The Astrophysics Program of NOvA

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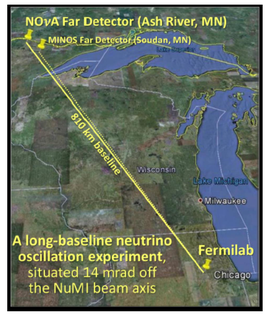
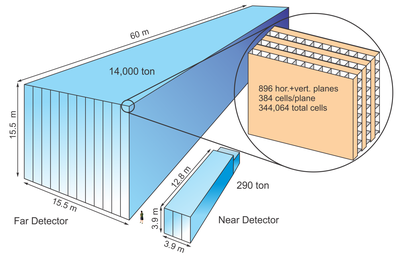
For the NOvA Collaboration

The NOvA detectors, designed primarily to discover and measure electron neutrino appearance in a muon neutrino beam, are versatile instruments being used for a variety of astrophysical analyses.

The NOvA Detectors

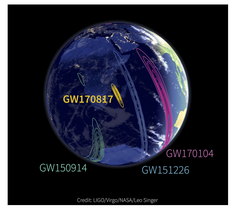


- Segmented liquid scintillator
- Far Detector on surface
- Near Detector underground, 300 meters water equivalent
- All data continuously digitized
- Buffered for ~20 min while trigger decisions are made
- Triggers read out 50μs to 45s

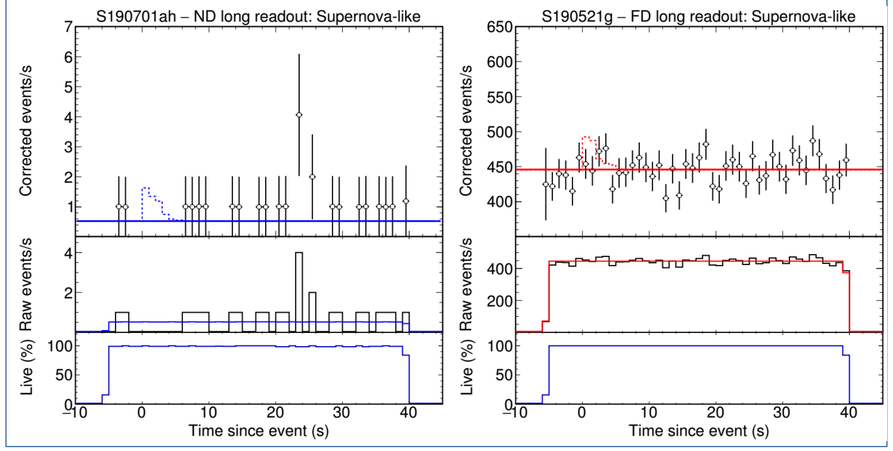


Multimessenger Astronomy with Gravitational Waves

- MeV-TeV signals: broad search for any excess
- Especially sensitive to supernova-like neutrinos
- Pre-2019: 100% live for some topologies ≳100MeV, otherwise 0.5% minimum bias
- 2019-present: 100% live for few-MeV+ 45s window

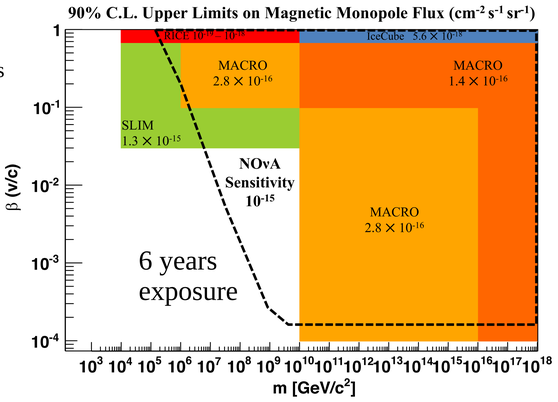


- No excesses in 28 LVC events. arXiv:2001.07240. Accepted by PRD.
- Galactic supernova origin of GW largely ruled out for 5 fully-triggered events in 2019

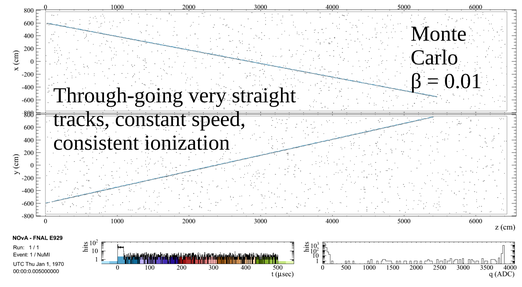


Magnetic Monopoles

- Little theoretical guidance on mass
- Far Detector unique in being a large surface tracking detector
- Light monopoles would not reach underground
- β < 0.01: unmistakable slow track
- β > 0.01: highly ionizing track
- 1700 live-days and counting



$$\nabla \cdot E = 4\pi\rho_e$$
$$\nabla \cdot B = 4\pi\rho_m$$
$$-\nabla \times E = \frac{1}{c}\left(4\pi J_m + \frac{\partial B}{\partial t}\right)$$
$$\nabla \times B = \frac{1}{c}\left(4\pi J_e + \frac{\partial E}{\partial t}\right)$$

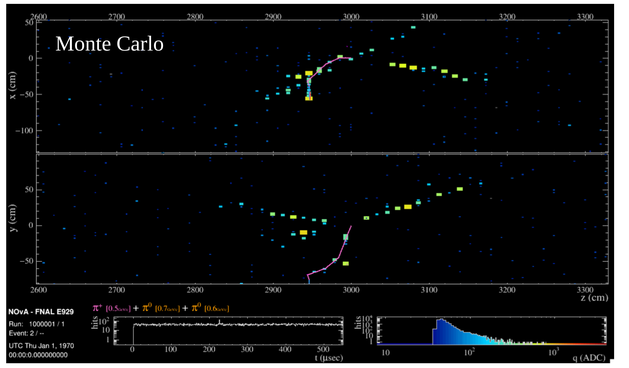


Neutron/Anti-neutron Oscillations

- Search for n → $\bar{n}$ conversion in ^{12}C
- Typically pions in symmetric star
- Suppressed in nuclei; less in C than O: advantage over water detectors
- Surface detector, but expect to be limited by **atmospheric neutrinos**
- 700 live-days and counting

$\bar{n}+p$		$\bar{n}+n$	
$\pi^+\pi^0$	1%	$\pi^+\pi^-$	2%
$\pi^+2\pi^0$	8%	$2\pi^0$	1.5%
$\pi^+3\pi^0$	10%	$\pi^+\pi^-\pi^0$	6.5%
$2\pi^+\pi^-\pi^0$	22%	$\pi^+\pi^-2\pi^0$	11%
$2\pi^+\pi^-2\pi^0$	36%	$\pi^+\pi^-3\pi^0$	28%
$2\pi^+\pi^-2\omega$	16%	$2\pi^+2\pi^-$	7%
$3\pi^+2\pi^-\pi^0$	7%	$2\pi^+2\pi^-\pi^0$	24%
		$\pi^+\pi^-\omega$	10%
		$2\pi^+2\pi^-2\pi^0$	10%

Phys. Rev. D 91, 072006 (2015)

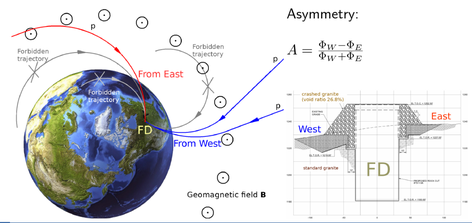


Supernova Neutrinos

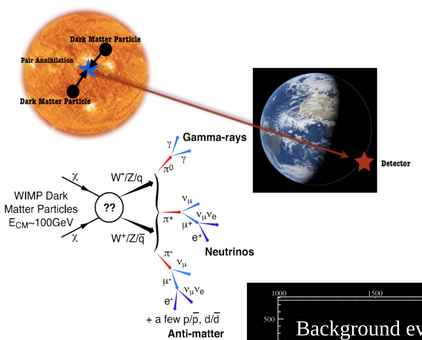
See poster #550.

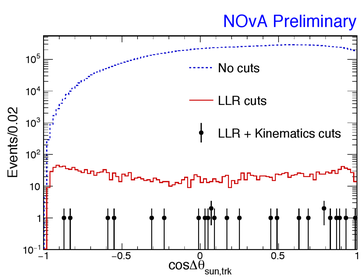
East/West Cosmic Muon Asymmetry

- Geomagnetic field: some low energy trajectories forbidden
- Input for low-energy atmospheric neutrino simulations

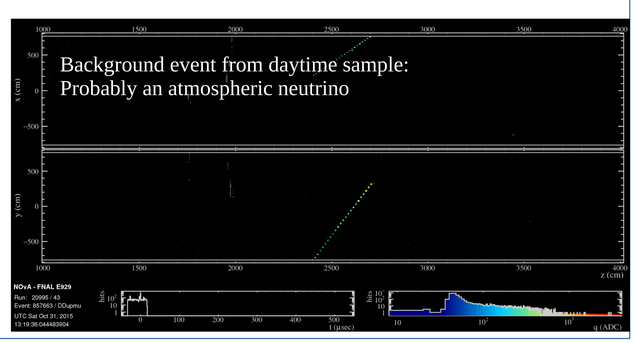


Dark Matter

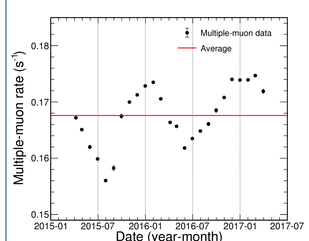


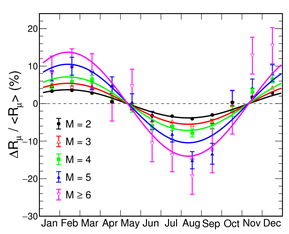


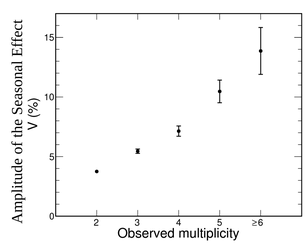
- Trigger on upwards-going muons at night
- Search for dark matter annihilation in the Sun
- Remove cosmic muons by timing
- Major background: **atmospheric neutrinos**



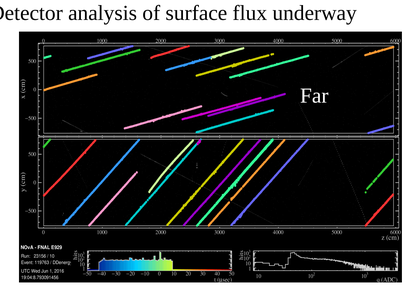
Seasonal Multiple-muon Effect

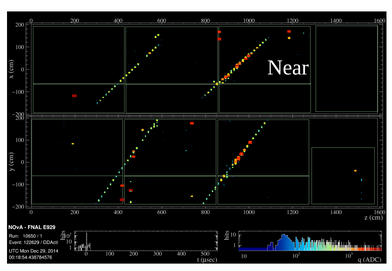






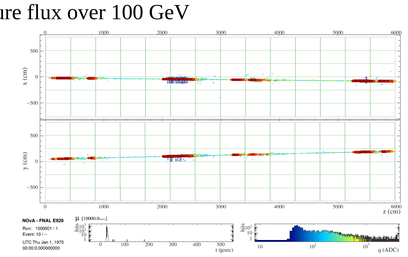
- Total muon rate underground well-known to be higher in summer
- MINOS observed winter maximum for *multiple* muons
- NOvA Near Detector confirms: Phys. Rev. D 99, 122004 (2019)
- Far Detector analysis of surface flux underway
- Increases with multiplicity
- Origin unknown, thought to be reinteractions of pions in denser winter atmosphere





Studies of the High Energy Cosmic Ray Flux

- Identify high energy muons by the showers they induce
- Measure flux over 100 GeV



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