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LoLX 2 First Run of Data Taking

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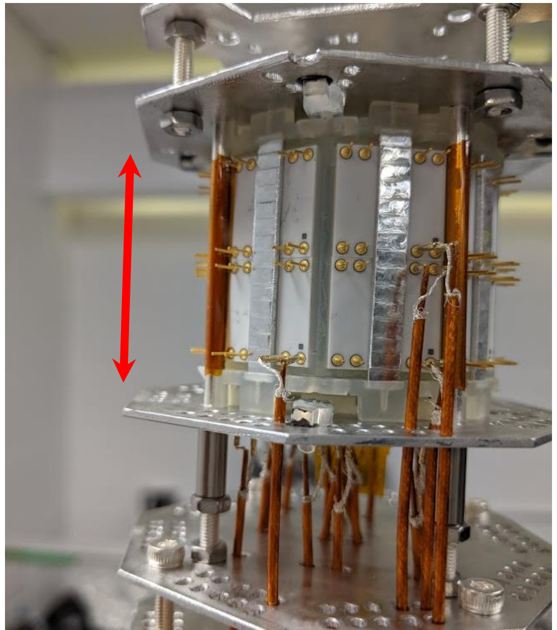
CAP 2024

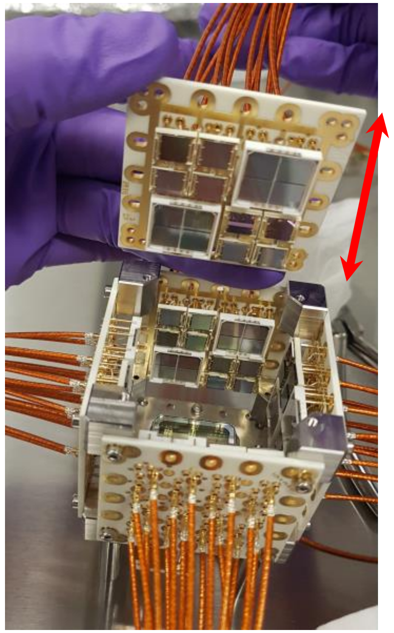
May 27th

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.

LoLX 1
4cm

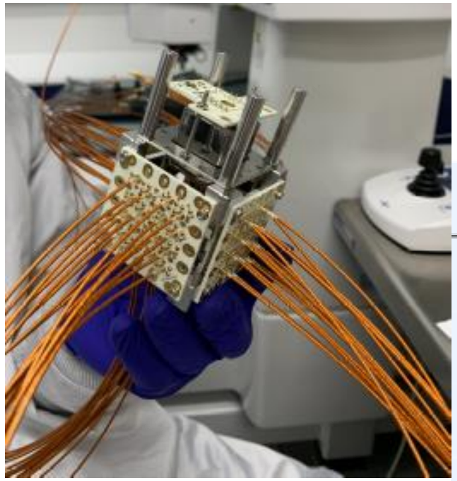




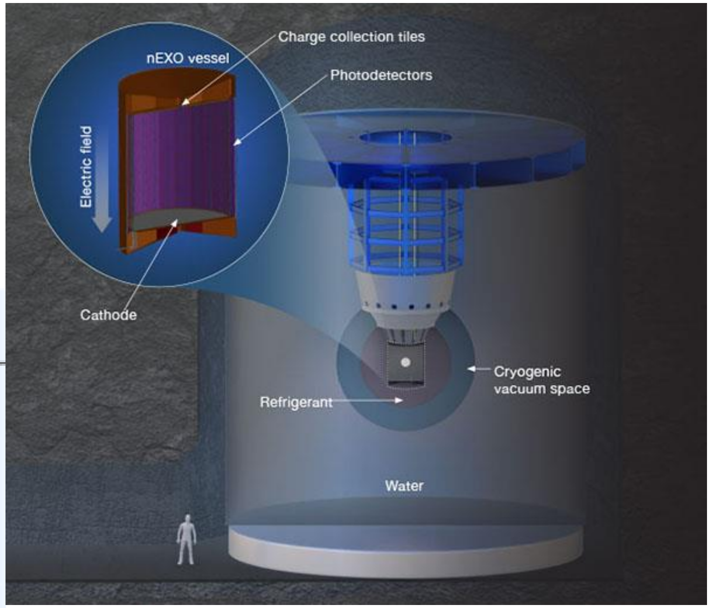
LoLX 2
4cm

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)

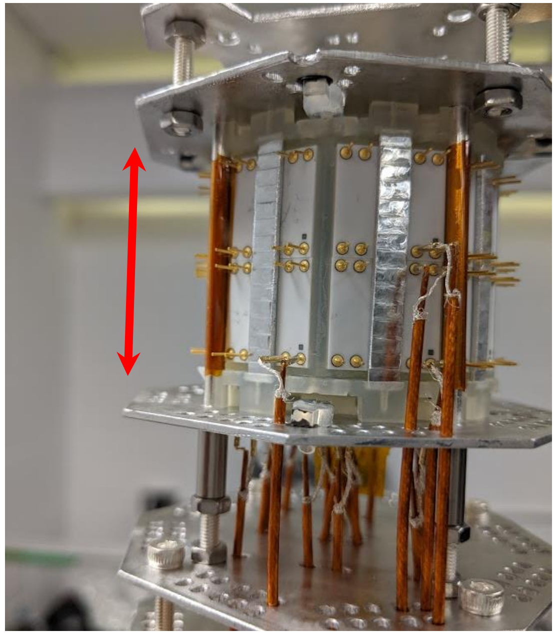


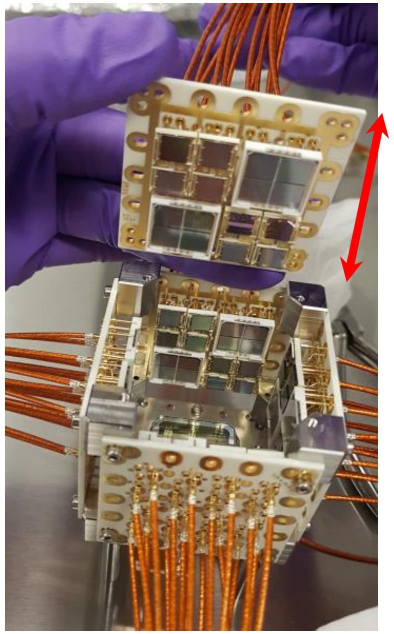
	LoLX	nEXO
LXe	4-5 kg	5 tons
E field	no	yes
Energy	$\sim 0.2 - 2$ MeV	$\sim$2.5 MeV
nSiPMs	80	50'000



Compare LoLX1 and LoLX2

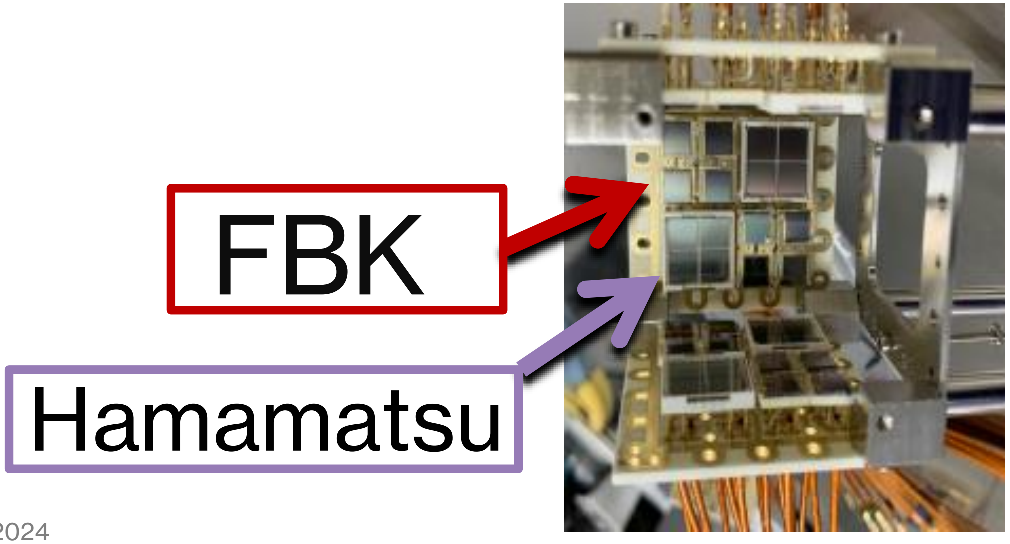
- Problems found in LoLX1:
  - Fluorescence from 3D-printed plastic.
  - Detector light yield is lower than expected.
    - LXe impurity?
    - SiPMs have lower efficiency?
- Improvements:
  - Adding a PMT.
  - Benchmarking SiPMs photon detection efficiency (PDE).
  - Comparing FBK and Hamamatsu SiPMs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

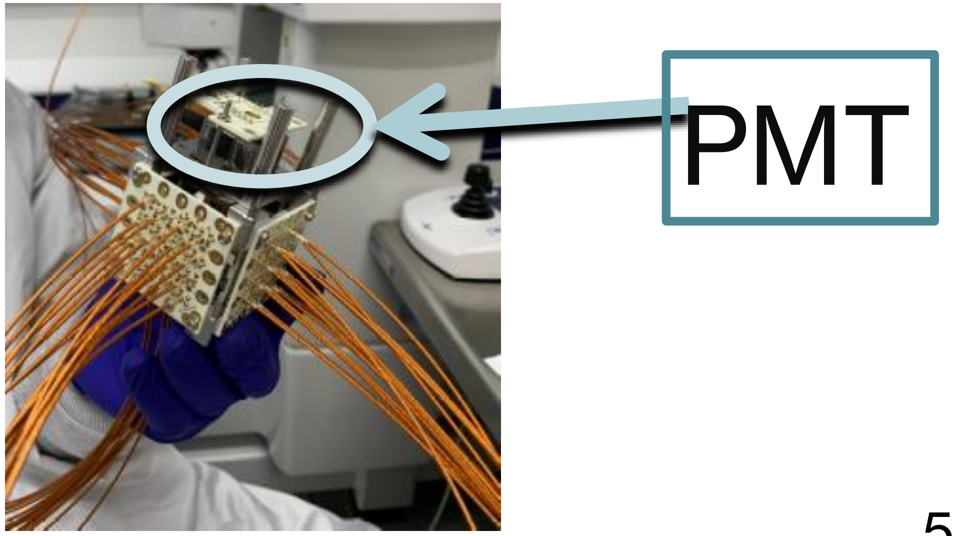




LoLX2 1st run data taking

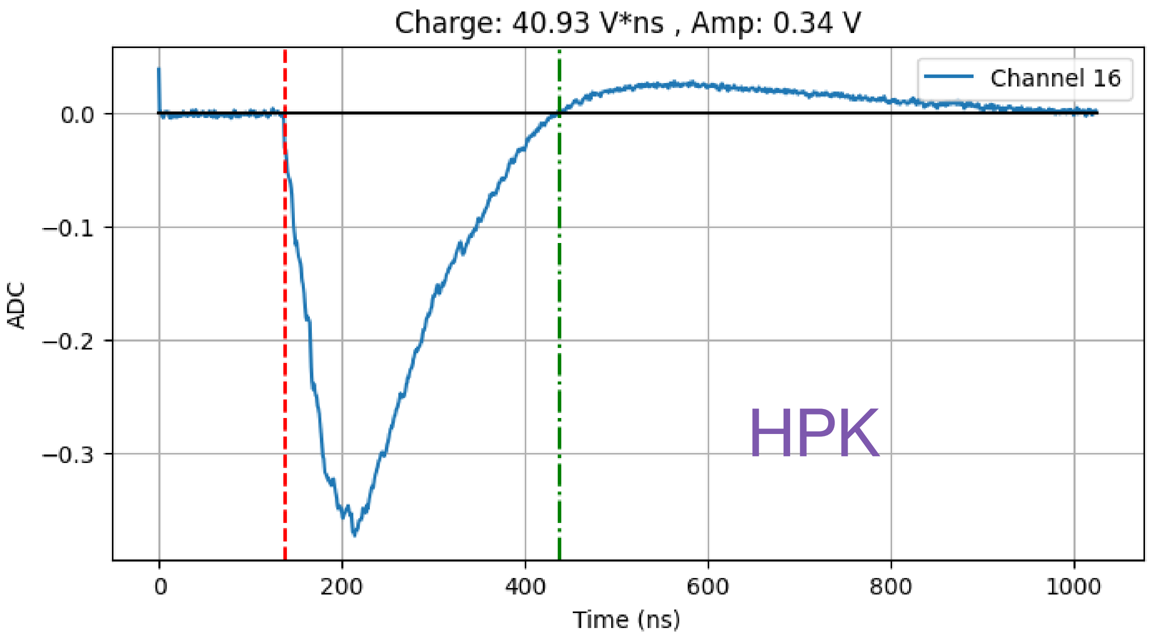
- August 2023.
- Laser calibration. (ADC voltage → Charge conversion)
- Sources calibration. (Light yield estimation)
  - $^{22}\mathrm{Na}$, $^{133}\mathrm{Ba}$, $^{137}\mathrm{Cs}$
- Background runs.
- Run 2 will start later this year.

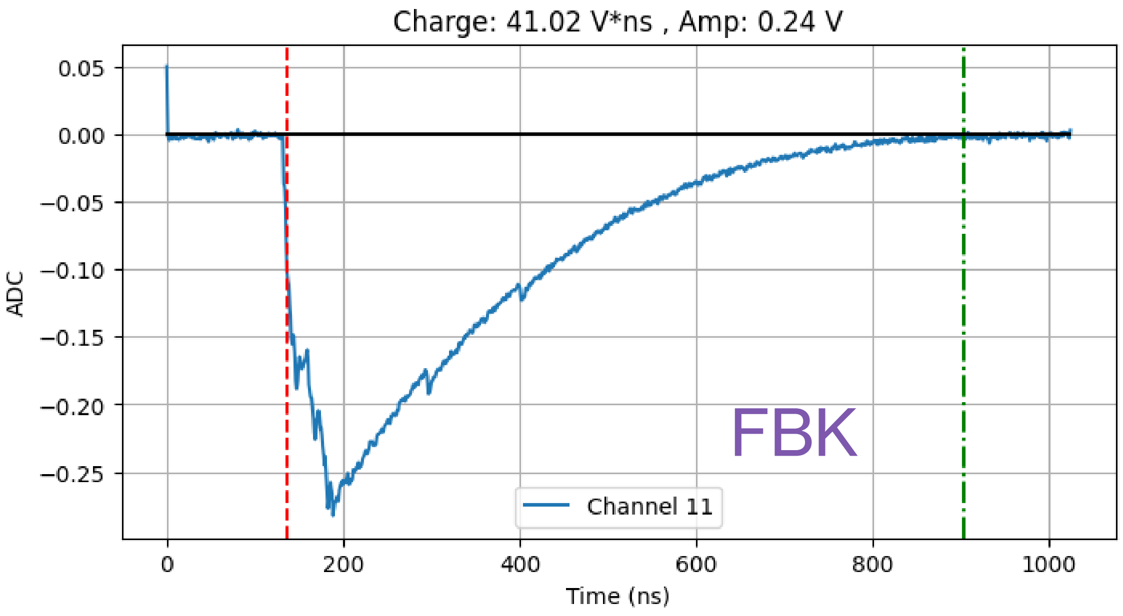




SiPM Waveform

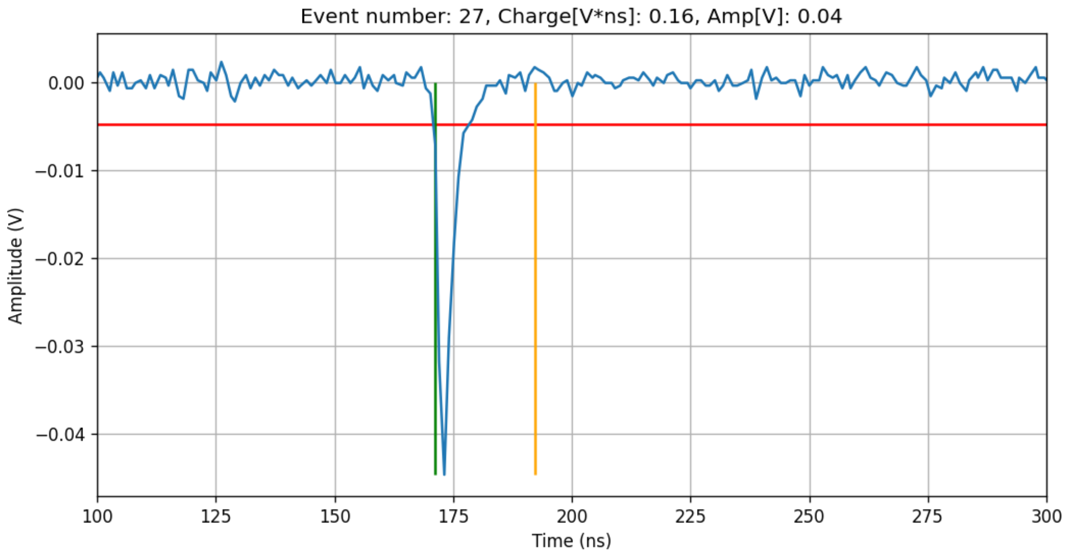
- Ba-133 example waveform
- Charge $\propto \int V_{ADC}(t)dt$



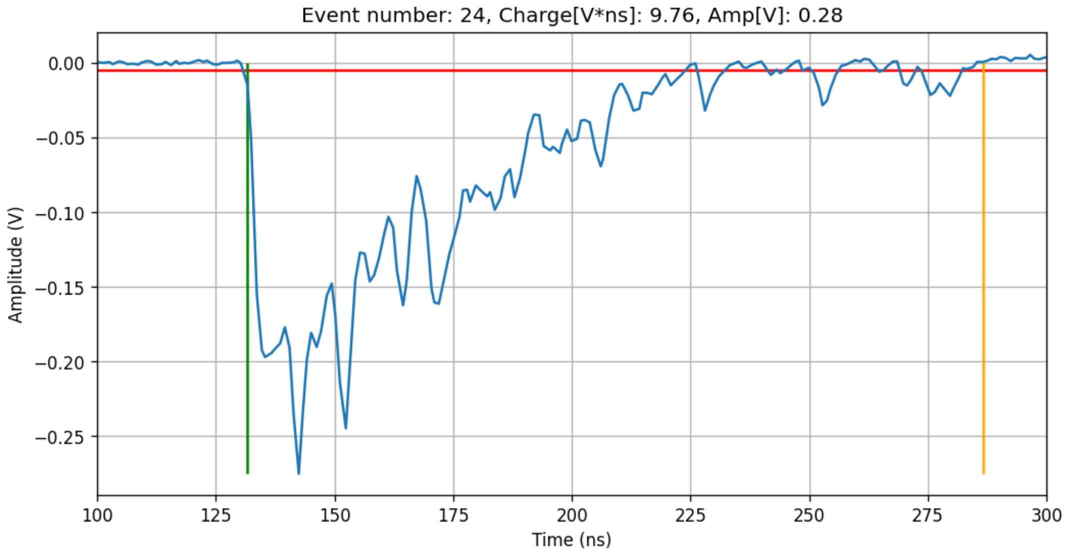


PMT Waveform

Laser



Cs-137



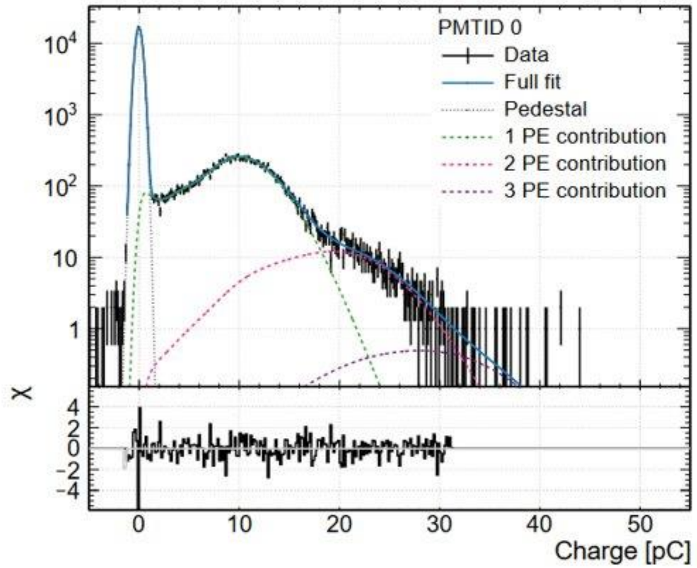
SiPMs/PMT calibration

- ADC voltage → Charge conversion
- The mean number of PE observed by a PMT/SiPM , λ , is approximate to ¶ :

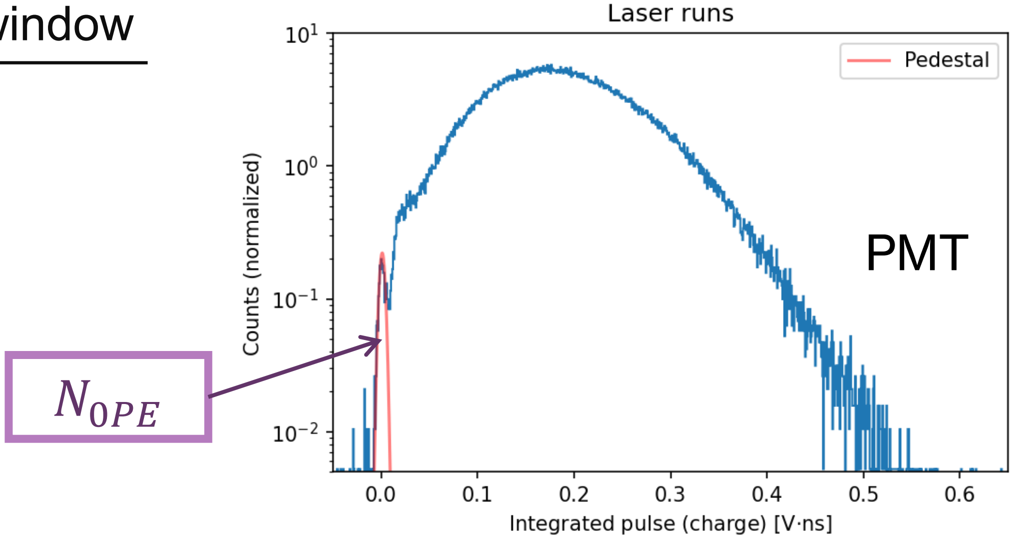
$$\lambda \approx \ln(N_{0PE})$$

- 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): https://doi.org/10.1016/j.nima.2018.12.058



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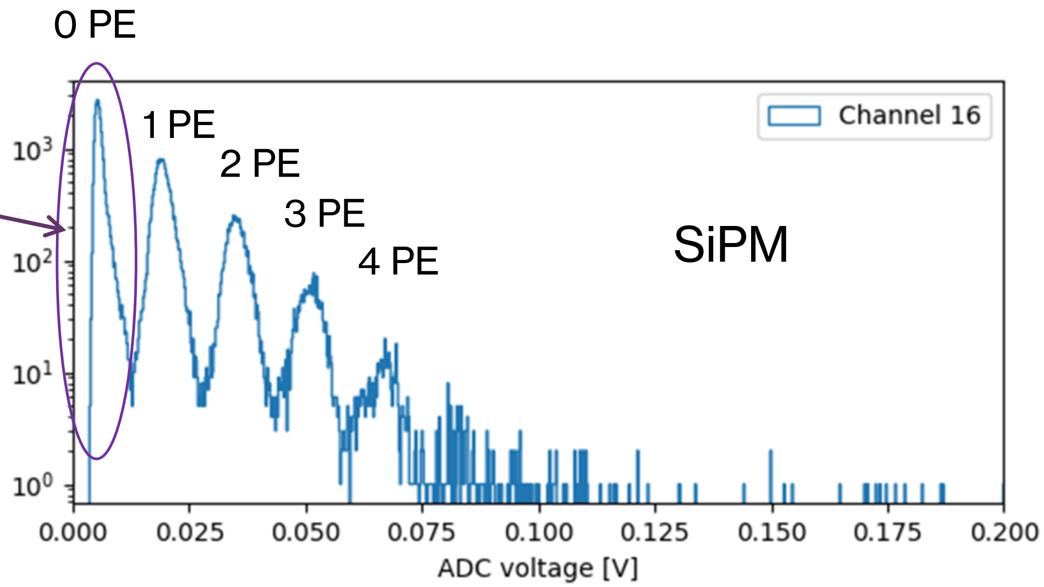
$\boxed{N_{0PE}}$

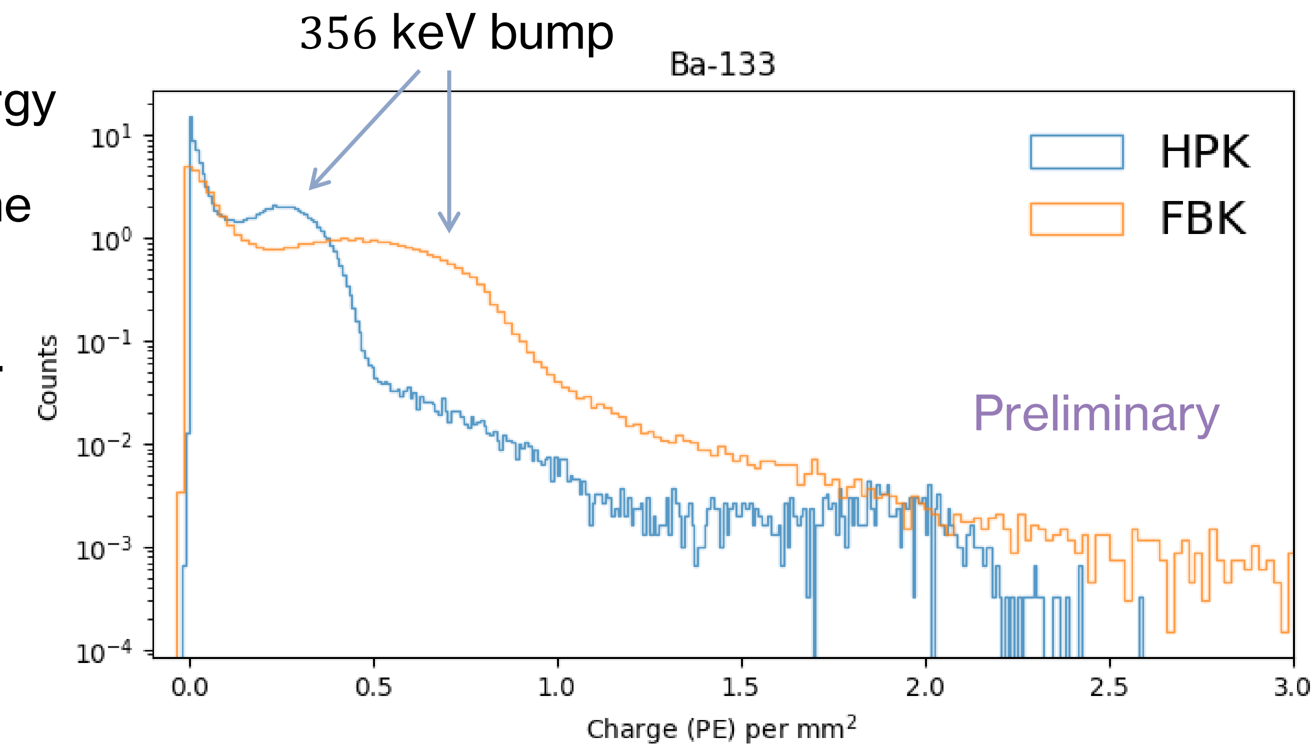


- Where N_{0PE} is called the pedestal, where.

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

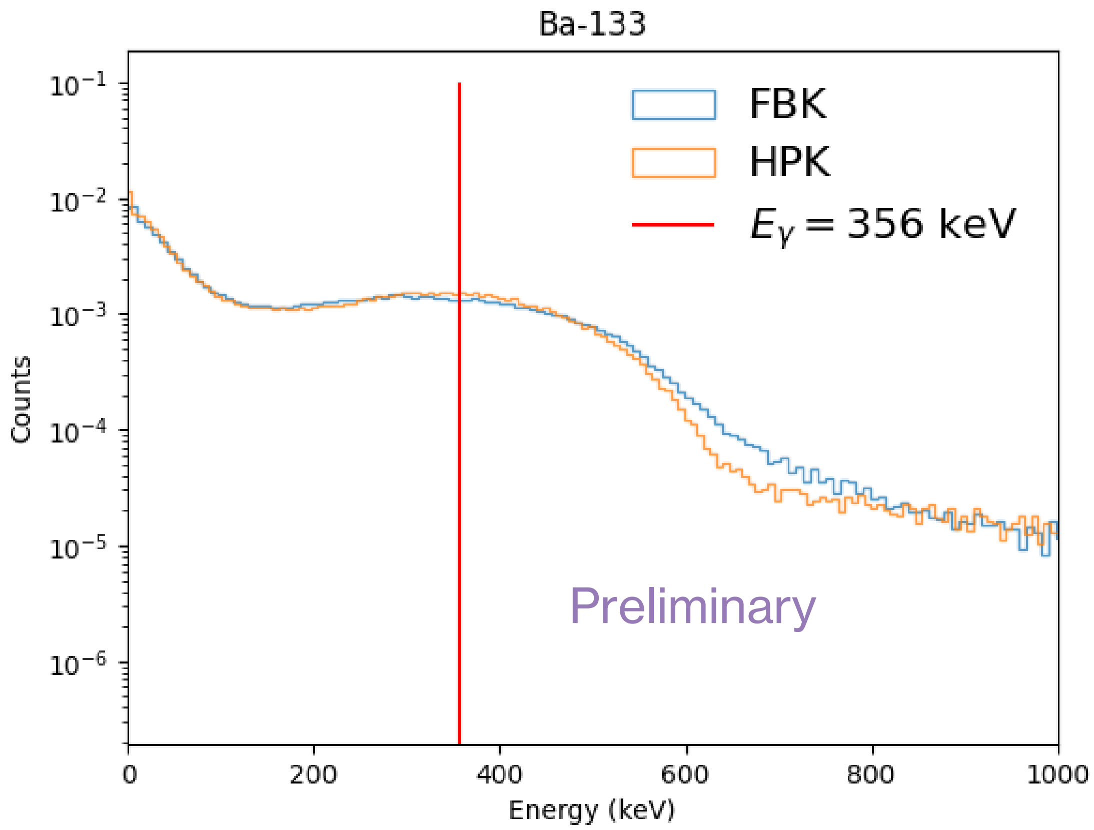
SiPM charge comparison

- Preliminary analysis shows that FBK SiPMs observed about twice as many photons as HPK SiPMs did.
  - $^{133}\mathrm{Ba}$ with $\mathrm{E}_{\gamma} = 356$ 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

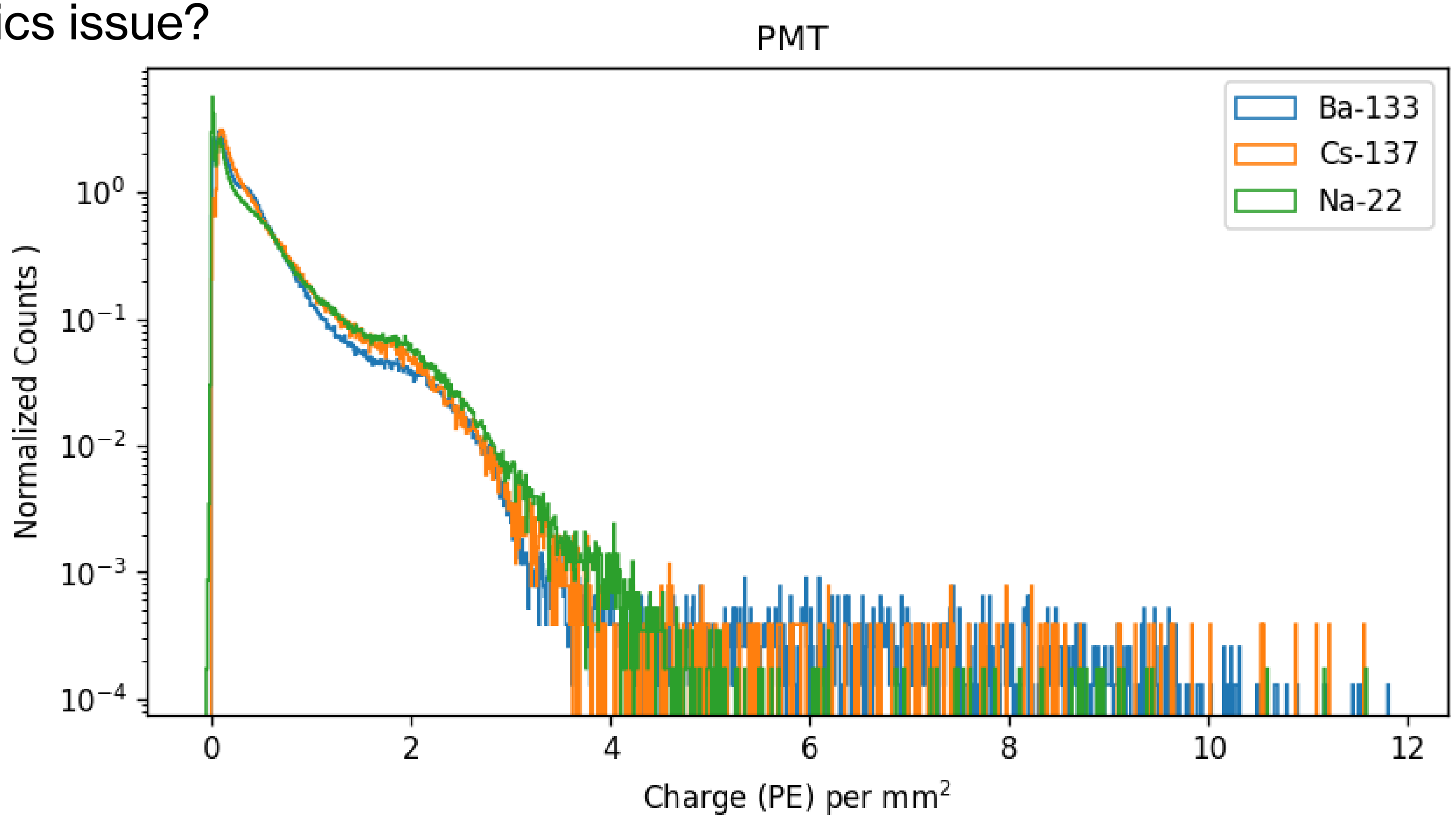
- Using the Ba-133 bump (356 keV) as a rough reference to rescale the x-axis to energy.
    - HPK: 2.7×10^{-2} PE/keV/mm ^{2}
    - FBK: 4.7×10^{-2} PE/keV/mm ^{2}
- ¶ In vacuum, HPK and FBK SiPMs show similar responses to previous measurements.



¶ G. Gallina *et al.*, Dec. 2022,
doi: 10.1140/epjc/s10052-022-11072-8.

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

- 2 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. Gallina *et al.*, Dec. 2022, doi: 10.1140/epjc/s10052-022-11072-8.

Thank you for your attention

Questions?

TRIUMF

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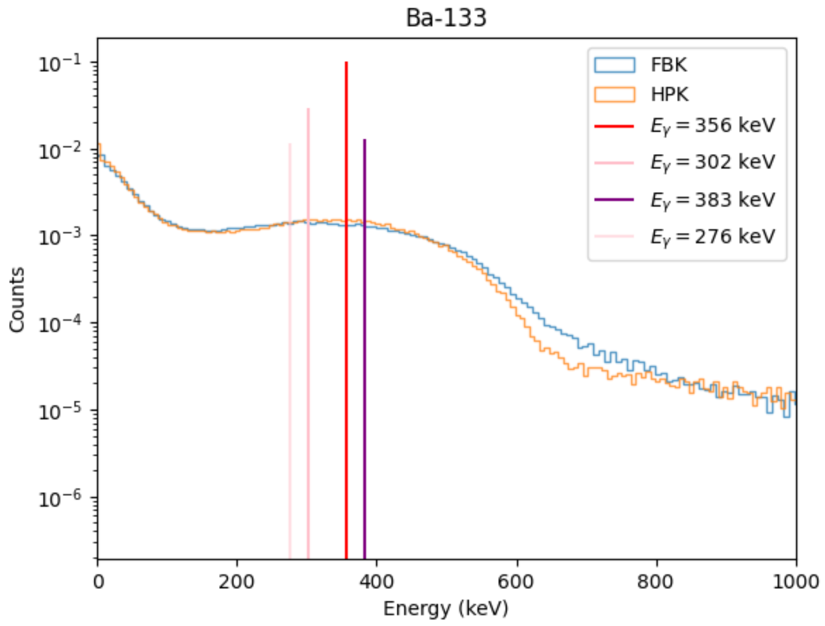
INFN

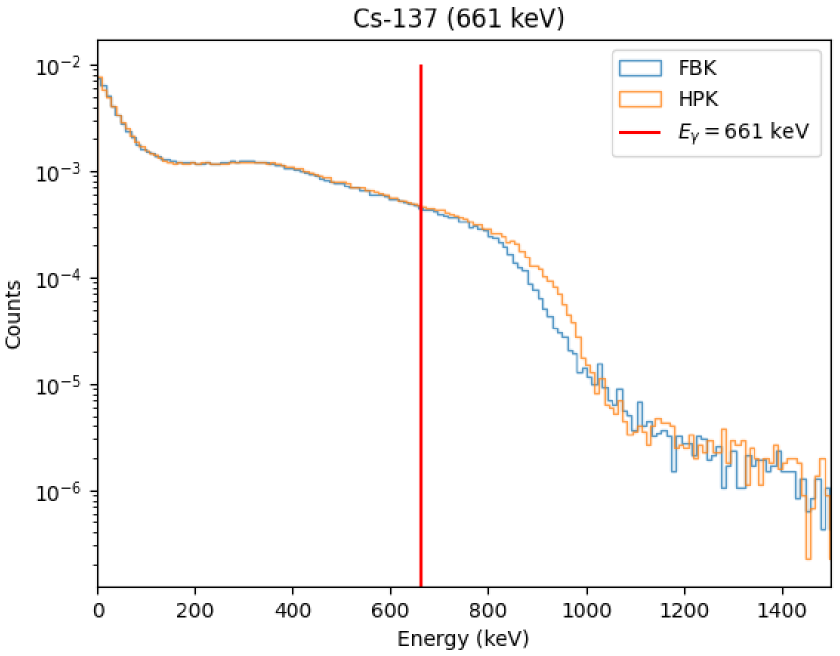
Luca Galli
Marco Francesconi

LoLX Collaboration: Canada-US-Italy

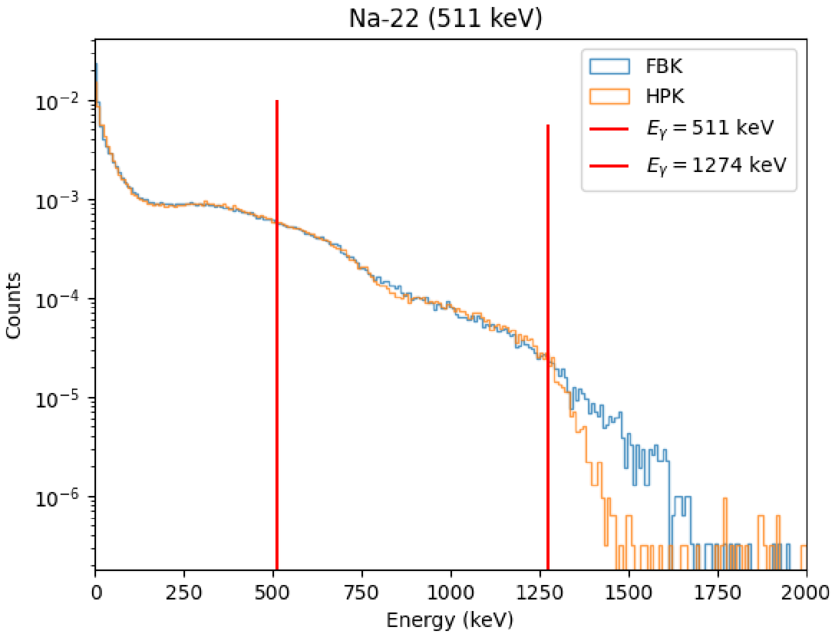
Backup



Ba-133
FBK
HPK
$E_\gamma = 356$ keV
$E_\gamma = 302$ keV
$E_\gamma = 383$ keV
$E_\gamma = 276$ keV
Counts
Energy (keV)



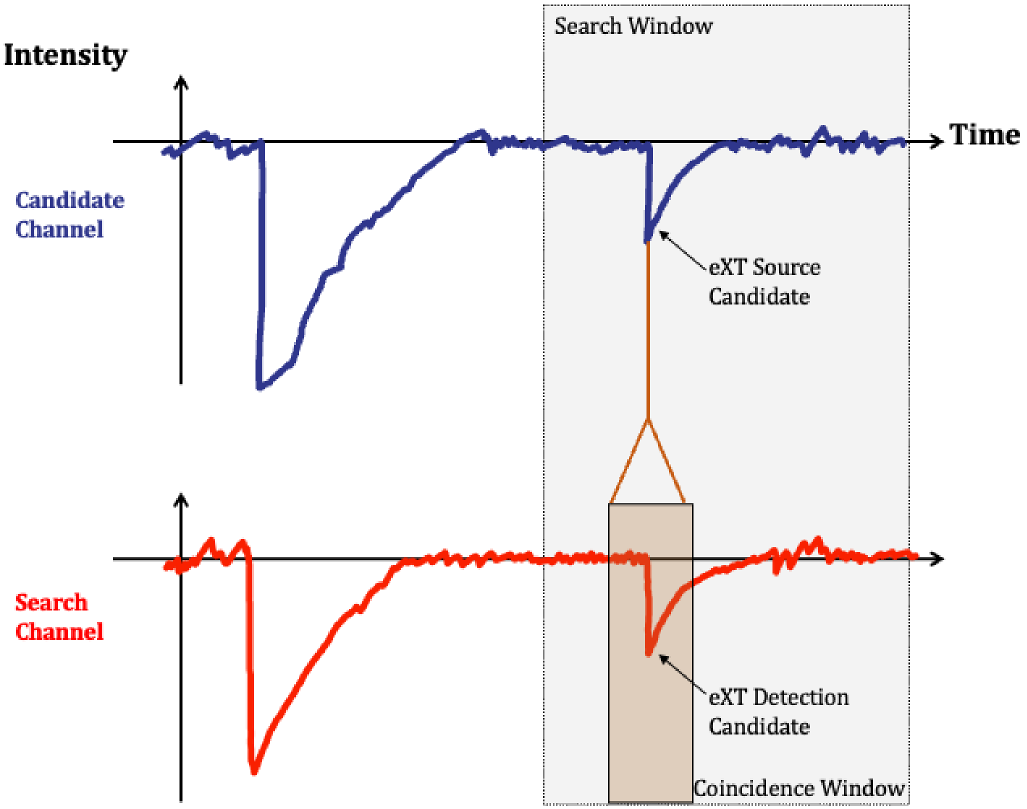
Cs-137 (661 keV)
FBK
HPK
$E_\gamma = 661$ keV
Counts
Energy (keV)



Na-22 (511 keV)
FBK
HPK
$E_\gamma = 511$ keV
$E_\gamma = 1274$ keV
Counts
Energy (keV)

Backup

trigger event low-occupancy region

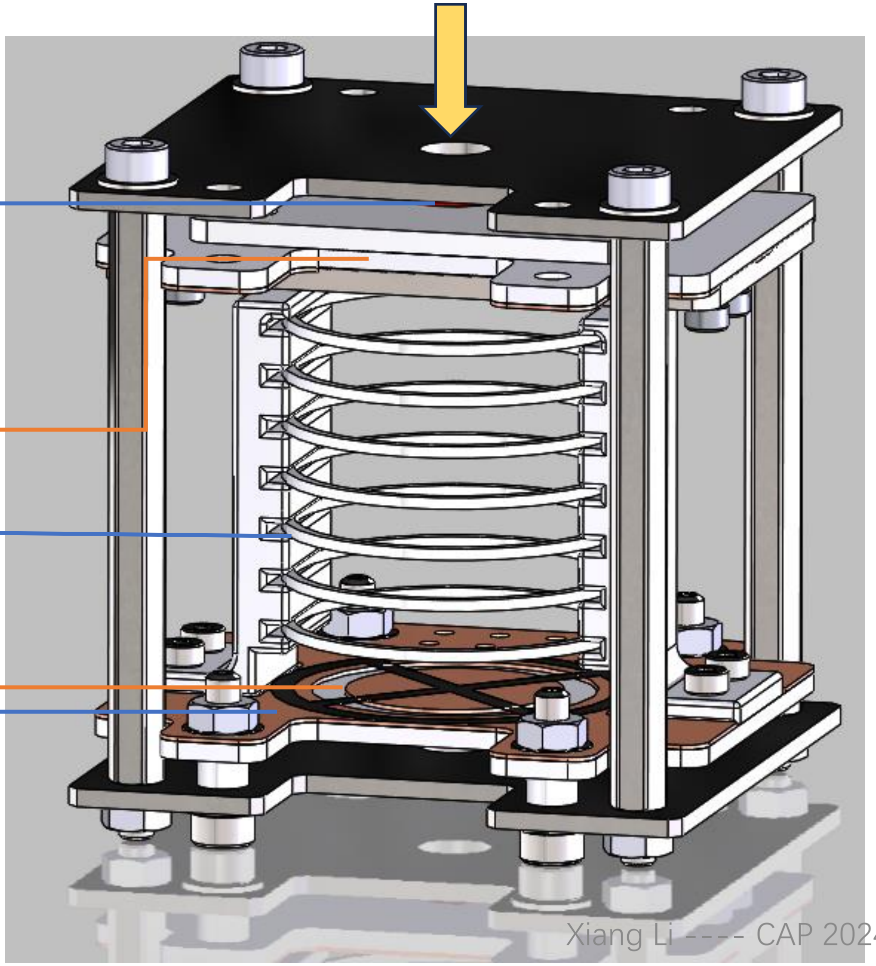


Credit: David Gallacher

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

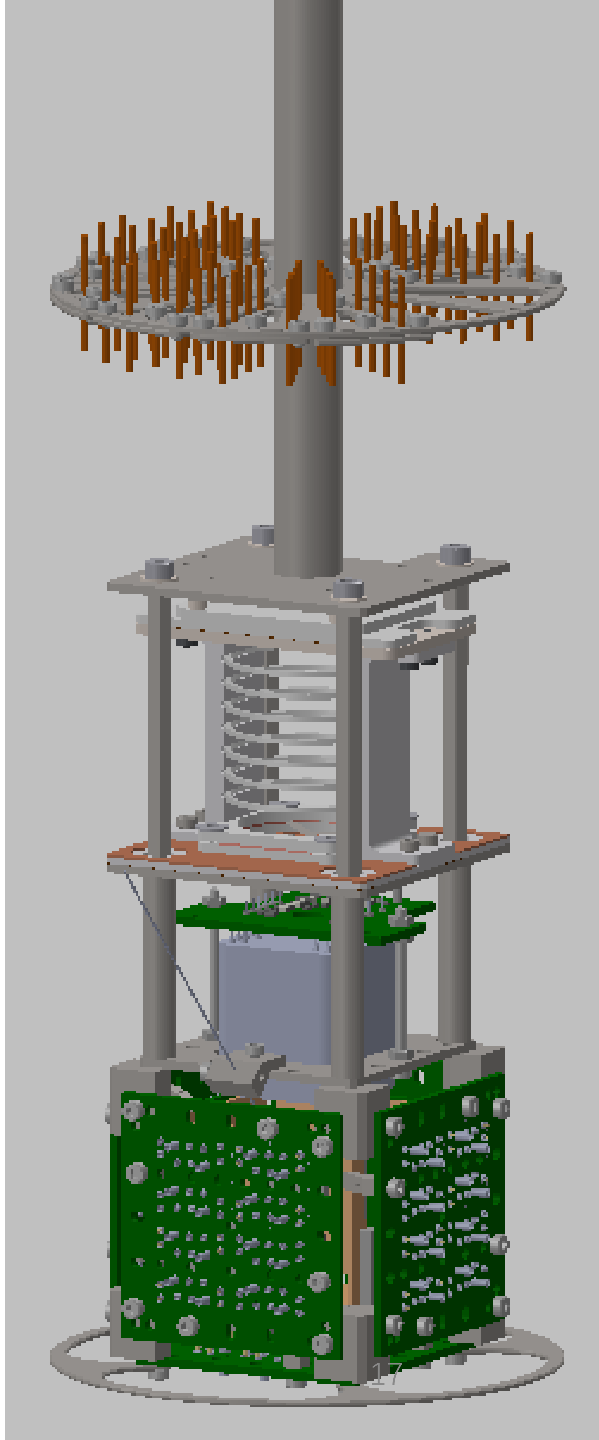
1. Identify **eXT source candidate** pulse in low occupancy region
2. Look for **time-coincident pulses** around source pulse
3. Record **time difference** ΔT

LoLX Purity Monitor



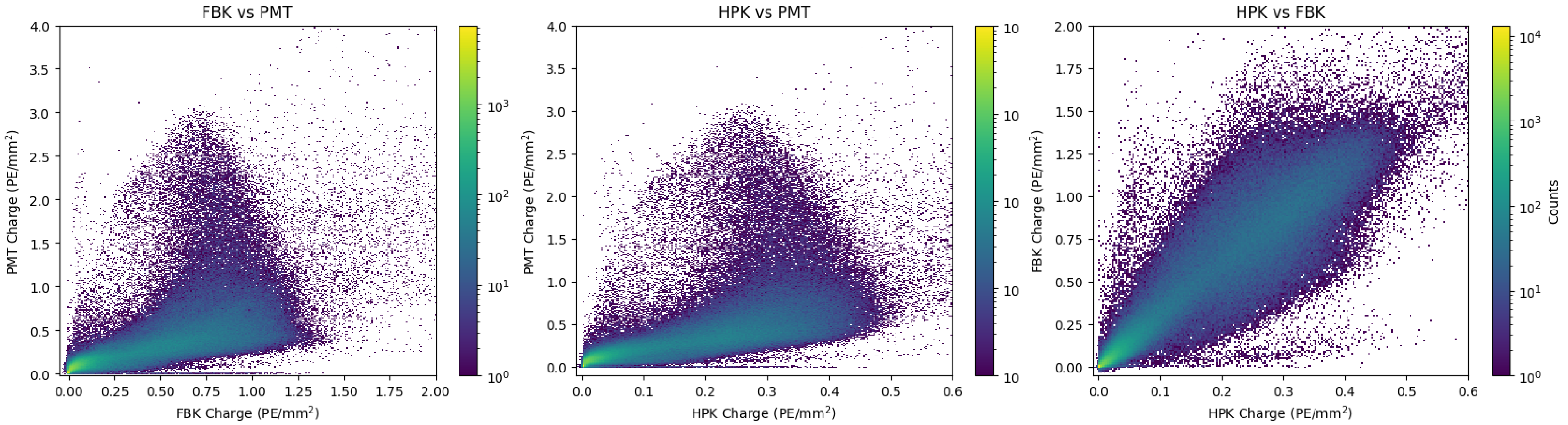
Drift direction

- 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



Correlation

- Ba-133 source data



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- Compton scattering is dominant for the gamma sources.
  - $^{22}\mathrm{Na}, \mathrm{E}_\gamma = 511$ keV
  - $^{133}\mathrm{Ba},\ \mathrm{E}_\gamma = 356$ keV
  - $^{137}\mathrm{Cs}, \mathrm{E}_\gamma = 661$ keV