LAr Scintillation Light Collection with PMTs

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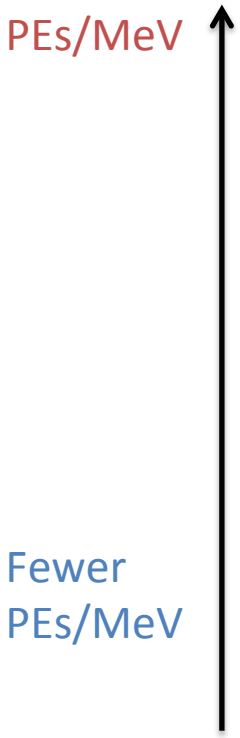
2nd Liquid Argon TPC R&D Workshop
July 8, 2014

Different Requirements, Different Approaches



Dark matter LArTPC detectors

- Low energy trigger threshold O(10 keVr)
- Gives drift time (fiducialization)
- Electron recoil background rejection (pulse shape discrimination)
- Improved energy resolution at low energies

Accelerator-based neutrino LArTPC detectors

- High energy trigger threshold > 10-100 MeV
- Gives drift time for non-accelerator events
- Cosmic background rejection (especially for a surface detector)
- Improved reconstruction at high energies? (PID, calorimetry)

Different Requirements, Different Approaches

LArTPC detectors

Photodetectors must fit behind anode and/or cathode

Light provides t_0—ionization gives remaining 4-vertex info

Light provides weak, position-dependent energy info

4π scintillator detectors

Photodetectors surround active volume

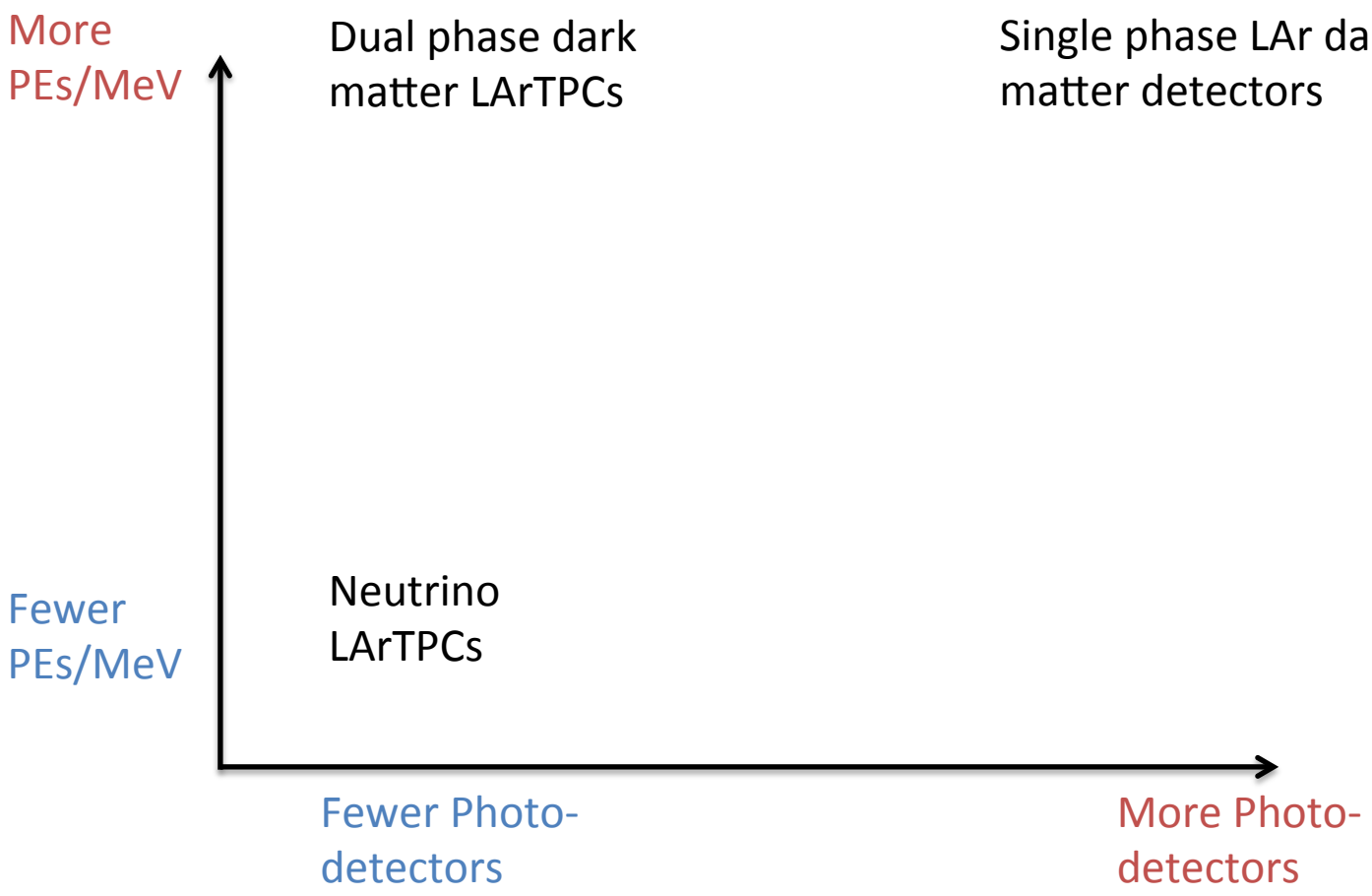
Light provides full 4-vertex reconstruction (fiducialization)

Uniform light collection efficiency with full energy reconstruction

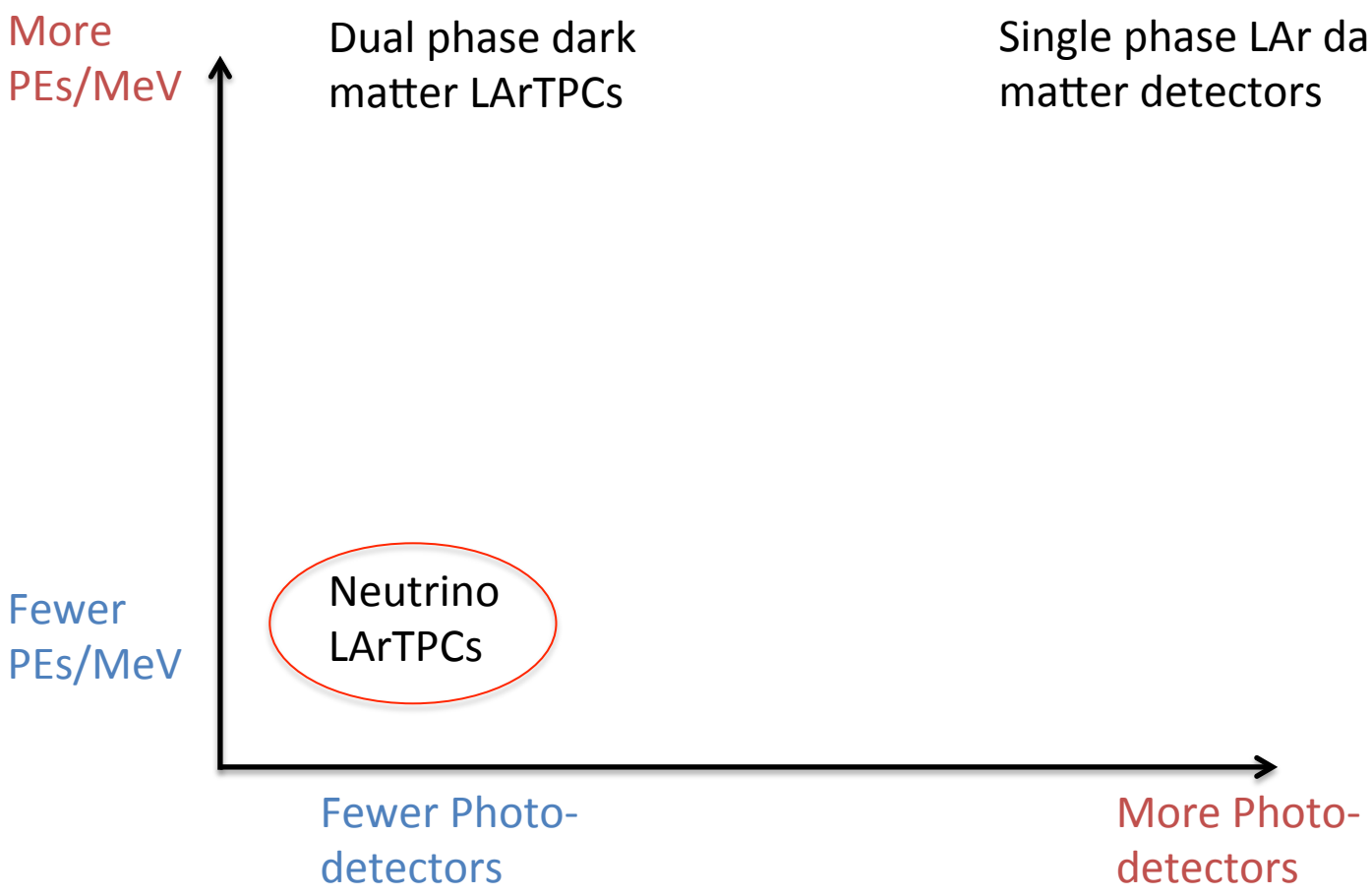
Fewer Photo-detectors

More Photo-detectors

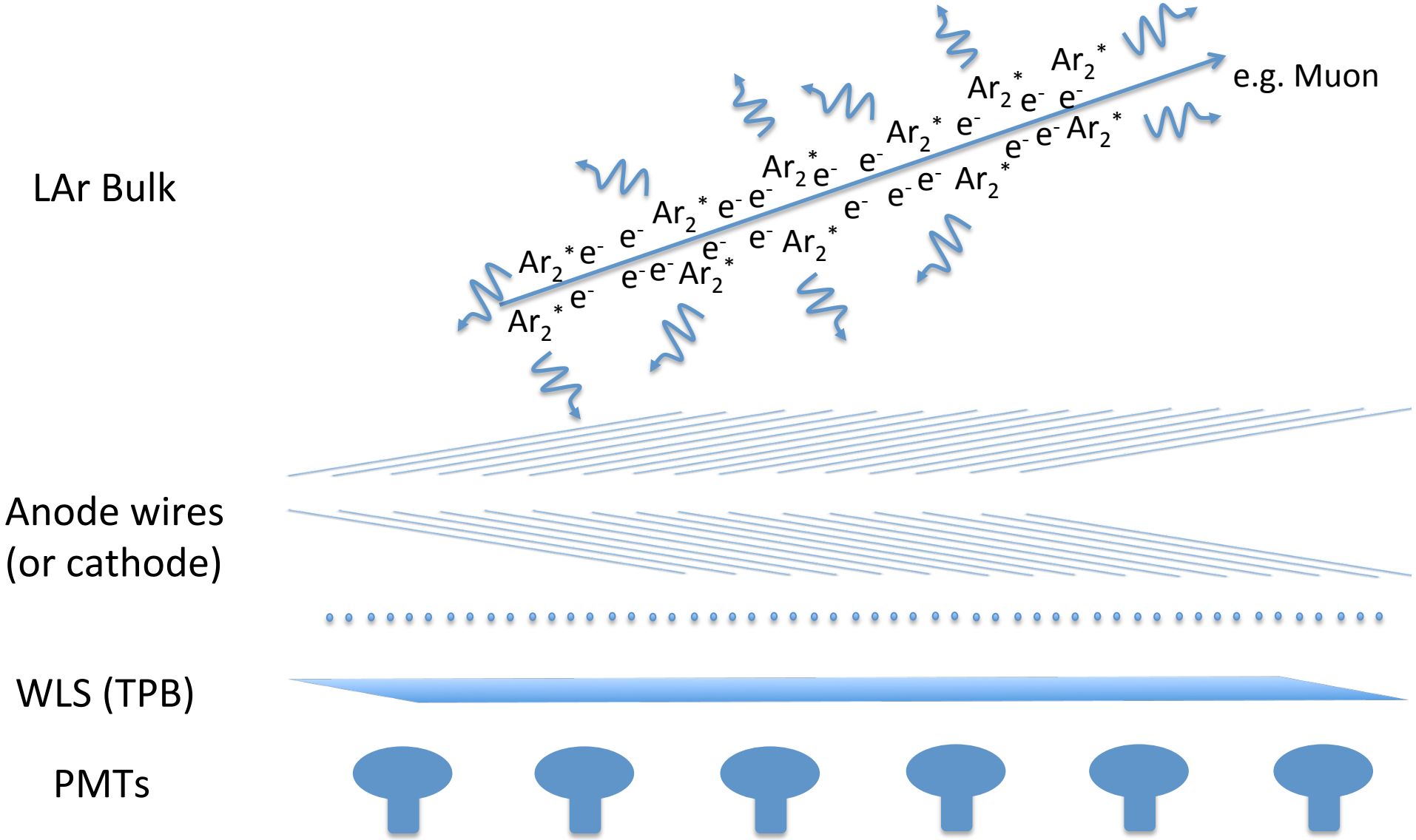
Different Requirements, Different Approaches

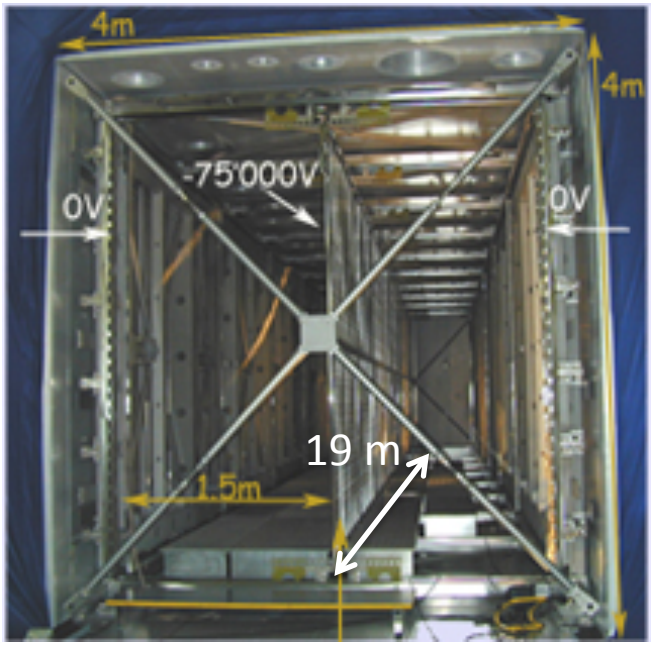


Different Requirements, Different Approaches

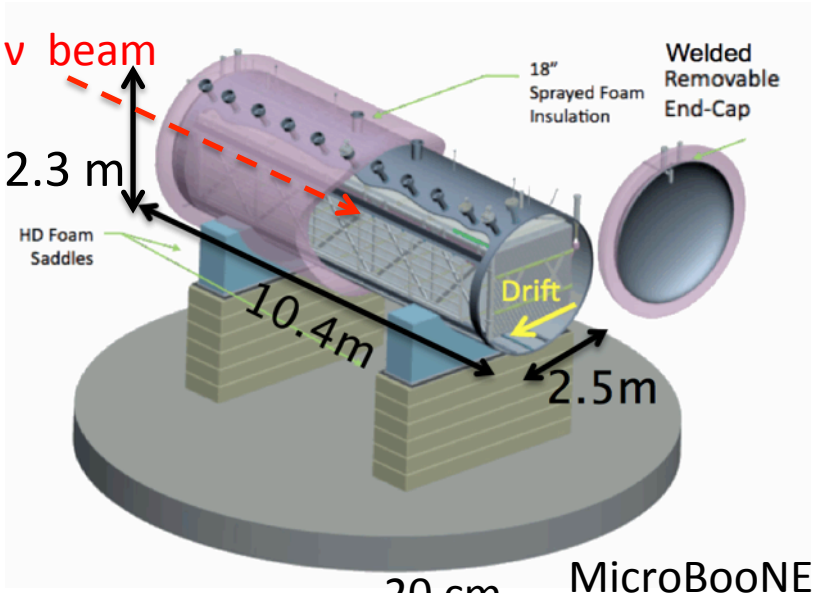


Standard Light Collection Approach in ν LArTPCs

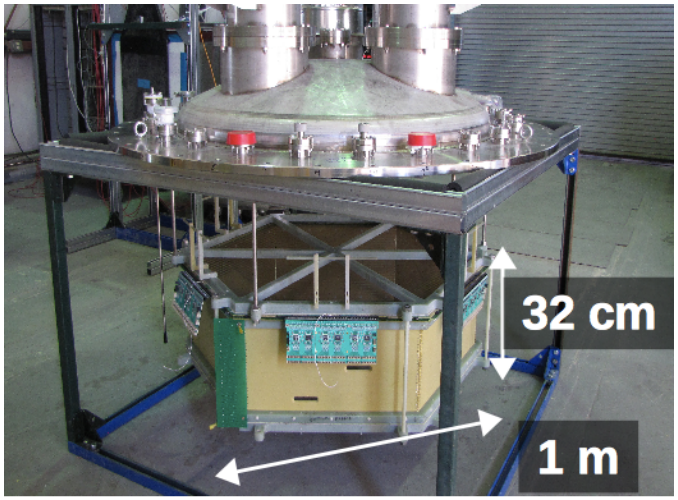




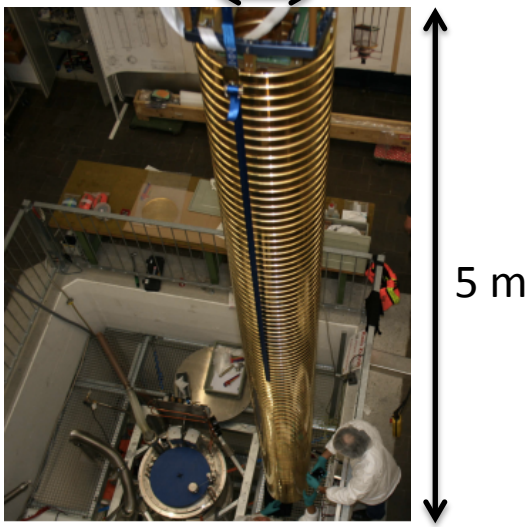
ICARUS



MicroBooNE



Mini-CAPTAIN



ARGONTUBE

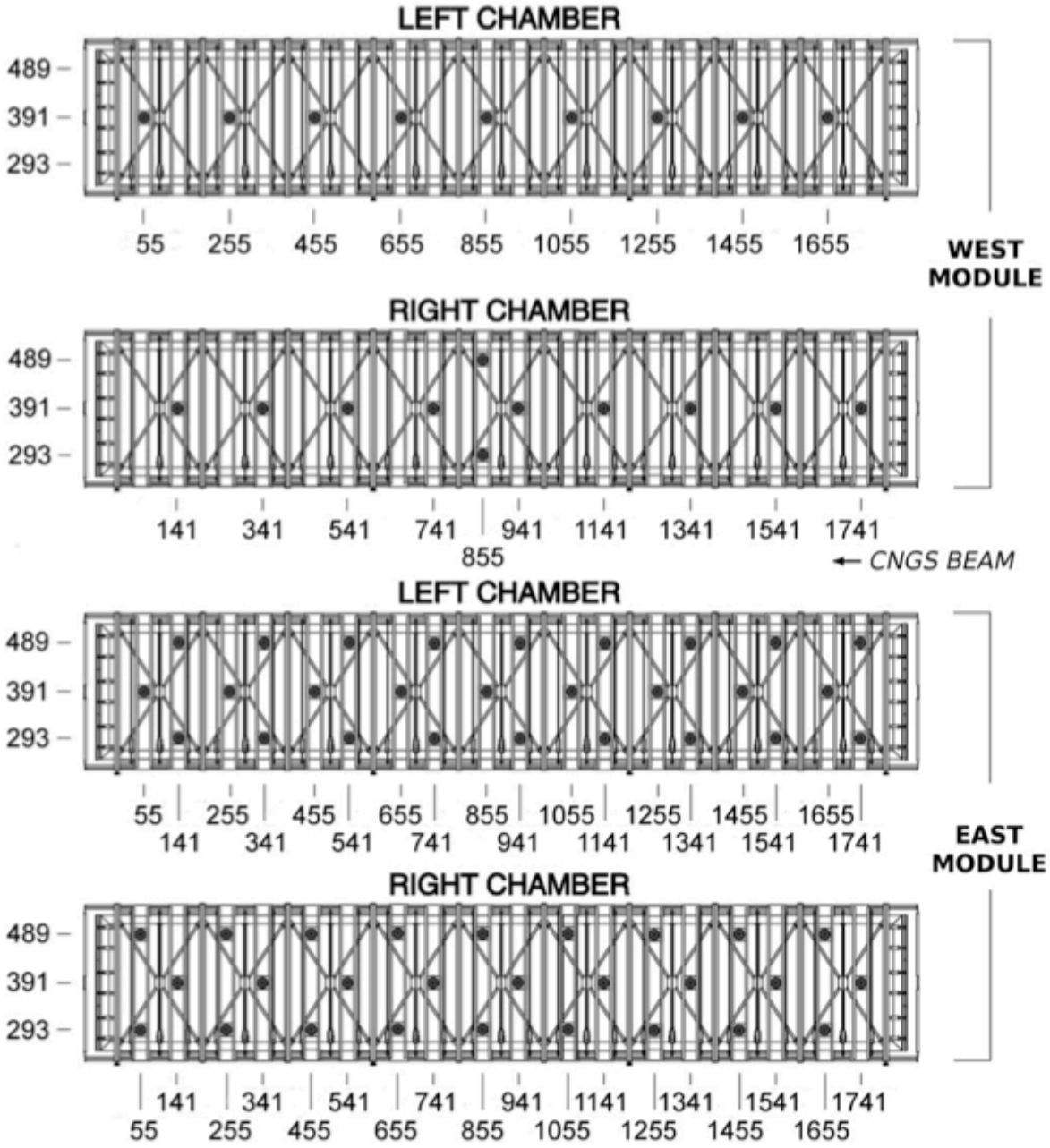
ICARUS Photo-detection Design

- 8” 12-stage PMTs (Electron Tube 9357FLA)
  - 18% QE (blue)
  - Pt underlayer
- Located 5 mm behind collection wires
- TPB evaporatively deposited on sand-blasted PMT glass
- Global quantum efficiency (PEs/γ) of 4-5%

See, for example arXiv:1405.7591

ICARUS Photo-detection Design

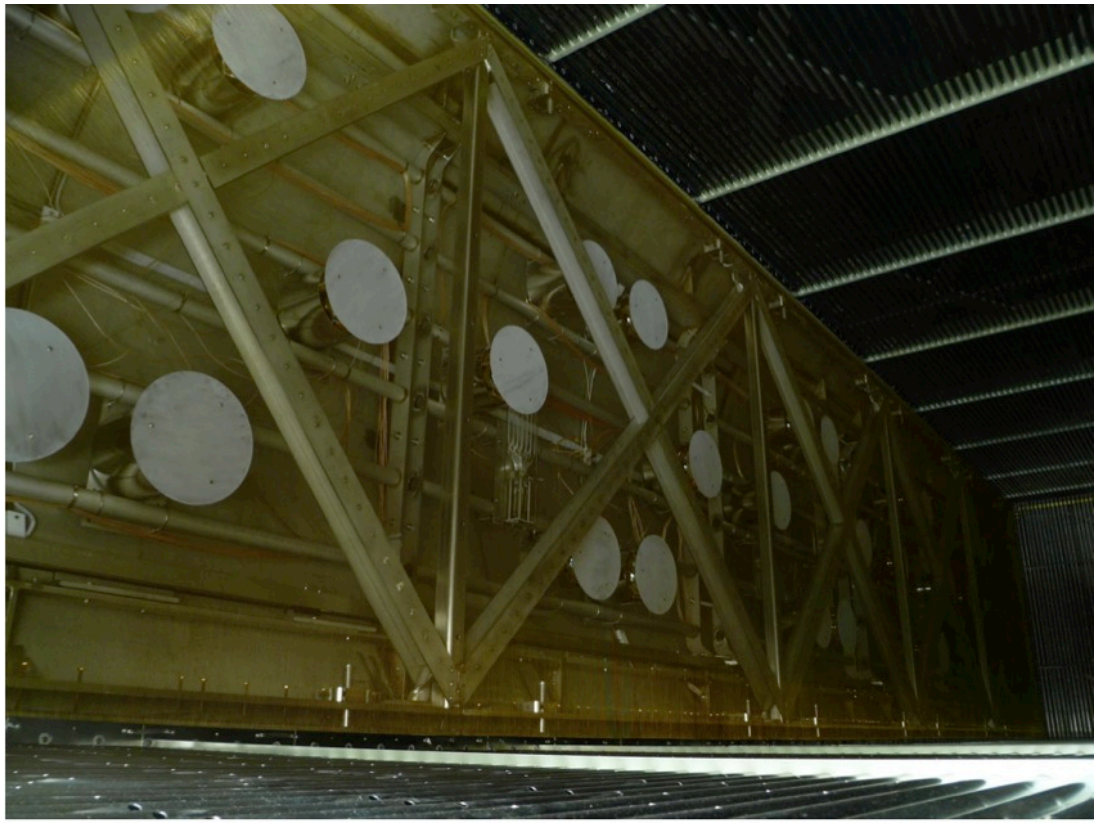
- 20 (west) + 54 (east) PMTs
- East module:
  - Three rows of 9 PMTs, 2 m apart
  - 86 cm between left & right
- Cathode is 58% transparent
- Solid angle coverage:
  - East: < 1 %
  - West: << 1%



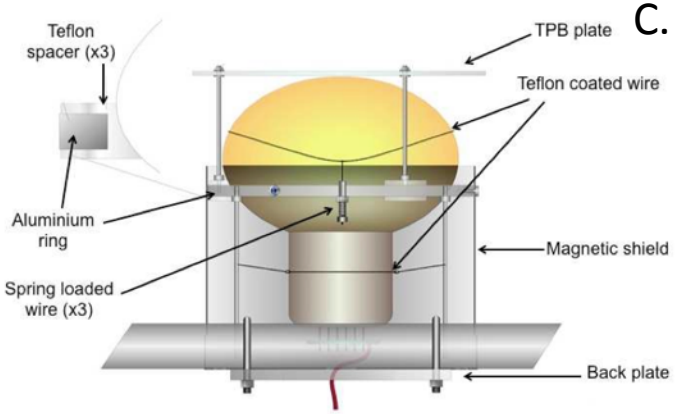
μBooNE Photo-detection Design

- 8” 14-stage PMTs (HPK 5912-02mod)
  - 18% QE (blue)
  - Pt underlayer
- Located 15 cm behind collection wires
- TPB coated on acrylic plate in front of PMT
- Mu-metal shield
- Global quantum efficiency (PEs/γ): $\mathcal{O}(1\%)$

See, for example arXiv:1304.0821

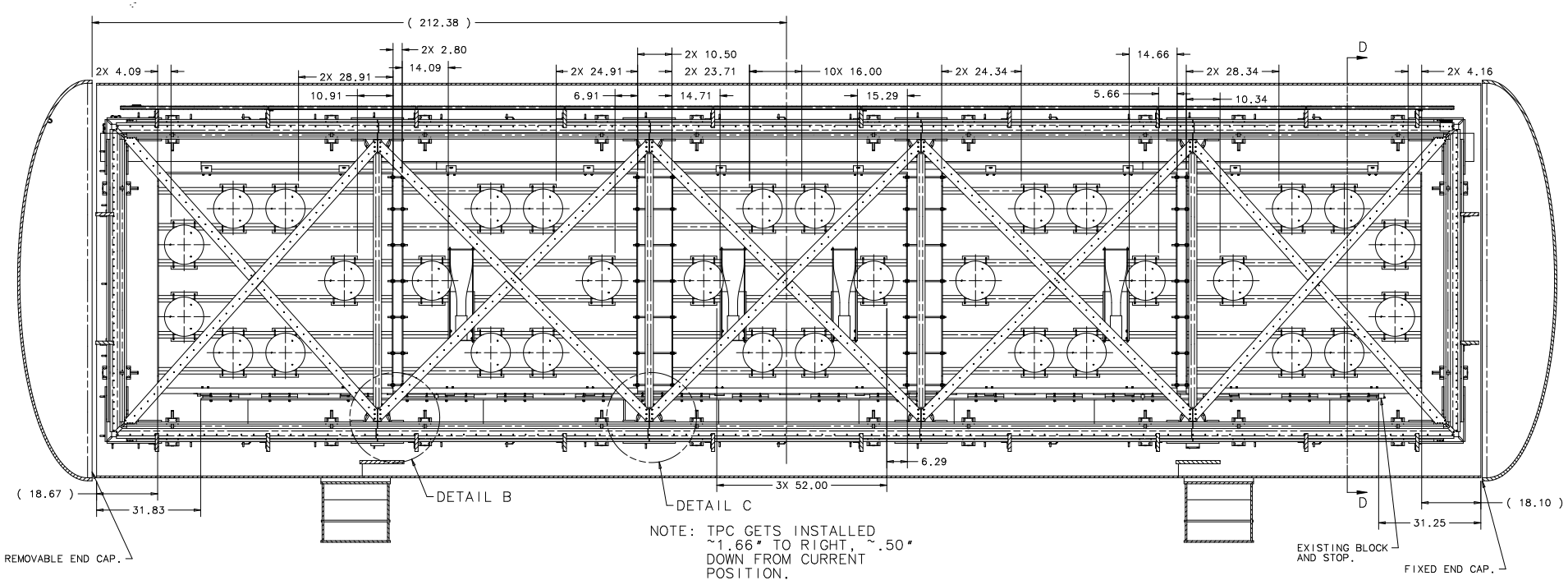


C. Rudolf Von Rohr



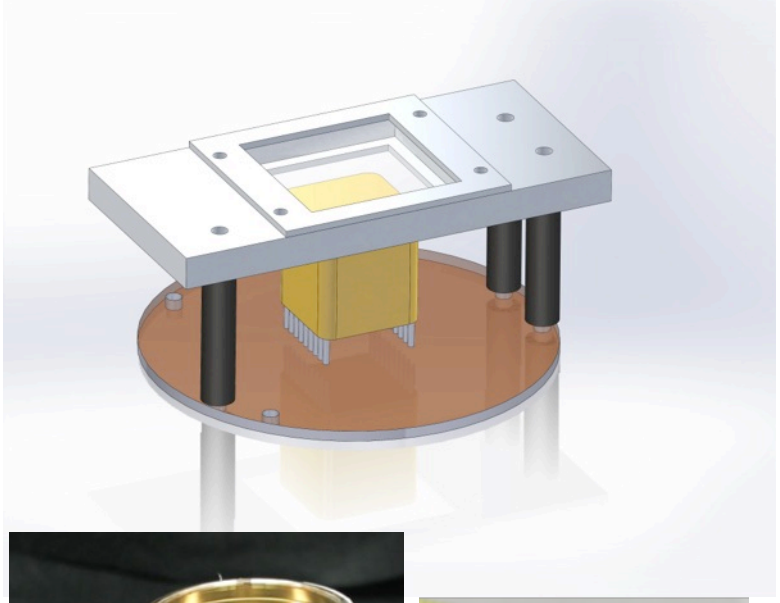
μBooNE Photo-detection Design

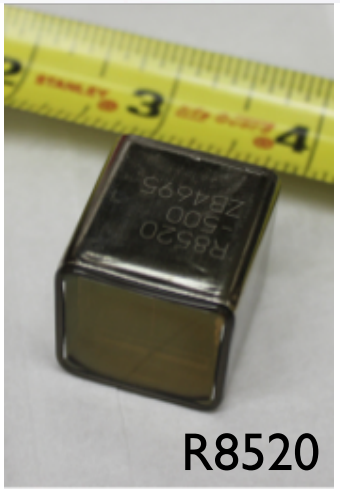
- 32 PMTs + 4 prototype light guide detectors behind anode
  - 5 groups of 7 – 8 photodetectors
- Solid angle coverage ~1-2%



Mini-CAPTAIN/CAPTAIN Photo-detection Design

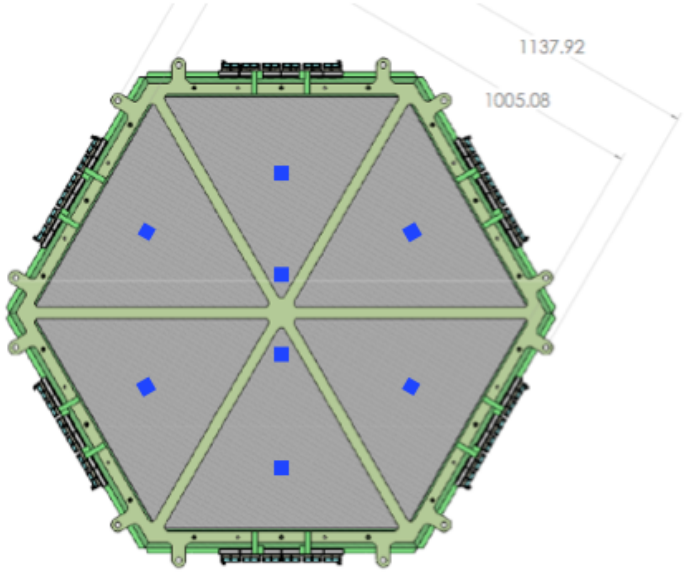
- Mini-CAPTAIN will use:
  - 16 -- 1” R8520 PMTs
  - TPB wavelength shifter on acrylic slide in front of PMT
    - Allows us to insert the TPB right before closing up to prevent degradation from UV and dust
- CAPTAIN will use:
  - 16 to 24 -- 1” R8520 PMTs
  - 2 to 4 -- 3” R11065 PMTs
- Will be mounted on top and bottom behind grounding plane

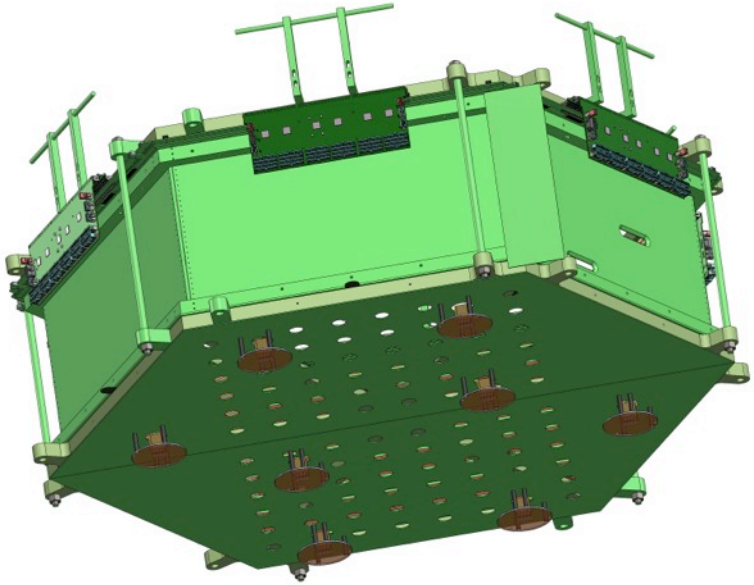


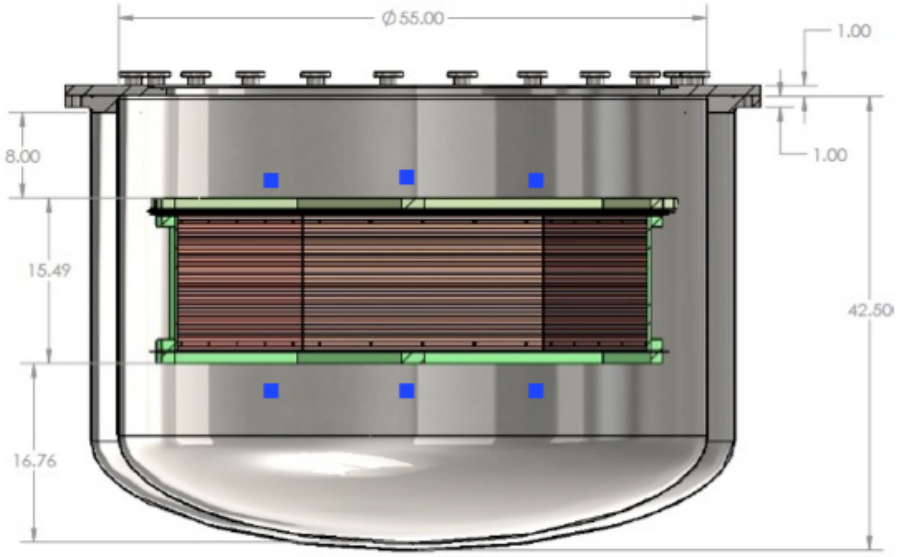


Mini-CAPTAIN Photo-detection Design

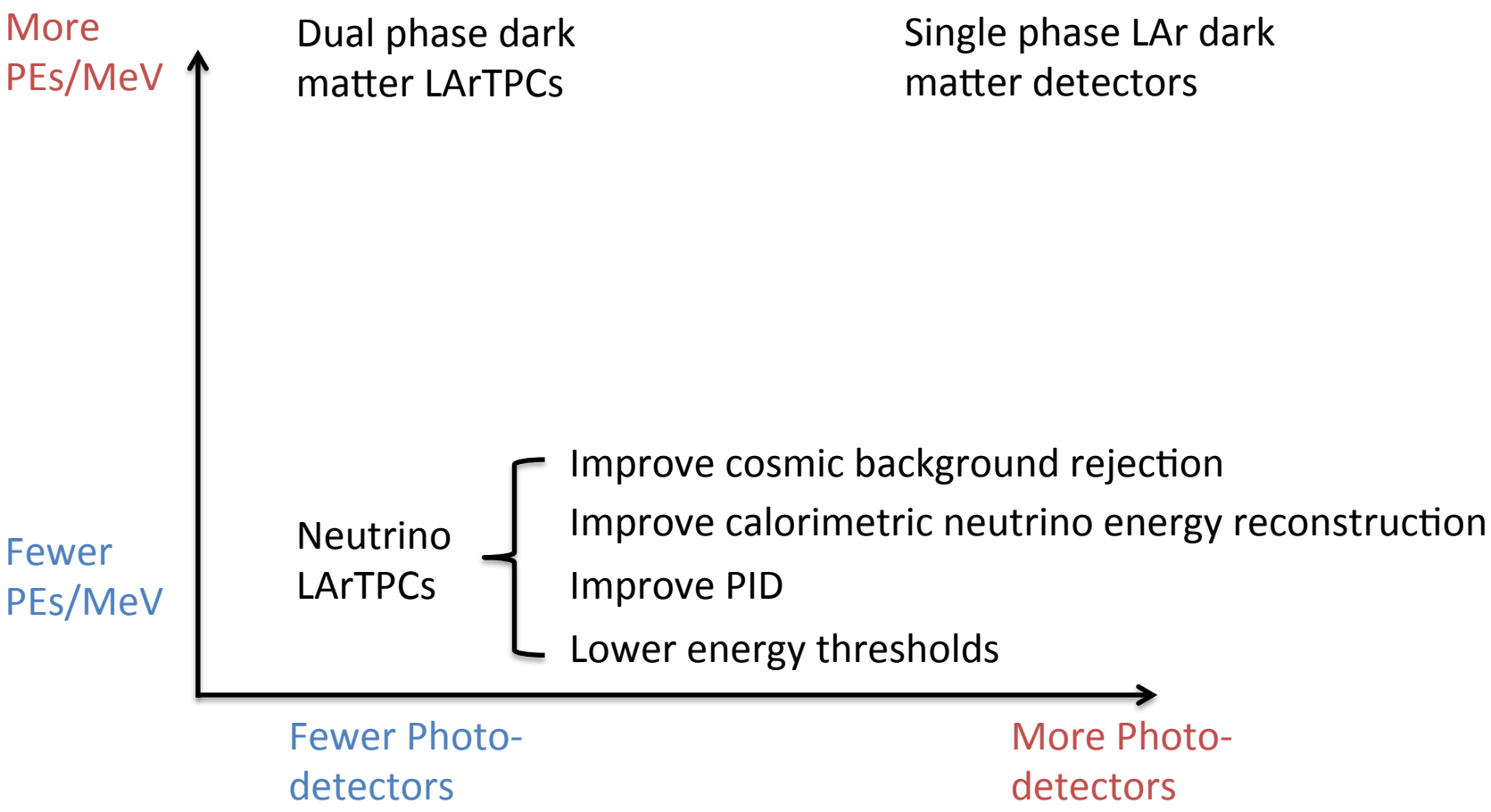
- 16 R8520 PMTs:
- 8 top, 8 bottom
- Solid angle coverage: << 1%



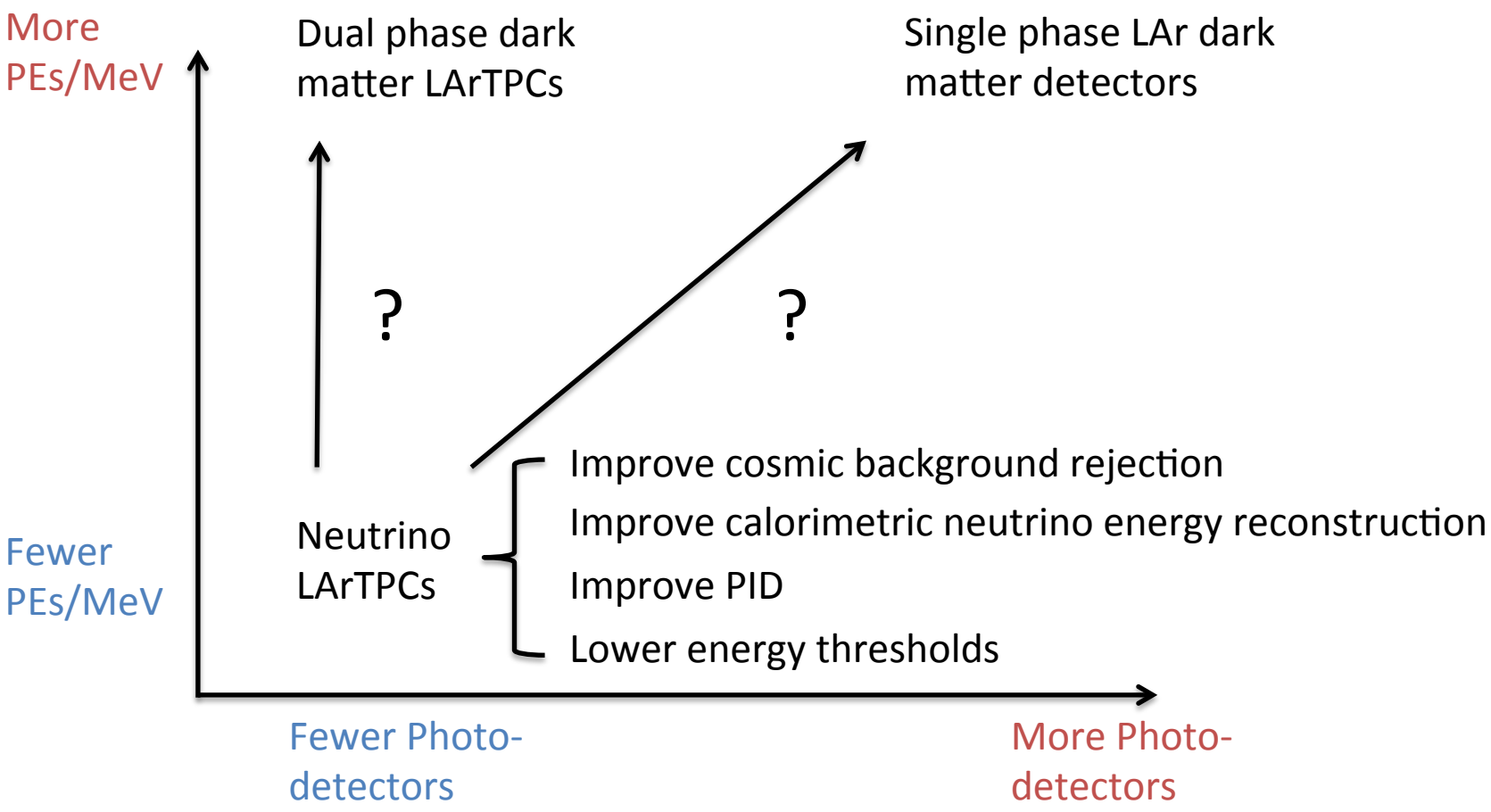




Future Directions



Future Directions



Stay Tuned…

15:35 Enhanced Light Collection with PMTs

Presenter(s): William FOREMAN *(University of Chicago)*
Room: CDF - Big Room (Building 327)
Location: Fermi National Accelerator Laboratory

15:45 Light Collection with LAPPDs

Presenter(s): Ranjan DHARMAPALAN *(The University of Alabama)*
Room: CDF - Big Room (Building 327)
Location: Fermi National Accelerator Laboratory

15:55 Light Collection with Paddles

Presenter(s): Ryan WASSERMAN *(Colorado State University)*
Room: CDF - Big Room (Building 327)
Location: Fermi National Accelerator Laboratory

16:15 Light Collection with Paddles II

Presenter(s): Denver WHITTINGTON *(Indiana University)*
Room: CDF - Big Room (Building 327)
Location: Fermi National Accelerator Laboratory

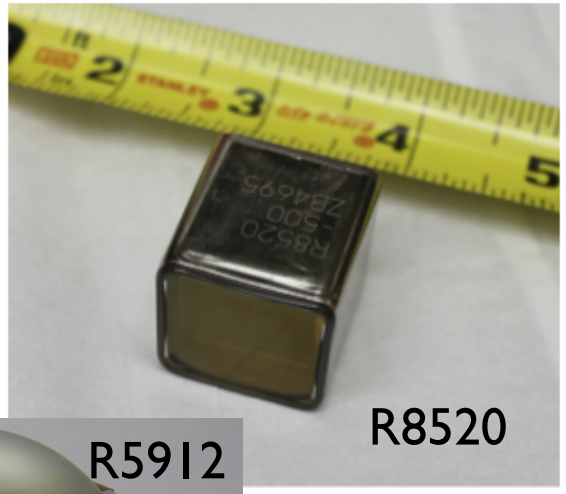
Backup

Technical Aspects

- LAr scintillates at 128nm - about 24,000 photon MeV in a 500V/cm for electronic recoils
- About 25% is prompt (<100ns) - used to trigger on non-beam events but all light could assist reconstruction
- Need to convert 128nm to visible
  - Use of tetraphenyl butadiene (TPB) or other wavelength shifter
- Need to maximize photon detection
  - Large coverage area (light guides, large surface photodetector)
  - High quantum efficiency
  - Efficient conversion to visible

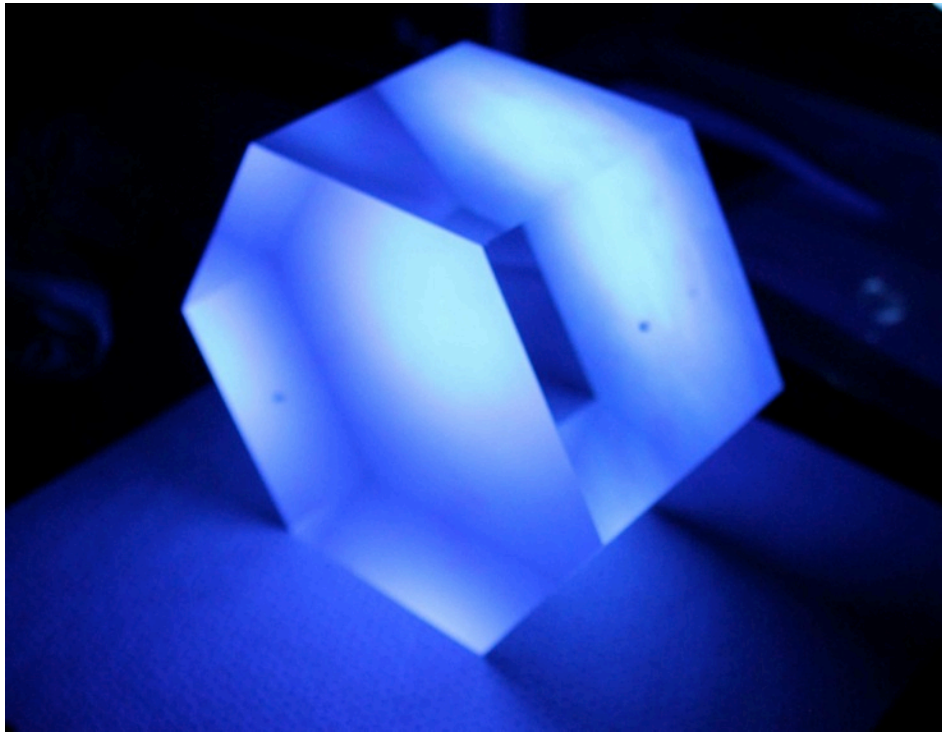
Photon Detector Options

- Four LAr PMT options:
  - Hamamatsu R8520-500
    - 1” square, 25% QE at LAr temperature, special Bialkali LT
  - Hamamatsu R6041-506
    - 2” diameter, 25% QE at LAr temperature, special Bialkali LT
  - Hamamatus R11065
    - 3” diameter, 25% QE at LAr temperature, special Bialkali LT
    - Used by DarkSide
  - Hamamatsu R5912-02Mod
    - 8” hemispherical, 18% QE at LAr temp, regular Bialkali with Pt flash
    - Used by MiniCLEAN, microBooNE



Photon Detection System

- Goals of CAPTAIN PDS
  - Triggering of non-beam events
  - Evaluation of photon timing to improve event reconstruction
  - Investigate alternative PDS schemes
- Time of flight for neutron run
- Baseline PDS will provide:
  - ~11 pe/MeV in Mini-CAPTAIN
  - >2.2 pe/MeV in CAPTAIN



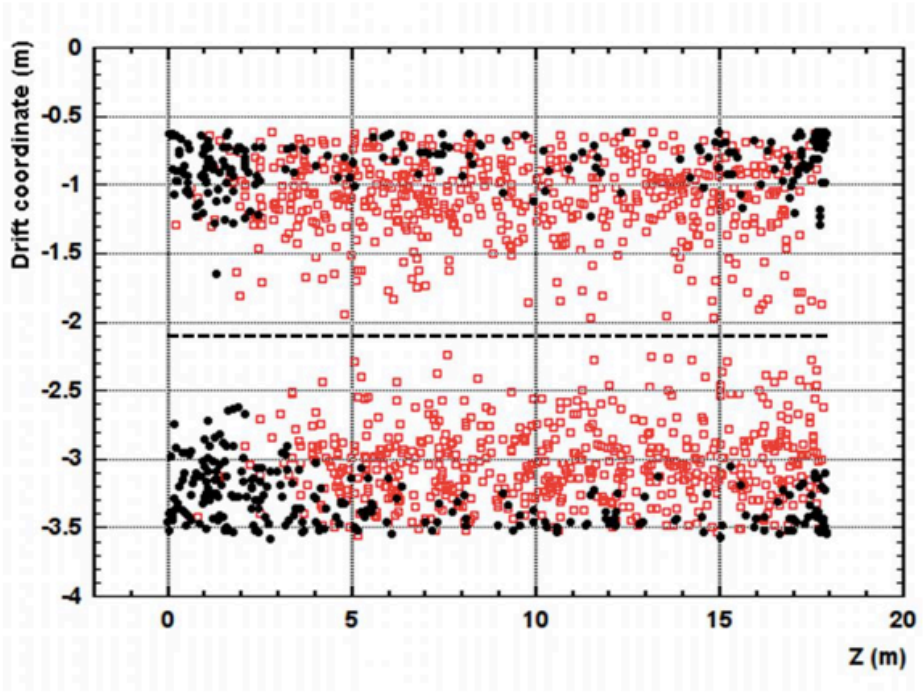


Figure 8. Spatial distribution of cosmic muon tracks in the WEST module as triggered by PMTs (red squares) and below the PMT detection threshold (black circles, see Chapter 4). PMT system inefficiency is mostly localized in the regions where PMTs were switched off.

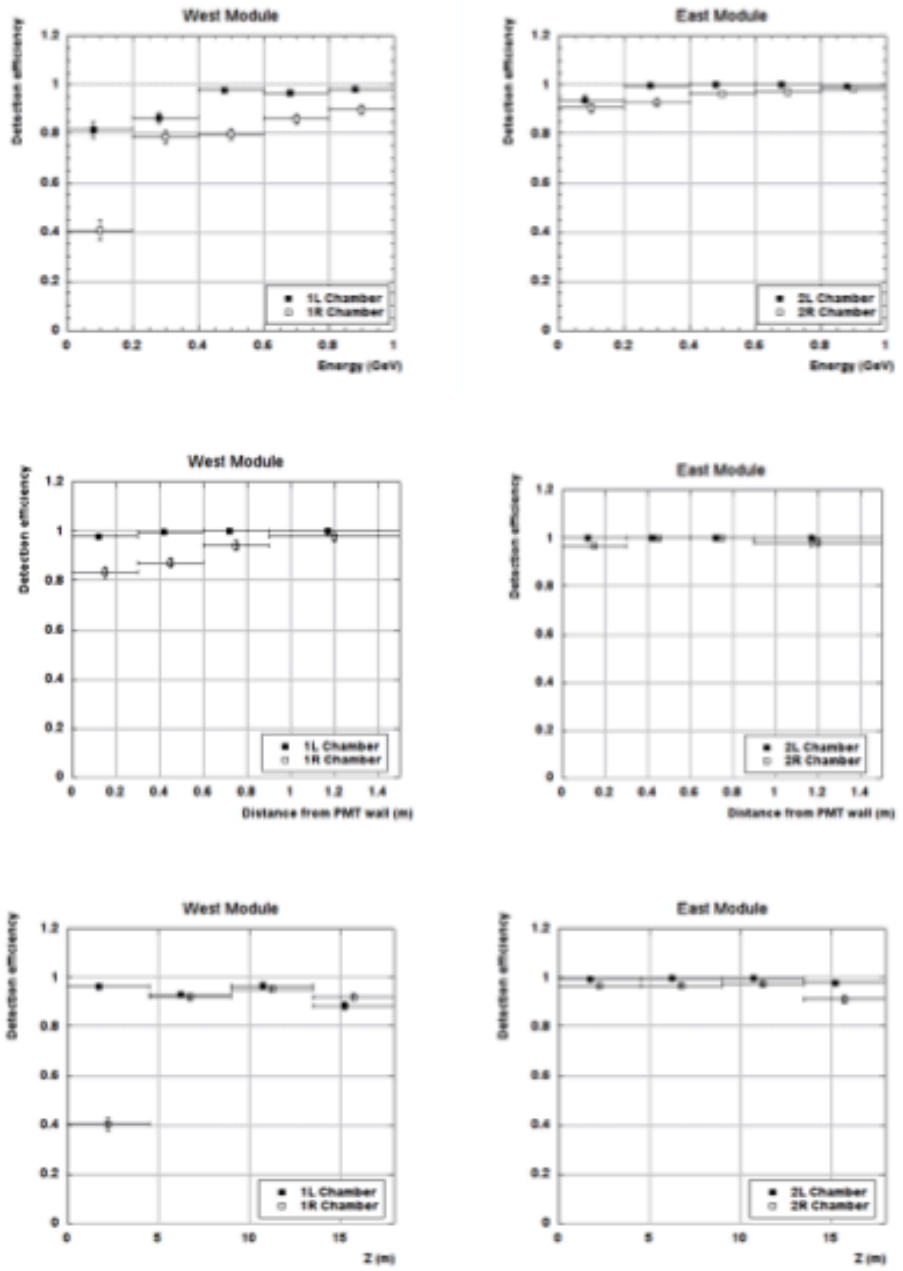


Figure 7. PMT sum signal efficiencies of each TPC chamber in the WEST (left) and EAST (right) modules, as a function of the energy deposited by cosmic muons (top), the track distance from the PMT wall (center) and the track longitudinal position (bottom). The represented error bars account only for the statistical error.

Spectrum of Approaches