

PMT R&D

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FNAL

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

Developmental Plan for 12 inch PMT

Date : August 6, 2008

2009

2008		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB
PMT Design	Simulation Electron Trajectory	Basic Design		Feedback Check											
	Electrode Design			Practical Design											
Material Preparation								Glass Bulbs			Electrodes			Insulating Plates	
Production for Prototypes												Initial conditioning is done during this period.			
Inspection														Various Tests	
Delivery															Sample Tubes

**Some sample tubes would be available in FEB. 2009.
We need 6 months for preparation of mass-production version.**

Tube production

Glass

Stamped metal and wire parts

First assembly

vacuum deposition of metal

platings

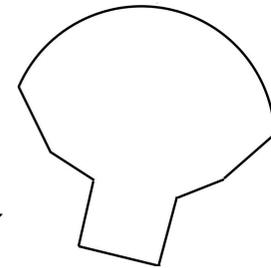
Graded seal

Final vacuum

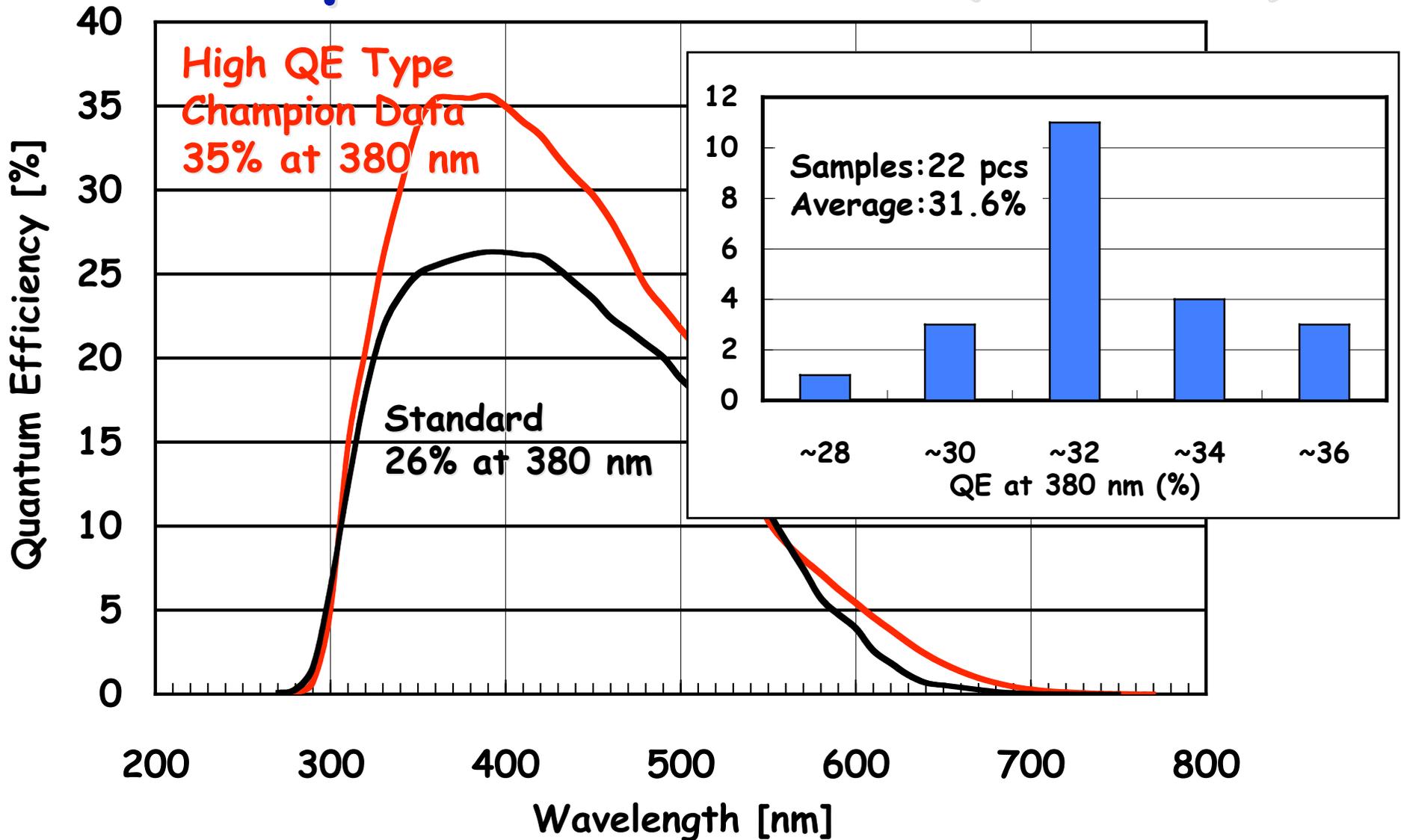
Cathode deposition

HPK and Photonis are
NOT concerned about
their ability to
manufacture at this
rate

Final assembly of 10 inch
tubes needs lab space of
30'x30'; six stations with 6
pmts/station; 1 full day =>
36tubes/day = icecube
production.
tripling this rate is not
difficult



Example data R7081 (10 inch)



Goal of development is 43%

Baseline Plan

- The Baseline plan is R708I.
- We will need 50000 to 60000 per chamber depending on shape to obtain similar amount of light collection as SK.
- The correct number to look at is $\text{Coverage} * \text{QE} * \text{Collection eff.}$
- R708I has been used by Icecube. There is also production for other projects.
- Only issue for us is pressure performance.

SPECIFICATIONS

Cathode Sensitivity

Anode Sensitivity

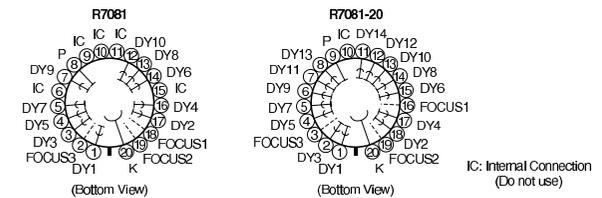
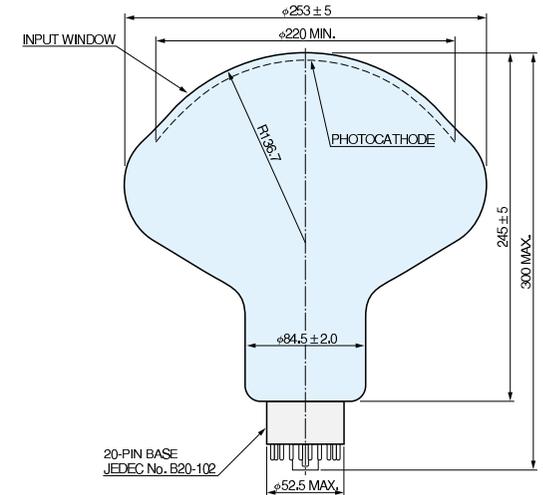
Type No.	Luminous (2856 K)		Radiant at 420 nm Typ. (mA/W)	Blue Sensitivity Index (CS 5-58)		Quantum Efficiency at 390 nm Typ. (%)	Luminous (2856 K) Typ. (A/lm)	Radiant at 420 nm Typ. (A/W)	Gain Typ.	Applied Voltage for Typical Gain Typ. (V)
	Min. (μA/lm)	Typ. (μA/lm)		Min.	Typ.					
R5912	40	70	72	6.0	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.

●R7081, R7081-20

Maximum Ratings

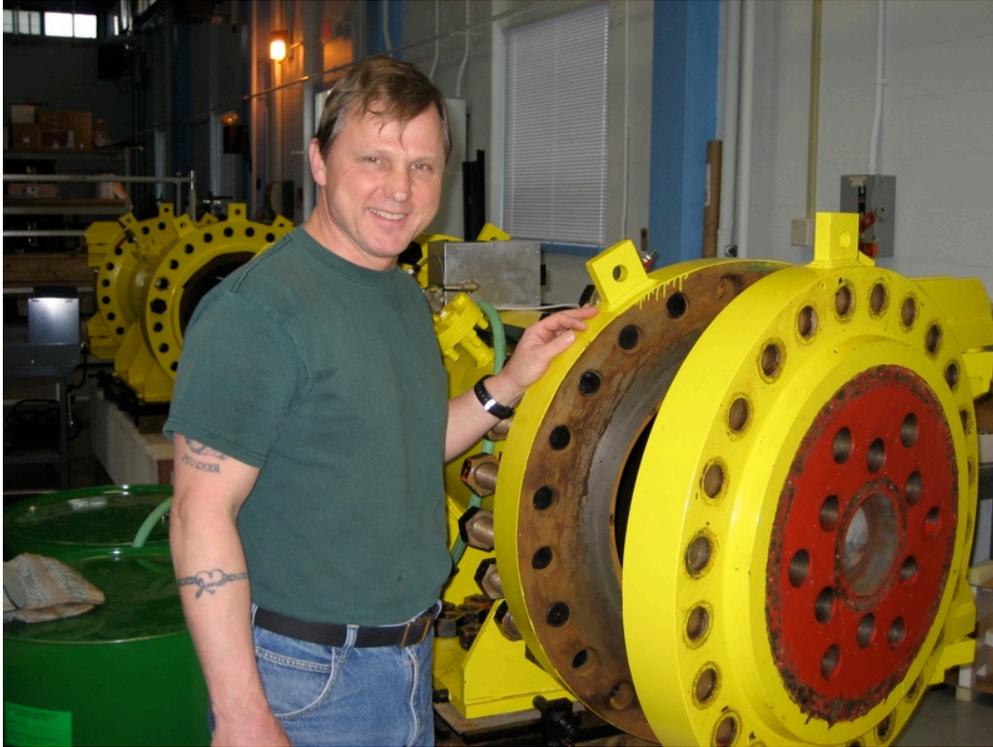
Type No.	Supply Voltage		Average Anode Current (mA)	Operating Ambient Temperature (°C)	Storage Temperature (°C)	Pressure (MPa)	Direct Interelectrode Capacitances	
	Anode to Cathode (V)	Anode to Last Dynode (V)					Anode to Last Dynode (pF)	Anode to All Other Dynodes (pF)
R5912	2000	300	0.1	-30 to +50	-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

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
XPI807 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/lowr 1	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,

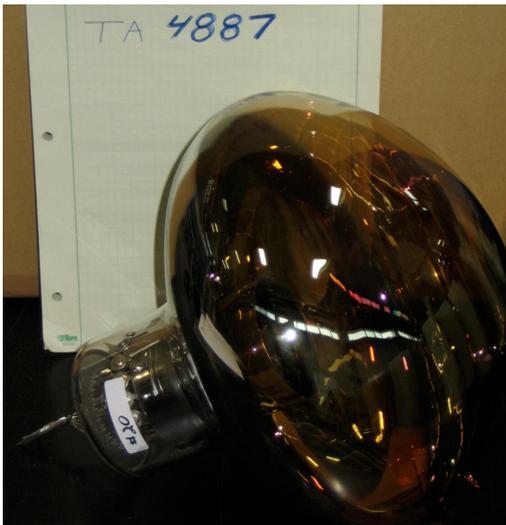
On each tube, there is data on glass thickness, pressure pulse duration, etc.

What kind of information ?

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

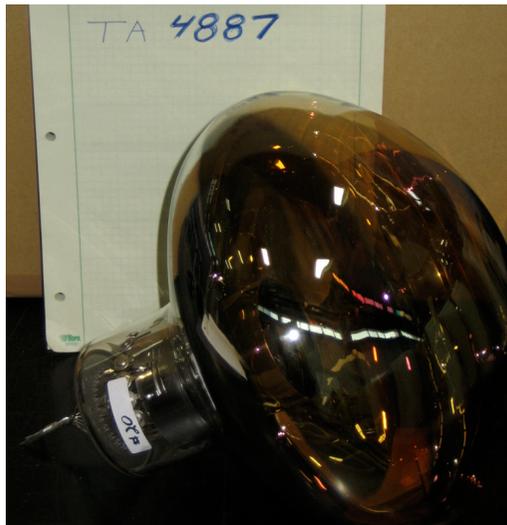
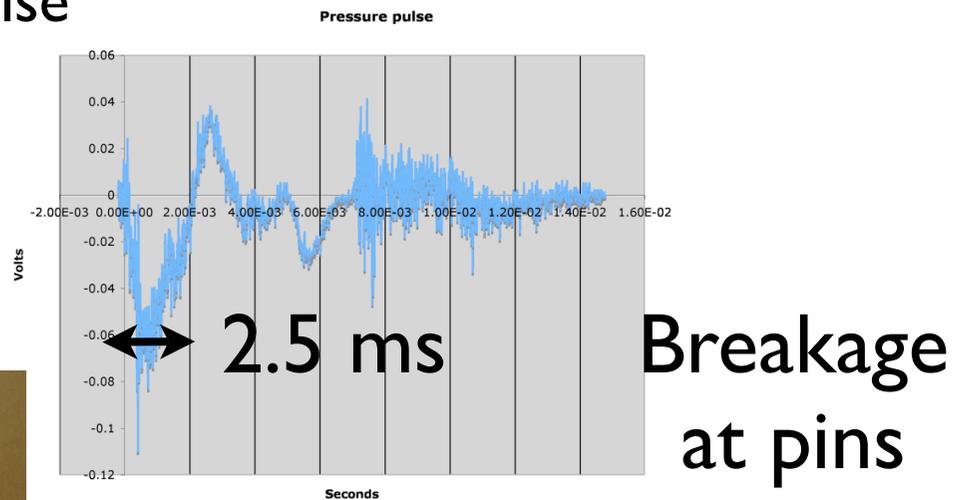
↔ 2.5 ms

Breakage
at pins



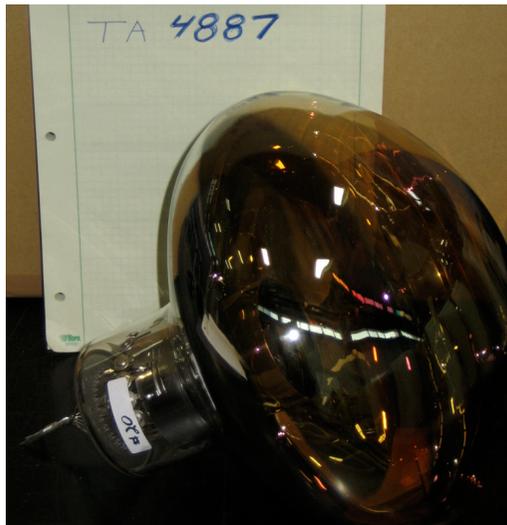
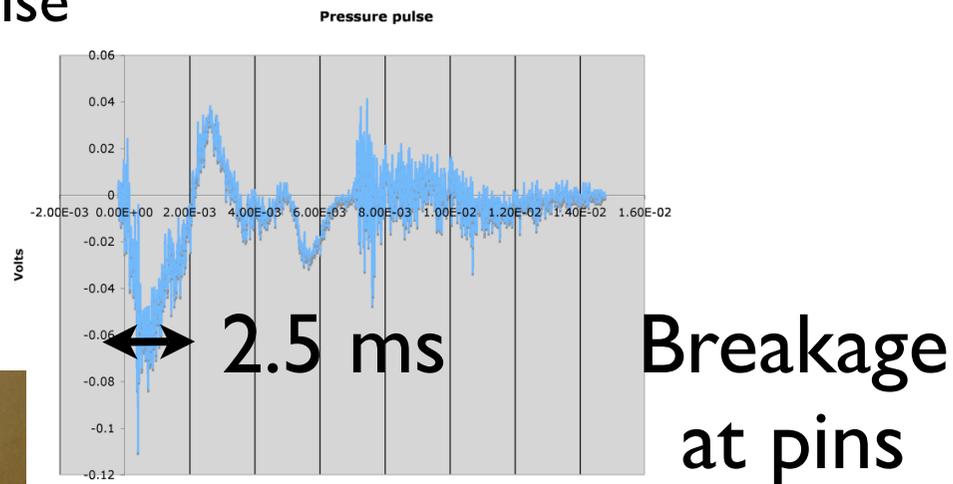
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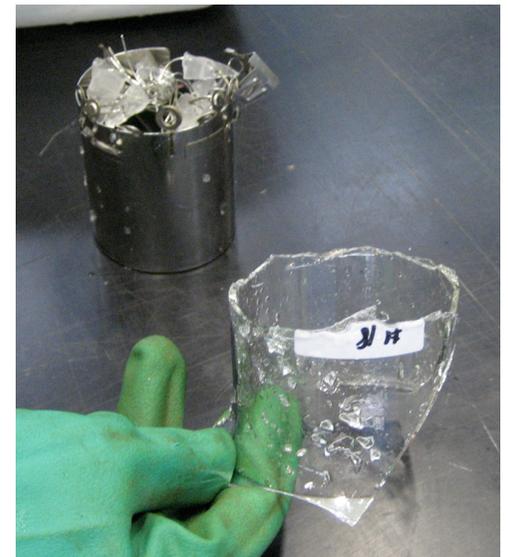
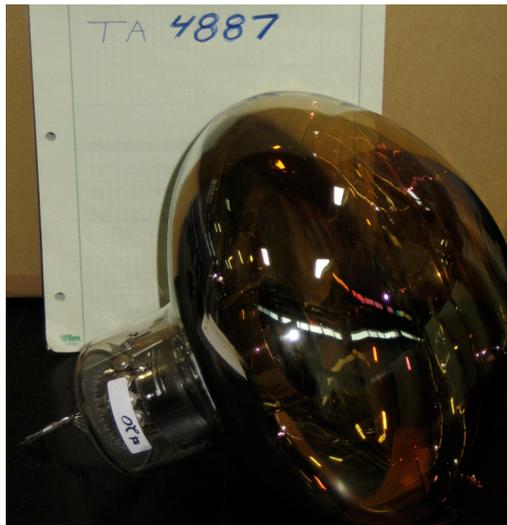
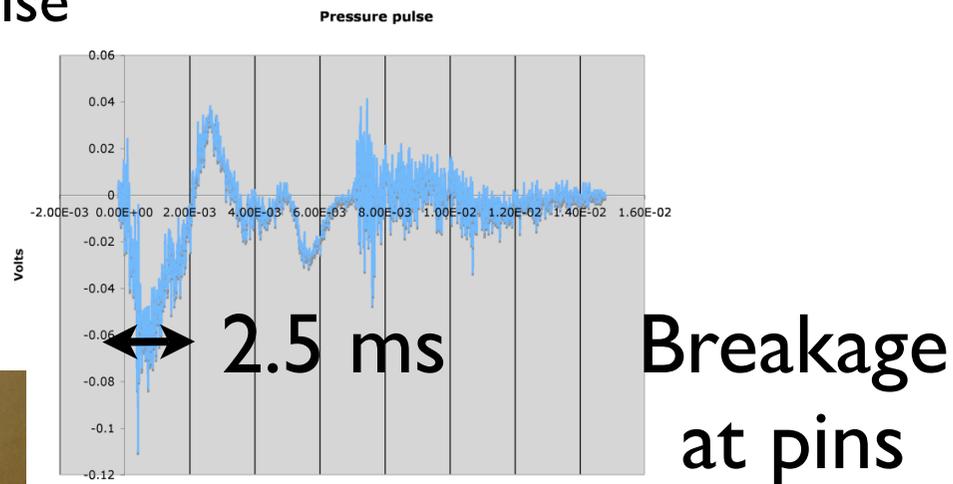
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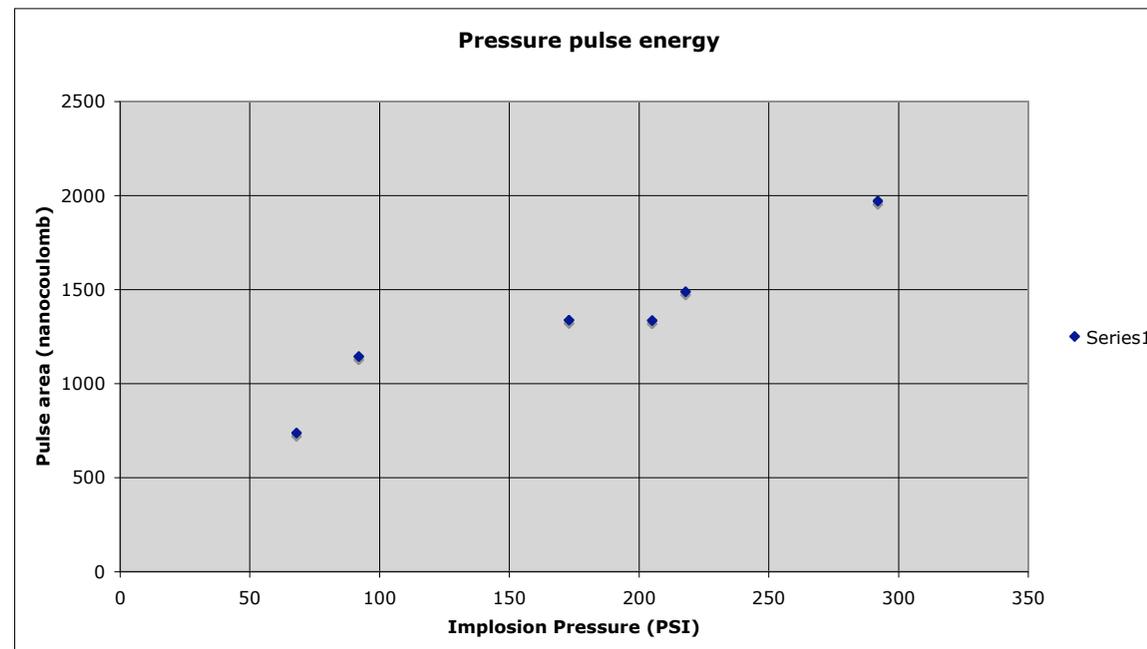
- Pressure at implosion
- Implosion process. (fast motion movie), photos
- Pressure pulse



another example

Analysis

- There are 3 modes of failure: pin failure, neck failure and dome failure.
- Pin failure is the best kind because the pressure pulse is spread out in time.
- The total energy in the pulse goes as $P \cdot V$ regardless of failure. It is up to us how to spread it in time.



Summary

- PMT R&D is in progress. There is considerable development in place at BNL, especially on pressure testing.
- Collaboration has started with Orsay. They have received an identical pressure vessel for testing both PMTS and electronics.
- Helpful to have more people involved and other setups.
- So far no funds at BNL in FY2009 for this work (LDRD is finished).
- French have euro 500k grant.