Activities Update

Sep 13, 2017

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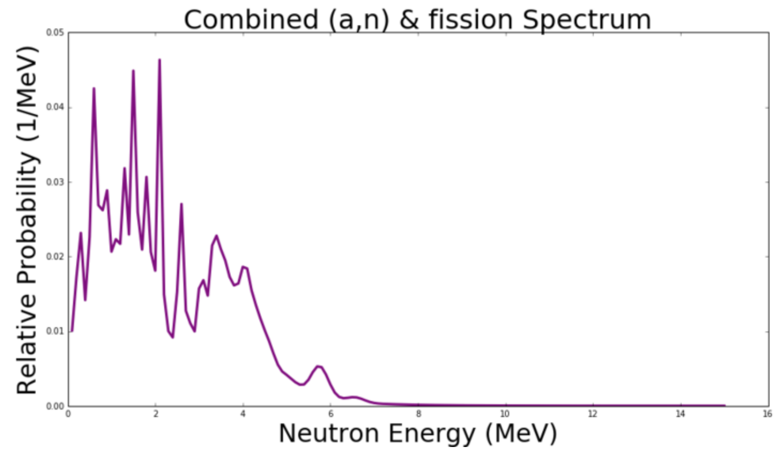
Neutron Background Simulations - LUX

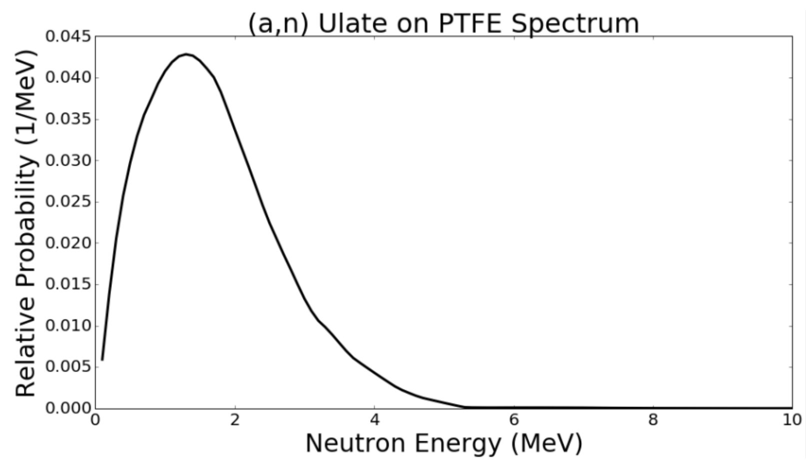
- Determine how many background events passing golden-event cuts may be due to neutron interactions

The Simulation

Simulated energy deposits from neutrons originating from the PMTs and from the PTFE



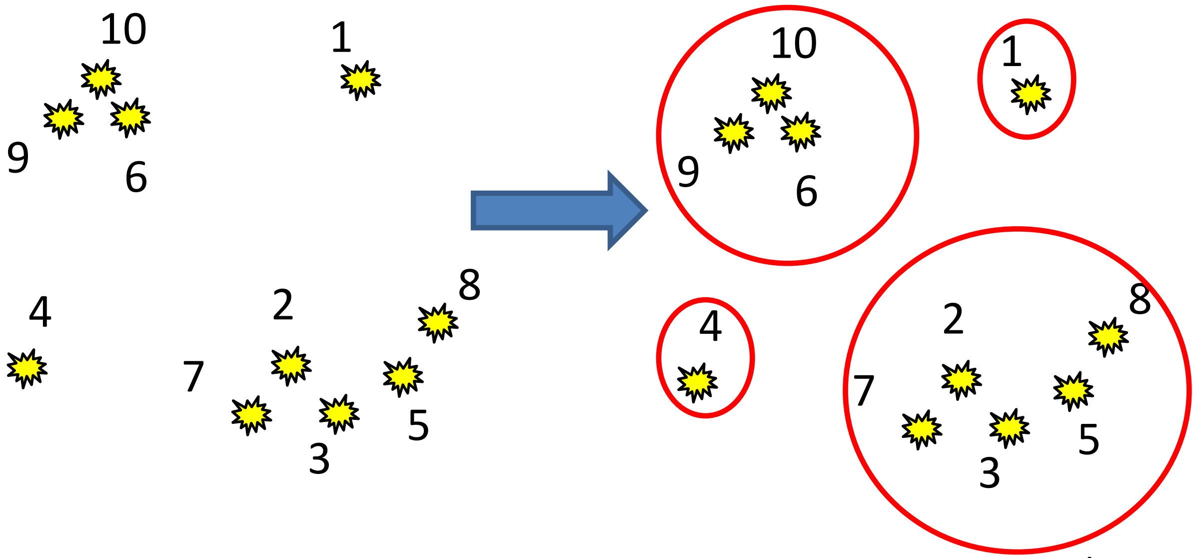
From PMTs

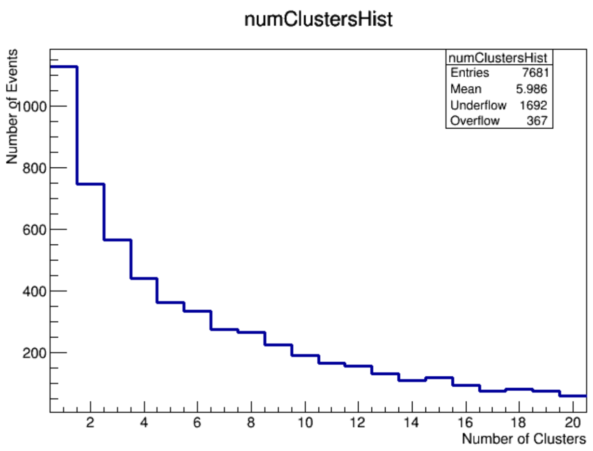


From PTFE

Clustering

- Clustered energy depositions that would be too close together for the detector to distinguish between them.

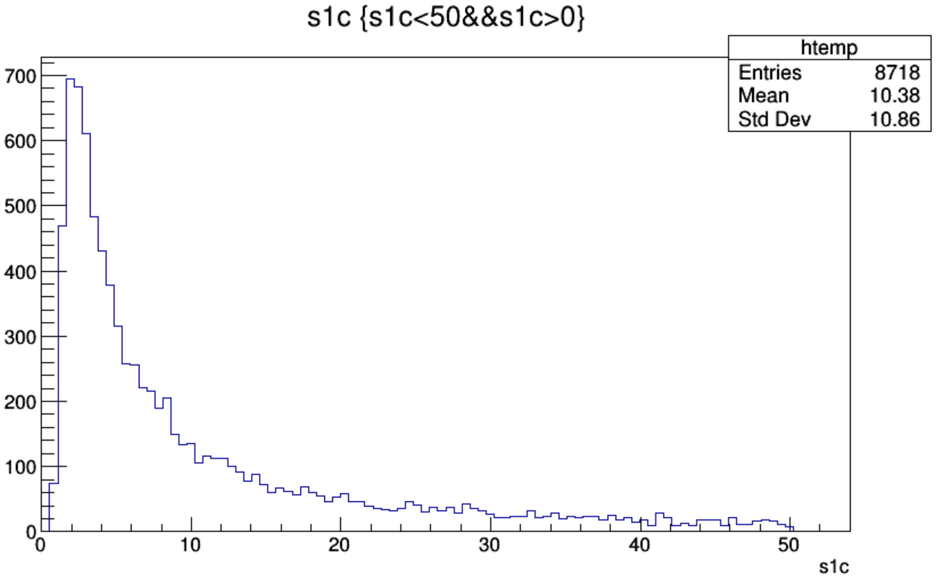


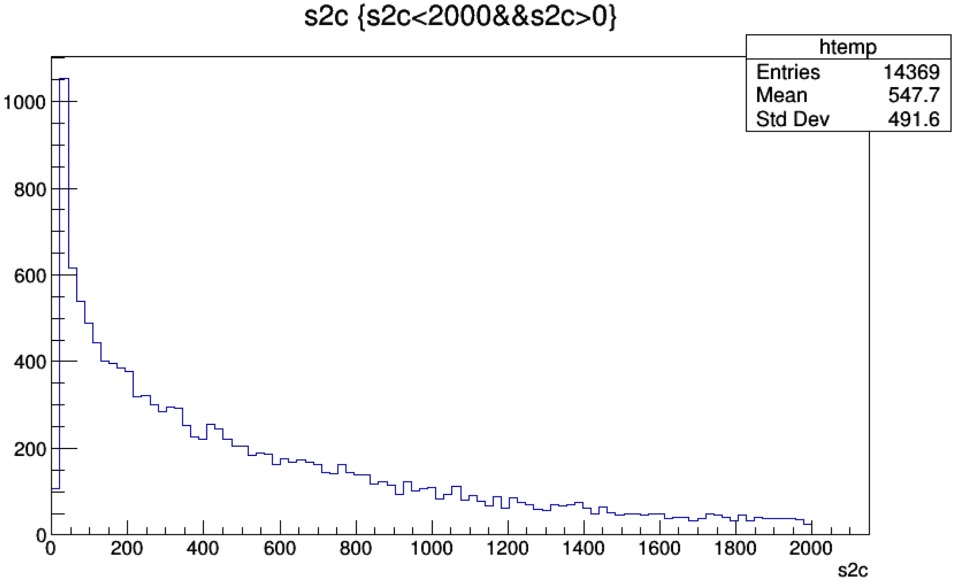


The number of depositions in each cluster.

Simulate Detector Response

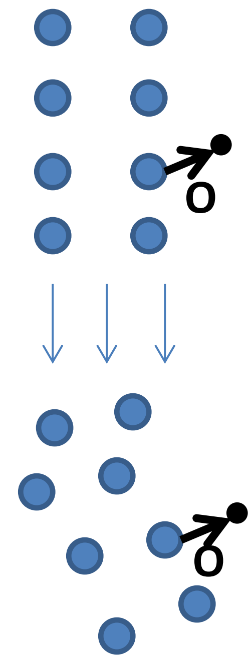
- Determine the amount of S1 and S2 measured from each cluster

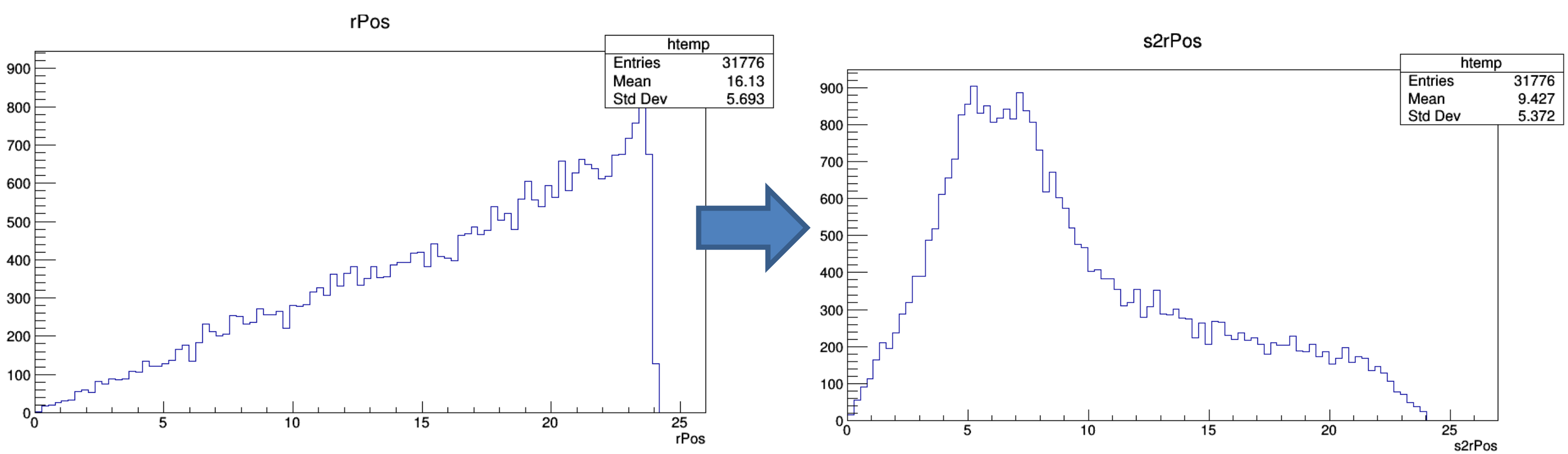




Map from Real Space to readout space

- Electric fields drift electrons, changing the positions of the read-out electrons from their interaction locations.





Implement cuts

- There’s a whole litany of them, I won’t include them in this presentation

Results

From all of run04…

- .16 from PMTs
- .016 from PTFE

```
Time bin 1: 46.766 live days.  17.67 PMT emitted neutrons
single scatter ratio: 0.00141287

Time bin 1: 46.766 live days.  1.22 PTFE emitted neutrons
single scatter ratio: 0.00208515


Time bin 2: 46.731 live days.  17.66 PMT emitted neutrons
single scatter ratio: 0.00135149

Time bin 2: 46.731 live days.  1.22 PTFE emitted neutrons
single scatter ratio: 0.00195149


Time bin 3: 91.552 live days.  34.59 PMT emitted neutrons
single scatter ratio: 0.0011604

Time bin 3: 91.552 live days.  2.38 PTFE emitted neutrons
single scatter ratio: 0.00177327


Time bin 4: 146.923 live days.  55.51 PMT emitted neutrons
single scatter ratio: 0.00123663

Time bin 4: 146.923 live days.  3.82 PTFE emitted neutrons
single scatter ratio: 0.00187525
pdsf6 $
```

Effective Field Theory Analysis - LUX

The Idea

- An interaction can have the arbitrary form:

$$\mathcal{L}_{\rm int} \;=\; \chi\mathcal{O}_\chi\chi N\mathcal{O}_N N.$$

- We generally consider the case where O_x=O_N=[identity] (spin independent) because this naively should be dominant for low momentum-transfer interactions
- In general, however, we can consider any operator that satisfies all known symmetries.

The Idea continued

- There are 5 quantities that are Galilean invariant.
  - **I**, i**q**, **v**, **S**$_{\chi}$, **S**$_N$
- These can be combined into 16 operators

$$
\begin{aligned}
\mathcal{O}_1 &= 1_\chi 1_N \\
\mathcal{O}_2 &= (v^\perp)^2 \\
\mathcal{O}_3 &= i\vec{S}_N \cdot (\frac{\vec{q}}{m_N} \times \vec{v}^\perp) \\
\mathcal{O}_4 &= \vec{S}_\chi \cdot \vec{S}_N \\
\mathcal{O}_5 &= i\vec{S}_\chi \cdot (\frac{\vec{q}}{m_N} \times \vec{v}^\perp) \\
\mathcal{O}_6 &= (\vec{S}_\chi \cdot \frac{\vec{q}}{m_N})(\vec{S}_N \cdot \frac{\vec{q}}{m_N}) \\
\mathcal{O}_7 &= \vec{S}_N \cdot \vec{v}^\perp \\
\mathcal{O}_8 &= \vec{S}_\chi \cdot \vec{v}^\perp \\
\mathcal{O}_9 &= i\vec{S}_\chi \cdot (\vec{S}_N \times \frac{\vec{q}}{m_N}) \\
\mathcal{O}_{10} &= i\vec{S}_N \cdot \frac{\vec{q}}{m_N} \\
\mathcal{O}_{11} &= i\vec{S}_\chi \cdot \frac{\vec{q}}{m_N}
\end{aligned}
$$

$$
\begin{aligned}
\mathcal{O}_{12} &= \vec{S}_\chi \cdot (\vec{S}_N \times \vec{v}^\perp) \\
\mathcal{O}_{13} &= i(\vec{S}_\chi \cdot \vec{v}^\perp)(\vec{S}_N \cdot \frac{\vec{q}}{m_N}) \\
\mathcal{O}_{14} &= i(\vec{S}_\chi \cdot \frac{\vec{q}}{m_N})(\vec{S}_N \cdot \vec{v}^\perp) \\
\mathcal{O}_{15} &= -(\vec{S}_\chi \cdot \frac{\vec{q}}{m_N})((\vec{S}_N \times \vec{v}^\perp) \cdot \frac{\vec{q}}{m_N}) \\
\mathcal{O}_{16} &= -((\vec{S}_\chi \times \vec{v}^\perp) \cdot \frac{\vec{q}}{m_N})(\vec{S}_N \cdot \frac{\vec{q}}{m_N}).
\end{aligned}
$$

The Idea continued more

- These different operators can give rise to different recoil energy spectra according to

$$\frac{dR}{dE_R} = \frac{\rho_0}{32\pi m_\chi^3 m_p^2} \int_{v>v_{min}} \frac{f(\vec{v})}{v} (c_i^{(N)})^2 \sum_{k=\mathrm{M},\Sigma'',\Sigma',\Delta,\Phi'',\tilde{\Phi}'} a_{iik} F_k^{(N,N)}$$

Where the quantity represented by the sum is O_i broken into calculable nuclear form factors.

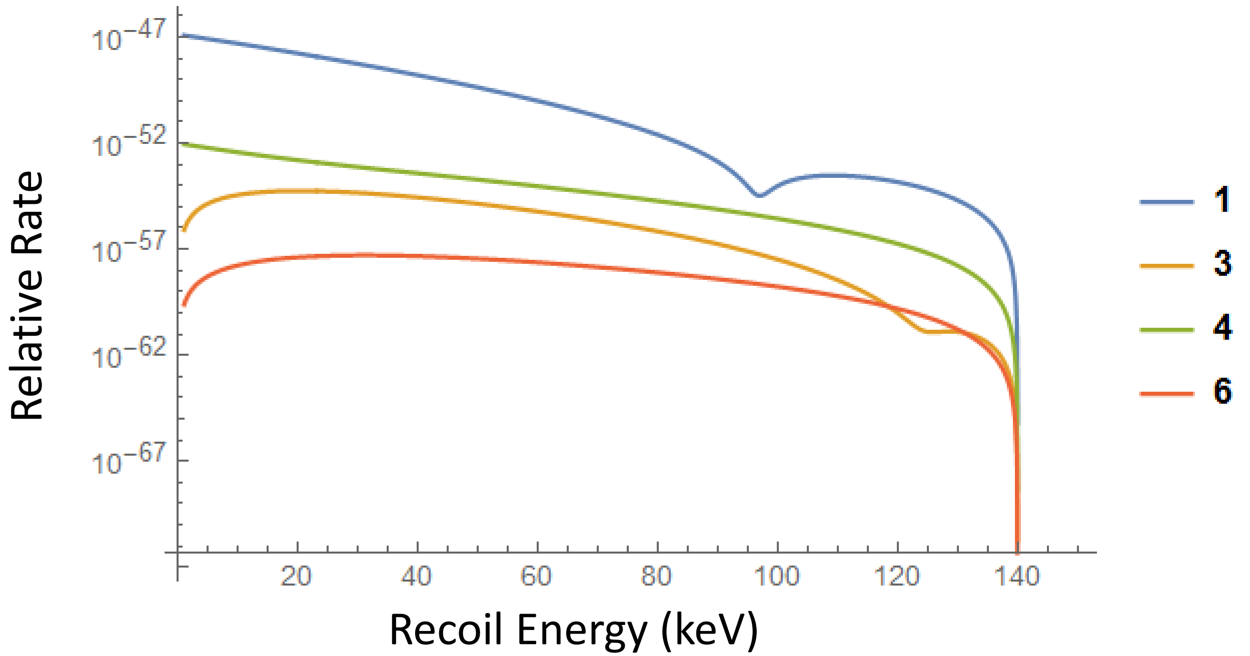
- Want to put limits on $c_i^{(N)}$

The process

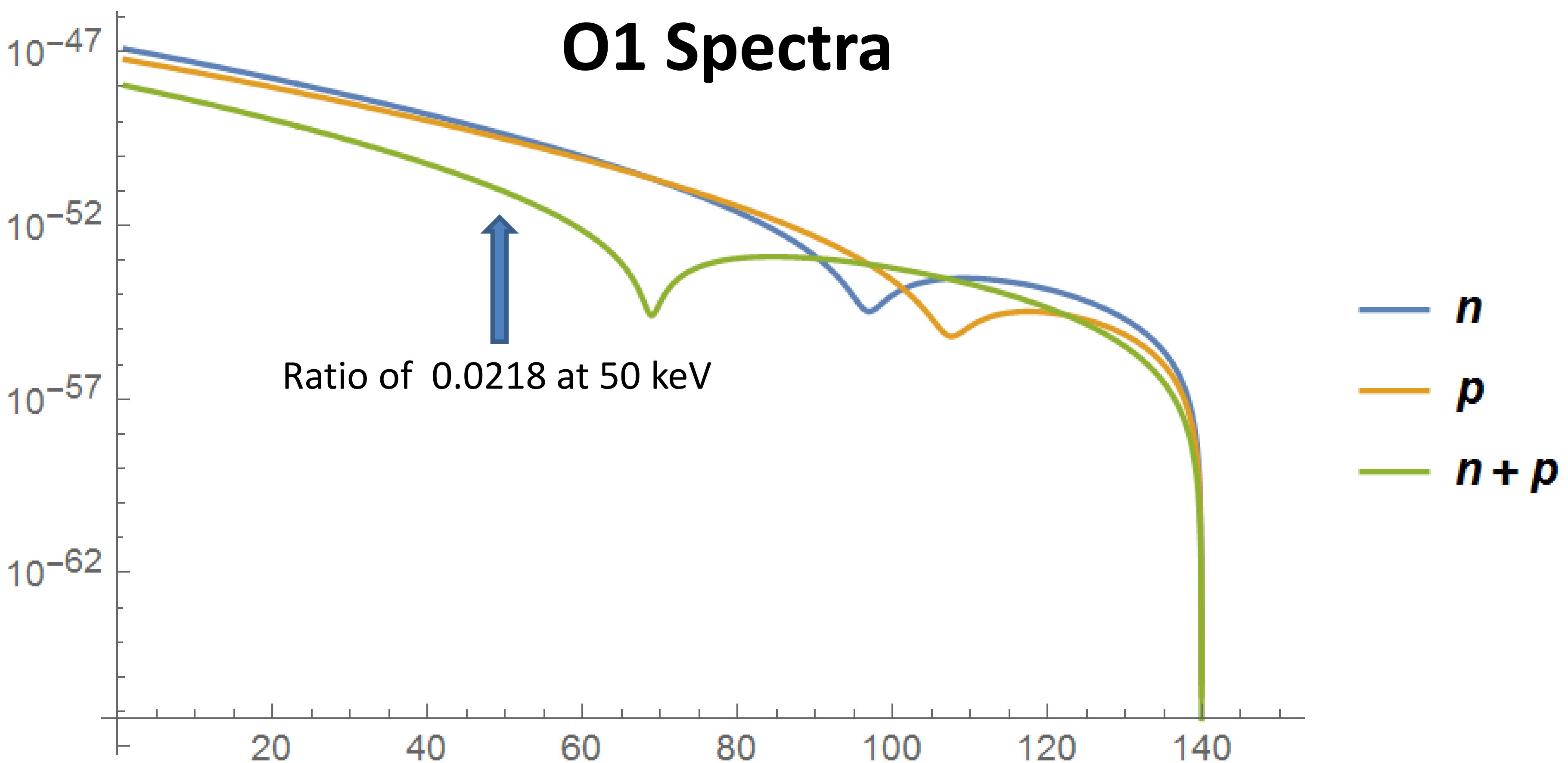
- Compare calculated spectra with observed.
  - Interference between operators is forbidden in most cases, so we can test 1 at a time.
  - Inteference between the proton and neutron operators is not, however, forbidden. Nevertheless, we still begin by doing these 1 at a time for simplicity.

Some sample neutron spectra

Generated using a mathematica package created for this purpose.



n-p Inteference Demonstration



(C^n_1=1, C^p_1=-1)

Integration into the PLR limit code

- The limits code main file is “SIRun4.cxx”
  - This calls “ImportSignalModel_5D”
- ImportSignalModel_5D is in “ImportSignalModel.h” and creates a “RooSignalPDF” object
  - ws->factory(TString::Format("SignalPDF::nrPop%d(mWimp,S1,log10S2,r,phi,drift,G2Var,NoNuisParam,%d,%d)",tt,tt,(int)useAnalyticIntegration));
  - Confusing, right?
- RooSignalPDF creates a 1D histogram and fills it using a function called “FillWimpHist”
- I have replaced FillWimpHist with “FillWimpHistEFT”

FillWimpHistEFT

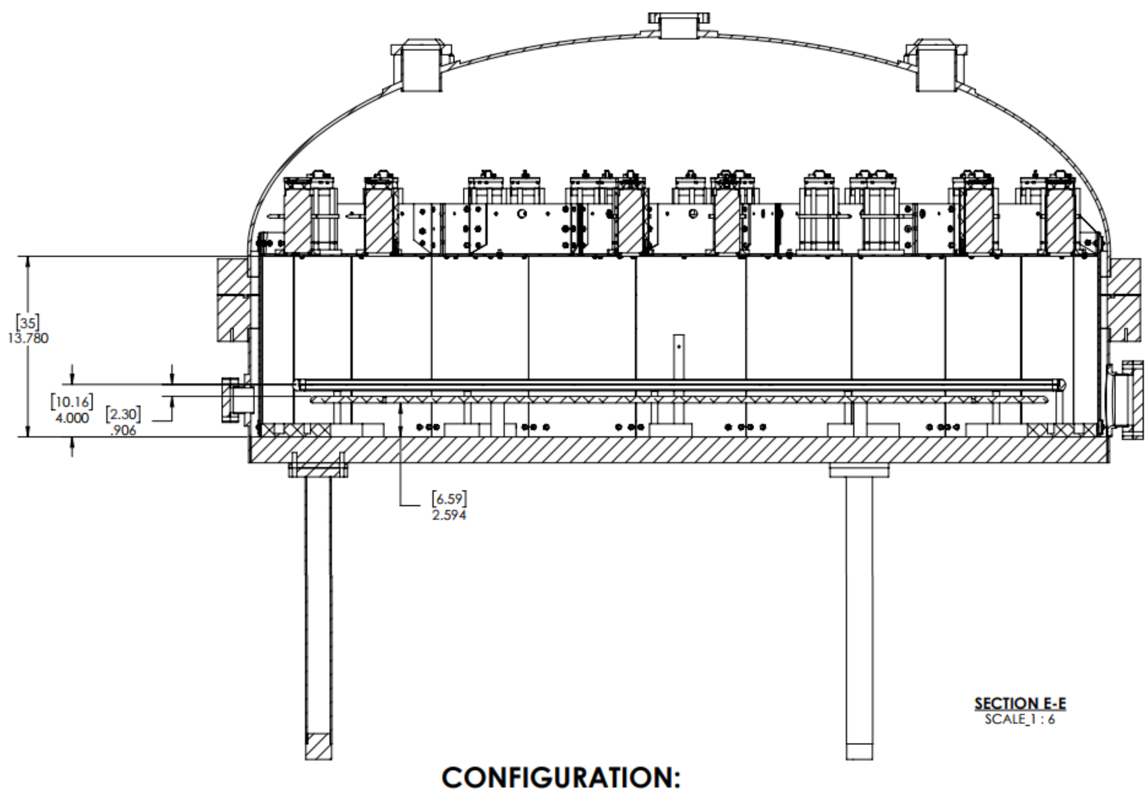
- Opens a file called o#c.dat, where # is the operator number, and c is either ‘p’ for proton, or ‘n’ for neutron.
- These files are tables of integrated rates in predefined bins and WIMP masses generated using mathematica.
- Parses the tables using the input WIMP mass, operator number, etc. to grab the correct data
- Fills the histogram with the appropriate values

Rate tables.

- Rates are calculated using a variety of WIMP masses, for only spin ½ WIMPS.
- Each operator (28 of them, 14x2) is its own table.

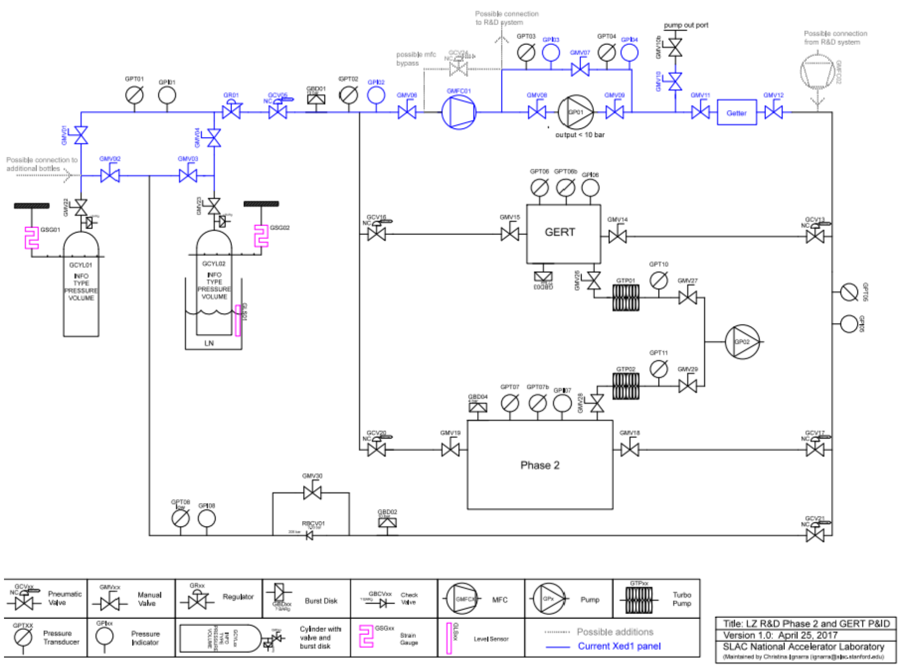
System Test Phase II - LZ

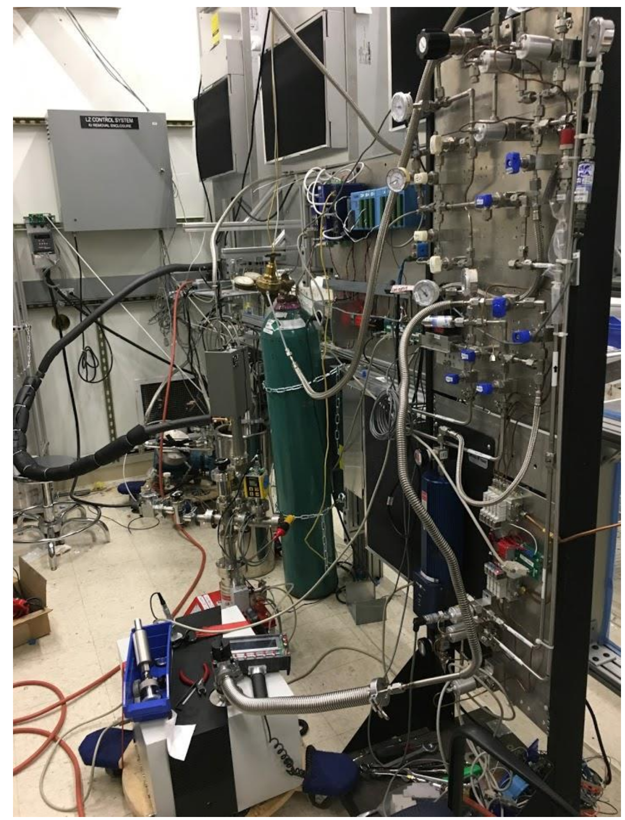
- Large Vessel designed to test the LZ field generating grids in Xe gas.



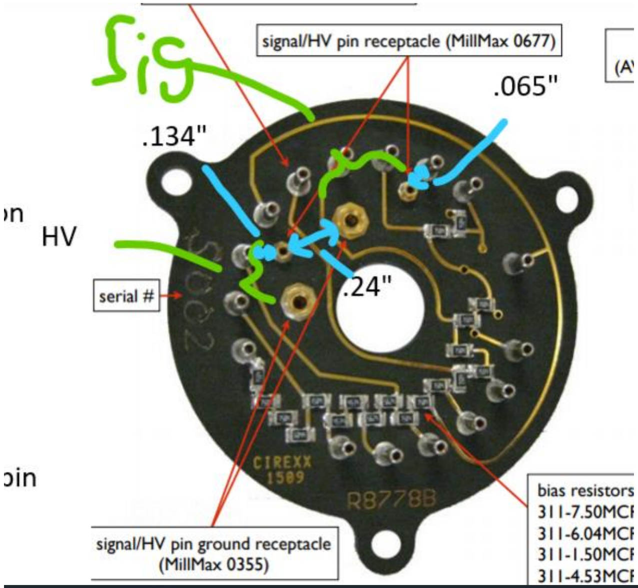
Gas Circulation

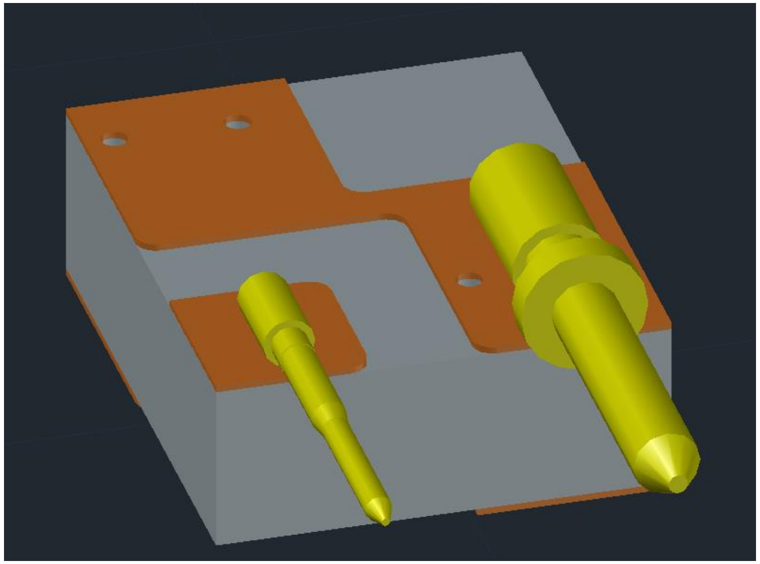
Assist in concept, design, and construction of Phase II/Gas Test gas system

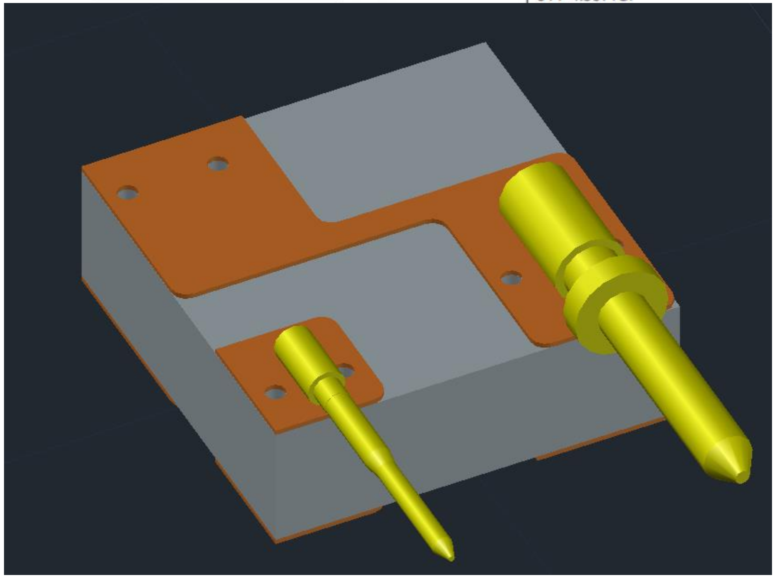


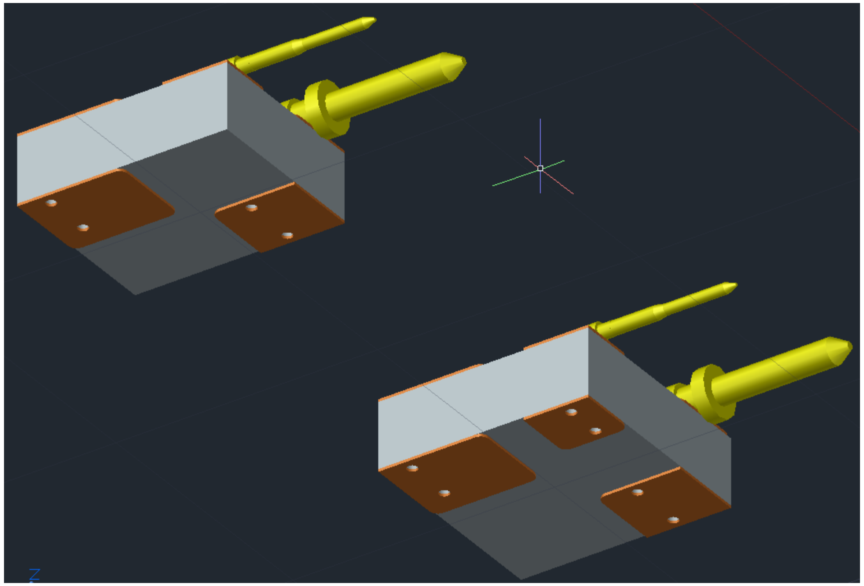


PMT connections









PMT array test assembly

- 43 bent sheet metal pieces
- Ensure they fit correctly and withstand manipulation and stress
- Thorough cleaning