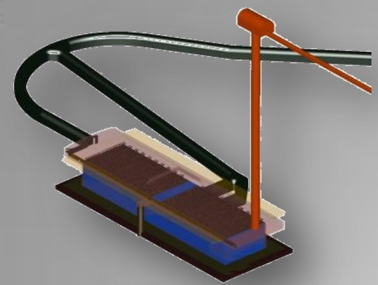
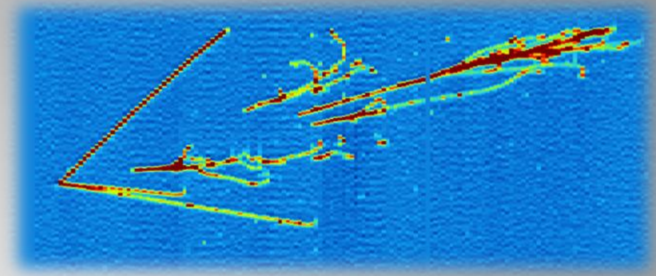




Membrane cryostat technology and prototyping program towards kton scale Liquid Argon Neutrino detectors

Russ Rucinski, Bruce Baller (Fermi National Accelerator laboratory)

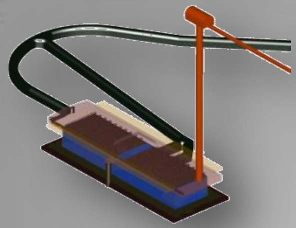
Bonnie Fleming (Yale University)

The Long Baseline Neutrino Experiment

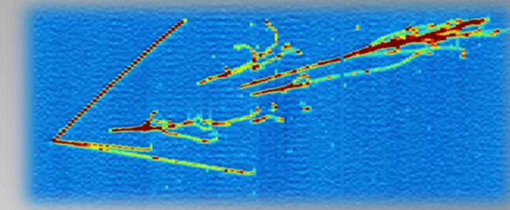
June 9, 2011

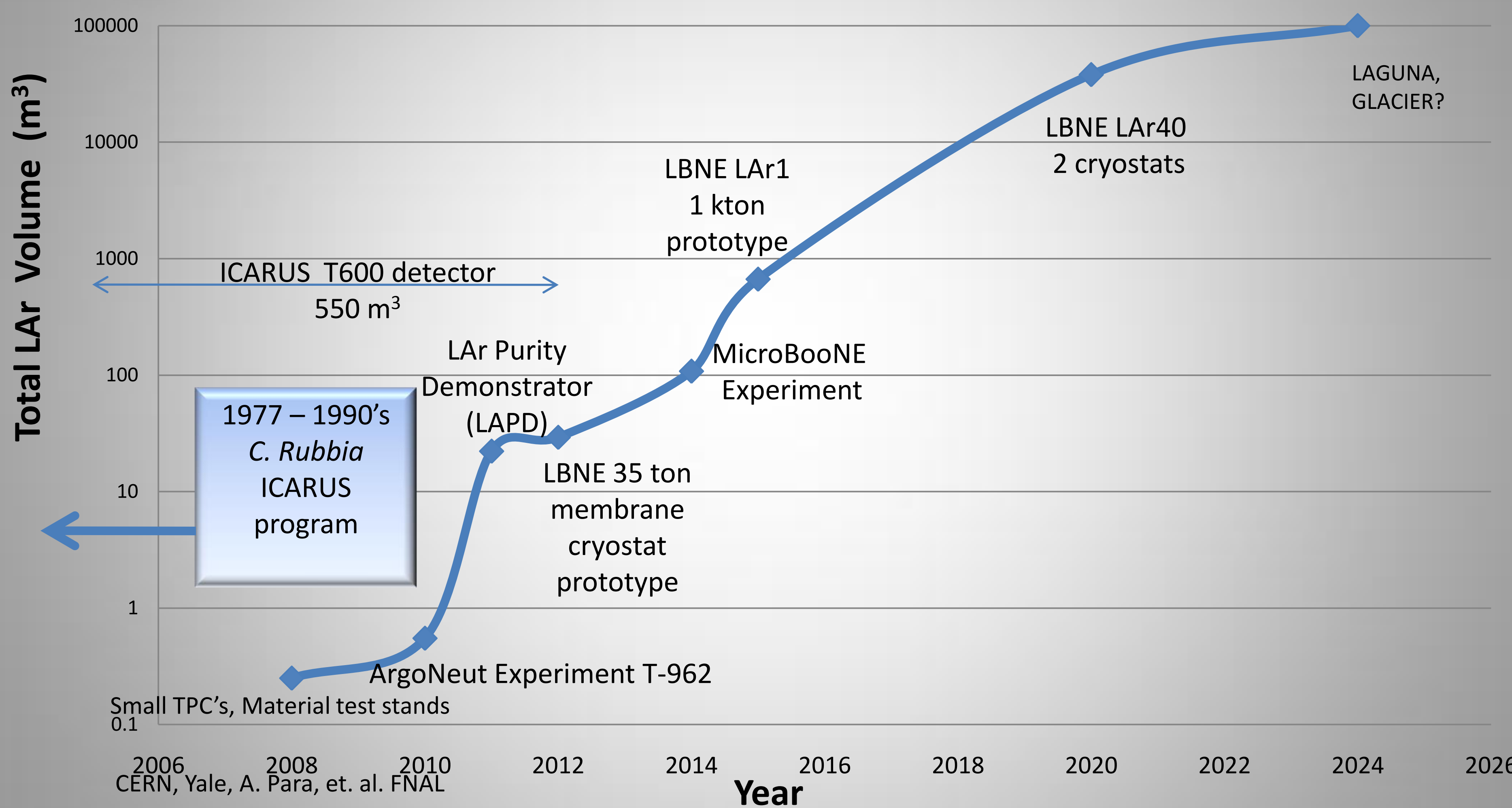
TIPP 2011 in Chicago, IL

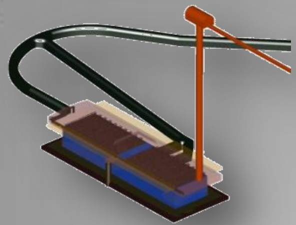
LBNE-doc-3836



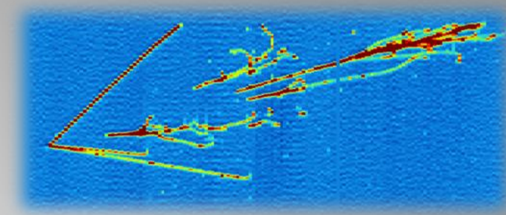
Volume of LAr TPC detectors with time



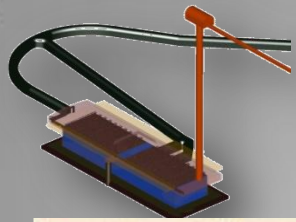




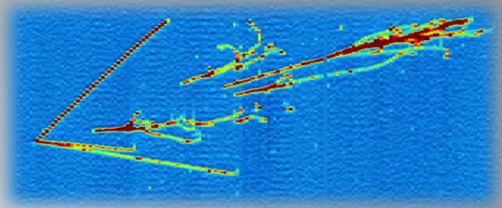
LAr TPC detectors, scaling with time



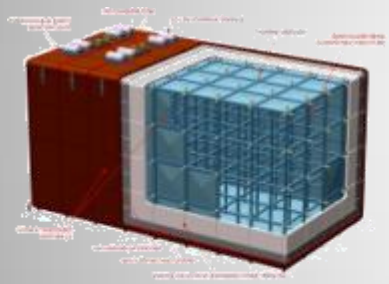
Year(s)	Experiment or prototype	LAr Volume (m³)	Total LAr Mass (tons)	Cryostat(s) Cost (x $1000)	Shape	Type	Insulation	Dimensions
2007 - present	Material Test Stand at FNAL	0.25	0.35	n/a	Cylinder, Vertical	commercial dewar	Vacuum	small
2009 - 2010	ArgoNeut Experiment T-962	0.55	0.76	$ 164K	Cylinder, Horizontal	pipe/plate	Vacuum	0.8 m x 1.3 m long
2011	LAr Purity Demonstrator (LAPD)	22.2	30.7	$ 140K	Cylinder, Vertical	plate shell	Foam, 0.3 m	3 m dia. x 3 m tall
2012	LBNE 35 ton membrane cryostat prototype	29.2	33.5	$ 600K	Rectangular	Membrane	Foam, 0.4 m	2.7 x 4.0 x 2.7 m high
2014	MicroBooNE Experiment	108	150	$ 1.0 M	Cylinder, Horizontal	1" thick plate	Foam, 0.4 m	4 m dia. x 12.2 m long
2003 - present	ICARUS T600 detector	550	761	?	Rectangular	Honeycomb panels	vacuum, LN2	2 vessels, 3.6 x 19.6 x 3.9 m high
2014	LBNE LAr1, 1 kton prototype	666	826	$ 4.0 M	Rectangular	Membrane	Foam, 1 m	7.1 x 10.2 x 9.2 m high
2020 ??	LBNE LAr40, in 2 cryostats	38,000	50,000	$ 90 M	Rectangular	Membrane	Foam, 1 m	2 vessels, 24 x 49 x 16 m high
2020 ??	LAGUNA	76,000	100,000	?	Cylinder, Vertical	?	?	?



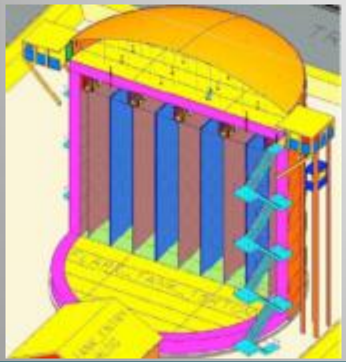
Cryostat Options



<u>Membrane</u>
Full containment
Very little design risk — Fid/Total ~70%
Passive insulation
Evacuable



<u>Modular</u>
Double containment
Some design risk — Fid/Total ~55%(?)
Passive or active insulation
Evacuable



<u>Cylindrical</u>
Double containment
Small design risk — Fid/Total 50% - 60%
Passive insulation
Not evacuable

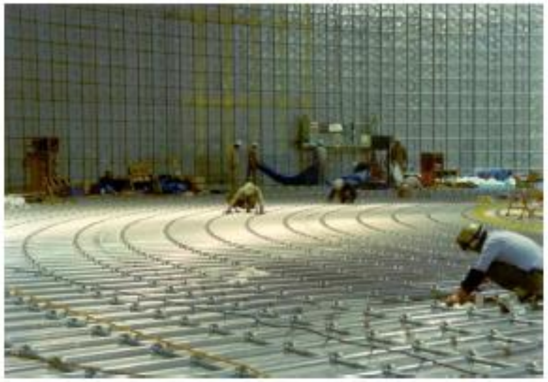
Membrane type tank shape options

Rectangular shape versus cylindrical shape

Octogonal shape (Ships)

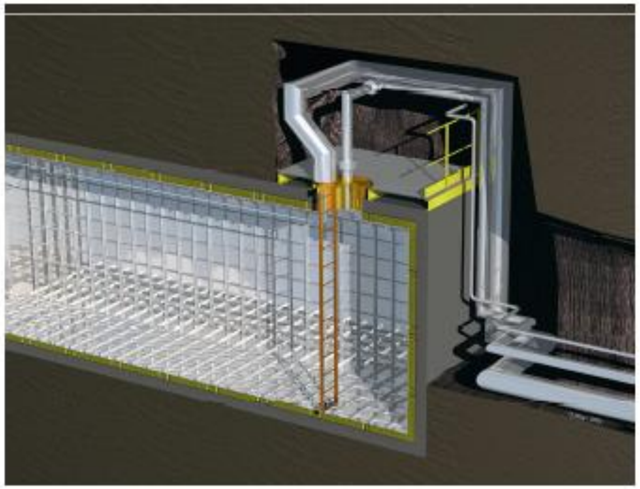
- Slopes to limit the liquid motion
- Optimized for a ship hull

Polygonal shape (Land storage)



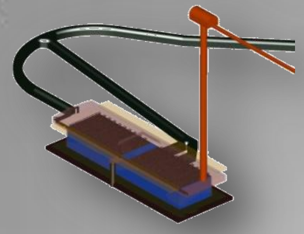
- Optimized shape to limit the B.O.R
- Optimized shape of the modular insulating panels
- Post tensioned concrete

Rectangular shape (cavern)

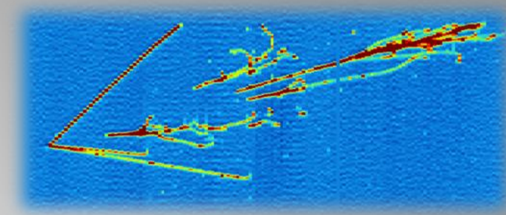


- Best optimization of the insulating panels
- Non optimized B.O.R
- Not adapted for above ground storage tank

B.O.R = Boil Off Rate



A Cylindrical vessel cost is higher compared to a rectangular Membrane in an underground cavern

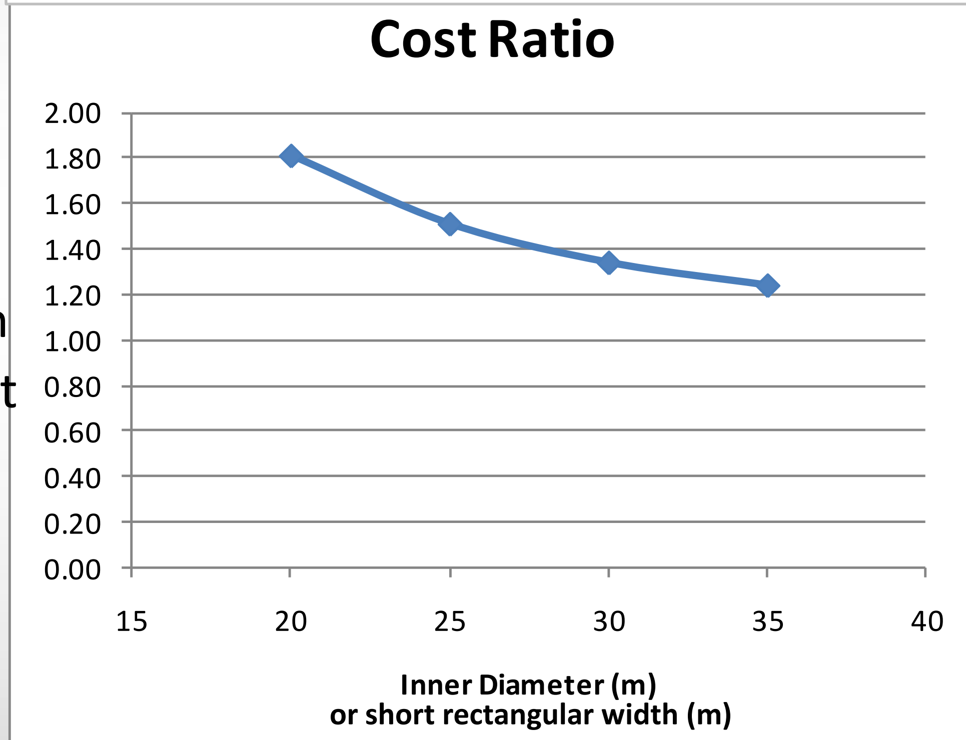


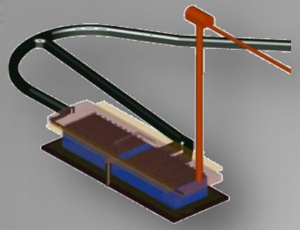
Scaling Parameters

- Cylindrical vessel – 1m insulation + 2m clearance
- Excavation cost $600/m^3
- LAr cost $1.08M/kt
- Membrane cryostat $9.27k/m^2
- Cavern span = Inner Diameter + 10m
- Cylindrical vessel $10.8M + $1.1M/kt

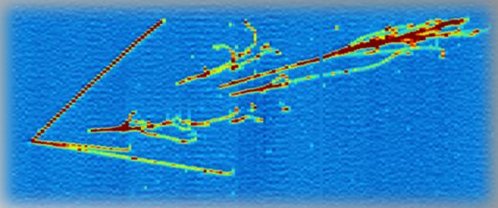
➢ Cost = (Excavation + LAr + cryostat) / kt fiducial

Cylindrical cost vs. Membrane cost



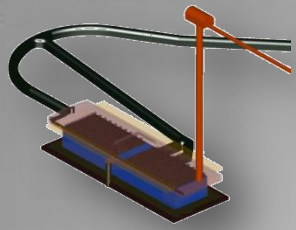


Why Membrane technology ?

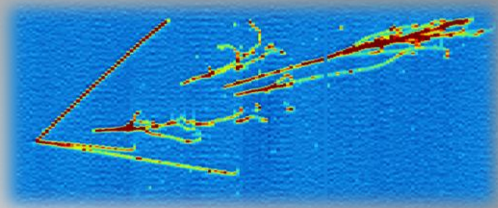


Deciding factors to apply membrane technology for larger (sizes ~+10 meters) LAr TPC's…..

- Membrane type tanks are the most economical solution for LAr tank sizes in 10's of meter dimension.
- Membrane cryostat technology is commonly used for Liquified Natural Gas (LNG) ships and storage vessels.
- It is a commercially optimized solution.
- It is a robust, economical design with a proven service record.



Membrane tank wall cross-section

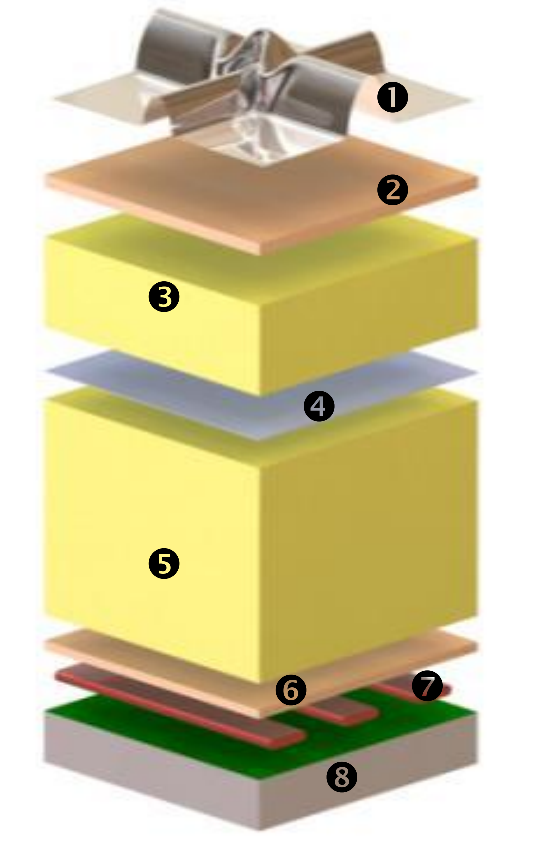


Detector volume
Purge, vacuum, LAr

Insulation space #1
Purge, test gas, vacuum

Insulation space #2
Purge, test gas, vacuum

Concrete bathtub
Ufer ground, heating



www.gtt.fr

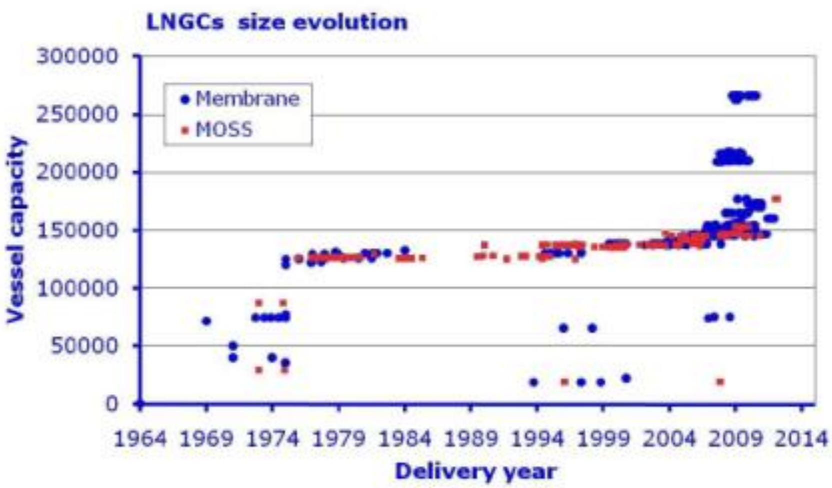
1. Stainless steel primary membrane
2. Plywood board
3. Reinforced polyurethane foam
4. Secondary barrier
5. Reinforced polyurethane foam
6. Plywood board
7. Bearing mastic
8. Concrete covered with moisture barrier

The LNGC "Tembek", one of the thirty-one 216,000 m^3 LNG carriers ordered by Nakilat and delivered in 2008

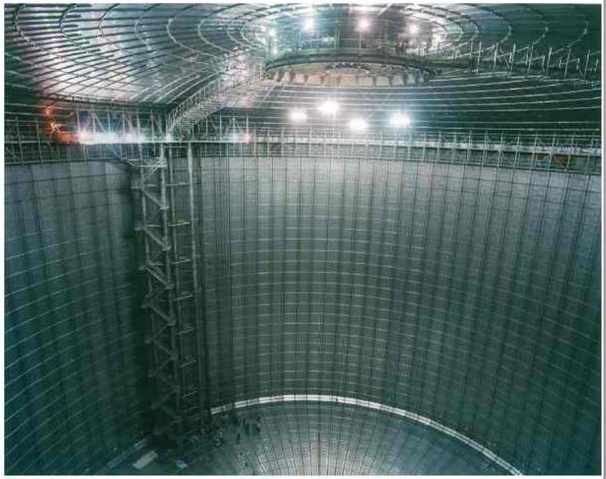
LNG tanker with Membrane from GTT

Vendors: Gaz Transport & Technigaz (GTT)
Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI)

m^3

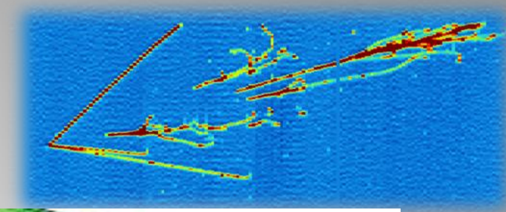


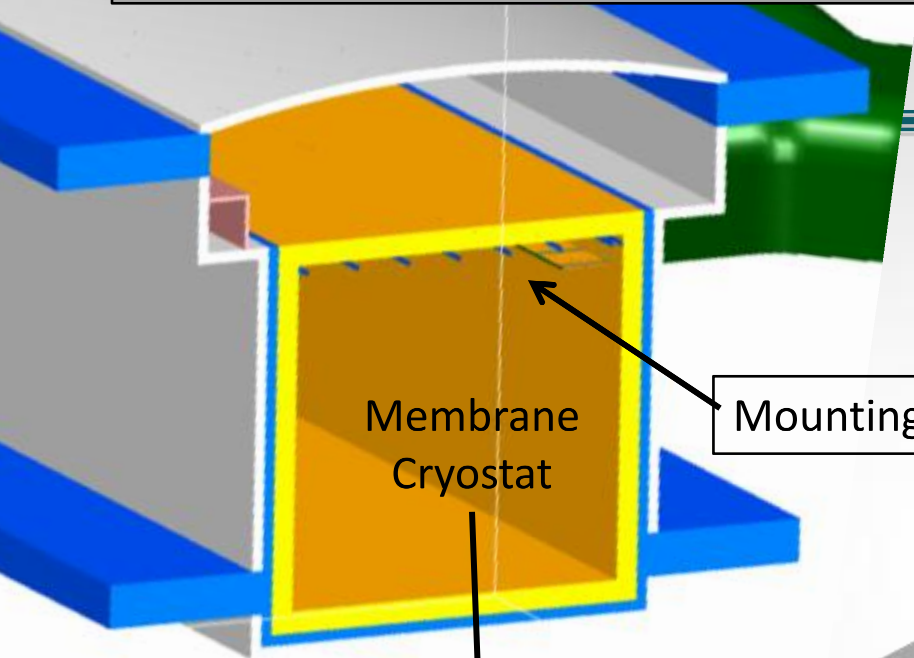
To date more than 200 vessels and 30 storage tanks are equipped with GTT licensed technology.

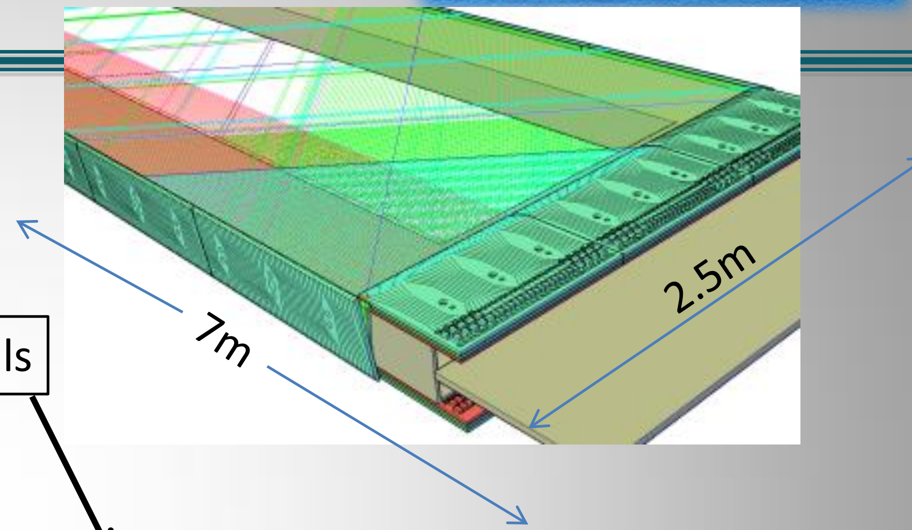


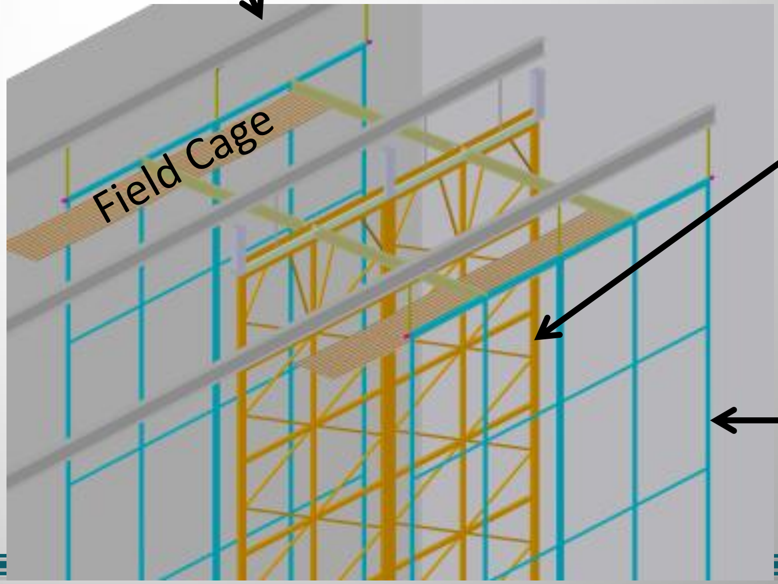
LNG Storage with Membrane from IHI

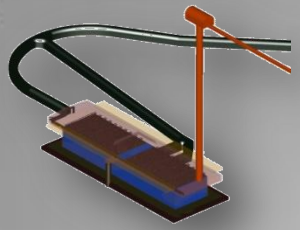
LBNE LAr 40 Detector Overview



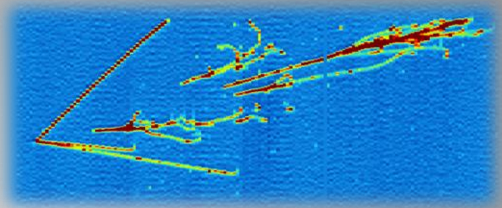


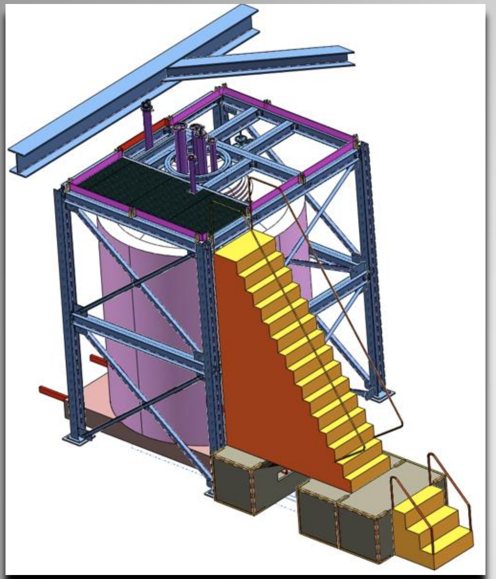


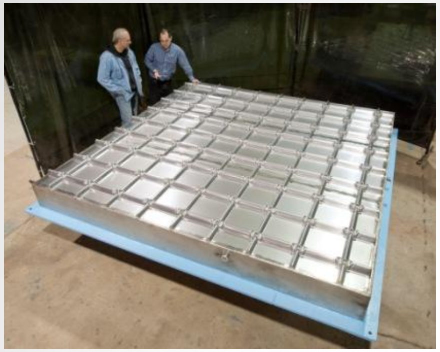


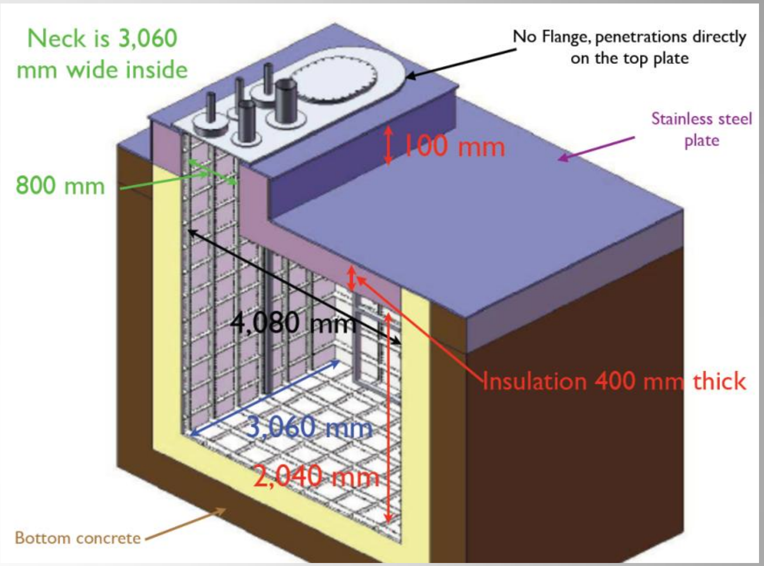


Happening now









<u>LAPD</u>

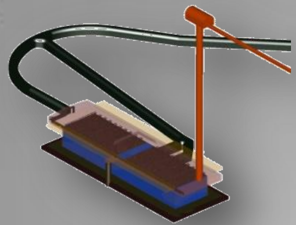
- 30 tons , 3 m dia.
- Obtain purity w/o evacuation
- Filter tests
- Almost complete

<u>Membrane wall</u>

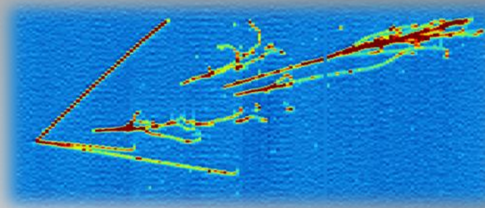
- 3 x 3 m
- Leak tightness
- Evacuation
- Experience
- Completed March 2011

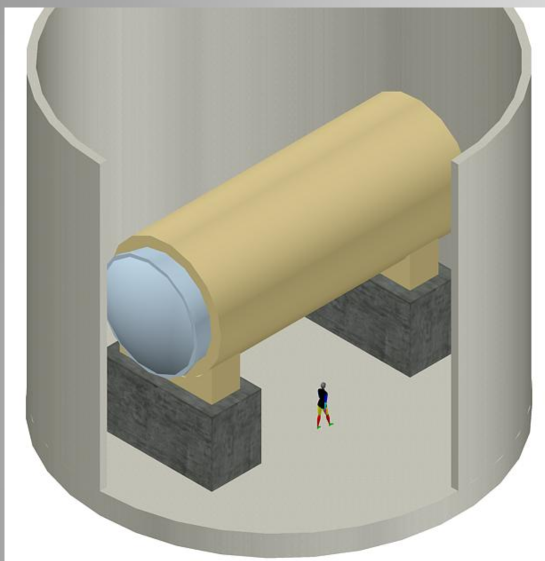
<u>Small Membrane cryostat</u>

- 35 ton, ~2 x 4 x 3 m
- Obtain purity w/o evacuation
- We are in process of ordering
- Operate with LAPD system, 2012



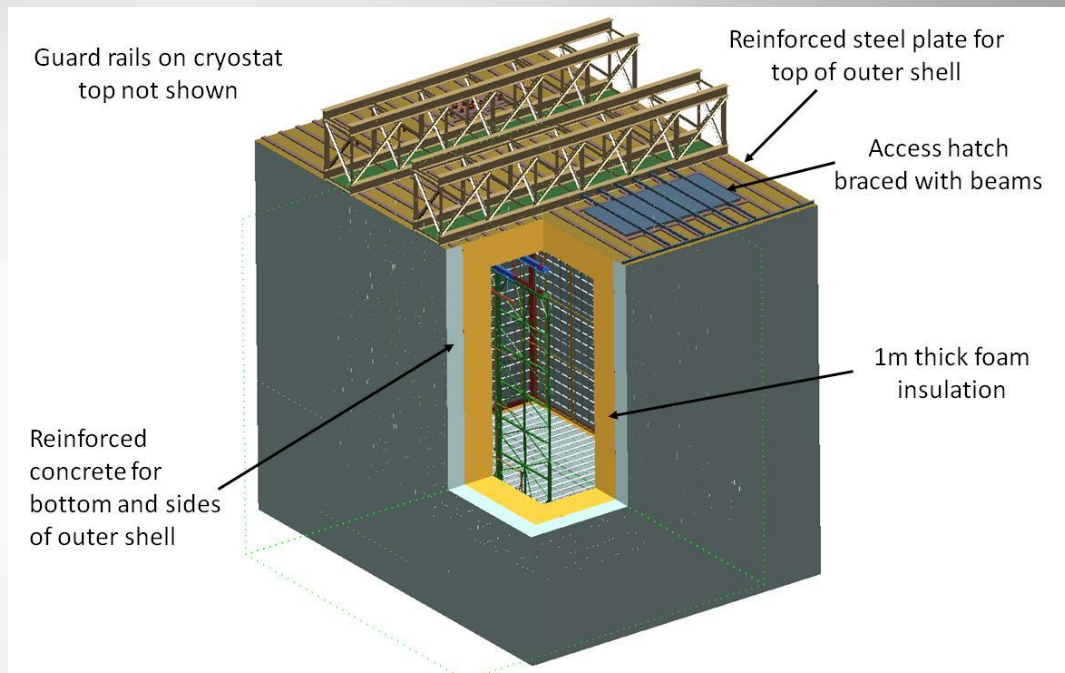
Operational around ~2014 ?





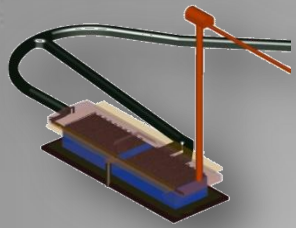
MicroBooNe

- 150 tons , 4 m dia. x 12 long
- Obtain purity w/o evacuation
- Physics goals
- ~ 2014 or sooner?

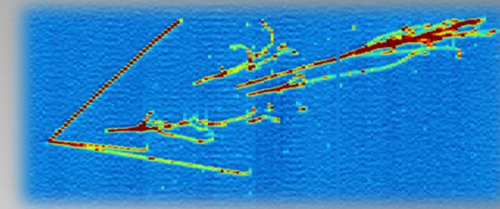


LAr1

- 826 tons , 7 x 10 x 9 m
- Obtain purity w/o evacuation
- LBNE LAr40 component integration
- Build in 2013, operate ~ 2014



Summary



- Membrane cryostat technology is a promising choice for large scale LAr TPC detectors because it is economical, commercially available and robust.
- A Prototyping program to ensure compatibility with LAr TPC detectors (mostly purity issues) is underway.
- A 2 x 3 x 4 m cryostat is planned for next year.
- A 7 x 10 x 9 m cryostat is planned for 2013-2014.

Supplemental Slides

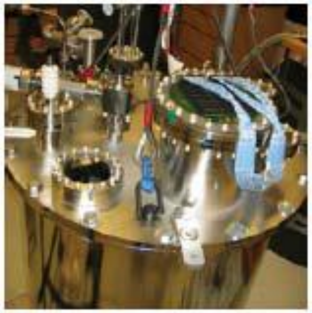
Supplemental Slides

Liquid-Argon Time Projection Chambers

Status of R&D Program in the US

The first TPCs in the United States:

Yale TPC



Location: Yale University
Active volume: 0.00002 kton
Year of first tracks: 2007

Bo

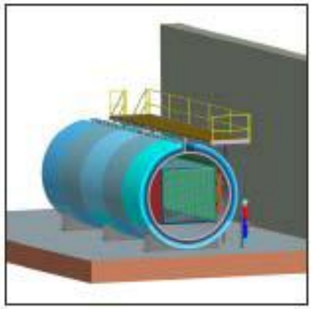
Location: Fermilab
Active volume: 0.00002 kton
Year of first tracks: 2008

CR Stand

ArgoNeuT

Location: Fermilab
Active volume: 0.0003 kton
Year of first tracks: 2008
First neutrinos: June 2009

MicroBooNE



Location: Fermilab
Active volume: 0.1 kton
Start of construction: 2010

Test stands to improve liquid-argon technology:

Luke

Location: Fermilab
Purpose: materials test station
Operational: since 2008

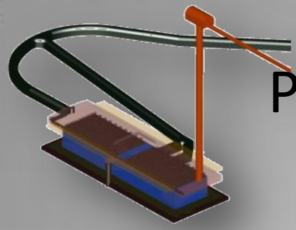
MTS

LAPD

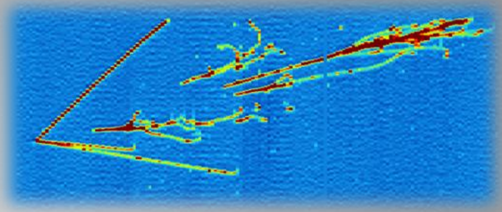
Location: Fermilab
Purpose: LAr purity demo
Operational: 2010

Proposed new R&D Activities (2009)

- Calibration test
- Cryostat prototype
- Installation/Integration mock-up
- Electronics stress test
- HV feedthrough prototype
- Review of FNAL cryo safety std



Program now is as we envisioned it in 2006



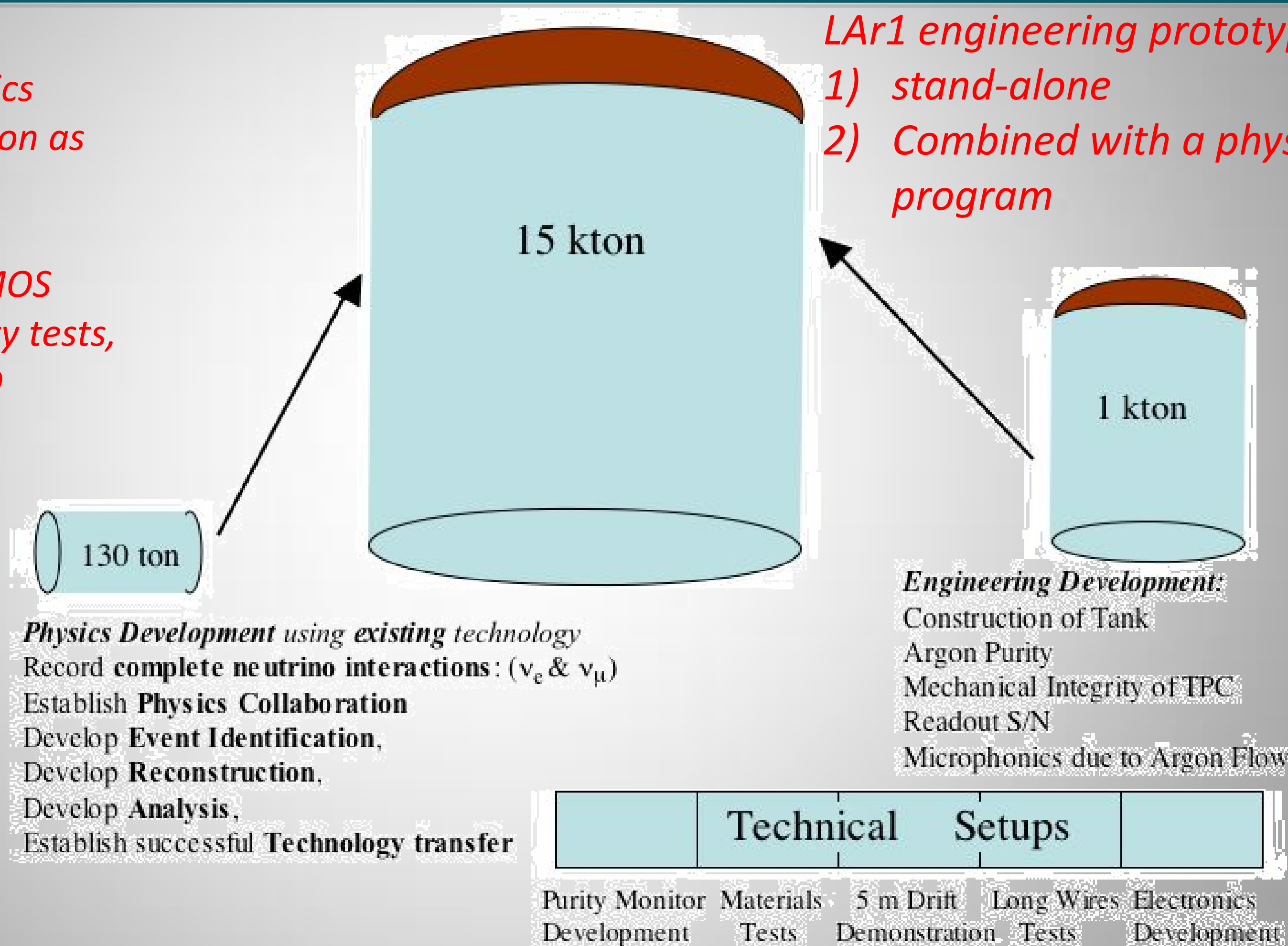
From NuSAG 2006 report

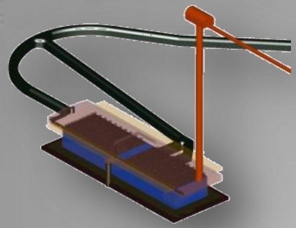
Running physics experiment as soon as possible

In addition, CMOS development, purity tests, physics R&D

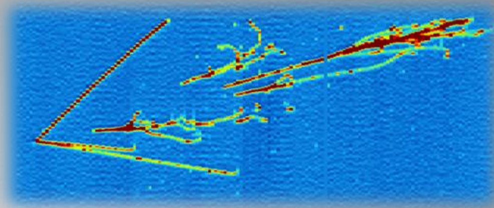
LAr1 engineering prototype

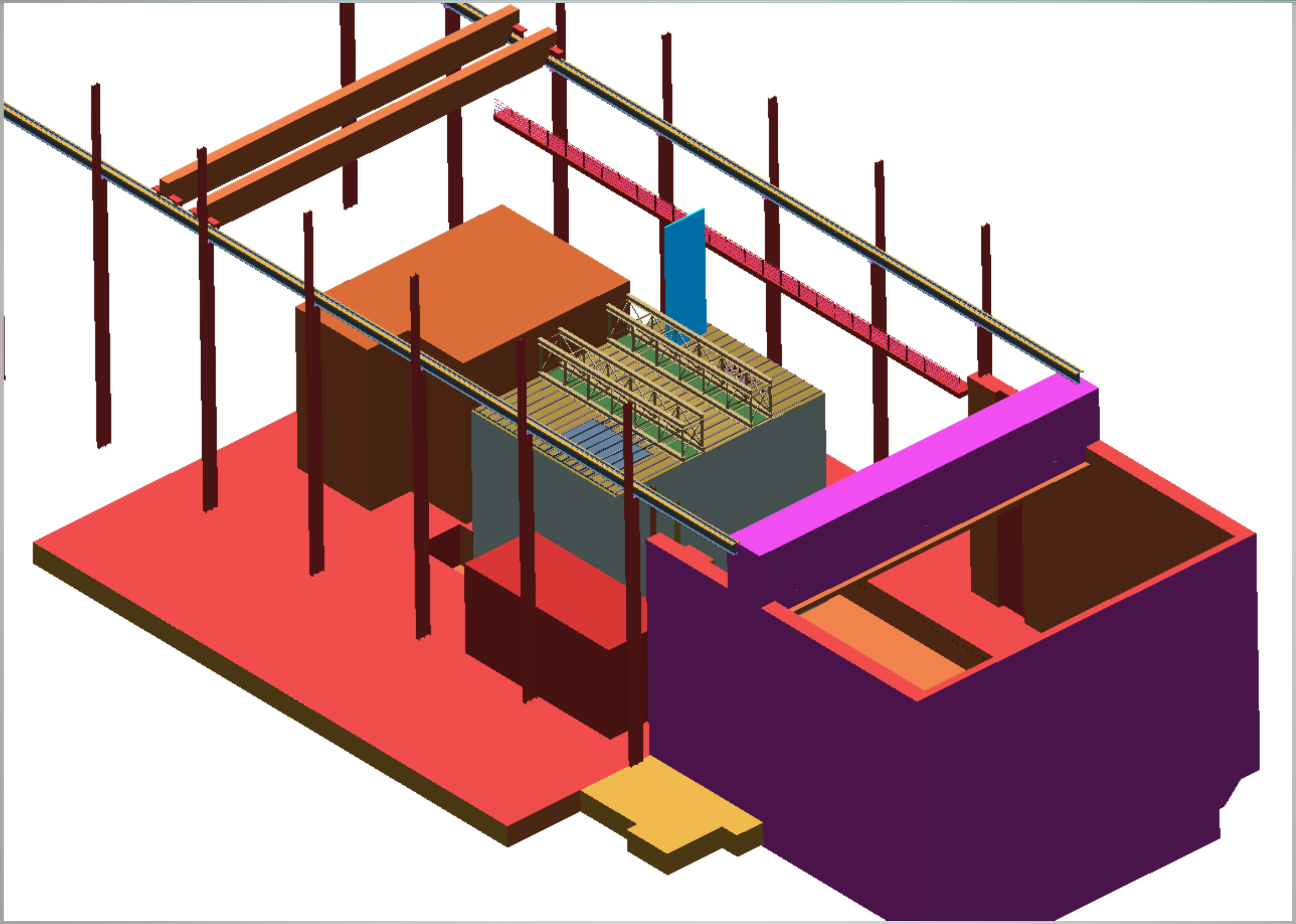
1) *stand-alone*
2) *Combined with a physics program*





LAr1 in DZero building at FNAL, Batavia, IL





Safety of LAr Containment

Storage tank classification – "Full Containment"