Gamma-X Event detection And Work at SLAC

Jonathan Nikoleyczik

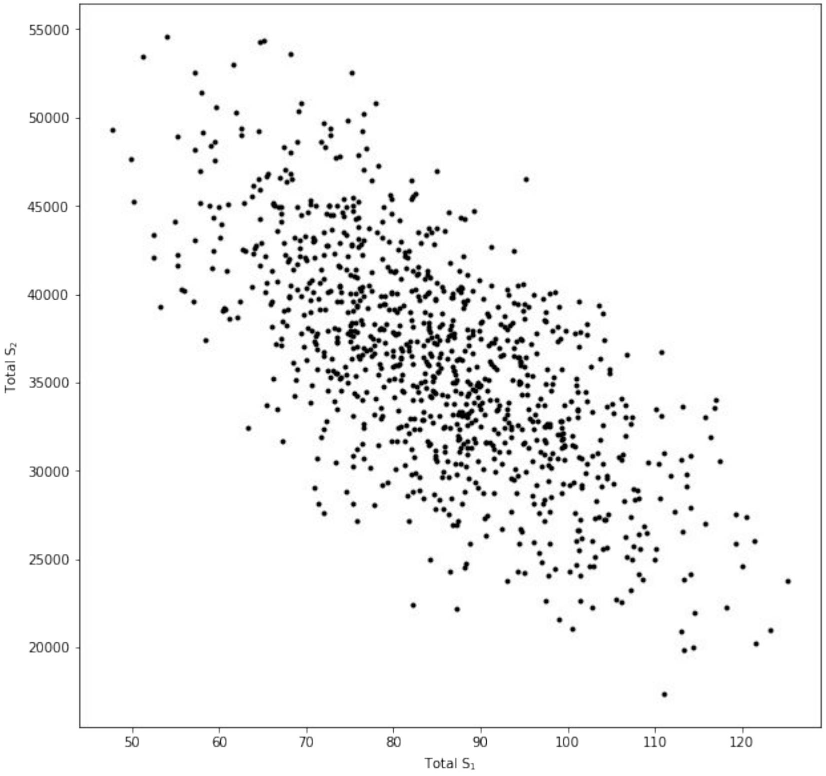
I am attempting to understand a potential background in the LZ detector, called Gamma-X events by analyzing simulations of background events.

Today's update starts on slide 46

Running BACCARAT

- Ran test Sims in latest version of BACCARAT (1.0.0)
- Will modify scripts to look for Gamma-X events
- Currently using simple rootpy analysis
- Plan to emulate Bhawna's Gamma-X study

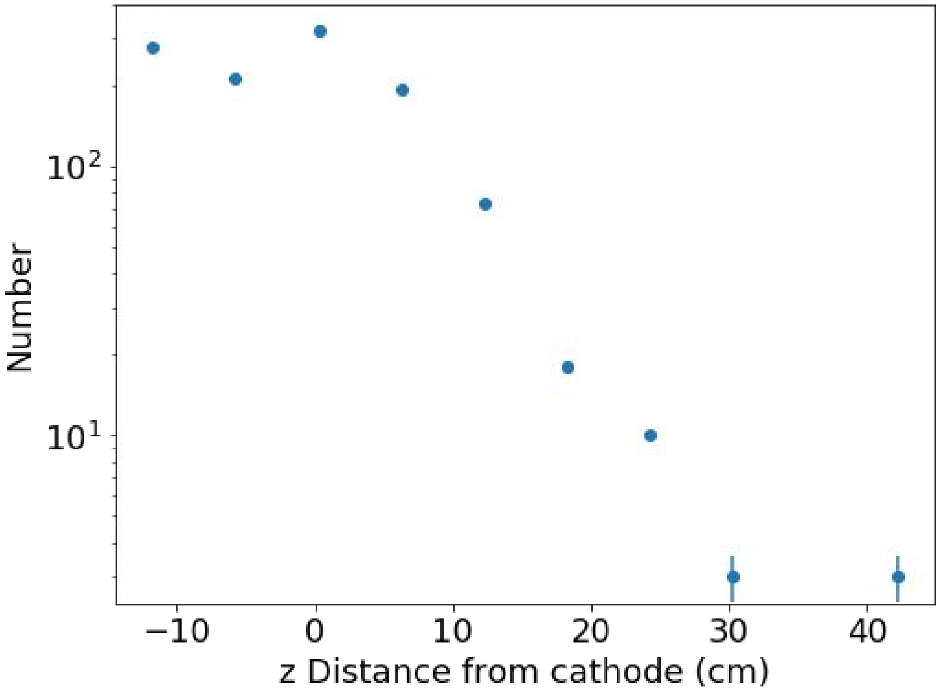
S1 vs. S2 from the BACCARAT test macro



More Gamma-X results

- 100,000 Th 232 Decay Chain Events
- Expected an exponential drop off (I see one if I don't require energy deposited)
-

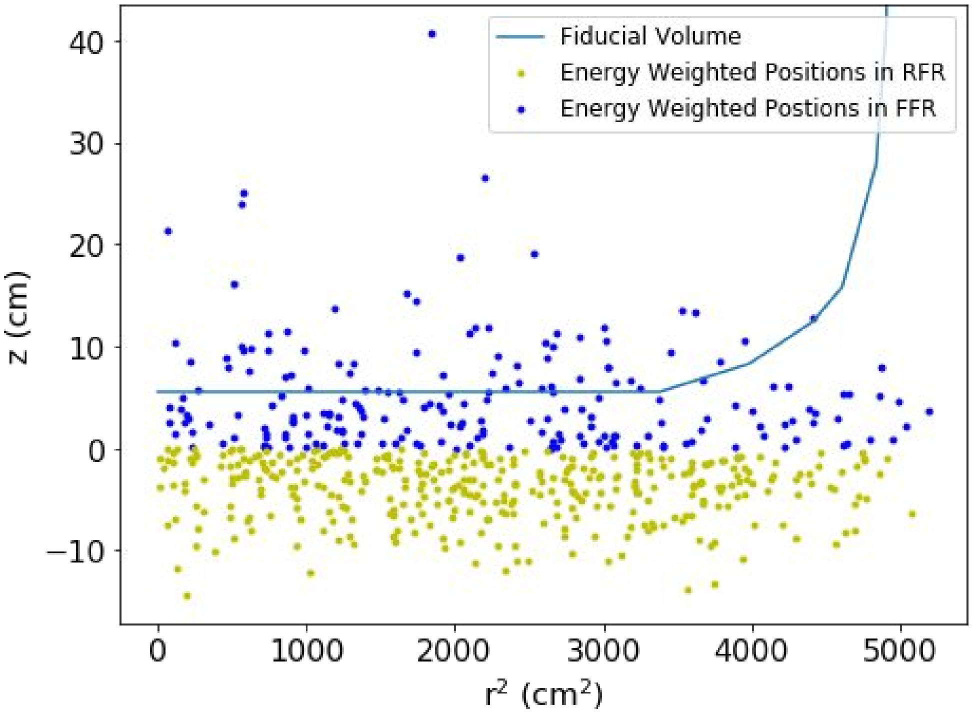
Events in both Forward and Reverse Field Regions



Gamma-X Update

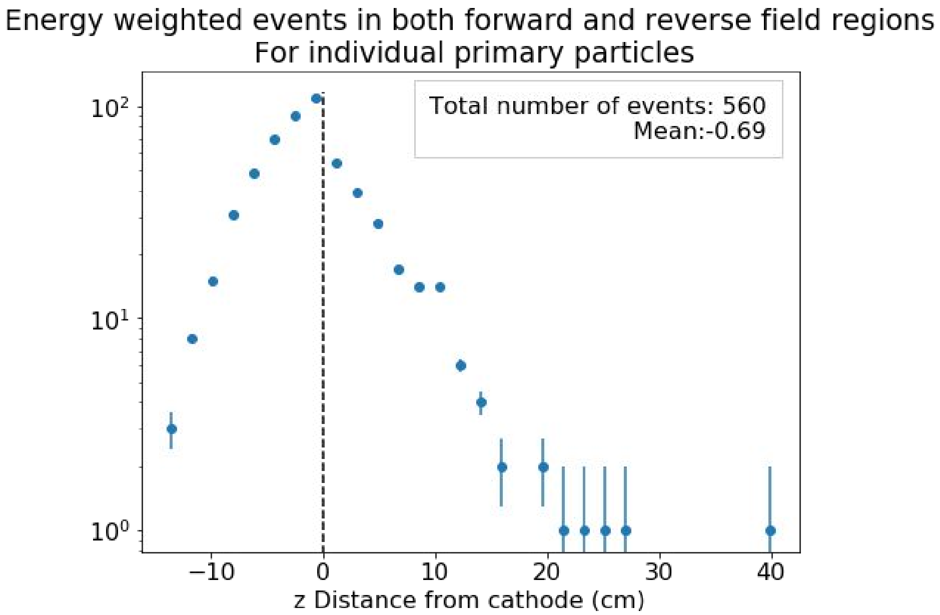
- Same 100,000 Events as last week
- Producing 560 events in both regions
- Now I add together events in forward and reverse field regions, then do the energy weighted sum
- There is now one dot for each decay event
- Issues getting S1 and S2
    - Needs libNEST
        - Needs Boost

Energy weighted depositions combining both the forward and reverse field regions



Fixed Histogram

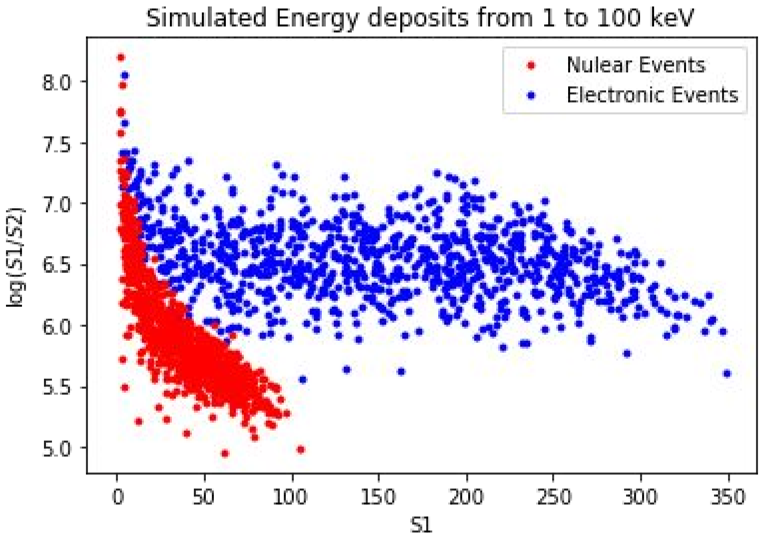
- This is a histogram of the data on the last slide as a function of z
- The RFR looks almost linear and the FFR looks exponential



fastNEST is up and running

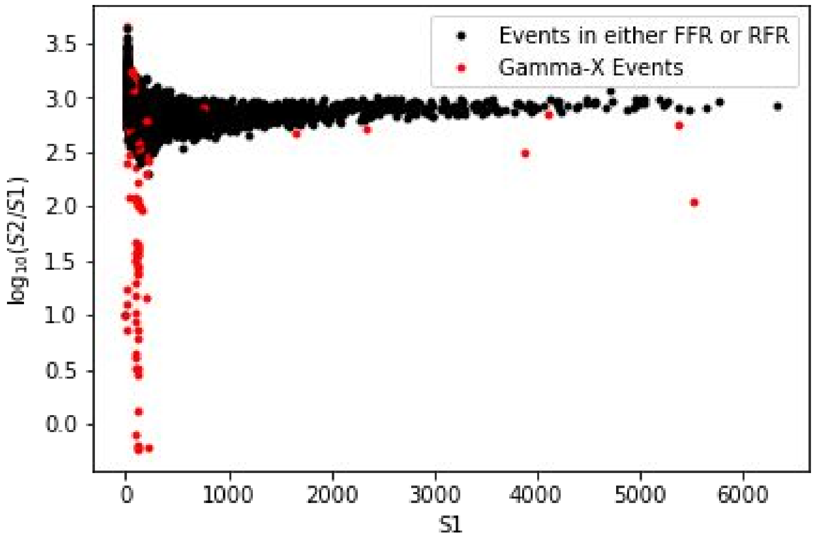
I’m able to get S1 and S2s

The plot on the right is just an example of S1 and S2 for Nuclear and Electronic events. They are for random energy depositions of 1 to 100 keV with no specification on location.



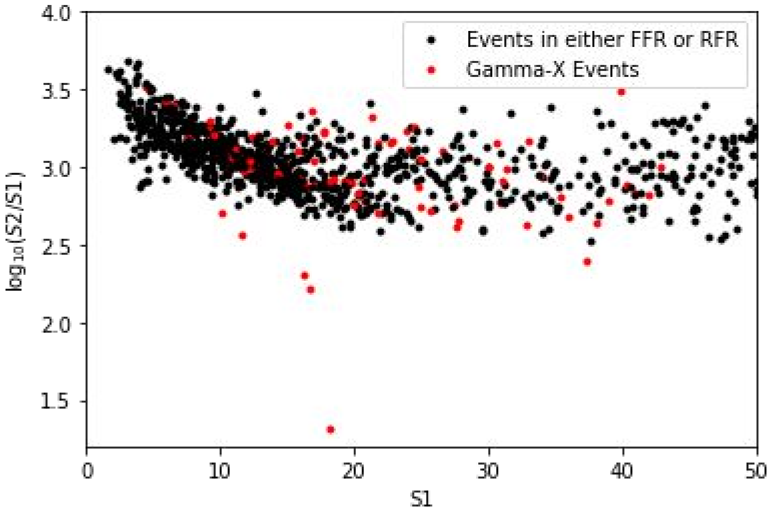
Real Gamma-X events in S1 and S2

- Gamma events create a lot of light compared to WIMP events
- See up to 6000 S1 but the WIMP search is only up to 50 S1
- See the expected suppression of S2



Just WIMP search region

- Same data, now only showing the WIMP search region defined in the TDR
- See ~5 events that appear to be closer to nuclear rather than electronic events.
- Need more statistics, this is with 100,000 decay events I can easily scale this up to a few million events



Search Region from TDR

This is the plot which I used to compare the normal and Gamma-X events to.

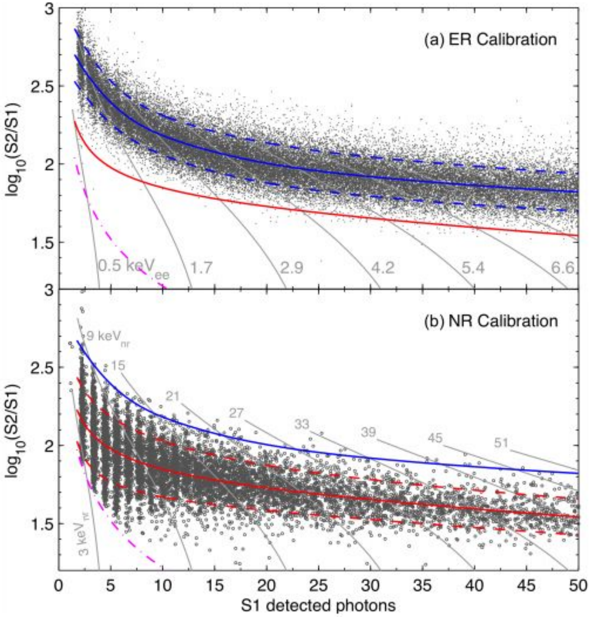


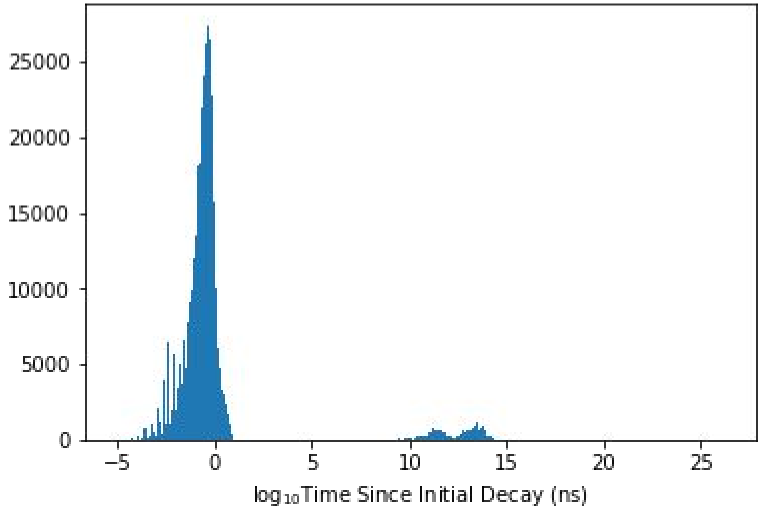
Figure 1.3.11: Discrimination parameter $\log_{10}$(S2/S1) as a function of S1 signal obtained with LUX calibration [58]. (a) ER band calibrated with beta decays from a dispersed ^{3}H source; the median is shown in blue, with 80 % population contours indicated by the dashed blue lines. (b) NR band populated by elastic neutron scattering from a D-D pulsed neutron source; the median (solid) and 80 % band width (dotted) are indicated in blue and red, respectively. The mostly vertical gray lines are contours of constant energy deposition. For more information, see Chapter 7.

Time resolution

I wanted to make sure that all of the events occur within the timeframe of one event in the detector

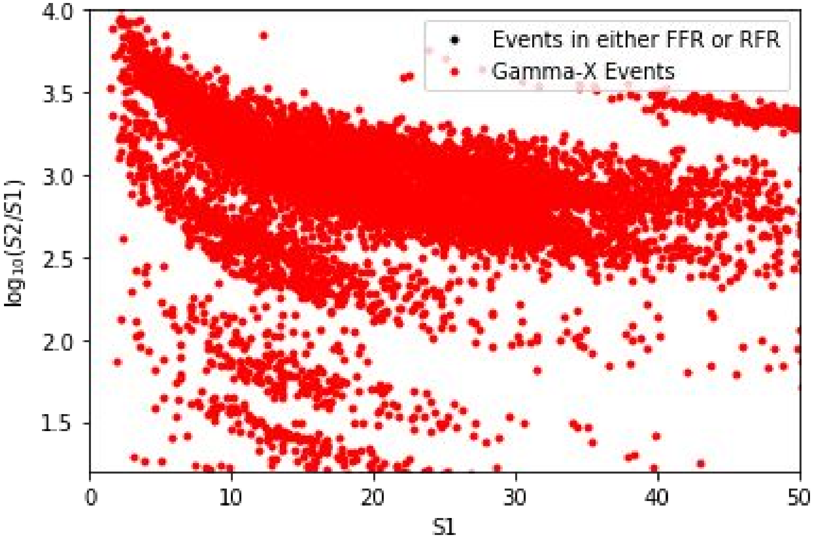
Almost all events occur within a few nanoseconds of the initial decay.

There is a much smaller population of secondary events which are handled separately from the primary events.



High statistics run

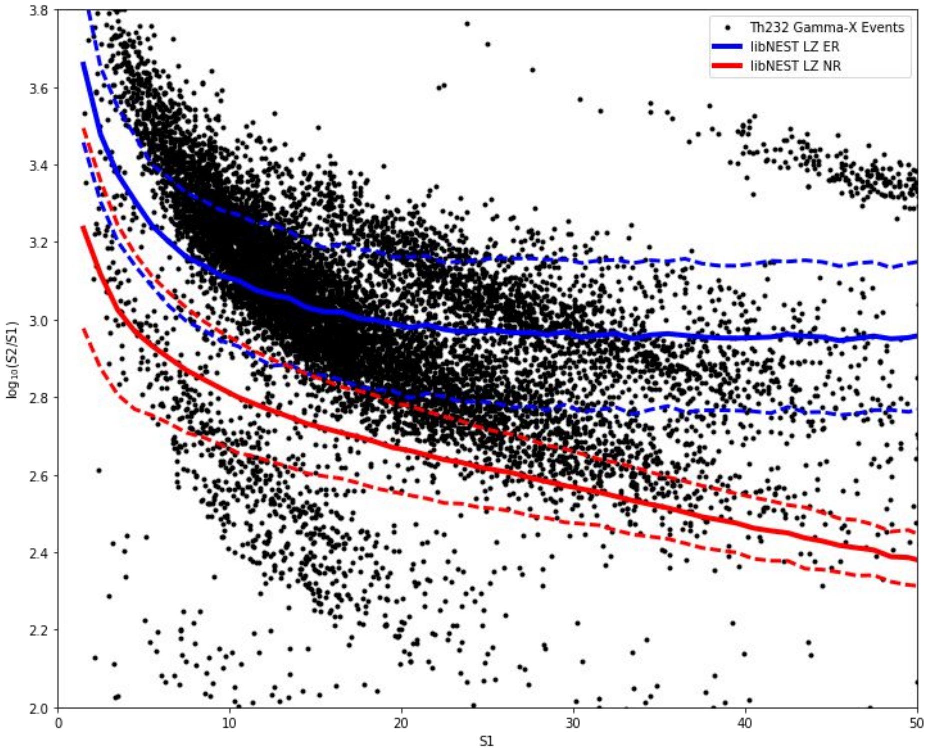
- Went from 100,000 decays to 10,000,000 decays in this data set
- There are band like structures in the S1 vs log(S2/S1) plot (shown right)
- I am only focusing on the WIMP search region
- There are ~12,000 Gamma-X events in this region



Including ER and NR bands

The Gamma-X events do not exactly follow the ER and NR bands. There is suppression of S2 at constant S1.

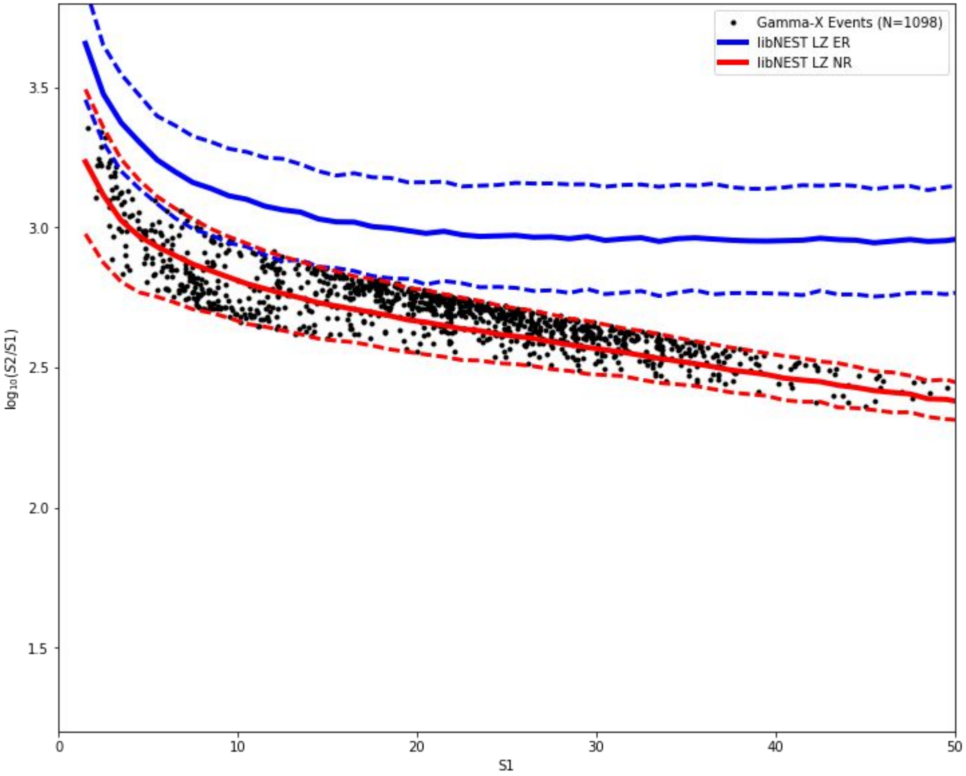
The bands shown here are the 90% bands.



Focusing just on the NR band

There are 1098 events that fall in this band.

So about 0.01% of Th232 decays from the PMT windows will be likely to cause Gamma-X events



Next Steps

- More high statistics runs of other radioactive sources. Likely Uranium as it also has a high rate from the PMT windows.
- Detailed analysis of these events. Likely just to determine the tracks and angles which create these events (Are they more likely in the edge or the center etc.).
- Determine the actual rate in cts/kg/day. This is likely to be an underestimation as there are more background sources than the PMT windows

Gamma-X Events

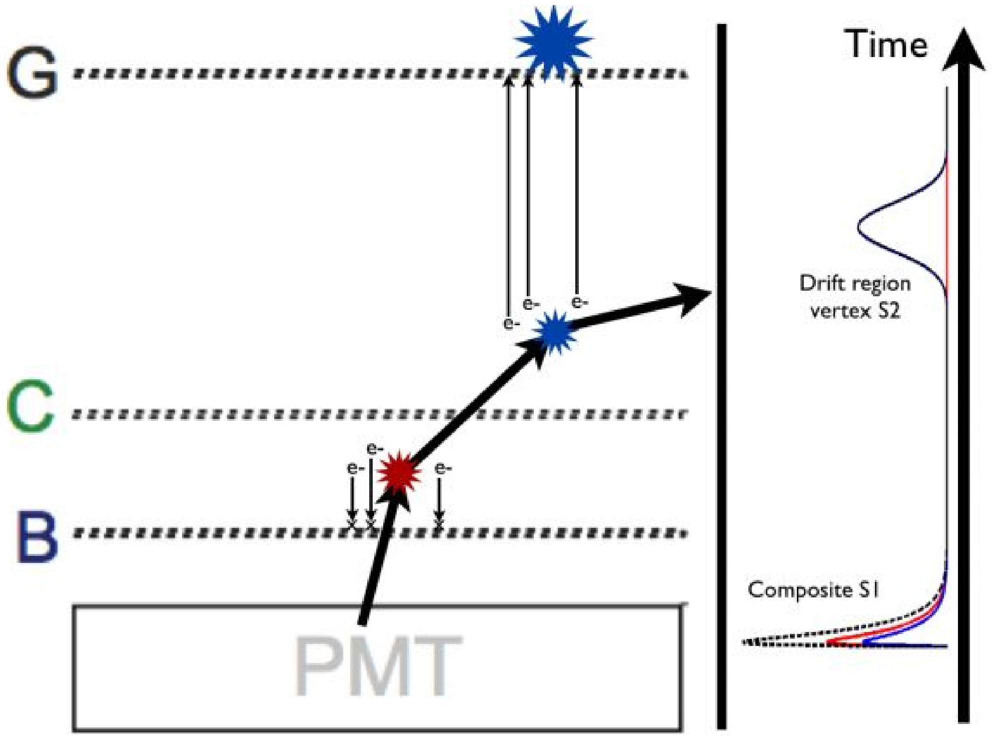
Jonathan Nikoleyczik
UW - Madison
Physics Meeting

Overview

- Simulate 20,000,000 Th232 decay chain events created at the PMT windows
  - Used BACCARAT 1.2.0 with BaccRootConverter
- Calculate S1 and S2 using libNEST
- Analysis code to look for events which deposit energy in both the forward and reverse field regions (Gamma-X events)
  - Jupyter Notebook Analysis Code (First method)
  - Analysis Code (Corrected method)
  - BACCARAT macro

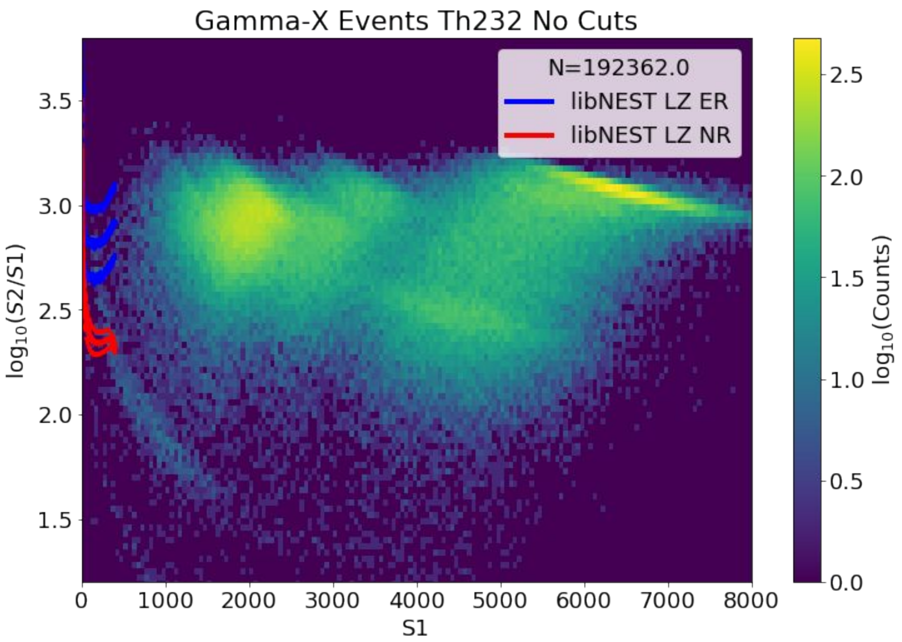
Gamma-X events

A diagram of a Gamma-X event. An interaction occurs in the reverse field region which creates an S1 but no corresponding S2. The track continues into the forward field region and creates a normal S1 and S2 which will have a suppressed S2 compared to the total energy deposited.



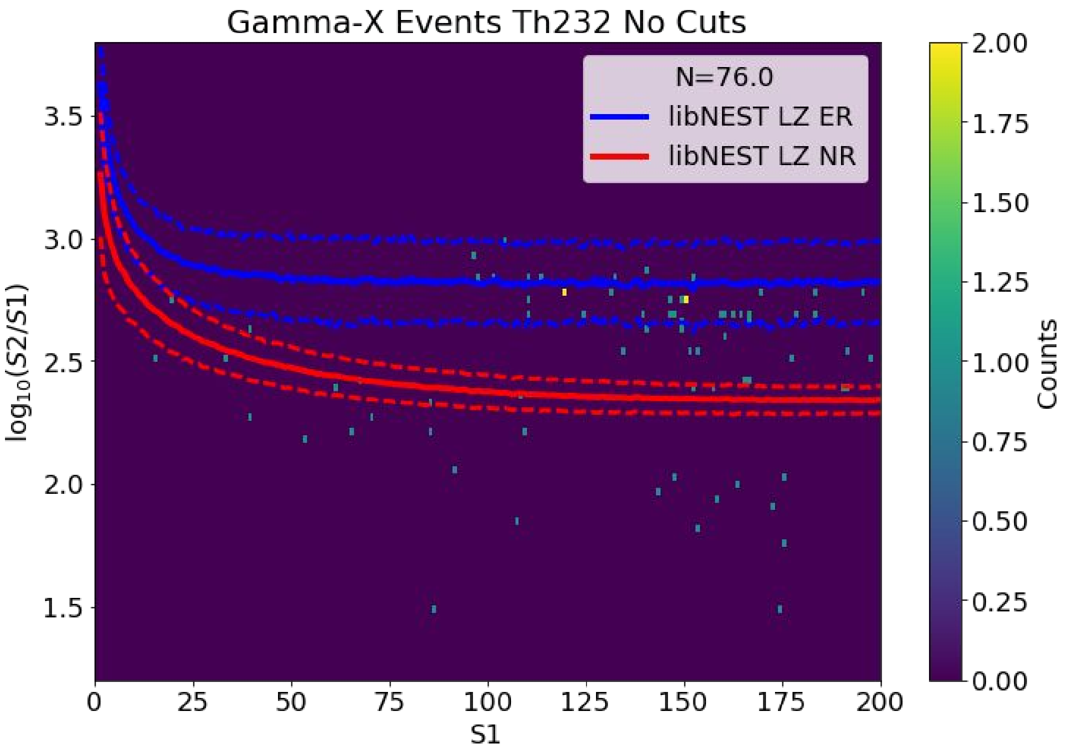
Analysis method

- Follow the method of the TDR ReducedAnalysisTree
- Group together events within a small region then calculate S1 and S2 based on the total energy deposited in that region
- Moves events out of the WIMP search region significantly reducing the rates
- Also decreases the S2 to S1 ratio



WIMP Search Region

- Since S1 and S2 are calculated with higher energy the S1 and S2 move out to higher values and we get fewer events in the search region



Improved method rates

Source	Decays Simulated	Fraction which produce Gamma-X (all)	Fraction in WIMP search region (Depending on S1 S2 cut)	Approximate rate (assuming production from PMT windows and **no cuts**)
Th-232	14,900,000	0.012887 192507 Events	~ 4.0×10^{-7}	0.24 events per year
U-238	4,150,000	0.013739 57094 Events	~1.2×10^{-6}	3.83 events per year
Co-60	9,800,000	0.080683 790704 Events	~4.0×10^{-7}	0 (No Co60 in PMT windows)
K-40	9,400,000	0.004208 39559 Events	< 1.0×10^{-7}	< 0.13 events per year

Agrees with rates from previous simulations of Gamma-X rates Bhwana Gombers slides

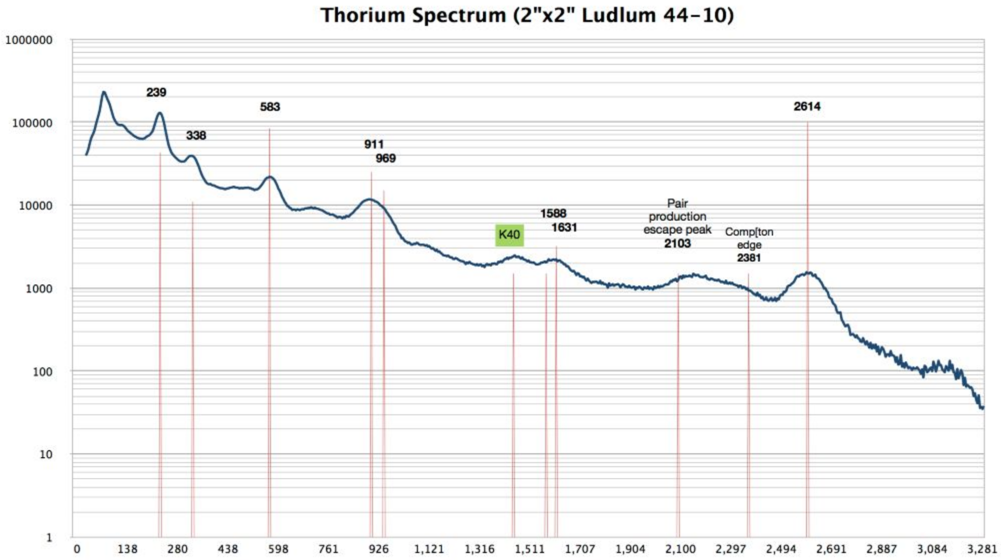
Future

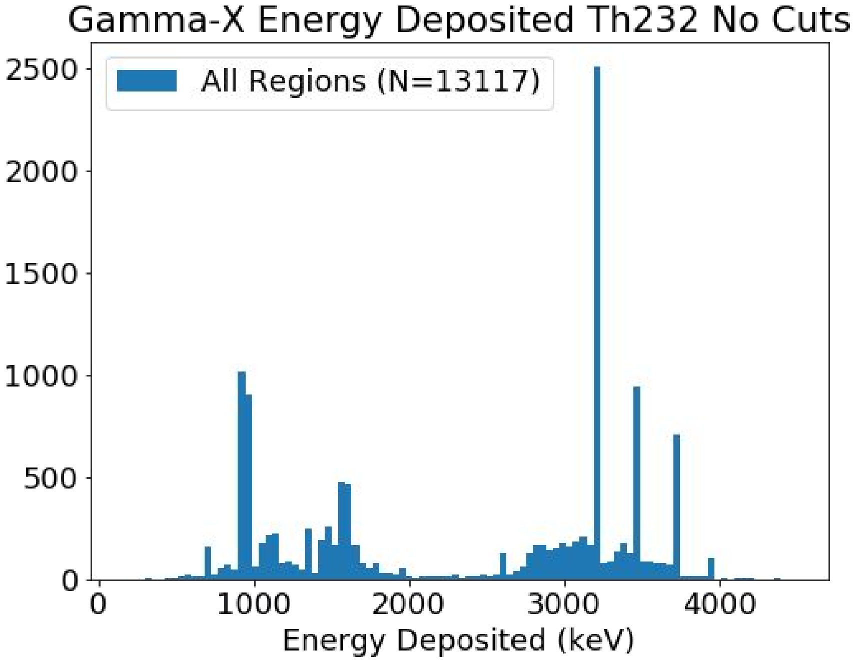
- Add cuts
  - Follow TDR cuts (energy, skin, outer detector, time, fiducial volume)
  - Preliminary but fiducial volume gets rid of almost all events
  - See if there are more that would be useful
- Look at decays from more sources
  - Include walls and PMT holder

Backup Slides

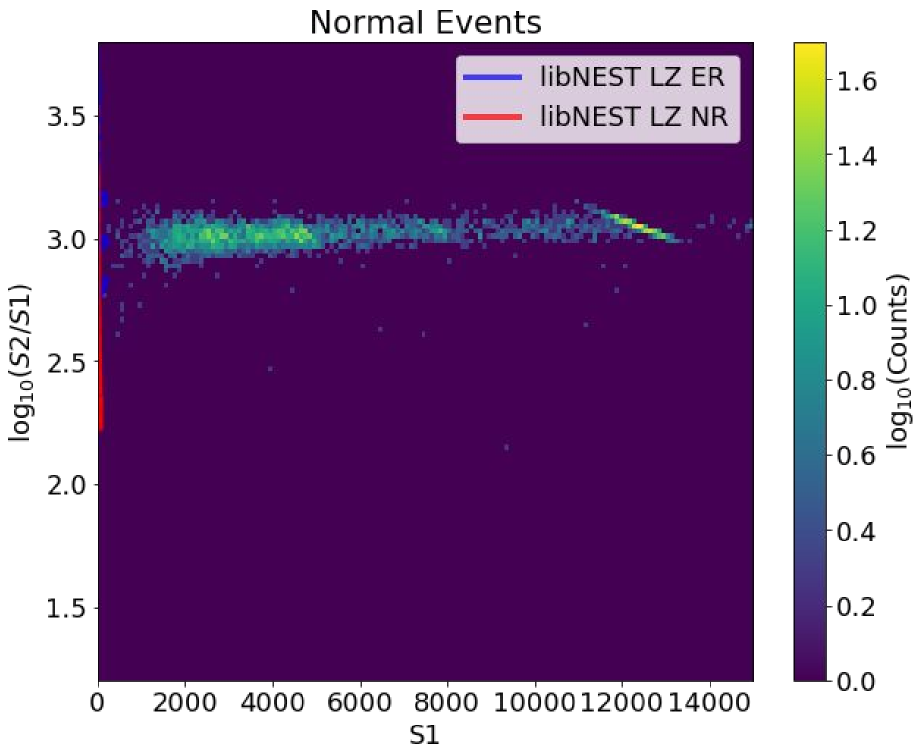
Continued on Slide 36:
Work at SLAC

Energy deposits agree with Th 232 spectrum



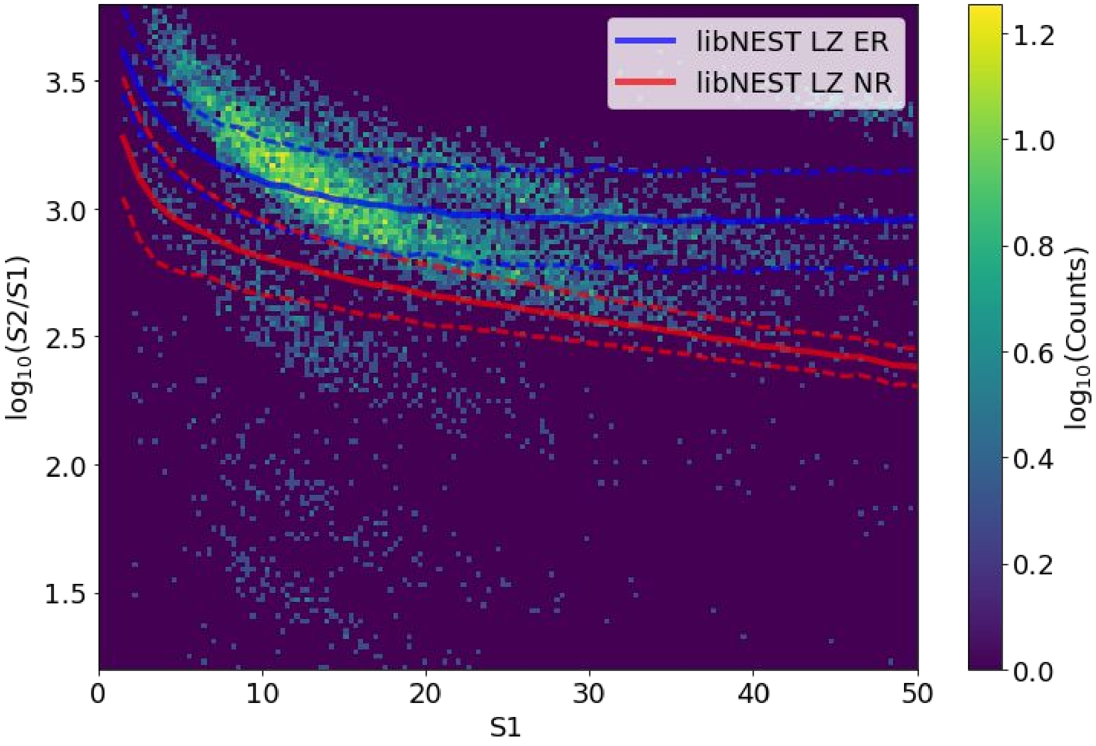


Normal Events (Th 232)



The First Method

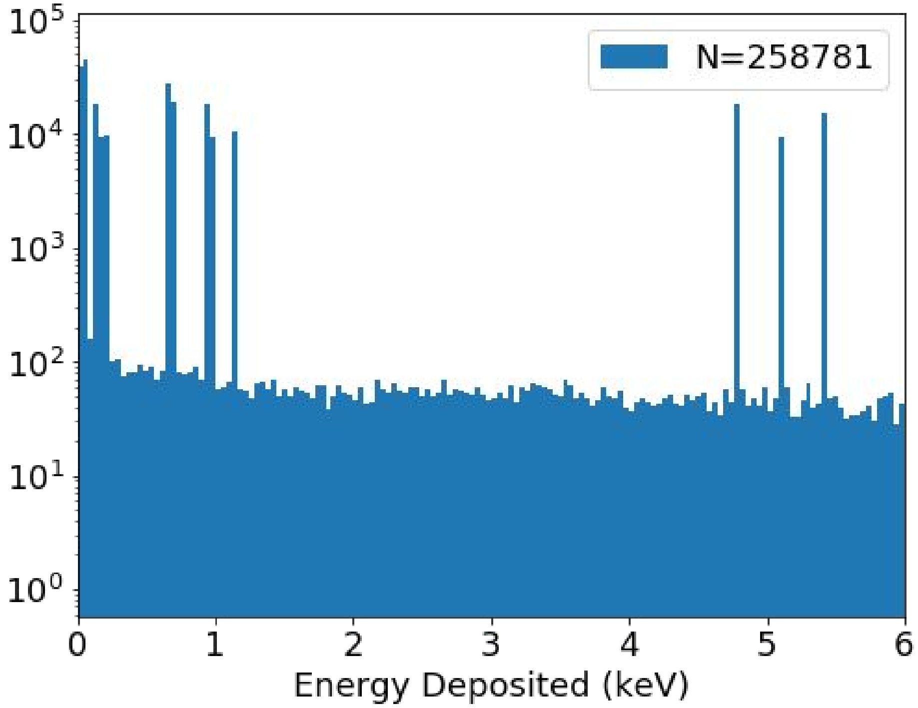
- Focus on only the Gamma-X events
- For each energy deposition calculate an S1 and S2. Then sum S1 and S2 for each event.
- This caused this band-like structure as energy depositions have sharp lines at very low energy (~ 1 keV).



Energy Depositions

There are very sharp lines in energy deposited which are more common in the banded S1/S2 events.

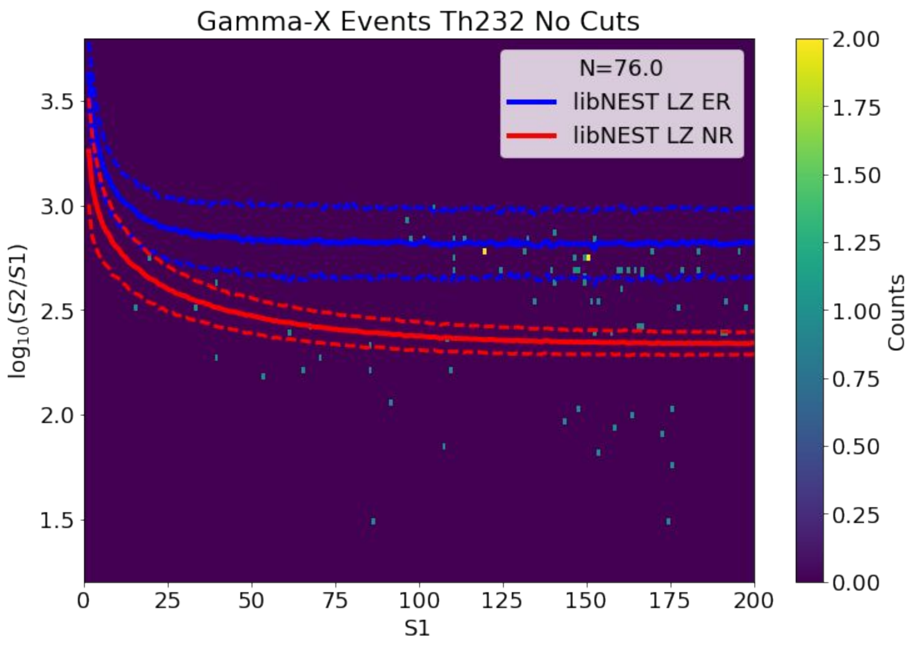
Energies correspond to Xe Energy Levels 4.78, 5.10, and 5.45 keV

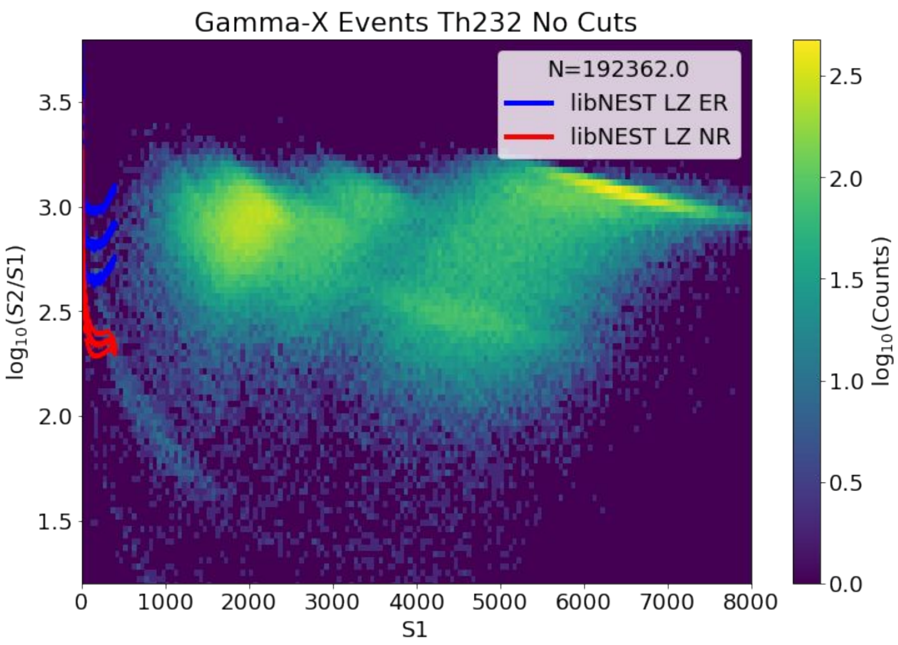


Approximate rate in first method

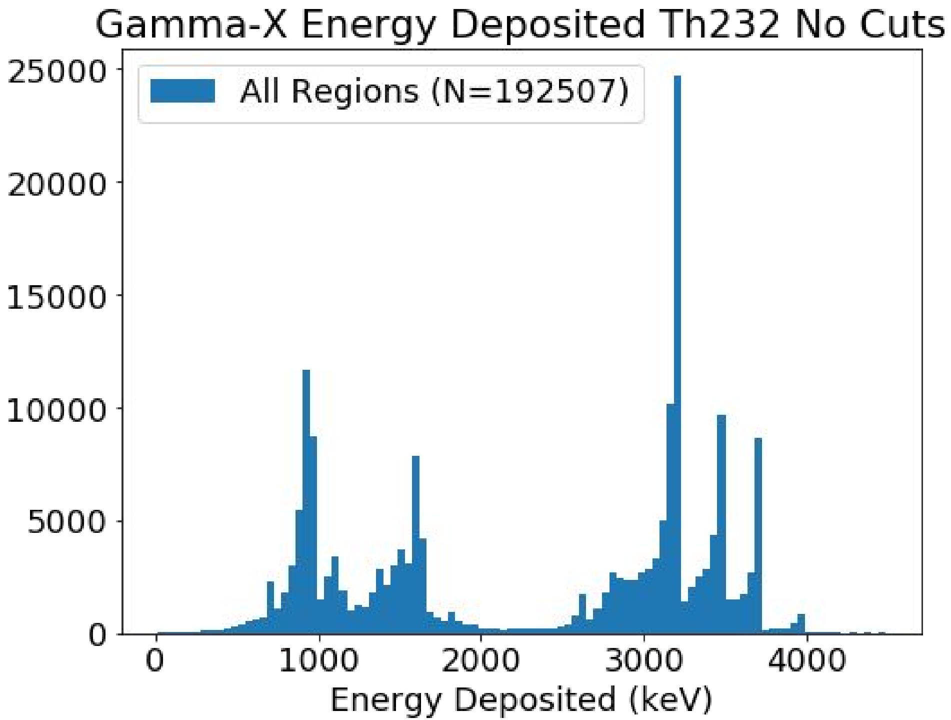
- Simulated 20,000,000 Decay chain events from the bottom PMTs
- 12,000 (0.6%) within the DM search region (0-50 S1 and 1.2-3.8 in log(S2/S1)
- 2,900 events (0.15%) fall below the 90% ER band (blue dotted line on previous plot)
- 1,100 events (0.05%) are within the NR band
- This corresponds to 2.5 events per day. Note that this is before any cuts are made. The fiducial volume cut will reduce this number significantly. And this is only from events originating in the bottom PMTs
- This is still much much larger than we expected from previous background studies

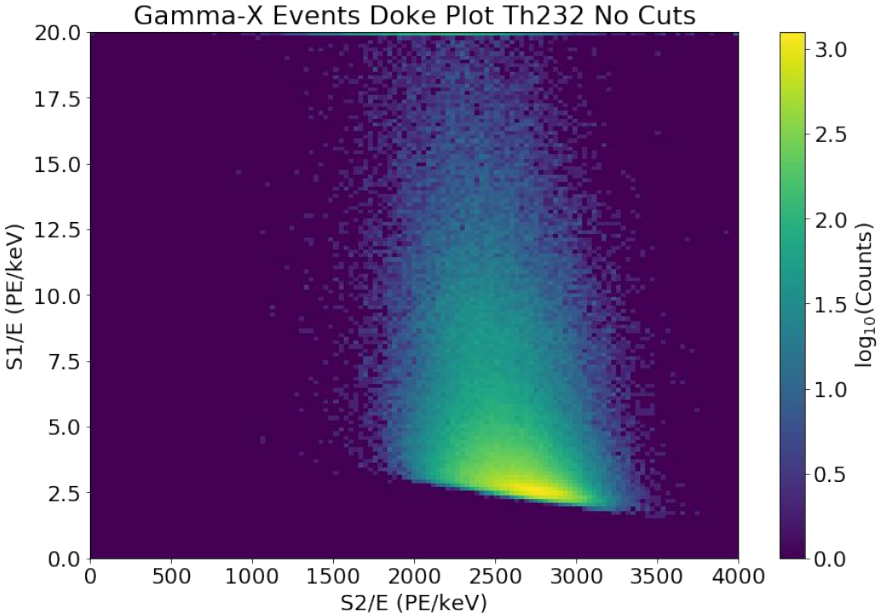
Th 232 Results (Improved Method)



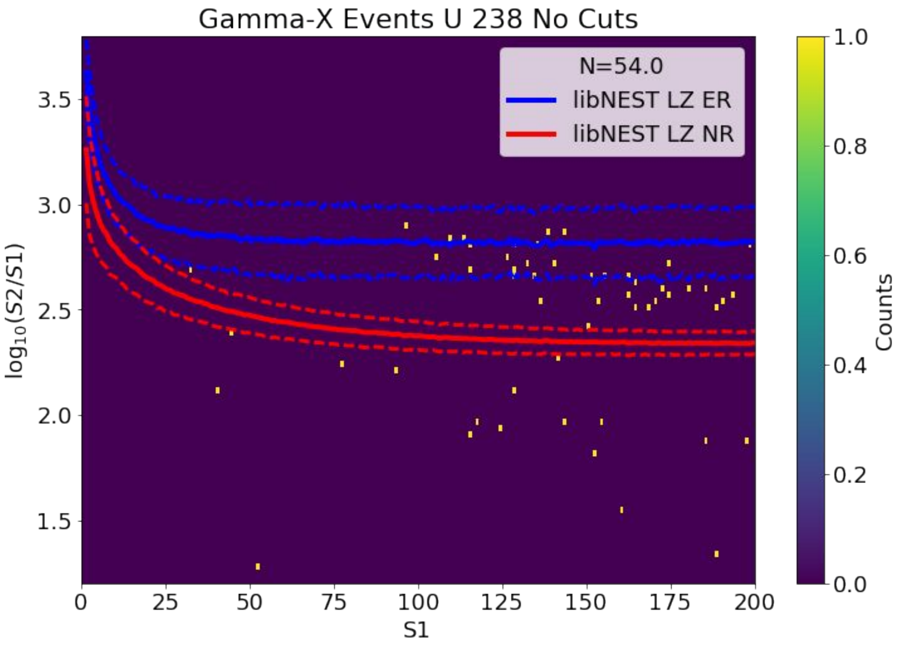


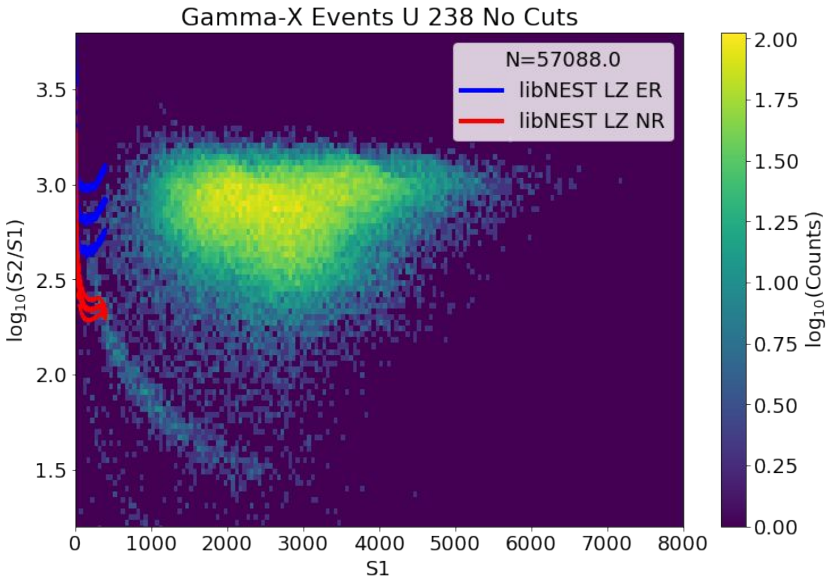
Th 232 Results



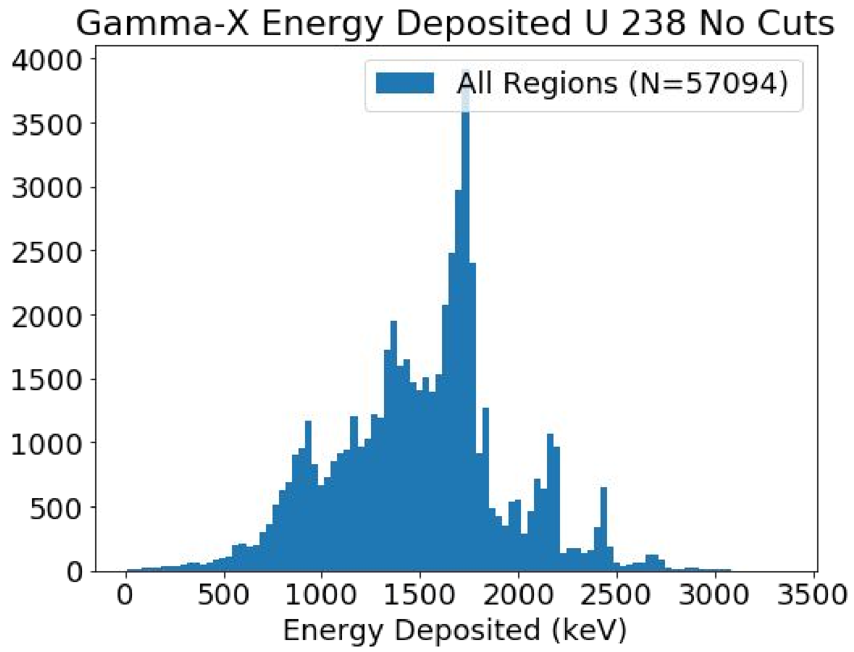


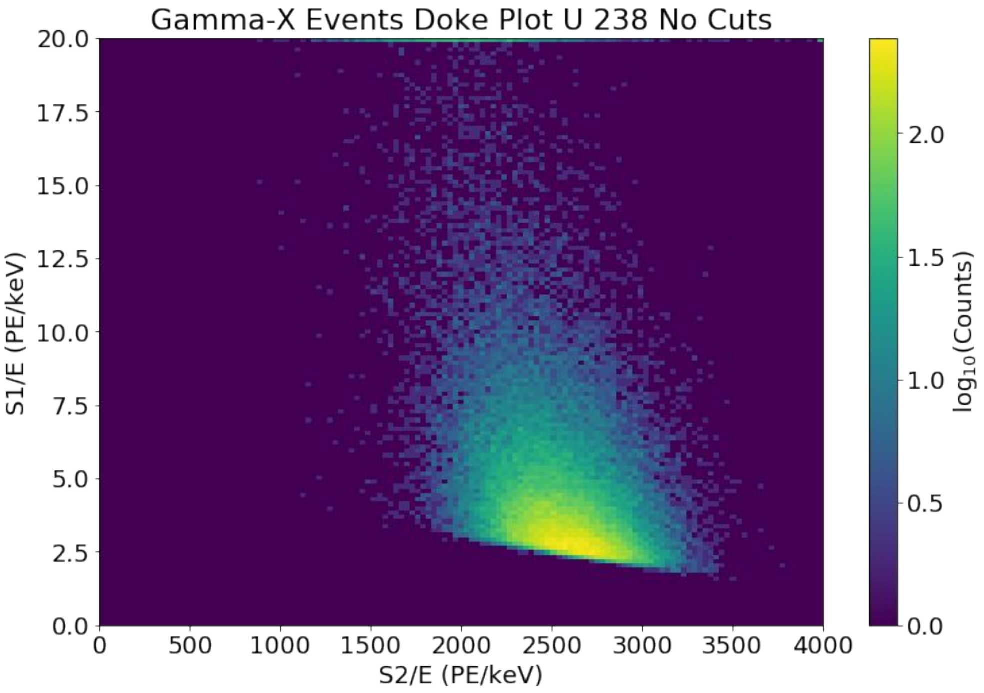
U 238 Results



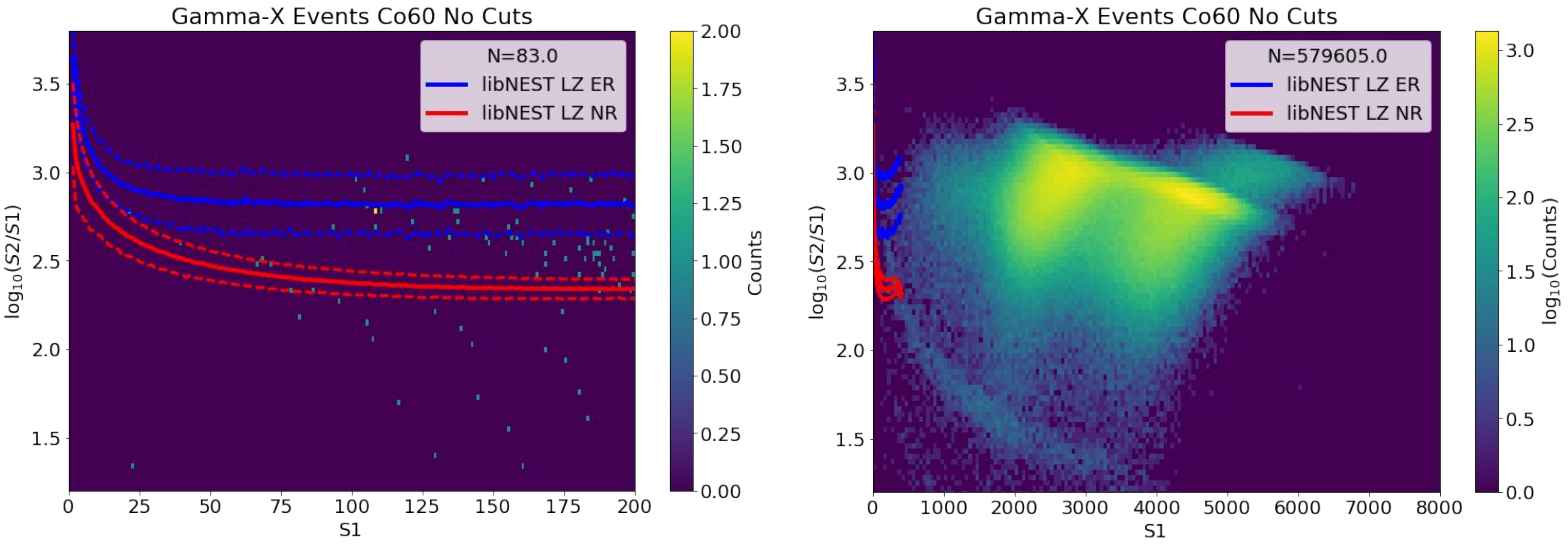


U 238 Results

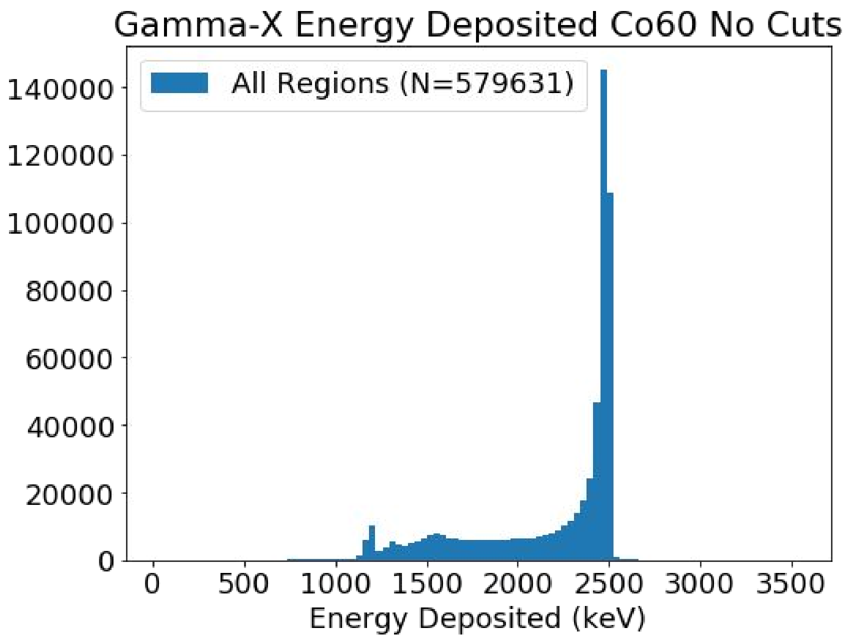


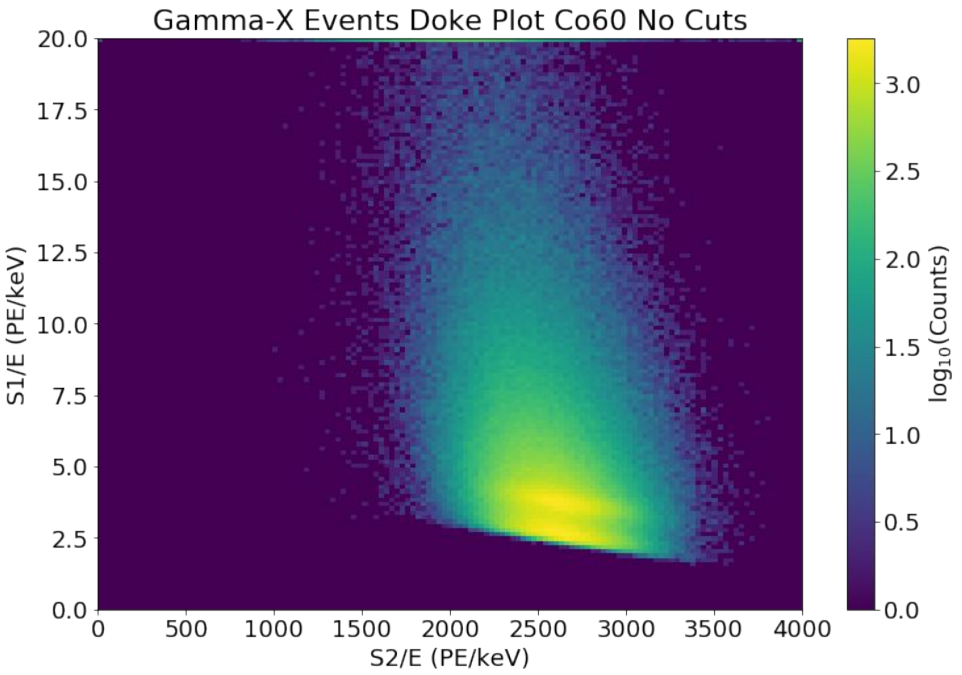


Co 60 Results

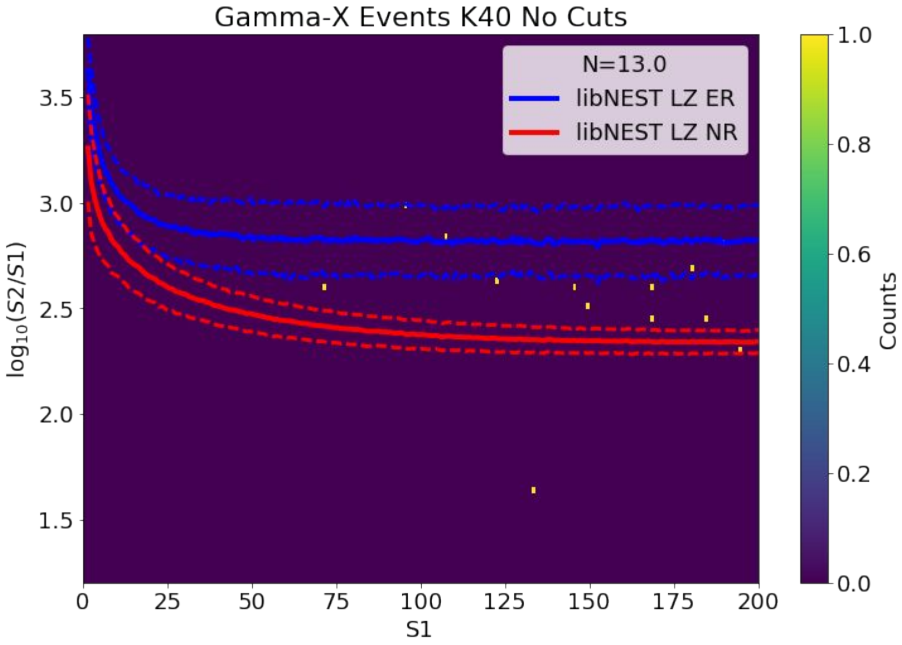


Co 60 Results

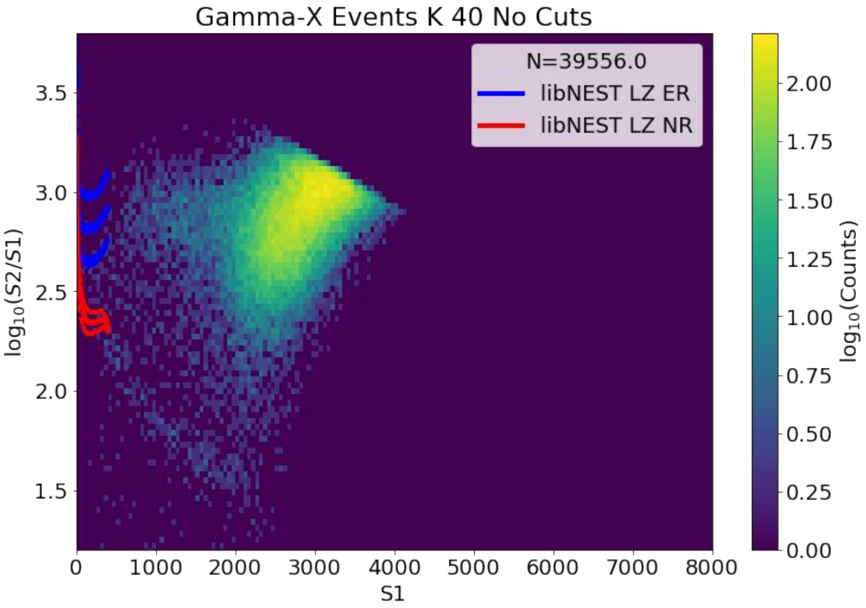




K 40 Results

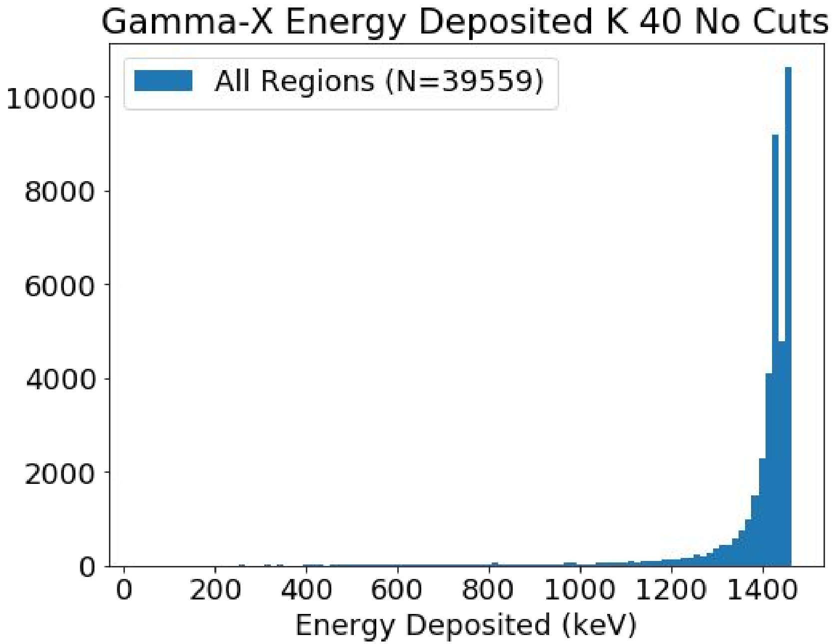


Gamma-X Events K40 No Cuts
N=13.0
libNEST LZ ER
libNEST LZ NR
log10(S2/S1)
S1
Counts

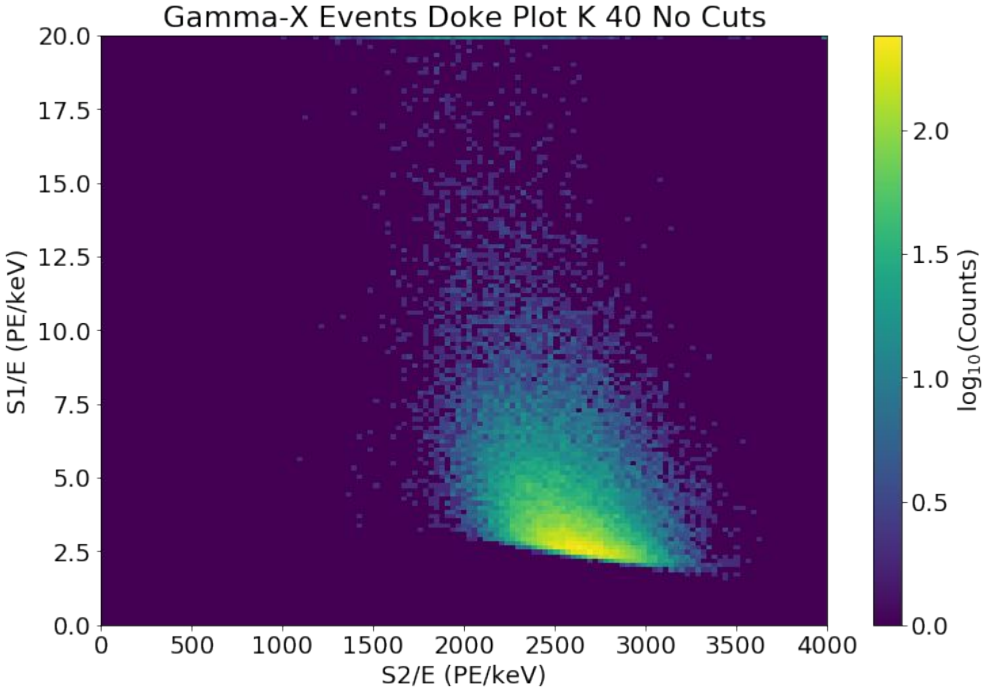


Gamma-X Events K 40 No Cuts
N=39556.0
libNEST LZ ER
libNEST LZ NR
log10(S2/S1)
S1
log10(Counts)

K 40 Results



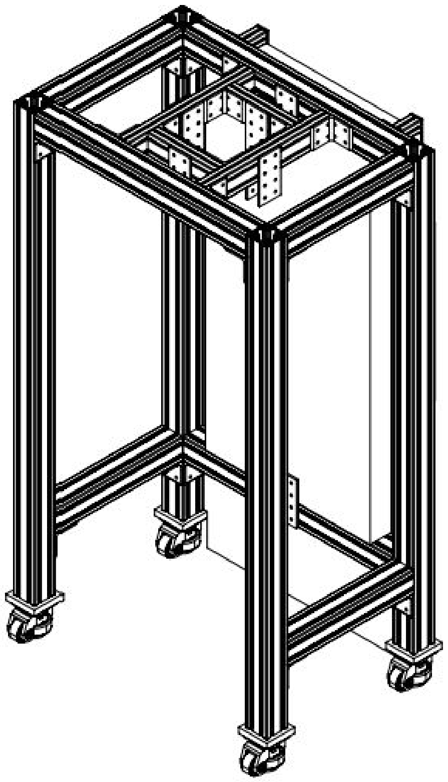
Gamma-X Energy Deposited K 40 No Cuts
All Regions (N=39559)
10000
8000
6000
4000
2000
0
0
200
400
600
800
1000
1200
1400
Energy Deposited (keV)



Gamma-X Events Doke Plot K 40 No Cuts
S1/E (PE/keV)
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
500
1000
1500
2000
2500
3000
3500
4000
S2/E (PE/keV)
log10(Counts)
2.0
1.5
1.0
0.5
0.0

Work at SLAC

- Almost finished the gas test hood
- Cut pieces of T-slot and plexiglass for the phase 2 clean room
- Disassembled the phase 1 breakouts for reassembly
    - We are redesigning the breakout to accommodate new thermosyphon lines which will be installed next week



Gas test hood drawing

Comments From Sims Meeting

Problems with what I've done thus far:

- Using wrong macro generator (Fixed)
- Check that the photon collection efficiency is correct below the cathode (I believe it is)
- Override the coincidence threshold in libNEST. Required 3 PMTs to trigger in order for an S1 or S2 to be nonzero

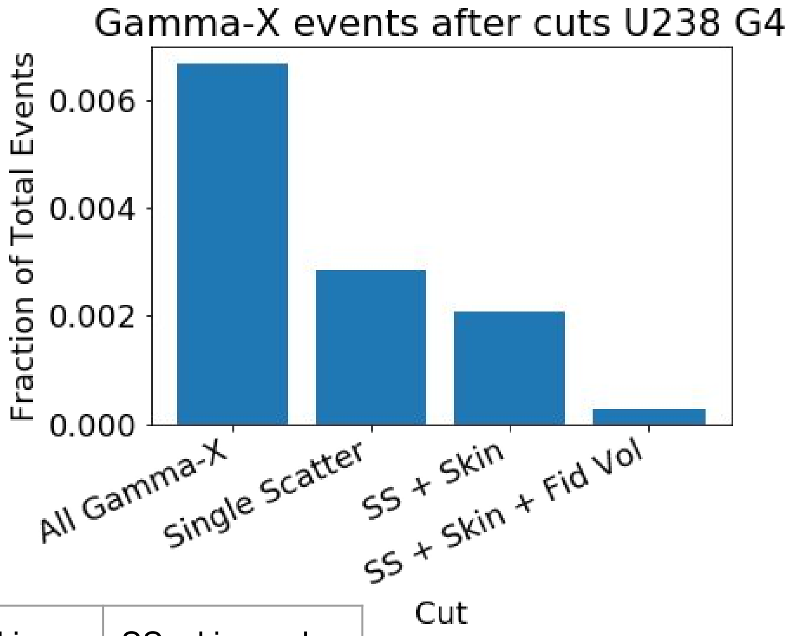
Other improvements:

- Use a range of monoenergetic gammas to see how the initial energy impacts the rate
- Move around the bottom of the fiducial volume to see how that impacts the rate

Question: Do I need to consider all Gamma-X events or can I apply a cut and just focus on those in the WIMP search region?

Applying Cuts

- The cuts on the right do not include the energy cut to select the NR events.
- If I include the NR band cut there would be zero events after the fiducial volume cut.
- I’m not sure if this means I need more stats or if that is a real result
- Talked with Evan Pease who worked on Gamma-X in LUX and he said that the outer detector was not a useful veto



All Gamma-X U238	Single Scatter	SS and Skin Veto	SS, skin, and fiducial volume
0.00664	0.00282	0.00206	0.00028

Recent Work at SLAC

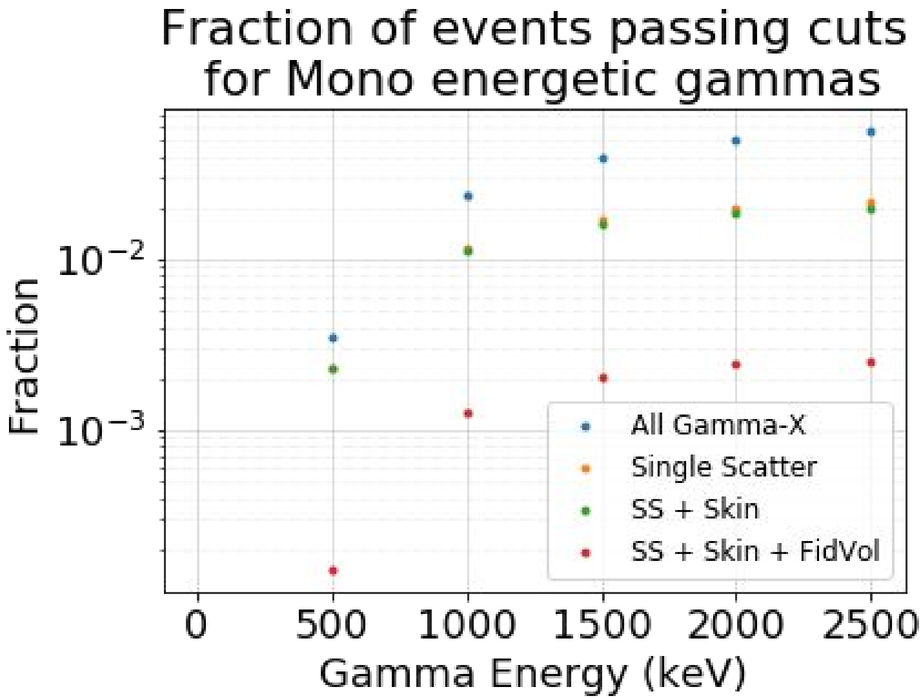
Gas test hood is complete. Its breakout is almost finished. We will be installing lines to it later this week

Thermosyphon lines are in progress, they are highest on my priority list

Work has begun on the Phase II clean room. Cleaning out the space today, installation to begin tomorrow.

Gamma-X Mono Energetic Gammas

- Put in gammas of a particular energy then determine the fraction of events which pass cuts.
- Plot on right shows that cuts impact all energies by the same fraction (spacing between points is constant across energy)
- See same outputs in the mono energetics as in the decay events
  - Similar band-like structure in S1 vs log(S2/S1)
  - Reconstructed total energy is not monoenergetic (lose energy to regions not tracked)



Work at SLAC

- Finished welding and test fitting one of the thermosyphon lines
  - Working today on welding second line. Will be installed this afternoon
- Finished the construction of the gas test breakout
  - Needs to be connected to gas system
- Working on a new level sensor for Phase 1
  - It is built, needs connectors and to be installed

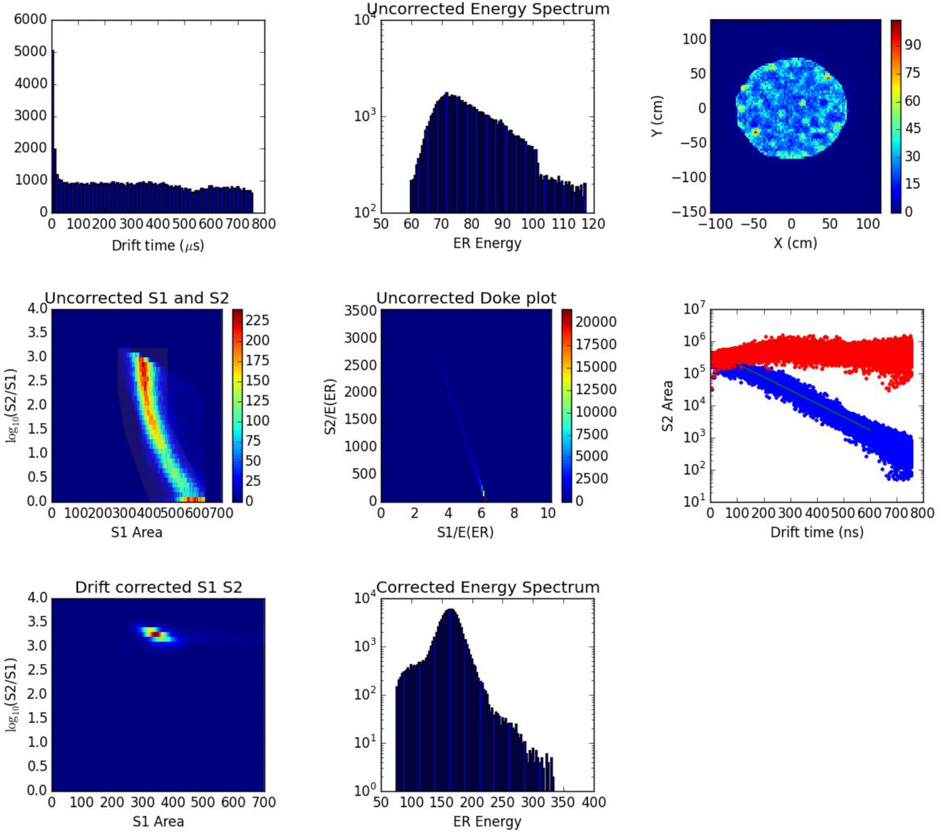
Work at SLAC

- Built the first wall of the clean room. HEPA units will hopefully be installed this afternoon
- TS lines are in place and will get final tightening later this week
- Will be working on a camera test to possibly go into phase 1 or 2

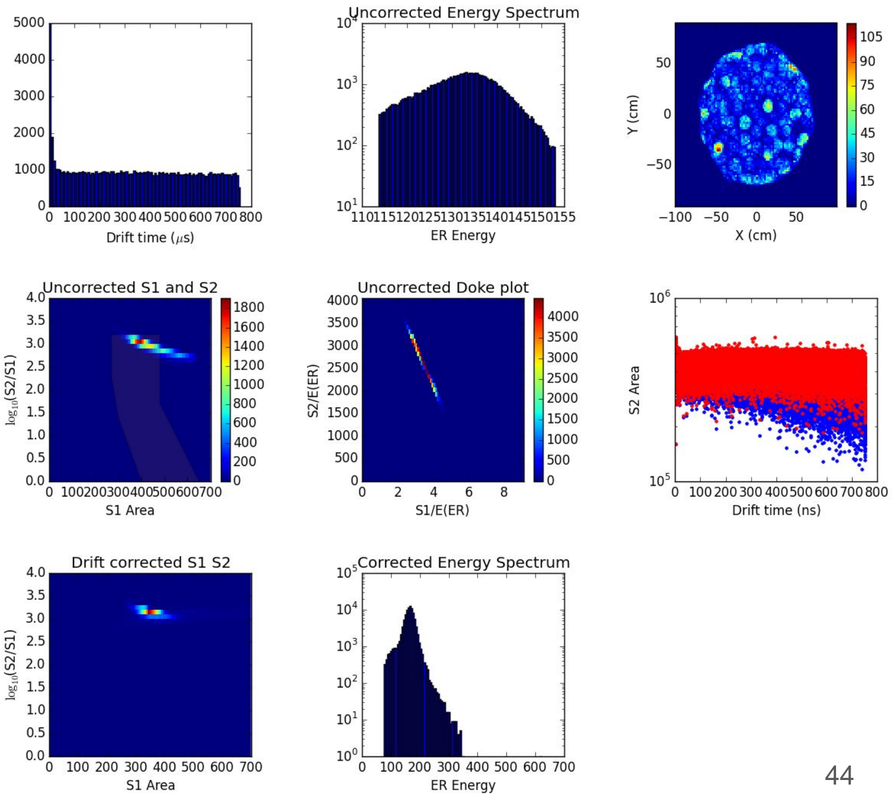
Collaboration Meeting

MDC 1

Day 1



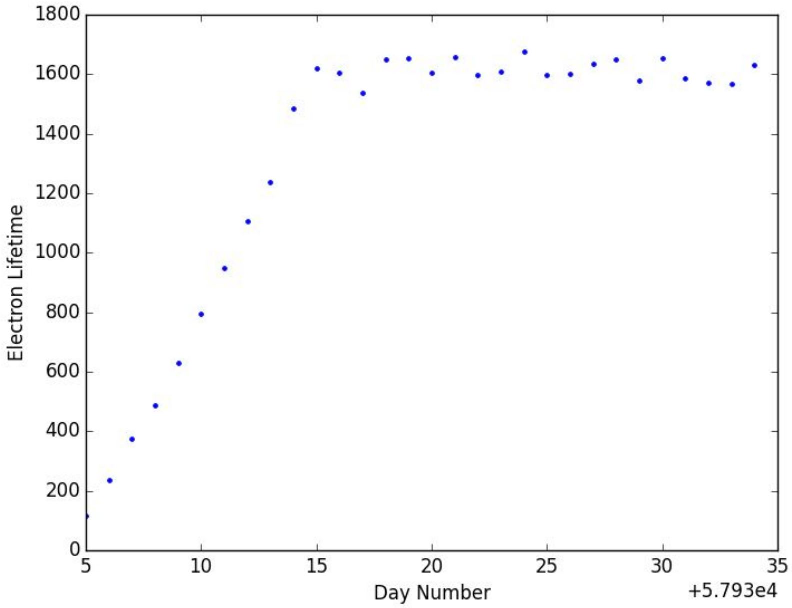
Day 30



MDC 1 Electron Lifetime

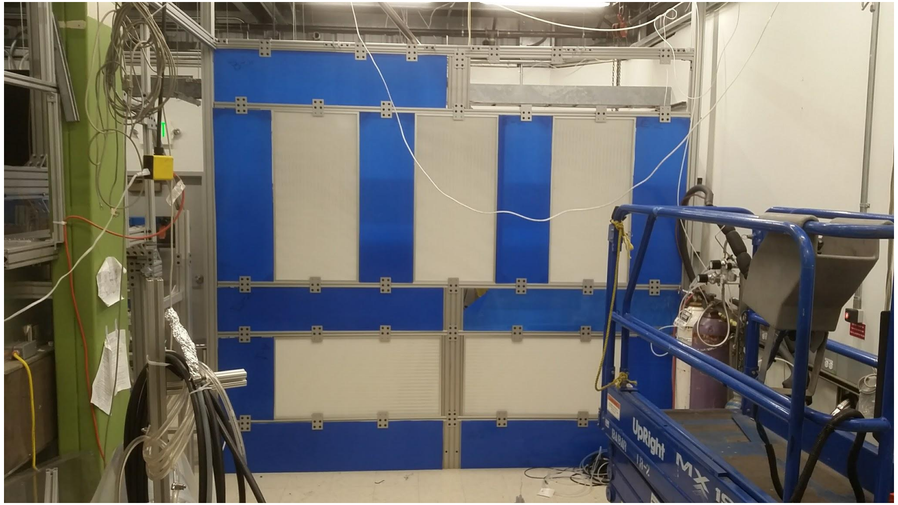
- Select only the Xe131 m line. This has a known energy of 164 keV
- Xe131 is uniformly distributed in the detector
- Expect events to be uniformly distributed use this to predict the electron lifetime
- Fit S2=A e^(-(drift time)/elifetime)
- Plot on right shows this fit parameter as a function of time
- We expect it to increase as the xenon becomes more pure
- Anyone interested can see the code here: https://lz-git.ua.edu/nikoleyczik/MDC1

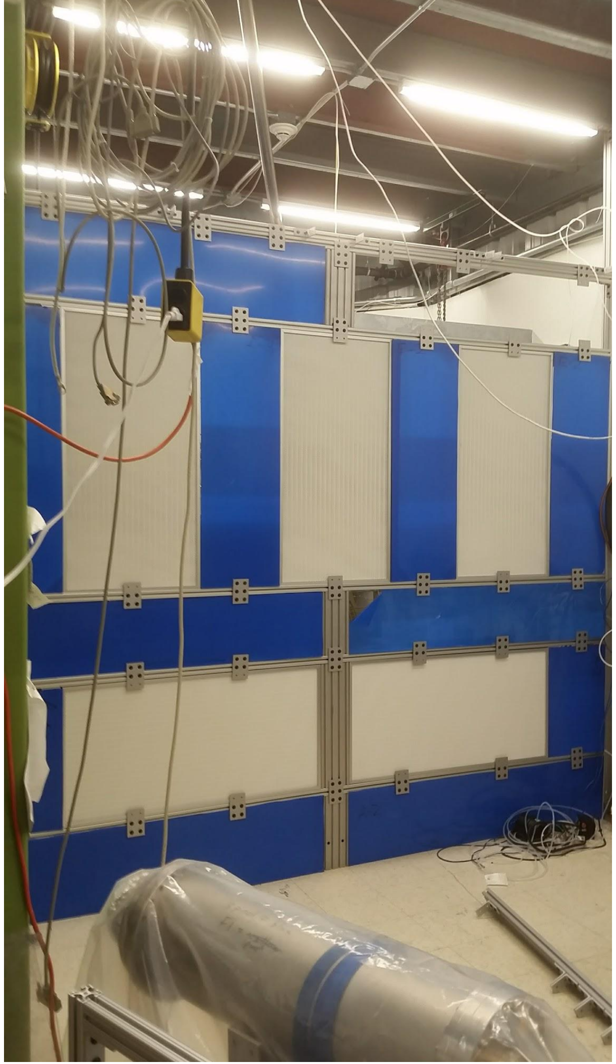
Electron lifetime (μs) as a function of time



Phase 2 clean room

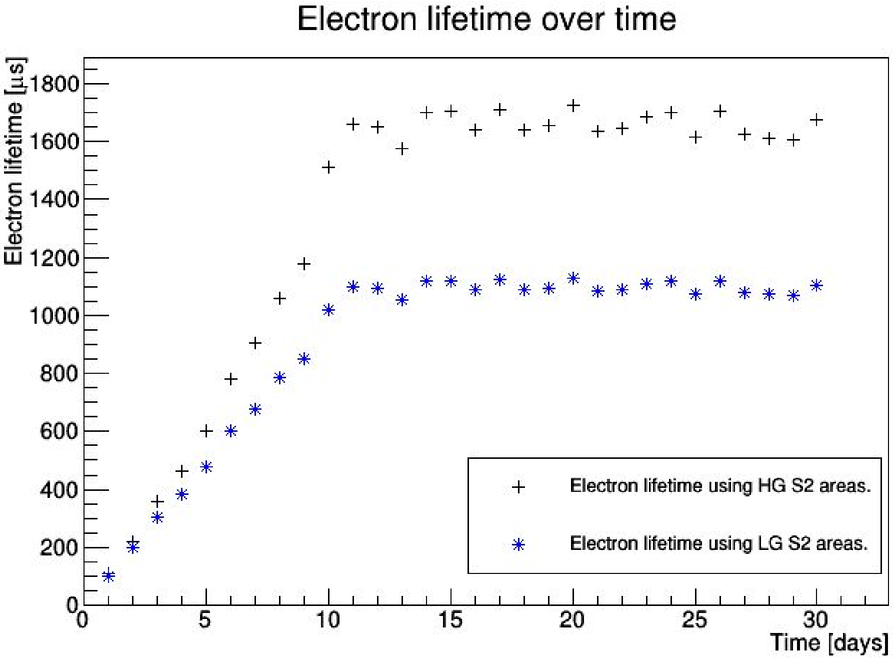
- Nearly finished with the first wall
- Ceiling installation to begin today





MDC 1

- I added an S1 correction from Asher’s results
- I had been using the high gain channel but that channel saturates so I need to switch to using the low gain channel instead



From Theresa’s results. Mine agree in the HG