Antares simulation tools

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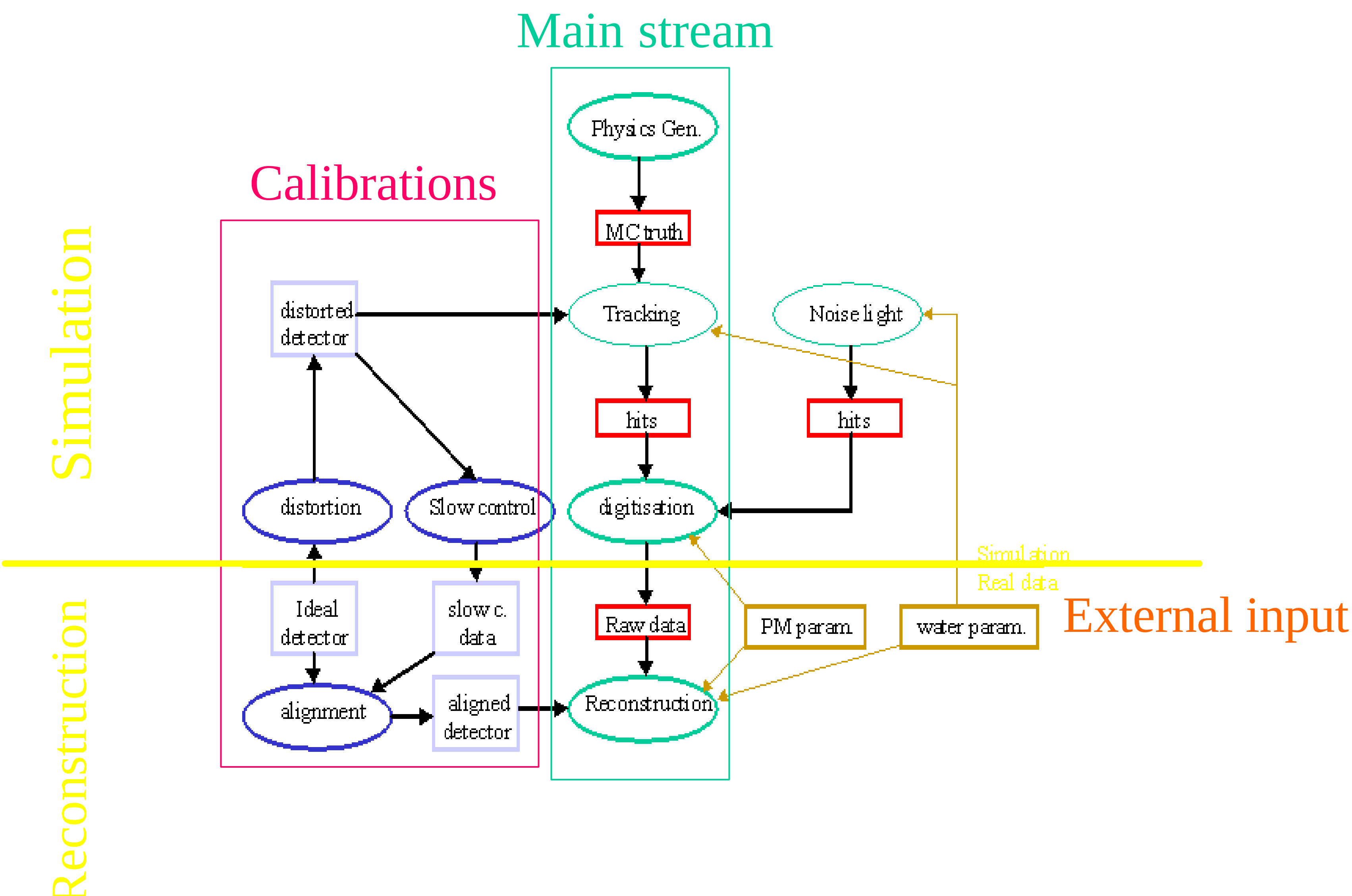
CPPM

Software scheme



Physics generators: Atmospheric showers

CORSIKA (Kascade et al.) versus HEMAS (Macro, DPMJET)

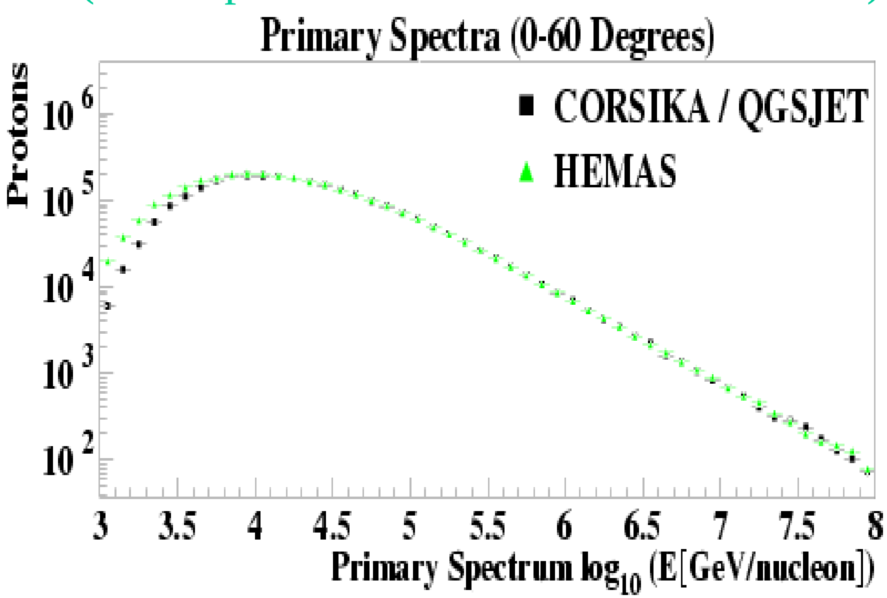
Extensive comparison made at sea level and detector level

Conclusion (E>500 GeV) (E > 20 GeV)

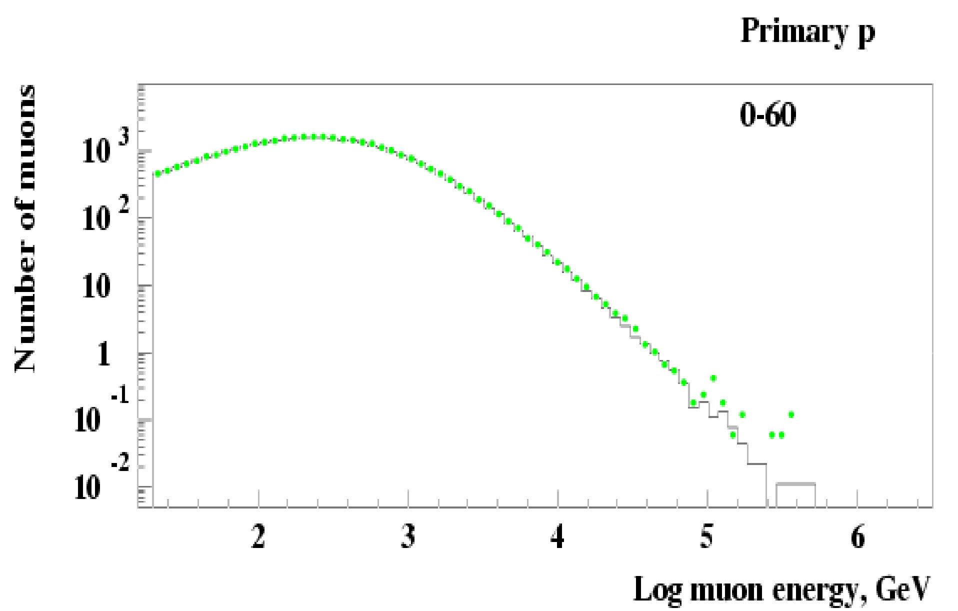
There are differences but both are compatible with data

Protons at sea level

(which produce at least 1 500 GeV muon)



Muons at detector level



Physics generators: Atmospheric showers

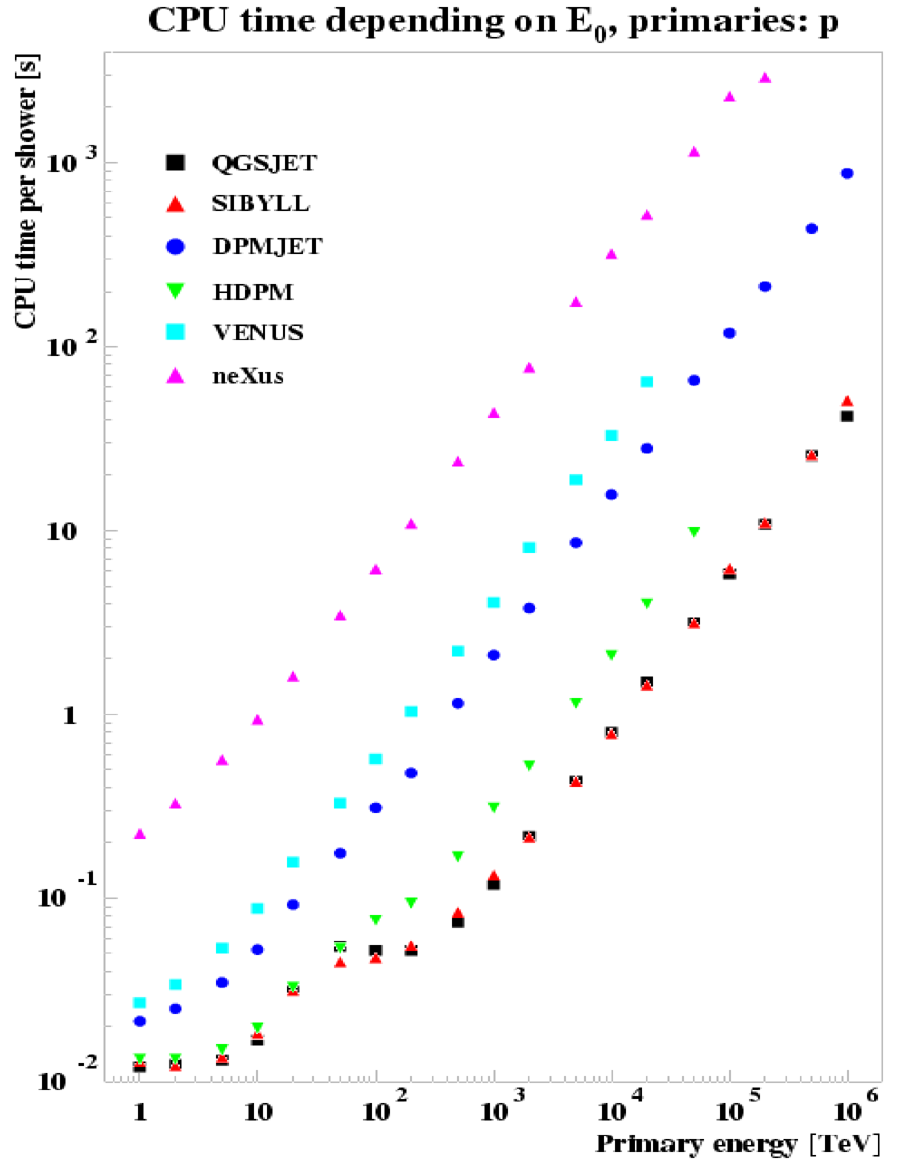
CORSIKA

Which hadronic model ?

Pragmatic choice:

authors recommendation +
CPU time argument

QGSJET



Physics generators: Neutrino Interactions

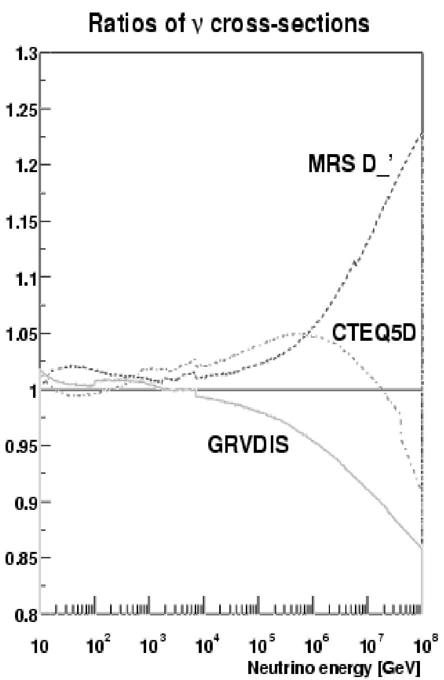
- LEPTO (interaction) + PYTHIA/JETSET (hadronisation)
- For ν_τ polarized τ decay with TAUOLA

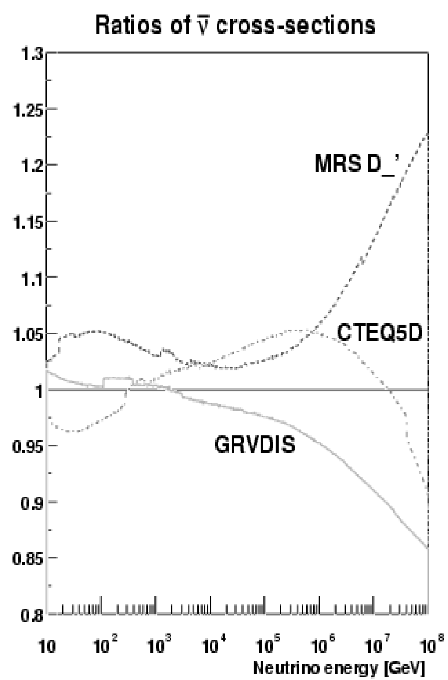
High energy

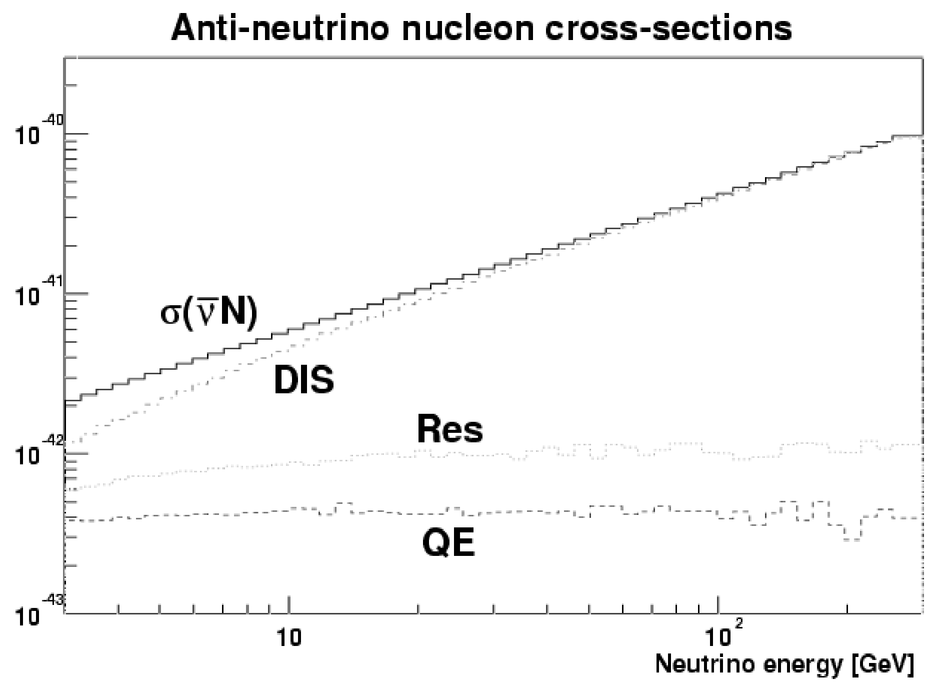
Structure function not well known
Present choice CTEQ5 + NLO
10% corrections w.r.t. CTEQ3 at 100 PeV

Low energy

QE + resonant processes added
RSQ (written for SOUDAN)
(10% at 100 GeV, negligible at TeV range)





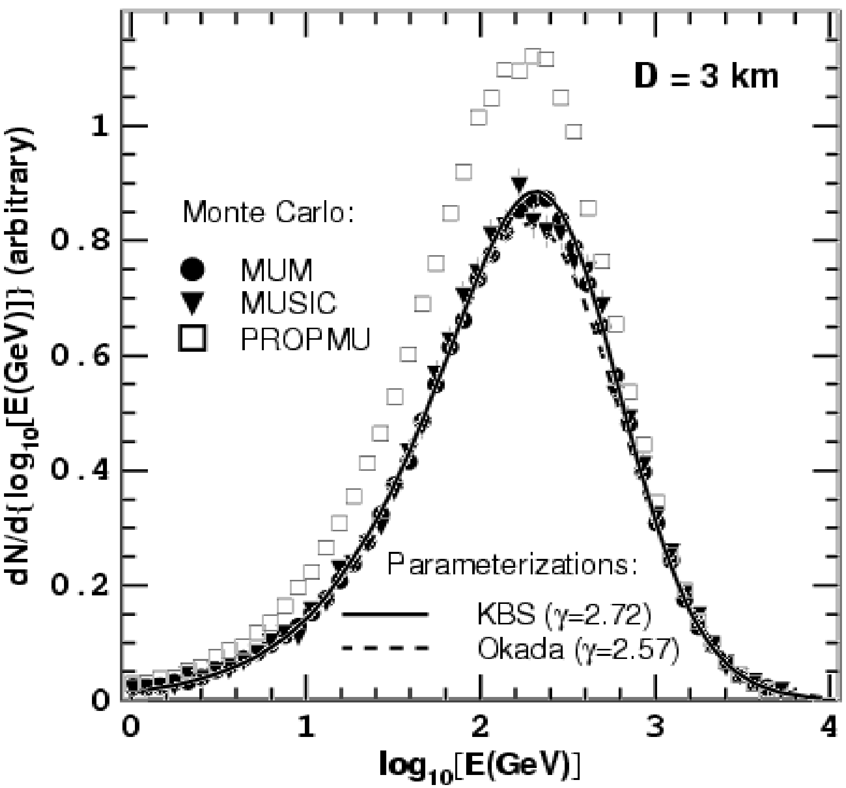


Interface: Muon propagation

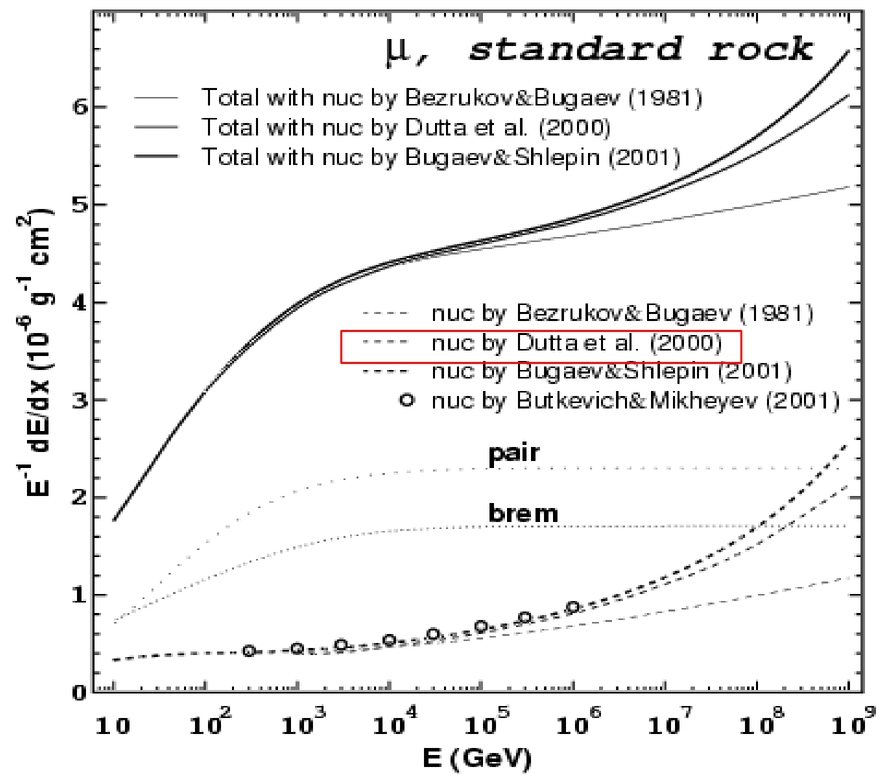
- From sea level to detector (atmospheric showers)
- From neutrino interaction vertex to detector
- Inside detector (KM3 package)

PROPMU (P.Lipari) MUM (I.Sokalski) MUSIC (V. Kudryavtsev)

PROPMU disqualified

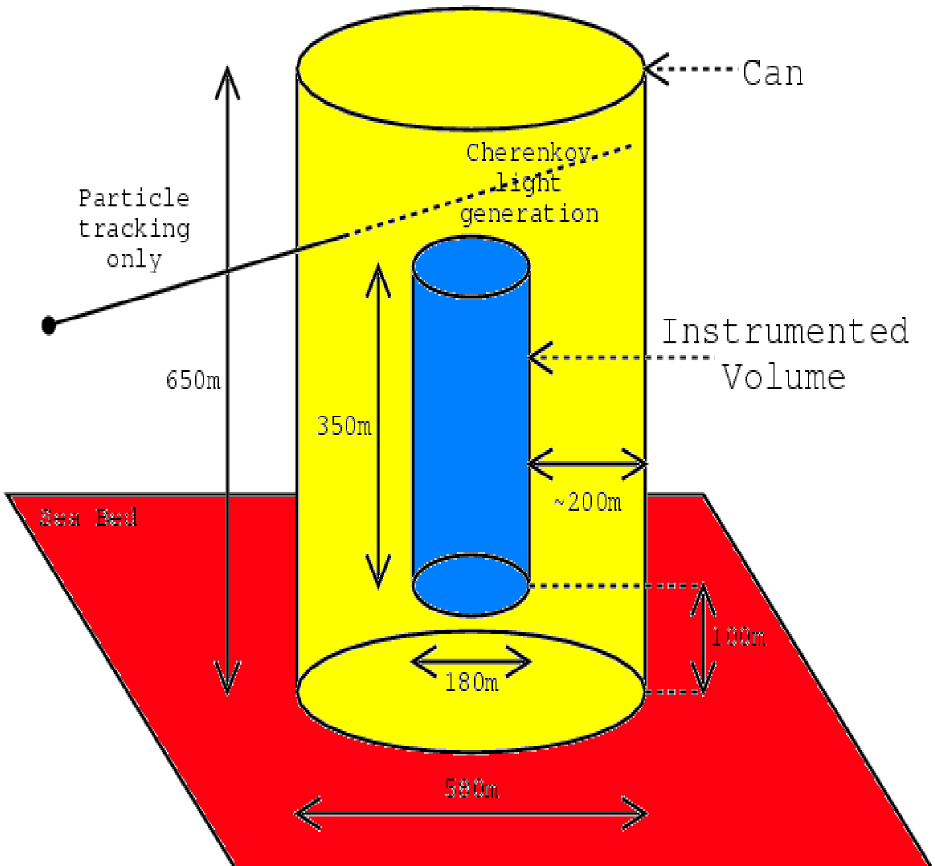


High energy problem
Muon nuclear cross section

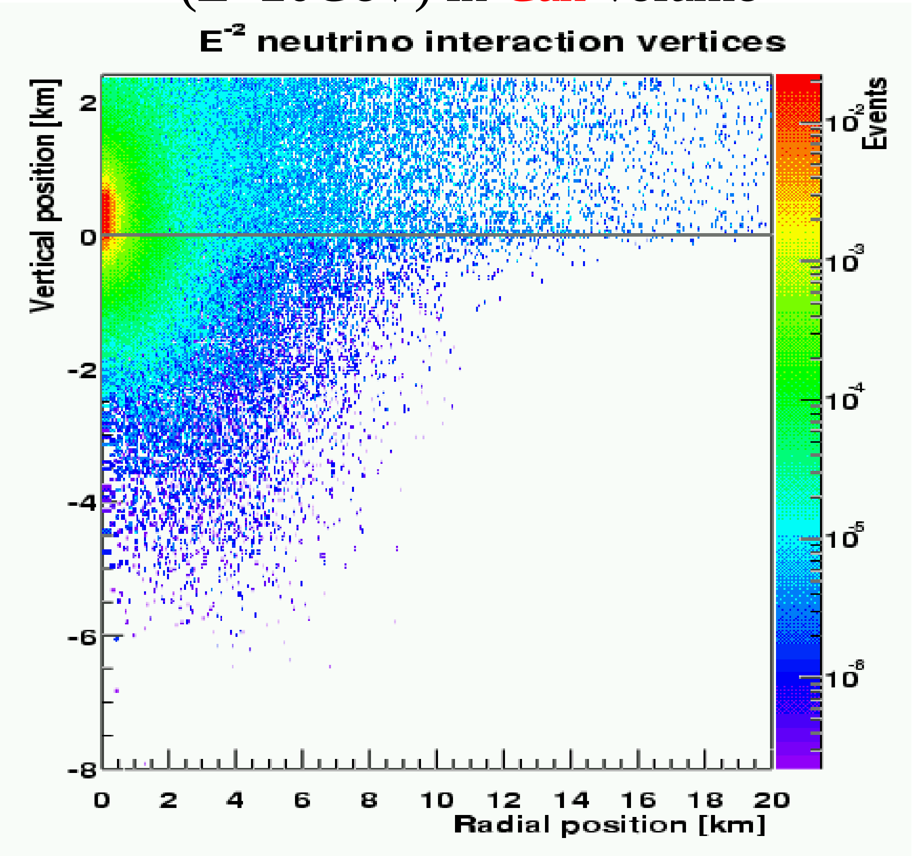


Interface: Can definition

Cherenkov light generation only inside Can which surrounds the Instrumented volume (about 3 absorption lengths)



Neutrino interactions which produce muon (E>20GeV) in Can volume



Fluxes

Many open questions

- Cosmic rays
  - Composition, Spectrum
- Atmospheric neutrinos
  - Spectrum
  - Contributions from prompt neutrinos
- Cosmic neutrinos

Needed for precise event numbers

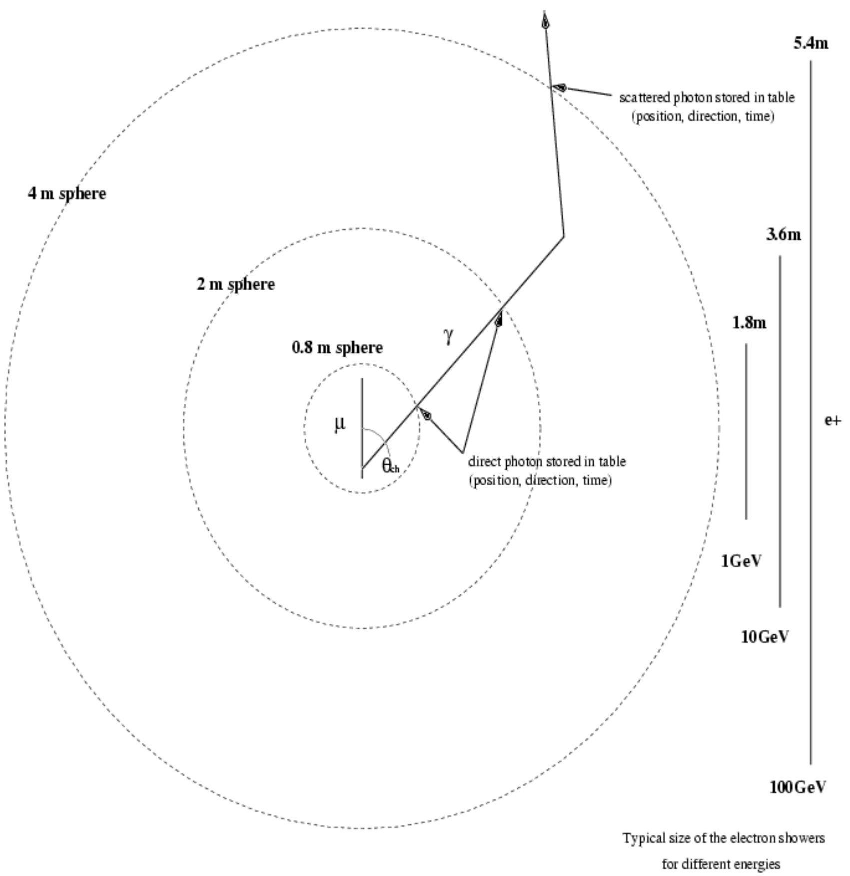
Not needed for comparative studies (detector,site,etc)
Generic fluxes are sufficient e.g. E^{-2}

Tracking & Cherenkov light

First step: scattering tables are created

Tracking of e/m showers (1-100 GeV) &1m muon track pieces

Tracking of individual Cherenkov photons with Geant 3



Use of light scattering & absorption storage of photon parameters when passing spherical shells (2m-160m) $(r,\theta,\theta_\gamma,\phi_\gamma,t,\lambda)$

Temporary tables, very big, rough binning

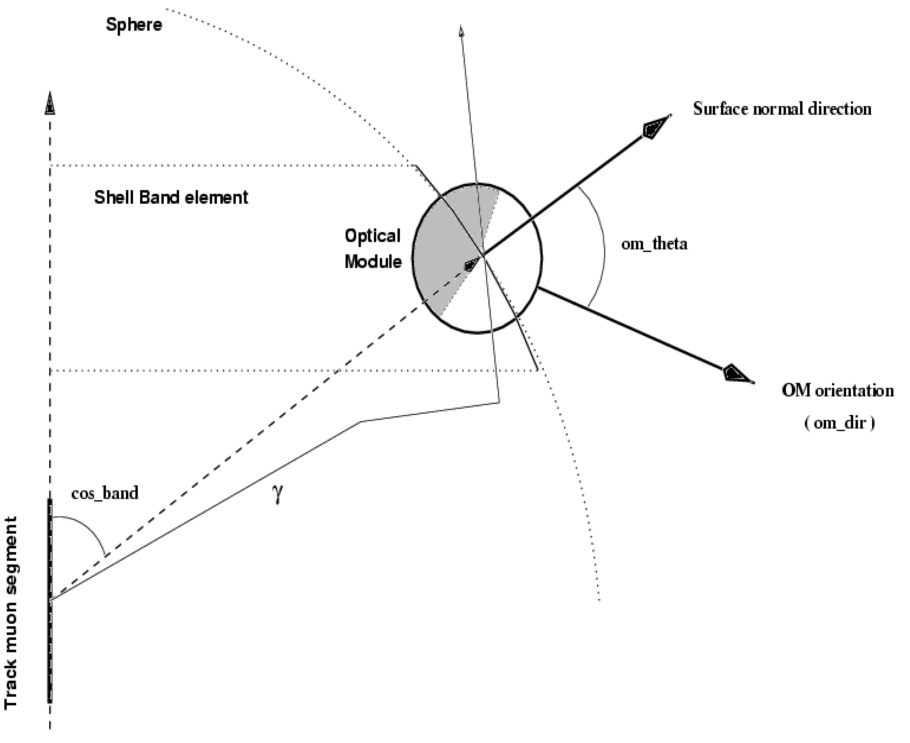
Tracking & Cherenkov light

Second step: Folding with PMT parameters
Wave length integration

One set of tables per
PMT & water model

$(r, \theta, \theta_{pm}, \phi_{pm}, t, Prob)$

Independent of detector geometry
and Physics input



Third step:

Tracking of muons (MUSIC)
Through water volume
(including bremsstrahlung etc)
Hits in free detector geometry

Tracking & Cherenkov light

What about hadronic showers at neutrino vertex ?
Problem of hadronic models in TeV/PeV range
What about ν_e , ν_τ interactions ?

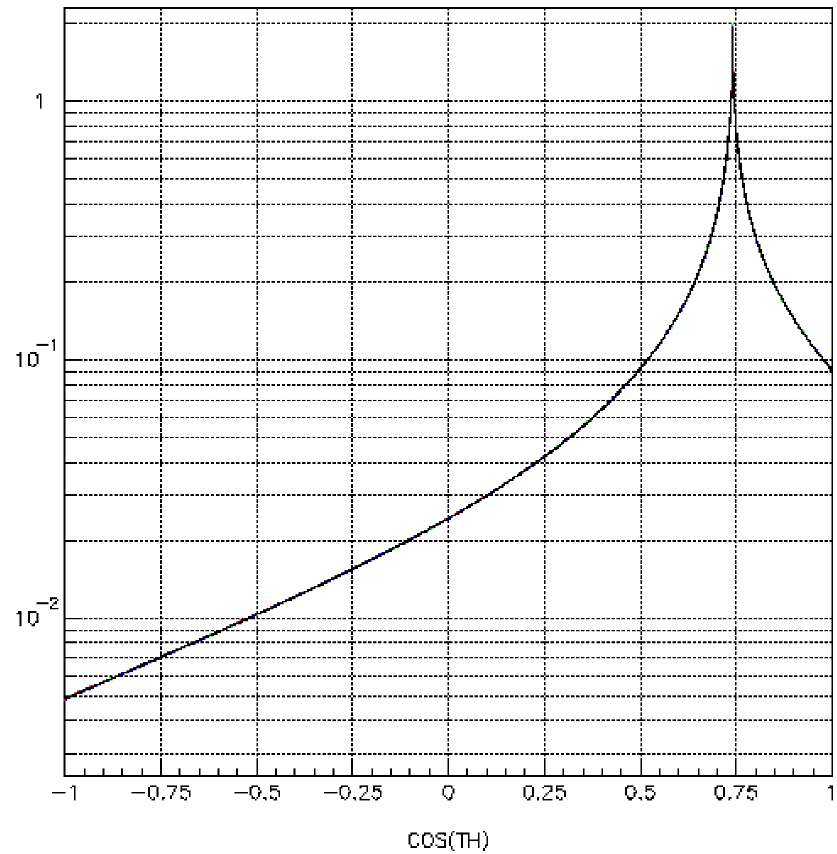
Angular distribution of Cherenkov photons and Time residuals more 'fuzzy' than for muons

Light Scattering less important

Treatment with Geant
No scattering, but attenuation
E/m showers parametrized to
Save CPU time

τ tracking ? Modification of muon propagation code work just started

Cherenkov light from e/m showers



Tracking & Cherenkov light

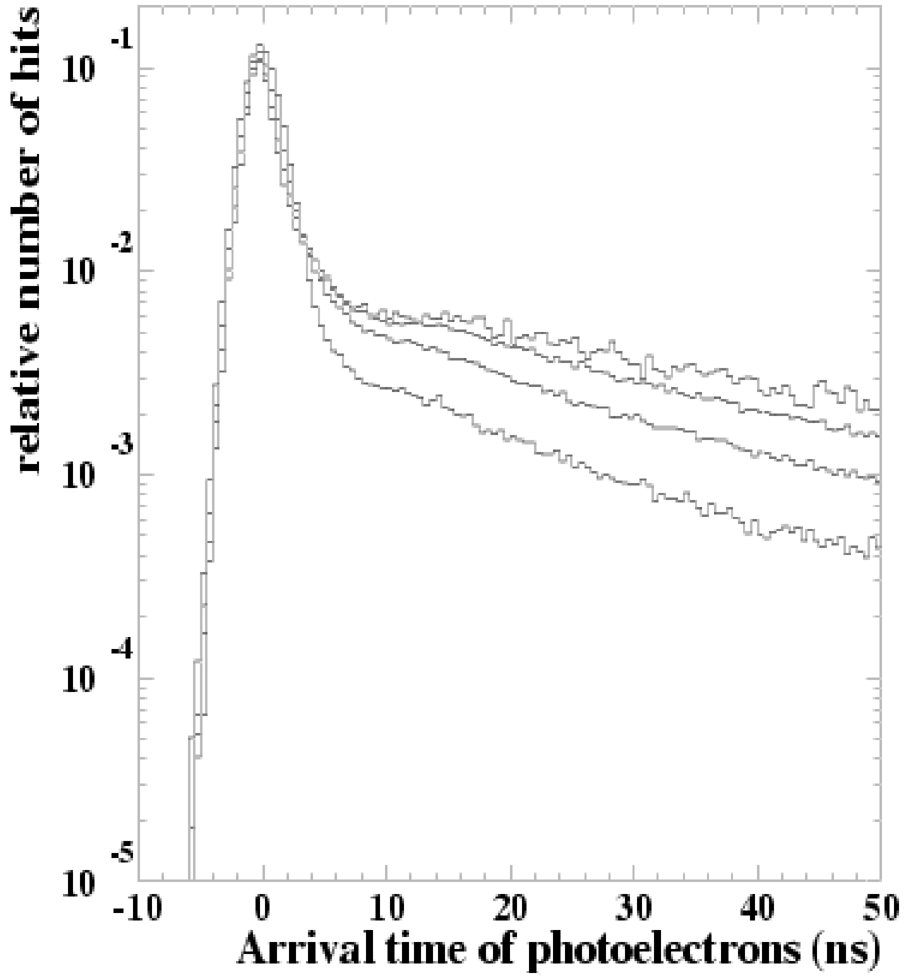
Time residuals for muons
Traversing the detector
(E=100 GeV – 100 TeV)

t=0 direct Cherenkov photons

Peak width
- PMT tts
- forward scattering

Tail
- Energy
- scattering

Peak/tail ratio
- distance
- orientation



Digitisation

Full simulation of ARS chip exists as independent package
Most analysis done with simplified digitisation:

- ignore wave forms
- few basic parameters per chip:
  - integration time
  - dead time
  - saturation

Results compatible

Suggestion for KM3 simulations:

start as well with simplified digitisation
(we will not know enough details)

Detector geometry

- Defined in external file (ASCII / Oracle)
- Basically OM positions & orientations
- Not restricted to Antares architecture
- Easily adaptable to other concepts
- (see work from D. Zaborov)

External inputs

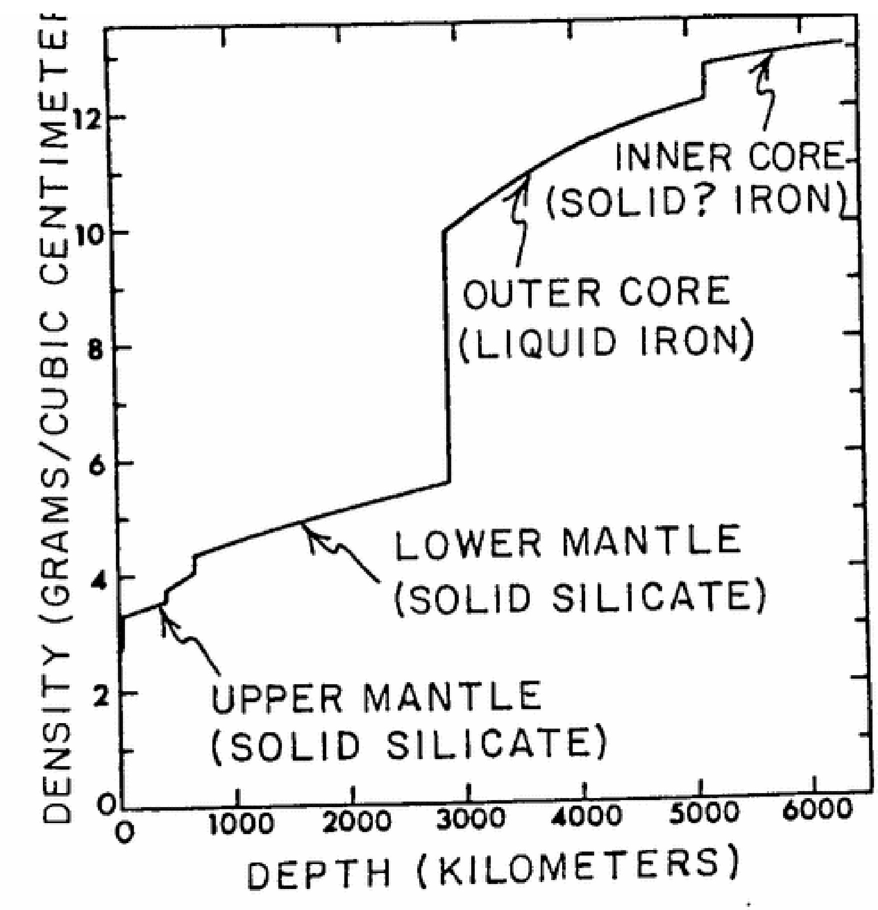
Large amount of input parameters/functions needed
Physics results depend sensitively on them
For comparisons of different simulations they must be under control

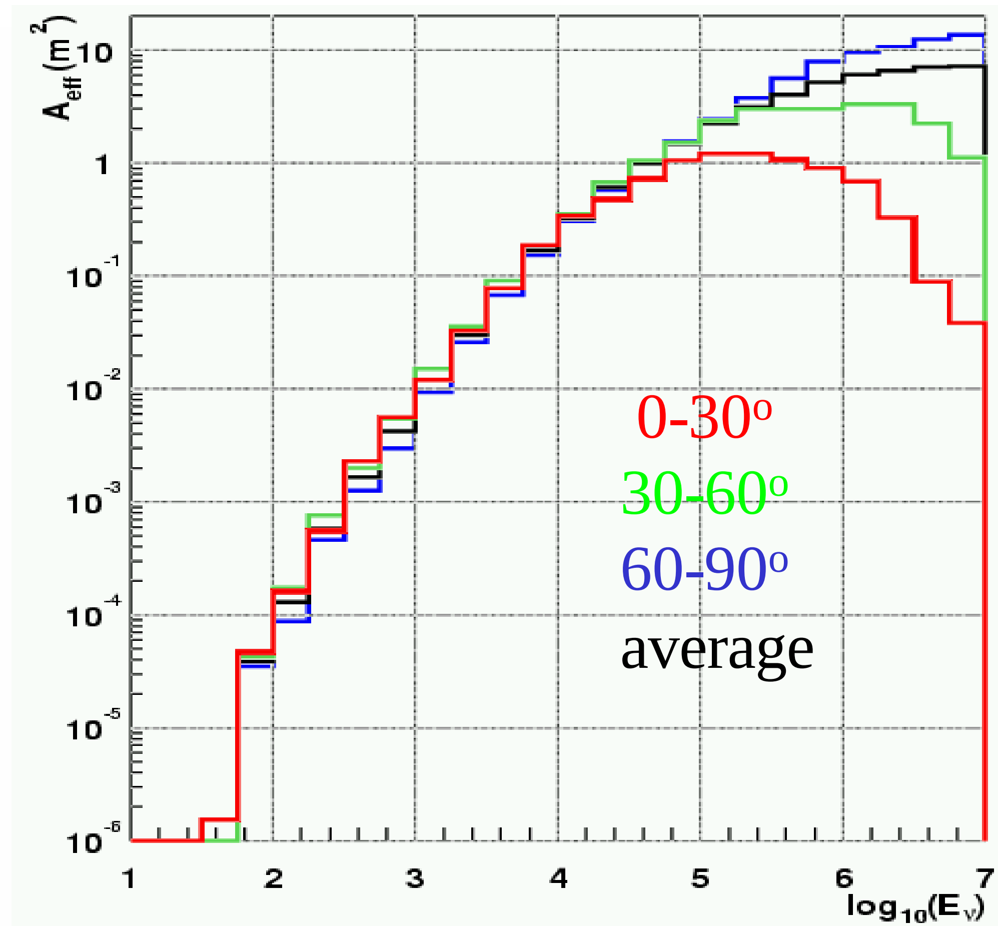
Earth density
PMT/OM characteristics
Water parameters

Earth density

Important above 10 TeV
5 layer model used in the code
No distinction NC/CC reactions

Result: neutrino eff. area

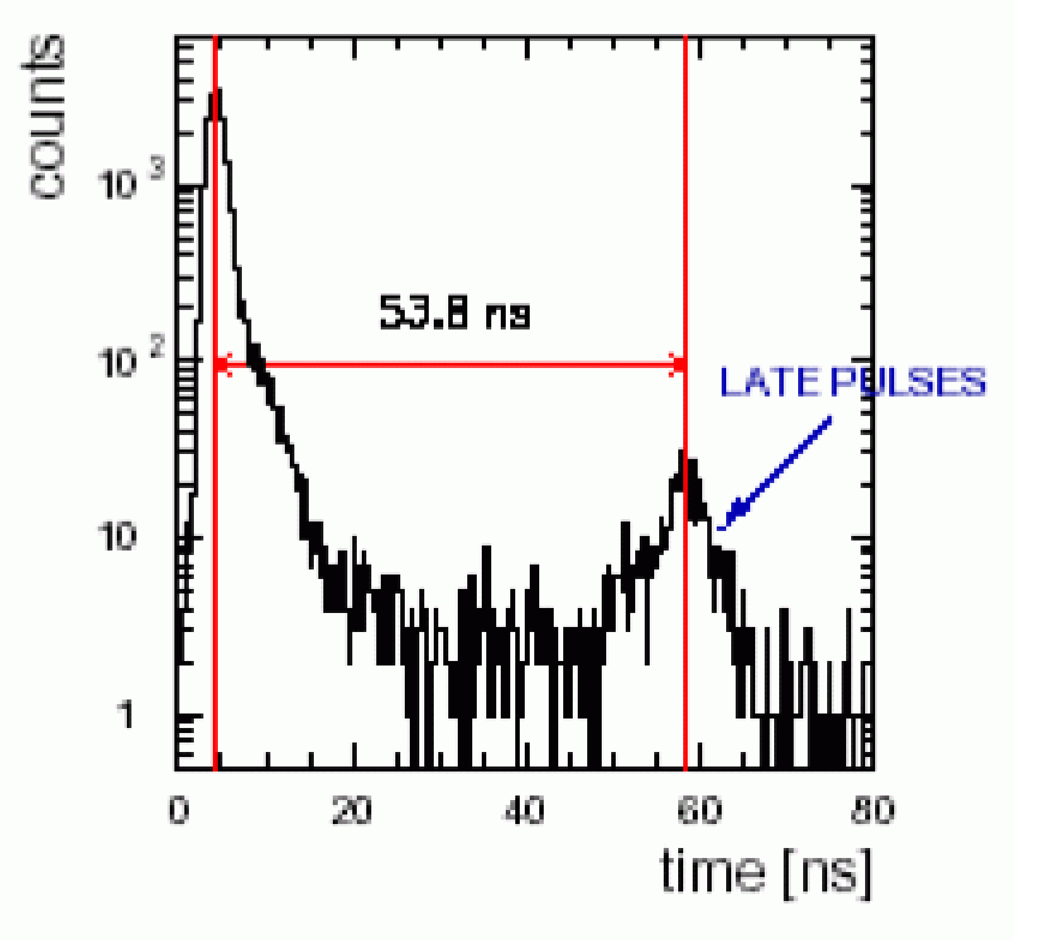




PMT properties

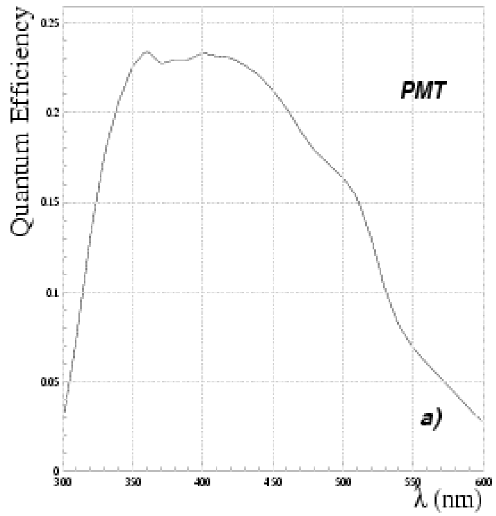
Some basic numbers

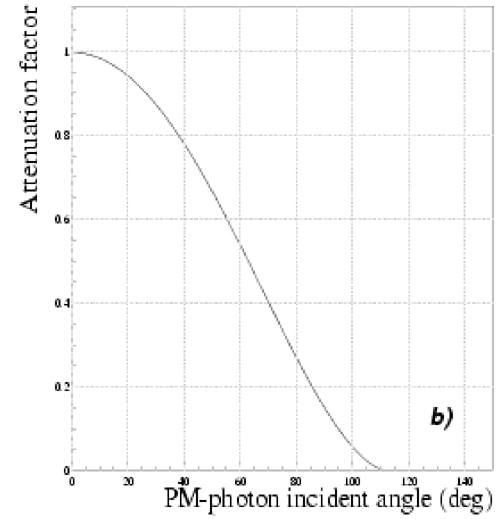
Time resolution
(tts sigma = 1.3nsec)
Amplitude resolution:
30% for 1pe
Pre/late/after pulses
(1.6%) not simulated



PMT & OM properties

QE
(Hamamatsu)

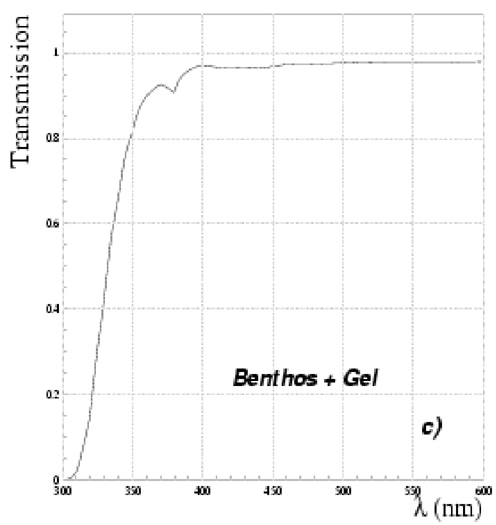




Angular
Acceptance
(cosmic muons)

Up to 80^{o} close to ‘flat disk’

Transmission
(measured)



Concept of directional PMTs
Can be easily introduced via
angular acceptance function

Water properties Refractive index

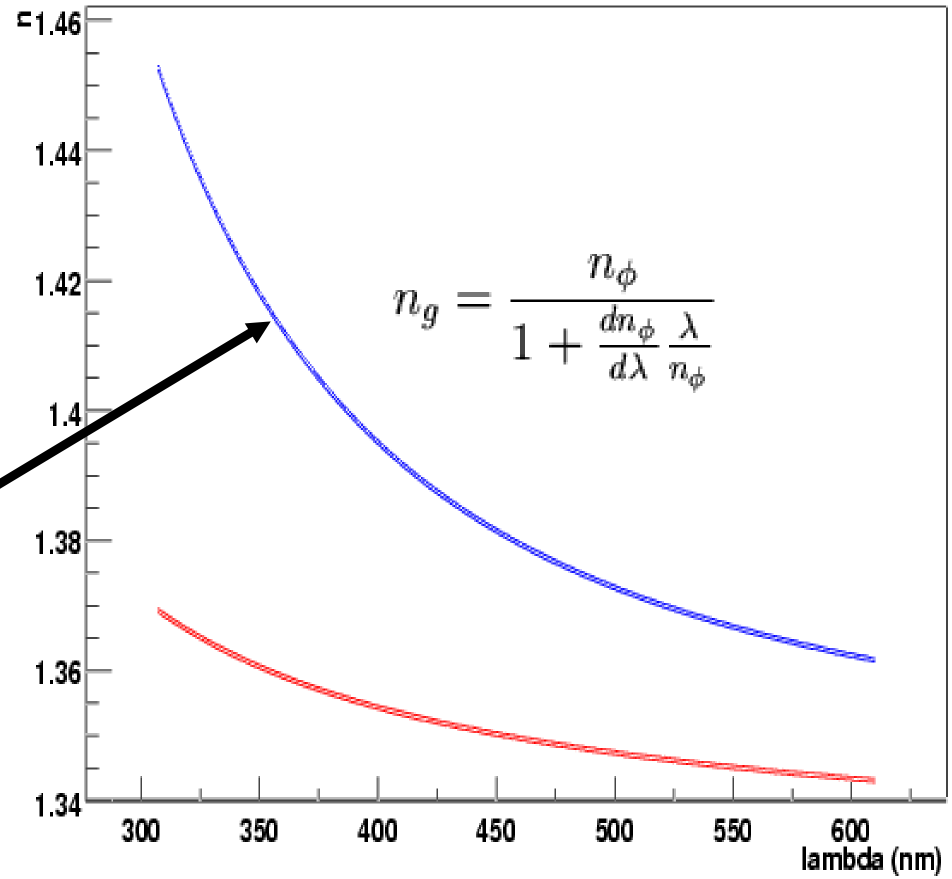
Wave length window

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)



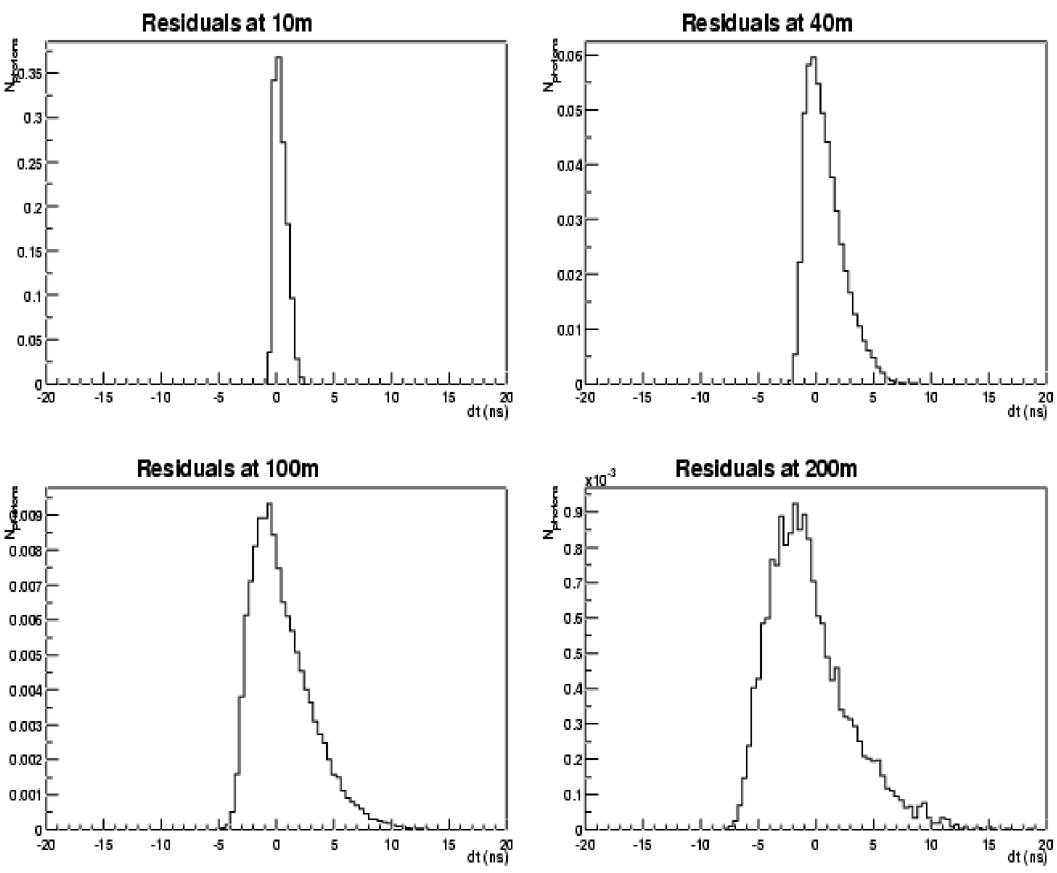
Water properties Dispersion

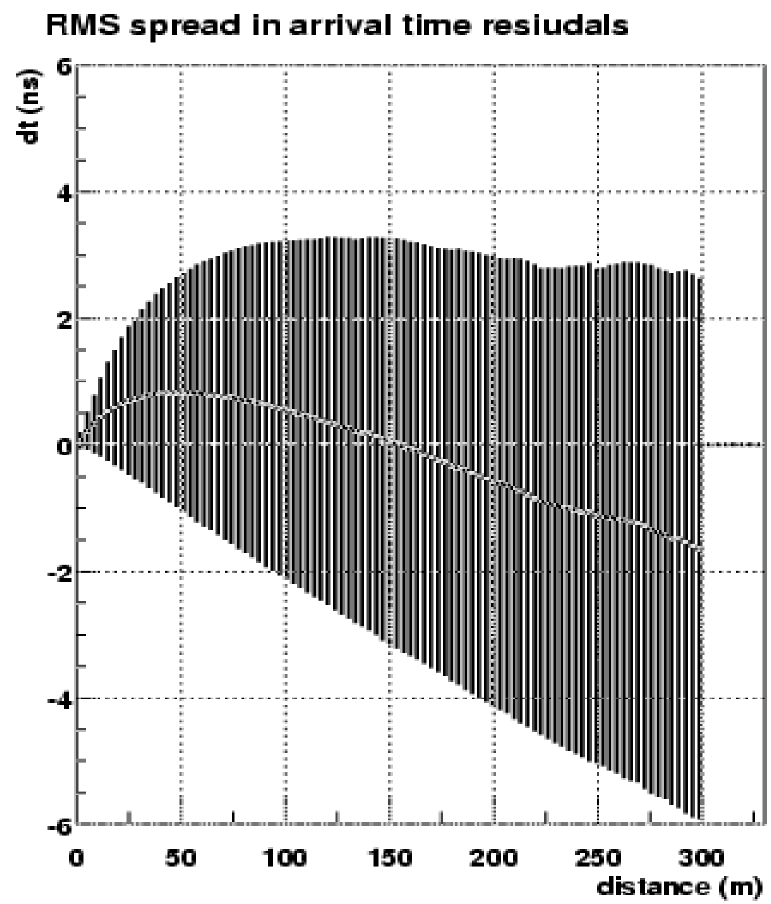
Cherenkov photon propagation done for ONE wavelength (CPU time)

Dispersion correction added at PMT depending on distance

At 50m comparable to PMT tts !

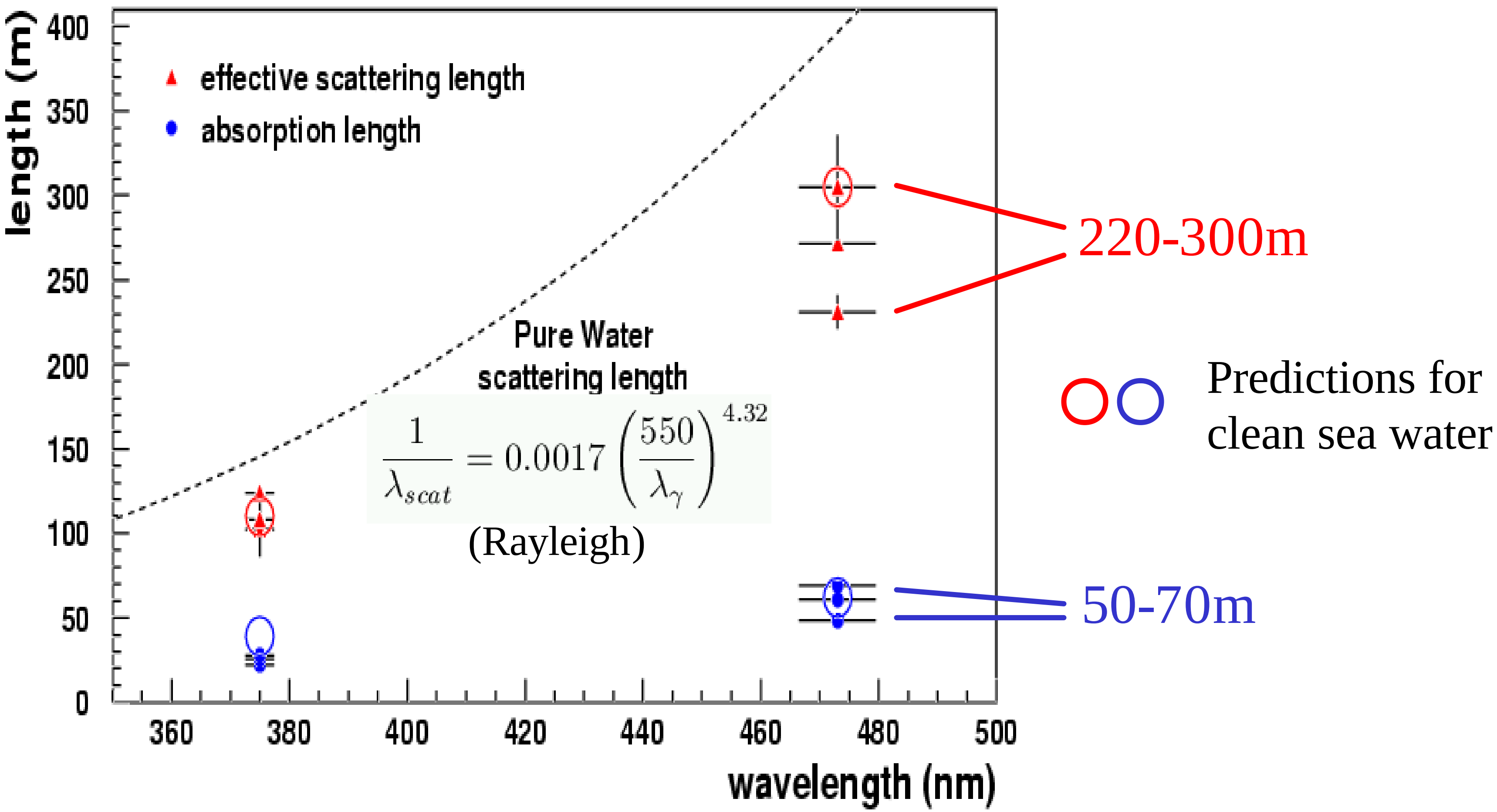
Examples: Effect of dispersion , no scattering





Water properties Measurements

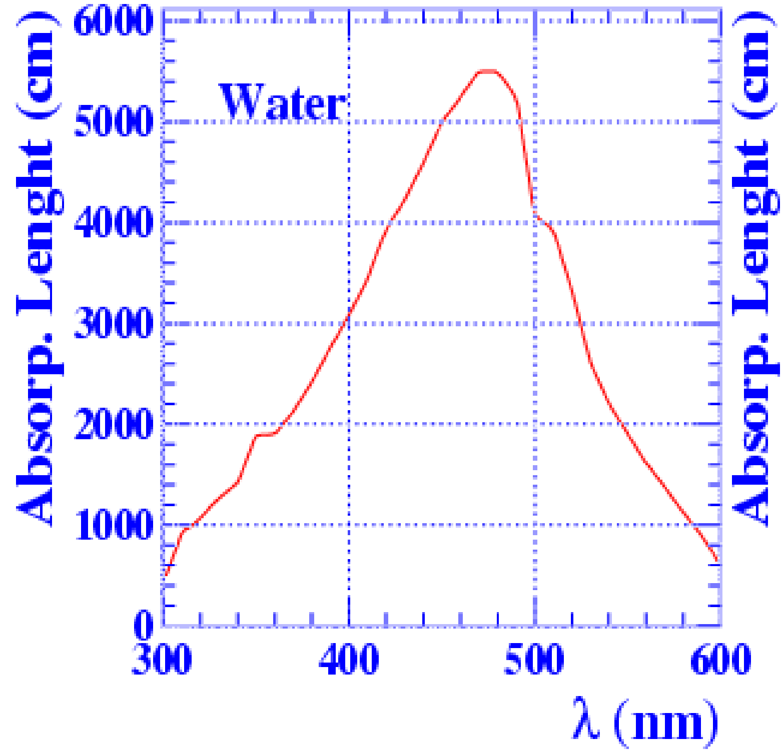
Summary of measurements at Antares site



Water properties Absorption

Wave length dependence
from external references
300-600nm

Peak value set to fit
measurements at Antares site
(55m)



Water properties Scattering

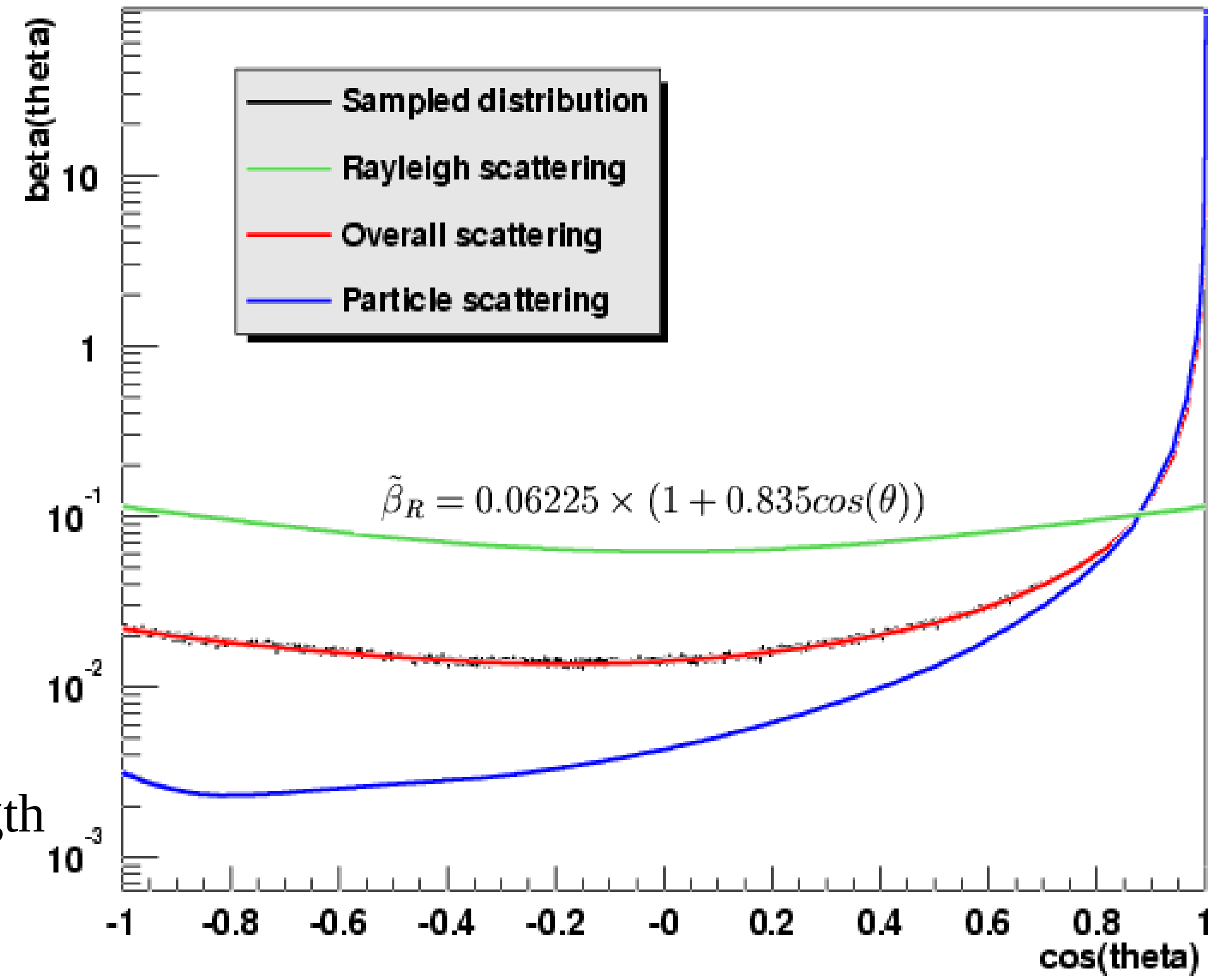
Rayleigh (molecular) scattering well described
(angular and wave length dependence)

Particle scattering strongly
forward peaked

Best fit Antares data
17% Rayleigh
83% Particle

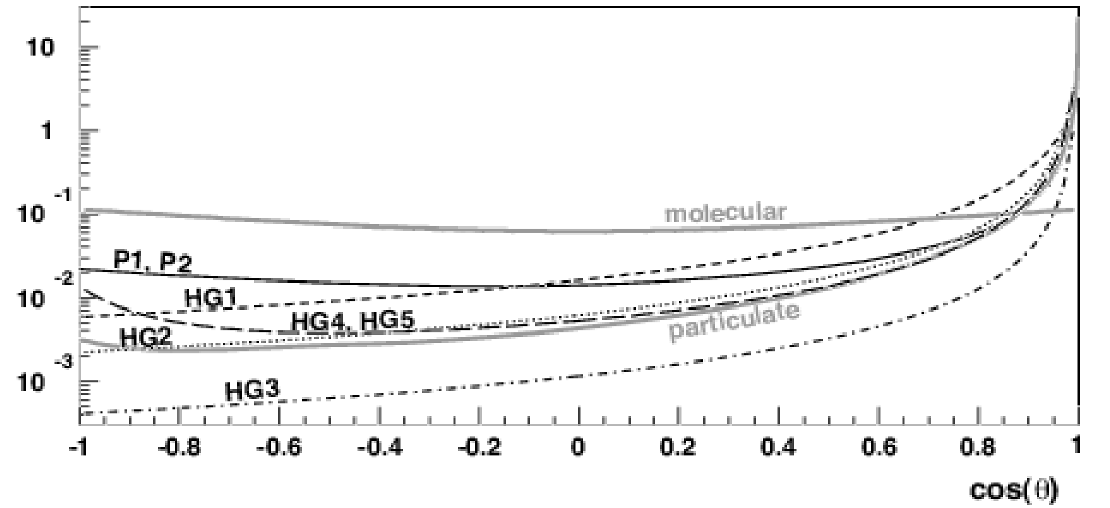
Measurements mainly on
Effective scattering length

Choice of angular function
and geometrical scattering length
Remains open

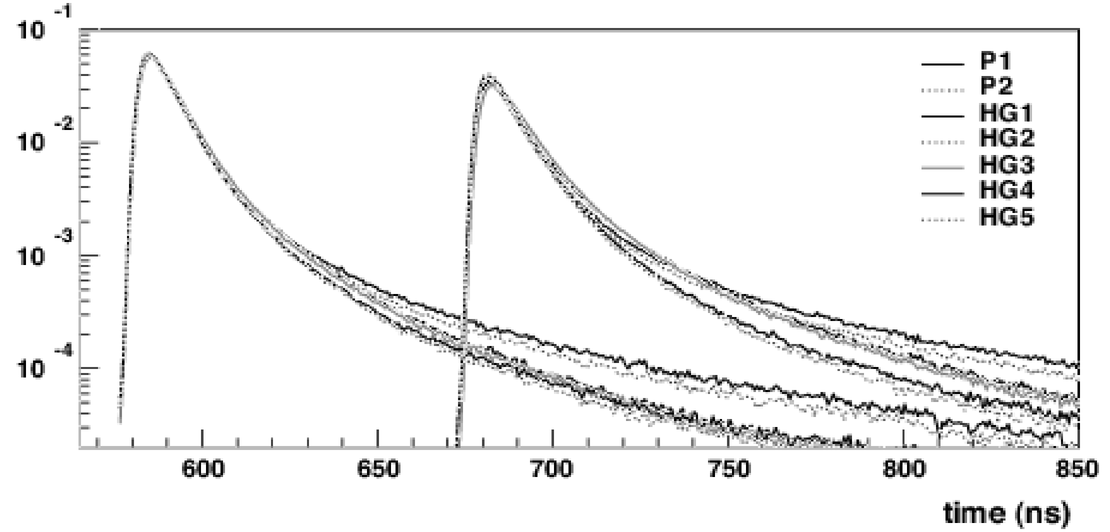


Water properties Scattering

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



Effect on time residuals:
Mainly tail but also peaks

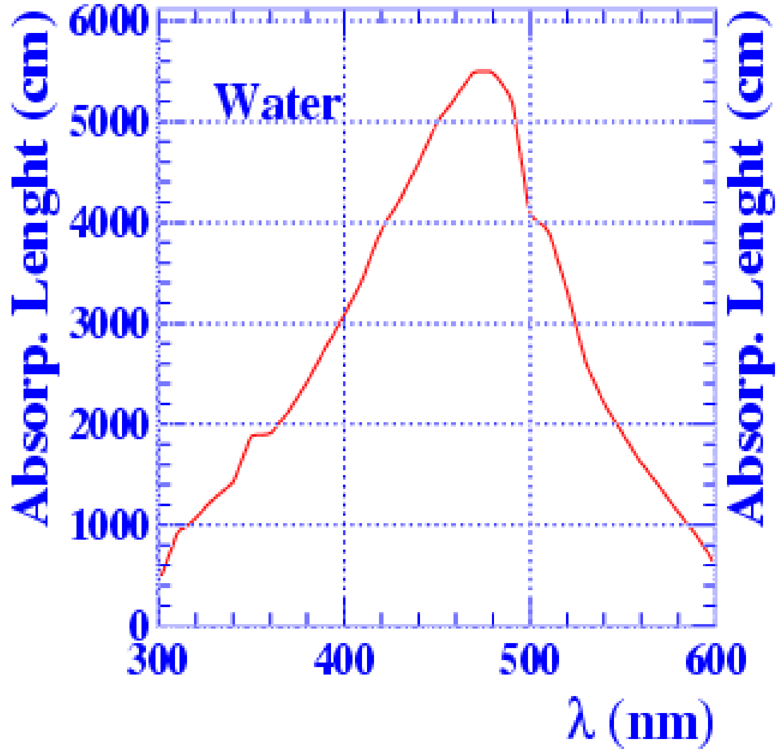


Result:
Ignorance on details of
Scattering introduces
30% error on angular resolution
10% error on eff. area

Water properties Absorption

Wave length dependence
from external references
300-600nm

Peak value set to fit
measurements at Antares site
(55m)



Water parameters Noise

Example:

3 months measurement

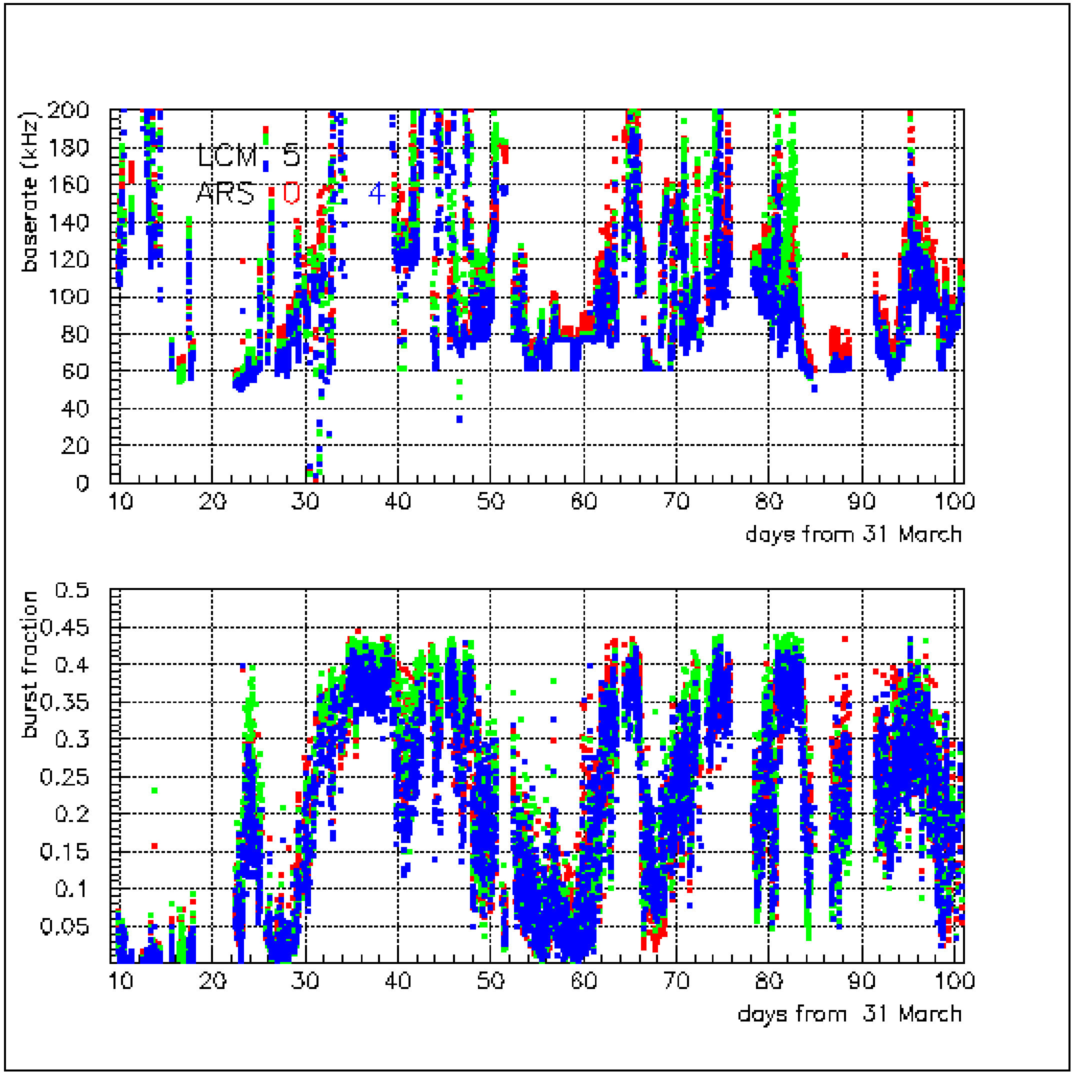
From Antares prototype

Baseline rate

Burst fraction

Highly variable

Difficult for simulations



Water parameters Noise

- Standard analyses:
  tunable but constant noise added
  (most analyses 60 kHz – too optimistic ?)
- Standalone noise study: data rate/trigger
- Bioluminescence bursts, time/position dependence: studies just started
  - How to treat effect ?
  - Fractions of PMTs ‘dead’ (in burst regime)
  - Individual noise rate per PMT
    (difficult to ensure stable physics results)

Conclusion

- 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