DUSEL LArTPC Membrane Cryostat

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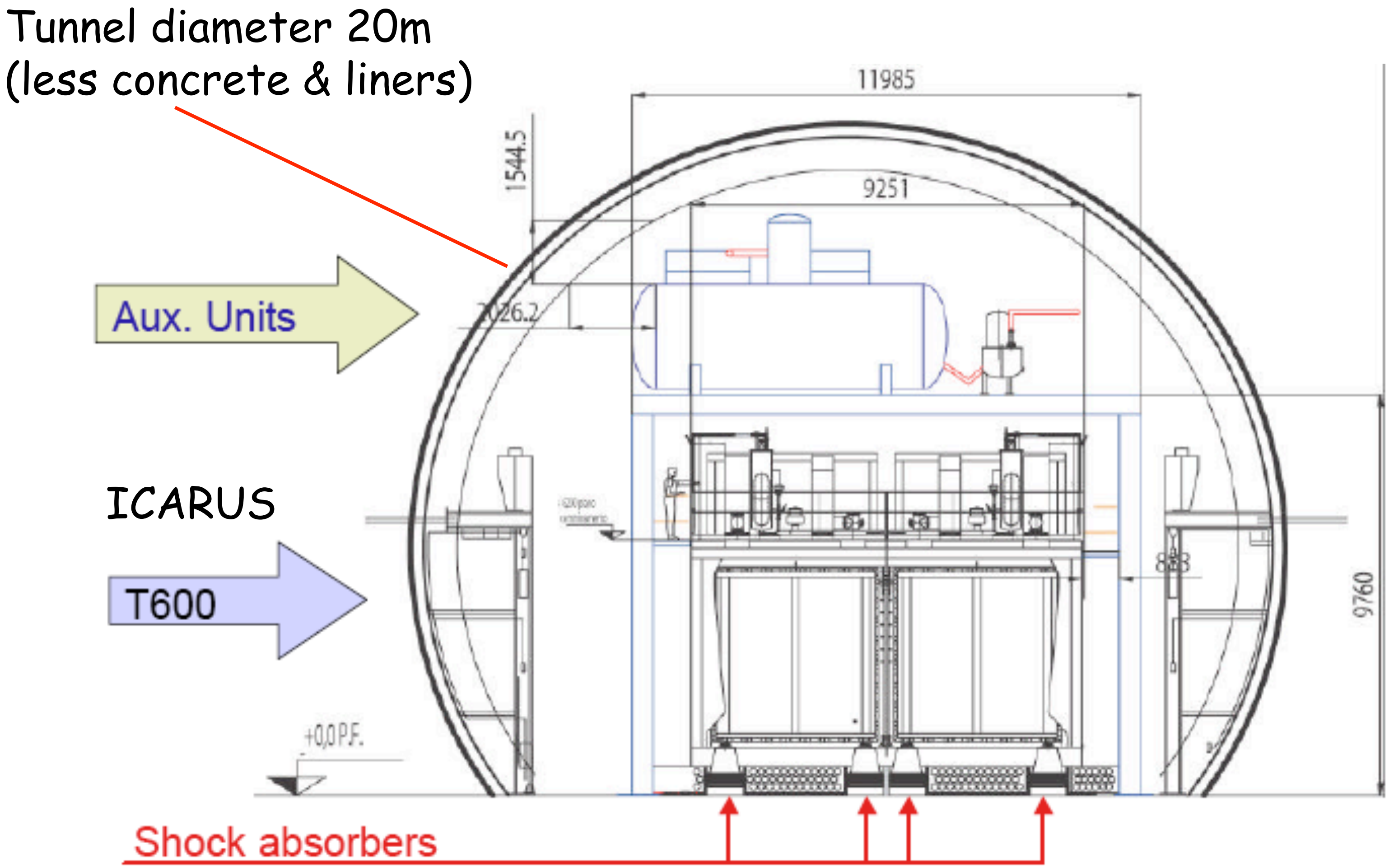
Independent Cryostats in a Cavern



State of the art "membrane" LNG ships

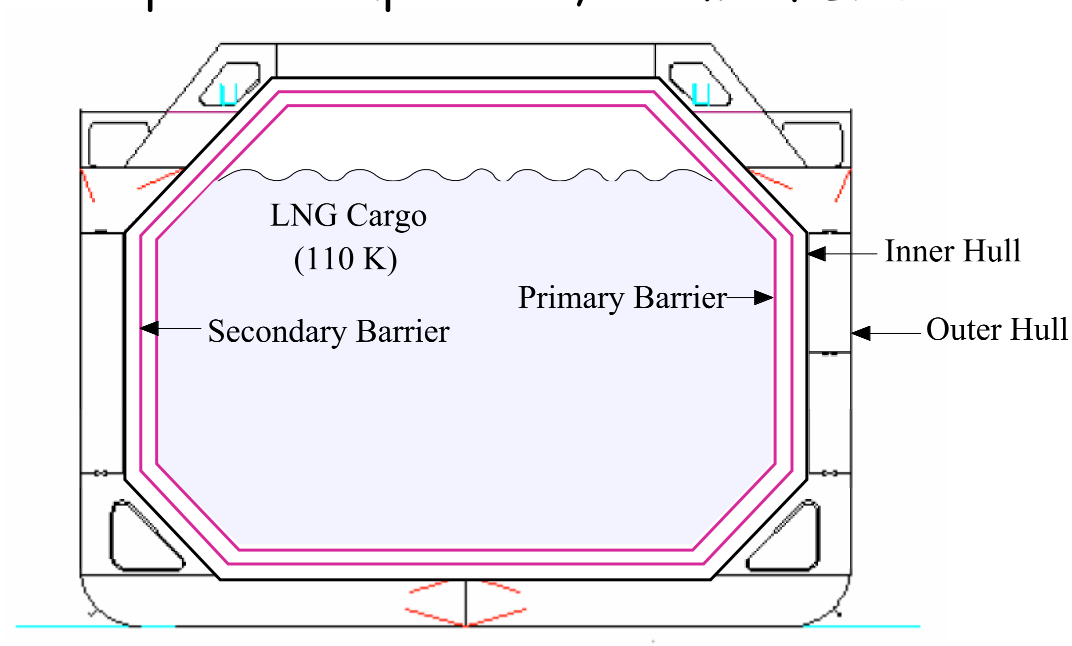
Many ships of this design are now in service. All new construction done this way.

Never had a leak of the Primary Barrier.

Single instance of Secondary Barrier leak detected by monitors. Later fixed.

Rough seas, sloshing shouldn't pose a problem for us.

Ship carries up to 200,000 m^3 of LNG



Hypothesis: If a cavern could be lined with a mild steel shell like the hull of a ship, it should be possible to build a membrane cryostat this way. Makes the best use of the available space.

Membrane LNG Cryostats

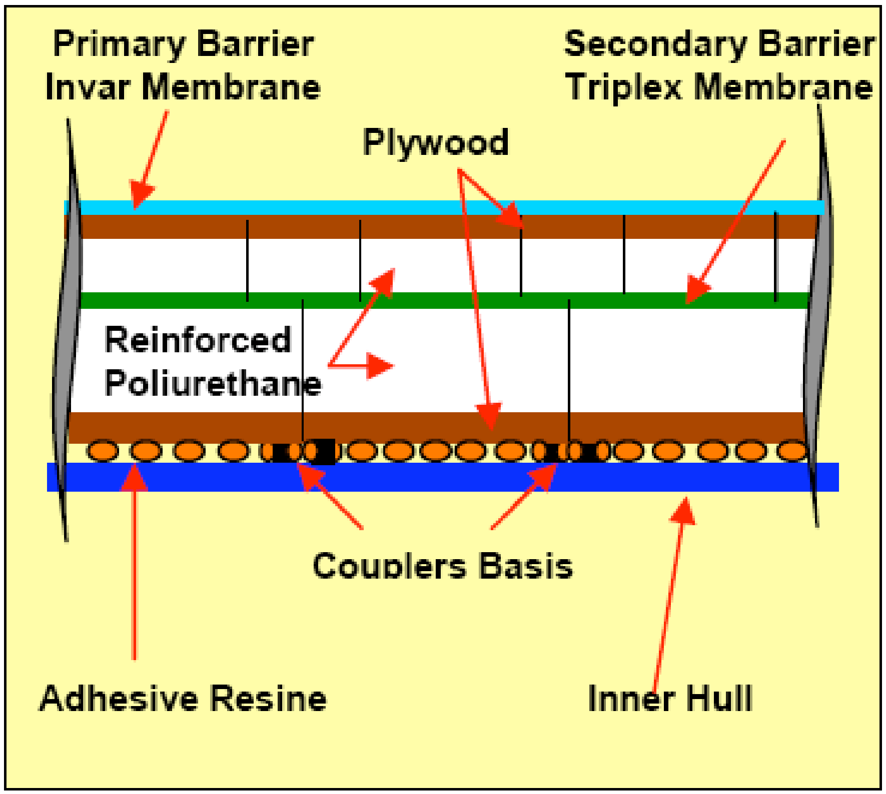
Primary barrier is 0.7 mm Invar (36% Nickel steel).

Secondary barrier is either Invar, corrugated stainless, or Triplex (foam & aluminum composite)

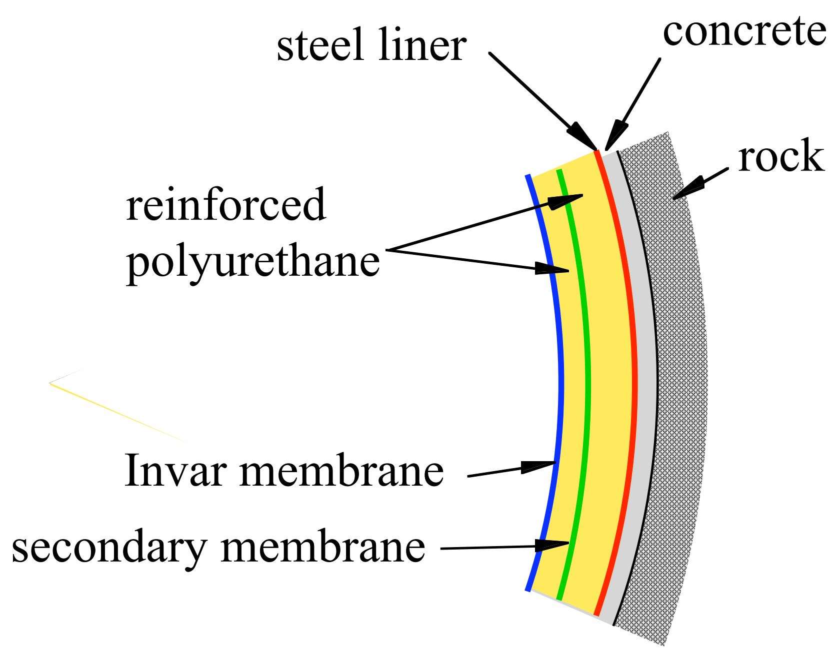
Welding techniques highly automated - shipyard workers can be trained to do this work. Mine works can learn this too. Testing procedures clearly work.

Membrane Details

Ship details



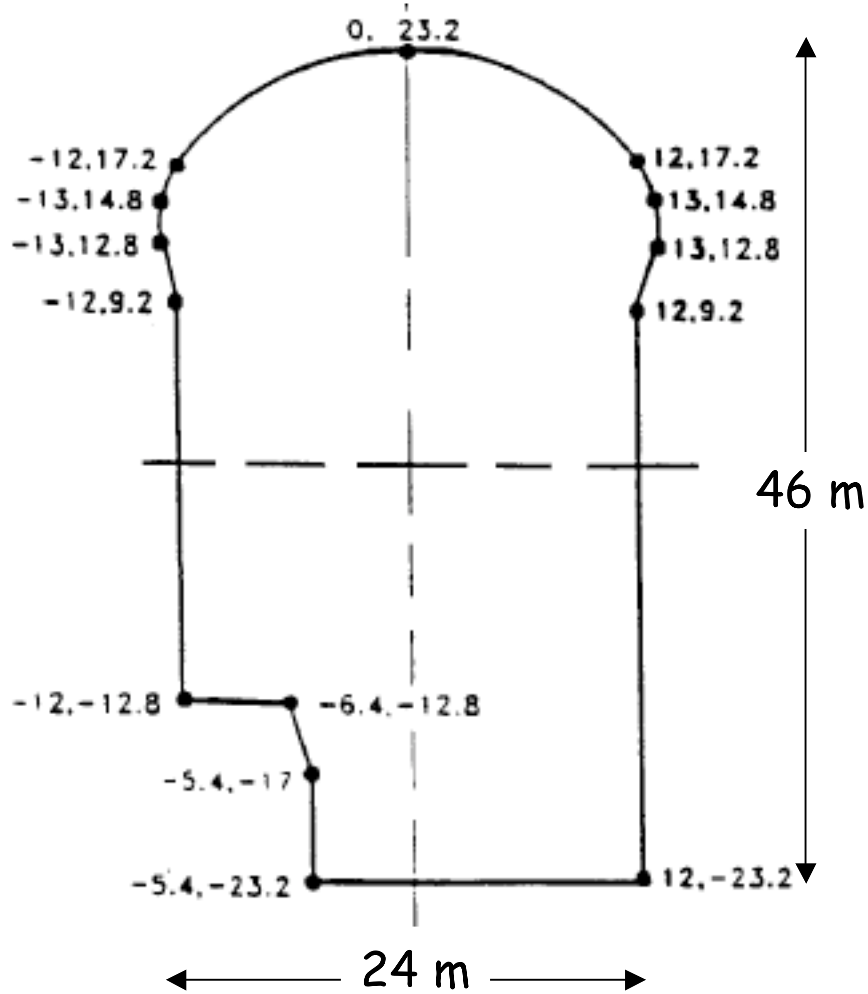
Rock Cavern Cryostat



Argentina's Rio Grand HydroElectric Project

Truck

Coordinates are in meters



Length and Spacing of Rock Bolts

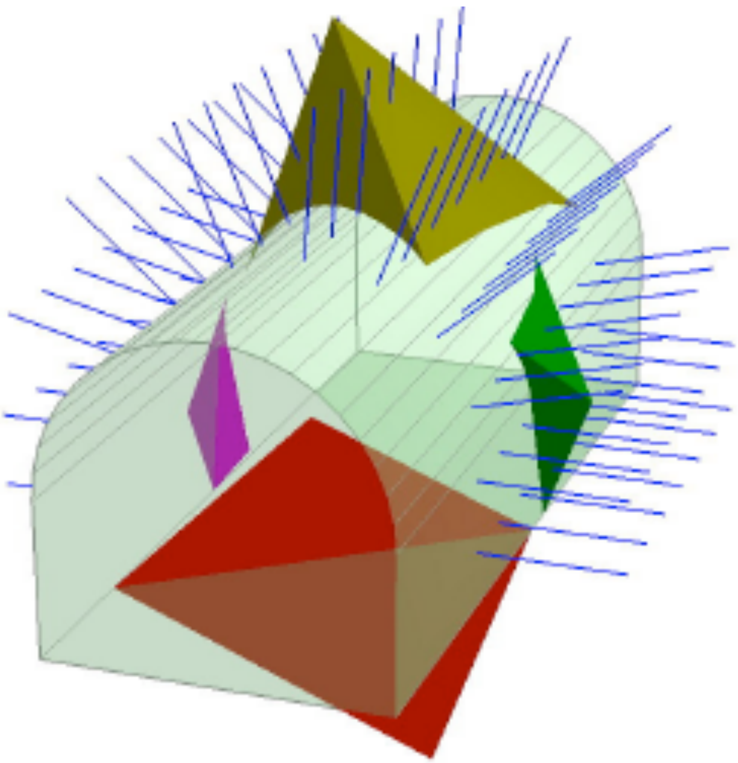
Table 5: Guidelines for excavation and support of 10 m span rock tunnels in accordance with the *RMR* system (After Bieniawski 1989).

Yates

Rock mass class	Excavation	Rock bolts (20 mm diameter, fully grouted)	Shotcrete	Steel sets
I - Very good rock *RMR*: 81-100	Full face, 3 m advance.	Generally no support required except spot bolting.		
II - Good rock *RMR*: 61-80	Full face , 1-1.5 m advance. Complete support 20 m from face.	Locally, bolts in crown 3 m long, spaced 2.5 m with occasional wire mesh.	50 mm in crown where required.	None.
III - Fair rock *RMR*: 41-60	Top heading and bench 1.5-3 m advance in top heading. Commence support after each blast. Complete support 10 m from face.	Systematic bolts 4 m long, spaced 1.5 - 2 m in crown and walls with wire mesh in crown.	50-100 mm in crown and 30 mm in sides.	None.
IV - Poor rock *RMR*: 21-40	Top heading and bench 1.0-1.5 m advance in top heading. Install support concurrently with excavation, 10 m from face.	Systematic bolts 4-5 m long, spaced 1-1.5 m in crown and walls with wire mesh.	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1.5 m where required.
V – Very poor rock *RMR*: < 20	Multiple drifts 0.5-1.5 m advance in top heading. Install support concurrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wire mesh. Bolt invert.	150-200 mm in crown, 150 mm in sides, and 50 mm on face.	Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert.

Remedial procedures for rock problems

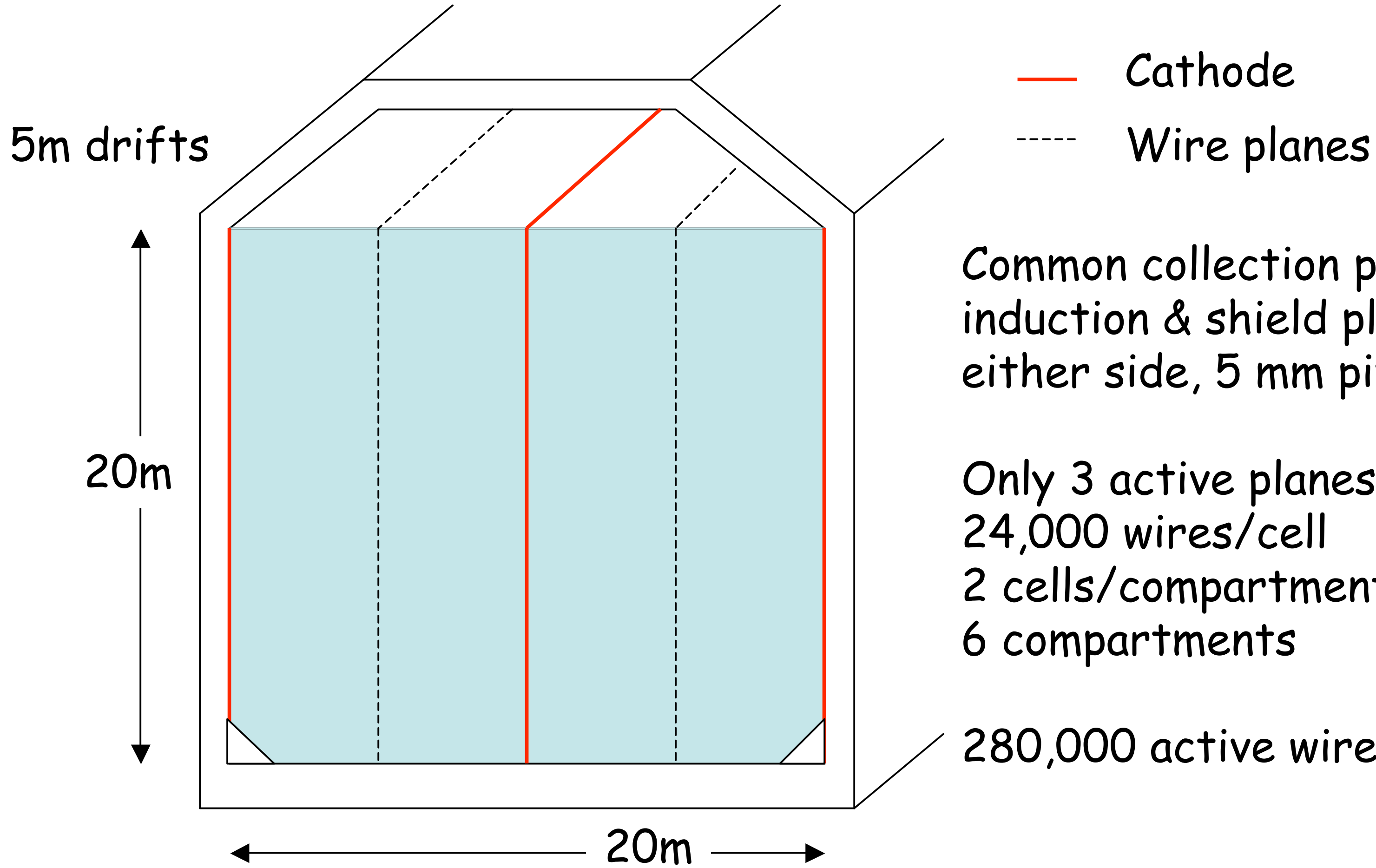
Known rock problems



Unknown rock problems

Example

Cavern in "mailbox" shape, 23 m x 125 m, walls 20 m tall, vaulted ceiling.
Conservatively, the width reduced to 20m by concrete & insulation.
Six compartments (20 m)^3 - 8000 m^3 or 10 kT active mass, 60 kT total.



Common collection plane induction & shield planes either side, 5 mm pitch

Only 3 active planes/cell,
24,000 wires/cell
2 cells/compartment
6 compartments

280,000 active wires

Show stoppers ?

Water pressure relief - but plenty of drainage in Homestake mine to lower levels and existing pumps are always working.

Ice - keeping any H_2O in the rock liquid would be best (insulation thickness), but even some ice might be OK, rock quality dependent.

Creep of rock - cavern dimensional stability. Need to investigate similar issues with a ship in water +/- 20° C.

Wire planes - wire planes must be hung from the top with supports through the membranes to the rock. Can the rock hold the wire plane weight? When and how are the wire planes put into the cryostat?

Membrane Cryostat Positives

Safety - big leaks are impossible; sudden vapor generation is impossible, liquid has no place to go; earthquakes are not an issue

Lift size - Membrane materials (Invar, steel) brought down by lift in rolls. Hugely expensive to change the lift.

Cost -

- Minimum amount of excavation for a given detector volume
- Minimum length of welded seams & uses automated welding
- Invar is expensive but thin - perhaps cheaper than thick tank steel
- Cavern wall preparation (concrete/steel) is common
- Choice of cavern shape - no hydrostatic pressure constraints
- Steel bulkheads separate long cavern into independent compartments

Next?

If rock is OK, get tunnel engineers together with membrane ship engineers to review feasibility. Scale costs from known projects.

When will there be $ to hire engineering firms?

Example guesstimate:

A ship 300 m in length to carry 70 kton of LNG cost < $200 M in 2004. The example cryostat is 125 m long. If the ship builders do it (minus the hull, engines, etc.), it would cost ~$60 M, plus the 70,000 m^3 cavern excavation costs. Still need electronics area (on top).

Serious work needs to be done on how to make the wire planes. This is much tougher than the cryostat. Ideal would be to build on the surface or in the electronics gallery, then install in the cryostat.

Electronics: preamp, filters & mux in the liquid, optical cables out to, and in from, the (mux) ADC-FPGA. Challenge is to make it cost less than ~10% of the total detector cost (about $10M, or $30/channel).