University of Sussex

DEEP UNDERGROUND NEUTRINO EXPERIMENT

Alexander Booth for the DUNE Collaboration
University of Sussex, UK

Triggering on Supernova Burst Neutrinos at DUNE

Introduction

DUNE is a planned, broad band on-axis neutrino oscillation experiment located at **Fermilab**, Illinois and **Sanford Underground Research Facility**, South Dakota.

The far detector will consist of **4** liquid argon **10 kt** time projection chambers **(LArTPCs)**, 4850 ft underground and 1300 km from the point of neutrino production [1].

LArTPCs are sensitive to low energy **electron neutrinos** via charged current interaction on Ar with threshold **5.9 MeV** for a superallowed transition [2].

A typical supernova (SN) burst from the galactic centre would produce **~3x10³** neutrino events in the far detector over 10's of seconds [1].

The detection of such bursts requires a data acquisition system capable of triggering the readout of a data stream of order **1 TB / (sec 10 kt)** during these 10's of seconds.

From the SN time profile, **many astrophysics observables** and the neutrino **mass ordering** may be measured [1].

Simulation

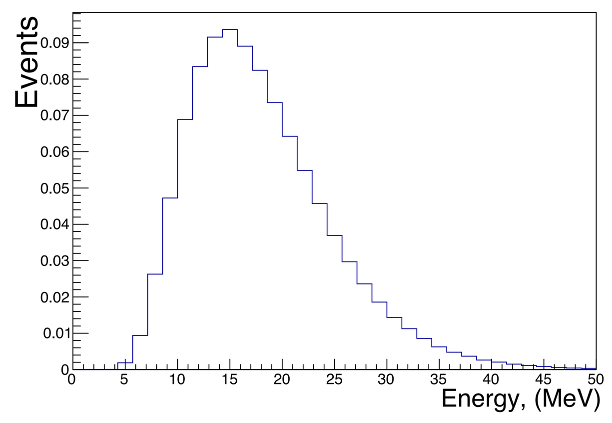
Use the **MARLEY** event generator [3] to simulate low energy electron neutrino interactions on argon nuclei.

The pre-SN progenitor is 11.2 solar mass, main sequence star [4]. The time profile model is taken from Hudepohl [5].

Overlay signal events with **radiological backgrounds**, currently the dominant sources are **neutrons** and **radon.**

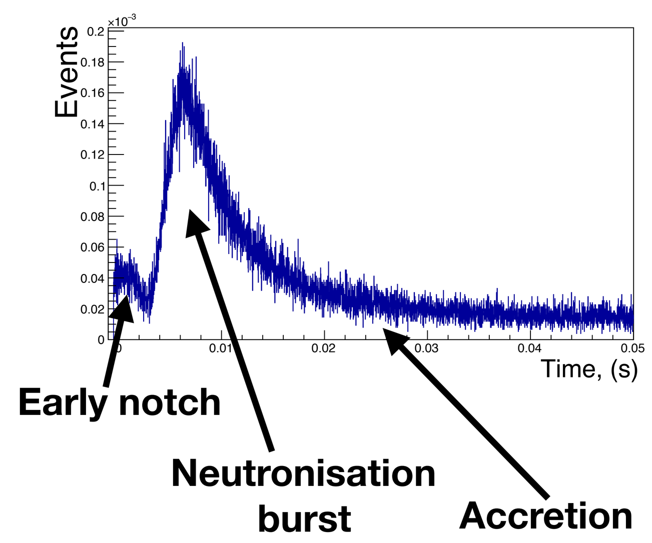
Source	Rate (Bq/cm³)	Energy (MeV)
Neutrons, Ur-238 in concrete.	13.8	<10
Rn222, LAr (contamination).	5.6×10^{-5}	5.49
Ar42, intrinsic to LAr.	1.3×10^{-7}	3.5
Ar39, intrinsic to LAr.	1.4×10^{-3}	0.6
Kr85, LAr.	1.6×10^{-4}	0.69
K40, CPA frame.	2.7×10^{3}	1.4
Co60, APA frame.	8.2×10^{-5}	1.3
Po, simulates Rn daughters on PDs.	5×10^{-6}	5.49

Neutrino Energy



Gives rise to a primary lepton peak energy at 10 MeV.

Neutrino Time Profile

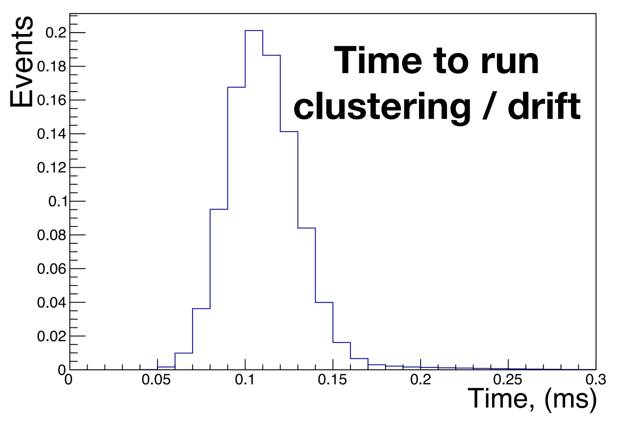


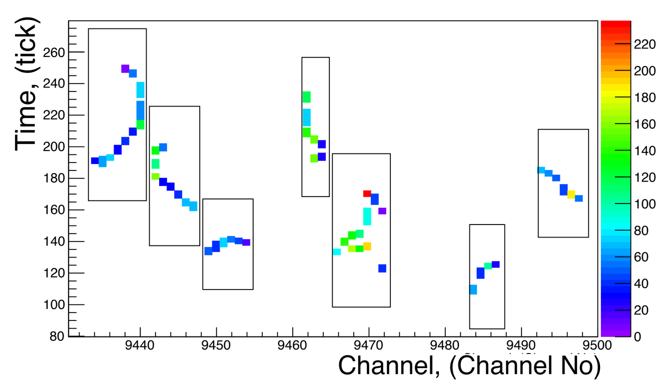
Exponential cooling.

Events extra-polated to 120 secs.

Oscillations suppress the number of events in the first 10 ms.

Hit Clustering



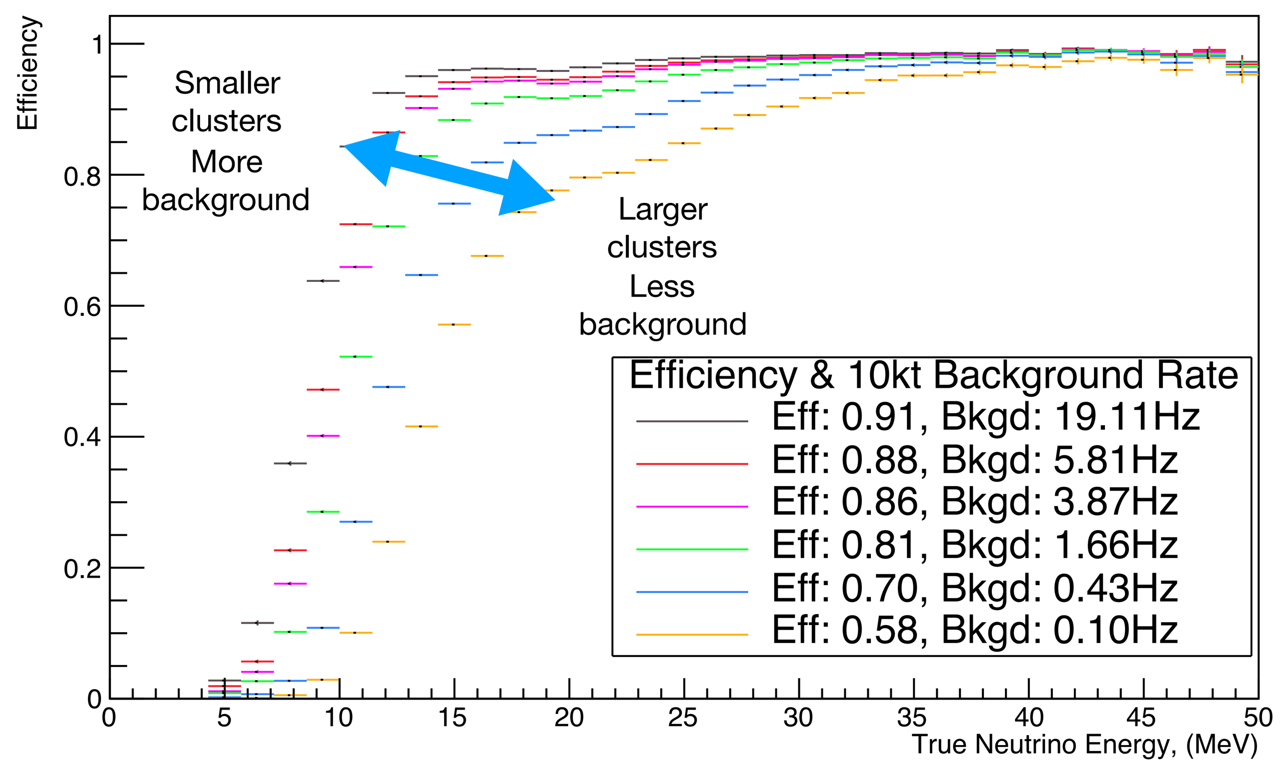


A **hit finder** is run to isolate deposits of charge above some **threshold**. Clustering then groups these hits close in **time** and **channel space**.

For triggering, this must be **fast**.

'Typical' electron from a SN neutrino event spans **5 cm x 5 cm** around the interaction vertex.

To differentiate the SN neutrinos from background, make **simple cuts.**



Cut on **width,** minimum number of **channels** and **total energy** of the clusters.

Finally require a certain **number of hits** in the clusters.

Given the simulated hit rate and assuming an ordered list of hits is provided, clustering for 10 kt could be done on a single CPU. 81% efficiency for single SN neutrinos, 1.7 Hz background.

Burst Trigger

Method in a Nutshell

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.

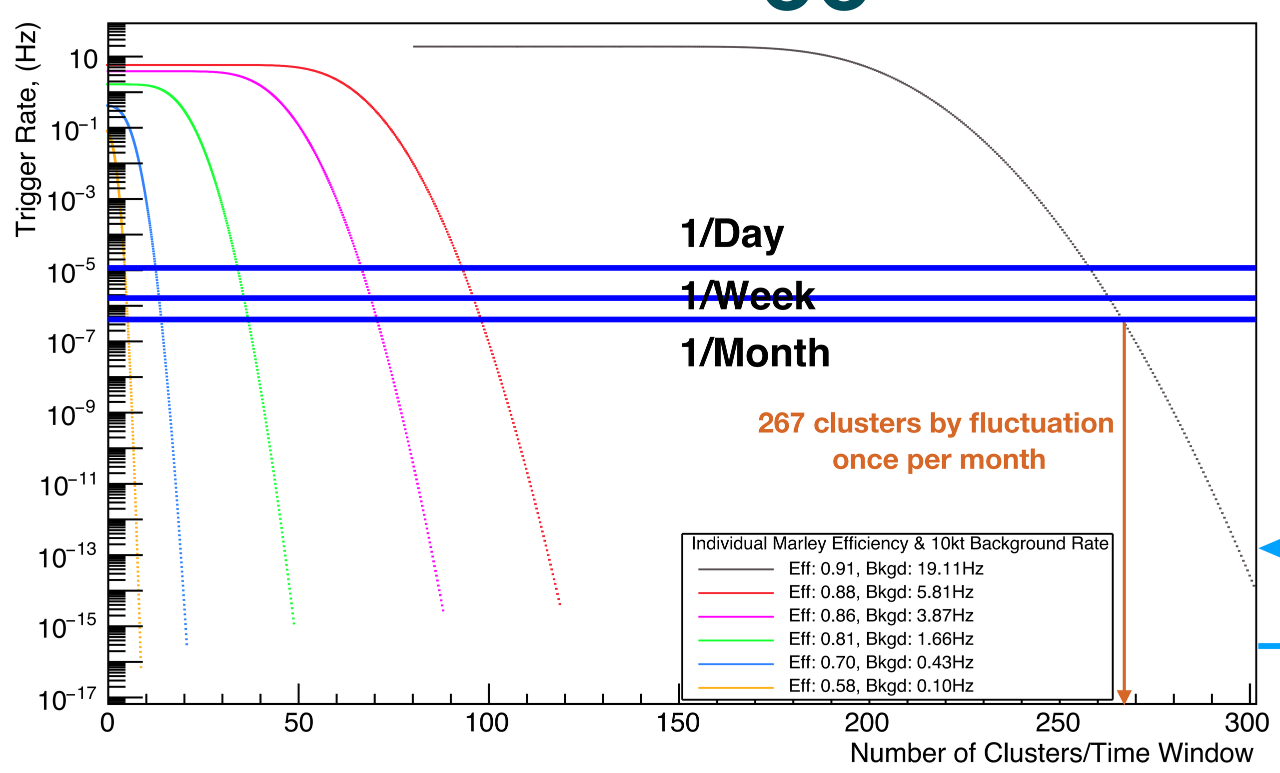
Strategy: keep it very simple.

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

Fake triggers:

Use the **background rate from the clustering algorithm**, assume it fluctuates in a **Gaussian** way.

Can map out the **burst-trigger rate** as a function of the **threshold number of hit-clusters.**



Background model: Gaussian with mean equal to the background rate from the hit clustering algorithm and RMS equal to the square root of this mean.

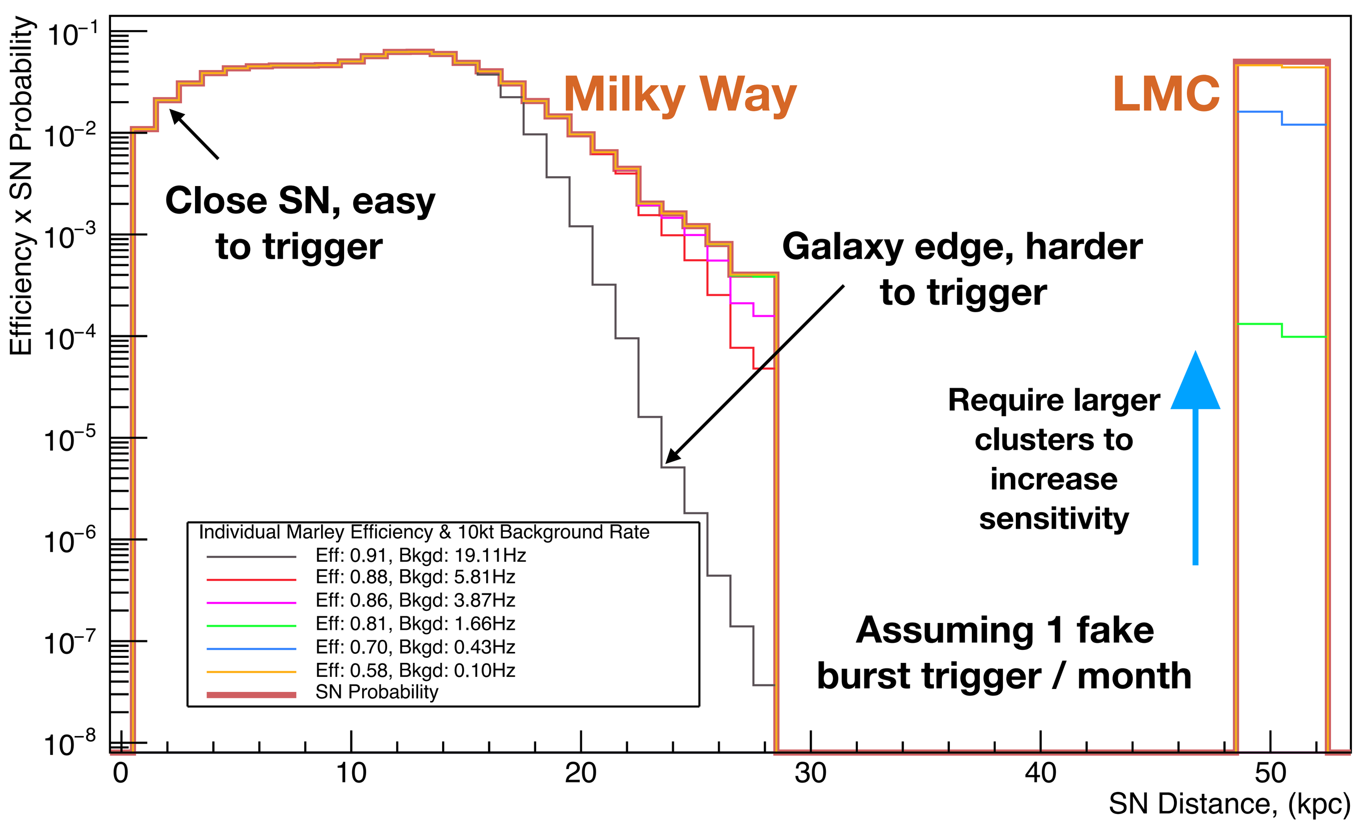
Trigger: Is the number of SN like clusters in the time window greater than some cut?

Signal: Overlay different sized supernova bursts on top of background and calculate the signal efficiency.

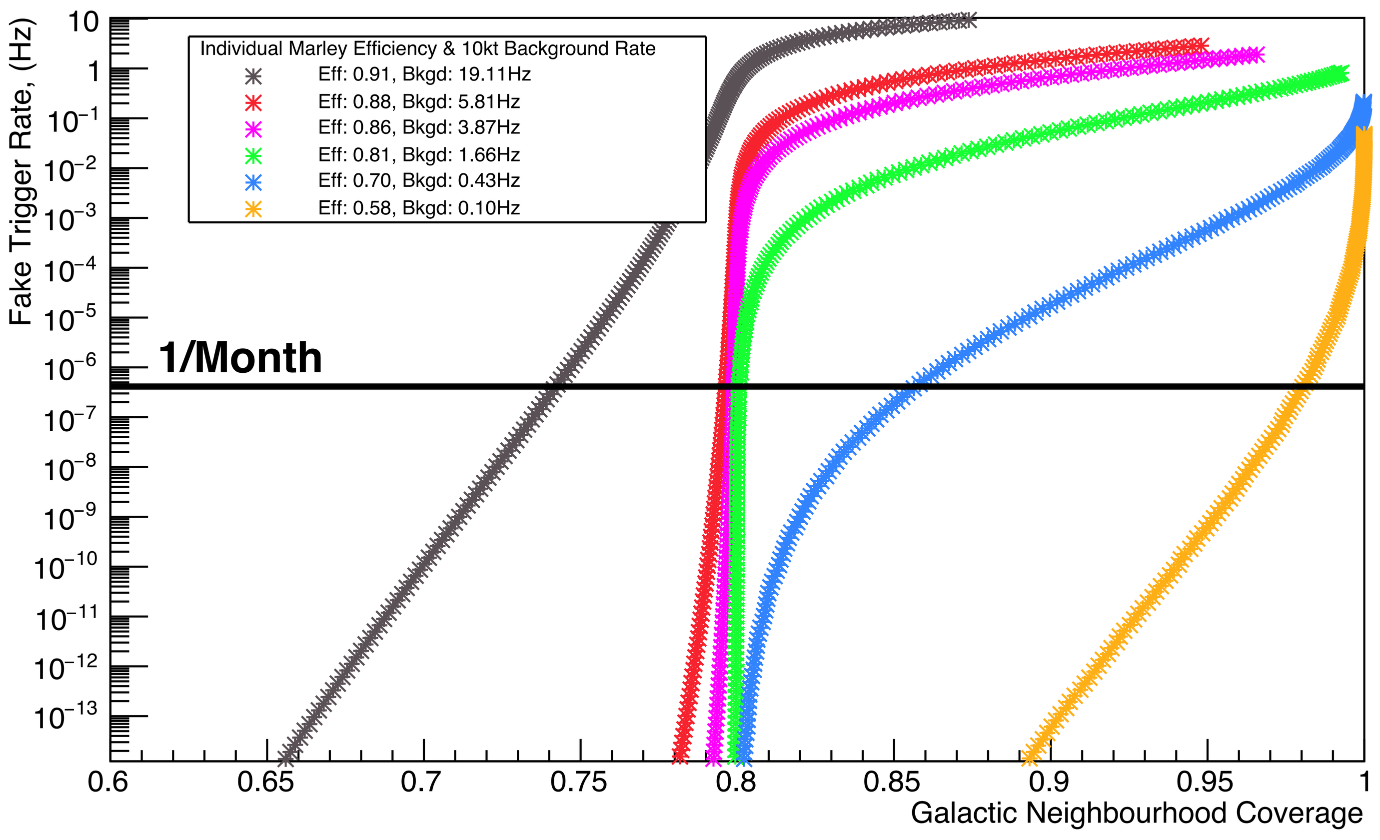
$$\text{SN Burst Efficiency} = \sum_{N}^{\infty} \text{Poisson}(\mu = \text{Mean background rate} + \text{Number of Events in Burst})$$

Coverage: Compare the burst efficiency with the distribution of galactic progenitor candidates [6].

Fake triggers: Can vary the fake trigger acceptance to meet DAQ requirements.



Trigger on 98% of supernovae in the Milky Way and LMC, issuing 1 fake trigger per month on average due to radiological backgrounds.



References:

[1] DUNE Collaboration. *LBNF/DUNE CDR*. arXiv:1512.06148
[2] Bahcall, J. N. et al. Physical Letters B 178 (1986) 2/3.
[3] Gardiner, S. J. http://www.marleygen.org/index.html
[4] Woosley, A. et al. Rev. Mod. Phys. 74 (2002) 1015.
[5] Hudepohl, L. *PhD Thesis*. Technishe University Munchen (2014).
[6] Mirizzi, A. et al. arXiv:astro-ph/0604300.