Photon Detection System (PDS) and SN triggering

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Introduction

Outline

• Introduction

  • Final aim:
    • What to expect from the PDS for SN triggering?
    • Can we motivate from SN/DAQ point of view?
      • Addition of reflective foil on the cathode
      • Use of ARAPUCA / higher efficiency/granularity PDS
    • Photon detection in LAr

• PDS hit level information

• Clustering

• Results

• Other info:
  • MCC10 SN samples and geometry:
    snb_timedep_dune10kt_1x2x6_snb_timedep_bkg_reco
  • Using Jason’s photon backtracker after recent fix (28th June)
Introduction
Photon detection in LAr

• LAr scintillation, 2 components:
  • Fast light from singlet $\text{Ar}_2^*$ state
  • Slow light from triplet state

- Fast Component $\tau \approx 8$ ns (29%)
- Intermediate Component $\tau \approx 140$ ns (8%)
- Slow Component $\tau \approx 1.6$ µs (63%)

• Effect of HV, impurities can change (marginally?) the timing of the different components.
Event Displays (Time and Space)

- LArSoft event (full drift window)

- Hit time distribution:
  - Arrow: true time of generation
  - Histogram: timing of the optical hits

- Hit spatial distribution:
  - Pink line: wire hits backtracked to SN$_\nu$
  - Overlaid histogram: optical hits in the PDS backtracked to SN$_\nu$
    - 10 scintillation bars / APA
    - Red cross: true neutrino interaction position

... With all the hits:
Hit level
Information

- Full drift window
- OpHit
  - Unmatched hits: noise, dark current

Number of hits per drift window

\[
\begin{align*}
\text{Number of hits per drift window} & \approx 1k \text{ events} \\
\end{align*}
\]
Hit level information
Signal features

- Efficiency:
  1 or more optical hits from SN / N events

- Drops the further you get from the APA
- Number of hits scales linearly with $E_N$
- Edge effect, photons escape

First hit + other fast light hits
Other slow light hits
Clustering

- I went ahead and clustered optical hits:
  - Reused the code from Alex Booth:
    - Timing: 800 ns (maybe too small wrt the simulations)
    - Z position: 300 cm (1 APA)
    - No Y clustering
  - Composition of the clusters:
    - Biggest contributor of hit to tag as SN or not.
    - Neutron is still the worst background
      - Background contributions are more evenly spread out → Pile up is important! (Unlike for wire cluster where the main contributor is neutrons)
Cluster properties

- Splitting the SN events!
  - First pass, still trying to get better at clustering time properly.
  - Number of background clusters is large without cuts

12m clusters!!

~ Size of the 1x2x6 → not appropriate for these studies

Something smarter has to be done for the time
• Clustering efficiency (no cut)

• Nhit (and n PEs) can be used to suppress backgrounds

• Next: use 10, 12, 15, 17 hits as cut (still missing stats to go further)
• Use a 5s timing window to count the number of clusters
• Can trigger on almost all of the milky way using only PDS info!
• Trying to get to the LMC where you get 10-20 events.

Results
Conclusion

Future work

• First pass at using PDS for SN trigger
• Basic simple clustering implemented (needs improvement)
• Currently can trigger on Milky Way SN but not on the 20% of SN coming from LMC
• 1x2x6 geometry is not really big enough to avoid bias in PDS (light leaks out sides)
• Photons travel far → triggering cannot be done so efficiently on the APA level (few APAs at least).
• The slow component of the light is important.

• Future work
  • Motivate improved design for the PDS:
    • Consider the addition of reflective foil on the cathode
    • More granular/efficient detector can do better?
  • Combine PDS with wire information at the trigger level?