

# Supernova and Burst Systems in SNO+

Berjer Ding

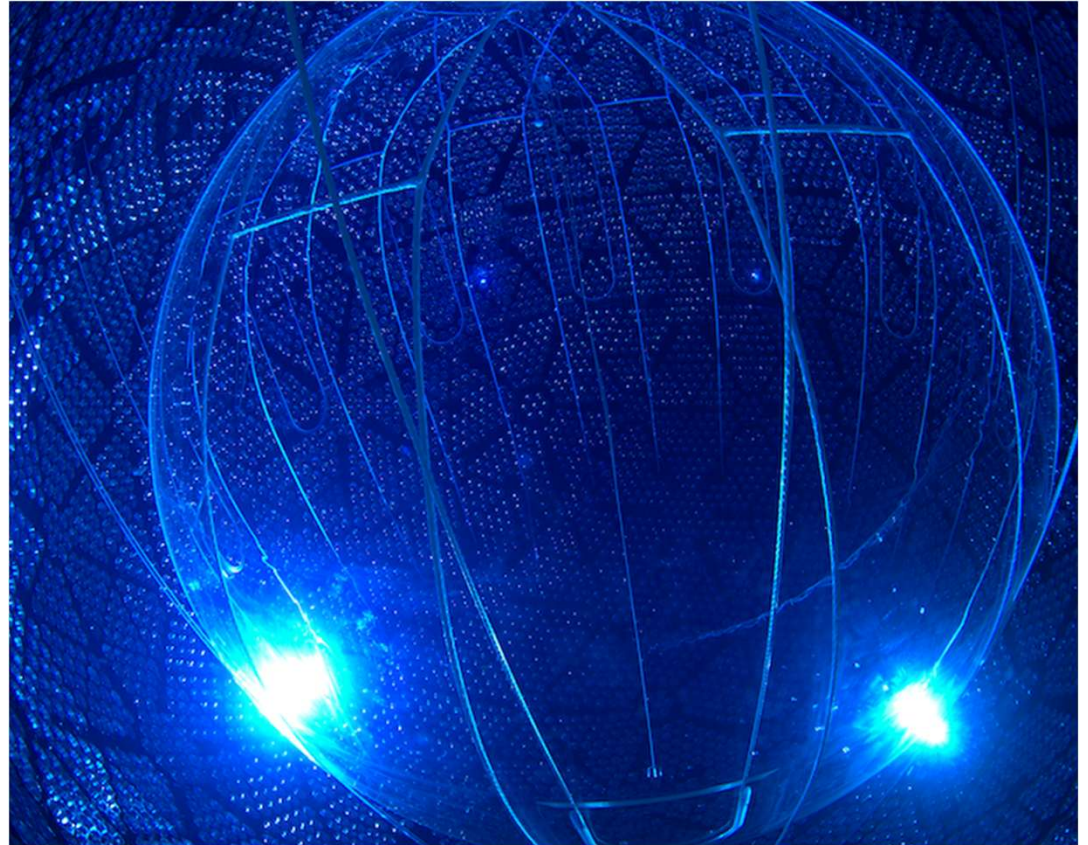
Supervised by Dr. Erica Caden

April 17<sup>th</sup>, 2026



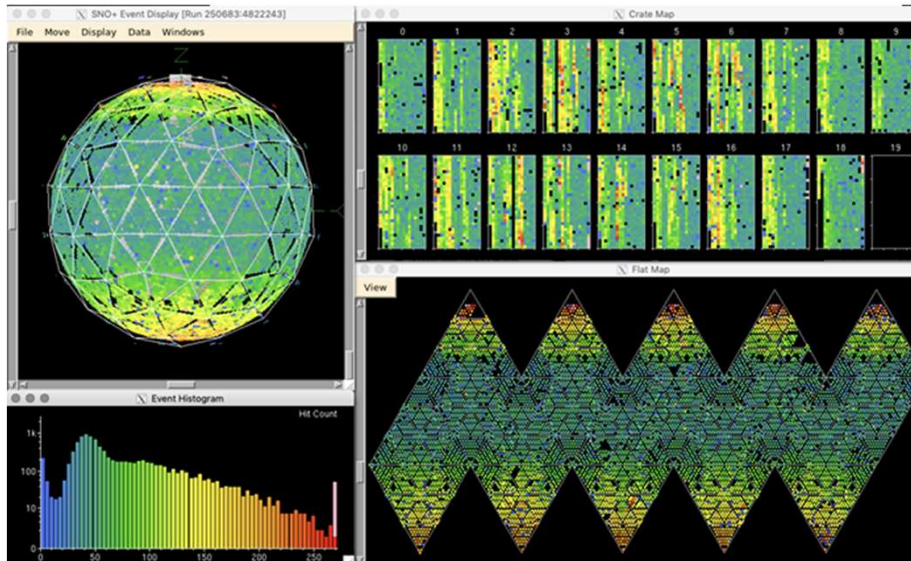
# SNO+ Detector

- ❑ Multipurpose neutrino detector
  - ❑ Sensitive to solar, reactor, geoneutrino, and astronomical neutrinos
- ❑ The acrylic vessel (AV) is filled with 780 tons liquid scintillator
- ❑ The outer shell (PSUP) is composed of  $\approx 9300$  photomultiplier tubes (PMTs)
  - ❑ Reconstruction comes from these PMTs



# SNO+ DAQ

- ❑ 32 PMT connects to one Front End Card
- ❑ 16 Front End Cards are organized in 19 crates on the detector deck
- ❑ The Master Trigger Card decides if data is written to DAQ servers
- ❑ 32 PMT channels  $\times$  16 cards  $\times$  19 crates



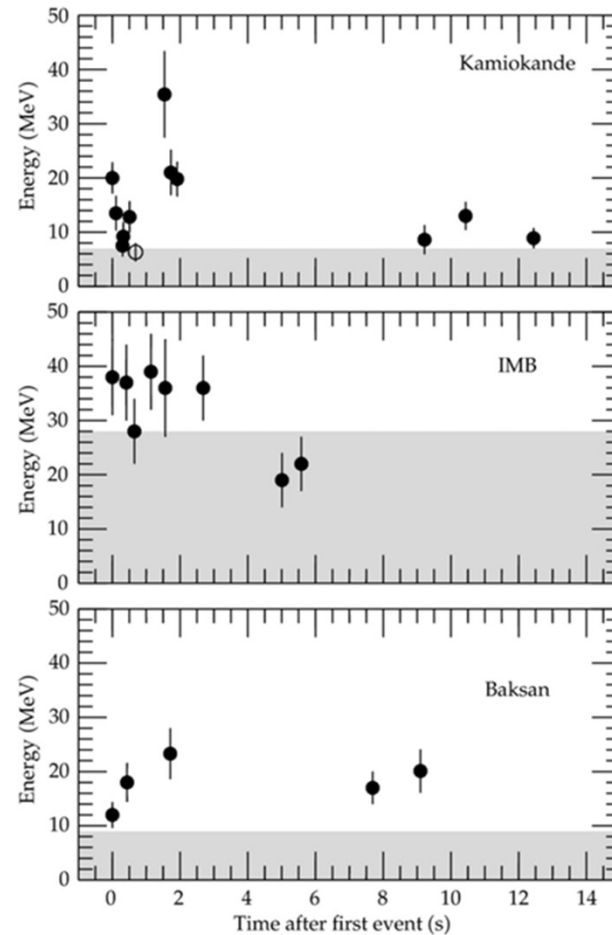
# Supernovae

- ❑ Supernovae are the ultimate event of the life of massive stars
- ❑ 99% of the energy goes to neutrinos produced in the event
- ❑ Key tool to answer important questions
  - ❑ Neutrino mass hierarchy
  - ❑ Sterile neutrinos
  - ❑ Supernova models



# Supernovae

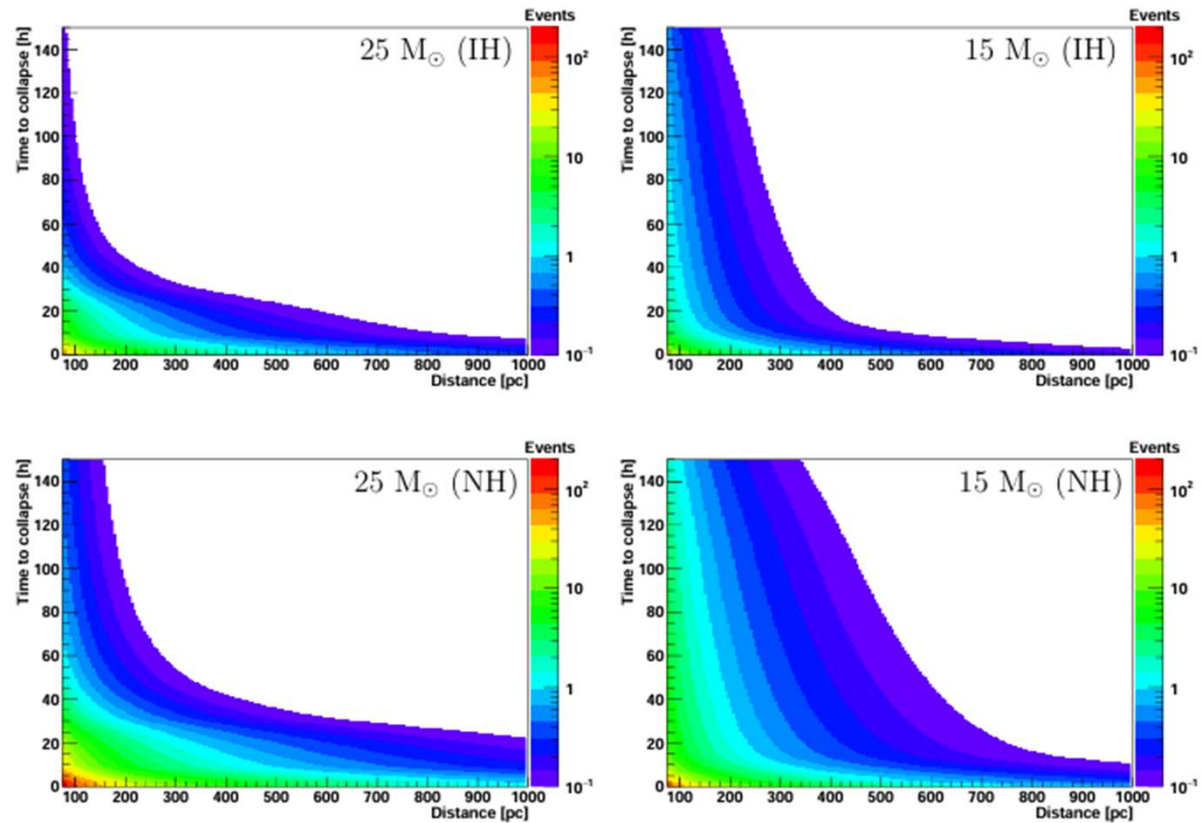
- ❑ A supernova detection may be one of the most significant events in particle and astrophysics
- ❑ The event itself lasts on the order of tens of seconds
- ❑ The estimated rate is  $1.63 \pm 0.46$  per 100 years, or every  $61^{+24}_{-14}$  years

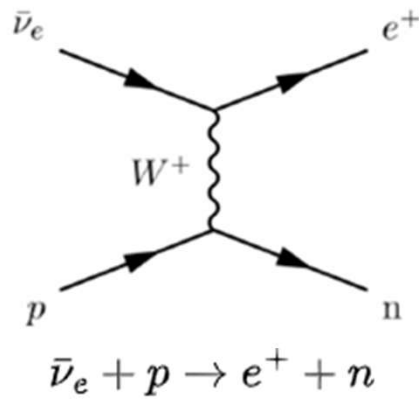


# Pre-Supernova

□ A period of interesting physics

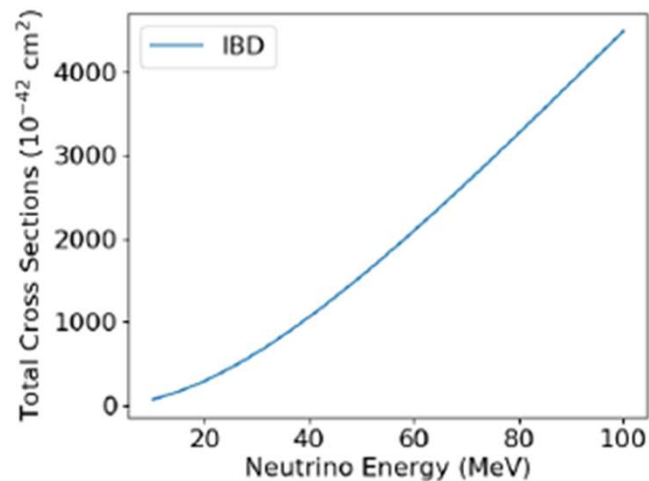
□ Provides a warning for a supernova





$$E_{\bar{\nu}_e} \approx E_{e^+} + 1.8 \text{ MeV}$$

$$E_{\text{vis}} \approx E_{e^+} + 1.022 \text{ MeV}$$

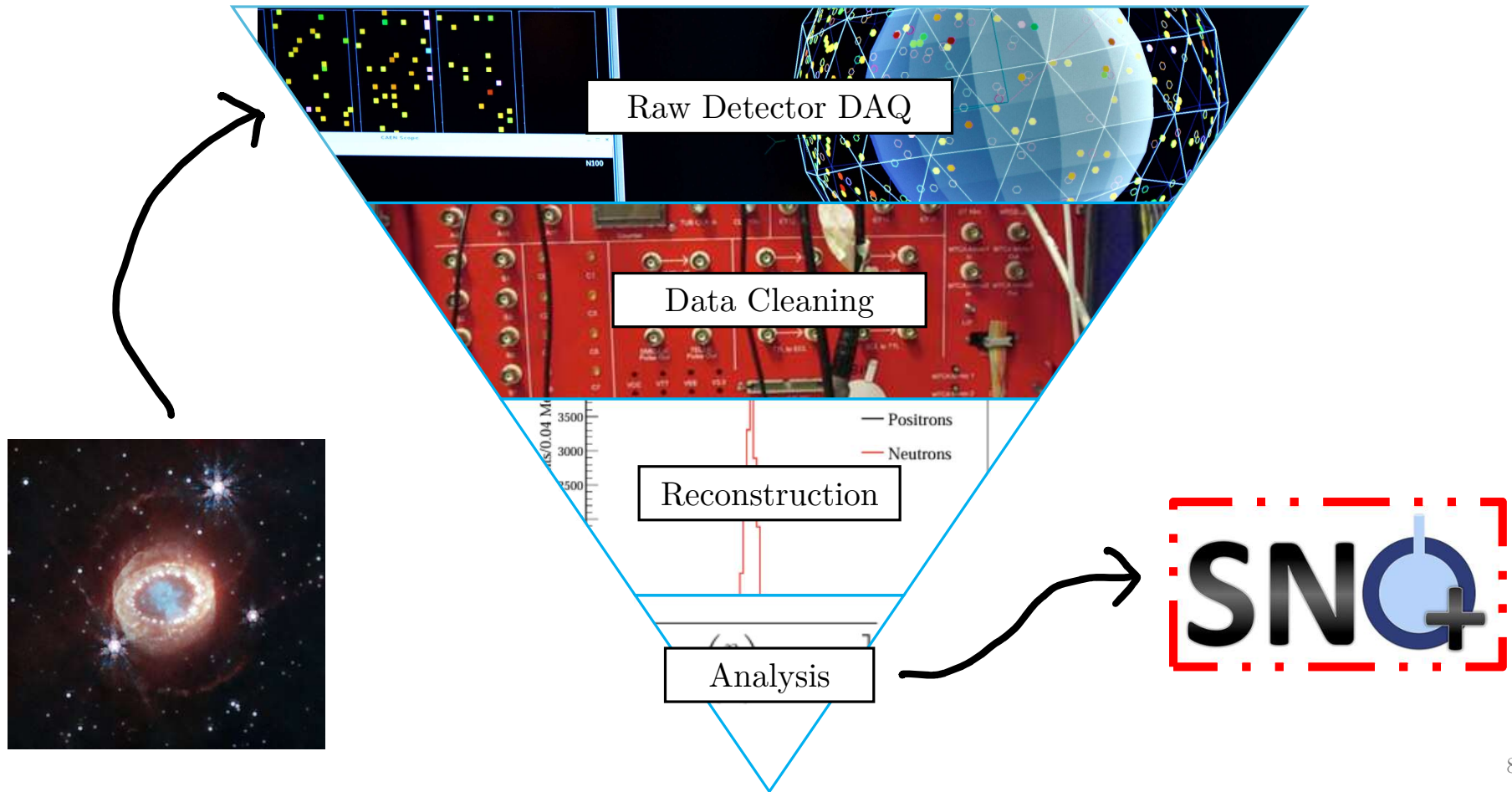


# Inverse Beta Decay (IBD)

- ❑ The positron is annihilated immediately producing total 1.1 MeV gammas – ‘Prompt Event’
- ❑ The neutron thermalizes in  $O[10 \text{ ms}]$  producing a 2.2 MeV gamma - ‘Delayed Event’
- ❑  $\geq 90\%$  tagging efficiency in SNO+

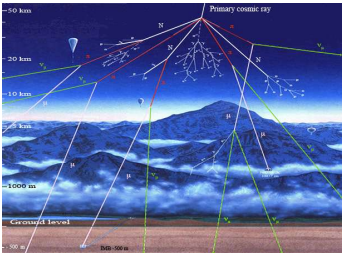
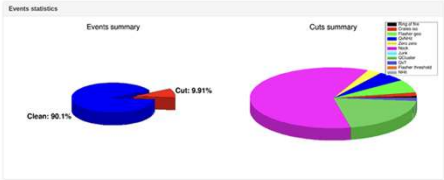
# Pre-Supernova Monitor

- Instantaneous IBD data-analysis system to monitor for pre-supernova signals



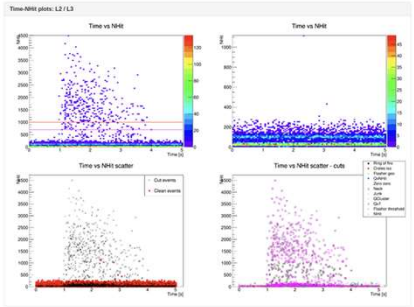
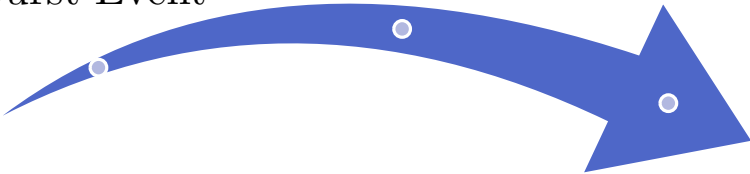
# Burst Trigger Monitor

❑ Automated burst classification machine

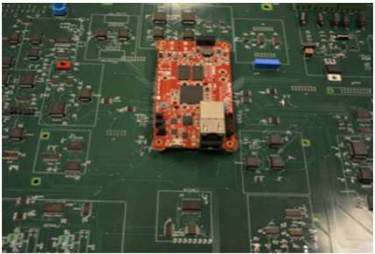


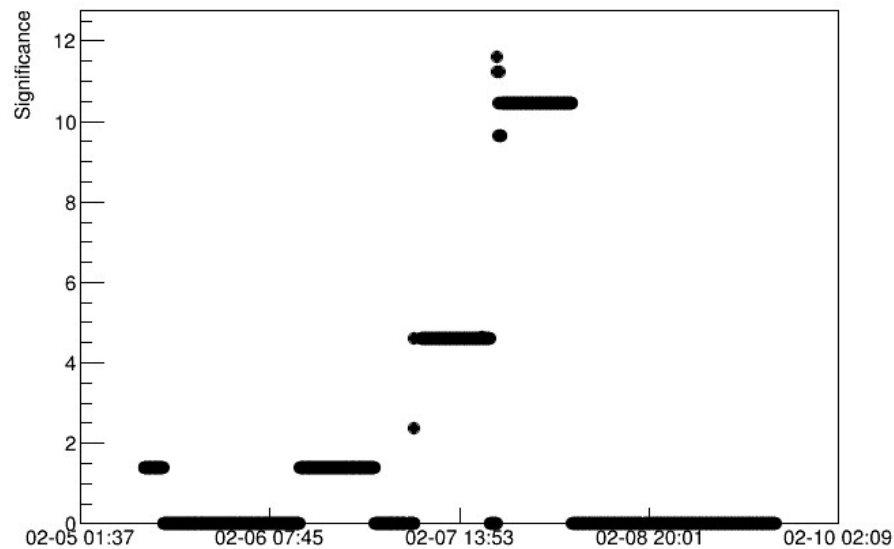
L1 – Define  
Burst Event

L2 – High Level  
Analysis



L3 – Classification

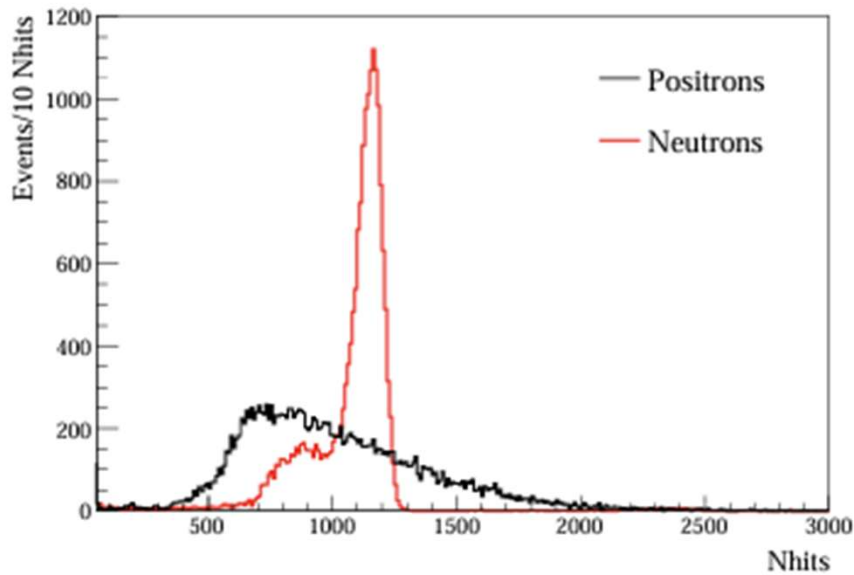




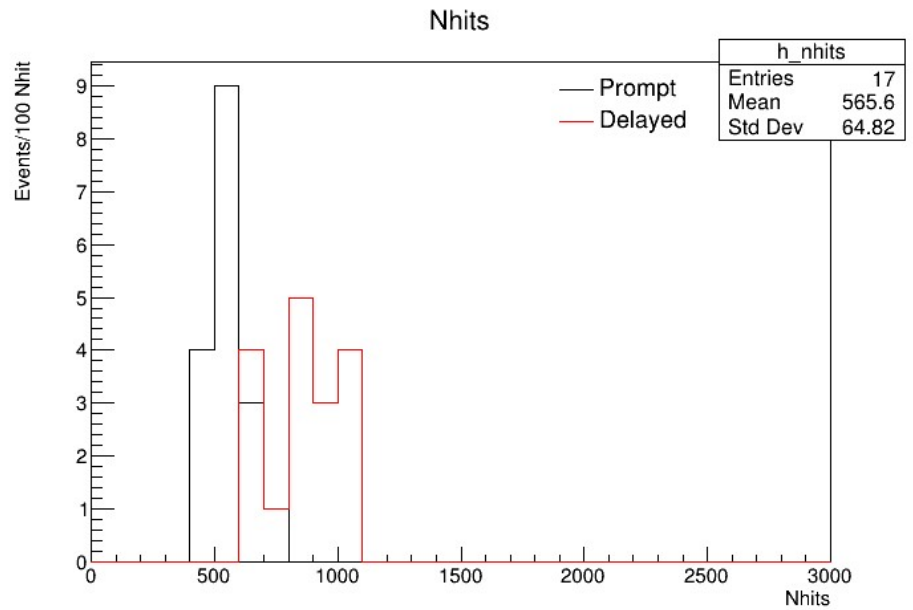
## Suspicious Runs on February 7<sup>th</sup>...

- ❑ The Pre-Supernova Monitor on February 7<sup>th</sup> picked up a ramping sequence of highly significant events
- ❑ From the significance either a supernova is actually occurring (not corroborated by other detectors), or a bug. Either way investigations are required...

# Run 377360 Nhit Plot

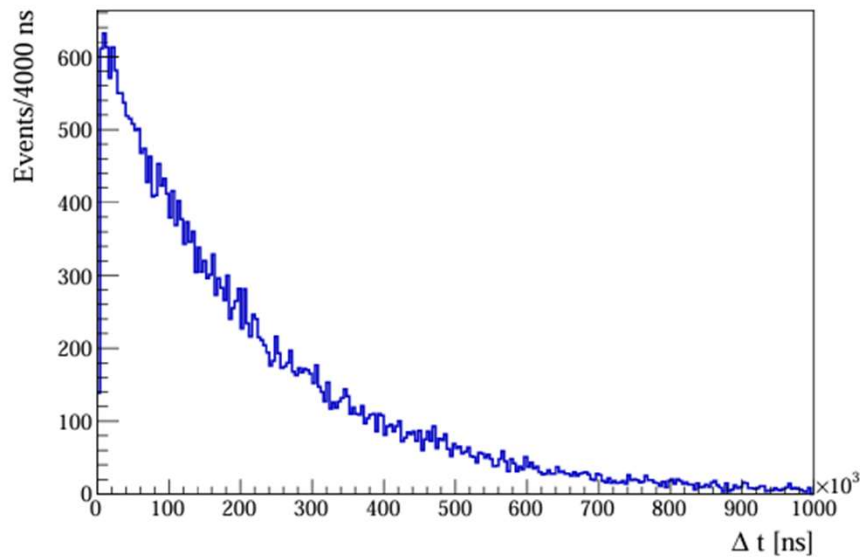


Simulated Data

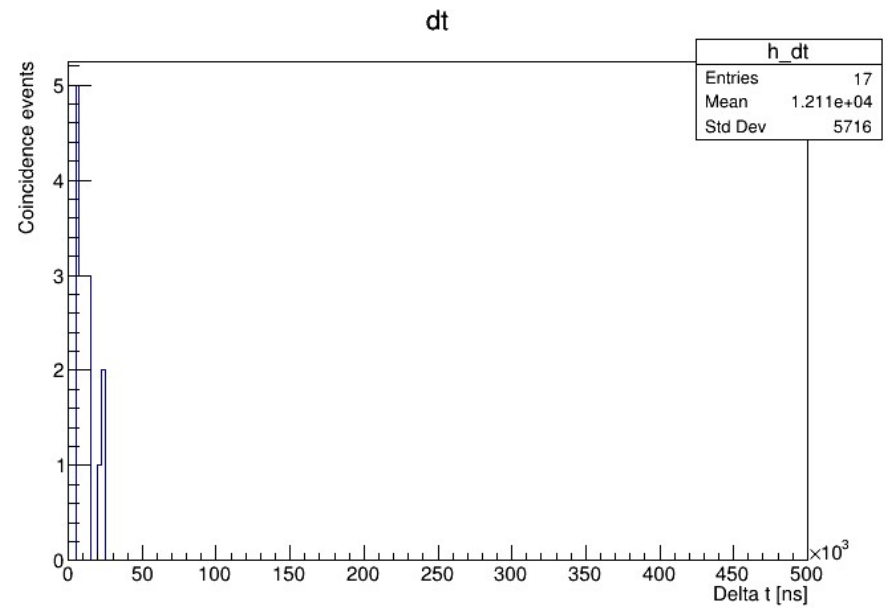


Actual Data

# Run 377360 $\Delta t$ Plot

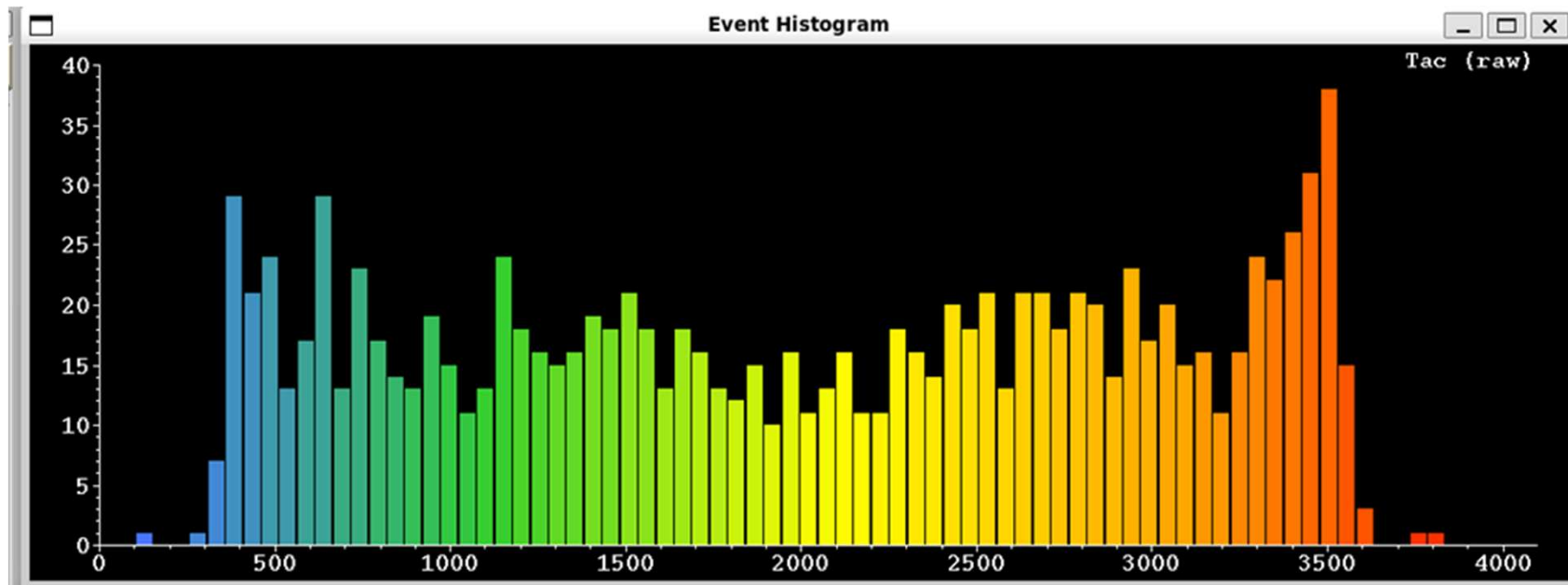


Simulated Data



Actual Data

# Run 377360 Flat Tac Plot Sample



Actual Data

# Seismicity by the Detector



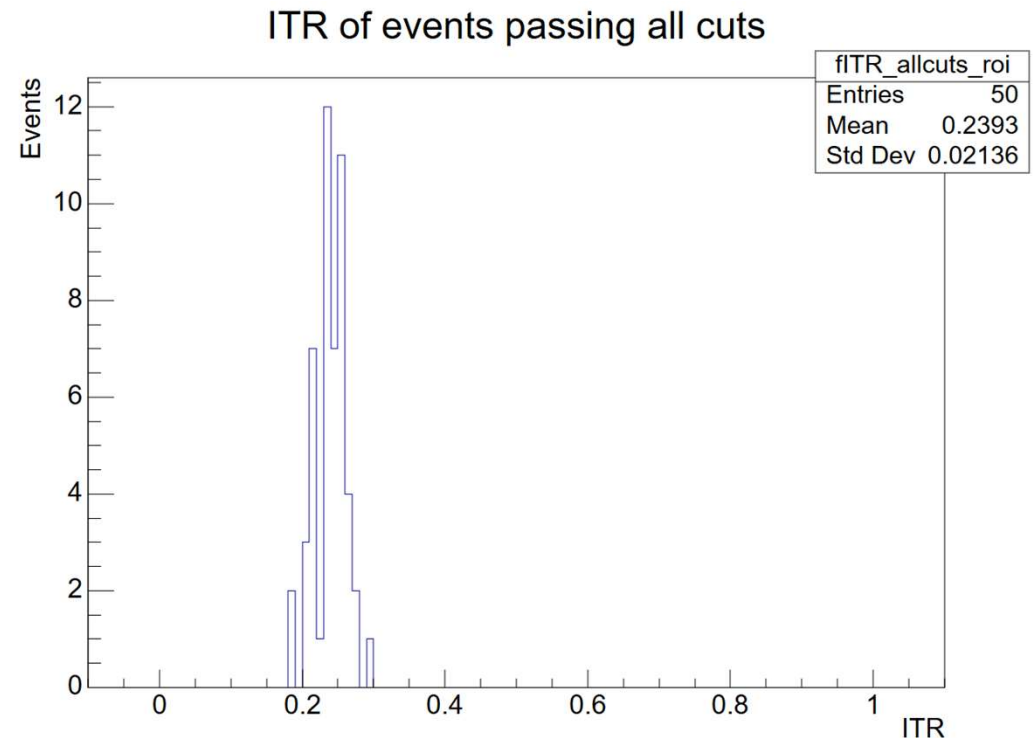
- ❑ On February 7<sup>th</sup> a seismic event occurred in Northern Ontario!
- ❑ Magnitude 2 (Very Weak) at the Detector Site
- ❑ The rumbling may have shaken the electronics, producing the uniform signals seen previously

# Post-Fix Run 337360 ITR Plot

- ITR – (In Time Ratio) is the ratio of PMTs hit in the prompt period to the entire period

$$\text{ITR} = \frac{\sum_{t=0}^{T_{\text{prompt}}} \text{Nhit}(t)}{\sum_{t=0}^{T_{\text{total}}} \text{Nhit}(t)}$$

- Characterizes forms of gamma radiation within the detector
  - Scintillator  $\in [0.1, 0.5]$
  - Cherenkov  $\in [0.5, 0.9]$
  - Instrumental  $\in [0.0, 0.1] \cup [0.9, 1.0]$



Plot of Delayed Events ITR Distribution

No Prompt Events were found

Thank You!

Special Thanks To:

Erica Caden

Christine Kraus

Ryan Bayes

Matt Depatie

Mark Ward

and the rest of SNO+



# Backup

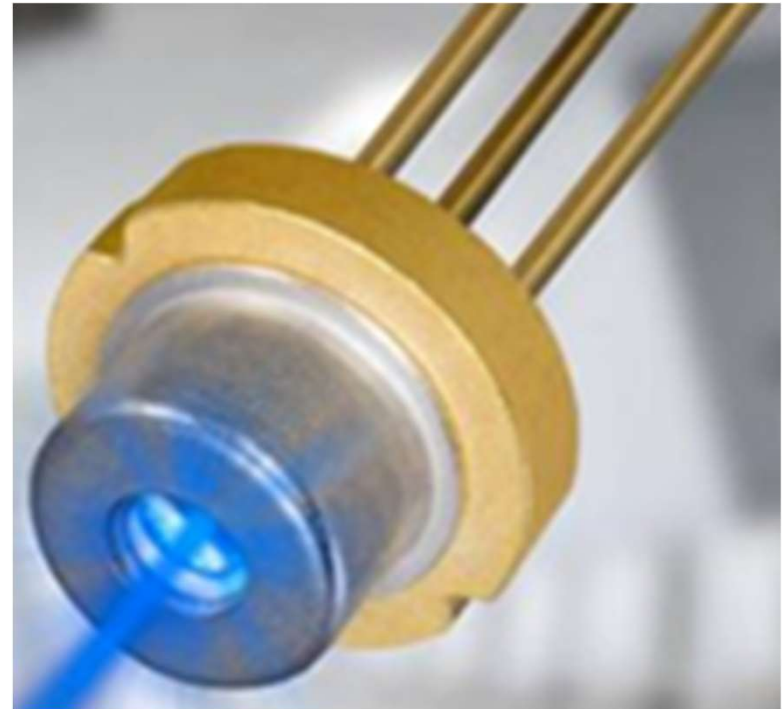
# SNEWS

- ❑ SNEWS is a consortium of neutrino detectors tracking pre-supernova signals globally
- ❑ Historically SNO was the third experiment to join
- ❑ SNO+ is in SNEWS, but no alarms have been sent as the systems are being recommissioned



# Supernova Calibration Source

- ❑ We do have a light source meant to mimic a supernova signal
  - ❑ Calibrate our systems
  - ❑ Stress-test the DAQ and electronics
- ❑ High rate, high occupancy, tunable frequency and energy
- ❑ In need of R&D (electronics issues)
  - ❑ Please see Ryan Bayes for more info



# Problems and Steps Taken

