DeepCore: Opening a New Energy Window for the IceCube Neutrino Observatory

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CCAPP: Novel Searches for Dark Matter Workshop
The IceCube Neutrino Observatory

- Very large scale “hybrid” observatory
  - approximate diameter 1 km

- IceTop:
  - Surface air shower detector array.
  - Threshold approx. 300 TeV.

- AMANDA:
  - historical predecessor to IceCube.
  - 19 strings, 677 optical modules (OMs).
  - Densely instrumented for lower energy threshold (approx. 100 GeV).

- IceCube:
  - 80 strings with 60 Digital OMs per string.
  - Interstring spacing approx 125 m, Digital OM spacing 17 m.
The Energy Gap in neutrino physics...

Accelerator based

100 GeV 1 TeV 10 TeV
AMANDA

IceCube/KM3Net

Non-accelerator based

10 MeV 100 MeV 1 GeV 10 GeV

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The Energy Gap in neutrino physics...

Accelerator based

Solar neutrinos

10 MeV 100 MeV 1 GeV 10 GeV 100 GeV 1 TeV 10 TeV 10 PeV

IceCube/KM3Net

RATIO TO SSM PREDICTION

ENERGY (MeV)

November 17,

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The Energy Gap in neutrino physics...

Accelerator based

Solar neutrinos
10 MeV

100 MeV
atmospheric neutrinos

1 GeV

10 GeV

100 GeV

1 TeV

10 TeV

10 PeV

IceCube/KM3Net

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The Energy Gap in neutrino physics...

Non-accelerator based
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Accelerator based

Non-accelerator based

Solar neutrinos
10 MeV
100 MeV atmospheric neutrinos
1 GeV
10 GeV
100 GeV
1 TeV
10 TeV
10 PeV

K2K
MINOS
Opera

IceCube/KM3Net

100 MeV
1 GeV
100 GeV
10 TeV

Gap
Closing the Gap: The DeepCore

- 6 new strings - 60 High Quantum Efficiency PMTs each in the deepest/clearest ice. (Fiducial volume ~15 MT; $\sigma_t \sim 2$ns)

- Dense instrumentations (7.0 m DOM spacing; 72 m inter-string spacing). Energies few GeV - 1 TeV.

- $4\pi$ detector using the IceCube detector as an active veto. Access to the Southern hemisphere and year round for the Sun.
The DeepCore

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SPE Charge histogram averaged over many DOMS. HighQE DOMs look just like the standards.

Optical Efficiency - measured at 405 nm. Efficiency ratio \(<\text{high-QE DOM}>/<\text{Standard DOM}> = 25.1/18.1 = 1.39\)
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Shown is the measured noise rates for HighQE DOMs (purple) and standard DOMs (blue).
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Shown is are the high voltage setting to achieve a gain of 1e7.
The DeepCore

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Preliminary Trigger Level
The DeepCore

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- 375 m thick detector veto - three complete IceCube DOM layers surround DeepCore.
The **DeepCore**

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A first Monte Carlo based filter algorithm shows $10^{-4}$ background rejection with >98% signal efficiency.

This should be compared to the previously utilized IceCube first filter steps, an improvement factor of nearly 500.
The **DeepCore**

Physics Potential - Indirect WIMP Searches

- Addition of DeepCore provides significant improvements in WIMP searches for masses between 50 and 500 GeV.

\[
\begin{align*}
\chi\chi &\rightarrow \bar{b}b(\tau^+\tau^-) \rightarrow \nu, & \text{soft } E_\nu \text{ spectrum} \\
\chi\chi &\rightarrow W^+W^- \rightarrow \nu, & \text{hard } E_\nu \text{ spectrum}
\end{align*}
\]

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**Soft Channel**

**Hard Channel**

![Effective Volume vs. Neutralino Mass](image1)

![Effective Volume vs. Neutralino Mass](image2)

*November 12, 2008*
Summary...

- Initial studies for the HighQE DOMs show excellent performance.
- First veto algorithms show great promise to reach $10^6$ rejection levels with >95% signal efficiency.
- Current efforts directed at new reconstruction algorithms for the low energy events.
- DeepCore represents incredible opportunity for complimentary physics (Indirect WIMP searches; NuMu disappearance; NuTau appearance...) between the accelerator and non-accelerator based communities and closes the historical energy gap with smaller scale neutrino experiments.