October 2021

The University of Texas at Austin
Department of Physics
College of Natural Sciences

TEXAS
The University of Texas at Austin

Particle Physics in the UT Lang Lab

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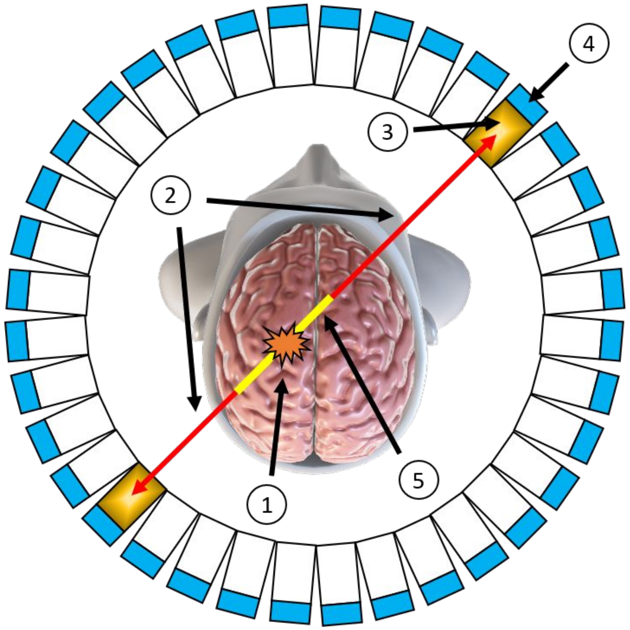
Positron Emission Tomography (PET)

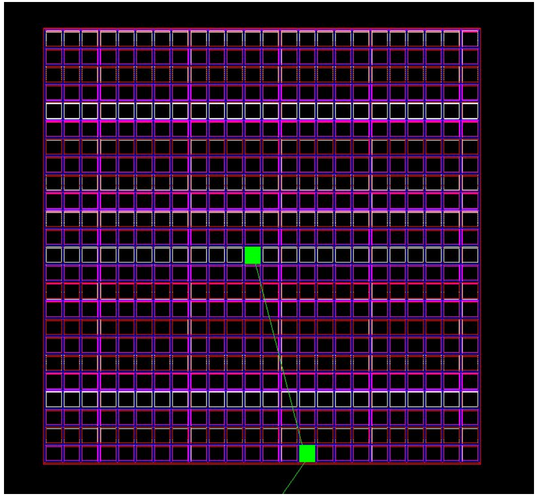
- Image Patients from “inside-out”!
  - Patients are injected w/ position-producing radio-pharmaceutical

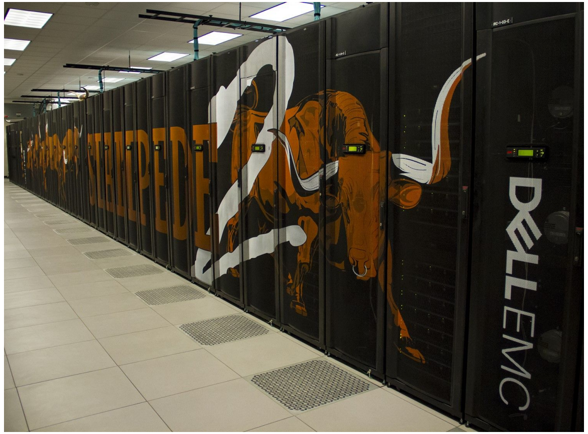
- Scintillators convert gamma rays to “optical photons” for better detection efficiency
  - optical photons then detected using Silicon Photomultipliers (SiPMs)



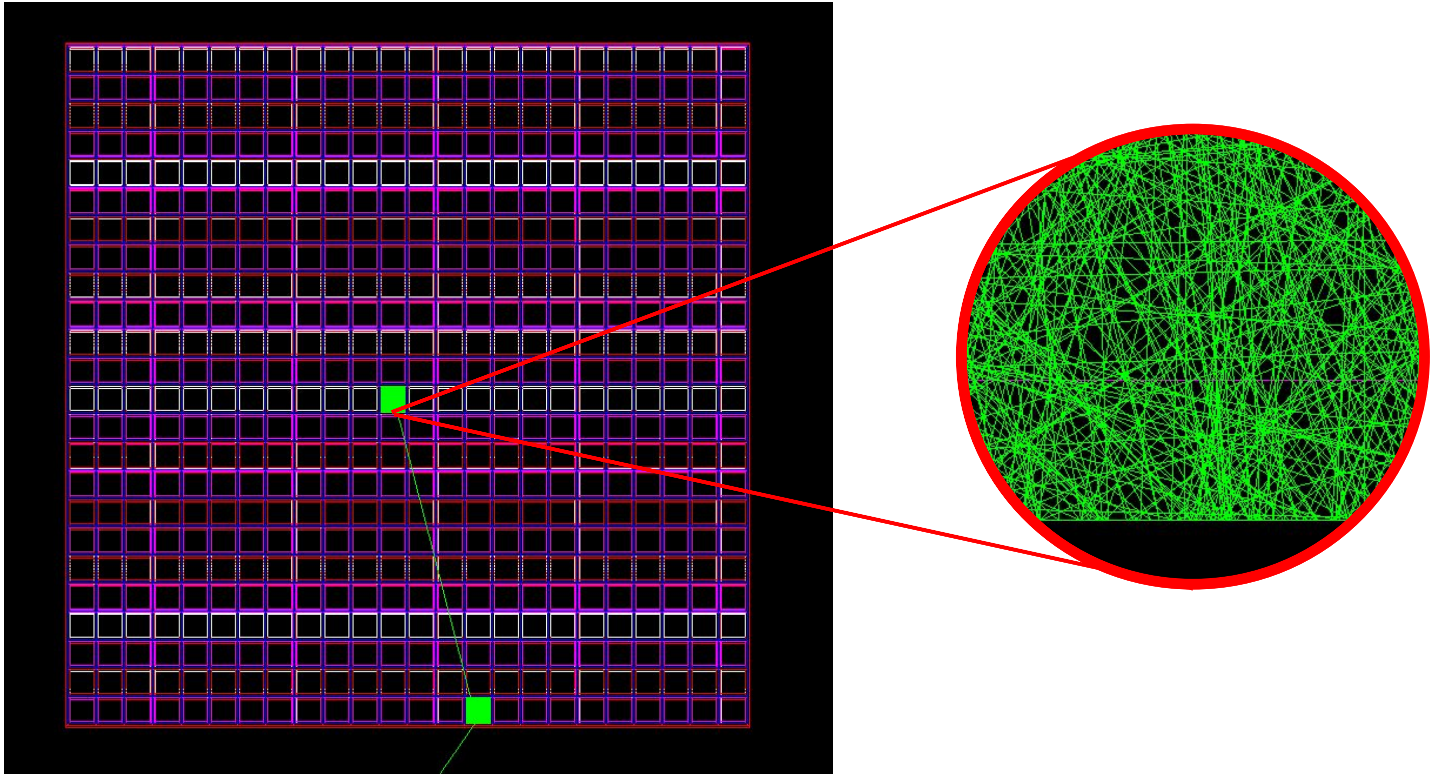
Simulation in GEANT4

- Scanners are expensive….
  - crystals alone can cost ~$100,000!
- Before investing in a prototype, we simulate scanners in Geant4!
- Simulation can be computationally expensive…
  - We make use of the Texas Advanced Computing Center (TACC)



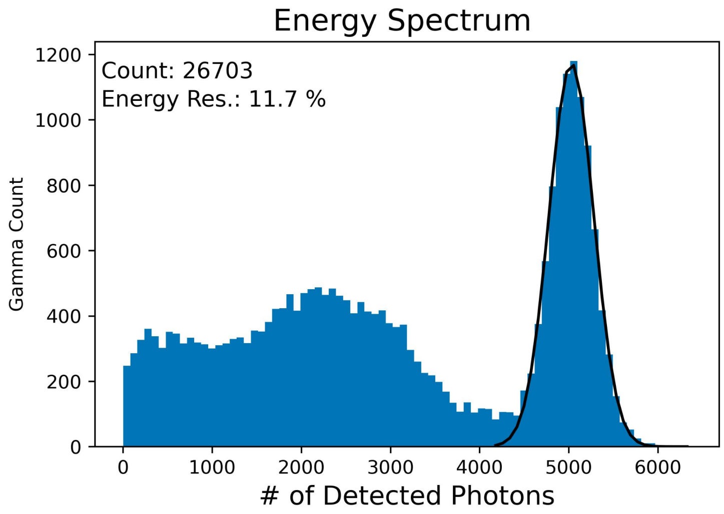


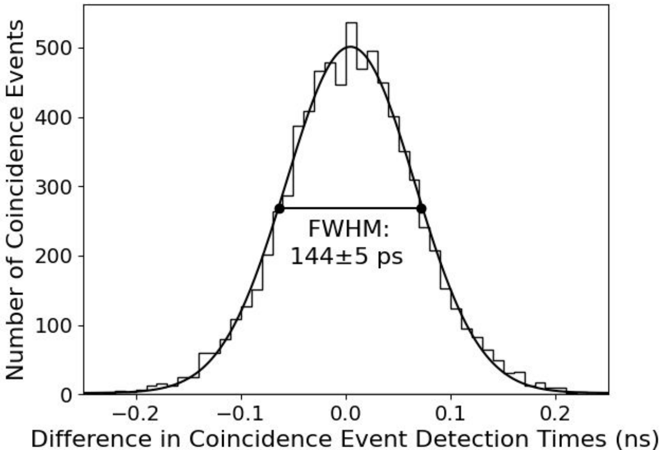
Simulation in GEANT4



What are we testing for anyway?

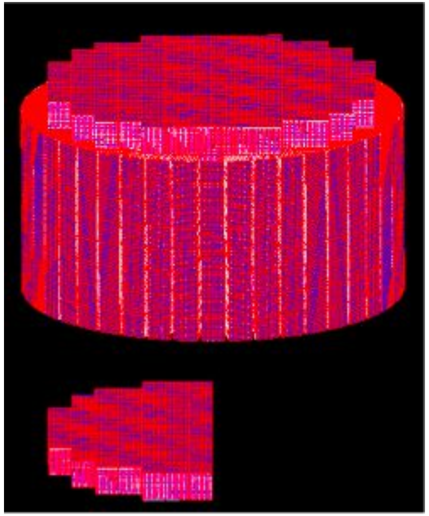
- Energy Resolution
  - How good are we at telling what the gamma ray’s energy is?
- Coincidence Resolving Time (CRT)
  - How well can we tell when the annihilation occurs?
- Sensitivity
  - What percent of the annihilations are we detecting?

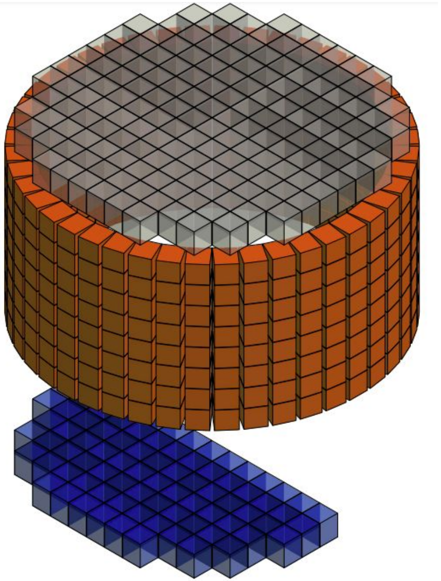




“NIH” Brain PET Scanner

- “Corona” and “Chin” modules
  - augment sensitivity
- “Double-Ended Readout”
  - Where in a crystal does the gamma ray convert to photons?





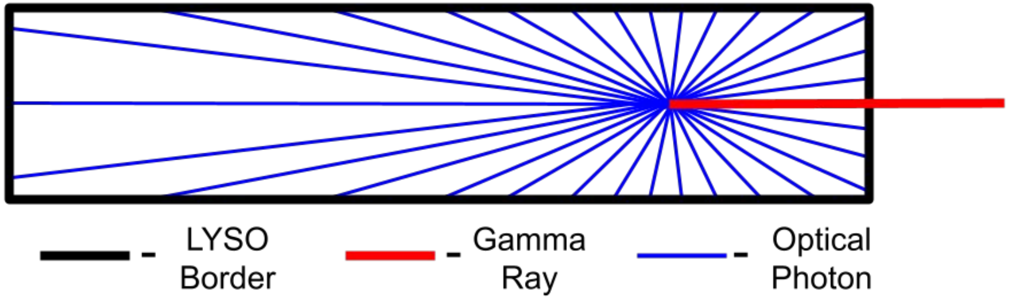
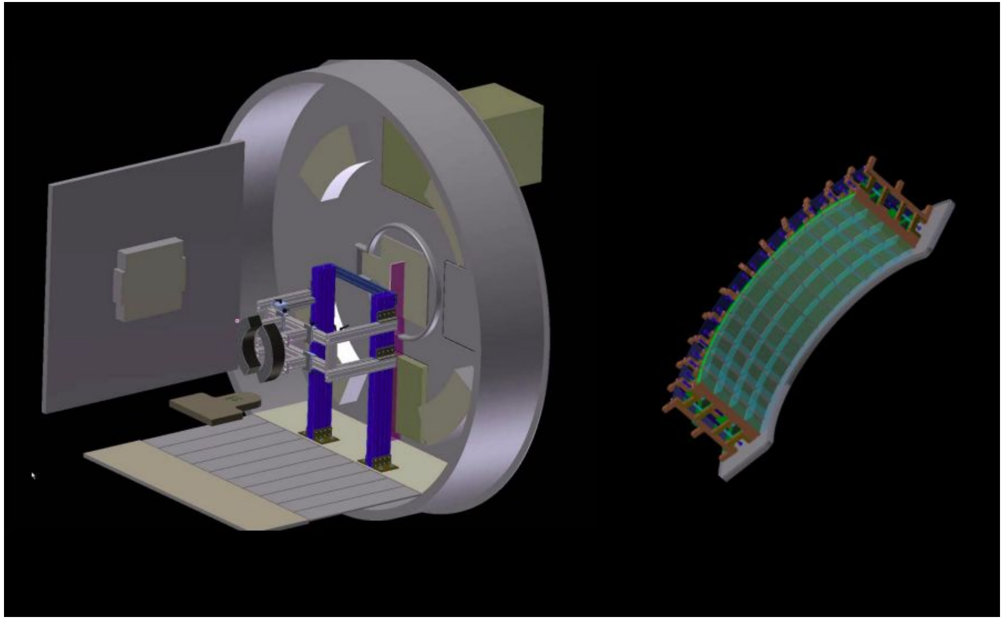
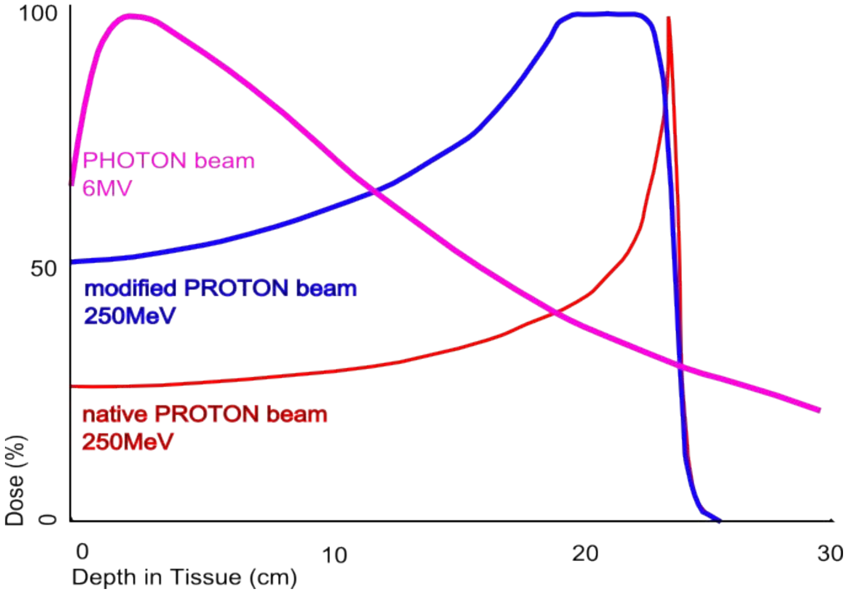


Image Courtesy of Marek Proga

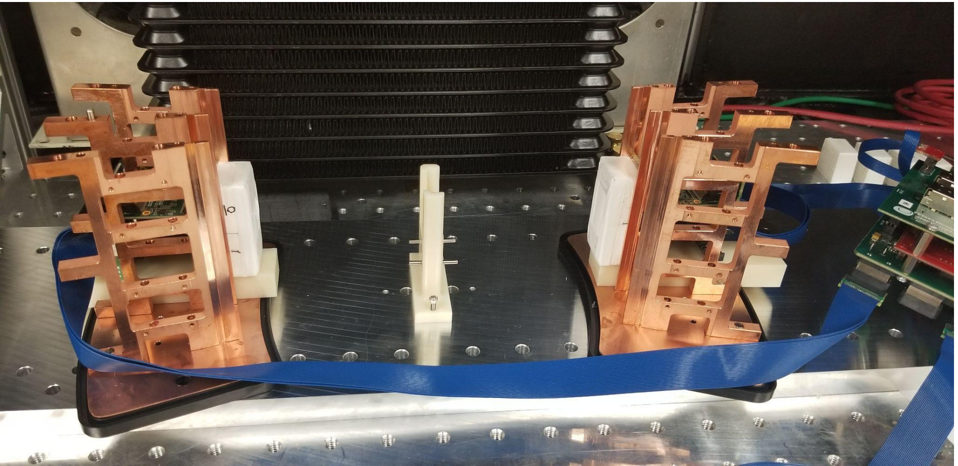
Time of Flight PET for Proton Therapy (TPPT)

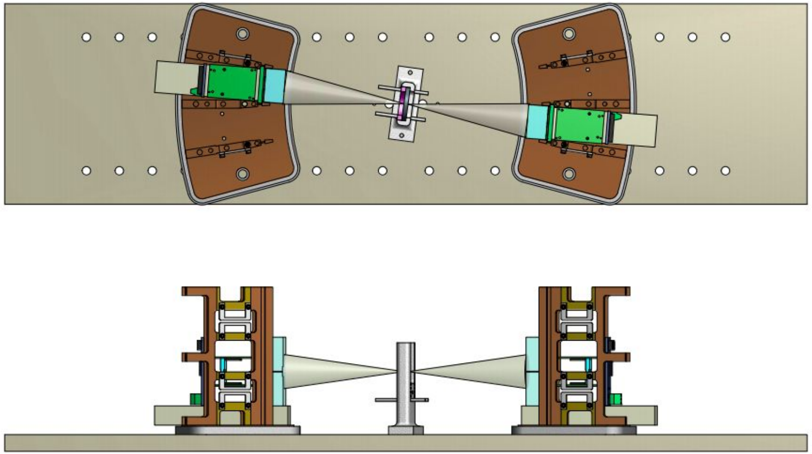




Evaluating Experimental Arrays

One by one, each array is tested with a Na-22 Source for Timing and Energy Performance to ensure the end scanner has the optimal data quality.





Why we care about Scanner Metrics

Each metric we measure corresponds to some uncertainty in the source we are measuring:

Sensitivity: Less data means more general uncertainty

CTR: Uncertainty along the Line of Response

Position Resolution: Uncertainty along the “cross-section” of the crystal

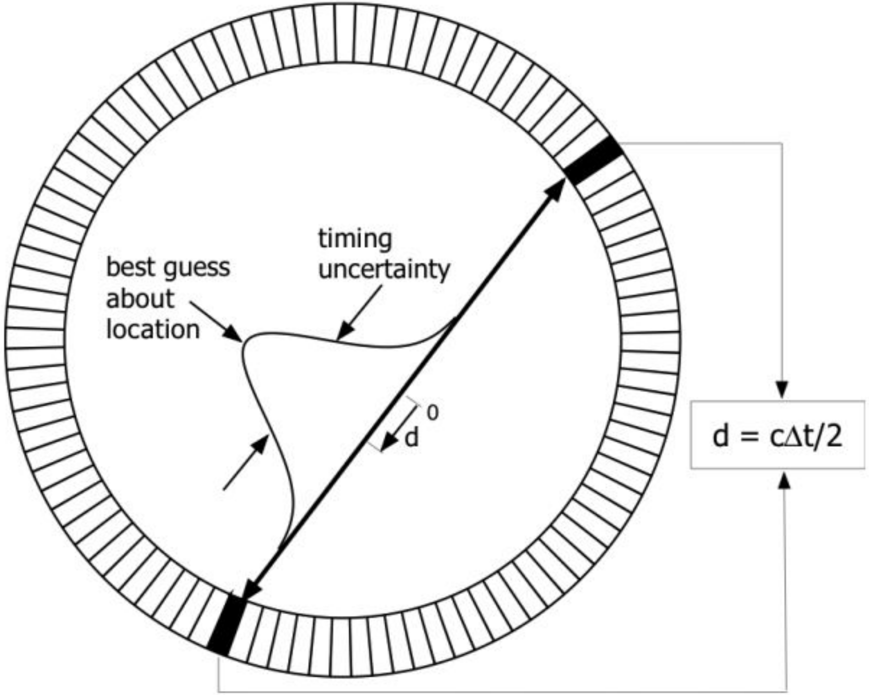
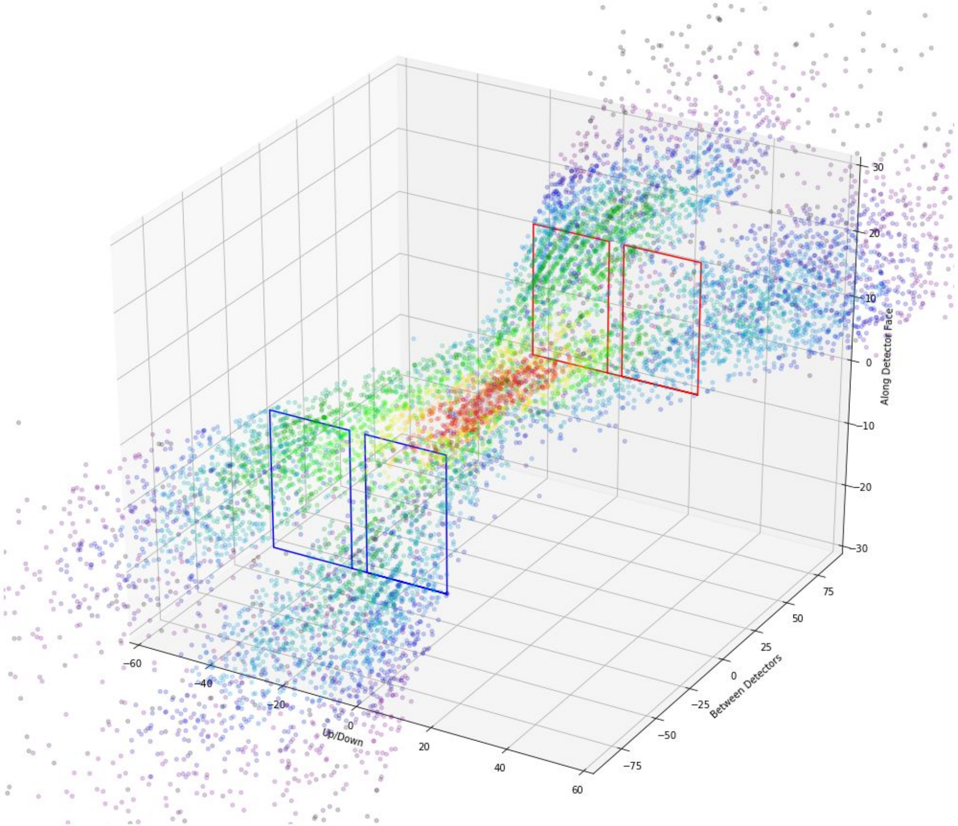
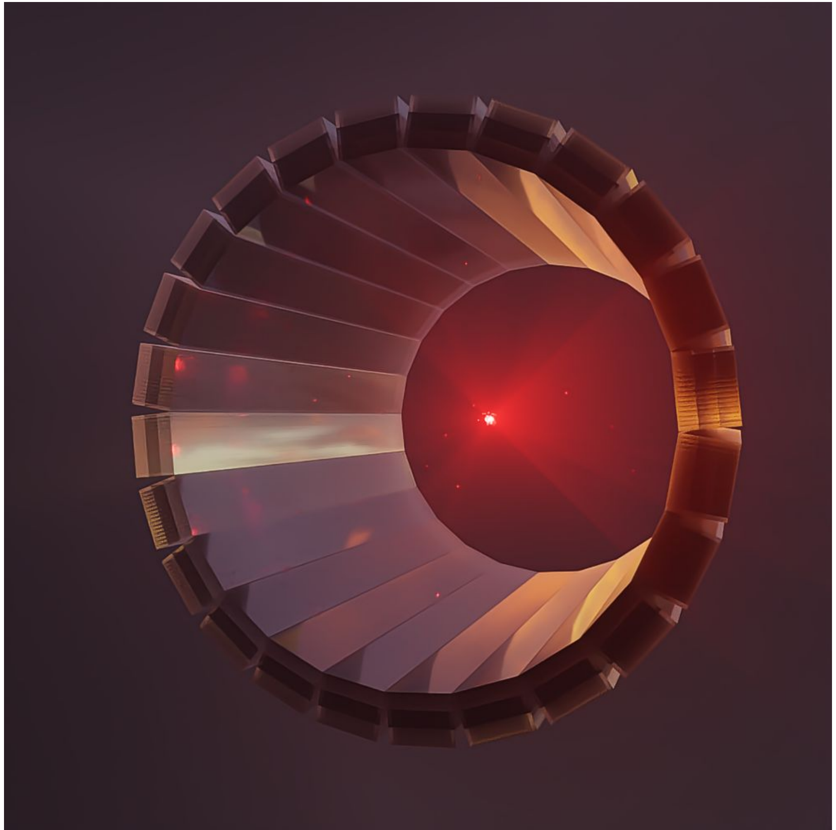


Photo Credit: R. Schmitz et. al, University of Washington, “The Physics of PET/CT Scanners”

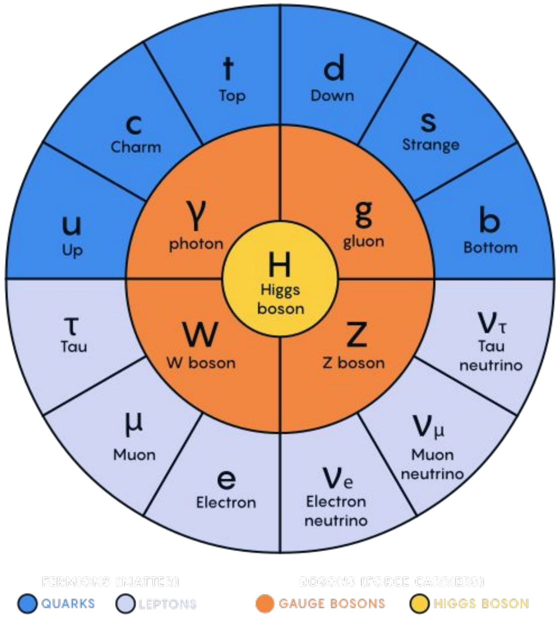
End Goal: Imaging the Proton Beam





Neutrino Physics

- Neutrinos are the smallest and most elusive particles described by the Standard Model.
- Neutrino oscillations demonstrate that neutrinos have mass.
- Other theories predict that neutrinos are Majorana particles, once again defying the Standard Model.
- We work in national and international experimental neutrino collaborations.



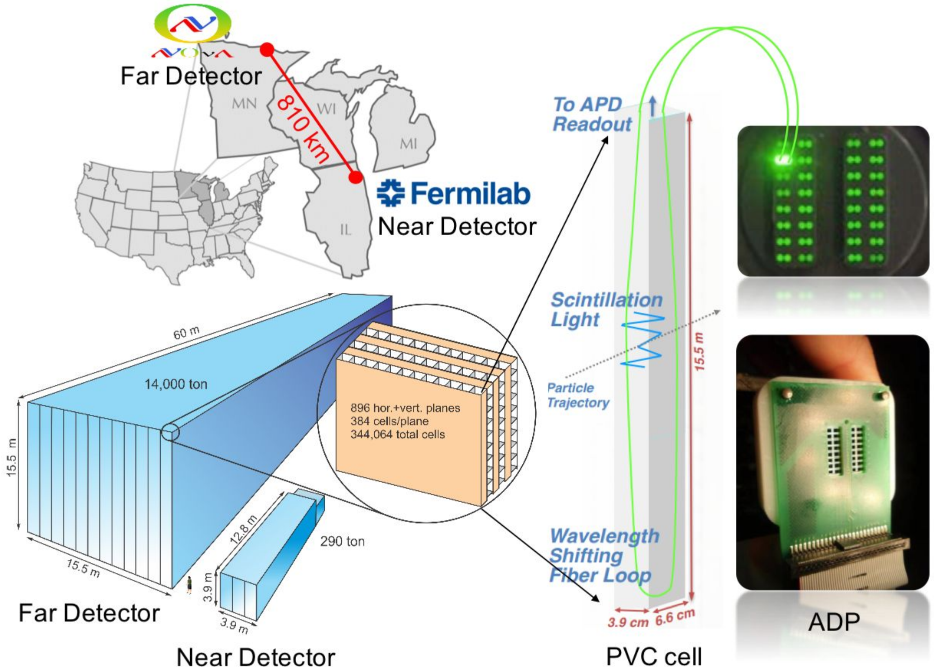
Wolchover, N., Velasco, S., & Reading-Ikkanda, L. (2020). *The Standard Model*. Quanta Magazine. Retrieved from https://www.quantamagazine.org/a-new-map-of-the-standard-model-of-particle-physics-20201022/.

NOvA Fermilab

- NOvA (NuMI Off-axis ν_e Appearance) is long -beamline neutrino experiment.

- NOvA uses some of the most sensitive detectors in world to gain insight into neutrino mass hierarchy and the parameters which describe neutrino mixing.

- Our group is involved in detector R&D, simulations, and data analysis for the NOvA experiment.



http://www.hep.utexas.edu/utkl/nuosc.html

NuMI and the Hadron Monitor

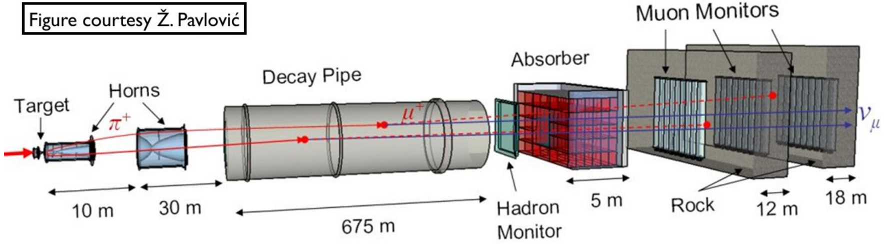
- NuMI beamline

(protons → mesons → muons + muon neutrinos → neutrinos)

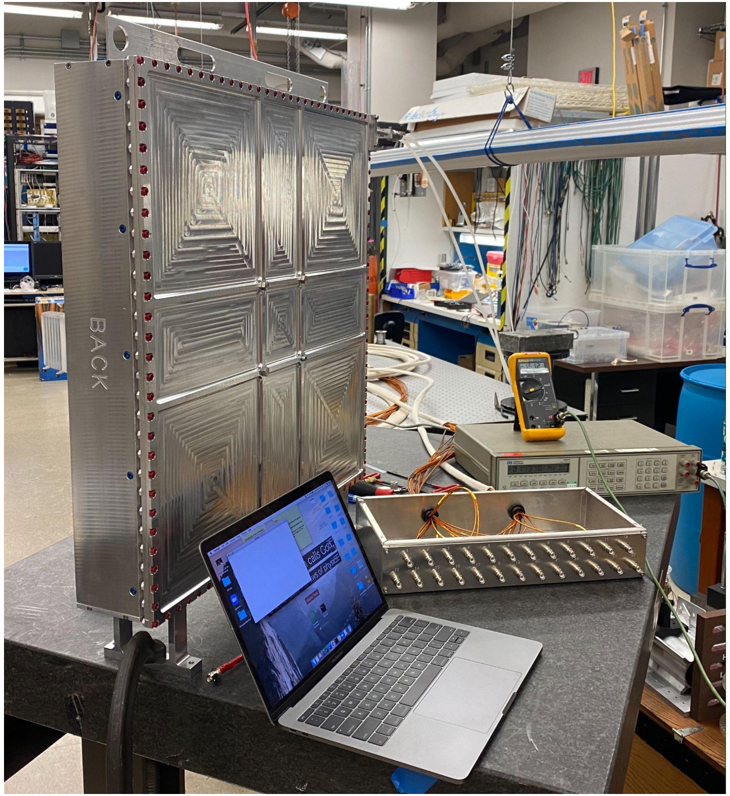
- The Hadron monitor (HM) is a pion monitor, which works under the principle of ionization.

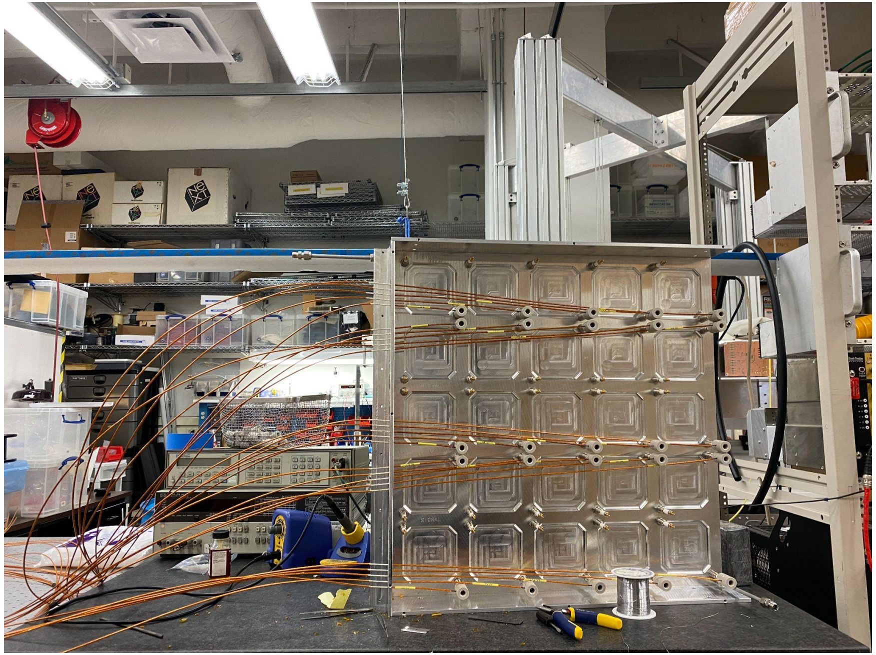
- HMs are fabricated, assembled and tested here at UT!

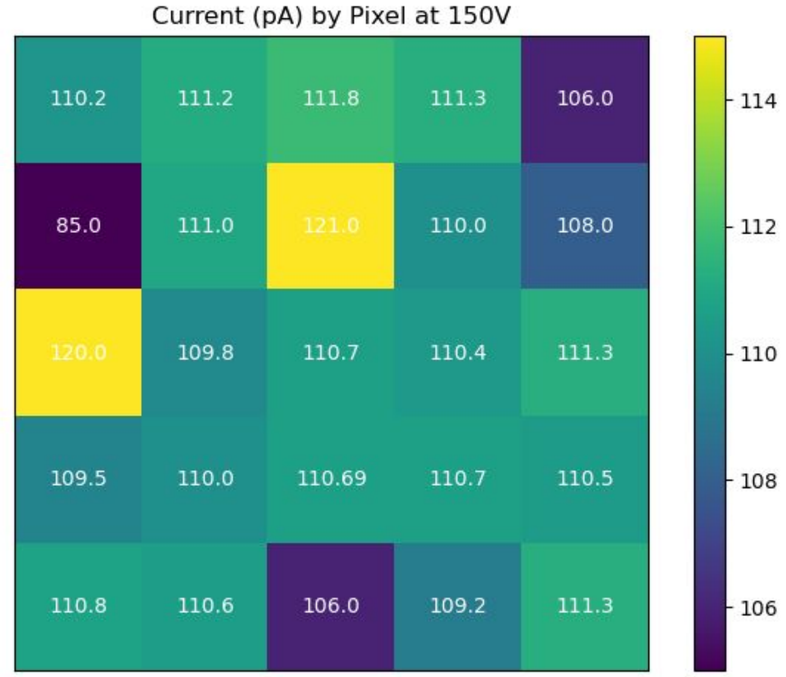
Figure courtesy Ž. Pavlović



Z. Pavlovic, “A Measurement of Muon Neutrino Disappearance in the NuMI Beam,” PhD Thesis, UT Austin (2008).






Current (pA) by Pixel at 150V
110.2
111.2
111.8
111.3
106.0
85.0
111.0
121.0
110.0
108.0
120.0
109.8
110.7
110.4
111.3
109.5
110.0
110.69
110.7
110.5
110.8
110.6
106.0
109.2
111.3
114
112
110
108
106

Interested? Come work with us!

- We’re currently looking for motivated student to join the UTKL lab
  - Get involved with data-taking and simulation!
  - Relevant experience for graduate school!
  - Contact: kyle.klein@utexas.edu for more details