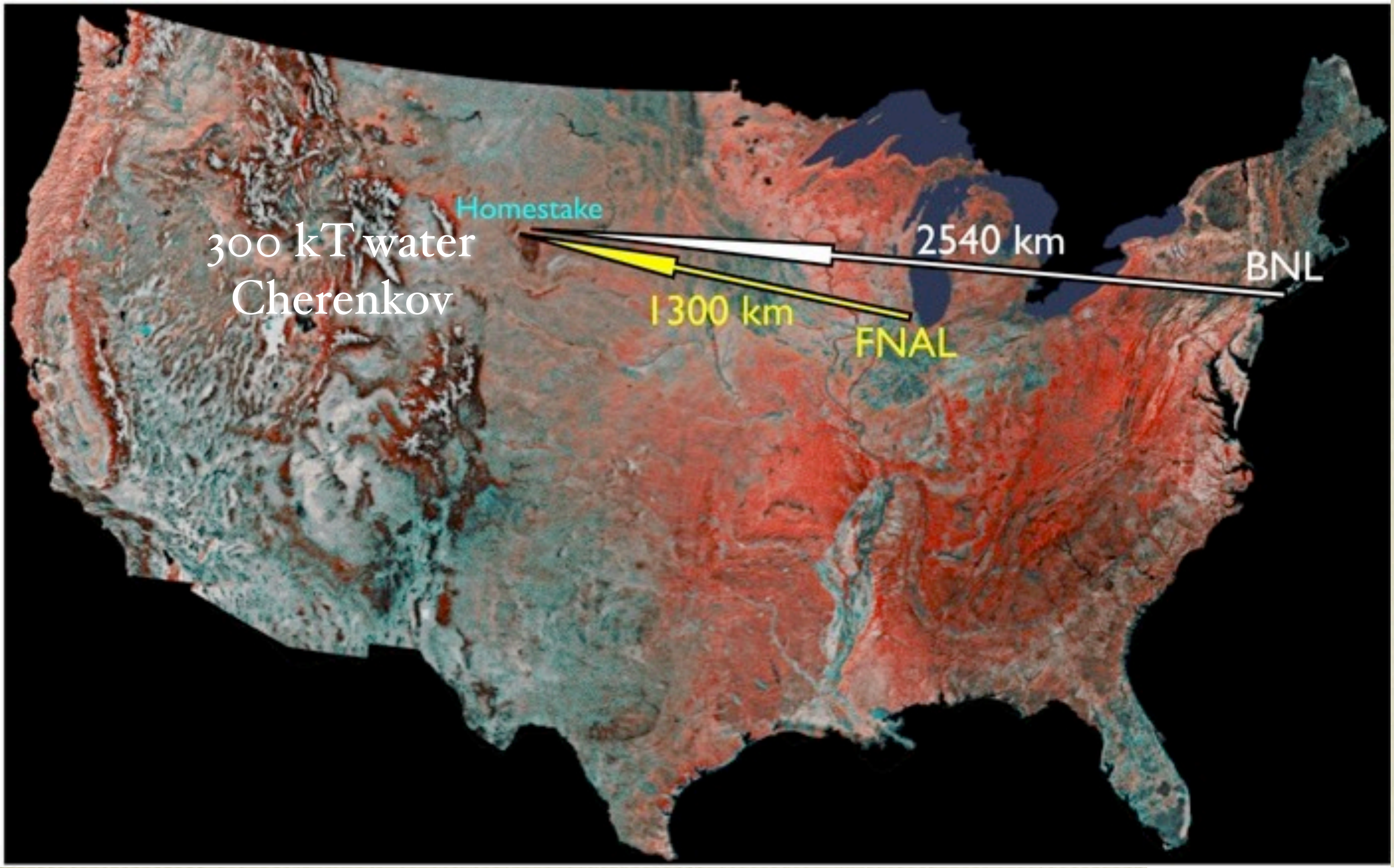
FNAL to DUSEL long baseline experiment

- Milind Diwan (BNL, USA) 6/16/2009 CAEAI Briefing



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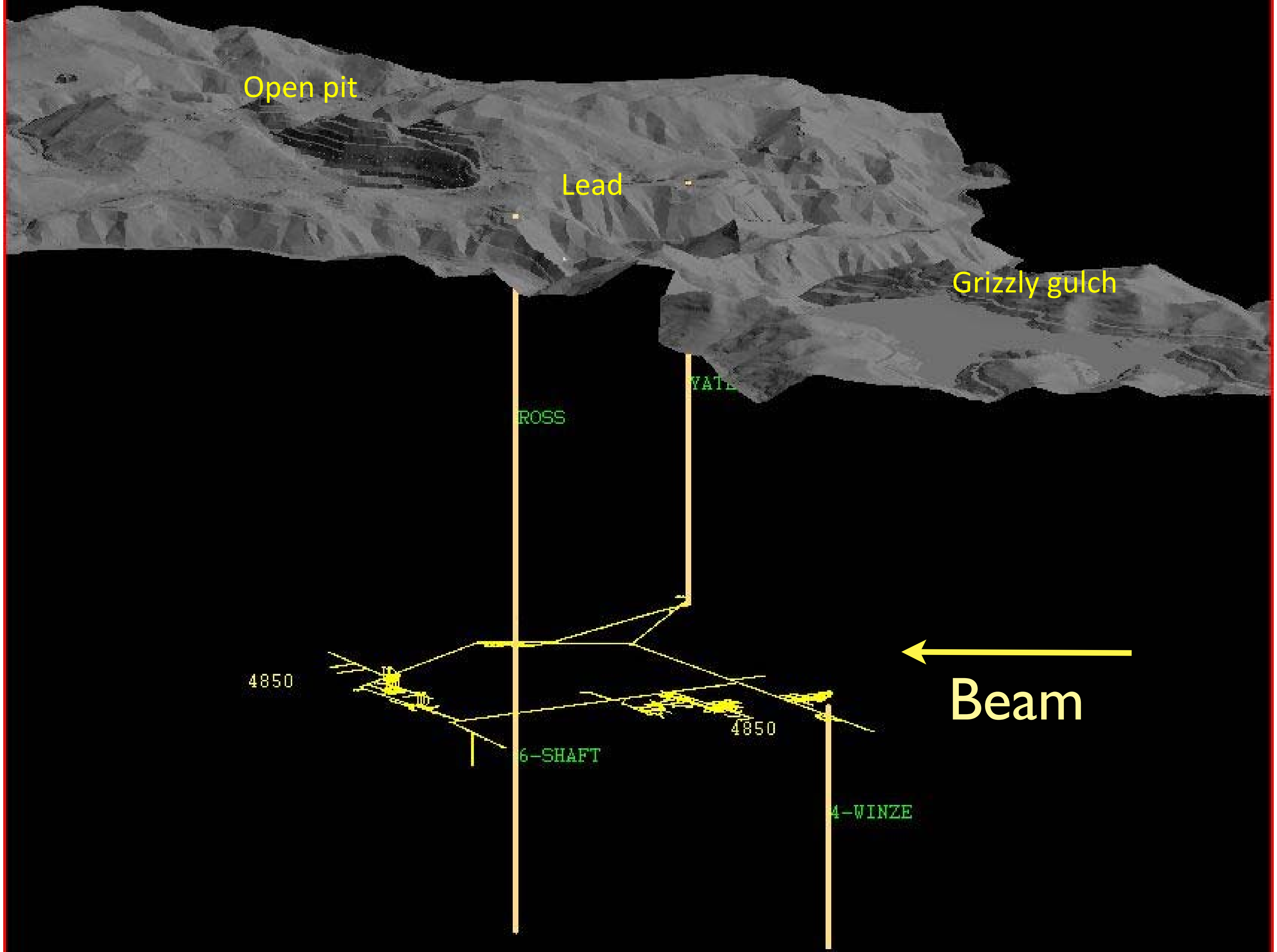
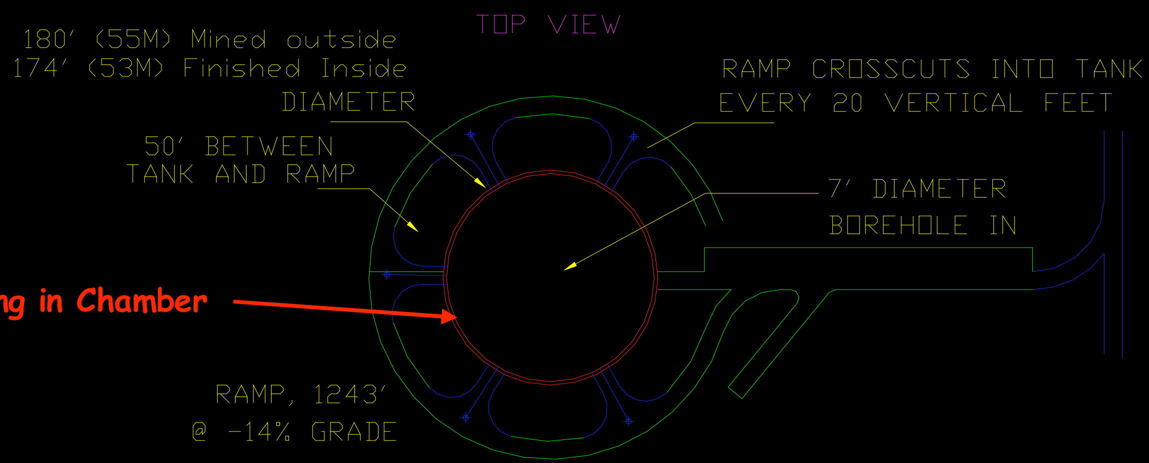


The Detector @ homestake

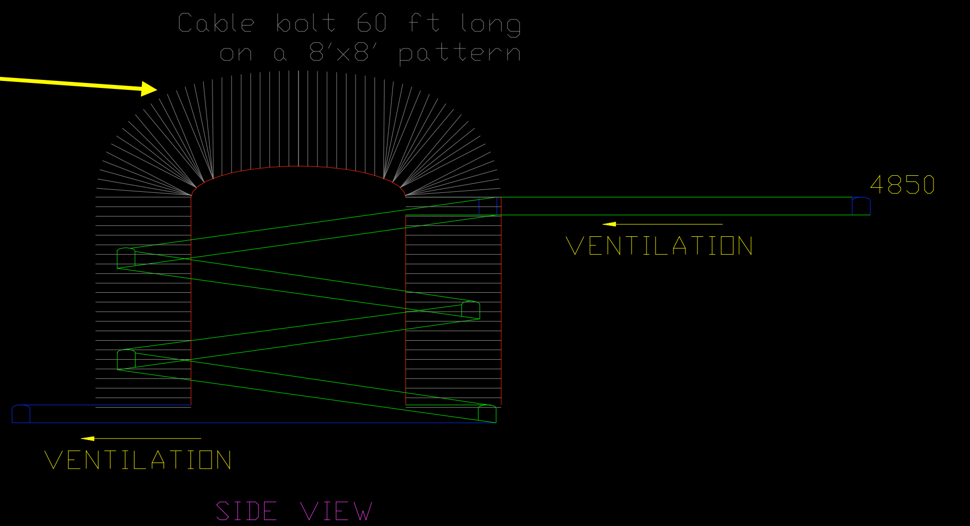
MEGATON MODULAR MULTI-PURPOSE NEUTRINO DETECTOR

✓ Chamber Design



Controlled Blasting in Chamber

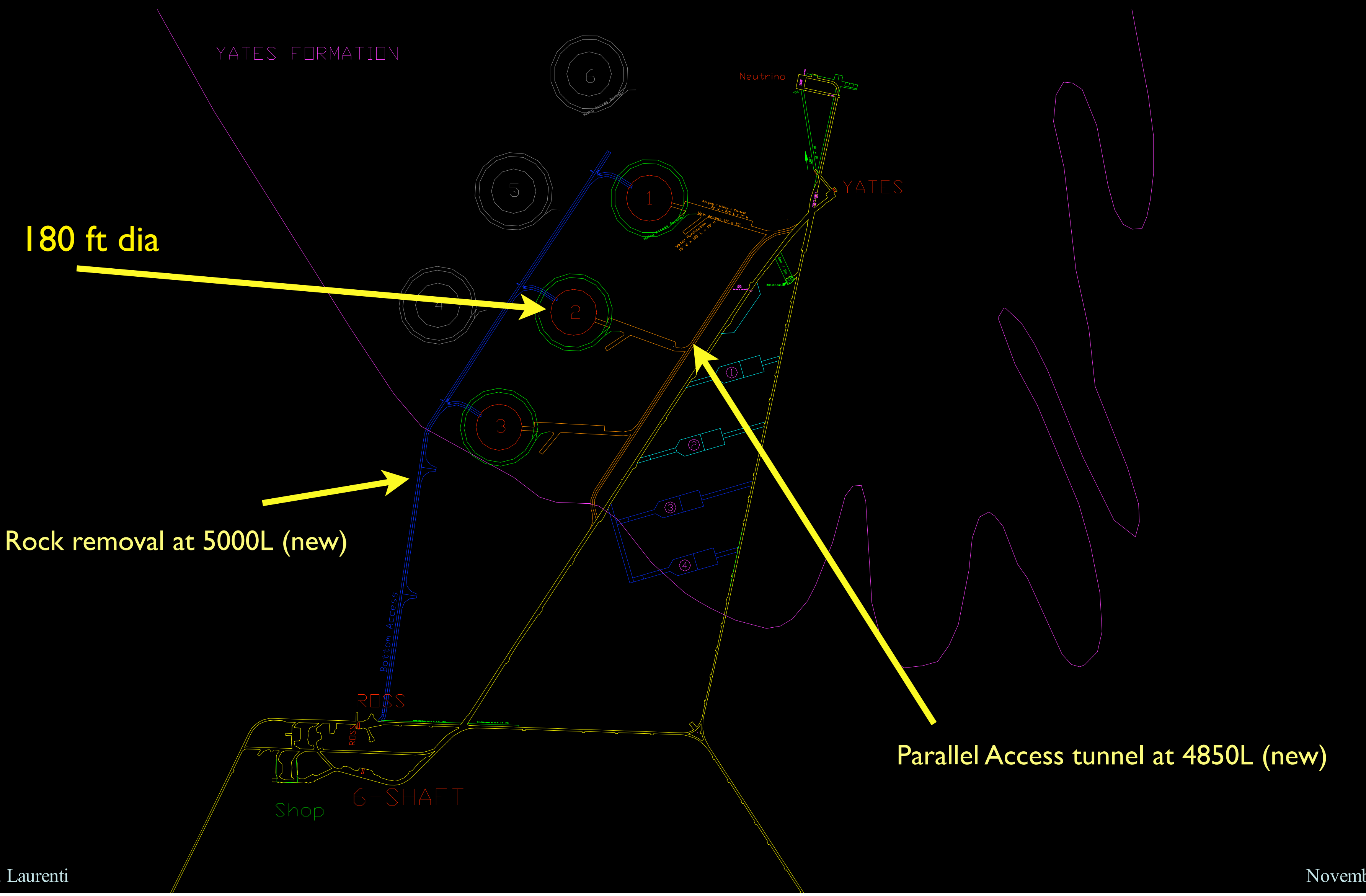
Could use Instrumented Cables for Engineering / Geotechnical Study



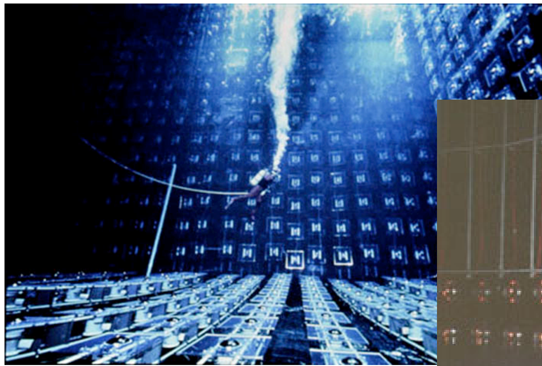
Megaton Modular Multi-Purpose Neutrino Detector

✓ **Modular Configuration**

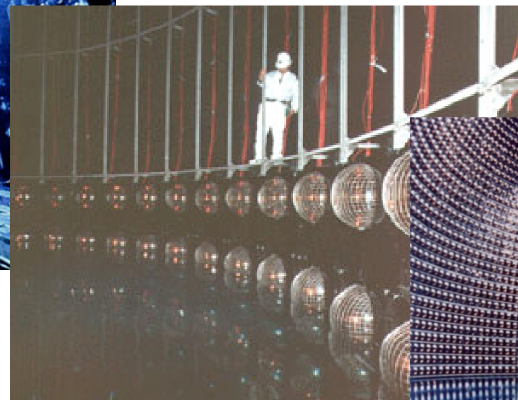
muon rate/cavern 0.1-0.3 Hz



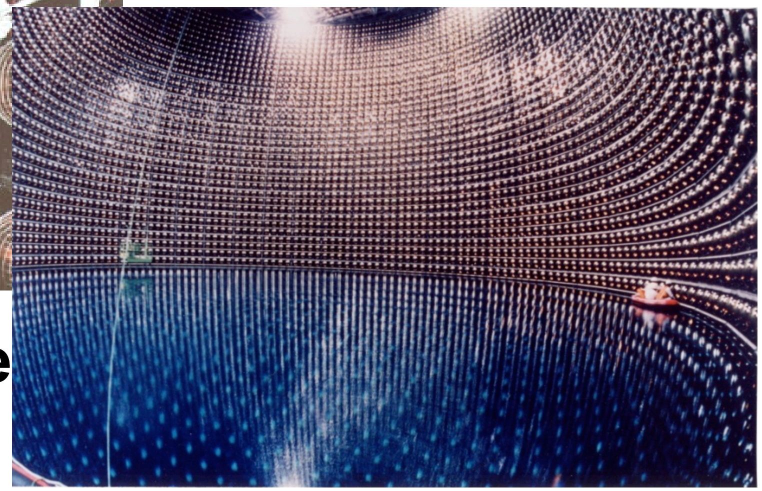
Water Cherenkov Detector



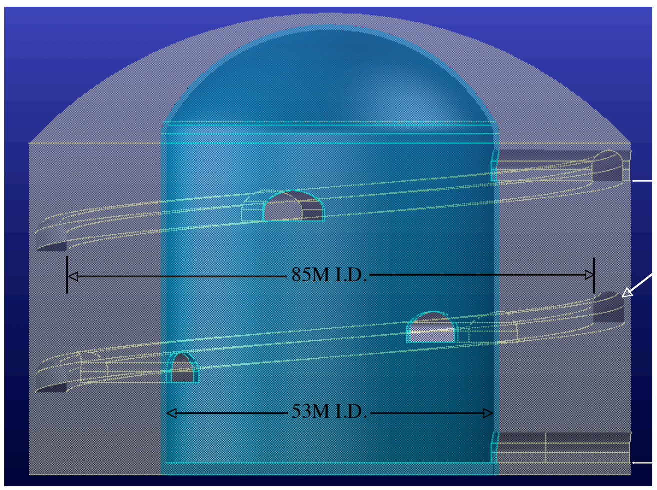
IMB
3 ktons



Kamiokande
1 kton



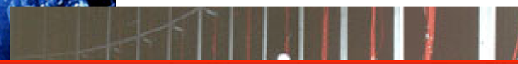
Super-Kamiokande
22 ktons



1 module fid:100 kT

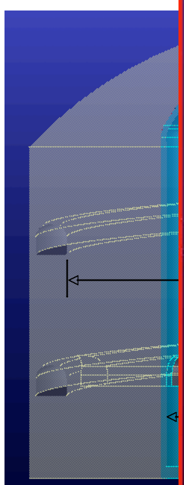
300 kT

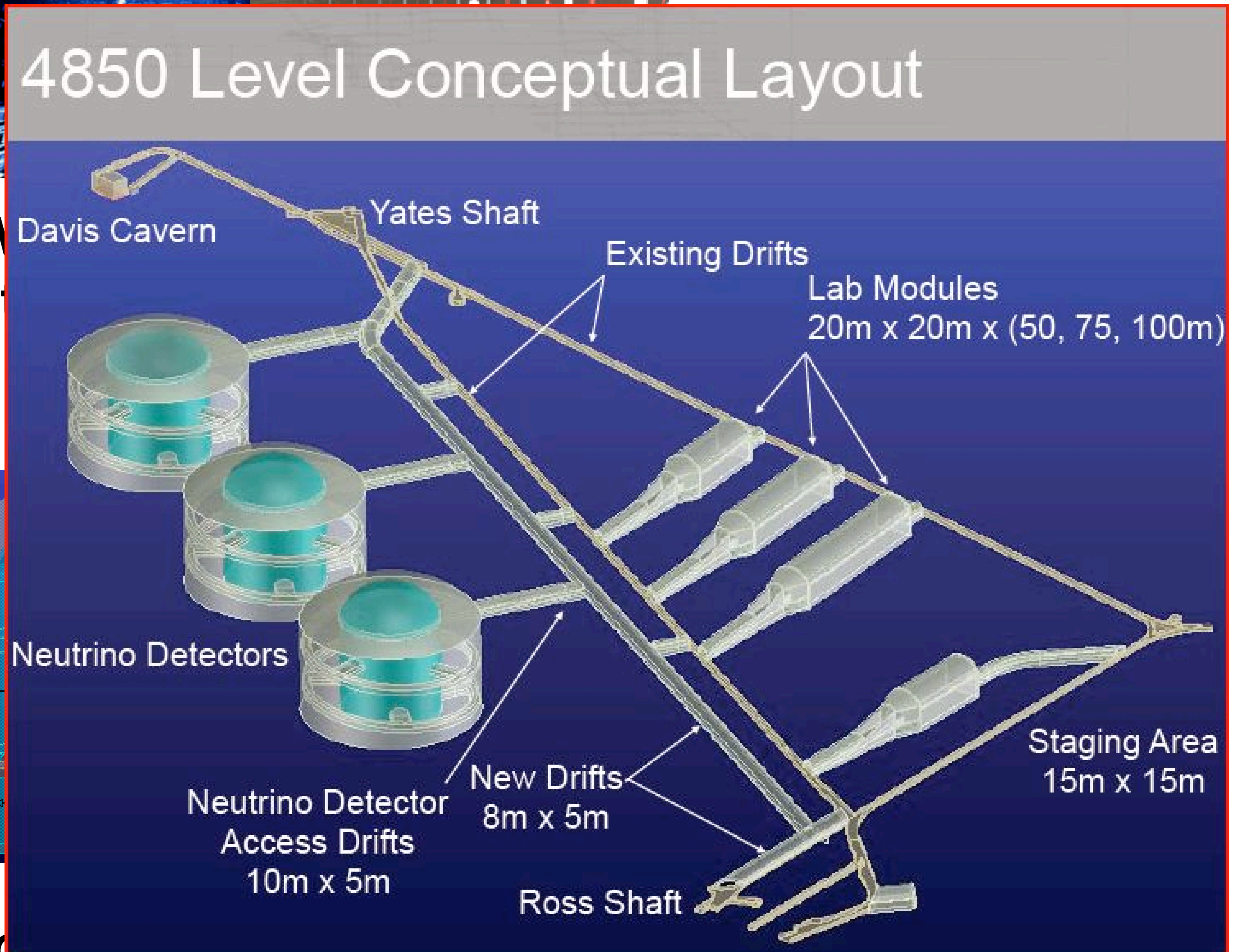
Water Cherenkov Detector



IM

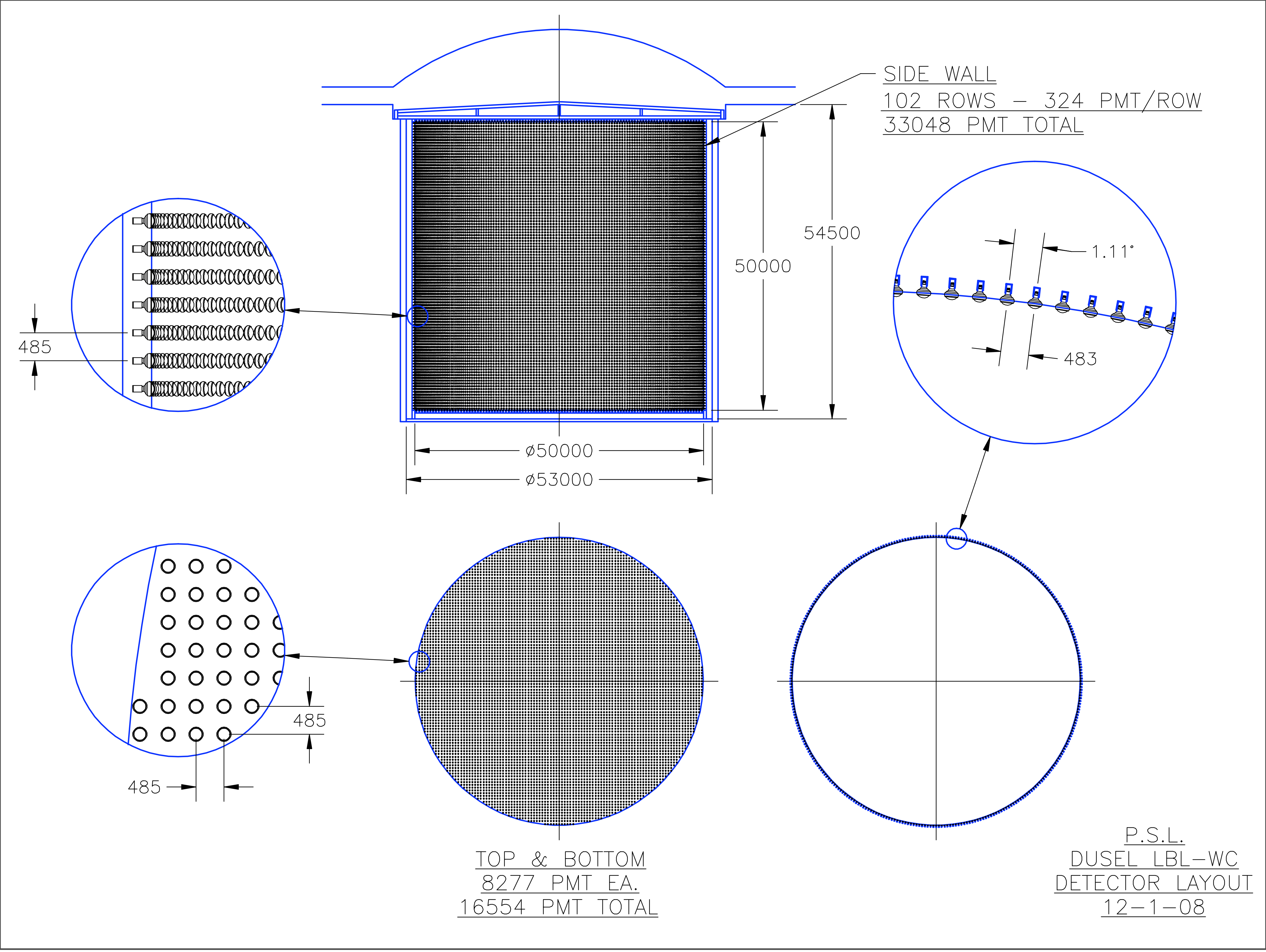
3 k





1 mo

300 kT



Tuesday, June 16, 2009

Why deep ? Cosmic Muons

Depth (mwe)	Rate (Hz)	Spallation (Hz)
0	500 kHz	8.5 kHz
265	3 kHz	50 Hz
880	400 Hz	7 Hz
2300	5 Hz	0.1Hz
2960	1.3 Hz	0.022Hz
3490	0.6 Hz	0.010 Hz
3620	0.26 Hz	0.0044 Hz
4290	0.09 Hz	0.002 Hz

Uncorrelated rate - few hundred/day

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Various Signal Event Rates

Physics	Rate/100kT/yr	Energy Range
1 MW, 120 GeV FNAL Beam	~30000	0.5-10 GeV
Proton decay	1	1 GeV
Atmospheric nu	14000	1-100 GeV
Solar nu_e	45000	>5 MeV
Supernova at 10kpc	23000	>5 MeV
Relic Supernova	30	15-25 MeV

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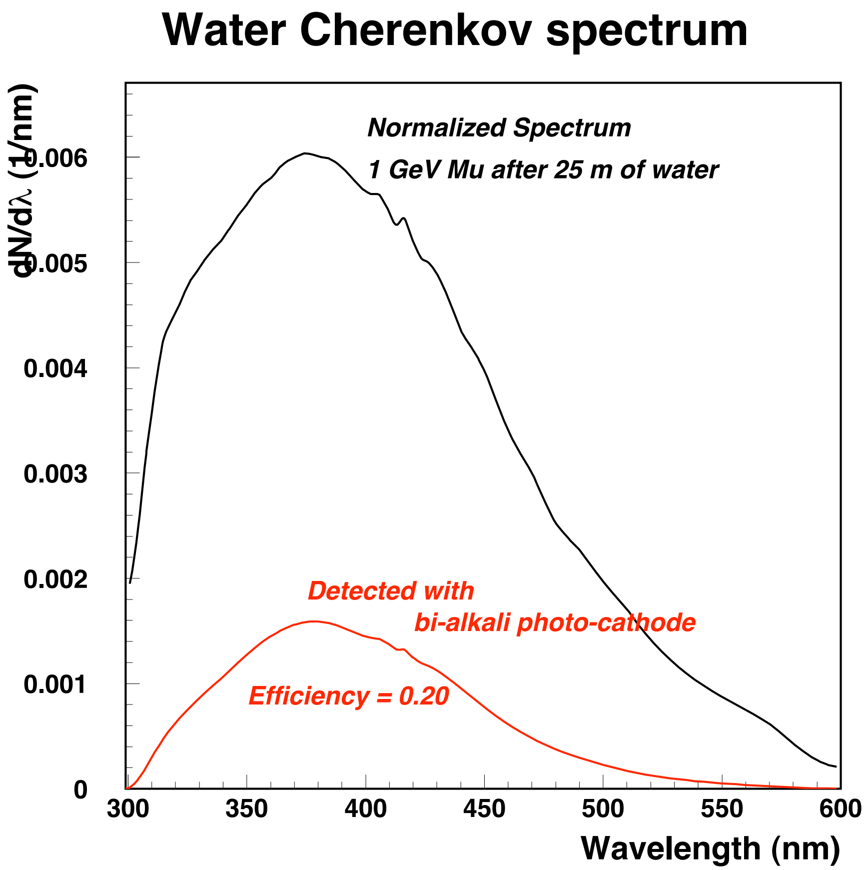
Amount of signal

5 MeV = 25 p.e.

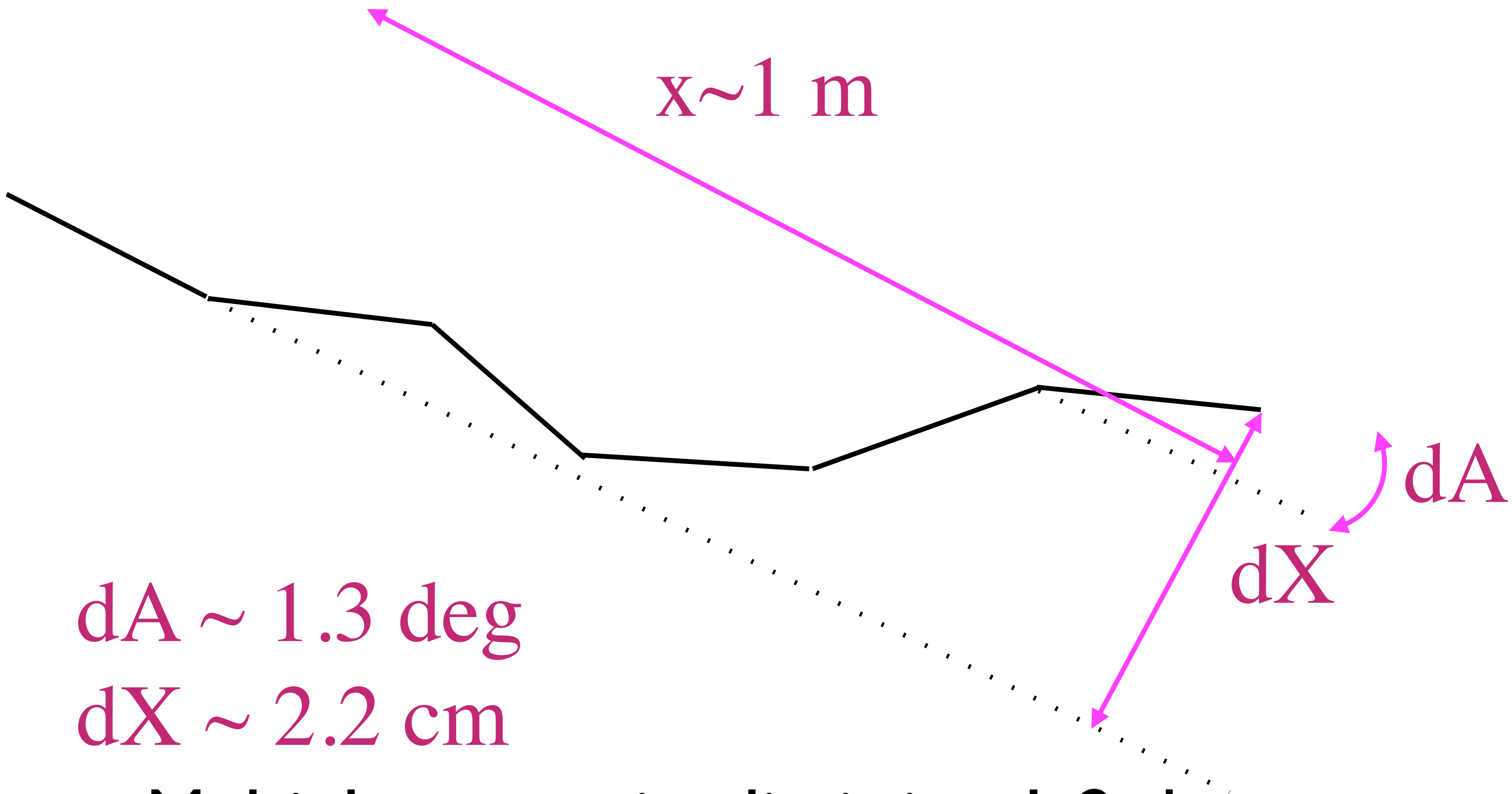
for 25% coverage with 20 % Q.E.

Gammas, Showers fluctuate due to electrons below threshold



n= 1.35 1.34 1.33

Muon Pattern



Multiple scattering limit is ~1-2 deg.

For average light path length of 25 m =>
~50 cm spacing between tubes is sufficient.

PMT R&D

- Issues are: making 150000 tubes in 6 years time, their efficiency, and their pressure performance.
- If PMTs can stand higher pressure, the cavern can be taller => more fiducial volume.
- Have had meetings with Photonis and Hamamatsu: no barrier to PMT production except money.

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

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M.Diwan

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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


R5912
R5912-02
R7081
R7081-20
R8055
R3600-02
R7250

SPECIFICATIONS

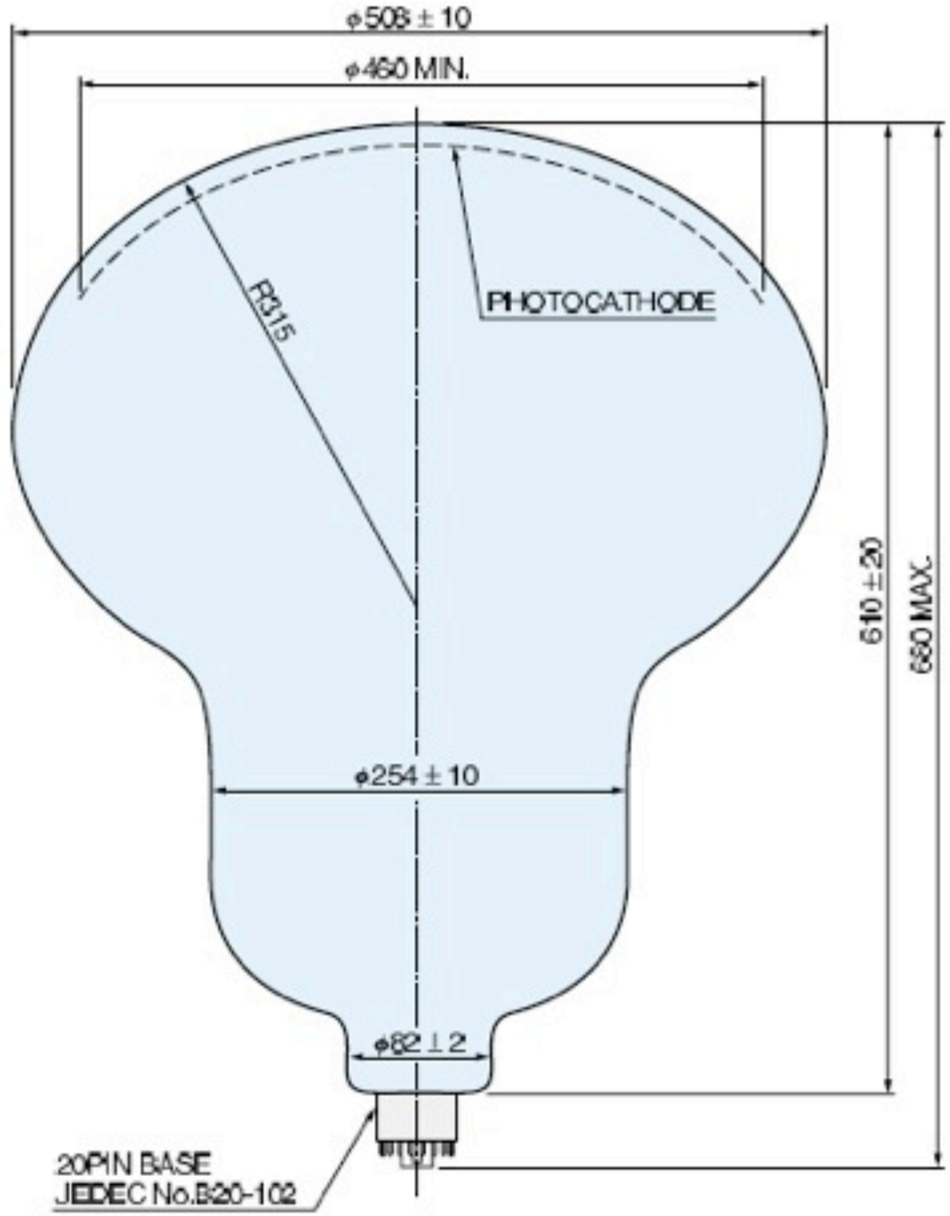
Type No.	Cathode Sensitivity: Luminous (2856 K) Min. (µA/lm)	Cathode Sensitivity: Luminous (2856 K) Typ. (µA/lm)	Cathode Sensitivity: Radiant at 420 nm Typ. (mA/W)	Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Min.	Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Quantum Efficiency at 390 nm Typ. (%)	Anode Sensitivity: Luminous (2856 K) Typ. (A/lm)	Anode Sensitivity: Radiant at 420 nm Typ. (A/W)	Anode Sensitivity: Gain Typ.	Anode Sensitivity: Applied Voltage for Typical Gain Typ. (V)
R5912	40	70	72	6.0	9.0	22	700	7.2×10^5	1.0×10^7	1500
R5912-02	40	70	72	6.0	9.0	22	70 000	7.2×10^7	1.0×10^9	1700
R7081	40	80	80	6.0	10.0	25	800	8.0×10^5	1.0×10^7	1500
R7081-20	40	80	80	6.0	10.0	25	80 000	8.0×10^7	1.0×10^9	1700
R8055	35	60	65	5.5	8.0	20	600	6.5×10^5	1.0×10^7	1500
R3600-02	35	60	65	5.5	8.0	20	600	6.5×10^5	1.0×10^7	2000
R7250	35	60	65	5.5	8.0	20	600	6.5×10^5	1.0×10^7	2000

NOTE: Anode characteristics are measured with the voltage distribution ratio shown below.
(   ): Measured with the special voltage distribution ratio (Tapered Divider) shown below.

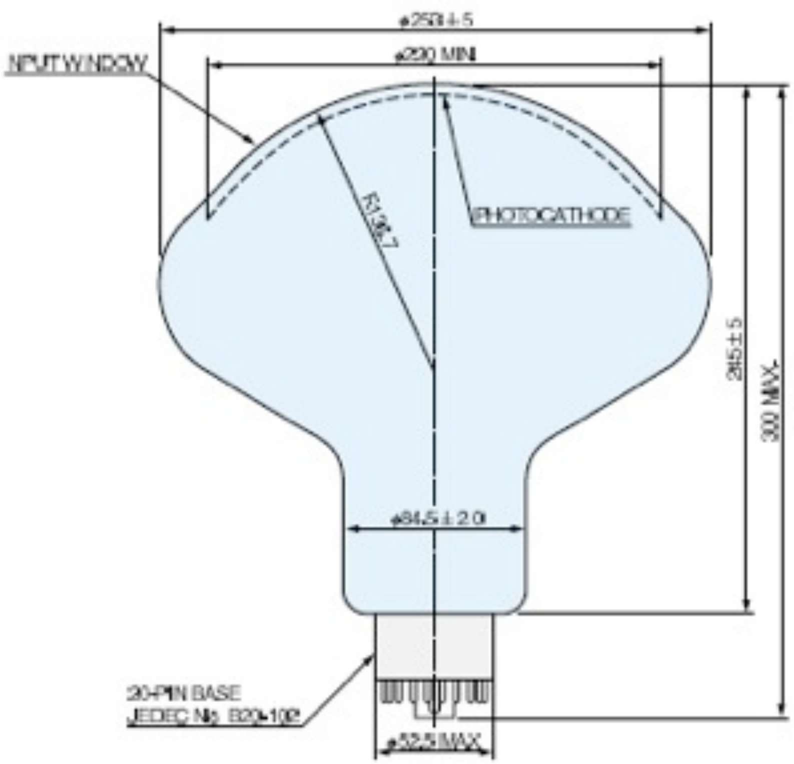
Type No.	Maximum Ratings: Supply Voltage Anode to Cathode (V)	Maximum Ratings: Supply Voltage Anode to Last Dynode (V)	Maximum Ratings: Average Anode Current (mA)	Maximum Ratings: Operating Ambient Temperature (°C)	Maximum Ratings: Storage Temperature (°C)	Maximum Ratings: Pressure (MPa)	Direct Interelectrode Capacitances: Anode to Last Dynode (pF)	Direct Interelectrode Capacitances: Anode to All Other Dynodes (pF)
R5912	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R5912-02	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R7081	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R7081-20	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R8055	2500	300	0.1	-30 to +50	-30 to +50	0.15	approx. 10	approx. 20
R3600-02	2500	300	0.1	-30 to +50	-30 to +50	0.6	approx. 36	approx. 40
R7250	2500	300	0.1	-30 to +50	-30 to +50	0.6	approx. 10	approx. 15

We are focussed on the R7081 tube
It is more efficient than the R3600.
25% *R7081 => 35% *R3600

●R3600-02



●R7081, R7081-20

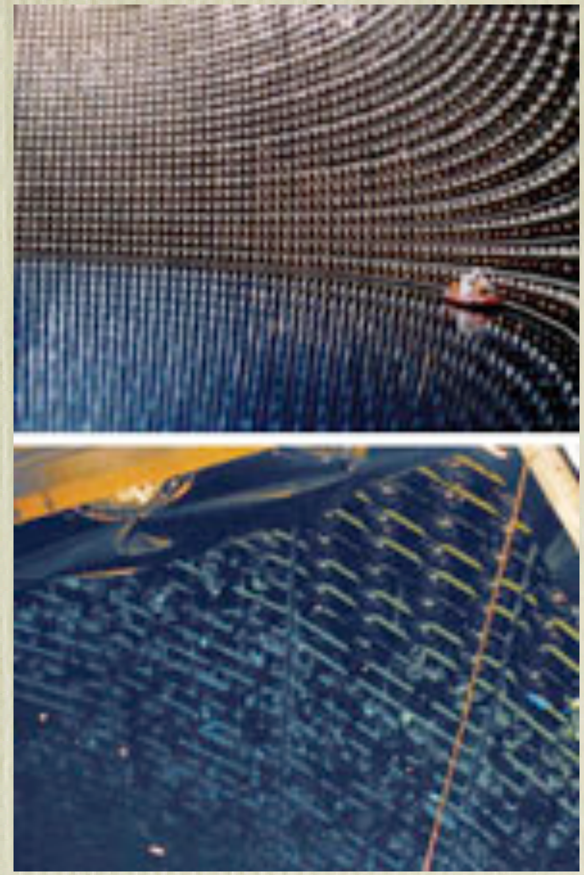


Baseline Plan

- The Baseline plan is R7081 with 25%cov*25%QE(Learned recently that high QE can be made at same rate).
- The correct number to look at is Coverage*QE*Collection eff.
- We will need 30000 to 60000 per chamber depending on shape and QE to obtain similar amount of light collection as SK.
- R7081 has been used by Icecube. There is also production for other projects.
- Only issue for us is pressure performance.

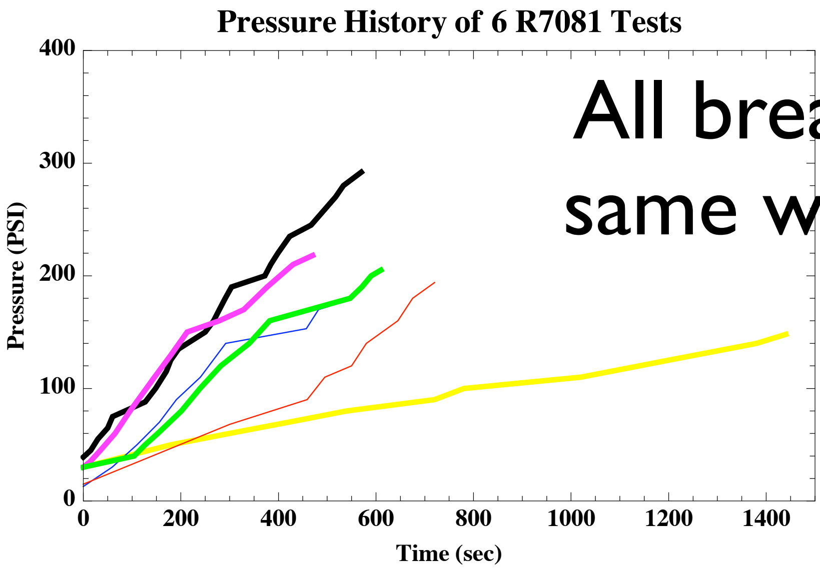
SuperK incident.

- On November 12, 2001, a single failed 20 inch PMT at the bottom of the tank caused a chain reaction and imploded 6777 out of 11146 PMTs.
- Support structure, black optical barriers, cables, suffered damage.
- Subsequent analysis: time to generate shockwave - 10 ms, shock strength on neighbor - >10 MPA, 50 microsec.



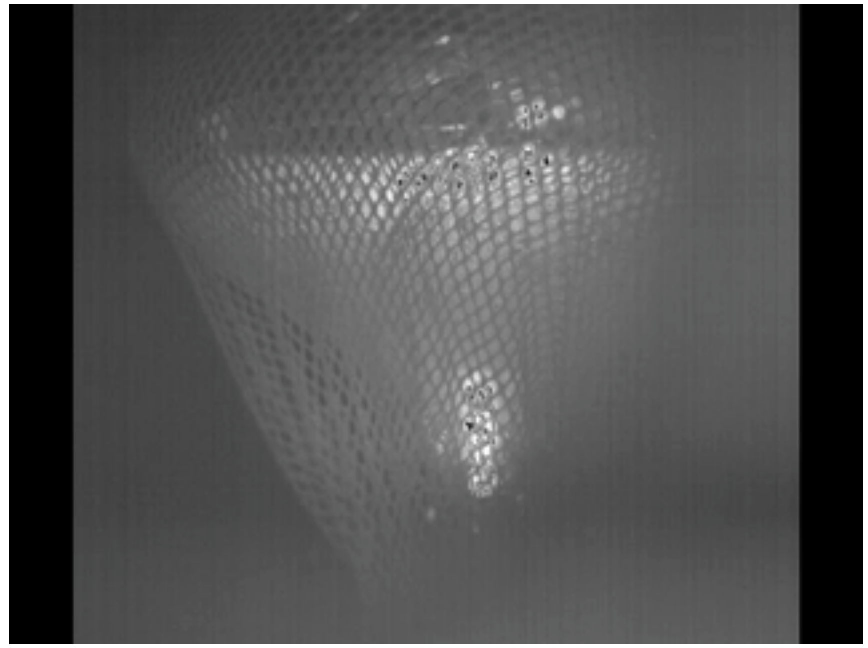
What kind of information ?

- Pressure at implosion
- Implosion process. (fast motion movie), photos
- Pressure pulse



All break same way

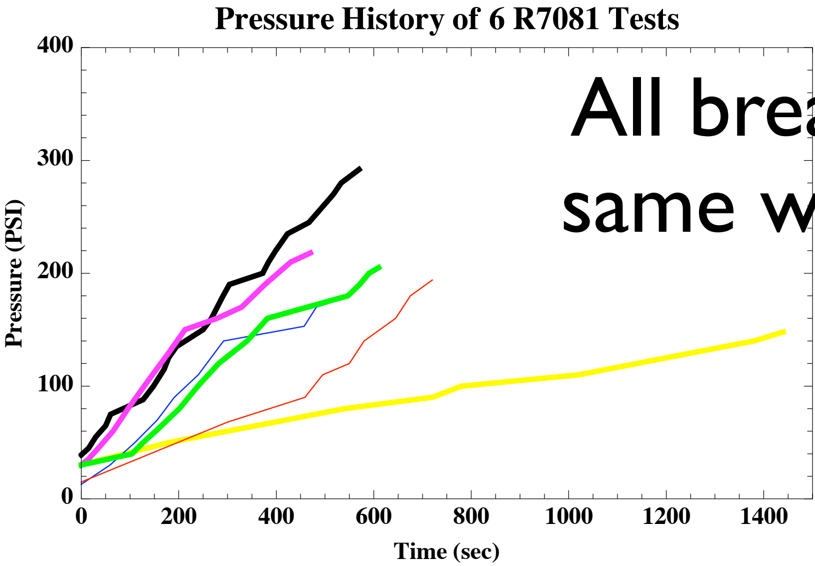
ta4769



Breakage at pins

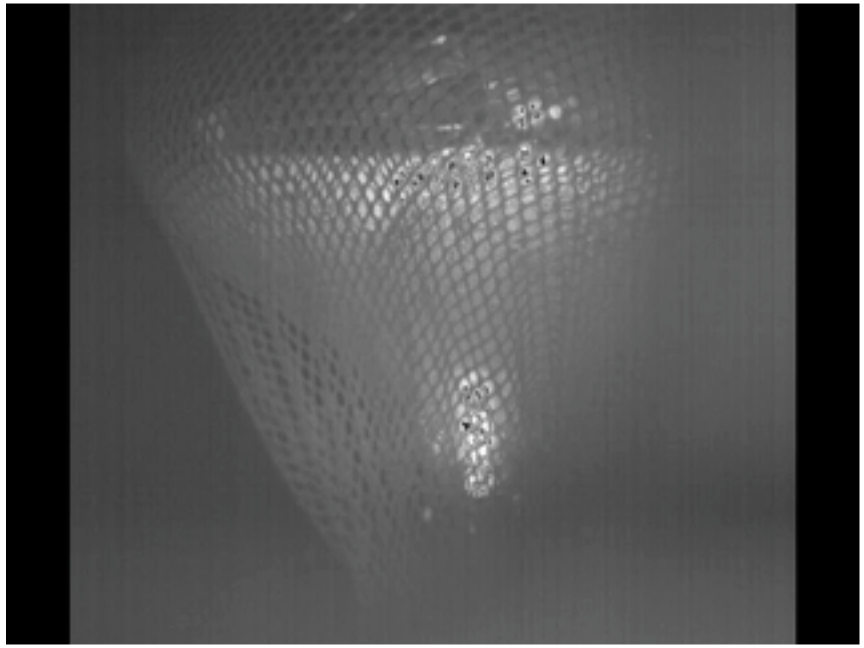
What kind of information ?

- Pressure at implosion
- Implosion process. (fast motion movie), photos
- Pressure pulse



All break same way

ta4769



Breakage at pins

What kind of information ?

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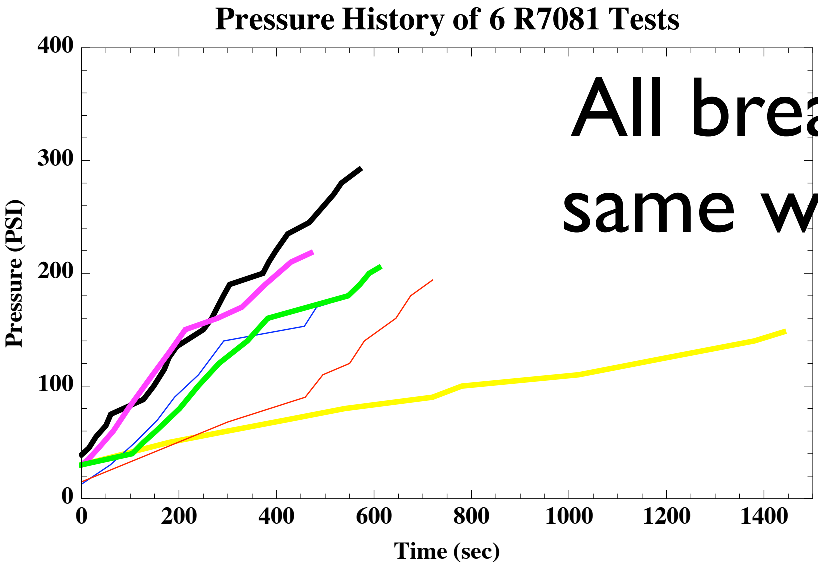

All break same way

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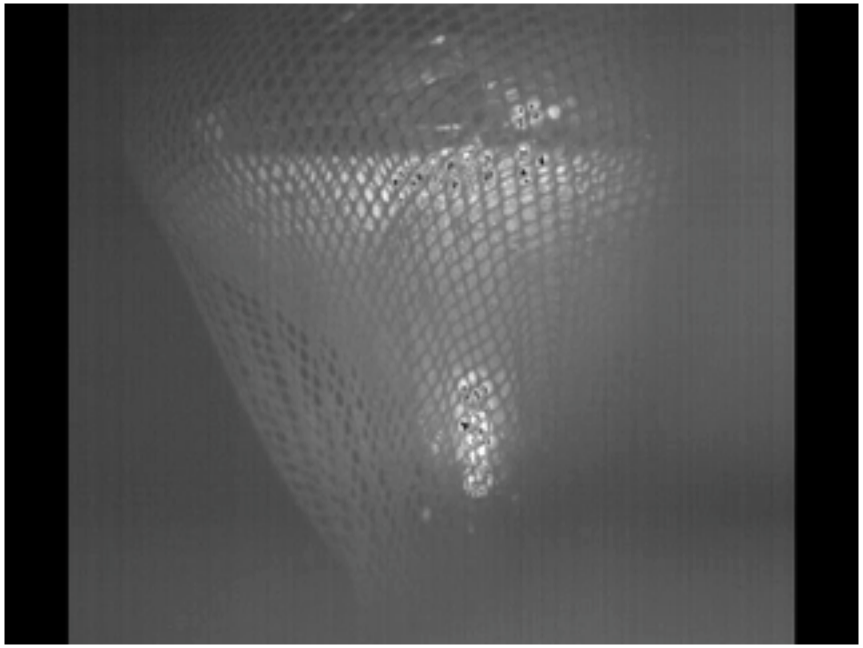
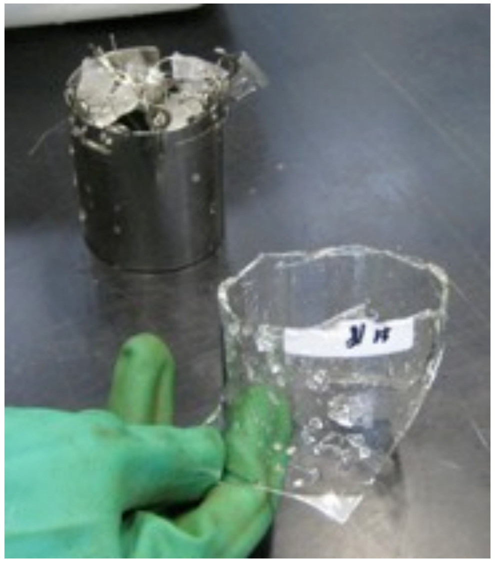


Breakage at pins



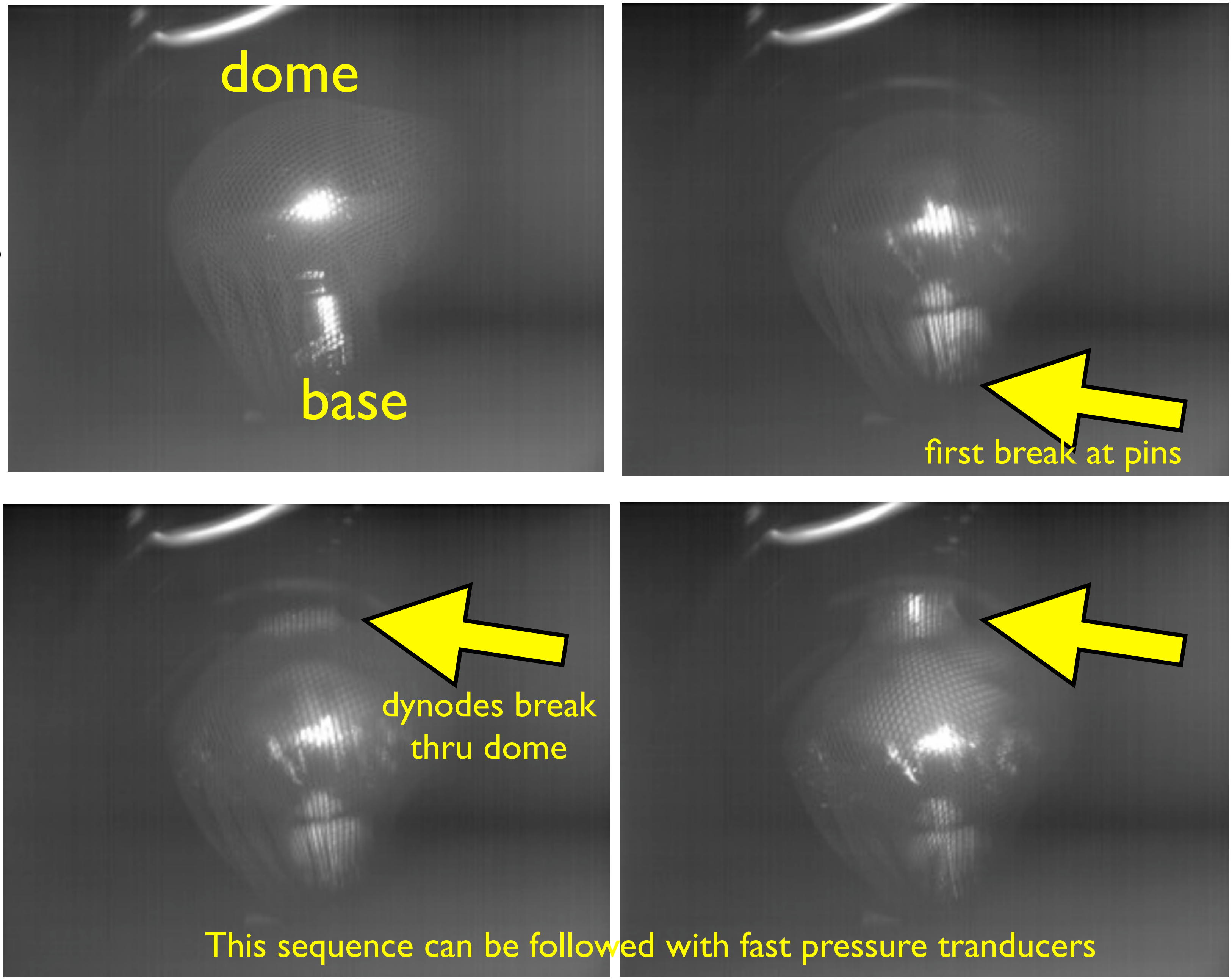
Typical R7081 failure
(TA3085 failed at 13.4 bar)

0 ms

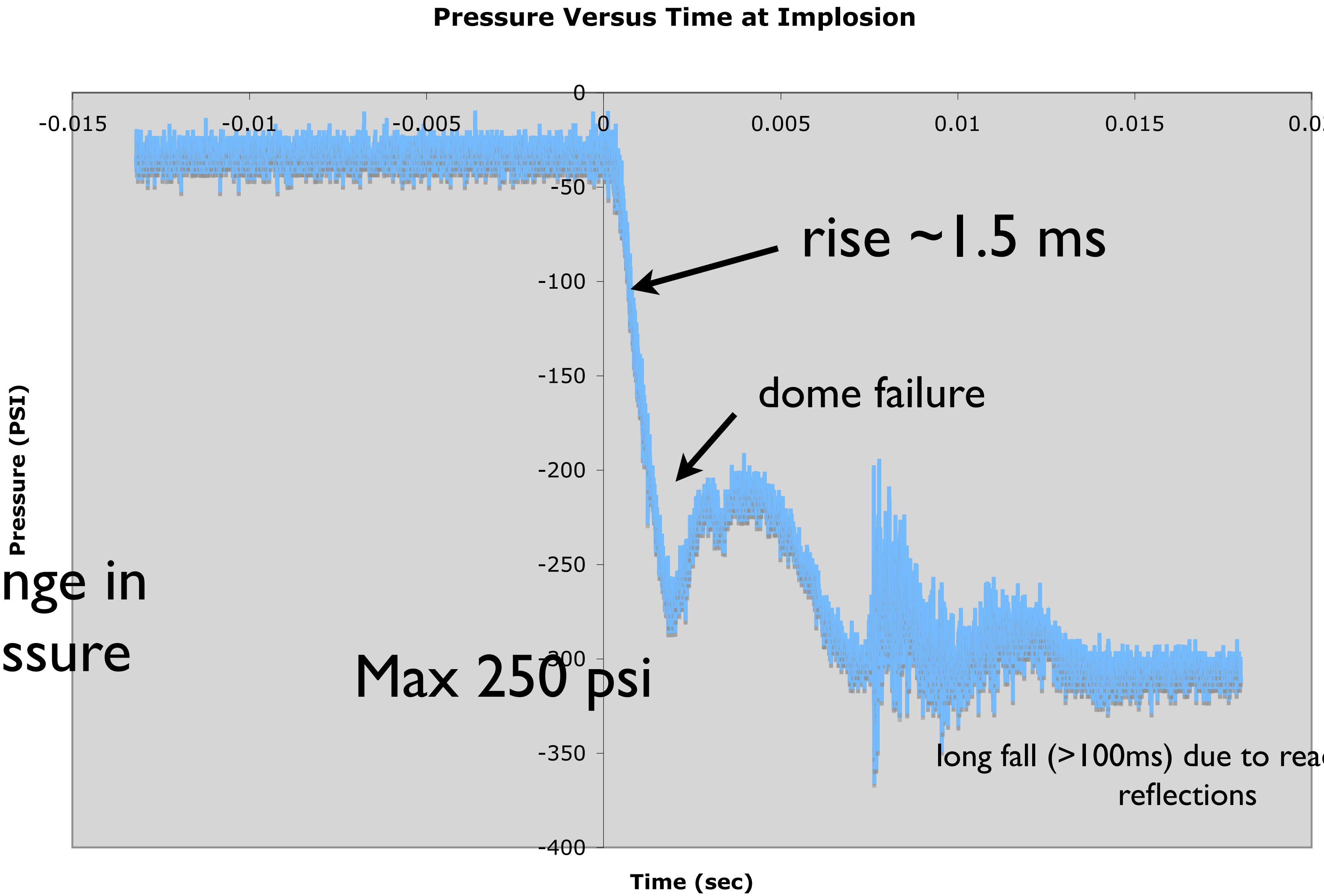
2 ms

4 ms

6 ms



Typical R7081 (ta3085 at 13.4 bar (194 psi))



Change in Pressure

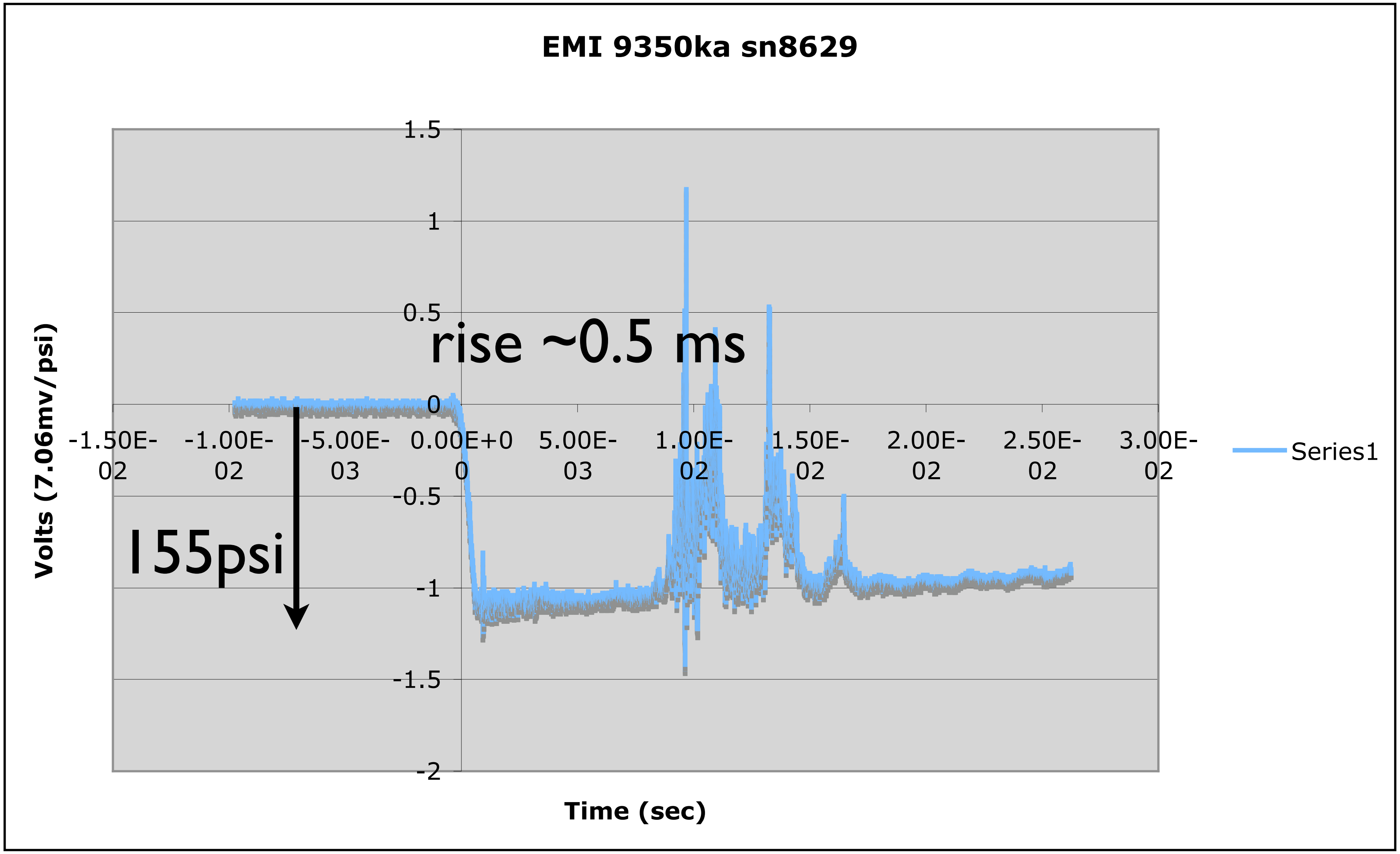
sensor at 40 inch

No shock wave because tank too small

ETL tube #2

broke at 104 psi   sn 8629   2 microsec/frame

Broke at 104 psi

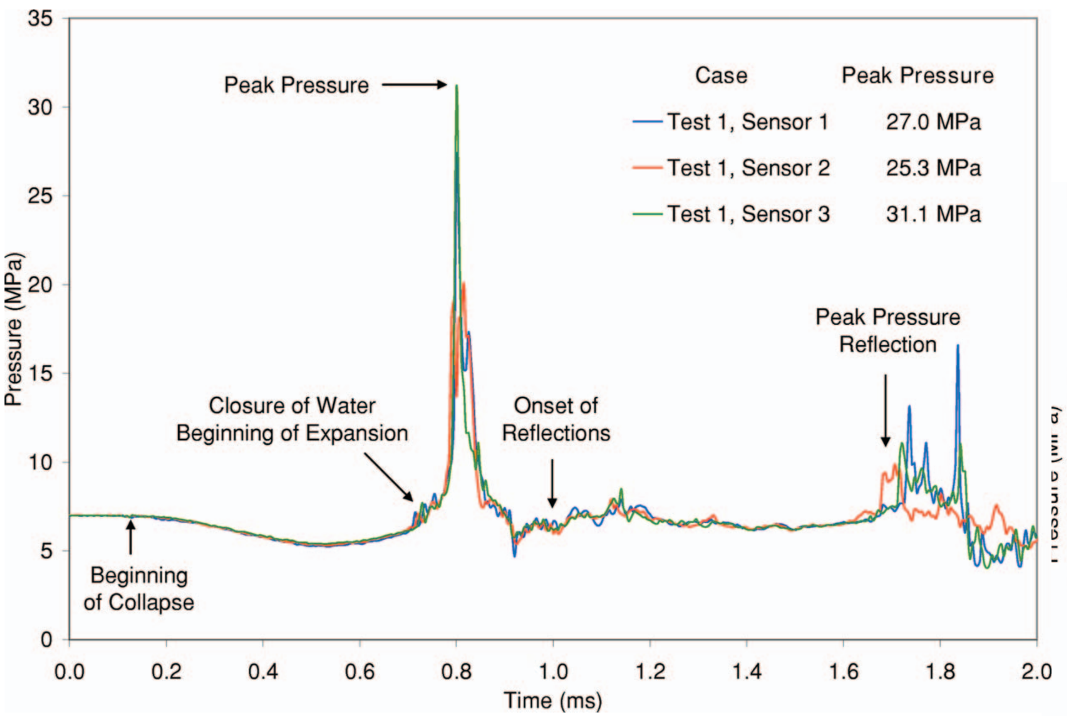


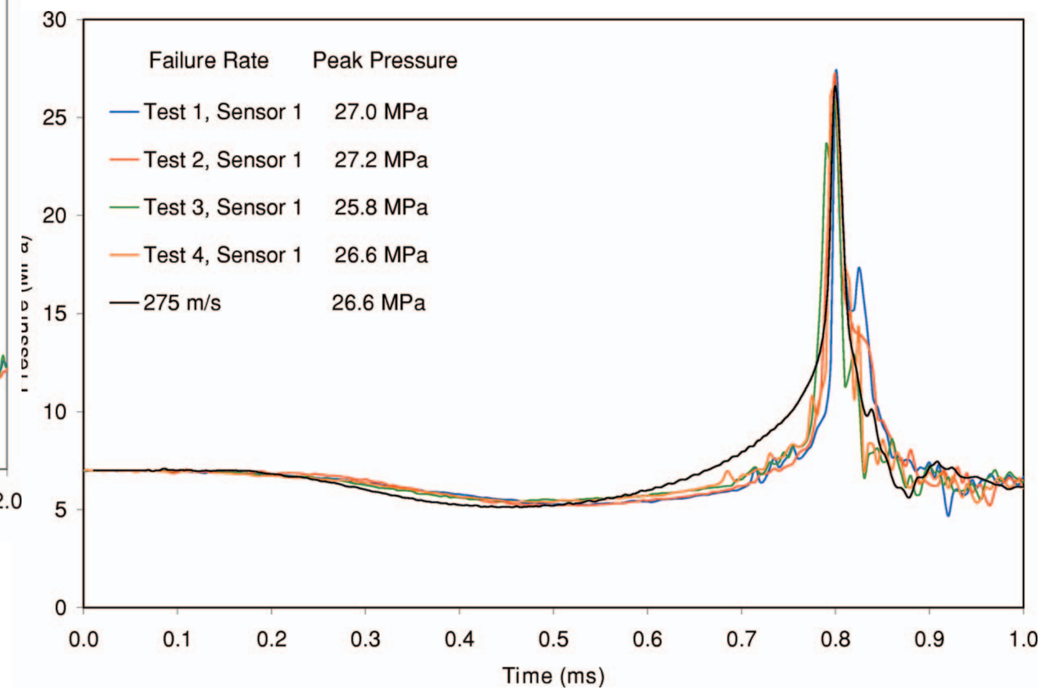
sensor at 40 inch

Materials

- http://nwg.phy.bnl.gov/~diwan/300kt/
- analysis example
  - J. Acoust. Soc. Am. 121 (2), Feb. 2007
  - Stephen E. Turner, Underwater implosion of glass spheres, Naval Undersea Warfare Center, Newport RI.

Simulation from paper





Problem 1

- Assume instantaneous glass failure and calculate the pressure history for following conditions
  - 10, 12 inch diameter sphere with vacuum
  - infinite volume. 6 bar of static pressure at failure.
  - 40 cm, 50 cm, 100 cm distances.

Problem 2

- Introduce some boundary conditions in problem 1. In particular,
  - Place tube 50 cm, 70 cm, 100 cm from tank wall.
  - calculate pressure history at neighbor's location 30 , 50, 100 cm away.

Problem 3

- Introduce different failure modes in the tubes and introduce asymmetries. Two failure modes most important
  - Complete Dome failure. Assume back remains intact.
  - neck failure. Assume Neck failure only and water rushes in.
  - use measured time constants in the calculation.

Problem 4

- Mitigation of shock wave on neighbors.
  - Introduce a simple rigid cylindrical baffle around PMT.
  - calculate the shock wave field around the tube and in particular the neighbors and opposite wall.

Problem 5

- How to validate the calculations ?
- This is more open-ended at this moment, but a design for a test would be helpful.