WWU MÜNSTER

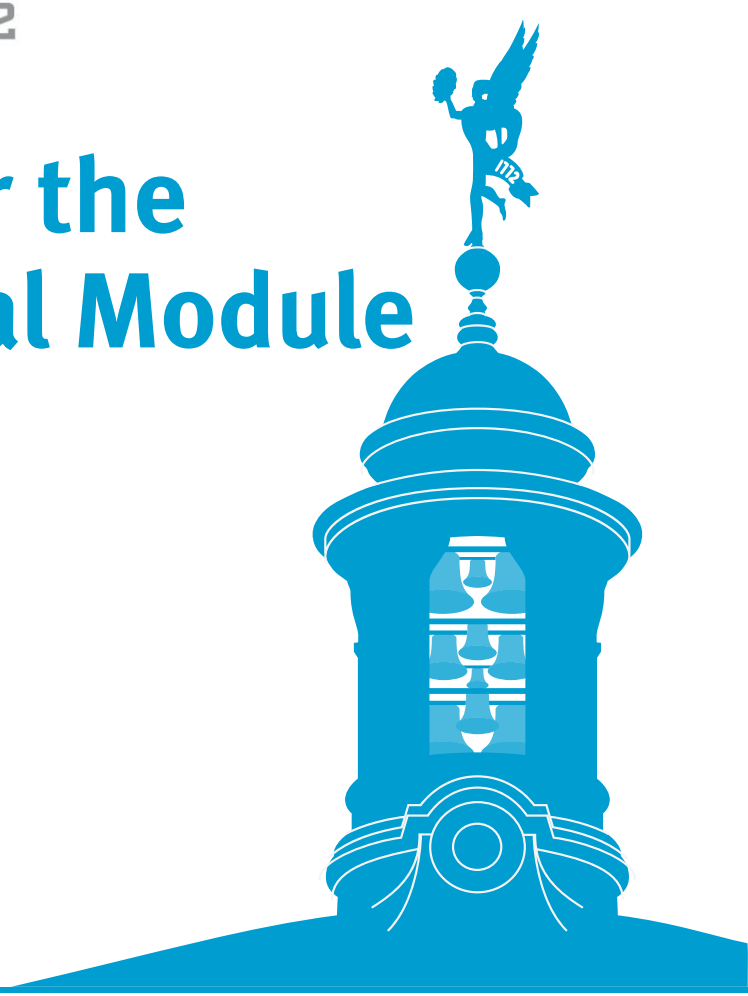
IceCube GEN2

PMT characterization for the multi-PMT Digital Optical Module

Very Large Volume Neutrino Telescope Meeting

02.10.18, Dubna

Lew Classen for the IceCube-Gen2 Collaboration



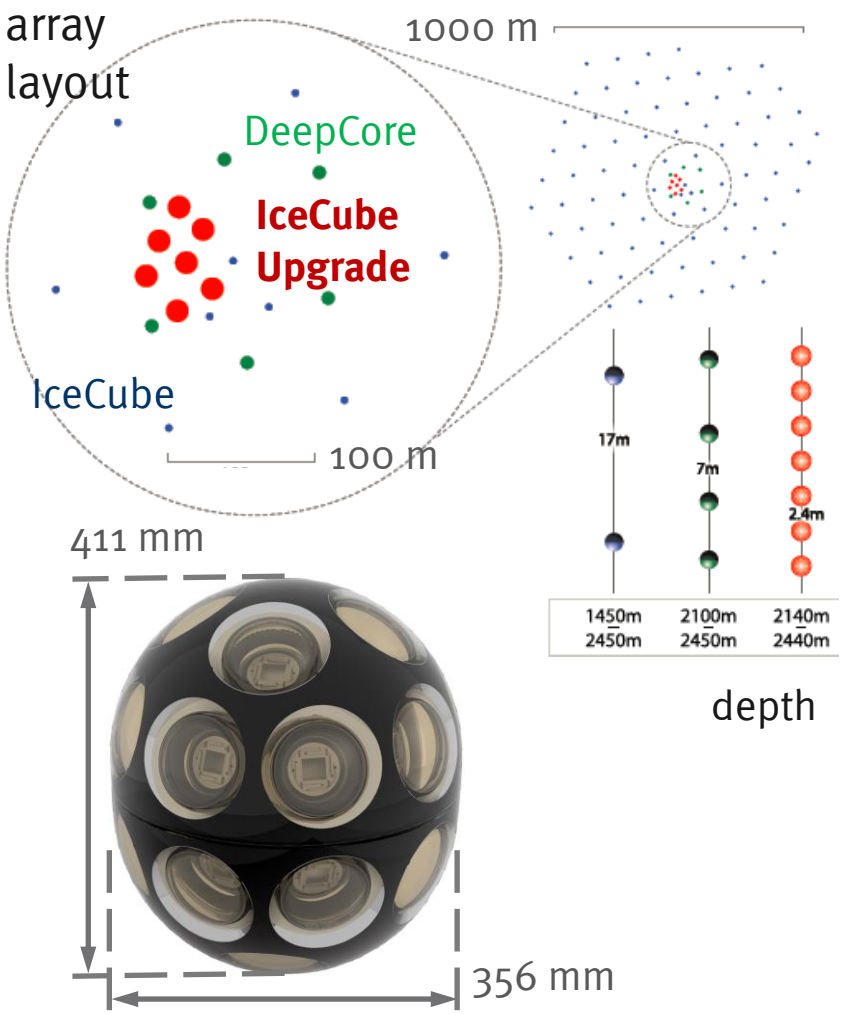
mDOM – a multi-PMT optical module

IceCube-Upgrade

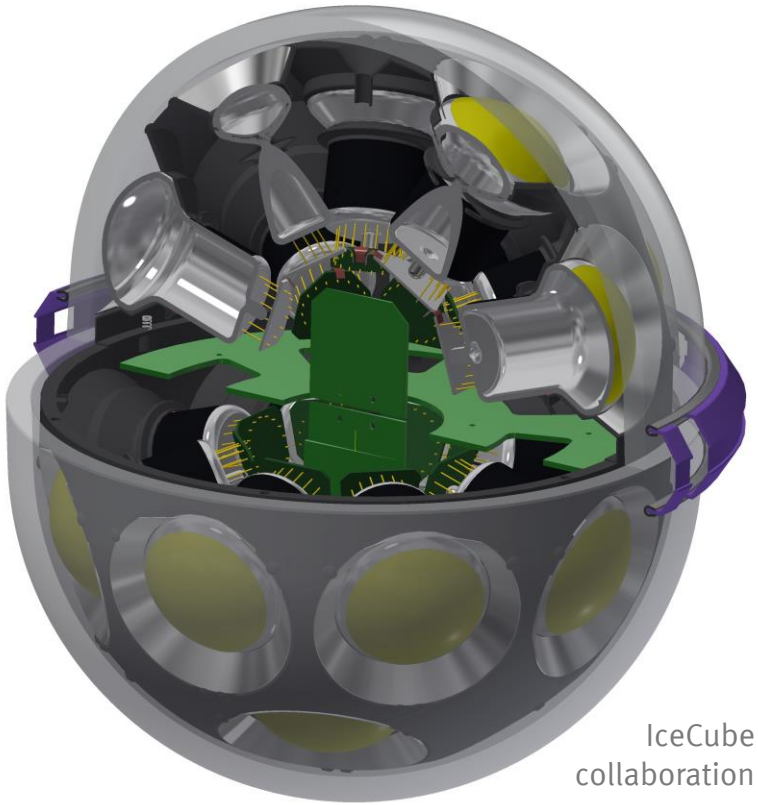
- dense infill with ~ 800 optical modules
- neutrino energy range: 5 – 100 GeV
- **neutrino oscillation parameters**

the mDOM

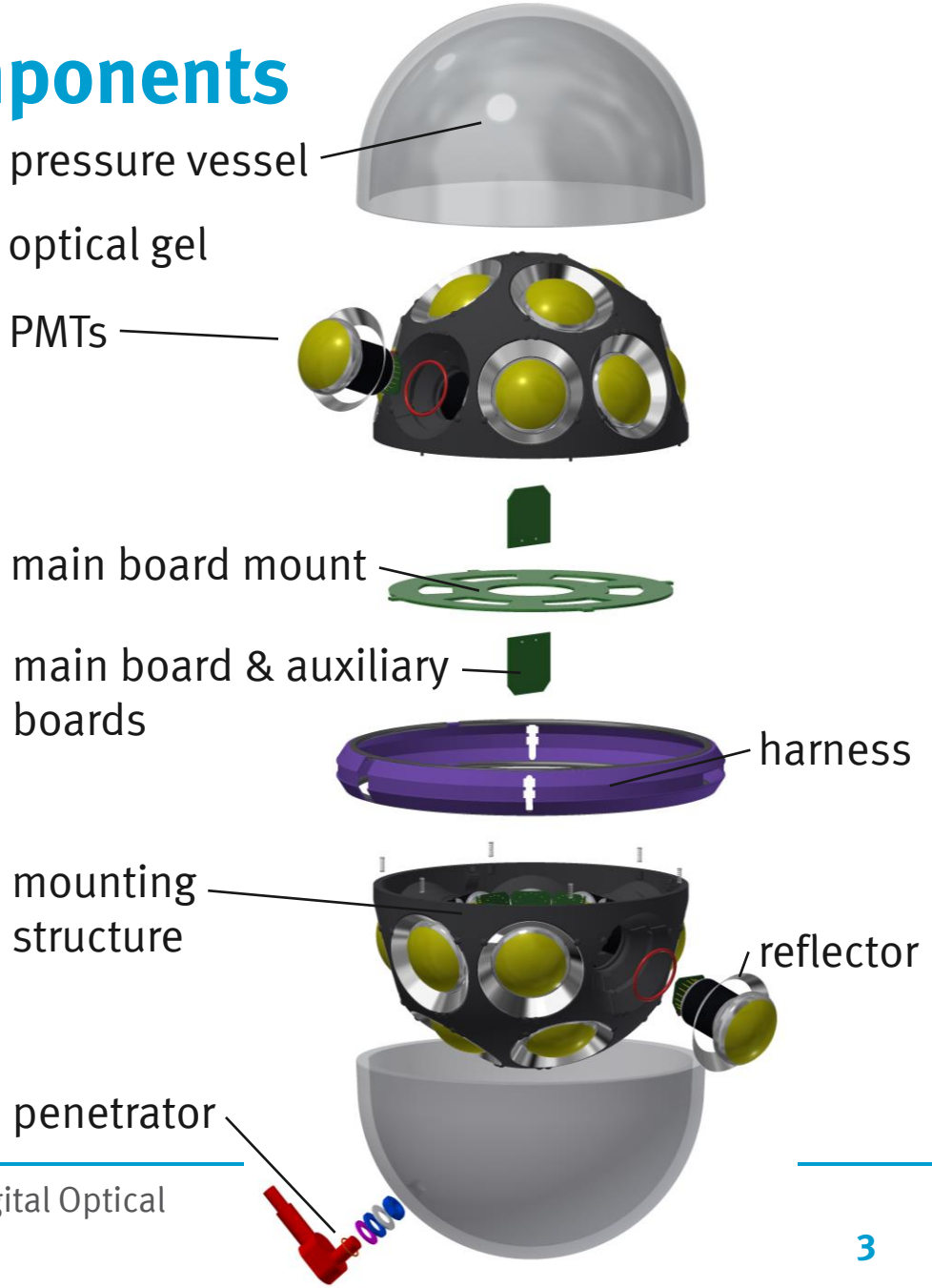
- large photocathode area
- homogeneous 4π solid angle coverage with directional information
- simple photon counting
- large dynamic range
- inter-PMT coincidences



mDOM – components



IceCube collaboration



demonstrator module by end of the year

PMT options

Hamamatsu R12199-02 HA mod

- baseline tube for mDOM production
- diameter 80 mm
- noise-reducing coating
- new: copper strip for reflector high voltage connection

tested in Erlangen & Münster

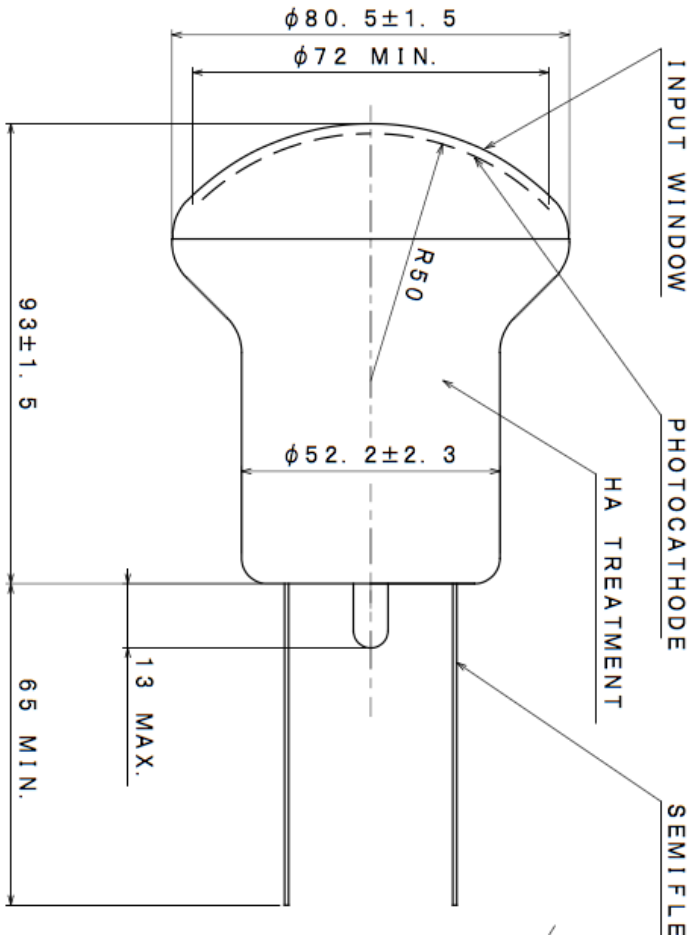
HZC XP 82B2F

- diameter 87 mm
- pin-compatible to Hamamatsu model
- length mDOM-compatible
- coating optional

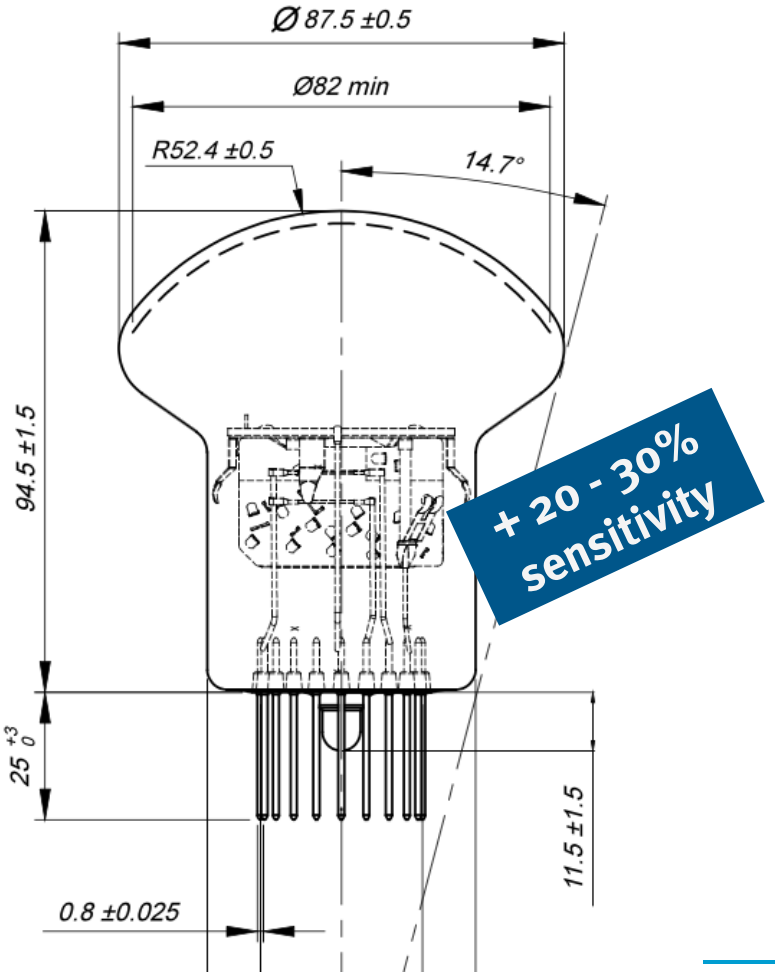
Wisconsin

PMT dimensions

Hamamatsu R12199-01 HA mod



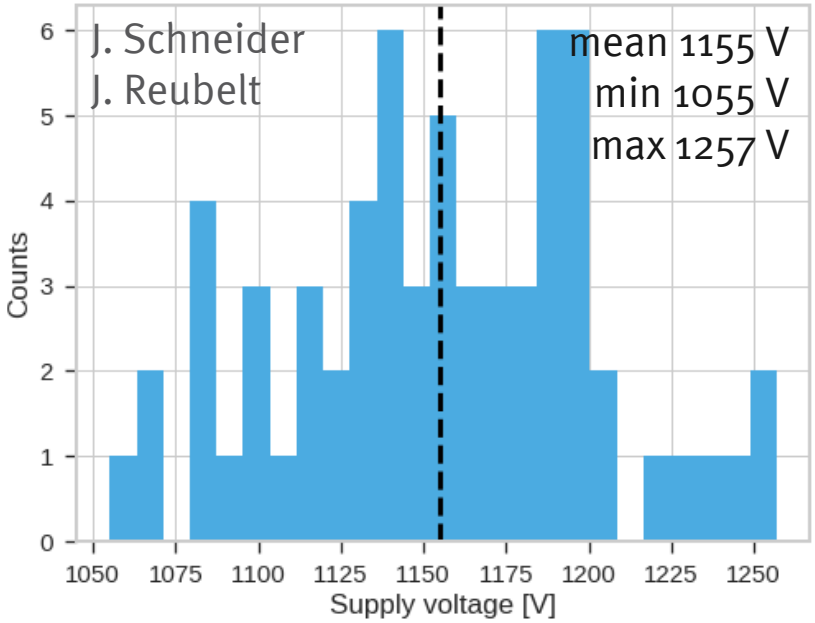
HZC XP 82B2F



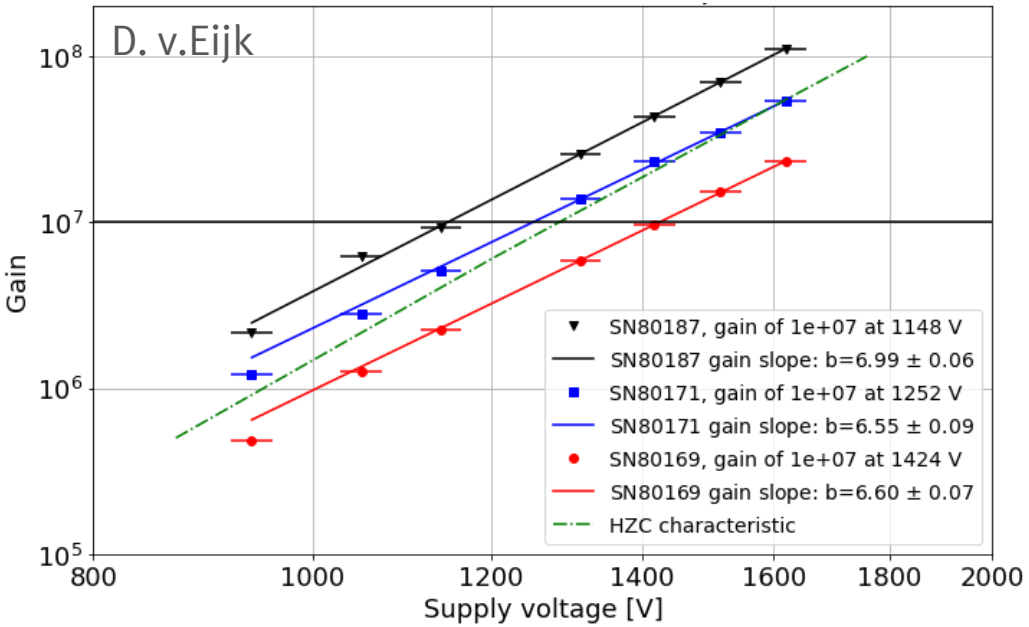
Gain

- gain calibration as function of supply voltage

Hamamatsu



HZC

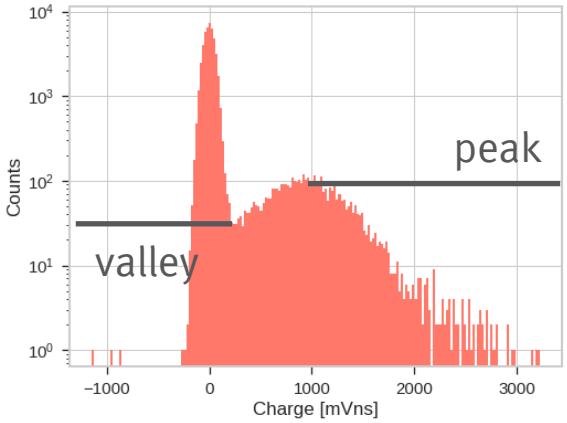


- current nominal gain $5 \cdot 10^6$
- current voltage generation limits: 900 V – 1400 V

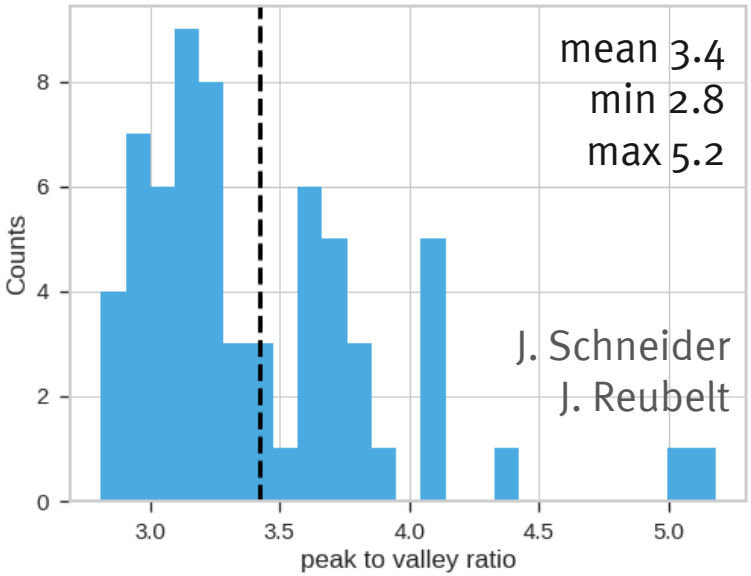
Peak-to-valley ratio

- combined quality parameter for baseline noise and single phe resolution
- increases with gain

charge histogram



Hamamatsu gain: $5 \cdot 10^6$



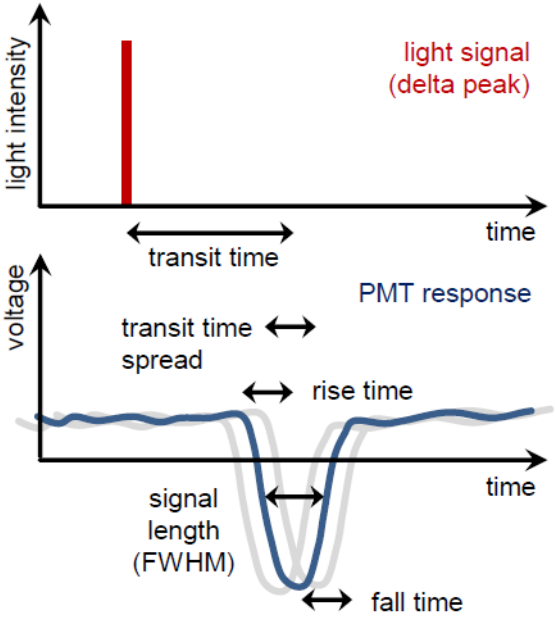
HZC gain: 10^7

PMT	peak/valley
SN80187	3.1
SN80171	4.3
SN80169	3.6

D. v.Eijk

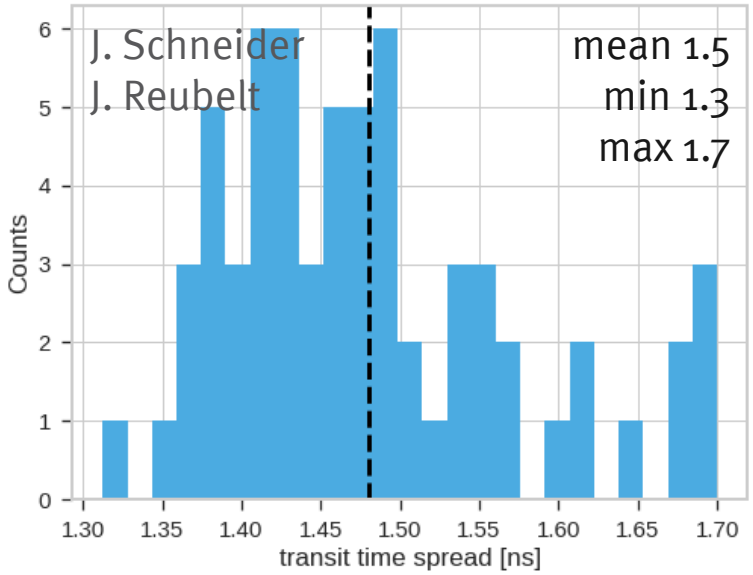
Transit-time spread

- defines time resolution of PMT
- given as standard deviation of main peak in arrival time distribution
- decreases with gain



Hamamatsu

gain: $5 \cdot 10^6$



HZC

gain: 10^7

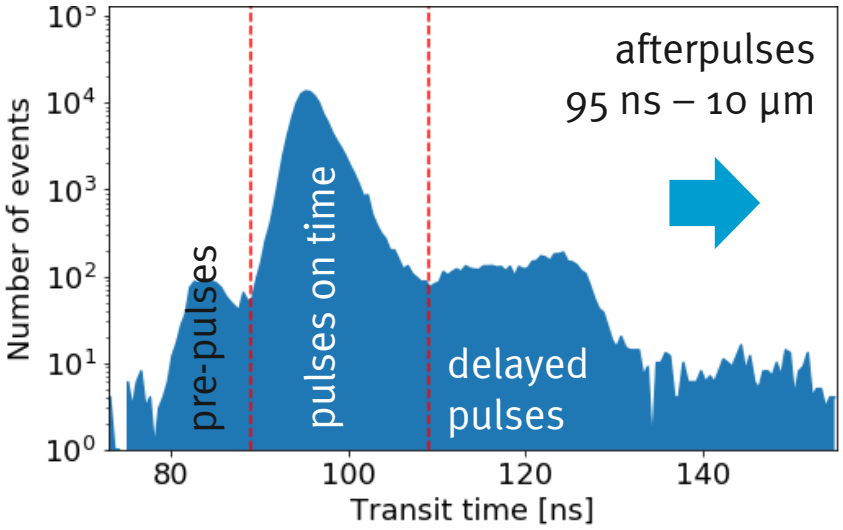
PMT	TTS [ns]
SN80187	1.8
SN80171	1.8
SN80169	1.4

D. v.Eijk, rescaled

Spurious pulsing

- derived from long waveforms
- external trigger
- illumination level:

  Hamamatsu ~ 1 phe
  HZC ~ 0.1 phe



Hamamatsu

PMT SN	pre-pulses [%]	delayed pulses [%]	afterpulses [%]
BA0373	< 0.03	3.9	6.2
BA0375	< 0.02	4.0	4.7

M. Unland

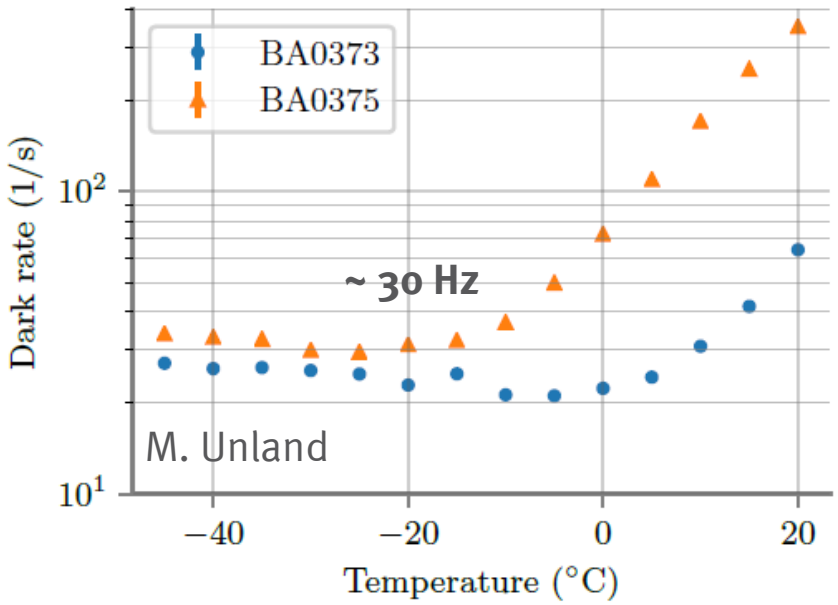
HZC

PMT	pre-pulses [%]	delayed pulses [%]
SN80187	0.8	1.9
SN80171	0.9	1.8
SN80169	0.8	1.4

D. v.Eijk

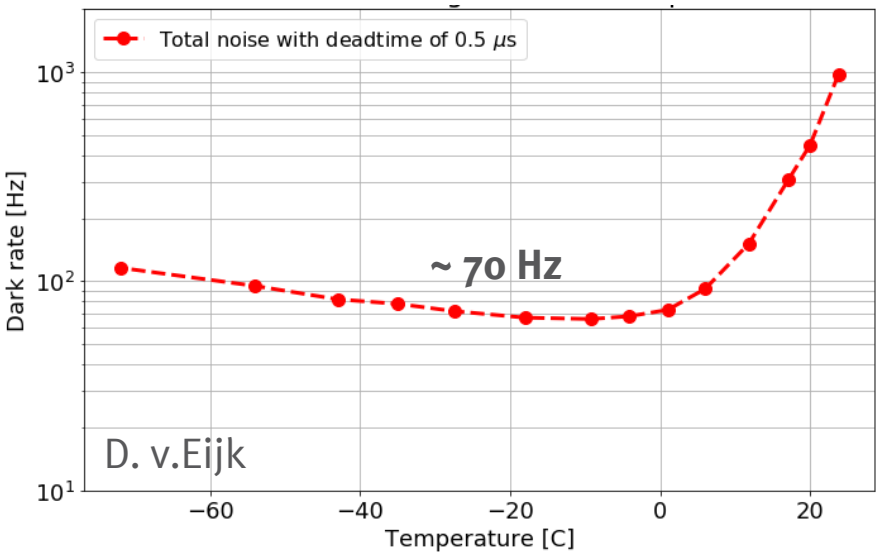
Dark rate

Hamamatsu



- gain $5 \cdot 10^6$
- via time for fixed pulse number
- threshold ~ 0.2 phe
- dead time 1 µs

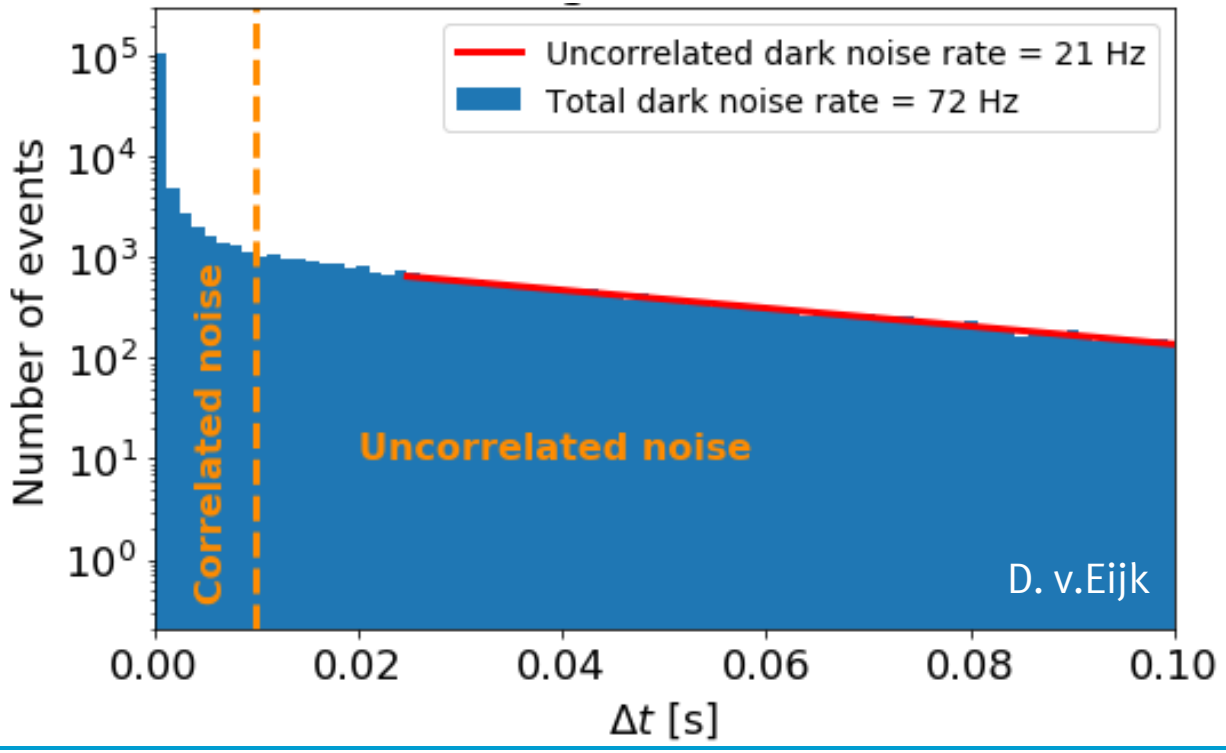
HZC



- gain $1 \cdot 10^7$
- via pulse number in fixed time window
- threshold ~ 0.3 phe
- dead time 0.5 µs

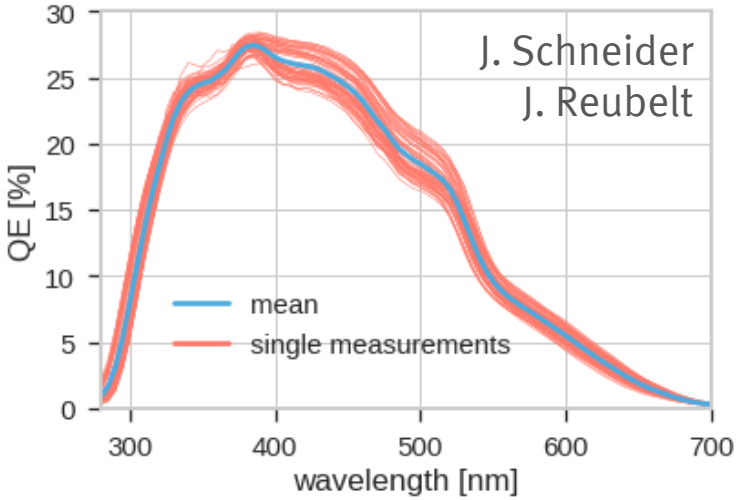
Dark rate in detail

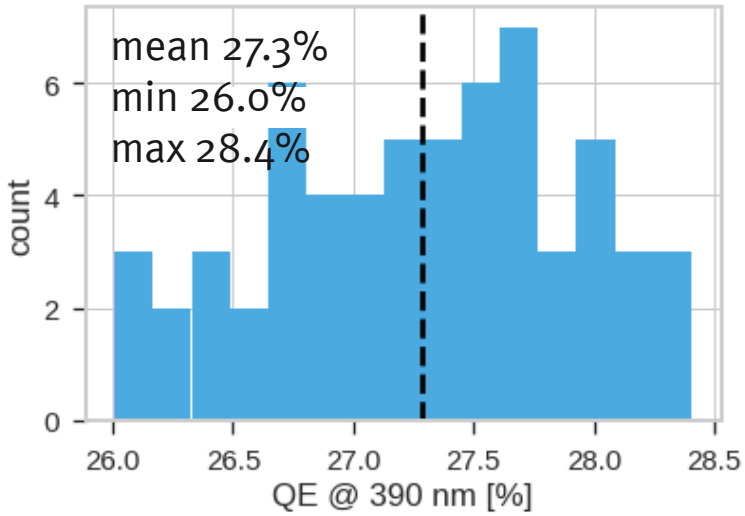
- dark noise = correlated noise + uncorrelated noise
- correlated components more critical for event reconstruction
- HZC PMT only, measurement at -30 °C

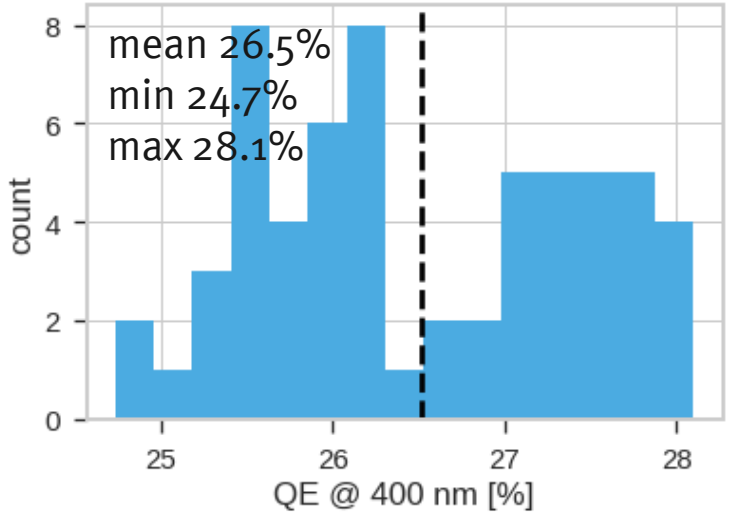


Quantum efficiency

- measured using monochromator setup in Erlangen
- average over central ~ 1 cm²
- only Hamamatsu PMT so far

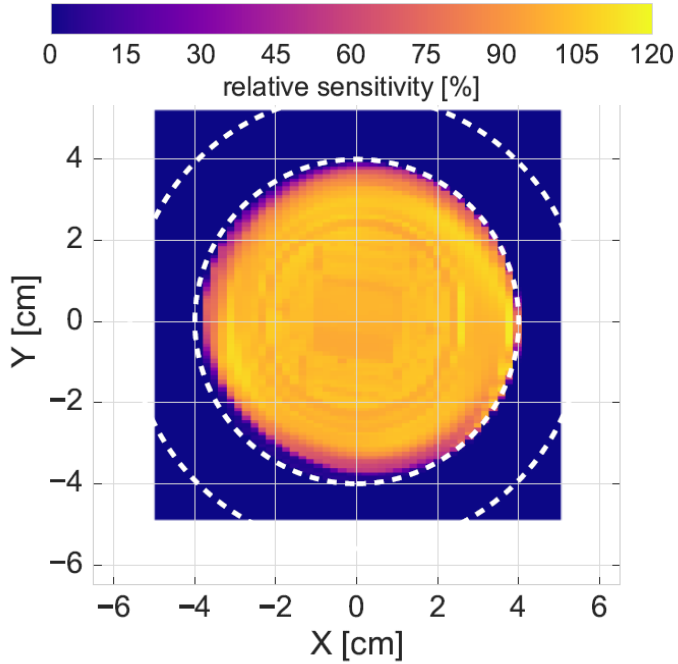


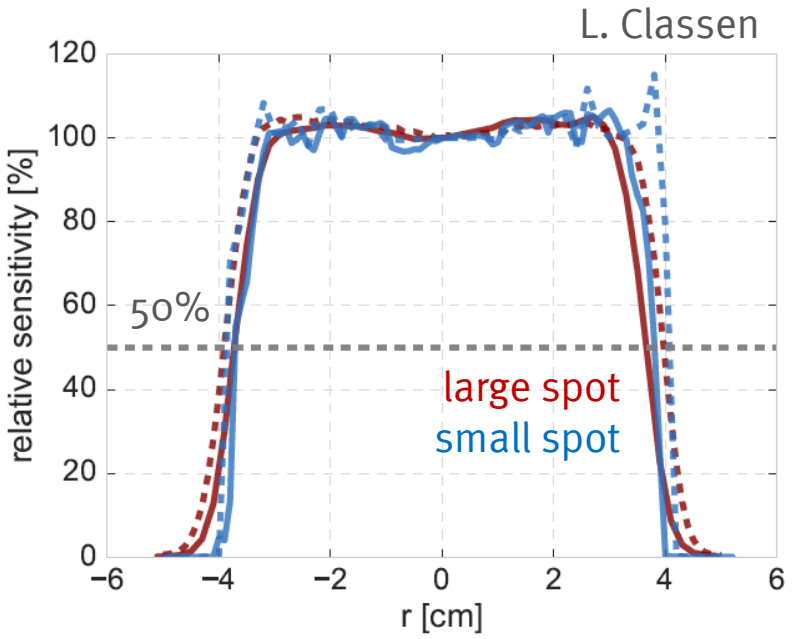




Response uniformity & effective diameter

- via pencil beam scan of photocathode





- Hamamatsu PMT only so far
- effective diameter 77 – 78 mm

Conclusion

Hamamatsu R12199-01 HA mod

- latest R12199 modification behaves as expected
- well-characterized baseline model

HZC XP 82B2F

- promising alternative PMT available
- possible mDOM sensitivity enhancement: 20 – 30%
- tested PMTs feature comparable performance to Hamamatsu model
- need to measure quantum efficiency and effective diameter
- testing of larger batch planned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Questions?
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Federal Ministry of Education and Research