DUNE FD Calibration workshop: How are things going?

Sowjanya Gollapinni (UTK)
Kendall Mahn (MSU)

DUNE Monthly Collaboration Call
March 15, 2018

The workshop hasn’t ended yet :)

Friday, March 16, 2018

10:25 - 11:30 **Dual Phase Considerations**

Zoom link: https://fnal.zoom.us/j/965470841
Meeting ID: 965 470 841

Conveners: Prof. Sowjanya Gollapinni (University of Tennessee, Knoxville), Prof. Kendall Mahn (Michigan State University)

Location: Race Track WH7-XO

- 10:30 **DP Photo detector calibration** *20'*
  Speaker: Clara Cuesta (CIEMAT)
- 10:50 **Dual Phase Considerations** *20'*
  Speaker: Bo Yu (Brookhaven National Lab)
- 11:10 **Discussion: DP vs SP considerations** *20'*

11:30 - 12:00 **Discussion - Any remaining or tabled discussion** *30'*

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12:00 - 13:00 **Lunch** *1h0'*

13:00 - 15:00 **Summary & Next Steps**

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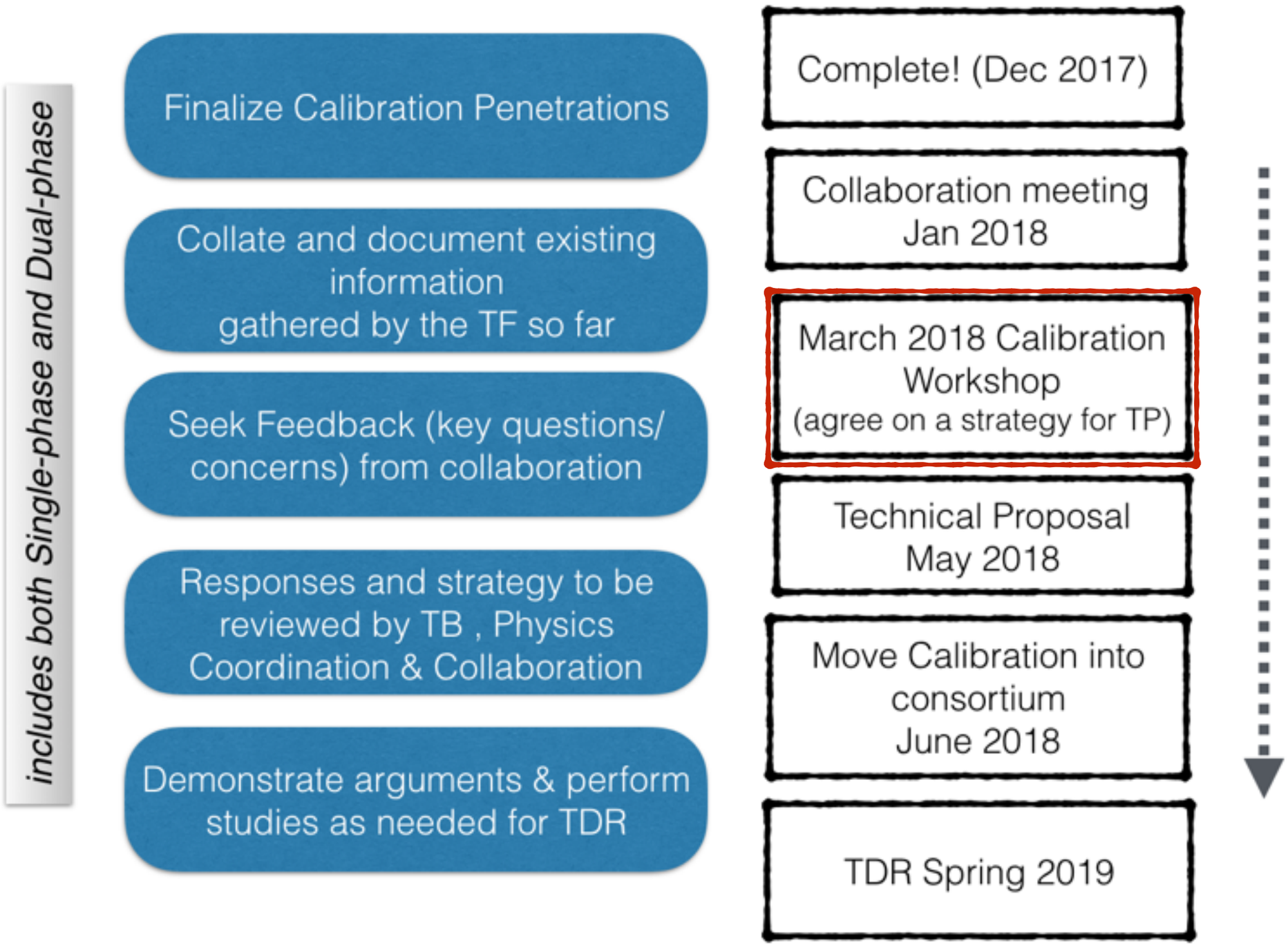
- 13:00 **Workshop Summary** *45'*
  Speaker: Prof. Kendall Mahn (Michigan State University)
- 13:45 **Discussion: Agreement on Strategy & outstanding concerns** *45'*
- 14:30 **Next steps & Future plan** *30'*
  Speaker: Prof. Sowjanya Gollapinni (University of Tennessee, Knoxville)

Calibration Strategy: Collaboration Process Timeline



Workshop Goals/Format

(https://indico.fnal.gov/event/16087/other-view?view=standard)

- *Wednesday*:
  - Summary of current status
  - Existing calibration sources
- *Thursday:*
  - External Systems: Motivation, physics benefits etc.
  - Discuss Key Questions/Concerns received so far
    - ***https://docs.dunescience.org/cgi-bin/private/ShowDocument?docid=7449***
    - Note down possible studies for TDR
- *Friday:*
  - Dedicated session on DP considerations
  - Summary, Agree on external systems and what goes into TP
- *Workshop focus:* External calibration systems & Physics benefits

Attendance:
20 in-person
and 5-10 remote
(productive discussions!)

Existing Sources Discussion

- *Better categorization of sources*: Not all are calibration sources, some can only be used to test models

- *Emphasis that each source comes with unique challenge* (e.g. Michels, Pi0s) — strong argument for redundancy

- *Exchange rate of argon* through the purification system can impact estimates timescales for measurements, need to take it into account

- Would be good to understand what are the *measurements we need from ProtoDUNE* and also how we can use it to test things for DUNE (e.g. DUNE electronics test)

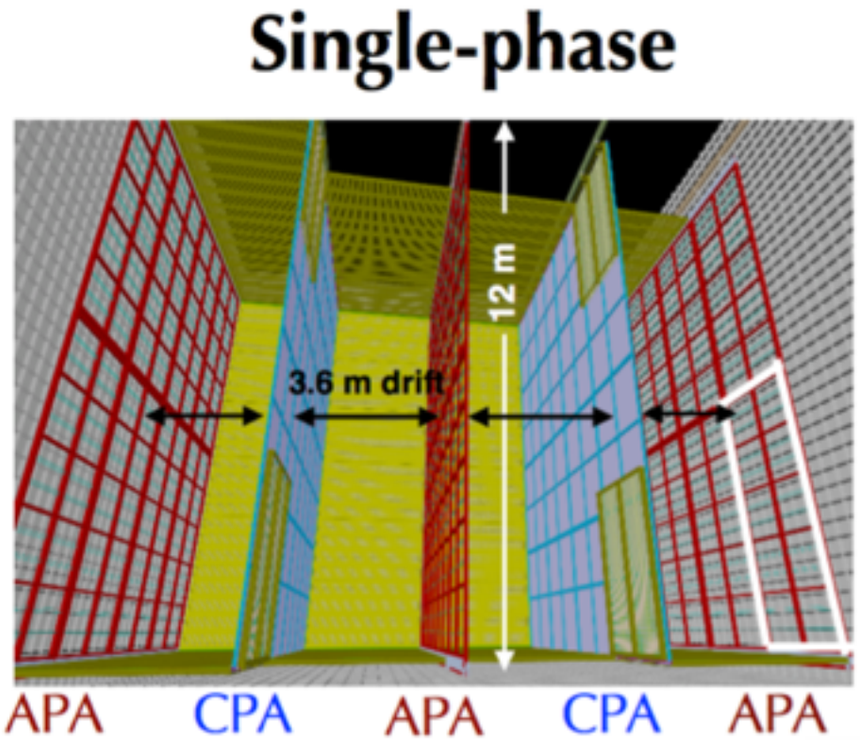
- New estimates for cosmic muons from the MUSUN Cosmic Simulation shown

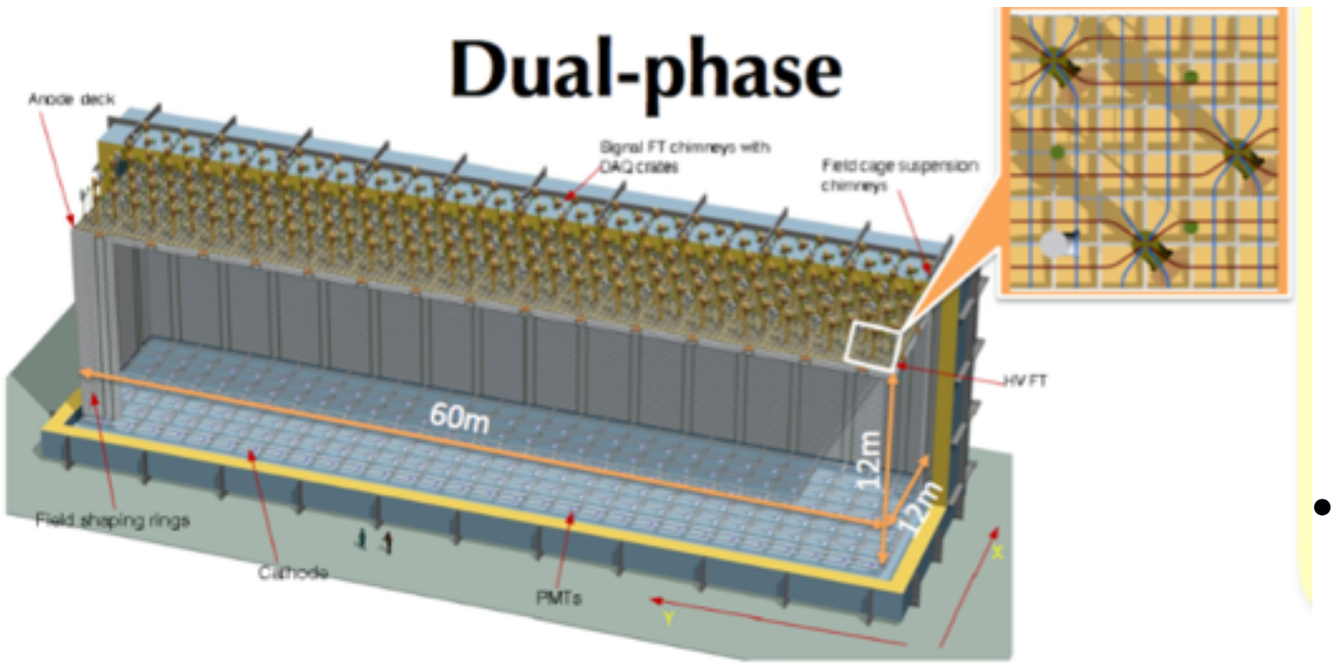
- *Ar39:* good source but (noise) threshold dependent; lifetime critical

    - Need to understand *radiological background and requirements* for the detector. All consortia need to thinking about

- *Current monitors* as a source to diagnose resistor failures

Dual Phase Considerations





- *Dual Phase:*
  - Liquid and gas phase
  - Ionization signals amplified and detected in the gaseous phase above liquid level
  - 12m vertical drift in liquid argon
  - Benefit of vertical drift: Cosmics provide enormous number of APA-CPA crossers
- Dedicated discussion on this later today

Dual Phase Considerations

- *E-field distortions & impact on dQ/dx*

  - Space charge from Ar-39 for DP: not small; E-field1.0% (dQ/dx < 0.3%); Spatial 5 cm (dQ/dx 2 – 3%)

  - plus E-field distortions from drift field deformations (cathode bowing, misalignment, APA flatness etc.)

  - Argon flow pattern (steady state or turbulent) can significantly impact this. Even more complicated for DP: +ve ions may collect above the liquid and create surface interface issues.

- *Does the gain vary with time?* charge up from cosmic rays, how long does it take to go away?

- Interplay b/n Electron lifetime (3 ms requirement) and gain; Lower lifetime risky

- Requirements (and the ability to measure things) will change if we cannot achieve our nominal drift field

- Do impurities from gas enter the liquid phase? Will that an issue for lifetime? Temperature variations b/n gas and liquid phase can be an issue; flow pattern can also impact

Current Proposed Systems

External Calibration Systems (currently considered)

- Laser (e.g. MicroBooNE, SBND)
- Photo-electron (Laser) Calibration System (e.g. T2K)
- Radioactive source Calibration
- Portable (external) Neutron source
- Photon Detector Calibration system
- Cosmic Ray Tagger (CRT)
- Field response calibration devices — not discussed

- *New systems proposed/considered/ discussed*
  - Radioactive sources also attached to cathode; injecting sources into argon
  - T2K photo-calibration system — feasibility study planned
  - Re-use of PDS system as light emitter? — bench tests and protoDUNE for feasibility
  - Electron accelerator — exploratory studies needed

Discussion on Laser

- T2K-style photoelectron laser calibration system: similar to pulsing the cathode, a nice wake-up system to know things are alive
- Safety associated to SBND-style laser system discussed
  - Laser head is plastic, but motor may include metal parts — need to assess
  - Laser will sit 40 cm (in X) from APAs, low field; will NOT penetrate ground plane
- Post-workshop activity: Laser vs Cosmics statistics arguments require updating with new simulation-based cosmic numbers from T. Junk

Low energy relevant energy scales

K. Scholberg, E. Conley, J. Stock, J. Reichenbacher, R. Svboda, B. Littlejohn

Gammas: 9 MeV

Electrons: Muon decay (Michels) endpoint ~50MeV

Neutrons: 6 MeV (captures)

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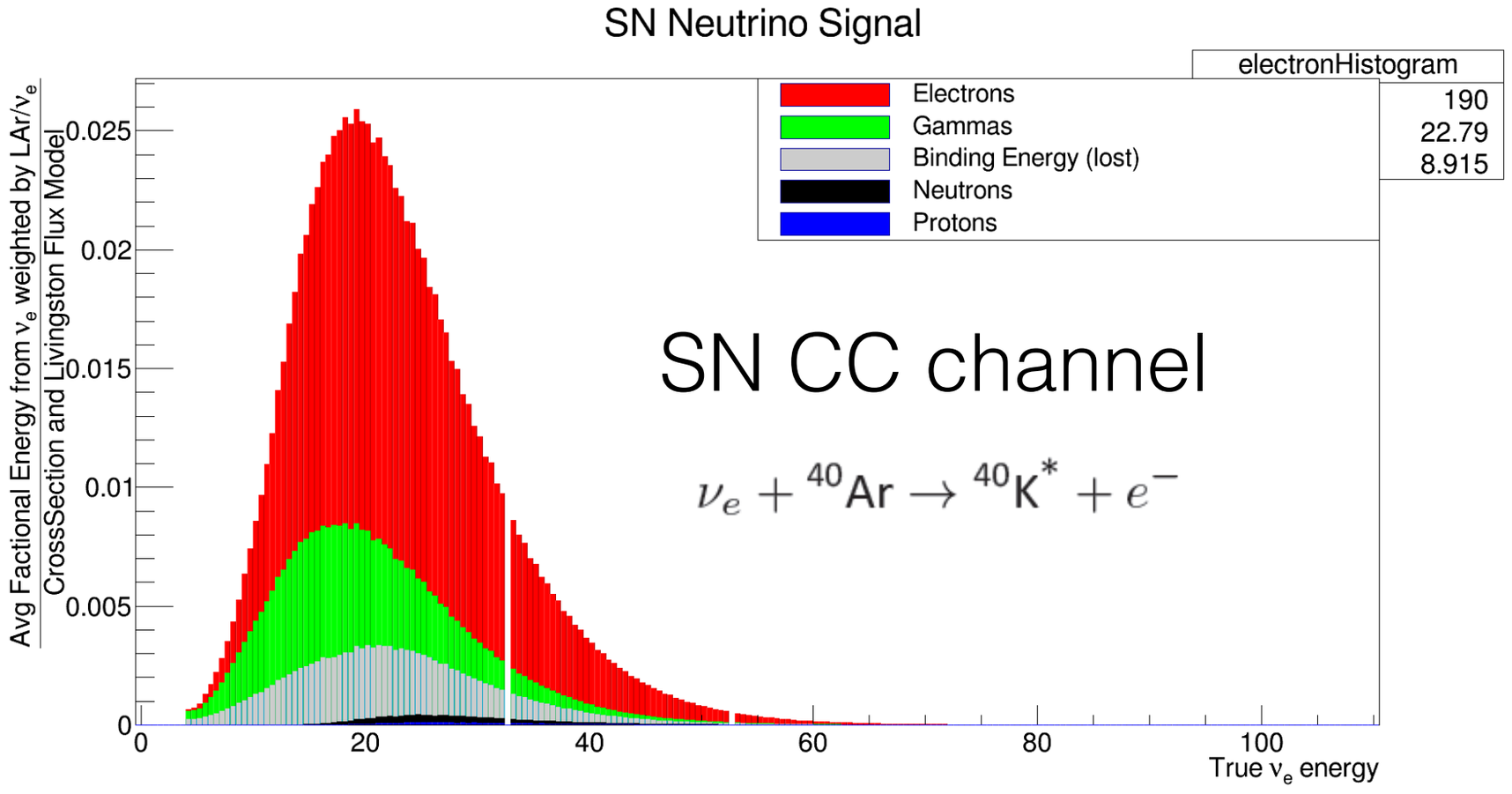
SN NC channel (10 MeV)



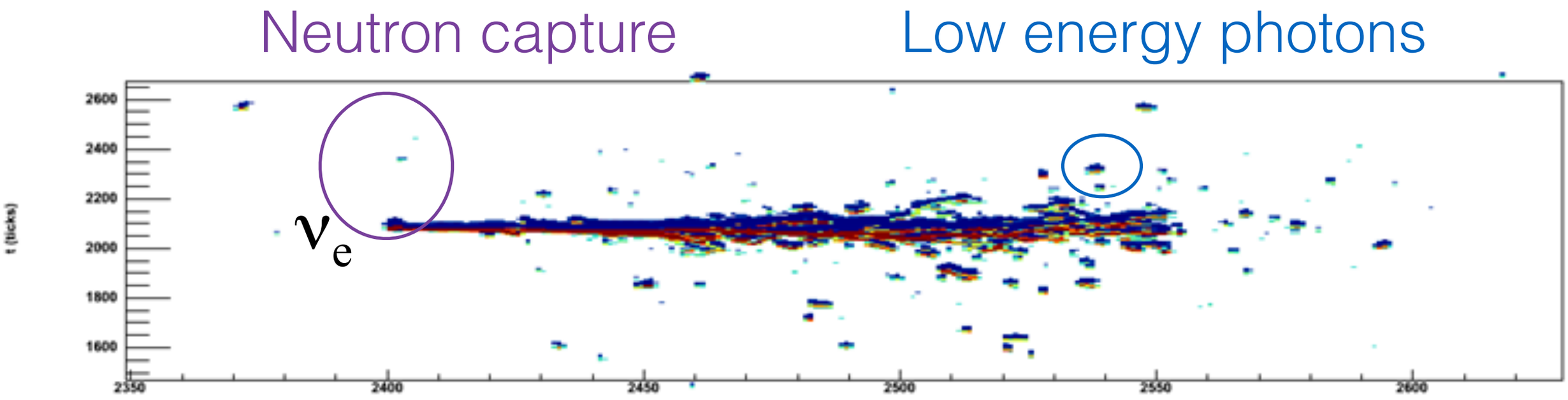
Low energy EM response also relevant for LBL

K. Scholberg, E. Conley, J. Stock, J. Reichenbacher, R. Svboda, B. Littlejohn

Gammas: 9 MeV

Electrons: Muon decay (Michels) endpoint ~50MeV

Neutrons: 6 MeV total photon signal



EM shower outliers

Source Calibration

K. Scholberg, E. Conley, J. Stock, J. Reichenbacher, R. Svboda, B. Littlejohn

- Sources serve as “standard candles”, direct test of efficiency of signal, background LE events with fixed position/energy/trigger

- Radiological sources:
  - Deployment on cathode, outside field cage, or in fluid
  - Some natural (Ar39) some not (Thoron, Nickel)
  - Range in gamma energy, ability to stage deployments

- Neutron generator:
  - Outside field cage, illuminates entire detector with capture events due to a anti-resonance
  - Characterizable capture spectrum (“bunch of standard candles”)

Discussion on Sources

- *External Neutron Source (Bob Svoboda)*
  - Better estimates on size of the system: 2 x 2 m cylindrical tank; 3 systems (fixed) can span the detector
  - Human safety needs to be taken into account
  - Will need a hole in insulation as in Feedthroughs, need to do shielding studies and understand needs
  - Proposal to understand argon capture gammas at the LANSCE facility, LANL as a test bench
- *Radioactive sources (Juergen/Jason)*
  - Studies from Juergen/Jason on charge-light correlation using simulation of Ni Calibration Source in the DUNE FD
    - Developed MC cheating tools — huge effort ongoing

Photon Calibration System (Zelimir Djurcic)

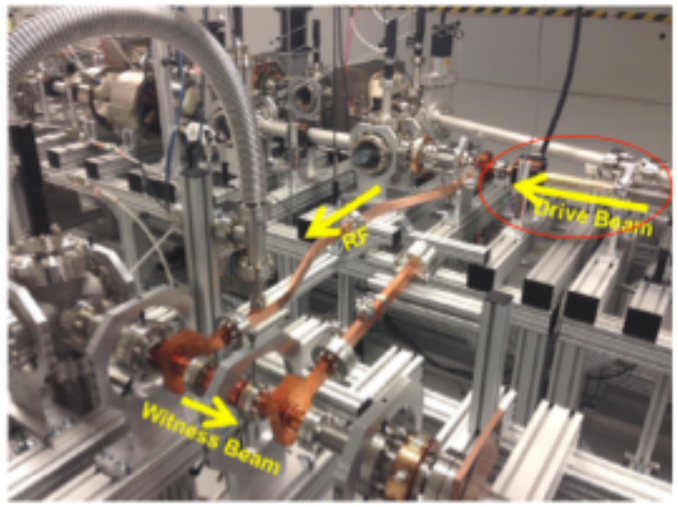
- *UV-light based Photon Calibration System*
  - verifies gain, timing resolution; monitors stability and response over time
  - light diffusers on cathode: safety discussed; some concern in how we route fibers safely
  - Interesting idea (Stephen Pordes): can one use a flash lamp and generate electrons off the mirror? much simpler system
    - Bench tests at ANL and an eventual test at ProtoDUNE as feasibility tests/ studies
- Absolute Calibration ($N_{photons}$ to ADC Charge)
  - Radioactive sources; cosmics
  - New idea: Electron Accelerator?

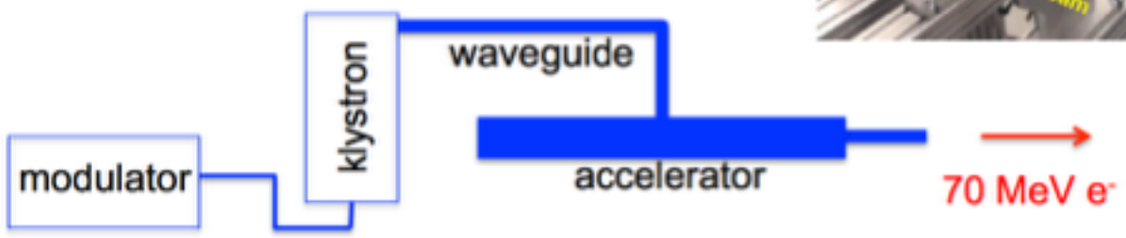
Electron Accelerator (Zelimir Djurcic)

Electron Accelerator?

- ANL "hand-made" 70 MeV electron linac:

-50 kV HV Power Supply
-Modulator (~250k M&S)
-Klystron: L-Band 1.3 GHz (~$275k)
-Waveguide
-Accelerator Structure (L-band -100k)





- But all these components are commercially available: medical applications

Electron Accelerator Exploratory Study

- Is it "useful"?
  - -What do we learn (low-E physics)?
  - -Can the intensity dial-down to single electron?
- Interface with Cryostat/TPC
  - -ProtoDUNE will bring the test-beam inside TPC, can we do the same with DUNE?
  - -Beam pipe penetrations?
- Operational Requirements (power requirements, DAQ interface, cooling needs?)
- Noise issues?
- Space requirements?
- What else?

Cosmic Ray Tagger

(Josh Klein, Richard Diurba)

- Studies underway to understand the feasibility of the system
- Availability of space a consideration
- Agreement that a small portable system is more useful
- Provides simple/direct triggers
- In terms of motivation, growing agreement that it is best served as an independent handle for t0 and also as a reconstruction efficiency check

DAQ Needs for Calibration

(Matt Graham, Josh Klein, Kurt Biery)

- Better understanding of limitations from the DAQ side
  - A total bandwidth of 30 PB/year for all 4 FD modules
  - Other than random triggers, it is anticipated that the TPC threshold will be >10 MeV for normal running
  - If event rate in detector is > 0.5 Hz, in existing paradigm event builder cannot keep up
  - All data from front-end is passed to a temporary buffer, without zero suppression (~10 Tb/s/10 kt)
  - If event rate in detector is > 1.6x106/year, you are dominant source of data for DUNE (unless events are zero-suppressed or geo-suppressed)

DAQ Needs for Calibration

- Some (very) rough initial estimates for annual data rates currently in TP (see backup)
  - Doesn't include some systems (e.g. Ar39, PDS)
- Need to clarify estimates in the coming weeks
- Mitigation strategies on the 0.5 Hz event rate and transfer rates from underground location to surface discussed
- Didn't loop in offline folks into the discussion yet, there maybe challenges on that front that needs to be considered

TP & Post Workshop Goals

- A document summarizing current status is in works
- The immediate goal after the workshop is to incorporate workshop discussions/responses/considerations into the summary document
- This document will form basis for the calibration section in Technical Proposal (2 to 3 page long?)
- Technical Proposal text due in April — *we don't have a lot of time*
  - *Need to understand how much of calibration related discussions will be included in individual consortium chapters?*
  - *Some coordination required here so details are up to date with discussion in Calibration TF meetings*

Summary

- Workshop has been fun so far:
    - Additional ideas and their motivation raised
    - Many key questions answered or studies identified
    - Please join us for the final discussion at the workshop!