LOLX 2 First Run of Data Taking

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LoLX: Light-only Liquid Xenon experiment

- Modularized cube of photosensors.
- Immersed in liquid xenon (LXe).
- Operation at McGill University, Canada.
- Design, development, and analysis of LoLX detectors, McGill and TRIUMF.
Physics goals

- Study LXe scintillation and validate simulations.
  - Cherenkov light in liquid xenon.
- Photosensor R&D: silicon photomultipliers (SiPMs).
  - Examine SiPM performance in LXe over long time periods.
  - Rare-decay experiments, such as nEXO and PIONEER.
- Estimate external crosstalk. (David Gallacher’s talk)

<table>
<thead>
<tr>
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<th>LoLX</th>
<th>nEXO</th>
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<tbody>
<tr>
<td>LXe</td>
<td>4-5 kg</td>
<td>5 tons</td>
</tr>
<tr>
<td>E field</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Energy</td>
<td>( \sim 0.2 - 2 \text{ MeV} )</td>
<td>( \sim 2.5 \text{ MeV} )</td>
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<tr>
<td>nSiPMs</td>
<td>80</td>
<td>50'000</td>
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Compare LoLX1 and LoLX2

- Problems found in LoLX1:
  - Fluorescence from 3D-printed plastic.
  - Detector light yield is lower than expected.
    - LXe impurity?
    - SiPMs have lower efficiency?
- Improvements:
  - Adding a PMT.
  - Benchmarking SiPMs photon detection efficiency (PDE).
  - Comparing FBK and Hamamatsu SiPMs performance.
    - Never did it in LXe before, only in vacuum.
  - Installing a purity monitor.
  - Upgrading to a faster DAQ system.
LoLX2 1st run data taking

- August 2023.
- Laser calibration. (ADC voltage → Charge conversion)
- Sources calibration. (Light yield estimation)
  - $^{22}\text{Na}$, $^{133}\text{Ba}$, $^{137}\text{Cs}$
- Background runs.
- Run 2 will start later this year.
SiPM Waveform

- Ba-133 example waveform
- Charge $\propto \int V_{ADC}(t)\,dt$
PMT Waveform

Laser

Cs-137
SiPMs/PMT calibration

• ADC voltage → Charge conversion

• The mean number of PE observed by a PMT/SiPM, $\lambda$, is approximate to $\ln$:

$$\lambda \approx \ln(N_{0PE})$$

• Where $N_{0PE}$ is called the pedestal, where.

$$N_{0PE} = \frac{\# \text{ events observe no photons in a time window}}{\# \text{ light flashes emitted}}$$

¶ DEAP collaboration (2019):
SiPMs/PMT calibration

- ADC voltage $\rightarrow$ Charge conversion

- The mean number of PE observed by a PMT/SiPM, $\lambda$, is approximate to $\ln(N_{0PE})$:

$$\lambda \approx \ln(N_{0PE})$$

- Where $N_{0PE}$ is called the pedestal, where $N_{0PE} = \# \text{events observe no photons in a time window} / \# \text{light flashes emitted}$.
SiPM charge comparison

- Preliminary analysis shows that FBK SiPMs observed about twice as many photons as HPK SiPMs did.
  - $^{133}\text{Ba}$ with $E_\gamma = 356$ keV gamma energy
  - Compton scattering is dominant over the photoelectric for this energy of gamma source, so the peaks are not prominent.
SiPMs energy resolution

- Using the Ba-133 bump (356 keV) as a rough reference to rescale the x-axis to energy.
  - HPK: $2.7 \times 10^{-2}$ PE/keV/mm$^2$
  - FBK: $4.7 \times 10^{-2}$ PE/keV/mm$^2$

- ¶ In vacuum, HPK and FBK SiPMs show similar responses to previous measurements.

PMT problem?

- The PMT doesn't show any signs of energy resolution.
- We don't see difference between different sources.
  - Set voltage too high?
  - Electronics issue?
Summary

- LoLX 2 benchmarks Hamamatsu and FBK in LXe environment.
- FBK SiPMs have better performance.
- In vacuum, HPK and FBK SiPMs show similar responses to previous measurements, but this is not the case for preliminary measurements in LXe.

Next steps

- Run will be started later this year
- Operate the PMT with lower voltage in the next run.
- Understand the cause of widely spread peaks in the SiPM spectra.
- Perform simulations to understand the data.
- Adding a purity monitor.
- Planning to adding alpha or beta internal source.

\[ G. \text{ Gallina et al., Dec. 2022, doi: 10.1140/epjc/s10052-022-11072-8.} \]
Thank you for your attention

Questions?
1. Identify eXT source candidate pulse in low occupancy region
2. Look for time-coincident pulses around source pulse
3. Record time difference $\Delta T$

→ Data: 4-day run in October 2021
→ Pulse-finding algorithm
  → timing, charge and height of pulses
→ Data-cleaning cuts
LoLX Purity Monitor

- Drift length: 5cm
- Electrode width: 1cm
- Resistors (not shown) will be on the scale of GΩs or MΩs
- 2 options being investigated: with or without grid

- Xe Flashlamp
- Photocathode
- Field-shaping rings
- Anode
- Upper grid
- Lower grid

Drift direction
Correlation

- Ba-133 source data
SiPM charge comparison

- Preliminary analysis shows that FBK SiPMs observed about twice as many photons as HPK SiPMs did.
- Compton scattering is dominant for the gamma sources.
  - $^{22}\text{Na}, E_\gamma = 511 \text{ keV}$
  - $^{133}\text{Ba}, E_\gamma = 356 \text{ keV}$
  - $^{137}\text{Cs}, E_\gamma = 661 \text{ keV}$