Liquid Argon as an Imaging Detector – an effort at Fermilab

All Experimenters Meeting – February 27, 2006

Presented by Petros Rapidis

(for Doug Jensen, Hans Jostlein, John Krider, David Finley, Alberto Marchionni, Stephen Pordes, Terry Tope, Richard Schmitt, Walter Jaskierny, and Cary Kendziora and his wonderful crew at PAB; not to mention our friends from Michigan, Princeton, Tufts , Yale, York, and UCLA)

1. Why and Whence ?
2. Liquid Argon elsewhere
3. Ultimate objective and the R&D plan at FNAL towards that objective
4. Test setups at PAB and at the Village
5. Recent work at PAB and our first success at obtaining highly pure Liquid Argon
6. Other work (purging big tanks, long wire chamber studies)

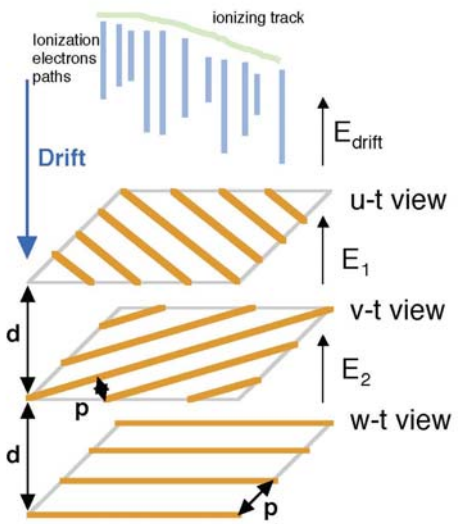
Historical aside on the use of LAr as an imaging detector :

Carlo Rubbia (1977), H. Chen at Irvine (1978), BNL (1979)

ICARUS experiment at Gran Sasso (LAr purification 1993)

Talks by Adam Para 18 months ago, and by Rubbia in October 2005

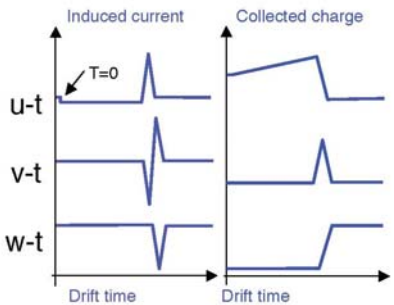
Multiple, non destructive charge readout



Yield ~ 6000 electrons/mm
≈1 fc/mm

In the ICARUS T600

E_{drift} = 500 V/cm
p = 3 mm
d = 3 mm
r = 0.1mm



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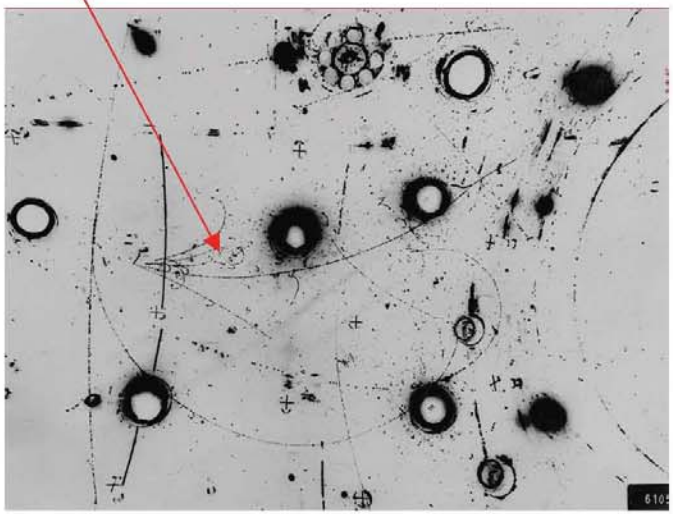
Thirty years of progress.....

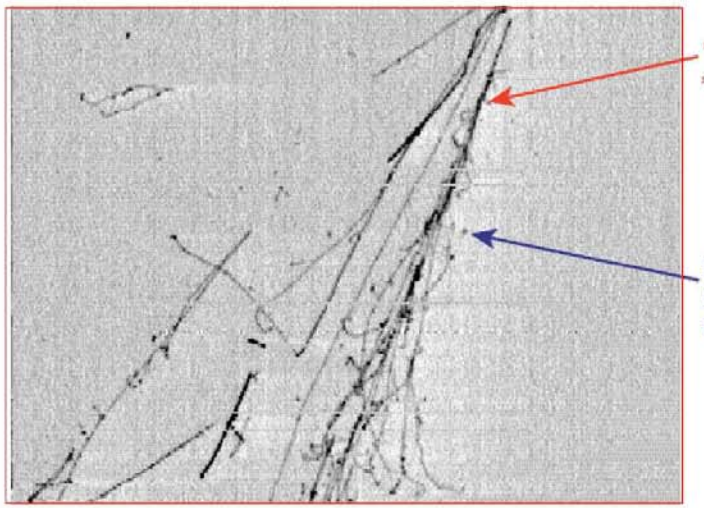
Bubble diameter ≈ 3 mm (diffraction limited)

LAr is a cheap liquid (≈1CHF/litre), vastly produced by industry

Gargamelle bubble chamber



ICARUS electronic chamber



Medium	*Heavy freon*	
Sensitive mass	3.0	ton
Density	1.5	g/cm3
Radiation length	11.0	cm
Collision length	49.5	cm
dE/dx	2.3	MeV/cm

Medium	*Liquid Argon*	
Sensitive mass	Many ktons	
Density	1.4	g/cm3
Radiation length	14.0	cm
Collision length	54.8	cm
dE/dx	2.1	MeV/cm

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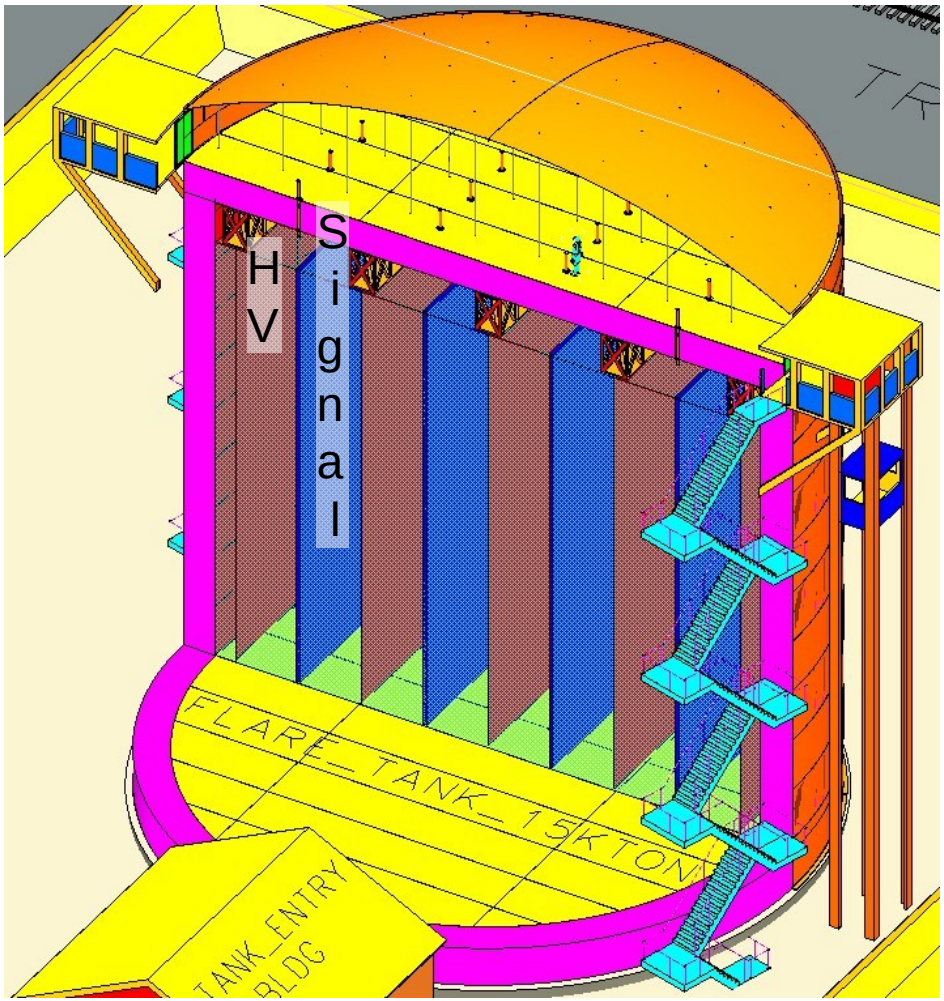
The Large Liquid Argon TPC: Sketch



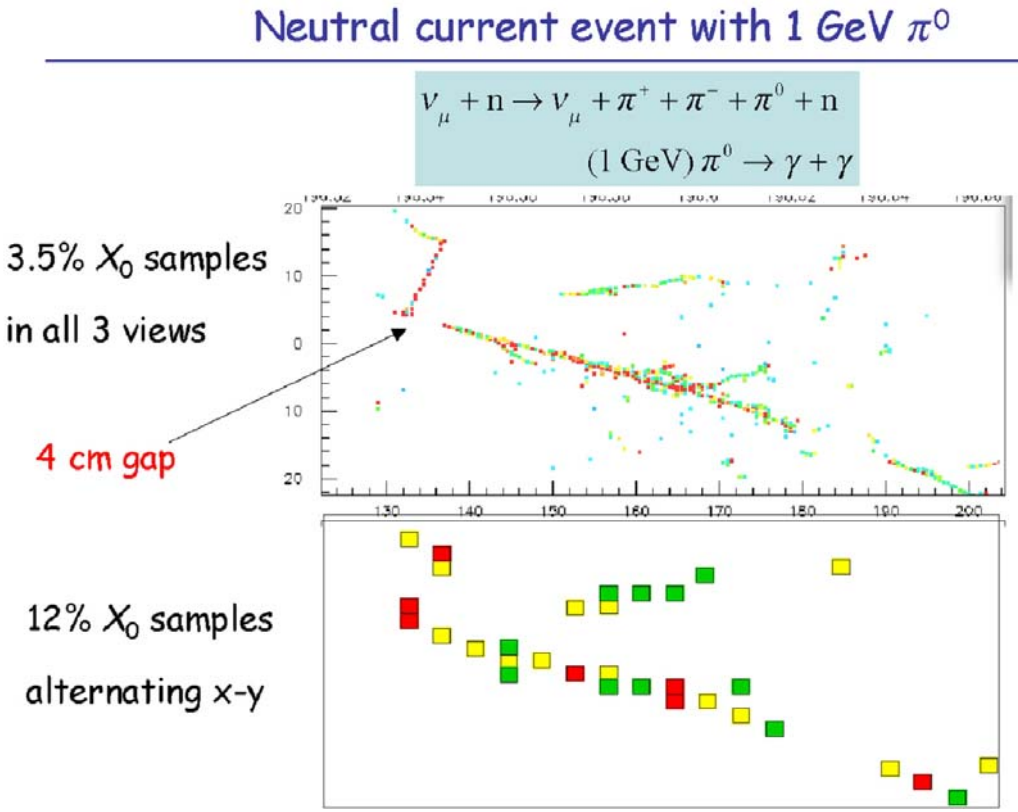
A large size, low rate, fully active, high efficiency, fine spatial resolution, imaging detector of relatively low cost.
(5mm wire spacing, 3 meter drift)

Perfect for neutrino work (esp. off axis), but also for other uses (proton decay, super nova neutrino detection, and double beta decay)

In contrast to low resolution, low efficiency, high rate detectors being considered.

But note that it is not a fully proven technology, if it is to be based on an LNG tank design.

The promise :

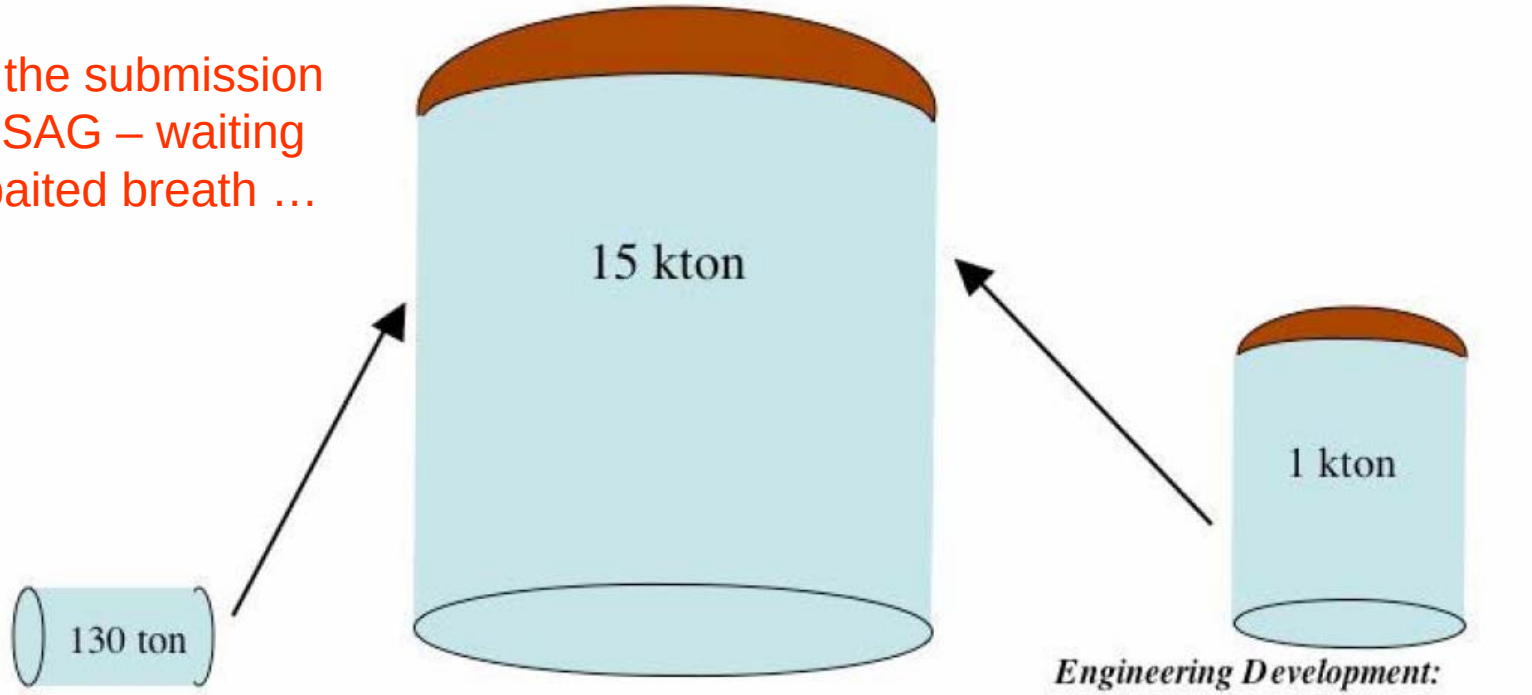


The outstanding issues : a) Purity (without evacuating)

b) Huge wire chambers (20+ meters) in LAr

NuMI Liquid Argon TPC Overview

From the submission to NUSAG – waiting with baited breath …



Physics Development *using* ***existing*** *technology*
Record **complete neutrino interactions**: (ν_e & ν_μ)
Establish **Physics Collaboration**
Develop **Event Identification**,
Develop **Reconstruction**,
Develop **Analysis**,
Establish successful **Technology transfer**

Engineering Development:
Construction of Tank
Argon Purity
Mechanical Integrity of TPC
Readout S/N
Microphonics due to Argon Flow

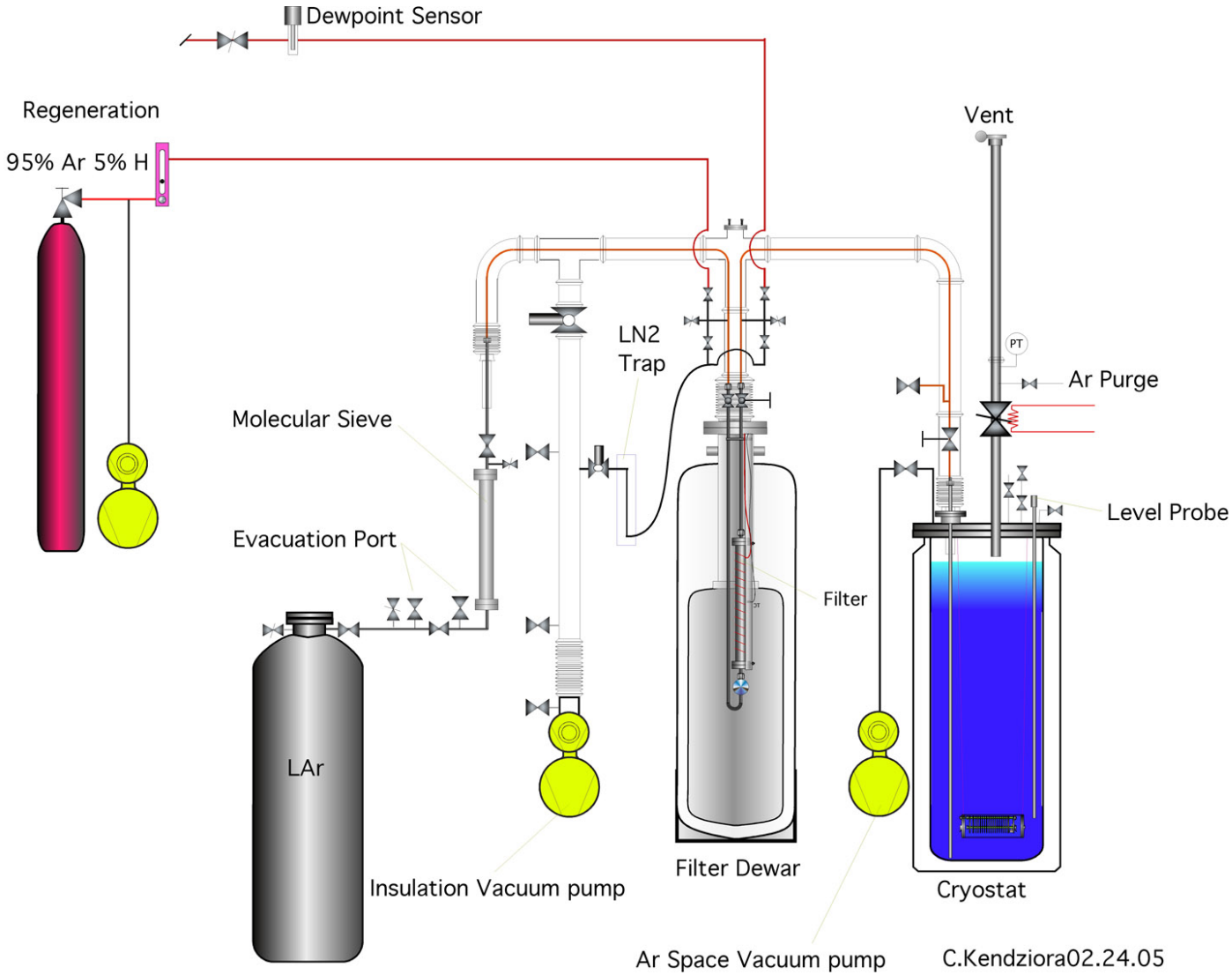
Technical Setups

Purity Monitor Development	Materials Tests	5 m Drift Demonstration	Long Wires Tests	Electronics Development

Setup at PAB

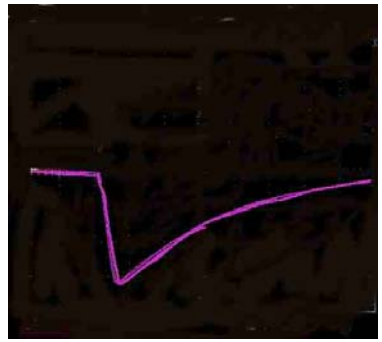
A test station to study (a) the contamination of LAr by various materials and (b) the efficacy of various ‘filters’ for the removal of oxygen (and other electronegative species)

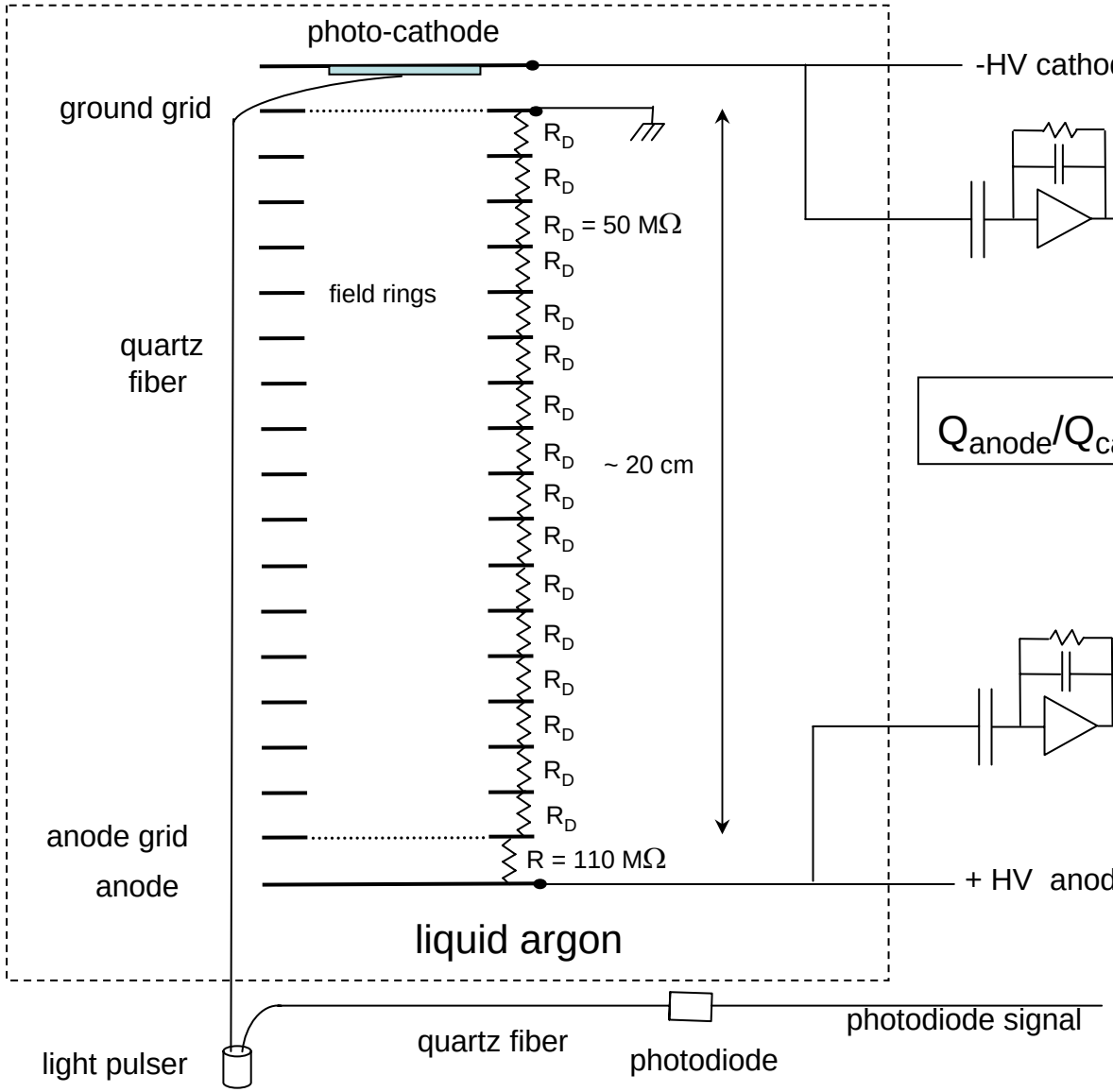
Mostly recycled equipment



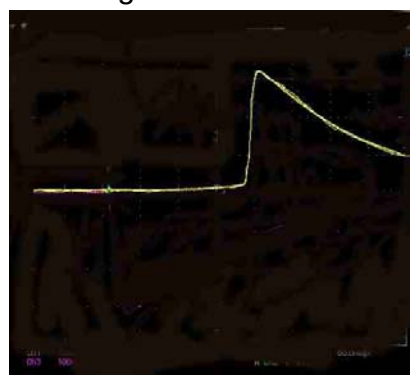
First use of new ‘filtering’ material based on reduced Cu and Cu oxides. (a significant ‘local’ contribution)

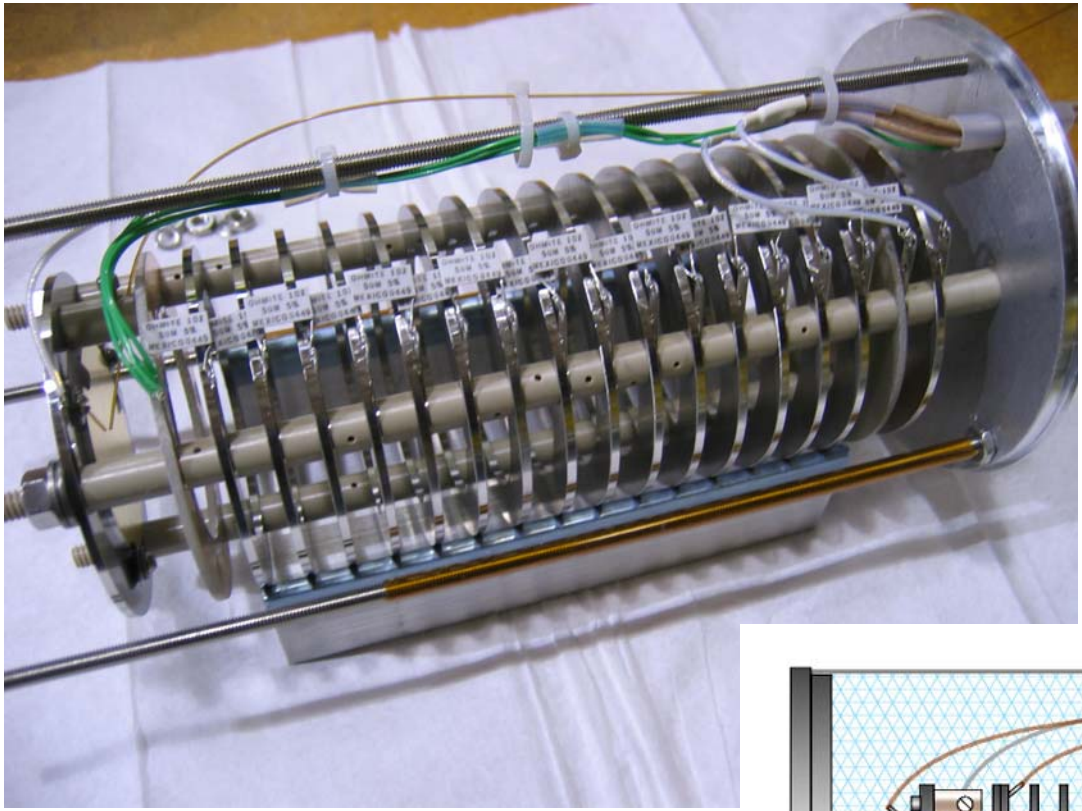
Schematic of Liquid Argon Purity Monitor (PrM)

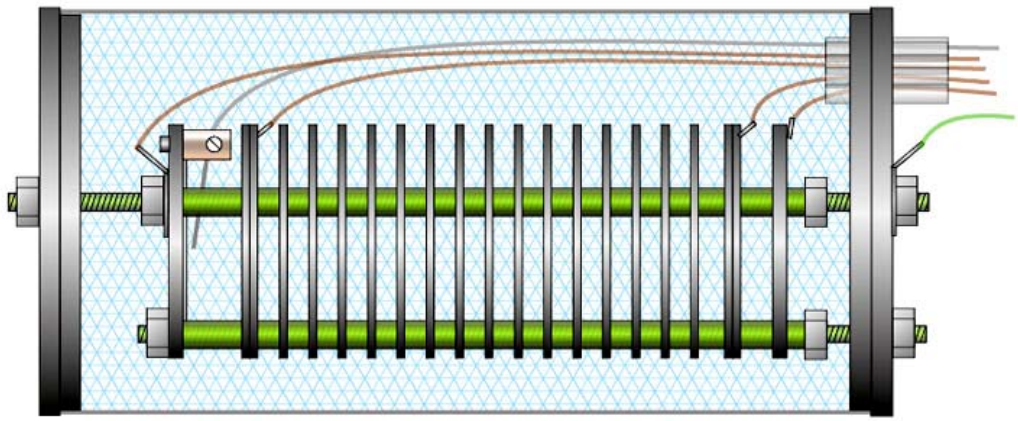




$$Q_{anode}/Q_{cathode} = e^{-t_{drift}/\tau}$$







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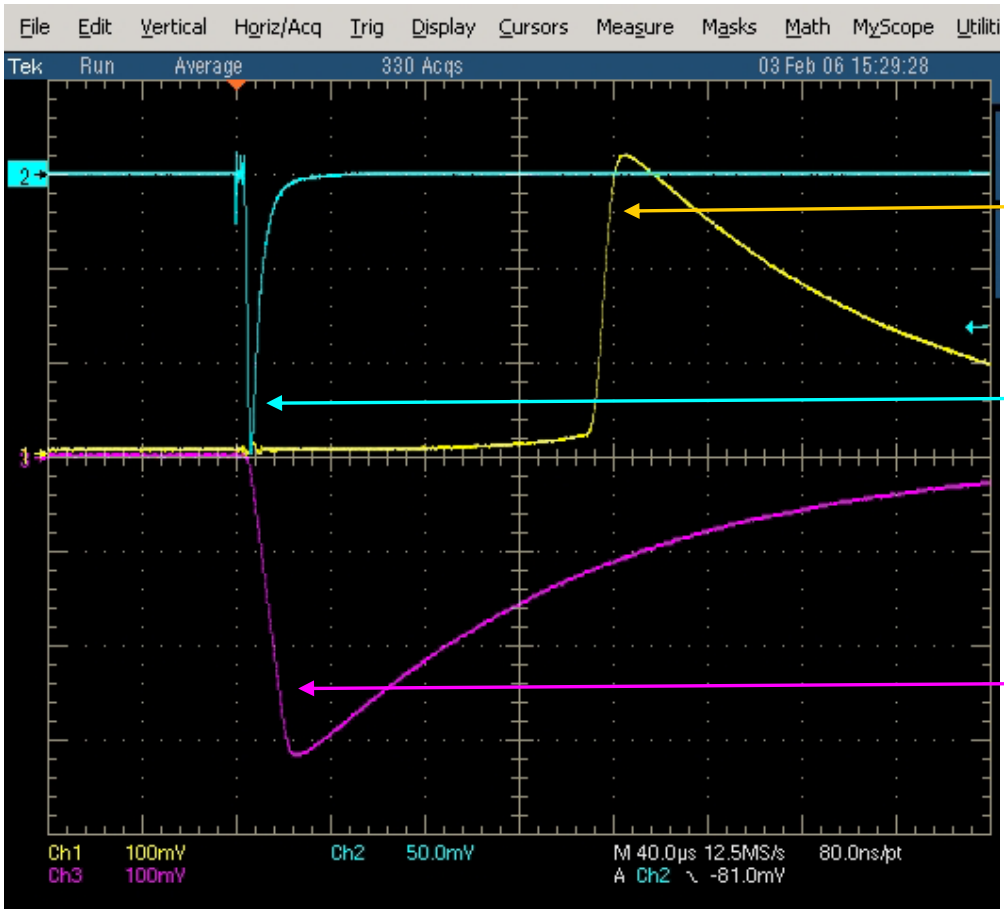
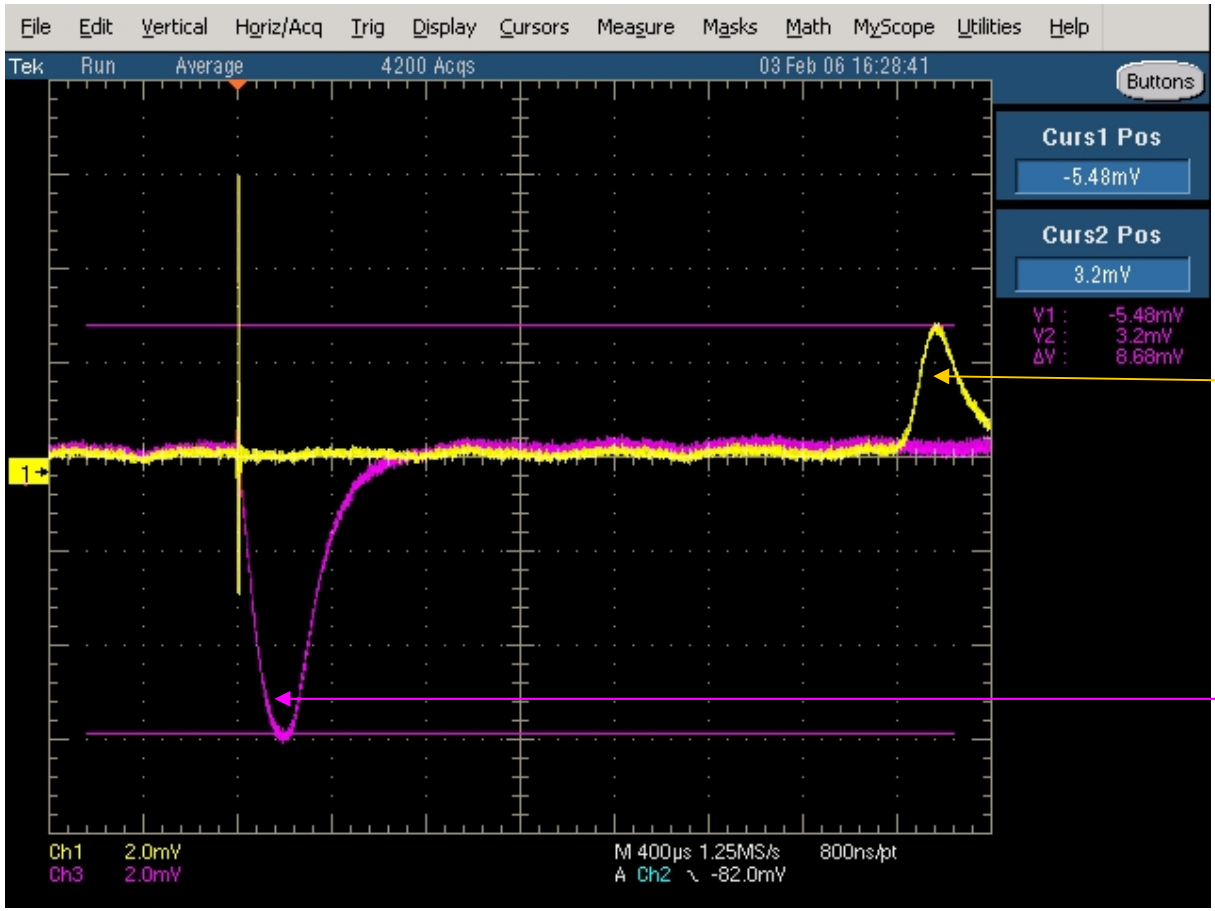


anode signal

photodiode

cathode signal

t_{drift}= 150 µs, $Q_{anode}/Q_{cathode}$= ~1

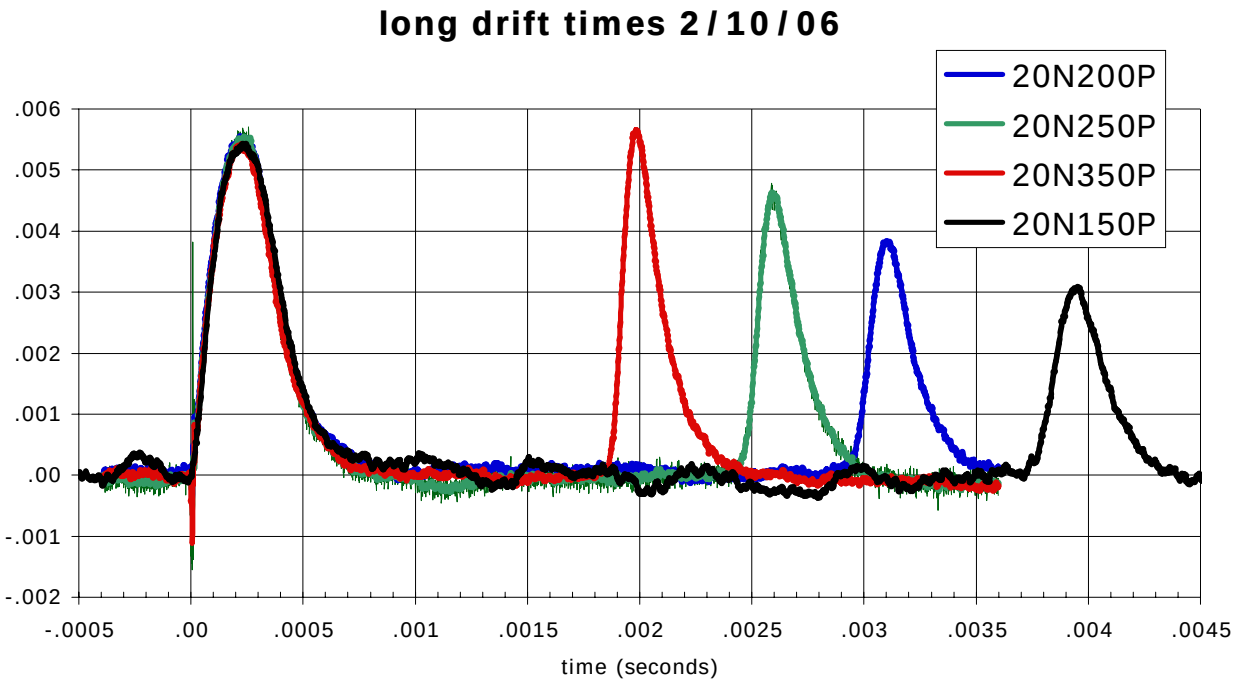


anode signal

cathode signal

a 2.8 millisecond drift, $Q_{anode}/Q_{cathode} \sim 0.4$ (*)

(*) peaks need some correction for cathode signal rise-time



a plot of long drift times from another run a week later with fresh argon.
An alternative way to calculate lifetimes would be to use just the anode signals at different drift times, making appropriate compensation for the different transmission efficiencies as the drift field changes at fixed cathode fields.

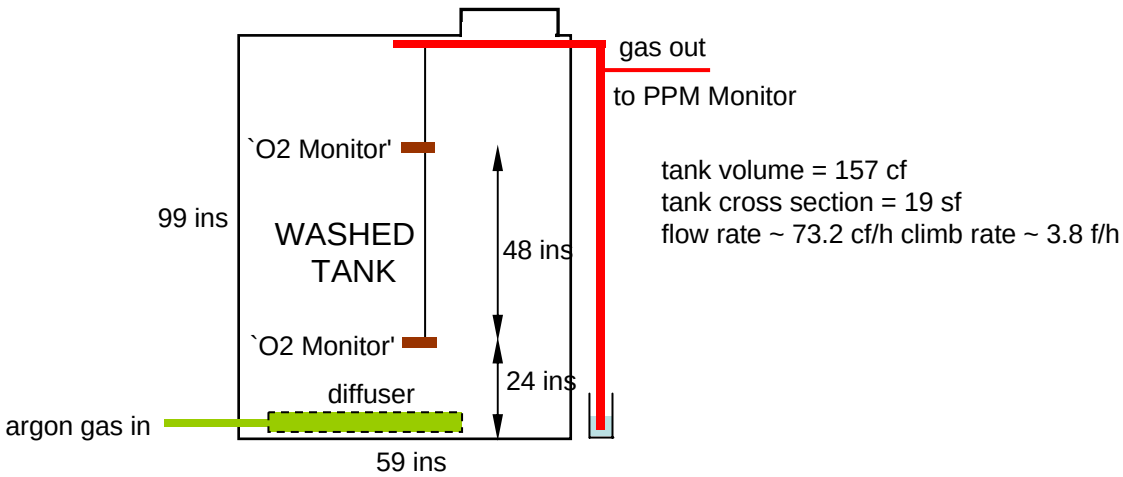
Lifetime is in excess of ~5 msec - for a single pass thru the filter!

Test of purging a volume from atmosphere:

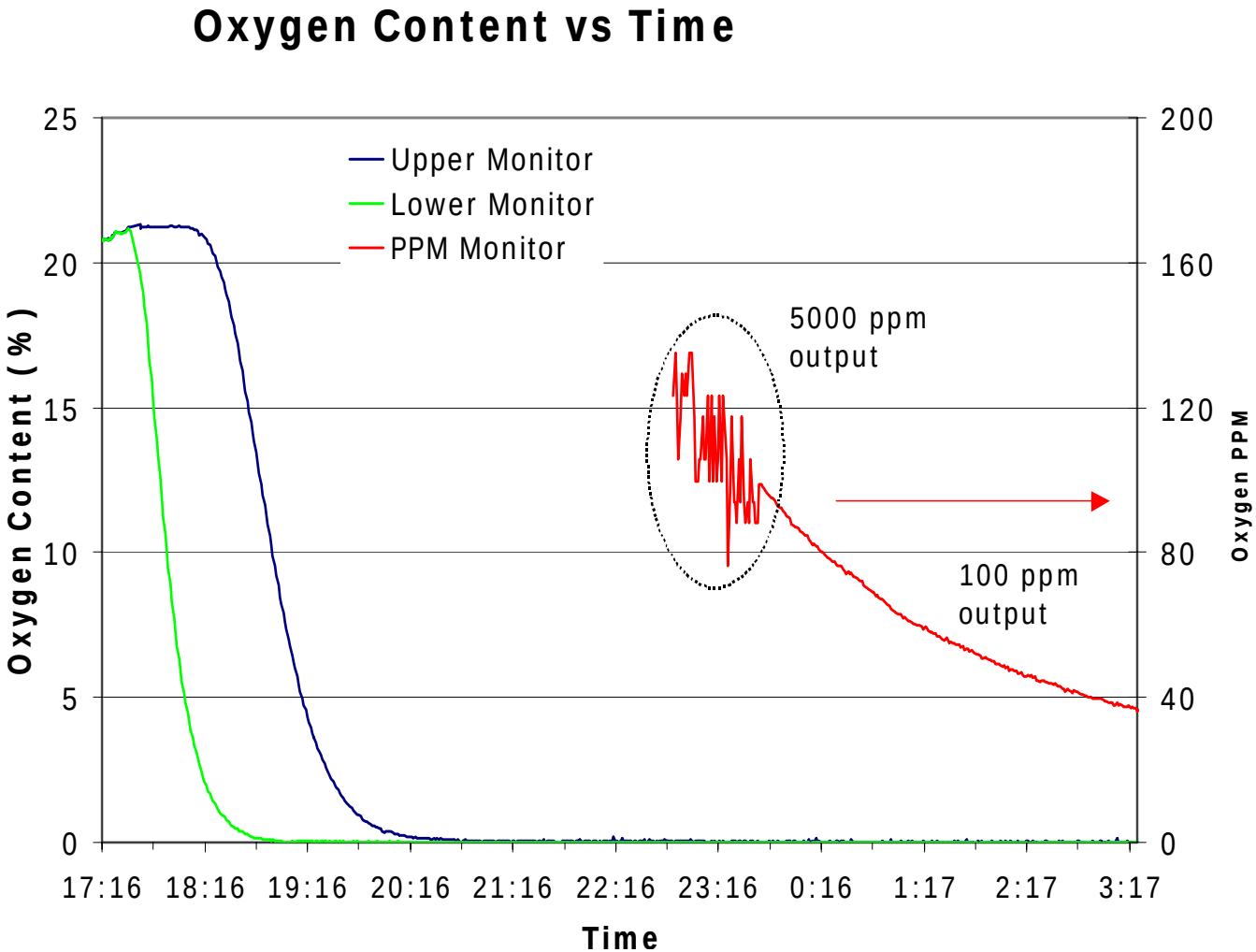
insert Argon gas at bottom of tank over large area at low velocity;

the Argon introduced being heavier than air will act as a piston and drive the air out of the tank at the top;

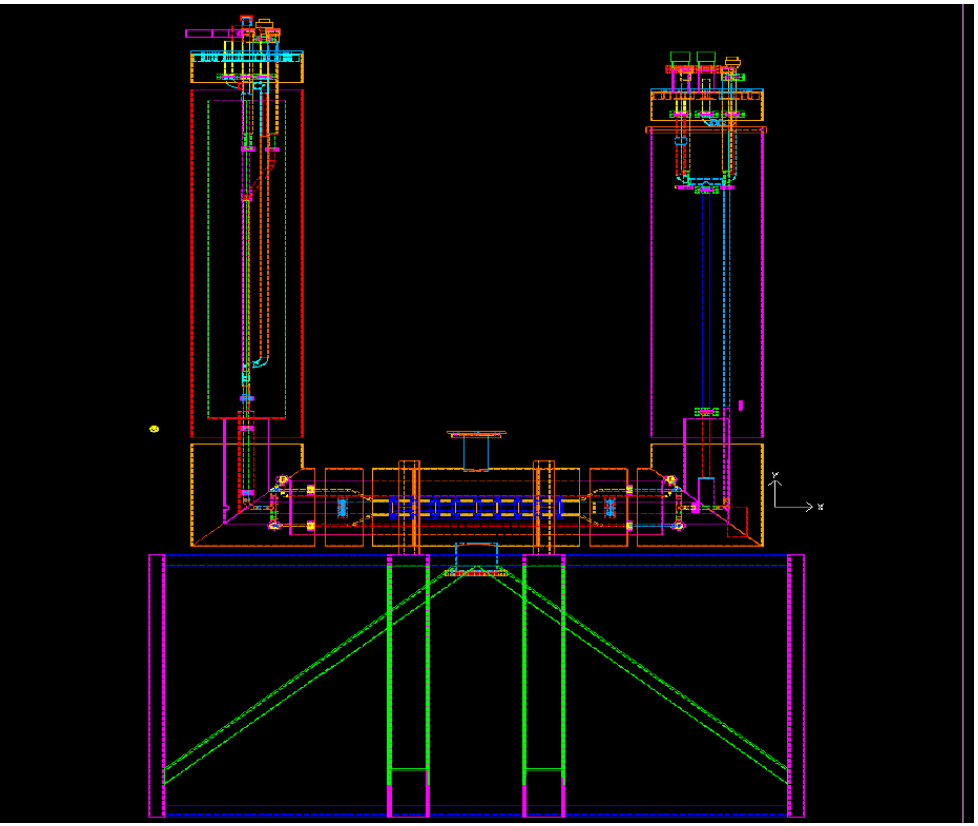
fewer volume changes than simple mixing model will achieve a given reduction in air concentration.



tank volume = 157 cf
tank cross section = 19 sf
flow rate ~ 73.2 cf/h climb rate ~ 3.8 f/h



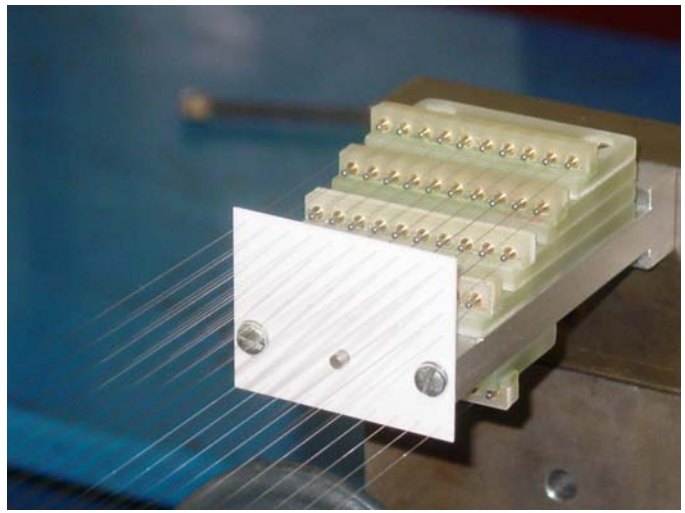
to 100 ppm (reduction of 2,000) takes 6 hrs = 2.6 volume changes
(cf simple mixing, which predicts ln(2000) = 7.6 volume changes)

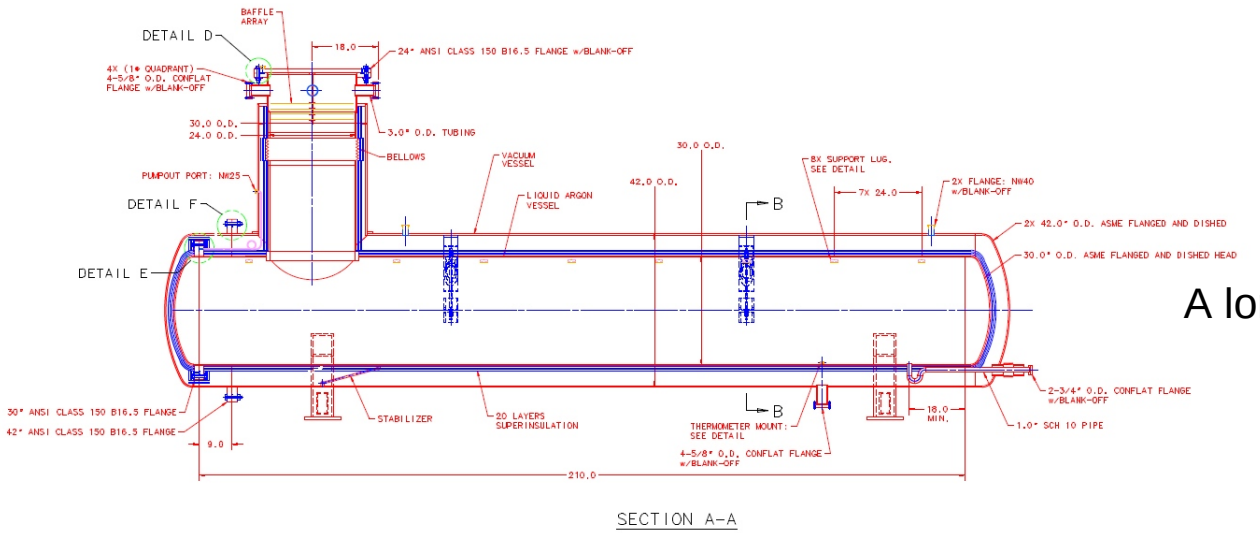


Other work

Long wire tests (ultimately in a LN_2 vessel)

A first setup in air of 20 meter long wires to study noise (microphonics) and have a first stab at electronics.





A long (>5 meter) drift test


Thank you and good bye