Supernova Neutrino Event Generator for Liquid Argon

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Overview:

We have written an event generator that:

1. Calculates the event rate of supernova neutrino interactions for energies from 1 to 100 MeV and up to ten seconds in time. This provides a source of time dependence for the energy-dependent event generator.
2. Utilizes the times and energies determined from the event rate to throw events in the event generator that are output in HEPEVT format.
3. Divides the events into 1.6ms frames.

All of this depends only on C++ and ROOT as executables. The generator only takes into account the $\nu_e + {}^{40}\mathrm{Ar} \rightarrow e^- + {}^{40}\mathrm{K}^*$ channel.

We have implemented a simulation of the currently envisioned algorithm for recording supernova data.

Supernova-Neutrino Spectrum

We use a pinched-thermal form given by:

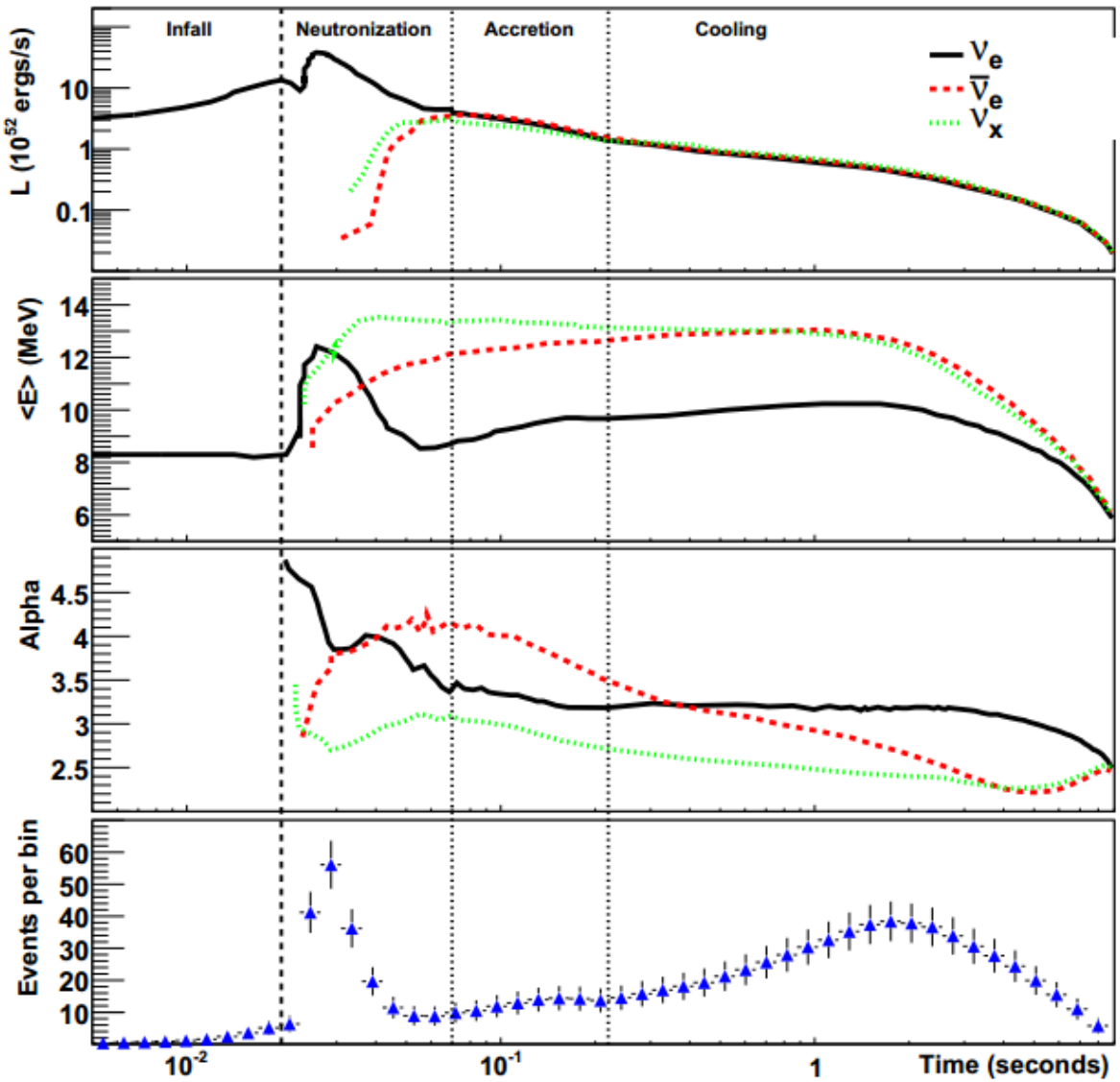
$$\phi(E_\nu) = N(\frac{E_\nu}{\langle E_\nu \rangle})^\alpha \exp(-(\alpha+1)(\frac{E_\nu}{\langle E_\nu \rangle}))$$

[Taken from *The Long-Baseline Neutrino Experiment Exploring Fundamental Symmetries of the Universe* Document.]

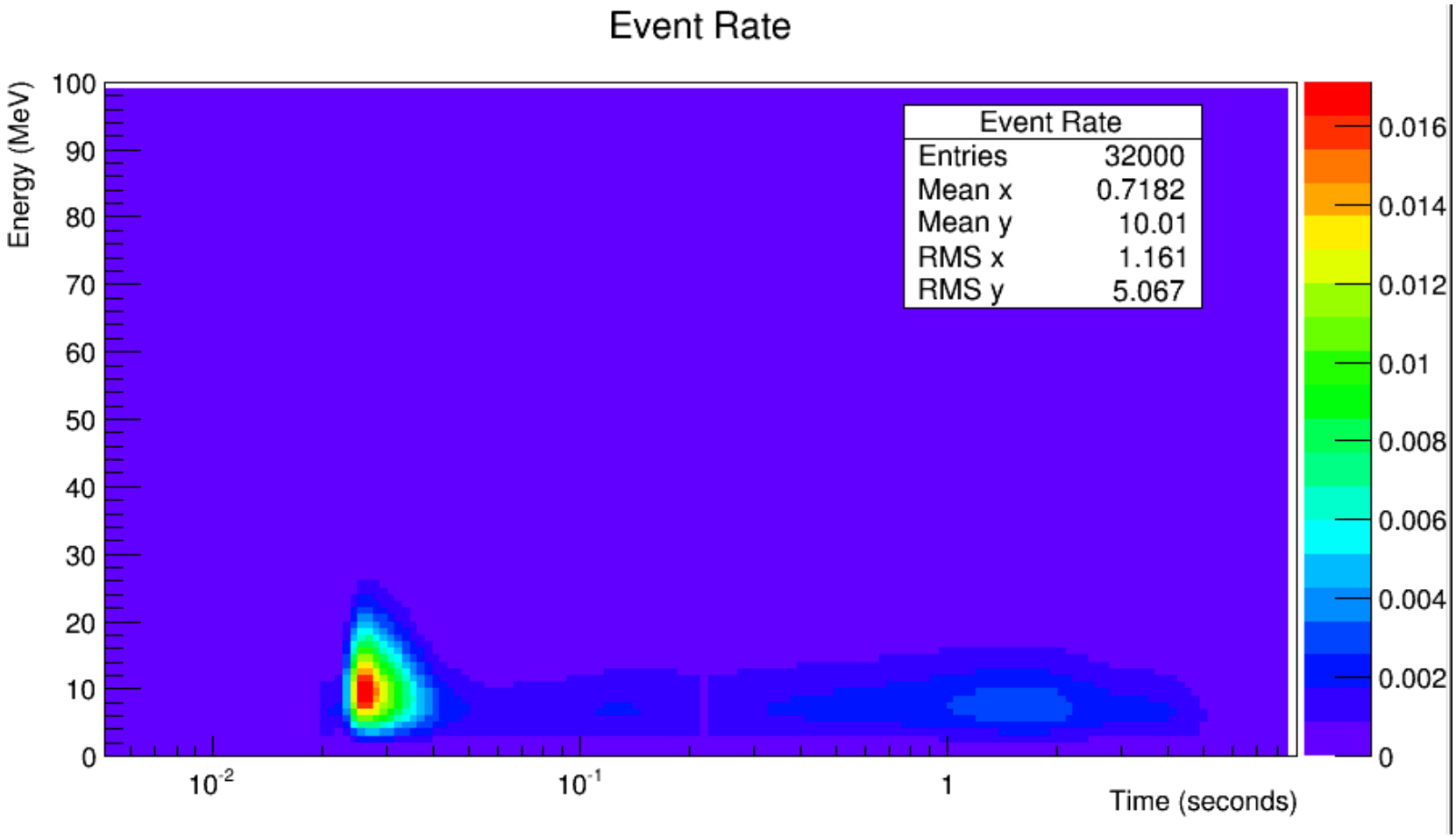
We have, for the energy-dependent spectrum ϕ, N a normalization constant that depends on the volume of liquid argon and luminosity, α a pinching parameter, and mean energy $\langle E_\nu \rangle$.

The luminosity, α, and $\langle E_\nu \rangle$ have all been digitized from theoretical models (and are model-dependent).

Parameters


Infall
Neutronization
Accretion
Cooling
ν_e
$\bar{\nu}_e$
ν_x
L (10^{52} ergs/s)
10
1
0.1
<E> (MeV)
14
12
10
8
6
Alpha
4.5
4
3.5
3
2.5
Events per bin
60
50
40
30
20
10
10^{-2}
10^{-1}
1
Time (seconds)

Event Rate Distribution

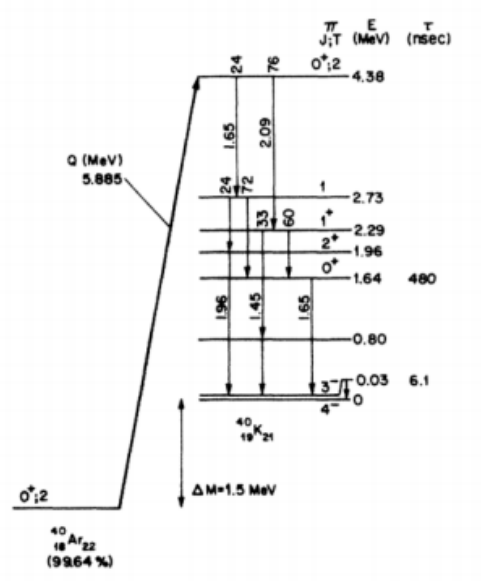


Logarithmic with time

Event Generator

The event generator takes input energy to calculate the position and momentum of the electrons and photons produced by the neutrino events using the cross-section provided by Kate Scholberg and AJ Roeth of SNOwGLoBES.

These parameters, along with the time of their creation, are output to a HEPEVT file and the de-excitation gamma energies are stored in a ROOT file.



Nuclear energy level diagram for $^{40}K^{*}$

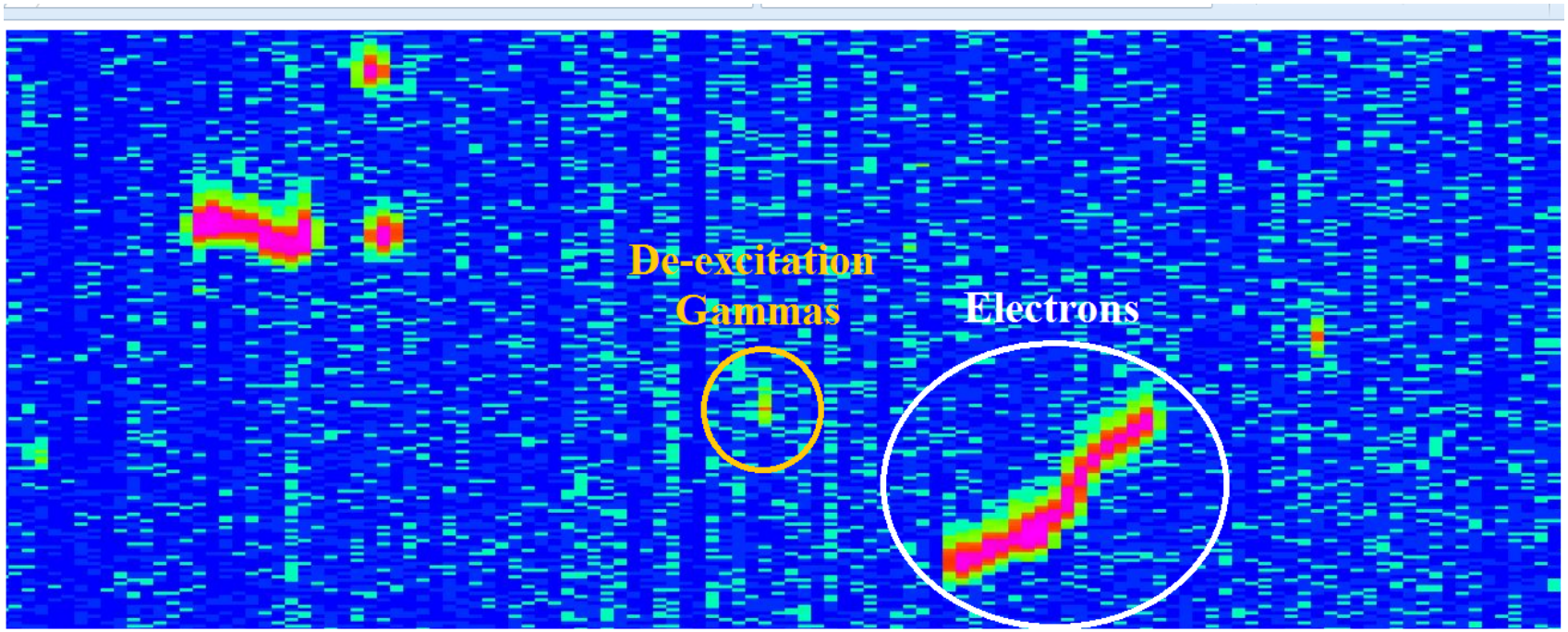
Splitting into Frames

The final part of the event generator splits the resulting HEPEVT file into separate 1.6ms frames.

The times are then put in terms of where the event took place within that 1.6ms frame.

The final output is a single HEPEVT file containing all the dynamics and times of the particles produced by the interaction for each frame.

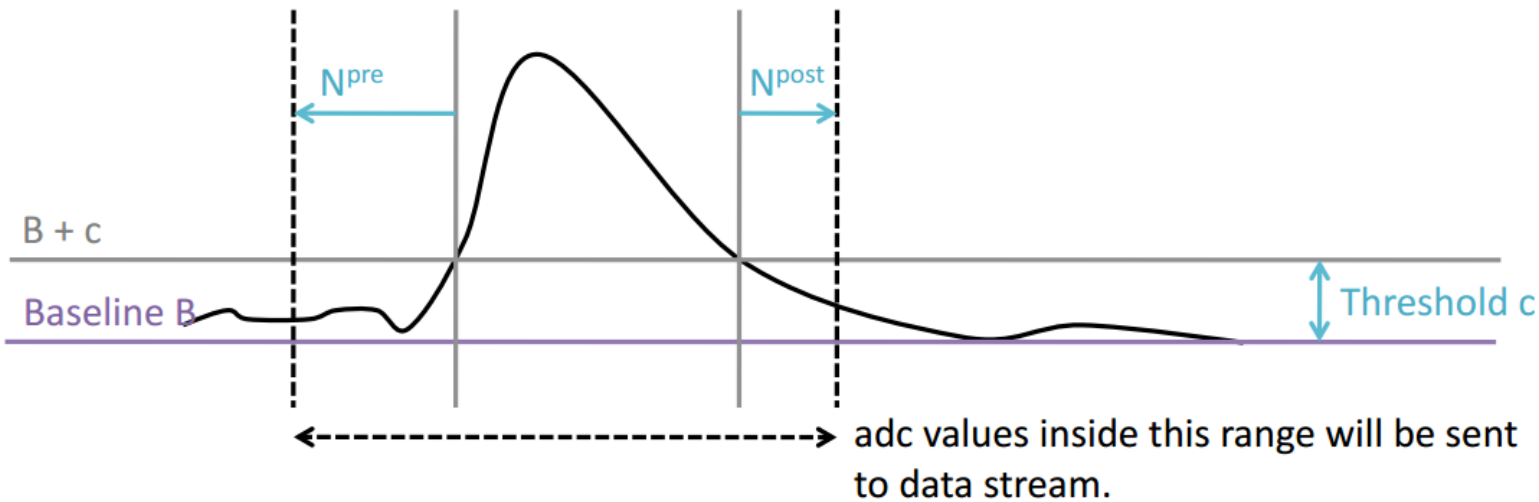
LArSoft Event Example



The x-axis is the wire-number and the y-axis is the time-tick. The color represents the ADC amplitude of the raw waveform and this is a zoom-in of the collection plane of the TPC.

Compression Scheme

We are currently implementing a compression algorithm for supernova data within the LArLight scheme. The algorithm checks for an appropriate level of variation in baseline and variance and, if the variation is larger than some optimizable threshold constant c, the data and a surrounding window of ticks (given by N_{pre} and N_{post}) are saved.



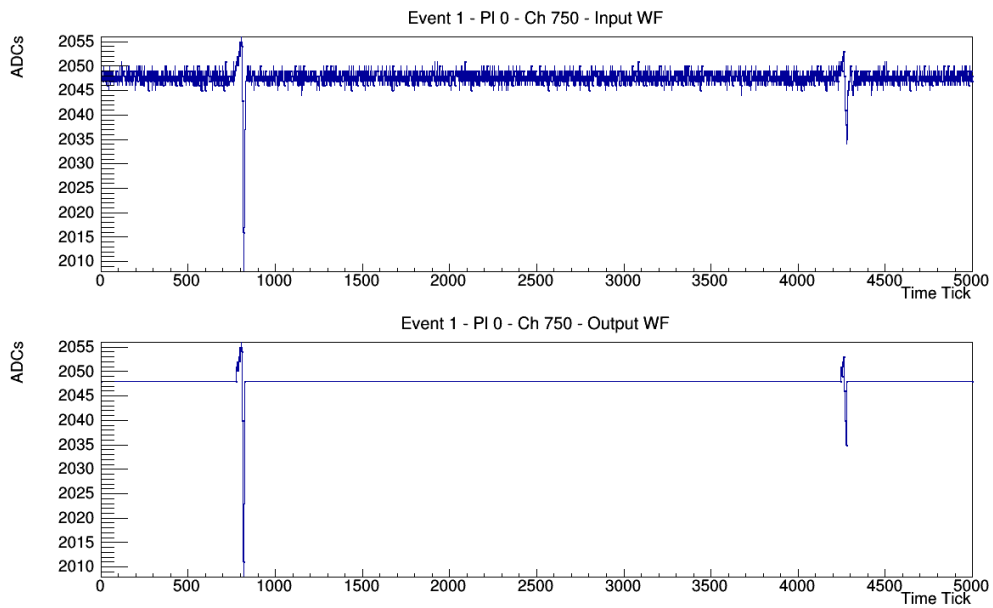
[Taken from Doc-DB 3764.]

Developments for Compression

The algorithm is already in action in LArLight, but some parameters still need to be optimized. We are trying to optimize the algorithm's performance based on MCC5 data.

Have already optimized N_{pre} and N_{post} for all three channels. Currently optimizing the threshold constant c.

Intend to apply the compression scheme to the products of the supernova generator to see what kind of data we can expect to see.



Thanks!

Thanks to Professor Mike Shaevitz, Georgia Karagiorgi and David Caratelli at Nevis as well as Professor Kate Scholberg and AJ Roeth at Duke!