Photon Detection in CAPTAIN

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The CAPTAIN Detector

CAPTAIN: Cryogenic Apparatus for Precision Tests of Argon Interactions with Neutrinos

Cryostat

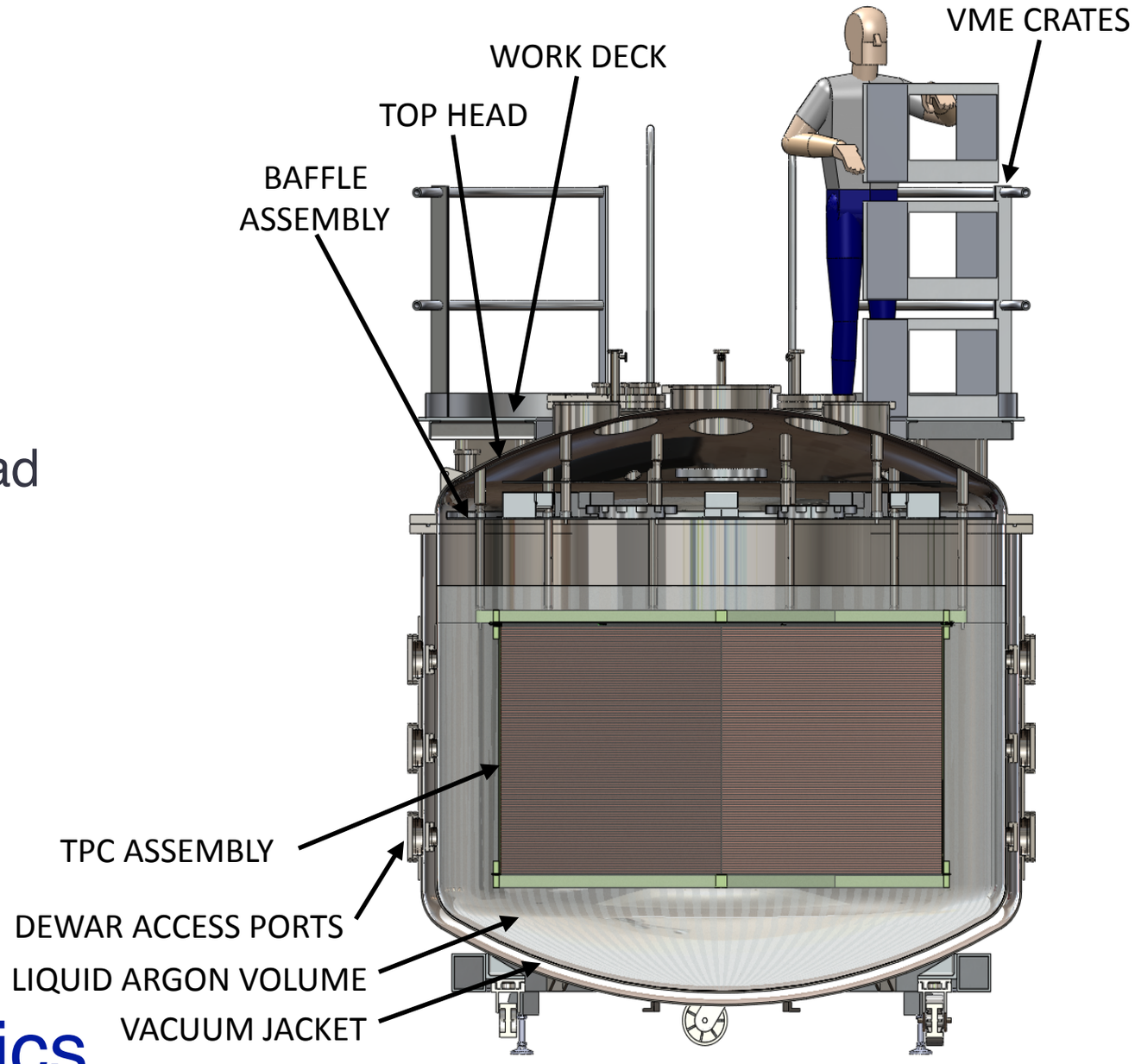
- Capacity: ~7700 L
- External dimensions
  - Flange diameter: 111”
  - Work deck height: 101”
  - All cryogenic and instrumentation connections made through top head
  - Work deck for worker safety and convenience

TPC

- hexagonal prism, vertical upward drift
- **5** instrumented **tons**
- 2k channels with **3 mm** spacing

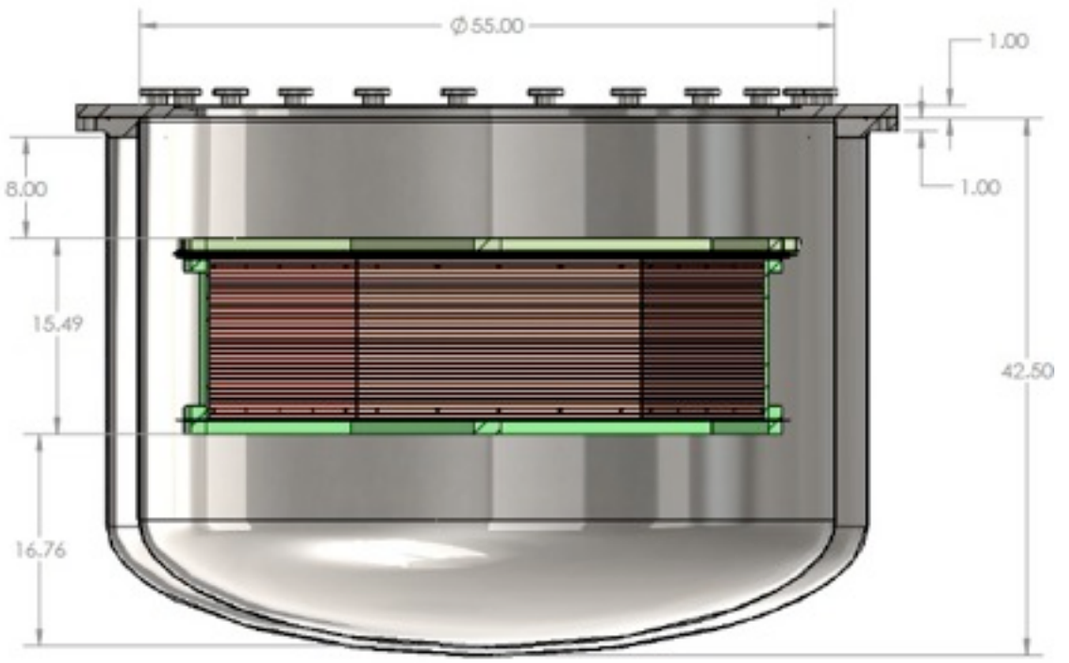
Laser calibration system

MicroBooNE Cold electronics



The CAPTAIN Prototype

- Reuses cryostat from UCLA
- About 1m tall x 1.1 m diameter
- TPC 30cm drift by 99cm
- 3mm wire spacing
- 500 V/m drift field
- Laser system (top view ports
- Photon detection system
- Neutron run at LANSCE next FY



Physics Goals: By end of FY14

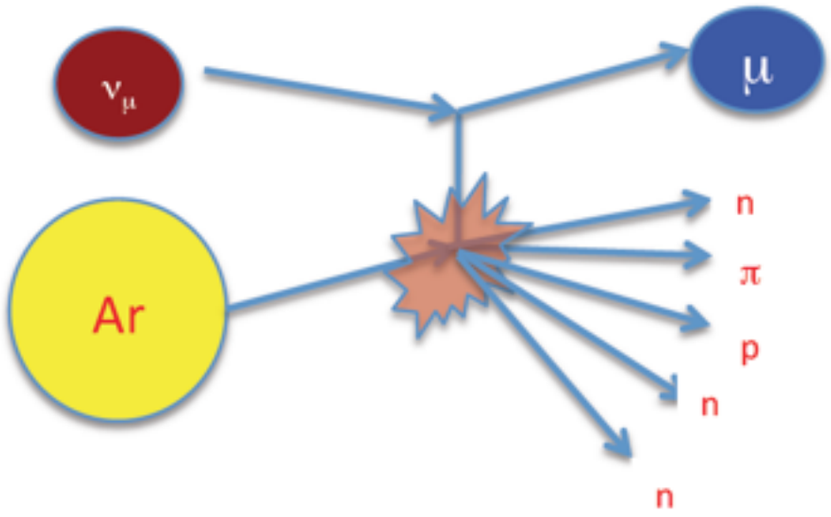
- Within the scope of the LDRD (Laboratory Directed Research & Development program)
  - Studies for future ~~CP~~ experiments (e.g. LBNE)
    - The LBNE far detector will not be magnetized, cannot do μ^+/μ^- separation by track curvature
    - Approximately 75% of μ^- are captured by the argon nuclei
    - Gamma and neutron cascade
    - All μ^+ will decay
    - If we can identify the captures with high purity and with reasonable and quantifiable efficiency, we can do neutrino/anti-neutrino separation
    - This allows CP studies of long-baseline and atmospheric neutrinos
  - Supernova-related studies
    - spallation backgrounds
    - low energy particle identification, e.g. β/γ
  - Calibration system development – laser calibration
  - Photon detection system development

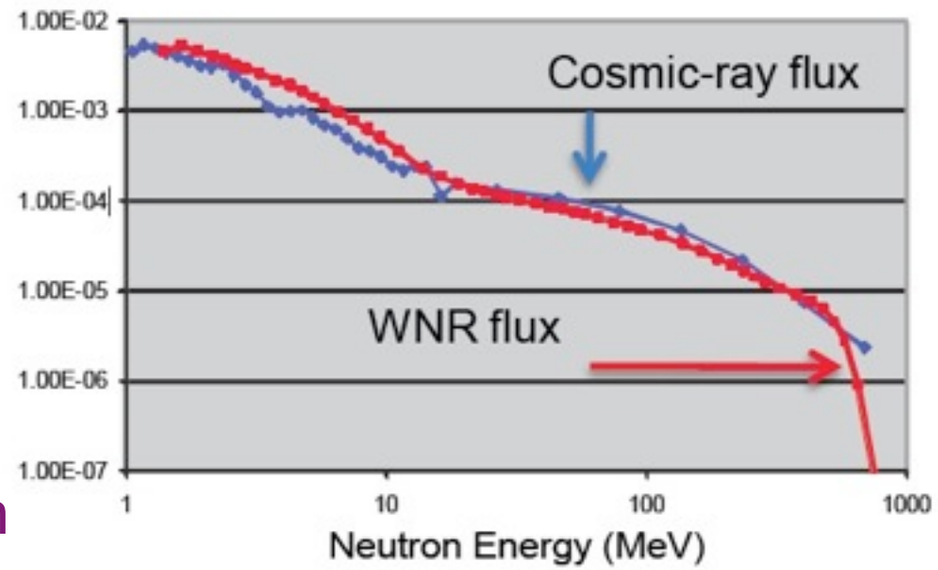
Physics Goals: Future

- Outside the scope of the LDRD
  - Run in a neutron beam (at LANL)
    - neutrino energy reconstruction
    - neutron induced pion production
    - neutron induced radioactive background
  - Neutrino running
    - SNS running -- energies relevant to supernovae
      - neutrino argon cross sections
      - study de-excitation gammas from nuclear decays
      - reconstruction demonstration with real data
    - NUMI running -- energies relevant to long-baseline oscillations
      - exclusive and inclusive neutrino interaction in resonance and DIS region
      - explicit experience with neutrino energy reconstruction

Neutron Running at LANSCE

- Characterize neutron interactions to understand energy by neutrons in neutrino interactions with Ar
- Measure response of LArTPC to neutrons
  - multi-particle events in high-energy regime
  - characterize reconstruction efficiency of these events
- Measure “cosmogenic” production of radioactive isotopes
  - validate simulations of spallation
  - background for neutrino interactions
- Want neutron beam with cosmic-ray energy spectrum
- Ability to know neutron energy, event-by-event
- Run prototype this Fall at LANSCE
  - WNR Facility provides a high-flux neutron beam with spectrum similar to cosmic-ray neutrons
  - Energy via time of flight with photon detection system
- Will attenuate the beam flux to achieve 1 neutron per drift time (200 μs)

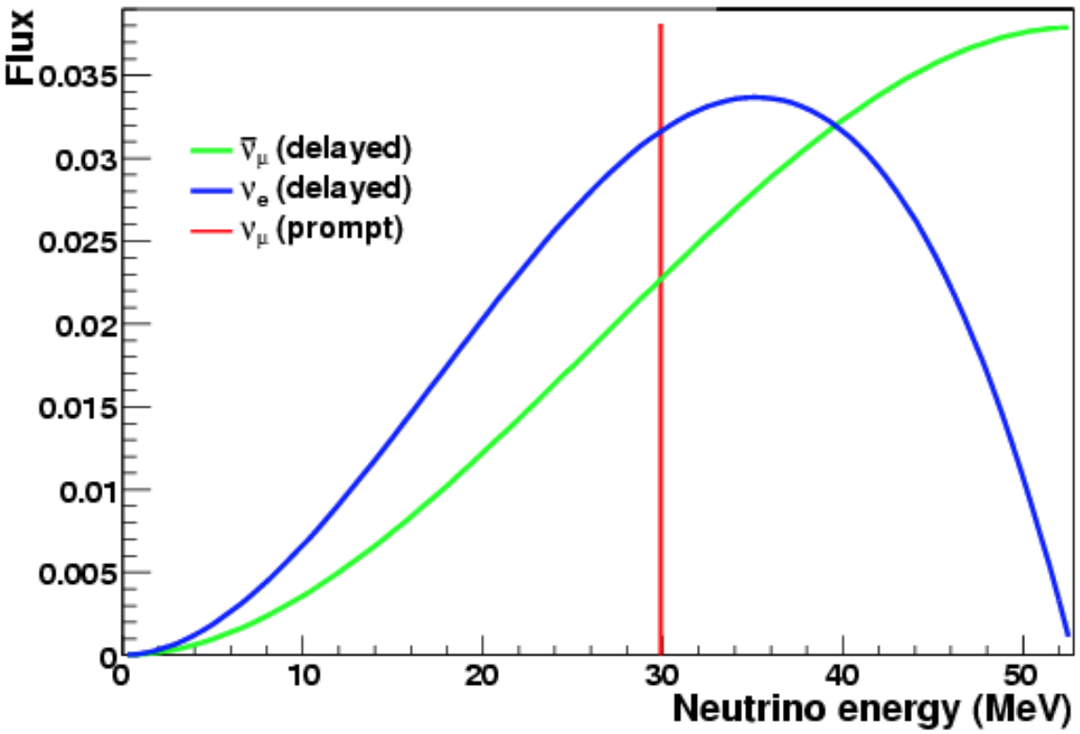


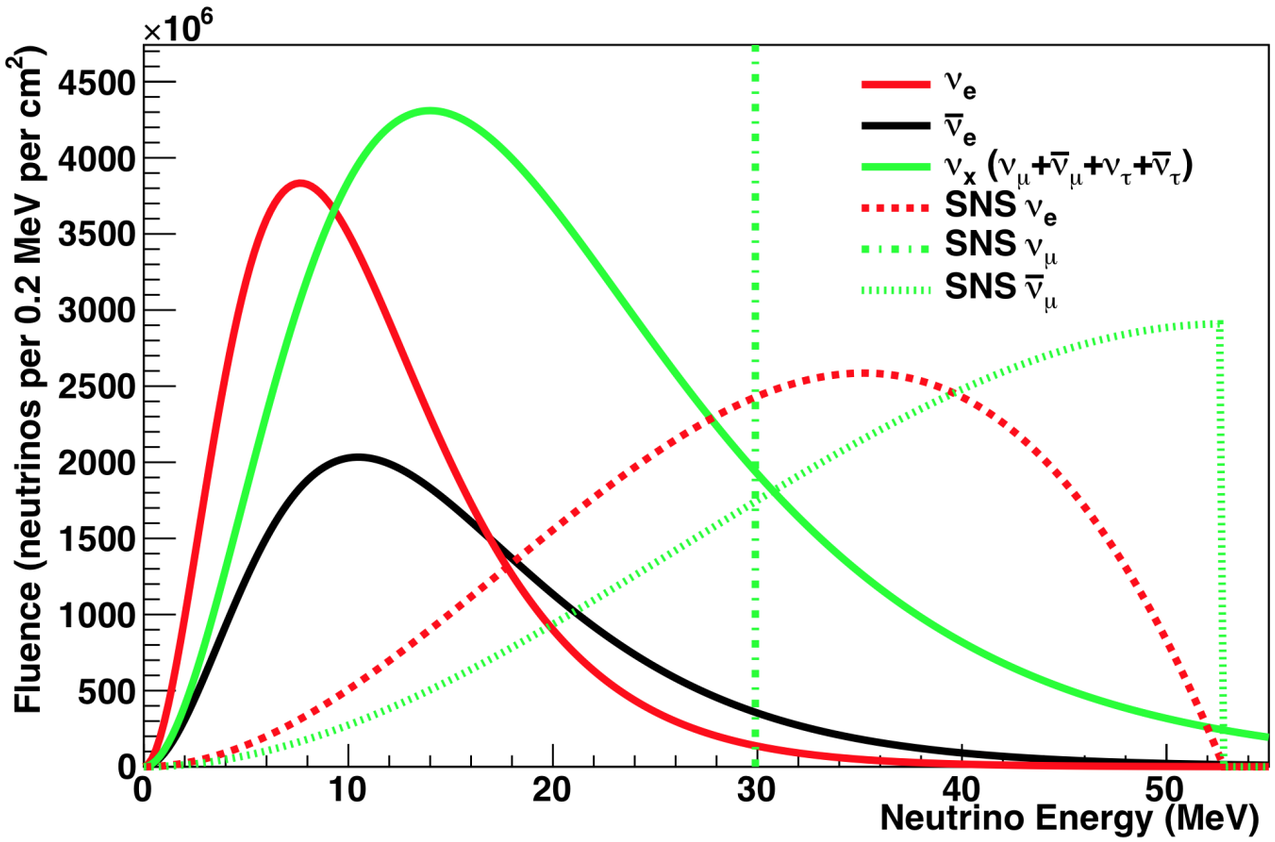


SNS: Spallation neutron source

- Neutrino beam from stopped π available at Oak Ridge National Laboratory

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$
$$\mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e$$



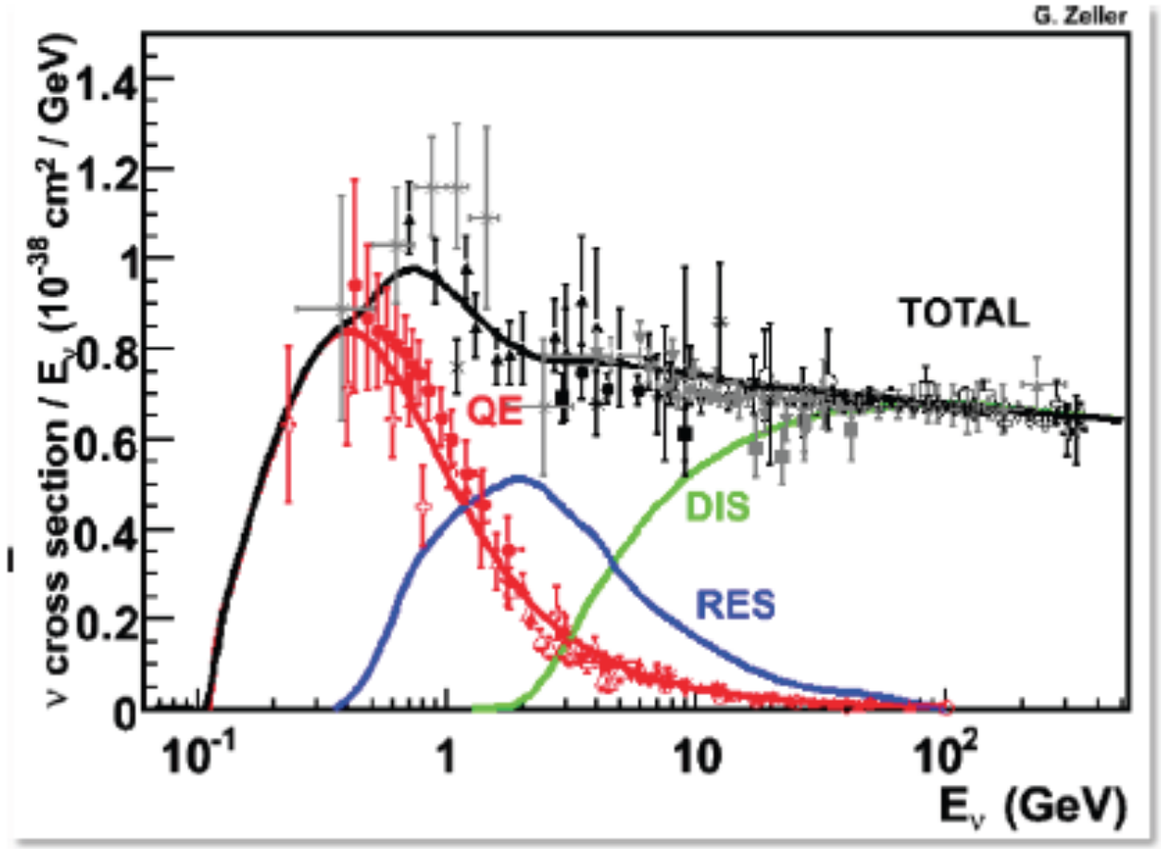


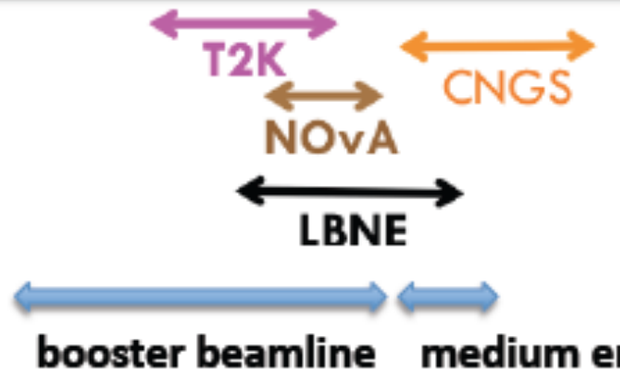
- Supernova neutrino spectrum overlaps with stopped π neutrino spectrum
- Fluence at ~50m from the SNS amounts to ~a supernova a day

Figures by Kate Scholberg

NuMI Run

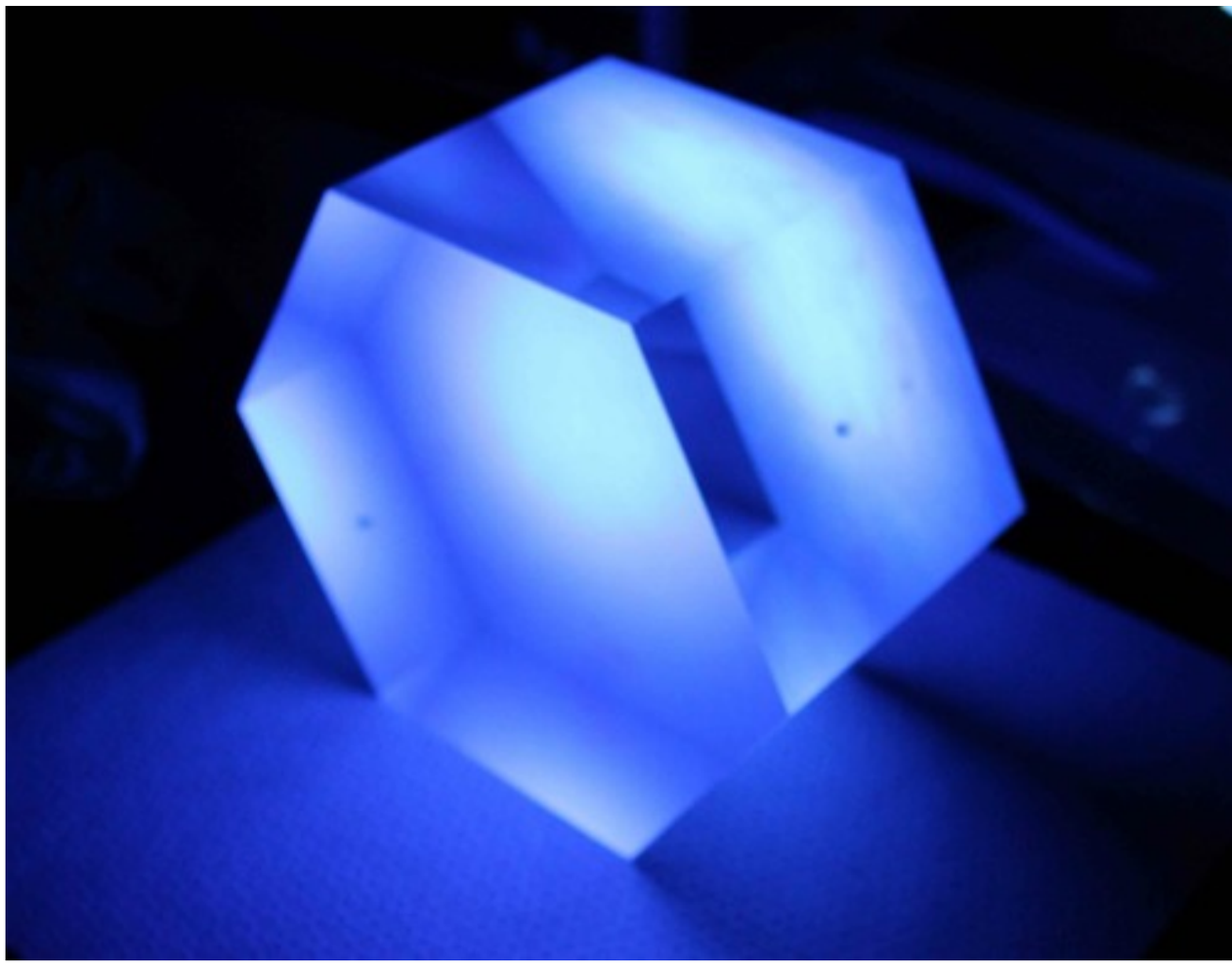
- Use NuMI beamline at Fermilab -- on-axis location
- Captain will "contain" 10% of events
  - excluding muons and neutrons
  - 370,000 events/year
- Measure neutrino-Ar cross sections above 2 GeV
- Understand event reconstruction in this energy regime
  - particle id and energy in high multiplicity events





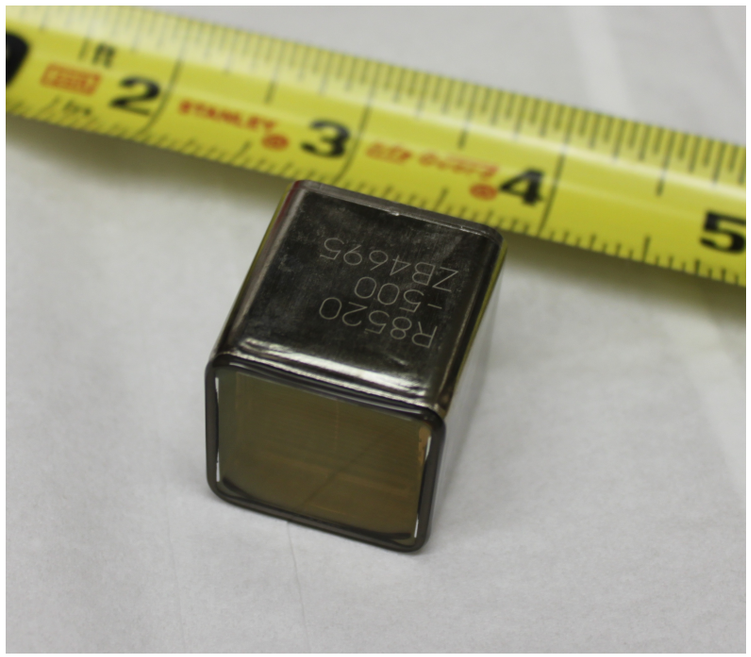
Photon Detection System

- 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 prototype
  - 2.2 pe/MeV in CAPTAIN



Photon Detector

- Baseline:
  - Hamamatsu R8520-500
    - 1” square
    - 25% QE at LAr temperature, special Bialkali LT
- Have 16 PMTs currently
- Place one in each of the 6 hexagon triangles on both top and bottom, and two each at center
- Developing base voltage divider based on parts used on MiniCLEAN bases



Electronics

- Digitizer
  - Have two CAEN V1720
    - Eight channels each, 250 MHz
    - Optical fiber readout
- May use TDC for timing studies
- DCDaq software -- currently used for MiniCLEAN and DEAP with digitizer
- Will integrate with time syncing into the rest of electronics (MicroBooNE's for TPC cold frontend and backend)

Options

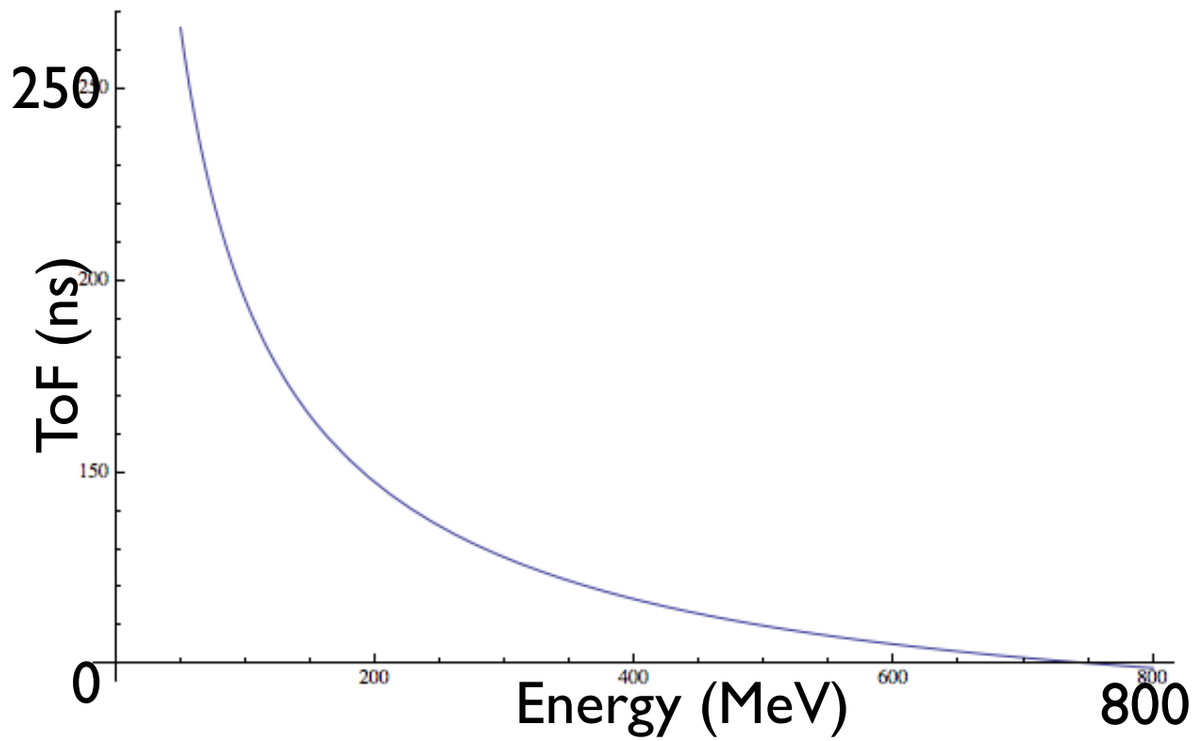
- Wavelength Shifter
  - TPB
    - current baseline
    - experience from MiniCLEAN
    - degradation from UV
  - Bis-MSB
    - may be more stable
    - cheaper
  - Others?
- Will put WLS on thin acrylic slide in front of PMT
  - Can easily change the WLS
  - Insertion at last minute before closing up to minimize degradation

More Options

- Use prototype and CAPTAIN to test many other options for PDS
  - Acrylic light guides
  - Other readout devices (SiPMTs, larger PMTs, etc.)
  - Other electronics

Neutron ToF

- Use PDS to determine time of flight of neutrons to assess energy
  - For prototype expect ~2 pe/MeV of prompt light
  - Should be able to have about 2-3 ns uncertainty above 10 MeV
  - Could improve if we delay signal and use second digitizers (500 MHz effective)



Current Schedule

- Prototype schedule
  - TPC parts in hand June 1
  - August -- TPC in LAr
  - Cosmic runs
  - Neutron run when beam time granted at LANSCE
- CAPTAIN
  - Cryostat in fabrication, delivery September 2013
  - TPC fabrication this summer
  - TPC assembly in October
  - Laser and PDS integration in November
  - Cosmic runs

Summary

- Two LAr TPCs are under construction at LANL
  - Plan to serve as test benches for PDS options as well as test laser calibration and other systems
  - Will be used in neutron and neutrino beams
  - Still time to get involved -- let myself or Chris Mauger (cmauger@lanl.gov) know