



ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS



KM3NeT and ORCA: Status and future plans

Thomas Eberl



Alliance for Astroparticle Physics

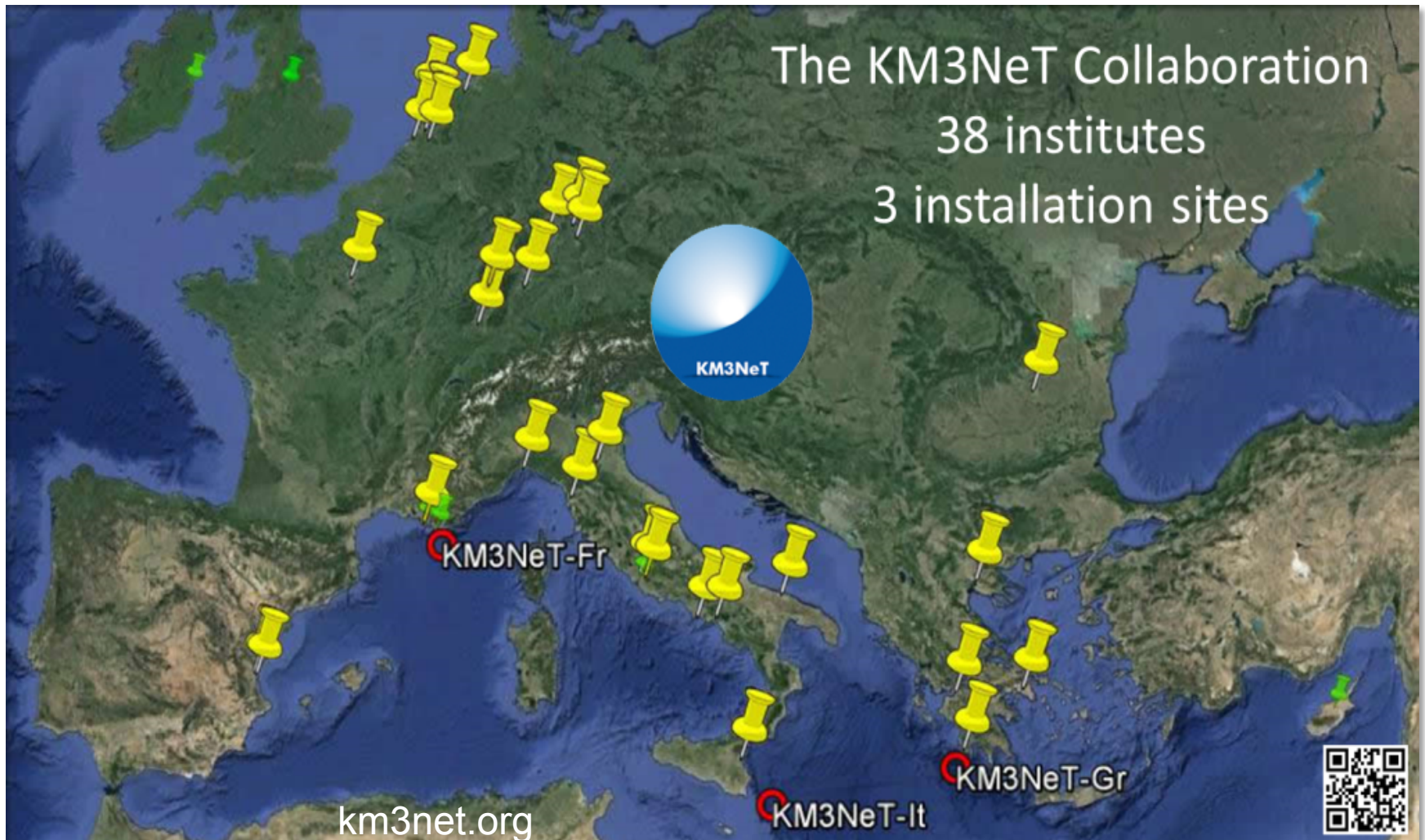


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Astroteilchenphysik in Deutschland - Status und Perspektiven

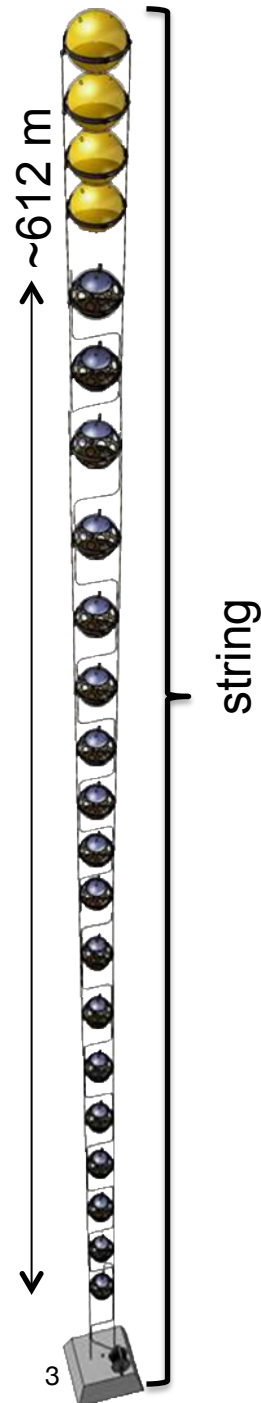
KIT, Karlsruhe, 30. September 2014

KM3NeT: a distributed multi-purpose research infrastructure

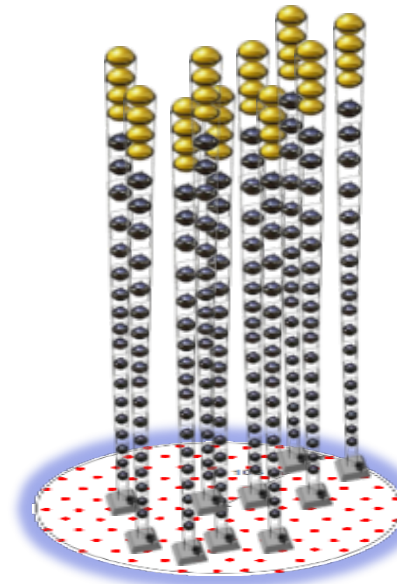
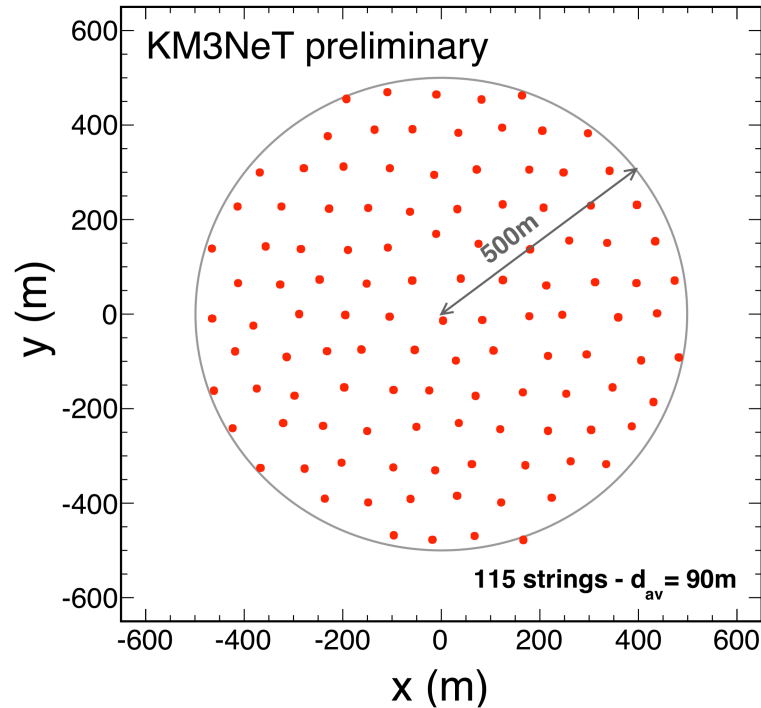


KM3NeT: neutrino telescope design

- 6 building blocks, 6 cables to shore
- 115 strings per block
- 18 optical modules (DOMs) per string
- 31 photomultiplier tubes (PMTs) per DOM
- Power and data transmission infrastructure on seabed, all-data-to-shore concept
- Installation requires ship and remotely operated submersible
- Building block design allows for phased implementation!



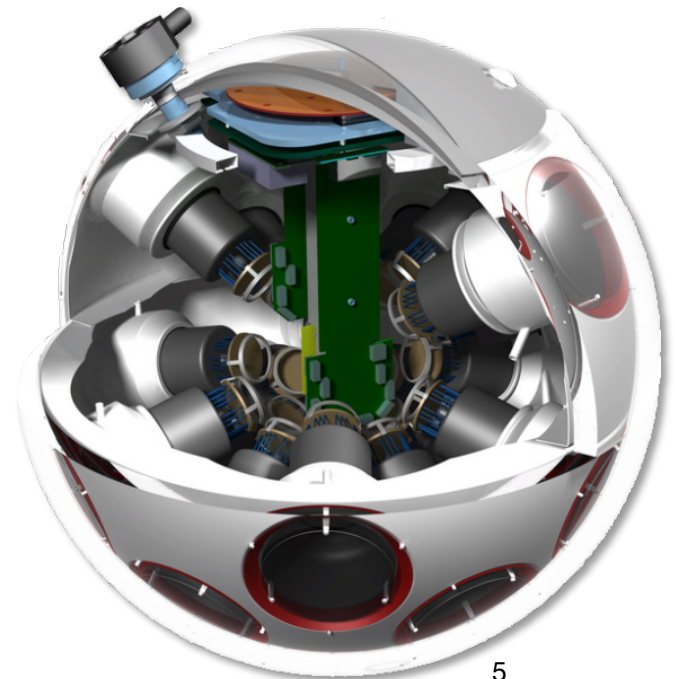
KM3NeT: detector building block



- Instrumented volume:
 $V \sim 0.5 \text{ km}^3$ for 90 m average spacing, 500 m radius, height 612 m
- Depths: $\sim 2500 - 4500 \text{ m}$
- Distance to shore: $\sim 40 - 100 \text{ km}$

KM3NeT: optical module

- 17-inch glass sphere
- Segmented cathode area with 31 x 3-inch PMTs, 19 down, 12 up
- Light concentrator ring
- LED and piezo inside sphere for time and position calibration
- Compass and tiltmeter inside sphere for orientation calibration

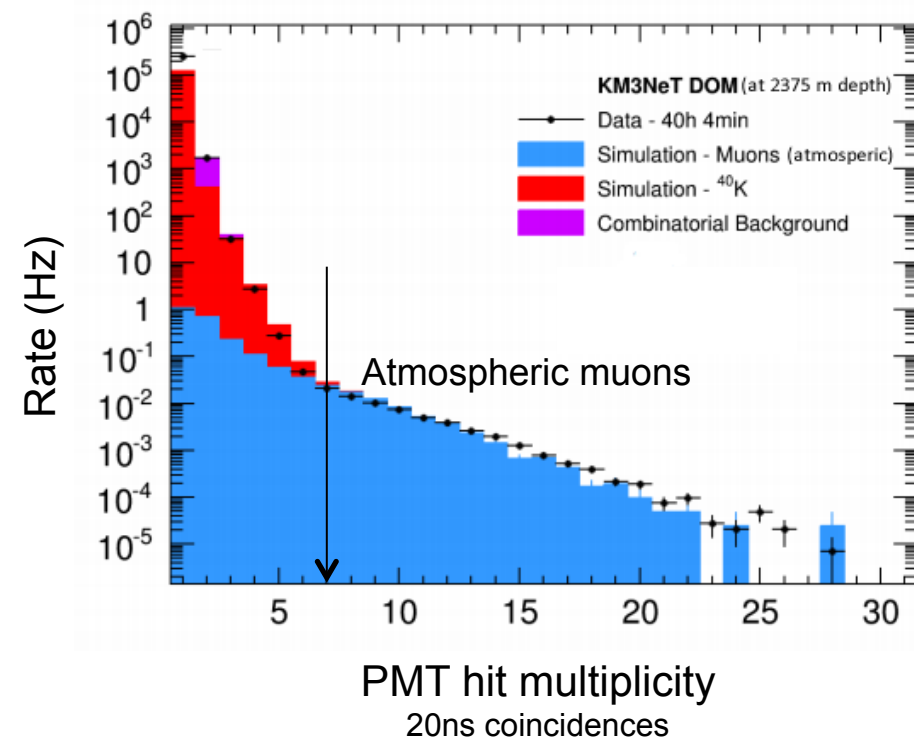


KM3NeT: in-situ OM prototype

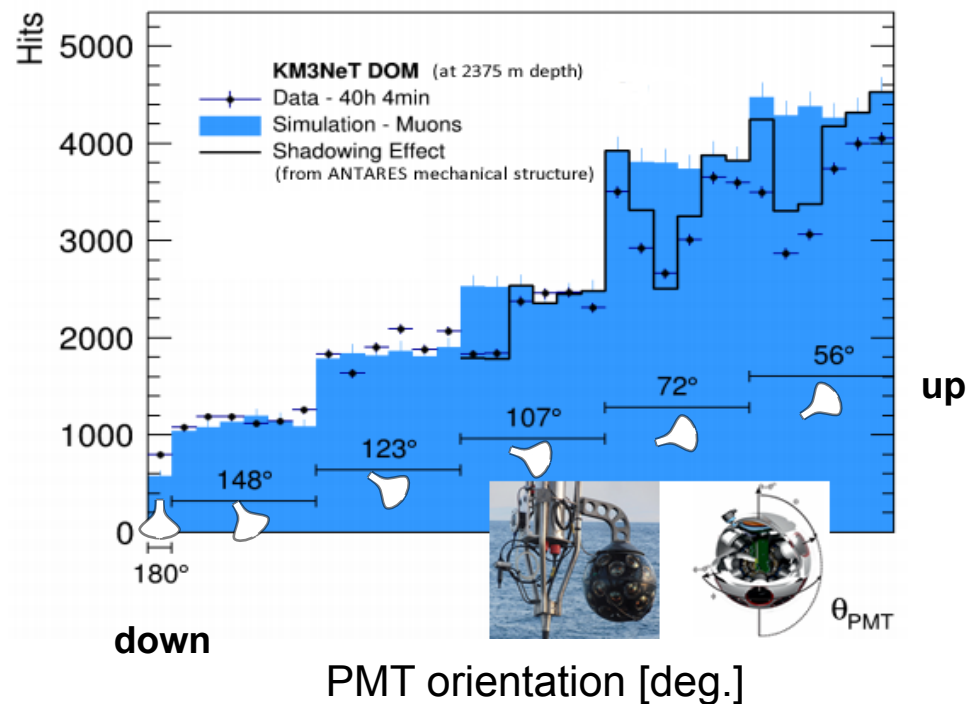
- Single OM prototype on ANTARES line, at -2375 m
- Preliminary electronics
- Deployed April 2013, working since 17 months!



<http://arxiv.org/abs/1405.0839>
accepted by EPJ



✓ photon counting



✓ directionality

KM3NeT: plans and status of phase 1

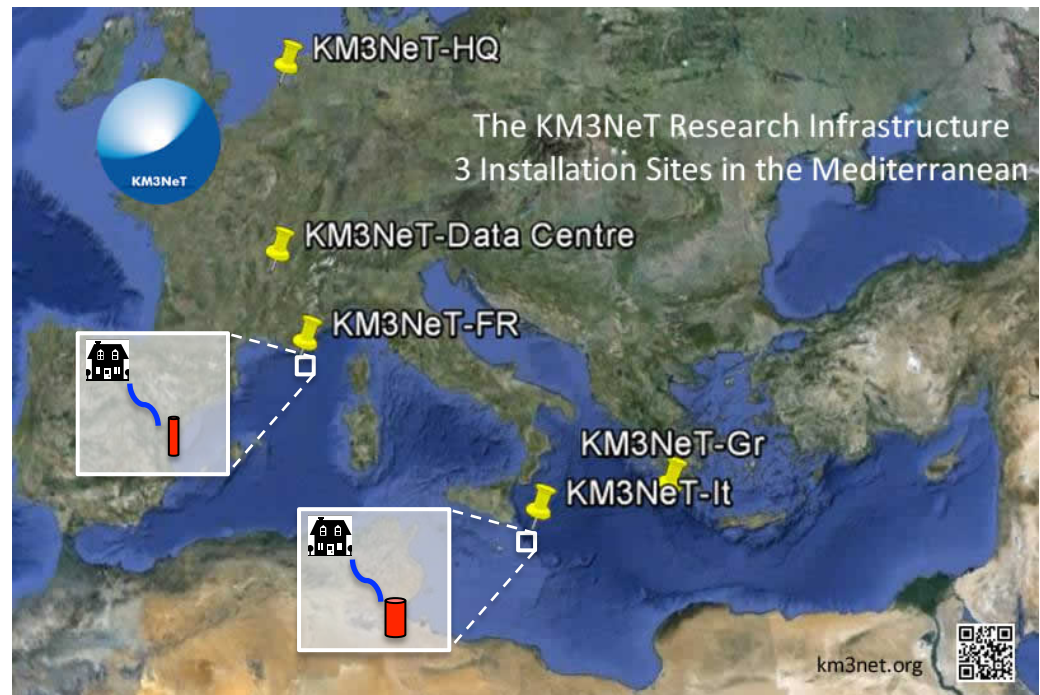
- 24 strings at KM3NeT-It (1/5 of full block, Capo Passero)
- 7 strings at KM3NeT-Fr (Toulon)
- > 3x ANTARES sensitivity

Status:

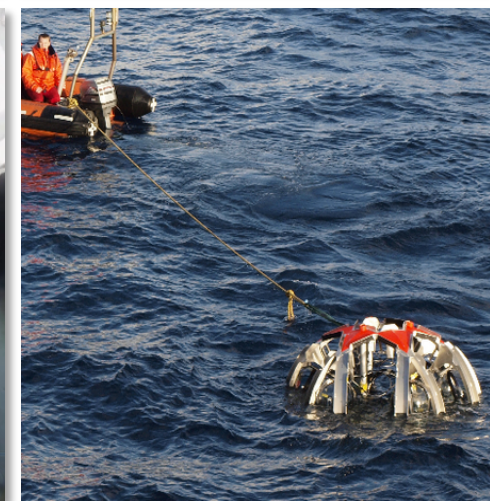
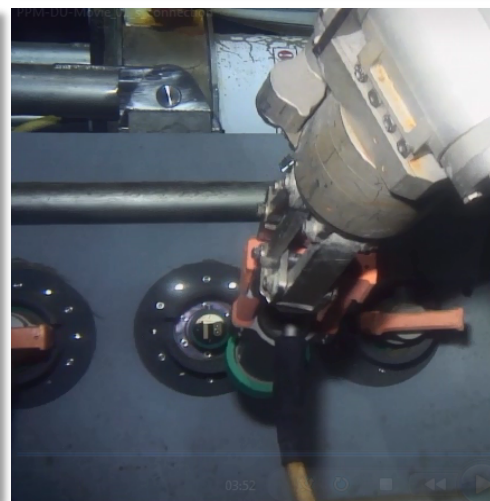
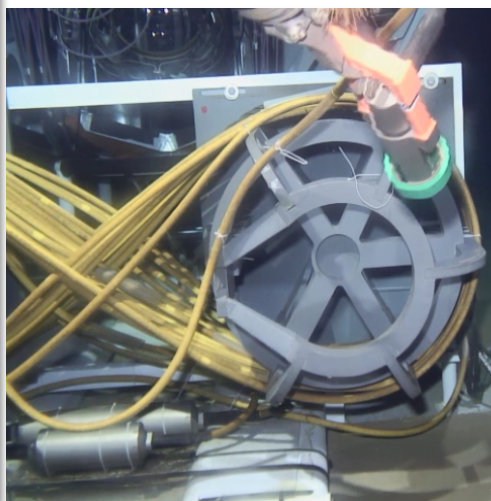
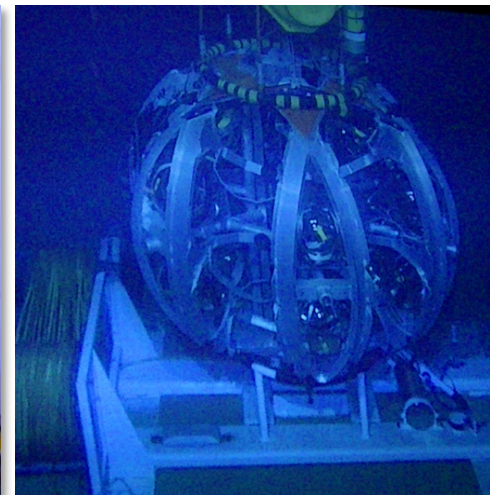
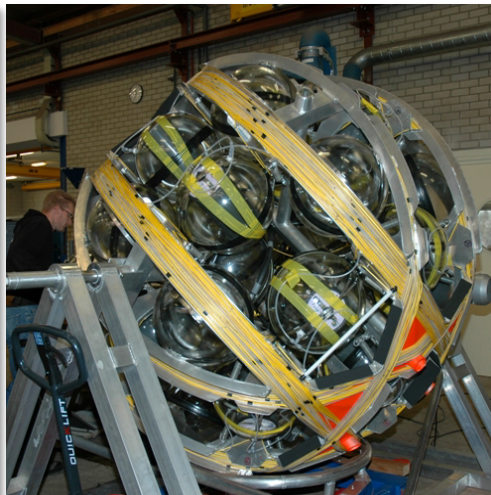
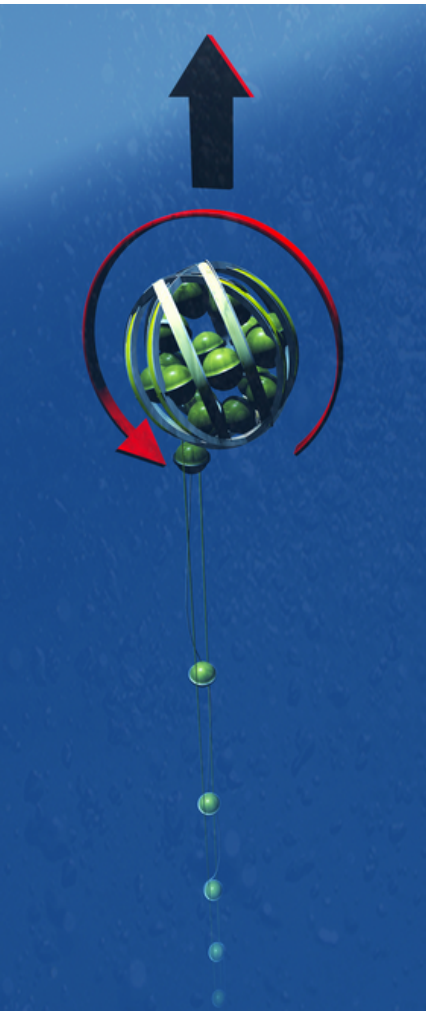
- Funded
- Construction begun
- Completion 2016

Goals:

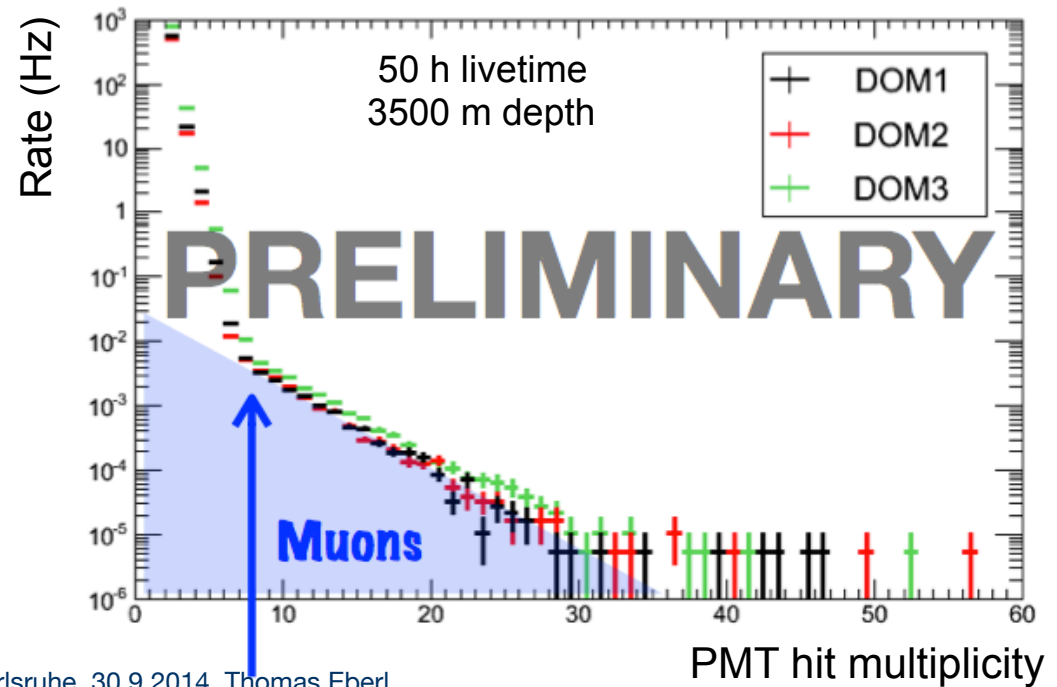
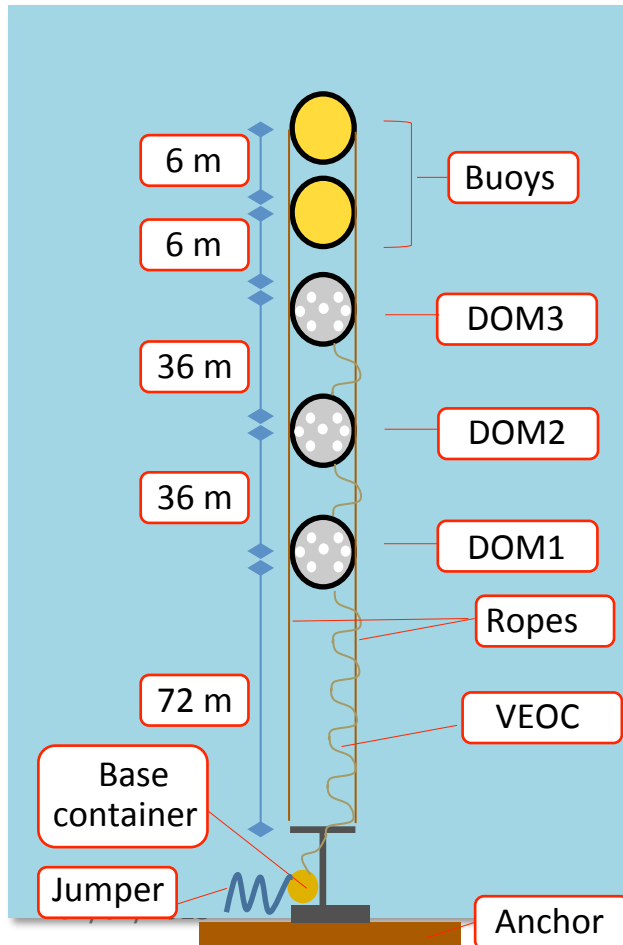
- Proof of technology
- Validation of distributed detector concept



KM3NeT phase 1: deployment of test string, 100 km off-shore Sicily at -3500 m



KM3NeT phase 1: in-situ prototype string operational since May 2014



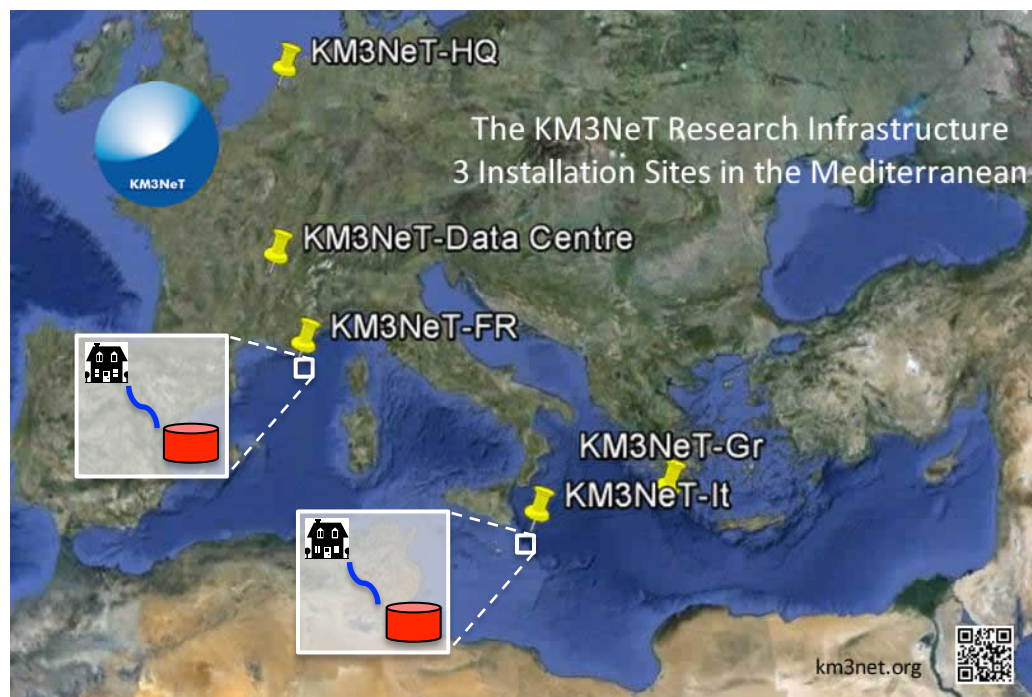
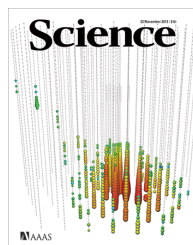
KM3NeT: phase 1.5

- 2 building blocks: KM3NeT-Fr (Toulon), KM3NeT-It (Capo Passero)
- „IceCube-scale“ detector

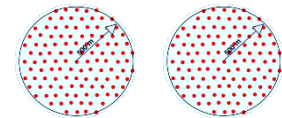
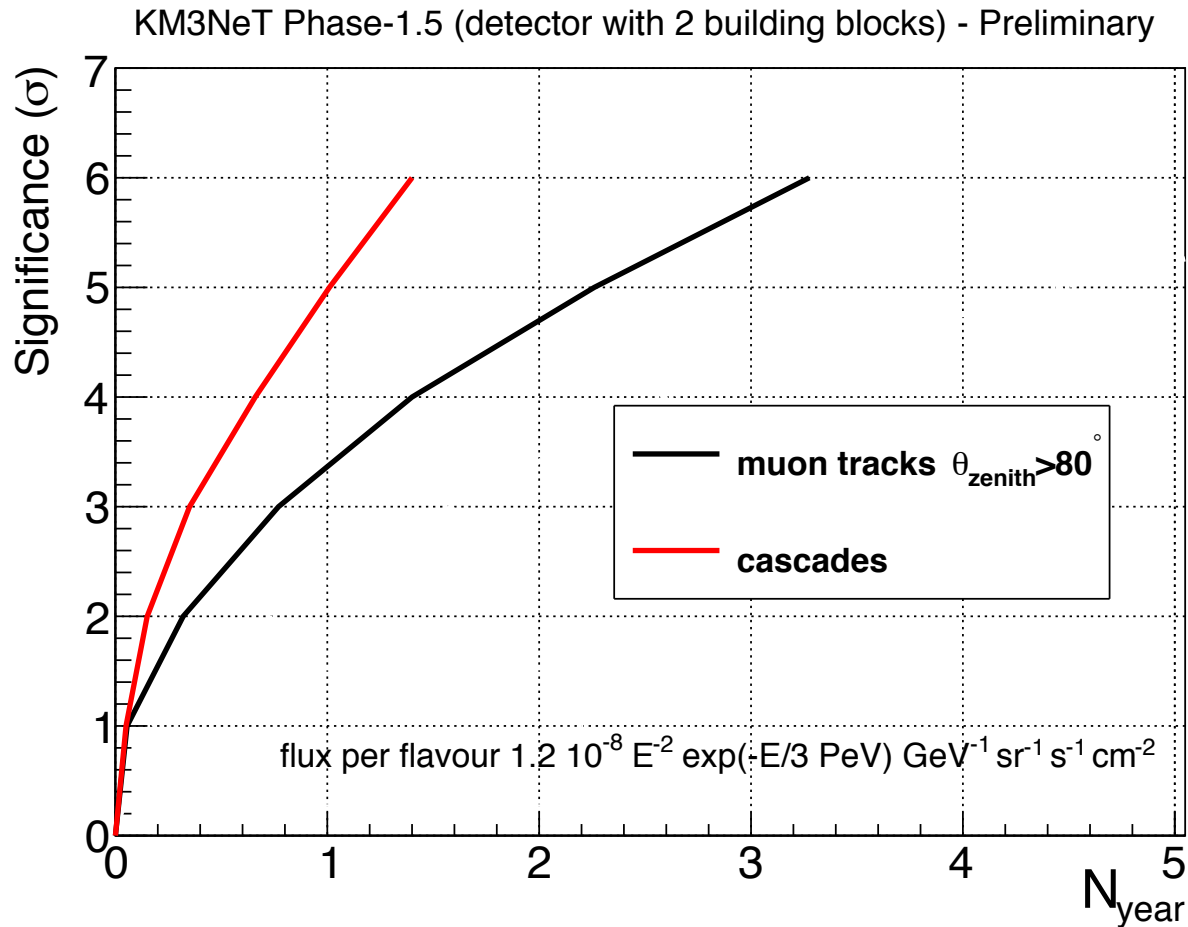
- Primary science goal:

Study IceCube signal with

- different detector
- different systematics
- different field of view



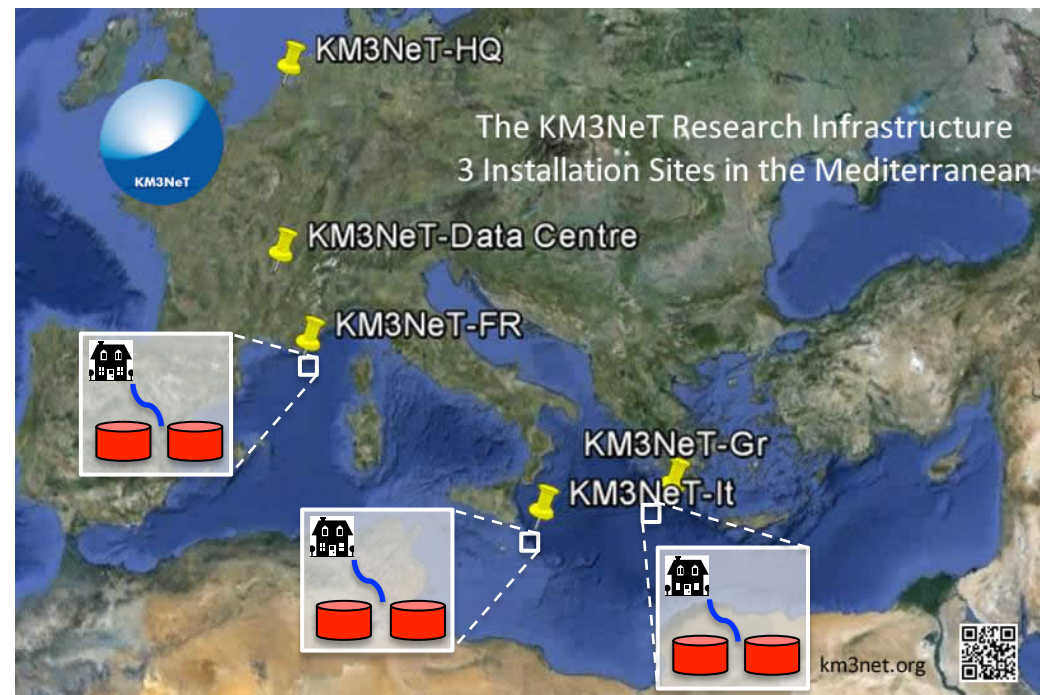
KM3NeT phase 1.5: sensitivity



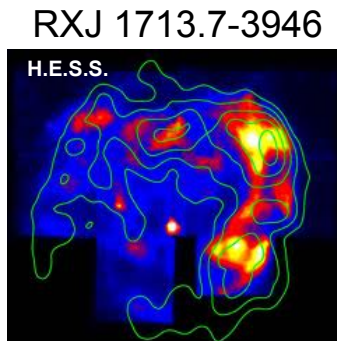
Detailed investigation of „IceCube signal“ within a few years, with different *field of view*, different *systematics* and better *angular resolution*

KM3NeT: phase 2

- 6 building blocks, 2 at each of KM3NeT-Fr (Toulon), KM3NeT-It (Capo Passero), and KM3NeT-Gr (Pylos)
- Volume > 3x IceCube
- Neutrino Astronomy:
 - Galactic point and extended sources
 - Diffuse flux



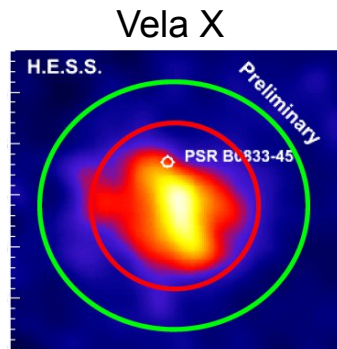
Searching for galactic neutrino sources



$$\Phi(E) = 1.68 \cdot 10^{-14} \left(\frac{E}{1 \text{ TeV}} \right)^{-1.72} \exp\left(-\sqrt{\frac{E}{2.1 \text{ TeV}}}\right) \text{ GeV cm}^{-2} \text{ s}^{-1}$$

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

- Spectrum expected to cutoff at a few TeV



$$\Phi(E) = 7.2 \cdot 10^{-15} \left(\frac{E}{1 \text{ TeV}} \right)^{-1.36} \exp\left(-\frac{E}{7 \text{ TeV}}\right) \text{ GeV cm}^{-2} \text{ s}^{-1}$$

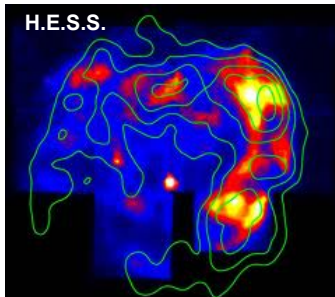
F.L. Villante and F. Vissani, Phys. Rev. D 78 (2008) 103007

- Spectrum expected to extend to higher energies

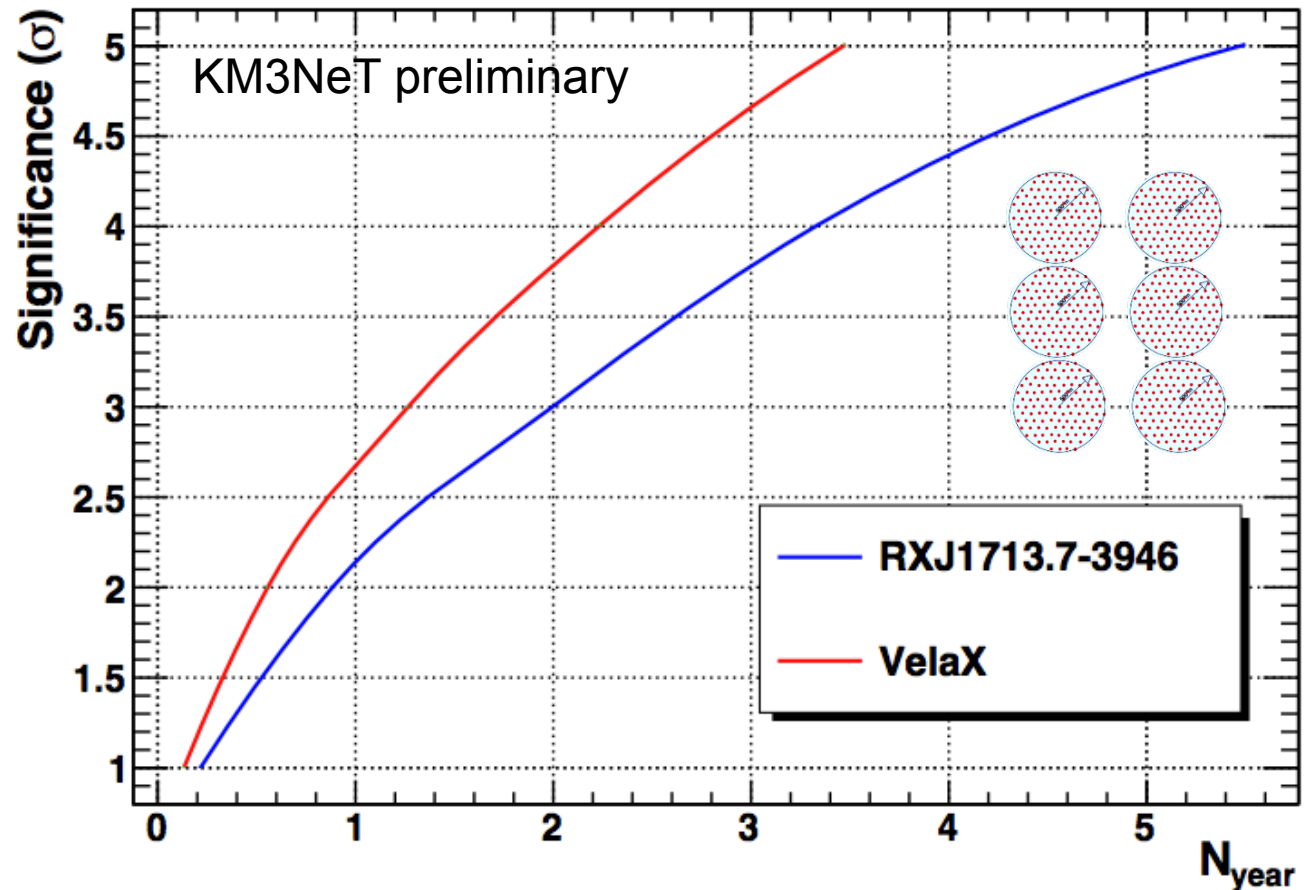
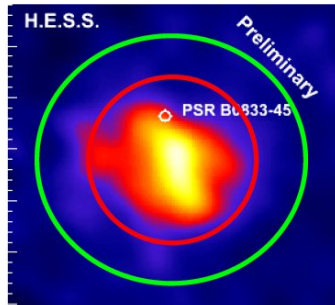
Excellent angular resolution removes random background!

KM3NeT phase 2: sensitivity to galactic sources

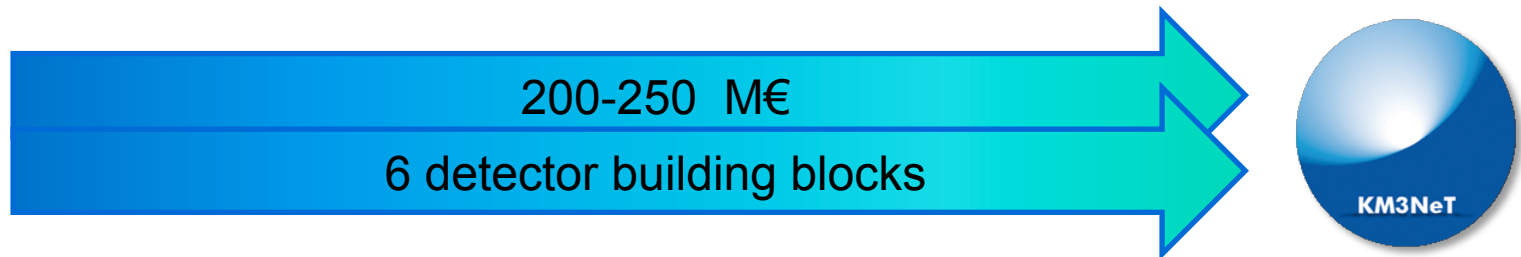
RXJ 1713



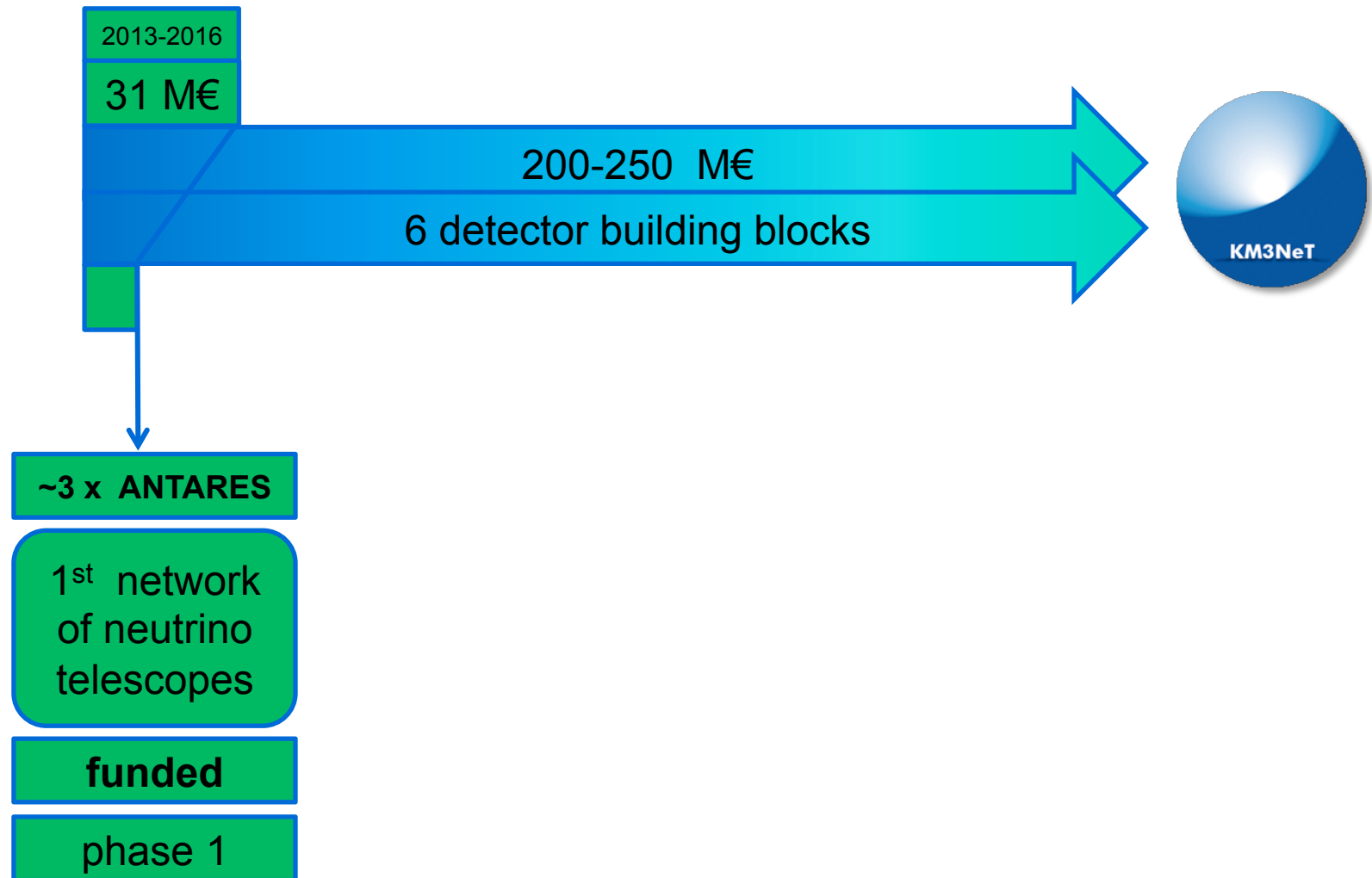
Vela X



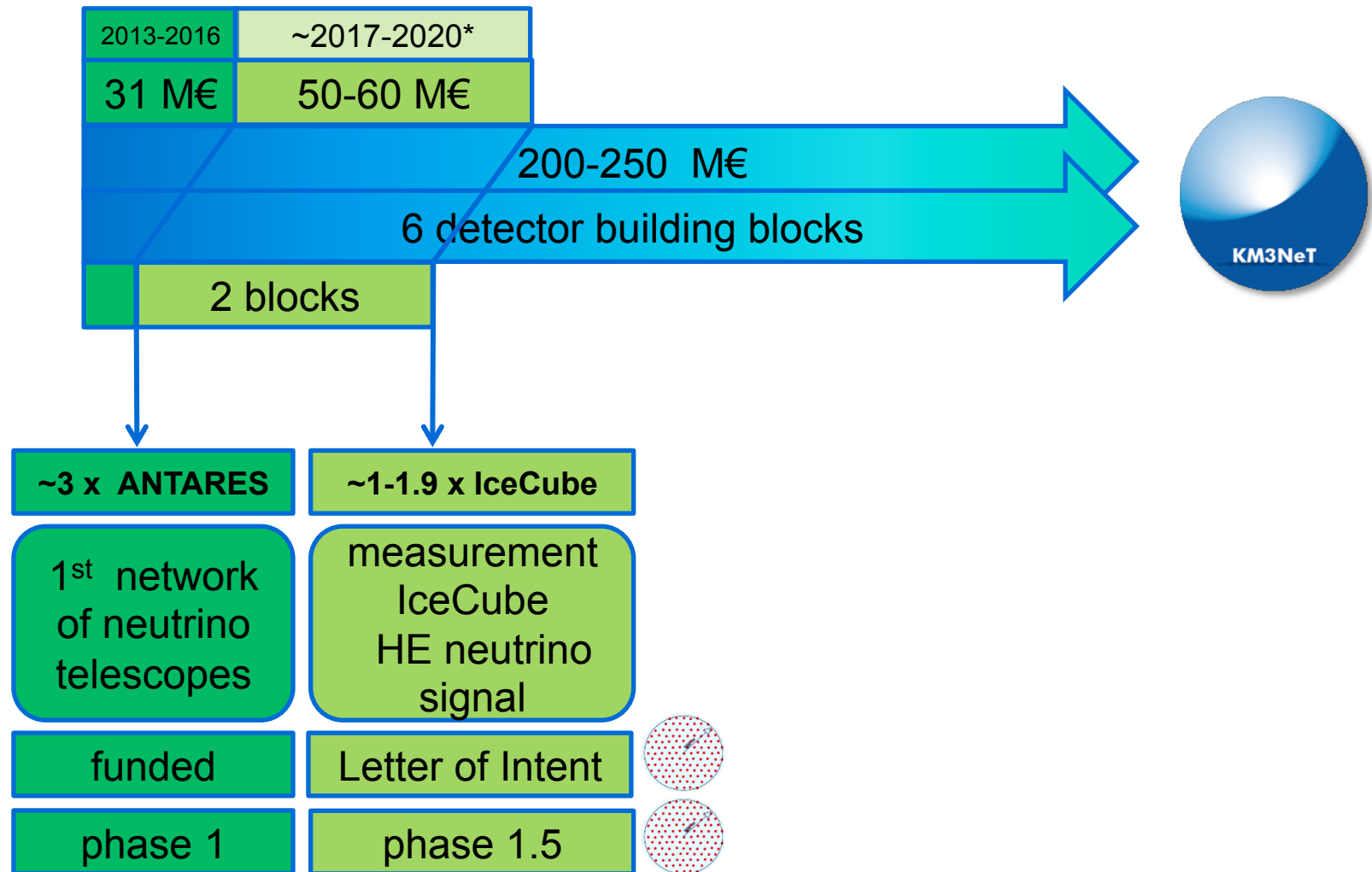
KM3NeT: phased construction



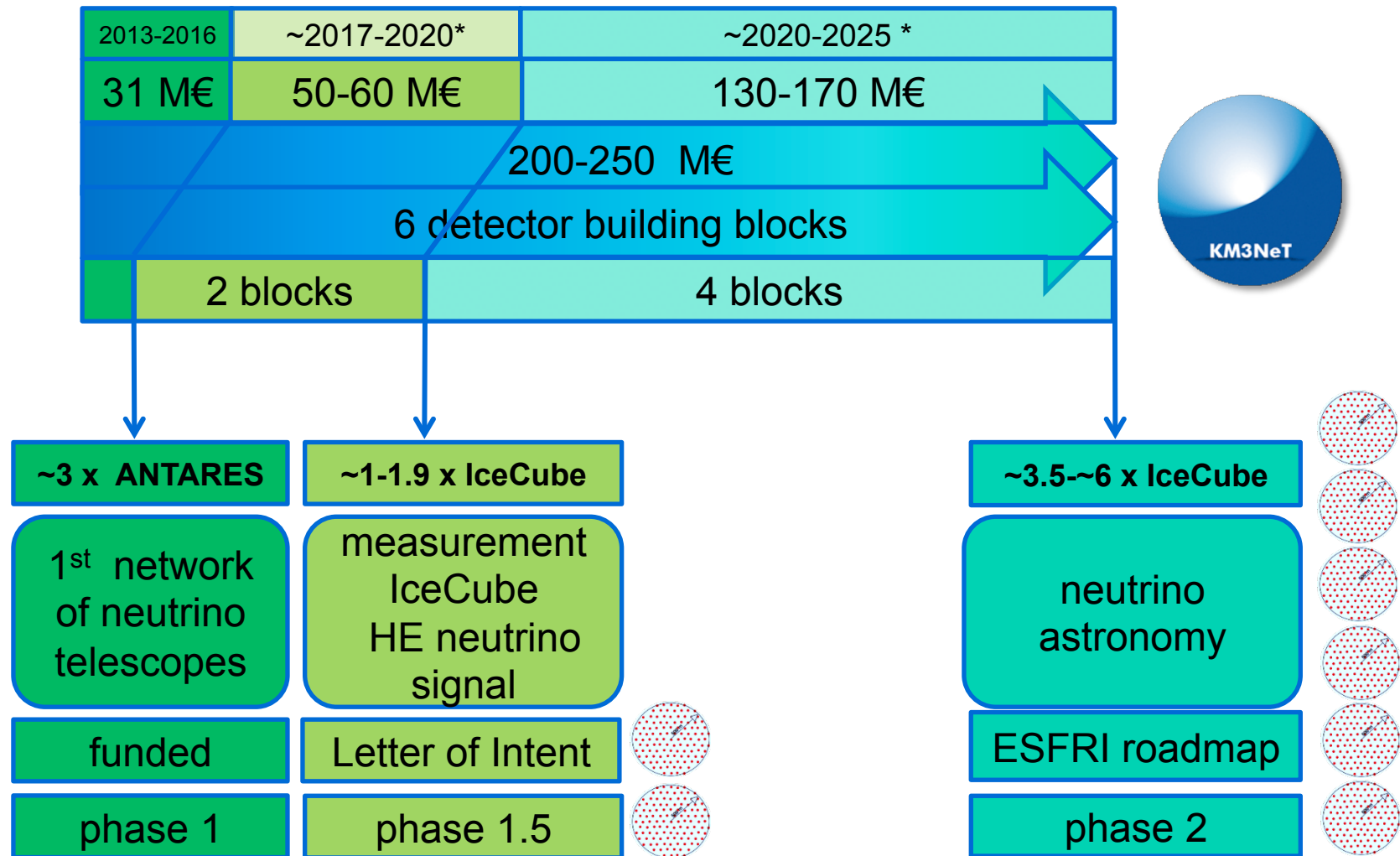
KM3NeT: phased construction



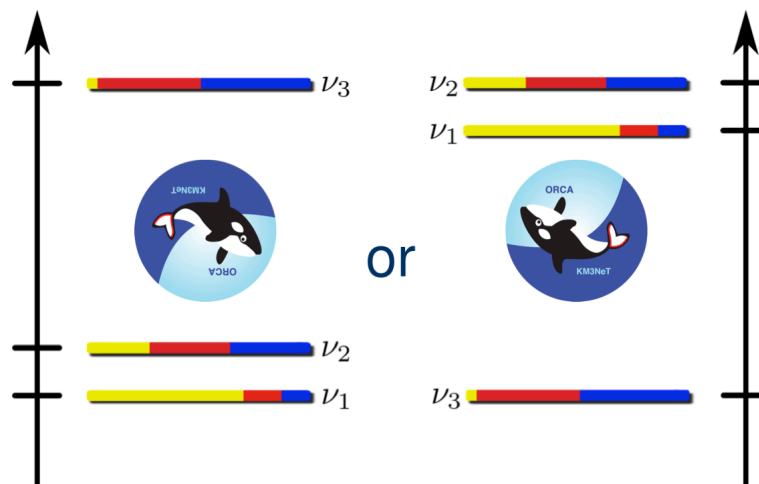
KM3NeT: phased construction



KM3NeT: phased construction

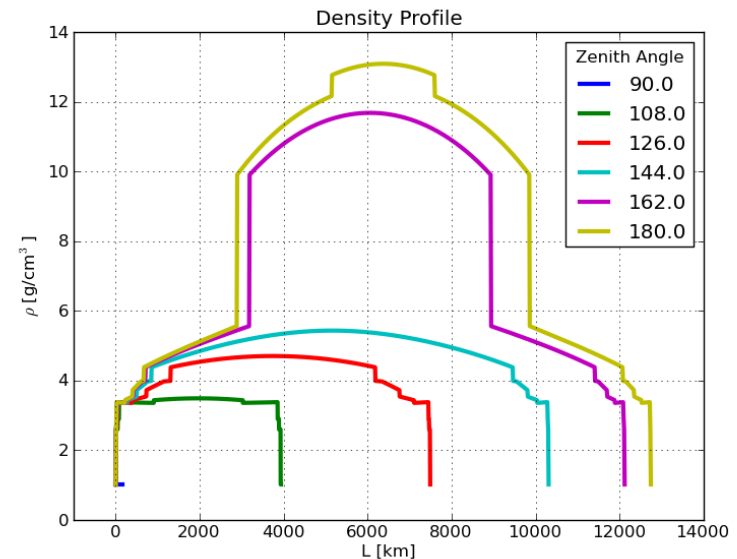
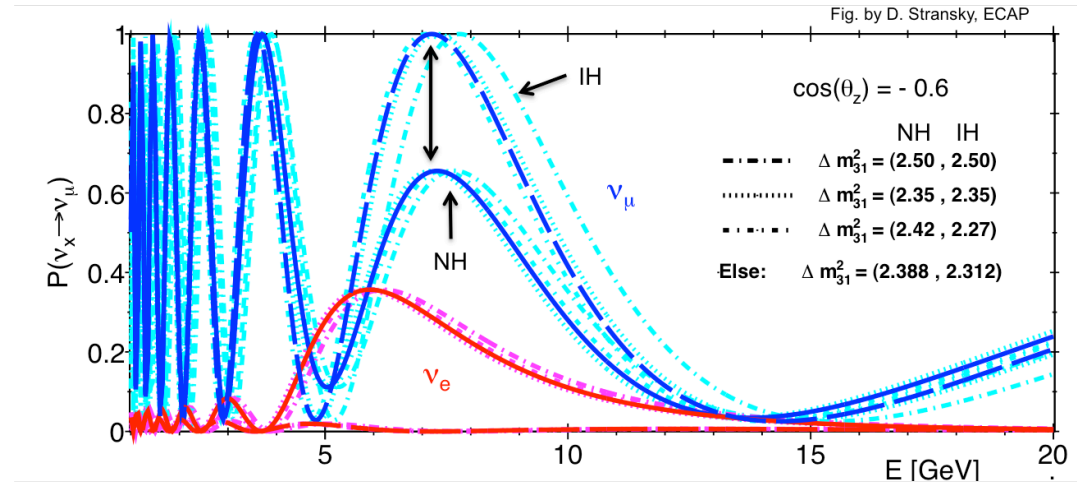


Oscillations with Cosmics in the Abyss (ORCA): Determining the neutrino mass hierarchy with KM3NeT



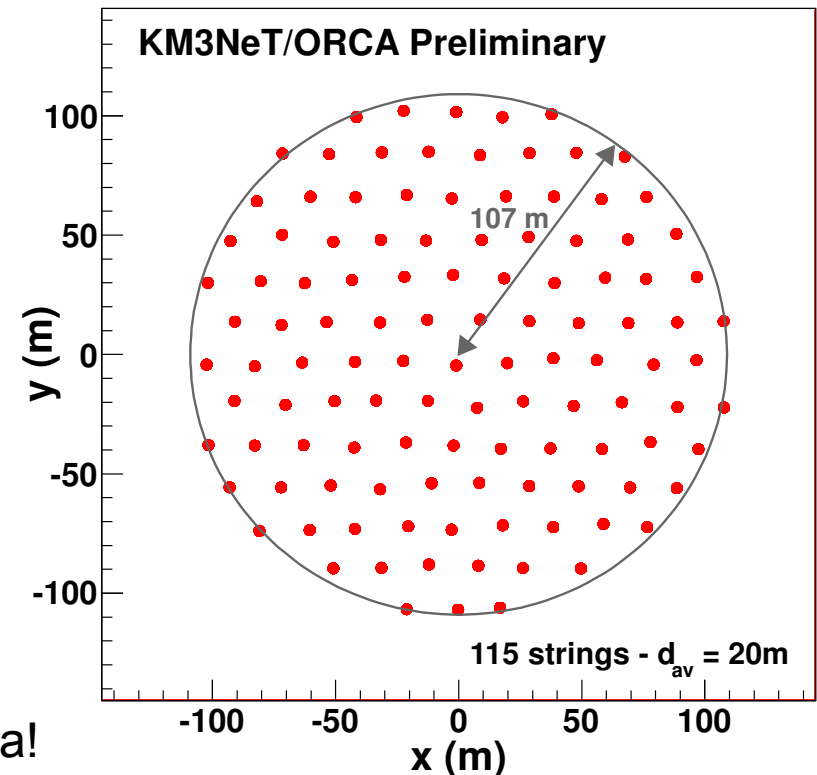
ORCA: neutrino mass hierarchy

- 3-flavour oscillation resonance in Earth for $E_\nu \sim 3 - 10$ GeV usable to determine sign of Δm_{31}^2 , i.e. the neutrino mass hierarchy!
- Unequal fluxes and cross-sections for atmospheric neutrinos and anti-neutrinos result in percent-level differences in count rates.
- Measure zenith angle and energy of upgoing atmospheric GeV-scale neutrinos precisely, identify and count muon and electron channel events.
- Improve measurement of Δm_{atm}^2 and θ_{atm} .



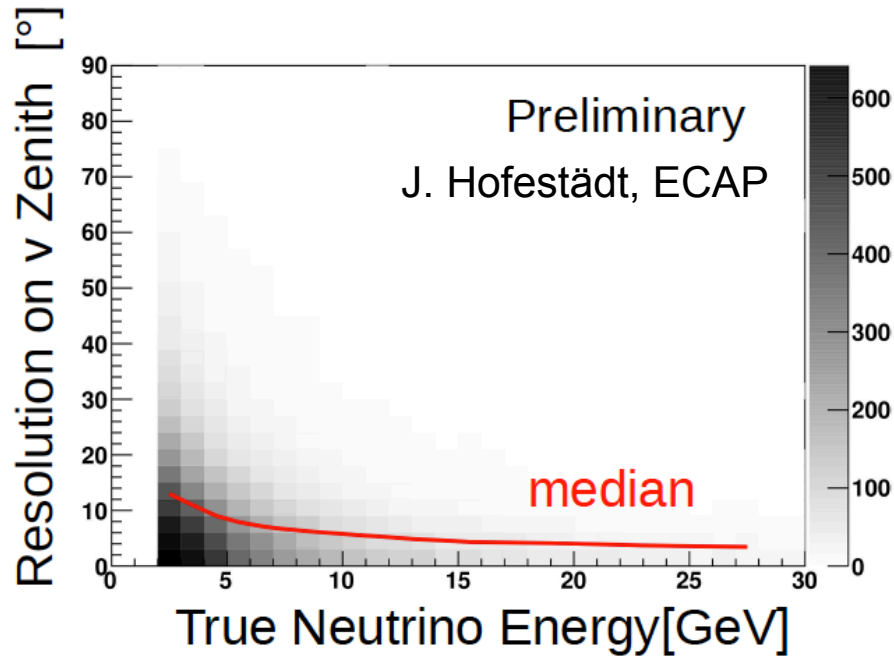
ORCA: detector design

- Resonance signature below 20 GeV requires dense detector
 - Use technology identical to KM3NeT
 - ORCA building block
 - 115 strings
 - 2070 DOMs
 - Optimization parameters under study:
 - Detection unit distance: ~ 20 m
 - DOM vertical spacing: 6 - 12 m
 - 100 m radius, 100 - 200 m height
- $\sim 1 - 2\%$ volume of KM3NeT building block: same overall photocathode area!

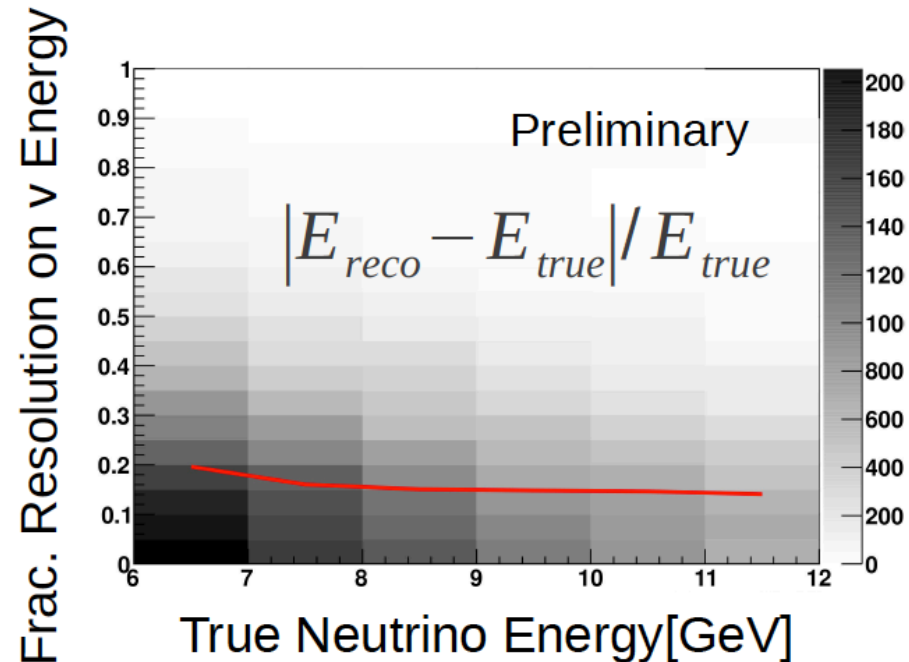


ORCA: cascade resolutions

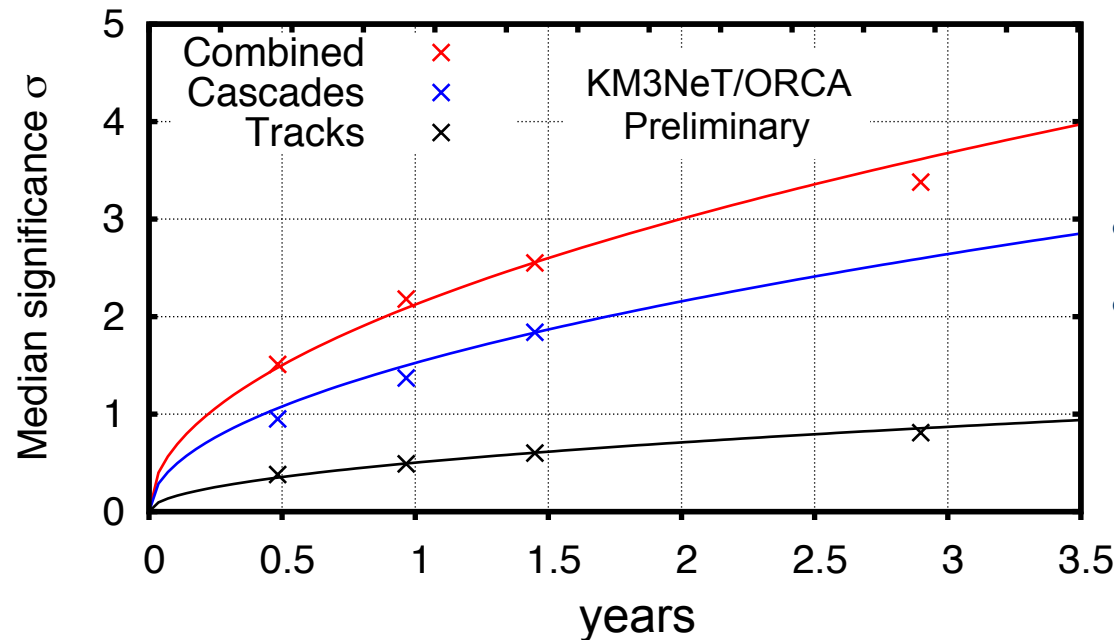
Zenith resolution $< 8^\circ$ @ 5GeV



Energy resolution $\sim 20\%$



ORCA: sensitivity to mass hierarchy



- Points: exact calculation
- Lines: $t^{1/2}$ scaling

- Promising, but work in progress.
- Uncertainties in mixing angles, CP-violating phase etc. included.
- Neutral-current ‘noise’ *not* included, particle id optimistic.

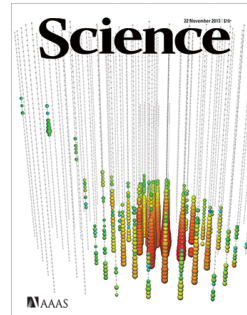
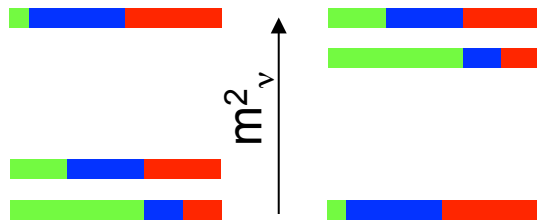
ORCA: phased implementation

Phase	Total costs [M€]	Planned installations	Status
A	Funds phase 1	6 – 10 ORCA strings, proof of - Deployment of dense detector - Detection of low energy ν	Discussions within KM3NeT
B	40	1 building block, parallel to HE Phase 1.5, funds permitting	Feasibility study

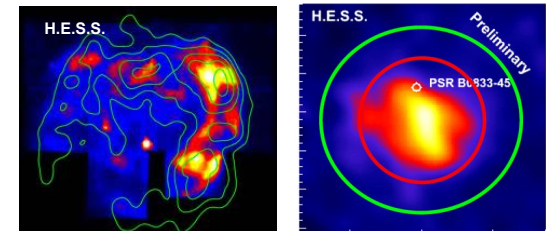
- KM3NeT multi-site concept allows for parallel construction of ORCA & high-energy phase-1.5 detector
- Candidate site for ORCA: Toulon
- Possible future option under discussion: neutrino beam from Protvino

Outlook on KM3NeT science potential

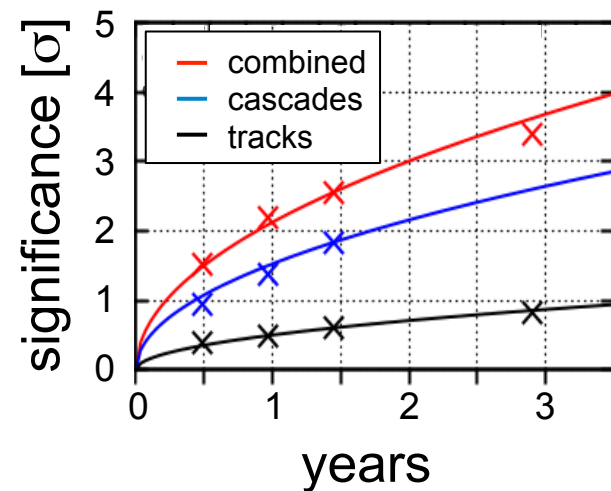
Neutrino physics



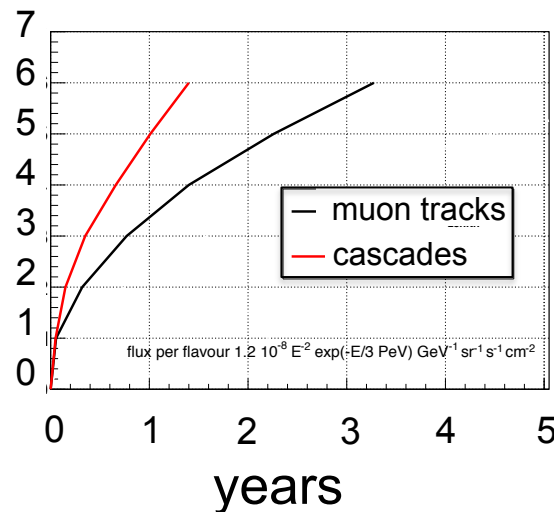
Neutrino astronomy



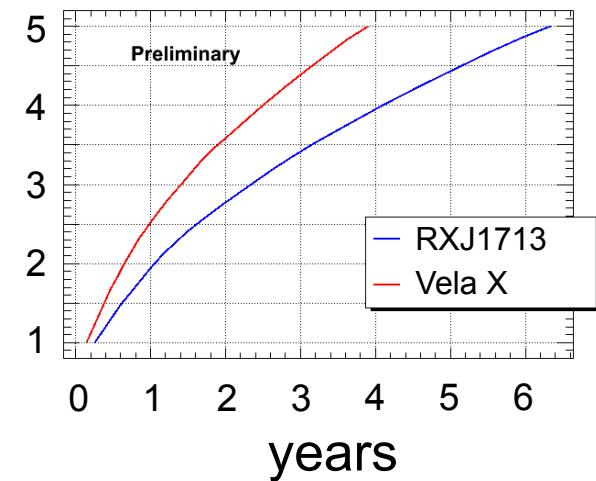
ORCA



Phase-1.5



Phase-2



Thank you for your attention !



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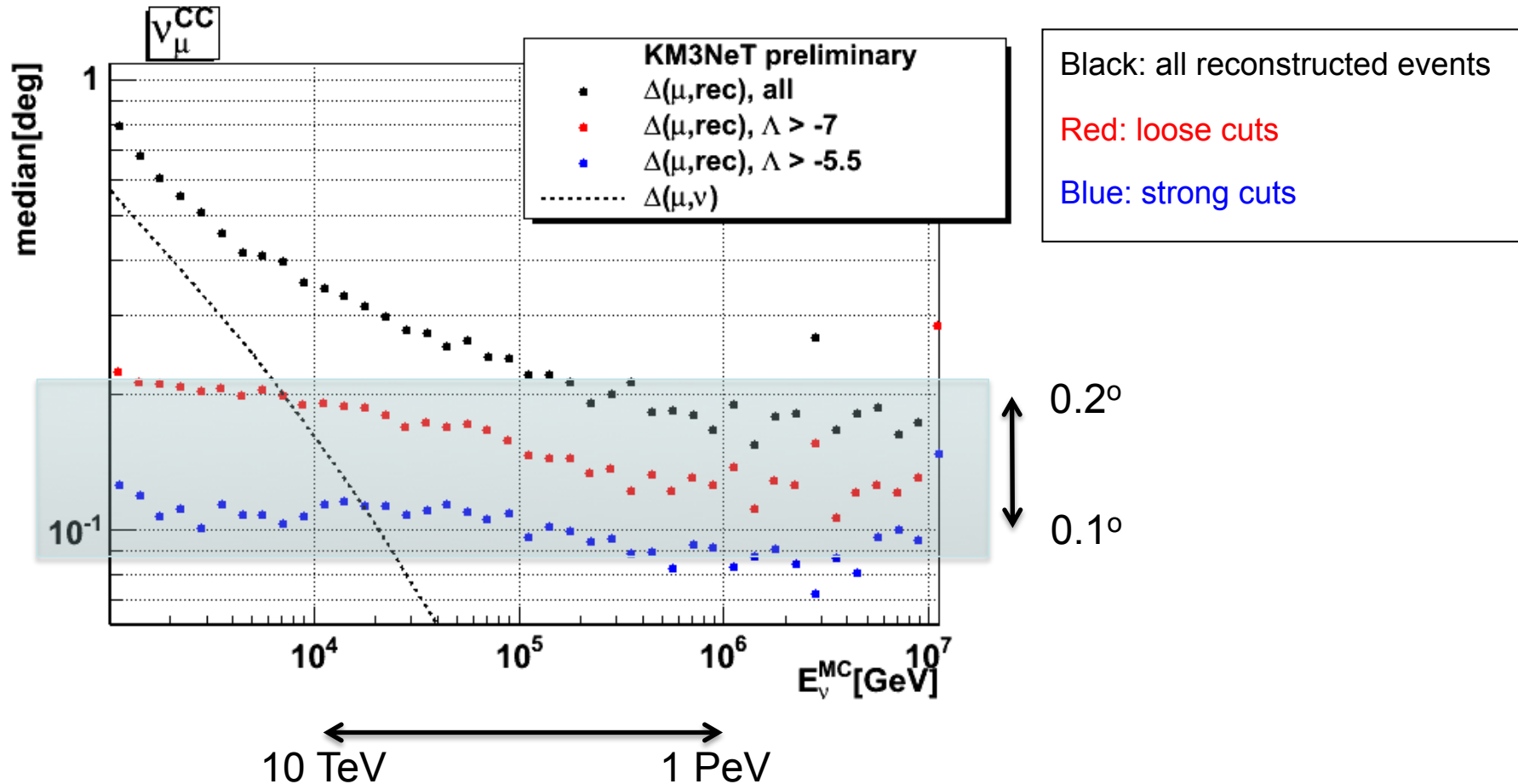
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Backup

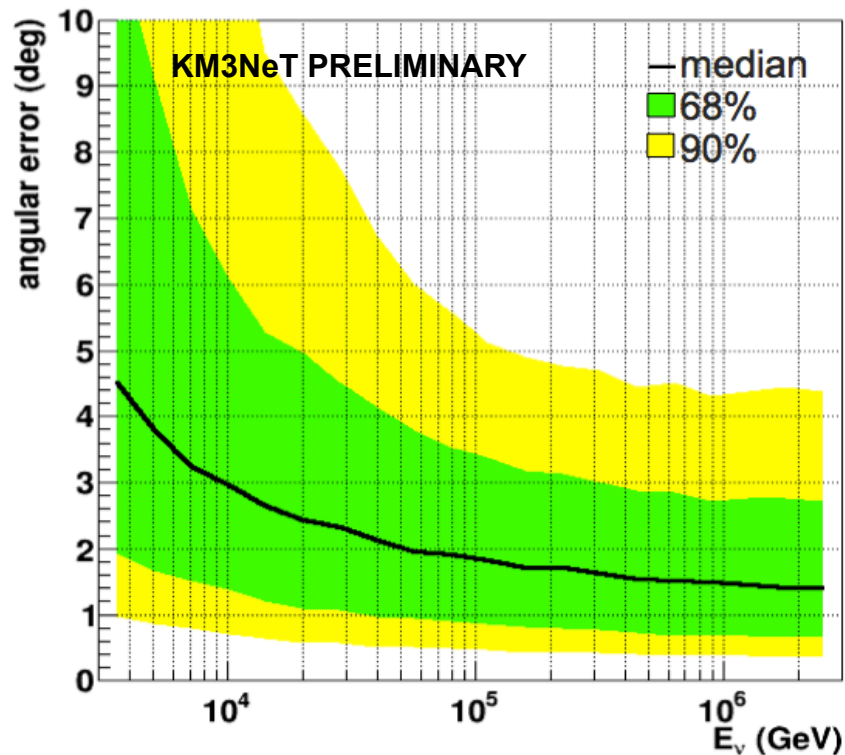
KM3NeT: muon track resolution



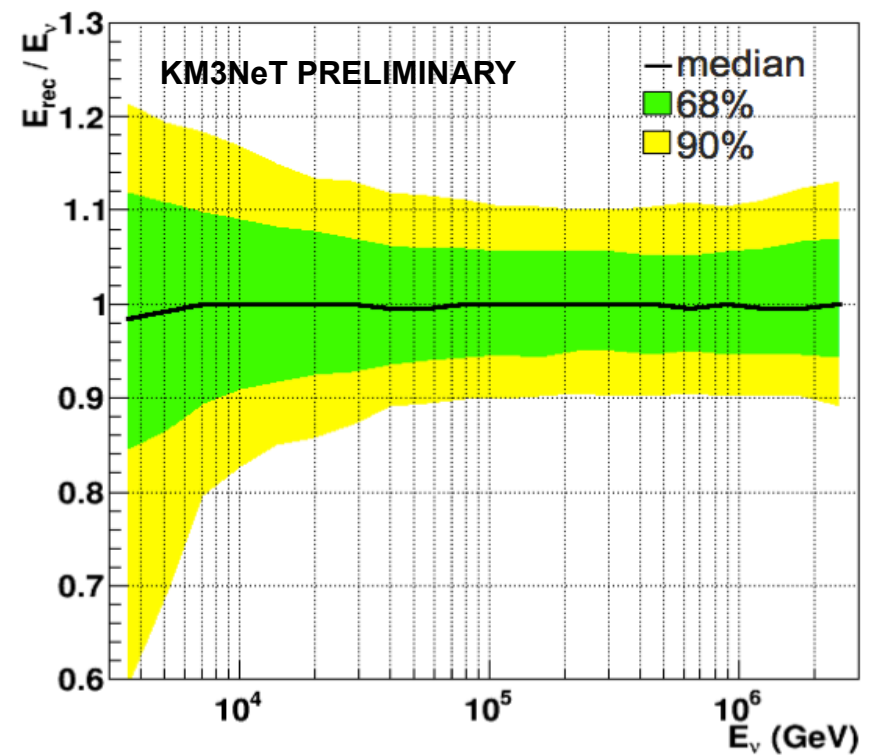
Characteristic angular resolution: 0.1°

KM3NeT: cascade channel resolutions

Angular error: $< 2^\circ$, $E > 50$ TeV

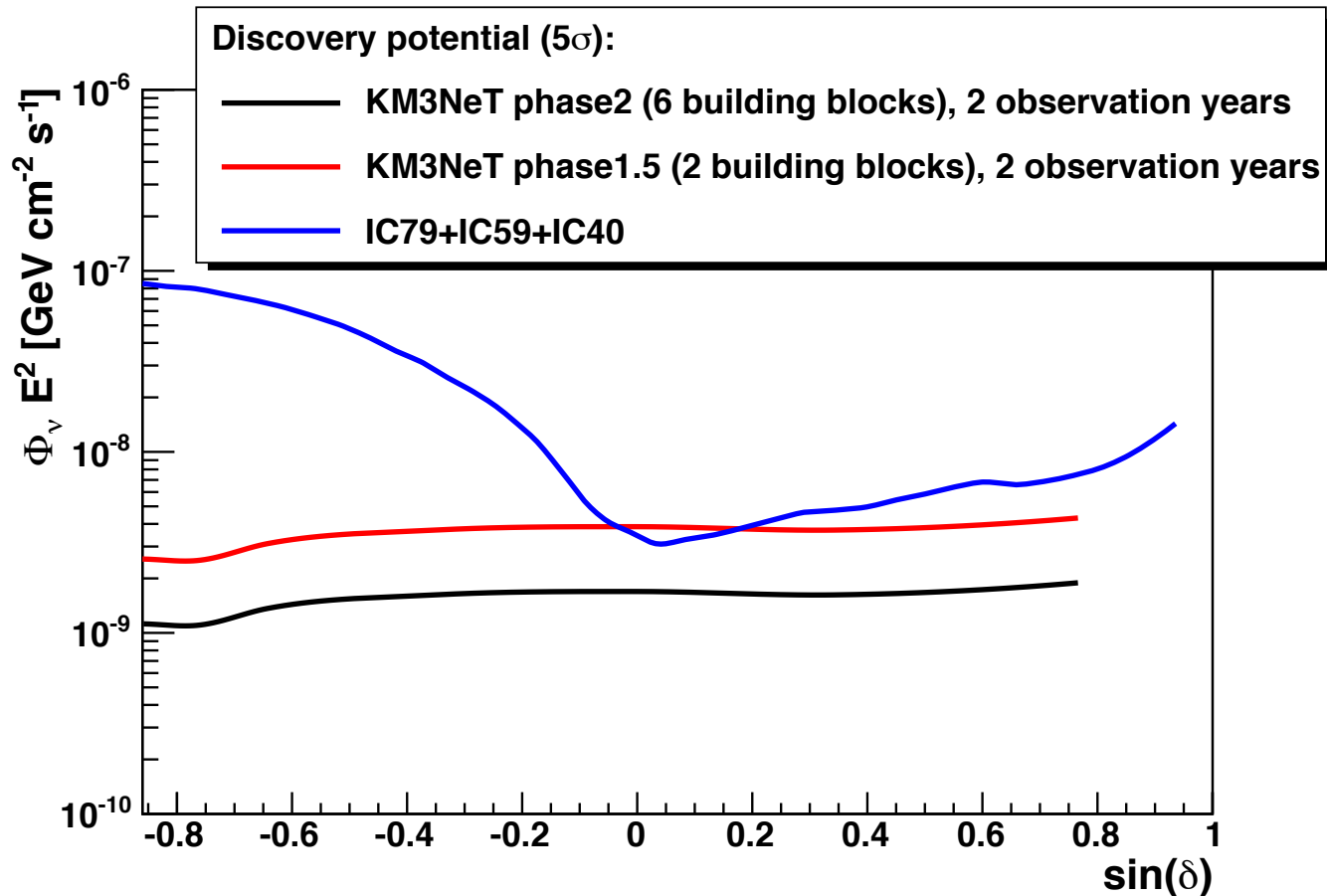


Energy resolution: $< 10\%$



- Figures for fully contained events only
- Angular error of < 2 degrees at 100 TeV!
- Astronomy with cascade channel in reach!

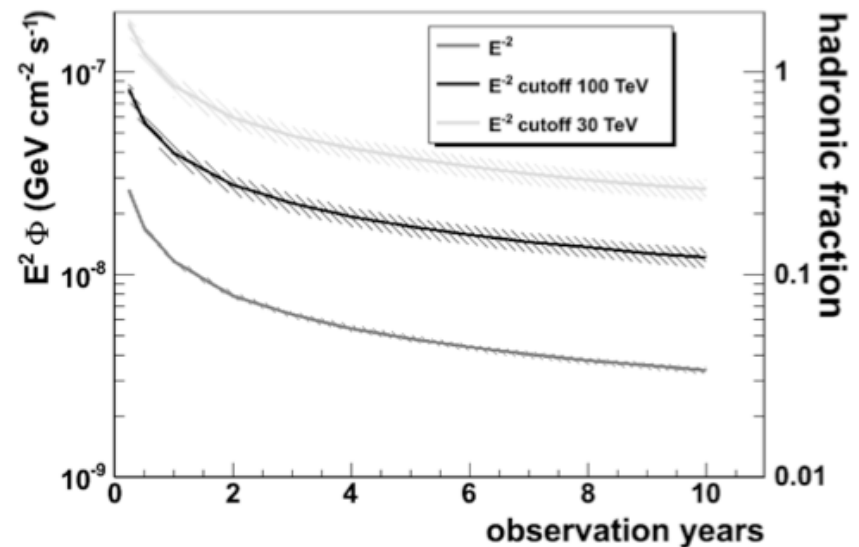
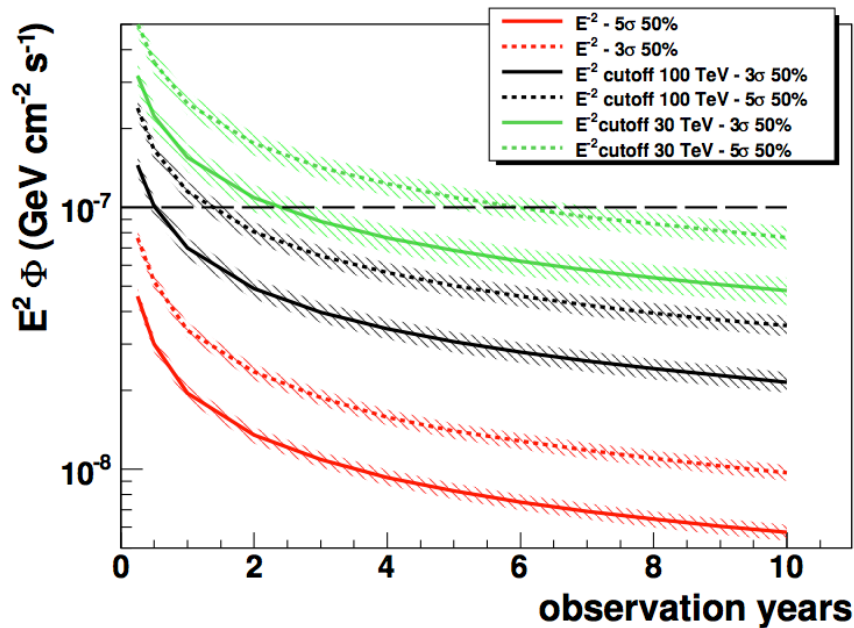
KM3NeT: point source discovery potential



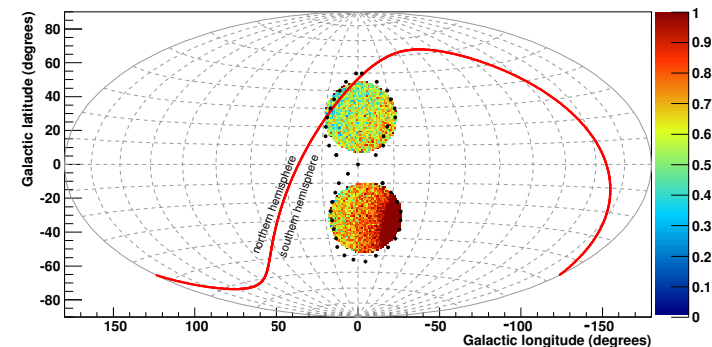
- 5σ declination dependent discovery potential for point sources
- Assumption: neutrino and antineutrino flux with E^{-2} spectrum

KM3NeT: Sensitivity to Fermi Bubbles

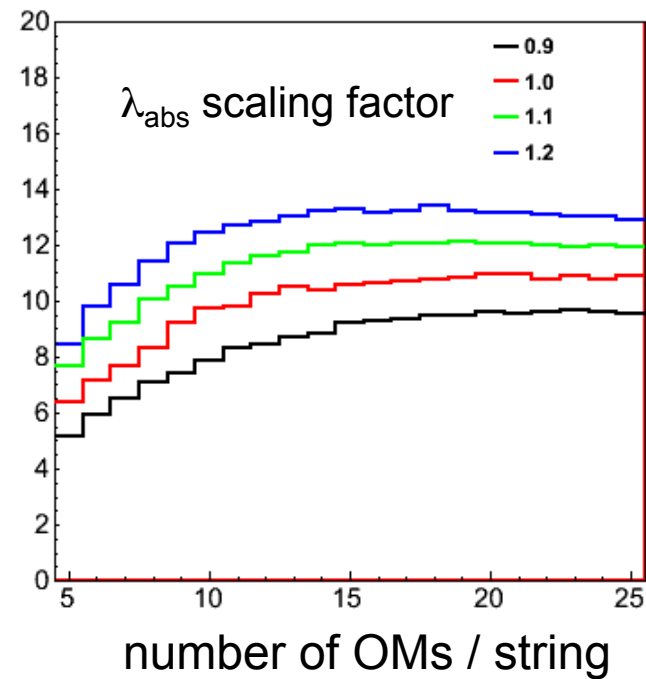
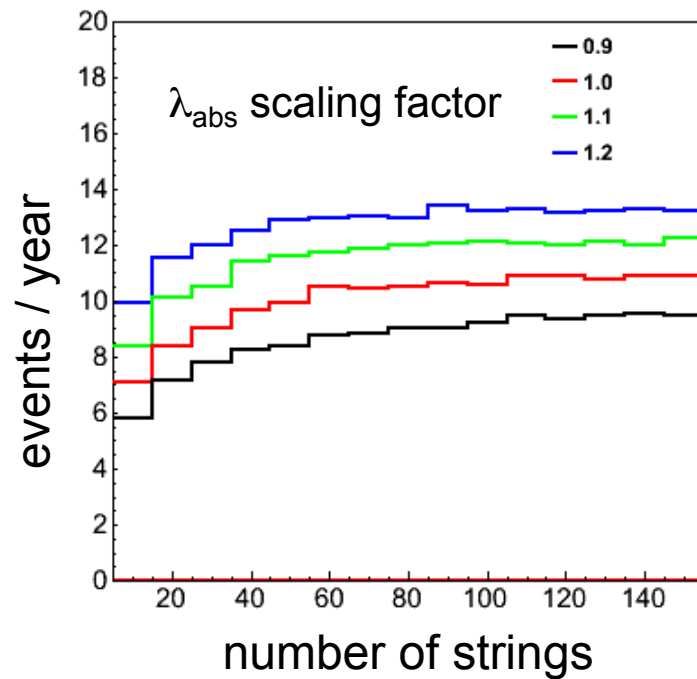
Astroparticle Physics, Volume 42, p. 7-14



- Approximate spatial distribution
- E^{-2} spectra with 3 different cutoffs simulated
- Sensitivity strongly dependent on cutoff
- 3 sigma 50% in 5 years for 30 TeV cutoff

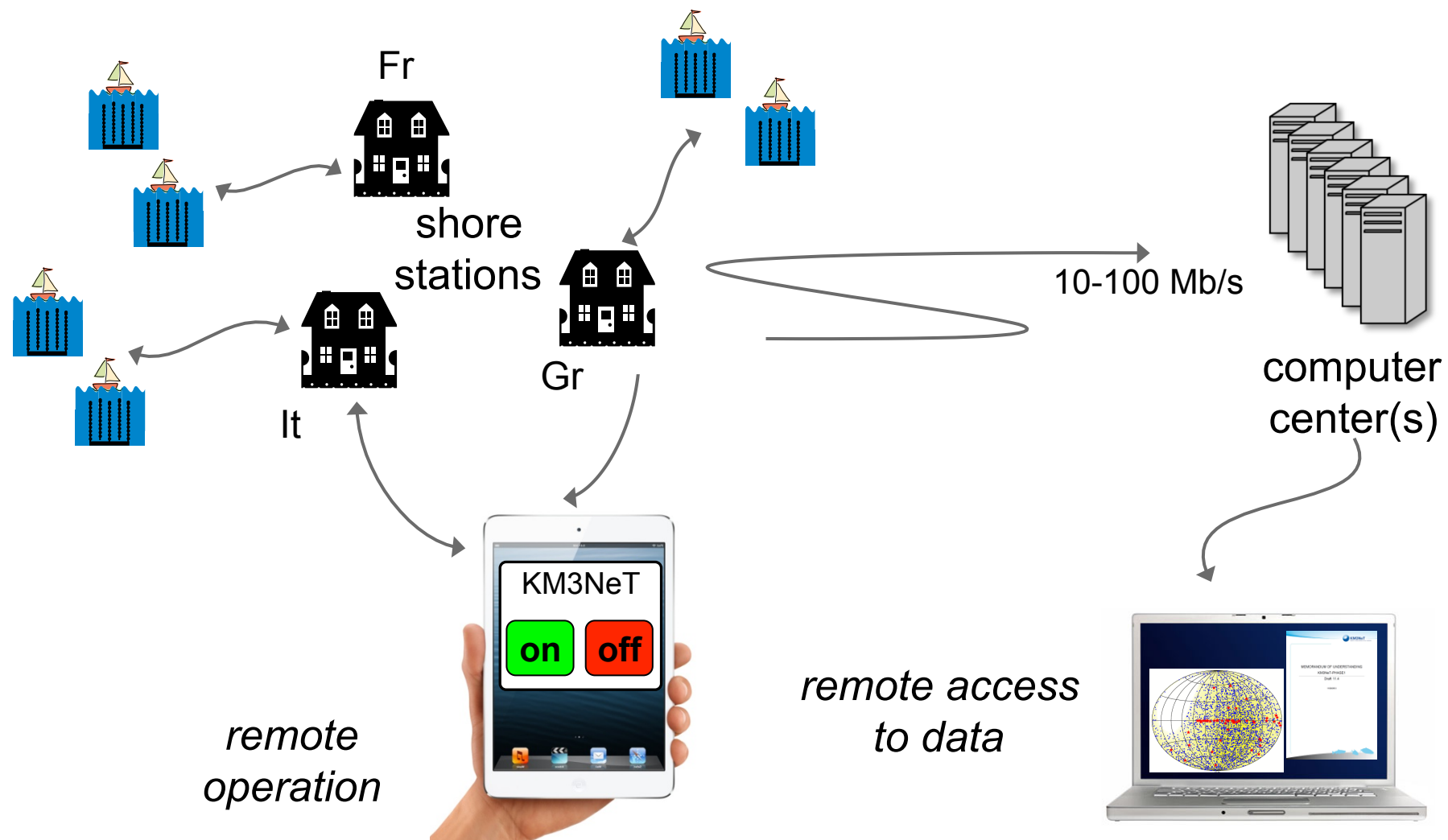


KM3NeT: optimisation study for building block geometry



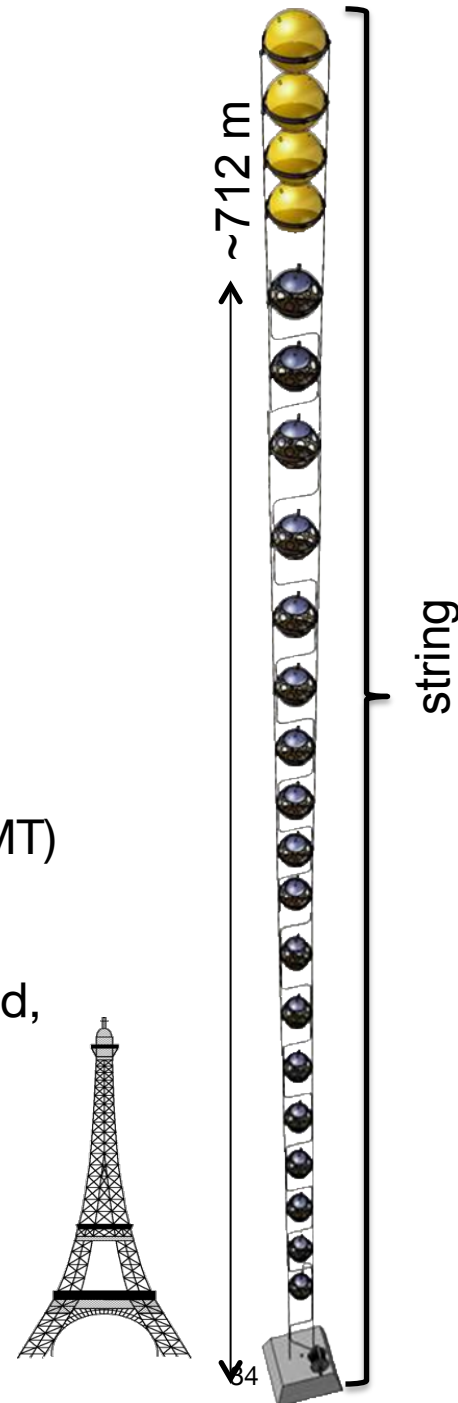
- absorption length $\lambda_{\text{abs}} \sim 60 - 100$ m
- scattering length $\lambda_{\text{scat}} \sim 50 - 70$ m

KM3NeT: distributed facilities

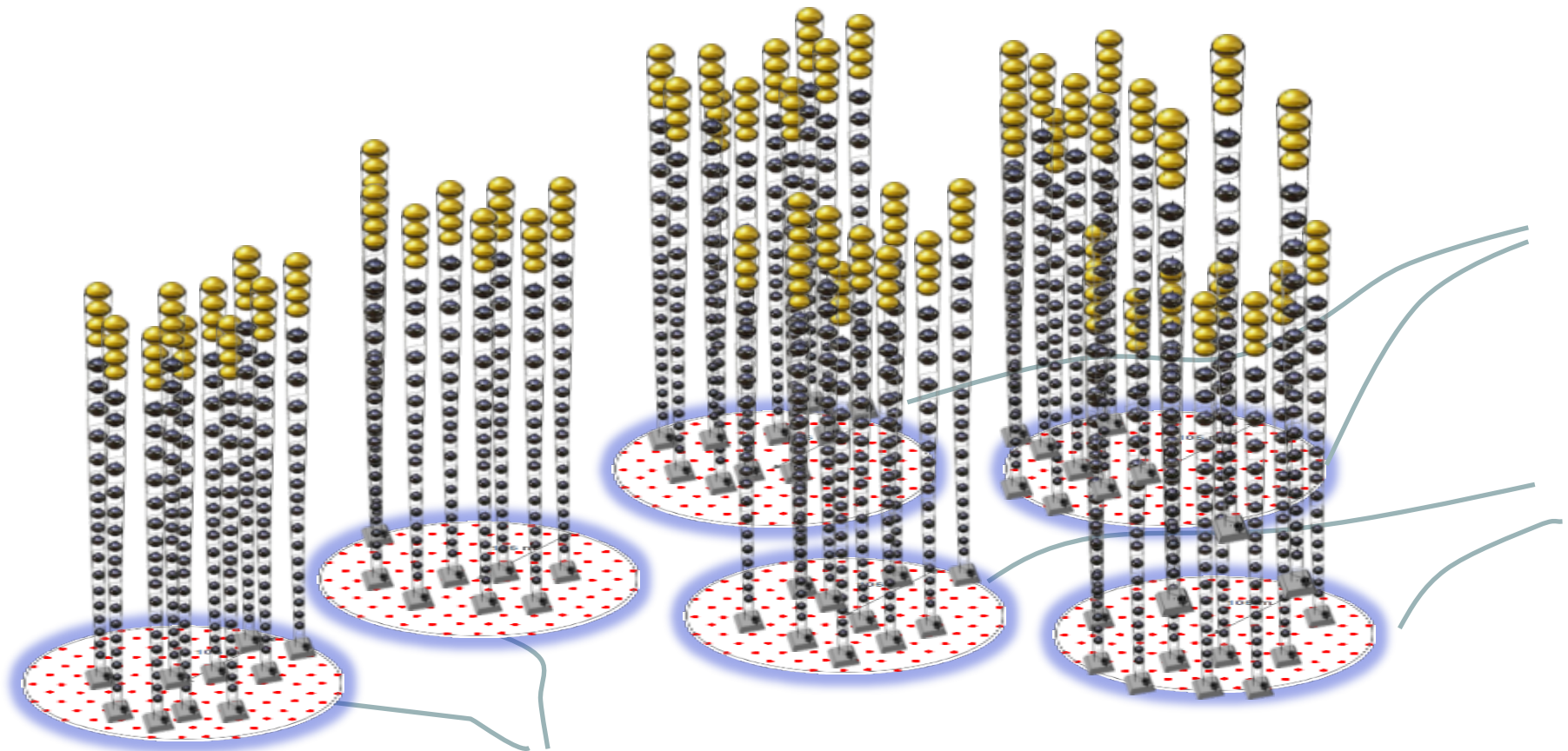


KM3NeT: neutrino telescope design

- 6 building blocks, 6 cables to shore
- $6 \times 115 = 690$ strings
- $6 \times 115 \times 18 = 12420$ optical modules (DOM)
- $6 \times 115 \times 18 \times 31 = 385020$ photomultiplier tubes (PMT)
- Power and data transmission infrastructure on seabed, all-data-to-shore concept
- Installation requires ship and remotely operated submersible



KM3NeT: a distributed multi-purpose research infrastructure



+ nodes for environmental and sea sciences
at each site

KM3NeT: building block

