The DUSEL Long Baseline Science Collaboration

Some History

- NSF establishes DUSEL Experiment Development Committee (DEDC) late 2007
- DEDC asks M. Diwan and R. Svoboda to help organize a collaboration acting as Interim Project Coordinators (IPC's). First meeting at Homestake, April 2008
- FNAL meetings June and August. Formation of DUSEL LB Interest Group

LB DUSEL Interest Group

- **ANL:** M.Goodman, M.Sanchez
- **Boston Univ.:** E.Kearns, J.Stone
- **BNL:** M.Bishai, M.Diwan, H.Chen, S.Hightower, D.Jaffe, de Geronimo , J.S.Kettell, F.Lanni, D.Lissauer, Makowiecki, J.Mead, D.W.Morse, T.Muller, V.Radeka, S.Rescia, J.Sondericker, B.Viren, B.Yu
- **Univ. of California, Davis:** T.Classen, M.Tripathi, R.Svoboda
- **Univ. of California, Irvine:** W.R.Kropp, M.Smy, H.Sobel, M.Vagins
- **Univ. of California, Los Angeles:** D.Cline, F.Sergiampietri, H.Wang
- **Caltech:** R.McKeown
- **Univ. of Chicago:** E.Blucher, M. Dierckxsens
- **Colorado State Univ:** N.Buchanan
- **Columbia University:** Z.Djurcic, M.Shaevitz
- **Drexel Univ.:** C.Lane, J.Maricic
- **Duke Univ.:** K.Scholberg, C.Walter
- **FNAL:** J.Appel, B.Baller, G.Bock, S.Brice, S.Childress, D.Harding, J.Hylen, H.Jostlein, G.Koizumi, C.Laughton, P.Lucas, B.Lundberg, M.Martins, R.Plunkett, S.Pordes, G.Rameika, R.Ray, N.Saoulidou, R.L.Schmitt, D.Schmitz, P.Shanahan,J.Strait, L.Stutte, G.Velev, R.Zwaska
- **Univ. Of Illinois, Urbana:** P.Kammel, C.Polly
- **Indiana Univ.:** C.Bower, M.D.Messier, S.Mufson, J.Musser, J.Paley, J.Urheim
- **INFN:** R.Potenza, V.Bellini
- **Kansas State Univ.:** G.Horton-Smith
- **Univ. of Kansas:** D.Marfatia
- **LBL:** J.Detwiler, R.W.Kadel, B.Fujikawa, K.T.Lesko, J.Siegrist
- **LLNL:** A.Bernstein, S.Dazeley
- **LNGS:** M.Antonello**,** O.Palamara
- **Louisiana State University:** T.Kutter
- **Univ. of Maryland:** G.Sullivan
- **Massachusetts Institute of Technology:** W.A.Barletta, J.Conrad, P.Fisher, G.Sciolla, D.Yamamoto
- **Michigan State Univ.:** C.Bromberg, D.Edmunds
- **Univ. of Minnesota, Duluth:** A.Habig
- **Univ. of Minnesota:** M.Marshak, W.Miller
- **Univ. of Pennsylvania:** W.Frati, J.Klein, K.Lande, A.K.Mann, R. van Berg
- **Penn. State. Univ:** D.Elsworth
- **Princeton Univ.:** K.McDonald
- **Rensselaer Polytechnic Institute:** J.Napolitano
- **Univ. of S.Carolina:** S.Mishra, R.Petti, C.Rosenfeld
- **Univ. of Sussex:** E.Falk, J.Hartnell, S.Peeters
- **Univ. of Texas, Austin:** K.Lang, S.Kopp
- **Tufts Univ.:** T.Mann, J.Schneps, W.Oliver, T.Kafka.
- **William and Mary:** M.Kordosky, J.Nelson, P.Vahle
- **Univ. of Wisconsin**: B.Balantekin, H.Band, F.Feyzi, K.Heeger, W.Wang
- **Yale:** B.Fleming, M.Soderberg

- IPC's appoint Interim Executive Board (IEB) in August
- This IEB is currently drafting a recommendation to the NSF for what depth would be appropriate to begin studying for location of a large detector
- In October, an Institutional Board (IB) was formed under a charter document drafted by the IEB. The IB consists of a representative from each institution.
- The IB met for the first time as a collaboration in October at BNL.

The Interim Executive Board

- E. Blucher, Chicago (Chair)
- A. Bernstein, LLNL
- B. Fleming, Yale
- E. Kearns, Boston
- J. Klein, Penn
- K. Lande, Penn
- D. Lissauer, BNL
- R. KcKeown, Caltech
- R. Rameika, FNAL
- K. Scholberg, Duke
- J. Siegrist, LBL
- H. Sobel, UC Irvine
- G. Sullivan, Maryland
- R. Svoboda, UC Davis and M. Diwan, BNL (ex-officio)

This Board has met 7 times since August 1, 2008.

This Interim Board will eventually be replaced by an Executive Board formed by the more representative Institutional Board

Institutional Board

- **ANL:** M. Goodman
- **Boston:** E. Kearns
- **BNL:** M.Diwan
- **Caltech:** R. McKeown
- **UC Davis:** R.Svoboda
- **UC Irvine:** H.Sobel
- **UCLA:** H.Wang
- **Chicago:** E.Blucher
- **Colorado State:** N.Buchanan
- **Columbia:** L.Camilieri
- **Drexel:** C.Lane
- **Duke:** K.Scholberg, C.Walter
- **FNAL:** R.Rameika
- **Indiana:** M.Messier
- **INFN(Catania):** R.Potenza
- **Kansas State:** T.Bolton
- **LLNL:** A.Bernstein
- **LBL:** R.Kadel
- **LSU:** T.Kutter
- **Maryland:** G.Sullivan
- **MIT:** J.Conrad
- **Minnesota:** M.Marshak, W.Miller
- **Minnesota(Duluth):** A.Habig
- **Penn:** K.Lande
- **Princeton:** K.McDonald
- **RPI:** J.Napolitano
- **S.Carolina:** C.Rosenfeld
- **Tufts:** H.Gallagher
- **Wisconsin:** K.Heeger
- **Yale:** B.Fleming

Current Issues:
Depth Document
Election of Chair
Mission Statement
White Paper
Collaboration Governance

Geotechnical Planning

- Science Collaboration (SC) Geotechnical Working Group. “Depth Document” specifications. Now meeting weekly to draft geotechnical engineering plan and S4 proposal. Scientists and Engineers.
- Geotechnical Advisory Committee (GAC). Set up under DUSEL S3 organization at LBL. Working closely with SC to draft engineering plan and S4 proposal.
- Large Cavern Board (LCB). “Arm’s Length” blue ribbon panel being organized by DUSEL to independently evaluate SC/GAC plan. Exact charge still being formulated.

Geotechnical S4 Group

Geotechnical

WG/GAC S4 team

- Zbignew Hladysz (Chair), SDSTA
- Sydney De Vries, LBL
- Steve Marks, LBL
- Hank Sobel, UCI
- Bill Miller, UMN
- Ken Lande, Penn
- Richard Kadel, LBL
- Farshid Feyzi, U.Wisconsin
- Charles Fairhurst, ITASCA (NAE)
- Joe Labuz, UMN
- Herb Wang, U.Wisconsin
- Derek Elsworth, Penn State
- Bob Svoboda, UC Davis

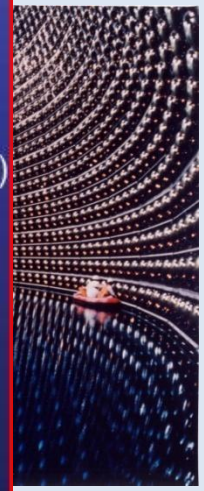
Depth Document

- Depth dependence of physics goals studied
- Geotechnical input from DUSEL for possible sites/levels
- Nearing completion, this document will recommend coring studies at the 4850L in the Yates Formation

Visiting Collaborators Here Today

- M. Diwan, BNL
- M. Goodman, ANL
- B. Fleming, Yale
- F. Feyzi, Wisconsin PSL
- A. Karle, Wisconsin
- H. Wang, UCLA

WC Detector Development

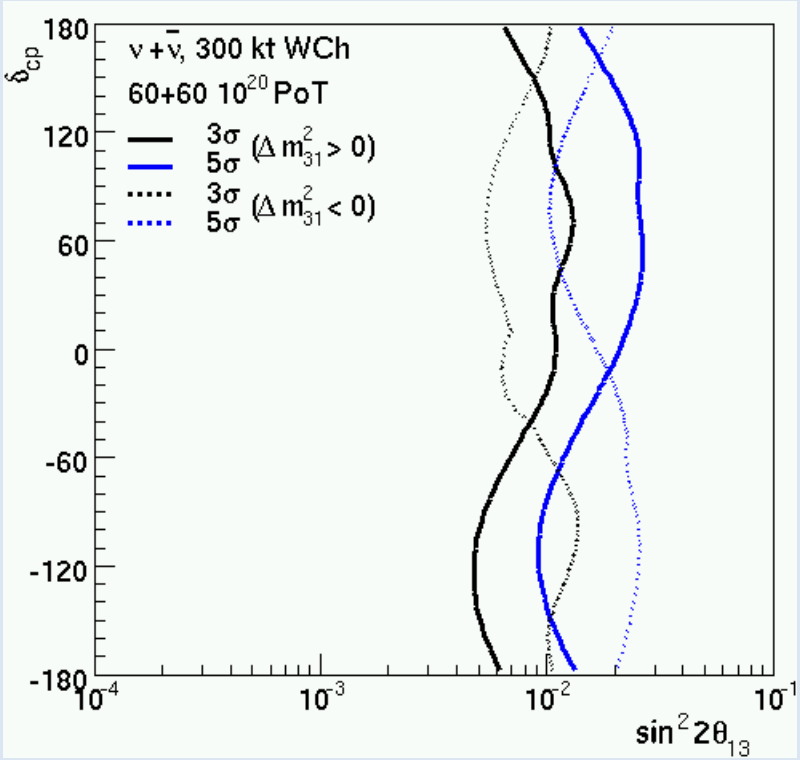


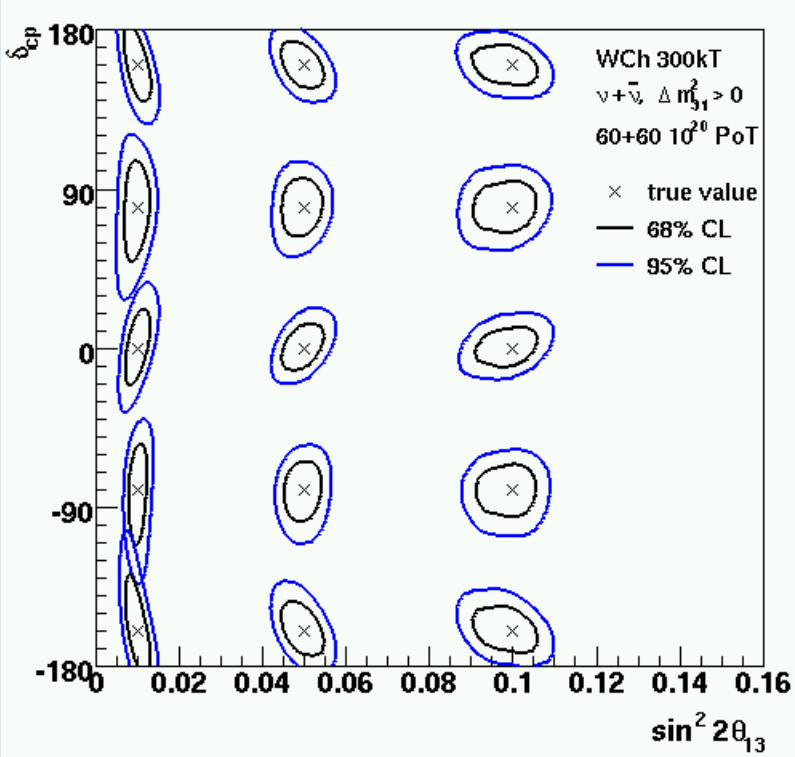
IM
3 kt

nde

DUSEL 300 ktons

300 kTon + 2.4 MW





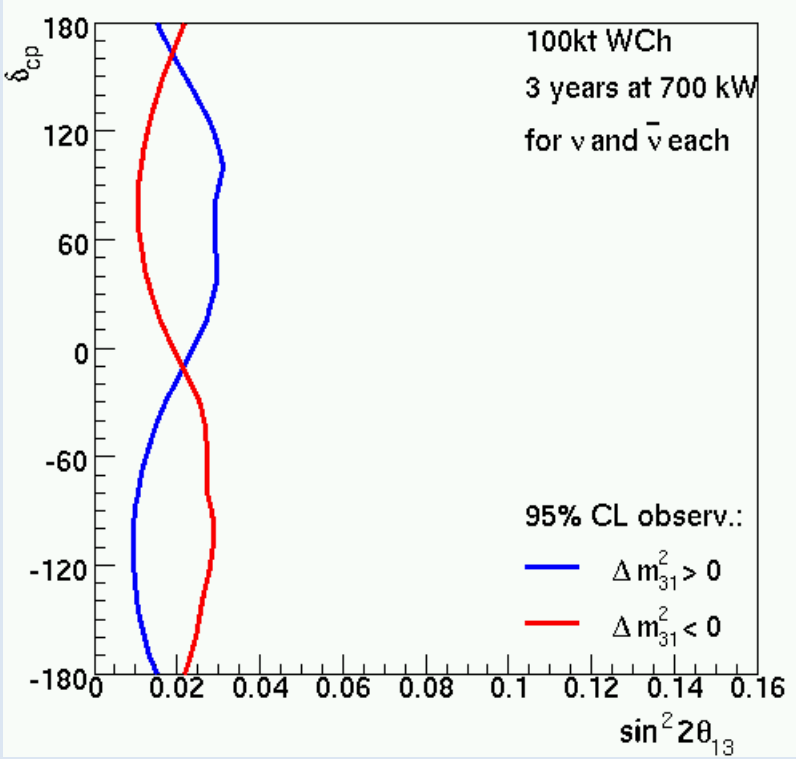
Mass Hierarchy

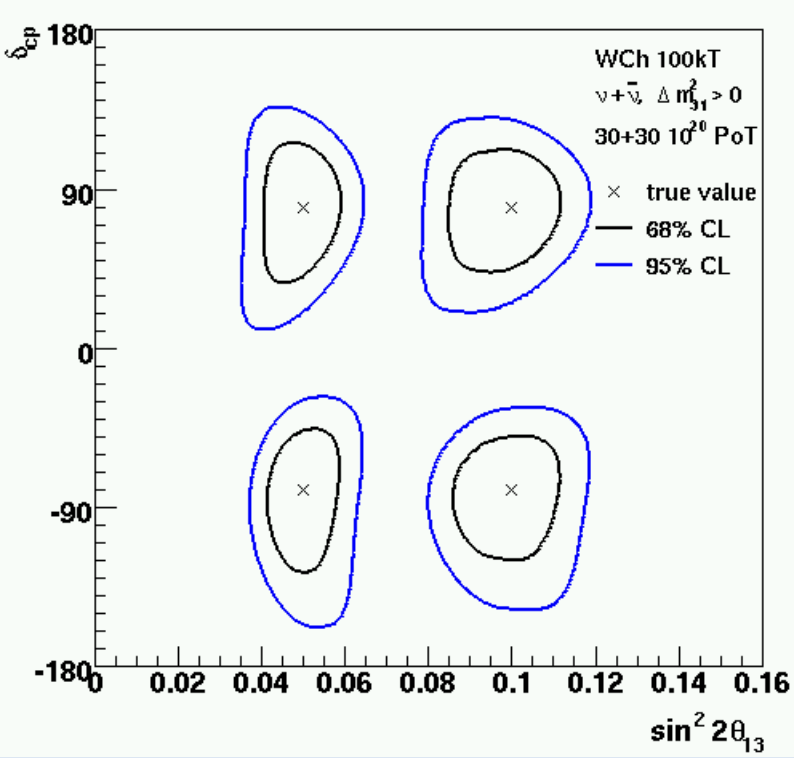
M.Dierckxsens

CP violation

5% background uncertainty
120 GeV 0.5 OA

100 kTon + 700 KW





Hierarchy

M.Dierckxsens

5% background uncertainty
120 GeV 0.5 OA

A Mature Detector Technology

"Key issues for scaling up the current generation of water Cherenkov detectors (Super-Kamiokande, SNO, etc.) and locating such detectors in underground locations in DUSEL are well understood. The cost and schedule for such a detector could be created with high degree of confidence."

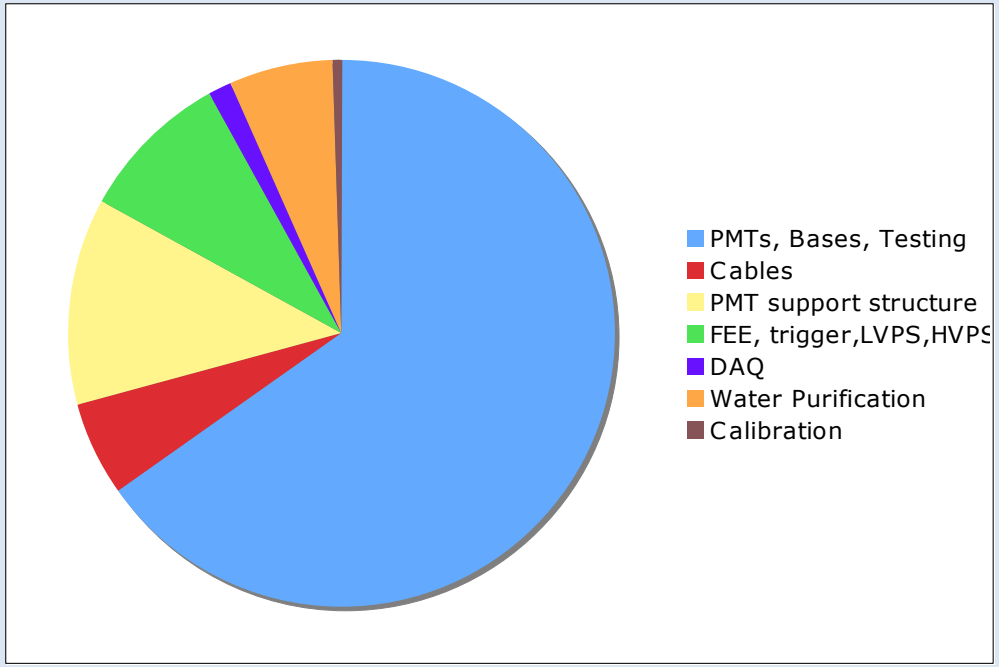
- Executive Summary of the Long-Baseline Study Group Report

- **IMB, Kamiokande, Super-K, SNO(D2O), miniBooNE (oil)**
- **"Mature" = 3/5 did not have serious accident**
- **"Mature" = We know some of the major problems that can cause disasters**
- **"Mature" = We know what to do to improve sensitivity and lower costs with little technical or schedule risk**
- **This project has little technical risk. Cost and schedule are main concerns.**

Cost Drivers

- Study done for NuSAG: 30% cavern, 70% instrumentation
- Instrumentation costs driven my PMT's, mounts, electronics
- Cost analysis for CD-0 is in progress

Instrumentation only
~70% of total cost



Controlling Costs

- **Cavern:** timely geotechnical investigation
- **Cavern:** reduce container cost, shape optimization
- **Cavern:** improve PMT mechanical strength
- **PMT's:** improve quantum efficiency
- **PMT's:** enhance industrial capability and competitiveness
- **PMT's:** Optimization for scope, possible phasing
- **Water System:** materials testing and selection
- **Electronics:** development of distributed, low-cost HV distribution and electronics

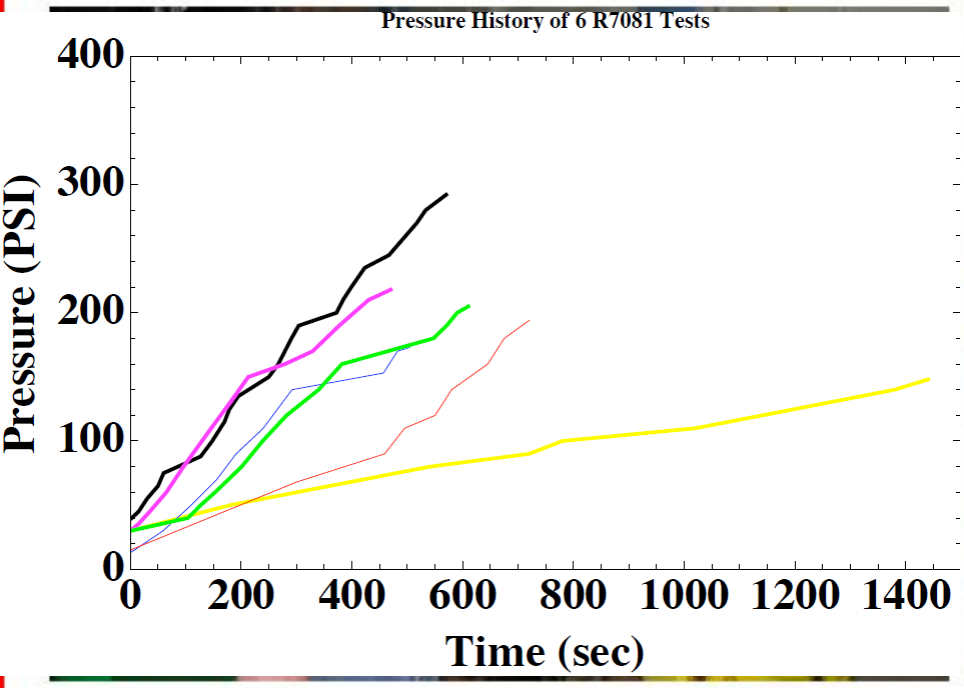
PMT's

- Roof spans are an important factor in cavern cost
- cavern depth is currently limited by ability of PMT's to withstand implosion
- BNL program to investigate *how* PMT's implode is underway in collaboration with Hamamatsu
- BNL, RPI, Wisconsin PSL proposal for improving PMT strength submitted to NSF PNA program
- With help from BNL, Orsay has begun a similar program

Reducing Cost of PMT's

- New high Q.E. PMT's from Hamamatsu would reduce number of PMT's required. SK has 11,200 20" PMT's with ~23% QE (40% coverage and 4 MeV threshold)
- New 10" PMT's would require ~50,000 for 100 kton detector for "effective" 25% coverage
- We do not need a low threshold, but we do want to keep tracking resolution
- *What is the optimal number of PMT's?*

Pressure testing

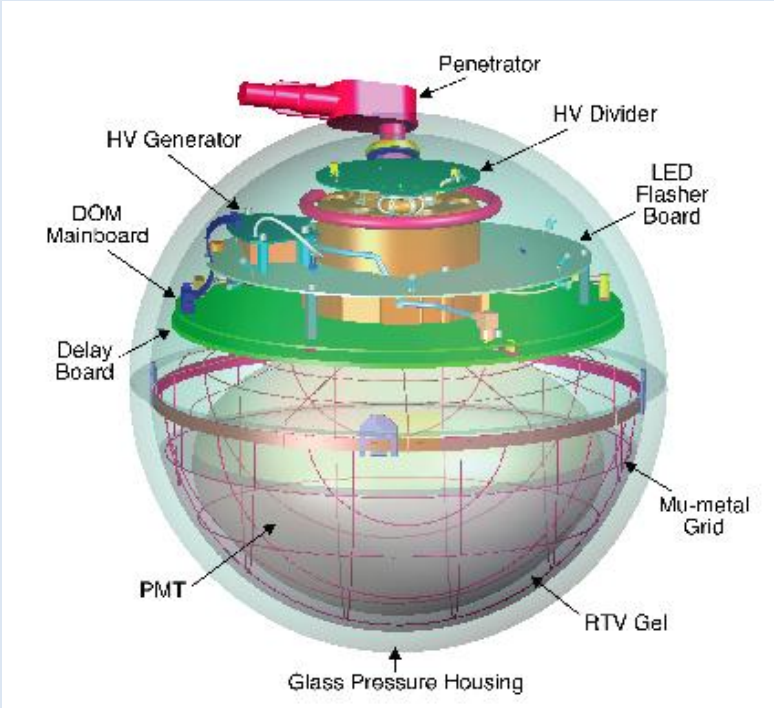


Have 32 phototubes from Hamamatsu. Pressure vessel from BNL. Evolving testing protocol.

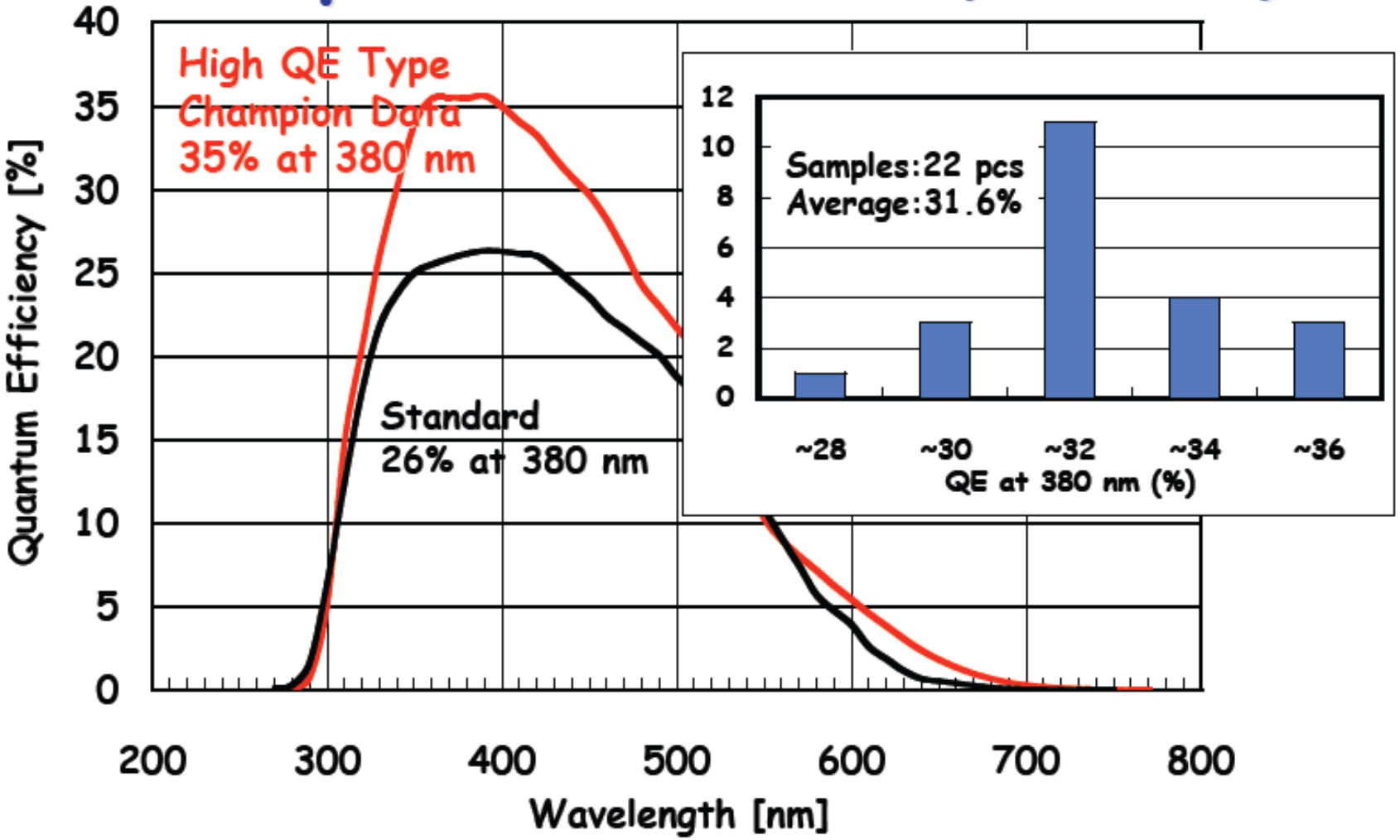
Hamamatsu rating is ~7atm. Tested this tube until it broke at 148 psi (~10atm)

78 high quantum efficiency 10”PMT successfully tested for use in IceCube

- More than 4000 sensors with standard 10” PMT (R7081-02) integrated and tested in IceCube
- 78 high quantum efficiency PMT (10”) tested with IceCube standard production test program.
- Result:
  - Quantum efficiency ~38% higher (405 nm, -40C)
  - No problems found
  - Low temperature (-40C) noise behavior scales with quantum efficiency as expected.
- Plan to use high QE PMT on 6 Deep Core strings for enhanced sensitivity at low energies (<100GeV, dark matter)
- Sensors already at the South Pole



Example data R7081 (10 inch)



Goal of development is 43%

PMT: further choice

Items	Example 12-inch PMT	R7081 10-inch PMT	R5912 8-inch PMT
Diameter	300 mm	253 mm	202 mm
Effective Area	280 mm min.	220 mm min.	190 mm min.
Tube Length	330 mm	245 mm	220 mm
Dynodes	LF/10-stage	LF/10-stage	LF/10-stage
Applied Voltage	1500 V	1500 V	1500 V
GAIN	1.00E+07	1.00E+07	1.00E+07
T.T.S.(FWHM)	2.8 ns	2.9 ns	2.4 ns
P/V Ratio	2.5	2.5	2.5
Dark Counts	10,000 cps	7,000 cps	4,000 cps

NEW !

HAMAMATSU
HAMAMATSU PHOTONICS K.K. Electron Tube Division

Office of Science
U.S. DEPARTMENT OF ENERGY

M.Diwan

BROOKHAVEN
NATIONAL LABORATORY

Electronics

- If we have 50,000 PMT's and use same cabling scheme as used by SK, we need 13,000 km of cable!
- cross-talk, signal degradation, **high cost** associated with cable installation and storage
- how to improve this situation?

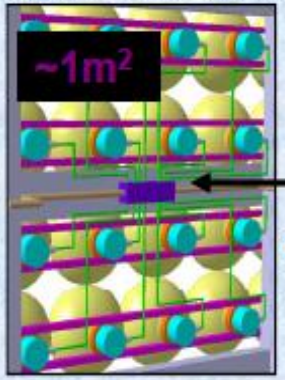
R&D : PMm2

contact: J.E.Campagne
campagne@lal.in2p3.fr

- 500k€/3yrs funded by French National Research Agency (ANR) for 2007-2010
- Participating: LAL-Orsay, IPN-Orsay, LAPP-Annecy, Photonis

PMm2 philosophy for large detectors:

Replace large PMTs (20") by groups of smaller ones (eg.12") originally proposed by Photonis Co. at NNN05



x16

"Local"

FE-ASIC | Monitoring | HV

FPGA + µC

Network Controller

"No possible local coincidence"
(low energy event
10PMs/MeV over 81000 PMs)

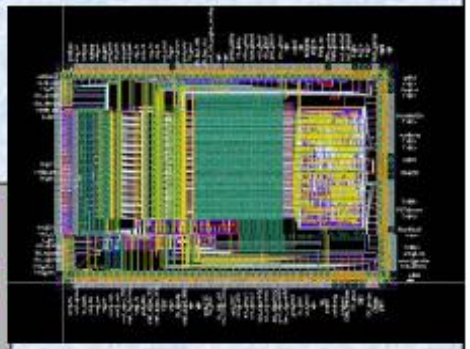
⇓

TRIGGER LESS DAQ

Twisted pairs cables for Clock sync. - Digitized Data - Power

"Outside" Ethernet switches + server

DAQ | GPS receiver



*: MEMPHYS ~ 3 x 81,000 PMTs; LENA & GLACIER ~ 20,000 ÷ 30,000 PMTs

Possible Sensitivity Enhancements for non-beam physics

- Gadolinium doping:
  - sensitivity to neutron capture
  - diffuse neutrino flux from relic SN
  - nuebar tagging for Home/Andromeda SN
  - use in proton decay/QE tagging?
- Wavelength shifting dyes:
  - enhanced light collection without PMT's

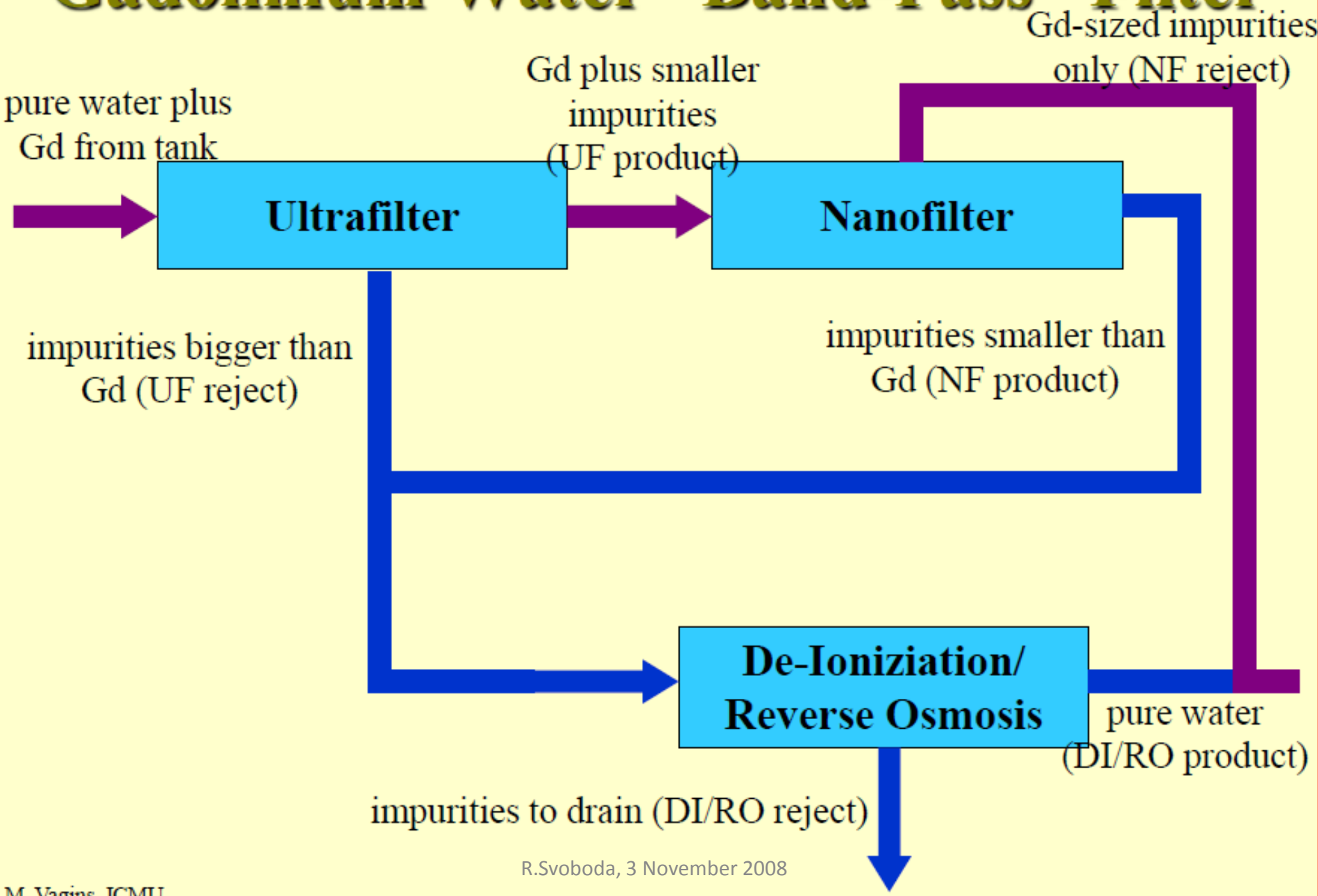
Gadolinium Doping

- Sensitivity to neutron capture via 8 MeV gamma cascade (e.g. M.Vagins, NNN08)
- Inexpensive, low risk. Could be implemented after construction completed, no schedule risk.
- Technical challenges:

  - material compatibility (LLNL) Chose materials that do not contaminate the water.

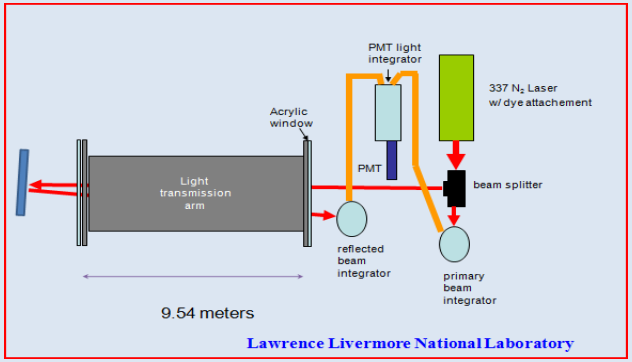
  - water treatment (UC Irvine). Remove impurities but leave gadolinium in solution.

Gadolinium Water "Band-Pass" Filter



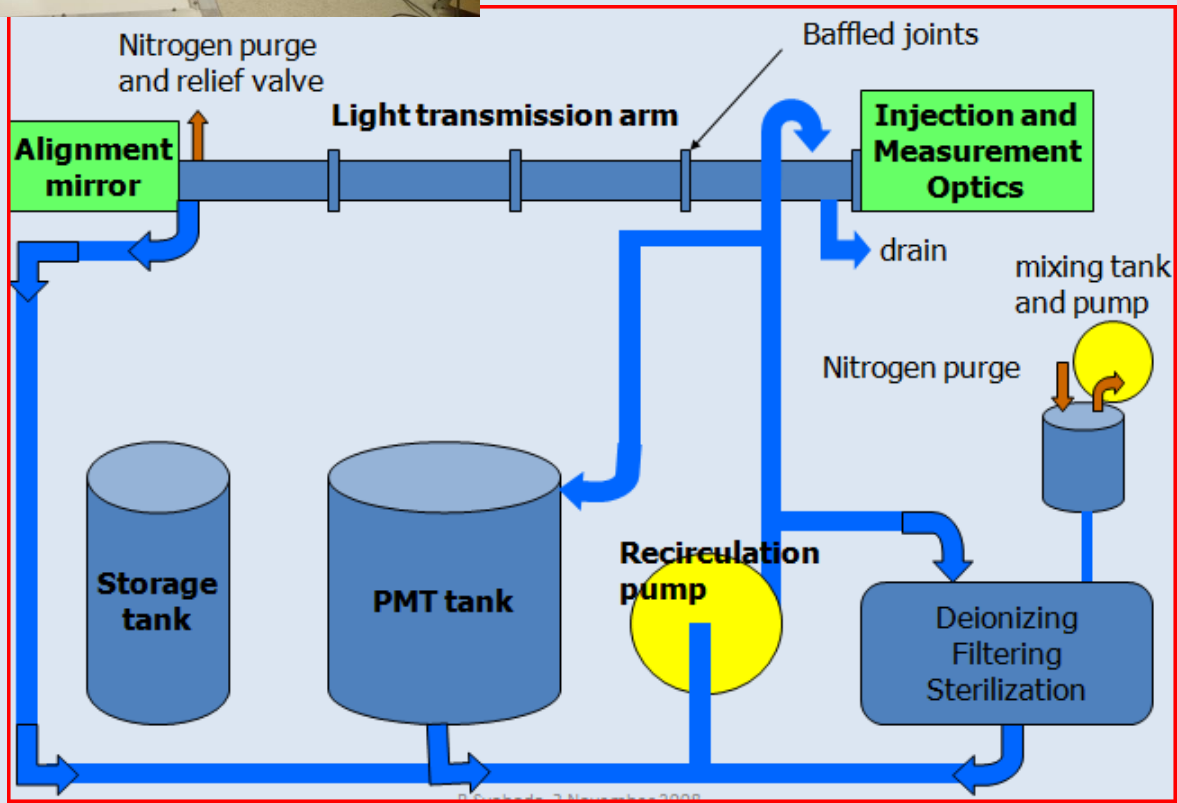
M. Vagins, ICMU

Testing of Material Compatibility at LLNL



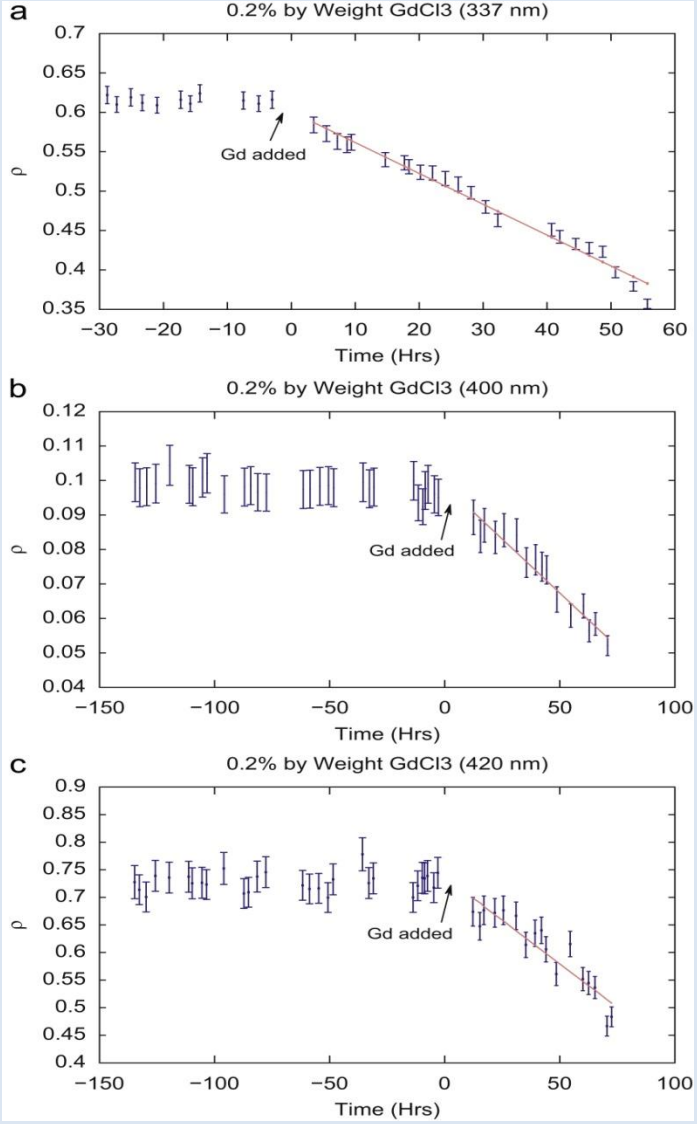
LLNL program to develop water-based neutron detectors

goal: determine cause of water “aging”, identify “clean” materials



Water quality test (0.2% $GdCl_3$ in water): Results

- 1) $GdCl_3$ has no immediate effect on water quality
- 2) Subsequent deterioration is constant in time – suggesting exposure of $GdCl_3$ to surface of stainless pipe is the problem
  - Note: leaching of Fe from stainless steel was suspected (Fe is a strong UV and blue absorber)
- 3) Later additions to pipe from $GdCl_3$ water stored in polypro tank showed no sign of deterioration
- 4) Tests with $FeCl_3$ suggest that 14ppb Fe is enough to destroy water quality instantly
  - Again Suggests Fe leaching from SS



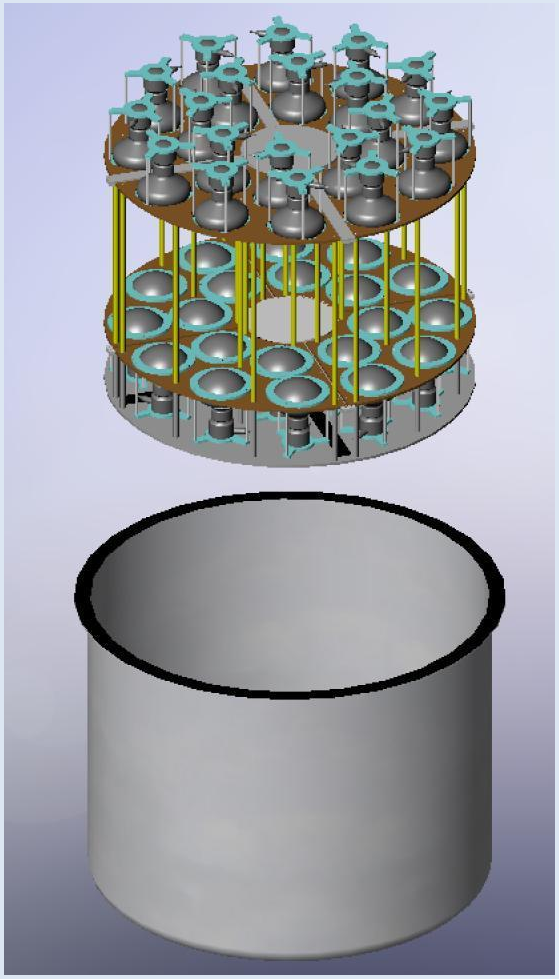
W. Coleman et al. / Nuclear Instruments and Methods, A 595 (2008) 339–345

Wavelength Shifting Dyes

Use of water soluble dyes can increase Cerenkov light detection by up to a *factor of three* (SNO collaboration)
X.Dai, et al, NIM A 589 (2008) 290-295

carbostyril 124 (CS124) and Alexa Fluor 350 (AF350) are highly soluble, have strong absortion at 200-250 nm, and strong emission at 390-480 nm. Many other candidate dyes.

UC Davis test cell



LLNL WND test detector
(under construction)

Project Management

- We are *now* at the point where formal project management is required.
- The Collaboration looks forward to working with National Lab based management.

Conclusions

- There are many areas to work on to reduce costs, increase reliability, improve sensitivity
- Many areas could move faster with assistance from national labs: electronics, chemistry, engineering, physics optimization. Industrialization.
- WC Working Group, S4 Proposal
- *Our goal: bring WC detector to CD-1 readiness by end of 2009*

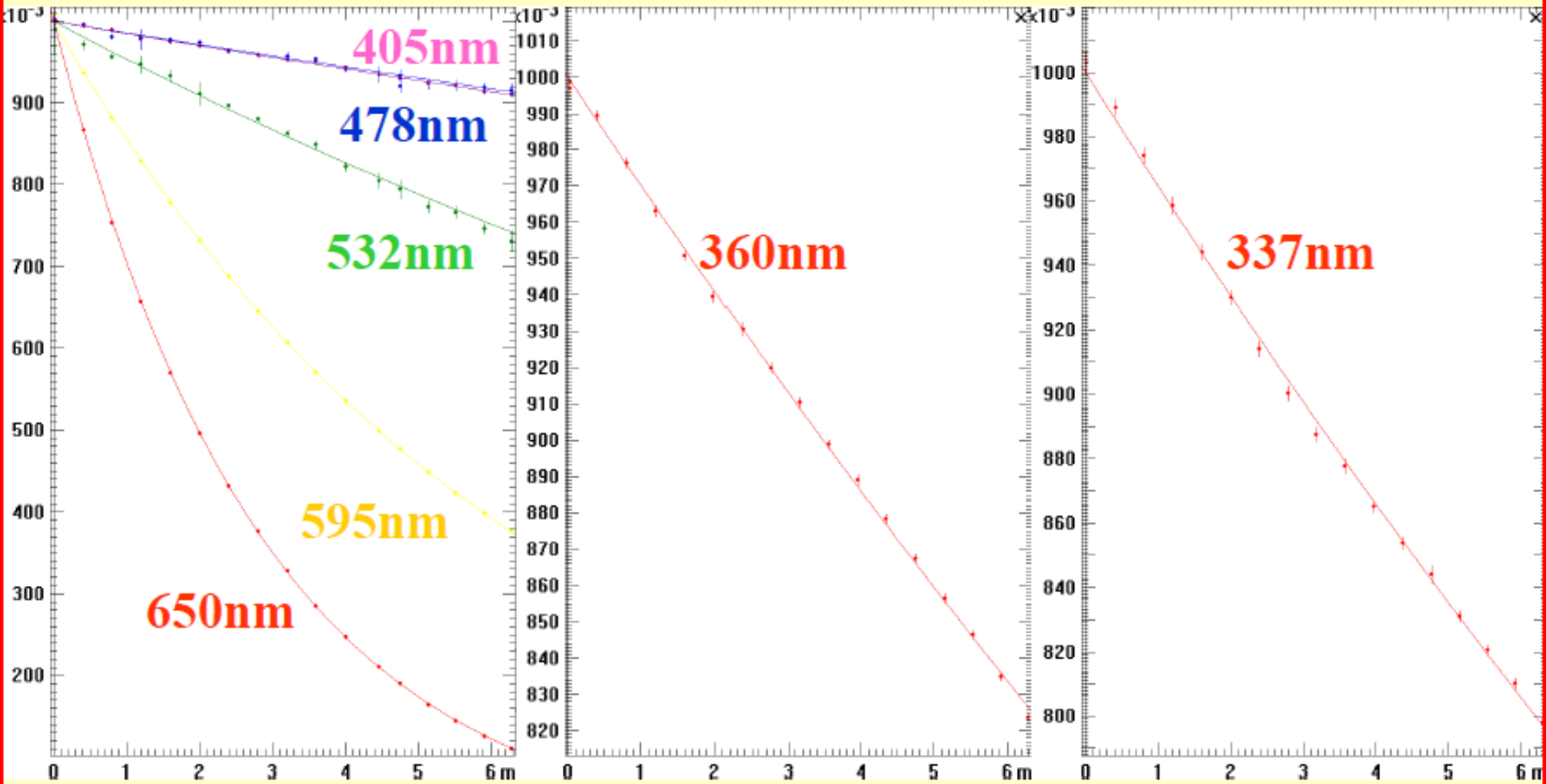
backup

$Gd_2(SO_4)_3$ Filtering Progress

- took data with ultrafilter and two types of nanofilters
- basic principle is sound
- UF passed ~100% of $Gd_2(SO_4)_3$
- NF rejected >98% of $Gd_2(SO_4)_3$
- next: try multiple stages of NF; clean up product with RO units (before 2009)
- next: measure water transparency of $Gd_2(SO_4)_3$ (before 2009)

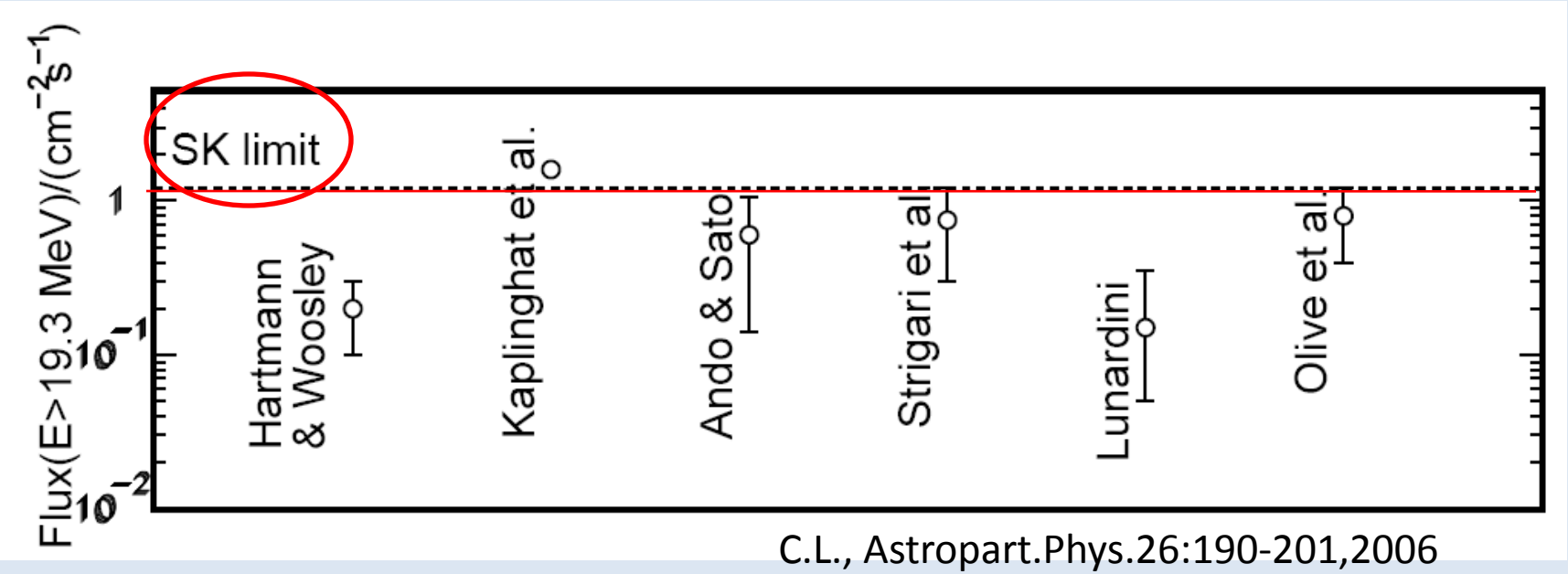
$GdCl_3$ Solution

0.8% Solution: 4xGadzooks! Concentration



Michael Smy, UC Irvine

Potential Discovery for DUSEL



C.L., Astropart.Phys.26:190-201,2006

- Depends on stellar formation rate at z>0.5
- Test collapse models without waiting for galactic SN

C.Lunardini

(10-20) x SK : event rate

- Exposure 1.6 Mton x year
  - e.g., 0.2 Mt for 8 years
  - Threshold 11.3 MeV, 100% efficiency

SN1987A-motivated (conservative)	Model-motivated (generic)	Max. allowed by SK limit
~22-128	~250	...

C.L., Astropart.Phys.26:190-201,2006, Fogli et al. JCAP 0504:002,2005, Volpe & Welzel, 2007, C.L. & O.L.G. Peres, to appear soon.

PMT considerations

	10 inch R7081	20 inch R3600
Number (25% cov)	~50000	~14000
QE	25%	20%
CE	~80%	~70%
rise time	4 ns	10 ns
Tube length	30 cm	68 cm
Weight	1150 gm	8000 gm
Vol.	~5 lt	~50 lt
pressure rating	0.7Mpa	0.6Mpa
∢ coverage/pmt	0.6 deg	1.1 deg
∢ granularity	1.0 deg	2.1 deg