Photon Detection in CAPTAIN

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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
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 $\mu^+/\mu^-$ separation by track curvature
- Approximately 75% of $\mu^-$ are captured by the argon nuclei
- Gamma and neutron cascade
- All $\mu^+$ 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. $\beta/\gamma$

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)
• Neutrino beam from stopped $\pi$ 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 $\pi$ 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 $\sim 2$ 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
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