Detecting galactic supernova with NOvA Far Detector

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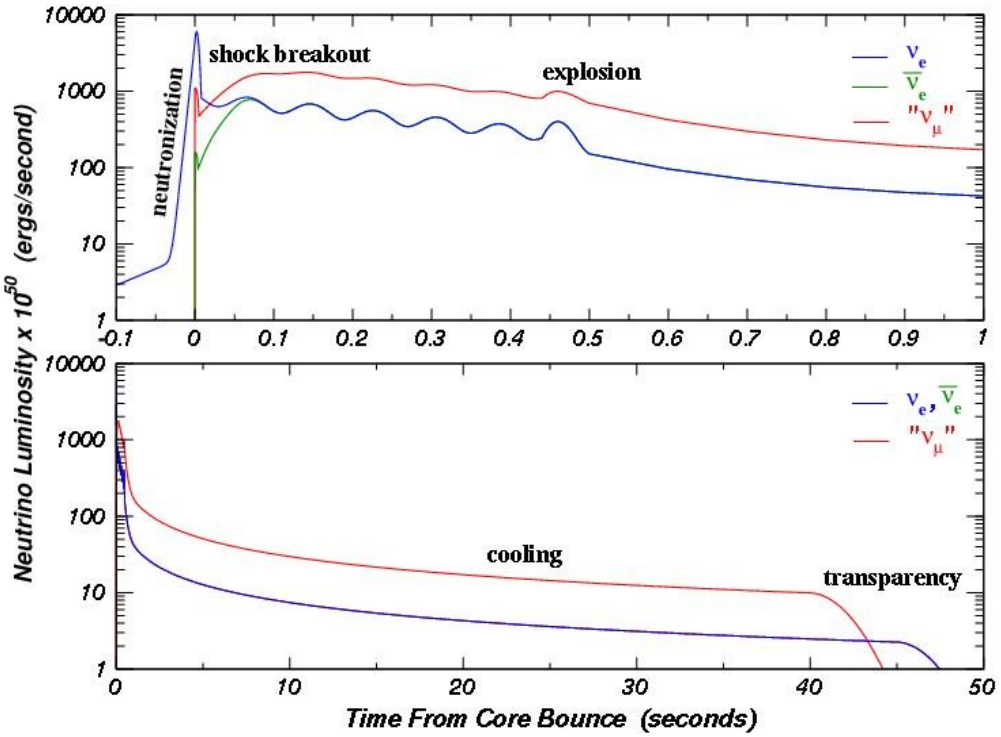
Supernova neutrino signal

- **Core collapse SN explosion emits ~10^{58} neutrinos**
- **They carry ~99% of explosion energy**



Motivation

- SN physics probe
  - Neutrinos carry information from SN center
  - Many different models exist
- Neutrino properties
  - Signal shape and spectrum depends on neutrino masses, mixing angles, sterile neutrinos etc.

    arXiv:1508.00785 [astro-ph.HE]
- Early SN warning for astronomers and other neutrino experiments

  Supernova Early Warning System (SNEWS)

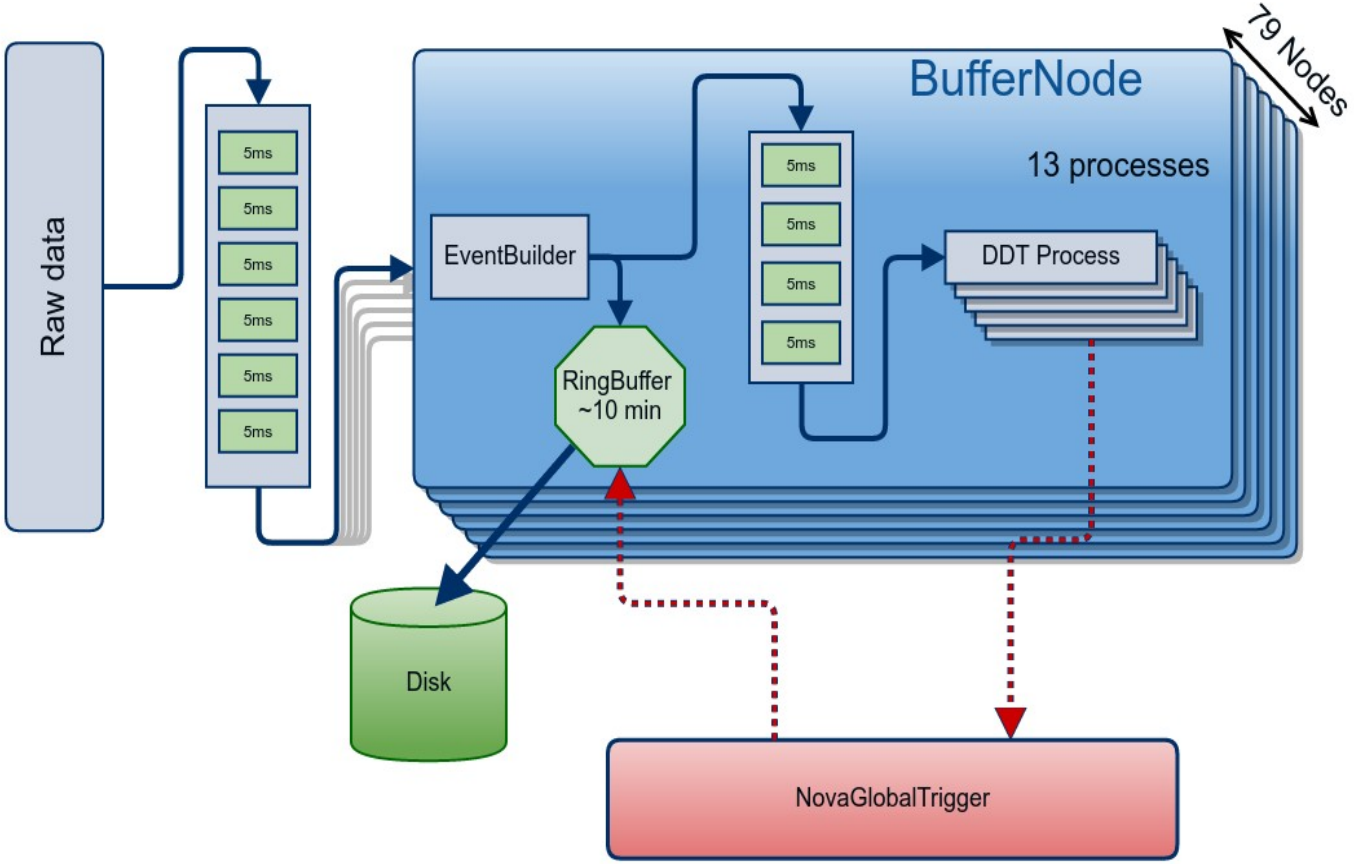
Challenges

- Need huge detectors
  - Collaborate with other experiments → global network
- Previously observed only once : SN1987a
- Galactic supernovas are rare: ~3 per century

  arXiv:1306.0559v1 [astro-ph.HE]

  We need to be ready!

NOvA Data-Driven trigger system



- All the data is sliced in 5ms blocks: *millislices*.
- Millislices are processed in parallel on *BufferNodes* in *DDT Filter processes*
- Filter process checks milliblock for:
  - Beam neutrino interactions
  - High cosmic ray activity
  - Monopoles, etc
- If something is found, *trigger signal* is sent, telling buffers to save data to disk for offline analysis

SuperNova neutrino detection in NOvA FarDet

SN neutrinos interacting in FD:

- nu_x: **NC** on **nucleus**
- anu_e:**QEL** on **nucleus** (IBD)
- nu_e: **elastic** on **electrons**

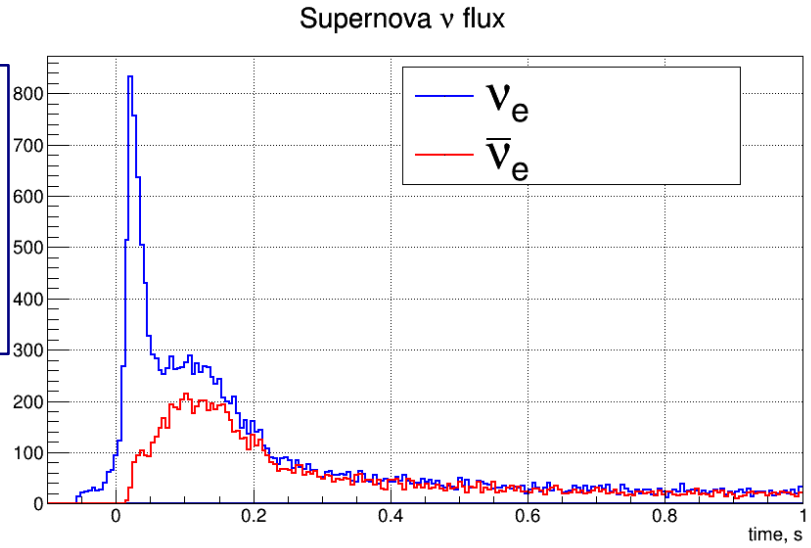
1) NOvA FD is on the surface
2) NOvA detectors are designed for measuring ~**2 GeV** neutrino interactions,

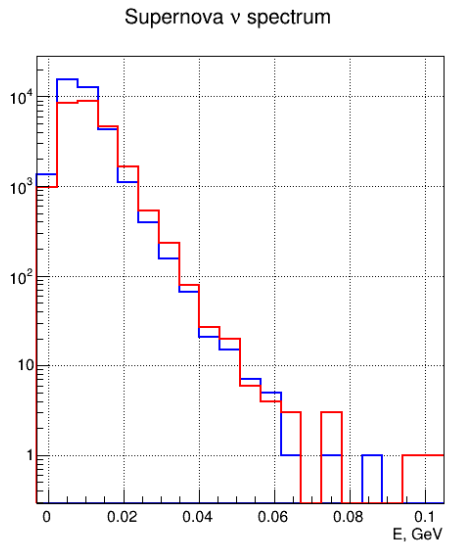
   but SN neutrinos are ~**10 MeV**

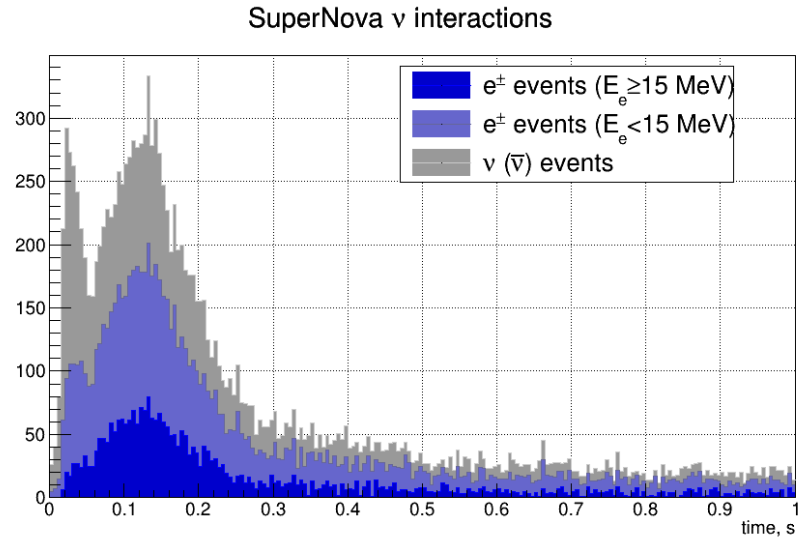
   - A dedicated background rejection procedure is required
3) NOvA DDT system works with milliblocks: **5ms** data chunks

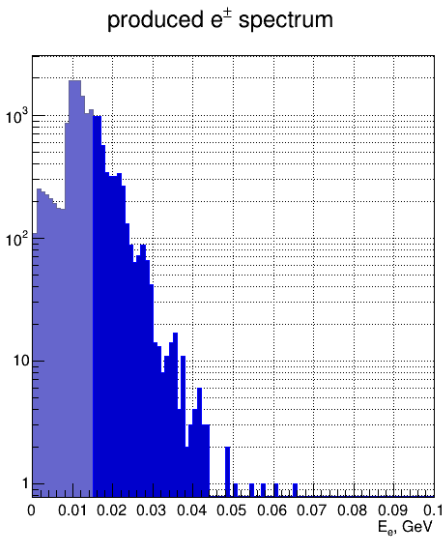
   But neutrino signal is extended in time for ~**1s**

   - We need to analyze the time structure continuously on the separate node









Analysis scheme

- **Neutrinos interact in FD**
- **Find SN neutrino interactions per milliblock (5ms)**
  - Selection of neutrino interactions to reduce BG
    - Reject muon track parts
    - ADC cut
    - Noise hits rejection
  - Count number of interaction candidates
- **Monitor interactions rate vs. time**
  - Filter the time sequence, to enhance signal shape
  - If we see a signal shape above BG level:
    - send trigger signal
- **Save the data for triggered time range**

Analysis scheme

- **Neutrinos interact in FD** — DAQ

- **Find SN neutrino interactions per milliblock (5ms)**
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  - Count number of interaction candidates — DDT

- **Monitor interactions rate vs. time**
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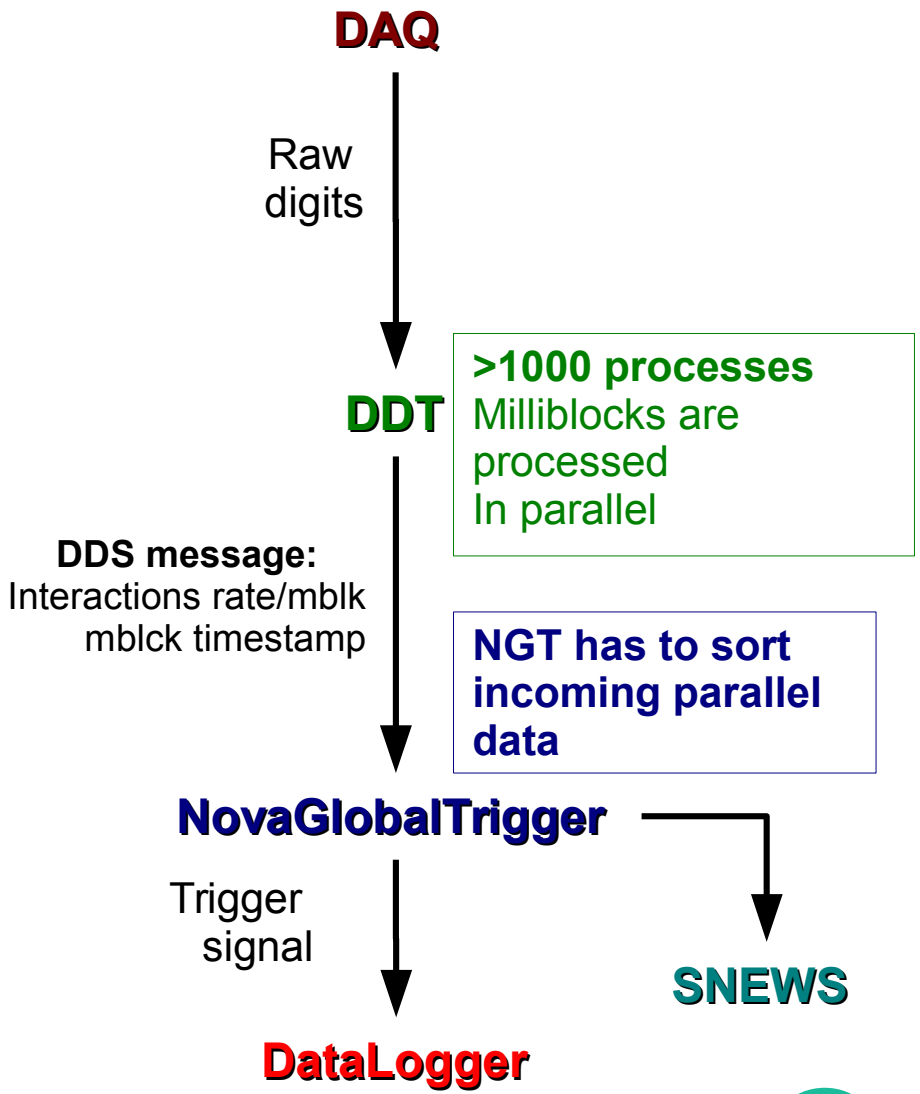
  - If we see a signal shape above BG level:
    - send trigger signal — NovaGlobalTrigger

- **Save the data for triggered time range** — DataLogger



Signal vs. Background selection

Signal model for BG rejection:

- Garching SN flux model
- distance=7.5 kpc (galactic center)
- Only IBD positrons are considered
- Positrons are input for geant detector simulation

Signal candidates are uncorrelated in space

Background sources are numerous:

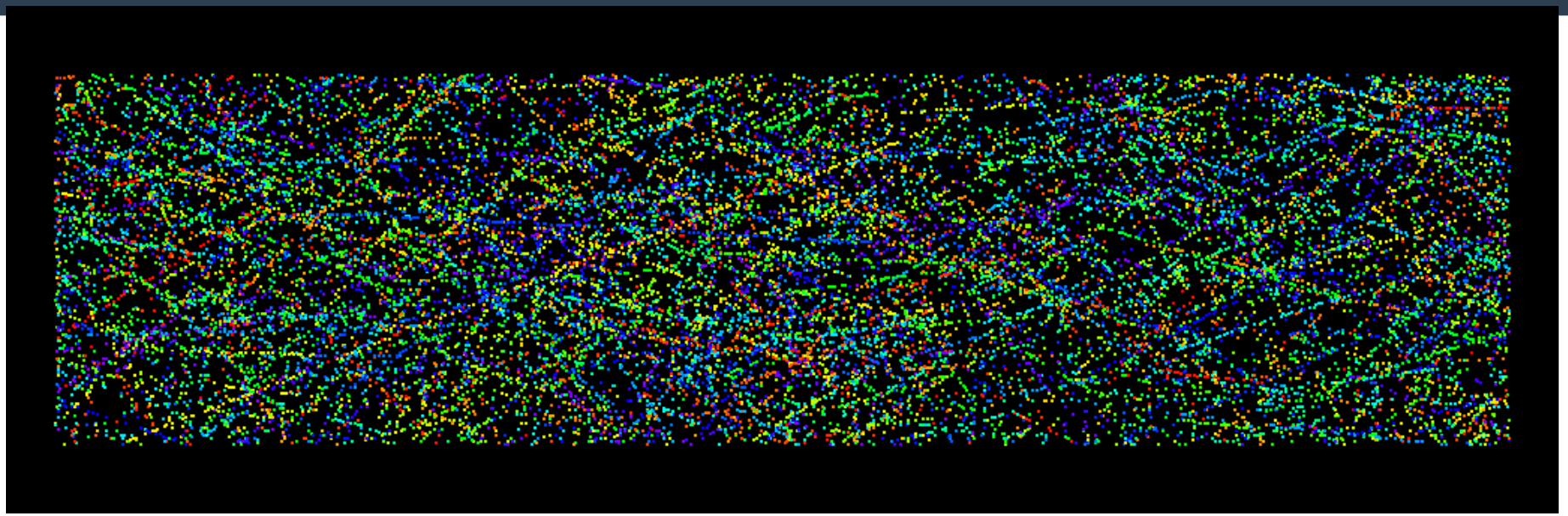
- Muon induced background
  - atmospheric muons
  - delta,michel electrons
- Random hits coincidence (in time in space)
  - Mostly noisy channels
- Other
  - Neutrons, neutrinos

Background should be uncorrelated in time

We don't need a precise BG model: we can use data readout

Have to be careful with the signal model though...

Inspecting BG



Continuous readout data: all candidates position

- Mostly parts of muon tracks.

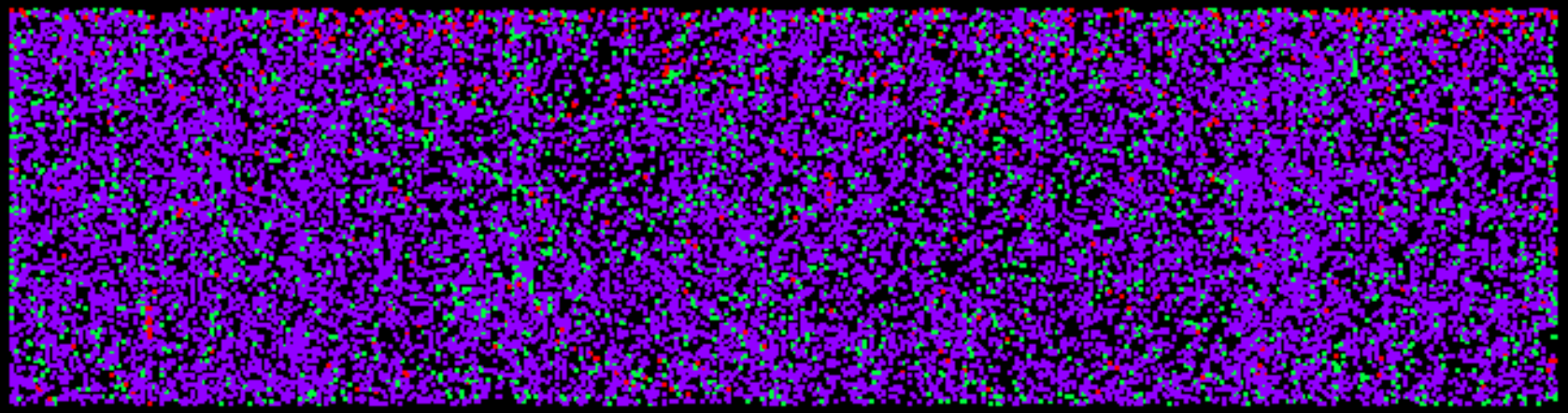
  Reject hits, associated with reconstructed tracks

Interaction candidate:

- Several hits in X and Y
- Close in time and Z plane
- Hits in both views (XZ and YZ) are required

BG suppression: ADC cut

Color: ADC cut



ADC (signal amplitude):

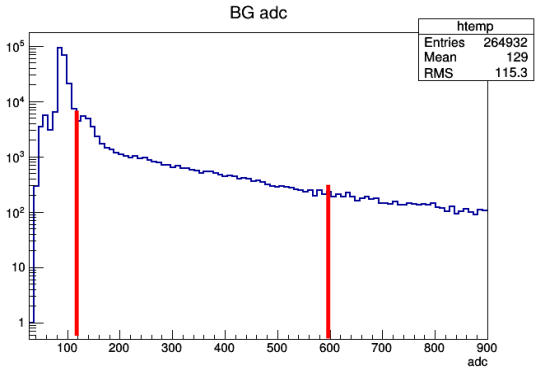
adc<120 – random coincedence clusters

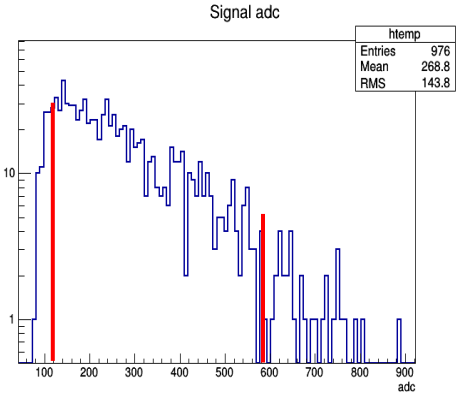
adc>600 – High ionizing particles

120<adc<600 – SIGNAL

This is rough cut!

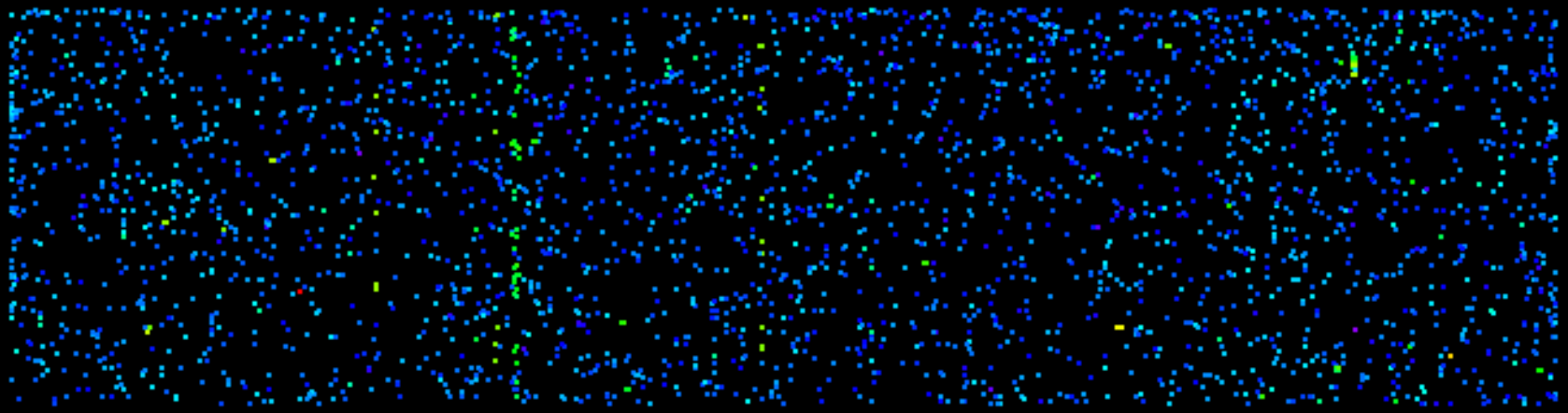
ADC for the same energy depends on the distance to readout





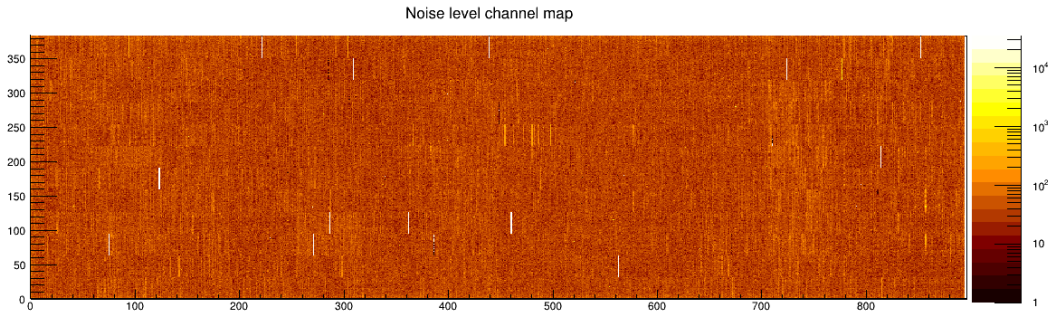
BG suppression: noisy channels

Color: channel noise level

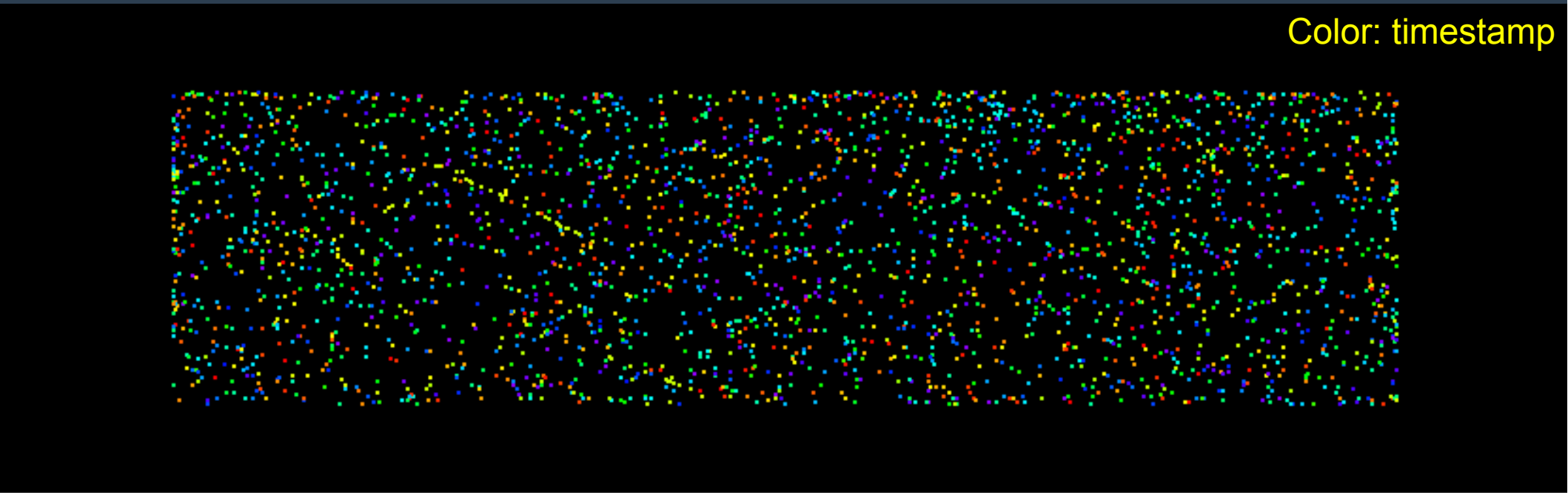


Noisy channels cut:

- Lines along X and Y are caused by random coincidence with high-noise channels.
- To remove it we use the map of channel activity for last 250ms



BG suppression: result



Some tracks are still visible

- Apparently, these tracks were not reconstructed

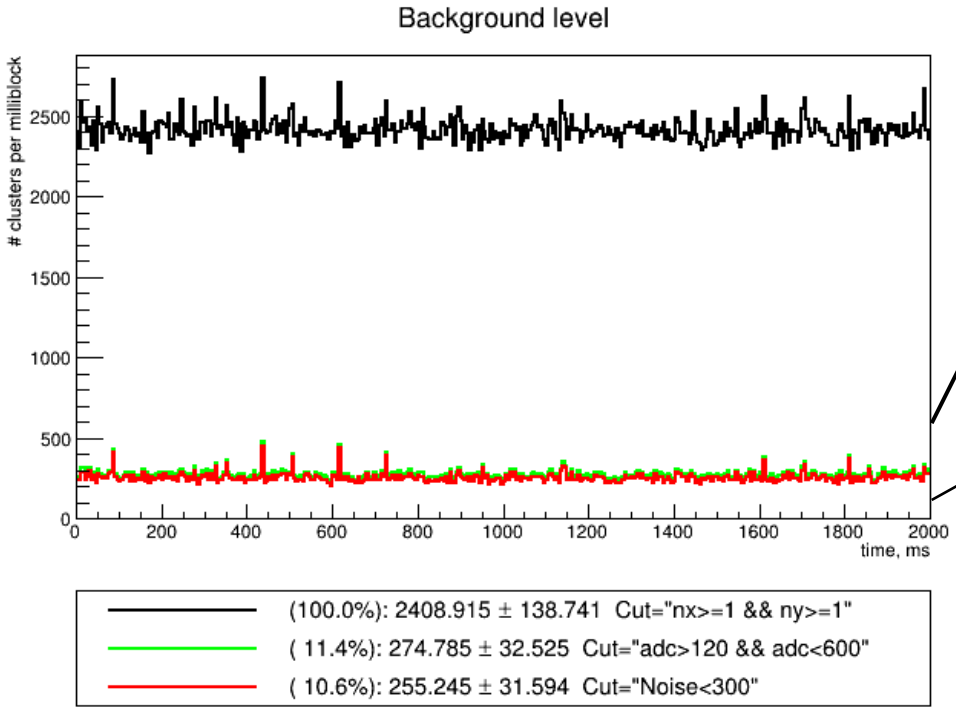
  We need to study and improve tracking efficiency

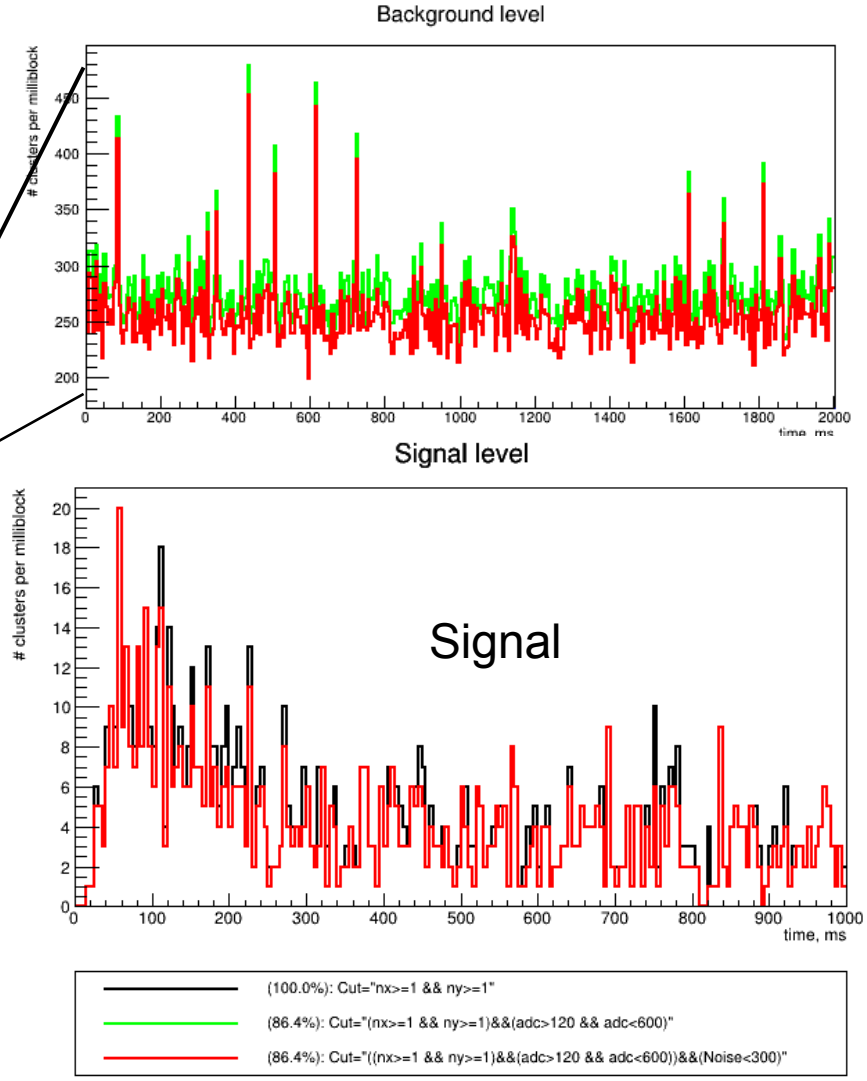
Uncorrelated background

- Random hits coincidence?
  - Slicing algorithm improvement
  - Better ADC cut is needed
- Michel electrons from muons decay?

  MichelE filter is needed

Background rejection efficiency





- **BG is still too high, but we're getting closer**
- **BG variation is higher than poisson sqrt(250) → BG is corellated (not just independent clusters)**
  - "spikes" mostly because of unreconstructed muon tracks
- **Next step: Overlay SN signal with cosmics, to control the cut efficiency for signal sample**
- **Recheck with new simulation**

Summary

- **Conclusions**
  - Detecting neutrino signal from a galactic supernova provides many physical opportunities
  - NOvA far detector can be used for galactic SN detection
  - A Supernova trigger system has been developed

    and deployed on NOvA Far Detector buffer nodes
  - Background rejection study is in progress

    there are many ways to improve s/n ratio
- **Next steps**
  - Improve track reconstruction
  - Find and remove hits from Michel electrons
  - Test the SN signal simulation with different models
  - Use machine learning for signal selection
  - Using Near Detector can increase sensitivity