Simulations of EM Shower Acceptance

Wenjie Wu, Jianming Bian

University of California, Irvine

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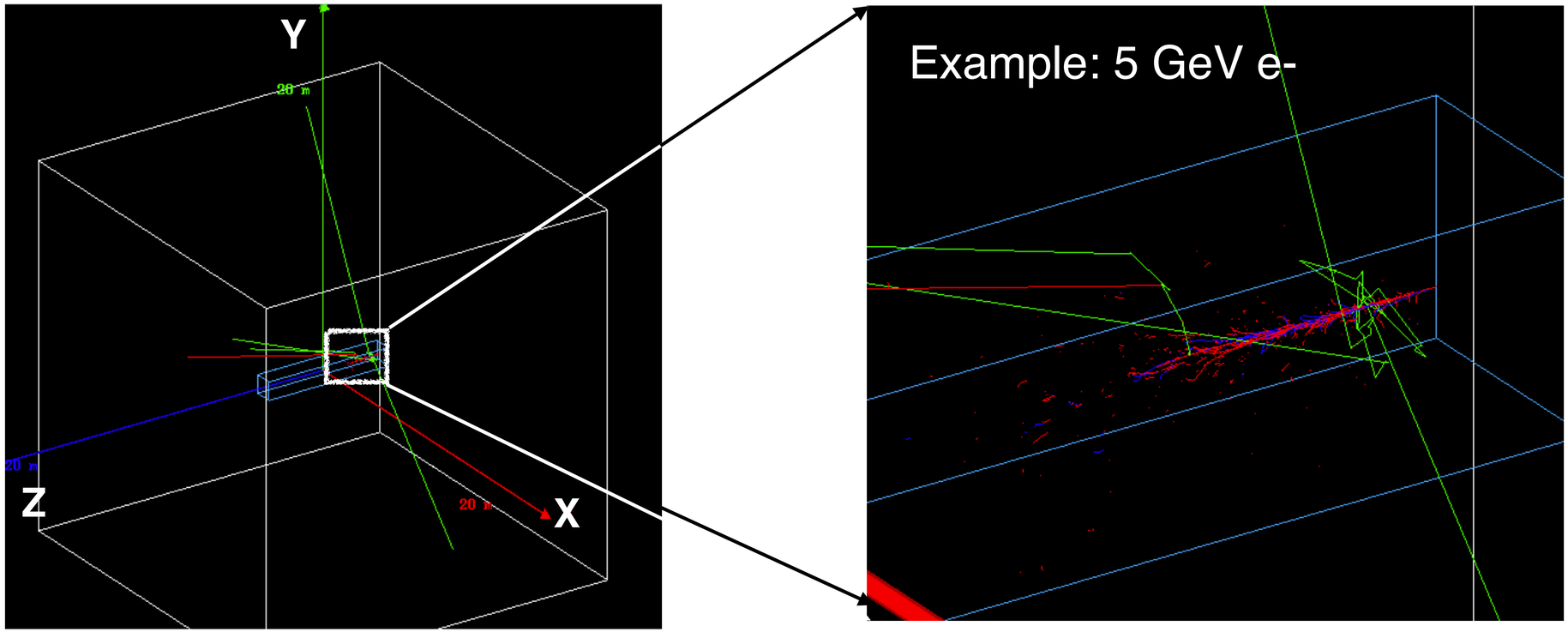
Introduction

- Liquid argon has excellent EM-shower and muon ID and could be a good candidate for the detector
  - LAr radiation length is 14 cm
  - LAr density is 1.4 g/cm^3
- Use Geant4 to simulation electron showers in a LAr detector to study EM shower acceptance
  - **Detector Size (cuboid)**: 1.5x1.5x7 or 1x1x7
  - **Electron energy in the simulation**: 200 MeV, 500 MeV, 1 GeV, 5 GeV, 10 GeV, 50 GeV, 100 GeV, 200 GeV, 300 GeV
  - Electron direction: (0, 0, 1). Currently no beam spread or angle smearing
  - **Vertex of electron is uniformly distributed along Z-axis** (0, 7000) mm
  - PhysicsList used in the simulation: FTFP_BERT
- Simulation of a liquid scintillator detector as a comparison
  - LS (LAB-based) radiation length is ~50 cm, density is 0.859 g/cm^3

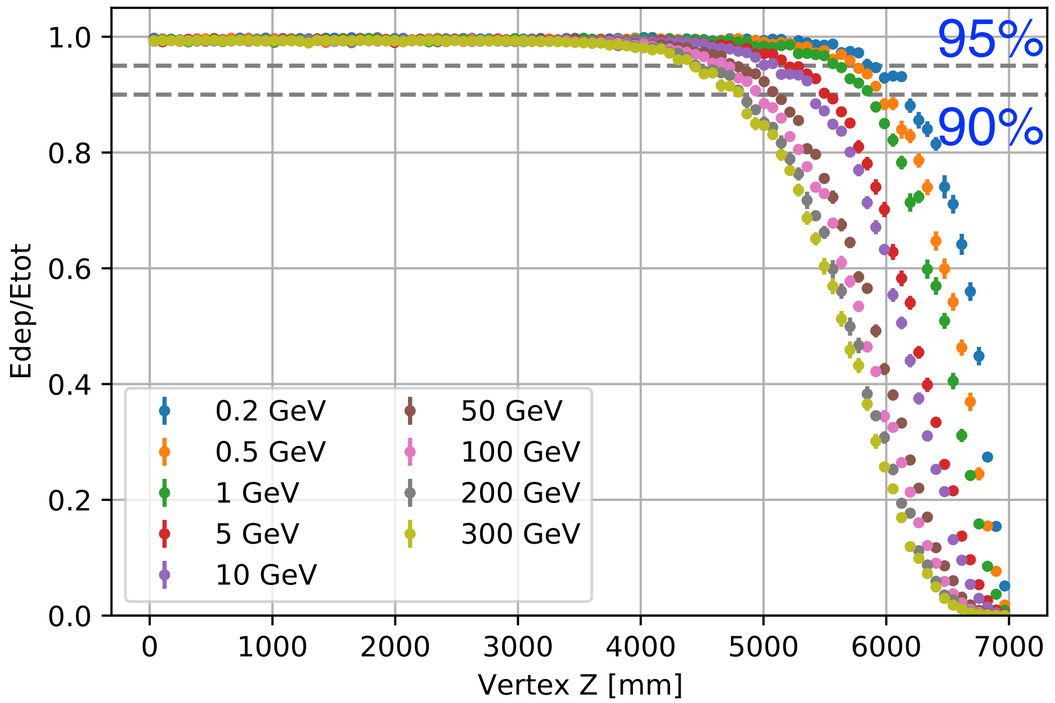
Detector Construction in Geant4

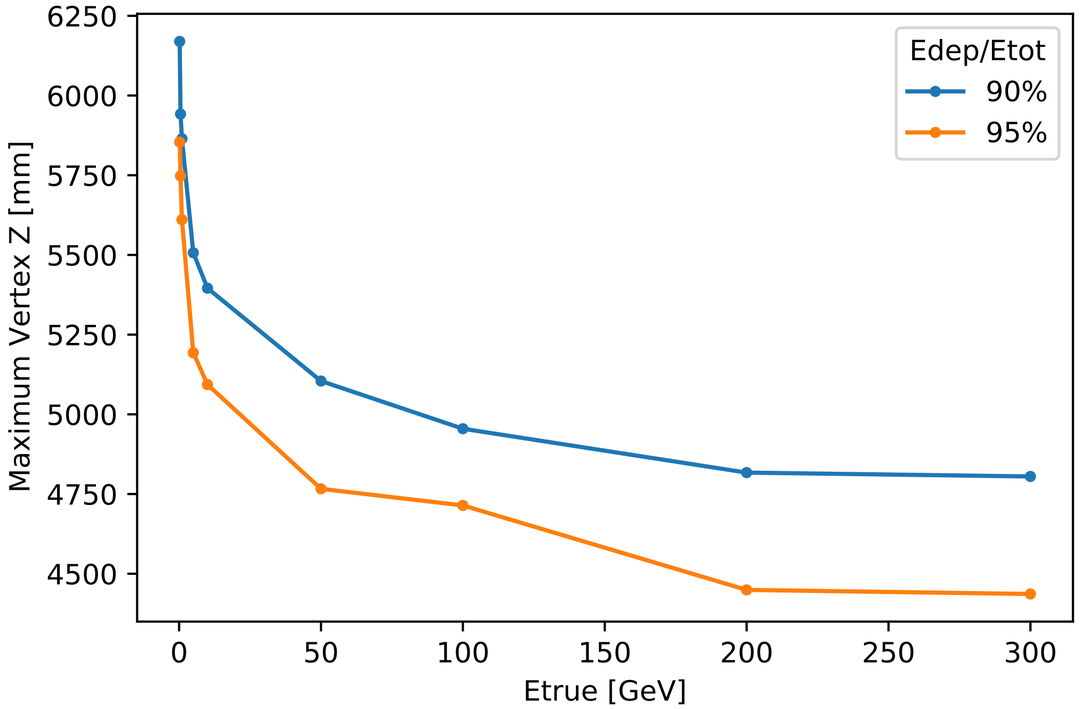
- A simple cuboid detector made up of LAr
  - Size: 1.5x1.5x7 and 1x1x7
  - Electron energy in the simulation: 200 MeV, 500 MeV, 1 GeV, 5 GeV, 10 GeV, 50 GeV, 100 GeV, 200 GeV, 300 GeV



Energy deposition

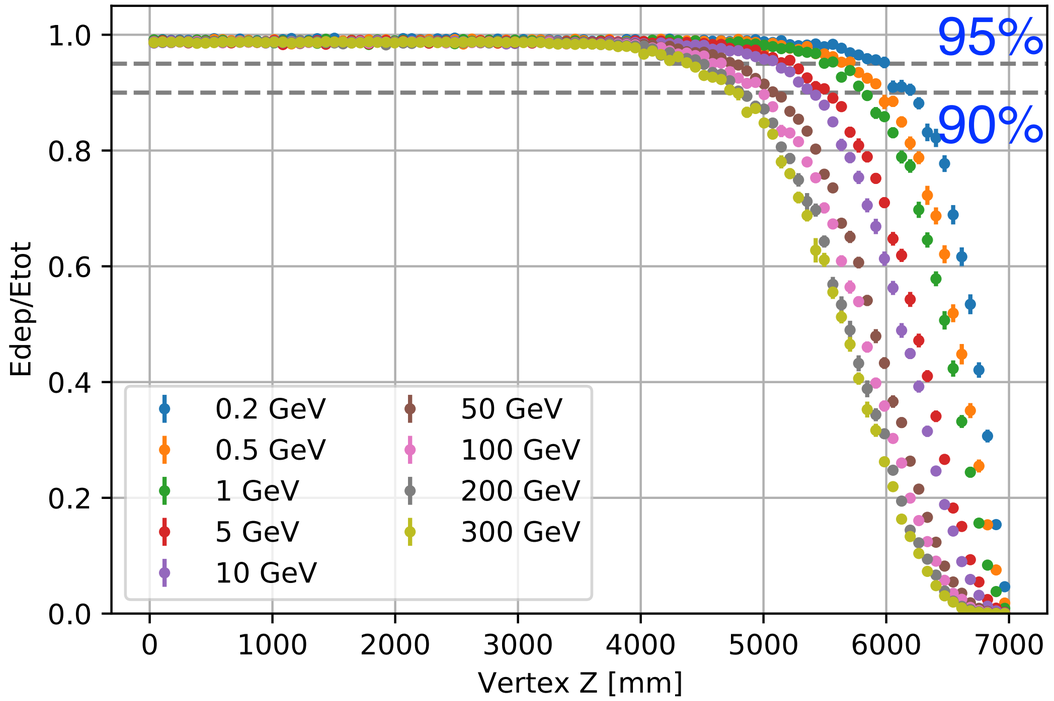
- Size configuration: 1.5x1.5x7 m
  - Left: The fraction of energy deposited inside the LAr region V.S. electron vertex Z
  - Right: Maximum vertex Z that can contain 90% (95%) of the energy V.S. true electron energy

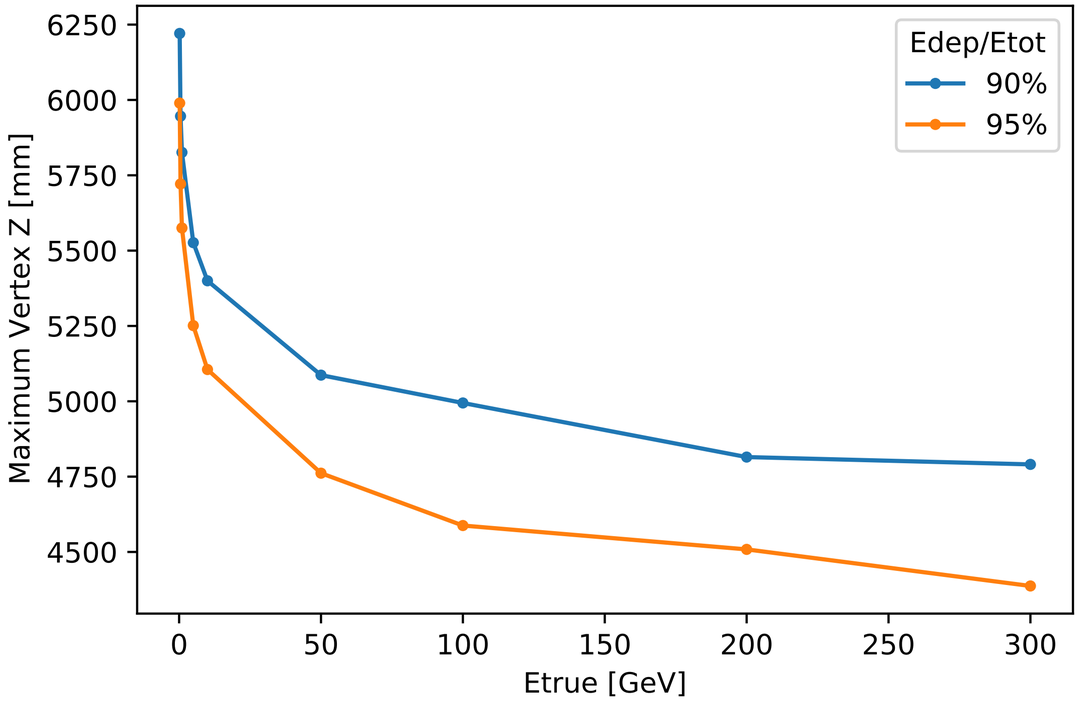




Energy deposition

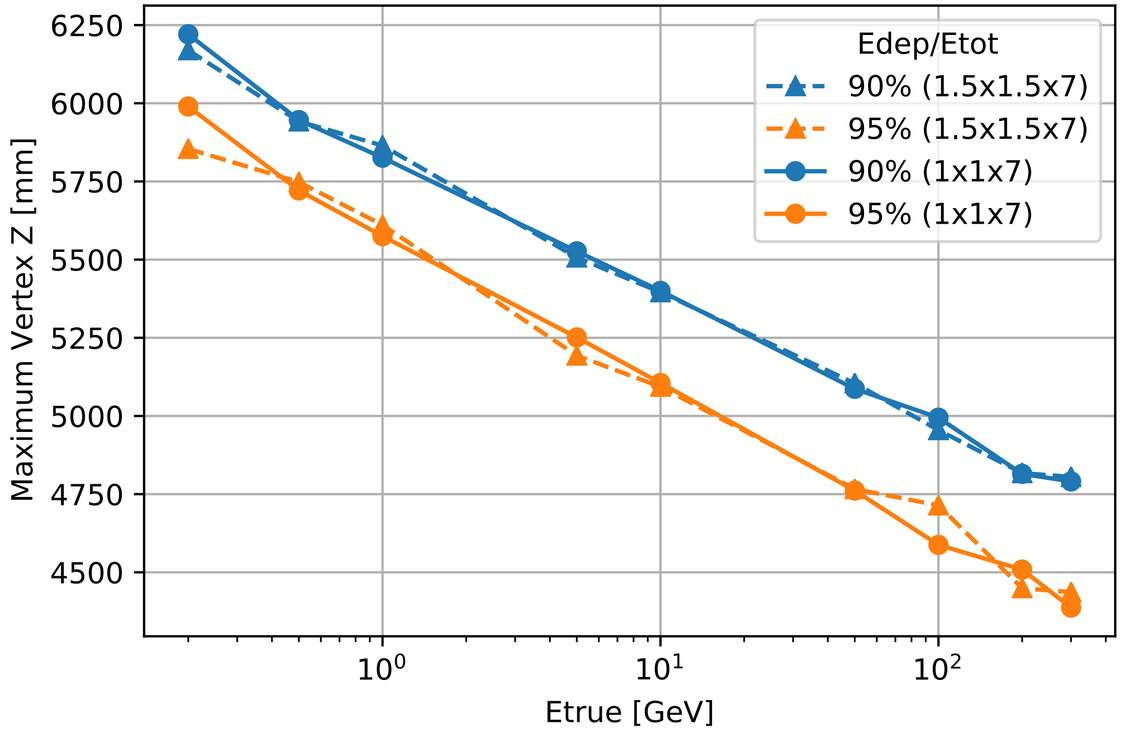
- Similar plot for the size configuration: 1x1x7 m
  - Left: The fraction of energy deposited inside the LAr region V.S. electron vertex Z
  - Right: Maximum vertex Z that can contain 90% (95%) of the energy V.S. true electron energy





90% and 95% energy containment

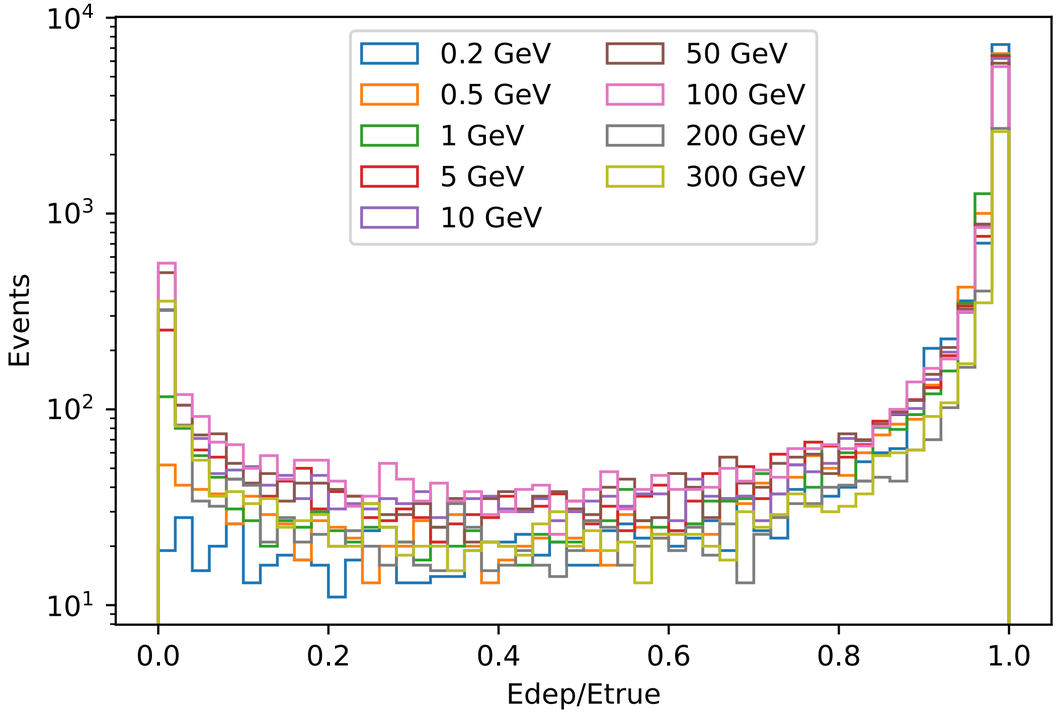
- Comparison of two size configurations
  - Two configurations have almost the same acceptance for EM shower up to 300 GeV
  - **300 GeV EM Shower with 95% E containment: z < 4.4 m, 90% E containment: z < 4.8 m**



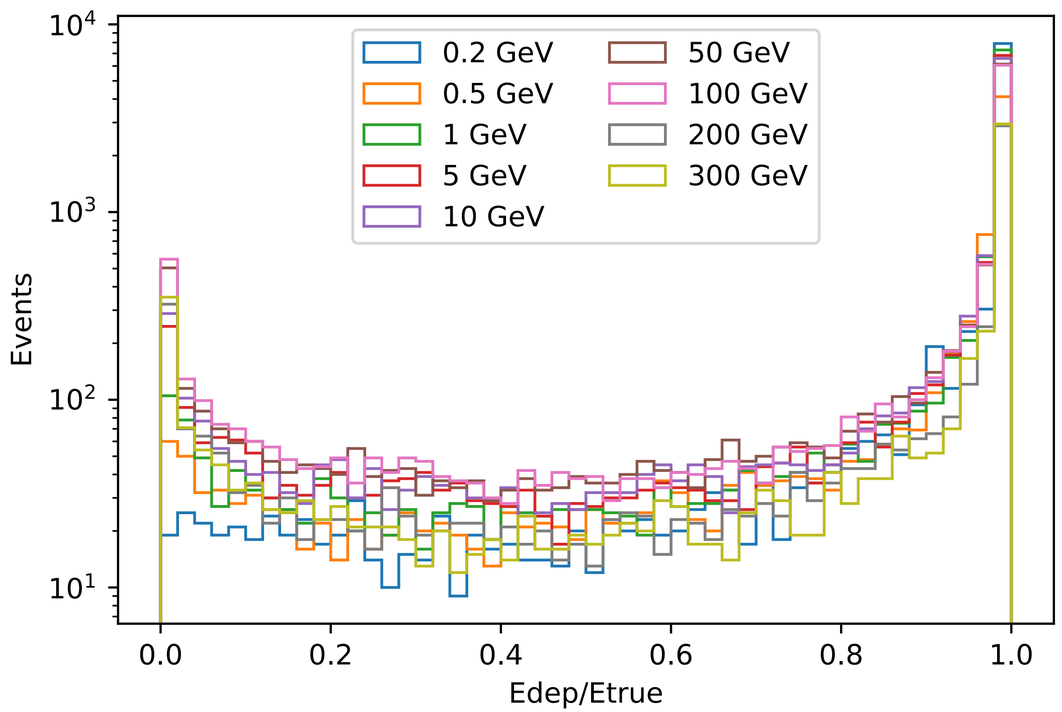
Fraction of Energy deposition

- The distribution of the fraction of deposited energy in the LAr at different energies

1x1x7

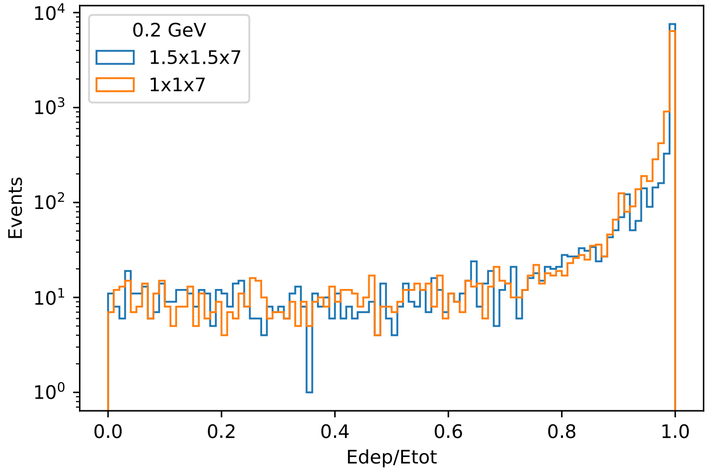


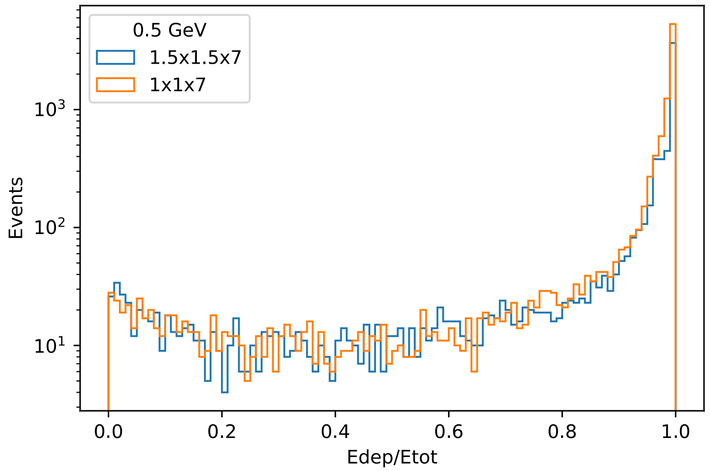
1.5x1.5x7

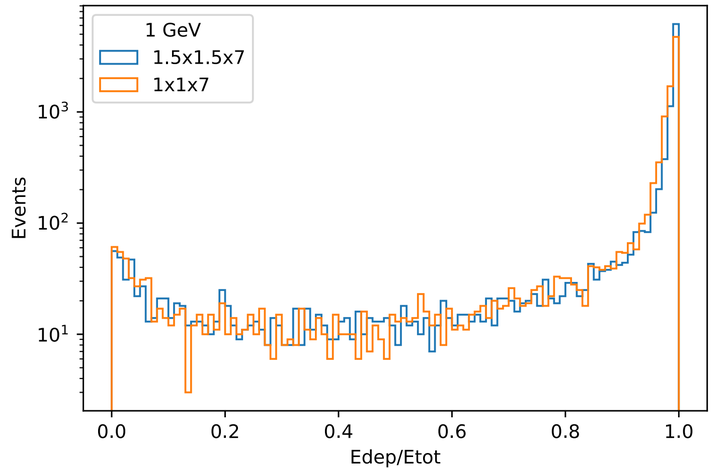


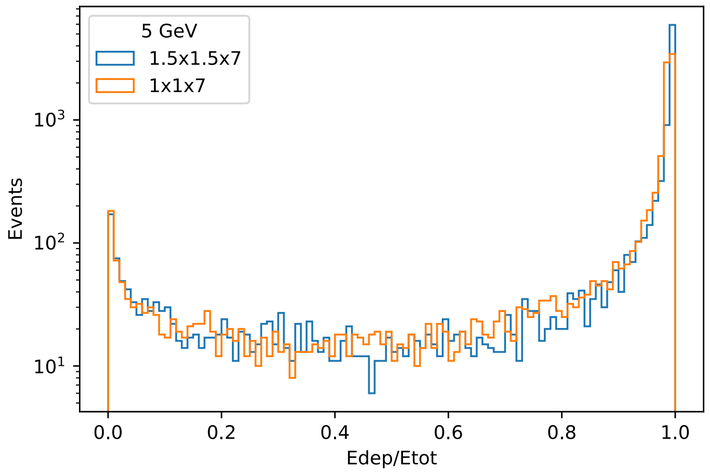
Fraction of Energy deposition

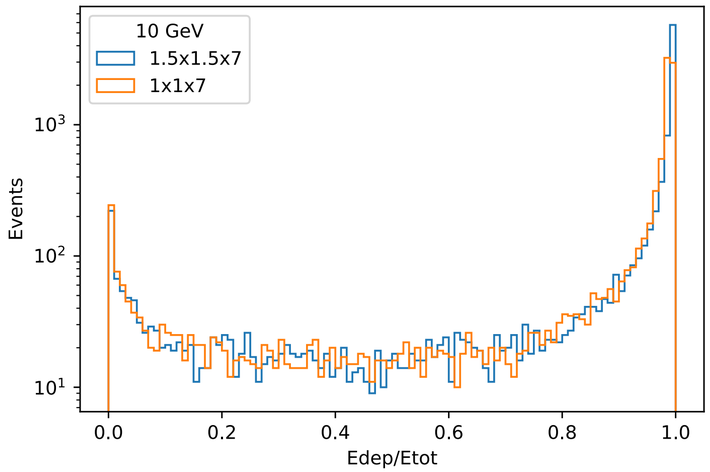
- Comparison of two size configurations at different energies





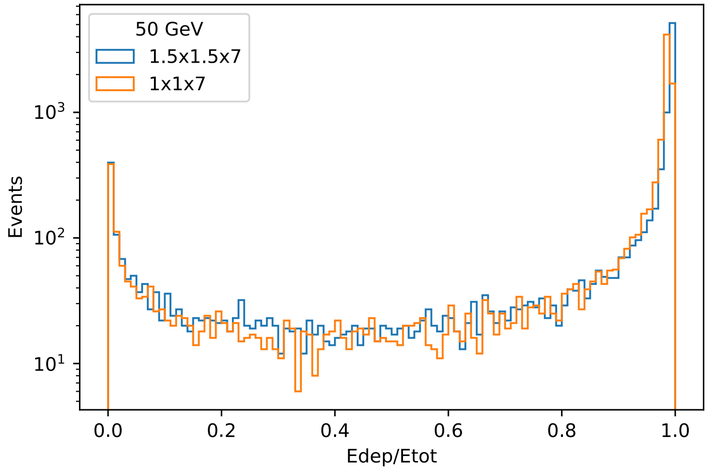


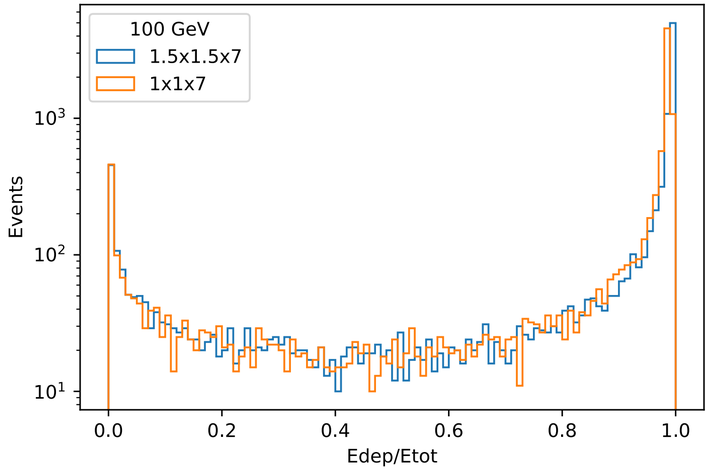


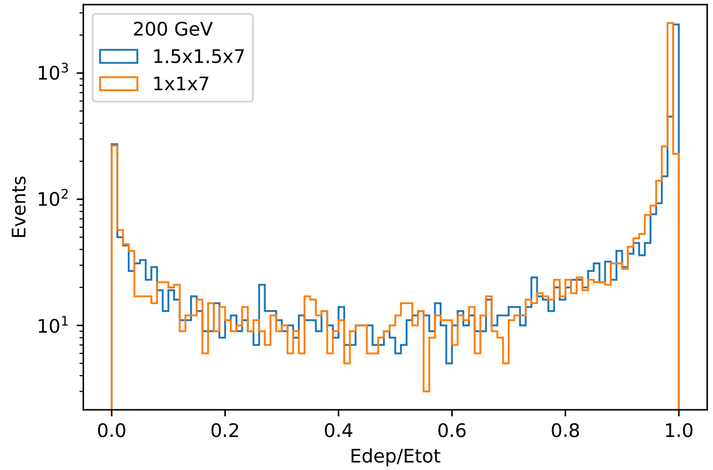


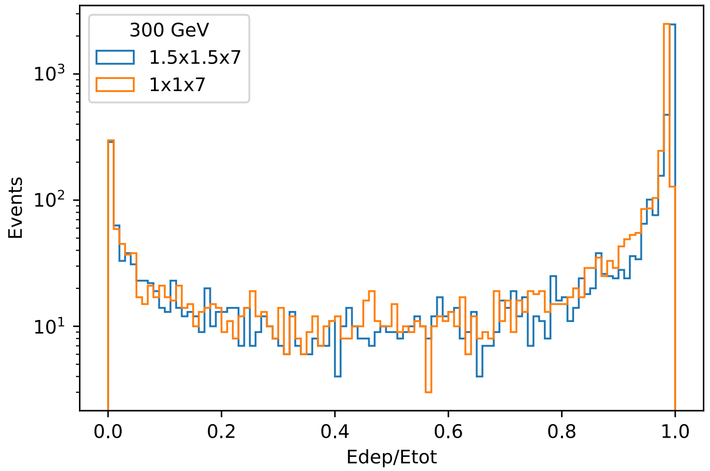
Fraction of Energy deposition

- Comparison of two size configurations at different energies



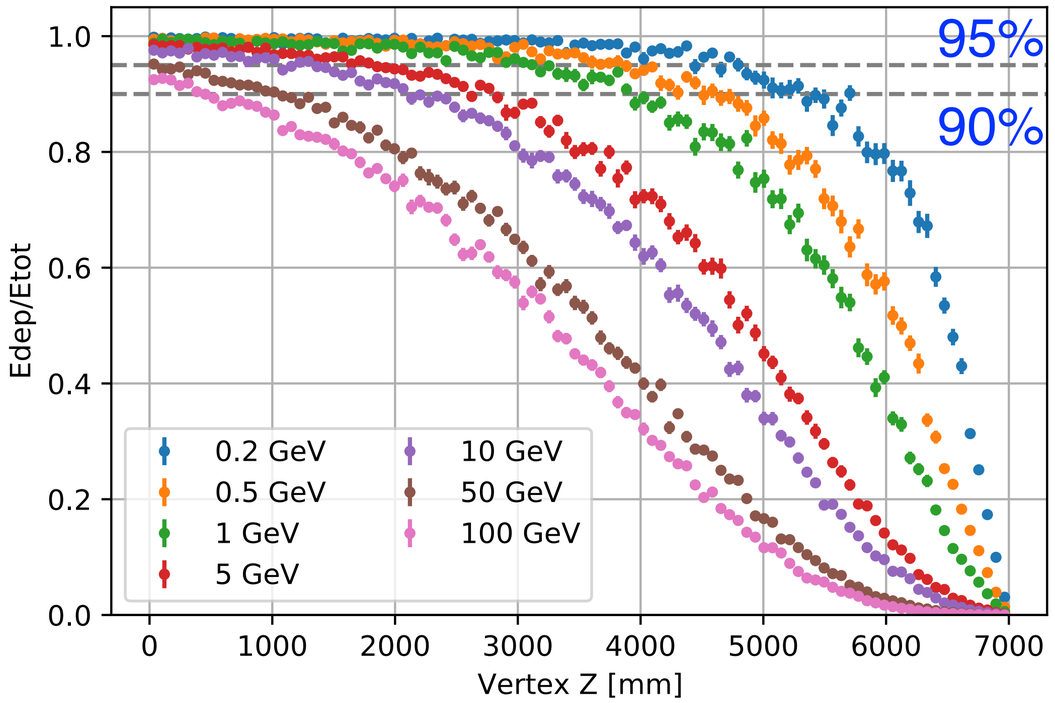


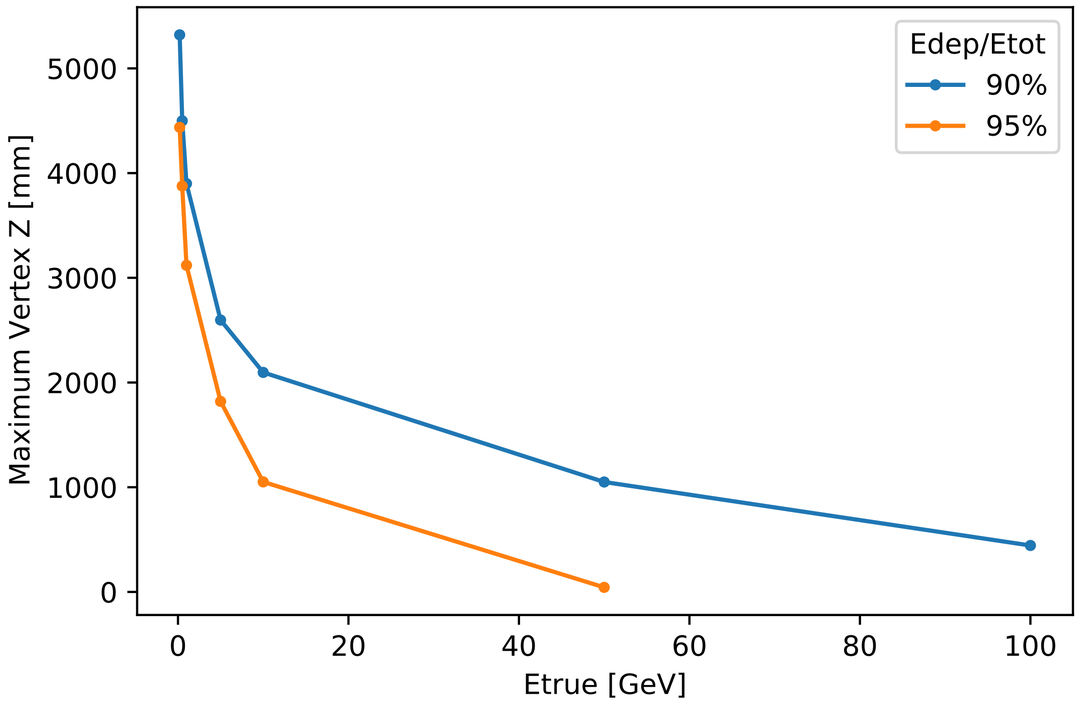




Energy deposition in Liquid Scintillator

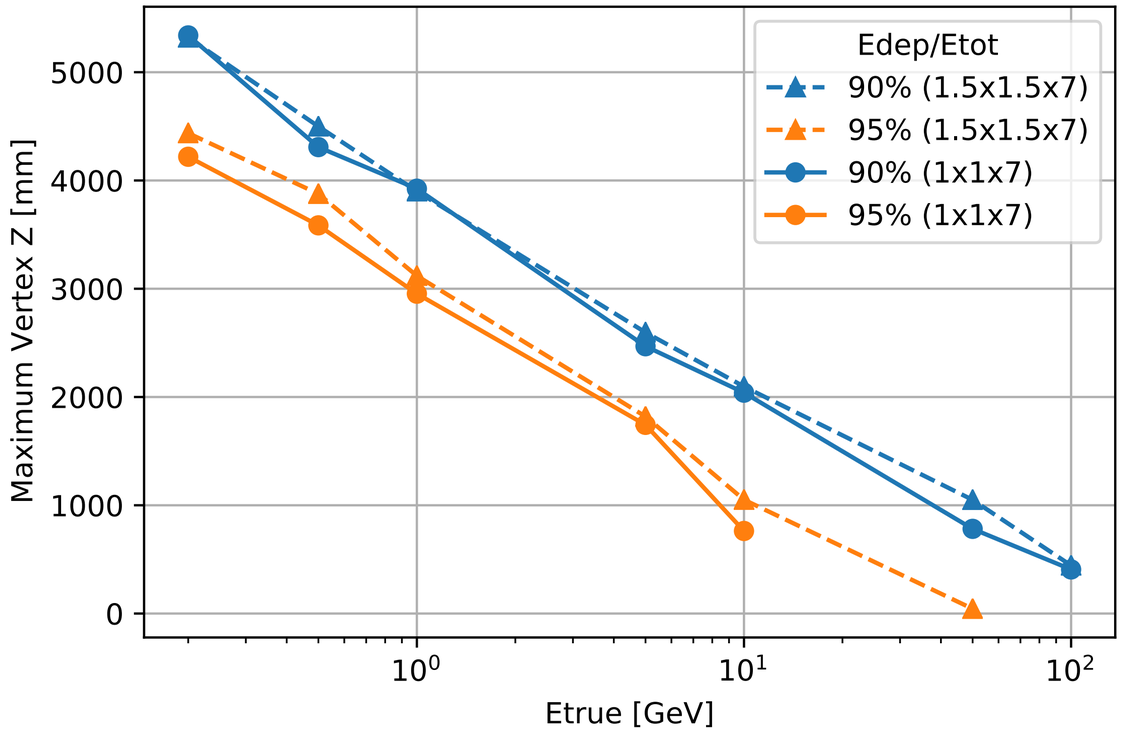
- Size configuration: 1.5x1.5x7 m
  - LS is hard to contain high energy (>100 GeV) EM shower





Energy deposition in Liquid Scintillator

- Comparison of two size configurations
  - 1.5x1.5x7 has slightly better acceptance than 1x1x7
  - **100 GeV EM Shower with 90% E containment: z < 0.44 m**



Fraction of Energy deposition

- The distribution of the fraction of deposited energy at different energies

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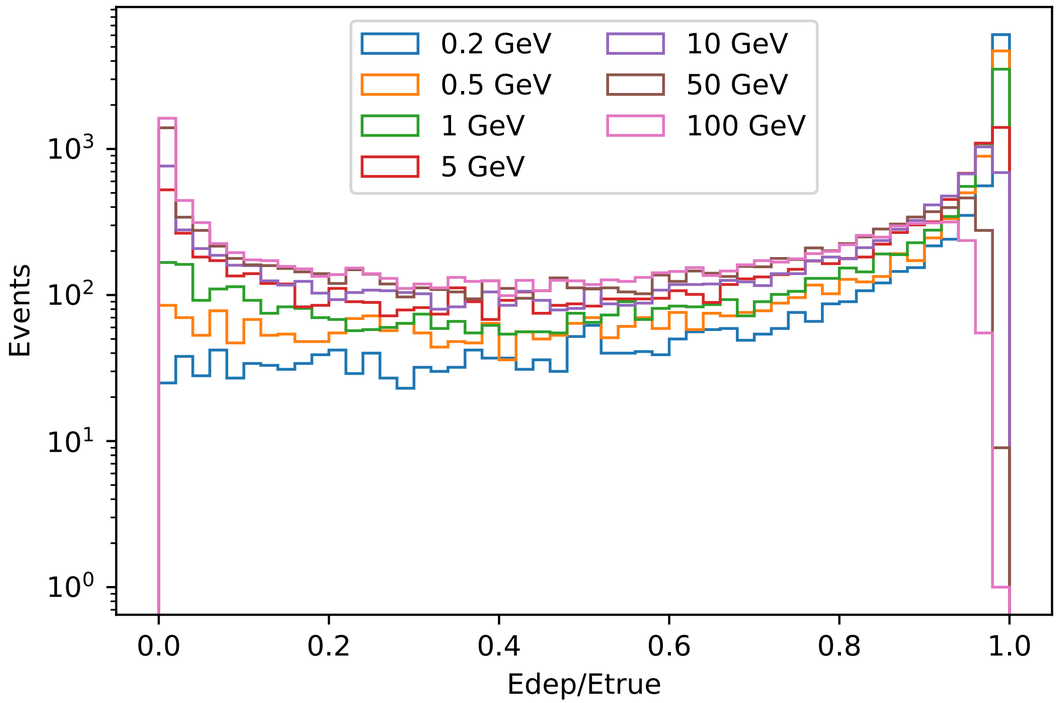
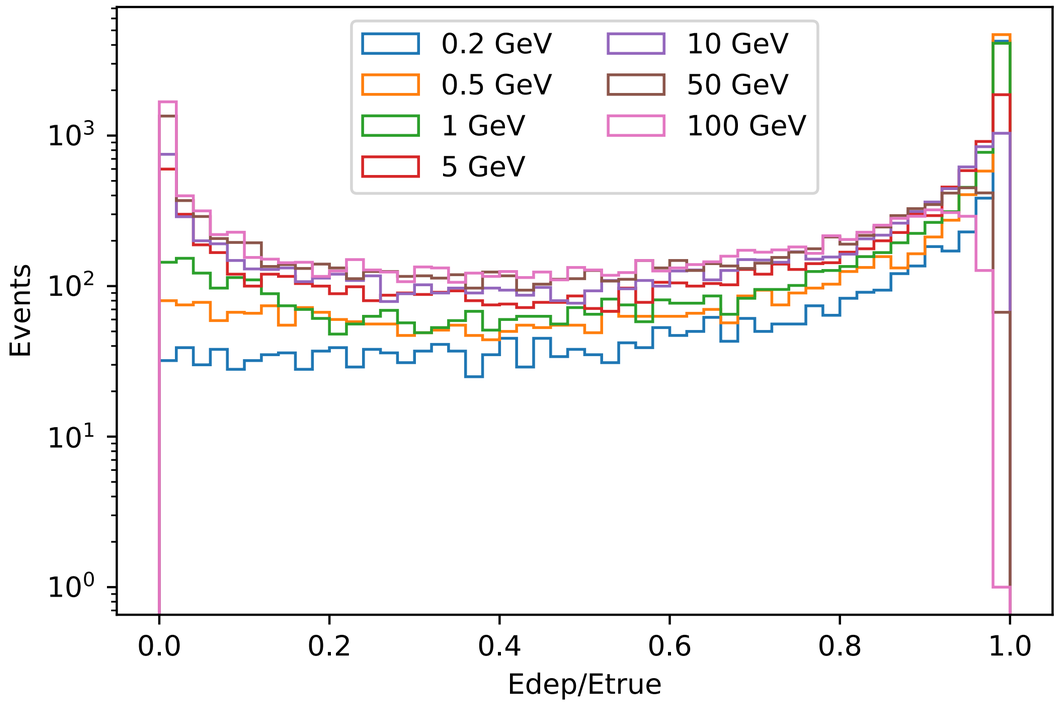


1.5x1.5x7



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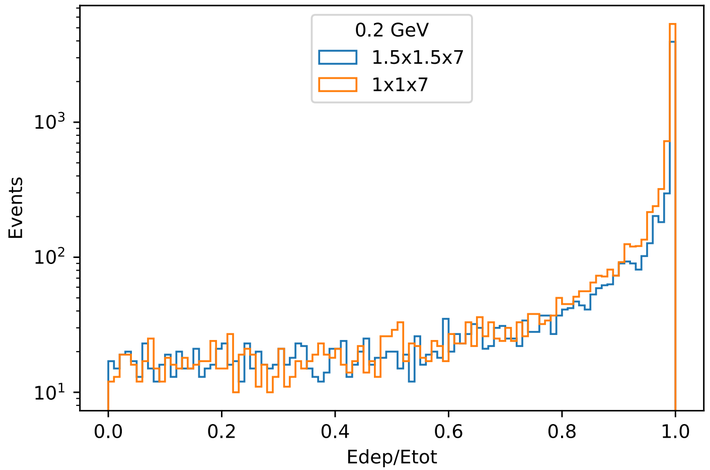

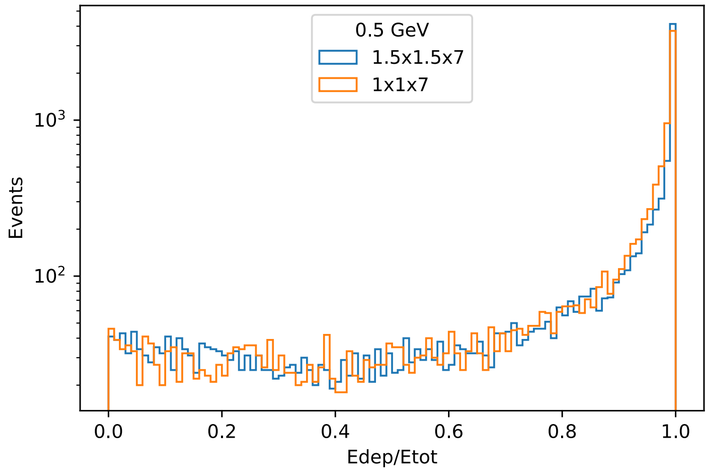

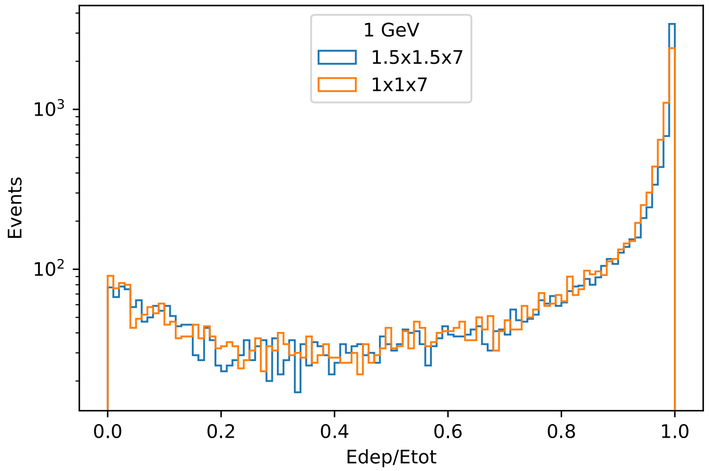

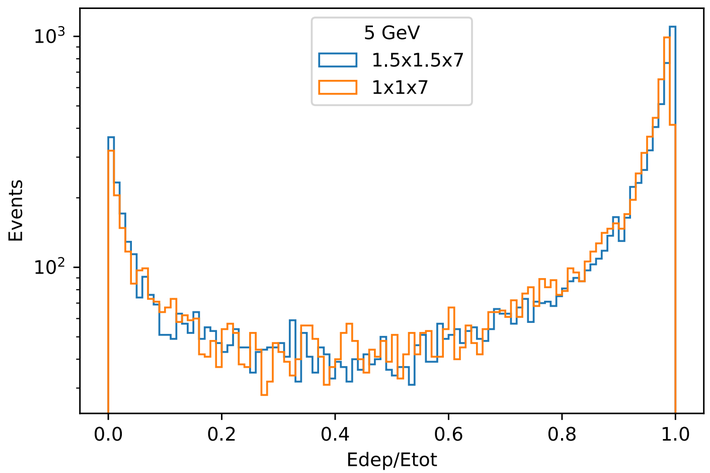

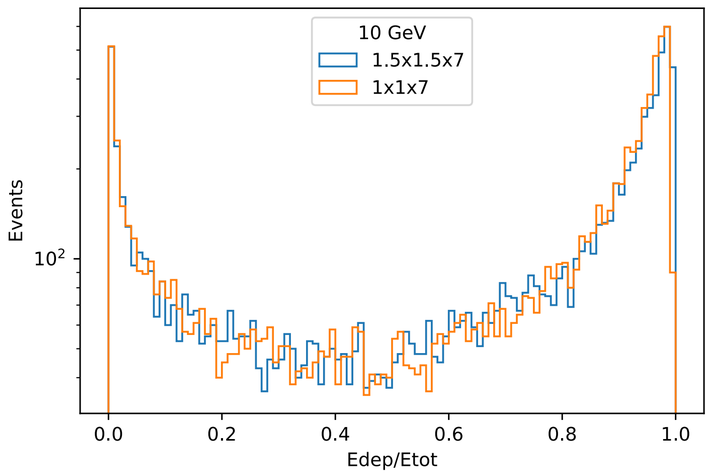

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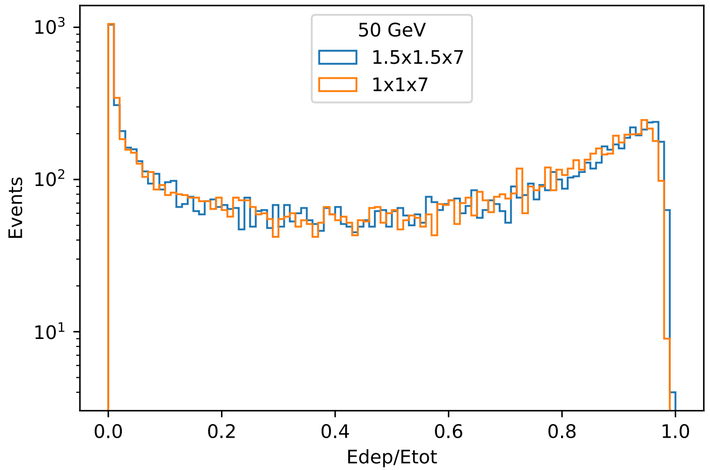

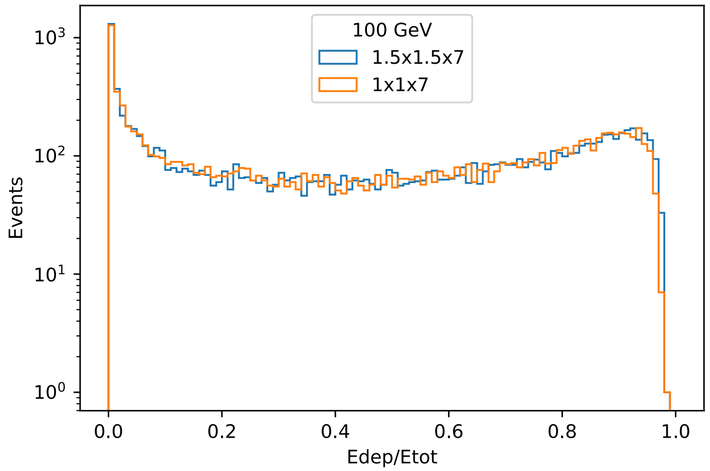

Summary

- LAr detector with the size of 1.5x1.5x7 (or 1x1x7) can effectively contain high energy EM shower
  - 300 GeV EM Shower with 95% E containment: $z < 4.4$ m, 90% E containment: $z < 4.8$ m
- This simulation only have electrons in the +Z direction, so we might need to consider more scenarios like beam spread and angle smearing in order to have a more comprehensive result