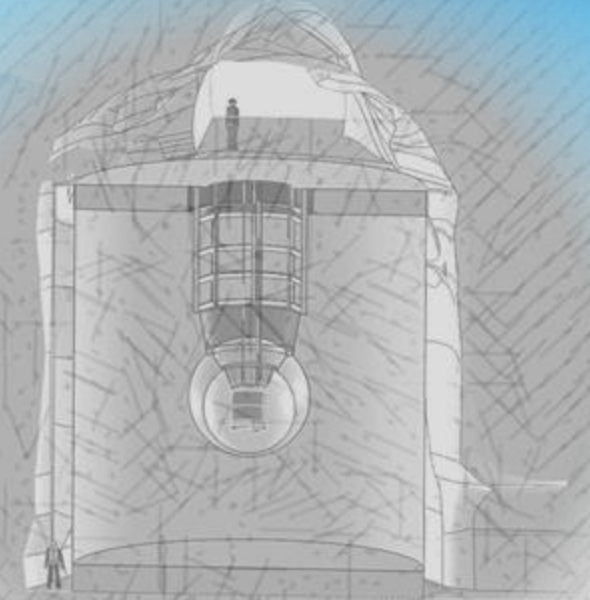




# Yale nEXO group update

David Moore

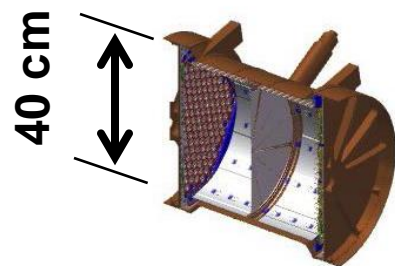
March 3, 2025



# Overview

- Our group is developing liquid Xe TPCs to search for the neutrinoless double beta decay of  $^{136}\text{Xe}$

## EXO-200

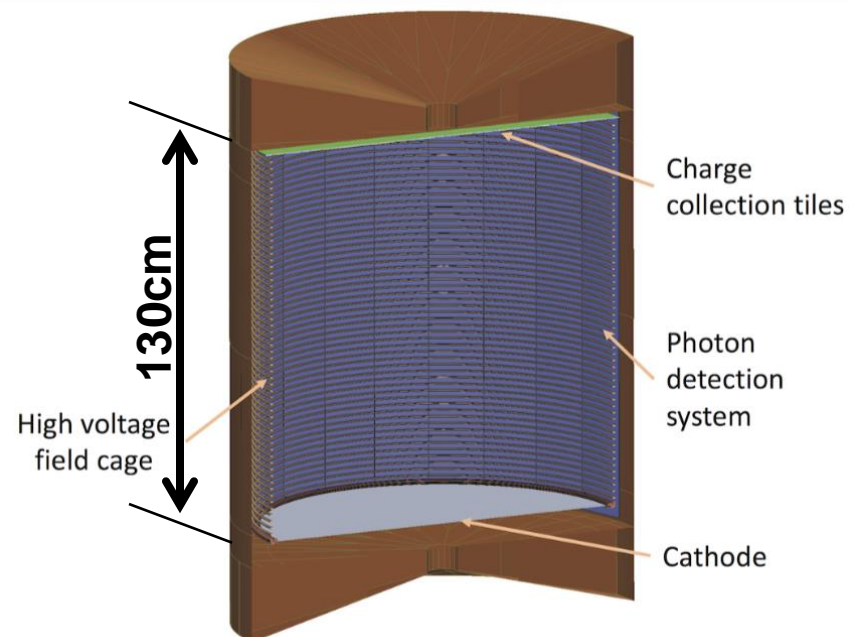


**~150 kg  $^{136}\text{Xe}$**

2011 - 2018

$T_{1/2} = 0.5 \times 10^{26}$  yr

## nEXO

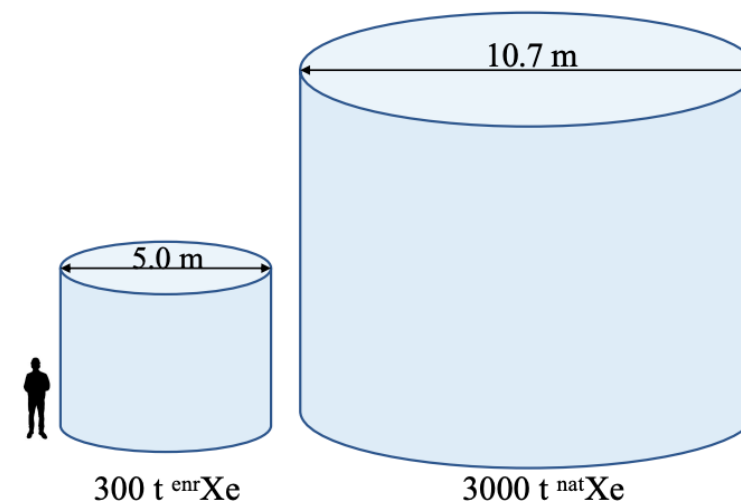


**~5000 kg  $^{136}\text{Xe}$**

Operation in ~2030 (?)

$T_{1/2} = 1.4 \times 10^{28}$  yr

## Future kton scale detector (?)



**~300 t  $^{136}\text{Xe}$**

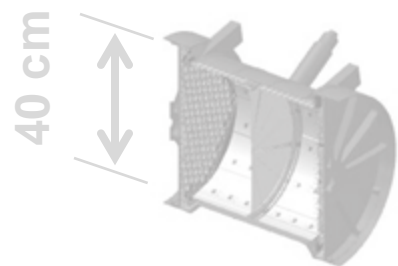
Operation in ?

$T_{1/2} = 10^{30}$  yr

# Overview

- Our group is developing liquid Xe TPCs to search for the neutrinoless double beta decay of  $^{136}\text{Xe}$

## EXO-200

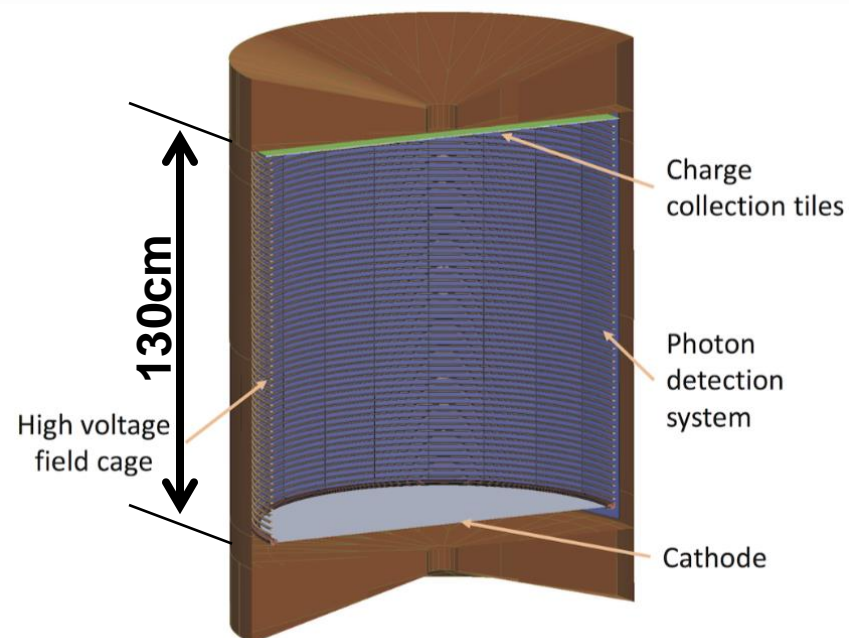


~150 kg  $^{136}\text{Xe}$

2011 - 2018

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## nEXO

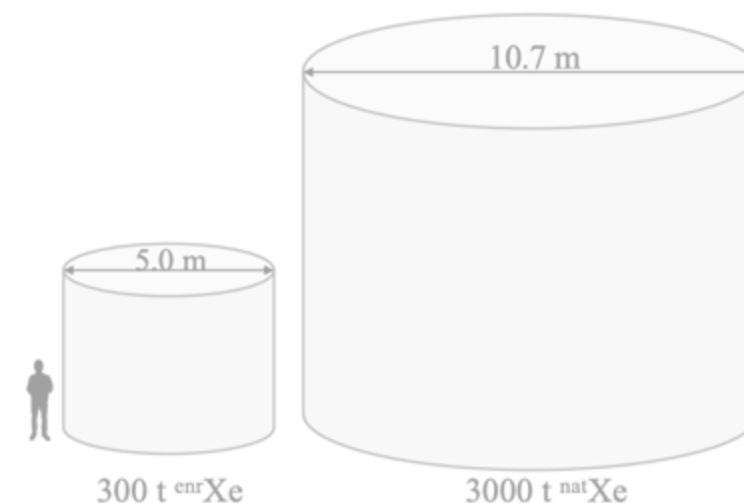


~5000 kg  $^{136}\text{Xe}$

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## Future kton scale detector (?)



~300 t  $^{136}\text{Xe}$

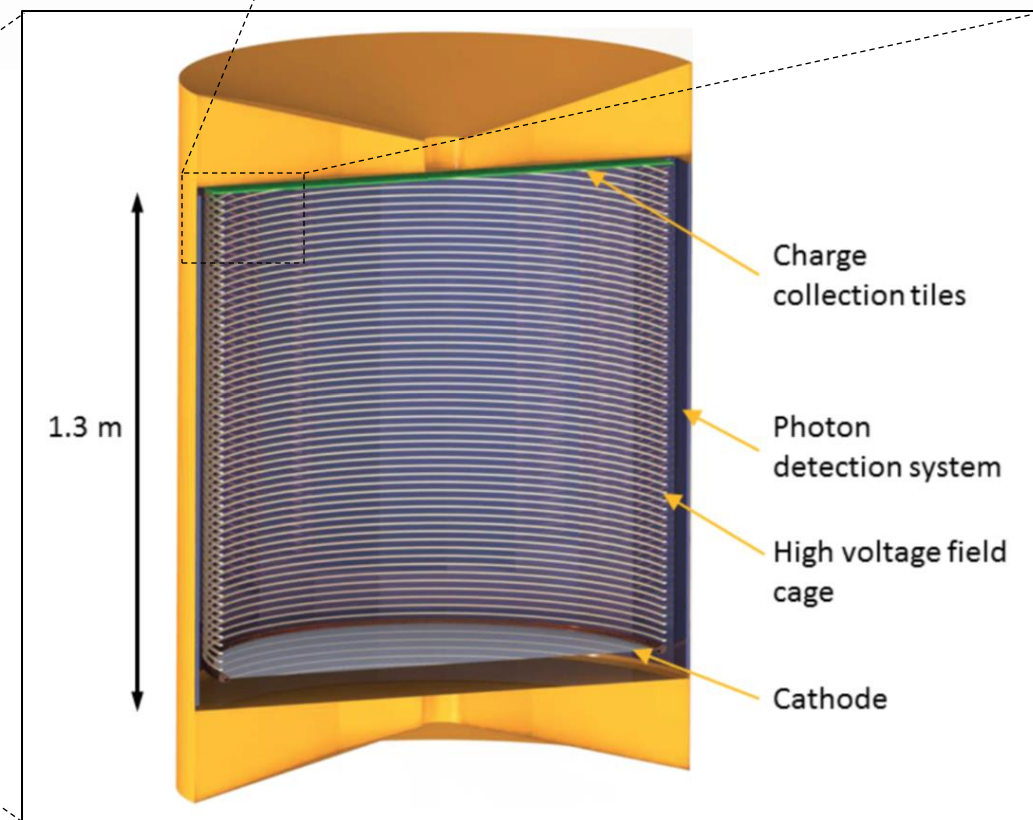
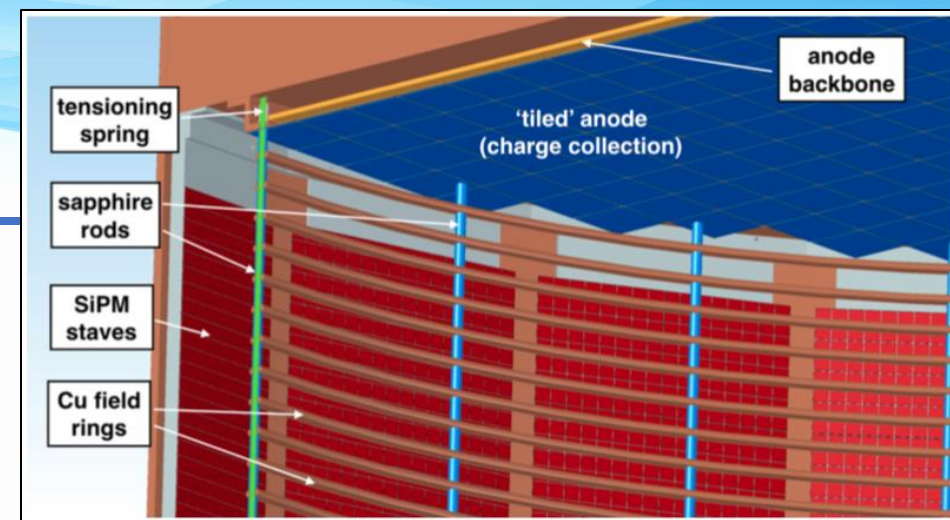
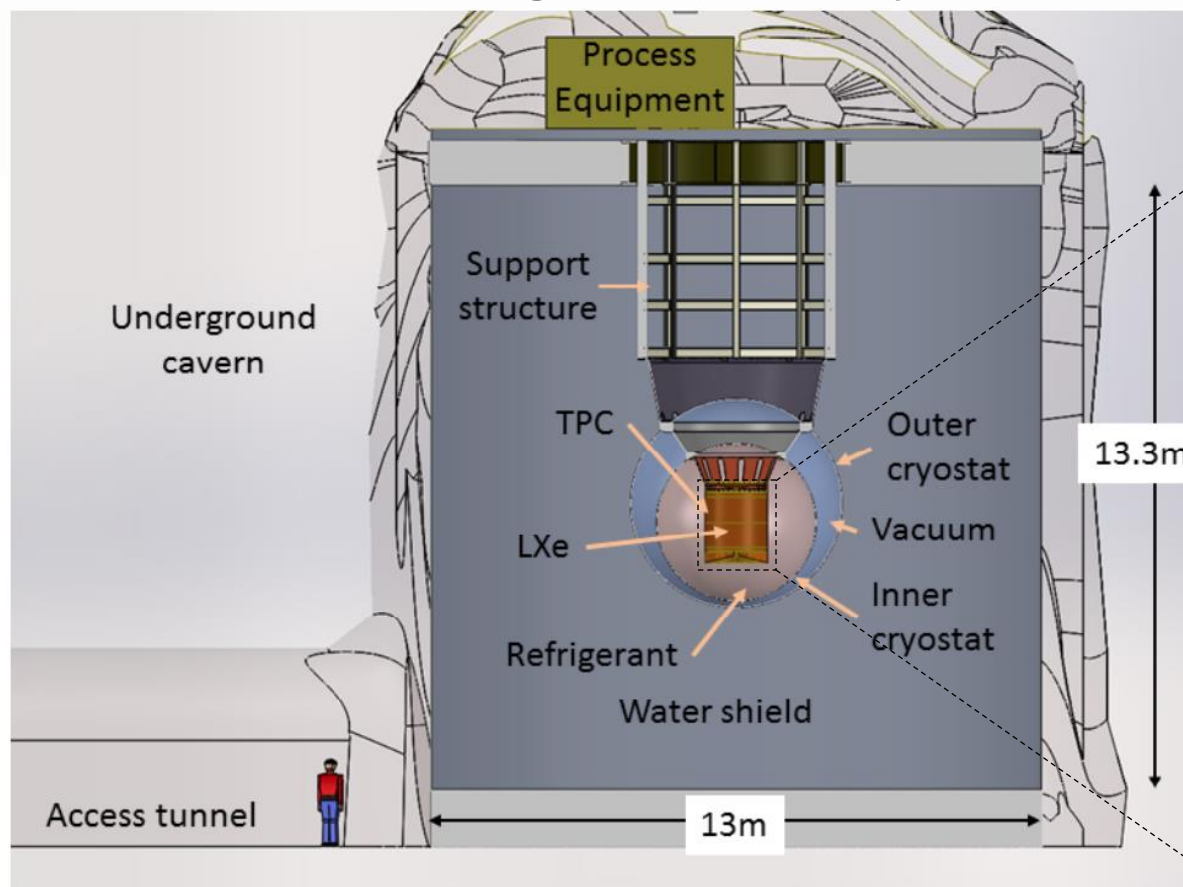
Operation in ?

$T_{1/2} = 10^{30}$  yr

# nEXO Concept

- nEXO provides a multi-ton scale extension of the single-phase LXe TPC technology demonstrated for  $0\nu\beta\beta$  in EXO-200

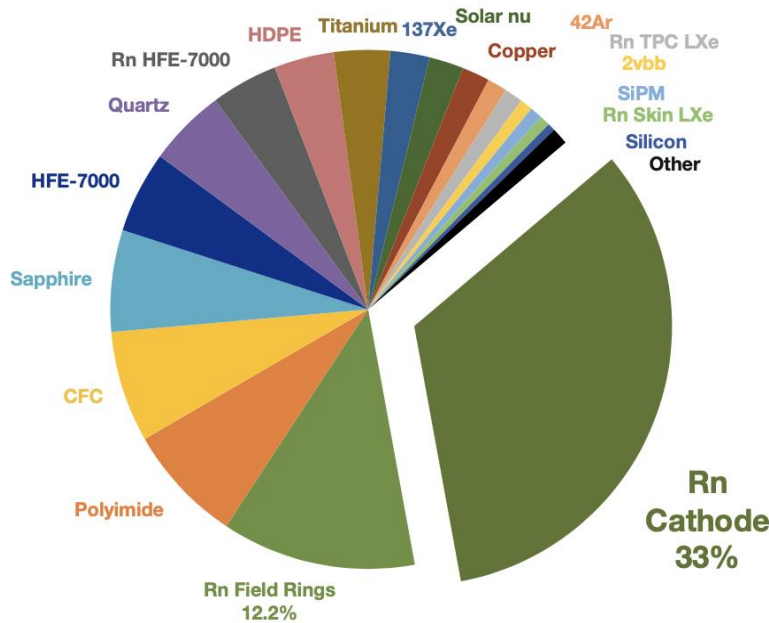
## Conceptual design in SNOlab Cryopit:



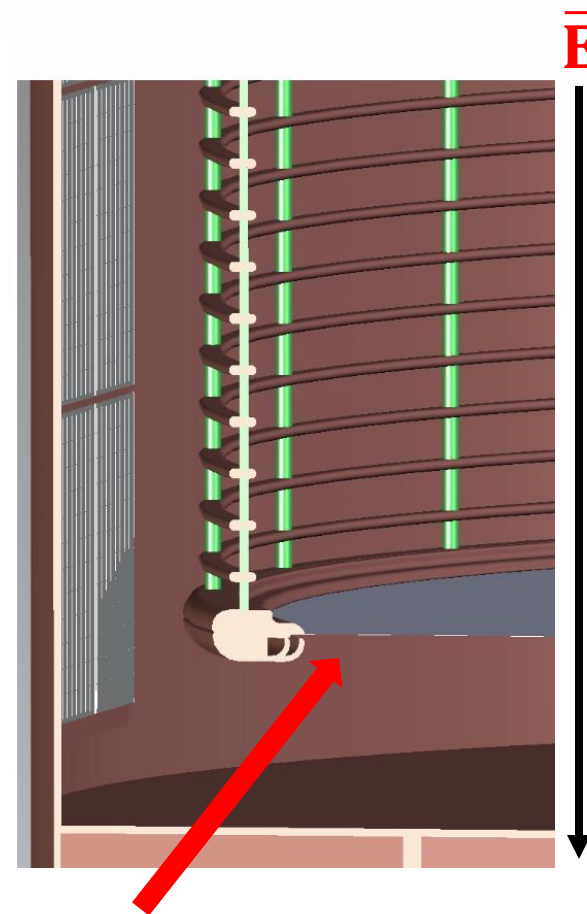
# Work at Yale ( $^{222}\text{Rn}$ backgrounds)



Molly Watts



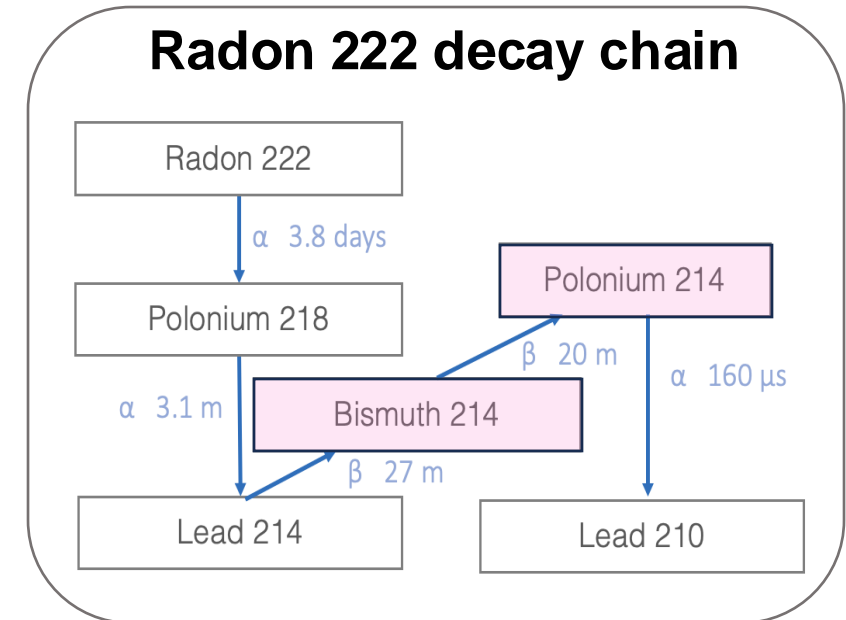
In our **LOW** background experiment, Rn decay chain is largest source of background



Rn-222 ionized daughters can plate out on cathode in electric field

### Backgrounds

Bi-214 is a dominant background with a gamma within 10 keV to our 2.5 MeV Q-value with 1.548% branching ratio

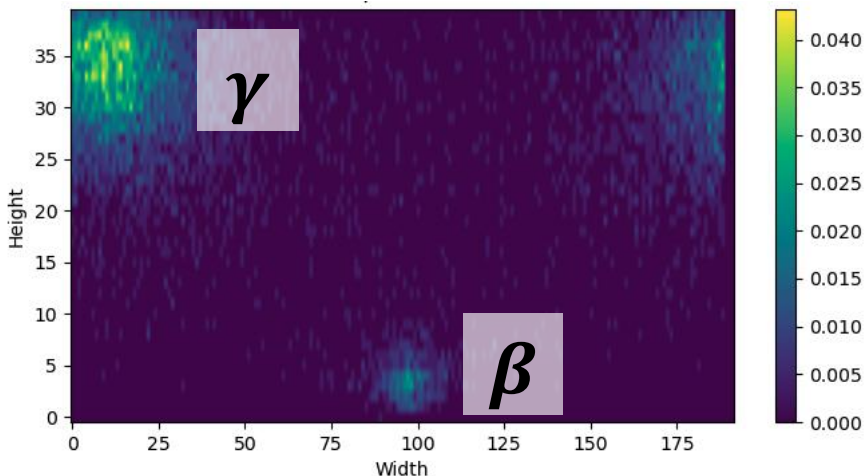


# CNNs for $^{222}\text{Rn}$ rejection



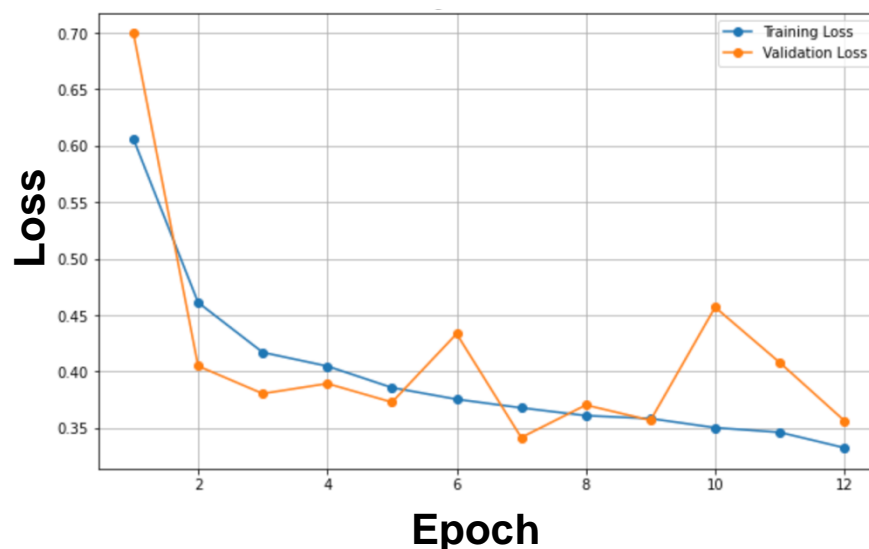
Molly Watts

## Normalized Bi-214 background inputs



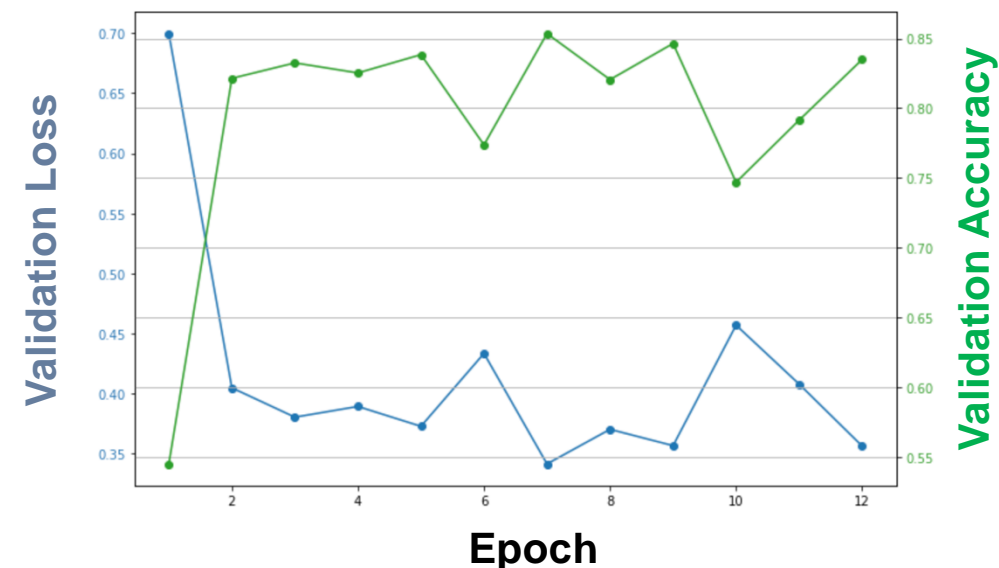
- Use convolution neural net (CNN) to identify background events where beta coincident with 2448 keV gamma (0vbb ROI) is missed
- Photodetector design with SiPMs surrounding the barrel of the detector and high pixelation enables light reconstruction not possible in other large LXe TPCs

## Training vs Validation Loss



Preliminary work on 130,000 background and signal events

## Validation Metrics



# Work at Yale (SiPM saturation)



Lucas Darroch



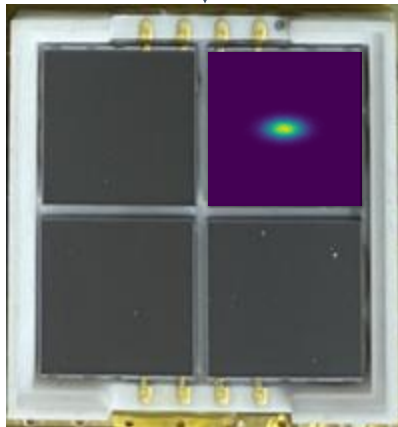
Darya Dayanim



- Developing model for onset of SiPM saturation with high rates of photoelectrons (and validating with measurements)

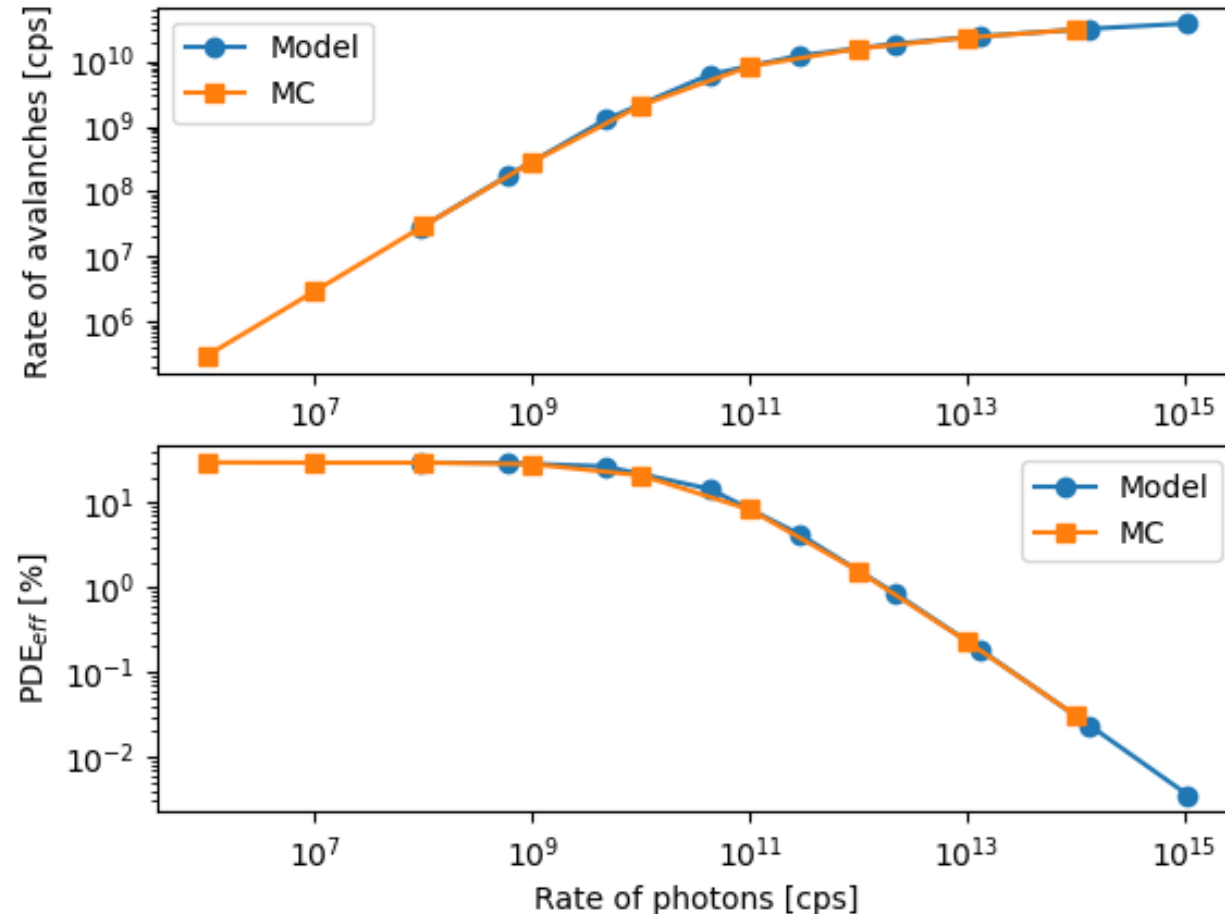
$$\langle N \rangle = \sum_{ijk}^{n_x n_y n_t} (1 - \exp(-PDE_{ij} \cdot U_{ijk}))$$

$$\langle N \rangle = \int \frac{dx dy dt}{\Delta x \Delta y \Delta t} (1 - \exp(-PDE \cdot \Phi(x, y, t) \Delta x \Delta y \Delta t))$$



$$\langle R \rangle = \frac{2\pi\sigma_x\sigma_y}{\Delta x\Delta y} \left[ \gamma + \log \left( \frac{PDE \times N_{photons}}{2\pi\sigma_x\sigma_y/\Delta x\Delta y} \right) - \text{Ei} \left( \frac{-PDE \times N_{photons}}{2\pi\sigma_x\sigma_y/\Delta x\Delta y} \right) \right]$$

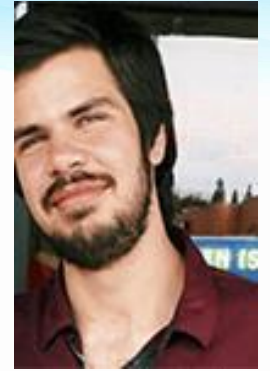
Saturation model and simulation:



# Work at Yale (solar $\nu$ , ML)

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- Other ongoing projects (currently working towards publications):
  - Sensitivity for  $^{136}\text{Xe}$  detectors to charged current interactions (e.g. solar  $\nu$ , fermionic dark matter) using delayed coincidence from  $^{136}\text{Cs}$  excited state
  - Finalizing simulation studies aimed at optimizing nEXO anode design (electrode configuration, shielding grid)
  - Dedicated measurement and analysis of level structure and excited states in  $^{136}\text{Cs}$
  - Machine learning based studies of nEXO light response reconstruction (in collaboration with Jason Brodsky at LLNL)



*Glenn Richardson*



*Sierra Wilde*