B. T. Fleming
Sept 16th, 2006
LB study workshop

LAr working group: Group report

- Group charge
- Direction from NuSAG
- Progress:
  - -Event rates, Simulation, Reconstruction etc.
  - -Cosmics rates
  - -Sensitivities
  - -Technical progress
- Conclusions

LB Study: Liquid Argon working group

Study Homepage
Working Group Homepage
Beams Considered
Simulations
Sensitivities
Detector Depth
Additional Physics
Technical Issues
Costing
Contacts

FNAL-BNL Long Baseline Study 2006: Liquid Argon TPCs working group

This webpage outlines the goals and progress of the Liquid Argon TPC component of the FNAL-BNL Long Baseline Study. Links to the study webpage can be found below. The worklist for the Liquid Argon TPC component of the study is described below. Progress within specific smaller working groups can be found in the links bar to the left.

Worklist for LAr part of study from study leaders

1. Simulation studies using a off-axis (14 and 40 mrad) beam and a wide band beam: This should result in plots of efficiency and resolution for signal and background. This information should be in a form that can be used for studies of sensitivity for the parameters as requested by Sally and Mont.
2. Technical issues:
   - Depth versus background and energy threshold and/or access to physics other than accelerator neutrinos
   - Short summary of technical feasibility versus detector size and the R&D that is needed

Deadlines: Preliminary report due in mid-July. Final report due in October.

Please send questions/comments to Bonnie Fleming
Last modified: Sun May 28 09:08:40 CDT 2006

www-lartpc.fnal.gov/LBStudy_LAr/2006LB.html

Updated as work is completed -- ie: See new Simulations page -- A. Curioni

Long Baseline Study: LAr worklist

Simulation Studies:

- Scenarios
  - Off axis NuMI beam at 14 mrad, 810 km
  - at 40 mrad, 810km, and 200km
  - Wide-band beam

efficiencies and resolutions for signal and background

↓

sensitivity studies

Technical Issues:

- Depth vs background
- energy threshold for different channels

  physics beyond accelerator neutrino oscillations
- Technical feasibilty vs detector size
- R&D towards massive detectors

For Liquid Argon:

13. NuSAG recommends that the Liquid Argon group reweight its emphasis from sensitivity/reconstruction/pattern recognition to hardware issues and cost estimates. We realize that a full switch cannot occur if the LAr group is a big part of the more generic off-axis calculations in the Working Group, but, for example, LAr-specific reconstruction and particle ID algorithms seem less pressing than technical feasibility.

14. What has actually been measured on purity of the Ar in a tank made with industrial technology? If not yet tried, when will the first tests be?

15. When do you expect to have tried 3-m drifts and long wires in the US? What effect will the capacitance of very long wires have on electronic noise?

16. What are the R&D milestones, with an estimated schedule, that would lead to a first realistic cost estimate for a detector of the 2nd-off-axis or wide-band class?

Questions from NuSAG after May mtg...

What I'll present here:

From write-ups on:

-Event rates, simulation and reconstruction -- A. Curioni
-Surface rates -- S. Pordes and D. Gerstle
-Underground construction -- C. Bromberg

Writeups in progress:

-Sensitivities -- P. Huber
-Technical Progress -- D. Jensen and B. Fleming
-New ideas on tank design -- H. Jostlein

What this does not include:
Review of work beyond this group
(ie: A. Rubbia's group -- see his talk)

Long Baseline Study: LAr

Simulation Studies:

- Scenarios
  - Off axis NuMI beam at 14 mrad, 810 km
  - at 40 mrad, 810km, and 200km
  - Wide-band beam

efficiencies and resolutions for signal and background sensitivity studies

Developed tools for calculations of

-event rates

-MC simulation

-automated reconstruction

Included study of 3kton LArTPC on-axis at Soudan

Calculated Sensitivites using GLOBES

-> some sensitivites from S. Menary

-> New calculations from P. Huber

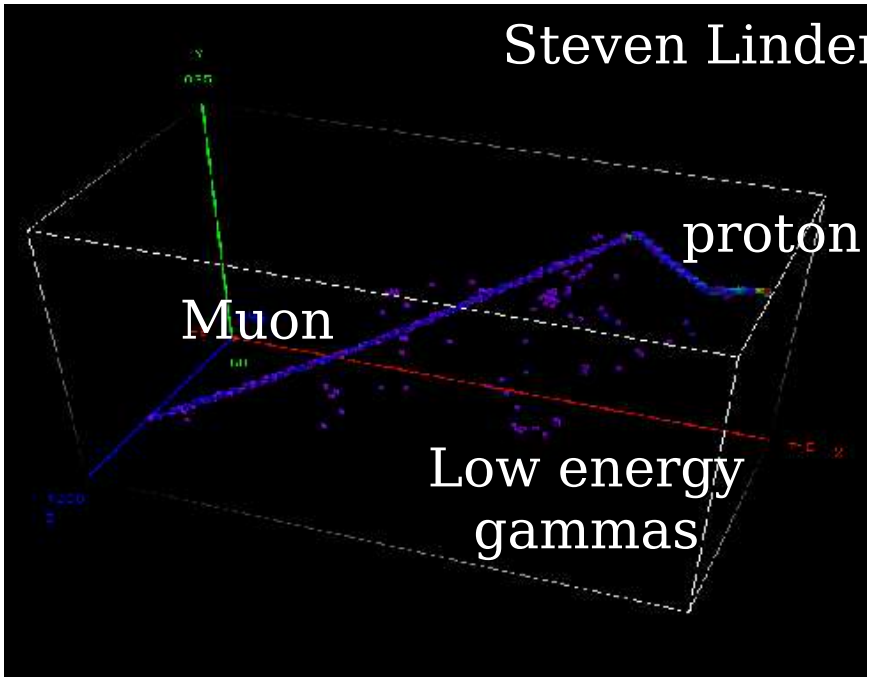
Simulation and Reconstruction:

Monte Carlo study of a liquid Ar time projection chamber for long baseline neutrino experiments

A. Curioni

Yale University

see tech note



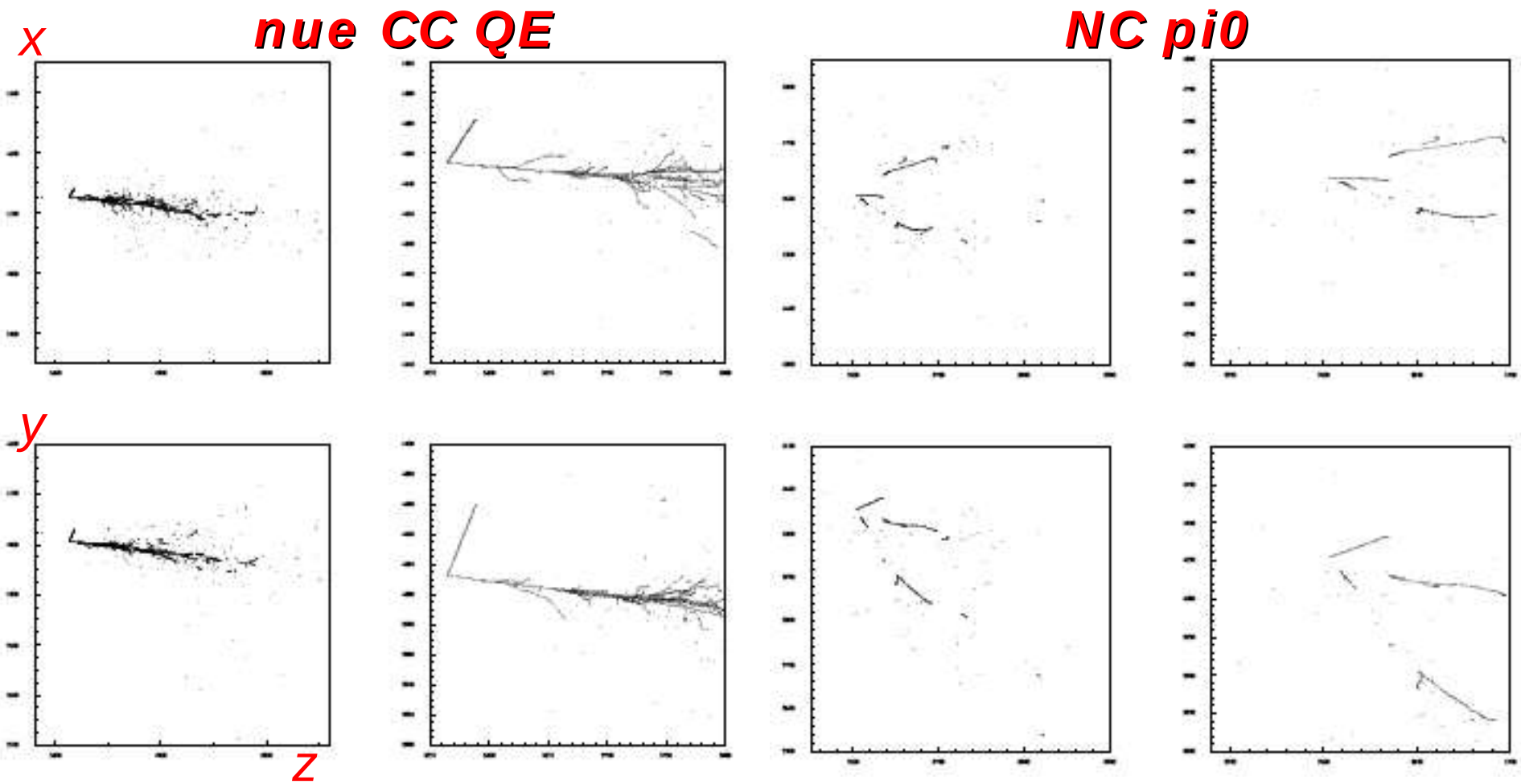
Simulation:

- Geometry: 10x10x7 m^3 i.e. about 1 kton of LAr
- MC provides both MC truth and digitized events for reconstruction studies
- MC has been expanded to follow gammas from pi0 decay (MC truth)

reads in NUANCE evnt files, generated for
-off axis beams and wide band beams

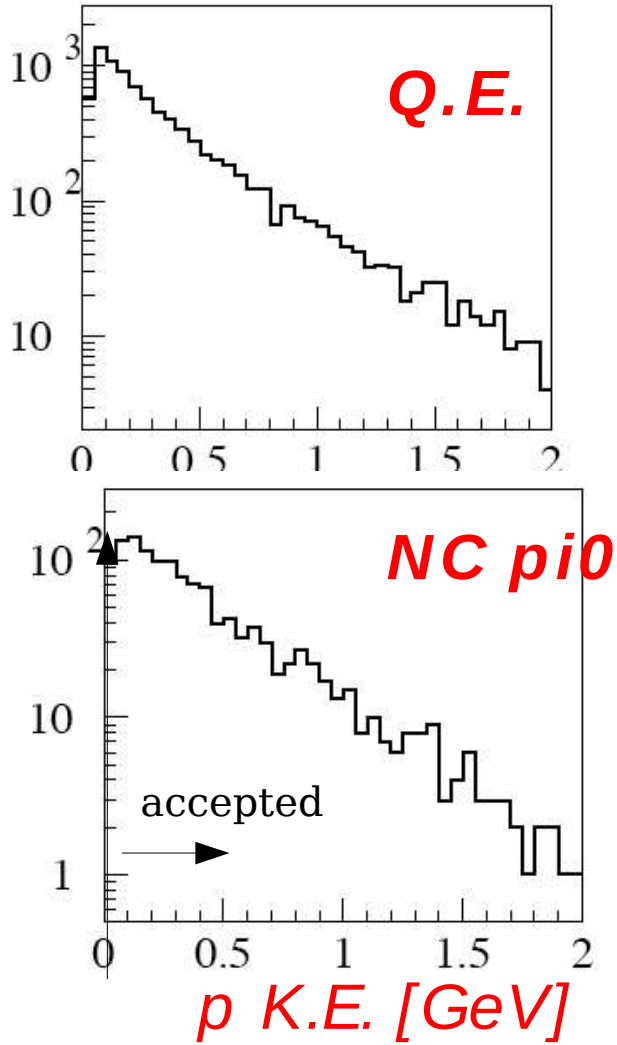
event rates consistent with other calculations

Truth studies: first pass to differentiate NCpi0 from signal
-identify proton track as separate from gamma showers
-identify gamma showers

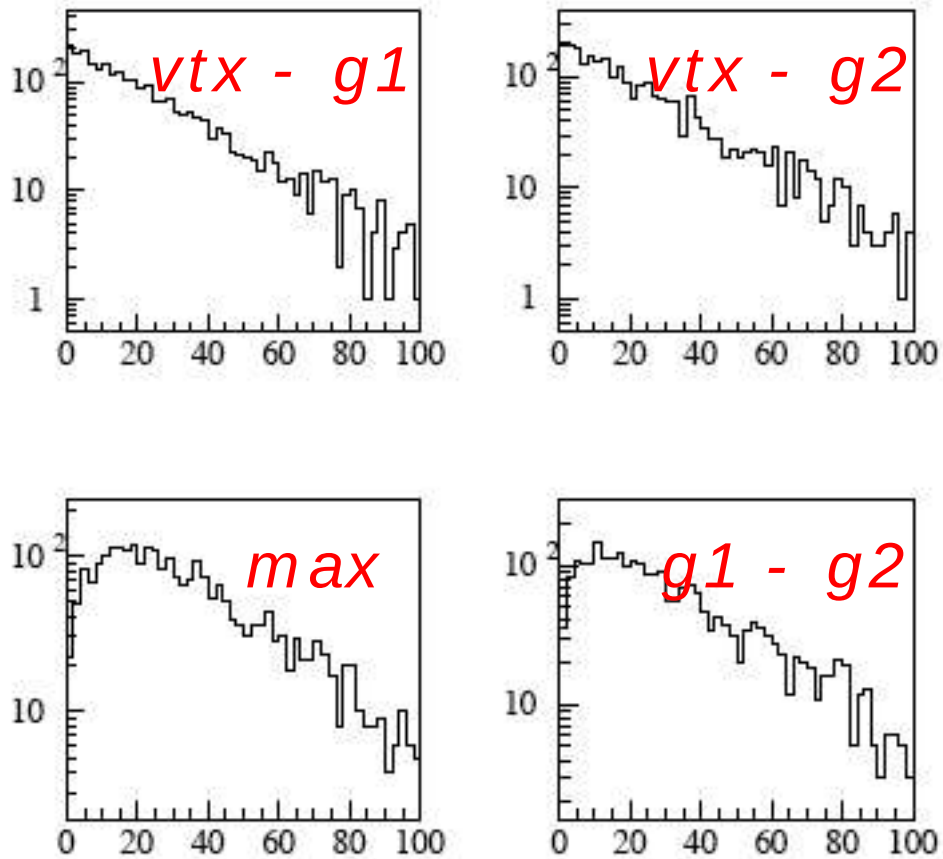


Wide band beam - 40 GeV

proton track with energy
> 50 MeV can be identified



also look for gap between neutrino vertex and gammas (g1 or g2)



With this criteria:

1) Efficiency of CCQEW events is ~90%
2) NCpi0 events with a proton in final state are almost all rejected (about 50% of NCpi0 events)

Summary

- Ask for a proton w/ kinetic energy > 50 MeV to tag the vertex in a CC QE nu interaction
- Efficiency > 90%
- Background (NC pi0) rejection:
  - About **50%** NCpi0 events have a proton in the final state w/ kinetic energy > 50 MeV
  - Asking for a gap (separation between vertex & gamma conversion point) **> 2cm** leaves **1%** of NC pi0 events

Combination of two criteria leaves ~0.5% of NCpi0 events (well below level of intrinsic electron neutrino events)

still to do: reconstruct showers to
-measure dE/dx
-> efficiency of electron events
-> further rejection of pi0 events

Reconstruction:

GEANT 3 simulation of a $\nu_\mu \mathbf{p} \rightarrow \mu p$ event in 1kton LArTPC

Automated Reconstruction algorithms for hit assigment and vertex finding tracks

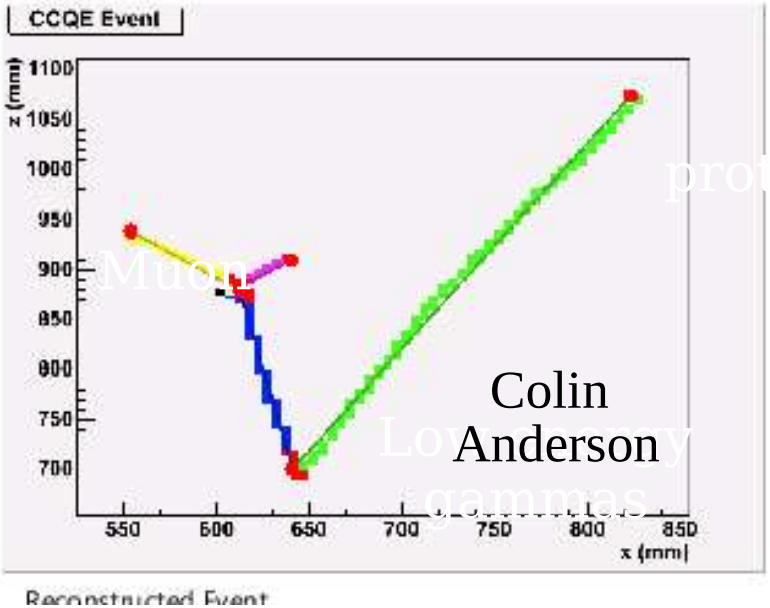


Figure 5: Algorithm skeleton, from [7].

Tested track finding algorithms:
- IDs primary and secondary vertecies

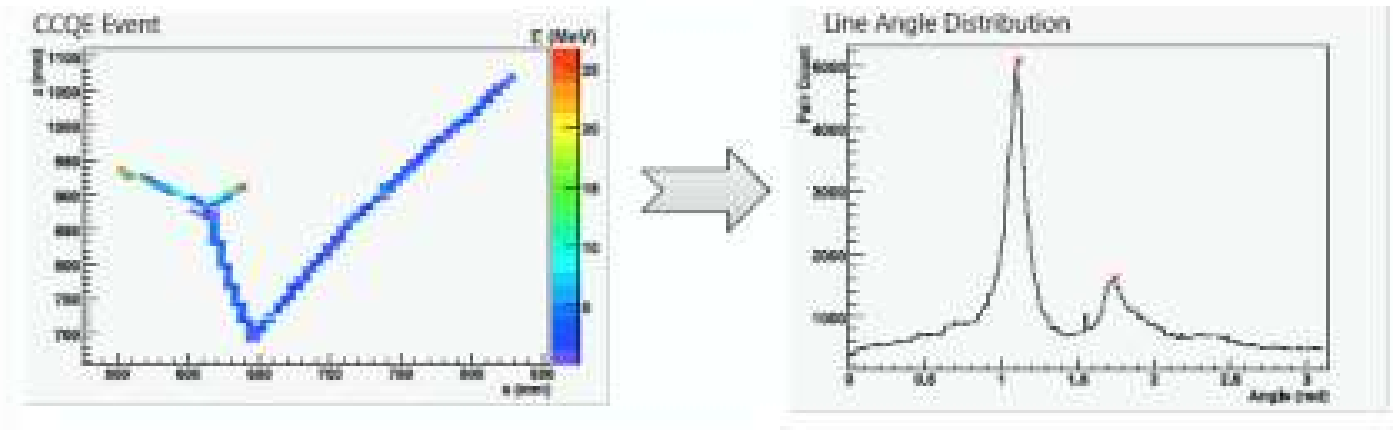
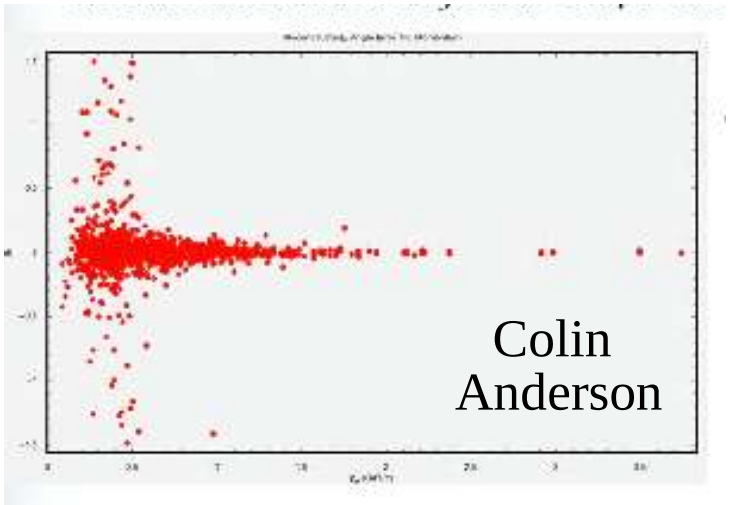


Figure 6: Line angle identification, from [7].



1st pass: can find vertex and rough direction for muons (rms < 2 deg.)

shower recon: in progress

Sensitivities:
-Assume (based on...
    -hand scanning from Tufts Study (shown previously)
    -truth studies here
    -other's work

-> no NC background, 80% nue efficiency

Seen some sensitivities from Scott Menary on 2nd osc max using massive LArTPCs

new calculations from Patrick Huber using GLOBES
-LArTPC equivalent to Water Cerenkov
    -using WBB flux
    -using 2nd osc max flux
    -study sensitivity of NOvA + these scenarios

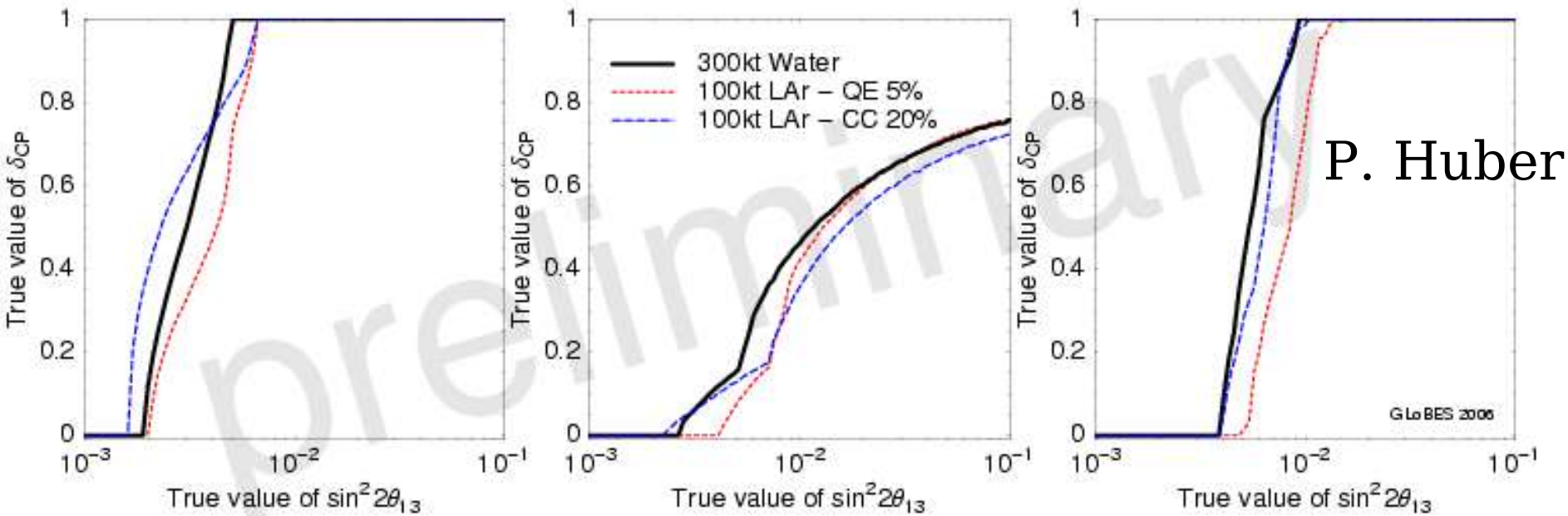
in progress

Wide Band beam flux: 100kton LAr to 300kton Water Cer

100 kton LAr with : 80% nue efficiency, no NC background, intrinsics including WS

red: 5% energy resolution for QE events
blue: 20% energy resolution for CC events

Take aways:
-details are important
-where there are few events, spectral information does not help...



P. Huber

work in progress, machinery in place for direct comparisons

Technical Issues:

- Depth vs background
- energy threshold for different channels

  physics beyond accelerator neutrino oscillations
- Technical feasibilty vs detector size
- R&D towards massive detectors

Progress on (see write-ups)

Surface rates

Underground construction issues

Large tank design issues

Re-visit questions....

Cosmic ray rates on a surface Liquid Argon TPC

David Gerstle (Yale) and Stephen Pordes (Fermilab) *

21 August 2006

Cosmic Ray Issues for Large Liquid Argon Detectors on surface:

- Burden on Data Acquisition
- Inefficiencies (obscuring good events)
- Burden on Reconstruction/Analysis
- Physics Backgrounds (generating fake events)

Beam-spill only:

Argon Drift time : 2 milliseconds (3 meters at 500 V/cm)

In progress

D. Gerslte and S.Pordes

Cosmic rates calculation: see tech note
In summary:

Muon rate on 50 kton(ne) detector ~ 250 kHz (sides are 1/2 of total)

Number in sensitive time (2 milliseconds) ~ 500

Each muon crosses 3000 wires on average..so there are
~ 7 signals/wire (1.5 x 10^6 hits/225,000 wires) from cosmic rays.

Do these rays blind the detector?

Take a 1 cm diameter (full signal width) tube around each ray =>
loss of 500 cm^2 out of 1000 m^2 < 1 part in 10^3 => small inefficiency

Rejecting/ignoring these hits is a major issue for the reconstruction & analysis -> affects (eg) the raw data structures & the pattern recognition approach.

Do muon interactions (hadronic or wide-angle bremsstrahlung where the photon travels a distance from the parent muon) give background events? Follow the muon - but
$3x10^{20}$ NuMI protons @ $3x10^{13}$ proton/spill =>$5x10^9$ muons =>
need rejection of > 10^8.

photon rejection studies: in progress

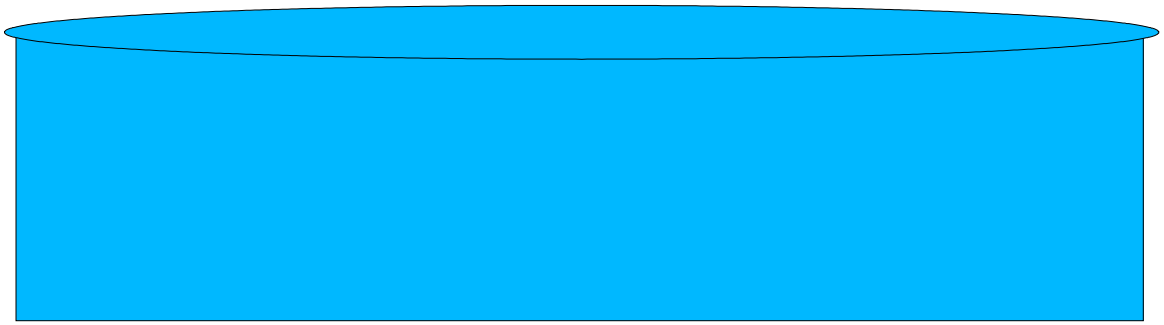
D. Gerslte and S.Pordes

Deep Underground Cryostat for a LArTPC

Carl Bromberg
Michigan State University

Things to consider:
-long TPC wires present S/N problems unless
cold pre-amps are implemented

shorter TPC wires mean squat cylinders



or long cavern spans -- difficult in mine environments

Combine vessel structure for LNG on ships
-durable, flexible in terms of construction
with shape constraints for underground caverns
and shape constraints for TPCs

transport caverns in ships:

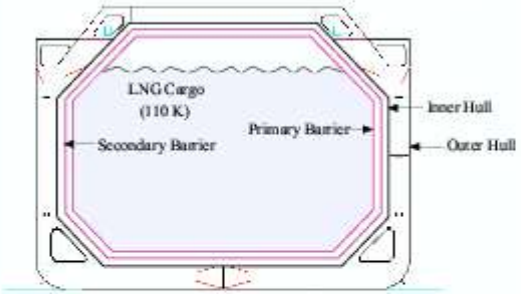
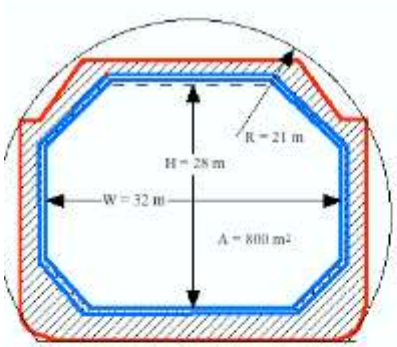
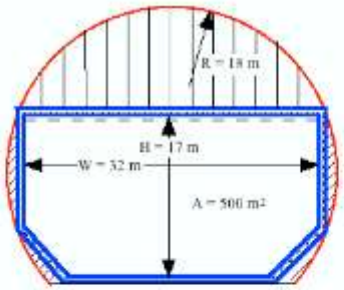


Fig. 2 Membrane LNG tanker design fundamentals

new technology:
Invar barriers

translation to LAr
underground vessels





Cellular Design for a Large Liquid Argon TPC Detector

Presented by Carl Bromberg (with minor edits)
for Hans Jostlein

- Design goal
- Cellular Design
- Additional Possibility:
  - Light Detection
  - Tracking by light

Very speculative

Only briefly mentioned

Some large tank issues

Differential thermal contraction - perhaps manageable

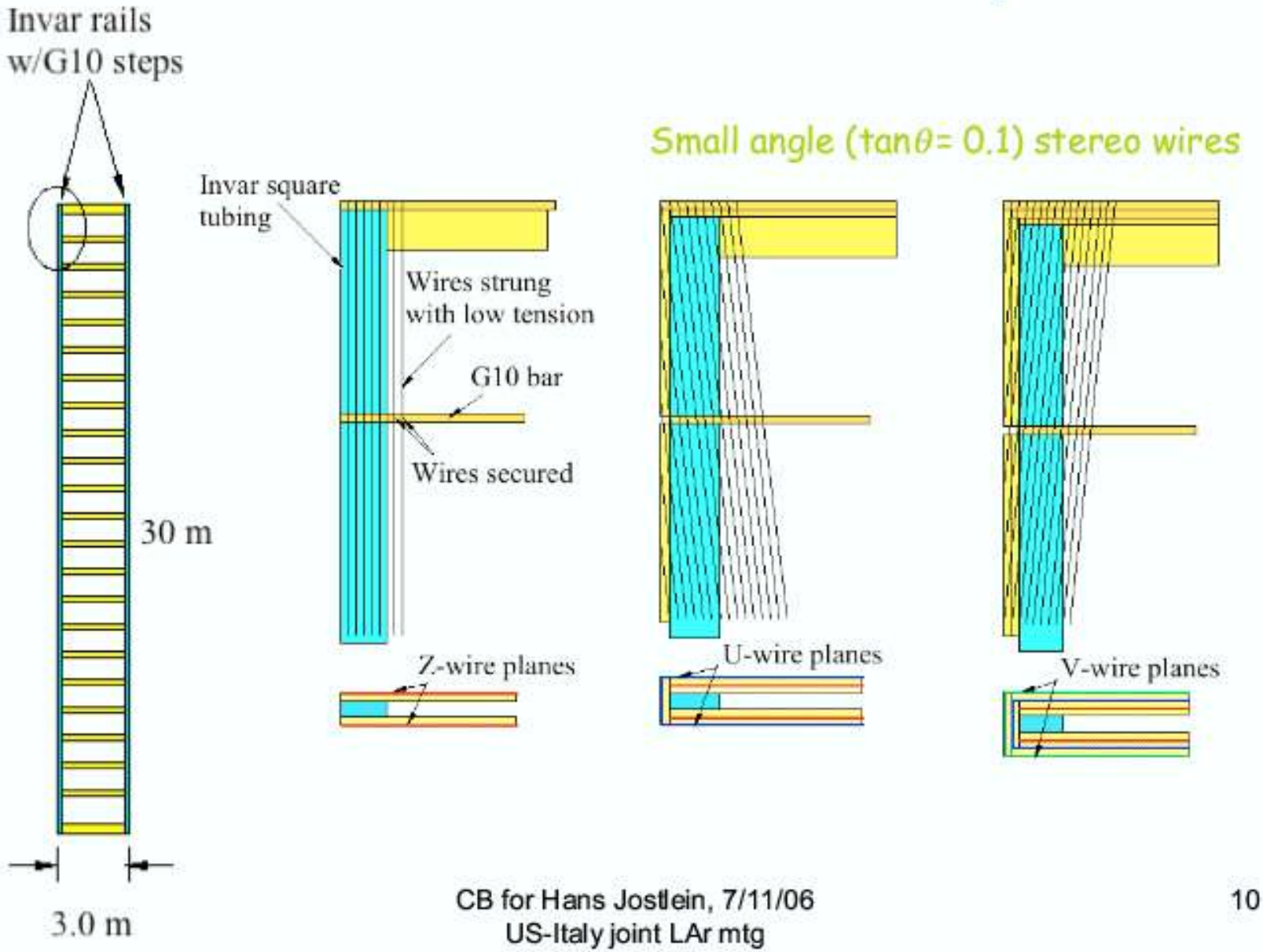
Construction difficulties - but not impossible

- Wires strung in-situ by "craftsmen"
- High risk of disaster for people/wires
- Stringing the wires waits until tank is done
- First fill is the first test of the wire integrity
- Could take up to 1 year to install all the wires
- Wire breakage issues before and after filling

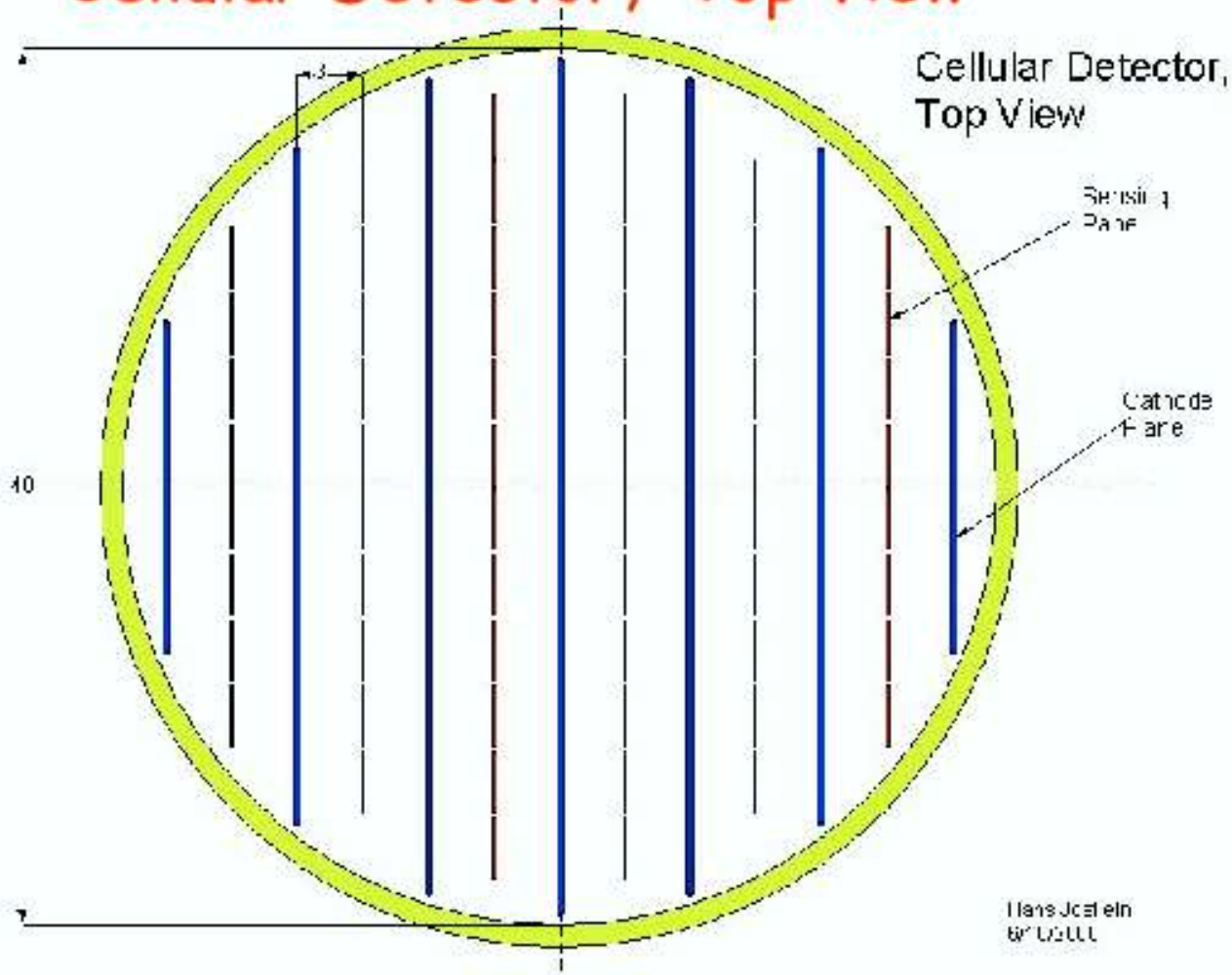
Challenge: avoid the issues while keeping tank concept

"Ladders" may be the answer

Wire ladders: tank & wires independent



Cellular Detector, Top View



Cellular Detector

What do we gain ?

Ladders are made off-site and shipped (by truck or cargo plane) to the detector site

Ladders are made while the tank is being built

Ladders are fully tested and cold-shocked

Ladder installation is fast and low-risk

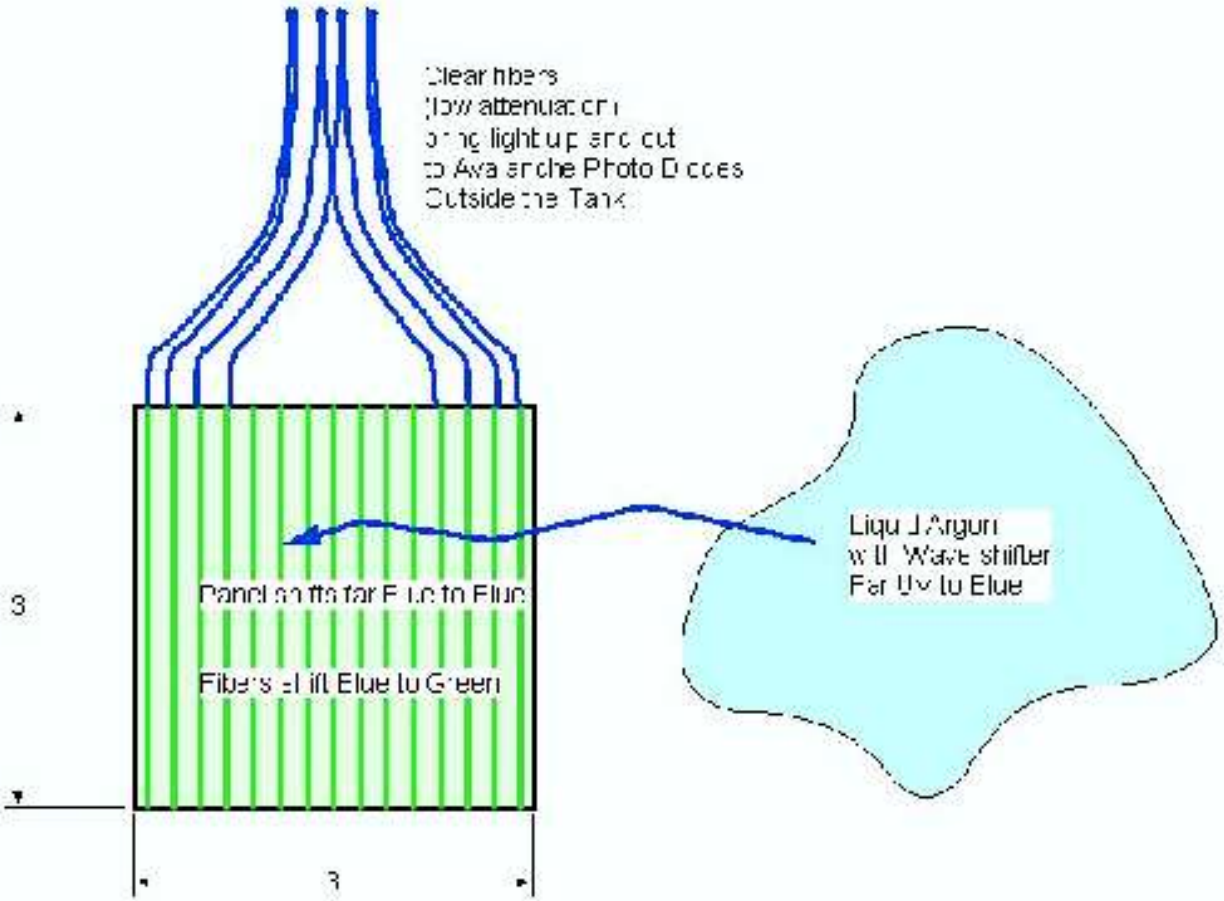
Ladders provide ideal platform for plug-in electronics

Ladders largely decouple tank design from wire requirements

Ladders result in the same number of channels as free standing wires

Light Collection

Light Gathering and Sensing



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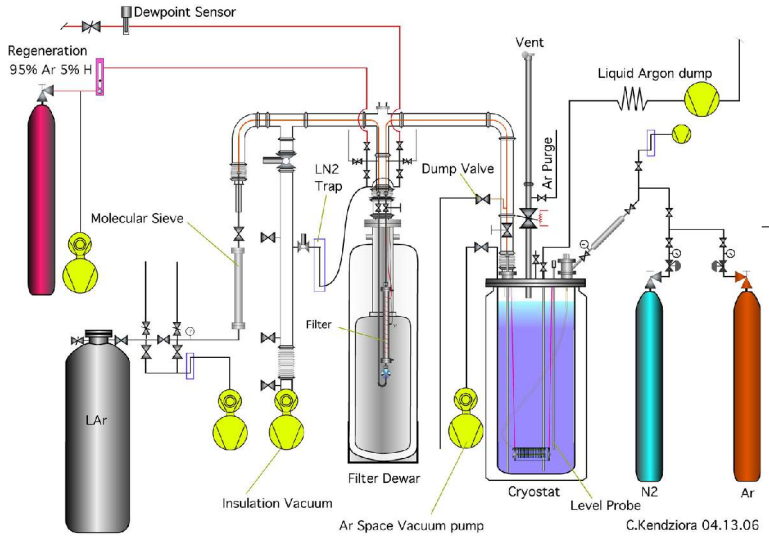
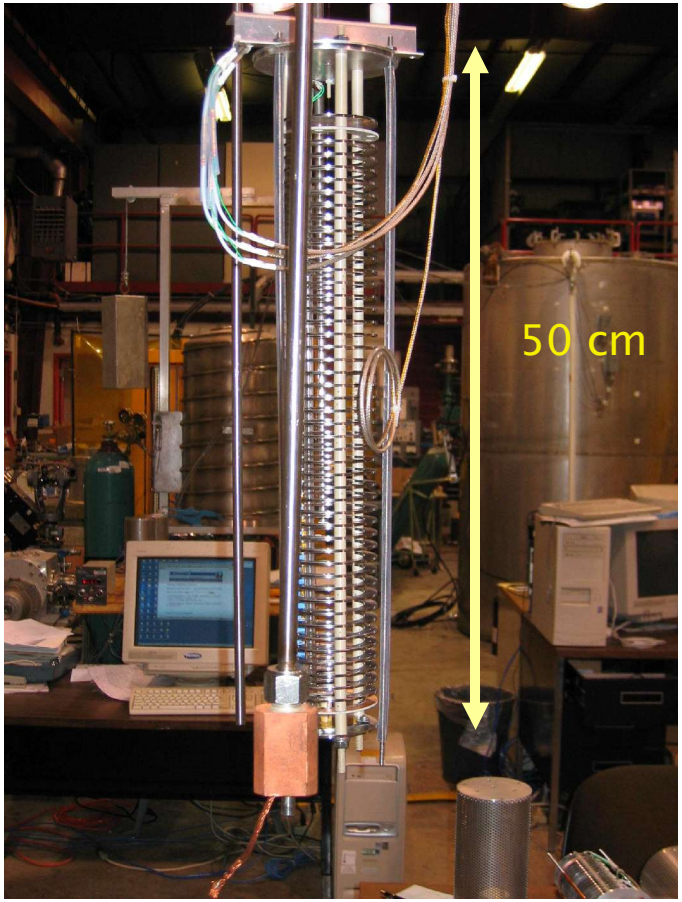
Questions from NuSAG after May mtg...

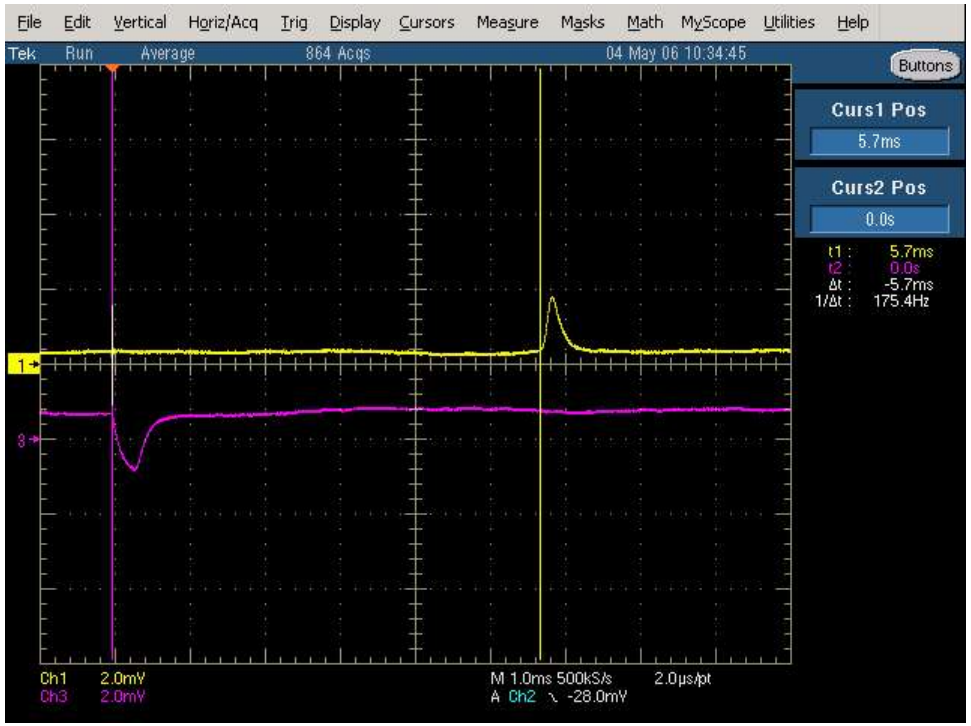




Long drift test studies using Materials Test Stand at FNAL:
-Trigon filter, developed at FNAL
→ regenerated in line
-measure purity via ICARUS style purity monitor
50 cm long drift

S. Pordes, FNAL

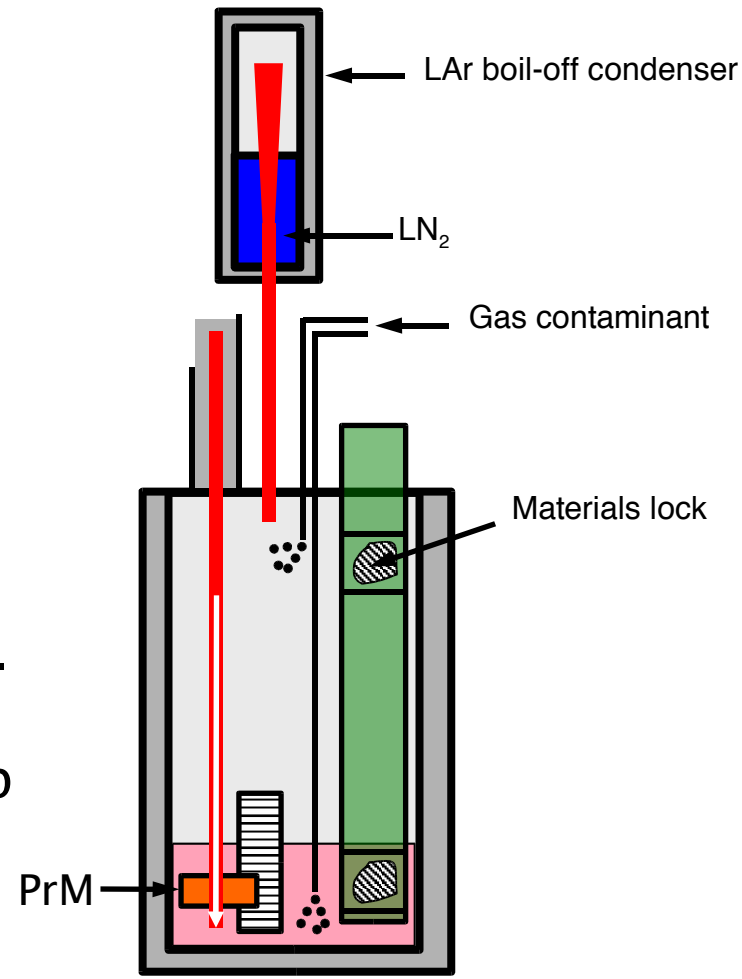
a 5.7 millisecond drift with the long PrM



Lifetime Measurements:
> 8ms lifetimes achieved.
Example here: 5.7ms drift

Next step:

Implement the Materials test station..
(new closed system cryostat)
Developing in-cryostat thermal pump



T. Tope

S. Pordes, FNAL

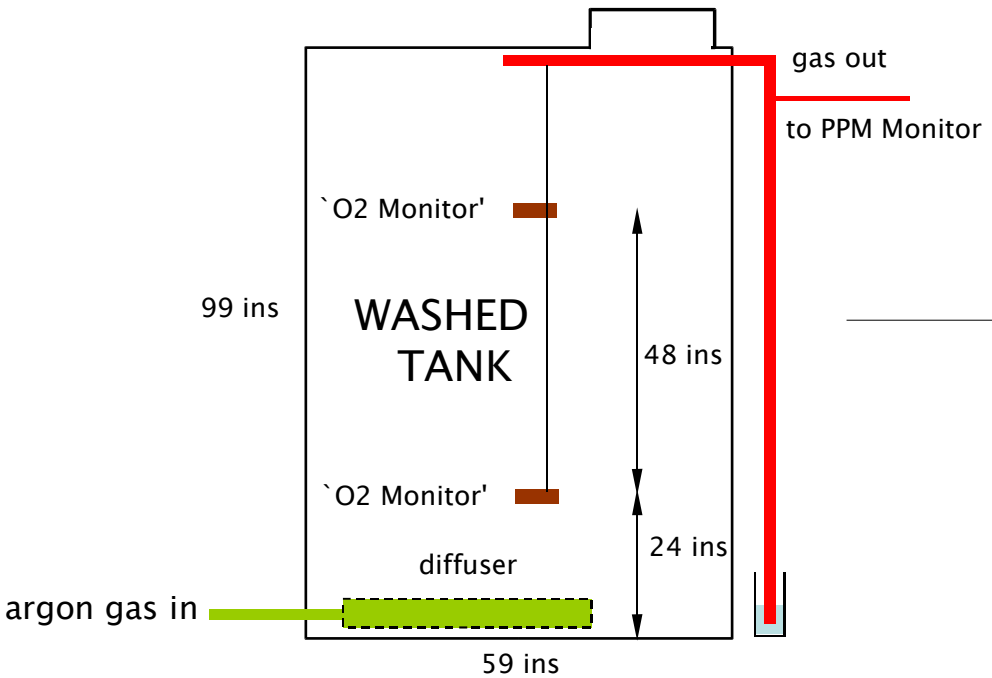
Purity in “industrial” vessel

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;

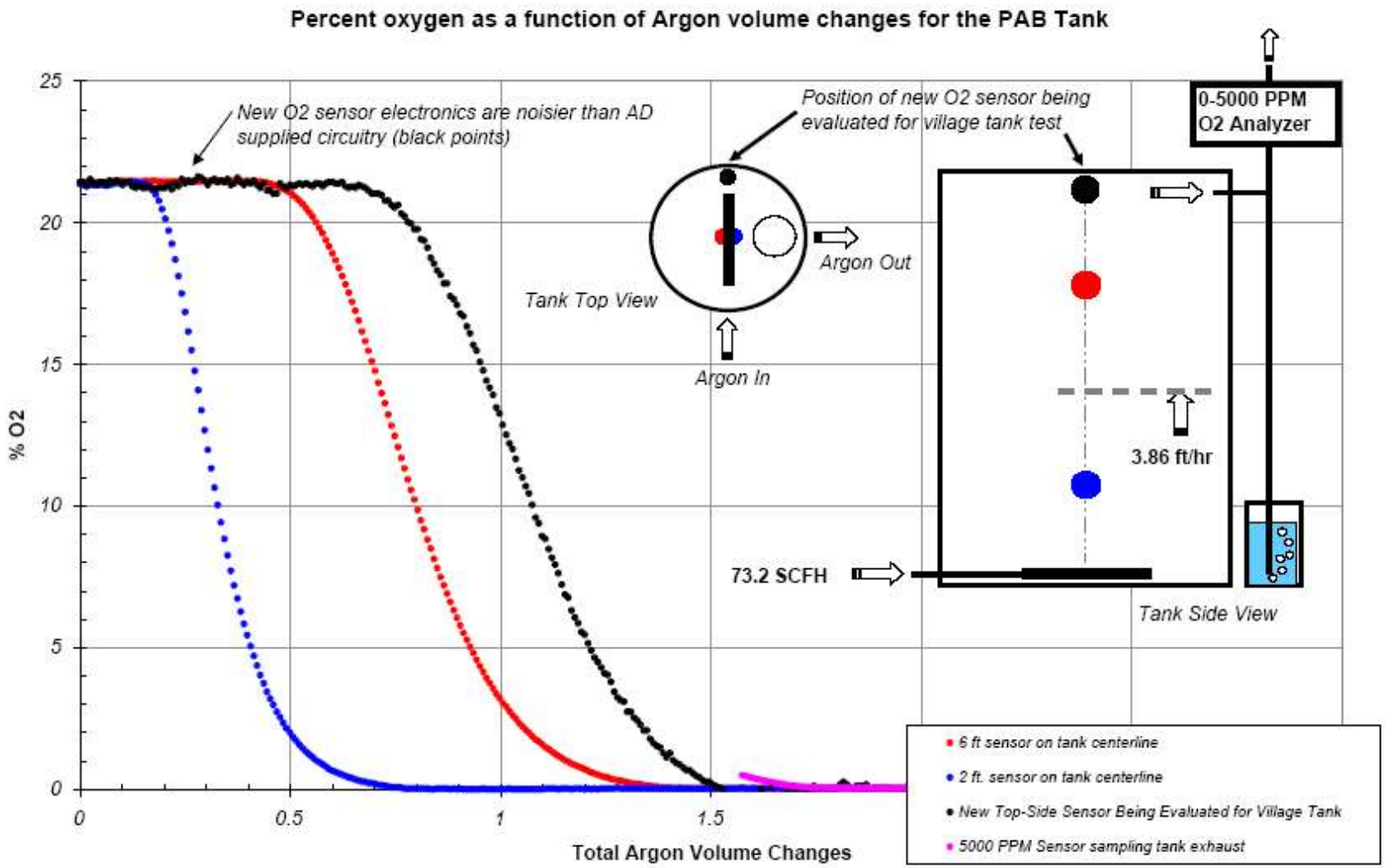
fewer volume changes than simple mixing model will achieve a given reduction in air concentration.



tank volume = 157 cf
tank cross section = 19 sf
flow rate ~ 73.2 cf/h (reading for air was 86 scfh)
climb rate ~ 3.8 f/h

S. Pordes, FNAL

Terry Tope
6/5/06



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)

S. Pordes, FNAL

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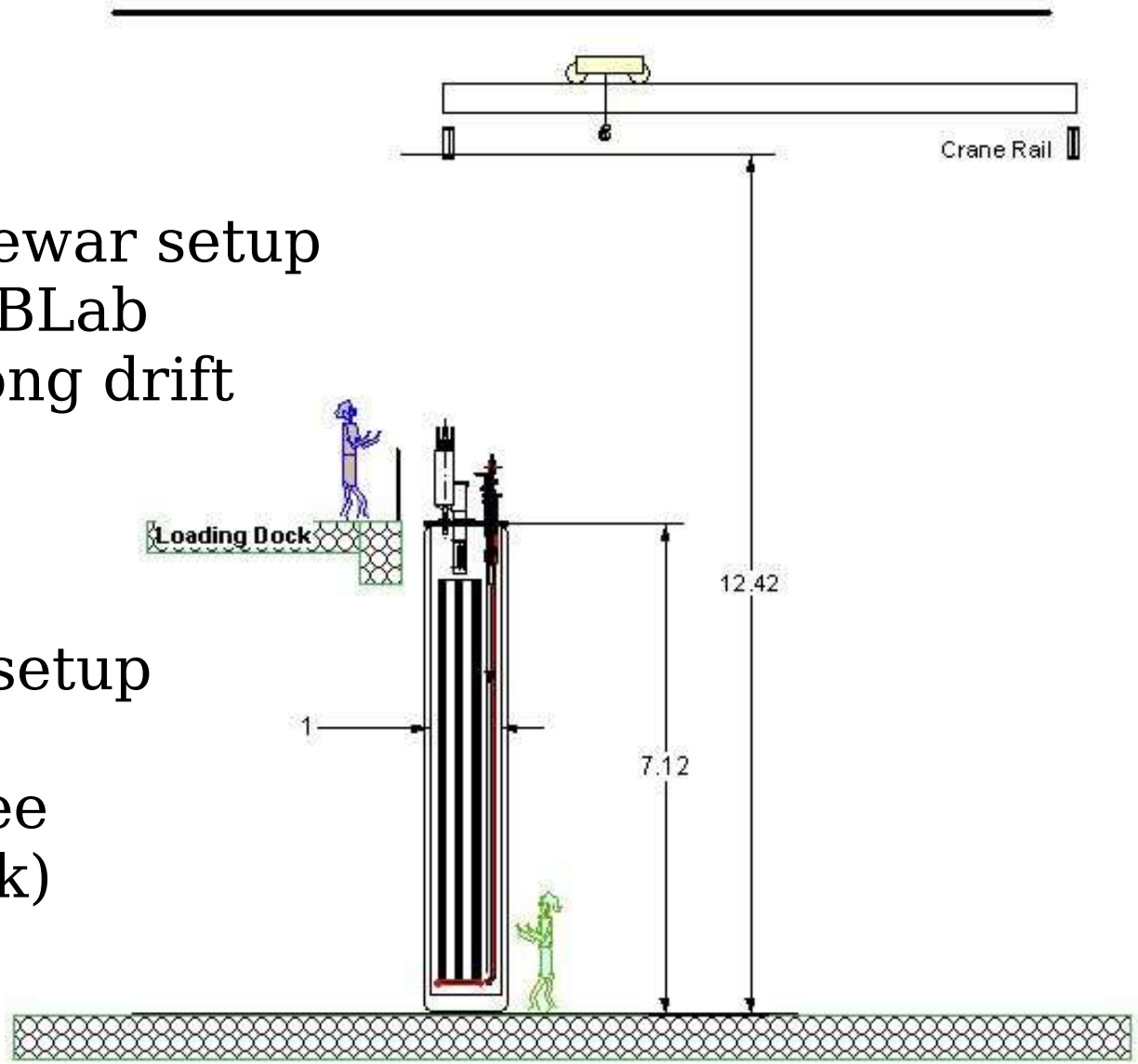
Questions from NuSAG after May mtg...

5 m Drift Vertical Dewar in the Wide Band Lab

Vertical Dewar setup
in WBLab
-tests long drift

Also 5m drift setup
-UCLA/CERN
-U. of Bern (see
Andre's talk)



5 m Cryostat in Wideband Lab

Hans Jostlein
7/26/2006

Long wires tests

- ***measurements of the mechanical properties of the wires both at room temperature and in LAr***
  - *100 μ and 150 μ Stainless Steel 304V*
- ***develop wire holders that work at cryogenic temperature and do not pollute LAr***
- ***determination of wire tension***
  - *electrostatic stability*
  - *restriction of sagittas*
  - *wire supports*
- ***study of noise on long wires***
  - *mechanical vibrations (i.e. induced by LAr flow)*
  - *measure damping effect of LAr on wire oscillations*
  - *study of electronics coupled to long wires (large input capacitance !)*

Test setup in Lab6 at FNAL

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in progress

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Conclusions:

Progress on
-Simulations and Reconstruction
(see Curioni tech note)
-Sensitivities (P. Huber has machinery in place
studies ongoing -- but on appropriate timescale)
-Site issues
-Surface rates (see Pordes tech note)
-Underground construction issues
(see Bromberg tech note)
-Technical issues
-Large tank cellular design
-Purity and long wire studies
-R&D path, schedule and costing -> final piece
brings this all together -- work in progress