Simulations with directional optical module

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Outline

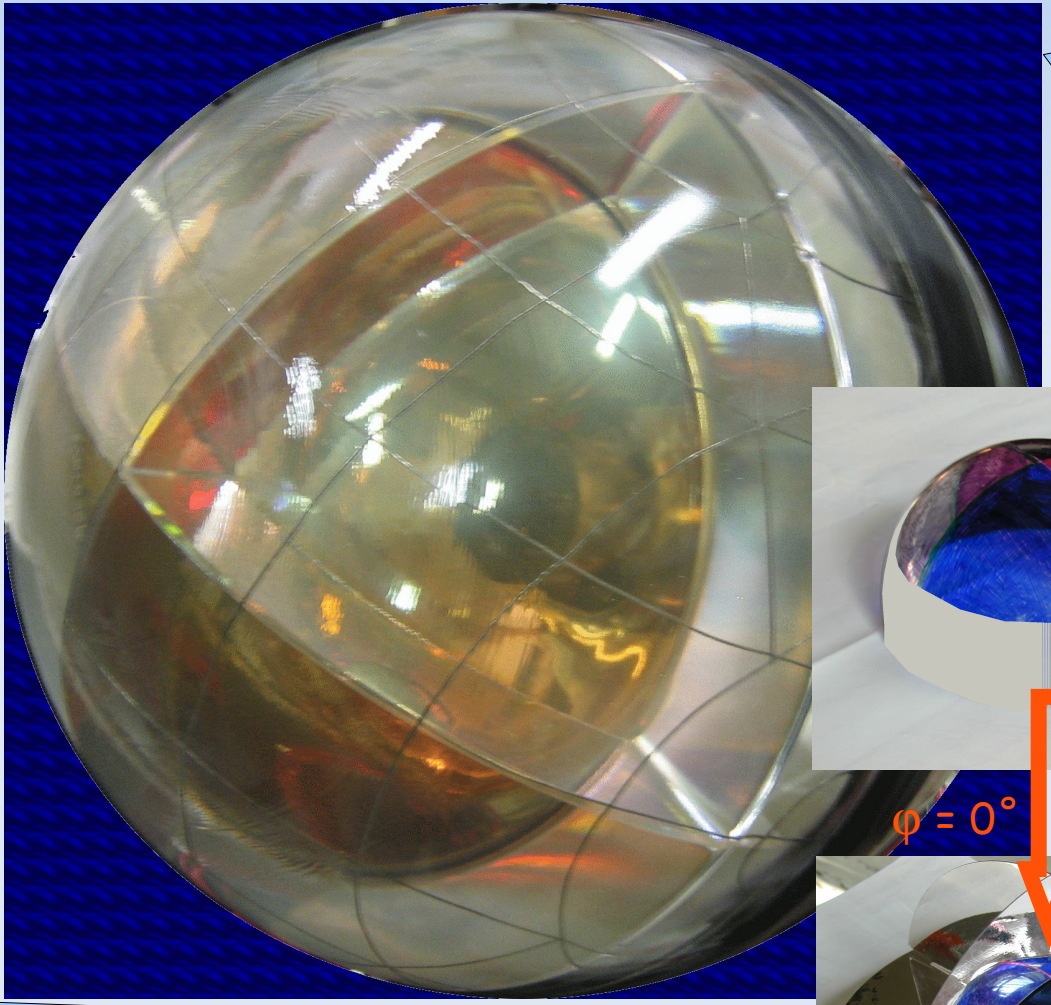
the Directional Optical Module (DOM)
comparison with standard OM calculating

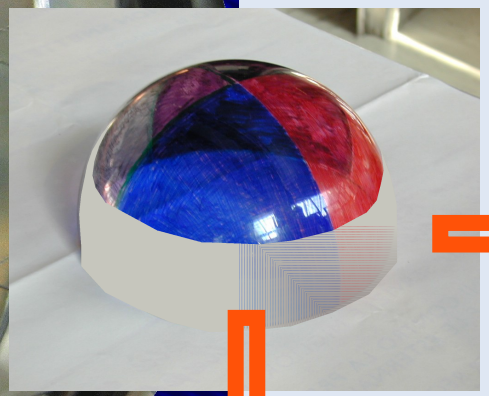
- effective area
- angular resolution

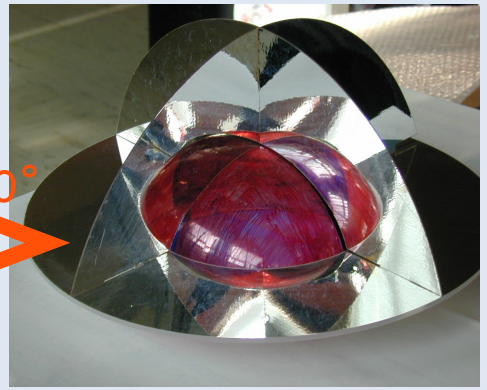
considering different detector geometries

- NEMO-KM3
- Optimized NEMO-KM3 geometry
- ANTARES

Directional Optical Module

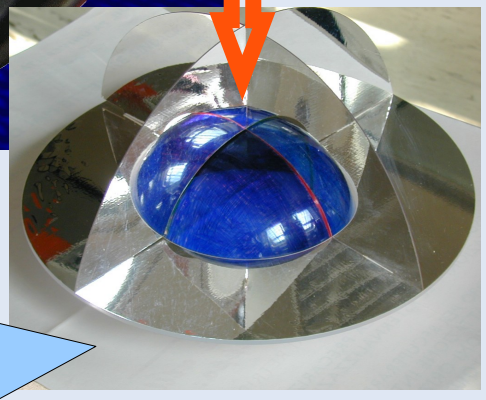




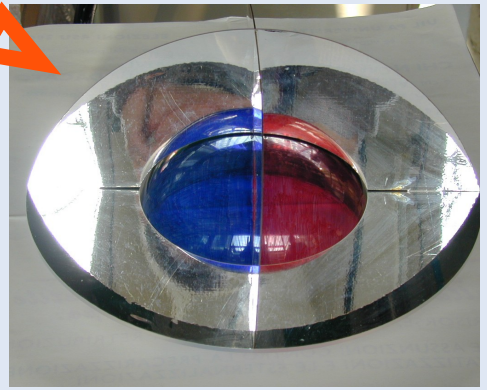


φ = 90°

φ = 0°



φ = 45°



Effective area

Effective area - quantity which, when multiplied by a differential neutrino flux and integrated gives a rate of observed events:

$$N_{observed} = \int V_{eff}(E_\nu, \theta_\nu)(\rho N_A)\sigma(E_\nu)P_{Earth}(E_\nu, \theta_\nu)\frac{d\Phi_\nu}{dE_\nu d\theta_\nu}dE_\nu d\theta_\nu$$

number of selected events, divided by number of generated events multiplied by generation volume gives effective volume for some selection

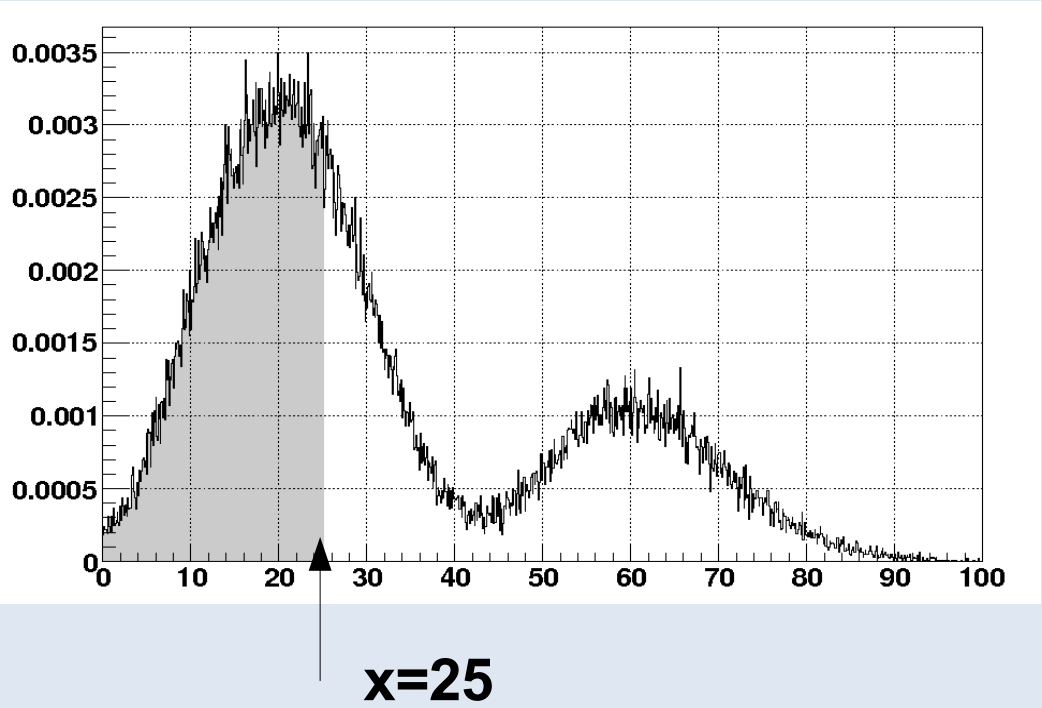
$$V_{eff}(E_\nu, \theta_\nu) = \frac{N_{selected}(E_\nu, \theta_\nu)}{N_{generated}(E_\nu, \theta_\nu)} \times V_{generation}$$

So, the effective area of the detector for fluxes from the source will be

$$A^\nu_{eff}(E_\nu, \theta_\nu) = V_{eff}(E_\nu, \theta_\nu) \times (\rho N_A) \times \sigma(E_\nu) \times P_{Earth}(E_\nu, \theta_\nu)$$

Angular resolution

For angular resolution difference between directions of reconstructed μ and true μ tracks was used. Exactly it was median of this distribution.



Median - the number separating the higher half of a probability distribution from the lower half.

Simulation parameters.

Range of neutrino energy – 100GeV-10PeV.

Direction – upgoing ($\theta = 90^{o}$ -180^{o}).

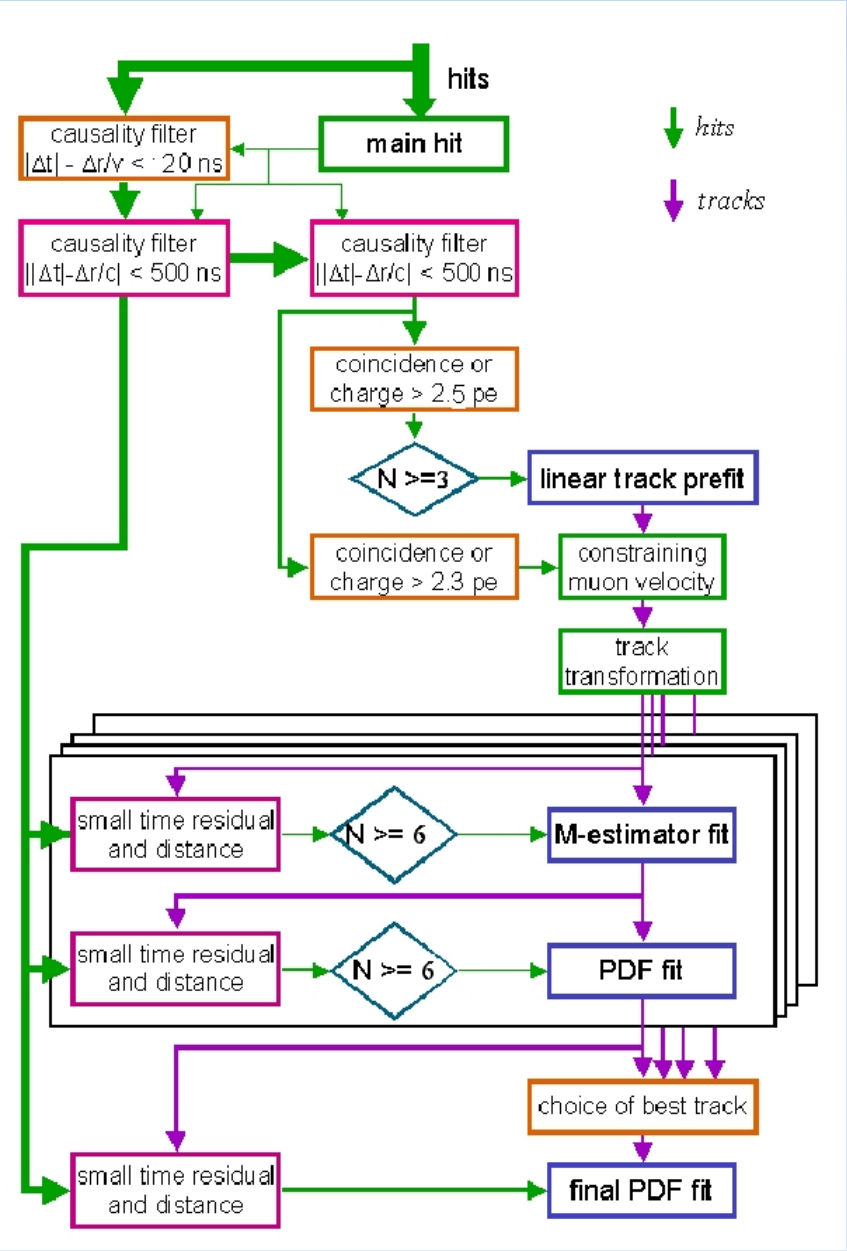
Type – muon neutrino

Number of generated neutrino – $5*10^{8}$ (for km^{3})

$5*10^{9}$ (for ANTARES)

Number of events, saved for reconstruction ~ 10^{6}

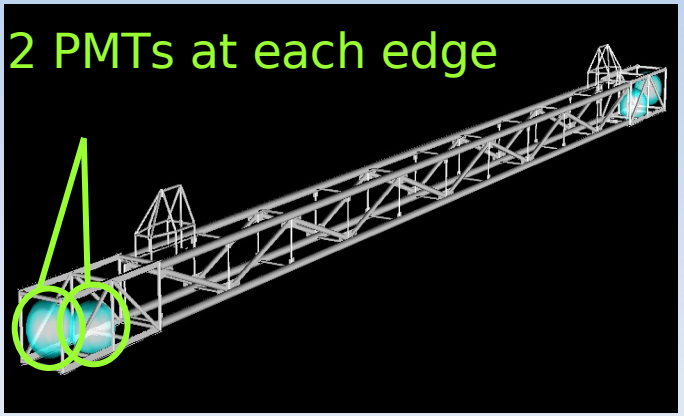
RECOnstruction Software

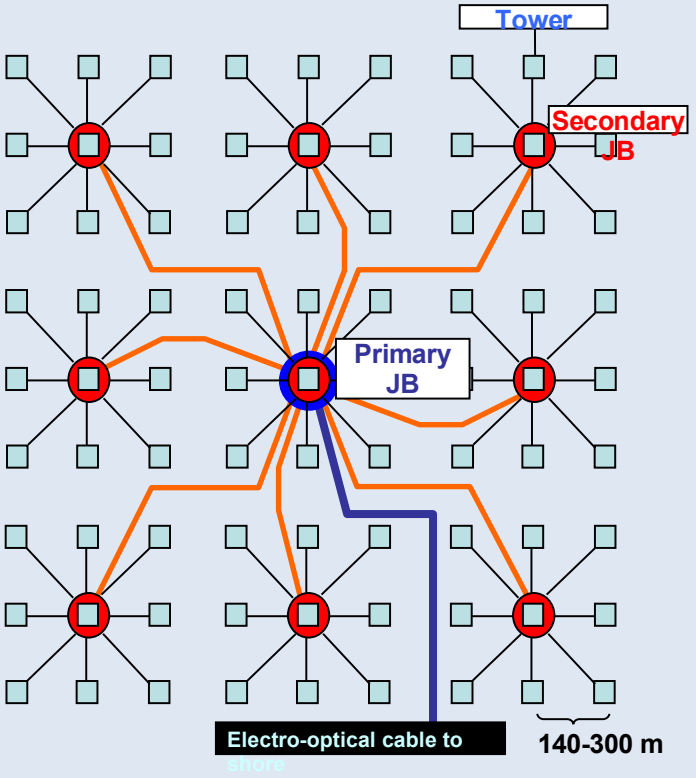


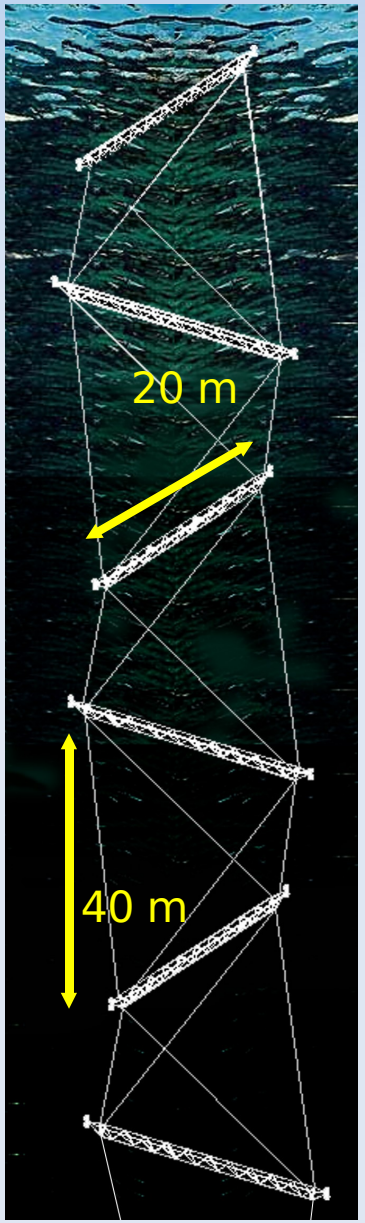
- Using ANTARES RECO 4.4 modified for NEMO project (for standard OM)
- The same RECO was optimized for DOM
- After reconstruction only artificial cut applied – difference between true & reconstructed tracks should be less than 2°(5°)

NEMO-KM3 configuration

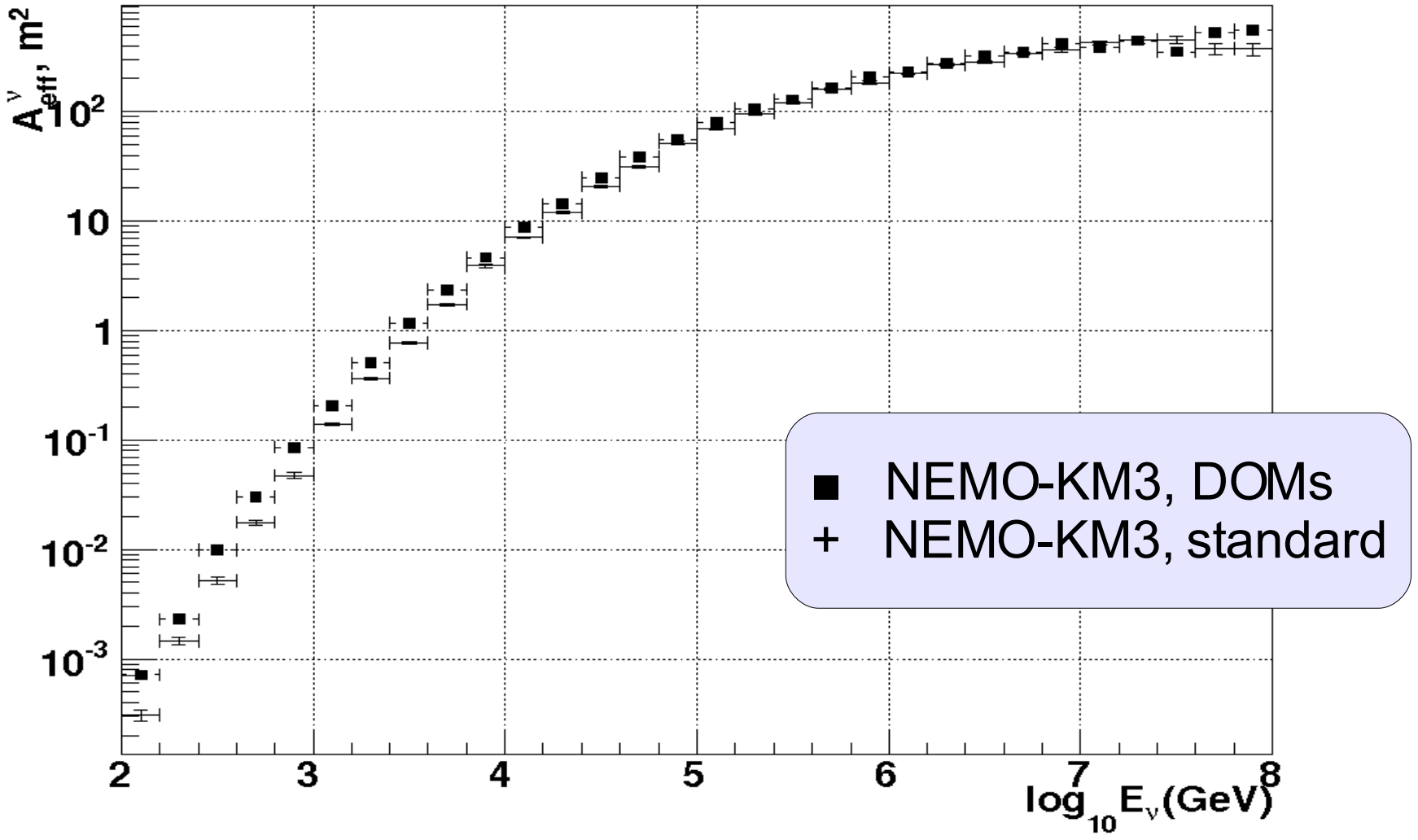
- 81 towers (9x9)
- distance between towers from 140m
- 18 bars at each tower
- length of console 20m
- 2 PMT at each end of a bar
- 1 PMT looking down
  1 PMT - horizontal
- standard or directional PMT



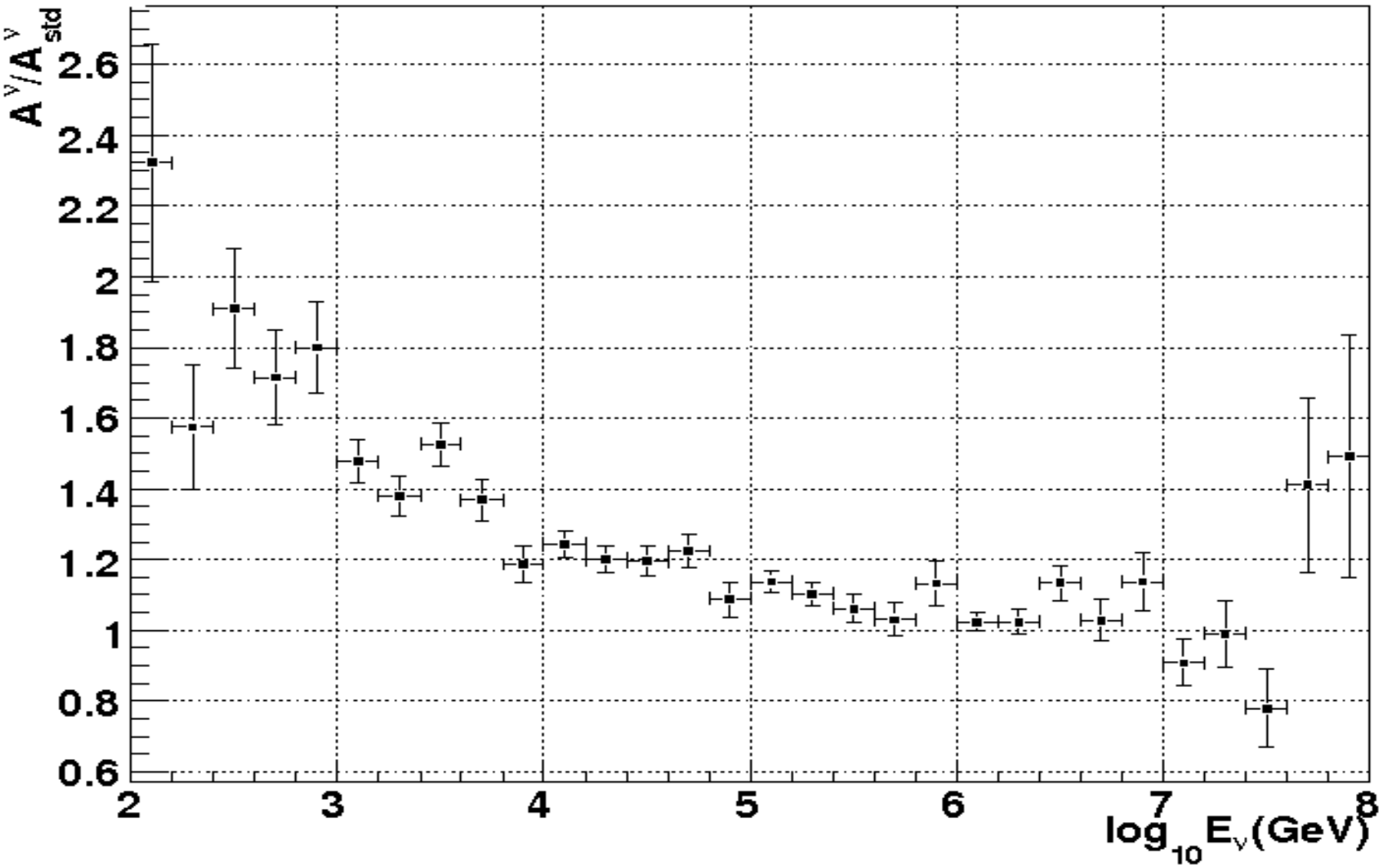




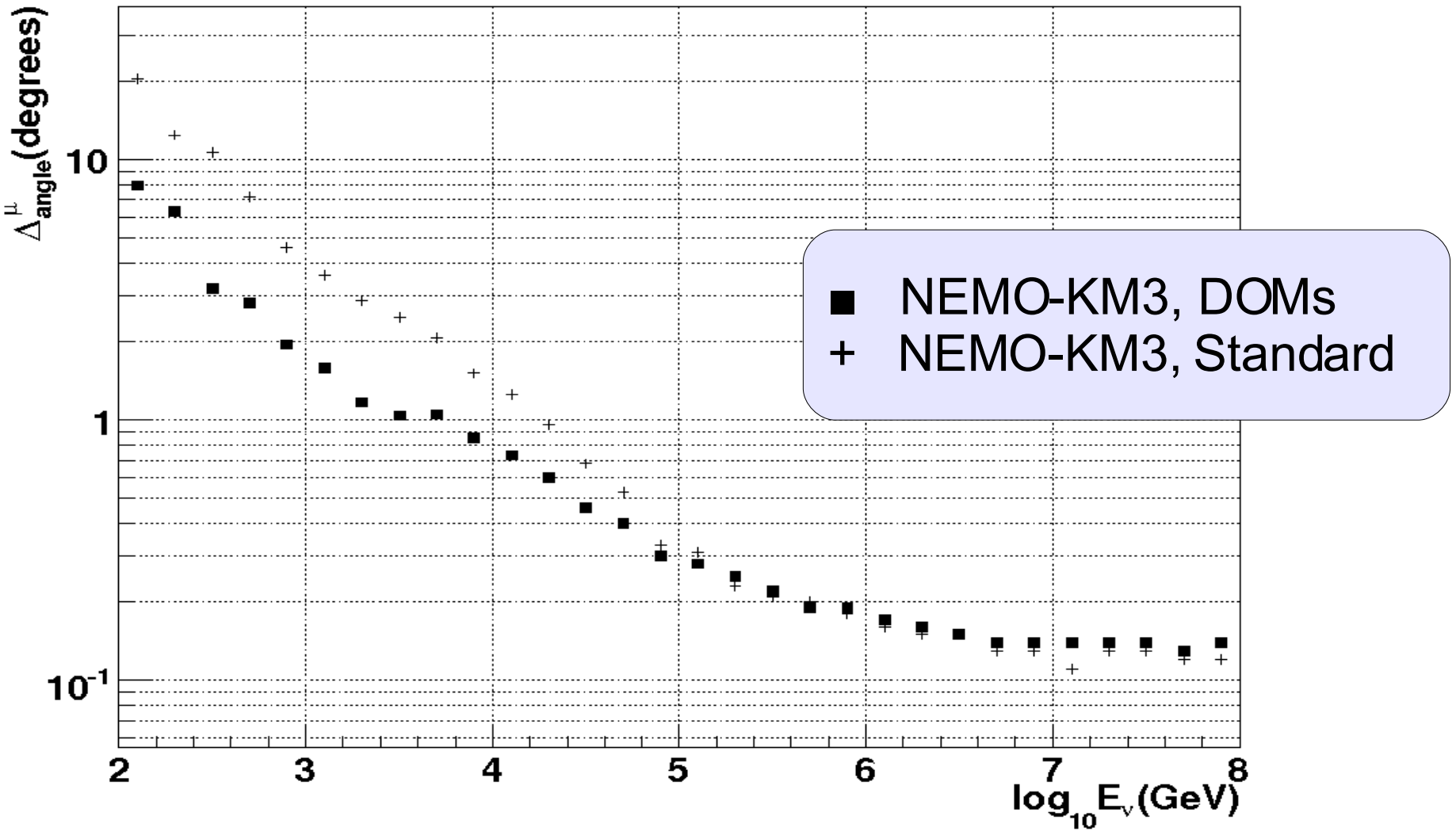
Effective area for NEMO-KM3



Effective area for NEMO-KM3 (ratio of DOM to STD)



Angular resolution of NEMO-KM3



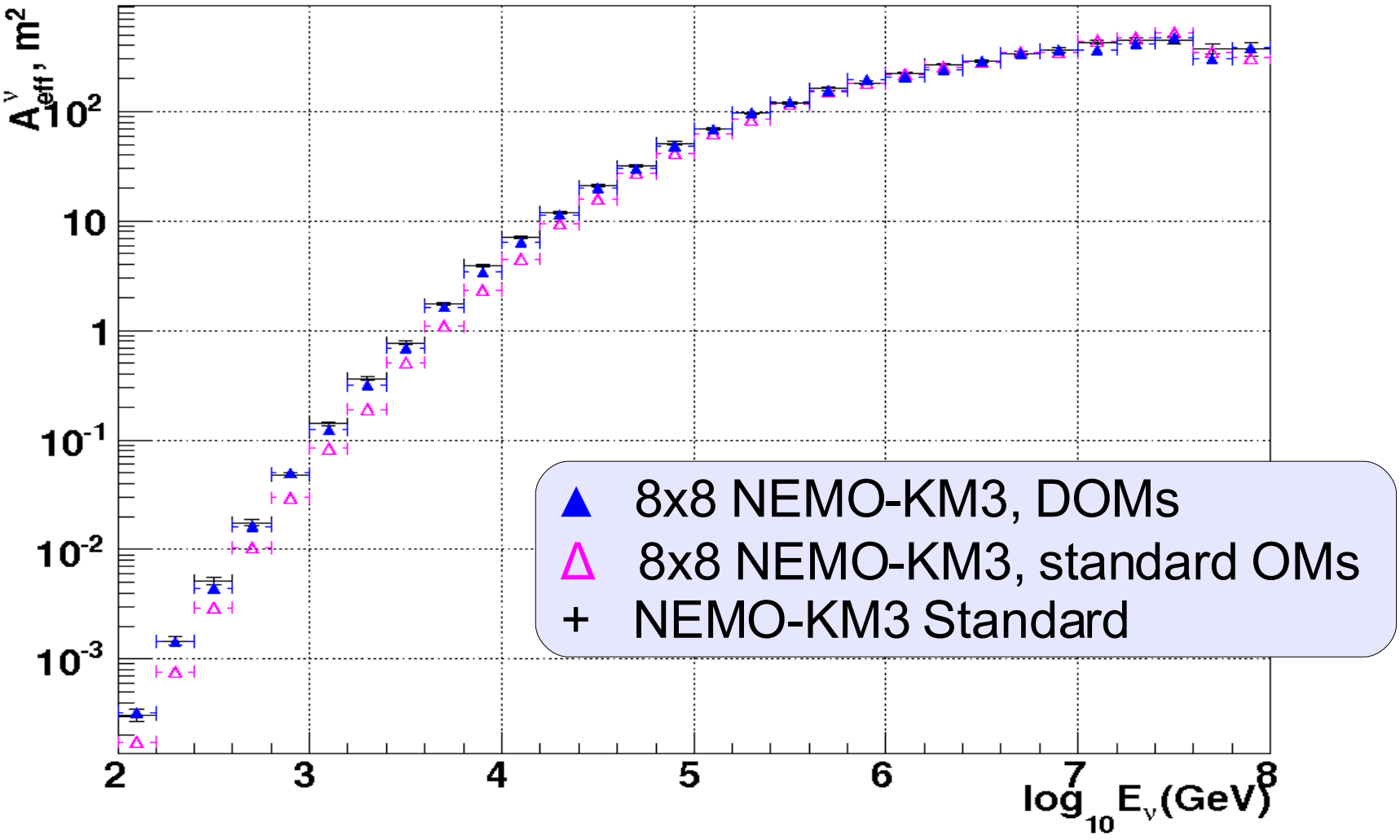
NEMO-KM3 optimization

Achieve the same effective area, like standard NEMO-KM3 detector has, but using lower number of towers.

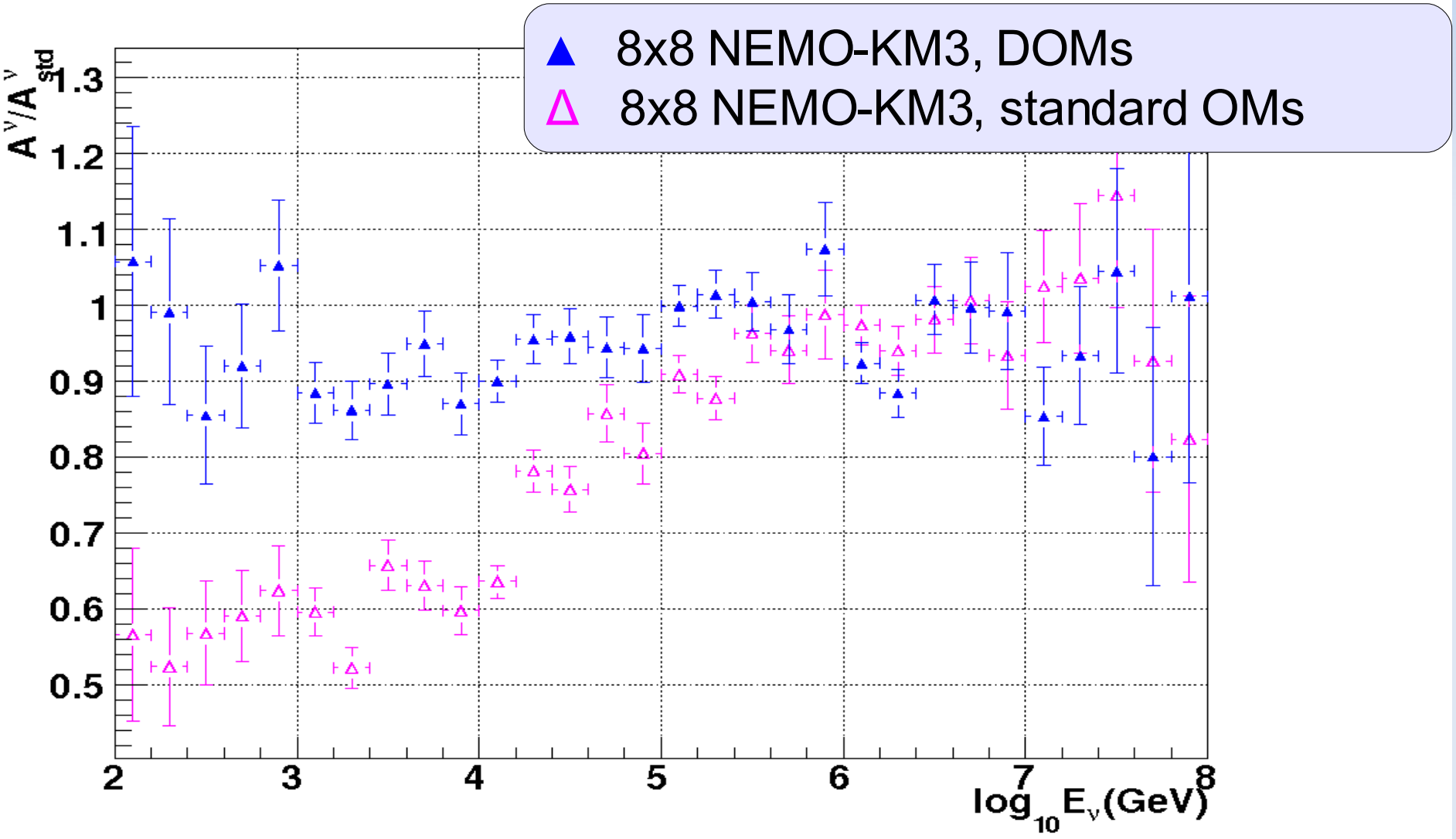
- DOM optical modules gives a possibility to increase effective area at lower energies.
- At high energy effective area depends generally on detector instrumental volume.

8x8 towers with 180m distance between them was accepted for simulations

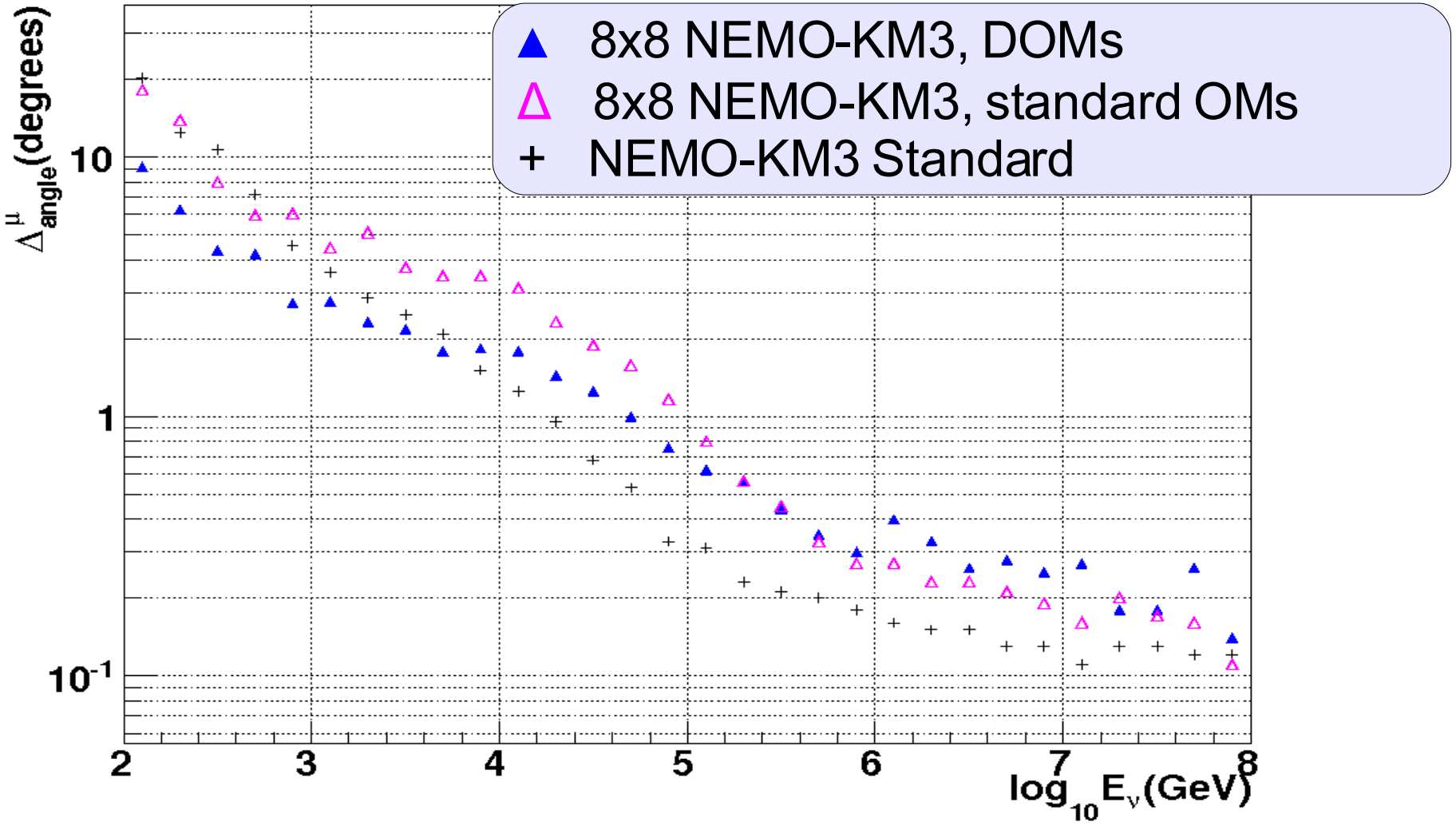
Effective area of 8x8 NEMO-KM3 180m



Effective area of NEMO-KM3 180m (ratio to standard)



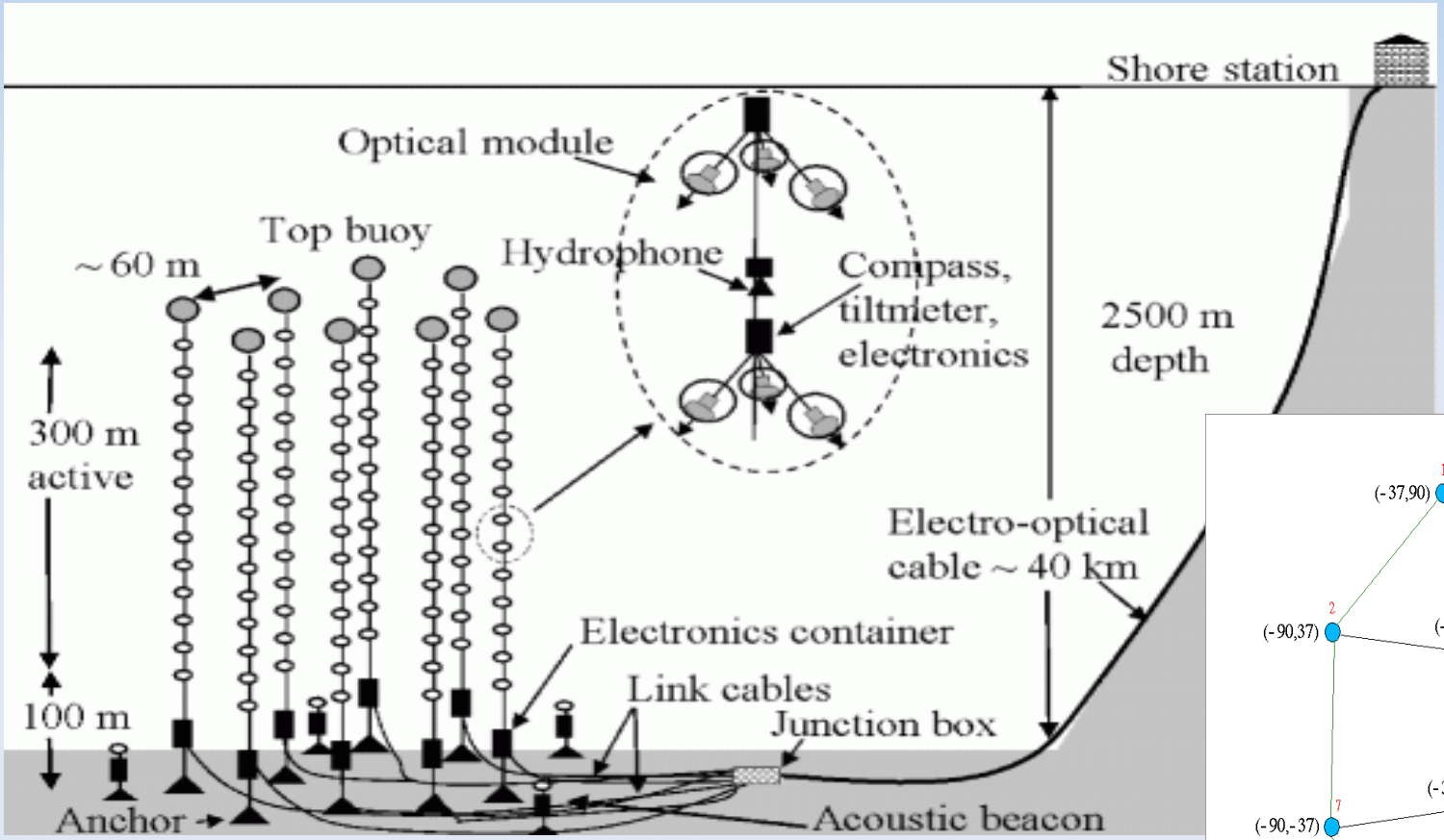
Angular resolution of NEMO-KM3 180m

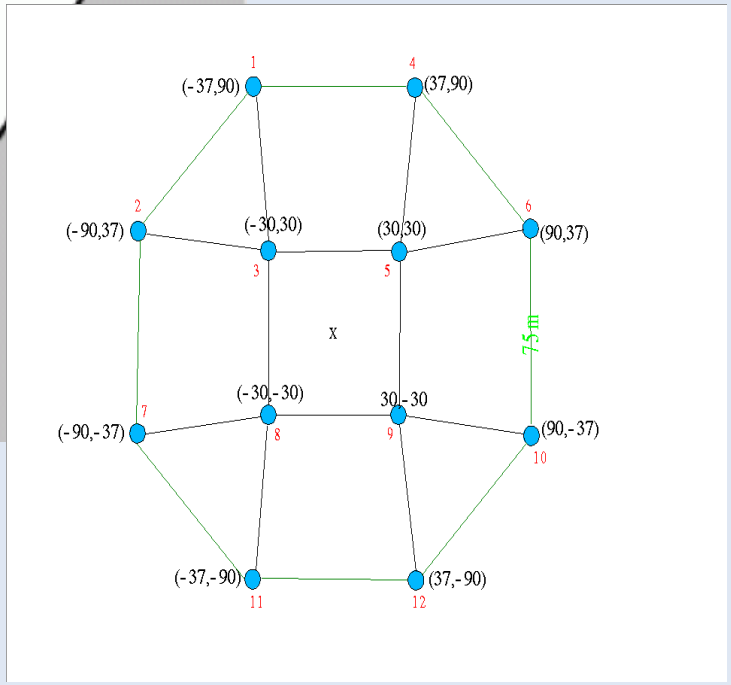


Conclusion about reducing towers using DOM

- Using DOM can increase reconstruction quality at low energies.
- Using DOM to decrease the number of towers seems to be resonable. It was proved, that practically one can reach the same effective area as with standard NEMO-KM3 configuration, allowing potential reduction of constuction elements to 80% from original.

ANTARES 0.1km^3 configuration



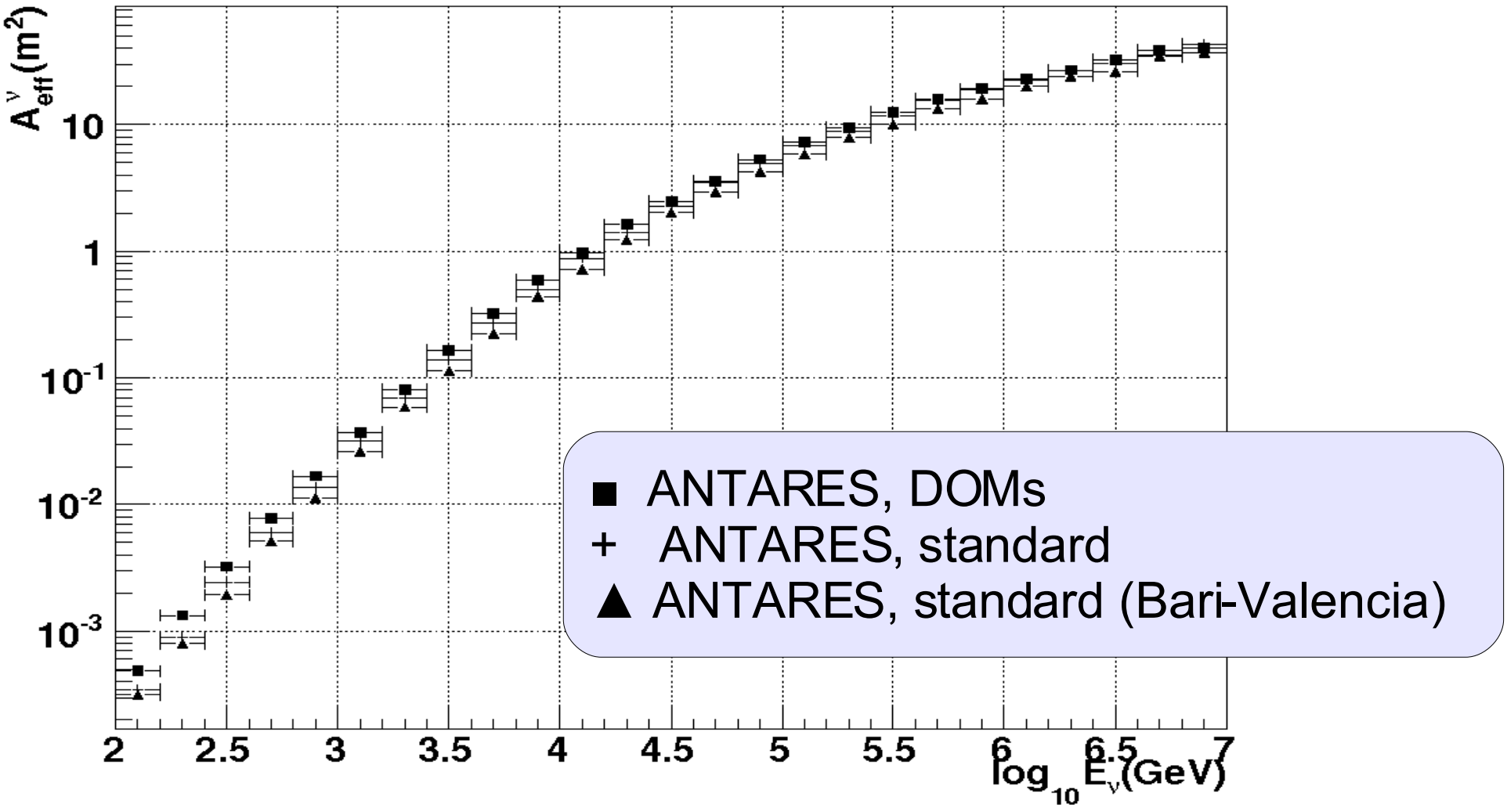


- 12 strings
- 25 storeys on each string
- 3 OMs on each storey

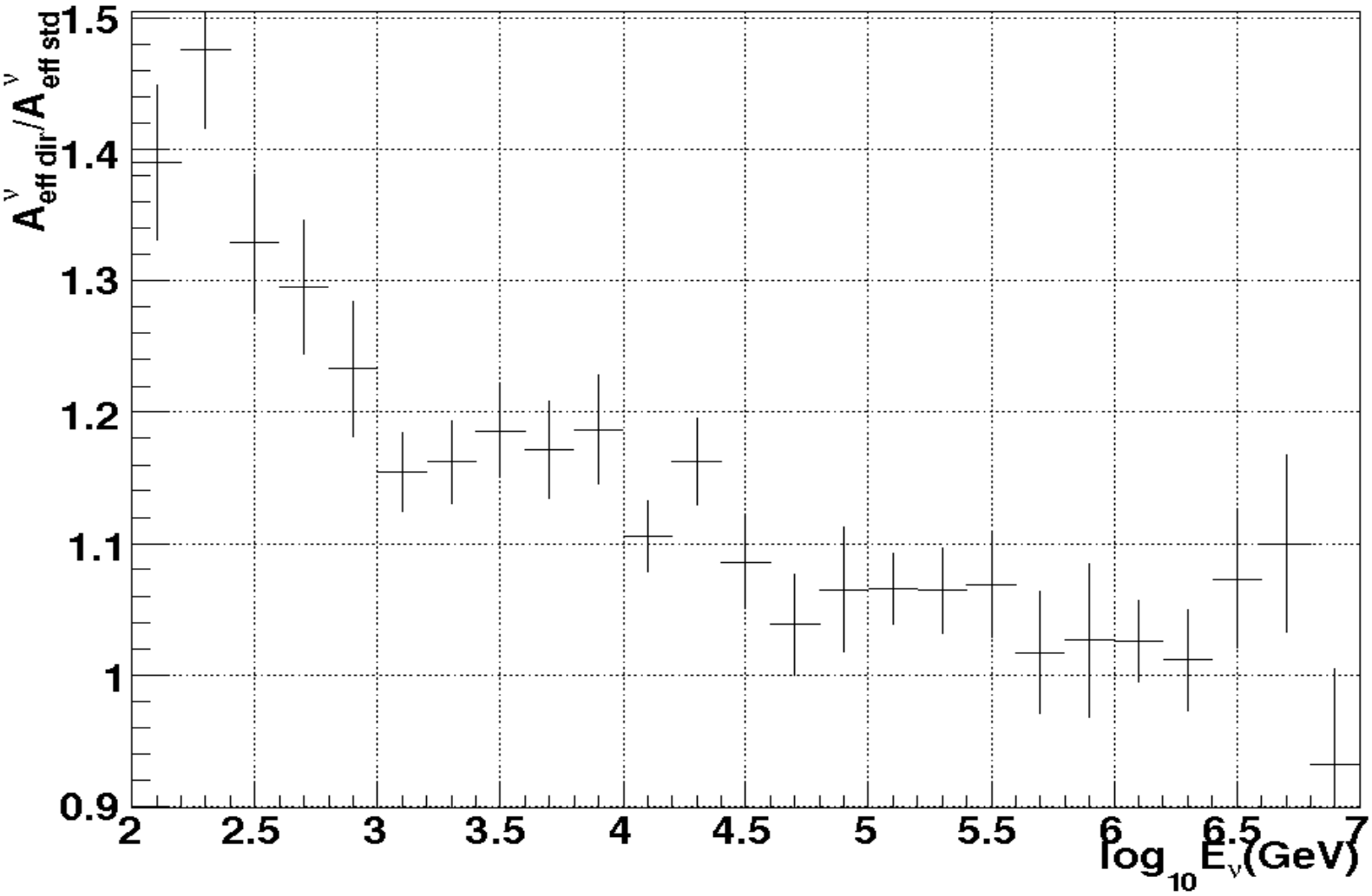
MC Simulations

	Simulations made by me	**Bari-Valencia production**
Number of events	$5*10^9$ (ν_μ)	$5*10^{10}$ (ν_μ)
Energy range	10^2-10^8 GeV	$10 - 10^7$ GeV
Direction	upgoing	upgoing
Software	genhen v5r5km3 km3 v2r1km3 modk40 v4r8km3 reco v4r4km3_new	genhen v5r6 km3 v2r2 geagmu v4r9 modk40 v4r9 recov4r4

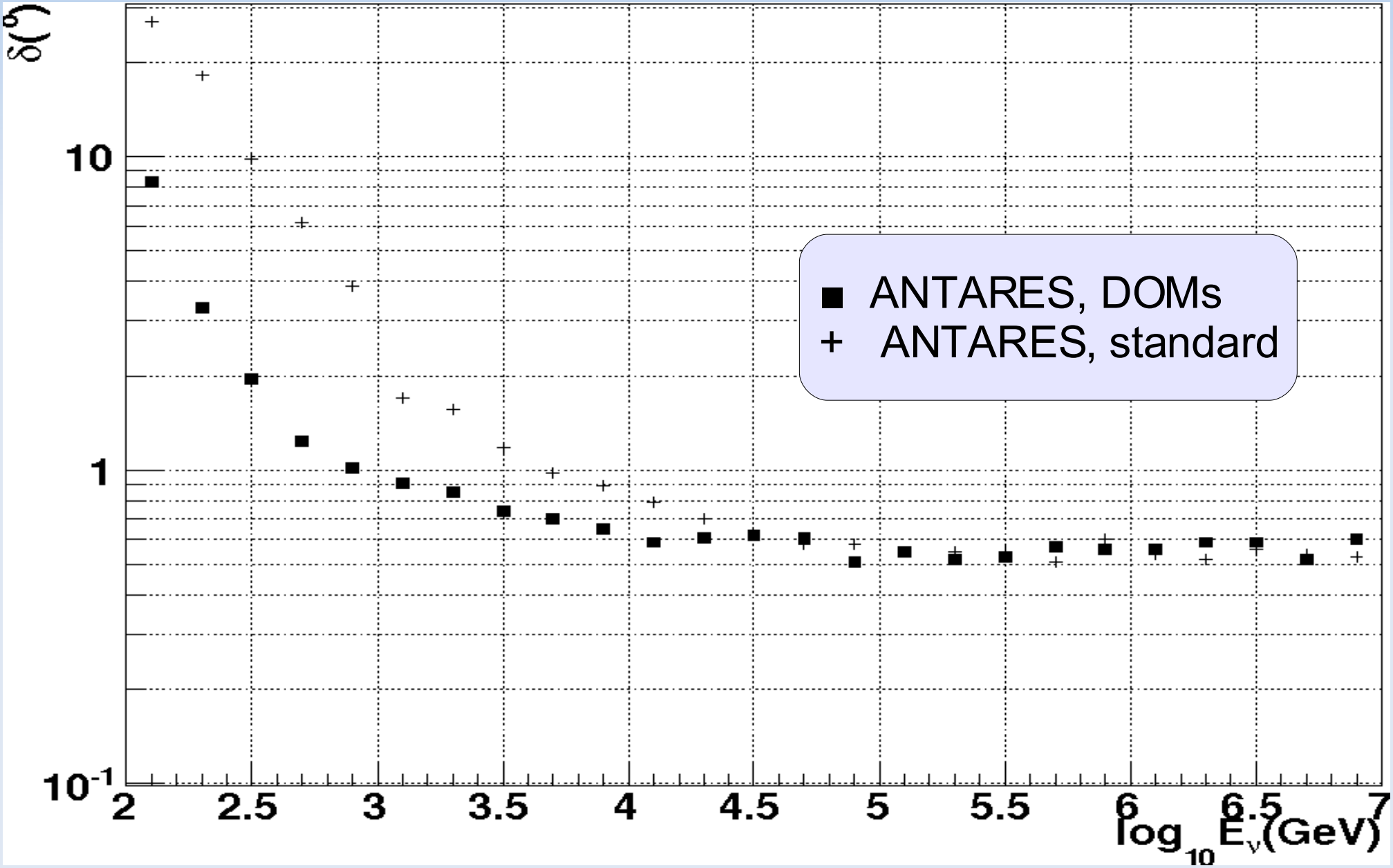
Effective area of ANTARES detectors



Efffective area of ANTARES detectors (ratio to standard)



Angle resolution of ANTARES detector

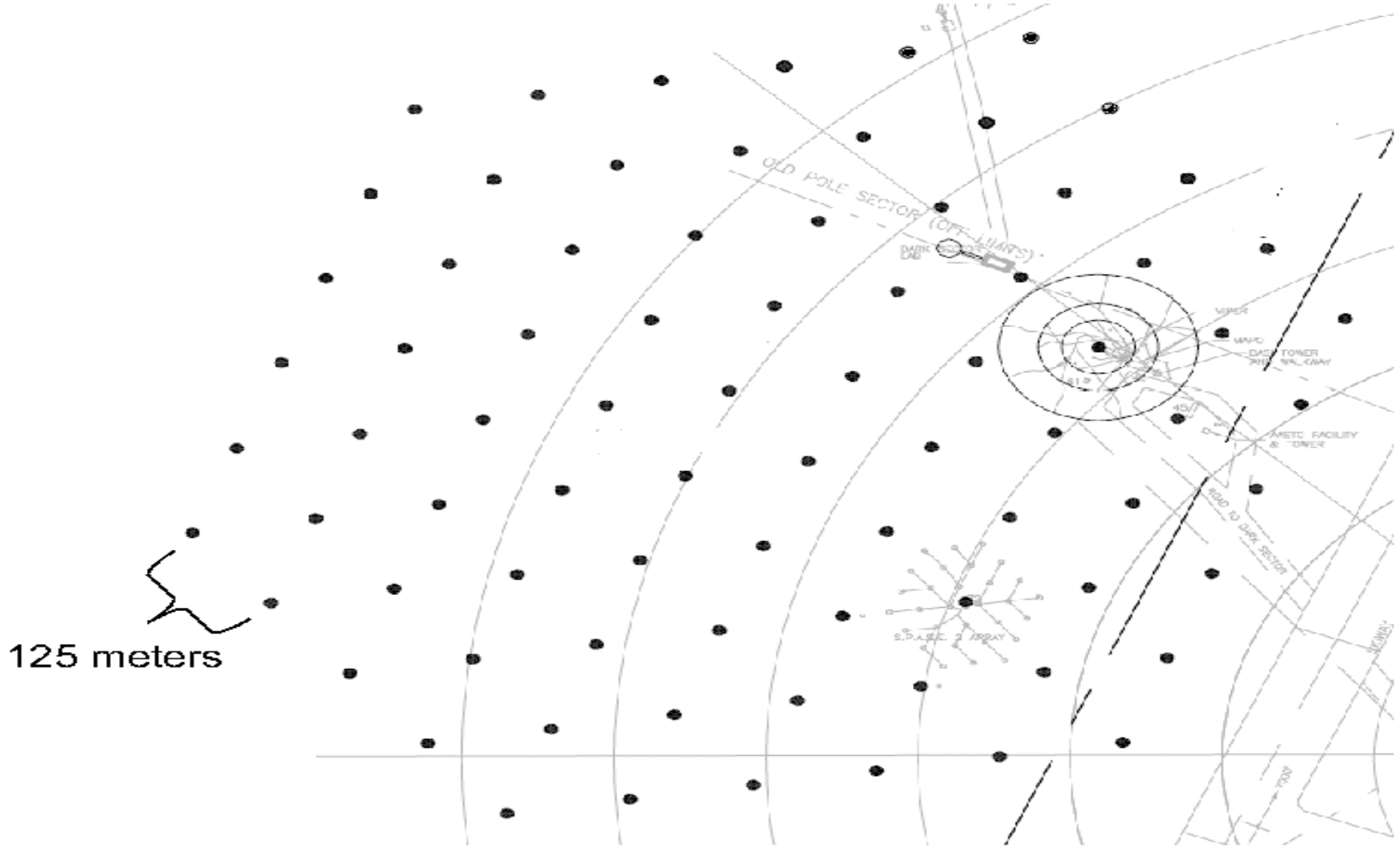


Further goals

- Work with reference configuration
  (WaterCube geometry)
  - reprodude Sebastian Kuch simulations,
    which were done for KM3 Project
  - work with WaterCube equipped with DOMs
- Sensitivity calculations
  - for configurations from this presentation
  - for WaterCube configuration

WaterCube geometry

IceCube Geometry: 9600 OMs looking up & down in a hexagonal grid.
80 Strings, 60 storeys each. 17m between storeys



THANK YOU !