Development of a multi-PMT optical module for PINGU

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

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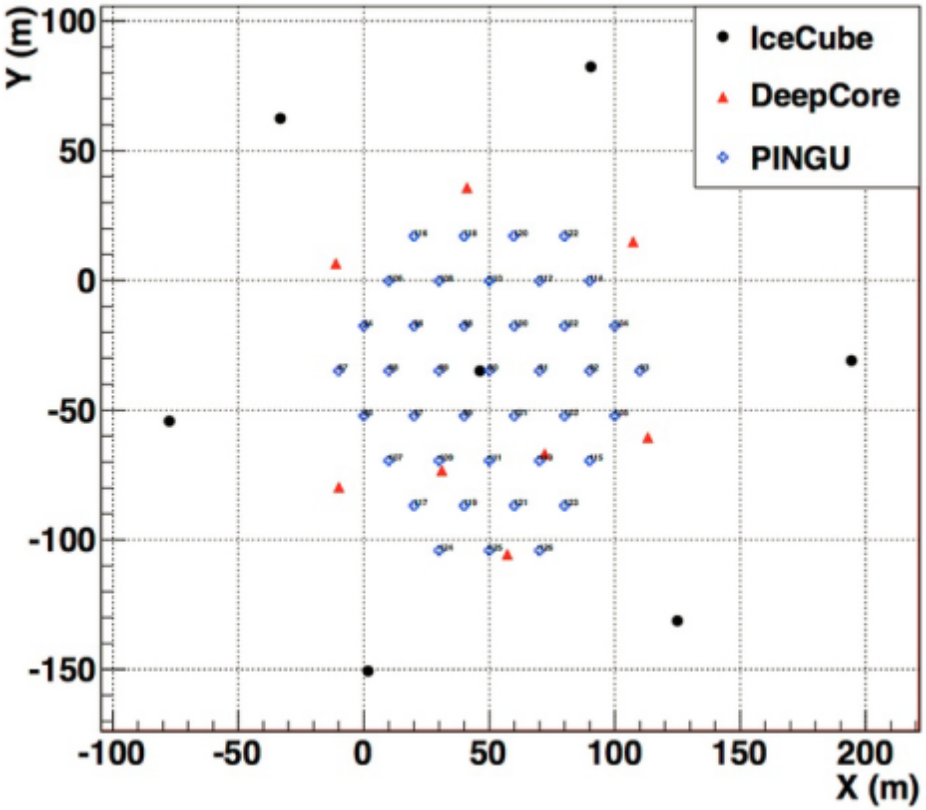
PINGU

- **P**recision **I**ceCube **N**ext **G**eneration **U**pdate
- 40 additional strings
- standard optical modules
- opportunity for module R&D

example configuration



Grant 2013

physics goals

- energy limit ~ GeV
- neutrino mass hierarchy
- low-mass WIMPs

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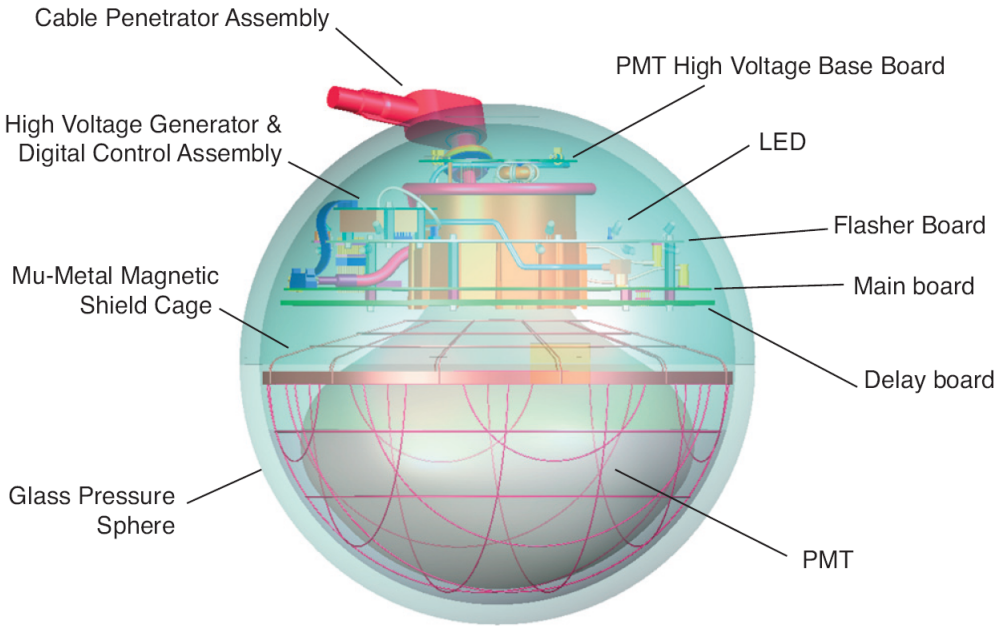
Multi-PMT module



IceCube & DeepCore	KM3NeT
13 inch sphere	17 inch sphere
1 × 10 inch PMT	31 × 3 inch PMT

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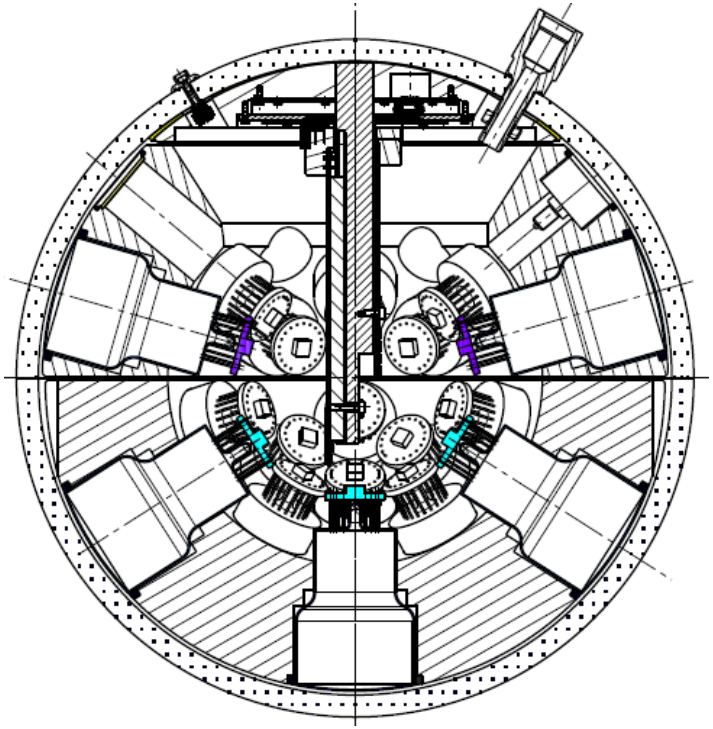
Advantages

- superior photo-electron counting:

  from number of hit PMTs, rather than signal waveform
- angle of signal acceptance up to 4π
- direction sensitivity
- no magnetic shielding needed
- increase of sensitive area



- similar overall price

  per photocathode area

KM3NeT 2011

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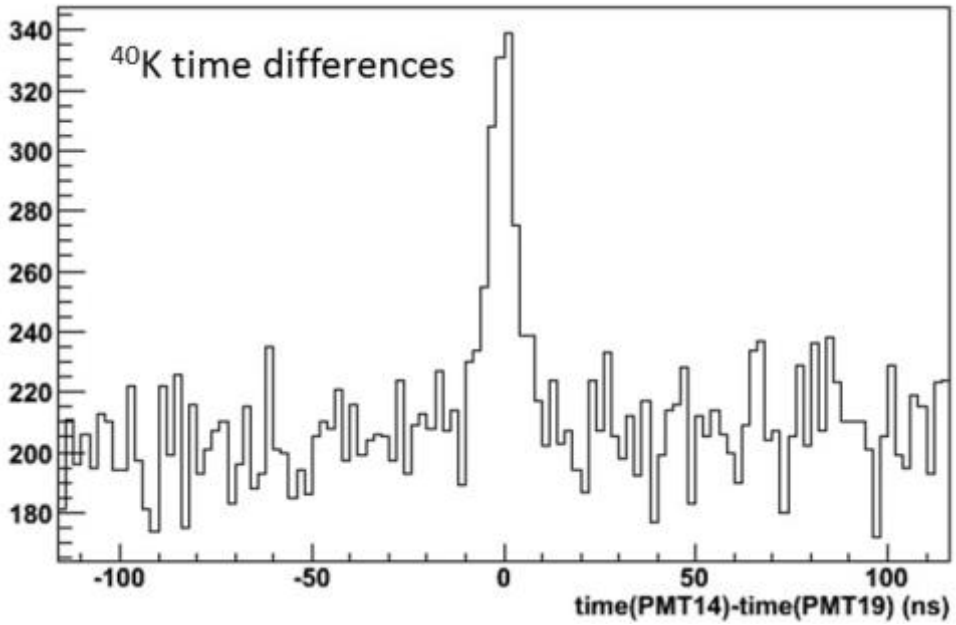
PPM-DOM

- first multi-PMT DOM deployed
- mounted on instrumentation line

  at Antares site
- opportunity of in-situ calibration



KM3NeT 2013

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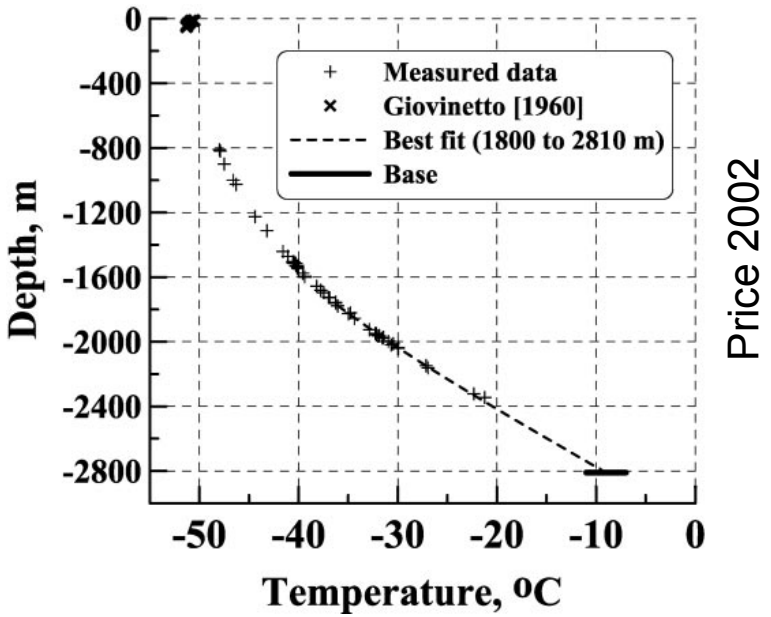
Adaptation for ice

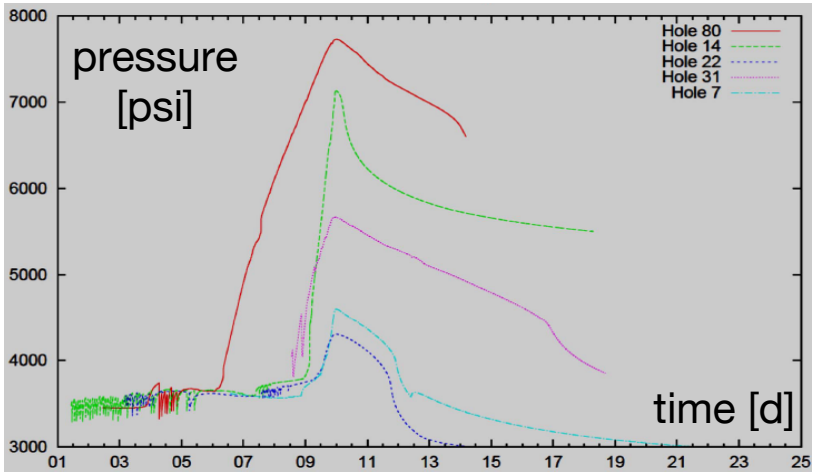
- maximum diameter: ~13 inch
- temperature: - 35°C
- overpressure during refreezing



Price 2002

- reuse of 3-inch PMTs & low voltage bases

redesign of vessel



Benson 2012

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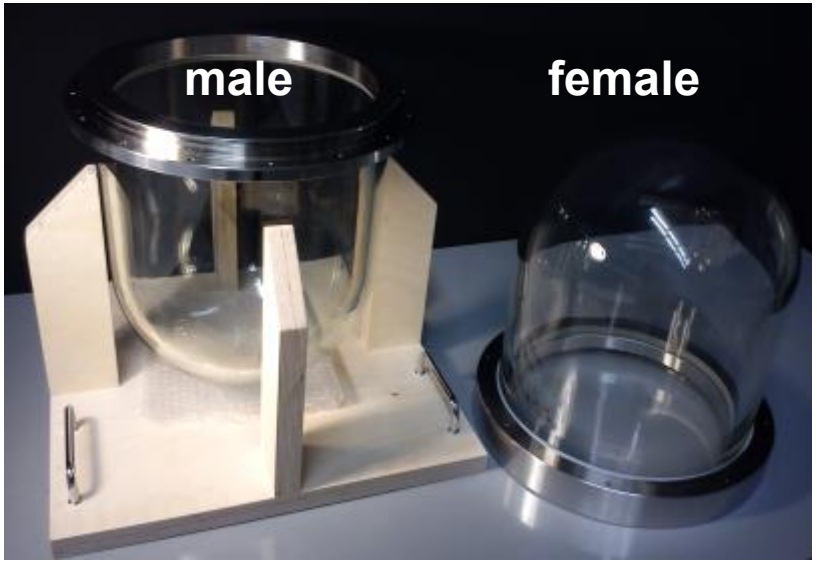
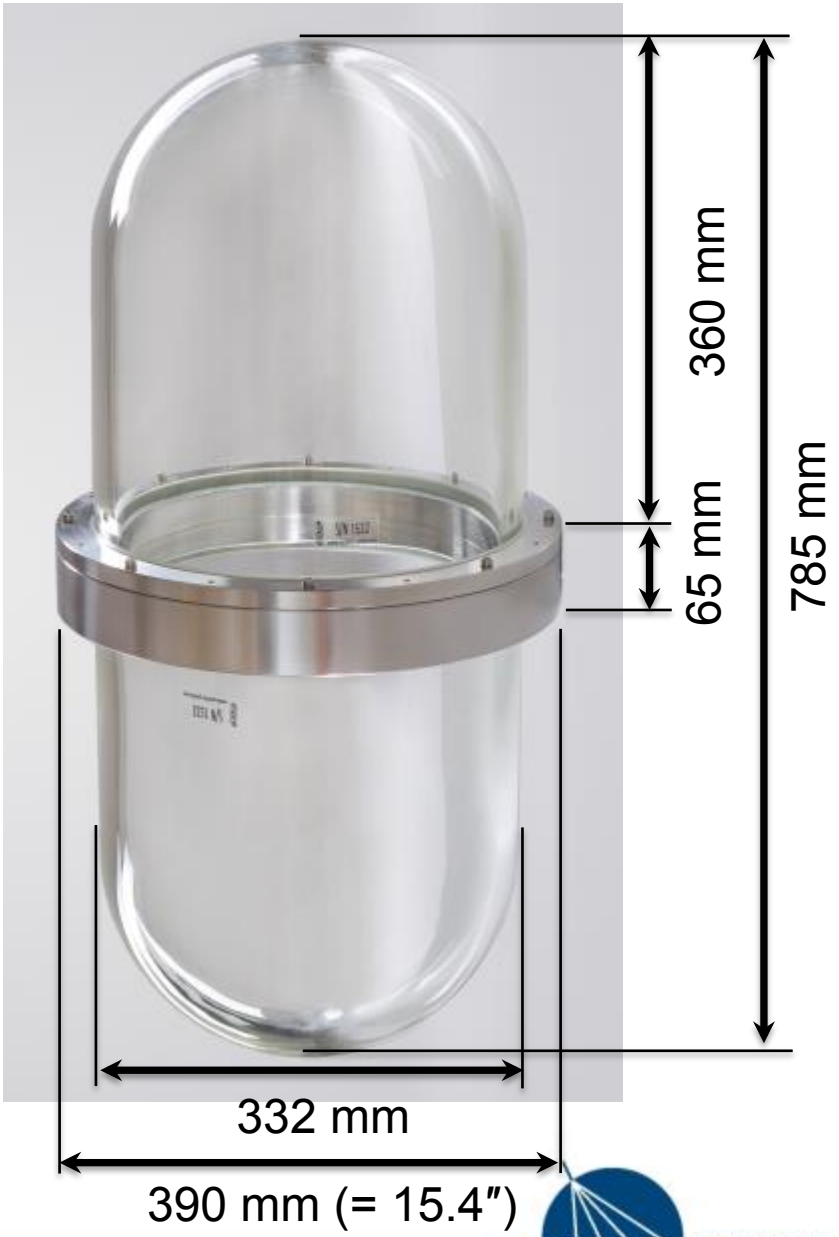
Cylindrical vessel

- stainless steel flanges & titanium screws
- wall thickness up to 18 mm
- rated for 700 bar (≈ 10 000 psi)
- mass (f/m): 28.2 kg/22.5kg





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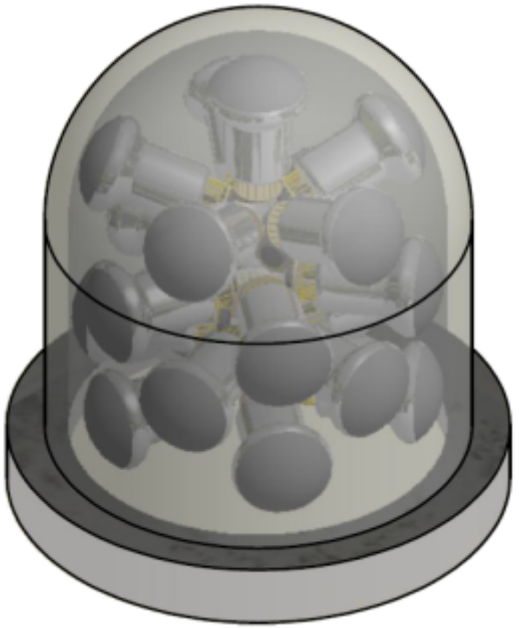
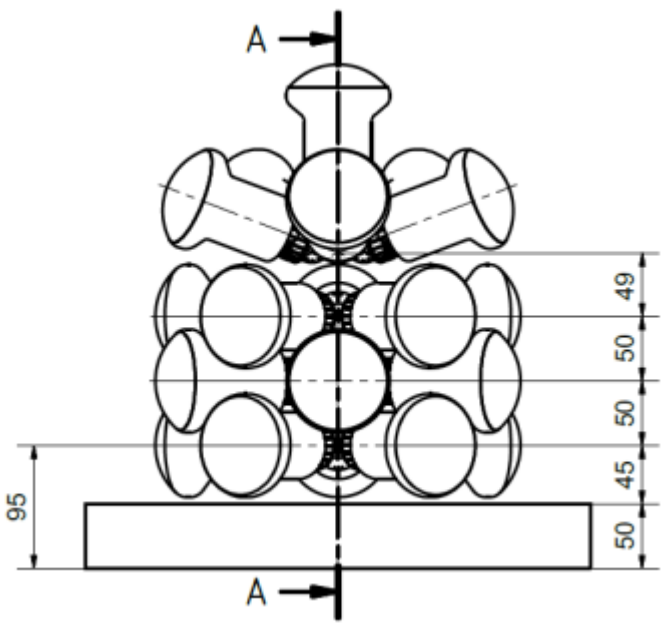
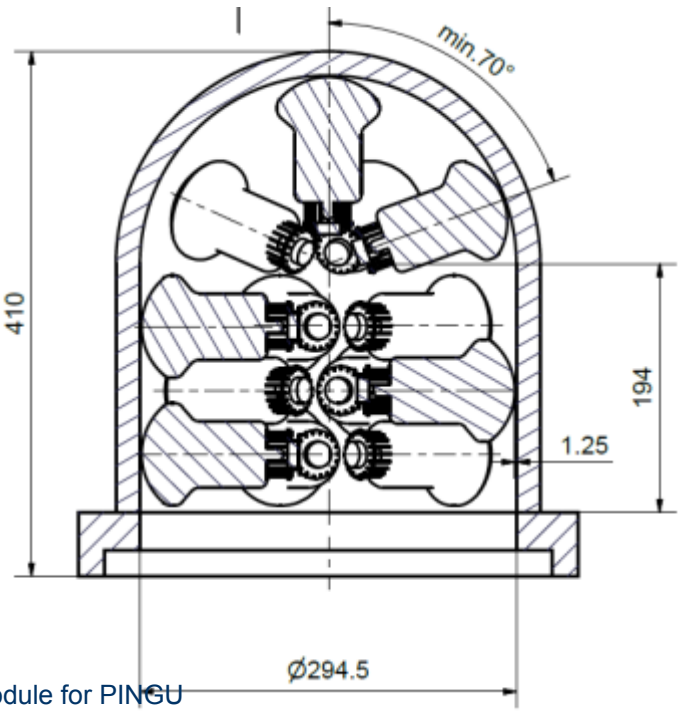
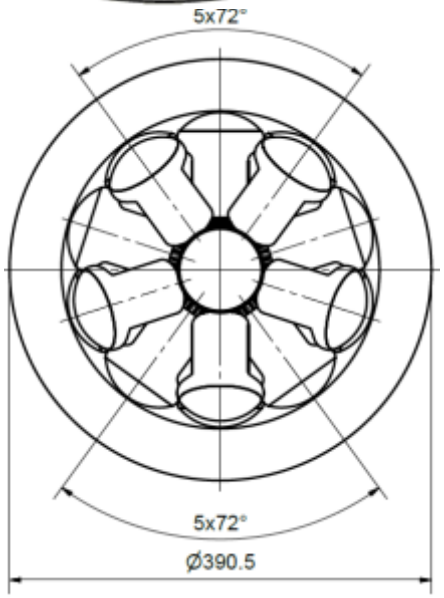
mDOM interior

- segmented cylindrical vessel
- **41× 3” PMT**
- main electronics in center
- ~ four times larger photocathode area









PMT candidates

- testing in Amsterdam, Catania, Erlangen, Patros

R12199	D792KFL	XP53B20
Hamamatsu	ET Enterprises	HZC
180x	12x	2x

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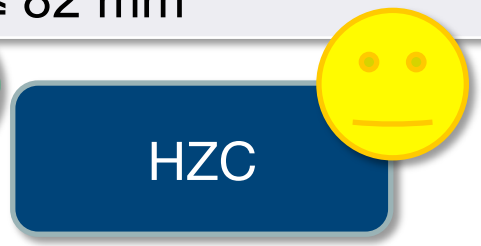
PMT testing status

requirements (KM3NeT)	
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
outer diameter	≤ 82 mm



- talk by Leonora
- talk by Kalekin

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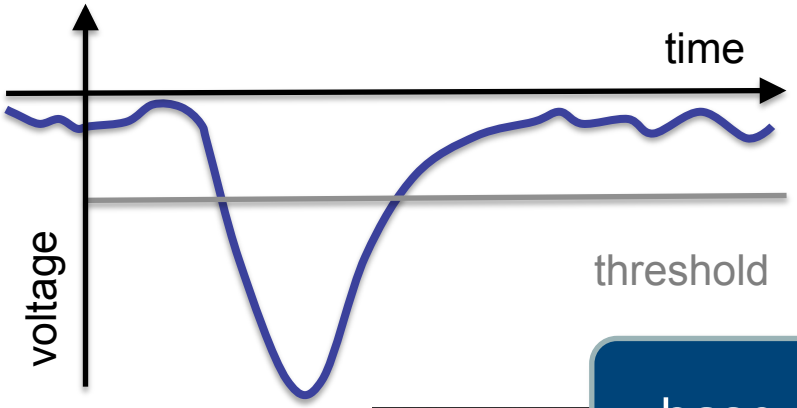
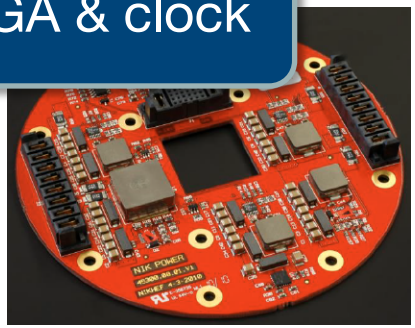
Readout principle

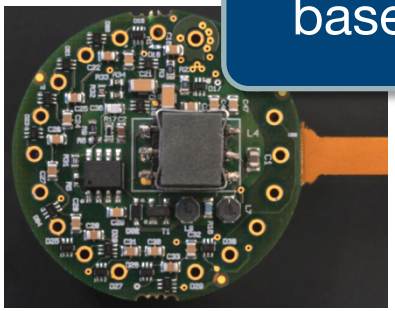
- from analogue signal to time stamped data (talks by Real & Calvo)



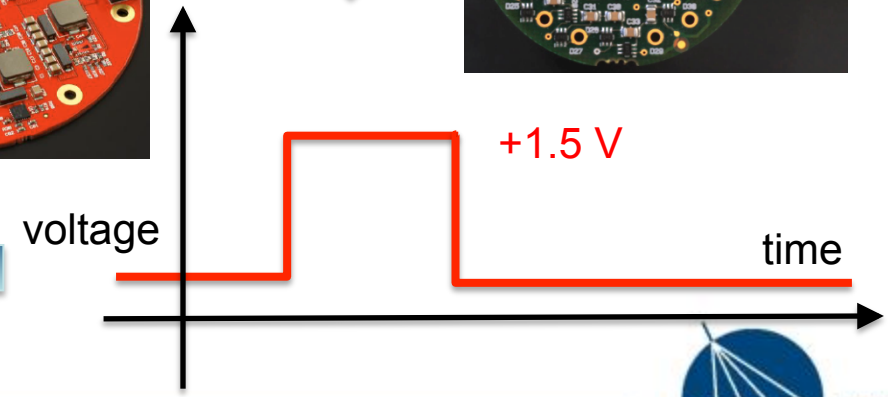
FPGA & clock



base



signal word
start time
duration
PMT id



NIKHEF 2012

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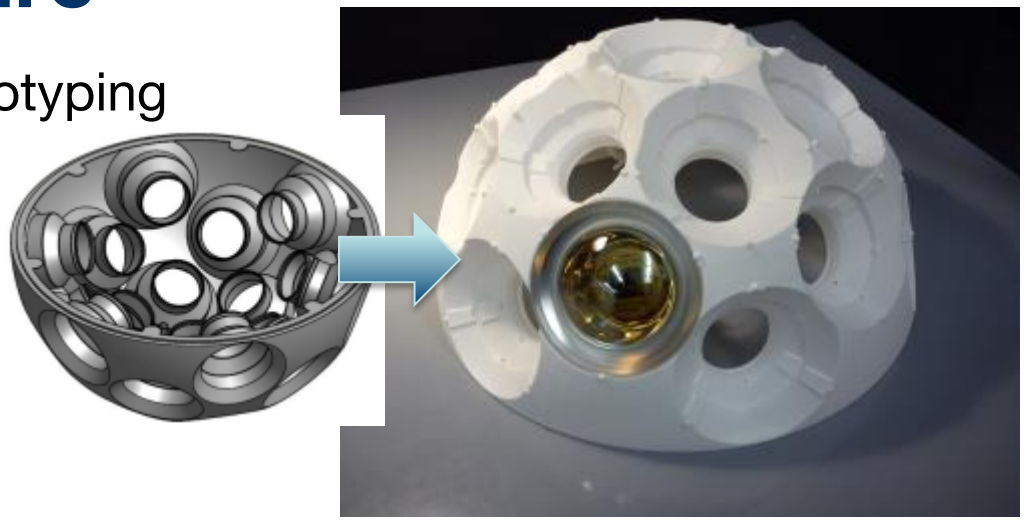
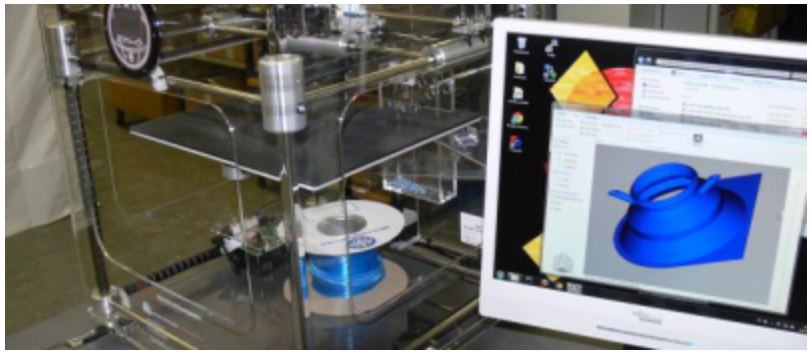
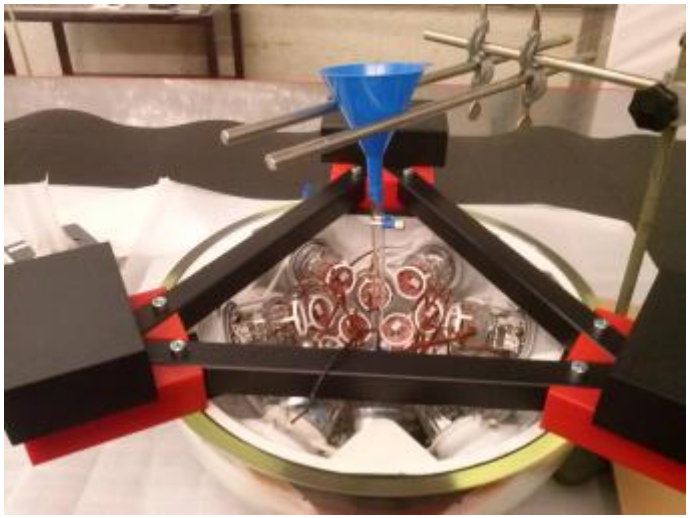
Holding structure

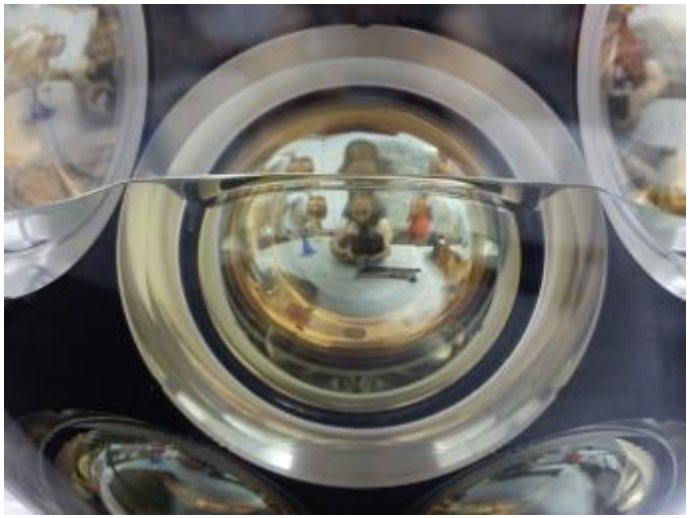
- 3D printing / rapid prototyping
- adequate precision
- low price (prototyping)
- segmentation possible
- high flexibility
- alternatives considered for mass production

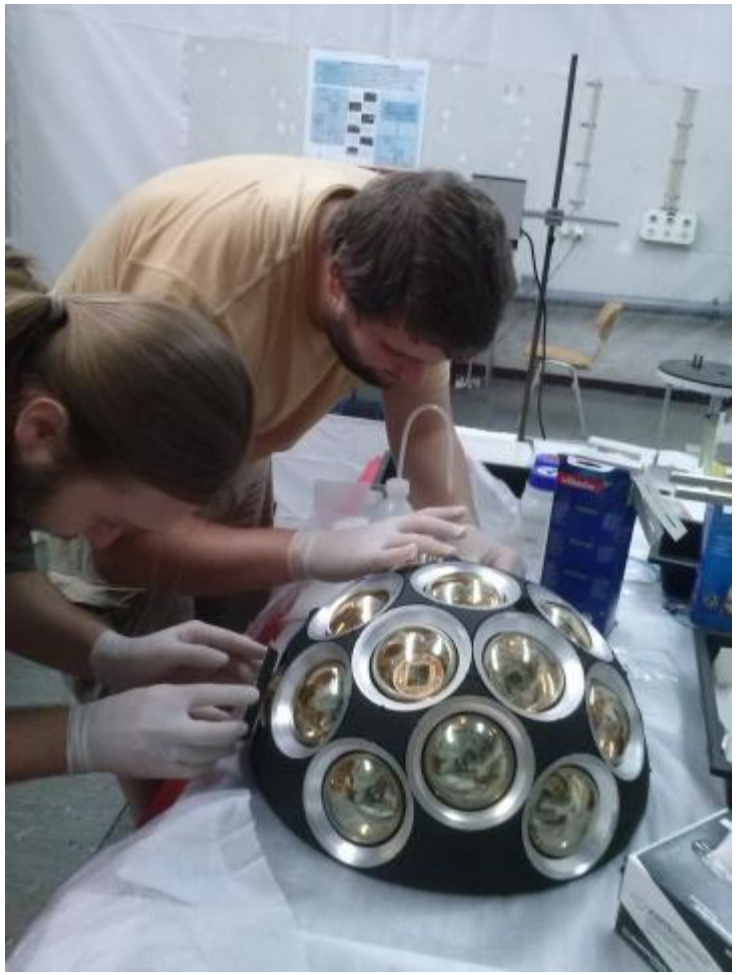




Module integration







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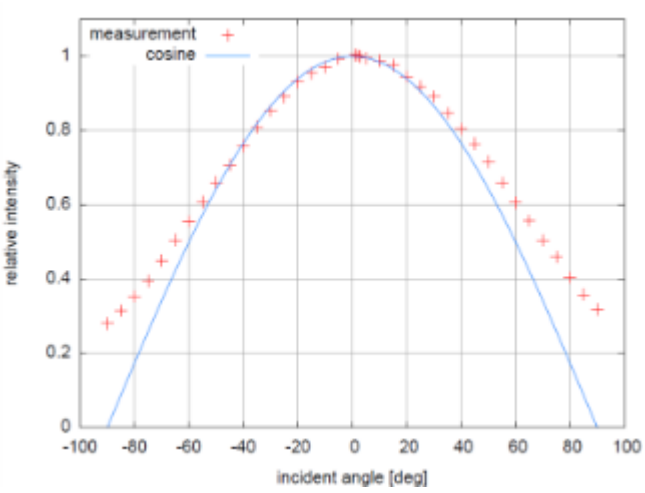
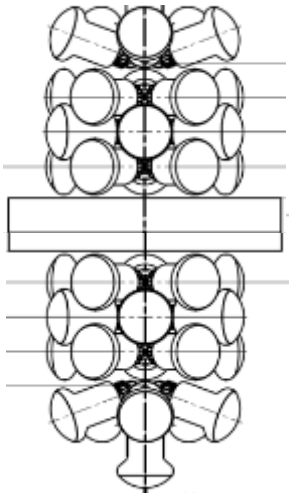
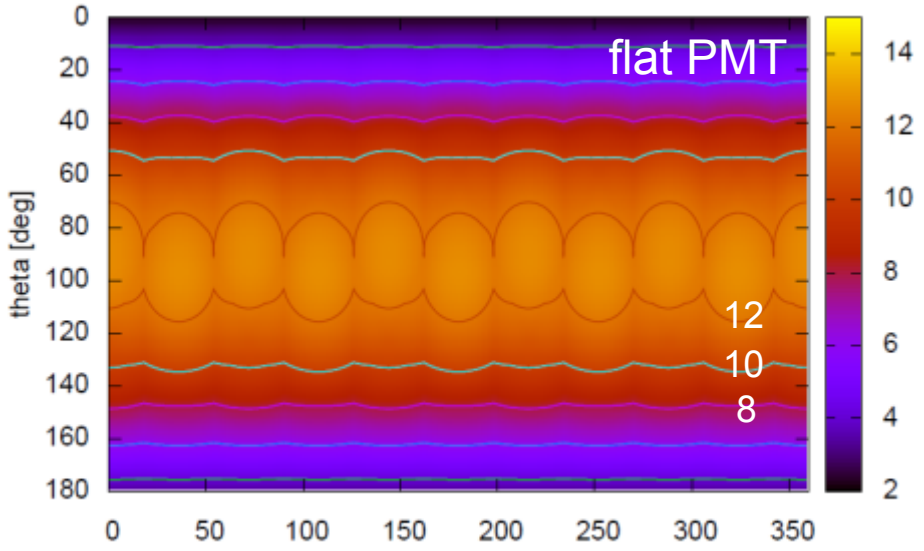
Angular acceptance

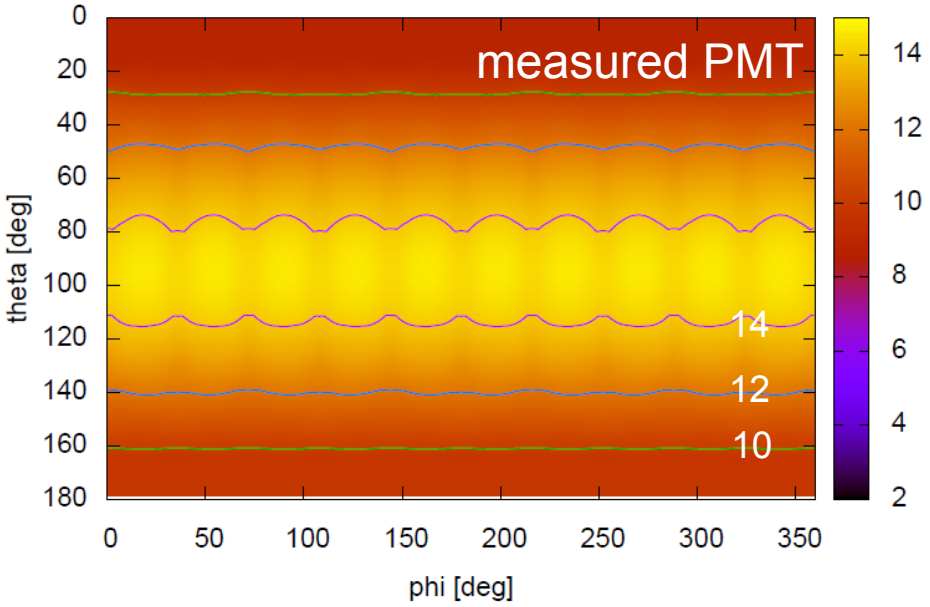
- 41 PMT mDOM
- flat vs. measured PMTs
- area scaled in single PMT

  effective areas (1 PMT ≈ 50 cm²)









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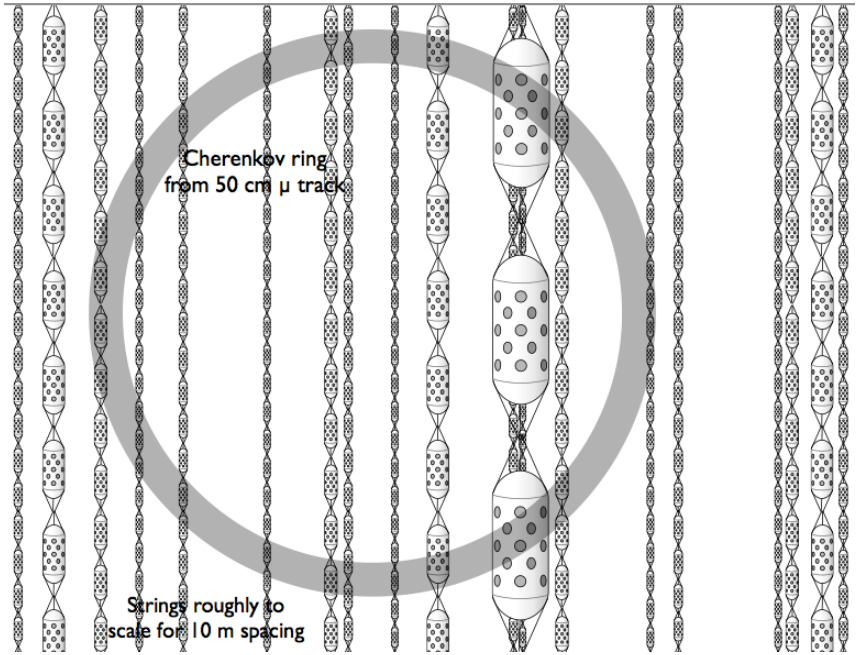
MICA

- **M**egaton **I**ce **C**herenkov **A**rray
- denser instrumentation
- new optical module technology

physics goals

- energy threshold ~ 10 MeV
- Cherenkov ring imaging
- supernova neutrinos
- proton decay



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Detector simulations

- different detector configurations
- number of strings 20 – 41

common detector properties	
string spacing	7 m
OMs per string	151
OM spacing	2 m
height	300 m
location	2148 – 2448 m*

framework	IceTray
ice model	SPICE-Mie
decay propagation physics	GEANT4
photon propagation	CLSim

* $z \in [-500\ \text{m}; -200\ \text{m}]$

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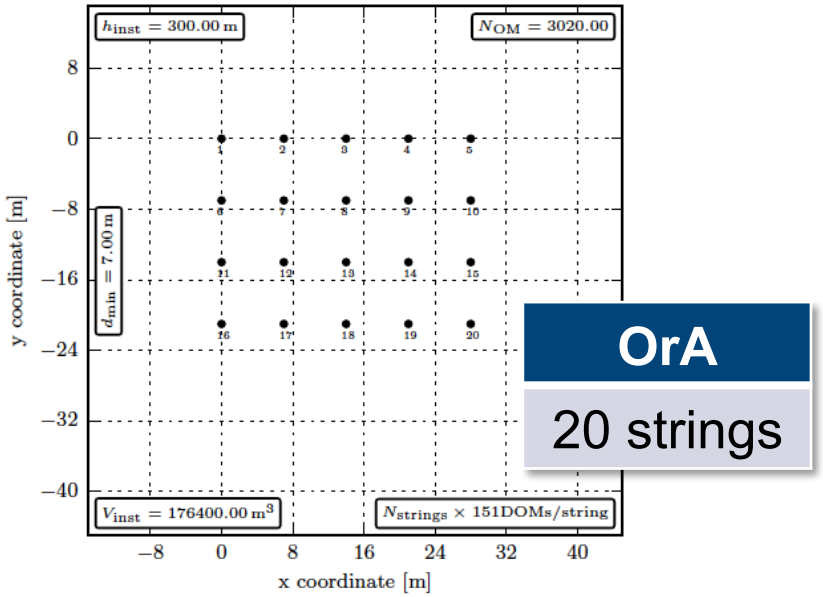
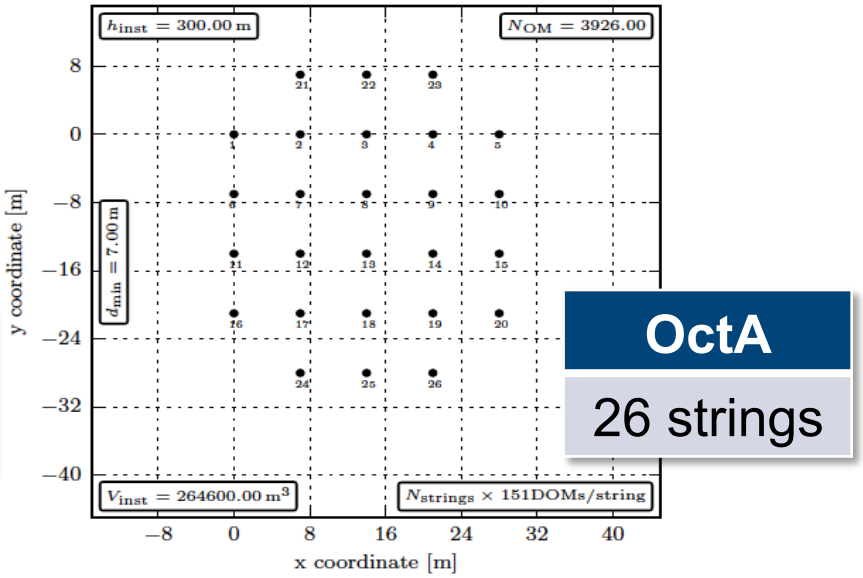
Simulated footprints



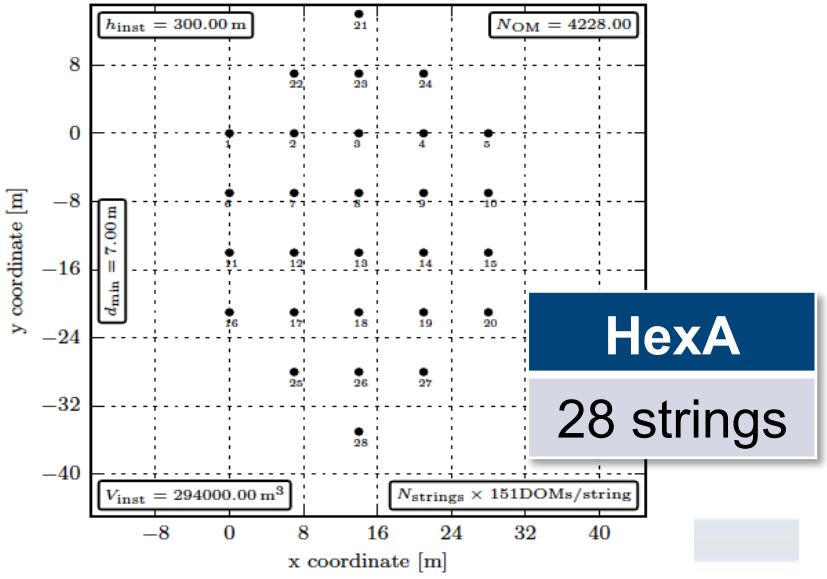
OrA

20 strings



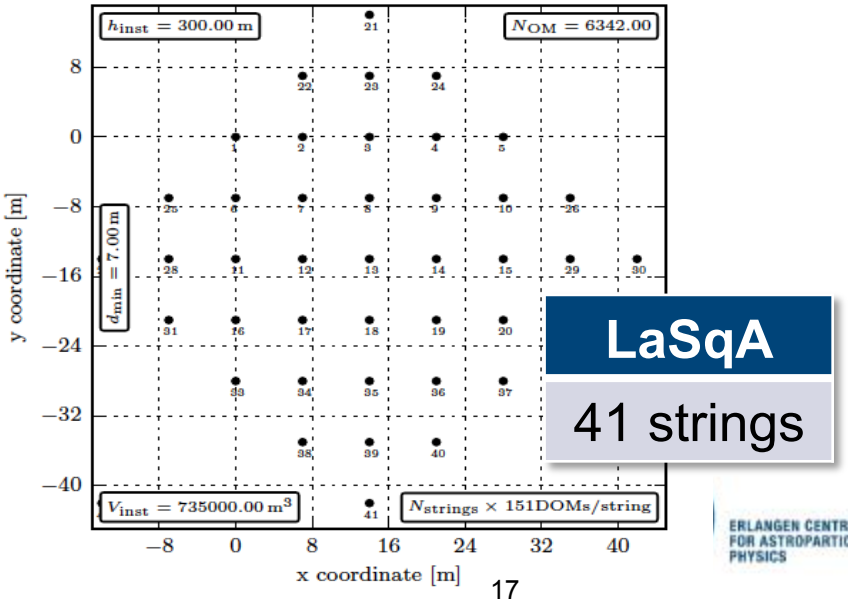
OctA

26 strings



HexA

28 strings



LaSqA

41 strings

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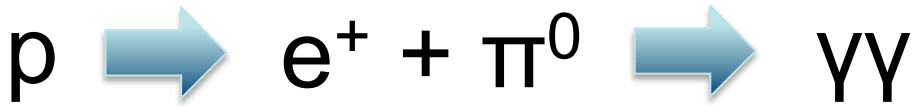
Proton decay simulation

- 10 proton decays generated inside cylinder
- radius 10 m
- x_0 = 10 m
- y_0 = -10 m
- $z \in$ [-490 m; -210 m]



configuration	number of strings	number of OMs	hits / decay
OrA	20	3020	2688
OctA	26	3926	3592
HexA	28	4228	3724
LaSqA	41	6191	4354

Next steps…

radioactivity of holder & glass

low temperature behaviour

adaptation of electronics

design holding structure

build prototype for testing

Thank you for your attention!

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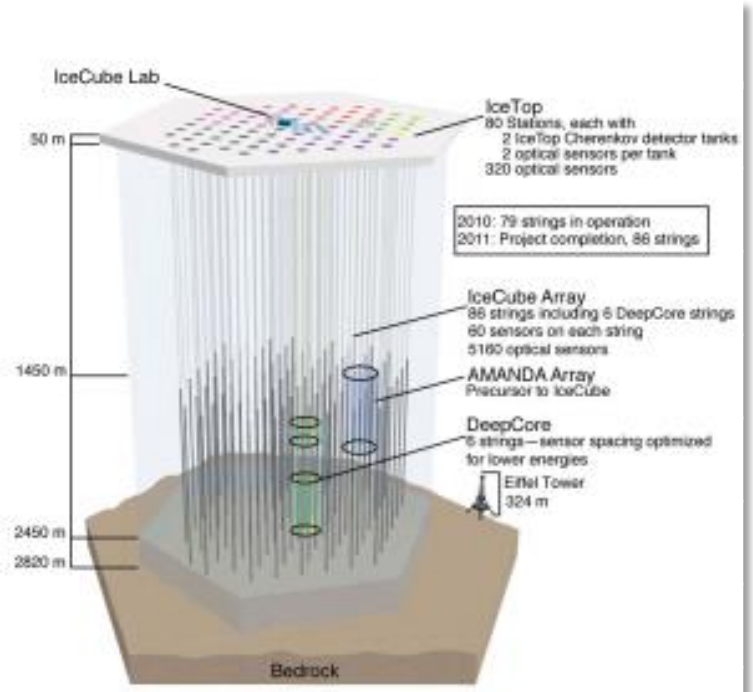
Picture graveyard

requirements (K	
quantum efficiency @ 470 nm	
transit time spread (σ, FWHM)	
gain	
supply voltage	
dark count rate @ 15°C	
cathode response inhomogeneity	
peak to valley ratio	
length	< 120 mm
outer diameter	≤ 82 mm



- talk by Leonora

Hamamatsu | ETEL | HZC

- talk by Kalekin

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