Light-only Liquid Xenon (LoLX) Detector for Cherenkov and Scintillation Light Investigation

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LoLX Research Goals

- Demonstrate the use of many silicon photo-multipliers (SiPMs) in liquid xenon (LXe)
  - Develop an understanding of SiPM **external cross-talk**
  - **Long-term operation** of SiPMs in LXe
  - Investigate possible **VUV detection efficiency degradation**
- Measure the **Cherenkov and scintillation light yields** of MeV-scale energy deposits in LXe
- Study the **prompt light characteristics of LXe with fast electronics**
  - sub-nanosecond timing resolution

Cherenkov vs Scintillation in LXe

- When energy is deposited in LXe:
  - Scintillation
  - Cherenkov Radiation

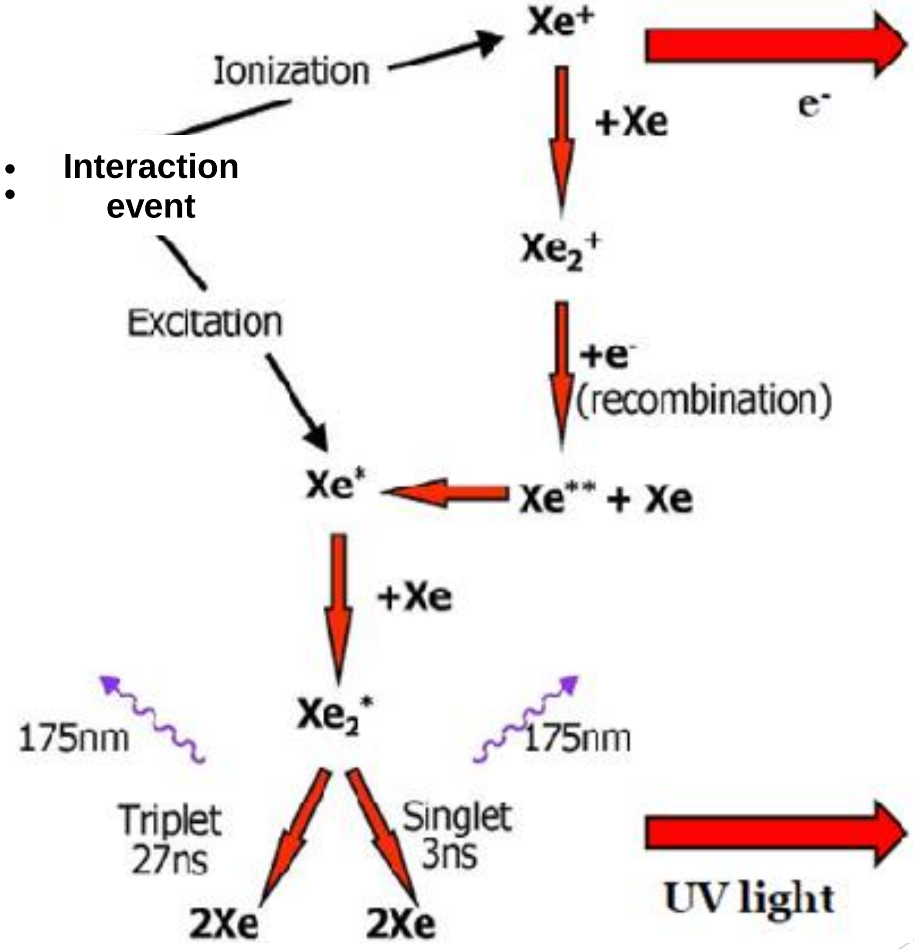


Fig. from N. Larsen (2012) Thesis Prospectus Yale University

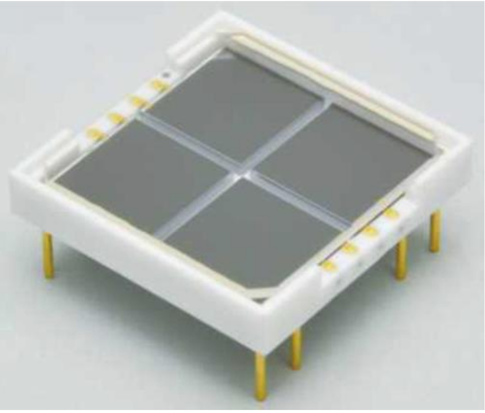
Two handles for discrimination

Scintillation light is **delayed (ns)**
Cherenkov light is **prompt (ps)**

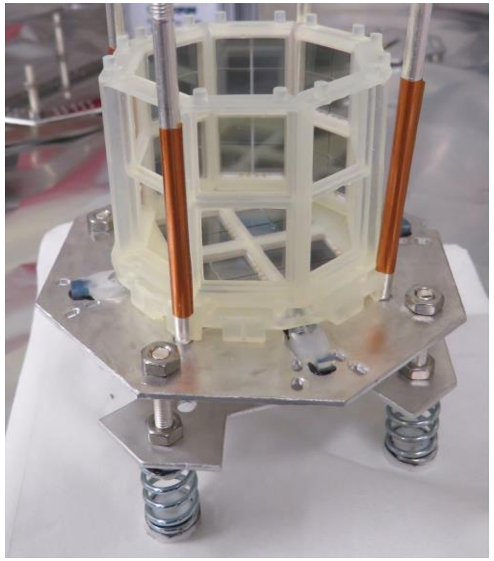
Scintillation light is **Narrow-band**
Cherenkov light is **Broad-band**

What is LoLX?

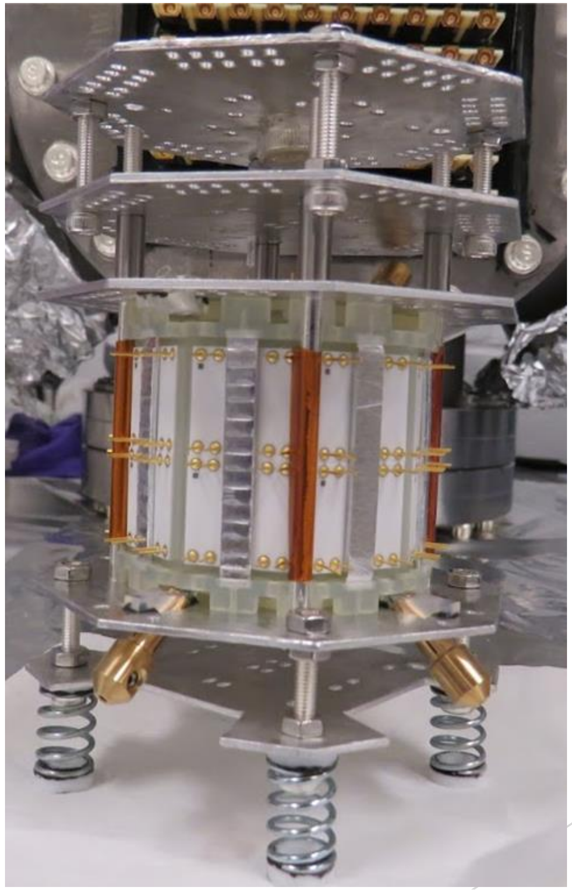
- Small volume, light-only, 3D-printed liquid xenon (LXe) detector
- Instrumented with silicon photomultipliers (SiPMs)
- Internal beta source provides events



1.5 cm x 1.5 cm SiPM module



3D printed cage for SiPMs during construction

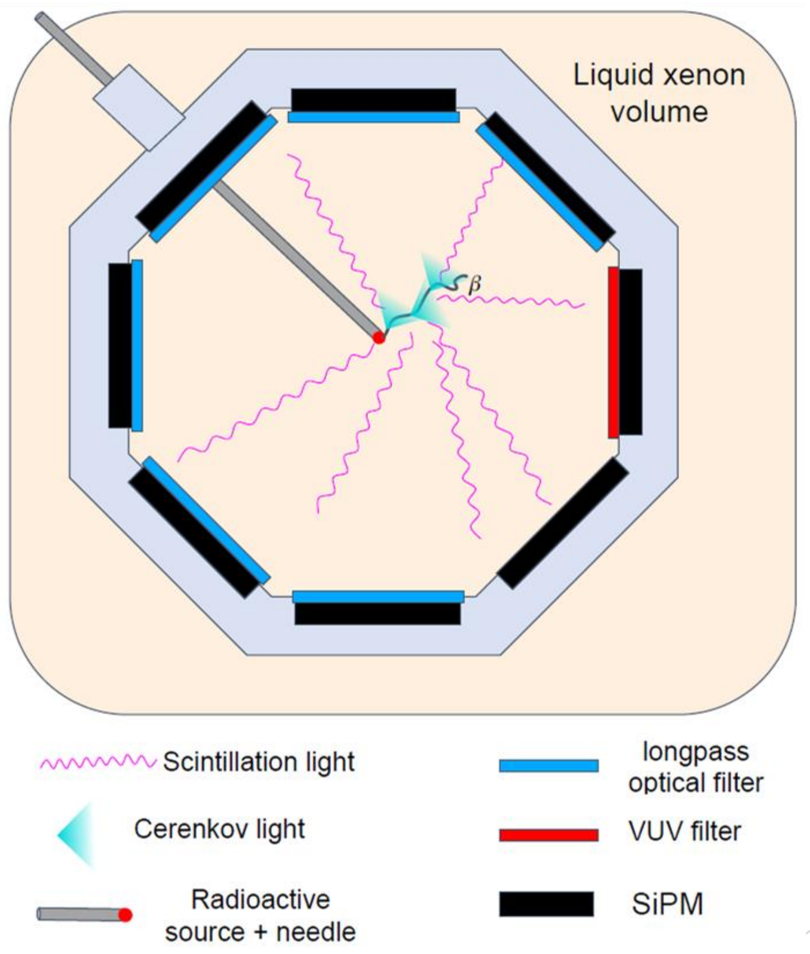


Assembled LoLX Detector

Operational since December 2020

LoLX Operating Principle

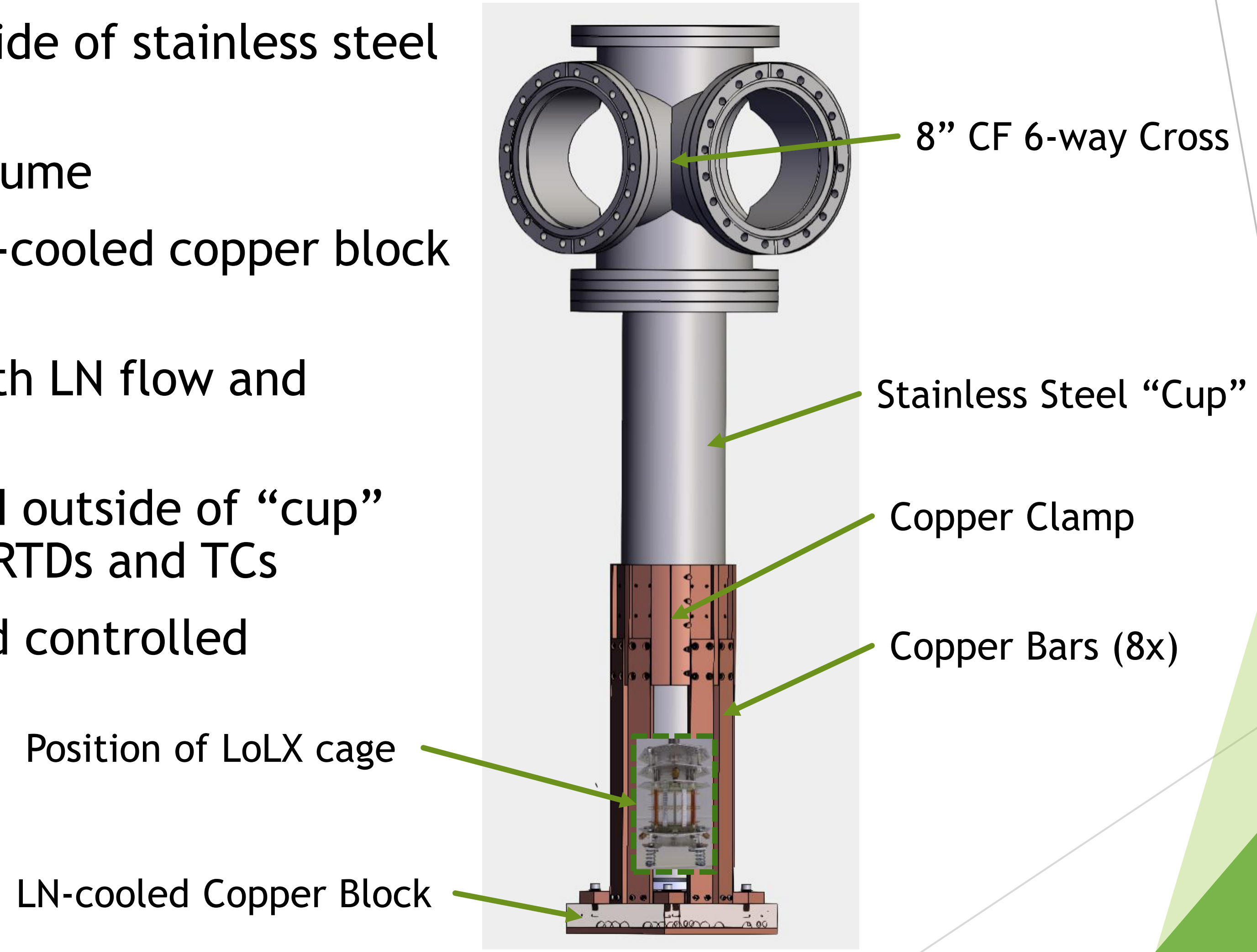
- ^{90}Sr (Q_β = 0.546 MeV)⟶ ^{90}Y (Q_β = 2.28 MeV) produces electrons above Cherenkov threshold in the LoLX detector
- Energy deposited in LXe causes scintillation in **narrow-band** at 175 nm **(Bright)**
- Long-pass filters block light below 220 nm allowing **broad-band** Cherenkov light to be detected **(Faint)**



LoLX will measure scintillation **and** Cherenkov light yields in LXe

LoLX Cryogenics

- LoLX cage is located inside of stainless steel “cup” filled with LXe
- Insulated by vacuum volume
- Copper bars connect LN-cooled copper block to the “cup”
- Control temperature with LN flow and heaters on “cup”
- Temperatures inside and outside of “cup” measured with suite of RTDs and TCs
- Remotely monitored and controlled

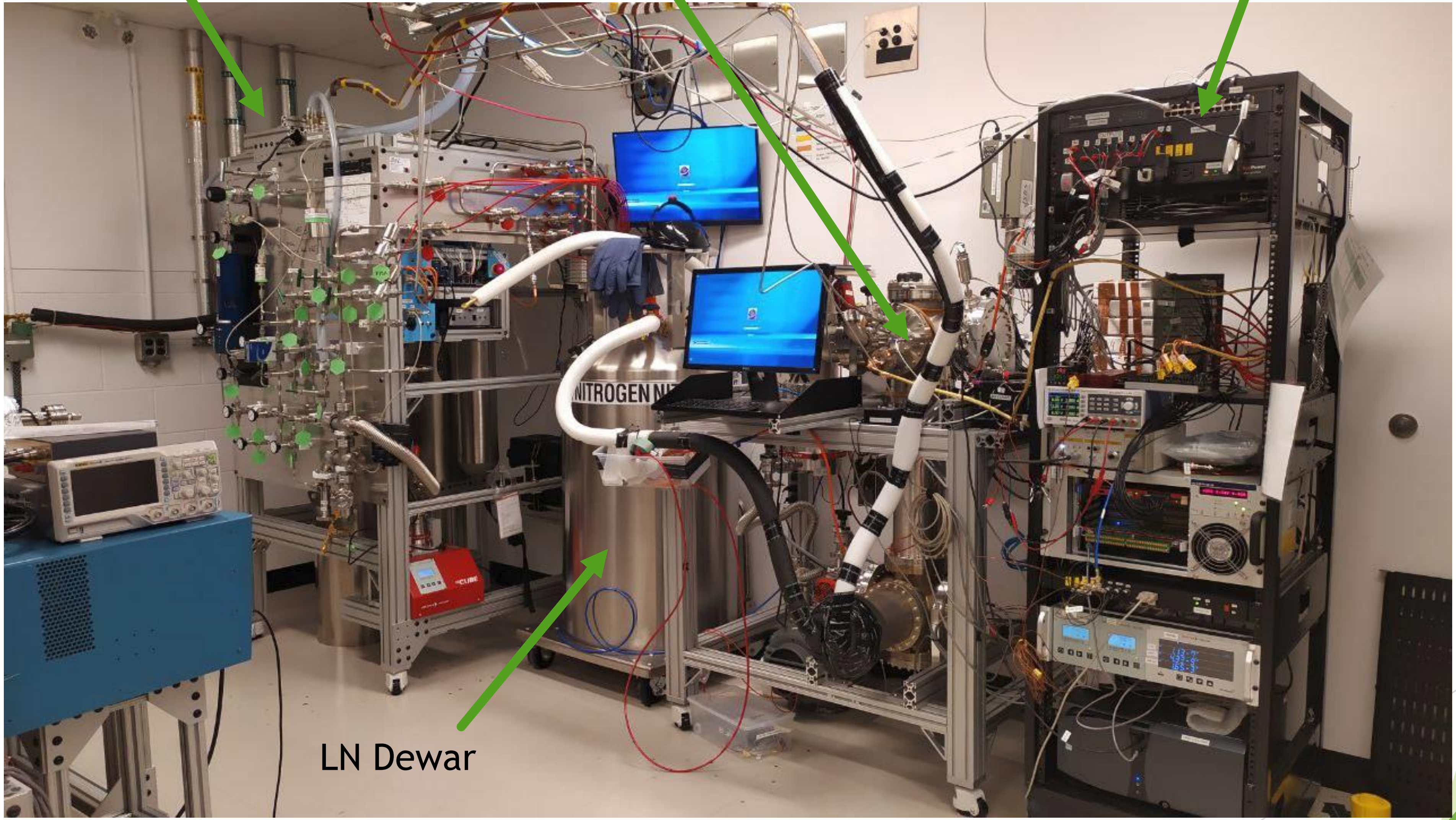


LoLX at McGill

Xe Gas Handling System

LoLX Assembly

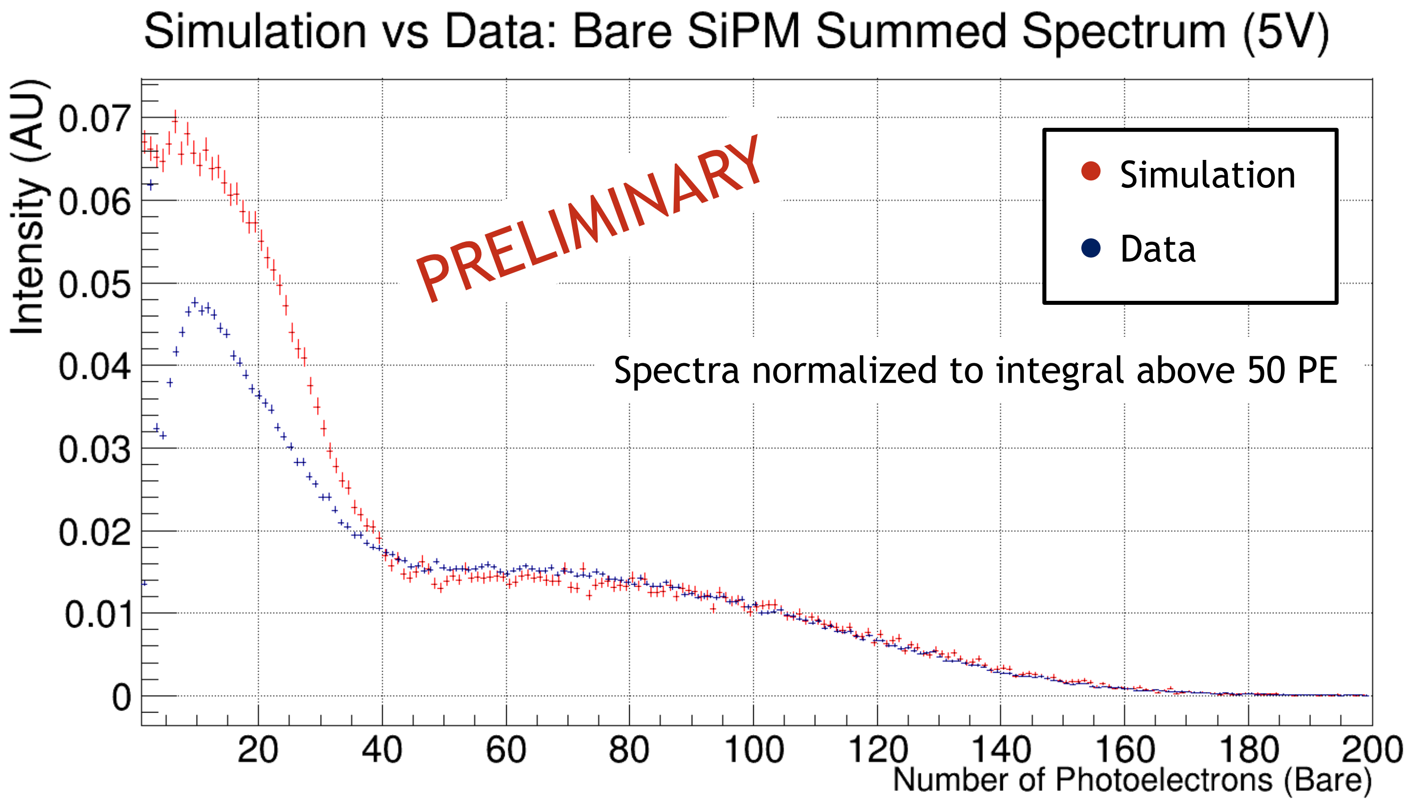
DAQ and Cryo Control



LN Dewar

Results: Beta Energy Spectrum

- Number of detected photons (NPE) in the unfiltered SiPM channels used to compare data to simulation



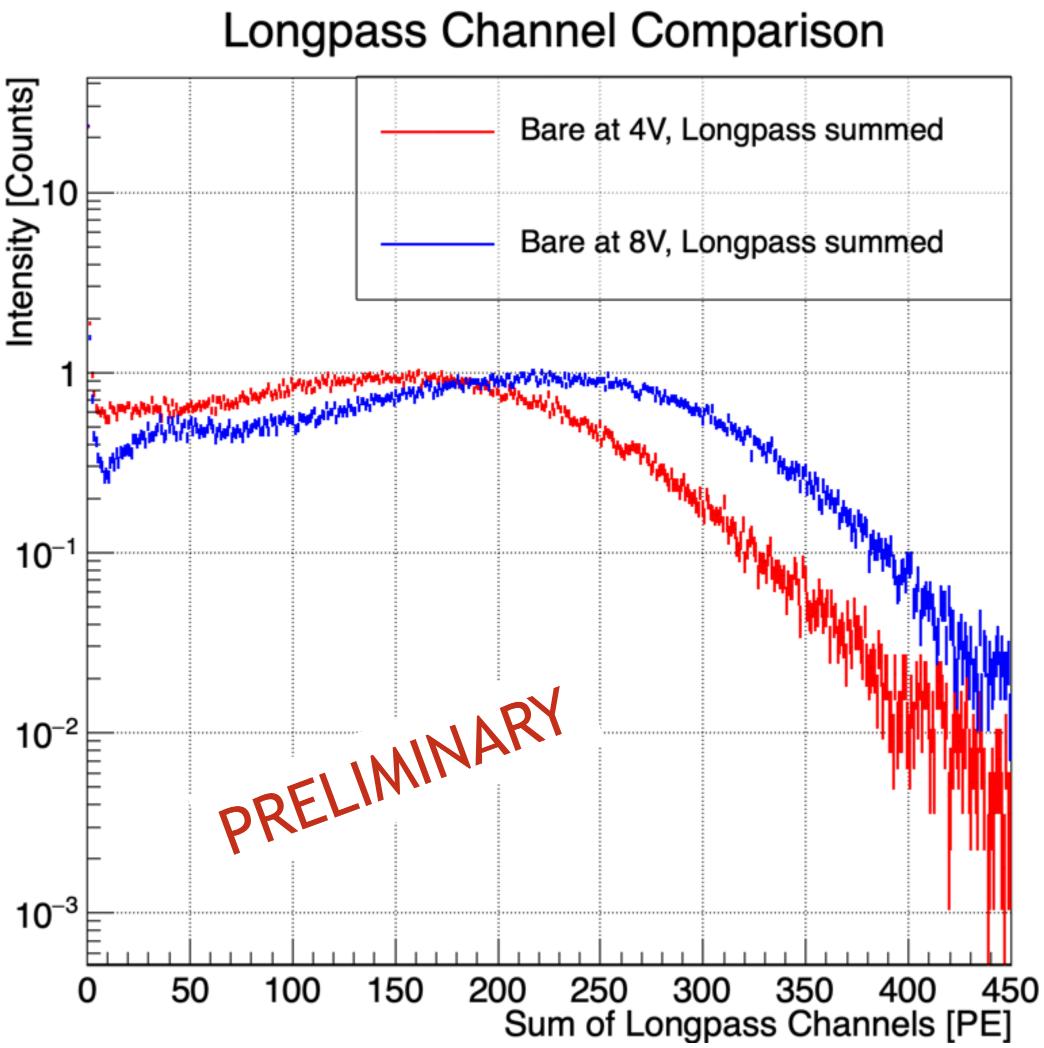
Plot courtesy of David Gallacher

Simulation has excess in low-PE region:

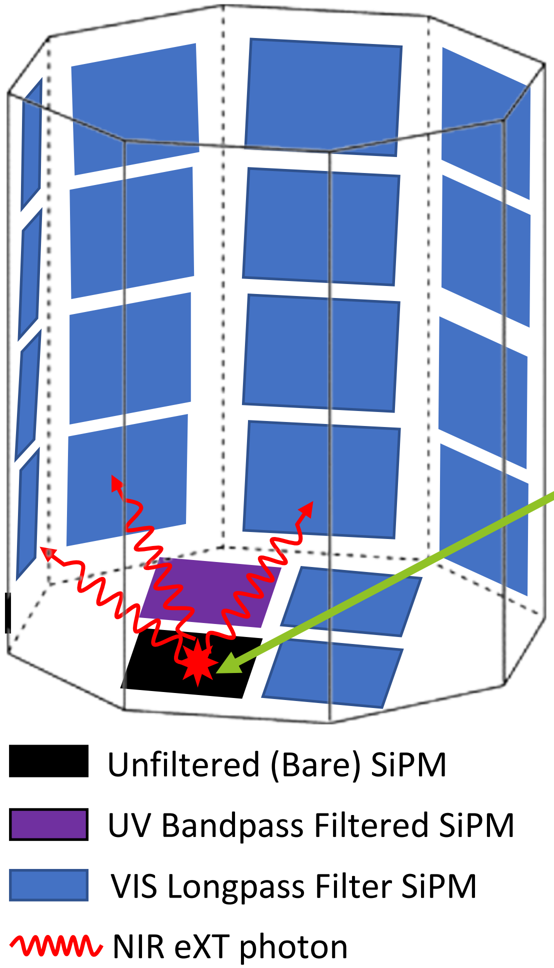
- ✗ Input Beta Spectrum
- ✗ Trigger Pile-up
- ? Energy loss in detector
- ? Geometry/shadowing

Good agreement at high PE, investigating low PE region

Results: External Cross-talk



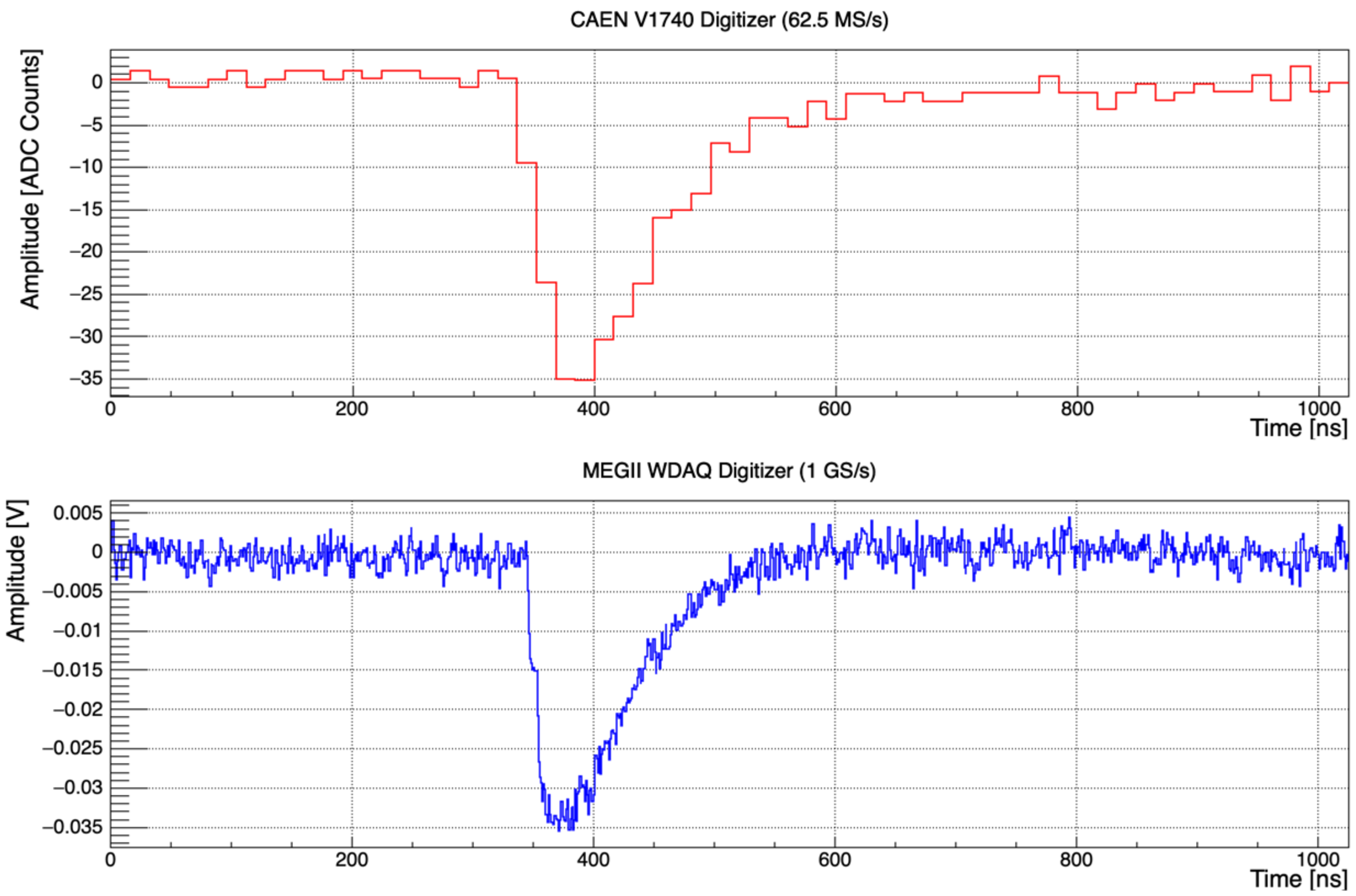
Plot courtesy of David Gallacher



Bare SiPM may release NIR photons that are detected by other SiPMs

Sum of long-pass channel signals shows an increase in average PE with increase in bare SiPM bias

LoLX WaveDAQ Upgrade



Tunable ADC allows for 1 GHz to 3GHz stable sampling frequencies

Commissioned WaveDAQ from MEG2 with cold gas Xe run (Nov 2021)

LoLX Looking Ahead

- Full data-taking campaign with upgraded WaveDAQ
  - Re-take source data and repeat external cross-talk runs
  - Focus on timing studies for scintillation/Cherenkov emission in LXe
  - Use 405 nm laser to improve timing calibration (target ~100 ps resolution)
- Analysis Plans
  - External cross-talk study to be completed
  - Measure VUV detection efficiency
  - Investigate observed differences in simulation/data

- Upgrade LoLX cryogenics to use cryocooler instead of LN
  - Long-term study of VUV detection efficiency in LXe
    - Decrease observed in MEG II
      - R. Onda, https://meg.web.psi.ch/docs/talks/JPS/2020s/onda_jps2020s.pdf
    - Not observed in initial vacuum studies at LN temperatures with high-intensity VUV source

LoLX Looking (Further) Ahead

- Source Changes
  - **No source:** background
  - **Alpha source (^{226}Ra):** scintillation only to study potential SiPM damage from intense VUV radiation

- Upgrade LoLX cabling to "plug-and-play" scheme
  - Change detector configuration
  - Investigate other SiPM types (plans for Hamamatsu and FBK)
  - Eventually use Photon-to-Digital Converters (Digital SiPMs)
    - Factor of 10 better timing resolution

Thank You from the LoLX Collaboration!

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