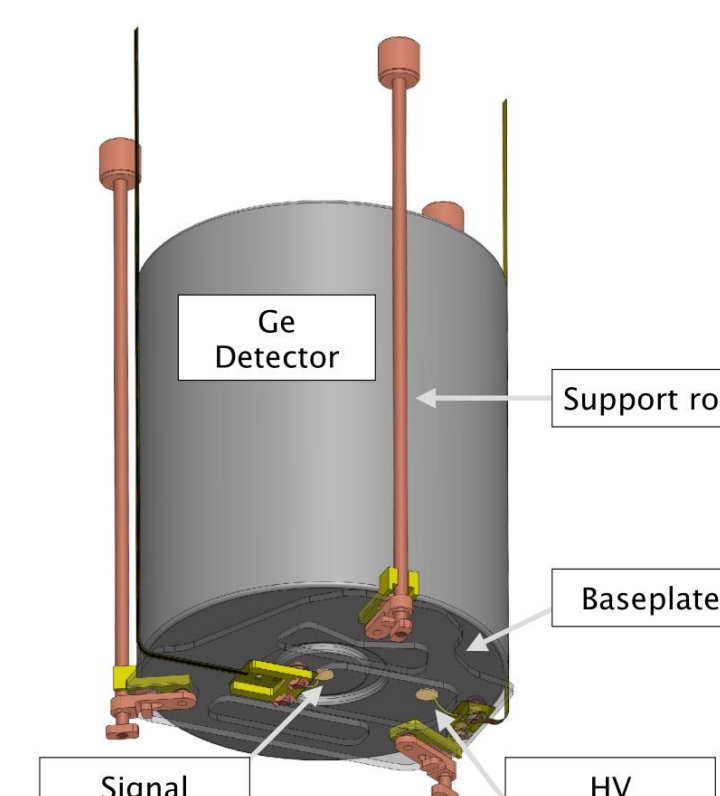
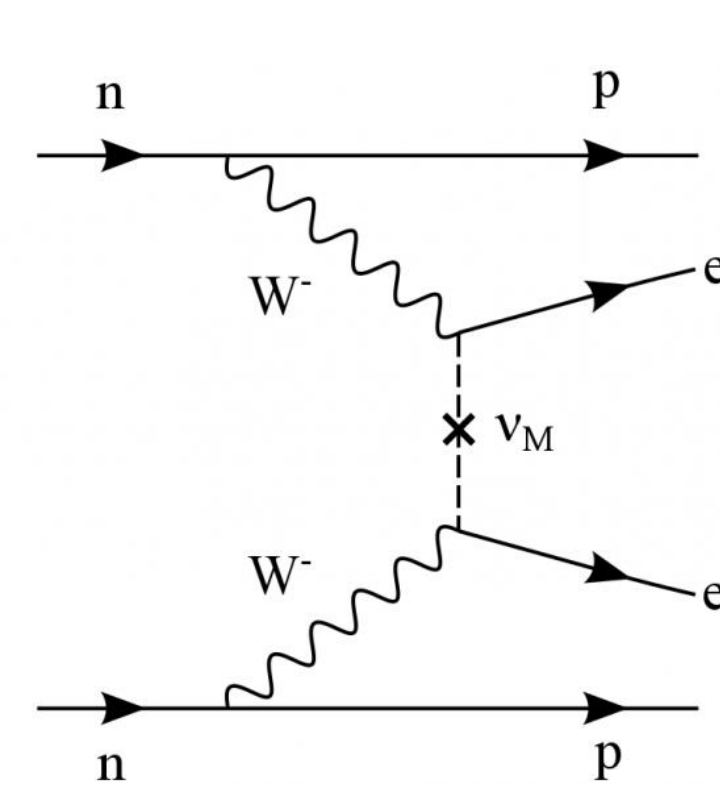


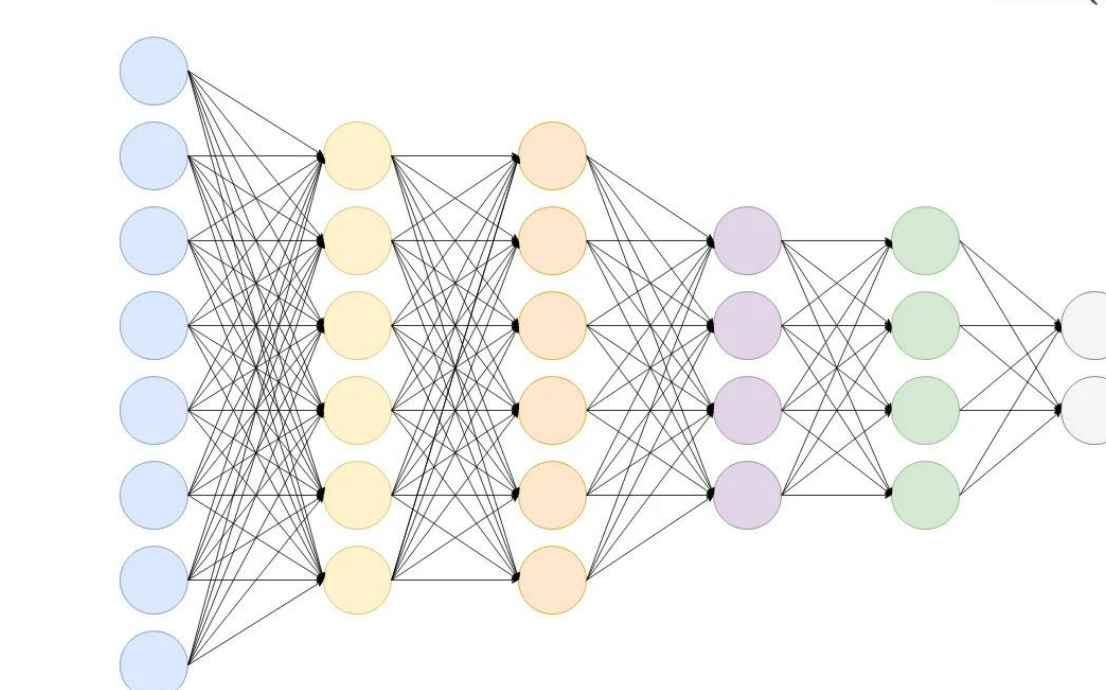
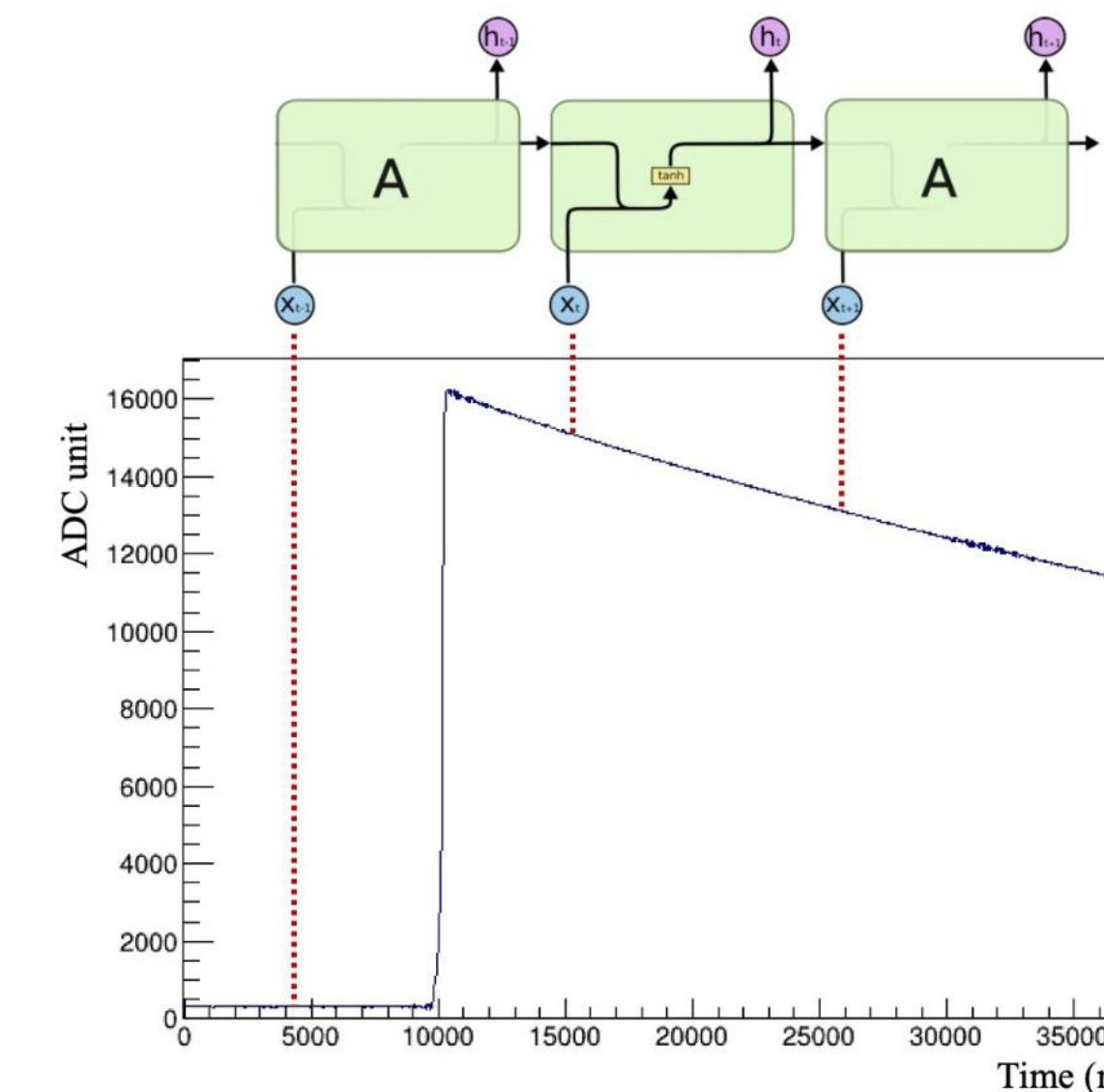
The LEGEND Experiment



- Neutrinoless Double-Beta Decay: $2n \rightarrow 2p + 2e^-$ ($0\nu\beta\beta$)
- Possible if the neutrino is its own antiparticle
- Direct observation of lepton number violation; could explain matter-antimatter asymmetry
- LEGEND: next generation $0\nu\beta\beta$ detector¹
- Uses High Purity Germanium (HPGe) detectors for high energy resolution; Ge-76 acts as $0\nu\beta\beta$ source
- Identifying backgrounds during initial 200-kg phase key to creating background model for 1000-kg phase

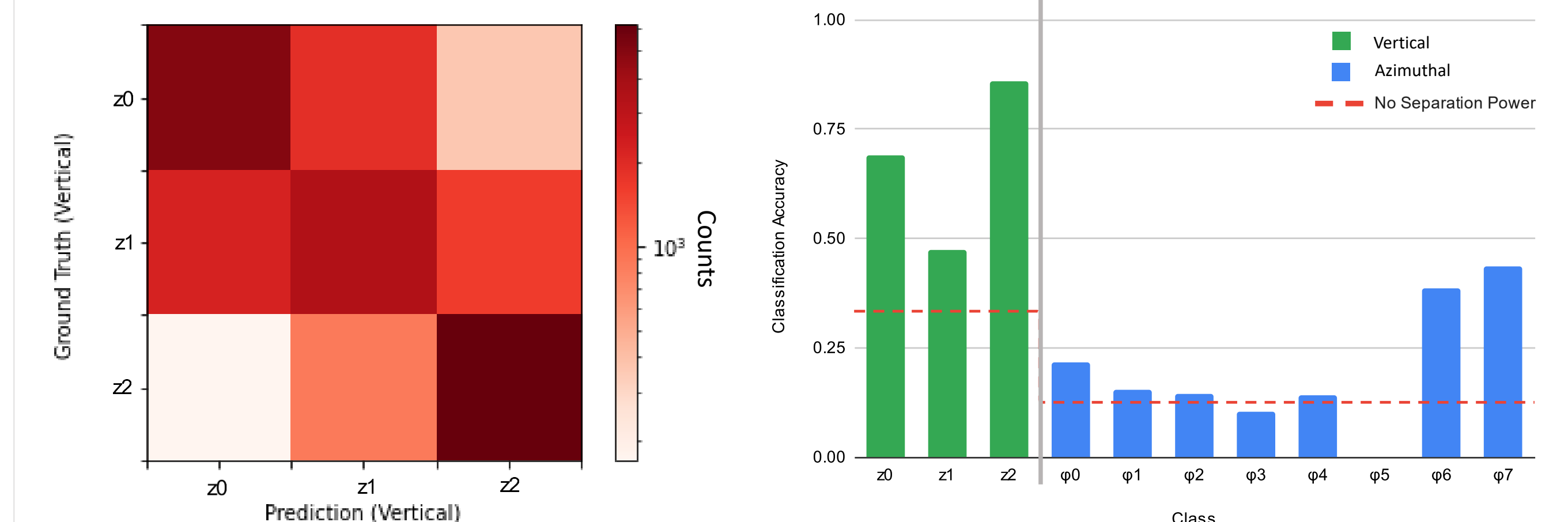
Neural Networks

- Recurrent neural networks: specialized for time series data such as waveforms³
- Information retained from sequential inputs
- Network implemented using Pytorch library in Python
- Adapted from Aobo Li's NetworkPSA model
- Recurrent layer feeds into fully connected network
- Classifies each waveform into vertical and azimuthal position classes



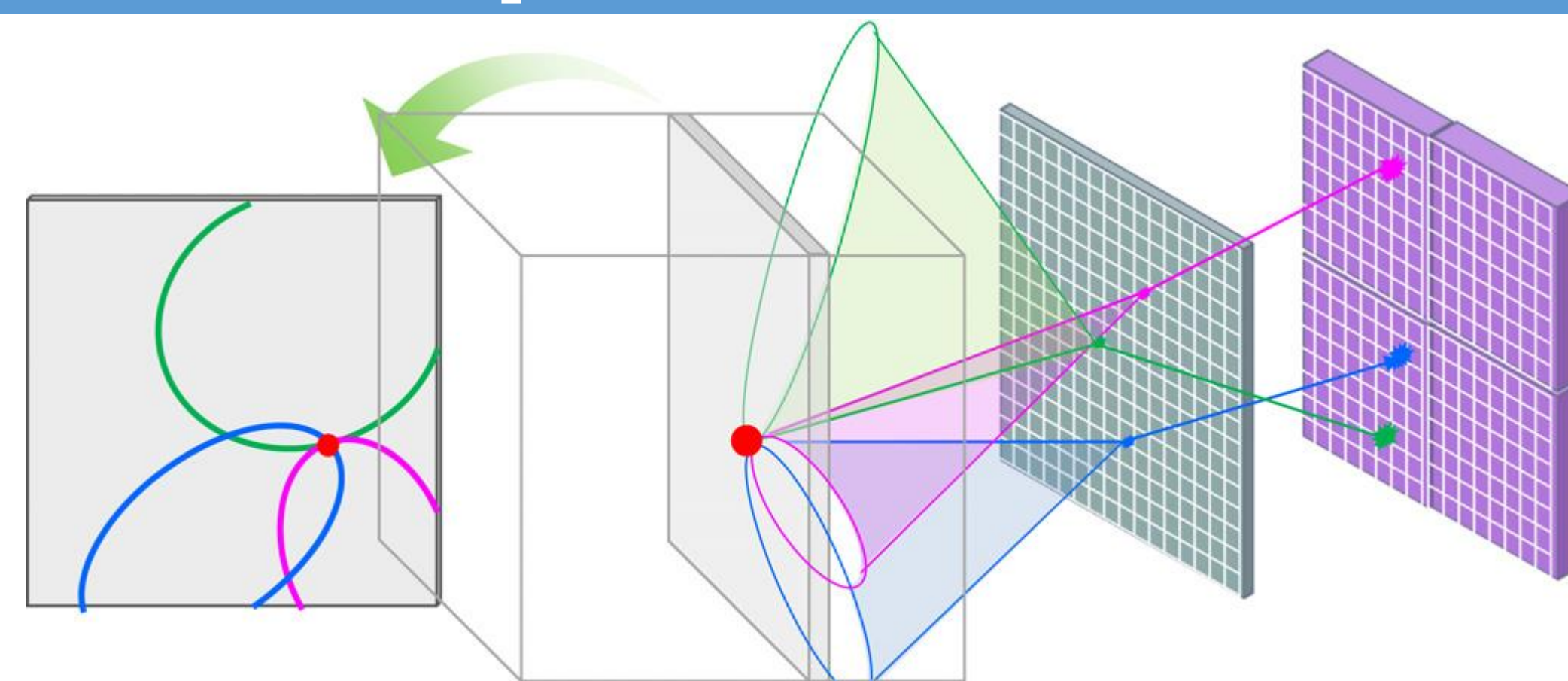
Diagrams of Recurrent Neural Network (top) and Fully Connected Network (bottom)

Results



- Significant separation power for both vertical and azimuthal classes was found
- 70% average classification accuracy for vertical position classes indicates significant separation power
- Best at classifying top (z0) and bottom (z2) positions, worse for middle (z1) position
- Network had preference for two azimuthal classes; may indicate that detector was off-center in cryostat

Compton Cameras



Soo Mee Kim et al. DOI: 10.1088/0031-9155/58/9/2823

- Compton scattering: elastic collision between photon + charged particle → scattering angle related to magnitude of energy loss²
- Compton camera technique measures scattered photons to determine location of gamma source
- My Project: train neural network to reconstruct source position from waveforms to improve potential HPGe detector Compton camera setups for LEGEND

Data Collection



- Co-60 source; two gamma peaks at 1172 & 1330 keV used for study
- Source holder was designed to aim source at detector from different angles
- Detector cooled w/ liquid nitrogen, biased to +4000 V
- Data collected at 3 vertical positions, 8 azimuthal positions

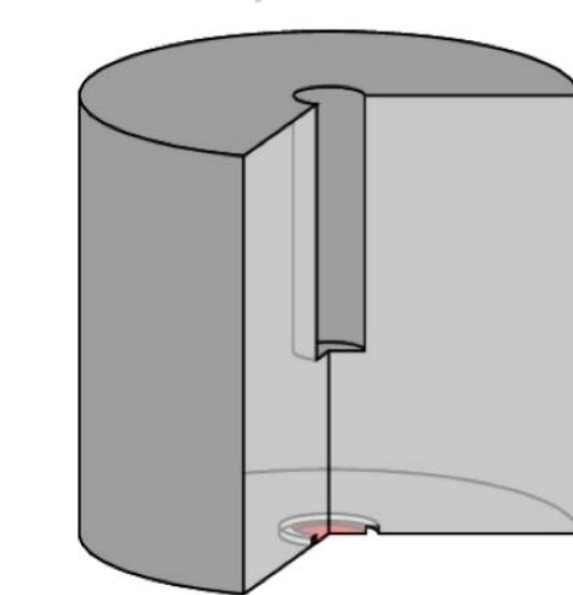
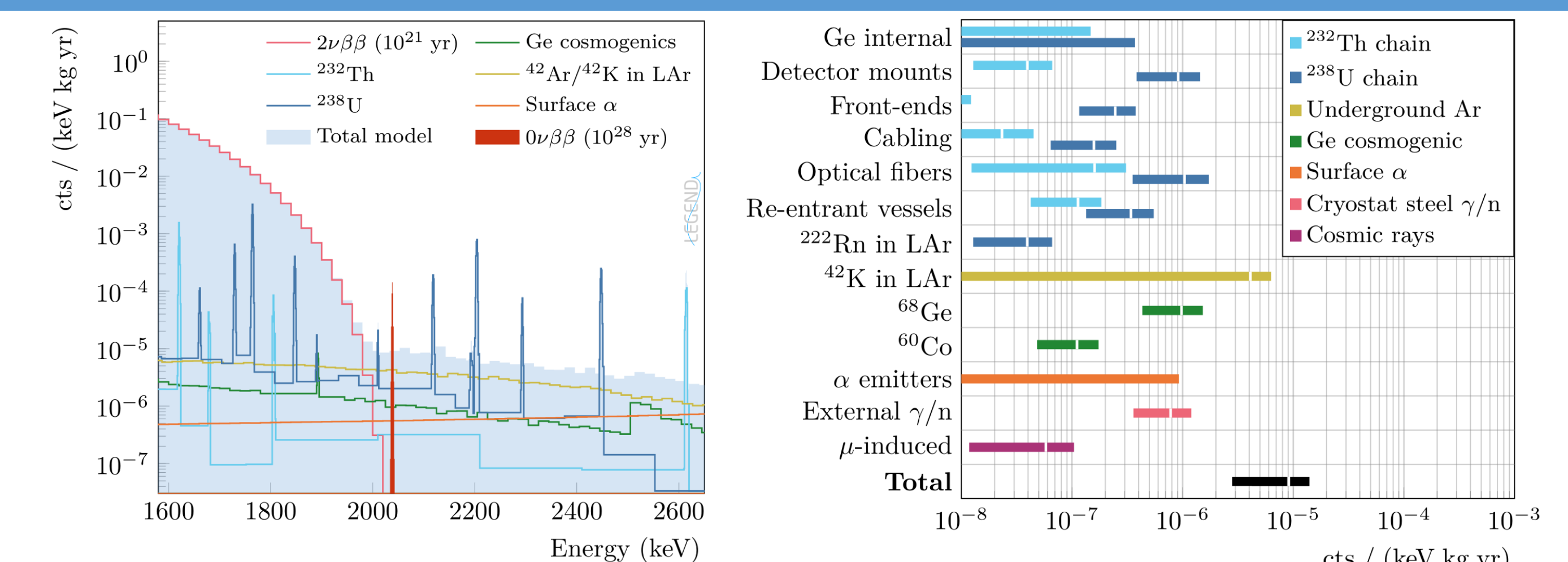


Diagram of a Germanium Detector

Future Work



- Explanation of azimuthal classification anomaly
- Simulations of gamma interactions with the detector could inform interpretation of result
- LEGEND-200 background identification
- Test network performance on low energy events
- Investigate backgrounds, with Compton camera technique, including liquid Ar scatter information

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3. I. Goodfellow, Y. Bengio, and A. Courville, *Deep learning*, <http://www.deeplearningbook.org> (MIT Press, 2016).

Additional Image Credits: Aobo Li

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