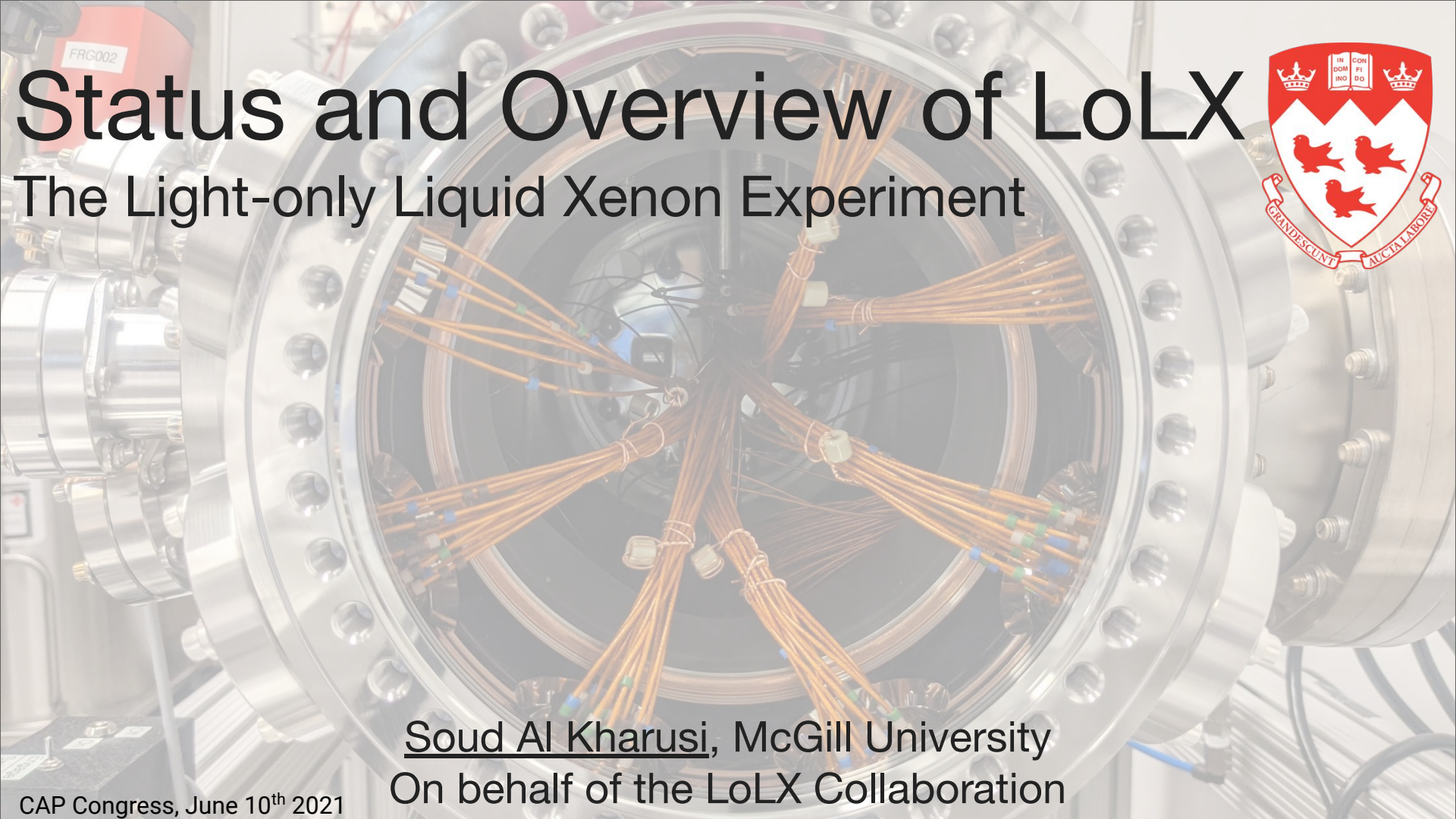
Status and Overview of LoLX

The Light-only Liquid Xenon Experiment



Soud Al Kharusi, McGill University
On behalf of the LoLX Collaboration

CAP Congress, June 10th 2021

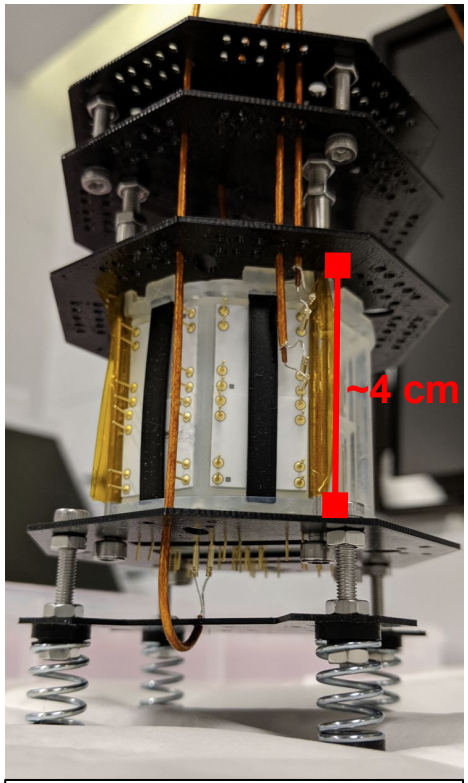
What is LoLX?

LoLX is a modular (3D-printed), zero-field, liquid xenon (LXe) detector which has three main scientific goals:

1. Demonstrate the use of many silicon photo-multipliers (SiPMs) in LXe and develop **an understanding of SiPM external cross-talk**

2. Measure the **Cherenkov and scintillation light yields** of MeV-scale deposits in LXe

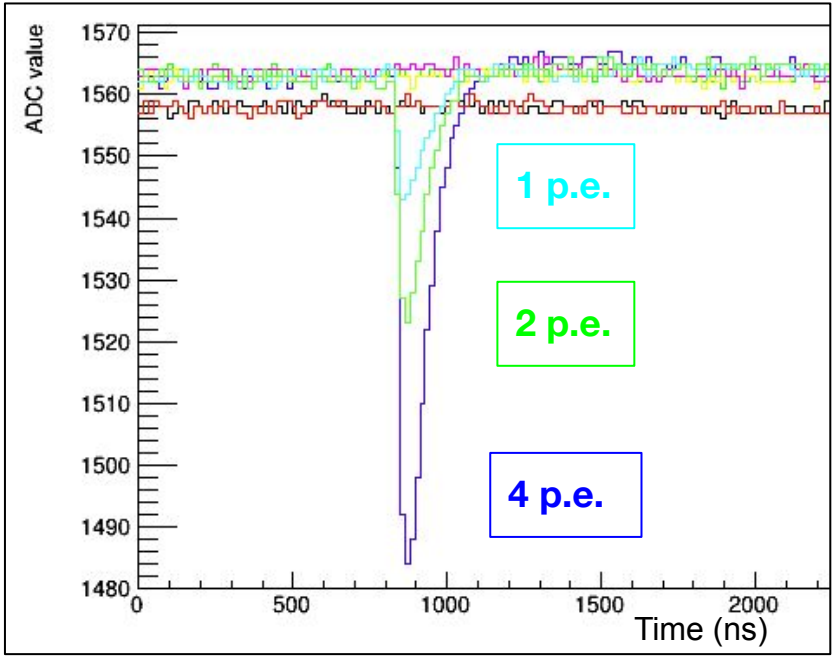
3. Study the **prompt light characteristics of LXe with fast electronics** (sub-nanosecond timing resolution)



LoLX detector body

Why SiPMs, and why LoLX?

- SiPMs are fast, single-photon counting detectors that can be made extremely radio-pure and sensitive to VUV photons
- Liquid xenon (LXe) scintillates at ~178 nm when energy is deposited in it, including
  - gamma scatters
  - nuclear recoils
  - beta / double beta decays ...
- This makes LXe a promising detector medium for low-background searches, e.g. WIMP dark matter & neutrinoless double beta decay searches

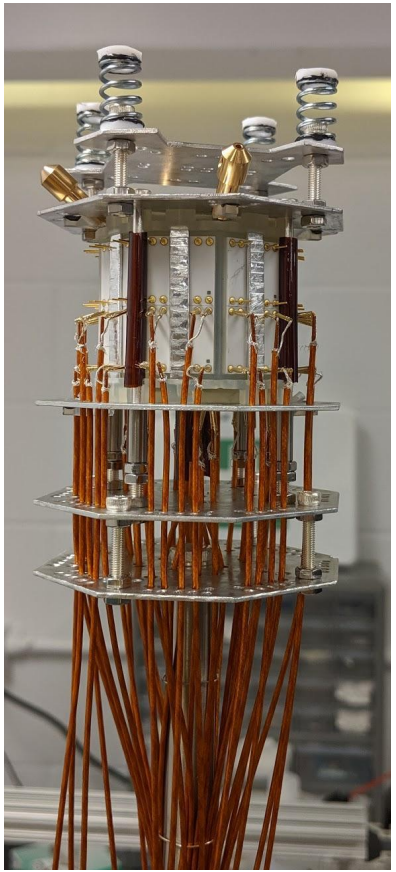


Example SiPM waveforms - LoLX cold GN2 data

SiPMs are the photo-sensors for low-background physics!

1... 2... 3... LoLX!

- Phase 1: Separation of light using optical filters, slow digitizer, Hamamatsu VUV4 SiPMs
  - ~ few ns resolution
- Phase 2: upgrade to GHz digitizer (from MEG2 experiment)
  - ~100 ps resolution, Fall 2021??
- Phase 3: Digital SiPMs (3dSiPM), temporal separation of Cherenkov and scintillation light
  - ~ 10ps resolution?



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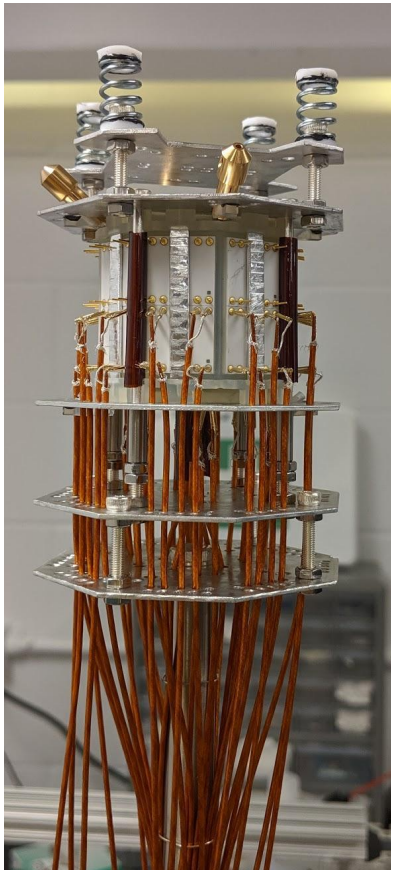


How does LoLX Work? (Phase-I)

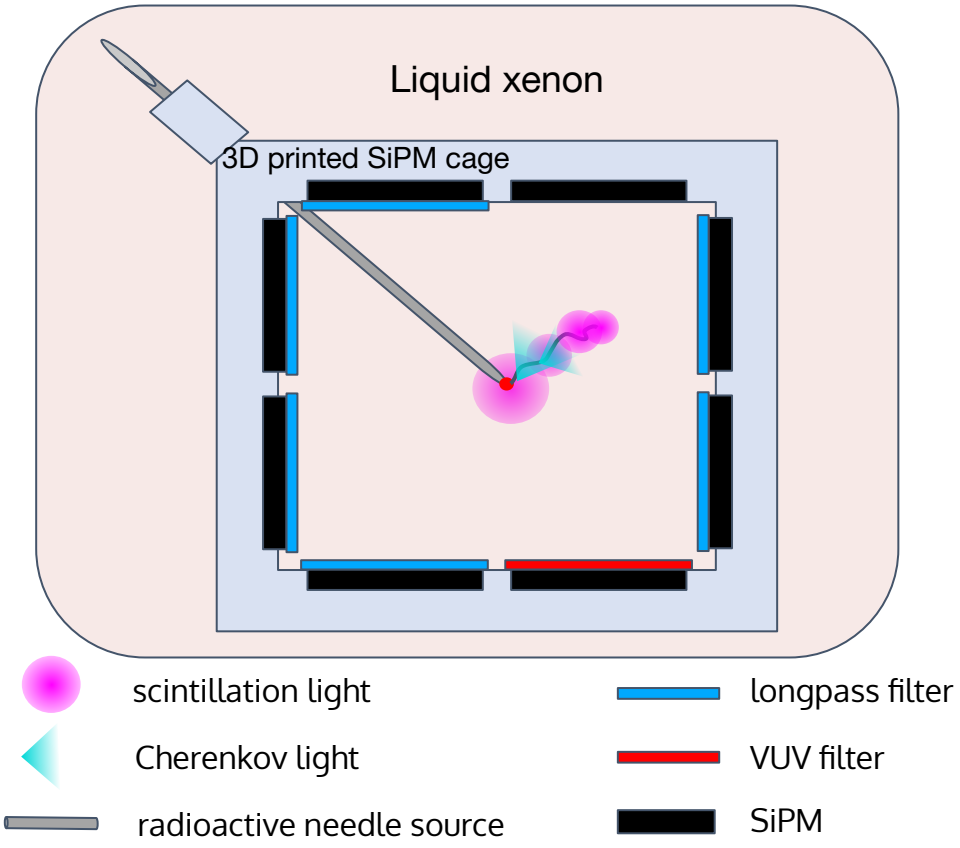
- ^{90}Sr (Q_β = 0.546 MeV)⟶ ^{90}Y (Q_β = 2.28 MeV) produces electrons above Cherenkov threshold in the LoLX detector

- Energy deposits cause LXe to scintillate emitting *narrowband* 178 nm light (bright)

- Longpass filters across SiPMs remove the 172 nm light, letting through only the *broadband* Cherenkov emission (faint)

This gives a **measurement of Cherenkov and scintillation yields in LXe**

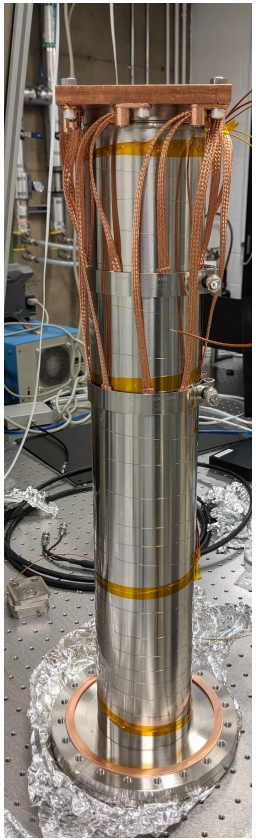
(Figure by A. de St. Croix)



LXe commissioning - December 2020

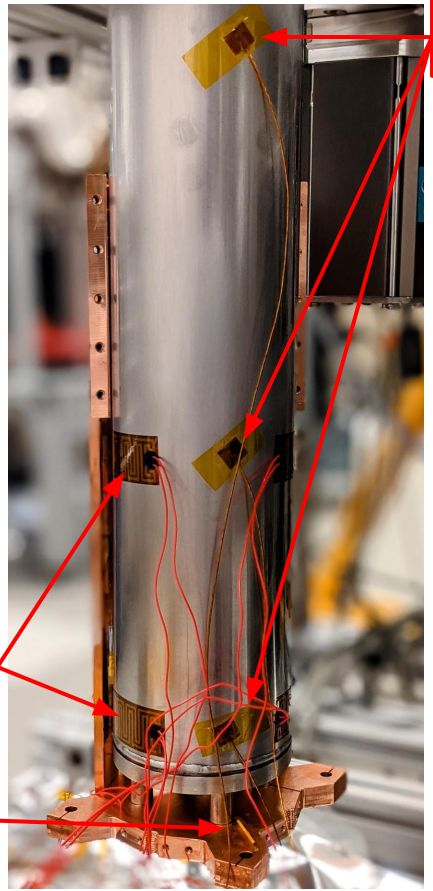
- Old cooling system had a lack of fine temperature control & issues with thermal gradients (left)
  - no heating capability
  - cooled from bottom only, suspect xenon freezing?

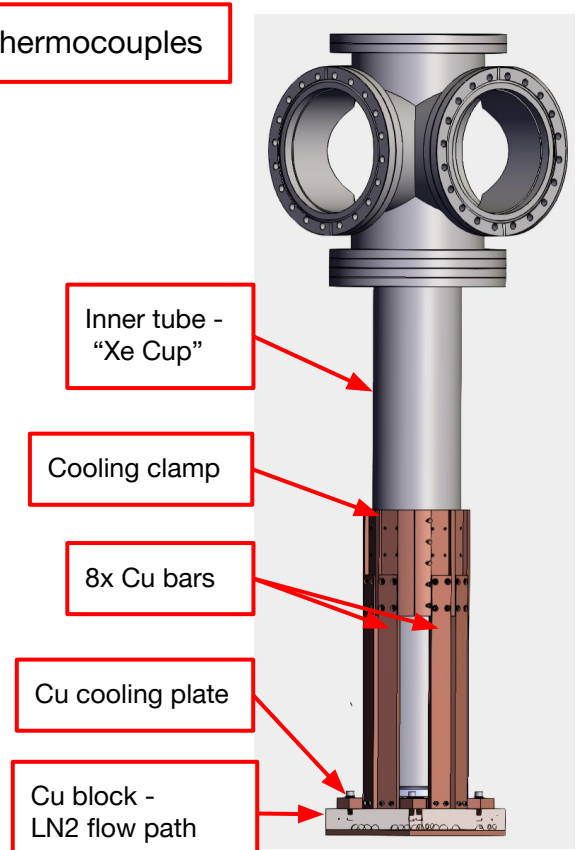
- Stycast epoxy MCX feedthrough for SiPM channels was difficult to deal with (right)
  - Leaky
  - Unreliable regarding connecting/reconnecting MCX cables



LoLX Cooling Upgrades

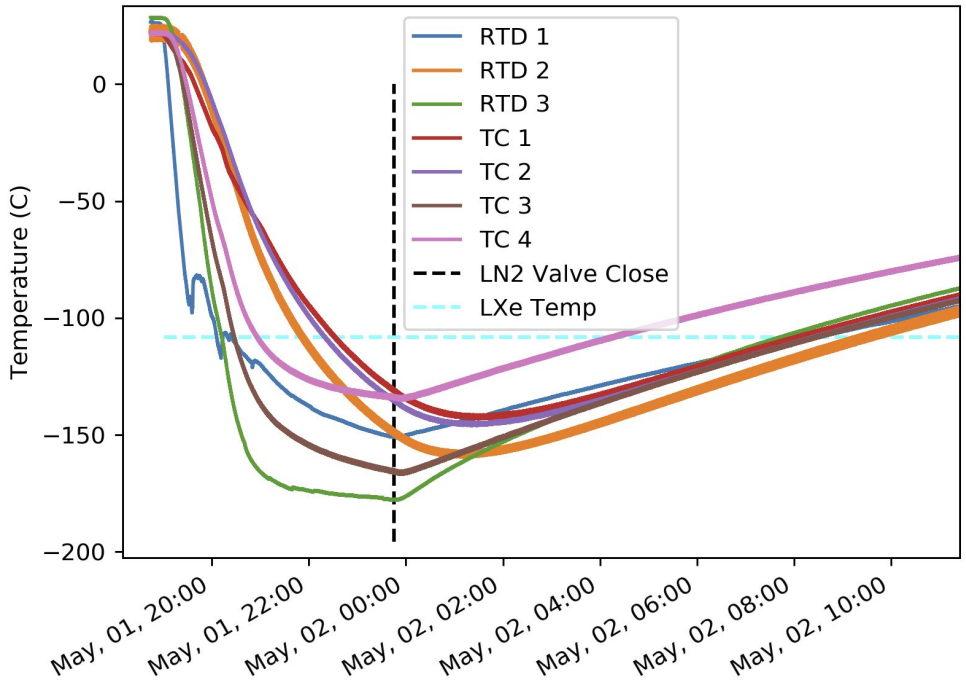
- New cryo system cools from top-down
  - provides more uniform thermal gradient in full LXe region (?)
- More sensors added into cryostat to provide better understanding of system
- Flex heaters added at key locations for finer temperature control

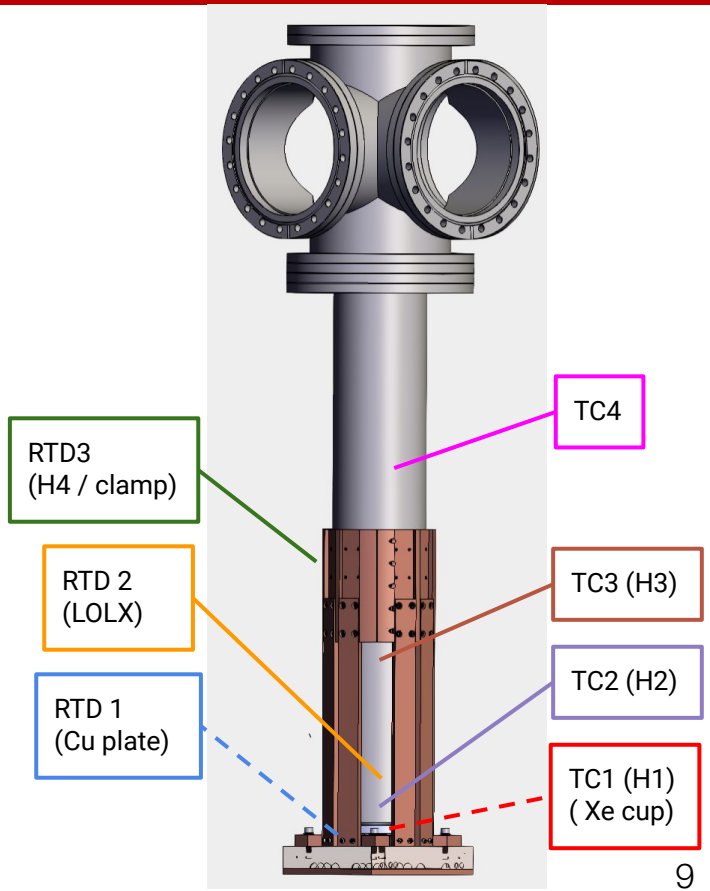




LoLX Cryostat 2.0: First Cooldown

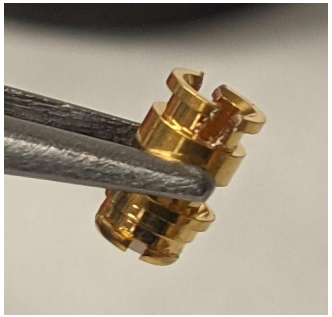
System behaves as expected!

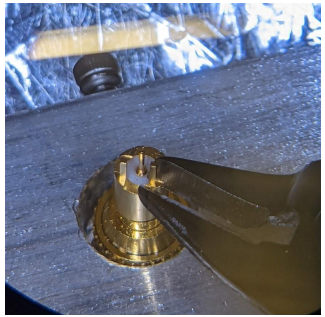


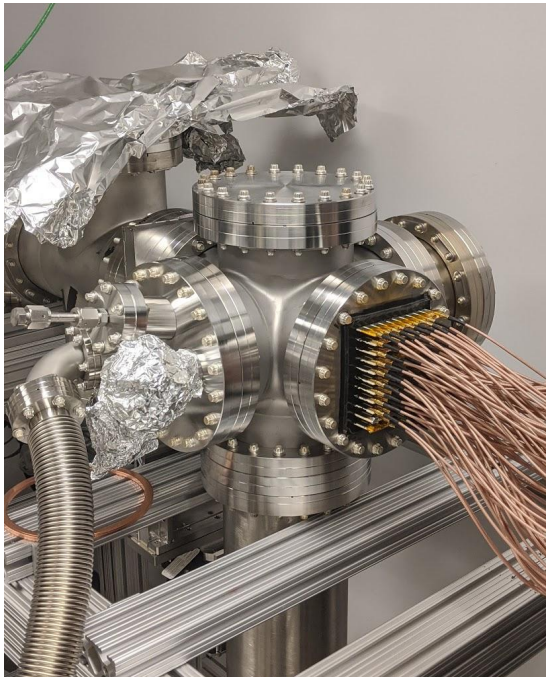


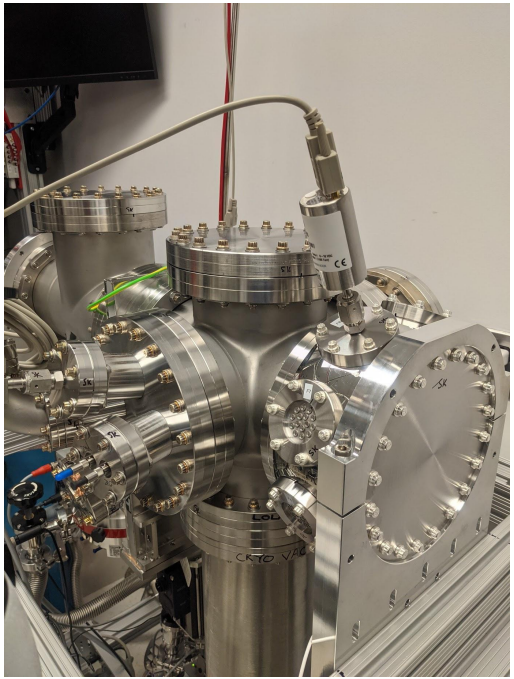
SiPM Feedthrough Upgrades

- Old scheme: “homemade” PCB-potted 96-channel MCX feedthrough made with epoxy
  - proved to be leaky and not stable
- New scheme uses 7 x 15 pin SMP-SMP 2.75” CF feedthroughs
  - Cables on inside of vacuum were MCX terminated ⟶ MCX-SMP adapters



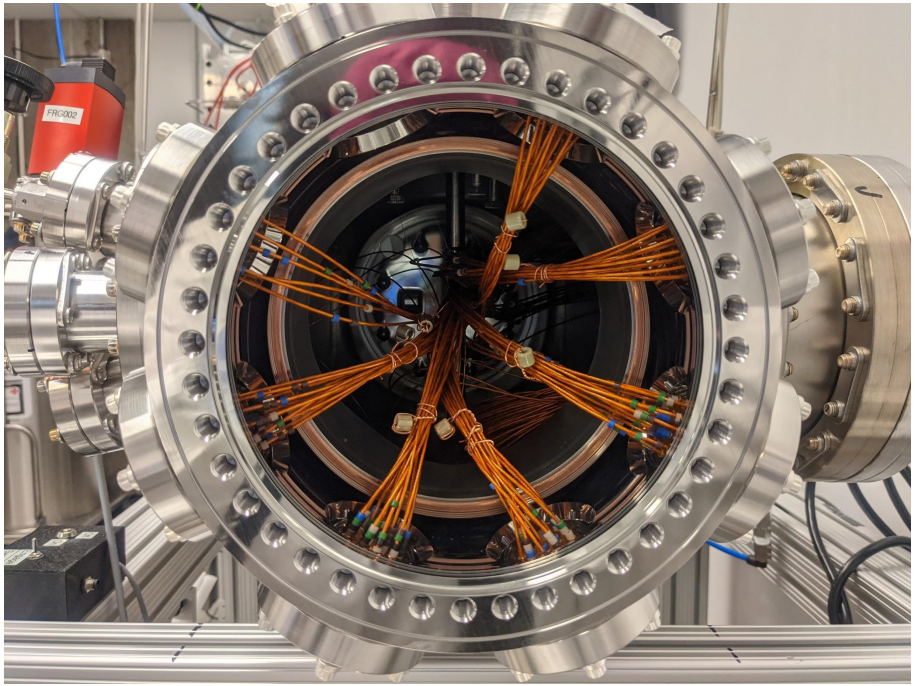






Summary and Status

- December 2020 LXe commissioning revealed issues with cooling system, leaks
  - New cryostat developed with better temperature control in mind
  - New SiPM feedthroughs installed , leak tight
- LoLX is Phase-I LXe run imminent!
  - Finalizing slow control systems
  - Updating operating procedures & DAQ
- External cross-talk analyses from cold SiPM data in vacuum underway (see POS-J81, M. Patel)



LoLX Collaboration

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Merci et voila c’est tout!

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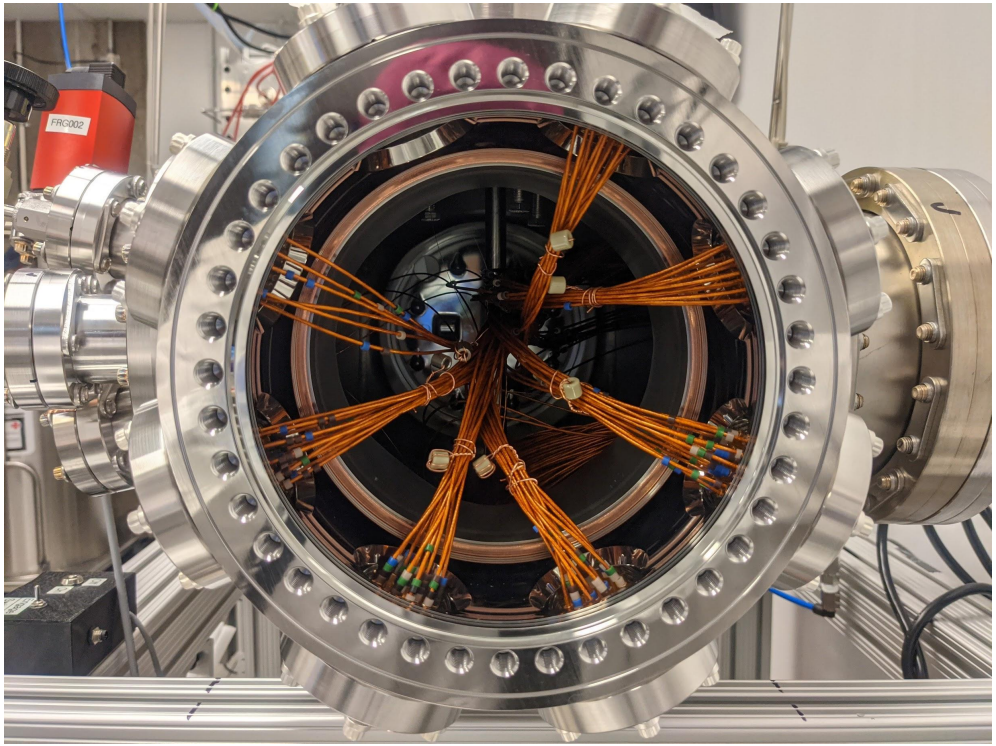
Canadian Astroparticle Physics Research Institute

NSERC
CRSNG

Fonds de recherche
sur la nature
et les technologies
Québec

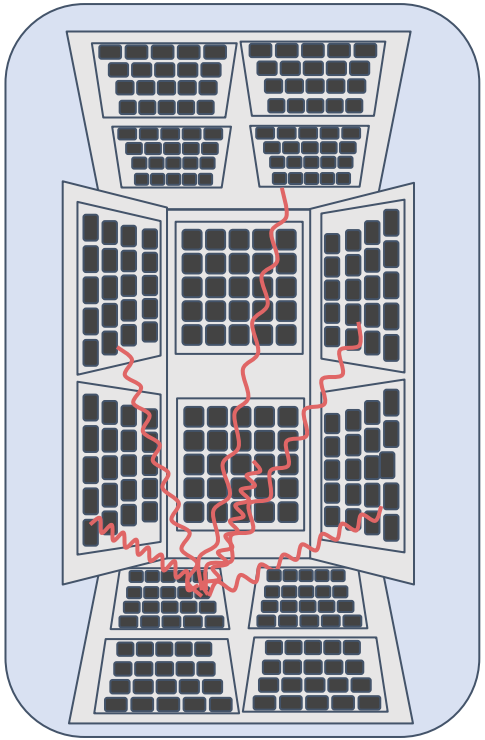


Motivation: large scale SiPM arrays in LXe TPCs

- Photon arrivals on the Si wafer trigger an avalanche
- The avalanche of electrons cause a current spike that is read as a photon hit "1 p.e."
- The avalanche causes infrared photons to travel and potentially trigger other SiPMs -- external cross talk (eXT)

This process skews the the total number of photons measured by the SiPM array -> affects the energy resolution of LXe detectors, light maps

See POS-J81, M. Patel



eXT between SiPMs in LoLX
(Fig. by A. de St. Croix)

Motivation: background discrimination in LXe

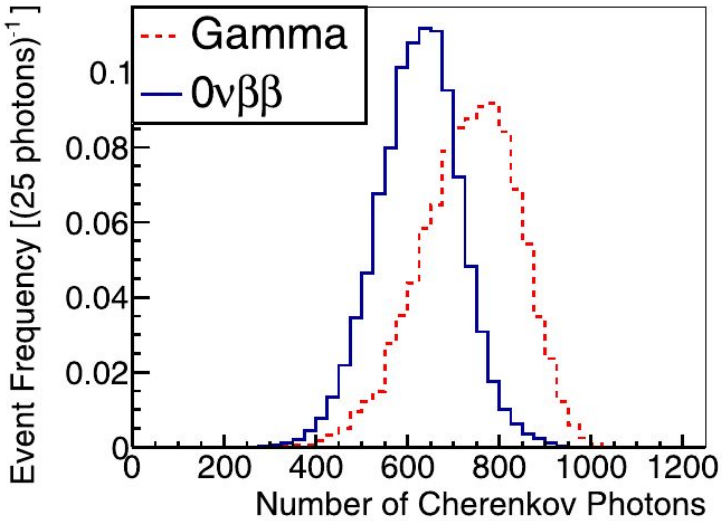
- Faster readout electronics allow for measurements of Cherenkov (prompt) and scintillation (~ns) in future LXe experiments
  - Cherenkov/scintillation ratio (C/s) gives us information about the microphysics of an event
- Event types, e.g. double beta decays vs single Compton scatters from background Gamma rays can be discriminated based on C/s yields

Background Discrimination for Neutrinoless Double Beta Decay in Liquid Xenon Using Cherenkov Light

Jason Philip Brodsky[a], Samuele Sangiorgio[a], Michael Heffner[a], Tyana Stiegler[a]

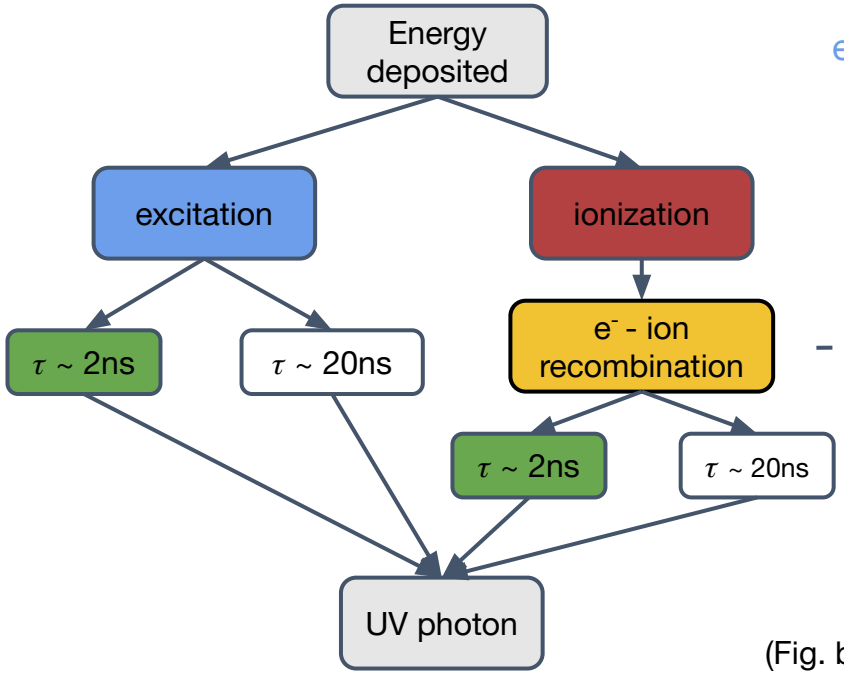
[a]*Lawrence Livermore National Laboratory*

Nuclear Inst. and Methods in Physics Research, A 922 (2019) 76–83



Motivation: modelling scintillation in liquid xenon

- With fast readout, LXe has potential for Pulse Shape Discrimination in future LXe experiments, as currently done with argon



excitation / ionization , singlet (~2ns) / triplet (~20ns)

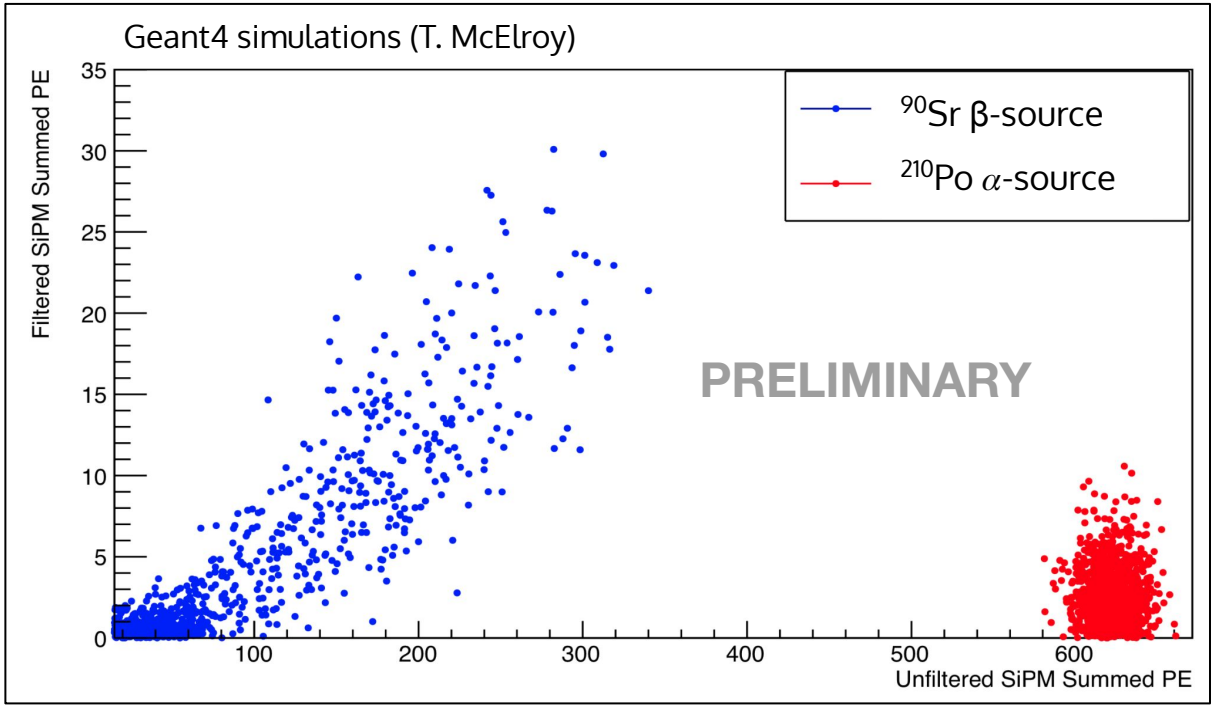
Prompt light!

- **alphas or nuclear recoils:** expect *fast* recombination
- **Electron Recoils:** expect *slow* recombination

(Fig. by A. de St. Croix)

Source Selection

- Different types of events will produce different amounts of scintillation and Cherenkov light
- By utilizing the filters on various SiPMs, we will be able to classify event types and calculate the different light yields of Cherenkov/scintillation



^{90}Sr: Q_β = 2.28 MeV

^{210}Po: Q = 5.4 MeV

What have I been doing?

- Interfacing between LoLX & local group at McGill
- Help design & build the LoLX Cryostat 2.0
- Upgrading the SiPM vacuum feedthrough

LoLX Cooling System