Supernova neutrino detection in the NOvA experiment

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Neutrino signal from the core-collapse supernova

Type II SN radiates ~**99%** of the collapse energy in neutrinos:

~10^{58} neutrinos: **E_ν~10-60 MeV** within **T ~10s**

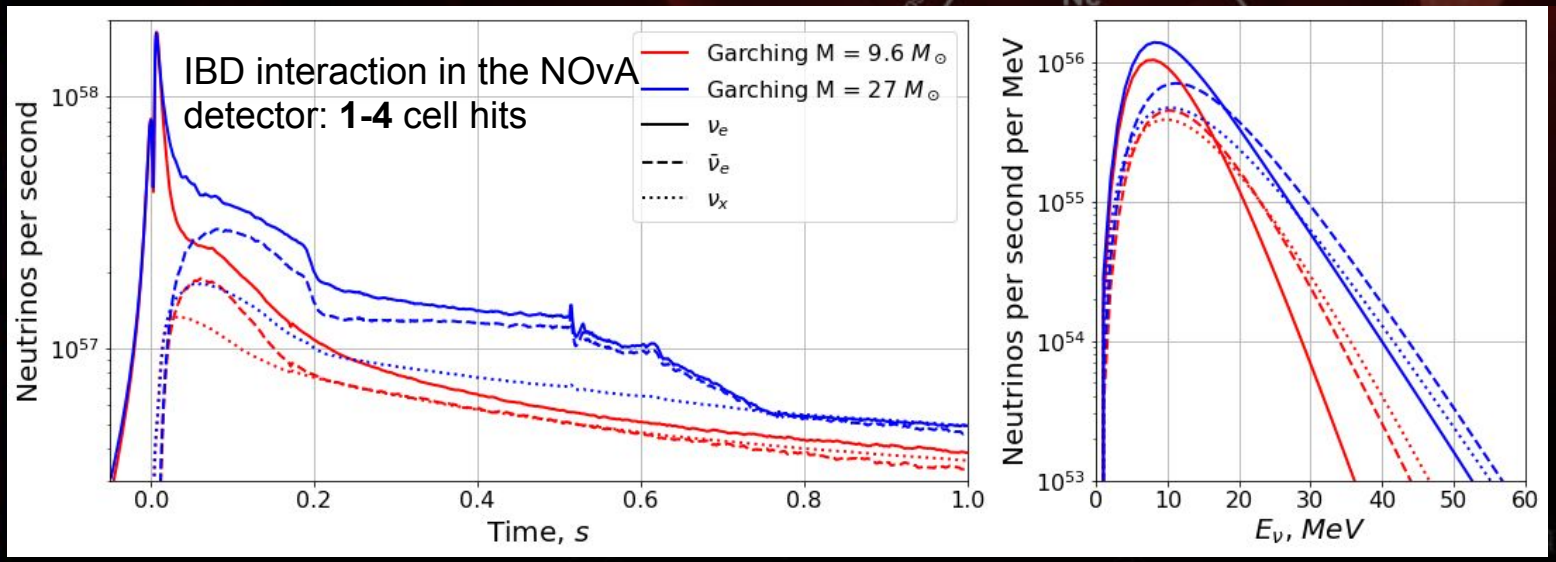
Neutrino signal: probe of

- Neutrino properties
- Supernova properties

arXiv:1508.00785 [astro-ph.HE]

Galactic SN are very rare: **~1-3** per century!

(and were never observed in the neutrinos in our galaxy)



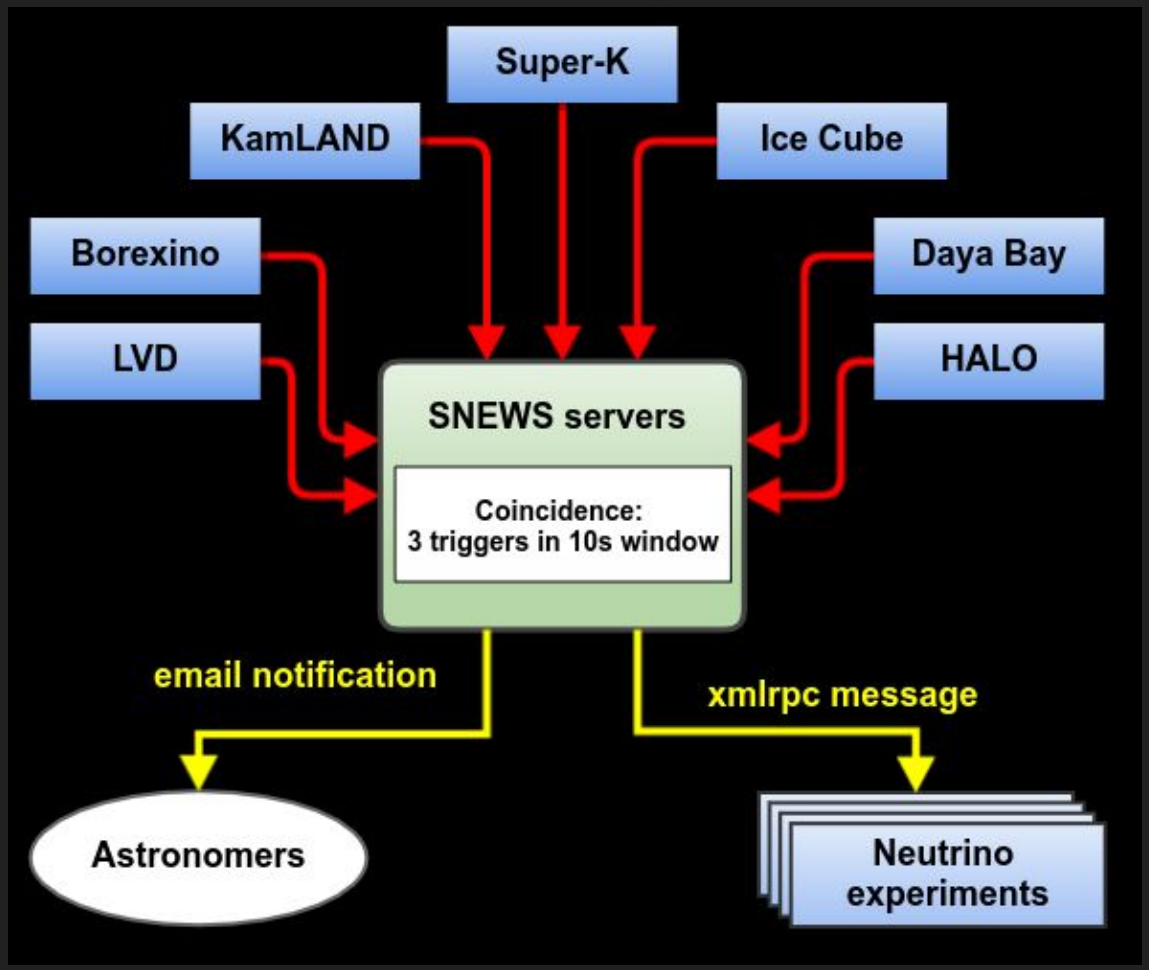
SuperNova Early Warning System

snews.bnl.gov

A global network to make sure we don't miss a galactic event.

Neutrinos arrive several hours prior to optical signal

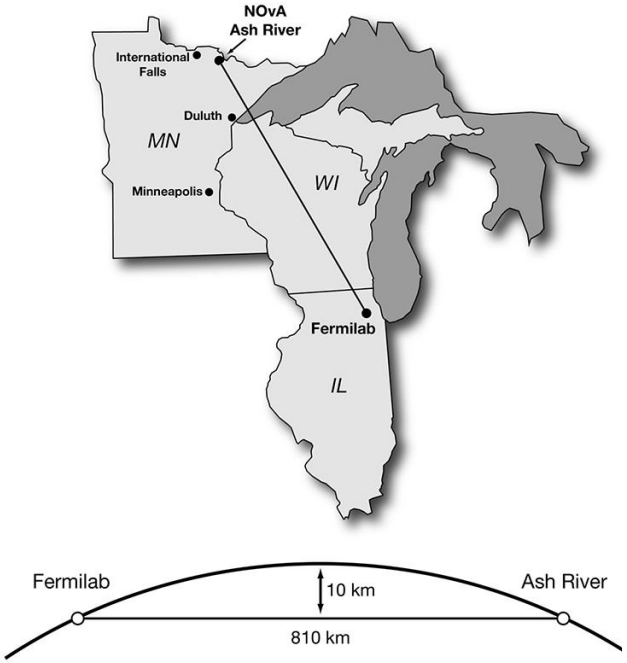
NOvA currently listens to a trigger from SNEWS, to save data in case of supernova.

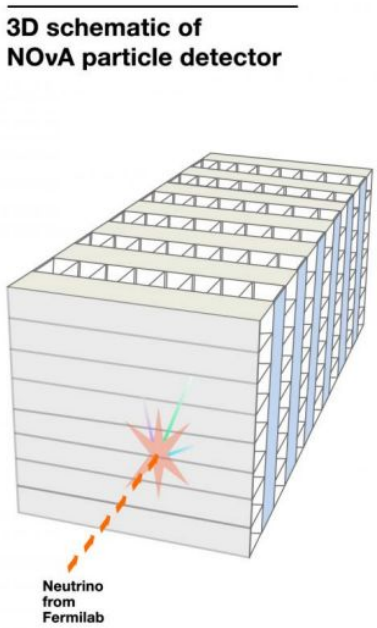


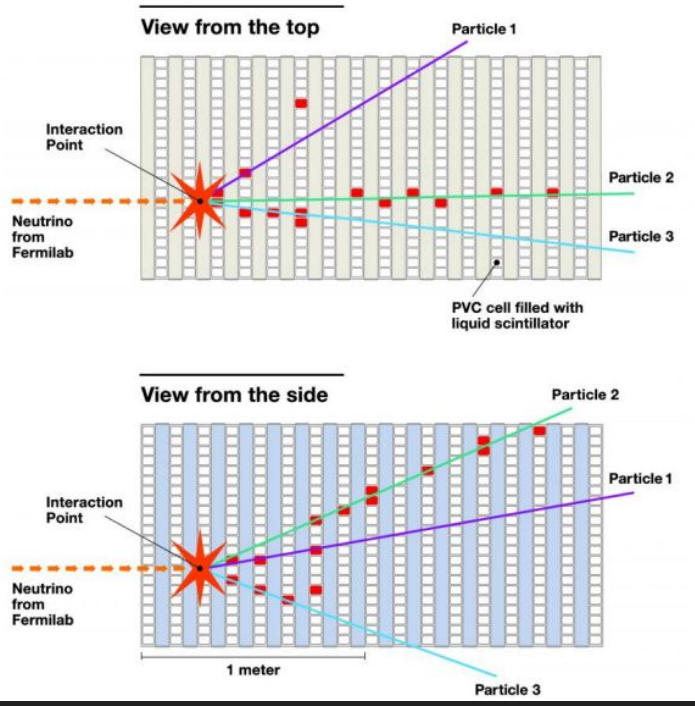
The NOvA experiment

Main goal: study of neutrino oscillations in a muon neutrino beam with **<E>=2 GeV**.
See next talk for more details on the main analysis!

Detectors are composed of extruded PVC cells filled with liquid scintillator.
The scintillation light is transported by the wavelength shifting fibers, then read by APD







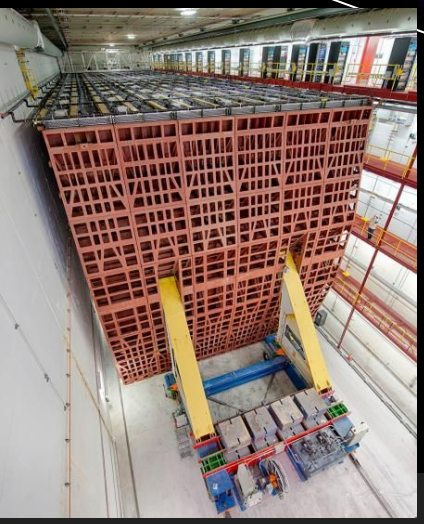
Large and segmented NOvA detectors can be used for additional physics goals.

NOvA Near detector: 5ms time slice

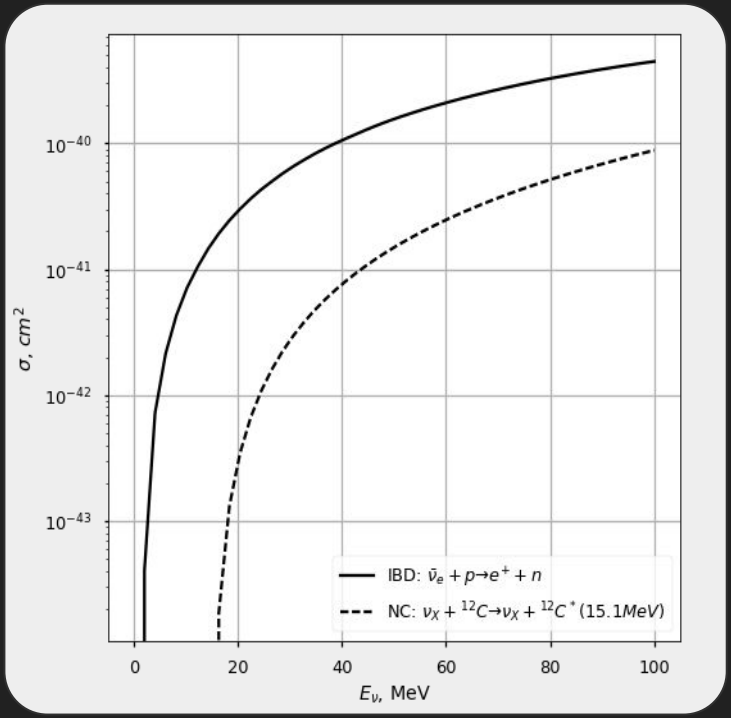
- M = **300 ton**
- Nchannels = **21504**
- Location: Fermilab 100m underground

NOvA Far Detector: 5ms time slice

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



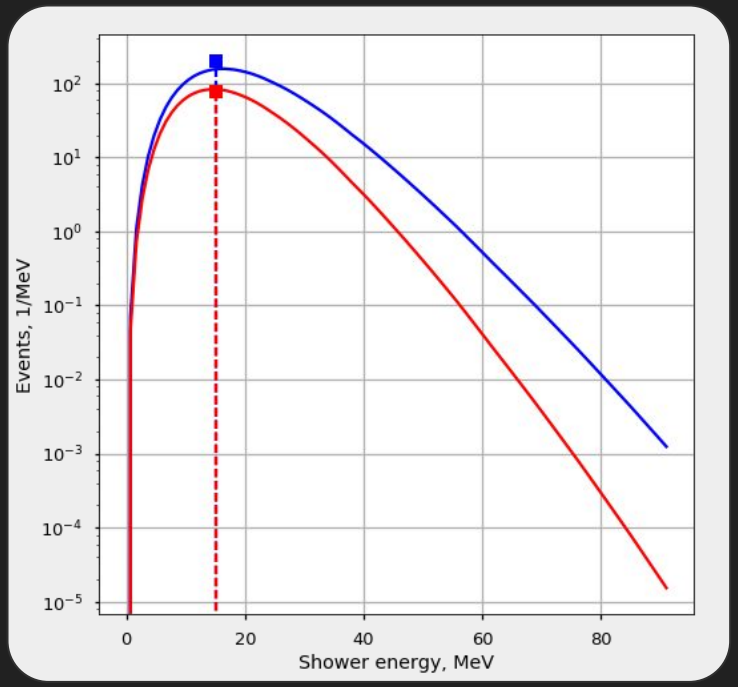
SN neutrinos interactions in the Far Detector



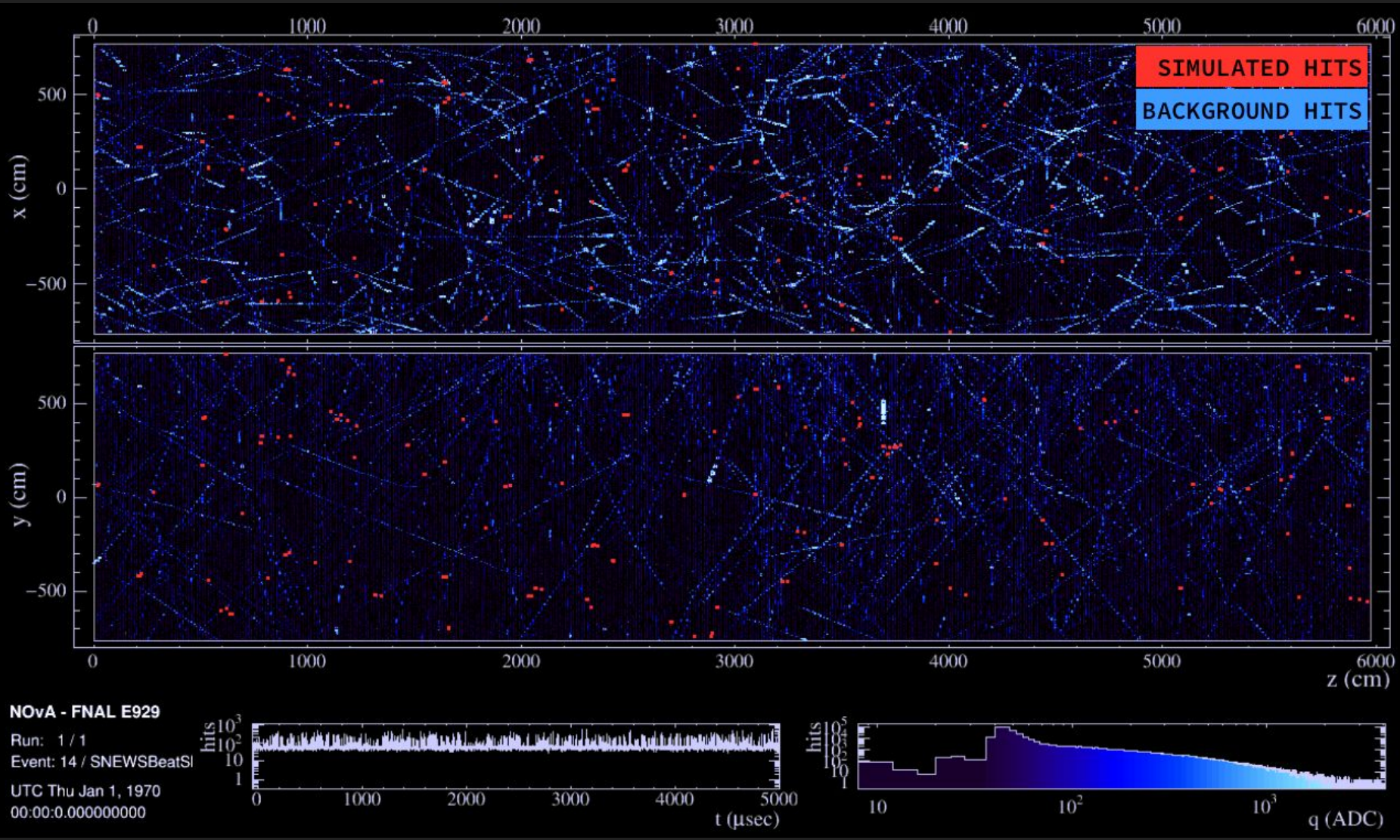
Other channels give negligible contribution: energy too low or small interaction rate

Main detection channels:

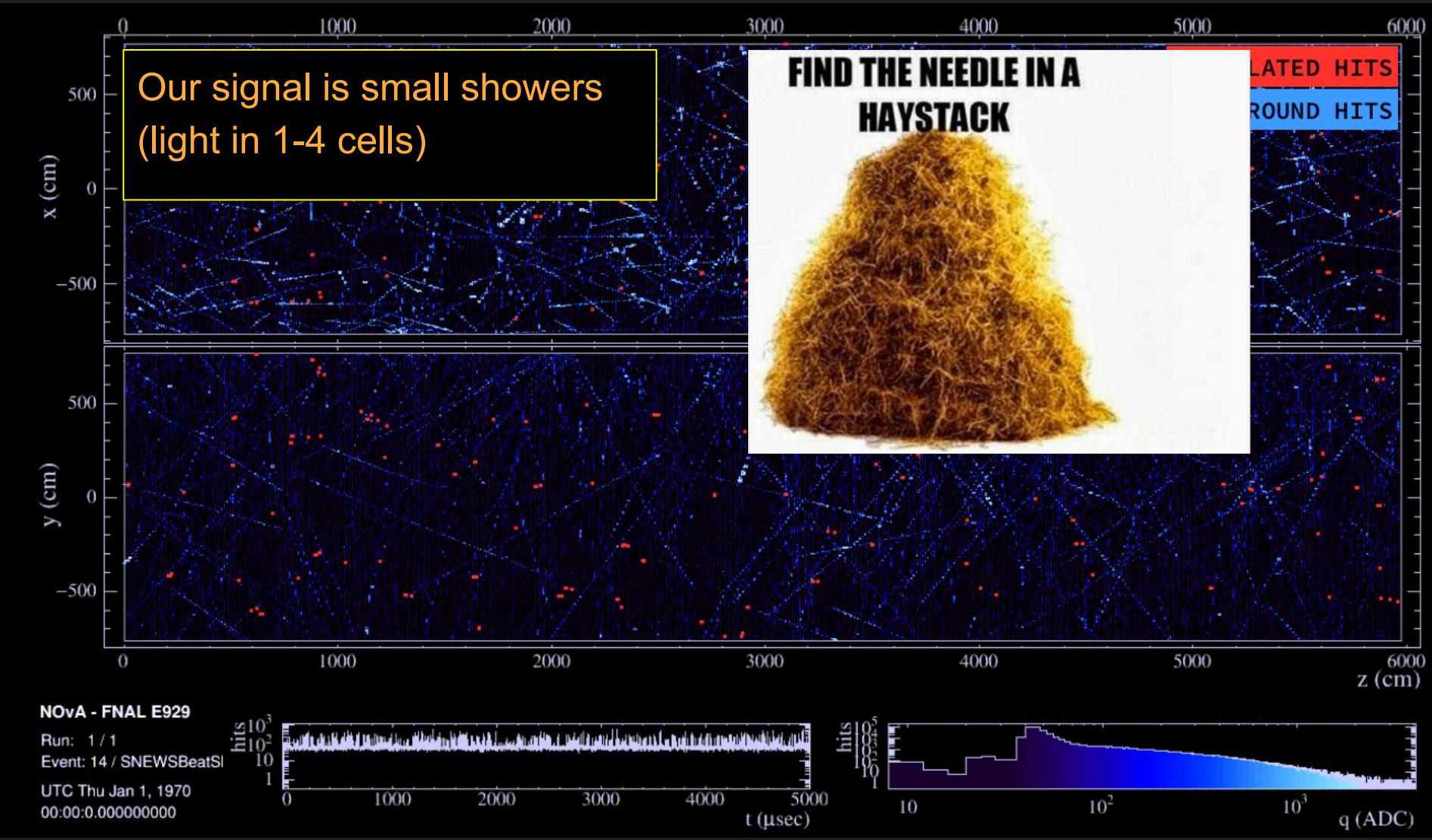
- **Inverse Beta Decay**
  - signature:
    positron shower (10-60 MeV)
- **Neutral Current**
  - signature:
    deexcitation gamma (15.1 MeV)



Far Detectors: 5ms of cosmic data + SN simulation



How do we find signal in this mess?



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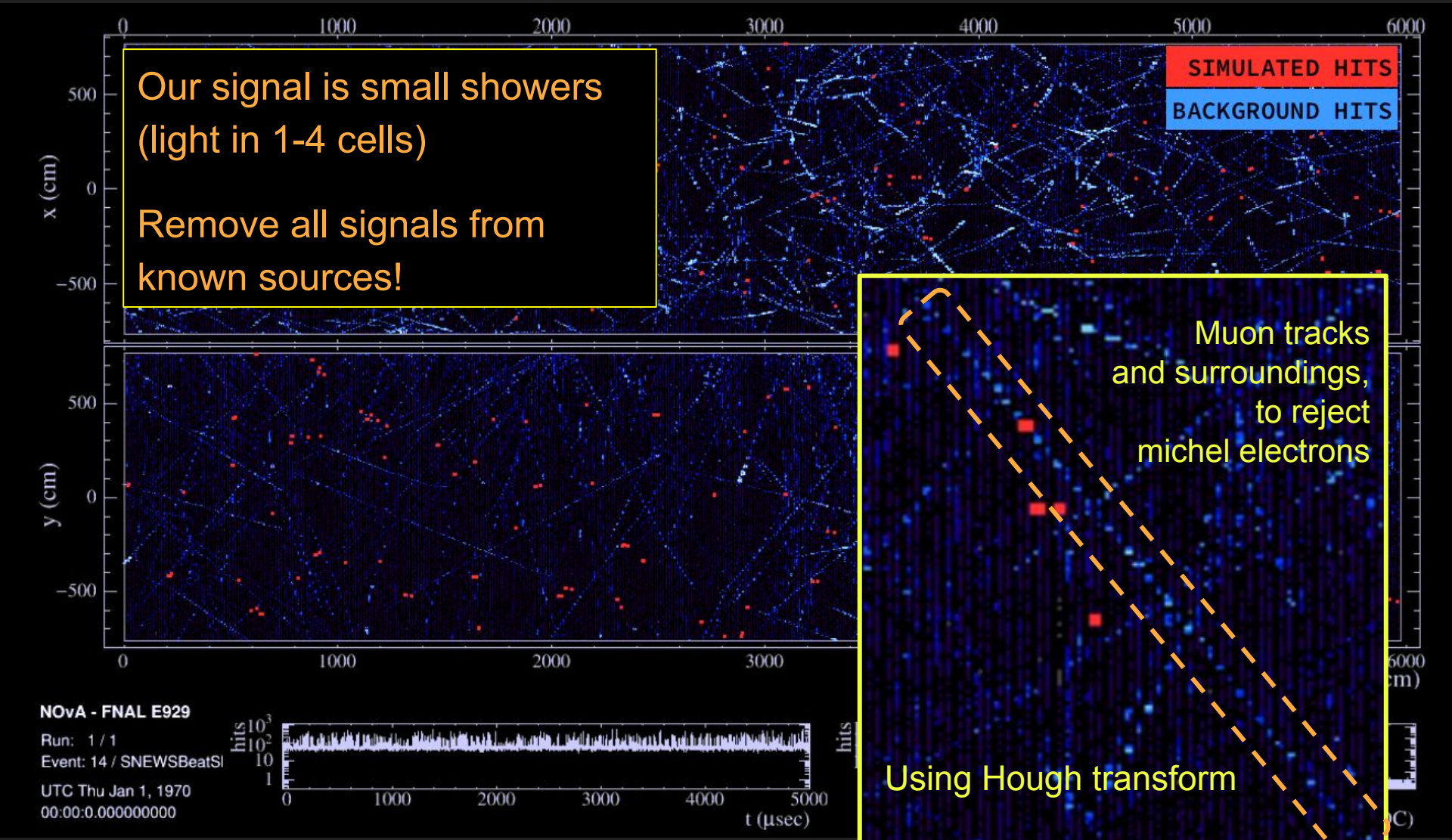

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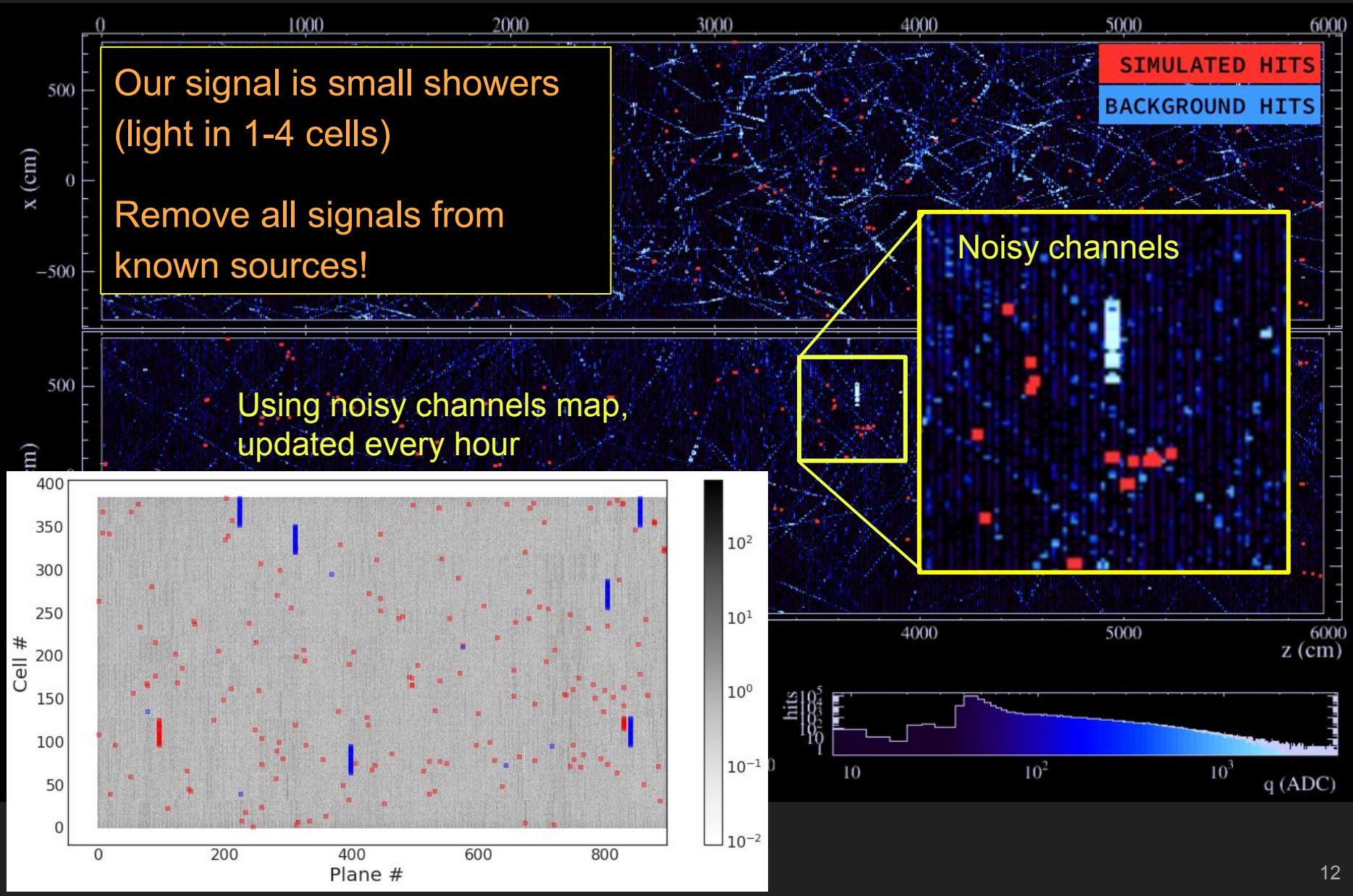

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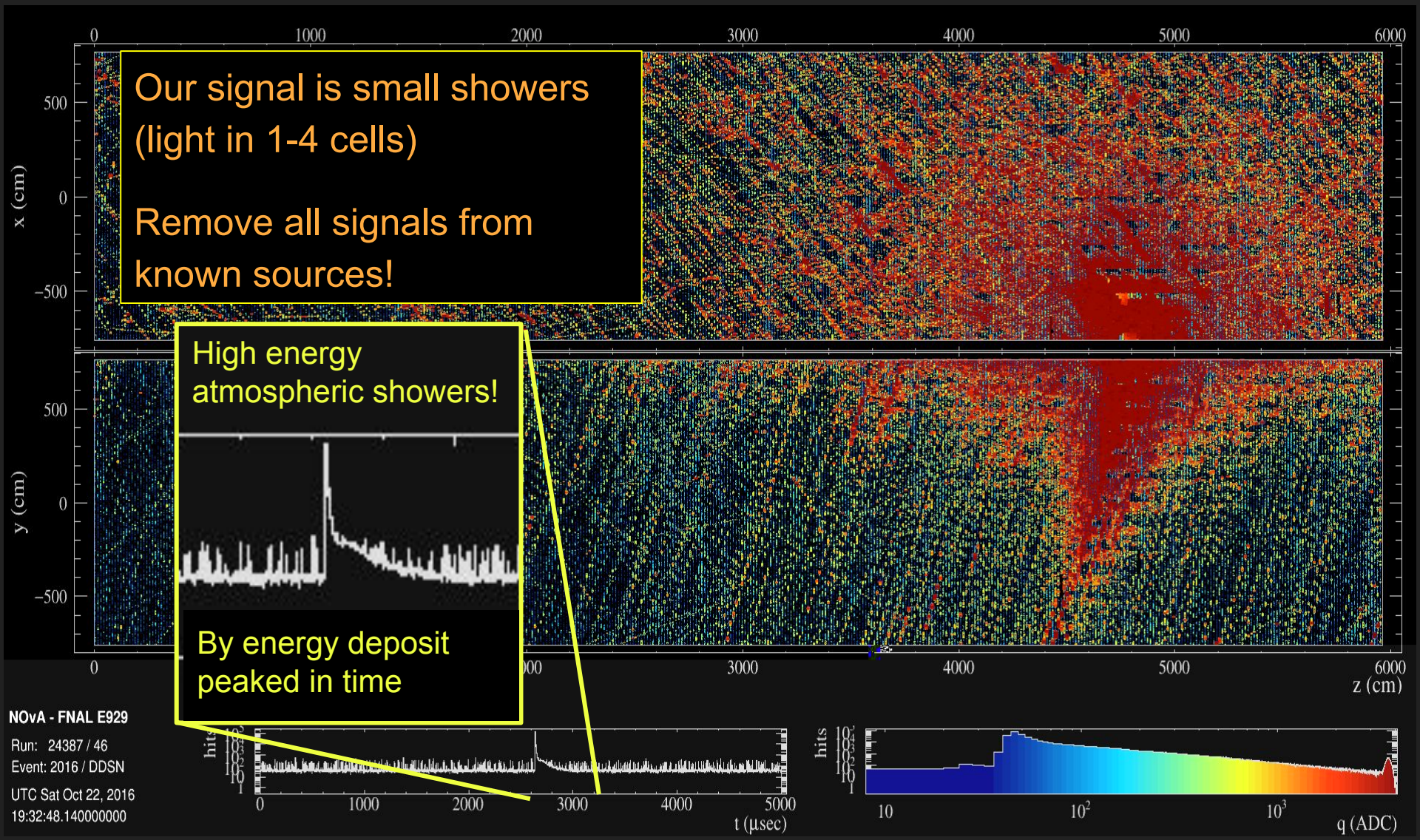

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Among remaining signals find groups:

- Close in space:
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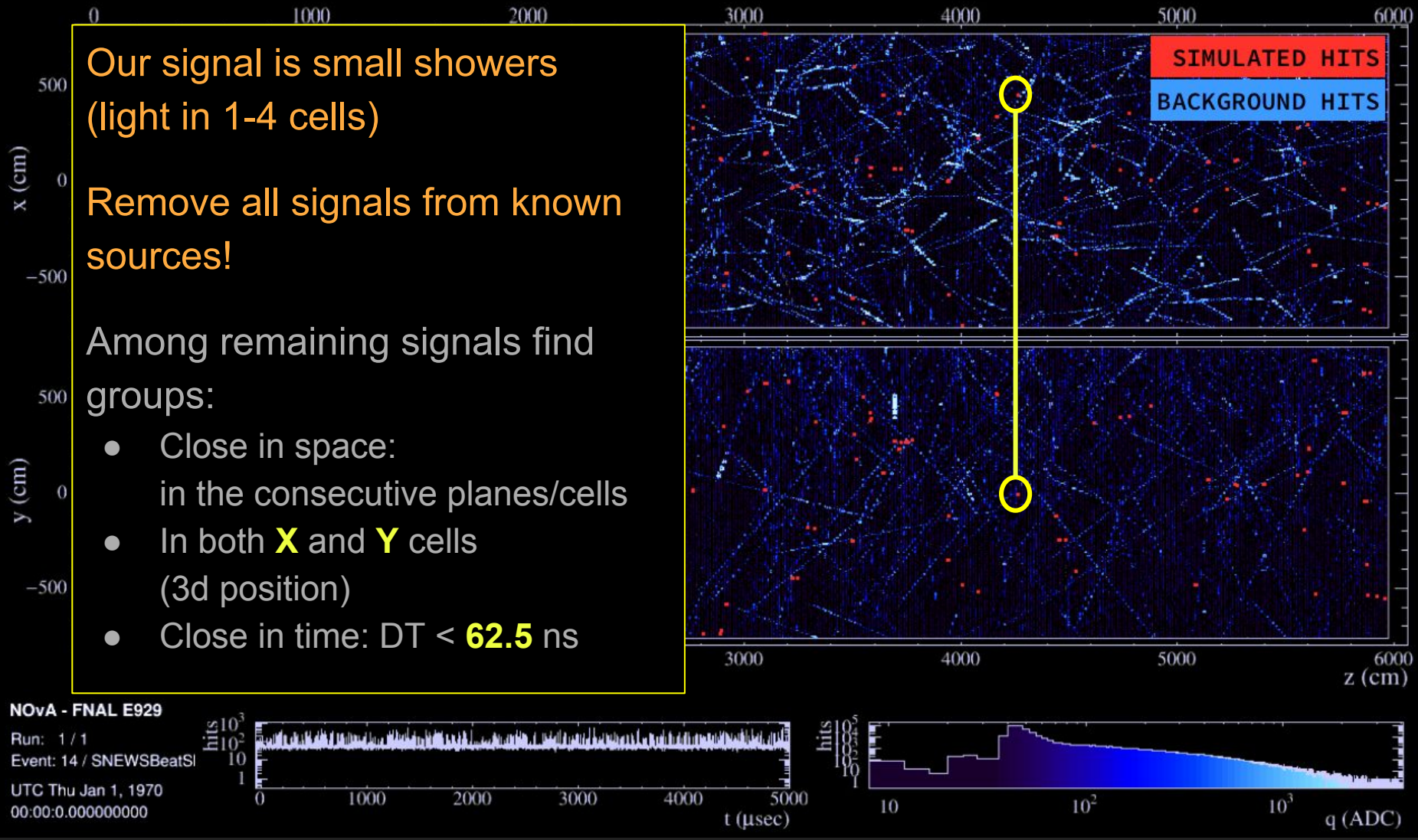
- In both **X** and **Y** cells
  (3d position)
- Close in time: DT < **62.5** ns



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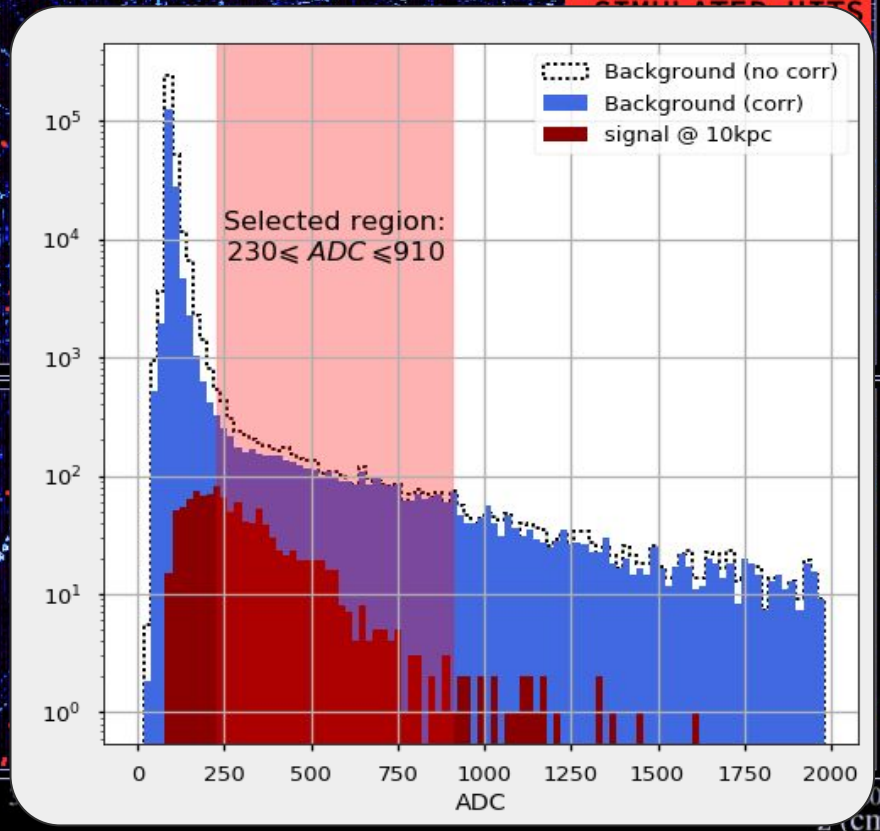
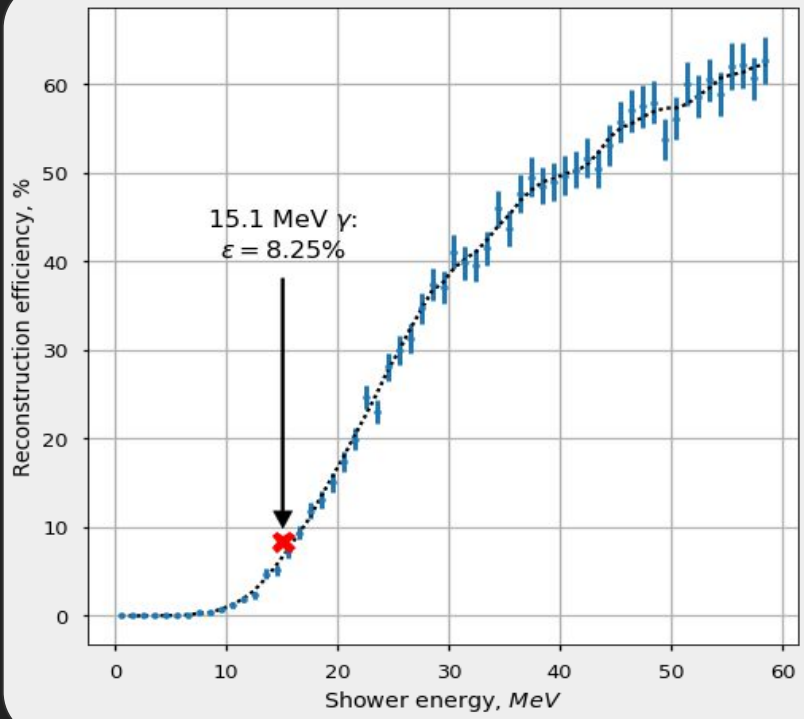
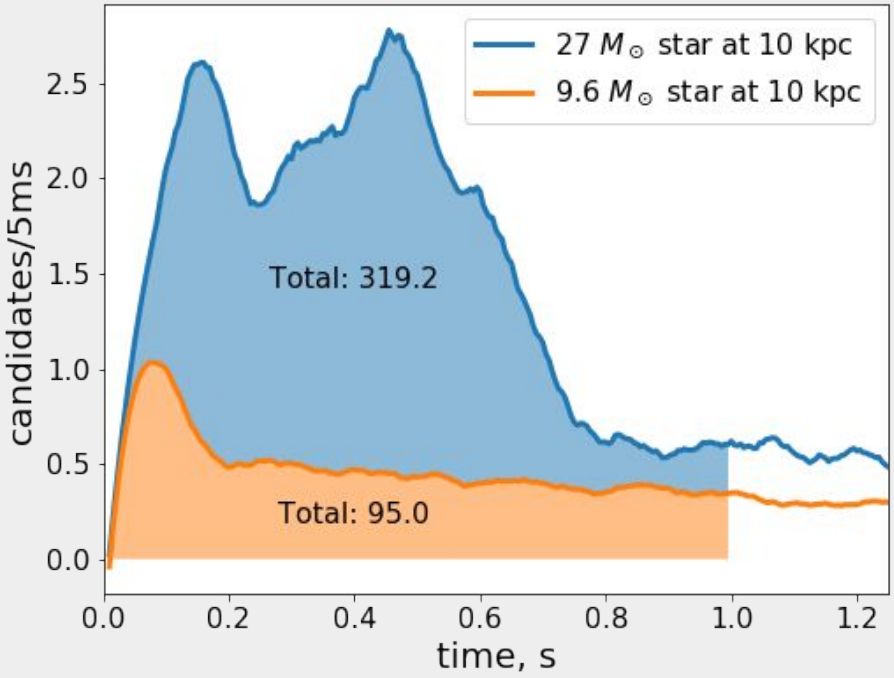
Select the signal region in the light amplitude



Results of the signal selection



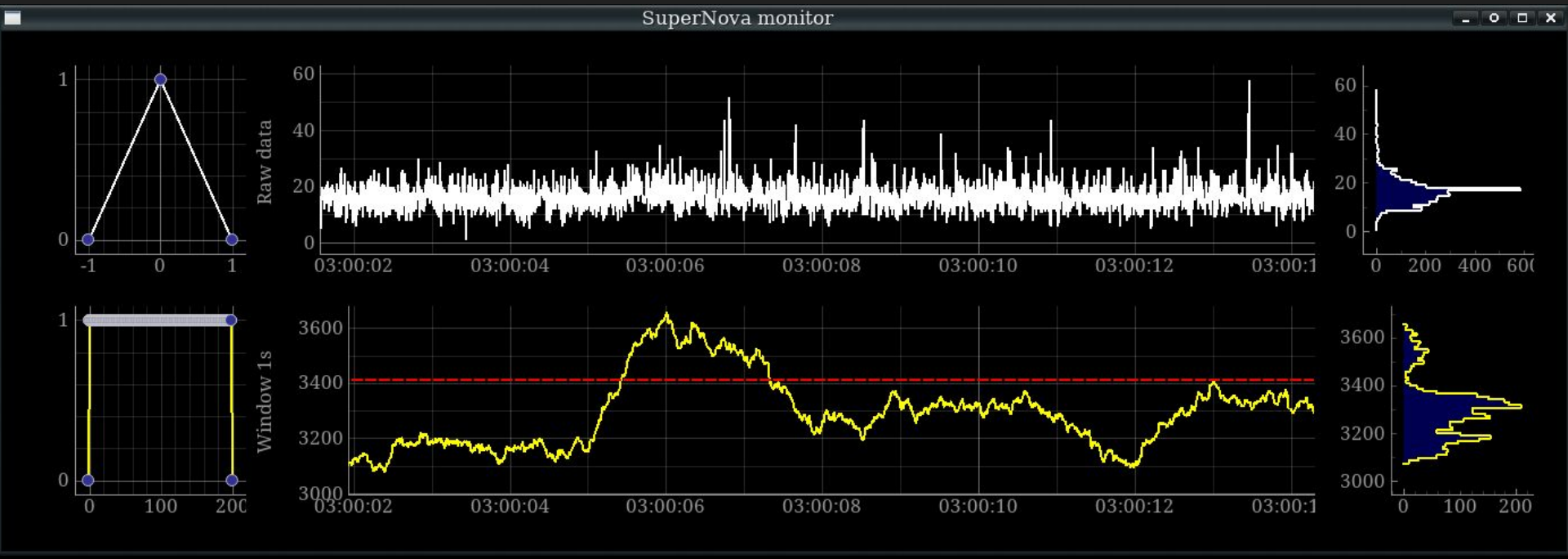


We trigger on the galactic supernova:
if we see the excess of interaction candidates in 1 second window.

Sounds easy, but we need to be monitoring this constantly, doing reconstruction in real time!

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 dedicated triggering system extends the NOvA physical program.

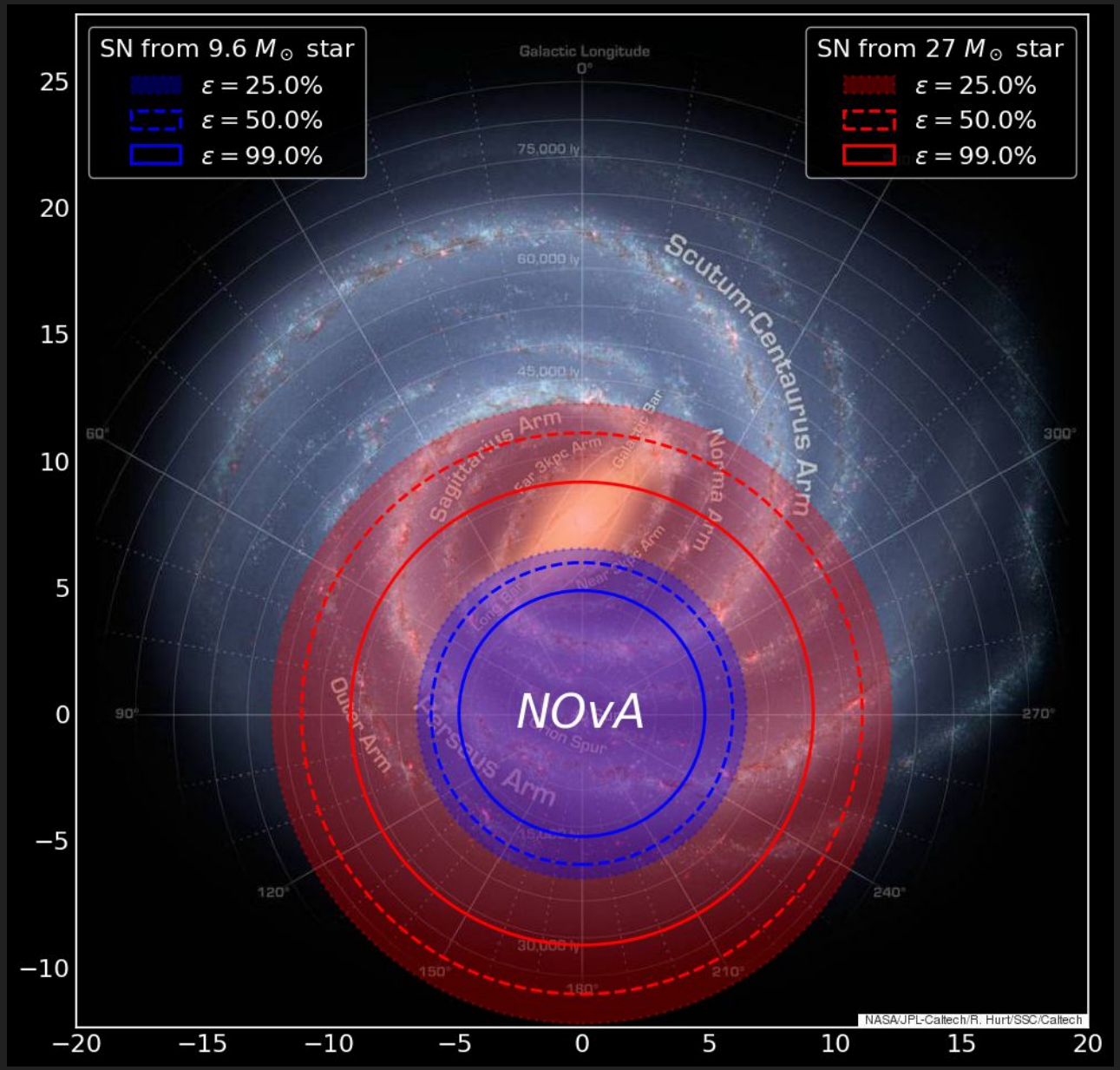
Supernova triggering system is performing signal selection and reconstruction in real time.

Operating since Nov 2017 with false triggering rate ~1/week.

We're getting ready to contribute to SNEWS.

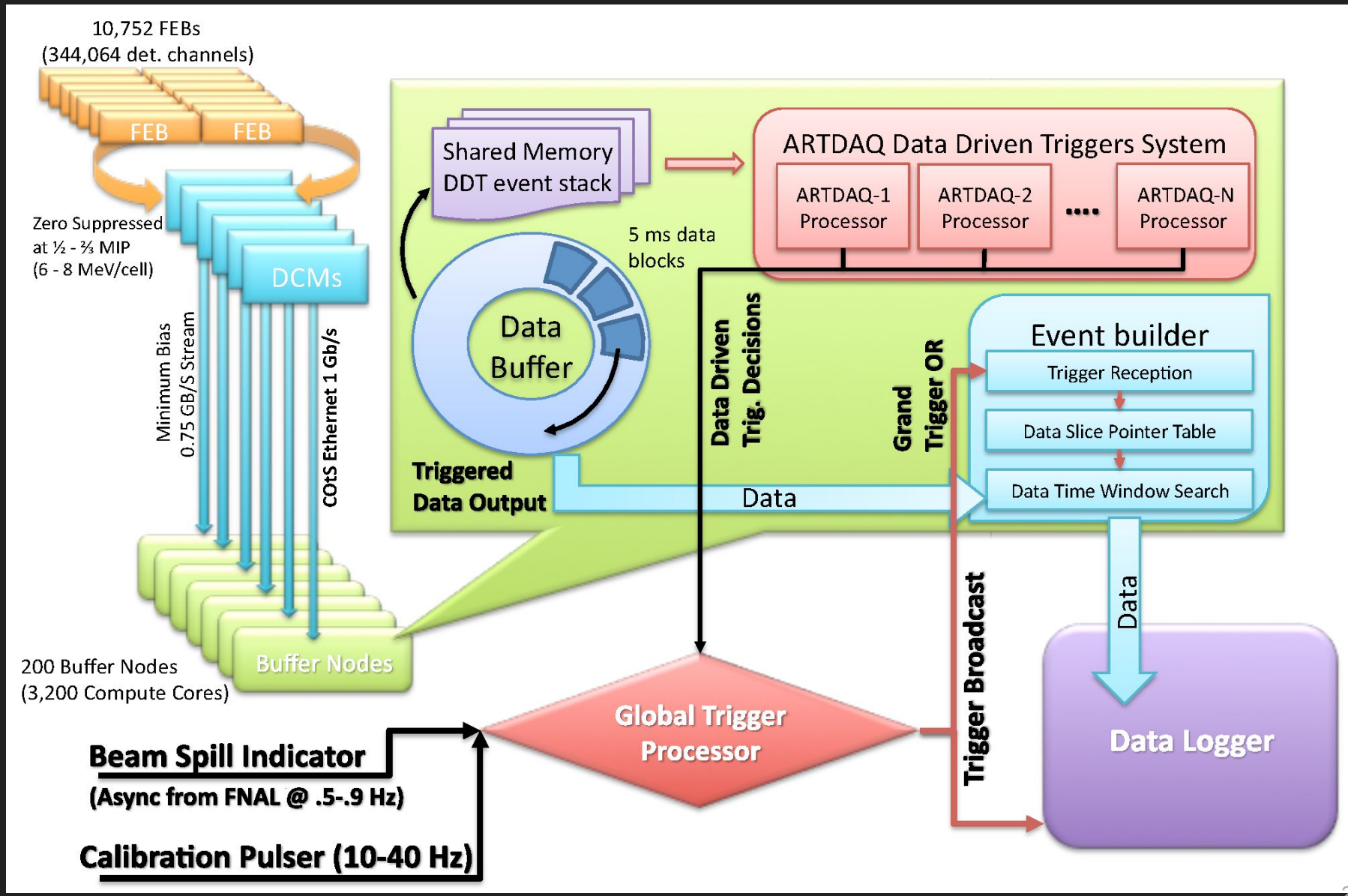
Upgrade is planned for this summer shutdown, including:

- new selection
- clustering
- statistical analysis
- lower threshold

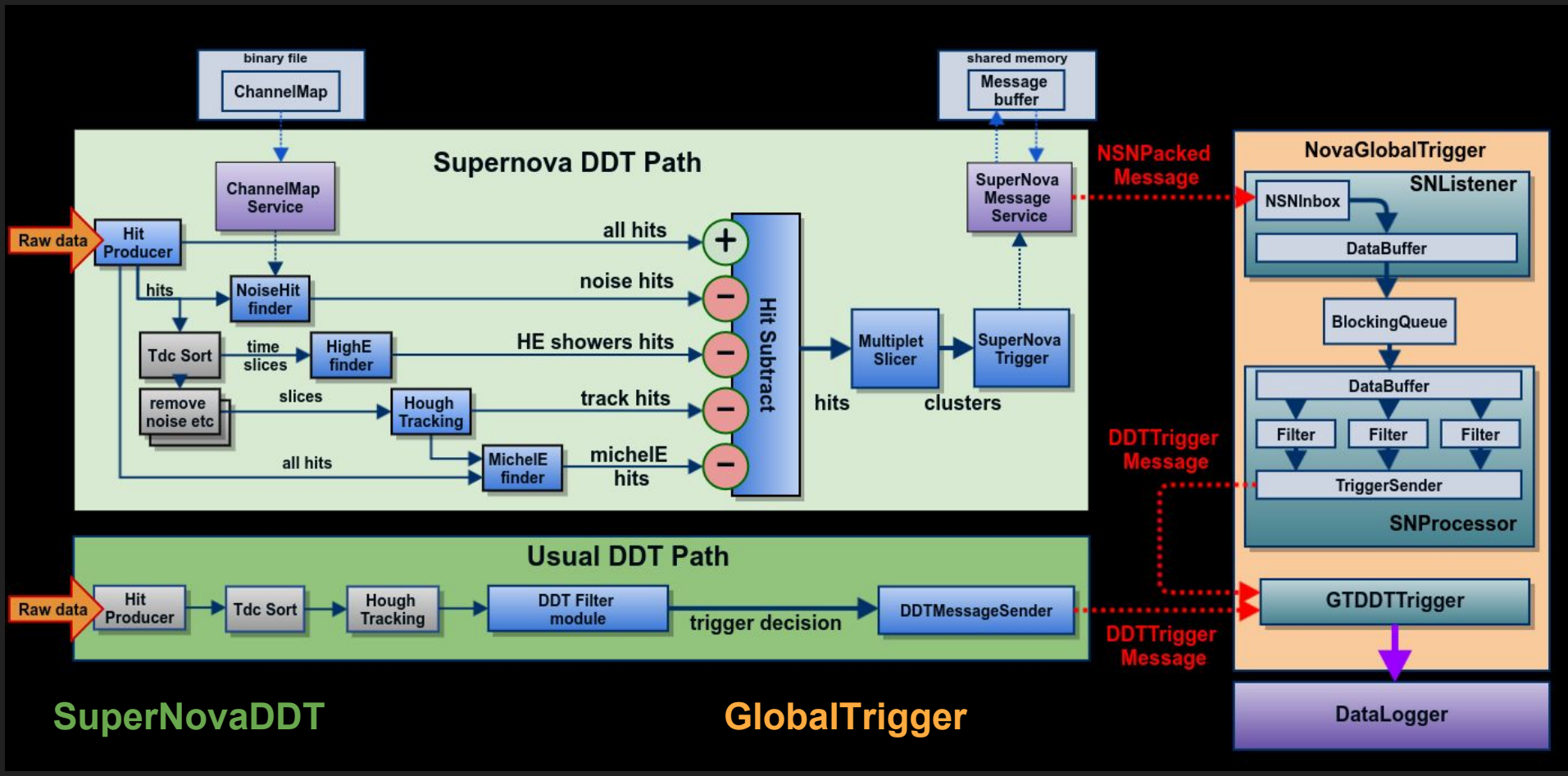


BACKUP

Data Acquisition system



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