E_{ECL} study through comparisons.

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30 May 2023

Comparisons performed:

- Select a clean channel to compare (signal efficiency, signal resolution):
  - Belle vs Belle II data
  - Different FEI algorithms? (going-to-be future release)
  - MC15ri vs MC15rd
  - Different FEI calibration: overall vs mode-by-mode
  - Different ROE masks
- Select an ongoing analysis to compare:
  - Background conditions and sensitivity

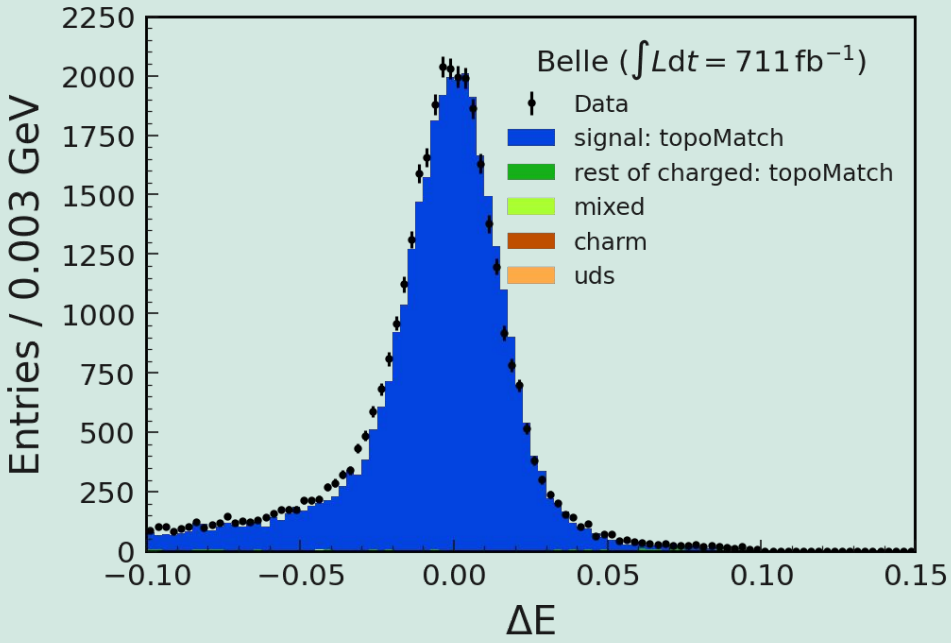
Select a clean channel: $B^{\pm} \to J/\psi\, K^{\pm}$

B_{sig}

- tracks: |dr| < 0.5 cm and |dz| < 2 cm
- e: eID > 0.9
- μ: μID > 0.9
- K: L(K/π) > 0.6
- $M_{J/\psi}$: 2.8 - 3.2 GeV/c^2

- M_{bc} > 5.27 GeV/c^2
- |ΔE| < 0.1 GeV

Yield in Belle data : 4955 per 100 fb^{-1}
Yield in Belle II data : 4896 per 100 fb^{-1}
(counting #events including background)



No background, except for tiny π → K mis-id.

Select a clean channel: $B^{\pm} \rightarrow J/\psi\, K^{\pm}$

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B_{tag}

- M_{bc} > 5.27 GeV/c^2
- |ΔE| < 0.1 GeV
- FEI SigProb > 0.001
- BCS on FEI SigProb

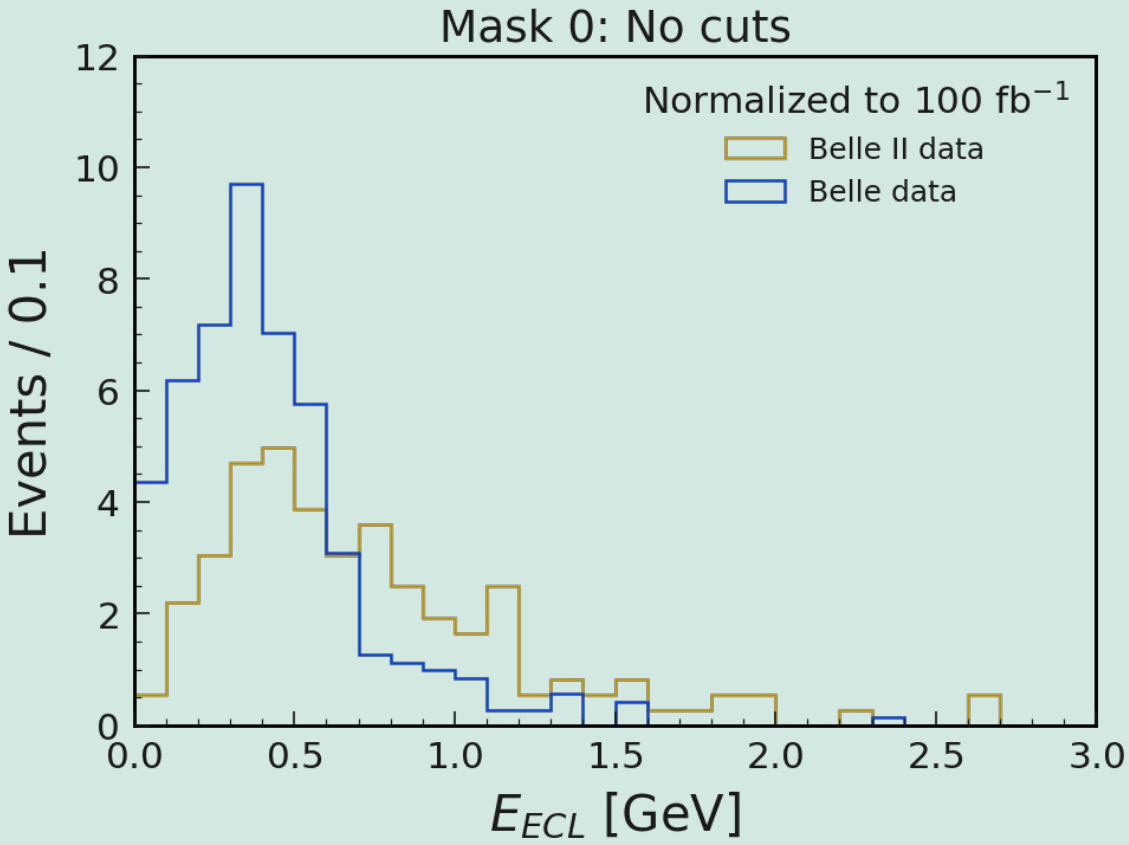
After B_{tag} reconstruction,

Yield in Belle data : 49.4 per 100 fb^{-1}
Yield in Belle II data : 37.8 per 100 fb^{-1}
(counting #events)

FEI calibration factor from Dπ sample in [BELLE2-NOTE-PH-2023-004]

Belle : (0.74 ± 0.03)%
Belle II : (0.65 ± 0.03)%

Belle vs Belle II comparison: data

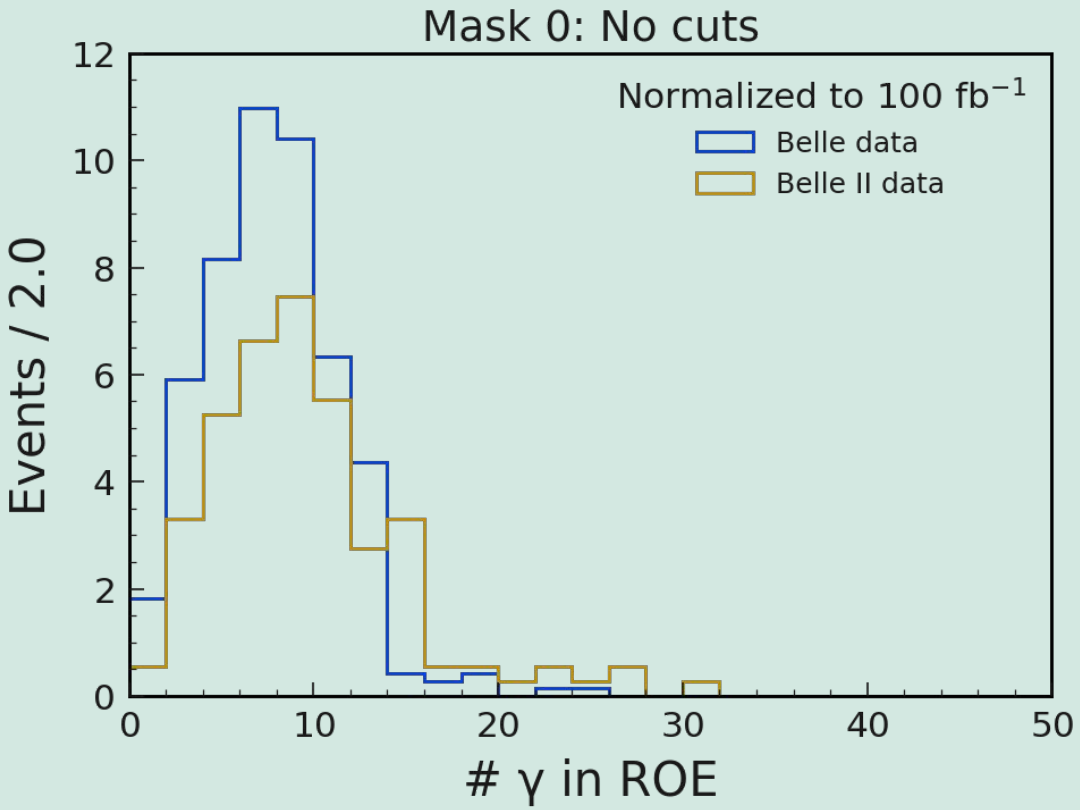


Hadronic FEI has ~22% lower efficiency in Belle II than in Belle.
→ Could be improved (later slides).

On top of that, the E_{ECL} distribution in Belle II is clearly wider with mask 0, no cuts on ROE.

This is a comparison of signal only directly in data and it is important to compare with background (to get the sensitivity)

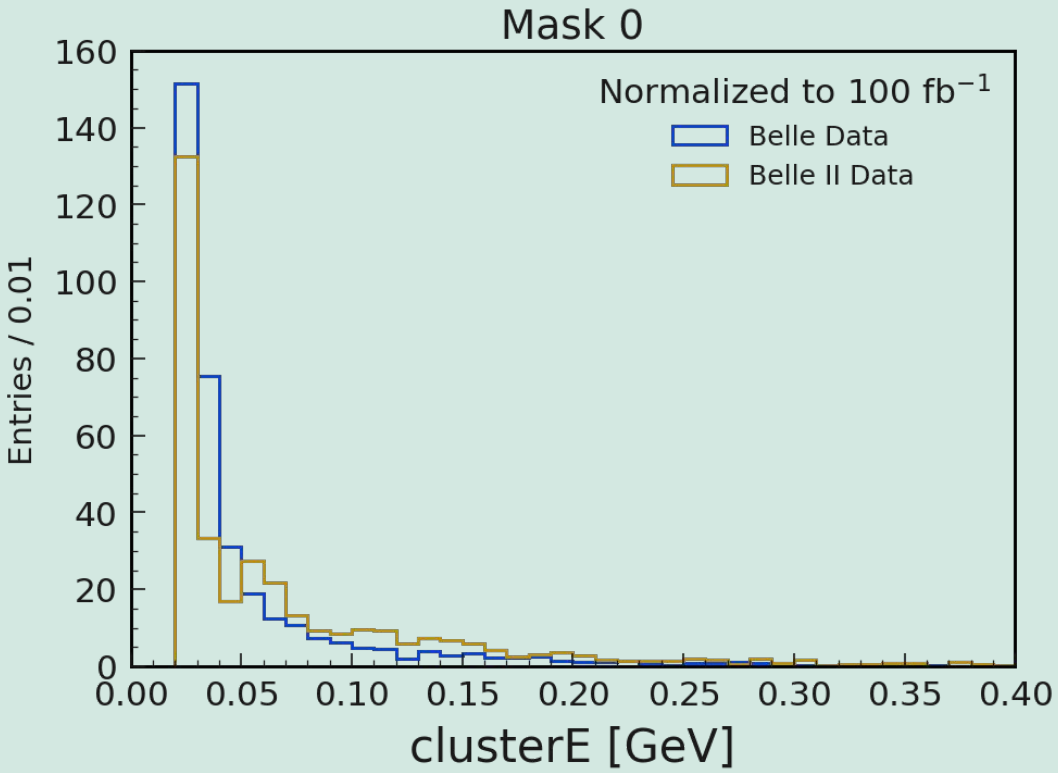
γ in ROE: Belle vs Belle II comparison



Hadronic FEI has ~22% lower efficiency in Belle II than in Belle.
→ Could be improved (later slides).

And the difference is not mostly coming from the multiplicity of photons in the ROE?

clusterE: Belle vs Belle II comparison

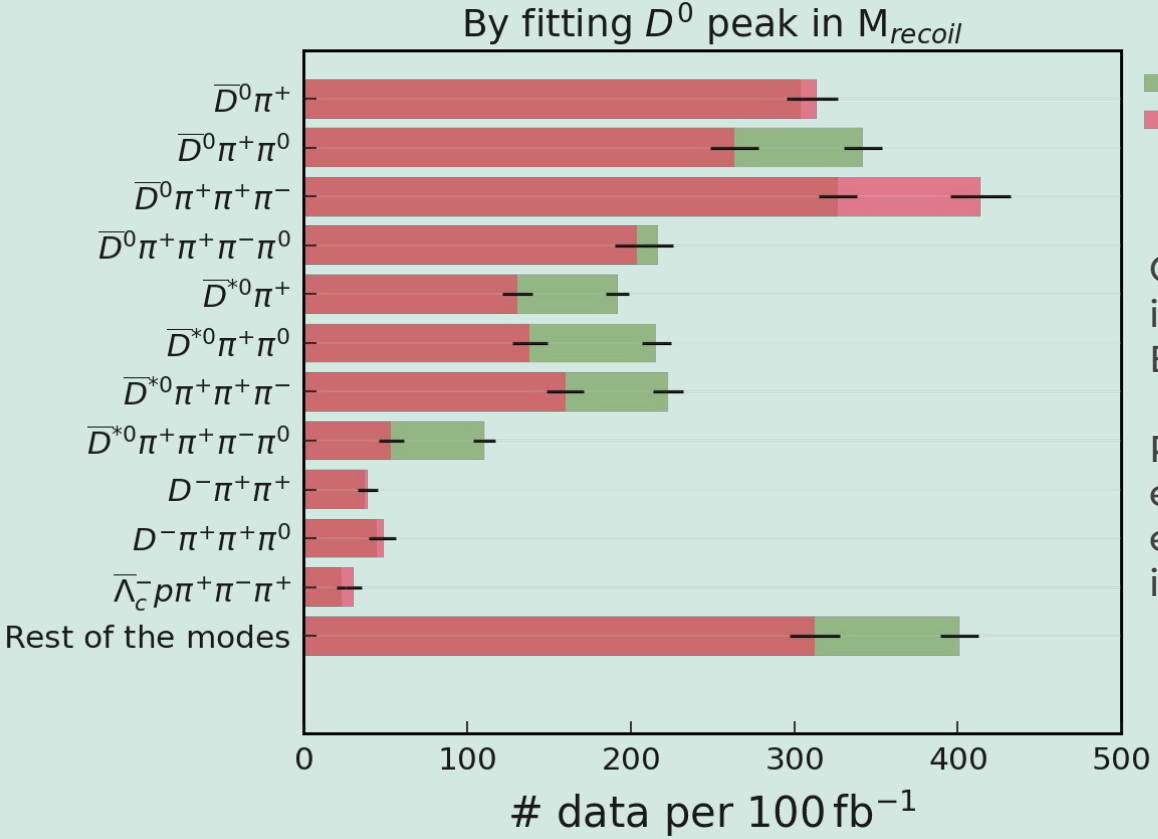


Hadronic FEI has ~22% lower efficiency in Belle II than in Belle.
→ Could be improved (later slides).

But rather from higher E(γ) in Belle II?

This comparison is with tight selection:
$|\Delta E| < 0.05$ GeV; SigProb $> 10^{-2}$

Efficiency compared to FEI in Belle



Overall, the yield/efficiency of FEI in Belle II is ~22% lower than in Belle. 😦

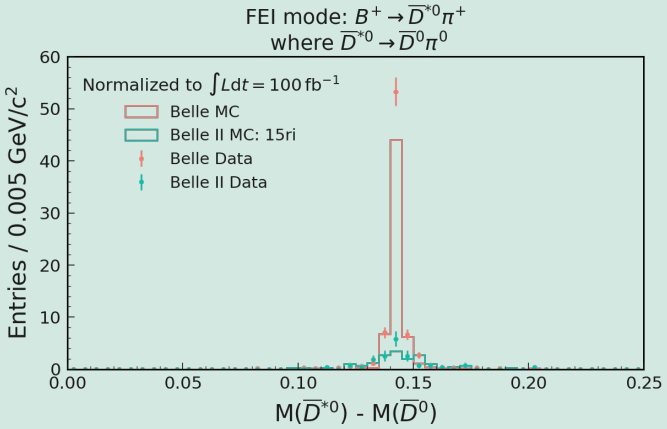
Partly because of the tight energy cuts on γ in FEI, effecting the slow π^0 i.e., D^{*0} reconstruction efficiency.

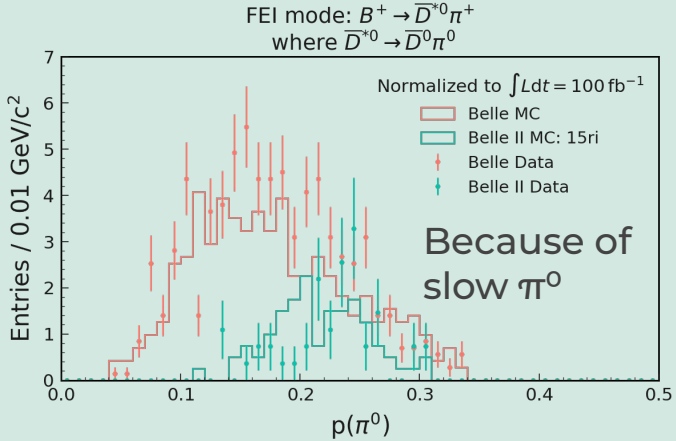
This comparison is with tight selection:
$|\Delta E| < 0.05$ GeV; SigProb > 10^{-2}

D^{*0} reconstruction efficiency

$D^{*0} \rightarrow D^0 \pi^0$

Belle II has much worse yield than Belle.

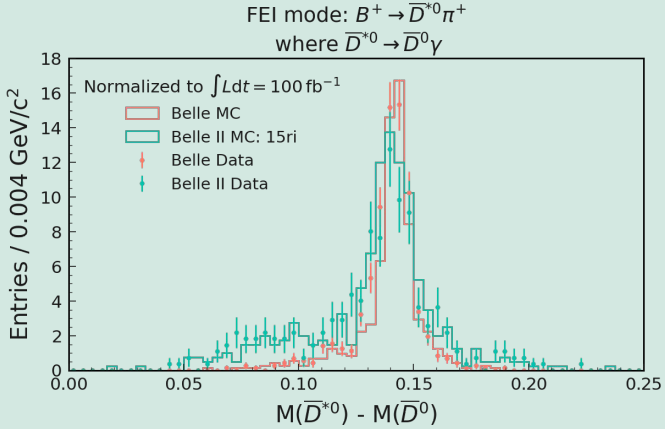




$D^{*0} \rightarrow D^0 \gamma$

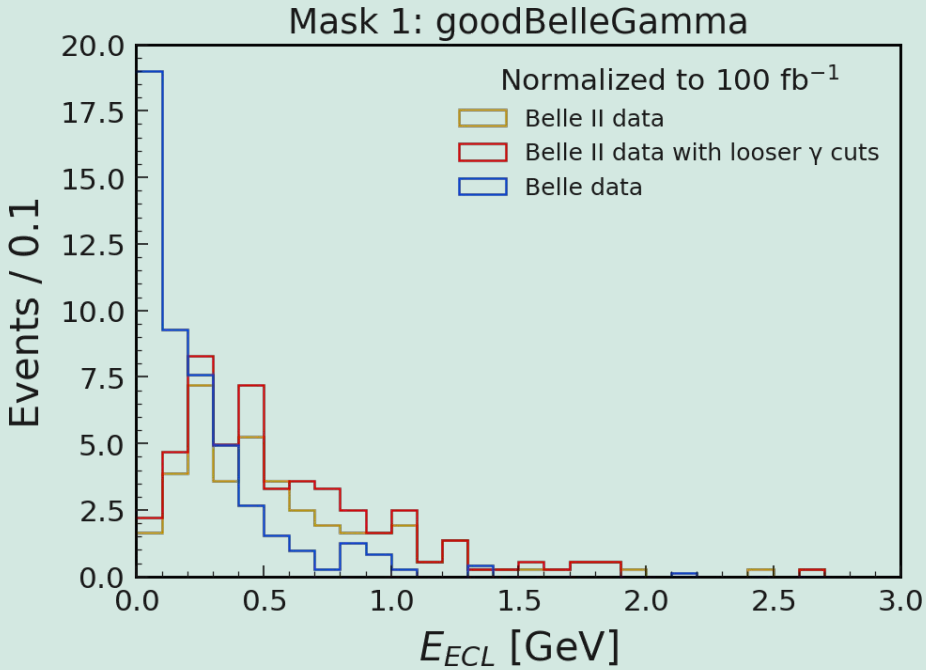
A part of it is recovered in the tail of $D^{*0} \rightarrow D^0 \gamma$, but not ideal.

This also shows that a tight ΔM constraint, which could bring high purity is not effectively utilized.



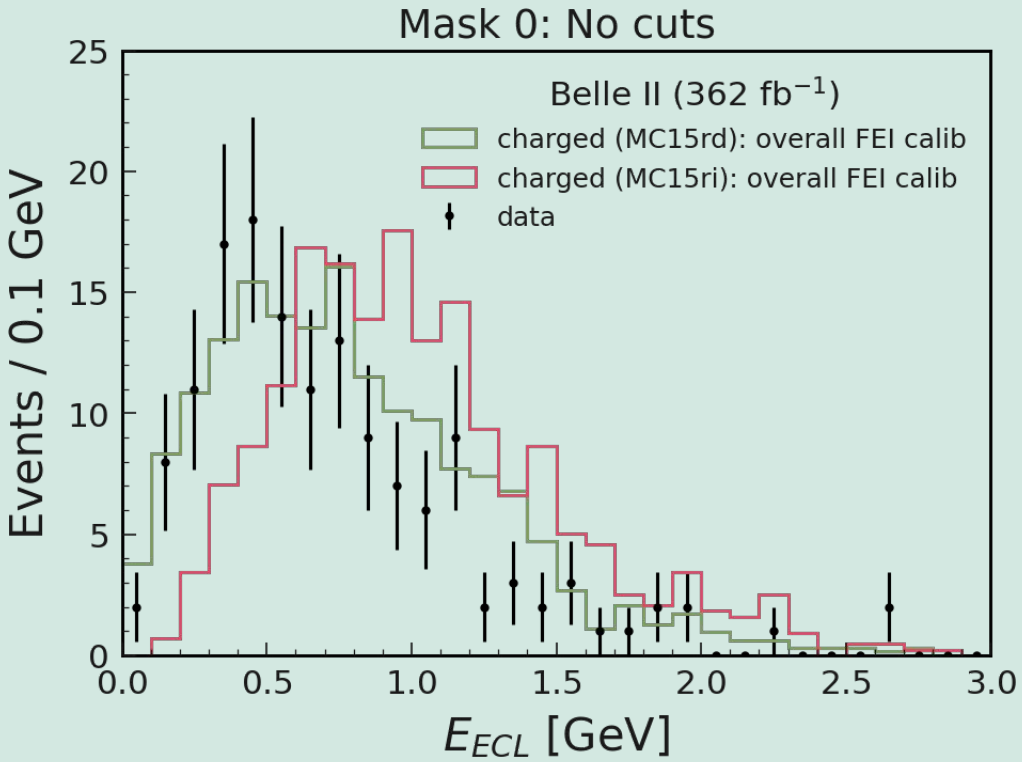
Different FEI algorithms

- Current FEI pre cuts on γ are {0.1, 0.09, 0.16} in {forward, barrel, backward} regions.
- The barrel is too tight.
- Proposal is to match with goodBelleGamma for Belle:
  {0.1, 0.05, 0.15} in {forward, barrel, backward} region.



Looser energy cuts on the γ in FEI, increases the yield/efficiency, but does not significantly change the shape, at the level of Mask 0 (no cuts).

MC15ri vs MC15rd comparison



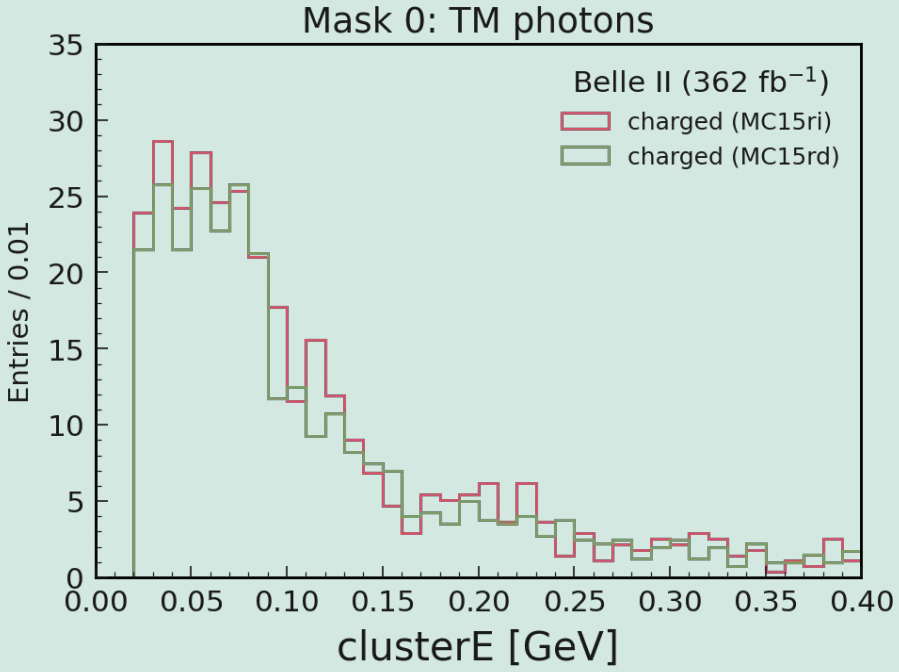
Without any cuts on the ROE, the run-independent MC (generic, so with Phase 3 BG overlay) looks very different from data.

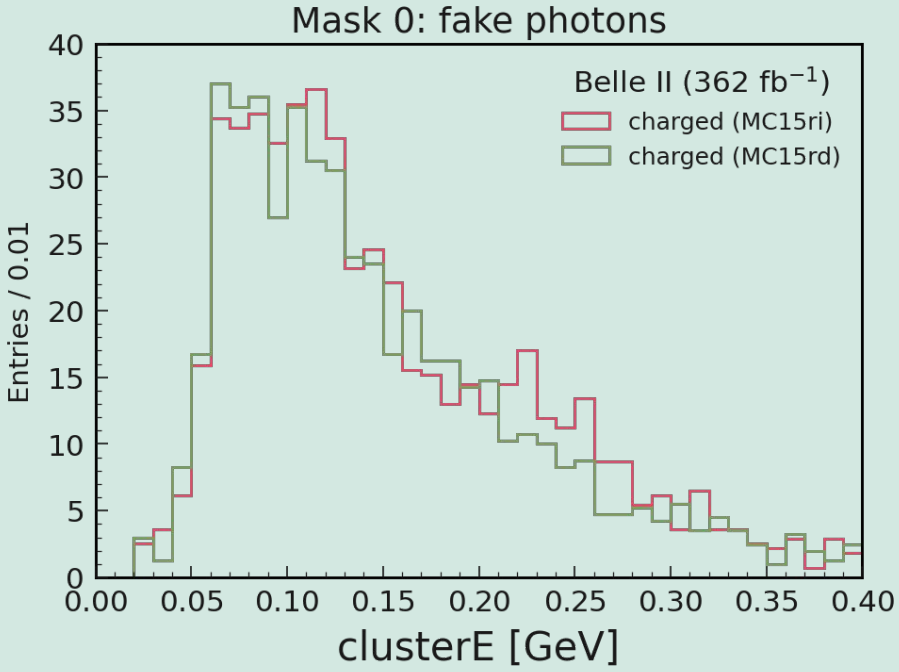
Most of this discrepancy could be coming from beam background modeling, and could be smaller with a tighter mask?

But even compared to run-dependent MC, there is a significant discrepancy, around 1.2 GeV?

Conclusion: Use rd MC when possible, avoid ri.

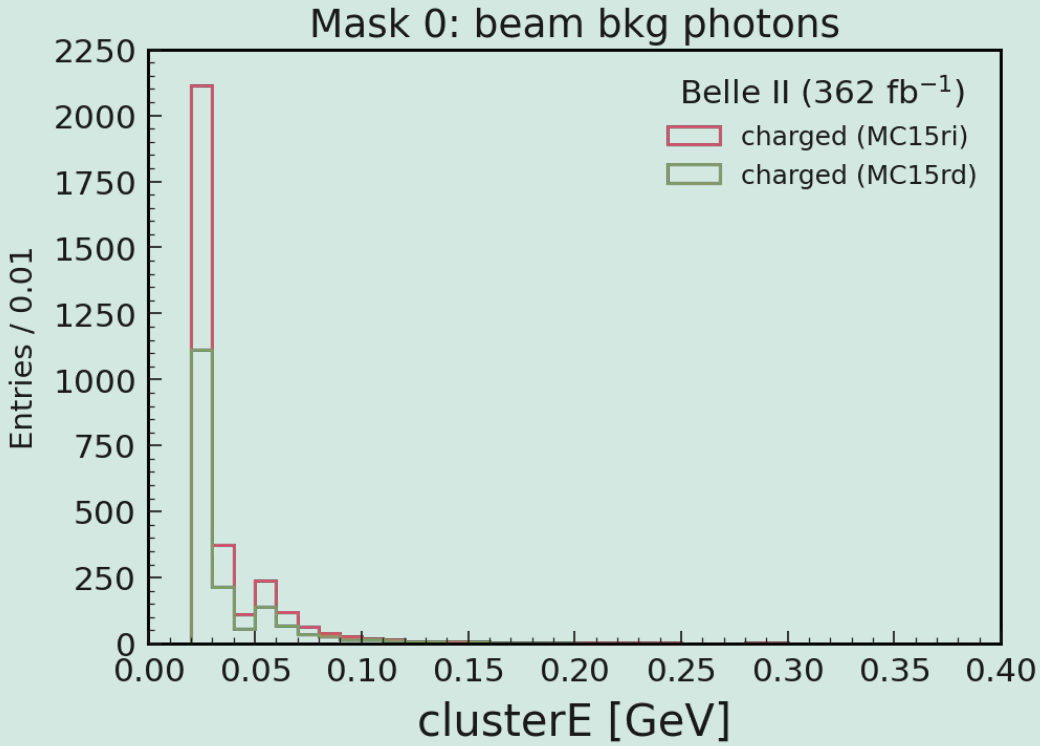
MC15ri vs MC15rd comparison





There is no significant difference in TM and fake photons between both MCs.

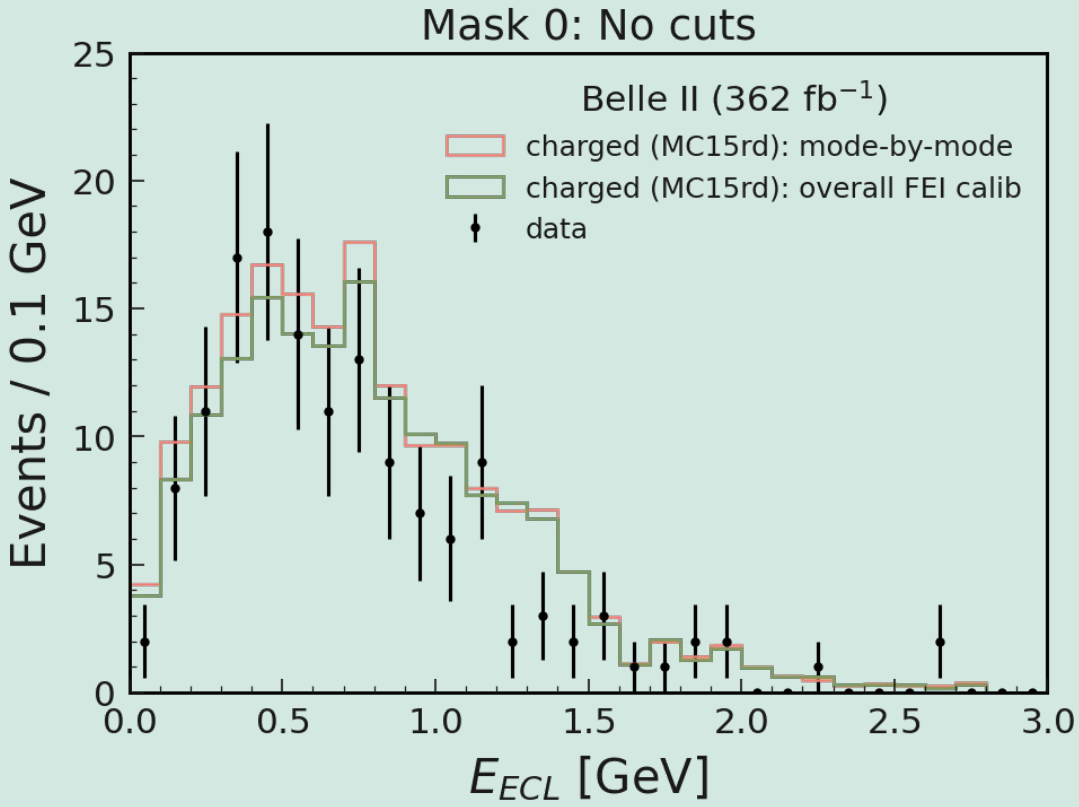
MC15ri vs MC15rd comparison



The difference comes from the beam background photons as expected.

The beam bkg is highly overestimated in run-independant MC and should be avoided in studies with E_{ECL}.

FEI calibration: overall vs mode-by-mode



Within the statistical uncertainty of this sample, applying overall FEI calibration and mode-by-mode calibration appears to be equivalent.

The discrepancy around 1.2 GeV appears in both.

Mask choices

Mask 0: No cuts

Mask 1: goodBelleGamma

Mask 2: goodBelleGamma + timing cut

Mask 3: goodBelleGamma + timing cut + minC2TDist cut

Mask 4: goodBelleGamma + timing cut + FakePhoton BDT cut

Mask 5: goodBelleGamma + BeamBackground BDT cut + FakePhoton BDT cut

Mask 6: goodBelleGamma + timing cut + BeamBackground BDT cut + FakePhoton BDT cut

Focus on mask choices

Mask 0: No cuts
Mask 1: goodBelleGamma
Mask 5: goodBelleGamma + BeamBackground BDT cut + FakePhoton BDT cut

goodBelleGamma:
- barrel: E > 50 MeV
- forward: E > 100 MeV
- backward: E > 150 MeV

Do we need different variants of goodBelleGamma for Belle and Belle II?

In Belle, both BDTs are trained on:
- clusterE
- clusterHighestE
- clusterE9E25
- clusterLAT
- clusterNHits
- clusterPhi
- clusterTheta
- minC2TDist

Cuts on outputs: > 0.3

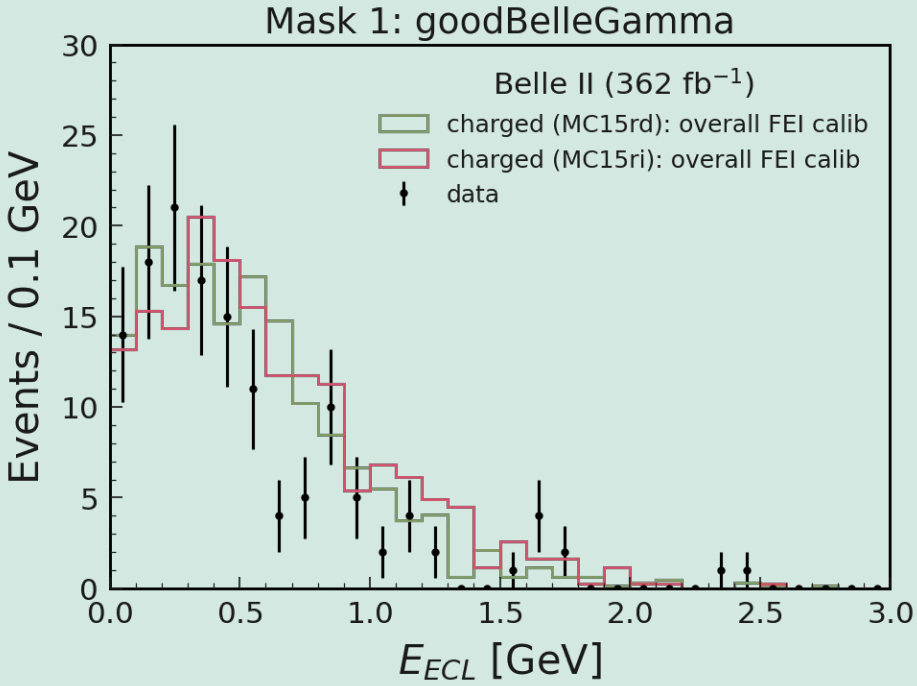
In Belle II, both BDTs are trained on:
- clusterTiming
- clusterPulseShapeDiscriminationMVA
- clusterE
- clusterTheta
- clusterZernikeMVA

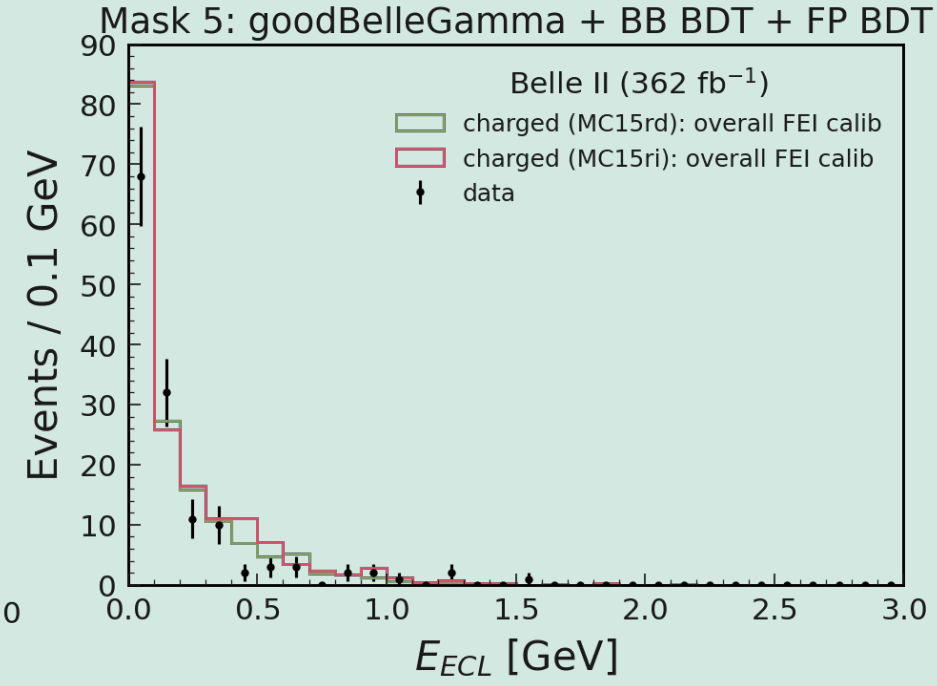
\+ minC2TDist for FakePhoton BDT

Cuts on outputs: > 0.3

PR for calculating pseudo minC2TDist in B2BII by Meihong Liu

Different ROE masks: data vs MC

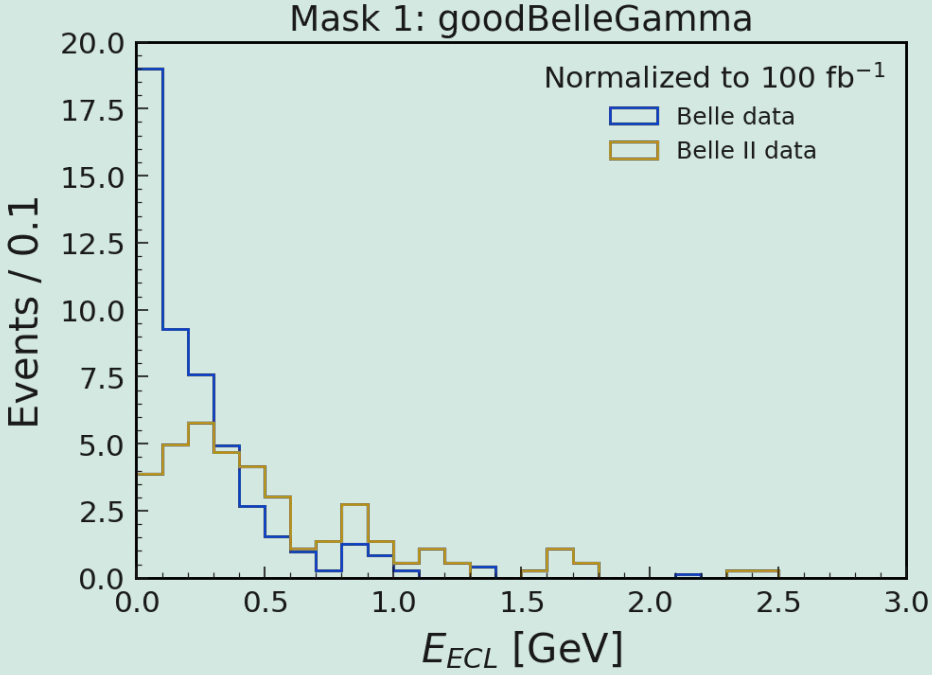


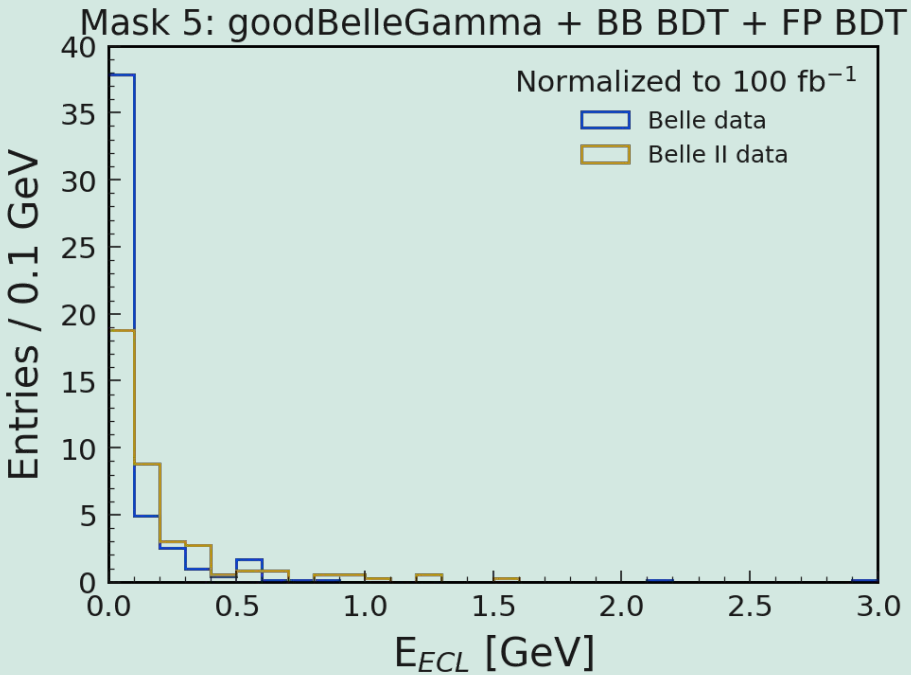


With tighter masks, MC15ri and MC15rd look closer, because most of the beam background is removed.

But a significant discrepancy with data is still seen.

Different ROE masks: Belle vs Belle II





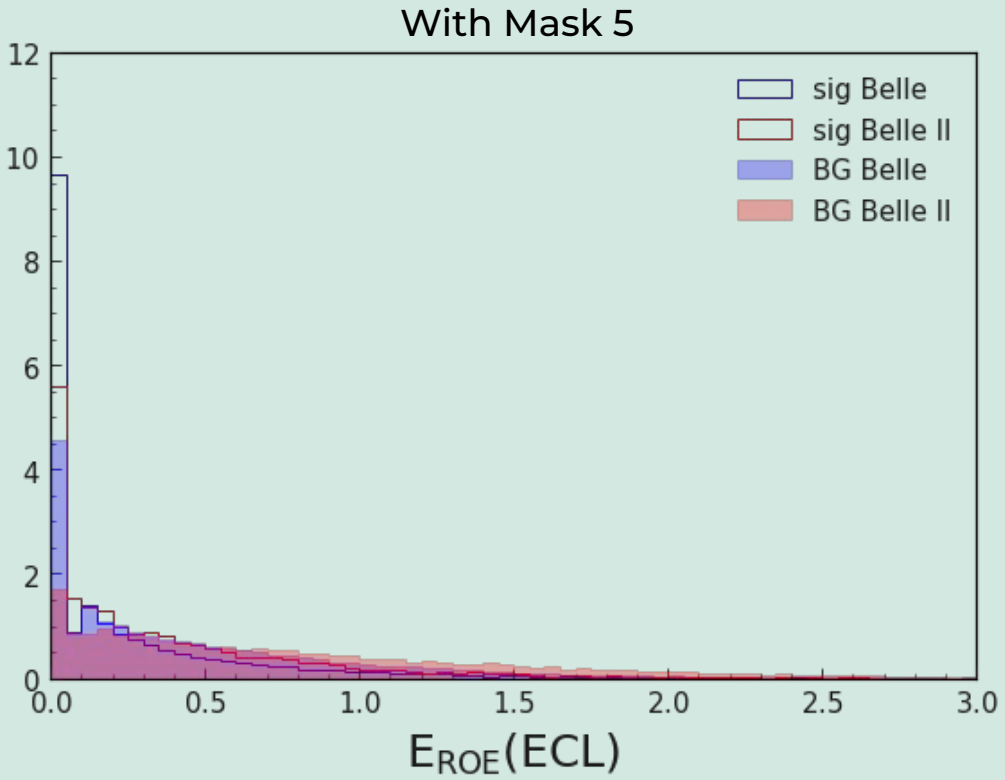
Even with tighter masks, the signal resolutions looks worse in Belle II.

Select an ongoing analysis: $B^0 \to K_S^0 \tau l$

The limitation with $B \to J/\psi K$ sample is that it is pure signal and does not demonstrate anything about the background and consequently the sensitivity.

Using an ongoing analysis to compare Belle and Belle II performance,
we see that the E_{ECL} distribution is more spread in Belle II in both Signal and background MC (both MC15ri).

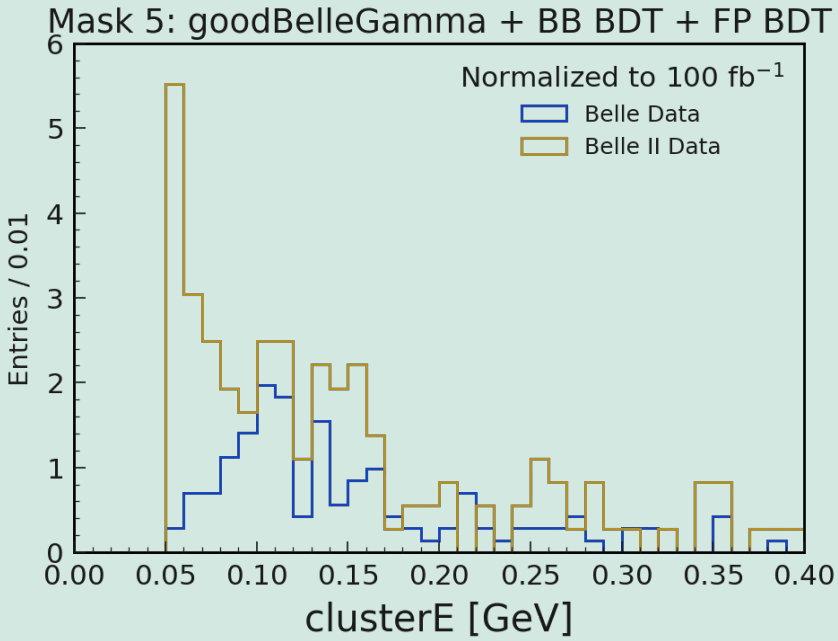
So, effectively the sensitivity might be comparable?

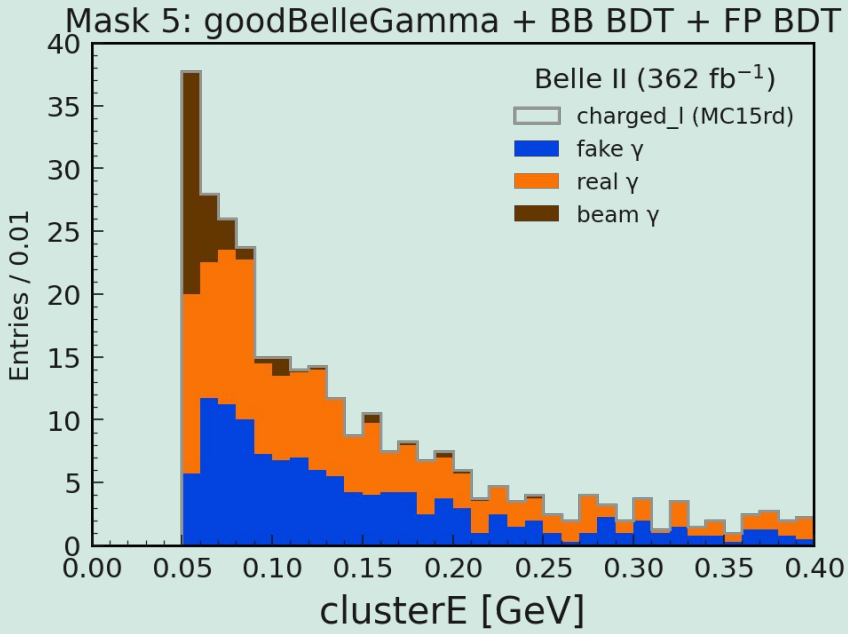


Summary

- A clean channel like $B^{\pm} \rightarrow J/\psi\, K^{\pm}$ helps to study the signal-only distribution of E_{ECL}.
- Comparing Belle II with Belle, shows worse signal resolution, but as background also follows similar pattern, the sensitivity might be comparable.
- Fixing the bug leading to lower Hadronic FEI efficiency in Belle II does not change the shape of E_{ECL} in any significant way at the level of Mask 0.
- Beam background is highly overestimated in MC15ri, so for analysis with E_{ECL}, prefer MC15rd.
- Tighter masks reduces the discrepancy between ri and rd, but discrepancy with data still remains.
- Within the statistical uncertainty of this sample, applying overall FEI calibration and mode-by-mode calibration appears to be equivalent.
- This sample can be used as a perpendicular cross-check for any proposed correction to E_{ECL}.

clusterE in Mask 5





Dominated by TM photons at the level of Mask 5?

clusterConnectedRegionID