High Voltage Tests for MicroBooNE

Byron Lundberg
Fermilab

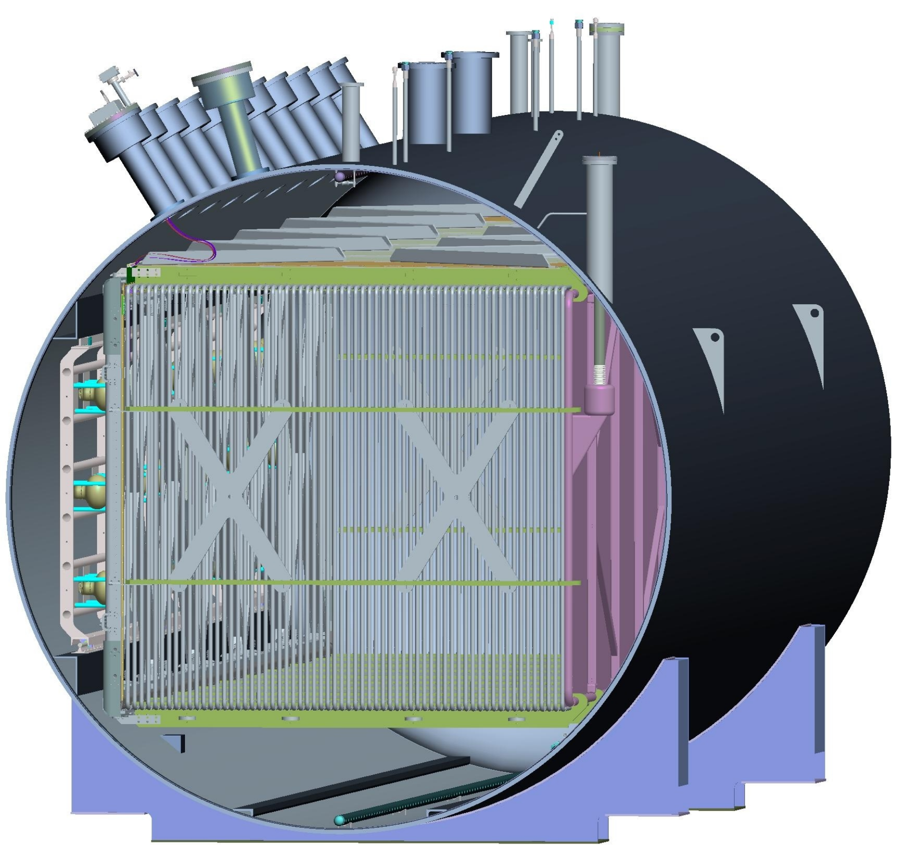
presenting for the Collaboration &
Task Force 4

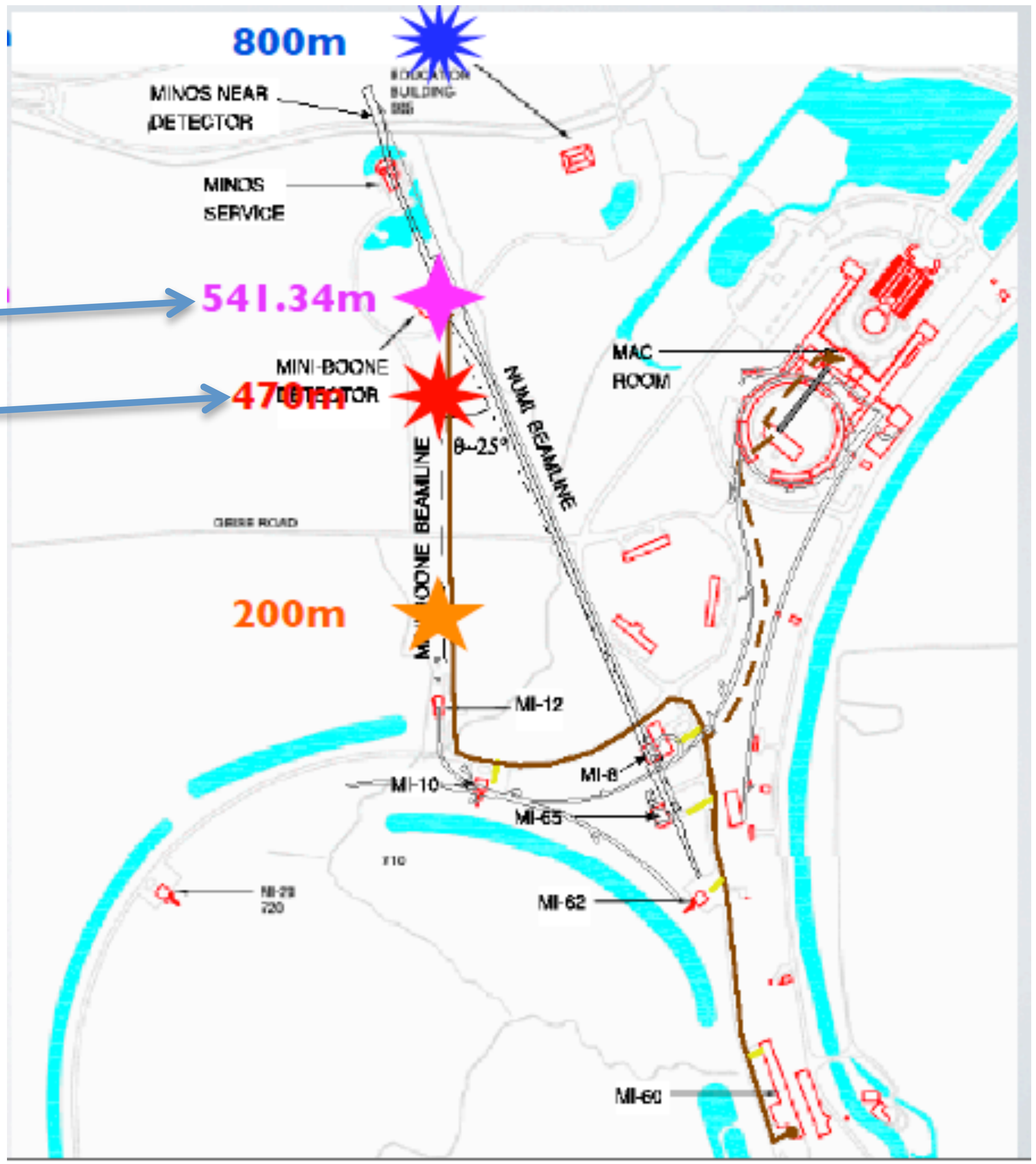
8 Nov 2013

MicroBooNE Experiment

- A liquid argon time projection chamber (LAr TPC) containing 170 tons of liquid argon, and located on the Booster Neutrino Beamline.
  - MiniBooNE
  - MicroBooNE

@LArTF

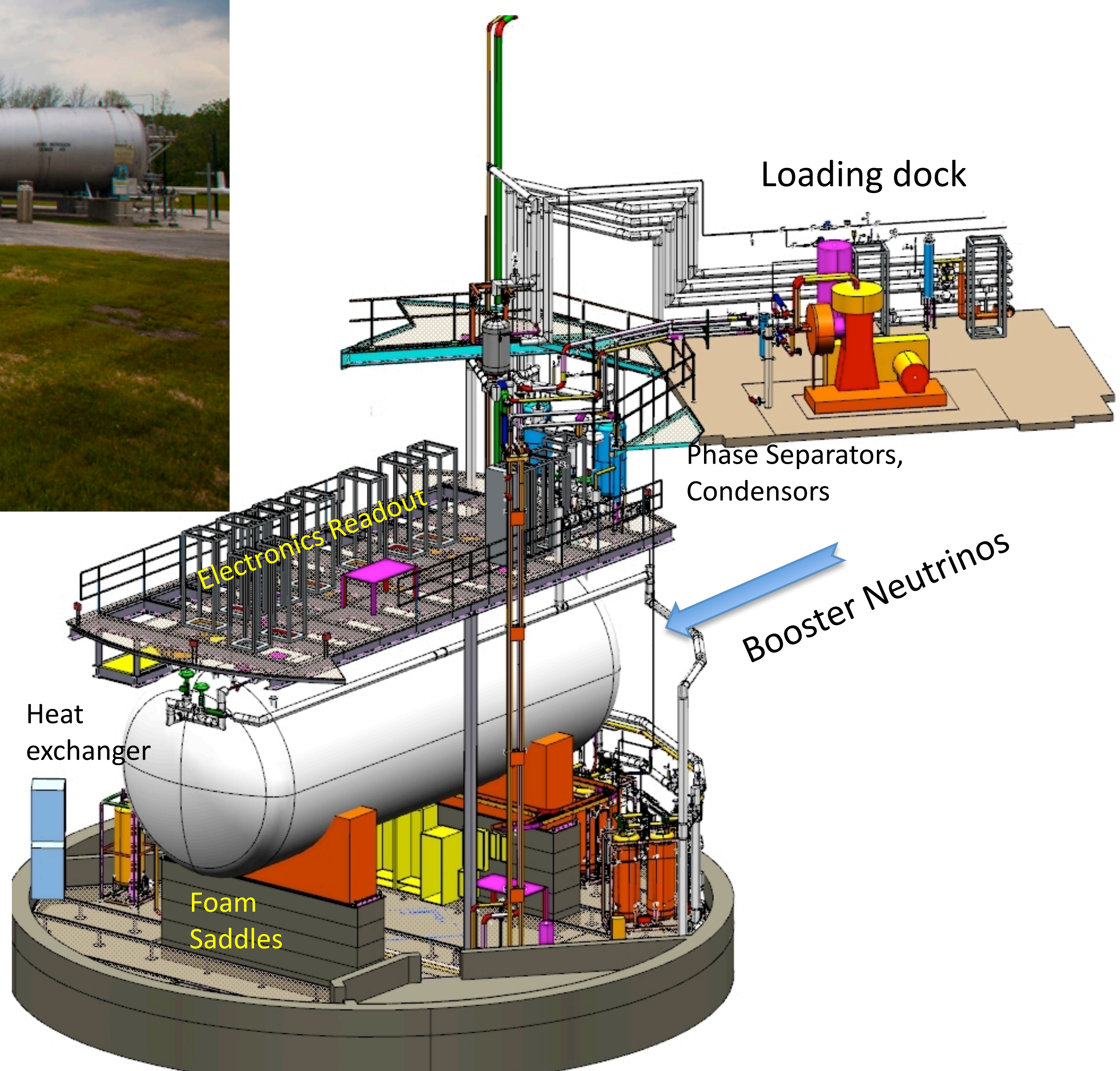




8, 256 wires; U,V,Y planes; 3 mm spacing

32 PMTs for fast light collections

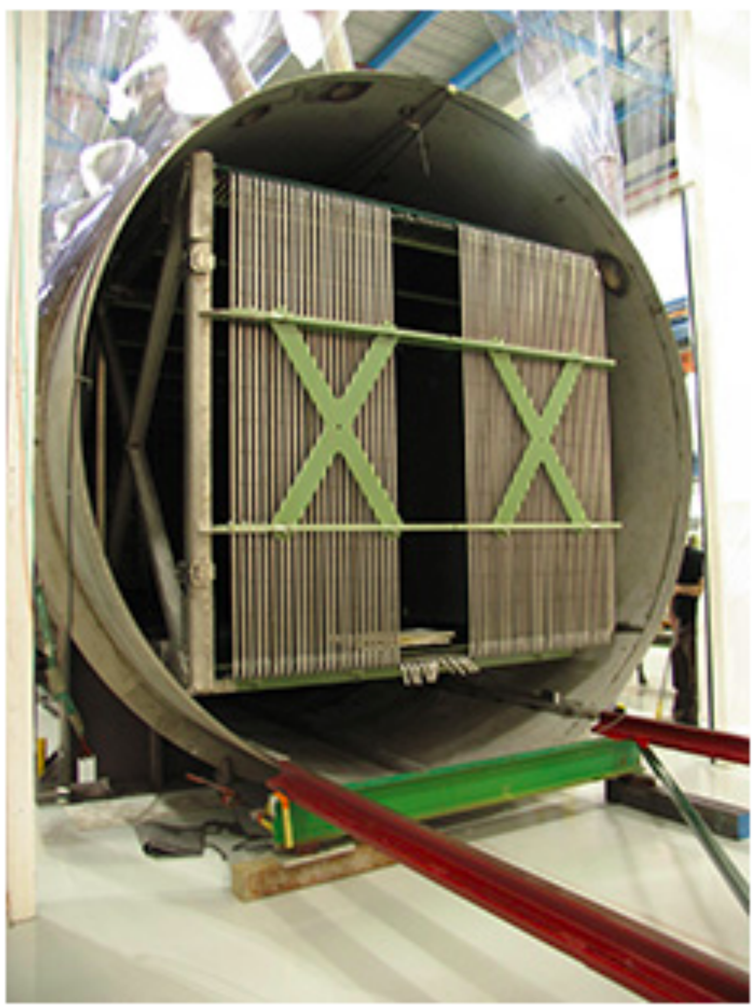
MicroBooNE @ LArTF



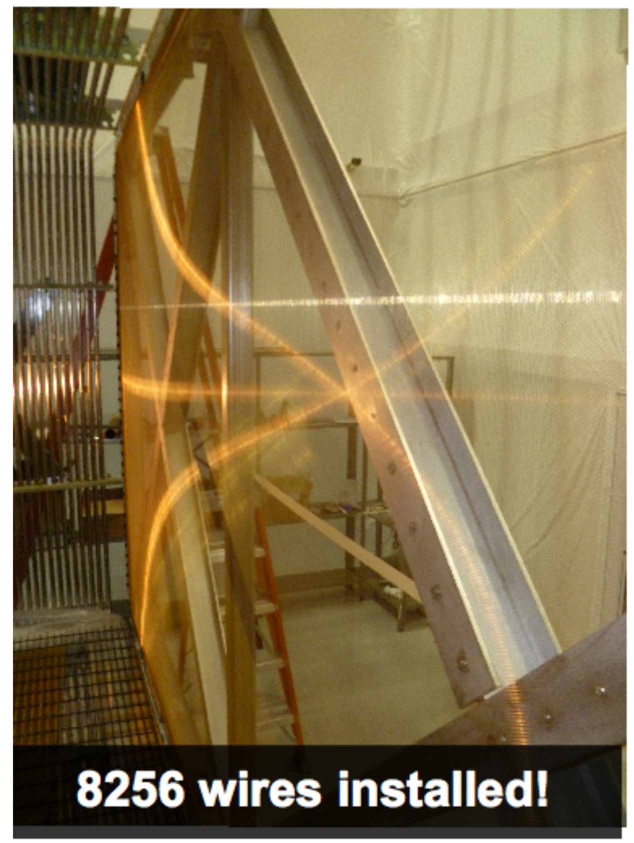
Detector Construction

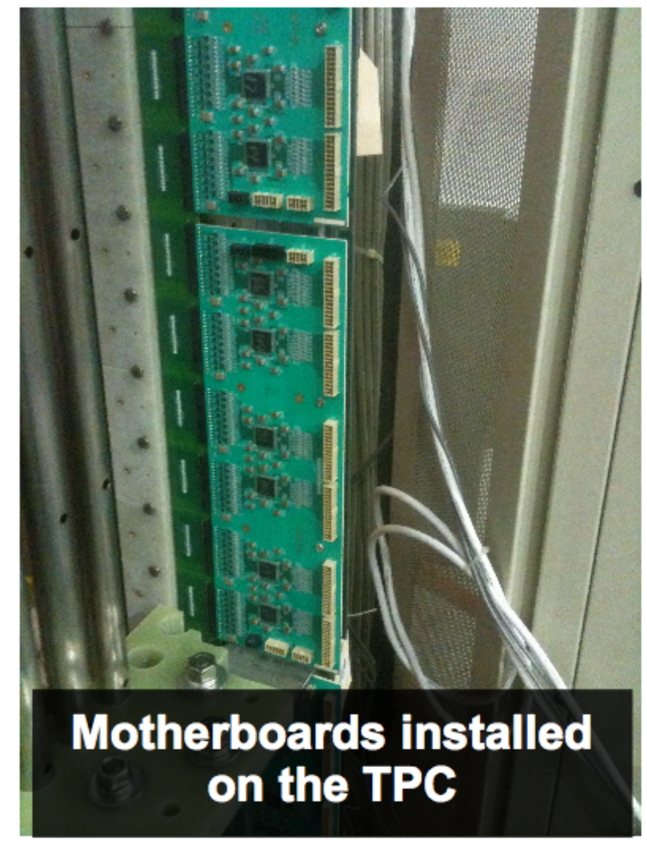
Feature

Liquid-argon time projection chamber gets a test fit



A 6-ton time projection chamber now sits inside the MicroBooNE cryostat. *Photo: Sarah Khan*





Detector Overview

- MicroBooNE : 170 t (~70 t fid.) liquid argon TPC
- TPC dimensions : 10.3m × 2.3m × 2.5m

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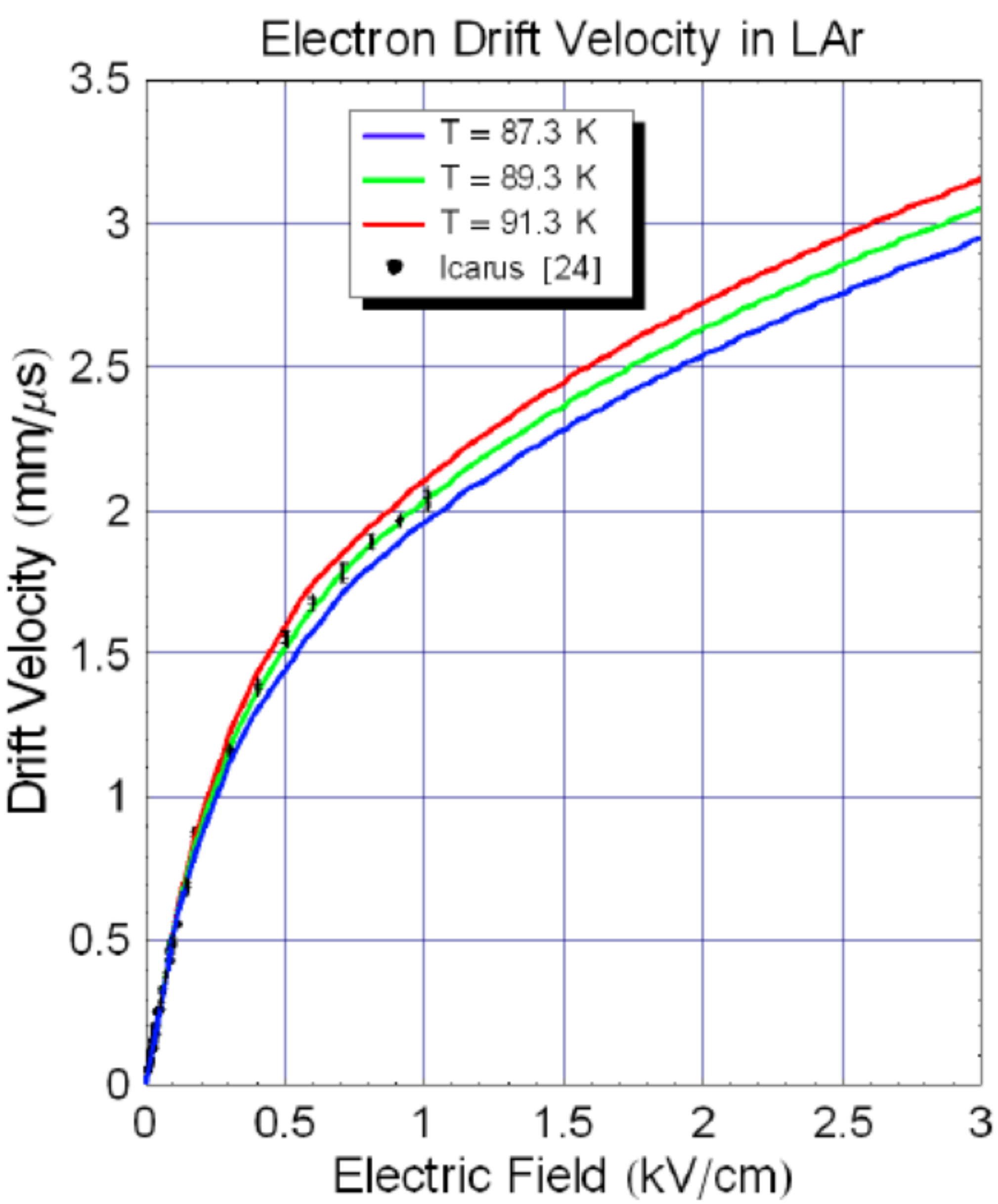
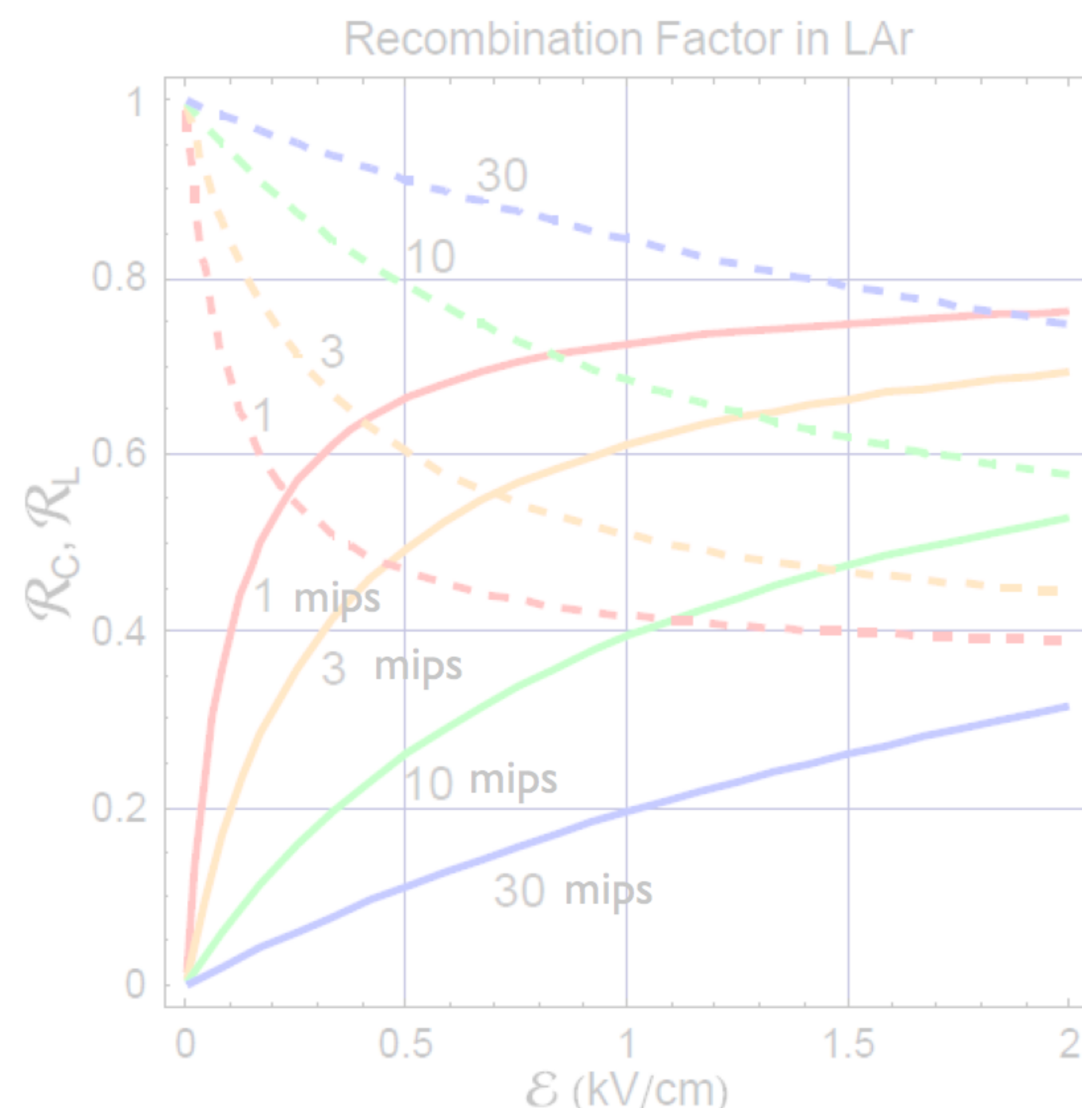
- 8256 channels (*vert.&±60^0*)
- 32 PMT
- UV laser → calibration tracks

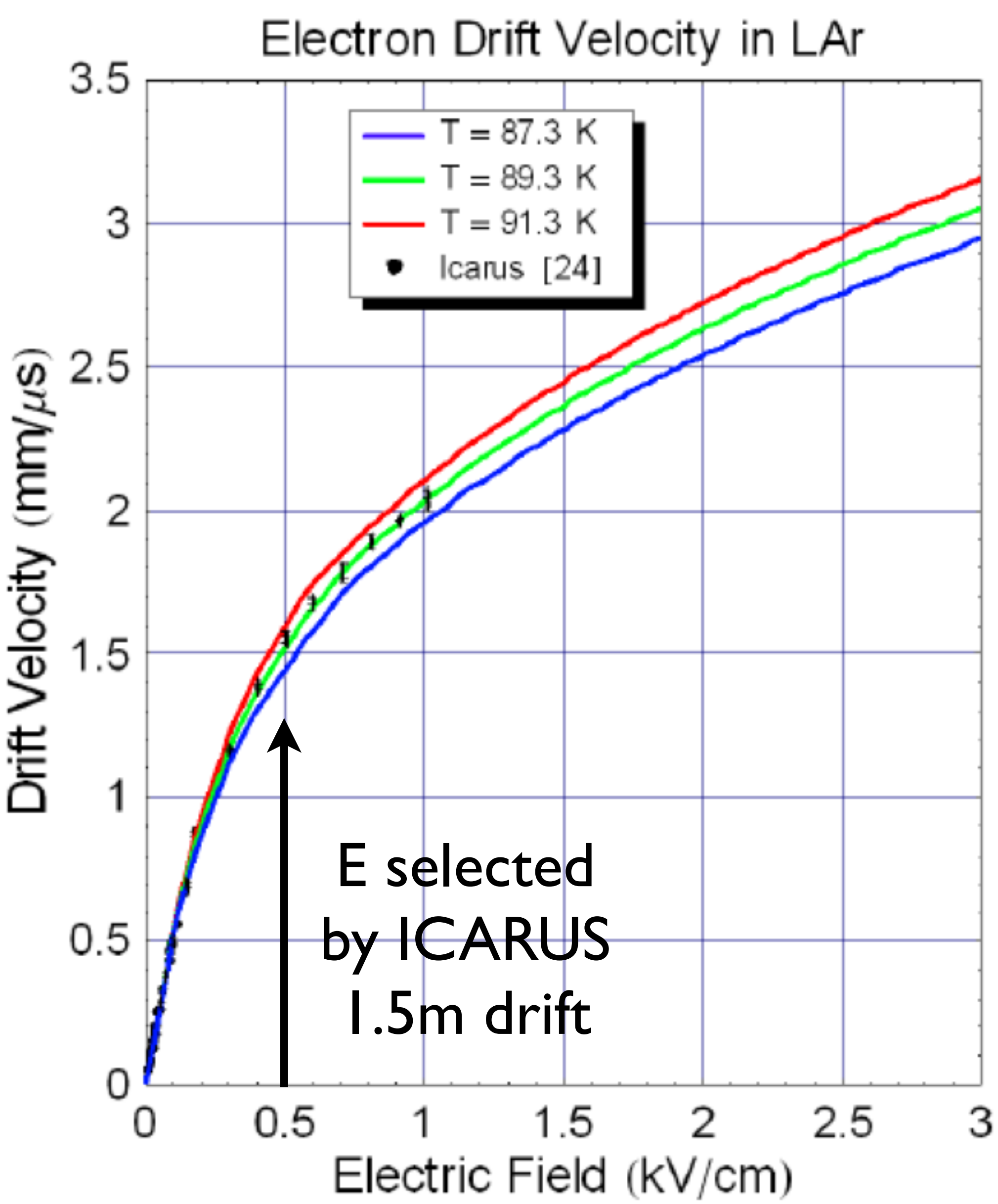
Drift velocity vs *E* field

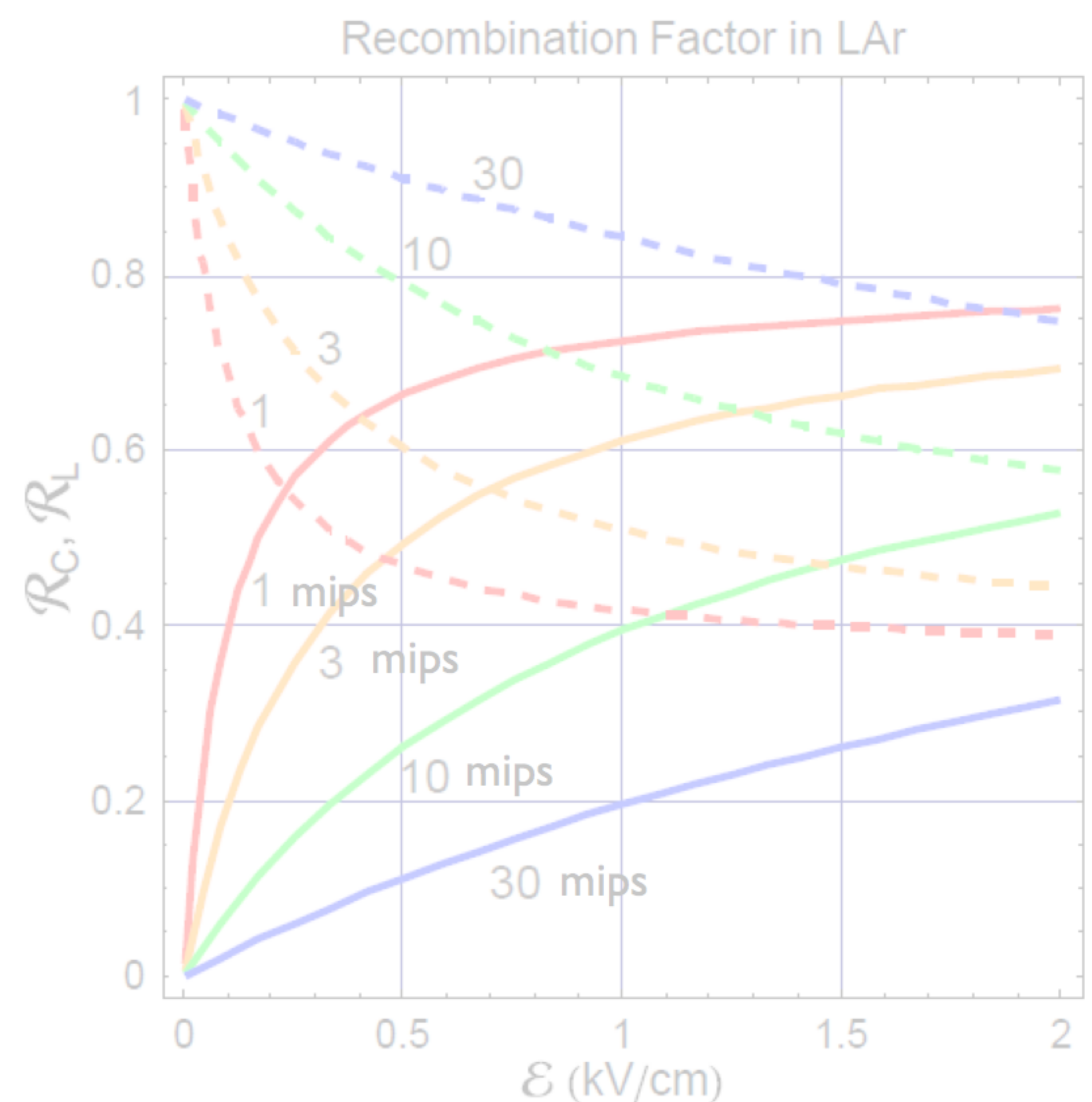




Solid lines are the recombination factor for charge (charge collected at finite field divided by charge collected at infinite field) [31, 32]. Dashed lines are the light recombination factor (light collected at field divided by light collected at zero field) [43]. The numbers labeling the curves are the specific energy loss (dE/dx) in units of mip.

Electron Drift velocity





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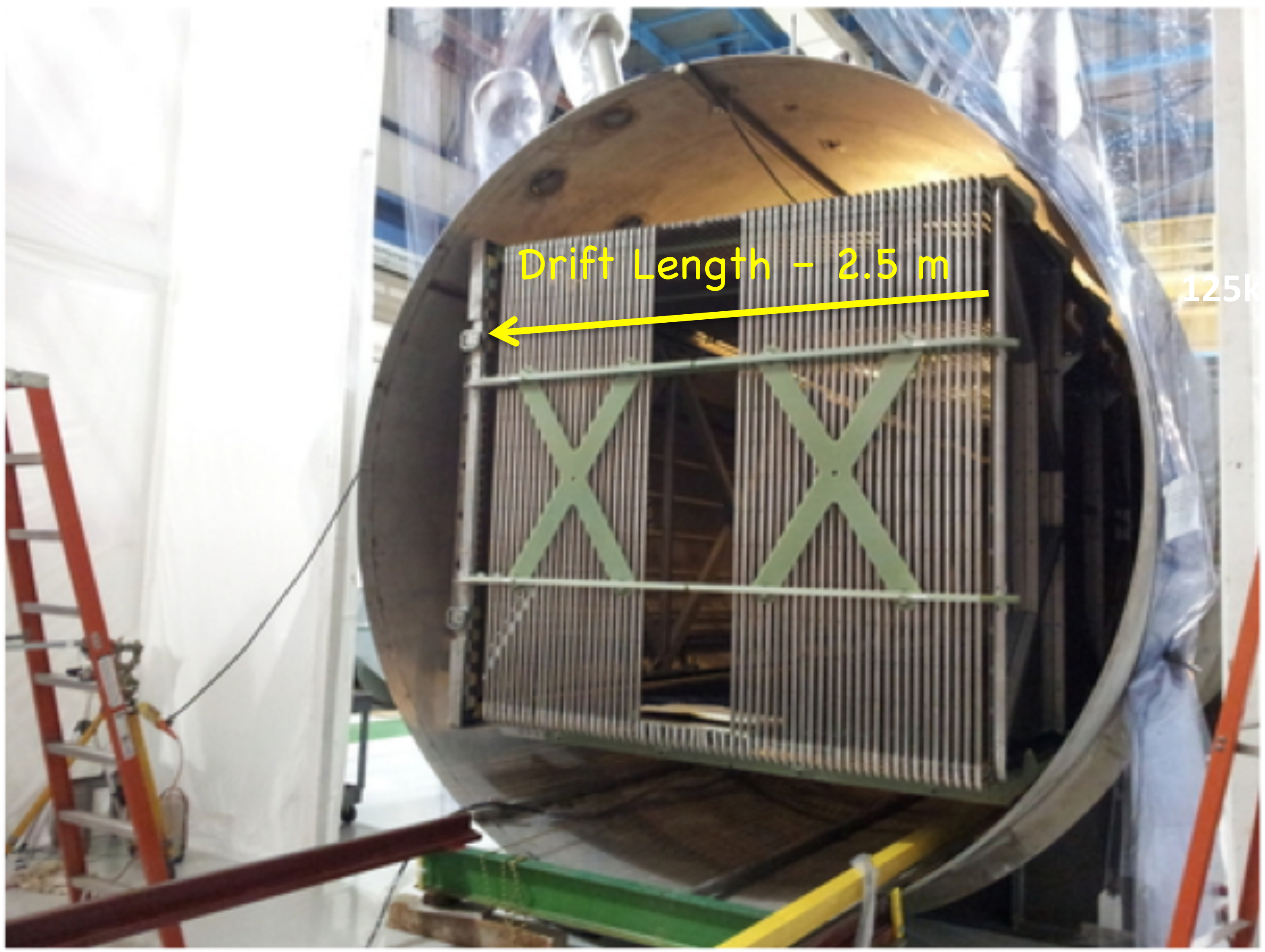
⇒ ~125kV for 2.5m drift

Focus of this Talk

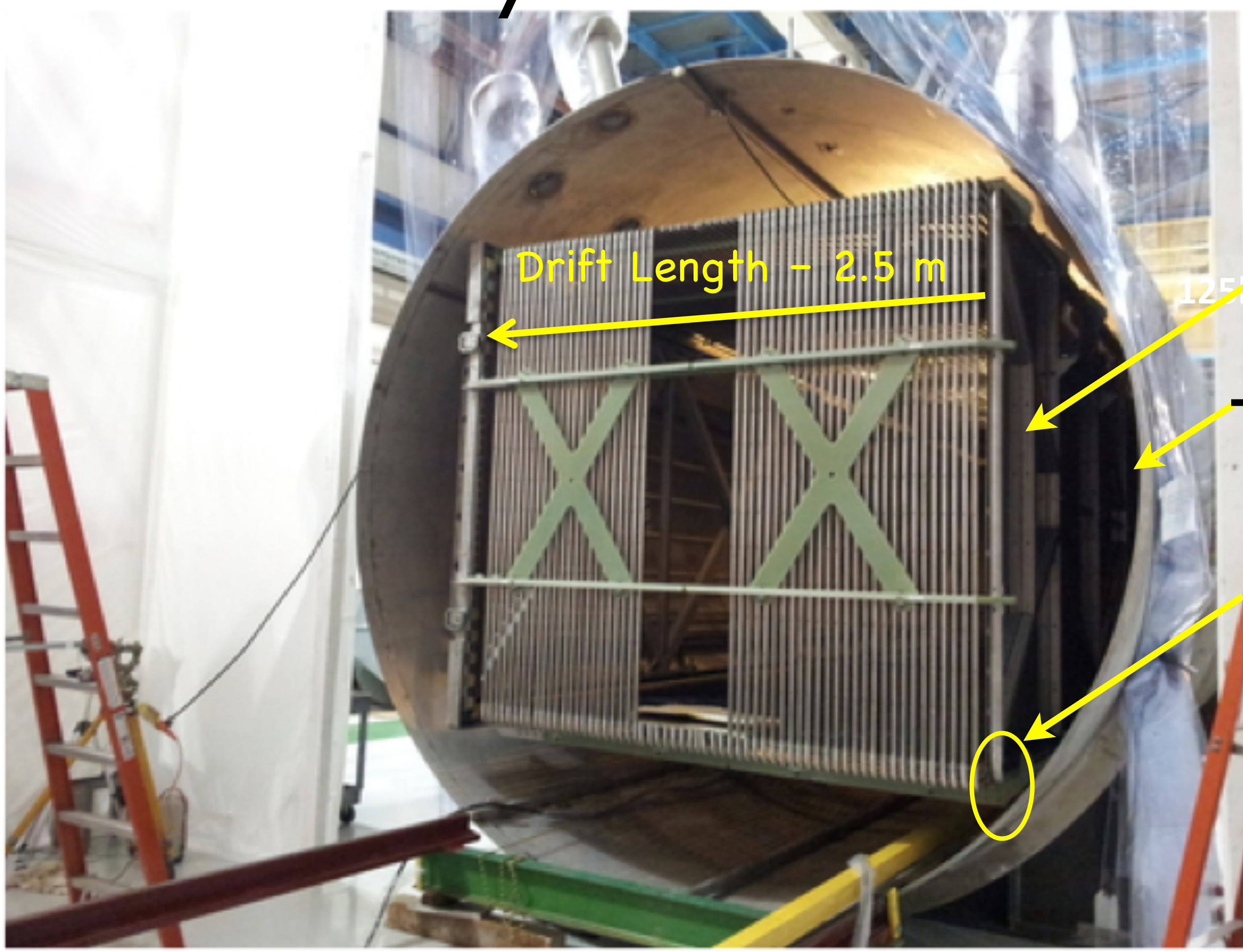
- MicroBooNE has started a set of initiatives prior to installing detector
- One of these, an auxiliary, or "test" cryostat with instrumentation is the subject of this talk
- Will conduct a suite of measurements re: HV properties of LAr (generic and specific)
- No data yet ...

Cryostat / TPC



Cryostat Vessel

Proximity of HV to vessel wall



HV

~10 cm

Motivations for Test

Table 3.3 *Maximum breakdown strengths of some liquids*

Liquid	*Maximum breakdown strength (MV/cm)*
Hexane	1.1–1.3
Benzene	1.1
Transformer oil	1.0
Silicone	1.0–1.2
Liquid Oxygen	2.4
Liquid Nitrogen	1.6–1.9
Liquid Hydrogen	1.0
Liquid Helium	0.7
Liquid Argon	1.10–1.42

<u>Example from literature #1:</u> breakdown field strength

Maybe so...

Motivations for Test

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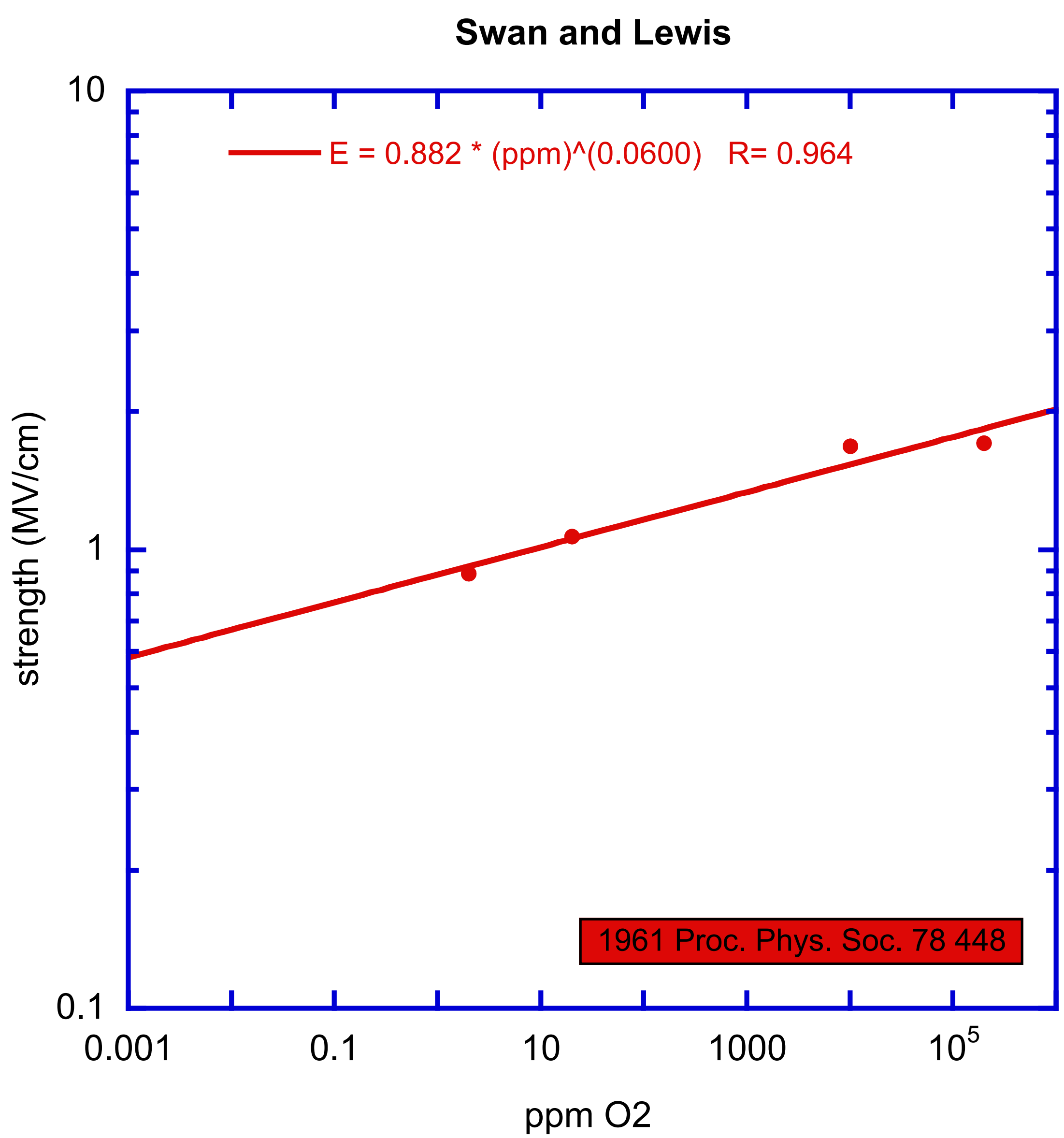
<u>Example from literature #1:</u> breakdown field strength

Maybe so...
but under what conditions?
<u>perhaps not ours!</u>

Motivations for Test

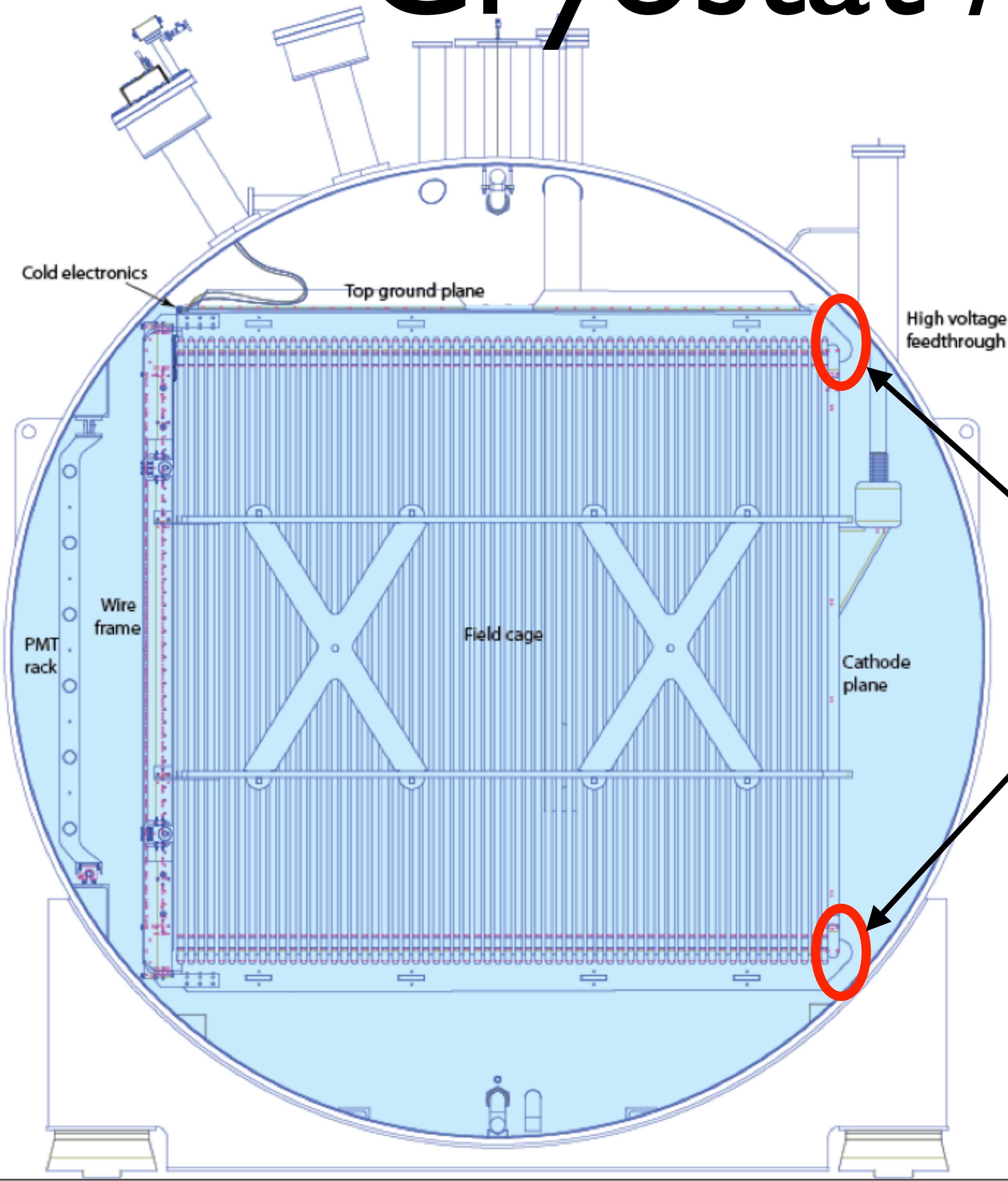


<u>Example from literature #2:</u>

breakdown field vs purity

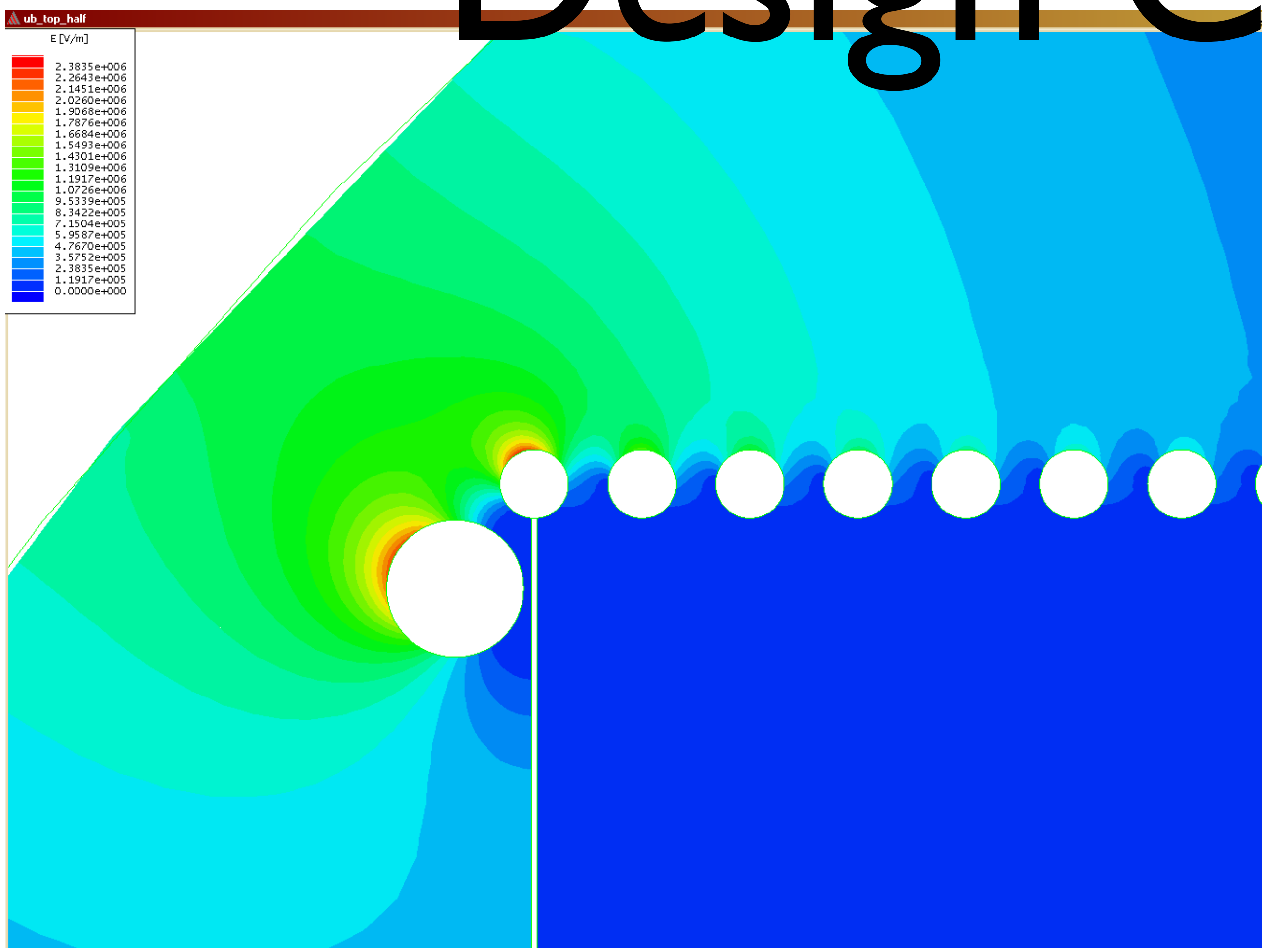
"extrapolation anxiety"

Cryostat / TPC



"regions of concern"

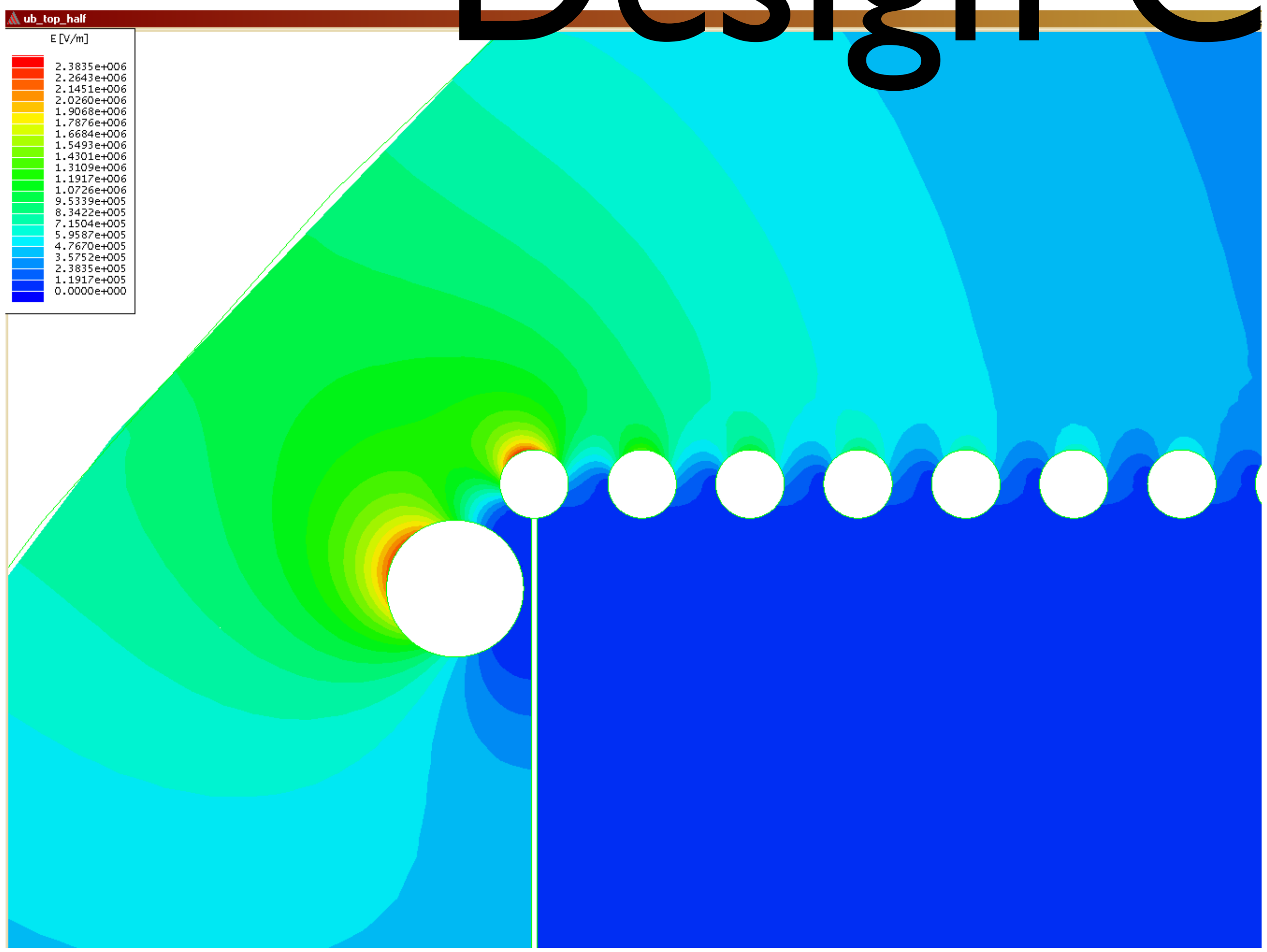
Simulations & Design Criteria



Simulation near point(s) of closest approach

max E → 24 kV/cm @ HV=125kV

Simulations & Design Criteria



current rule-of-thumb:

maintain maximum field less than ~10 X breakdown voltage

begs the following --- what E_{max} is appropriate?

Simulation near point(s) of closest approach

max E → 24 kV/cm @ HV=125kV

Motivations for Test

Specific

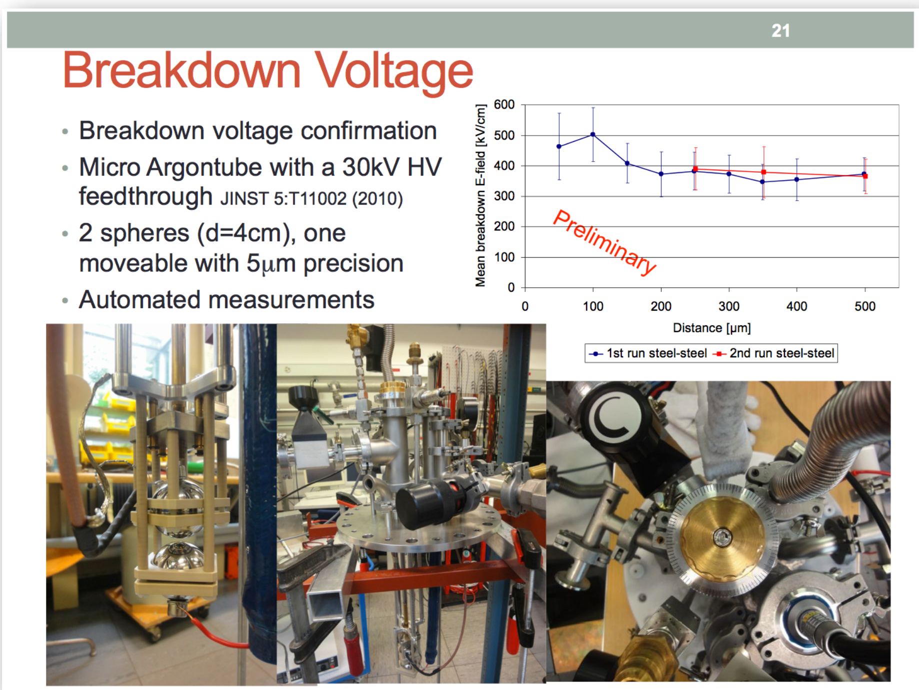
- We want to operate at ~500 V/cm
- 250cm cathode to wire ⇒ 125 kV
  - verify feedthrough performance
  - “optimum” purity (lifetime)
  - PMT considerations
  - operation at surface

Motivations for Test

Generic

- Explore LAr dielectric properties wrt:
  - Applied voltage
  - LAr purity
  - conductor geometry
- Breakdown / Corona / ε
- Careful control / monitoring of conditions

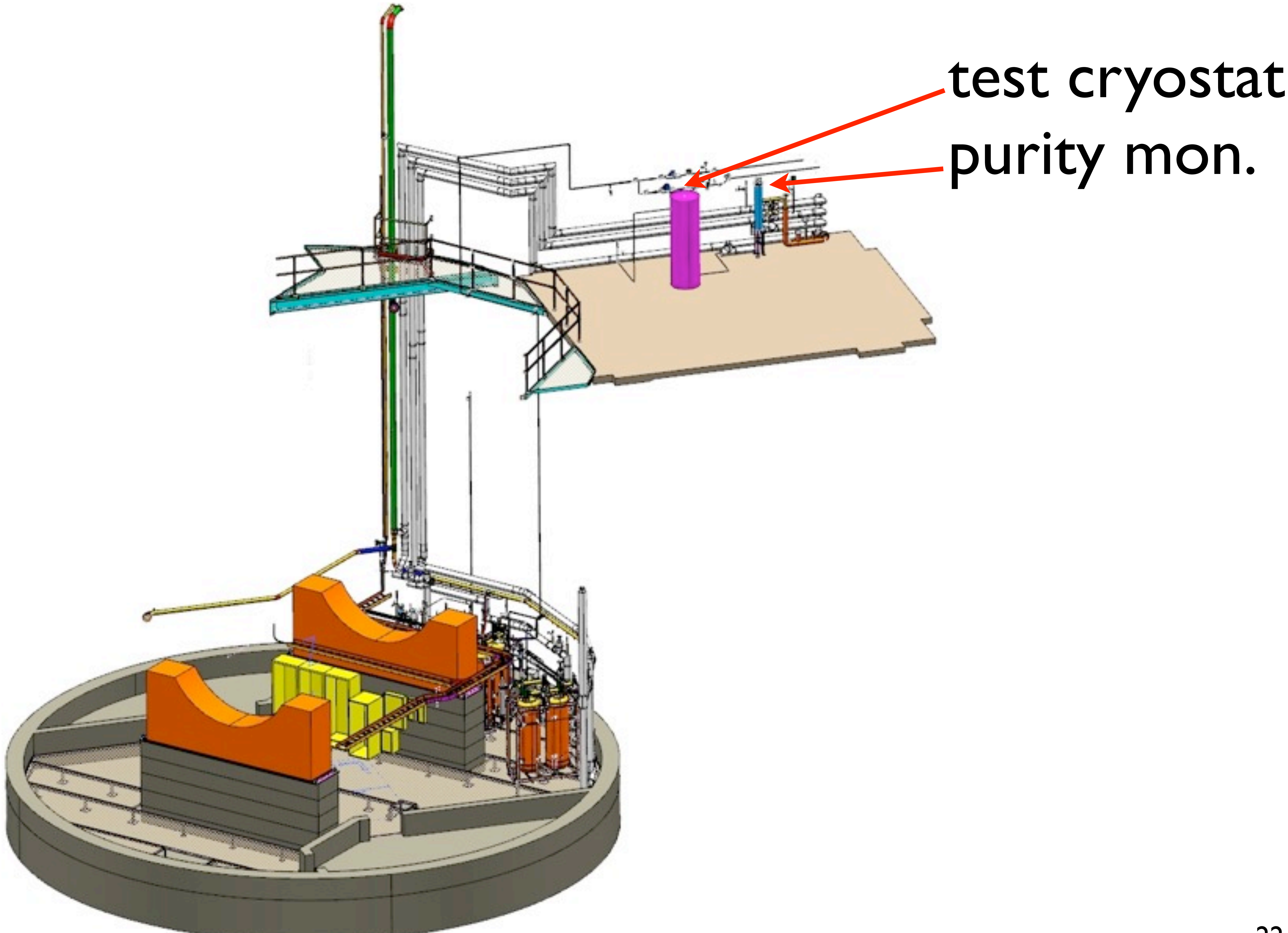
Recent Data



Recent breakdown field measurements at Bern

Stay seated for Thomas' presentation to follow

The Setup

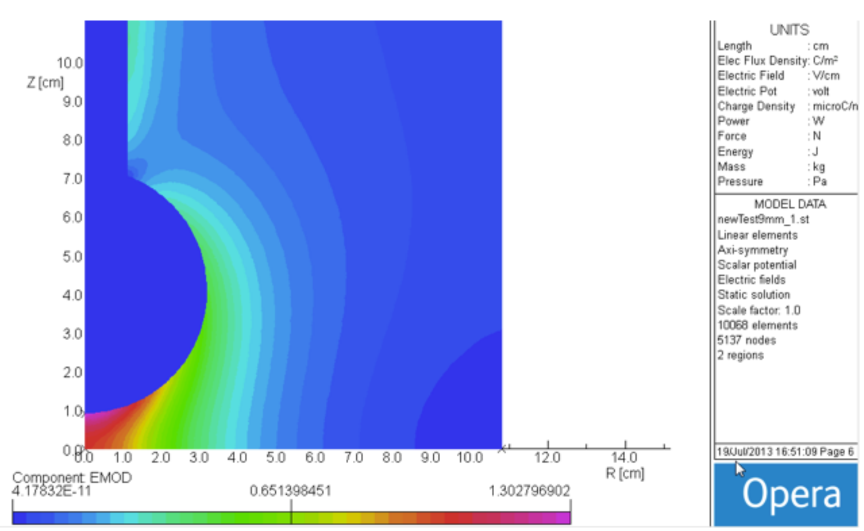


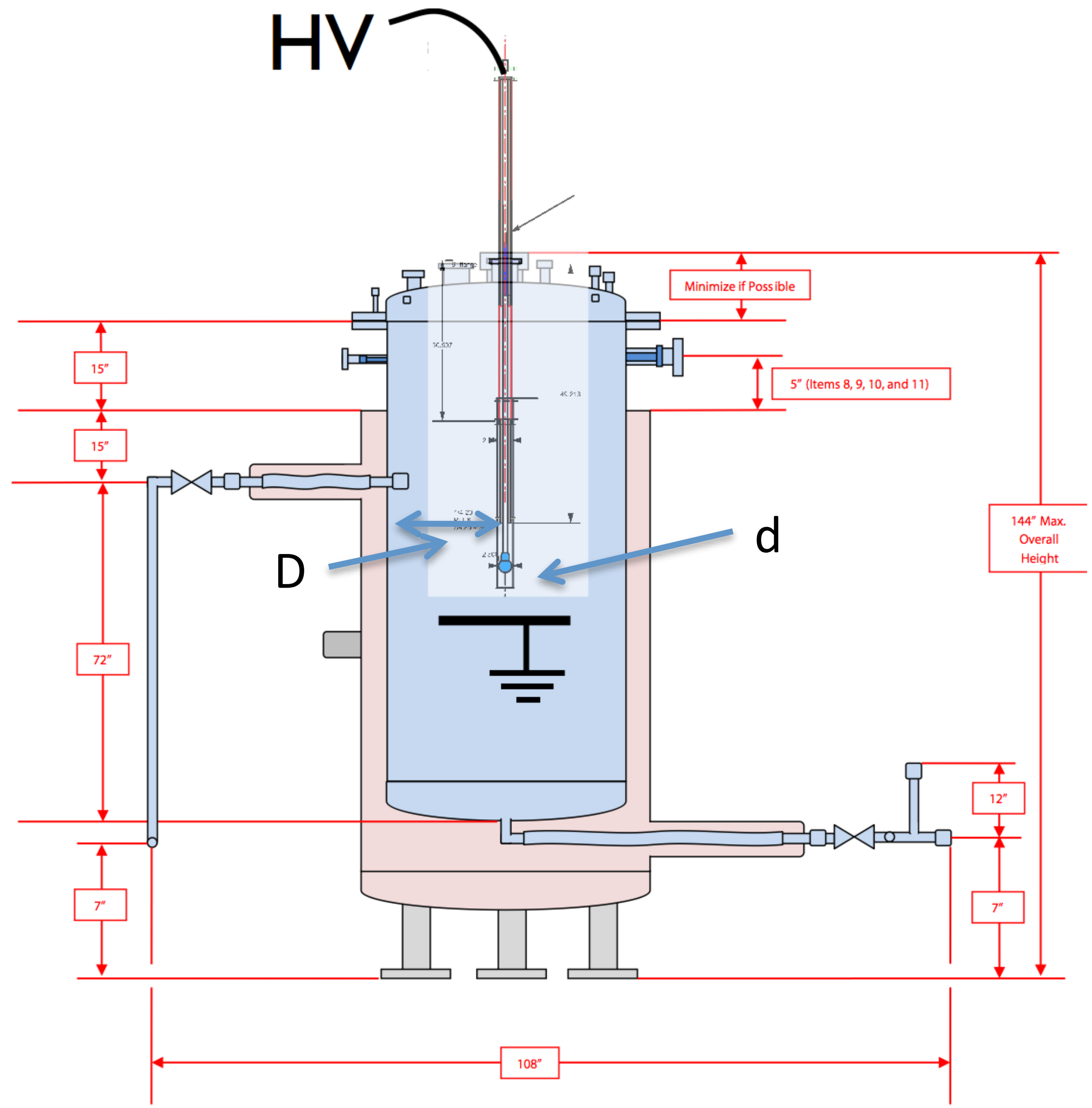
The Setup

- 800 liter cryostat at LArTF (expt. bldg.)
- plumbed to MicroBooNE cryo system
- in-line purity monitor (column lifetime vessel)
- fixed flat electrode (0V) and HV electrode on FT
  - changeable FT electrodes (1.3mm to 57mm dia.)
  - HV up to 150 kV
  - FT electrode movable from 0 to 100mm

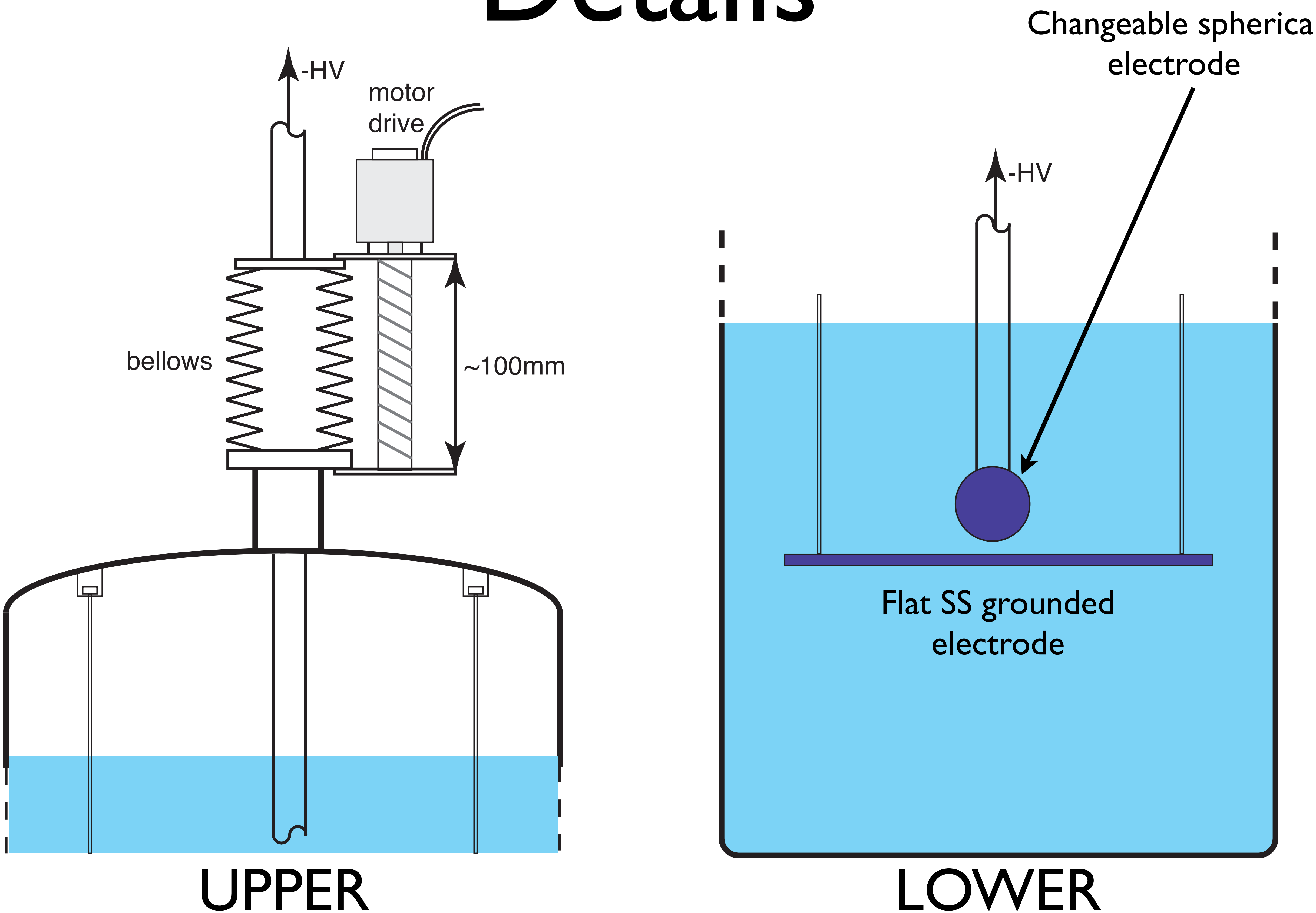
The Setup

- D >> d
- 0 cm < d < 10 cm
- Shape and quality of the electrodes
- Ability to model the set-up





Details


-HV
motor
drive
bellows
~100mm
UPPER
Changeable spherical
electrode
-HV
Flat SS grounded
electrode
LOWER

Test Schedule

- Cryostat just arrived ✓
- Parts assembled ~22 Nov
- Cryostat filled early December
- First measurement series before Xmas

Test cryostat removed when large cryostat set in place

Measurements

- Breakdown characterization (V, dist., purity)
- Test HV production feedthrough
- Corona ignition(?)
- Dielectric constant ε
- Positive HV
- LAr additives (quenching agents CH_4 CF_4)

A Test Sequence

Measurements example - breakdown:

- 57mm spherical electrode
- scan voltage and distance @ purity level 0
- ~1 day repeat scan @ purity level 1

Anticipate significant lifetime changes ~ day

Estimate electrode changeout ~2 days

Test results may answer...

- Can we diagnose/understand breakdown quantitatively?
- What are the optimum operating parameters?
- Are there additives to improve / stabilize performance?

- Looking forward to discussions ...

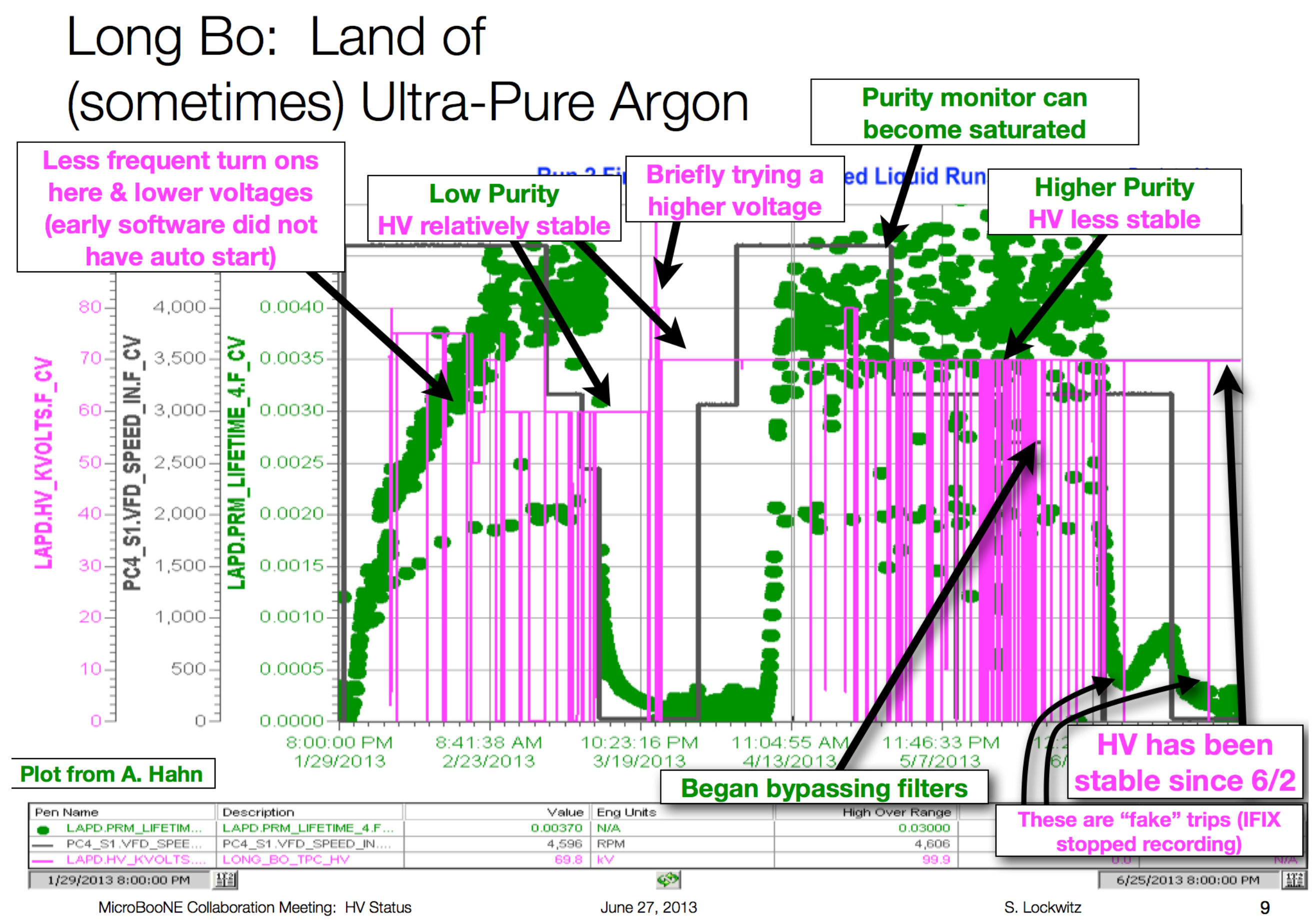
MicroBooNE Schedule

- Load large cryostat with TPC in December
- Install cryostat / TPC in beamline by next March
- First data by summer 2014

Backup

Breakdown vs Purity

- Many factors can affect the performance of a HV system
  - Properties of the FT itself
  - Environment
- Simultaneous with our uB FT studies, data was being taken with the "Long-Bo" TPC in LAPD
  - A variety of different HV affects were observed
  - Breakdown was correlated with the purity



This plot is confusing, and should not be used to draw quantitative conclusions.
It's just meant to remind us that the HV-LAr purity connection is real