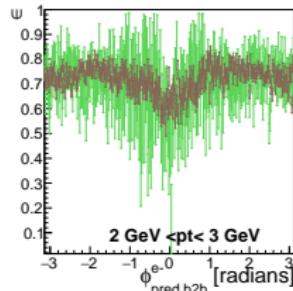


Phase2 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Barrel

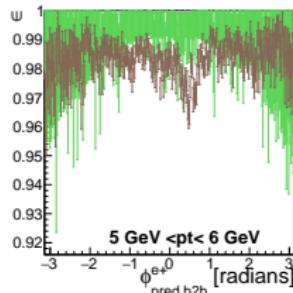
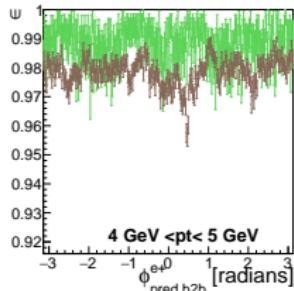
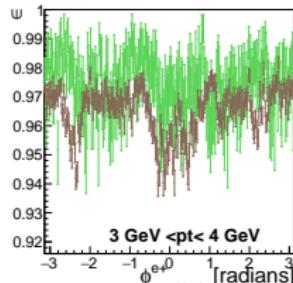
Phase2 MC10

e⁻

Phase2 Data



e⁺

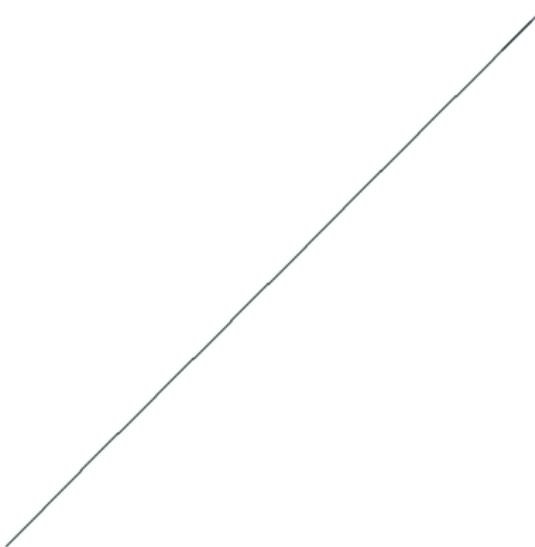


Phase2 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Backward End-Cap

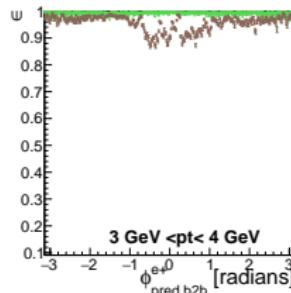
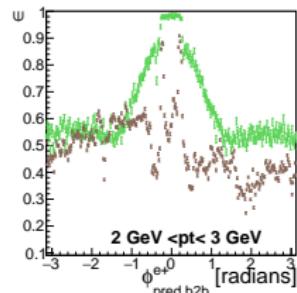
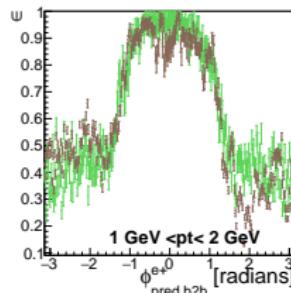
Phase2 MC10

e^-

Phase2 Data



e^+

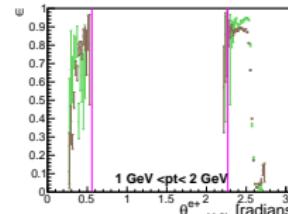
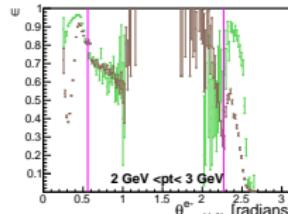
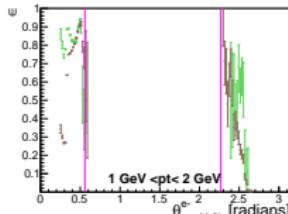


Phase2 pt Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

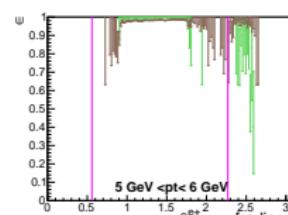
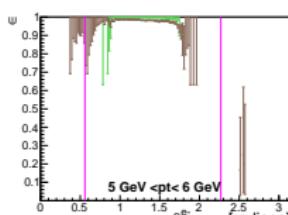
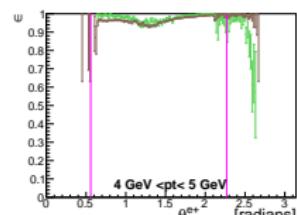
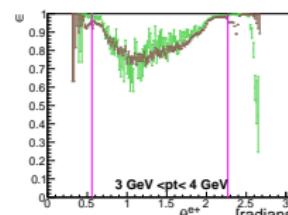
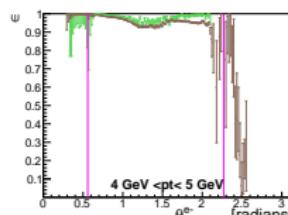
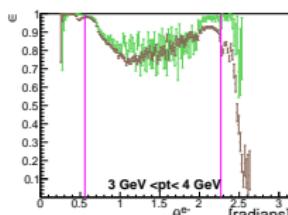
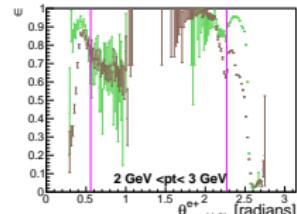
Phase2 MC10

e^-

Phase2 Data



e^+

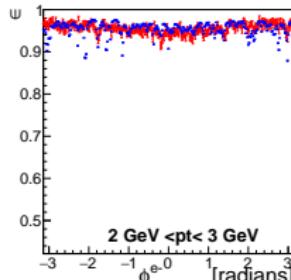
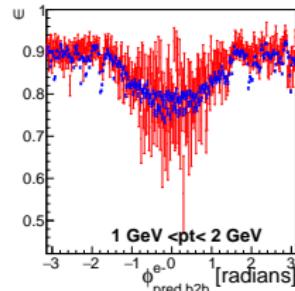


Phase3 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Forward End-Cap

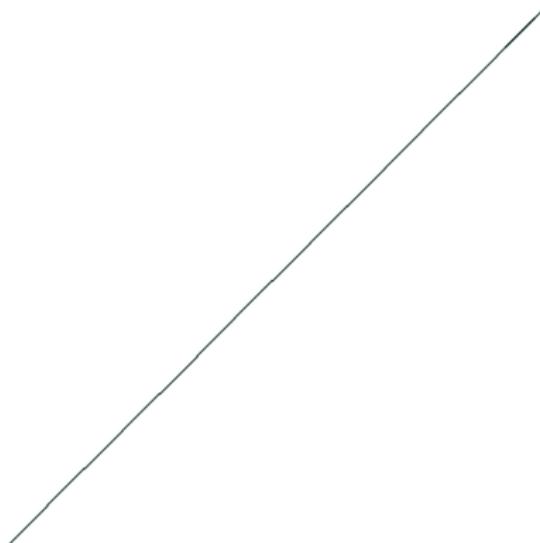
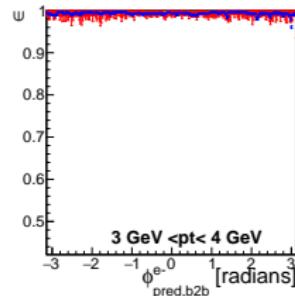
Phase3 MC10

Phase3 Data

e⁻



e⁺

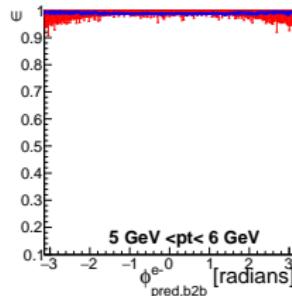
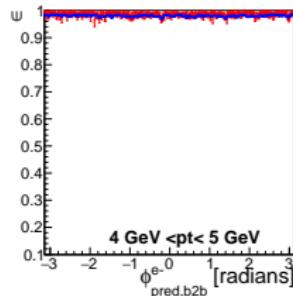
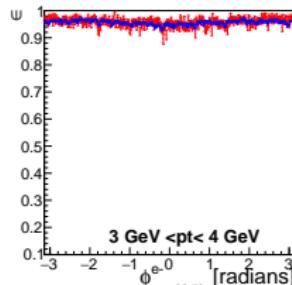
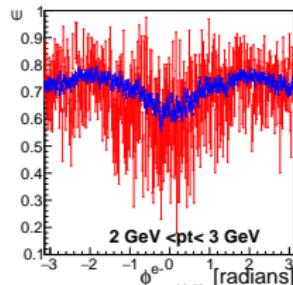


Phase3 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Barrel

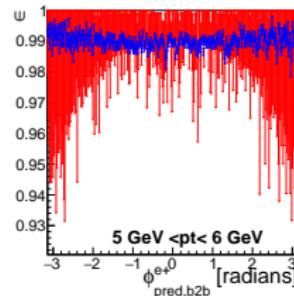
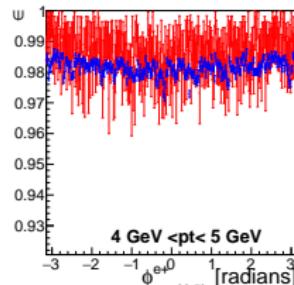
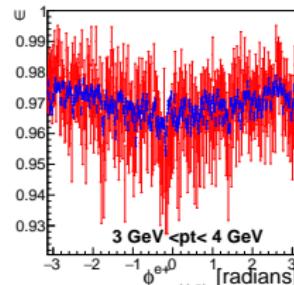
Phase3 MC10

e⁻

Phase3 Data



e⁺

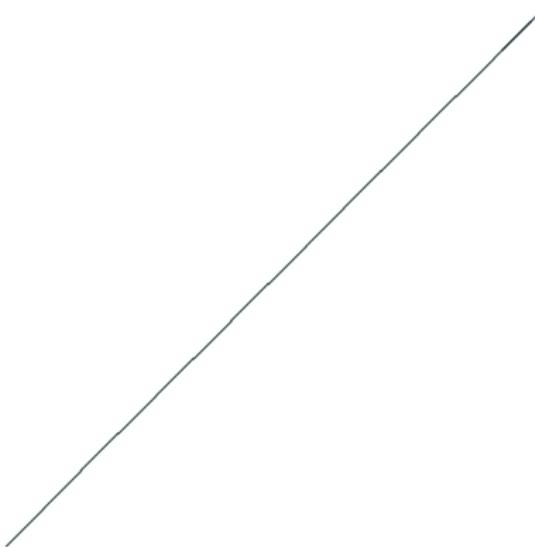


Phase3 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$; Backward End-Cap

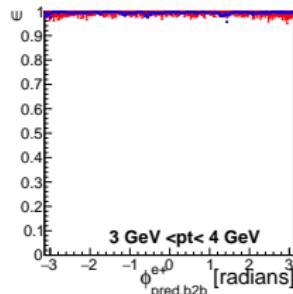
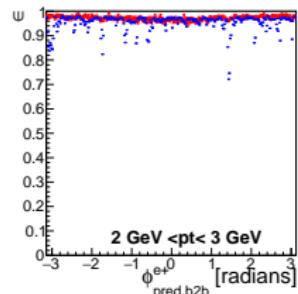
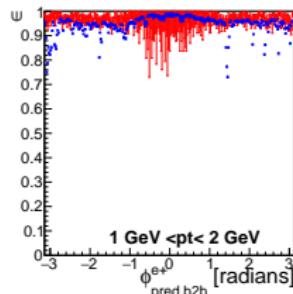
Phase3 MC10

e^-

Phase3 Data



e^+

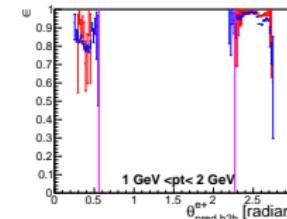
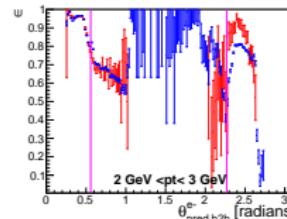
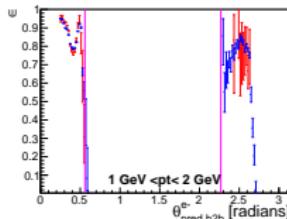


Phase3 pt Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase3 MC10

e⁻

Phase3 Data



e⁺

