Mechanical Performance of Large Format Underwater Photomultiplier for the Long Baseline Neutrino Experiment Water Cherenkov Detector

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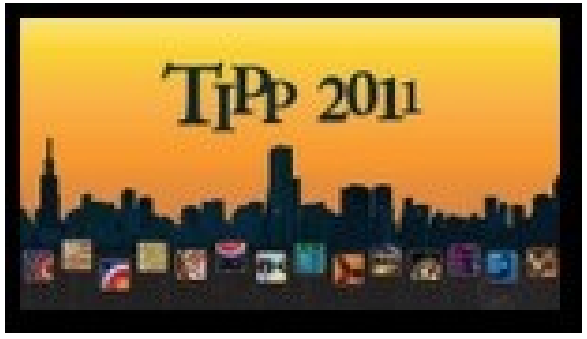
TIPP2011@Chicago



BROOKHAVEN
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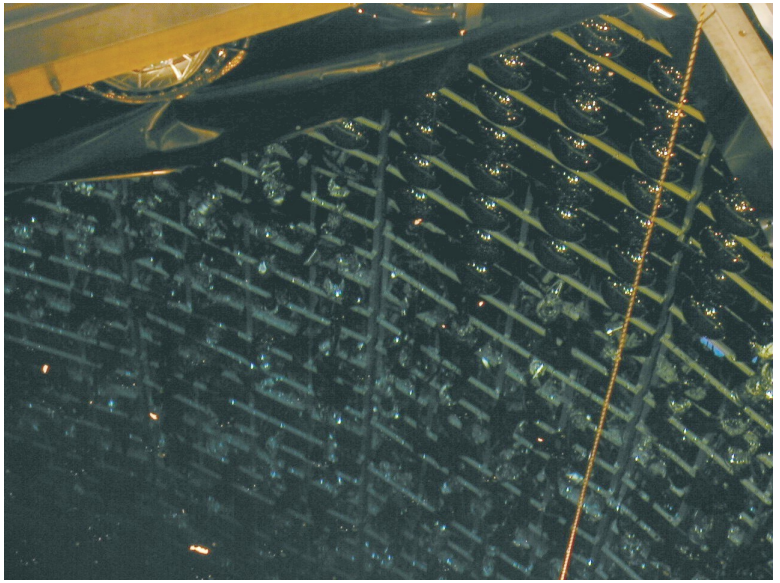
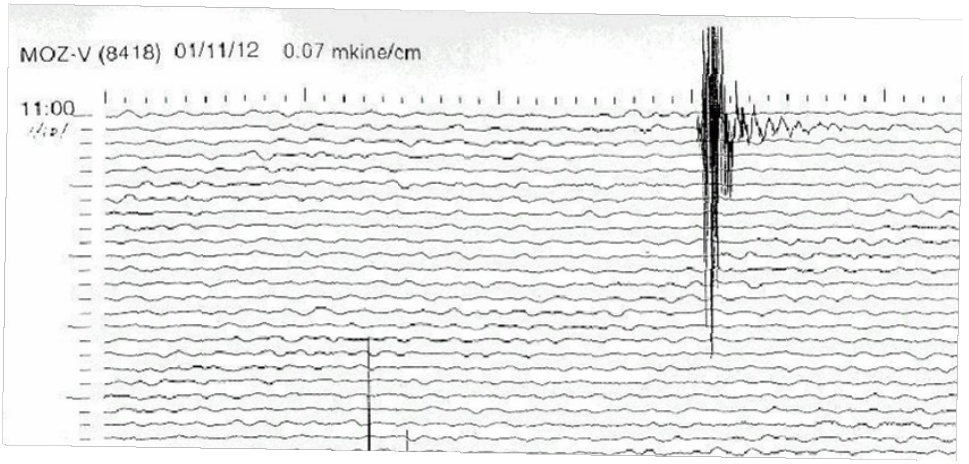
Introduction

Mechanic performance of large format semi-hemispherical photomultiplier (PMT) within large water cherenkov detector

- Determine if the PMT can withstand expected hydrostatic pressure and potential shock waves in the water
  - 6600 PMTs imploded in Super Kamiokande in a chain reaction by the shock wave in 2001

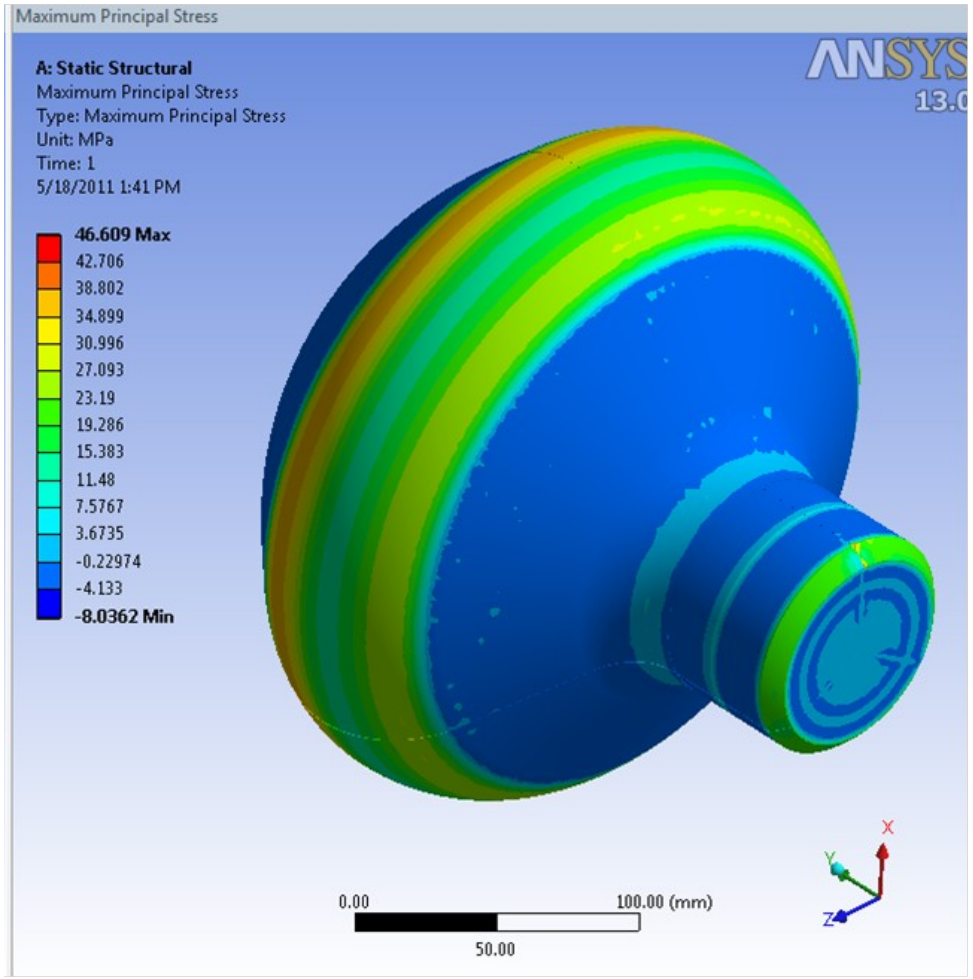


Seismic recording 2.3km from superK



Hydrostatic Stress Analysis

R. Sharma

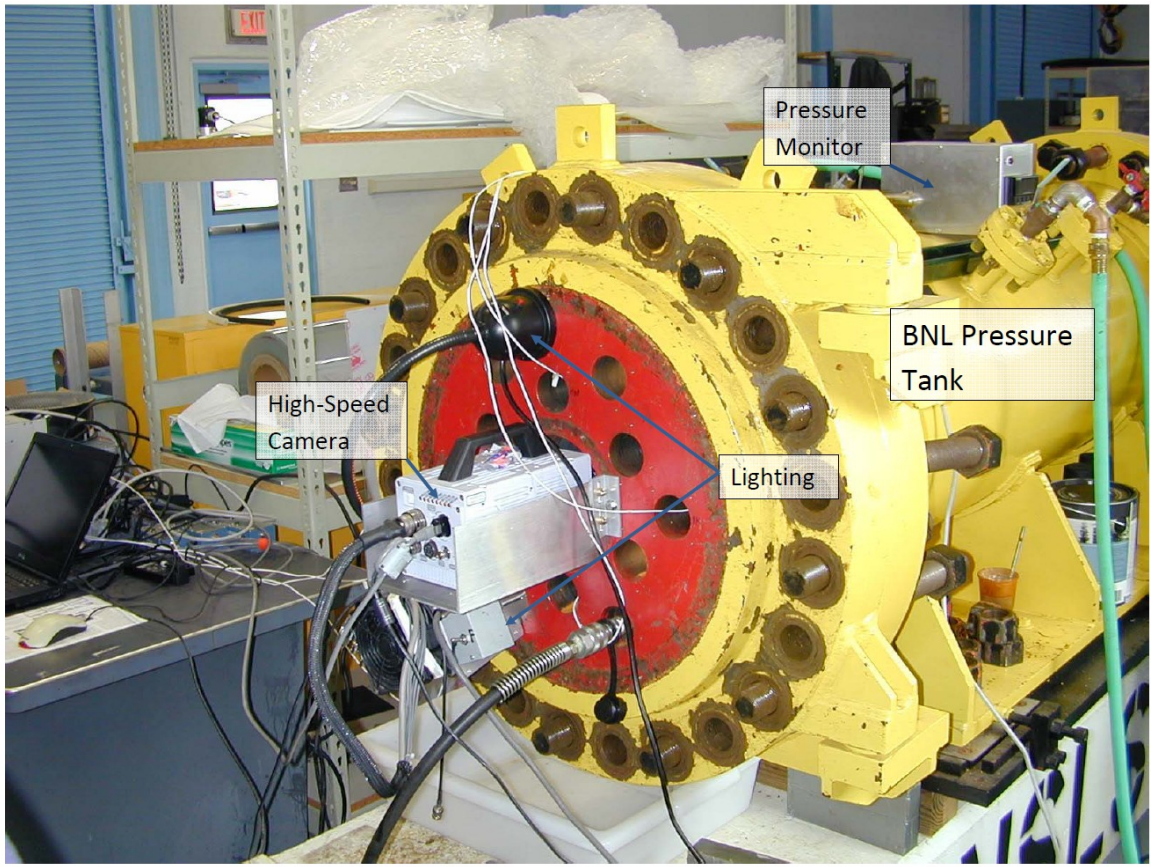


Hamamatsu R7081 under 1MPa (10 bar)

dydrostatic Stress Table (Hamatsu R7081)

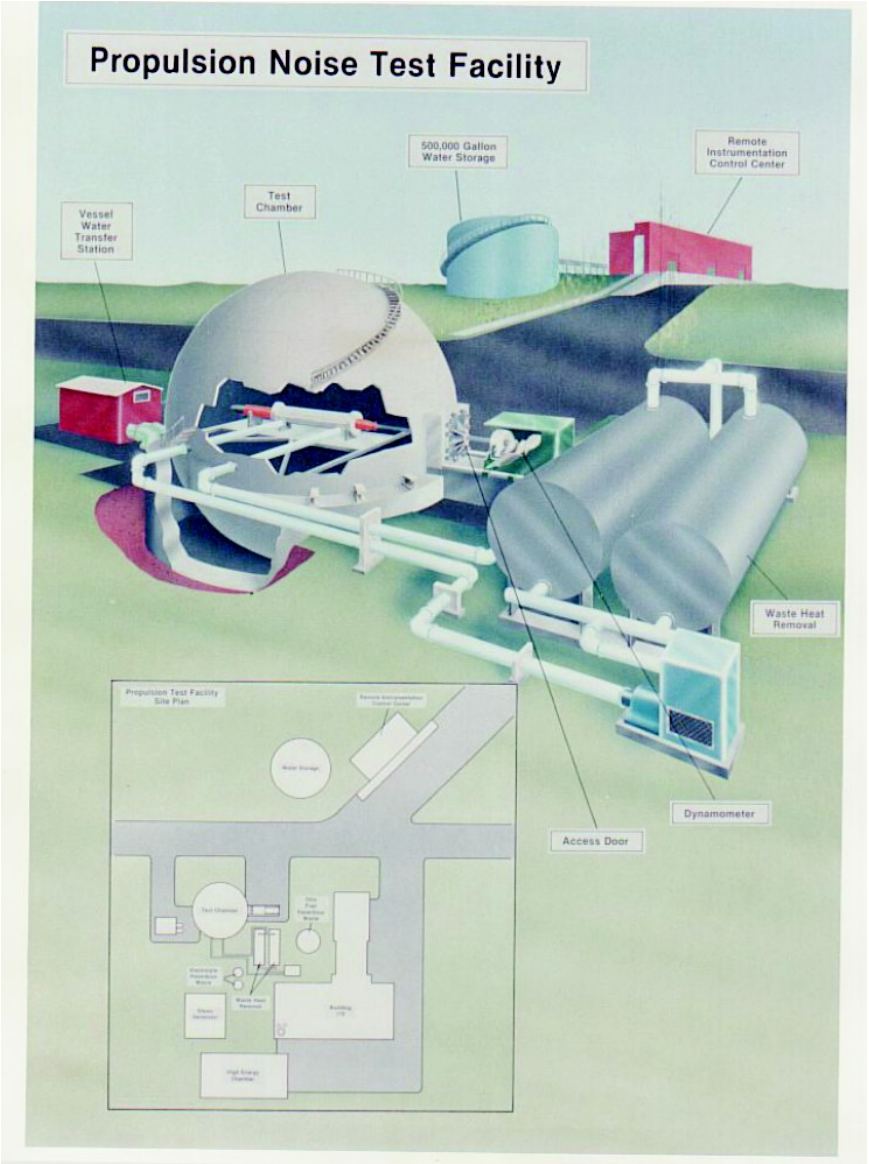
Stress	Compressive (MPa)	Tensile (MPa)
maximal principal stress	46.6	-8.0
Maximal shear stress	47.5	0.0
Normal stress along X	37.7	-82.3
Normal stress along Y	34.6	-68.6
Normal stress along Z	37.9	-82.4
Shear stress in XY plane	42.7	-44.0
Shear stress in YZ plane	42.8	-42.6
Shear stress in XZ plane	36.9	-37.1

BNL Facility for the Pressure Test



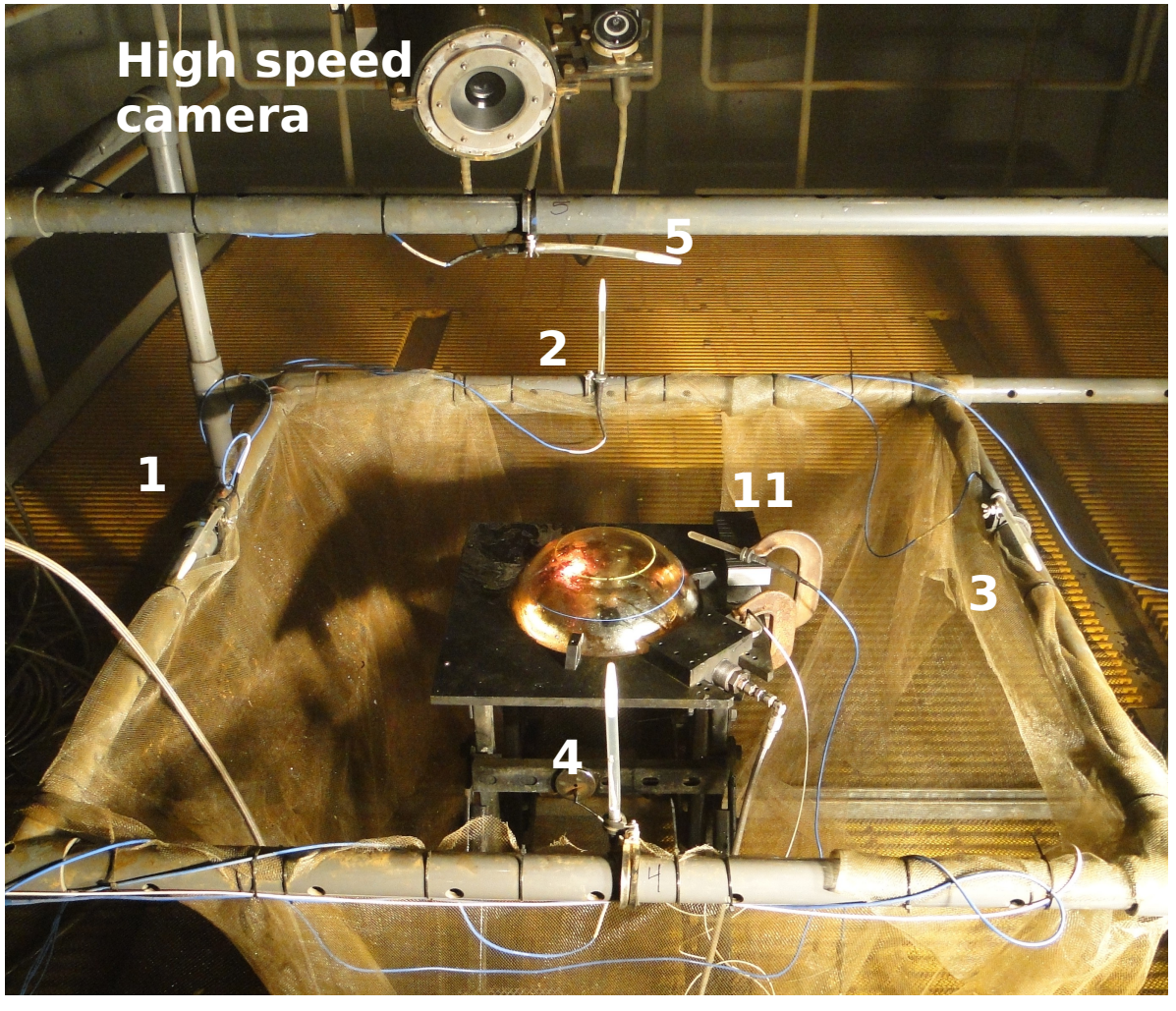
- BNL pressure vessel (~400 liters, up to ~350 psi)
- Good for the hydrostatic pressure tests
- Deficiency for the dynamic pressure tests:
  - The tank is small compared with the PMT size (~5 liters)
  - Unable to form the same shock wave pattern as the real detector
  - Unable to distinguish the shock wave from the acoustic reflections from the wall.

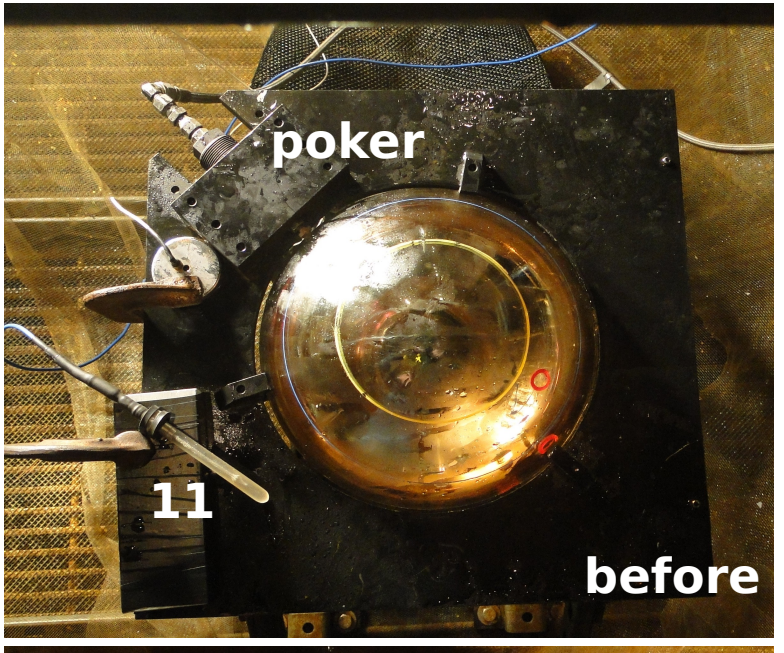
Navy Undersea Warfare Center (NUWC) Facility



- Cooperation between BNL and NUWC through Cooperative Research And Development Agreement (CRADA)
- 15m diameter
- 500,000 gallons of water
- Rated for 100 psi at the center

Experimental Setup



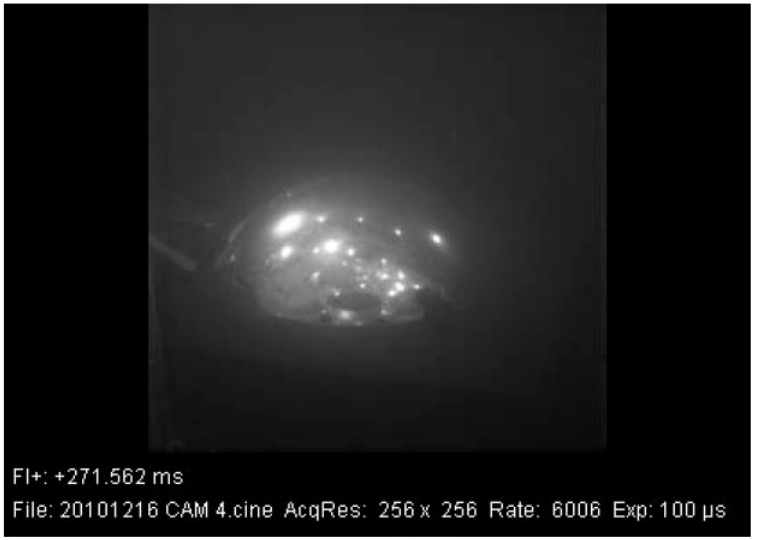


7 Water proof pressure sensors (PCB ICP)
2 High speed cameras

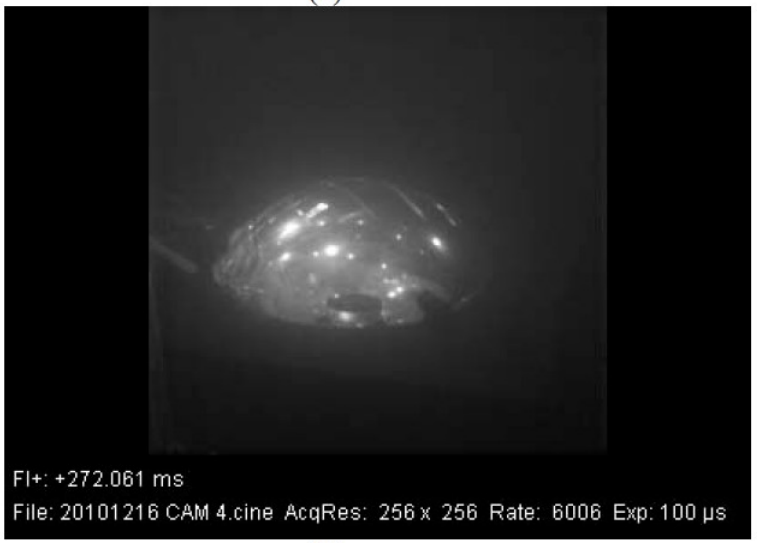
NUWC Control Room

12/16/2010 Implosion Test

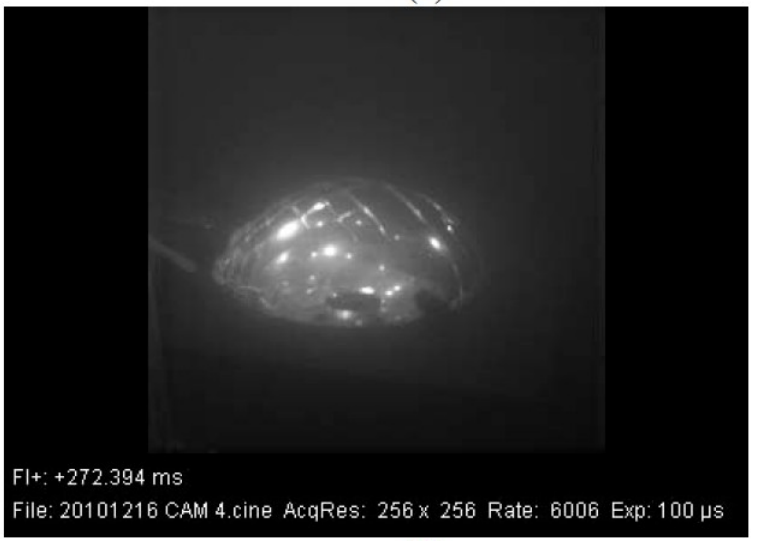
(a)



(b)



(c)



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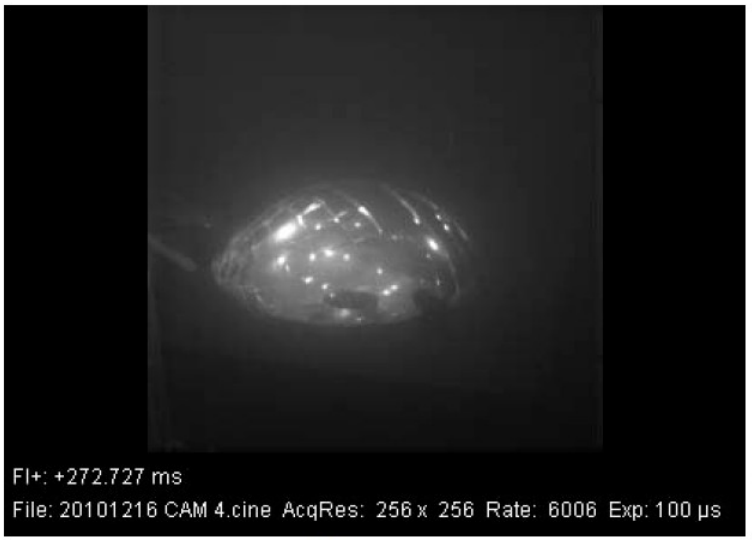
12/16/2010 Implosion Test



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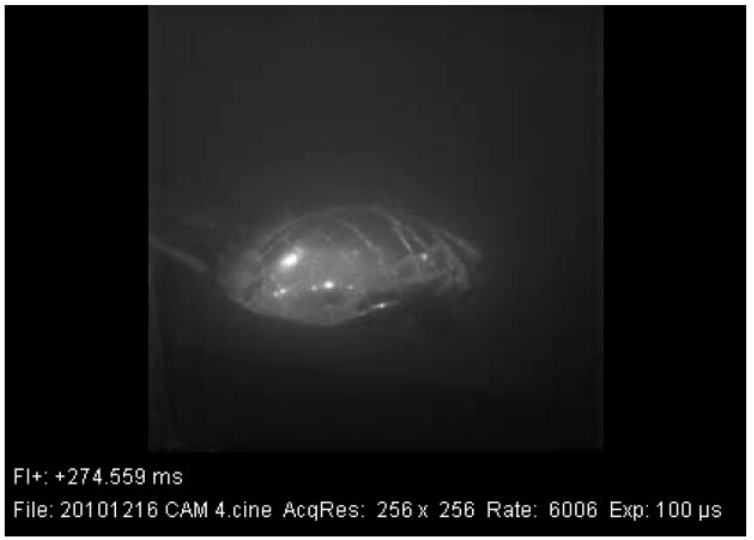


(f)

(g)

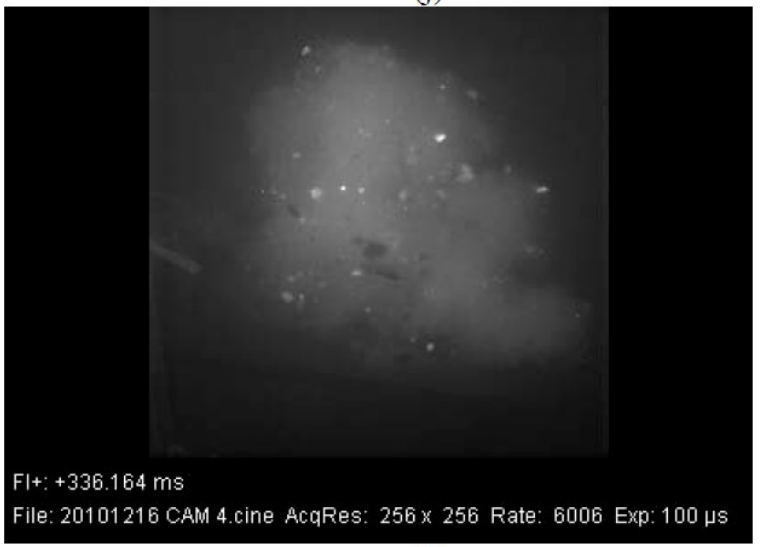
(h)

12/16/2010 Implosion Test

(i)

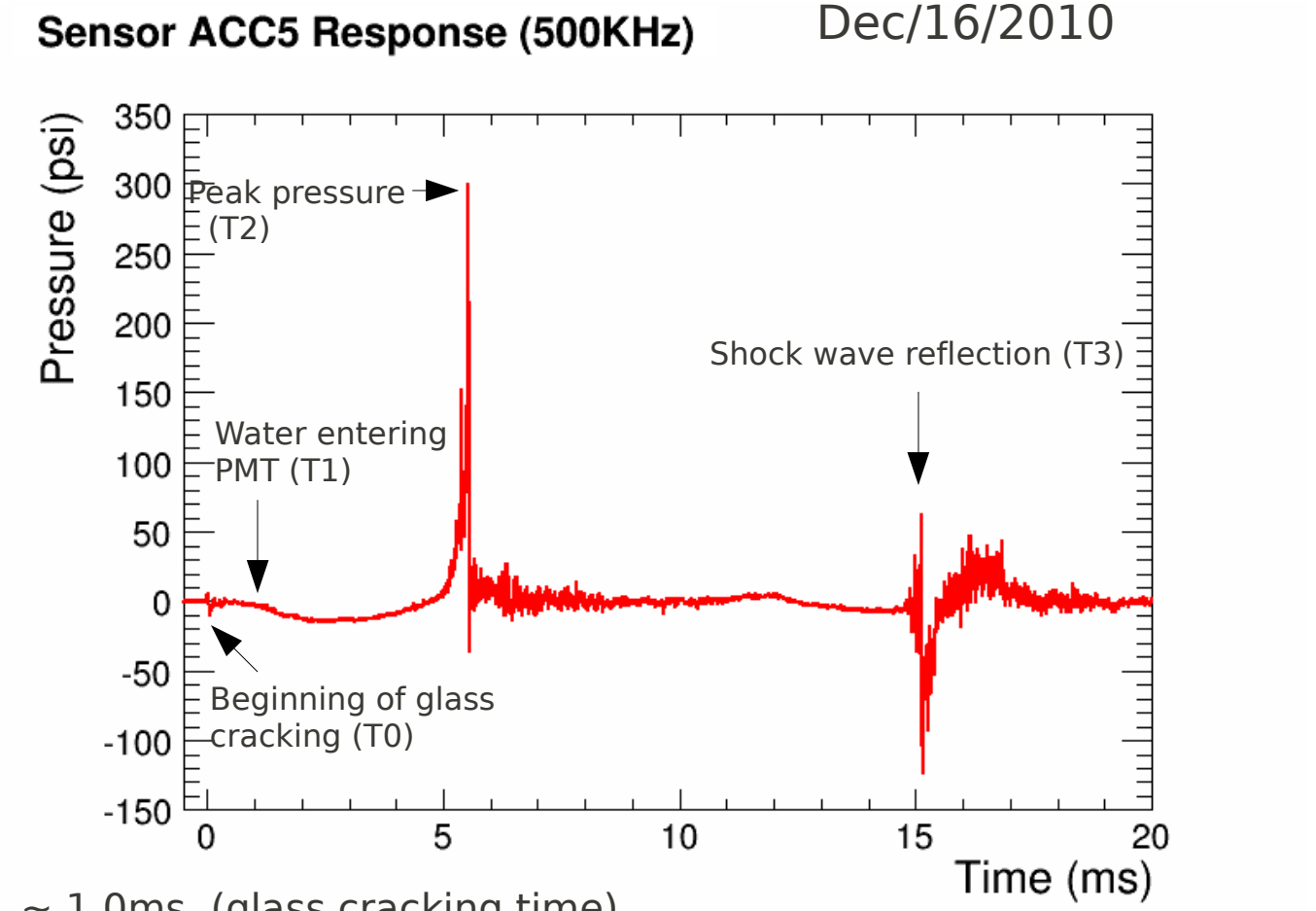
(j)

(k)



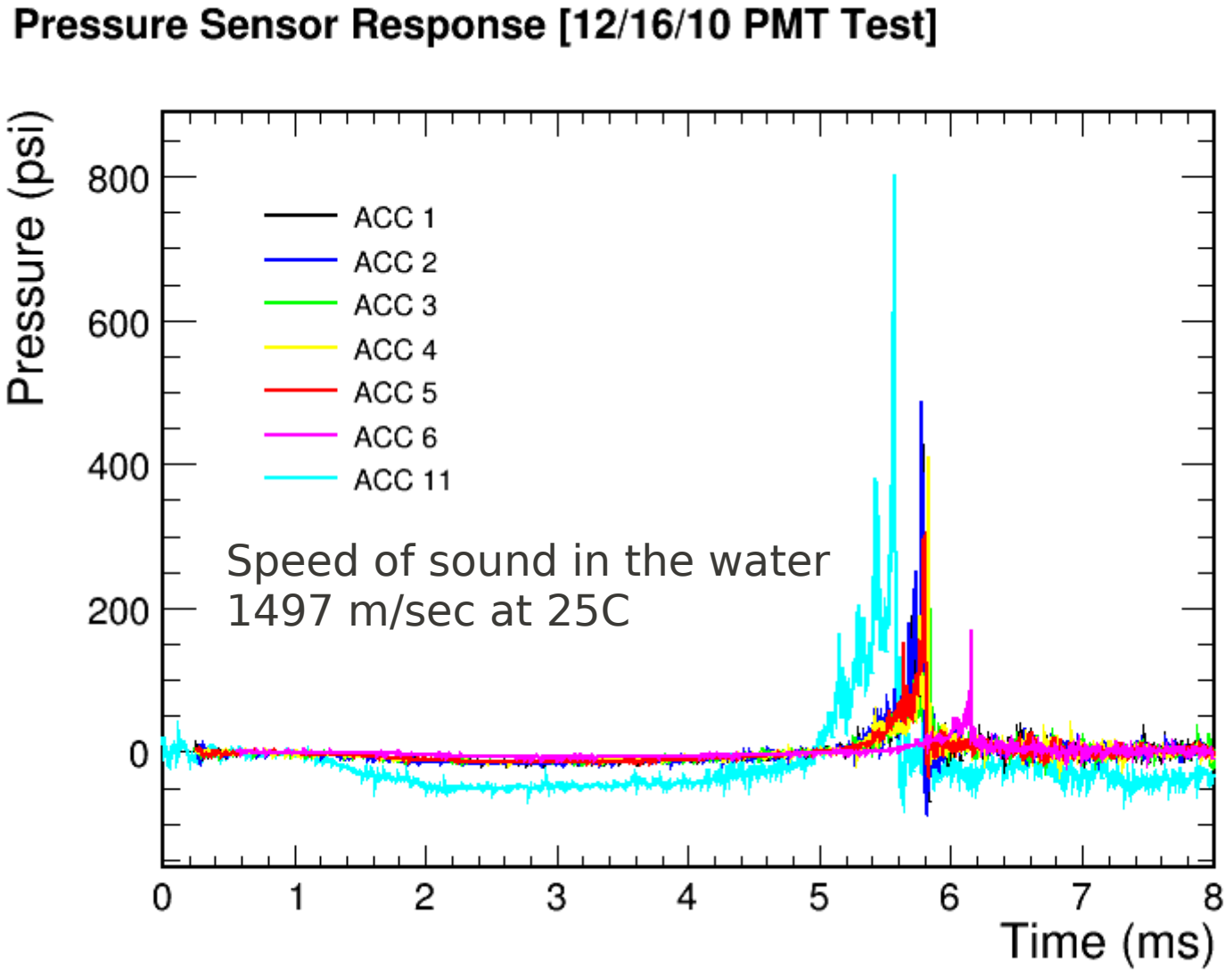
(l)

Blast Sensor Pulse Structure



T1 – T0 ~ 1.0ms (glass cracking time)
T2 – T1 ~ 4.5ms >> 0.8ms (sound traveling time)
T3 – T2 ~ 10 ms (close to the speed of sound)

Multiple Sensors



Sensors Table

12/16/2010

Sensors	distance(mm)	T0 (ms)	T2(ms)	T2-T0 (ms)	Peak (psi)	Intensity (psi*ms)
ACC11	152	0.000	5.570	5.570	801.6	150.0
ACC5	482	0.260	5.800	5.540	300.2	37.8
ACC1	521	0.260	5.785	5.525	426.9	38.0
ACC2	521	0.245	5.780	5.540	488.3	43.2
ACC3	521	0.235	5.830	5.595	287.2	35.8
ACC4	521	0.245	5.825	5.580	410.0	36.3
ACC6	991	0.560	6.150	5.590	169.2	20.3

12/17/2010

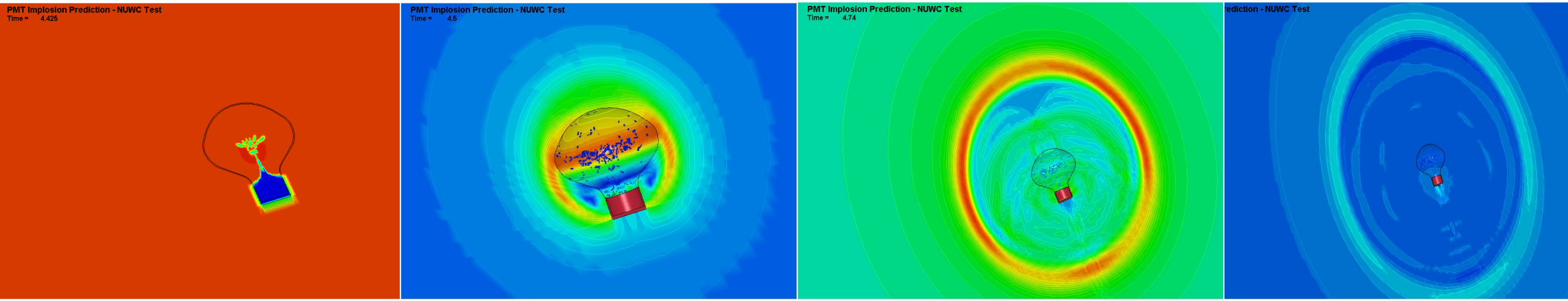
Sensors	distance(mm)	T0 (ms)	T2(ms)	T2-T0 (ms)	Peak (psi)	Intensity (psi*ms)
ACC11	152	0.000	5.770	5.770	1800.3	165.0
ACC5	482	0.230	5.979	5.750	347.2	41.9
ACC1	521	0.255	6.055	5.800	337.1	38.5
ACC2	521	0.252	6.022	5.770	353.6	40.4
ACC3	521	0.250	6.030	5.780	291.5	38.2
ACC4	521	0.245	6.030	5.785	223.5	37.1
ACC6	991	0.575	6.360	5.785	155.1	20.5

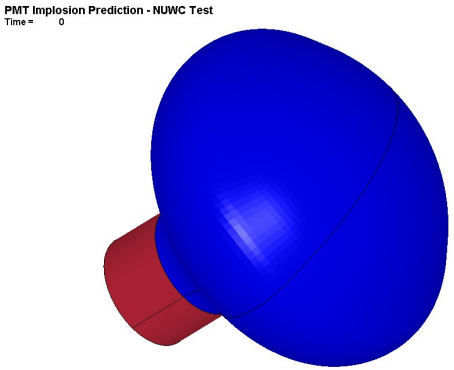
Some characteristics:

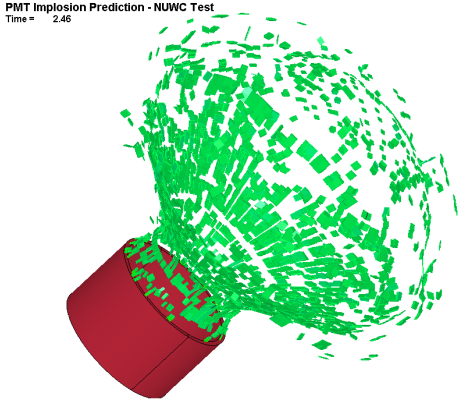
- T2-T0: shared by all the sensors; The difference between two tests may be related with the PMT break pattern (some proof from the movie)
- Intensity attenuates as a function of 1/R with the distance
- Shock wave speed is close to the speed of sound in water.

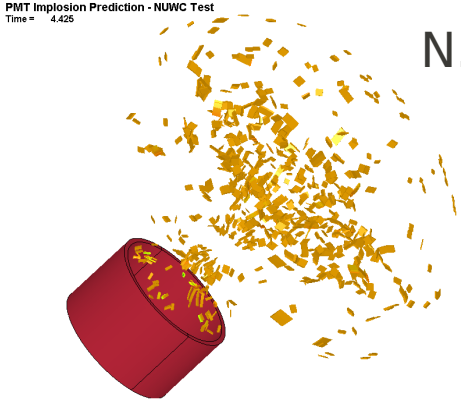
Simulation

LS-DYNA (general purpose transient dynamic finite element program)
Arbitrary Eulerian-Lagrangian (ALE) formulation that allows PMT glass and fluid to interface.
Based on a 2M+ fluid/solid element model and “adjusted” PMT glass constitutive and fracture relations, the implosion at 88 psi water pressure are simulated (~240 hrs)





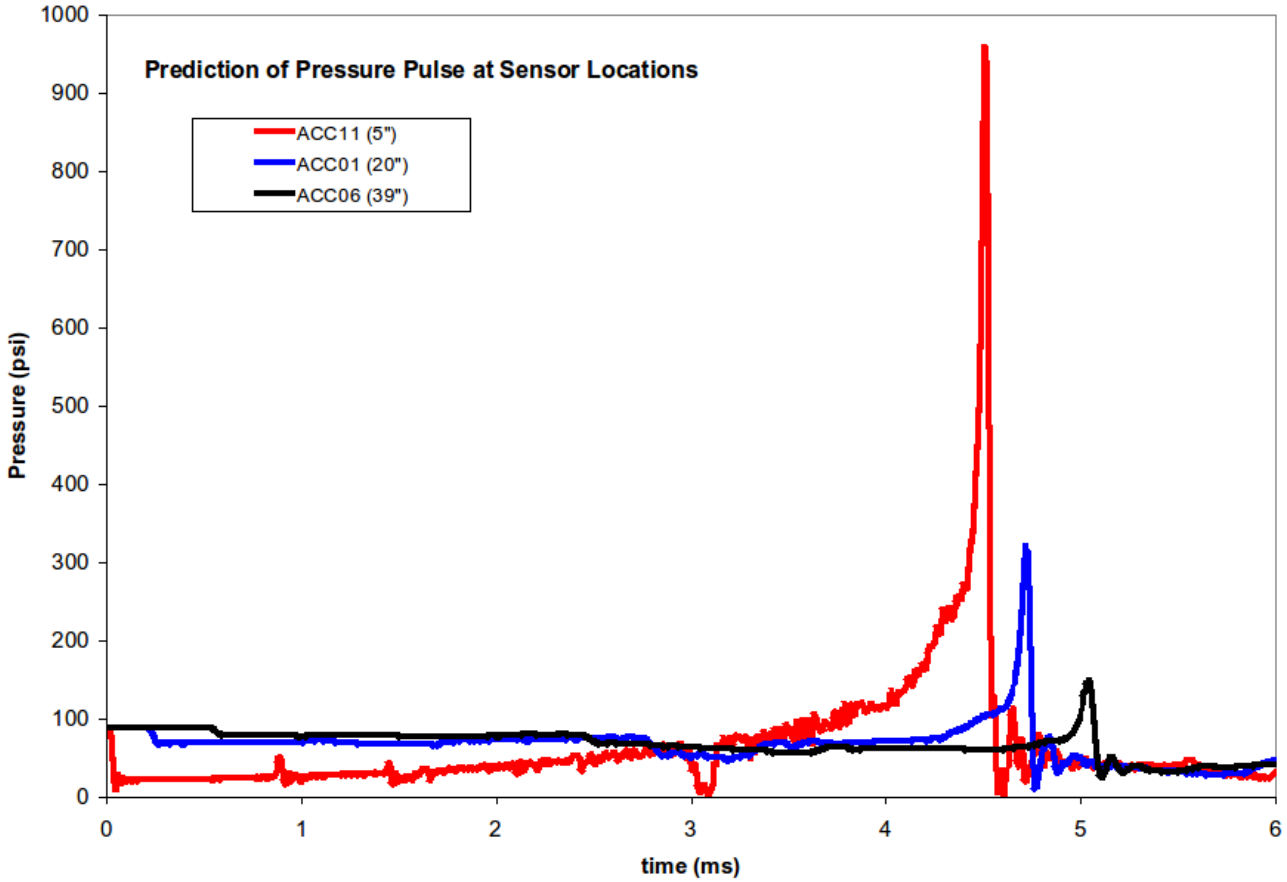




N. Simos

Blind Prediction before Tests

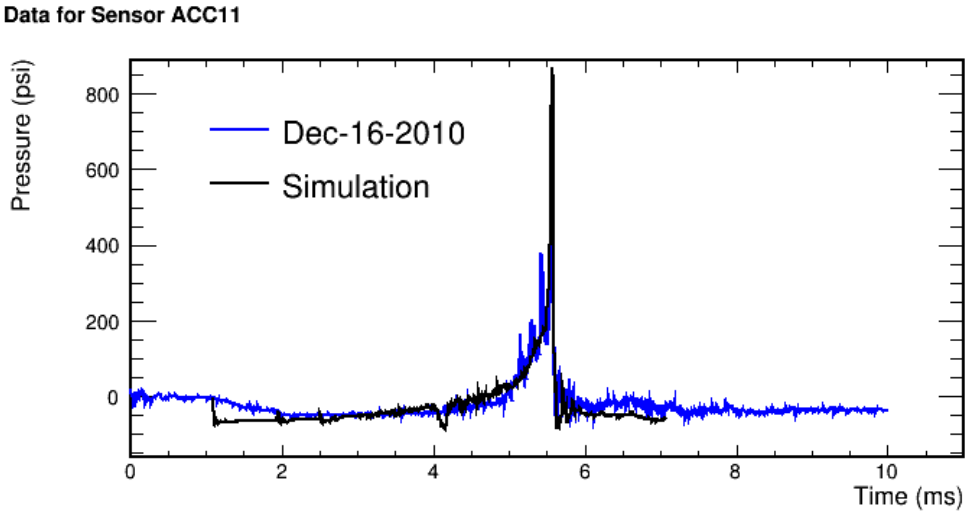
N. Simos

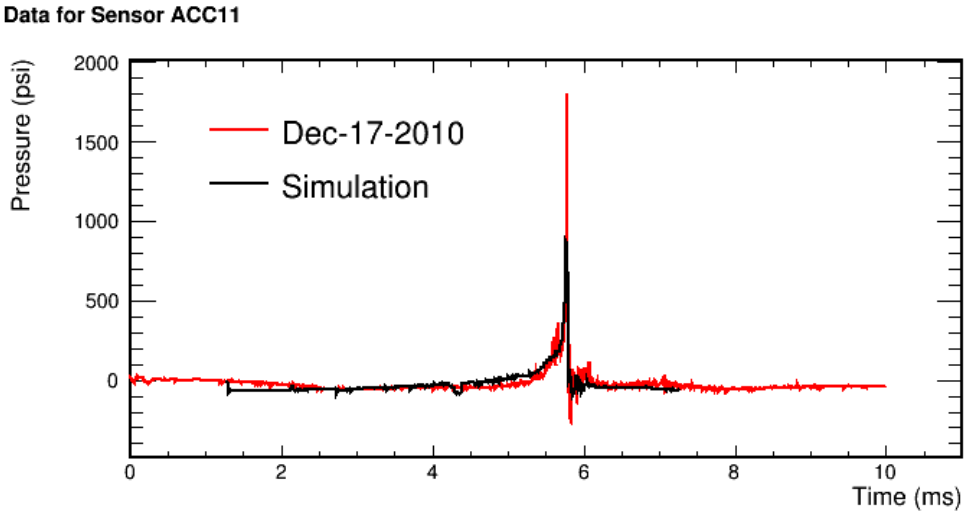


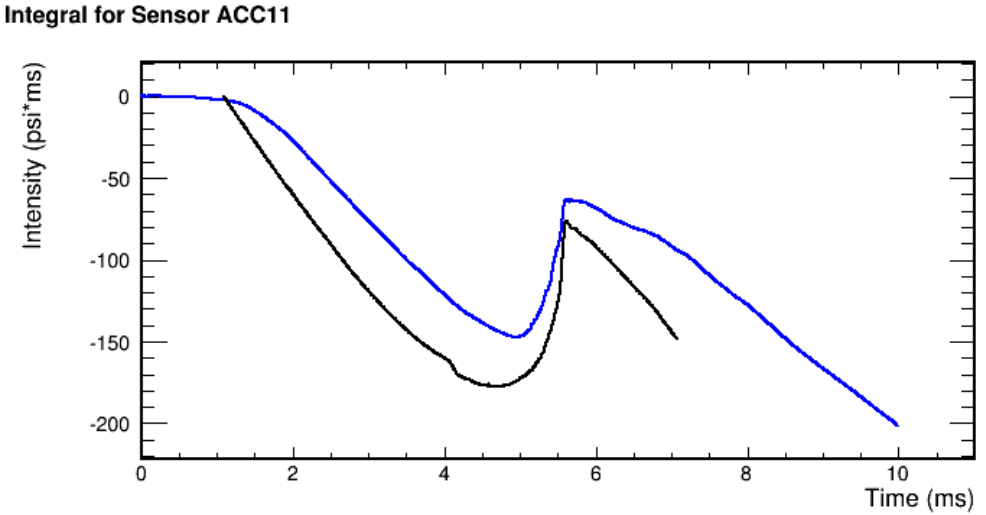
Prediction of pressure pulse at various sensor locations are close to the test results.

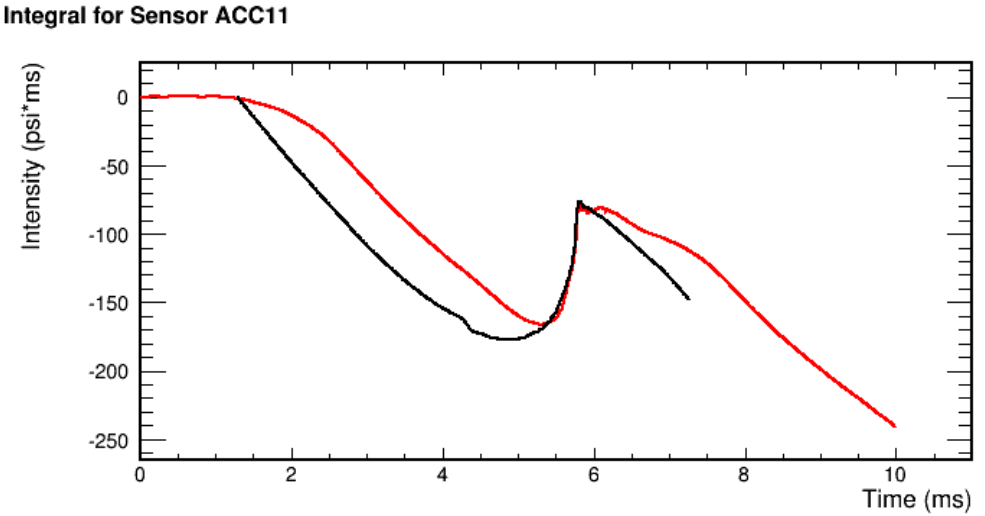
Confirm the attenuation (as a function of 1/r) and pulse propagation velocity (~1500m/sec).

Data and MC Comparison









Conclusions

- Successfully established the PMT pressure test setup.
- Simulation has a good agreement with the test data.
- Future work:
  - Multiple PMTs shock wave tests
  - Bucket-protected PMT pressure tests
  - Further tuning the simulation with better agreement with the data.

People Involved

- BNL physicists: Milind Diwan, Jiajie Ling, Hidekazu Tanaka
- BNL engineers and technicians: Rahul Sharma, Jeffery Dolph, Kenneth Sexton
- NUWC staffs: Steve Turner, Philip Tabor, Doug Arnold, etc.