Search for Secluded Dark Matter with the IceCube Neutrino Telescope

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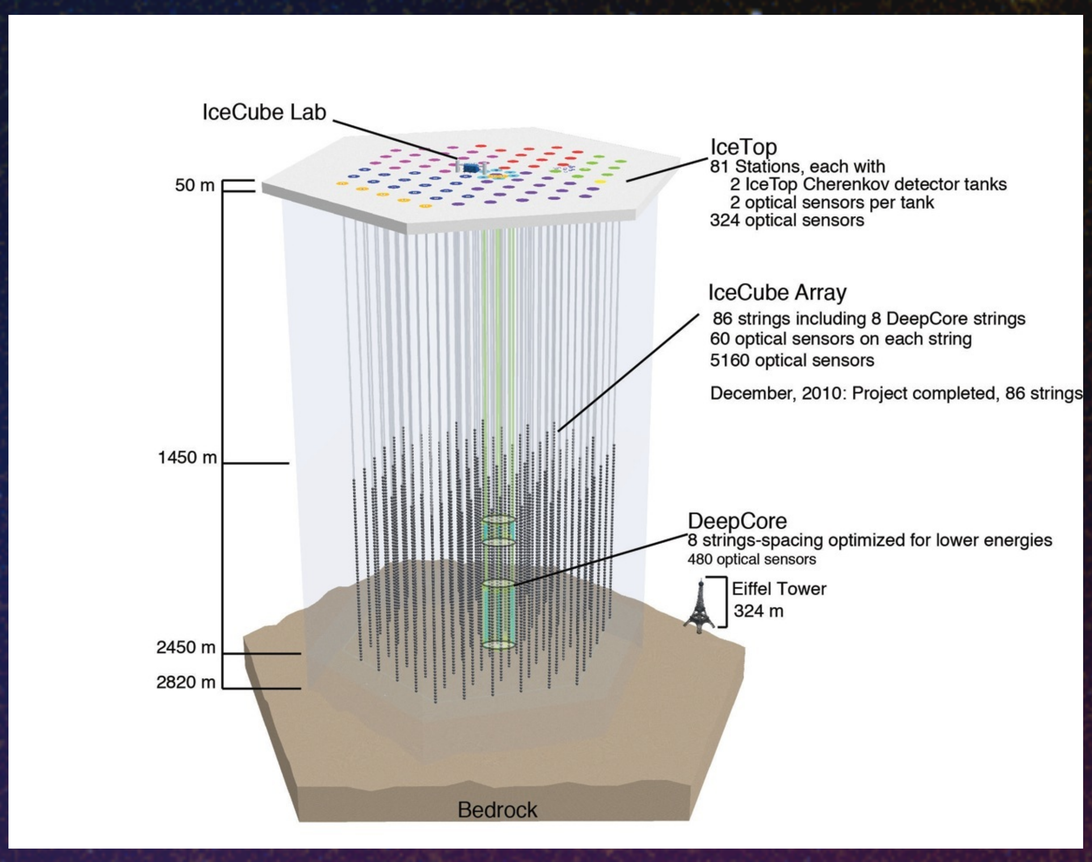
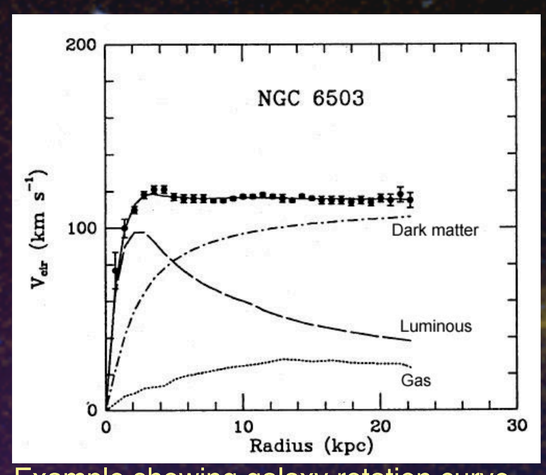
Normal Matter



The IceCube neutrino detector is a km cube instrumented volume in the deep Antarctic ice where optical sensors detect light from particles traveling through the ice. Cascades and tracks within the detector allows the reconstruction of the interactions or decays near the detector, including the direction and energy of neutrinos.



Example showing galaxy rotation curve with theoretical contributions.
Begeman, Broels, Sanders (1991)

Dark Matter

The existence of dark matter is the hypothesis that best explains the observations of new physics which demonstrate that our cosmology and particle physics is incomplete. Clear evidence comes from galaxy rotation curves demonstrating additional mass beyond that of gas and luminescent matter. Additional evidence (i.e. bullet cluster) includes the separation of mass and luminous matter in some recent observations of galaxy cluster collisions.

Secluded Dark Matter

Secluded dark matter is separated from the standard model by a mediator. If the mass of the dark matter was greater than the mediator then the dark matter would be leptophilic. This mediator could be the higgs, a gravitino, a composite goldstone boson, or some new vector or scalar boson.

$$\chi\chi \rightarrow \phi\phi \rightarrow \mathbf{SM}$$

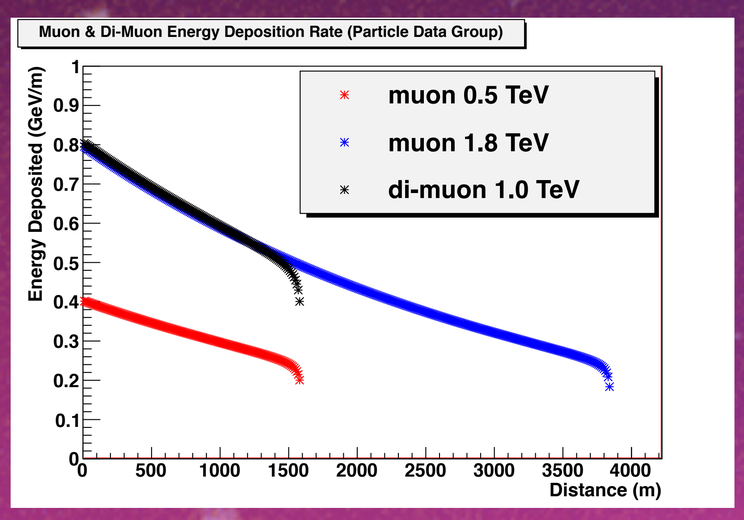
$$\epsilon_V F'_{\mu\nu} B^{\mu\nu}\, m_\chi > m_\phi$$

$$\mathcal{L} = \mathcal{L}_{SM} + \mathcal{L}_{WIMP} + \mathcal{L}_{mediator}$$

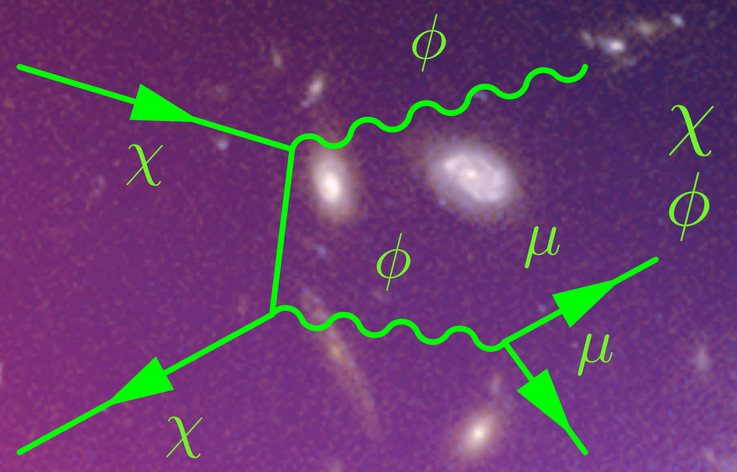
This mediator could be some new vector boson force carrier in the dark sector, and would only mix with the photon (kinetic mixing). Leptophilic dark matter could explain the excess in positron fraction as seen in PAMELA/fermi. A new force within the dark sector allows the possibility of explaining the INTEGRAL excess as due to exciting dark matter (XDM) and the DAMA discrepancy as due to inelastic dark matter (iDM).

Event Selection using Energy Deposition Topology

It is difficult to distinguish high energy muons from boosted di-muon events with IceCube's energy resolution. By selecting stopping tracks, the signature of twice the energy deposited allows the di-muon signal to be separated from the muon background.



Without great energy resolution or contained tracks, stopping di-muon tracks demonstrate greater deposition.



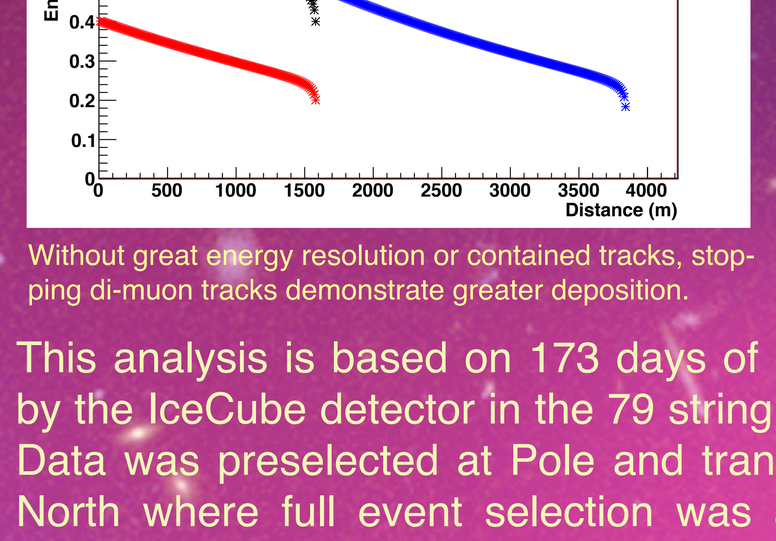
$\chi \sim 1\mathrm{TeV}$

$\phi \sim 1\mathrm{GeV}$

Event Hypothesis

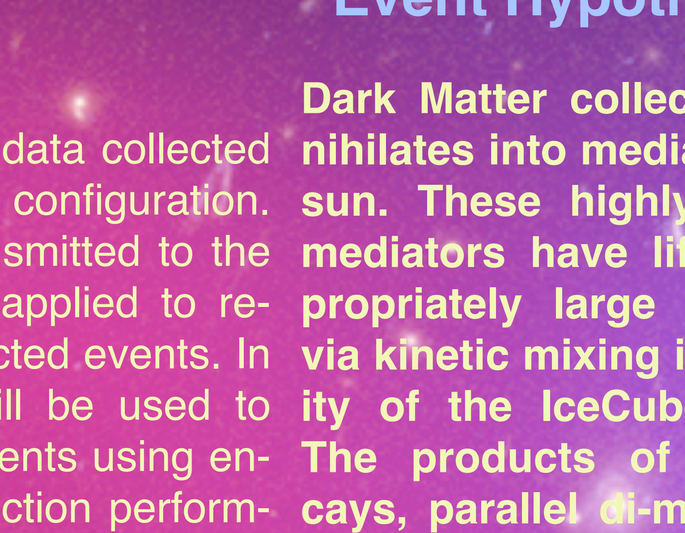
Dark Matter collects and annihilates into mediators in the sun. These highly energetic mediators have lifetimes appropriately large and decay via kinetic mixing in the vicinity of the IceCube detector. The products of these decays, parallel di-muons, supply the signal in the detector.

This analysis is based on 173 days of data collected by the IceCube detector in the 79 string configuration. Data was preselected at Pole and transmitted to the North where full event selection was applied to remove down going and poorly reconstructed events. In the final step, new reconstructions will be used to identify and select stopping di-muon events using energy deposition topology and reconstruction performance. Finally, the direction of the sun will be unblinded.

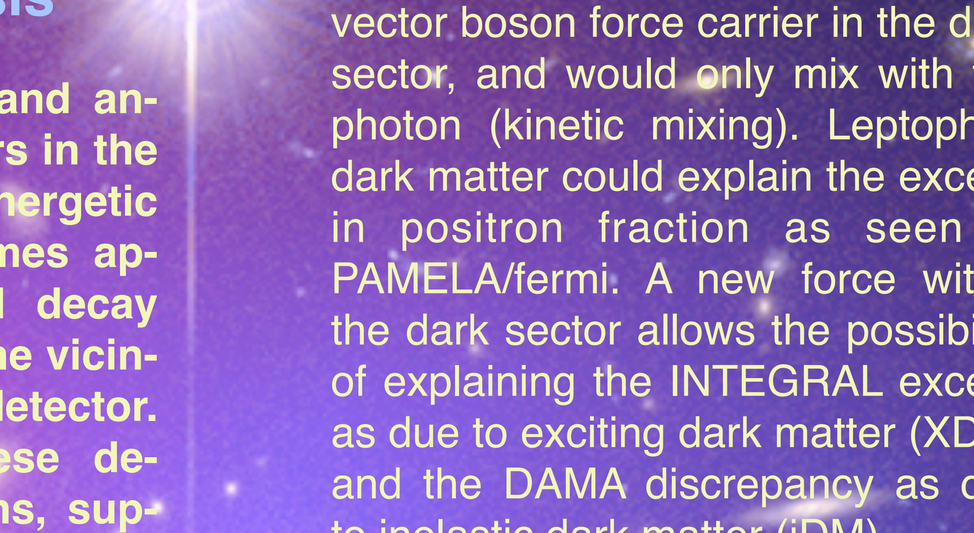


One variable, from a new reconstruction, used in energy deposition topology event selection.

Luminous — Bosonic Mediator — Dark



Sensitivity before energy topological event selection with 79-string configuration detector.



Theoretical calculation of expected sensitivity to various models.
Meade, Nussinov, Papucci, Volansky (2009)

IceCube
SOUTH POLE NEUTRINO OBSERVATORY