Magnetic Shielding Tests for MicroBooNE Photomultiplier Tubes in a Cryogenic Environment: First Results and Future Plans

Evan R Shockley, Timothy D McDonald, and Paul J Nienaber
Department of Physics
Saint Mary's University of Minnesota

- 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
- future plans

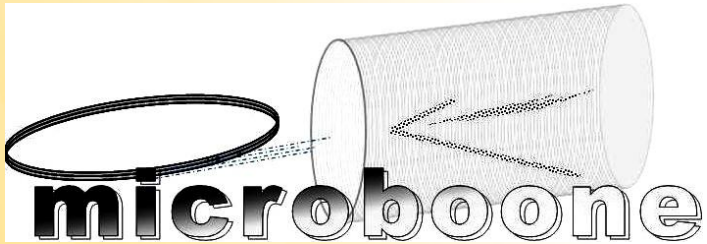
MicroBooNE

- Main detector: 170 t Liquid Argon Time Projection Chamber (LArTPC) in Booster Neutrino Beam (BNB)
- Physics goals:
  - investigate MiniBooNE low-energy "e^-" excess
  - measure BNB-energy cross-sections on argon

MicroBooNE

- MicroBooNE R&D: explore next milestone on path toward larger-scale LArTPCs (→LBNE)
- MicroBooNE is first occupant of new Liquid Argon Test Facility

(see Ellen Klein's poster)

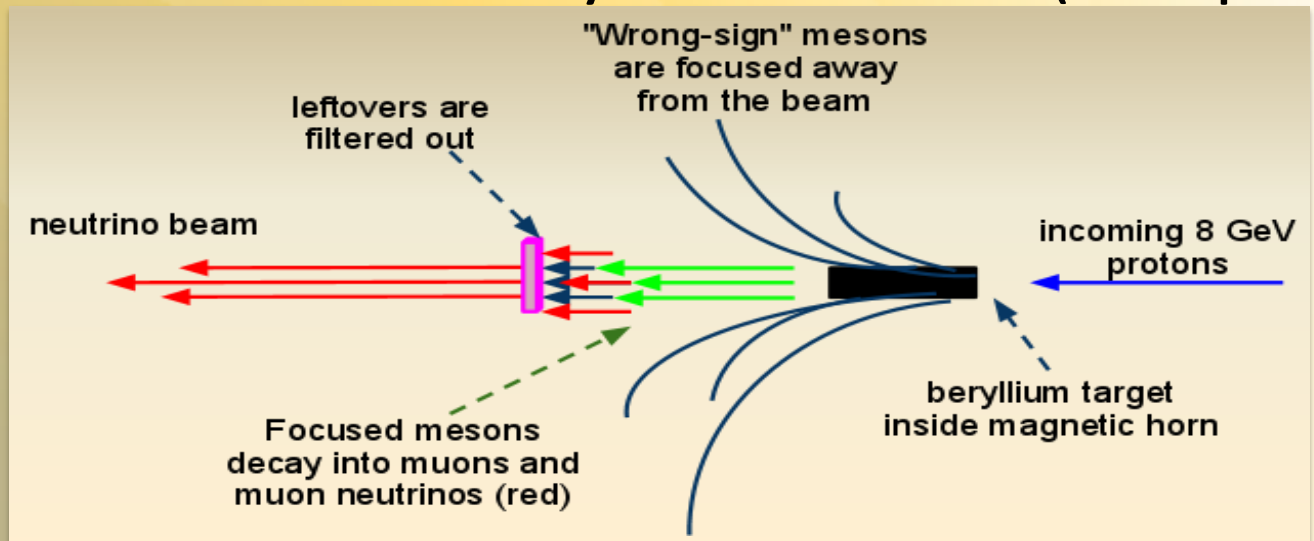


LArTF building construction as of June 4 2012

photo: Cindy Arnold, FNAL VMS

Booster Neutrino Beam (BNB)

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



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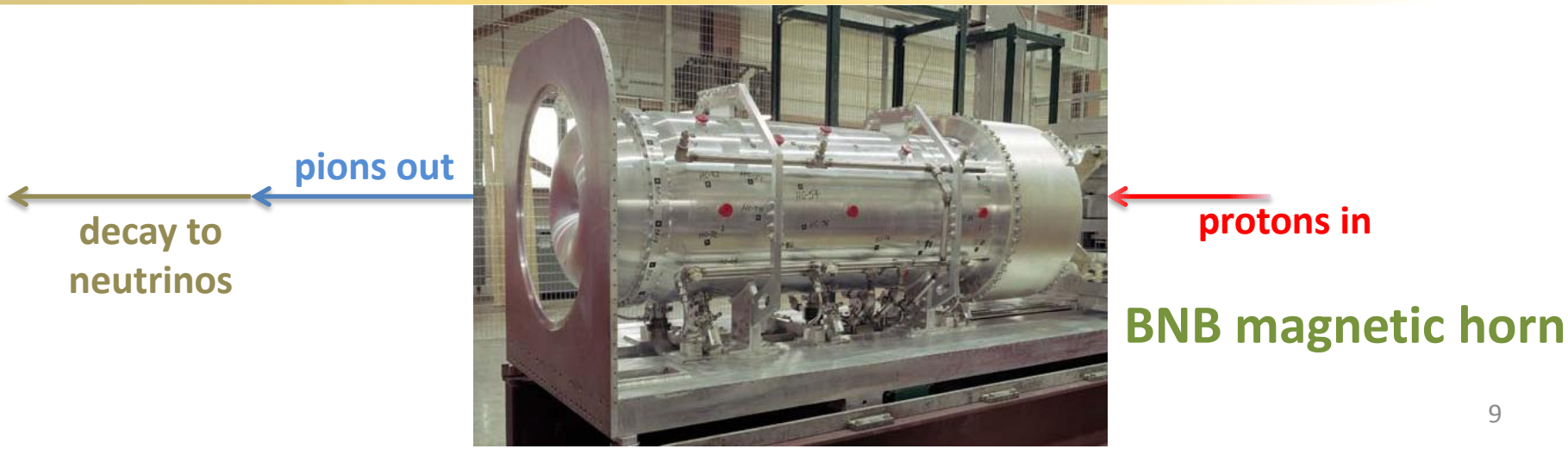
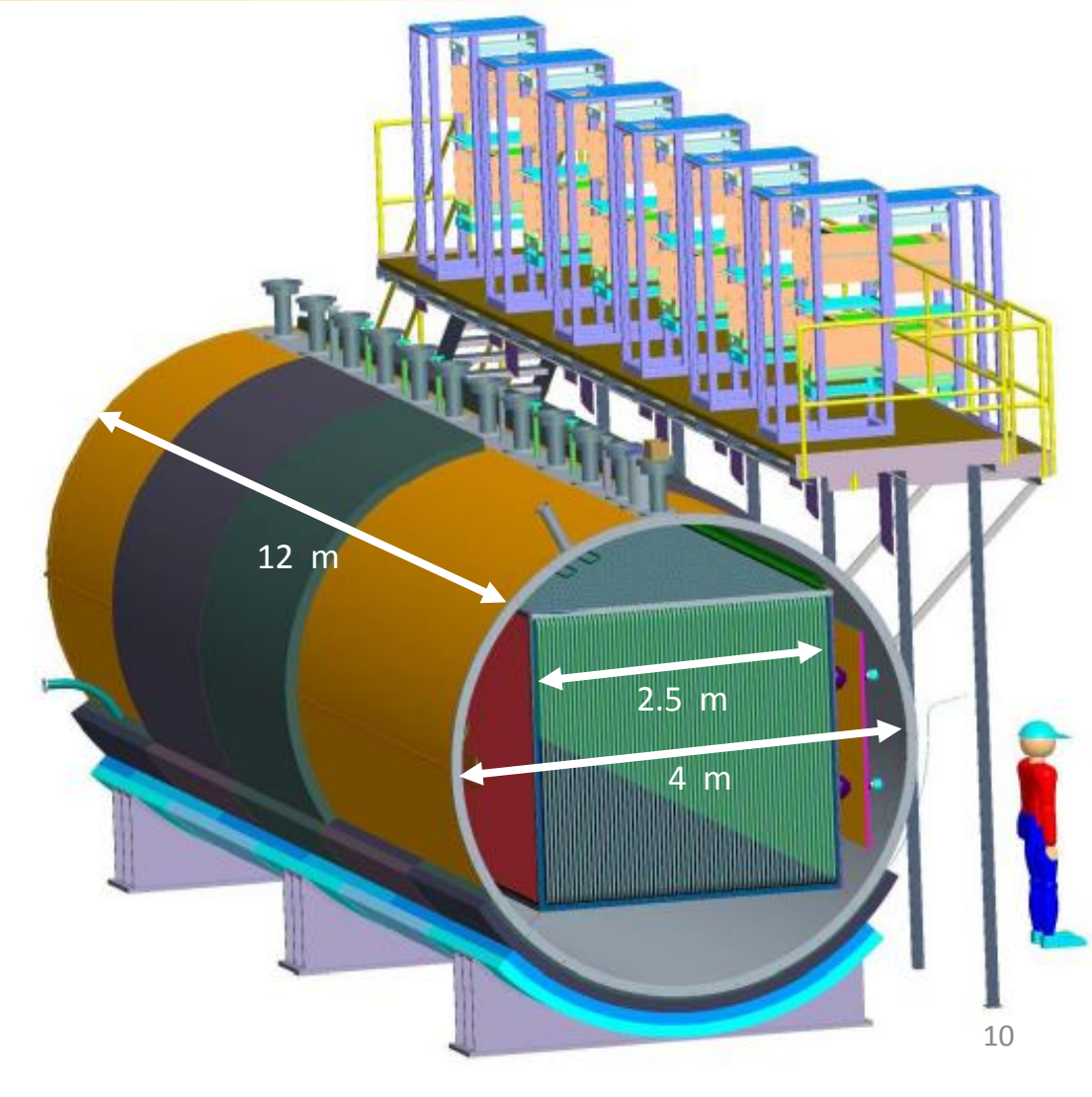


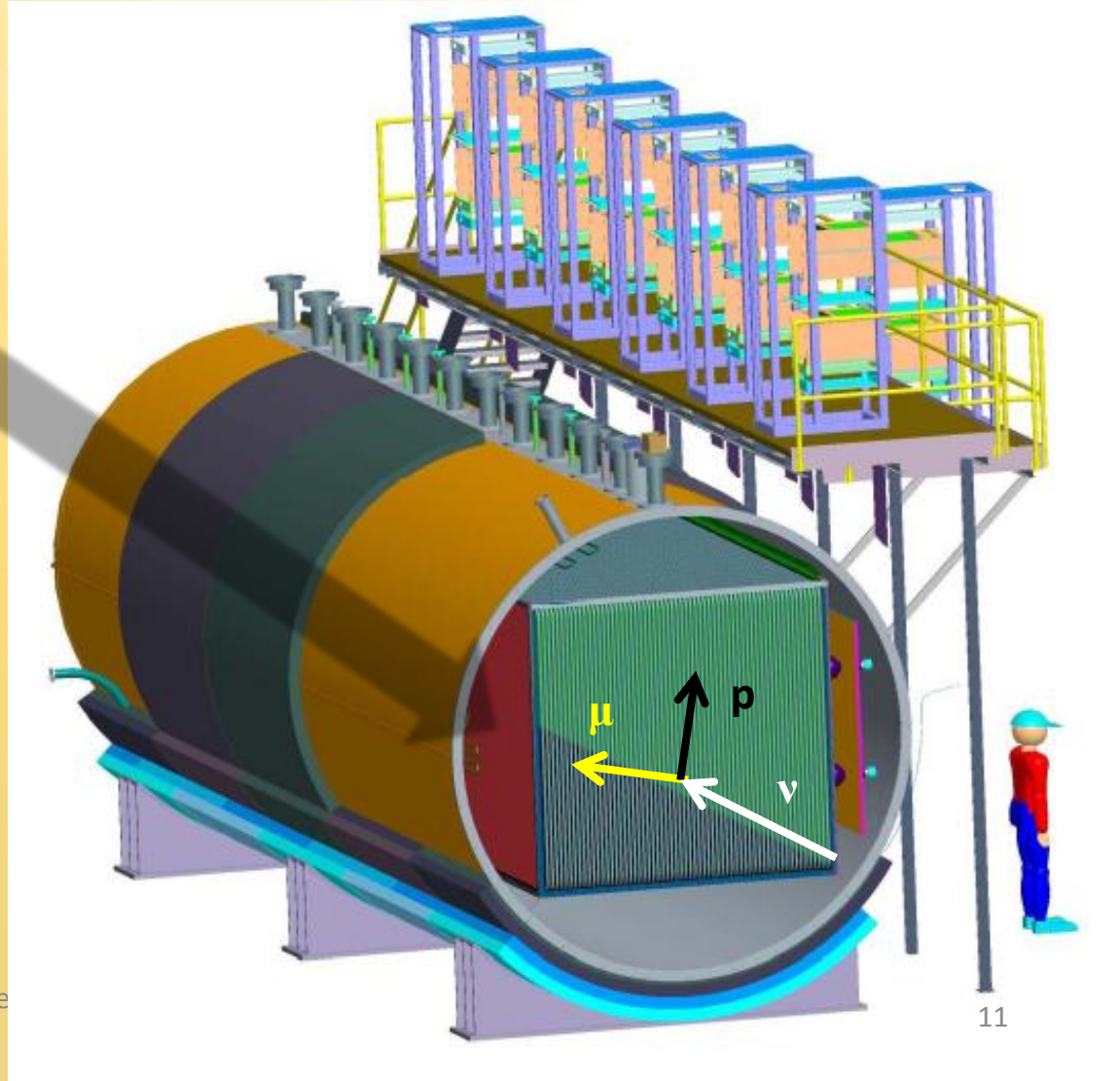
MicroBooNE

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



MicroBooNE

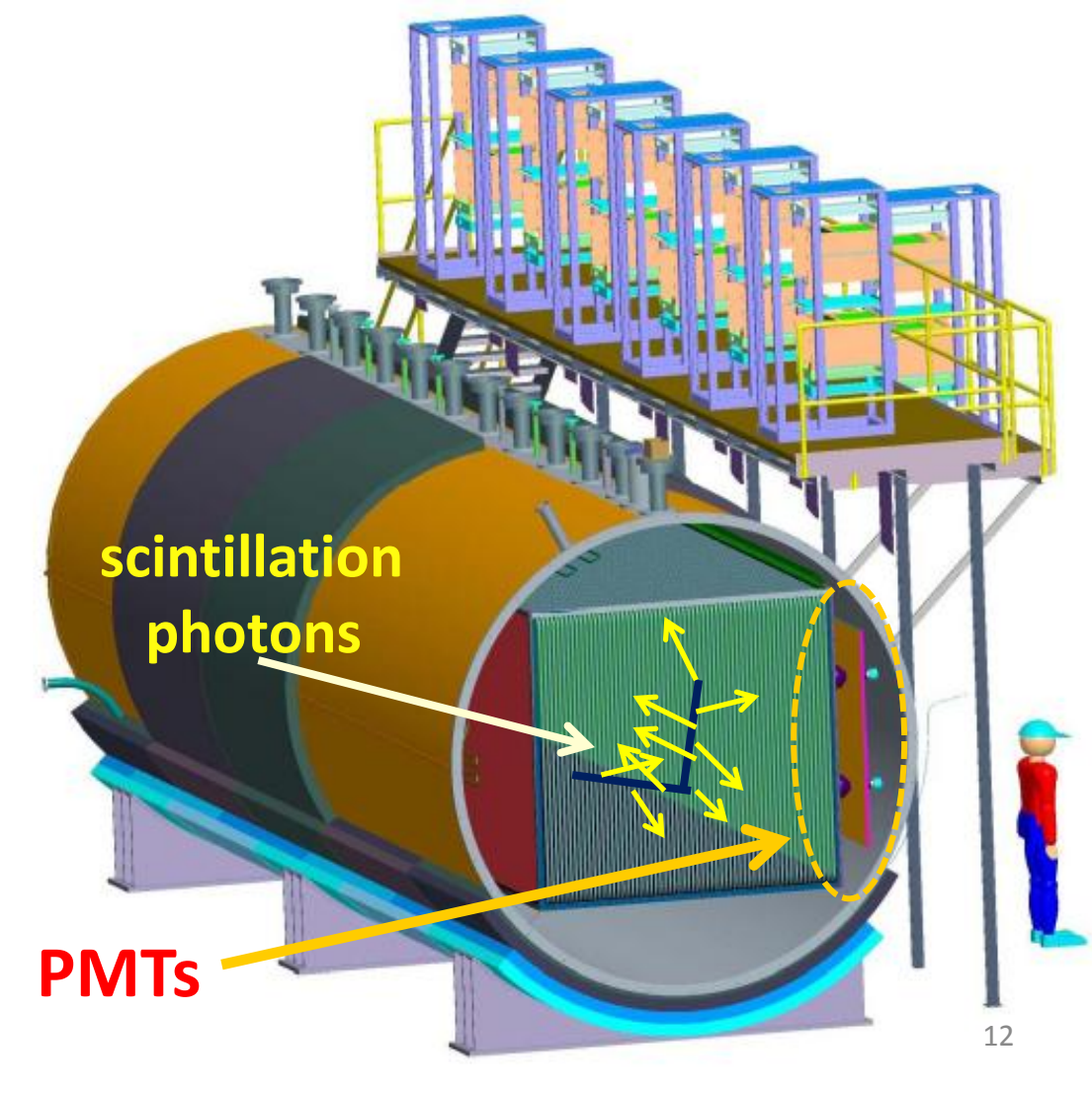
- Liquid argon time projection chamber (LArTPC): measure particle direction and energy (by ionization loss) → **particle ID**



MicroBooNE

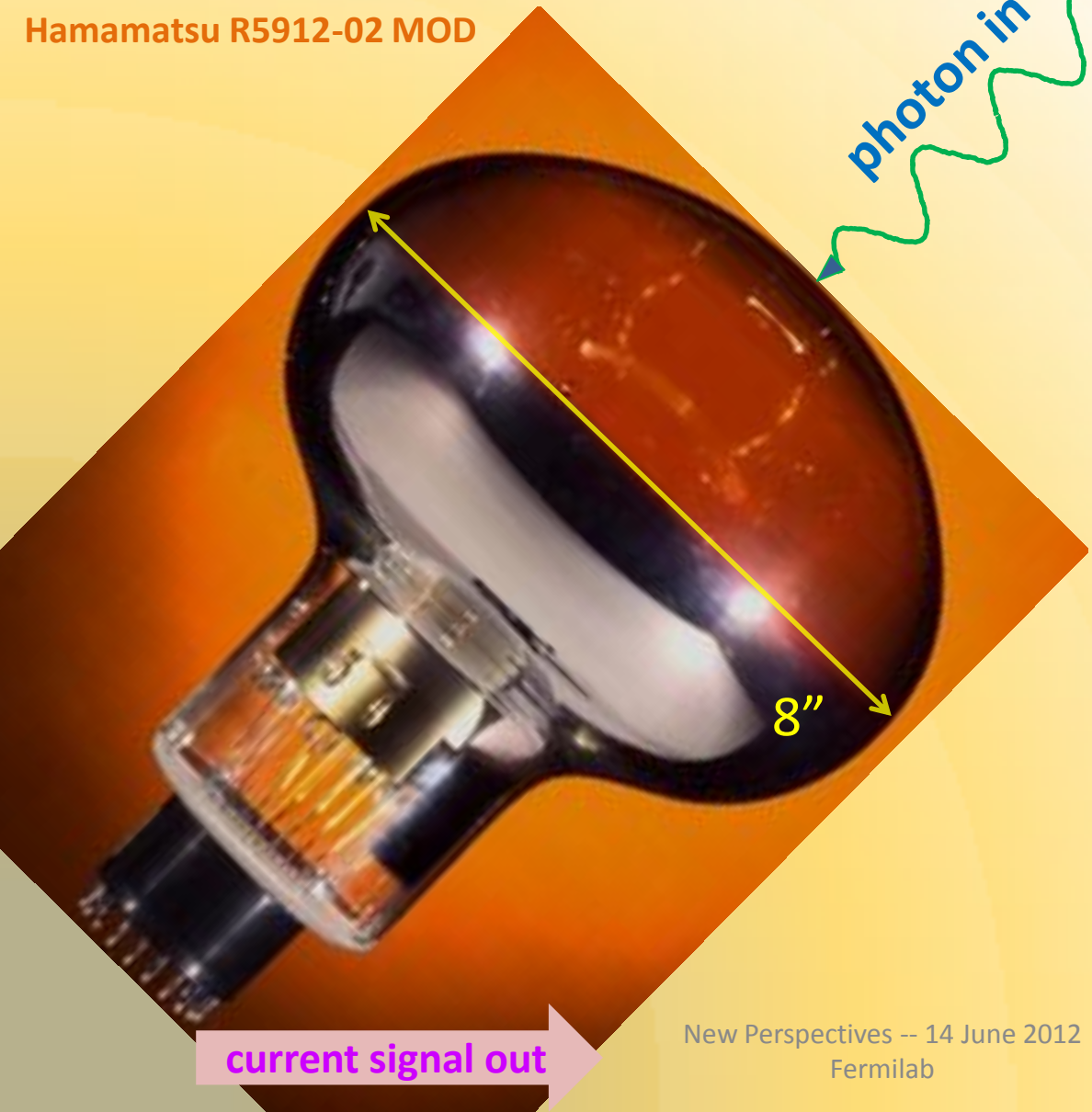
- liquid argon produces 6000 prompt scintillation (UV) photons/MeV deposited
- λ-shifted (via TPB plate) scintillation light detected by photomultiplier tube (PMT) array

  →PMTs measure **event time, energy**



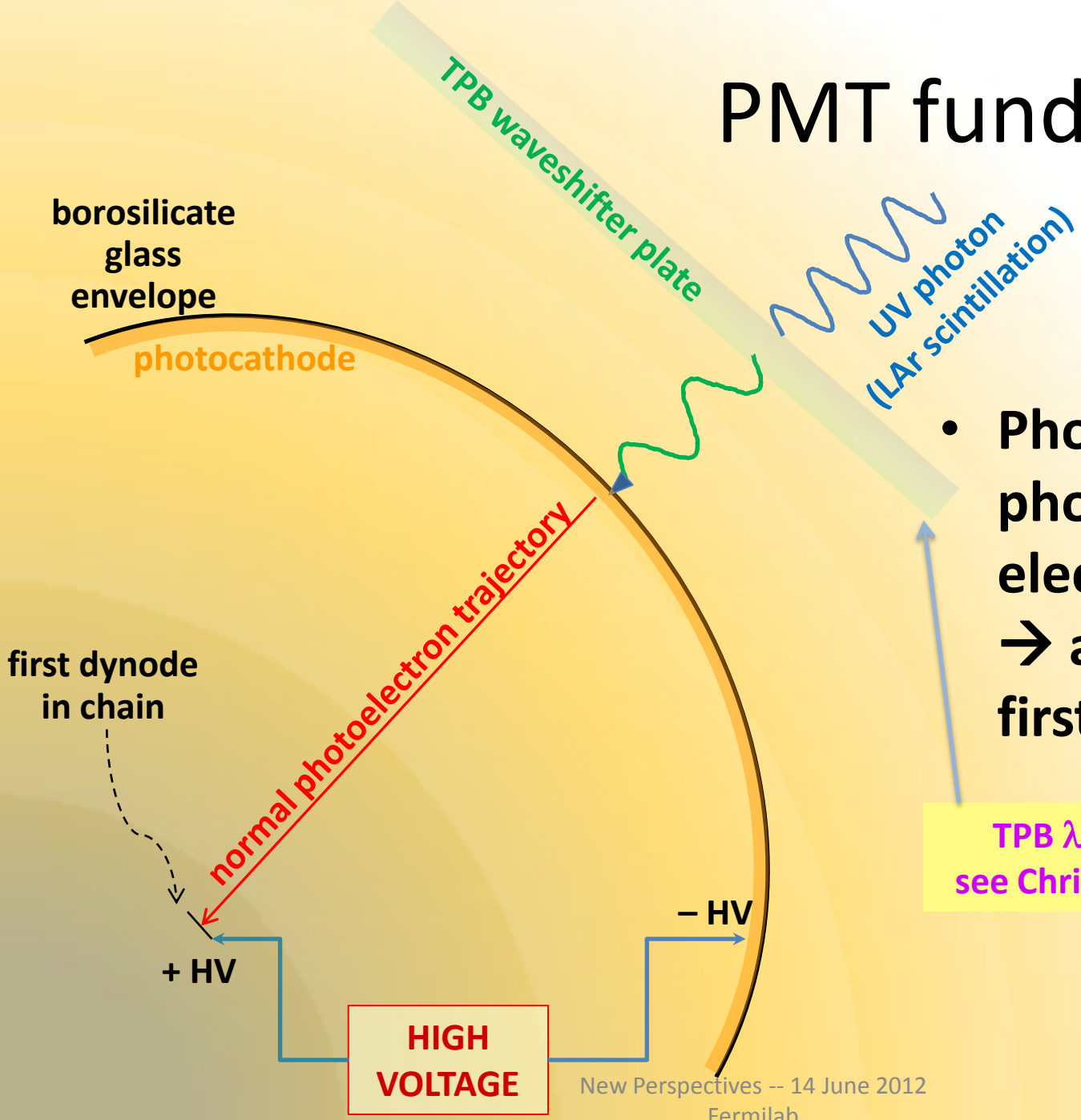
PMT fundamentals

Hamamatsu R5912-02 MOD



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

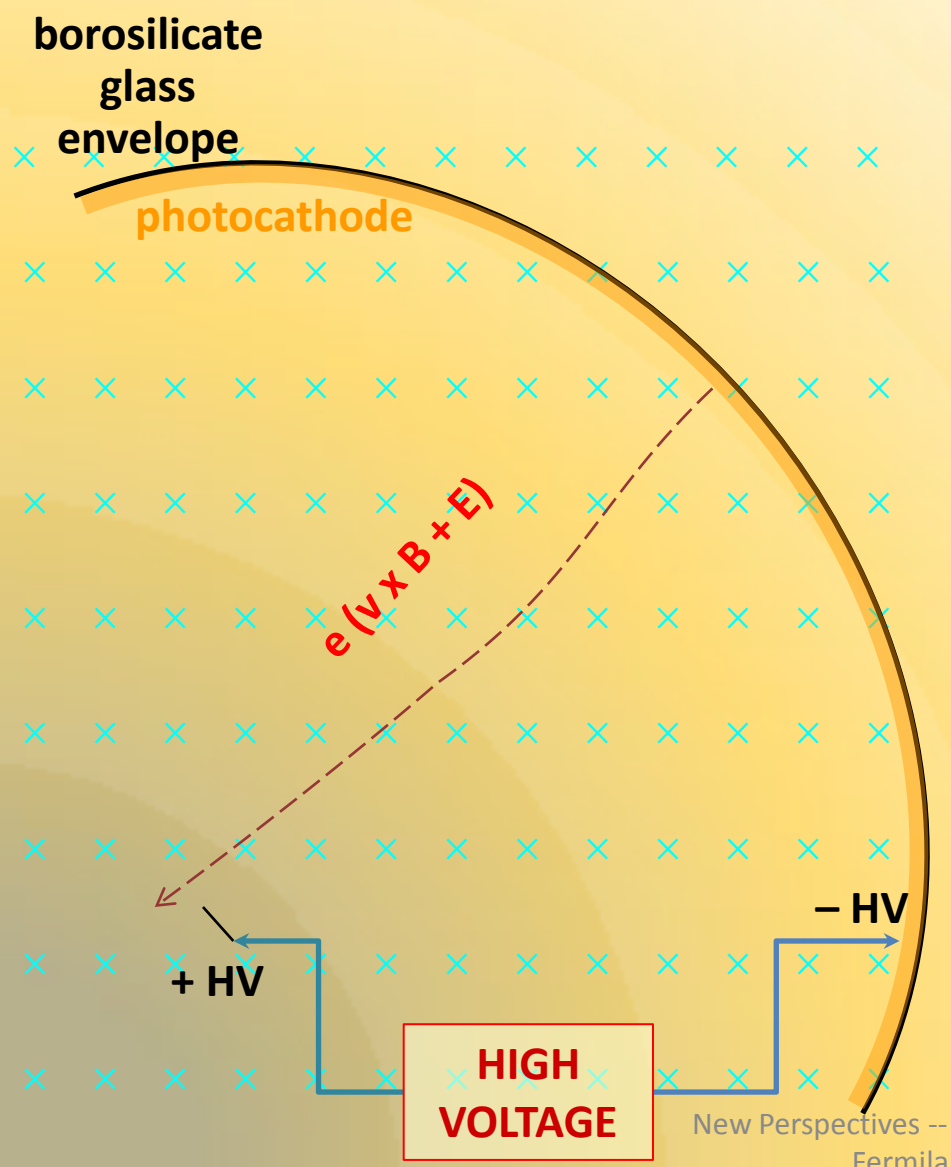
PMT fundamentals



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

TPB λ-shifter plates: see Christie Chiu's poster

PMT fundamentals



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

test stand design

- need light-tight enclosure with capability for manipulating the PMT and 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

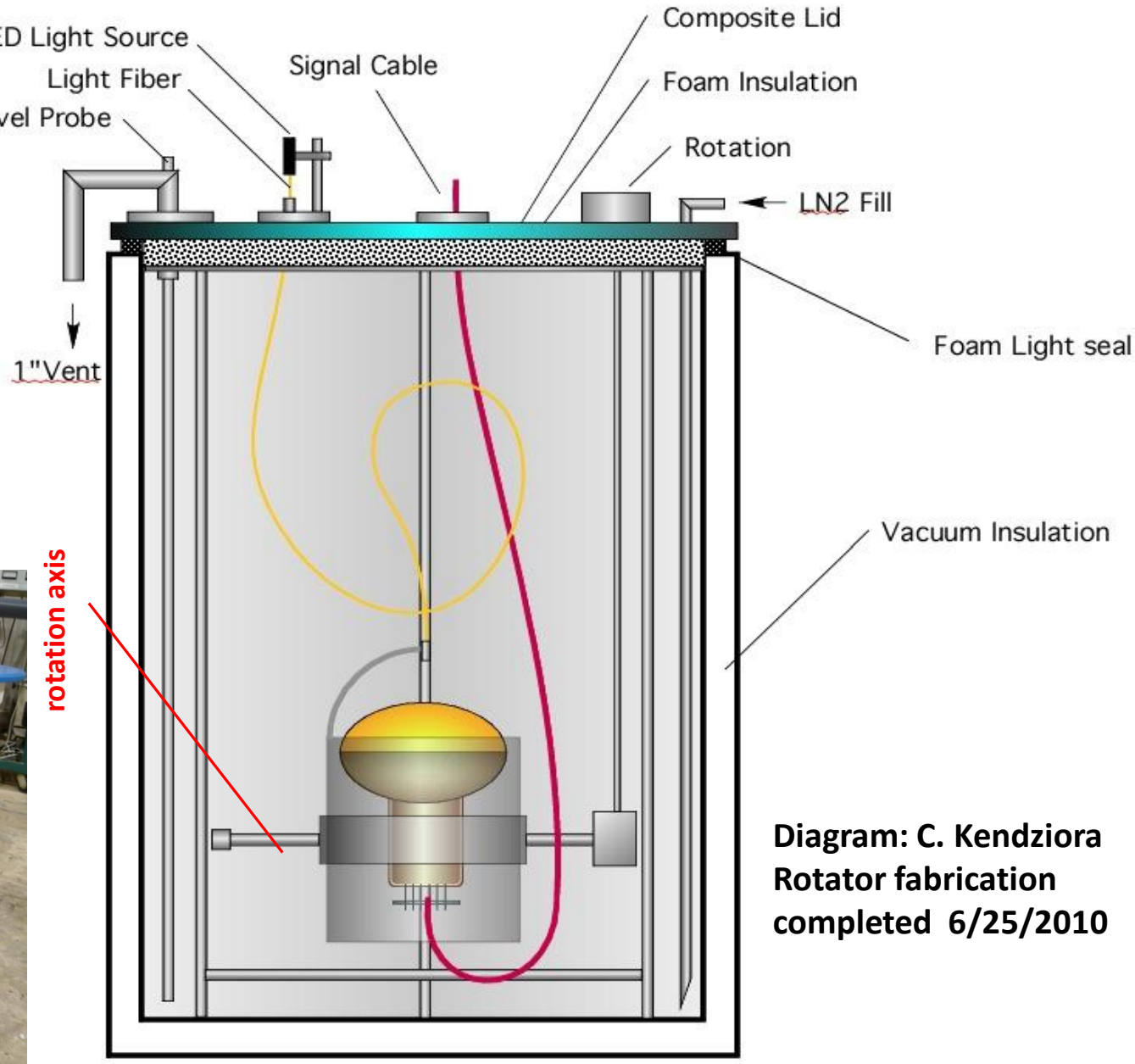
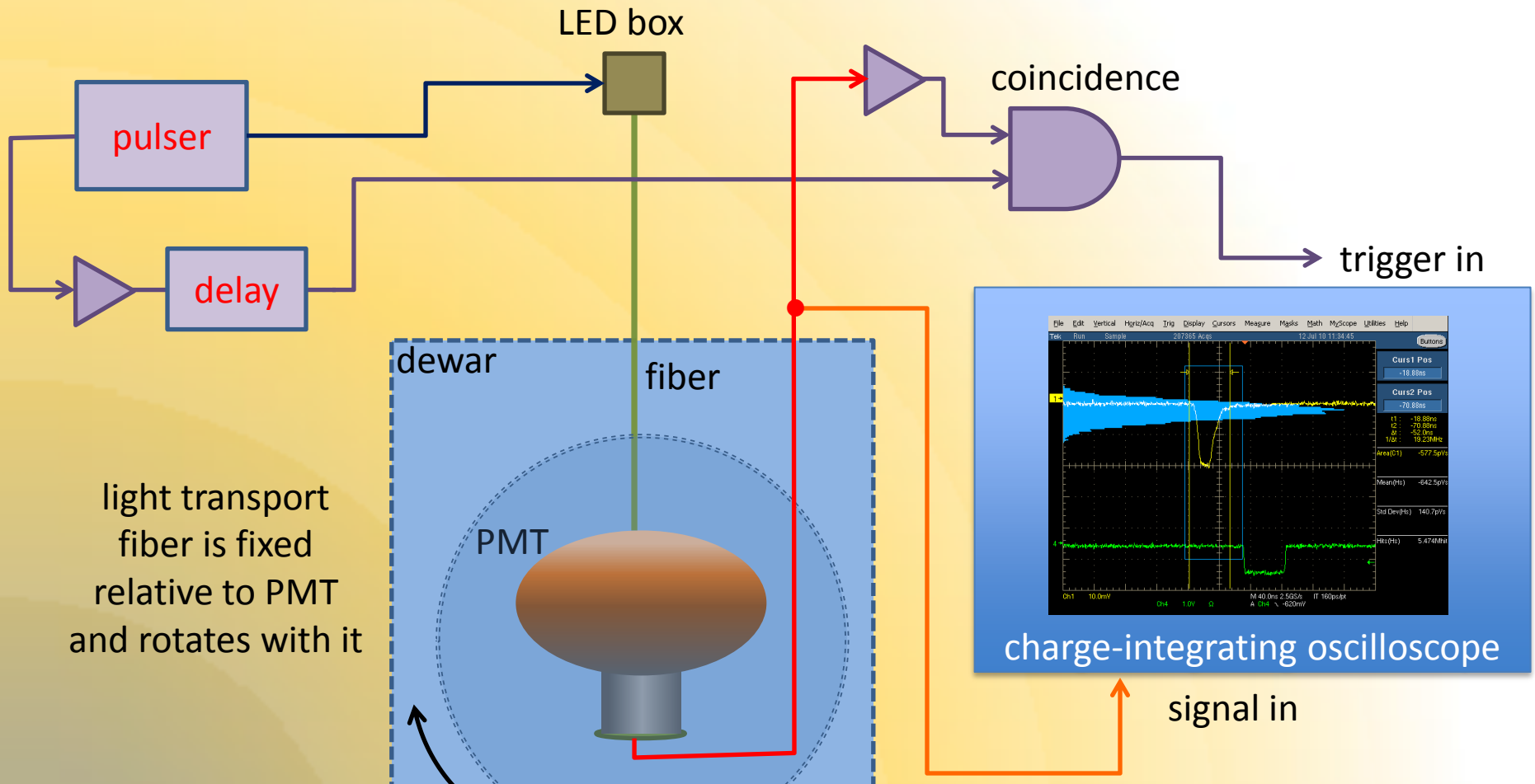


Diagram: C. Kendziora
Rotator fabrication completed 6/25/2010

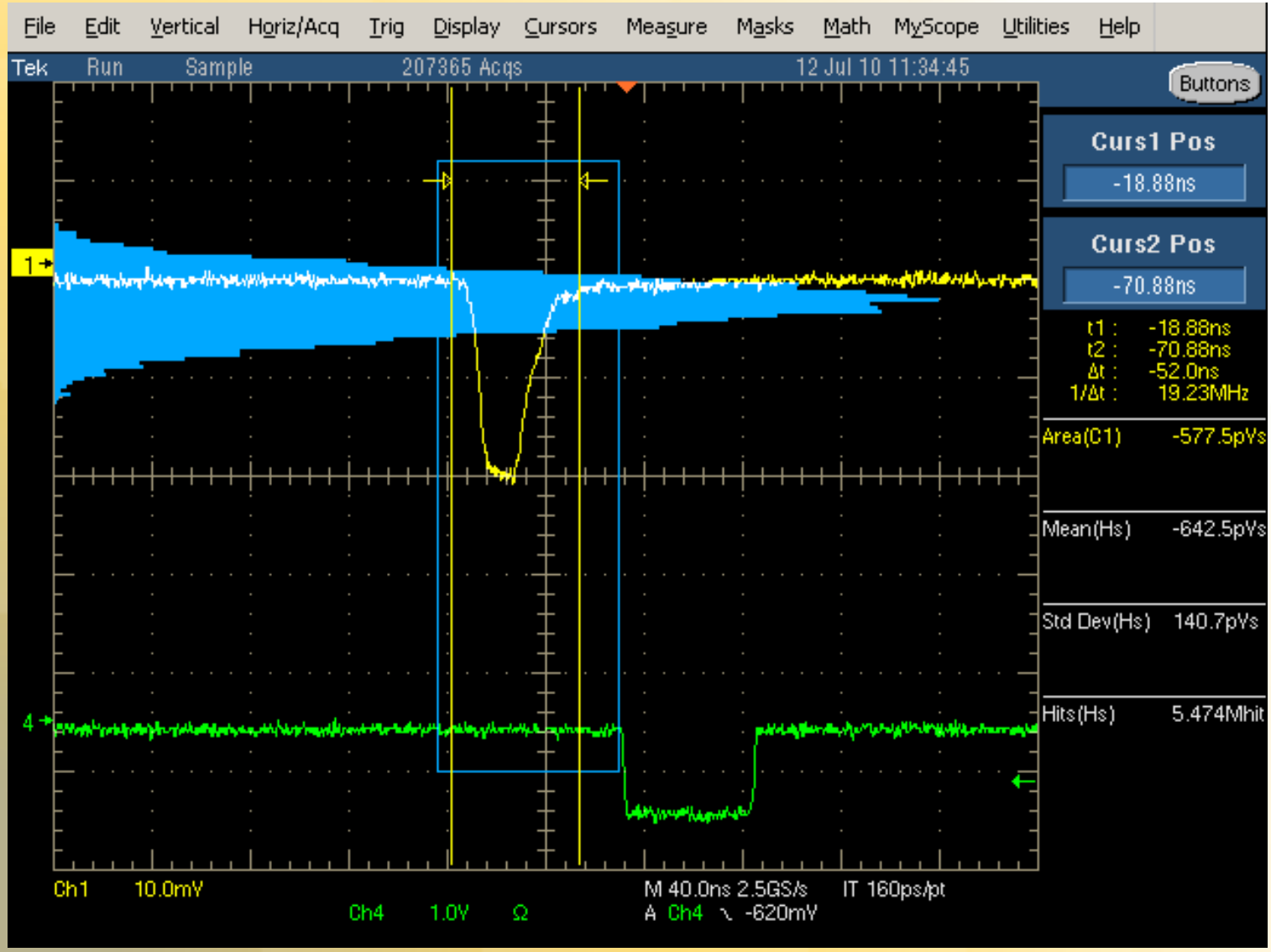

PMT
optical fiber
rotator axis
magnetic shield

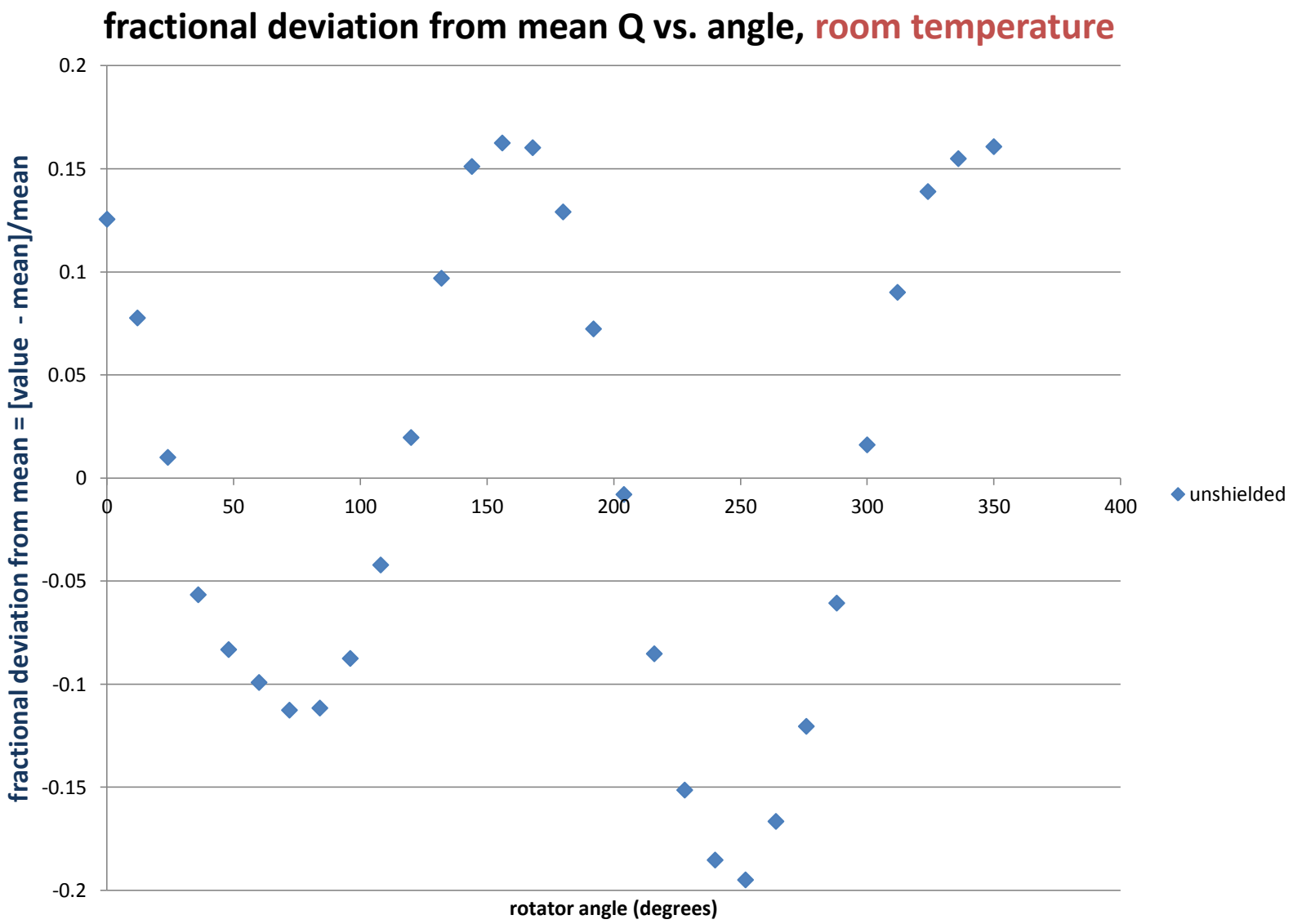
block diagram



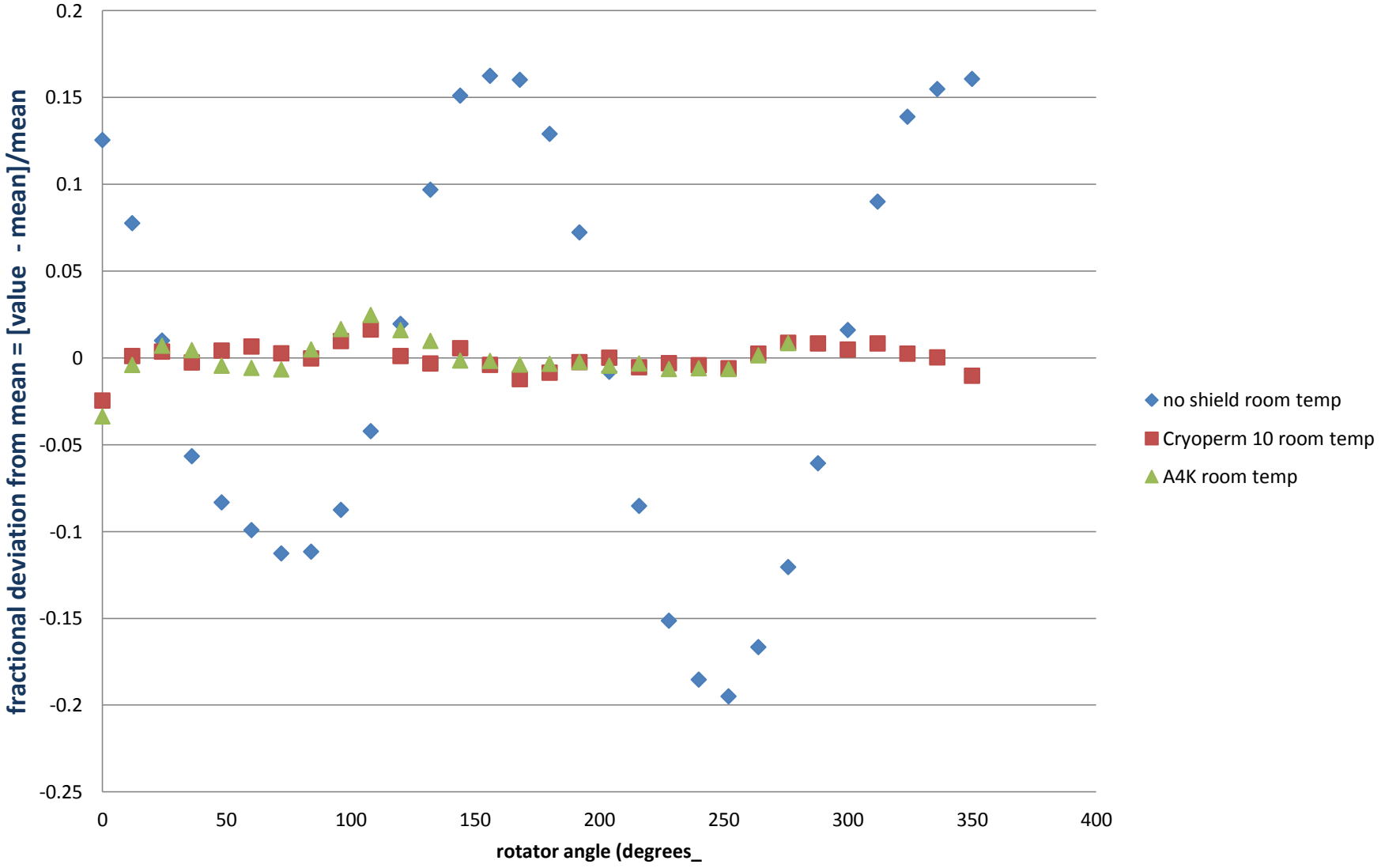
light transport fiber is fixed relative to PMT and rotates with it

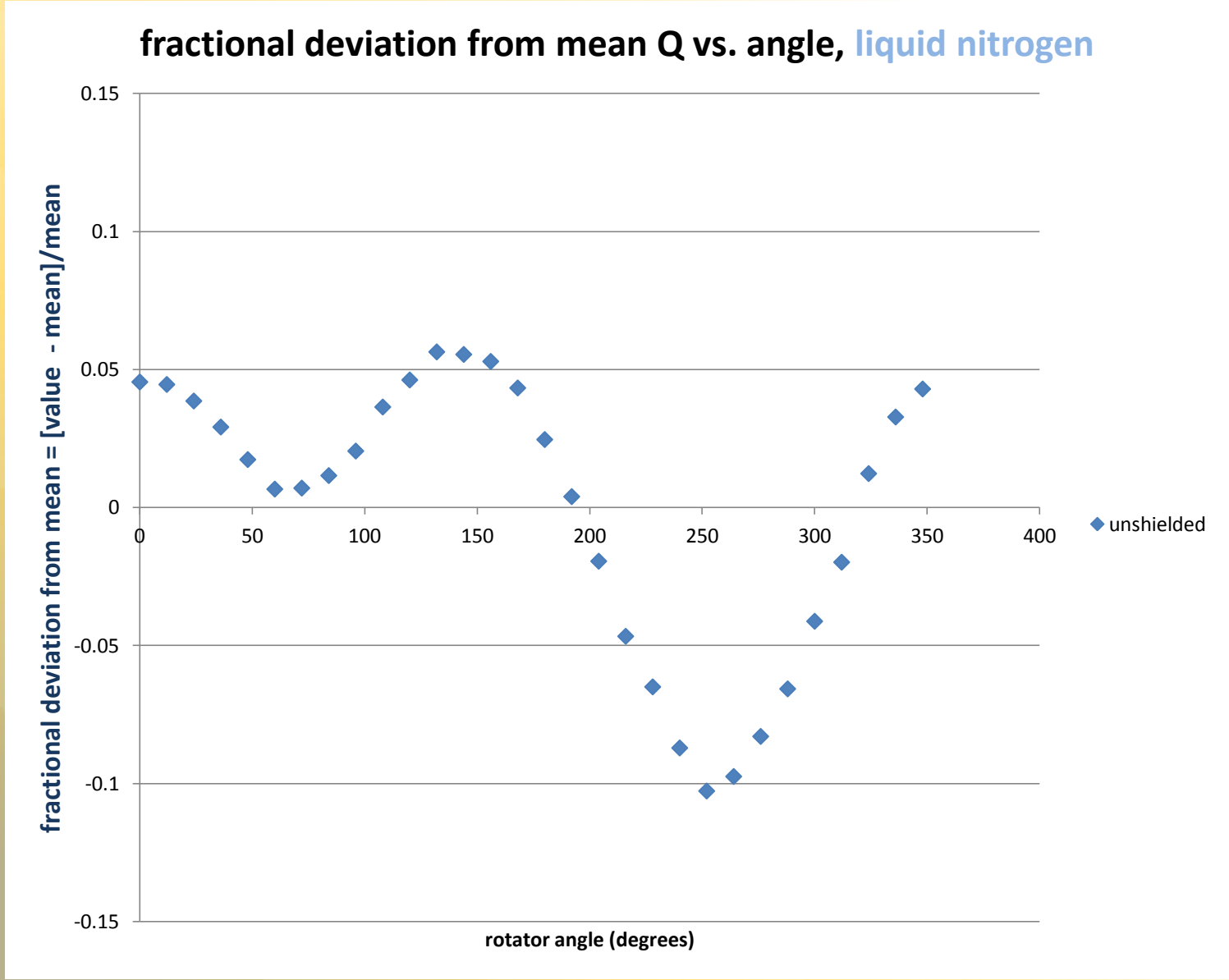
integrated Q – variation w/ angle?




fractional deviation from mean Q vs. angle, room temperature
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
50
100
150
200
250
300
350
400
rotator angle (degrees)
unshielded

fractional deviation from mean Q vs. angle, room temperature




fractional deviation from mean Q vs. angle, liquid nitrogen
fractional deviation from mean = [value - mean]/mean
0.15
0.1
0.05
0
-0.05
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100
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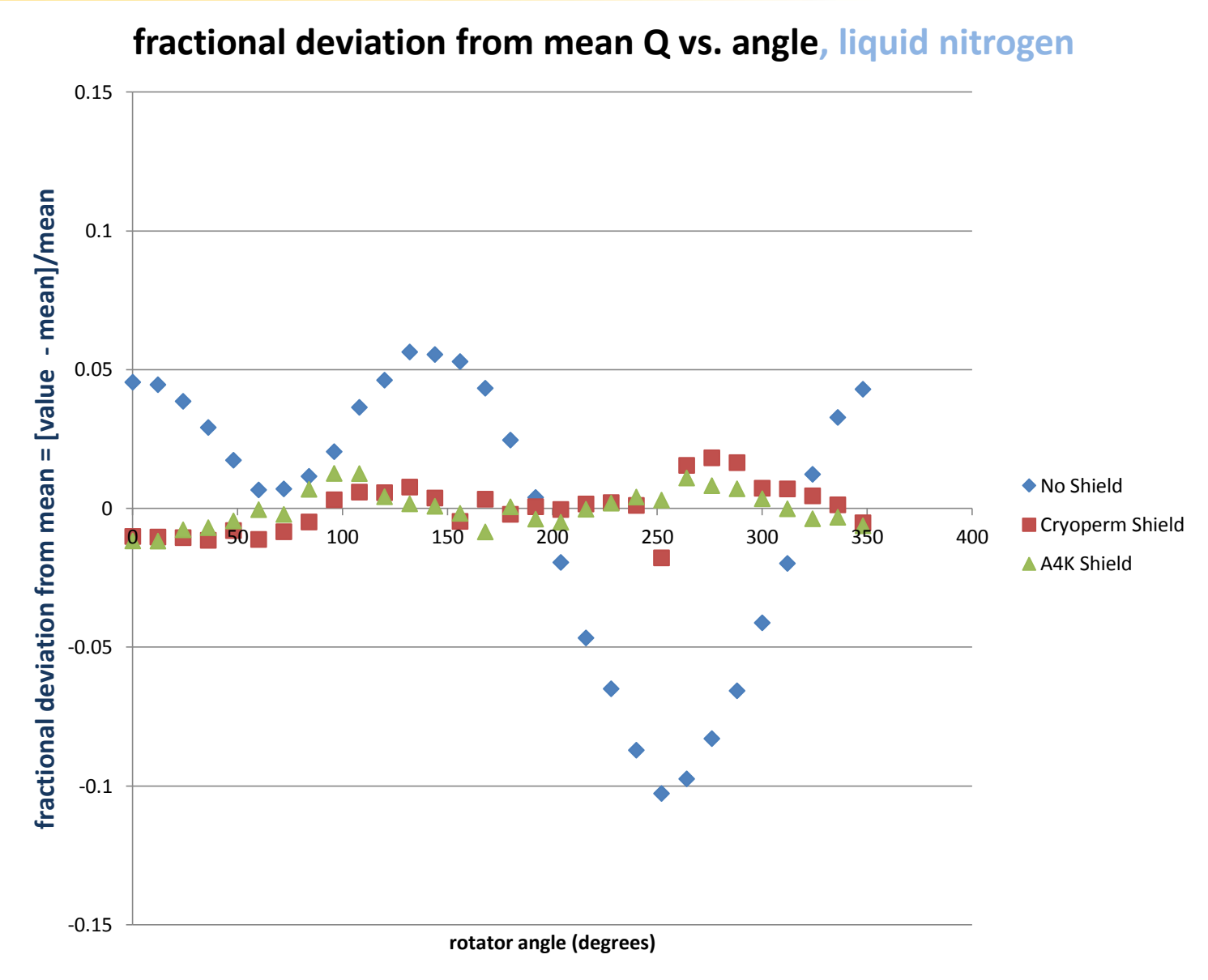
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100
150
200
250
300
350
400
fractional deviation from mean = [value - mean]/mean
rotator angle (degrees)
No Shield
Cryoperm Shield
A4K Shield

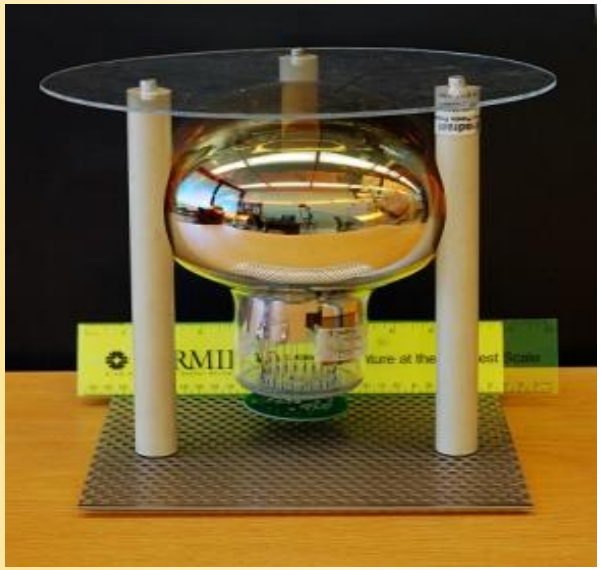
results

- 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

- **for completeness (final report)**
  - **repeat tests (room temperature, LN2) with second tube**
  - **check effect with room temperature shield (Amumetal)**
- **continue to investigate (Monte Carlo) potential wave-shifter plate shadowing by magnetic shield**



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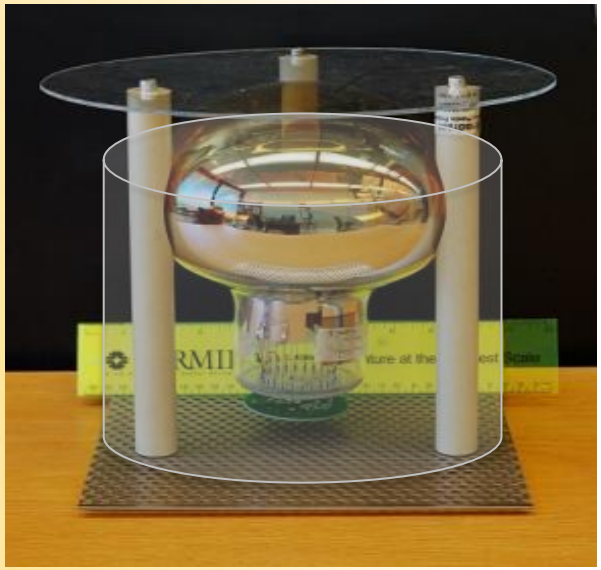

acknowledgements

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- Helpful assistance was also provided by our MicroBooNE collaborators from MIT, led by Professor **Janet Conrad**
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Thank you very much.

Saint Mary's University OF MINNESOTA

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