Expression of Interest
for a Full-Scale Detector Engineering Test and Test Beam Calibration of a Single-Phase LAr TPC

Thomas Kutter, LSU
on behalf of the EOI authors

SPSC Meeting
CERN, Oct. 21st 2014

Preamble

- Letter by LBNE leadership to CERN SPSC in April 2014 regarding potential use of CERN neutrino platform cryostat for LBNE detector test
- Submitted an "Expression of Interest for a Full-Scale Detector Engineering Test and Test Beam Calibration of a Single-Phase LAr TPC" to SPSC in early October 2014
  - CERN-SPSC-2014-027 ; SPSC-EOI-011
- 186 authors, 43 institutes, 6 countries

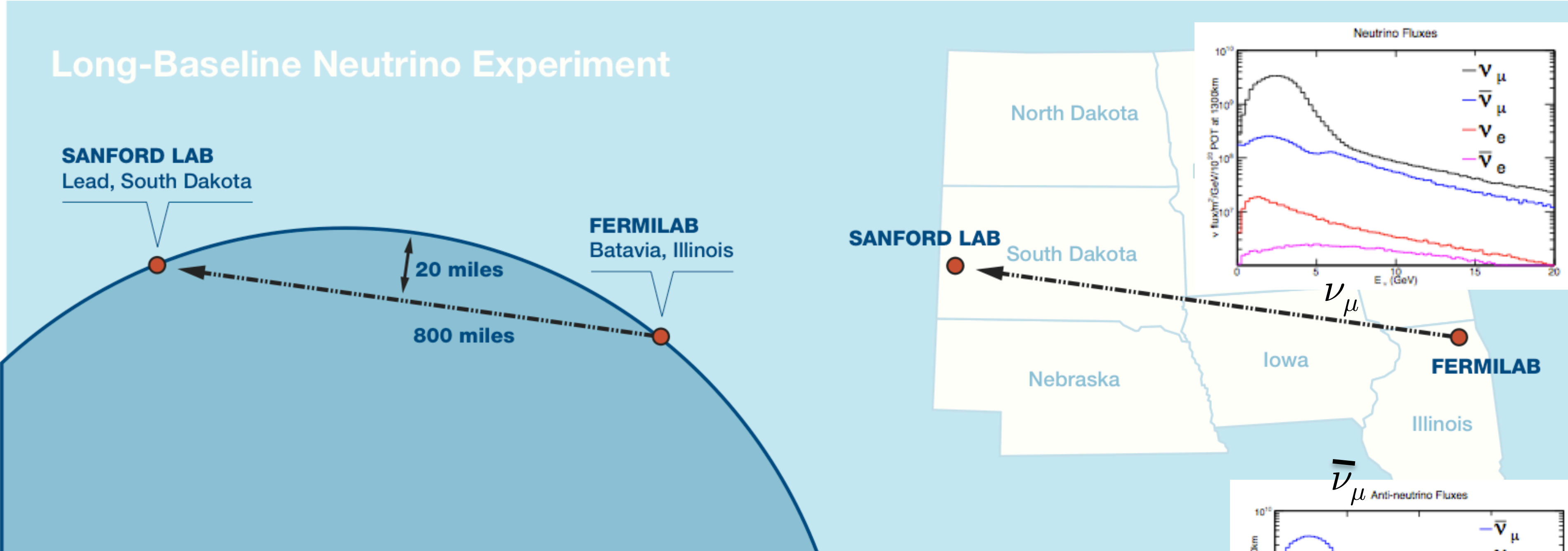
(from LBNE, LBNO and ICARUS collaborations)

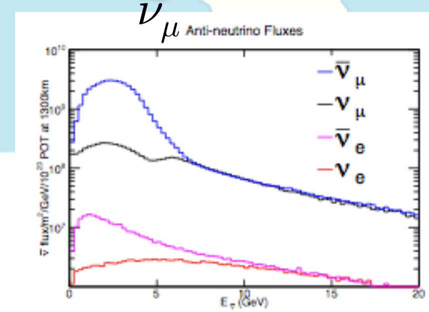
Outline

- Introduction
  - Science goals
- Experimental approach
- Full scale LAr detector prototype test at CERN
  - Goals
  - Experience
  - Schedule
- Summary

Physics Program of a New

arXiv:1307.7335





- Search for CP violation in $\overset{(-)}{\nu}_\mu \rightarrow \overset{(-)}{\nu}_e$ oscillations
- Measure mass hierarchy
- Perform precision neutrino oscillation studies
  - resolve the θ_{23} octant
- Neutrino interaction measurements
- Search for non-standard phenomena (using neutrinos)

Physics Program with a future very large underground detector

- Search for proton decay:
  $p \rightarrow K^+ + \bar{\nu}$
  allows to test GUT models

- Detect and measure neutrino flux from core-collapse supernova

- Measure neutrino oscillation phenomena in atmospheric neutrinos
  - also gives access to mass hierarchy

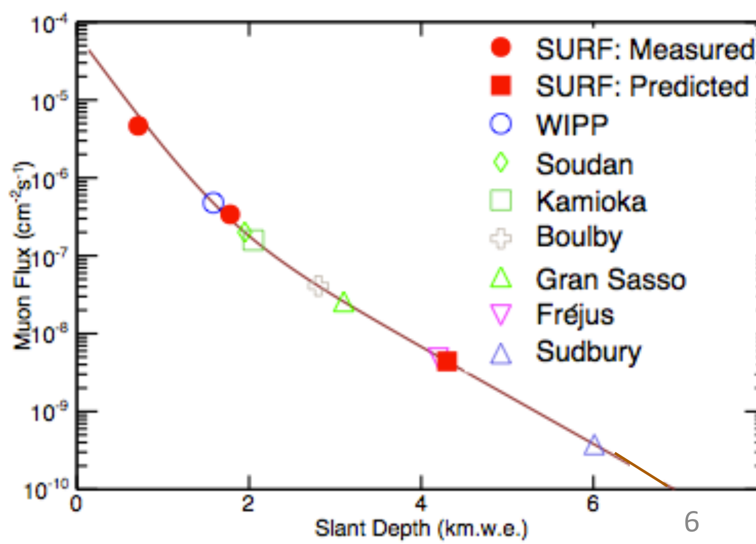
Experimental Strategy

- Wide-band, high purity ν_μ beam with peak flux at 2.5 GeV (optimized for 1,300 km baseline) operating at ~1.2MW and power upgrade capabilities

- **modular** single phase* liquid argon time-projection chamber (LAr TPC) far detector with fiducial mass of 34 kt

- Deep underground detector location

- High precision near detector



* Single phase: ionization detection in liquid phase
WA105 pursues a double phase LAr detector: charge extraction into and detection in gas phase

Single Phase LAr TPC

Expect excellent detector Performance :

- Neutrino energy resolution: 15%/sqrt(E) for ν_e CC; 20%/sqrt(E) for ν_μ CC
- Energy resolution: 3%: stop μ; 15% exit μ; ~1%/sqrt(E) electron; 30%/sqrt (E) hadronic system
- Position resolution
- Angular resolution: 1°: e,μ 10° : hadron shower

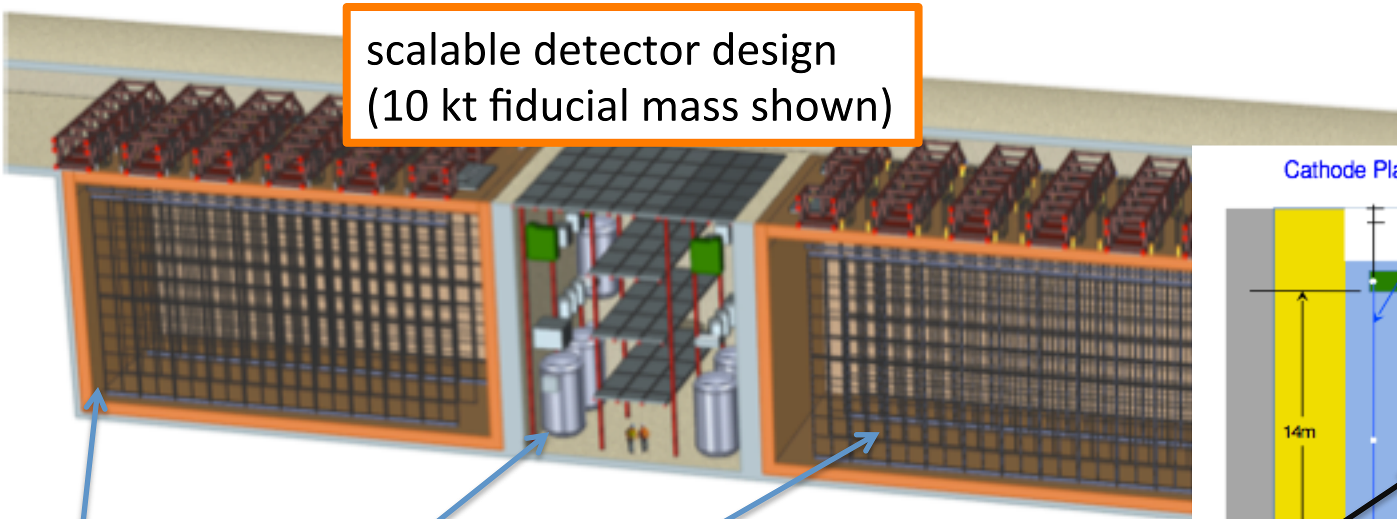
→ high precision event reconstruction capabilities

→electron/gamma (π^0) separation

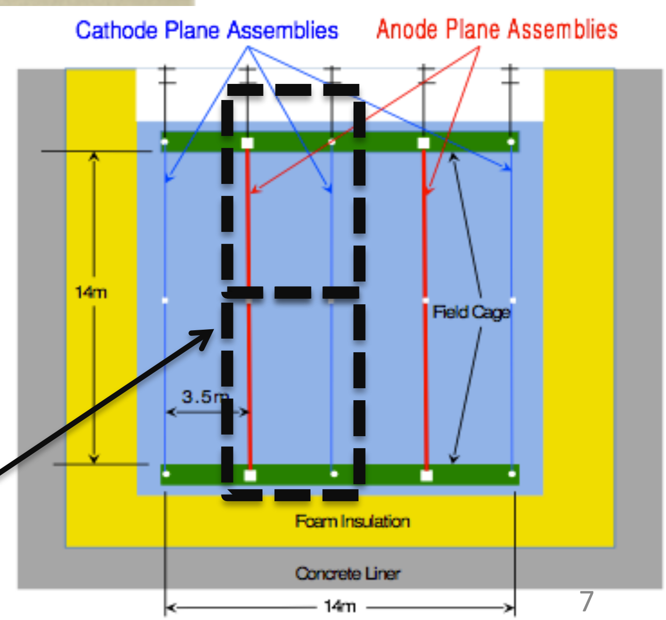
depends on **charged particle detector response**

↕

to be measured in full scale prototype detector



modular TPC within a cryostat module



cross section view of the TPC components inside the cryostat

Single phase LAr detector test at the CERN neutrino platform

- Propose a full scale-prototype and beam test of a LBNE-style (ICARUS based design) single phase detector

- Work jointly with various teams to learn about and compare different technological approaches to sub-systems:

  e.g. membrane cryostats, cryogenics, HV, …

- Compare detector responses (single and double phase) to a charged particle test beam with energy, angular and position resolutions as metric

Expected outcome:

- Verify performance and optimize design of different LAr based particle detection technologies

→ inform decision regarding detector design and phasing options for far detector of future long baseline experiment

Goals: 1) Technical Detector Performance

- Engineering test of full scale detector components

- Check performance of large membrane cryostat and cryogenics system
  - LAr purity

- Cold test a full scale TPC module

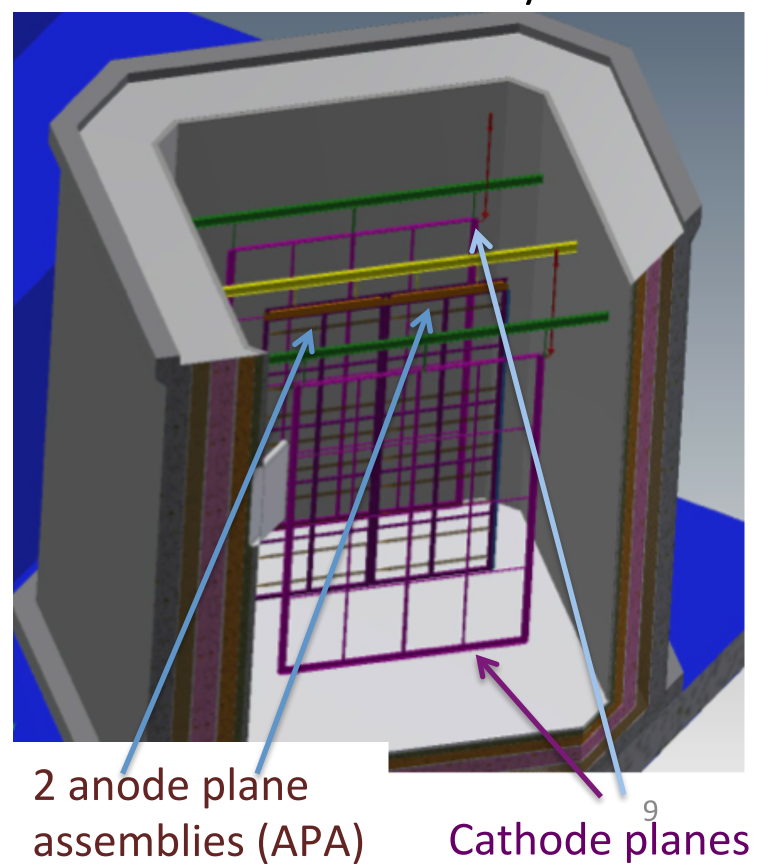
→ Demonstrate reliable operation of
  - pre-production TPC
  - photon detection system
  - cold electronics (analog and digital)

- Check robustness of HV design
  and field cage

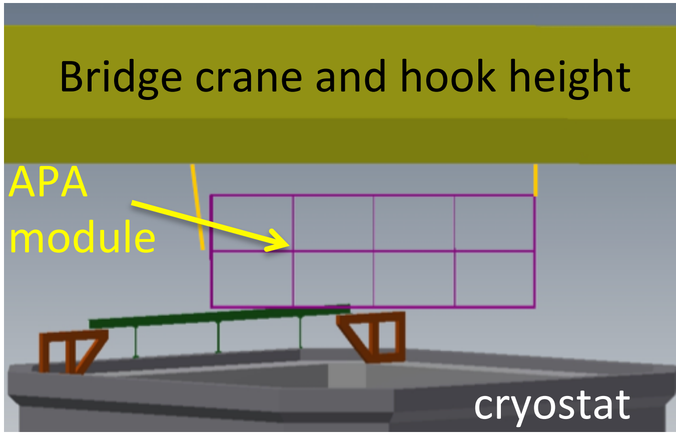
- Establish low noise operation

  - used a WA105 style cryostat for initial studies
  - propose a 2nd cryostat

8x8x8 m^3 WA105 cryostat



Details of Prototype Tests

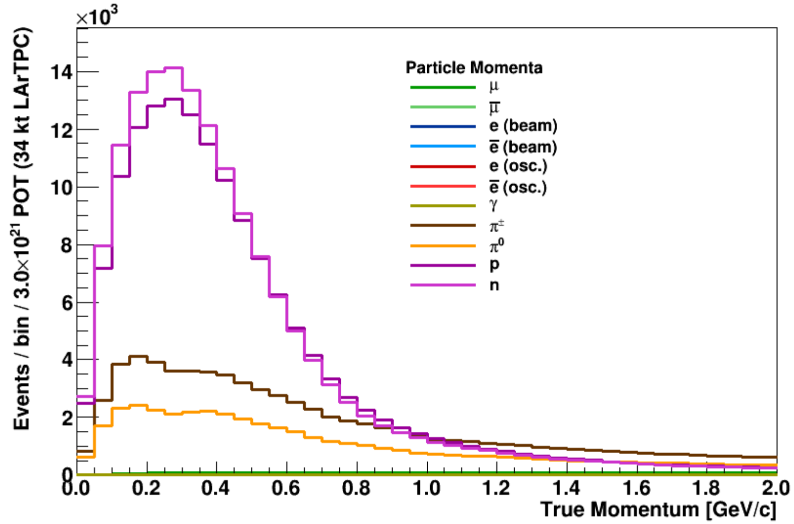


- Installation feasible assuming present infrastructure design
- Dimensional stability of cold APAs
- Demonstrate HV discharge mitigation design and grounding scheme
- Demonstrate operation with cold ullage and contamination mitigation
- Validate vibration isolation strategy (pump and mechanical support related)
- Verify performance of cold electronics for full scale detector
- Test triggering schemes and DAQ system
- Study detector response using cosmic rays

Goals: 2) Study detector response to charged particle interactions

- Demonstrate that detector performance achieves design goals
- Measure hadronic and electromagnetic shower parameters to determine shower reconstruction precision
- Use beam measurements to model final detector performance
- Study detector response as function of energy deposition, drift distance, contaminations, …
- Test and improve event reconstruction algorithms

Test beam requirements



Generator level single particle momentum spectra from LBNE ν beam interactions for reverse horn current (enriched in anti-neutrinos)

- Study low momentum range with accurately known particle momenta
- Particle types: μ , π , K, p, e
- High statistics samples of low multiplicity events
- Time to potentially test different detector orientations

LAr detector activities in the US and CERN prototype and beam test

R&D:

- Bo
  - (cold) electronics
- Long Bo
  - cold electronics, HV, LAr purity, photon detectors
- LArIAT
  - LAr detector ($90\times40\times47$ cm^3) in a charged particle test beam at FNAL
  - limited containment for high energy pions
- CAPTAIN
  - neutron beam,(neutrino beam)
- 35t membrane cryostat + detector

ν beam:

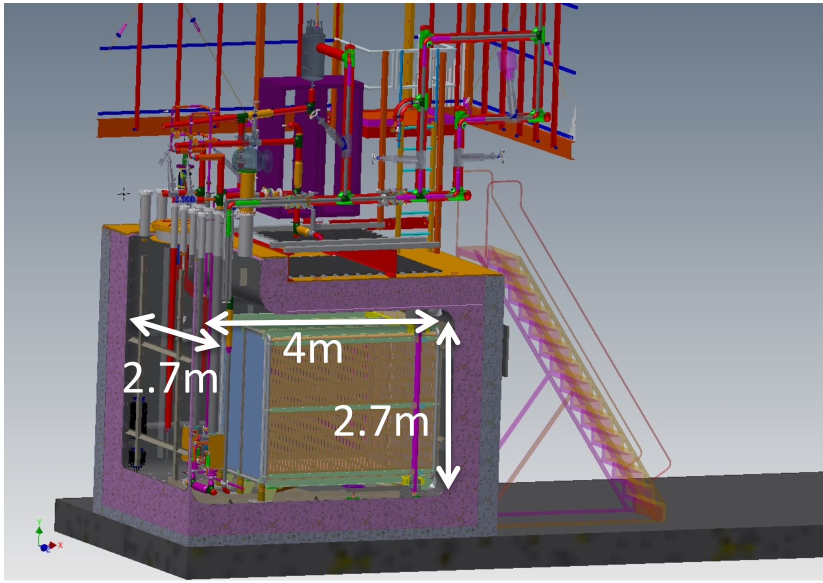
- Argoneut
- MicroBOONE
  - e/γ separation; physics
  - TPC, HV
- LAr1ND
  - sterile νs; reconstruction tools
- ICARUS at FNAL
  - sterile νs

- CERN ***full scale*** prototype and beam test with ***good containment***
  - provides opportunity to test performance of pre-production detector module
  - study response to charged particles with full scale detector design
    → model final detector performance

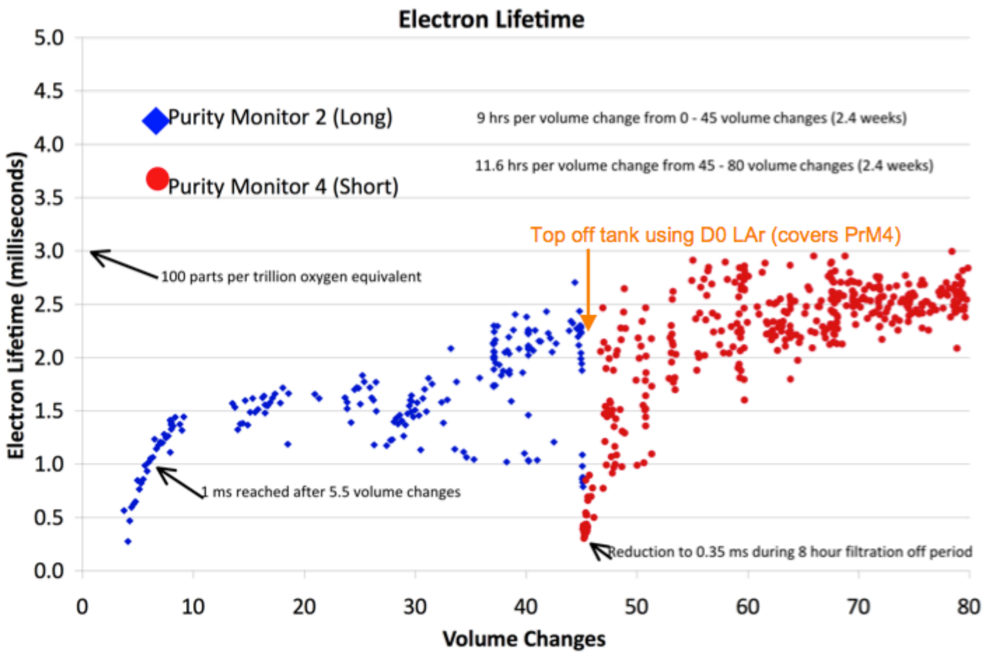
35t Single Phase LAr Detector at FNAL

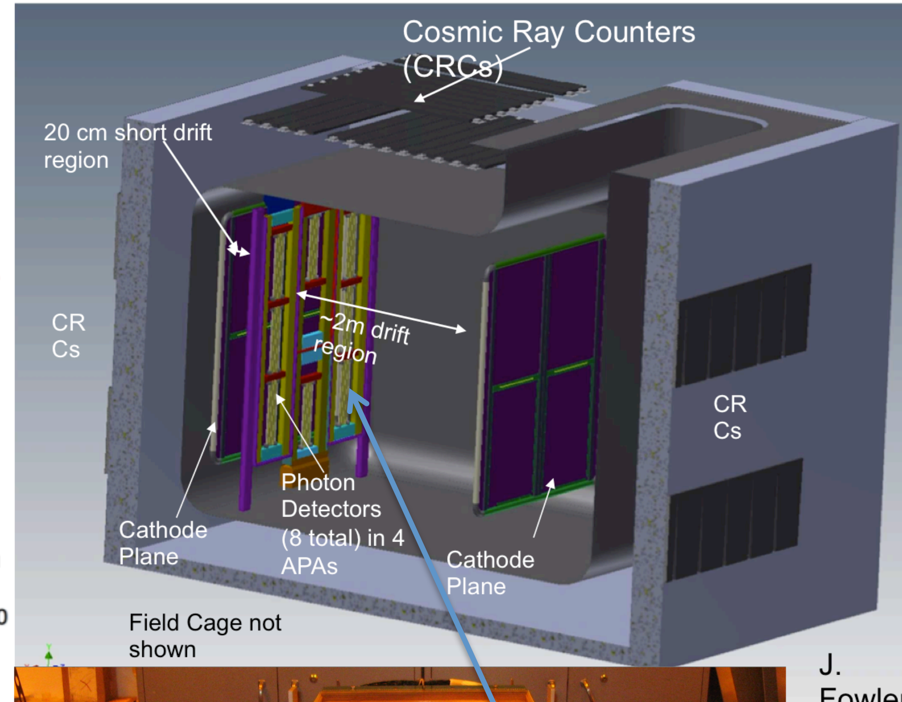
- 35 t detector in membrane cryostat (no beam)
  - Cryogenics checks, LAr purity measurement -- completed

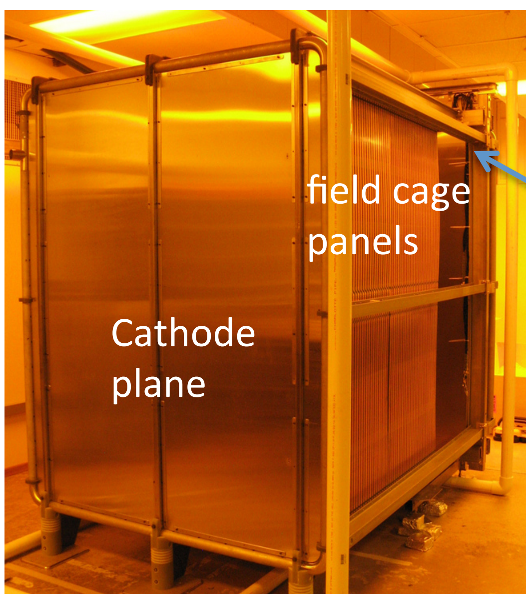
  in progress:
  - TPC prototype:
    - Produced multiple anode plane assemblies with wrapped wires
  - photon detection system:
    - TPB coated acrylic panels (WLS fiber) and SiPM readout
  - cold electronics
  - event triggering
  - event reconstruction



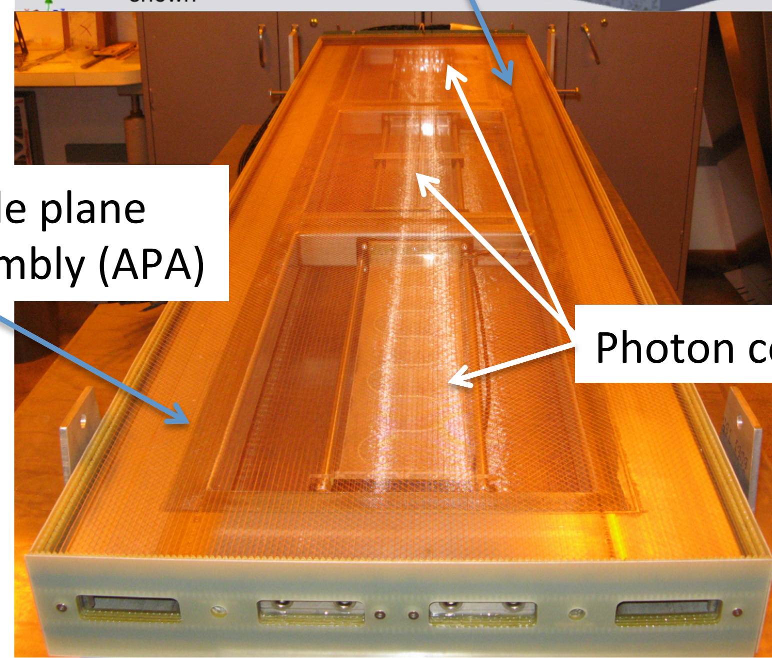
35t Single Phase LAr Detector at FNAL







Anode plane Assembly (APA)



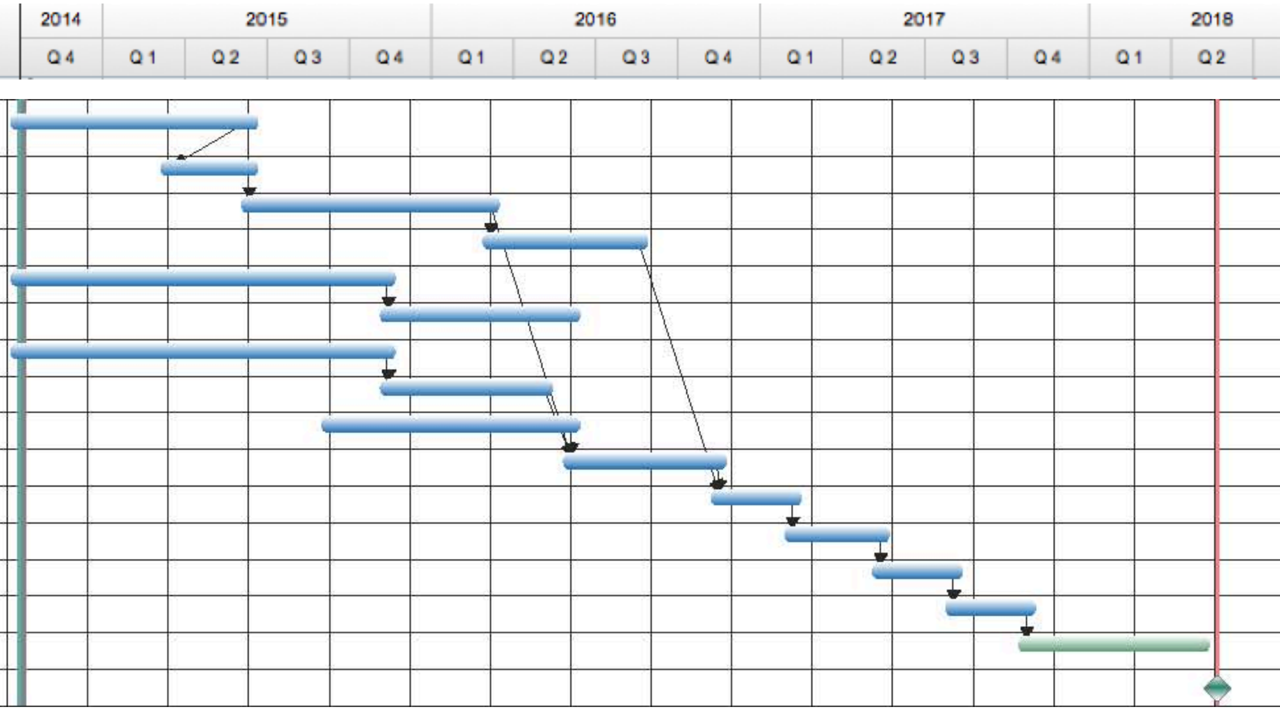
Team includes members from ICARUS and LBNO/WA105 collaborations

- ICARUS pioneered LAr detection technology
  - LBNF prototype based on ICARUS detector design
- LBNO has long LAr detector expertise
  - Expect to work together on cryostat, cryogenics, HV feed-throughs, and possibly other topics

Tentative Timeline

for a Single Phase Detector Test at CERN

Activity Name	Duration (Days)	Start Date	Finish Date
Design Anode Plane Assembly (APA)	187.00	10/13/14	6/30/15
Prototype APA Frame	65.00	4/1/15	6/30/15
Build + Test APA 1	197.00	7/1/15	3/31/16
Build + Test APA 2	120.00	4/1/16	9/15/16
CPA Field-Cage design	300.00	10/13/14	12/4/15
CPA Field-Cage Construction	149.00	12/7/15	6/30/16
Develop Photon Detectors	300.00	10/13/14	12/4/15
Build Photon Detectors	127.00	12/7/15	5/31/16
Build Electronics	196.00	10/1/15	6/30/16
Local Test Installations	120.00	7/1/16	12/15/16
Ship to CERN	60.00	12/16/16	3/9/17
Install at CERN	70.00	3/10/17	6/15/17
Commission	60.00	6/16/17	9/7/17
Data Run 1	60.00	9/8/17	11/30/17
Contingency	140.00	12/1/17	6/14/18
Start Long Shutdown 2	0.00	7/2/18	7/2/18



continue detector and beam tests after shutdown (iterate component designs)

→ Full detector performance results in 2018 to inform final detector design

Propose to have a second cryostat at EHN1 to allow parallel development of single and double phase LAr detectors to inform planning of future long-baseline neutrino facility.

Summary

- Science of future long-baseline neutrino experiment is extremely compelling and has been recommended to be high priority by long-term planning panels in the US, Europe and Asia

- Our proposed prototype detector tests at CERN enhances international, and in particular US-European, collaboration in developing the next generation of a long-baseline neutrino experiment

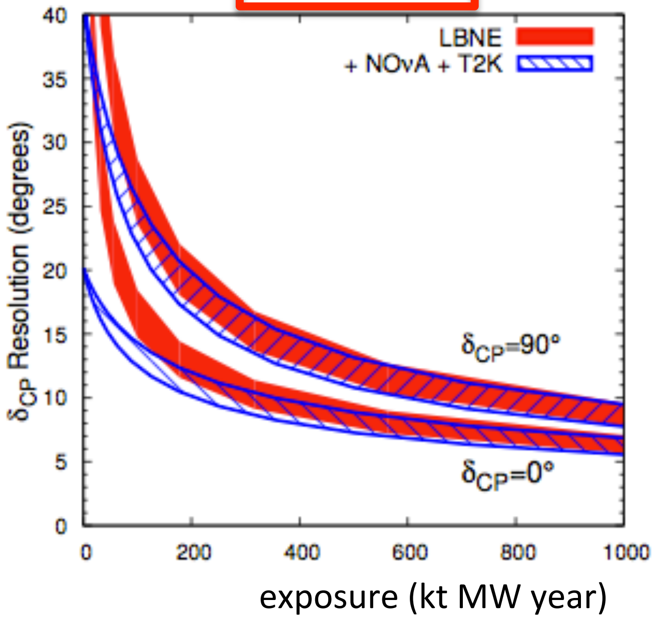
- Performance tests of full scale prototype detector components are critical to validate detector designs to reduce risk provide calibrations

- The neutrino platform at CERN offers a unique environment to test large LAr detectors and compare various technological approaches and their performance in a charged particle beam

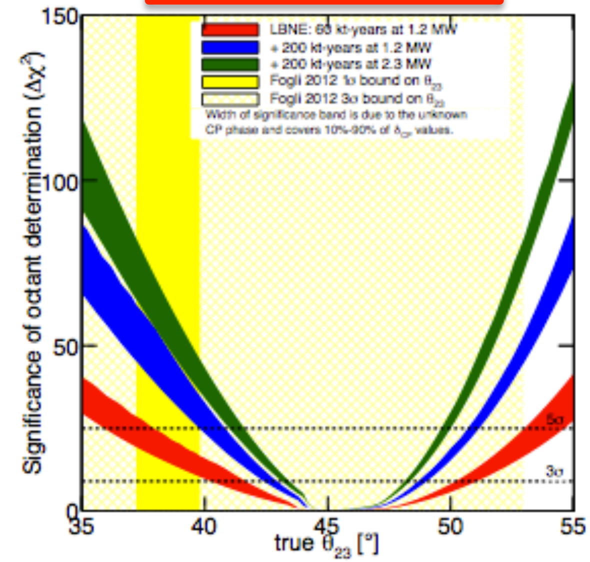
Backup slides

Sensitivities

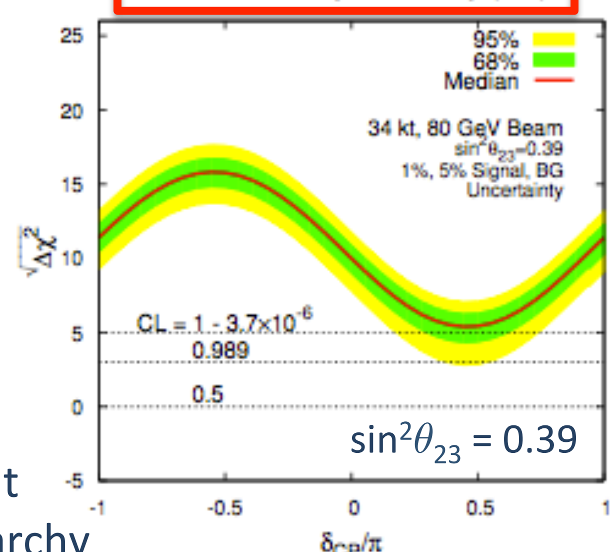
δ_{CP} Resolution



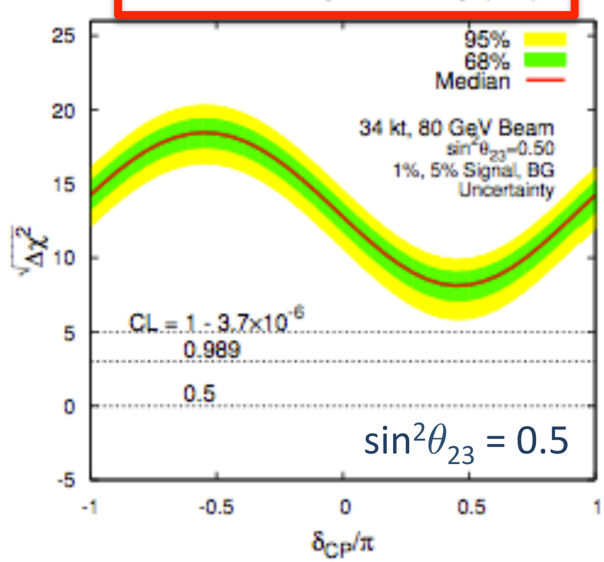
Octant Sensitivity (NH)



Mass Hierarchy Sensitivity (NH)



Mass Hierarchy Sensitivity (NH)



assumes:
normal hierarchy (NH)

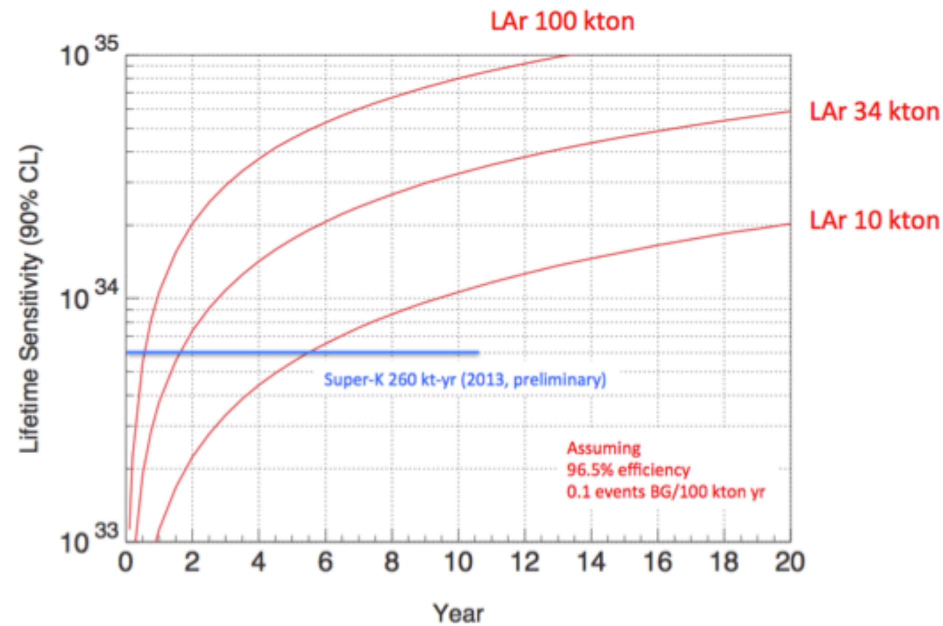
1.2 MW
3+3 yrs: $\nu + \overline{\nu}$

→ definitive measurement of mass hierarchy

Physics Program with a future very large underground detector

- Search for proton decay

  $p \rightarrow K^+ + \overline{\nu}$



- Detect and measure neutrino flux from core-collapse supernova
- Measure neutrino oscillation phenomena in atmospheric neutrinos
  - also gives access to mass hierarchy
- Other neutrino measurements (e.g. diffuse SNe flux, astrophysical, …)