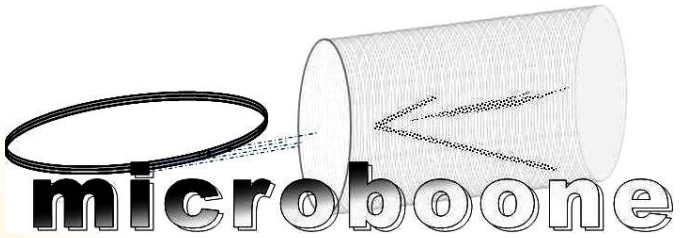
Tests of Magnetic Shielding of MicroBooNE Photomultiplier Tubes at Cryogenic Temperatures: Demonstration of Efficacy



Saint Mary's University
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- Booster Neutrino Beamline at Fermilab
- The MicroBooNE neutrino detector

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- Scintillation light and photomultipliers
- Photomultiplier tube (PMT) testing

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- results I: room temperature
- results II: performance in liquid nitrogen

MicroBooNE

- MicroBooNE: 170 t LArTPC in Booster Neutrino Beam
- investigate MiniBooNE low-energy excess; measure BNB-energy cross-sections
- detector R&D for upscaling LArTPCs
- to be housed in LArTF

Regina Rameika, MicroBooNE Project Manager at LArTF groundbreaking January 23 2012

Booster Neutrino Beam (BNB)

- low energy (spectrum peaks around 1 GeV) neutrino beam line
- start with protons from Fermilab Booster (8 GeV); impinge on Be target inside magnetic focusing device ("horn") to sign-select 2ndaries
- positive 2ndaries decay to neutrinos ($\pi^+ \rightarrow \mu^+ \nu_\mu$)

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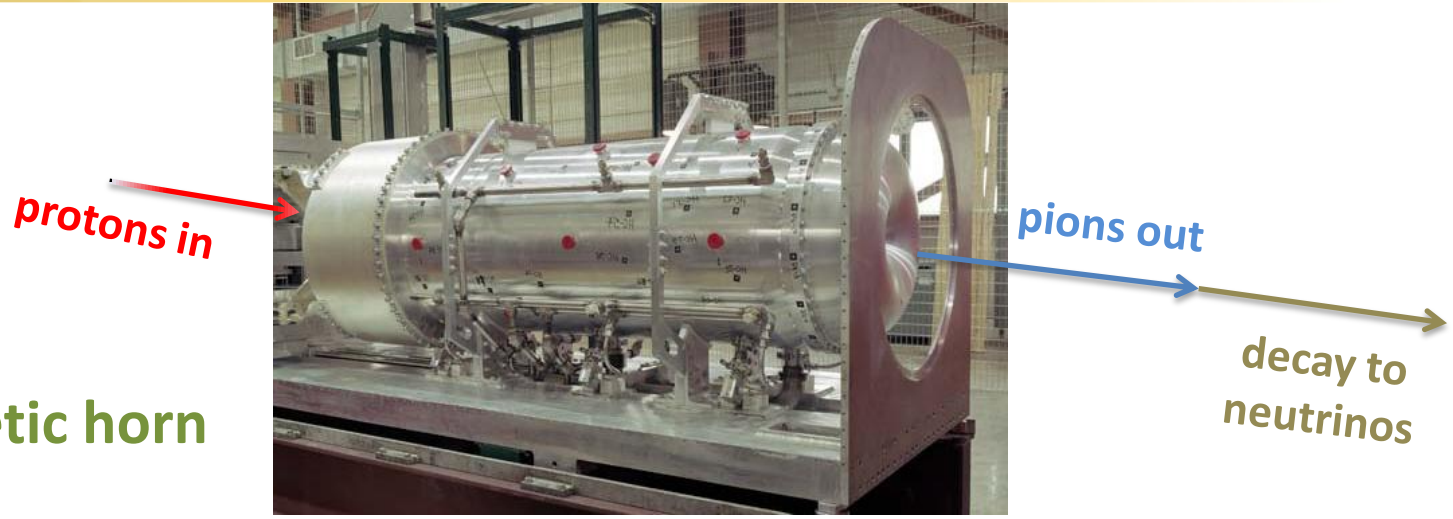
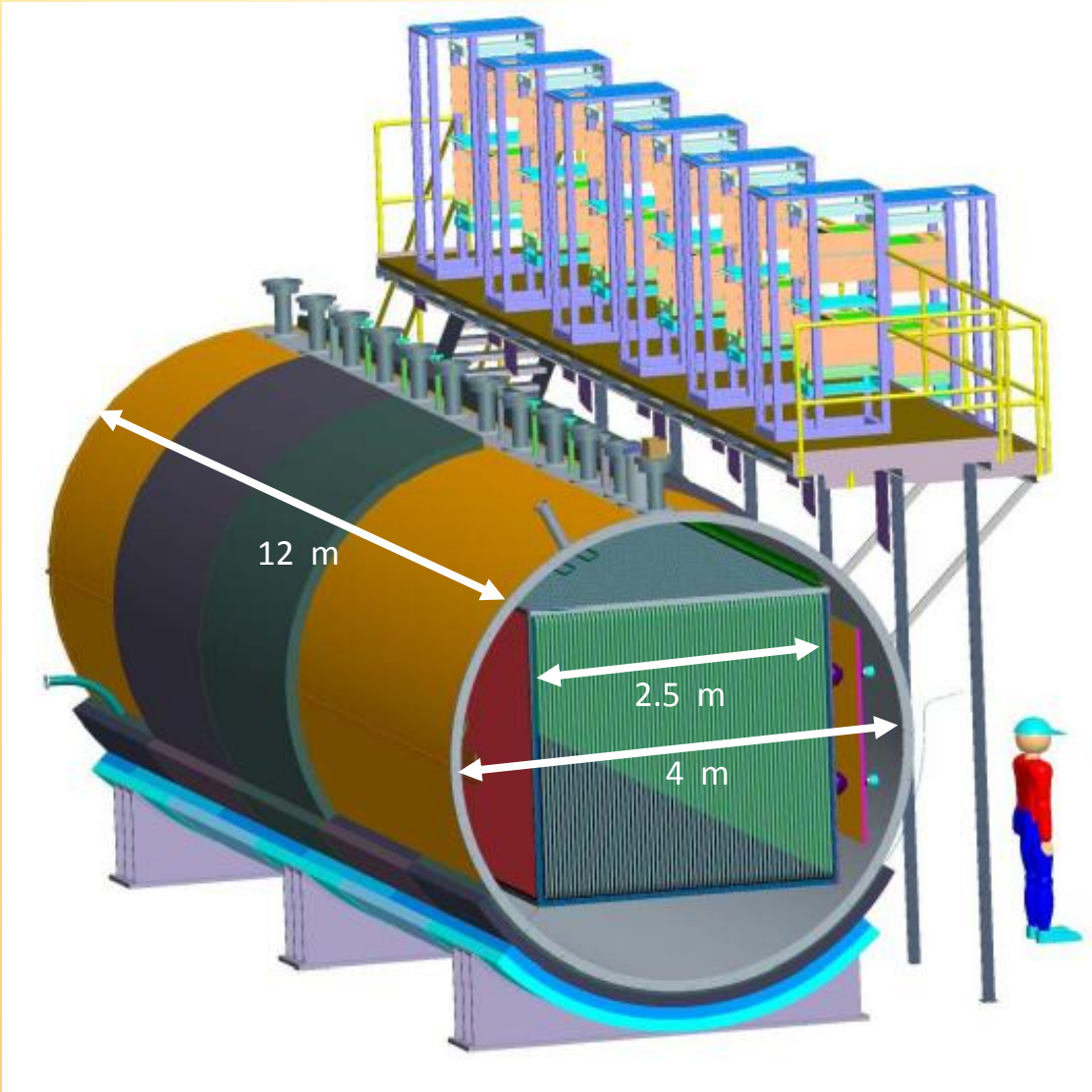


BNB magnetic horn

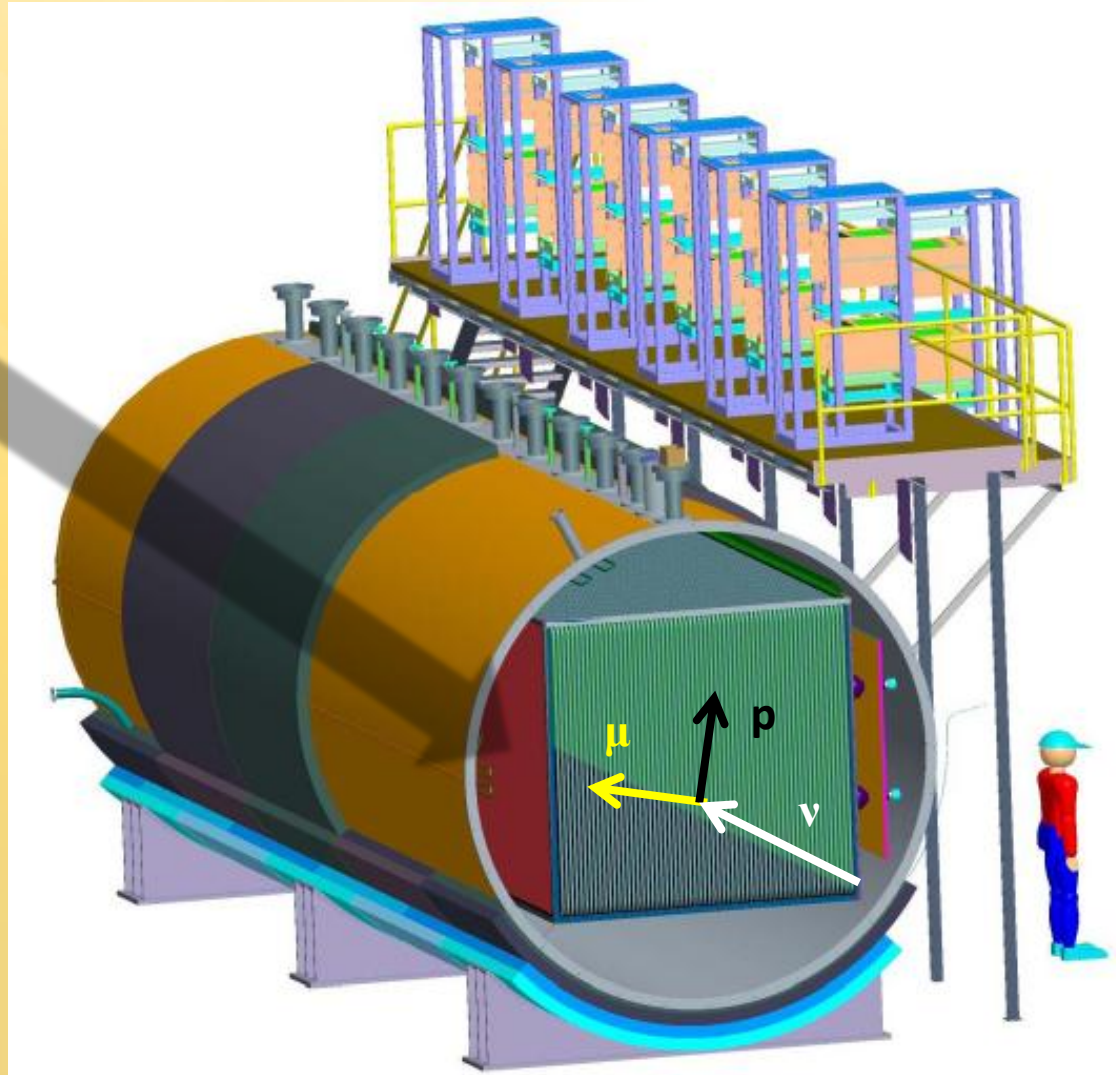
MicroBooNE

- active detector: serves both as interaction target and charged debris tracker / identifier
- filled with 170 tons of liquid argon



MicroBooNE

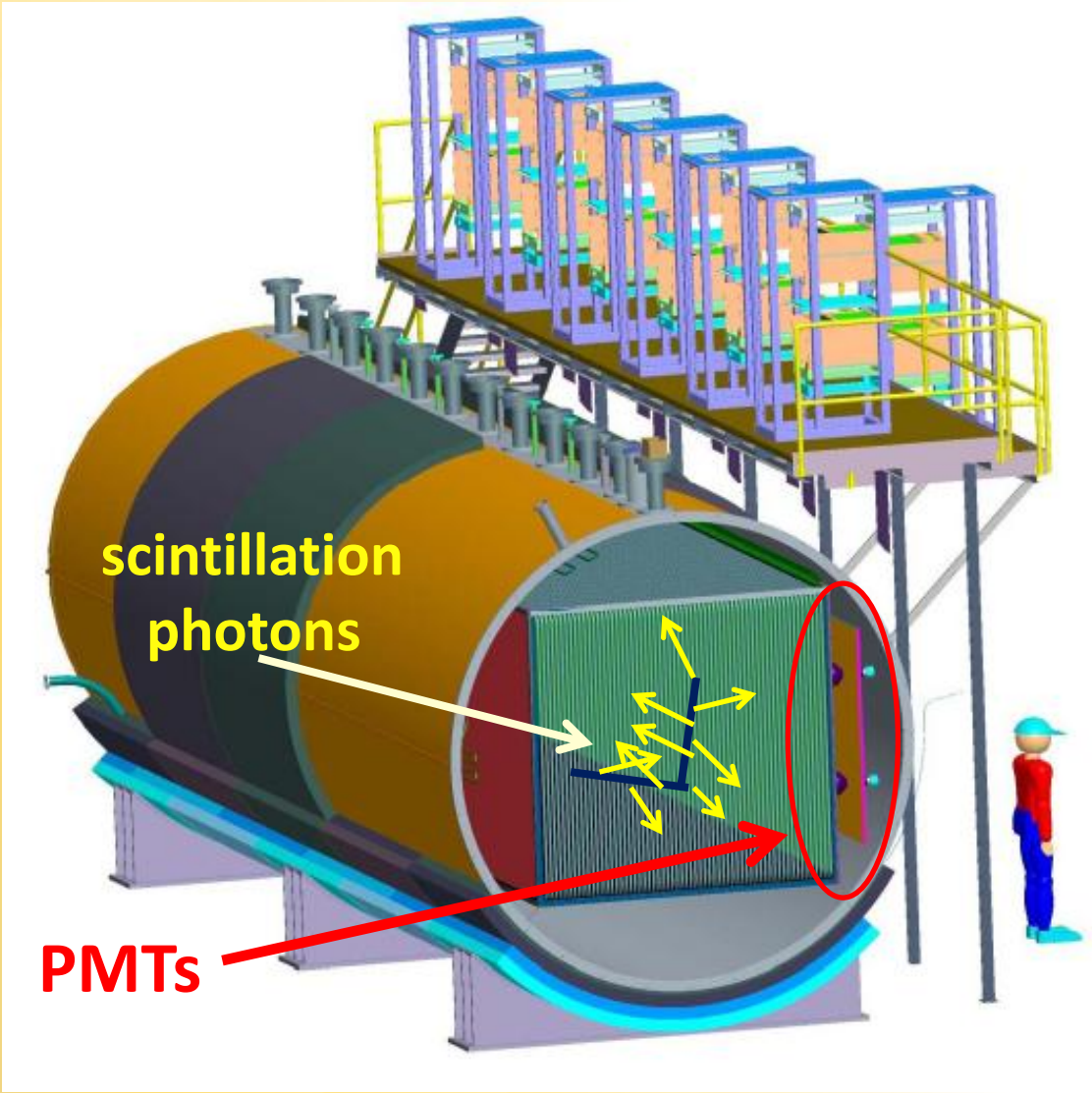
- Liquid argon time projection chamber (LArTPC): measure particle direction and energy (by ionization loss)
  → **particle ID**



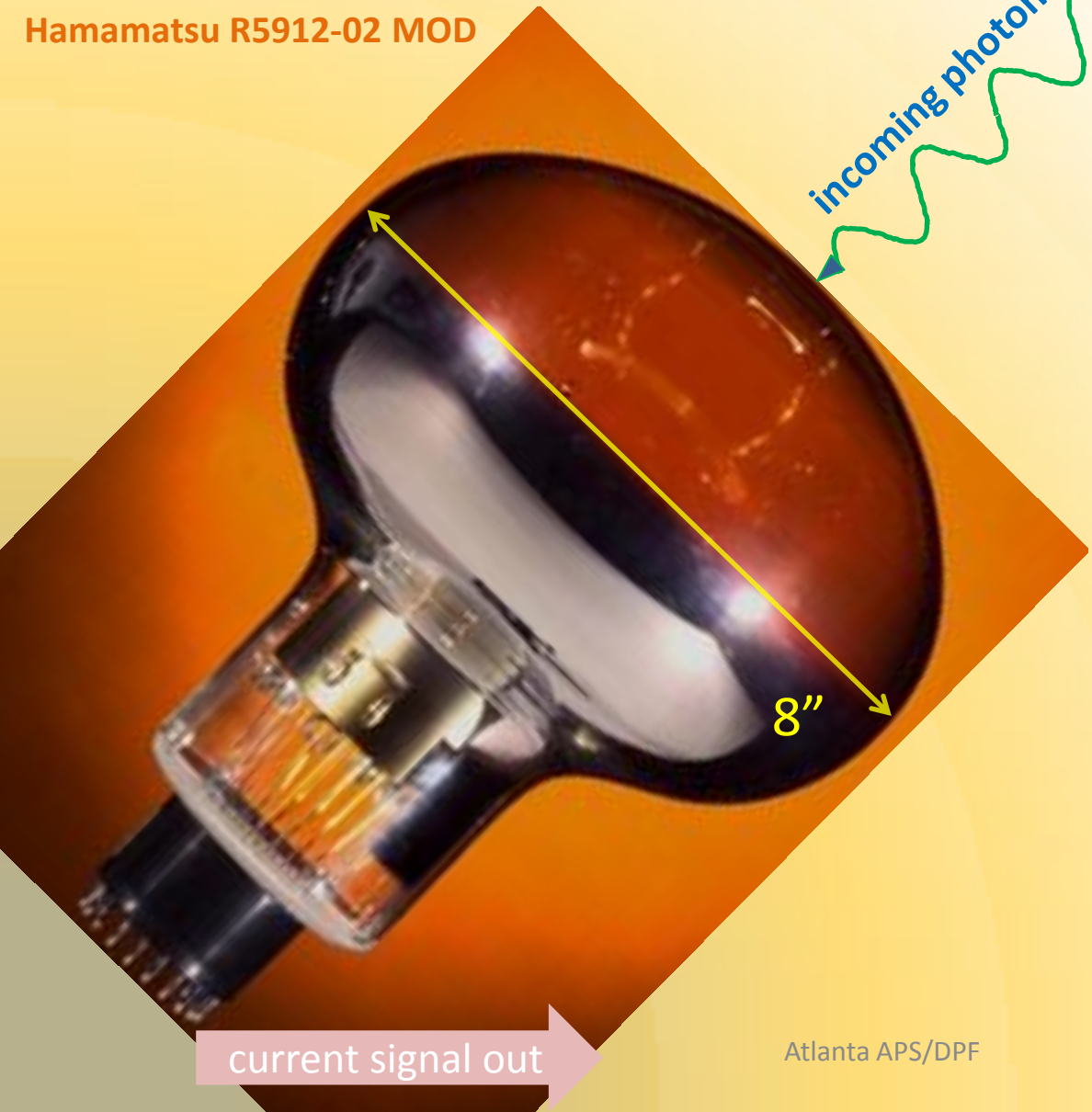
MicroBooNE

- LAr produces 6000 scintillation (UV) photons/MeV deposited
- wave-shifted (via TPB plate) scintillation light detected by photomultiplier tube (PMT) array

  →measure of **event time, energy**

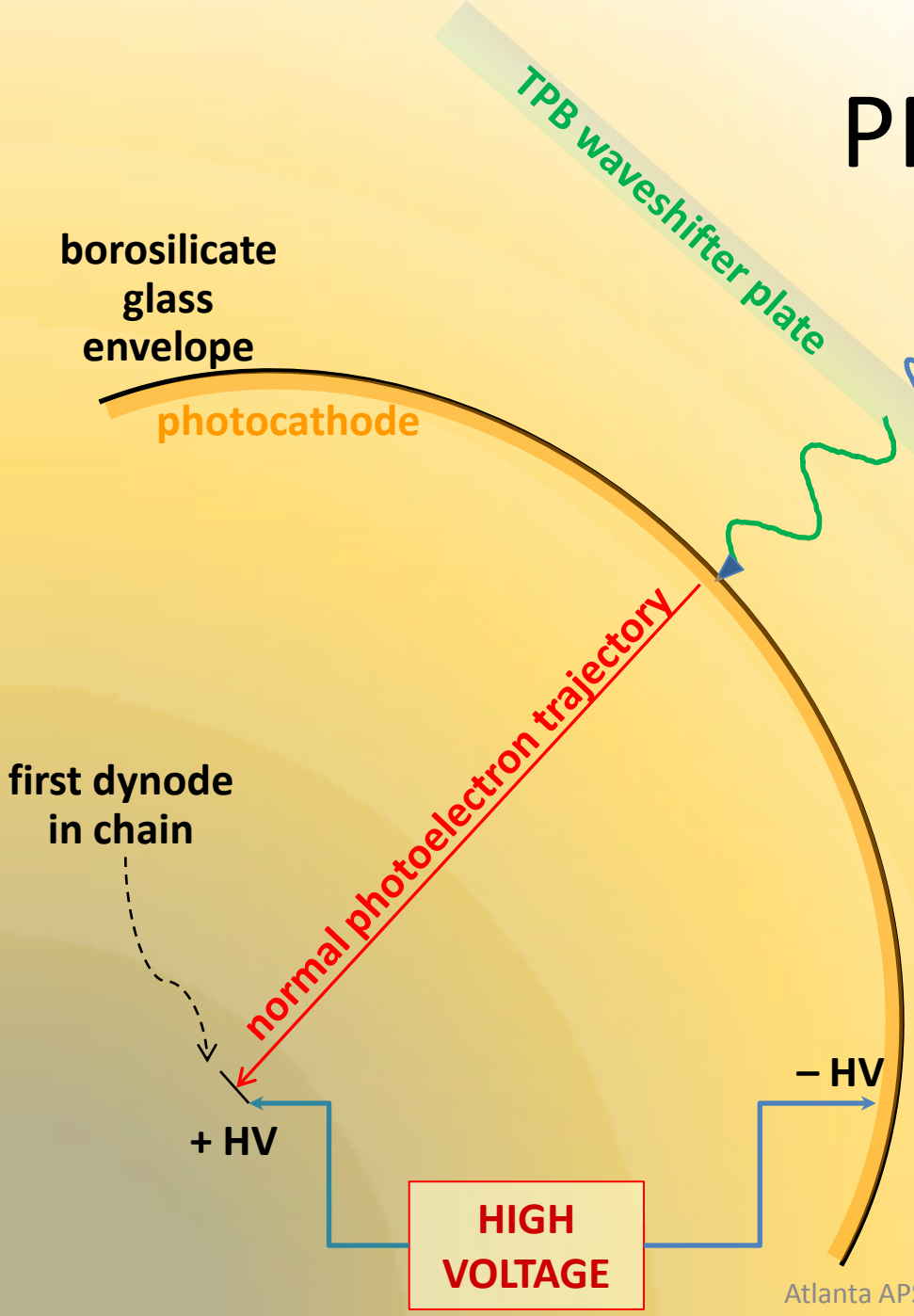


PMT fundamentals



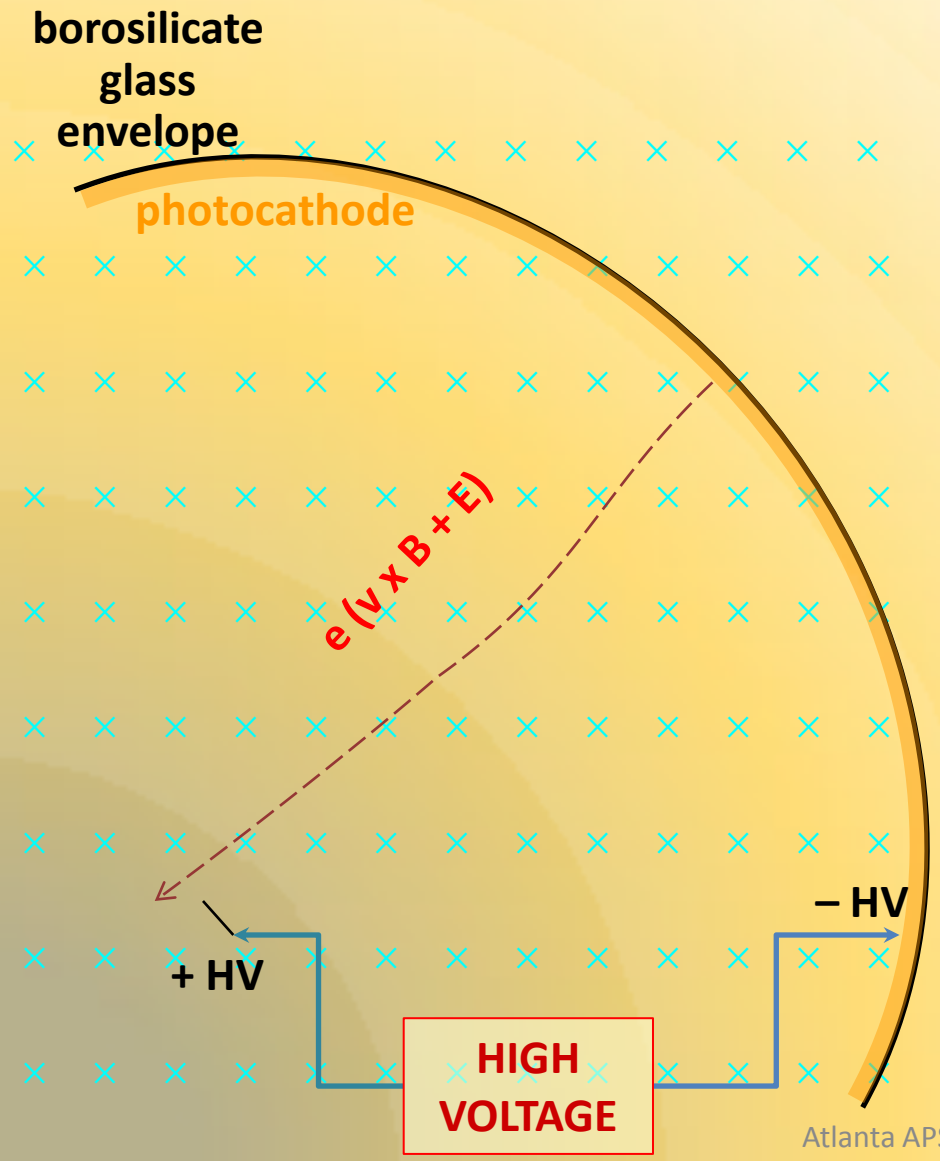
- **photomultiplier tubes are light-sensitive detectors that use the photoelectric effect to generate measurable electrical signals from small numbers of photons**

PMT fundamentals



- **Photon strikes photocathode → electron emission → accelerated to first dynode by HV**

PMT fundamentals



- Photon hitting photocathode → electron emission → accelerated to first dynode by HV
- **Magnetic field can deflect electron → miss first dynode**

test stand design

- tube is very light-sensitive: need light-tight enclosure with capability for LN_2 immersion
- examine impact of geomagnetic fields on PMT performance by
  - exposing PMT to short bursts of very low intensity light (from LED) presented to tube via optical fiber
  - measure integrated charge output (Q) for PMT pulses in coincidence with LED pulse
  - rotate tube + fiber (with and without shield), and measure change in Q as rotation angle changes

NOTE: (“pitch”) rotation occurs out of plane of drawing, NOT around the cylinder axis of symmetry

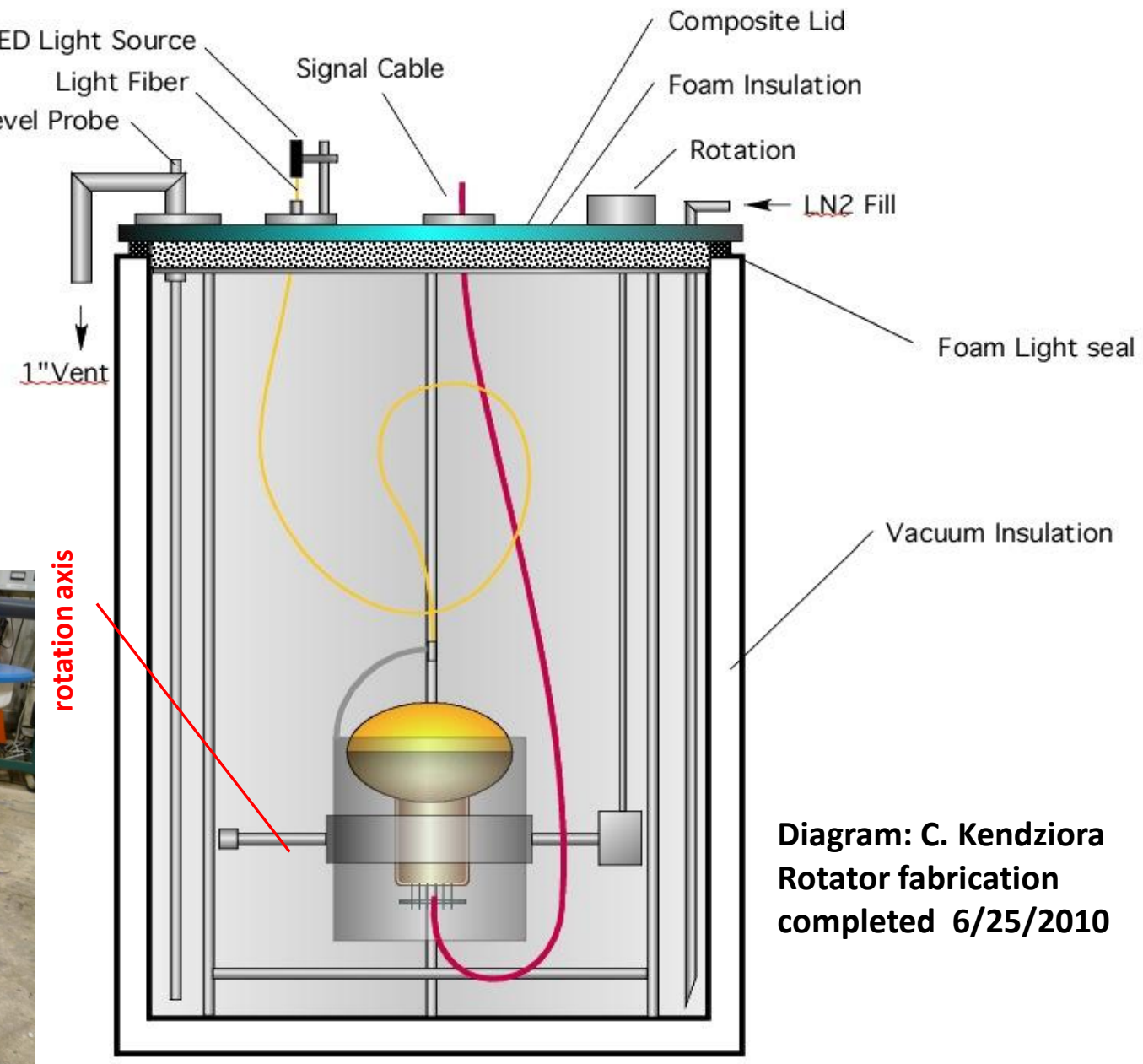
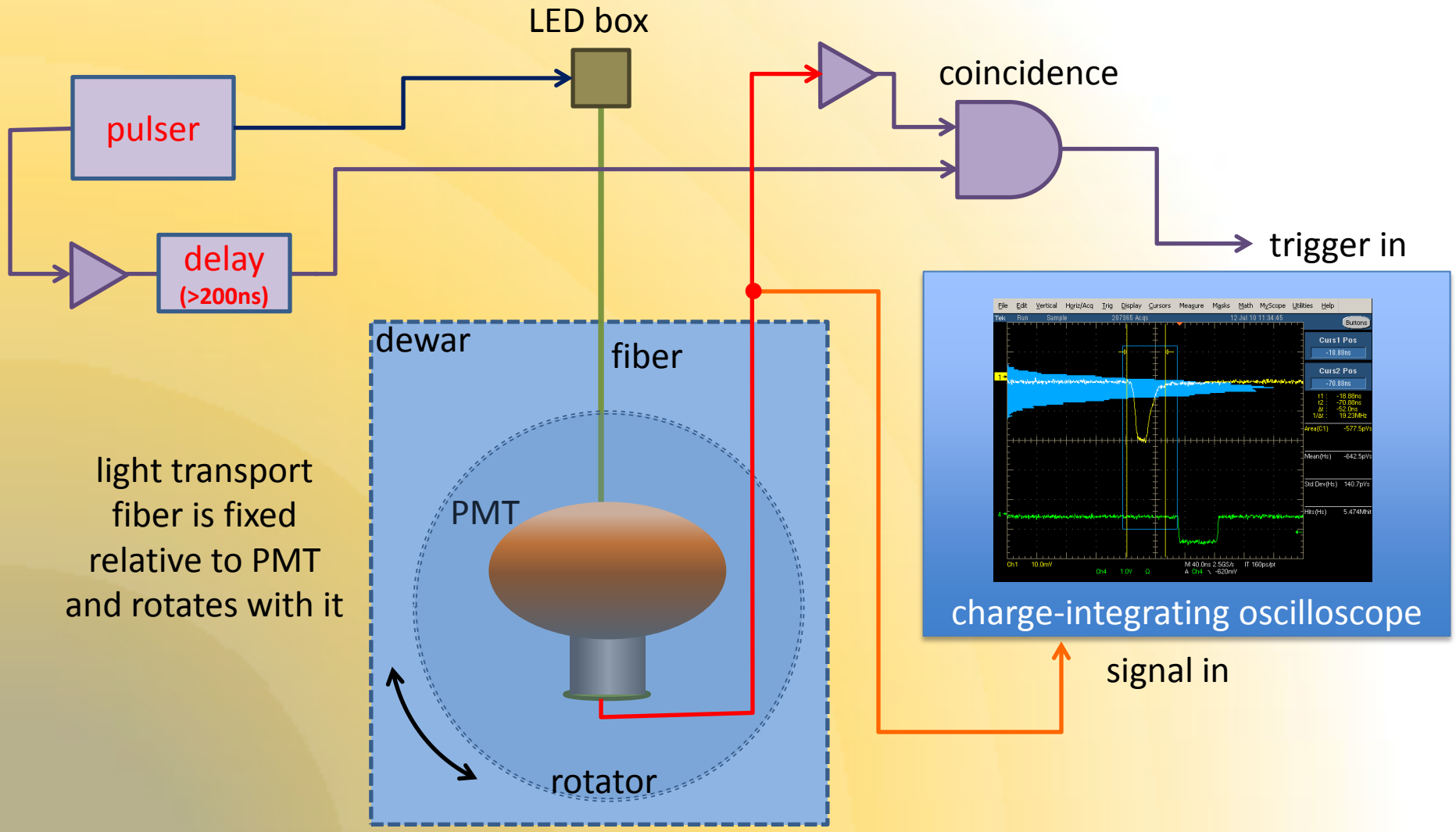


Diagram: C. Kendziora
Rotator fabrication completed 6/25/2010

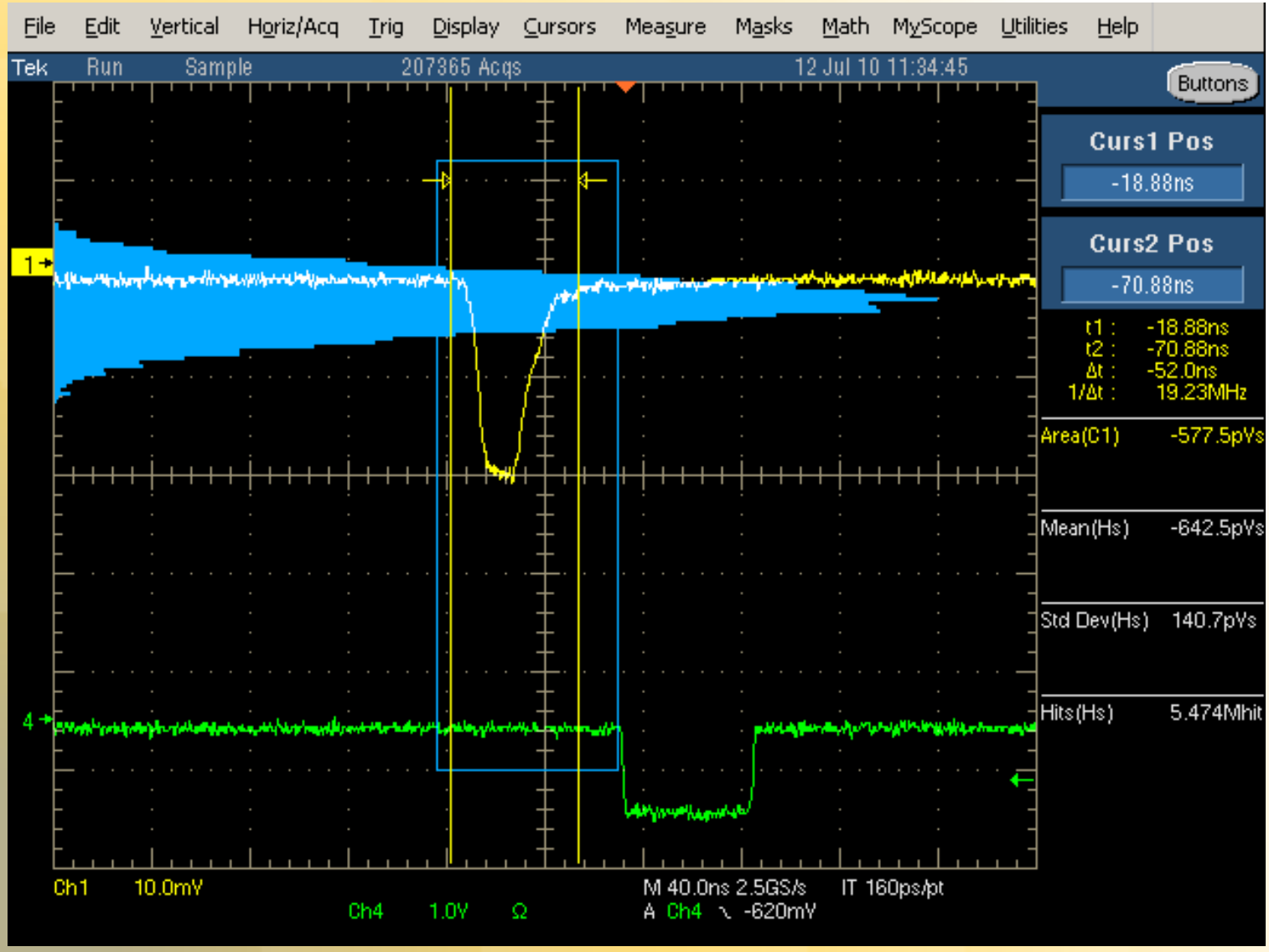

PMT
optical fiber
rotator axis
magnetic shield

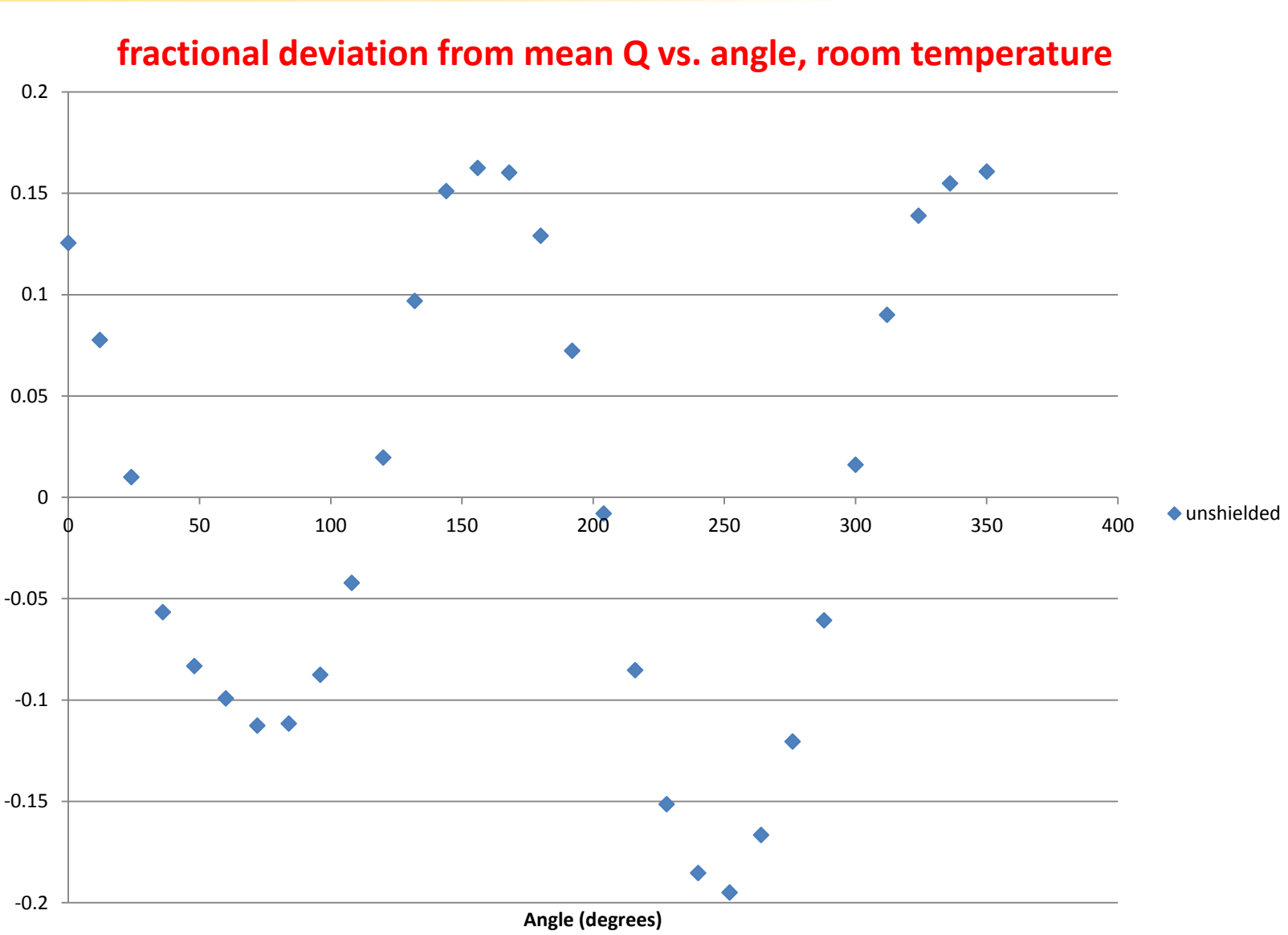
block diagram

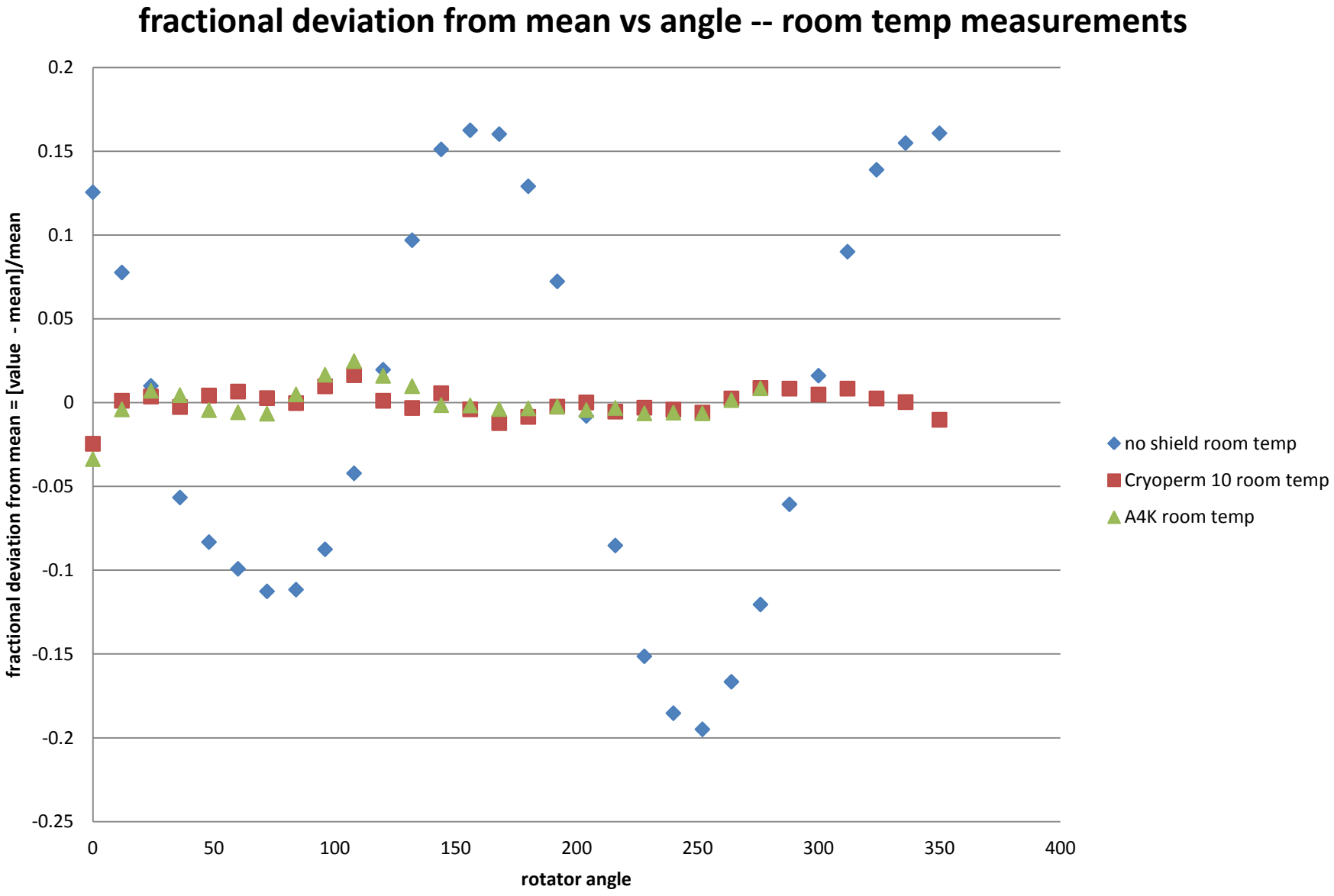


light transport fiber is fixed relative to PMT and rotates with it

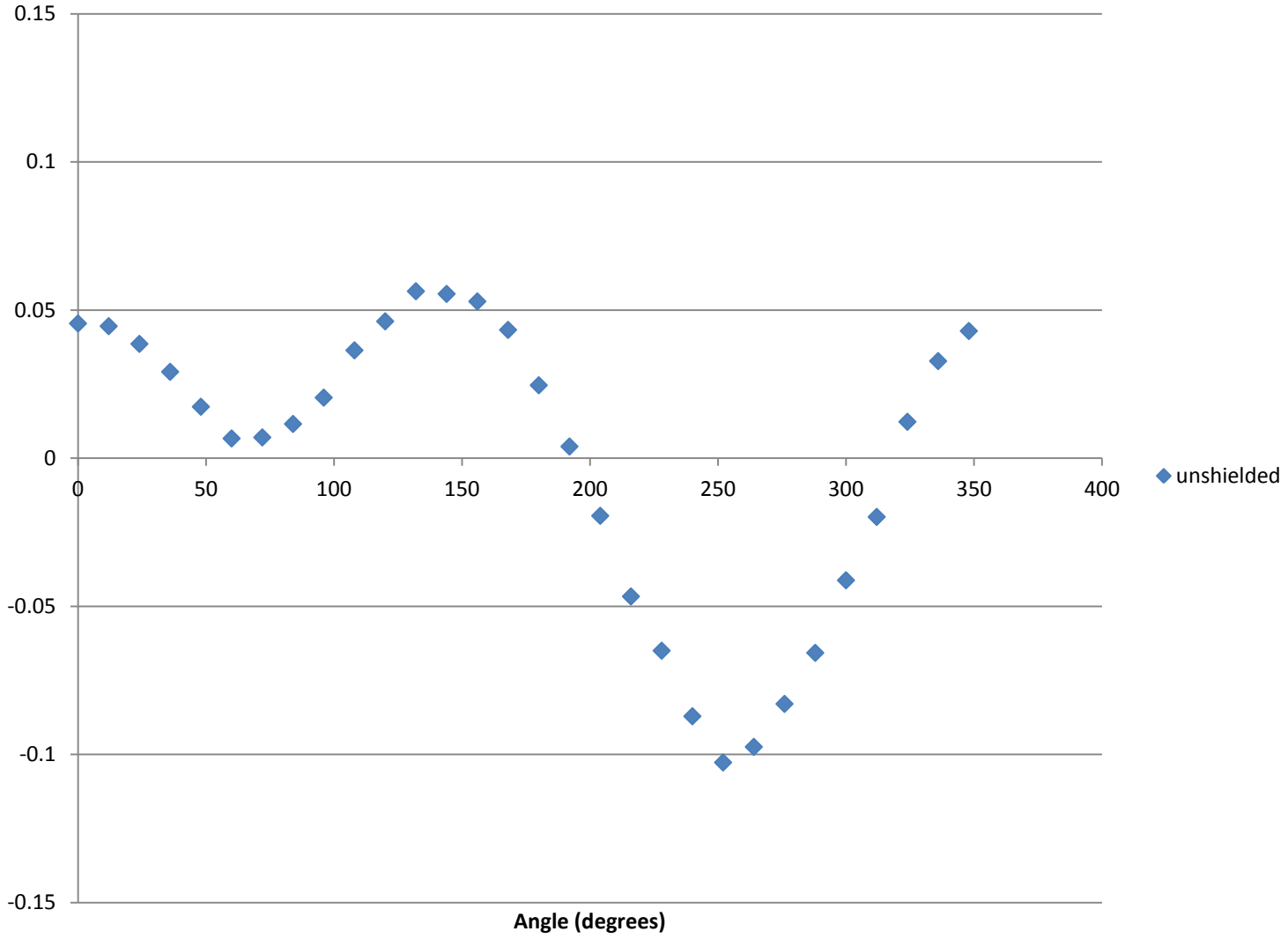
integrated Q – variation w/ angle?



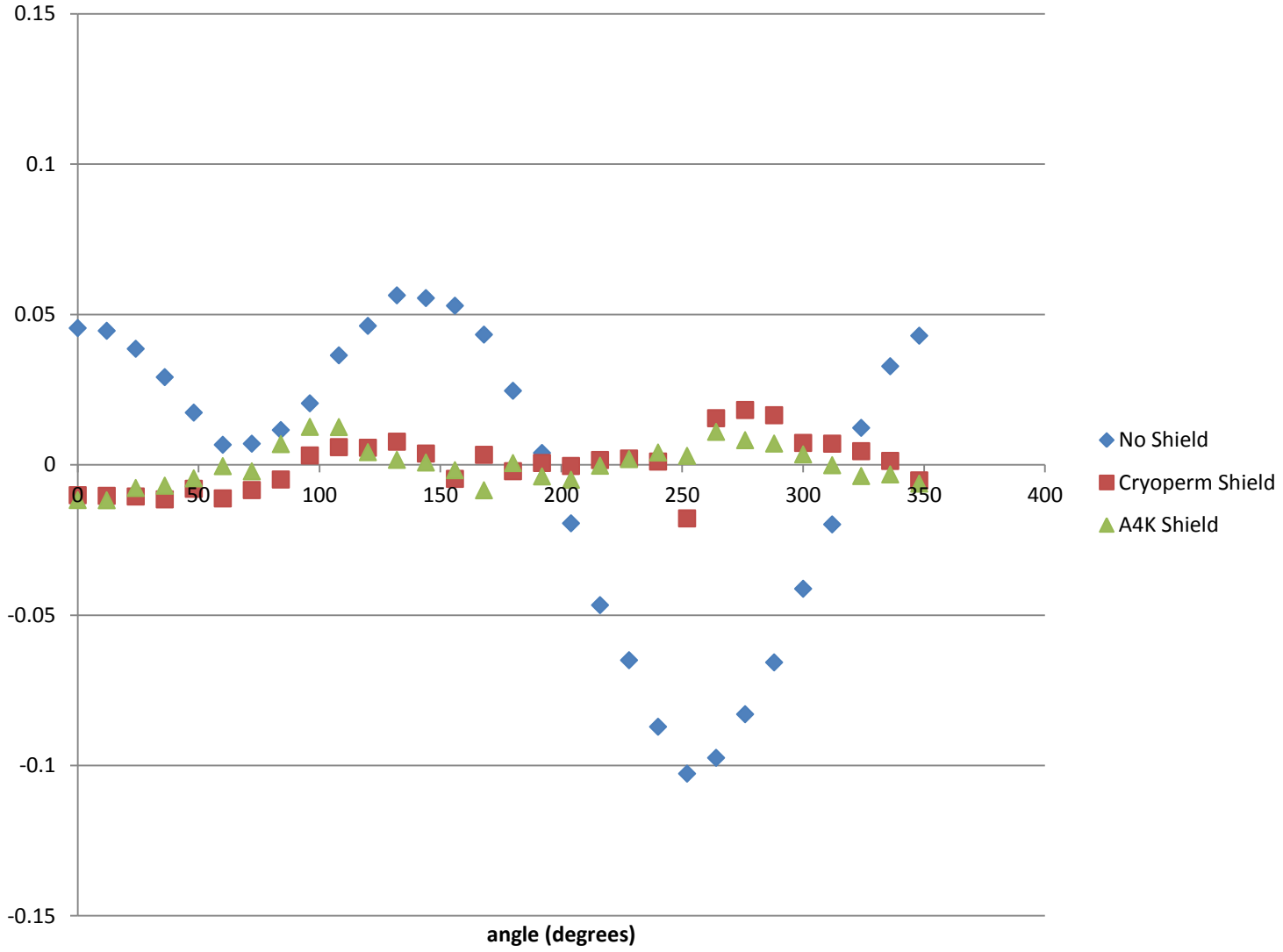

fractional deviation from mean Q vs. angle, room temperature
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0
50
100
150
200
250
300
350
400
Angle (degrees)
unshielded


fractional deviation from mean vs angle -- room temp measurements
fractional deviation from mean = [value - mean]/mean
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
0
50
100
150
200
250
300
350
400
rotator angle
no shield room temp
Cryoperm 10 room temp
A4K room temp

fractional deviation from mean Q vs. angle, liquid nitrogen



fractional deviation from mean Q vs. angle, liquid nitrogen



conclusions

- this work is one of the first demonstrations of cryogenic magnetic shielding for large diameter PMTs

- to the extent this apparatus is able to measure, these shields effectively remove the performance change caused by geomagnetic fields

next steps

- investigate (Monte Carlo) potential wave-shifter plate shadowing by shield
- for completeness (final report)
  - repeat tests with second tube
  - check effect with room temperature shield (Amumetal)

acknowledgements

- Particular thanks for major support are due to Fermilab staff physicist **Steven Pordes**, design engineer **Cary Kendziora**, fabrications machinist **Kelly Hardin**, and the PAB group
- Helpful assistance was also provided by our MicroBooNE collaborators from MIT, led by Professor **Janet Conrad**
- this work was supported by the **National Science Foundation** under grant PHY-1000214

Thank you very much.

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