Fast (large-area) PMT Measurements

Workshop on Hybrid Cherenkov / Scintillation Detection Techniques

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Current generation of large-area PMT options

Eos
TTS ~ 1.0 ns

8-inch PMT
R14688 (R5912)
T. Kaptanoglu et al, NIM A 19 02 (2024)

IceCube
TTS ~ 3.0 - 3.5 ns

10-inch PMT
R7081
IceCube Collaboration, NIM A 618 (2010)

LBNE
TTS ~ 3.0 ns

12-inch PMT
R11780
J. Brack et al., NIM A 712 (2013)

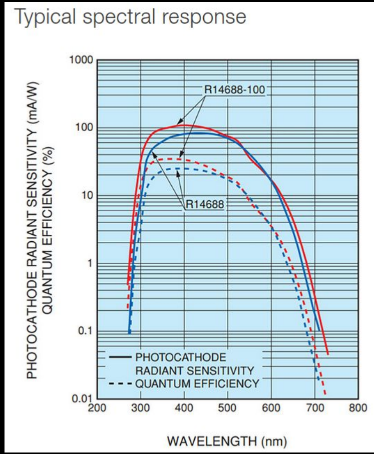
Hyper-K & JUNO
TTS ~ 3.0 ns

20-inch PMT
R12860
C Bronner et al., J. Phys.: Conf. Ser. 1468 (2020)

Some details

Hamamatsu can make these PMTs with either the standard bialkali photocathode (Q.E. ~25% @ 400 nm) or super bialkali photocathode (Q.E. ~35% @ 400 nm).

Many other large-area PMTs, such as JUNO 20'' PMTs, but most are fairly "slow".



Y. Chang et al., NIM A 824 (2016)

20-inch PMT TTS > 5 ns
EPJC 82 12 (2022)

Focus on 8-inch PMTs

Eos
TTS ~ 1.0 ns

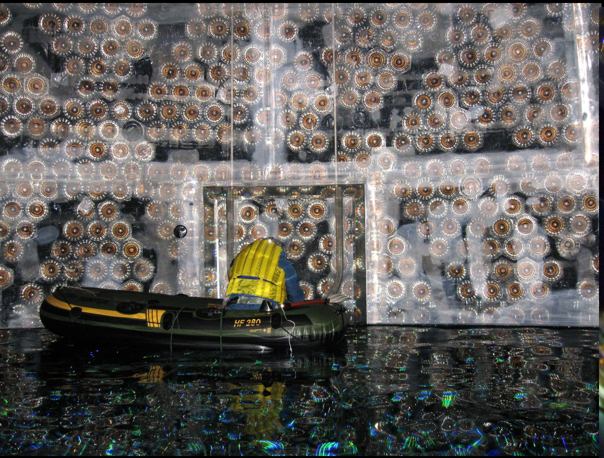
IceCube
TTS ~ 3.0 - 3.5 ns

LBNE
TTS ~ 3.0 ns

Hyper-K & JUNO
TTS ~ 3.0 ns

This talk will focus on the 8-inch PMTs, which are significantly faster.

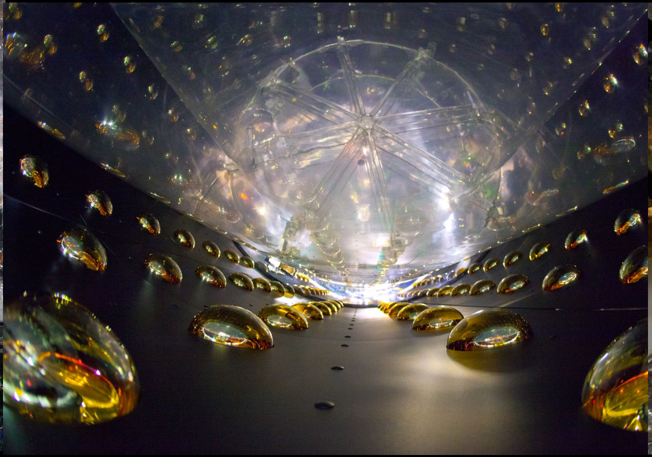
8-inch PMT development



R1408 (SNO, LSND)

S.D.Biller et al., NIM A 432 (1999)

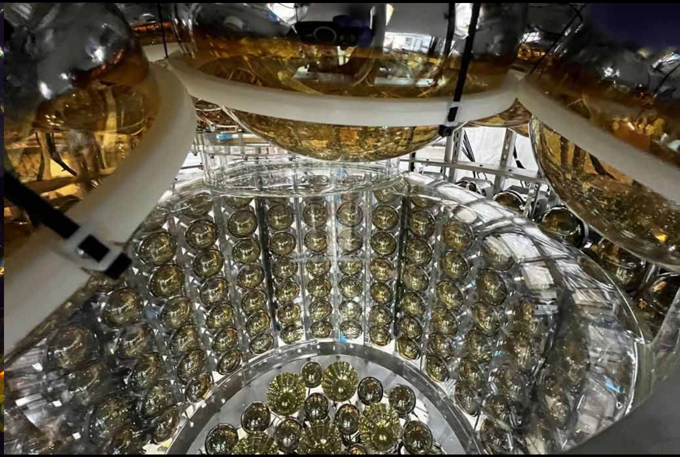
TTS ~ 3.0 - 4.0 ns (FWHM)



R5912 (Daya Bay, MiniBooNE)

Daya Bay Collaboration, NIM B 229-232 (2012)

TTS ~ 2.0 - 3.0 ns (FWHM)

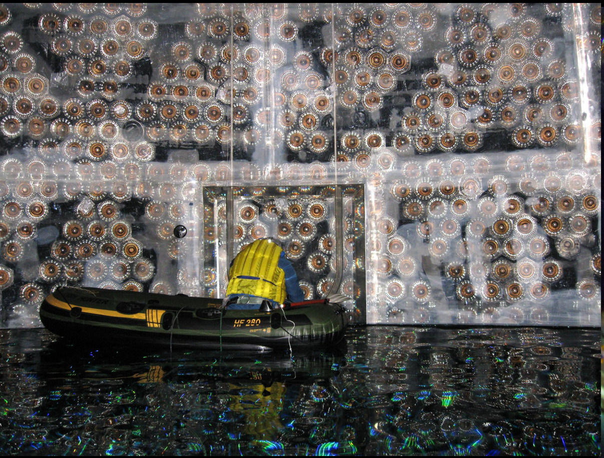


R14688

T. Kaptanoglu et al, NIM A 19 02 (2024)

TTS ~ 1.0 - 1.5 ns (FWHM)

8-inch PMT development



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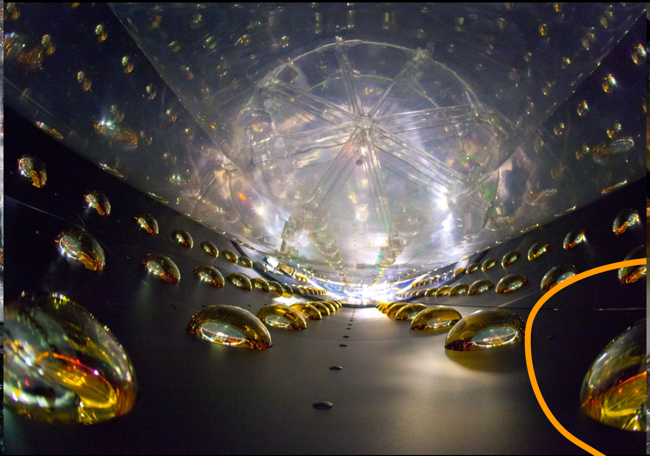

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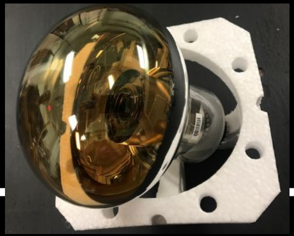
TTS ~ 2.0 - 3.0 ns (FWHM)

R14688
T. Kaptanoglu et al, NIM A 19 02 (2024)
TTS ~ 1.0 - 1.5 ns (FWHM)

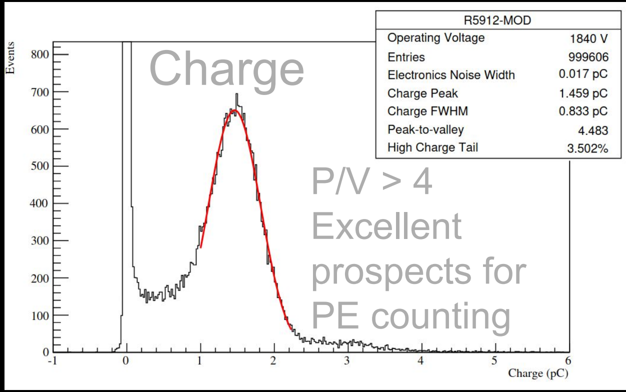
R5912-MOD (not cryogenic)
Towards developing R14688

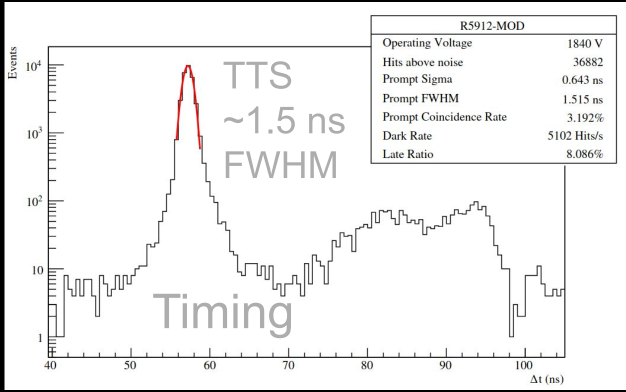
R5912-MOD characterization

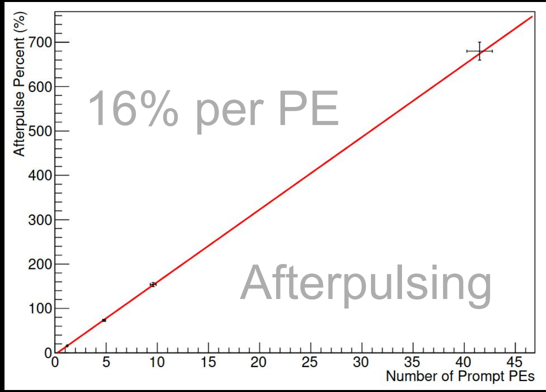


Characterized at UPenn in coordination with Hamamatsu development.

Exhibited excellent charge & timing response, with lots of afterpulsing.

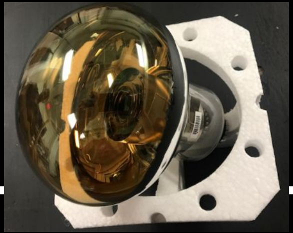






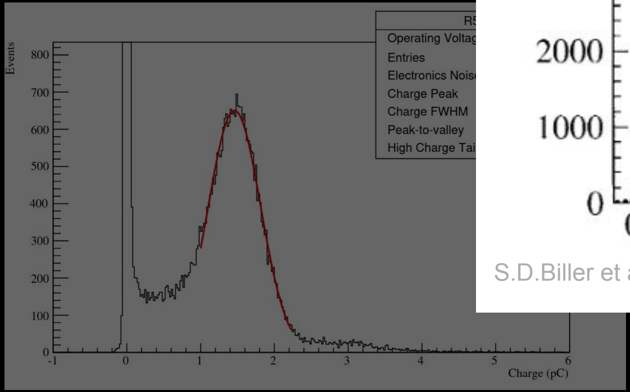
T. Kaptanoglu, NIM A 889 (2018)

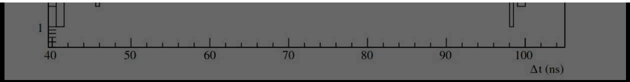
R5912-MOD characterization

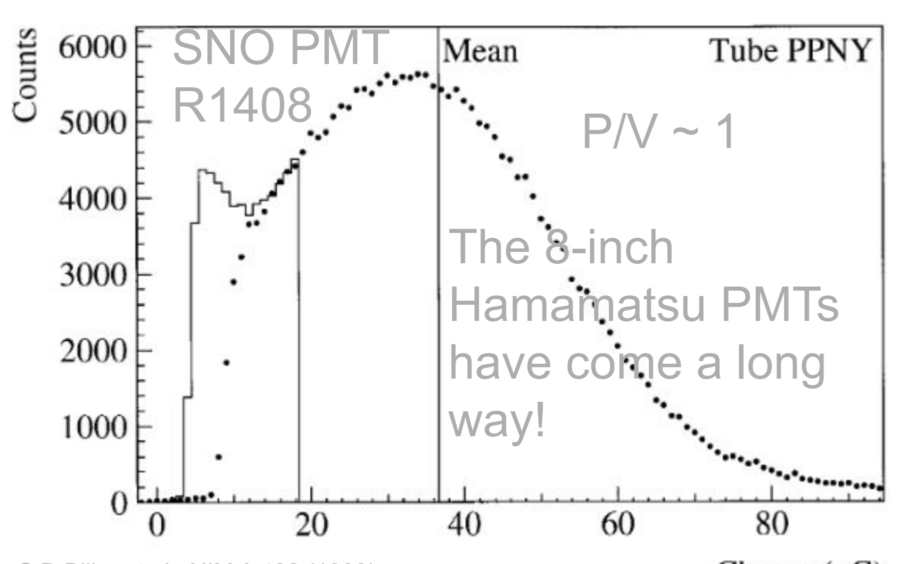


Characterized at UF lopment

Exhibited excellent pulsing







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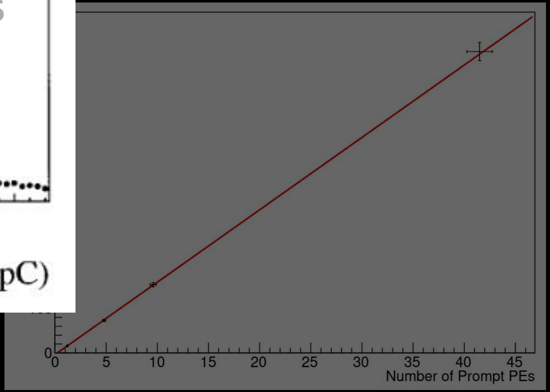
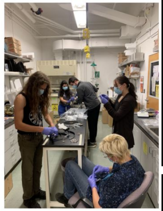
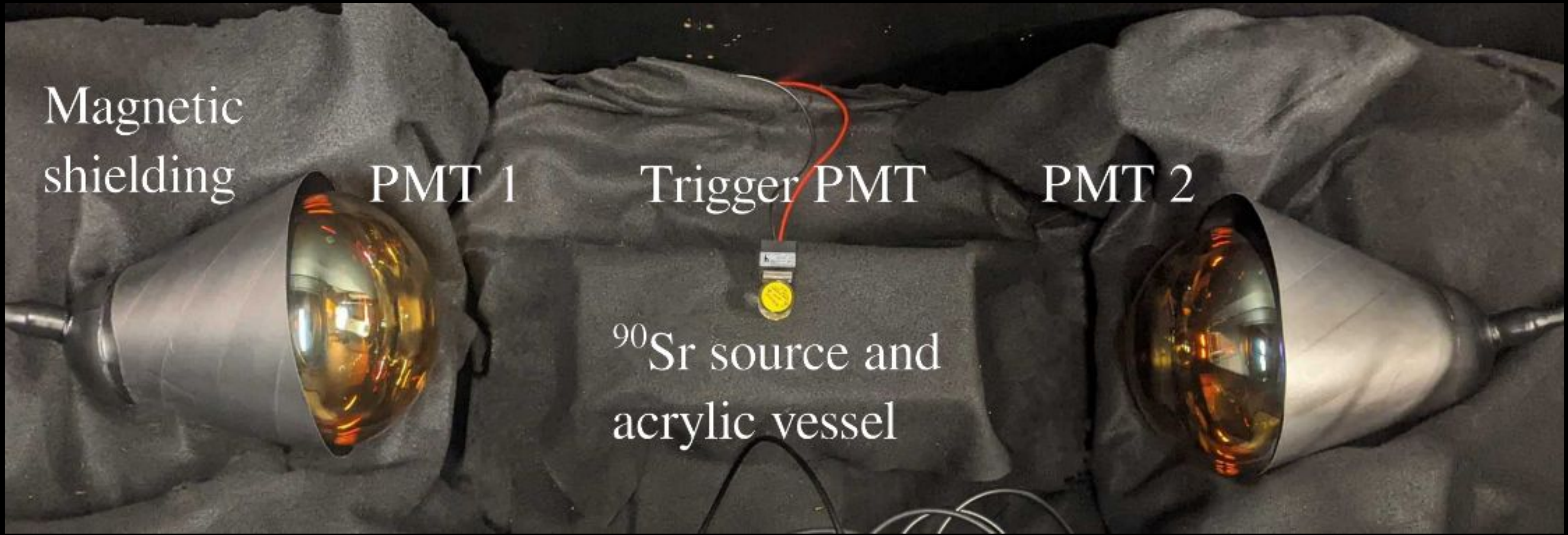


R14688 characterization

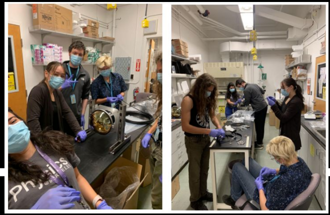


Commercially available Hamamatsu 8'' PMT that is a direct upgrade to the R5912

Characterized for and deployed in Eos (T. Kaptanoglu et al., *JINST* 19 (2024))



R14688 characterization



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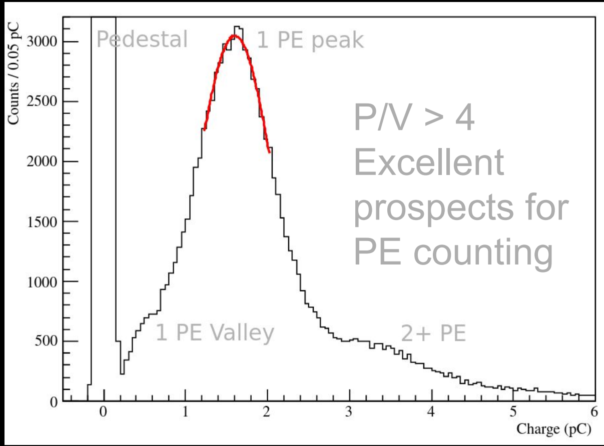
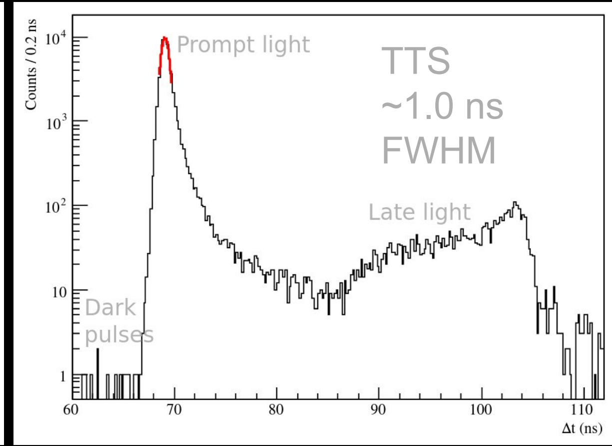
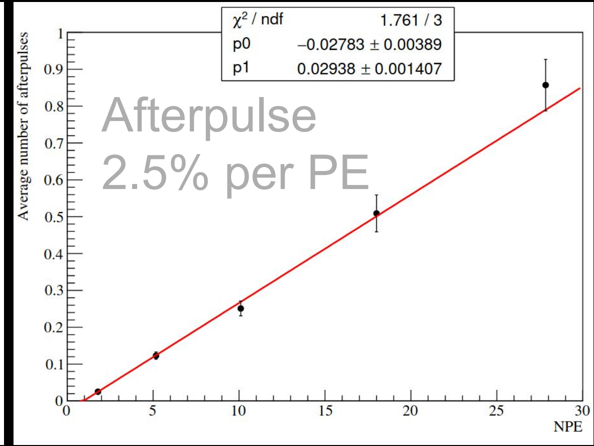
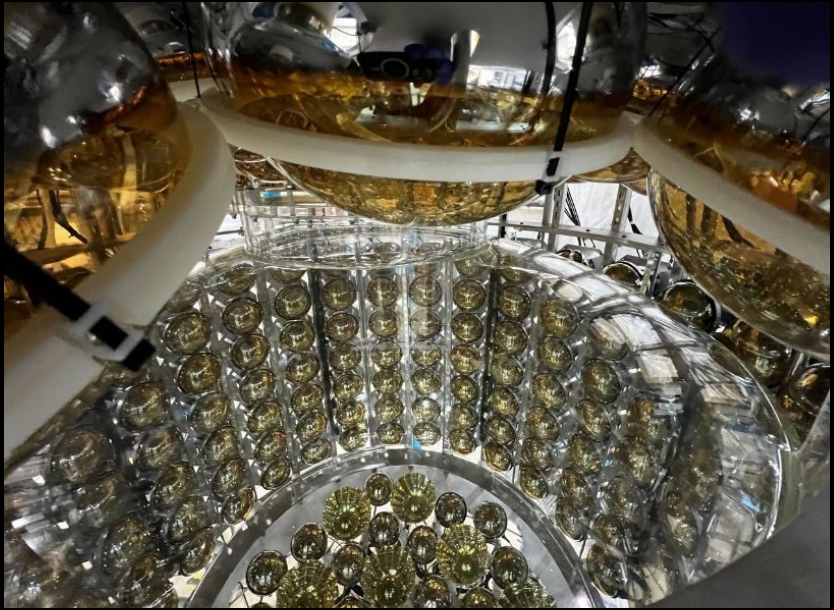


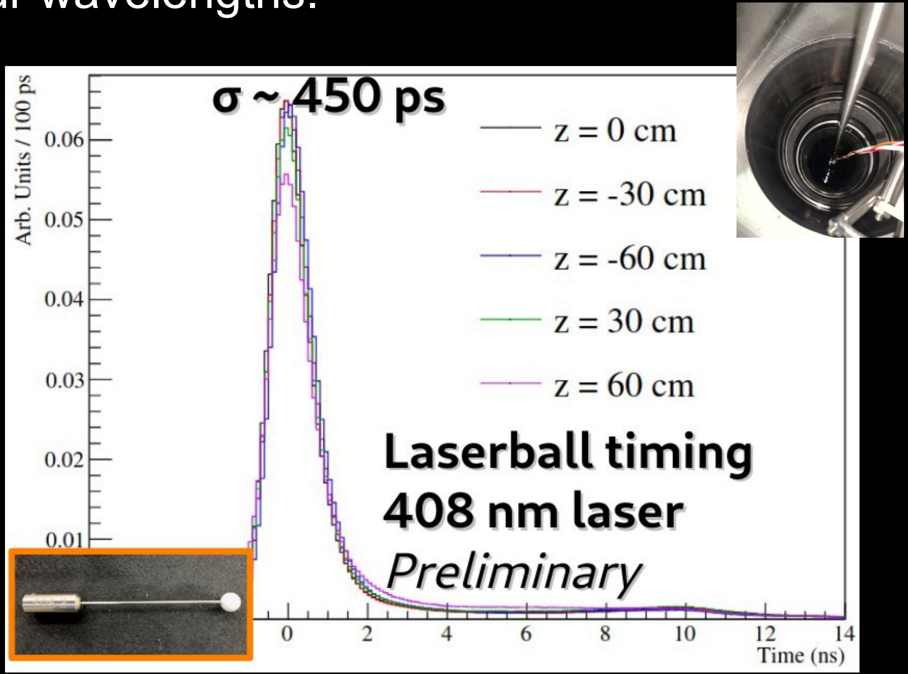




R14688 in EOS

R14688 PMTs deployed in EOS have been characterized in the water phase using a central deployed, isotropic laserball at four wavelengths.





Other R14688 measurements

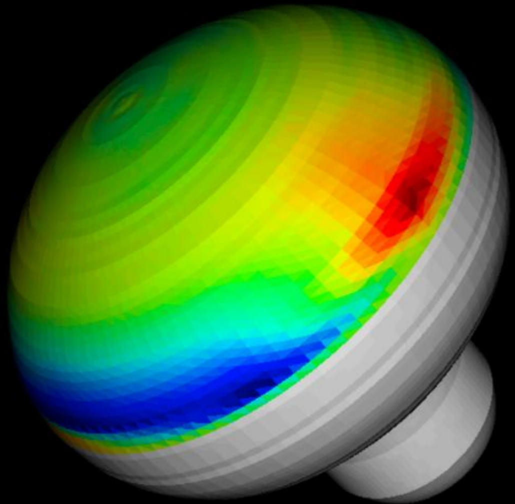
Radiopurity of the glass measured @ SURF. According to Hamamatsu, low radioactivity glass is possible.

Dark-rates around ~5 kHz, similar to other large-area PMTs.

Future work: understanding performance across the photocathode & magnetic field effects.

Sample	U (mBq/kg)	Th (mBq/kg)	K (mBq/kg)
PMT glass	3144 ± 158	4486 ± 257	7874 ± 398
PMT dynode	421.2 ± 28.2	55.8 ± 5.0	219 ± 24

Table 2. The results of the radiological assay of the PMT parts, performed at SURF.

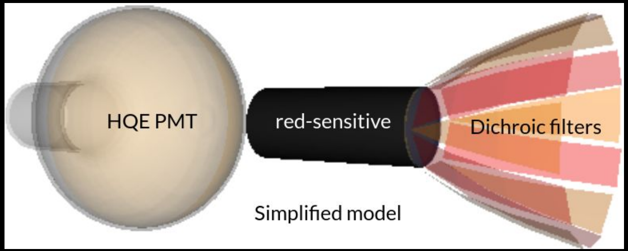


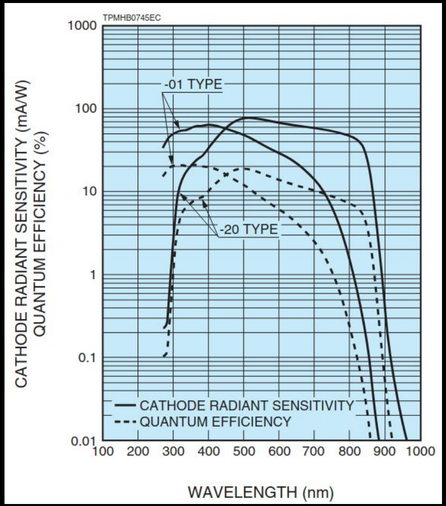
J. Brack et al., NIM A 712 (2013)

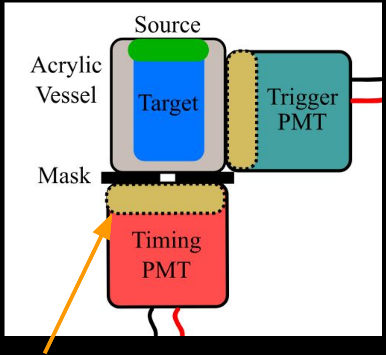
Other future considerations

What is the best layout for the dichroicon? Fast cylindrical PMTs for the aperture?

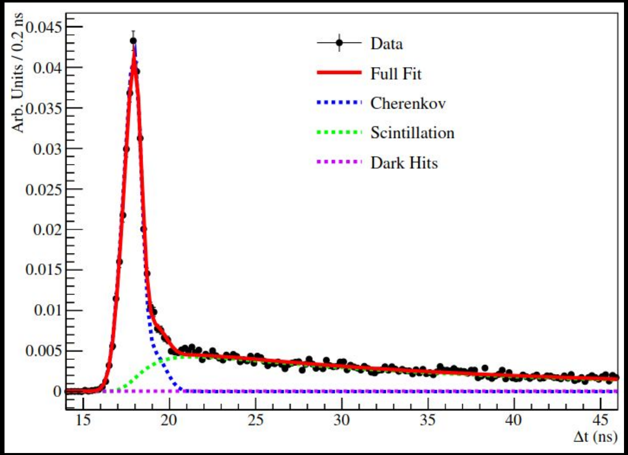
Red-sensitive photocathodes for large-area PMTs?







Extended red multialkali photocathode



Conclusions

The 8-inch R14688 PMT is an excellent candidate for a future hybrid detector given its relatively large size and excellent timing and charge response.