Update on PMT work in U.S.

- Completion of 12" Hamamatsu PMT testing
- Building a test facility at Davis for light collector testing
- Work with ADIT/ETL on 11" HQE PMT

Testing of 12" PMT completed and published

Characterization of the Hamamatsu R11780 12 inch Photomultiplier Tube

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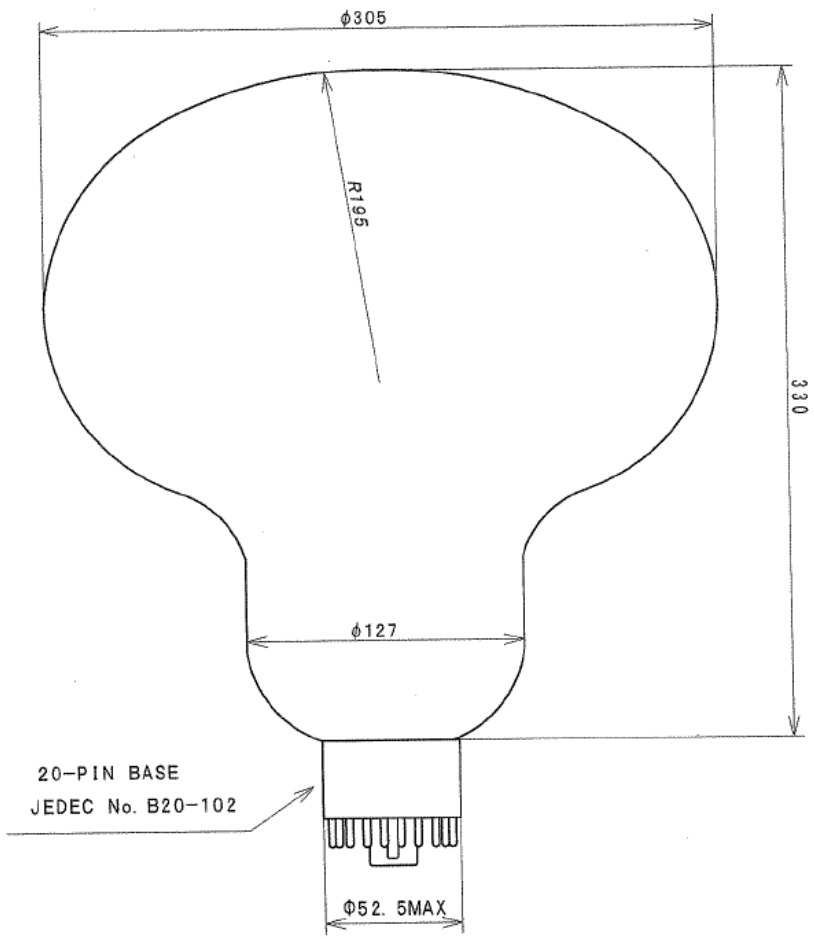
Accepted by NIM, you can see at arXiv:1210.2065


ϕ305
R195
330
ϕ127
20-PIN BASE
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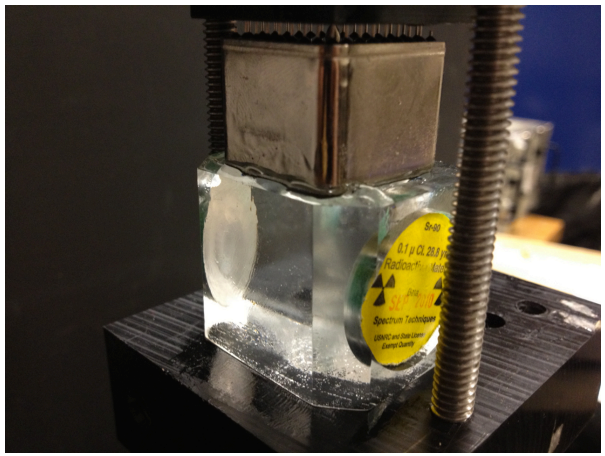
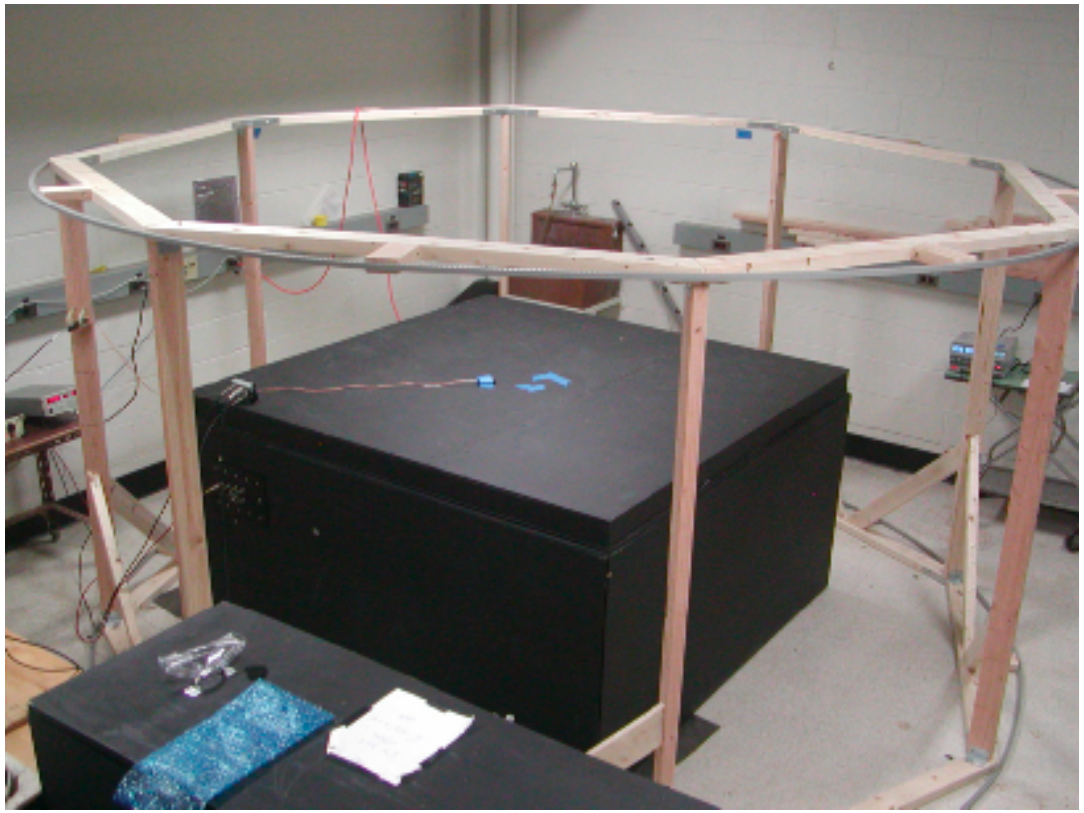
Electrical Response

- s.p.e. P/V and other charge response
- s.p.e. timing response
- standard and HQE relative performance



0.2μCi 90-Sr source embedded in 2.5 cm acrylic cube, with 2.5 cm PMT as fast trigger. 250 ps Resolution.



Test setup at Penn.

	Mean	Standard Deviation	Minimum	Maximum
Transit Time Spread (σ_{prompt}) (ns)	1.37	0.15	1.20	1.6
Late Pulses (fraction)	4.48%	0.32%	3.93%	4.92%
Noise Rate (Hz)	3669	5110	1962	16807
Operating Voltage (V)	1848	75	1920	1740

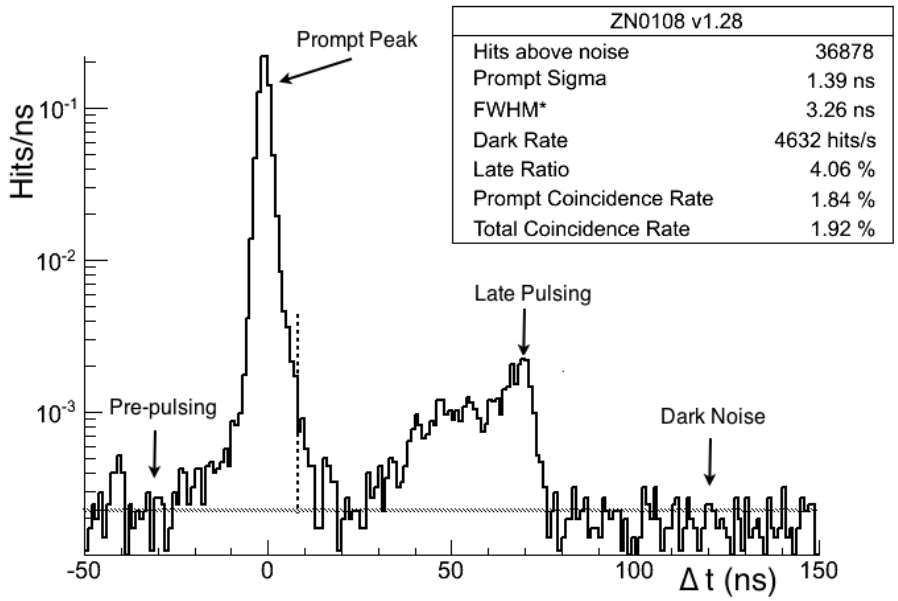
Table 3: Summary of PMT SPE timing characteristics results for the R11780 standard quantum efficiency PMT. The operating voltage was adjusted to achieve a gain of 1×10^7, which corresponds to a SPE charge peak of 1.6 pC. All measurements were made at room temperature (20° C).

12inch normal QE
(seven tested)

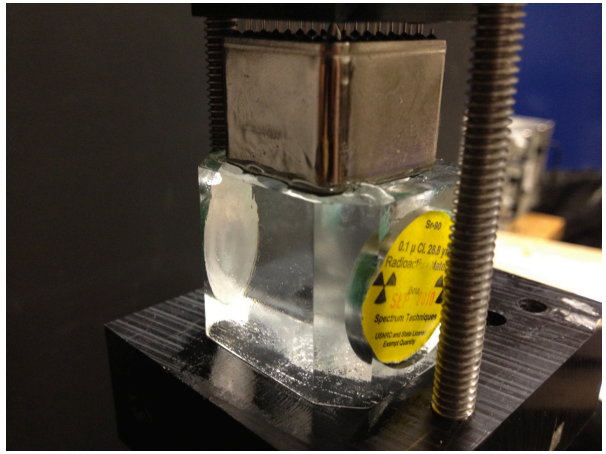
	Mean	Standard Deviation	Minimum	Maximum
Transit Time Spread (σ_{prompt}) (ns)	1.29	0.14	1.16	1.52
Late Pulses (fraction)	4.3%	0.35%	3.6%	4.8%
Noise Rate (Hz)	4428	1897	2398	8217
Operating Voltage (V)	1950	221	1750	2500

Table 4: Summary of PMT SPE timing characteristics results for the R11780 high quantum efficiency PMT. The operating voltage was adjusted to achieve a gain of 1×10^7, which corresponds to a SPE charge peak of 1.6 pC. All measurements were made at room temperature (20° C).

12inch high QE
(ten tested)



U.Penn 250 ps



Single p.e. response with Cherenkov light source, full face illumination

	Average	Standard Deviation	Minimum	Maximum
Charge FWHM (pC)	1.42	0.4	1.18	2.32
Peak/Valley	2.8	0.28	2.3	3.0
High Charge tail (%)	2.86%	0.84%	2.5%	4.94%
Operating Voltage (V)	1848	75	1920	1740

Table 1: Summary of PMT SPE charge characteristics results for the R11780 standard quantum efficiency PMT. The operating voltage was adjusted to achieve a gain of 1×10^7, which corresponds to a SPE charge peak of 1.6 pC. All measurements were made at room temperature.

12inch normal QE (seven tested)

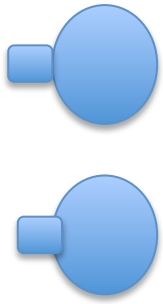
	Average	Standard Deviation	Minimum	Maximum
Charge FWHM (pC)	1.64	0.62	1.19	3.36
Peak/Valley	2.24	0.27	1.78	2.76
High Charge tail (%)	3.75%	0.66%	2.73%	5.2%
Operating Voltage (V)	1950	221	1750	2500

Table 2: Summary of PMT SPE charge characteristics results for the R11780 high quantum efficiency PMT. The operating voltage was adjusted to achieve a gain of 1×10^7, which corresponds to a SPE charge peak of 1.6 pC. All measurements were made at room temperature.

12inch high QE (ten tested)

Relative Q.E. test

Normal QE



High QE

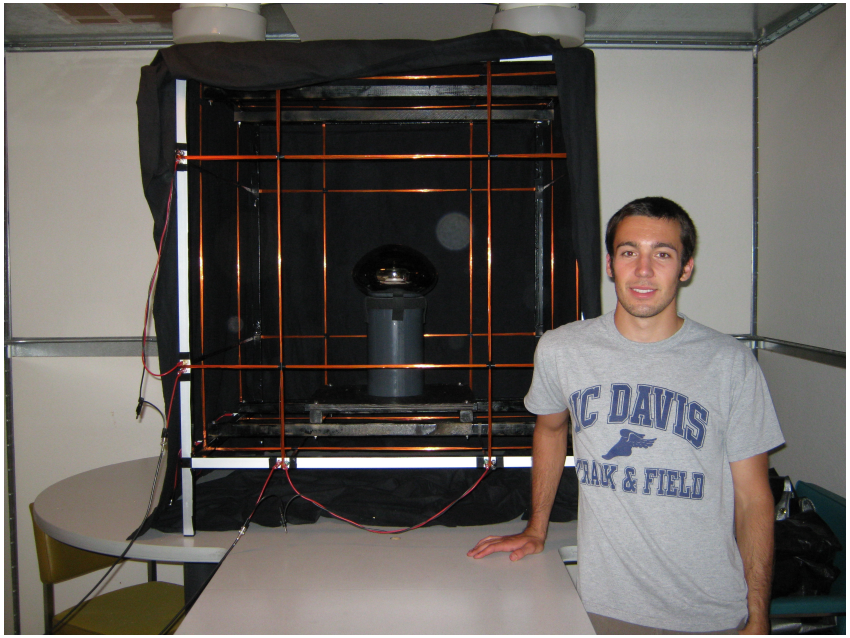
Cherenkov light source

PMT's were tested in pairs with symmetric geometry in zero-field environment

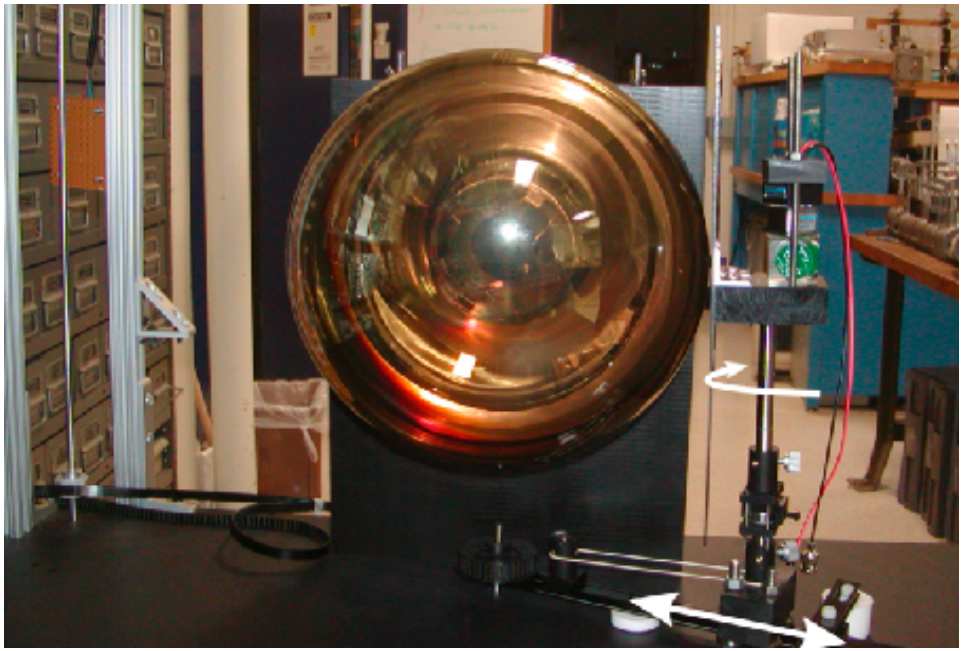
	Relative Efficiency
Tested Pair 1	1.56
Tested Pair 2	1.49
Tested Pair 3	1.66
Tested Pair 4	1.64
Tested Pair 5	1.32
Tested Pair 6	1.32
Average	1.50
Standard Deviation	0.15

Table 5: Observed relative efficiency of the high quantum efficiency configuration of the R11780 PMT compared to the standard quantum efficiency configuration. The relative efficiencies were measured using using the relative coincidence rates, which is a reasonable metric for a pure single photoelectron source.

Magnetic testing facility and Position Dependent Scanning Machine

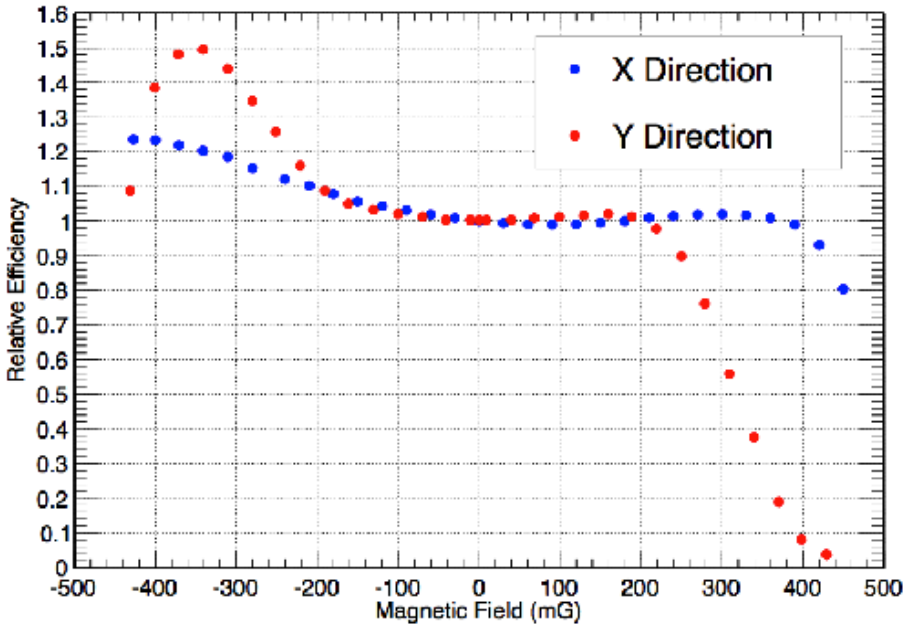


UC Davis tri-axial coil system inside large Faraday cage dark room. The field can be set to a wide range if magnitudes and Directions without moving the PMT.



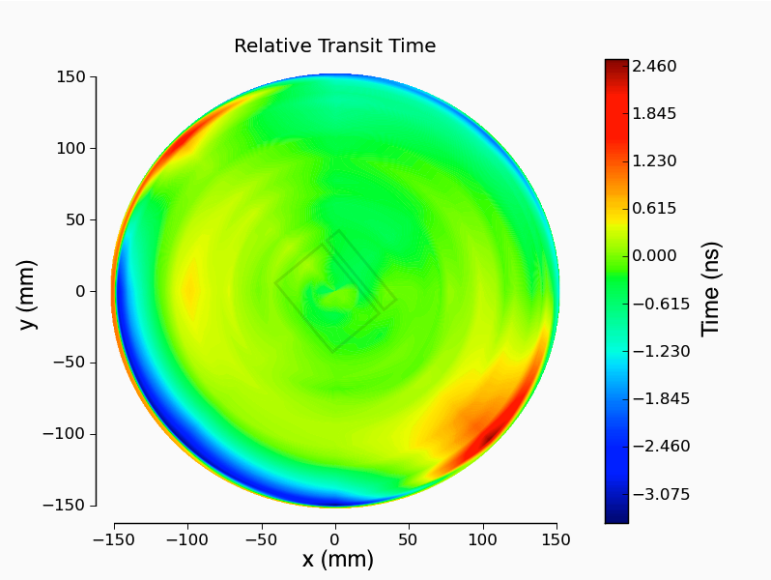
Penn auto scanning machine for position-dependent response. The Cherenkov light was used with a 3mm pinhole mask.

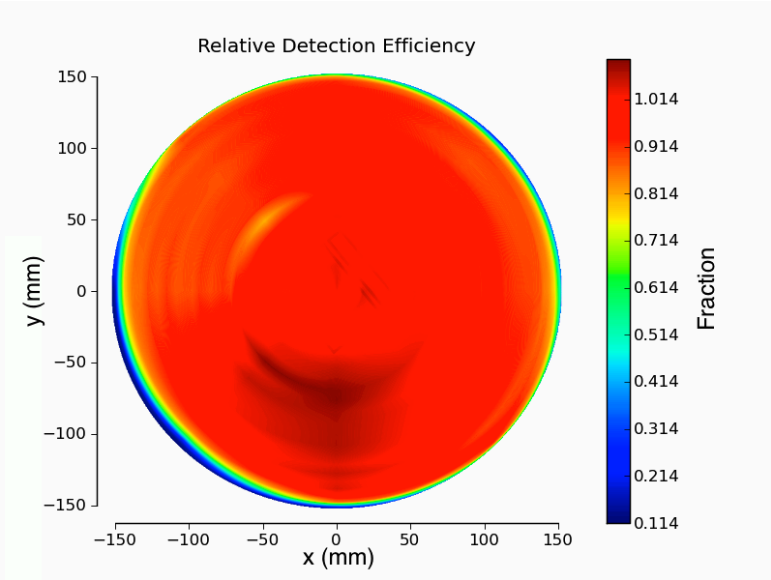
Magnetic Effects



- Full face illumination at 570nm
- Strange increase in performance due to discovery of magnetized internals in all PMTs
- Good performance if fields <200 mG

Position Dependent Efficiency and TTS





The relative TTS and efficiency were measured in a very low magnetic field (<35 mG) using coils and finemet shielding. There are definite variations across the face. MC-friendly versions of this dependence are available.

New In water Test Facility at UC Davis

- We are building 3.3 x 3.3 meter cylindrical test tank for characterizing light collectors (WLS plates and reflectors)
- We have the water system already.
- The electronics and tank are being ordered
- The goal is to have it running by summer in order to test the existing LBNE light collectors
- Such light collectors would be very useful either in the Outer Detector (where exact timing is not critical) or in the Inner Detector if light collection becomes more important than timing, and budgets are too small to have all PMTs.

New ADIT/ETL PMTs

- We visited the company in October and discussed the details of the requirements and agreed on a price for 20 prototypes to be delivered by end of 2013.
- Ed Kearns has contracted to develop 20 of these new PMTs
- He expects an initial delivery of four prototype PMTs (perhaps by summer) then later delivery of 16 more.
- These PMTs could be a candidate for either Inner Detector or Outer Detector PMTs

Conclusions

- In depth testing of Hamamatsu 12" PMT's have been completed and have been submitted for publication
- A new in-water facility is being constructed to continue light collector testing
- ADIT/ETL are producing a 11-inch PMT and we will test prototypes as they are available.