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

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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

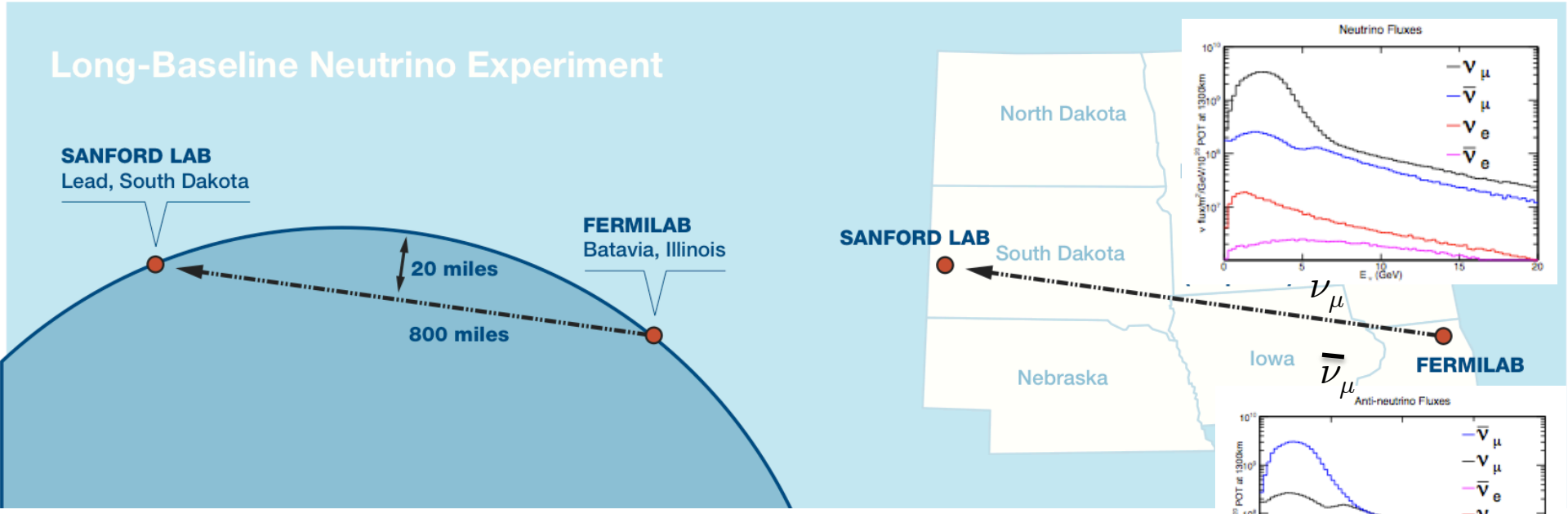
- 186 authors, 43 institutes, 6 countries
  (from LBNE, LBNO and ICARUS collaborations)

Outline

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

Physics Program of a New Long Baseline Neutrino Experiment

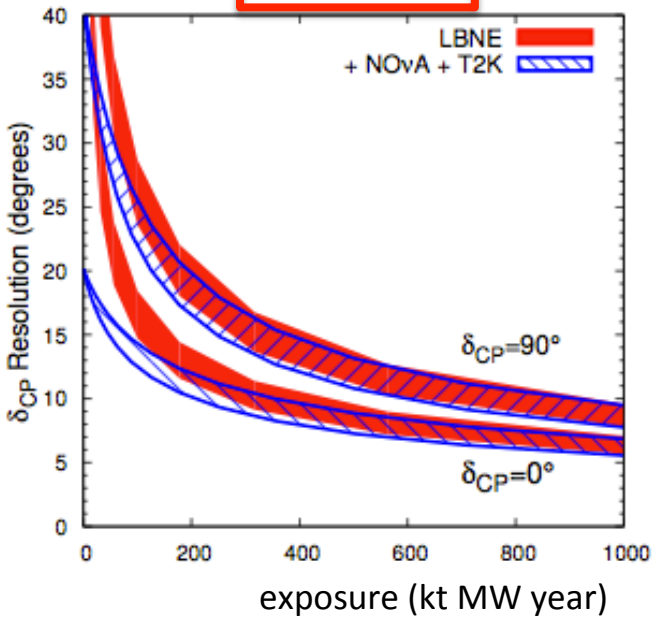
arXiv:1307.7335



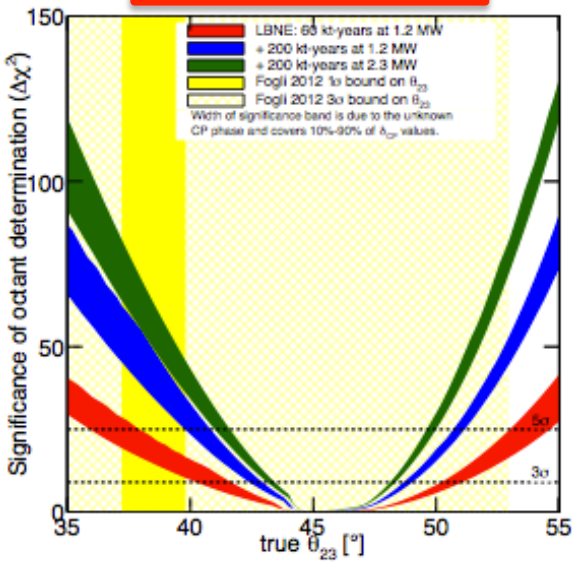
- Search for CP violation in $\nu_\mu \rightarrow \nu_e$ oscillations
- Measure mass hierarchy
- Perform precision neutrino oscillation studies
  - resolve the θ_{23} octant
- Neutrino interaction measurements
- Search for non-standard phenomena (using neutrinos)

Sensitivities

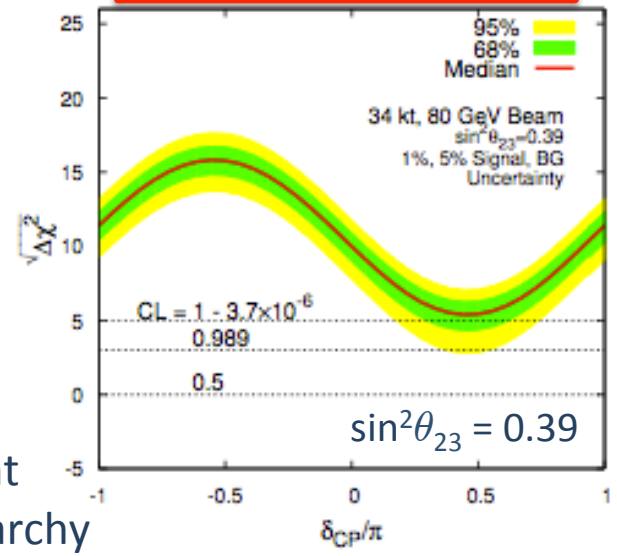
δ_{CP} Resolution



Octant Sensitivity (NH)



Mass Hierarchy Sensitivity (NH)



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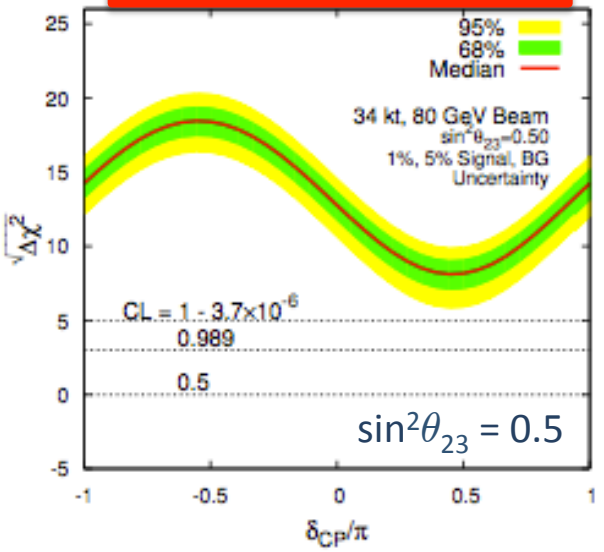


assumes:
normal hierarchy (NH)

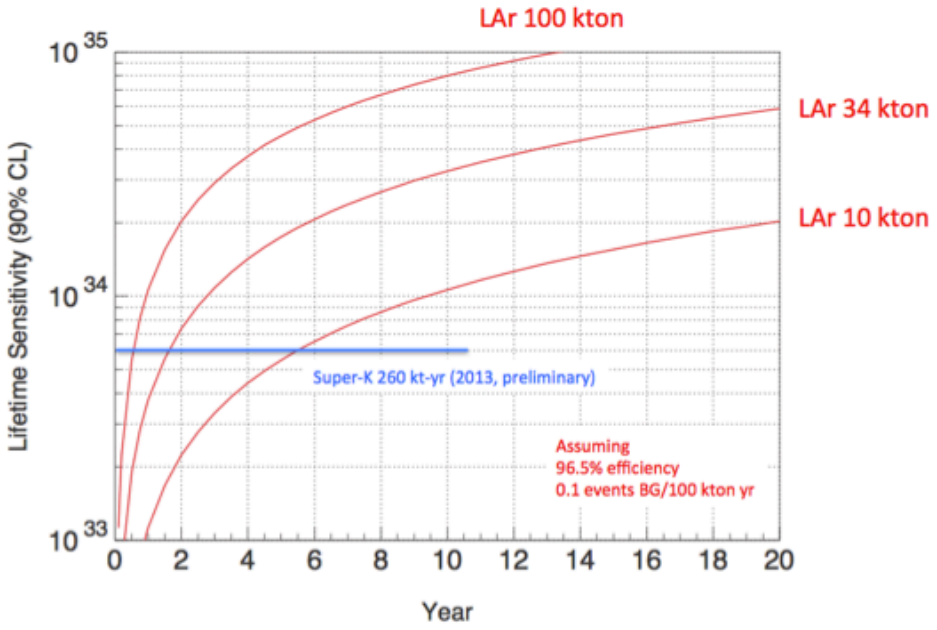
1.2 MW
3+3 yrs: $\nu + \overline{\nu}$

→ 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, …)

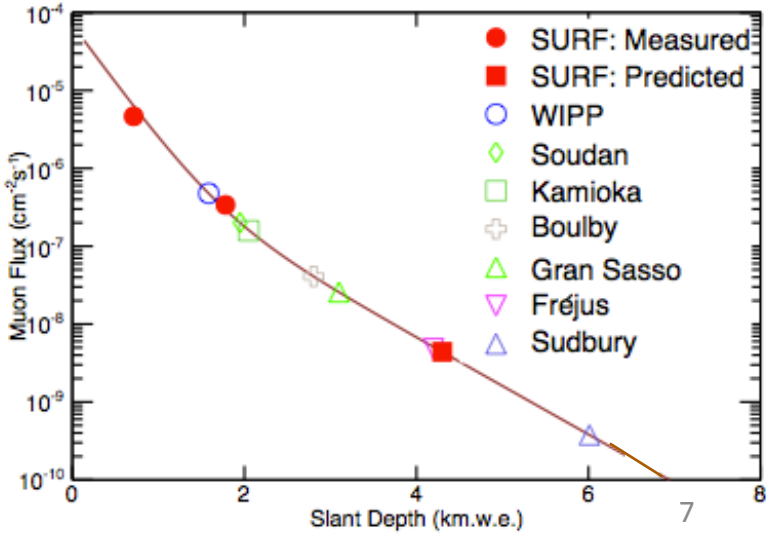
Experimental Strategy

- 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** 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 LAr TPC

Expect excellent detector Performance :

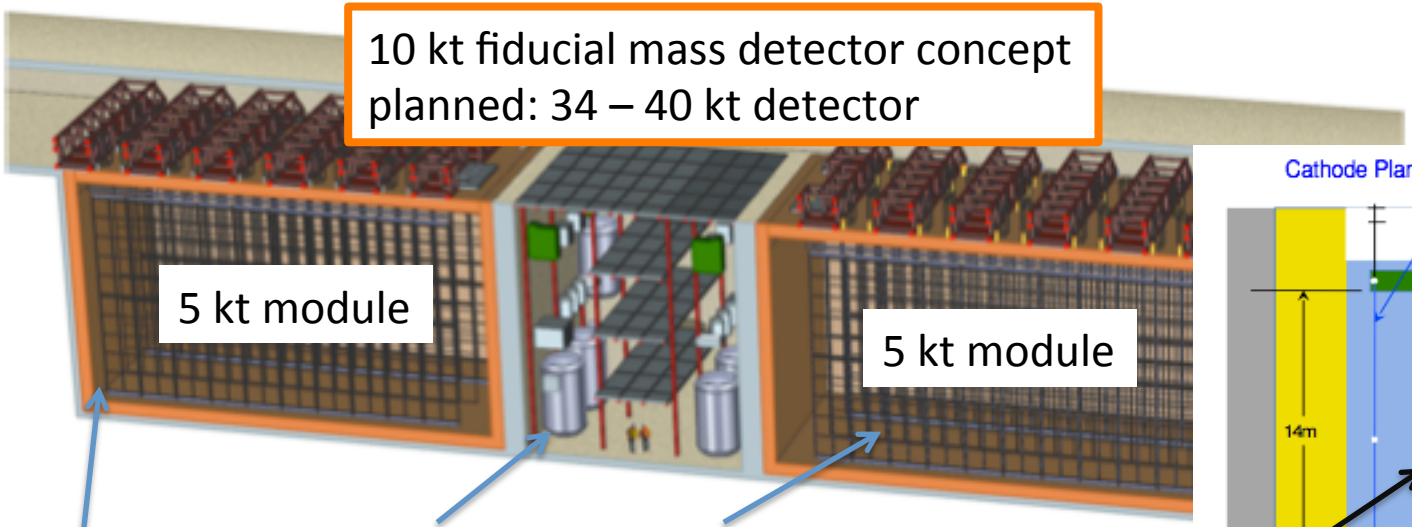
- Neutrino energy resolution: 15%/sqrt(E) for ν_e CC; 20%/sqrt(E) for ν_μ CC
- Energy resolution: 3%: stop μ; 15% exit μ; ~1%/srt(E) electron; 30%/sqrt (E) hadronic system
- Position resolution
- Angular resolution: 1°: e,μ 10° : hadron shower

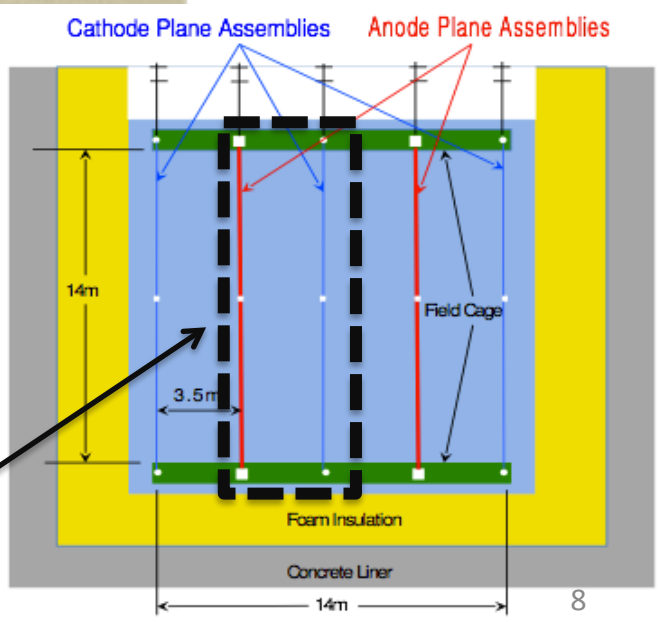
→ high precision event reconstruction capabilities

→electron/gamma (π^0) separation

to be measured in full scale prototype detector

10 kt fiducial mass detector concept
planned: 34 – 40 kt detector





cross section view of the TPC components inside the cryostat

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, HV, …

- Compare detector responses (single and double phase) to a charged particle test beam

Expected outcome:

- Identify strengths and weaknesses in 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

- WA105 cryostat *could* accommodate a LBNE style TPC module

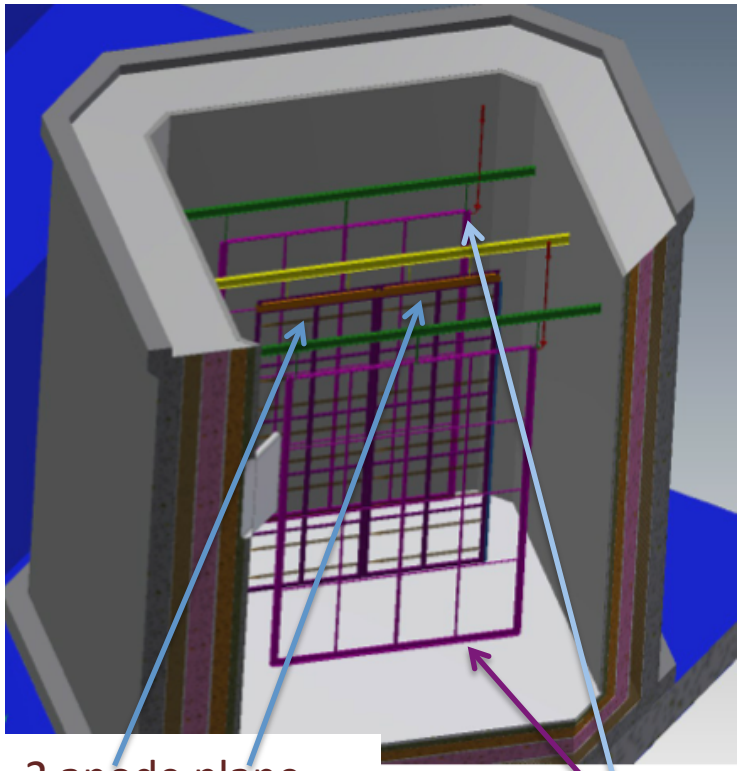
→ EHN1 *could* accommodate 2 such cryostats

- 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

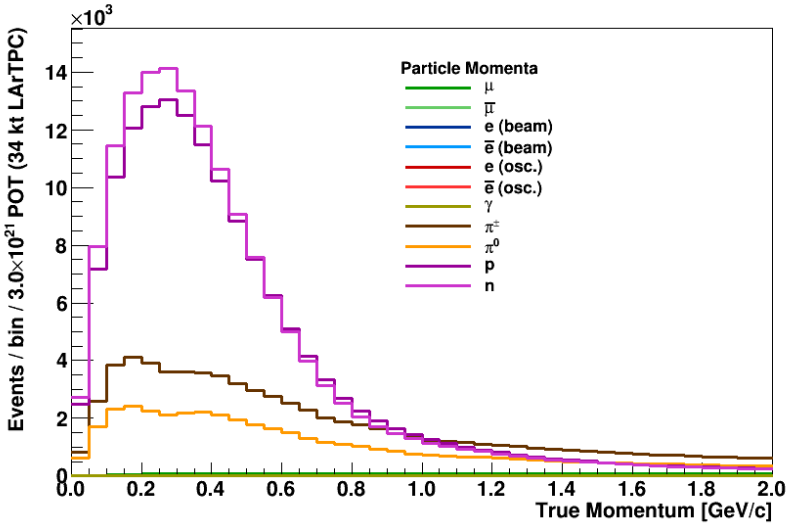
8 m^3 WA105 cryostat

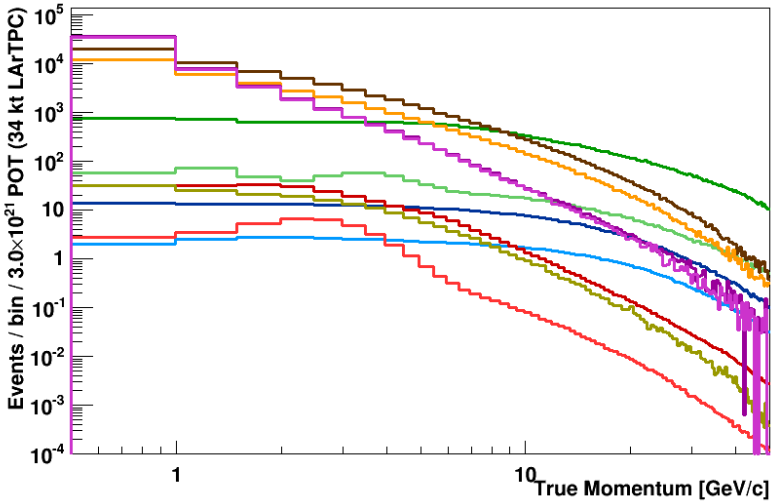


Goals: 2) Study detector response to charged particle interactions

- Demonstrate that beam measurements and data analysis can achieve required accuracies
- Measure hadronic and electromagnetic shower parameters to determine shower reconstruction precision
- Use beam measurements to model 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)

- Span large 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

Experience of team

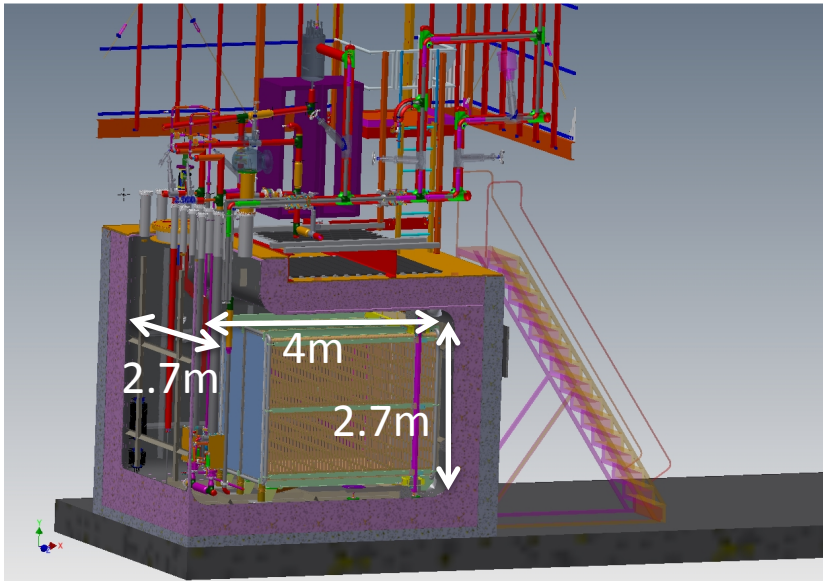
Team includes members from ICARUS and LBNO/WA105 collaborations

- ICARUS pioneered LAr detection technology
- LBNO has long (>10yr) LAr detector expertise

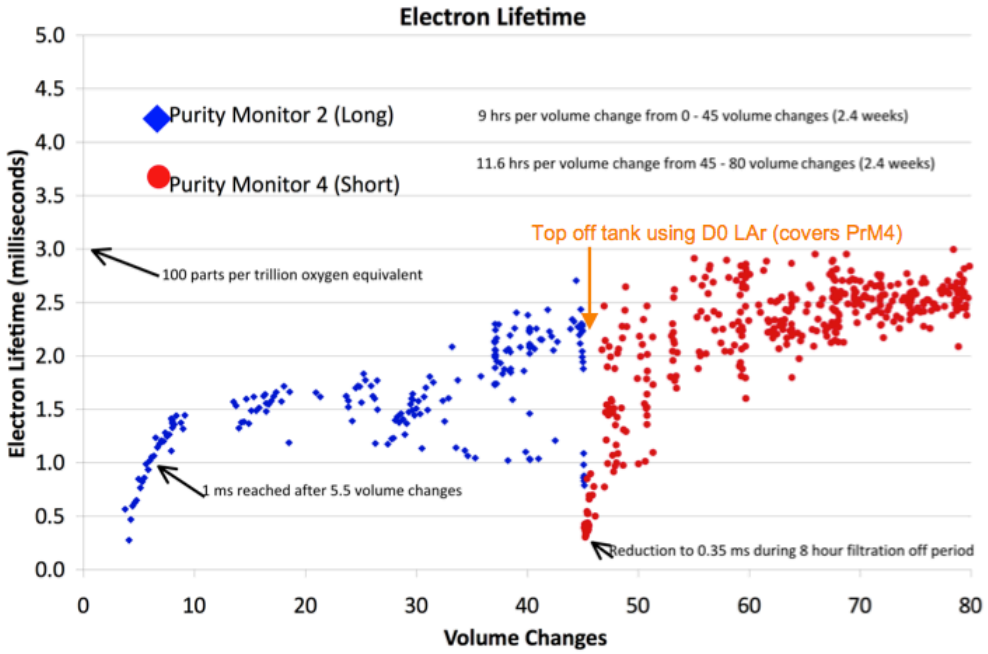
LBNE/FNAL

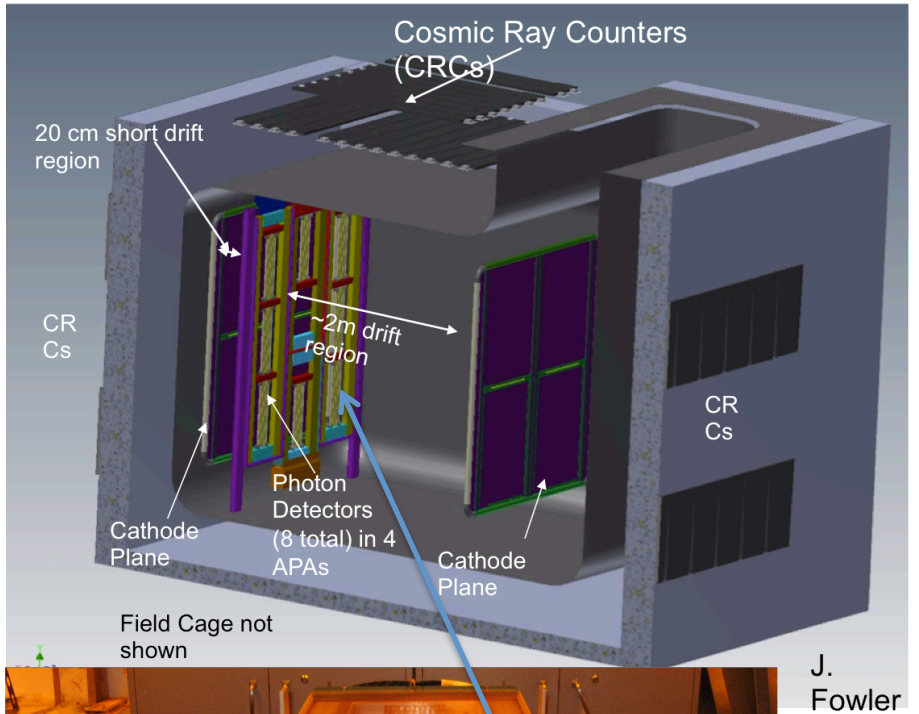
- 35 t detector in membrane cryostat
  - Cryogenics checks, LAr purity measurement -- completed

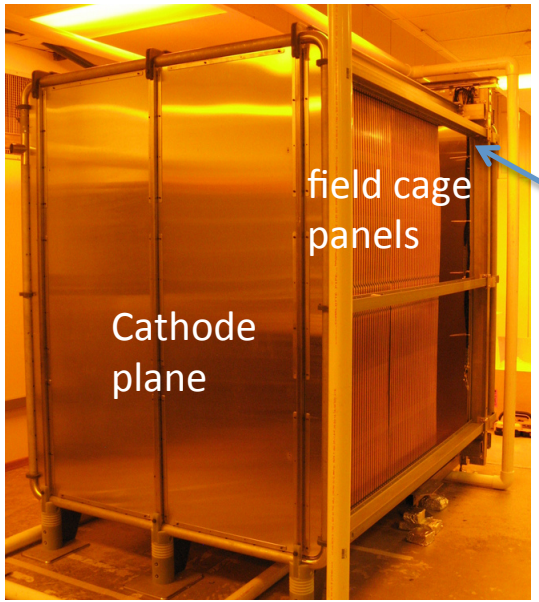
  in progress:
  - TPC prototype:
    - Produced multiple anode plane assemblies with wrapped wires
  - photon detection system:
    - TPB coated acrylic panels (WLS fiber) and SiPM readout
  - cold electronics
  - Event triggering and reconstruction



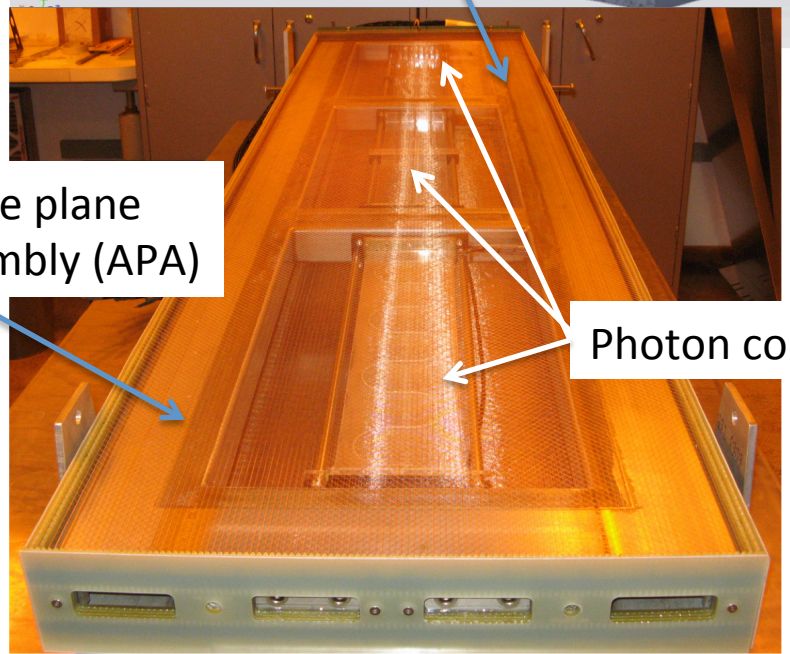
35t Single Phase LAr Detector at FNAL







Anode plane Assembly (APA)



Other LAr detector activities in the US and relation to CERN prototype and beam test

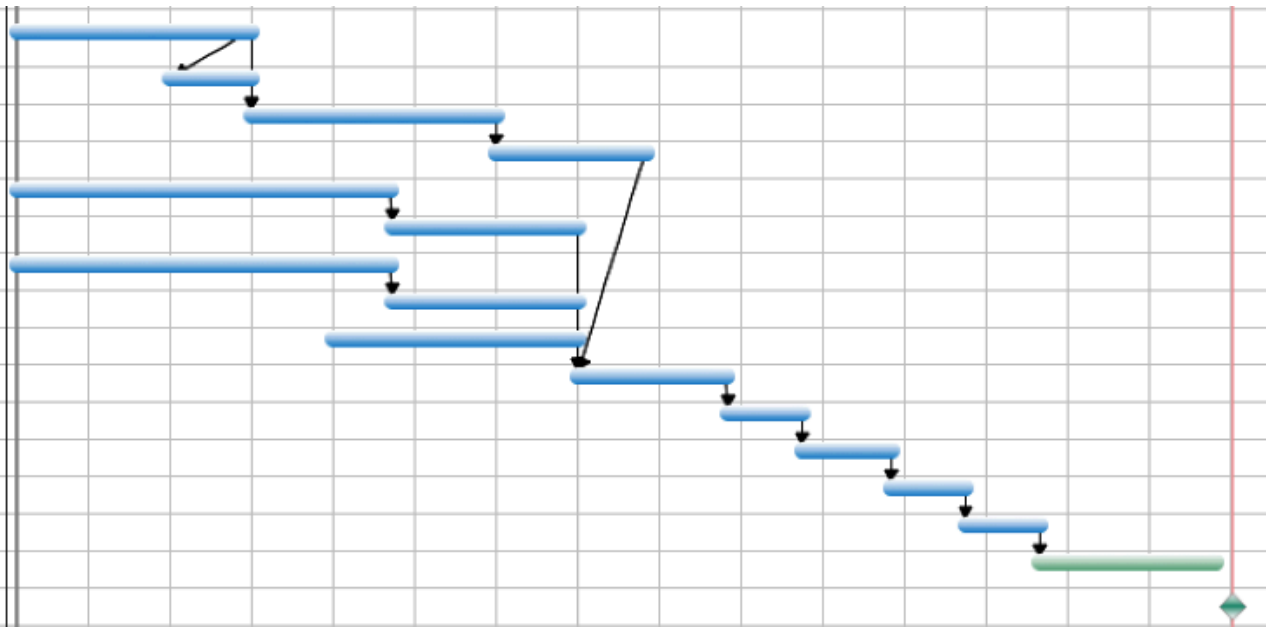
- LArIAT
  - LAr detector ($90 \times 40 \times 47$ cm^3) in a charged particle test beam
  - limited containment for high energy pions
- (Tall)Bo
  - (cold) electronics, readout testbed, HV, LAr purity
- CAPTAIN
  - neutron beam ,(neutrino beam)
- MicroBOONE
  - e/γ separation; physics
  - TPC, HV
- LAr1
  - sterile νs; reconstruction tools
- ICARUS at FNAL
  - sterile νs
- …

CERN ***full scale*** prototype and beam test with ***good containment***

→ Common software tool and event reconstruction development

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	149.00	12/7/15	6/30/16
Build Electronics	196.00	10/1/15	6/30/16
Test Installation US	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



Full data analysis expected to continue into CY 2018

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

For a full comparison of different technological approaches (e.g. double phase) in a timely manner a 2nd cryostat to test single and double phase approaches in parallel may be the best option.

Funding for detector components (capital expenses) is in place

Summary

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

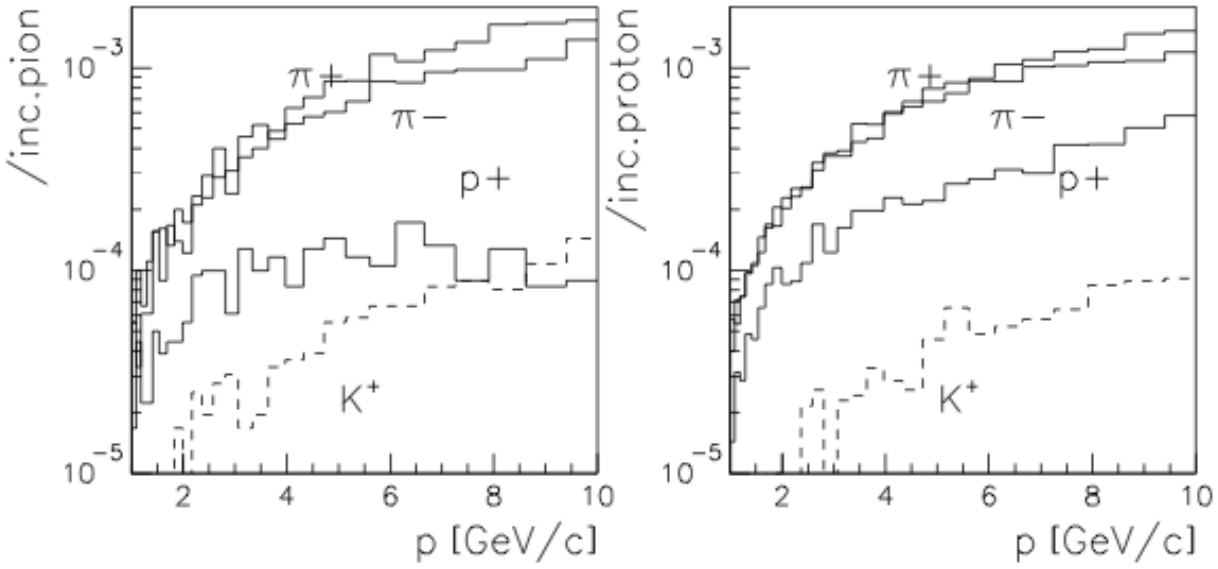
- Performance tests of full scale prototype detector components are critical to validate existing designs

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

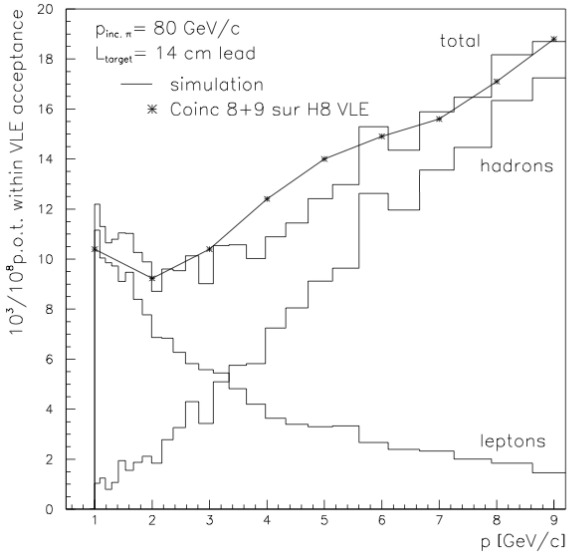
- Our proposed prototype detector tests at CERN enhances international, and in particular US-European collaboration in neutrino physics thereby helping to establish the next generation of neutrino experiments

Backup slides

Tertiary beam composition of H8 beam line

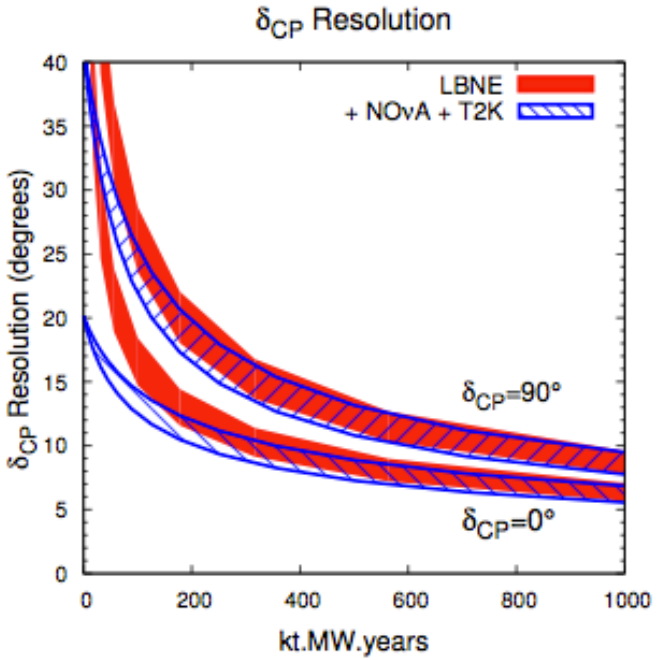


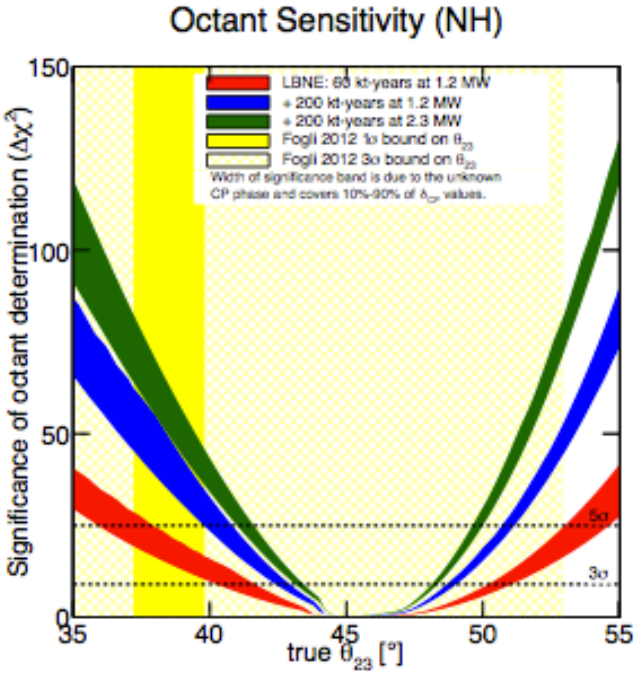
Simulated hadron composition of VLE hadron beam.
Production of tertiaries from 15cm Pb target.

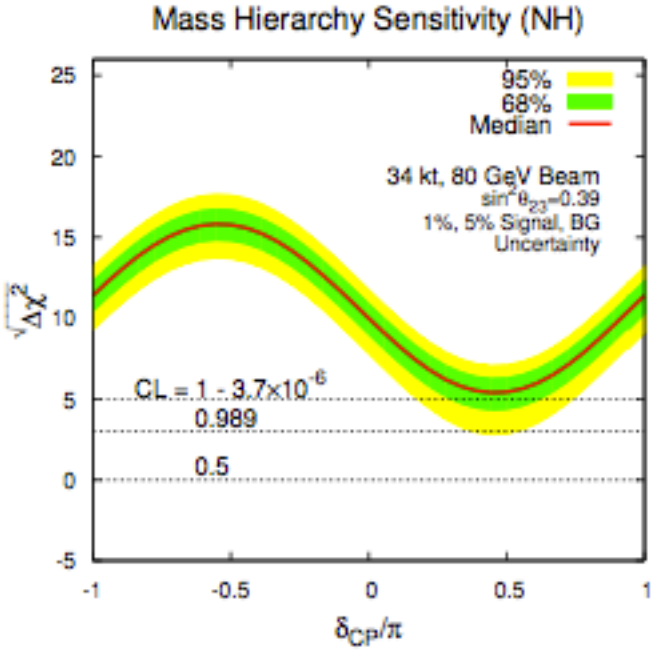


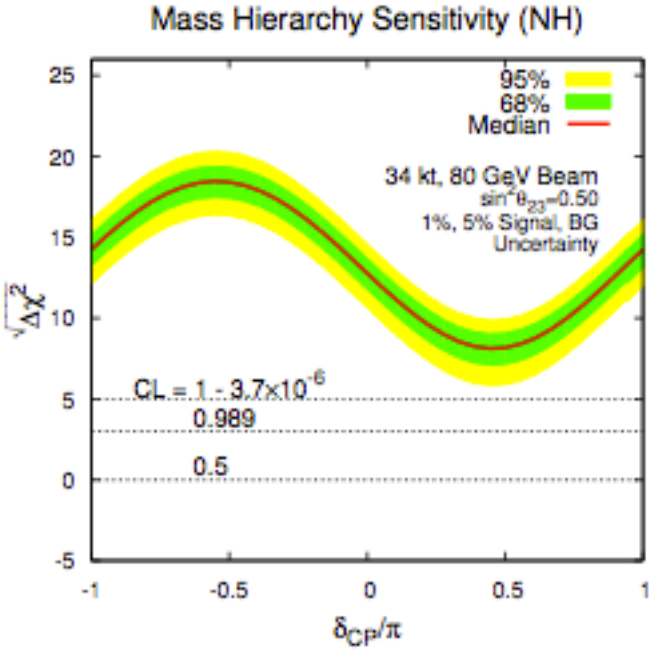
Tertiary beam:
Incident hadron beam of 80 GeV/c
on 15cm Pb target

Figures from:
CERN-AB-2005-036


δCP Resolution
LBNE
+ NOvA + T2K
δCP=90°
δCP=0°
δCP Resolution (degrees)
kt.MW.years


Octant Sensitivity (NH)
LBNE: 60 kt-years at 1.2 MW
+ 200 kt-years at 1.2 MW
+ 200 kt-years at 2.3 MW
Fogli 2012 1σ bound on θ23
Fogli 2012 3σ bound on θ23
Width of significance band is due to the unknown CP phase and covers 10%-90% of δCP values.
Significance of octant determination (Δχ2)
true θ23 [°]
5σ
3σ


Mass Hierarchy Sensitivity (NH)
95%
68%
Median
34 kt, 80 GeV Beam
sin²θ23=0.39
1%, 5% Signal, BG Uncertainty
CL = 1 - 3.7x10-6
0.989
0.5
δCP/π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