SoLid: New potential for Inverse Beta Decay Analysis

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The SoLid Experiment

Situation

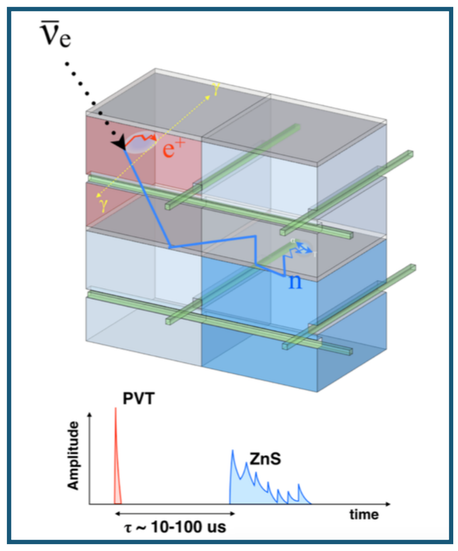
- Standard Model: 3 massless neutrinos
- Observations suggest neutrinos oscillate
  - Nobel Prize in 2015 for confirmation
- Some inconsistencies remain
  - need an extended model for neutrinos
    - no weak, but special (sterile) coupling

SoLid's strategy

- Investigate reactor antineutrino oscillations at very short baseline (5.5m - 10m)
  - confirm sterile neutrino hypothesis?
  - precise ^{235}U spectrum measurement
- Using new segmented detector technology
  - PVT scintillator for EM detection
  - $^{6}LiF:ZnS(Ag)$ sheets for neutron capture

SoLid Detection Principle

- $\bar{\nu}_e$ from the reactor is detected via an inverse beta decay (IBD): $\bar{\nu}_e + p \rightarrow n + e^+$
- **e^+** gives prompt scintillation
- **n** thermalizes before capture
  - delayed signal
- IBD selection based on different signatures of e^+ and n, the time delay and the detector's high segmentation



☞ *Dedicated poster on SoLid construction and technology: see Céline Moortgat*

Experimental Backgrounds

Accidental background

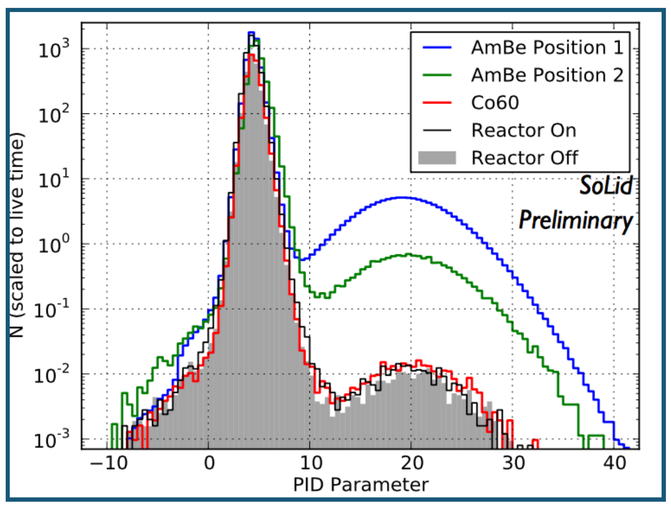
- Random coincidence of an EM event and neutron like signal
  - reactor gammas
  - reactor neutrons
- Reduce with topology and energy thresholds

Correlated background

- Time correlated EM and neutron event
  - spallation neutrons from cosmic muons
  - cosmic high energy neutrons
  - radioactive induced neutrons (BiPo)
- Reduce with cosmic vetos, topology and pulse shape discrimination

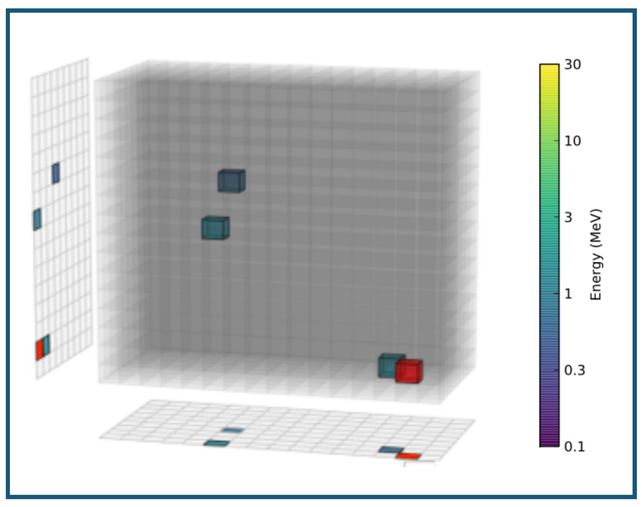
Particle Identification

- Preselection of data based on energy threshold, x-y trigger coincidences, …
- Pulse shape discrimination to identify the different particle signals
  - Ratio of waveform integral to amplitude gives excellent discrimination between neutrons and EM signals

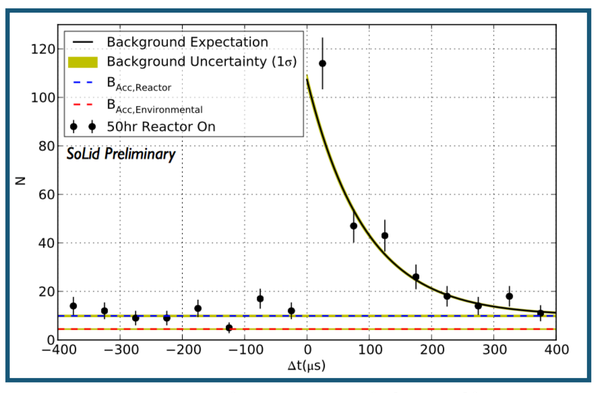


Event Reconstruction

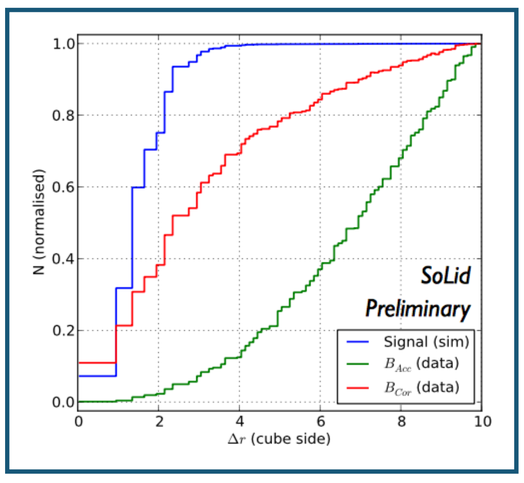
- Time and spatial correlation of e^+ and n absorption signals from an IBD event
  - Time difference Δt: O(100)μs
  - Separation Δr <3 cubes in most cases
- Positron energy contained in one or two touching cubes in most cases



IBD event + accidentals in SM1 detector prototype



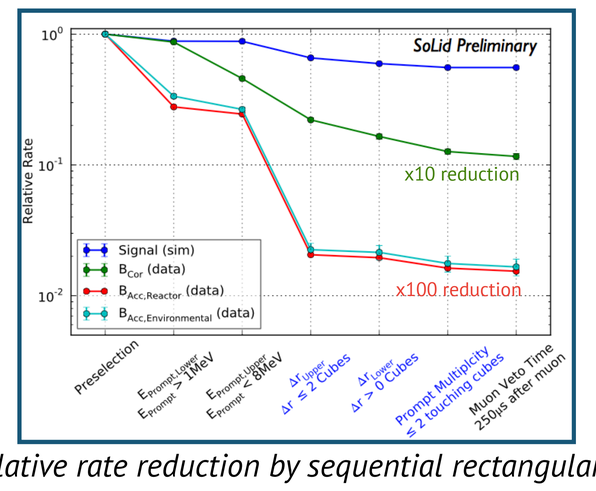
Detector segmentation provides direct methods for discriminating signal from backgrounds



Background Reduction

Sequential Cut Based Analysis

- B_{acc} studied from shifted time windows
  - significantly reduced using lower energy threshold and limitation on Δr
- B_{corr} harder to eliminate
  - multiplicity cut effective to reduce fast neutron induced proton recoil events
  - more advanced techniques needed

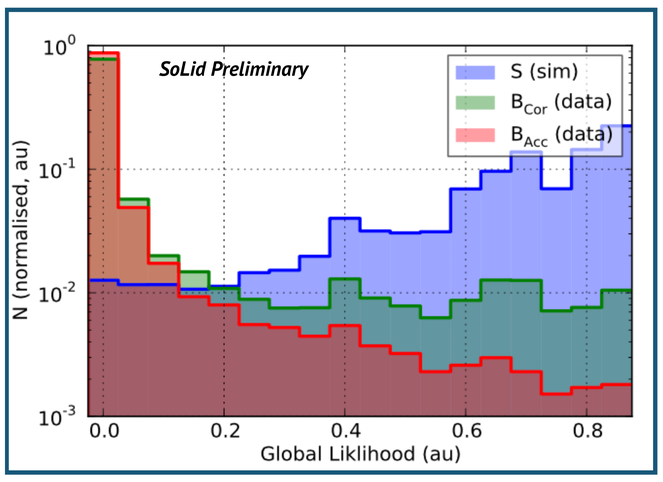


Relative rate reduction by sequential rectangular cuts

Likelihood Discriminator

- Evaluation on event-by-event basis
- New parameter: $GL_i = L_{sim,i}/(L_{uncorr,i}+L_{corr,i}+L_{sim,i})$

with $L_{sim,i}=P^{\Delta x}_{sim}(\Delta x_i)\cdot P^{\Delta y}_{sim}(\Delta y_i)\cdot P^{\Delta z}_{sim}(\Delta z_i)\cdot P^{\Delta t}_{sim}(\Delta t_i)$
for event i (same for $L_{corr,i}$, …)



- provides extra correlated background reduction w.r.t. rectangular cuts

Summary

- Sequential rectangular cuts: reduce B_{acc} with factor 100 and B_{corr} with factor 10
- Likelihood Discriminator can further reduce B_{corr} with signal retainment ~50%

Outlook

- SM1 prototype has given valuable insights in experimental backgrounds
- Developed various background reduction methods & checked with data and MC
- Machine Learning techniques (BDT, SVM), are being investigated and show even better background reduction is possible

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