

# Systematic Studies On Track Reconstruction Efficiency At Belle II

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22.01.2020

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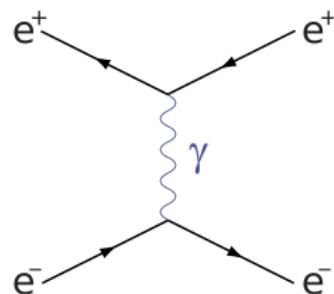
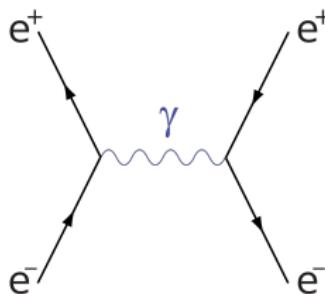


# Outline

- Overview of the Belle II experiment
- Kinematics at Belle II
- Method for calculating the tracking efficiency
- Tracking efficiency
- Comparing the tracking efficiency of different phases of the data taking
- Conclusion

## Motivation

- At an electron-positron collider most events are  $e^+e^- \rightarrow e^+e^-$  (these events are called Bhabha events)
- These events have 2 charged particles in the final state, and can therefore be used to estimate the performance of the detectors
- If one particle (tag particle) in a Bhabha event is associated with a track than the other particle (probe particle) should have a track associated, too  
→ a tracking efficiency can be calculated
- Knowing the tracking efficiency is highly important for analysis



## **Overview Of The Belle II Experiment**

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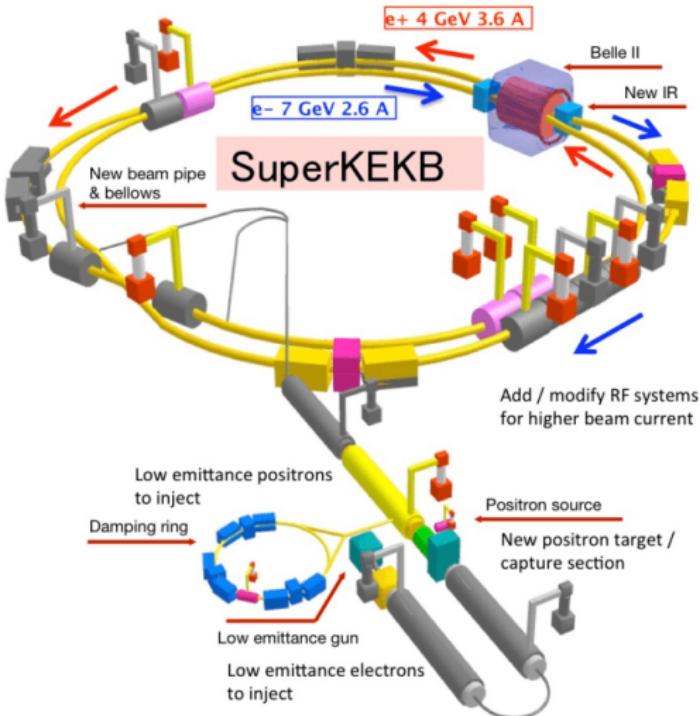
# The SuperKEKB $e^+e^-$ Collider And Luminosity Goals

- Located at Tsukuba, Japan



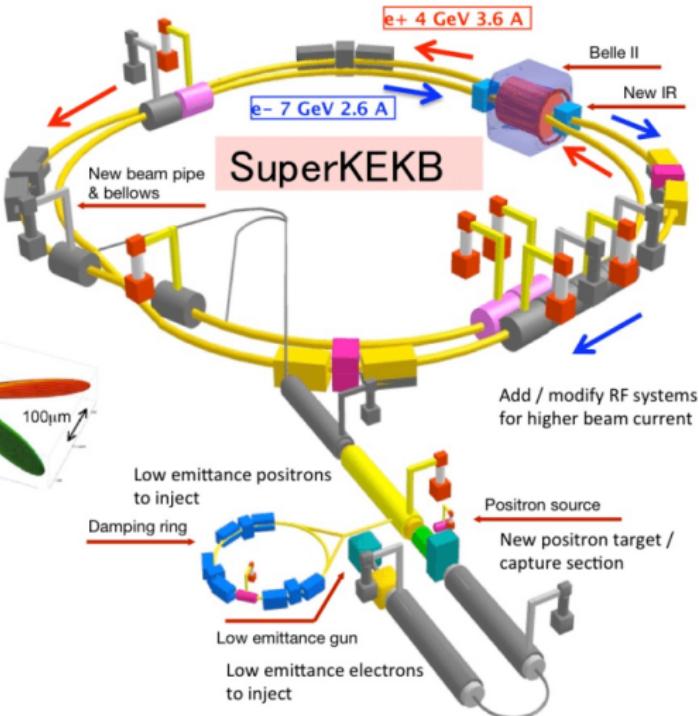
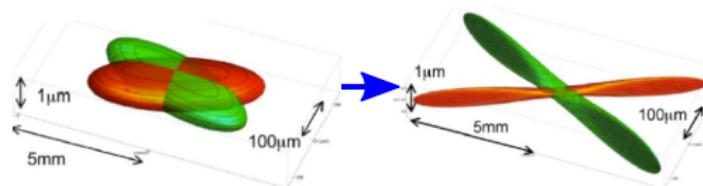
# The SuperKEKB $e^+e^-$ Collider And Luminosity Goals

- Located at Tsukuba, Japan
- Asymmetric collider
- Center-of-mass equal to  $\Upsilon(4S)$   
 $\sim 10.58 \text{ GeV} \rightarrow B\text{-factory}$
- Upgrade of the KEKB collider:
  - Larger beam currents
  - Reduced beam size at interaction region



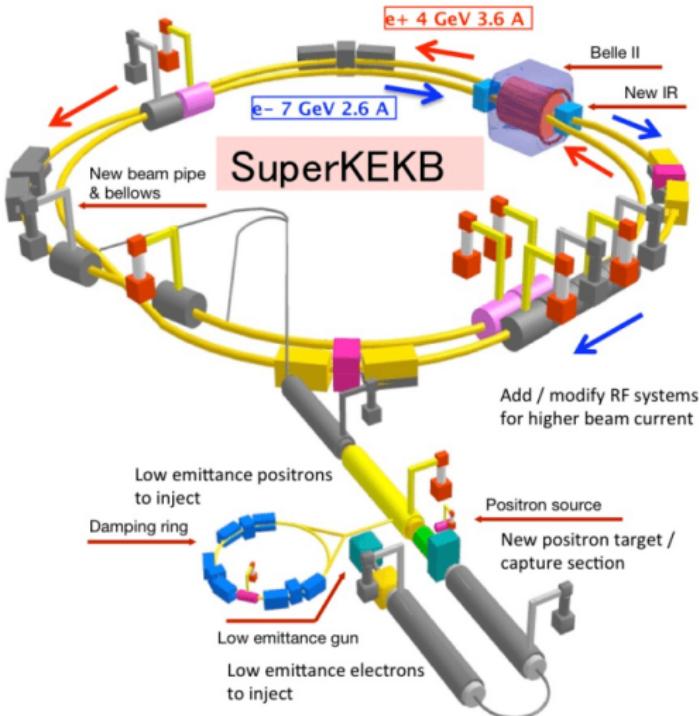
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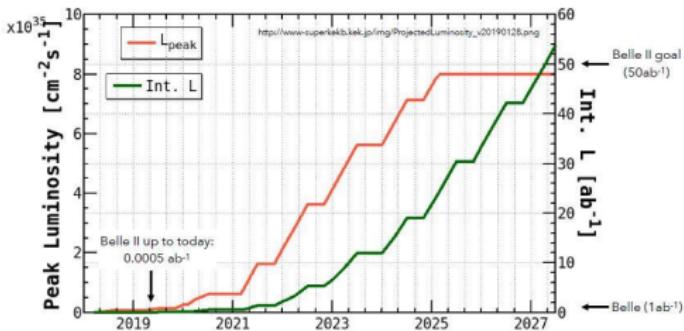
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- $\rightarrow$  Luminosity increase  $\times 40$
- Design peak luminosity of  
 $8 \cdot 10^{35} \text{ cm}^{-2}\text{s}^{-1}$
- Desired data sample corresponding to a recorded integrated luminosity of  
 $\sim 50 \text{ ab}^{-1}$  (50x the integrated luminosity of Belle)



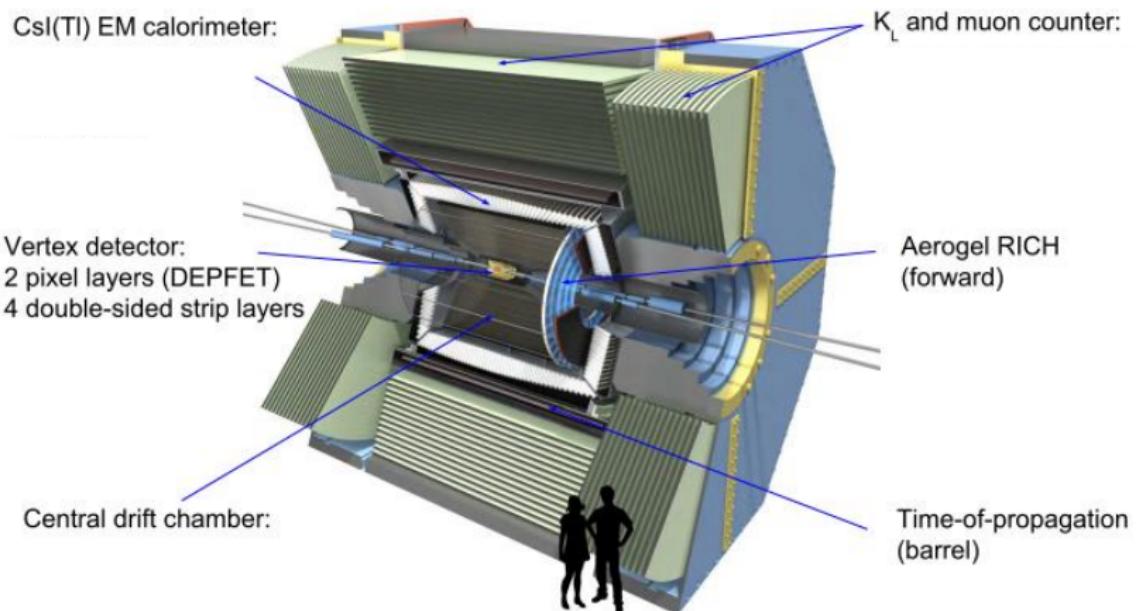
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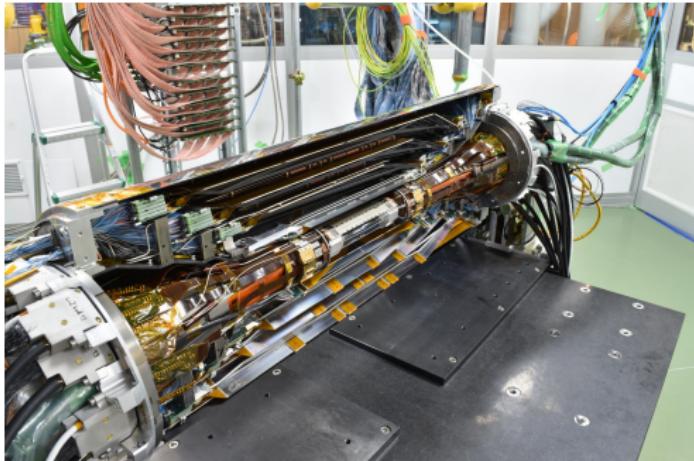
- Phase1: accelerator commissioning and background estimation (completed in 2016)
- Phase2: collision runs and background studies with partially installed detector (completed in 2018)
- Phase3: data taking with the whole detector (started in April 2019)

# The Belle II Detector



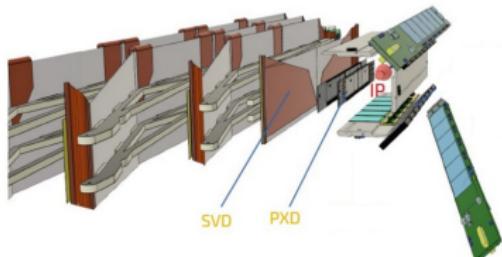
## Vertex Detectors (VXD)

- Consist of Pixel Detector (PXD) and Silicon Vertex Detector (SVD)
- Both detectors consist of multiple ladders organized in multiple layers (2 layer of PXD with radii of 14 and 22 mm, and 4 layers of SVD with radii of 39, 80, 104 and 135 mm)
- Charged particles create electron-hole pairs, which are separated by an electric field  
→ particle position can be determined

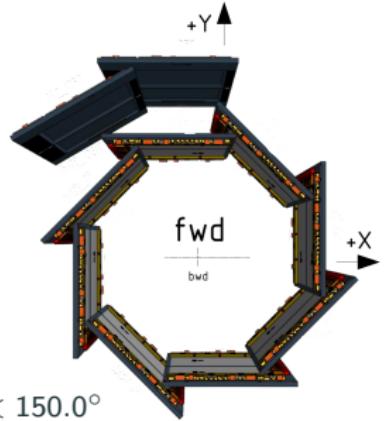


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  - particle position can be determined
- During phase2, only a fraction of the VXD detectors were installed
- During phase3, the complete SVD and half of the PXD are installed

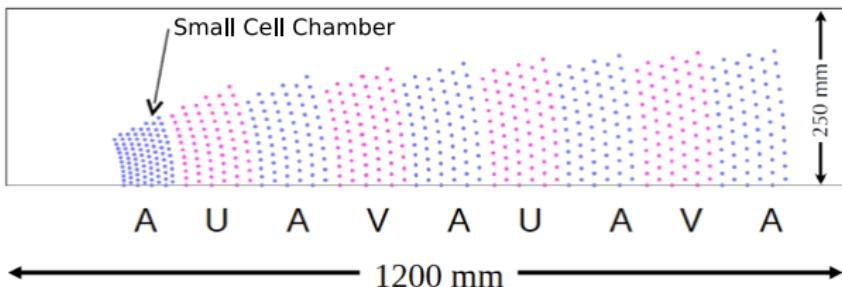
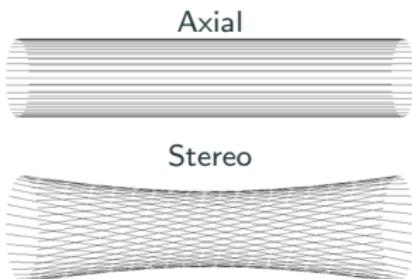


Acceptance:  $17.0^\circ < \theta < 150.0^\circ$

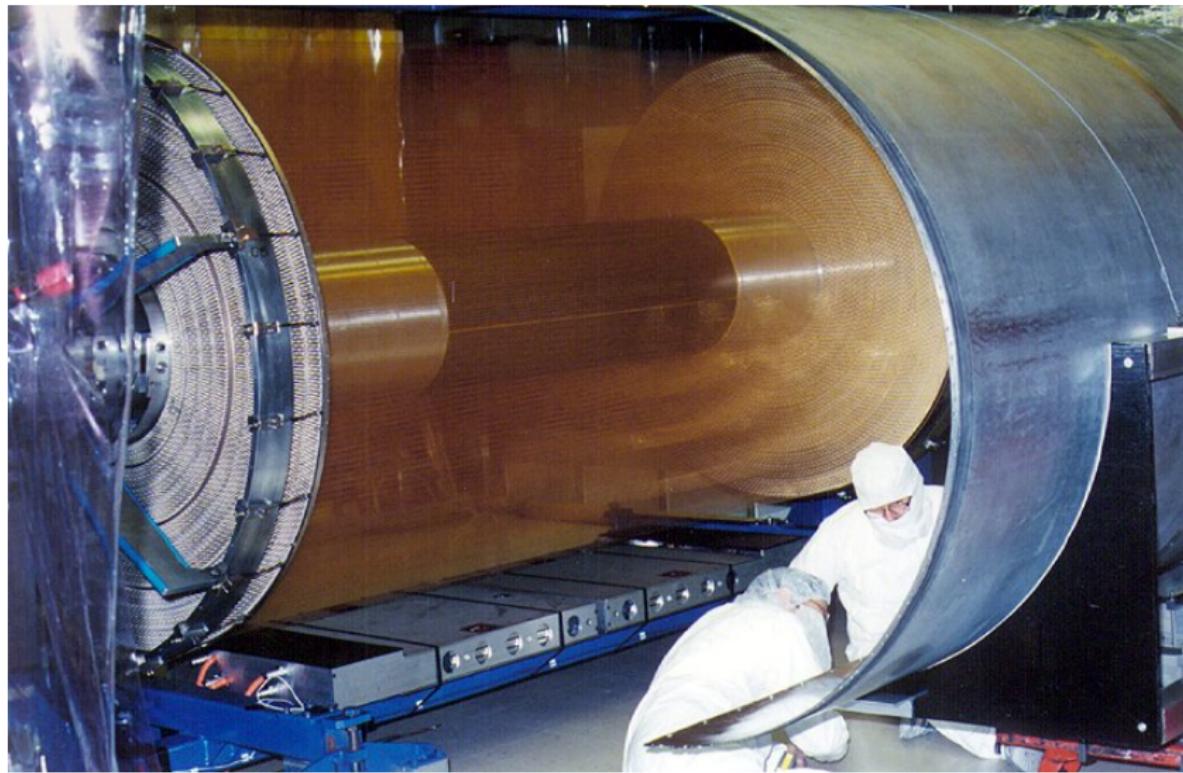


# Central Drift Chamber (CDC)

- 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)
- The CDC is immersed in a 50 % helium and 50 % ethane gas mixture
- Charged particles ionize the gas  
The signal is then read out by the sense wires  
→ Determination of momenta and tracks of charged particles
- Acceptance:  $17.0^\circ < \theta < 150.0^\circ$

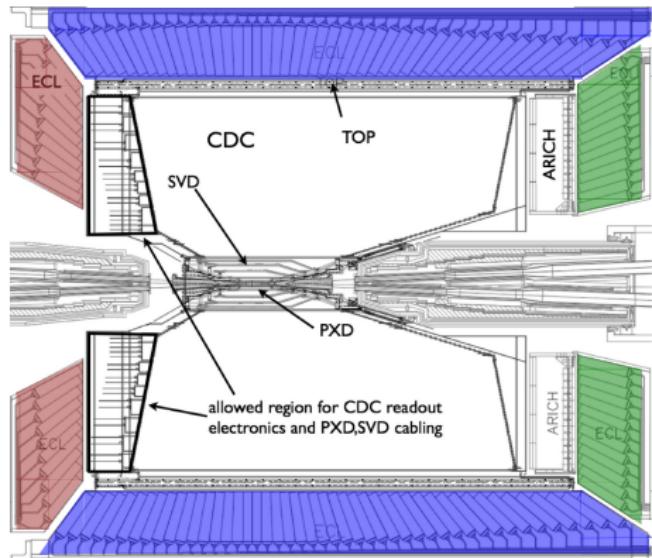


## Central Drift Chamber (CDC)



# Electromagnetic Calorimeter (ECL)

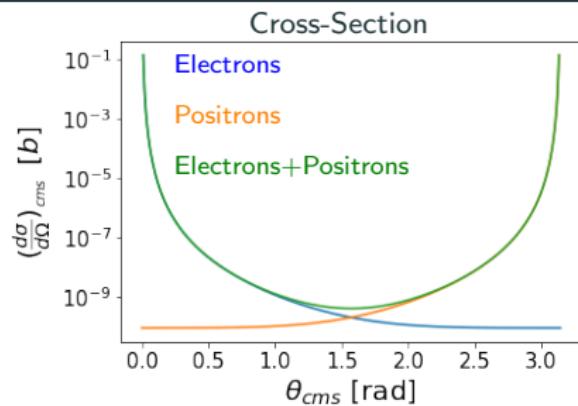
- Consists of 8936 CsI(Tl) crystals
- Electromagnetically interacting particles are creating electromagnetic shower when they pass through the crystals  
These shower spread through multiple crystals
  - The position and the energy of the particles can be determined
- Separation in **barrel**, **forward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



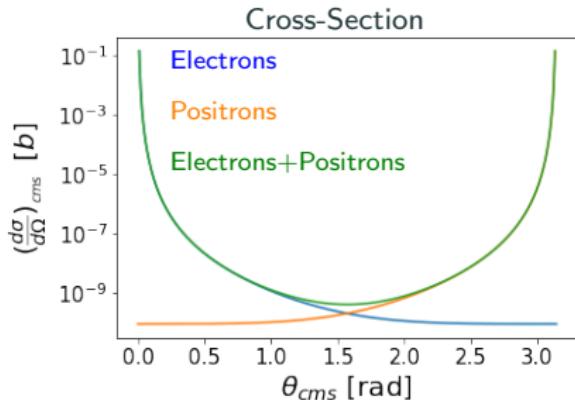
## Bhabha Kinematics At Belle II

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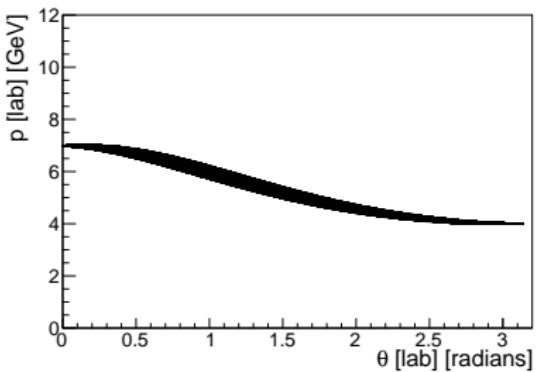
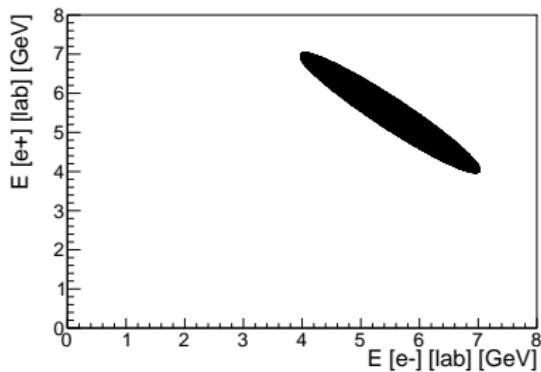
# Bhabha Kinematics At Belle II



# Bhabha Kinematics At Belle II



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



## **Method For Calculating The Tracking Efficiency**

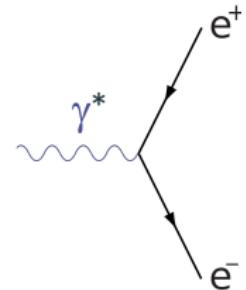
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## Introducing Cuts

Strategy: Reconstruct Bhabha events using only ECL information

$$\gamma^* \rightarrow \text{ECL-Object(HcIE)} + \text{ECL-Object(LcIE)}$$

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



## Introducing Cuts

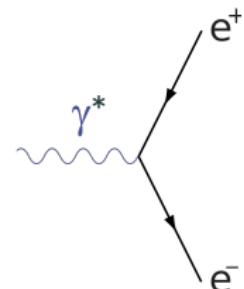
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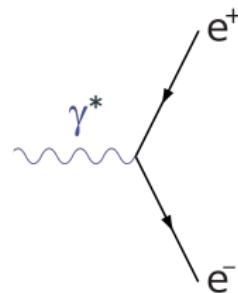
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- $8 \text{ GeV} < M_{\gamma^*} < 12 \text{ GeV}$
- 2 clusters with at least 3.5 GeV per event; One cluster has to have at least 4.5 GeV
- Number of reconstructed tracks per event  $< 7$
- Total energy in the ECL  $< 15 \text{ GeV}$
- ECL-Trigger signal is required on data (the trigger simulation does not work reliably on MC)



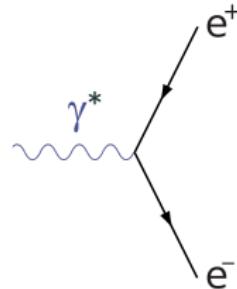
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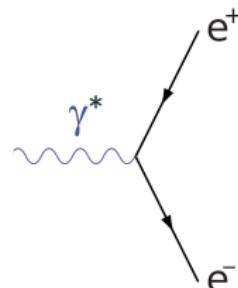
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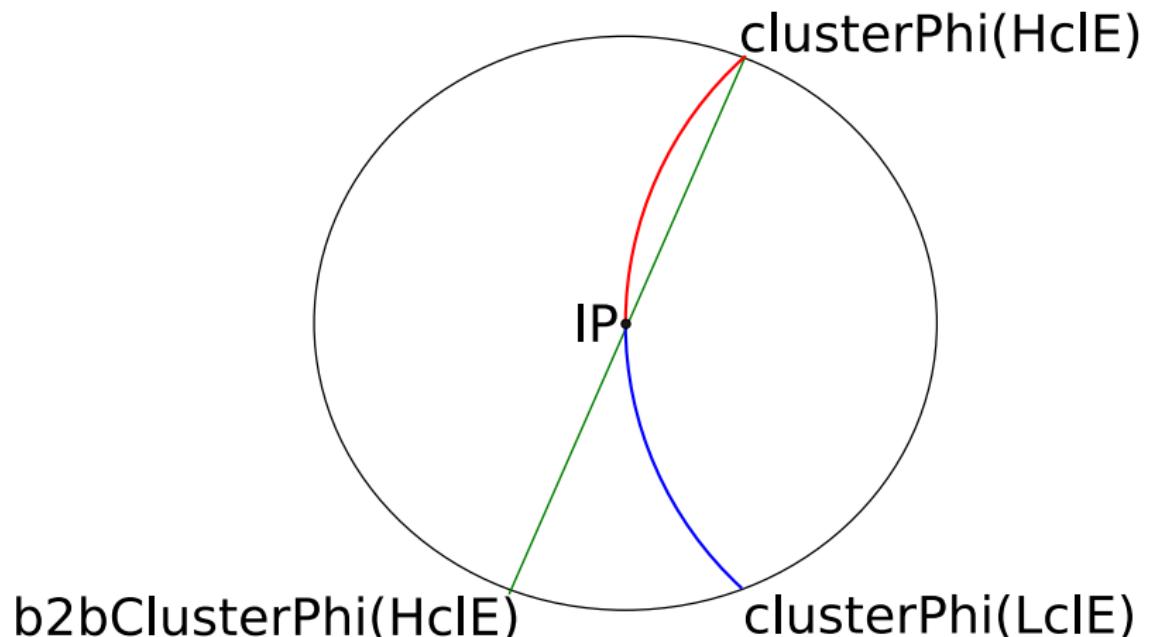
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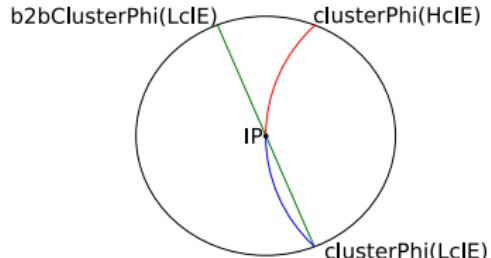
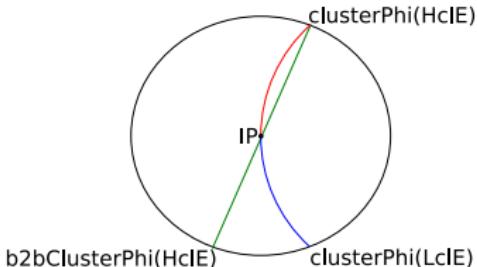
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- Only 1 reconstructed virtual photon candidate survives these cuts in both MC and data
- Problem: Data also contains  $e^+e^- \rightarrow \gamma\gamma$  events



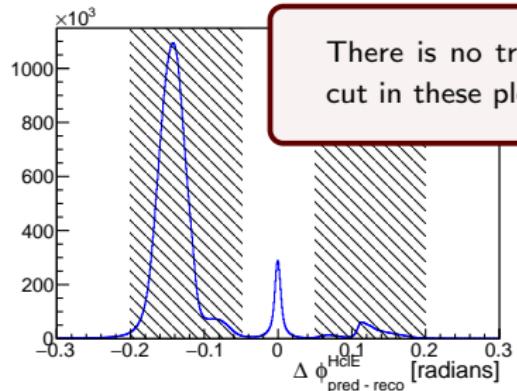
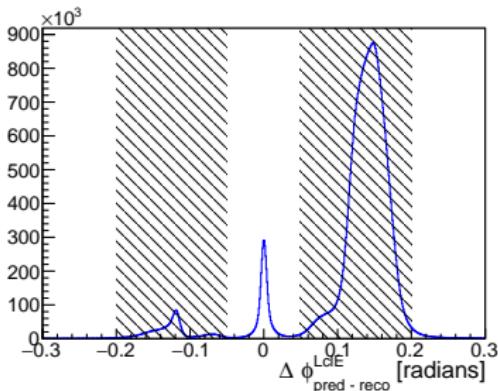


# Bhabha Event Selection



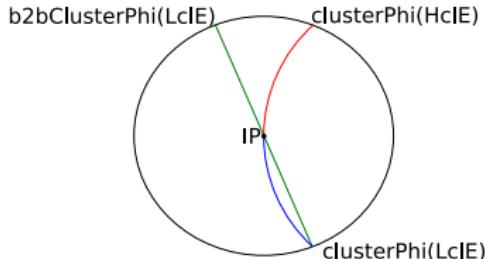
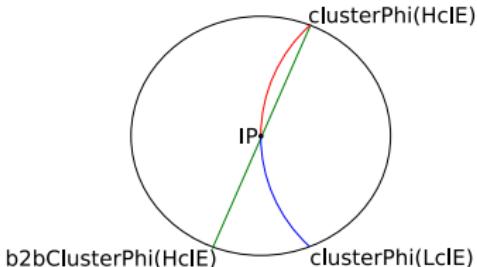
$$\Delta\phi_{\text{pred-reco}} = \phi_{\text{pred,b2bcl}} - \phi_{\text{Cluster}}$$

Only events with  $0.05 < |\Delta\phi_{\text{pred-reco}}| < 0.2$  are taken into account



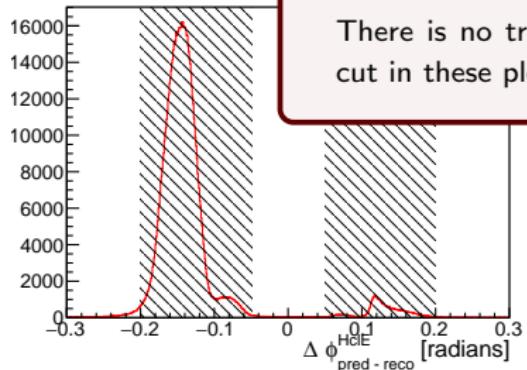
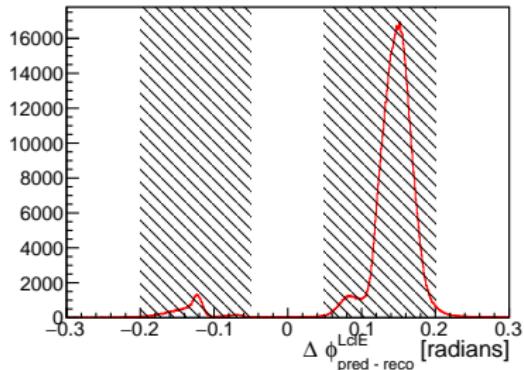
Phase3 Data:  $5.3 \cdot 10^7$  events survive (after trigger cut)

# Bhabha Event Selection



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Only events with  $0.05 < |\Delta\phi_{\text{pred-reco}}| < 0.2$  are taken into account



Phase3 Data:  $5.3 \cdot 10^7$  events survive (after trigger cut)

Phase3 MC:  $8.5 \cdot 10^5$  events survive

# Selection Of Momentum With Enough Statistics

As function of azimuthal angle

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

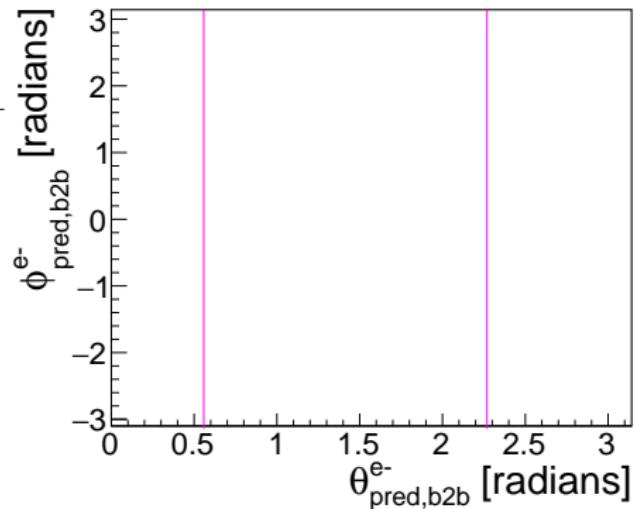
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$$p(e^-)$$

Forward End-Cap

Barrel

Backward End-Cap



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

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$$p$$

# Selection Of Momentum With Enough Statistics

As function of azimuthal angle

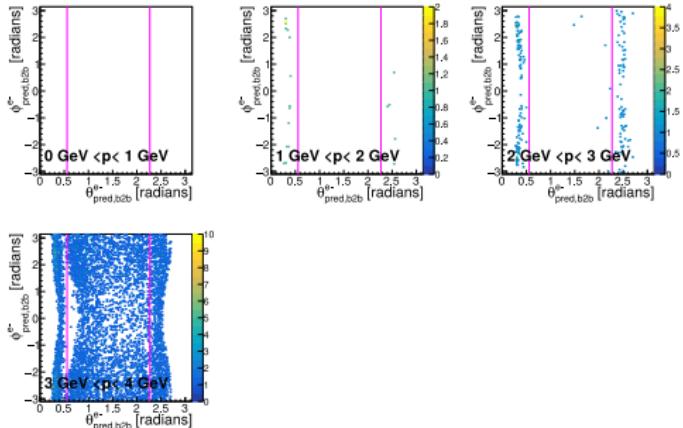
$$\phi_{\text{pred},\text{b2b}}$$

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Backward End-Cap



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

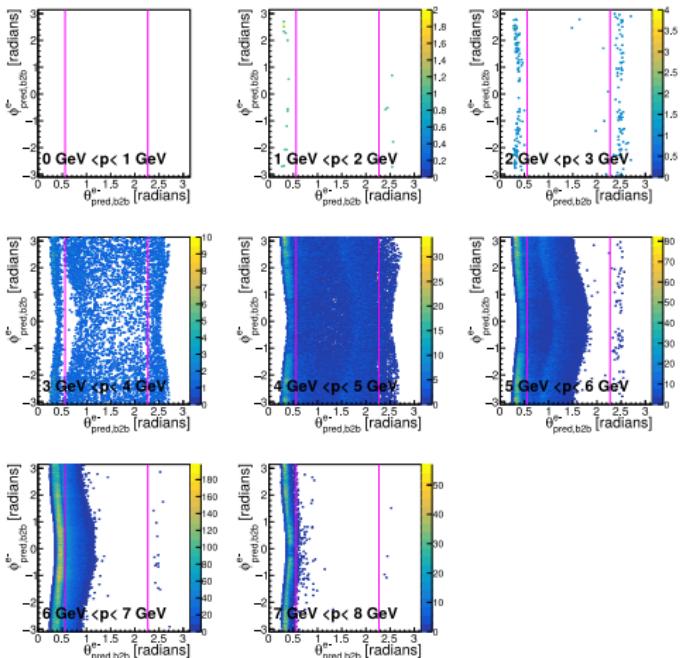
$$p$$

# Selection Of Momentum With Enough Statistics

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

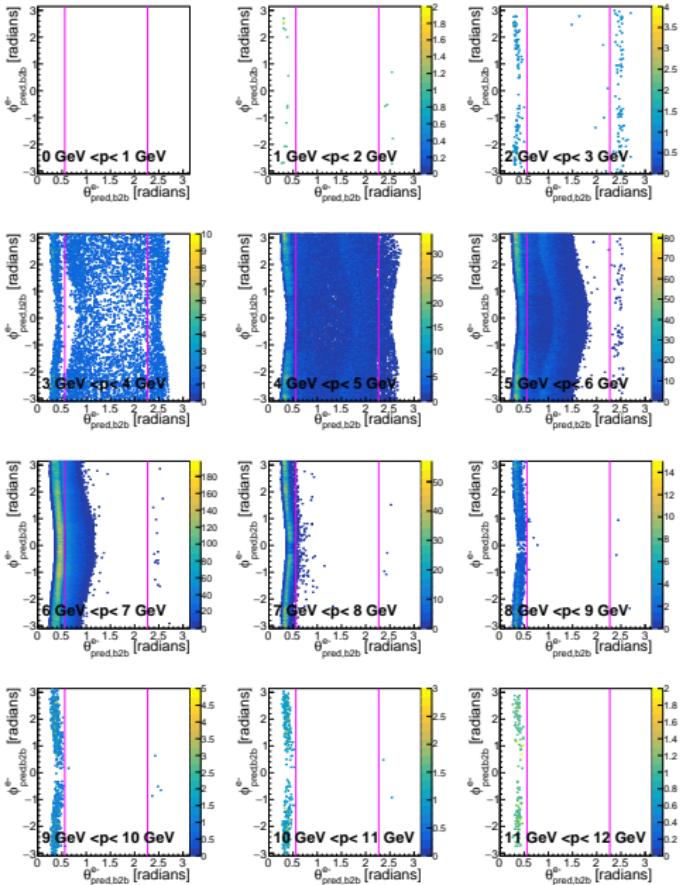
$p$

# Selection Of Momentum With Enough Statistics

As function of azimuthal angle

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

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



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

$p$

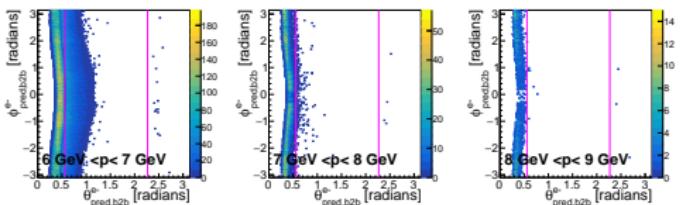
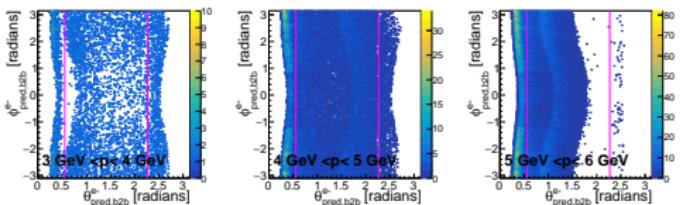
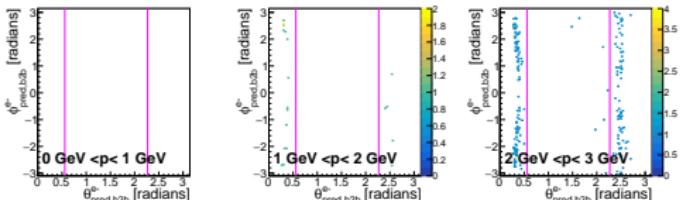
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As function of azimuthal angle

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

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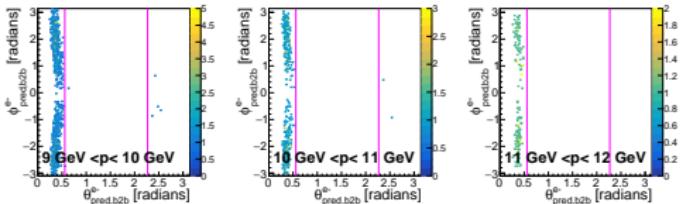
Forward End-Cap	4 GeV – 8 GeV
Barrel	4 GeV – 7 GeV
Backward End-Cap	/



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

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



# Selection Of Momentum With Enough Statistics

As function of azimuthal angle  $\phi_{\text{pred,b2b}}$

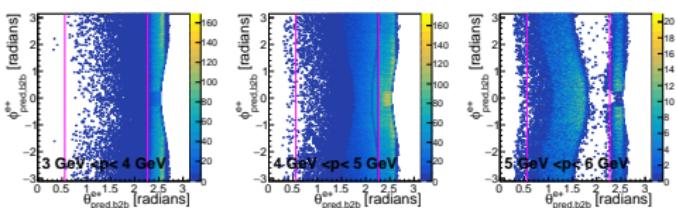
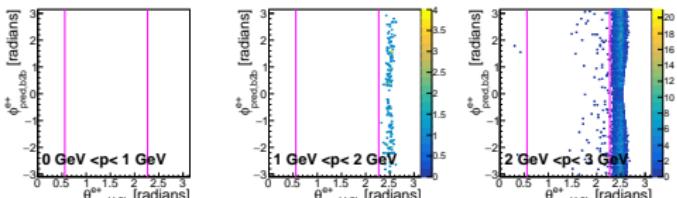
$$\phi_{\text{pred,b2b}}$$

$$p(e^-)$$

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

$$p(e^+)$$

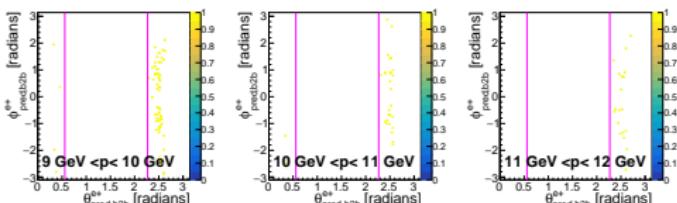
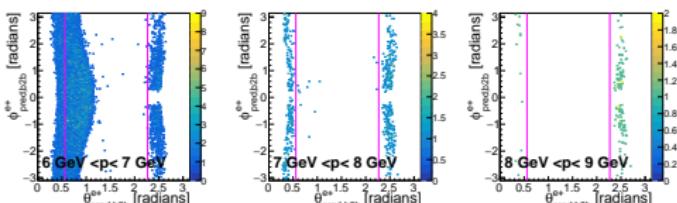
Forward End-Cap	/
Barrel	3 GeV – 7 GeV
Backward End-Cap	2 GeV – 6 GeV



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

$$p$$

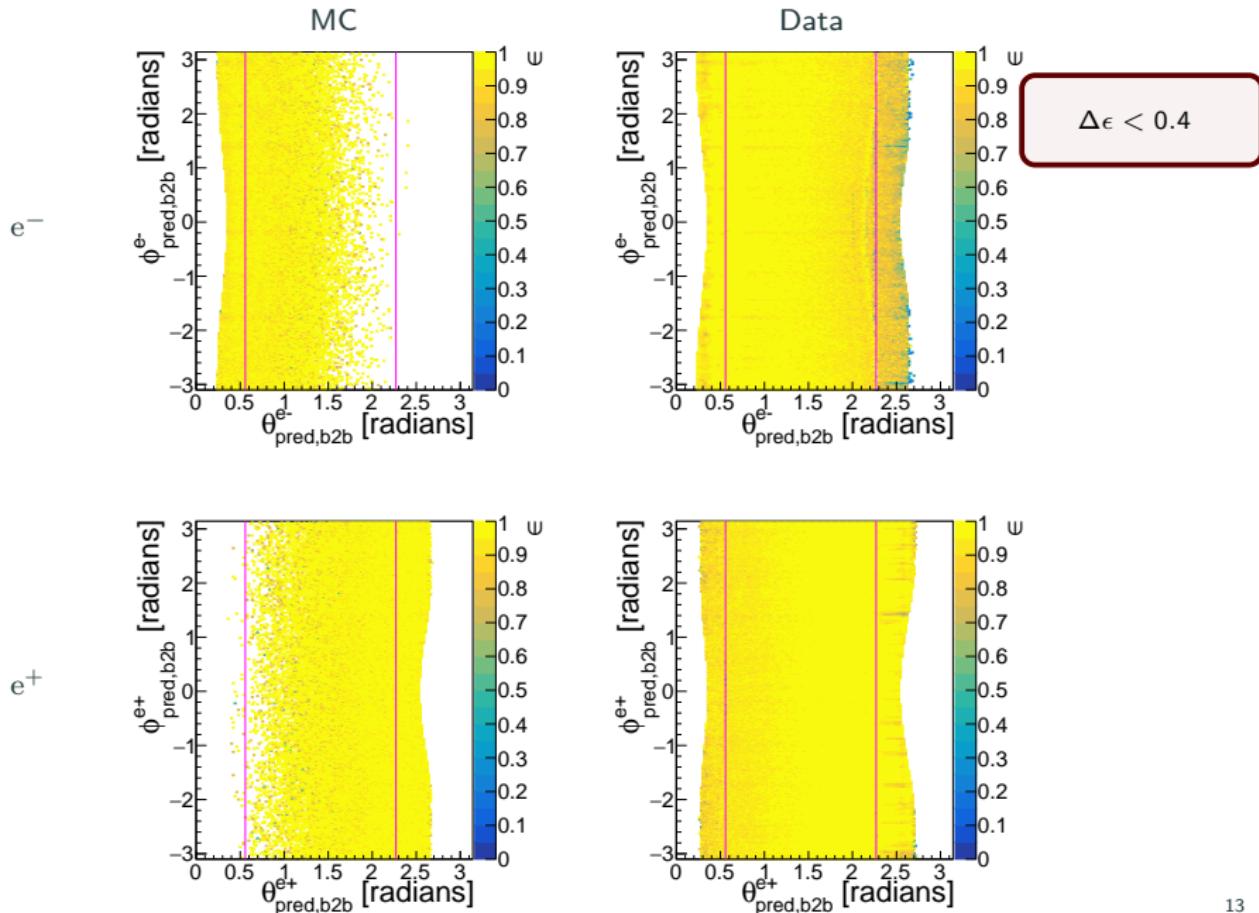
$e^-$	4 GeV – 9 GeV
$e^+$	2 GeV – 7 GeV



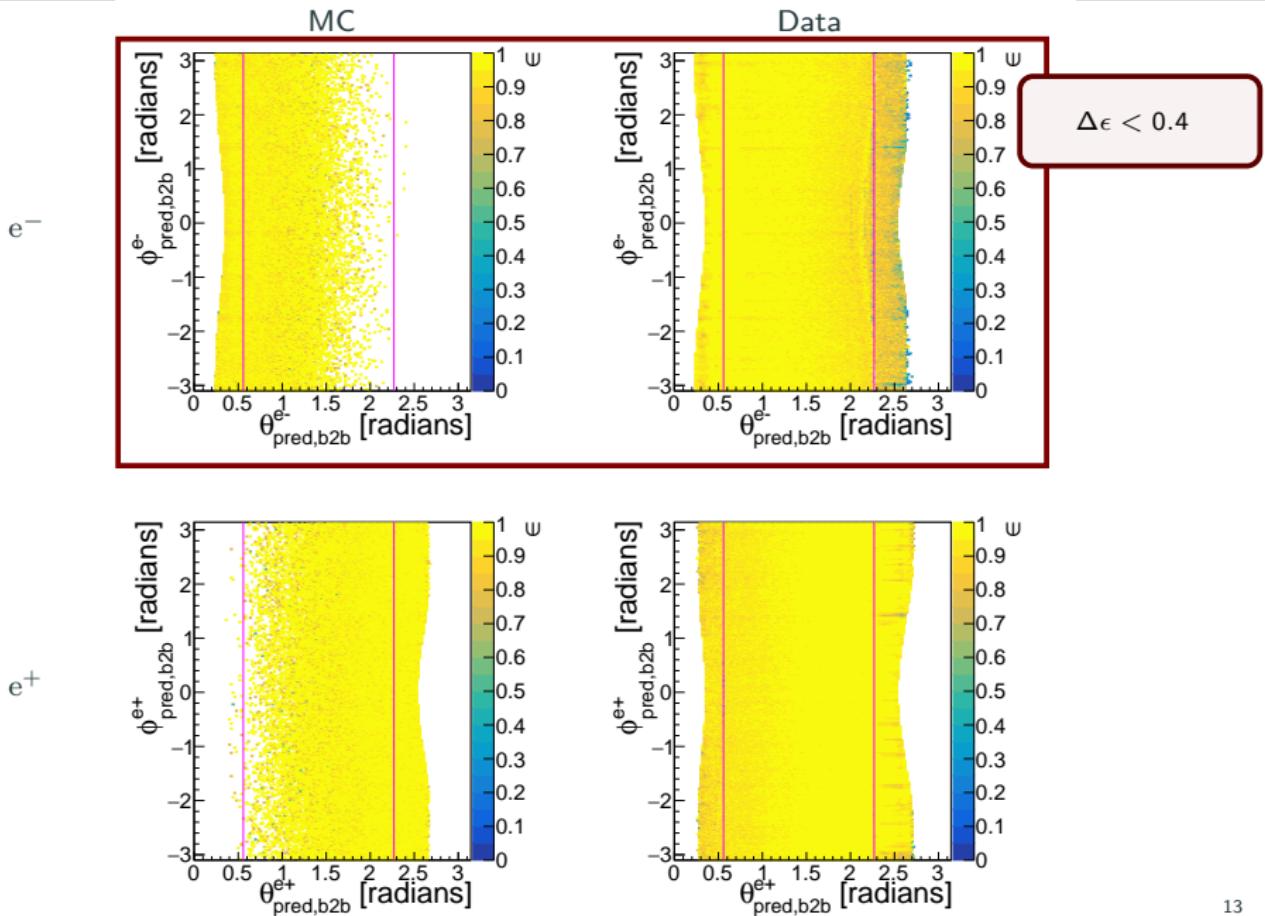
## Phase3 Tracking Efficiencies

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

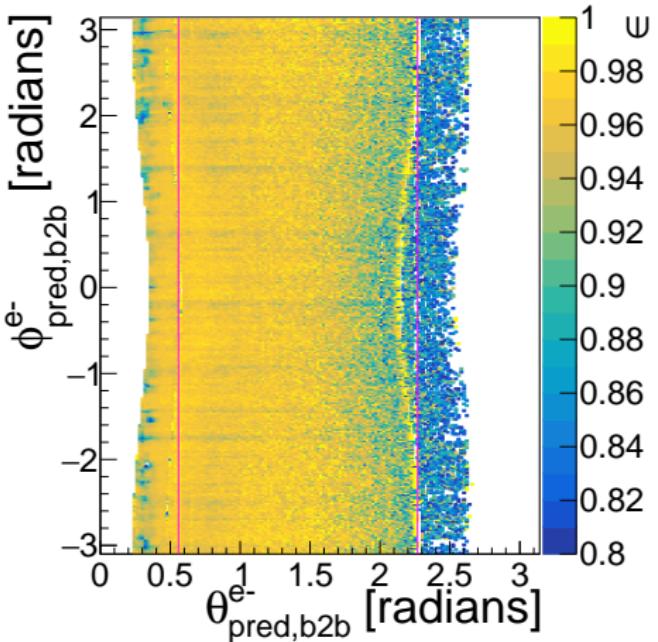


# Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}} - \phi_{\text{pred,b2b}}$



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

Phase3 Data

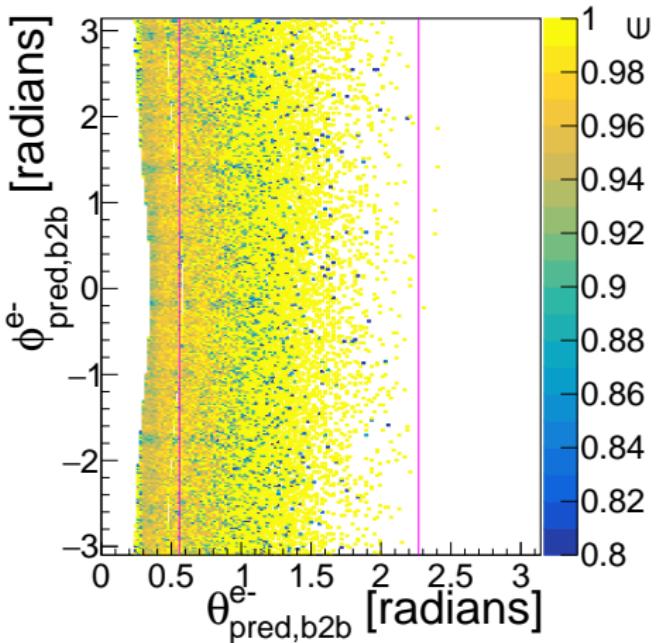


$\Delta\epsilon < 0.4$

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

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

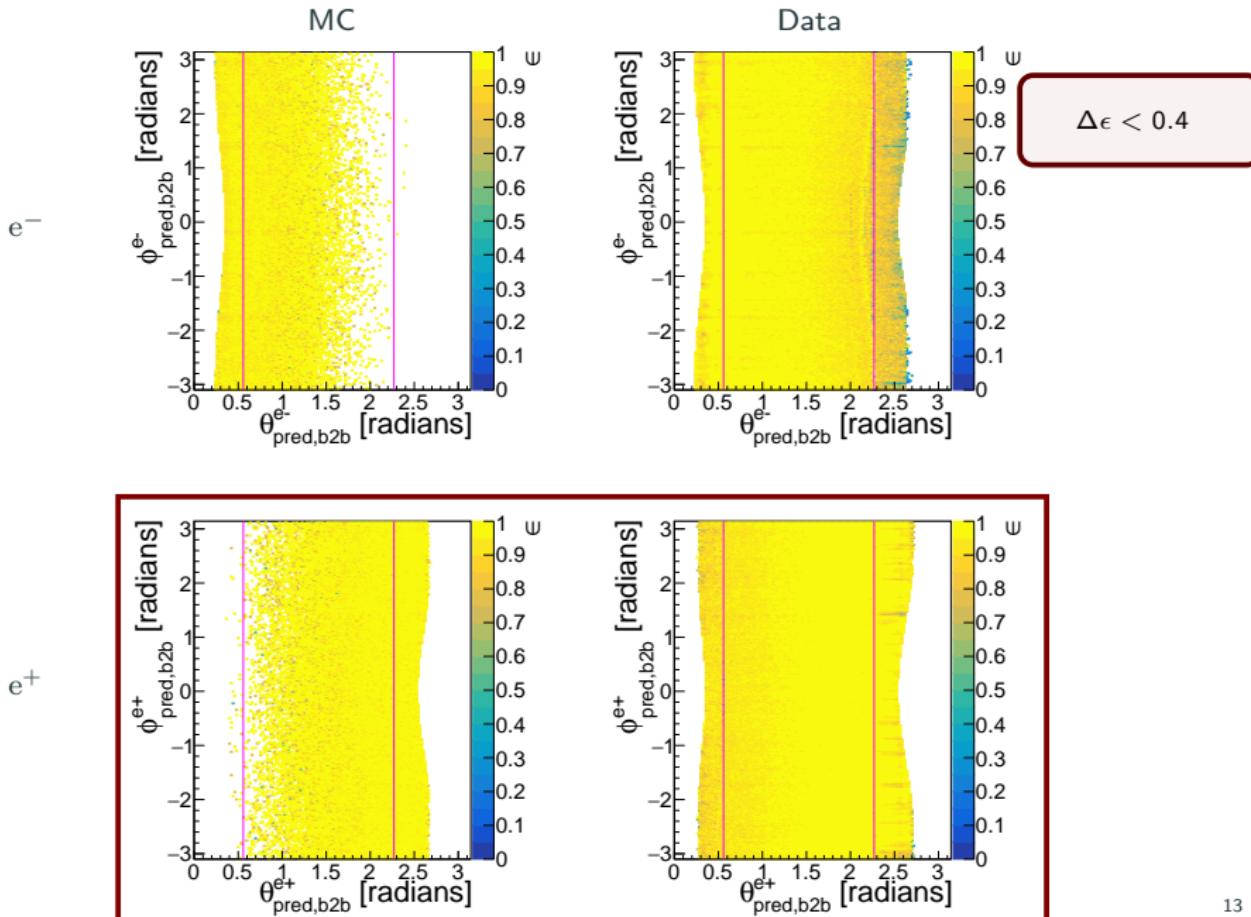
Phase3 MC



$\Delta\epsilon < 0.4$

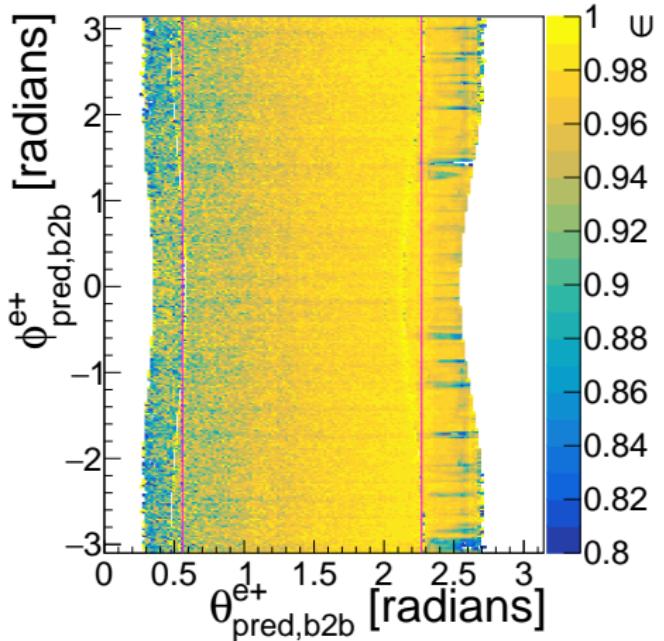
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Phase3 Data

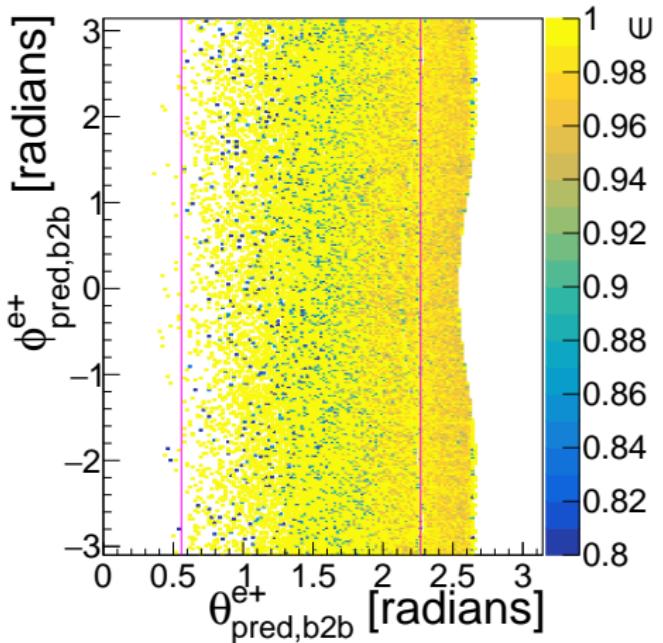


$$\Delta\epsilon < 0.4$$

The same kind of drops are also visible in the positron tracking efficiency in the backward end-cap

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

Phase3 MC



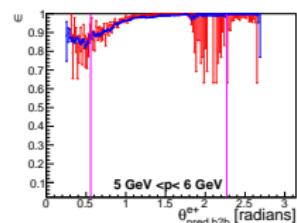
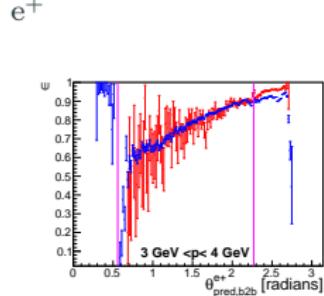
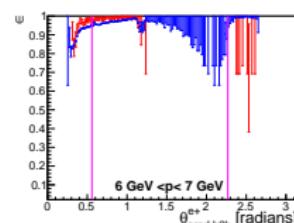
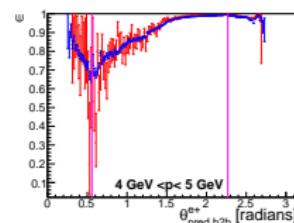
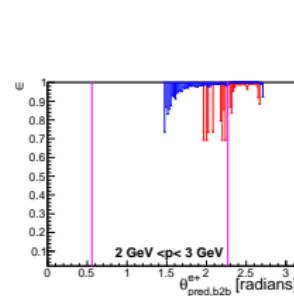
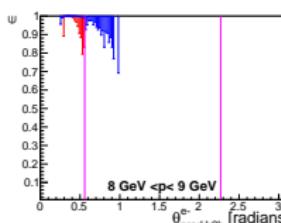
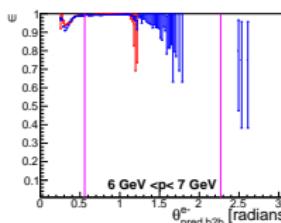
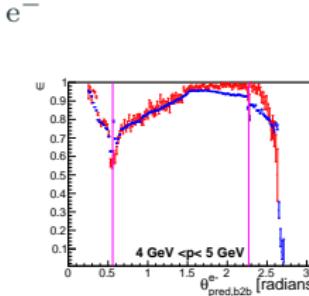
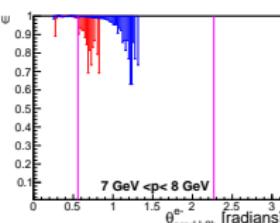
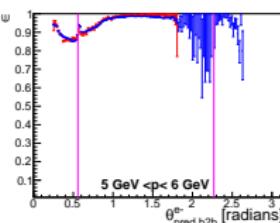
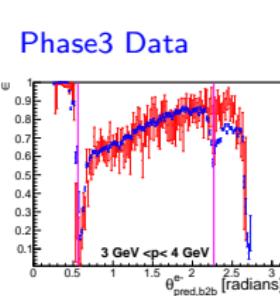
$\Delta\epsilon < 0.4$

The same kind of drops are also visible in the positron tracking efficiency in the backward end-cap

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

Phase3 MC

Phase3 Data

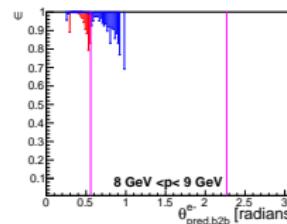
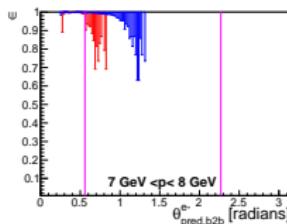
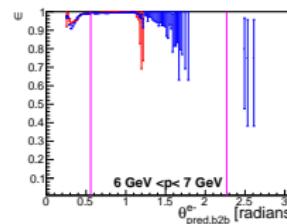
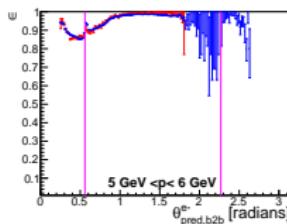
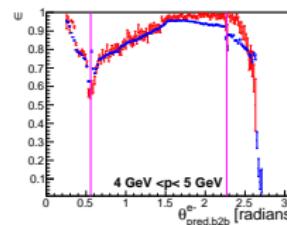
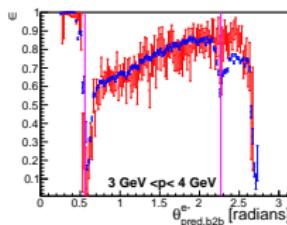


# Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase3 MC

Phase3 Data

e<sup>-</sup>



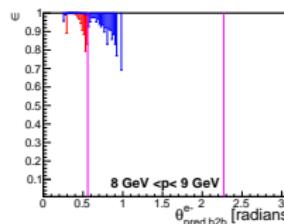
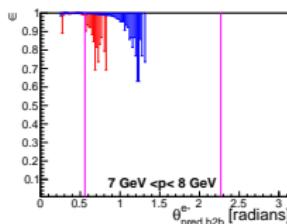
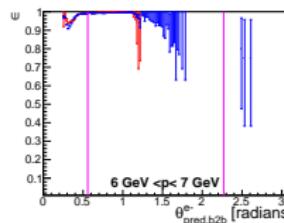
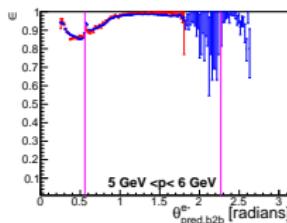
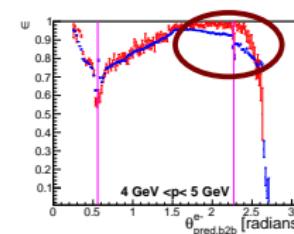
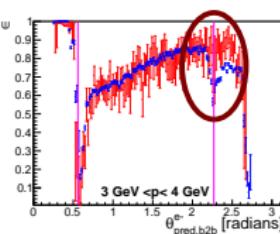
Electron Tracking Efficiency:

- Phase3 MC and phase3 data are very close to each other (an exception occurs for momenta between 3 GeV and 5 GeV)

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

Phase3 MC

Phase3 Data



Electron Tracking Efficiency:

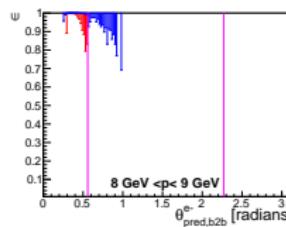
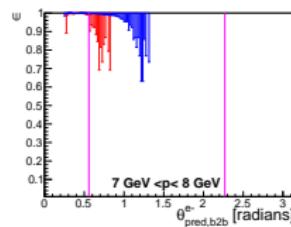
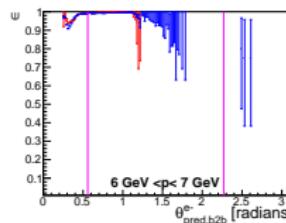
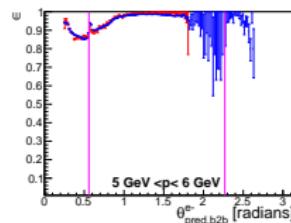
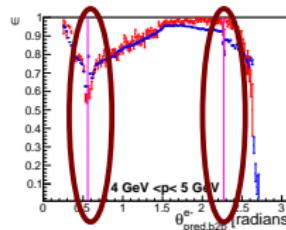
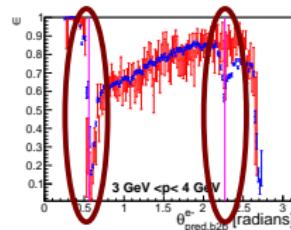
- Phase3 MC and phase3 data are very close to each other (an exception occurs for momenta between 3 GeV and 5 GeV)

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

Phase3 MC

e<sup>-</sup>

Phase3 Data



Electron Tracking Efficiency:

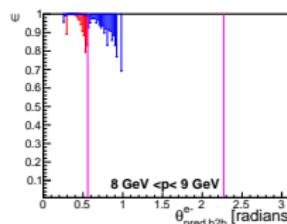
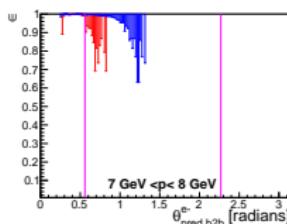
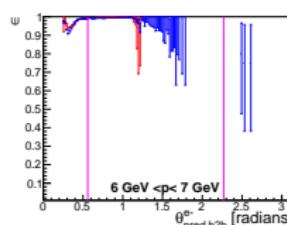
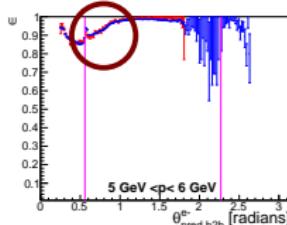
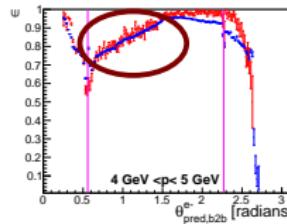
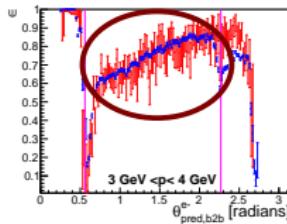
- Phase3 MC and phase3 data are very close to each other (an exception occurs for momenta between 3 GeV and 5 GeV)
- Efficiency drops at transition between barrel and end-caps

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

Phase3 MC

Phase3 Data

e<sup>-</sup>



Electron Tracking Efficiency:

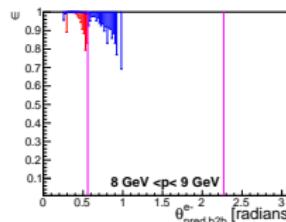
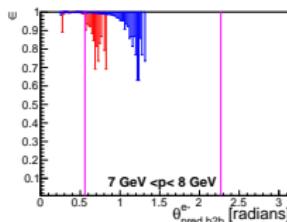
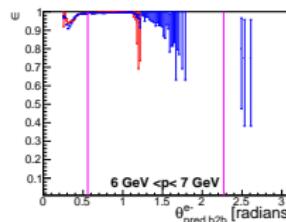
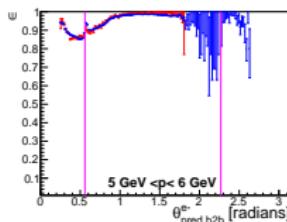
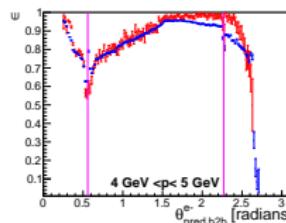
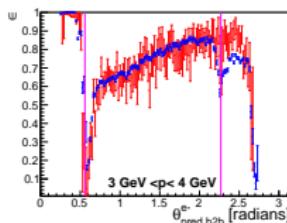
- Phase3 MC and phase3 data are very close to each other (an exception occurs for momenta between 3 GeV and 5 GeV)
- Efficiency drops at transition between barrel and end-caps
- There is a slope in the barrel

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

Phase3 MC

Phase3 Data

e<sup>-</sup>



Electron Tracking Efficiency:

- Phase3 MC and phase3 data are very close to each other (an exception occurs for momenta between 3 GeV and 5 GeV)
- Efficiency drops at transition between barrel and end-caps
- There is a slope in the barrel

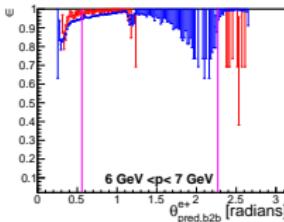
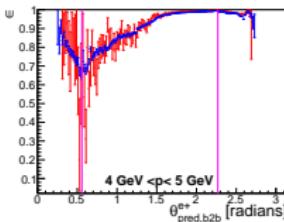
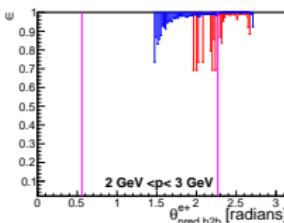
# Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

## Positron Tracking Efficiency:

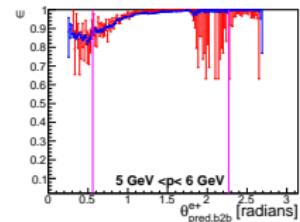
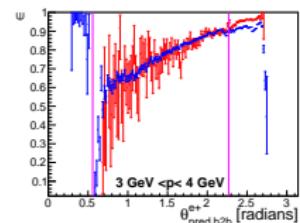
- The tracking efficiency of phase3 MC and phase3 data are close to each other (an exception occurs in the backward end-cap for momenta between 3 GeV and 4 GeV and between 6 GeV and 7 GeV)

Phase3 MC

Phase3 Data



e<sup>+</sup>



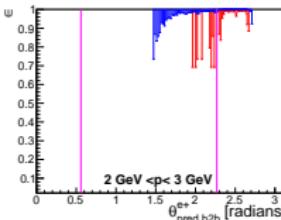
# Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

## Positron Tracking Efficiency:

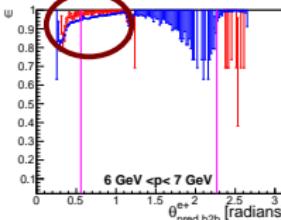
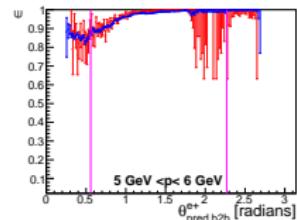
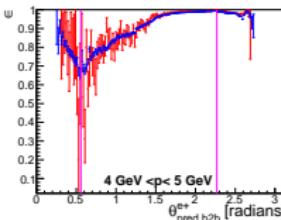
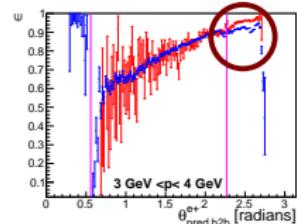
- The tracking efficiency of phase3 MC and phase3 data are close to each other (an exception occurs in the backward end-cap for momenta between 3 GeV and 4 GeV and between 6 GeV and 7 GeV)

Phase3 MC

Phase3 Data



e<sup>+</sup>



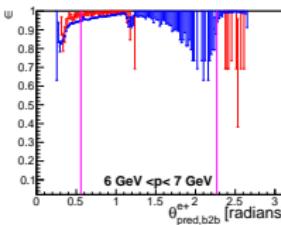
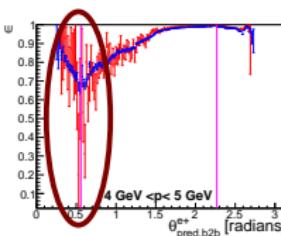
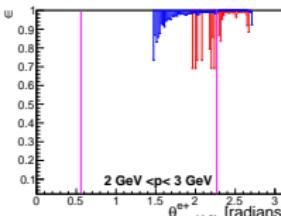
# Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

## Positron Tracking Efficiency:

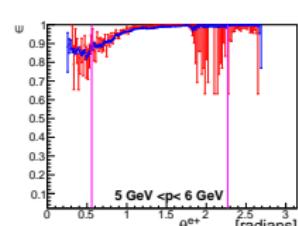
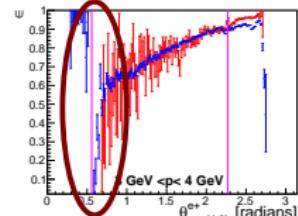
- The tracking efficiency of phase3 MC and phase3 data are close to each other (an exception occurs in the backward end-cap for momenta between 3 GeV and 4 GeV and between 6 GeV and 7 GeV)
- Efficiency drops at transition between barrel and end-caps

Phase3 MC

Phase3 Data



$e^+$



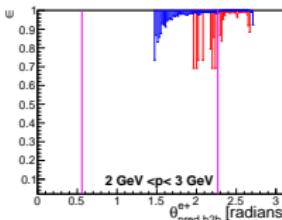
# Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

## Positron Tracking Efficiency:

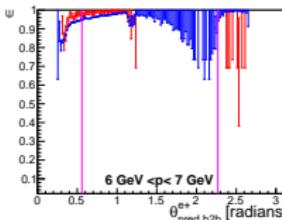
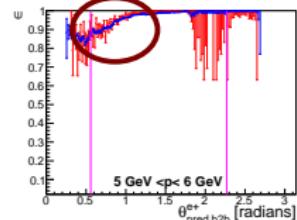
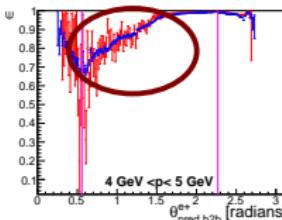
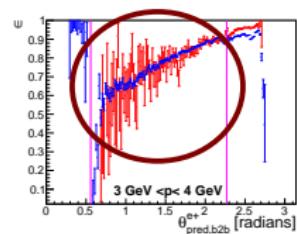
- The tracking efficiency of phase3 MC and phase3 data are close to each other (an exception occurs in the backward end-cap for momenta between 3 GeV and 4 GeV and between 6 GeV and 7 GeV)
- Efficiency drops at transition between barrel and end-caps
- There is a slope in the barrel

Phase3 MC

Phase3 Data



e<sup>+</sup>



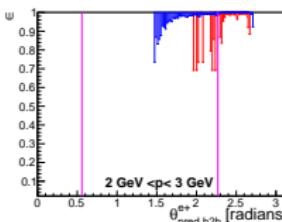
# Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

## Positron Tracking Efficiency:

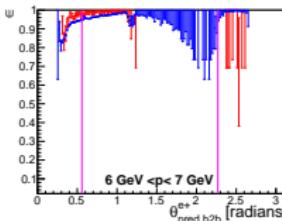
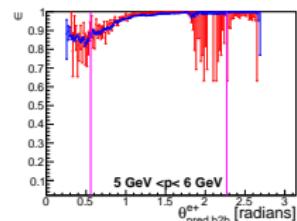
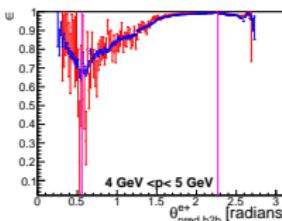
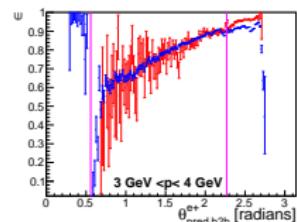
- The tracking efficiency of phase3 MC and phase3 data are close to each other (an exception occurs in the backward end-cap for momenta between 3 GeV and 4 GeV and between 6 GeV and 7 GeV)
- Efficiency drops at transition between barrel and end-caps
- There is a slope in the barrel

Phase3 MC

Phase3 Data



e<sup>+</sup>

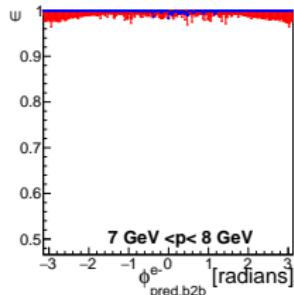
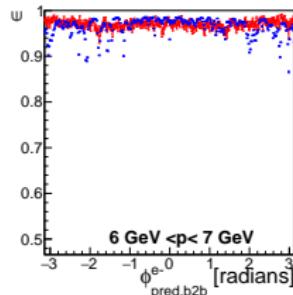
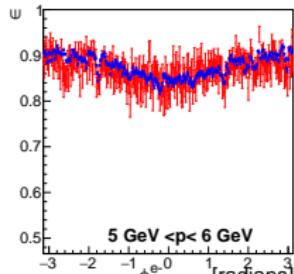
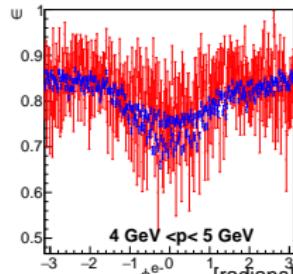


# Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Forward End-Cap

Phase3 MC

Phase3 Data

e<sup>-</sup>



e<sup>+</sup>

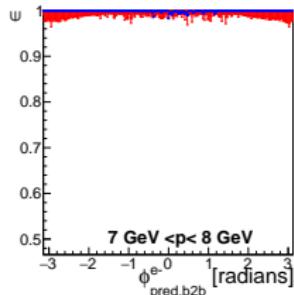
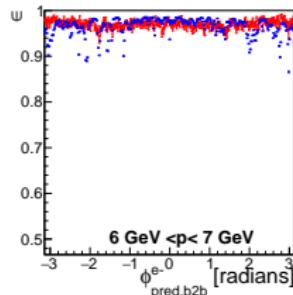
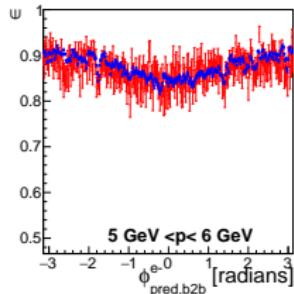
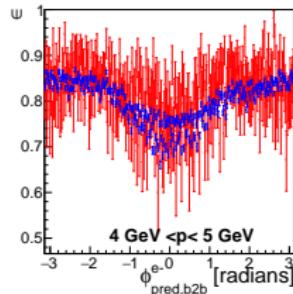
Not enough statistics to calculate the positron tracking efficiency in the forward end-cap

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

Phase3 MC

Phase3 Data

e<sup>-</sup>



Electron Tracking Efficiency:

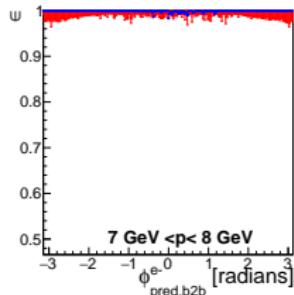
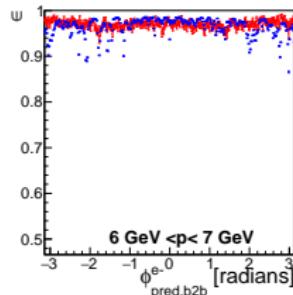
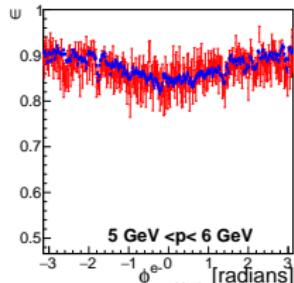
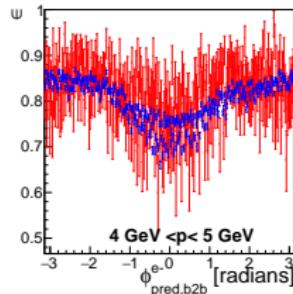
- Highest tracking efficiency for momenta between 7 GeV and 8 GeV

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

Phase3 MC

e<sup>-</sup>

Phase3 Data



Electron Tracking Efficiency:

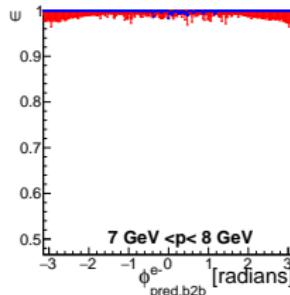
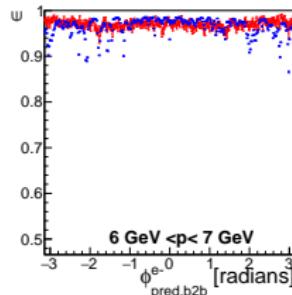
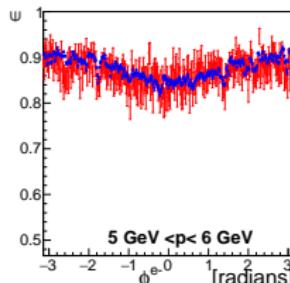
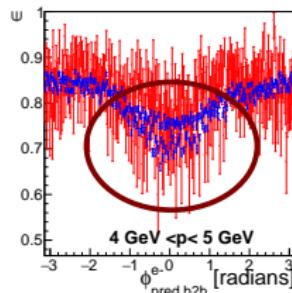
- Highest tracking efficiency for momenta between 7 GeV and 8 GeV
- Minimum at  $\phi_{\text{pred,b2b}} \approx 0$  for momenta between 4 GeV and 6 GeV

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

Phase3 MC

e<sup>-</sup>

Phase3 Data



Electron Tracking Efficiency:

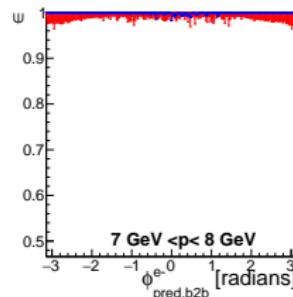
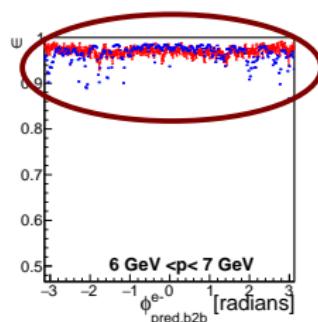
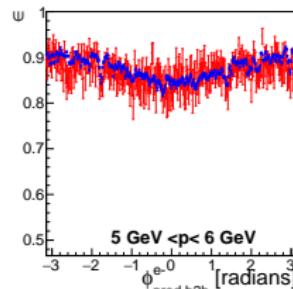
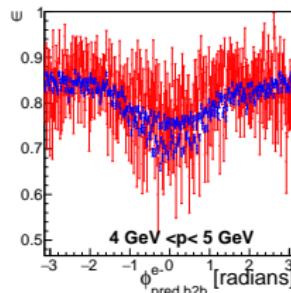
- Highest tracking efficiency for momenta between 7 GeV and 8 GeV
- Minimum at  $\phi_{\text{pred,b2b}} \approx 0$  for momenta between 4 GeV and 6 GeV
- Weird *ribbon* structure in the phase3 data tracking efficiency at  $\phi_{\text{pred,b2b}} \approx 0$  for momenta between 4 GeV and 5 GeV

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

Phase3 MC

e<sup>-</sup>

Phase3 Data



## Electron Tracking Efficiency:

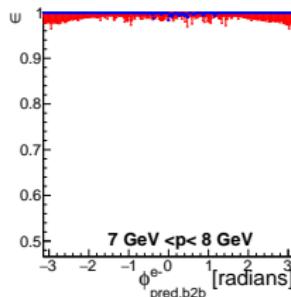
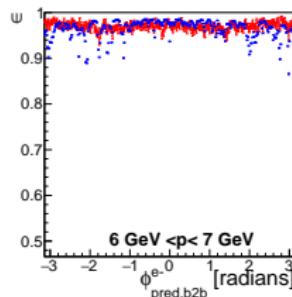
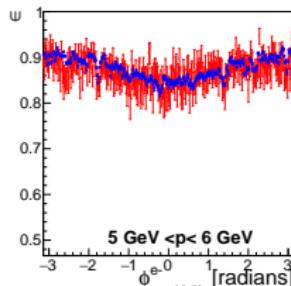
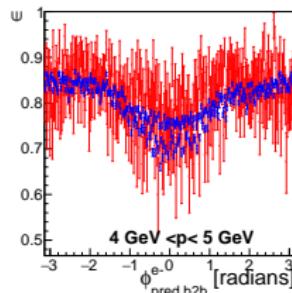
- Highest tracking efficiency for momenta between 7 GeV and 8 GeV
- Minimum at  $\phi_{\text{pred,b2b}} \approx 0$  for momenta between 4 GeV and 6 GeV
- Weird *ribbon* structure in the phase3 data tracking efficiency at  $\phi_{\text{pred,b2b}} \approx 0$  for momenta between 4 GeV and 5 GeV
- Weird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

e<sup>-</sup>

Phase3 Data



## Electron Tracking Efficiency:

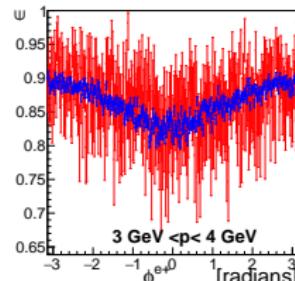
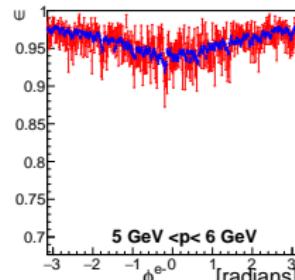
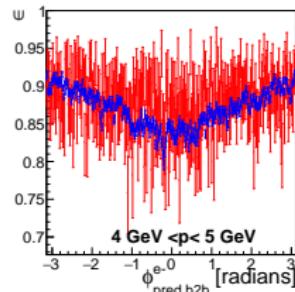
- Highest tracking efficiency for momenta between 7 GeV and 8 GeV
- Minimum at  $\phi_{\text{pred,b2b}} \approx 0$  for momenta between 4 GeV and 6 GeV
- Weird *ribbon* structure in the phase3 data tracking efficiency at  $\phi_{\text{pred,b2b}} \approx 0$  for momenta between 4 GeV and 5 GeV
- Weird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

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

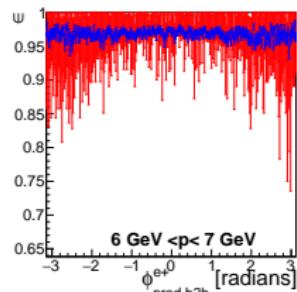
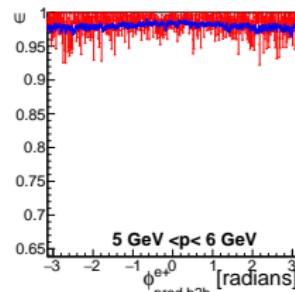
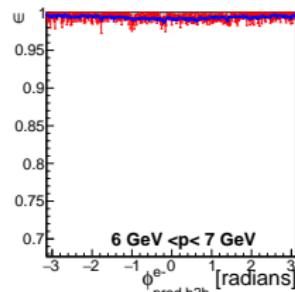
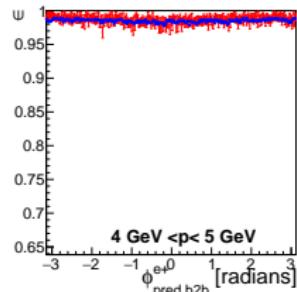
Phase3 MC

$e^-$

Phase3 Data



$e^+$

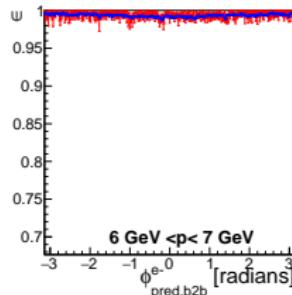
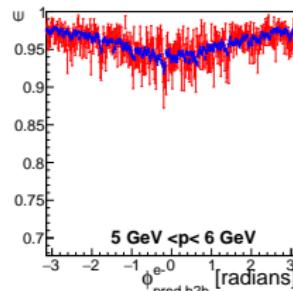
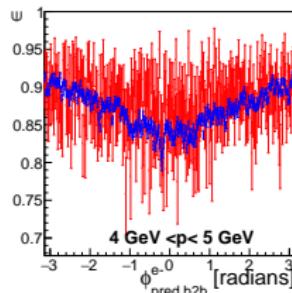


# Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Barrel

Phase3 MC

e<sup>-</sup>

Phase3 Data



## Electron Tracking Efficiency:

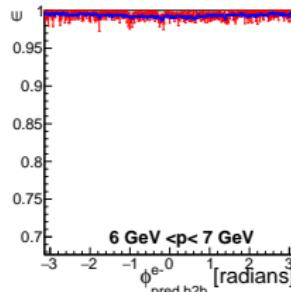
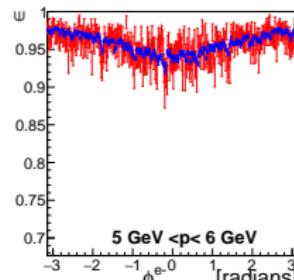
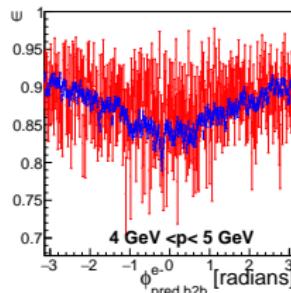
- Highest tracking efficiency for momenta between 6 GeV and 7 GeV
- Lowest tracking efficiency for momenta between 4 GeV and 5 GeV

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

Phase3 MC

e<sup>-</sup>

Phase3 Data



## 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

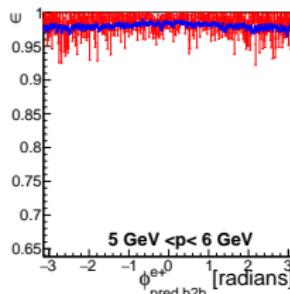
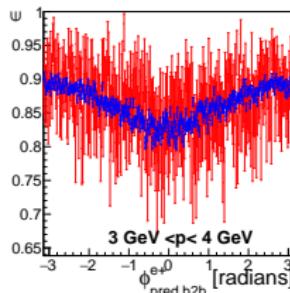
# Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Barrel

## Positron Tracking Efficiency:

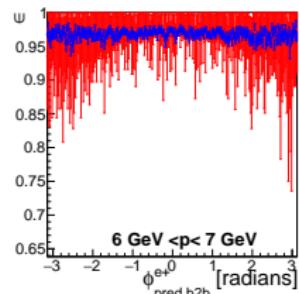
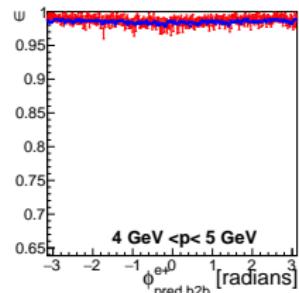
- Highest tracking efficiency for momenta between 4 GeV and 6 GeV
- Lowest tracking efficiency for momenta between 3 GeV and 4 GeV

Phase3 MC

Phase3 Data



$e^+$



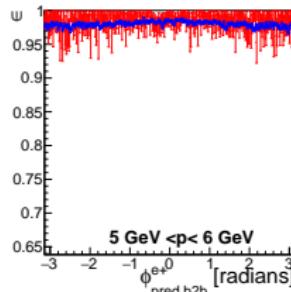
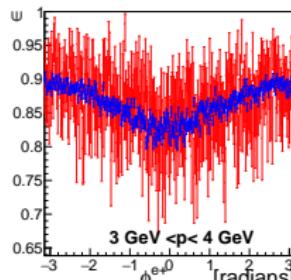
# Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Barrel

## Positron Tracking Efficiency:

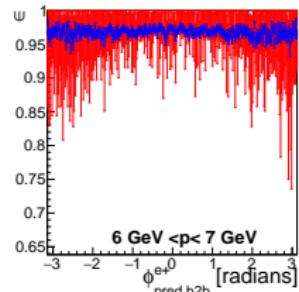
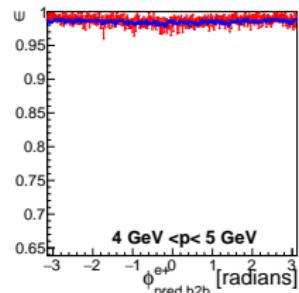
- Highest tracking efficiency for momenta between 4 GeV and 6 GeV
- Lowest tracking efficiency for momenta between 3 GeV and 4 GeV
- Minimum at  $\phi_{\text{pred,b2b}} \approx 0$  for momenta between 3 GeV and 4 GeV

Phase3 MC

Phase3 Data



$e^+$



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

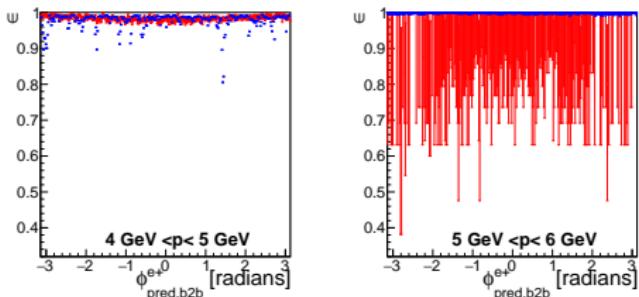
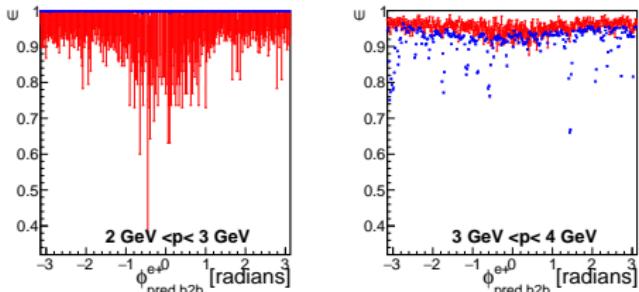
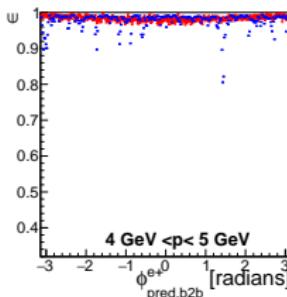
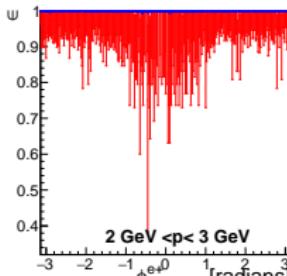
Phase3 MC

e<sup>-</sup>

Phase3 Data

Not enough statistics to calculate the positron tracking efficiency in the forward end-cap

e<sup>+</sup>



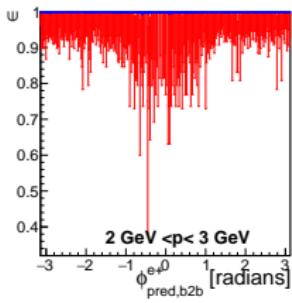
# Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

## Positron Tracking Efficiency:

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

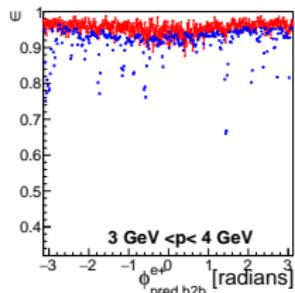
Phase3 MC

Phase3 Data

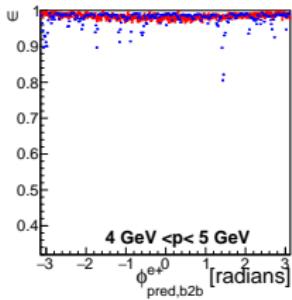


2 GeV  $< p <$  3 GeV

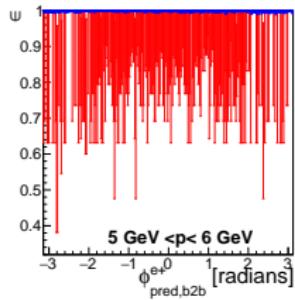
e<sup>+</sup>



3 GeV  $< p <$  4 GeV



4 GeV  $< p <$  5 GeV



5 GeV  $< p <$  6 GeV

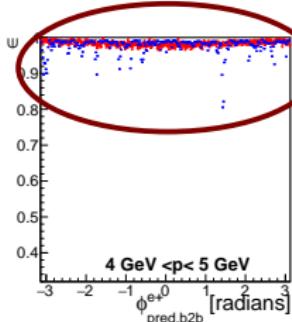
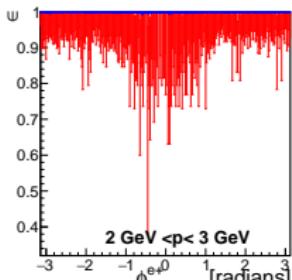
# Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

Positron Tracking Efficiency:

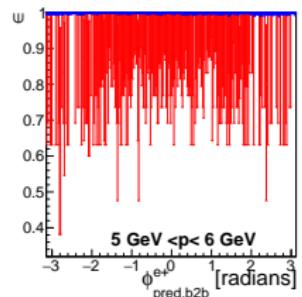
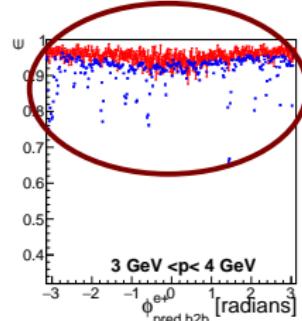
- The highest phase3 data tracking efficiency occurs for momenta between 2 GeV and 3 GeV and 5 GeV and 6 GeV
- Weird efficiency drops in the phase3 data tracking efficiency for momenta between 3 GeV and 5 GeV

Phase3 MC

Phase3 Data



e<sup>+</sup>



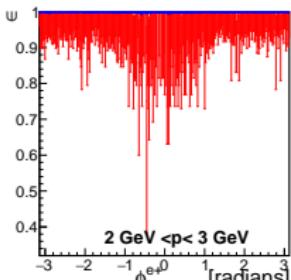
# Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

## Positron Tracking Efficiency:

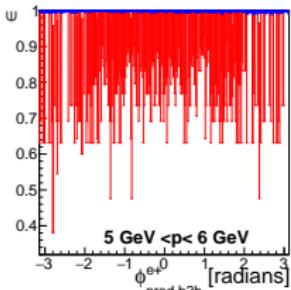
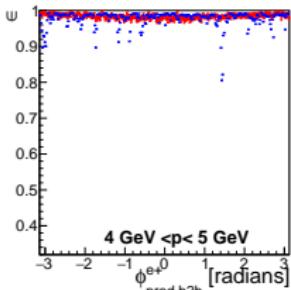
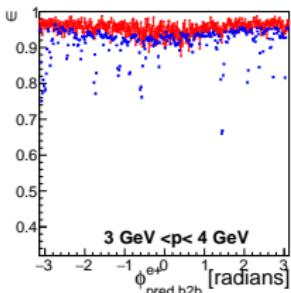
- The highest phase3 data tracking efficiency occurs for momenta between 2 GeV and 3 GeV and 5 GeV and 6 GeV
- Weird efficiency drops in the phase3 data tracking efficiency for momenta between 3 GeV and 5 GeV

Phase3 MC

Phase3 Data



$e^+$



## Comparing The Tracking Efficiency Of Phase2 Data with Phase3 Data

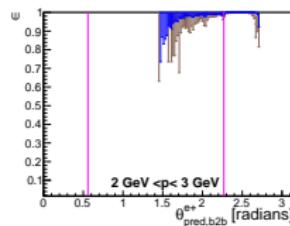
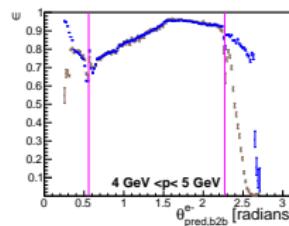
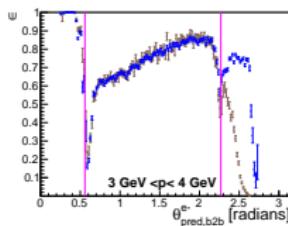
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# Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

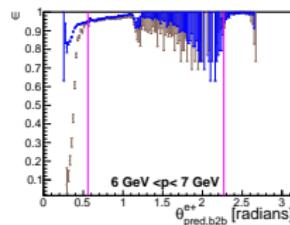
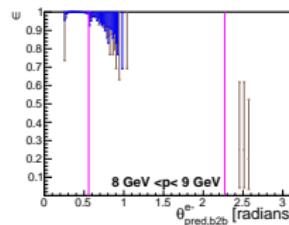
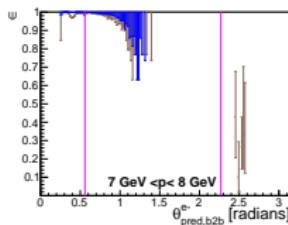
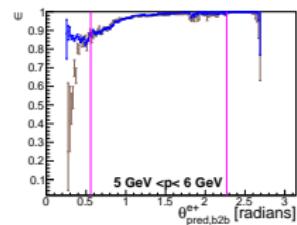
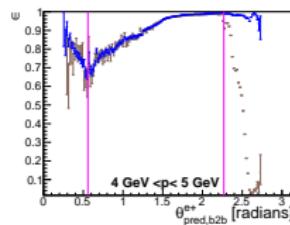
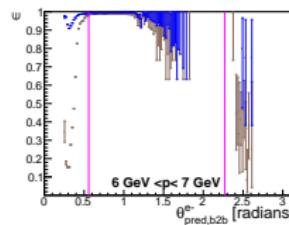
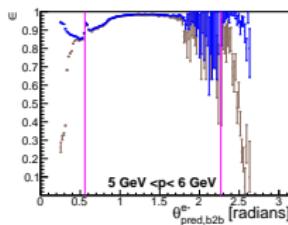
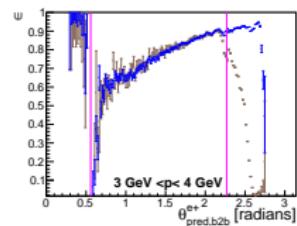
Phase2 Data

$e^-$

Phase3 Data



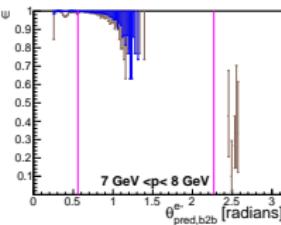
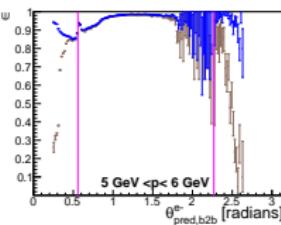
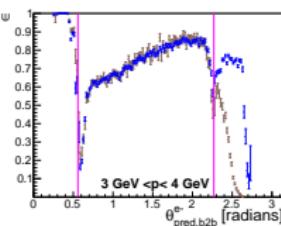
$e^+$



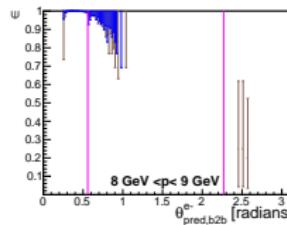
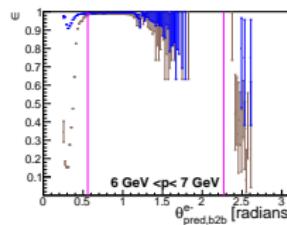
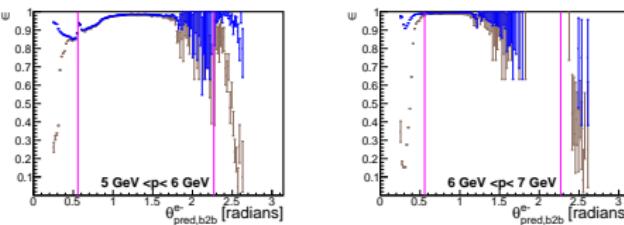
# Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 Data

Phase3 Data



$e^-$



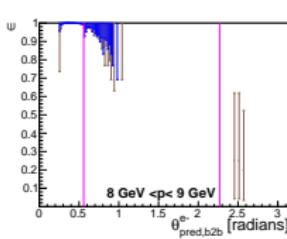
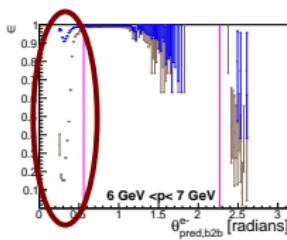
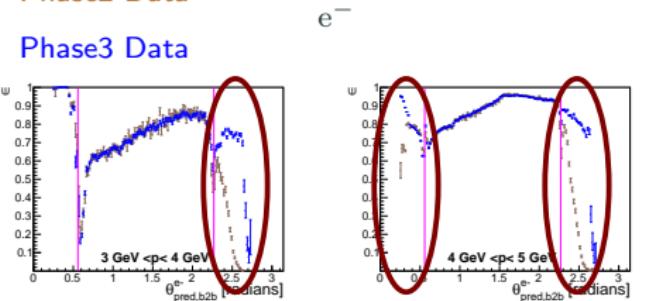
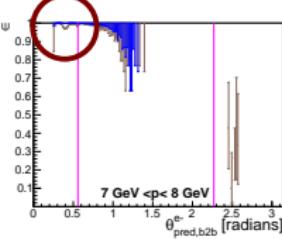
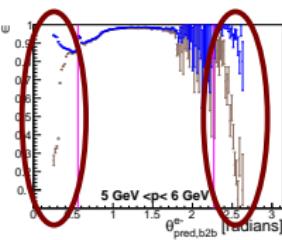
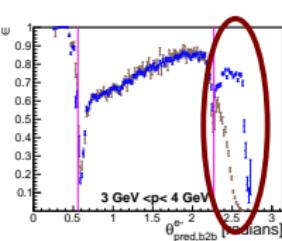
Electron Tracking Efficiency:

- Drastic improvement in the end-caps

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

Phase2 Data

Phase3 Data



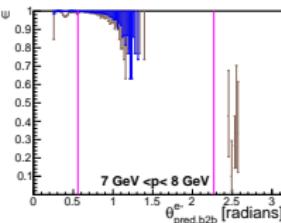
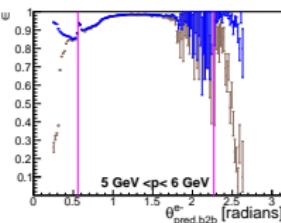
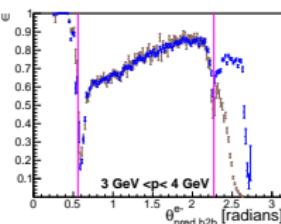
Electron Tracking Efficiency:

- Drastic improvement in the end-caps

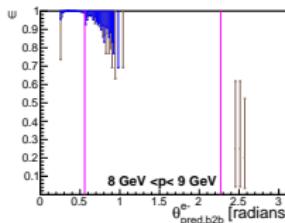
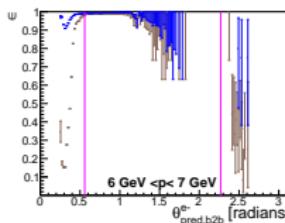
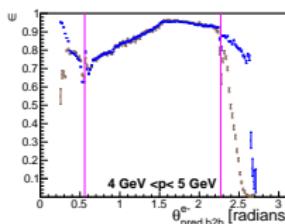
# Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 Data

Phase3 Data



$e^-$



Electron Tracking Efficiency:

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

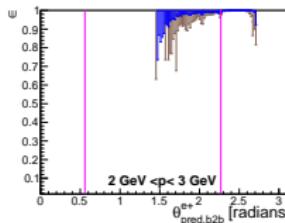
# Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Positron Tracking Efficiency:

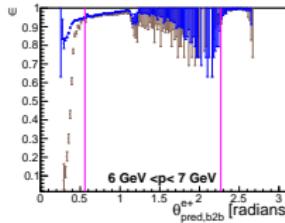
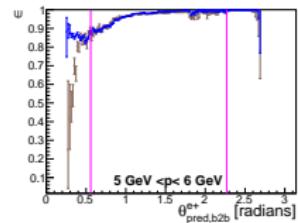
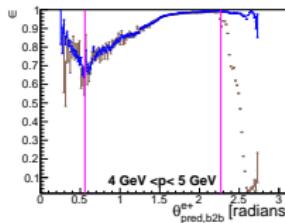
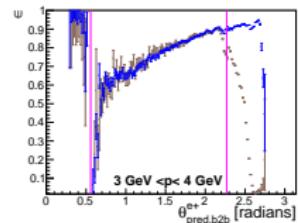
- Drastic improvement in the end-caps

Phase2 Data

Phase3 Data



$e^+$



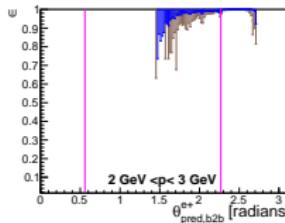
# Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Positron Tracking Efficiency:

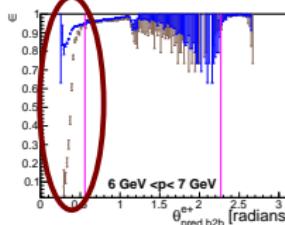
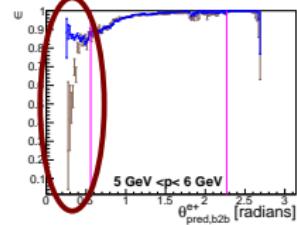
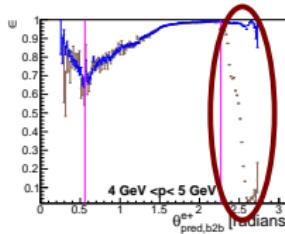
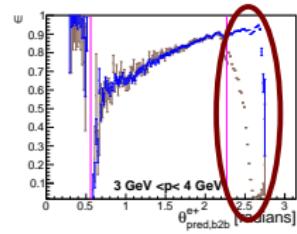
- Drastic improvement in the end-caps

Phase2 Data

Phase3 Data



$e^+$



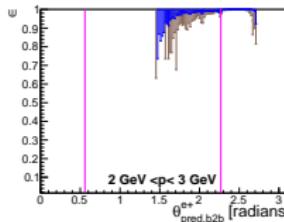
# Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

## Positron Tracking Efficiency:

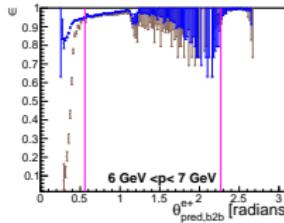
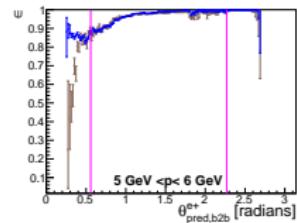
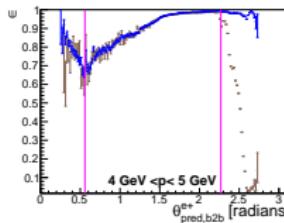
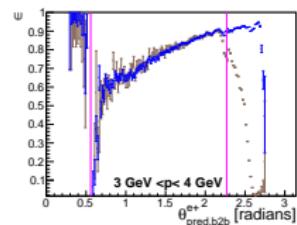
- Drastic improvement in the end-caps
- Tracking efficiency in the barrel stayed more or less the same

Phase2 Data

Phase3 Data

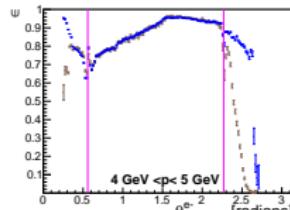
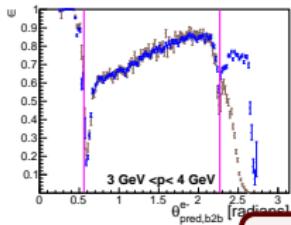


e<sup>+</sup>



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

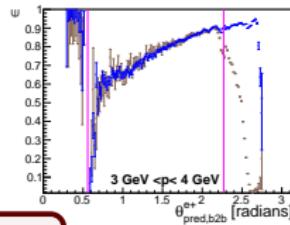
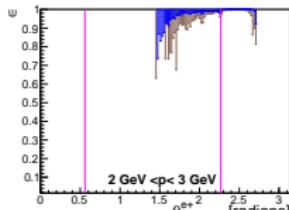
$e^-$



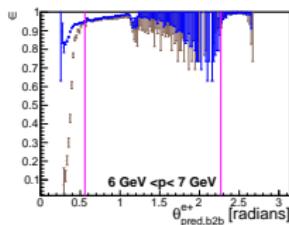
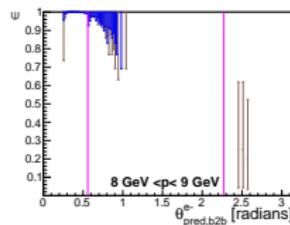
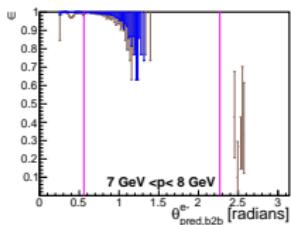
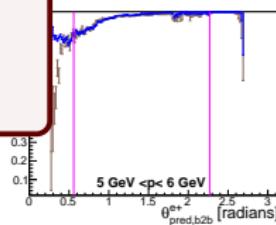
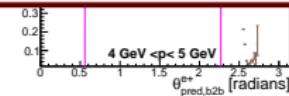
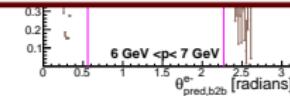
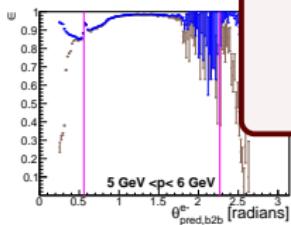
Phase2 Data

Phase3 Data

$e^+$

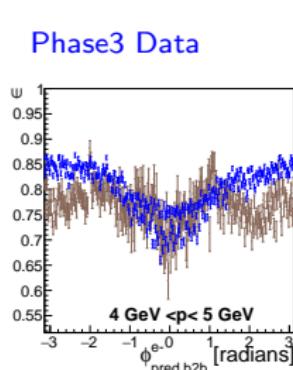


We will only compare the tracking efficiencies for electrons in the forward end-cap and the tracking efficiencies for positrons in the backward end-cap

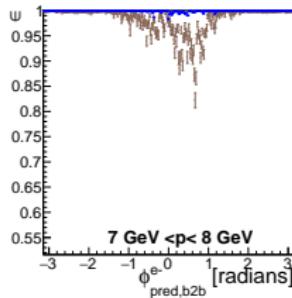
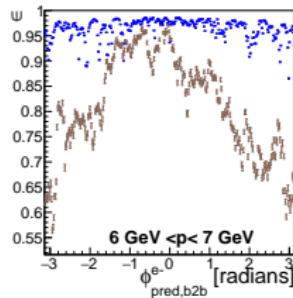
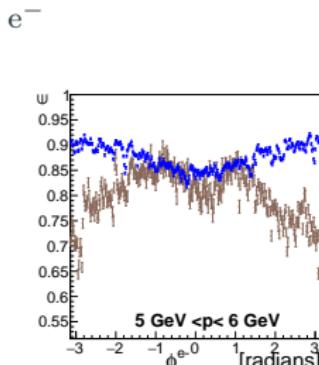


# Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Forward End-Cap

Phase2 Data



Phase3 Data



Electron Tracking Efficiency:

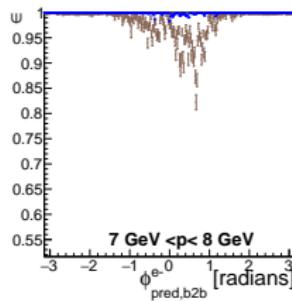
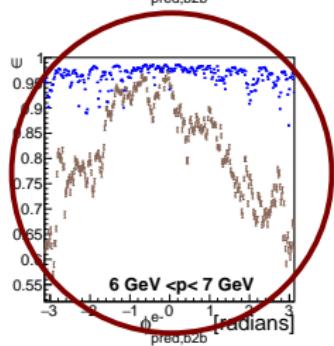
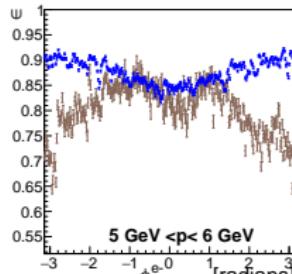
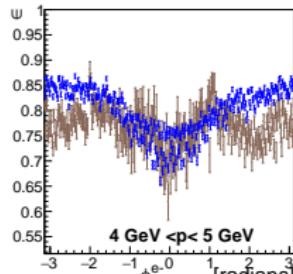
- The tracking efficiency improved for all  $\phi_{\text{pred,b2b}}$

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

Phase2 Data

e<sup>-</sup>

Phase3 Data

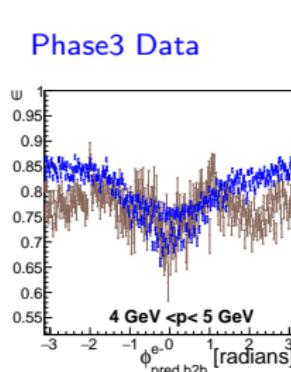


Electron Tracking Efficiency:

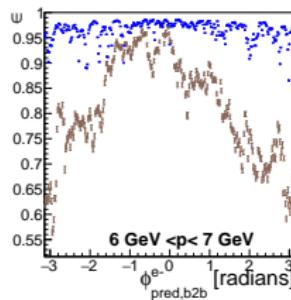
- The tracking efficiency improved for all  $\phi_{\text{pred,b2b}}$
- The tracking efficiency improved drastically for momenta between 6 GeV and 7 GeV

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

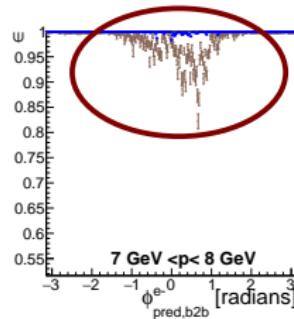
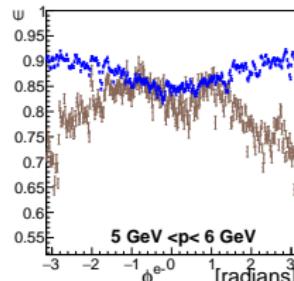
Phase2 Data



Phase3 Data



$e^-$



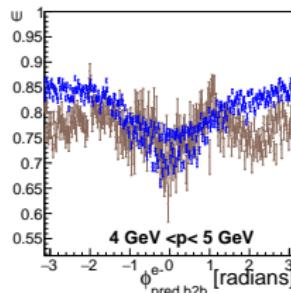
Electron Tracking Efficiency:

- The tracking efficiency improved for all  $\phi_{\text{pred},\text{b2b}}$
- 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

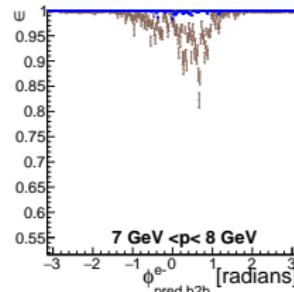
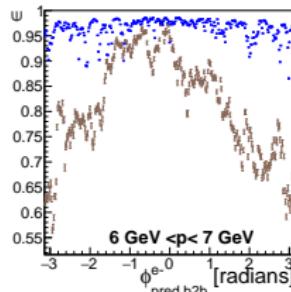
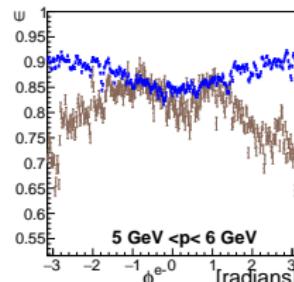
# Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Forward End-Cap

Phase2 Data

Phase3 Data



$e^-$



Electron Tracking Efficiency:

- The tracking efficiency improved for all  $\phi_{\text{pred,b2b}}$
- 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

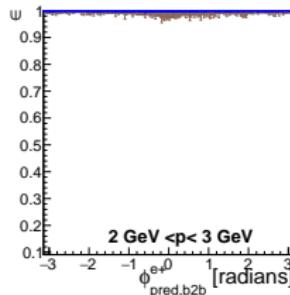
# Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

Positron Tracking Efficiency:

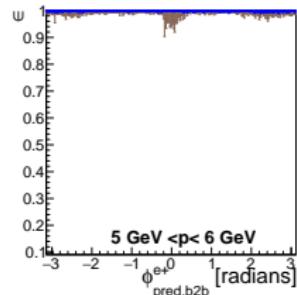
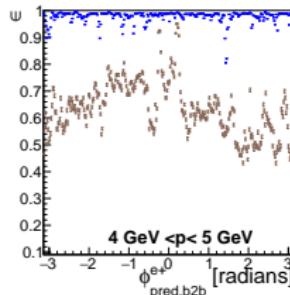
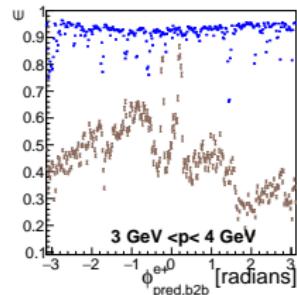
- The tracking efficiencies for momenta between 2 GeV and 3 GeV and between 5 GeV and 6 GeV look very similar

Phase2 Data

Phase3 Data



$e^+$



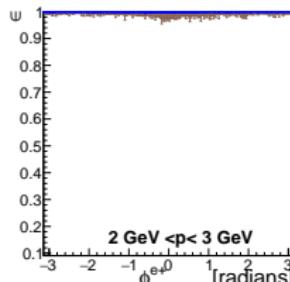
# Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

## Positron Tracking Efficiency:

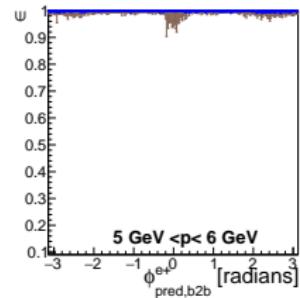
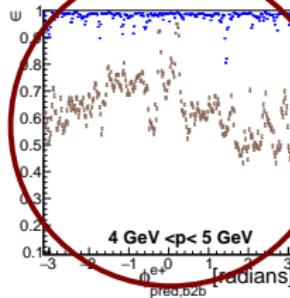
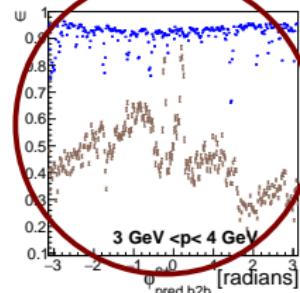
- The tracking efficiencies for momenta between 2 GeV and 3 GeV and between 5 GeV and 6 GeV look very similar
- The tracking efficiency for momenta between 3 GeV and 5 GeV improved drastically

Phase2 Data

Phase3 Data



e<sup>+</sup>



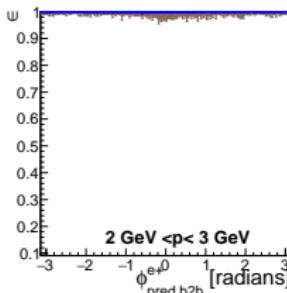
# Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

## Positron Tracking Efficiency:

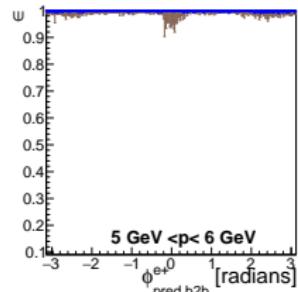
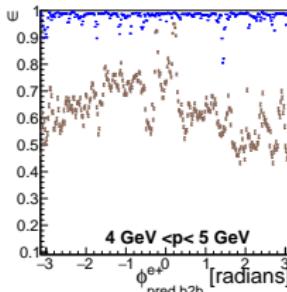
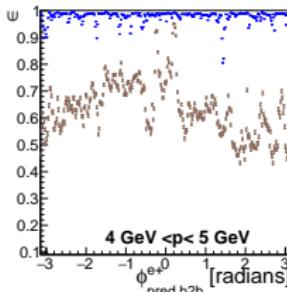
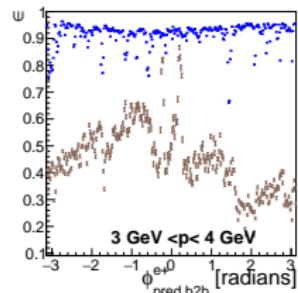
- The tracking efficiencies for momenta between 2 GeV and 3 GeV and between 5 GeV and 6 GeV look very similar
- The tracking efficiency for momenta between 3 GeV and 5 GeV improved drastically

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 *unexpected* low efficiency structures 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:

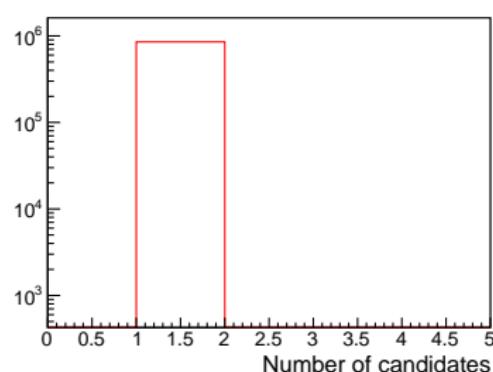
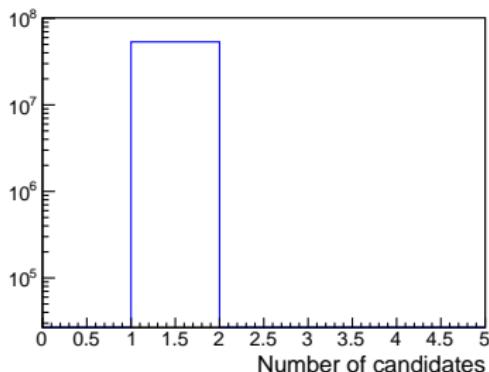
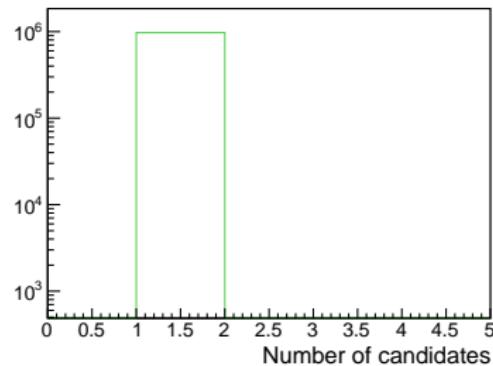
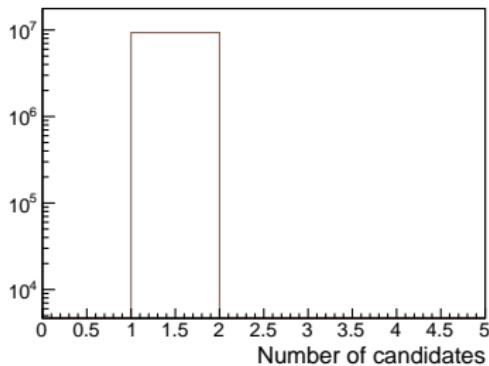
- /belle/MC/release-01-00-02/DB00000294/MC10/  
prod00004668/s00/e1002/4S/r00000/3600520000/mdst/sub00

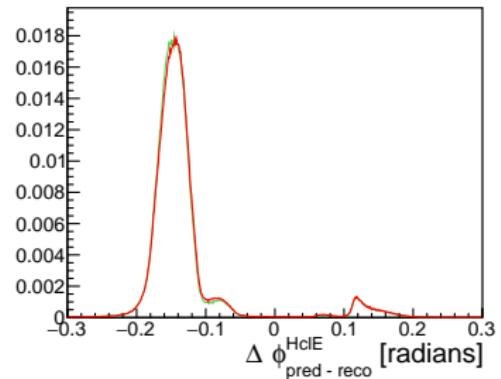
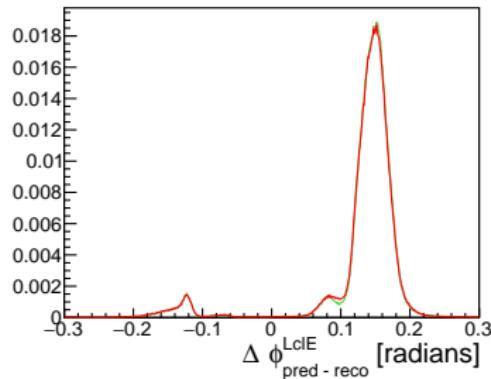
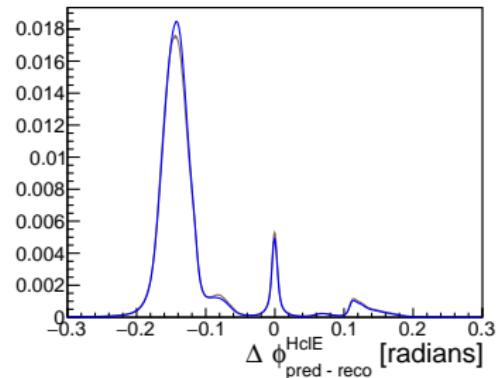
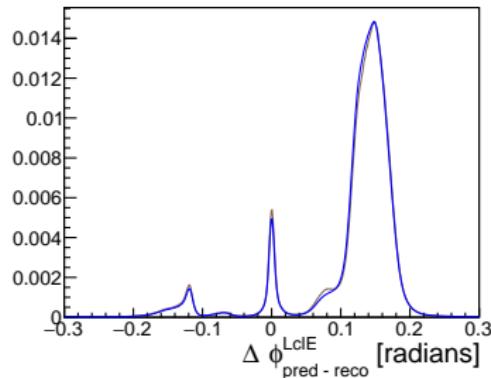
Phase3 data:

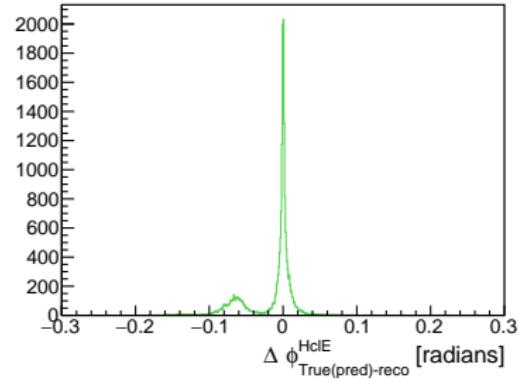
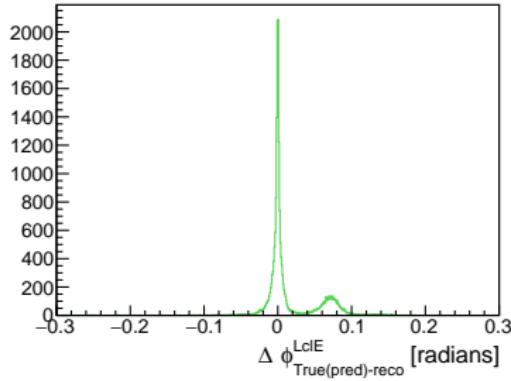
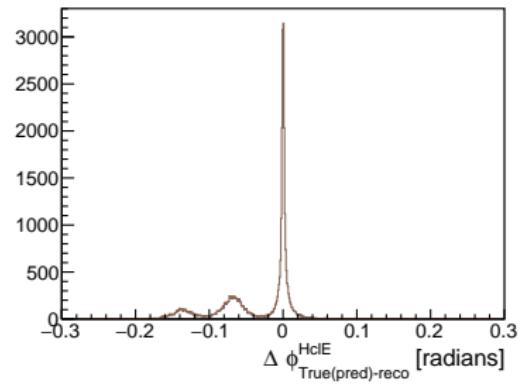
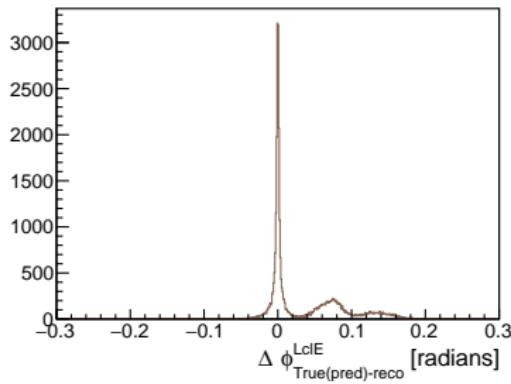
- Exp7: /group/belle2/dataprod/Data/release-03-02-  
02/DB00000654/proc9/e0007/4S/r0\*/all/mdst/sub00/\*.root
- Exp8: /group/belle2/dataprod/Data/release-03-02-  
02/DB00000654/proc9/e0008/4S/r0\*/all/mdst/sub00/\*.root
- proc9

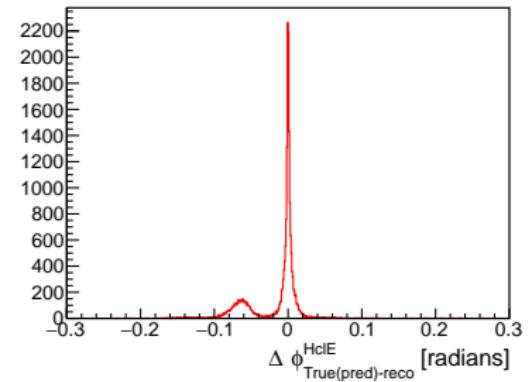
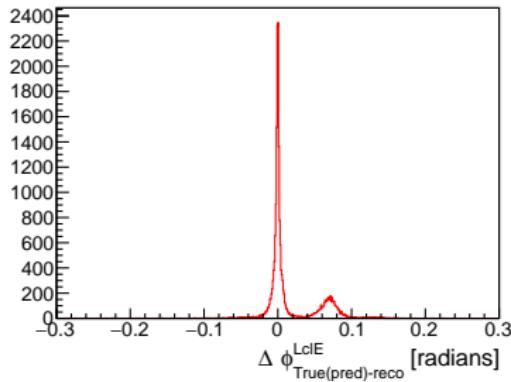
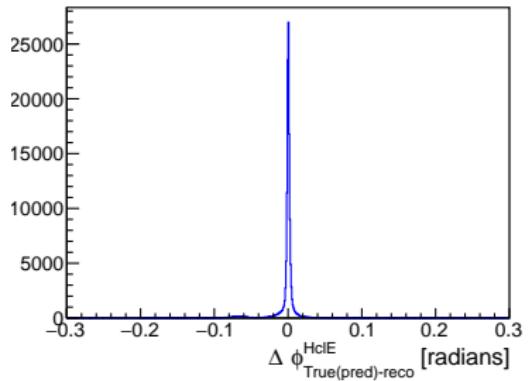
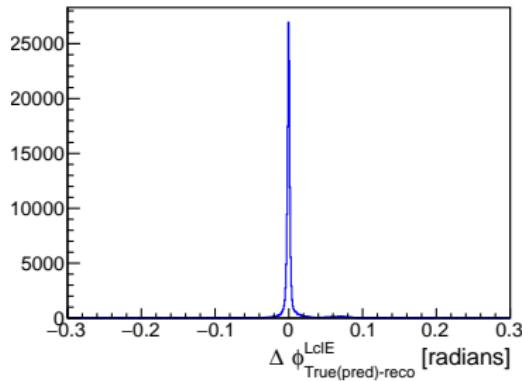
Phase3 MC:

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









# Trigger

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

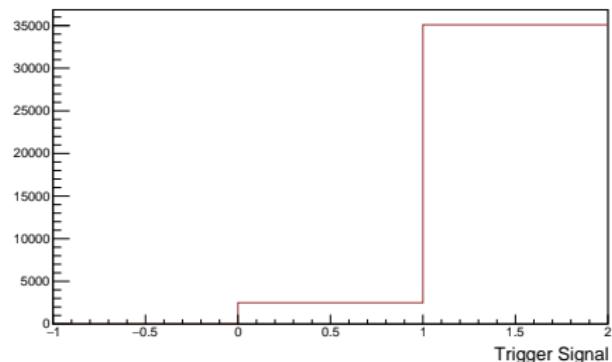
Otherwise there could be a bias

→ 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
- $160^\circ < \sum \theta_{cms} < 200^\circ$
- $140^\circ < \Delta\phi_{cms} < 220^\circ$

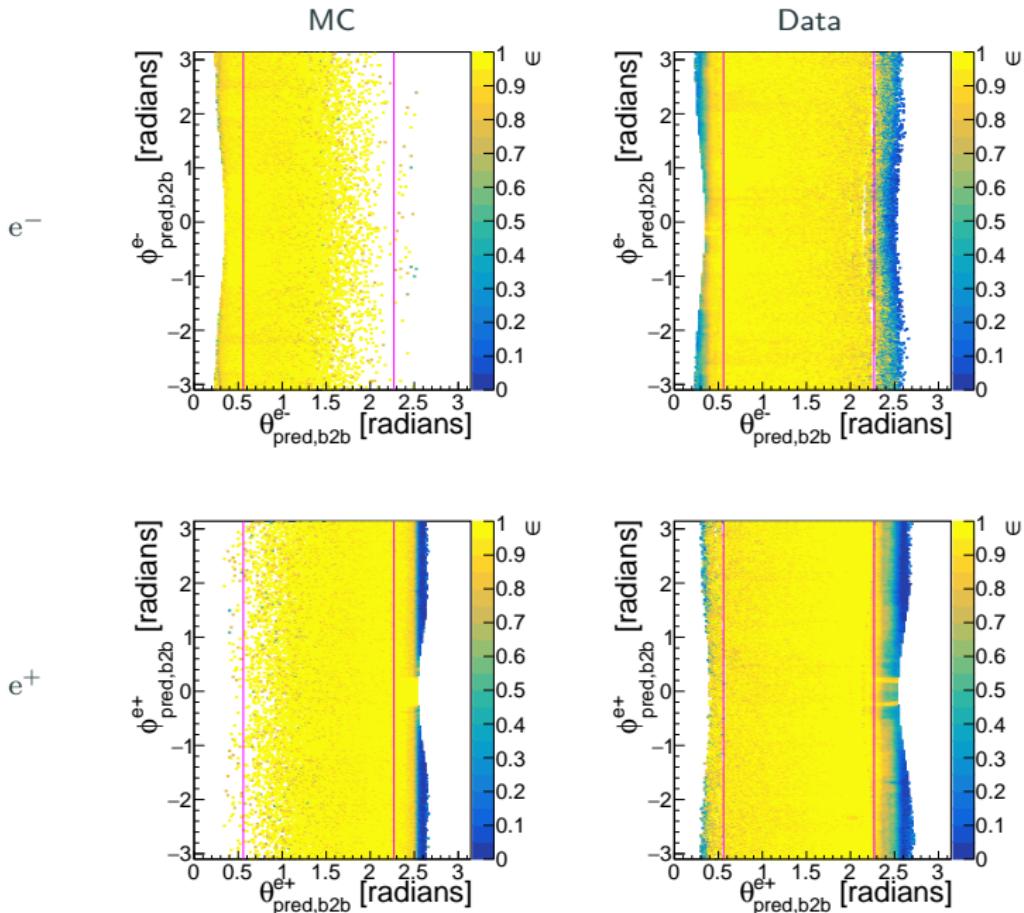
The trigger cut will not be applied to MC since the trigger simulation does not work reliably on MC



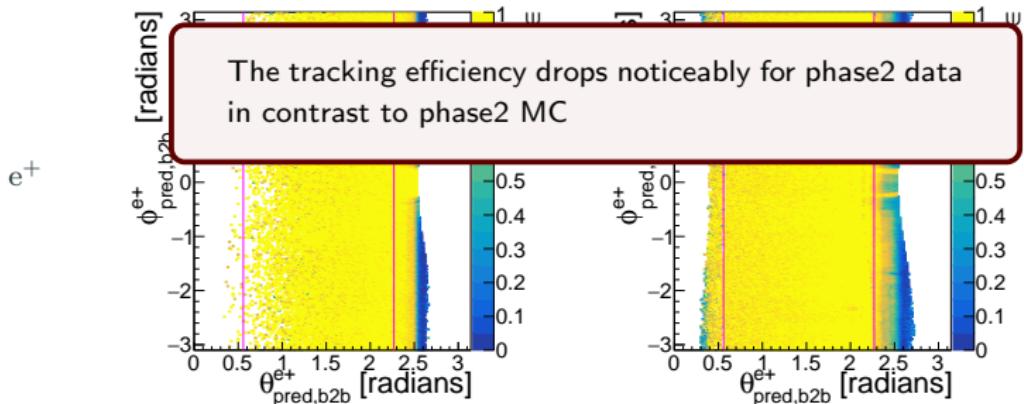
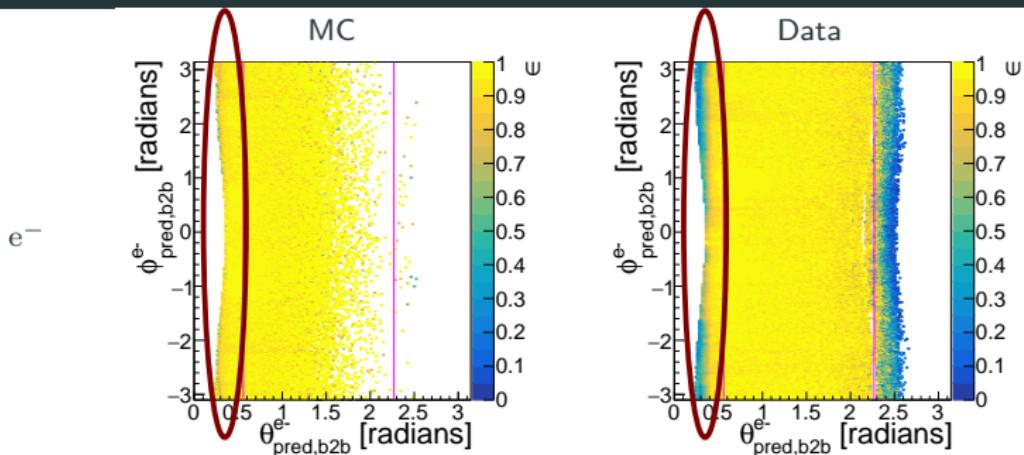
## Phase2 Tracking Efficiencies

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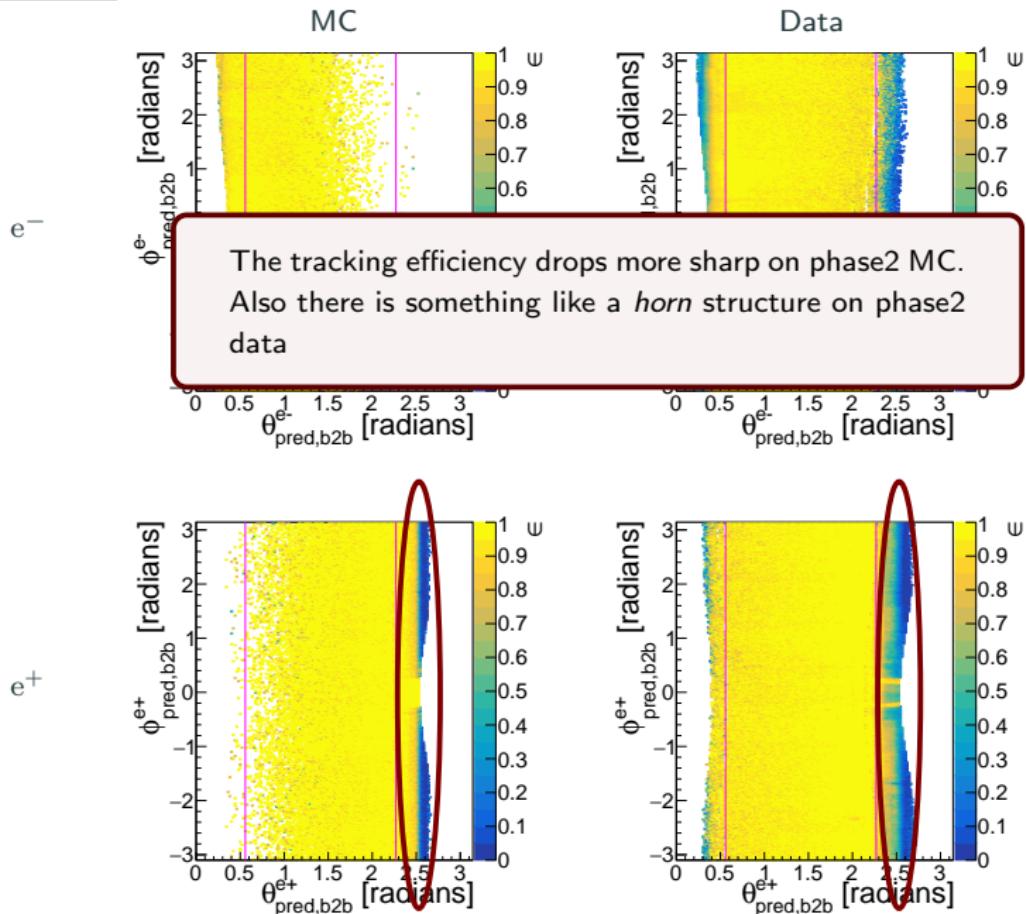
# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}} - \phi_{\text{pred,b2b}}$



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



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

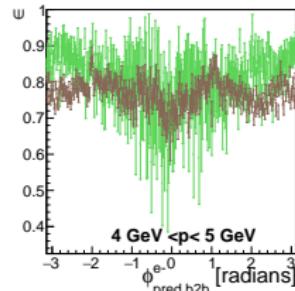


# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Forward End-Cap

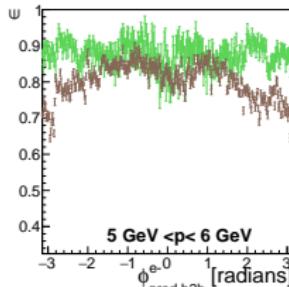
Phase2 MC

Phase2 Data

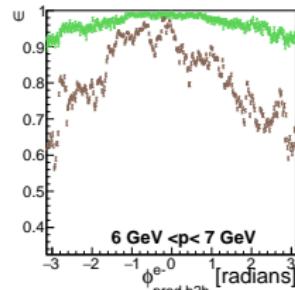
e<sup>-</sup>



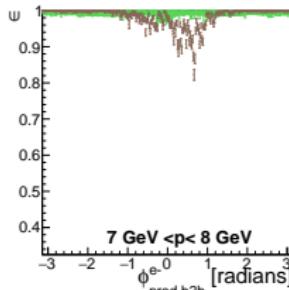
$4 \text{ GeV} < p < 5 \text{ GeV}$



$5 \text{ GeV} < p < 6 \text{ GeV}$

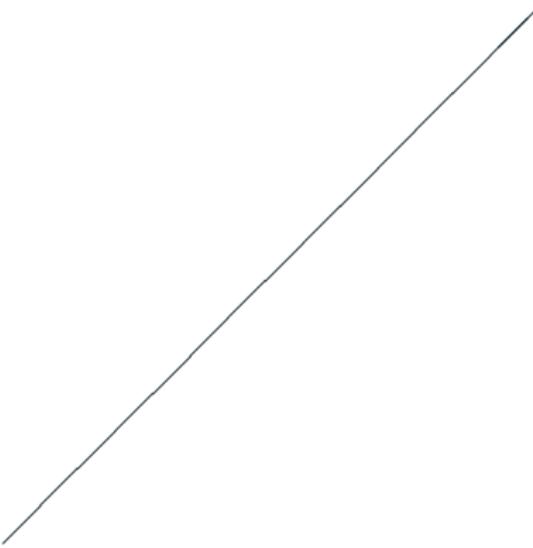


$6 \text{ GeV} < p < 7 \text{ GeV}$



$7 \text{ GeV} < p < 8 \text{ GeV}$

e<sup>+</sup>

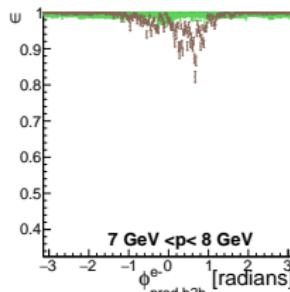
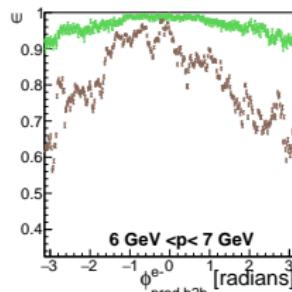
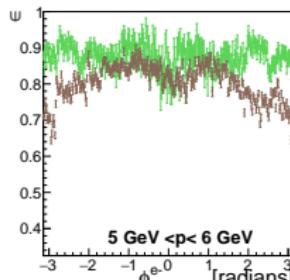
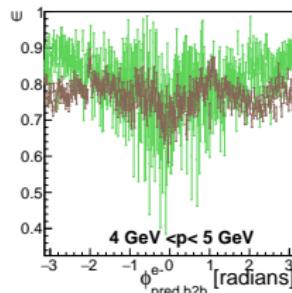


# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Forward End-Cap

Phase2 MC

e<sup>-</sup>

Phase2 Data



## Electron Tracking Efficiency:

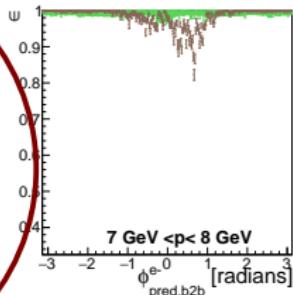
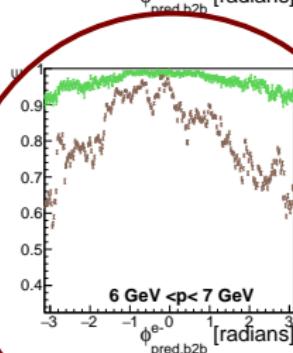
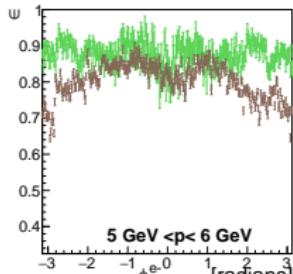
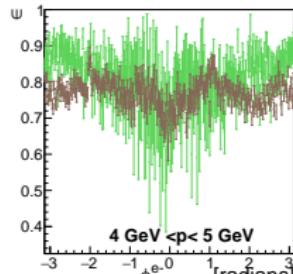
- Phase2 MC has almost always a higher tracking efficiency compared to phase2 data
- For most momenta the biggest difference between phase2 MC and phase2 data occurs for  $|\phi_{\text{pred,b2b}}| \gtrsim 2$

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

Phase2 MC

Phase2 Data

e<sup>-</sup>



Electron Tracking Efficiency:

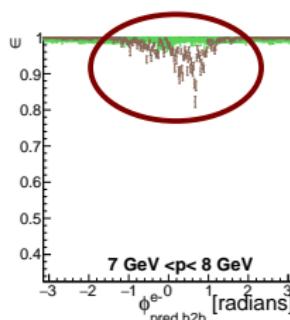
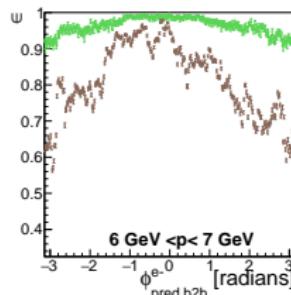
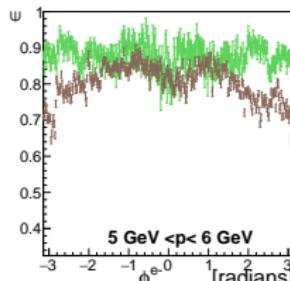
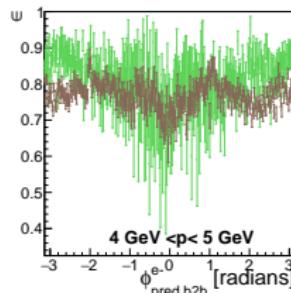
- Phase2 MC has almost always a higher tracking efficiency compared to phase2 data
- For most momenta the biggest difference between phase2 MC and phase2 data occurs for  $|\phi_{\text{pred,b2b}}| \gtrsim 2$
- There is no similarity in the structure for momenta between 6 GeV and 7 GeV

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

Phase2 MC

e<sup>-</sup>

Phase2 Data



Electron Tracking Efficiency:

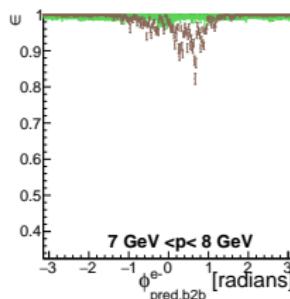
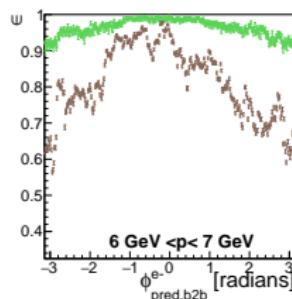
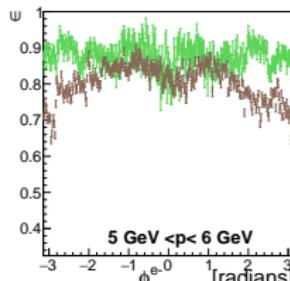
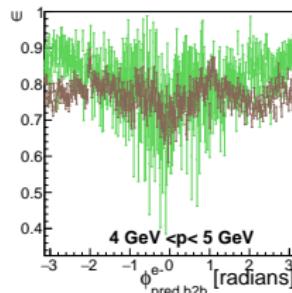
- Phase2 MC has almost always a higher tracking efficiency compared to phase2 data
- For most momenta the biggest difference between phase2 MC and phase2 data occurs for  $|\phi_{\text{pred,b2b}}| \gtrsim 2$
- There is no similarity in the structure for momenta between 6 GeV and 7 GeV
- Highest tracking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

e<sup>-</sup>

Phase2 Data



## Electron Tracking Efficiency:

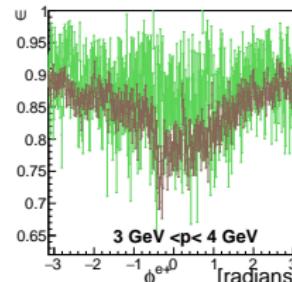
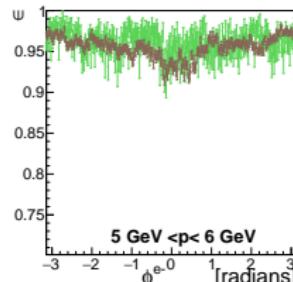
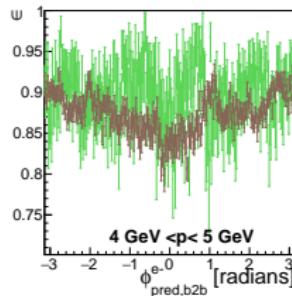
- Phase2 MC has almost always a higher tracking efficiency compared to phase2 data
- For most momenta the biggest difference between phase2 MC and phase2 data occurs for  $|\phi_{\text{pred,b2b}}| \gtrsim 2$
- There is no similarity in the structure for momenta between 6 GeV and 7 GeV
- Highest tracking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

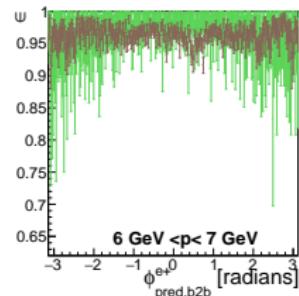
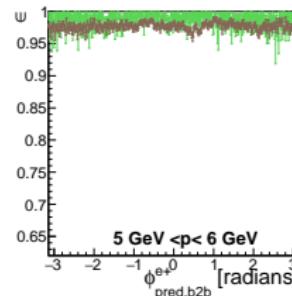
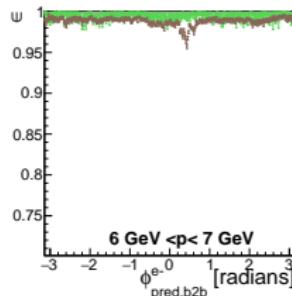
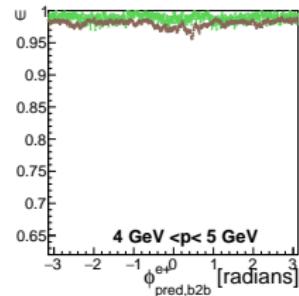
Phase2 MC

e<sup>-</sup>

Phase2 Data



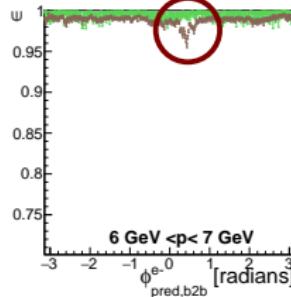
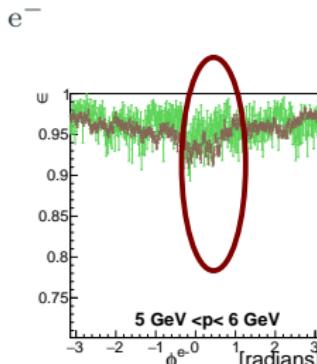
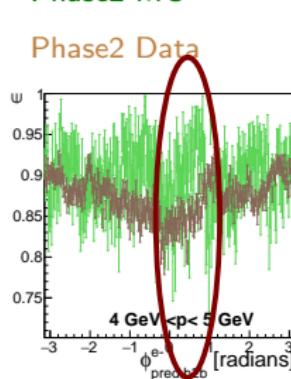
e<sup>+</sup>



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

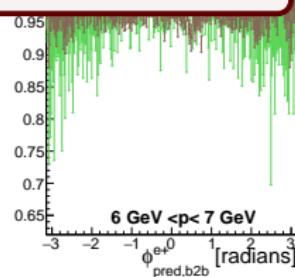
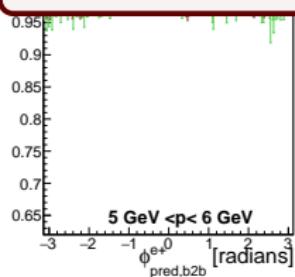
Phase2 MC

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

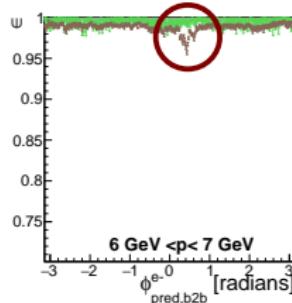
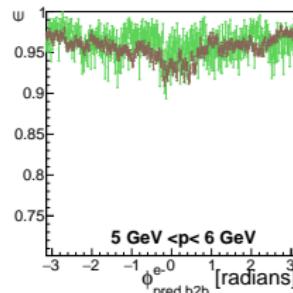
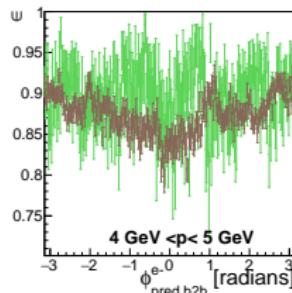


# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Barrel

Phase2 MC

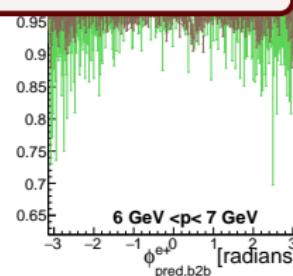
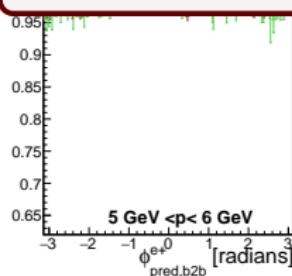
e<sup>-</sup>

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

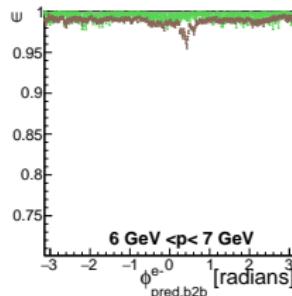
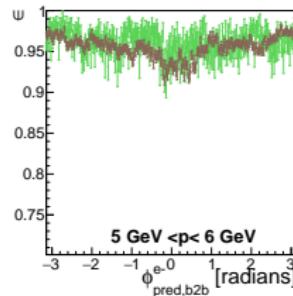
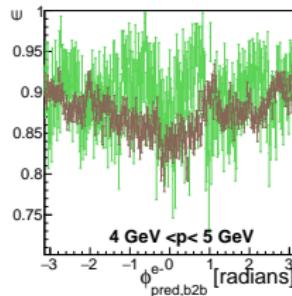


# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Barrel

Phase2 MC

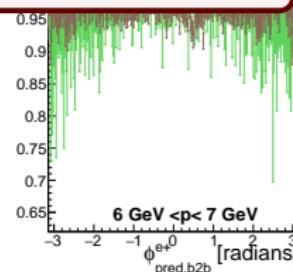
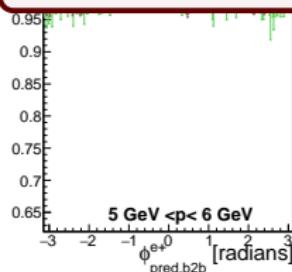
e<sup>-</sup>

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

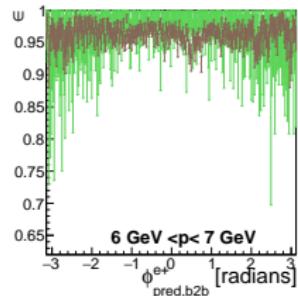
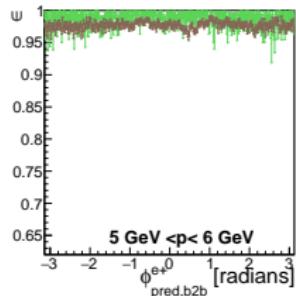
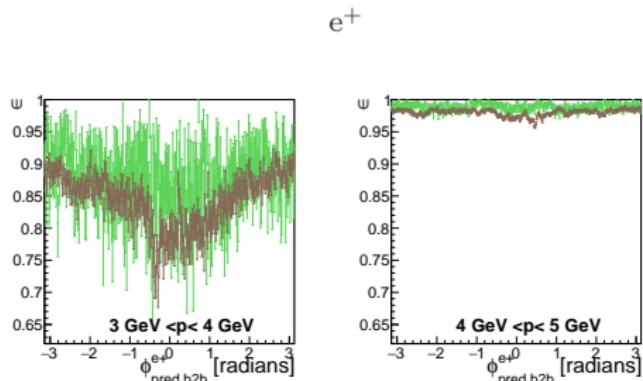
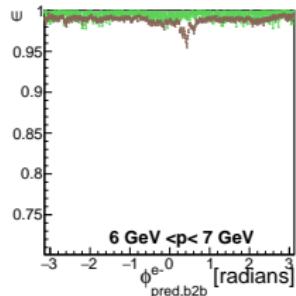


# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Barrel

## Phase2 MC

### 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  $\phi_{\text{pred,b2b}} \approx 0$

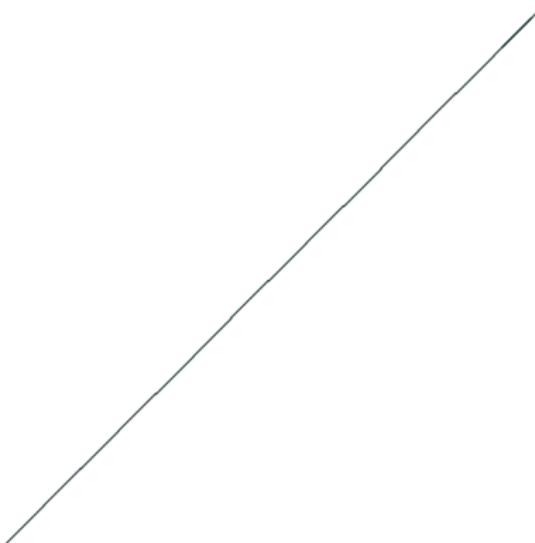


# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

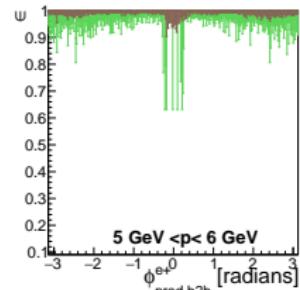
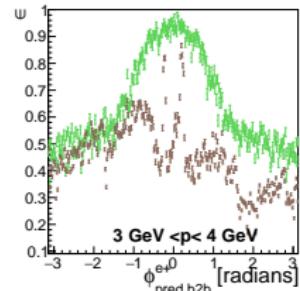
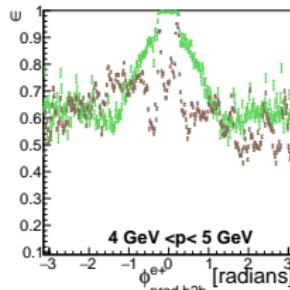
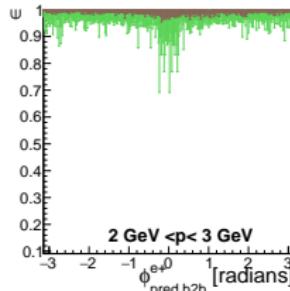
Phase2 MC

$e^-$

Phase2 Data



$e^+$



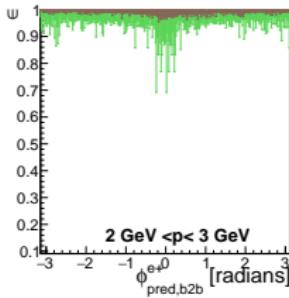
# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

## Positron Tracking Efficiency:

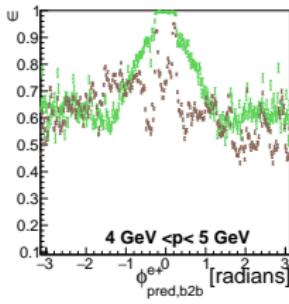
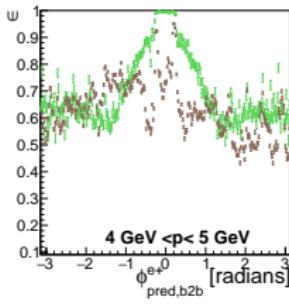
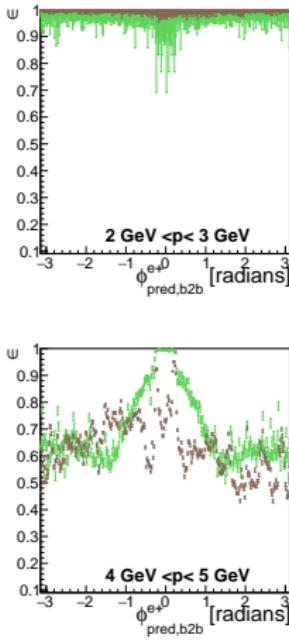
- The highest tracking efficiency occurs for momenta between 2 GeV and 3 GeV and 5 GeV and 6 GeV

Phase2 MC

Phase2 Data



$e^+$



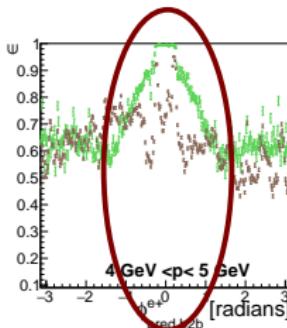
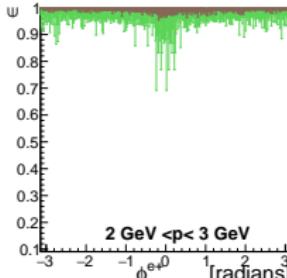
# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

## Positron Tracking Efficiency:

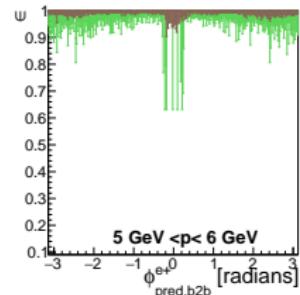
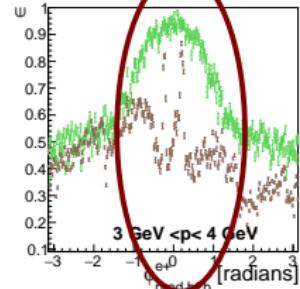
- The highest tracking efficiency occurs for momenta between 2 GeV and 3 GeV and 5 GeV and 6 GeV
- Weird *horn* structure we saw earlier
- Phase2 MC tracking efficiency peaks at  $\phi_{\text{pred,b2b}} \approx 0$

Phase2 MC

Phase2 Data



$e^+$



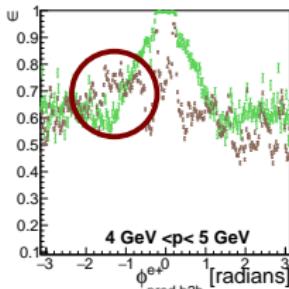
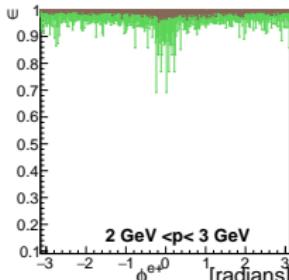
# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

Positron Tracking Efficiency:

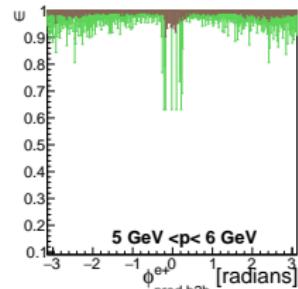
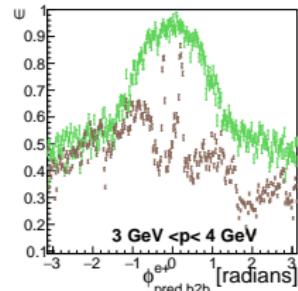
- The highest tracking efficiency occurs for momenta between 2 GeV and 3 GeV and 5 GeV and 6 GeV
- Weird *horn* structure we saw earlier
- Phase2 MC tracking efficiency peaks at  $\phi_{\text{pred,b2b}} \approx 0$
- For momenta between 4 GeV and 5 GeV phase2 data appears to have a higher tracking efficiency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

Phase2 MC

Phase2 Data



e<sup>+</sup>

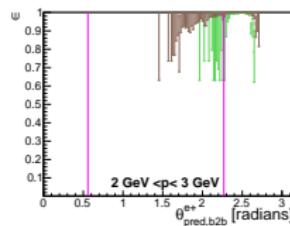
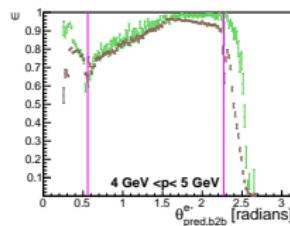
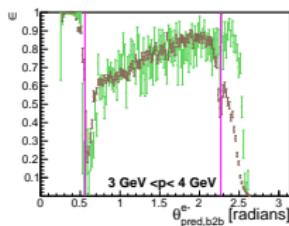


# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

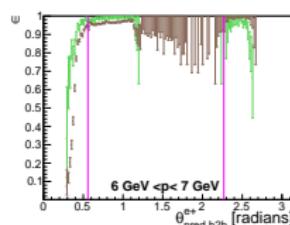
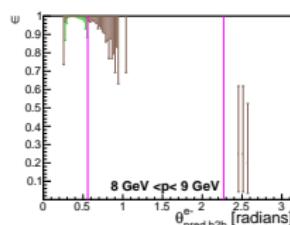
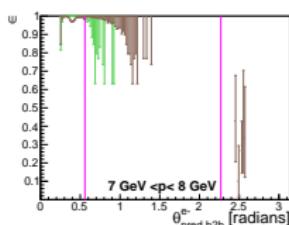
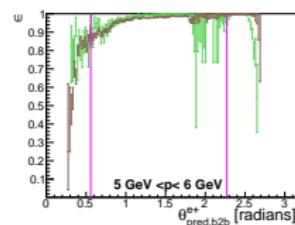
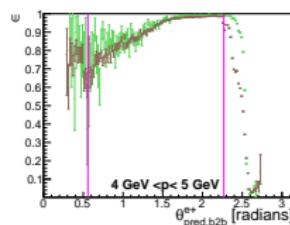
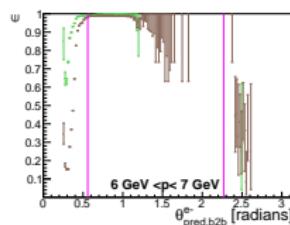
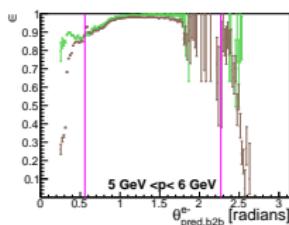
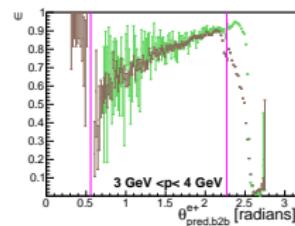
Phase2 MC

$e^-$

Phase2 Data



$e^+$

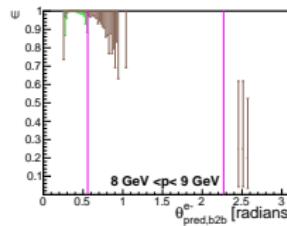
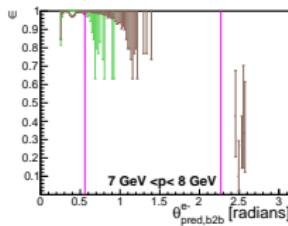
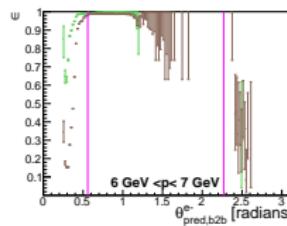
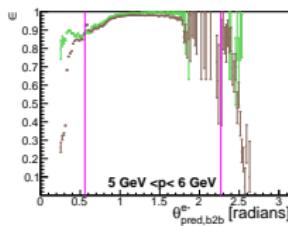
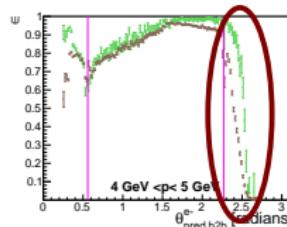
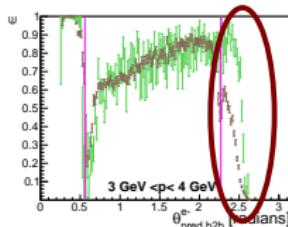


# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 MC

Phase2 Data

e<sup>-</sup>



Electron Tracking Efficiency:

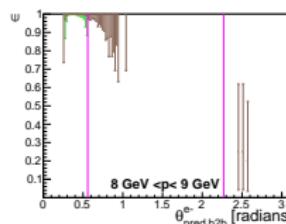
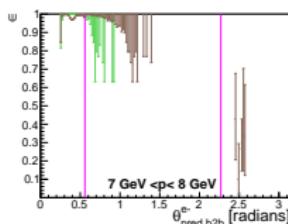
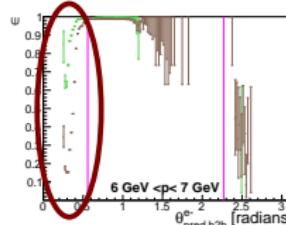
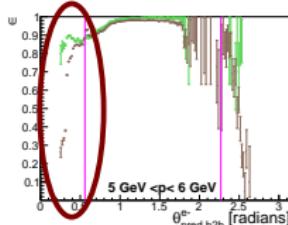
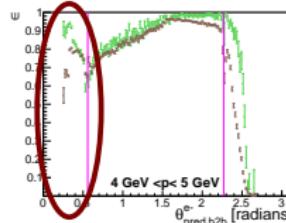
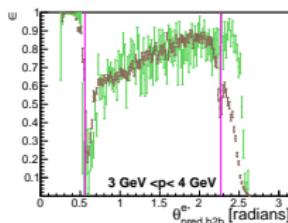
- For momenta between 3 GeV and 5 GeV the tracking efficiency in the backward end-cap is worse for phase2 data compared to phase2 MC

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

Phase2 MC

Phase2 Data

e<sup>-</sup>



## Electron Tracking Efficiency:

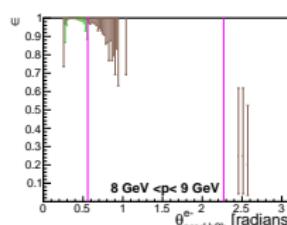
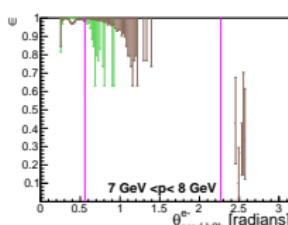
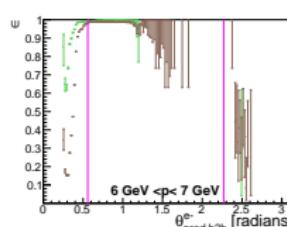
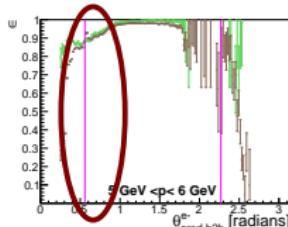
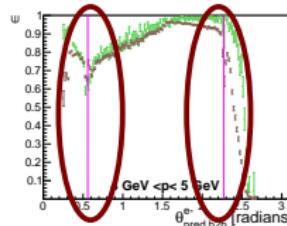
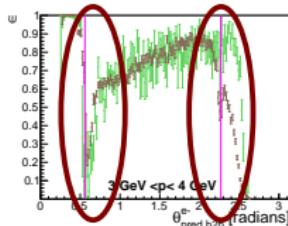
- For momenta between 3 GeV and 5 GeV the tracking efficiency in the backward end-cap is worse for phase2 data compared to phase2 MC
- For momenta between 4 GeV and 6 GeV the tracking efficiency in the forward end-cap is worse for phase2 data compared to phase2 MC

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

Phase2 MC

Phase2 Data

e<sup>-</sup>



Electron Tracking Efficiency:

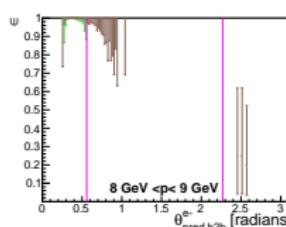
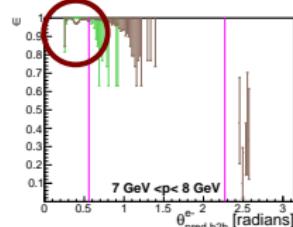
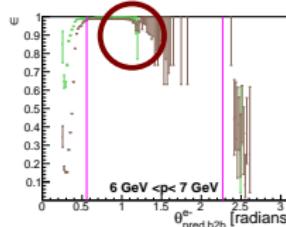
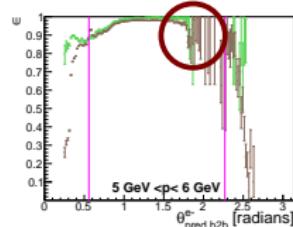
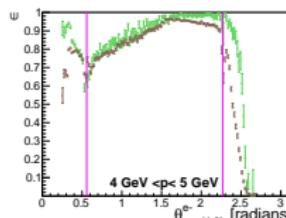
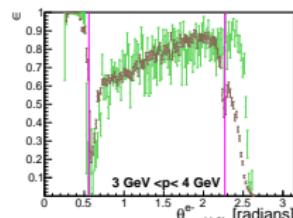
- For momenta between 3 GeV and 5 GeV the tracking efficiency in the backward end-cap is worse for phase2 data compared to phase2 MC
- For momenta between 4 GeV and 6 GeV the tracking efficiency in the forward end-cap is worse for phase2 data compared to phase2 MC
- Drops in efficiency at transition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

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

Phase2 MC

Phase2 Data

e<sup>-</sup>



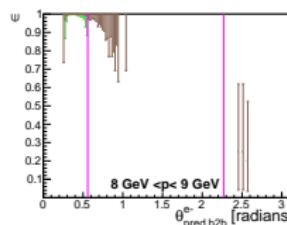
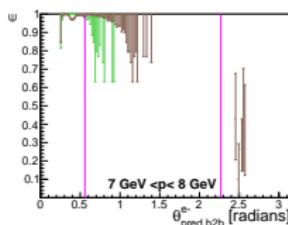
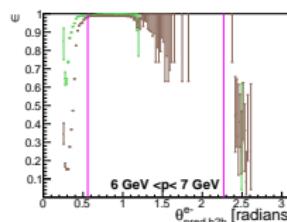
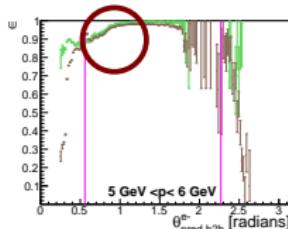
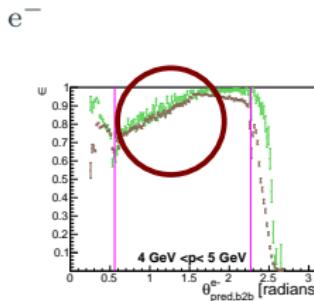
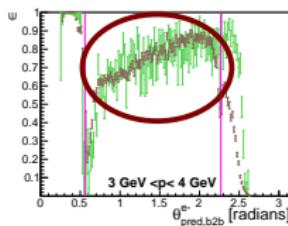
## Electron Tracking Efficiency:

- 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 MC

Phase2 Data



## Electron Tracking Efficiency:

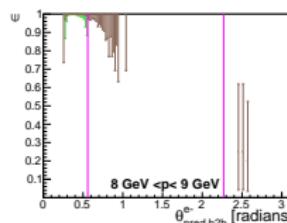
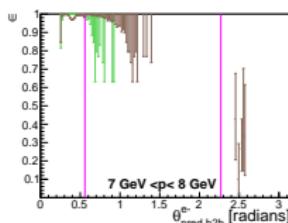
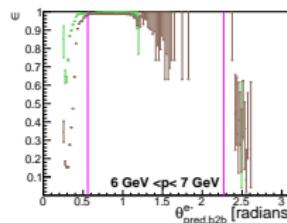
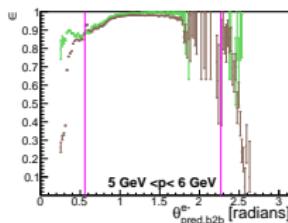
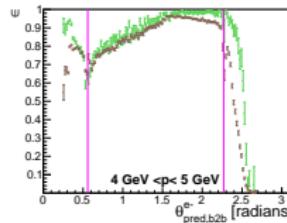
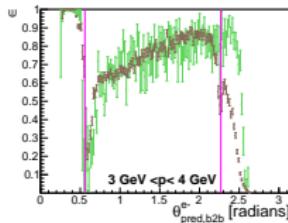
- For momenta between 3 GeV and 5 GeV the tracking efficiency in the backward end-cap is worse for phase2 data compared to phase2 MC
- For momenta between 4 GeV and 6 GeV the tracking efficiency in the forward end-cap is worse for phase2 data compared to phase2 MC
- Drops in efficiency at transition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

Phase2 Data

e<sup>-</sup>



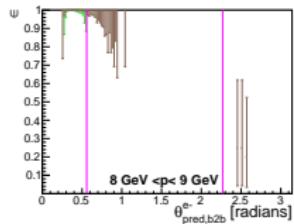
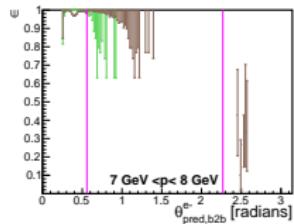
Electron Tracking Efficiency:

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

Positron Tracking Efficiency:

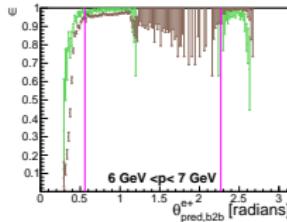
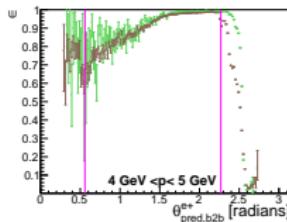
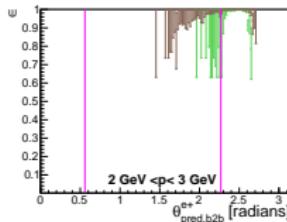
Phase2 MC

Phase2 Data

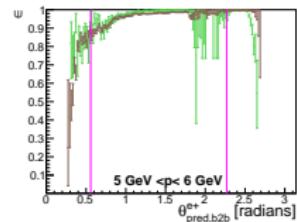
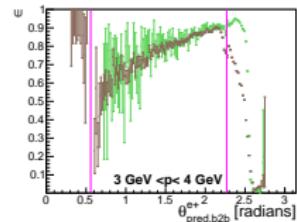


Phase2 MC

Phase2 Data



e<sup>+</sup>



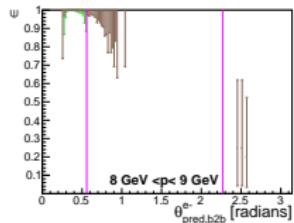
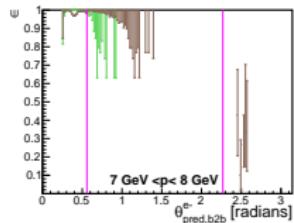
# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

## 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

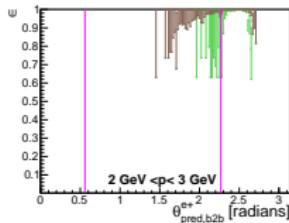
phase2MC

phase2Data

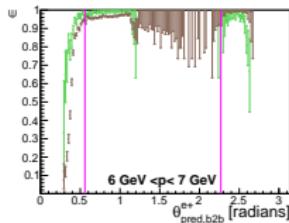
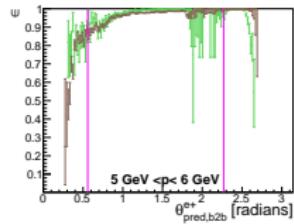
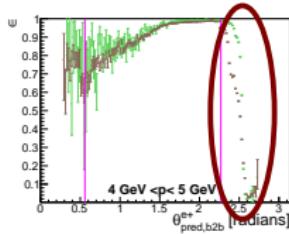
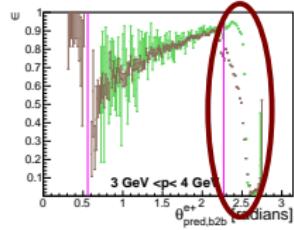


## Phase2 MC

## Phase2 Data



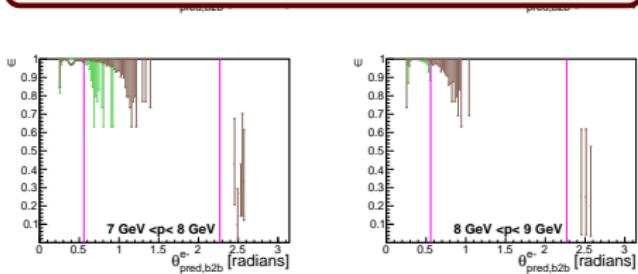
e<sup>+</sup>



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

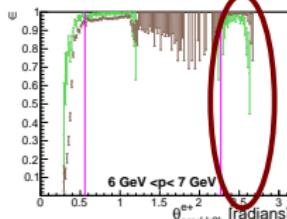
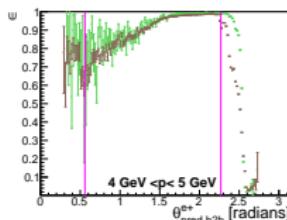
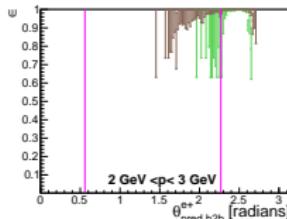
## Positron Tracking Efficiency:

- 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

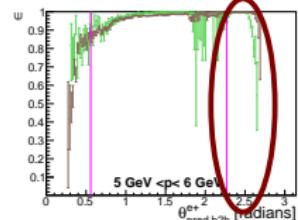
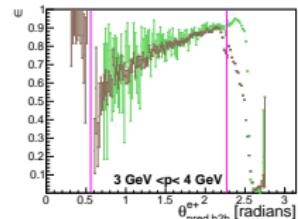


## Phase2 MC

## Phase2 Data



e<sup>+</sup>



# 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

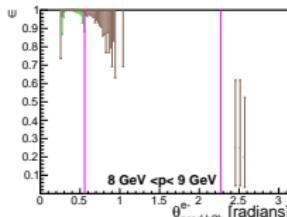
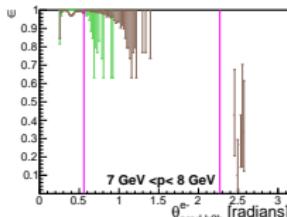
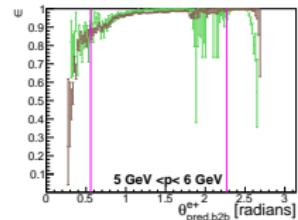
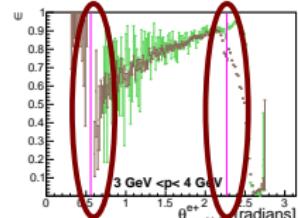
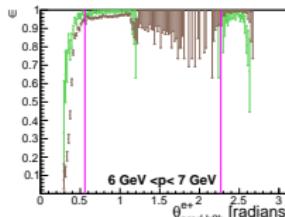
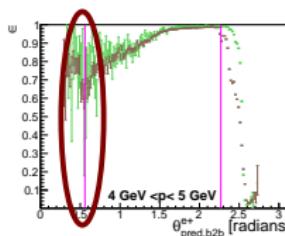
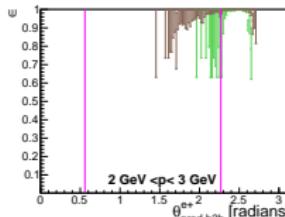
Phase2 MC

Phase2 Data

## Phase2 MC

## Phase2 Data

e<sup>+</sup>



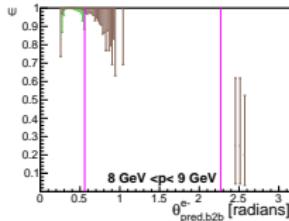
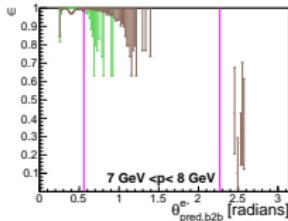
# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

## 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

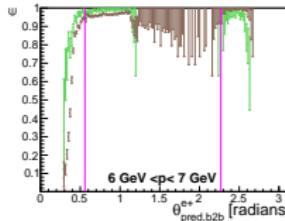
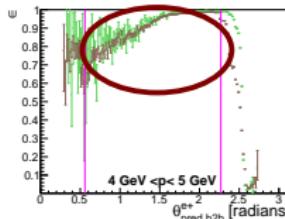
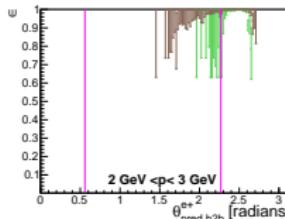
Phase2 MC

Phase2 Data

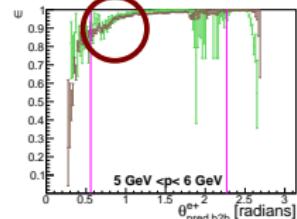
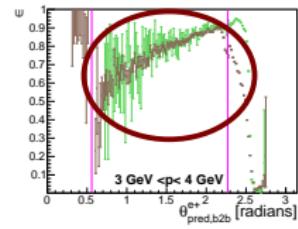


## Phase2 MC

## Phase2 Data



e<sup>+</sup>

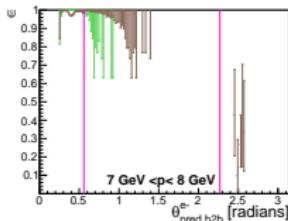


# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

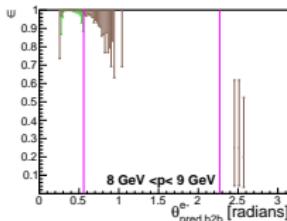
## Positron Tracking Efficiency:

- 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 Data

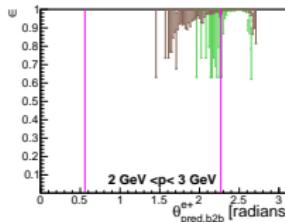


Phase2 MC

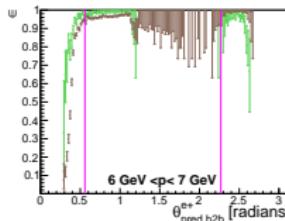
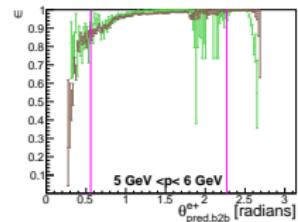
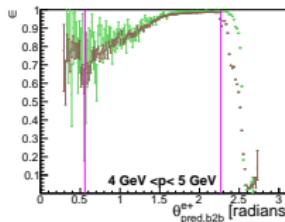
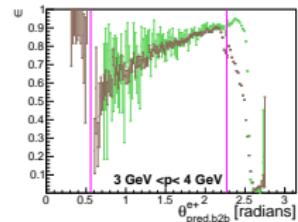


## Phase2 MC

## Phase2 Data



e<sup>+</sup>



## **Transverse Momentum**

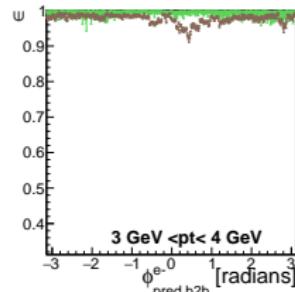
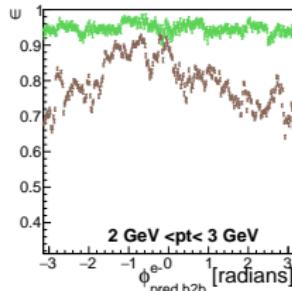
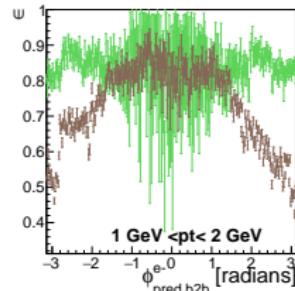
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# Phase2 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Forward End-Cap

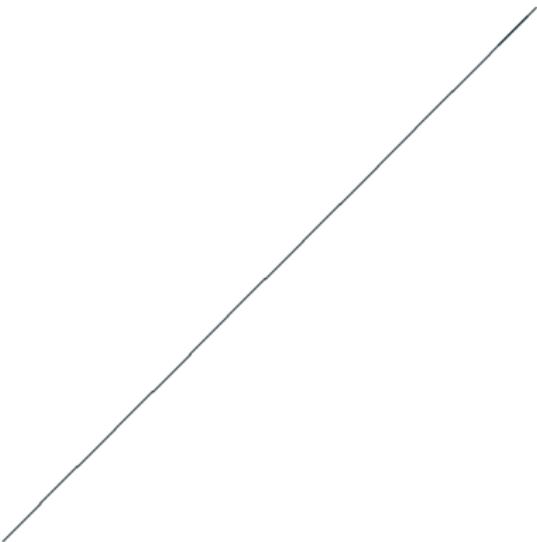
Phase2 MC

e<sup>-</sup>

Phase2 Data



e<sup>+</sup>

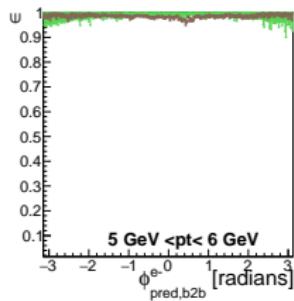
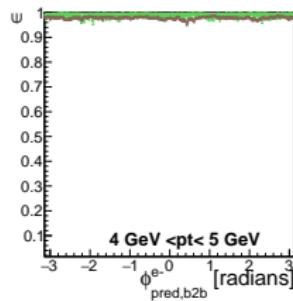
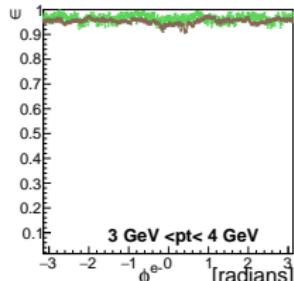
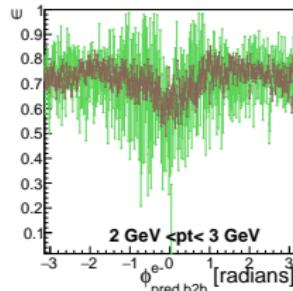


# Phase2 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Barrel

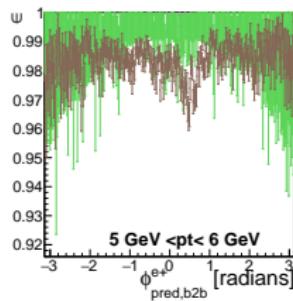
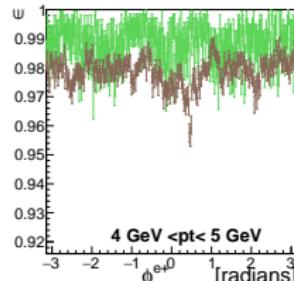
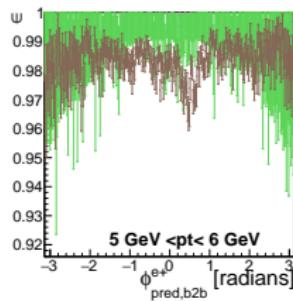
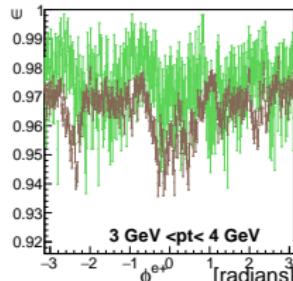
Phase2 MC

e<sup>-</sup>

Phase2 Data



e<sup>+</sup>

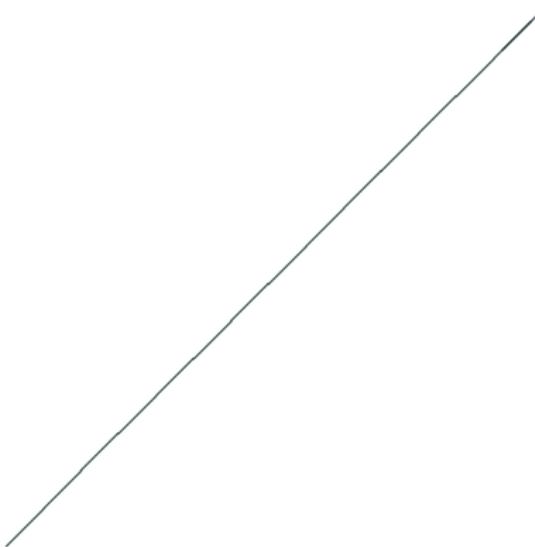


# Phase2 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

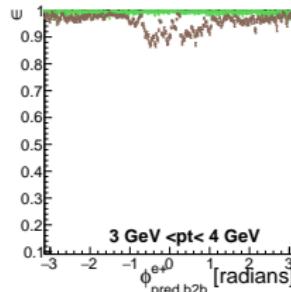
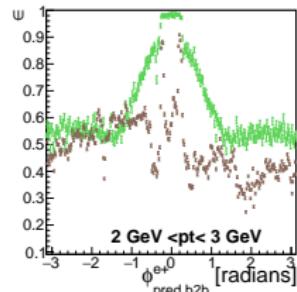
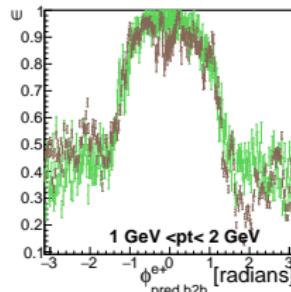
Phase2 MC

$e^-$

Phase2 Data



$e^+$

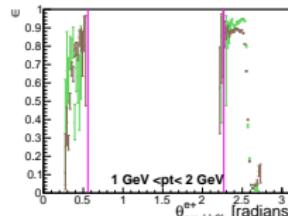
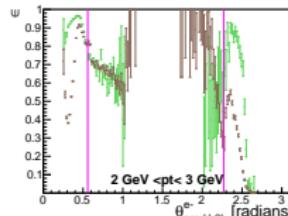
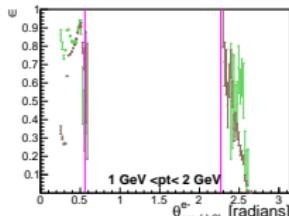


# Phase2 pt Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

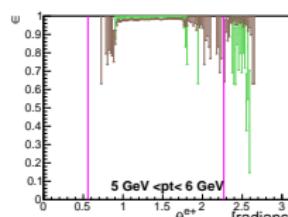
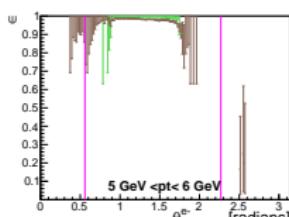
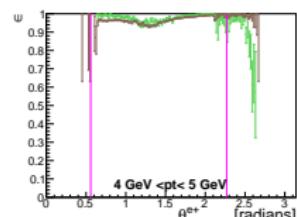
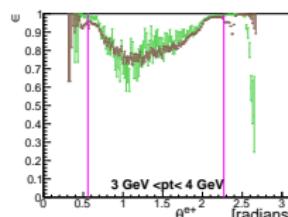
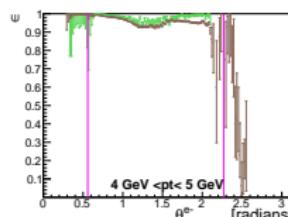
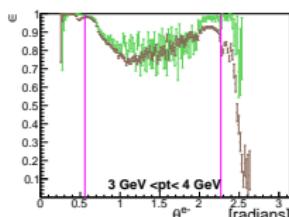
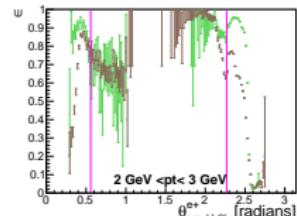
Phase2 MC

$e^-$

Phase2 Data



$e^+$

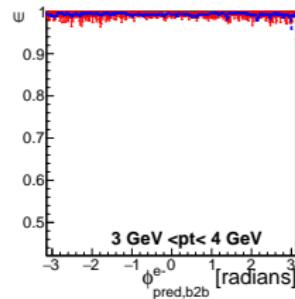
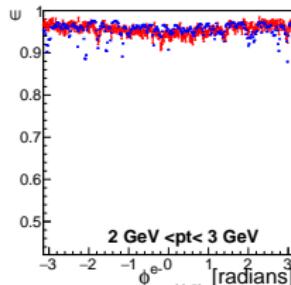
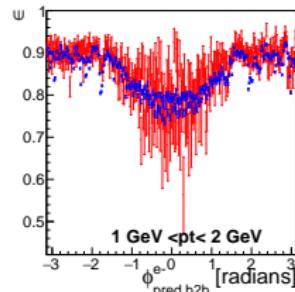


# Phase3 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Forward End-Cap

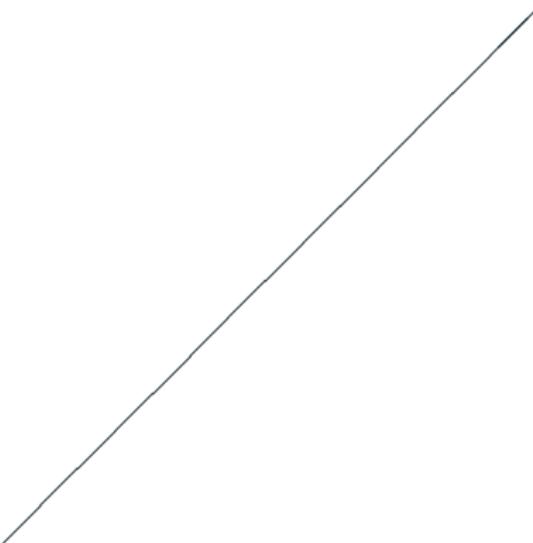
Phase3 MC

e<sup>-</sup>

Phase3 Data



e<sup>+</sup>

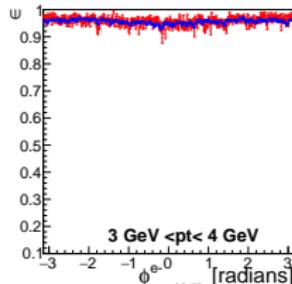
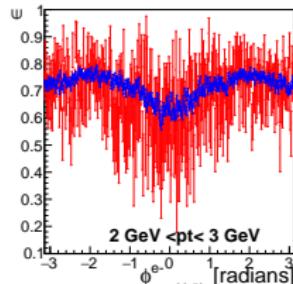


# Phase3 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Barrel

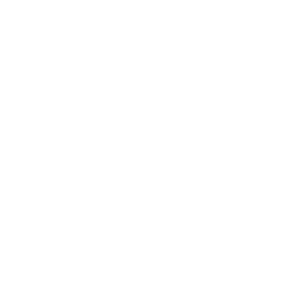
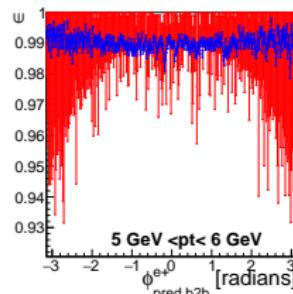
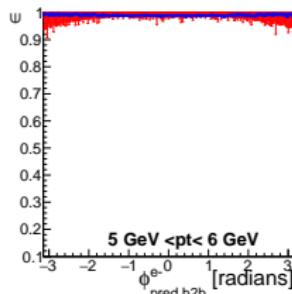
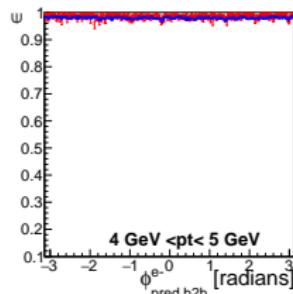
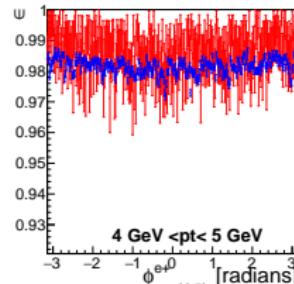
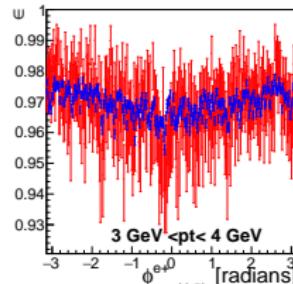
Phase3 MC

e<sup>-</sup>

Phase3 Data



e<sup>+</sup>

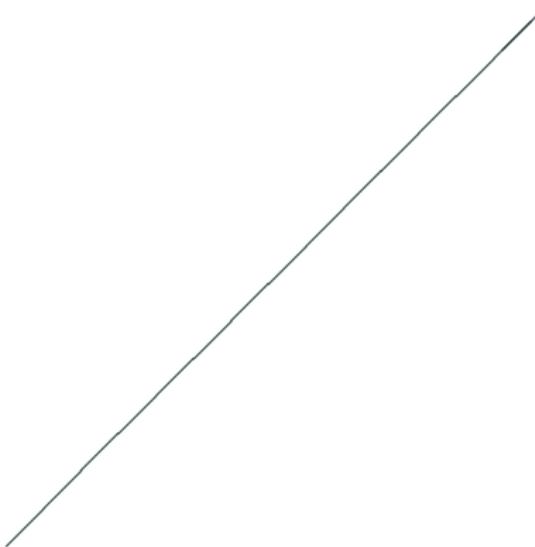


# Phase3 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

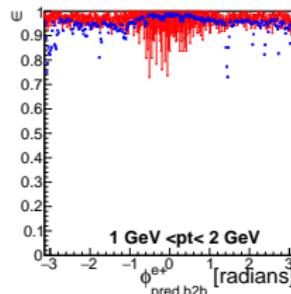
Phase3 MC

$e^-$

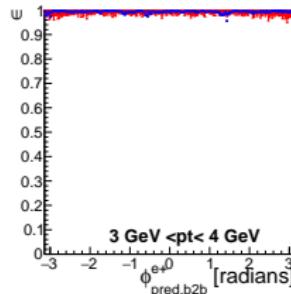
Phase3 Data



$e^+$



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

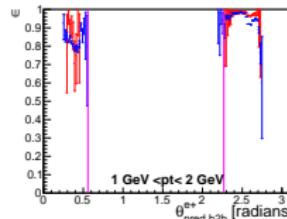
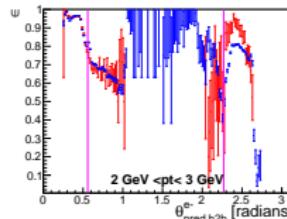
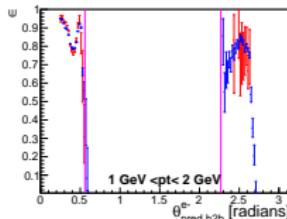


# Phase3 pt Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase3 MC

e<sup>-</sup>

Phase3 Data



e<sup>+</sup>

