

# Neutron Backgrounds

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# Strategy

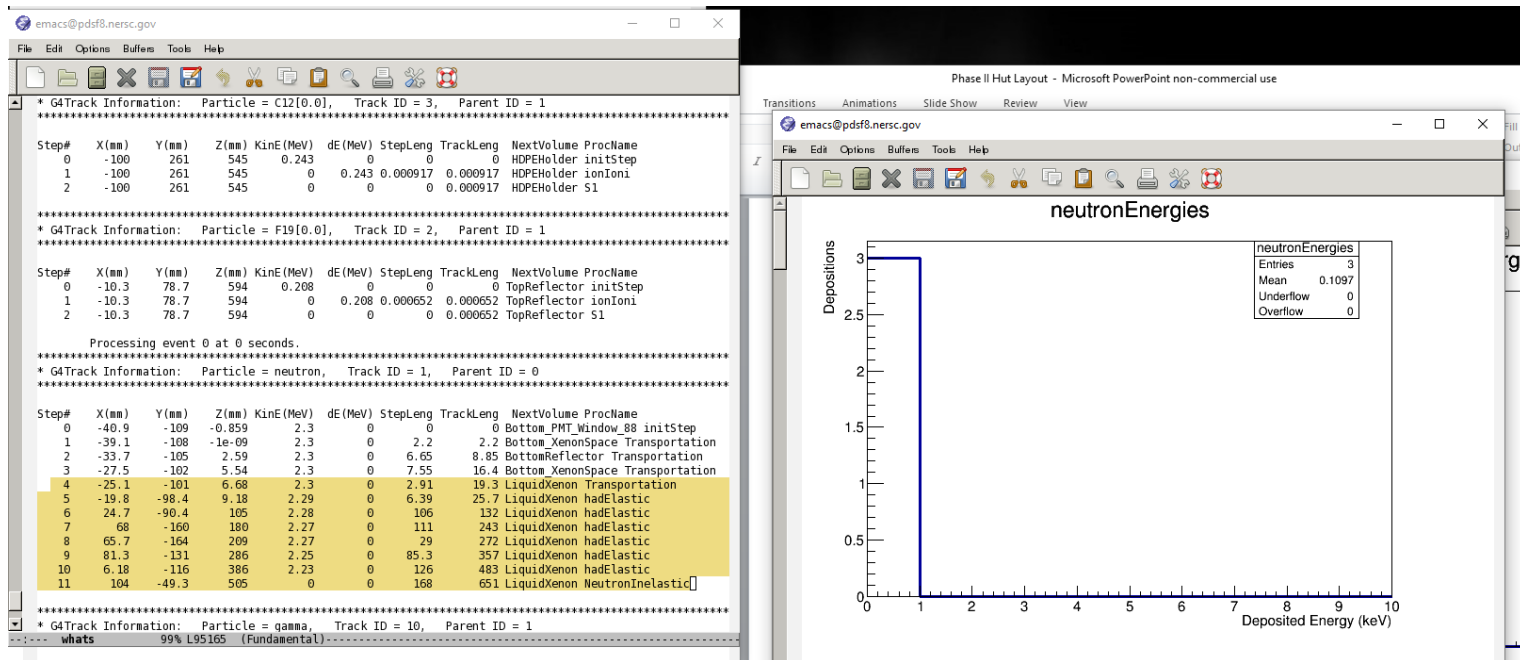
- Simulate neutron energy depositions
- Cluster depositions
- Use libNEST to get S1c, S2c
- Determine dimensionality of PDF needed and create it

# Disclaimer about plots

- All plots here are made using simulated data from one run of the neutrons originating in the PMTs as discussed previously. This run had 7681 events recorded, 1692 of which seem to have recorded a primary, but no actual energy deposits in the Lxe.

# Where have all the Neutrons gone?

- First thing to notice...
  - Can't just look at neutron depositions.

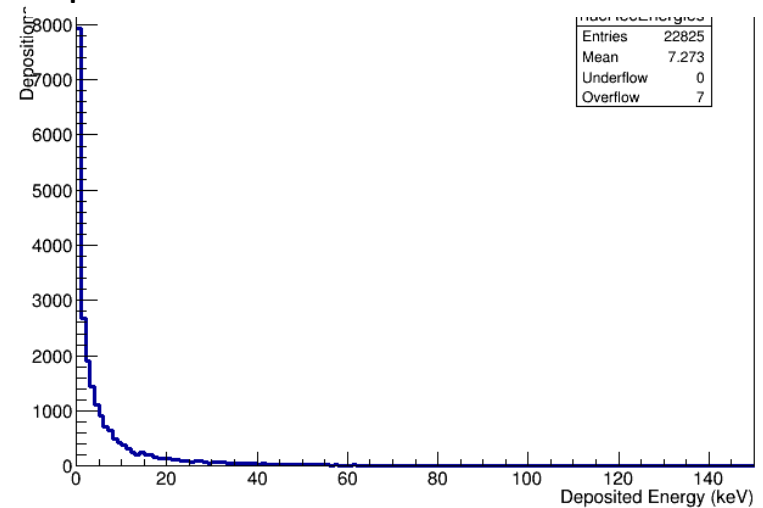


Neutron depositions above a certain energy are not counted, but instead have their energy imbued into heavy particles which instantly deposit their energy.

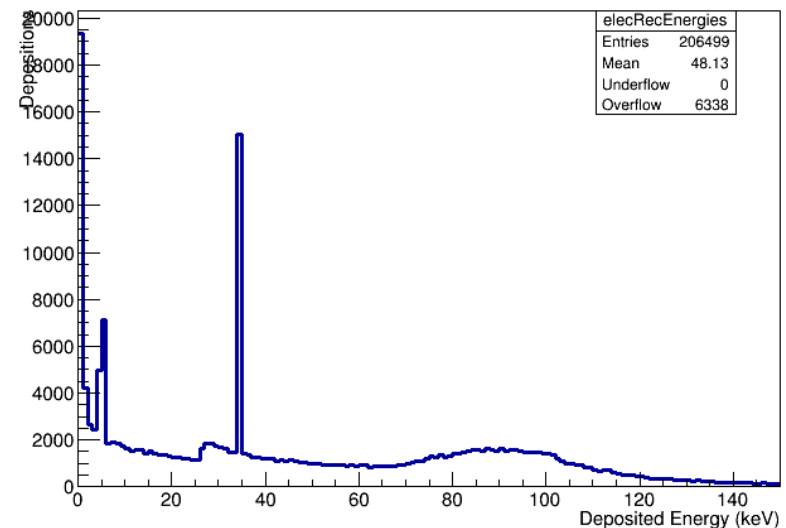
# What are we going to do about it?

- Include both heavy particle (atom sized) as well as neutron depositions as NR.
  - This INCLUDES kinetic energy gained by heavy particles which gain their energy via decay after neutron capture.
- Call interactions from gammas, electrons, and positrons ER.
- Doing this, get the following spectra

Spectrum of all nuclear recoils



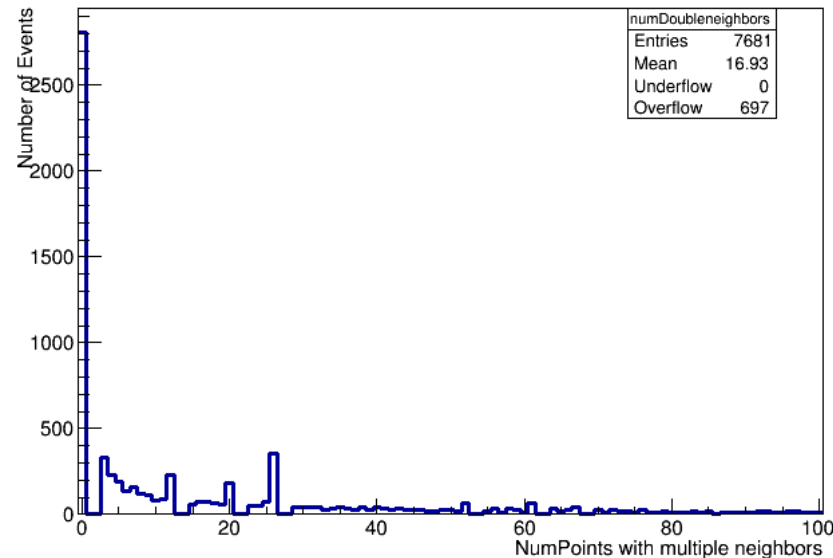
Spectrum of all electron recoils



# Do I need to practically worry about the case where a cluster would have more than 2 depositions?

- Yes

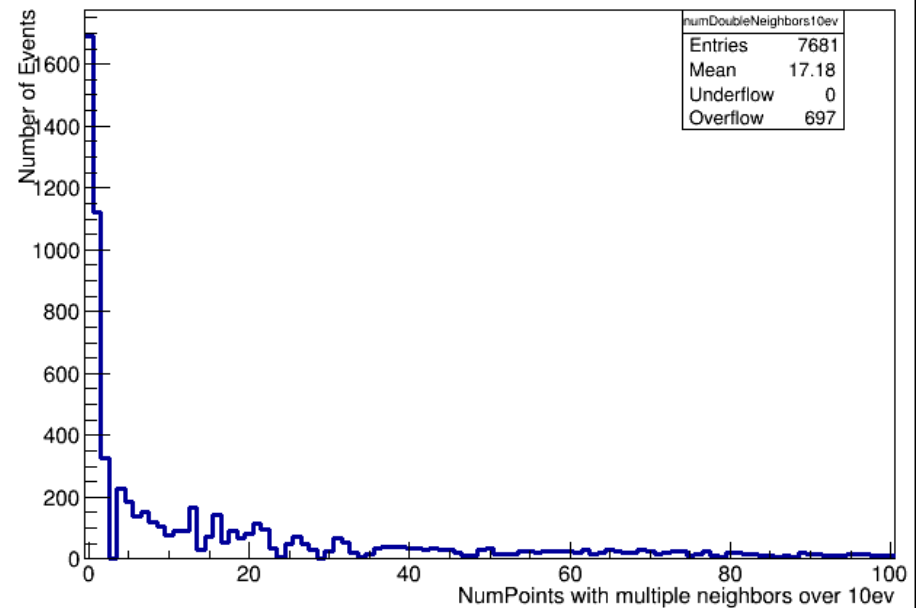
numDoubleneighbors



Number of depositions in a given event with two or more neighboring depositions within .5 cm

Maybe many of them are tiny and negligible?  
Nope.

numDoubleNeighbors10ev

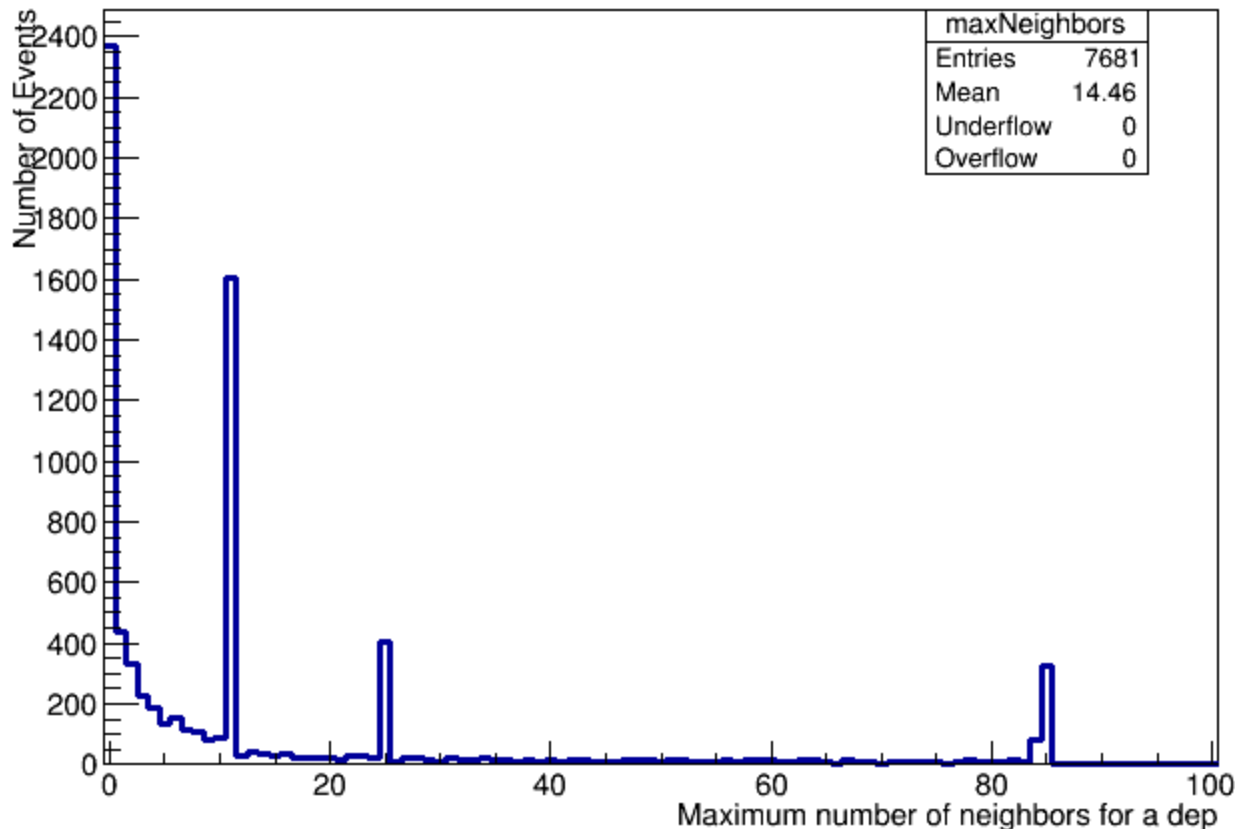


Number of depositions in a given event with two or more neighboring depositions within .5 cm *that deposit 10 eV or more.*

# Do I somehow have to account for many, or can I cut it off at a few?

Must account for many.

maxNeighbors



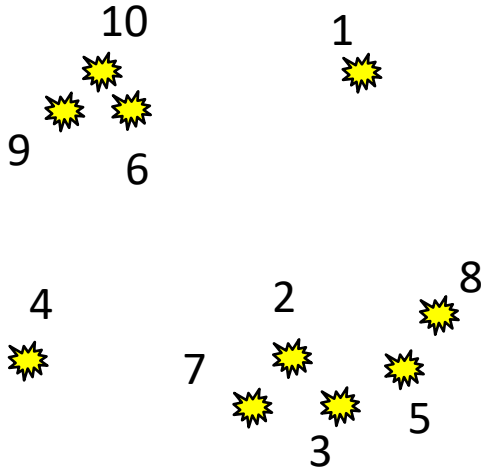
Number of depositions within 0.5 cm of the deposition with the most in any given event.

# The Clustering algorithm

- Cluster into cylinders (right now  $\Delta xy < 0.5$  cm,  $\Delta z < 1$  cm)
- Pick a deposition,
  - add it to a cluster,
  - check around it for any others.
    - If found, add that one.
    - check around *that one* for any others
      - and add them continue on in this fashion.
      - Once no more are found, step back up to the last and keep searching.
- Once all in a cluster are found, start with another point (not in the cluster)
- Illustration on next slide.



# Clustering Algorithm illustration

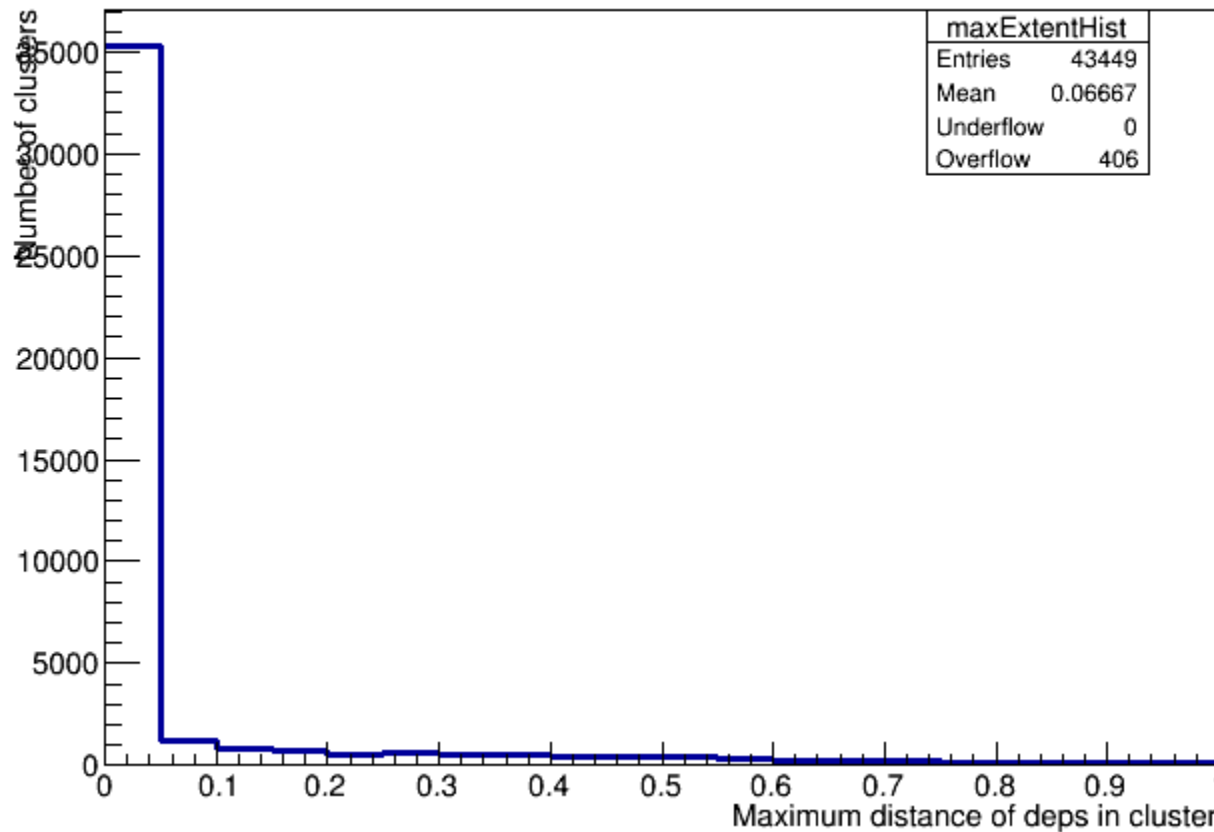


1. Creates new cluster containing dep 1 (cluster 1)
2. No more neighbors. Marks dep 1 as clustered and moves on to a new point.
3. Creates new cluster containing dep 2 (cluster 2)
4. Looks around dep 2 for neighbors, finds dep 3, adds dep 3 to cluster 2
5. Looks around dep 3 for neighbors, finds dep 5, adds dep 5 to cluster 2
6. Looks around dep 5 for neighbors, finds dep 8, adds dep 8 to cluster 2
7. No more neighbors, resumes search around dep 5.
8. No more neighbors, resumes search around dep 3, finds dep 7, adds dep 7 to cluster 2.
9. No more neighbors. Marks deps 2, 3, 5, 8, and 7 as clustered and moves on.
10. Creates new cluster containing dep 4 (cluster 3)
11. No more Neighbors. Marks dep 4 as clustered and moves on.
12. Creates new cluster containing dep 6 (cluster 4)...

# This can create a cluster out of chains, is this a problem?

- Fortunately, it doesn't seem like it.

maxExtentHist



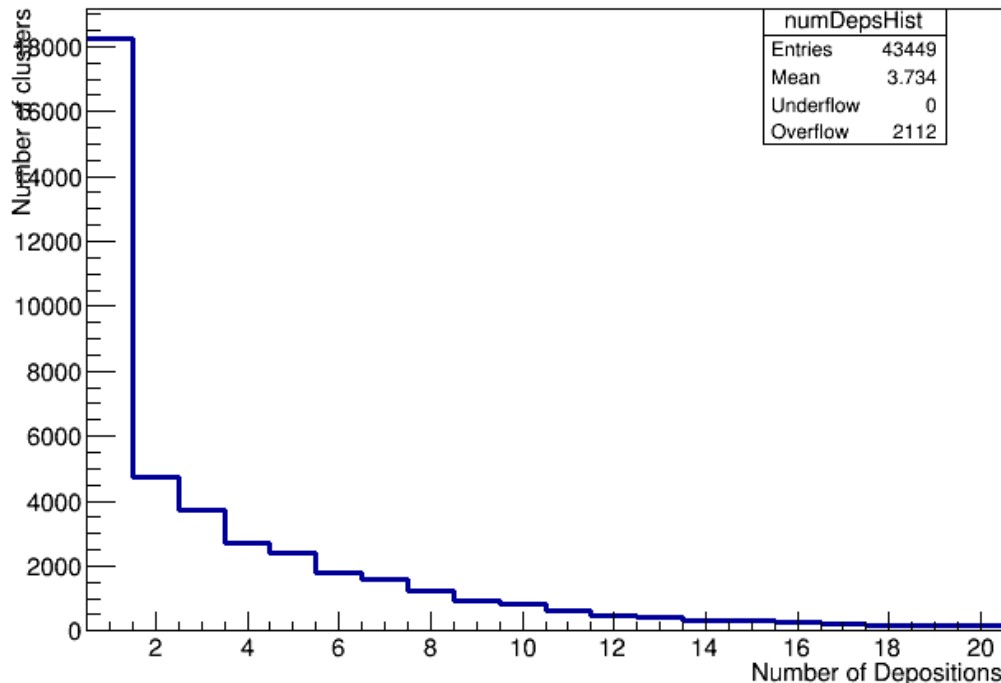
Distance (in cm)  
between the two most  
distant depositions in  
each cluster.

The vast majority are  
still very compact.

# Then was this level of clustering sophistication really necessary?

- Maybe not... But the ability to include arbitrarily many depositions in a cluster *is* and is easy to accomplish with recursion.

numDepsHist



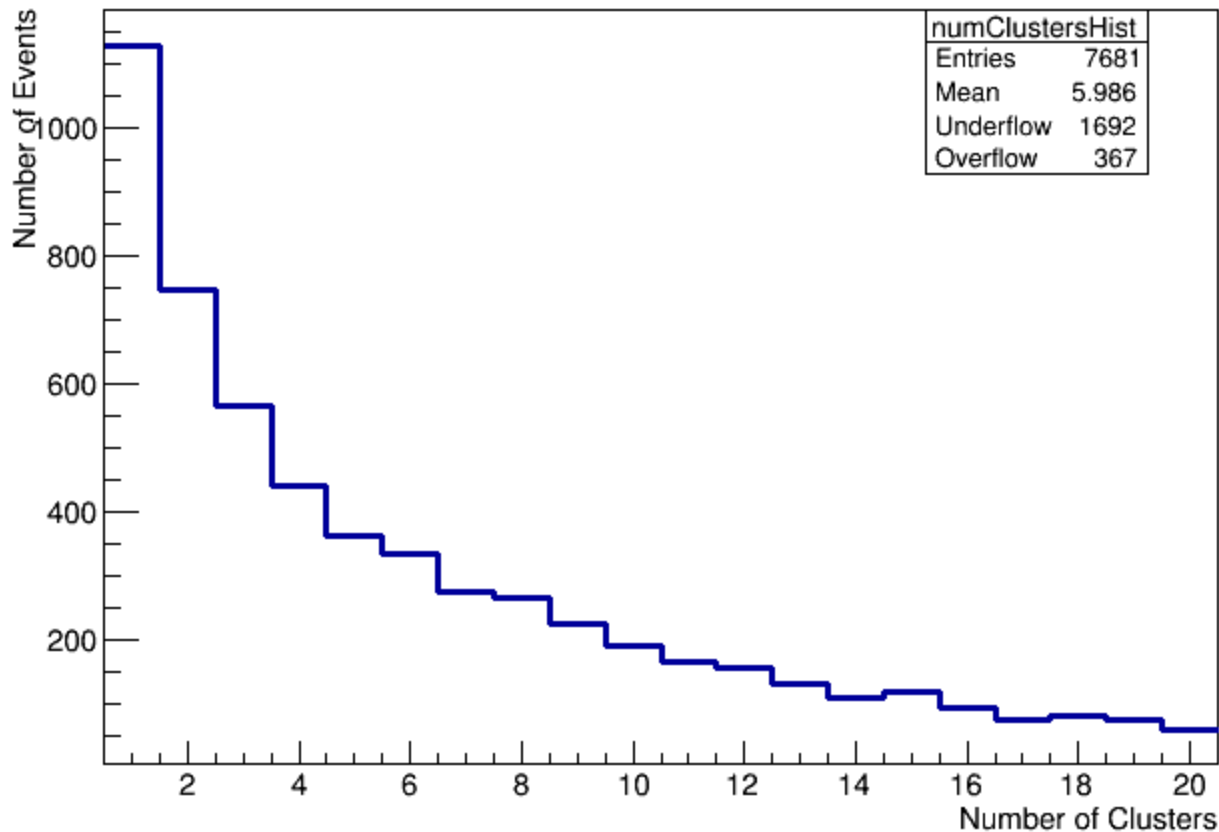
Number of depositions that make up each cluster.

Left-most bin is 1, and has the most, but comprises less than  $\frac{1}{4}$  of all the depositions.

Numbers  $>2$  are occur frequently

# How many clusters are in each event, then?

numClustersHist

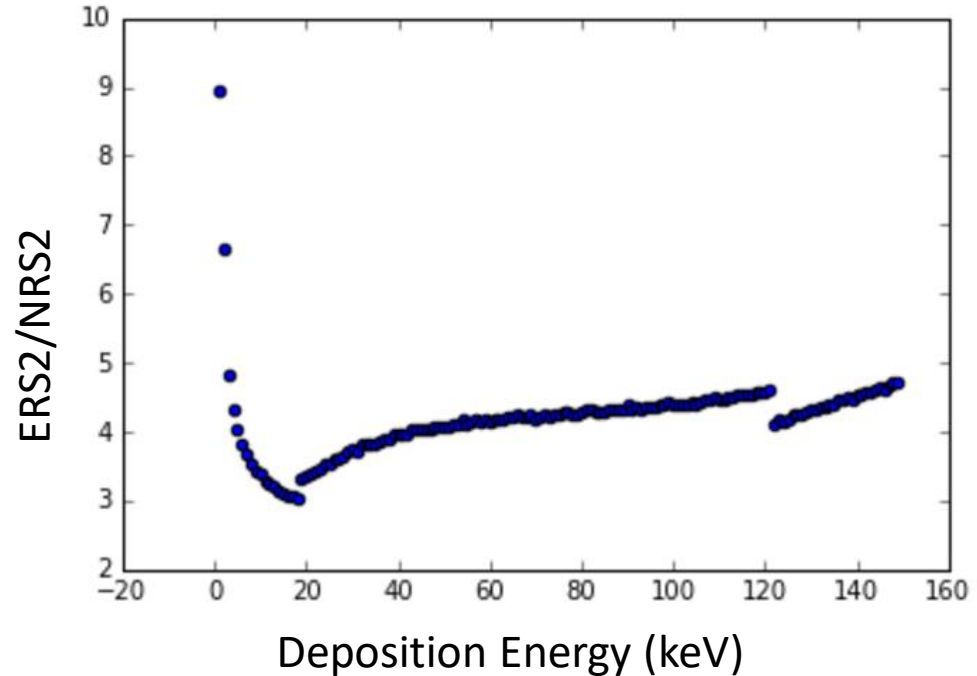


The number of clusters in each event.

The number that have enough energy to be detected has not yet been determined...

# The unmentioned part of the clustering algorithm.

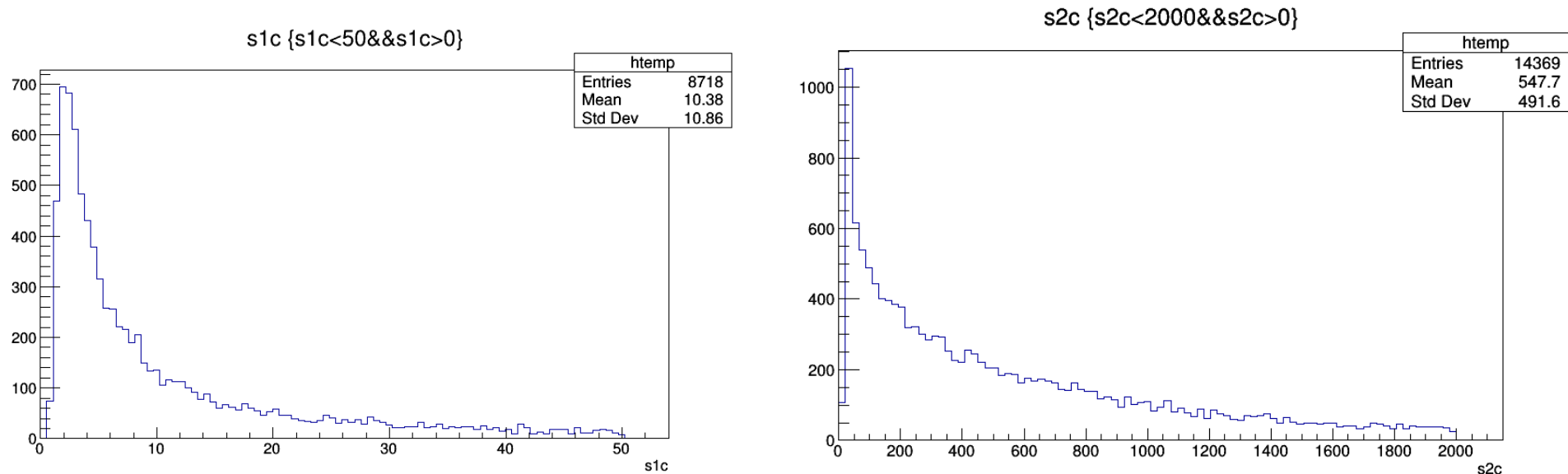
- Where should the cluster be?
  - The xy cluster position is determined by an expected-S2 weighted average in x and y
  - The z cluster position is determined to be at the location of the uppermost deposition in the cluster



- What is the cluster's energy?
  - Energy from NR are summed into an NR total energy.
  - Energy from ER are summed into an ER total energy.
    - This is because in the end what we want to simulate is the total S1 and S2 from the cluster, so the energy deposited via different methods needs to be distinguished.

# libNEST

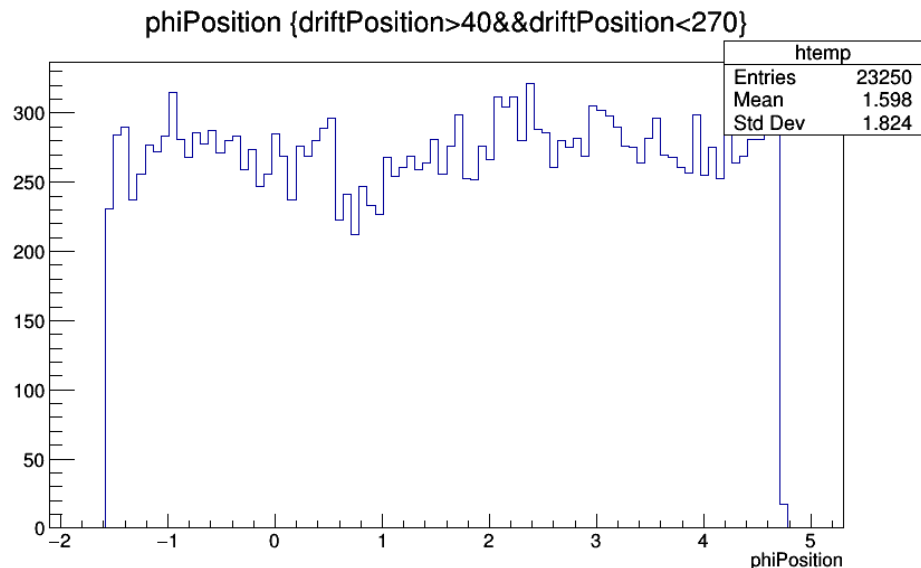
- Run libNEST twice for each cluster.
  - Once with the NR energy in NR mode
  - Once with ER energy in ER mode
- Sum the S1c and S2c from the two runs



# PDF creation

- 5-d PDF may well kill the PLR (drastic increase in integration time)
- Luckily, PDF is made in  $r$ ,  $\phi$ , drift\_time,  $S1c$ ,  $\log(S2c)$ .  $\phi$  seems uniform to within bin-scale inside fiducial volume.

- Should be able to  
Make a 4x1-d PDF  
With uniform  $\phi$



# Future

- Actual creation of PDF
  - In progress
- Implementation of PDF into PLR
  - Not started
- Inclusion of real fields and drift lengths into both libNEST and PDF calculations (dummy models right now)
  - In progress
- Correct overall normalization & validation of current energy spectra
  - Not started



# From Last Time...

# Considered Backgrounds

- PMTs
  - Neutrons from (alpha, n) from U238 chain alphas
  - Neutrons from (alpha, n) from Th232 chain alphas
  - Neutrons from U235 fission
- PTFE
  - Neutrons from (alpha, n) from Po210 (U238 late) chain alphas

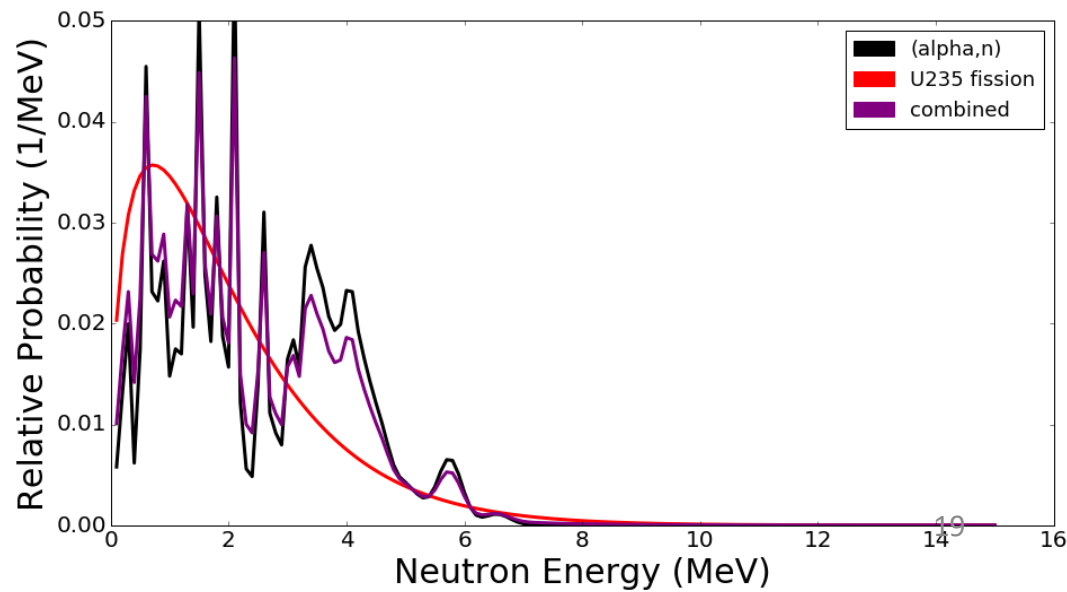
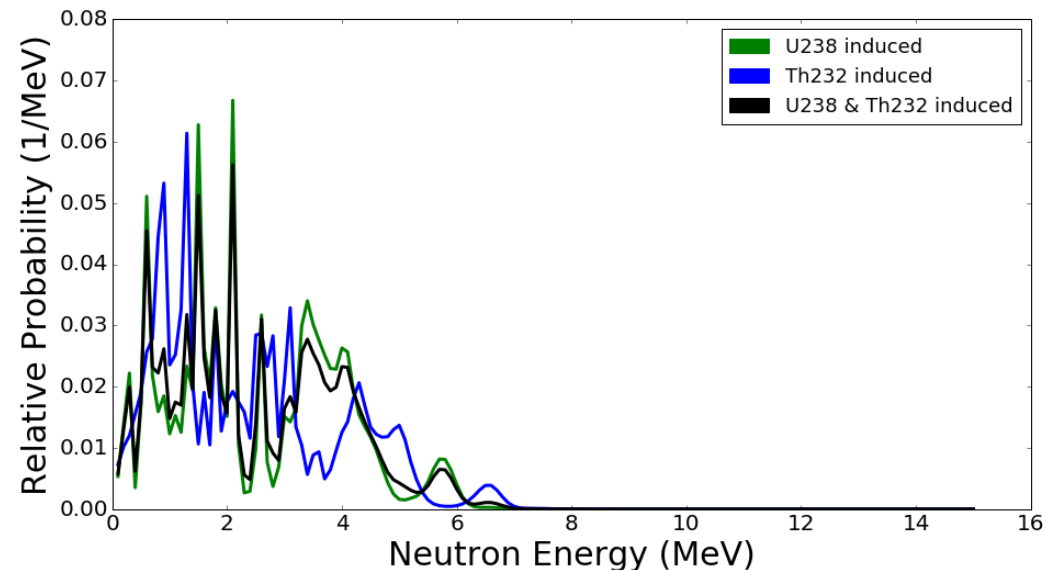
# Background Energy Spectra - PMTs

(alpha, n) from

[neutronyield.usd.edu](http://neutronyield.usd.edu)

With the following concentrations

Compound	Mass [g]	$(\alpha, n)$ Yield [n/mBq/yr]		$(\alpha, n)$ Neutron Rate [n/PMT/yr]		
		$^{238}\text{U}$	$^{232}\text{Th}$	$^{238}\text{U}$	$^{232}\text{Th}$	Total
B2O3	4	1.17	0.950	2.67E-01	6.13E-02	3.28E-01
Al2O3	15	0.219	0.271	1.86E-01	6.55E-01	2.52E-01
Fe	63	0.0134	0.0426	4.78E-02	4.33E-02	9.11E-02
SiO2	26	0.0272	0.0303	4.02E-02	1.27E-02	5.29E-02
Na2O	1.3	0.329	0.322	2.43E-02	6.76E-03	3.10E-02
Co	13.6	0.0148	0.0524	1.14E-02	1.15E-02	2.29E-02
Li2O	0.22	0.764	0.554	9.54E-03	1.97E-03	1.15E-02
Cr	1.8	0.0502	0.187	5.13E-03	5.42E-03	1.06E-02
Al	0.26	0.402	0.502	5.93E-03	2.11E-03	8.04E-03
Mn	0.4	0.0378	0.100	8.59E-04	6.48E-04	1.51E-03
Ni	41	$2.01 \times 10^{-4}$	$1.45 \times 10^{-3}$	4.68E-04	9.62E-04	1.43E-03
Si	0.21	0.0449	0.0522	5.35E-04	1.77E-04	7.12E-04
BaO	0.44	$1.22 \times 10^{-3}$	$1.17 \times 10^{-3}$	3.06E-05	8.28E-06	3.88E-05
C	0.008	0.0306	0.0278	1.39E-05	3.59E-06	1.75E-05
S	0.0051	$5.01 \times 10^{-3}$	$7.63 \times 10^{-3}$	1.45E-06	6.28E-07	2.08E-06
Zr	0.042	$5.34 \times 10^{-6}$	$9.10 \times 10^{-5}$	1.27E-08	6.17E-08	7.44E-08
P	0.0068	$5.16 \times 10^{-8}$	$5.26 \times 10^{-7}$	1.99E-11	5.78E-11	7.77E-11
<b>Sum ((<math>\alpha, n</math>) only)</b>				<b>0.60</b>	<b>0.21</b>	<b>0.81</b>
<b>Sum ((<math>\alpha, n</math>) + fission)</b>				<b>0.93</b>	<b>0.21</b>	<b>1.15</b>

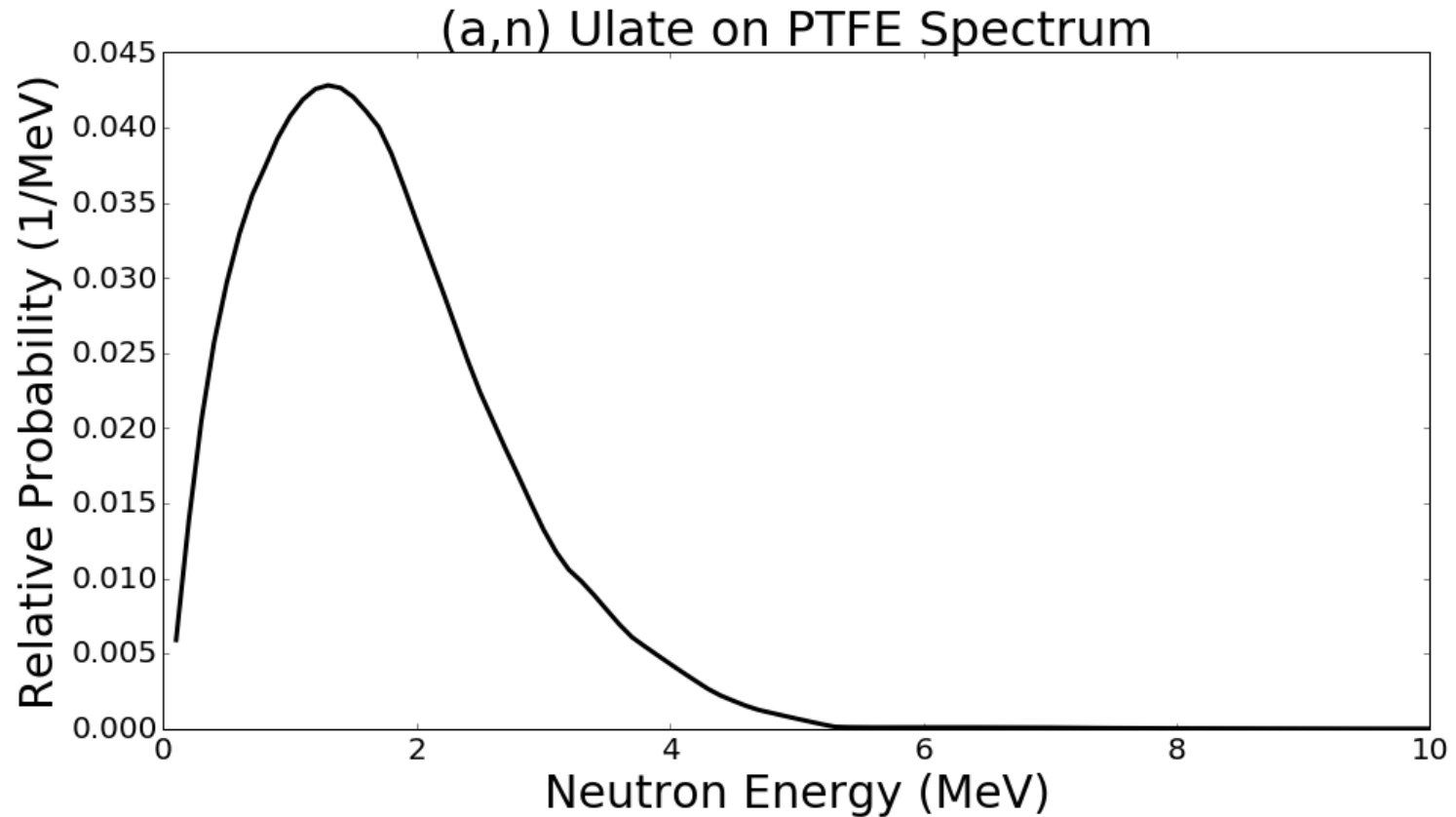


U238 fission from a parameterization I found in a lecture online...

<https://indico.cern.ch/event/145296/contributions/1381141/attachments/136909/194258/lecture24.pdf>

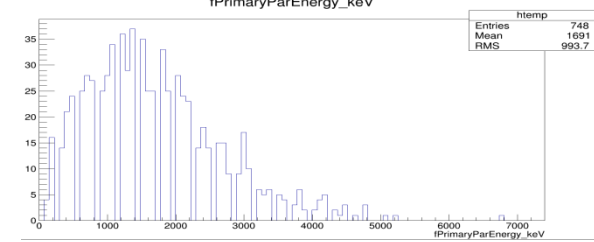
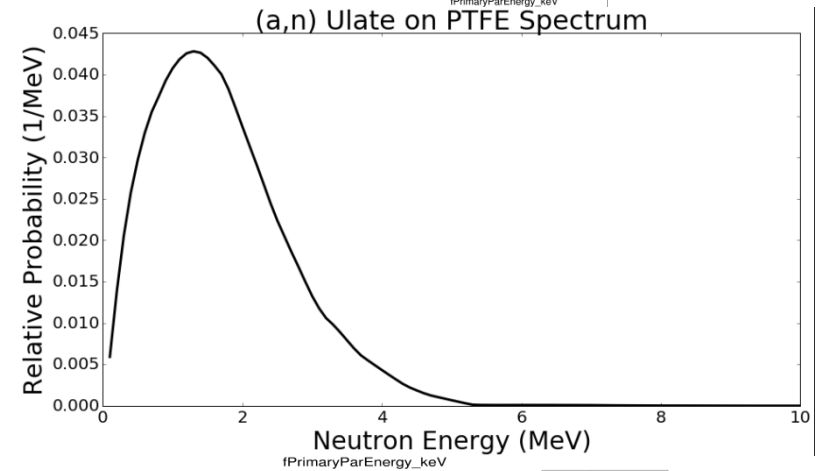
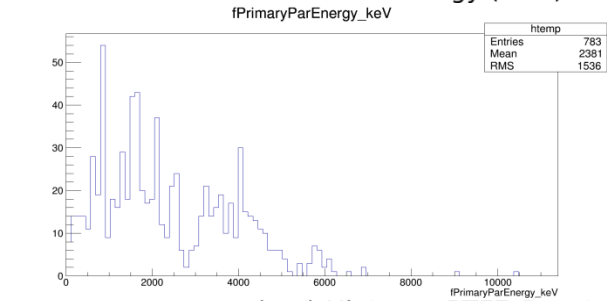
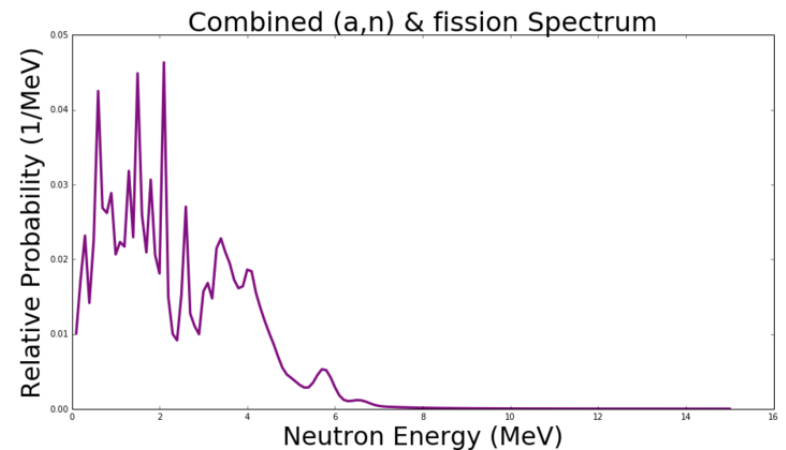
# Background Energy Spectra - PTFE

From Paolo...



# What was actually simulated?

- All components of PMTs, but all neutrons originating in the PMT window.
- All PTFE is the source (specifically, anything with PTFE in the name in LUXSim...)
- Discrete energies normalized to approximate the correct spectrum.



# Current status

- 490,000 Energy deposition only sims of PMT backgrounds run (batches of 10,000, one must have failed)
- PTFE ready to run (I think), but haven't actually been run (error in first submission).

# Future work

- Clustering
- Further determine what the detector would see for each event (an average of 29 interactions occur in LXe for each neutron, most of which deposit some energy, maybe mostly taken care of with clustering, maybe not)
- libNEST -> S1c, S2c PDFs for each spacetime bin (time bin and z-slice)

# The Macros

## PMT Macro

```
# I need to do this
/run/initialize
# set how frequently the sims will update it's progress, i.e. every n events
/LUXSim/io/updateFrequency 100
# choose a directory to which to save the output
/LUXSim/io/outputDir .
# choose name of output files
/LUXSim/io/outputName PMT_an_
# geometry?
/LUXSim/detector/select 1_0Detector
# no grids (faster and not doing optics or activity from them)
/LUXSim/detector/gridWires off
# no cryostand
/LUXSim/detector/cryoStand off
# I need to do this as well
/LUXSim/detector/update
# record energy deposits in the volume "LiquidXenon" (i.e., in the active xenon)
/LUXSim/detector/recordLevel LiquidXenon 2

# place source
/LUXSim/source/set PMT_Window SingleParticle_neutron 0.0100862457815 Bq/kg 0.1 MeV
/LUXSim/source/set PMT_Window SingleParticle_neutron 0.0172169043921 Bq/kg 0.2 MeV
/LUXSim/source/set PMT_Window SingleParticle_neutron 0.0231564684468 Bq/kg 0.3 MeV
/LUXSim/source/set PMT_Window SingleParticle_neutron 0.0141594862236 Bq/kg 0.4 MeV
/LUXSim/source/set PMT_Window SingleParticle_neutron 0.0225755162408 Bq/kg 0.5 MeV
/LUXSim/source/set PMT_Window SingleParticle_neutron 0.0425102014676 Bq/kg 0.6 MeV

(more of the same, a LOT more)

# optics off
/LUXSim/physicsList/useOpticalProcesses false
# set number of particles to simulate
/LUXSim/beamOn 10000

# later!
exit
```

PTFE is the exact same,  
but with PTFE in place  
of PMT\_Window and  
different numbers.