



The Single-Phase Prototype at CERN



This Talk



★ This Talk:

- **Introduction: The LBNE TPC Concept**
 - The LBNE FD concept
 - LBNE → LBNF/ELBNF: the single-phase LAr option
- **From Concept to Reality**
 - 35-ton prototype
- **The Single-Phase Prototype at CERN**
 - Key Aims
 - Current concept
 - Status
- **What will we Learn?**
- **How to get involved?**
- **Final Words**

★ **Thanks to:** Mark Convery, Jack Fowler, Thomas Kutter
Greg Pawloski, Michelle Stancari, Jim Stewart



LBNE TPC Concept

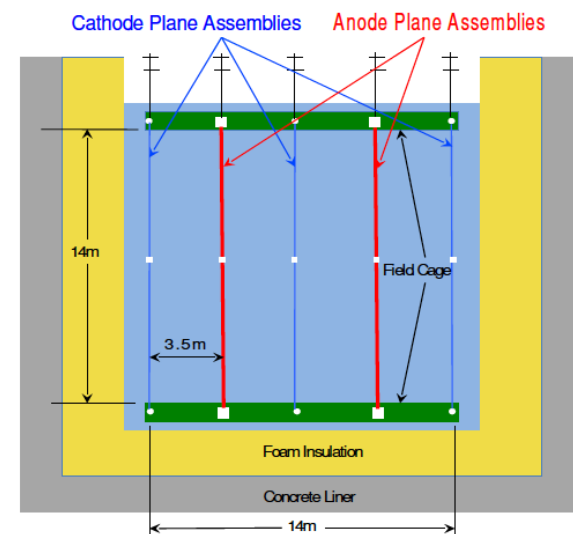
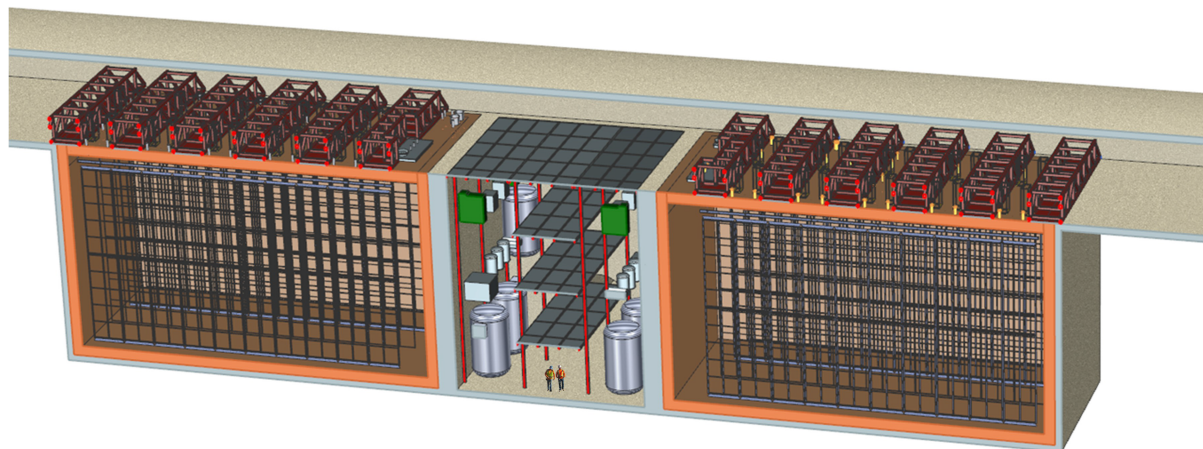


Towards ELBNF?



★ The LBNE TPC Design

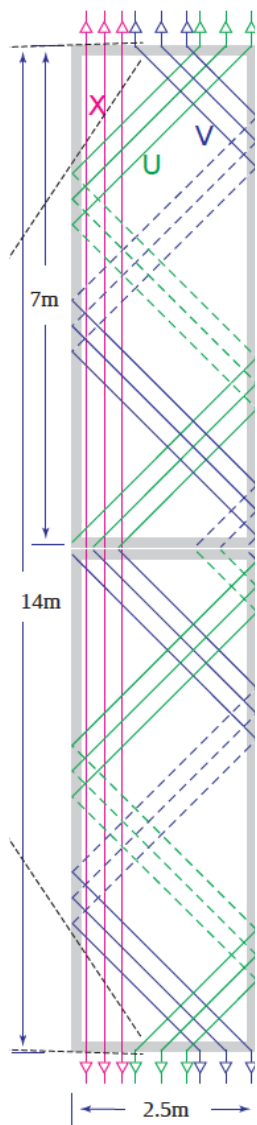
- Single-phase “ICARUS-inspired” design
- The challenge: scale up by a factor $\sim 50+$
 - Industry “standard” membrane cryostat
 - **Modular** wire plane readout “Anode Plane Assemblies” **APAs**
 - **Hang many identical readout planes in cold volume**
 - Analogue and digital electronics inside cryostat
 - **APAs**: wrapped – reading out two drift volumes
 - Wire mesh cathode planes: $\sim -185\text{kV}$
 - FR4 PCB/copper Field Cage



cross section view of the TPC components inside the cryostat

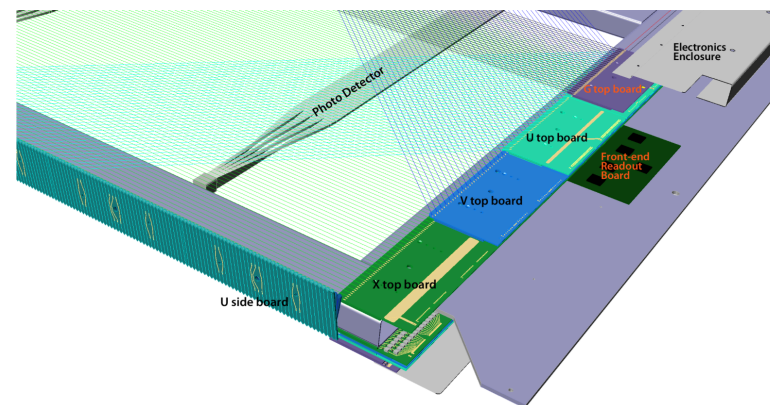


LBNE APAs



★ LBNE CDR APA Design

- Stacked 2.5m x 7m modules
- Three readout wire planes
 - X (vertical) : collection
 - U (45°)
 - V (45°)
- Wire pitch ~4.5 mm
- Readout at ends of APAs



★ Questions

- Impact of wrapping
 - Ambiguities/disambiguation
- Gaps between APA modules
 - Impact on physics
- Optimal wire spacing/pitch/angle
 - Impact on physics



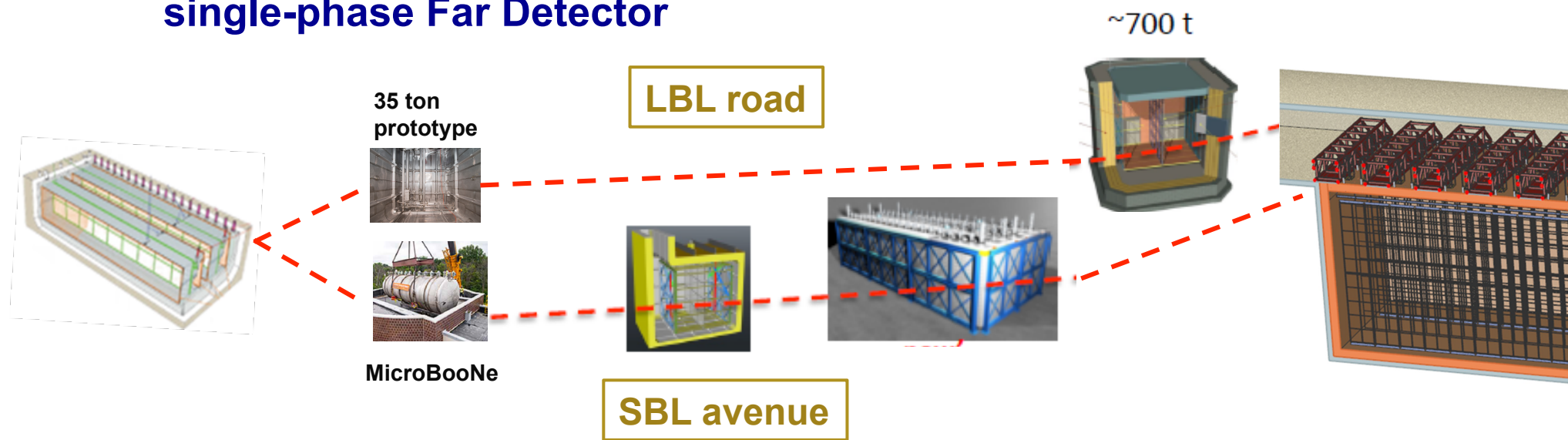
From Concept to Reality



Evolution



- ★ Goal is to provide **option** for construction of a 10 kton far detector (~2021) + 30 kton (~2025)
- ★ Road to 10 kton by 2021 is challenging (& **exciting**)
 - Need a **program** of single-phase **development** that minimizes **risk**
 - Builds from strength, e.g. existing experience
 - **ICARUS**, Argoneut, ...
 - Now embarking on a **development paths** towards a “ELBNF”-scale single-phase Far Detector



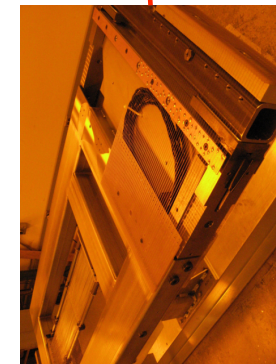
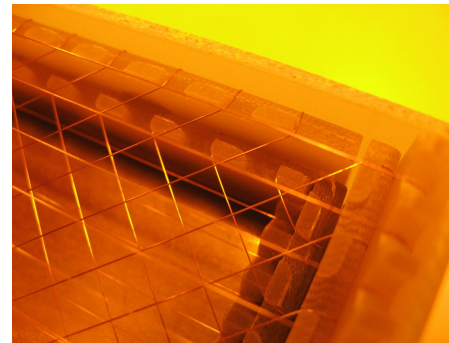
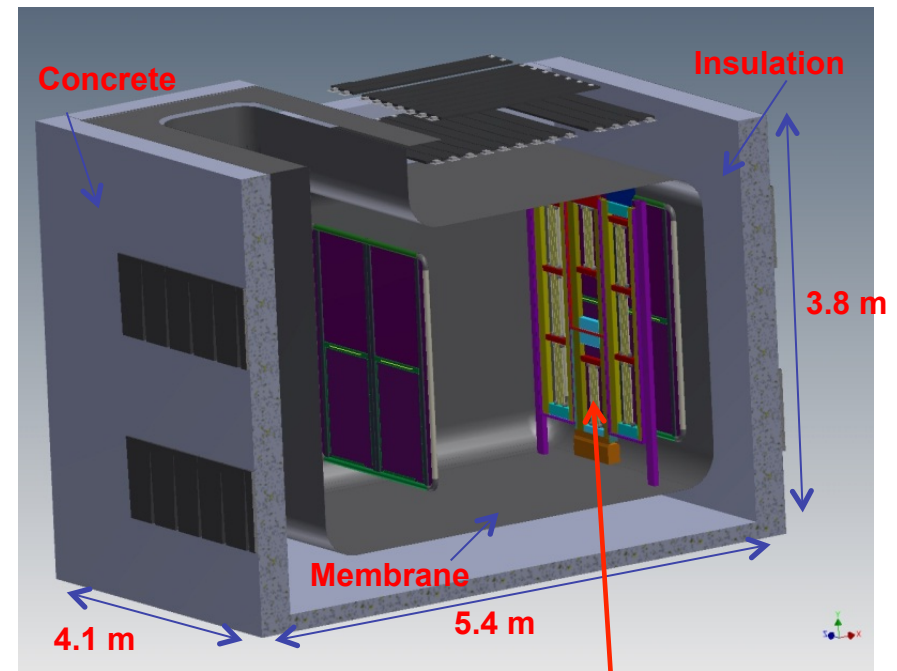
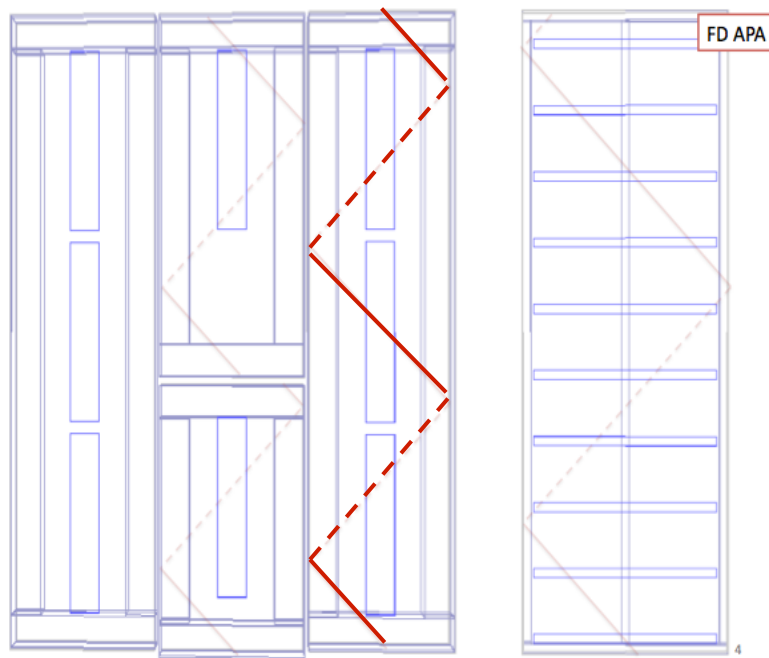


35 ton Prototype



★ 35 ton prototype

- **Crucial** test of LBNE TPC concept
- Installed at **Fermilab**
- 2m x 2m x 2m TPC
- Two drift volumes (long/short)
- 4 APA modules (8 sets of wires)



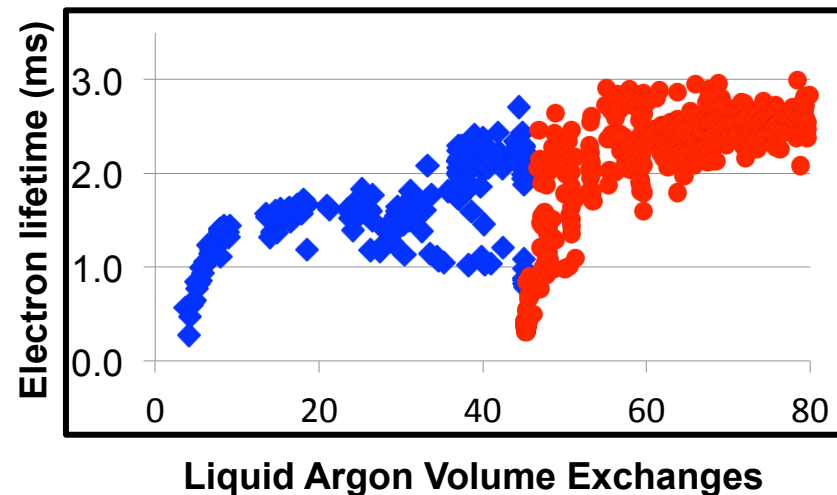


35 ton Prototype Goals



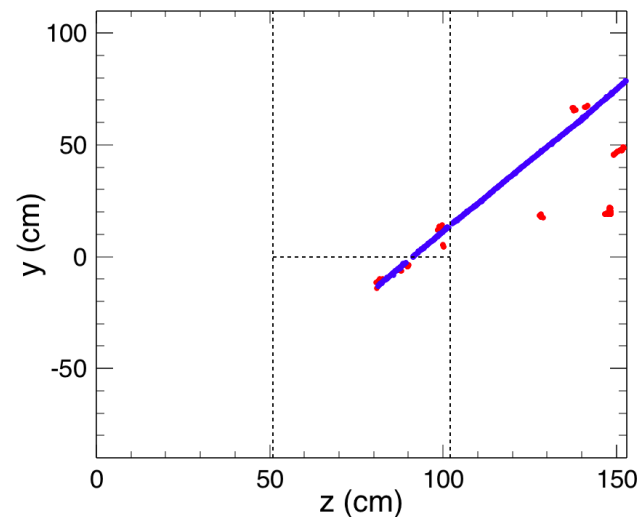
★ Phase-I (completed early 2014)

- Validation of cryostat design/performance
- Demonstrate argon purity required for physics
- **No TPC**



★ Phase-II (~second quarter 2015)

- Crucial test of LBNE TPC concept
- Exposed to cosmic-rays
- First test of reconstruction with wrapped APAs
- Evaluate physics performance using **cosmic rays**





R&D Issues Addressed



★ 35 ton Prototype addresses many R&D issues

- **APA performance:**
 - wrapping ambiguities,
 - gaps, tracks crossing APAs,
 - energy resolution
- **Photon detector performance:**
 - event time resolution
 - photons/MeV
- **Electronics/DAQ performance:**
 - Signal/Noise with cold pre-amp and ADC
 - triggerless DAQ operation
- **Cryostat performance:**
 - Argon purity
 - acoustic noise
- **FR4 printed-circuit field cage performance.**

All crucial to demonstrating LBNE TPC concept



Single-Phase Prototype at CERN



Single Phase Option for ELBNF

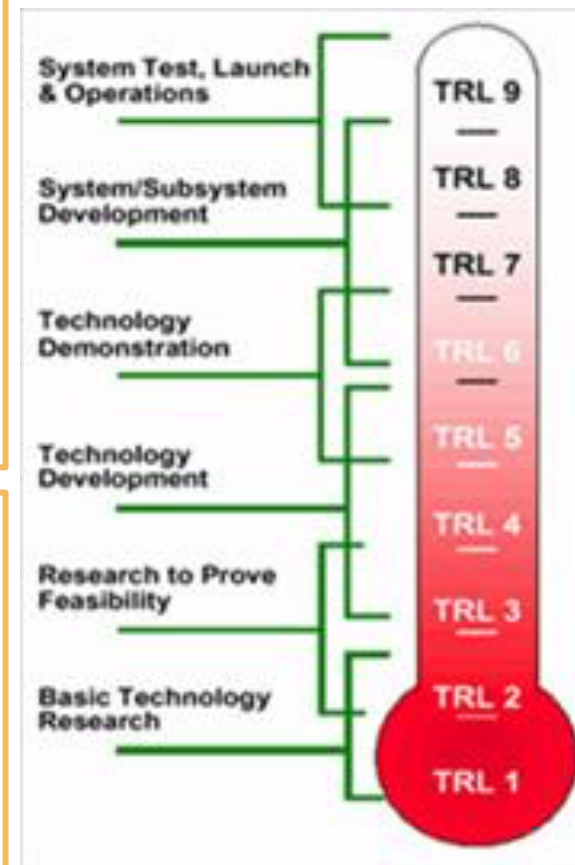


★ The LBL road to a single-phase ELBNF FD

- **ICARUS**
 - Established single-phase concept
 - Demonstrated long-term operation/stability
- **35 ton prototype**
 - Validate novel aspects of LBNE concept
 - Experience → motivate design
- **What Next?**

★ Some key questions

- **TRL: are we ready to “launch” an ELBNF FD ?**
 - Maybe, but risk...
- **Do we understand the performance sufficiently to control systematic uncertainties ?**
 - Almost certainly not



✦ **Single-phase prototype at CERN will address these key issues**



Single-Phase Prototype at CERN



★ EoI

- “Expression of Interest for a Full-Scale Detector Engineering Test and Test Beam Calibration of a Single-Phase LAr TPC” **submitted to SPSC in October**
 - 186 authors, 43 institutes, 6 countries from LBNE, LBNO and ICARUS collaborations
- SPSC invites technical proposal ~spring/summer 2015

★ Status

- Detailed plans/design still evolving
- Submit proposal on June 1st for June SPSC
- Beam: late 2017/early 2018 - challenging but plausible timeline

!!! Opportunity for new collaborators !!!



Goals



★ Main goals of single-phase Prototype:

- **Full-scale prototype** of LBNE-concept for single-phase TPC
 - Address engineering design issues – **RISK REDUCTION**
 - Effectively a pre-production test of the APA design
 - **Full validation** of concept prior to **possible** deployment as the initial ELBNF 10 kton FD
- **“Calibrate” physics performance:**
 - Calibrate performance with know charged particle beam
 - Systematic study of detector response
 - Validate/improve MC simulation, e.g. low-E hadronic showers in Argon

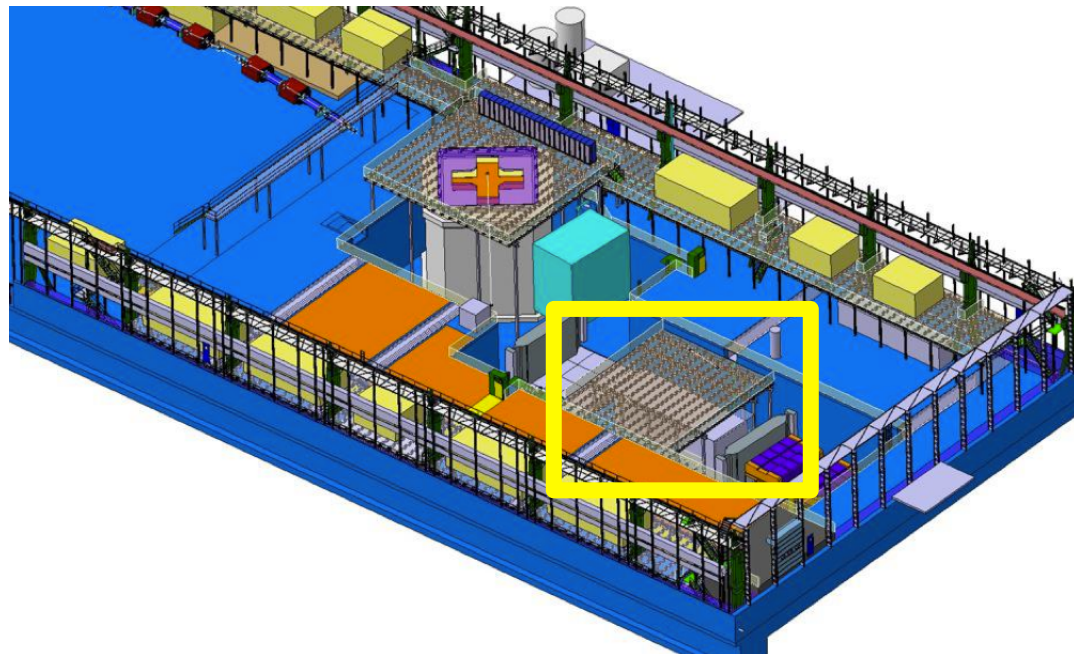


Single Phase at the CERN Platform



★ Single-Phase test

- Preferred option is a second cryostat
 - Obvious advantages over sharing single cryostat with double phase prototype (WA105)
 - Exact configuration depends on size/orientation



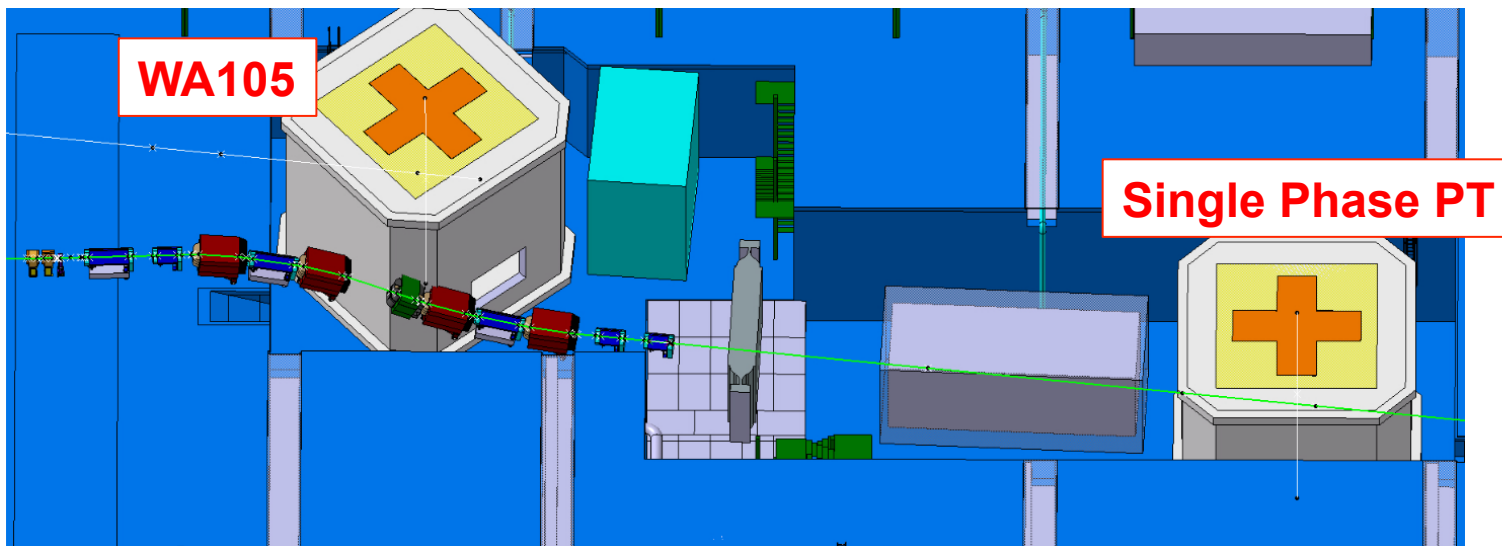


Basic Design: Beam



★ Beam (H4Ext beam line)

- **Calibrate on tagged particles: e , π , μ , p , ...**
- **Ideally, extending down to low energies $p \sim 200$ MeV/c**
 - relevant to second oscillation maximum
- **Possible to have steerable beam ~ 10 - 15°**
 - Test of potential angular dependence of recombination effects





TPC Configuration

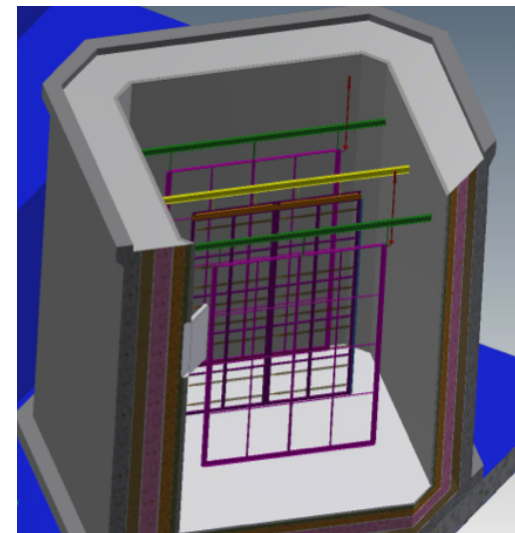
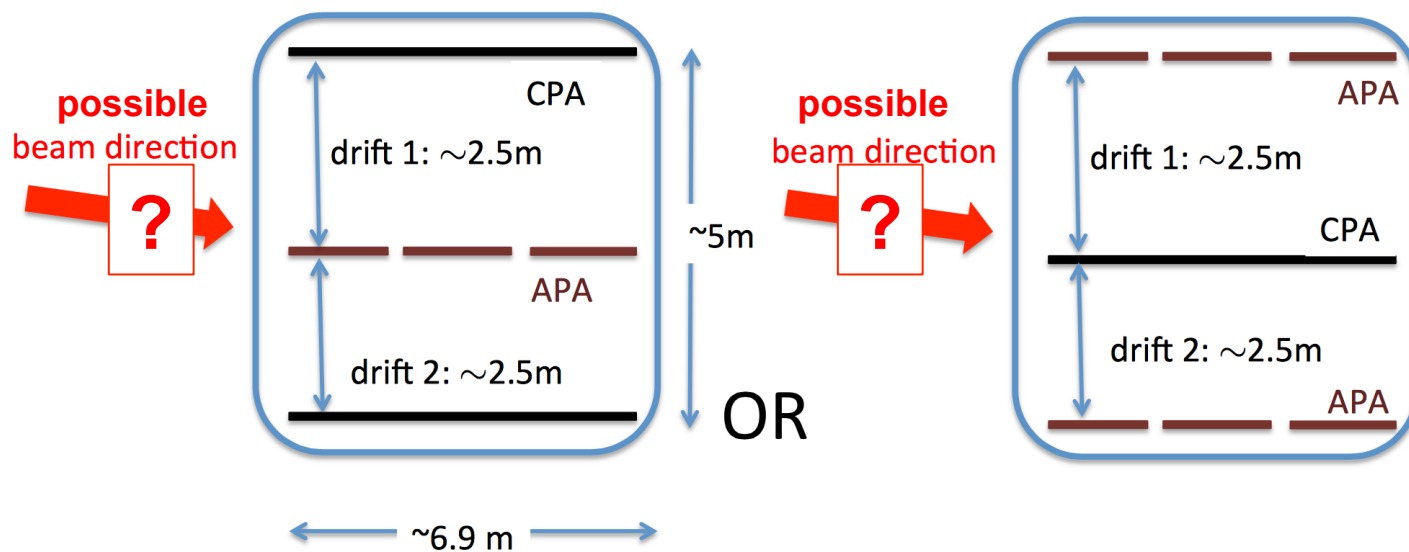


★ Evolution from 35 ton prototype

- Full-scale prototype of LBNE concept

★ Currently Two main options

- Central APAs vs APAs at sides: 3 vs. 6
- Dimensions motivated by containment studies



★ In each case there are multiple APAs

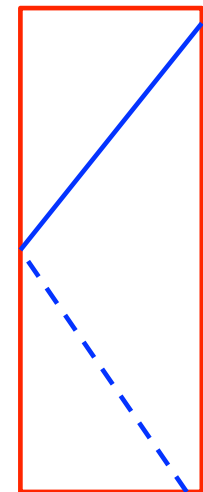
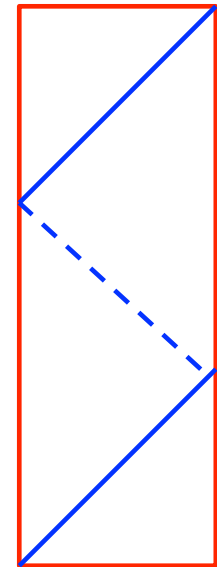
- Chance to **qualify fabrication** at several production sites



Details: APAs



- ★ Intended as a full-scale prototype
 - ➡ match ELBNF single-phase design
- ★ APA design recently revisited:
 - Rigidity of 7.0 m x 2.5 m frame
 - Concerns about disambiguation
 - Practical considerations, e.g. transport
- ★ New design
 - “single wrap”: removes ambiguities
 - Smaller frame, 6.0 m x 2.3 m
 - Standard transport, more rigid
 - **Wire angle** 35.7° (aspect ratio helps)
- ★ Other considerations
 - Increased cost of electronics
 - More modules, more gaps, impact?

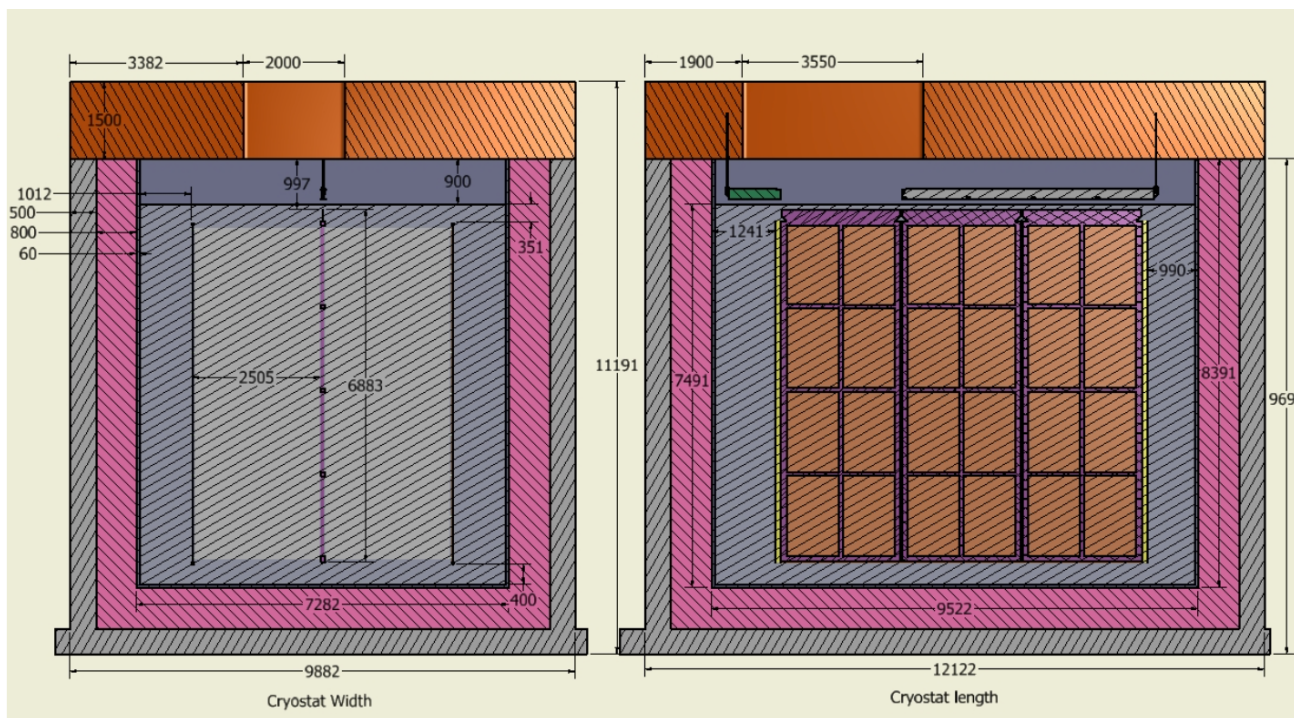




Cryostat



- ★ **First engineering designs of cryostat being developed**
 - Driven by size/configuration of APAs
 - Quite a big beast: 7.3 m x 9.5 m x 8.4 m (inner dimensions)



- ★ **Exposed to a charged particle test beam**
 - Need to get beam into LAr volume without interaction
 - **Beam window design requires serious engineering effort**



What will we Learn?



Goals



★ Technical

- **Full-scale test of LBNE single phase LAr-TPC design**
 - Engineering: rigidity of APAs, cooldown issues, ...
- Understand performance
 - Characterize noise, uniformity of response, ...
- Potential to qualify multiple construction hubs

★ Physics

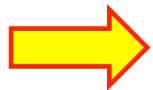
- Understand response to multiple particle types
 - Test-beam based calibration – limit FD systematic uncertainties
- Test MC simulation on particle interactions in Ar
 - e.g. characterize hadronic showers + feedback to GEANT4
- Test reconstruction & PID performance
 - Including impact of gaps
- Evaluate LAr-TPC response
 - e.g. recombination vs. angle to E-field
- ...



Impact

★ Technical

- **Initial operation** could establish a final single-phase FD design



Ready to move to FD construction

risk mitigation (for single-phase TPC design)

★ Physics

- **Establish physics performance**
 - **Potential to compare single-phase to double-phase**
- **Many interesting analysis topics**



How to Get Involved



Opportunity Knocks



★ **New groups/collaborators very welcome** (contact Thomas and Greg)

- **Opportunities for intellectual contributions**
 - **CERN prototype design/physics program are not fixed**
 - **Effort for proposal is needed now !**
- **Opportunities for hardware contributions**
 - **In new “ELBNF” world, funding model**
 - **Opportunities for contributions to TPC, DAQ, ...**
 - **Will need people: construction schedule ~2017/2018**
- **CERN is helping at many levels**
- **Great time to get involved**
....things have to move quickly

+ **35-ton would welcome new people** (contact Michelle and Mark)

- **For contributions to operations and analysis**



Final Words



LBNE → ELBNF Transition



★ LBNE → ELBNF

- **Single phase effort currently embedded in LBNE project**
- **Dedicated teams working on:**
 - 35-ton prototype & CERN prototype**
 - Many people are funded on existing LBNE DOE project
 - Need continuity through this transition period:
these activities are essential

Thanks again to: Mark Convery, Jack Fowler, Thomas Kutter
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Thank you