

# **Systematic Studies On Track Reconstruction Efficiency At Belle II**

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# Outline

- Overview on the Belle II experiment
- Bhabha kinematics at Belle II
- Preparation for calculating the tracking efficiency
- Phase2 tracking efficiency
- Phase3 tracking efficiency
- Comparing phase2 with phase3
- Conclusion

## Motivation

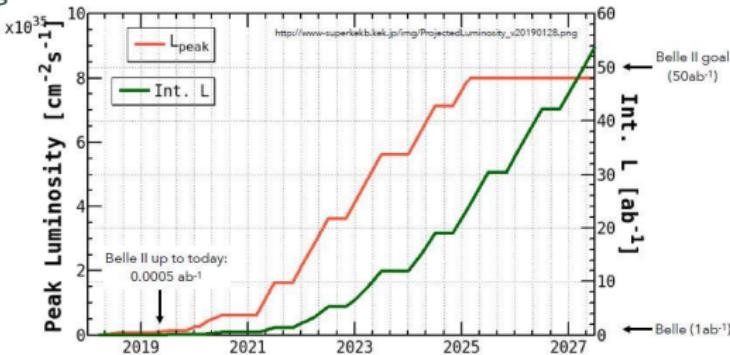
- At an electron-positron accelerator most outgoing particles are again electrons and positrons (these events are called Bhabha events)
- These events can be used to estimate the performance of the tracking detectors
- If the *tag* particle in a Bhabha event has a track than the *probe* particle also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

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

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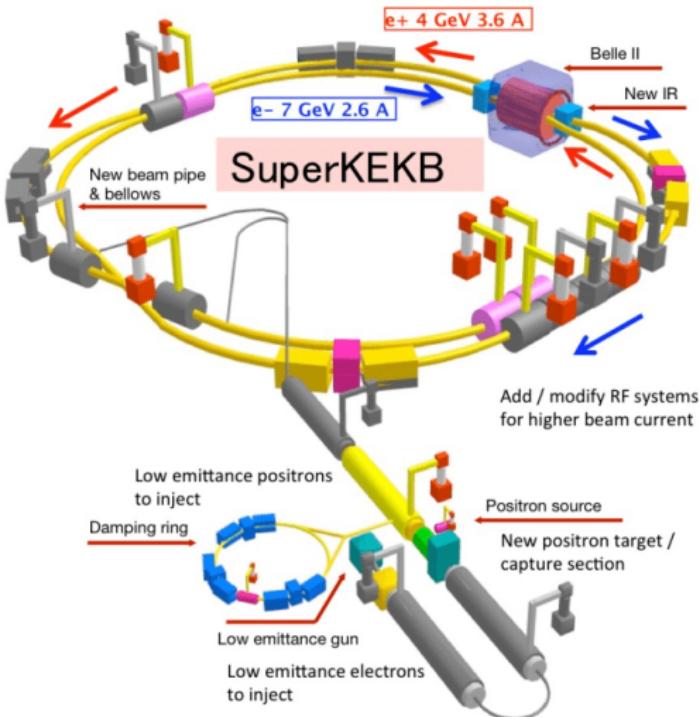
# Belle II Schedule And Luminosity Goals

- 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)



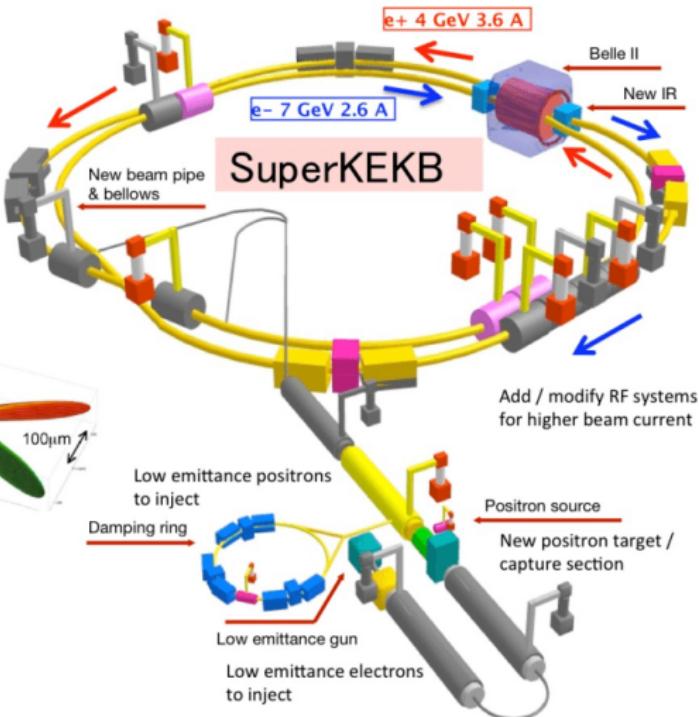
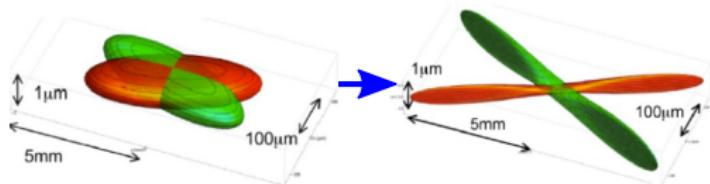
# The SuperKEKB $e^+e^-$ collider

- Asymmetric  $B$ -factory
- Center-of-mass close to  $\Upsilon(4S)$   
 $\sim 10.5$  GeV
- Upgrade of the KEKB collider:
  - Larger beam current
  - Reduced beam size



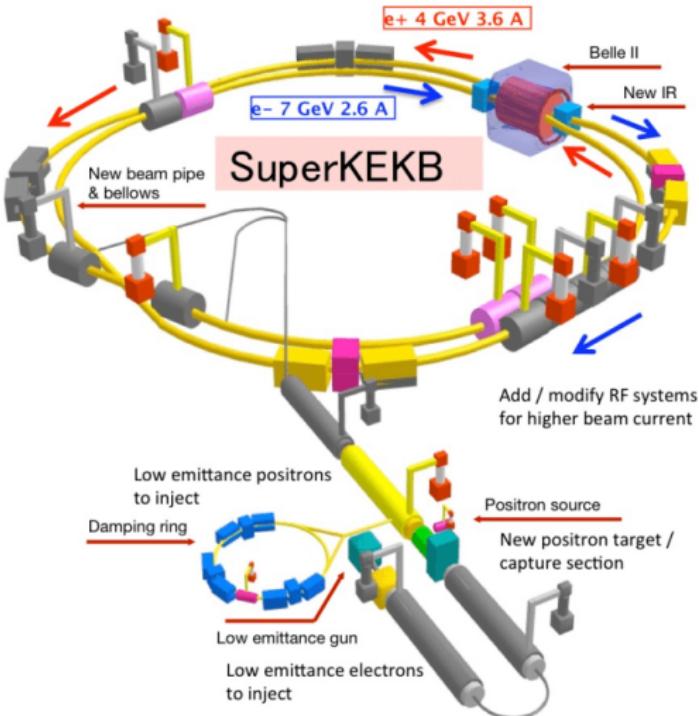
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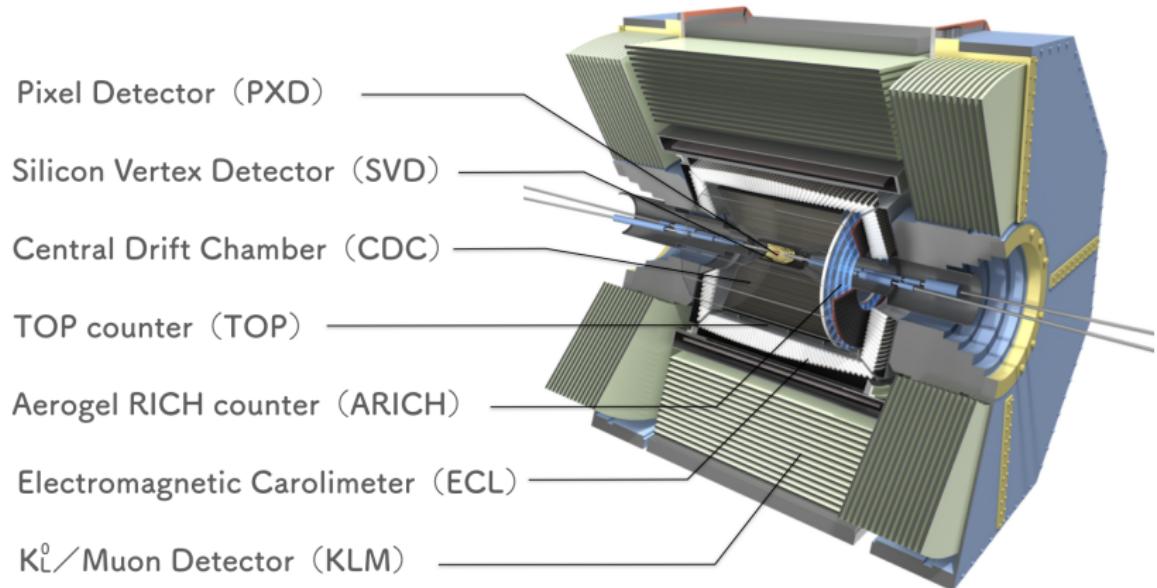


# The SuperKEKB $e^+e^-$ collider

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 $\sim 10.5$  GeV
- Upgrade of the KEKB collider:
  - Larger beam current
  - Reduced beam size
- $\rightarrow$  Luminosity increase  $\times 40$
- Designed peak luminosity of  
 $8 \cdot 10^{35} \text{ cm}^{-2}\text{s}^{-1}$
- Planned data sample corresponding to a recorded integrated luminosity of  
 $\sim 50 \text{ ab}^{-1}$



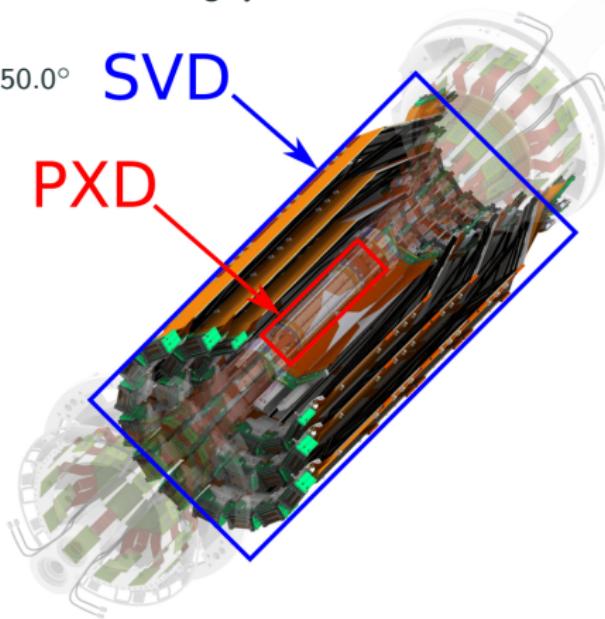
# The Belle II Detector



# Vertex Detectors

## Vertex Detectors:

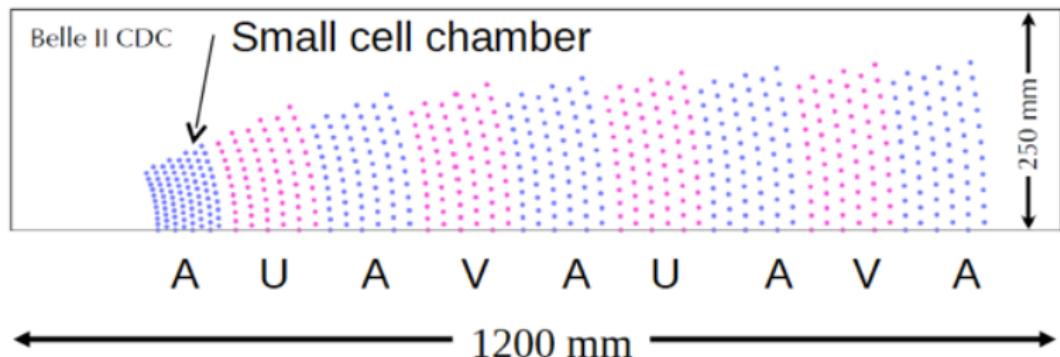
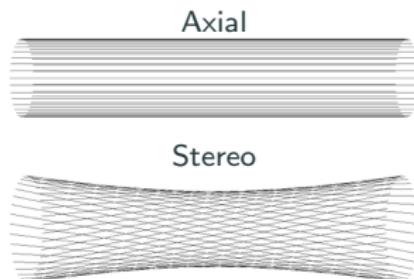
- Consists of Pixel Detector (PXD) and Silicon Vertex Detector (SVD)
- Both detectors consist of multiple ladders of strip detectors
- During phase2, only a fraction of the VXD detectors were installed
- During phase3, the complete SVD and roughly half of the PXD were installed
- Acceptance:  $17.0^\circ < \theta < 150.0^\circ$



# Central Drift Chamber

## Central Drift Chamber:

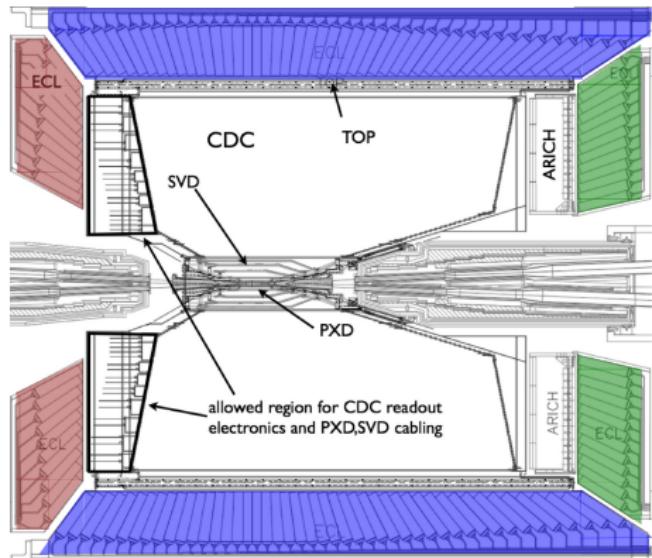
- Consists of 14336 sense wires arranged in 56 layers
- 6 layers are combined to a superlayer (with an exception to innermost superlayer)
- There are 5 axial and 4 stereo superlayers
- The electric field is provided by 42240 field wires
- Charged particles ionize the gas.  
The signal is then read out by the sense wires
- Acceptance:  $17.0^\circ < \theta < 150.0^\circ$



# Electromagnetic Calorimeter

Electromagnetic Calorimeter:

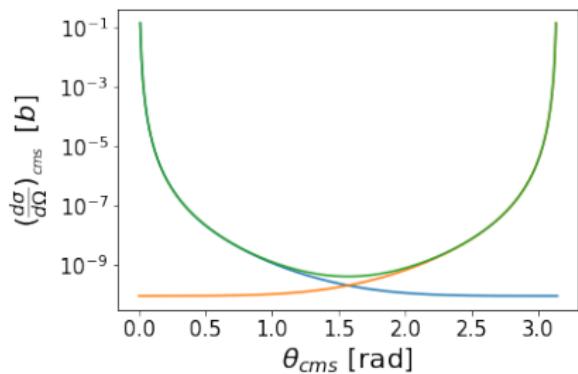
- Consists of 8936 CsI(Tl) crystals
- Separation in **barrel**, **forward end cap** and **backward end cap**
- There are two  $\sim 1^\circ$  wide gaps at transition between the regions
- Main tasks:
  - High efficiency photon detection, plus determination of their energy and angular coordinates
  - Electron identification
  - Generation of a proper signal for the trigger
- Acceptance:  $12.4^\circ < \theta < 155.1^\circ$



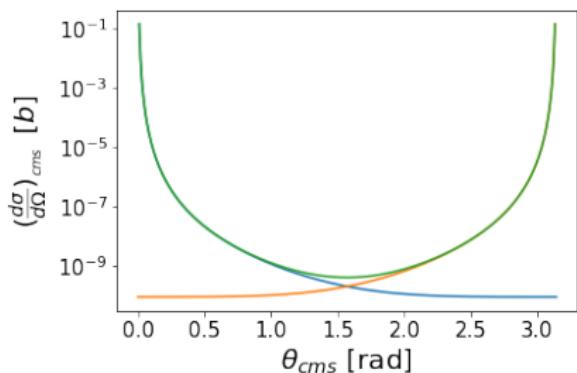
## Bhabha Kinematics At Belle II

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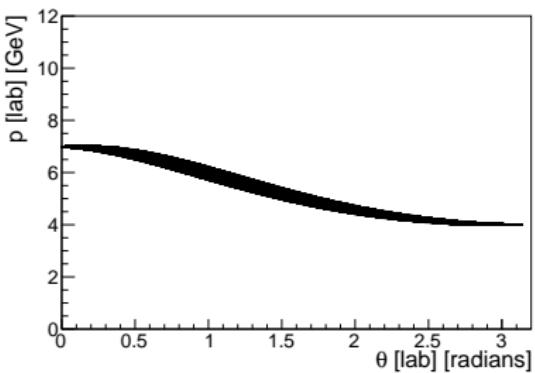
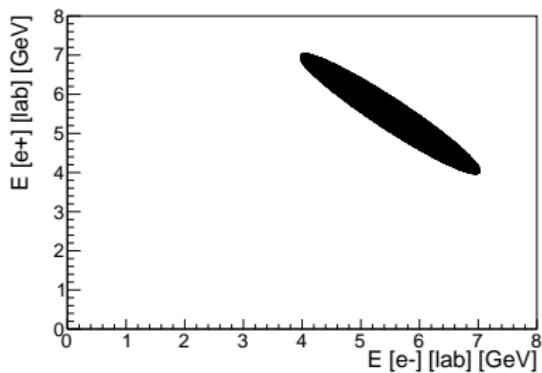
# Bhabha Kinematics At Belle II



# Bhabha Kinematics At Belle II



- The beams have asymmetric energies
- The beams are hitting each other under an angle of  $1.26^\circ$



## **Preparation For Calculating The Tracking Efficiency**

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## Reconstruction Bhabha Events

Goal: Reconstruct Bhabha events using only ECL information

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

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

- The particle have to pass the tracking detectors

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

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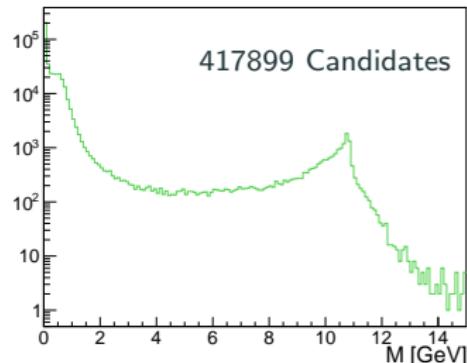
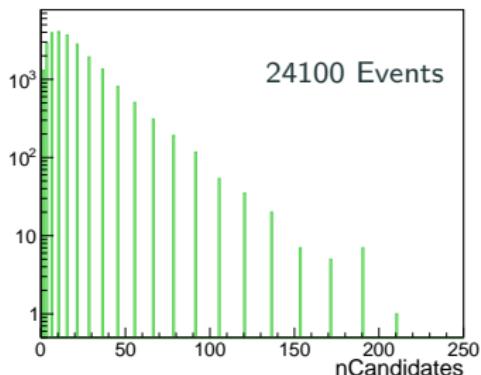
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Single phase2 MC10 Bhabha file



# Introducing Cuts

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

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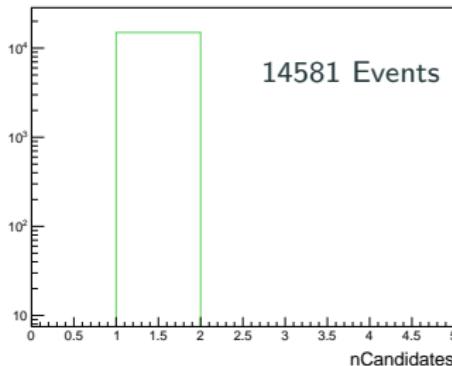
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Single phase2 MC10 Bhabha file



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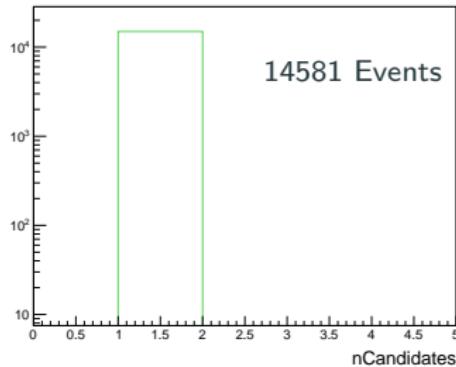
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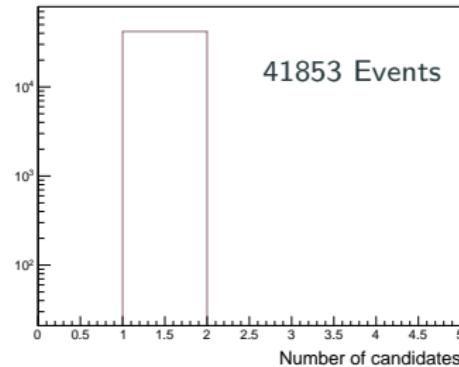
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Single phase2 MC10 Bhabha file



Single phase2 data file



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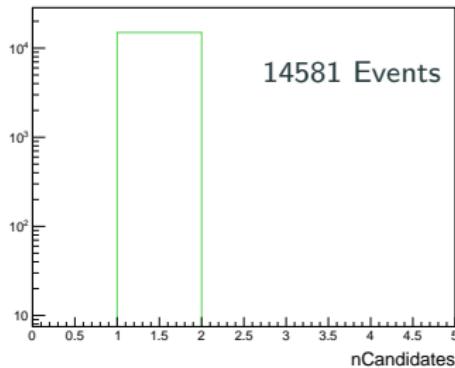
- The particles have to pass the tracking detectors

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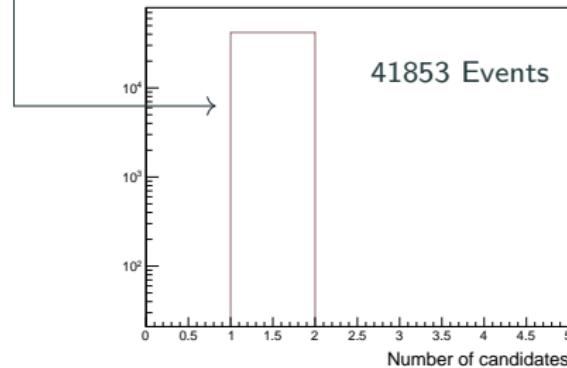
- $8 \text{ GeV} < M_{\text{vpho}} < 12 \text{ GeV}$
- 2 clusters with at least 3.5 GeV per event; One cluster has to have at least 4.5 GeV
- Number of reconstructed candidates
- Total energy in the ECL objects

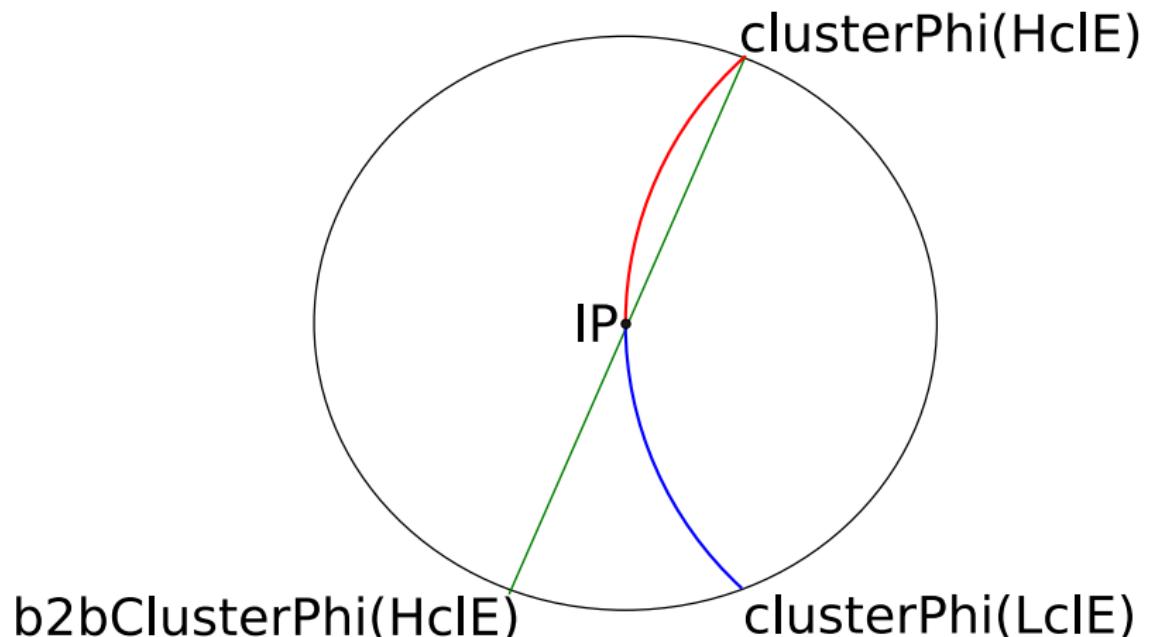
Also contains  $e^+e^- \rightarrow \gamma\gamma$  events

Single phase2 MC10 Bhabha file

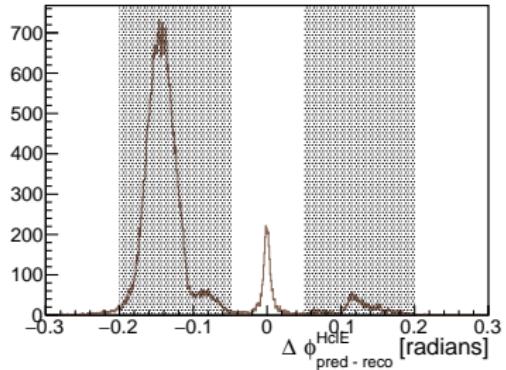
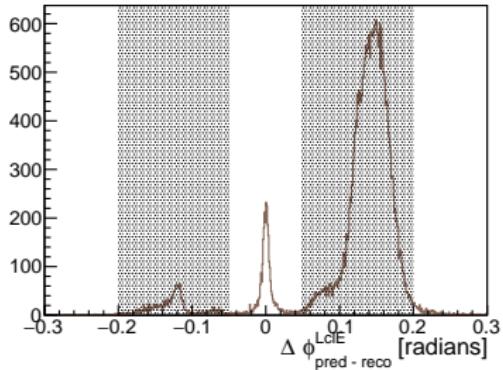
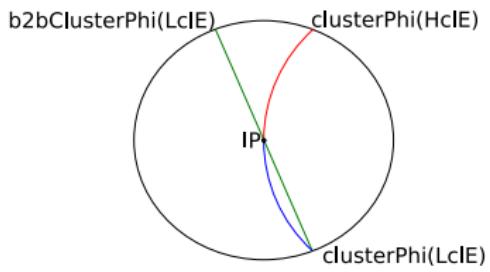
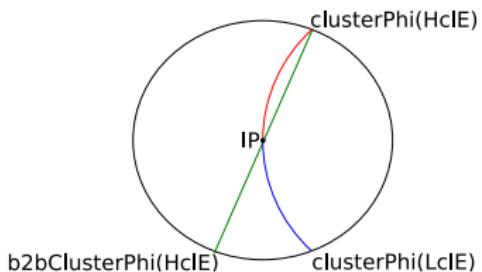


Single phase2 data file

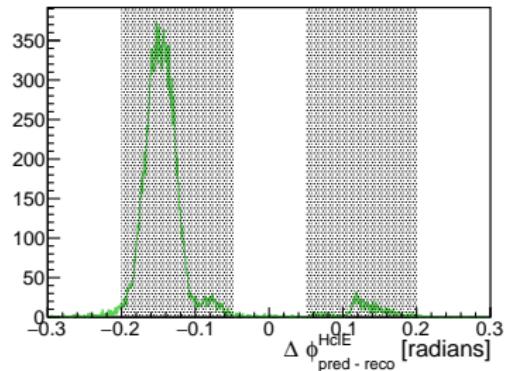
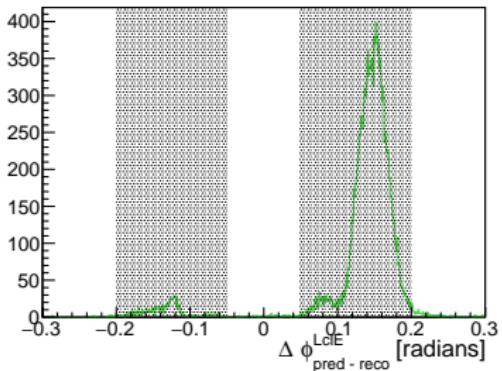
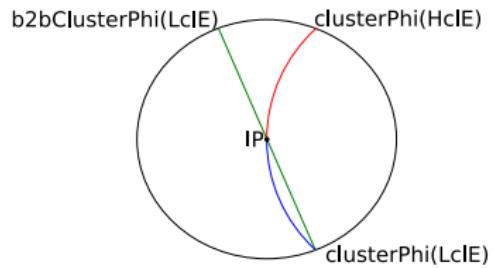
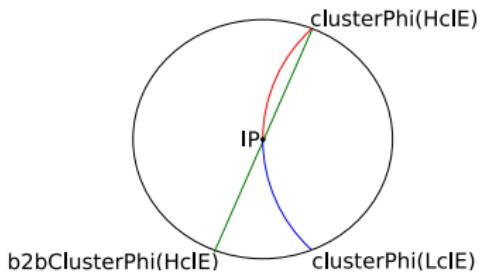




# Bhabha Event Selection



# Bhabha Event Selection



# Trigger

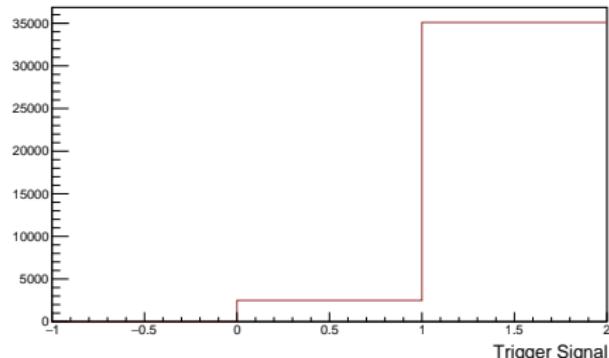
We need to be sure that a trigger signal is coming from the ECL. Otherwise there could be a bias

→ The bhabha trigger bit is used

This trigger requires several conditions:

- Trigger signal coming from the ECL
- Both reconstructed particles have to have a cluster energy of 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 is only applied on phase2 data (and phase3 data later on) since the trigger simulation does not work reliably on MC



# Dividing The ECL In Areas Of Interest

As function of azimuthal angle

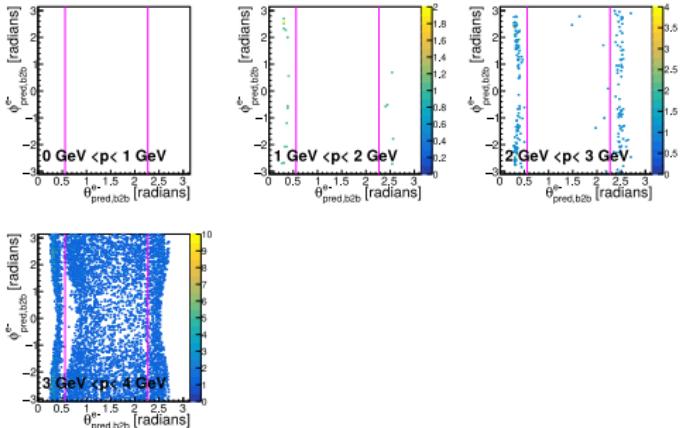
$\phi_{\text{pred},\text{b2b}}$

$p(e^-)$

Forward End-Cap

Barrel

Backward End-Cap



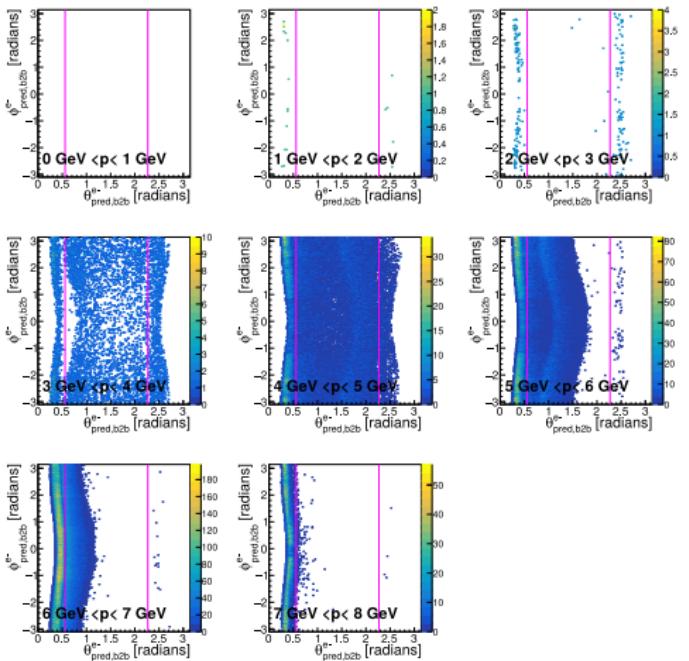
# Dividing The ECL In Areas Of Interest

As function of azimuthal angle

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

$$p(e^-)$$

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



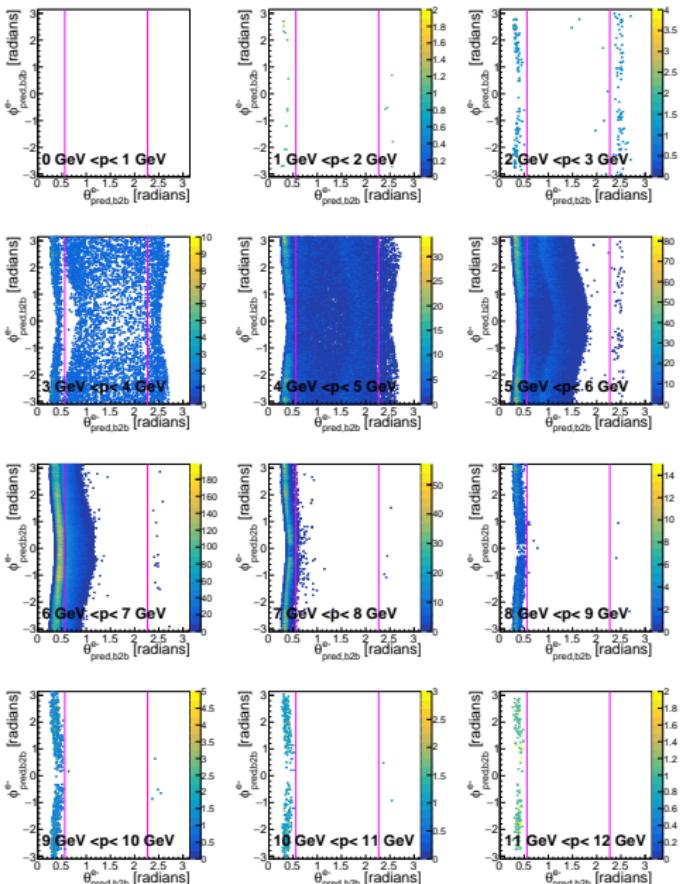
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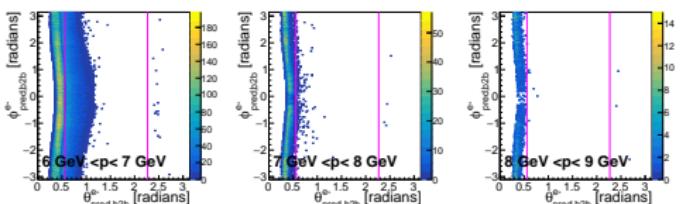
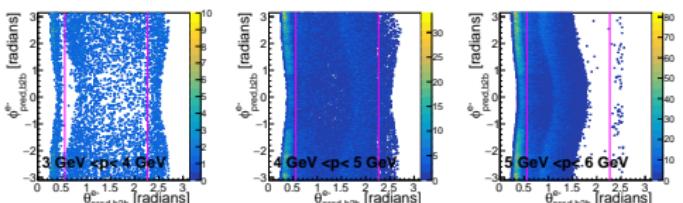
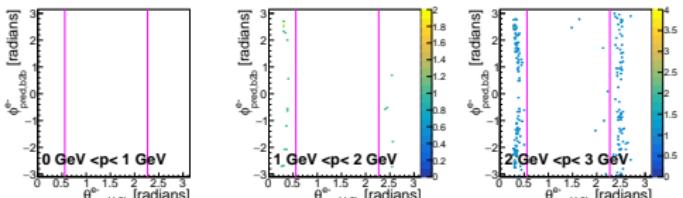


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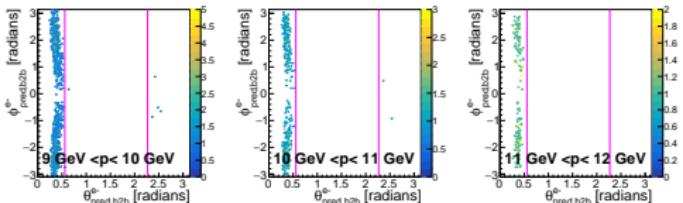
$$\phi_{\text{pred},\text{b2b}}$$

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



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

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



# Dividing The ECL In Areas Of Interest

As function of azimuthal angle

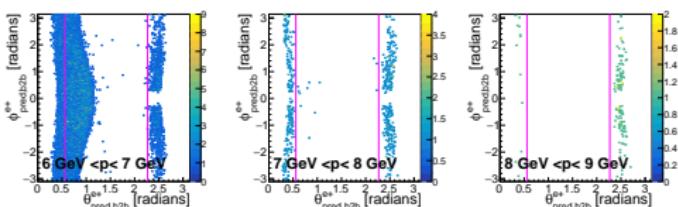
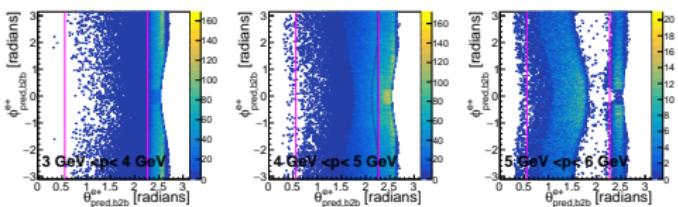
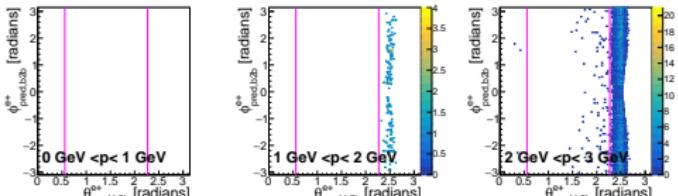
$$\phi_{\text{pred},\text{b2b}}$$

$$p(e^-)$$

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

$$p(e^+)$$

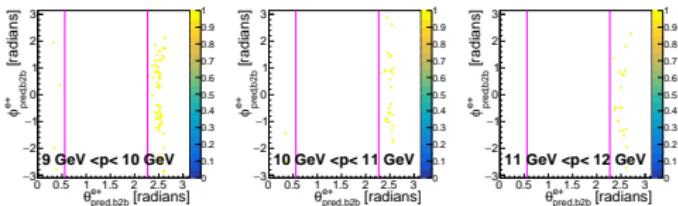
Forward End-Cap	/
Barrel	3 GeV – 7 GeV
Backward End-Cap	2 GeV – 6 GeV



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

$$p$$

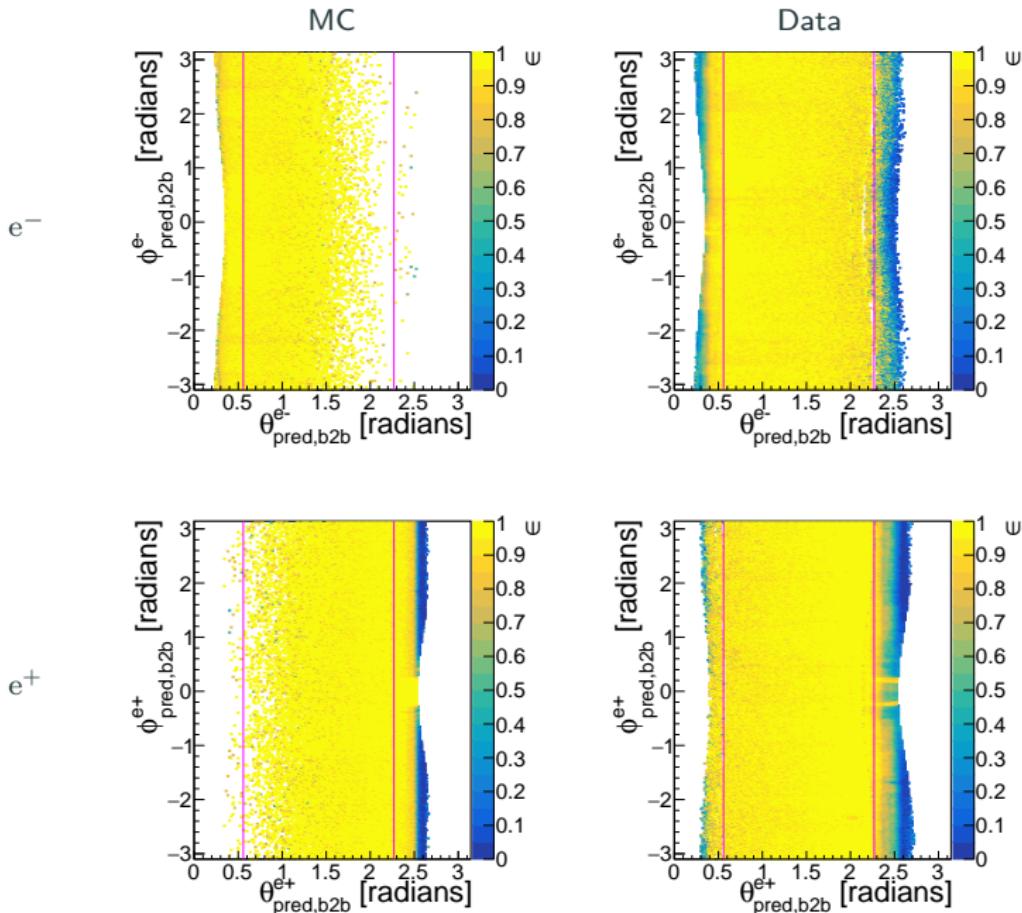
$$\begin{aligned} e^- & \quad 4 \text{ GeV} - 9 \text{ GeV} \\ e^+ & \quad 2 \text{ GeV} - 7 \text{ GeV} \end{aligned}$$



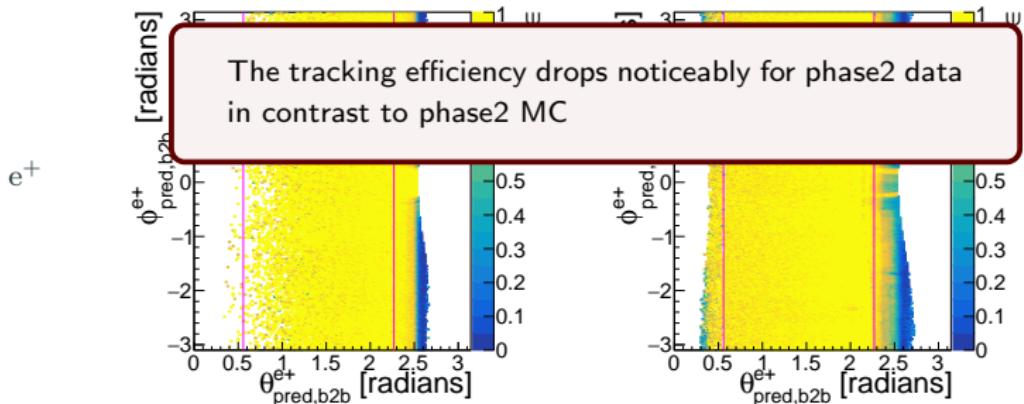
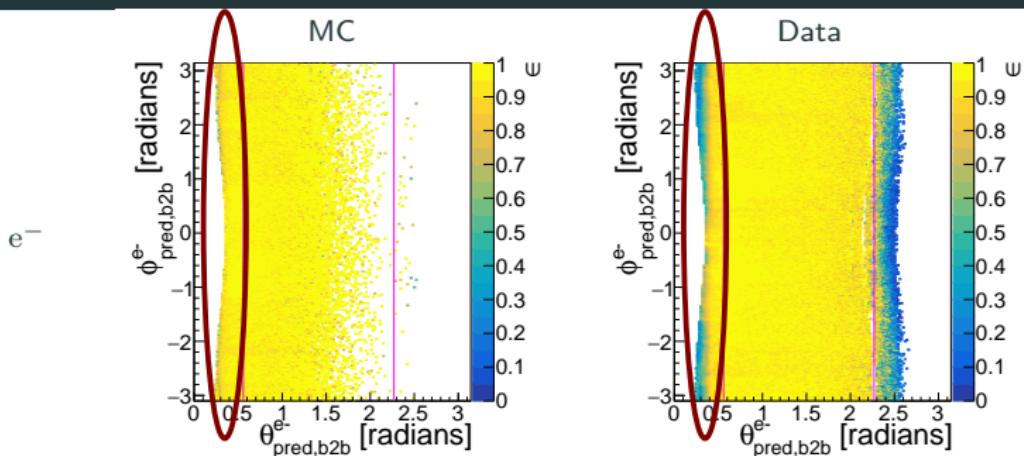
## Phase2 Tracking Efficiencies

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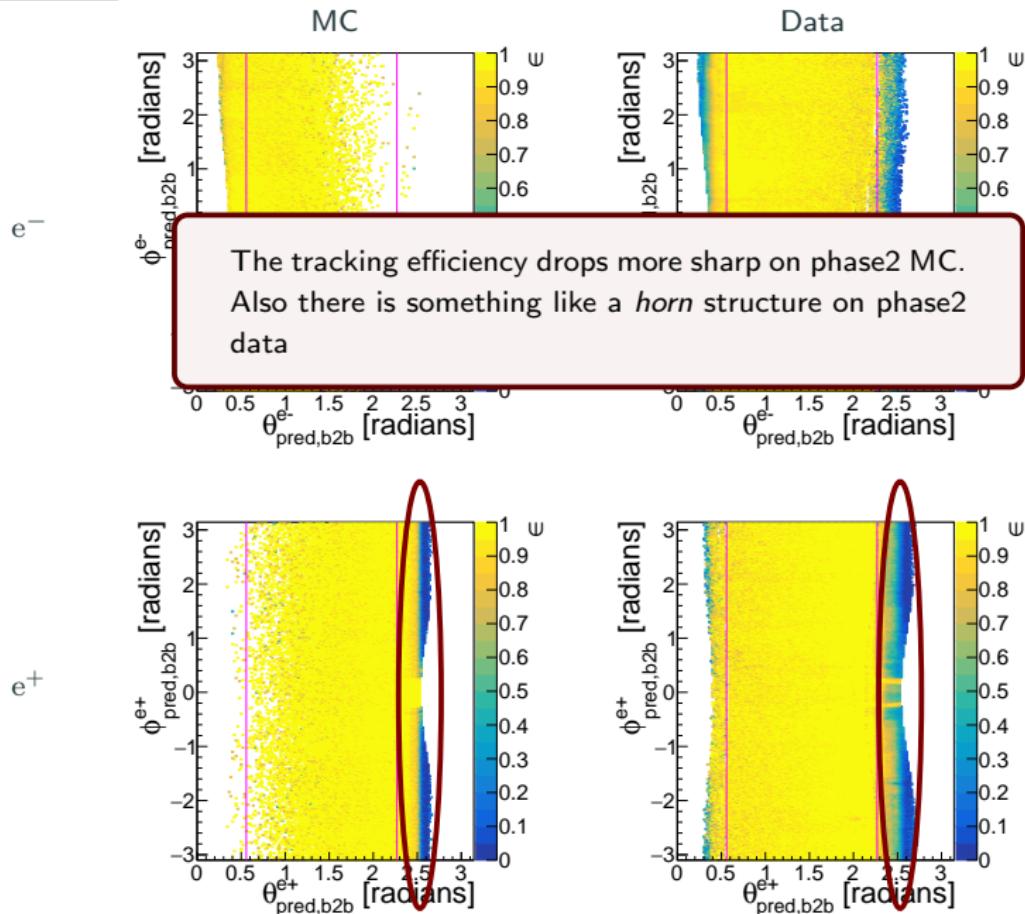
# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}} - \phi_{\text{pred,b2b}}$



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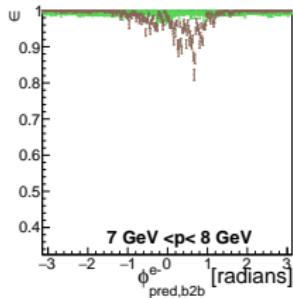
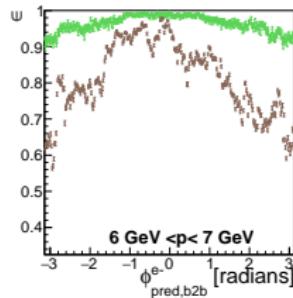
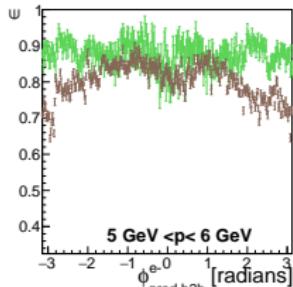
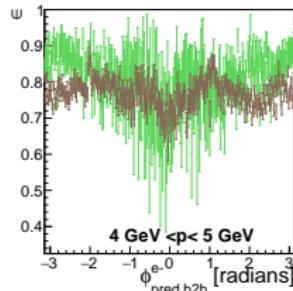


# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Forward End-Cap

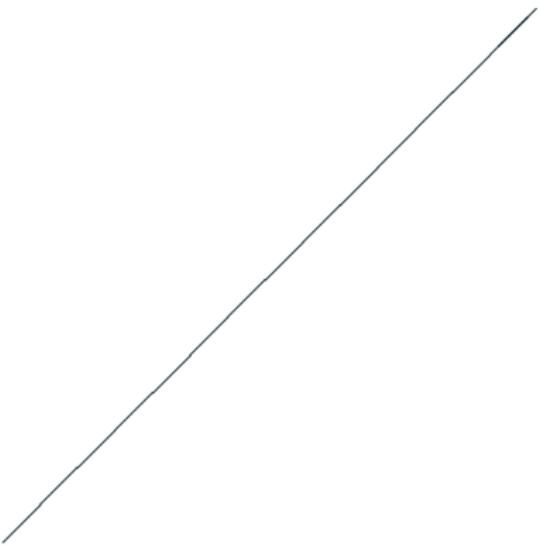
Phase2 MC10

Phase2 Data

e<sup>-</sup>



e<sup>+</sup>

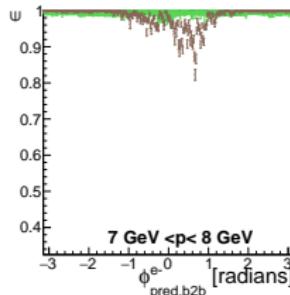
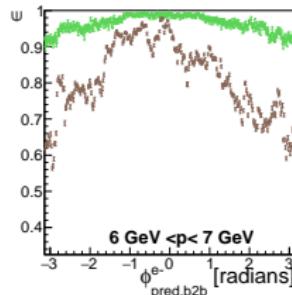
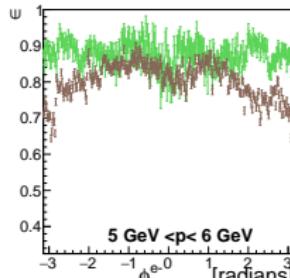
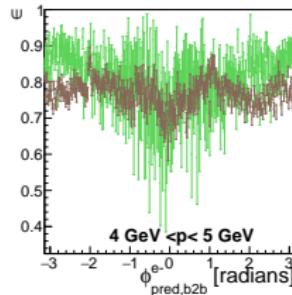


# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Forward End-Cap

Phase2 MC10

Phase2 Data

e<sup>-</sup>



Electron Tracking Efficiency:

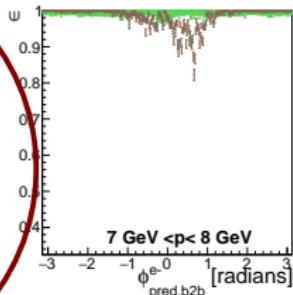
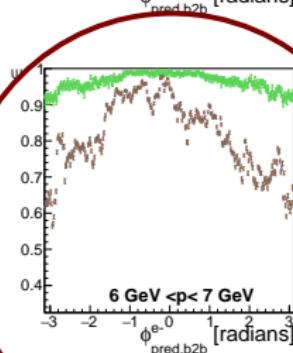
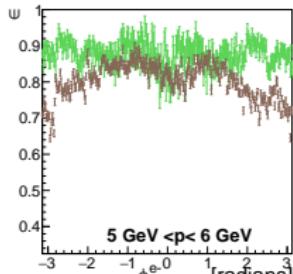
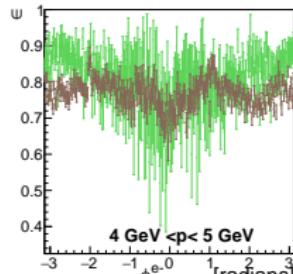
- Phase2 MC has almost always a higher tracking efficiency compared to phase2 data
- For most momenta the biggest difference between phase2 MC and phase2 data occurs for  $|\phi_{\text{pred,b2b}}| \gtrsim 2$

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

Phase2 MC10

Phase2 Data

e<sup>-</sup>



## Electron Tracking Efficiency:

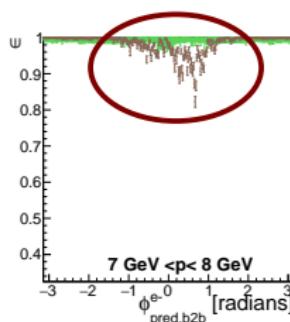
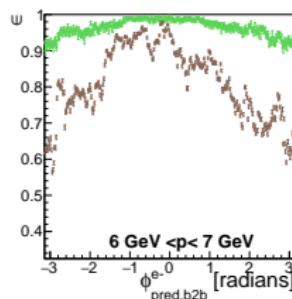
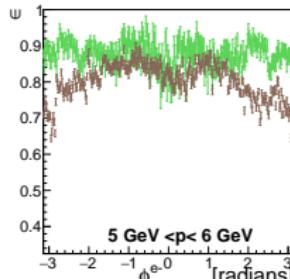
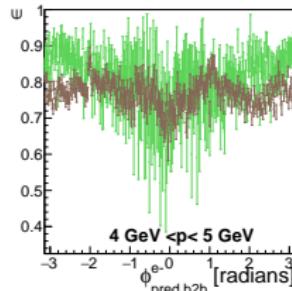
- Phase2 MC has almost always a higher tracking efficiency compared to phase2 data
- For most momenta the biggest difference between phase2 MC and phase2 data occurs for  $|\phi_{\text{pred,b2b}}| \gtrsim 2$
- There is no similarity in the structure for momenta between 6 GeV and 7 GeV

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

Phase2 MC10

Phase2 Data

e<sup>-</sup>



## Electron Tracking Efficiency:

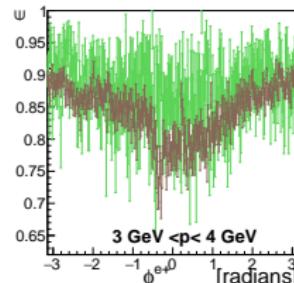
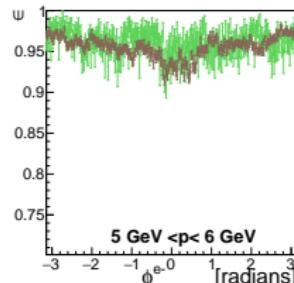
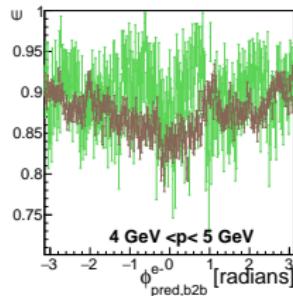
- Phase2 MC has almost always a higher tracking efficiency compared to phase2 data
- For most momenta the biggest difference between phase2 MC and phase2 data occurs for  $|\phi_{\text{pred,b2b}}| \gtrsim 2$
- There is no similarity in the structure for momenta between 6 GeV and 7 GeV
- Highest tracking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

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

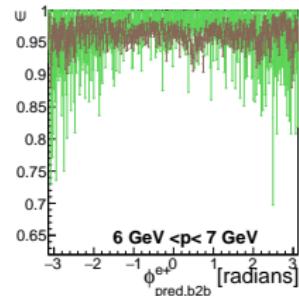
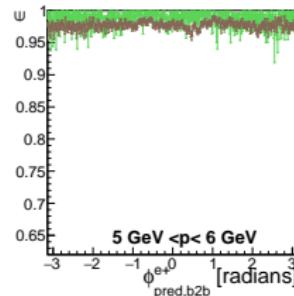
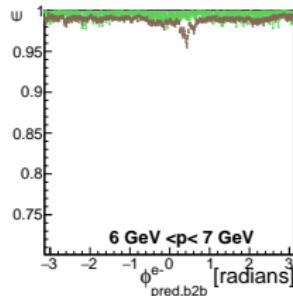
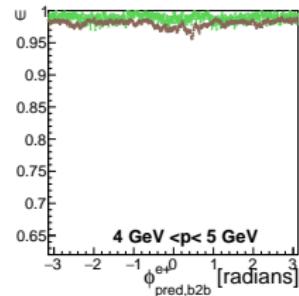
Phase2 MC10

e<sup>-</sup>

Phase2 Data



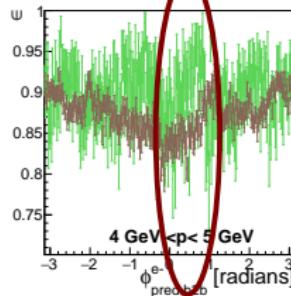
e<sup>+</sup>



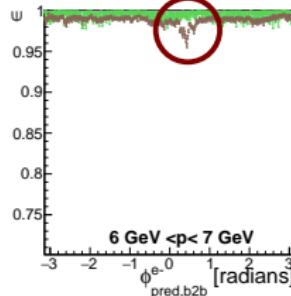
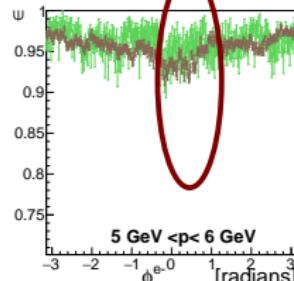
# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Barrel

Phase2 MC10

Phase2 Data

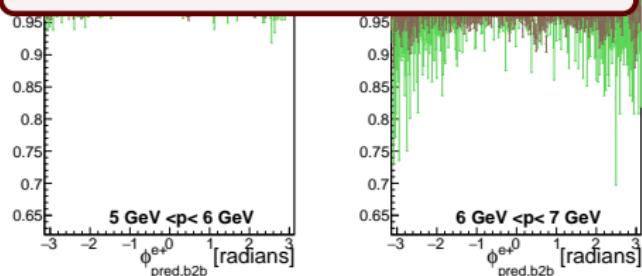


$e^-$



Electron Tracking Efficiency:

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

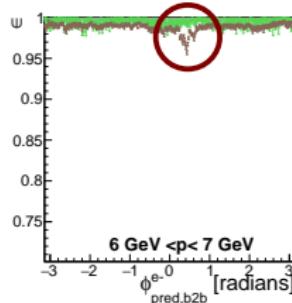
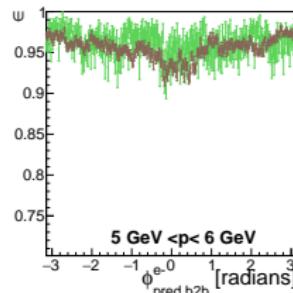
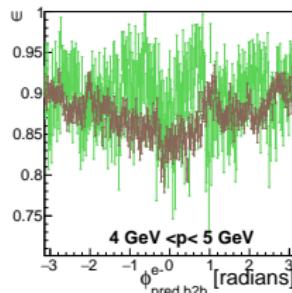


# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Barrel

Phase2 MC10

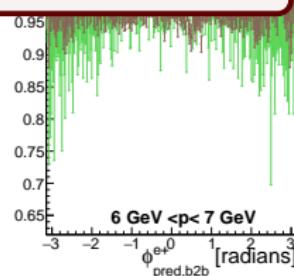
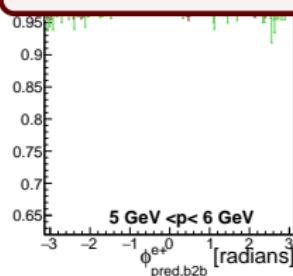
e<sup>-</sup>

Phase2 Data



Electron Tracking Efficiency:

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



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

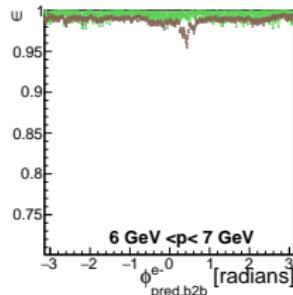
## Phase2 MC10

### Positron Tracking Efficiency:

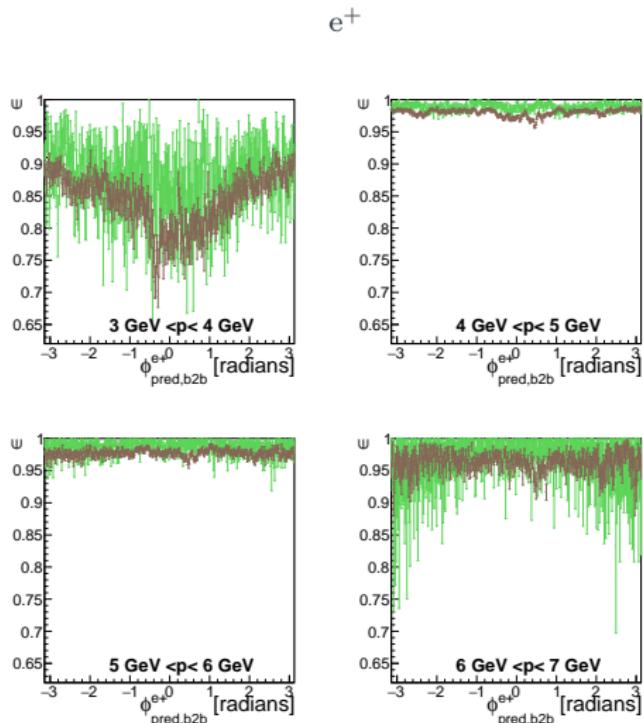
- The highest tracking efficiency occurs for momenta between 4 GeV and 5 GeV
- The lowest tracking efficiency occurs for momenta between 3 GeV and 4 GeV

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

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



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

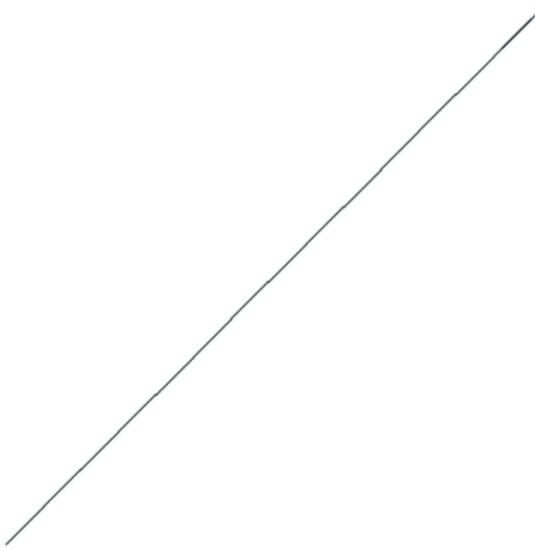


# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

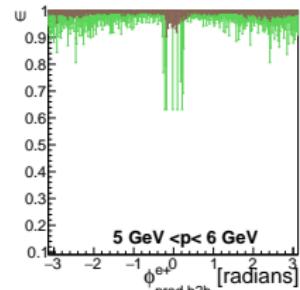
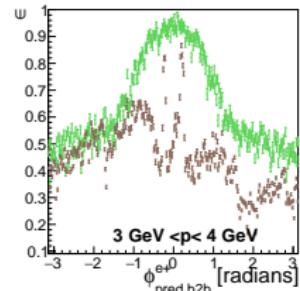
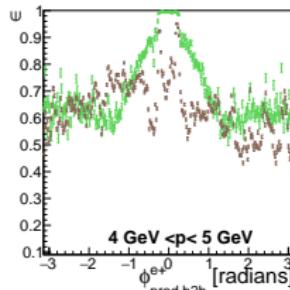
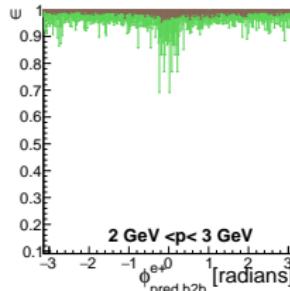
Phase2 MC10

$e^-$

Phase2 Data



$e^+$

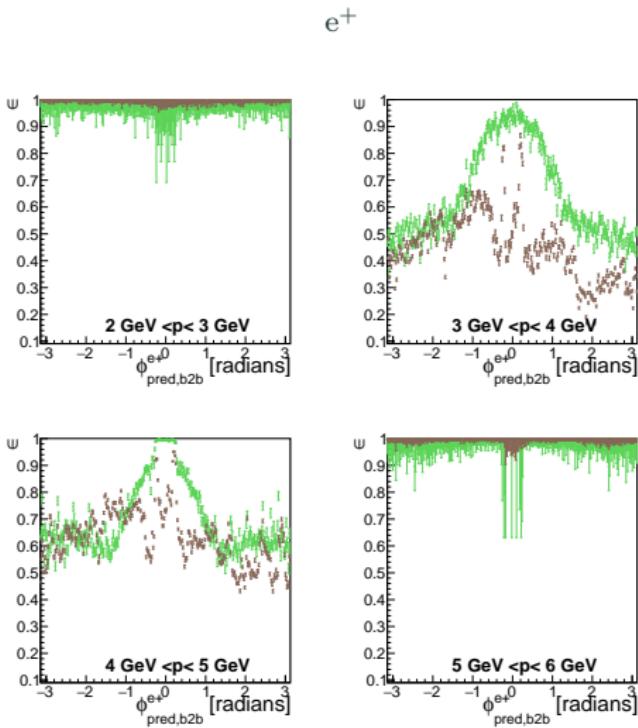


# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

## Phase2 MC10

### Positron Tracking Efficiency:

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

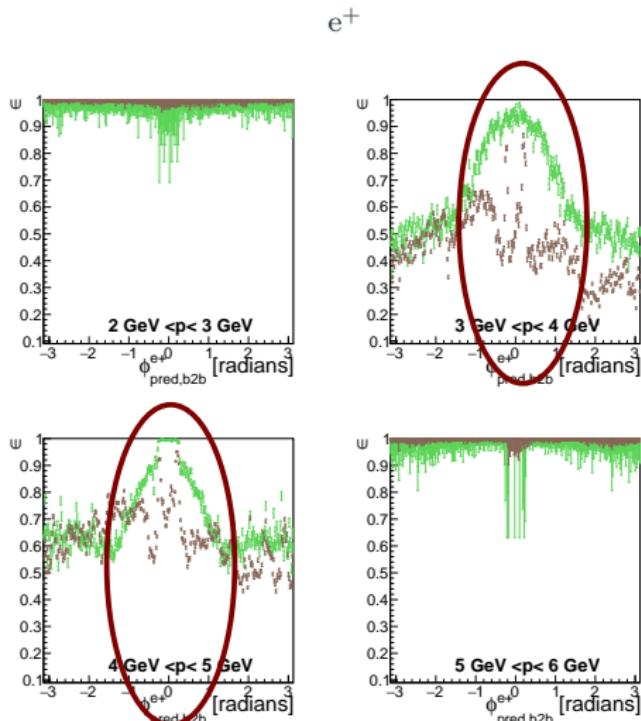


# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

## Phase2 MC10

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

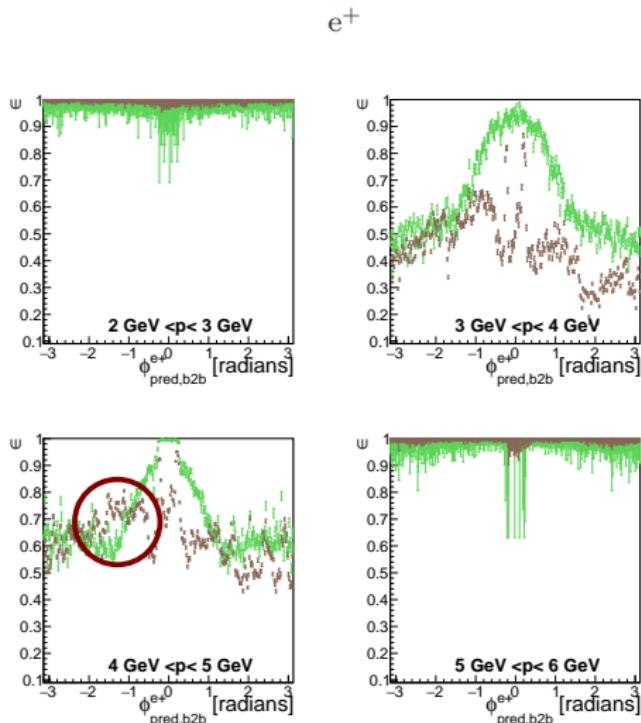


# Phase2 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

## Phase2 MC10

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  $\phi_{\text{pred,b2b}} \approx -1$

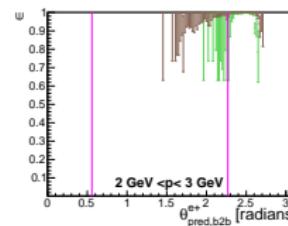
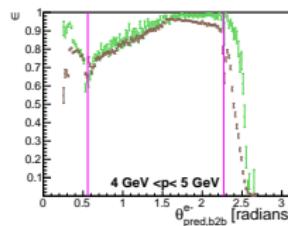
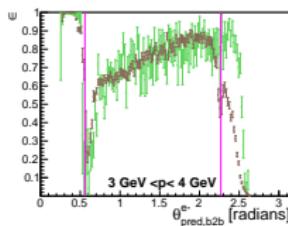


# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

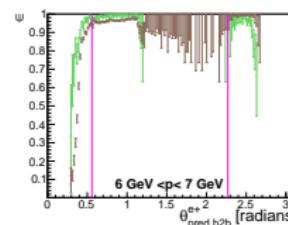
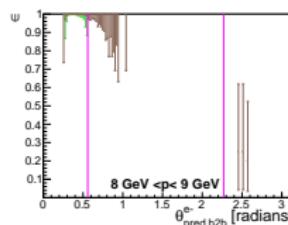
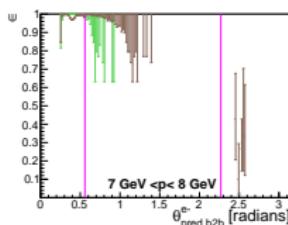
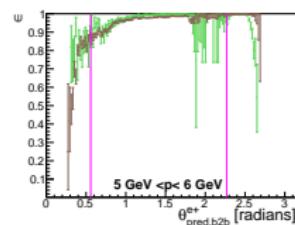
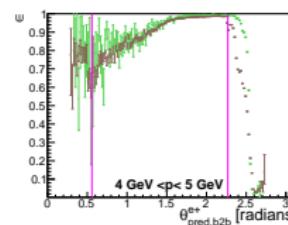
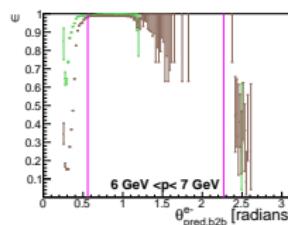
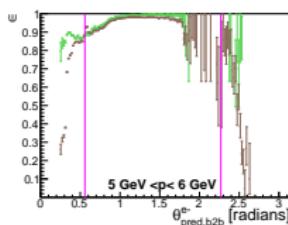
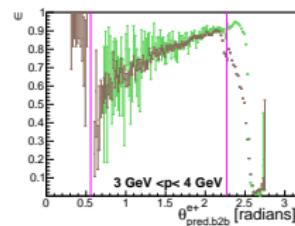
Phase2 MC10

e<sup>-</sup>

Phase2 Data



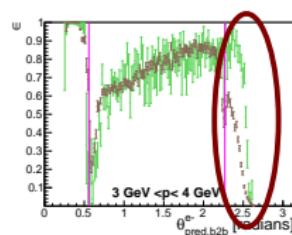
e<sup>+</sup>



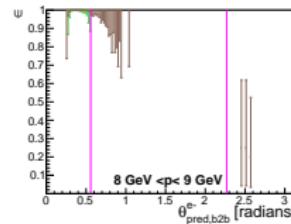
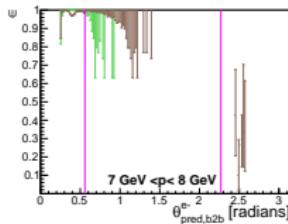
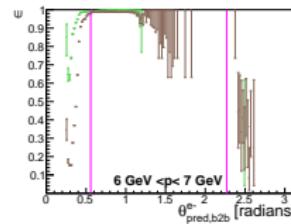
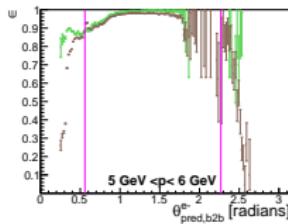
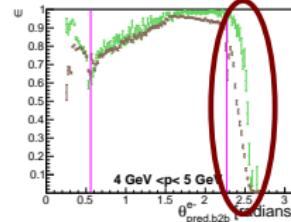
# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 MC10

Phase2 Data

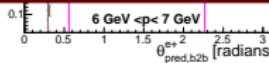


$e^-$



Electron Tracking Efficiency:

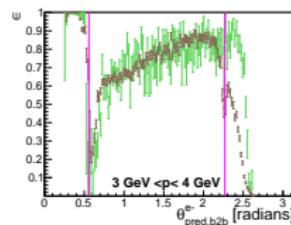
- For momenta between 3 GeV and 5 GeV the tracking efficiency in the backward end-cap is worse for phase2 data compared to phase2 MC



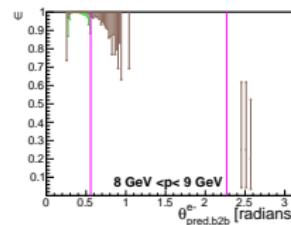
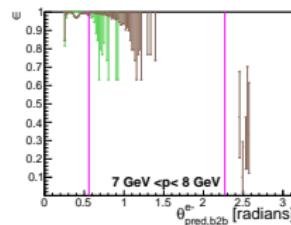
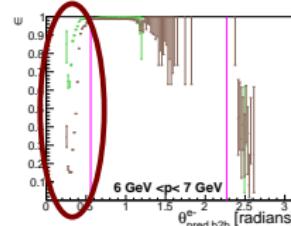
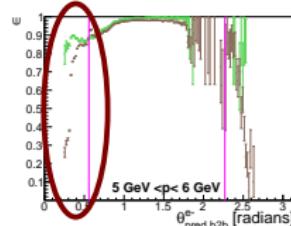
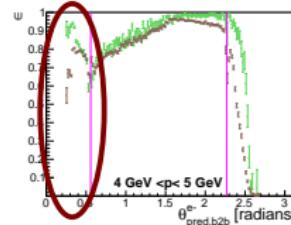
# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 MC10

Phase2 Data

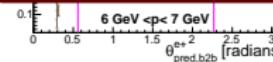


$e^-$



Electron Tracking Efficiency:

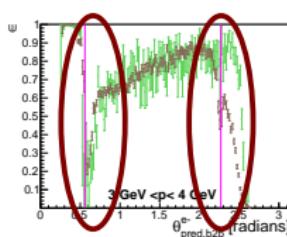
- For momenta between 3 GeV and 5 GeV the tracking efficiency in the backward end-cap is worse for phase2 data compared to phase2 MC
- For momenta between 4 GeV and 6 GeV the tracking efficiency in the forward end-cap is worse for phase2 data compared to phase2 MC



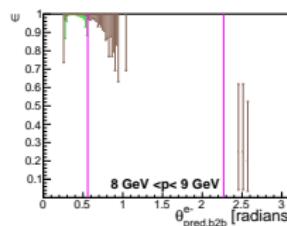
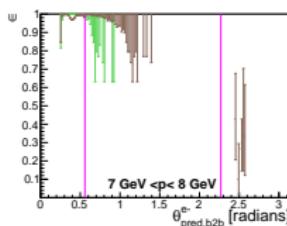
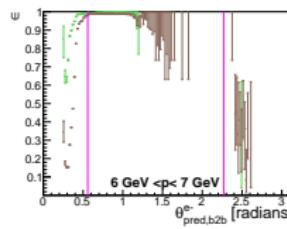
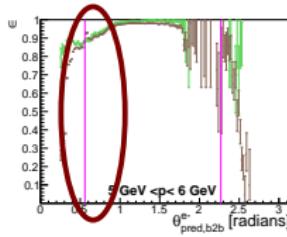
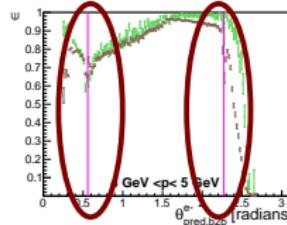
# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 MC10

Phase2 Data

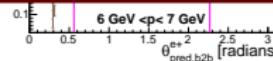


$e^-$



Electron Tracking Efficiency:

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

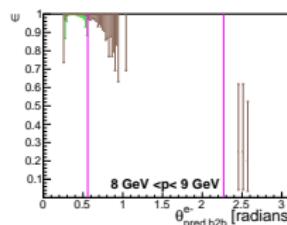
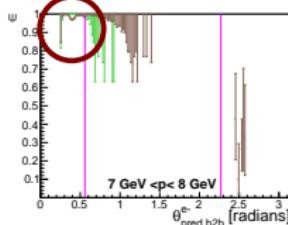
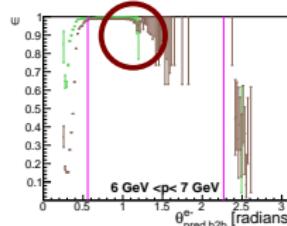
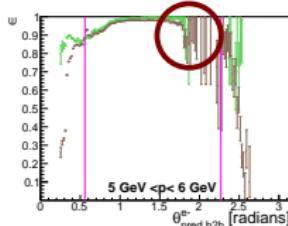
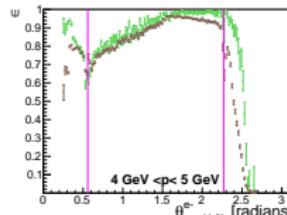
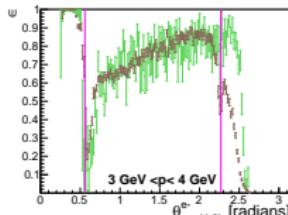


# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase2 MC10

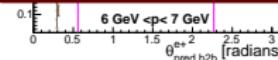
Phase2 Data

e<sup>-</sup>



## Electron Tracking Efficiency:

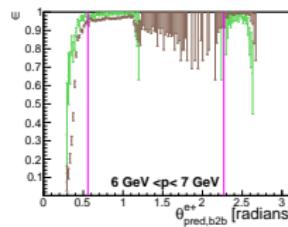
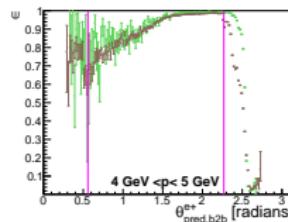
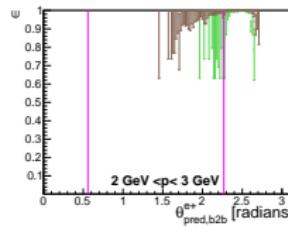
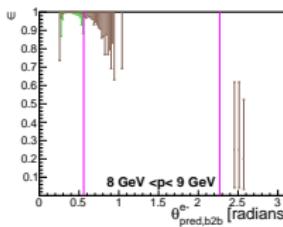
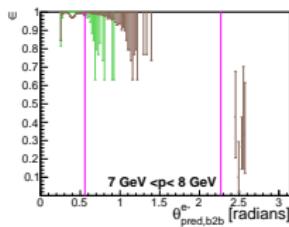
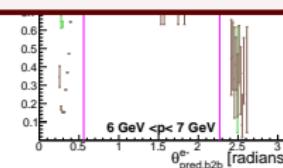
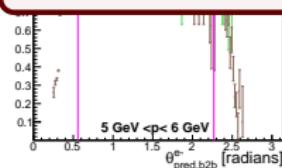
- For momenta between 3 GeV and 5 GeV the tracking efficiency in the backward end-cap is worse for phase2 data compared to phase2 MC
- For momenta between 4 GeV and 6 GeV the tracking efficiency in the forward end-cap is worse for phase2 data compared to phase2 MC
- Drop in efficiency at transition between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



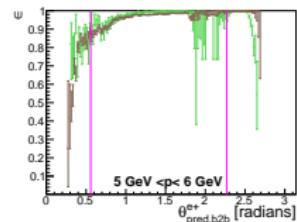
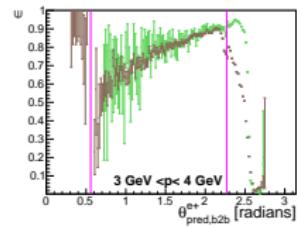
# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

## Phase2 MC10

Positron Tracking Efficiency:



$e^+$

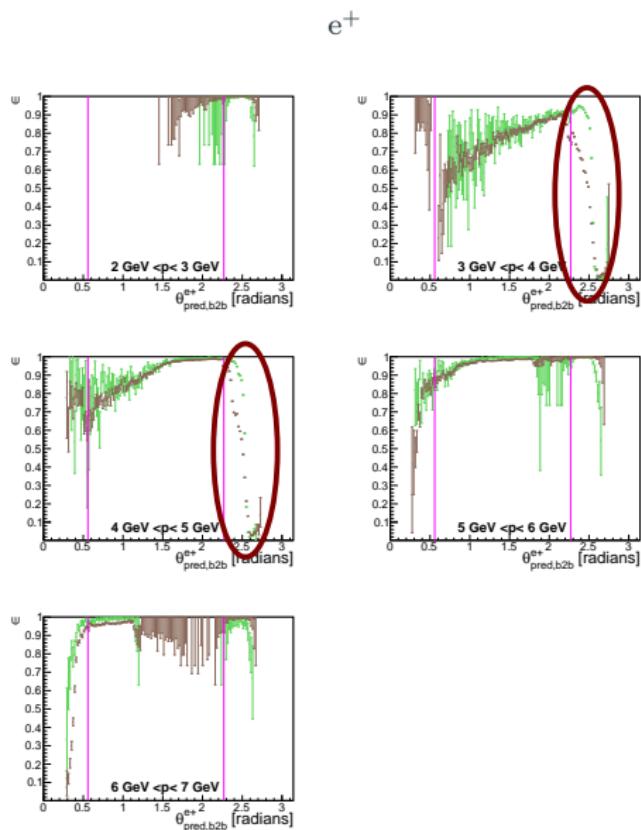
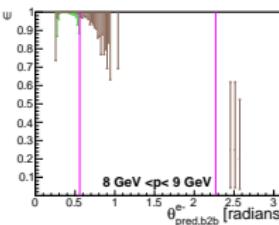
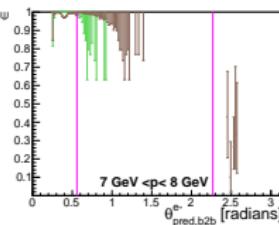
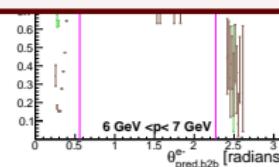
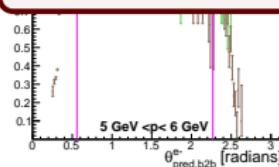


# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

## Phase2 MC10

### Positron Tracking Efficiency:

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

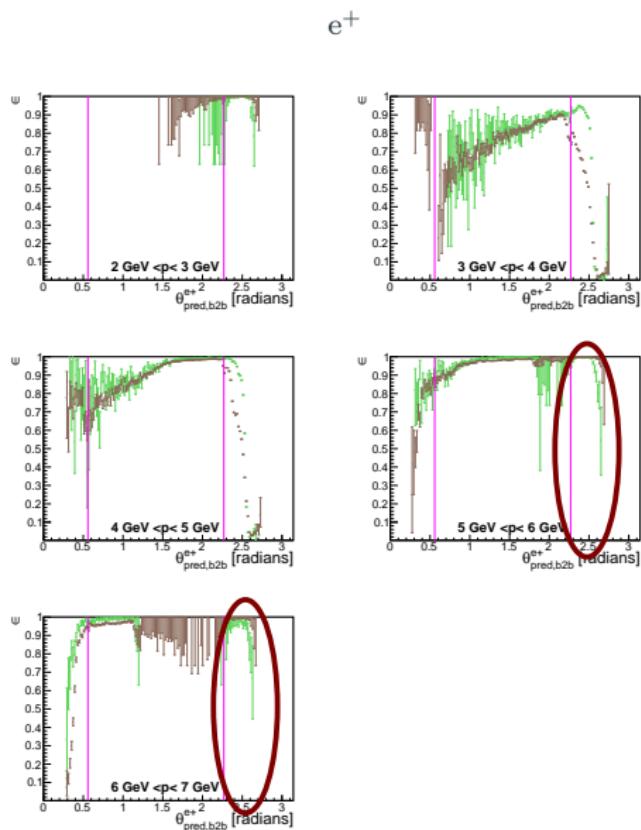
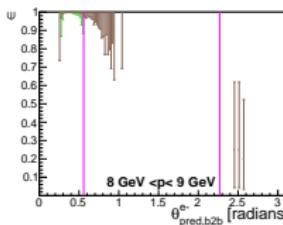
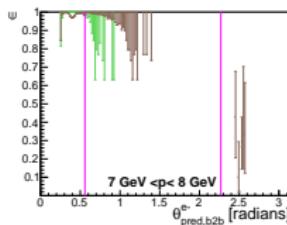
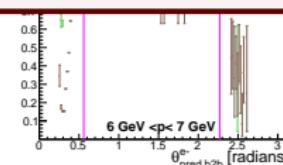
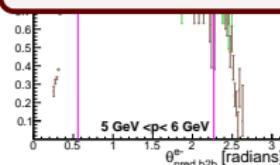


# Phase2 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

## Phase2 MC10

### Positron Tracking Efficiency:

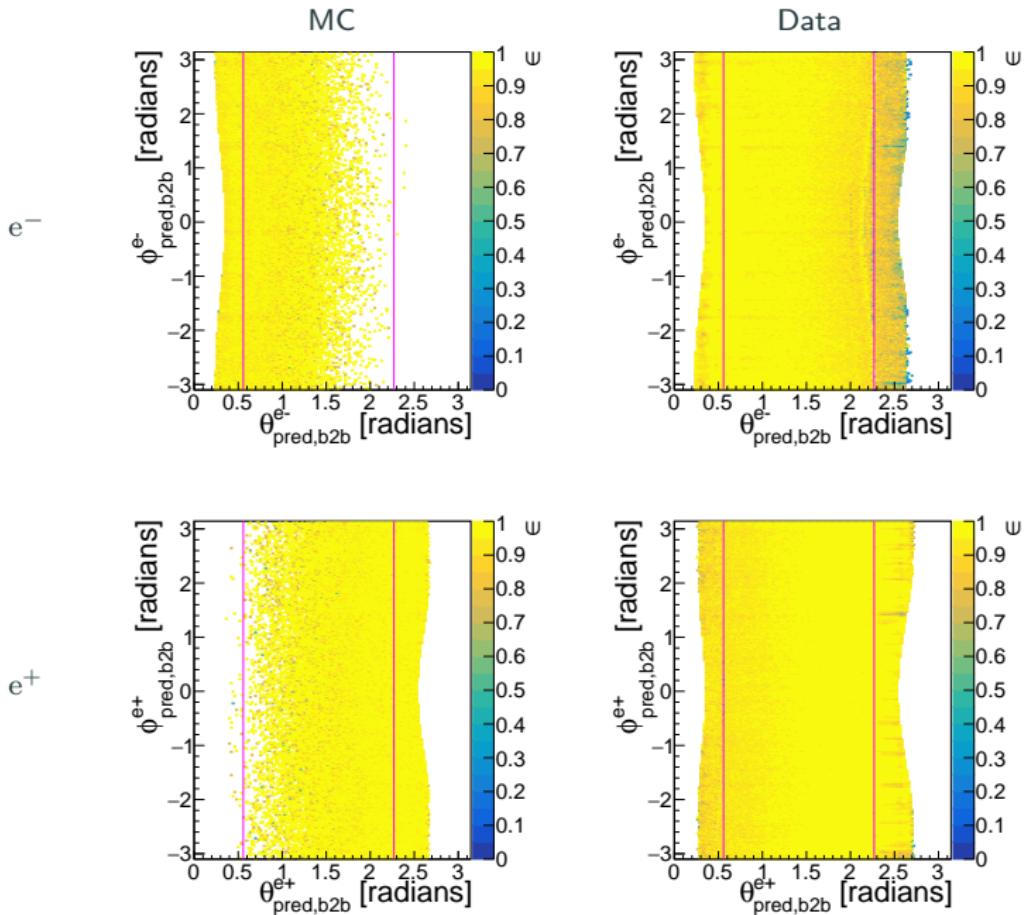
- For momenta between 3 GeV and 5 GeV the phase2 data tracking efficiency is lower compared to phase2 MC in the backward end-cap
- For momenta between 5 GeV and 7 GeV it is vice versa



## Phase3 Tracking Efficiencies

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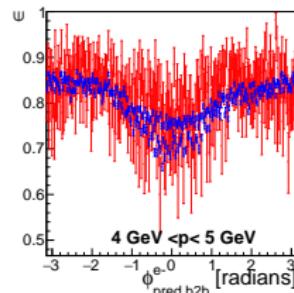
# Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}} - \phi_{\text{pred,b2b}}$



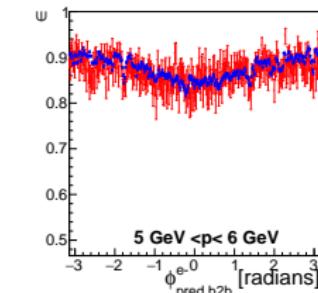
# Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Forward End-Cap

Phase3 MC10

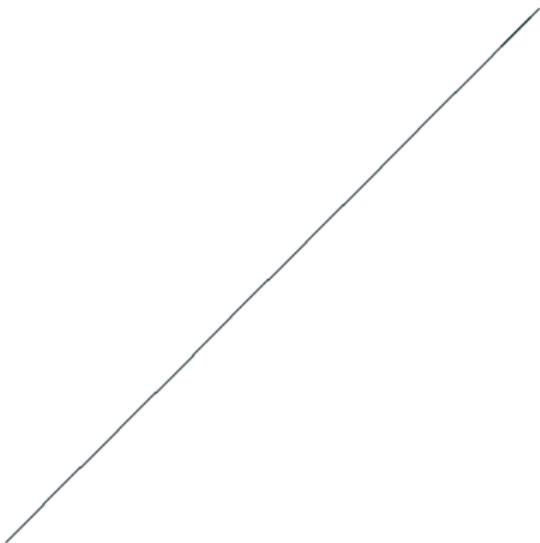
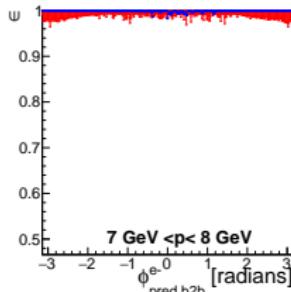
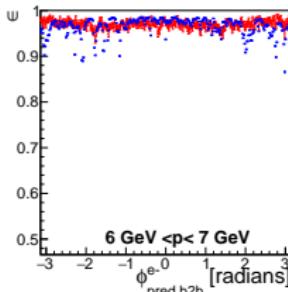
Phase3 Data



$e^-$



$e^+$

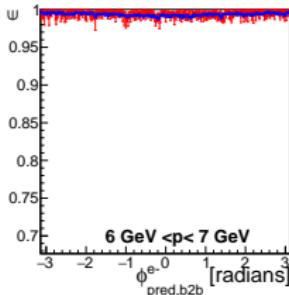
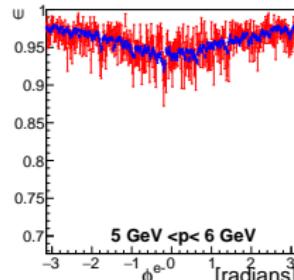
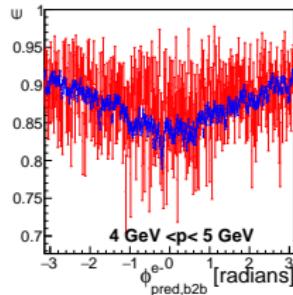


# Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Barrel

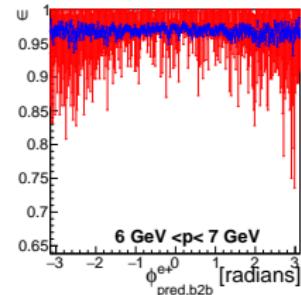
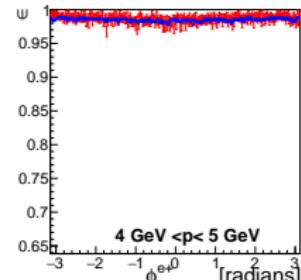
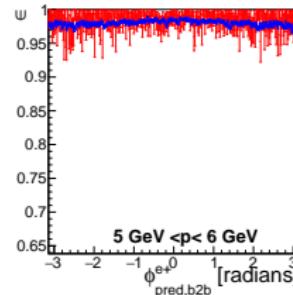
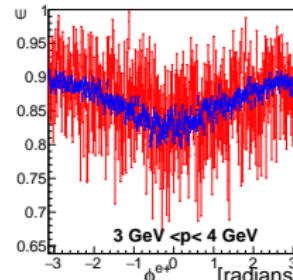
Phase3 MC10

Phase3 Data

$e^-$



$e^+$

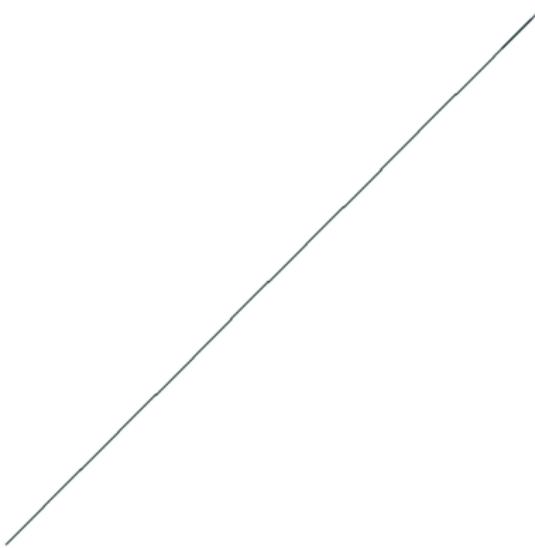


# Phase3 Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

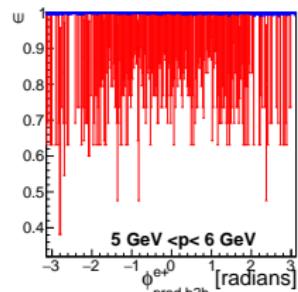
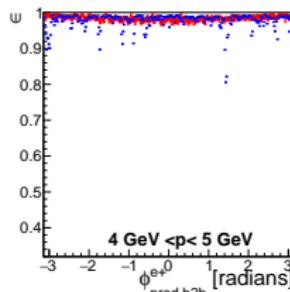
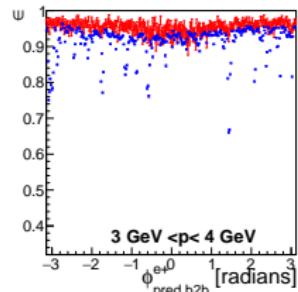
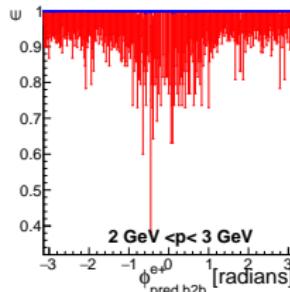
Phase3 MC10

Phase3 Data

$e^-$



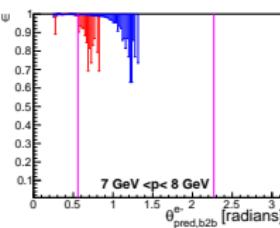
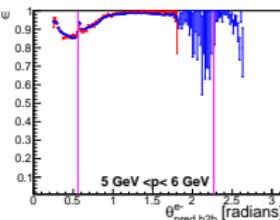
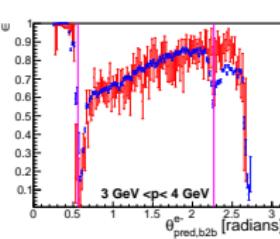
$e^+$



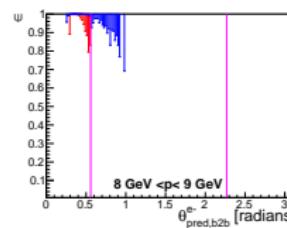
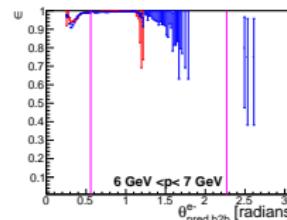
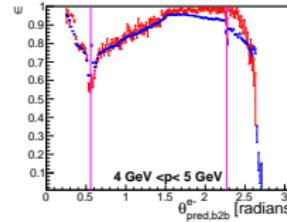
# Phase3 Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase3 MC10

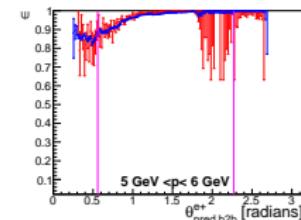
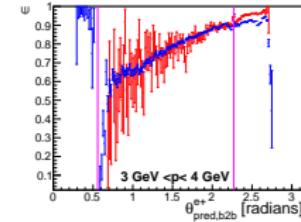
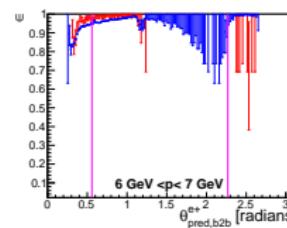
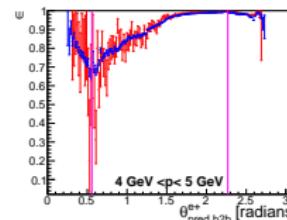
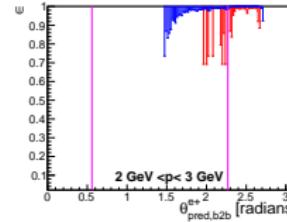
Phase3 Data



e<sup>-</sup>



e<sup>+</sup>



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

---

## **Conclusion**

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## Conclusion

## **Appendix**

---

## Code

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

## More Events

Phase2 data:

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

Phase2 MC:

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

Phase3 data:

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

Phase3 MC:

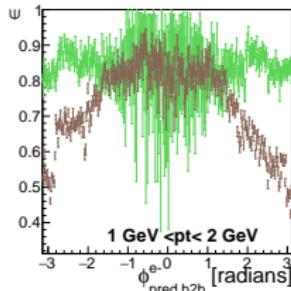
- /belle/MC/release-01-00-02/DB00000294/MC10/  
prod00004664/s00/e0000/4S/r00000/3600520000/mdst/sub00

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

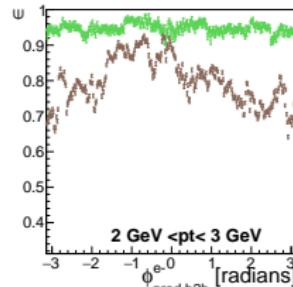
Phase2 MC10

Phase2 Data

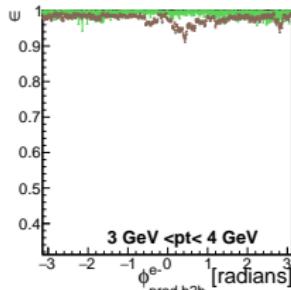
$e^-$



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

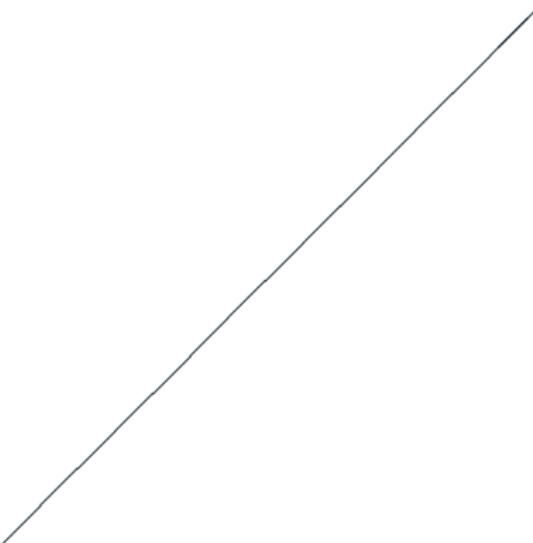


$2 \text{ GeV} < p_t < 3 \text{ GeV}$



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

$e^+$

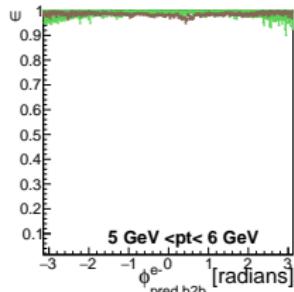
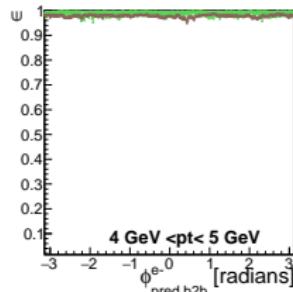
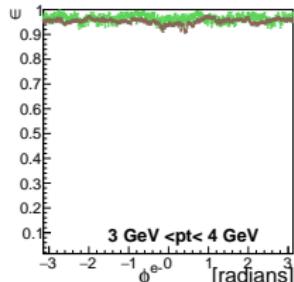
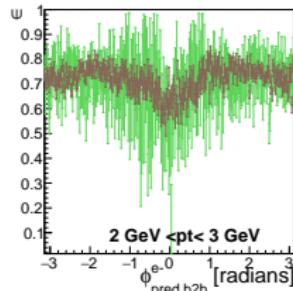


# Phase2 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Barrel

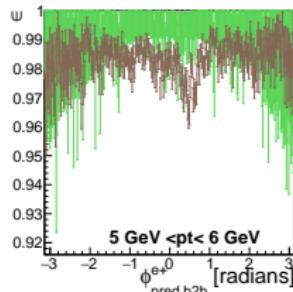
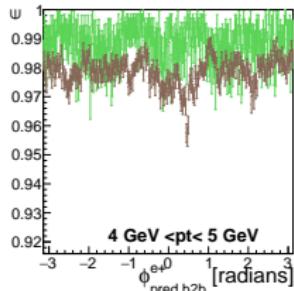
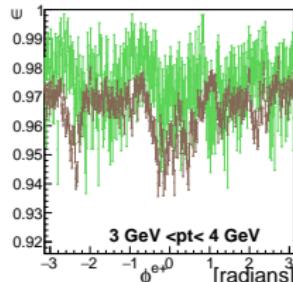
Phase2 MC10

e<sup>-</sup>

Phase2 Data



e<sup>+</sup>

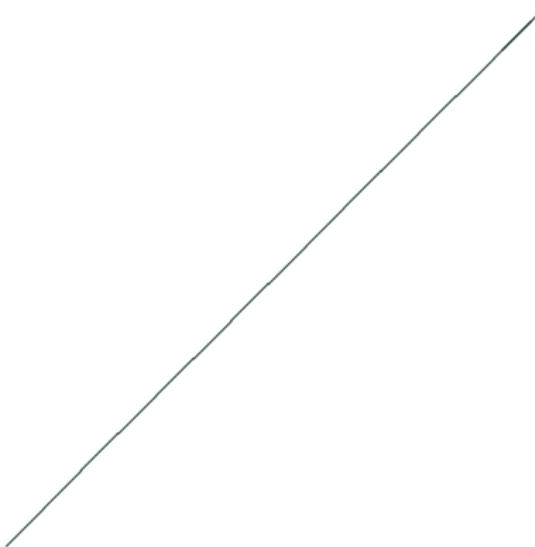


# Phase2 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

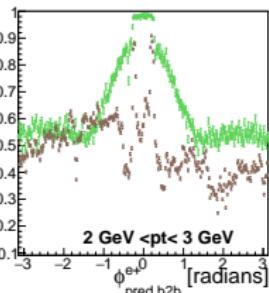
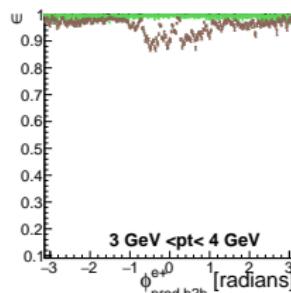
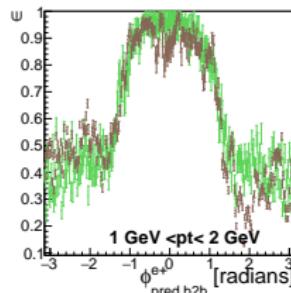
Phase2 MC10

$e^-$

Phase2 Data



$e^+$

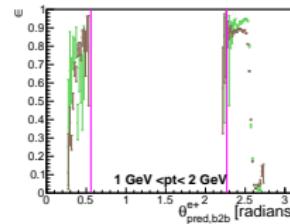
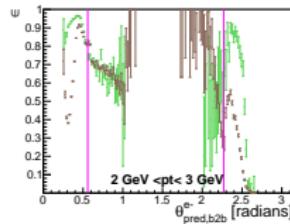
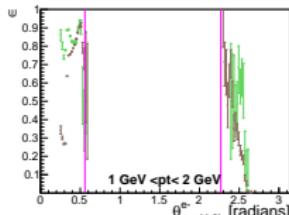


# Phase2 pt Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

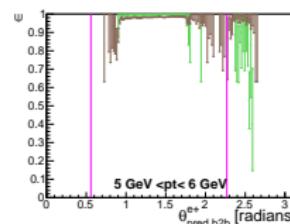
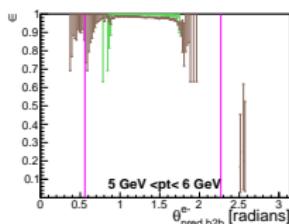
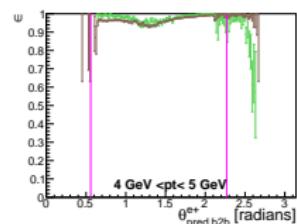
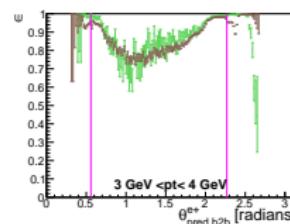
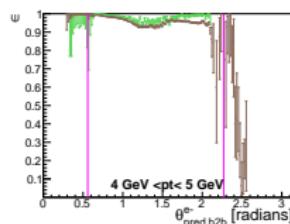
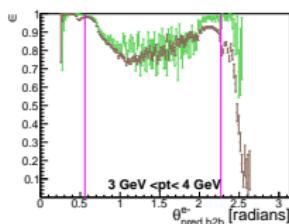
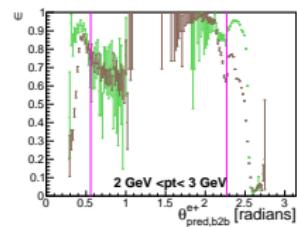
Phase2 MC10

$e^-$

Phase2 Data



$e^+$

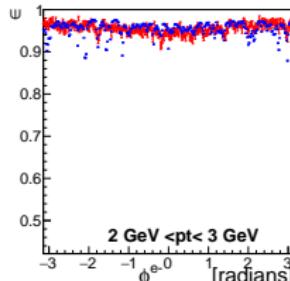
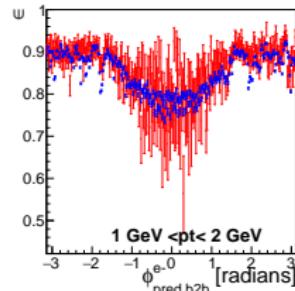


# Phase3 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Forward End-Cap

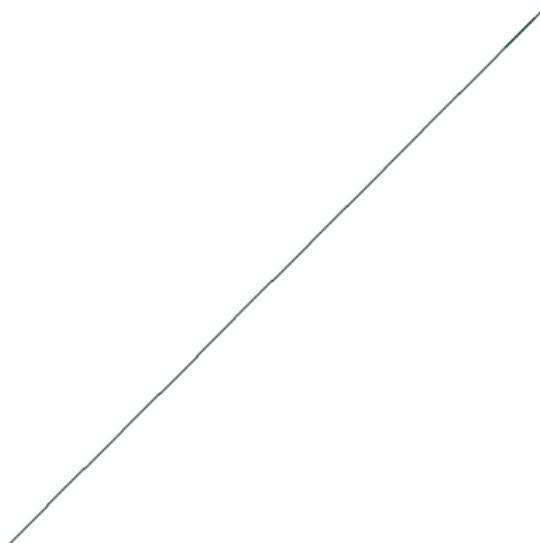
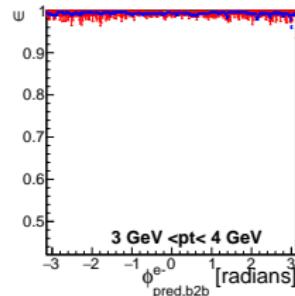
Phase3 MC10

Phase3 Data

e<sup>-</sup>



e<sup>+</sup>

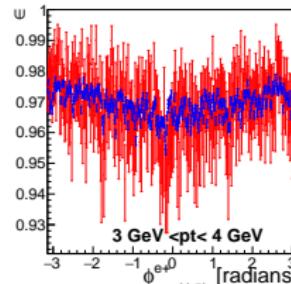
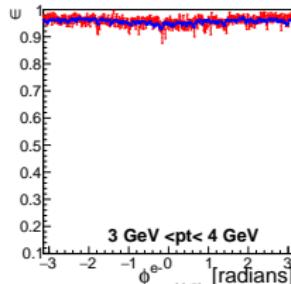
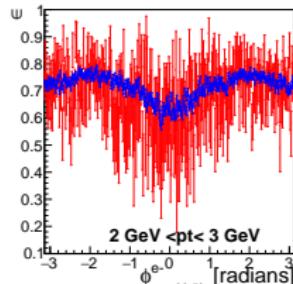


# Phase3 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Barrel

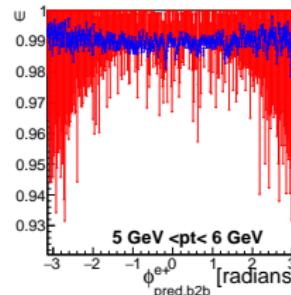
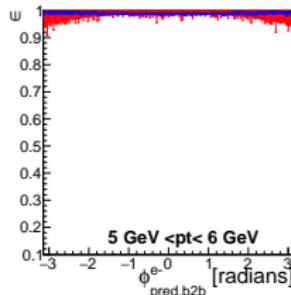
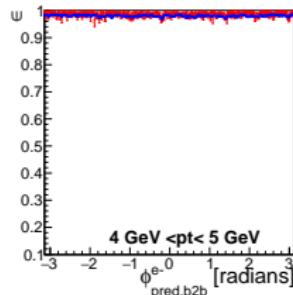
Phase3 MC10

e<sup>-</sup>

Phase3 Data



e<sup>+</sup>

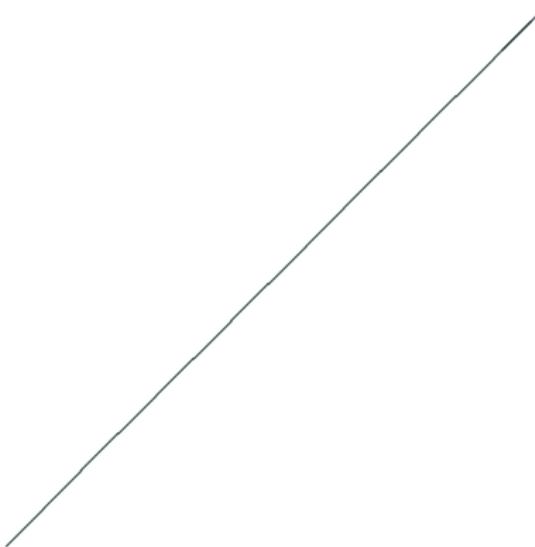


# Phase3 pt Tracking Efficiencies As Function Of $\phi_{\text{pred,b2b}}$ ; Backward End-Cap

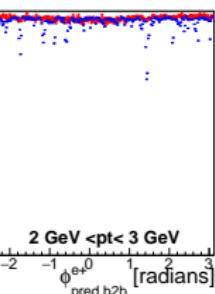
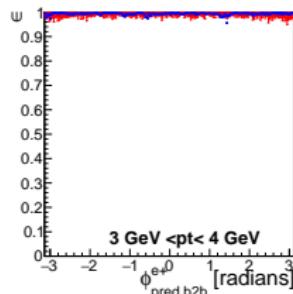
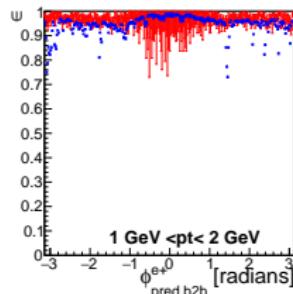
Phase3 MC10

$e^-$

Phase3 Data



$e^+$

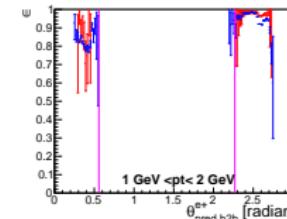
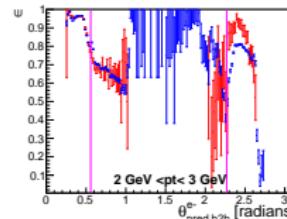
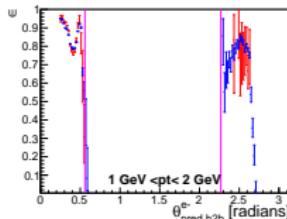


# Phase3 pt Tracking Efficiencies As Function Of $\theta_{\text{pred,b2b}}$

Phase3 MC10

e<sup>-</sup>

Phase3 Data



e<sup>+</sup>

