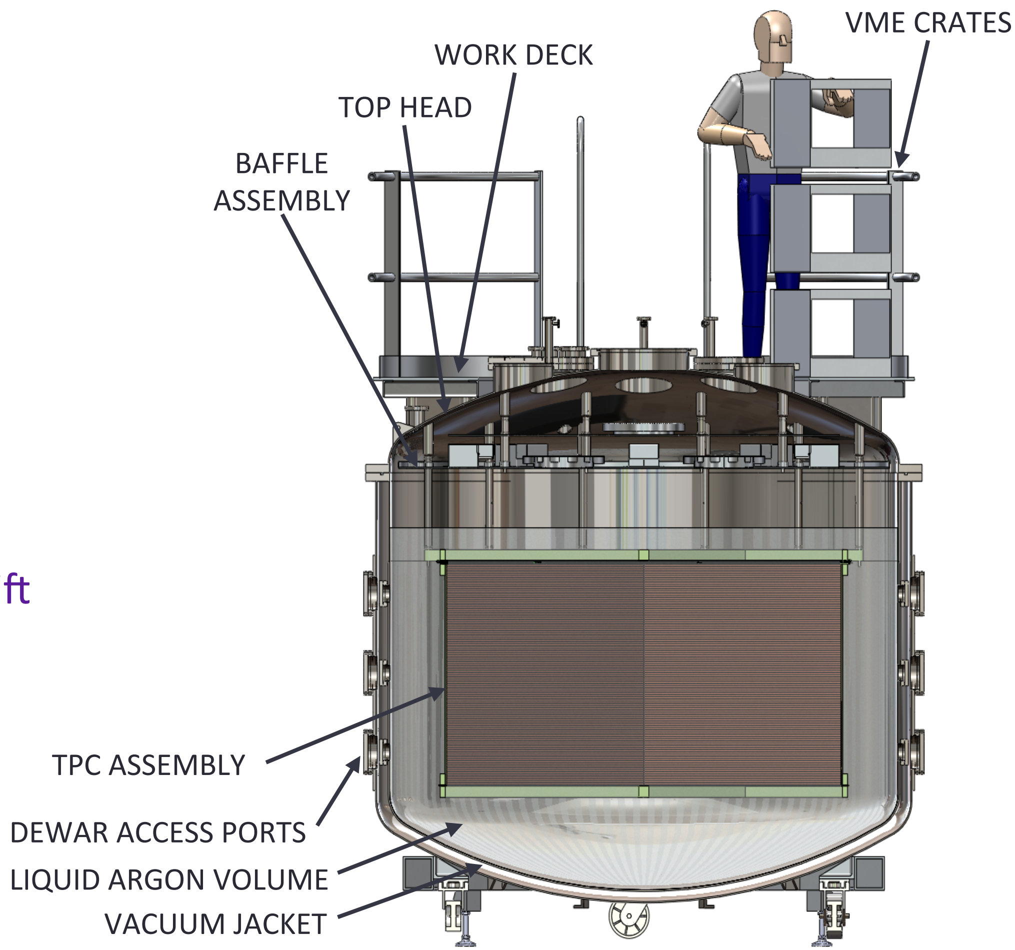
CAPTAIN

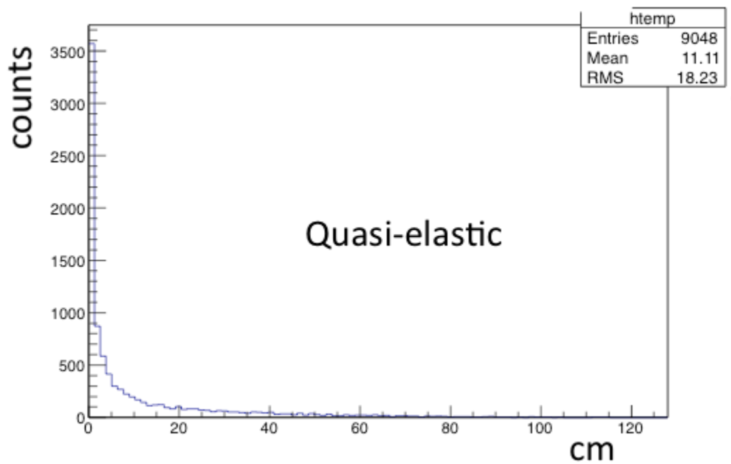
Elena Guardincerri – Los Alamos National Laboratory

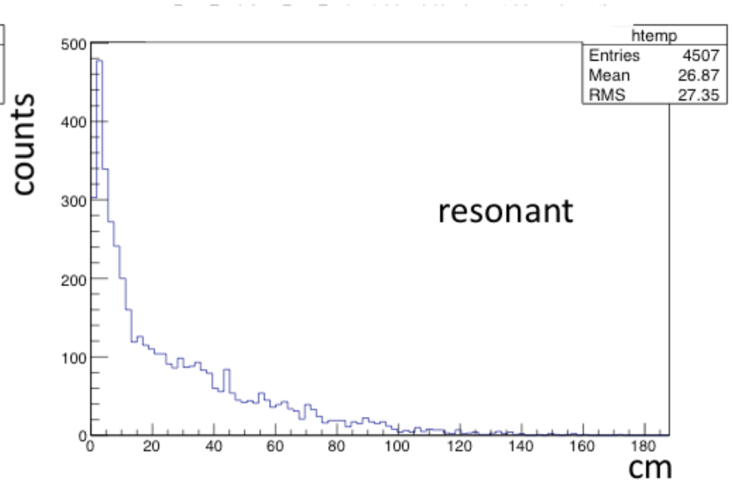
The CAPTAIN DETECTOR

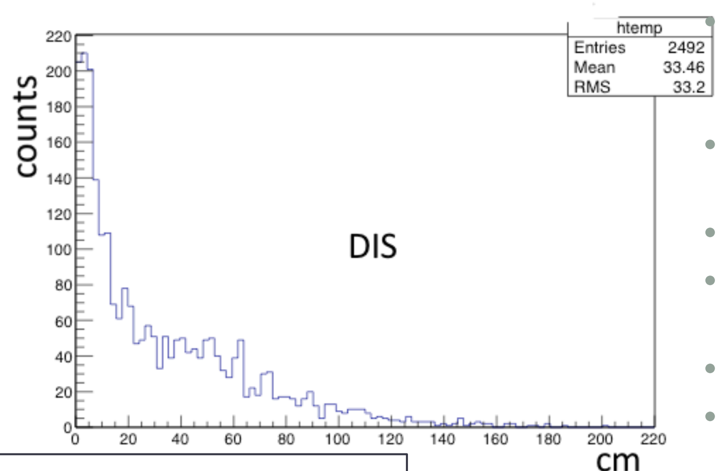
- CAPTAIN: Cryogenic Apparatus for Precision Tests of Argon Interactions with Neutrinos
- Cryostat
  - Capacity: ~7700 L
  - External dimensions
    - Flange diameter: 111”
    - Work deck height: 101”
    - All cryogenic and instrumentation connections made through top head
    - Work deck for worker safety and convenience
- TPC
  - hexagonal prism, vertical upward drift
  - **5** instrumented **tons**
  - 2k channels with **3 mm** spacing
- Laser calibration system
- MicroBooNE Cold electronics



Cryostat size from simulations







Kevin Yarritu - LANL

- Plots show the distance from the vertex to the endpoint of the longest track in the event for contained events
- Contained event: everything contained except the lepton and neutrons
- 10% containment with the chosen size
- 10^6 neutrino interaction per 10^{20} POT for NUMI ME tune
- Anticipate 4 x 10^{20} POT per year
- Would get 370,000 contained CC events per year during a NUMI ME run

Important dates

- Fabrication: 7/1/13 – 8/23/13
- Assembly: 8/24/13 – 9/20/13
- Installation inside cryostat: 9/23/13 – 10/11/13
- Integration of Laser calibration system: 10/14/13 – 11/1/13
- Commissioning and operation: 11/2/13 ->

Physics goals: before the end of FY 2014

- 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

Calibration system: motivations

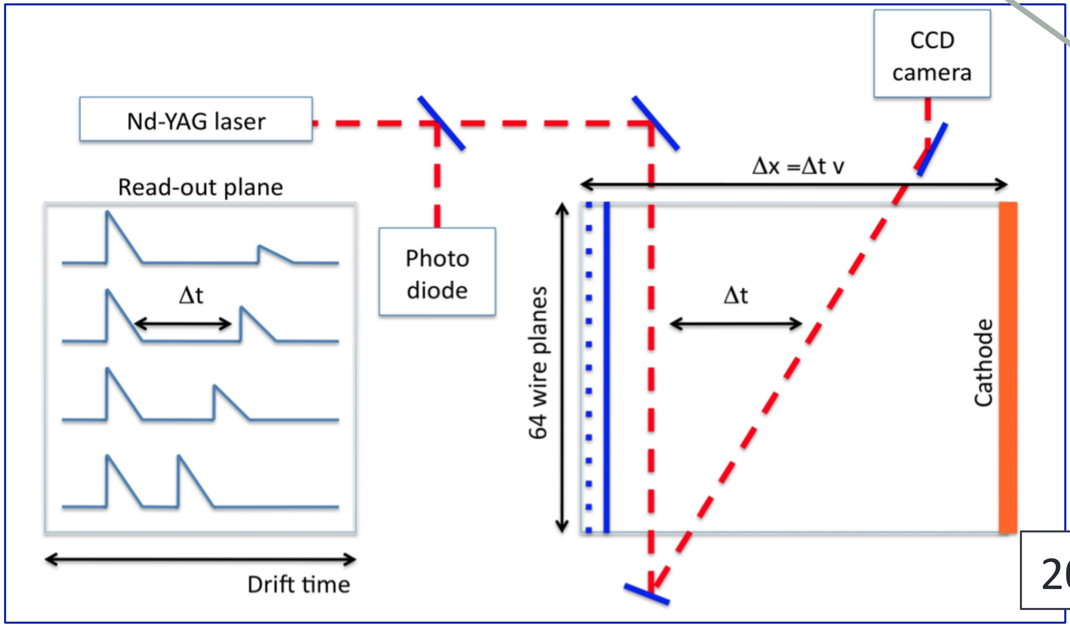
- Due to recombination in LAr only a fraction of the charge produced from ionization survives after drifting a time τ_{drift}

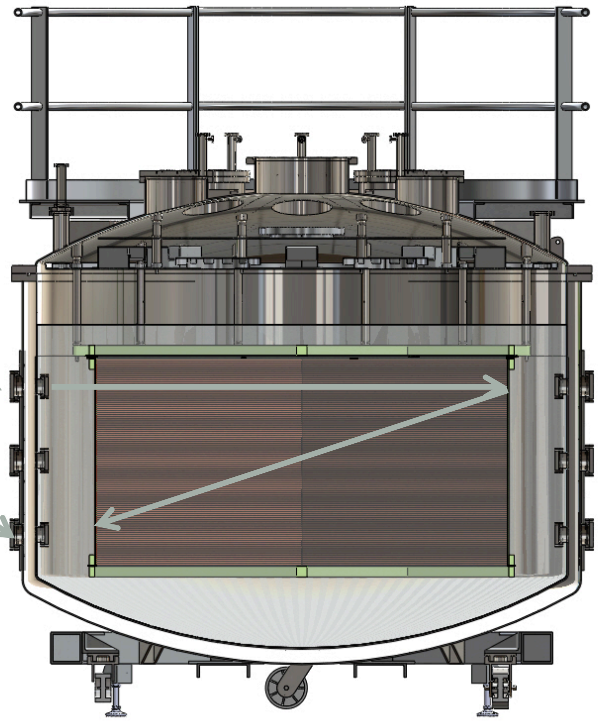
$$Q_{meas} = Q_{dep}\, R e^{-t_{drift}/\tau} \longleftarrow R = \frac{A}{1 + (k/\Sigma)\frac{dE}{dx}}$$

  - τ = 1 ms, Σ = 500V/cm
  - drift speed at 500V/cm is 1.6mm/µs
  - For 2.3m drift distance only 24% of the charge survives
  - 2% energy calibration requires ~1% uncertainty in τ_{drift}
- Due to the long drift time of ions the space charge effects are not negligible (-17 to 8V/cm in X and -5 to 12V/cm in Y)
  - $v_{drift} \cong$ 8mm/s ->$\tau_{drift} \cong$ 5min from anode to cathode
  - Changes in drift velocities will “compress” tracks distorting the measured dQ/dx (4% effect)

Laser calibration system

- Nd-YAG laser (Quantel "Brilliant B")
- 4 optical ports
  - 2 set 15cm from anode
  - 2 set 15 cm from cathode
- Based on a recent work by U. Bern (Rossi et al.)





Responsible: G. Sinnis - LANL

2009 JINST 4 P07011

Physics goals: future

Outside the scope of the LDRD

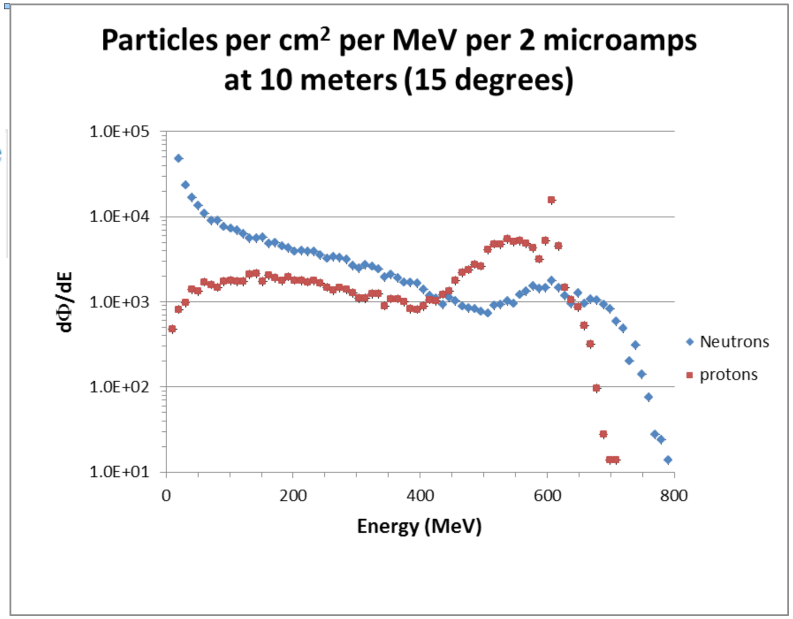
- Run in a neutron beam
  - spallation studies
  - surface running backgrounds
  - neutrino energy reconstruction
  - beam-induced backgrounds for the near detector
- Neutrino Running
  - SNS running – energies relevant to supernova
    - cross-sections
    - reconstruction demonstration with real data
  - 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

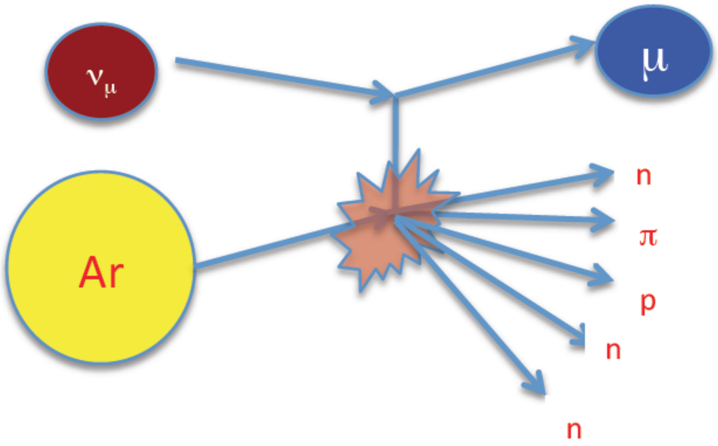
- Whitepaper:

Neutron running with a liquid argon TPC to study ν-Ar final state interactions and cosmogenic backgrounds important for LBNE

D. Cline[1], Z. Djurcic[2], E. Guardincerri[3], K. Lee[1], C. Mauger[3], K. Rielage[3], C. Sinnis[3], B. Svoboda[4], H. Wang[1]
UCLA(1), ANL(2), LANL(3), UC Davis(4)



- High energy neutron beam available at the Los Alamos Neutron Science Center
  - at a walking distance from the CAPTAIN commissioning laboratory
- Using time of flight, measuring interactions at specific energies up to this endpoint is possible
- Having Argon 40 nucleons interactions in the few GeV neutrino energy range can liberate several nucleons
  - measure neutron interactions in the detector to develop methodologies to constrain the energy carried away by neutrons in neutrino interactions



Neutron running

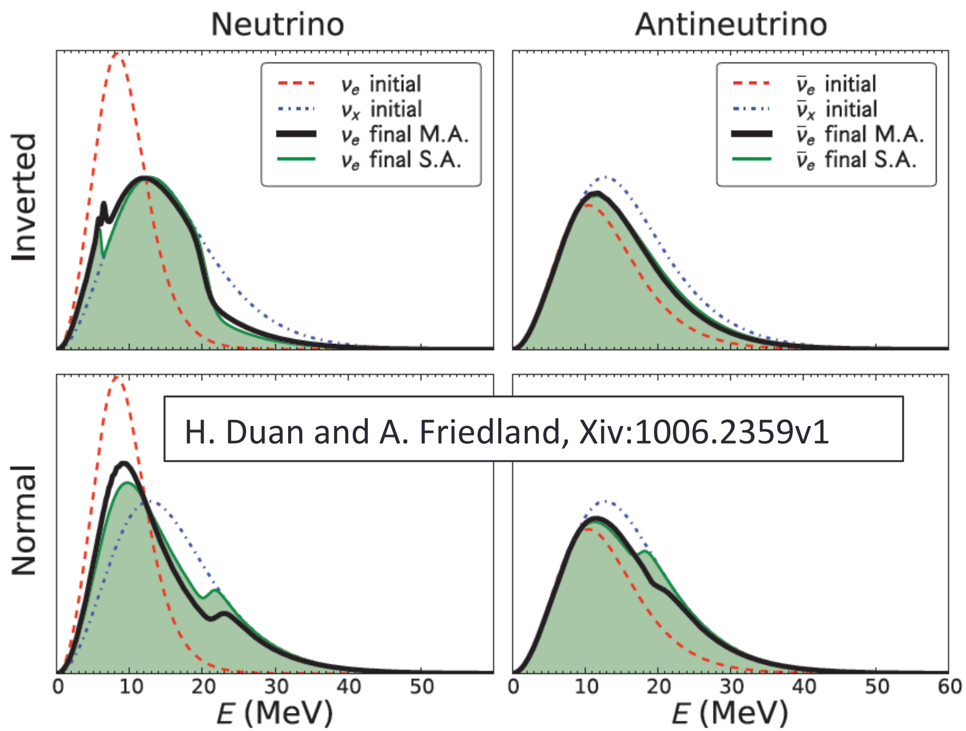
- Measure production of backgrounds to low energy neutrino events (e.g. supernova neutrino – E_ν peaks between 10 and 30 MeV)
- Measure processes that could be background to ν_e appearance, e.g. $^{40}Ar(n,\pi^0)^{40}Ar^{(*)}$ that may be important for near-surface running of the LBNE far detector
  - the outgoing π^0 could be mis-reconstructed as an electron
- Validate spallation simulations with production as a function of neutron energy measured by TOF

SNS: Spallation neutron source

- Whitepaper:

Measuring Neutrino Cross Sections on Argon for Supernova Neutrino Detection
J. Carlson, D. Cline, Z. Djurcic, A. Friedland, G. Fuller, E. Guardincerri, W. Louis, C. Mauger, K. Scholberg, G. Sinnis

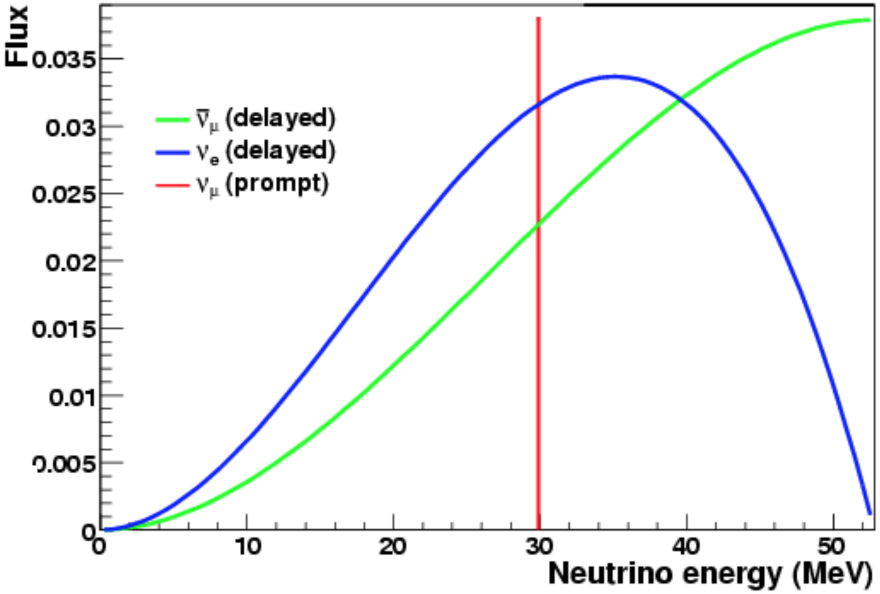
- Dominant channels for low energy neutrino interactions in Argon:
  - $\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K^*$
  - $\bar{\nu}^e + {}^{40}Ar \rightarrow e^+ + {}^{40}Cl^*$
- Expected ~ 3 events/s/kt over ~ 30 s for a SN @ 10kpc
- Measure cross sections for ν-Ar interactions at low energy (esp. vs from supernovae)
- Study CC and NC interactions below 50 MeV
- Study a realistic LAr detector response:
  - efficiency, resolution, event tagging

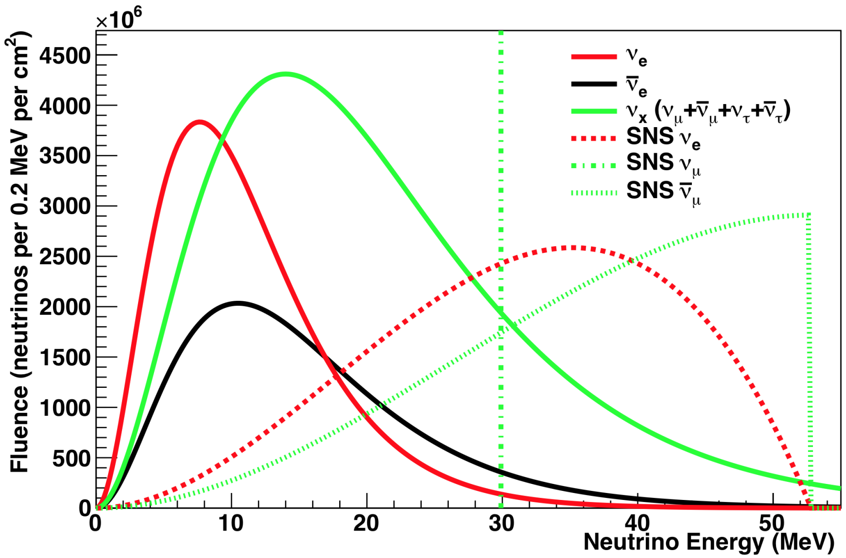


SNS: Spallation neutron source

- Neutrino beam from stopped π available at the OakRidge National Laboratory

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





- Supernova neutrino spectrum overlaps with stopped π neutrino spectrum
- Fluence at ~ 50 m from the SNS amounts to ~ a supernova a day
  - see talk by K. Scholberg at https://indico.fnal.gov/contributionDisplay.py?sessionId=6&contribId=67&confId=6122

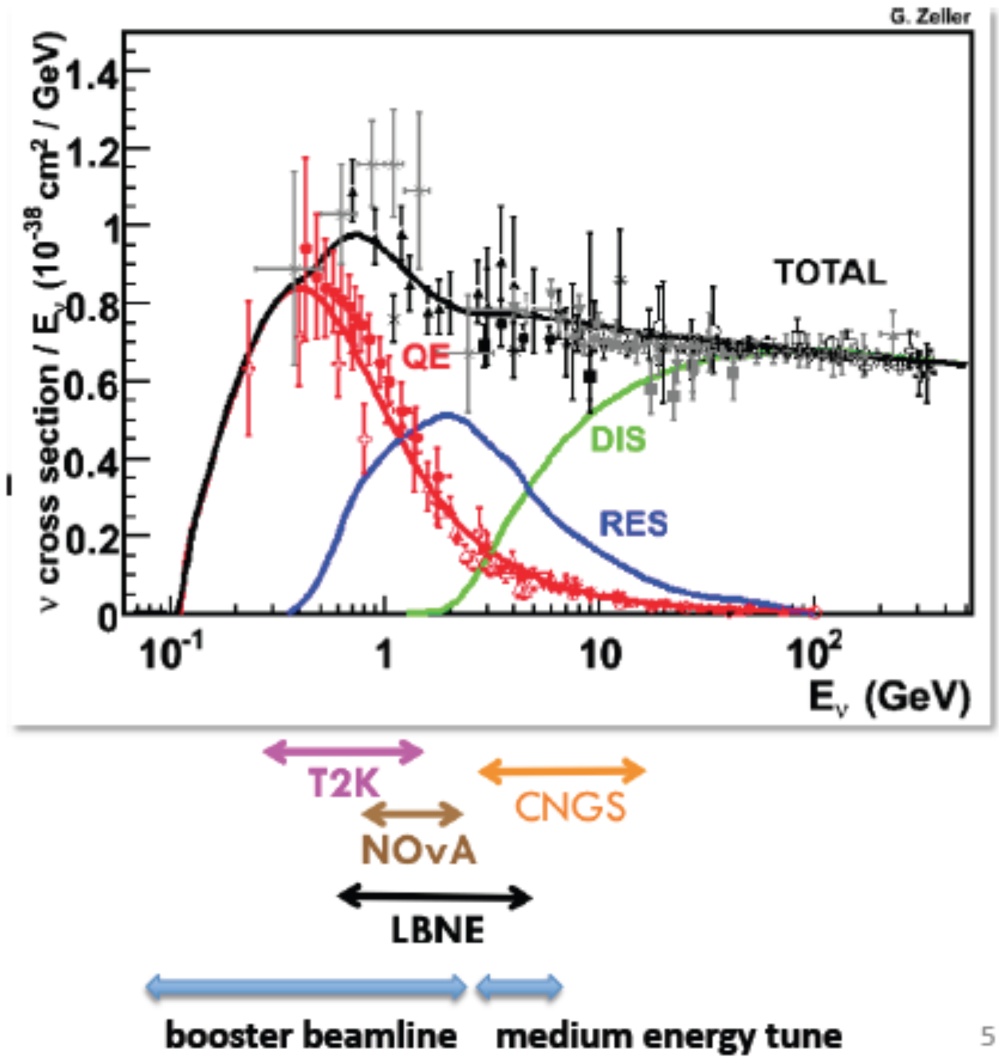
pictures by K. Scholberg

NUMI run

NUMI Running with the LANL LDRD Liquid Argon TPC

Z. Djurcic[1], E. Guardincerri[2], C. Mauger[2], C. McGrew[3], C. Sinnis[2], M. Tzanov[4], A. Yarritu[2]
ANL(1), LANL(2), Stony Brook(3), LSU(4)

- LBNE will detect neutrino with few GeV energy
  - rich and complex energy range
- Run in on-axis position in NUMI
- Energy regime complementary to MicroBooNE (booster)
  - booster + on-axis NUMI running covers entire LBNE energy regime
- 10% containment of "all but lepton and neutrons"
  - 370,000 "contained" CC events per year
- Measure exclusive and inclusive cross sections
  - cover the threshold region for pion production
  - cover the resonance regime
- Reconstruction experience with higher energy neutrino interactions



Conclusions

- A 5 tons LAr TPC will be built at Los Alamos National Laboratory in the next months and will start operating at the end of 2013
- It will be used to study different problems and topics
  - Experience in LAr TPC calibration
  - μ^+/μ^- discrimination for CP searches
  - Supernovae related studies (SNS)
  - Physics relevant to long-baseline oscillations (NuMI)
    - Neutron interactions in LAr (LANSCE)
- Numerous possibilities of collaborating (C. Mauger)