KM3NeT and Baikal-GVD
New Northern Neutrino Telescopes

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Nikhef/University of Amsterdam

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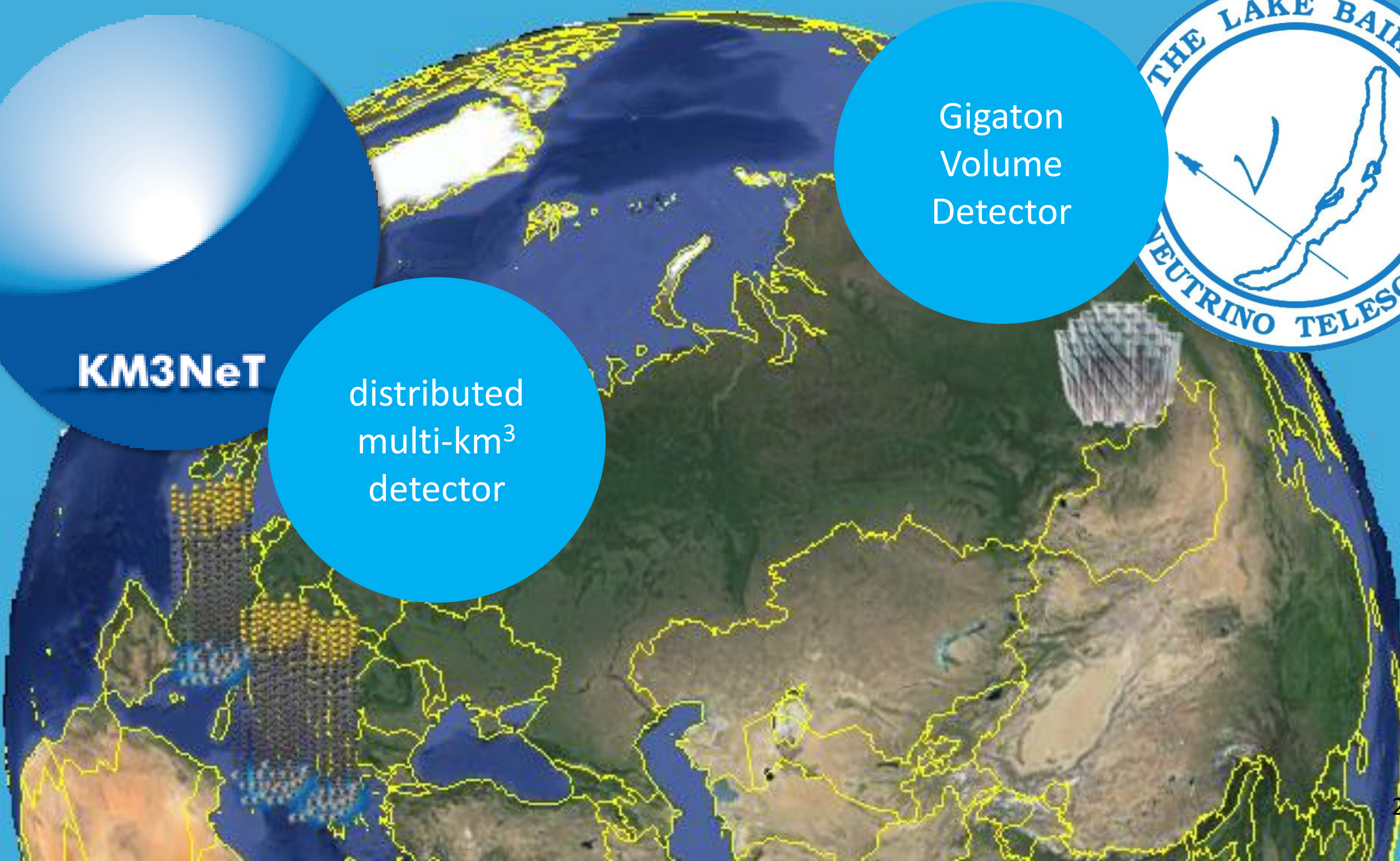
ICISE, Quy Nhon, Vietnam

KM3NeT and GVD
New Northern Neutrino Telescopes



KM3NeT

distributed multi-km^3 detector

Gigaton Volume Detector

THE LAKE BAIKAL NEUTRINO TELESCOPE

Water Cherenkov detectors

$\nu_e : \nu_\mu : \nu_\tau$

input

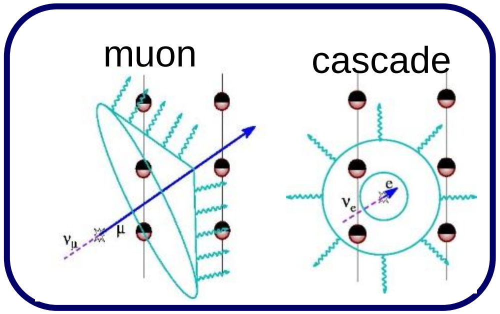
Target

water

muon (ν_μ)

cascade (ν_e,ν_τ ,ν_μ)

Telescope (E,Ω)



Two event topologies

output

Energy, direction, flavour

physics (σ_E,σ_Ω)

KM3NeT and GVD: different systematics

Baikal-GVD

Environmental parameters

Lake Baikal - fresh water

distance to shore ~6 km

L_{abs} ~22-25 m

L_{scat} ~30-50m

depth ~1360 m

icefloor during winter

Telescope design

~1.5 km3

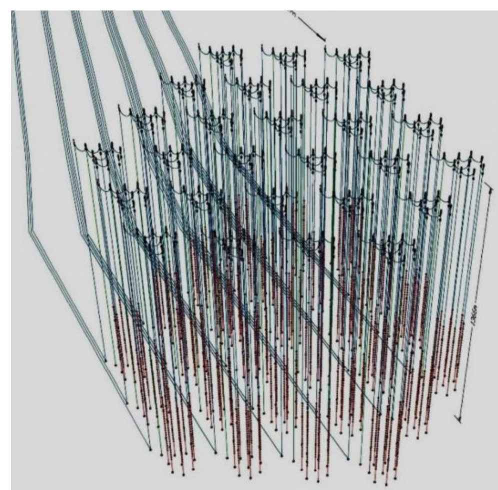
27 shore-cables for 27 clusters

27*8=216 strings

216*48=10368 OMs ¶

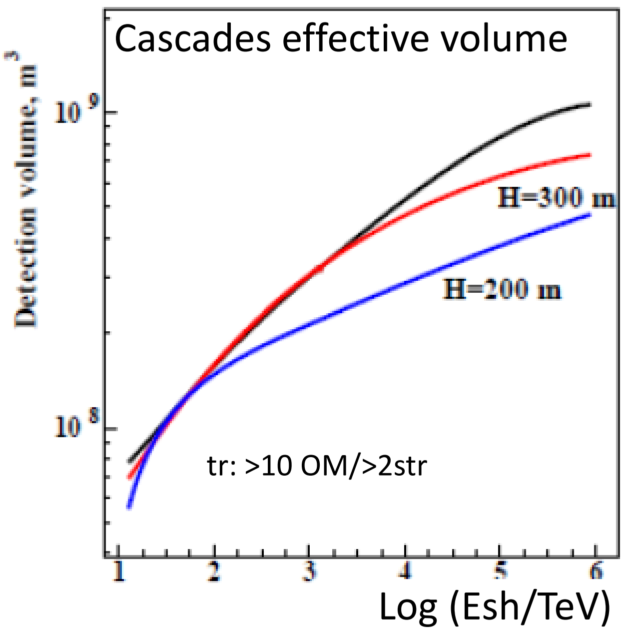
deployment from icefloor

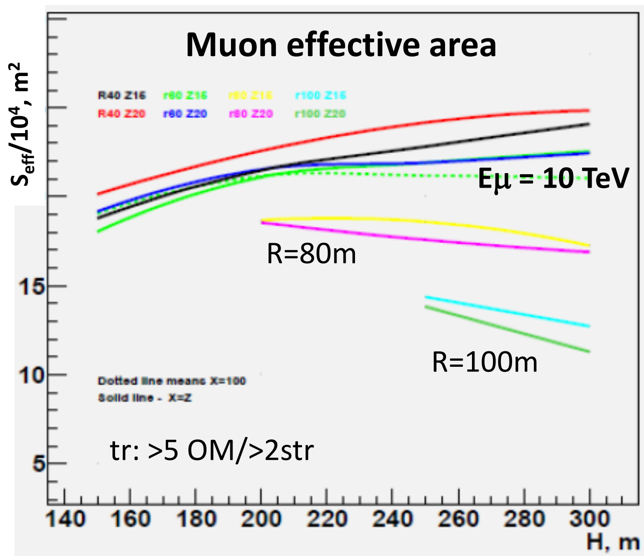
shallow water DAQ infrastructure



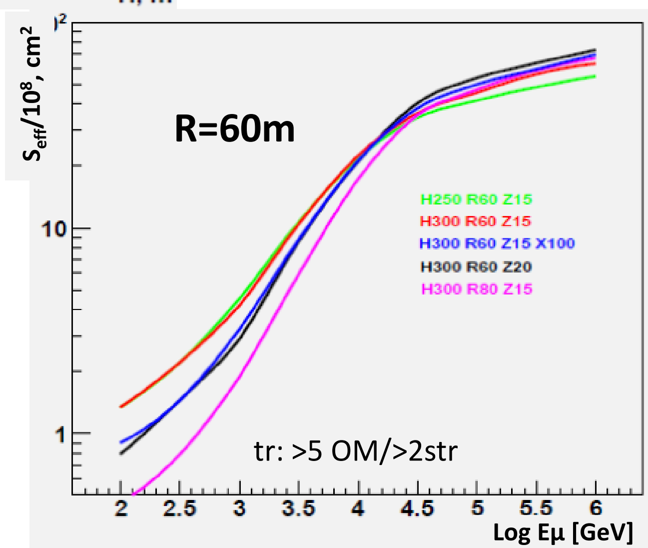
¶ OM – Optical Module

GVD geometry optimisation





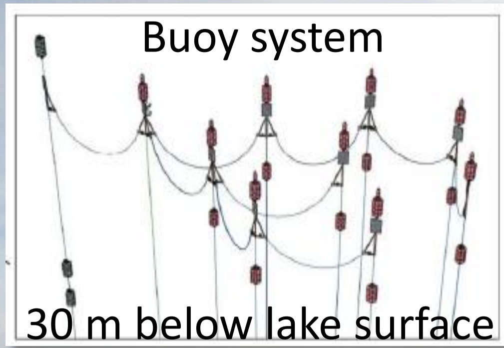
OM¶ spacing: Z=15 m
Radius cluster: R=60 m
Cluster spacing: H=300 m

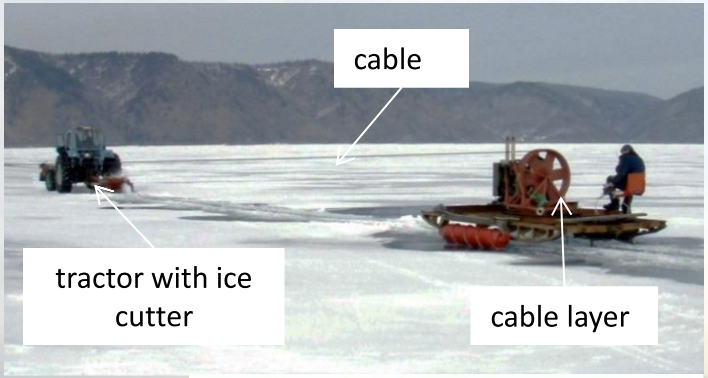


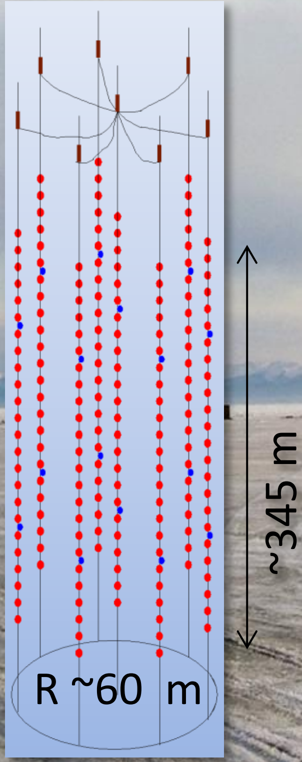
¶ OM – Optical Module

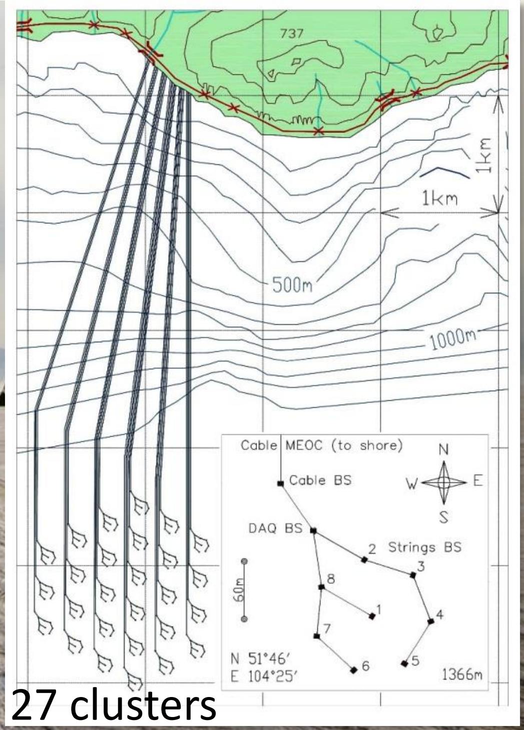
GVD technology

R7081HQE : D=10”, ~0.35QE





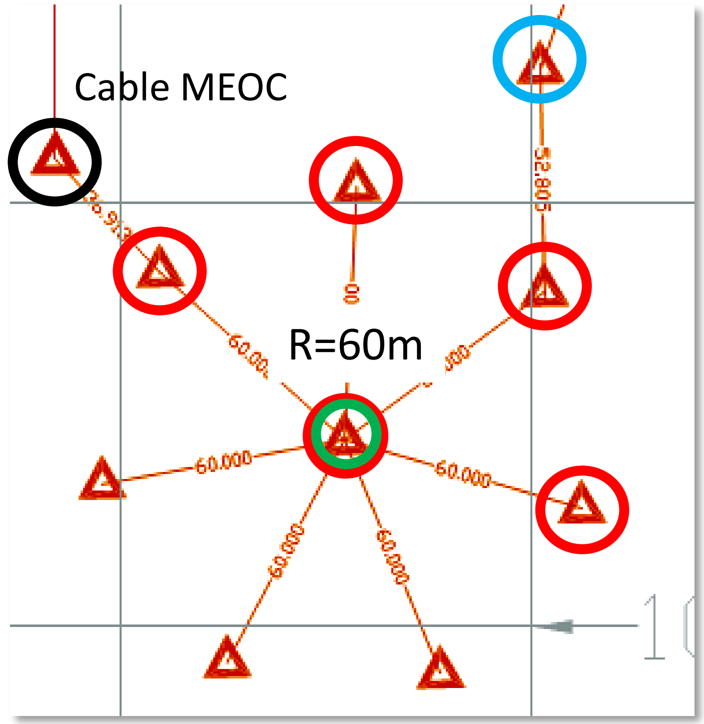




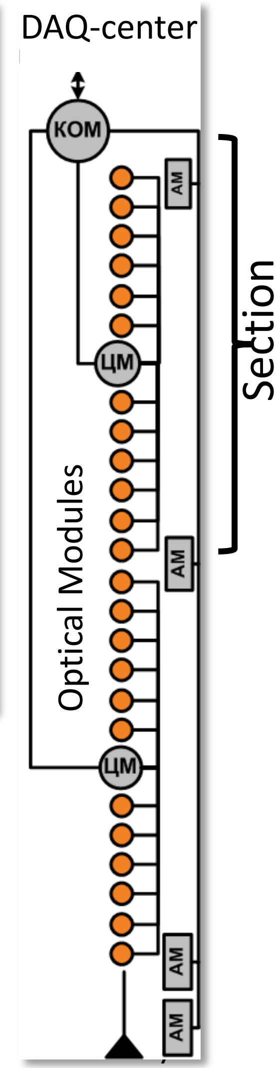
GVD 2014-cluster

Operational since April 2014

- 112 OMs at 5 strings
  - 9 sections with 12 OM/Sec.
  - 1 section with 4 OM/Sec.
- Calibration light beacon (LEDs)
- Upgraded section electronics
- Acoustic positioning system
- Instrumentation string:
  - Laser light source
  - 8 PMTs at 600-900m depth for b/g light monitoring
- 10 acoustic sensors for string shape monitoring



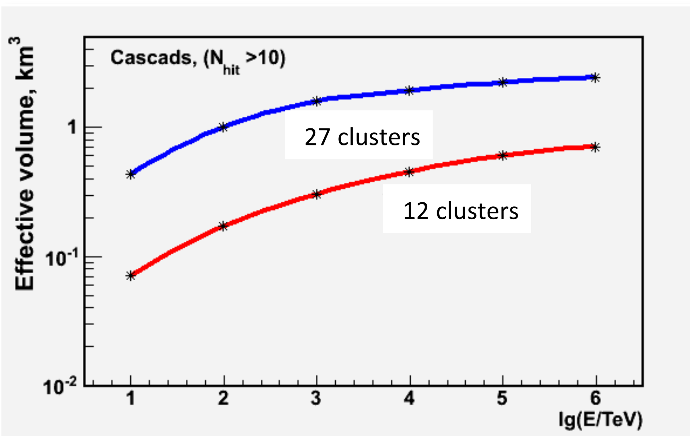
- DAQ center
- Instrumentation string
- o/e Cable Buoy Station
- Operating strings



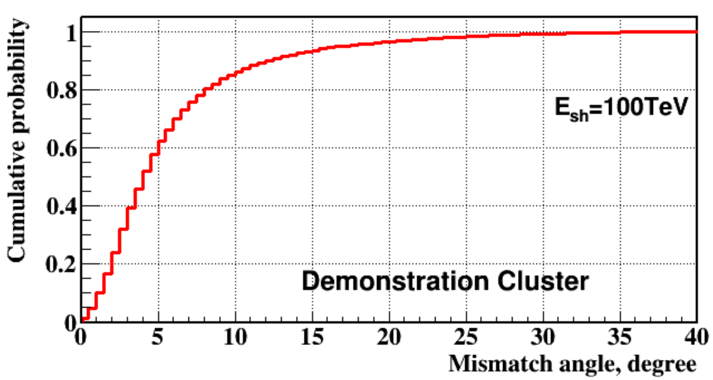
GVD performance

Cascades

V_{eff} between ~0.4–2.4 km^3

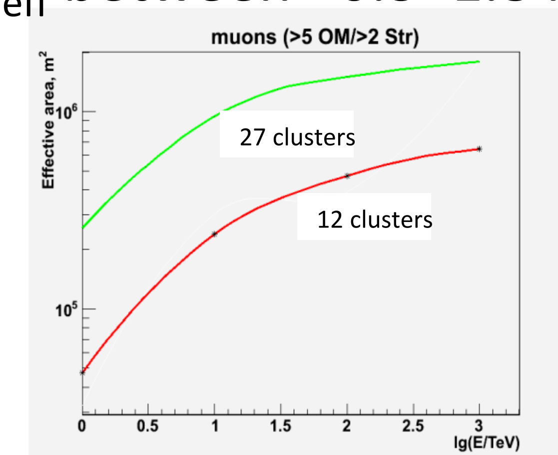


Directional resolution: 3.5º - 5.5º

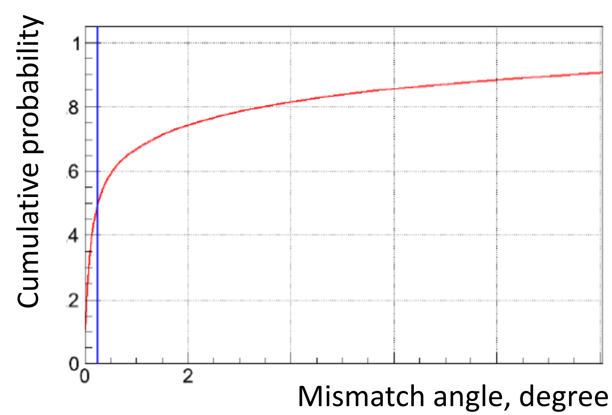


Muons

S_{eff} between ~0.3–1.8 km^2



Directional resolution: 0.25º



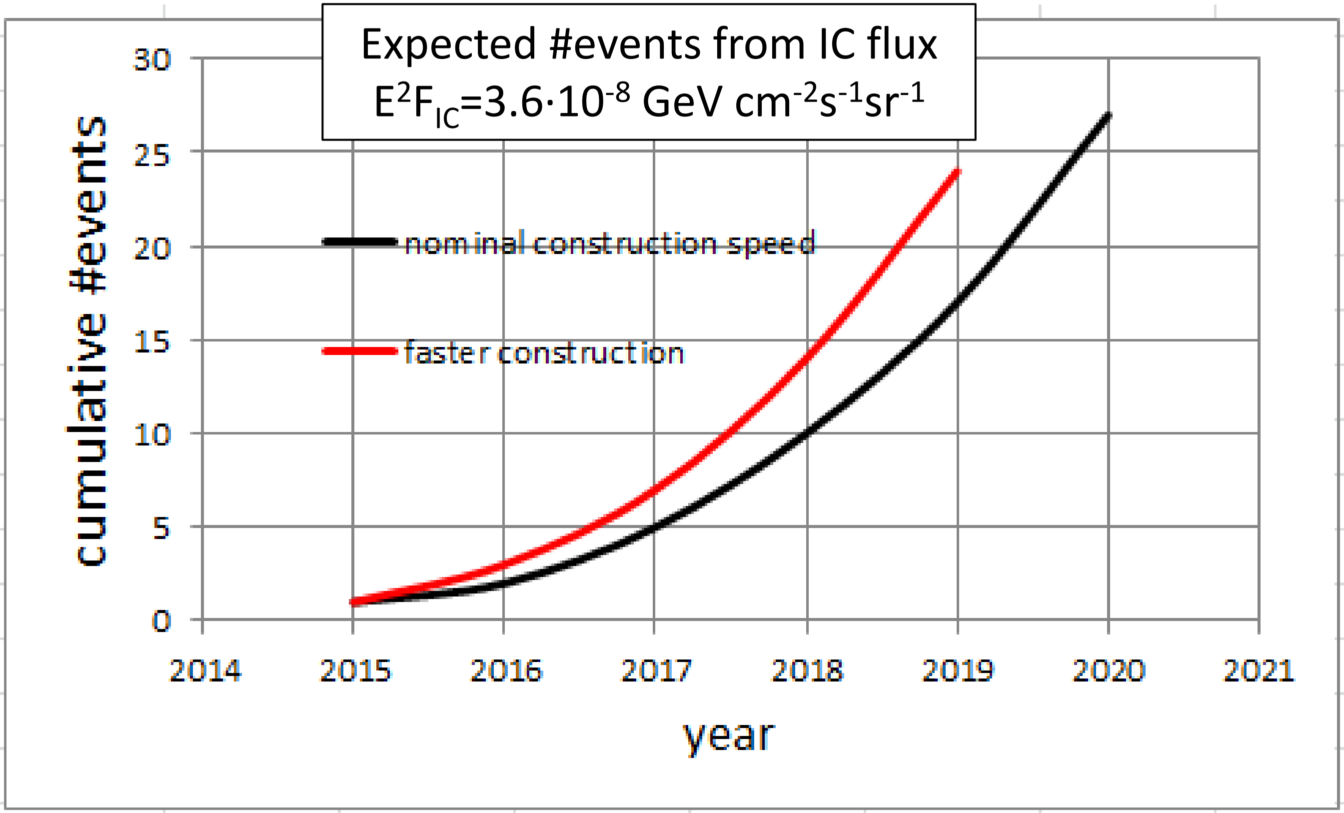
GVD phased construction

	Cumulative number of clusters operational						
Year	2014	2015	2016	2017	2018	2019	2020
Nominal installation	0.6[¶]	1	1	3	5	7	10
Faster installation		1	2	4	7	10	

1.5-2 clusters installed per season with 3 teams of 3 persons each
Design allows more teams working parallel

[¶]Cluster of 5 strings operational since winter 2014

Baikal-GVD: performance



E > 100 TeV: ~1 event/cluster/year

KM3NeT in the Mediterranean

Environmental parameters

Mediterranean Sea – salt water

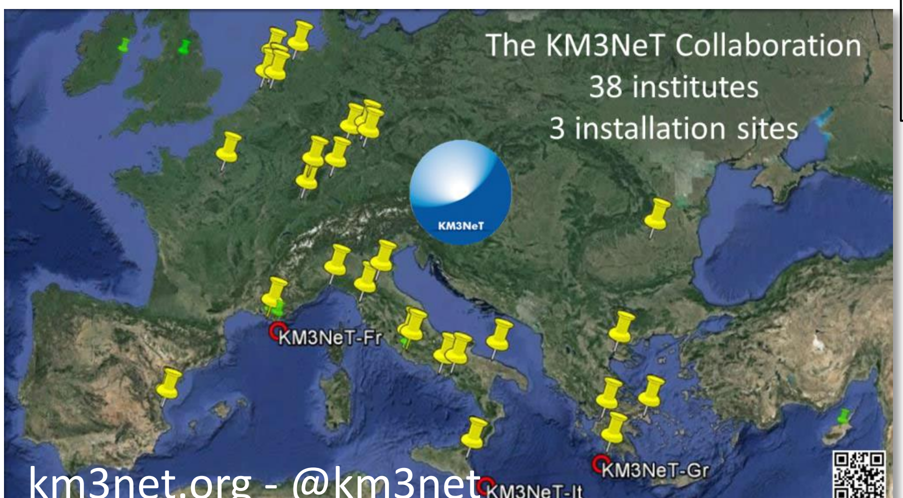
3 installation sites

distance to shore ~40-100 km

L_{abs} ~60-100 m

L_{scat} ~50-70m

depths ~2500-4500 m



Telescope design

~3.5-6 km^3 (depending on spacing)

6 shore-cables for 6 building blocks

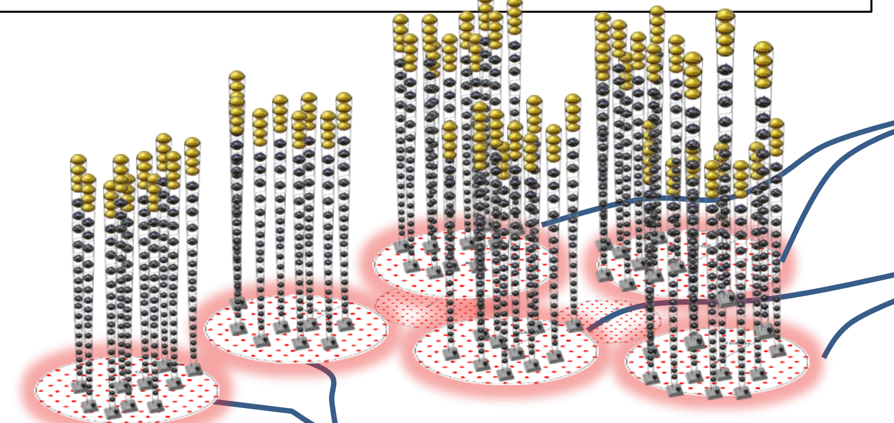
6 x 115 = 690 detection units

690 x 18 =12420 OMs

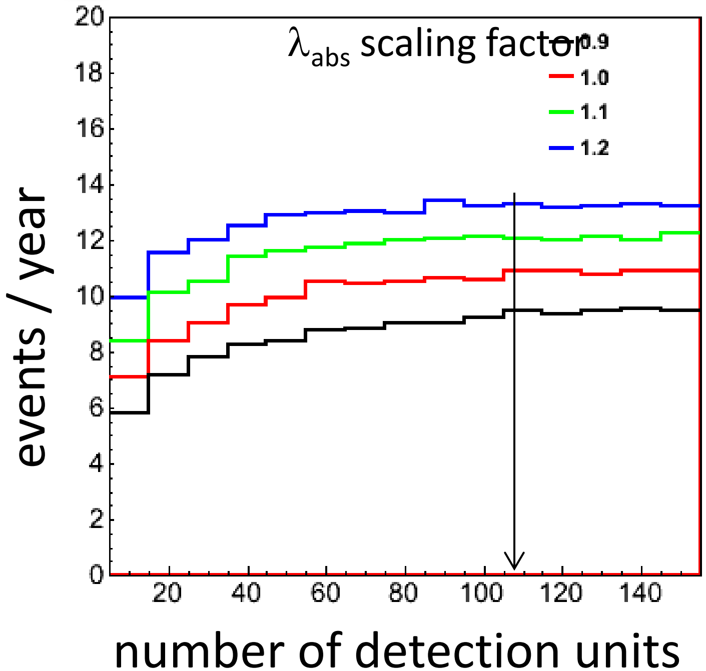
seabed data transmission infrastructure

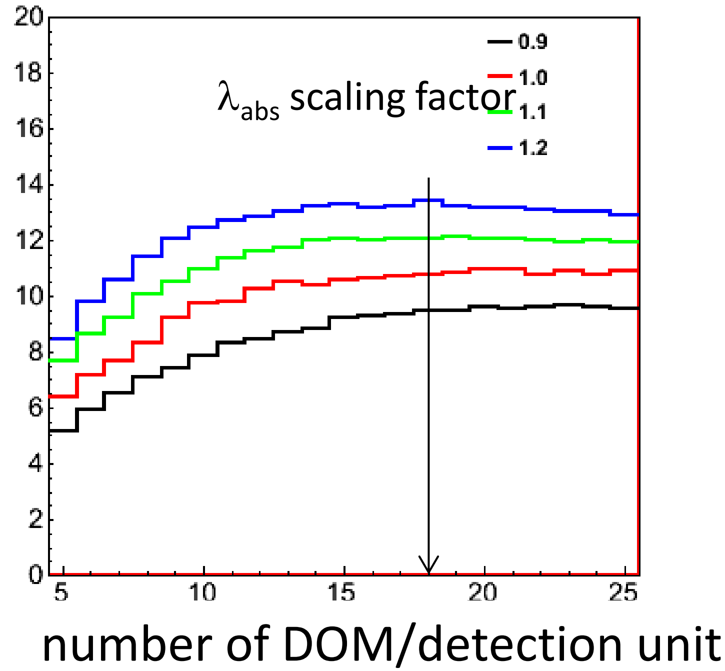
installation requires ship + ROV

all-data-to-shore concept



KM3NeT geometry optimisation: detector building block





Building block = smallest detector with optimal efficiency
= 115 detection units, 18 OMs/detection unit
= 1/6 total size
= ~0.56 km^3 with 90 m spacing and R=500 m
(=~0.95 km^3 with 120 m spacing and R=650 m)

KM3NeT Optical Module

Segmented cathode area: 31 x 3” PMTs

Light concentrator ring

Cathode area: ~ 3 x 10-inch PMT

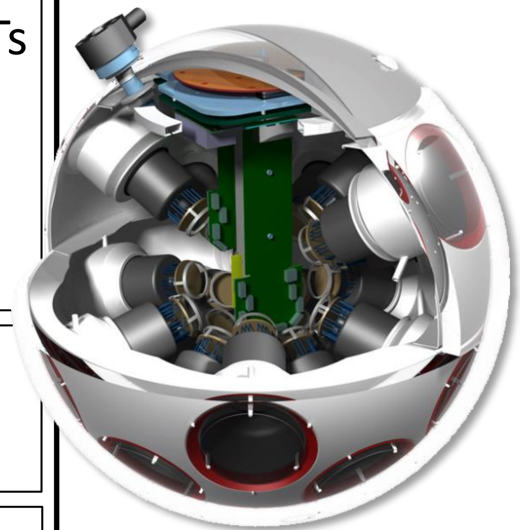
Custom low-power HV bases

LED & piezo inside

Compass and tiltmeter inside

PMT ToT measurements

FPGA readout, optical line terminator



ETEL D792

Hamamatsu R12199

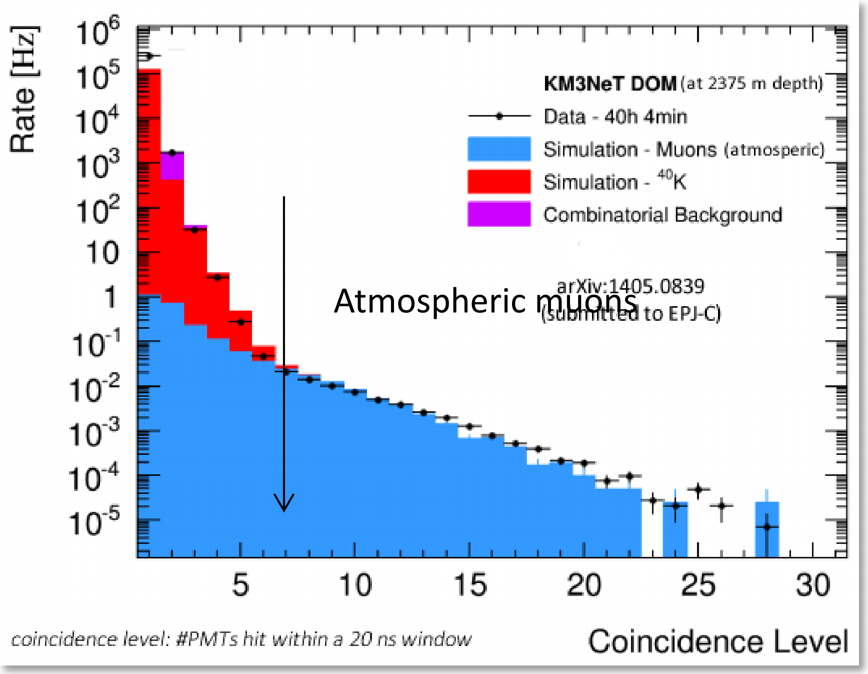
HZC XP53B20

In-situ prototype operational since April 2013

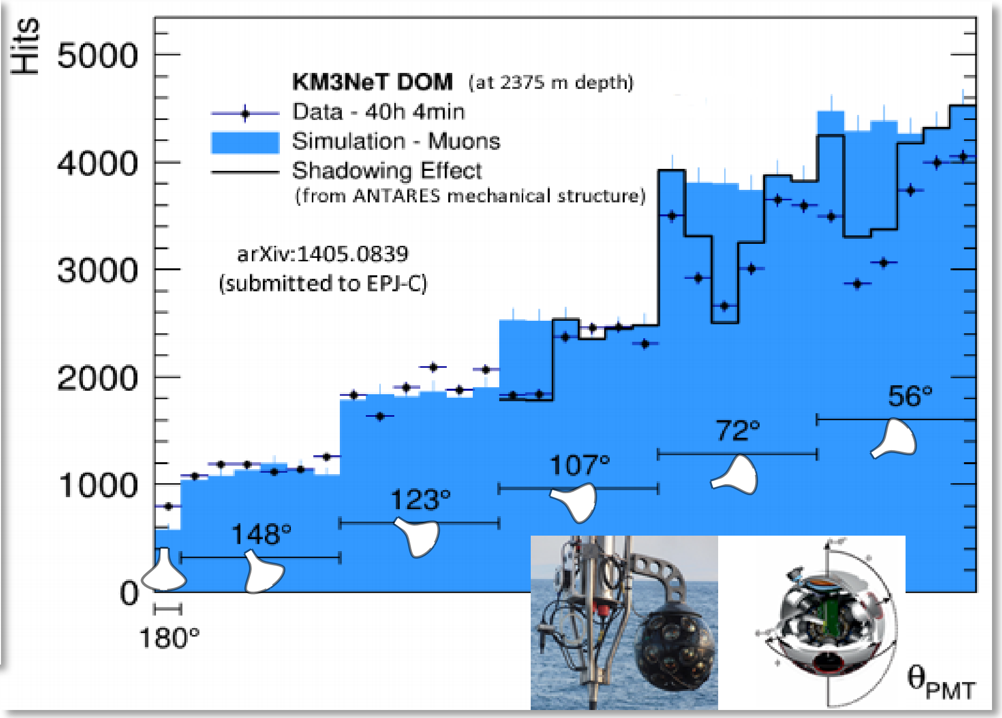
inside ANTARES at a depth of 2375 m
(close to KM3NeT-Fr site)

Results from prototype optical module

✓ photon counting



✓ directionality



PMT orientation

KM3NeT detection unit

String-type with 18 optical modules

~36 m between optical modules

Lowest optical module ~100 m above seabed

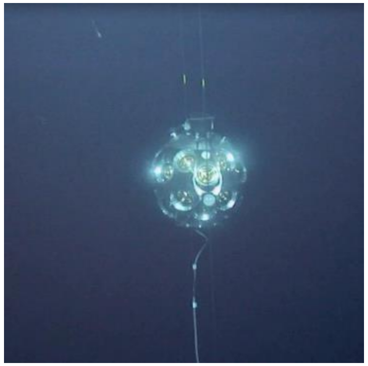
Two Dyneema® ropes

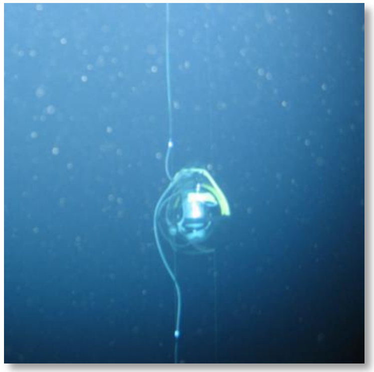
Backbone: 2 copper conductors; 18 fibres (+spares)

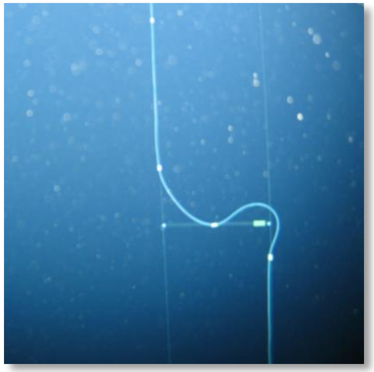
Break out of cable at each optical module

Base module with DWDM at anchor

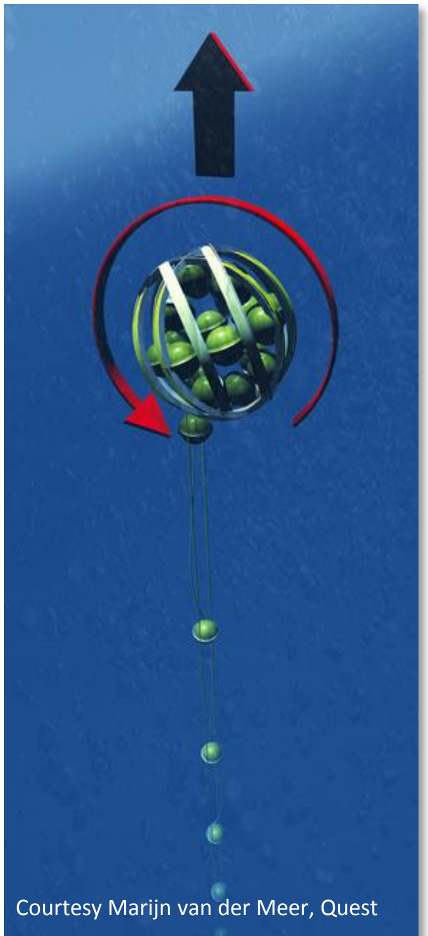
Cable for connection to seafloor network



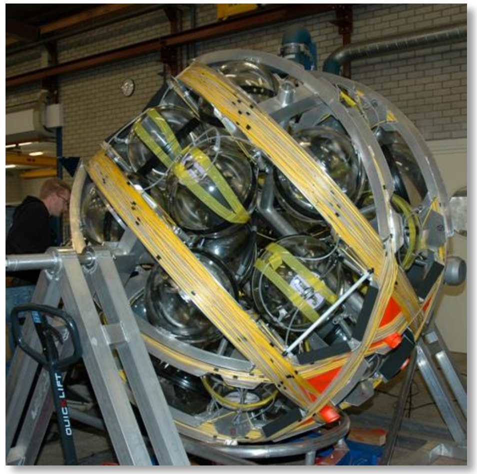


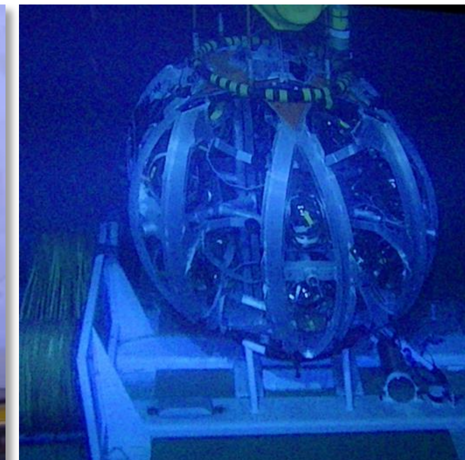


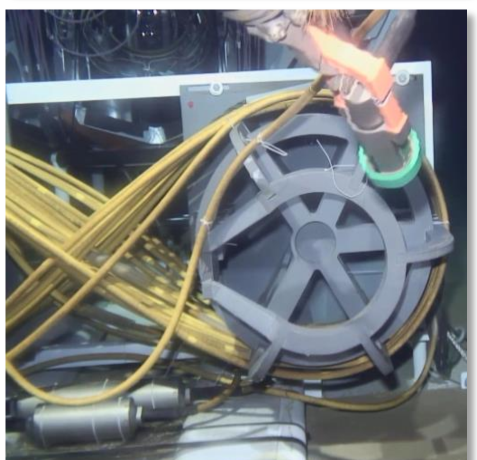
KM3NeT installation method

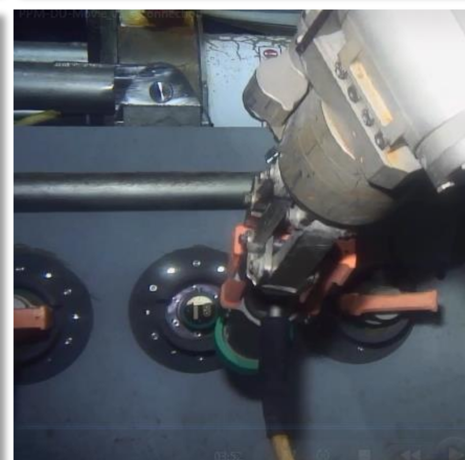


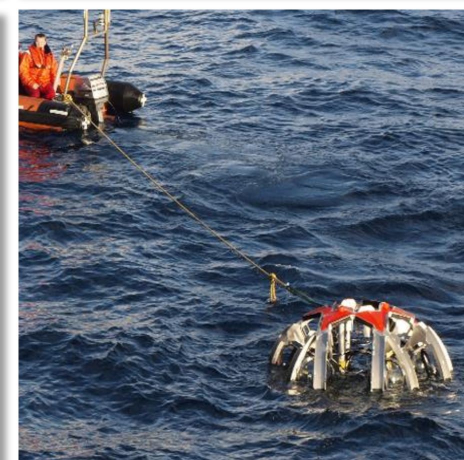
Courtesy Marijn van der Meer, Quest



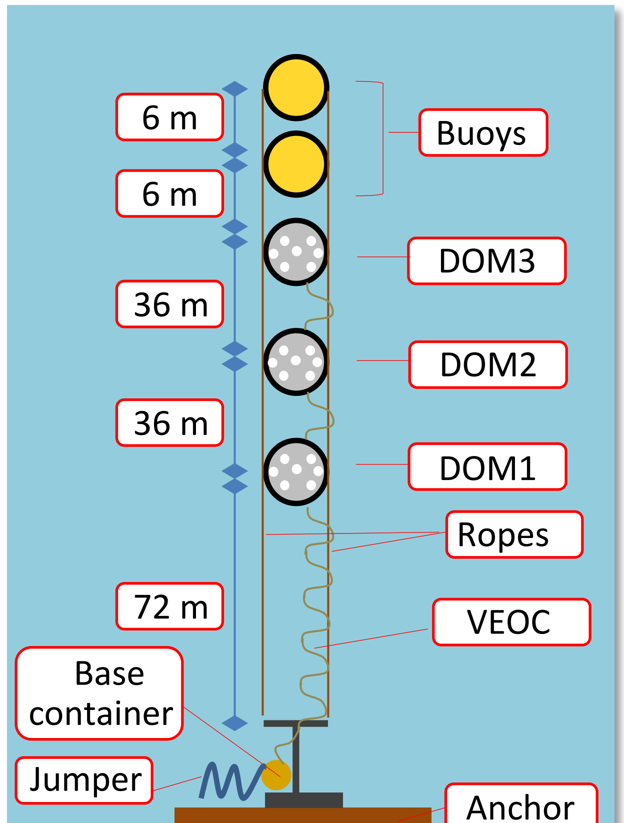


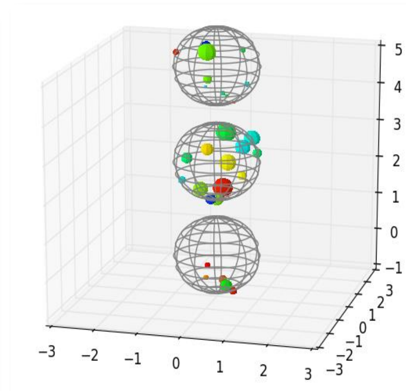


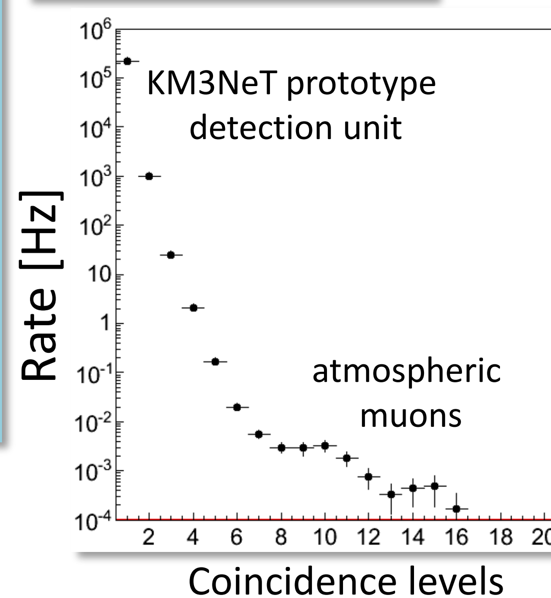




In-situ prototype detection unit operational since May 2014

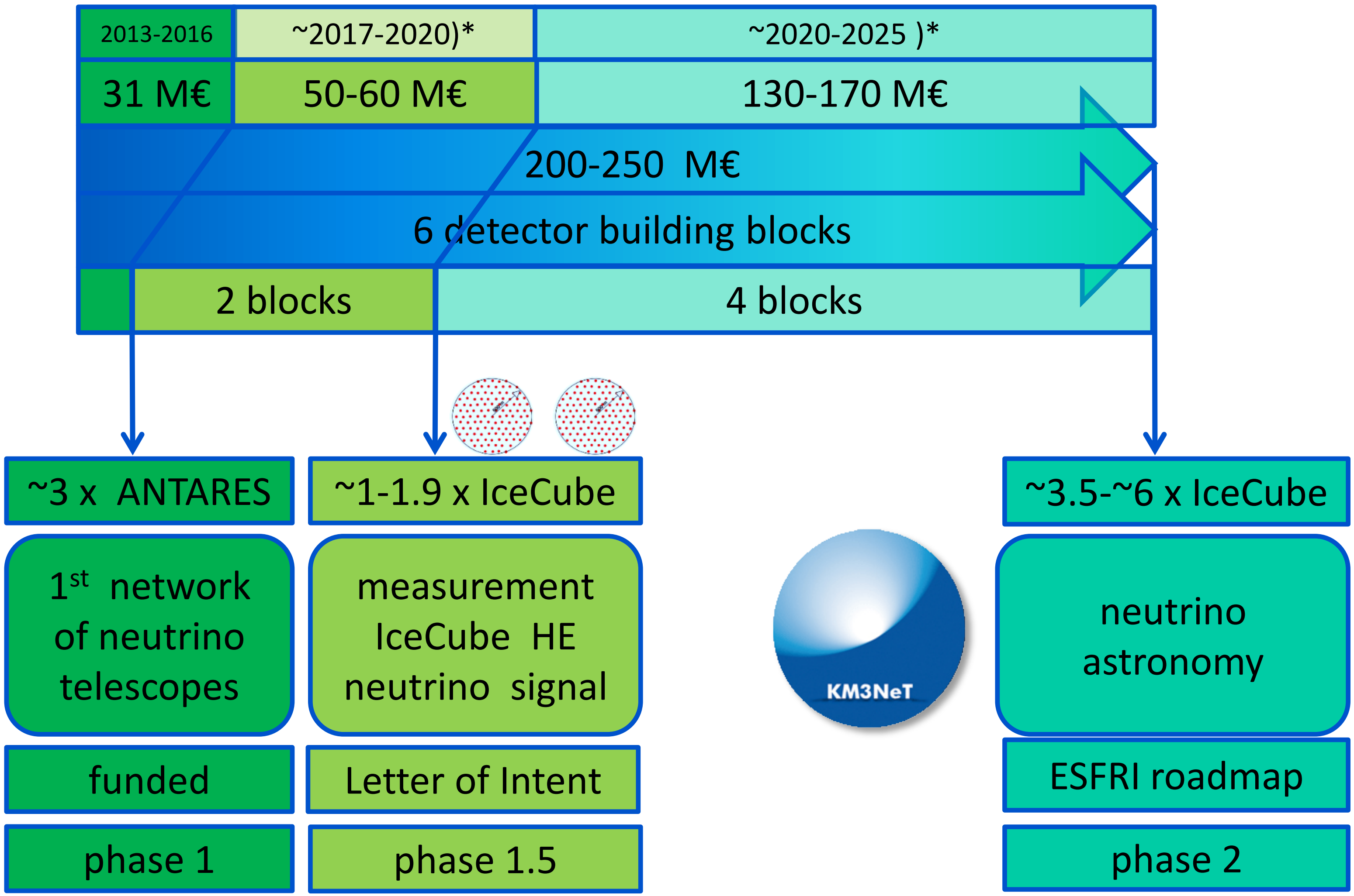






at KM3NeT-It site
depth of 3500 m, 100 km off-shore

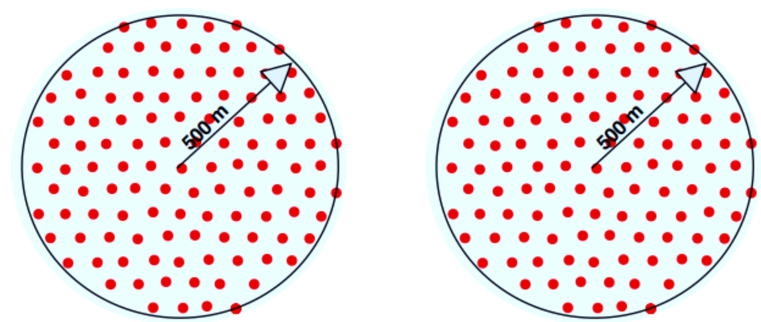
KM3NeT phased construction



)* depending on funding

KM3NeT-phase1.5

2 building blocks



2 building blocks each with 115 detection units
~1 - ~1.9 km^3
(depending on spacing of the detection units)

Cascade analysis

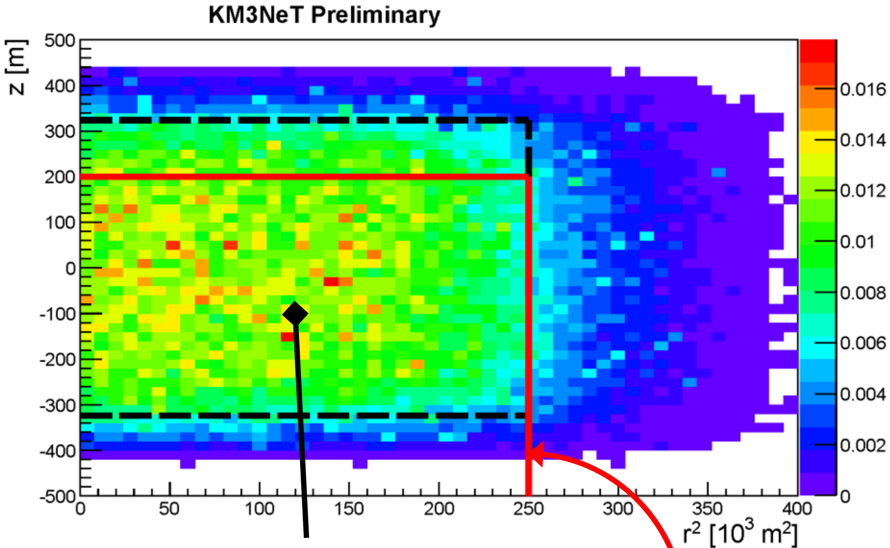
Cascade analysis: "cut and count"

Event selection:

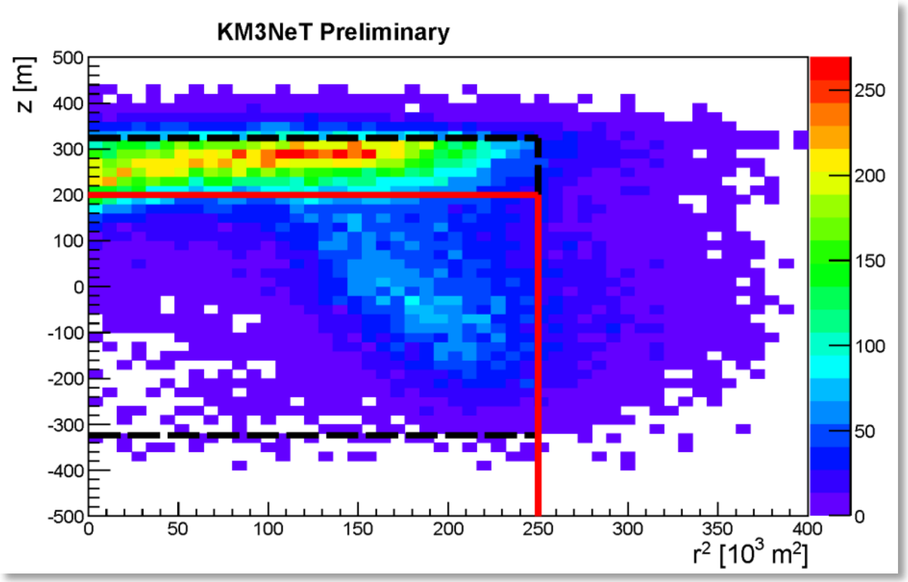
1. ≥ 5 coincidences between PMTs in same optical module (ΔT=10 ns)
2. Event filter: number of hits ≥ 2000 to remove ^{40}K background
3. Vertex cut: veto against atmospheric muons
4. Energy cut: total time-over-threshold ≥ 15 μs
5. MRF/MDP cut: 2D-cut based on Boosted Decision Tree & energy estimate

Cut on vertex

cosmic neutrinos



atmospheric muons



detector volume
(1 block, R=500 m)

vertex cut

Cascade analysis

Cascade event selection:

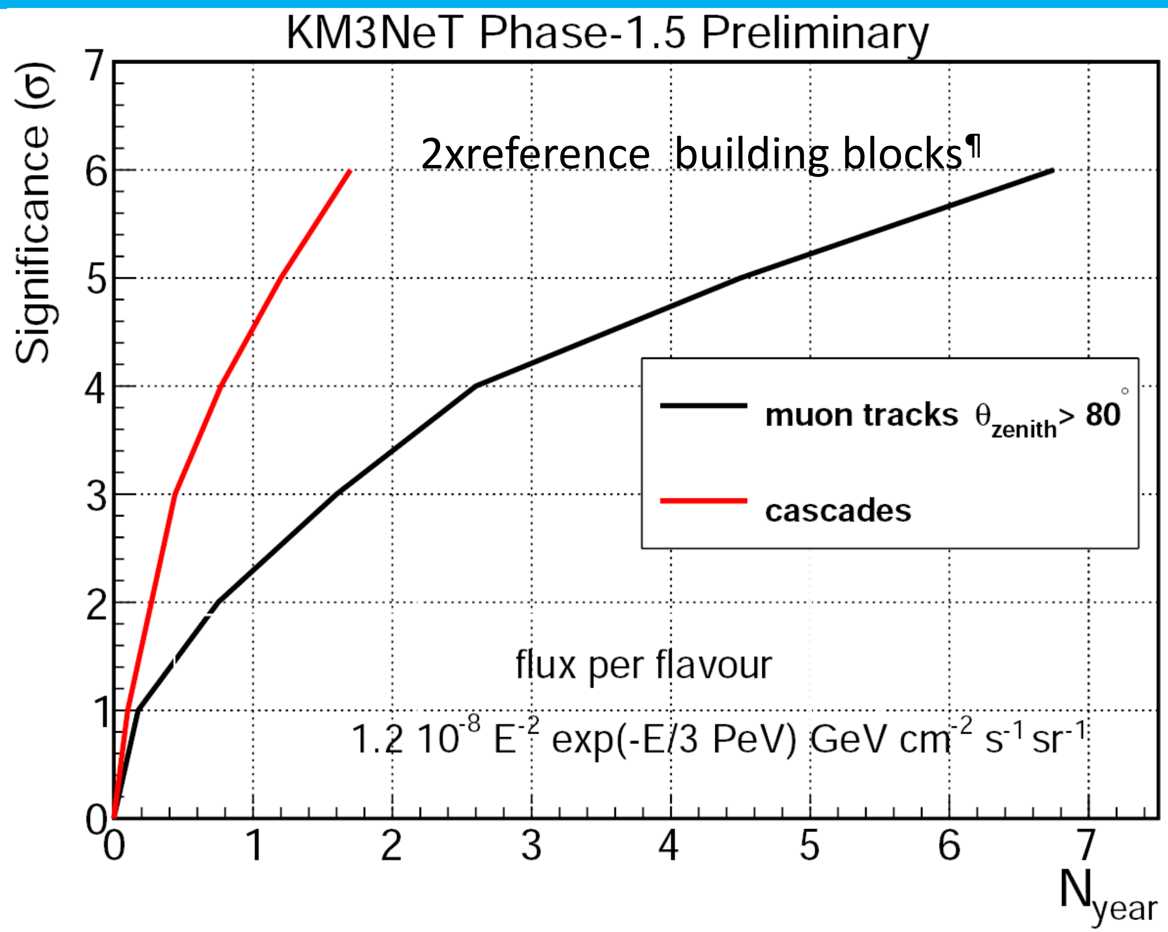
1. Online data filter: ≥ 5 coincidences between PMTs in same optical module (ΔT=10 ns)
2. Event filter: number of hits ≥ 2000
3. Vertex cut: veto atmospheric muons
4. Energy cut: total time-over-threshold ≥ 15 μs
5. MRF/MDP cut: 2D-cut based on Boosted Decision Tree & energy estimate

Cascade event reconstruction (work in progress):

- Results of two different algorithms are in agreement
- Recent improvements indicate resolutions for E > 100 TeV: direction approaching 1°, energy within 10%

→ Astronomy with cascade events seems feasible

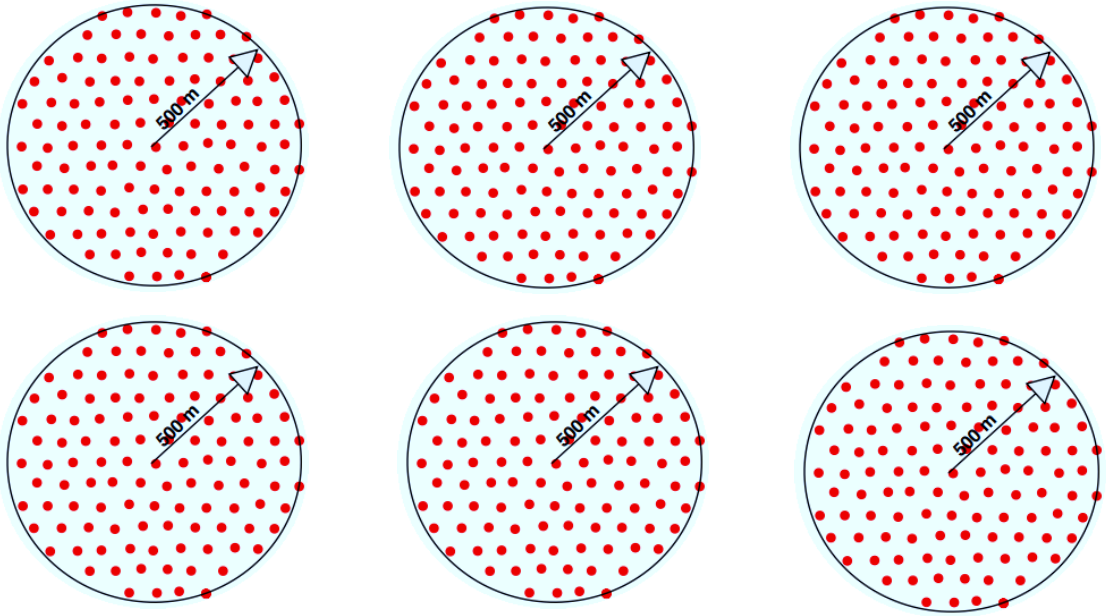
Performance



Detailed investigation of „IceCube signal“ within a few years, with different *field of view*, different *systematics* and better *angular resolution*

¶ 30% better FoM with HE blocks with 120 m spacing and R=650 m.

KM3NeT (-phase2)

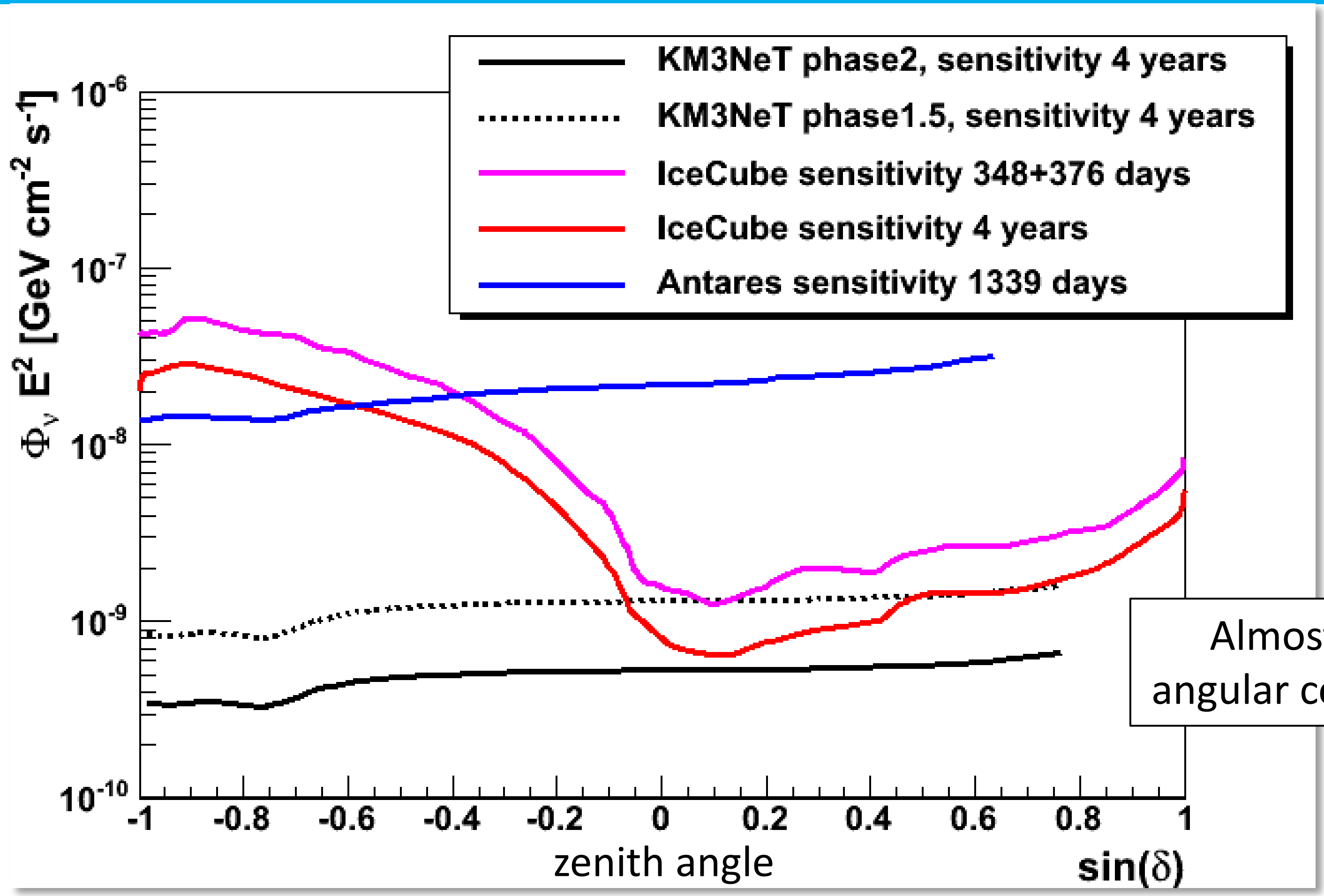


6 building blocks each with 115 detection units

~3.5 km^3 - ~6 km^3

(depending on spacing of the detection units)

Point source sensitivity

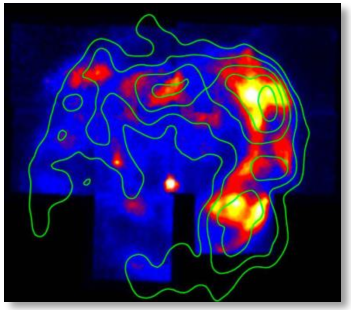


Almost full angular coverage

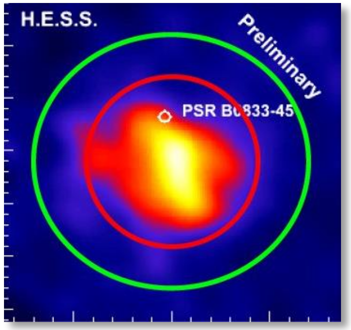
Assumptions: E^{-2} spectrum; unknown position

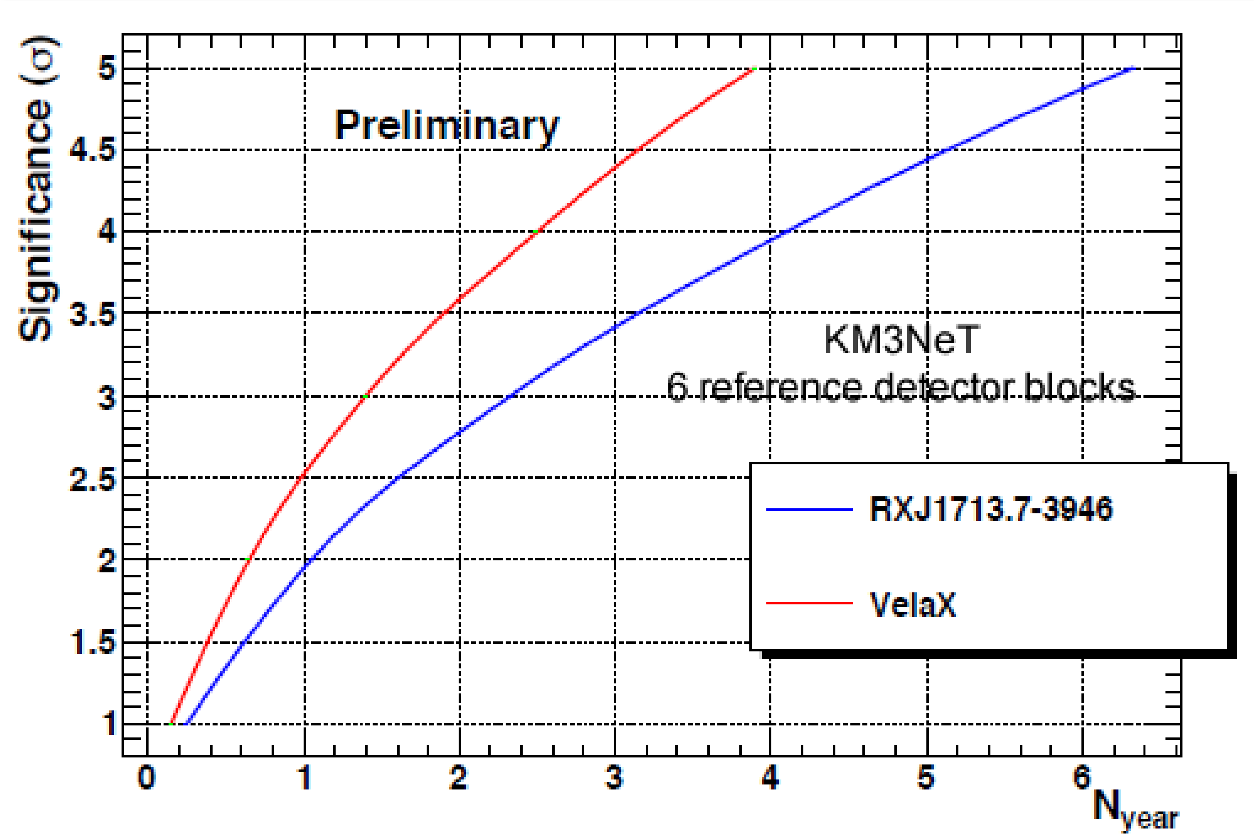
Sensitivity to galactic sources

RXJ1713[¶]



Vela X[§]

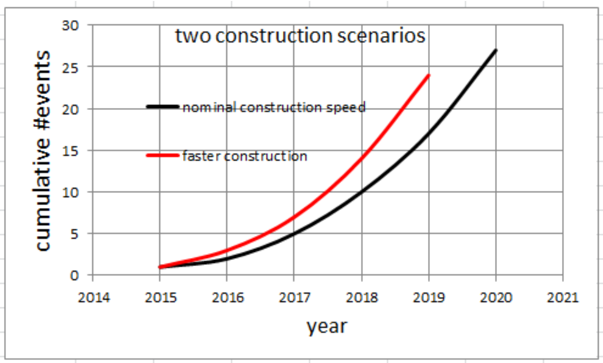




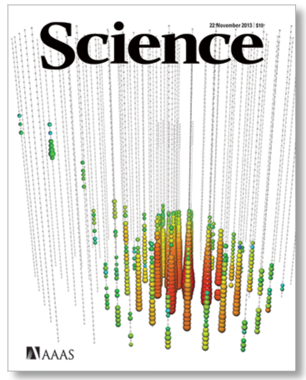
[¶] S.R. Kelner, *et al.*, Phys. Rev. D 74 (2006) 034018.

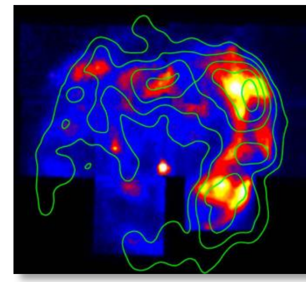
[§] F.L. Villante and F. Vissani, Phys. Rev. D 78 (2008) 103007.

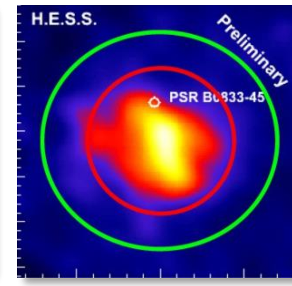
KM3NeT+GVD outlook for neutrino astronomy

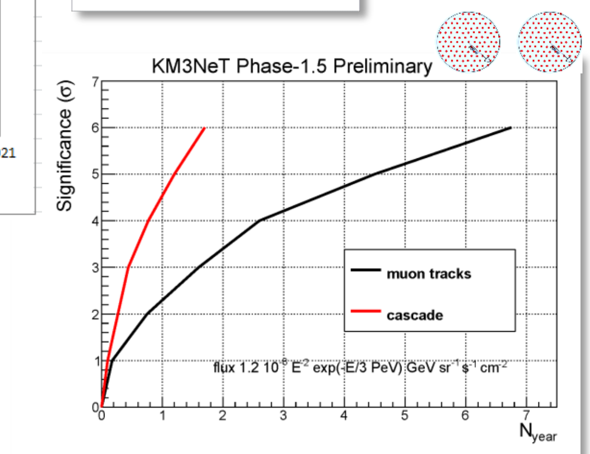


10 cluster GVD



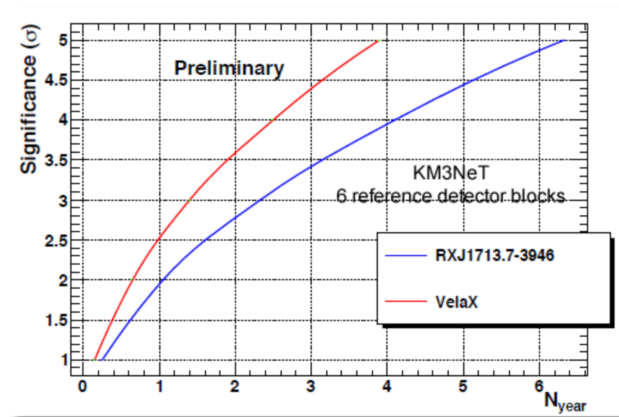






KM3NeT-phase1.5

(+50-60 M€)



KM3NeT-phase2

(+130-170 M€)

and ORCA for neutrino physics – see talk by Salvatore Galata

THE LAKE BAIKAL NEUTRINO TELESCOPE

KM3NeT

Opens a new window on our universe