Supernova Burst Trigger Studies in DUNE FD Single Phase TPC

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Overview

- Supernova burst time and energy profiles.
- Finding individual neutrino interactions - clustering algorithm.
- Performance of a simple SN burst trigger - galactic coverage and fake rate.
- DAQ requirements - time to record.

Strategy & Assumptions

Fast 'back of the envelope' approach to establish broad features of DUNE's ability and DAQ requirements to capture neutrinos from a SN.

Many questions and assumptions still to be addressed.

DESIGNED TO BE MODULAR:

Astronomical models.

- Number of events expected.
- Distribution of SN candidates in the galactic neighbourhood.
  - Simple minded addition of LMC to the distribution.

SN models.

- 1 specific supernova model used.
  - Hudepohl model.
  - 11.2 solar mass progenitor.
- Effect of oscillations?

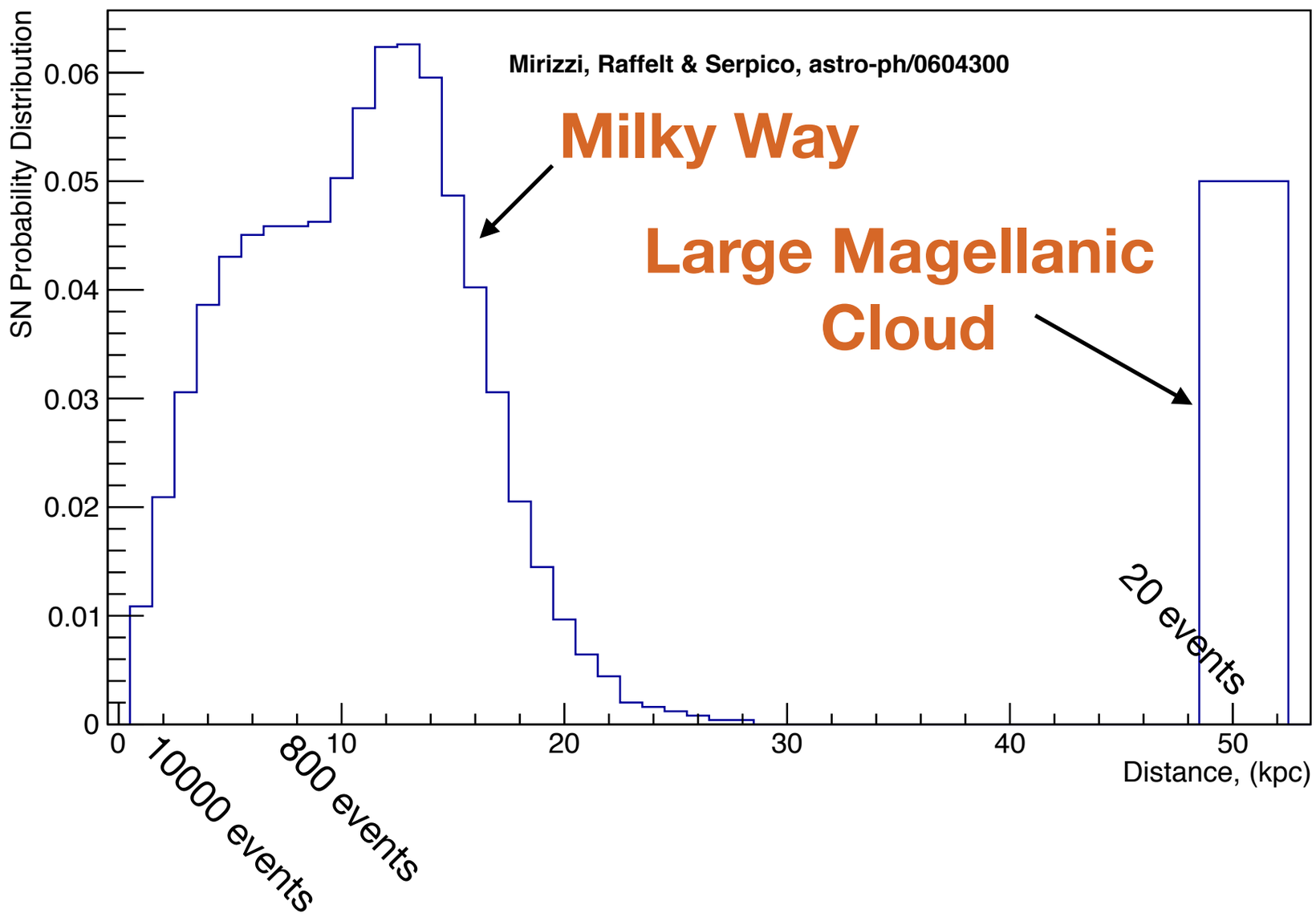
Background and noise models.

- 8 radiological backgrounds.
  - Are there more?
  - Correct rates?
- White noise.
  - Coherent noise?
- Not considered cosmics.

Hit finder/ hit clustering.

Burst trigger design.

Distribution of Supernovae

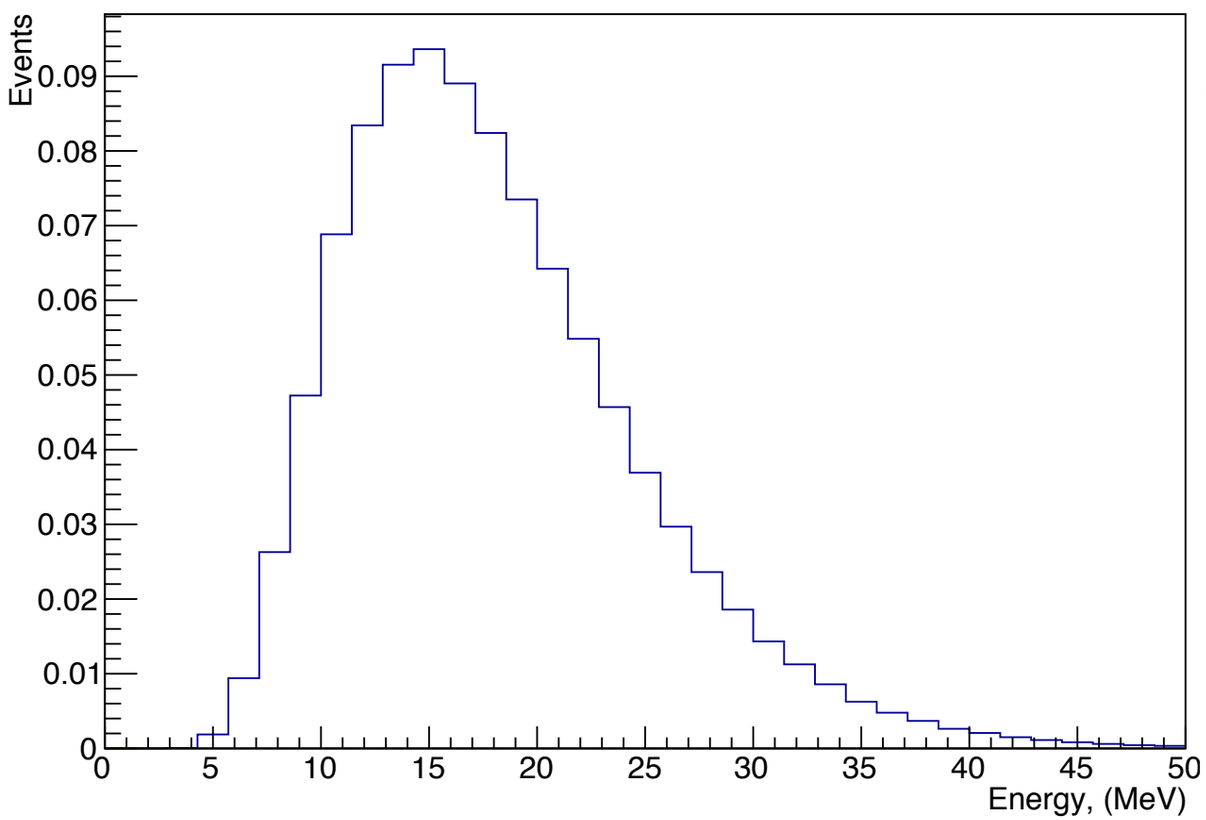


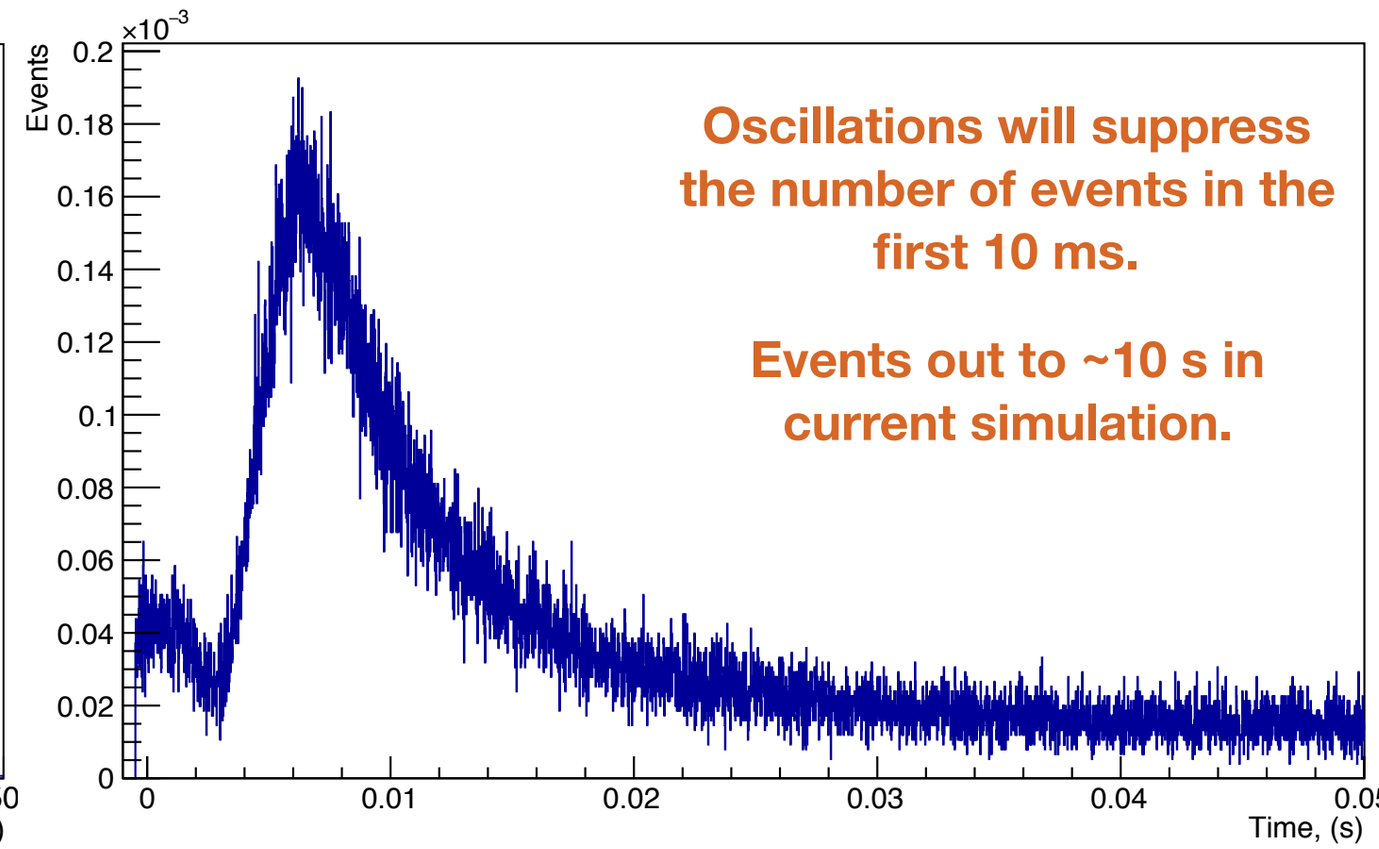
Empty space until Andromeda! (780 kpcs)

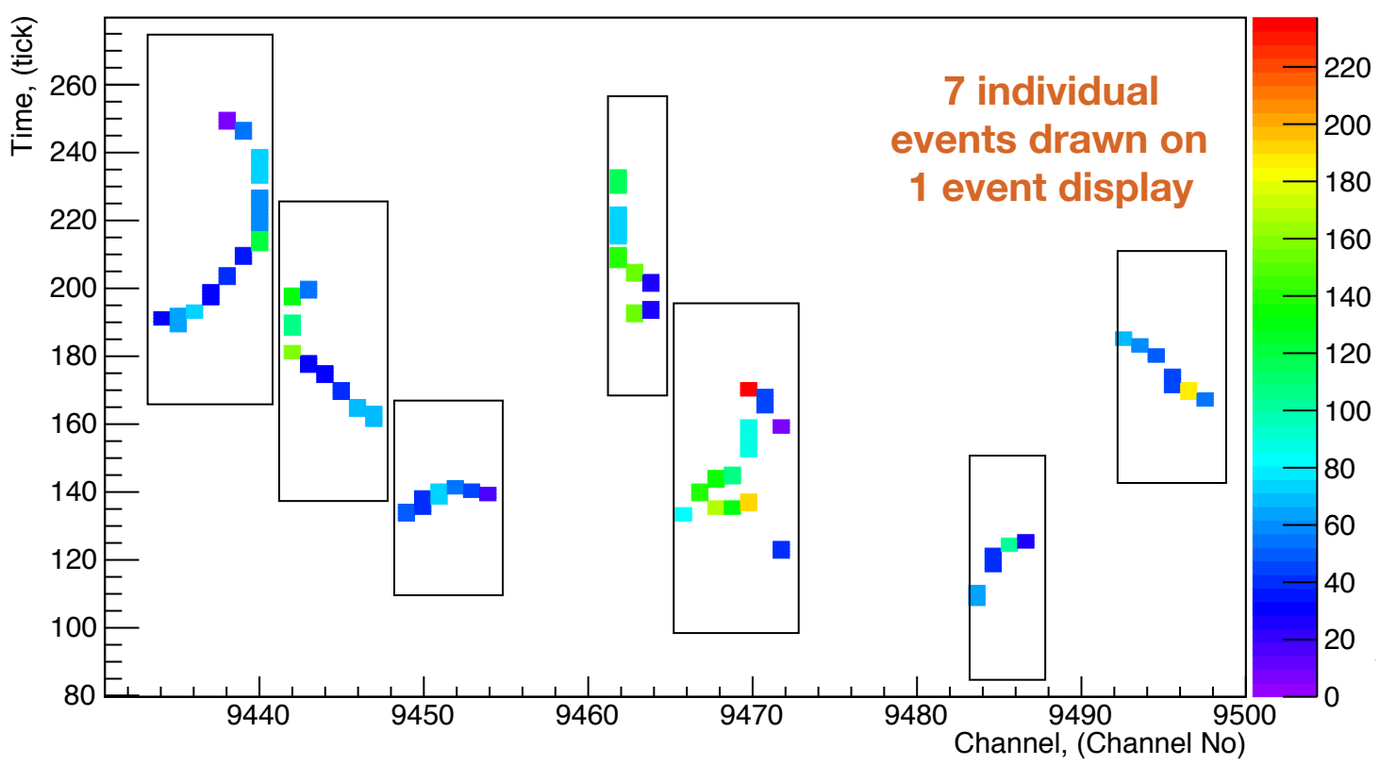
Define 'galactic neighbourhood' as Milky Way + LMC

We can reasonably consider issuing a burst trigger for SN in this region.

Supernova Event Generator - MARLEY







Only nue-CC on Ar nucleus, (~75% of total).

True primary lepton energy peaks ~ 10 MeV.

1 channel ~ 0.5 cm, 1 tick ~ 0.08 cm

'Typical event': 5 cm x 5 cm

Radiological Backgrounds

Simulation contains white noise and radiological backgrounds.

In current simulations, backgrounds are dominated by radiologicals, not noise.

Require a better understanding of these backgrounds.

Source	Notes
Ar39	Intrinsic to LAr
Ar42	Intrinsic to LAr
Co60	APA frame
Neutrons	Ur-238 in concrete
Po	Simulates Rn daughters on PDs
K40	CPA frame
Kr85	LAr
Rn222	LAr (contamination)

Dominant background of burst trigger.

https://www.overleaf.com/13924050chkrxfmktthr#/53974837/

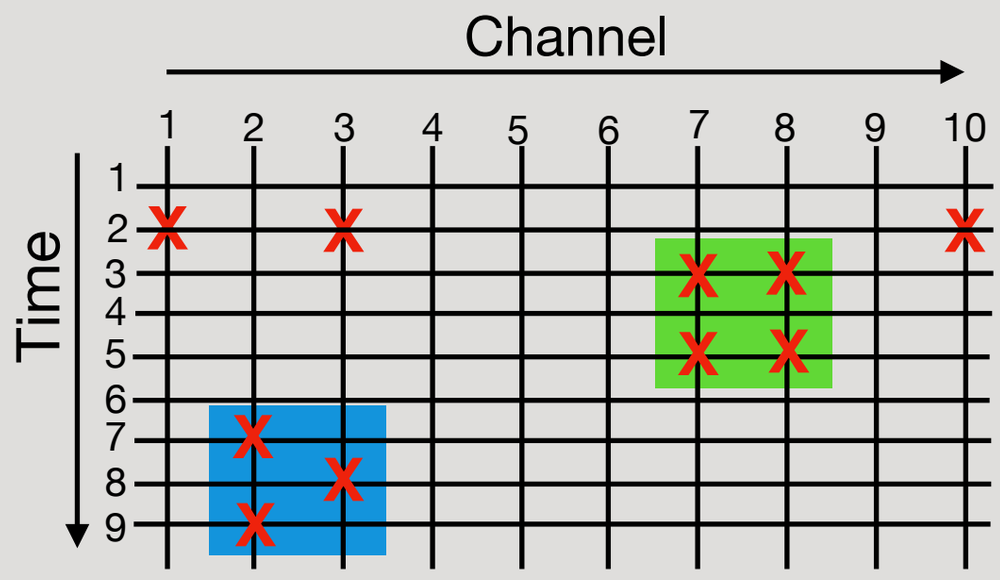
Clustering Individual SN Neutrinos

Clustering Algorithm

Takes channel ordered hits from a hit finder (currently Gauss hit).

CLUSTER IN CHANNEL AND TIME SPACE

- Hits ordered sequentially by channel. Walk along the wires looking for hits on **adjacent** channels.
- Within these channel cluster, group hits **close** in time.
- Cut on **total ADC sum of the hits in the cluster**, **minimum number of channels in a cluster** or **cluster width**.
- Finally require a certain **number of hits** in a cluster.



Require > 3 hits.

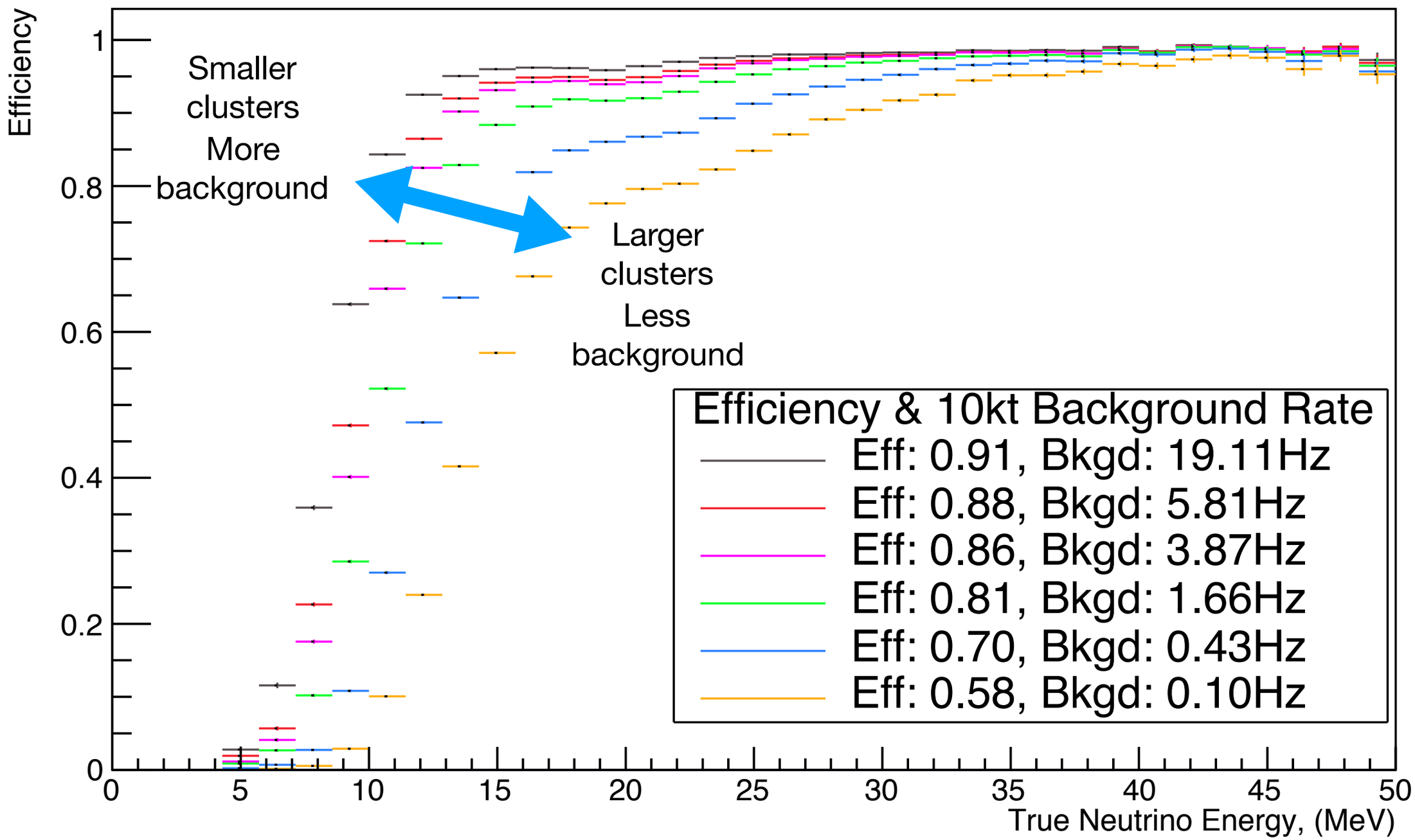
CLUSTER

NO CLUSTER

It's fast: Given the assumptions e.g. an ordered list of hits was provided, the clustering for 10kt could be run on a single CPU.

https://indico.fnal.gov/event/16859/contribution/1/material/slides/0.pdf

Efficiency & Background Rates



Input to burst trigger:

Different clustering algorithms allow the trade off between lower efficiency and background rate to be explored.

Supernova Burst Trigger

SN / radiological / noise simulations → **Hit-clustering** → **Clustering efficiency & background acceptance different clustering configurations** → **Burst trigger**

SN Burst Trigger

Unique signatures of SN burst:

- Events spread out over a long time (exponential cooling of SN with 2-3 second decay time).
- Events typically higher energy than background.

Strategy: keep it very simple for now.

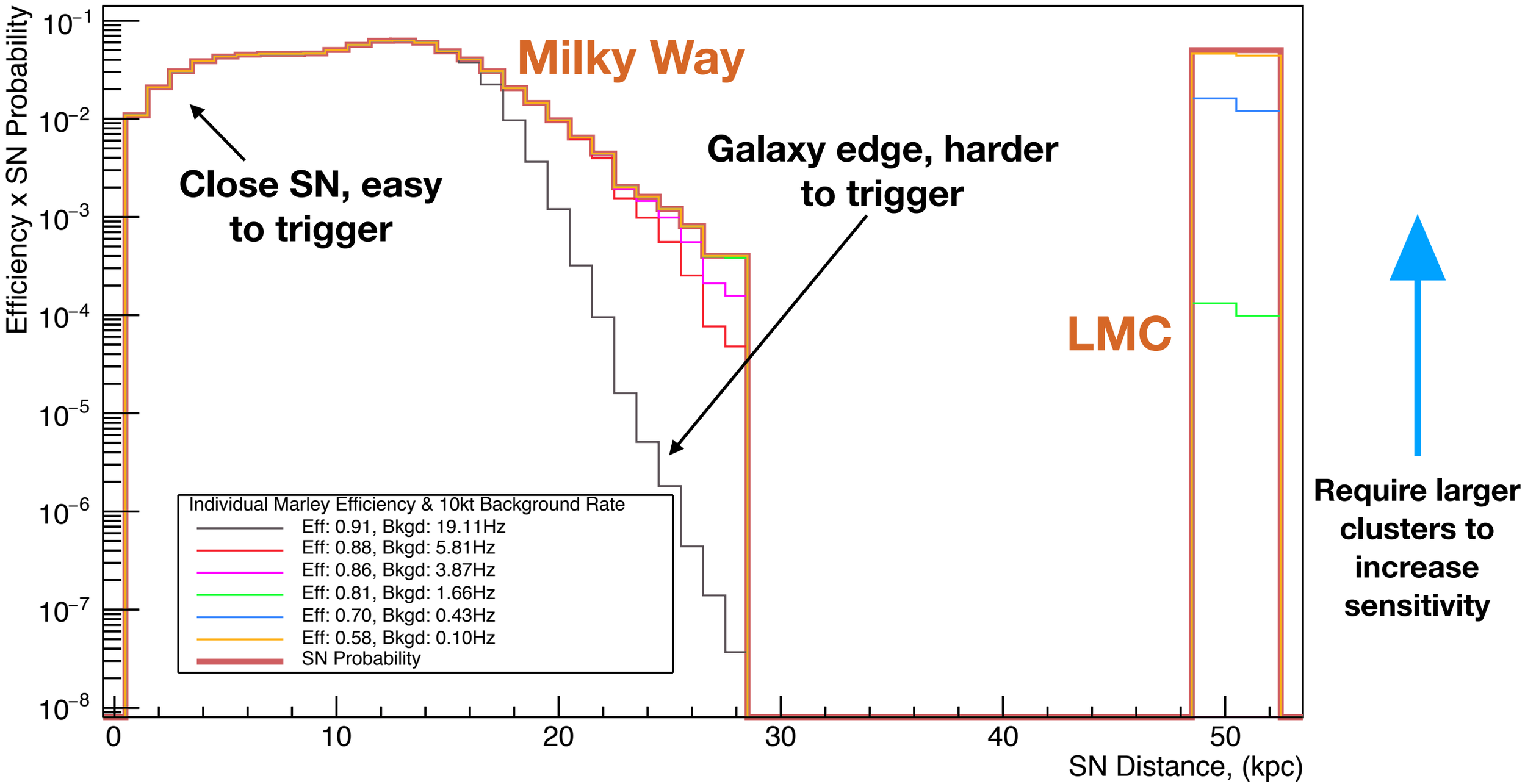
- Count the number of hit-clusters in a 10 second window.
- Trigger above a threshold number of hit-clusters.

Fake triggers:

- Use background rate from clustering algorithm, assume it fluctuates in Gaussian way.
- Can map out burst-trigger rate as a function of threshold number of hit-clusters.

Result: Galactic Neighbourhood Coverage

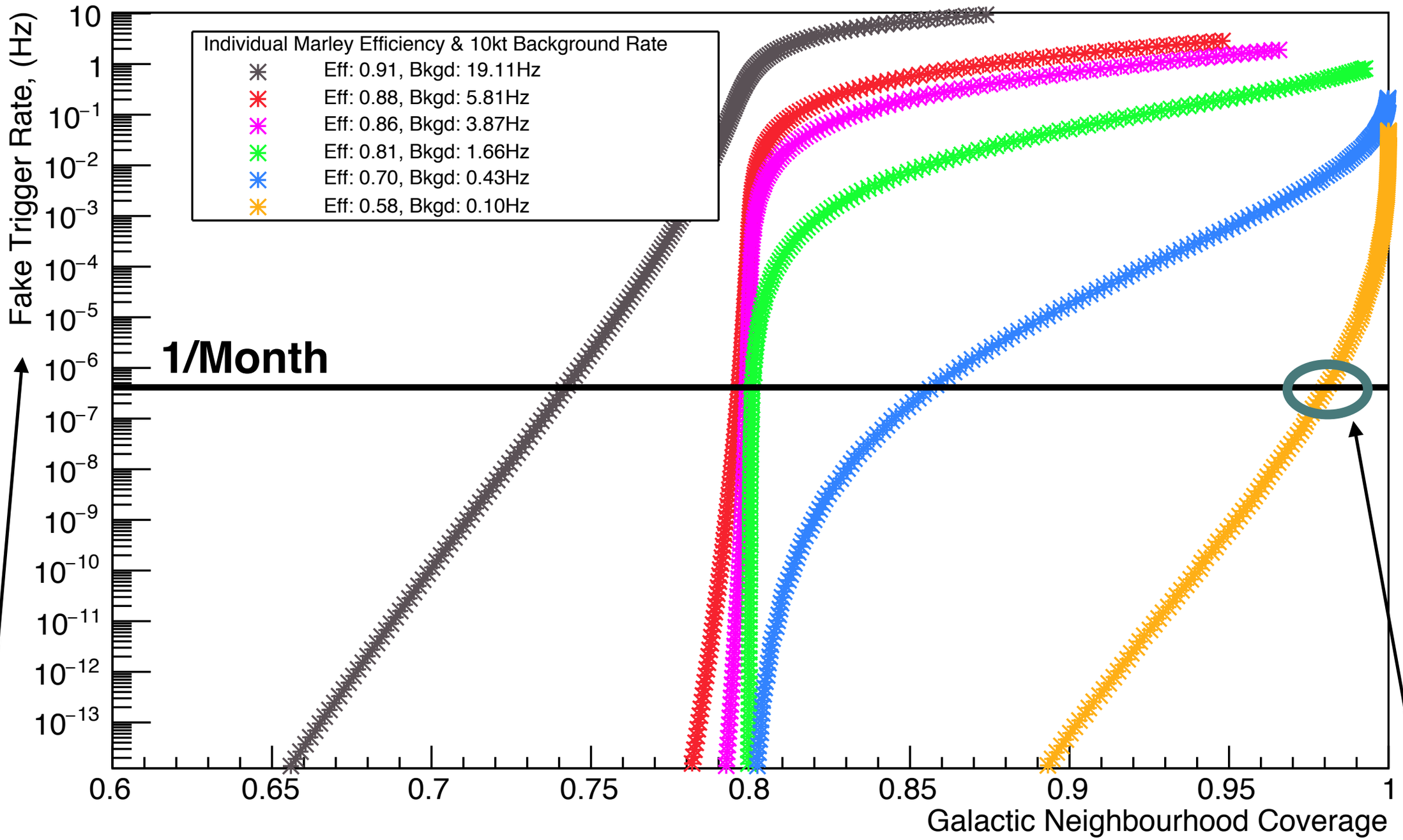
Assuming a fake burst trigger rate of 1/month, what is our SN sensitivity vs. distance?



Conclusion: can trigger on nearby SN easily.
However, capturing the 1/5 of SN coming from LMC requires more work and is more dependent on our assumptions (e.g. hard to model neutron bkg).

Result: Fake Trigger Rate vs. Galactic

Previous slide required 1/month fake trigger rate.
This slide shows trade off between efficiency and this rate.

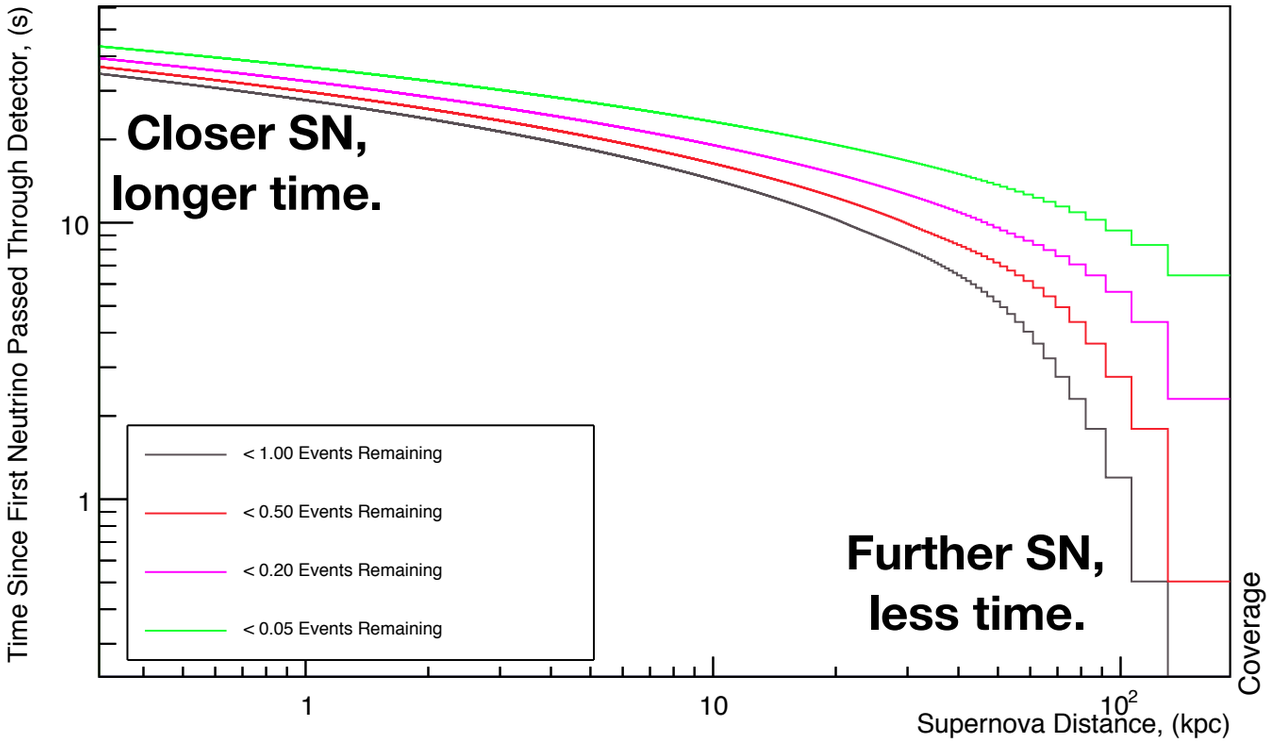


Trigger on 98% of SN in the neighbourhood, issuing 1 fake trigger per month.

In 10 kT

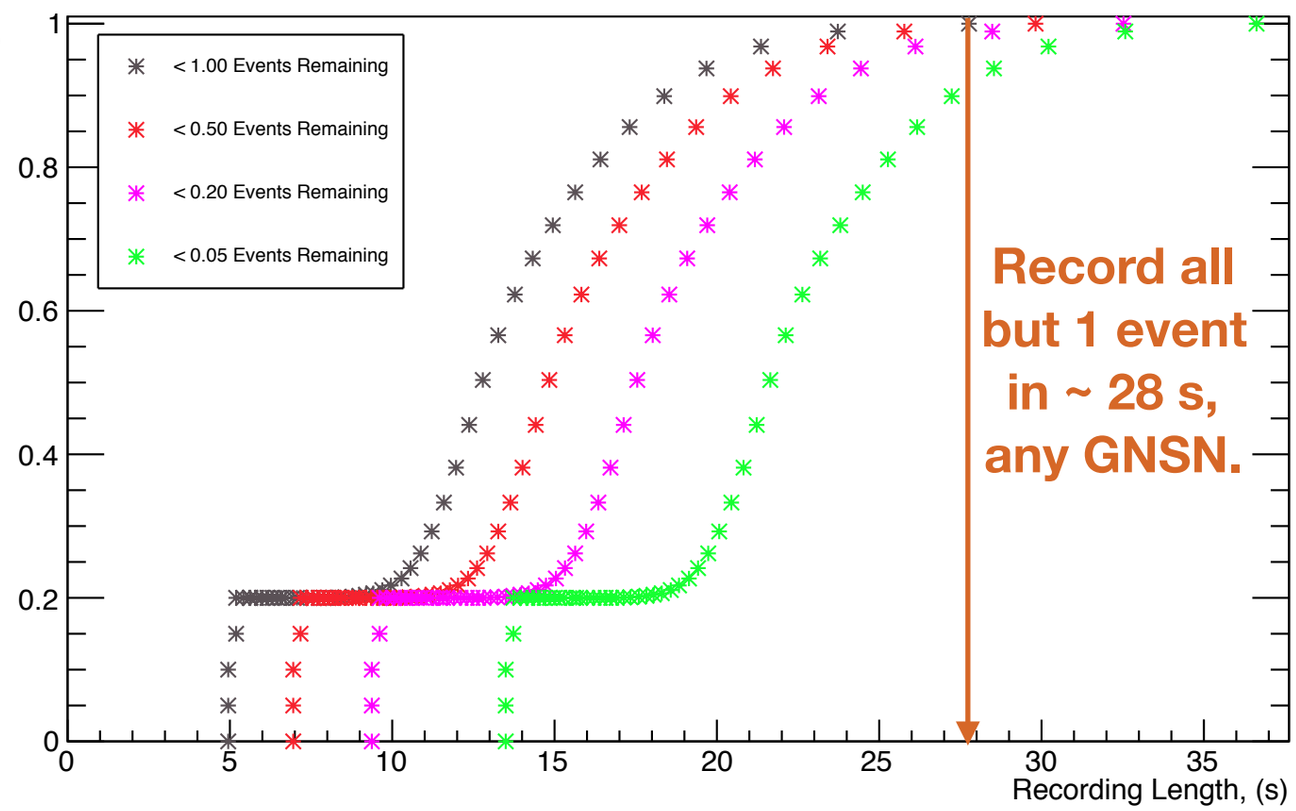
Time Profile Studies

Time Profile Studies



High data rate: 1.5 TB / s / 10kt module

Extract maximal information.



Establish DAQ requirements: Non-volatile buffer (read-out time).

Time profile studies potentially very sensitive to SN model.

Summary

Applied a fast 'back of the envelope' approach to establish broad features of DUNE's ability and DAQ requirements to capture neutrinos from a SN.

BURST TRIGGER:

- Reasonable to consider issuing a **burst trigger** for SN in the region of the **Milky Way and LMC**.
- In simulation shown that **radiologicals** are the **dominant background**.
- Demonstrated a simple burst trigger capable of catching **98% of supernovae in the galactic neighbourhood**, issuing on average 1 **fake trigger 1/month**.

TIME PROFILE STUDIES

- Shape of profile is **model dependent**, e.g. with/without oscillations.
- Studies influence DAQ requirements.
- Record all but 1 event of any **galactic neighbourhood SN in ~28s**.

Many questions and assumptions still to be ironed out.

Backup Slides

Analysis Details

GOAL: Understand supernova triggering efficiencies and corresponding background rates for different levels of trigger.

- Using an amended version of the DAQSimAna (M. Baird, K. Warburton) module in dunetpc (DAQSimAna/SNAnaClustering/SNAna_module.cc).

- Running on files produced at Christmas, SN+radiologicals+white noise.

- Non-compressed, ~**750000** events each of 1 drift window and containing 1 MARLEY neutrino per event. Include Ar42. **1x6x2 geometry**.

```
/pnfs/dune/scratch/dunepro/MCC10-Production/SuperNovaSamples/v06_60_00/reco/
snb_timedep_radio_dune10kt_1x2x6
```

- **Gauss hit finder** to pick out hits. **All collection plane.** Save hit primitives such as hit time, ADC sum of hit, hit RMS etc.

- Backtrack each of these hits to a generator - was it radiological/noise/ supernova.

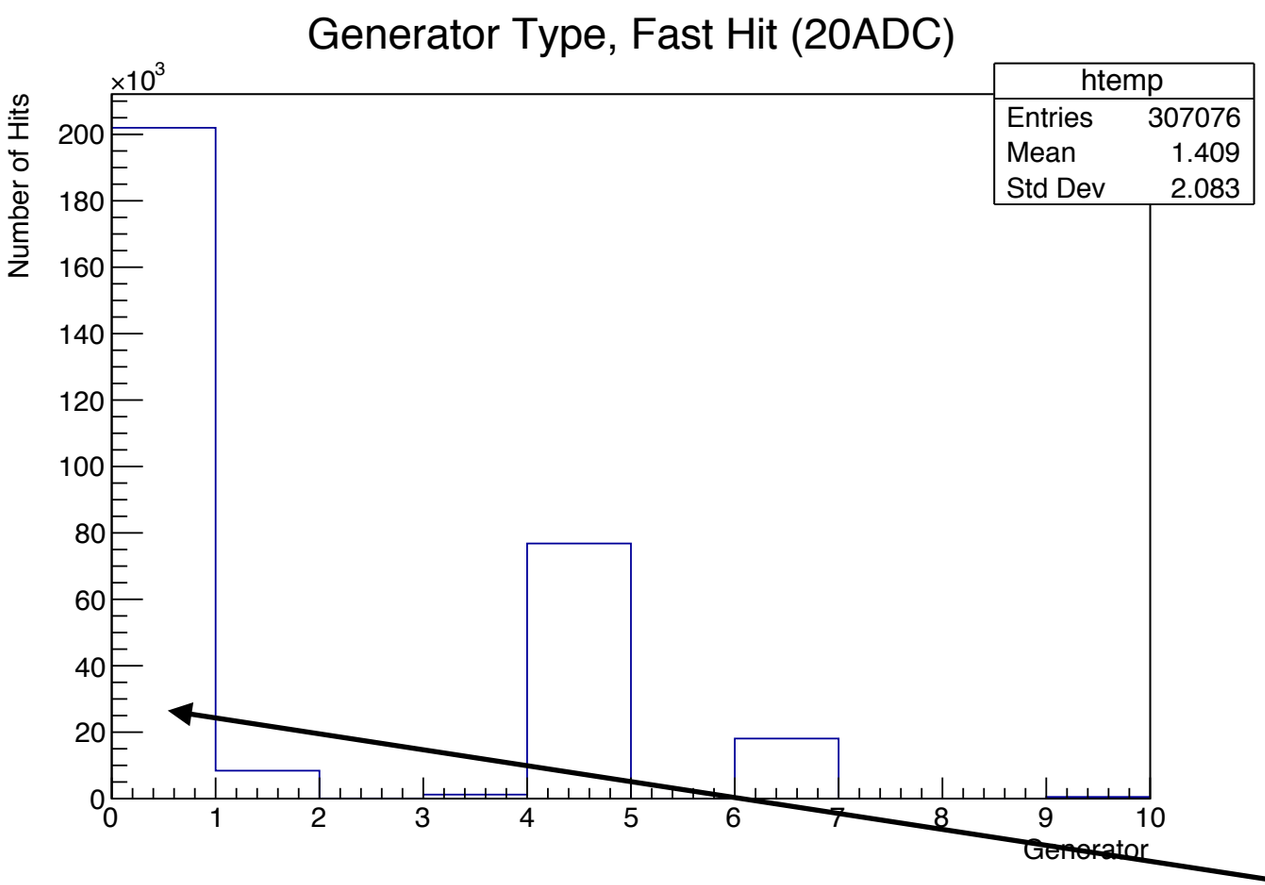
Cluster hits in channel and time space, make geometric cuts, trigger on number of hits in the cluster.

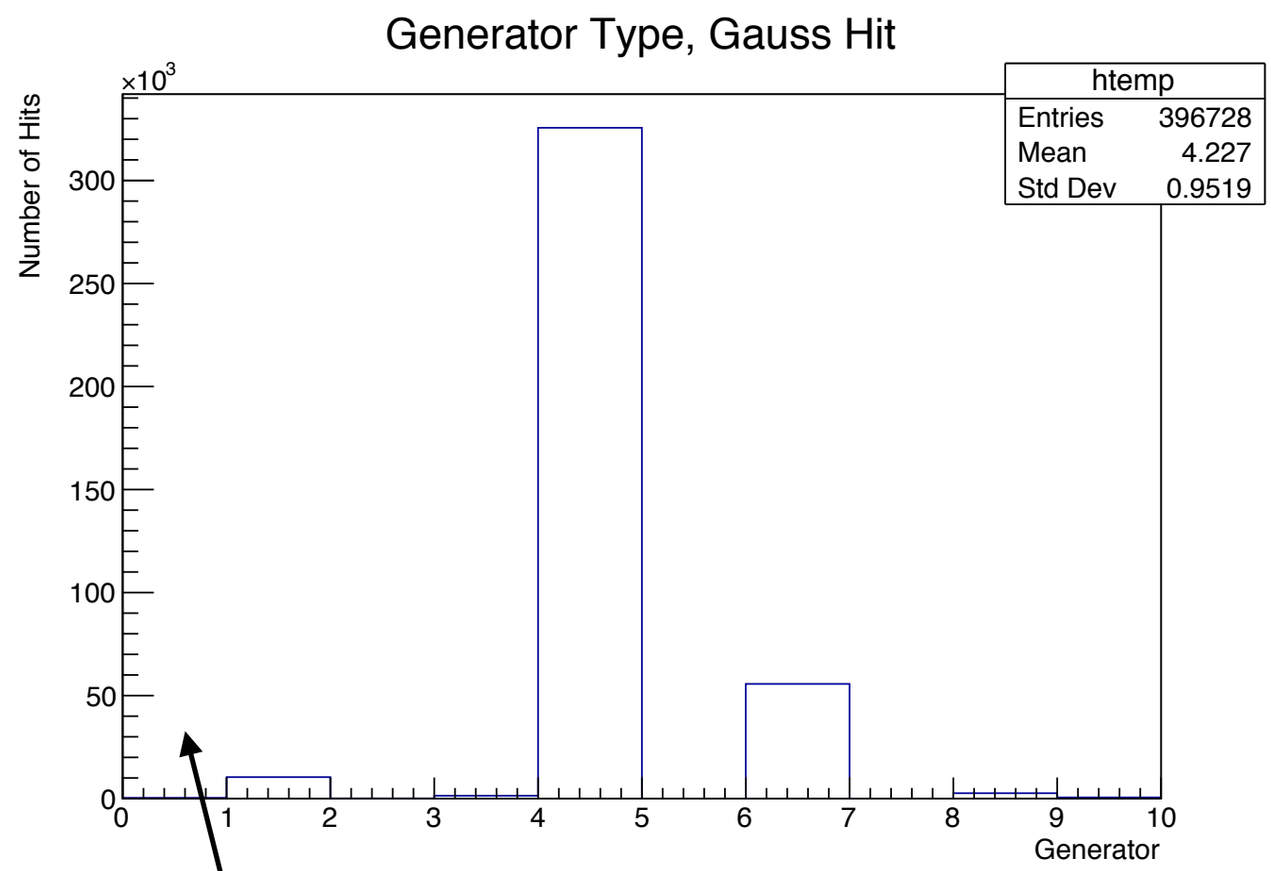
Why not fast hit yet?

Problems with Hit Size = End time - start time

- Fast hit looks for time bins with ADC above a user defined ADC threshold. >2 bins above threshold, calls it a hit.
- Start time = first bin above threshold, end time = last bin above threshold.

Results in many 'skinny' hits in time -> Many hits not correctly backtracked.





Generator type 0 is 'noise'.

Gauss Hit

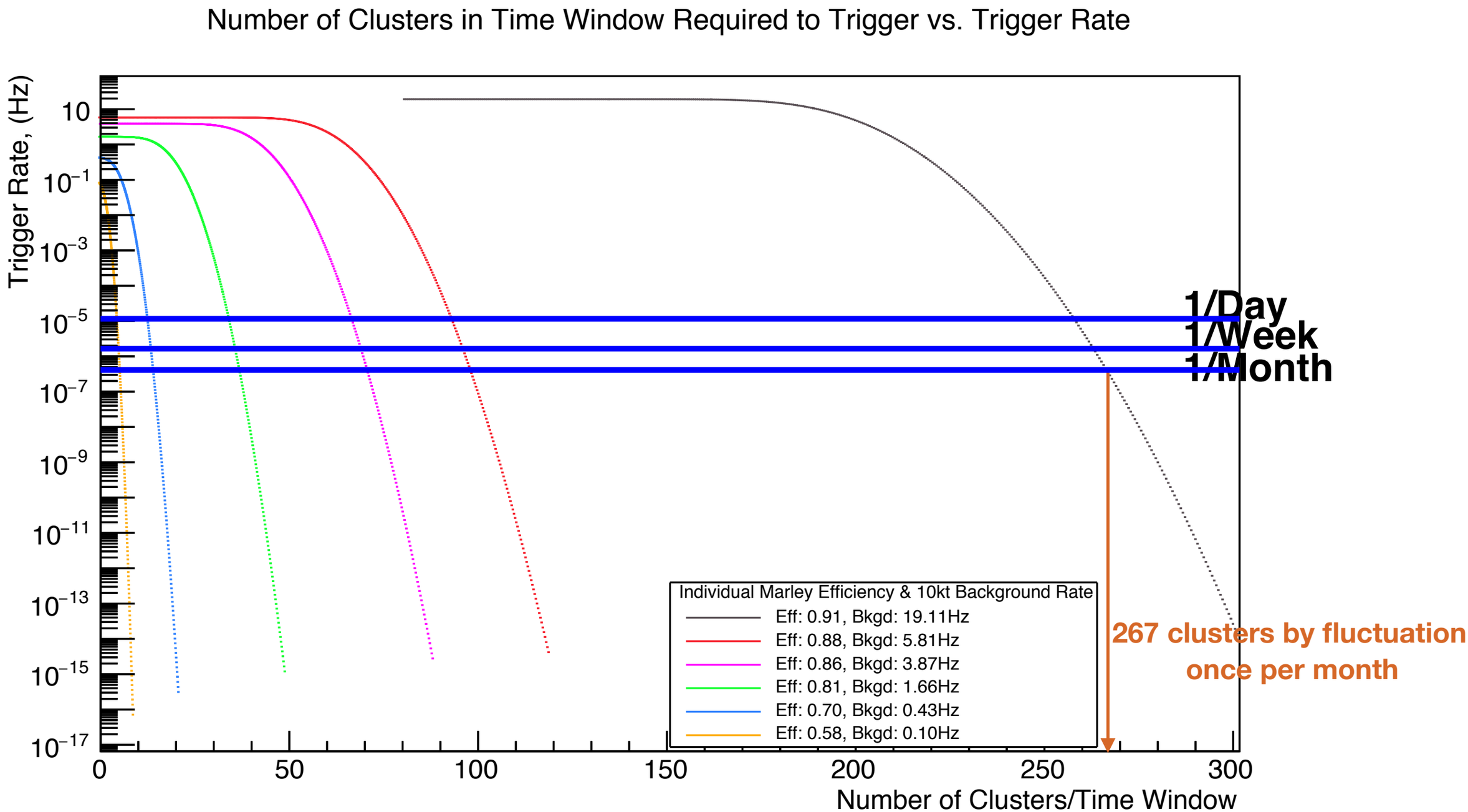
Originally developed by Jonathan Asaadi but expanded by many.

- Finds pulses in each view above individually configured thresholds.
- ‘Touching’ hits on a channel are merged up to a configurable max.
- Hits fit to a gaussian peak for:
    - Start and end time.
    - Peak time.
    - Peak ADC.
- **Total hit ADC** is integral of raw data, not fit by default.
- Default generous max Chi^2 for allowed hits.

Has a hard coded hit size minimum of 5 ticks.

SN Burst Trigger

Trigger rate = total background rate x fraction of Gaussian above cut.



Add trigger threshold to axis label. Ditch titles.

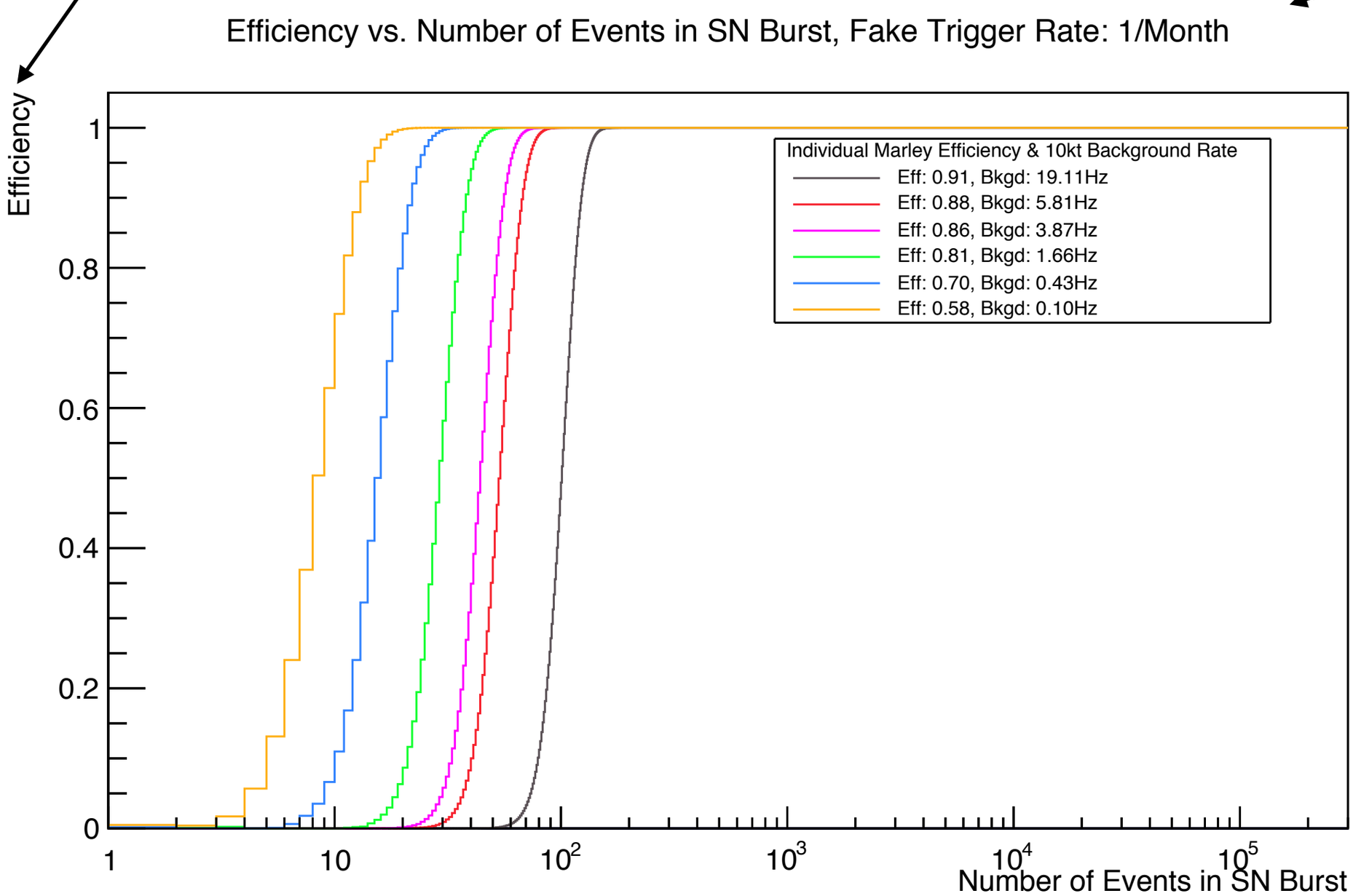
Metric: On what fraction of galactic SN bursts can we trigger for a given fake rate?

Background + Burst

Consider SN bursts of size 1->3x10^5 events.

$$\text{SN Burst Efficiency} = \sum_{N}^{\infty} \text{Poisson}(\mu = \text{Mean background rate} + \text{Number of Events in Burst})$$

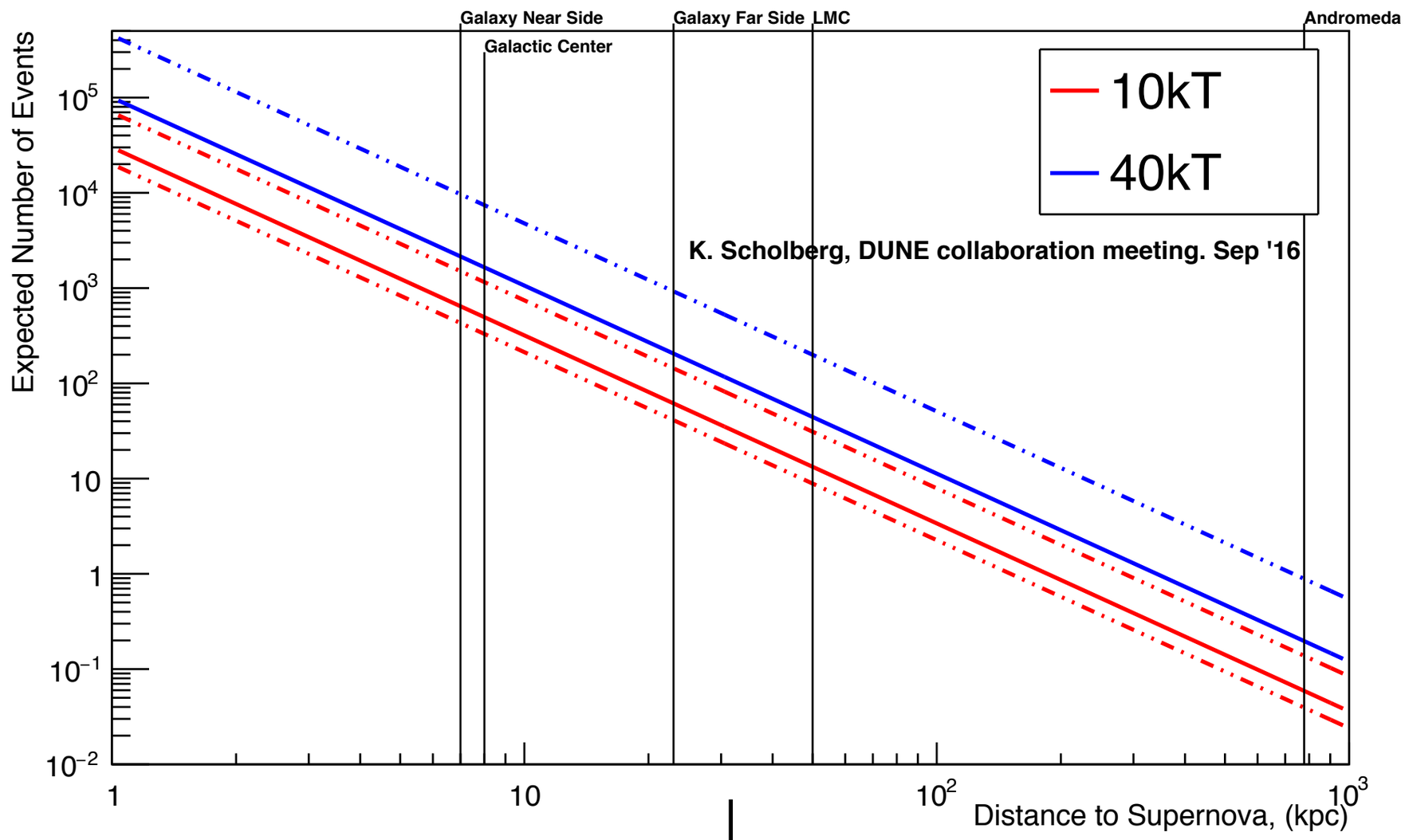
N = 267 clusters/month for <u>black</u> curve.



Burst -> Distance

SN Burst Efficiency vs. Number of Events in Burst (Unoscillated)

Expected Number of Events for a Given Supernova Distance

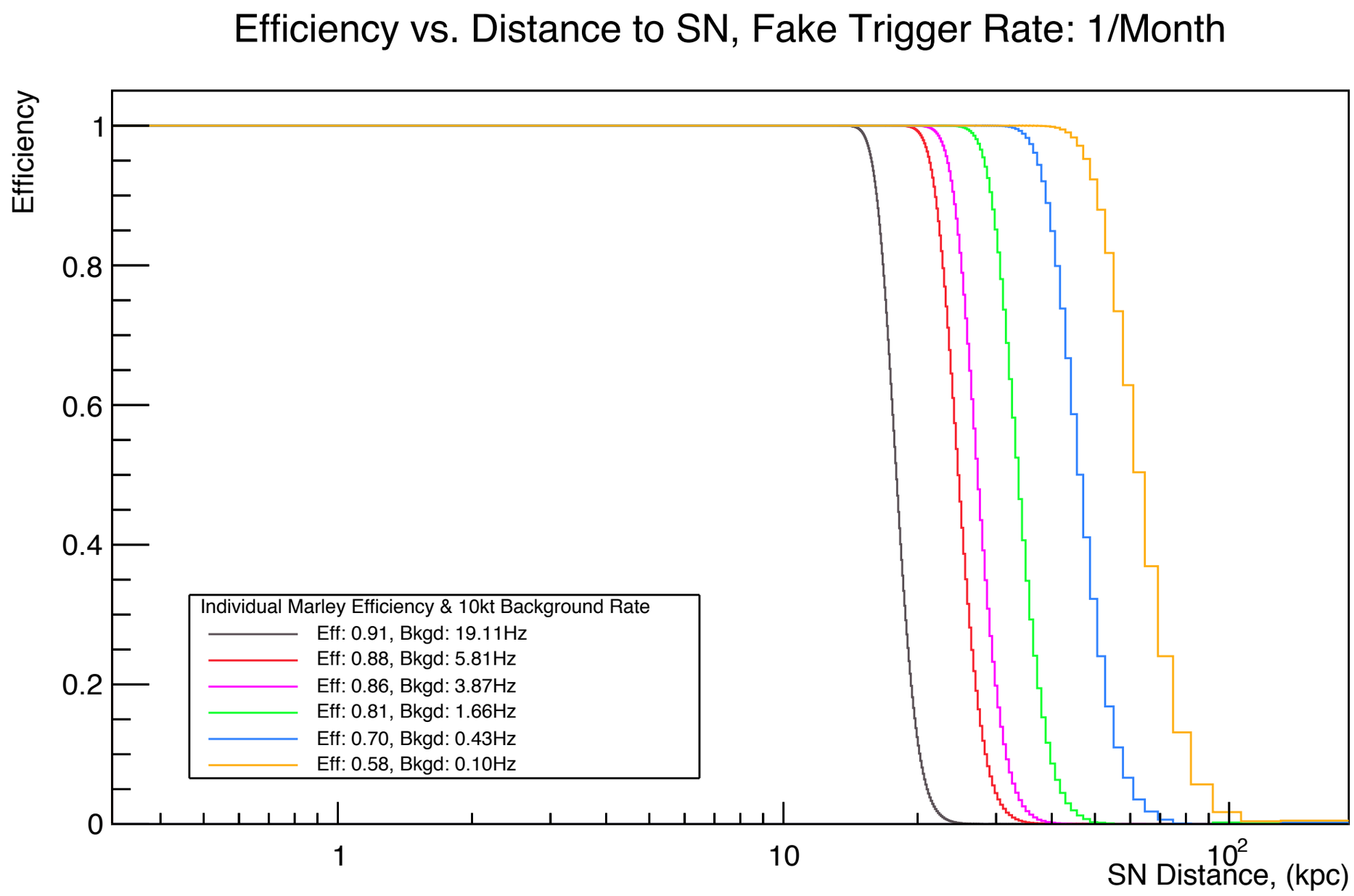


SN Burst Efficiency vs. Distance to Supernova

Rule of thumb:

~30 events at 30 kpc

Efficiency vs. Distance



“Galactic Coverage”