Triggering on SN with DUNE + some more on simulations

Pierre Lasorak

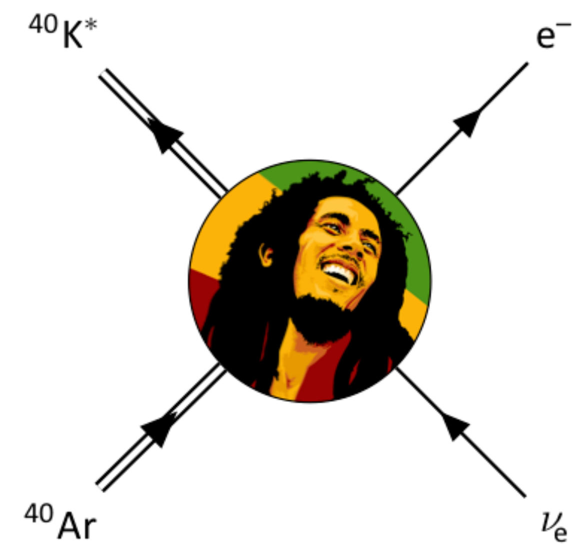
Content

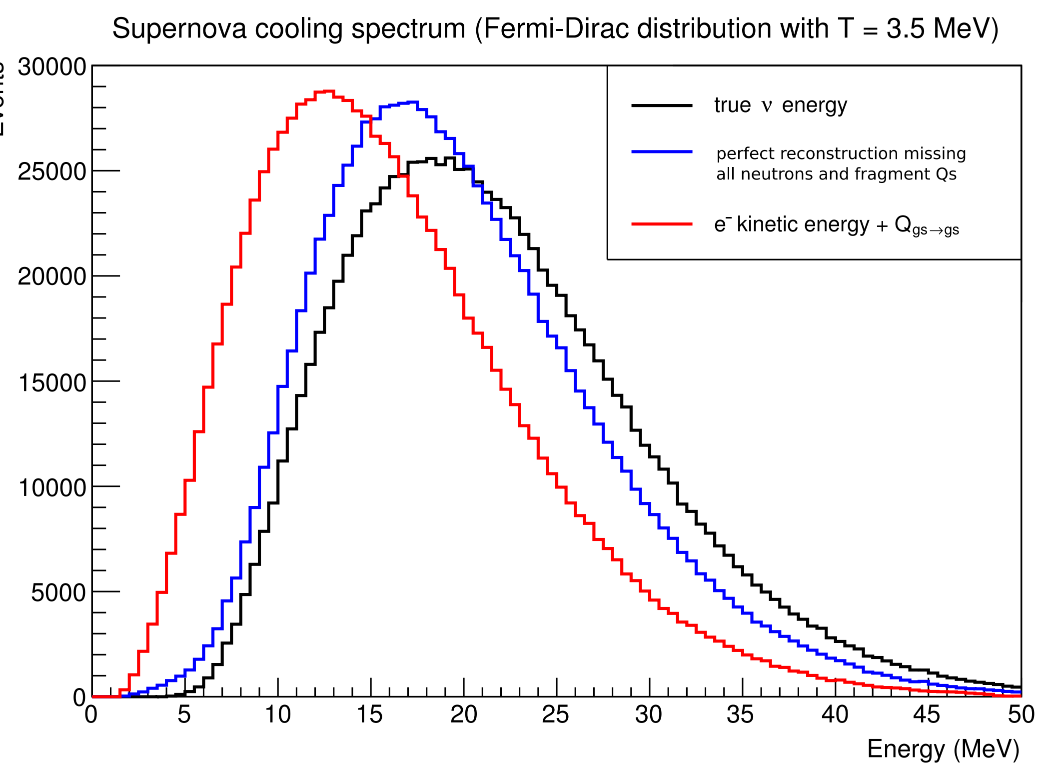
- More about the event generation for SN
- Back where we left it this morning.
  - Hit finder and then what?
- Clustering algorithm
- Burst trigger
- PDS triggering
- Future of these studies
- Other approach:
  - Machine learning

MARLEY

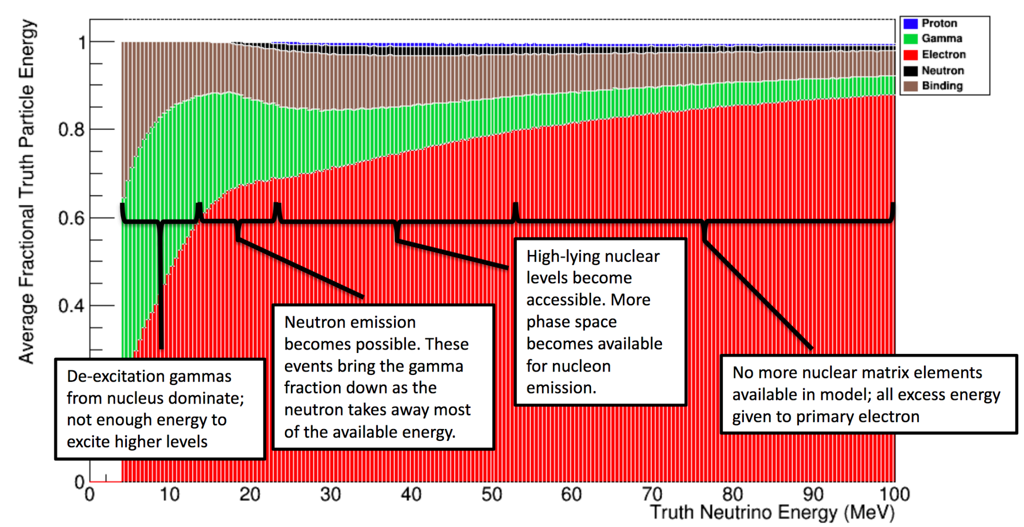
- Goal: generating a particle list, which are expected to come from a SNν interaction.
  - Implements ν_e + Ar → e^- + K^*
  - Implements all the decay gammas
- Main channel for neutrino interactions in Ar.

Note the * after K
→ FORBIDDEN TRANSITION

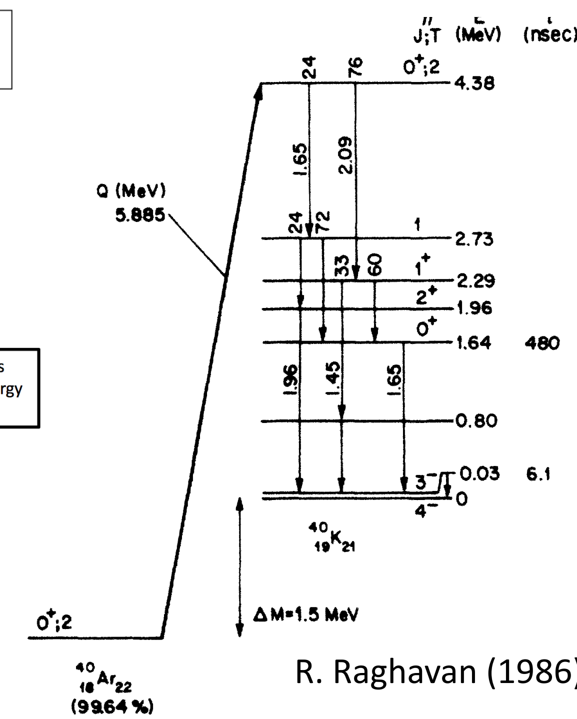




Steven Gardiner



Erin Conley



R. Raghavan (1986)

FIG. 1. Level scheme of ^{40}Ar-^{40}K relevant to ν_e capture in argon.

Radiological generator

- A event generator that generate the decay products of the radiological decays.

Background	Origin	Rate
Argon-39	Intrinsic in the Argon	1.01 Bq/kg
Krypton-85		115 mBq/kg
Radon-222		40 mBq/kg
Argon-42		92 μBq/kg
Cobalt-60	APA frame structure	45.5 mBq/^{60}Co kg
Potassium-40	CPA	4.9 Bq/^{40}K kg
Neutron	Surrounding rock material	10^{-5} cm^{-2}s^{-1}
Polonium-210	Photon detector system surface	0.2 Bq/m^2

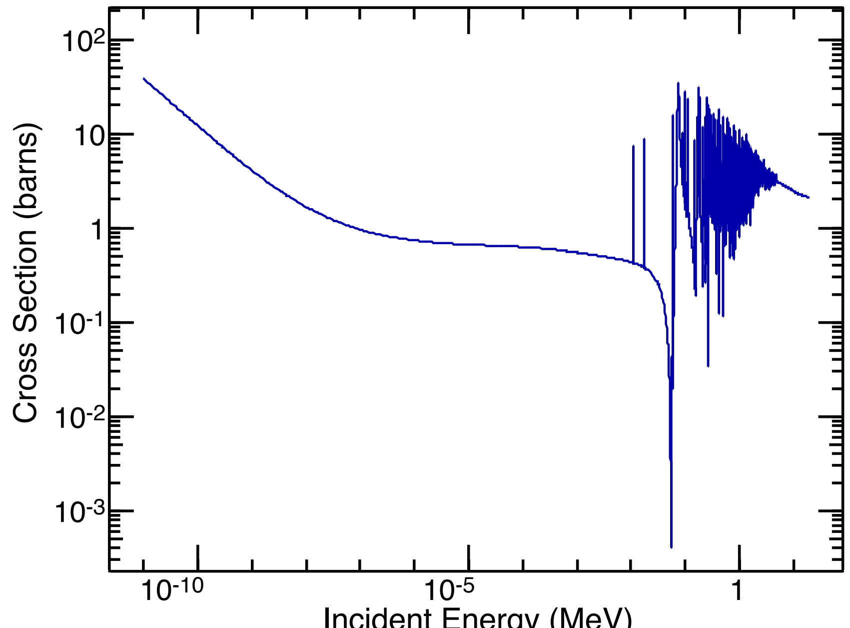
Think about this number for a moment. (← 1.01 Bq/kg)

- Takes into account the position:
  - Neutrons are coming from the side
  - Polonium from the surface of the PDS…
- Some of them have a rather "crude" implementation:
  - No coincidence (some decays do have several decays following each other c.f. BiPo, or Uranium-238 spontaneous decays…).
  - Some people are working on this, it's going to get better!!

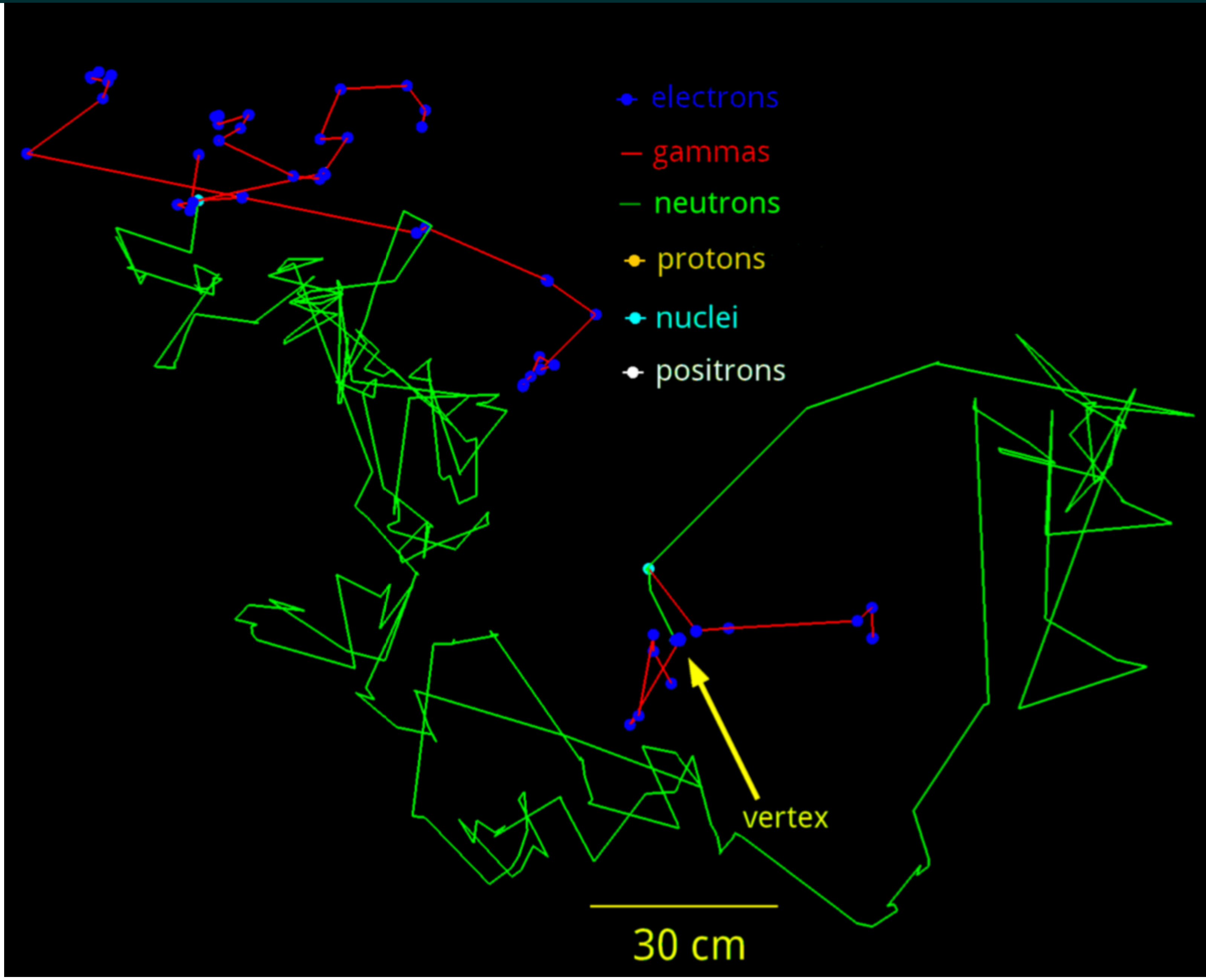
Challenges: Neutrons

- For energy reconstruction:
  - Neutrons travel long distance
  - Very small reactive cross section (anti-resonances!!)
- For background:
  - Neutrons have similar energy depositions to low-E ν
  - From spallation + uranium in the rock and cement

Neutron total cross section for ^{40}Ar



ENDF/B-VII.1

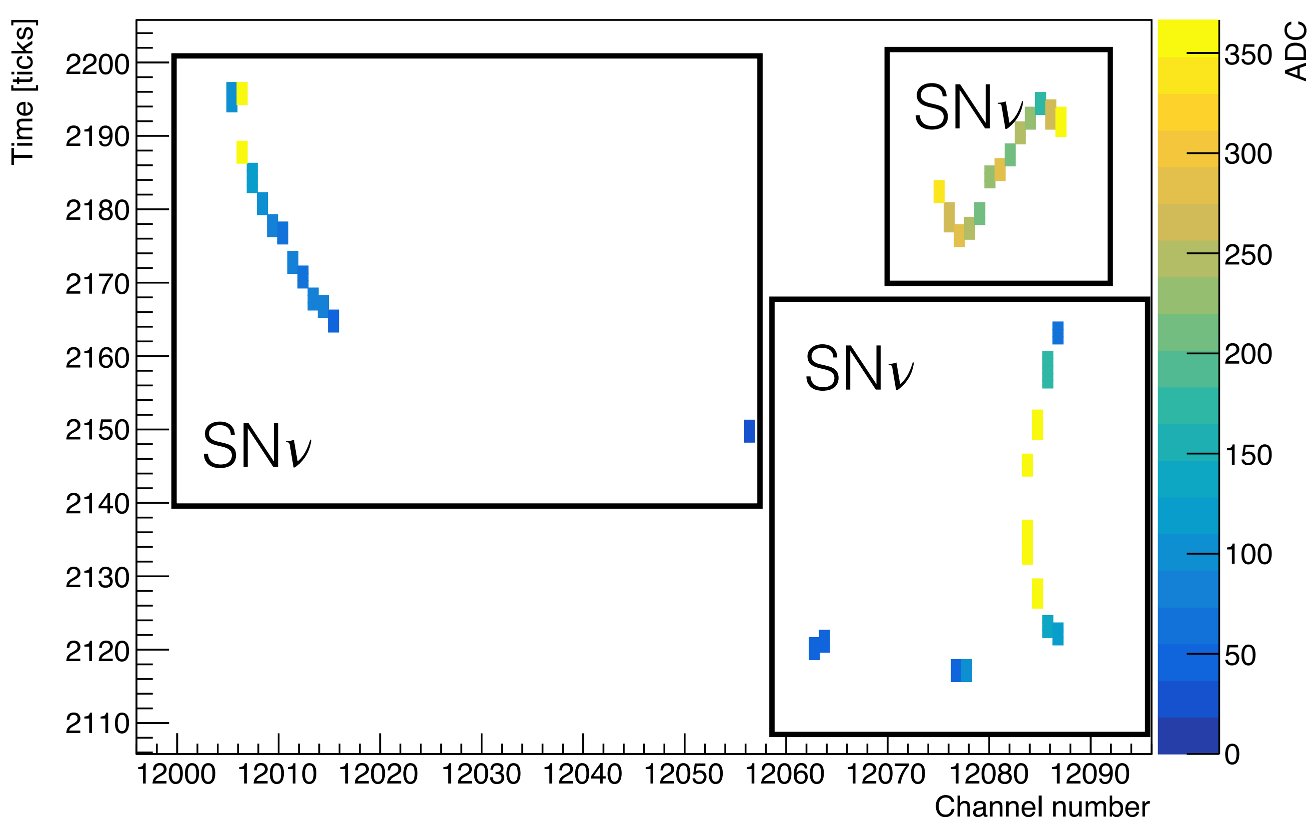


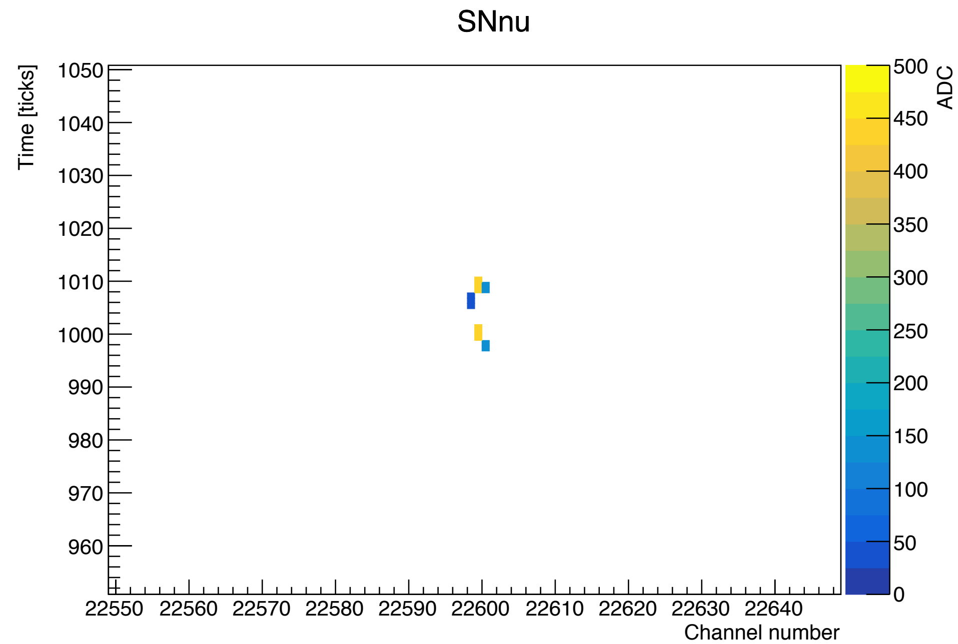
- This is why neutrons are a problem:
  - Energy deposition very close to low energy neutrino event (solar, SN)
  - They can be everywhere!

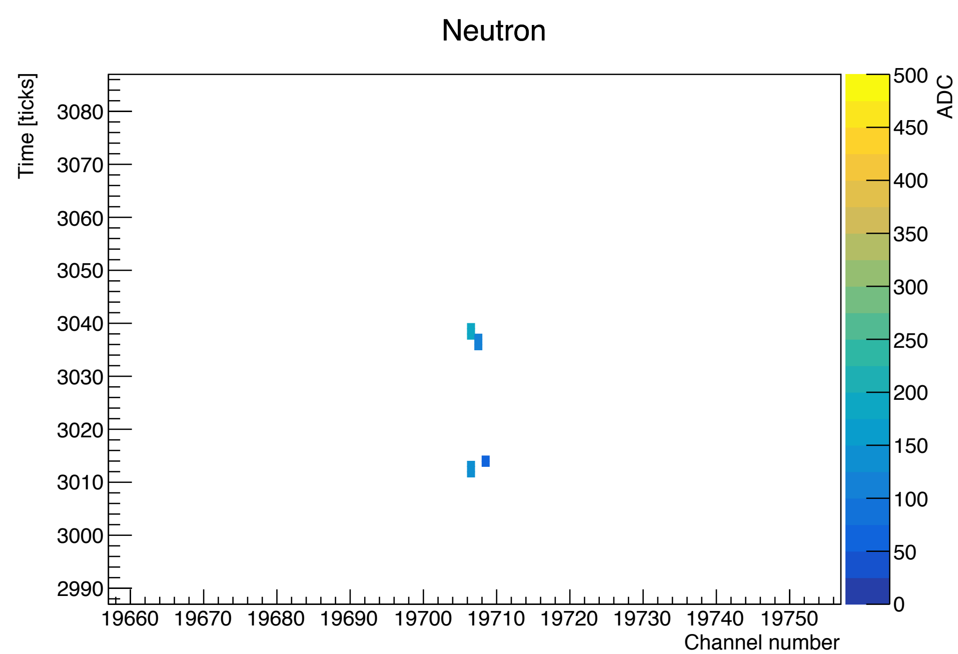
SN interactions
Neutron interactions

- Home-made event display (you should try to make yours!)
- Neutron can create similar energy deposition

High energy SN interactions
on collection wires

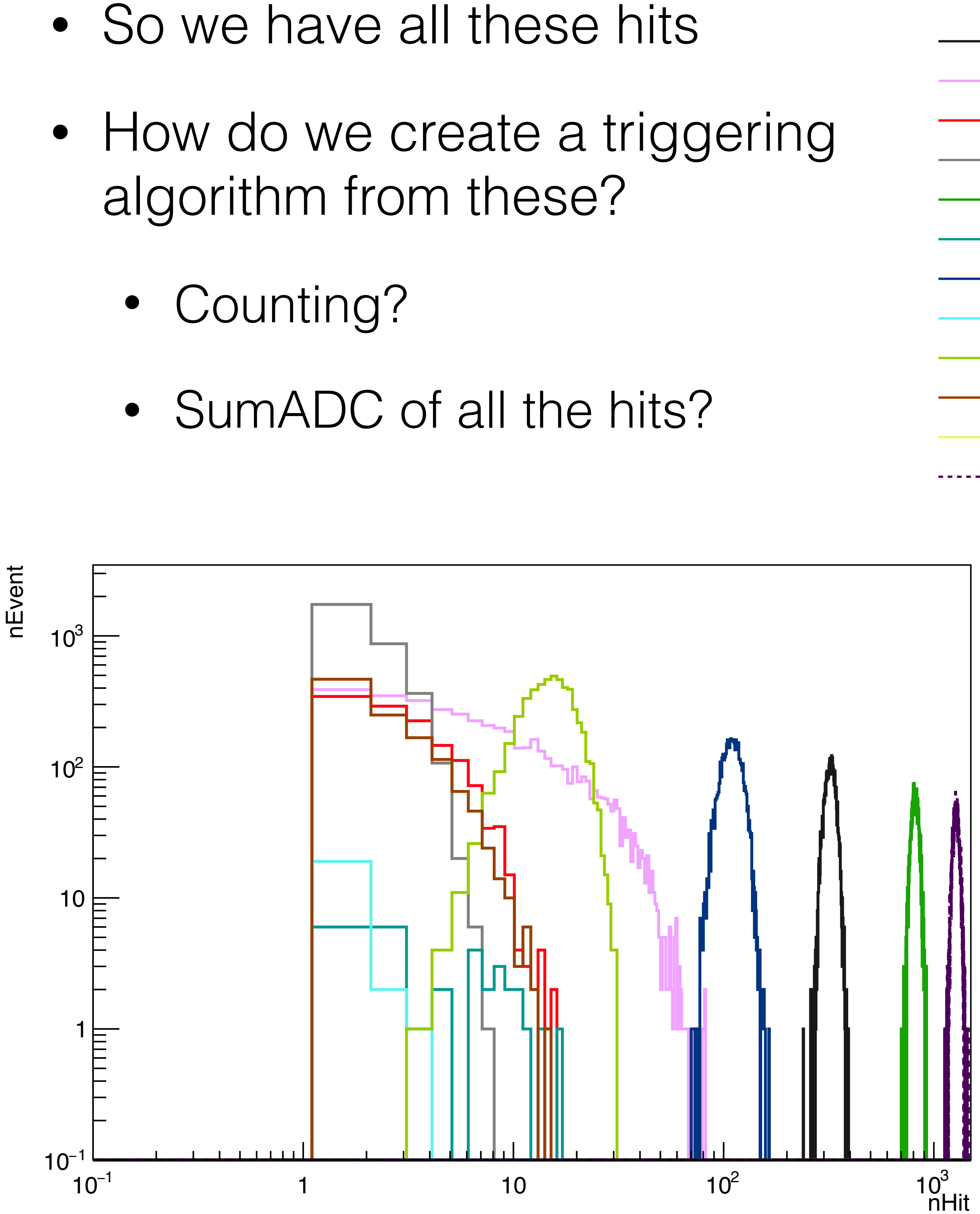




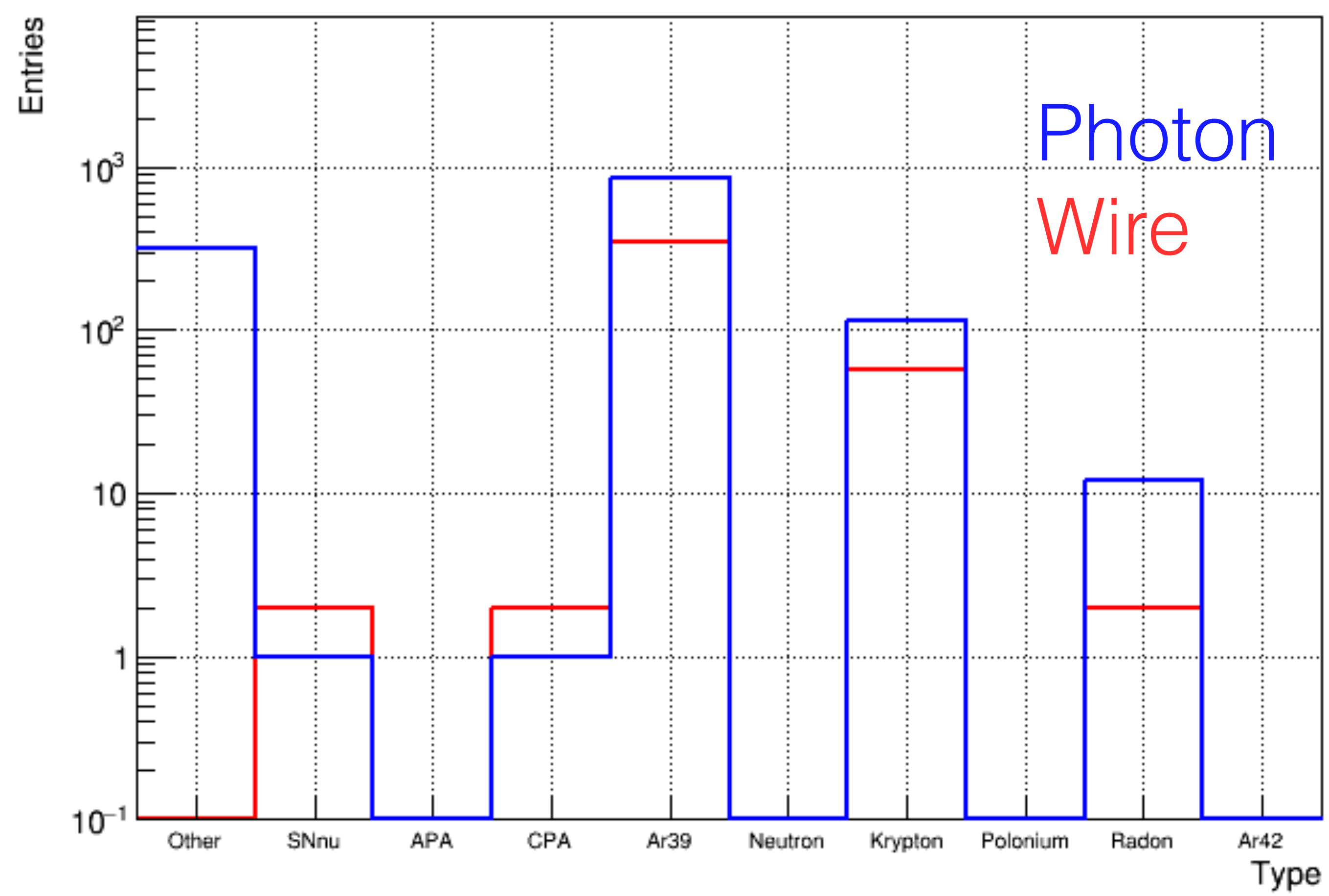


The triggering problem

- So we have all these hits
- How do we create a triggering algorithm from these?
  - Counting?
  - SumADC of all the hits?



"Hit" is a data object which contains:
- Time (tick)
- Time extent (RMS)
- Amplitude or integral (or both)
- Channel number



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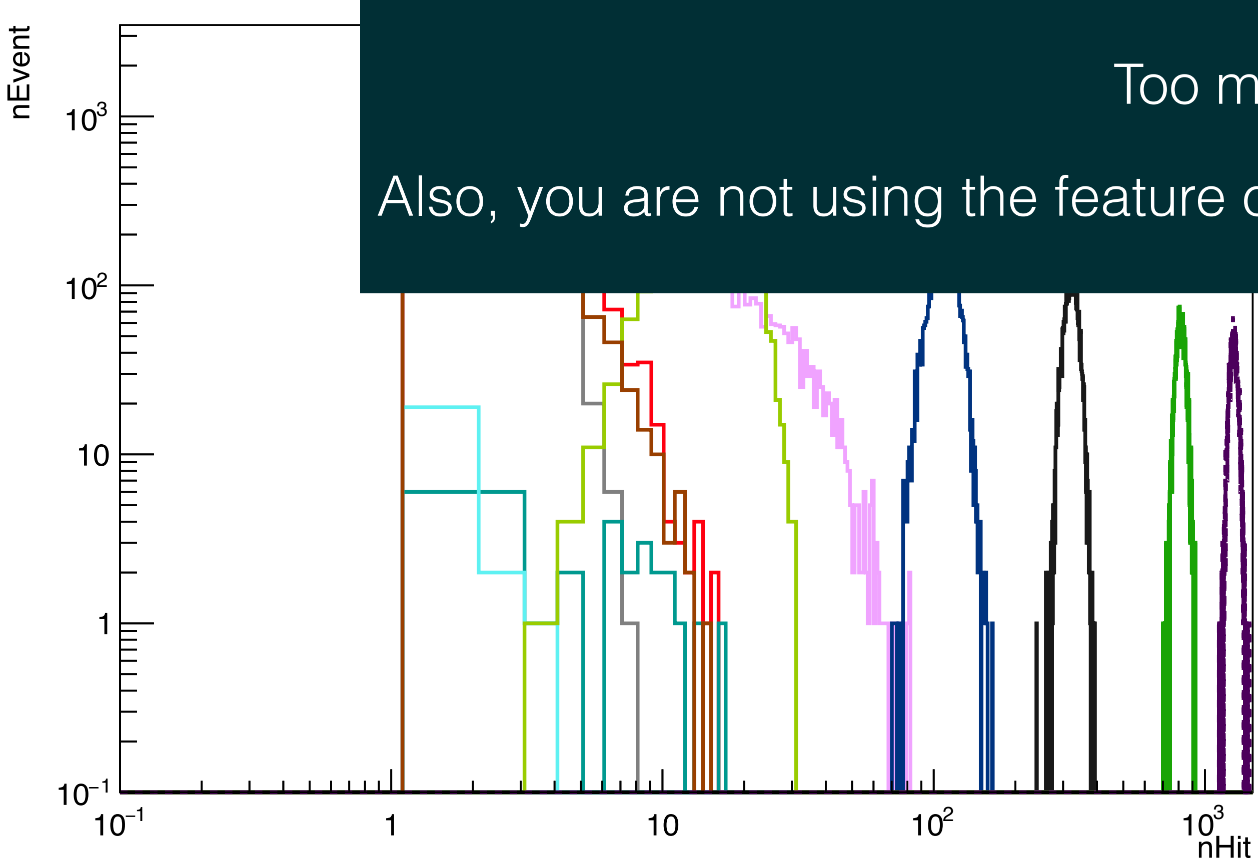
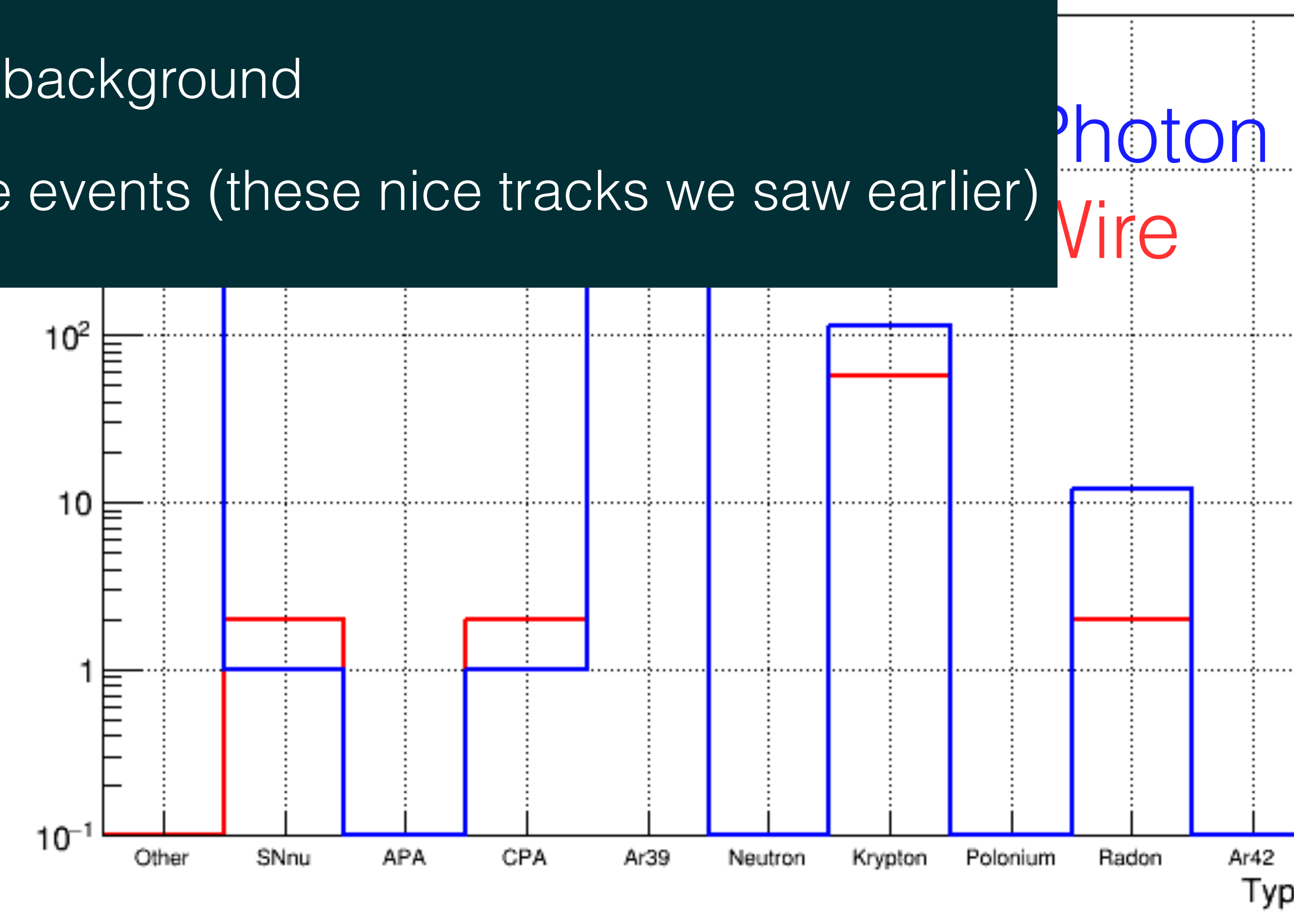
Other (not BT)
SNν
APA
CPA
Ar39
Neutron
Krypton
Polonium
Radon
Ar42
AllBackground
All



None of these will work:

Too much background

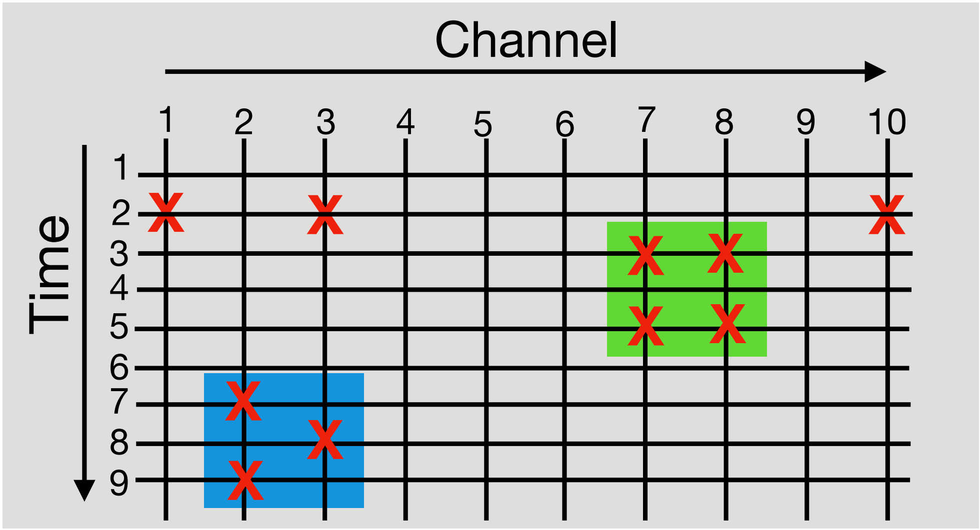
Also, you are not using the feature of the events (these nice tracks we saw earlier)



Clustering

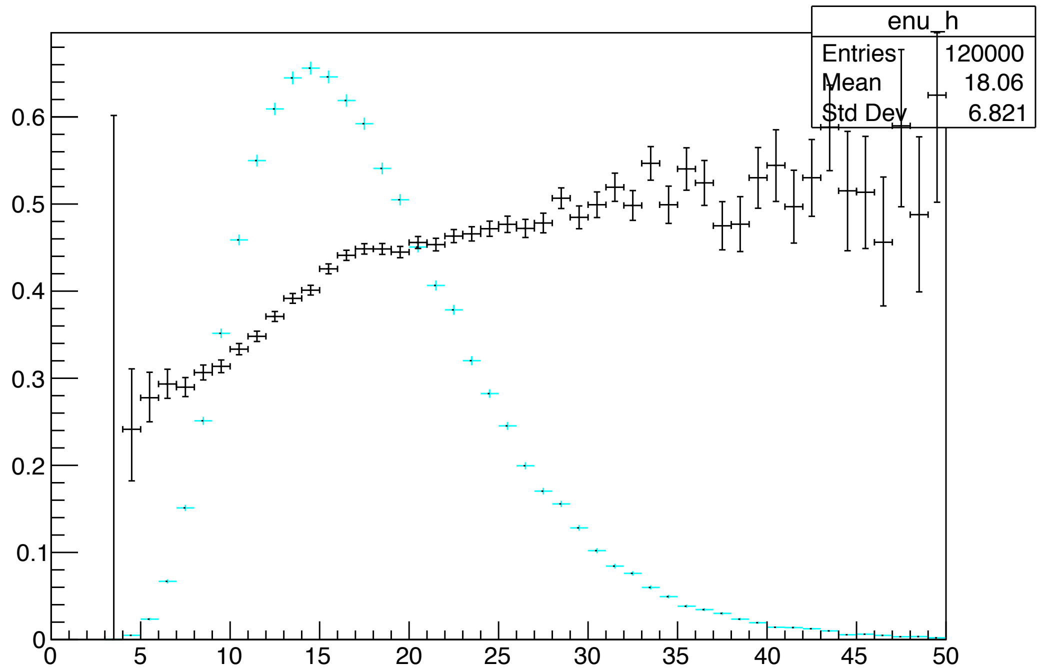
- Instead we cluster the hits:
  - Take the neighbouring hits in time and space and cluster them.
    - Order the hits by channel
    - Cluster by channel
    - Order the hits by time
    - Cluster by time
  - Require that the cluster has a certain extent and number of hit.
    - This step will get rid of single hits of Ar-39
    - Very simple reconstruction, that can be run online.
  - Good efficiency after 20 MeV
    - Unsure what the backtracker is doing here, take this plot with caution

Cluster is a bag of hits close in space and / or time



Alex Booth

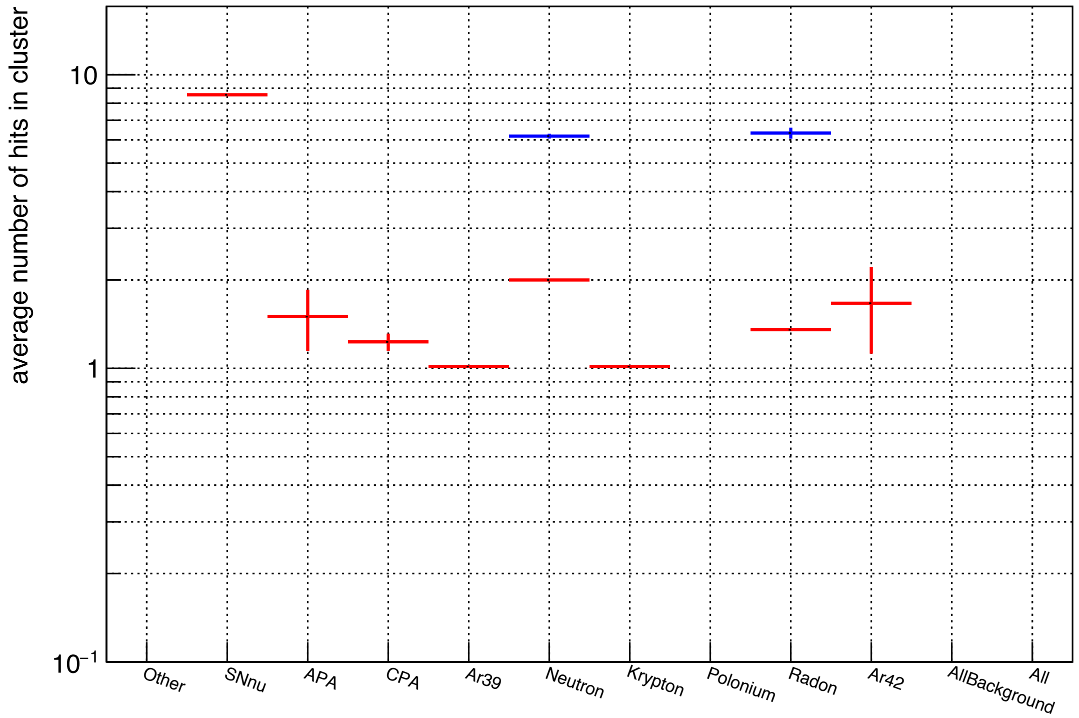
Eff



$E\nu$

Burst trigger

- Count the number of clusters in a time window (10 seconds).
- If the number of clusters is bigger than a threshold, issue a trigger that will record the whole FD for 30 seconds.
- What create the clusters when there is no SN?
  - Mainly neutron and Radon which have high energy.



- What should be this threshold so that there is not too much fake??
  - From Simon's talk, once per month is OK

Burst Trigger

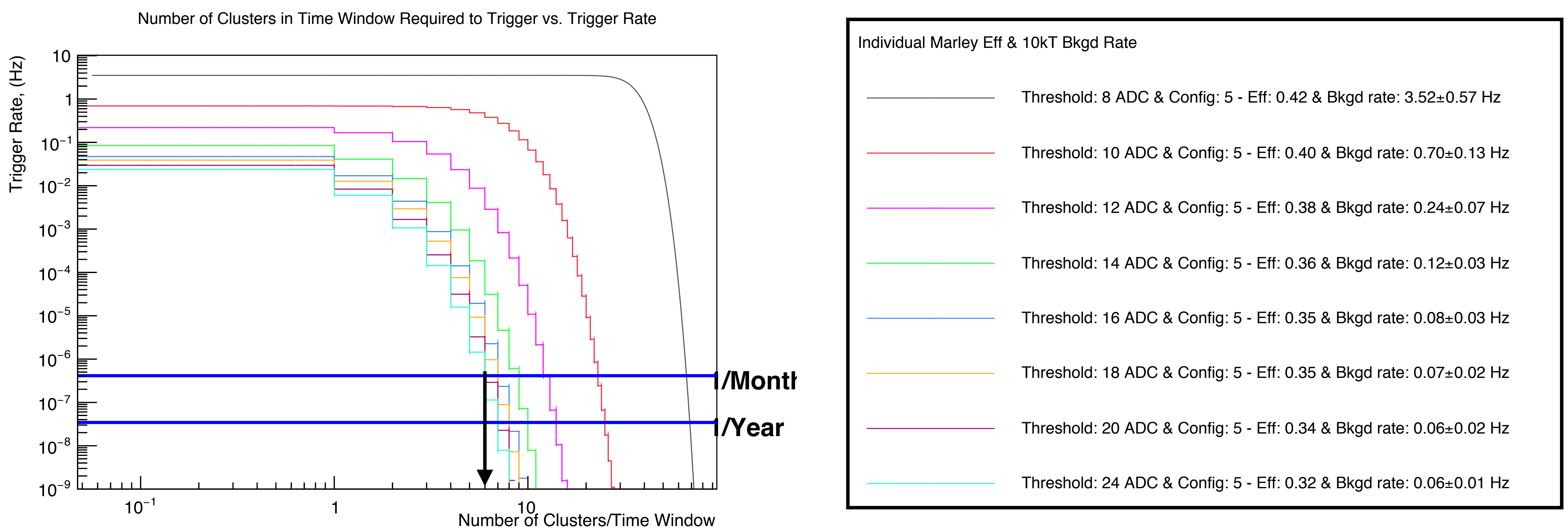
- From the background rate, one can derive the background cluster rate, i.e frequency of clusters when there is no SN.

$$BR = \frac{n_{\text{background clusters}}}{n_{\text{events generated}} \times T_{\text{event}}} \times \frac{V_{10\text{ kT}}}{V_{1\times2\times6}}$$

- What is the rate of few clusters?

$$FR = BR \times \sum_{n=n_{\text{Thr}}}^{\infty} \text{Poisson}\left(\mu = T_{\text{Integr}} \times BR, n\right)$$

- Integrate the tail of the Poisson distribution.

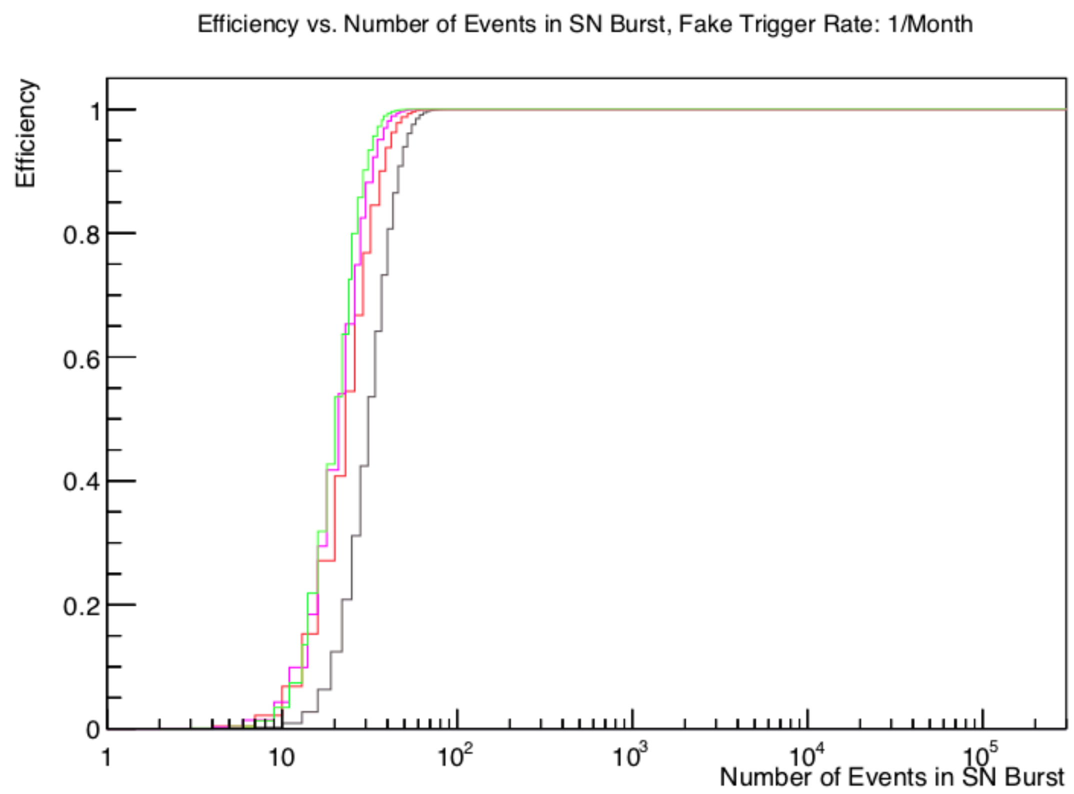


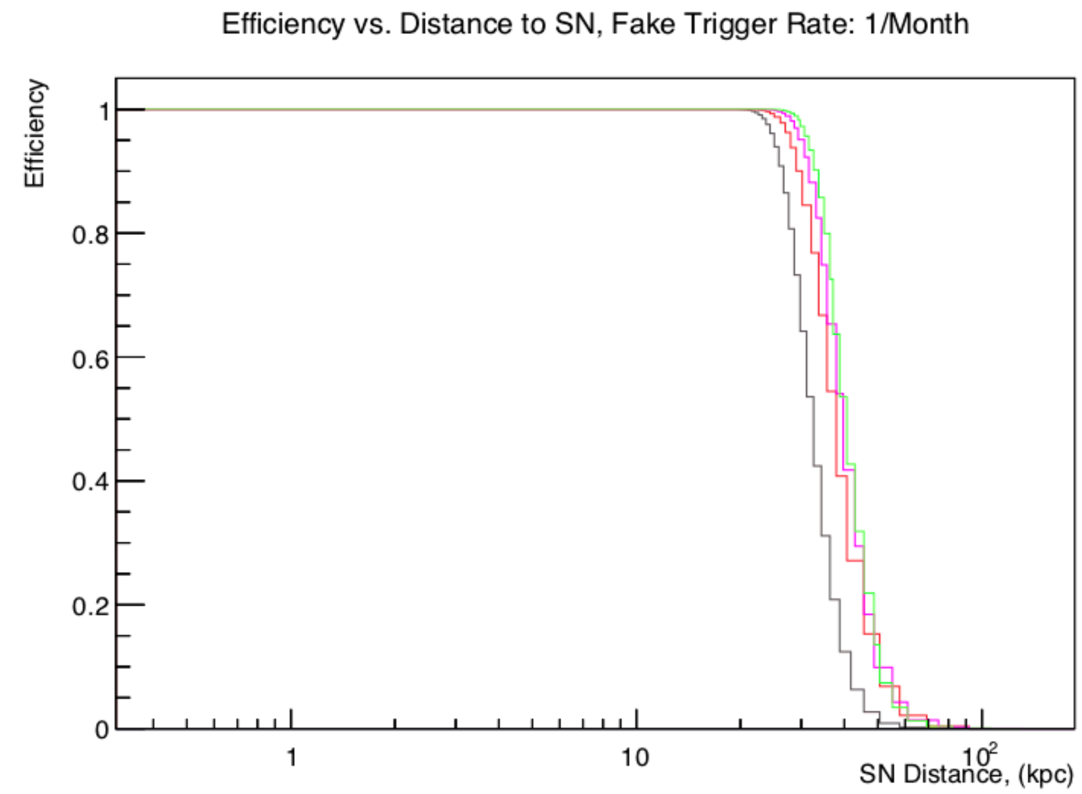
Burst Trigger

- Now want to know how much ν the SN has to create to trigger.

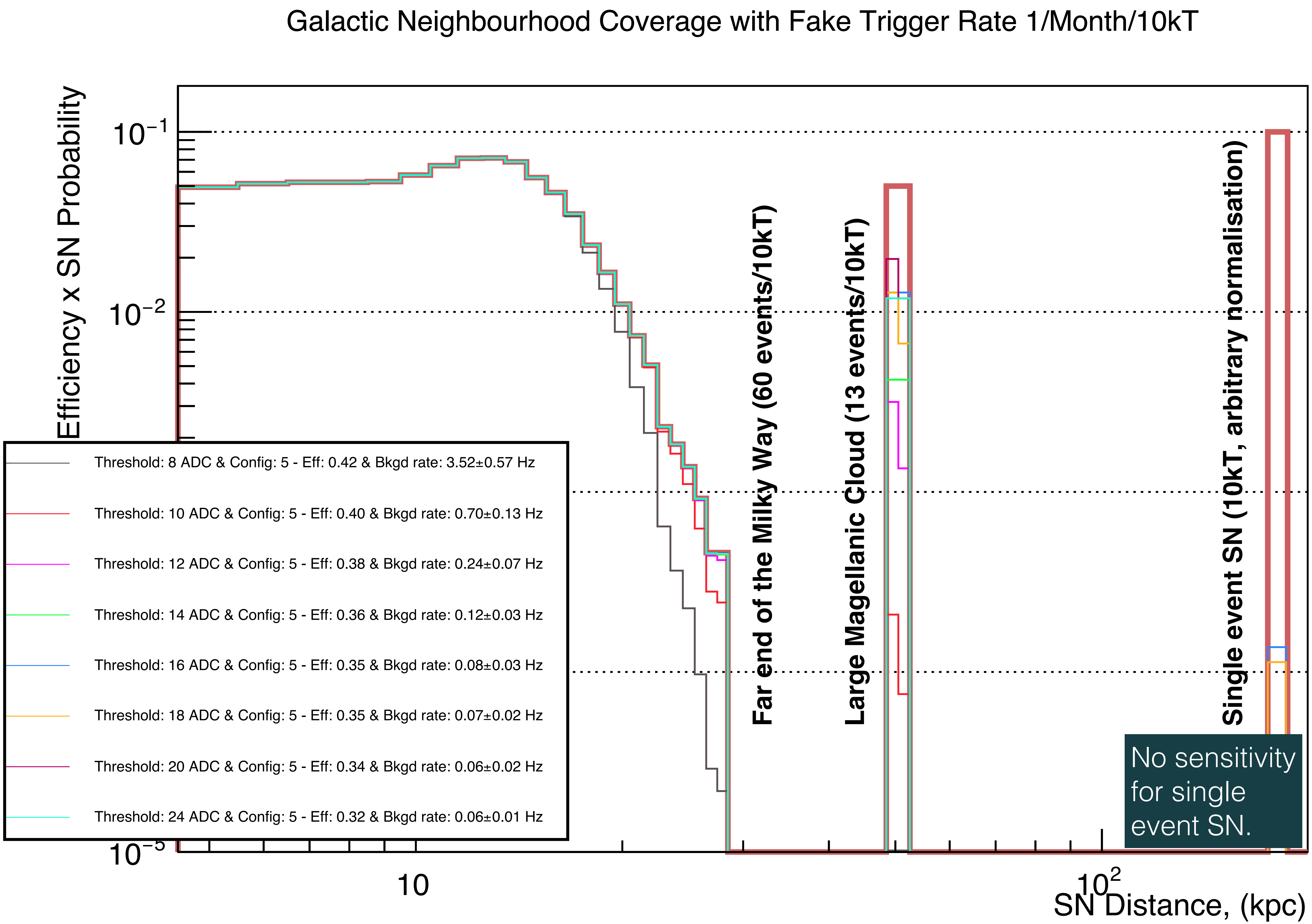
$$\epsilon_{\text{Trigger}} = \sum_{n=n_{\text{Thr}}}^{\infty} \text{Poisson}\left(\mu = n_{\text{detected clusters}}, n\right)$$

- Convert the threshold cluster + efficiency into SN triggering efficiency.
- Convert number of events to distance.



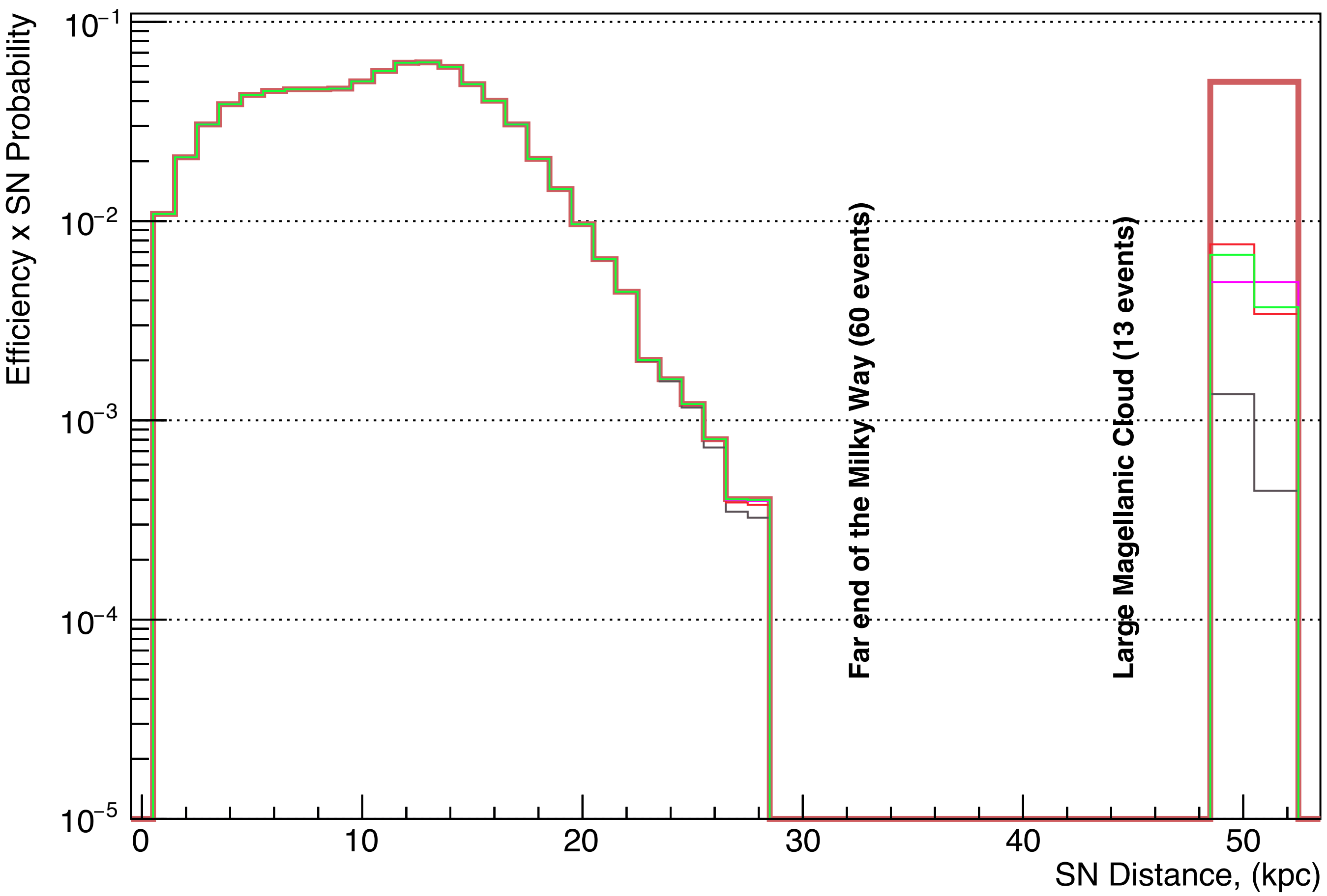


Burst Trigger

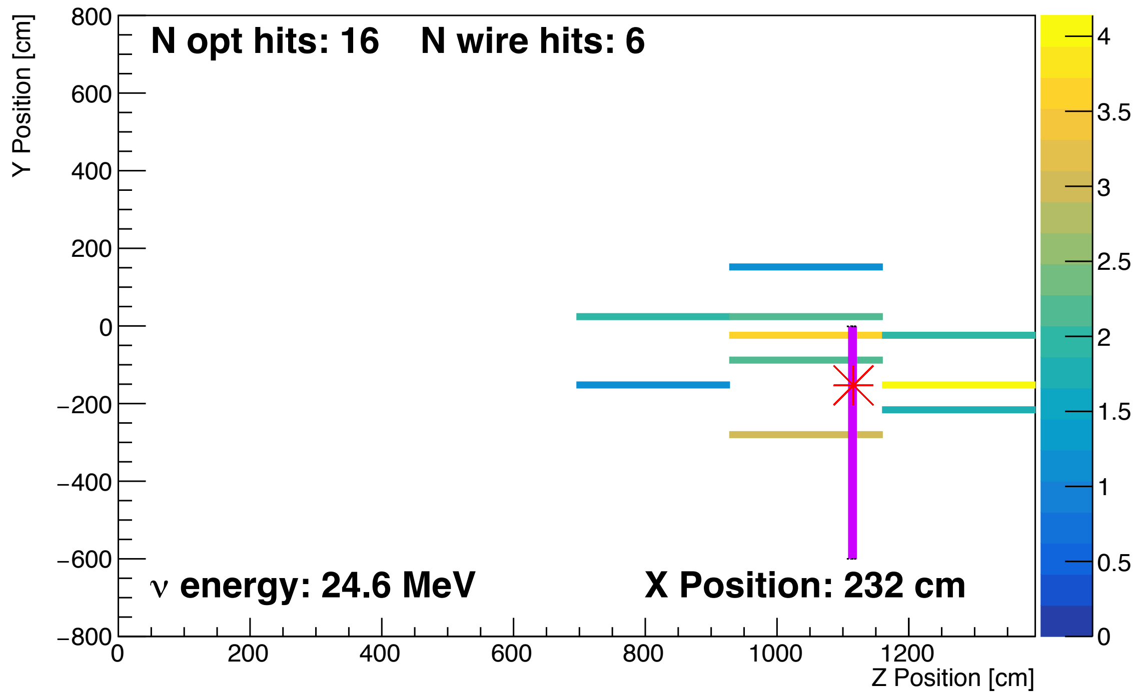


PDS SN triggering

- Same algorithm can be applied in the case of the PDS.
- Clustering on optical hits rather than TPC hit primitives.
- Gets comparable results to the TPC studies
  - Black → Nominal design
  - Red → Dip Coated design
  - Magenta → Improved double shift design
  - Green → ARAPUCA1.3 design



All the SN hits in an event



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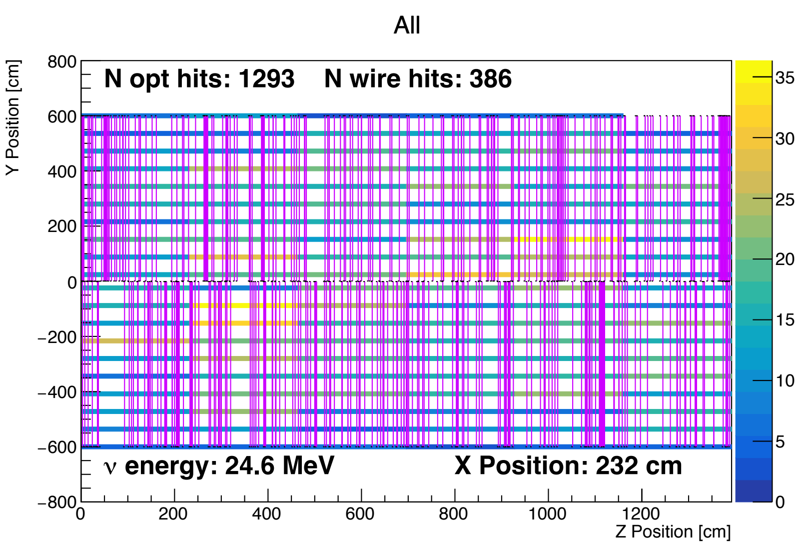
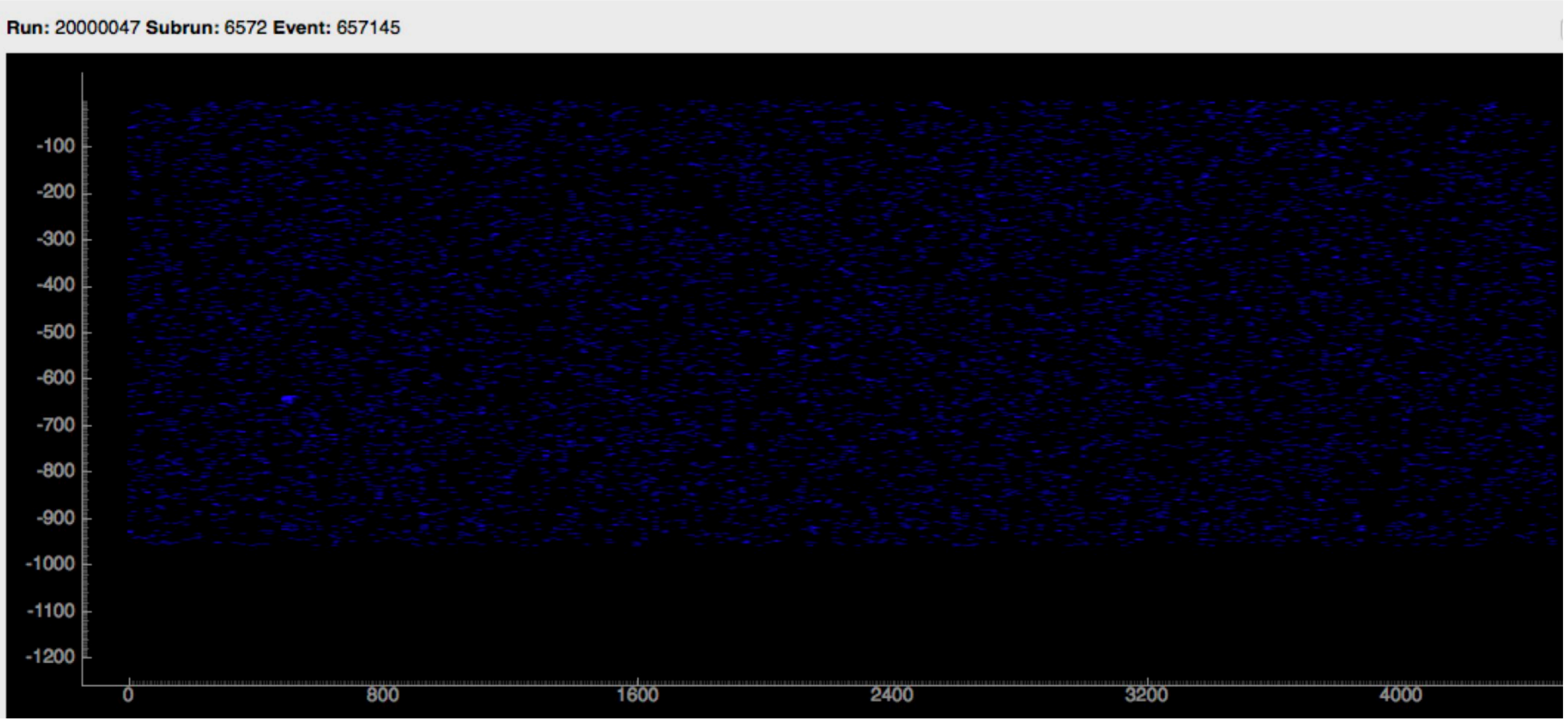


Future / Alternative approach

- Of course the TPC and PDS trigger should be somehow combined. This is work in progress.
- Aim is to get the background so low that you can do solar neutrinos…
- Alternative approach:
  - SNν interaction in 1 APA



  - University of Columbia *(it's Columbia not Colombia*) used machine learning to trigger.
  - Image recognition to classify event as SN, NDk, beam…
  - More involve on the hardware side, but got comparable results, see talk at previous CM.

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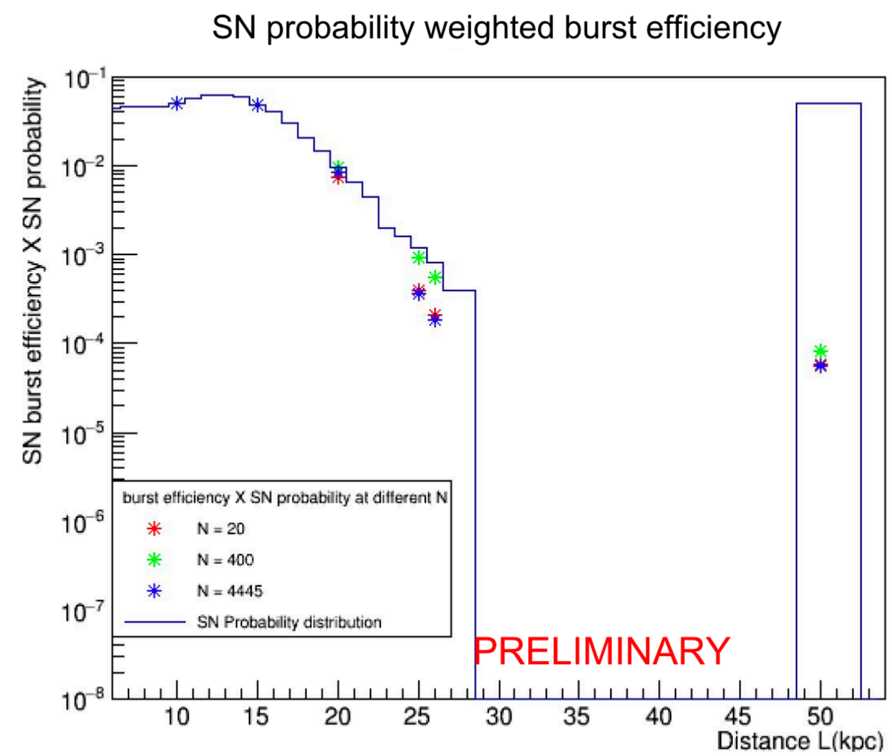
IN THE CITY OF NEW YORK

RAD score cut	RAD frame efficiency	Data rate (RAD)	SN frame efficiency	n-nbar frame efficiency	atmo. nu frame efficiency	p-decay frame efficiency	cosmic frame efficiency
<0.05	0.56% (99.44% rejection)	6.4 GB/s (201 PB/year)	89%	100%	92%	99%	92%
<0.01	0.18% (99.82% rejection)	2.05 GB/s (65 PB/year)	86%	100%	91%	99%	92%
<0.001	0.031% (99.969% rejection)	350 MB/s (11 PB/year)	77%	100%	89%	98%	90%
<0.0002	0.011% (99.989% rejection)	125 MB/s (3.9 PB/year)	69%	100%	87%	97%	88%



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Conclusion

- SN triggering is using a simpler reconstruction algorithm that and can be run online.
- We have shown that the combination Clustering + Burst trigger can trigger efficiently of SN from the Milky Way.
- More work to combine both triggering algorithms.
- More work to estimate the backgrounds.