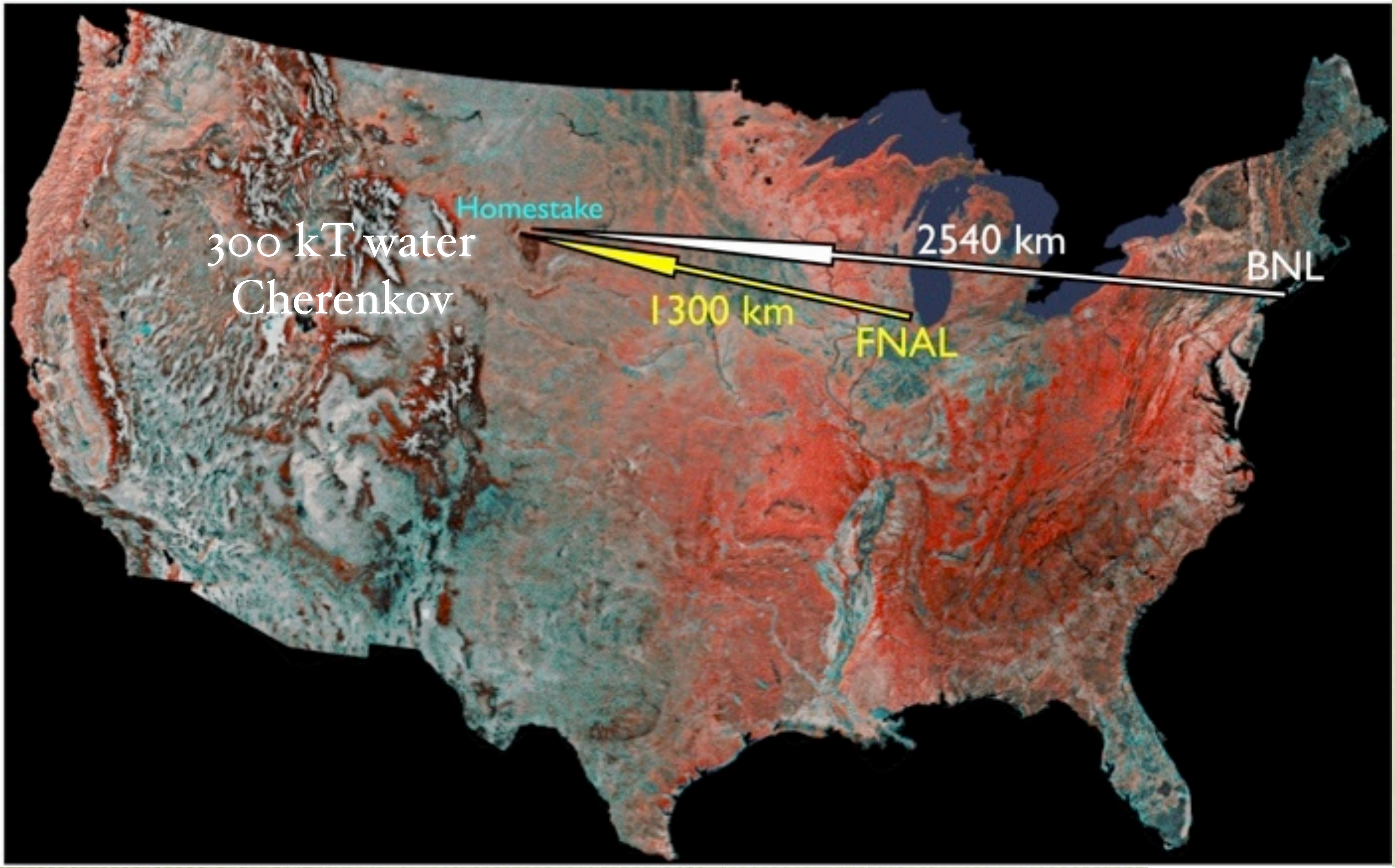
FNAL to DUSEL long baseline experiment

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



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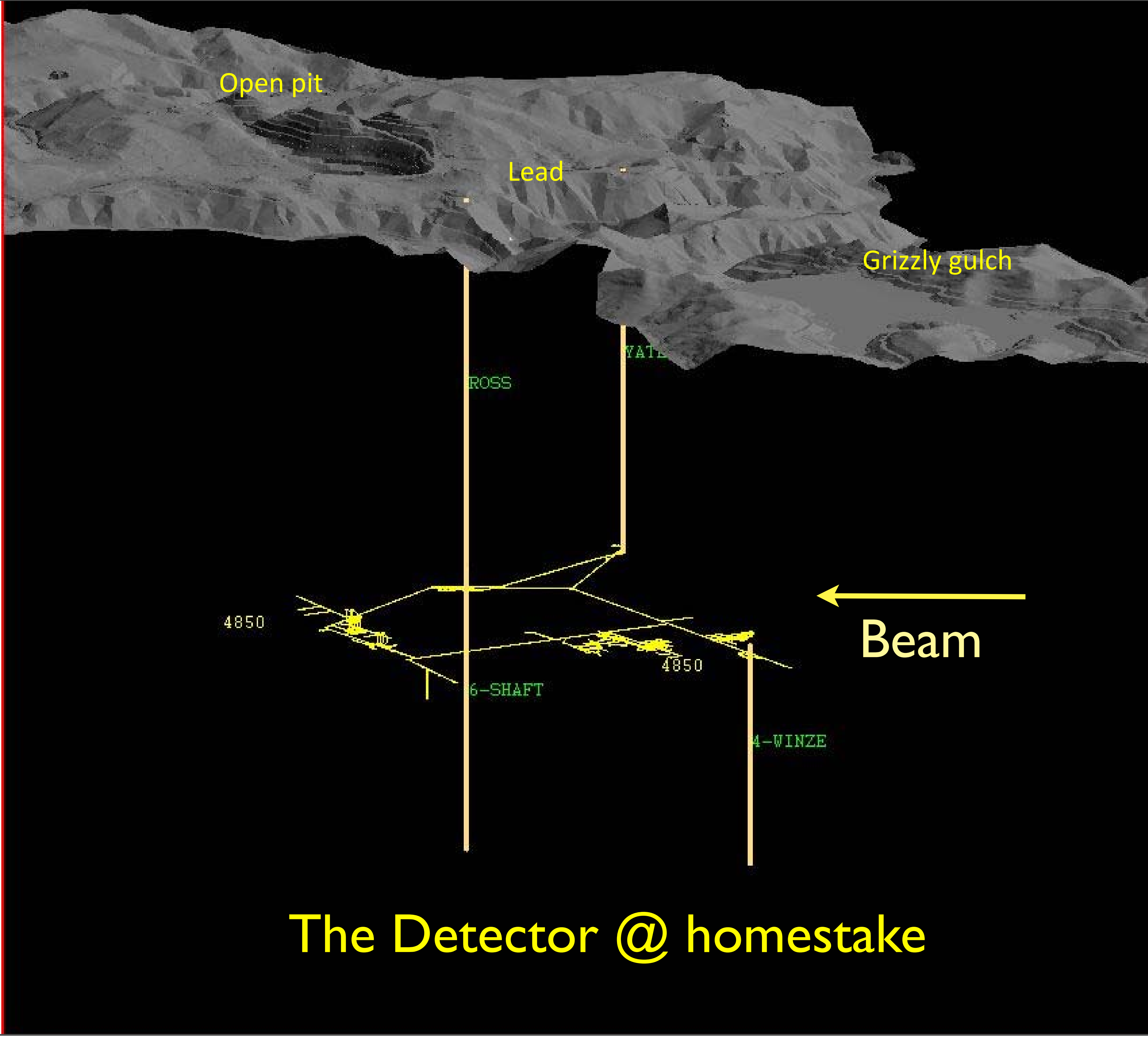
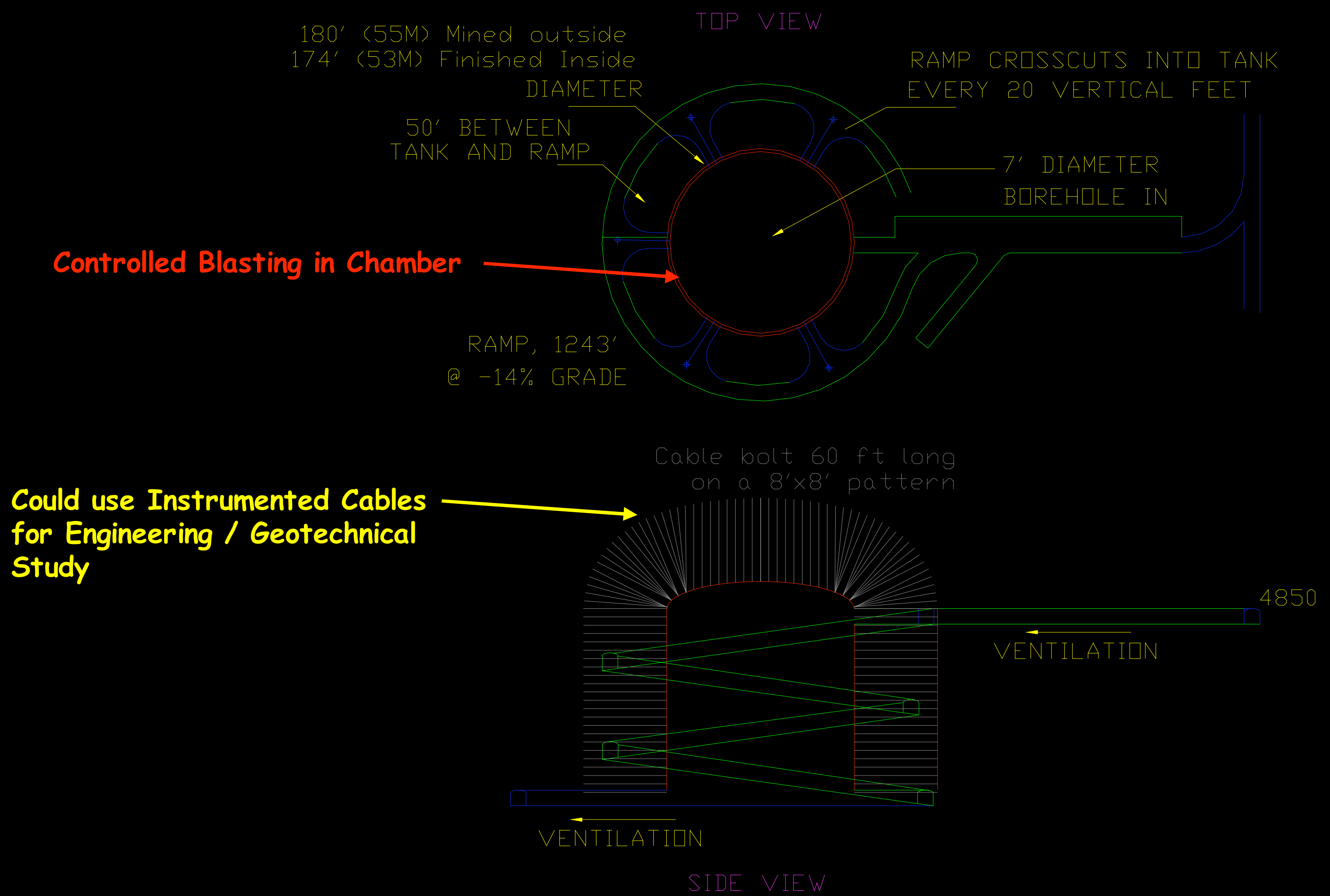

Open pit
Lead
Grizzly gulch
ROSS
4850
6-SHAFT
4850
4-WINZE
Beam
The Detector @ homestake

Megaton Modular Multi-Purpose Neutrino Detector

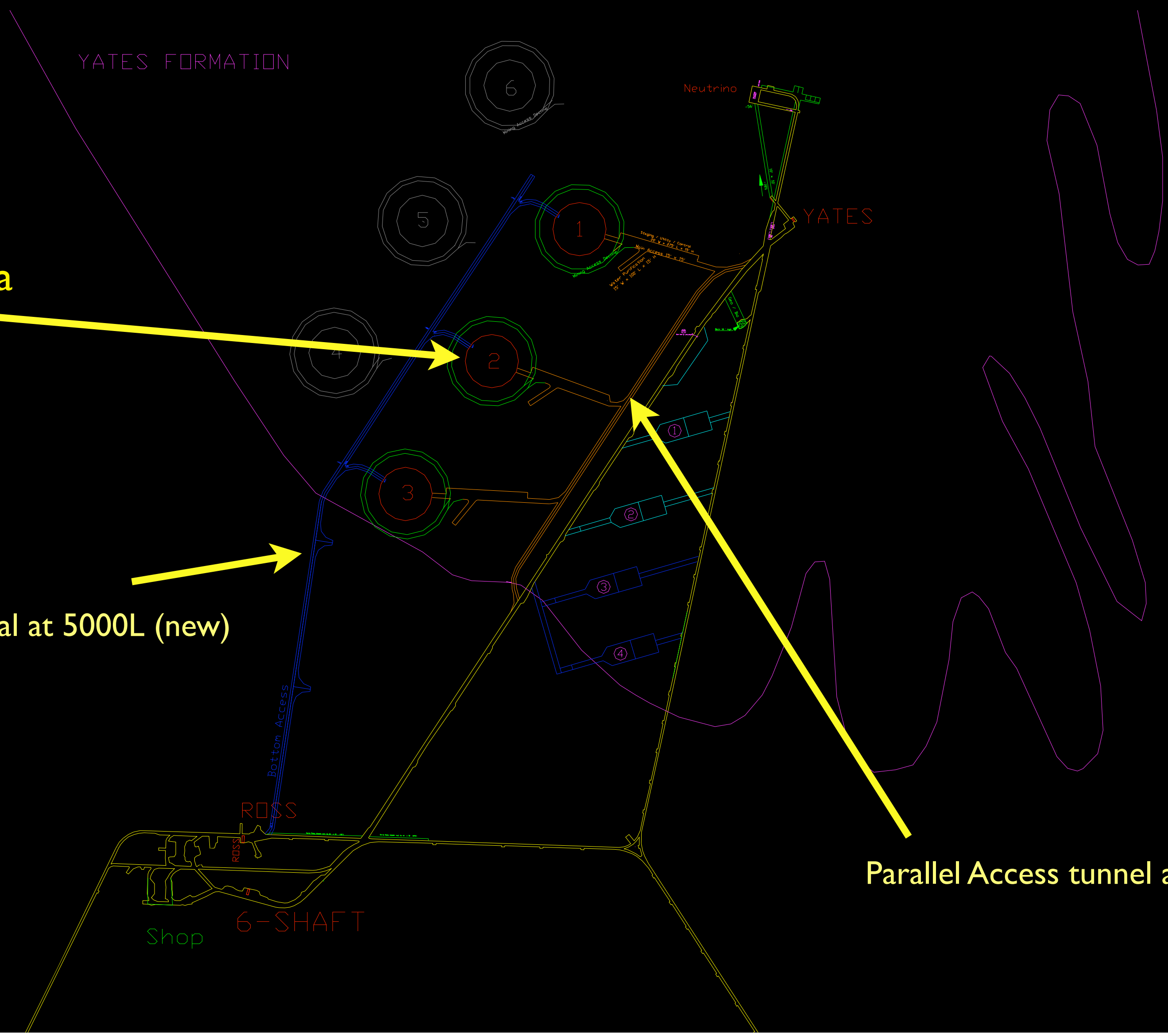
✓ Chamber Design



Megaton Modular Multi-Purpose Neutrino Detector

✓ **Modular Configuration**

muon rate/cavern 0.1-0.3 Hz

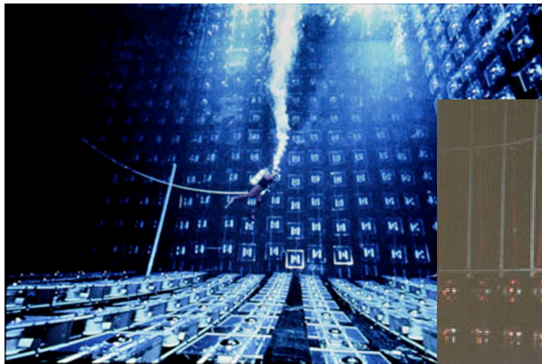


180 ft dia

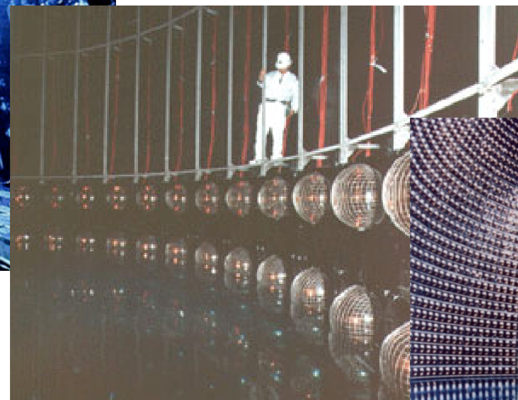
Rock removal at 5000L (new)

Parallel Access tunnel at 4850L (new)

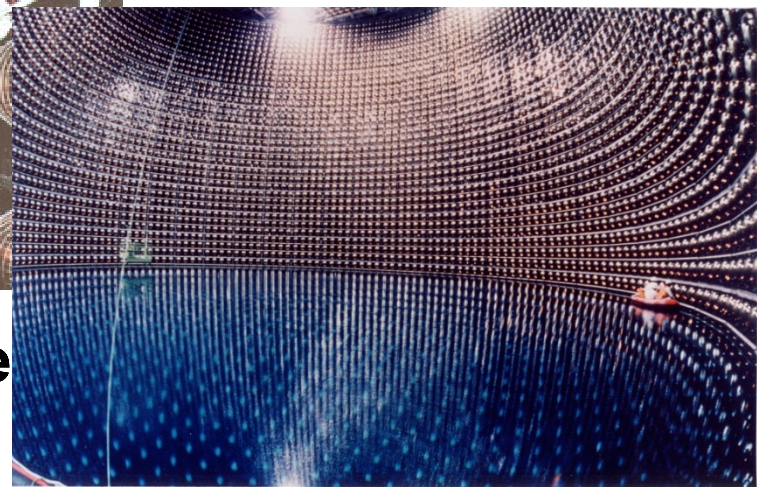
Water Cherenkov Detector



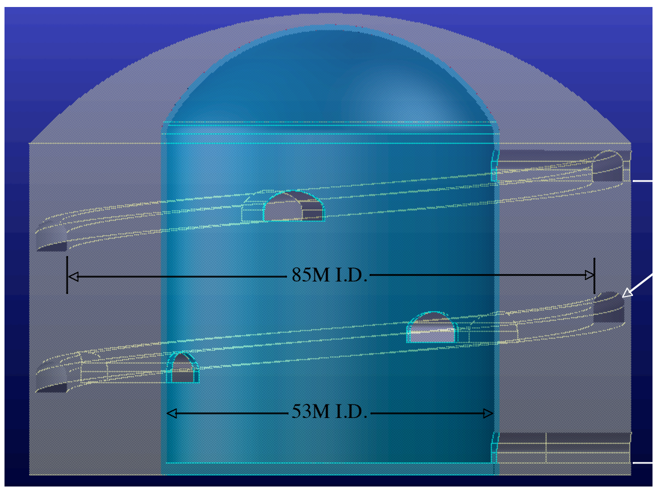
IMB
3 ktons



Kamiokande
1 kton



Super-Kamiokande
22 ktons



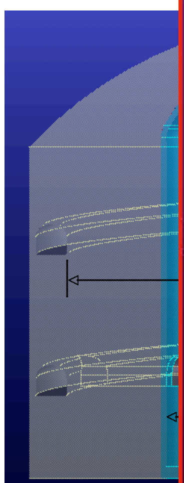
1 module fid:100 kT

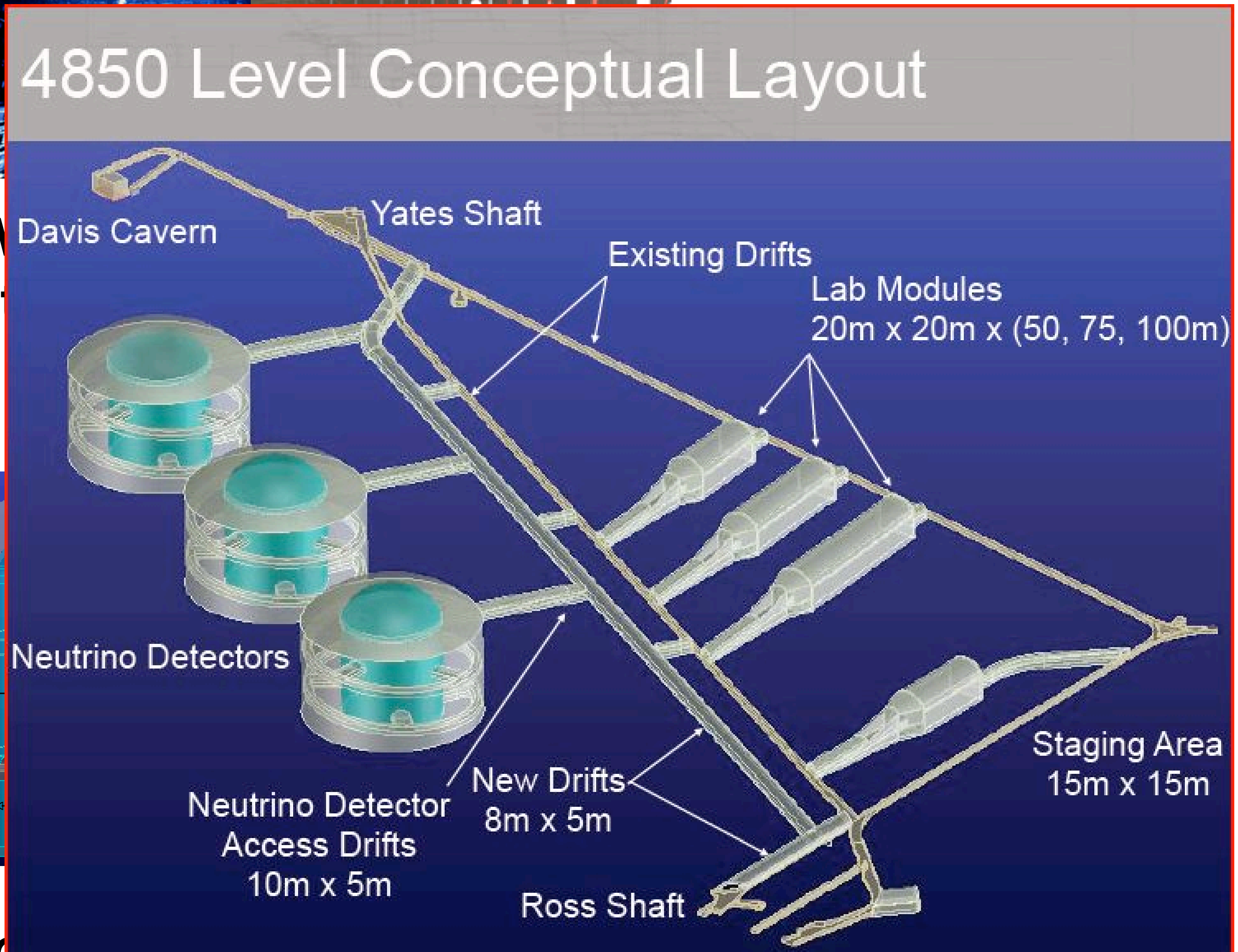
300 kT

Water Cherenkov Detector

IM

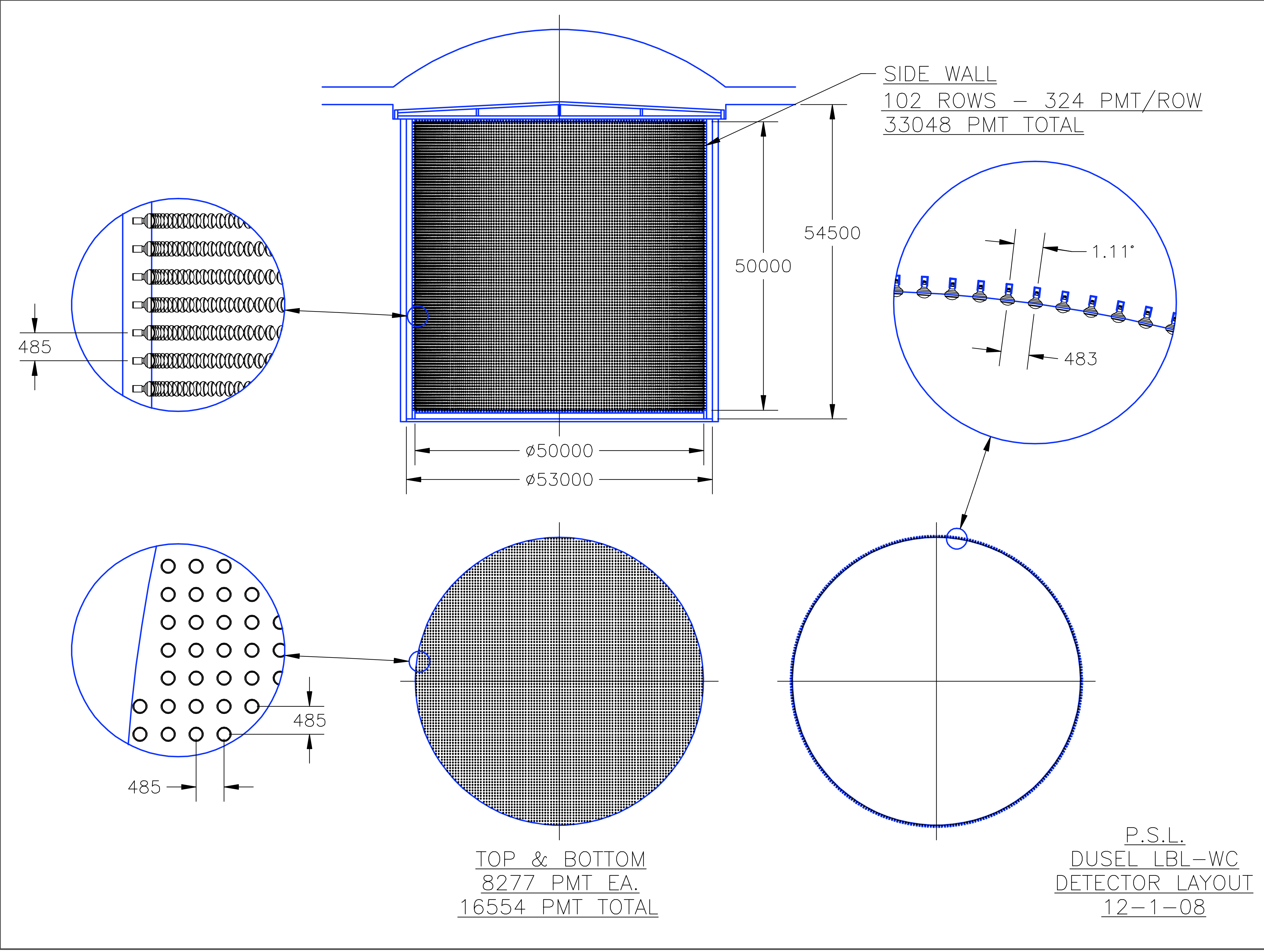
3 k





1 mo

300 kT


SIDE WALL
102 ROWS - 324 PMT/ROW
33048 PMT TOTAL
54500
50000
485
1.11°
483
ø50000
ø53000
485
485
TOP & BOTTOM
8277 PMT EA.
16554 PMT TOTAL
P.S.L.
DUSEL LBL-WC
DETECTOR LAYOUT
12-1-08

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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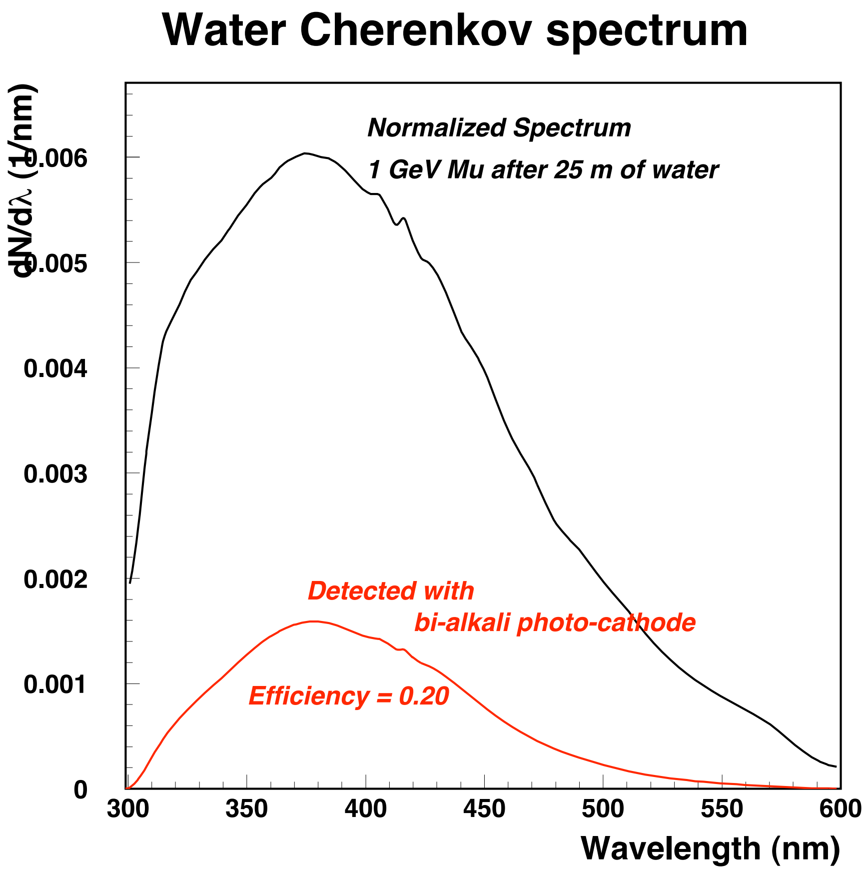
Amount of signal

5 MeV = 25 p.e.

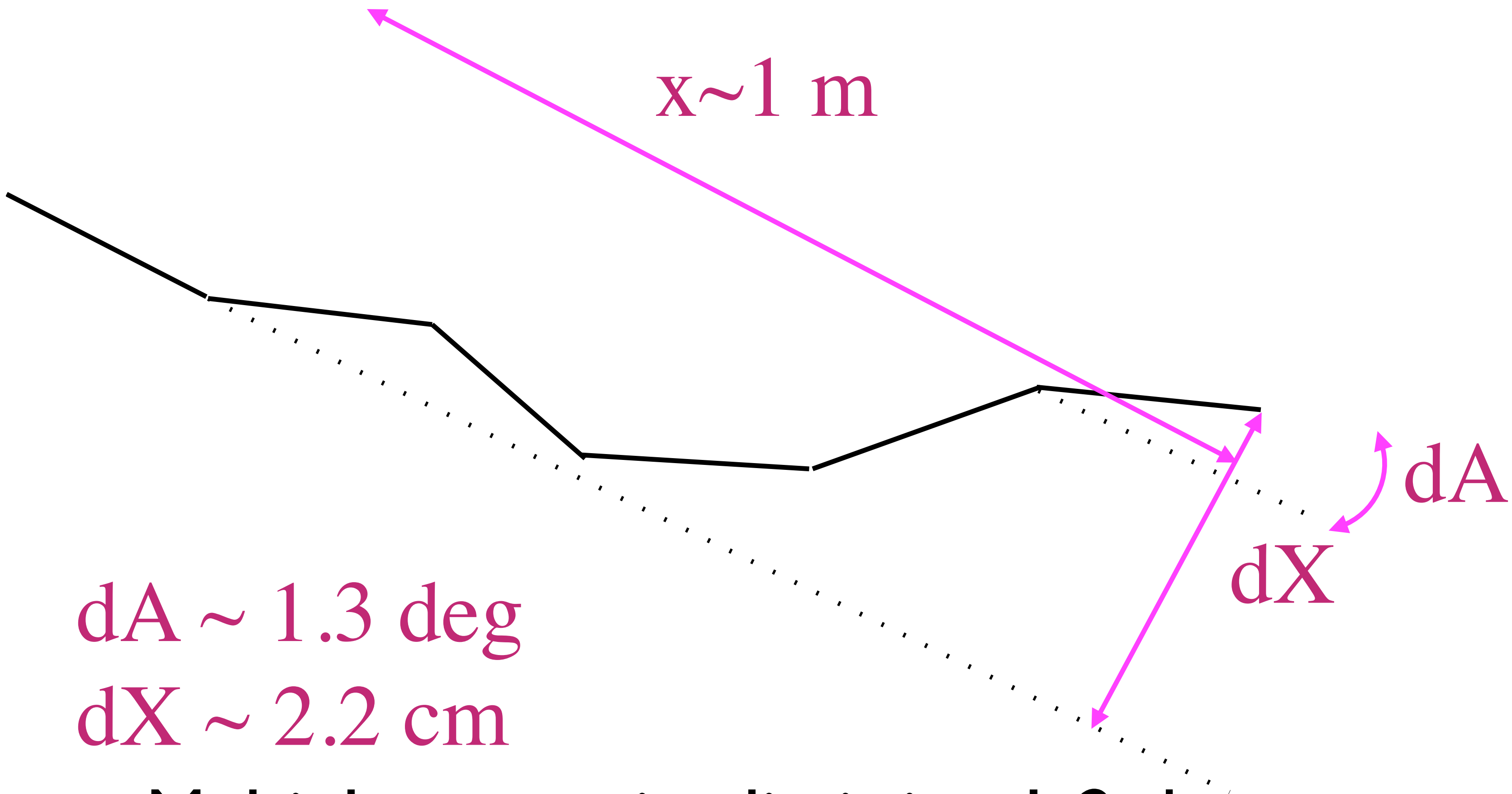
for 25% coverage with 20 % Q.E.

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

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)	Luminous (2856 K) Typ. (µA/lm)	Radiant at 420 nm Typ. (mA/W)	Blue Sensitivity Index (CS 5-58) Min.	Blue Sensitivity Index (CS 5-58) Typ.	Quantum Efficiency at 390 nm Typ. (%)	Anode Sensitivity: Luminous (2856 K) Typ. (A/lm)	Radiant at 420 nm Typ. (A/W)	Gain Typ.	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.

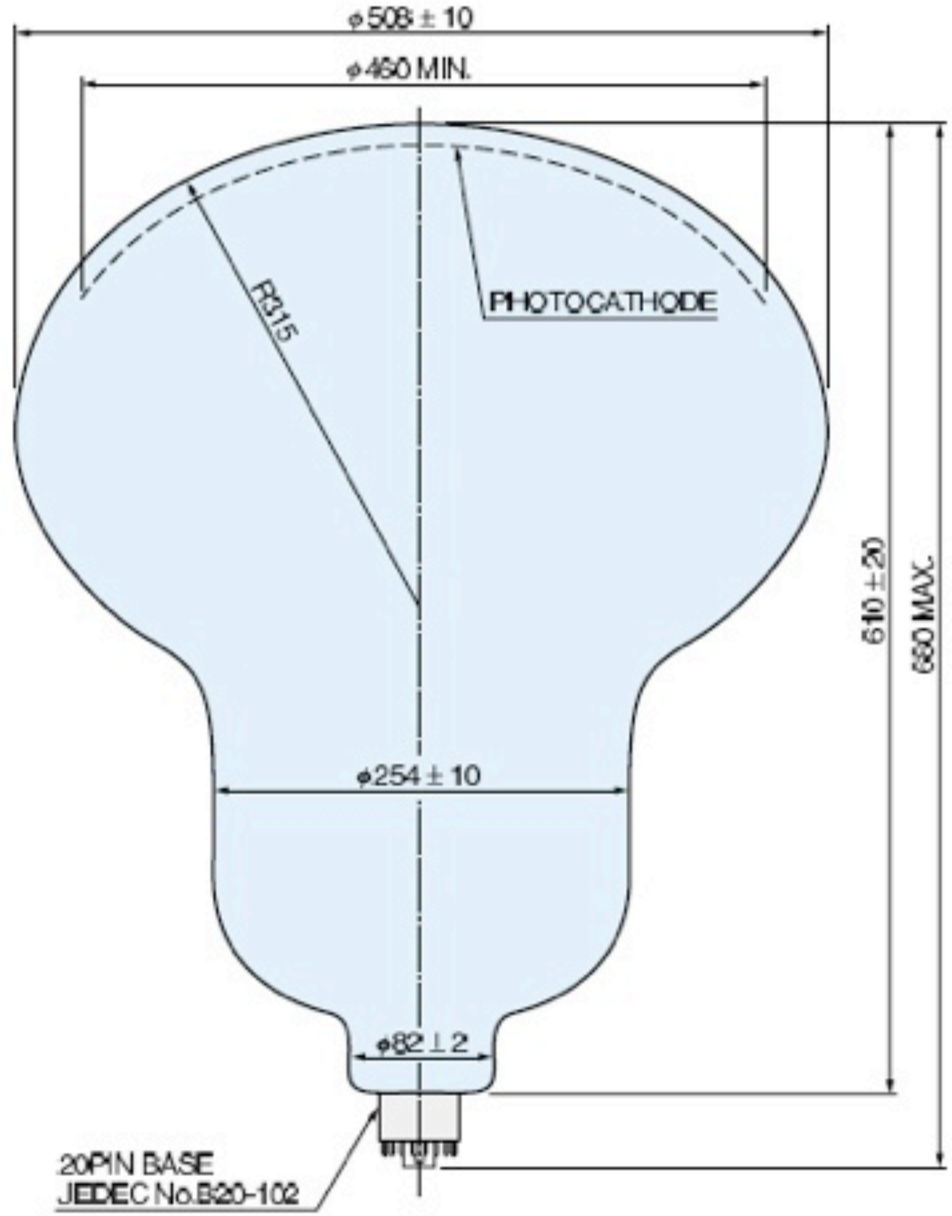
Type No.	Maximum Ratings: Supply Voltage Anode to Cathode (V)	Supply Voltage Anode to Last Dynode (V)	Average Anode Current (mA)	Operating Ambient Temperature (°C)	Storage Temperature (°C)	Pressure (MPa)	Direct Interelectrode Capacitances: Anode to Last Dynode (pF)	Anode to All Other Dynodes (pF)
R5912	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

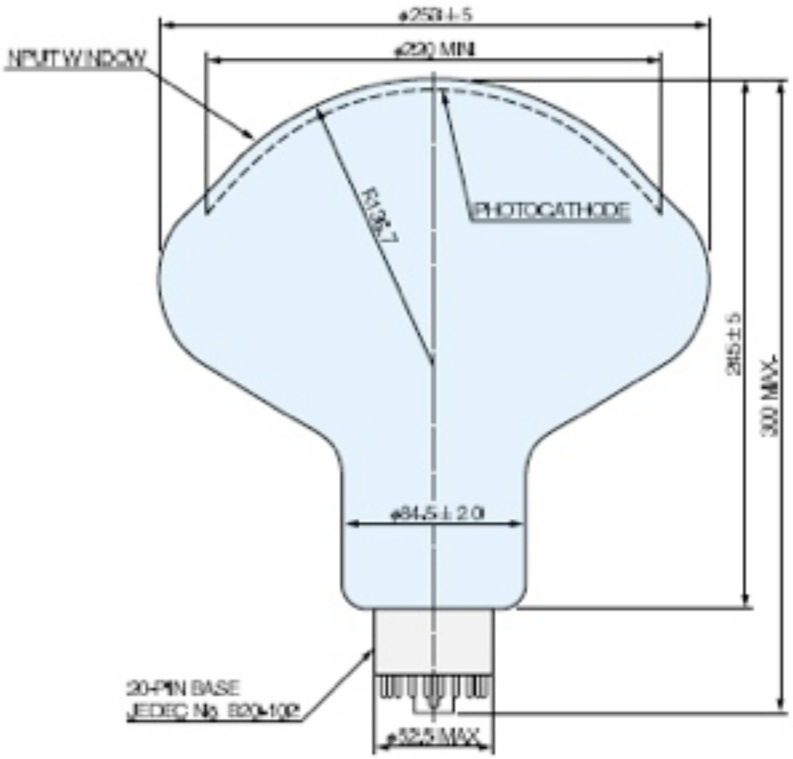
It is more efficient than the R3600.

25% *R7081 => 35% *R3600

●R3600-02



●R7081, R7081-20

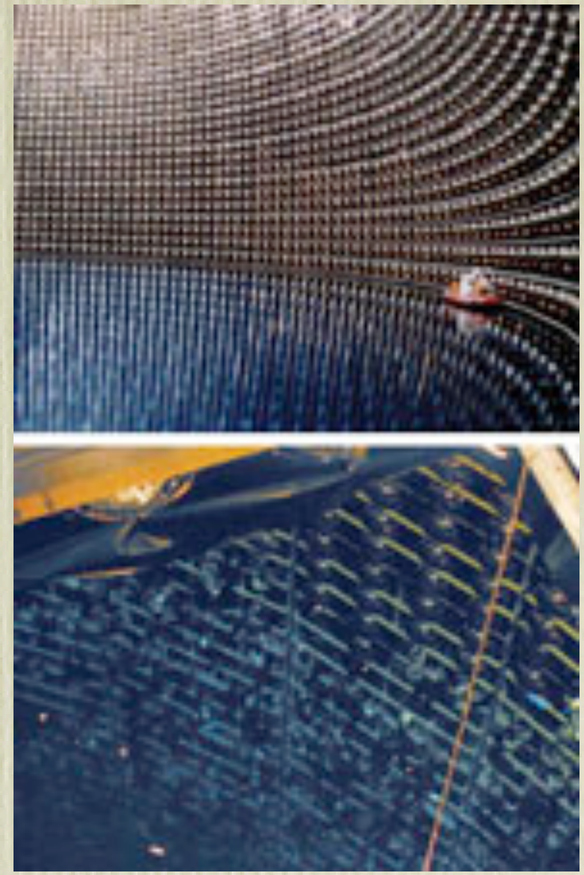


Baseline Plan

- 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.



Pressure testing

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

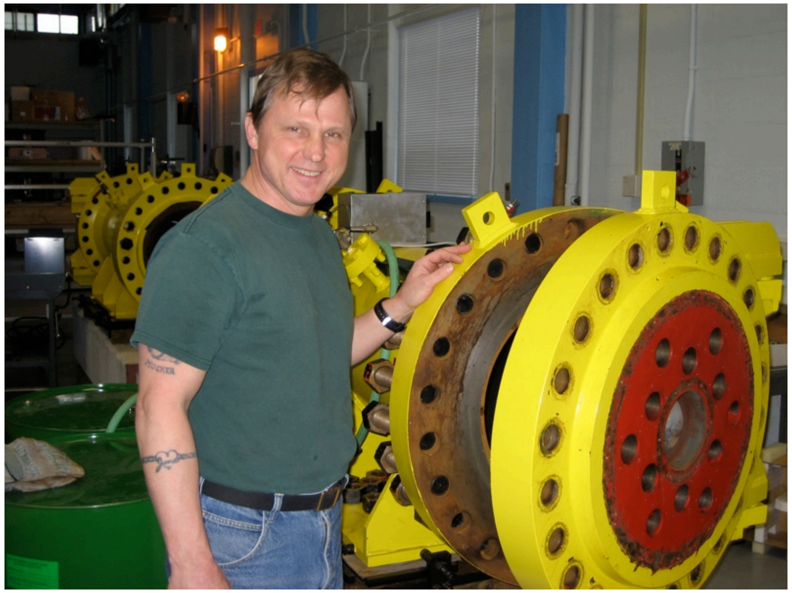
Hamamatsu rating is ~7atm. Tested this tube until it broke at 148 psi (~10atm)

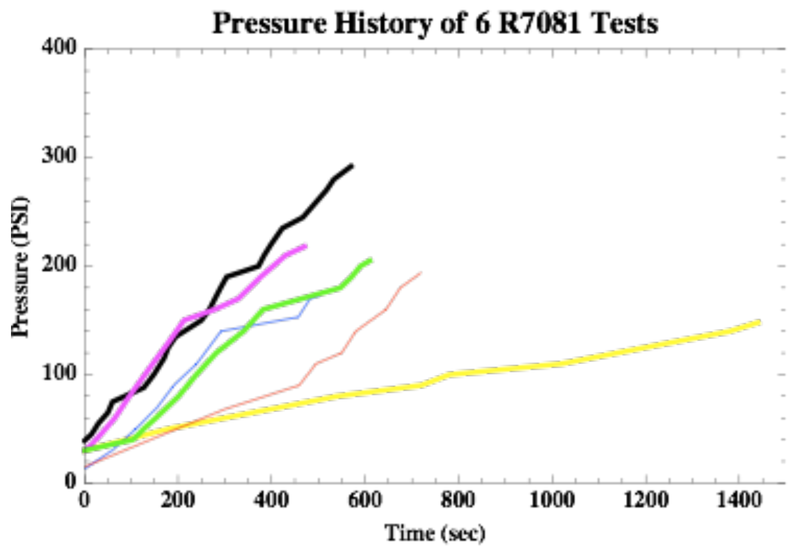
Data so far

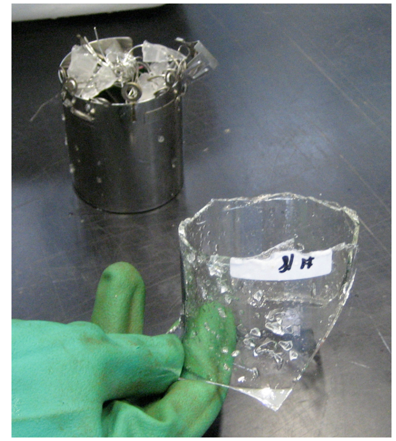
PMT	size	Break Press
R7081/ng 1	10inch	148 psi
XP1807 1	12 inch	92 psi
xp18060 1	8 inch	35 psi
R7081 2	10 inch	cycled 132psi
R7081 3	10 inch	cycled 132 psi
R7081 4	10 inch	cycled 132 psi
R7081/lowr1	10 inch	205 psi
R7081/lowr 2	10 inch	218 psi
R7081	10 inch	292 psi
ETL 9350ka	8 inch	68 psi
R7081	10 inch	173 psi

Hamamatsu tested 3 R7081 upto ~10 atm.
One broke at 10 atm,
On each tube, there is data on glass thickness, pressure pulse duration, etc.
This it borosilicate glass with thickness ranging from 0.08 to 0.12 inch.

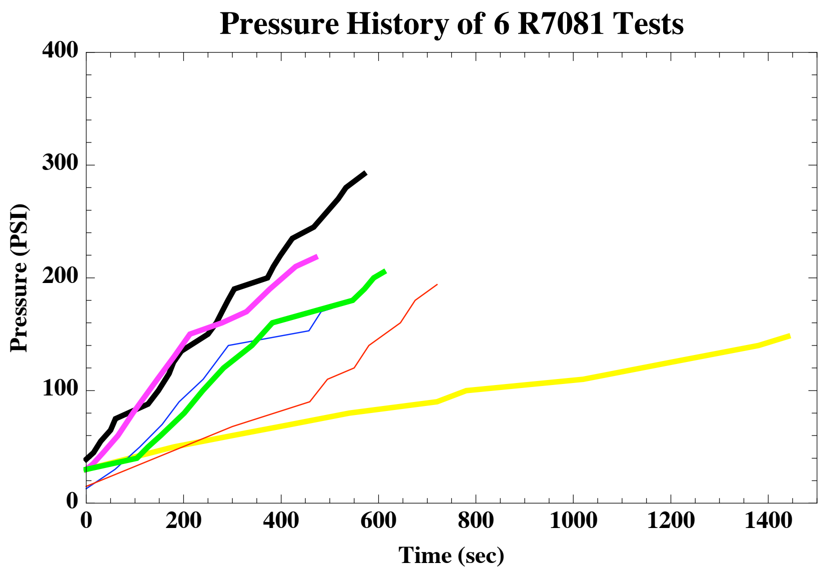
Development of pressure testing at BNL (Diwan, Goett, Sexton)

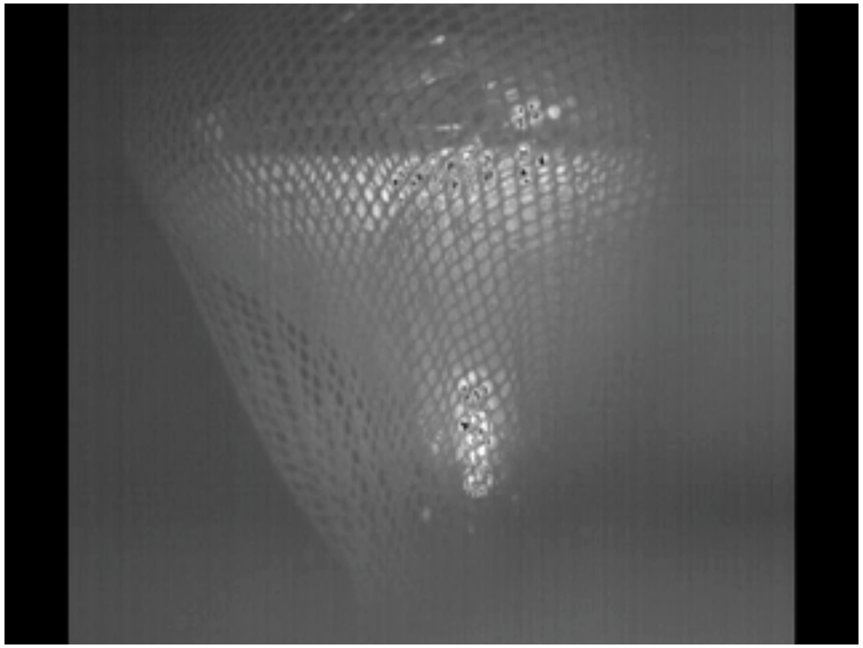






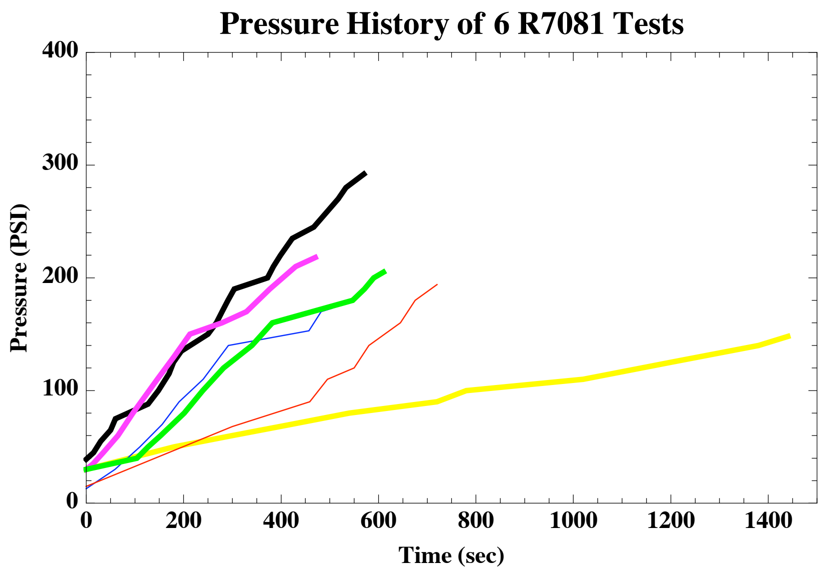
- What have we learned
  - Manufacturers have tubes with very distinct characteristics
  - Failure mode in Hamamatsu hemispherical tubes is at the pins. 7 atm is o.k.
  - Other manufacturers failure may occur at the dome in much more damaging way.
  - Data includes motion picture and recorded pressure pulses.
  - Funded mostly out of LDRD which is finished.

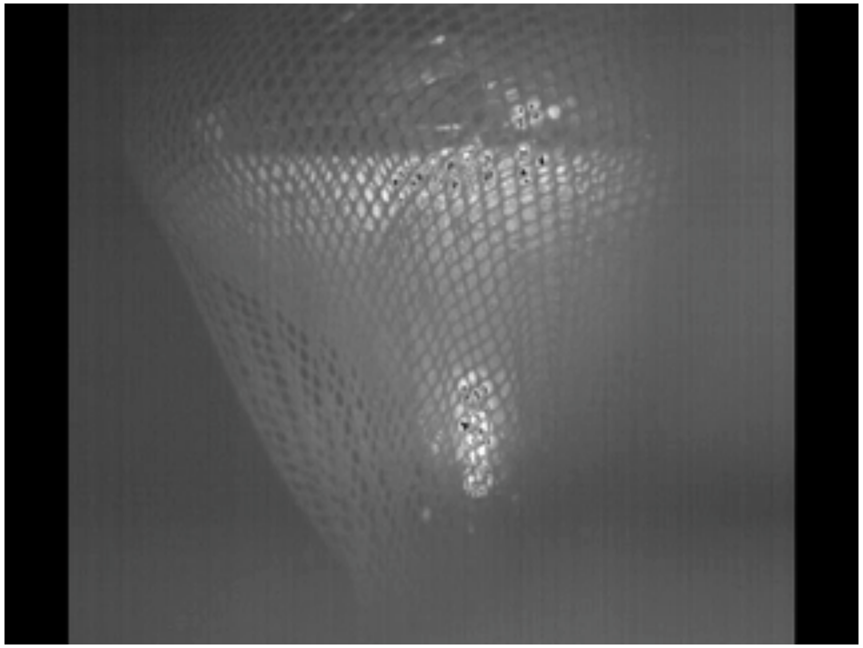

Pressure History of 6 R7081 Tests
Pressure (PSI)
Time (sec)
0
100
200
300
400
0
200
400
600
800
1000
1200
1400



ta4769

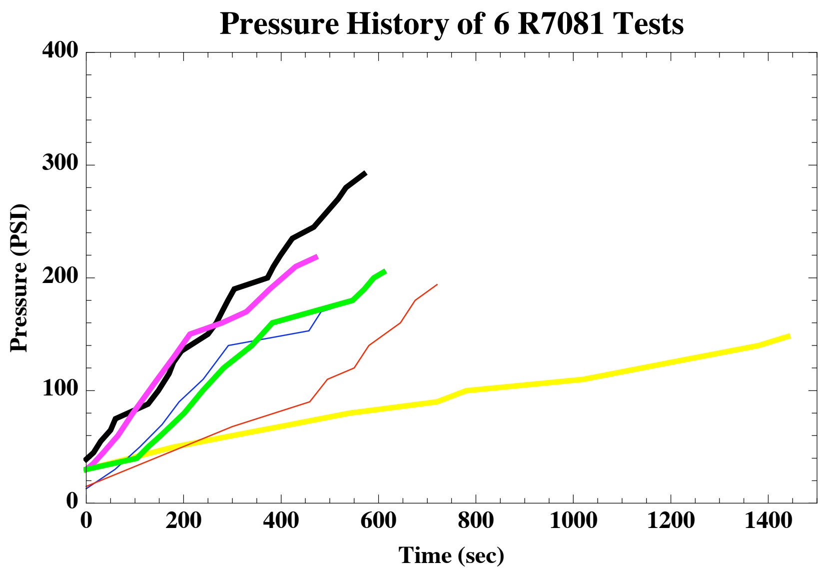

TA 4887


Pressure History of 6 R7081 Tests
Pressure (PSI)
Time (sec)
0
100
200
300
400
0
200
400
600
800
1000
1200
1400



ta4769


TA 4887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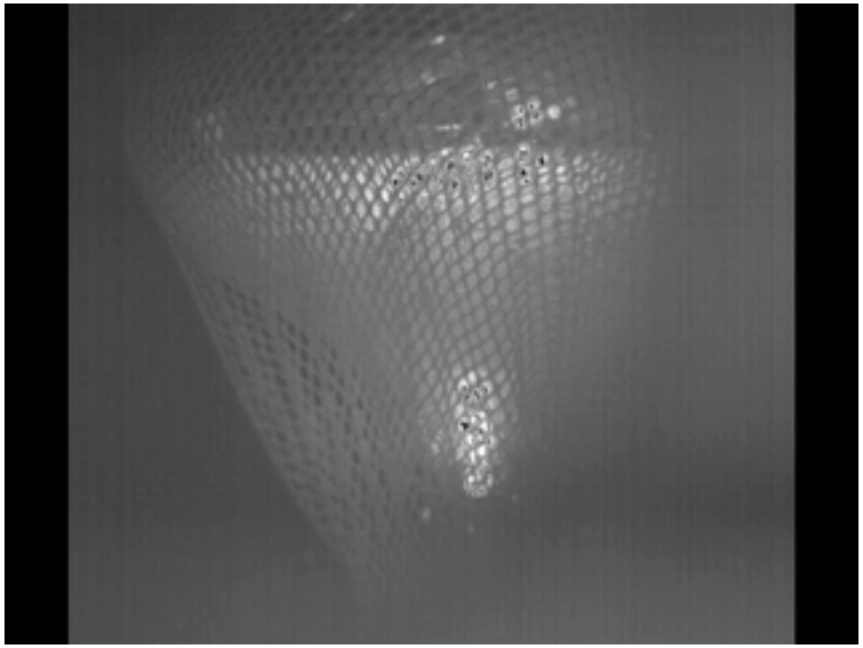
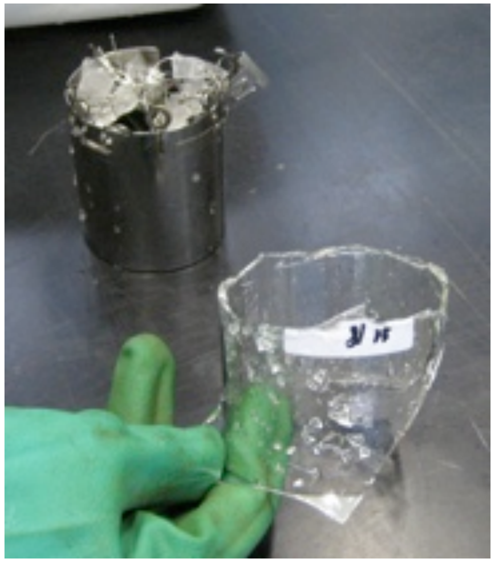
Time (sec)
0
100
200
300
400
0
200
400
600
800
1000
1200
1400

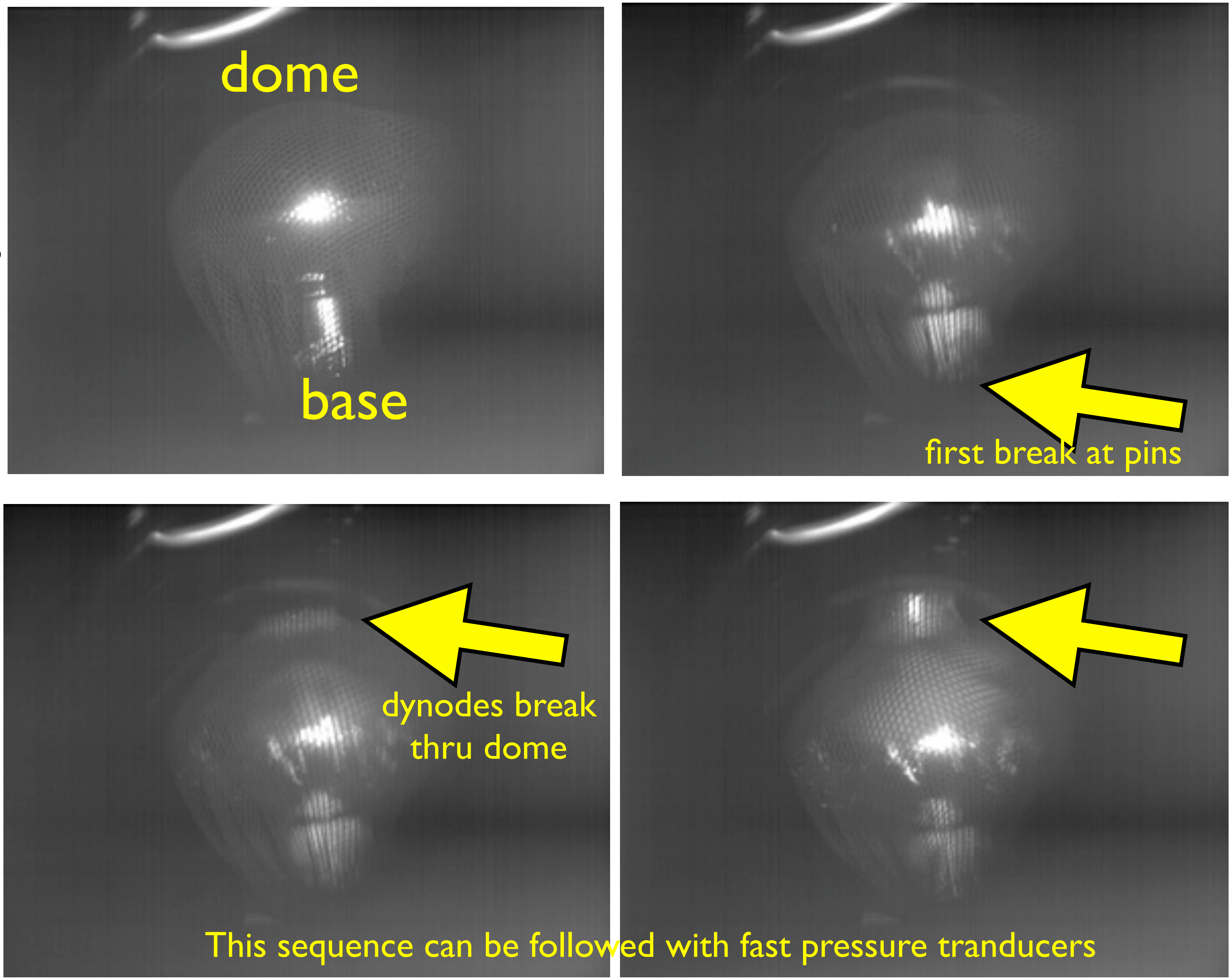


ta4769


TA 4887



Typical R7081 failure
(TA3085 failed at 13.4 bar)



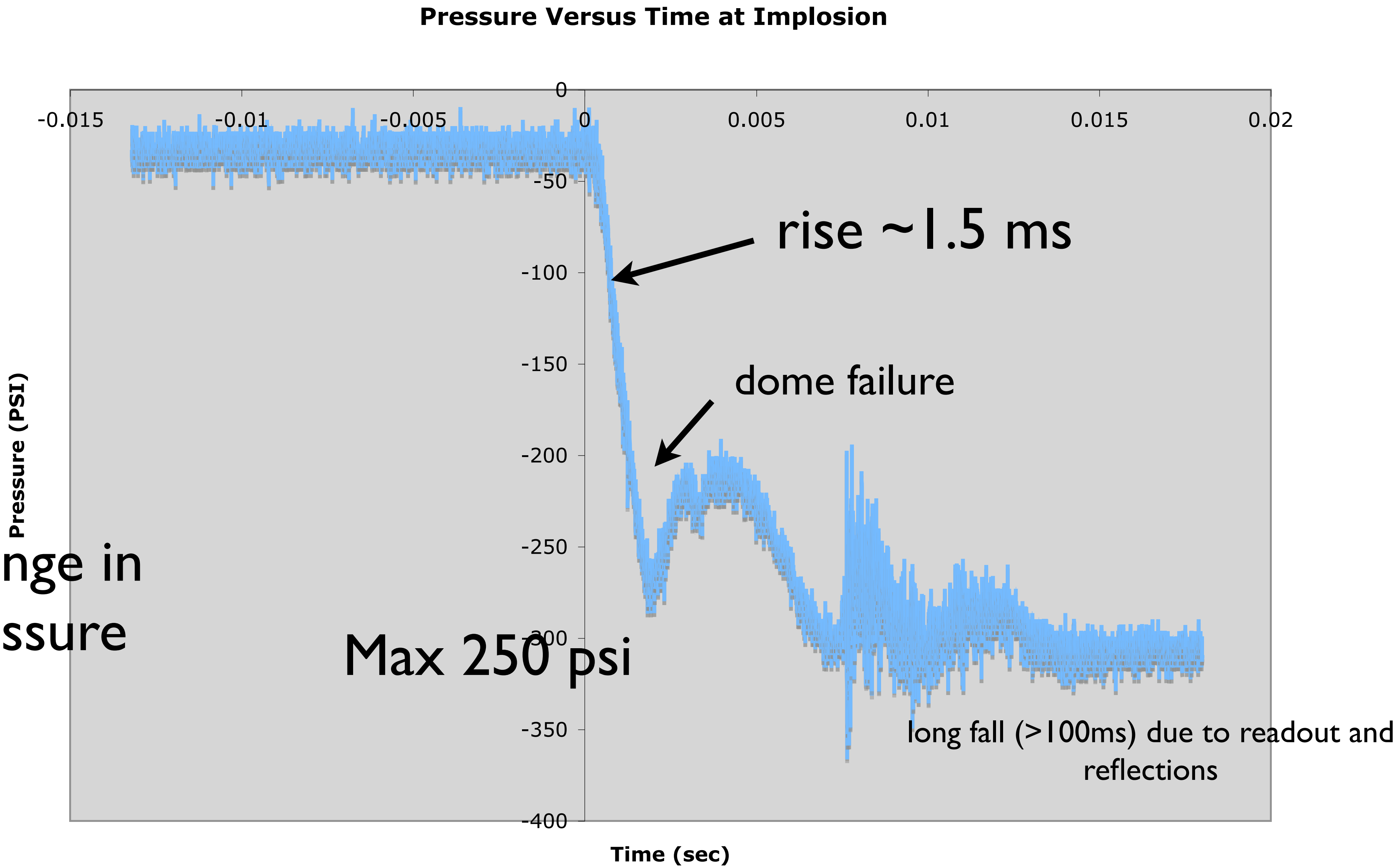
0 ms

2 ms

4 ms

6 ms

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



Change in Pressure

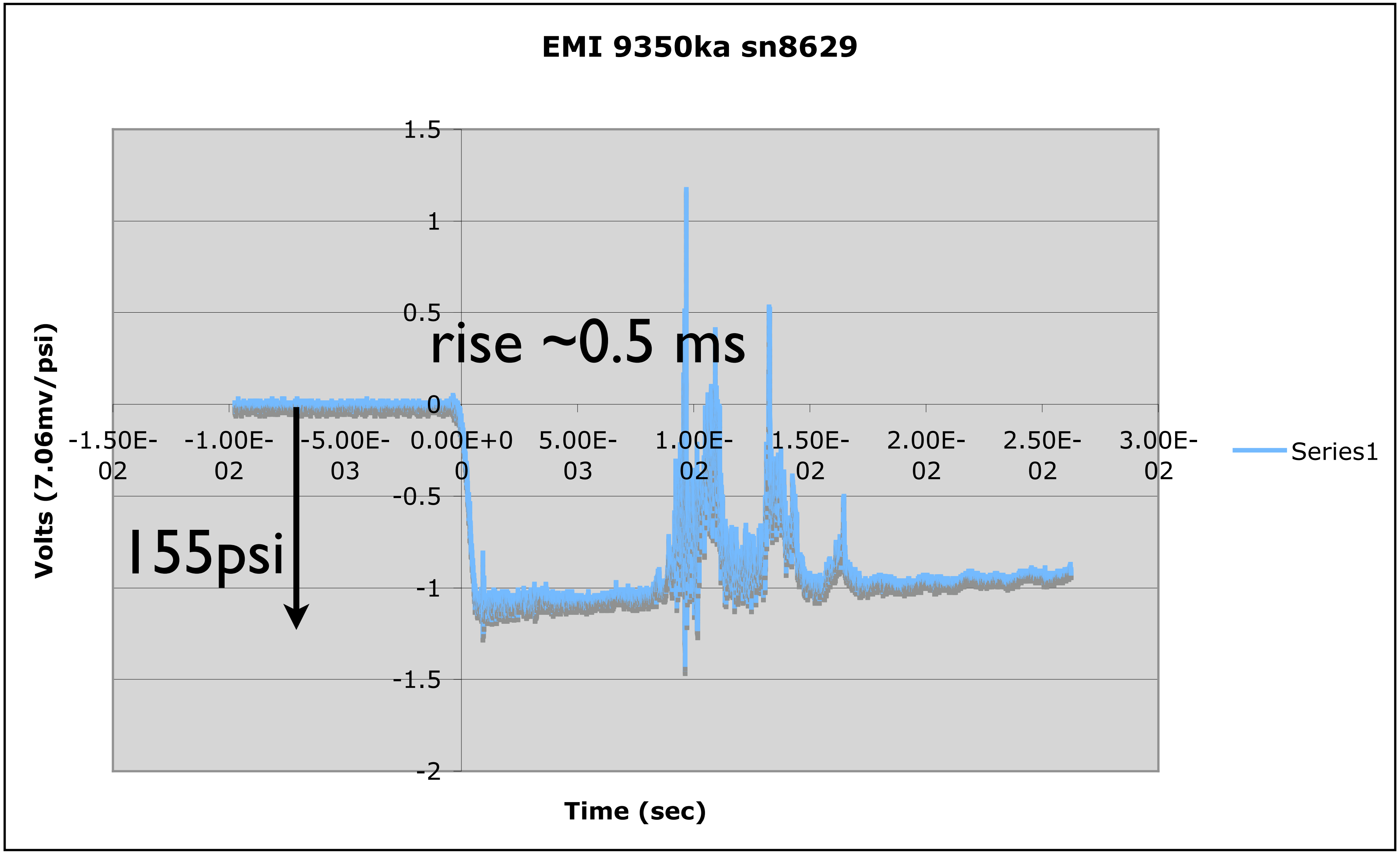
sensor at 40 inch

No shock wave because tank too small

ETL tube #2

broke at 104 psi   sn 8629   2 microsec/frame

Broke at 104 psi

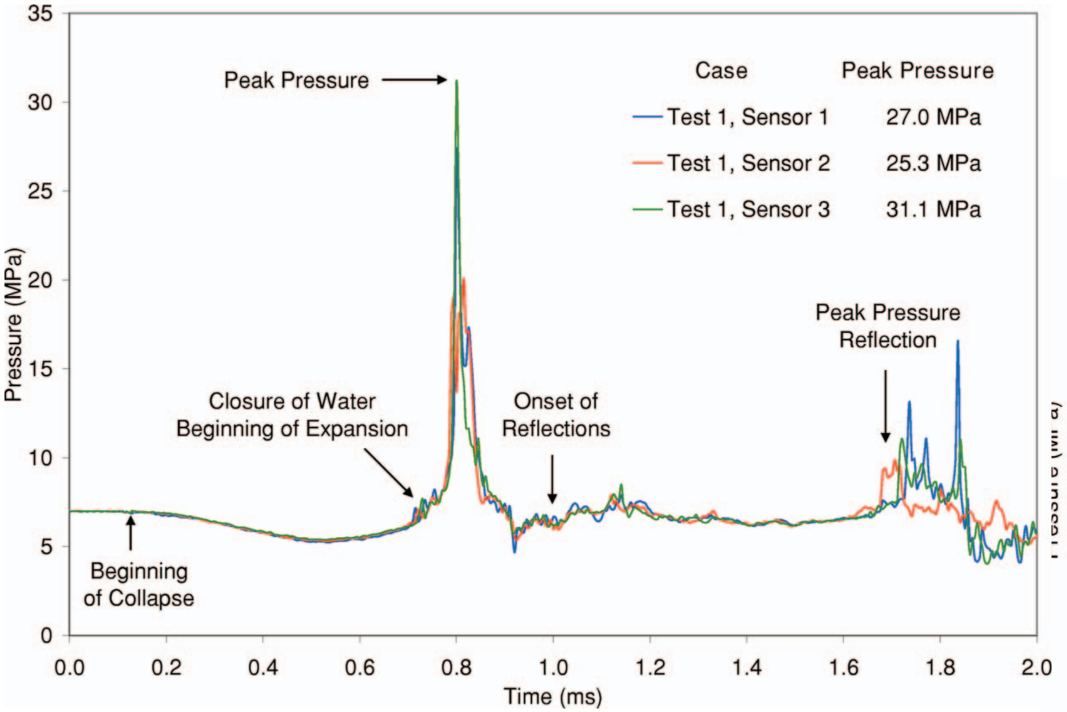


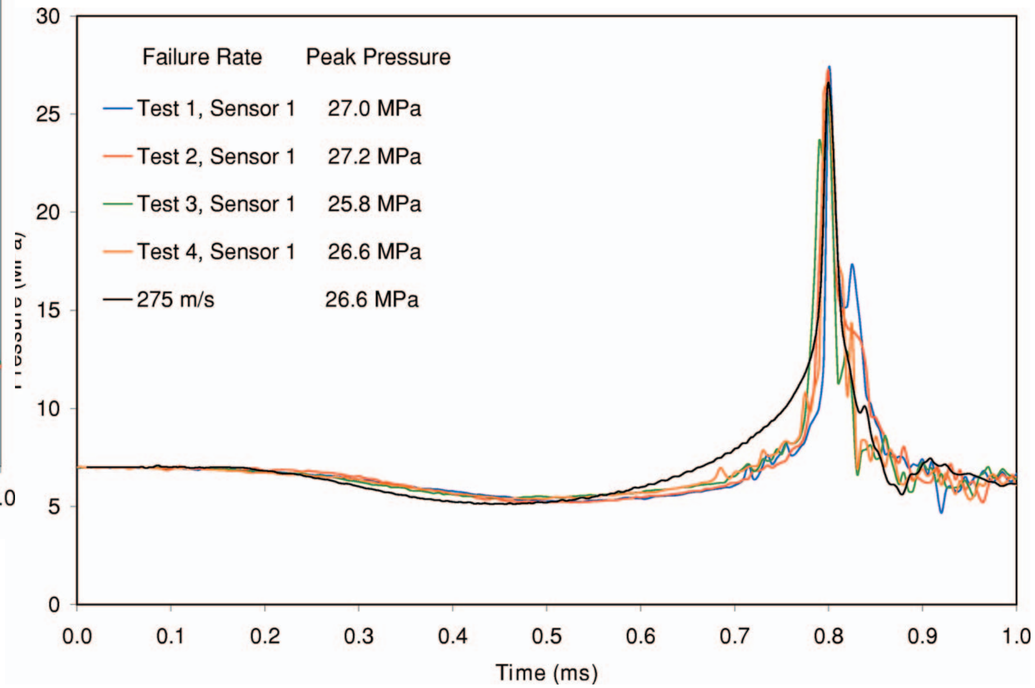
sensor at 40 inch

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.