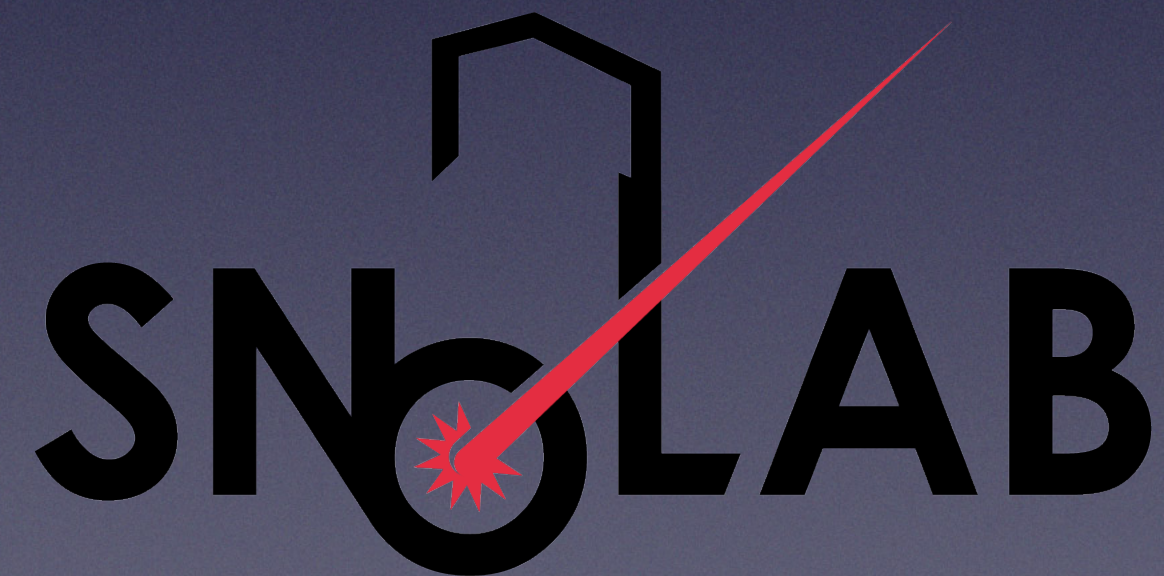


Simulations of Muon-Induced Backgrounds to nEXO



Regan Ross

Supervisors: Dr. Ubi Wichoski

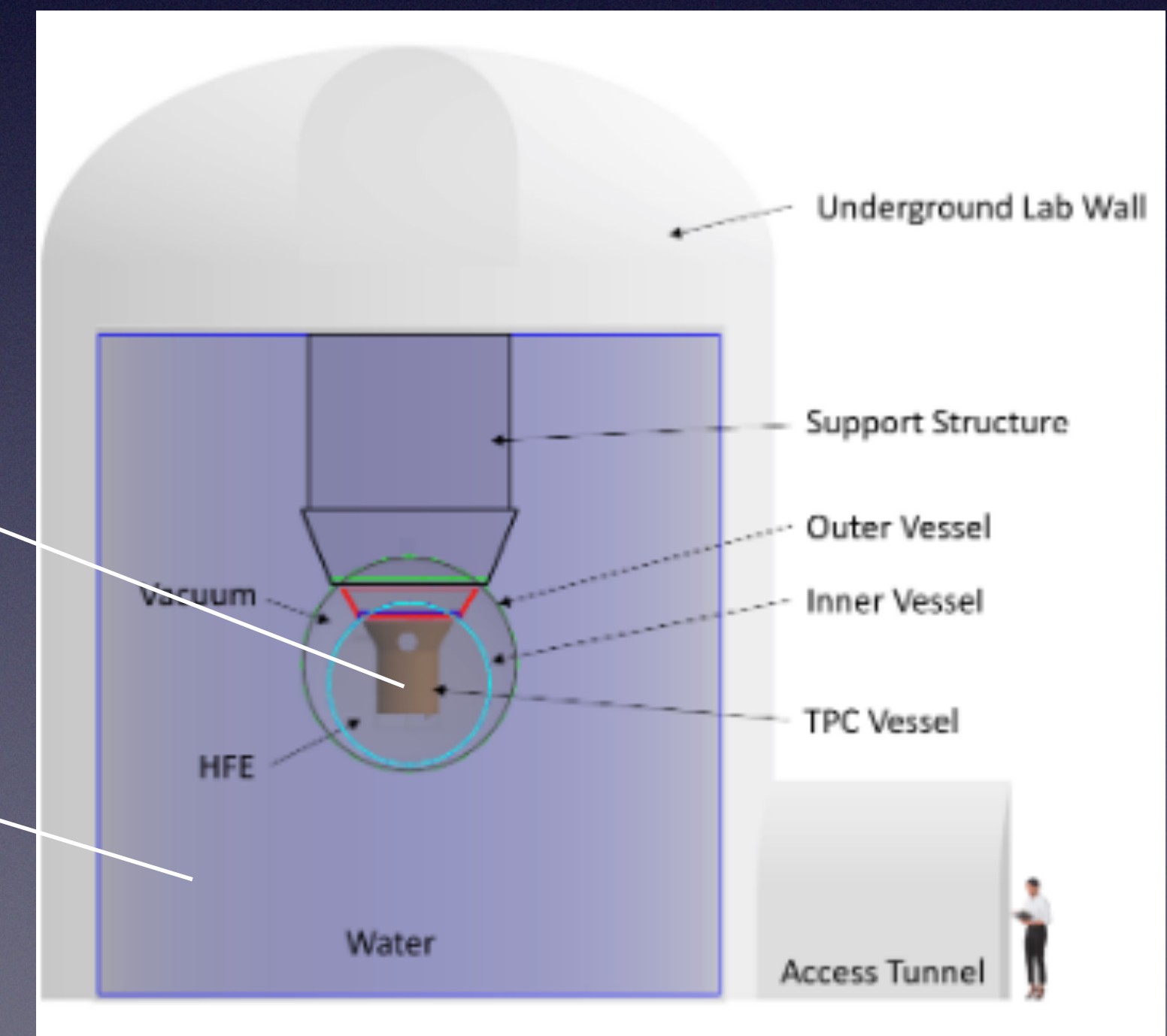
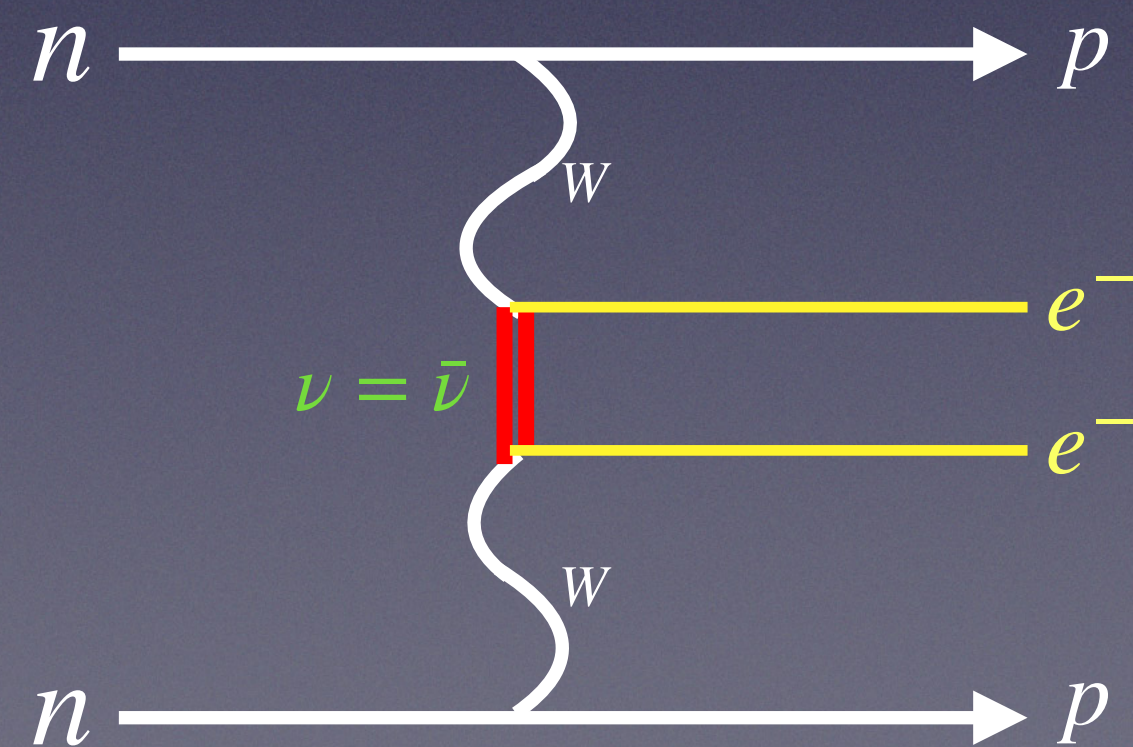


Laurentian University
Université Laurentienne

A Brief Overview of nEXO

- Searching for the hypothesized $0\nu\beta\beta$ process in enriched LXe
- Half life sensitivity of $1.35 \cdot 10^{28}$ years, $T_{1/2}^{0\nu} = \approx 10^{28}$ years [90 % CL] [1]

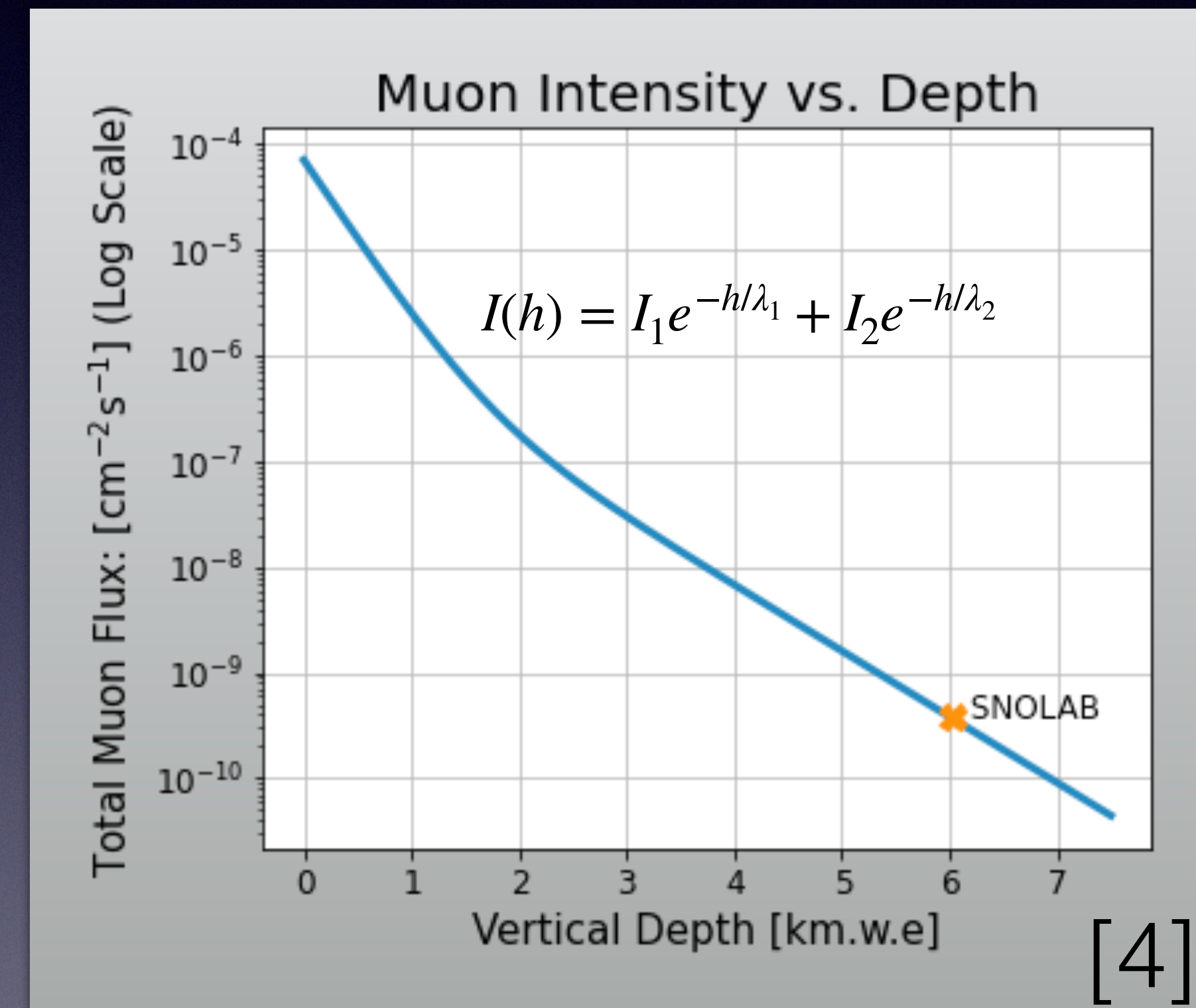
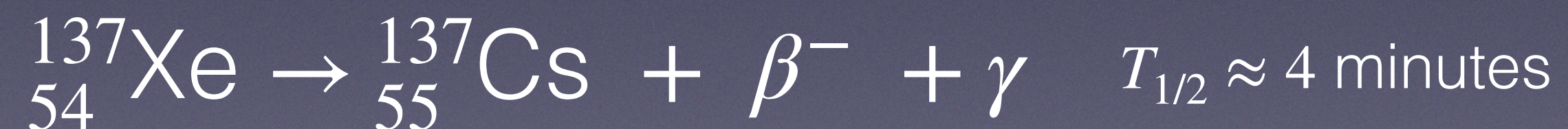
- 4811 kg of 90% liquid ^{136}Xe at $\approx -110^{\circ}\text{C}$
- Outer Detector (OD)



Backgrounds

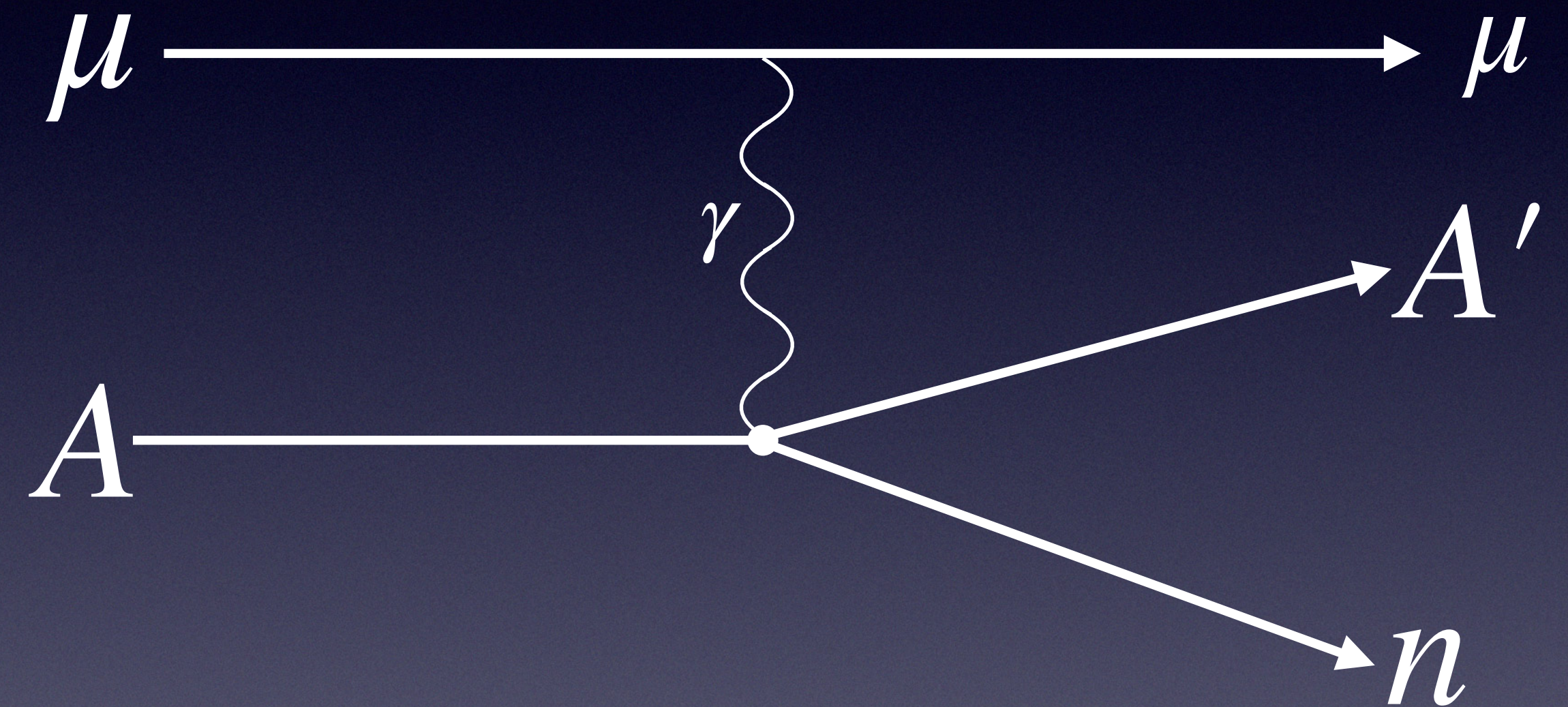
^{238}U ^{232}Th ^{60}Co ^{40}K

- Long-lived local radionuclides $\rightarrow \gamma$
- Xenon-137 beta decay spectrum overlaps with $Q_{\beta\beta}$ [1]



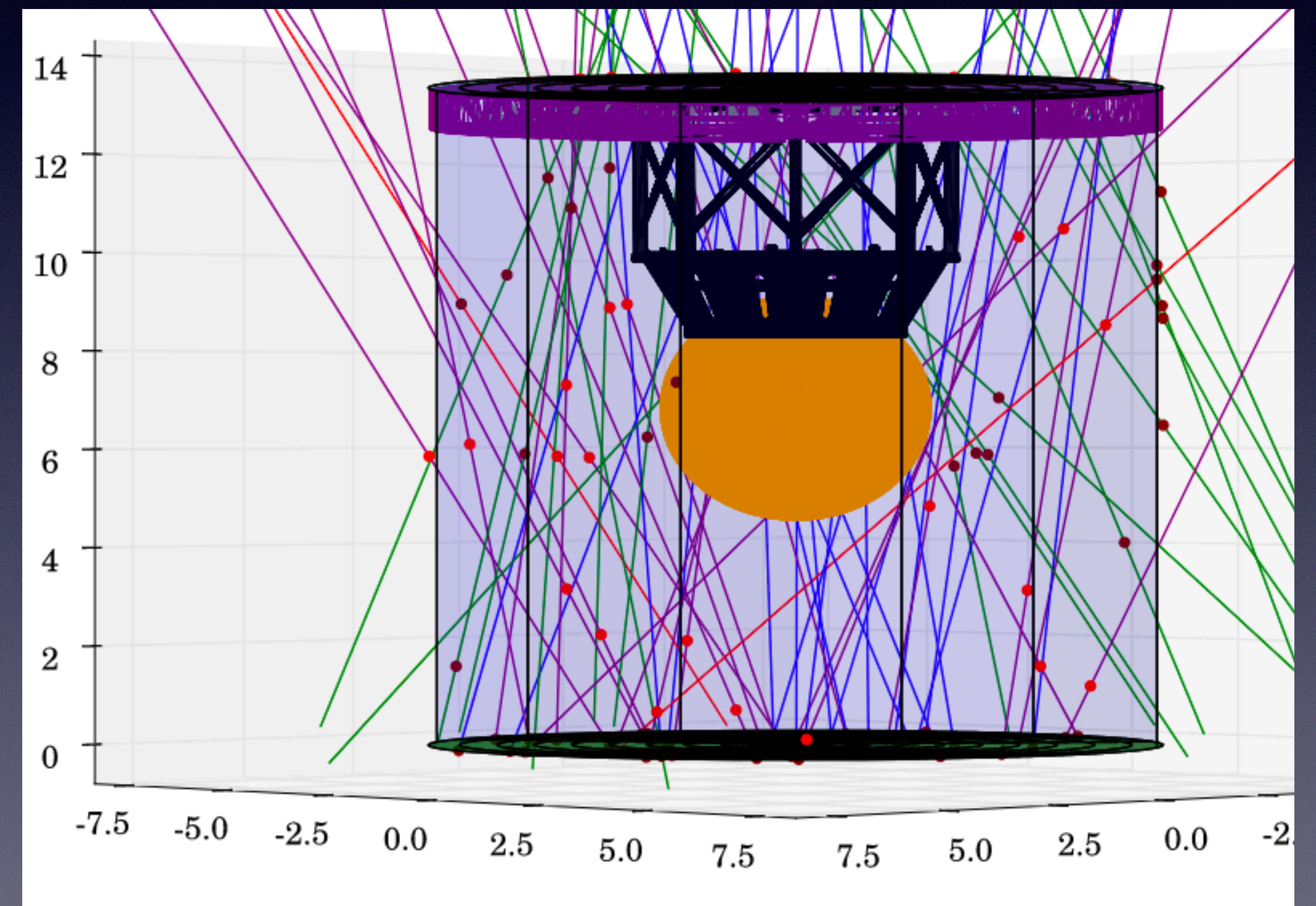
Muon Spallation

- Muon-induced nuclear disintegration
- Muon elastic scattering
- Photo-nuclear interactions
- Secondary neutron production due to the above [5]



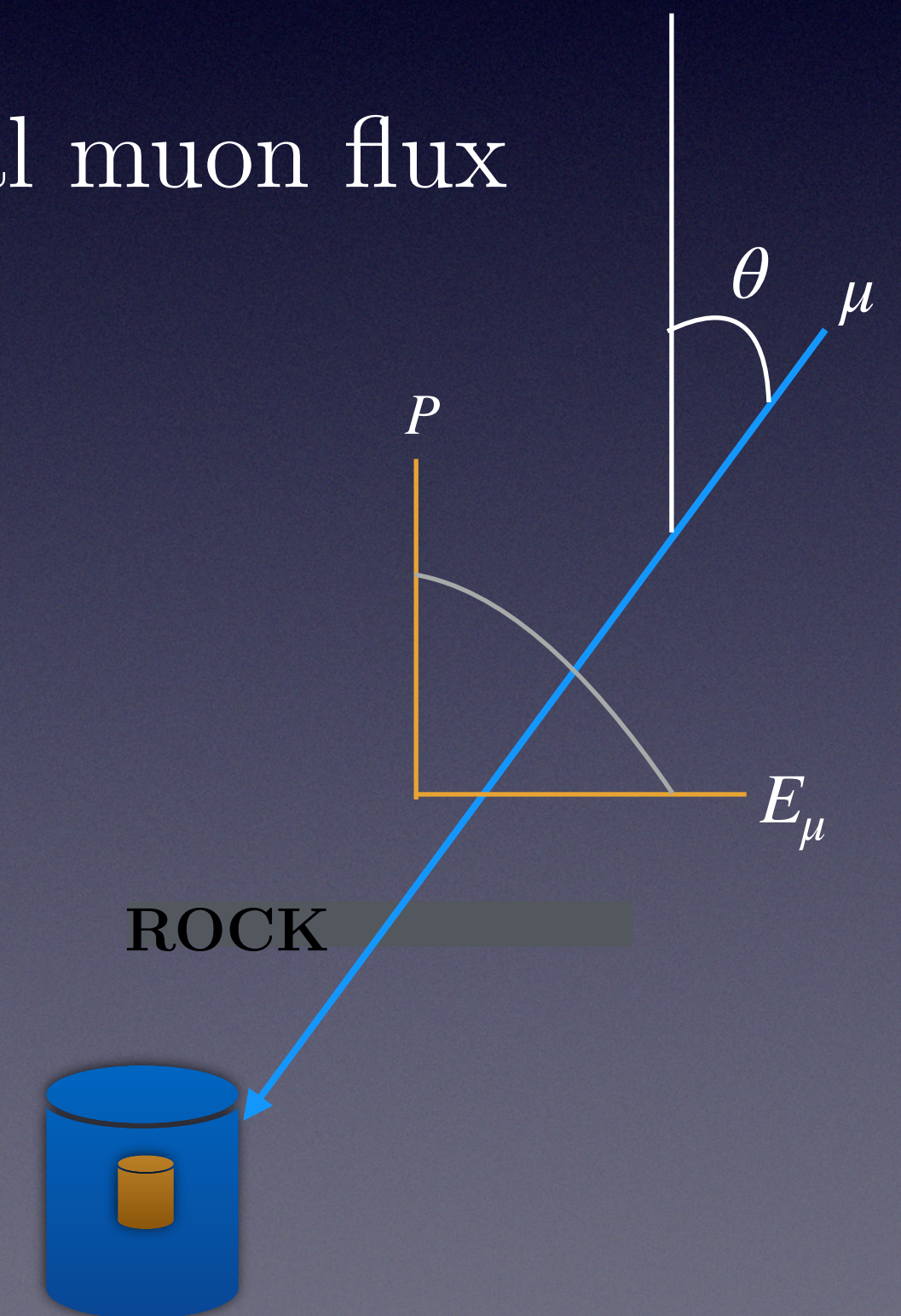
The Outer Detector (OD)

- Instrumented with 127 PMTs
- Full of ultra-pure water
- Shields internals from γ & n

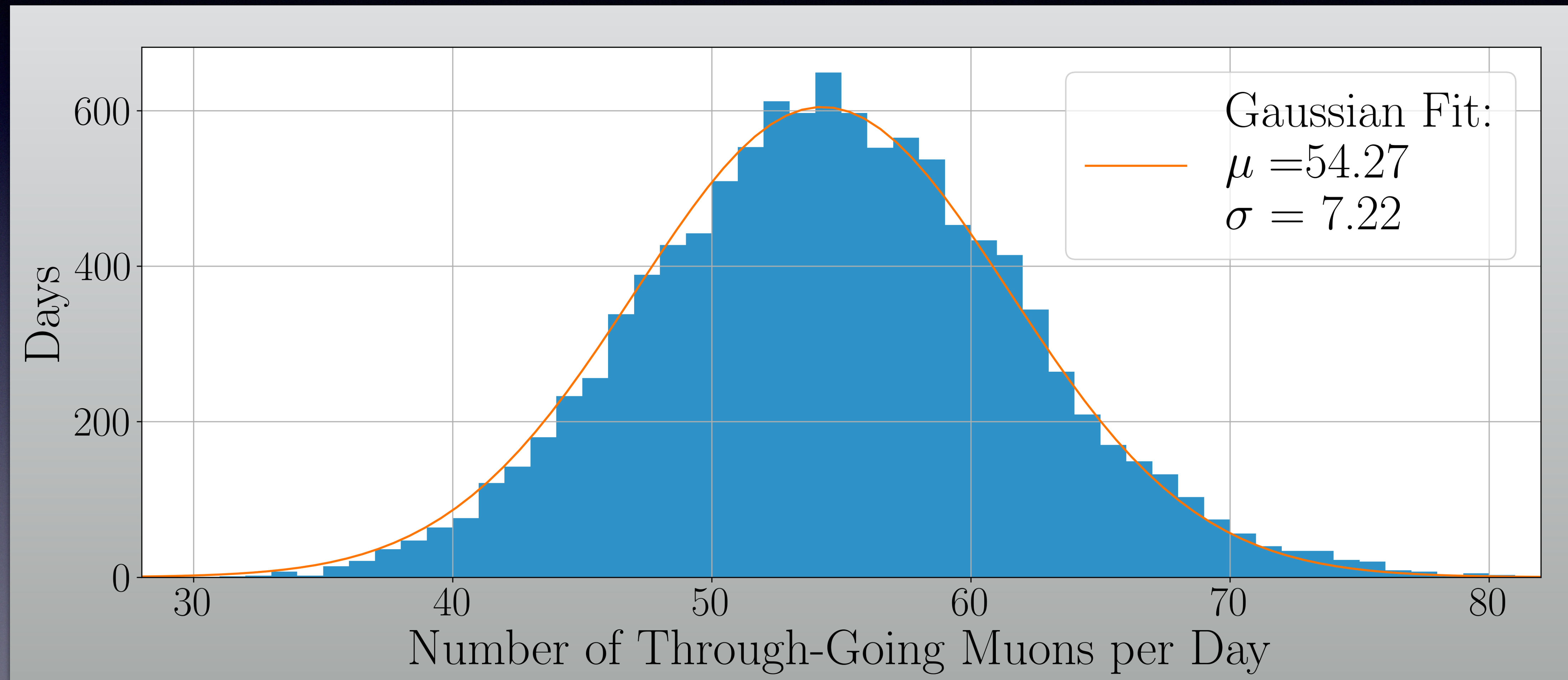


Muon Simulation μ

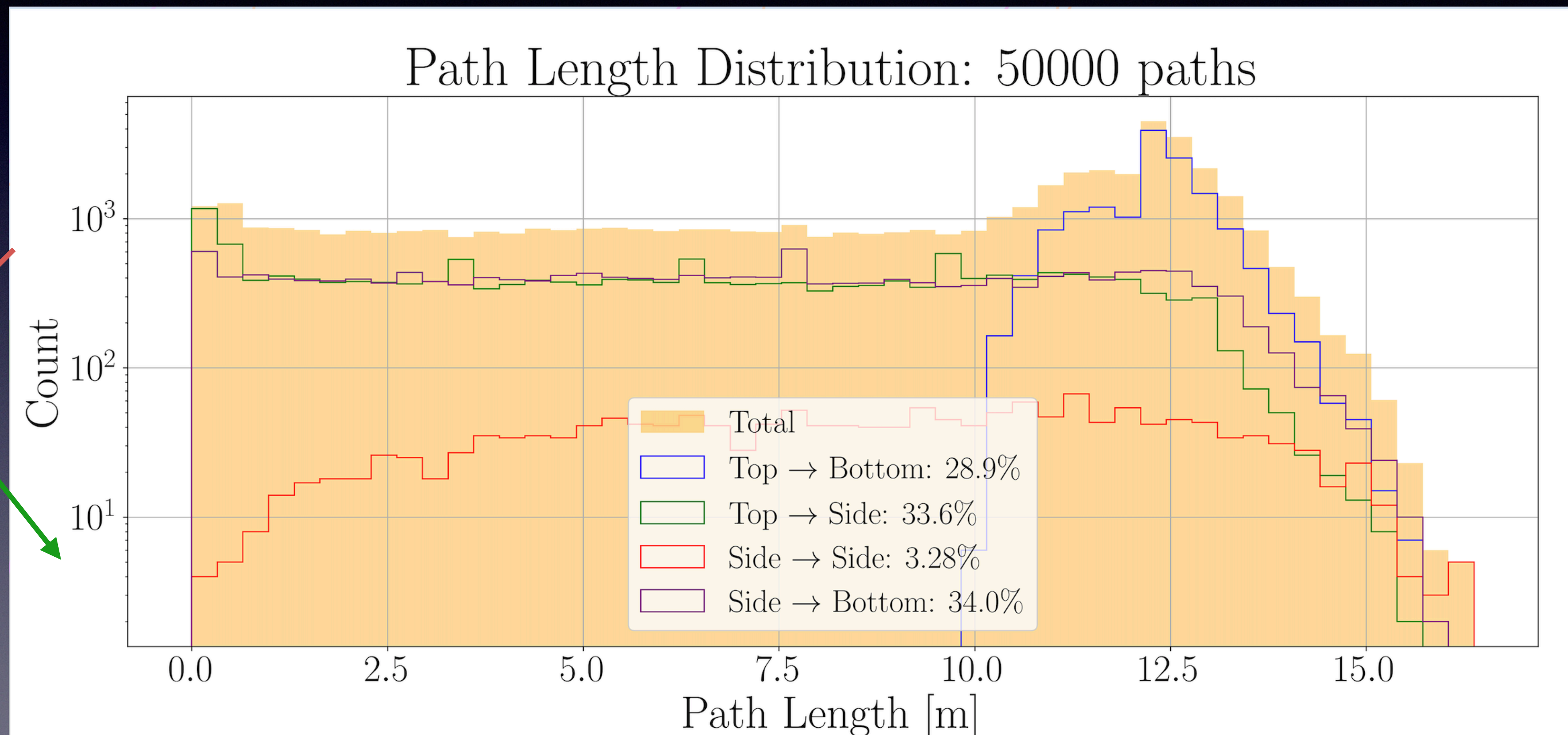
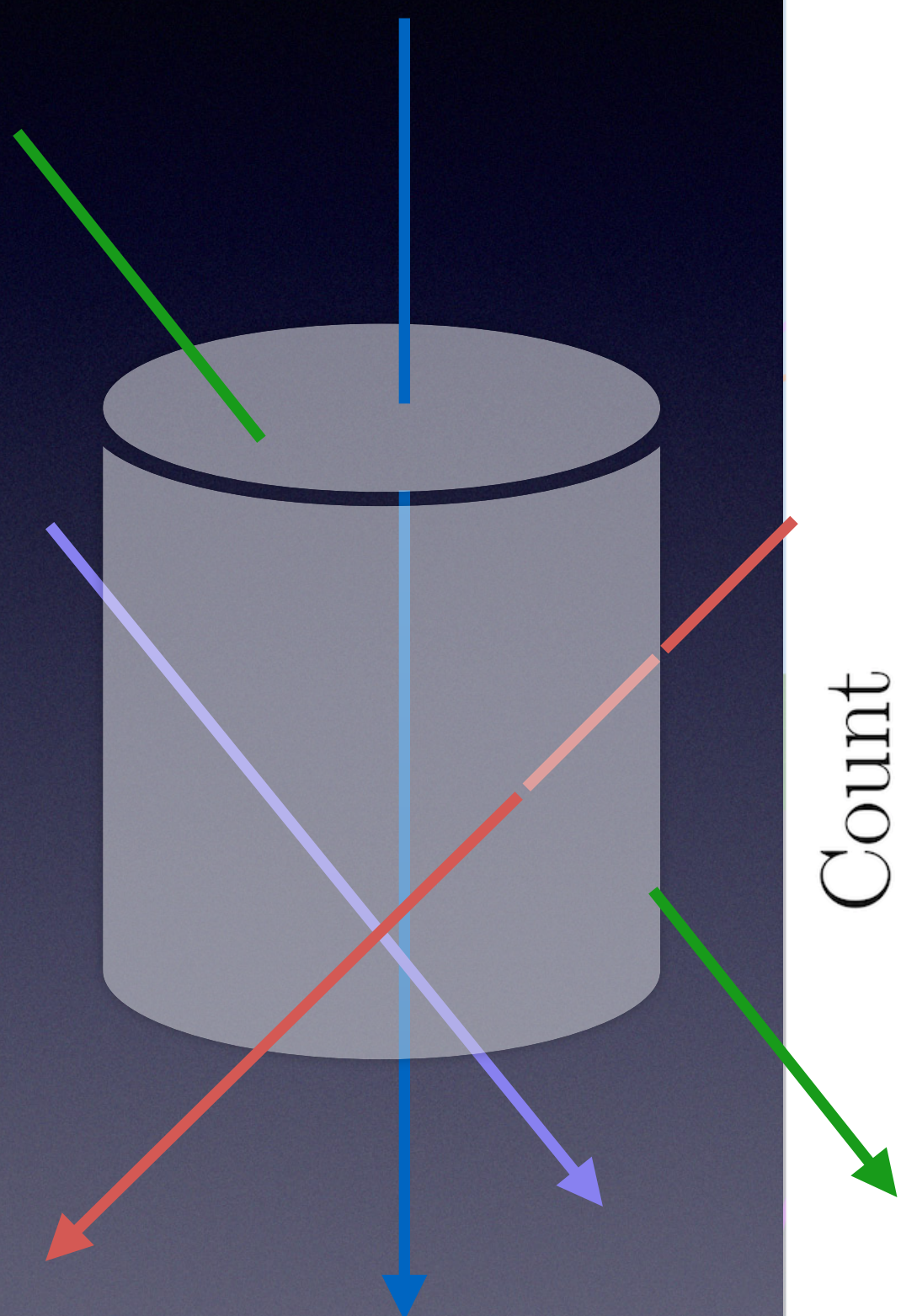
1. Normalize Mei & Hime [2] Zenith distribution to SNOLAB vertical muon flux
2. Sample zenith angle from distribution
3. Sample point on a disk above the OD
4. Sample energy from attenuated energy distribution [3]
5. Analytically calculate intersection points of muon with OD



Daily Muon Flux of nEXO OD

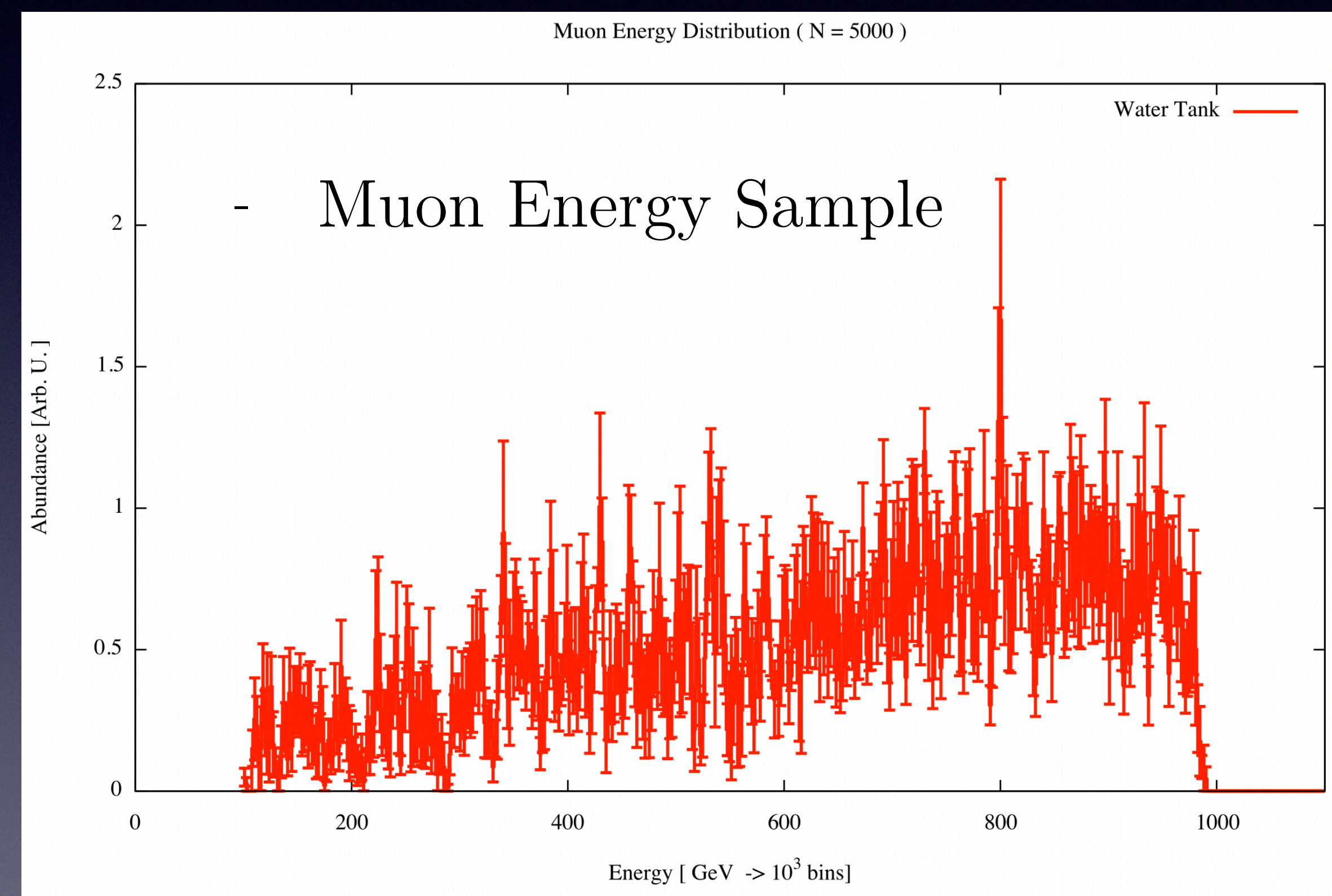
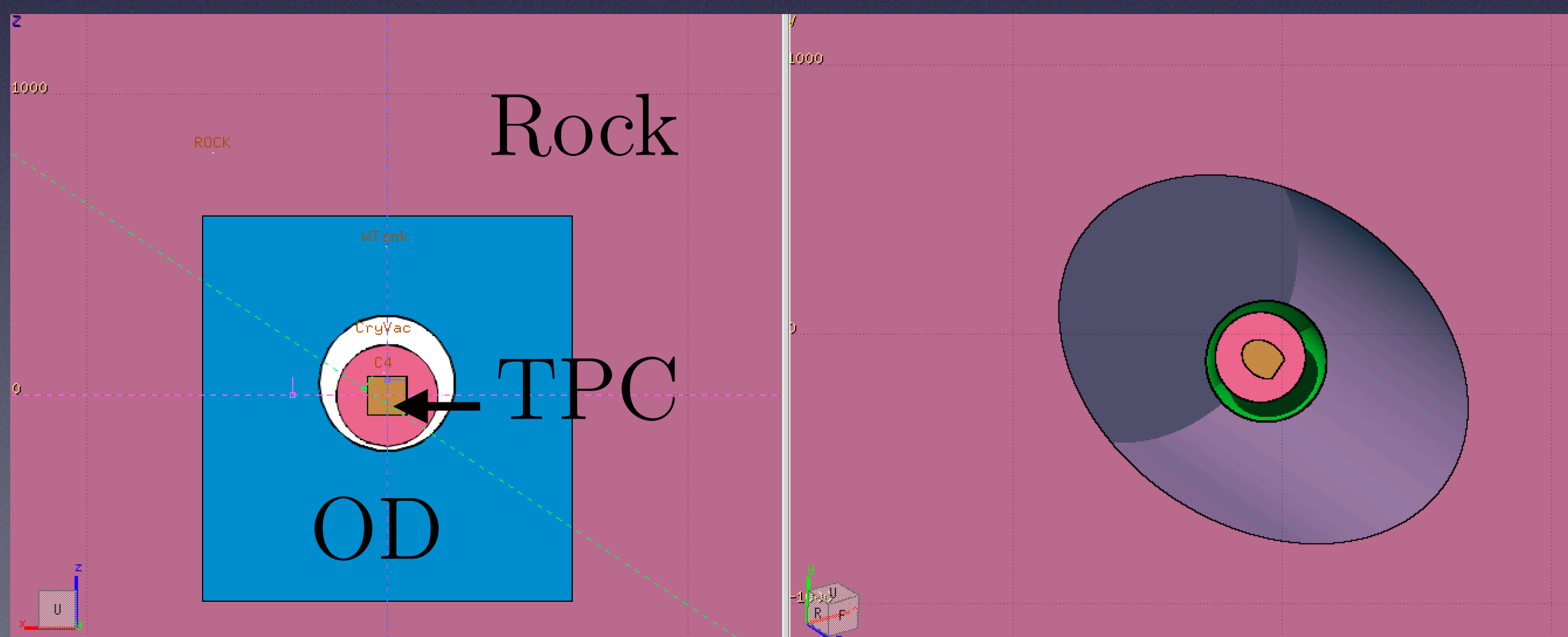


Muons @ nEXO



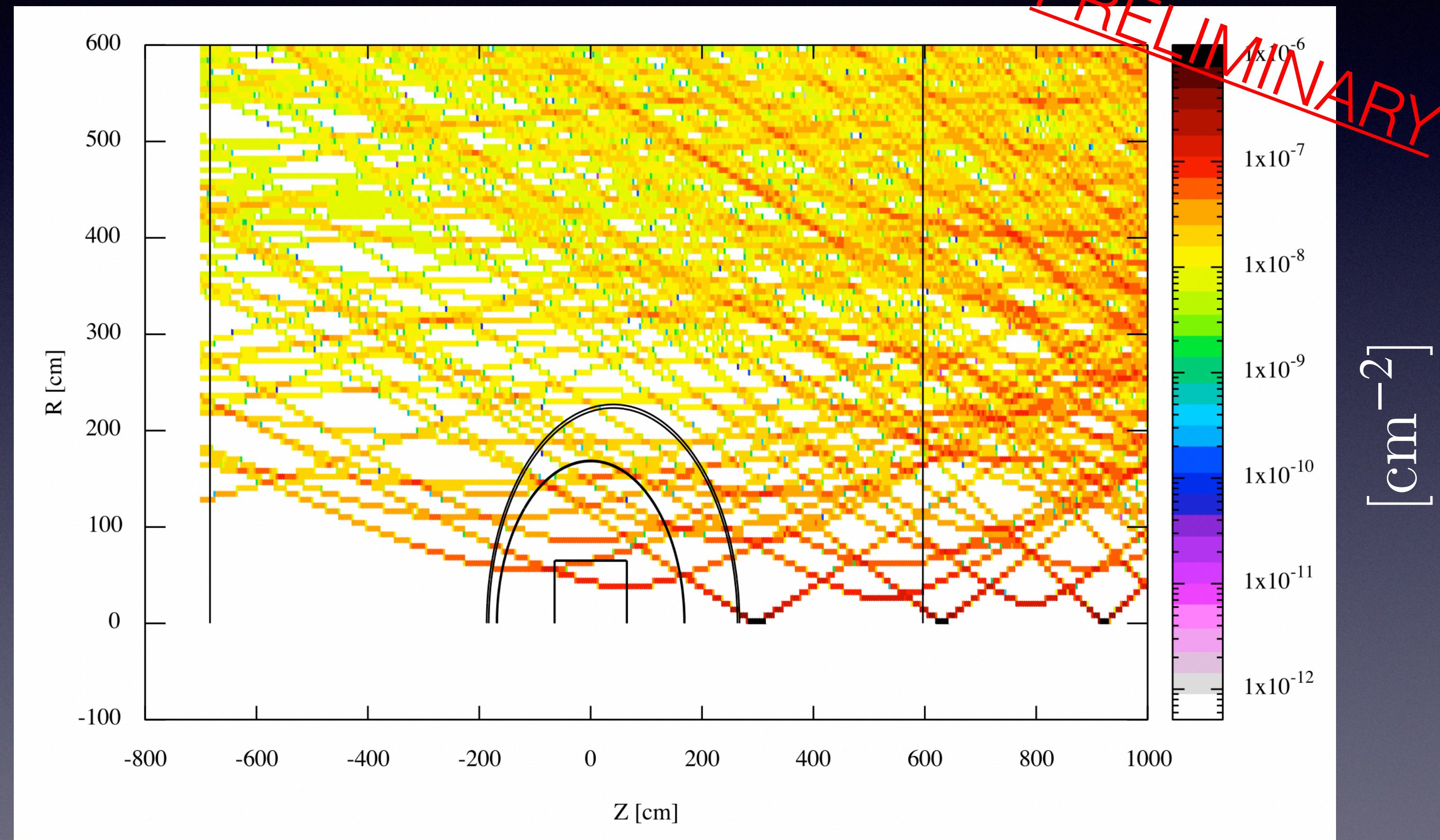
Deploying FLUKA

- Same muon generation process
- Simple combinational geometry
- Many ways to score quantities



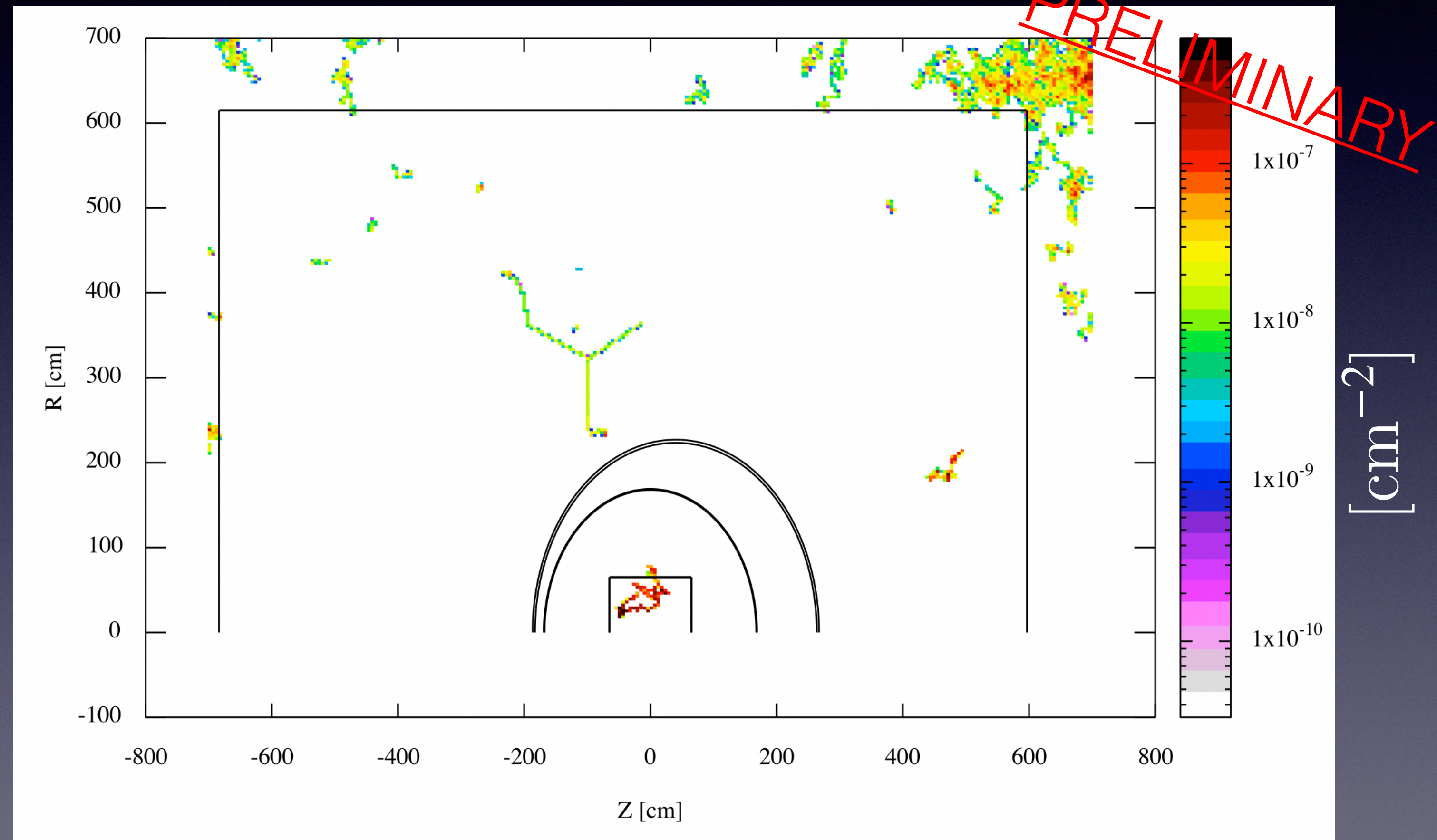
Muon Fluence

- Weighted mean over ϕ ; hence *curved* tracks
- Expected zenith θ used
- FLUKA USRBIN Detector
- Effectively showing muon paths



Neutron Fluence

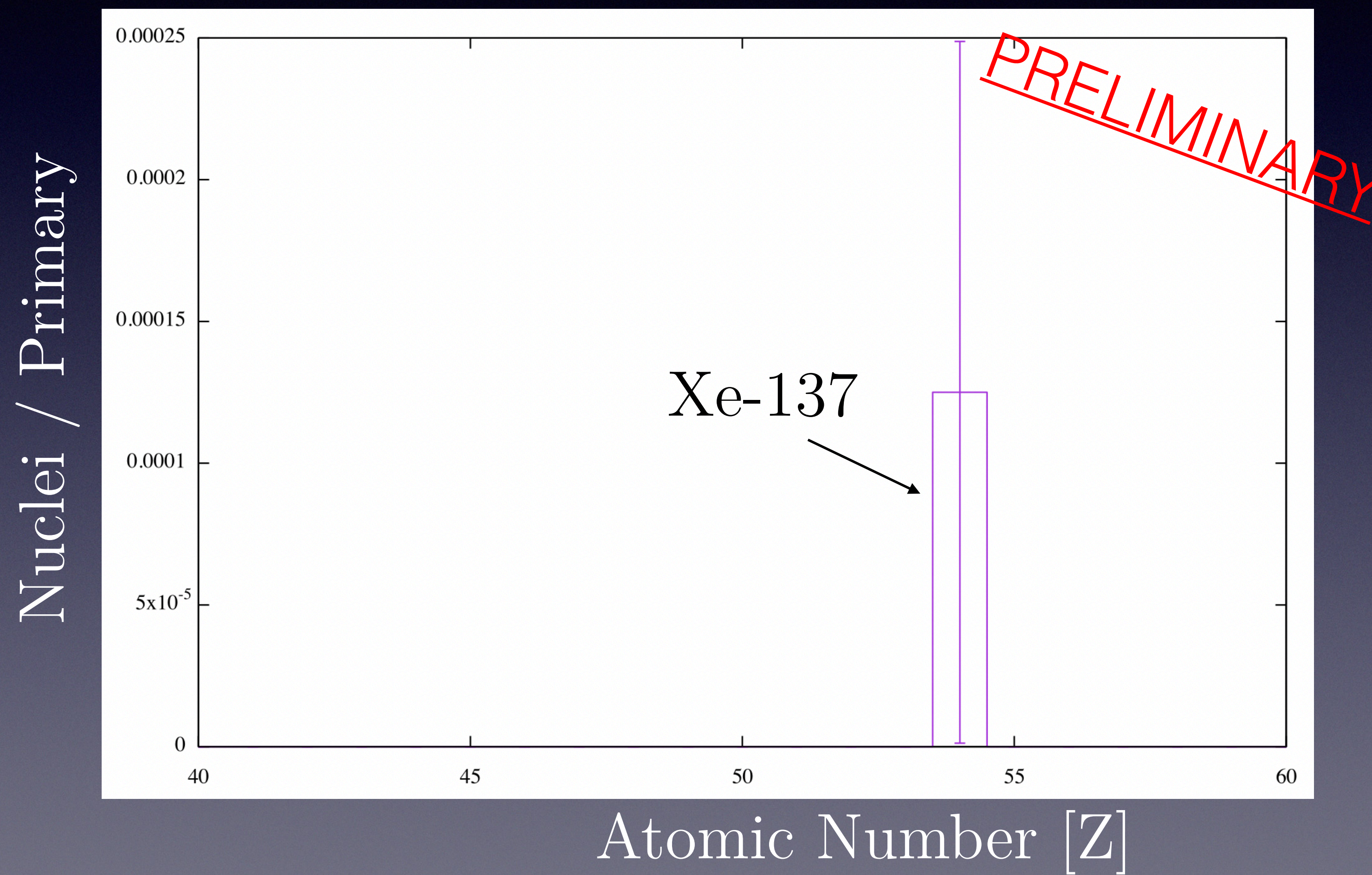
- Little bit of action in the TPC



Background Found

(With Poor Statistics)

- FLUKA RESNUCLE
- (RESidual NUCLEi)



Next Steps

1. Implement proper zenith distribution as opposed to expected value
2. Use larger computer

Things to determine:

Activation rate of xenon due to muonic activity

Relationship between impact parameter and activation rate

Time between muon entry and energy deposition in TPC

1. nEXO Collaboration et al., Neutrinoless double beta decay search beyond 10^{28} year half life sensitivity, 2021
2. Muon-Induced Background Study for Underground Laboratories, Mei & Hime, 2005
3. Review of Cosmic Rays, T.K. Gaisser, T. Stanev, 2009
4. Measurement of the Cosmic Ray and Neutrino-Induced Muon Flux at the Sudbury Neutrino Observatory, B. Aharmim et. al, 2018
5. Gratta et. al., Predicting Neutron Production from Cosmic-ray Muons, 2008

Contact:

Regan Ross

Email: rross@laurentian.ca

Acknowledgements:

Supervisor: Ubi Wichoski

Primary Collaborators: Soud Al Kharusi, Liam Retty, Caio Licciardi, Erica Caden, Thomas Brunner

Thanks also to Benjamin Tam and Christine Kraus for organizing this event.