Liquid Argon Detector R&D at FNAL

Ben Loer – Coherent NCvAS Workshop

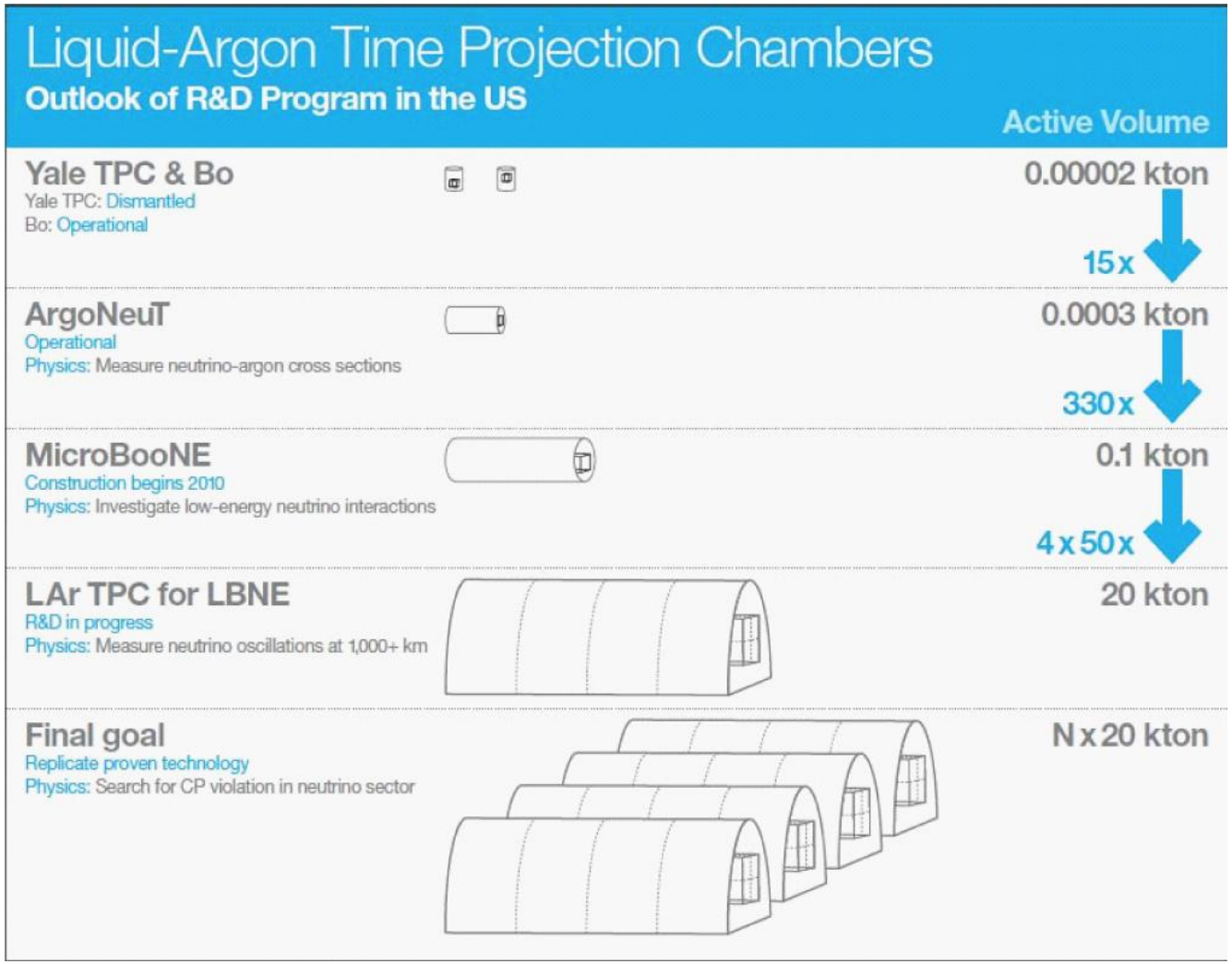
Outline

- General LAr R&D
- SCENE: SCintillation Efficiency of Noble Elements
- BNB 10-kg LAr prototype
- BNB 1-ton LAr plans

General LAr R&D at FNAL (most slides shamelessly stolen…)

- LArTPC and MicroBooNE
- Materials Test System and Liquid Argon Purity Demonstrator
- DarkSide and low radioactivity argon

LAr TPC Program



MicroBooNE

Dual Purpose

- **Physics:**
  - I. The MiniBooNE low energy Excess and the LSND anomaly .
  - II. Cross sections
  - III. SuperNova neutrinos
- **R&D**
  - I. Argon fill without first evacuation. (Evacuation capability exists)
  - II. Long Drift spaces (2.5m up from 1.5m).
  - III. Cold Front end electronics (up to and including shaper) in Liquid Argon
  - IV. Continuous readout for SuperNova events and storage for several hours, awaiting trigger from SuperNova Alert Network
  - V. Measurement of Background to Proton decay searches in Large Underground LAr detectors.
  - VI. Development of Reconstruction and Particle Identification techniques.

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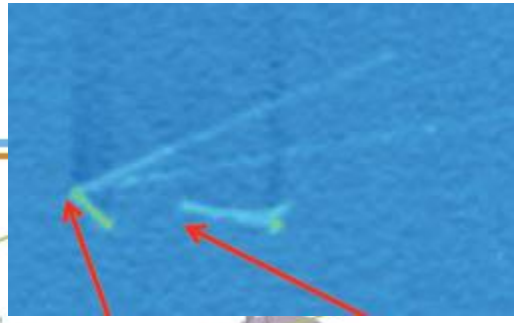
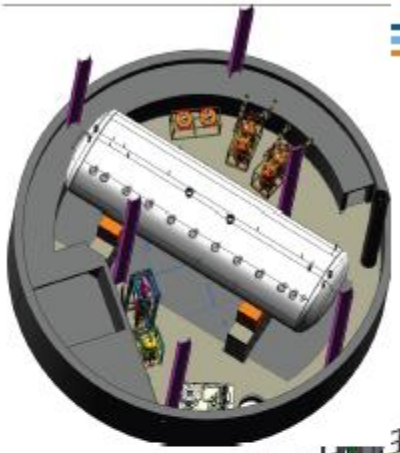
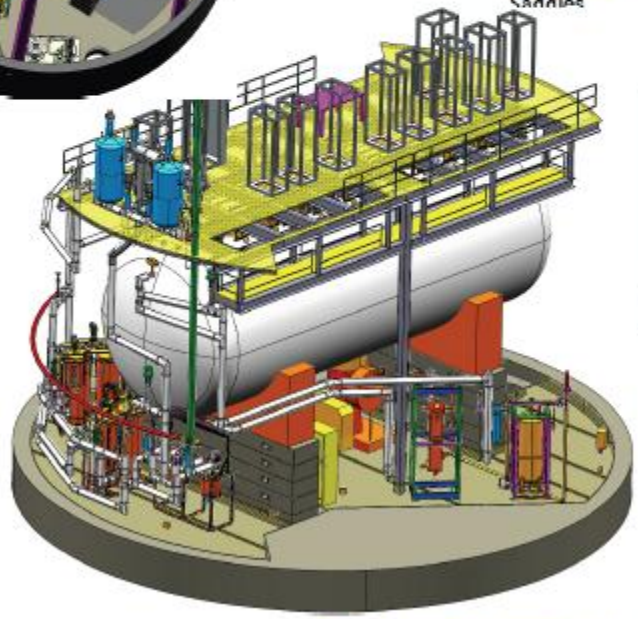
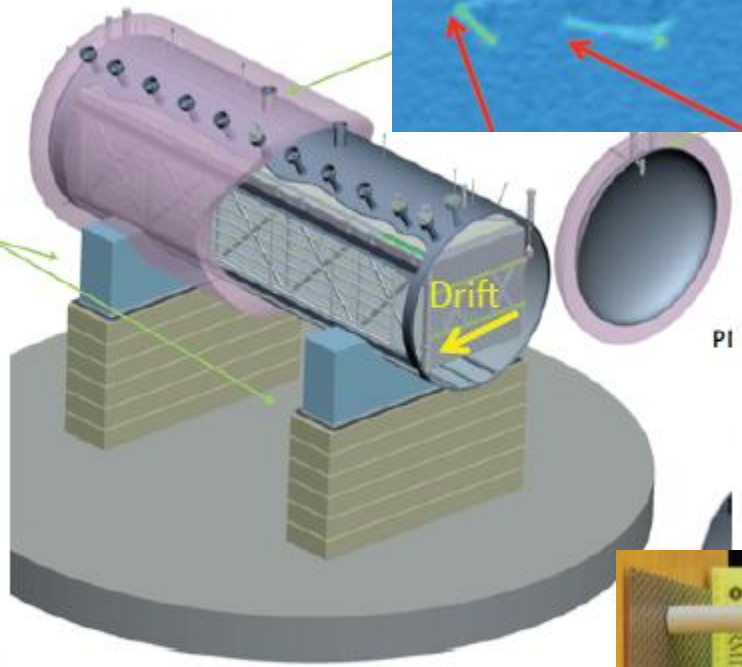
MicroBooNE

Detector description



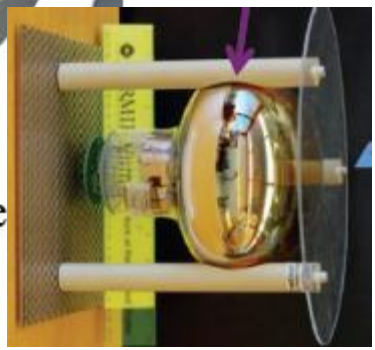






TPC: 100 tons of LAr
60 tons Fiducial volume

30 PMT's



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Materials Test System

Test Candidate Detector Materials for contamination of Argon:

Features

Home-made Filters - regenerated in place

Can insert materials into known clean argon

Can insert materials after purging only or after pumping on them

Can position materials into liquid and into ullage giving range of temperatures

Can insert known amounts of contaminant gases

Nitrogen-based condenser can maintain liquid for long (weeks) studies

Internal filter-pump can remove contamination introduced by materials – 2hr cycle

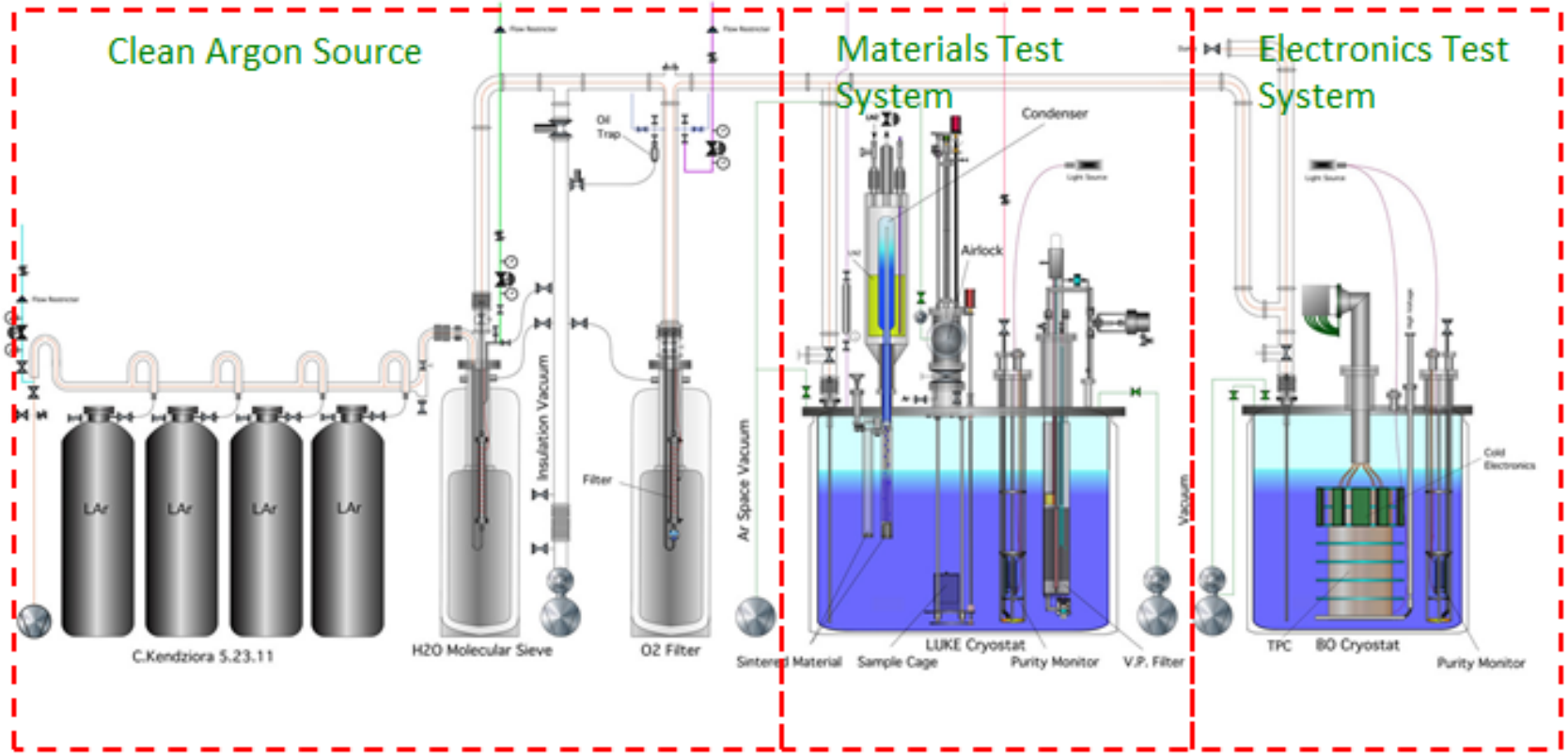
Argon sample points at source, after single-pass filters, and in cryostat gas and liquid.

H20 Meter

O2 Meter

Materials Test System

Schematic of Argon Source, Materials Test System and Electronics Test System

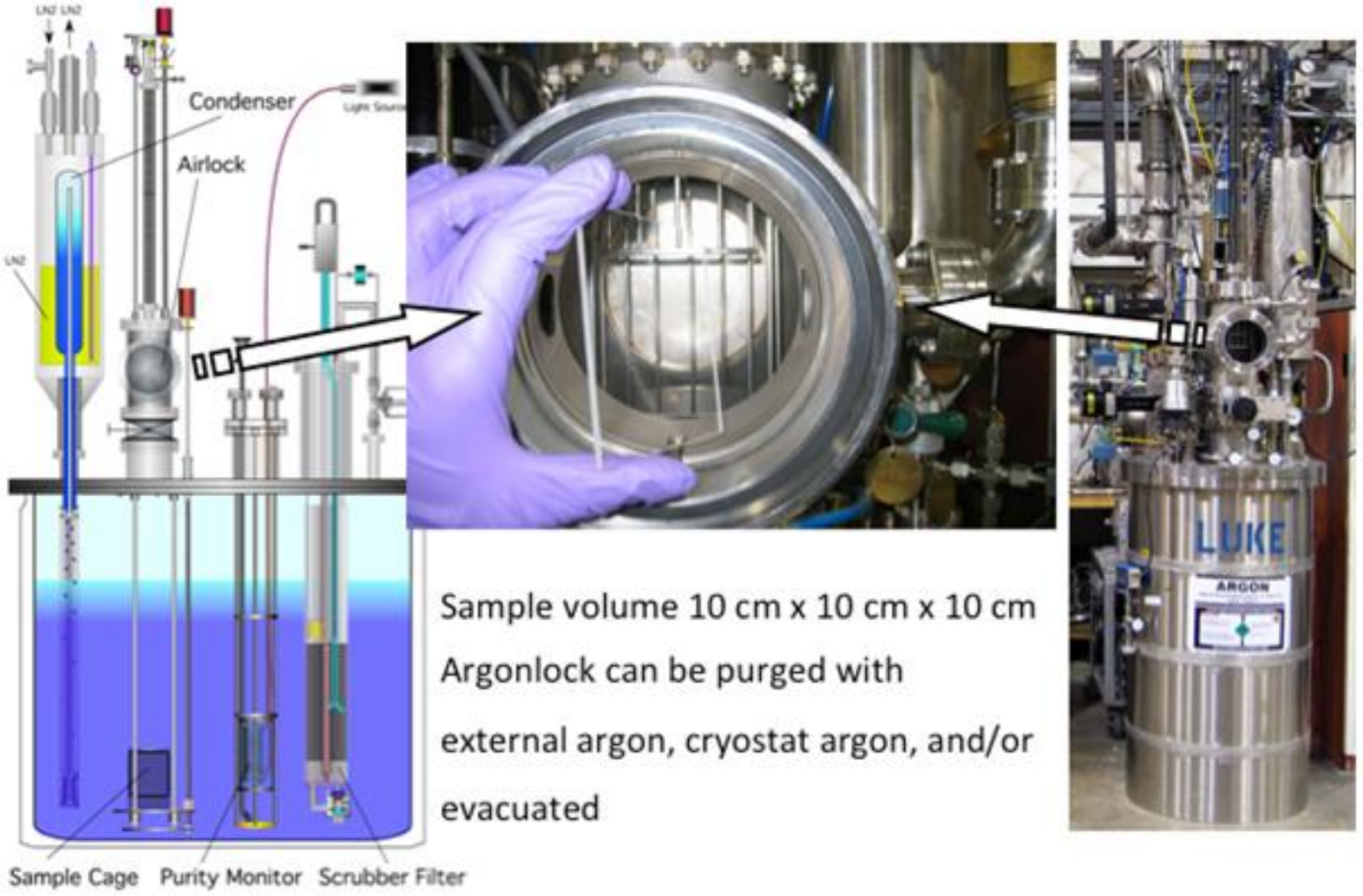


Commercial Argon, Home-made Filters for H20 (Zeolite) and Oxygen (Engelhard Cu-0226)

N2 Condenser, Insertion Cage, Purity Monitor, Bubble Pump

50 cm drift TPC, 3 readout planes, in-liquid electronics

Materials Test System

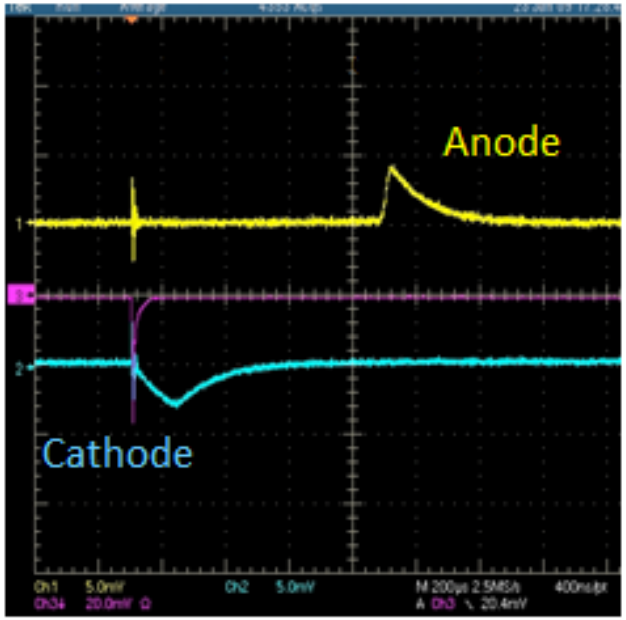


Sample volume 10 cm x 10 cm x 10 cm

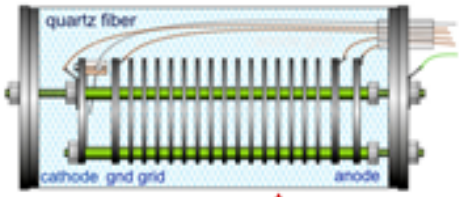
Argonlock can be purged with external argon, cryostat argon, and/or evacuated

Materials Test System

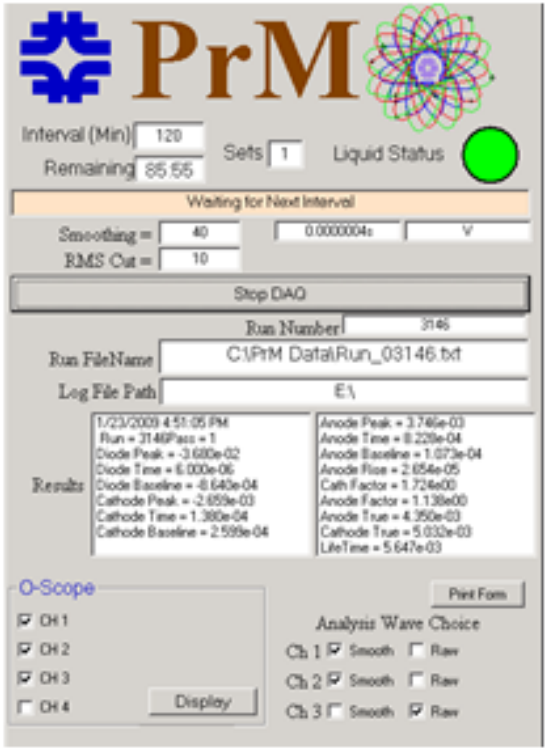
- Measure electron drift lifetime (0.3 milliseconds to 10 milliseconds)
- Measure Oxygen (0.5 ppb sensitivity) with oxygen meter (Delta-F & Tiger Optics)
- Measure H20 in gas (0.5 ppb sensitivity) with water meter (Tiger Optics)
- Cryogenic data, Lifetime Data, analytic instrumentation data in single data-base
- Runs 24/7 unattended - except for filter regeneration and argon refills



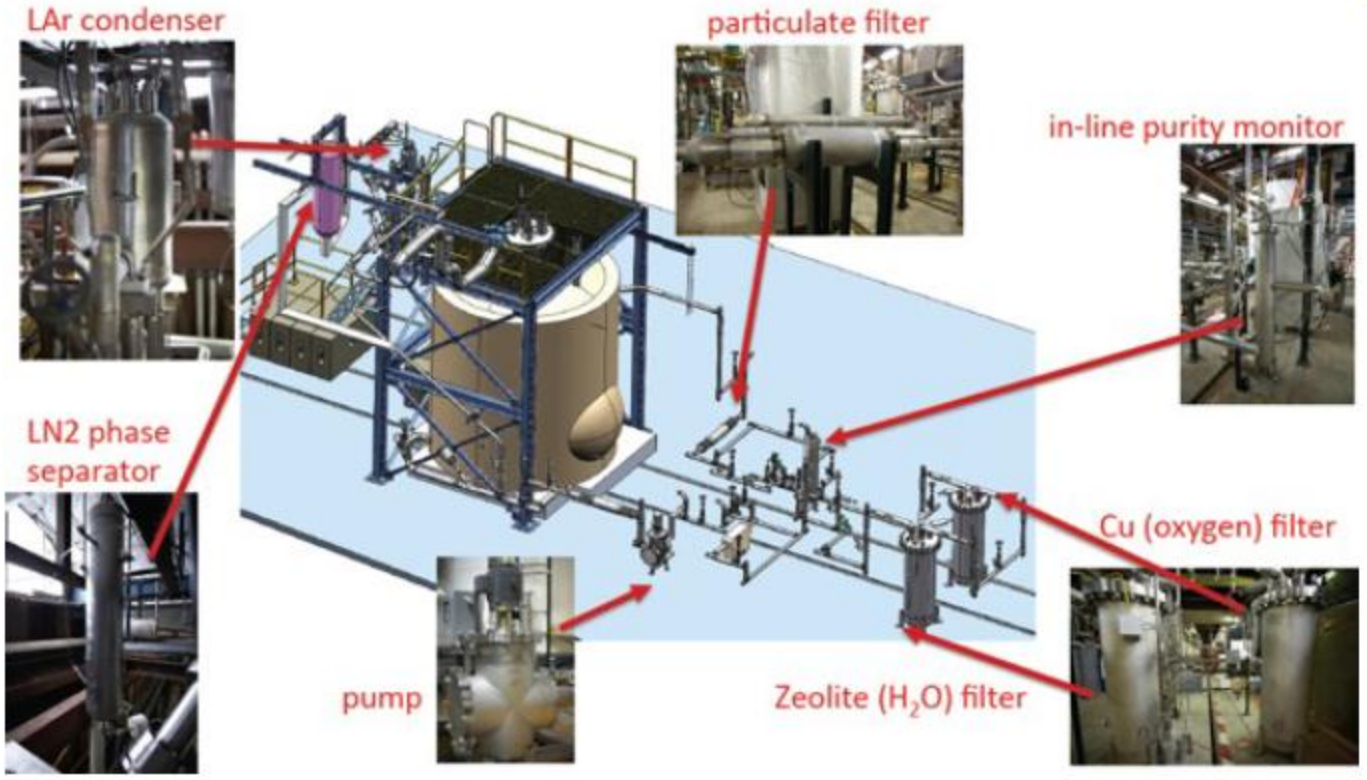
Lifetime Monitor Analysis →



Lifetime Monitor a la ICARUS



Liquid Argon Purity Demonstrator



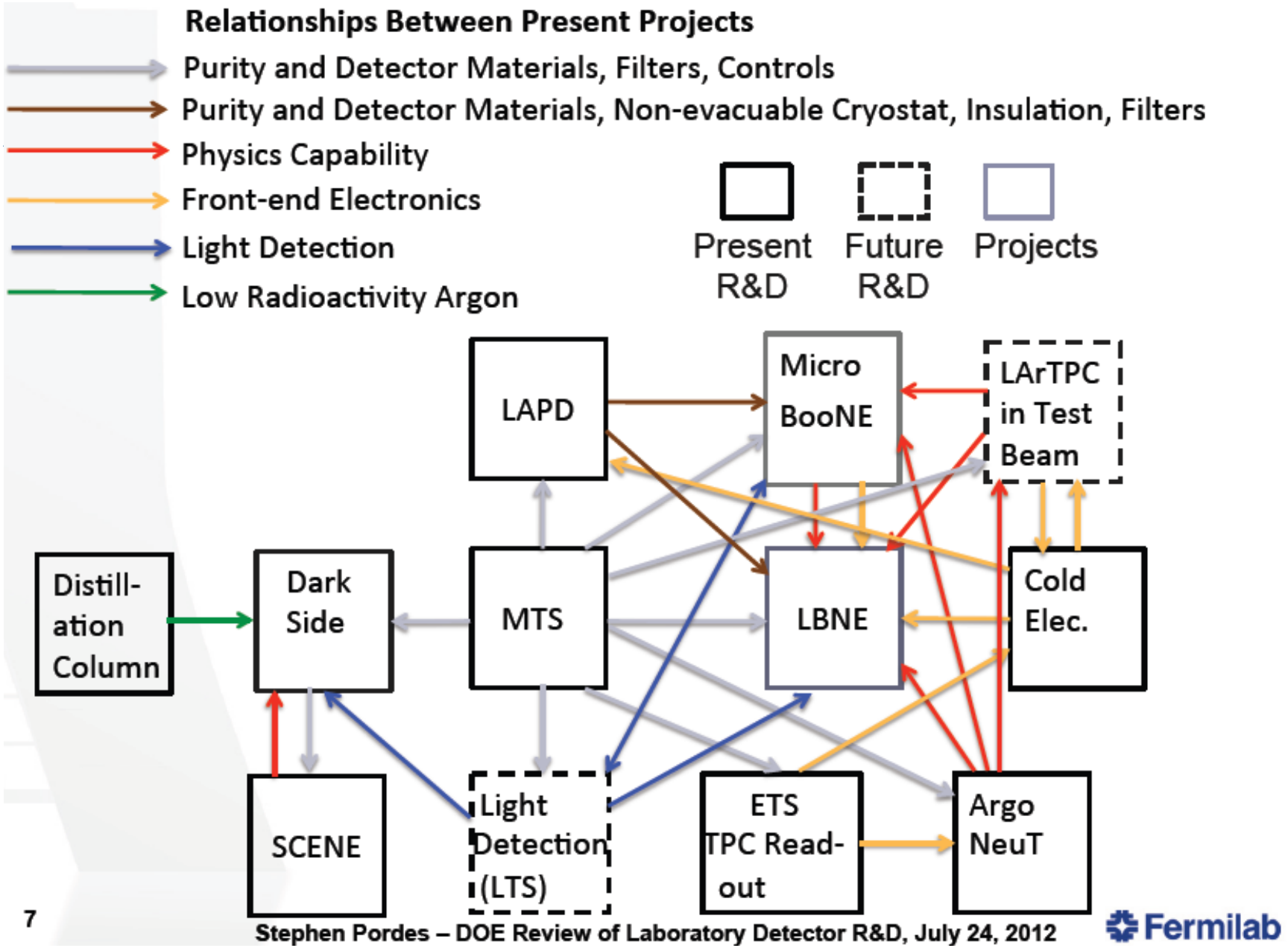
- Primary goal: show required electron lifetimes can be achieved without evacuation in an empty vessel using gaseous Ar purge, followed by gaseous Ar filtration, followed by liquid fill and filtration
- Fermilab program with contributions from Indiana University
  http://www.fnal.gov/directorate/program_planning/June2012Public/Brian_Rebel_lar_randd_june_pac_2012.pdf

Underground Argon Purification

- Underground argon has lower radioactive Ar-39
- Reduces WIMP search (and coherent scattering?) backgrounds
- Stage 1 is VPSA plant on-site in DOE Canyon CO2 plant, Cortez, CO
- Produces ~0.5 kg/day at few % purity

Underground Argon Purification

- Stage 2 is cryogenic distillation column in PAB
- Boosts VPSA output to <0.05% impurities at ~1 kg/day
- Plans to upgrade to 50 kg/day capability


Relationships Between Present Projects
Purity and Detector Materials, Filters, Controls
Purity and Detector Materials, Non-evacuable Cryostat, Insulation, Filters
Physics Capability
Front-end Electronics
Light Detection
Low Radioactivity Argon
Present R&D
Future R&D
Projects
LAPD
Micro BooNE
LArTPC in Test Beam
Distill-ation Column
Dark Side
MTS
LBNE
Cold Elec.
SCENE
Light Detection (LTS)
ETS TPC Read-out
Argo NeuT
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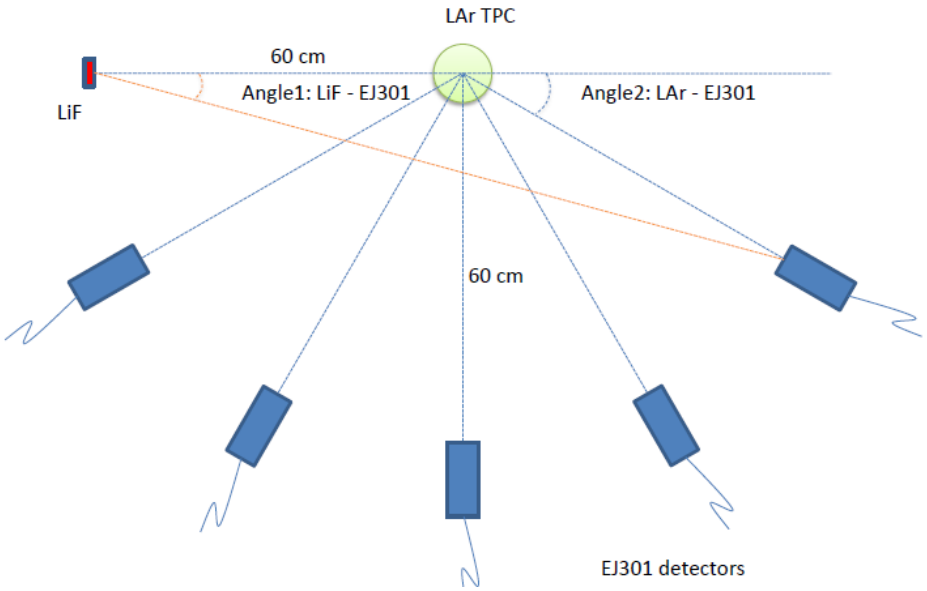
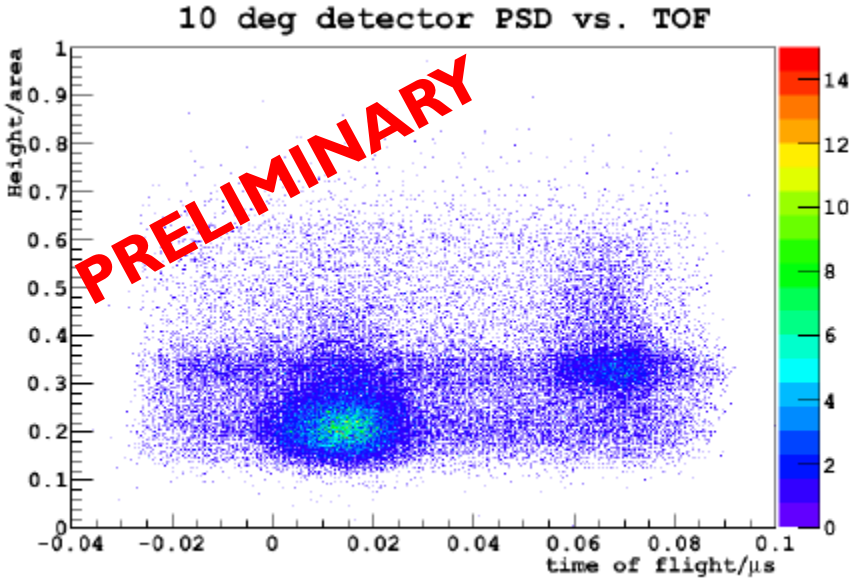
Stephen Pordes – DOE Review of Laboratory Detector R&D, July 24, 2012
Fermilab

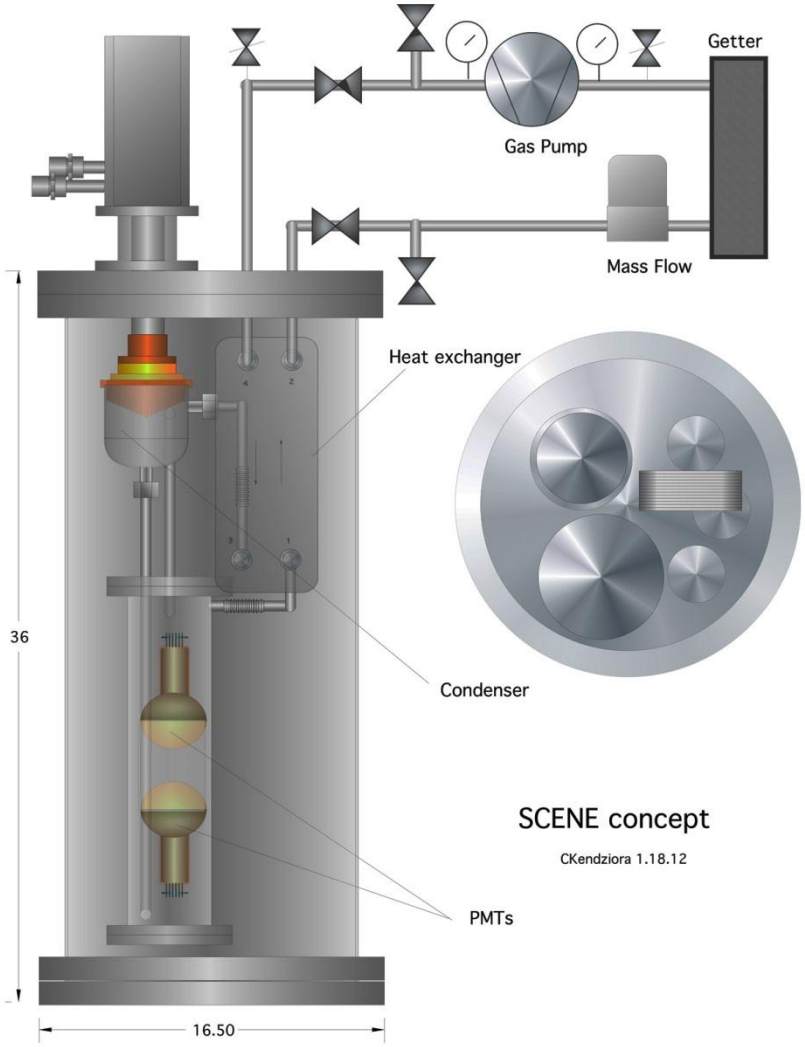
SCENE

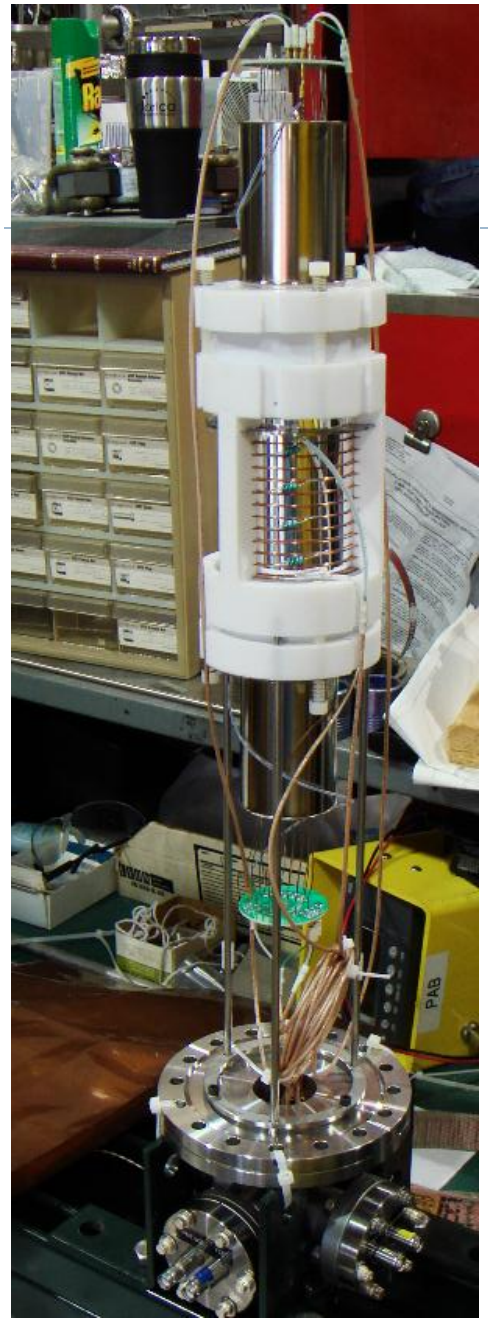
- Goal: measure scintillation and ionization response of liquid argon to low-energy nuclear recoils
- Select mono-energetic recoils by tagging angle of scattered neutron
- Use pulsed neutron beam at University of Notre Dame
- Time-of-flight and PSD reduce backround



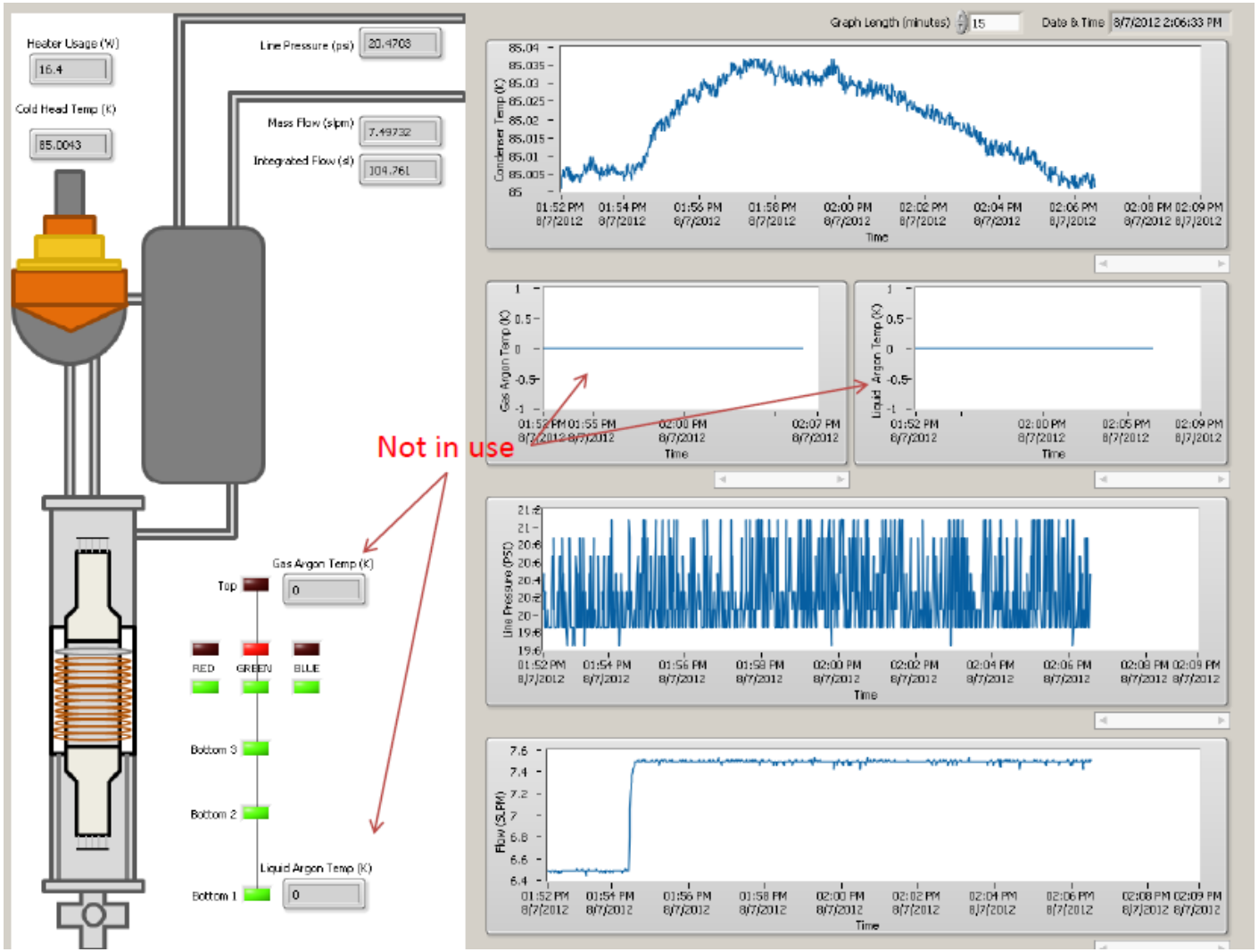


SCENE Detector

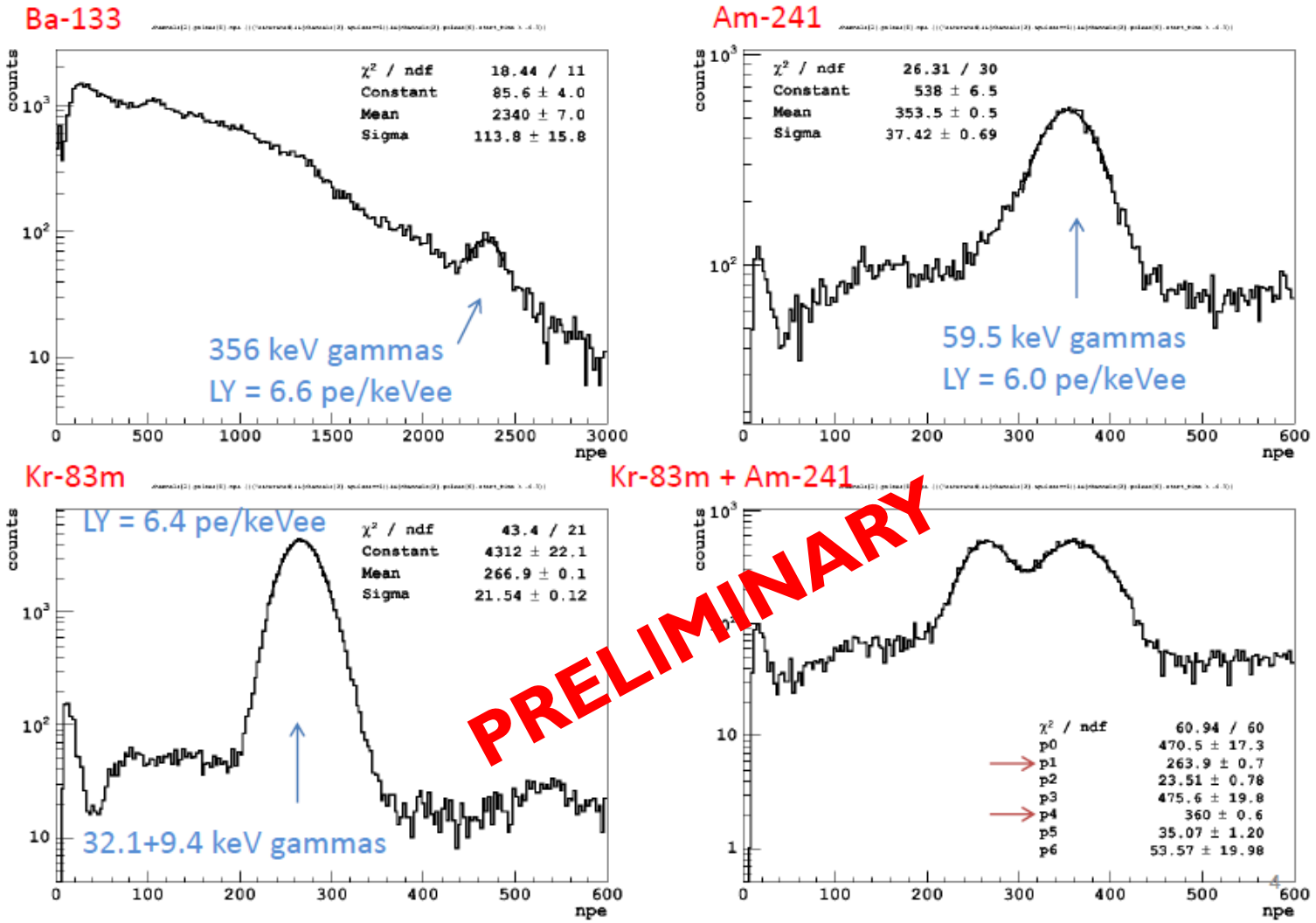




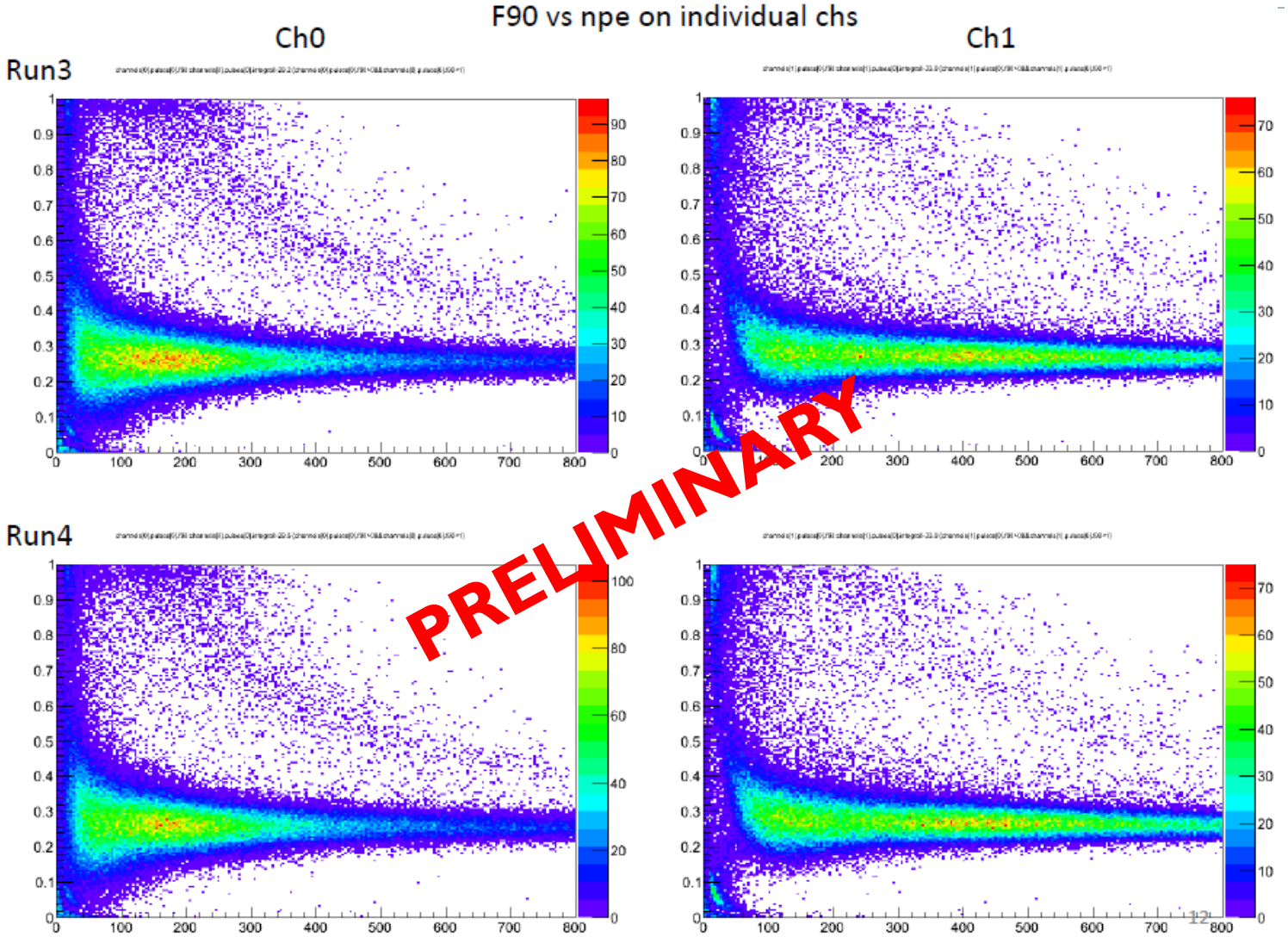
SCENE Control Panel



SCENE Gamma Light Yield

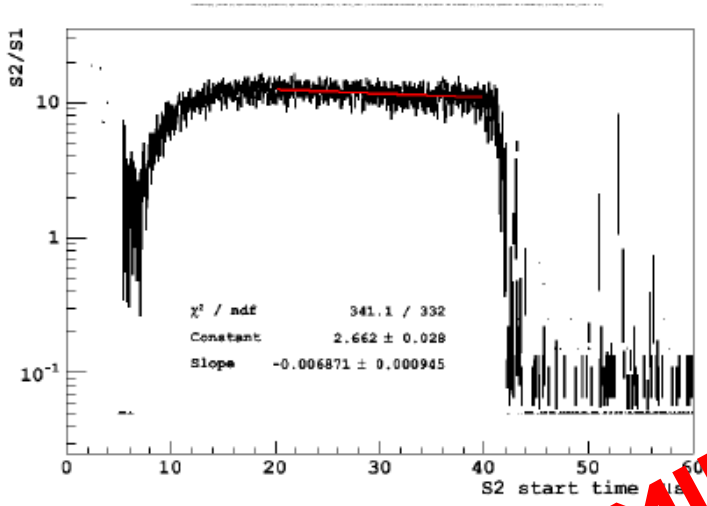


Simple LAr PSD in SCENE

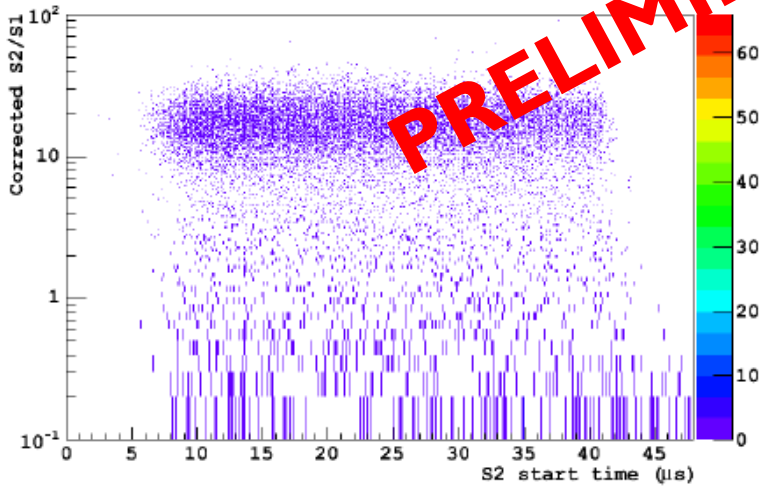


SCENE Purity / Drift Lifetime

S2/S1 vs. drift time and corrected S2/S1 vs. S1

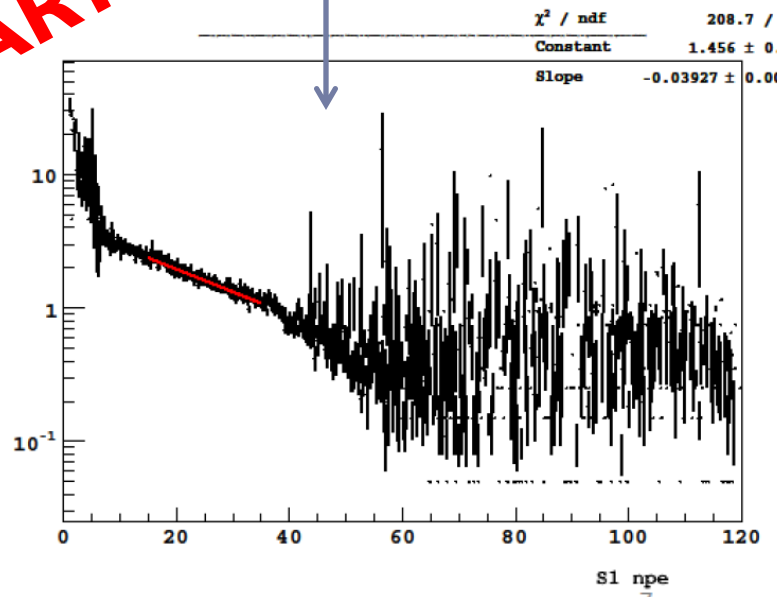


From Run 60
Used only S1 > 400 pe
Electron lifetime = 145 us



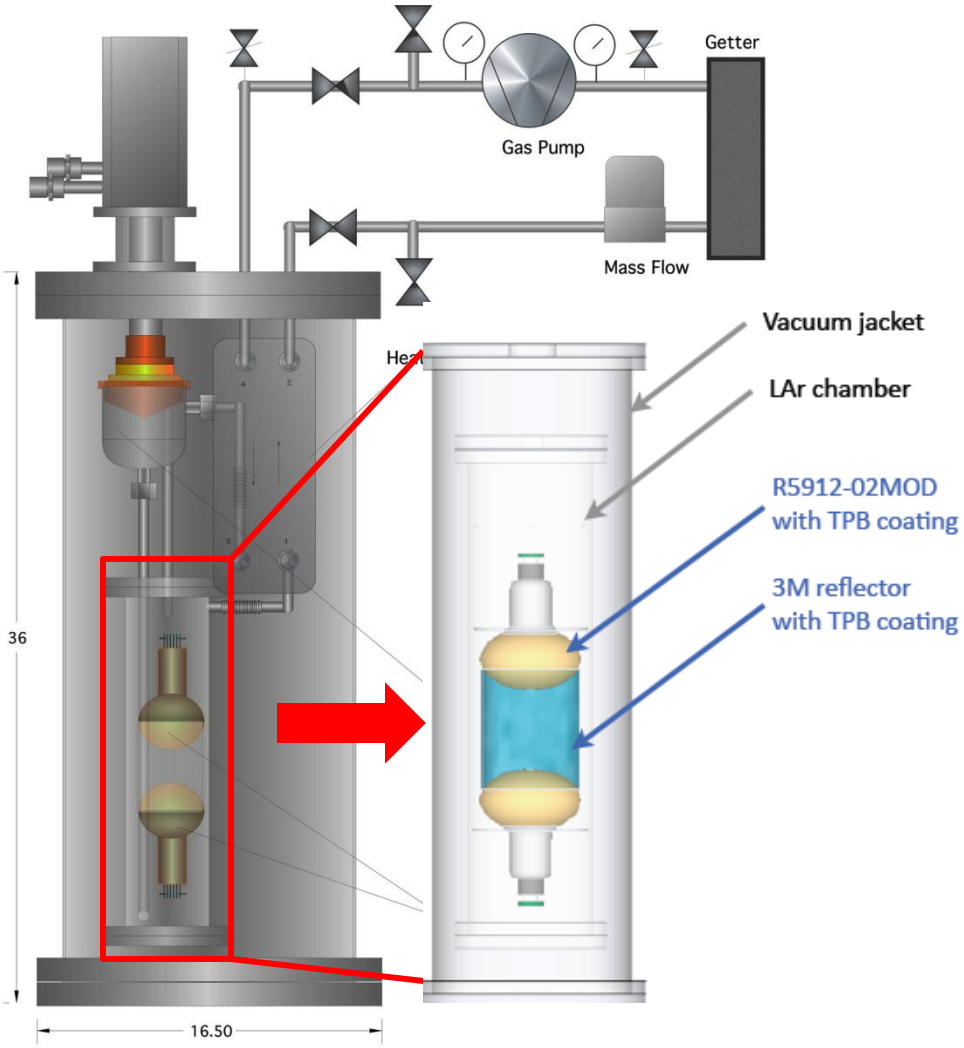
PRELIMINARY

Run 51: ~25 microsec livetime

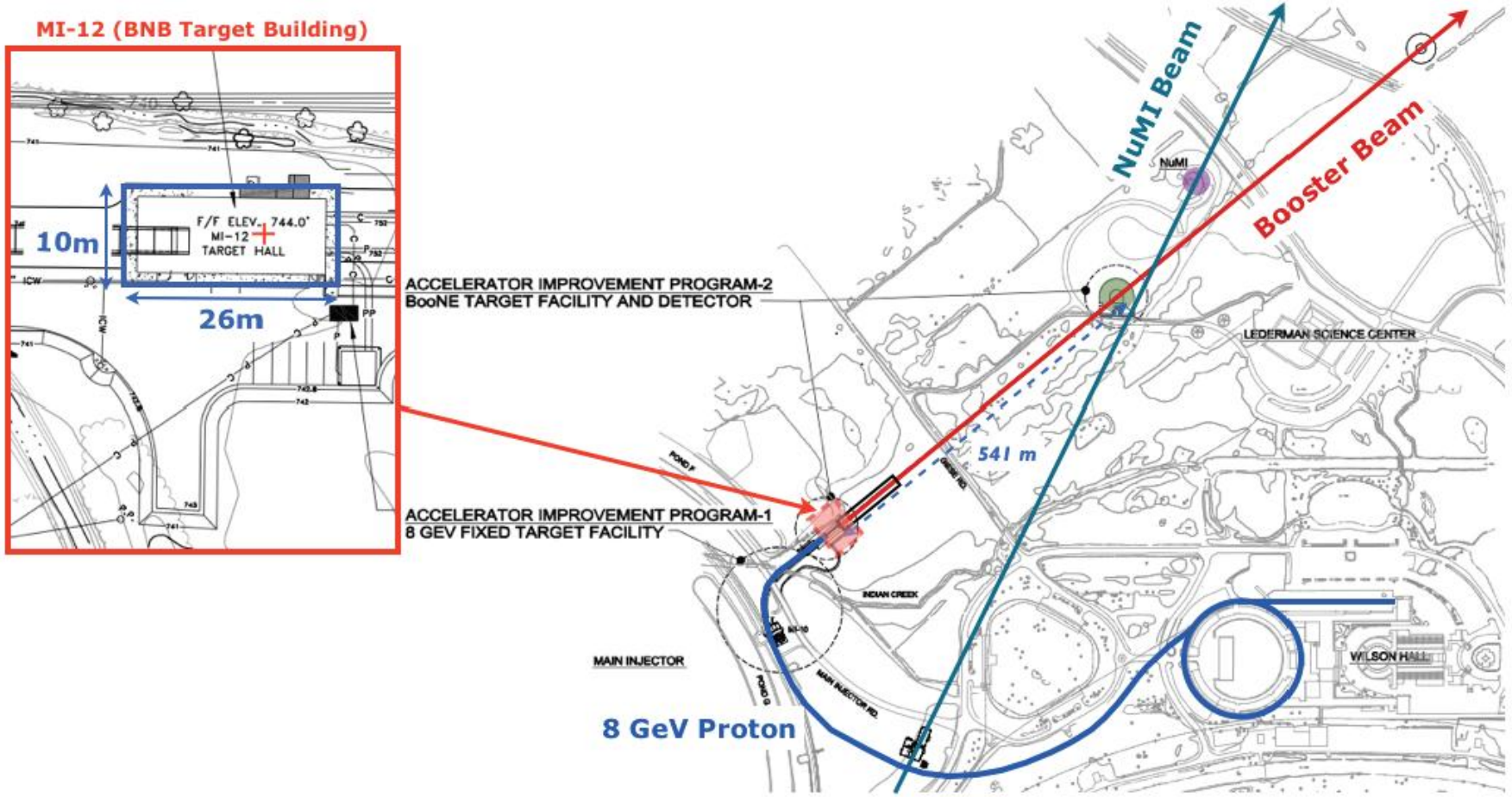


10 kg NCvAS Prototype

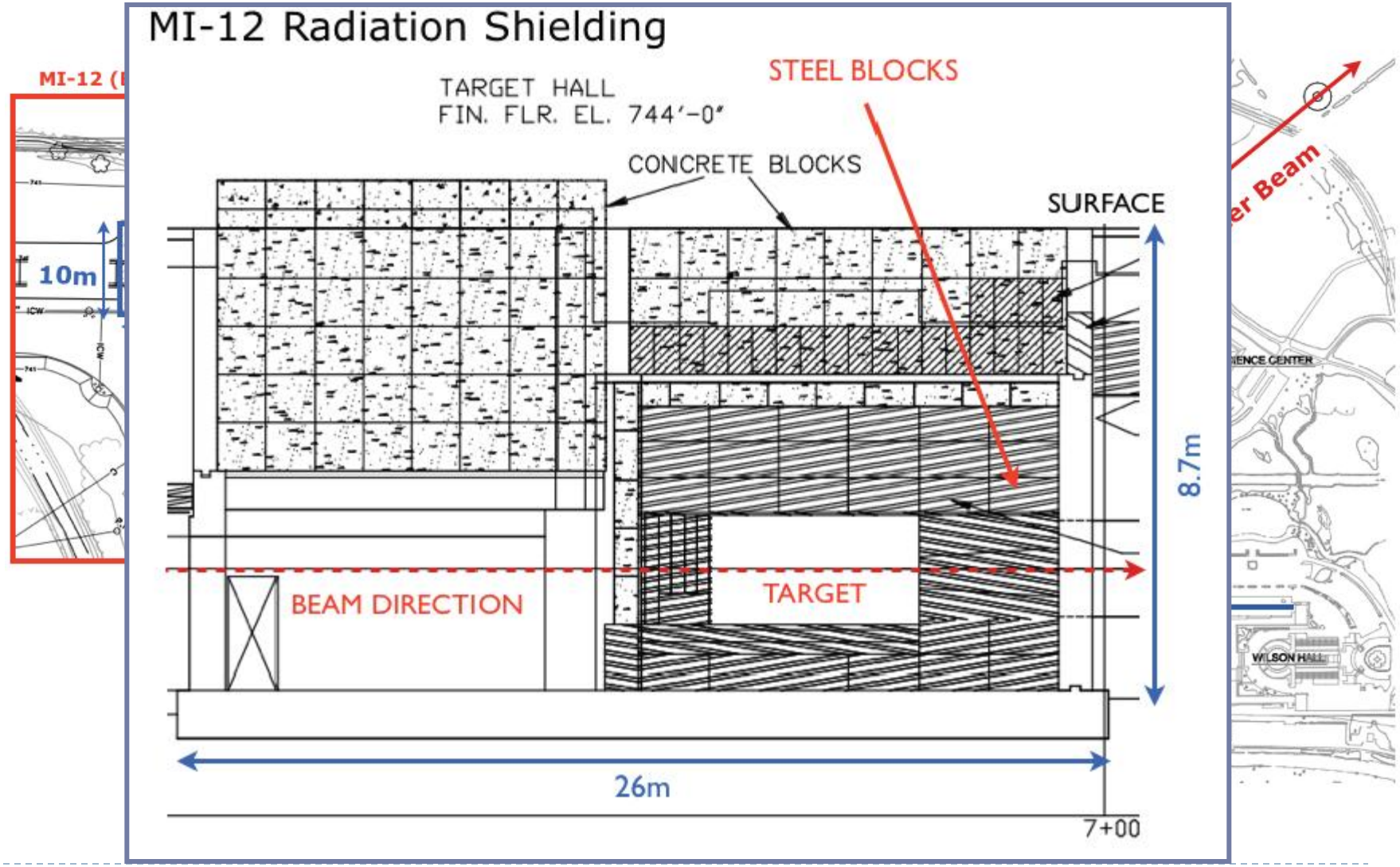
- SCENE cryostat has spare capacity – reuse or duplicate
- Replace inner detector with 10 kg single-phase
- View scintillation with 2 R5912-02MOD 8" PMTs
- 2 Goals:
  - Demonstrate capabilities
  - Evaluate backgrounds



Target Location



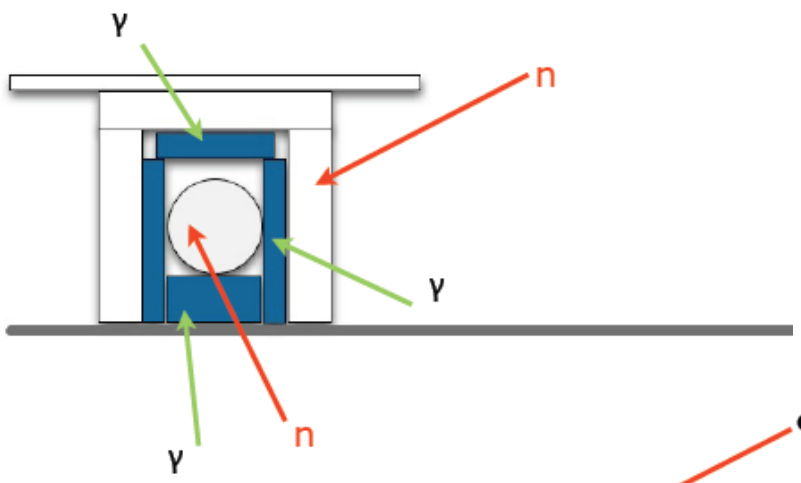
Target Location

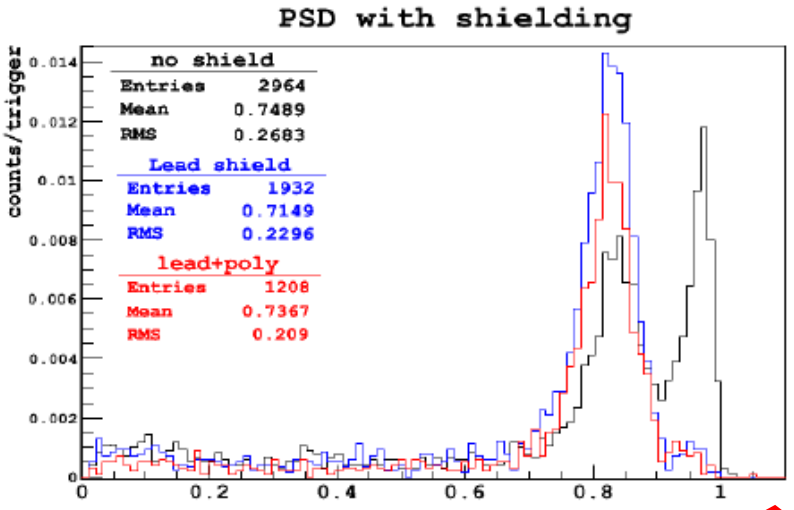


Background measurement at MI-12

- Lots of shielding around target: 2.6m iron +2.5m concrete
- Attempted to measure beam-induced backgrounds with 5" EJ301 scintillator cell

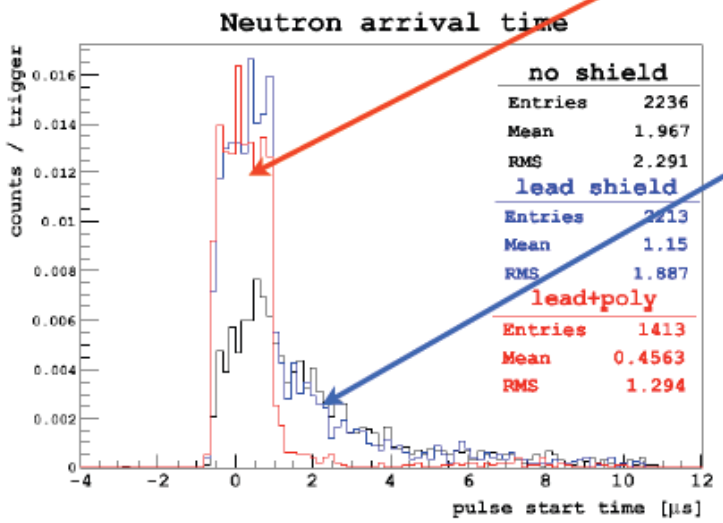
More beam-coincident background than expected…





PRELIMINARY

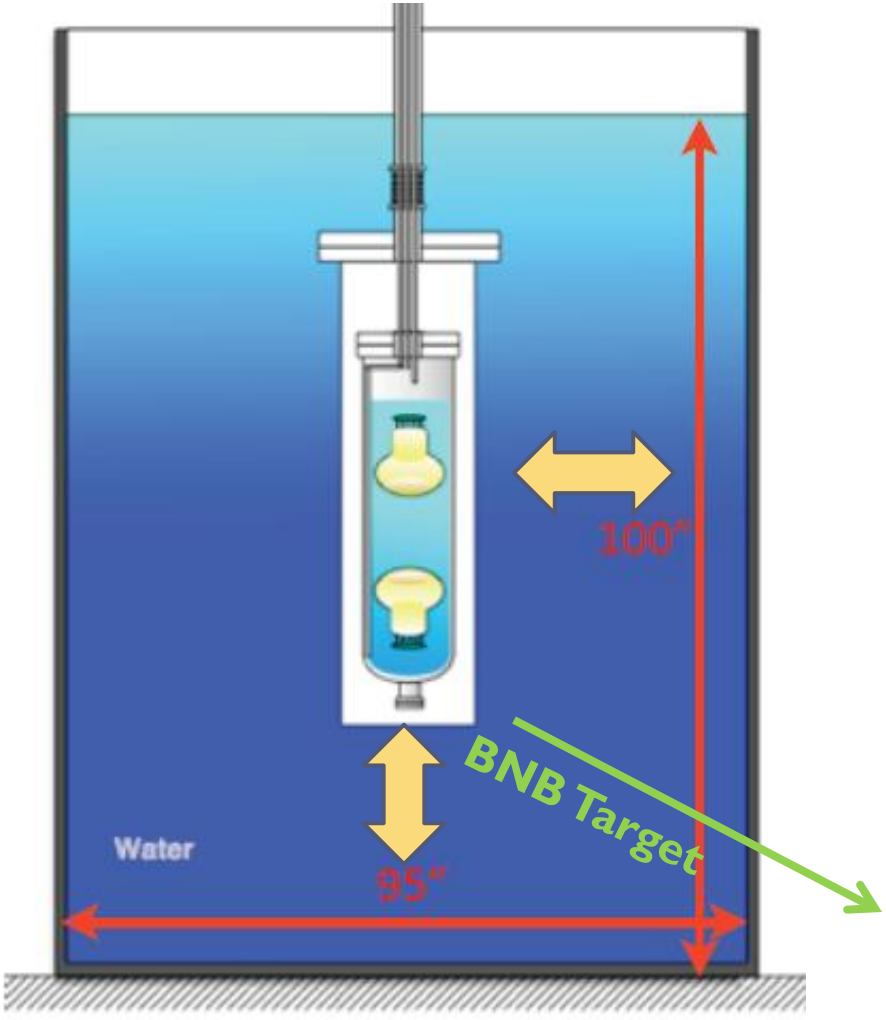
- Neutrons from the bottom or reflected in the lead cell
  - within beam time



- Bounce off neutrons in the building:
  - delayed in time
  - reduced by the poly shielding

10 kg Shielding

- Repurpose COUPP water tank (~2.5 m)
- Surround with lead and/or poly if need be
- A fun possibility: make the cryostat movable to see how background varies with shielding

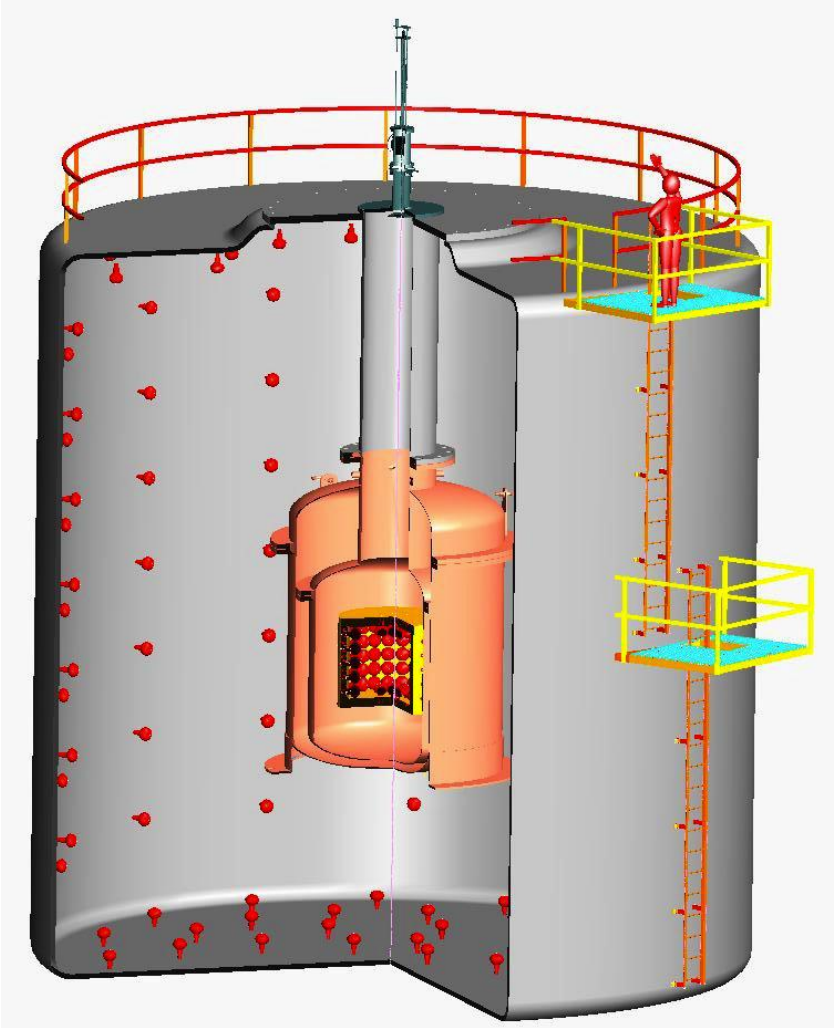


Rough Schedule Highlights

- 2012-08: Inner chamber design ready
- 2012-11: Inner chamber delivery, construct detector/PMT mounts
- 2013-01: Cryocooler power tests
- 2013-04: Finish detector calibrations
- 2013-05: Beam back on! Test runs
- 2013-07: Full data-taking mode

Ultimate goal: 1 Ton LAr NCvAS Detector

- Single-phase LAr active volume, viewed by ~100 PMTs in 4pi
- Water tank size determined by 10 kg studies
- If cosmogenic backgrounds are significant, can be instrumented as muon veto
- Expect O(100) NCvAS events /year



Extra slides

DarkSide-50

- First data-taking early 2012
- Radon-suppressed clean room
- 50 kg underground argon (~33 kg fiducial)
- 4m boron liquid scintillator neutron veto
- 11m water-cherenkov muon veto/shield