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ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Reconstruction of cascade-type neutrino events in KM3NeT/ARCA

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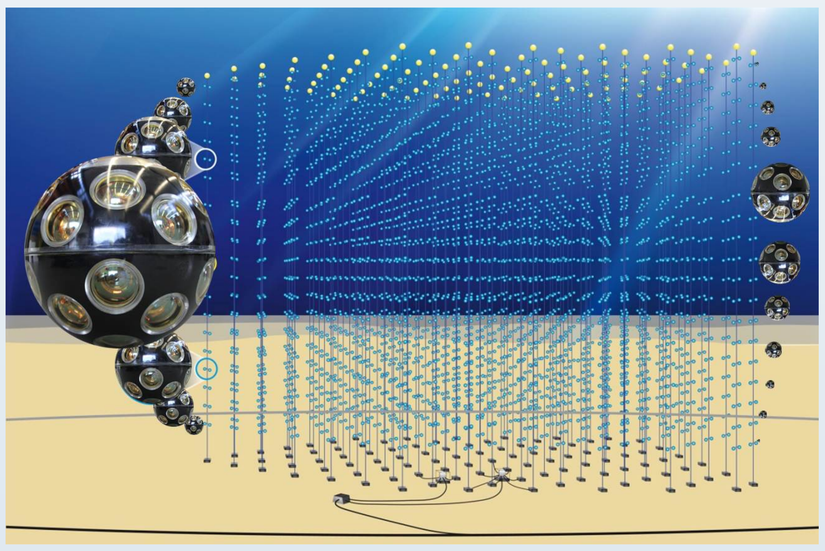
KM3NeT/ARCA (Astroparticle Research with Cosmics in the Abyss)

KM3NeT is a future research infrastructure hosting the next-generation underwater neutrino observatory in the Mediterranean Sea. Within KM3NeT the ARCA detector is planned as an intermediate step.

Detection principle: Cherenkov light from secondary particles induced by all-flavour neutrino interactions is detected with multi-PMT optical modules mounted on vertical strings that are anchored to the seabed.

ARCA detector:
- total of 1 km^3 instrumented volume
- 2 cylindrical detector blocks
- 115 strings per block
- 18 DOMs per string
- 31 PMTs per DOM
- Goal: investigation of high energy diffuse cosmic neutrinos and search for sources
- Needs: good energy and angular resolution for all-flavour neutrino interactions

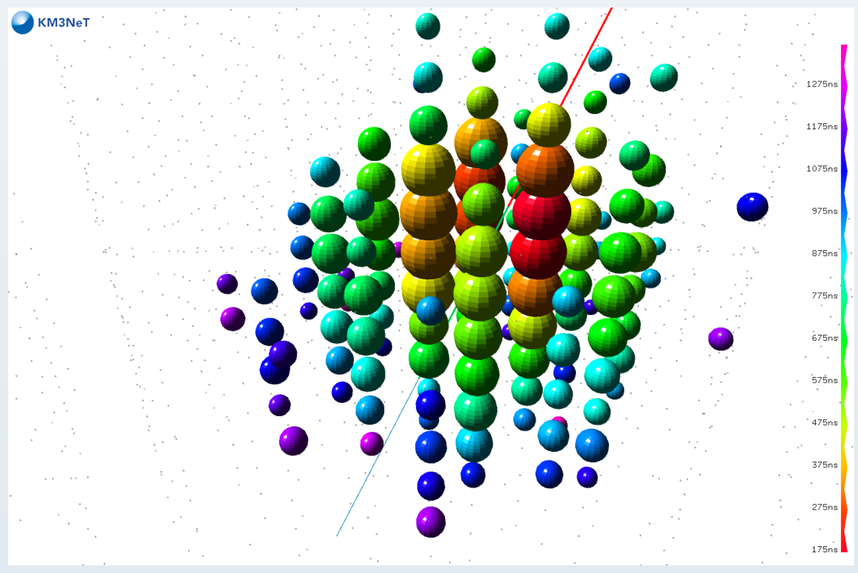
Full KM3NeT detector:
- total of 3 km^3 instrumented volume
- 6 detector blocks



Artist's impression of a KM3NeT/ARCA detector block.

Simulations

- event generation: ν_e, ν_μ, ν_τ, NC + CC, atmospheric μ
- secondary particle and light propagation
- ^{40}K background, PMT response and triggering



Event display for a 1 PeV simulated ν_e CC event inside the detector. The color scale gives the hit times with respect to the time of the neutrino interaction. The size of the spheres corresponds to the measured charge. A cut has been applied to reduce the ^{40}K background.

Reconstruction methods

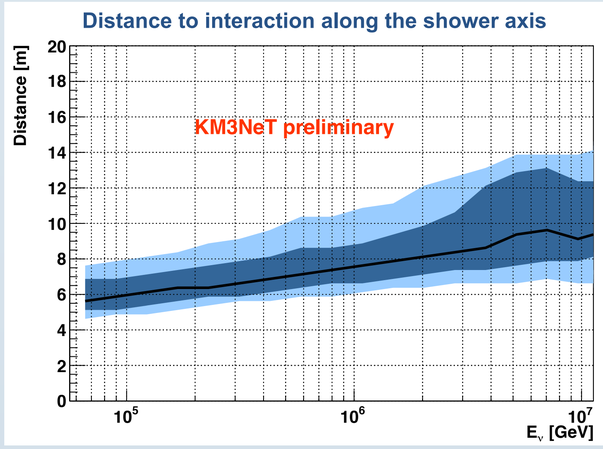
3 algorithms developed:
- *method 1:*
  - specifically developed for KM3NeT/ARCA
  - taking full advantage of multi-PMT digital optical modules (DOMs)
  - best performance regarding energy and angular resolution
  - only results for this method shown here
- *method 2 and 3:*
  - imported from ANTARES to new detector layout of ARCA
  - used for discriminating signal from background

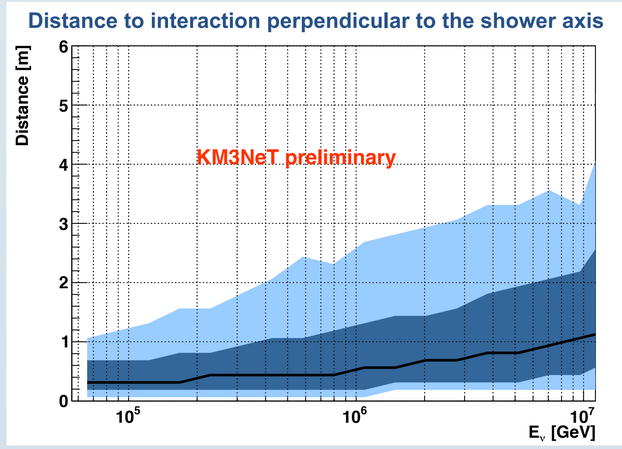
vertex determination (*method 1*)**:**
- merge hits within 350 ns on same PMT
- select coincidences as two merged hits within 20 ns on same DOM
- minimize time residuals assuming spherical light emission

energy and direction determination (*method 1*)**:**
- based on counting hit PMTs in a DOM (after vertex hit selection, see above)
- use three parameters (distance to DOM, angle to DOM, angle of PMT) for PDF
- PDF gives probability of a PMT being hit or not → simple and fast
- find shower direction and energy via likelihood-fit using this PDF

Vertex resolution

- figures show vertex resolution after proper event selection (see [1])
- fitted position to reconstruct the position of the shower maximum (see left figure)
- resolution well below 1 m perpendicular to the shower direction (see right figure)





Vertex resolution: In dark and light blue the 1 σ and 90 % quantile bands are shown.

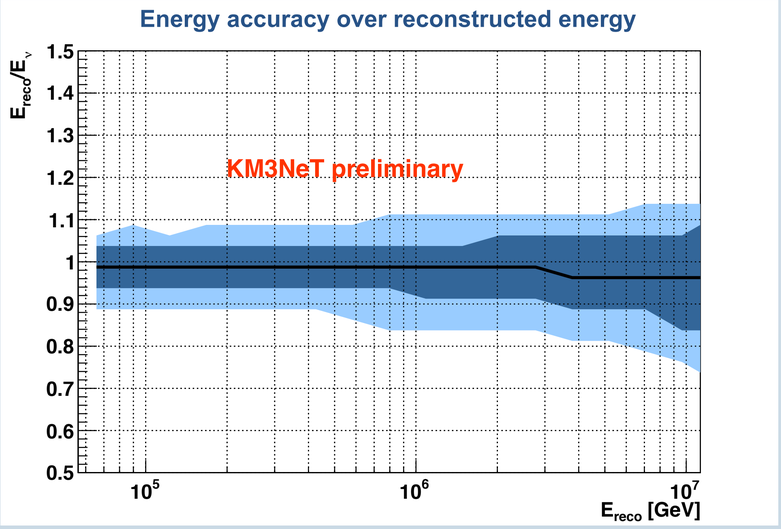
Energy and angular resolution

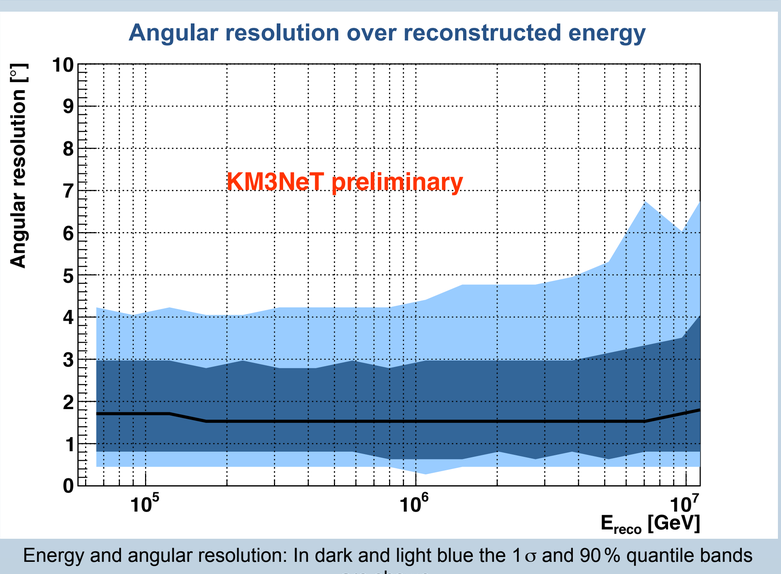
High-purity event sample:
Sensitivity analyses have been performed for ARCA [1] allowing for the selection of a high-purity event sample. The plots on the left show the energy and angular resolution for this event selection with roughly 16 signal events per operation year of ARCA.

From ~50 TeV energies:
- median angular error well below 2°
- energy resolution roughly 5 %
- (no strict containment cut)

Events outside the instrumented volume:
Outside the instrumented volume of the detector approximately one event per operation year of ARCA survive the event selection [1]. The plots on the right show the energy and angular resolution for these events. Thus, even those events can be very well reconstructed.

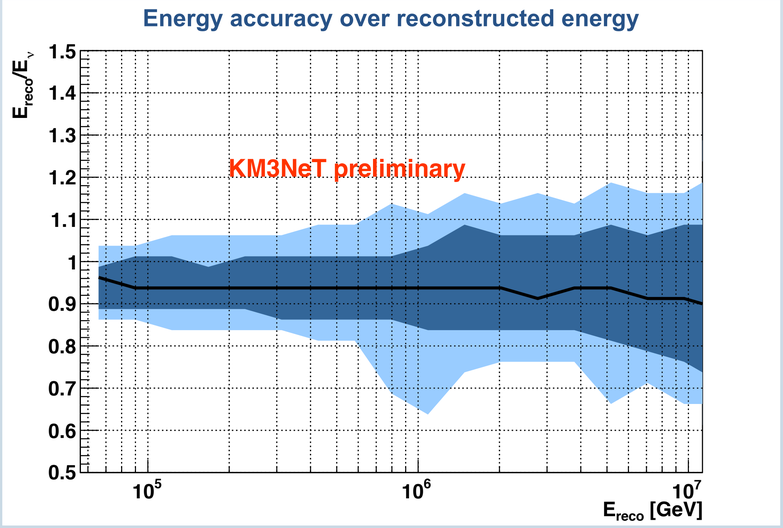
High-purity event sample

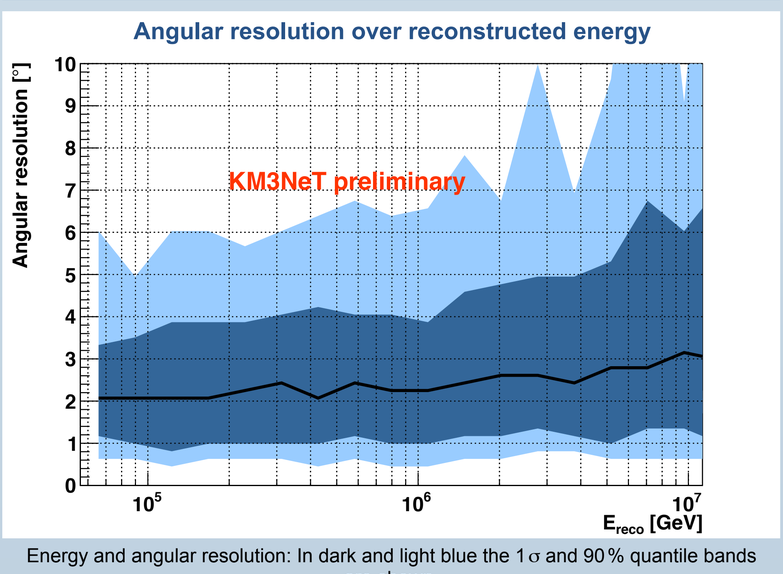




Energy and angular resolution: In dark and light blue the 1 σ and 90 % quantile bands are shown.

Events outside the instrumented volume





Energy and angular resolution: In dark and light blue the 1 σ and 90 % quantile bands are shown.

Reference:
[1] D. Stransky et al. for the KM3NeT Collaboration, proceedings of this conference ID 1108.

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