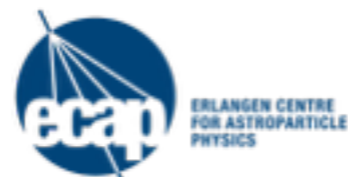


A multi-PMT module for IceCube GenTwo

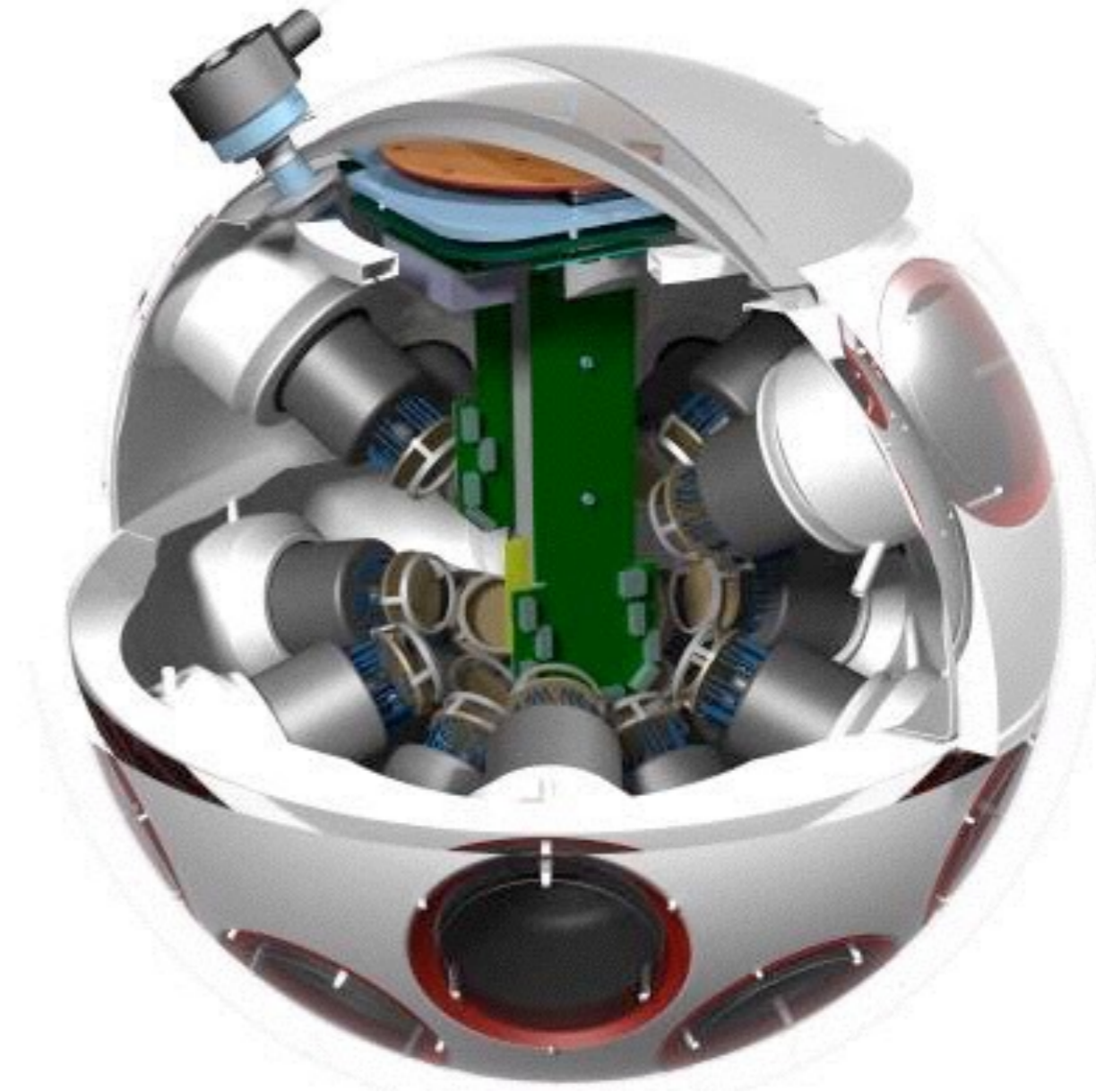
ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS

Lew Classen, Alexander Kappes, Uli Katz
HAP Workshop
Aachen, 10.12.2014



Multi-PMT OMs: Concept advantages

- Increased photocathode area at \leq price per photocathode area
- 4π angular acceptance
- Directional sensitivity
- Single photon counting
- Background suppression with local coincidences
- No magnetic shielding needed



KM3NeT DOM

mDOM: Adaptation for the use in the deep ice

Reusable components from KM3NeT

- PMTs
- PMT base

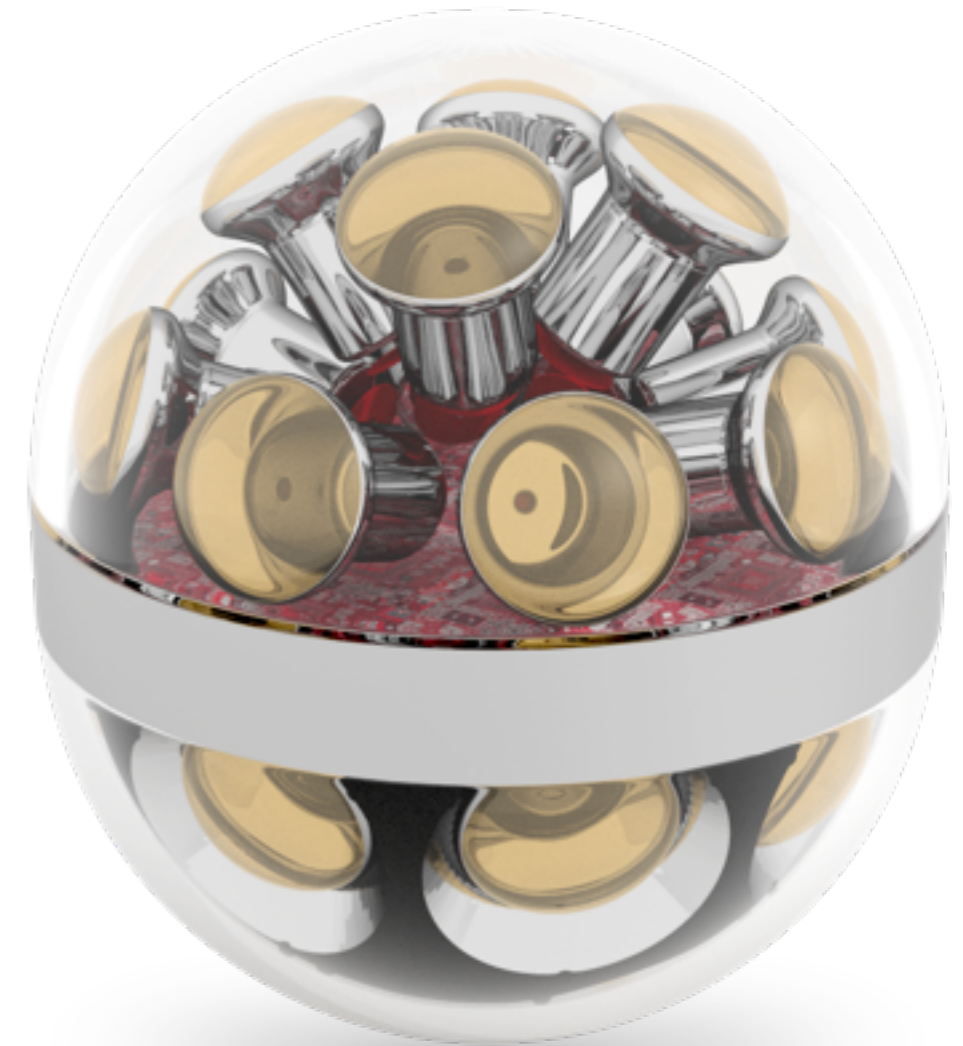
Adaption / new development

- Pressure vessel
- PMT holders + reflectors
- Signal processing
- Interface to IceCube DAQ



mDOM features

- Pressure vessel:
 - 14" diameter
 - rated for 700 bar
- 24× 3" PMTs (Hamamatsu R12199-02)
- 2× effective area of standard IceCube DOM
- Full 4π coverage
- Effective PMT saturation level: ~5000 p.e.
- Data readout (base concept)
 - time-over-threshold for each PMT
 - summed analog signal



PMT characteristics



**Hamamatsu
R12199
Ø = 80 mm**

KM3NeT requirements	
quantum efficiency @ 470 nm	> 20%
transit time spread (σ , FWHM)	< 2 ns, < 4.6 ns
gain	> $2 \cdot 10^6$
supply voltage	< 1400 V
dark count rate @ 15°C	< 1.5 kHz
peak to valley ratio	> 3
length	< 120 mm
power consumption incl. base	< 4 mW



**ETEL
D792KFL
Ø = 86 mm**

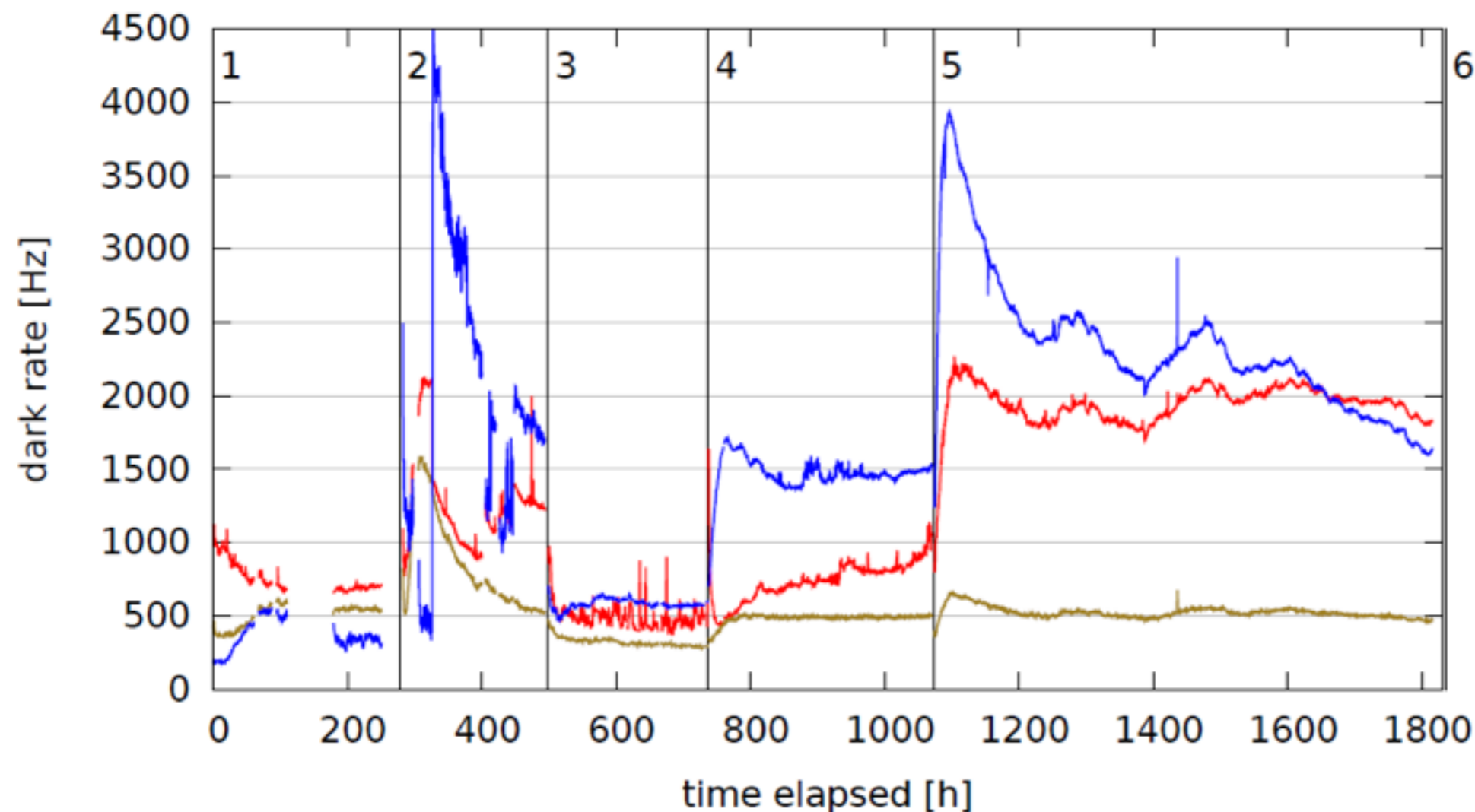


**HZC
XP53B20
Ø = 76 mm**

Hamamatsu R12199-02: Dark rate measurements I

Setup:

- 3 different PMTs with voltage divider base (cathode @ -1100 V)
- Threshold: 30 mV (with 10× amplifier)
- PMTs mounted in foam holding structure



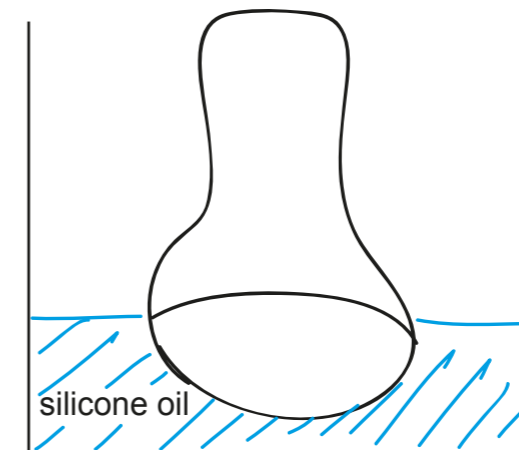
Anti-noise measures
(PMT shaft)

1. no measures
2. tape insulation + grounded copper foil
3. only tape insulation
4. +5. tape insulation + copper housing (1 PMT)

Hamamatsu R12199-02: Dark rates II

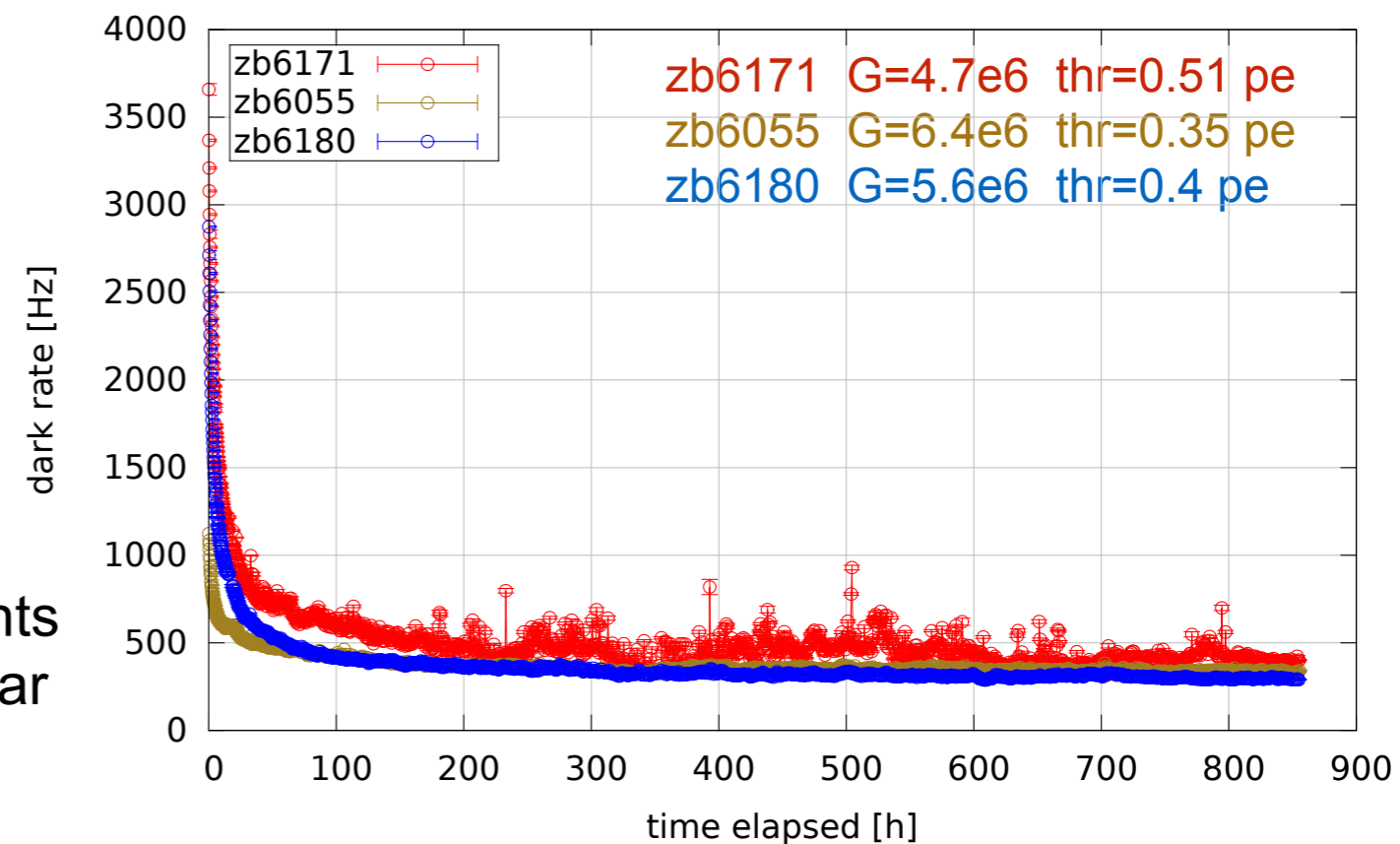
Changed setup

- photocathode part of PMT in silicone oil (same electrical properties as optical gel)



Long-term dark rates

- 500 – 700 Hz @20°C (dominated by thermal emission)
- @ -30°C
 - thermal emission: factor 2 decrease every ~6°C → factor ~300
 - field effects dominate → measurements in climate chamber beginning next year

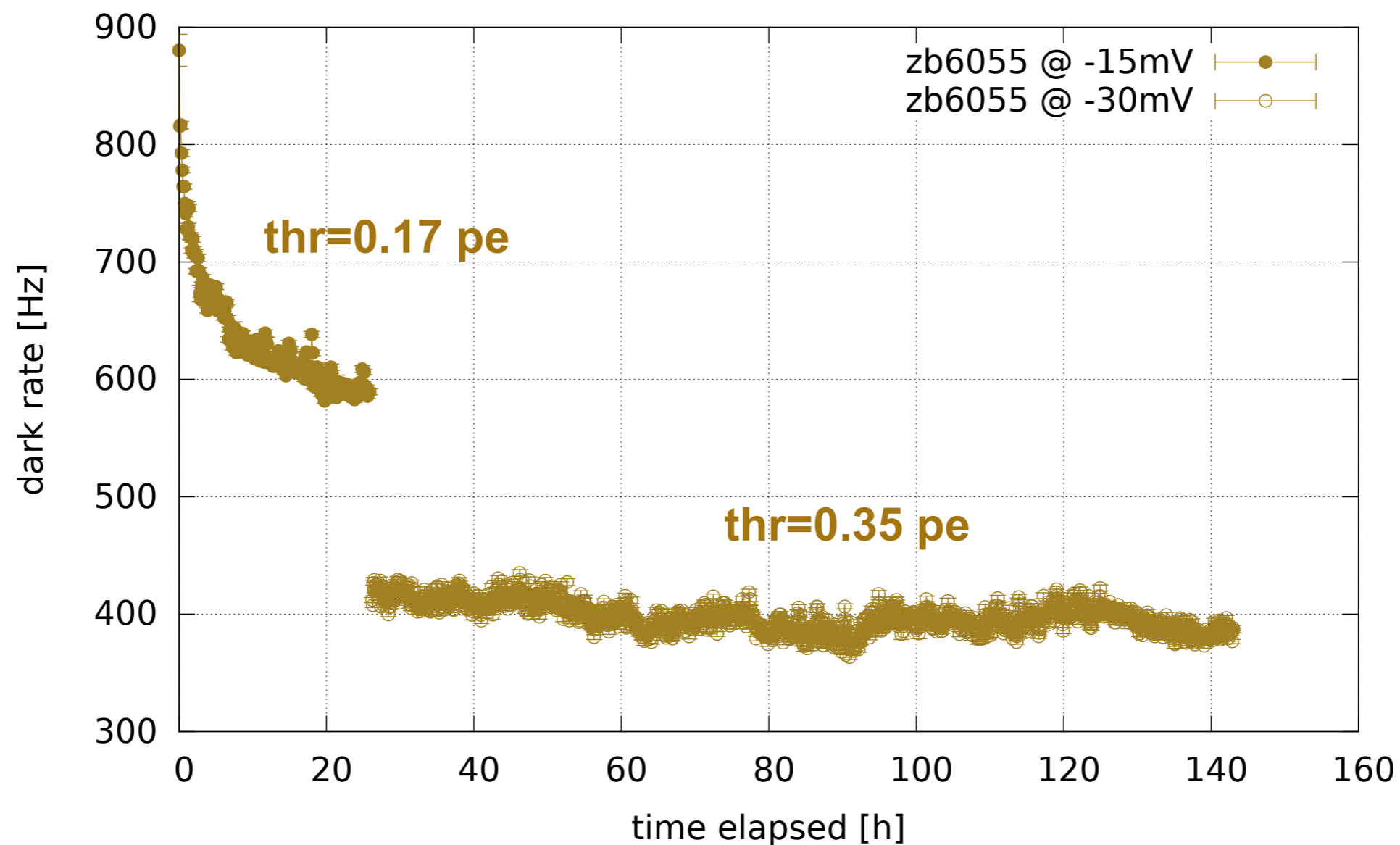


Ivren/Classen 2014

Hamamatsu R12199-02: Dark rates III

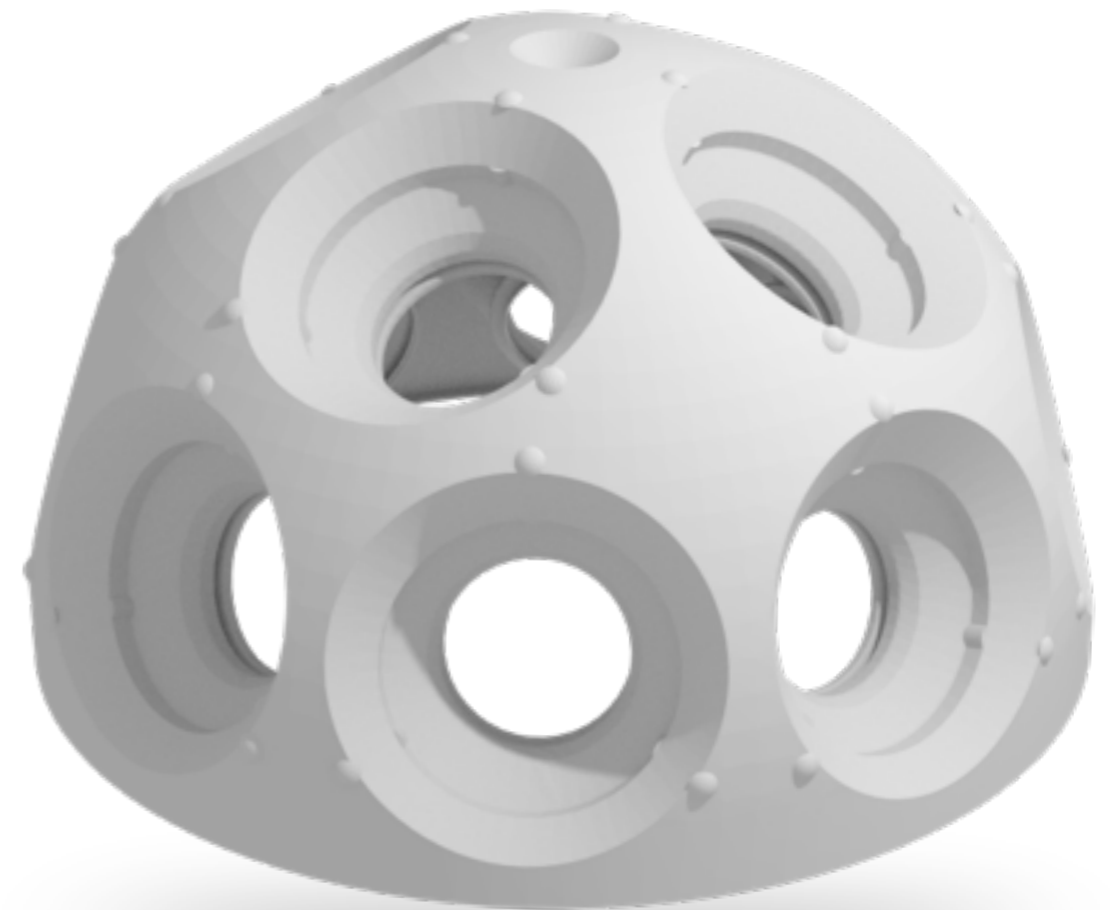
First measurement with reversed polarity (cathode @ 0 V, foam holding structure)

dark rate with positive HV polarity, PMTs inside foam holder (=no insulation)

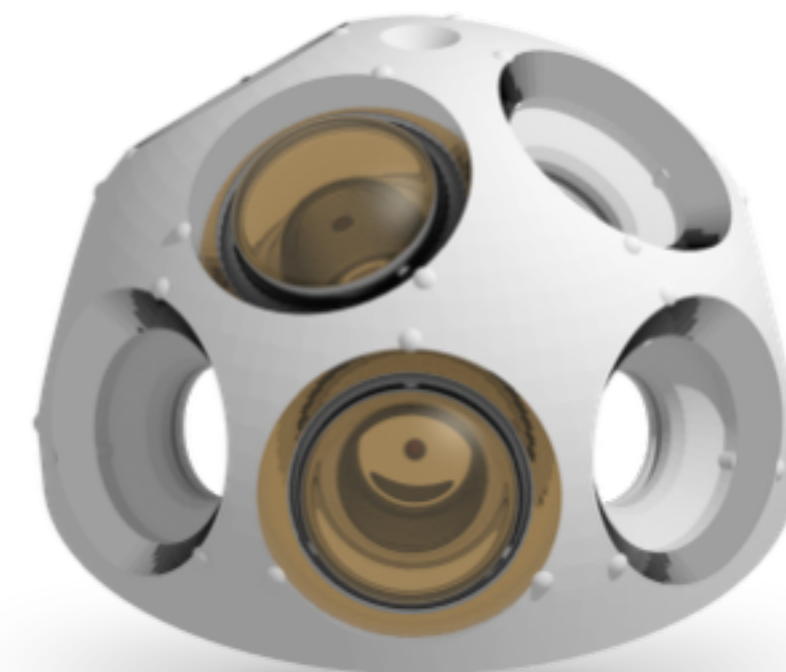
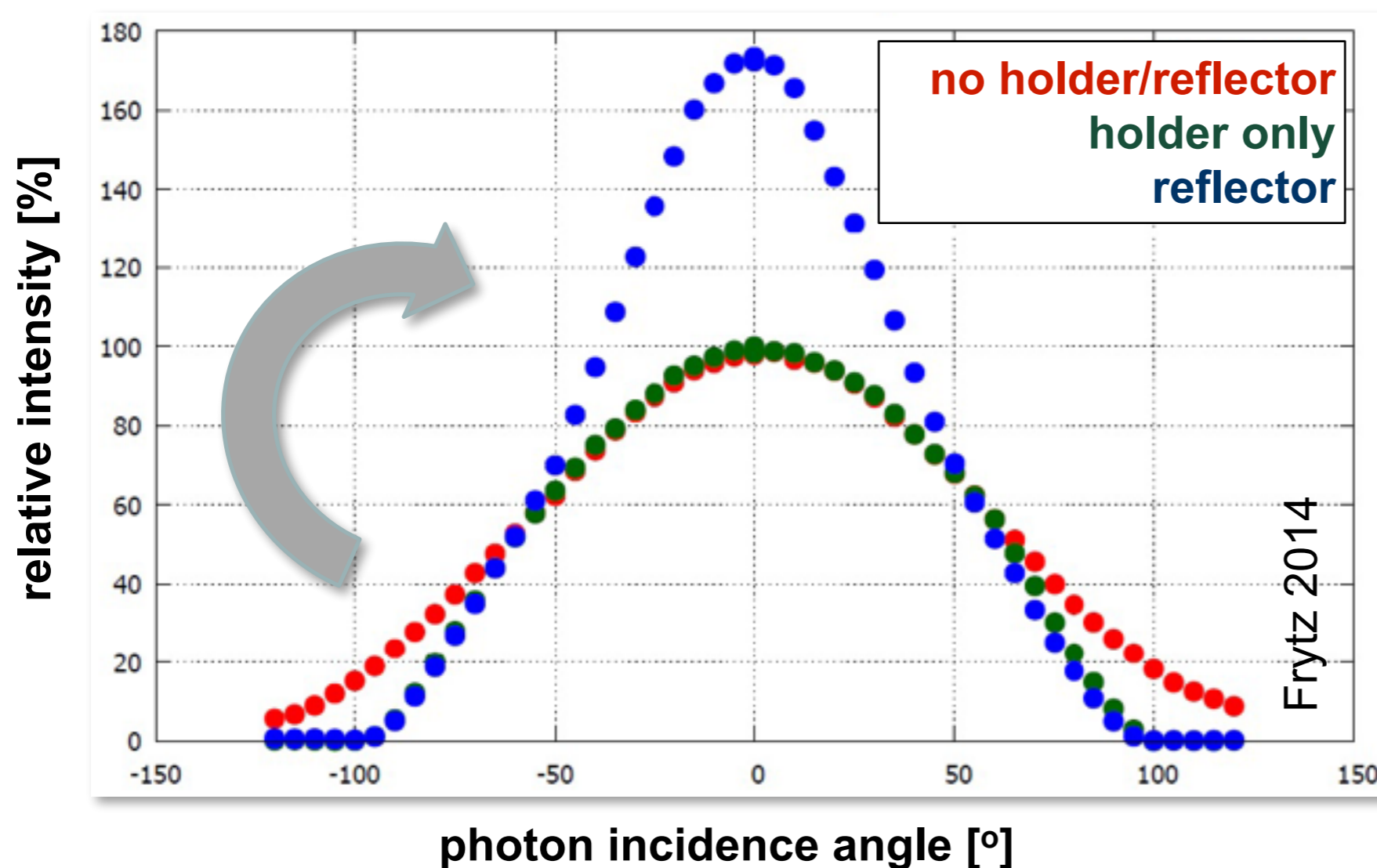


PMT holding structure

- Produced via laser sintering (type of 3D-printing) (first prototype delivered)
- Takes up 12 PMTs (4 + 8)
- Tube for pouring of optical gel
- Allows for mounting of reflective cones



Effect of reflectors



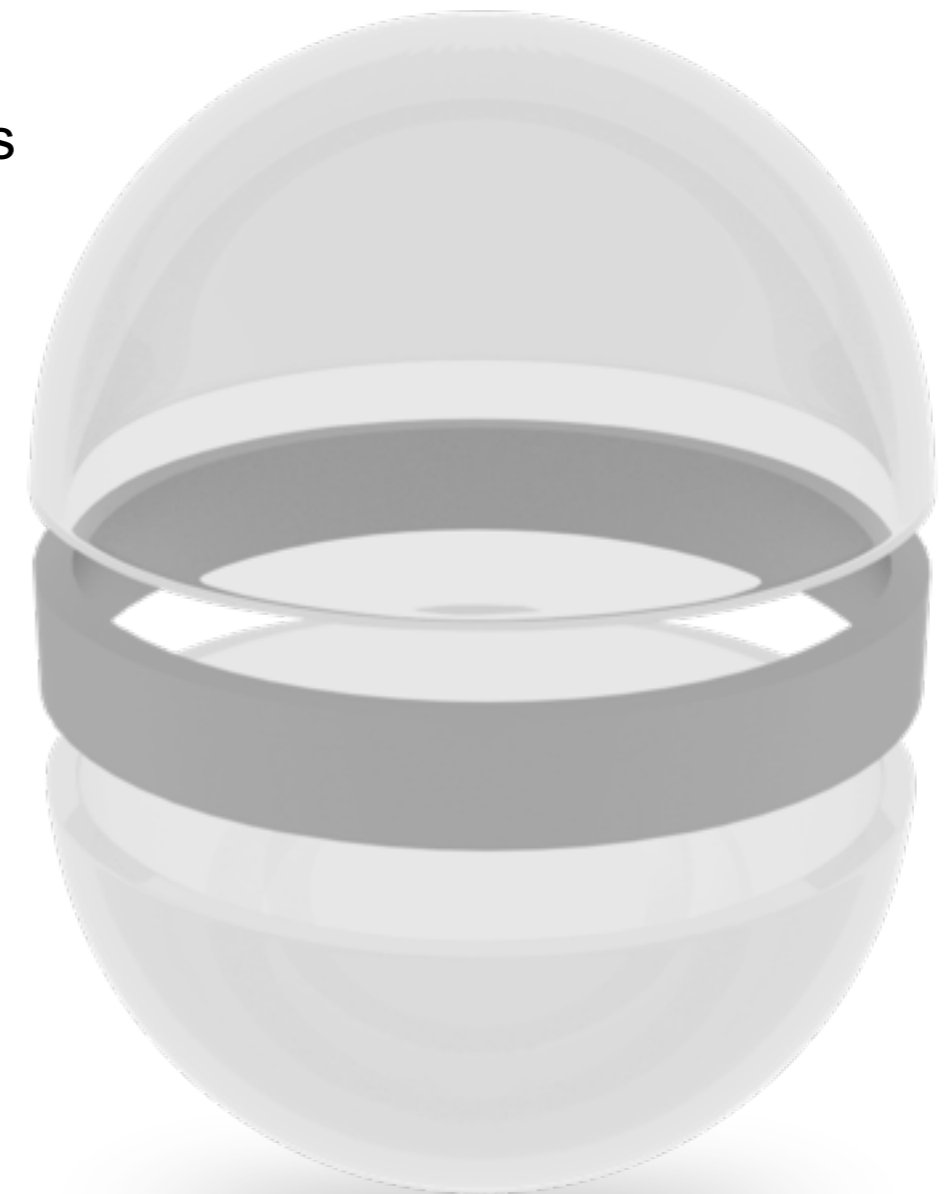
- Holding structure reduces amount of gel needed (screening recovered by reflectors)
- Reflectors increase directionality significantly (30% gain in intensity for $|\Phi| < 60^\circ$)

Pressure vessel

- Two 14" glass half spheres (borosilicate glass)
- Aluminium cylinder with 5–10 cm height for electronics (similar design used for first AMANDA modules)
→ potential stability/thickness issues

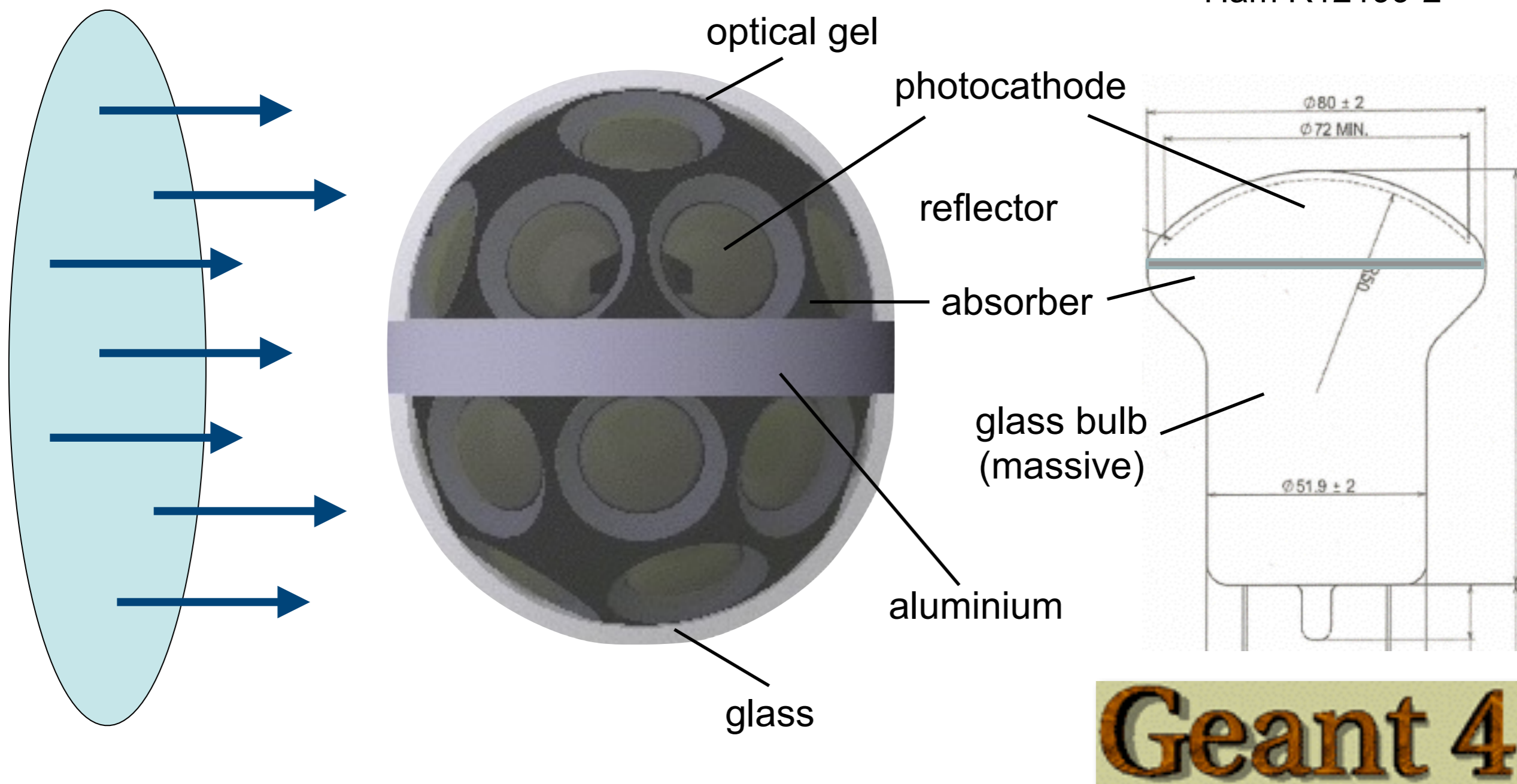
Alternative: cast glass half spheres with few cm cylindrical extension

- Connection of parts either via under-pressure or with flanges

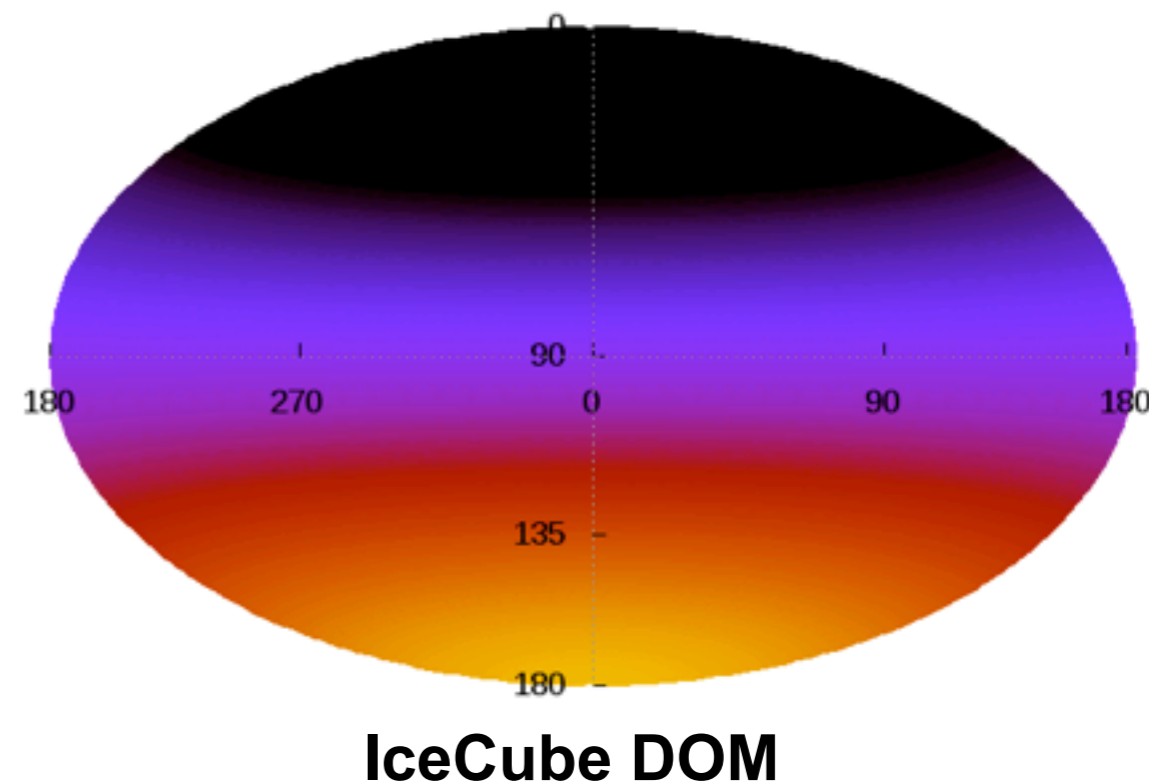
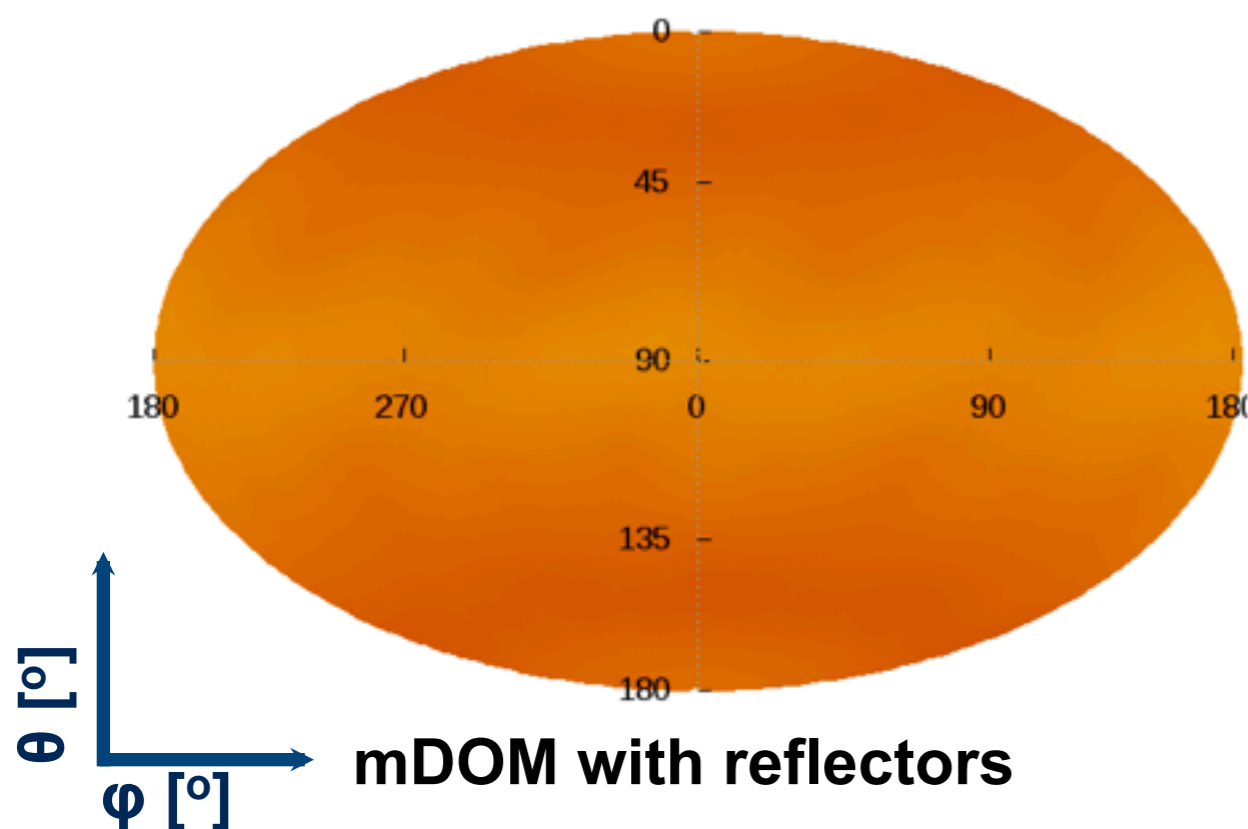


Angular acceptance simulation

PMT model
Ham R12199-2



Acceptance simulation results

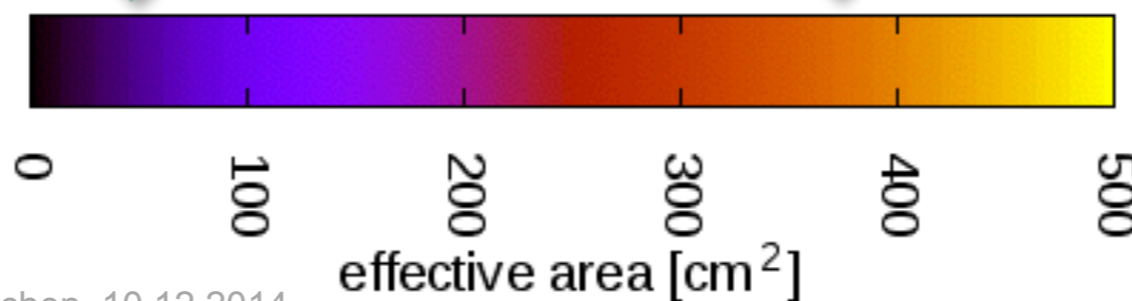


Average acceptance: mDOM = 2× DOM

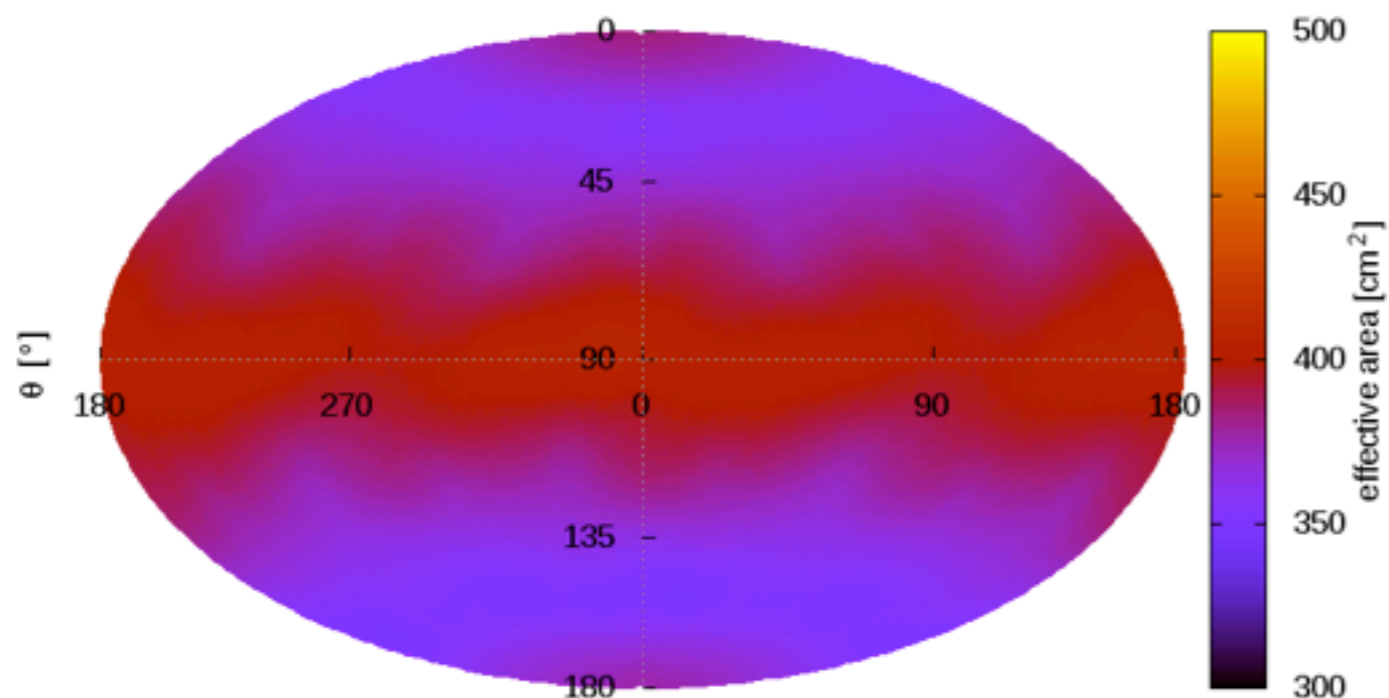


45 cm²

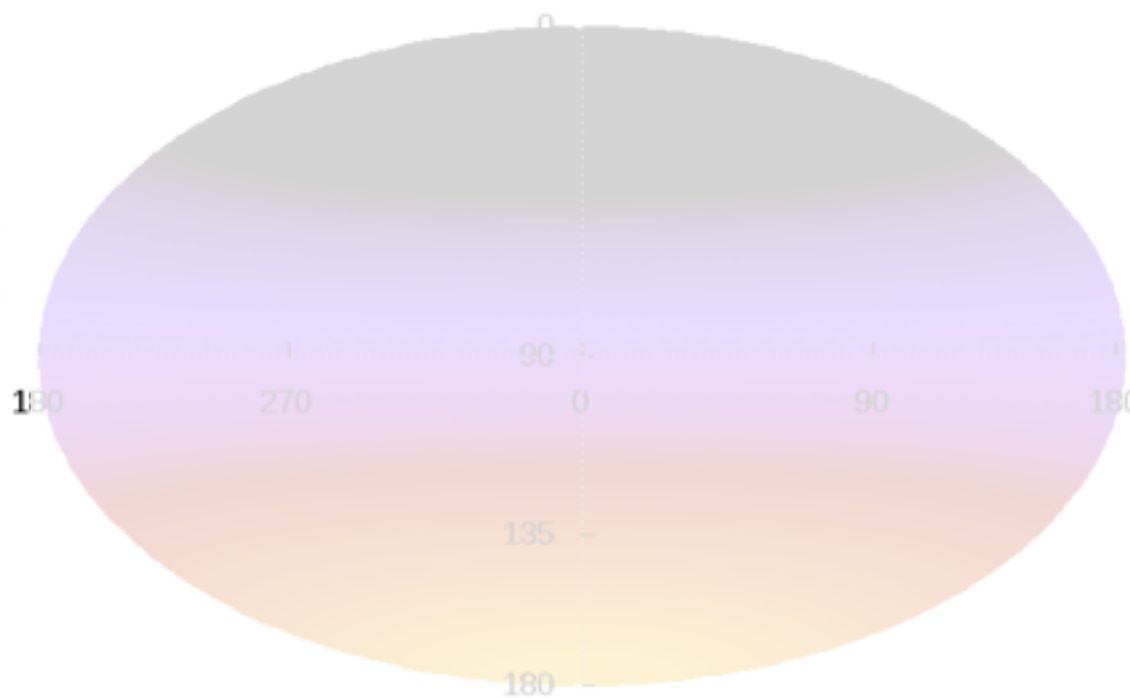
380 cm²



Acceptance simulation results



mDOM with reflectors



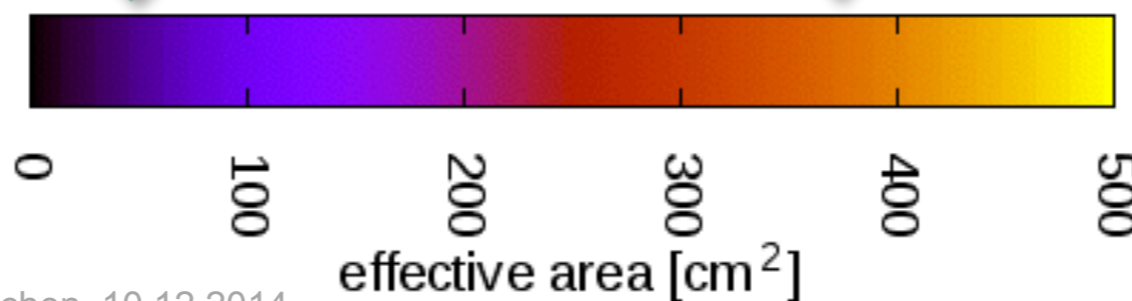
IceCube DOM

Average acceptance: mDOM = 2× DOM



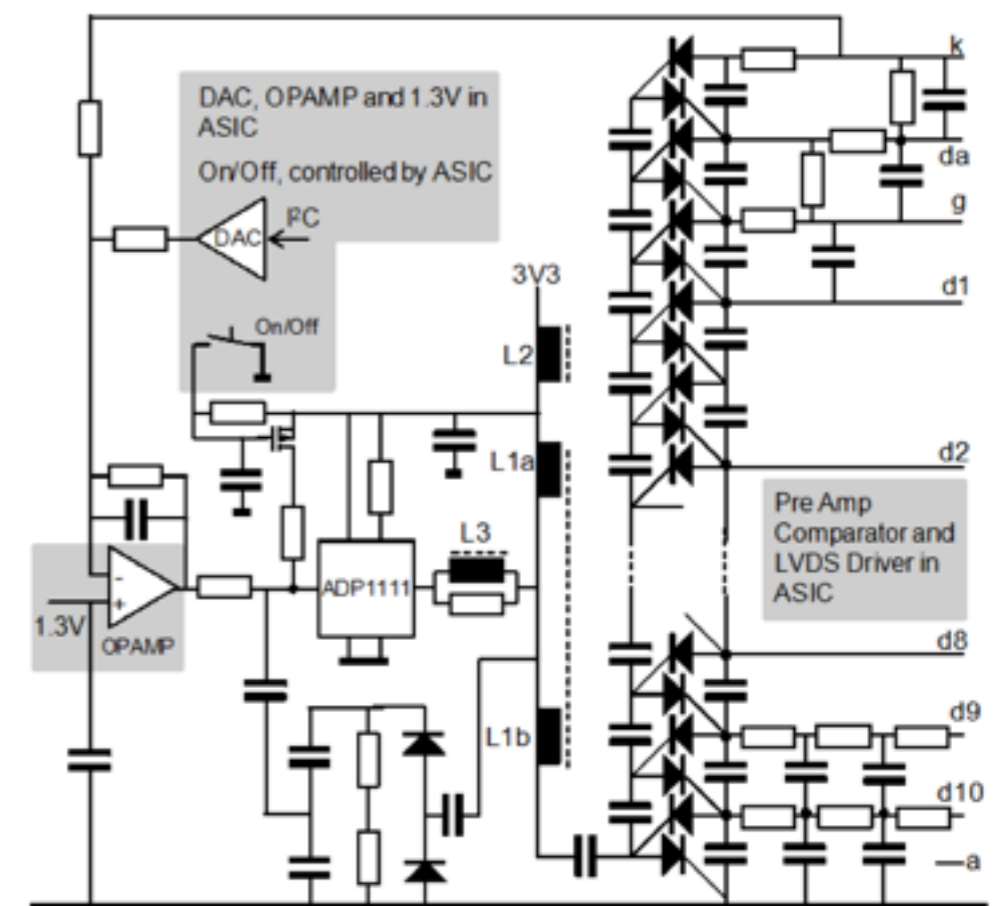
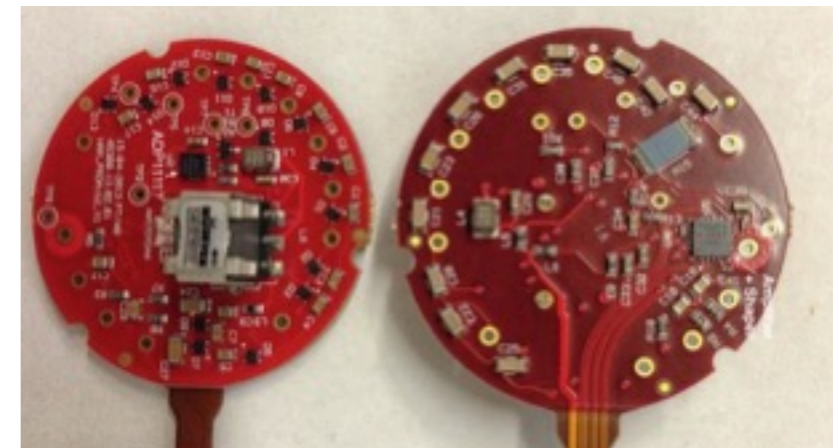
45 cm²

380 cm²



Electronics: PMT base

- High voltage supply
 - HV generation on base (Cockroft-Walton)
 - 3-4 mW power consumption
 - cathode @ ~1100 V; anode @ 0 V
- Signal processing
 - pre-amp + comparator (ToT) + LVDS drivers on ASIC
 - power consumption:
 - ToT signal only: ~20 mW
 - ToT + analog signal: ~50 mW (?)
- Voltage + threshold can be set via I2C

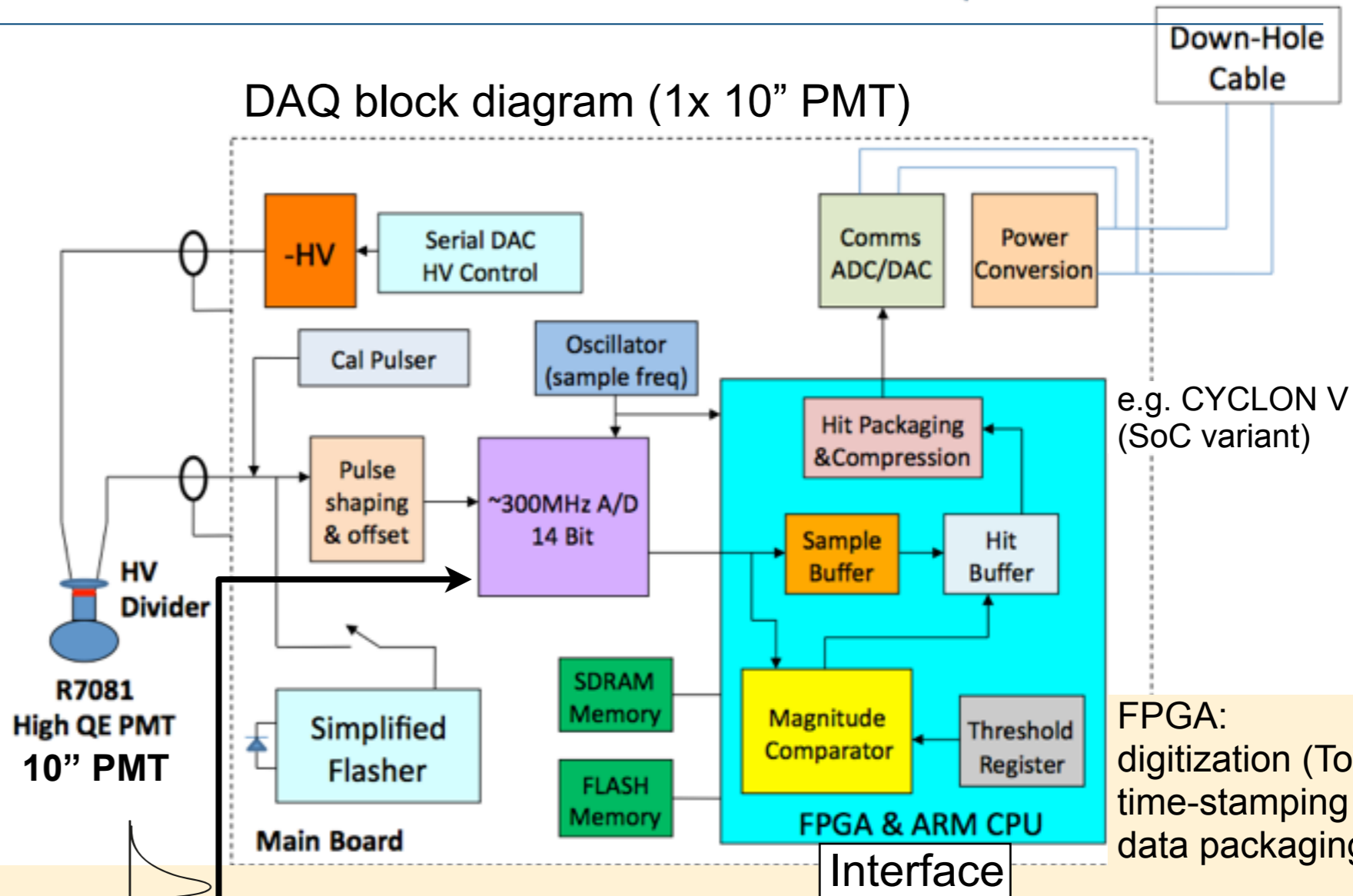


Modifications:

- Pre-amp/pulse shaping not optimal
→ probably needs adaption
- Reduction of power consumption of analog part?
(first have to check 50 mW)

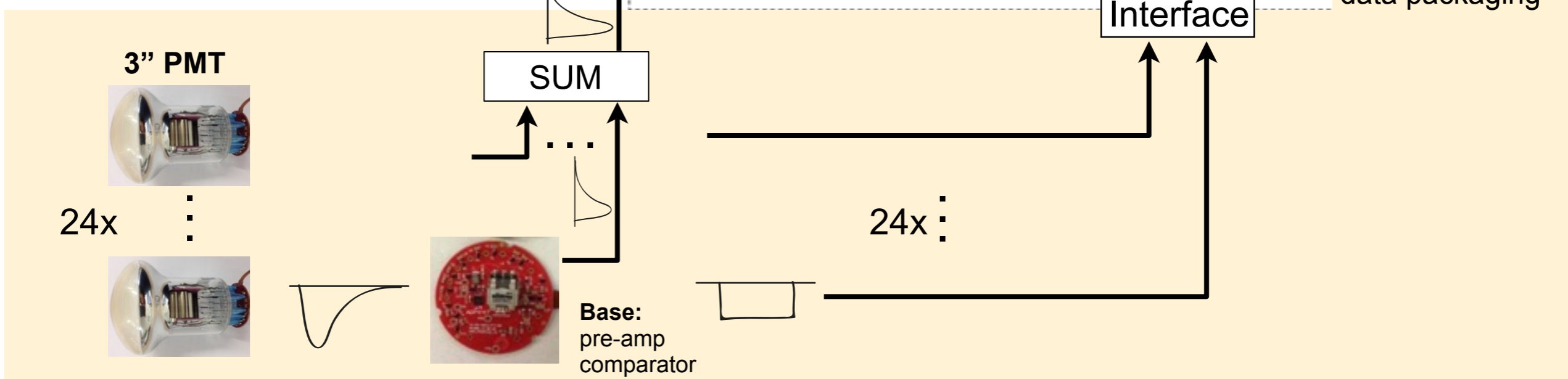
Timmer, 2010 JINST 5 C12049

DAQ block diagram (1x 10" PMT)



e.g. CYCLON V (SoC variant)

FPGA: digitization (ToT) time-stamping data packaging



Summary and timeline

- DOM with larger number of small PMTs provides several advantages (increased acceptance, 4π coverage, local coincidences, inherent directionality)
- mDOM design provides
 - 2× average acceptance of IceCube DOM
 - with almost uniform 4π coverage
 - and 24× segmented photocathode area
- Status
 - General mechanical layout close to final
 - PMTs for prototypes selected and available
 - Base: photocathode probably at negative voltage (KM3NeT design) (final decision requires some further measurements)
 - Electronics/integration into IceCube DAQ: major focus during next months

Timeline

- Mechanical prototype within ~6 months
- Prototype of electronics setup until end of 2015

