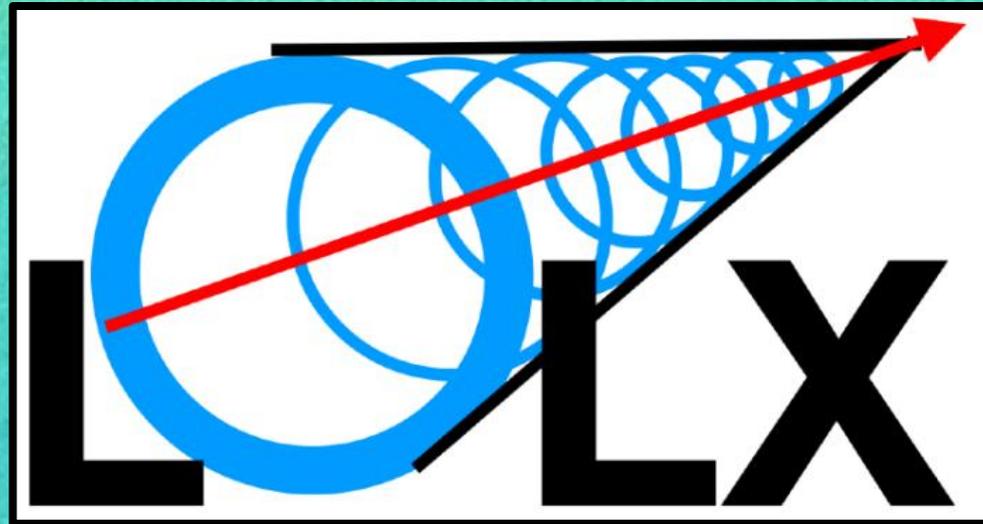


# Light only Liquid Xenon Experiment

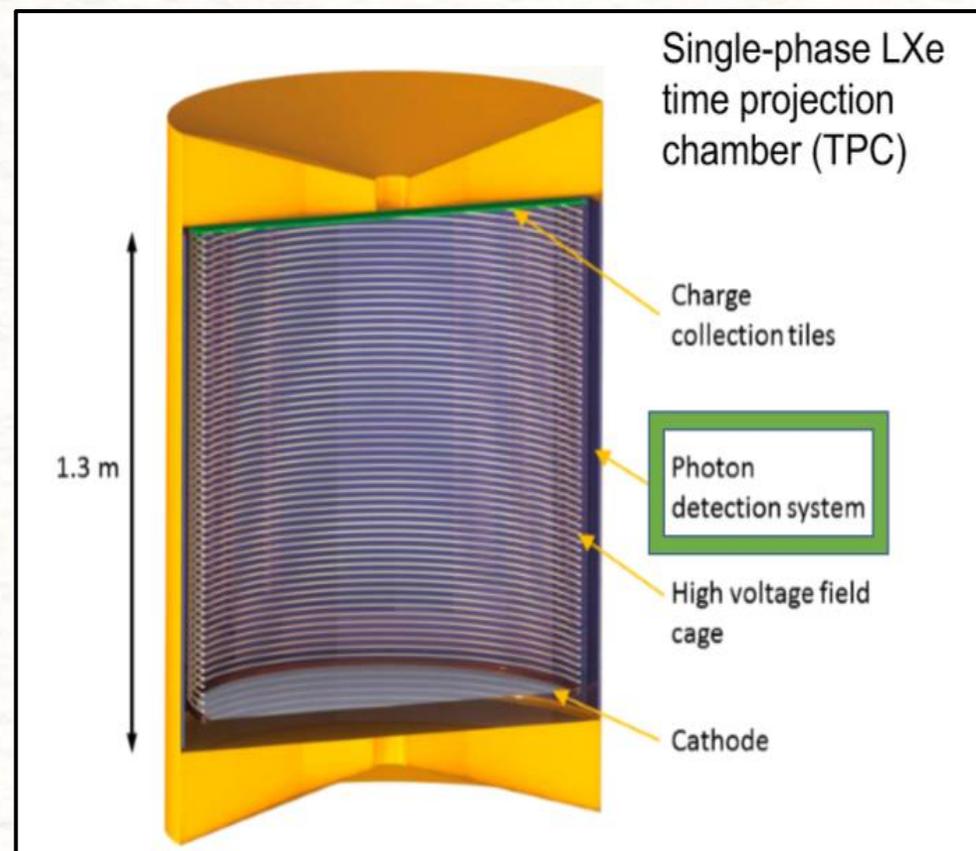


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WNPPC 2021

# Enriched Xenon Observatory (nEXO)

- nEXO is a single-phase tonne scale Liquid Xenon (LXe) experiment
- Looking for hypothetical neutrino-less double beta decay in an isotope Xe-136
- Silicon Photomultipliers sensitive to Xenon scintillation photon (175nm) are planned to deploy in light detection system of nEXO

**LoLX is a R&D project dedicated to SiPM based light detection system of nEXO**

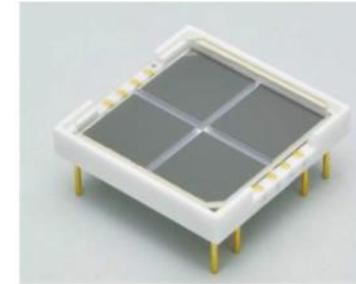


Sketch of the planned nEXO TPC;  
arXiv:1805.11142

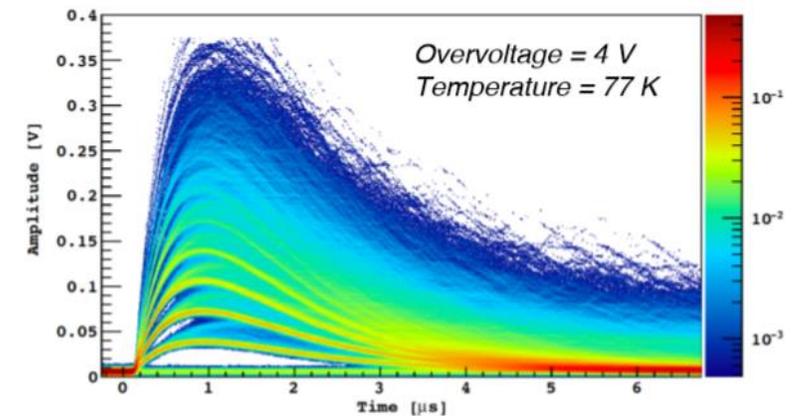
# Silicon Photomultipliers (SiPMs)

- Avalanche photodiode operating above breakdown voltage
- Capable to detect single photon
- High photon detection efficiency
- Operate at modest voltage

- Sensitive to light in 175nm region (scintillation light of liquid Xenon)
- Low mass and low radioactivity
- Operation at noble liquid temperatures!
- Additional correlated noise like cross-talk and after-pulsing comes into play in SiPMs.



*Hamamatsu VUV4  
2x2 MPPC array*



*Example persistence plot from  
FBK NUV-HD-LF-HRq SiPM*

# Motivation for LoLX

## Energy resolution of nEXO

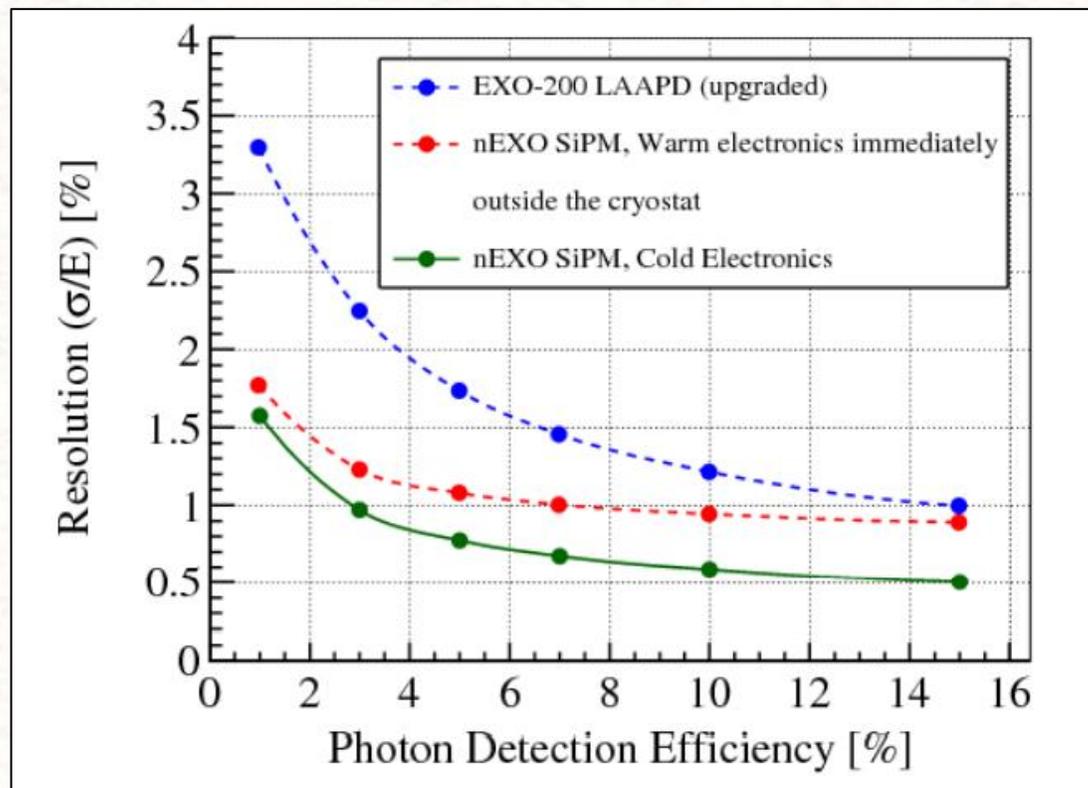
- nEXO aims to achieve 1% overall detector resolution to achieve its physics goals
- Scintillation light detection efficiency is a key factor

## Background discrimination techniques

- Discrimination between scintillation and Cherenkov light to explore new background rejection methods for future particle physics experiments

## Fast timing light processing

- Fast timing (~10 picoseconds) light detection for temporal separation of signals will lead to advancements in Time Of Flight (TOF)-Positron Emission Tomography (PET)



Energy resolution as a function of the overall scintillation light detection efficiency at a 400 V/cm drift field.

arXiv:1805.11142

# Objectives of LoLX

## Phase 1

- Gain experience in operating SiPMs in LXe
- Light production measurements in LXe using radioactive source Sr-90
- External cross-talk for SiPM and scintillation & Cherenkov yield measurement in LXe
- Compare the LoLX measurements with the simulations

## Phase 2

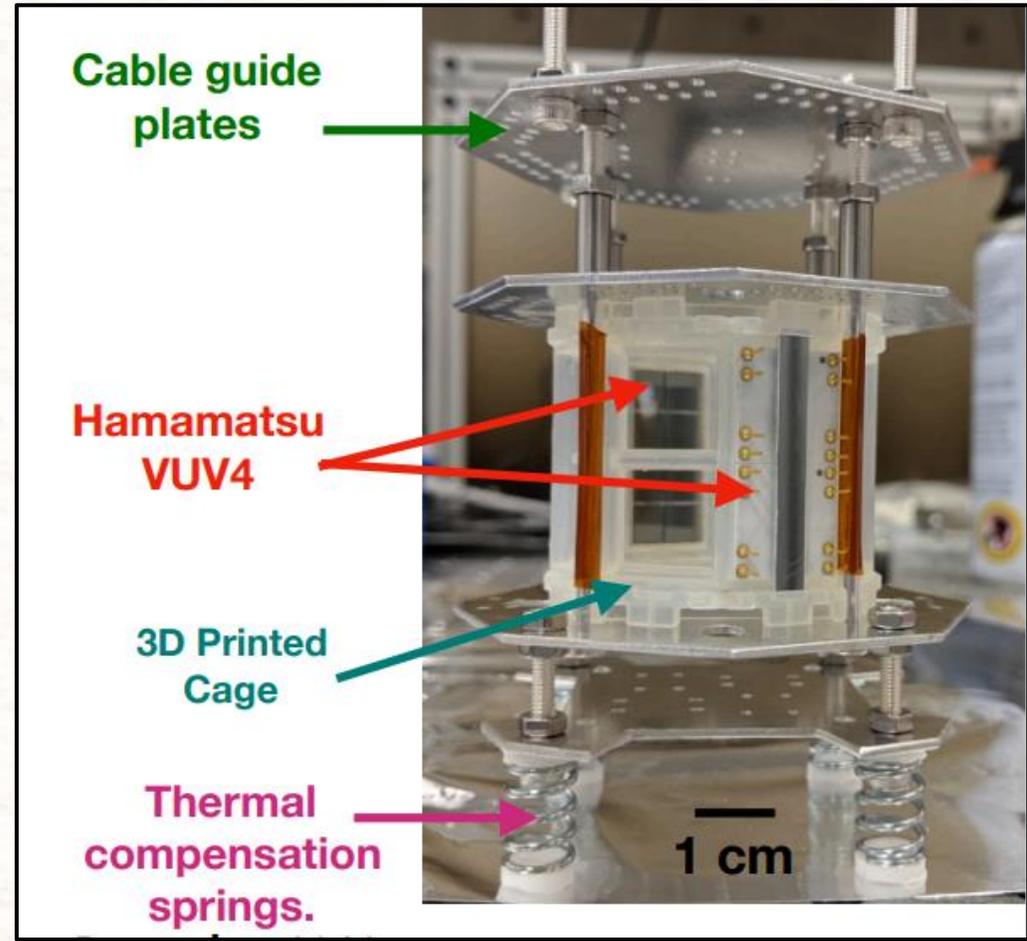
- Upgrade electronics with better resolution (~100 picoseconds)
- Study the time structure of scintillation light in LXe

## Phase 3

- Install fast timing 3D SiPM (resolution ~10ps) in LoLX and evaluate their performance in LXe
- Temporal separation of Cherenkov and scintillation photon signals

# LoLX detector (Phase 1)

- Octagonal prism geometry
- 3D printed cage to hold SiPMs
- 24 Hamamatsu Quad VUV4 SiPMs
  - 22 SiPMs are covered with long pass (longer than 240nm) optical filter
  - 1 SiPM is covered with band pass filter centred at  $(172\pm 20)\text{nm}$
  - 1 SiPM is left bare
- Radioactive source Sr-90 at the tip of needle at centre of detector
- Currently operational at McGill

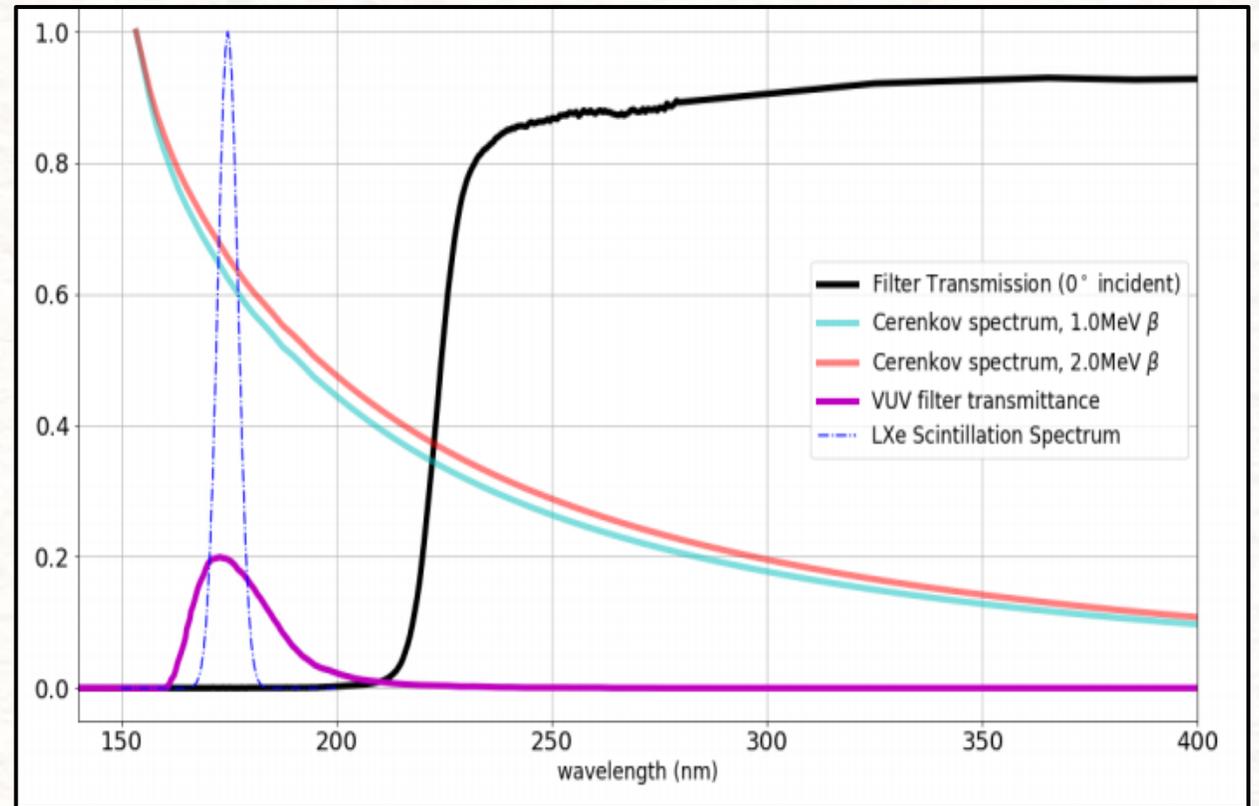


LoLX detector

# Optical Filters

**Long pass filters:** allow long wavelength (higher than 225 nm) Cherenkov light in LXe but block scintillation photon (175 nm) to trigger SiPMs

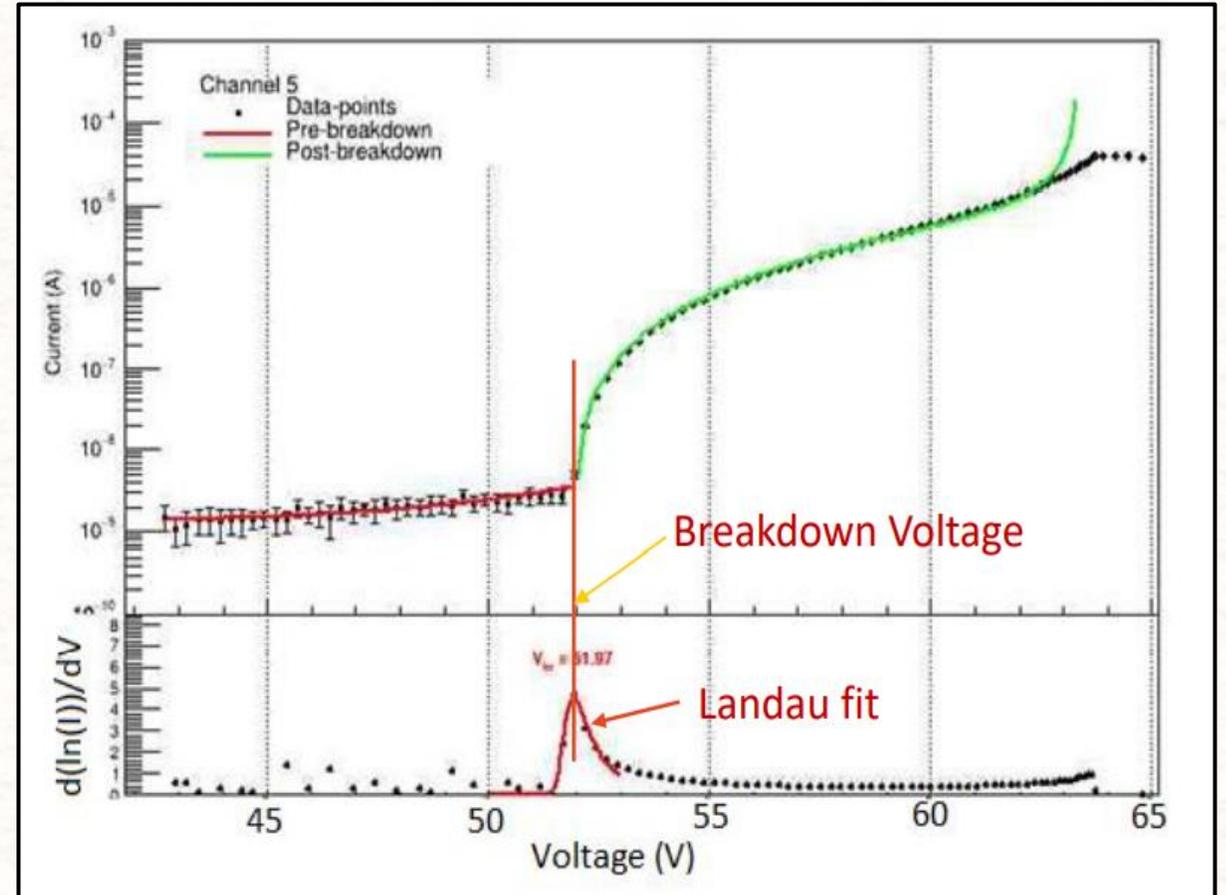
**Band pass filter:** centres at  $(175 \pm 20)$  nm allowing scintillation photons in LXe to trigger SiPM



Scaled scintillation and Cherenkov spectra overlaid with filter data taken at normal incidence

# SiPM IV curves

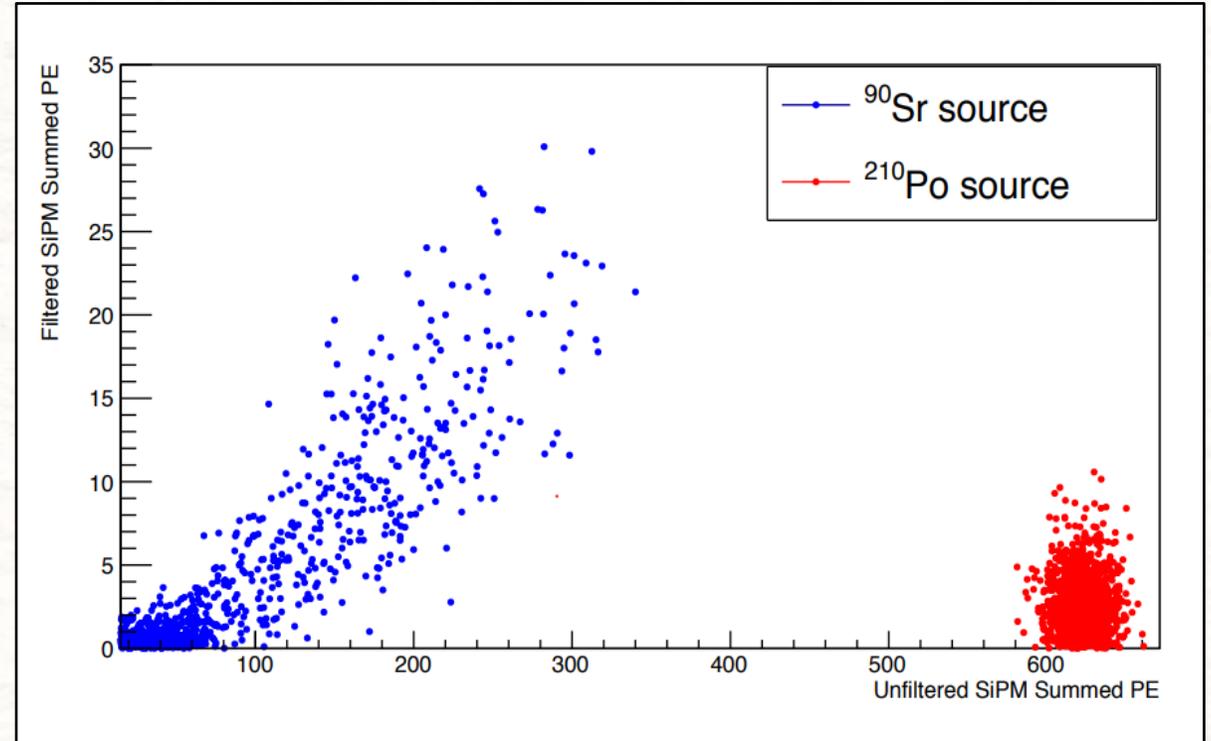
- IV characterisation for all 96 SiPMs
- Working on improving I-V fit for SiPMs.
- I-V fit functions used to extract the key parameter “**Breakdown Voltage**” for operation of SiPM
- Dark noise rate, after-pulsing probability, crosstalk probability can be extracted with some other measurements
- Developing I-V curve analysis as a quick tool for quality assurance for SiPMs for nEXO



Current as a function of reverse voltage for single SiPM channel in LoLX. The I-V curve taken at 21° C.

# Cherenkov and scintillation discrimination

- Preliminary simulation results using GEANT4 with input ex-situ optical measurements for all detector materials and components
- Sr-90 as beta source and Po-210 as alpha source
- A correlation between scintillation (unfiltered) and Cherenkov (filtered) signals can be seen for beta events
- Alpha events seen by unfiltered (Bare and band pass filter) as expected



**Preliminary simulation results comparing the expected signals for beta and alpha events in LoLX phase 1.**

# External cross talk

- External cross talk events occurs when avalanche photons escape the SiPM and trigger another SiPMs
- It leads to false counting of photon signals in the detector that could degrade the detector resolution
- Emitted photons are in Infra-Red(IR) range
- Band pass filter block these photons to trigger the SiPM, while long pass filters will allow them to pass.

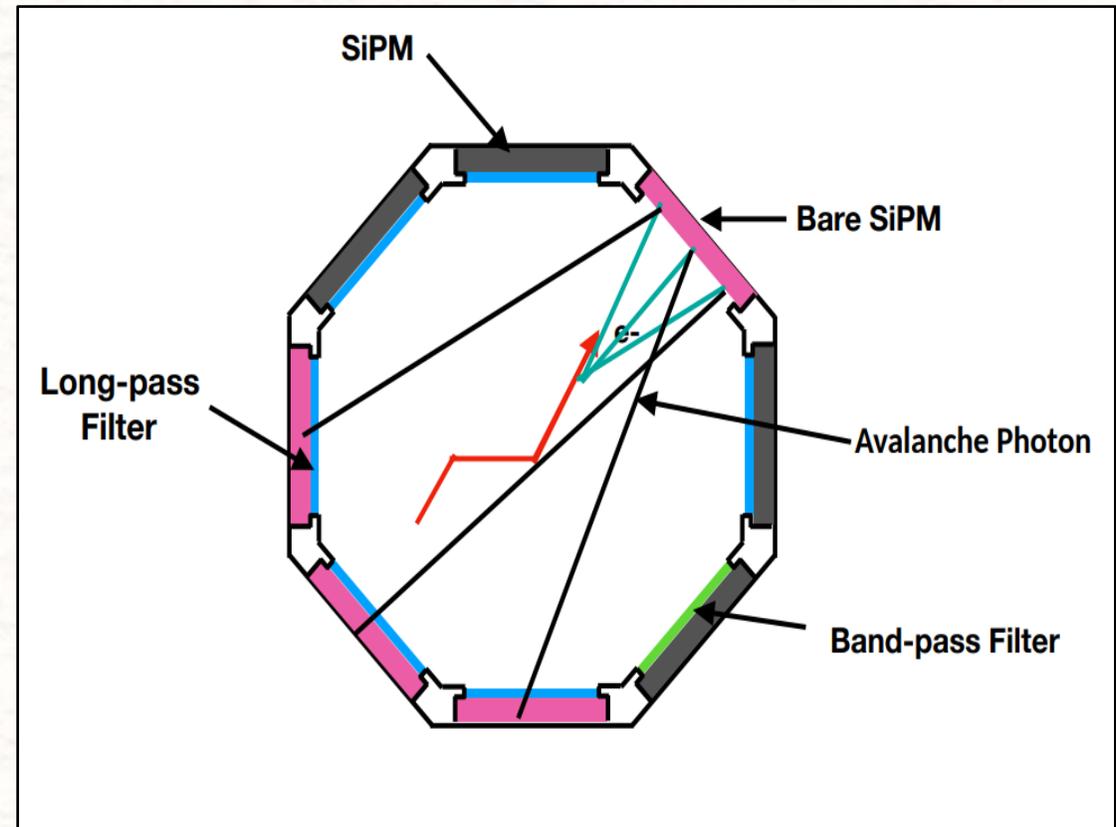
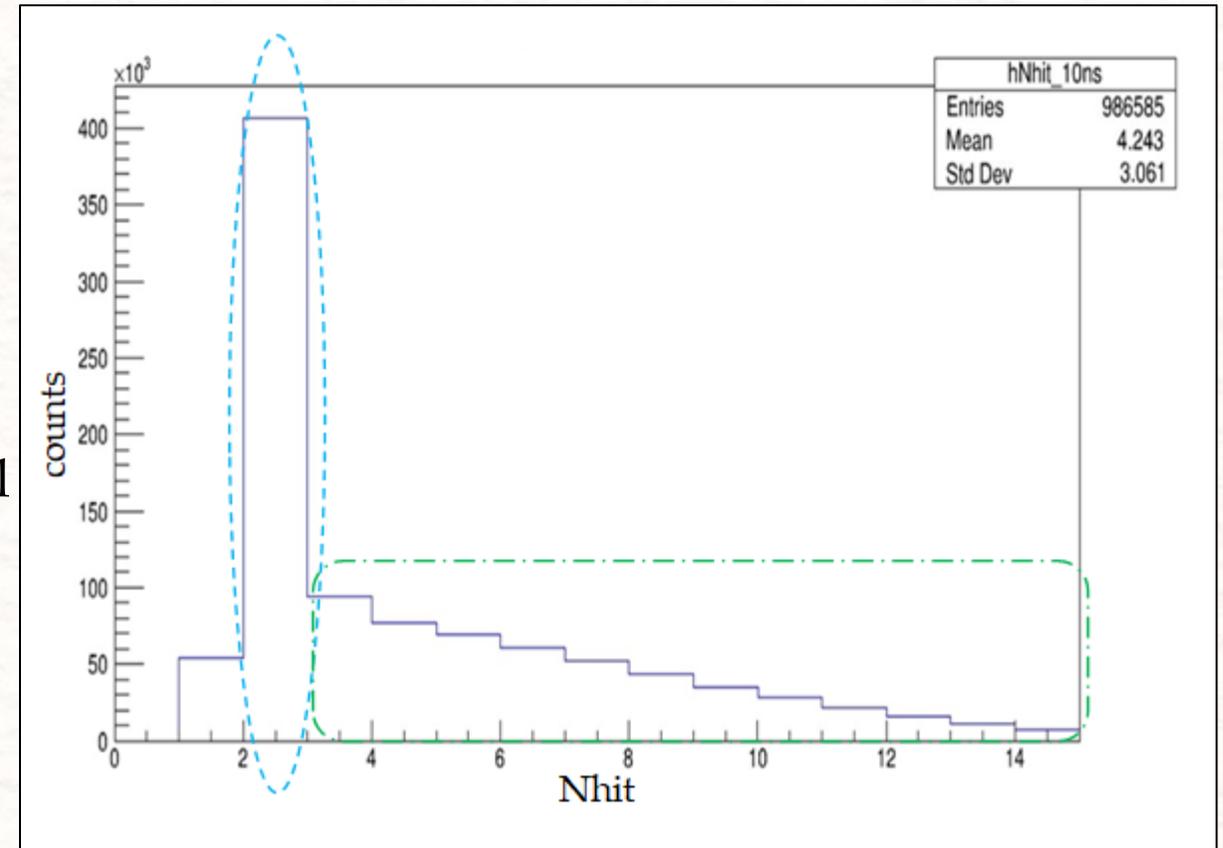


Diagram showing the external cross-talk by photons coming from bare SiPM triggering another SiPMs

# External cross-talk measurements

- The data set was taken in cold nitrogen gas with an objective of measuring the external cross-talk between SiPMs
- Nhit represents the number of channels being hit in a single event
- Nhit = 2 may be mainly contributed by external cross-talk events and Nhit > 2 may be light induced events
- A detailed data analysis and simulation for external cross talk is still in progress



Number of channels hit within a narrow time window in a single event

# Conclusions

- Successfully commissioned and installed the LoLX in cryostat and is operational at McGill
- In July 2020, LoLX was first operational in cool nitrogen gas. This run focussed on measuring the external cross-talk in SiPMs
- In Dec 2020, Xenon was condensed in the cryostat. A test physics data was taken in LXe
- I-V curve analysis used to extract SiPM working parameters.
- Data analysis and simulations for the measurements are ongoing.
- Physics data in Liquid Xenon is planned for LoLX in coming weeks

# LoLX group



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