Status of LBNE LAr and LAr1 at FNAL

Bruce Baller - Fermilab

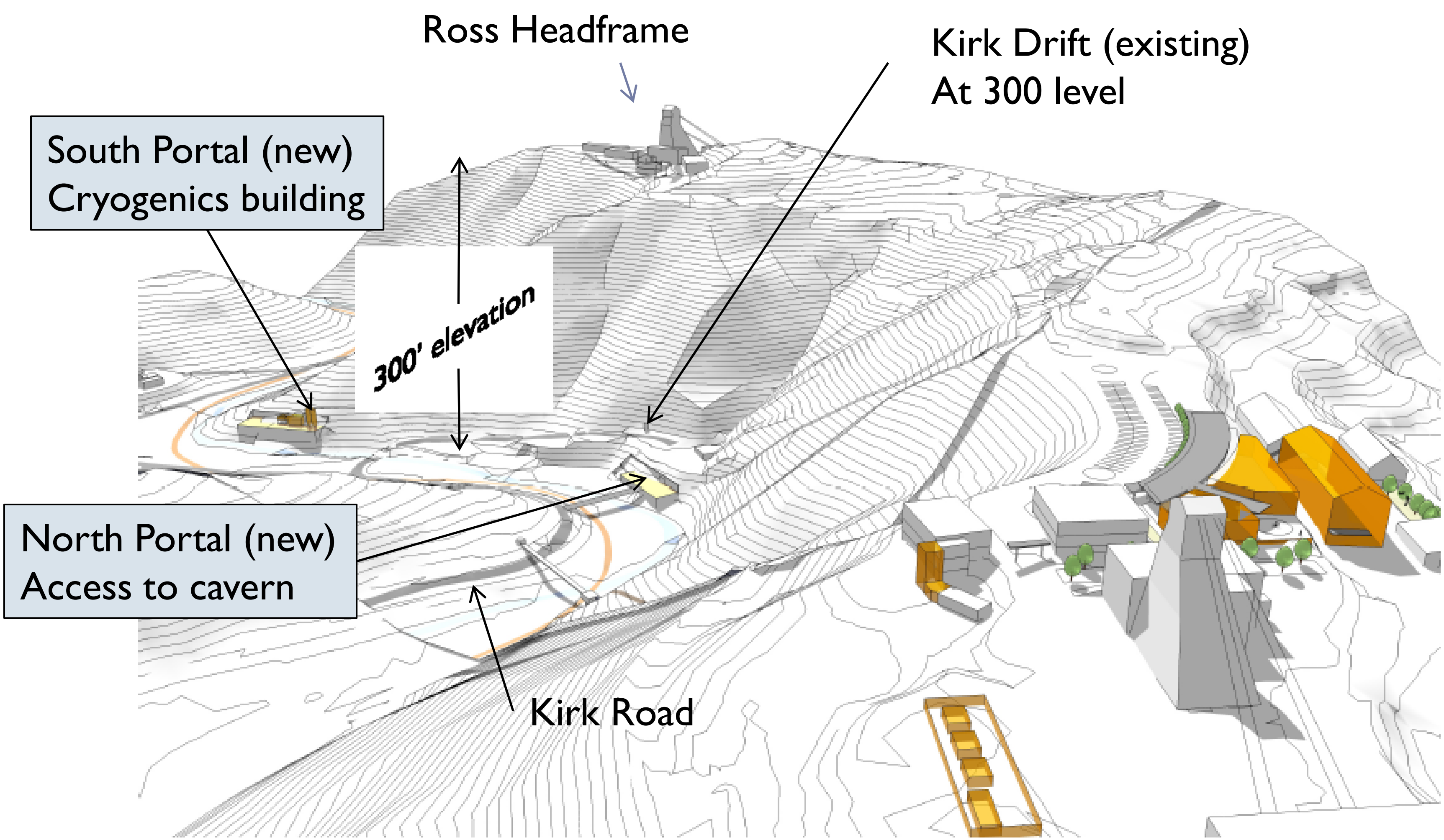
Outline

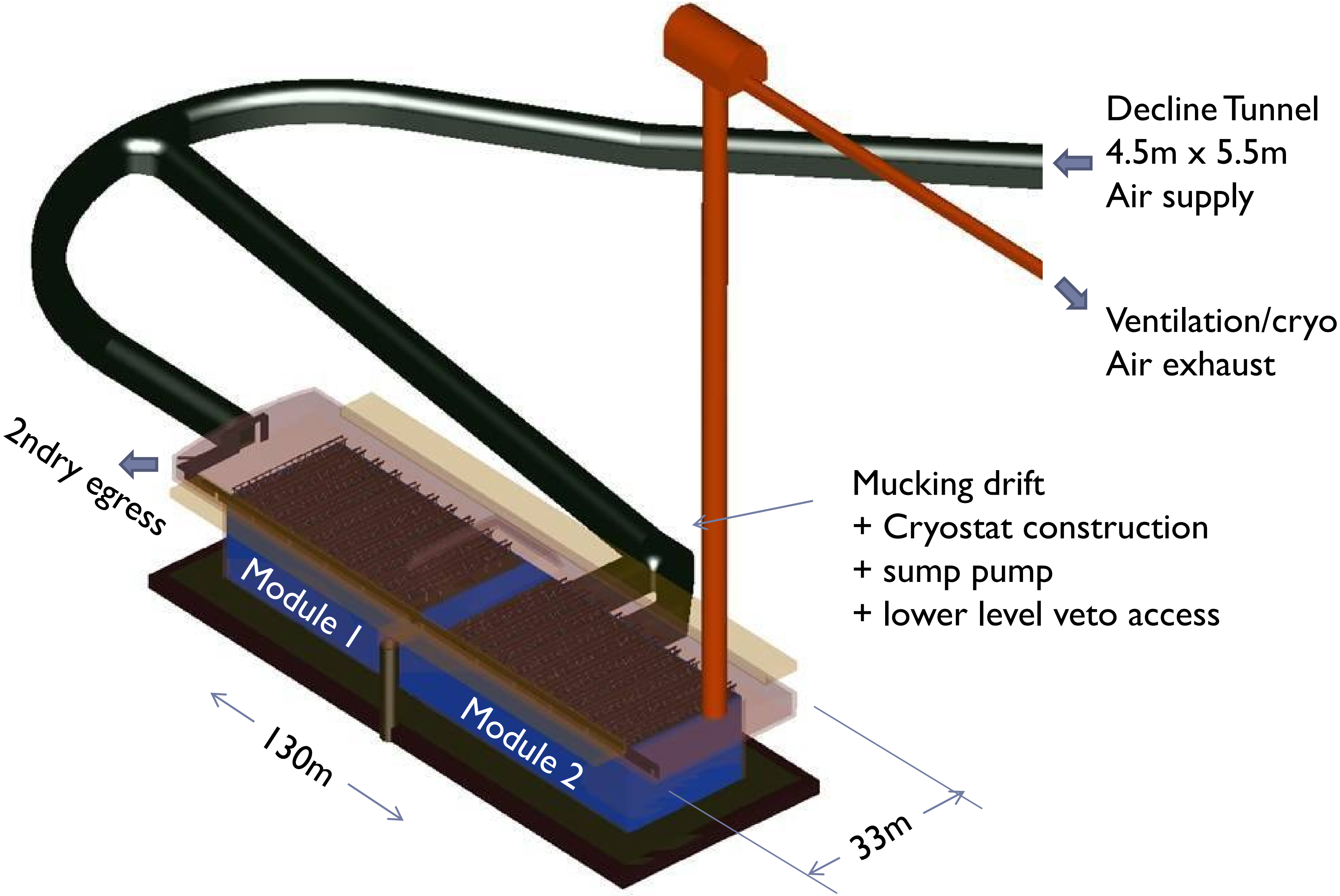
- LBNE LAr detector (LAr40) overview
  - Facility tour
  - Detector configuration
  - Membrane cryostat
  - Cost scaling
- Issues and Prototypes
- LAr1 – Engineering Prototype conception

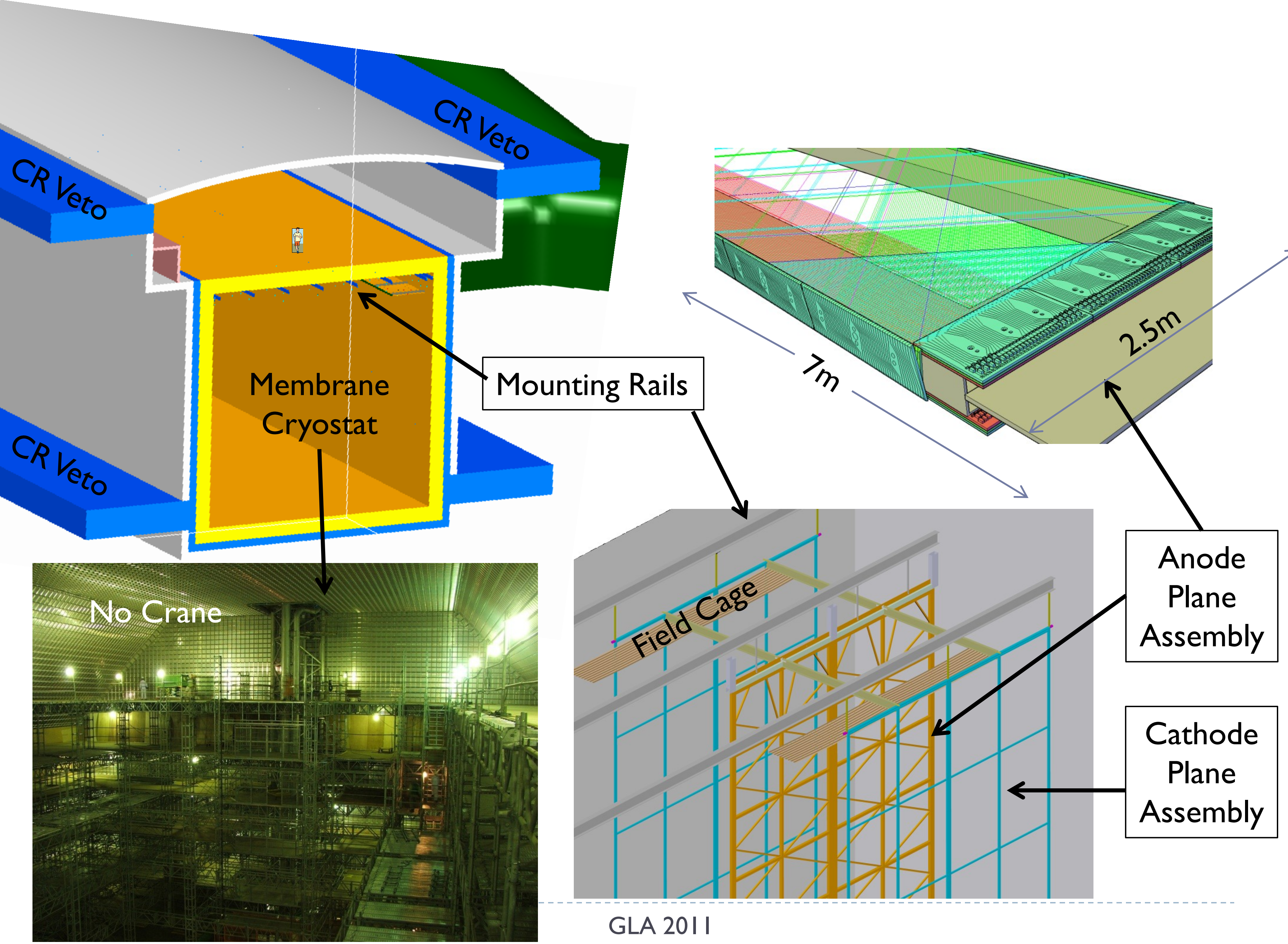
SITE PLAN


Access
Ramp
Access Portal
Utility Shaft Access Portal,
Cryogenics Building
Cavern
Existing 800 Level
Existing 300 Level
Ross Shaft

Facility Overview



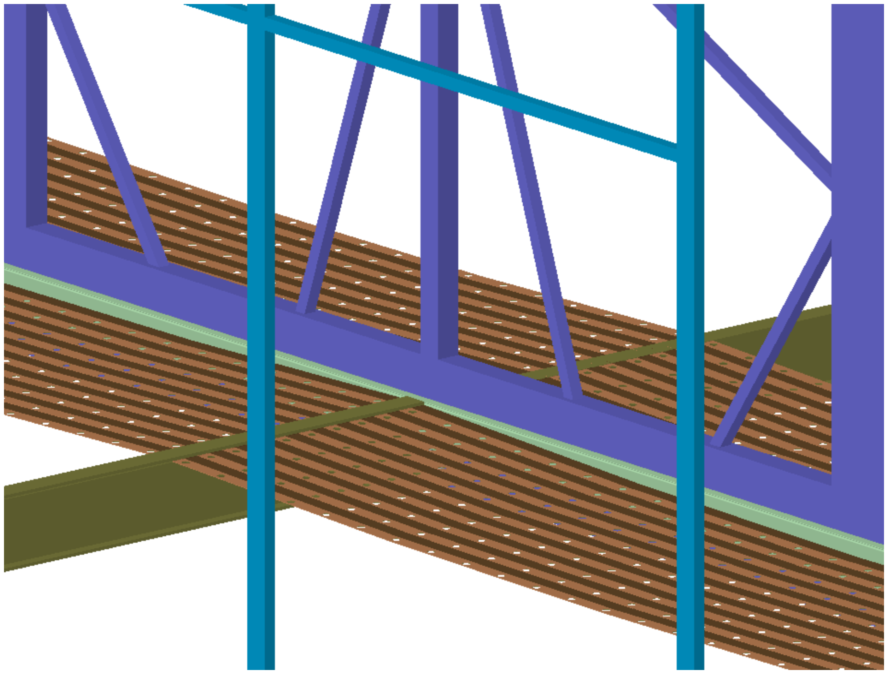

Decline Tunnel
4.5m x 5.5m
Air supply
Ventilation/cryo
Air exhaust
Mucking drift
+ Cryostat construction
+ sump pump
+ lower level veto access
2ndry egress
Module 1
Module 2
130m
33m


CR Veto
CR Veto
CR Veto
Membrane Cryostat
Mounting Rails
No Crane
7m
2.5m
Field Cage
Anode Plane Assembly
Cathode Plane Assembly

Reference Design - Key Parameters

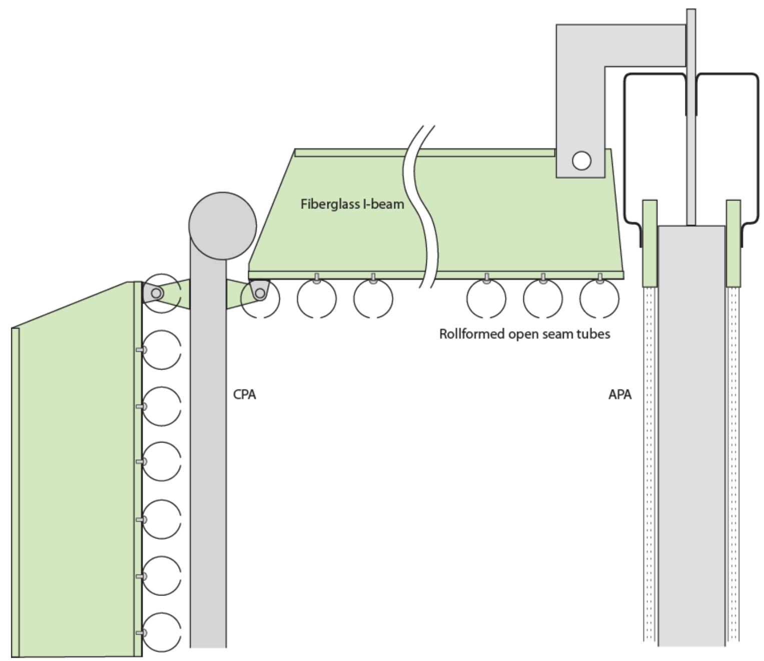
- Detector module configuration
  - 2 high x 3 wide x 18 long = 108 Anode Plane Assemblies (APA)
    - 5mm wire spacing
    - Four wire planes: Grid, Induction 1, Induction 2, Collection
    - 3 readout channels/APA
      - 2462 readout wires x 4x redundancy / 3840 MUX
    - 3.67m drift
  - 16.4 kt fiducial mass, 19.4 kt active mass, 25 kt total mass
  - Cooling required – 40 kW nominal, 57 kW max
- Two detector modules in one cavern – 32.9 kton ~ 200 kton Water Cherenkov detector equivalent

Field Cage Concepts

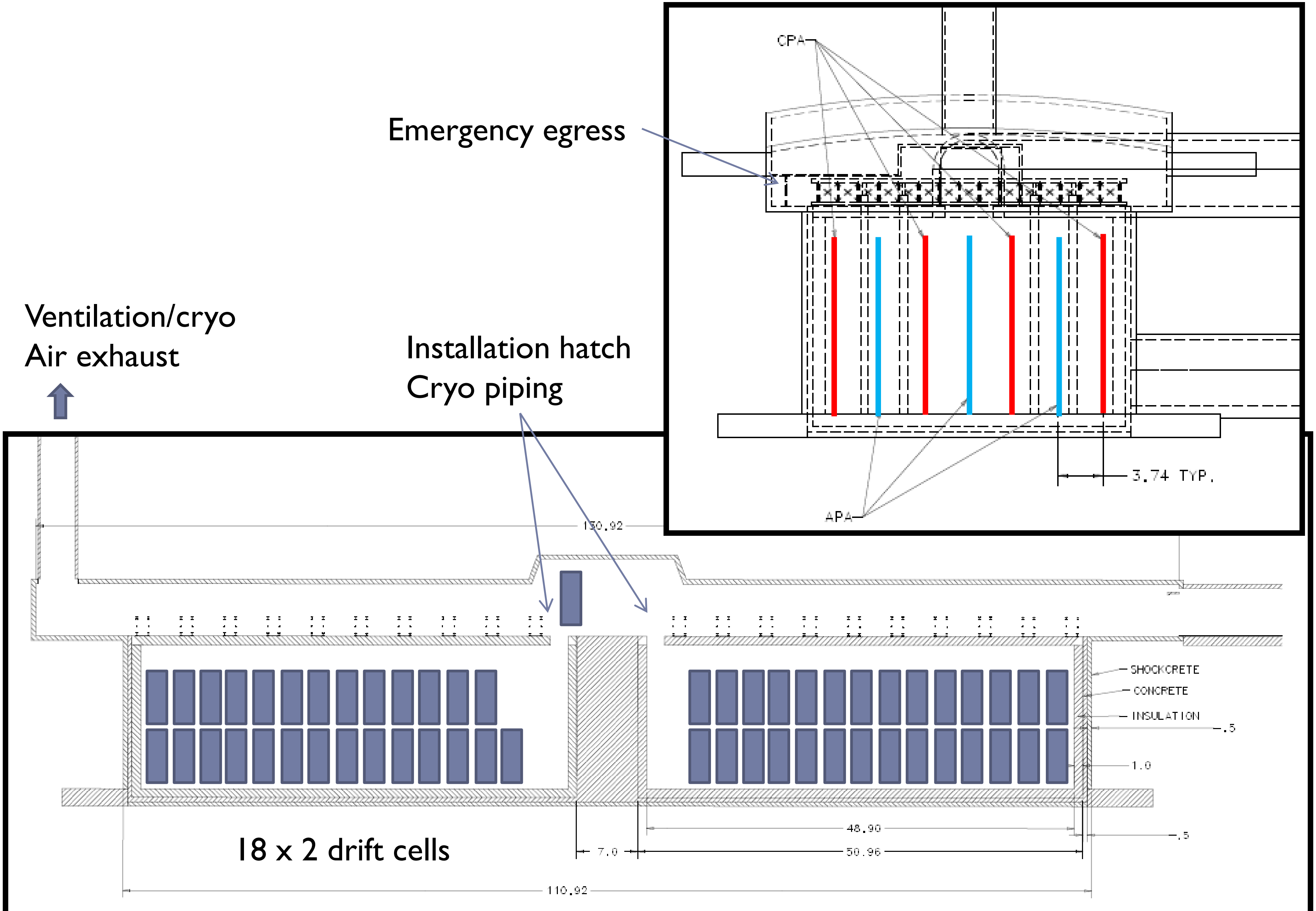


Field cage panels (2.5mx3.67m) pre-assembled on to the CPA

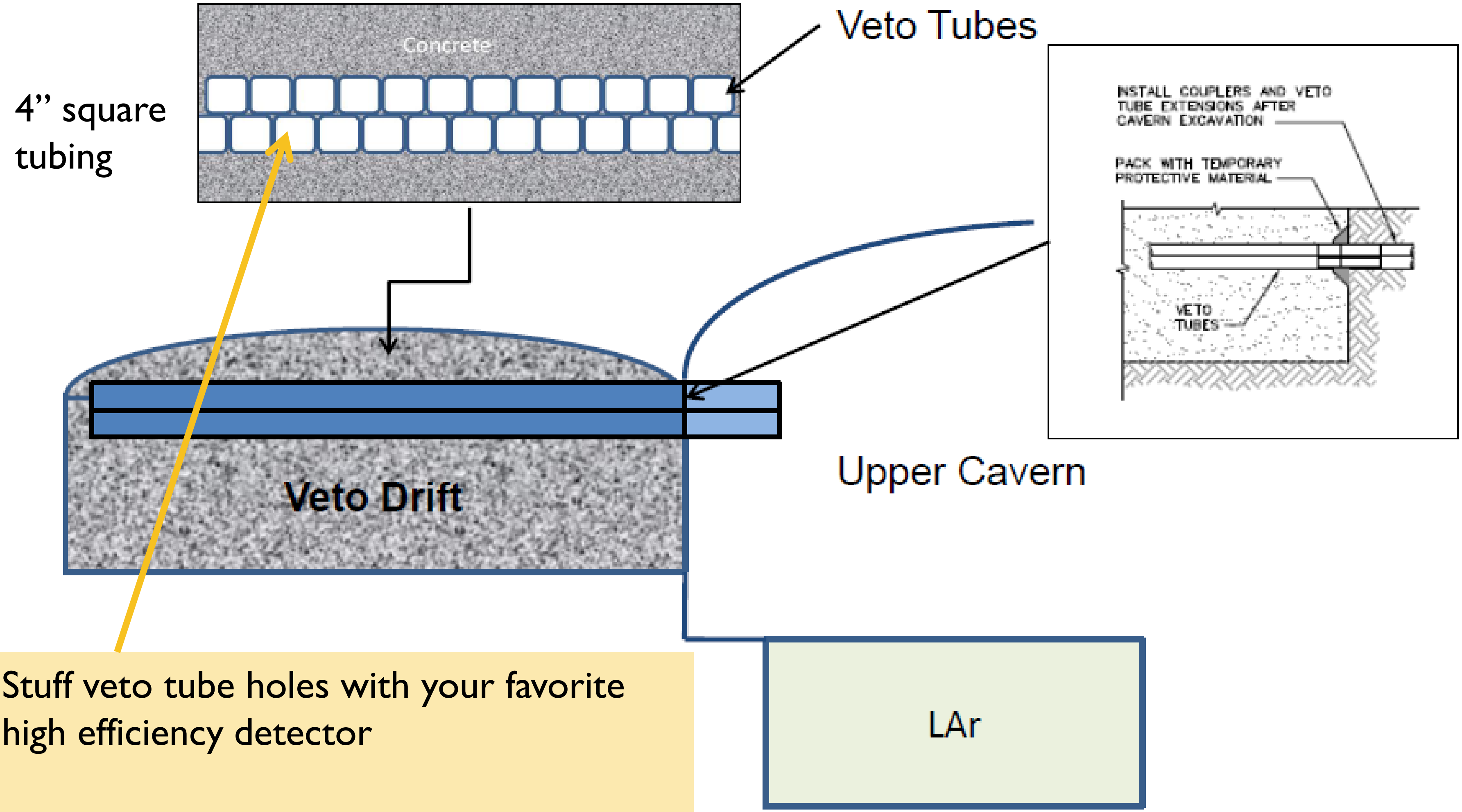
Each panel has its own resistor divider



- Light weight, flexible printed circuit material (30,000 sqft.)
- Supported by pultruded fiberglass beams between APA and CPA
- Perforated to allow LAr convection flow


Emergency egress
CPA
APA
3.74 TYP.
Ventilation/cryo
Air exhaust
Installation hatch
Cryo piping
130.92
SHOCKCRETE
CONCRETE
INSULATION
.5
1.0
48.90
7.0
50.96
.5
18 x 2 drift cells
110.92

Cosmic Ray Veto Tube Arrangement



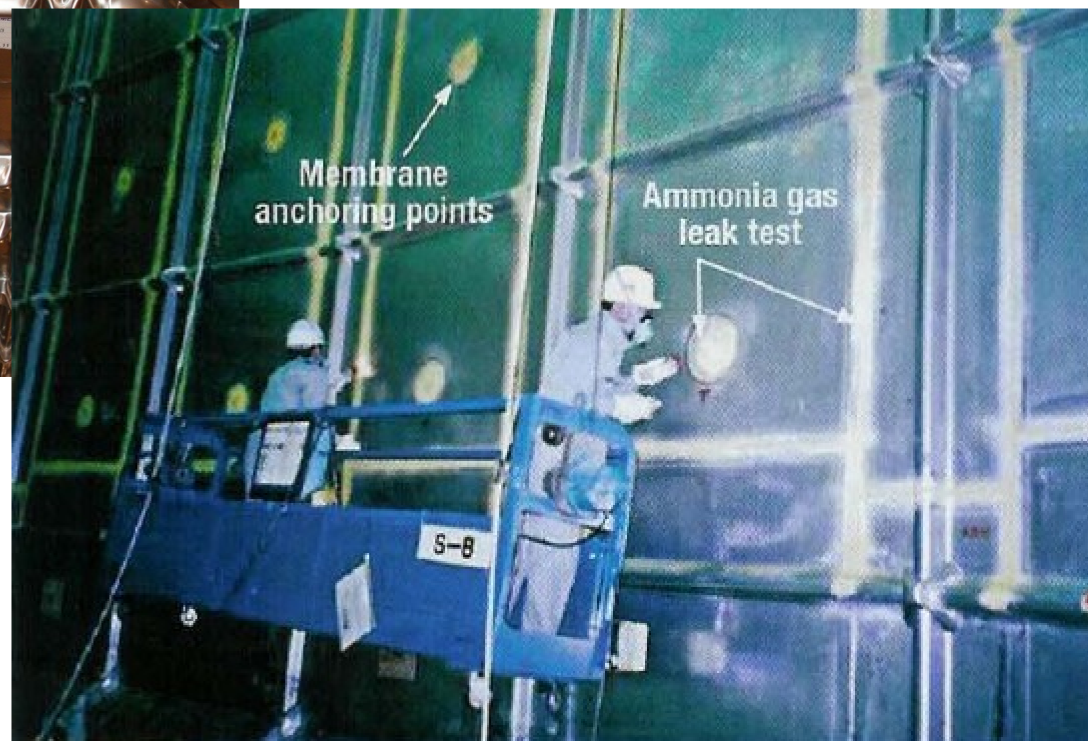
Stuff veto tube holes with your favorite high efficiency detector

Example: loop of WLS fiber inside a flexible light reflective bag containing liquid scintillator

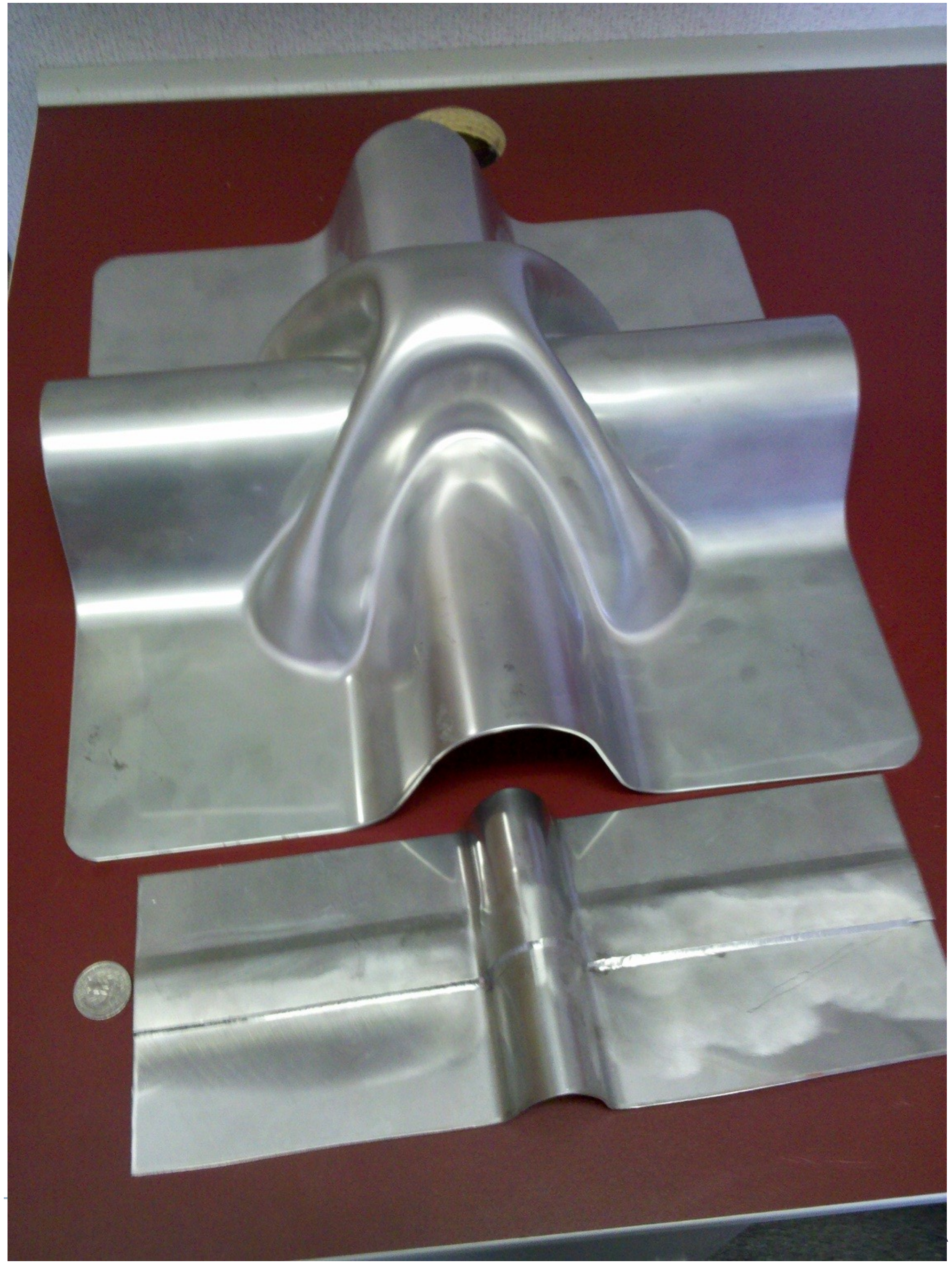
JACOBS ASSOCIATES
Engineers/Consultants

Cryostat

GTT membrane roof penetrations



IHI membrane leak checking



Ishikawajima-Harima
Heavy Industries (IHI)
3m x 8m panels
2mm 304 SS

Gas Transport & Technigaz
(GTT)
1m x 3m panels
1.2mm 304 SS

Membrane Cryostat

Benefits

- Full containment system
- Long record in LNG industry in more severe service
- ~standard industrial design
- "Cryostat in a kit" construction model
- High fiducial mass fraction

Concerns

- Long weld length on thin sheets
- Rock interactions
  - Freezing
    - Heat the concrete liner
  - Elastic rebound
    - mm - cm movements possible in first few months after excavation
  - Creep
    - Not suitable for use in rock with large creep

Detector Module Cooling Requirement

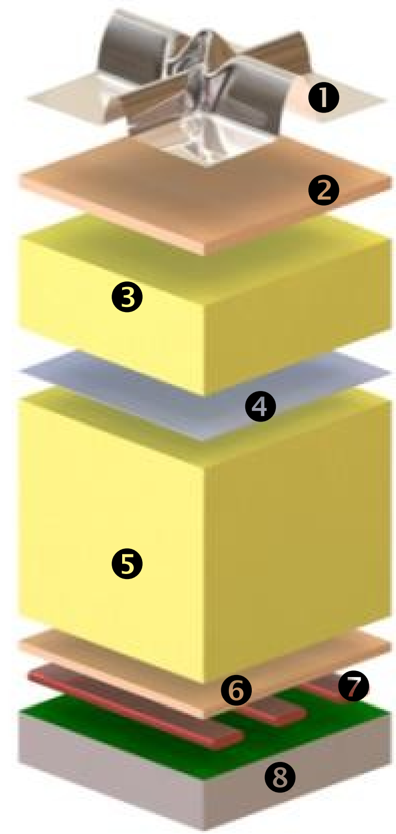
- Total ~ 40 kW
  - Insulation - 28 kW
    - 1m foam - 5.4 kW/m2
  - LAr Pumps - n x 6 kW
  - Electronics – 5 kW
    - Front end – 10 mW/chan
    - Digital – 5 mW/chan
- LN refrigerators designed for 60 kW cooling
  - Heat output 140 kW
- LAr40 = 2 detector modules

Detector volume
Purge, vacuum, LAr

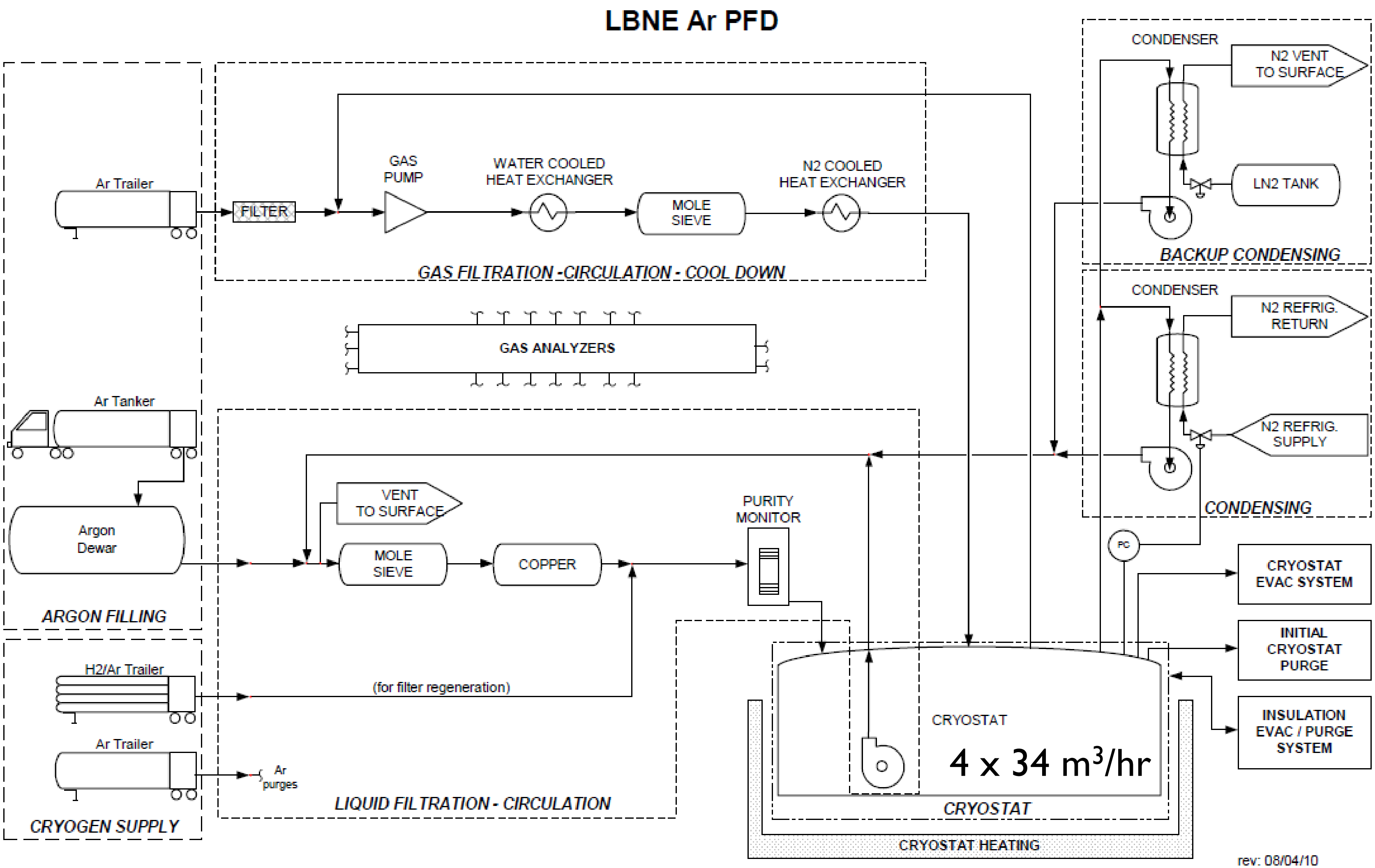
Insulation space #1
Purge, test gas, vacuum

Insulation space #2
Purge, test gas, vacuum

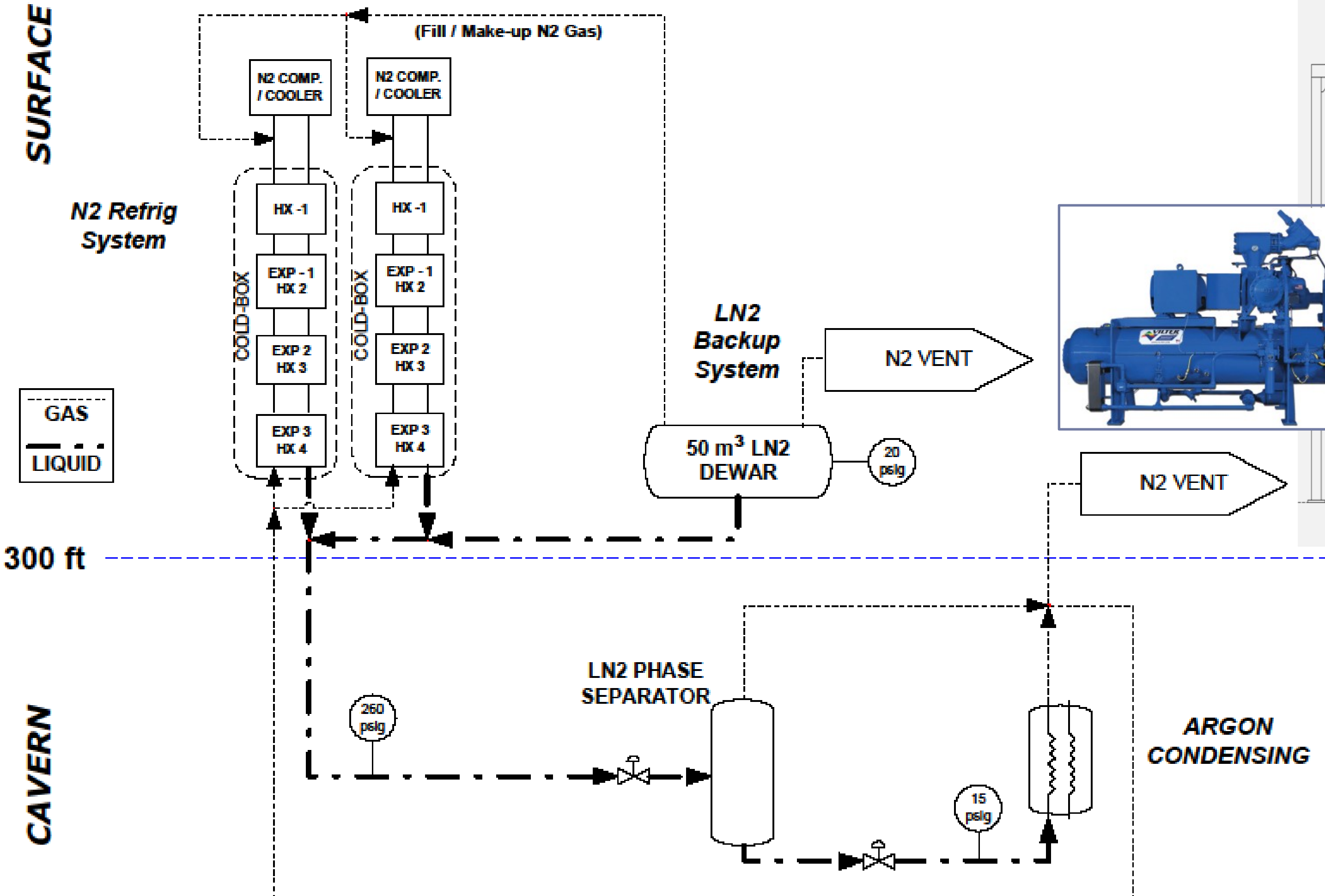
Concrete bathtub
Ufer ground, heating

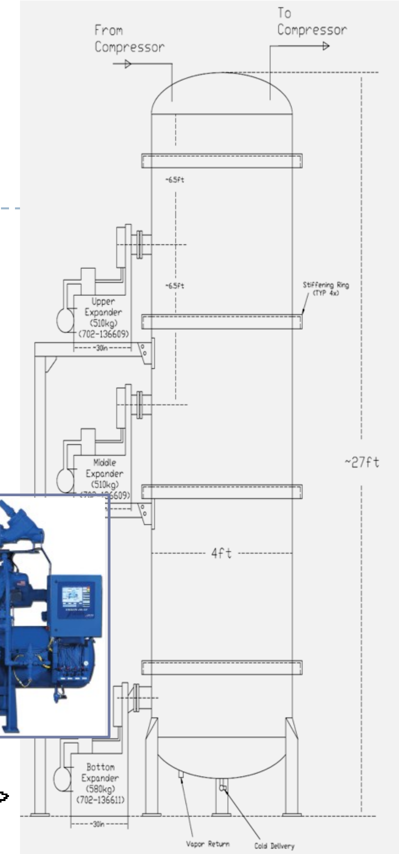


LAr Process Piping



LN Refrigeration System
2 operating + 1 spare



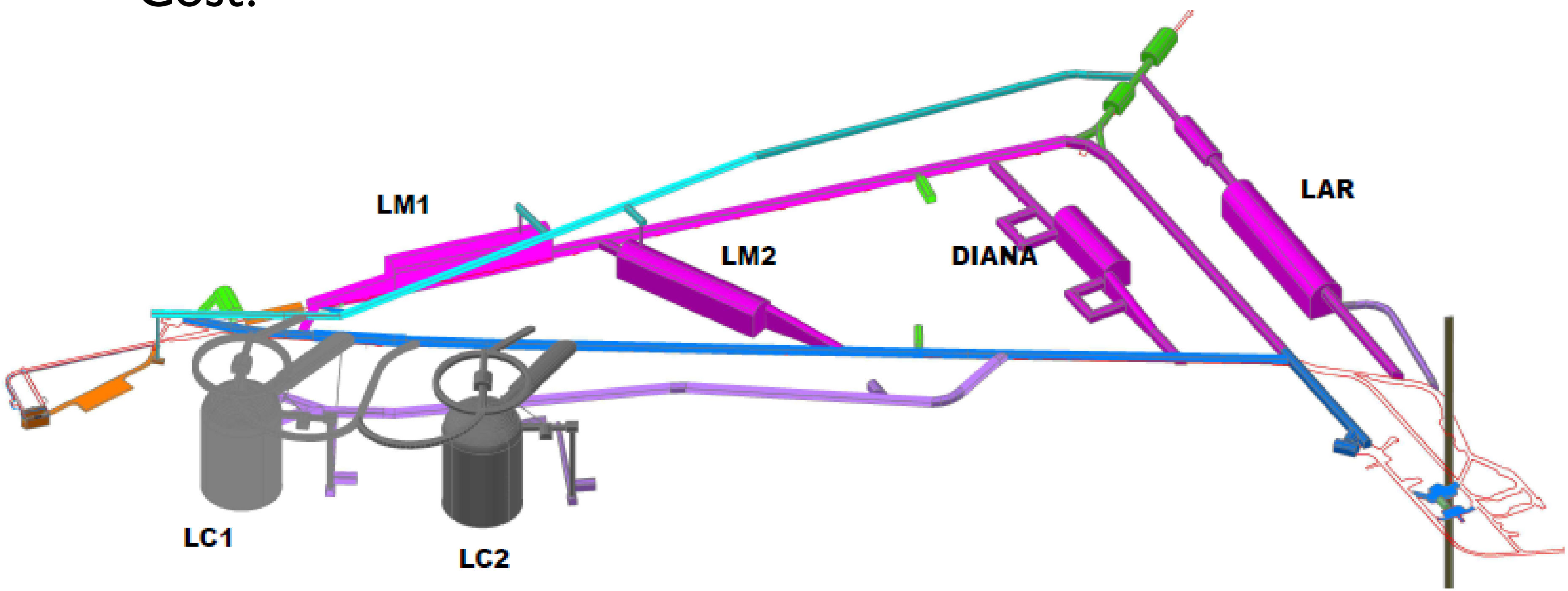


Detector and Associated Conventional Facilities Cost Scaling

- All $'s are Total Project Cost including direct cost, indirect cost, 40% contingency, 20% escalation
- Split into
  - Fixed cost (design, tooling, project management prototypes, etc)
  - Incremental cost that scales with the appropriate design parameter (e.g. volume of rock/LAr, surface area of cryostat pit, length of the cavern, number of readout channels)
- Wire spacing
  - Construction cost: $7.1M (Electronics, cabling, F/T) + $2.8M (wire winding labor) → $15.30/channel
- Anode Plane Assembly - $118k (5mm wire spacing)
- Cryostat - $9.3k/m^2
- Two detectors in one cavern
  - Excavate one long pit for two detectors + 5m concrete septum
    - $598/m^3 for pit excavation & shotcrete
    - $500/m^3 for highbay excavation only
    - $700/m^2 for highbay roof support & shotcrete

LAr40 at 4850 Level

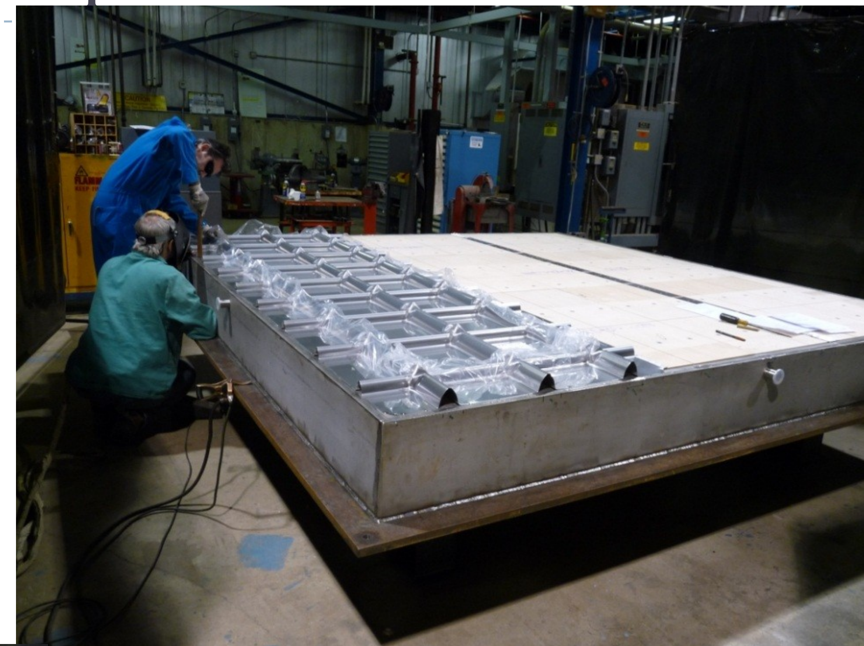
Concept utilizing existing access and ventilation shafts
Cost?

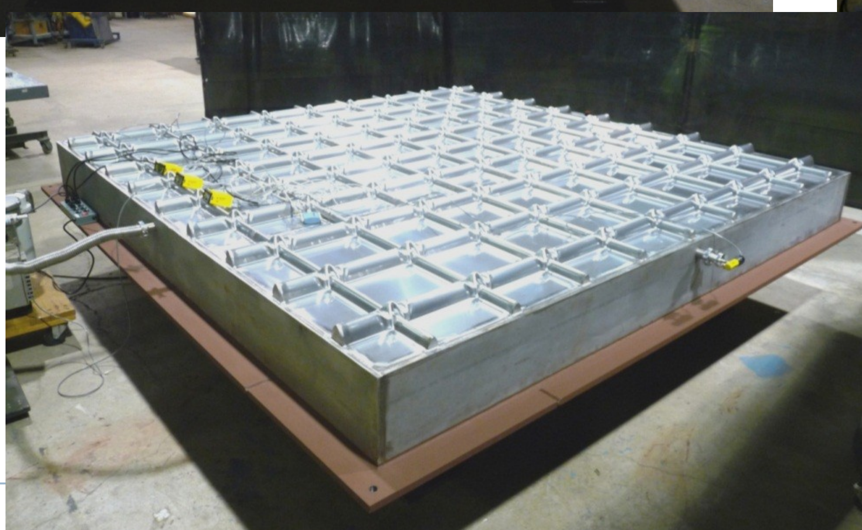


Issues & Prototyping Plan

- Achieving argon purity without vacuum pumping
  - Liquid Argon Purity Demonstrator (LAPD)
- Achieving argon purity in a membrane cryostat
  - 3m x 3m wall panel
    - Could one evacuate a membrane cryostat if it is found necessary?
    - Testing completed - yes
  - LAPD → 33 ton prototype (purity monitors)
    - Reviewing proposals for cryostat design and material procurement
      - Selected IHI
    - Construct in summer 2012
- Engineering and integration prototype – LAr1
  - Organized as a sub-project (Project Manager, Deputy, schedule, etc)
  - Internal cost and schedule review in July

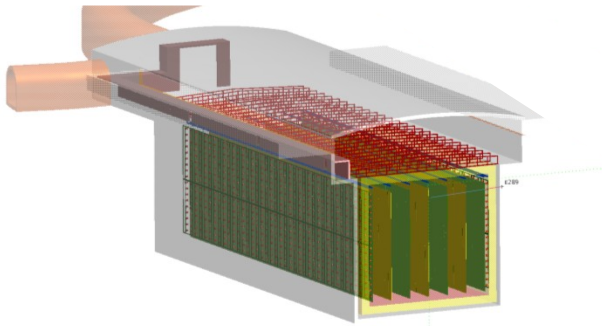
3m x 3m Wall Mock-up



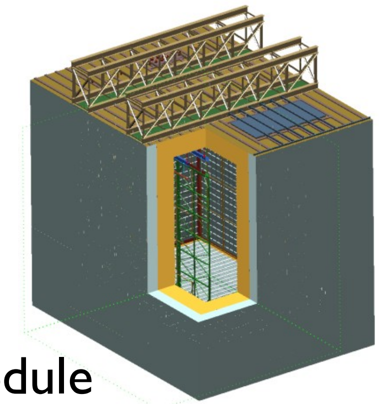


- A helium leak detector is connected to the insulation space. After 10 days of evacuation, the pressure was 0.60 Torr. Wall section was bagged and helium sprayed inside to give a global leak test for the membrane. There was no response to helium. Picture taken March 23, 2011
- Vacuum pumping of membrane cryostat is feasible

LAr1 Liquid Argon Engineering Prototype Objectives



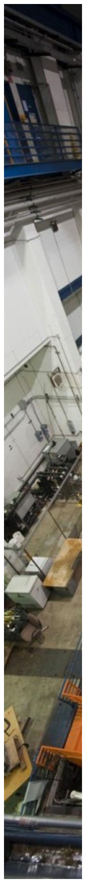
The Engineering Prototype includes the major features of the LAr40 detector

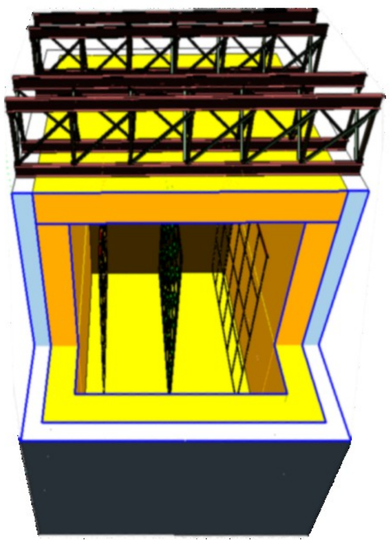


- Establish a credible basis for scaling to a 20 kton LAr TPC module
- Test the membrane cryostat design for high purity liquid argon service

  (Surface area ratio 1:11 , Argon mass ratio 1:30 with the 20 kton cryostat, same gas ullage height)
- Test the mechanical structure of the APA including wire tension stability
- Test argon purity and drift length
- Test full readout chain including cold electronics
- Test Integration features such as
  - TPC supports and installation
  - Signal/power feedthough, HV system/feedthrough/connection
  - Grounding scheme and common mode noise control
- Gain practical knowledge in membrane cryostat construction methods
- More complete list contained in LAr1 proposal by Russ Rucinski docdb #3452

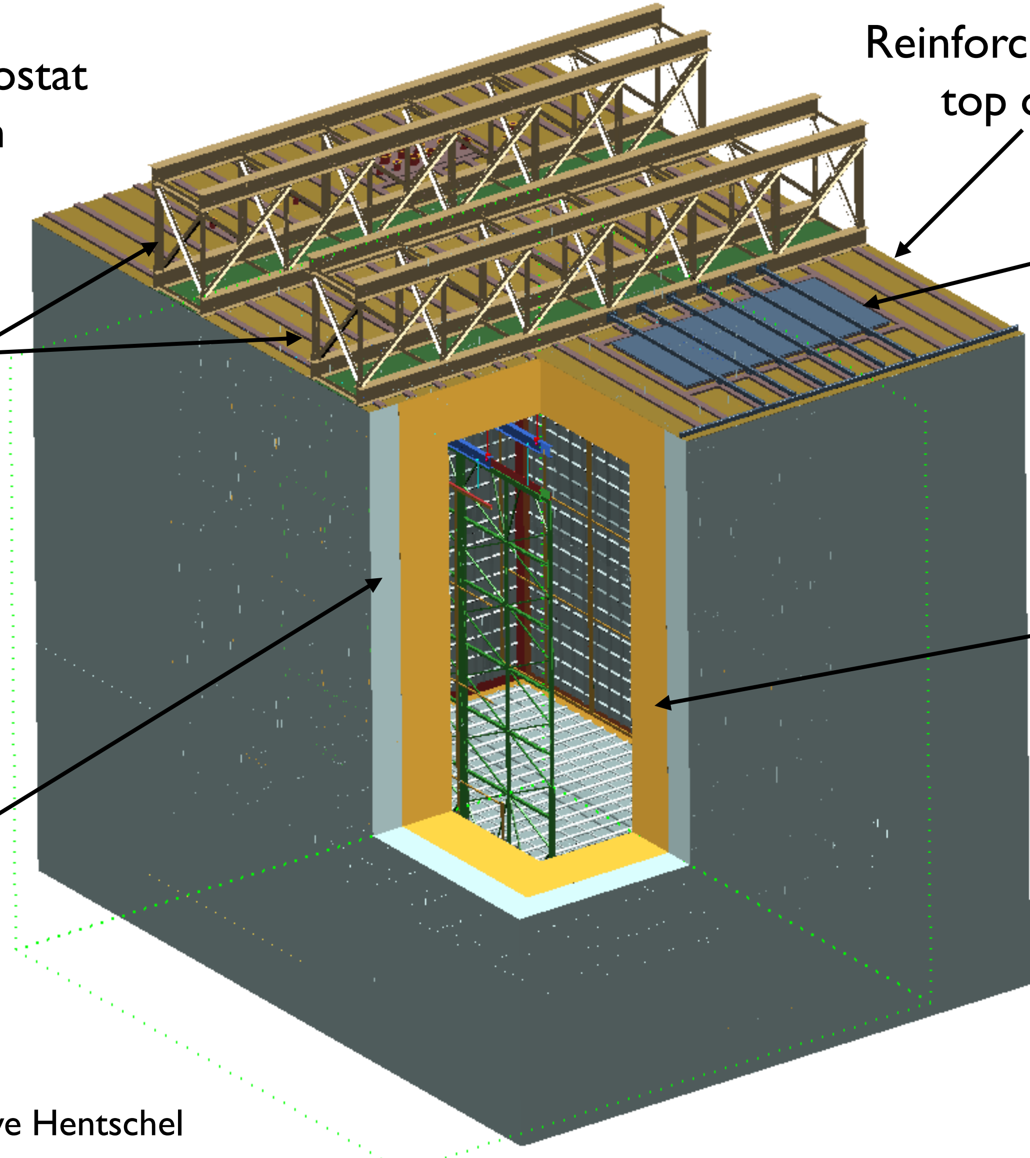
Major Schedule and Cost Savings from Reusing Established [illegible]erating Infrastructure at DZero





- No new building
- Cryostat concrete enclosure and steel roof construction is not affected by weather
- Existing liquid argon and nitrogen cryogenic systems for D0 Calorimeter
- Oxygen Deficiency Hazard (ODH) safety systems with argon spill management
- 50 ton and 10 ton building cranes
- Machining and welding shops
- FIRUS, High Sensitivity Smoke Detection (HSSD), Fire safety systems
- Emergency backup power diesel generator

LAr1 Cryostat Enclosure



Guard rails on cryostat top not shown

Trusses at same 5 m ctr-ctr spacing as LAr40 provide same cable/rack arrangement as a zone of LAr40

Reinforced concrete for bottom and sides of outer shell

Reinforced steel plate for top of outer shell

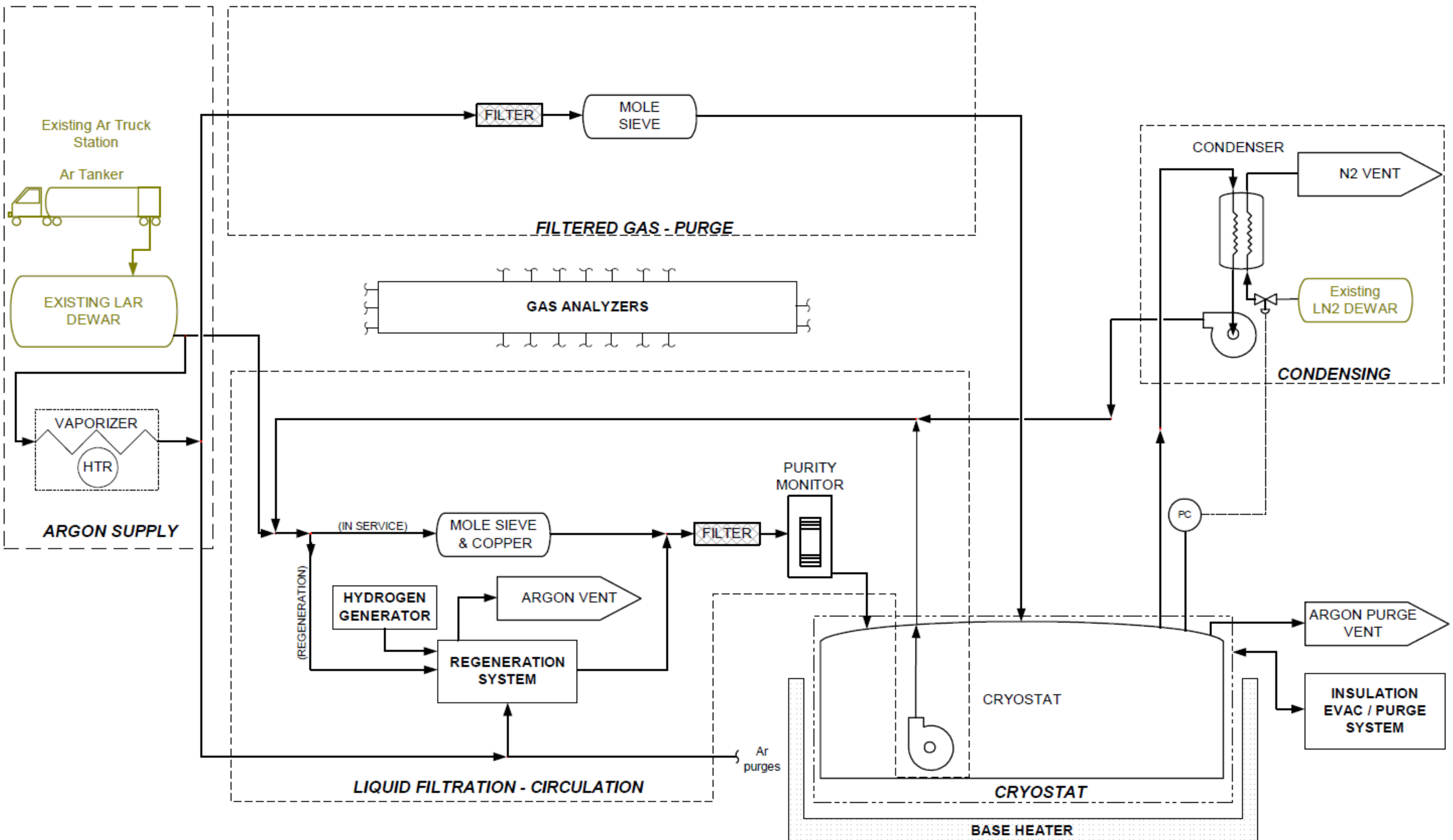
Access hatch braced with beams

1m thick foam insulation

Total mass = 1.1 kt
Active = 500 ton
Fiducial = 380 ton

CAD model by Steve Hentschel

LAr1 Cryogenic System Process Flow Diagram



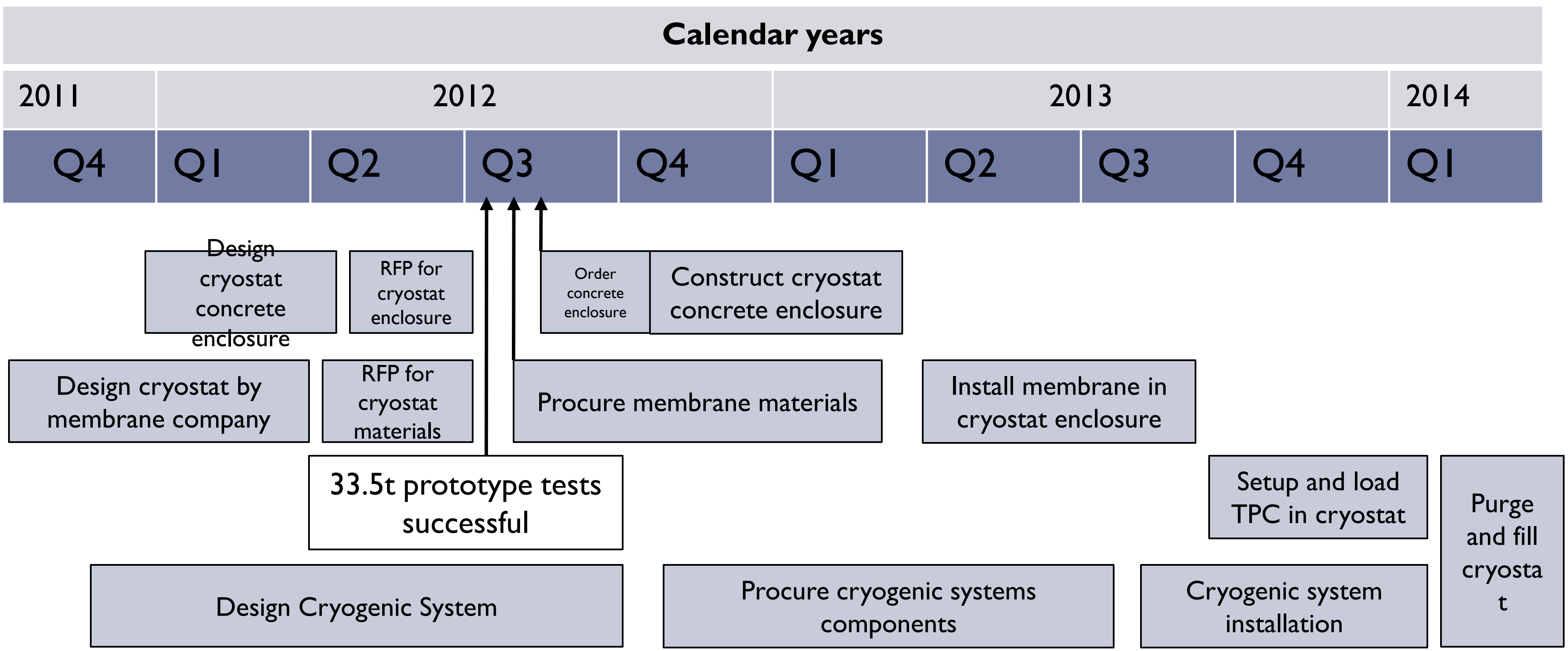
From Mark Adamowski

LAr 1 Preliminary Cost and Schedule

Labor without contingency, escalation
~ 4 M$

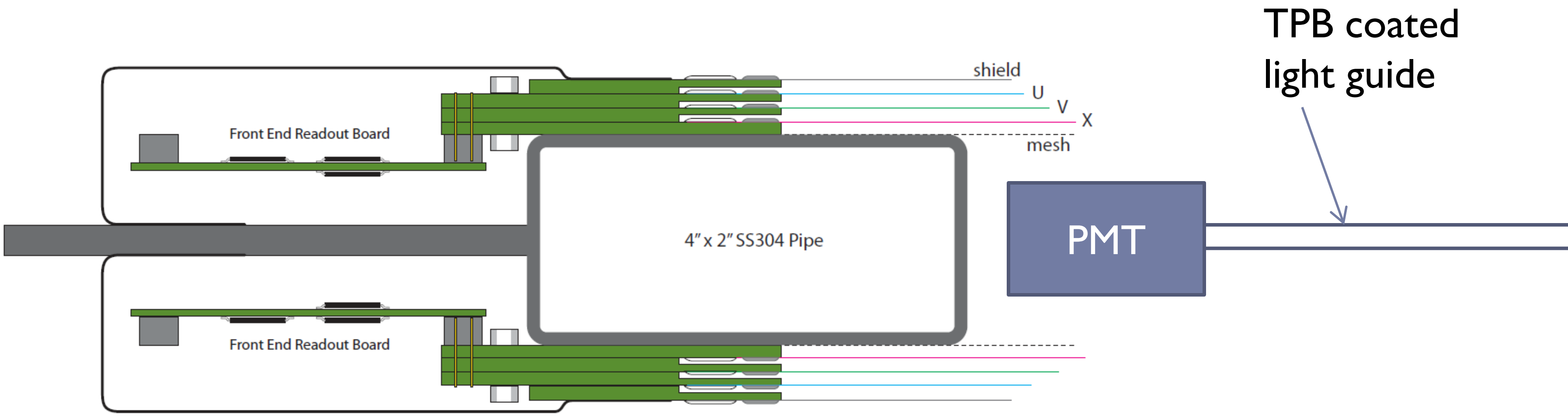
M&S without indirects, contingency, escalation
~ 10 M$

Critical Path Activities of a Technically Driven Schedule



Conclusions

- Conceptual design developed for a 34 kton LAr TPC for LBNE
  - Detector meets the scientific goals of LBNE (ref B. Svoboda talk)
  - Detector sited at shallow depth (210 m) with a cosmic ray veto system to enable proton decay physics
- Conceptual design for a LAr1 engineering prototype for LBNE
  - Different goals than LAr1 detector for short baseline physics
    - Goals are not incompatible – timescales might be
  - Prototype structured as a ~independent project



a) Cross section of the short, readout side of the APA