Astrophysics with the NOvA Experiment

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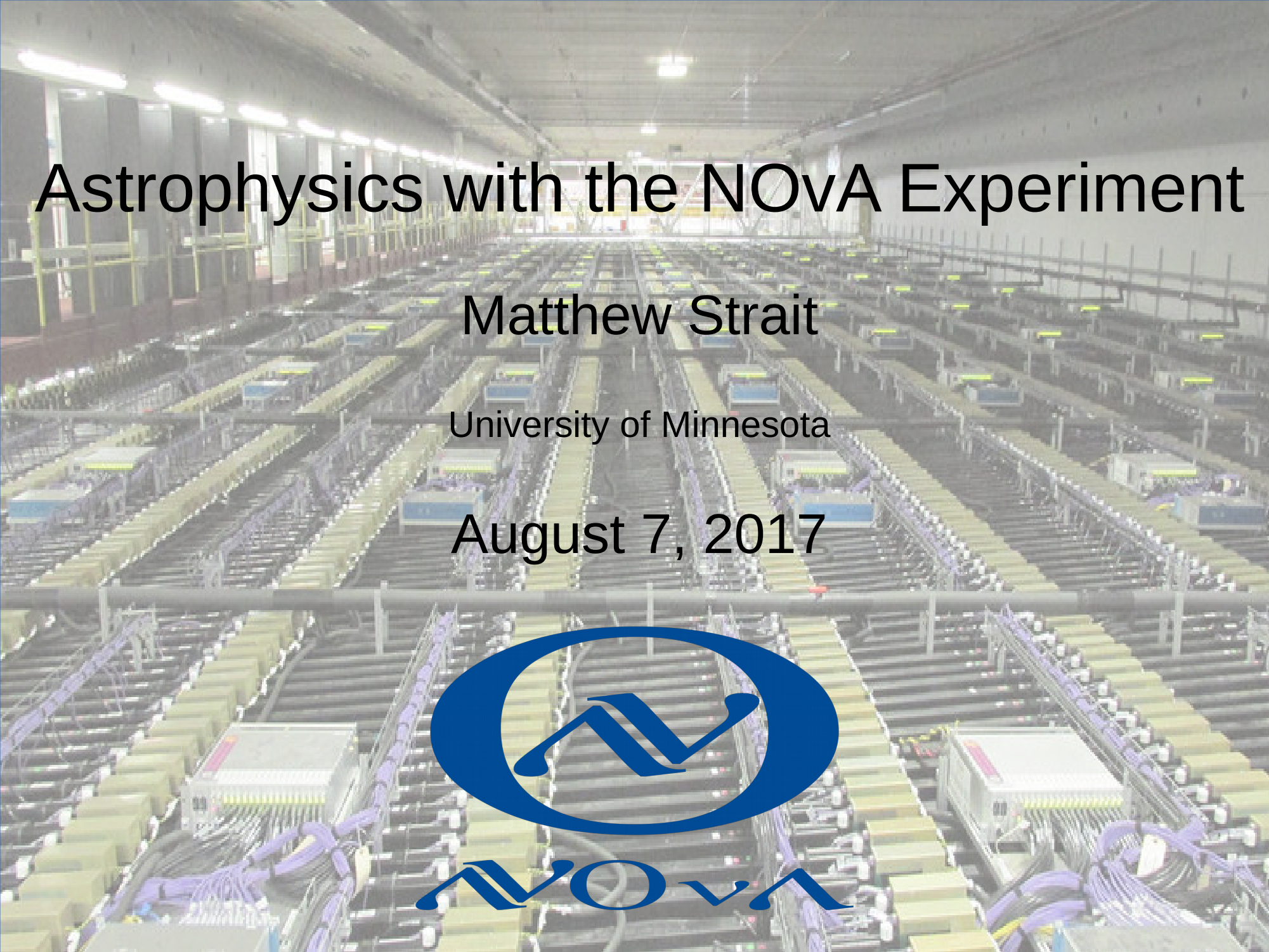
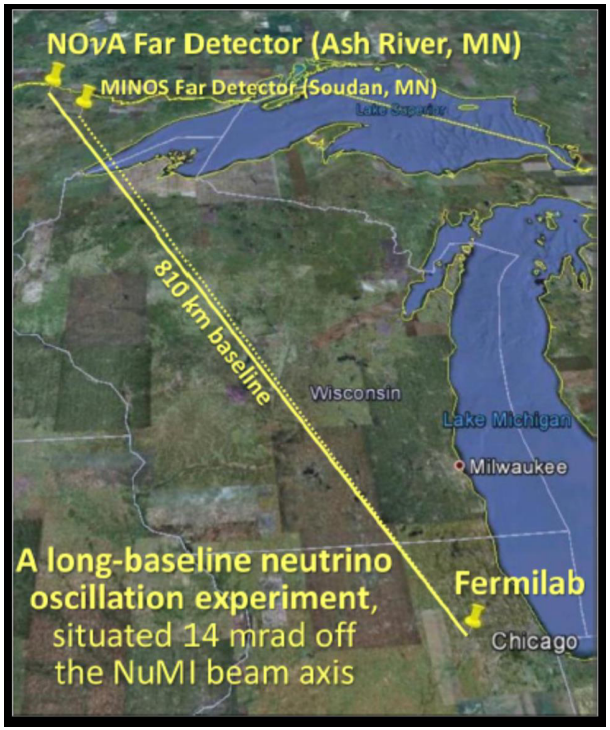
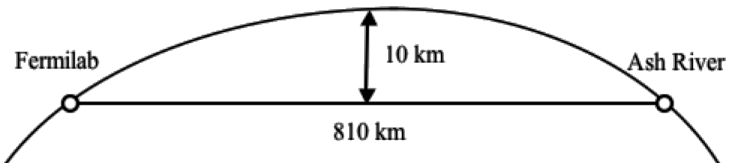
August 7, 2017



Design overview

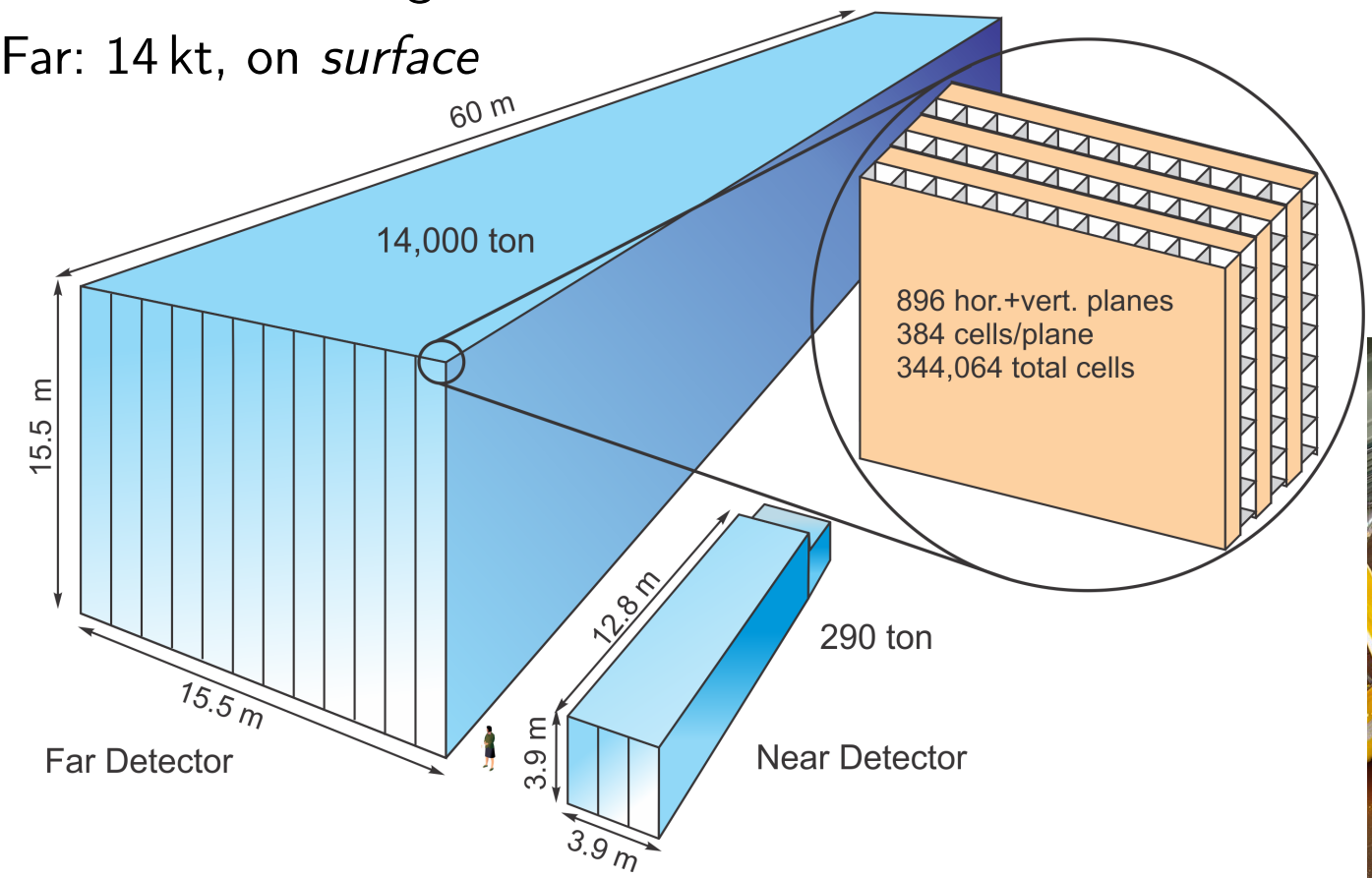
- NuMI beam
- Near Detector: Measures initial beam composition
- Far Detector: Observes oscillated beam



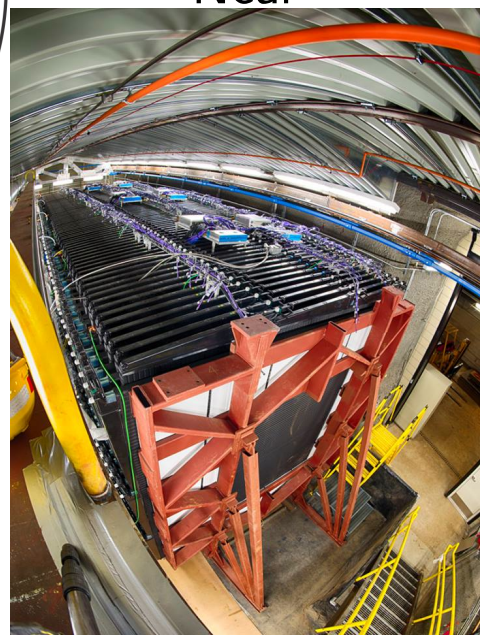


Detector Technology

- Segmented plastic and scintillator tracking calorimeter
- Two functionally identical detectors
- Near: 300 t, underground
- Far: 14 kt, on *surface*



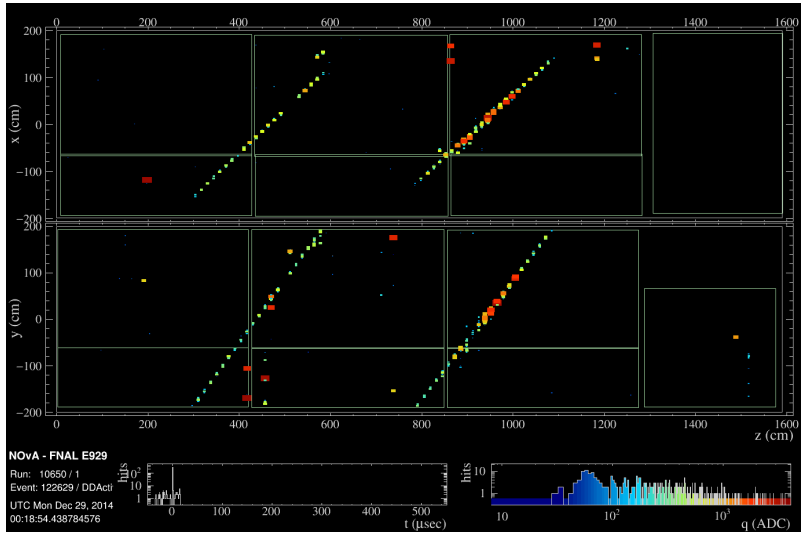
Near

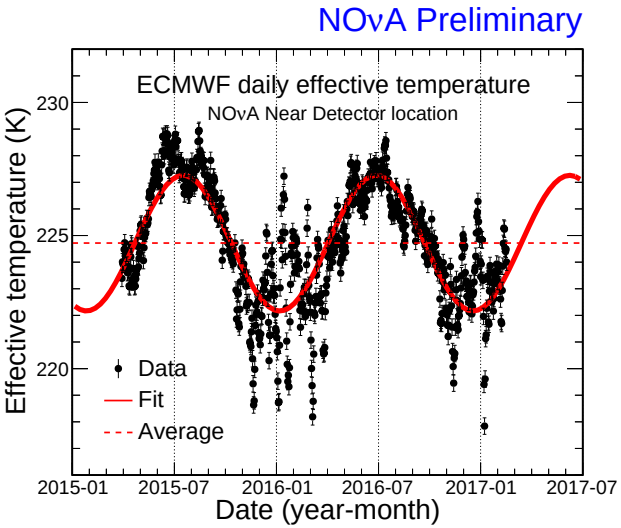


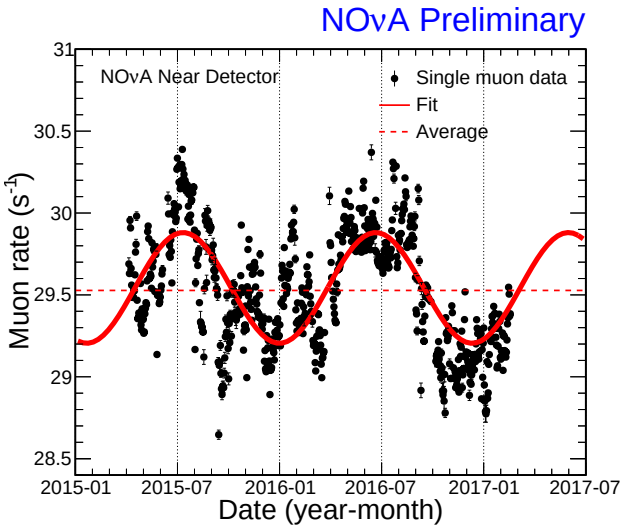
Airbus A380 for scale

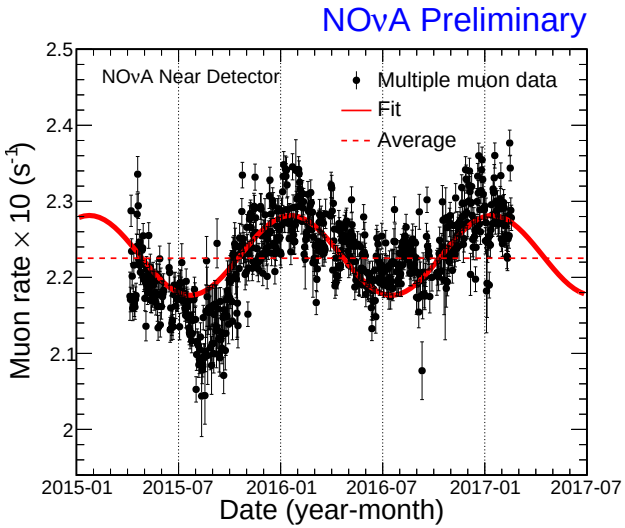
Multi-muon seasonal effect at the Near Detector

- Well known: underground muon rate higher in the summer
- Atmospheric profile depends on temperature
- Less dense $\rightarrow$ more π and K decay
- MINOS ND observed *more* multi-μ in winter
- NOvA ND in same location; effect confirmed

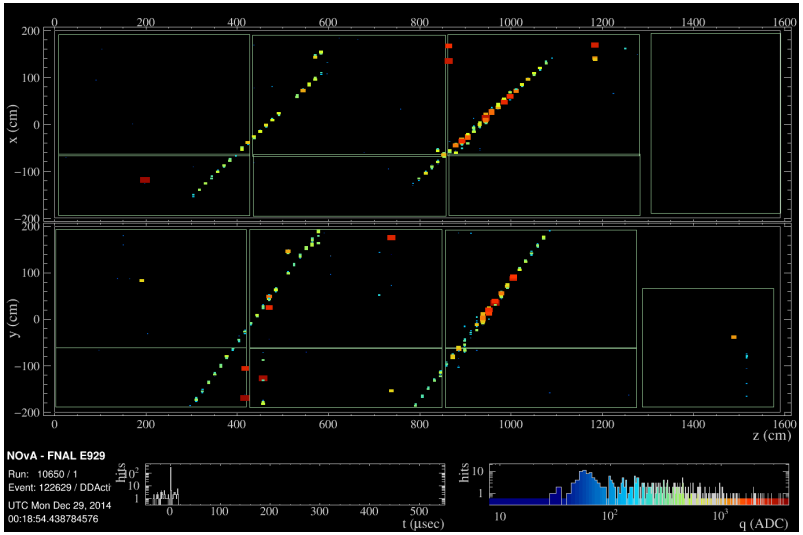








Multi-muon seasonal effect at the Near Detector

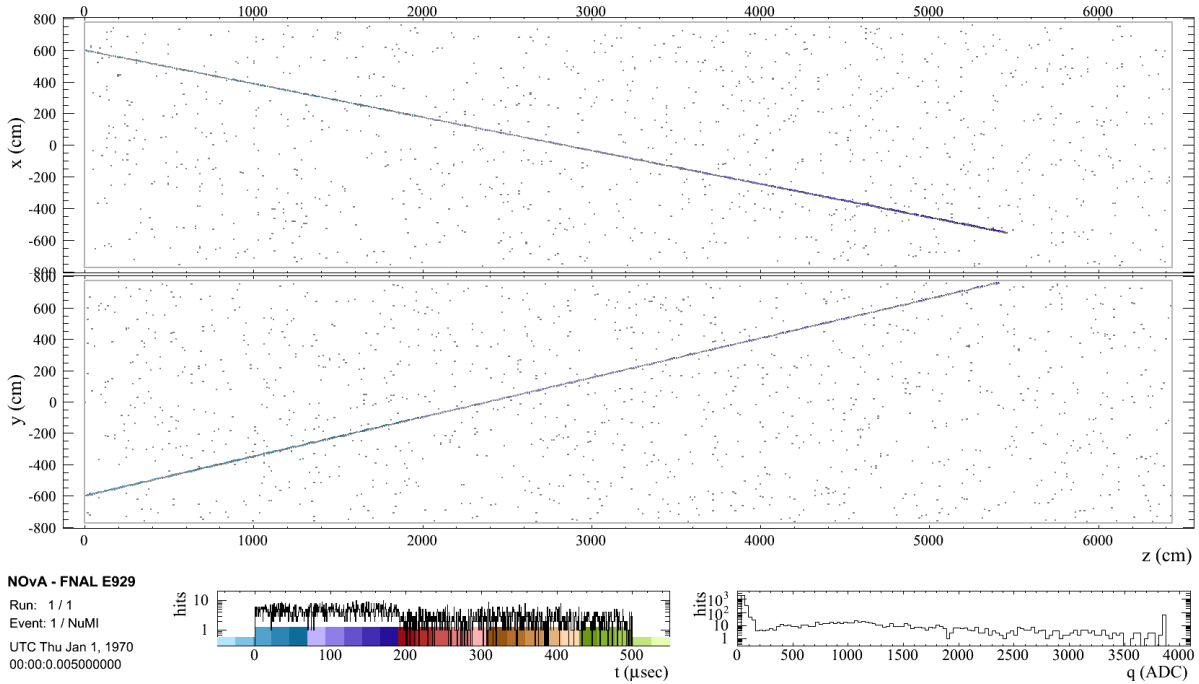


- No clear explanation
  - Dimuonic decays of η and ρ?
    No, branching ratios too small.
  - Geometric effect from high altitude decays?
    Effect too small.
  - From atmospheric layer hotter in winter?
    CORSIKA simulations do not support this.
  - Increased probability of pion interactions in the winter $\rightarrow$ more secondary pions?
    Seems like a good explanation, but a detailed study is lacking.
- NOvA collects statistics at 3 times the rate of MINOS
- Multi-muon rates will be studied as function of zenith angle, muon separation, multiplicity, year-to-year differences and other variables

Monopole Search

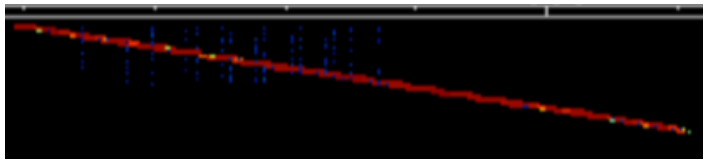
- Magnetic monopoles predicted by various grand unified theories
- Search for a monopole component of cosmic rays
- Far Detector: large surface area
- On surface $\rightarrow$ sensitive to lighter monopoles that don't reach far underground
- Signal: highly ionizing track. Acts like a charge of 68.5e
- Might be slow. NOvA is sensitive down to $\beta \approx 10^{-4}$

Simulation

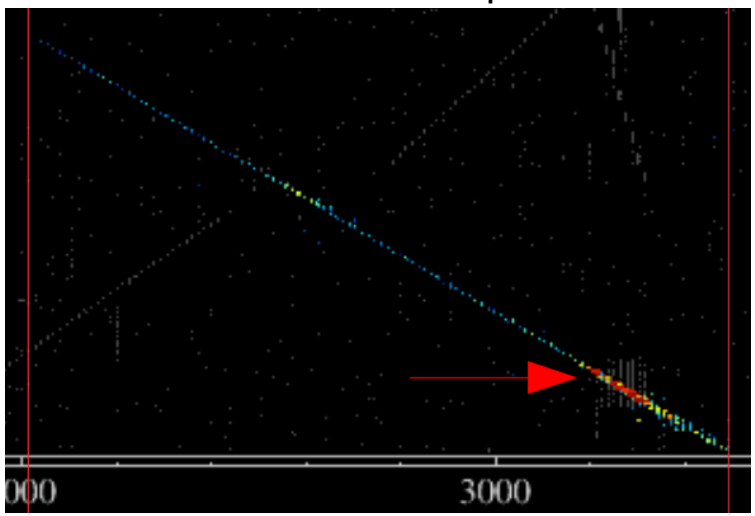


Monopole Search

- Separate triggers for fast ($\beta \approx 1$) and slow ($\beta \ll 1$) monopoles
- Slow: select by timing
- Fast: select by energy deposition

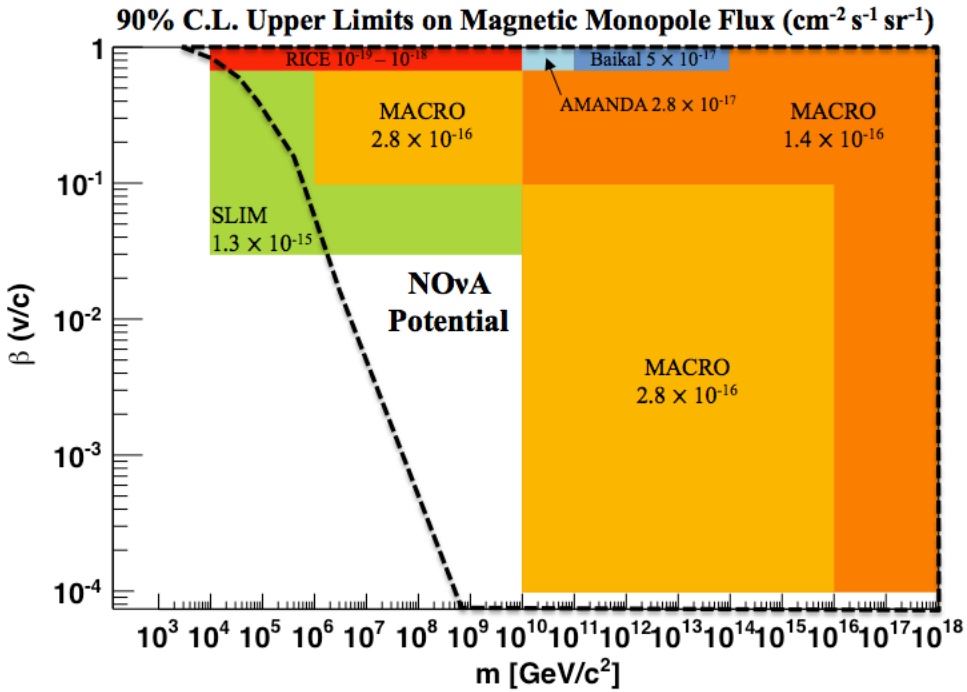


Simulated monopole



Background: Muon with brem

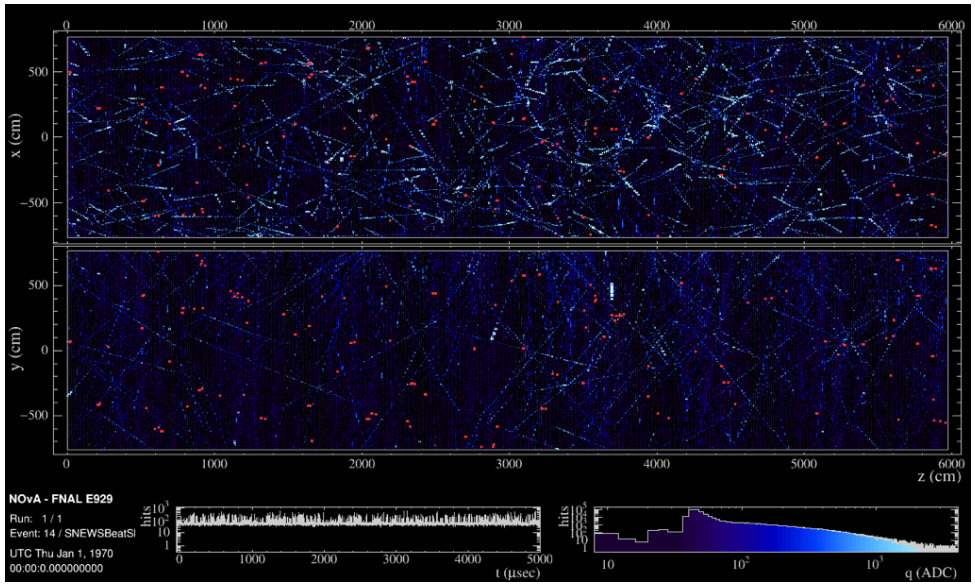
- Implicitly select any heavy particle that is slow or highly ionizing
  - Strangelets, black holes . . .
- Results targeted for this year



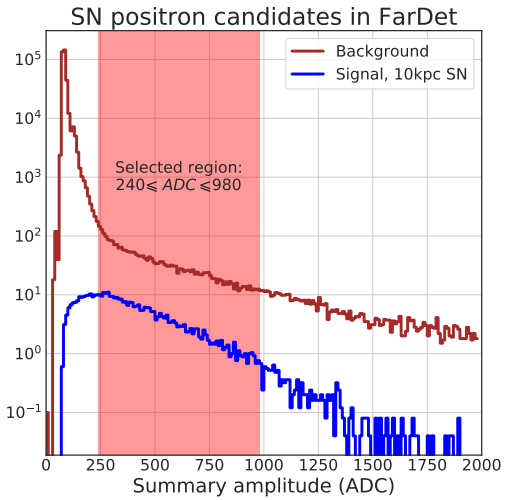
Sensitivity after 6 years

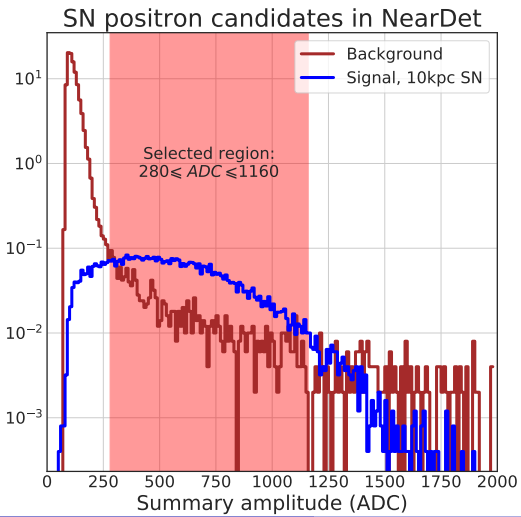
Supernova

- Sensitive to galactic core-collapse supernovae
- Primary channel is inverse beta decay: 10-50 MeV e^+
- Expect 2200 events for 10 kpc
- Trigger on excess of "noise" — burst of 2–4 hit clusters

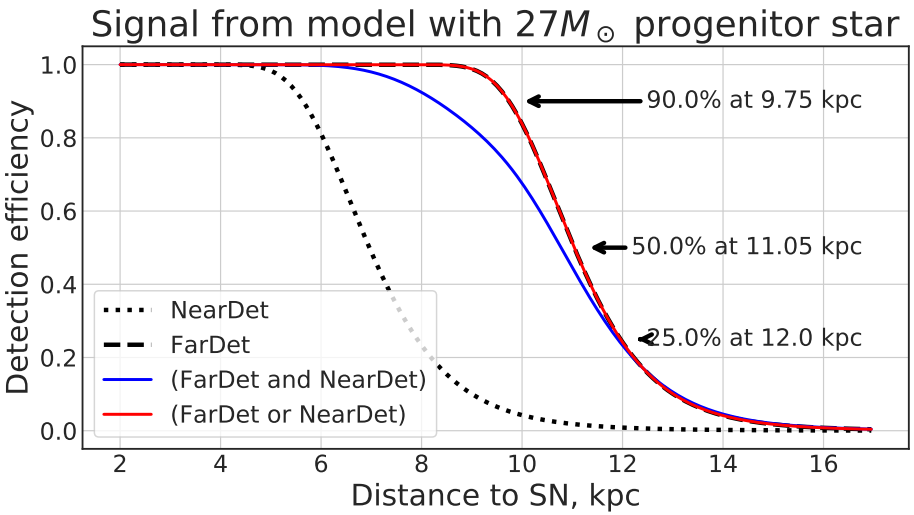


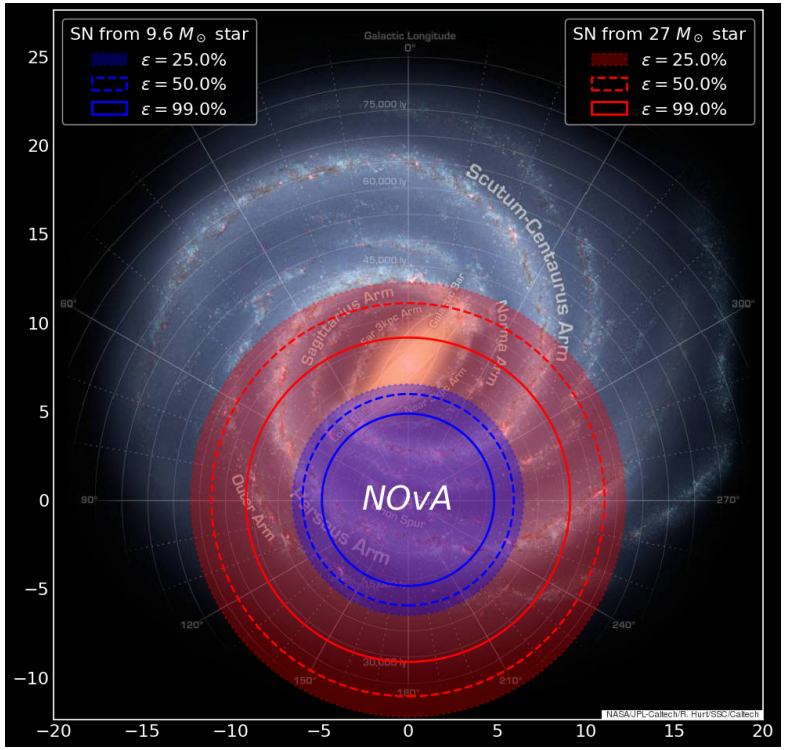
5 ms, 10 kpc:
Data cosmics, simulated SN events (e^+ only)





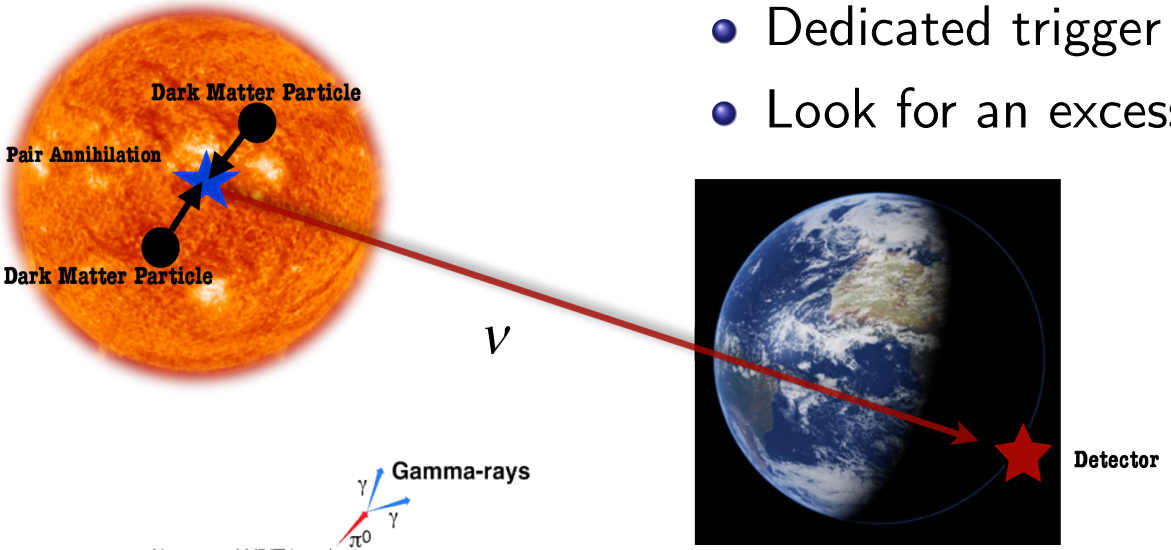
Supernova



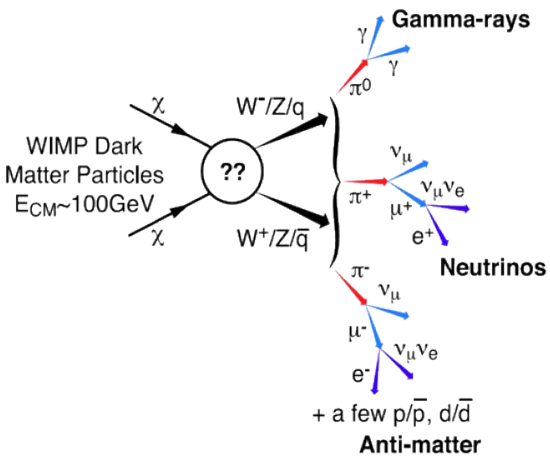


- Trigger $\rightarrow$ write out 45 s continuous data
- We also subscribe to SNEWS alerts
- And KamLAND's pre-supernova alerts (arXiv:1506.01175)

Upward-going muons

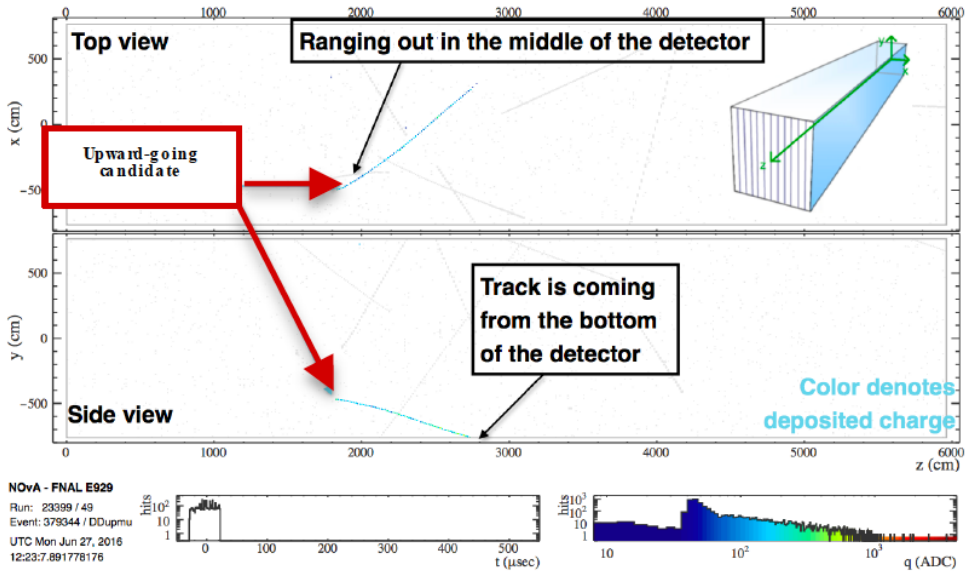


- Dedicated trigger running since Dec 2014
- Look for an excess pointing back to the Sun

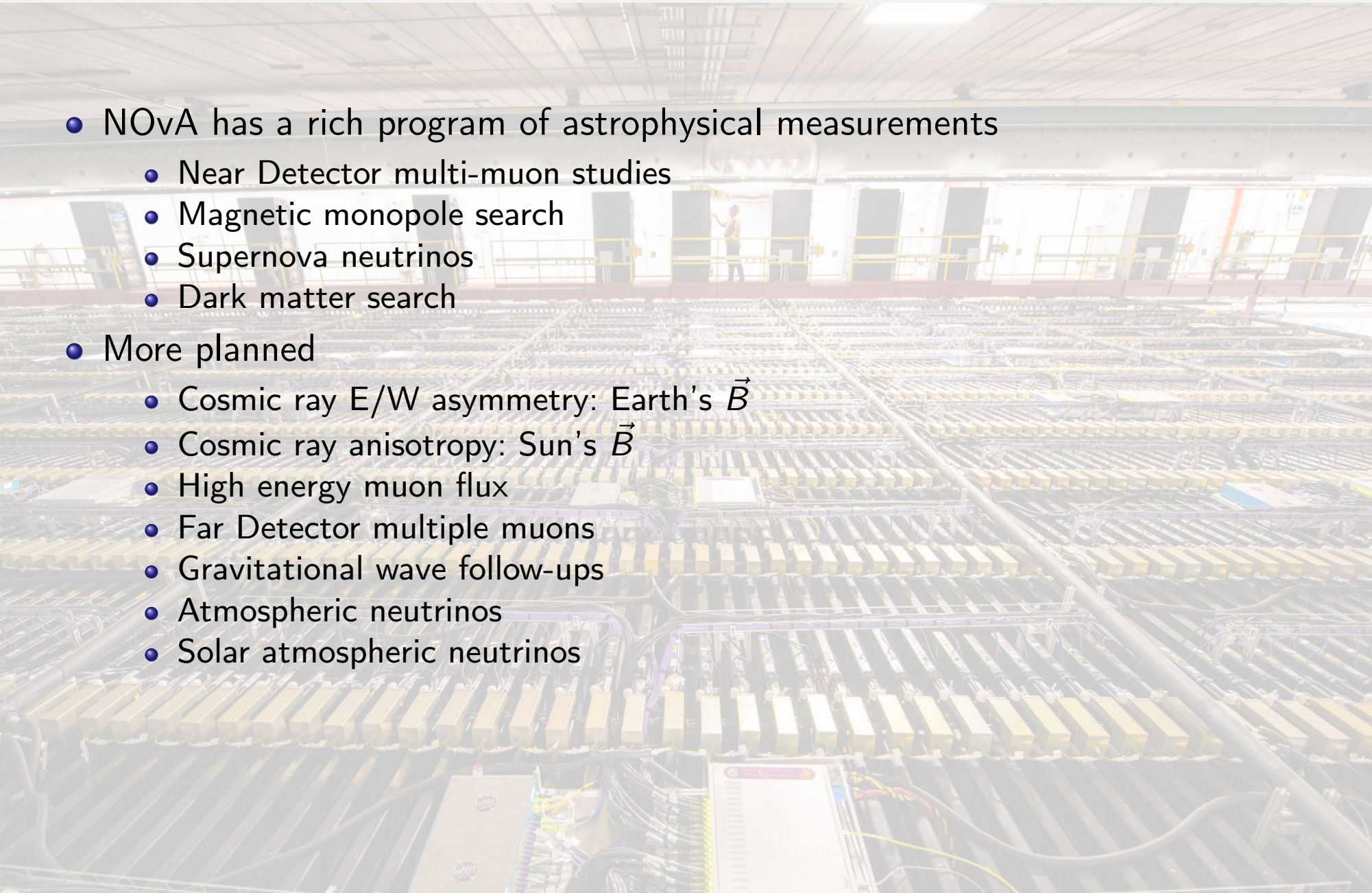


- Sensitive to lower mass WIMPS
- Focus has been trigger improvements
- Shifting to simulation and analysis

Timing is the main discriminant



Summary



- NOvA has a rich program of astrophysical measurements
  - Near Detector multi-muon studies
  - Magnetic monopole search
  - Supernova neutrinos
  - Dark matter search
- More planned
  - Cosmic ray E/W asymmetry: Earth's $\vec{B}$
  - Cosmic ray anisotropy: Sun's $\vec{B}$
  - High energy muon flux
  - Far Detector multiple muons
  - Gravitational wave follow-ups
  - Atmospheric neutrinos
  - Solar atmospheric neutrinos