towards a Multi kton Liquid Argon Detector for the NuMI Beam

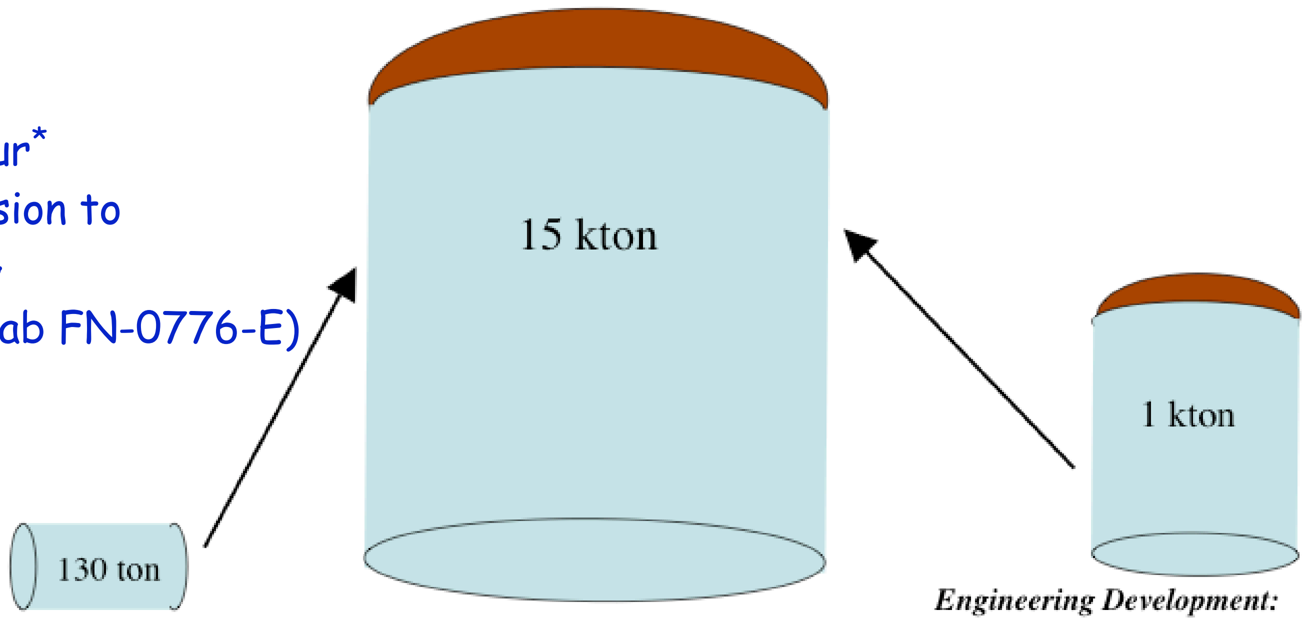
Fermilab, Michigan State, Princeton, Tufts, UCLA, Yale, York (Canada)

R & D Strategy

present work at Fermilab

towards a Multi kton Liquid Argon Detector for the NuMI Beam - R & D Strategy

from our*
submission to
NuSAG
(Fermilab FN-0776-E)



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**

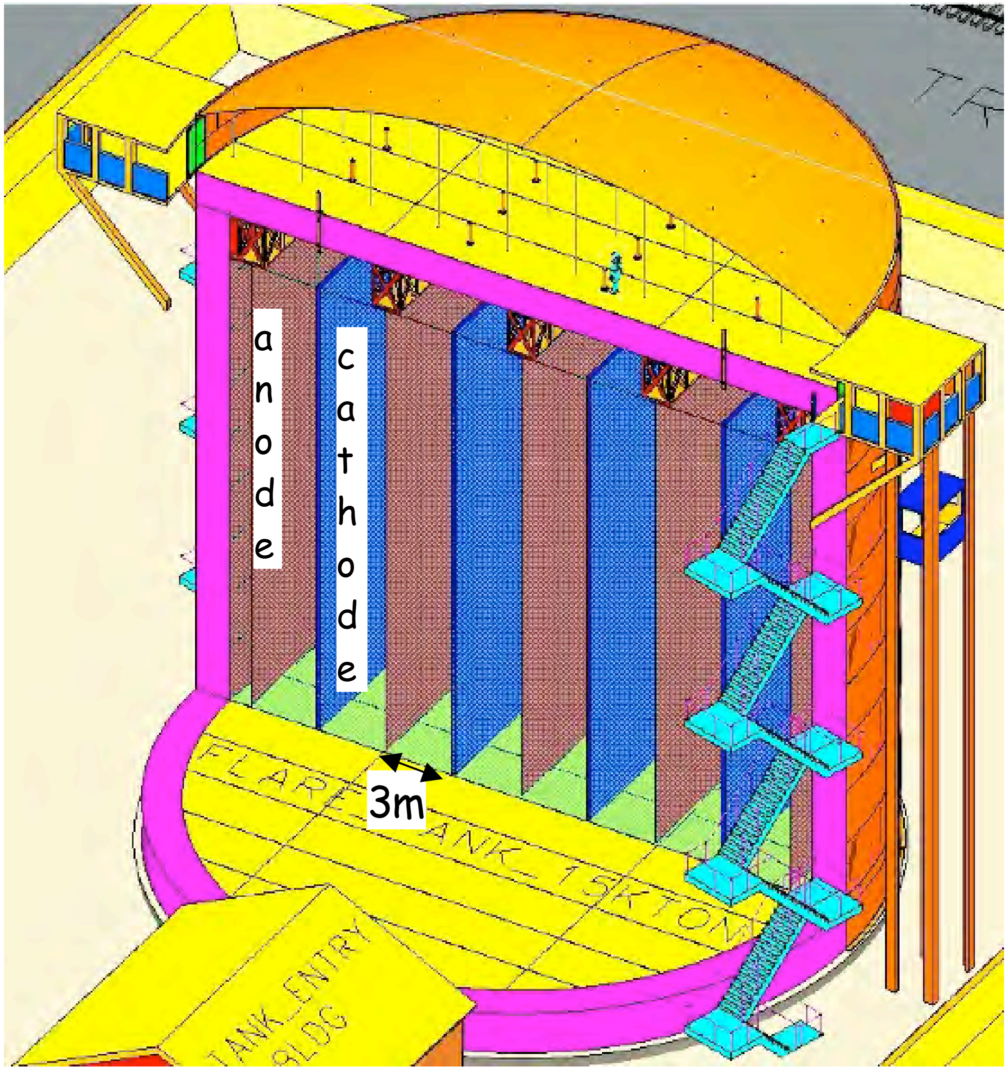
Engineering Development:
Construction of Tank
Argon Purity
Mechanical Integrity of TPC
Readout S/N
Microphonics due to Argon Flow

Technical Setups

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

* = Fermilab, Michigan State, Princeton, Tufts, UCLA, Yale, York (Canada)

towards a Multi kton Liquid Argon Detector for the NuMI Beam - R & D Strategy



concept of detector

based on LNG tank

long wires

long drift

start from atmosphere

towards a Multi kton Liquid Argon Detector for the NuMI Beam - R & D Strategy

Physics Development *using* ***existing*** *technology*
Record **complete neutrino interactions**: (ν_e & ν_μ)
Establish **Physics Collaboration**
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Develop **Reconstruction**,
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Emphasis to develop `physics analysis capabilities' on a unique sample of neutrino interactions:

B. Fleming will discuss in detail.

Technically state-of-the-art -
- can act as test-bed for technical developments but not the primary focus

towards a Multi kton Liquid Argon Detector for the NuMI Beam - R & D Strategy

Engineering Development:
Construction of Tank
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Microphonics due to Argon Flow

Emphasis on learning about and demonstrating we can resolve issues of large tank -beyond s.o.t.a

Appropriate scale is not certain (0.5 kton to ?)

Essential demonstration? at what scale?

Does such a device need a `physics' program?

towards a Multi kton Liquid Argon Detector for the NuMI Beam - R & D Strategy

Technical Setups

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Specific identifiable topics where we (outside ICARUS) need to gain experience, establish infrastructure and approach issues relevant to large tank.

towards a Multi kton Liquid Argon Detector for the NuMI Beam - at Universities

Electronics for small systems - Michigan State

Event Analysis and identification - Tufts

Purity and small chamber study - Yale
Event Reconstruction -Yale

LAr into the GLoBeS framework - York

towards a Multi kton Liquid Argon Detector for the NuMI Beam - at Fermilab

Fermilab Resources: ~ 4 physicists, 3.5 engineers, lead-technician, technicians

embedded in Lab: vacuum deposition (photocathodes)
wire plane fabrication (PrM grids and small chamber)
ANSYS analysis,
mechanical and electrical design and fabrication

Budget for materials: $100,000/year for this and next 2 years (severe limitation)

Status of work on Argon purity and plans for contamination studies.
Status of Mechanical tests on wires.
Status of Electronics and Electrical issues studies.
State of Mechanical Design for the large tank.

Rich. Schmitt will discuss plans & studies on purging large vessels.

Some of the important issues not under study :

Cosmic rejection - fundamental: effects on physics,
logistical: automated pattern recognition

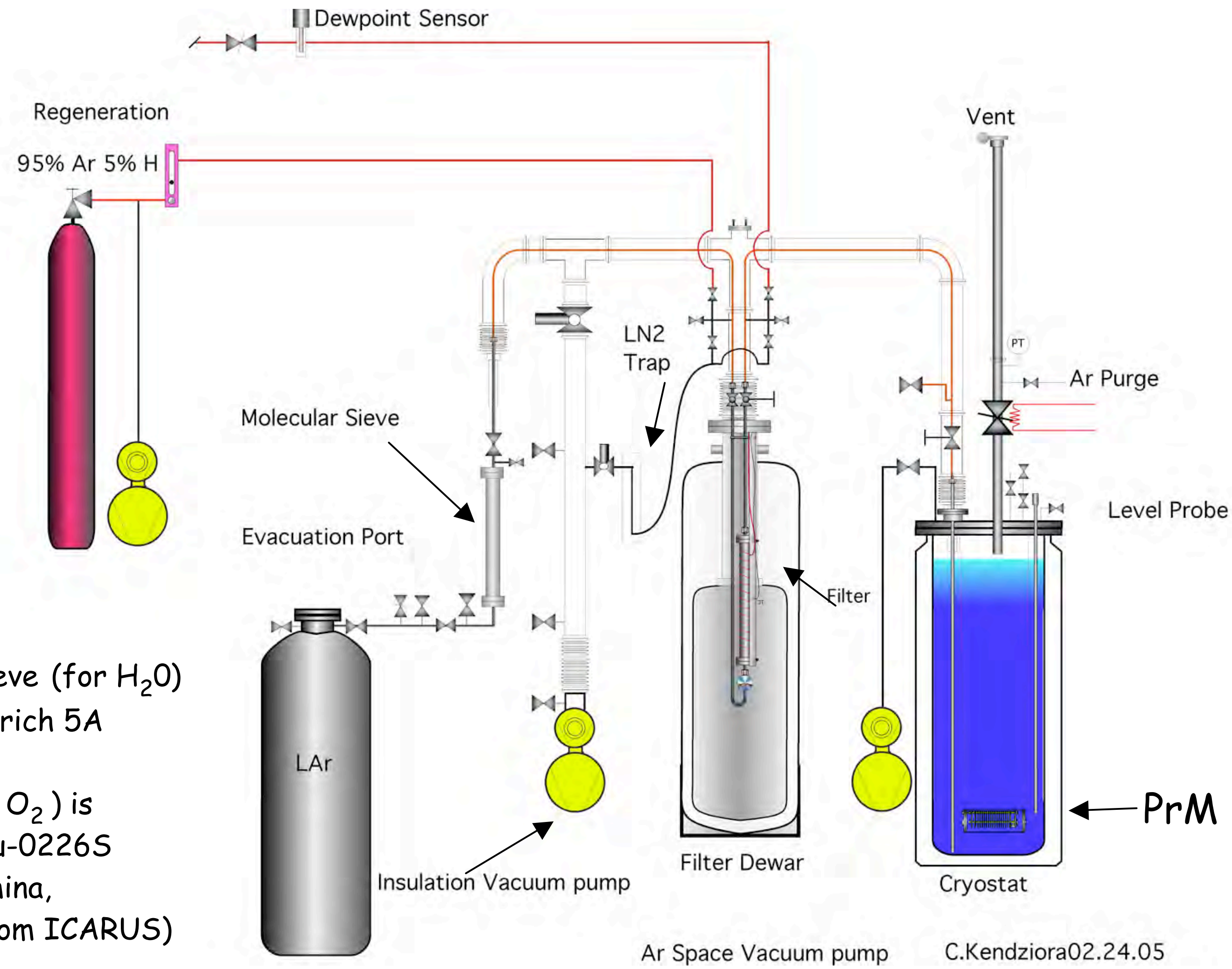
Electronics development - electronics nearer the wires (in cold)

Baseline Model

Maintain open attitude to novel technologies

Argon purity studies

Single Pass Liquid Argon Purification System Schematic

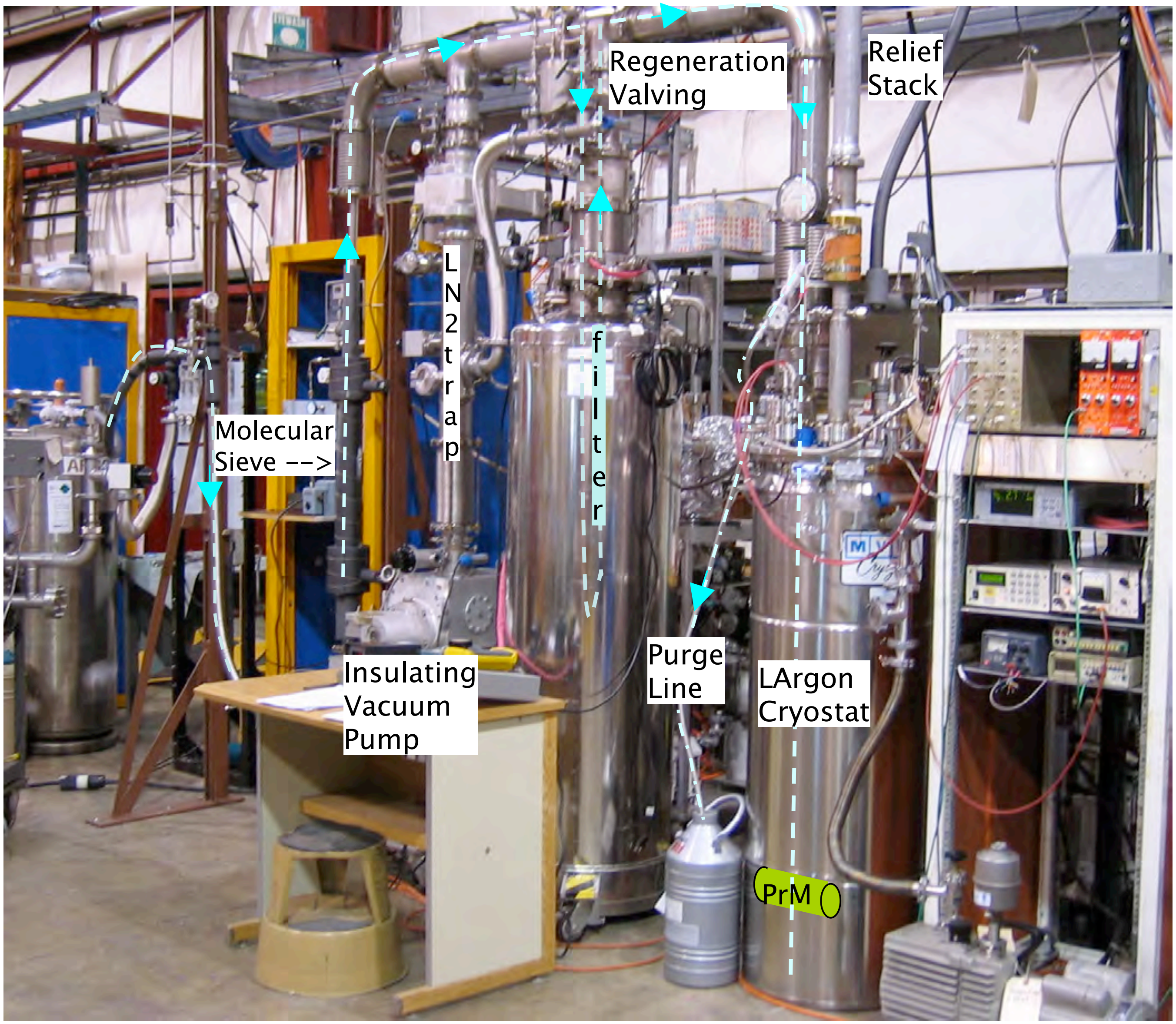


Molecular sieve (for H_2O) is Sigma-Aldrich 5A

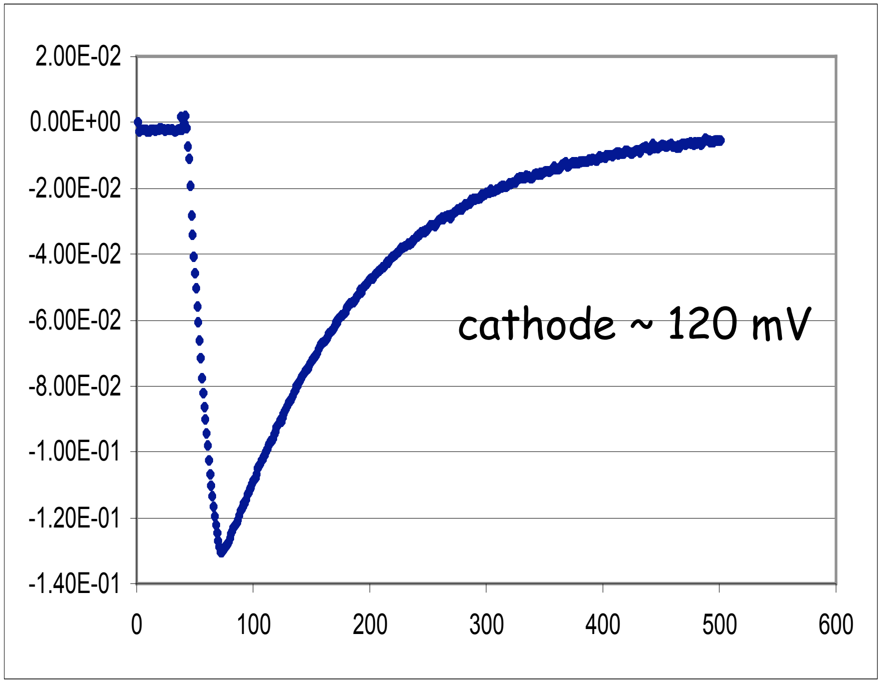
`Filter' (for O_2) is Engelhard Cu-0226S (CuO on alumina, different from ICARUS)

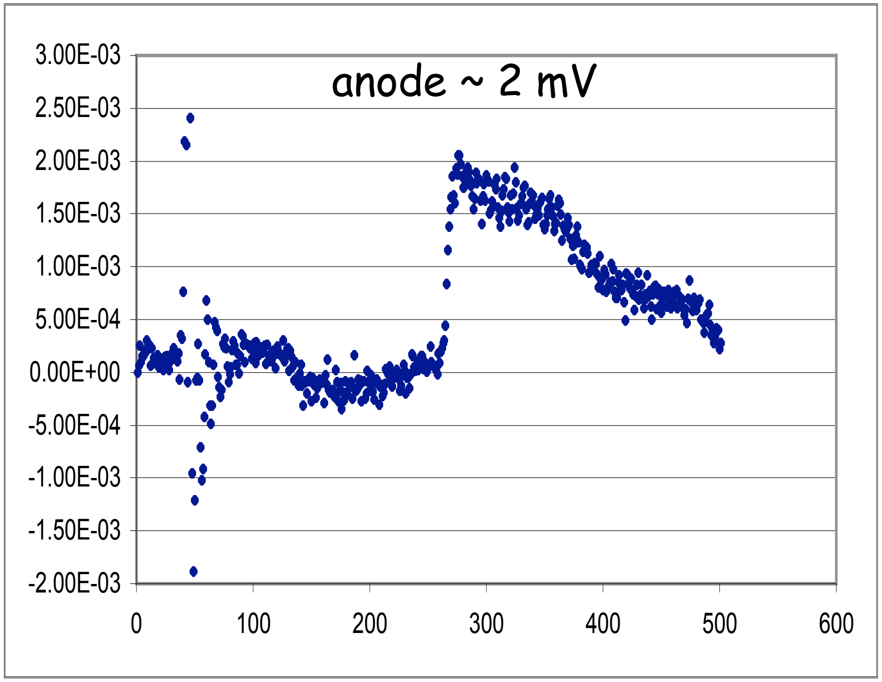
Argon purity studies

Single Pass Filtering System at PAB



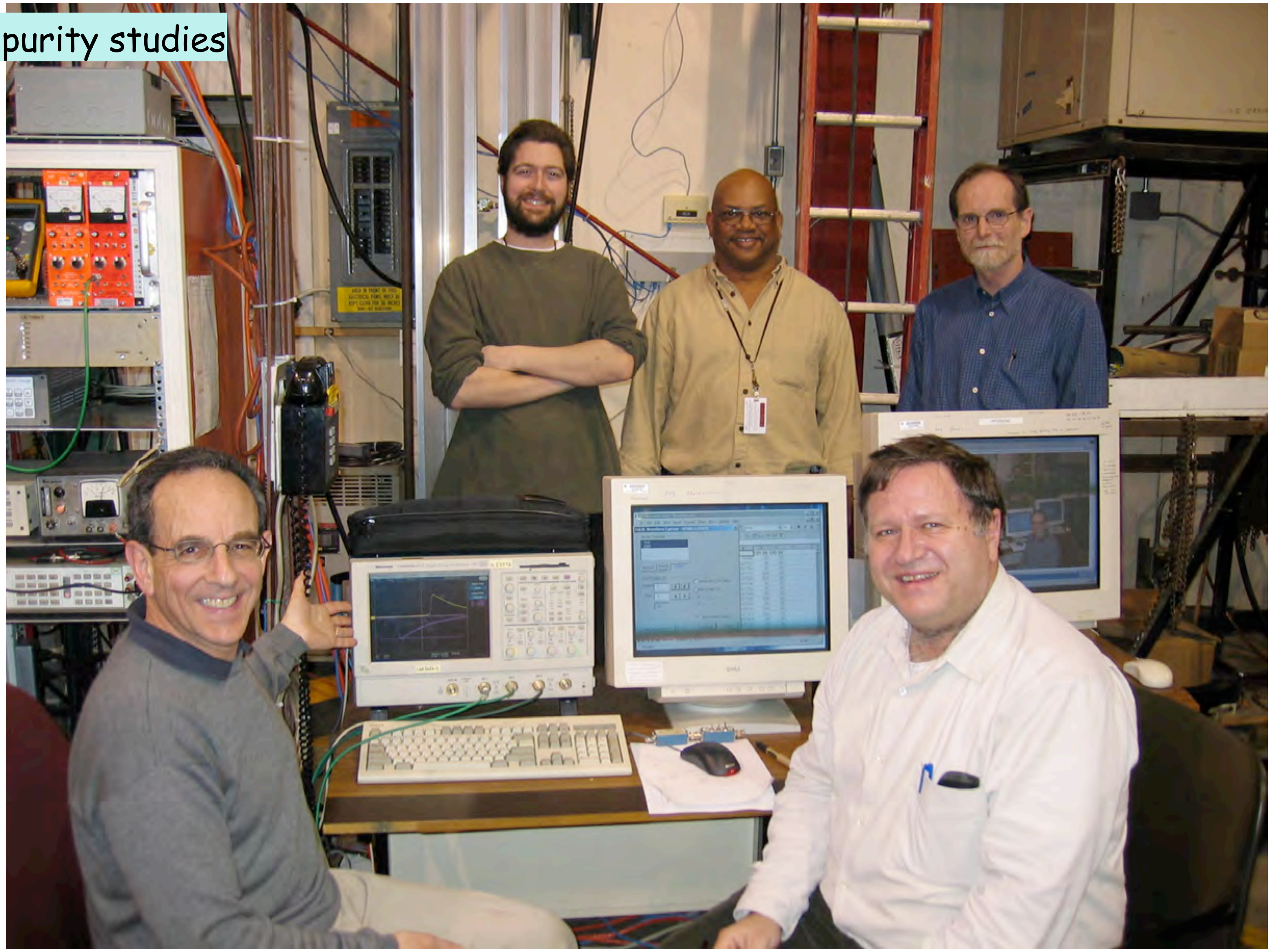
Argon purity studies





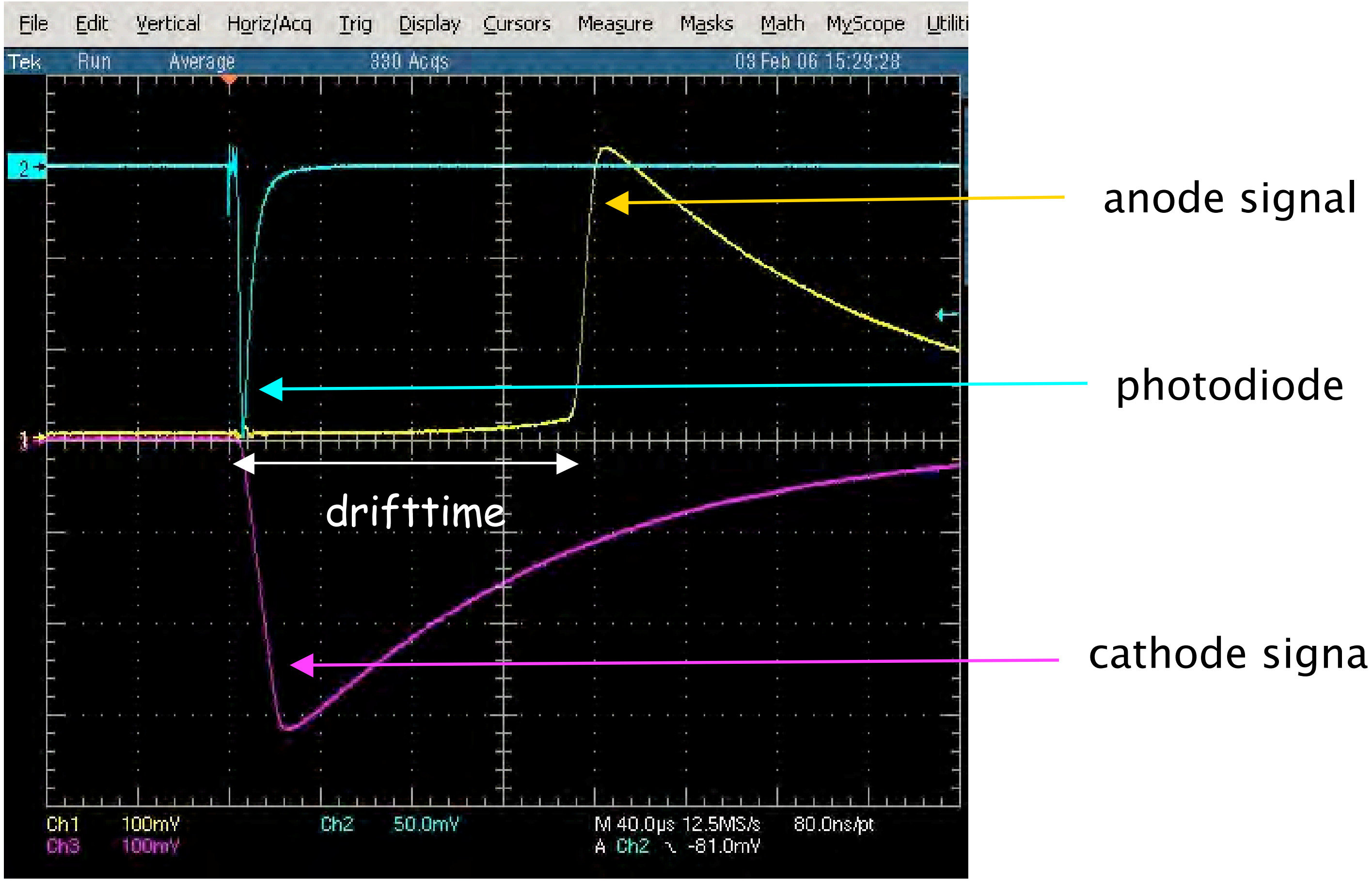
First Anode Signal of any sort (tiny) from Purity Monitor January 27th 2006

Argon purity studies



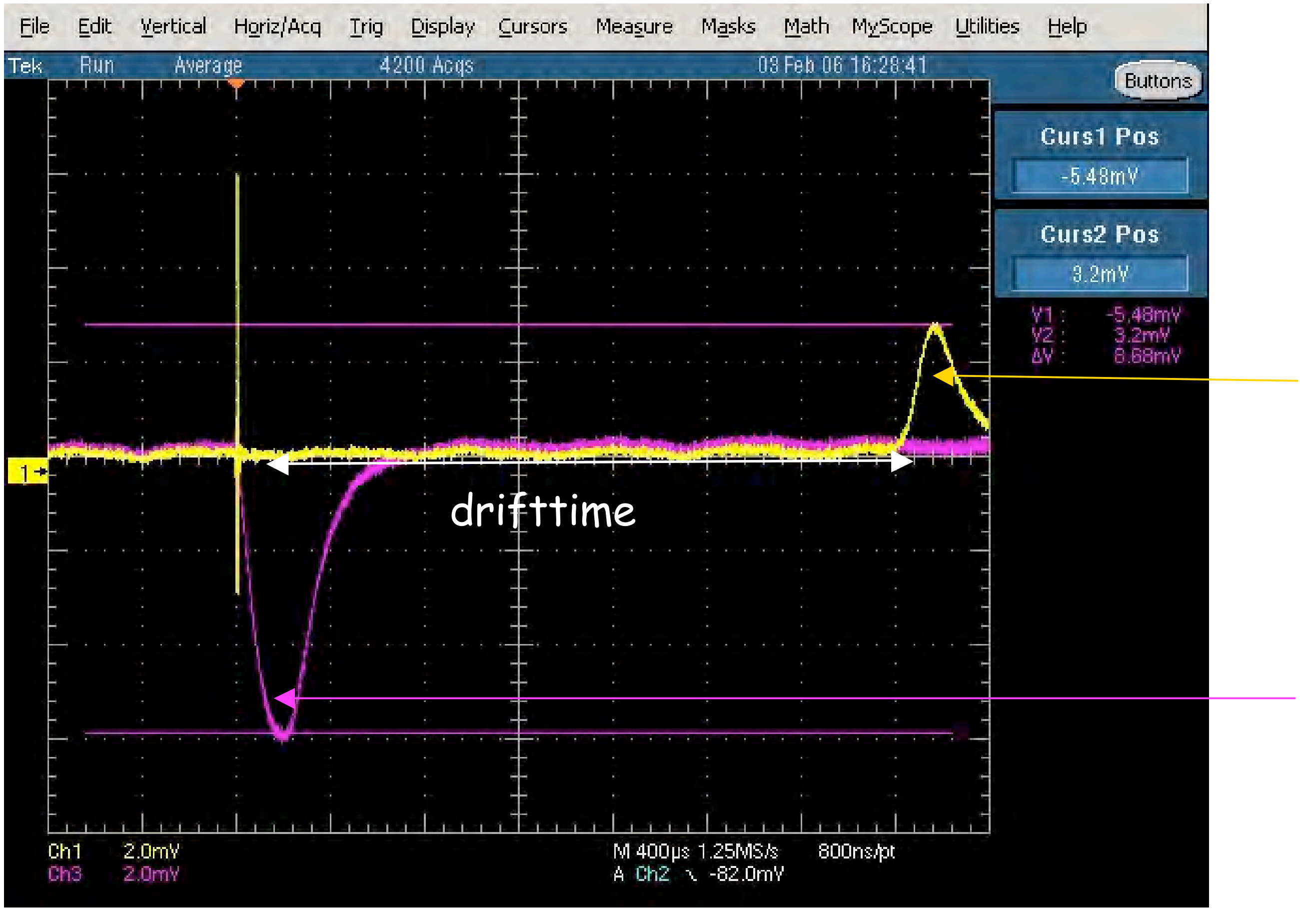
why are these people smiling?

Argon purity studies



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

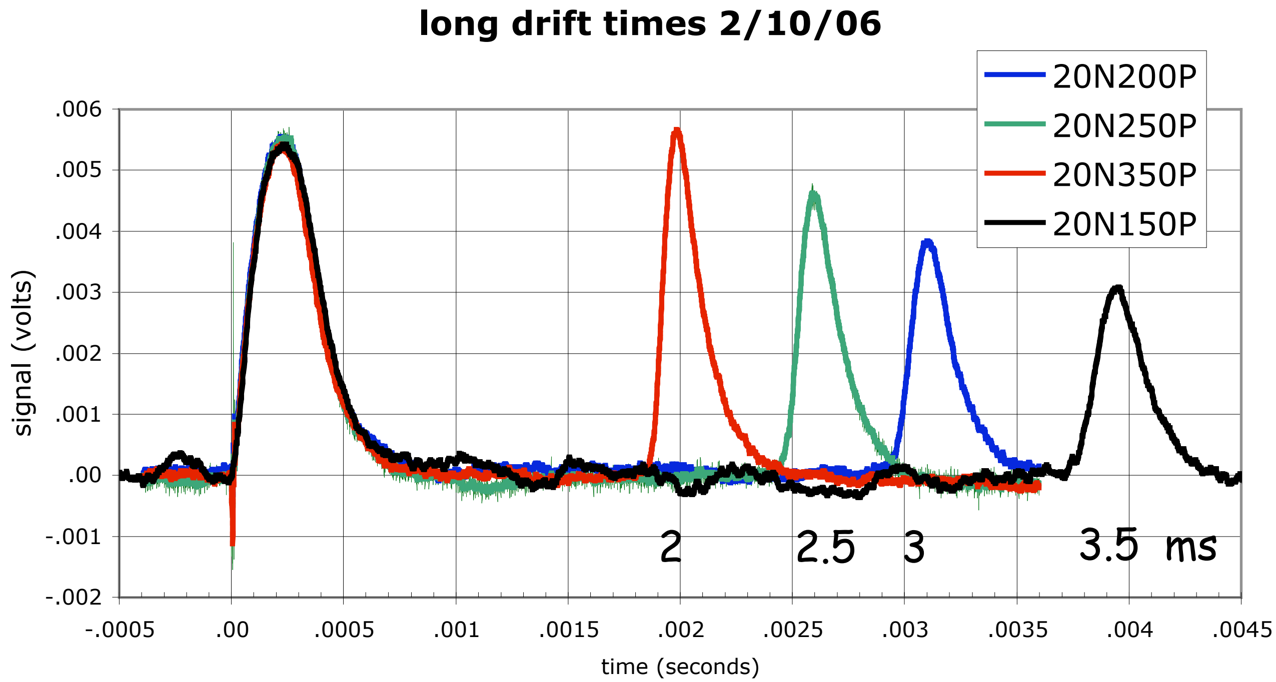
Argon purity studies



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

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

Argon purity studies

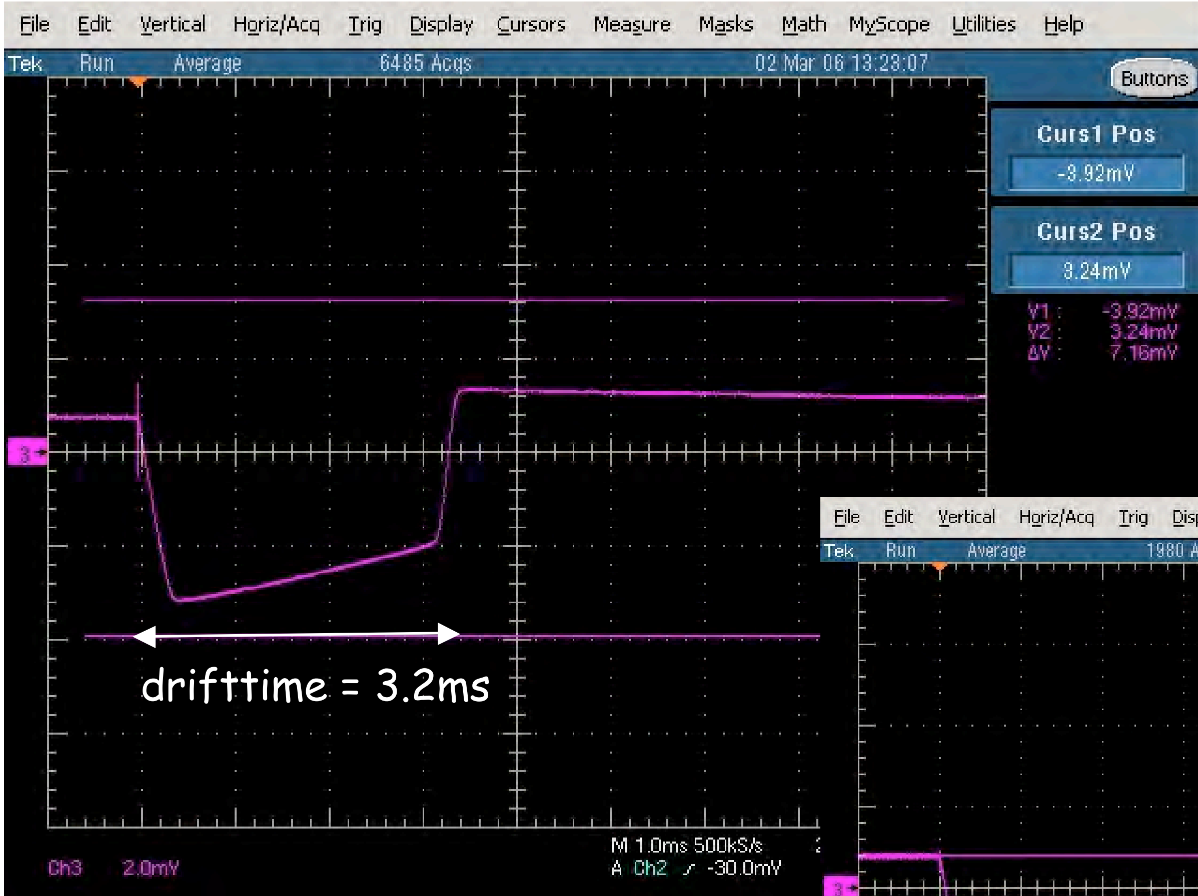


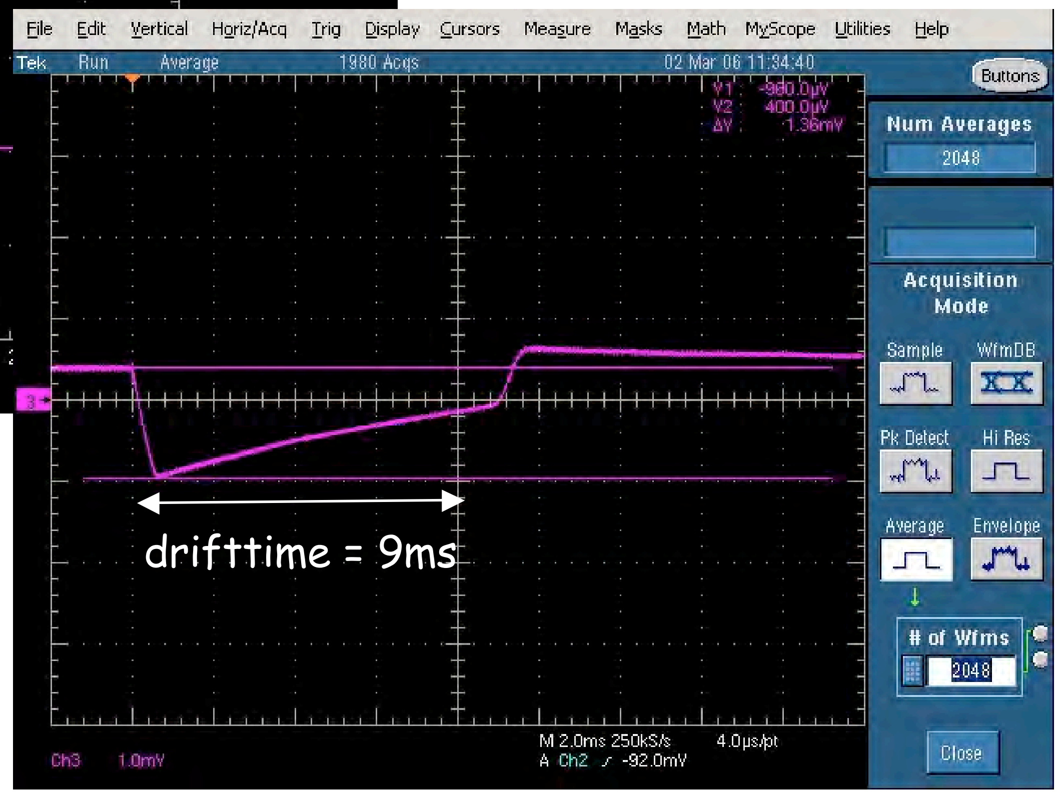
a plot of long drift times from another run a week later with fresh argon.

The cathode signal is affected by the (too short) decay time of the integrator - the anode signals can be used to derive a lifetime.

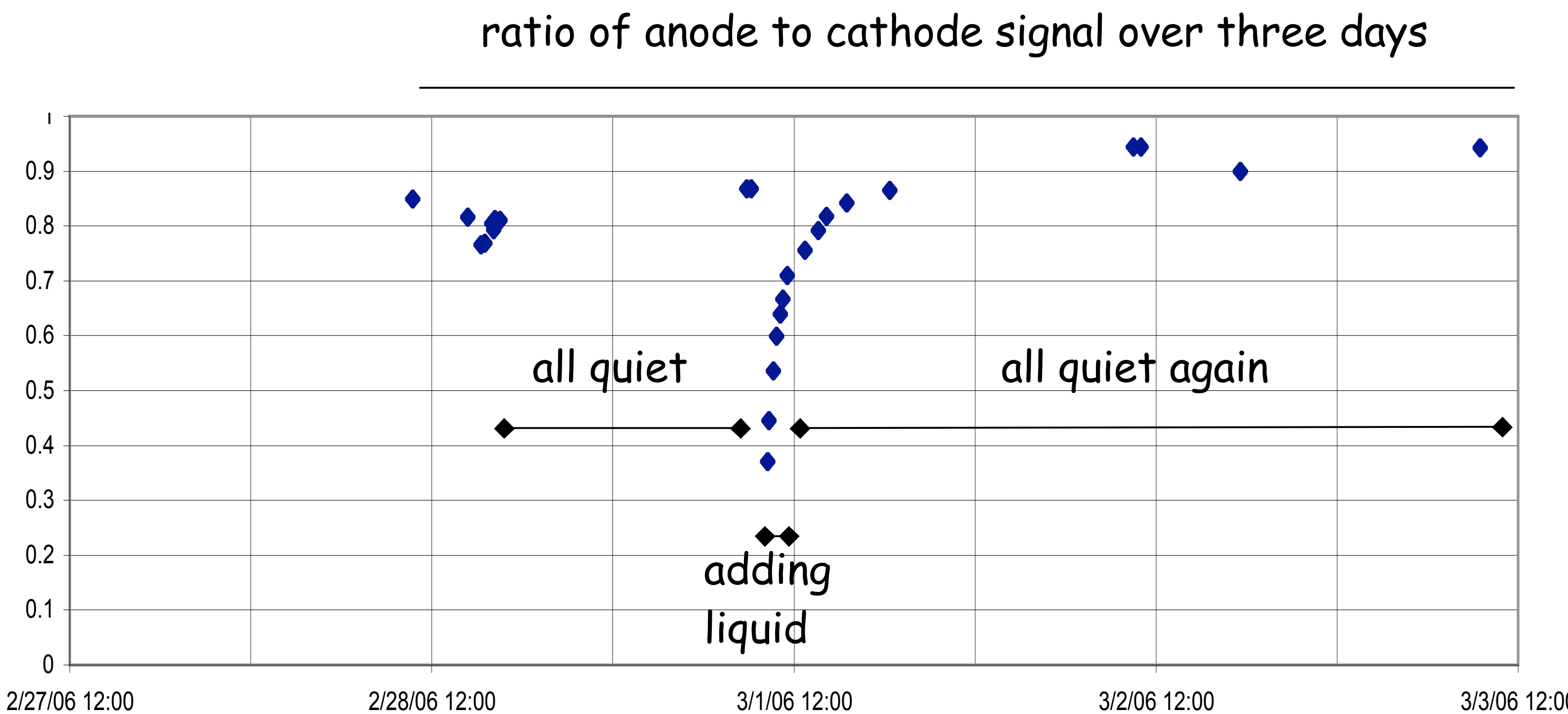
Argon purity studies

now with appropriate decay-time electronics

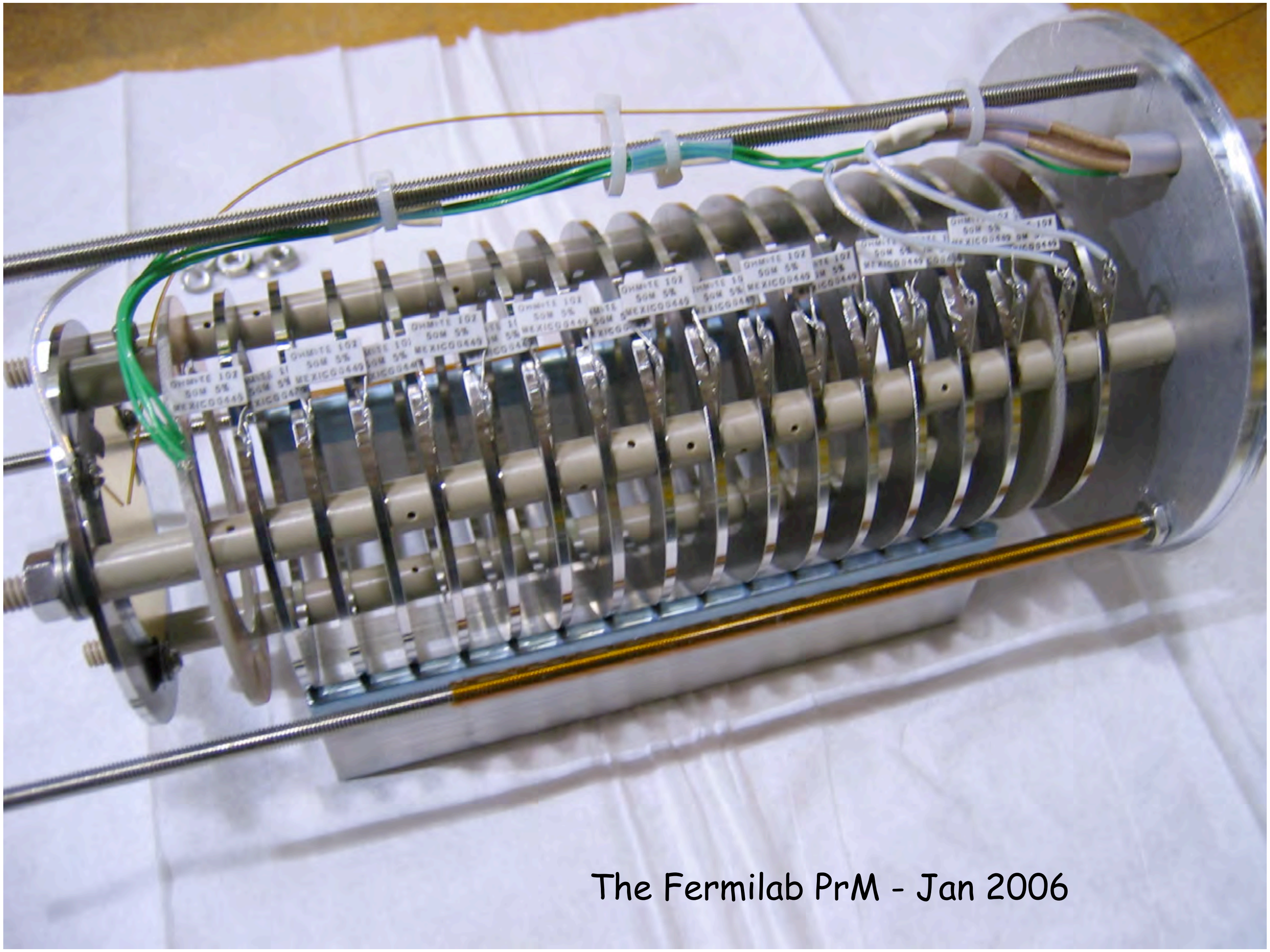




Argon purity studies



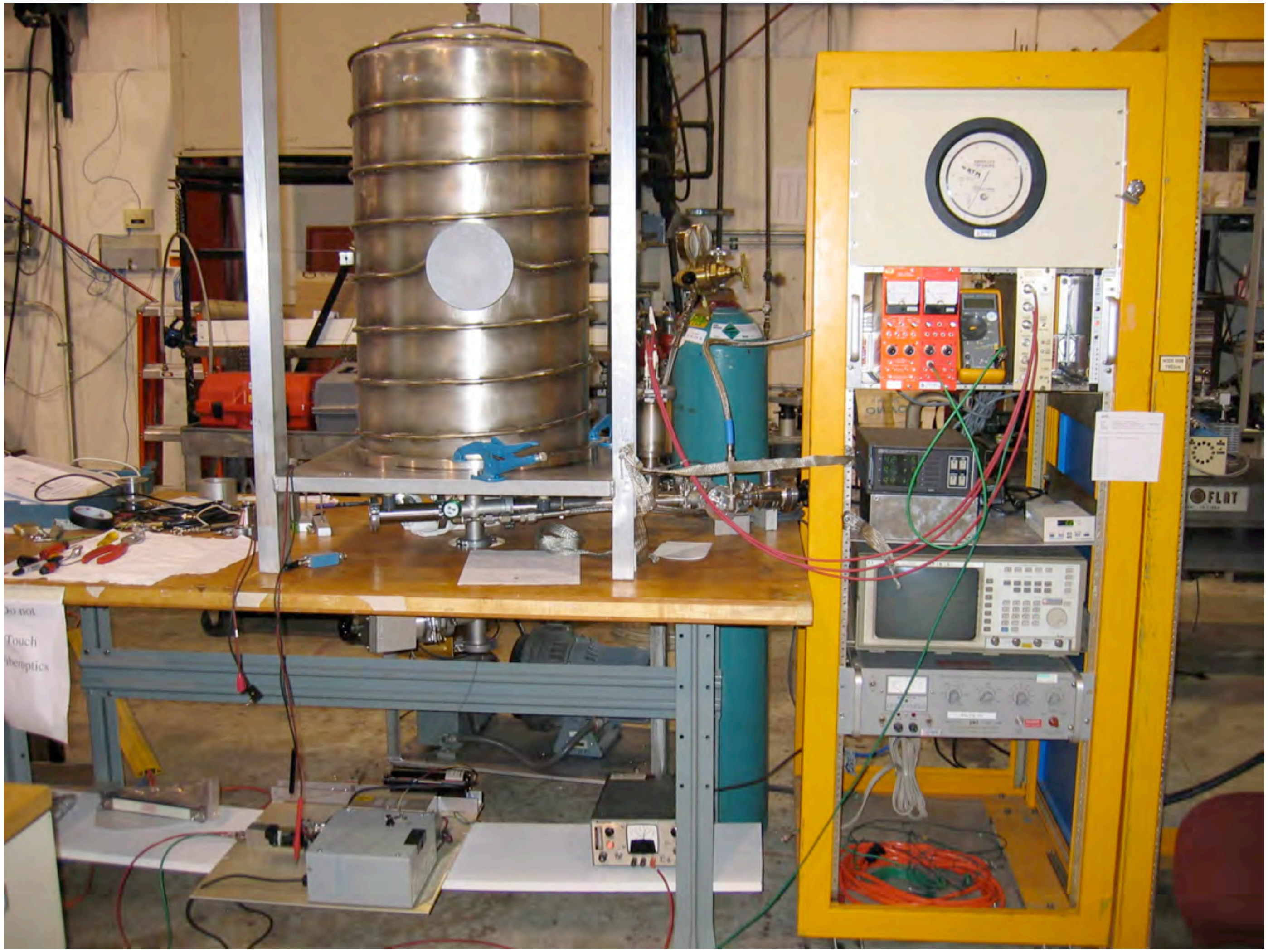
there is a transient deterioration from disturbing the liquid, short-term recovery and a possible long-term improvement.



The Fermilab PrM - Jan 2006

Argon purity studies

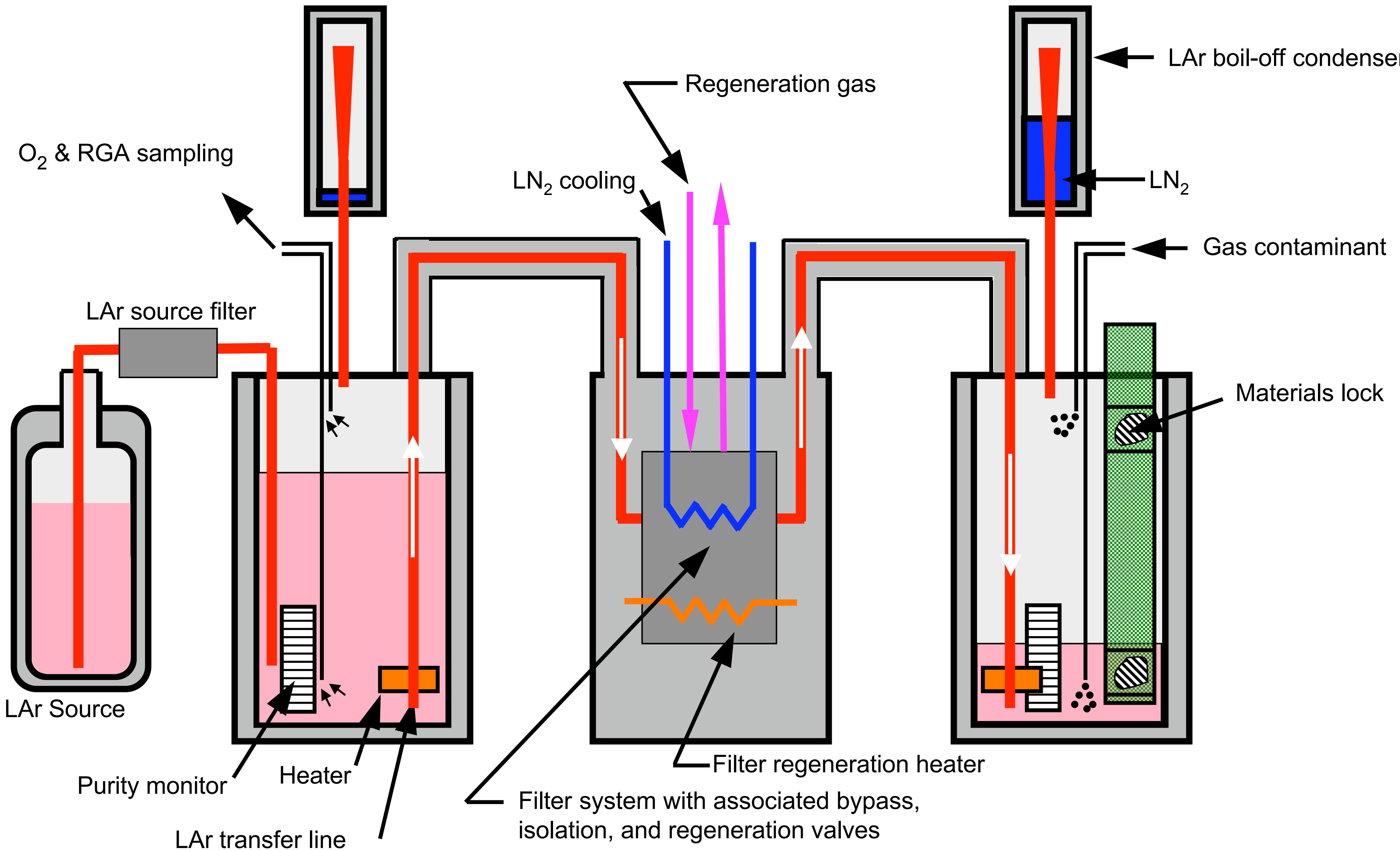
Belljar setup for testing PrM systems in gas



used for evaluating photo-cathodes, wiring schemes, HV connectors, light-pulsers

Argon purity studies

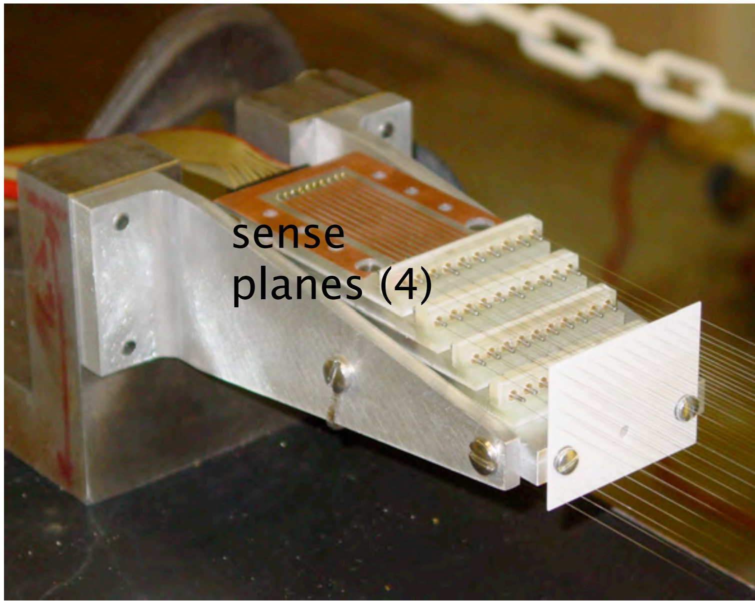
PAB Argon Purity Development Station - Phase 2 Schematic (T. Tope)



PAB Argon Purity Development Station Features

- Closed system after initial LAr charge
  - LN_2 heat exchangers condense LAr boiloff
  - Heaters create pressure to move LAr back and forth thru filter
  - Isolation valves allow individual cryostat separation
  - Filters can be regenerated in place, bypassed, and isolated
- Stainless Steel Construction
  - Top flange with double o-ring groove and seal monitoring port
  - All metal seals except for relief valve o-ring which is purged with GAr
  - System evacuated to 10^{-6} Torr with dry turbo before filling (no baking)
- Purity instrumentation
  - Purity monitor(s) in each cryostat
  - Capillary tubing for gas and liquid sampling with O_2 (75 ppt LDL) and RGA analyzers
- Purity testing
  - Capillary tubing introduces gas contamination into both liquid and vapor
    - N_2 and H_2O are of particular interest
  - Material lock places solid contamination into both liquid and vapor
    - Qualify materials for large tank construction
    - Material lock will be purged not evacuated once material is inserted

long wire studies - just starting

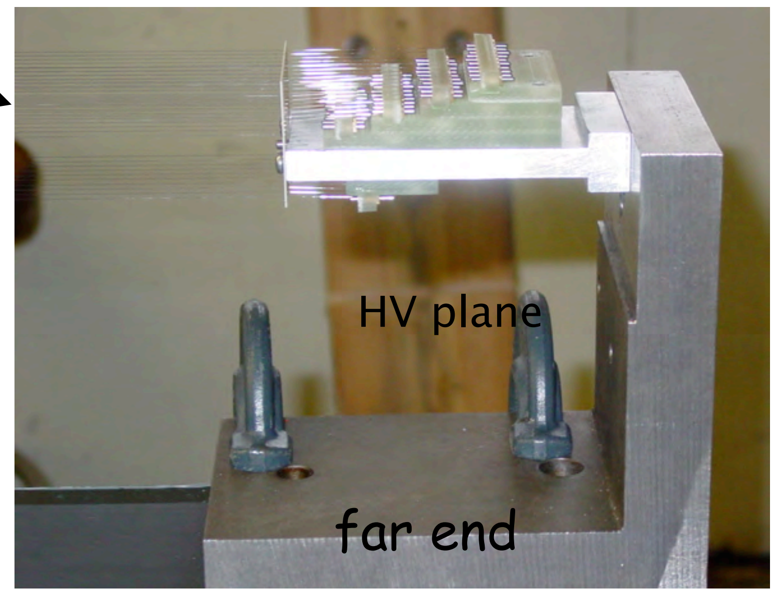


near end

We have setup to learn, check on, remind ourselves of the electrical implications of long wires - resistances, stability under HV, cross talk.

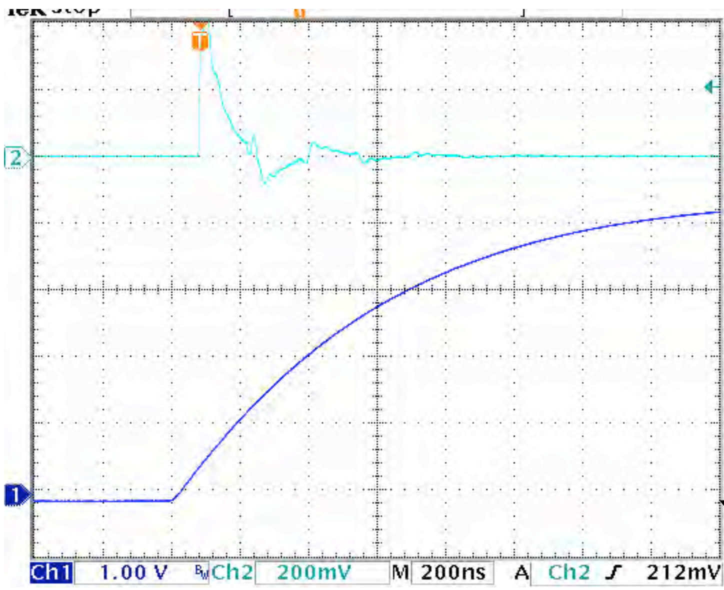
The wires are ~18 meters long arranged in
4 `signal' planes (10 wires/plane, 5mm spacing)
and 1 `HV' plane

18 m



the wires are held by a tapered pin in a tapered hole and position by a ceramic plate with precision holes

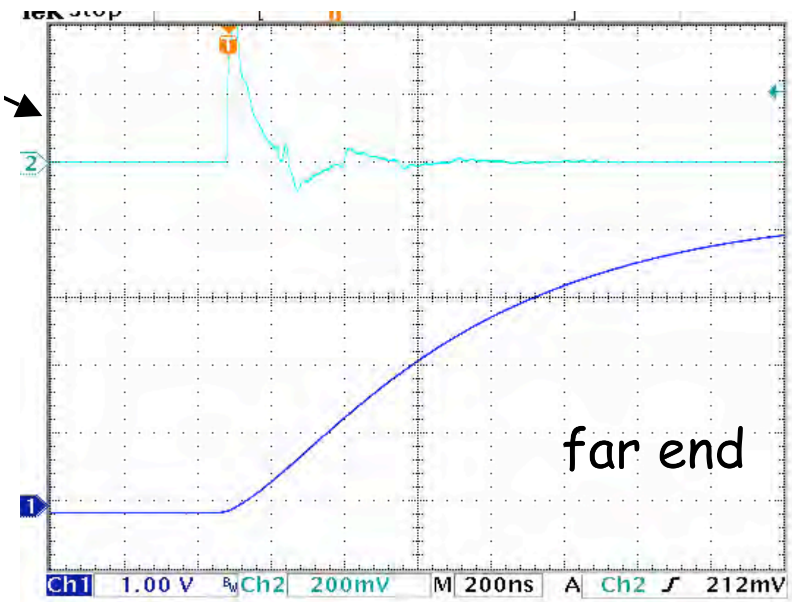
long wire studies - just starting



near end

will measure position-along-wire effects, cross talk and HV stability

18 m



response from near (left) and far (below) to pulsing; far is later and has slower rise

Mechanical Design of Tank - 50 kton for cost development

Important strategy choice - how to treat wires

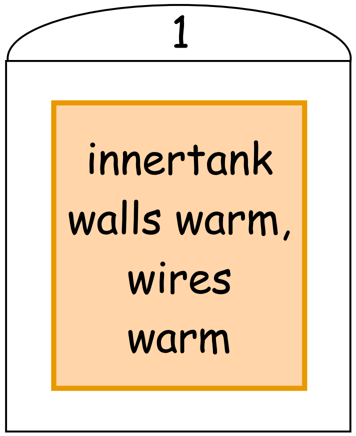
Abandon individual weights (very complicated)

Assume wires **fixed** to bottom and top of argon tank..

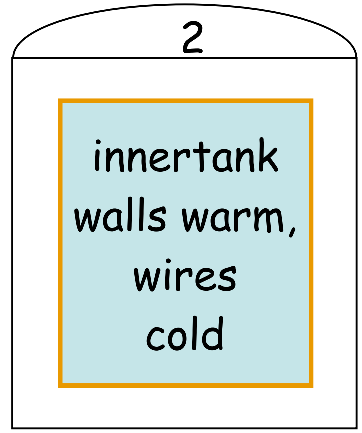
What takes the load of the wires? will the wires survive cool-down?

The dome of the outer tank may be an attractive possibility

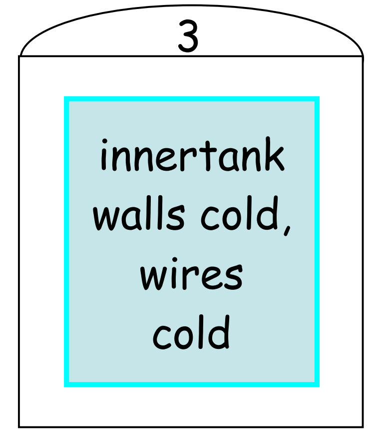
Mechanical Design Study

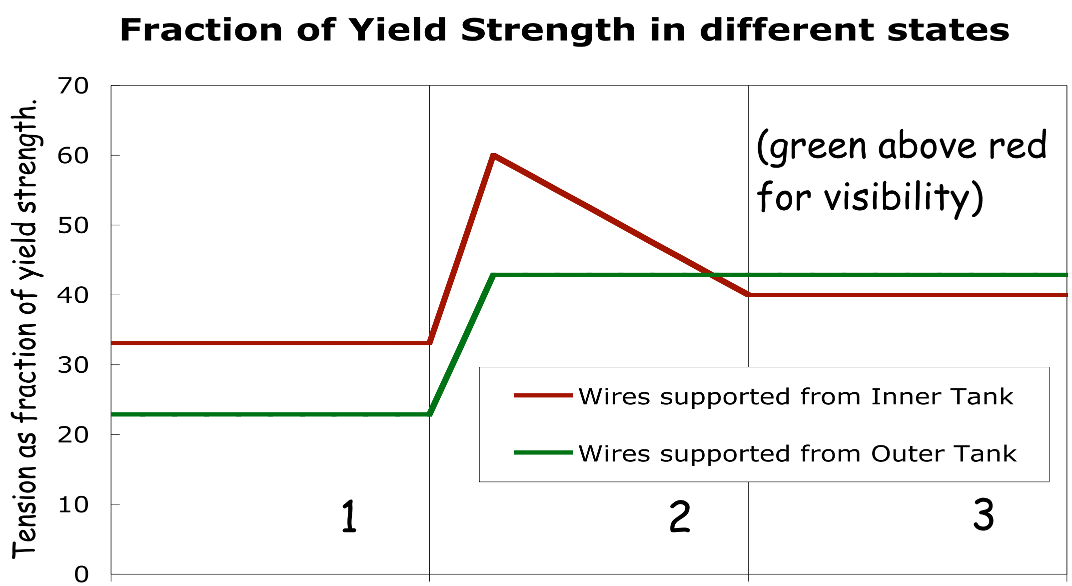


introducing the first amount of cold gas will cool the wires, but not the inner tank.



when full both the inner tank and the wires will be cold

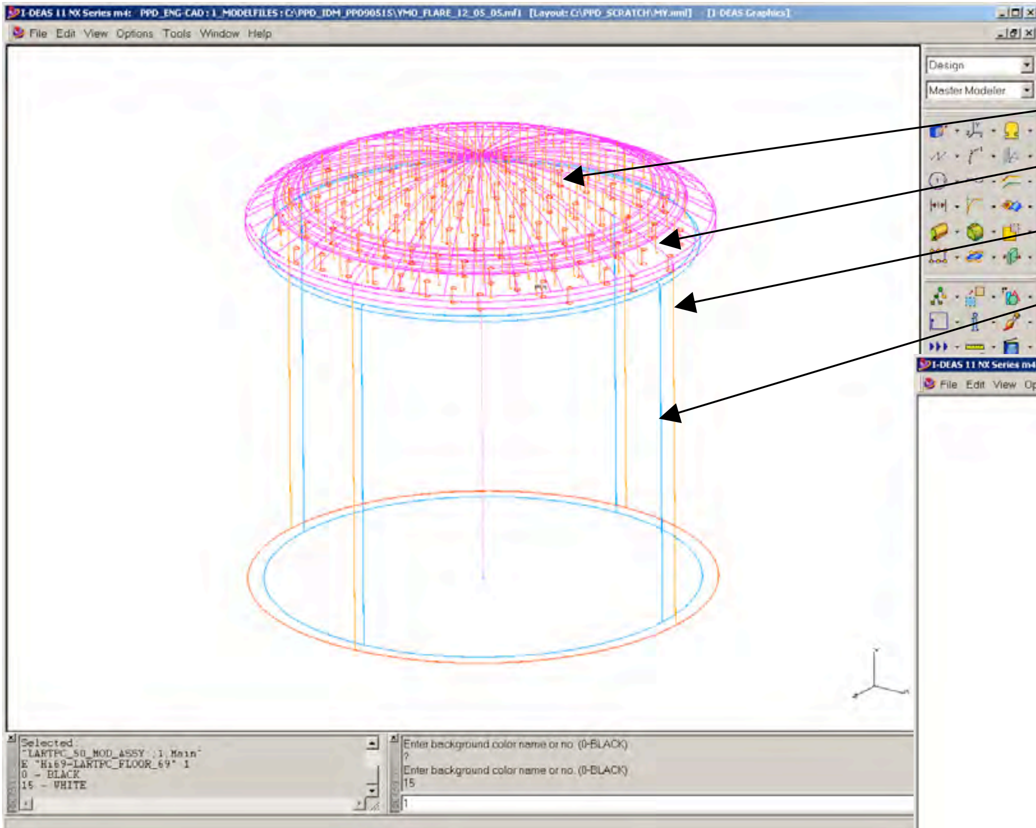




operating tension ~ 0.5 kg on 100 micron wire: gives ~0.4 mm max. shift

Mechanical Design Study

50kT parametric I-DEAS 11 model

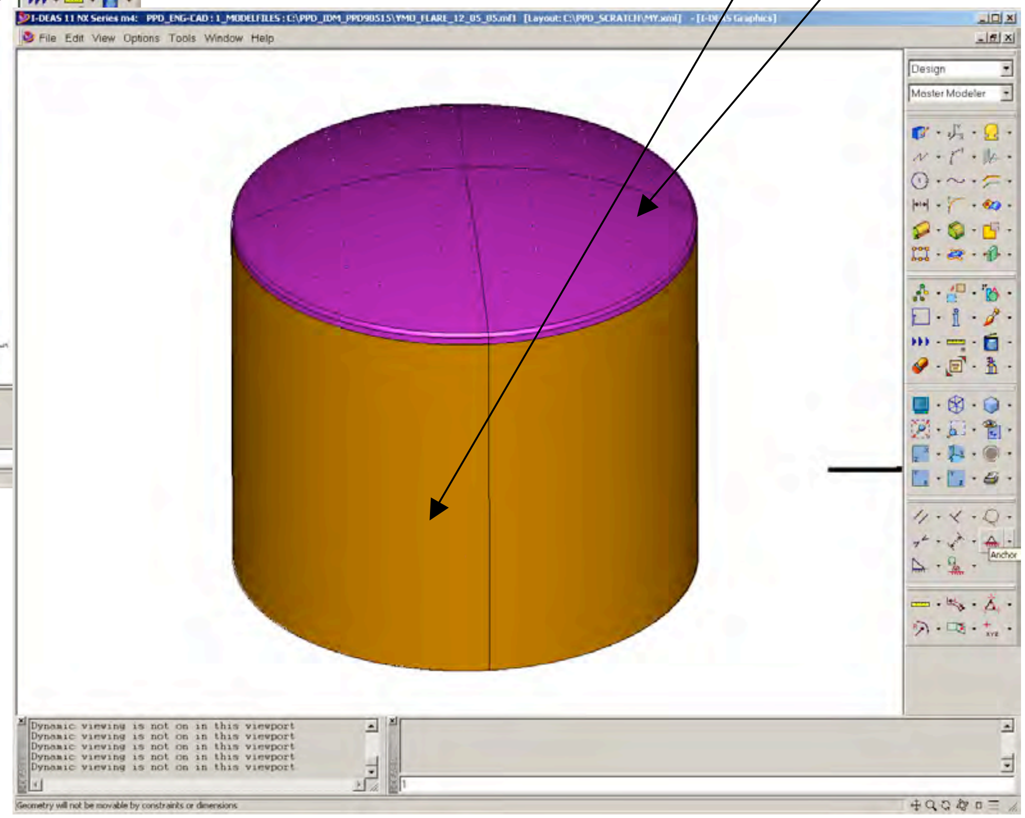


Dome with support tubes

Warm tank deck (with Chimney)

Warm tank (yellow)

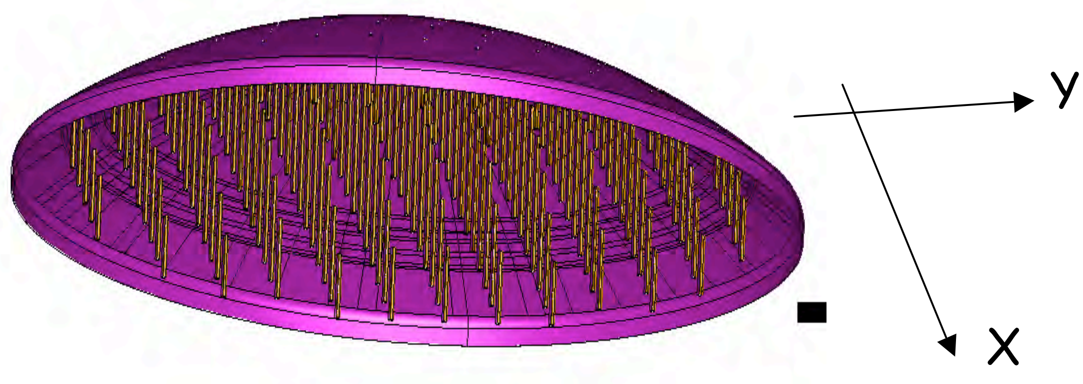
Cold tank (blue)

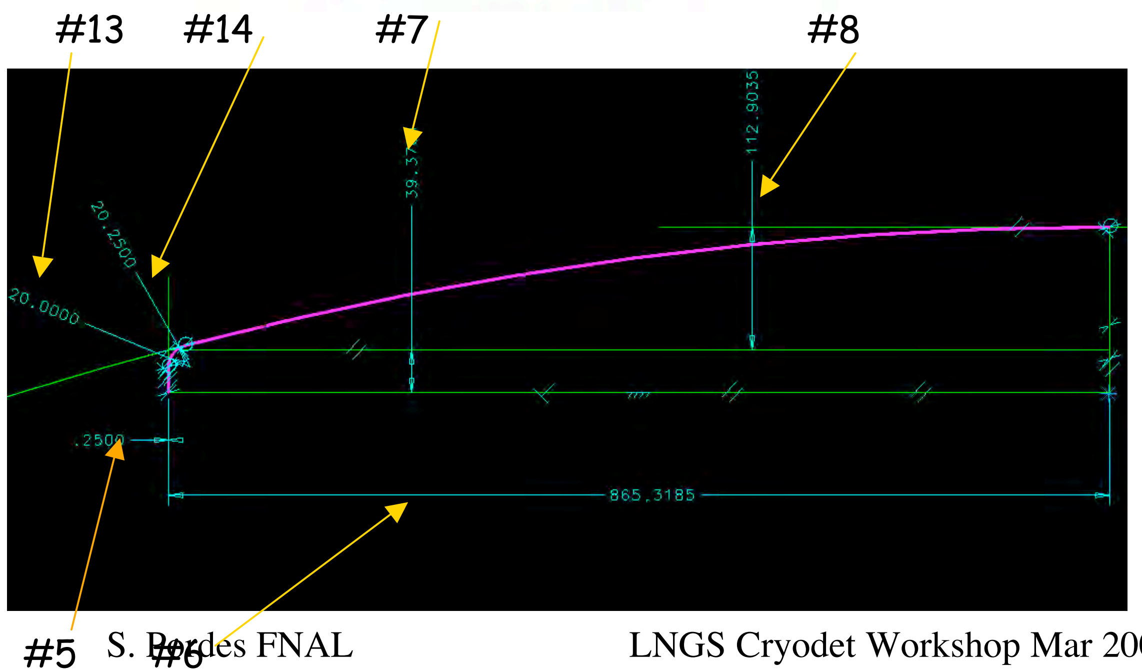


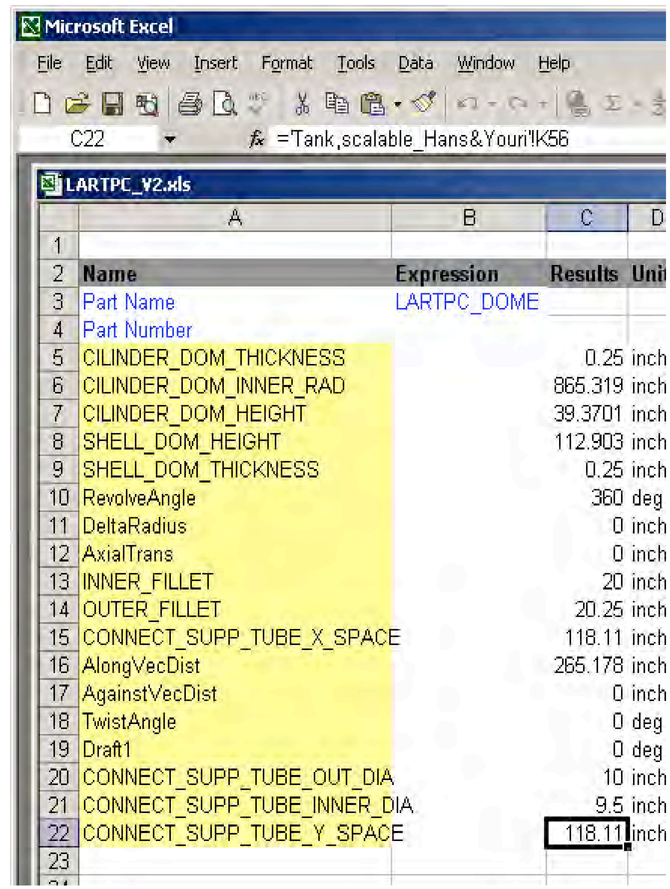
Wires attached to top of inner tank
with fixed attachments
(no weights or springs)

50kT. DOME

input tank parameters into excel spreadsheet -> IDEAS mechanical package







Microsoft Excel

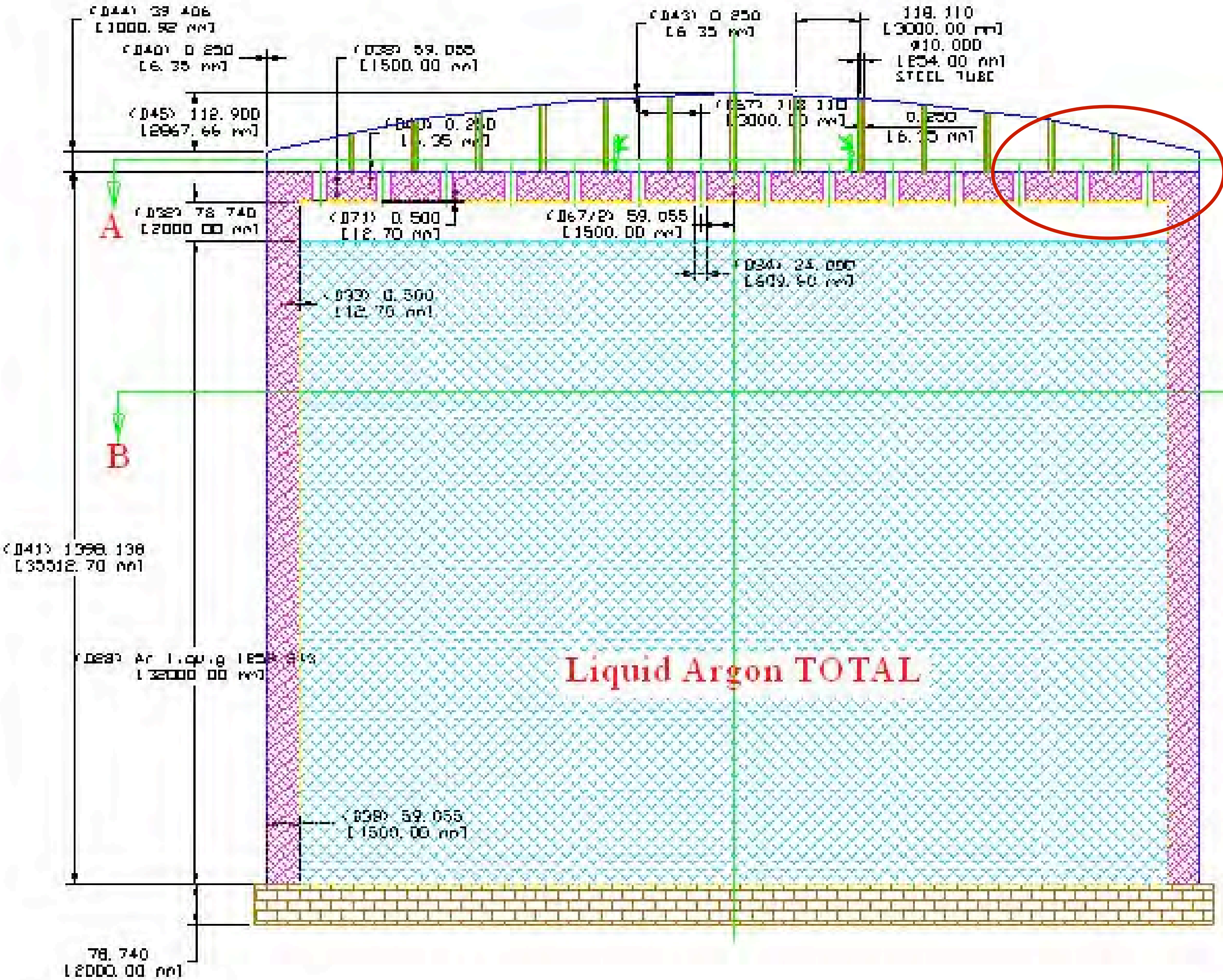
File Edit View Insert Format Tools Data Window Help

C22 =Tank,scalable_Hans&Youri'!K56

LARTPC_V2.xls

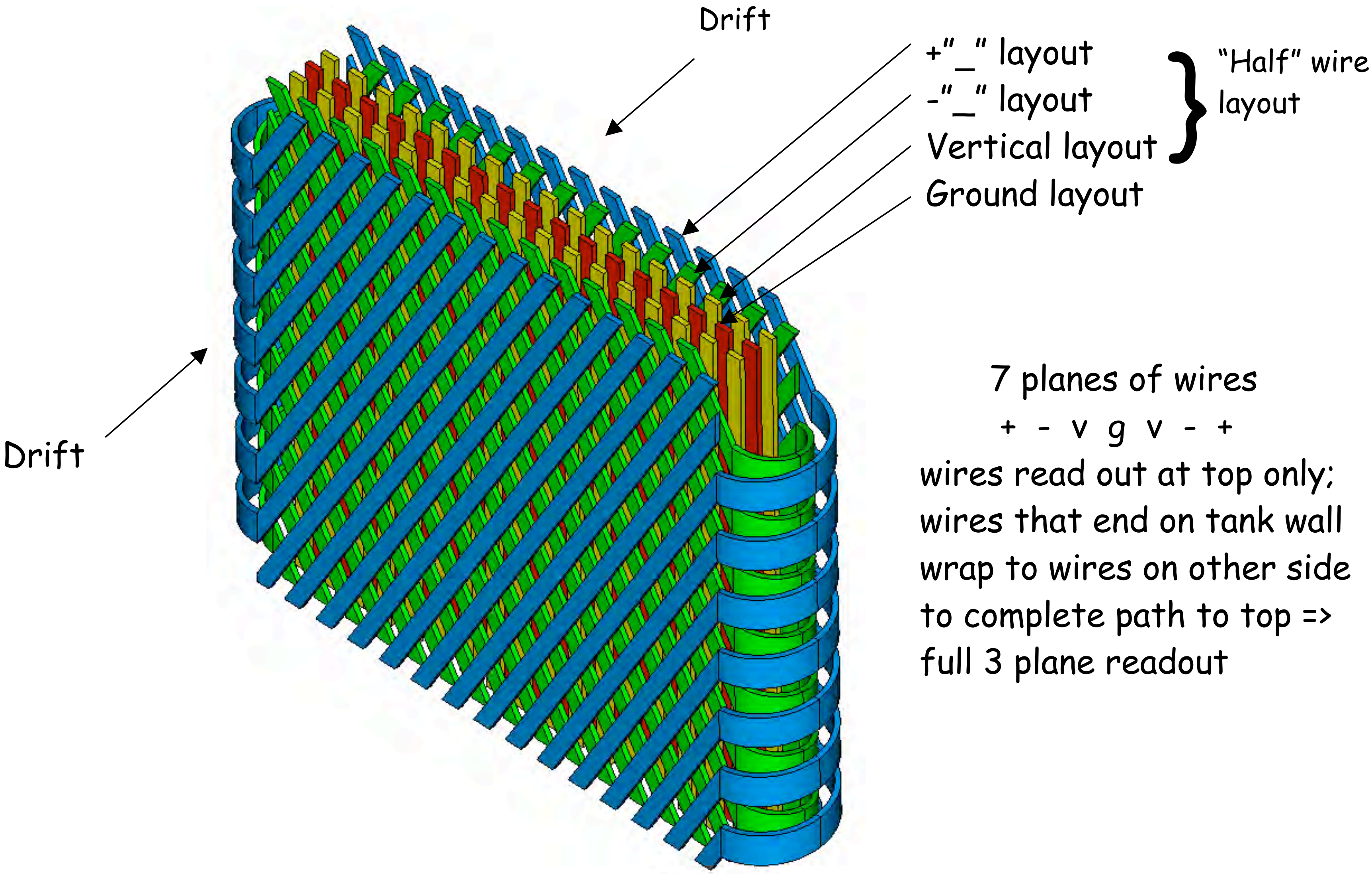
	A	B	C	D
1				
2	Name	Expression	Results	Unit
3	Part Name	LARTPC_DOME		
4	Part Number			
5	CILINDER_DOM_THICKNESS		0.25	inch
6	CILINDER_DOM_INNER_RAD		865.319	inch
7	CILINDER_DOM_HEIGHT		39.3701	inch
8	SHELL_DOM_HEIGHT		112.903	inch
9	SHELL_DOM_THICKNESS		0.25	inch
10	RevolveAngle		360	deg
11	DeltaRadius		0	inch
12	AxialTrans		0	inch
13	INNER_FILLET		20	inch
14	OUTER_FILLET		20.25	inch
15	CONNECT_SUPP_TUBE_X_SPACE		118.11	inch
16	AlongVecDist		265.178	inch
17	AgainstVecDist		0	inch
18	TwistAngle		0	deg
19	Draft1		0	deg
20	CONNECT_SUPP_TUBE_OUT_DIA		10	inch
21	CONNECT_SUPP_TUBE_INNER_DIA		9.5	inch
22	CONNECT_SUPP_TUBE_Y_SPACE		118.11	inch
23				

scheme for connection between inner and outer tank



pipes connecting inner tank top to dome

LArTPC 50kT. WIRE LAYOUT (proposal)

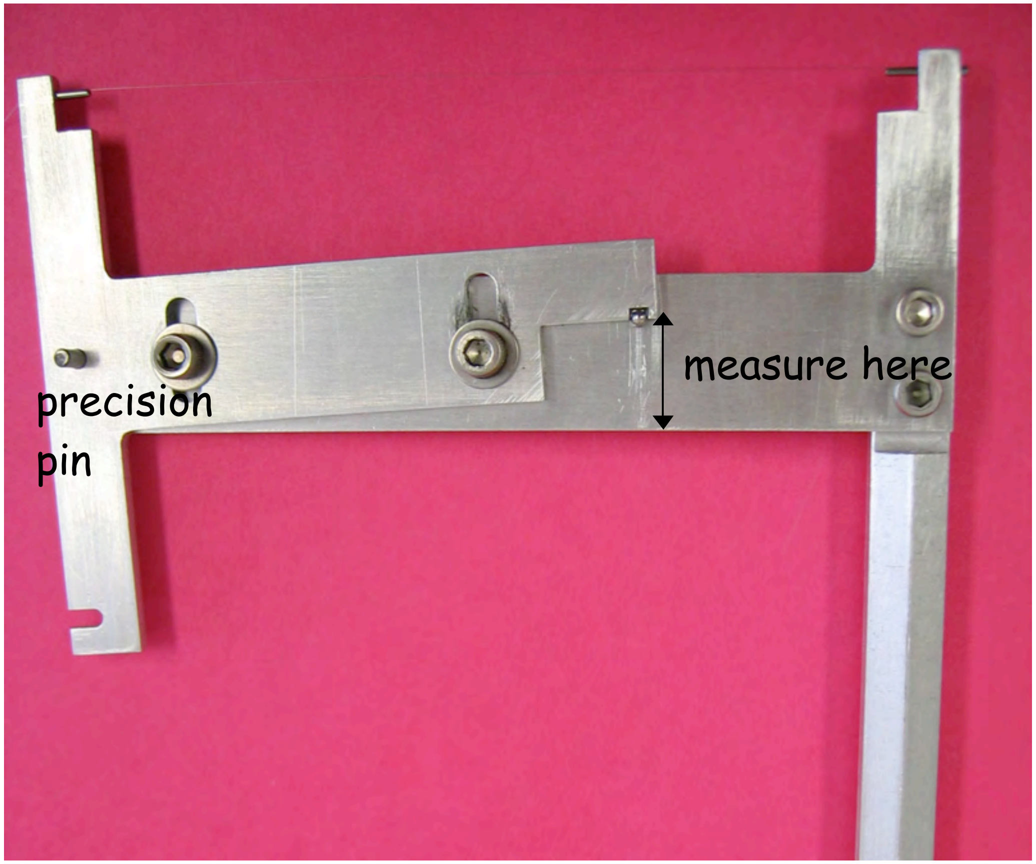


7 planes of wires

\+ - v g v - +

wires read out at top only; wires that end on tank wall wrap to wires on other side to complete path to top => full 3 plane readout

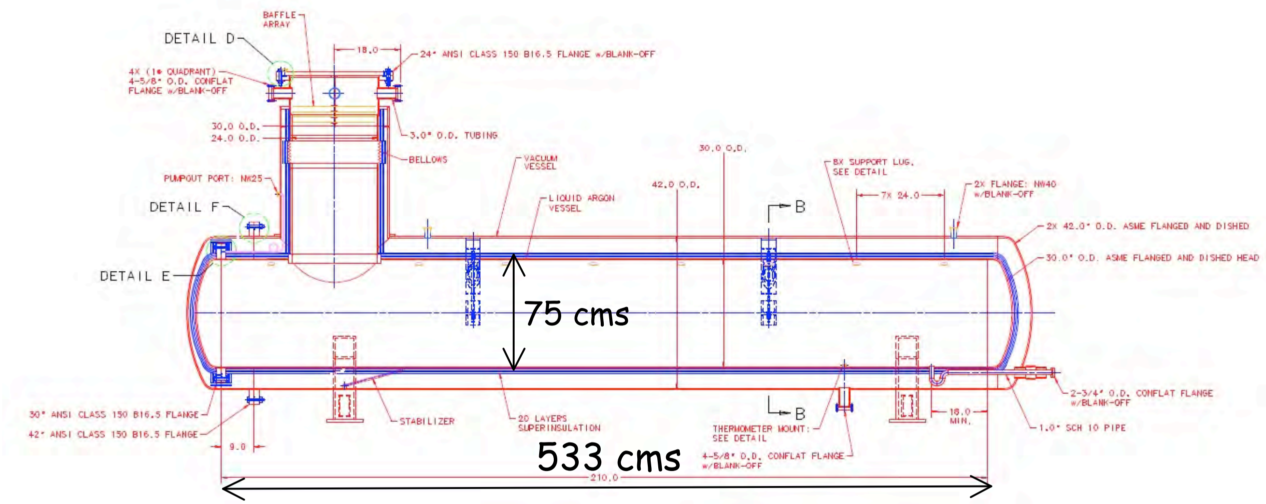
From the virtual & large to the actual and modest..



Device to check elastic limit of SS wire. The wire is put under tension, clamped by the two tapered pins and dipped into liquid nitrogen. The length is measured before and after immersion at the original tension to see if the wire has been stressed beyond the elastic limit.
In practice, the wire breaks almost at its elastic limit

Integrated System Test

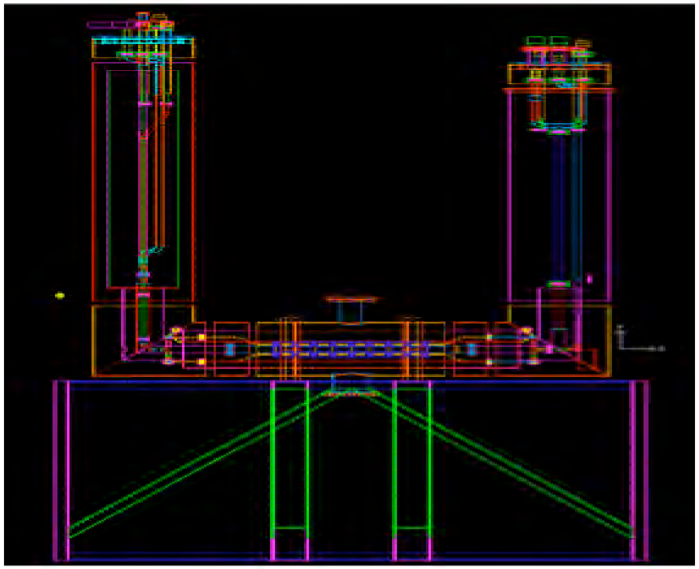
Long drift to 3 readout planes system test...



Drift distance > 5 meters, clear region 30 cms diameter

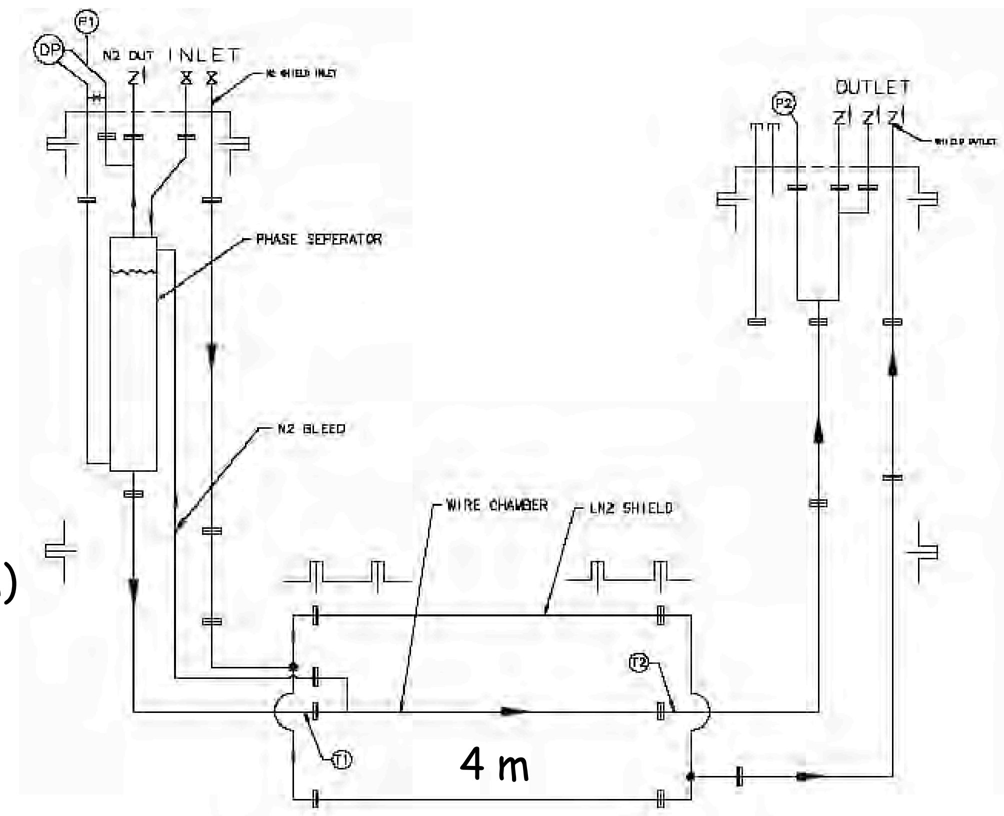
An essential (and challenging) experience for people outside ICARUS to build an integrated system, facing and resolving the issues of purification for long drift, HV and signal readout.

Complementary to the Pisa/UCLA system - uses different approaches to mechanical construction, HV distribution and details of purification.



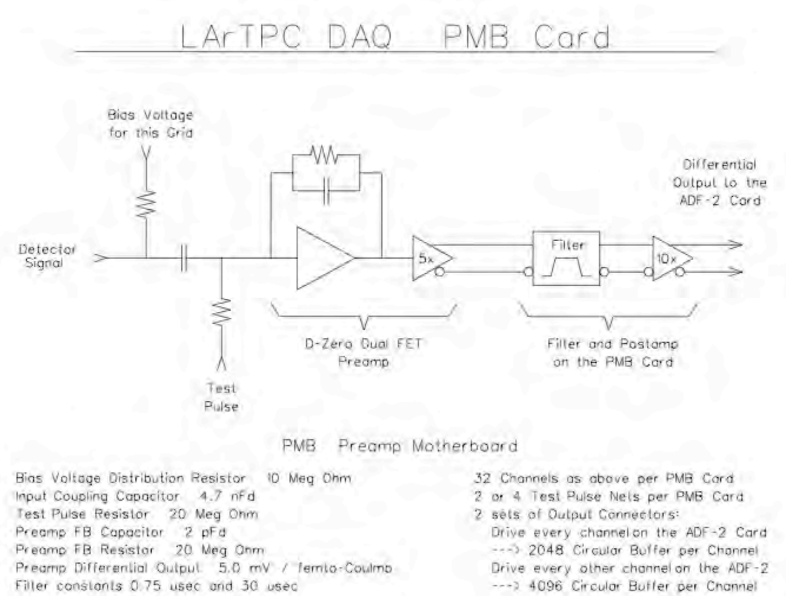
ex VLHC wire test assembly..

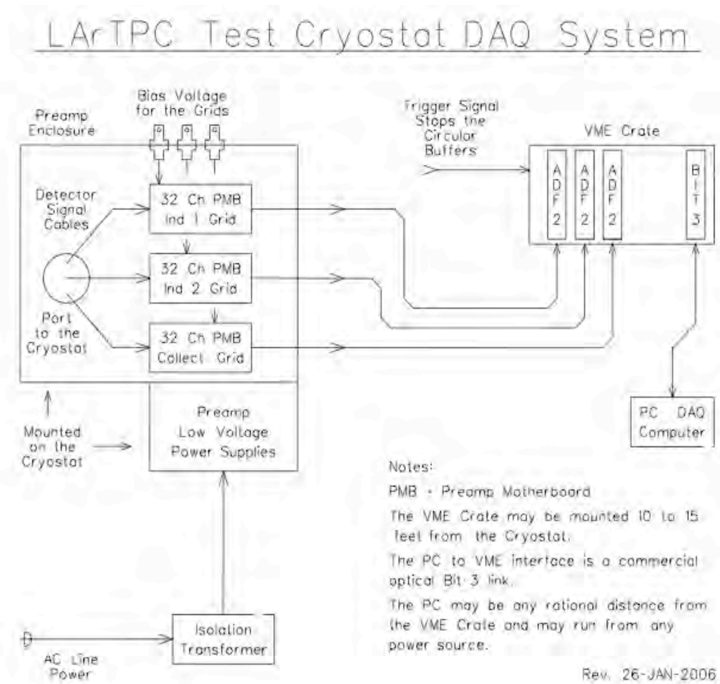
Longish (4 m) wires in a cryogenic environment which we can control

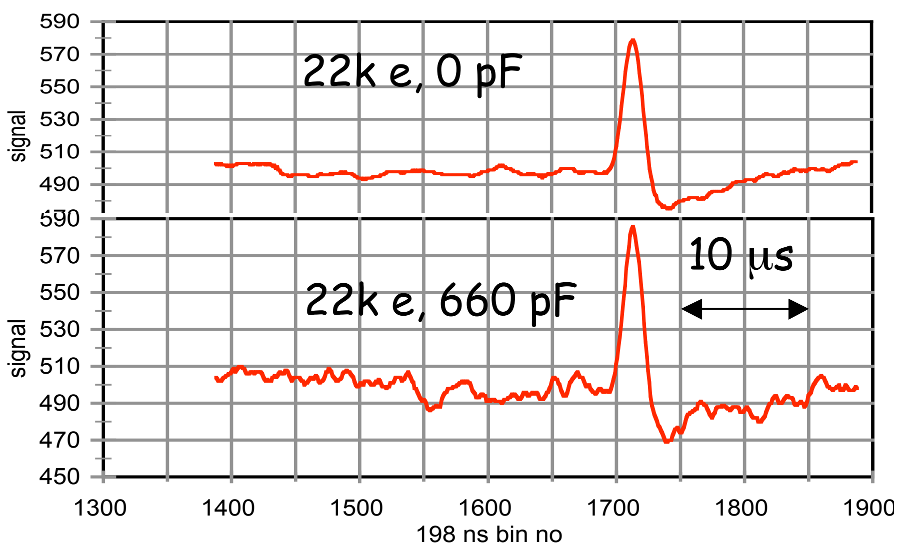


wire chamber (10 x 10 cm cross section)
4 m long in argon bath

Electronics for small setups - D. Edmunds MSU







use DZero Run II dual-fet preamp & DZero buffer memory - appropriate for small chamber and long drift system test

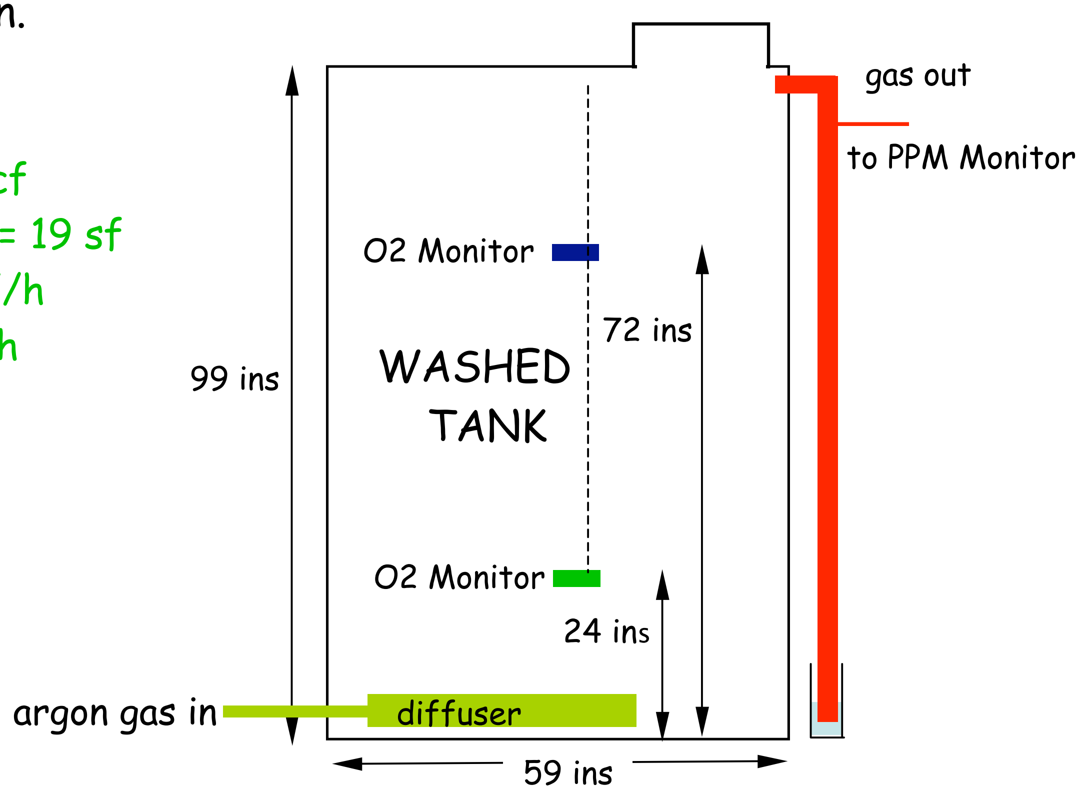
Test of purging a volume from atmosphere: (R. Schmitt)

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

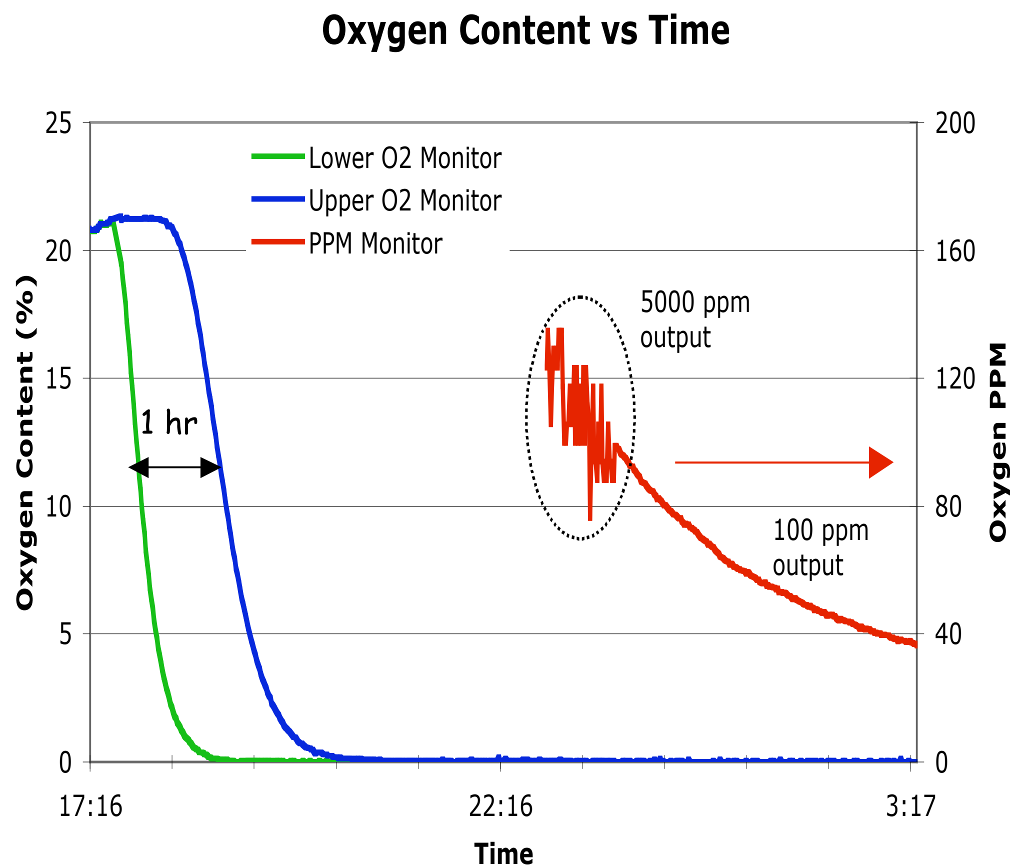
the Argon being heavier than air will act as a piston and drive the air out of the tank at the top;

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

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



Test of purging a volume from atmosphere:



to 100 ppm O_2 (reduction of 2,000) takes 6 hrs = 2.6 volume changes
(cf simple mixing, which predicts ln(2000) = 7.6 volume changes)

Thanks to:

ICARUS Collaboration for making any of this possible.

F. Arneodo, E. Calligarich, F. Cavanna, S. Centro, F. Sergiampietri,

for their hospitality and wisdoms.

Colleagues from Michigan State, Princeton, Tufts, UCLA, Yale & York.

at Fermilab

E. Hahn for production of photocathodes

W. Jaskierny for HV and readout electronics

C. Kendziora and PAB group for assembly of cryogenic system

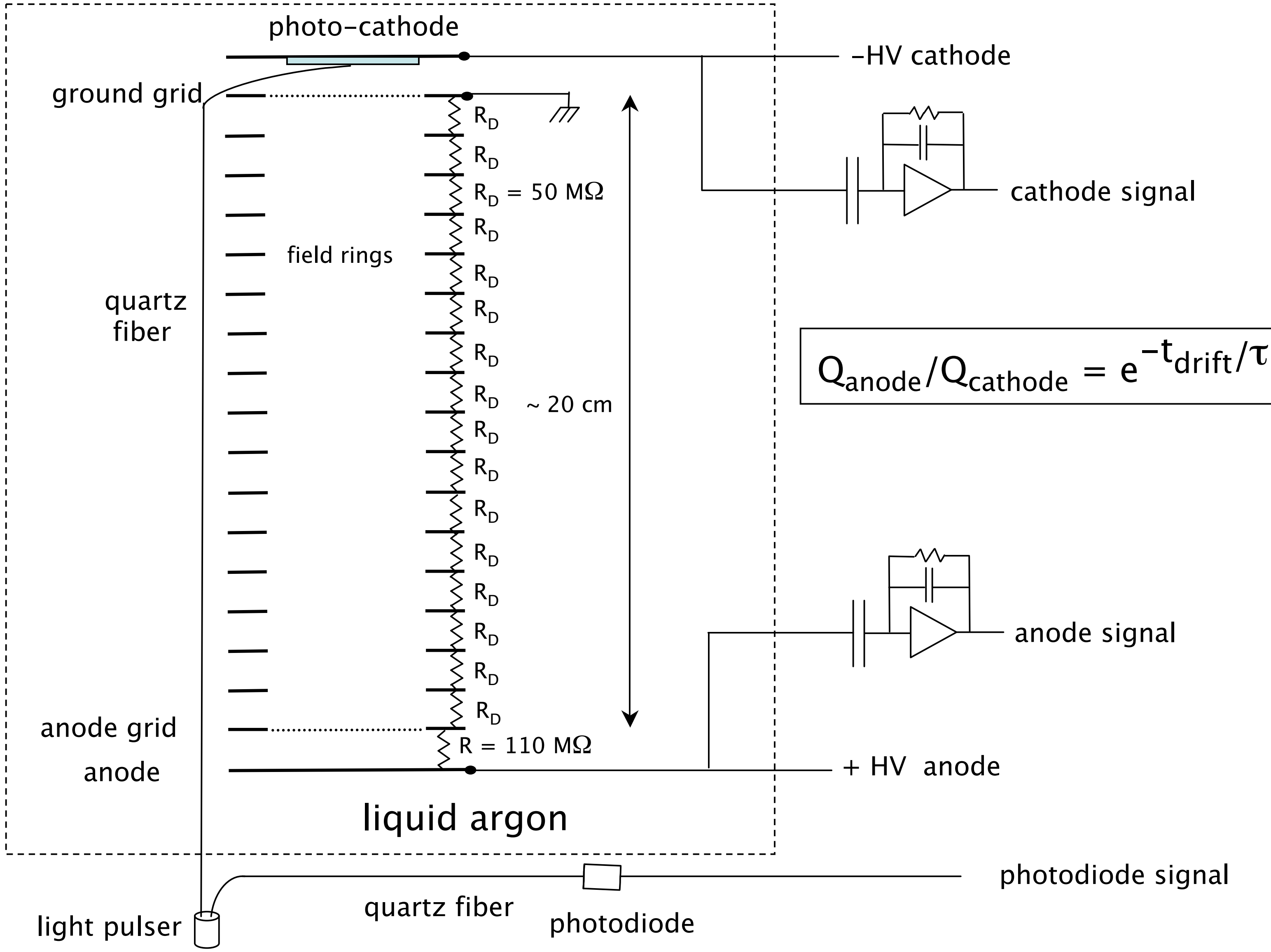
J. Krider for understanding and implementation of PrM system

T. Tope for design of Argon cryogenic system

Y. Orlov for mechanical design on big tank

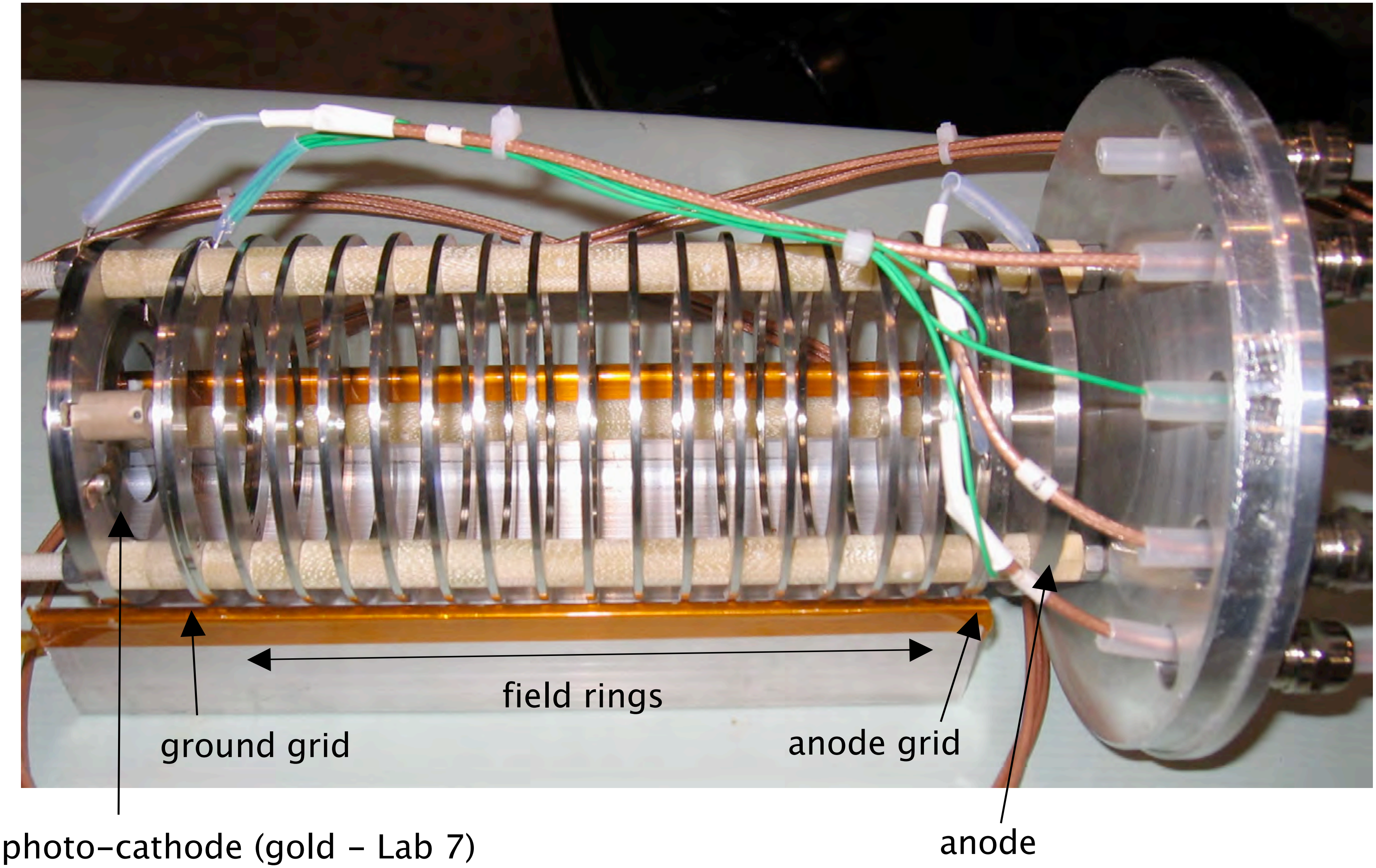
end

Schematic of Liquid Argon Purity Monitor (PrM)

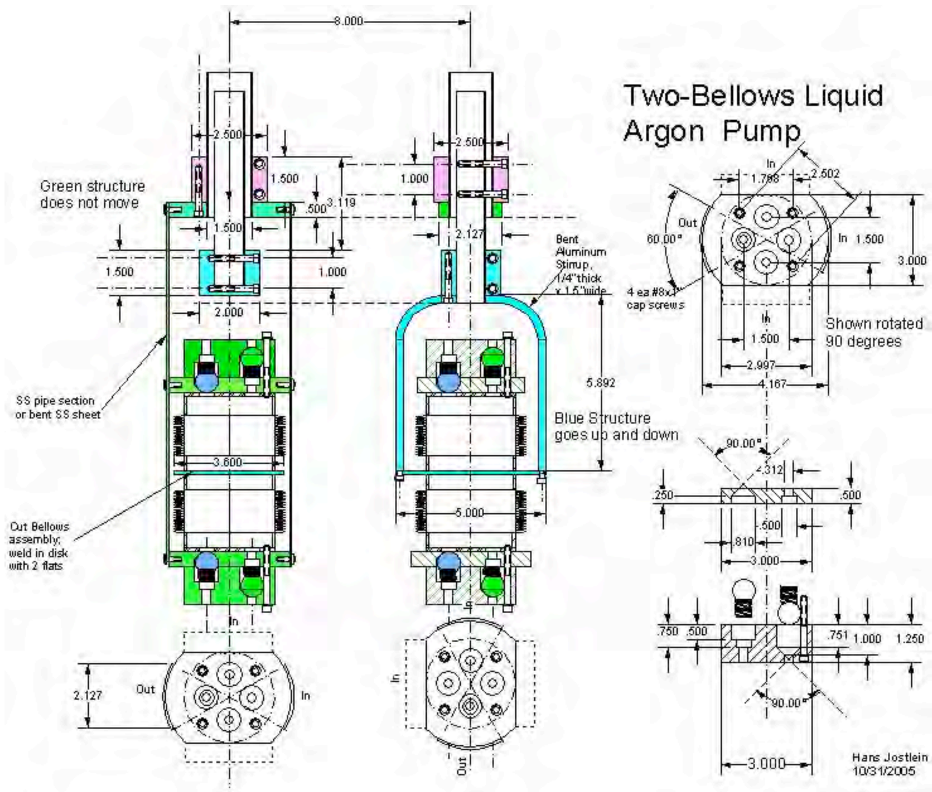


$$Q_{anode}/Q_{cathode} = e^{-t_{drift}/\tau}$$

ICARUS PURITY MONITOR



The Hans Jostlein Two-Bellows Liquid Argon Pump



in action