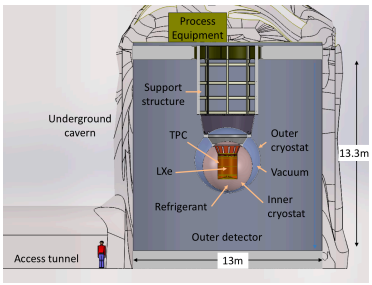
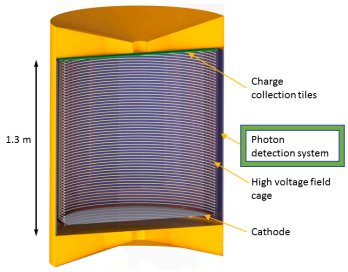
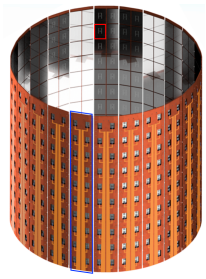
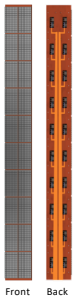
Silicon photomultipliers for the nEXO light detection system

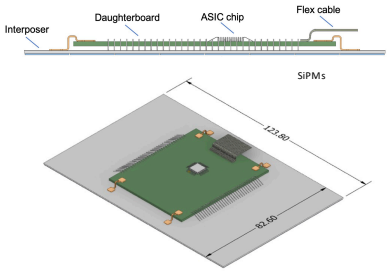
Prof. Simon Viel, on behalf of the nEXO Collaboration











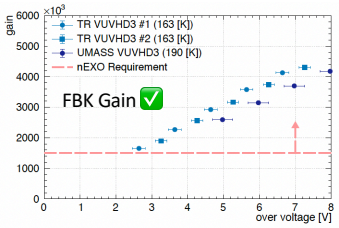
nEXO is a proposed experiment to look for neutrinoless double beta decay (**0νββ**) with 5 tonnes of liquid xenon (LXe) **enriched in ^{136}Xe** to 90% purity. The **SNOLAB Cryopit** cavern is committed to a large-scale 0νββ detector that could be nEXO, and is the nEXO collaboration's preferred site.

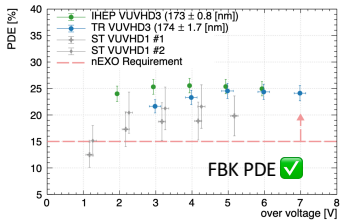
nEXO relies on both **charge and light detection** in the single-phase time projection chamber (TPC) to achieve the best possible energy resolution: 1% at the decay Q-value ($Q_{\beta\beta}$ = 2.458 MeV)

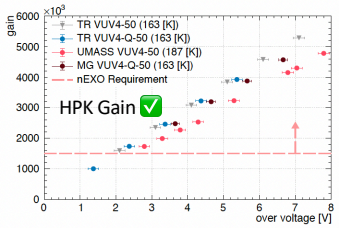
The **nEXO photodetection system** will be comprised of **silicon photomultipliers** (SiPMs):

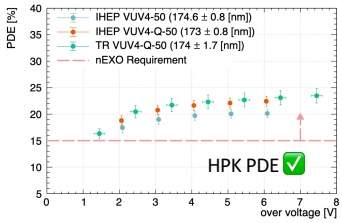
- 1 x 1 cm² SiPMs grouped in 6 cm² readout channels
- 96 SiPMs will be mounted on each 8 x 12 cm² tile, on the back of which an ASIC readout chip on the daughterboard will be connected via wire bonds to the interposer (silicon or quartz)
- 20 tiles will be mounted on each stave (electroformed copper)
- 24 staves will comprise the full barrel of the detector → **Total: 4.6 m² sensitive area**

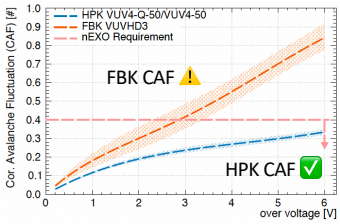
Two SiPM vendor candidates, Fondazione Bruno Kessler (FBK) and Hamamatsu Photonics (HPK) offering **vacuum ultraviolet (VUV) sensitivity** i.e. photodetection efficiency (PDE) > 15% at the LXe scintillation peak wavelength of 175 nm, are evaluated against nEXO photodetection requirements:

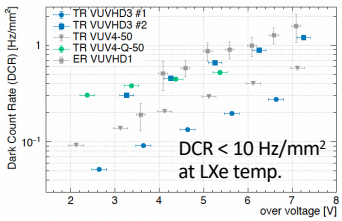






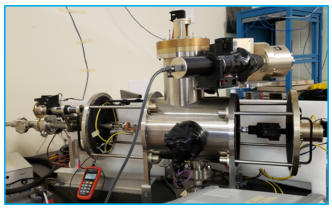


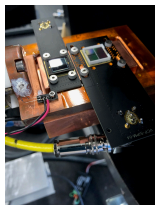




HPK devices appear to **satisfy all requirements**, and are available with through-silicon vias (TSV). FBK produced a new version of their VUV SiPMs that will be characterized by the collaboration. External cross-talk measurements are being carried out to ensure this will not be an issue for nEXO. Radiopurity assays are performed on components, and will be performed on the final devices.

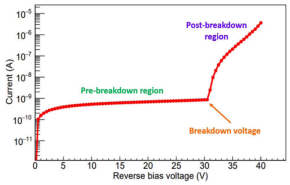
Several **cryogenic test setups** collect SiPM characterization data for nEXO, such as the "Vacuum ultraviolet efficiency, reflectivity and absorption" (VERA, shown) setup located at TRIUMF; and others at BNL, Erlangen, IHEP, McGill, Stanford, U. Alabama, U. Mass., and Yale.

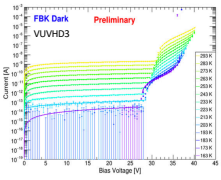


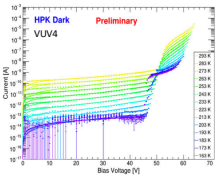


Rapid characterization methods are developed for quality control during nEXO construction. Current-voltage (IV) measurements could be carried out on each channel at the underground laboratory, with possible rework procedures before final installation into nEXO.

Dark noise rate and correlated avalanche probability can be extracted from fits to IV data:



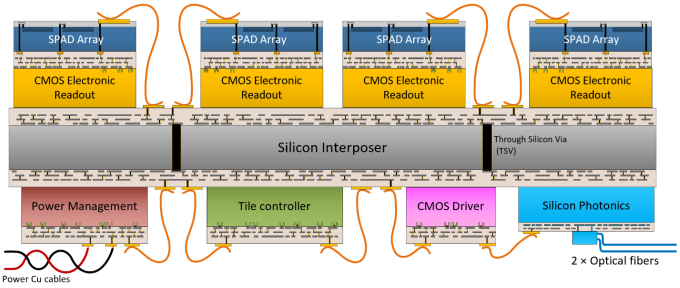




Photon-to-digital converters (also known as 3D digital SiPMs):

Developed by nEXO collaboration members at U. Sherbrooke with C2MI and Teledyne DALSA. Instead of analog front-end circuits, these devices feature digital active quenching circuits connected to each single-photon avalanche diode (SPAD), digitizing photon signals directly. Configurable **digital readout electronics** allow for reduced power consumption and lower noise. 3D integration is achieved by bump-bonding each SPAD array to a CMOS electronic readout chip. On the back of the silicon interposer, the tile controller has digital signal processing capability.

VUV sensitivity may not be demonstrated in time for this technology to be selected for nEXO. Development continues toward future experiments and other applications.



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