The Search for Lightly Ionizing Particles Using Data from the 90-Day Run of the LUX Detector

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LUX Collaboration
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Motivations for LIPs

- Monopole theories - Witten Effect
- String Theory, multidimensional scenarios.
- Hidden U(1) sector - as dark paraphoton.
  - The paraphoton will have an apparent small electric charge due to the kinetic mixing between EM photon and the hidden sector, in a massless scenario
- Charge quantization questions within the SM
- Leave no stone unturned (WIMP parameter space problem)

\[ \mathcal{L}_{\text{MIX}} = \frac{X}{4} F^{\mu \nu} F'_{\mu \nu} \]
Running out of Room to Find WIMPs

If we hit the Neutrino Floor, neutrinos would look like WIMPs. Then a WIMP search becomes more problematic.
The LUX Detector

● 370 kg Xe
  ○ 250 kg active region
  ○ Effective self shielding
● Dual phase gas-liquid Time Projection Chamber (TPC)
  ○ Using scintillation and ionization
● Located at SURF, South Dakota, USA
  ○ 1478 m underground
● Designed and optimized for WIMP search
  ○ But can use data for other physics results
Tracks - two types

We expect there to be many (more than 10 in many cases) hits along the detector forming a track line. These hits can be very small and there can be a lot of them. This is important from the perspective of data processing framework and reprocessing data.

These pose interesting problems for simulation and data processing.

For simulation use the Geant4 monopole class in LUXSim
magnetic charge = 0
Electric charge can be varied

It is possible that there could be a continuous or mostly continuous line of ionization in the detector, similar to a muon track.
-pulse chopping can help this.
Some Backgrounds & Mitigation

- Some of the more prevalent backgrounds include: baseline shifts, pulses resulting from built up charge, and photo-ionization on bulk impurities.
  - These backgrounds will have same/similar x-y position
- For pulse chopping require minimum pulse height in various parts of a merged/long pulse
- Require 1 phe/sample height on all pulses
- Cuts
  - Energy consistency cuts
    - to avoid high energy events that are depositing energy only in part of the event
    - Muons cut due to PMT saturation leading to inconsistent energy depositions and poor tracks.
  - Track goodness of fit to avoid compton scatters
  - Theta cut to avoid baseline shift and e-train
This is a test of goodness of fit for the reconstructed lines.

Chi$^2$ is minimized in track fitting.

DOF = Number of fit points - 4
(4 is due to 3D line)

Chi$^2$ = 1 cut line
Removed E-trains, E-burbs and baseline shifts which are all very straight due to the similar x-y positions of those events. Sims are more evenly distributed, having been generated isotropic from above.

Cut made at theta = 20
Decent efficiency is maintained with most losses due to not having energy deposited with a sufficient number of pulses for track reconstruction.
\[ \Phi(f) = \frac{n}{A \varepsilon t \Omega} \]

- \( n \) = number of observed lips (2.44 for 0 at 90\% CL)
- \( A \) = Cross sectional Area
- \( t \) = live time
- \( \Omega \) = Geometrical efficiency
- \( \varepsilon \) = Simulation efficiency

This result

Projected
Run3
result.

See you at
SUSY

LUX Preliminary
Questions?
Backgrounds - E - trains

- Often after high Energy event or multiscatter
- Can look like a lot of small impacts often reconstructed in the same x-y position.
- Can trail into the following event and make up an event of only e-train pulses.
Make sure that the line itself is subtending the detector. This will cut events that have several reconstructed positions very close together.

The x-axis variable is Reconstructed Track Length divided by Ldata.

Cut is at log10(2.7)
The x-axis is log of $\frac{\text{sum (first 2 s2 PA)}}{\text{sum (last 2 s2 PA)}}$.

Y-axis is log of $\frac{\text{STD of All S2s}}{\text{Total Energy}}$.

This is a test of energy consistency. Where we make sure that not too much of the PA is on the front or back of the event and that the STD is not too high - therefore roughly consistent.

Circle is centered at (-0.1, 1.25) with 0.7 radius in log10.

Not shown:
- S2 removed to kept ratio
- Pre-S1 ratio
These two avoid being inside of an e-train.