Trigger system and supernova detection in the NOvA experiment

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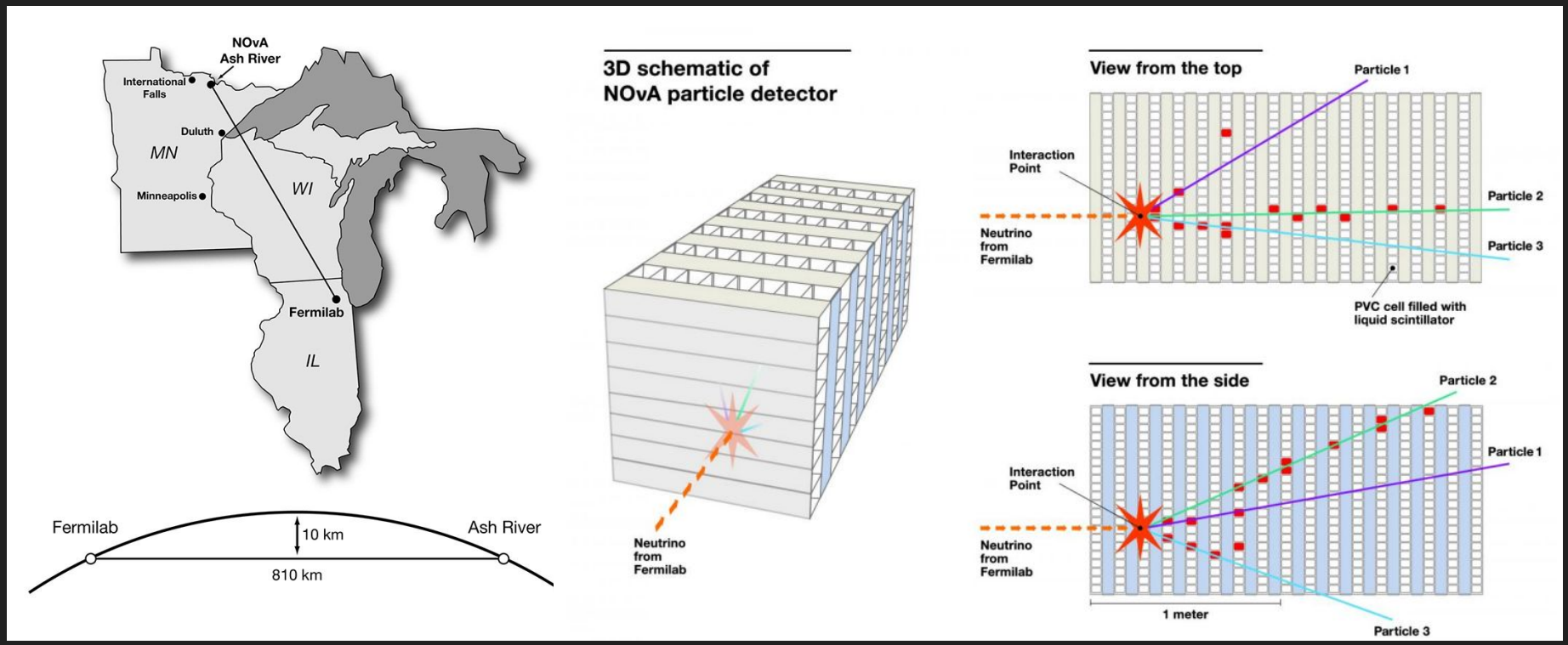
The NOvA experiment:

Main goal: study of neutrino oscillations in a muon neutrino beam with **<E>=2 GeV**.

Detectors are composed of extruded PVC cells filled with liquid scintillator.

Large and segmented NOvA detectors can be used for additional physics goals.



NOvA Near detector: 5ms time slice

- M = **300 ton**
- Nchannels = **21504**
- Location: Fermilab 100m underground

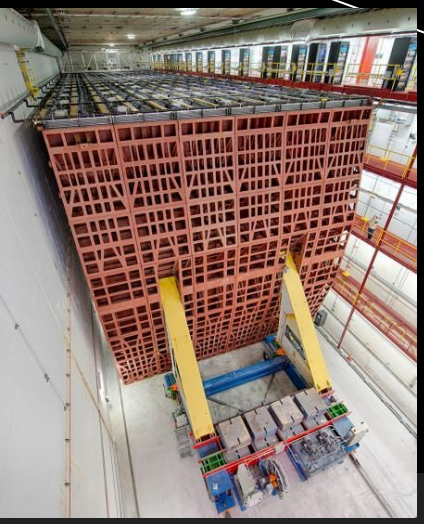
15 meters
256 planes

3.9 m

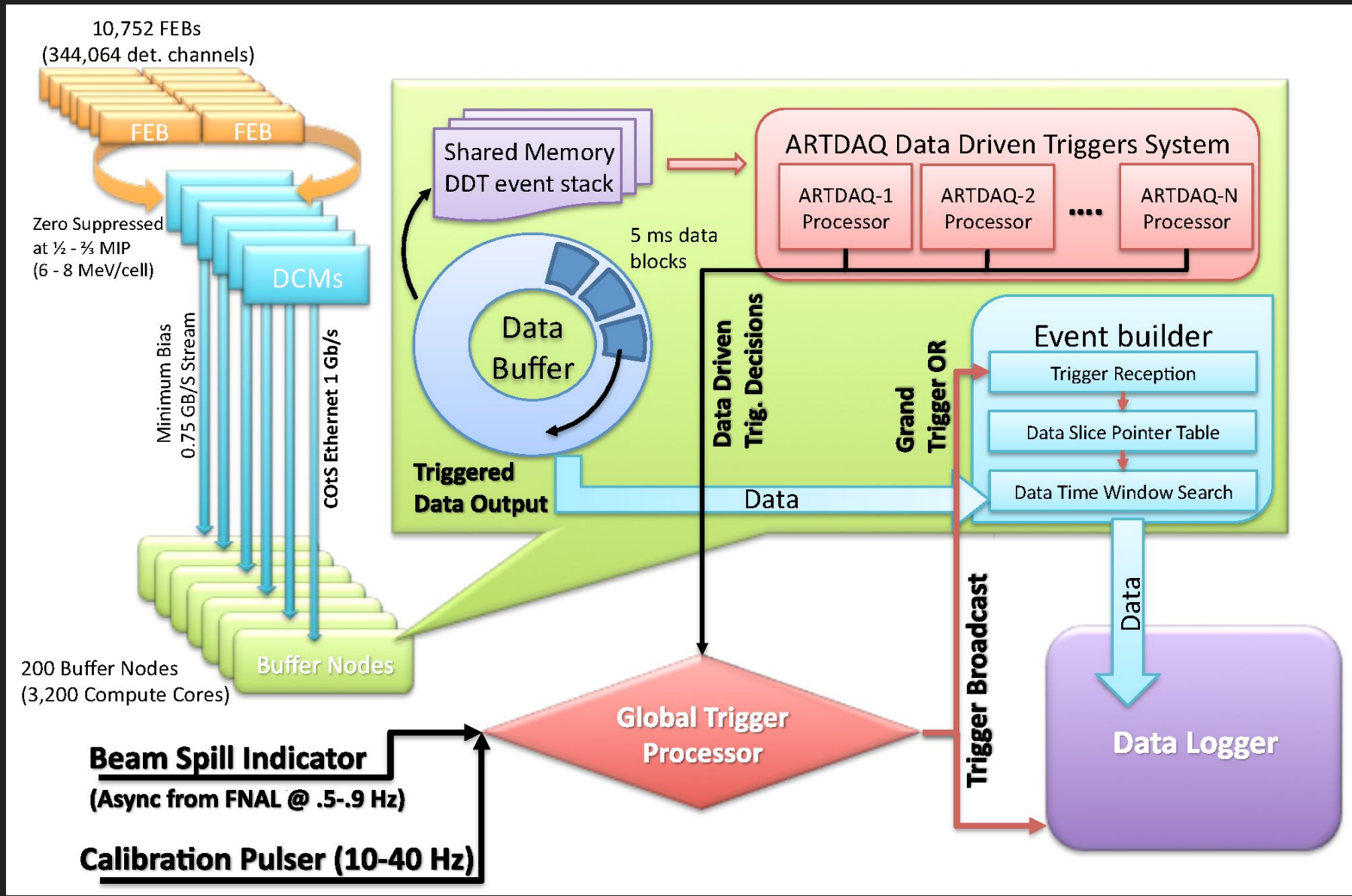
3.9 m
96 cells/ plane

NOvA Far Detector: 5ms time slice

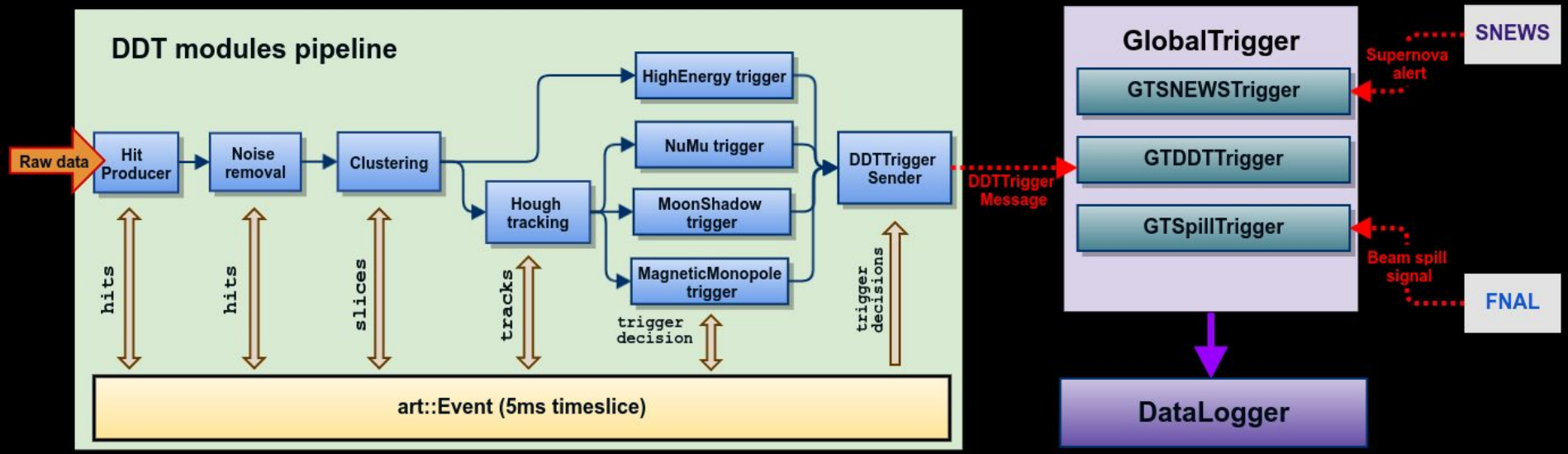
- M = **14 kton**
- Nchannels = **344064**
- Location: Ash river on surface



Data Acquisition system



Data Driven Trigger system



Based on the Fermilab **ART** framework:

- Configurable pipeline of modules, loaded at runtime.
- Each module is a visitor to the art::Event class, which stores the data products.

>1000 DDT processes (**13** processes x **80** nodes) running in parallel to provide fast online reconstruction and search for interesting signatures in 5ms data slices.

The Buffer Nodes can hold up to **~10 minutes** of data in the circular buffers.

Neutrino signal from the core-collapse supernova

Type II SN emits **~10^{58}** neutrinos: **E_ν~10-60 MeV, T ~10s**

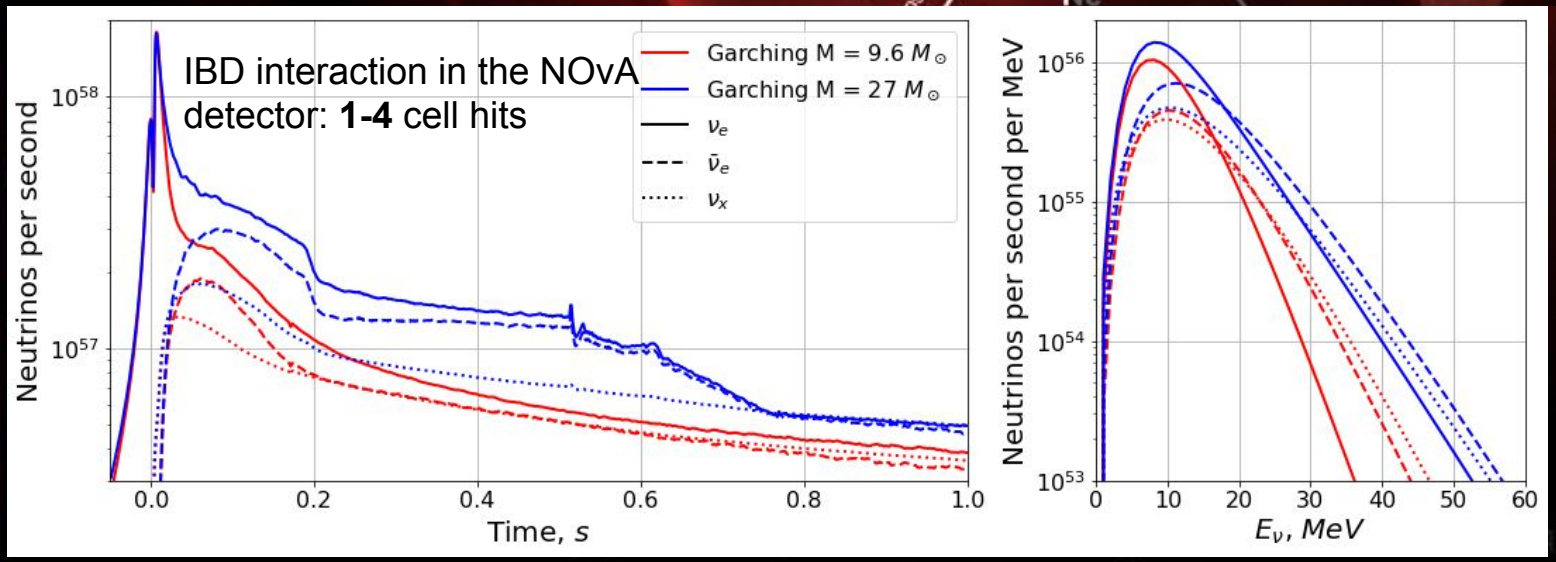
These neutrinos carry **99%** of the collapse energy.

Galactic SN are very rare: **~1-3** per century!
(and were never observed in the neutrinos)

Neutrino signal: probe of

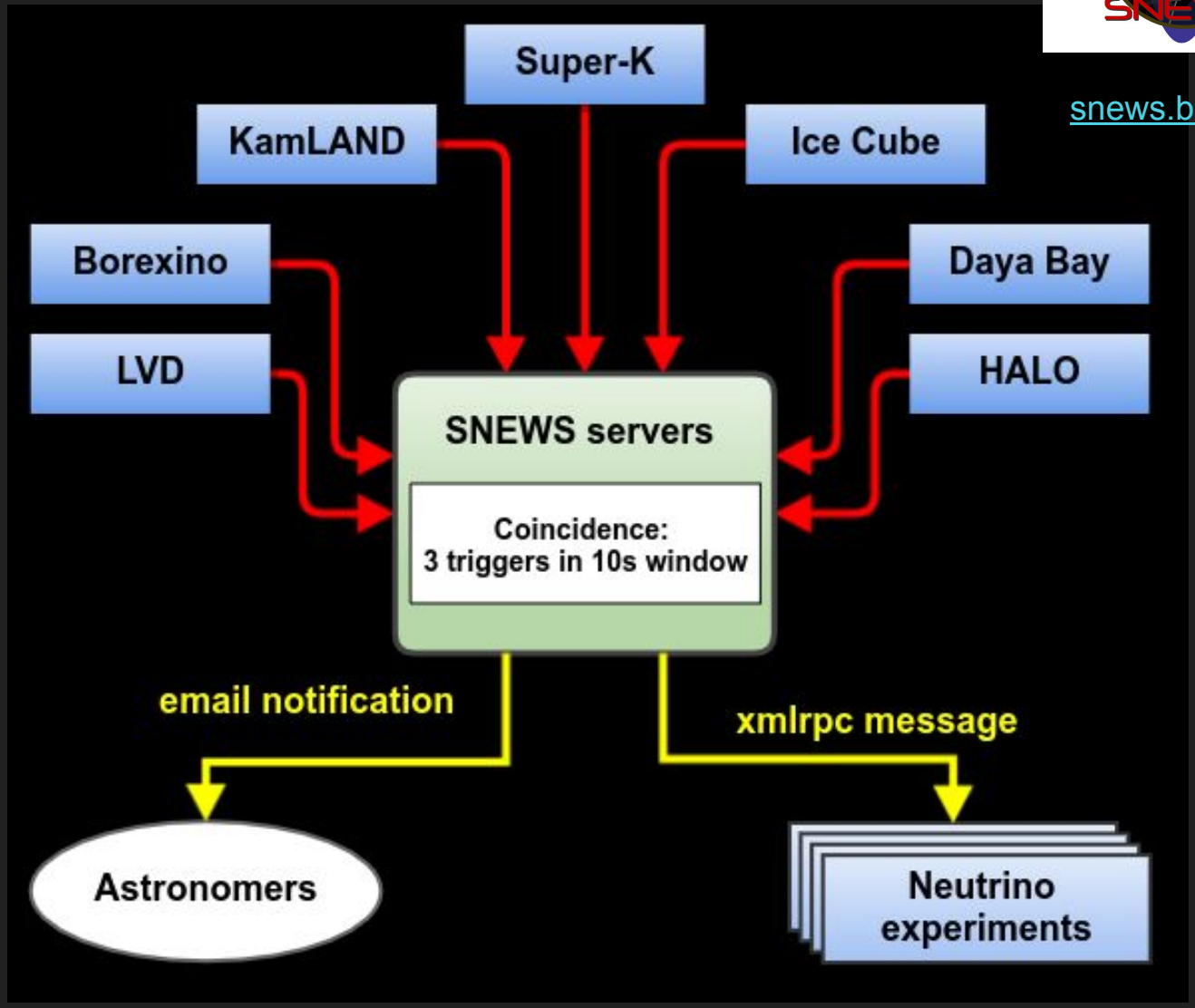
- Neutrino properties
- Supernova properties

arXiv:1508.00785 [astro-ph.HE]

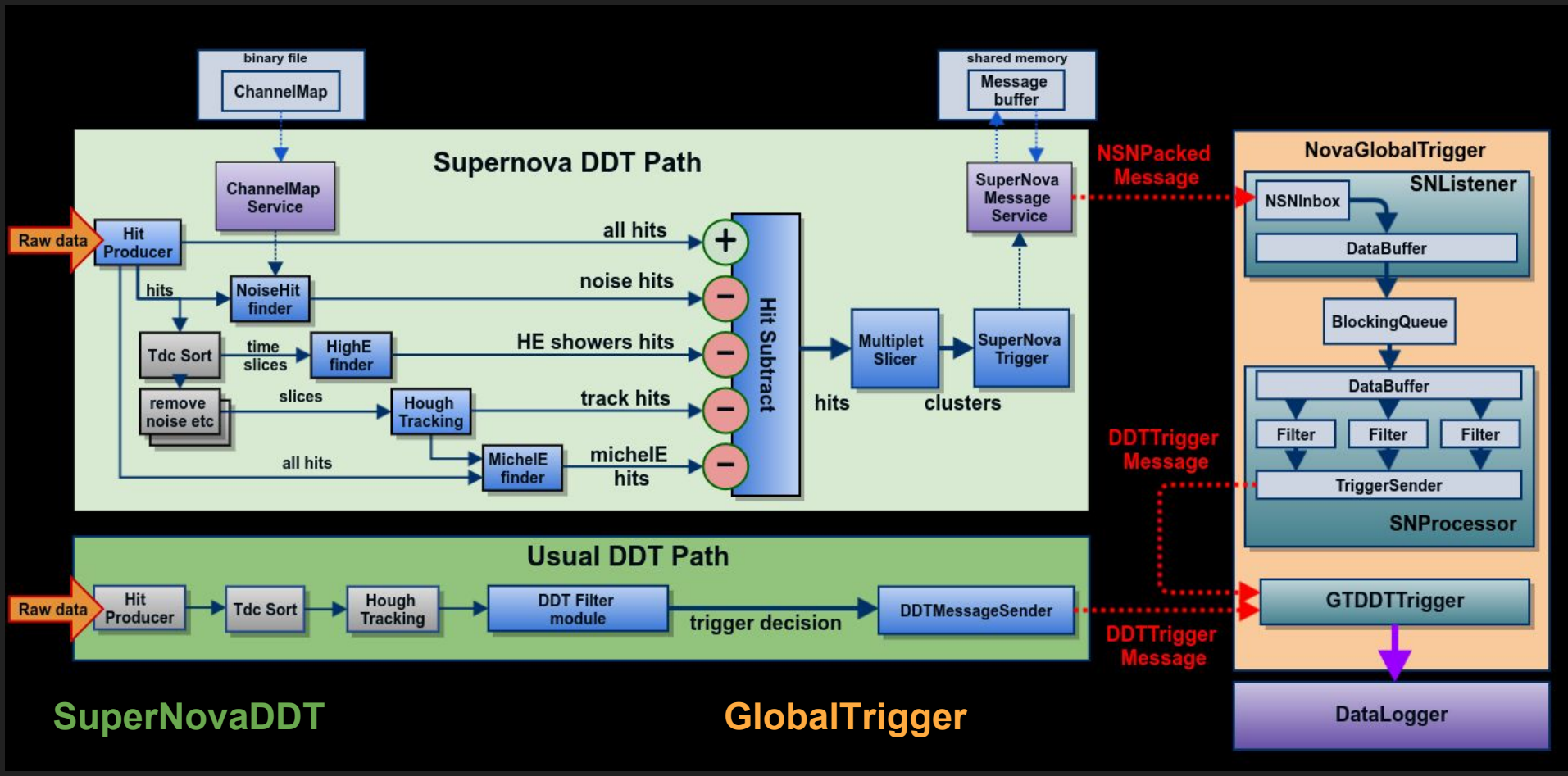


SuperNova Early Warning System

snews.bnl.gov



Supernova triggering system scheme

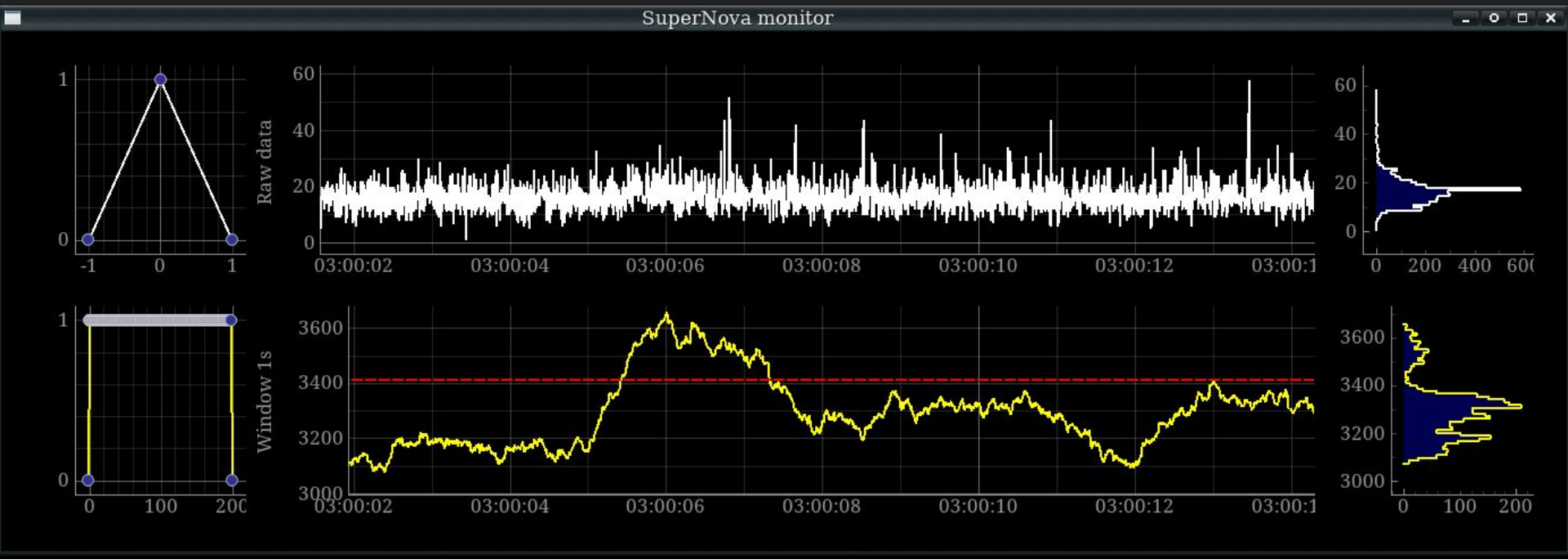


- **Remove tracks from the known sources:**
  - muons, HE showers, electronic noise
- **Reconstruct clusters:**
  - hit groups close in time and space
- **Select neutrino interaction candidates:**
  - by summary amplitude and Nhits
- **Send N_cands per 5ms to the Trigger node**

- **Receive N_cands per 5ms from all buffer nodes:**
  - Sort by timestamp, handle lost data ⇒ Time series
- **Process the time series:**
  - Estimate the background (in 1 minute window)
  - Apply filters to enhance the signal shape
- **Calculate the supernova likelihood**
  - And send trigger signal if threshold is exceeded

Signal processing and triggering: example

Min bias data from the Far Detector mixed with simulation of supernova at d=**10 kpc** distance.



- **Raw data** has a small bump above the noisy background, when SN starts.
- **Convolving** data with 1s window gives us a peak around the bump (signal maximum).
  The threshold is defined from the background and signal model. False trigger rate is required to be **<1/week**
- We can take into account expected signal shape using more complicated filtering kernel.

Conclusions

The NOvA triggering system extends the physical program of the experiment, allowing a wide range or physics goals.

Data Driven Triggers framework provides a flexible way for finding nteresting event signatures in real time.

Supernova detection infrastructure is in place and is ready to be deployed on both Near and Far detectors.

There are several future improvements:

- Advanced classification:
  Interaction candidates selection criteria tuning, ML
- Advanced filtering:
  Use expected signal shape
  Combined likelihood for both detectors
- Additional interaction channels:
  NC on carbon
  Neutron capture