Integration of the Supernova Early Warning System with the NOνA Trigger

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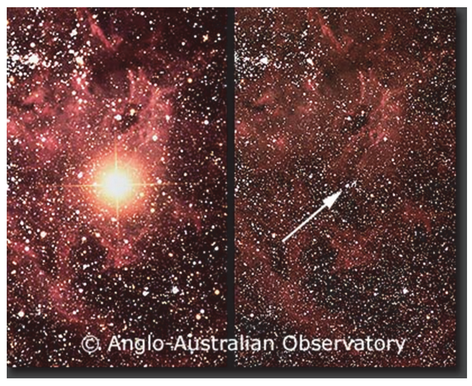
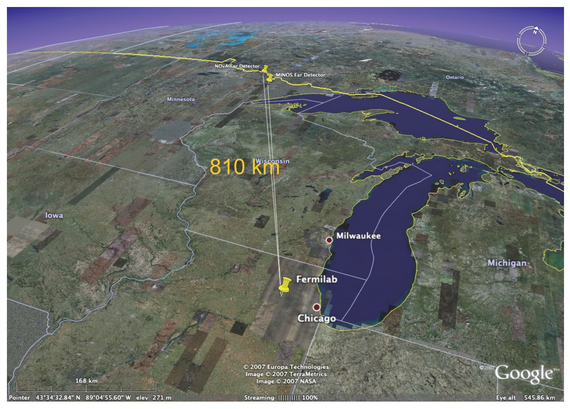
for the NOνA
Collaboration
and
the SNEWS project



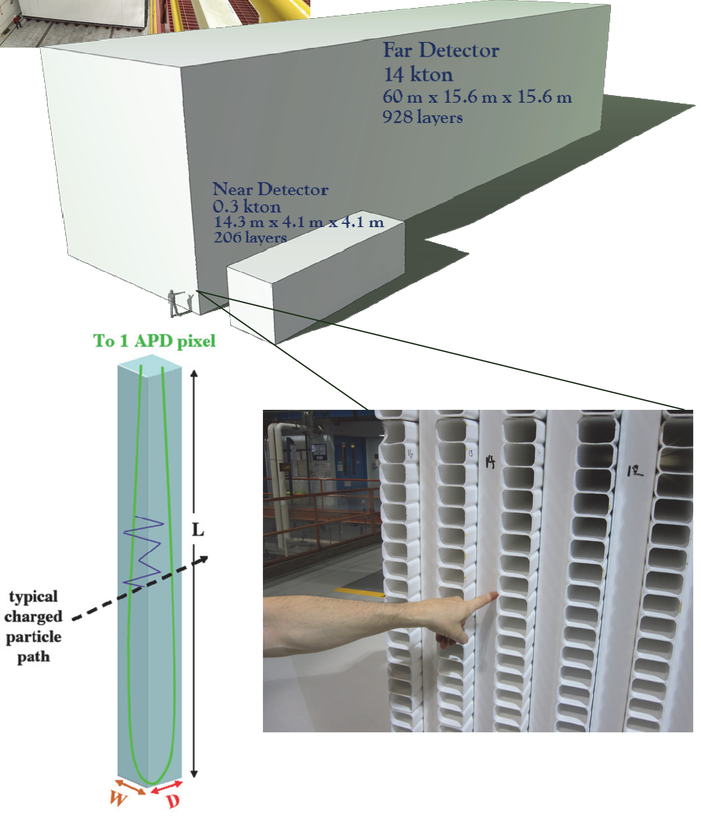
SN 1987A: a close enough core-collapse SN that neutrino experiments identified tens of neutrinos in their data after the initial optical discovery, confirming how Type II SN work.



Far Detector fully commissioned November 2014.

An upgraded NuMI beam (~400 kW now, improving to 700 kW) has provided ν from early 2014 onwards.

Will run three years with neutrinos, three years with anti-neutrinos.



NOνA is an off-axis (14mrad), long-baseline (810km), neutrino experiment using the NuMI ν_μ beam to look for ν_e appearance: thus measures θ_{13}, with a chance at δ_{CP} and the neutrino mass hierarchy.

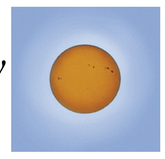
The Far Detector (FD) site near Ash River Falls, MN, is on the last road which the beam crosses going north in the USA.
The Near Detector (ND) is 100m underground at the start of the ν beam at Fermilab

NOνA is composed of highly reflective (15% TiO_2) extruded PVC cells filled with liquid scintillator. A loop of wavelength shifting fiber is placed in each cell to pipe the scintillation light out to the readout. Alternating horizontal and vertical layers provide stereo views.

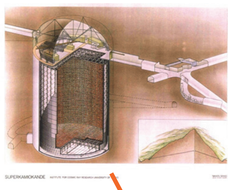
SNEWS

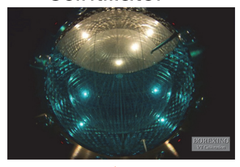
The SuperNova Early Warning System

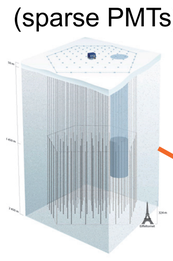
A star is opaque to photons, but transparent to ν: thus, the ν signal will lead the photon signal by ~hours (*shock breakout timescale*): Early Warning of galactic fireworks if you see the ν!

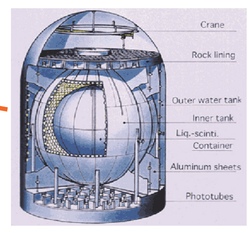


To allow for a quick (*human-free!*) alarm, six neutrino experiments automatically send any Supernova (*SN*) triggers via custom SSL sockets to a central coincidence server. A real SN neutrino front will show up in more than one detector, noise will not: an automated alarm is issued in the form of PGP-signed "Supernova alarm" emails.


Super-K
50 kt H_2O


Borexino
0.3 kt low-BG scintillator

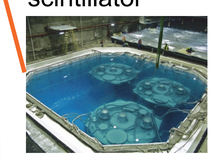

IceCube
km^3 ice
(sparse PMTs)



KamLAND
1 kt low-BG scintillator

LVD
1 kt scintillator

Daya Bay
8x 20t GD-doped scintillator



Servers (BNL & INFN-Bo) 10s coincidence window

email alarms to astronomers

xmlrpc message to NOνA

SN time coded into xmlrpc packet, sent from BNL→FNAL over internet

xmlrpc forwarding process @FNAL

Daemon @FD translates xmlrpc into DAQ message

Daemon @ND translates xmlrpc into DAQ message

NOνA's "Global Trigger" issues FD trigger for SN start time

NOνA's "Global Trigger" issues ND trigger for SN start time

FD Data continuously dumped from buffer to disk

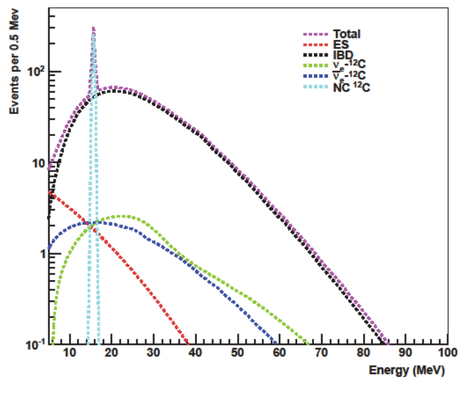
ND Data continuously dumped from buffer to disk

SNEWS remotely triggers NOνA

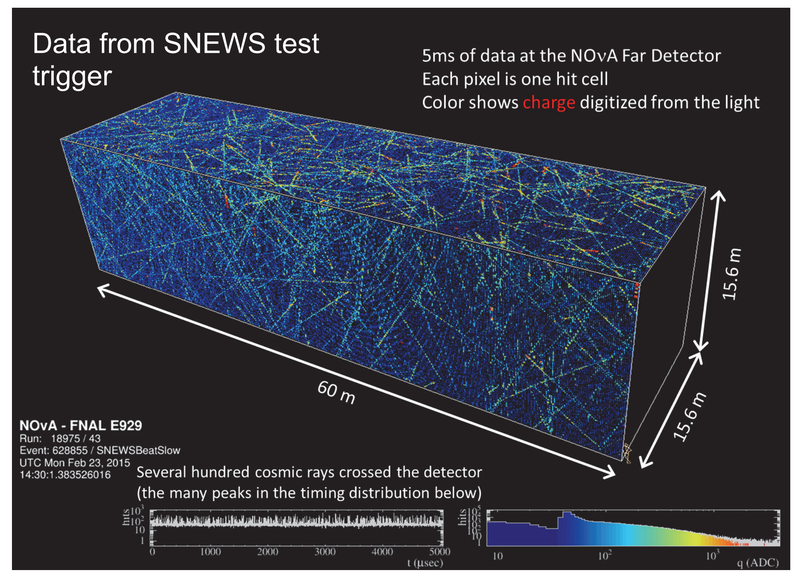
- NOνA's DAQ writes its ~700MB/s of raw data to a distributed buffer farm: holds a complete record of the last several minutes of data.
- NuMI beam spill times are distributed to both NOνA detectors, and the data corresponding with the neutrino spill time are pulled from that buffer and written as an event.
- >99% of such triggers reach the detector within 1s
- So, let's do the same with a "SN neutrino spill"
  - Supported by periodic "heartbeat" test triggers: 5ms trigger every minute, full length each day

SN ν in NOνA?

- Signal is dominated by anti-electron neutrino inverse beta decay interactions on protons: 10's of MeV positrons seen in detector
- $\mathcal{O}$(1000) ν interactions for a galactic SN over 10-20s



Simulated NOνA visible particle spectrum using SNOwGLoBES[1]
- MC truth plotted, since reconstruction still under development
- GKVM[2] flux used @ 8.5 kpc, ~4000 total interactions



NOνA is near the surface, resulting in a cosmic ray rate of 10's of kHz. A positron from an inverse beta decay interaction of a 10 MeV ν hits only 1-3 cells: but 14kt of detector would capture thousands of such interactions over 10s for a SN in our galaxy. Seeing this is a difficult but tractable analysis problem.

NOνA can do two things with SNEWS:

1) Watch its own SN-ν like data, provide trigger input to SNEWS (*work in progress*)
2) Save its own data if SNEWS says "a SN occurred 20s ago!" (*this poster*)

NOνA's SNEWS Trigger:

1) Receive t_0 of SN start from SNEWS
2) Issue trigger that goes into existing circular data buffer and saves all data starting at t_0 for as long as possible

Current buffer depth: 260s @ 700MB/s (*expanding to 1155s*)
Current SN trigger duration: 2s. (*Bottlenecks being eliminated to allow coverage of a full SN ν signal length of 20s*)

1. http://www.phy.duke.edu/~schol/snowglobes/
2. J. Gava, J. Kneller, C. Volpe, and G. C. McLaughlin, Phys. Rev. Lett. 103, 071101 (2009), 0902.0317

http://www-nova.fnal.gov
http://snews.bnl.gov

This Poster supported by NSF RUI grant #1306944 (NOνA) and Collaborative Grant #0969085 (SNEWS). NOνA is funded by the U.S. Department of Energy and National Science Foundation, and the State and University of Minnesota.