Modified photo of a charged kaon decay chain captured in a bubble chamber

The Effect of Charged Hadrons in ECL Reconstruction at Belle II

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CAP 2023 University of New Brunswick

Belle II

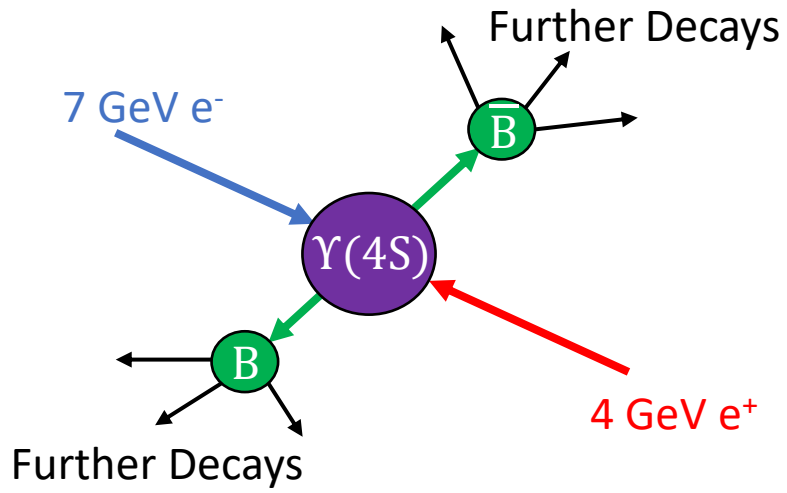
McGill

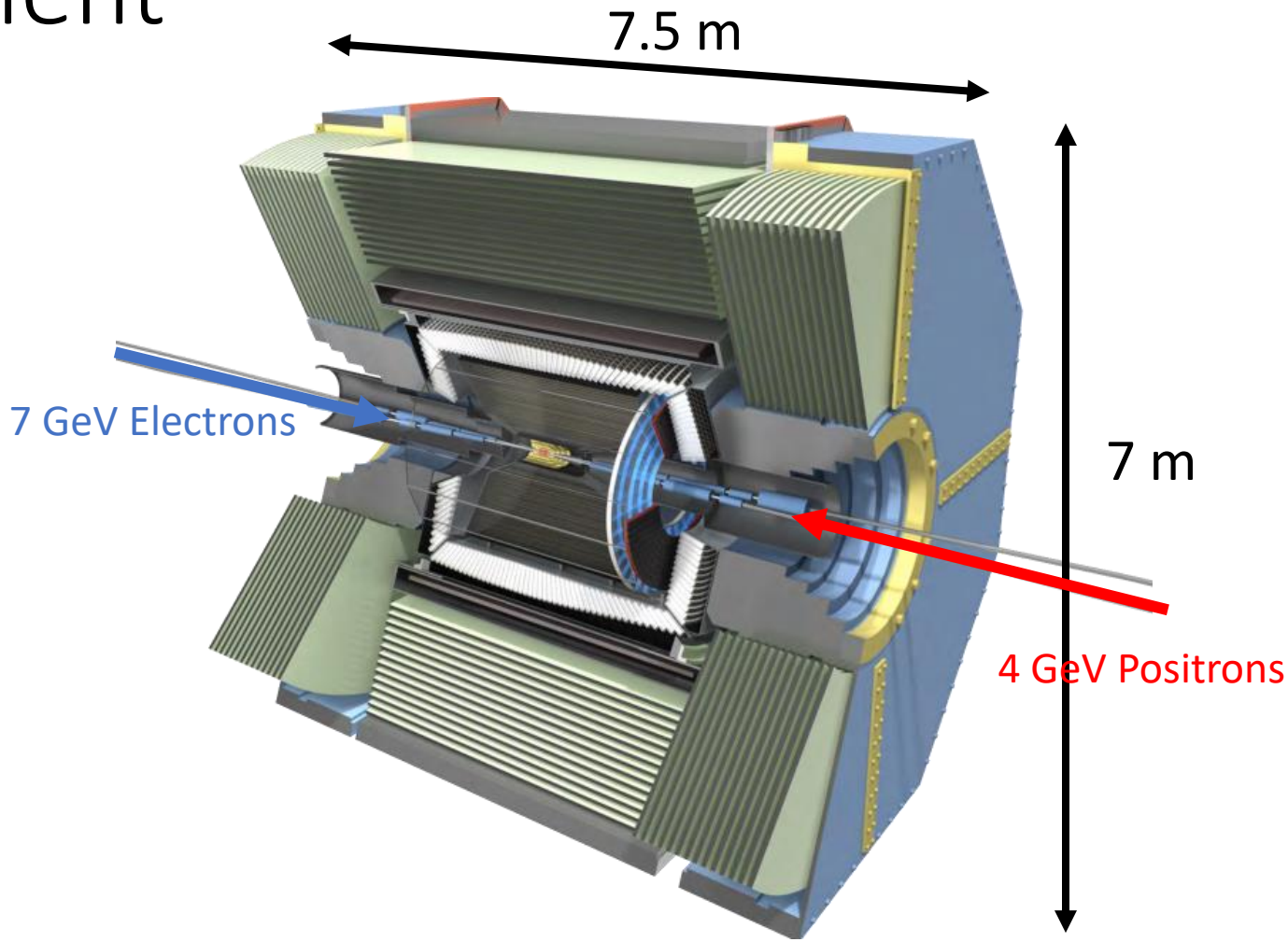
Introduction to Belle II

The basics

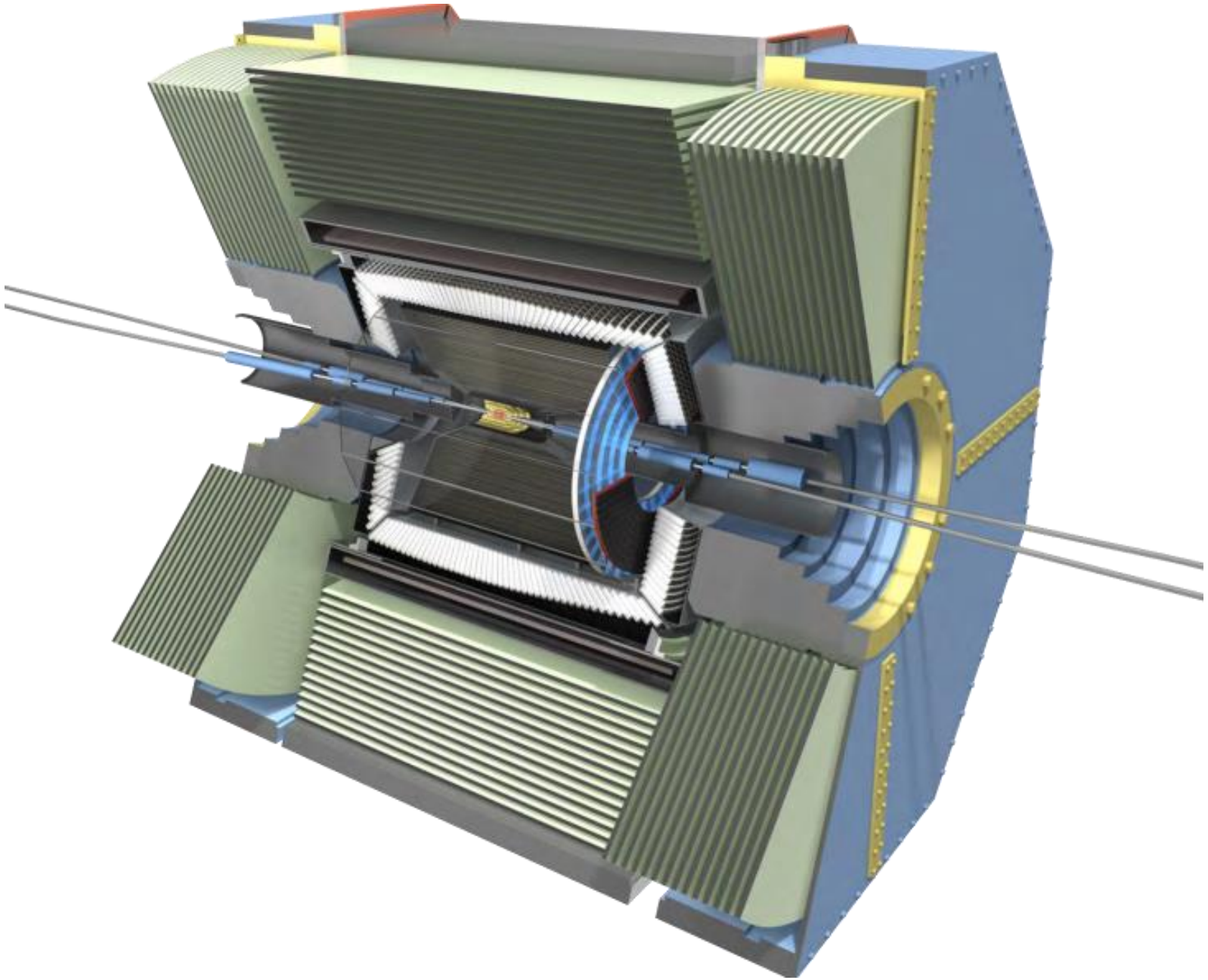
The Belle II Experiment

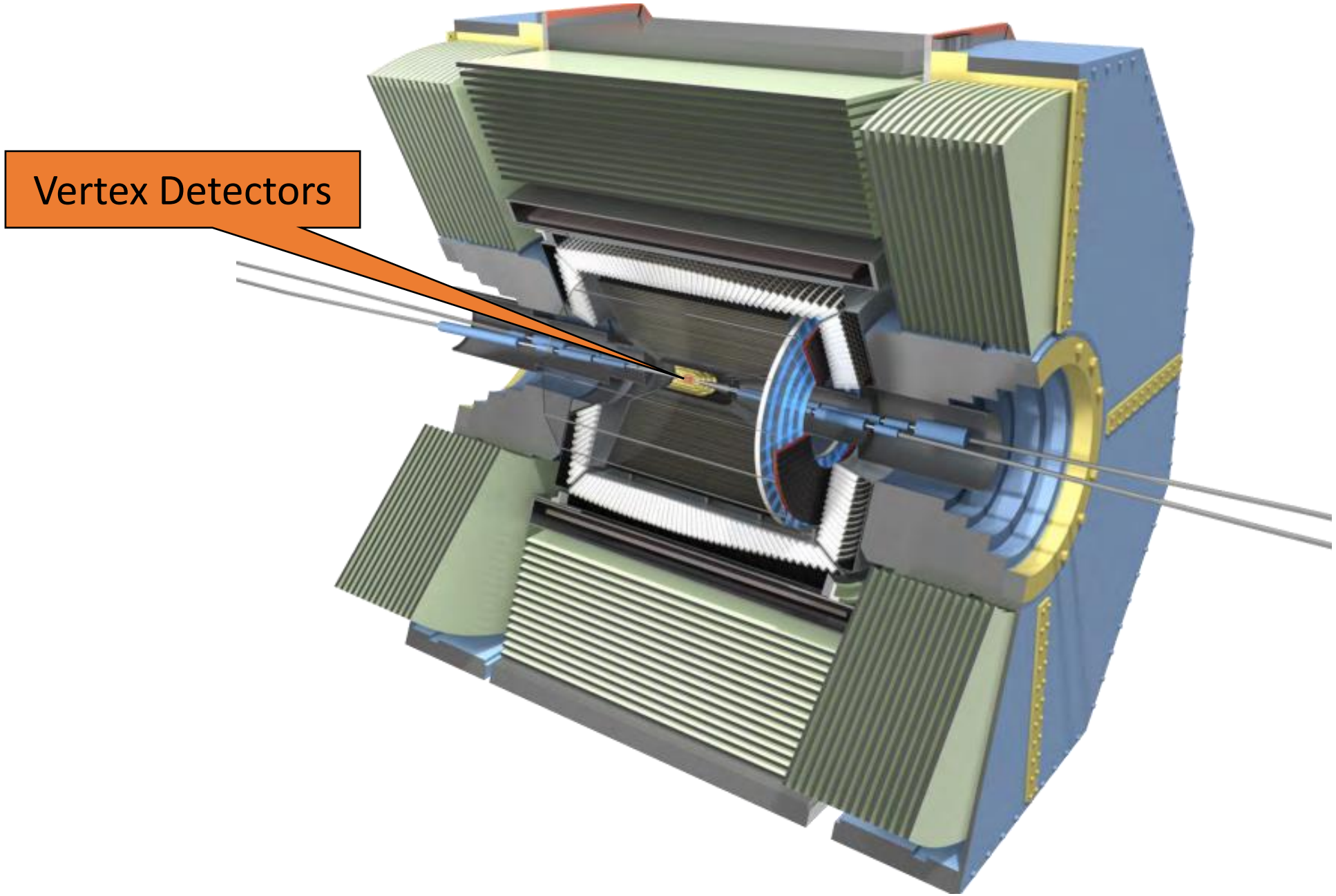
- e^+e^- collider B-factory
- Luminosity frontier
  - Sensitive to rare decays and BSM physics

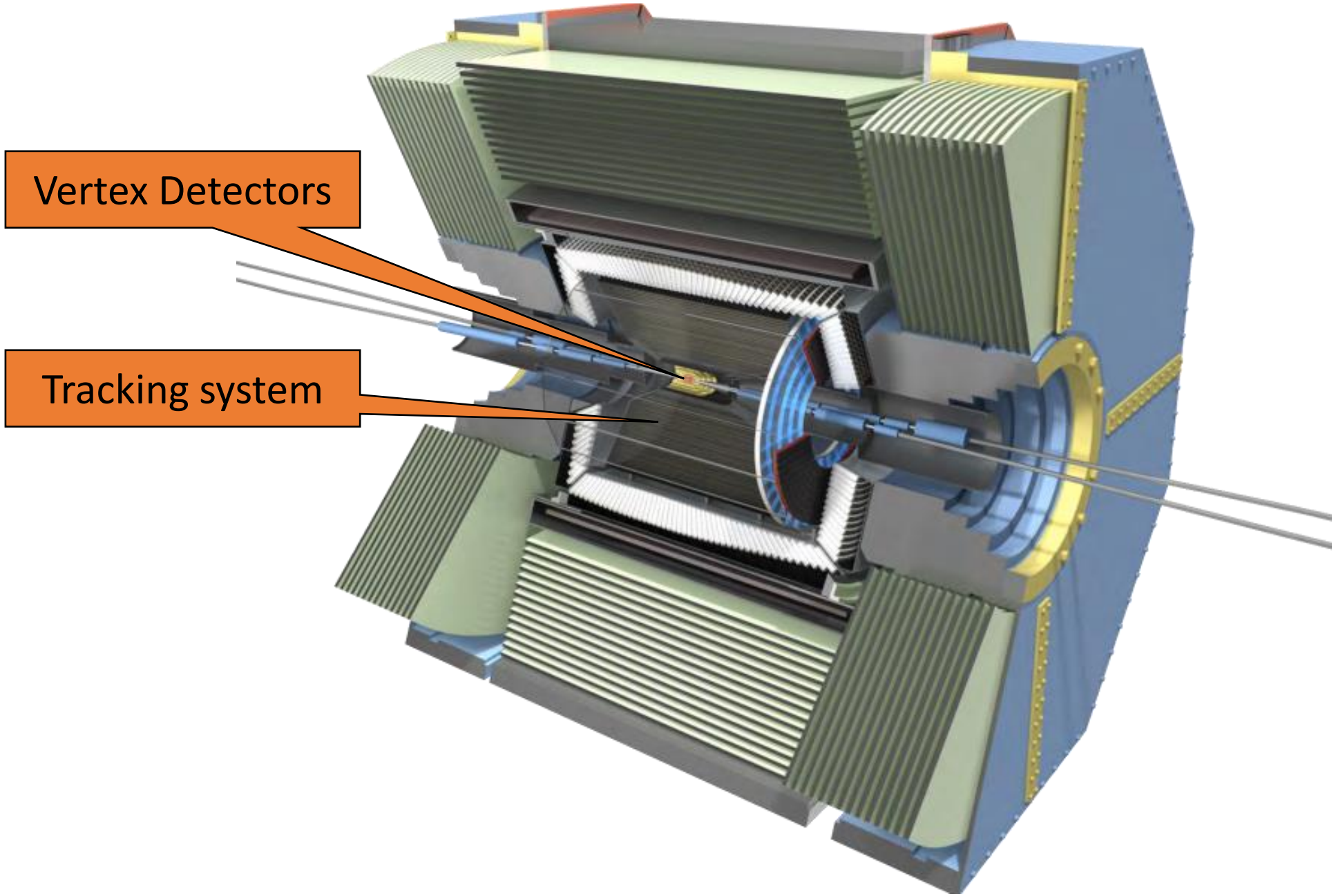


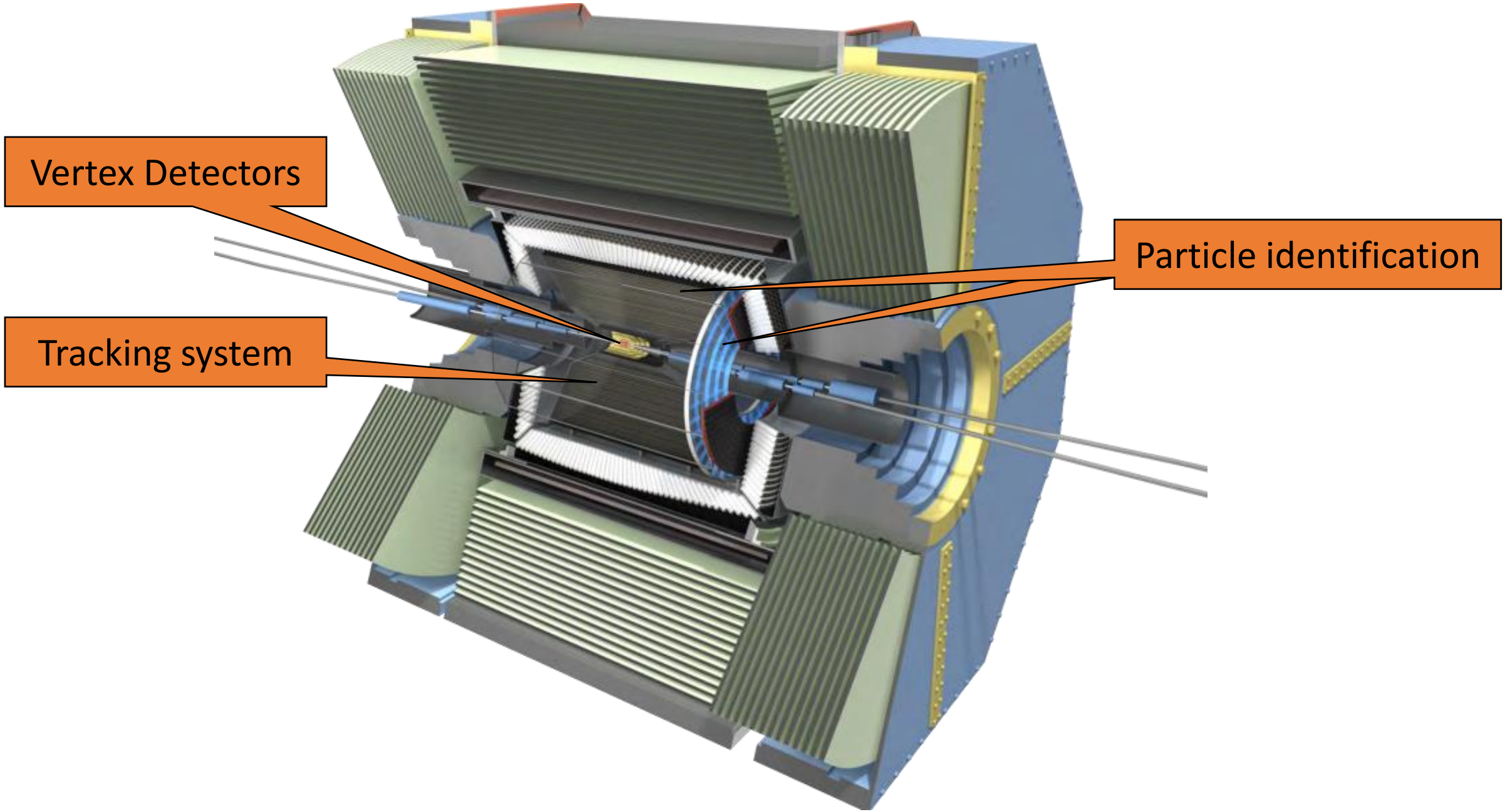


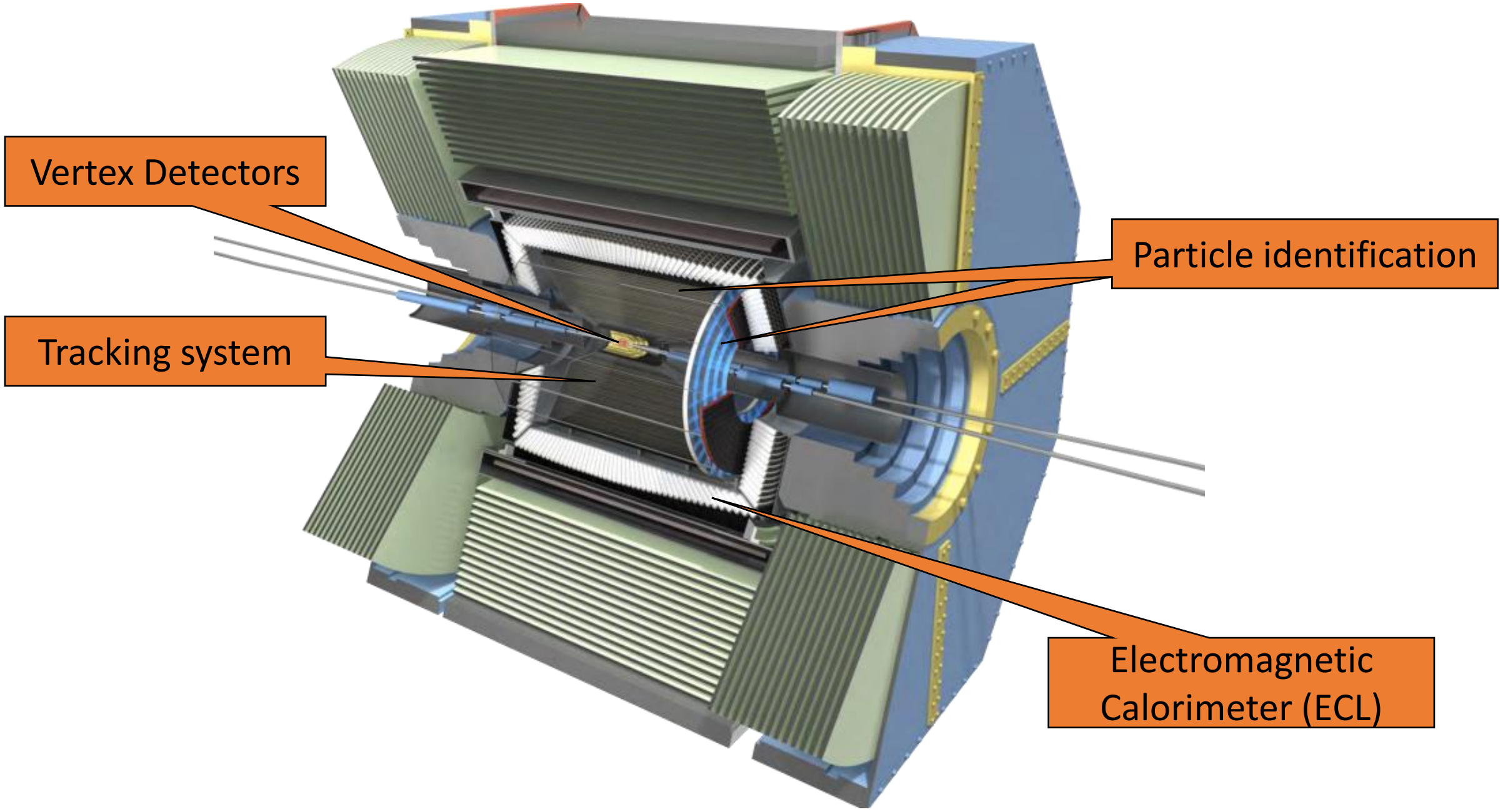
The Belle-II Detector

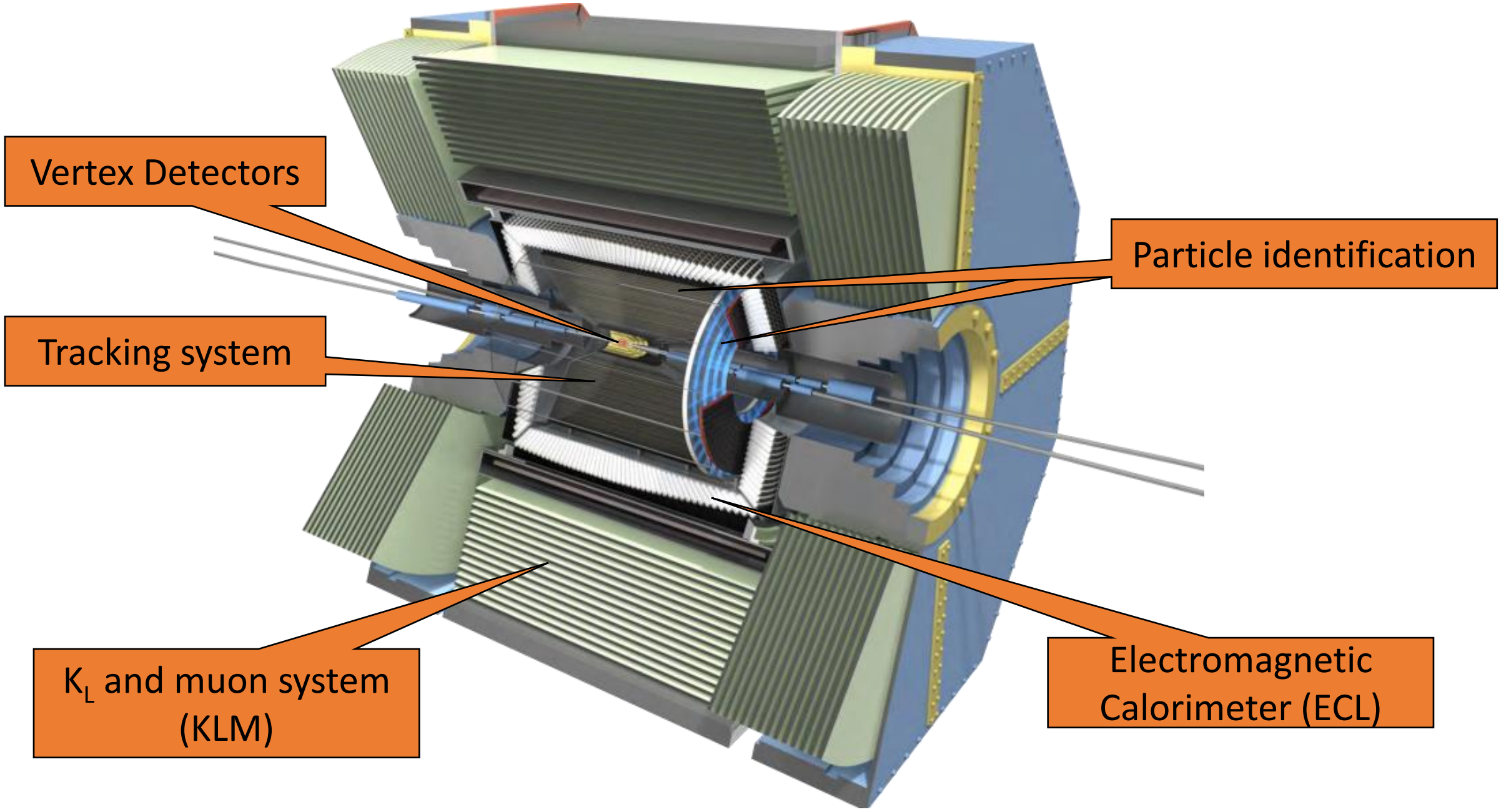



Vertex Detectors


Vertex Detectors
Tracking system


Vertex Detectors
Tracking system
Particle identification

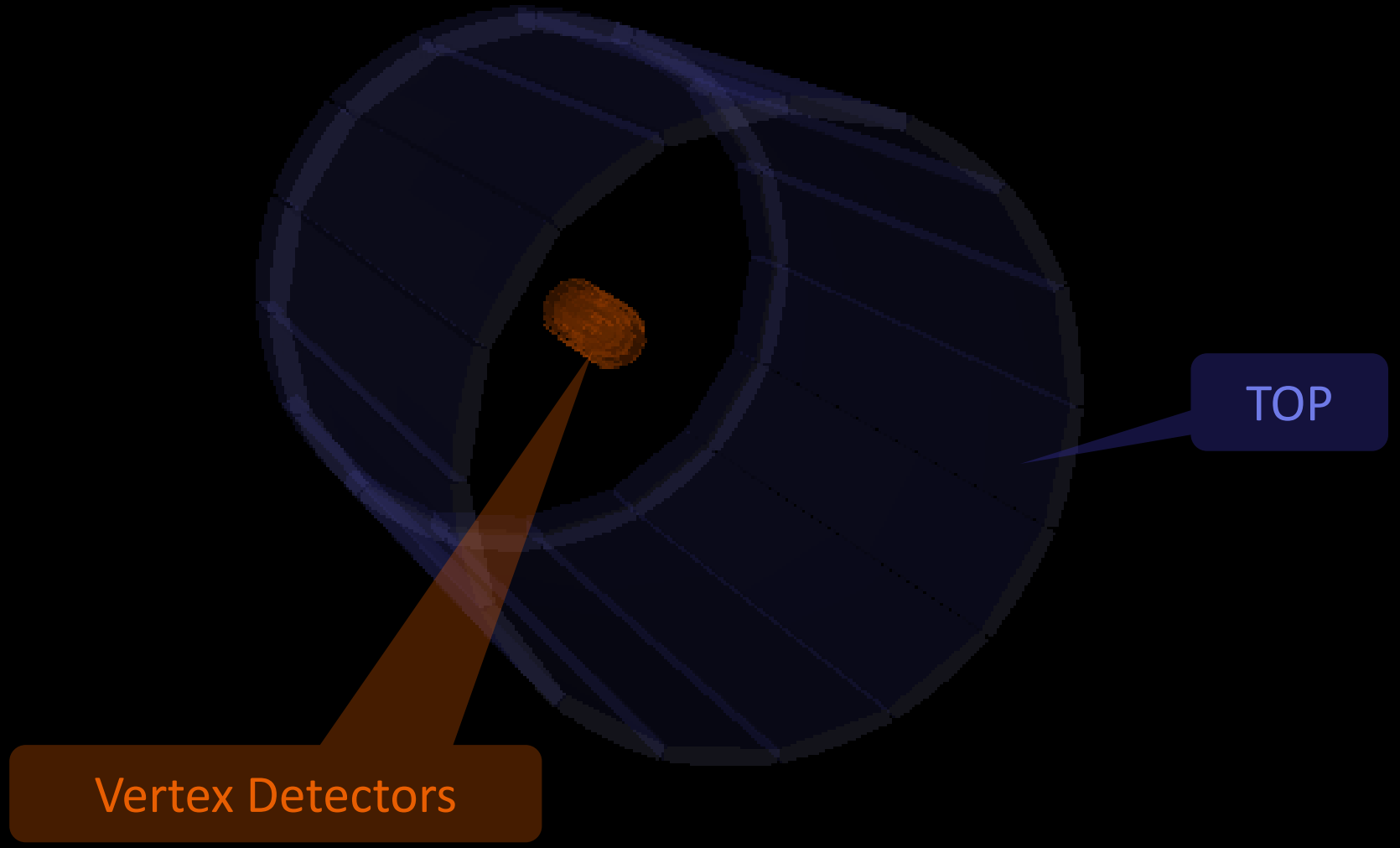

Vertex Detectors
Tracking system
Particle identification
Electromagnetic Calorimeter (ECL)


Vertex Detectors
Particle identification
Tracking system
K_L and muon system (KLM)
Electromagnetic Calorimeter (ECL)

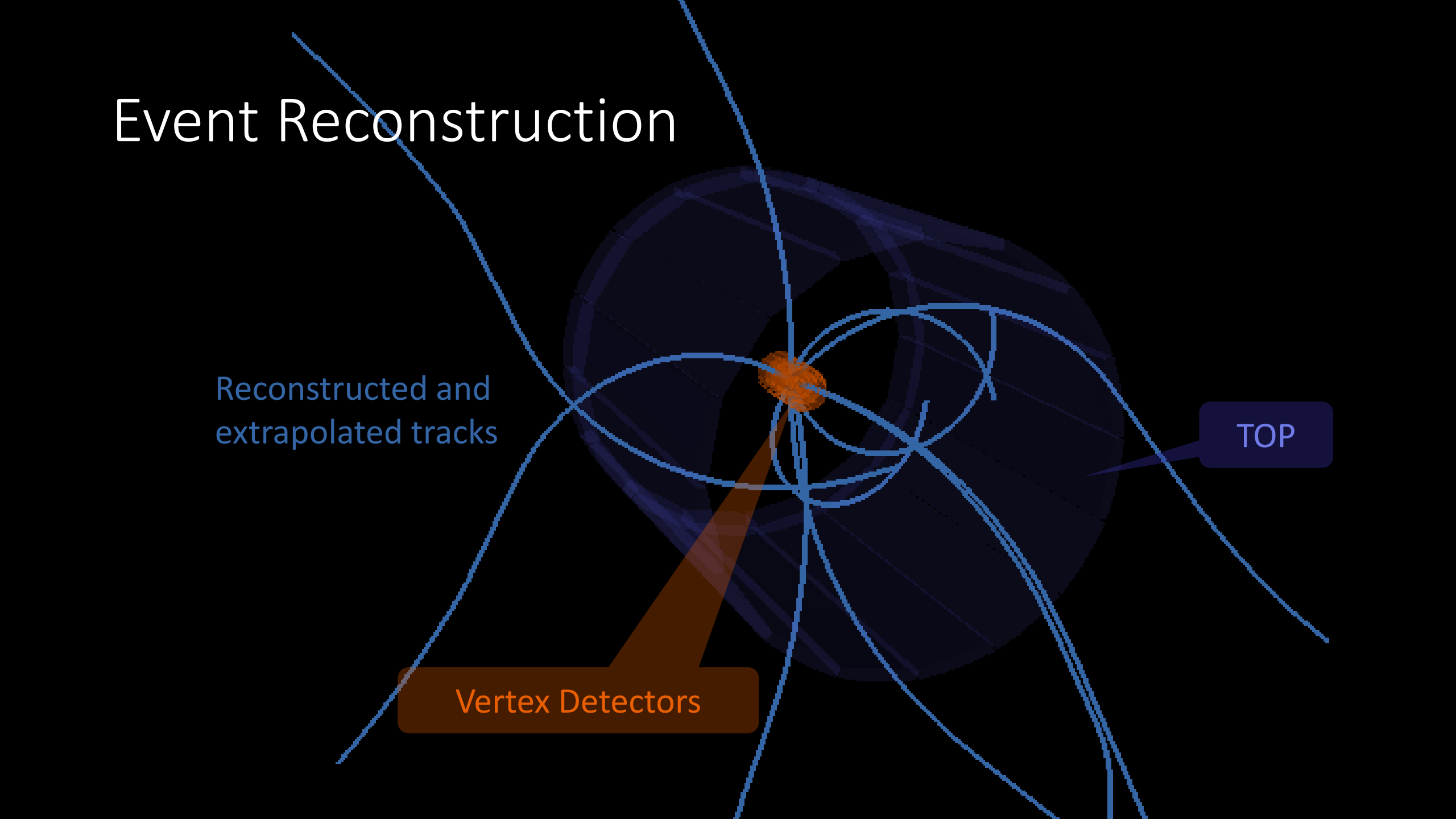
Reconstruction

Event interpretation and ECL reconstruction

Event Reconstruction



Event Reconstruction



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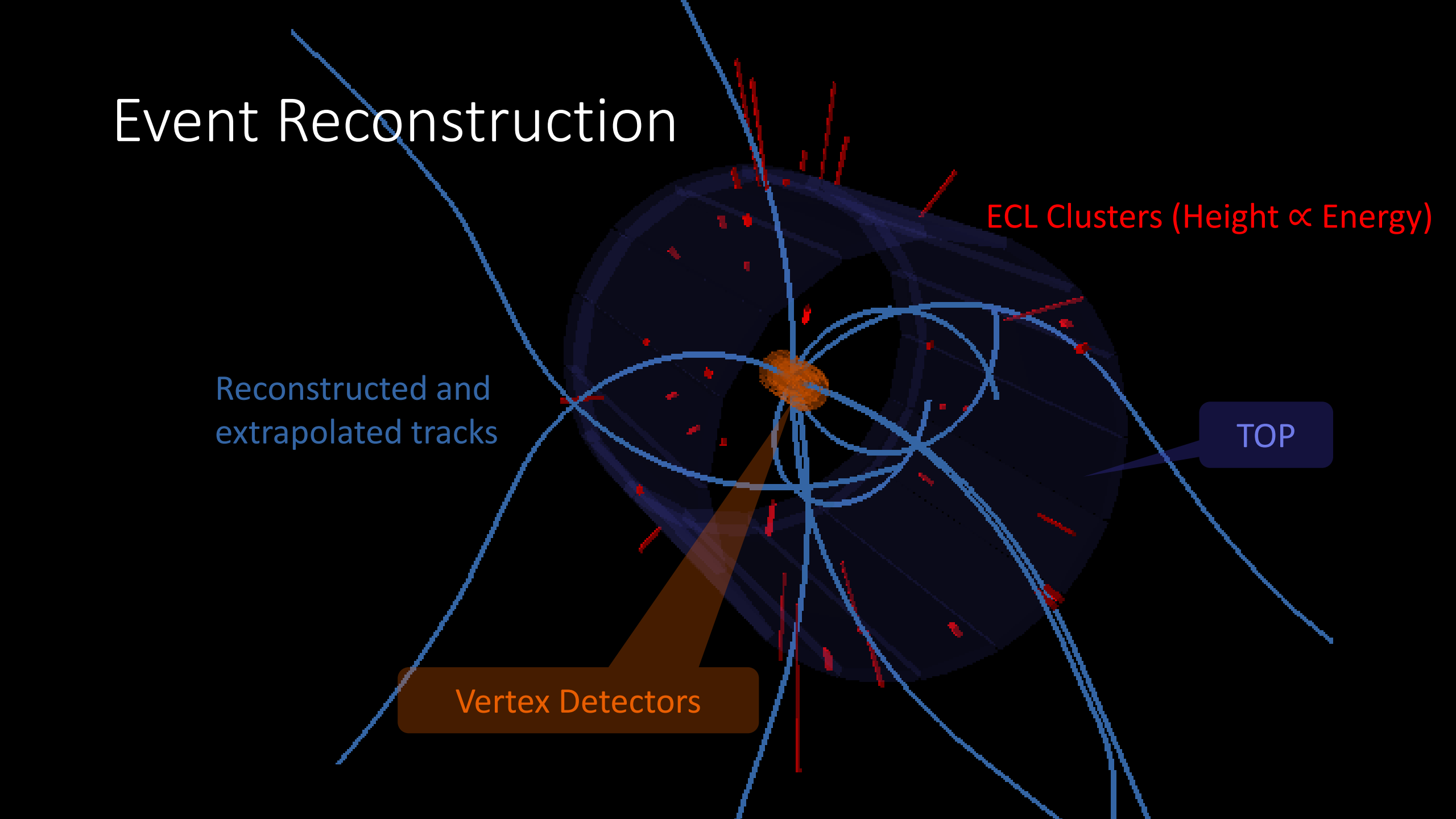
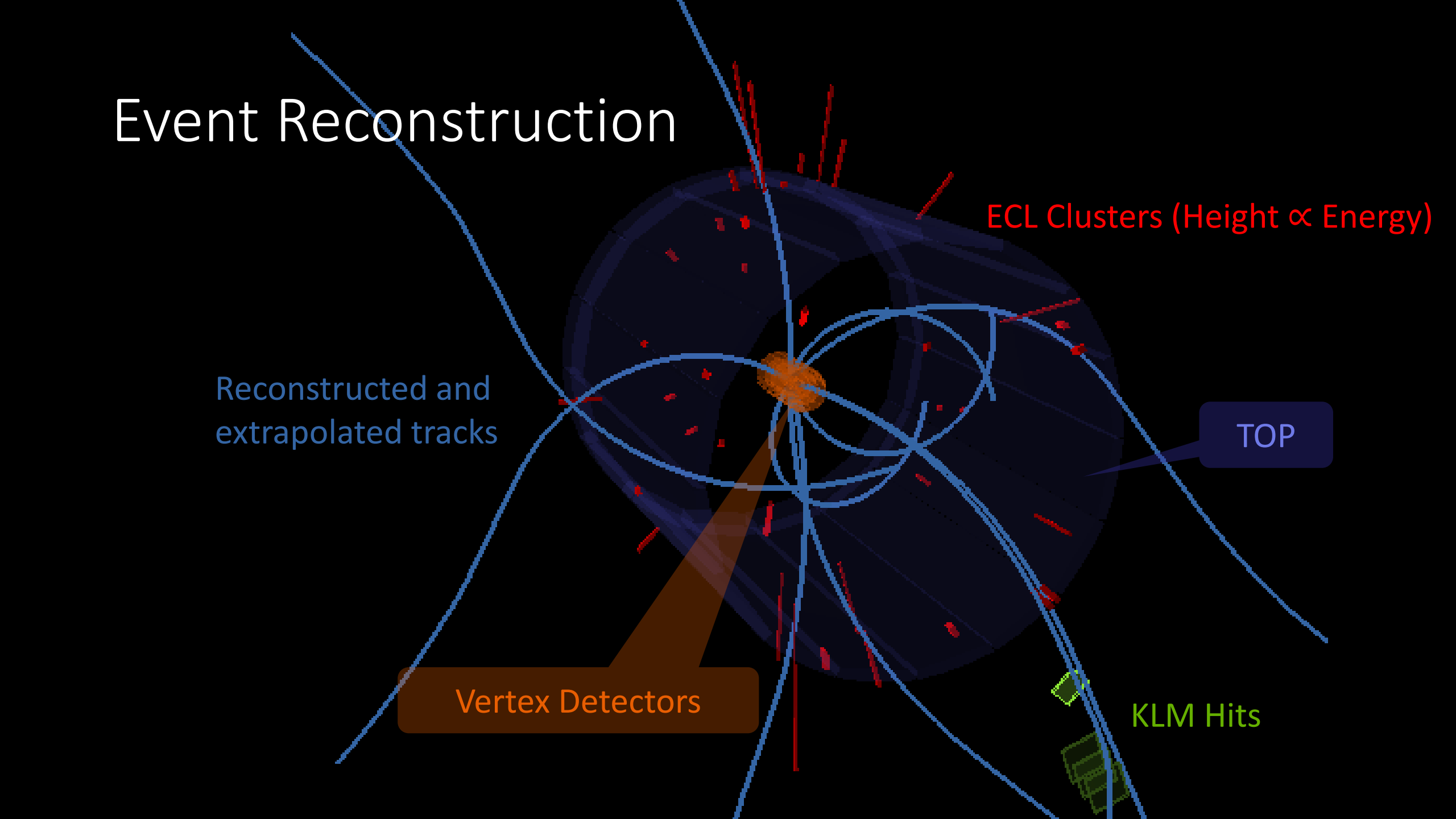
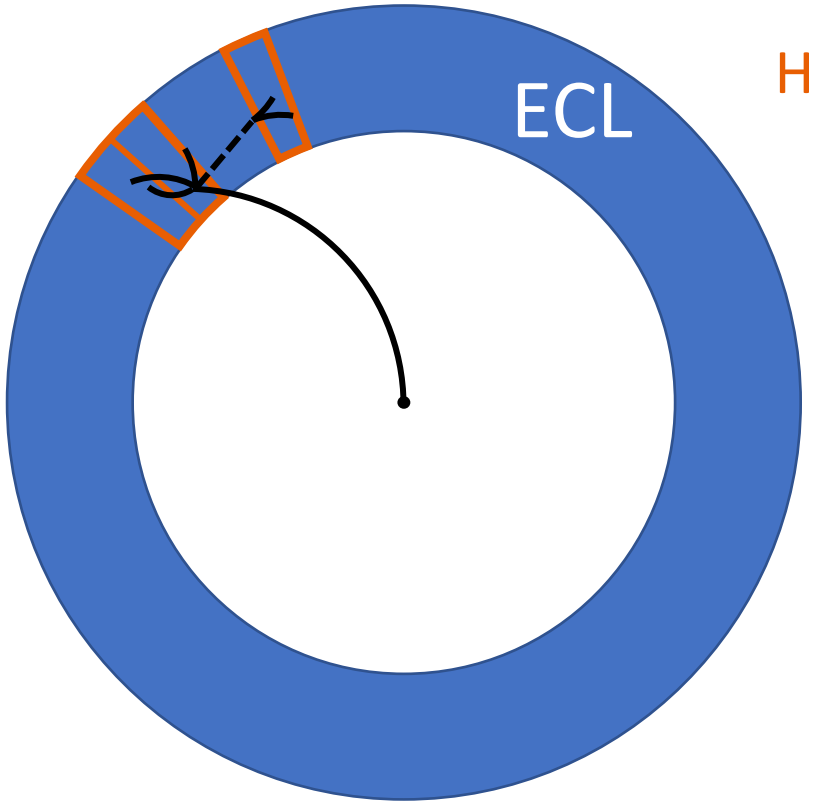


Event Reconstruction



Challenges in ECL Reconstruction

High momentum
Hadronic split off



Hit Crystals

Challenges in ECL Reconstruction

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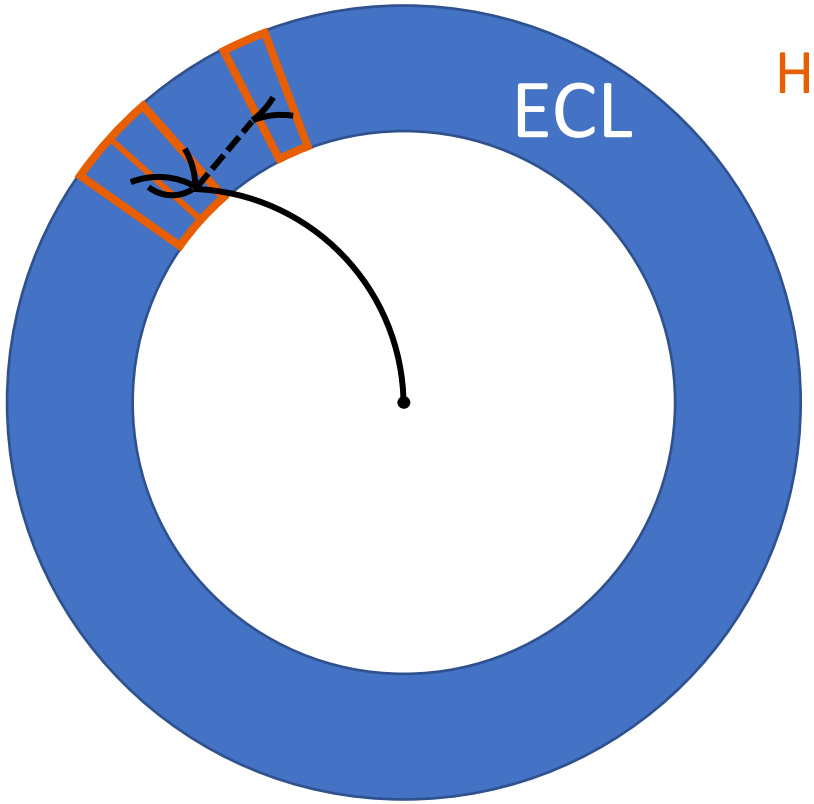
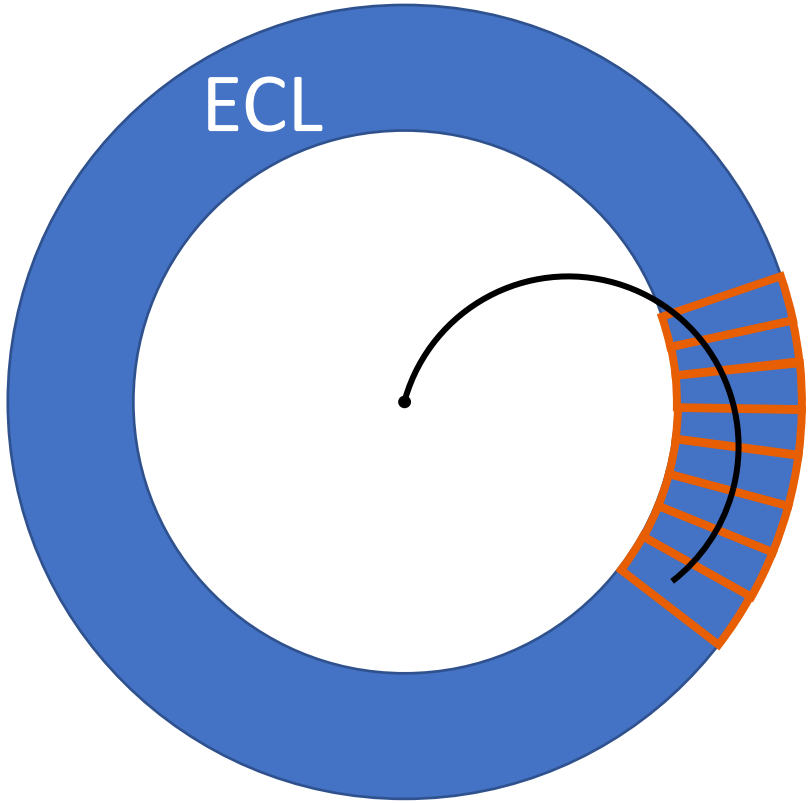
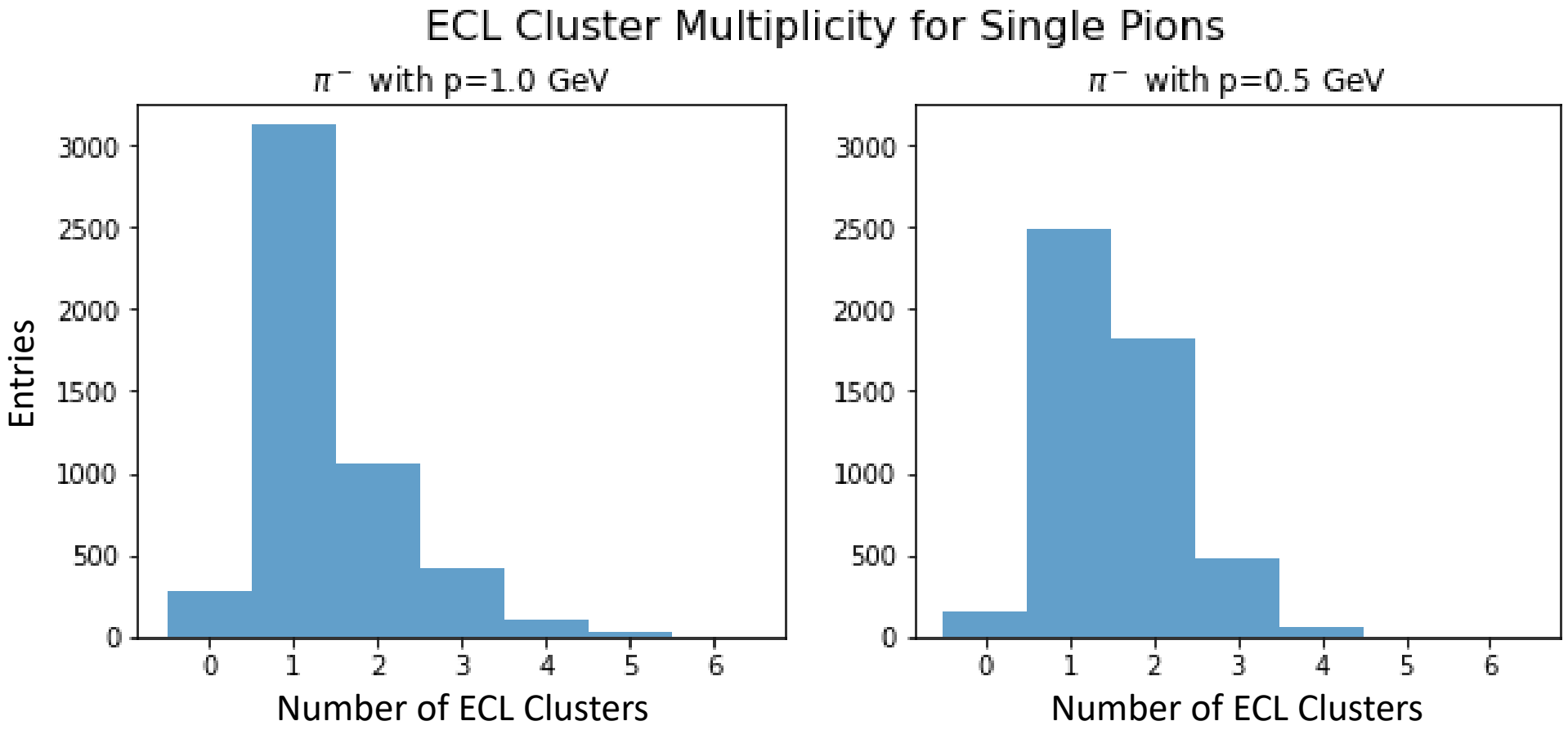


Hit Crystals

Low momentum
Long trails of ionization



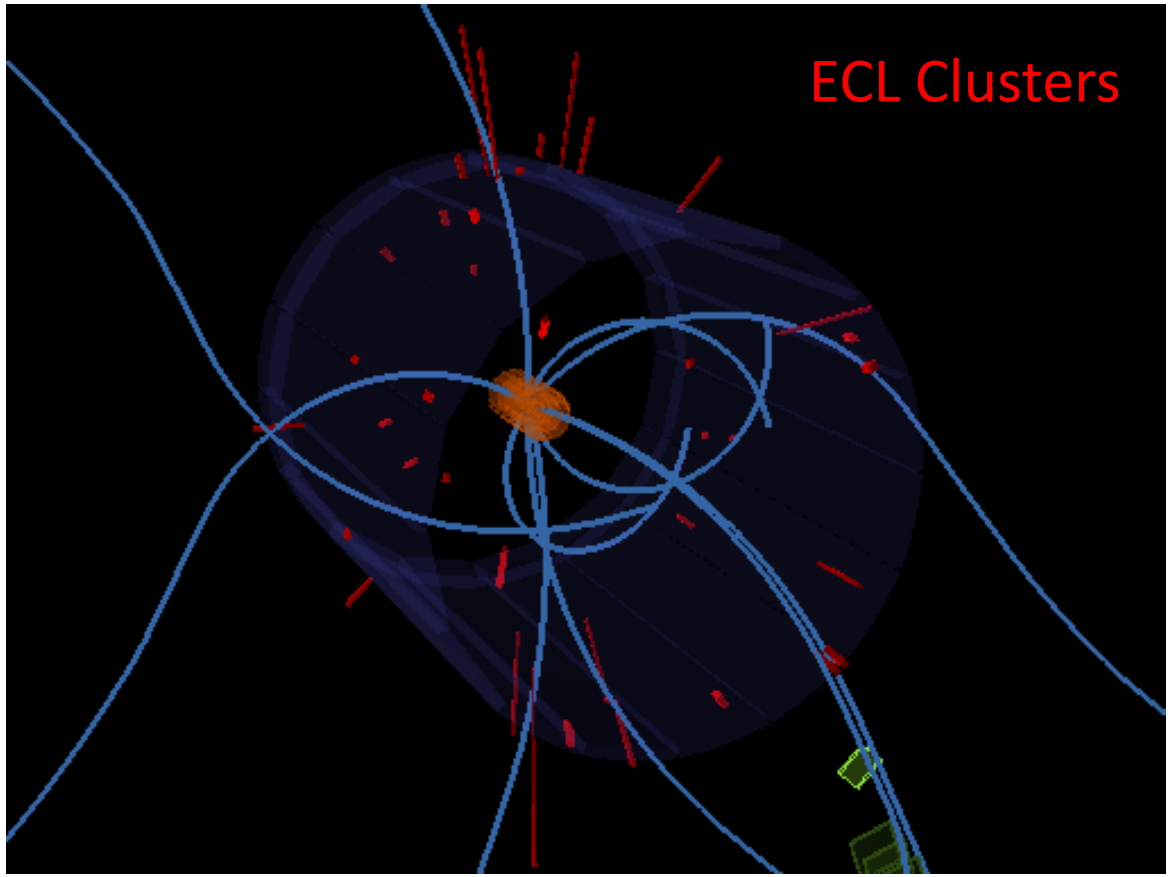
Number of Clusters from Single Pions



From a sample of 5000 simulated pions each

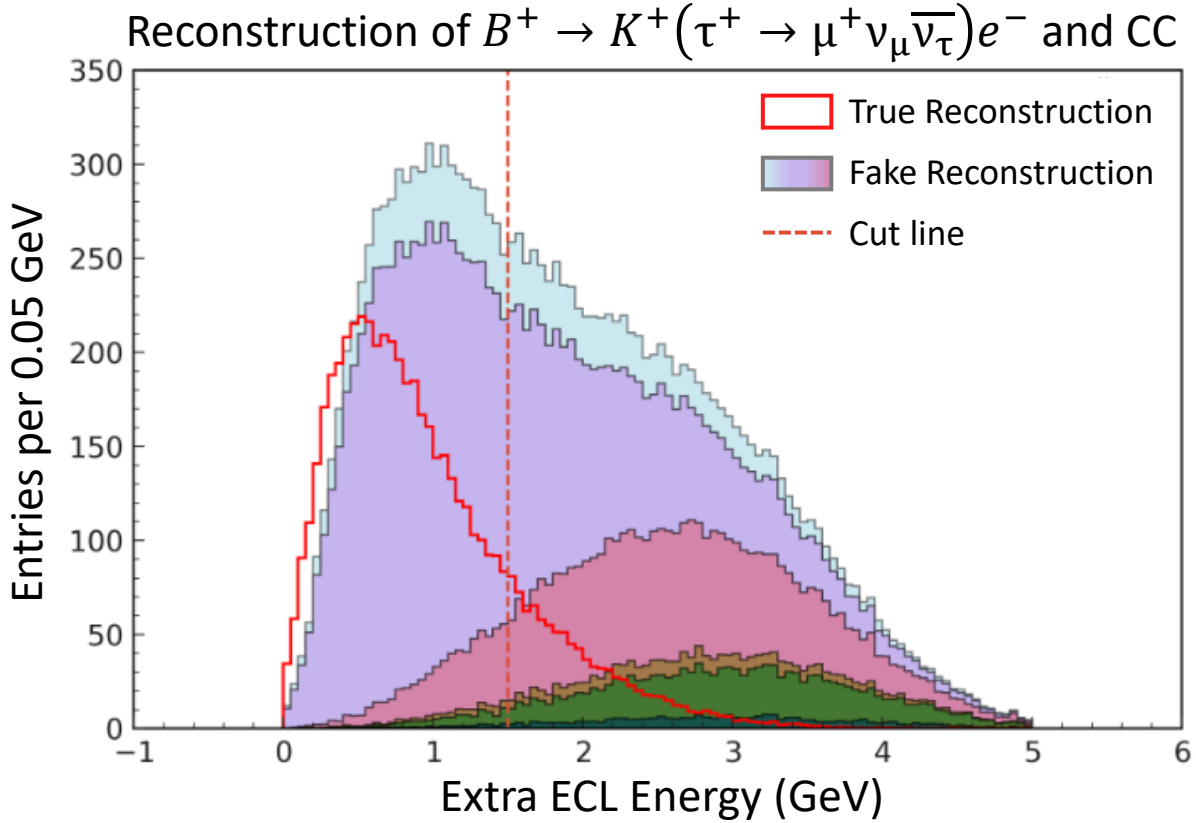
Problems with ECL Reconstruction Backgrounds

- Neutral pion reconstruction
  - Difficult with high ECL cluster multiplicity



Problems with ECL Reconstruction Backgrounds

- Neutral pion reconstruction
  - Difficult with high ECL cluster multiplicity
- Evaluation of event interpretation
  - Left over ECL clusters indicate a misinterpreted event



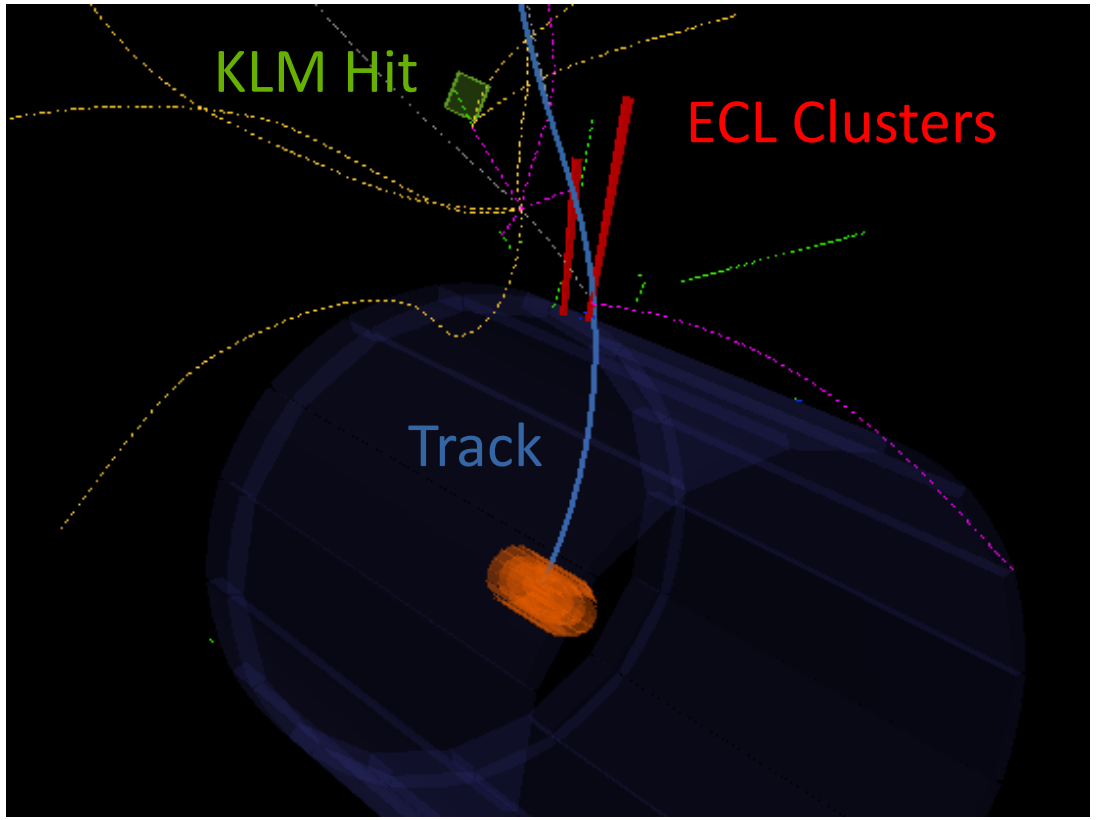
From Trevor Shillington's MSc Thesis

Charged Hadron Reconstruction

Based on simulation studies

Simulation Details

- Single particles coming from interaction point
- 5000 for each particle and momentum
- Direction of initial momentum: $\phi = 60$, $\theta = 90$



Instance of hadronic split off. Dotted lines are simulated particles.

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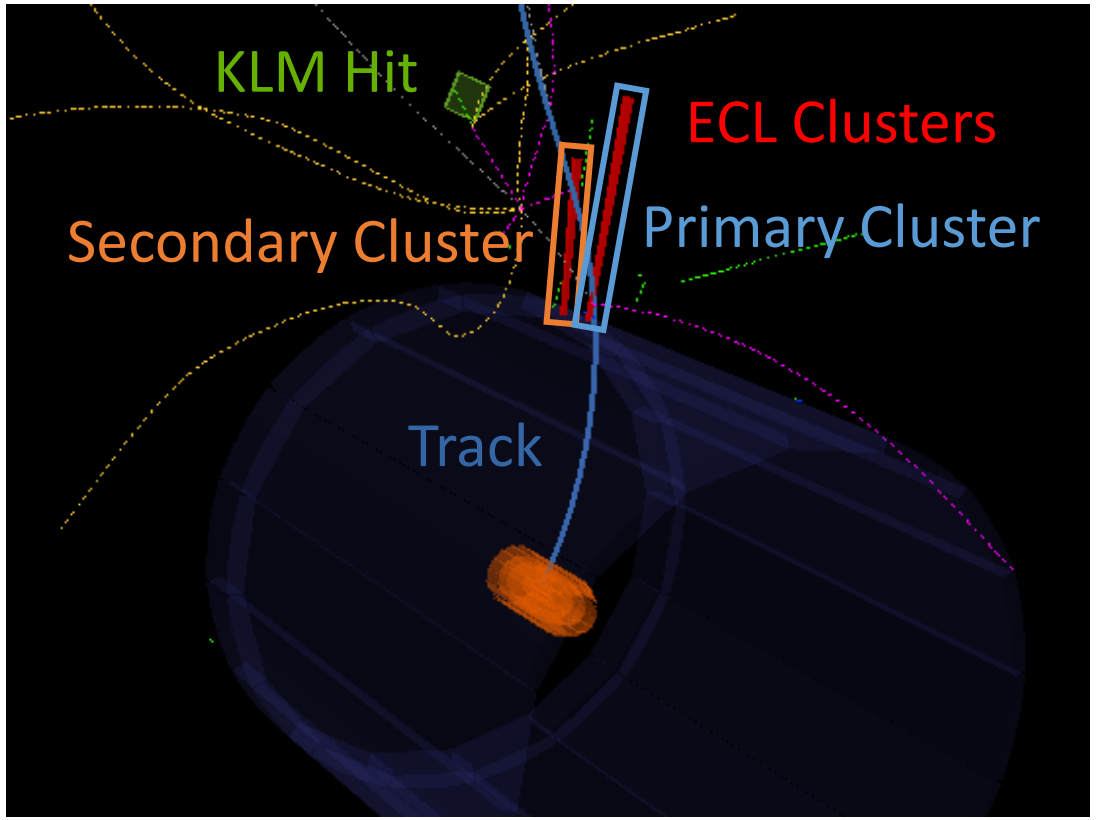
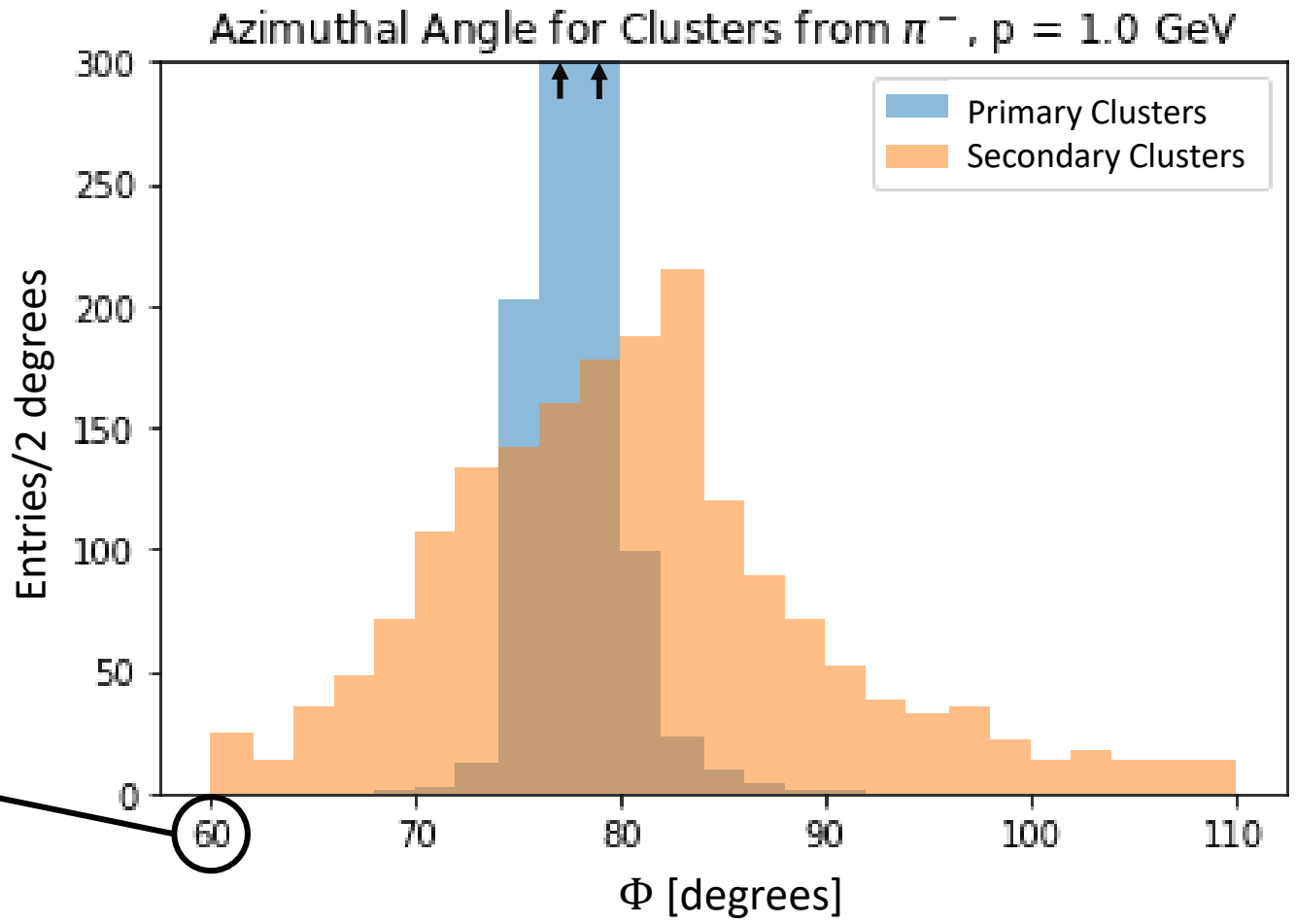


Instance of hadronic split off. Dotted lines are simulated particles.

Directionality

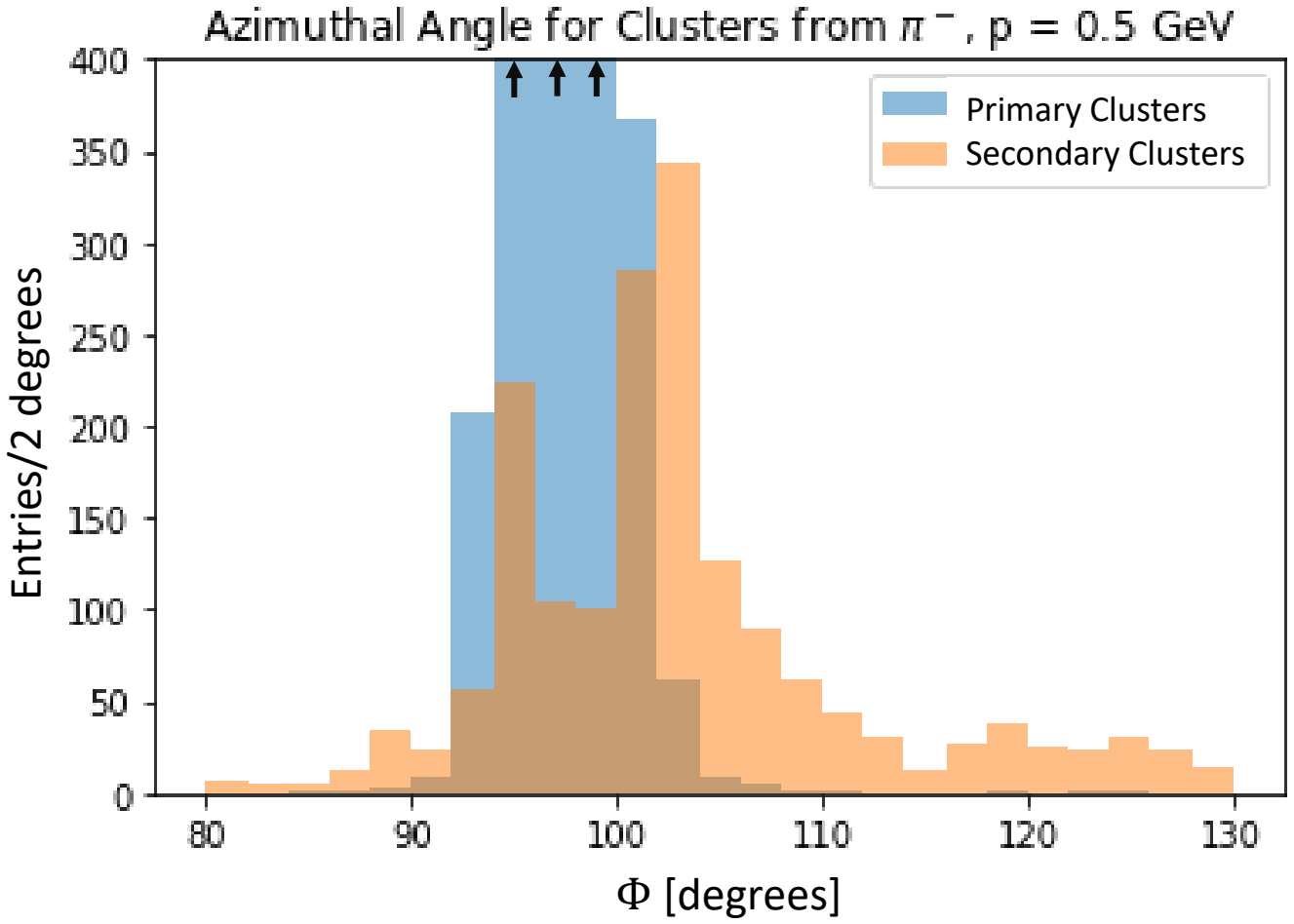
- Split offs continue in direction of particle bend
- Due to momentum conservation



Angle of initial pion momentum

Directionality at Lower Momentum

- At lower momenta, there is a stronger correlation with direction
- Due to low transverse momentum clustering



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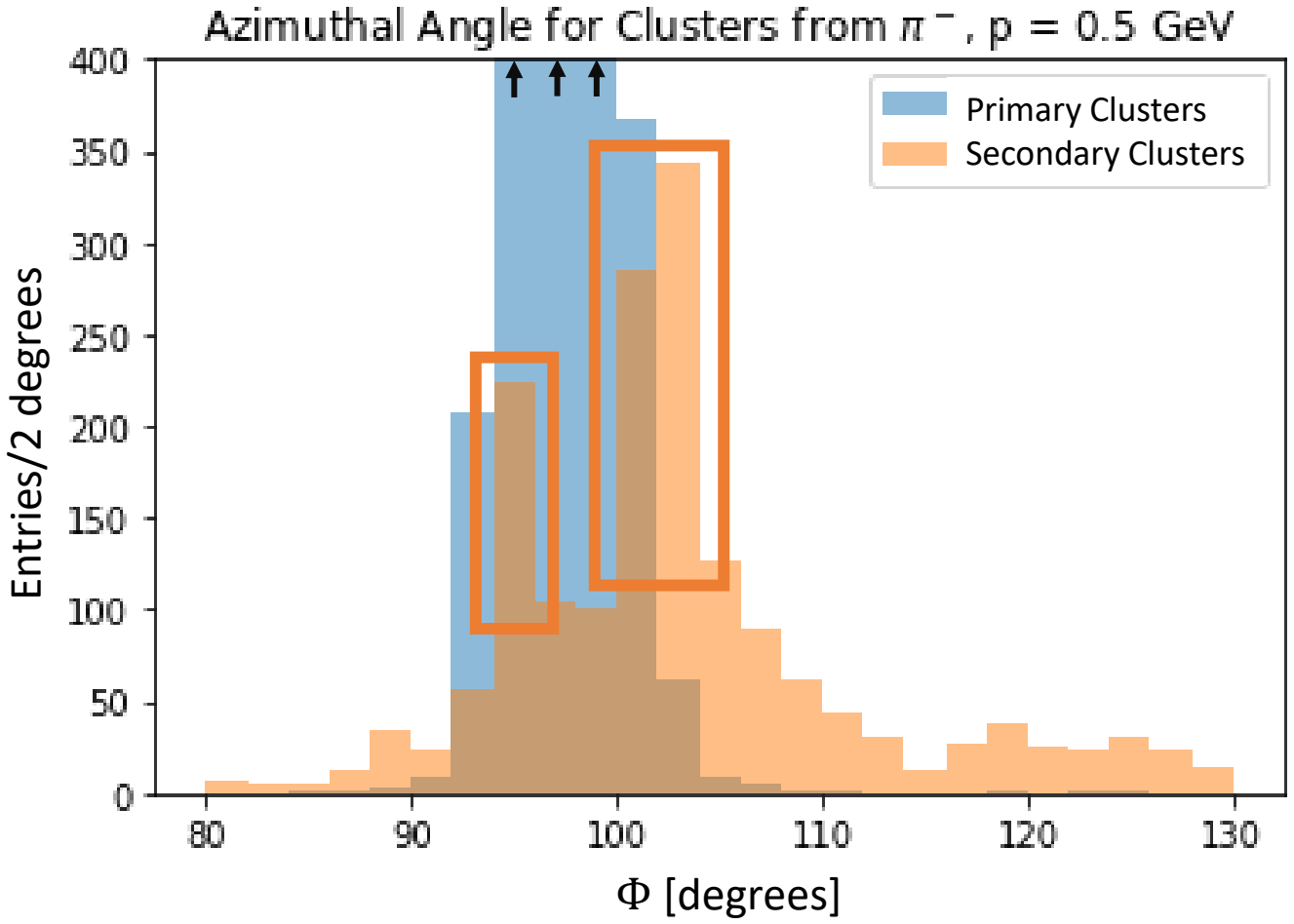
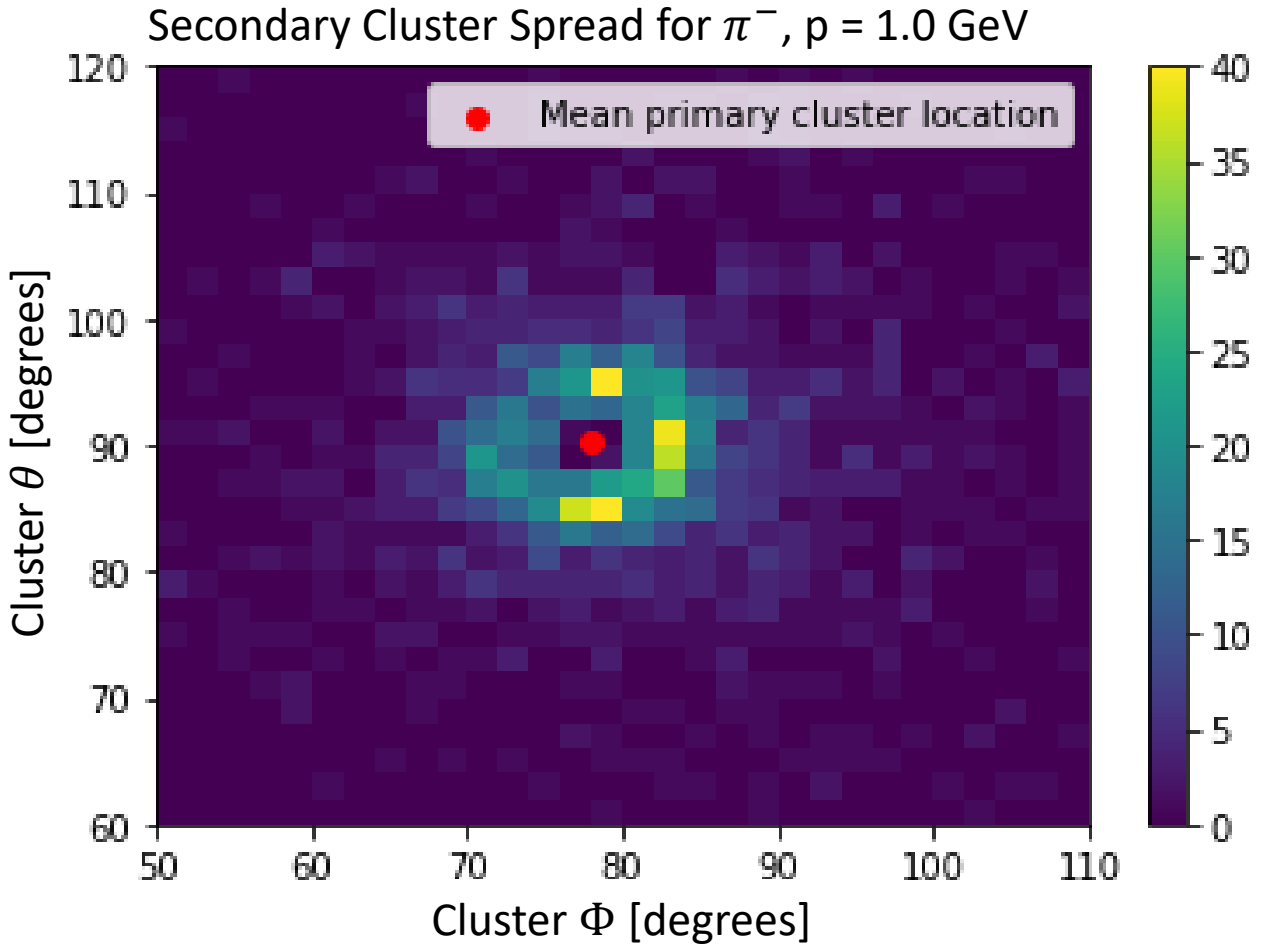


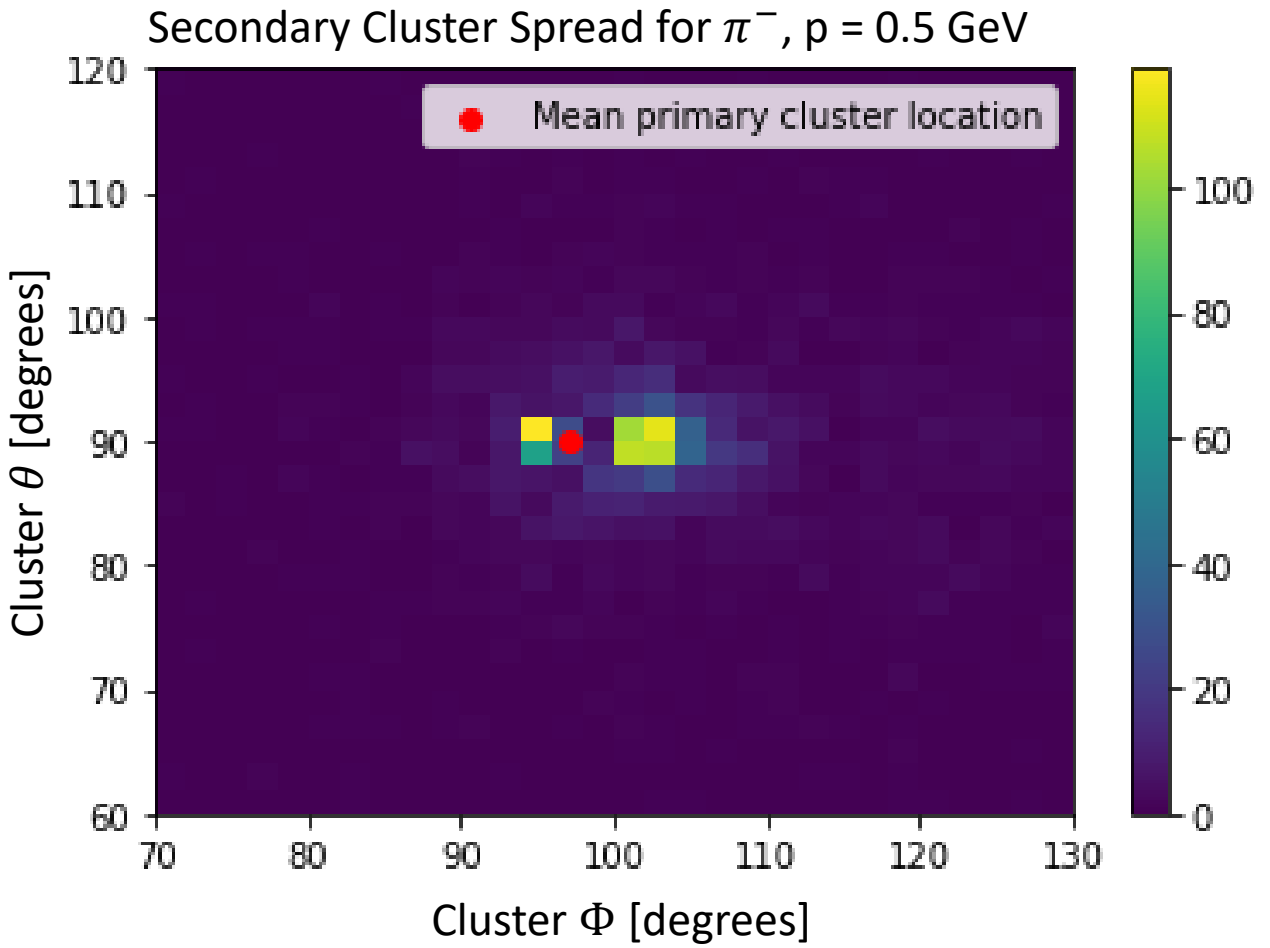
Directionality Including Polar Angle

- Visible ring around primary clusters at high momentum at high momentum

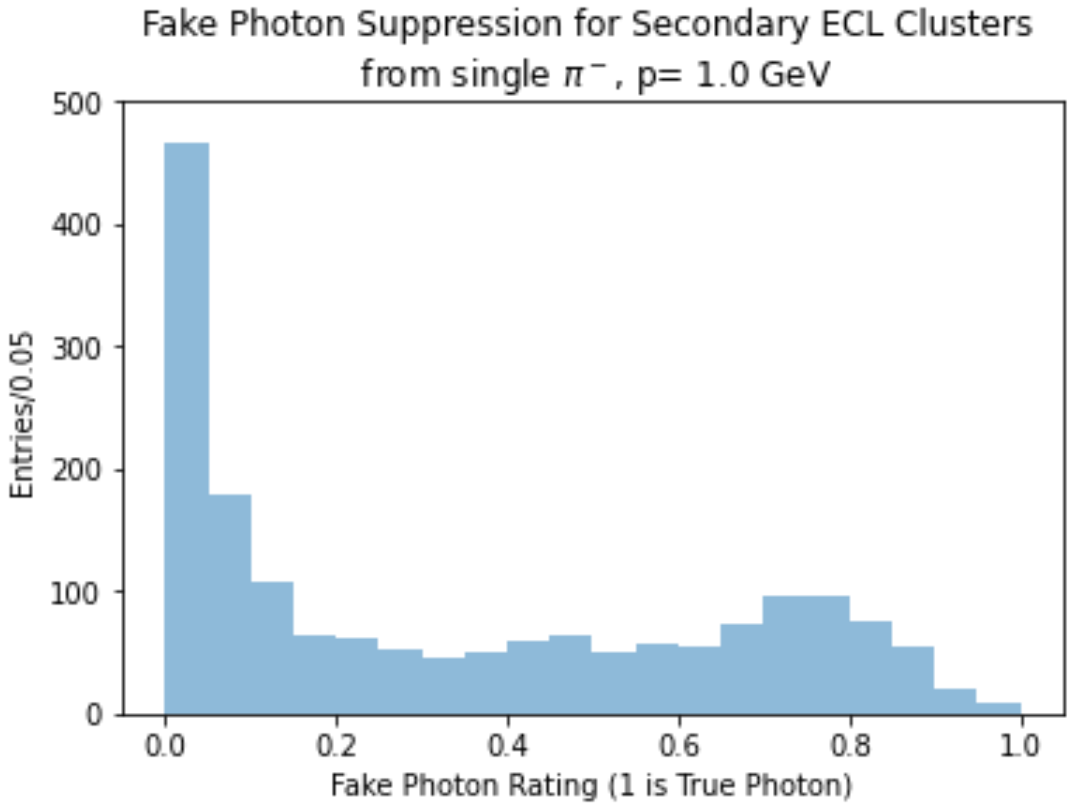


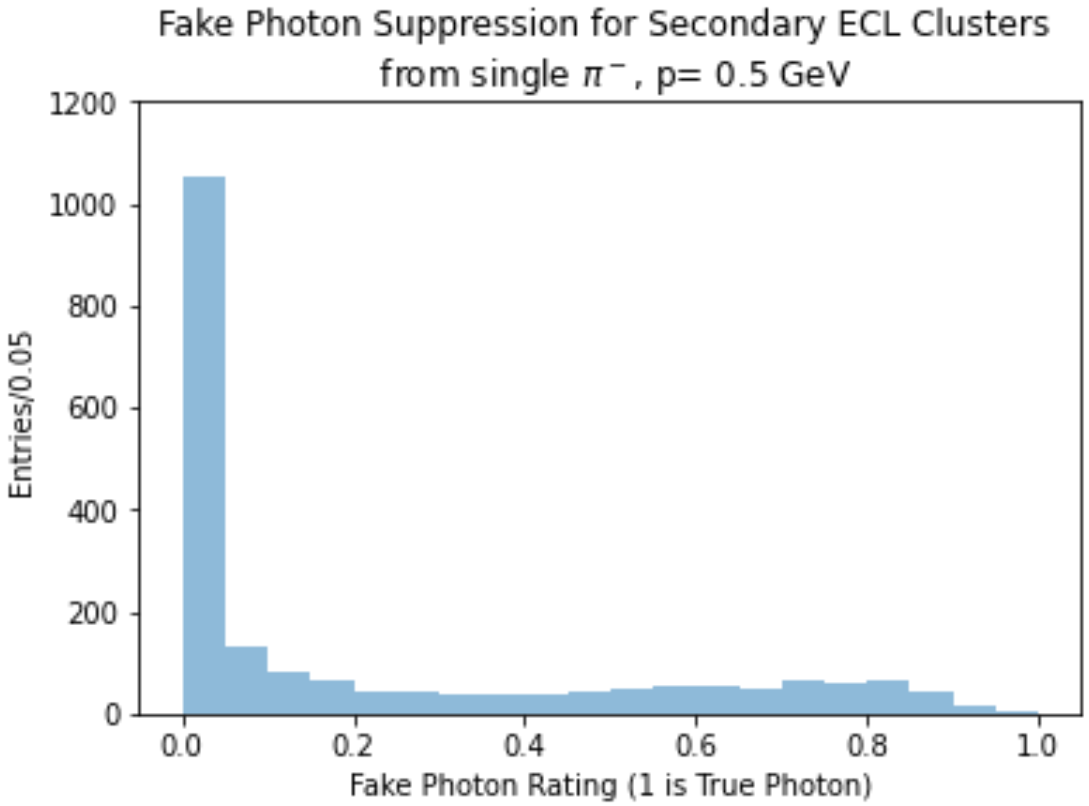
Directionality Including Polar Angle

- Visible ring around primary clusters at high momentum at high momentum
- No ring at at low momentum
  - Closer in theta



Methods For Suppressing Secondary Clusters





Summary & Conclusion

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- **Parameters of hadronic tracks** may be used to **discriminate secondary clusters** in the ECL

Acknowledgments

I would like to thank the following people for their help in this research and presentation

Steven Robertson
Trevor Shillington
Andreas Warburton
Savino Longo
Hannah Wakeling
Raynette van Tonder
Andrea Fodor
Ahmad Mahmood

Thanks for listening!

Questions are welcome.

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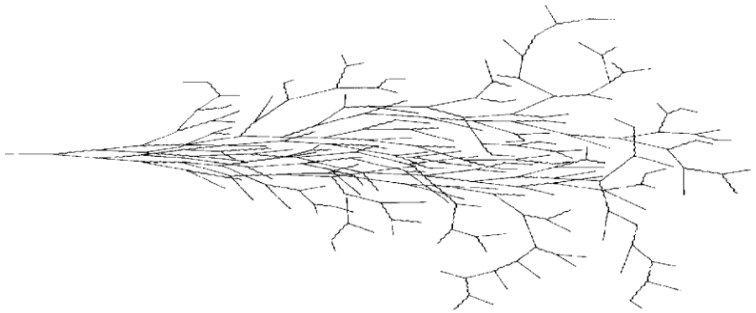
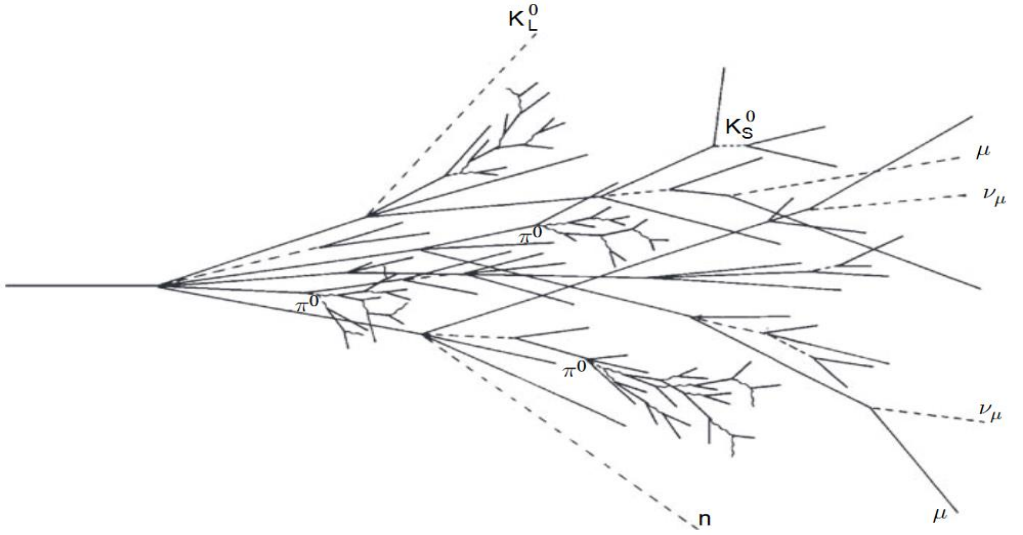
Extra Slides

Basics of EM and Hadronic Showers

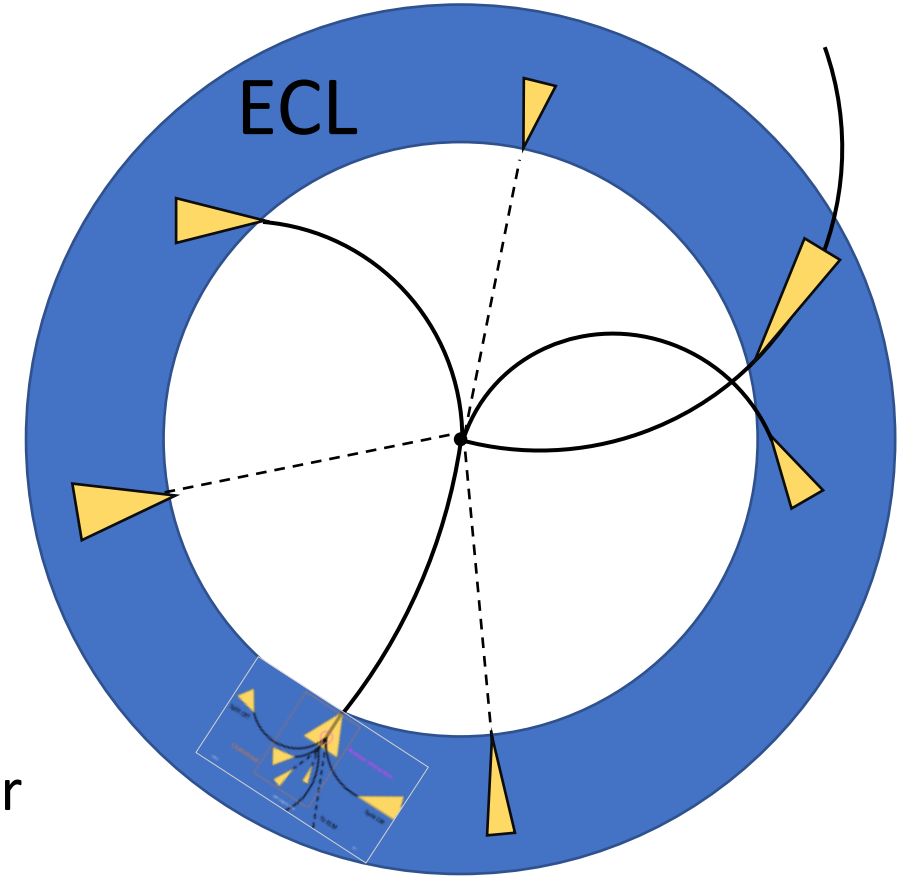
EM Showers	Hadronic Showers
• Develop via pair production and bremsstrahlung	• Develop via nuclear interactions, particle decays, and EM showers





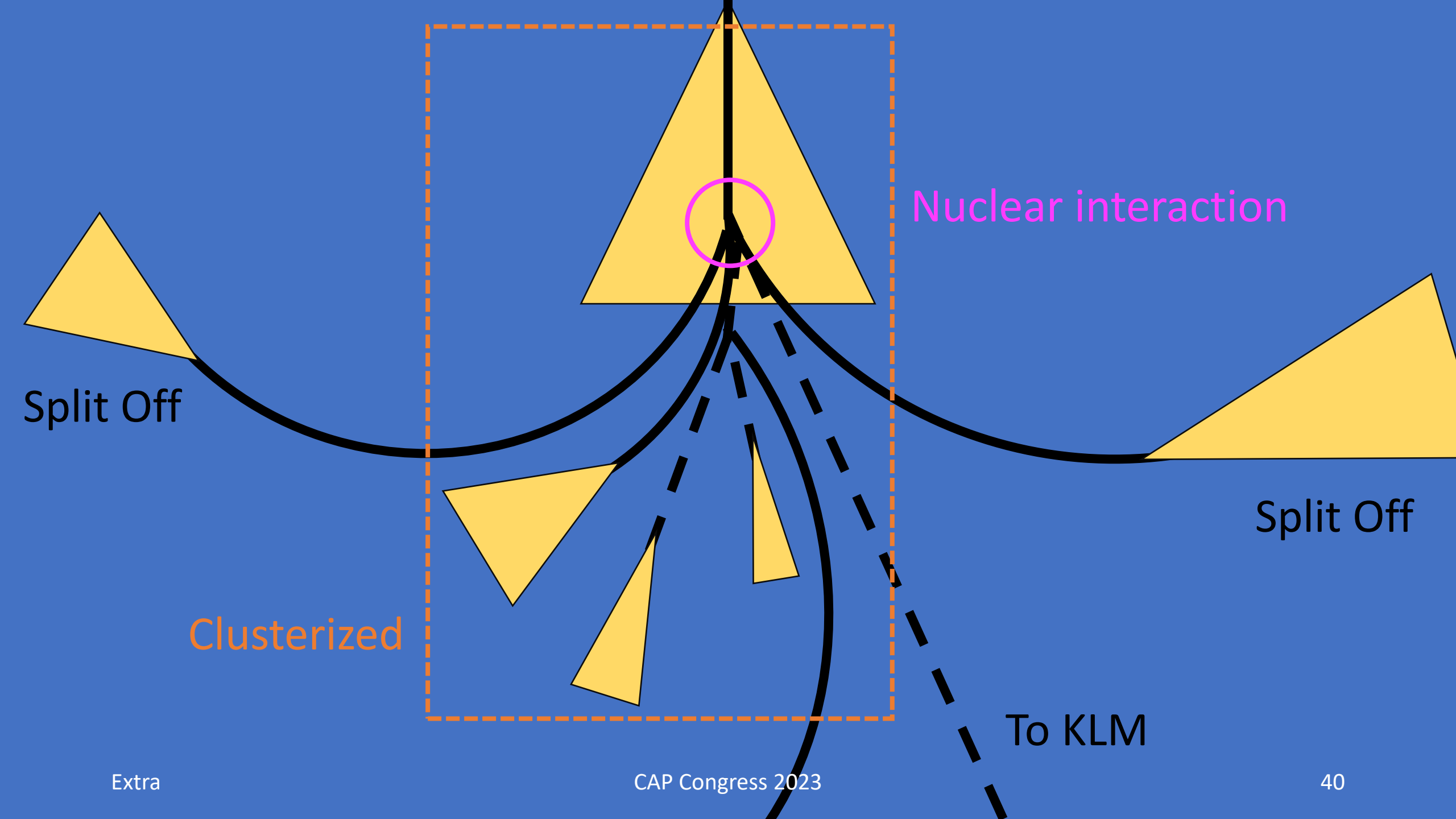
Hadronic showers in Belle II

- Hadrons are common in Belle II events
- They have ~60% chance of nuclear interaction in ECL
  - Otherwise, will interact with KLM

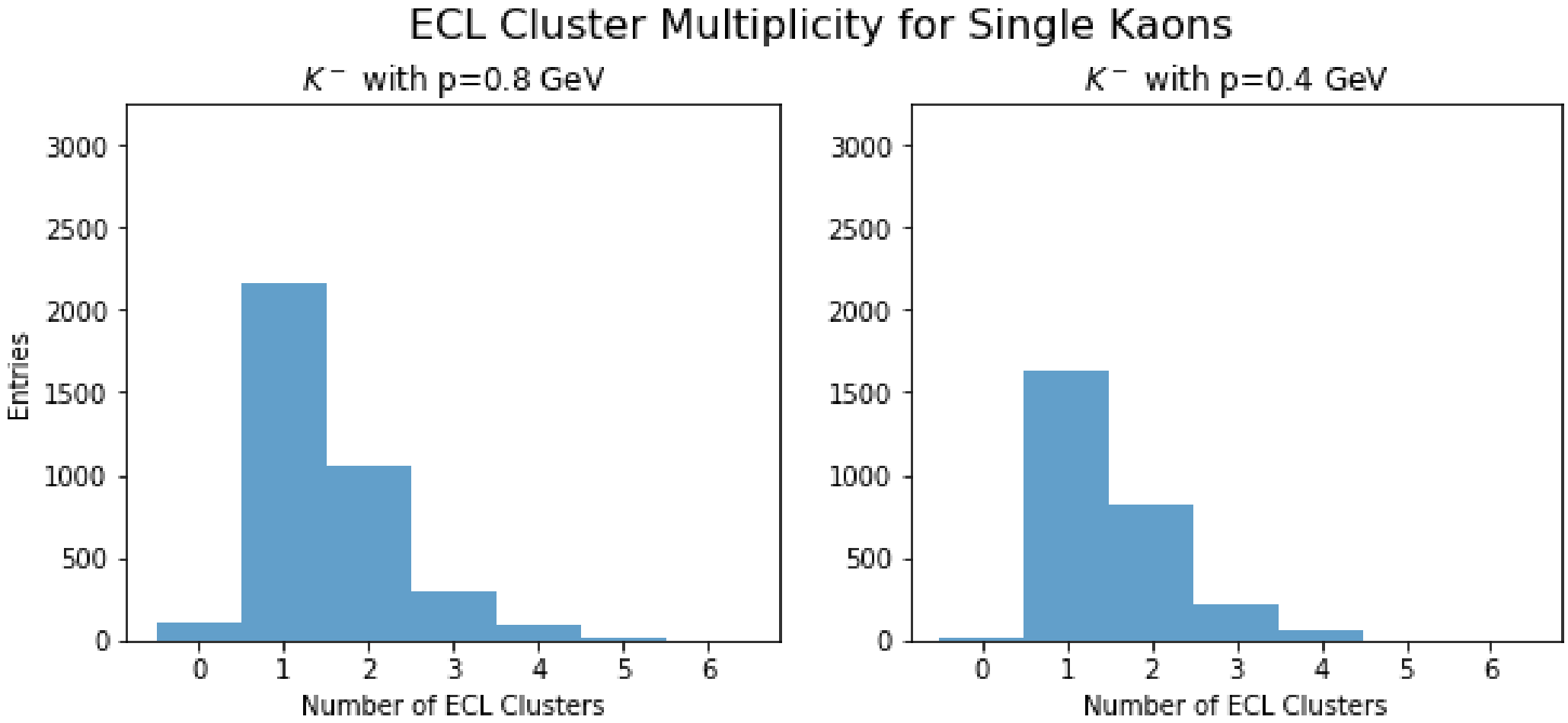


= EM shower

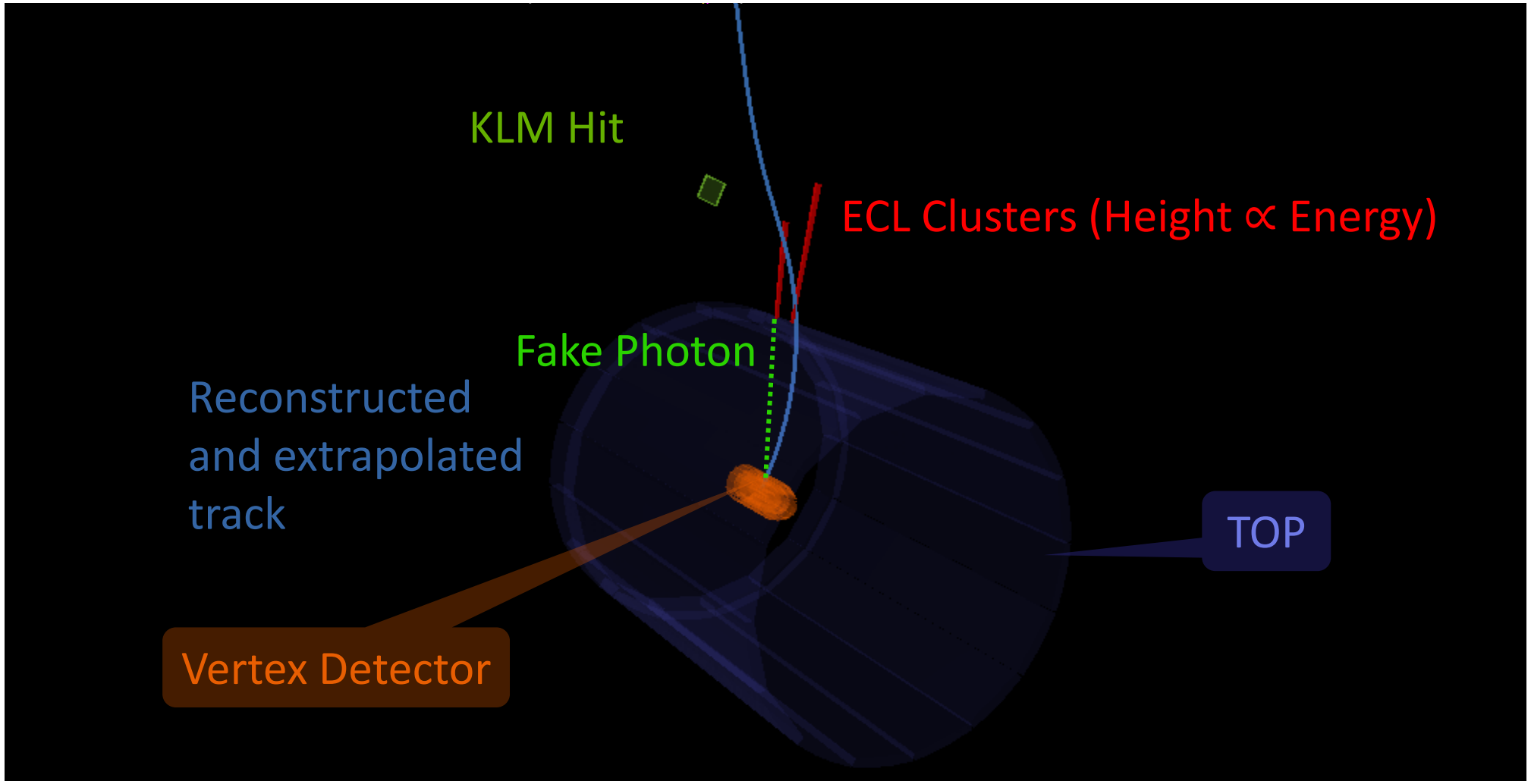
Simplified Event (Beam Perspective)


Nuclear interaction
Split Off
Split Off
Clusterized
To KLM

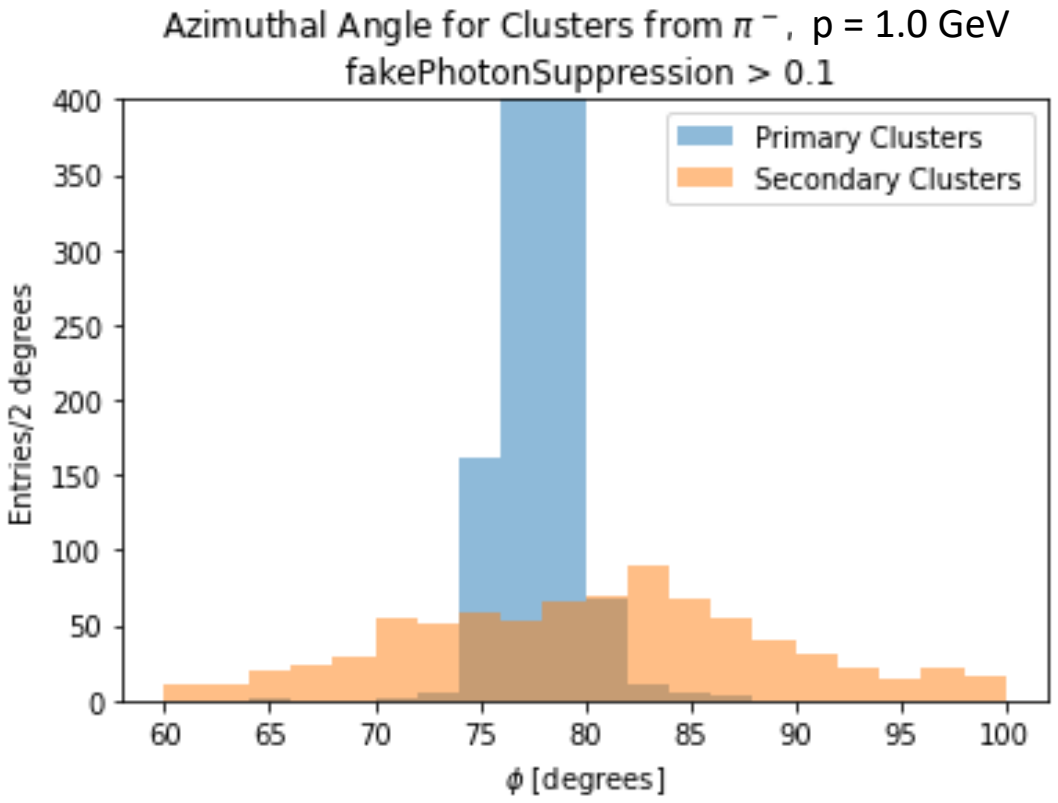
ECL Cluster Multiplicity for Kaons

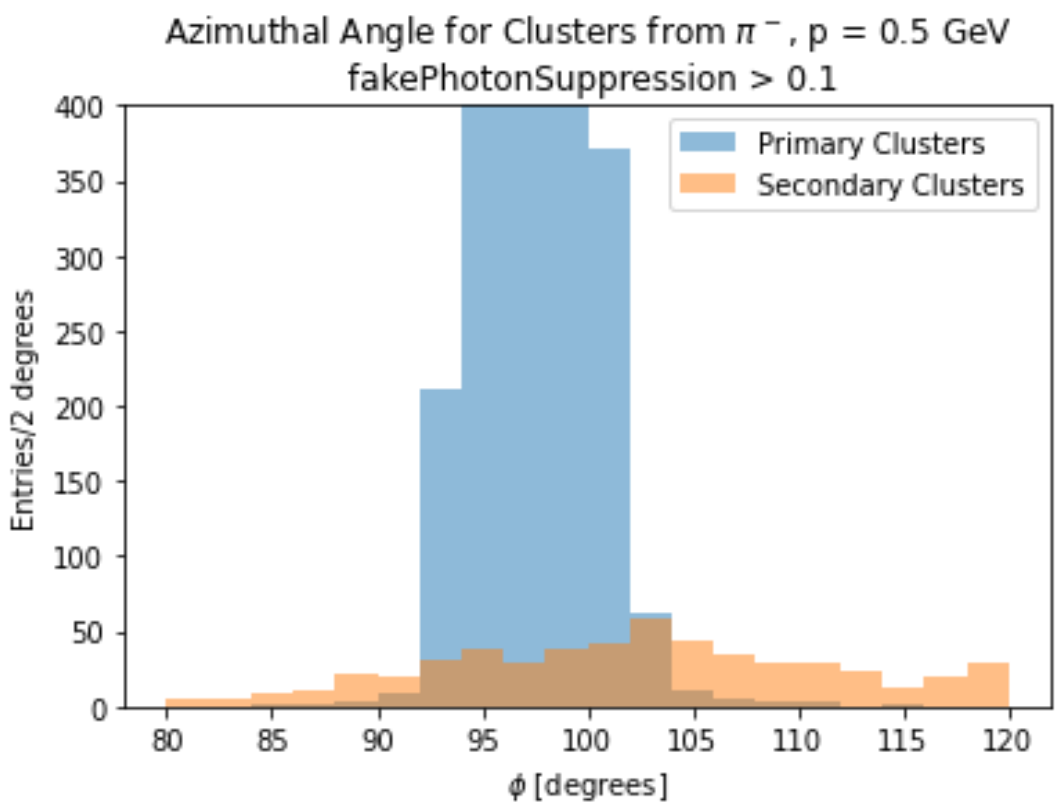


Split Off from Single Pion

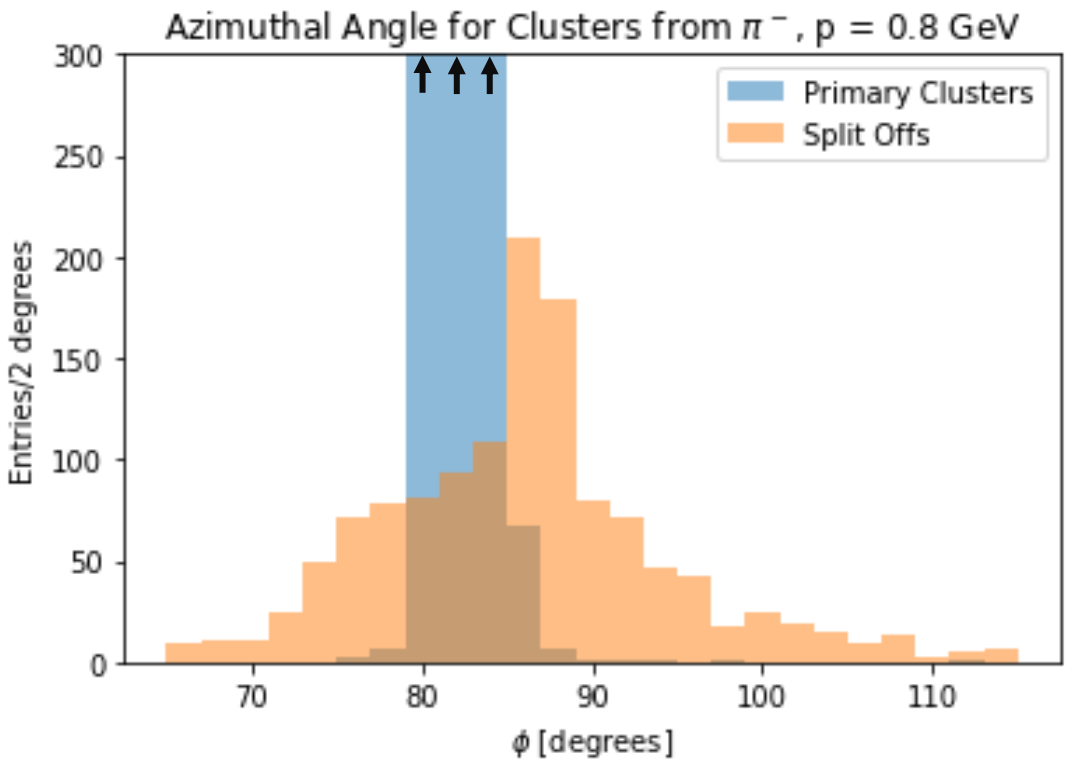


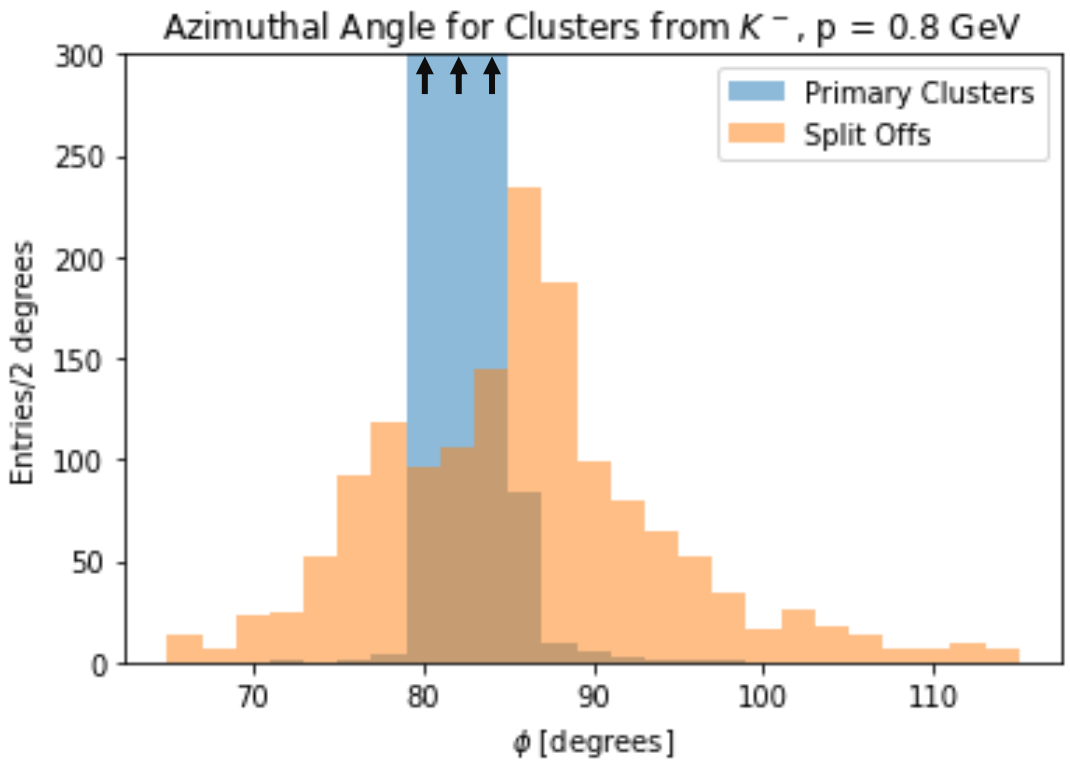
Split Off from Single Pion





Particle Type





KLM Multiplicity