Design Parameters
Sessions A1.1 and A2.1

Plenary Report

C.Spiering
VLVNT Workshop Amsterdam
October 2003

→ low bioluminescence

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→ far from big rivers

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→ low bioluminescence
→ far from big rivers
→ far from inflow of other debris
→ possibility to install an air shower
  array for calibration
→ total complementarity to IceCube
→ no problems with Coriolis force

North Pole !

ApPEC Recommendtions Neutrino Telescopes

→ With the aim of constructing a detector of km3 scale in the Northern hemisphere, both in view of size and competition with IceCube: form a single coherent collaboration collecting *all* the efforts underway

→ Prepare report to ApPEC PRC with following informations:
- optical properties of water, incl. seasonal variations and using the same devices
- optical background and sedimentation
- comparative simulations about impact of depth and water properties to some benchmark km3 detectors (focussing to the central goals of Nu Telescopes)

→ Single design study in the European FP6 framework

→ New review in one year (summer 2004)

Promising steps:

- Long term measurement of sedimentation a la Antares at NEMO site (just one example)

- next: measurement of volume scattering function

- Collaborations envisage to cross calibrate site informations by measuring water parameters at NESTOR site with AC-9 device

- Comparative studies of detectors at different depths, with different noise rates and with 3 principal architecures have been done in a first approach (Dmitry Zaborov, Piera Sapienza). Also Nestor has done a lot of km3 simulations.

Next steps in simulation:

Form a task force group on detector simulation:

- Agree on a working plan (October)
- Input to application for a European Design Study (November)
- First results on comparative studies to ApPEC (Next spring/summer)
- don‘t prioritize site decision in initial phase but just simulate benchmark detectors characterized by a tuple of basic parameters (say depth 2.5, 3.5 and 4.5 km, noise 25,50 kHz and „high“, 3-4 basic architetures)

- Translate to the „real site language“ in a later step

- only then, pure physics arguments should be confronted with technology/infractructure etc. arguments

- a site which is clearly weaker in „physics performance“ would have to have strong arguments on the technology/infractructure site to be selected for a km3 detector

- Input from the performance of detectors at the Antares/Nestor site as early as possible (not for simulations but for a final decision on architectiure and site).

	ANTARES	NEMO	NESTOR
Depth (km):	2.4	3.4	4-5
Factor downward muon intensity	← ~5 →	← ~ 3 →	
Absorption length (m):	50 **(60)**	65	55-70
	Same device (ANTARES and NEMO)		
External steady noise: (kHz/8 inch tube)	40-60	20-30	20-30 (10“)
Sedimentation:	strong	smaller	smaller
Distance to shore (km):	20 (10)	70 (70)	20 (15)

↗ Shore station (closest shore)

- Background from misreconstructed
  downward muons
- Visibility of sky
- Influence of bioluminescence.
  dead-times and background rejection
- Limitations due to sedimentation/biofouling
  (up/down OMs)
- Distance to shore

Direct effects

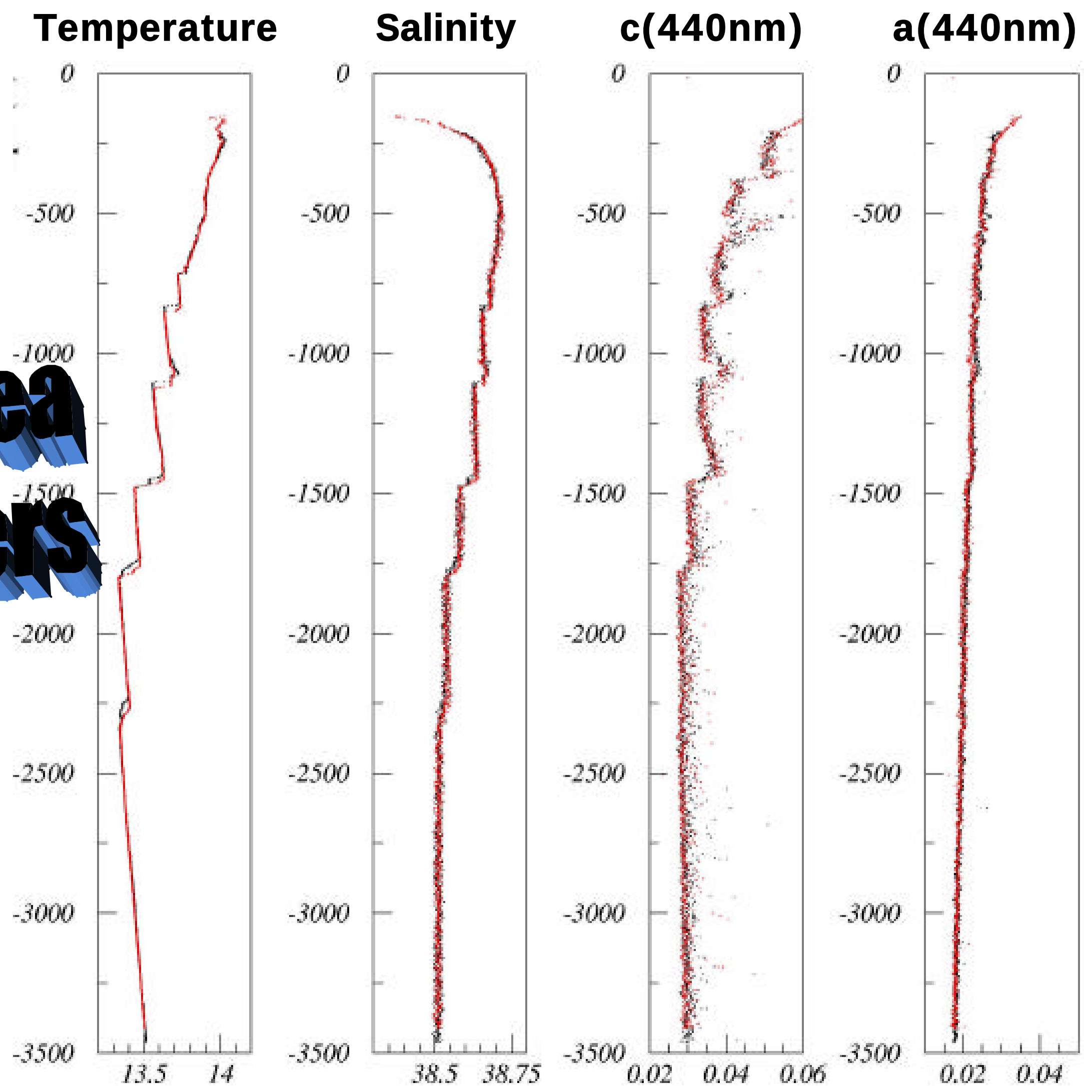
Light absorption coefficient (l)	number of Cherenkov photons on PMT
Light scattering coefficient (l) Volume scattering function (l)	timing of Cherenkov photons on PMT
Light refraction index (T, S, P, l)	timing of Cherenkov photons
Optical noise	spurious hits, PMT and electronics dead time

Indirect effects

Sound velocity (T,S,P)	position of PMTS
Sedimentation rate	light scattering + PMT temporary obscuration
Biofouling	PMT permanent obscuration
Currents	positioning increase bioluminescence reduce sedimentation

G. Riccobene

Alicudi: the Tyrrhenian Sea shows water layers



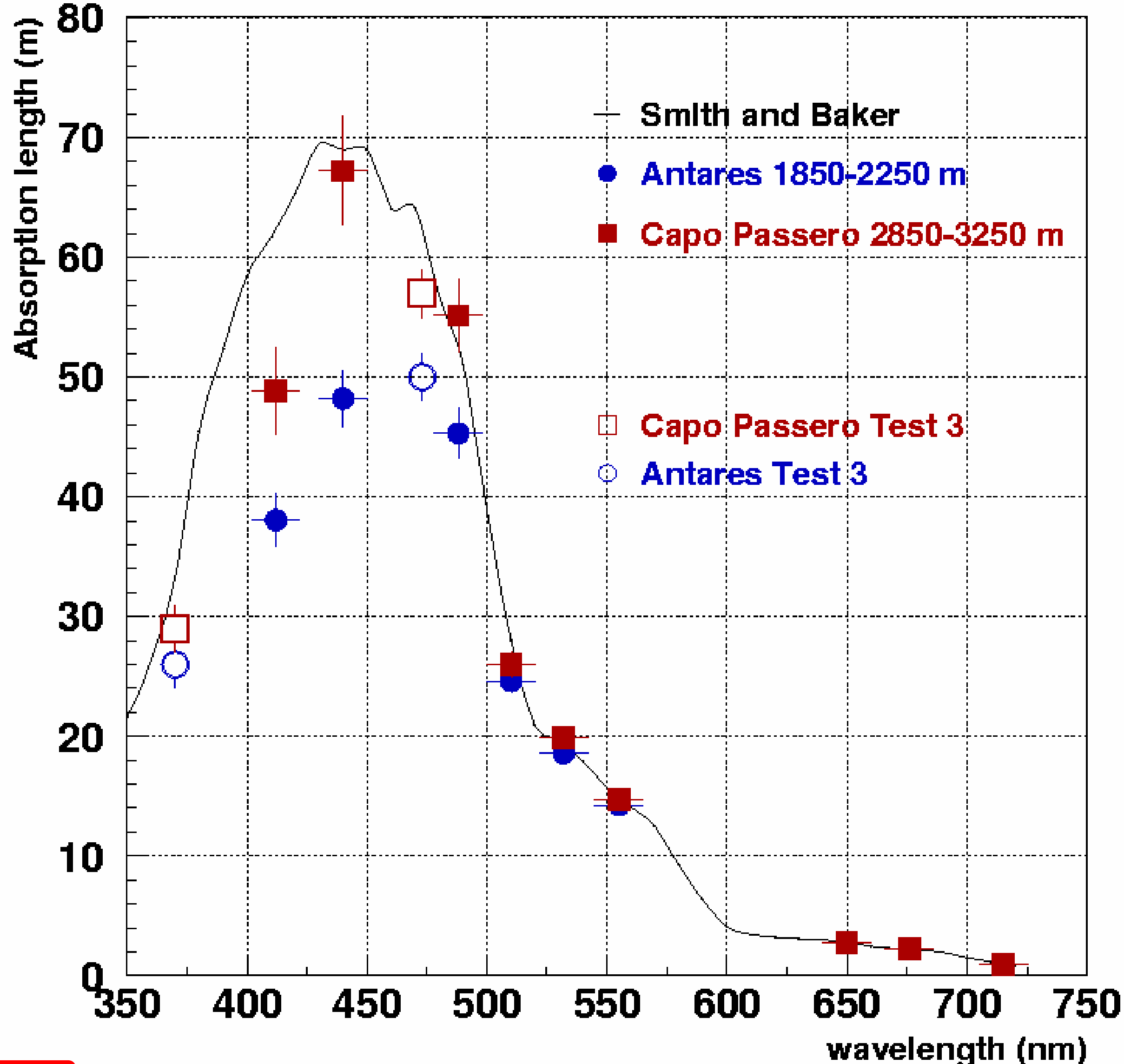
A.Capone et al., NIM 2001

The systematic error is due to the calibration of the instrument.

It has been evaluated to be: $\Delta a(\lambda) \approx \Delta c(\lambda) \approx 0.002 \ \ m^{-1}$

G. Riccobene

AC9+Test 3' data: Capo Passsero and Toulon

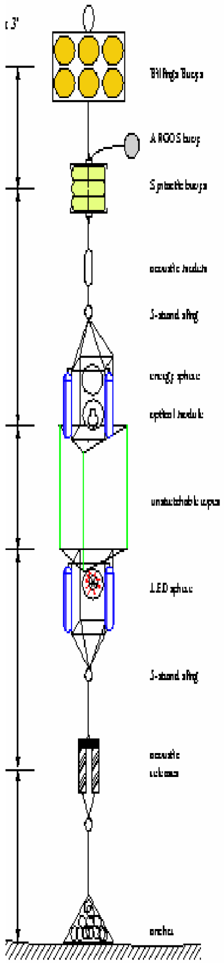


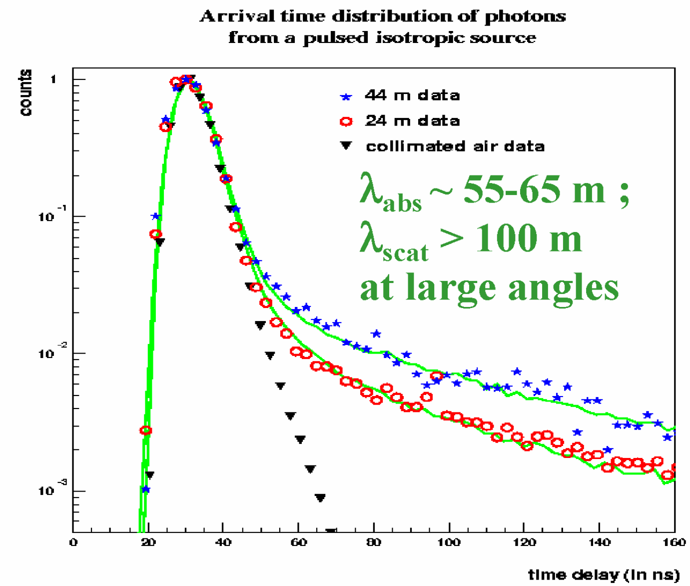
esy of J-P Schuller

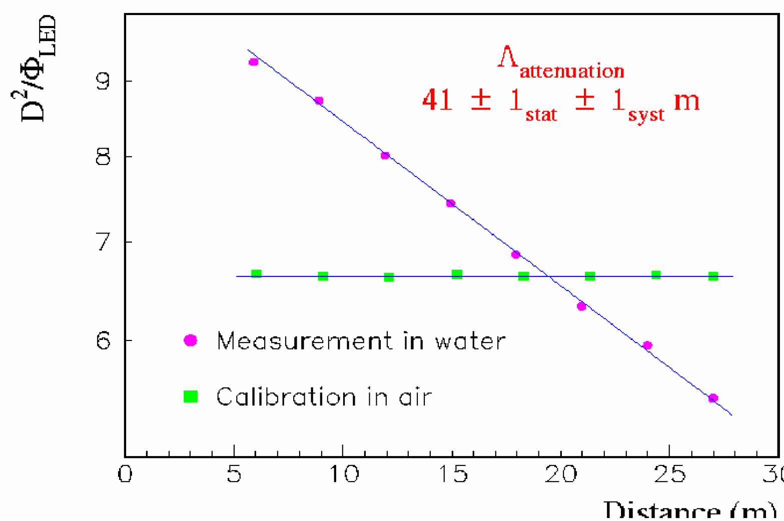
G. Riccobene

Toulon data from ANTARES Collaboration

Water Transparency





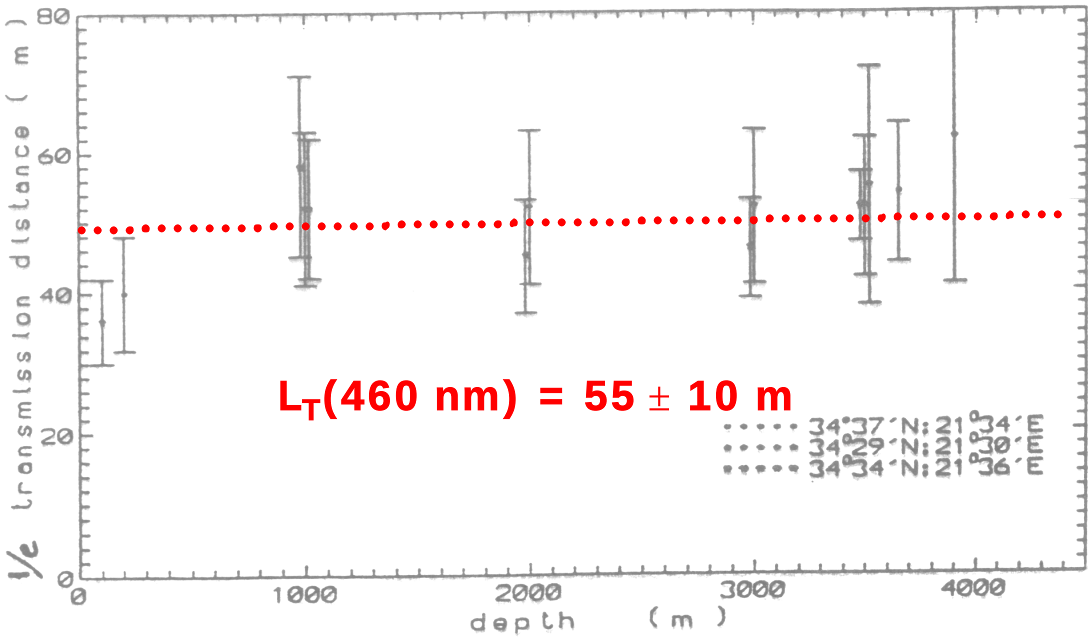


G. Riccobene

talk

Group velocity also determined

Pylos data from NESTOR Collaboration



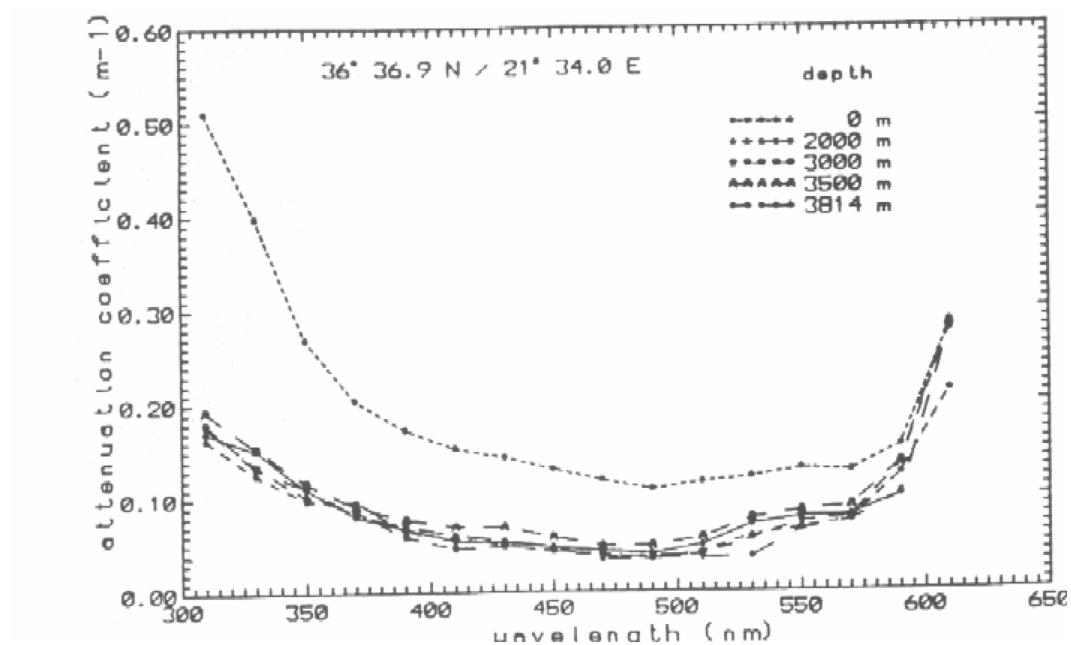
Transmission length

Measured in non-collimated geometry
(Annassontzis et al., NIM 1994)

G. Riccobene

Attenuation coefficient

Measured in collimated geometry using deep seawater samples
(Khanaev et al., NESTOR 1993)



Main physics goals proposed as basis for benchmarking procedure

→ Point source search (excluding WIMPs) **+**
- steady sources ? **+**
- transient sources **-**
- muons **+**
- cascades **-**
- energy range **?**

→ WIMPs
- Earth WIMPs not competitive with direct searches **-**
- Solar WIMPs **+**
- energy range go as low as possible

C.Spiering

Main physics goals proposed as basis for benchmarking procedure (cont‘d)

→ Atm.neutrino oscillations -

- not competitive with SK & K2K if not the spacing is made unreasonably small
- nested array a la NESTOR 7-tower ?
- proposal: → no optimization goal
  → no benchmark goal

→ Oscillation studies with accelerators -

- too exotic to be included now

C.Spiering

Main physics goals proposed as basis for benchmarking procedure (cont‘d)

→ Diffuse fluxes

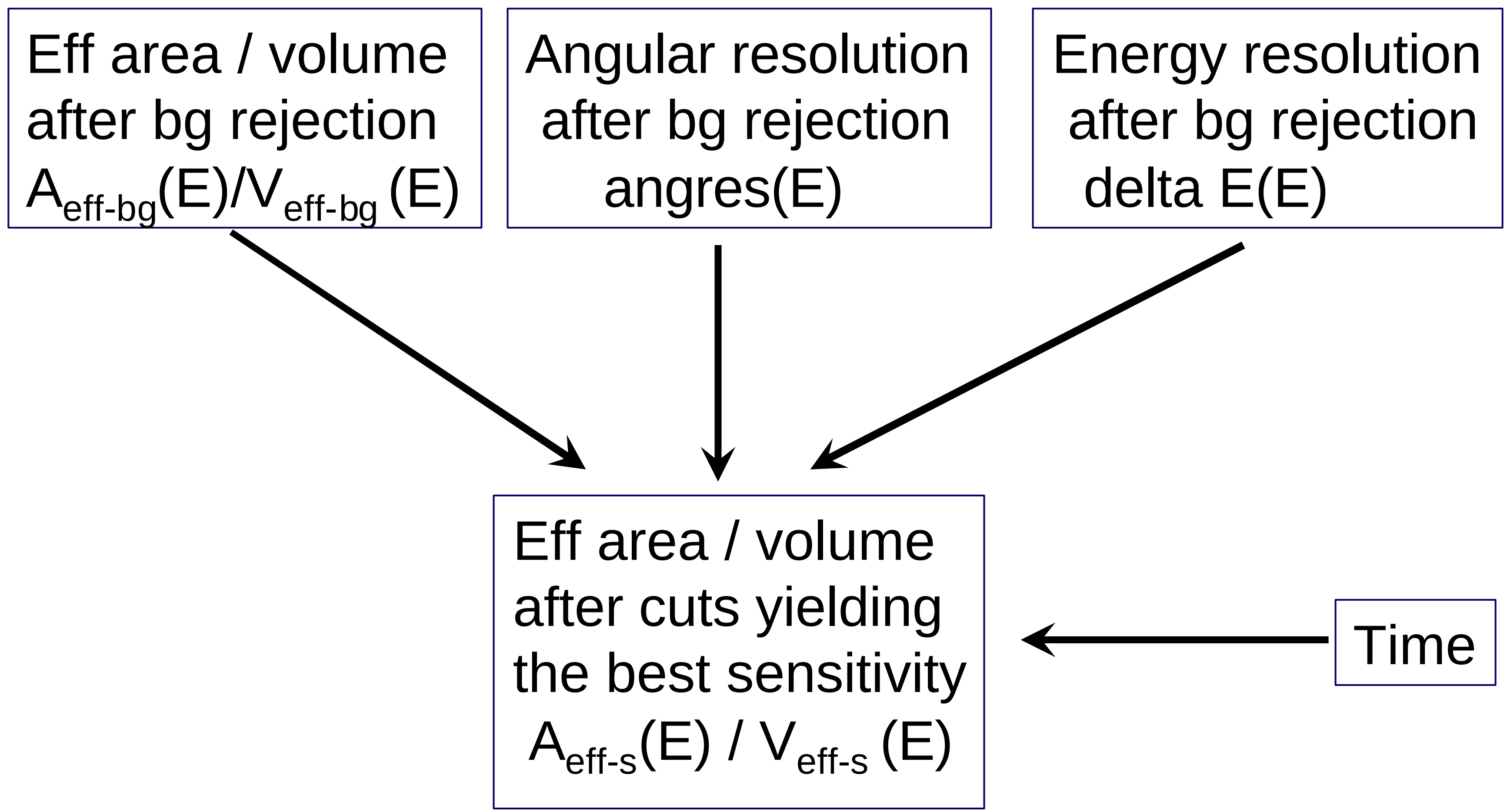
- muons up and down **+**
- cascades **+**

→ Others

- downgoing muons
  - → physics **-**
  - → calibration **?**
- monopoles **-**
- slowly moving particles **-**
- ...

C.Spiering

Benchmark Parameters



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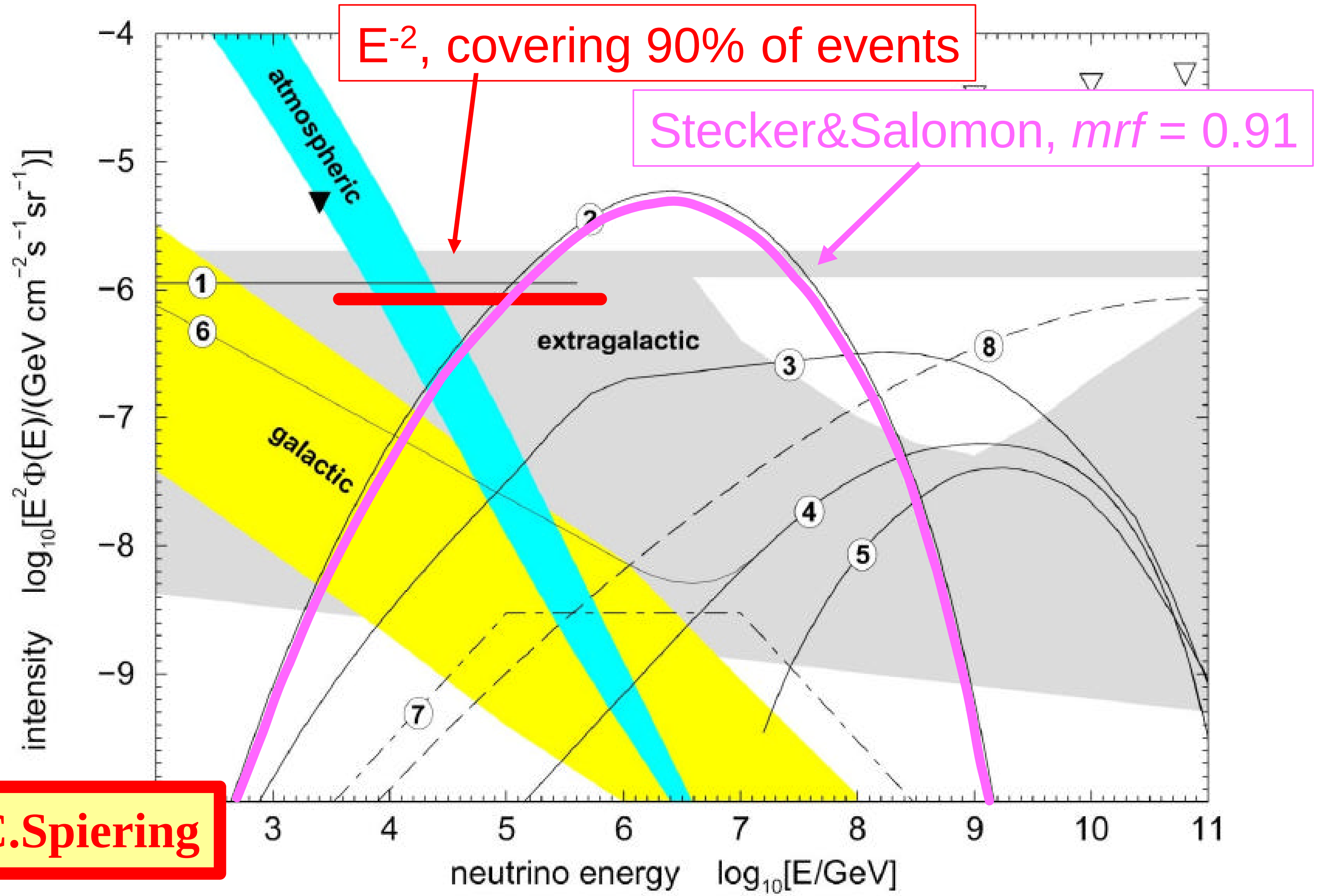
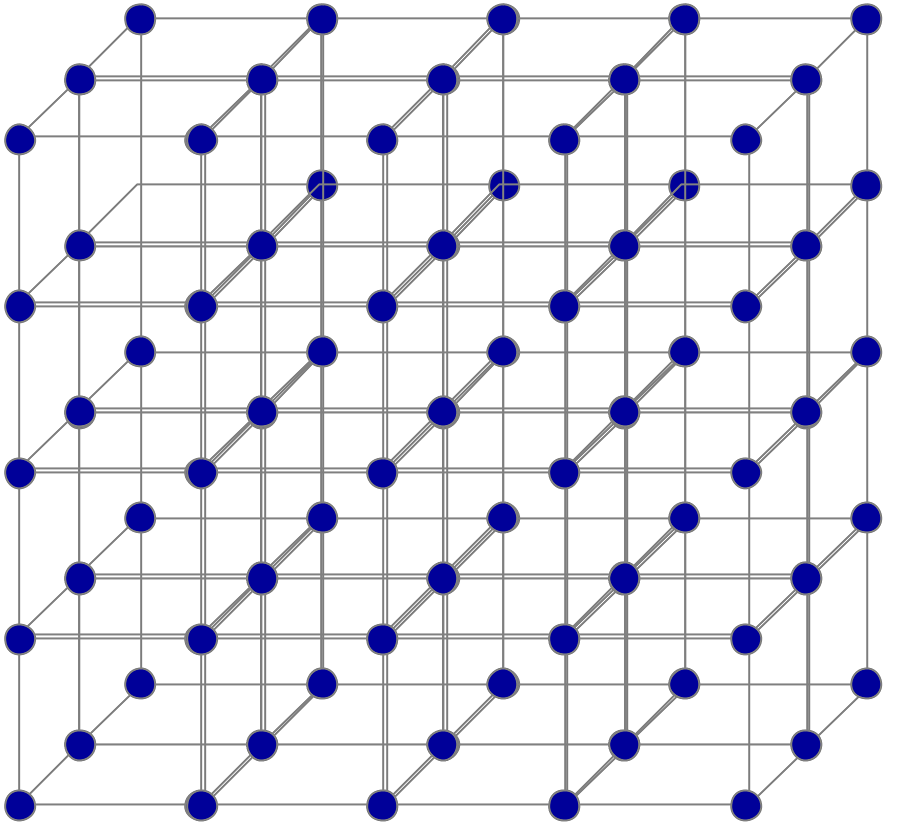
Integral Limits



C.Spiering

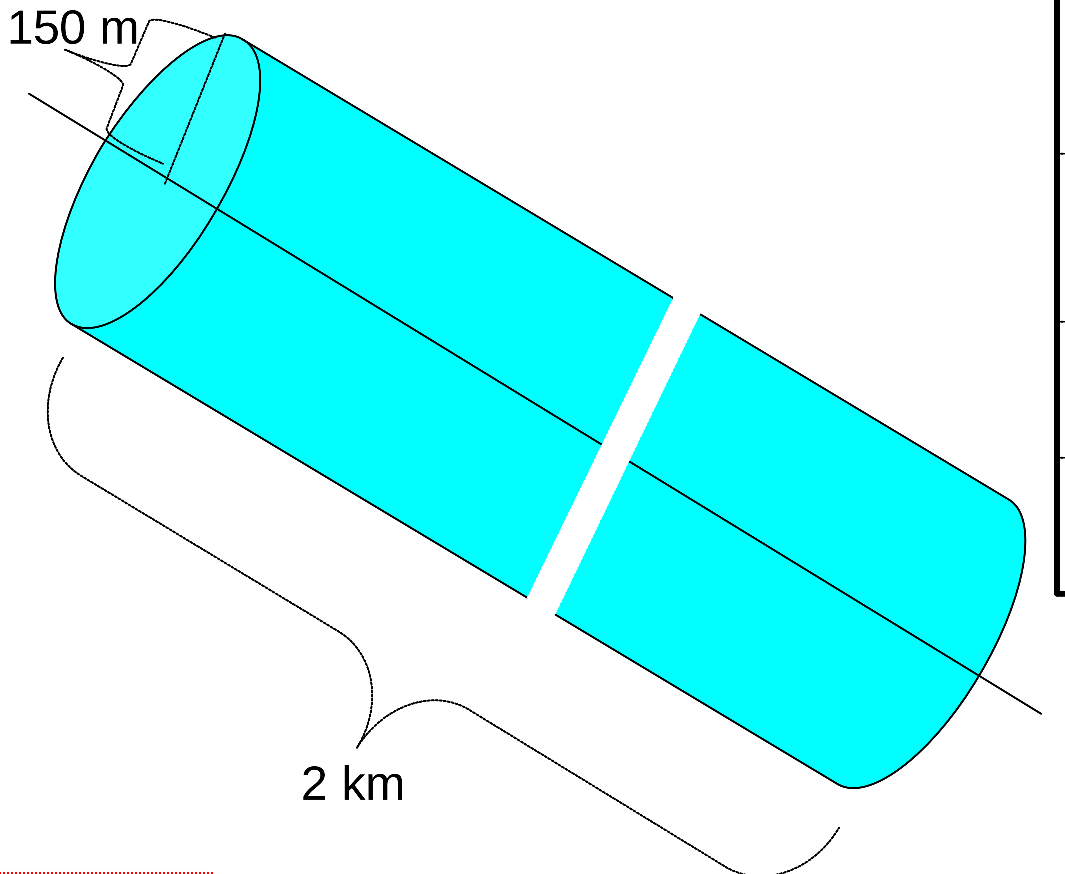
Can we use a generic, dense detector as the basic tool in our design studies?



A GRID type Detector

S.Tzamarias

Mean Number of "Candidate" PMTs per "Track"



	Mean Number of "Candidate" PMTs per Track
NEMO	550
NESTOR	1070
ANTARES	11000
GRID	140000

Shadowing

NESTOR: $0.4\ 10^{-3}$

GRID: $12\ 10^{-2}$

S.Tzamarias

The "obvious" way to proceed

Define the values of the relevant environmental parameters, for the candidate sites, based on published data (water optical properties, K40 background, bioluminescence activity, bio-fouling, atmospheric background fluxes and absorption)

Simulate the response of an optimum detector (at a given site) to e, μ and t (vertices). Events are produced equal (or almost equal) probably in phase space.

Use standard tools to simulate the physics processes. Include in the simulation the K40 background.

Simulate in detail the OM response and ignore effects of (in a first approximation will be the same to all the different designs) the readout electronics, triggering and DAQ.

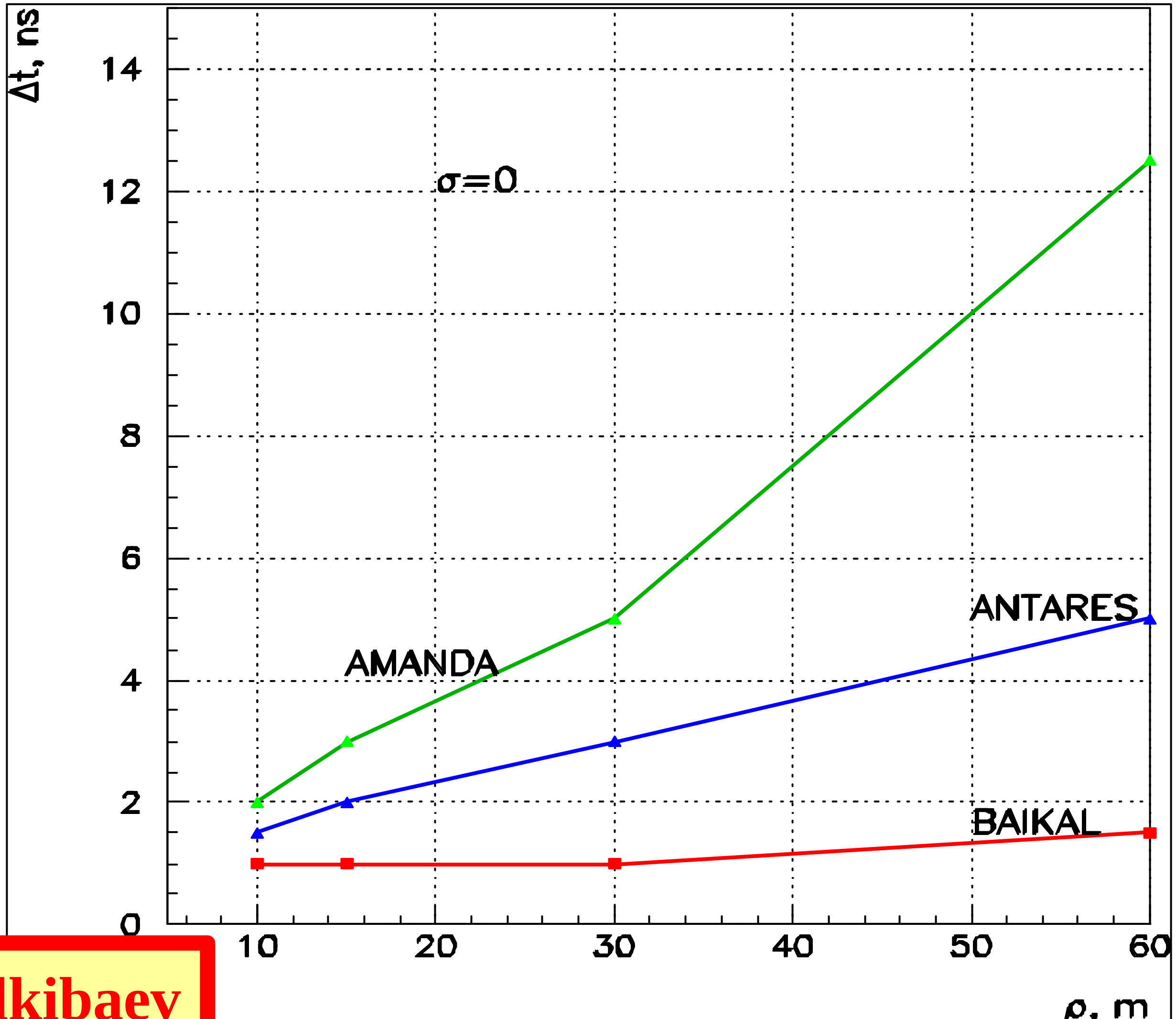
Produce "event tapes" including the "generation" information and the detector response (e.g. deposited charge and arrival time of each PMT pulse). The "event tapes" and the relevant data basis should be available to the other groups.

Reconstruct the events and produce DST's including the "generation" and reconstructed information (e.g. direction, impact parameter, flavor, energy) for each event. The DSTs should be available to the other groups.

S.Tzamarias

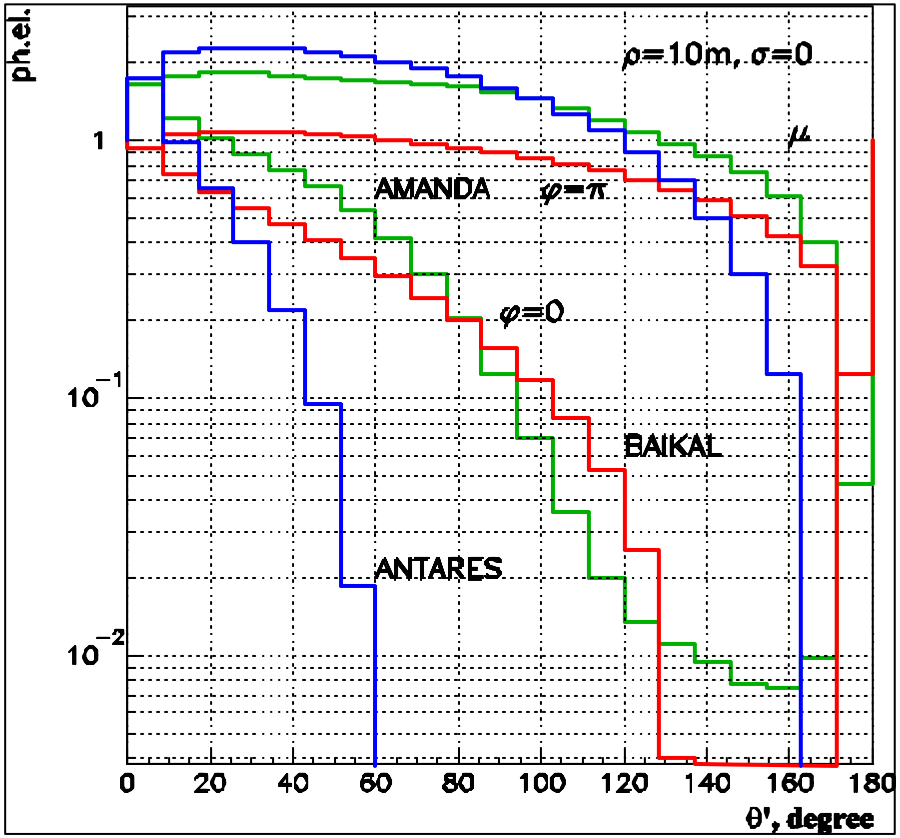
(Ntuples) to express the tracking efficiency and resolution as a
on of the direction and energy (and impact parameter)

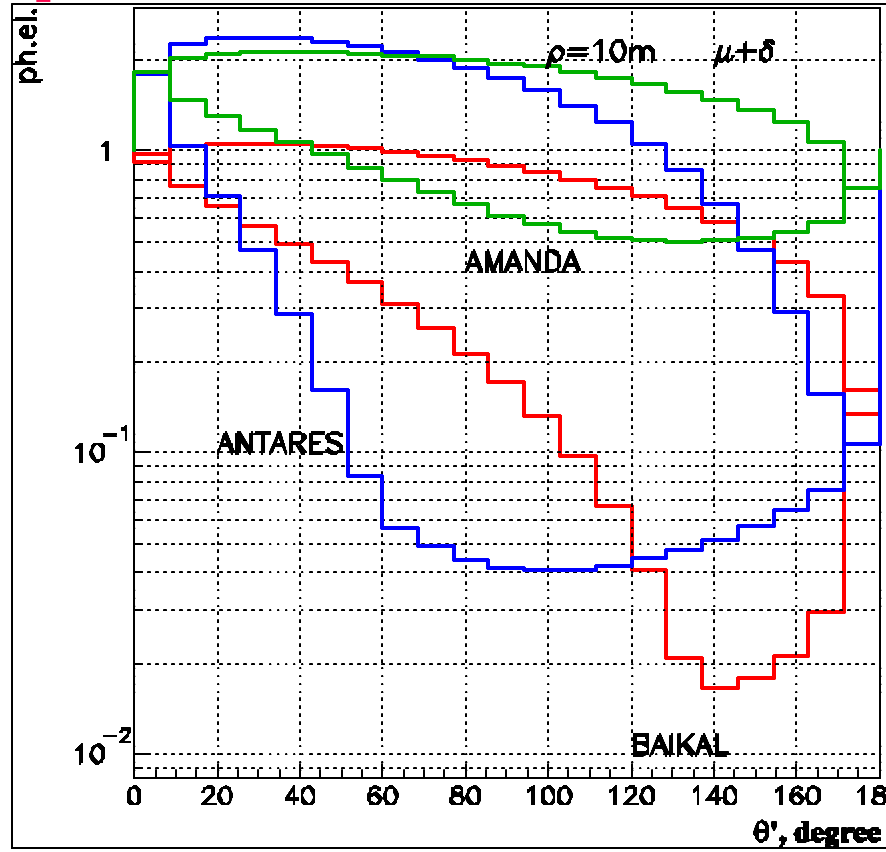
FWHM of the time distribution (without scattering)

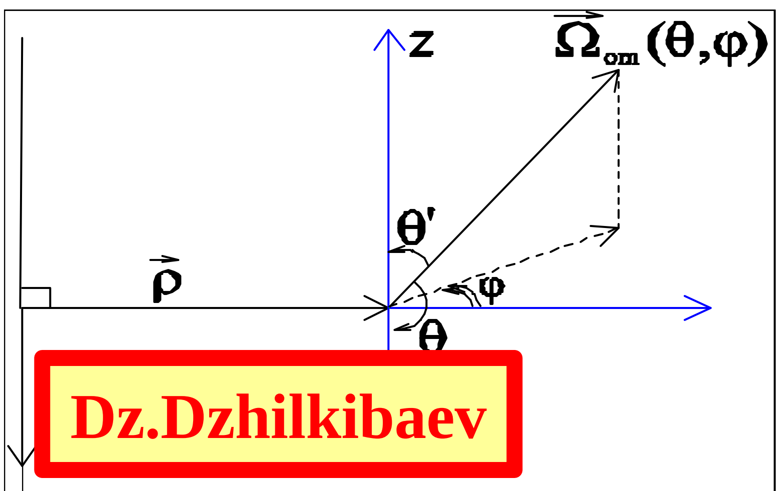


Dz.Dzhilkibaev

Dependence of OM response on its orientation





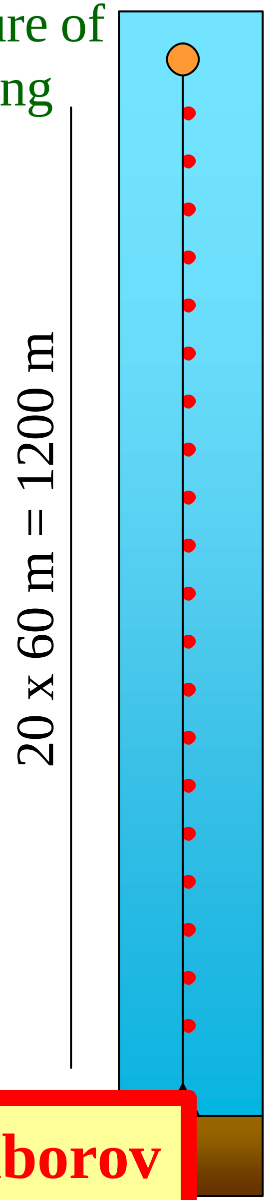


Dz.Dzhilkibaev

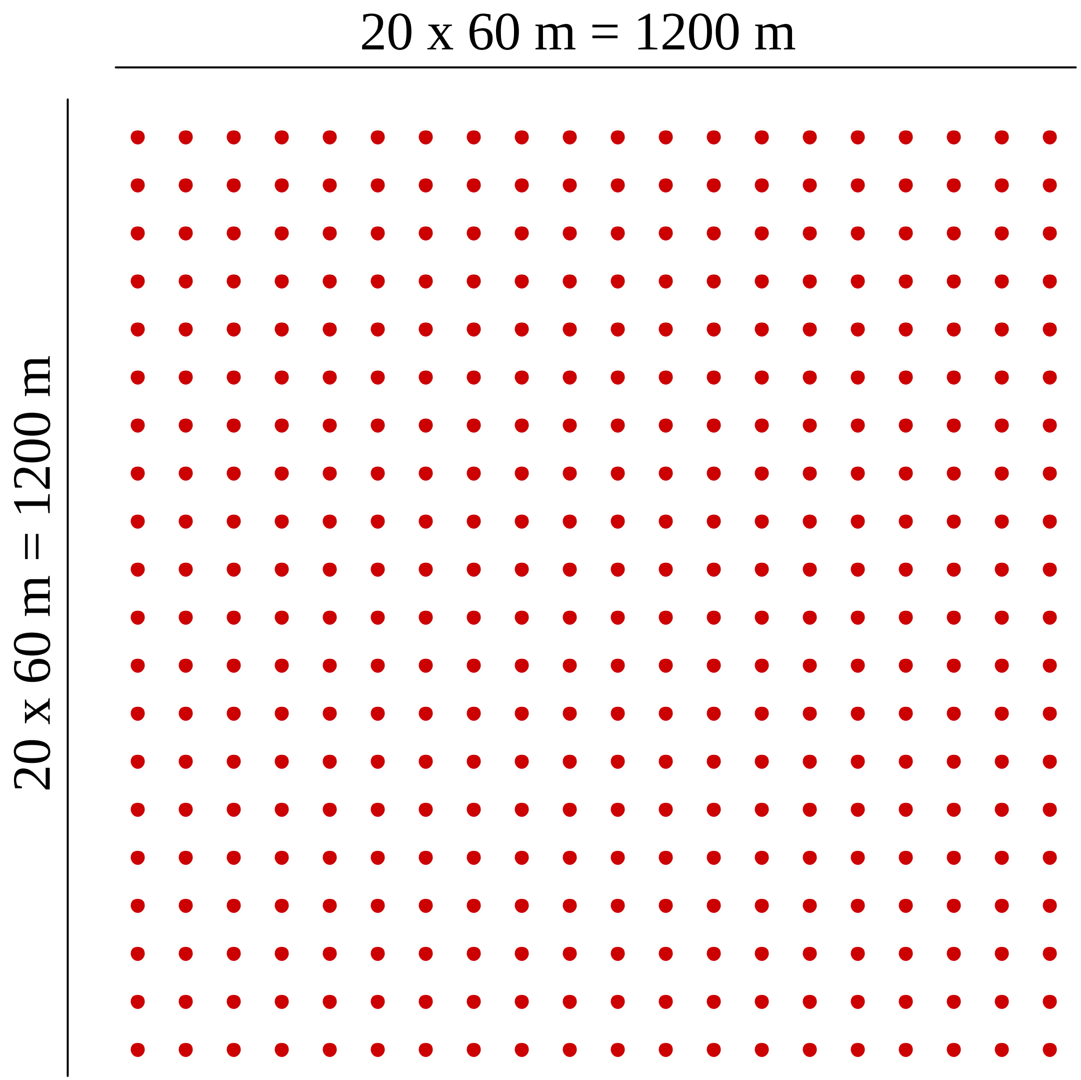
	anisotropy	Blind zone
BAIKAL	~50	4 %
ANTARES	~50	25 %
AMANDA	~ 4	-

A large homogeneous KM3 detector (8000 PMTs)

Structure of the string

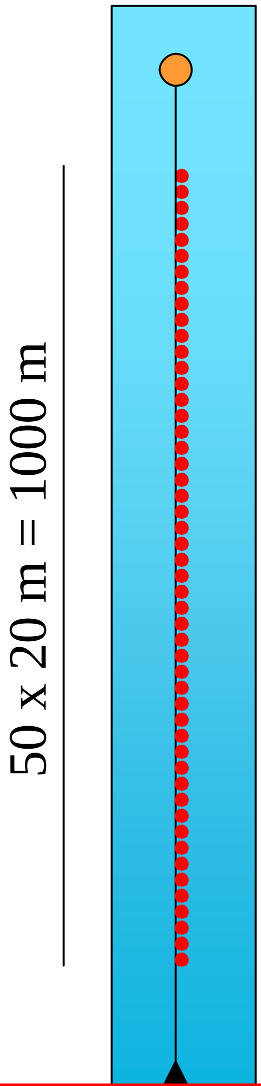


D. Zaborov

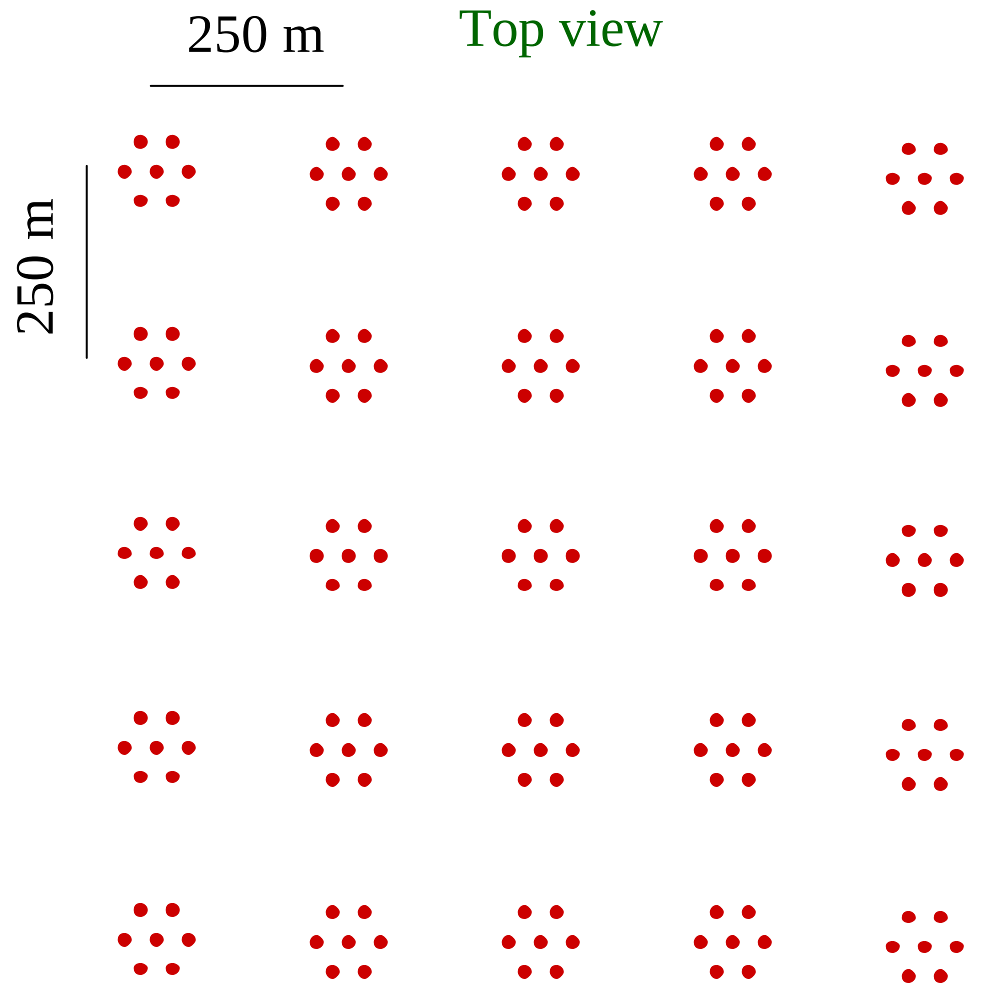


homogeneous lattice 20 x 20 x 20 downward-looking
10 “ photomultiplier tubes

A large NESTOR – like detector (8750 PMTs)



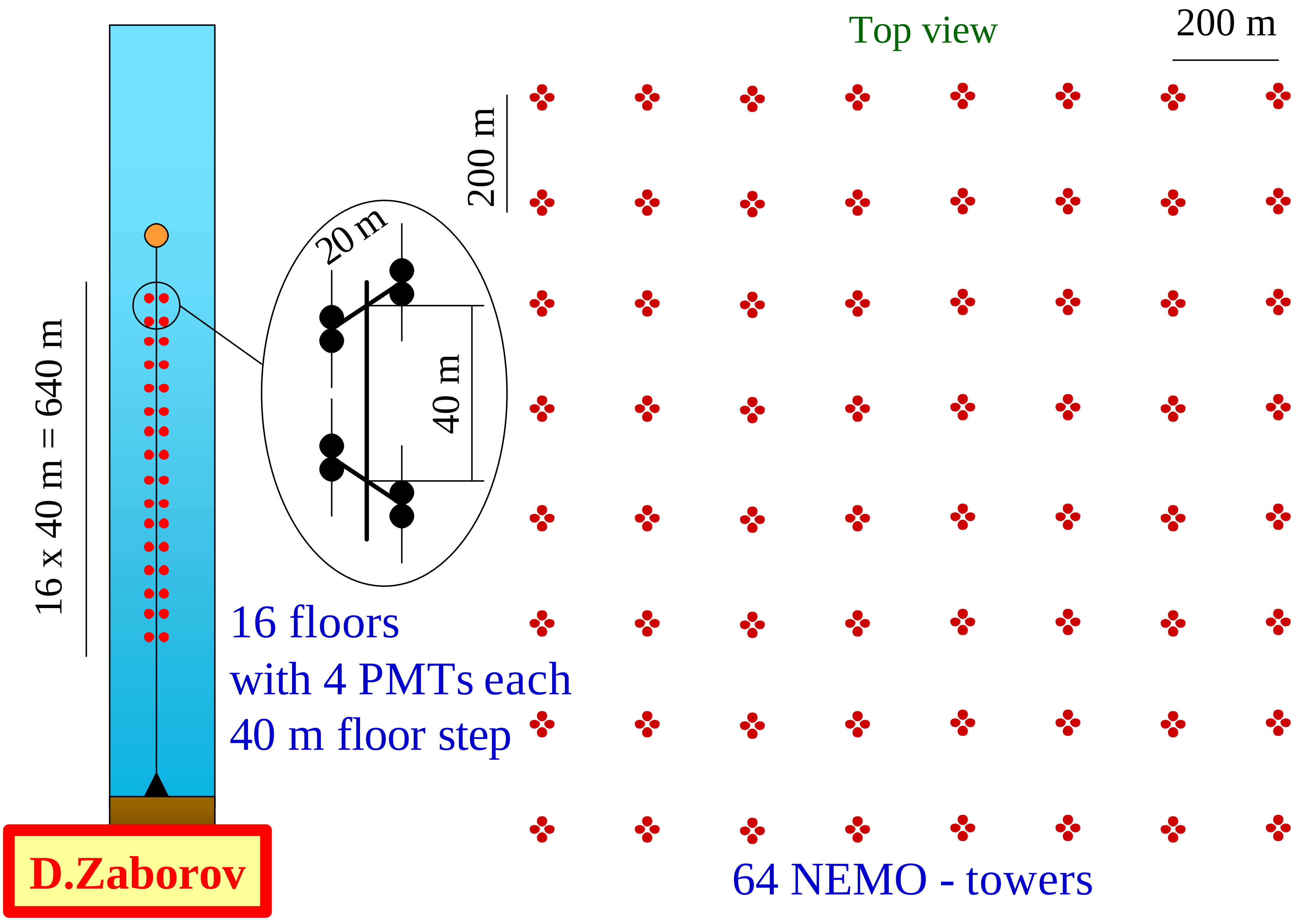
50 floors
20 m step



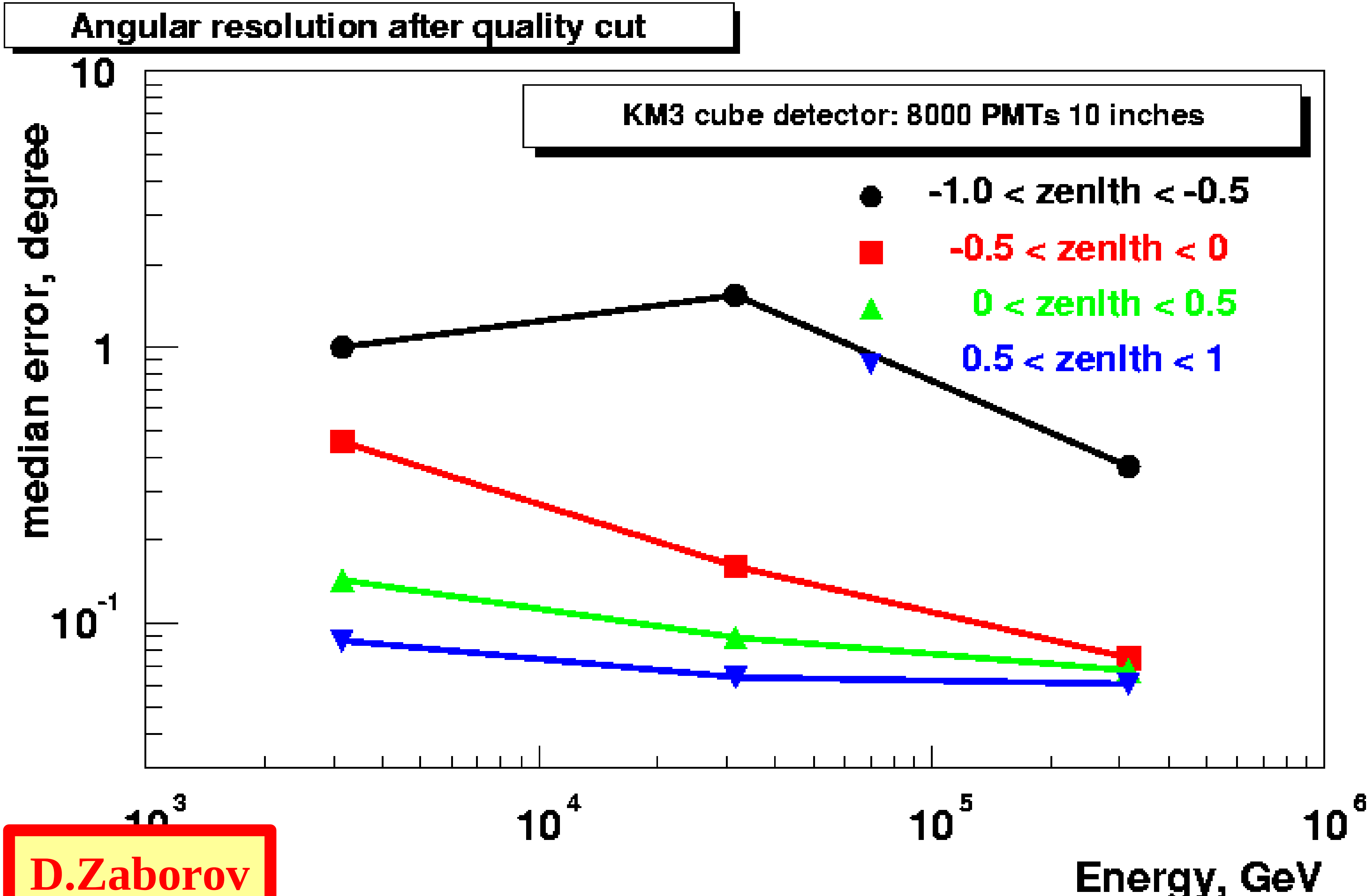
25 towers, each consists of 7 strings
PMTs are directed downwards

D.Zaborov

A large NEMO – like detector (4096 PMTs)

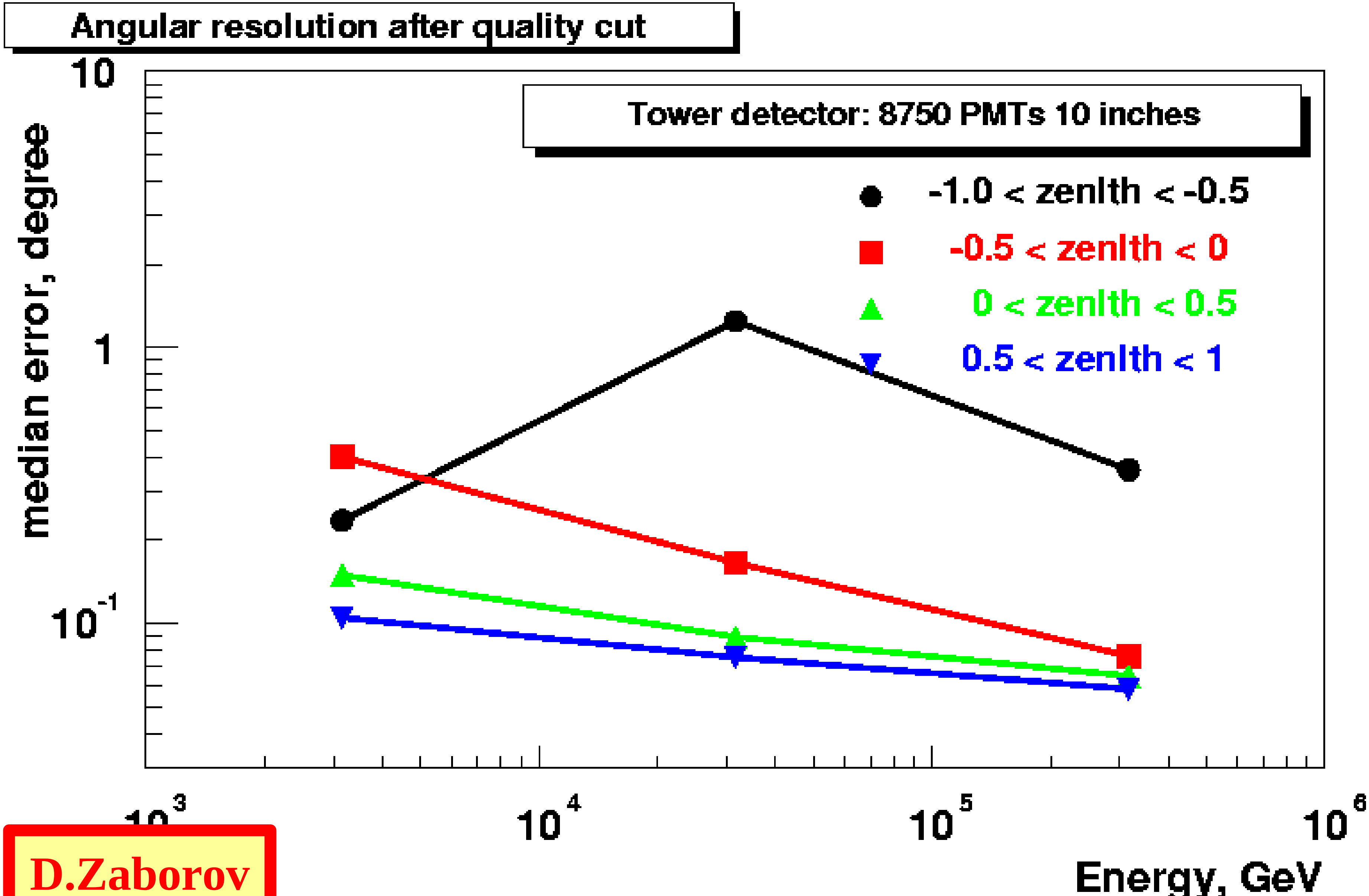


Angular resolution of the homogeneous detector



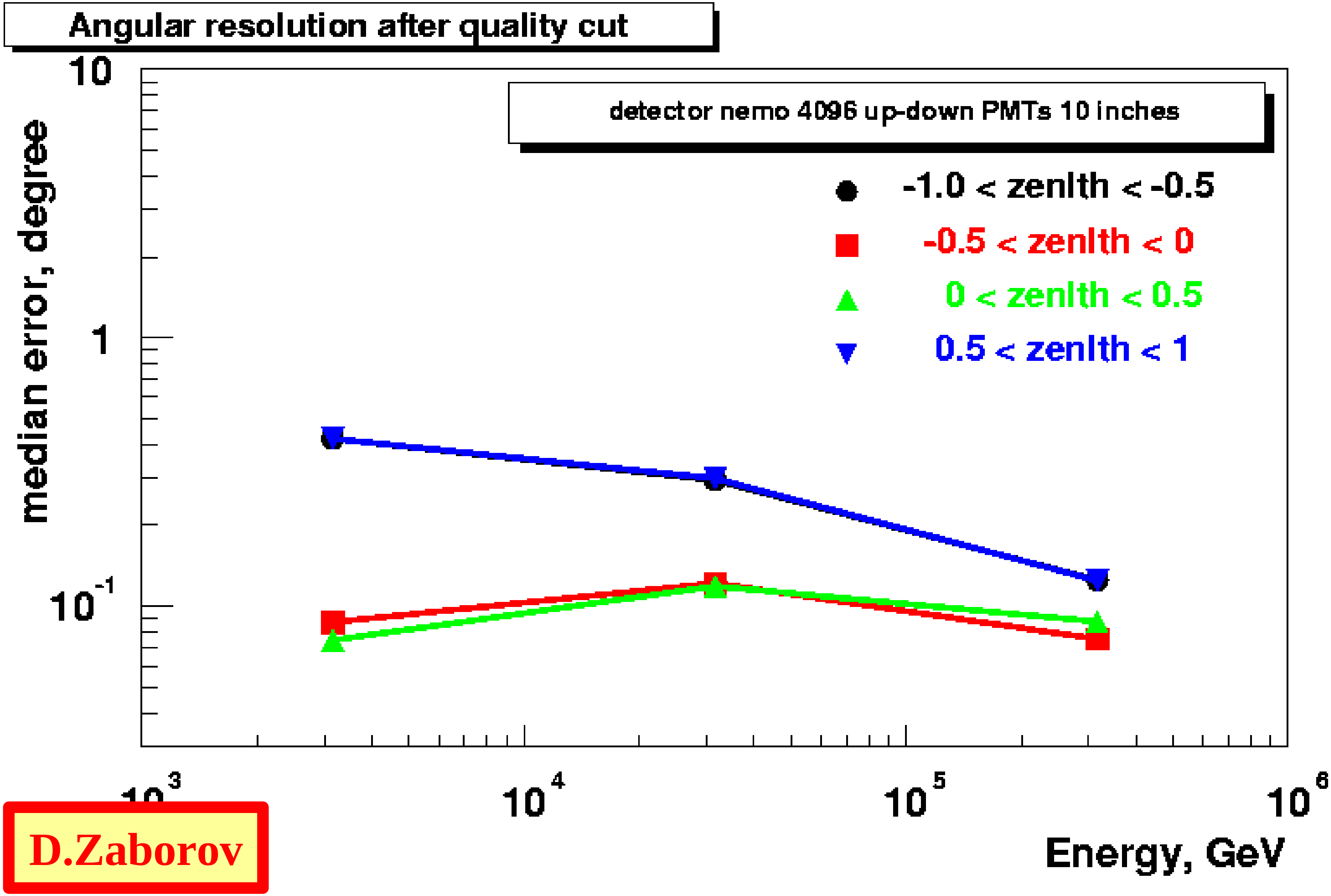
D.Zaborov

Angular resolution of the NESTOR-like detector



D.Zaborov

Angular resolution of the NEMO-like detector



D.Zaborov

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Sud

INFN

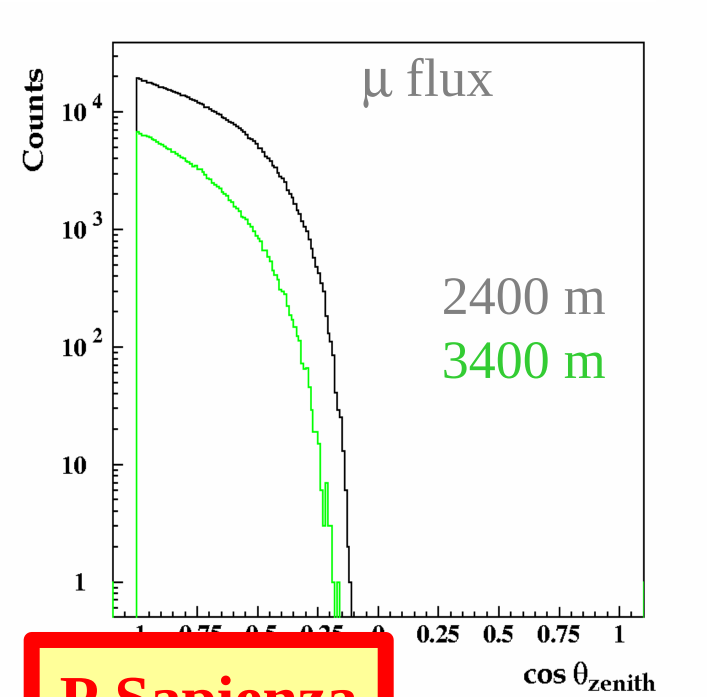
Atmospheric muon simulations

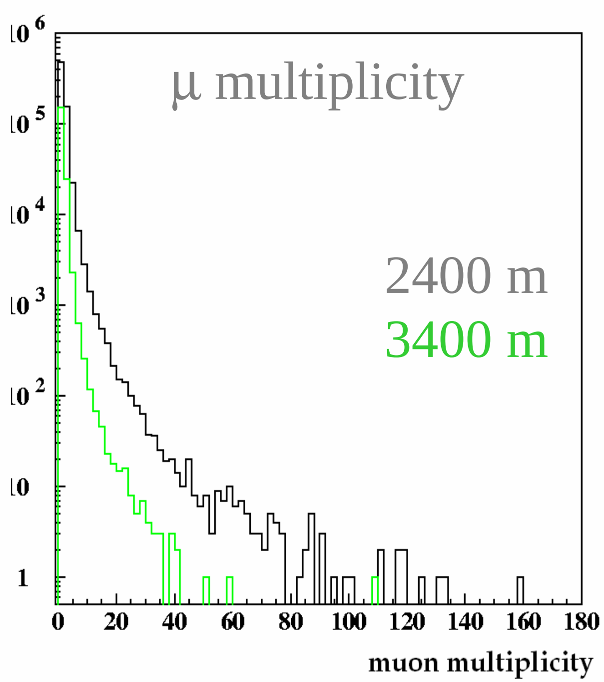
A. Margiotta et al

The depth of the site is related to the shielding from atmospheric muons

HEMAS code (vrs7-02) has been used to simulate the atmospheric down-going muon flux at sea level for zenith angles up to about 85°

MUSIC code has been used to propagate muons from sea level to the detector can at 2400 m and 3400 m underwater





Strong muon flux and multiplicty reduction at 3400 m, especially at large angle
Effect on detector performance is under investigation

P.Sapienza

Simulation of NEMO detectors with OPNEMO

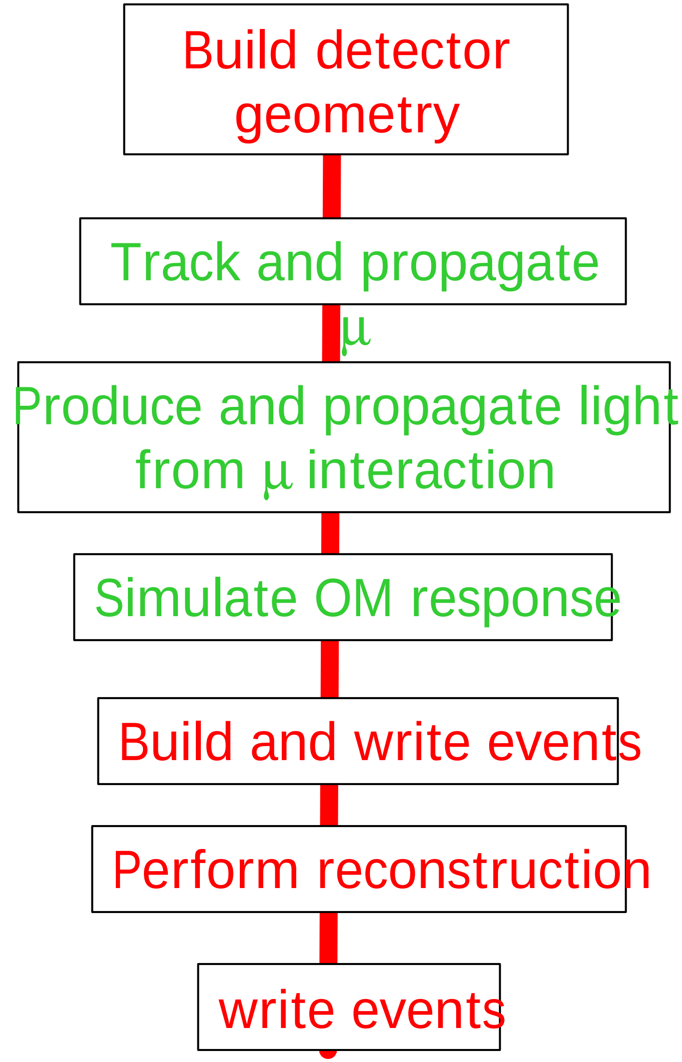
OPNEMO code (S. Bottai and T. Montaruli) is a fast first generation Monte-Carlo tool

OPNEMO has been used to define km^3 detector lay-out and triggers in the NEMO Collaboration

Main limitations:

- scattering of light not taken into account
- **track reconstruction in presence of optical background not implemented**
- …

It has provided indications for the detector lay-out



P.Sapienza

Detector configurations – *OM arrangement* -

OPNEMO without optical background (C. Distefano et al)

surf. μ generation

$N_{string/tower}$= 64

$H_{string/tower}$= 600 m

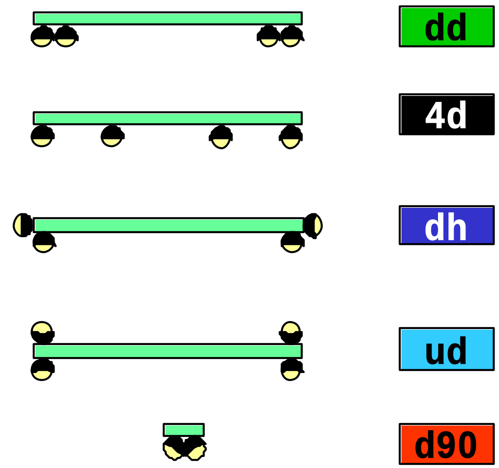
N_{PMT} = 4096

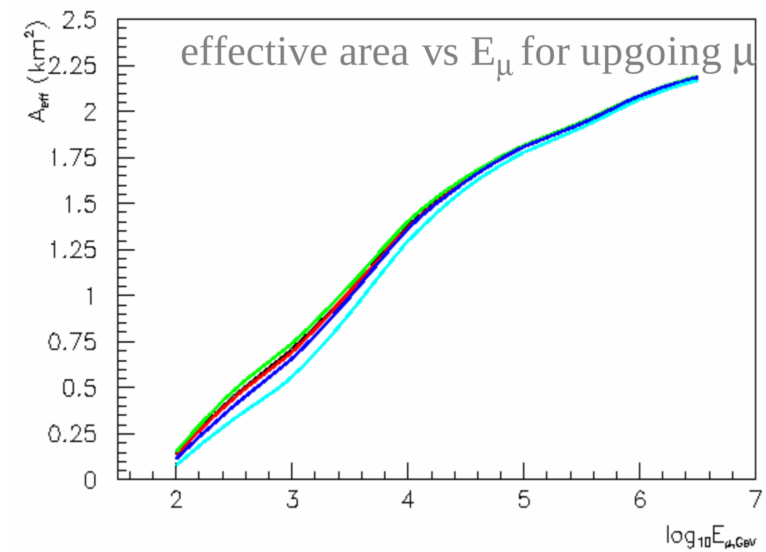
D_{PMT} = 10”

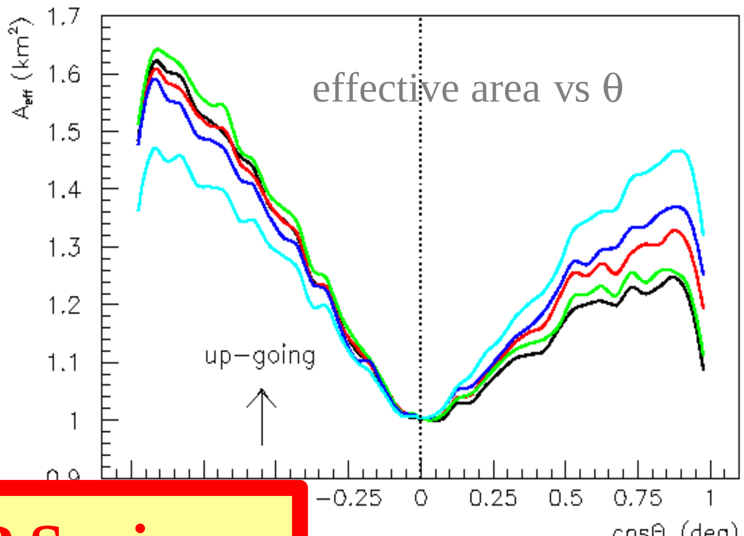
s_{PMT} = 2.5 nsec

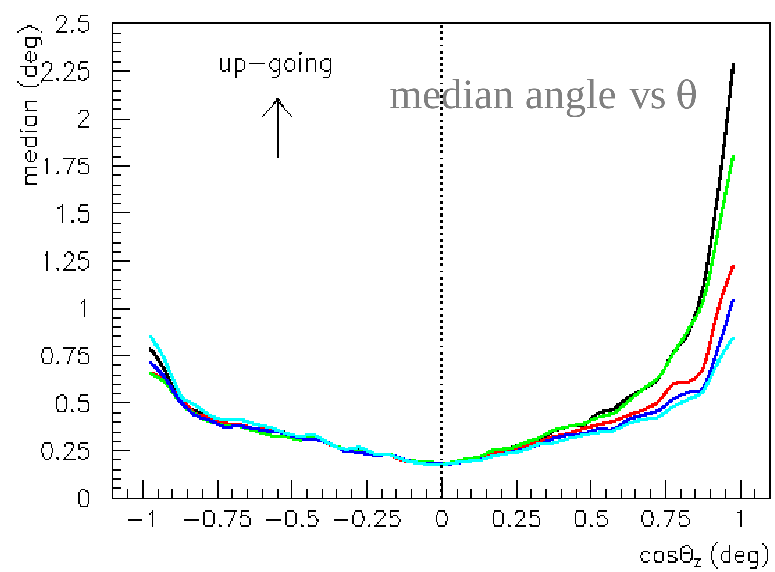
d_{xy} = 180 m

λ_a(450 nm) = 40 m









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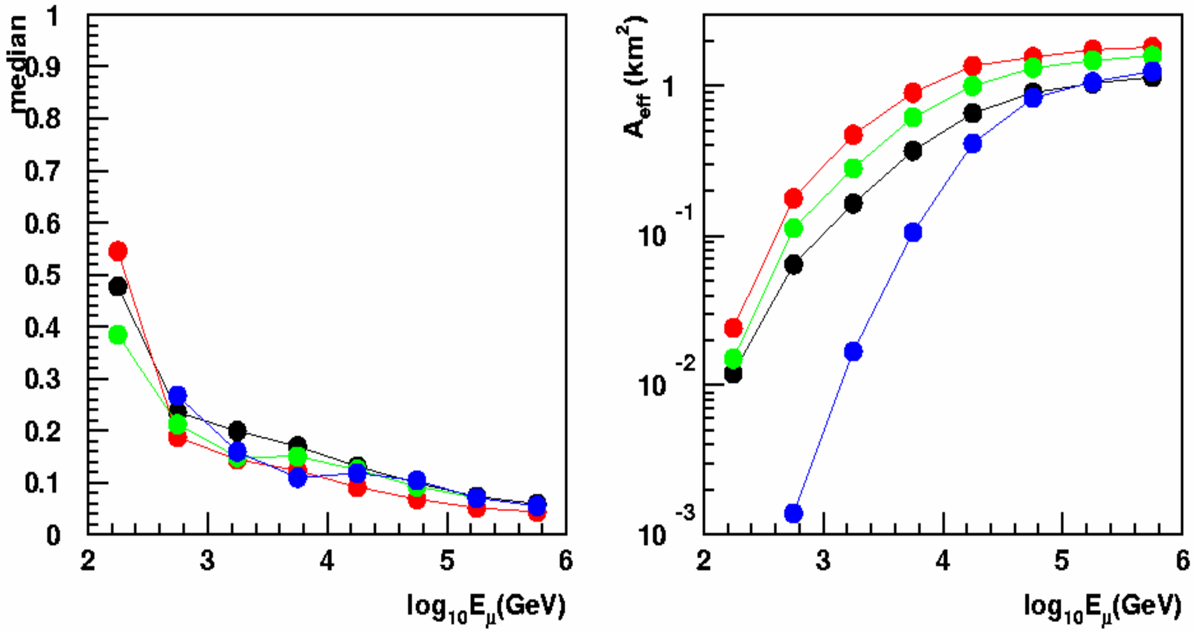
Simulations of NEMO detectors with the ANTARES software package (R. Coniglione, P.S. et al)

During the ANTARES meeting held in Catania on september 2002, the ANTARES and NEMO collaboration agreed to start a stronger cooperation towards the km^3.
In particular, activities concerning site characterization and software were mentioned.
By the end of 2002, ANTARES software was installed in Catania by D. Zaborov.

Optical background dependence



In order to make comparisons for the same angular resolution quality cuts must be applied

Regular lattice 400 strings 60m x 60m

NEMO 140 dh 9x9 20 kHz with qual. cuts

NEMO 140 dh 9x9 60 kHz with qual. cuts

NEMO 140 dh 9x9 120 kHz th. 1.5 p.e. & q. c.

P.Sapienza

Water properties Refractive index

Wave length window

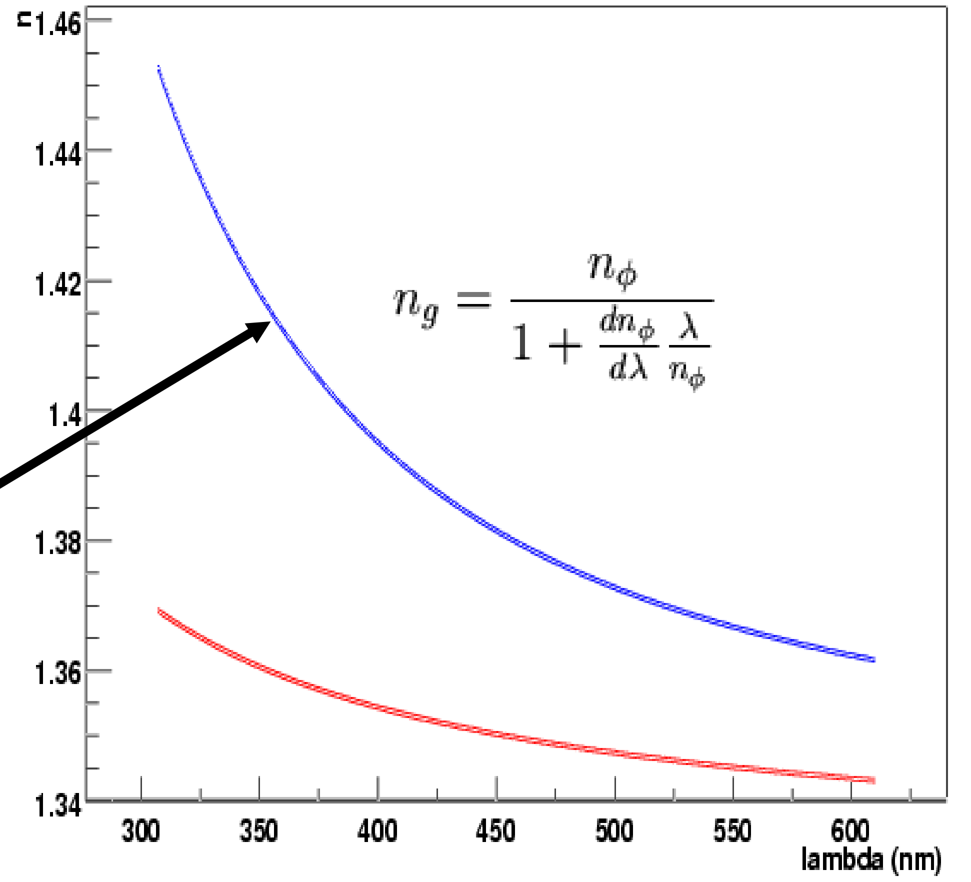
300-600nm

Refraction index function of pressure, temperature salinity

(depth dependence in the detector neglected)

Group velocity correction

(ignoring group velocity degrades Angular resolution by factor 3)



J.Brunner

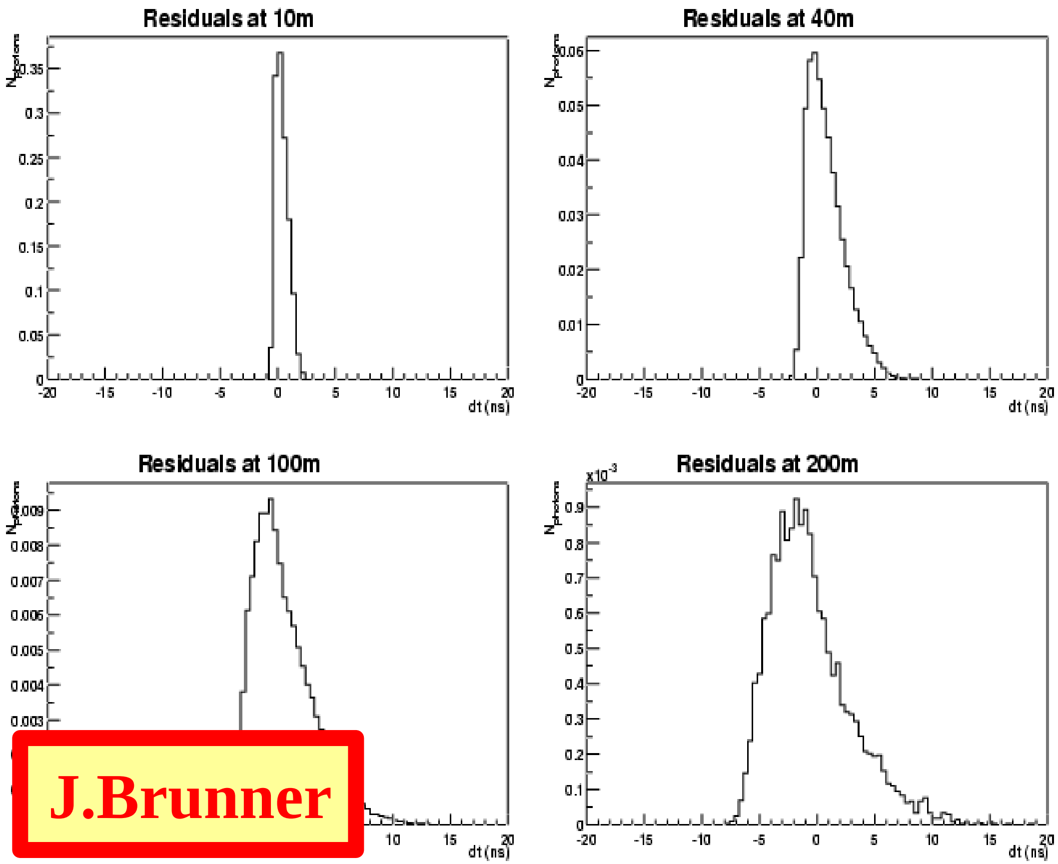
Water properties Dispersion

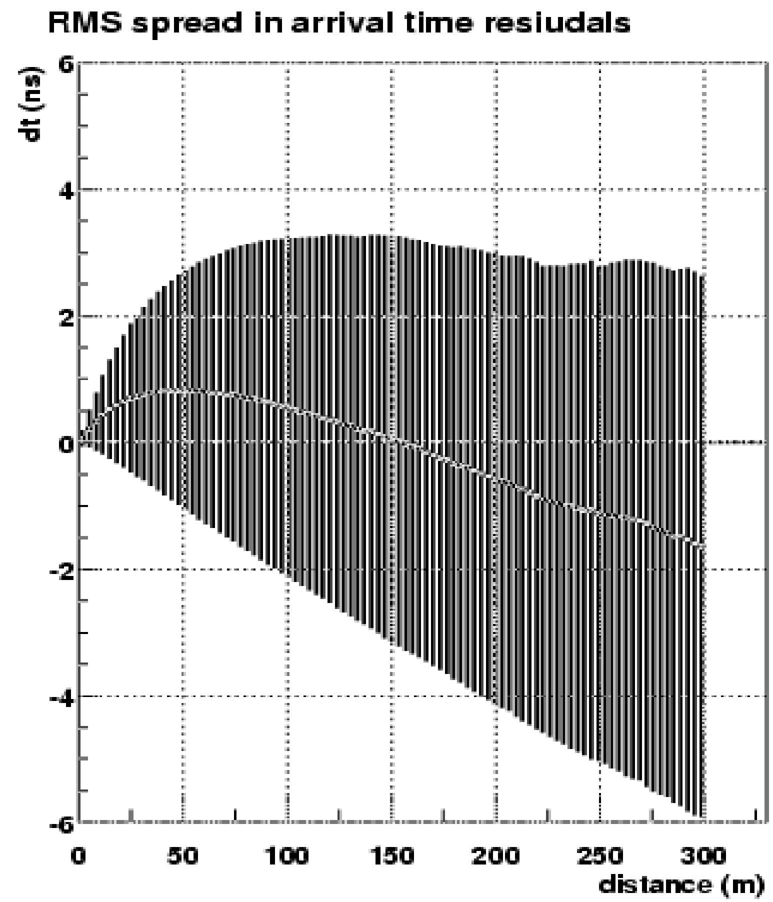
Cherenkov photon propagation done for ONE wavelength (CPU time)

Dispersion correction added at PMT depending on distance

At 50m comparable to PMT tts !

Examples: Effect of dispersion , no scattering

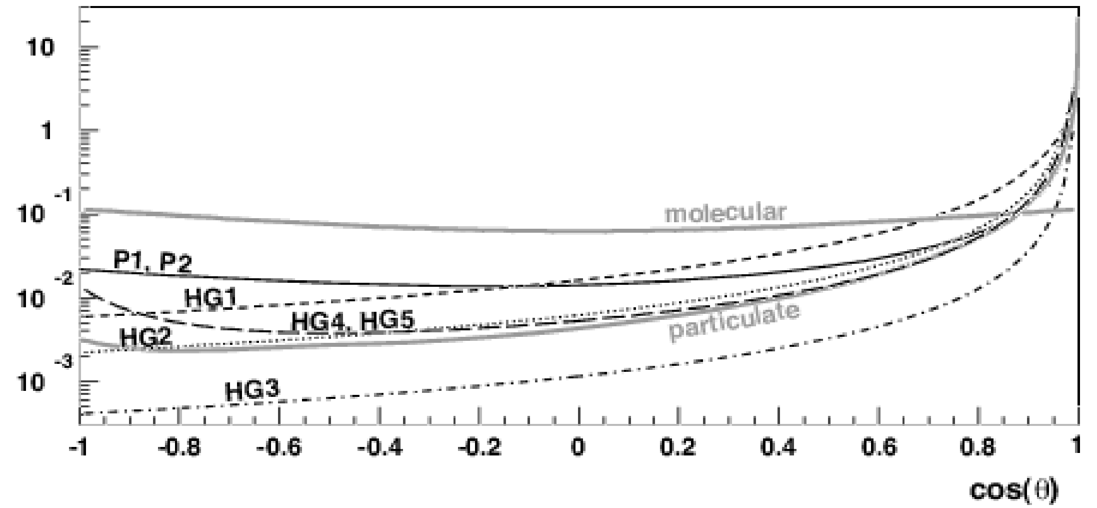




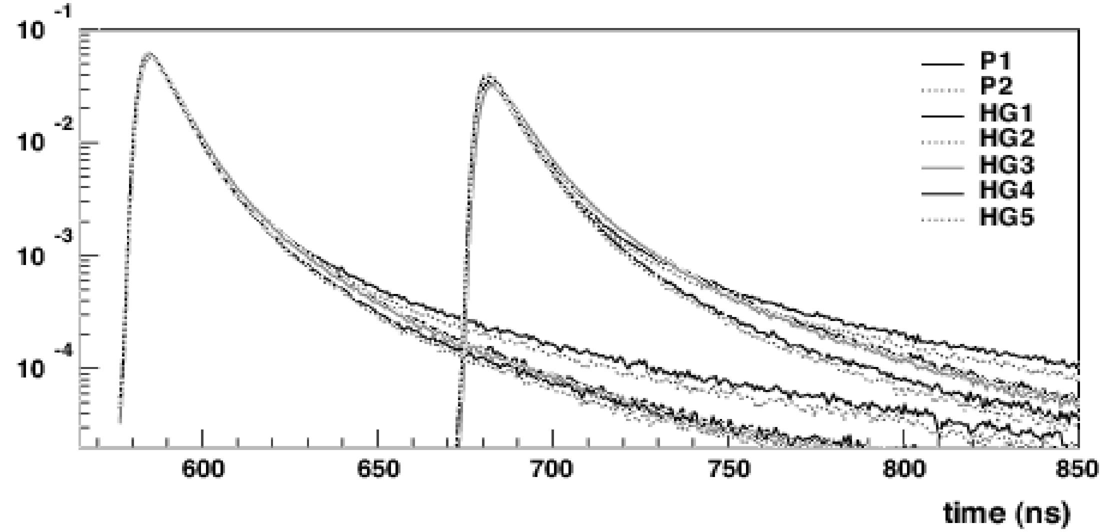
J.Brunner

Water properties Scattering

Study of various water models
Which are not incompatible with
Antares measurements



Effect on time residuals:
Mainly tail but also peaks



Result:
Ignorance on details of
Scattering introduces
30% error on angular resolution
10% error on eff. area

J.Brunner

- Full simulation chain operational in Antares
- External input easily modifiable
- Scalable to km3 detectors, different sites
- Could be used as basis for a km3 software tool box

Simulation tool

1. Light propagation :

L_{sc} » 30-50m; L_{abs} @ 20m Þ for showers with energy up to ~10 TeV and muons up to ~50 TeV scattering of light in medium can be ignored.

For higher energies scattering is taken into account on the base of long term measurements of

parameters of scattering.

2. Accurate simulation of time response of a channel on fact of registration

is provided.

3. Atmospheric muons:

CORSIKA with QGSJET.

4. Muons from atm. neutrino:

- cross-sections - CTEQ4M (PDFLIB)
- Bartol atm. neutrino flux

I.Belolaptikov

5. Angular distribution for hadronic showers is the same as for el.-m. showers.

4. Lepton transport in media and in the array is done by MUM.

Showers with energy > 20 MeV are considered as catastrophic losses.

5. Dead time and random hits of measuring channels are included in code.

Efficiencies of channels are measured experimentally in situ.

6. For simulation of **high energy neutrinos** we are going to use ANIS code.

I.Belolaptikov

S.Hundertmark:
Simulation in Amanda

- AMASIM

- Versatile, mature system, open for alternative modules

- Peculiar for Amanda: strong scattering layered ice

- Ang.error upgoing tracks ~ 2°

S.Hundertmark

- Physics Simulation
- Cherenkov light emition and propagation
- OM response

GEANT4

- PMT Waveform generation (signal)
- Trigger & Electronics Response

HOME MADE

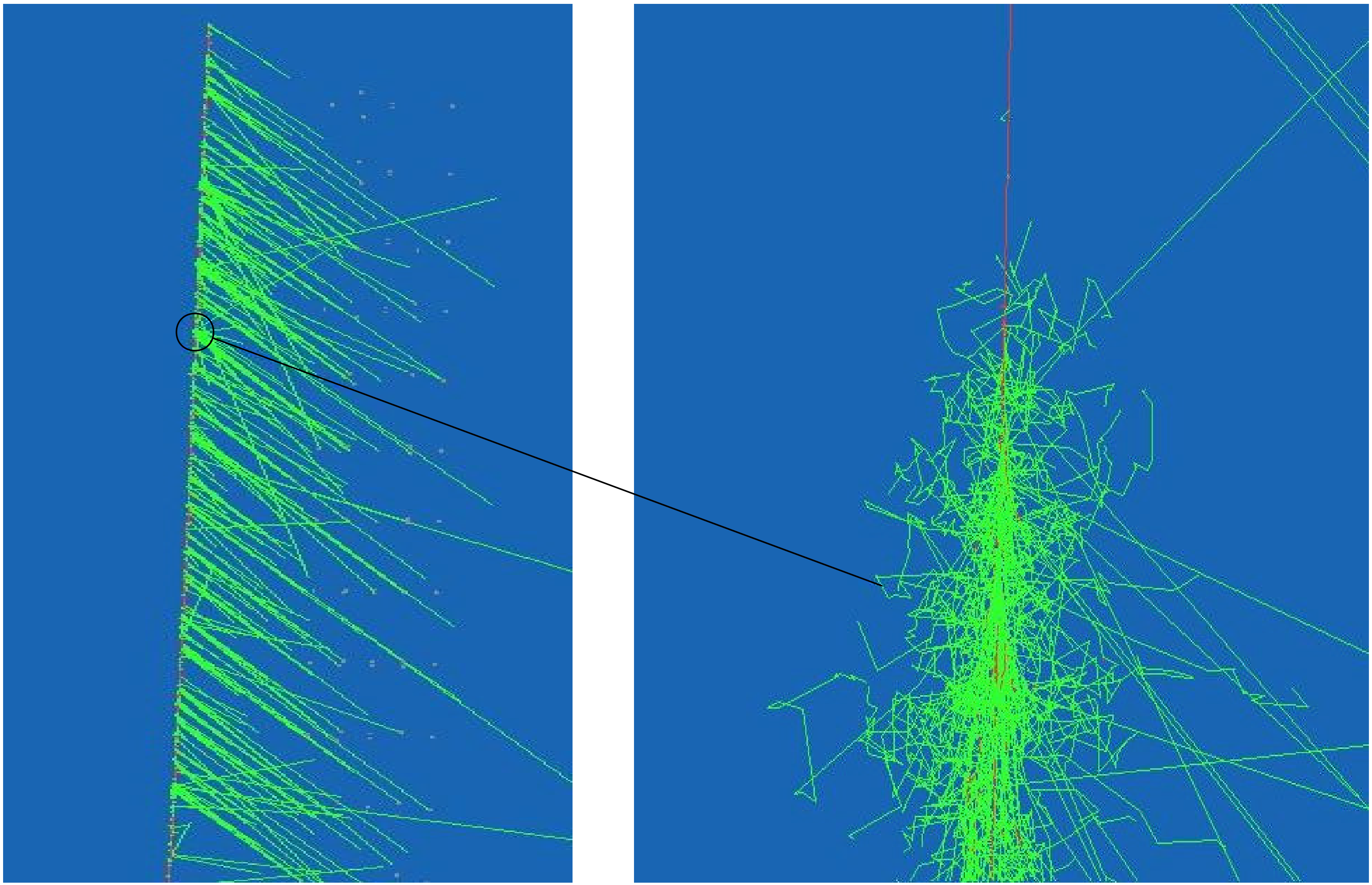
Raw Data Format

A.Leisos

Example of GEANT4 full simulation

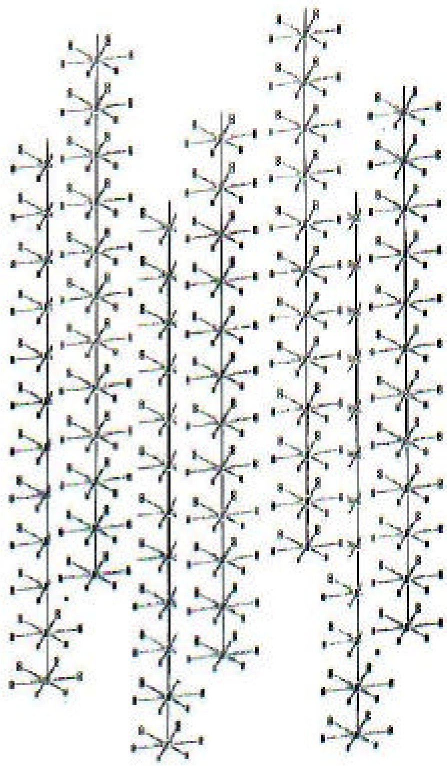
A muon track (100 GeV)

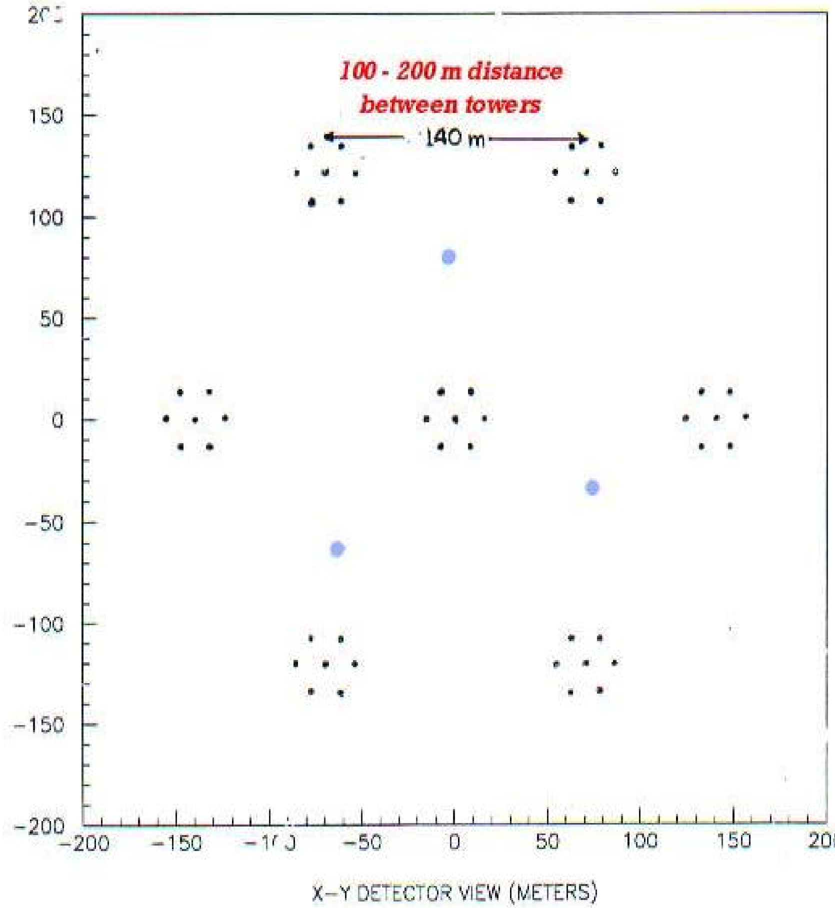
Shower Development



Example: Eff Area Calculation (a)

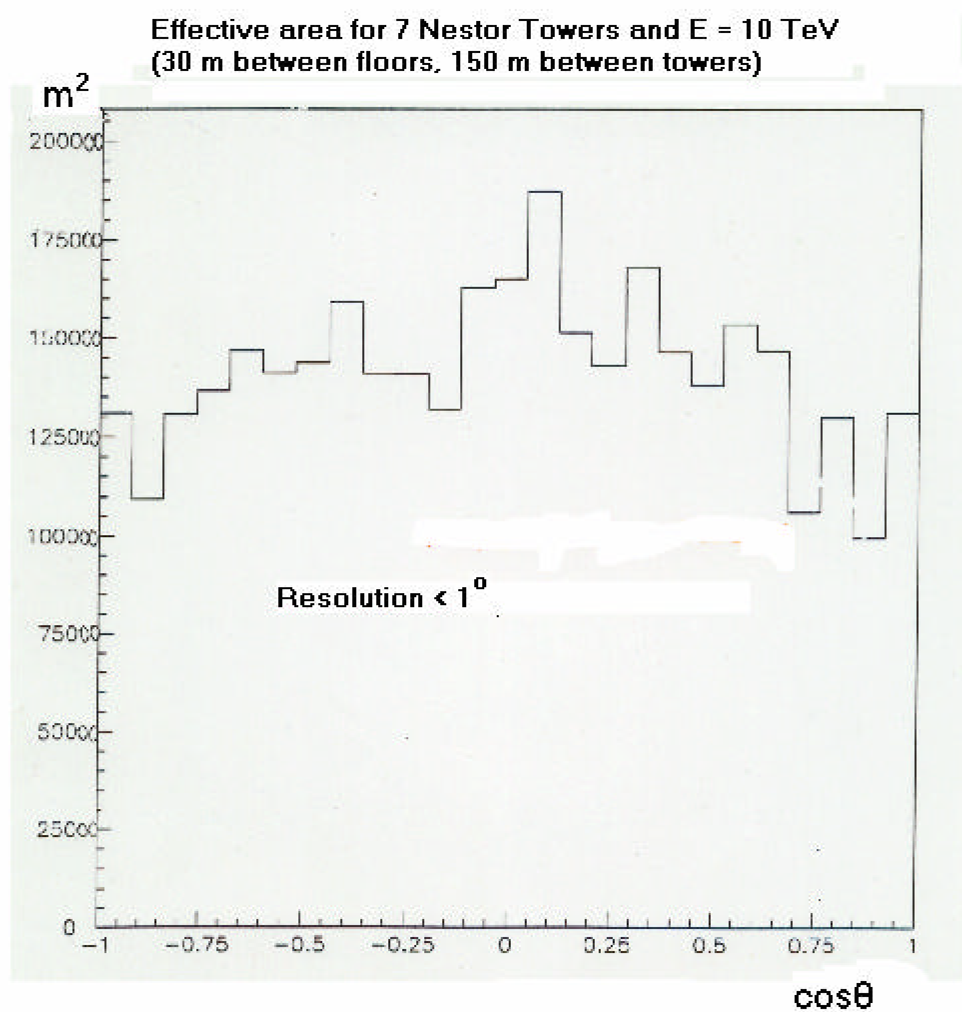
15% of a Km^2 NESTOR Detector





A.Leisos

Example: Eff Area Calculation (b)



A.Leisos

M-estimator strategy

linear prefit

fit with M-estimator

likelihood fit

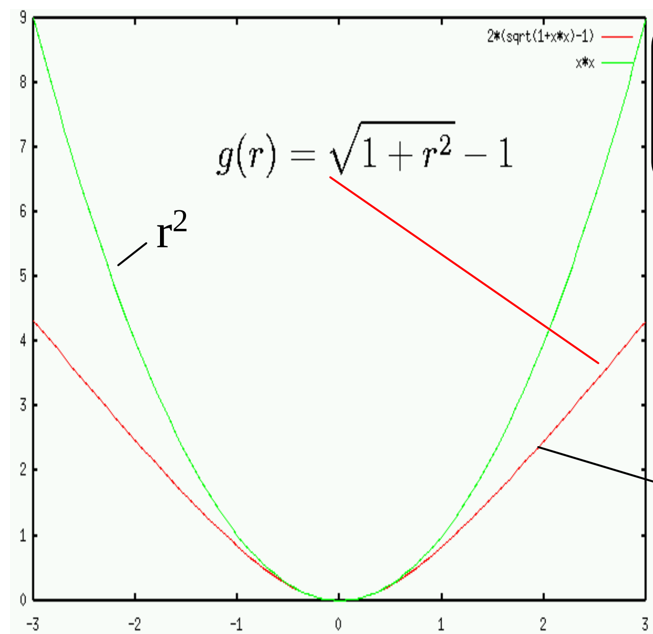
keep solution with best likelihood/ndof

repeat for different starting points

A.Heijboer mproved

od

Fitting technique that is resistant to'outliers', but still is able to find the global minimum by minimising a 'modified χ^2': called M



hit residual (ns)

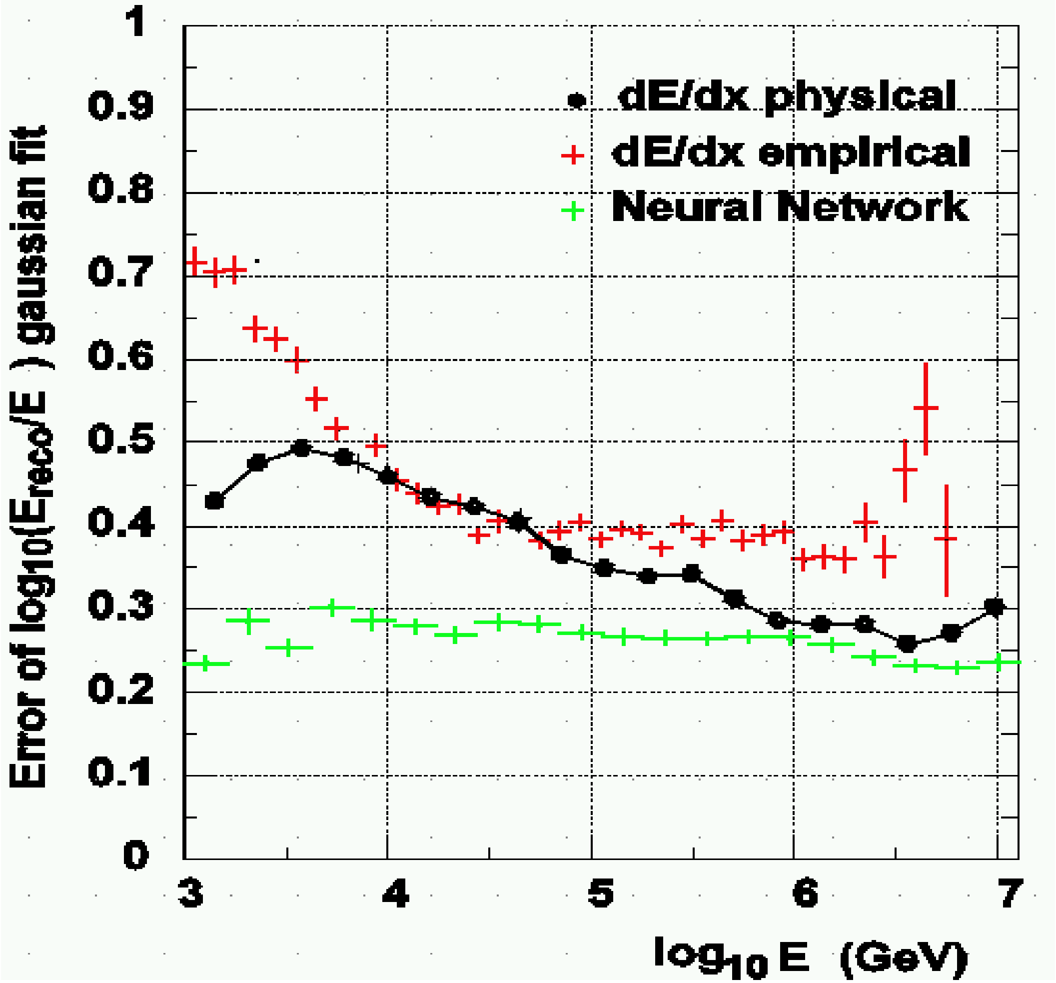
$$\chi^2 = \Sigma\, r_i^{\,2}$$
$$M = \Sigma\, g(r_i)$$

rises only linearly: outliers are not so important

also retain information on secondary solutions: can be used in cuts

buzzword: robust estimation (see e.g. numerical recipes)

Energy Reconstruction



Energy reconstruction accuracy factor 2-3.

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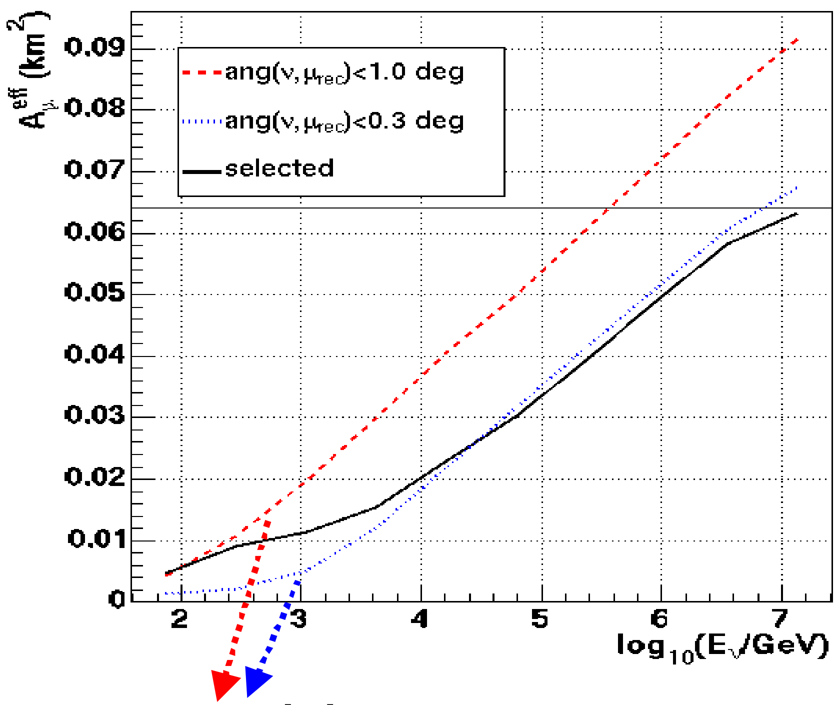
Results: Effective area and pointing resolution

Effective area



cut on MC truth: known sources

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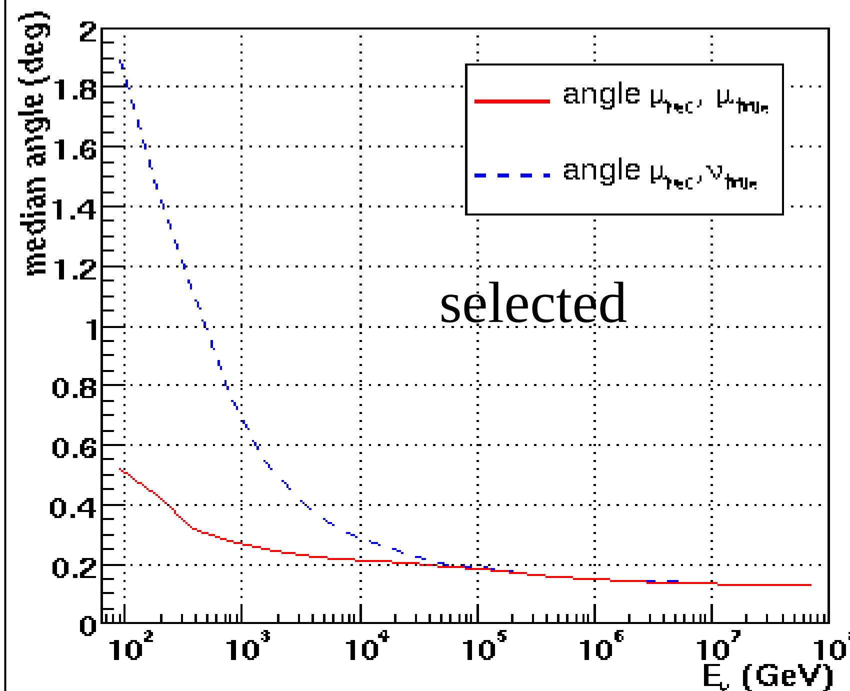
angular resolution

- below 0.2º for high energies
- dominated by physics below ~3 TEV

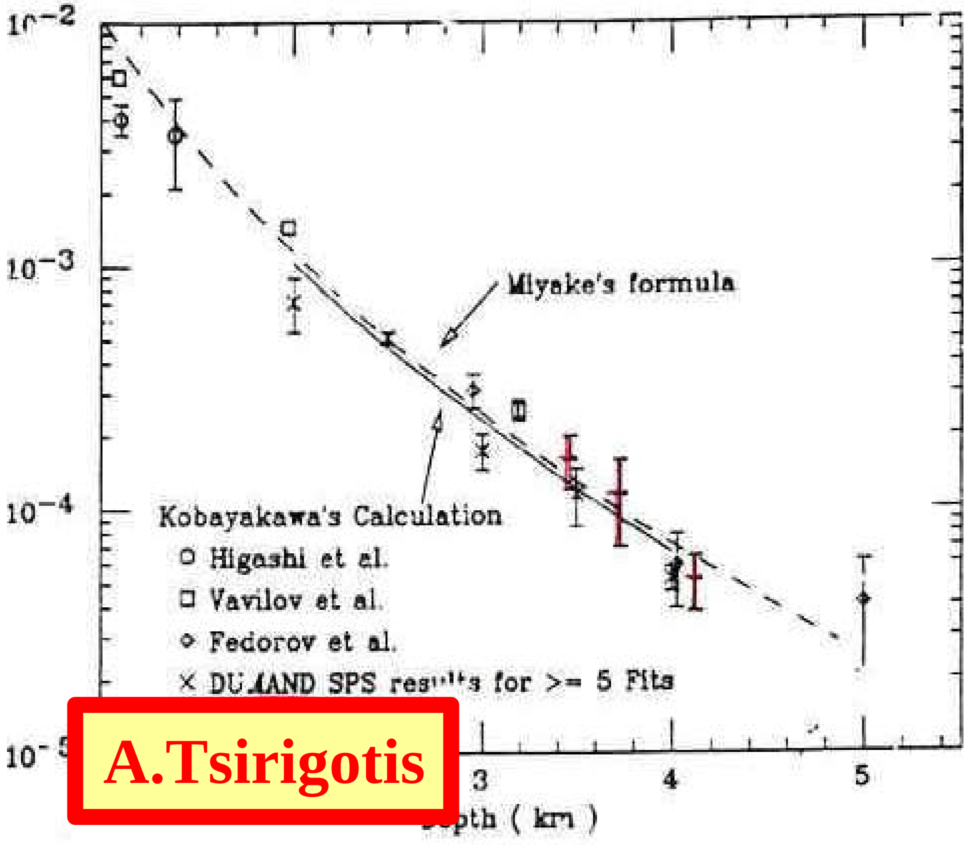


Background Sources

Cosmic ray muon background

Atmospheric muon angular distribution
Okada parameterization

Depth intensity curve



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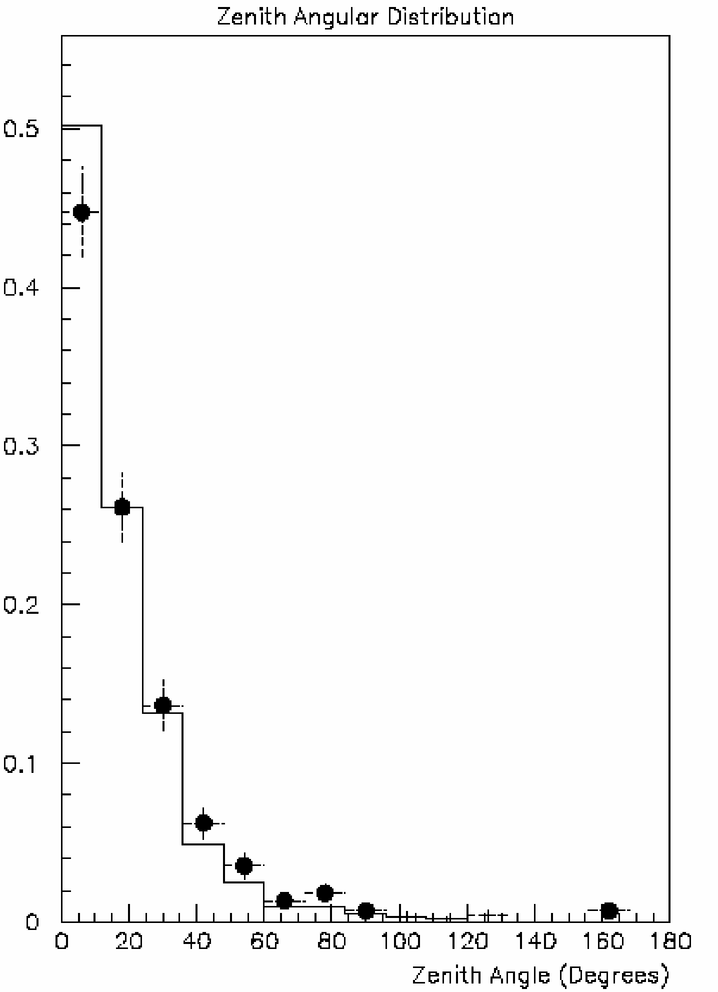
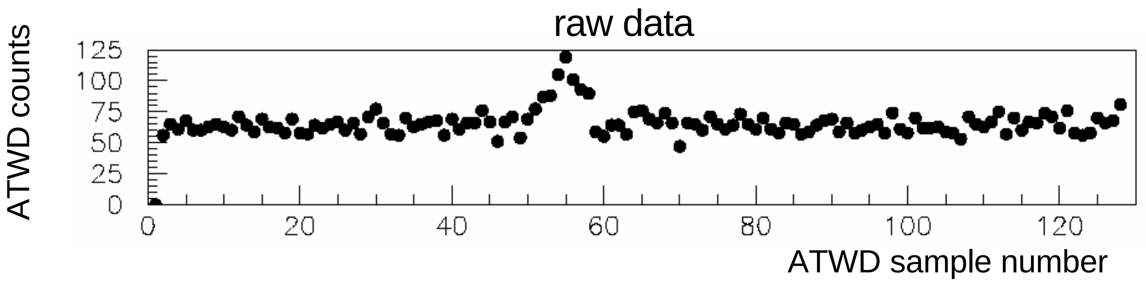
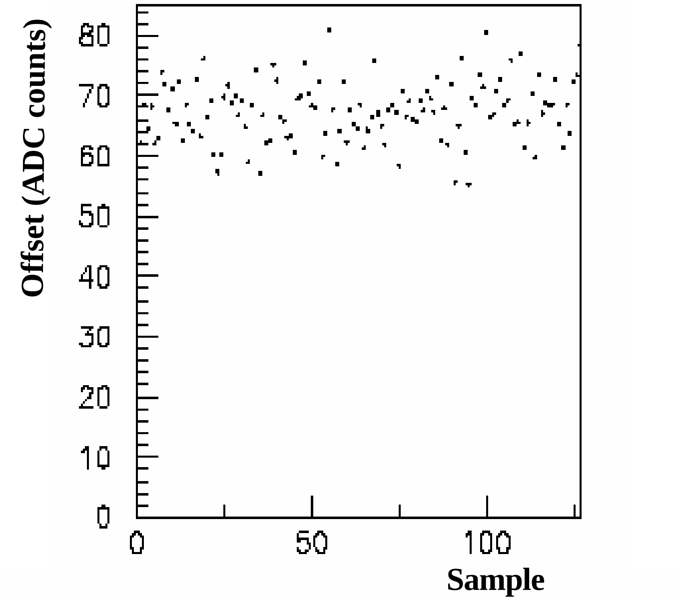
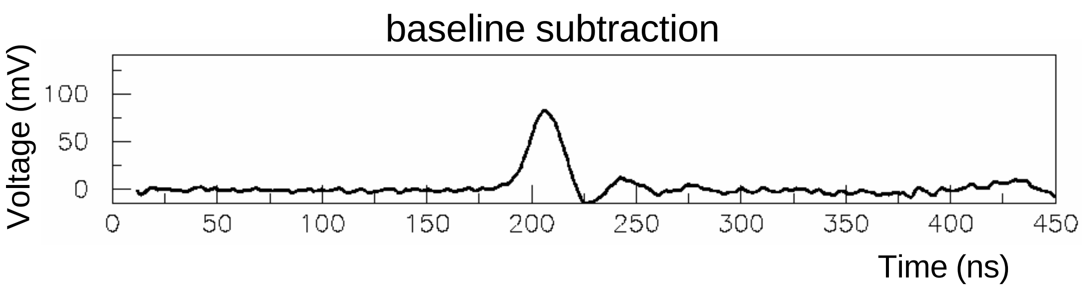
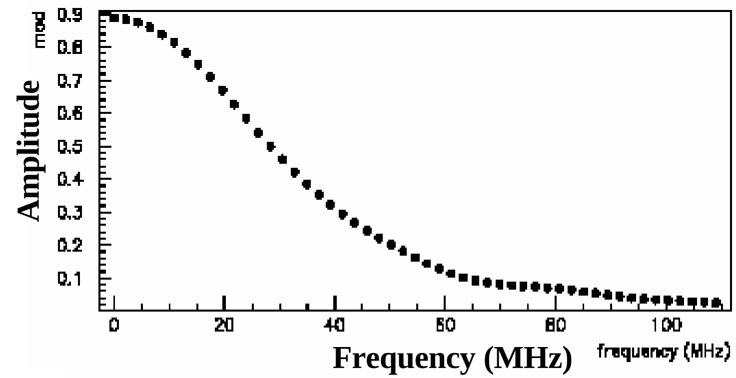


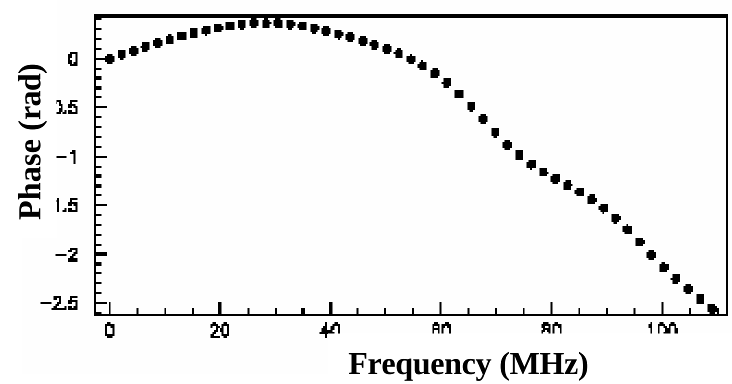
Signal processing

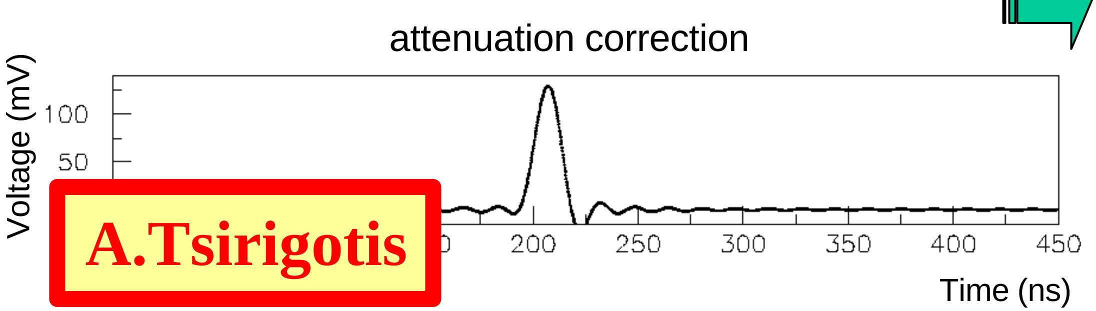












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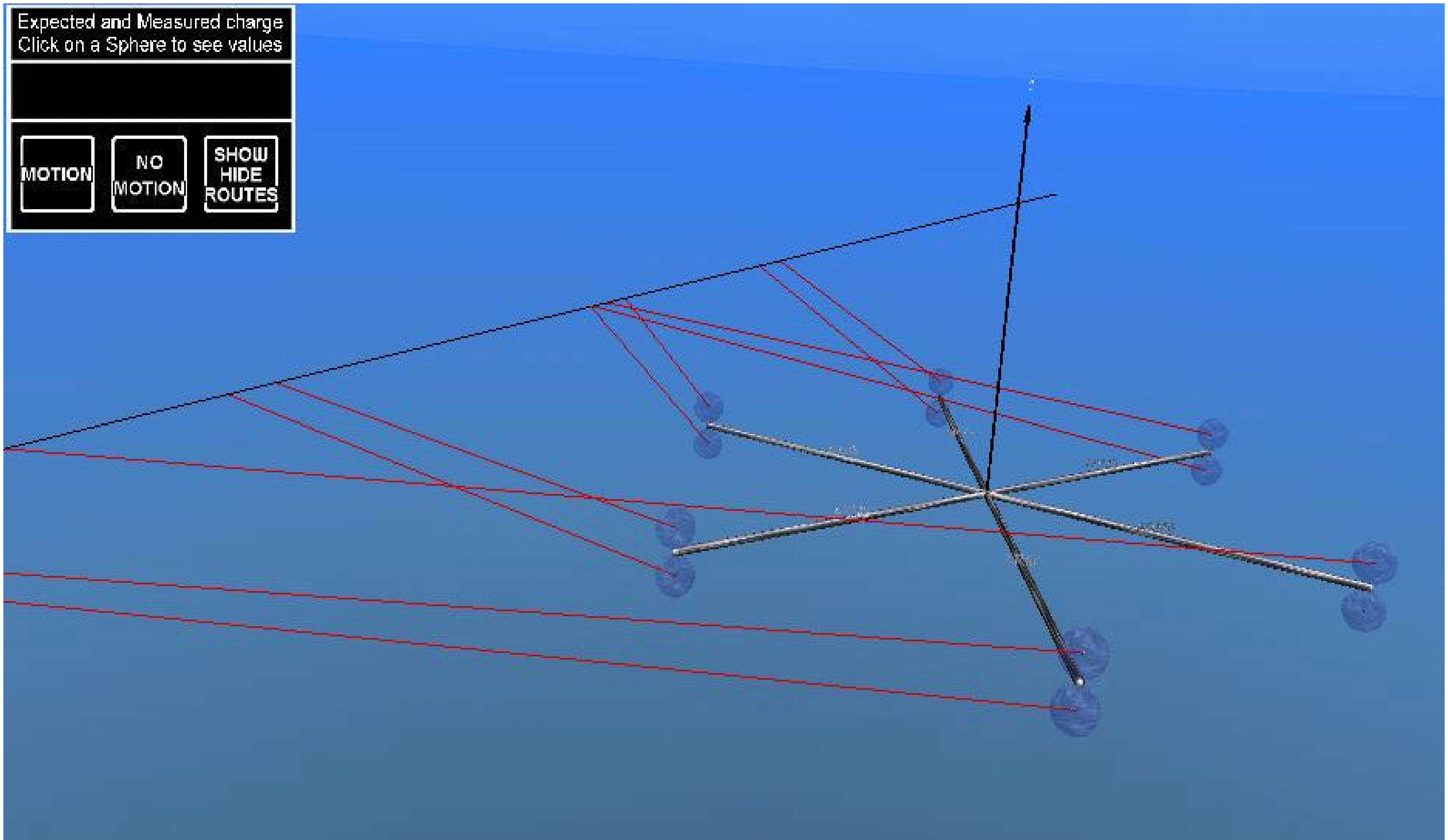
Track Reconstruction. . .



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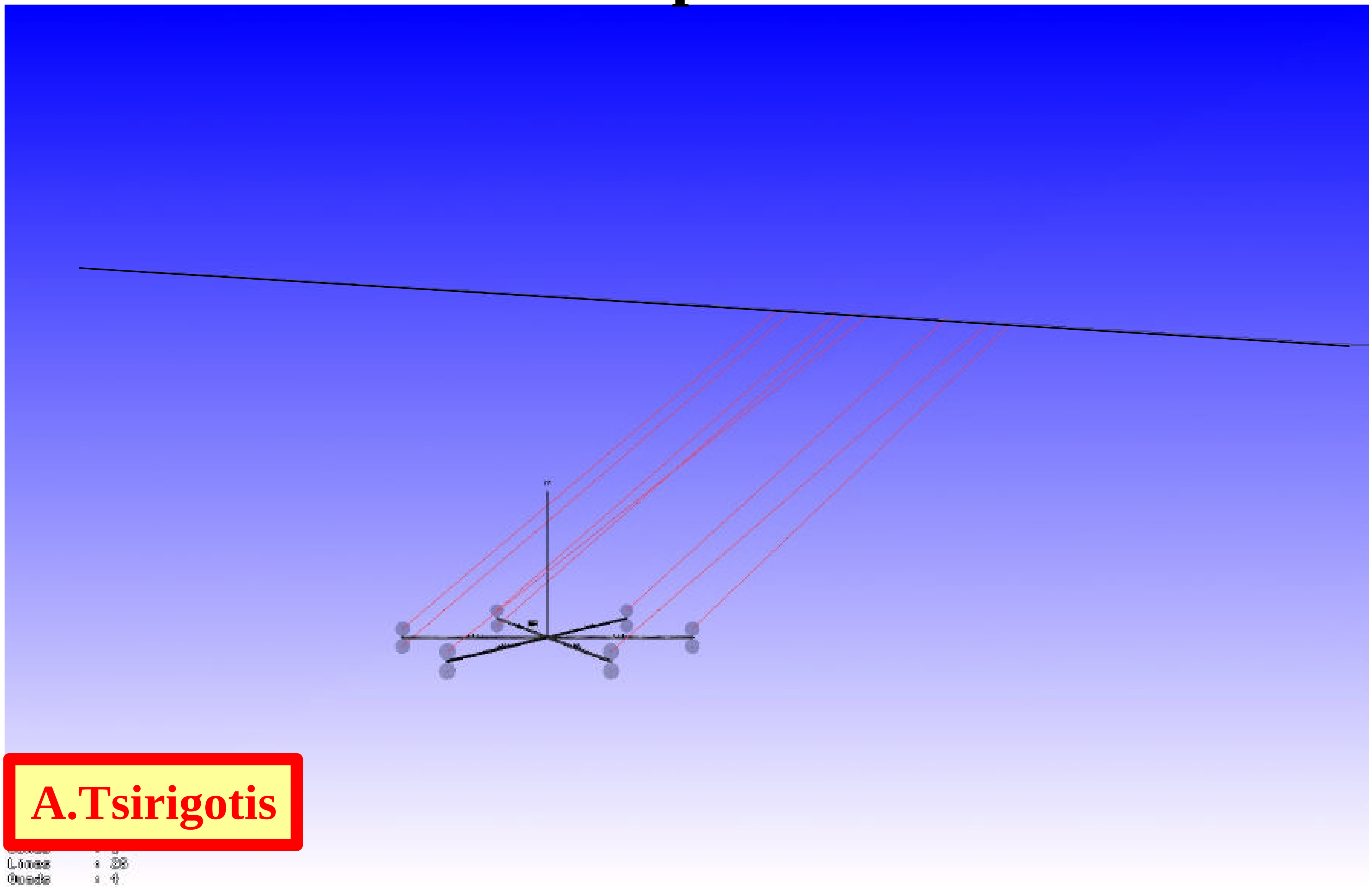
Run: 81_127   Event: 1789

Pictorial Representation



A.Tsirigotis

I.Belolaptikov: Reconstruction in Baikal

- Ang.error upgoing tracks ~ 3°

- „Allowed region“ → allowed theta, phi regions from time differences between pairs of OMs (no fit)

I.Belolaptikov

C.Wiebusch: Reconstruction in Amanda

- Critical due to light scattering
- appropriate likelihood („Pandel“) + clever cuts → effective bg reduction, ang. error for upgoing tracks ~ 2°
- Improvements: likelihood parametrization, layered ice, include waveform

C.Wiebusch

Summary

Much known about water properties – presumably enough for detector optimization and site comparison

Cross calibration measurements done/underway for Antares/Nemo sites, planned to include Nestor site.

Lot of comparative simulations done in all three collaborations.

Wide spectrum of tools for simulation and reconstruction. Many standard programs common to two or even all three collaborations (Corsika/Hemas, MUM/Music, Geant 3/4, ...)

May also use tools of Amanda/Baikal

Seems to be not too difficult to converge to to common simulation framework for optimization

Next steps in simulation:

Form a task force group on detector simulation:

- Agree on a working plan (October)
- Input to application for a European Design Study (November)
- First results on comparative studies to ApPEC (Next spring/summer)
- don‘t prioritize site decision in initial phase but just simulate benchmark detectors characterized by a tuple of basic parameters (say depth 2.5, 3.5 and 4.5 km, noise 25,50 kHz and „high“, 3-4 basic architetures)