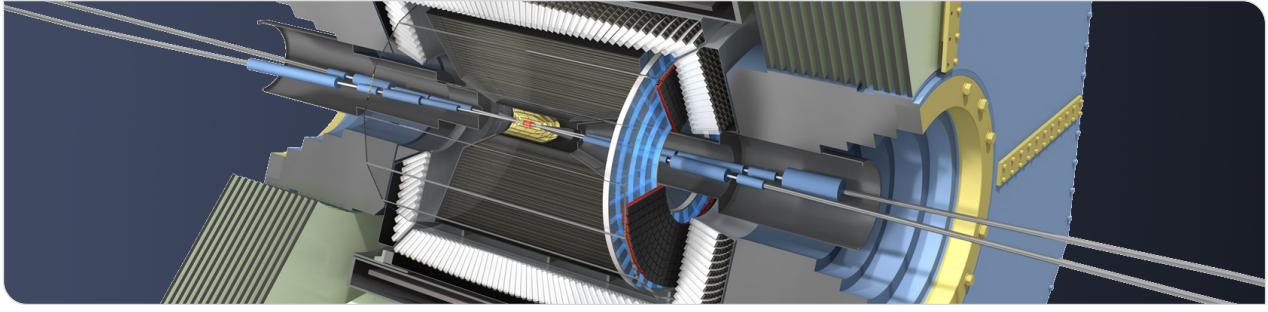
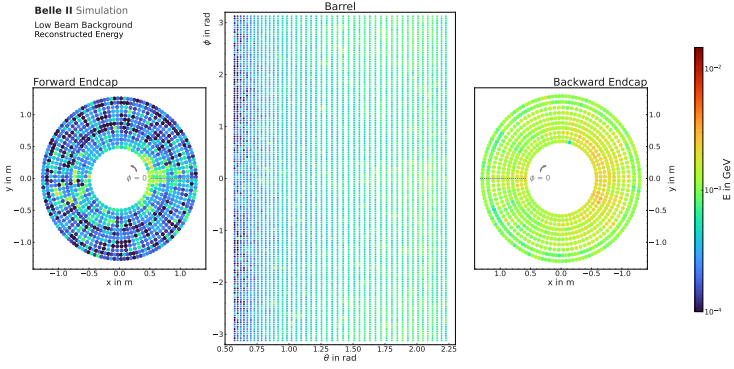
Object Condensation for ECL Clustering on Trigger Level

B2GM - Trigger Parallel Session
Isabel Haide, Torben Ferber | 02. June 2023



Project Overview

- Improvement of the current trigger algorithm of the ECL through graph neural networks



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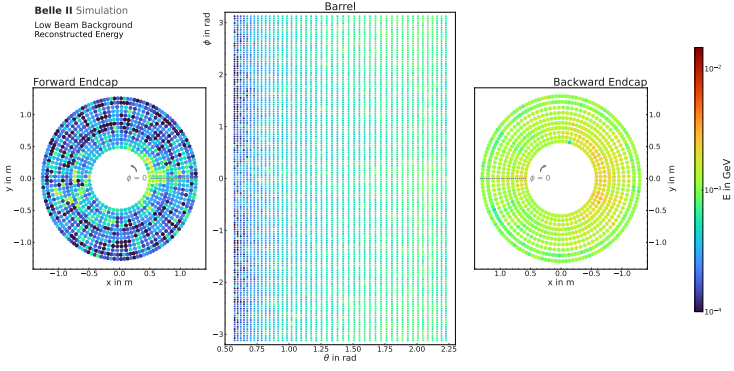
- Graph Neural Networks (GNNs) can easily adapt to different geometries and input sizes, well suited for ECL Clustering



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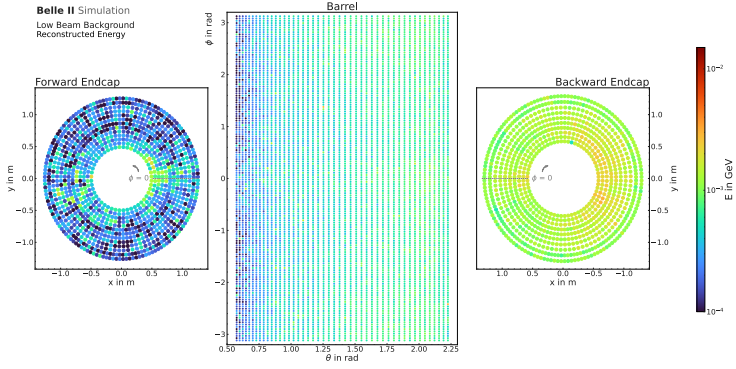
  $\rightarrow$ Possible loss of interesting signatures



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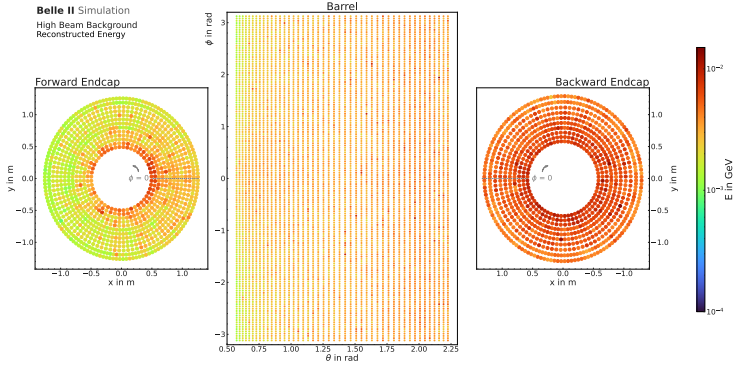
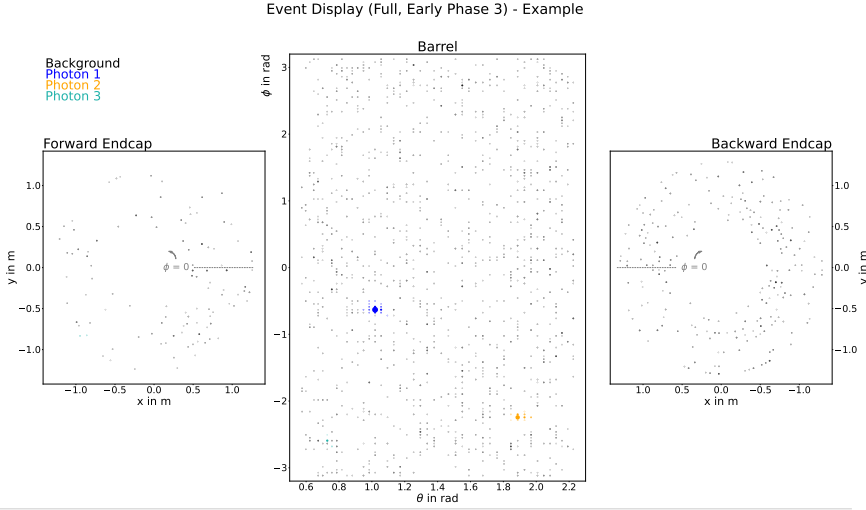
  $\rightarrow$ Possible loss of interesting signatures
- With increasing backgrounds necessary reduction of trigger rate



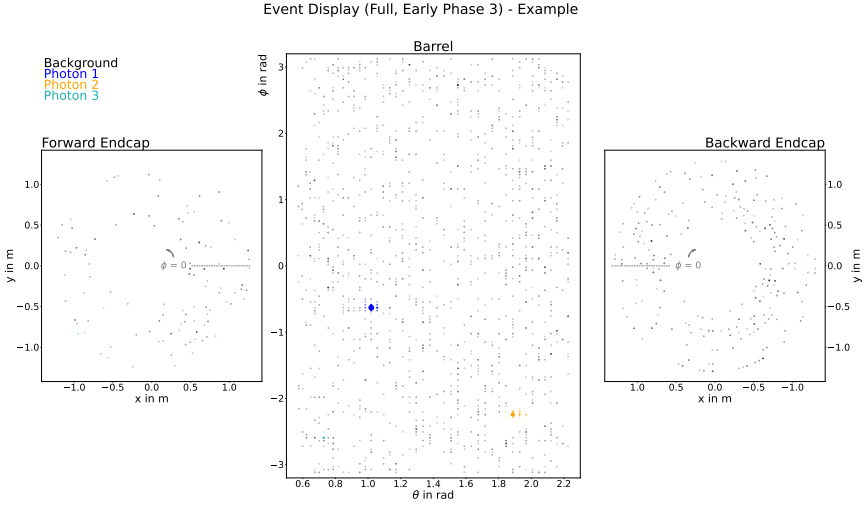
Triggercell Training Data

- Simulation of 1-6 photons, testing on up to 10
- Generated energy between 0.05 and 2 GeV
- Photon has to deposit at least 30 % of its energy in ECL
- $\theta \in [13°, 154°]$
- Each crystal with $E_{dep} \geq 1$ MeV is used
- Combination of crystals into triggercells



Triggercell Training Data

- Triggercells consisting of (mostly) 4x4 crystals are input to current trigger algorithm



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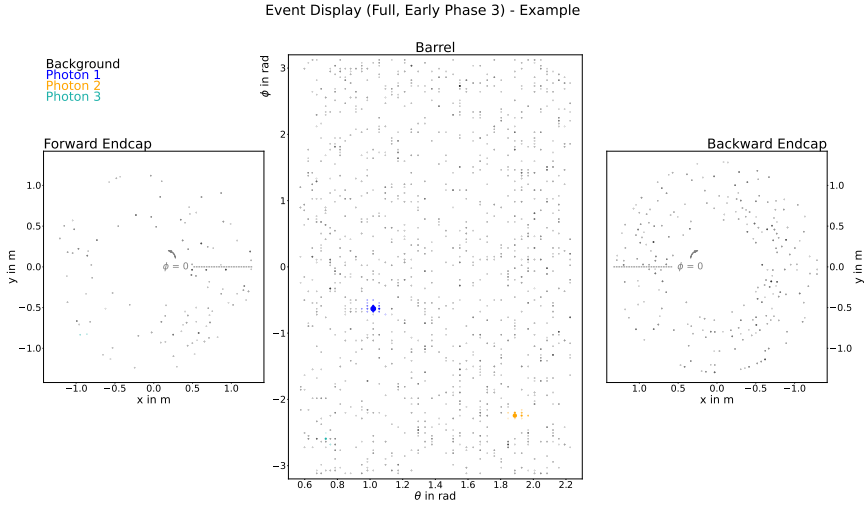

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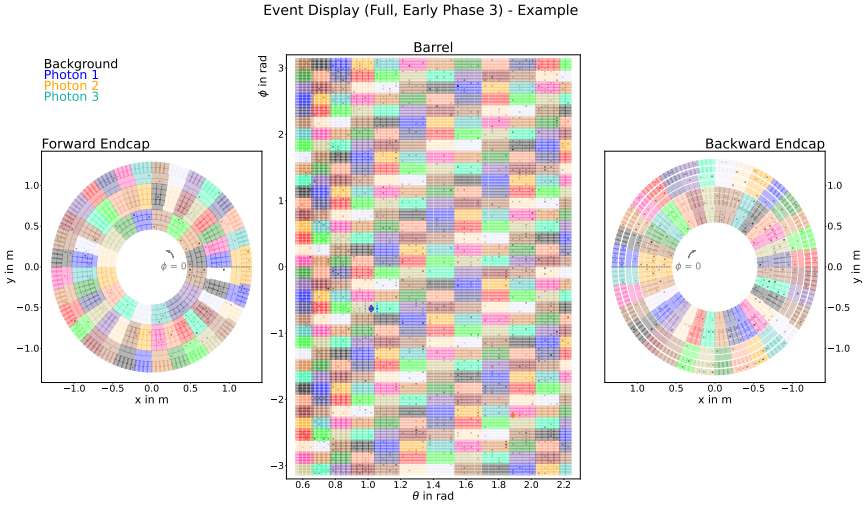

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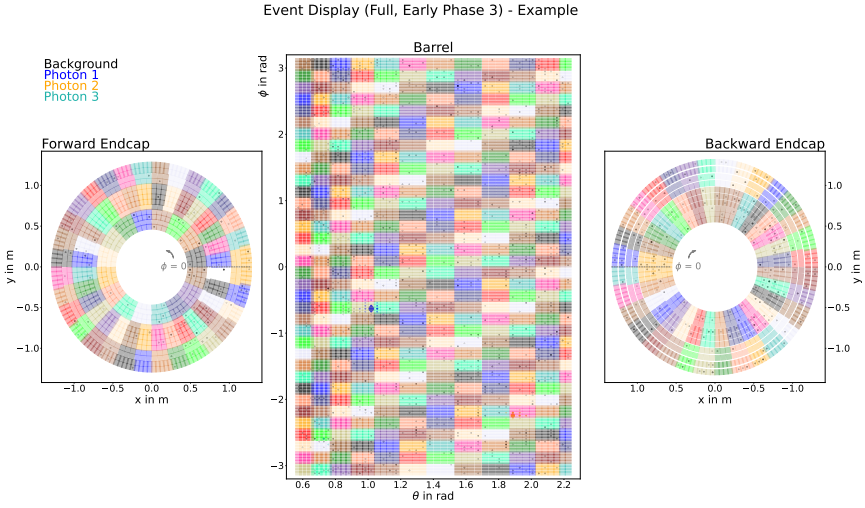

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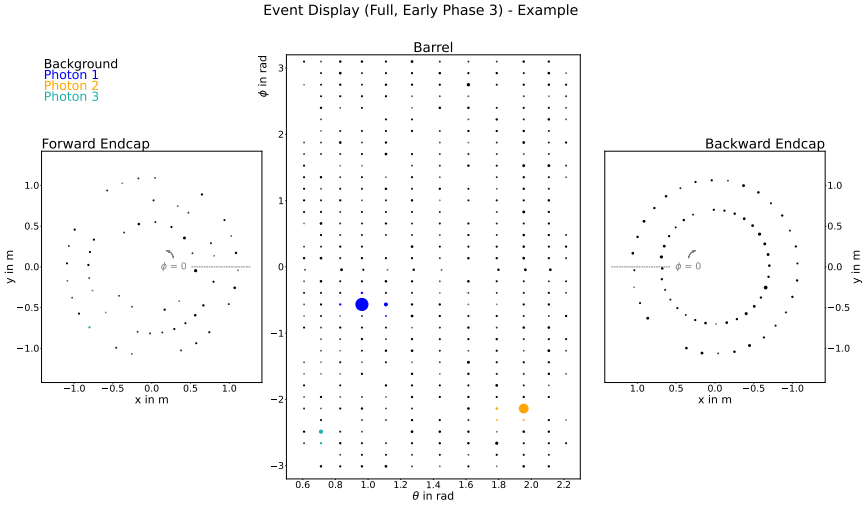

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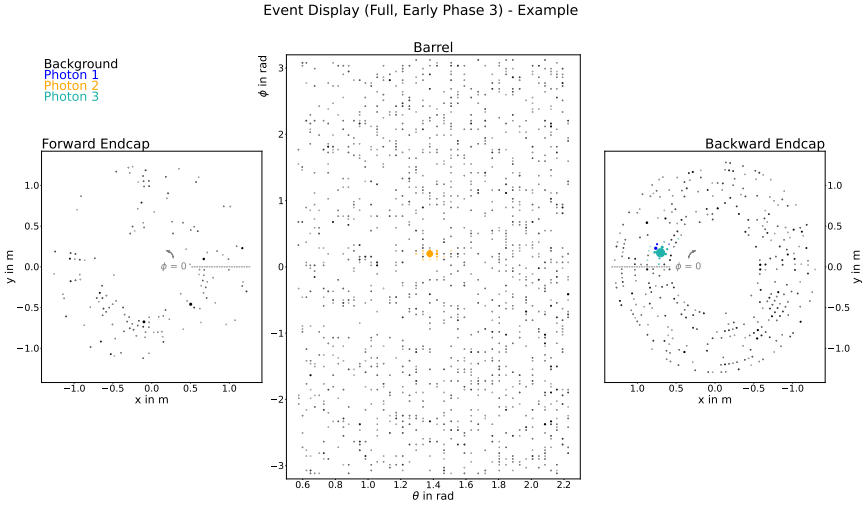

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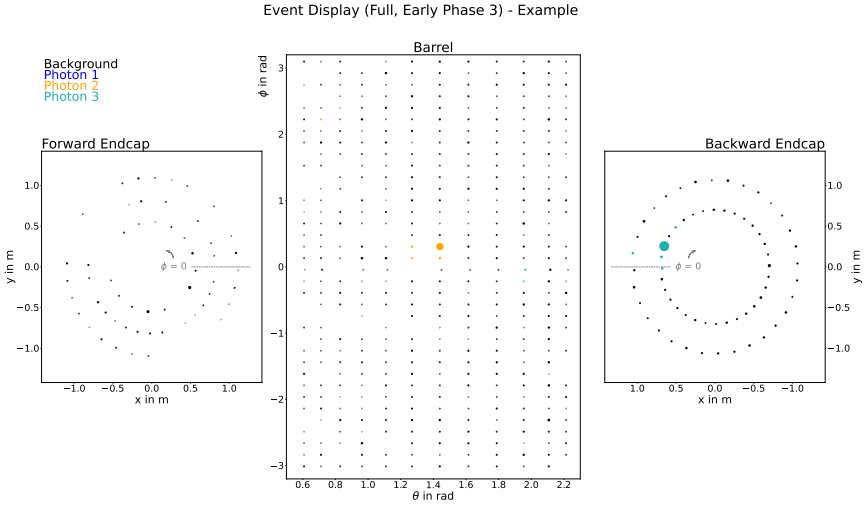


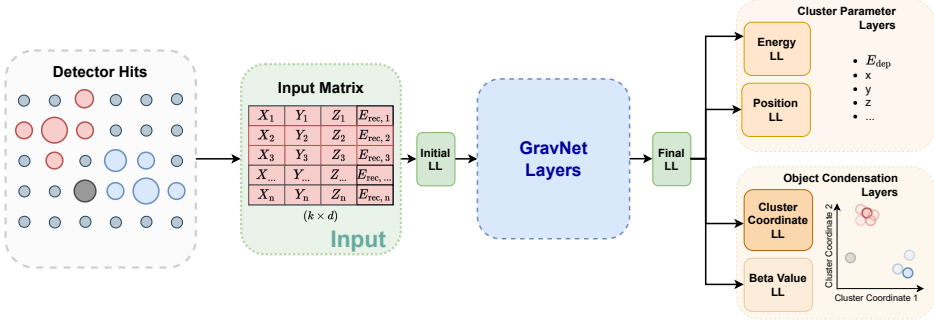
Algorithm Overview

Object Condensation:

- One-shot algorithm for both detection and reconstruction of clusters (arXiv:2002.03605)
- Irregular geometry and varying input sizes in the ECL $\rightarrow$ GNN as base algorithm
- Current network only has 12414 parameters

Fast Inference:

- OC introduces potential to cluster vertices from same object together
- Each vertex gets a β-value assigned $\rightarrow$ Vertex with highest β-value invokes potential (= condensation point)
- Condensation points carry prediction for clusters

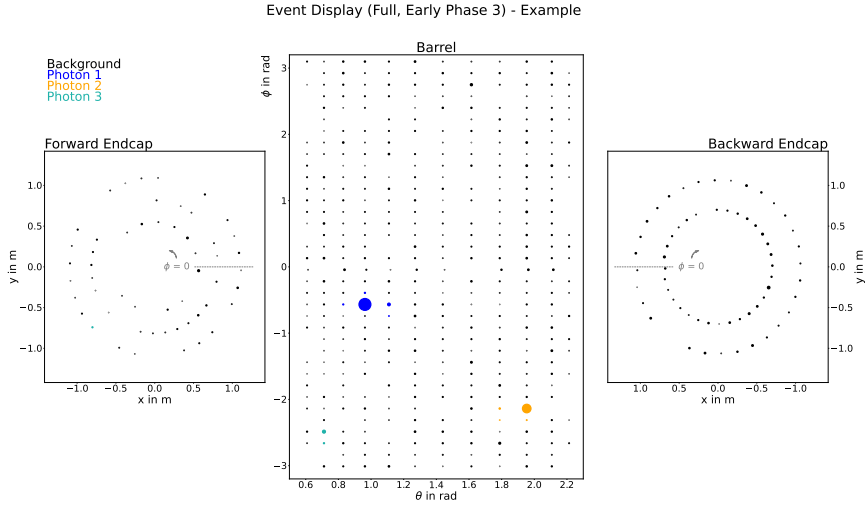


Adapted from L. Reuter

Triggercell Training Evaluation

Evaluation:

- Input: E_{rec}, x, y, z of triggercell



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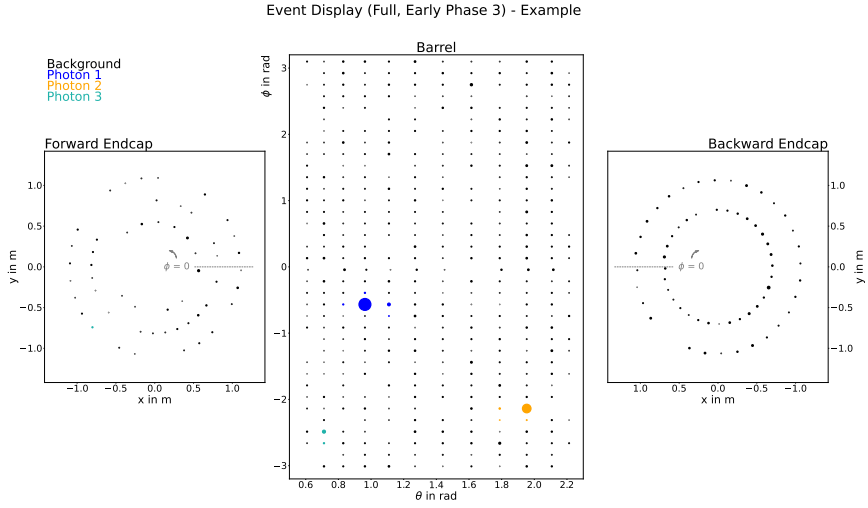

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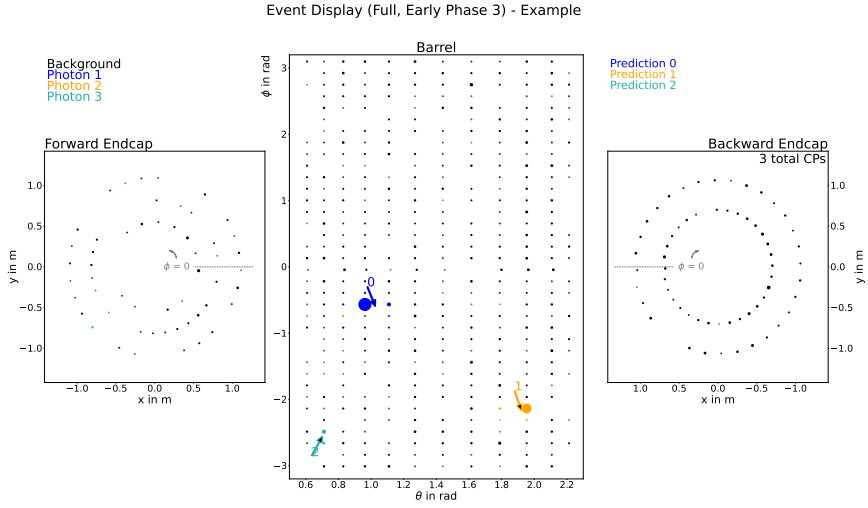

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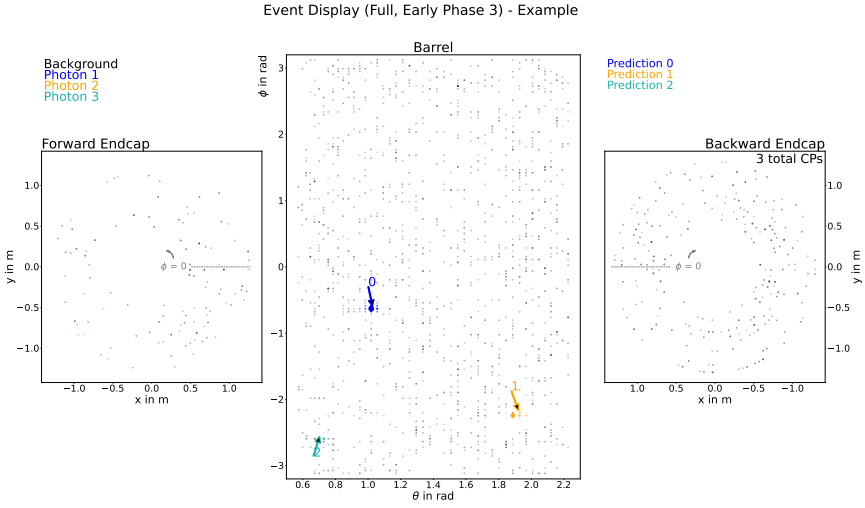

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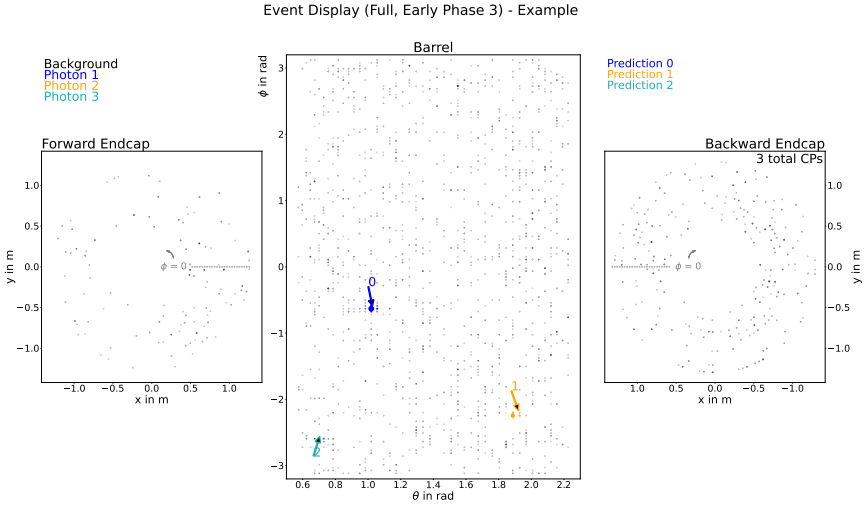

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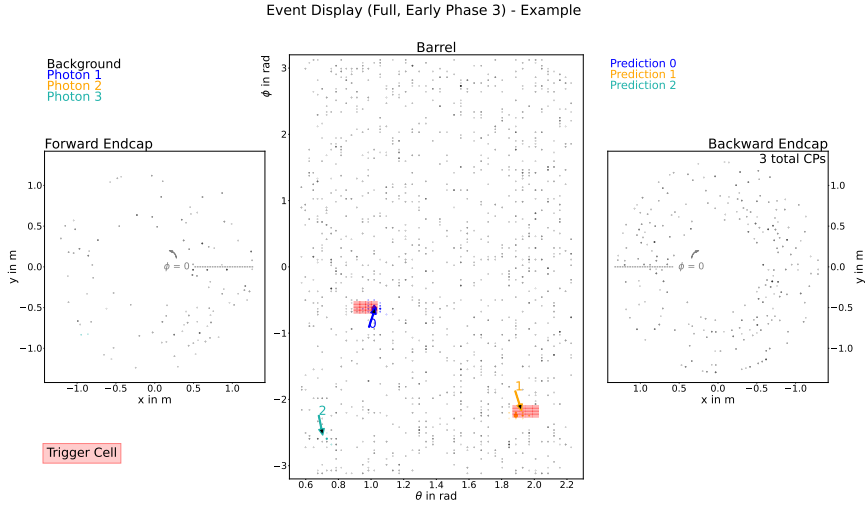
Truth Matching:



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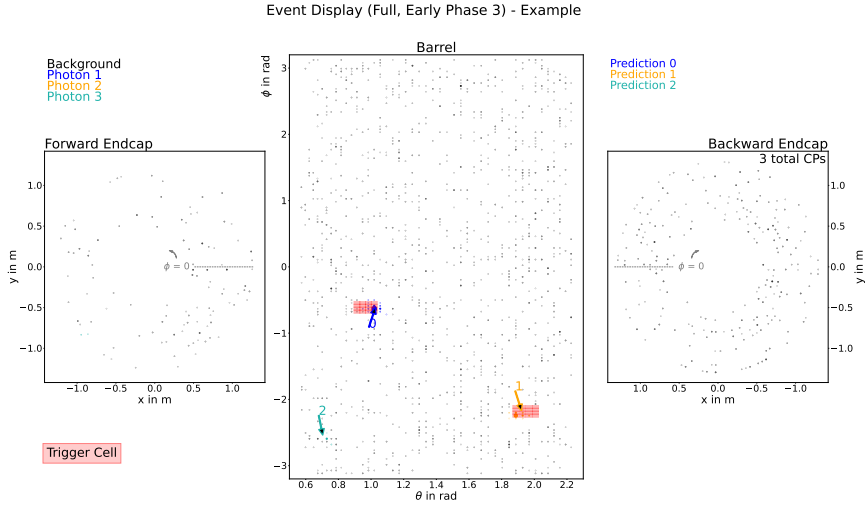
Truth Matching:

- $\Delta pos \leq 40\,cm$
- $0.1 \leq E_{pred}/E_{true,dep} \leq 2.0$



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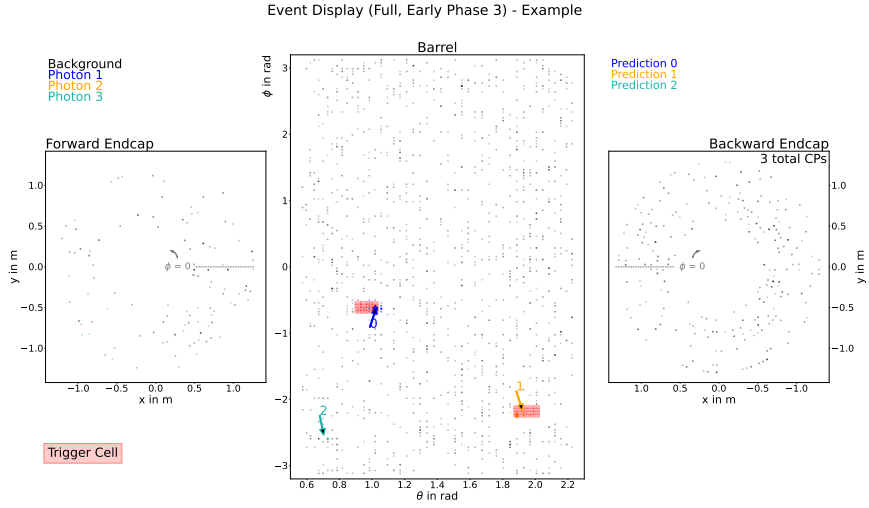
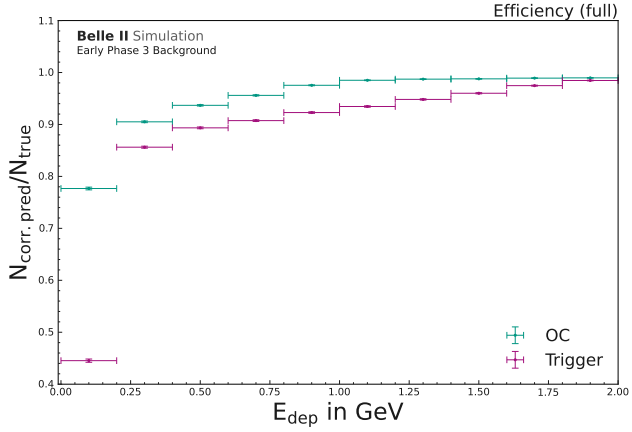
Truth Matching:

- $\Delta pos \leq 40\,cm$
- $0.1 \leq E_{pred}/E_{true,dep} \leq 2.0$
- Best prediction/triggercluster is matched to MC cluster



Efficiency and Precision

- Efficiency = (Nr. of corr. pred. clusters) / (Nr of corr. clusters)
- Precision = (Nr. of corr. pred. clusters) / (Nr. of all pred. clusters)
- Efficiency of OC algorithm on triggercell input shows improvement over all energy regions



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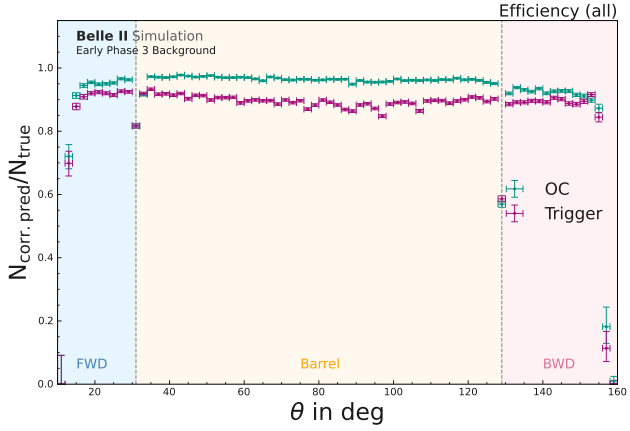

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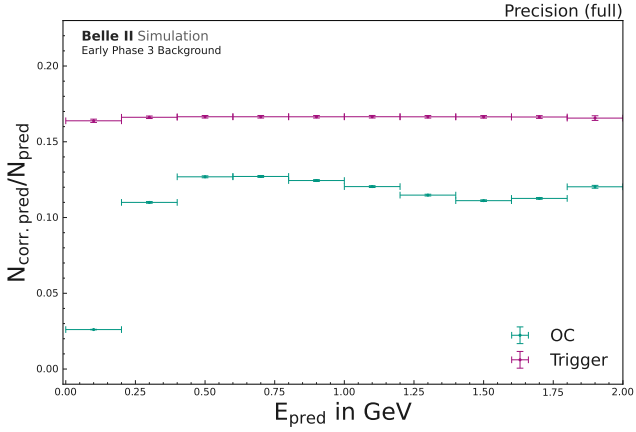
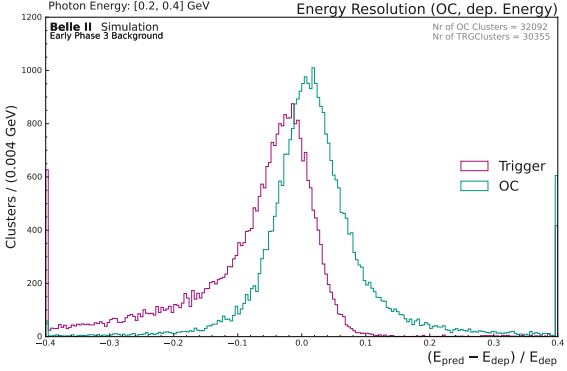
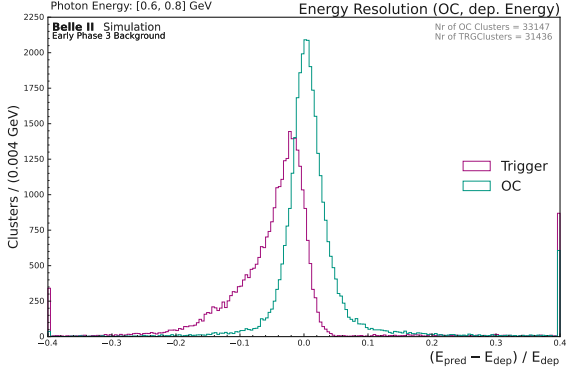
- Efficiency of OC algorithm on triggercell input shows improvement over all energy regions
- Additionally, increase in efficiency is consistent over full detector
- Precision does not worsen drastically



Energy Resolution

Deposited Energy:

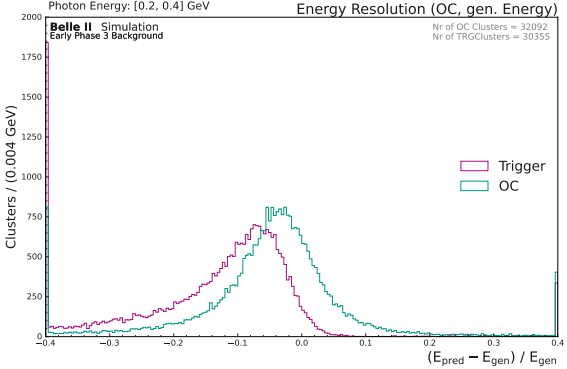


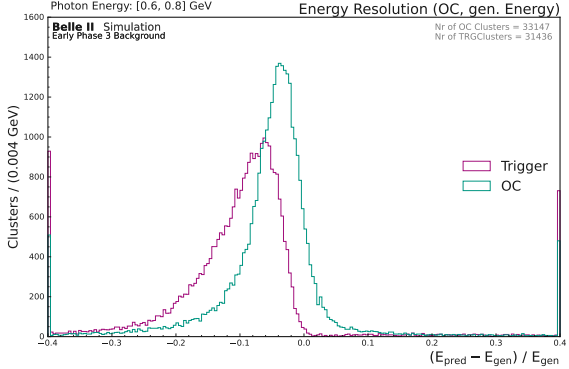


- Resolution is calculated on truth matched predictions/triggercells
- Network is trained on deposited energy, no leakage correction etc.
- OC shows more narrow peak and smaller tails, increasing improvement for higher energies

Energy Resolution

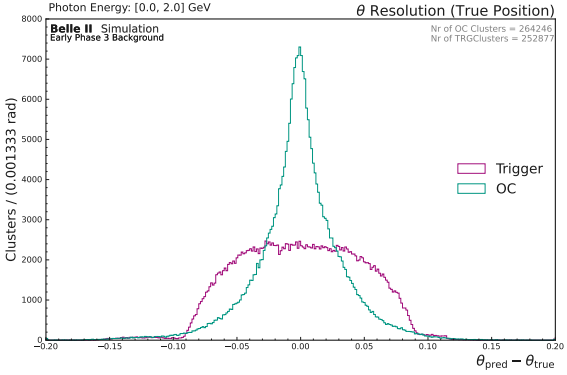
Generated Energy:

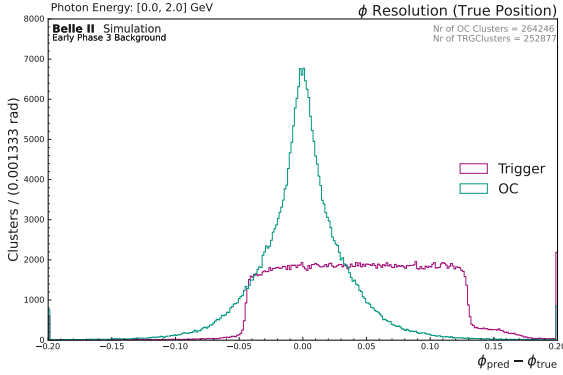




- Resolution is calculated on truth matched predictions/triggercells
- Network is trained on deposited energy, no leakage correction etc. → wider distribution for generated energy
- OC shows more narrow peak and smaller tails, increasing improvement for higher energies

Position Resolution





- θ and ϕ distance is calculated on correct photon position
- OC shows improvement for both θ and ϕ distribution
- Accuracy of prediction increases for higher-energetic clusters

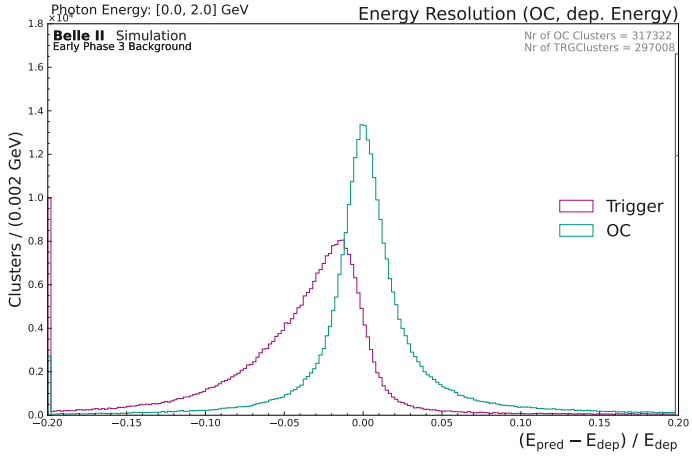
Results: Object Condensation

Summary:

- Training on triggercell input shows improvements in both efficiency and resolution
- Small network size for possible use on FPGAs

Next Steps:

- Evaluation on nominal background
- Possible inclusion of time as an input feature
- Evaluating network on different particles and overlapping particles



Nominal Background