Cosmogenic neutrinos in KM3NeT

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VLVνT workshop

Content of the talk

- KM3NeT: Mediterranean deep sea research infrastructure
- Cosmogenic-ν flux and expected event rates in KM3NeT
- Status of UHE-shower simulations
- Background processes
- Summary and outlook

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KM3NeT: deep sea research infrastructure

www.km3net.org

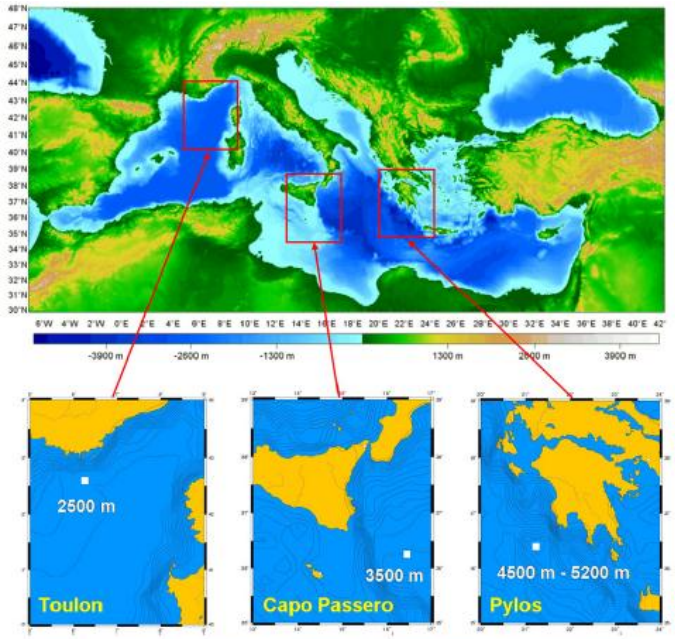
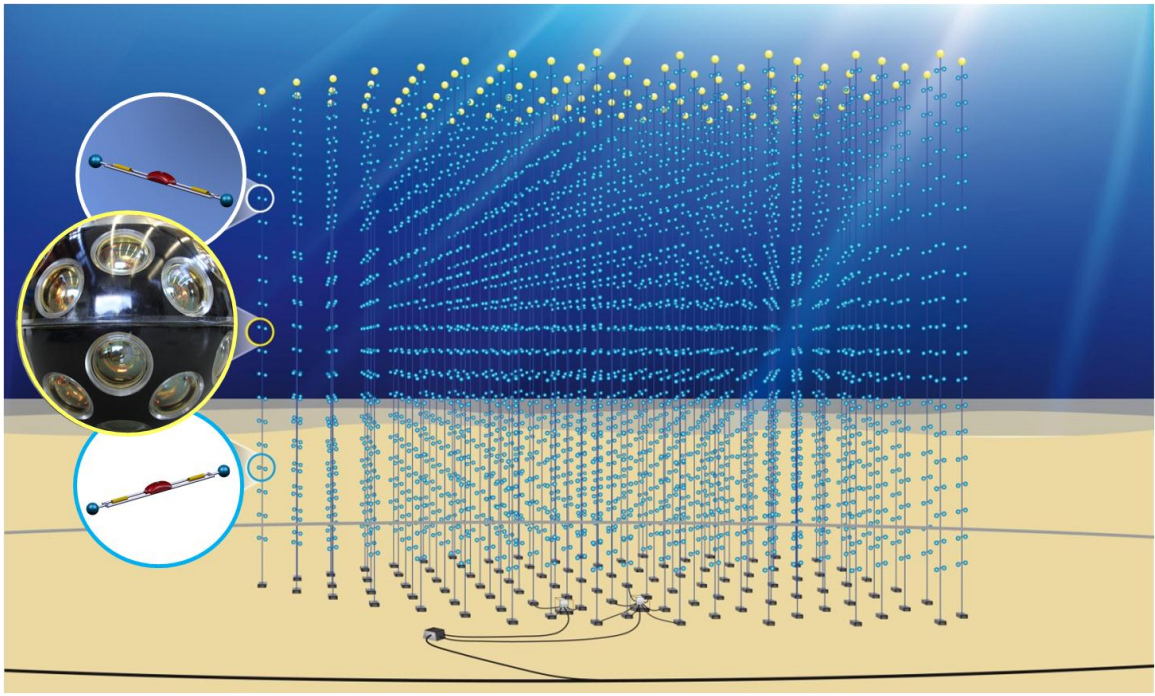


Figure 1-6: Locations of the sites of the three Mediterranean neutrino telescope projects.

The KM3NeT consortium:
ANTARES / NEMO / NESTOR



The KM3NeT Neutrino telescope:
multi-km^3 instrumented volume deep sea detector.

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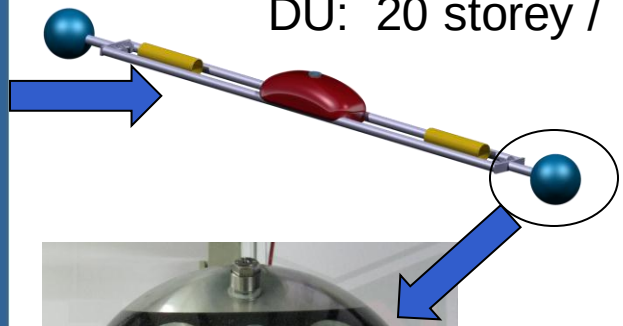
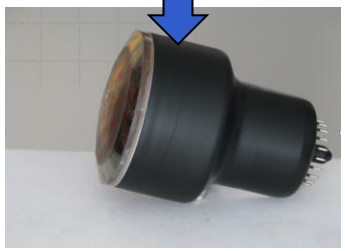
The KM3NeT neutrino telescope

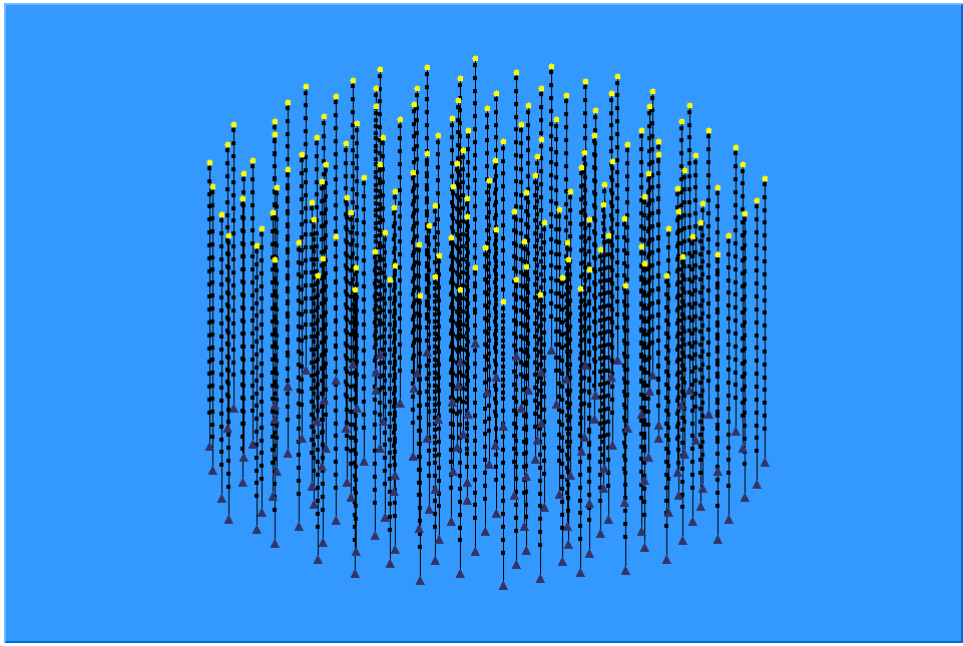
KM3NeT detector:

Set of detector units (DU)

DU: 20 storey / 2 multi-PMT DOM / 31 × 3 " PMT







KM3NeT "Reference detector":

154 DU (150-180m)

Storey-Storey: 40 m

instrumented volume ~ 3 km^3

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Neutrino signatures in KM3NeT

Cosmic neutrino fluxes: $\nu_\mu : \nu_e : \nu_\tau \sim 2 : 1 : 0 \rightarrow 1 : 1 : 1$

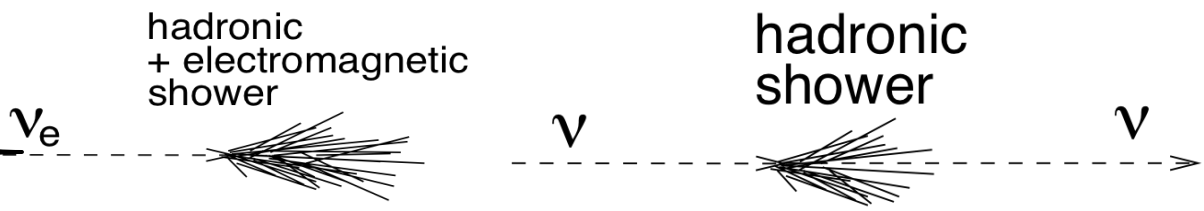
$\nu_\ell + N \rightarrow$ { CC ℓ (μ, e, τ) + X ; NC ν_ℓ + X }

$E_X = yE_\nu$, $E_\ell = (1-y)E_\nu$

CC ν_μ–μ events :
- long μ-track
- large effective area
- good angular resolution
- poor energy resolution

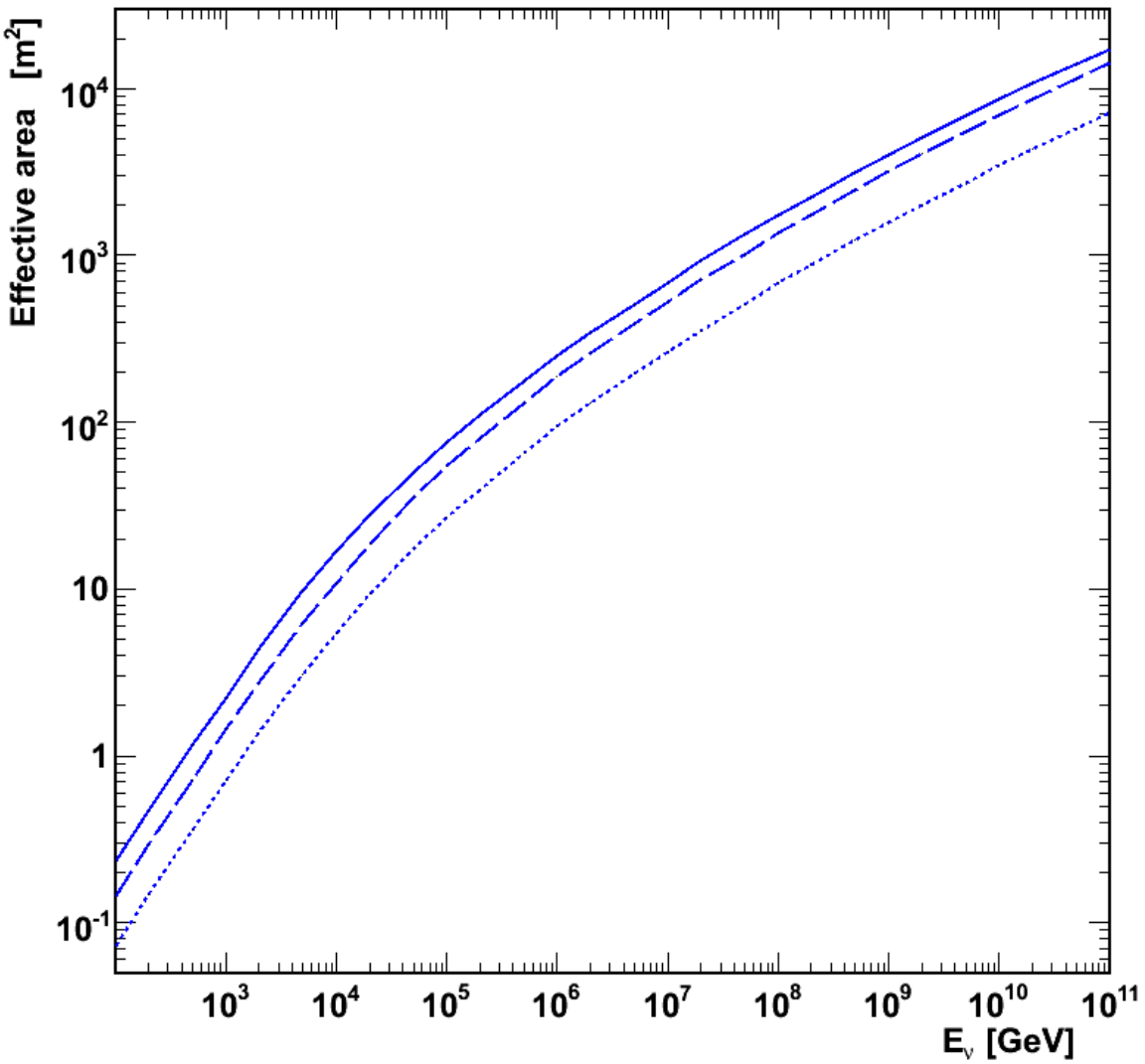
Used for a search of ν-sources
KM3NeT detector optimisation

CC $\nu_{e/\tau}$-e/τ and NC events:
- short shower length
- only "contained events"
- smaller effective area
- good energy resolution
- poor angular resolution



Diffuse flux search

Neutrino event rates in KM3NeT



Number of events:

$$N = 2\pi T \int \Phi(E)\, A(E)\, dE$$

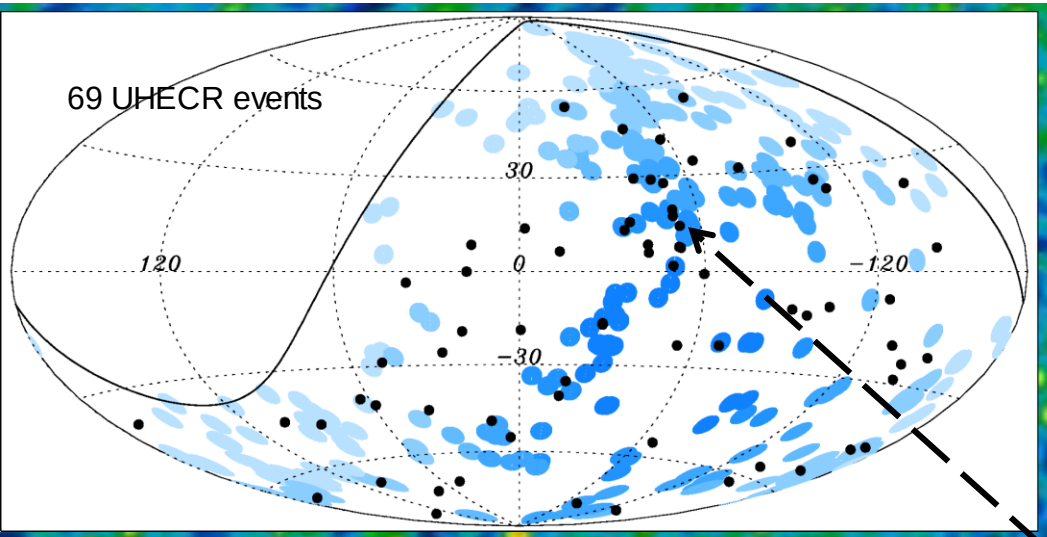
$\Phi(E)$ – neutrino flux,
$A(E)$ – effective area
T – time

Effective area for contained down going neutrino events (with perfect efficiency)

Lines:

- solid: All events
- dashed: CC events
- dotted: NC events

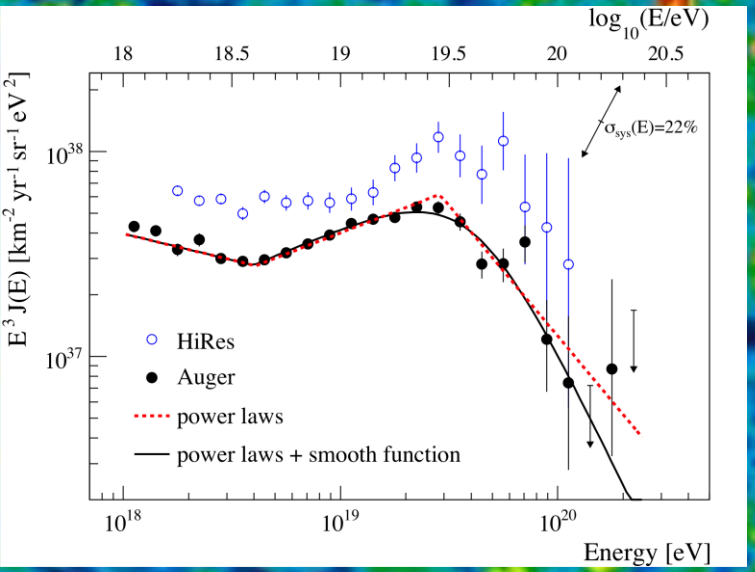
UHECR and cosmogenic ν

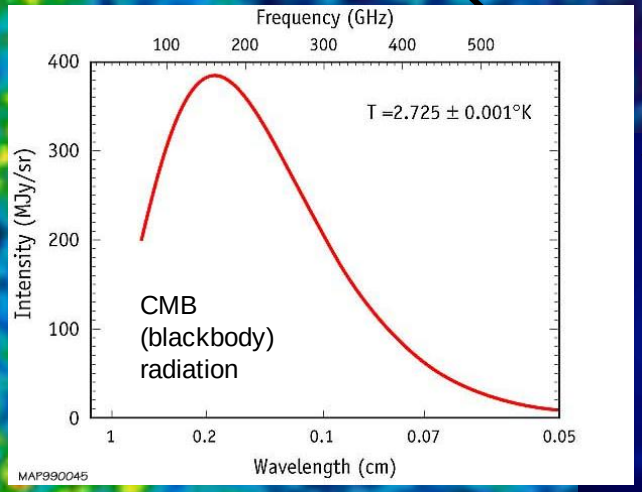


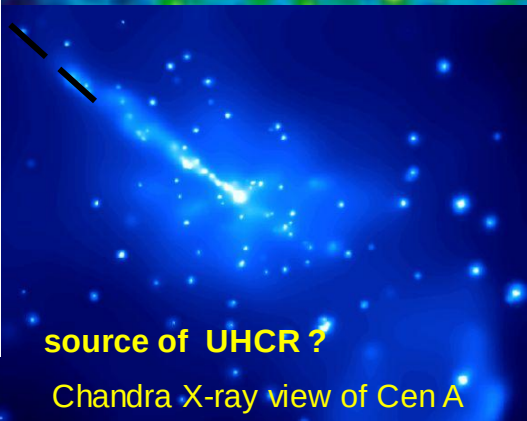
Cosmogenic neutrino flux

UHECR properties
- Injection spectrum ($\beta E^{-\alpha}$),
- Max. energy of acceleration (cut-off)
- Composition (p/Fe)
- Source z-evolution
- Transition models

$p + \gamma \rightarrow N\pi \rightarrow \mu\nu_\mu \rightarrow e\nu_\mu\nu_e$



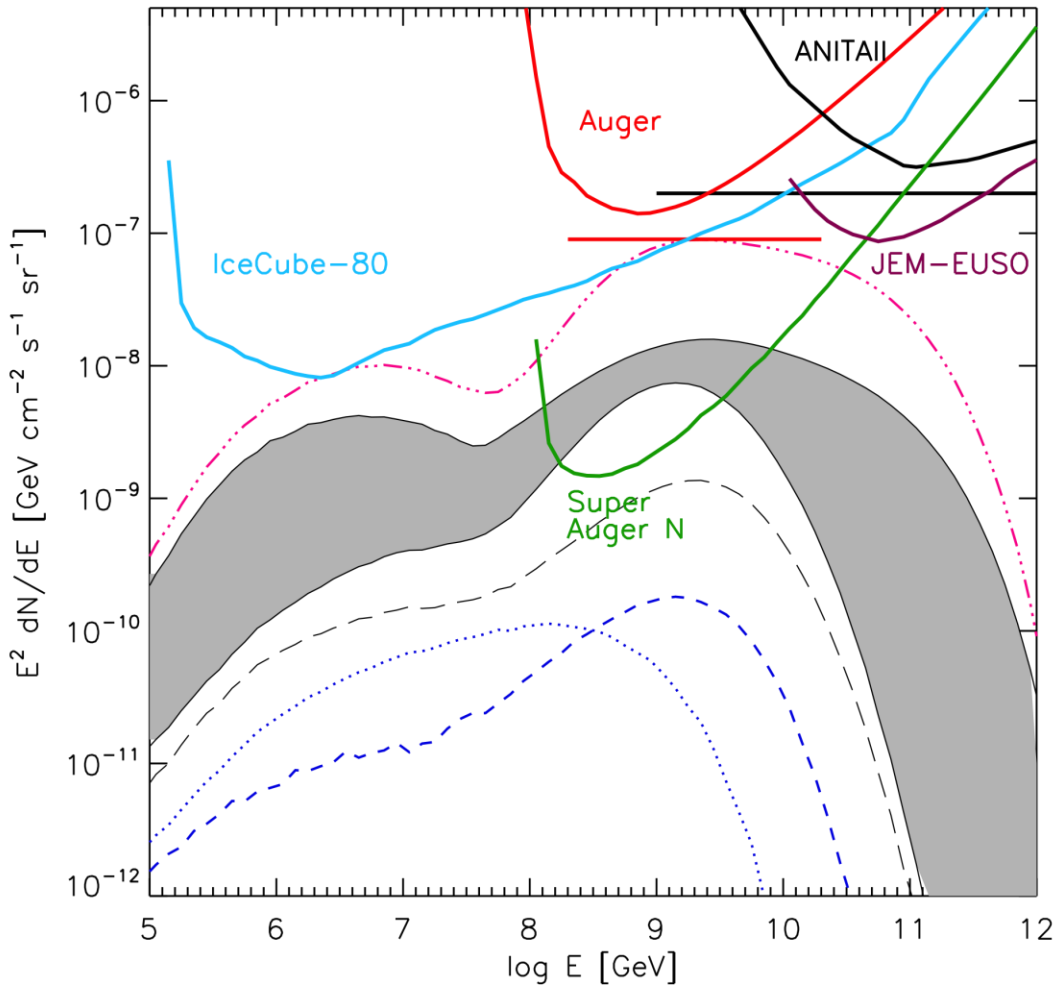




source of UHCR ?

Chandra X-ray view of Cen A

Cosmogenic ν flux



The pink dot-dashed line:
strong source evolution case
with a pure p-composition,
$E_{max} = 10^{21.5}$ eV.

Blue lines (extreme pessimistic cases):
the iron rich, low $E_{p,max}$ and
pure iron ($E_{p,max} = 10^{20}$ eV);

The shaded area includes a wide
range a parameters.

Experiments:

ICeCube, KM3NeT: $E_\nu > 10^5$ GeV

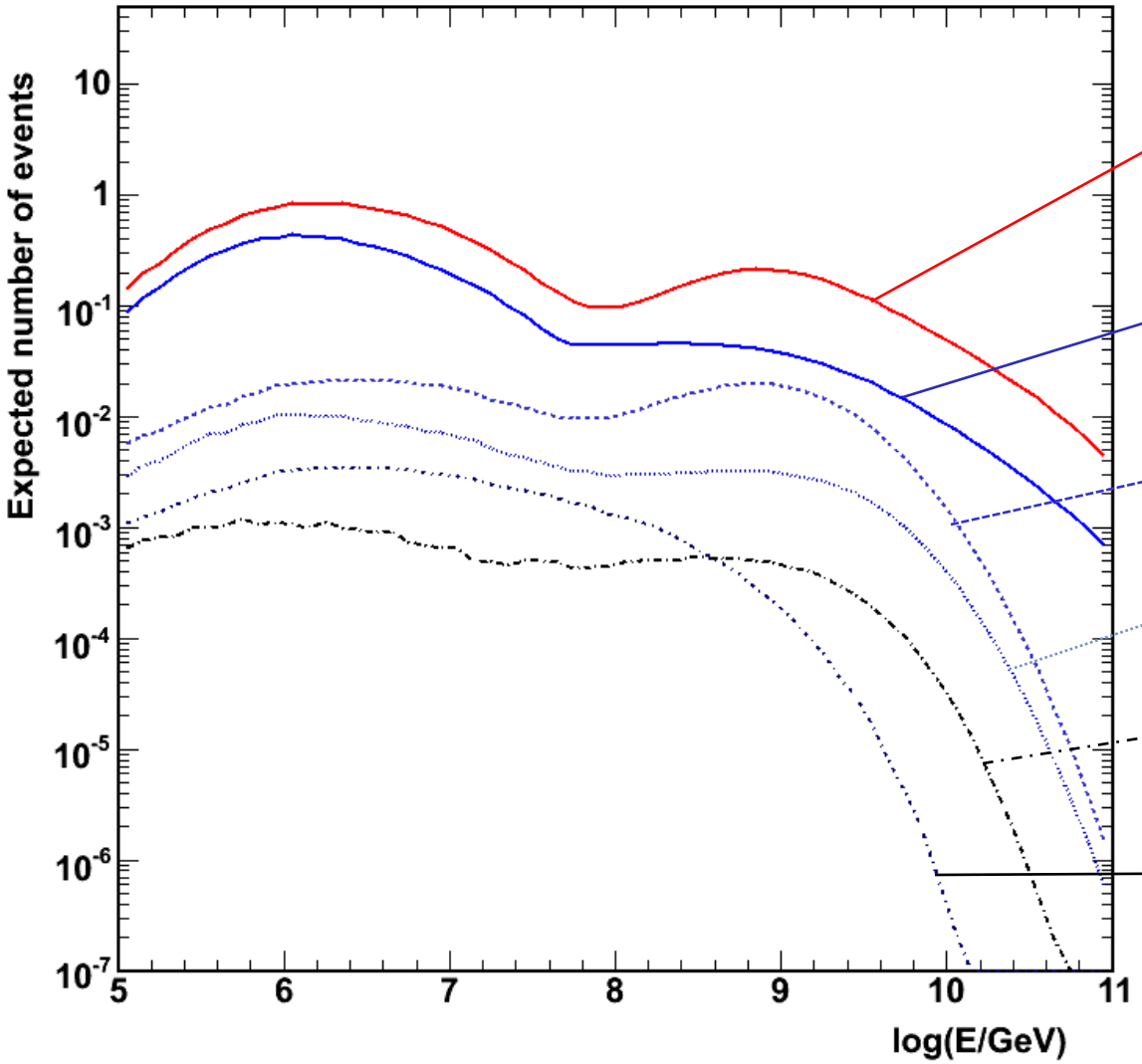
Auger: $E_\nu > 10^8$ GeV

ANITA, JEM-EUSO: $E_\nu > 10^{10}$ GeV

From:
K. Kotera, D. Allard and A.V. Olinto, JCAP10(2010)013
Cosmogenic neutrinos: parameter space and detectabilty from PeV to ZeV

Expected event rates in KM3NeT

Expected differential events rates/yr of cosmogenic-ν in the KM3NeT telescope



Strong evolution case, pure p-composition, E_{max} = 3160 EeV.

Source evolution: SFR1&GRB

SFR1, mix composition E_{max}=100 EeV

Uniform evolution

Low E_{max}

Iron composition, E_{max}=100 EeV

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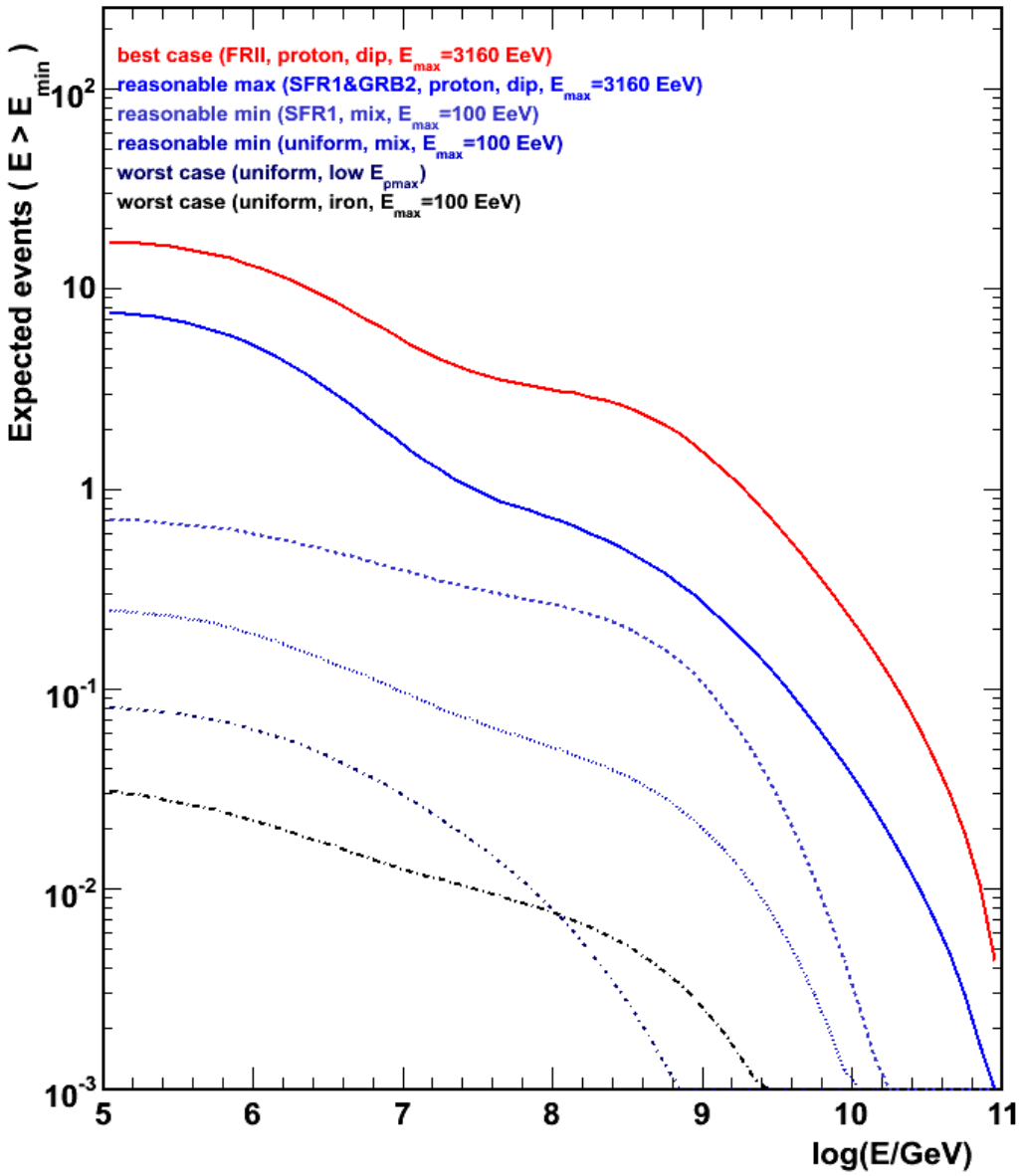
Expected event of cosmogenic-ν



Expected integrated rates/year cosmogenic neutrinos ($E>E_{min}$)

For down going neutrino events in a sensitive volume, assuming perfect detection and reconstruction efficiency

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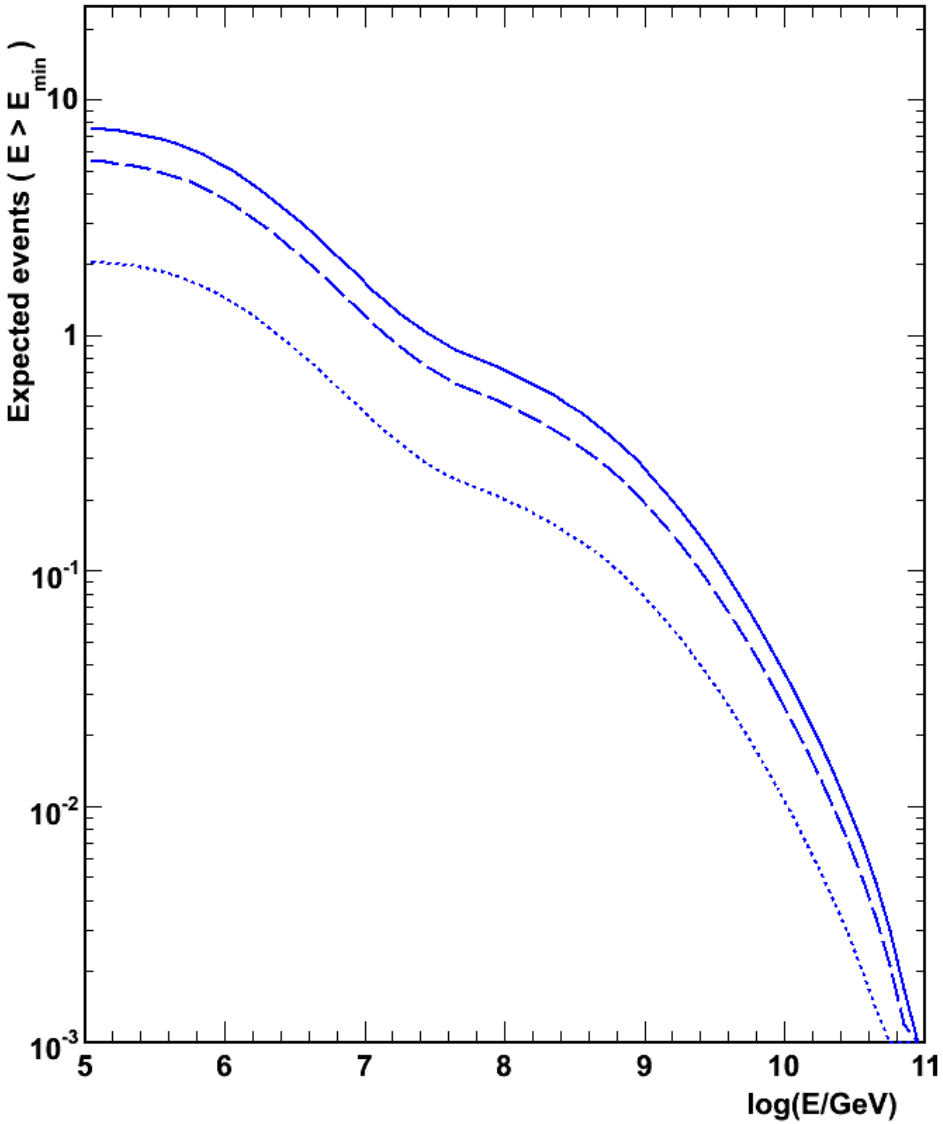
Expected event of cosmogenic-ν



Expected integrated event rates/year for cosmogenic neutrinos with $E>E_{min}$ taking for a "reasonable max" case.

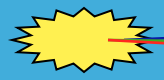
For down going neutrino events in a sensitive volume, assuming perfect detection and reconstruction efficiency.

- Dashed line: CC events
- Dotted line: NC events

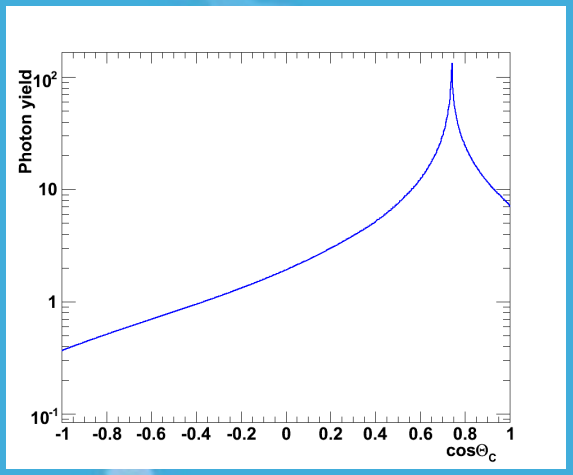
Simulation of neutrino induced shower events

Cherenkov photons

neutrino interaction

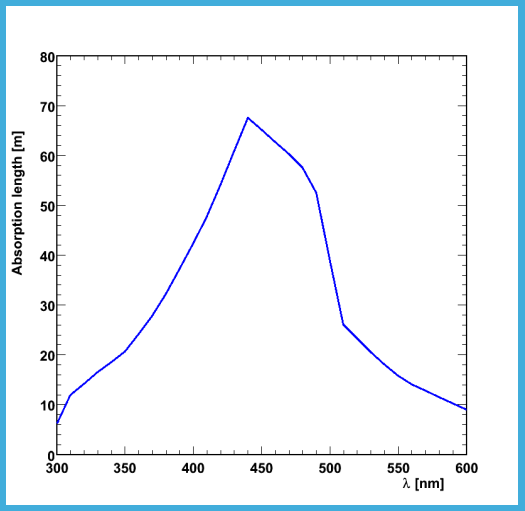


Cherenkov photons induced by relativistic charged particles



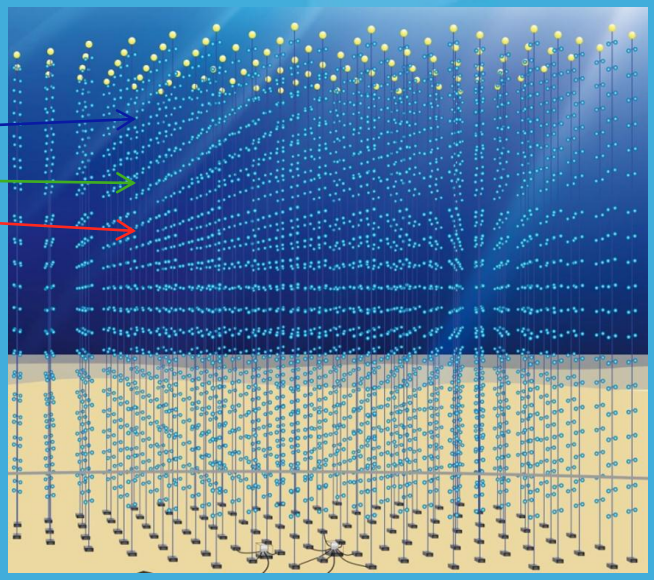
$\cos\Theta_C$ of photons from EM-shower

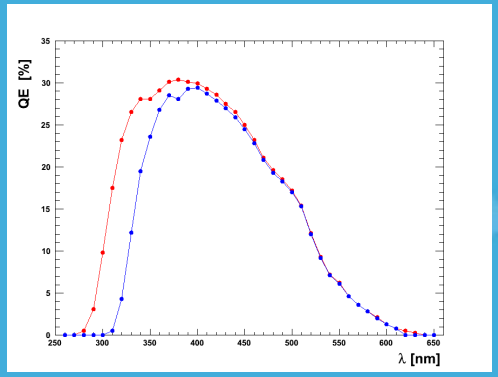
propagation



Propagation of Cherekov photons in a deep sea:
- absorption
- scattering

detection

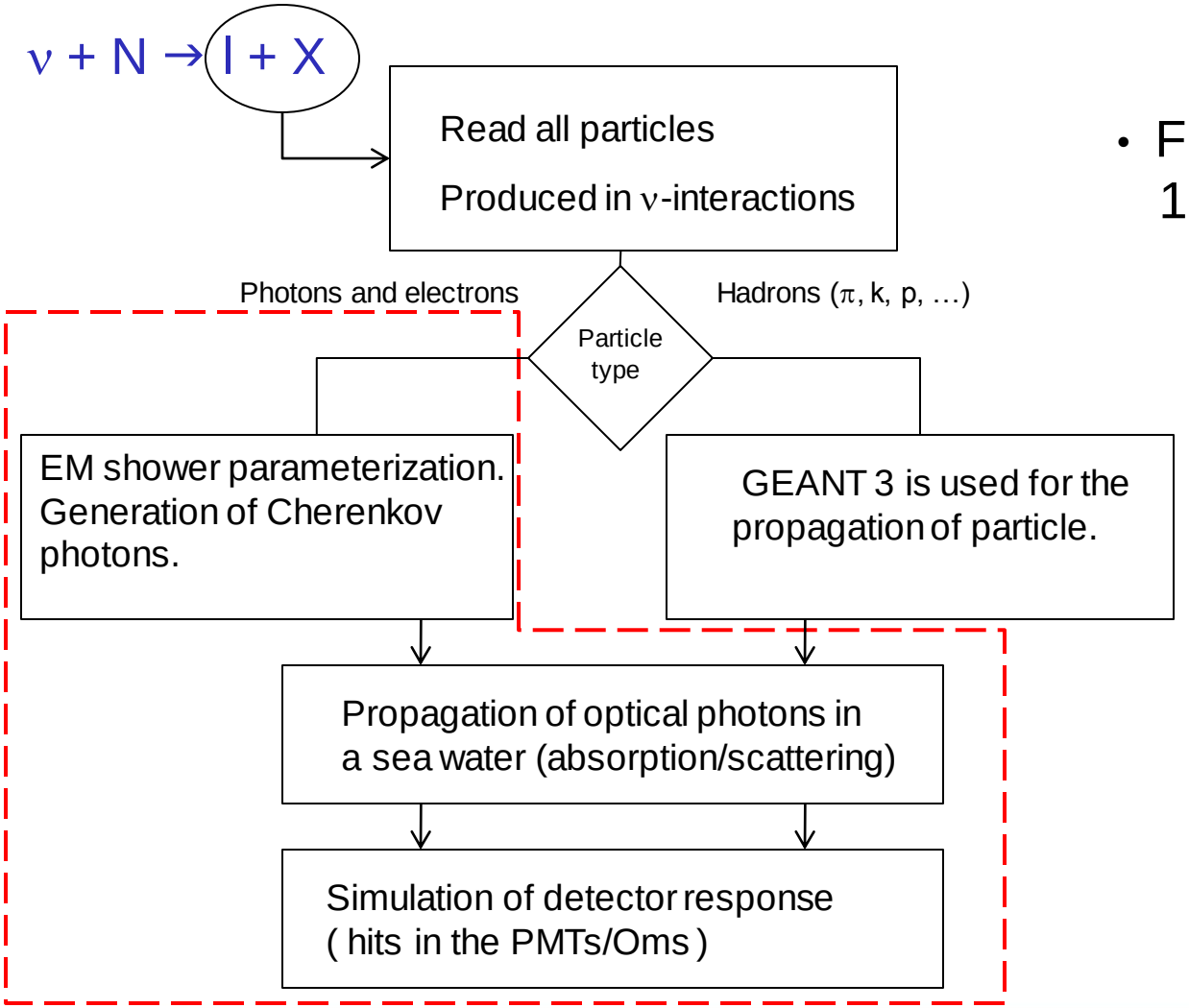




PMT properties: QE, acceptance

Simulation of neutrino induced shower events

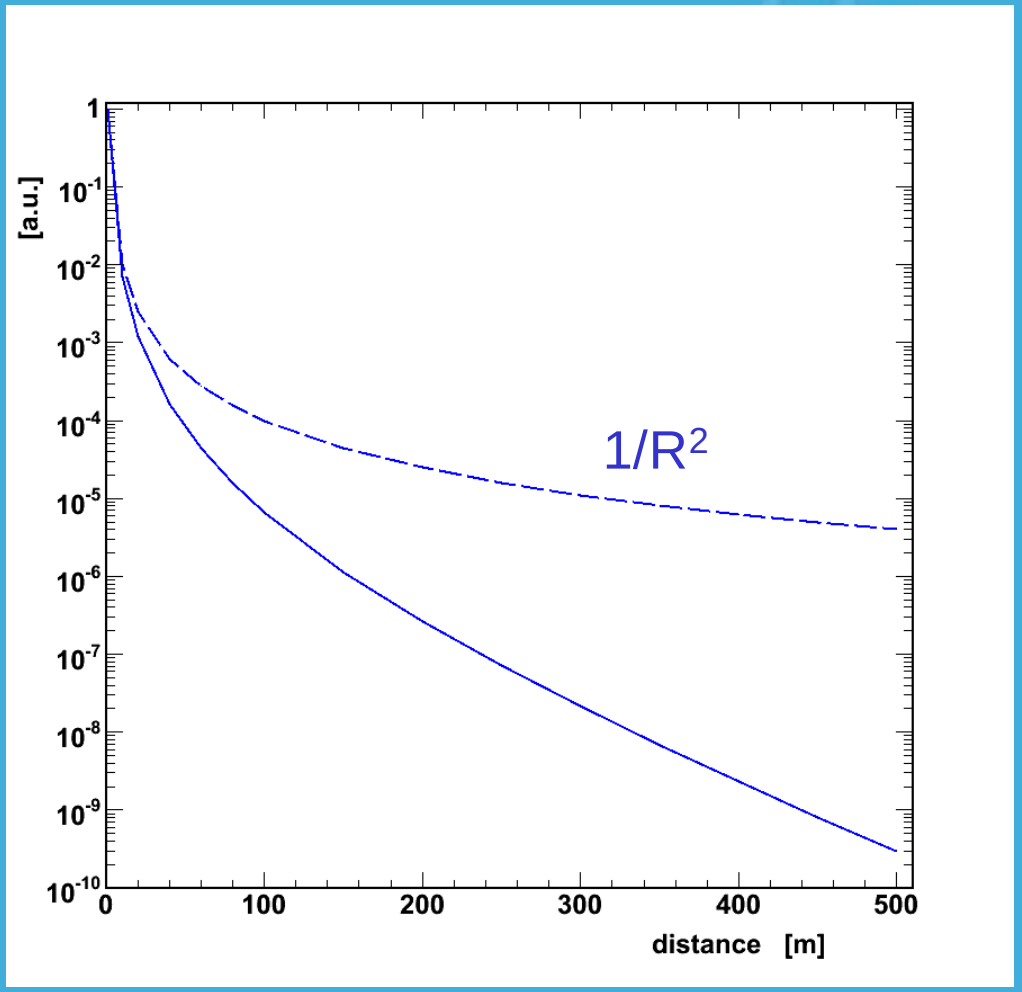
Shower simulations in ANTARES



- Fast simulations:
  1 particle approximation.

GEANT4 vs. fast simulation

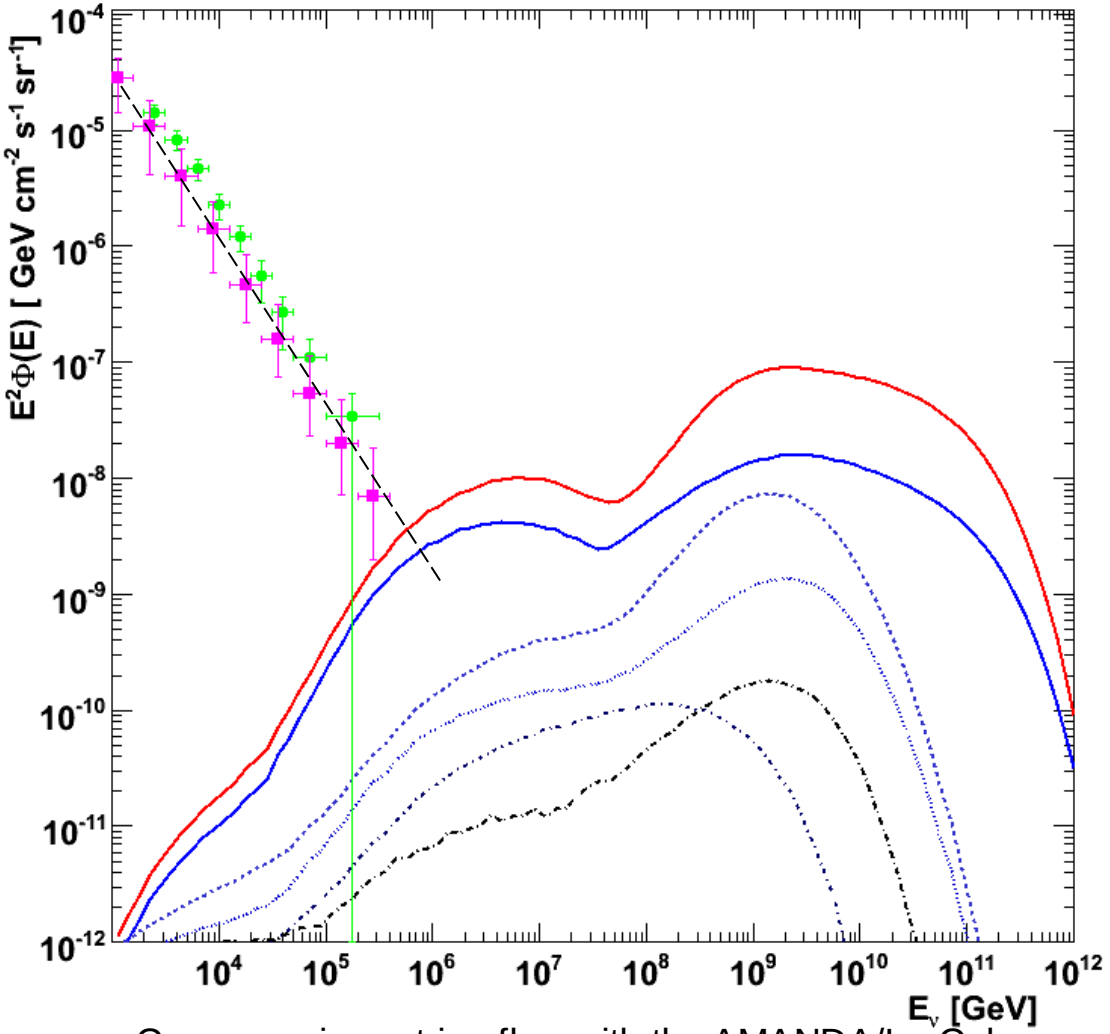
GEANT4 model of KM3NeT multi-PMT DOM used in a study of deep sea optical background (K40 signals).



Attenuation of Cherenkov radiation as a function distance source-OM (dashed line – no attenuation)

Background processes

- Irreducible background:
  atmospheric neutrinos
- atmospheric μ-bundles from the CR-showers
  (site dependent)
- deep sea background:
  - K40
  - bioluminescence
    (site dependent)



Cosmogenic neutrino flux with the AMANDA/IceCube measurement of atmospheric neutrinos.

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Summary and Outlook

- Very large sensitive volume of KM3NeT gives a possibility to detect cosmogec/UHE neutrinos for UHECR models favorable for neutrino production.

- The strategy of UHE neutrino signal detection for the contained events in KM3NeT neutrino telescope is currently under study with MC simulations.

- Low event rate of UHE neutrinos requires a good knowledge of background processes and detailed simulations.

- Significant reduction of the background for UHE events in KM3NeT could be achieved by the simultaneous detection of acoustic signal with the KM3NeT acoustic system.

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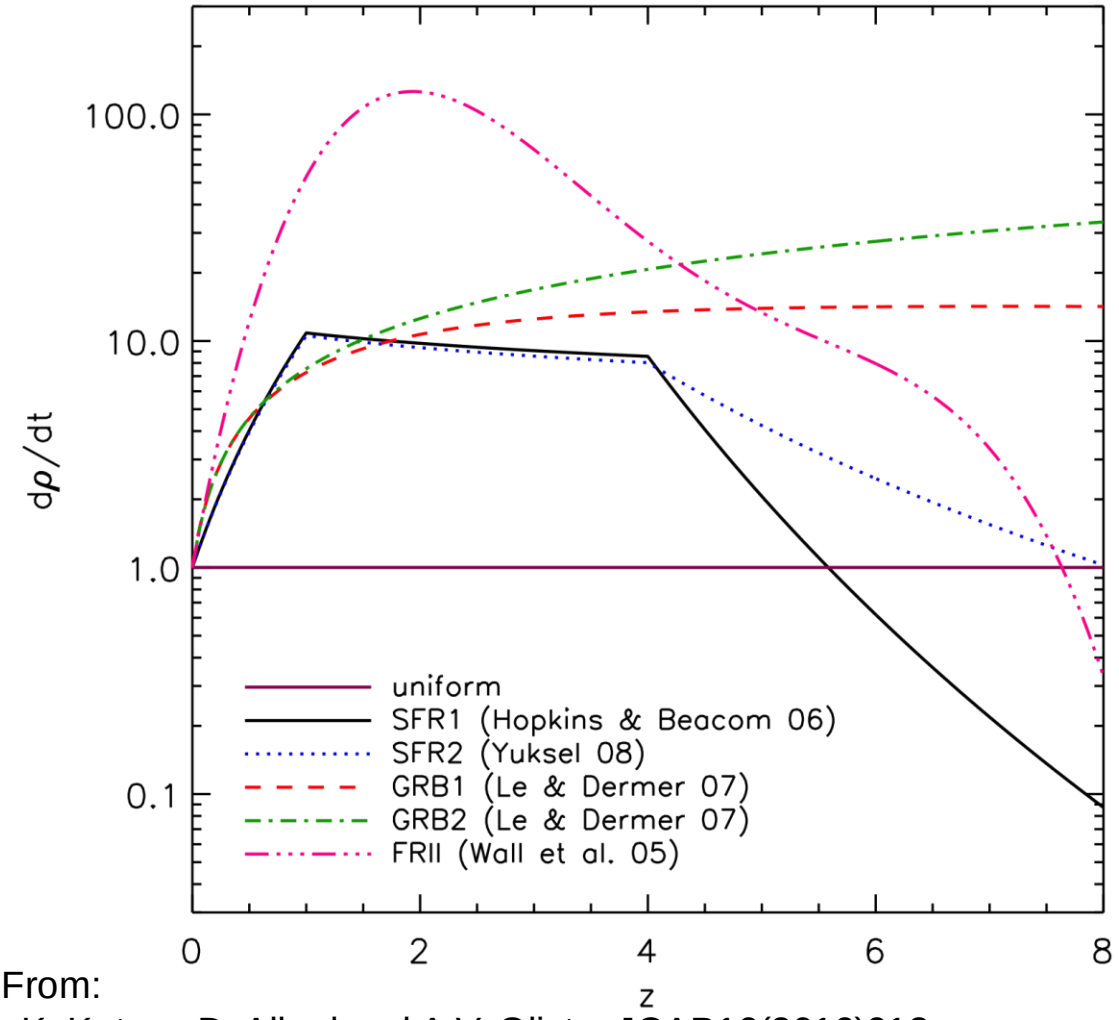
Source emissivity evolution with redshift



- Uniform
- SFR1:
  $(1 + z)^{3.4}$ $z < 1$,
  $(1 + z)^{-0.26}$ $1 \le z < 4$
  $(1+z)^{-7.8}$ $z \ge 4$.
- SFR2:
  $(1 + z)^{-0.3}$ $1 \le z < 4$
  $(1+z)^{-3.5}$ $z \ge 4$
- GRB1:
  $(1 + 8z)/[1+(z/3)^{1.3}]$
- GRB2:
  $(1 + 11z)/[1+(z/3)^{0/5}]$
- FRII
  $2.7z + 1.45z^2 + 0.18z^3 - 0.01z$

From:
K. Kotera, D. Allard and A.V. Olinto, JCAP10(2010)013
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