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IceCube was plenty exciting for the week as well, with two acopian power supply failures, IceACT requiring some attention along with the monthly IceTop DOMcal insertion. Further, a new version of pDAQ was successfully tested in a 24 hour test run, and ARA was successfully brought back online with replacement power supplies operating in parallel—though not without a bit of stress first!

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INDIRECT DETECTION WITH NEUTRINOS

Indirect

dark matter → b, W, τ → ν’s

Milky Way: Trevor Jones, Earth: NASA
NEUTRINO PHYSICS WITH ICECUBE

- 1 km$^3$ instrumented ice below the South Pole (finished 2010)
- 5160 light sensors for detecting Cherenkov radiation
- Measuring neutrino-initiated events
- Energies down to 10s GeV
- Stable operation and reliable hardware (> 99% livetime)
**SIGNAL AND BACKGROUND**

- **Background at trigger level**
  - Atm. muons: $10^{11}$/year
  - Atm. neutrinos: $10^5$/year

- **for Dark matter searches**
  - Sun: +/- 23° above horizon
  - Galactic center: 29° above horizon
DM SEARCHES IN ICECUBE

MORTEN MEDICI

ICECUBE EVENTS

- Two topologies:
  - Tracks (best pointing)
  - Cascades (contain all energy)

- Reconstructing the neutrino:
  - Charge, time, geometry
  - Direction, energy, position

Science 342, (2013)
GALACTIC HALO
TARGETED SIGNAL FROM GALACTIC HALO

- Spectrum model dependent
- Signal sensitive to assumed halo profile

\[
\Phi = \frac{\langle \sigma A \nu \rangle}{4\pi \cdot 2m_{\text{DM}}} \frac{dN}{dE}(E_\nu) \int_{\text{los}} \rho_{\text{halo}}^2(\Psi)
\]
ANALYSIS TECHNIQUE

- Likelihood approach with a mixture of:
  - **Signal**: Modelled from simulated neutrino events weighted to correspond to dark matter annihilation
  - **Background**: Estimated from exp. data

- Signal contamination in background is subtracted

- Same approach used across all presented galactic halo analyses
Three different event selections in IceCube are covering dark matter masses from 10 GeV to 1000 TeV

- **Muon tracks** (DM masses: 10-1000 GeV)
  Dedicated low energy reconstruction & events (3 years of data)
  Submitted [arXiv:1705.08103]

- **Muon tracks** (DM masses: 0.3-1000 TeV)
  Using sample for point source searches (4 years with an overlapping 3 years)
  Includes energy (relevant above DM mass of 10 TeV)

- **Contained cascades** (DM masses: 3-300 TeV)
  Using sample for neutrino spectrum unfolding (2 years of data)
  Includes energy, exploiting good energy resolution

- **No excess** above the expected background
RESULTING LIMITS: GALACTIC HALO WIMPS

- Assuming NFW dark matter halo profile
CONSERVATIVE HALO PROFILE

- Assuming Burkert dark matter halo profile
SOLAR SEARCH
TARGETED SIGNAL FROM THE SUN

- Accumulation of WIMP in the sun, assumed to be in equilibrium with the annihilation rate
SOLAR WIMP STUDIES

- New results using the finished IceCube with 86 strings
- Results published: EPJC 77 146 (2017) [arXiv:1612.05949]
- 3 years of data: 532 days of livetime
- Two independent analyses focusing on high and low dark matter mass
- No excess above the expected background
RESULTING LIMITS: SOLAR WIMP STUDIES

- Very competitive bounds on the spin-dependent nucleon-dark matter interaction cross-section
DECAYING DARK MATTER
DECRYPTING DARK MATTER STUDIES

- Dark matter signal: **Galactic halo** and **isotropic extragalactic** component
- Background: Simulated atmospheric muons/neutrinos and astrophysical neutrinos
- Analysis fit: Dark matter **mass/lifetime**, isotropic astrophysical **flux/index** (single power law)
- **Two independent analyses** using event selections designed for unfolding the neutrino spectrum:
  - 1) Using dataset with 6 years of northern hemisphere **tracks**
  - 2) Using dataset with 2 years of full sky **contained cascades**
- Focusing on the Hν- or Zν-channel which has a significant peak in energy from the neutrino line spectrum
- **No excess** above the expected background
EXPERIMENTAL LIMITS ON DECAYING DARK MATTER

- Adding limits on dark matter lifetime for dark matter masses above 10 TeV for high mass dark matter
SUMMARY

- No observation of a neutrino signal in IceCube compatible with dark matter annihilation or decay.

- More sensitive analyses and longer reach in dark matter masses provides very competitive limits on the annihilation cross section.

- IceCube is less sensitive to the exact distribution of dark matter in the galactic halo.

- First limits from IceCube on the search for dark matter decay extending to higher dark masses than probed before.
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SOLAR WIMP STUDIES

- Spin-independent dm-nucleon cross section
SOLAR WIMP STUDIES

- pMSSM model scans, indicating the fraction of hard and soft final states
DECAYING DARK MATTER

- Significant excess of high energy neutrinos above backgrounds
- Used to look for decaying heavy dark matter

[Graph showing event counts per 988 days with energy deposition in the detector displayed on a logarithmic scale.]

[Images of event visualizations at 1.0 PeV, 1.1 PeV, and 2.0 PeV.]