Status of the nEXO experiment

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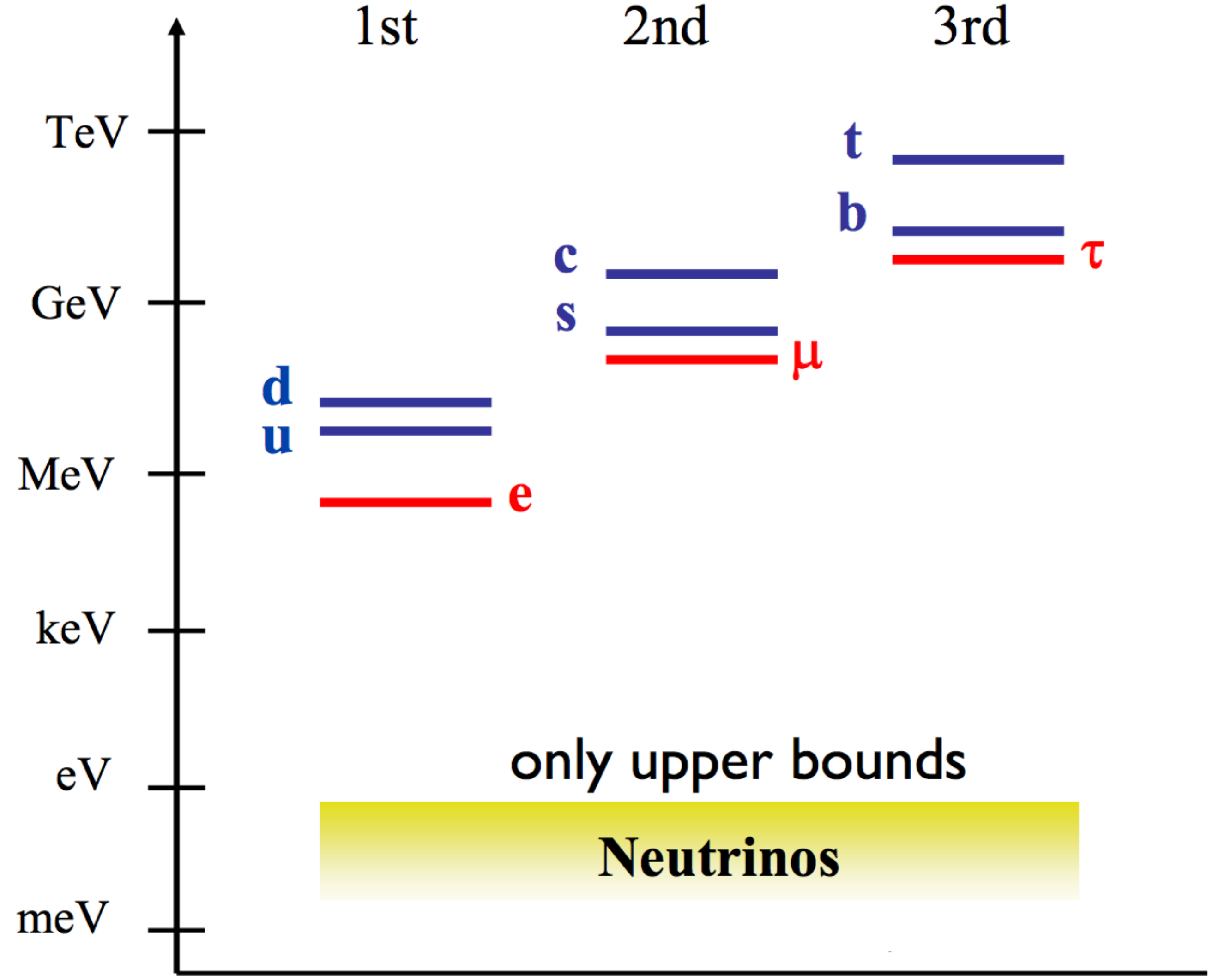
Generation of neutrino masses

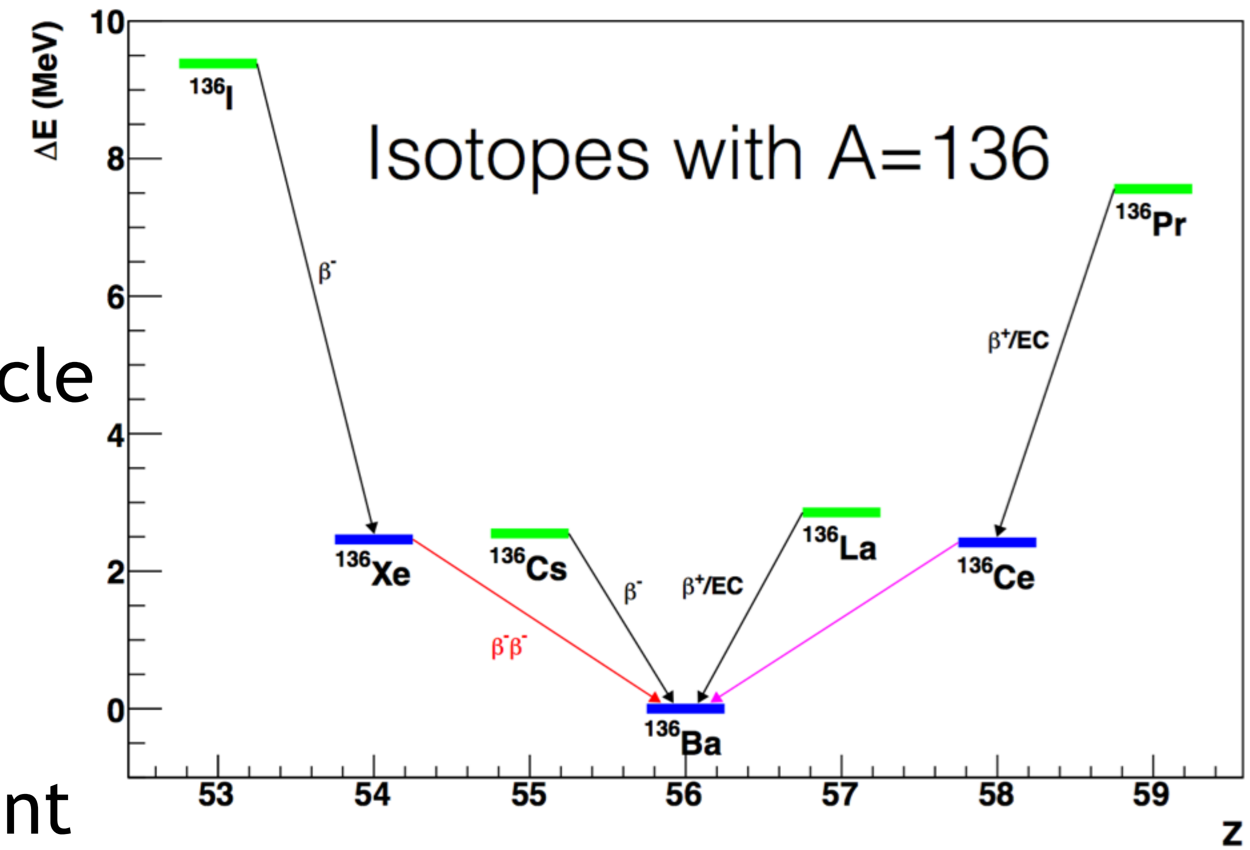
- Neutrinos are massless according to Standard Model (SM).
- Neutrino oscillations indicate tiny (thus non-zero) mass.
- One can generate neutrino mass similar as leptons by constructing a left-handed spinor with a right-handed one — Dirac mass term.
- For neutral particles, it is possible to construct a scalar by combining the spinor with itself — Majorana mass term.
- It's unknown to date about the neutrino mass generation mechanism.

Rest masses of fermions

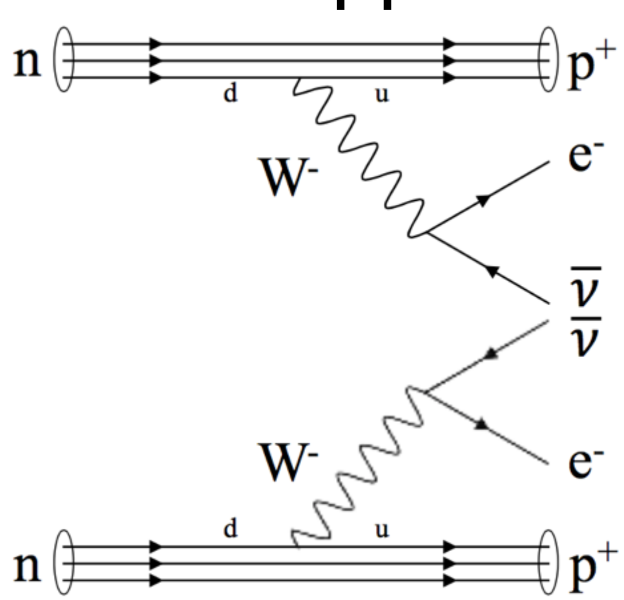


Neutrinoless double beta decay

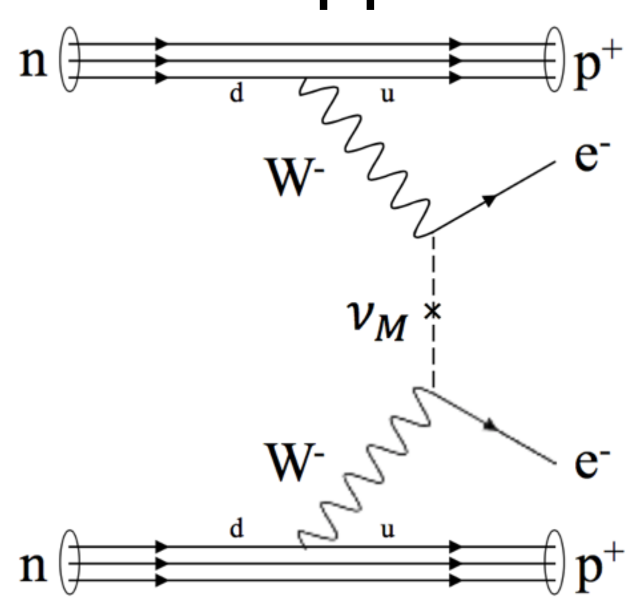
- Double beta decay is a second order process allowed by SM
- Neutrinoless (0νββ) double beta decay is possible if neutrino is a Majorana particle
- Observing 0νββ indicates:
  1. neutrino is Majorana particle
  2. lepton number is violated
  3. neutrino mass by lifetime measurement

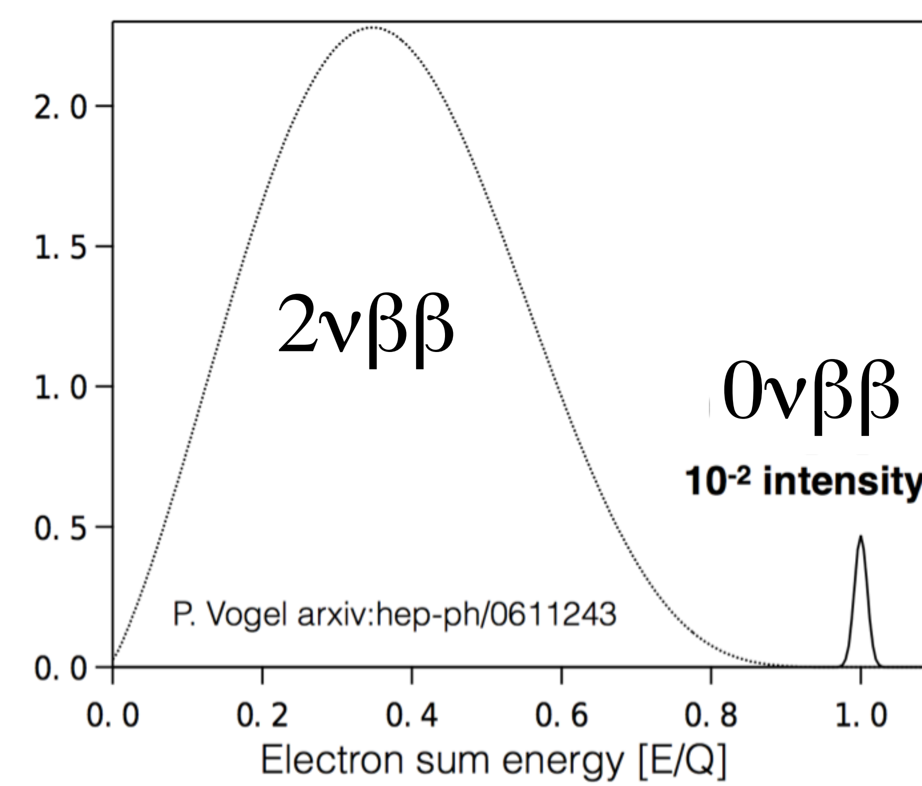


2νββ



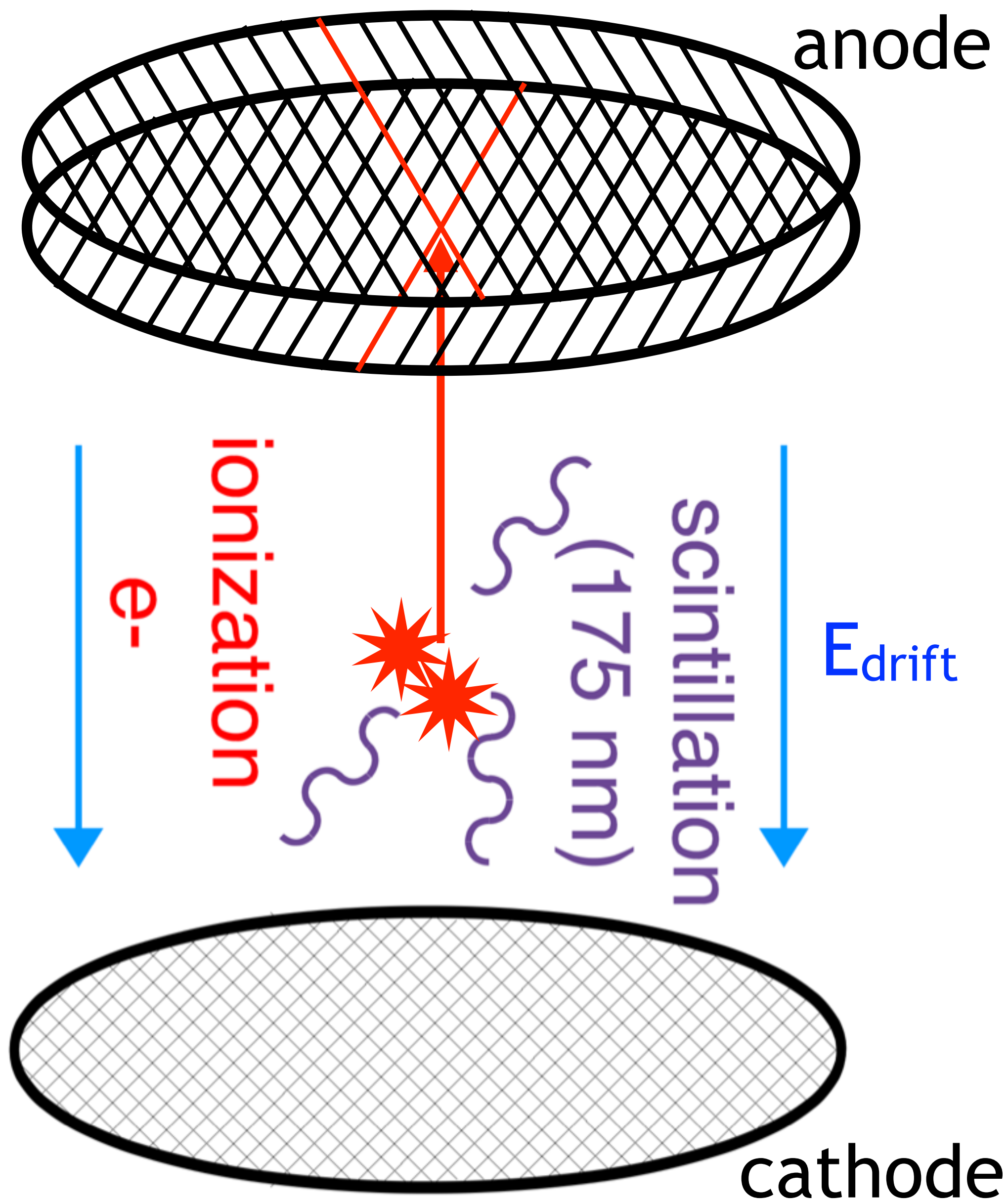
0νββ



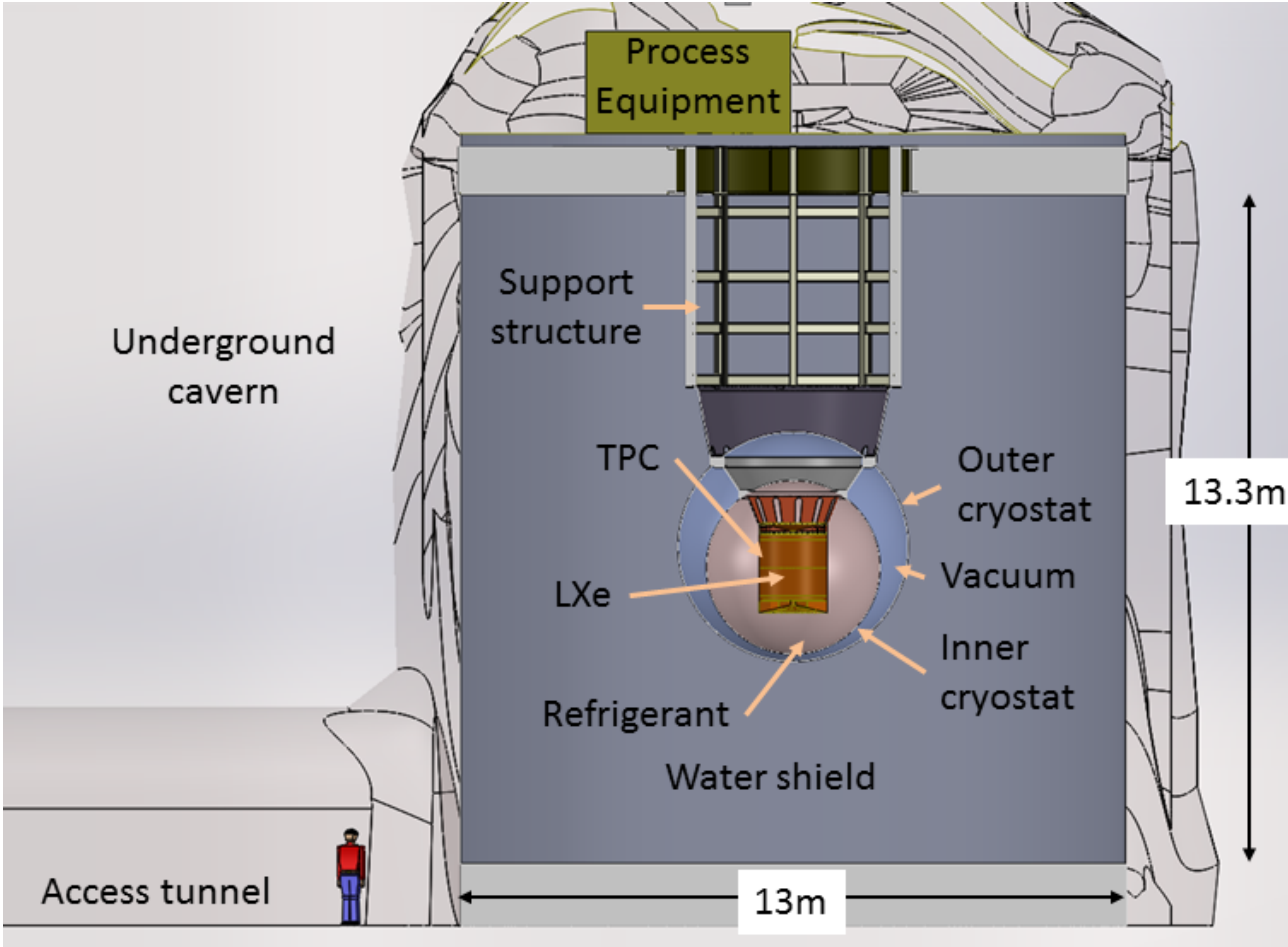


Liquid Xenon TPC for 0νββ search

- Liquid Xenon enriched with ^{136}Xe
- Q value at 2.5 MeV
- energy resolution at ~1%
- Detection of VUV scintillation light (175 nm)
- 2D read out of ionisation charge with segmented anode
- Full 3D event reconstruction:
  1. Energy and position reconstruction
  2. Event Multiplicity
- Powerful background discrimination
  1. Depth in the detector is (for large monolithic detectors) powerful for discriminating signal from external backgrounds.
  2. α discrimination (from e^-/γ) possible by light/charge ratio



Preliminary artist view of nEXO in the SNOlab Cryopit

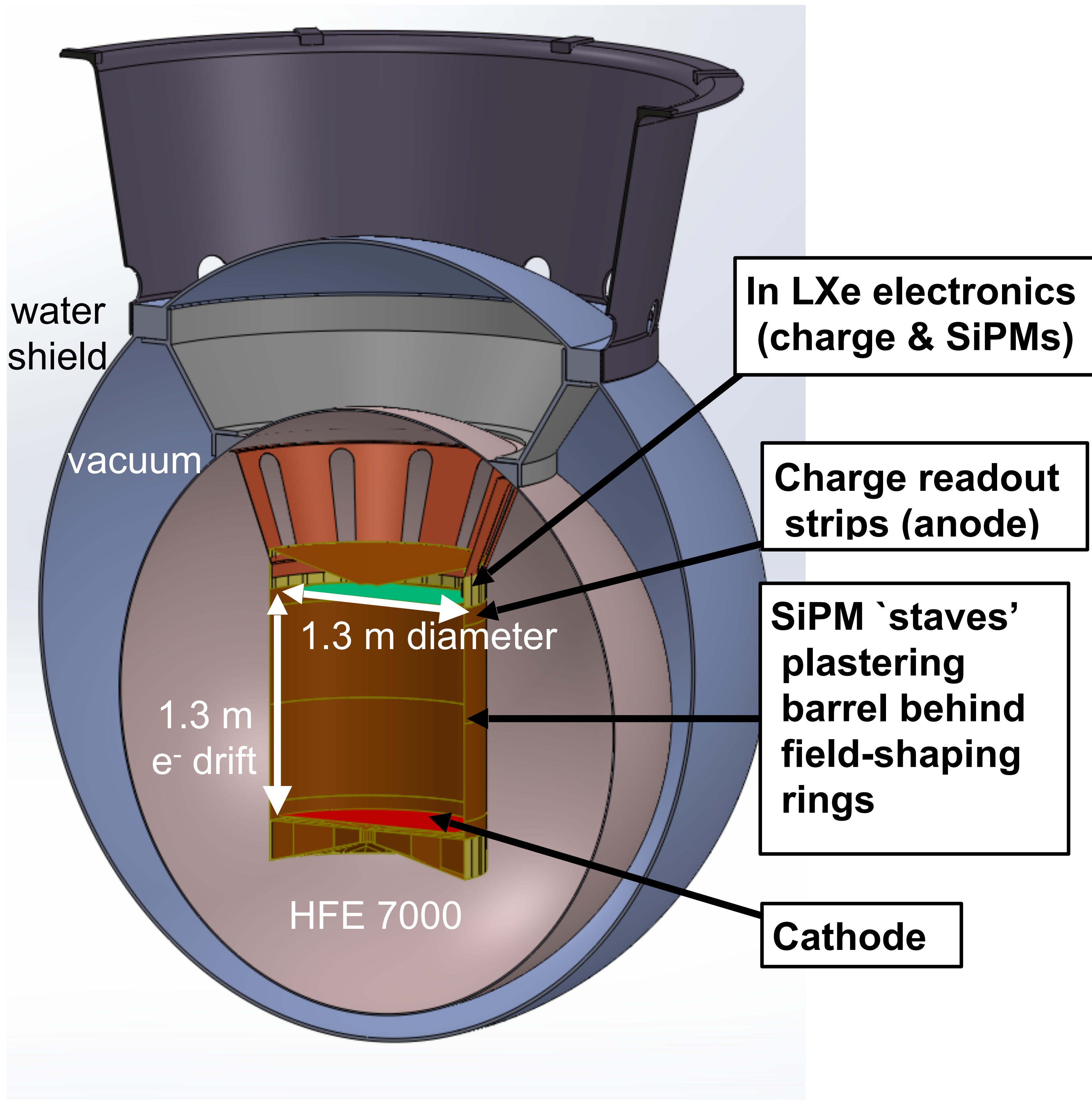


“nEXO Pre-Conceptual Design Report”, arXiv:1805.11142

The nEXO baseline TPC

Key parameters:

- 5t LXe with 90% enrichment in ^{136}Xe
- Drift length: 1.3 m
- Drift field: 400V/cm
- Single drift volume
- Diameter: 1.3 m
- 4 m^2 VUV-sensitive SiPM array
- 1% resolution at Q-value
- Low (known)-radioactivity materials



"nEXO Pre-Conceptual Design Report", arXiv:1805.11142

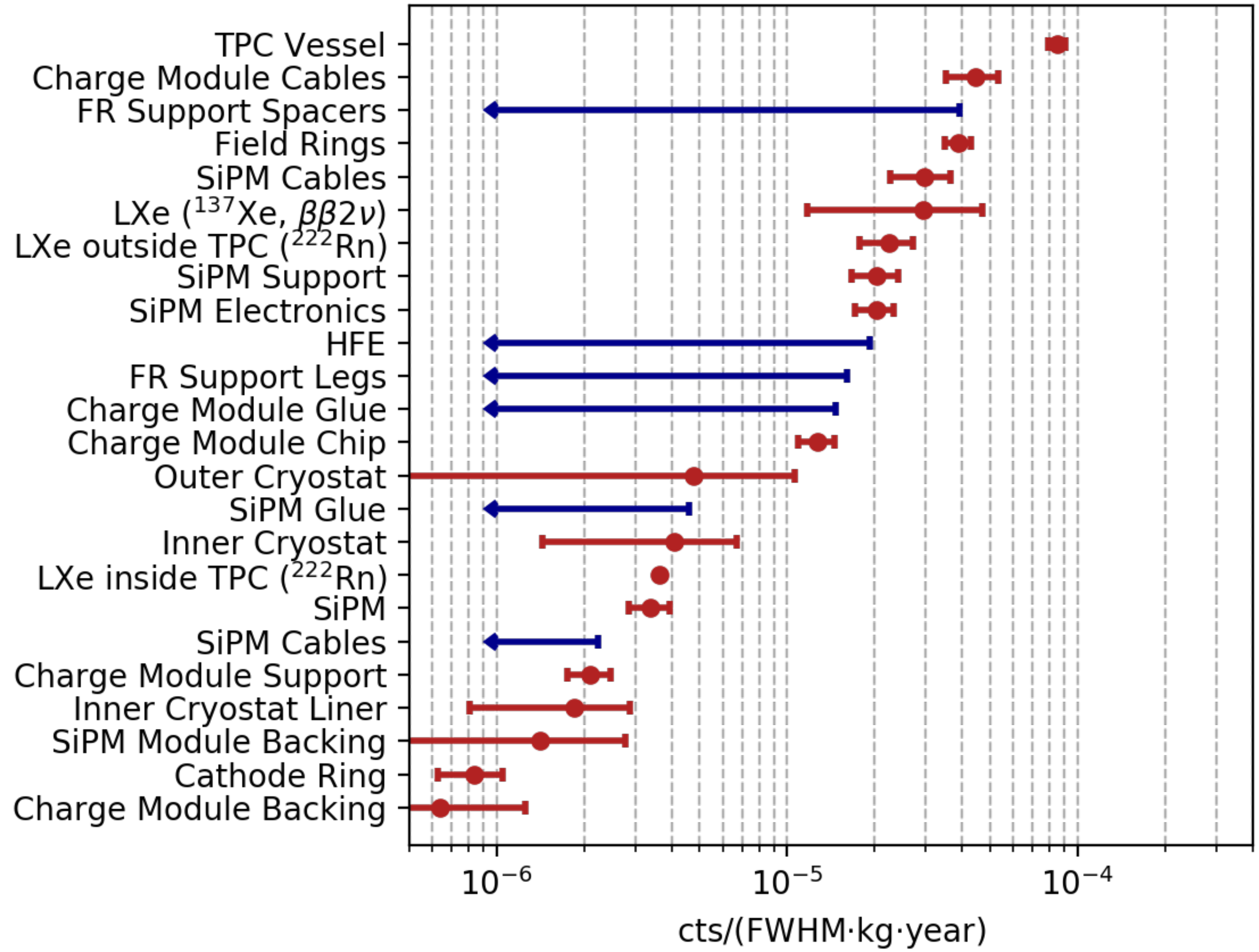
Background in nEXO

- Experience from EXO-200
- Cosmic muon veto
- external γ attenuation inside HFE-7000
- The inner from the TPC, the cleaner material selected
- low-background design

  ^{232}Th and ^{238}U ppt trace level

  ^{137}Xe (^{136}Xe neutron-capture)

Background in the central 2000 kg by component

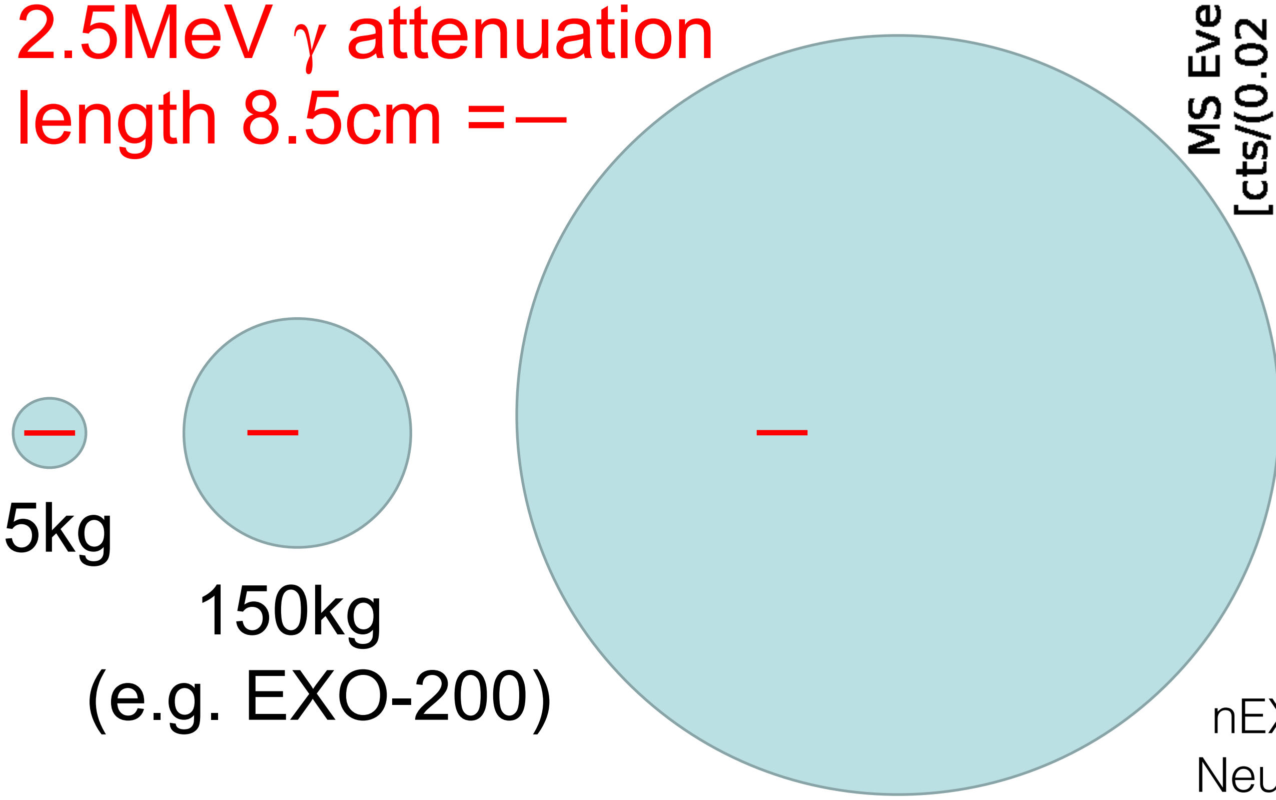


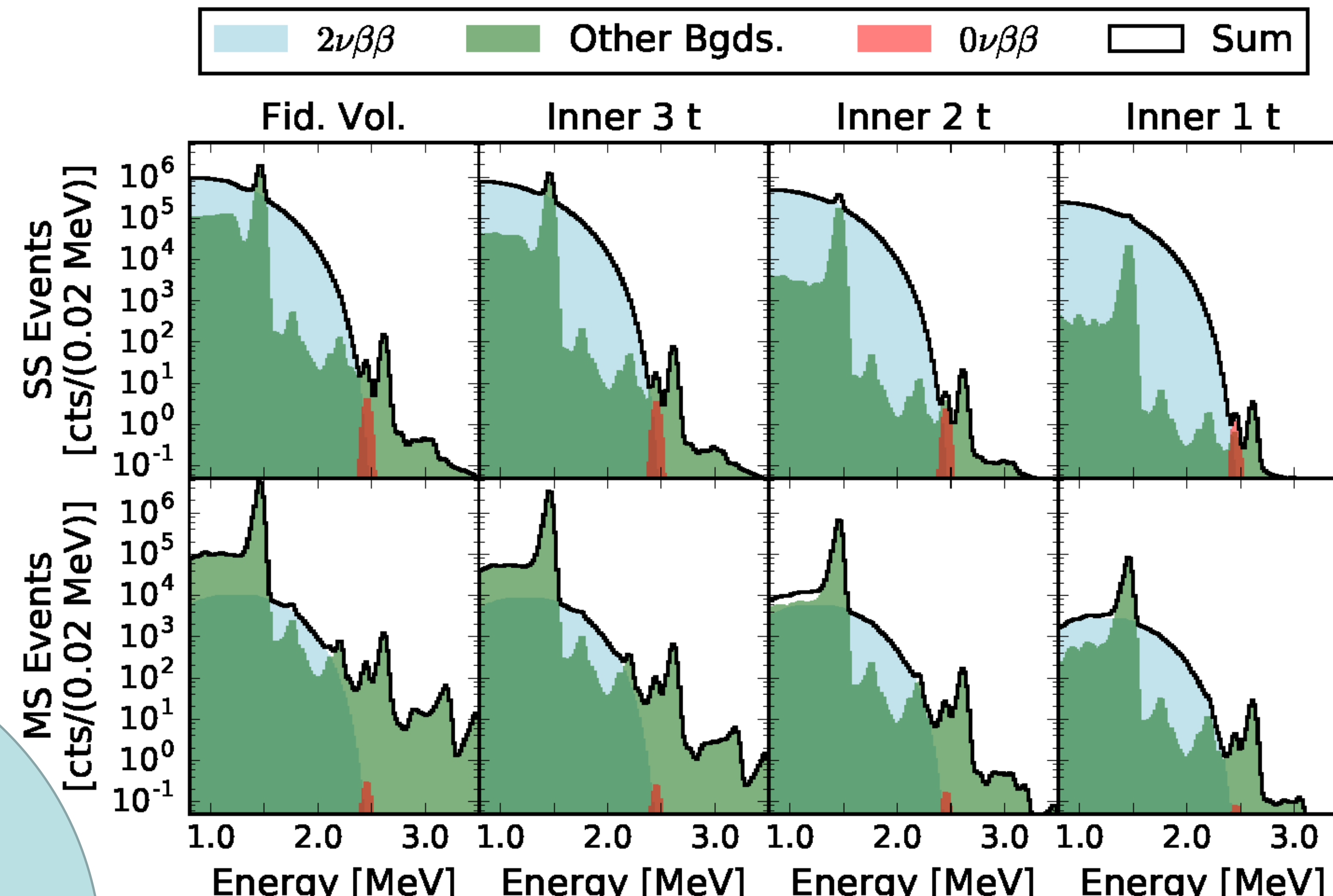
nEXO(J.B. Albert et al) "Sensitivity and Discovery Potential of nEXO to Neutrinoless Double Beta Decay", arXiv:1710.05075, to appear in PRC

The power of a monolithic detector

LXe mass (kg)	Diameter or length (cm)
5000	130
150	40
5	13

2.5MeV γ attenuation length 8.5cm = —



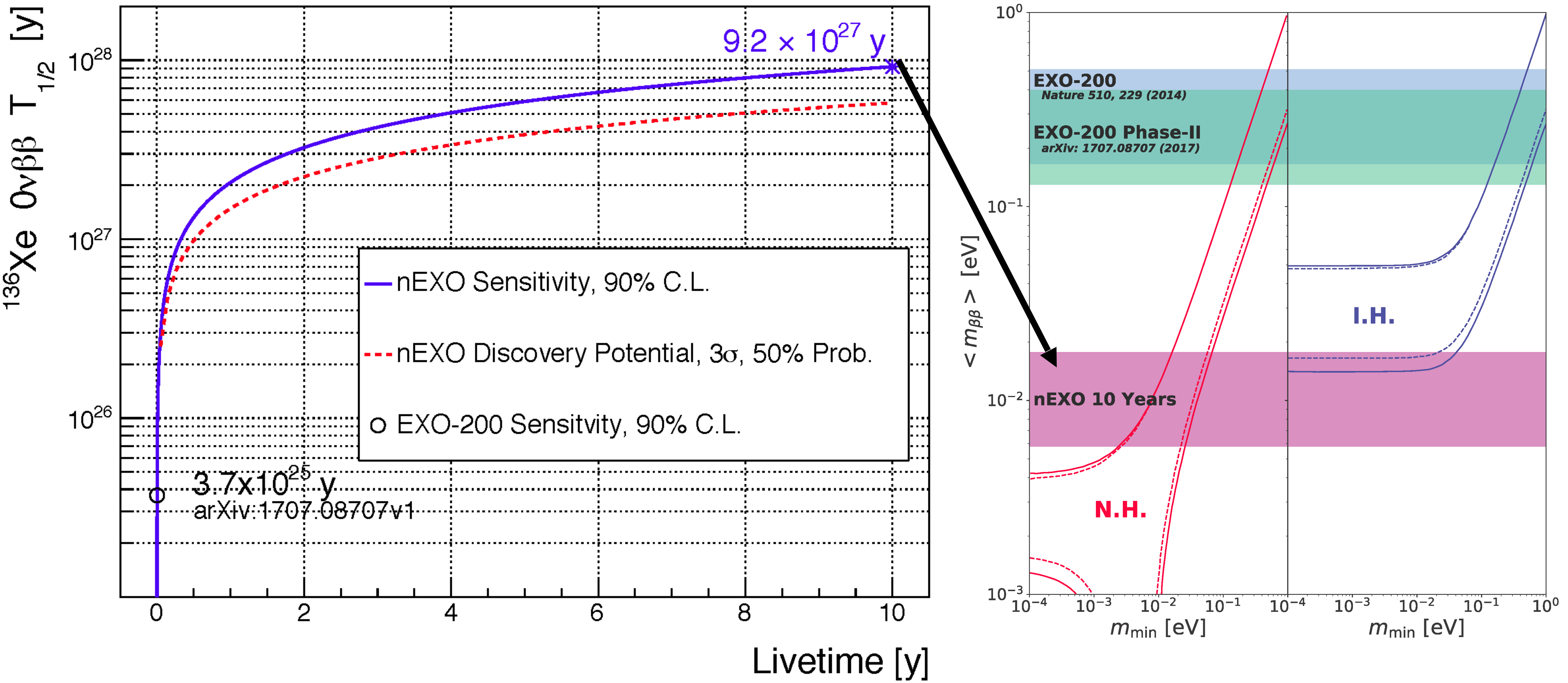


ss: single-site (discovery channel)

ms: multi-site (background dominating)

nEXO(J.B. Albert et al) "Sensitivity and Discovery Potential of nEXO to Neutrinoless Double Beta Decay", arXiv:1710.05075, to appear in PRC

nEXO sensitivity



after 10 years' data taking:

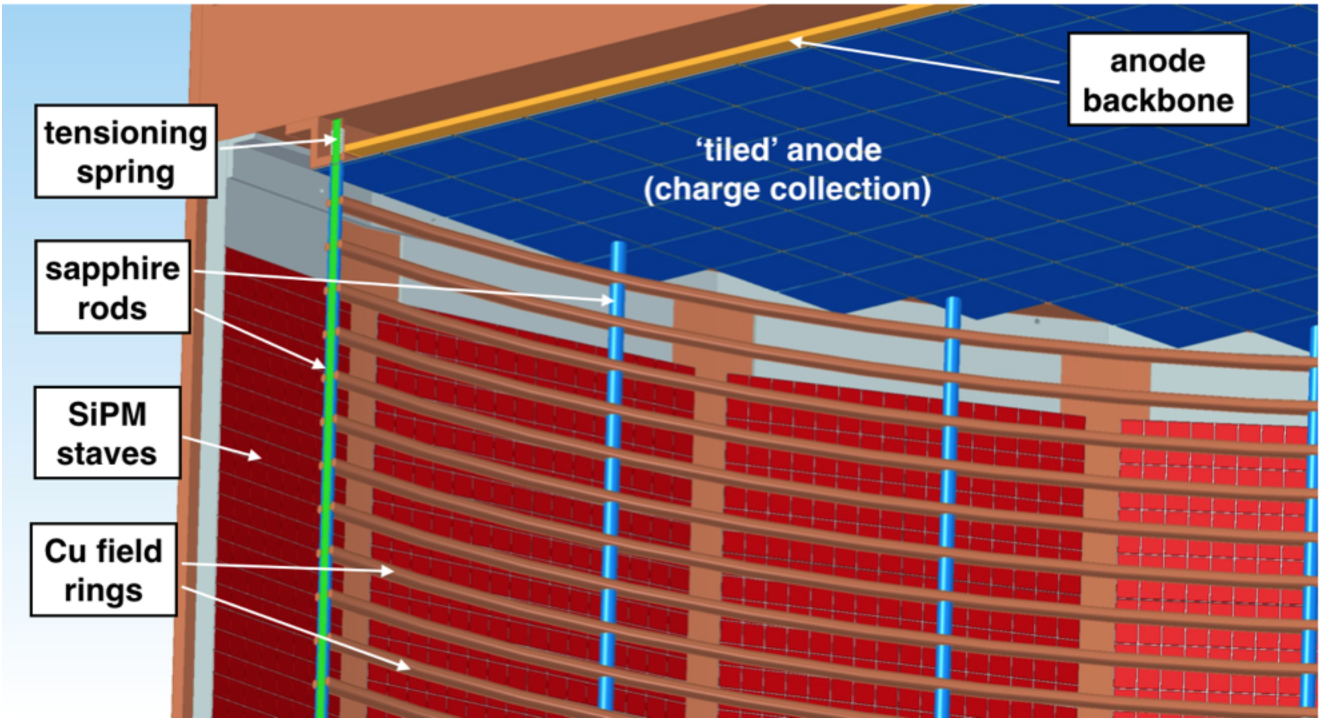
- 9.2×10^{27} year sensitivity on 0νββ $T_{1/2}$
- 5.7–17.7 meV sensitivity on Majorana mass

nEXO(J.B. Albert et al) "Sensitivity and Discovery Potential of nEXO to Neutrinoless Double Beta Decay", arXiv:1710.05075, to appear in PRC

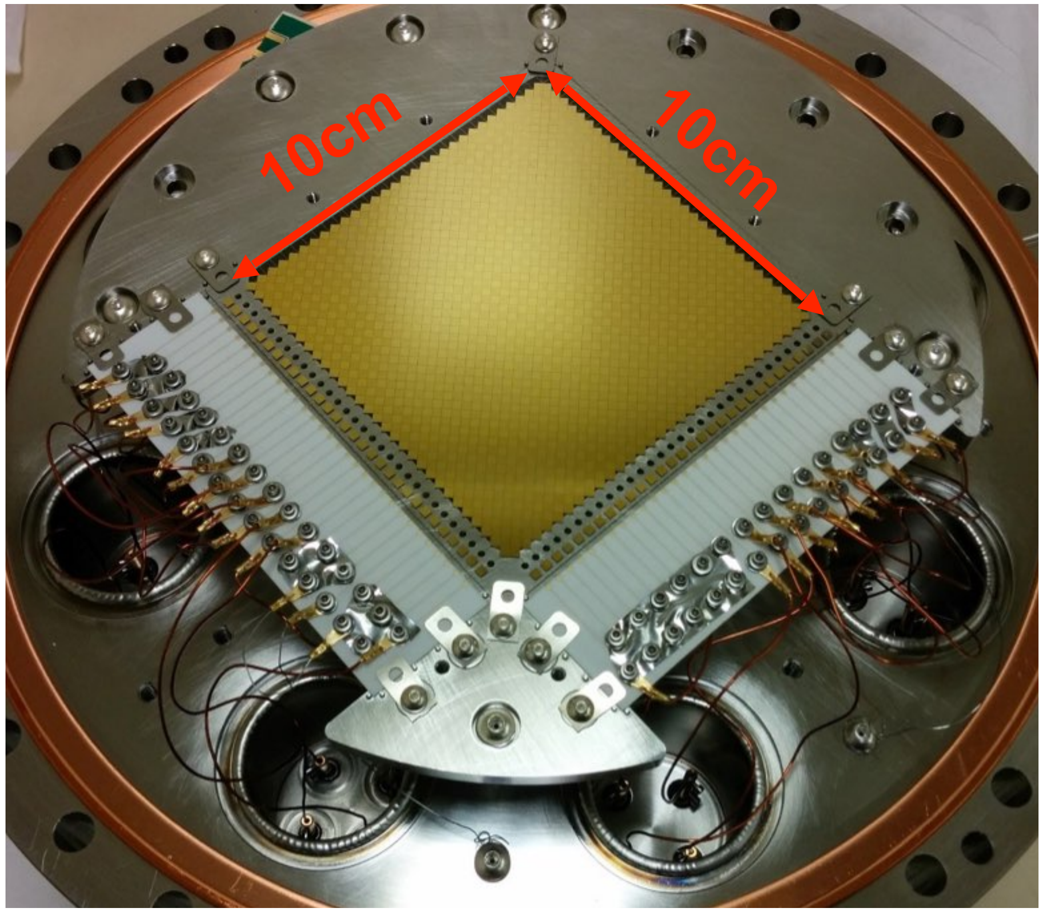
nEXO charge readout

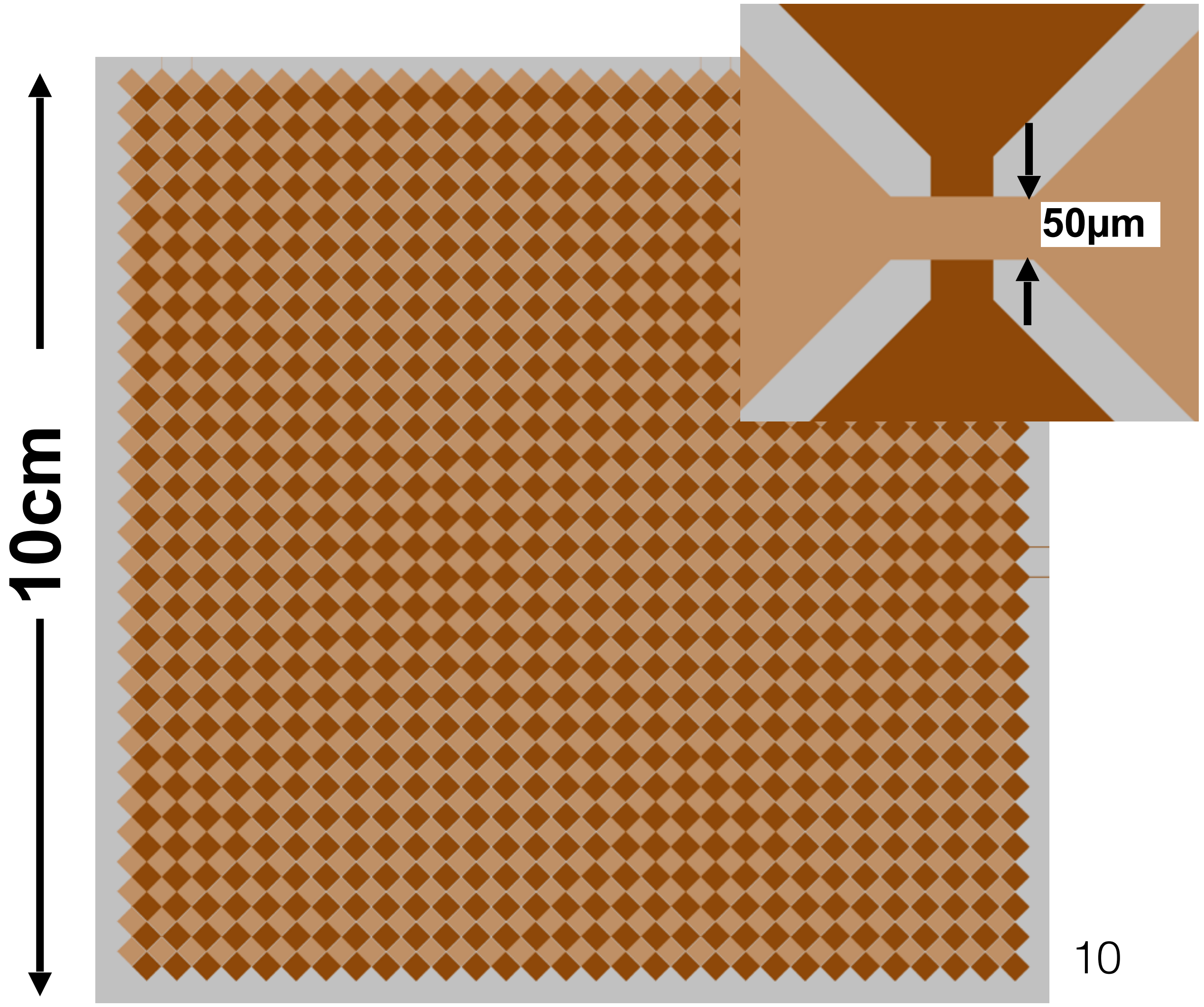
Charge will be collected on arrays of strips fabricated onto low background dielectric wafers (baseline is silica):

- **Self-supporting/no tension**
- **Built-on electronics (on back)**
- **Far fewer cables**
- **Ultimately more reliable, lower noise, lower activity**



prototype tile:

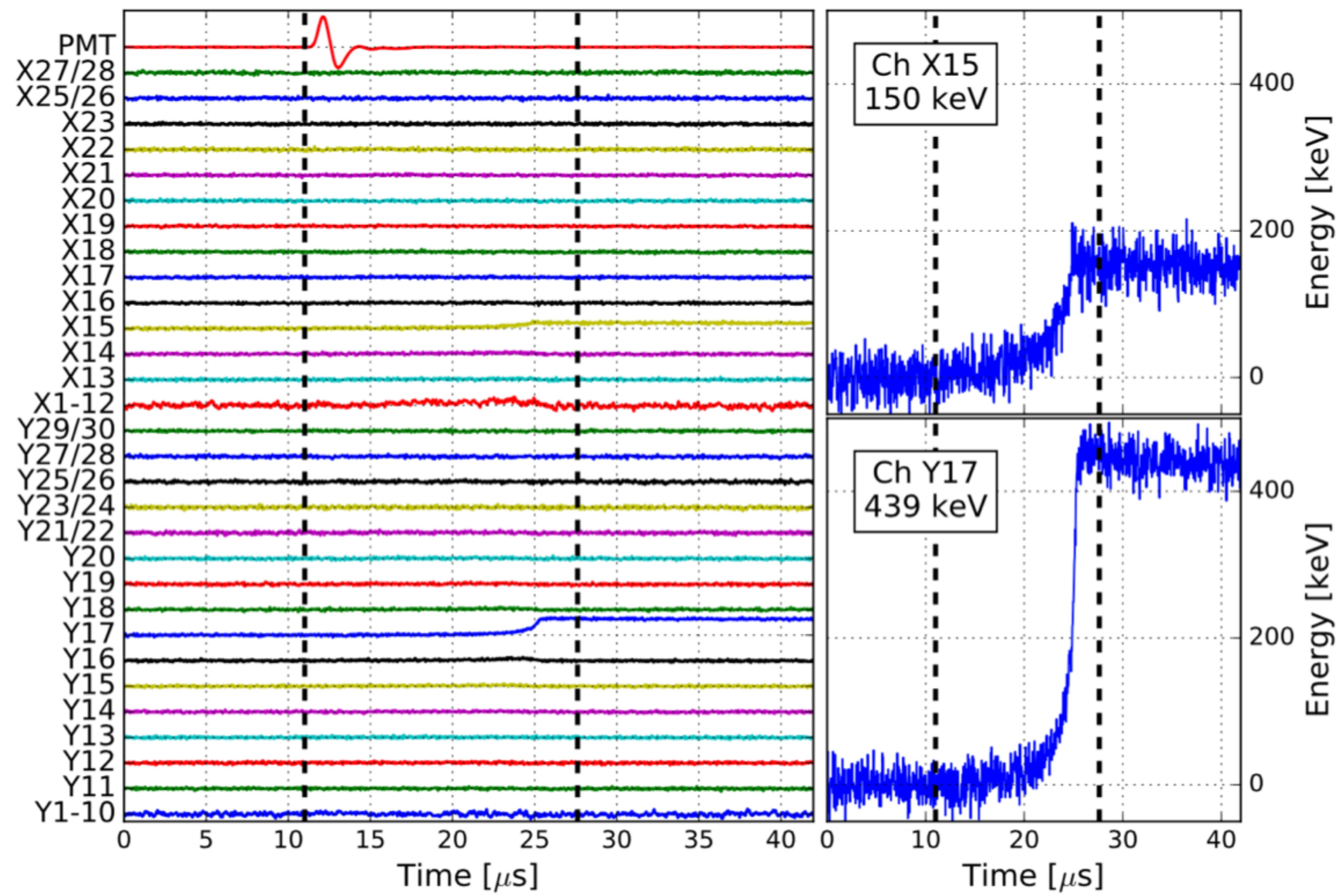




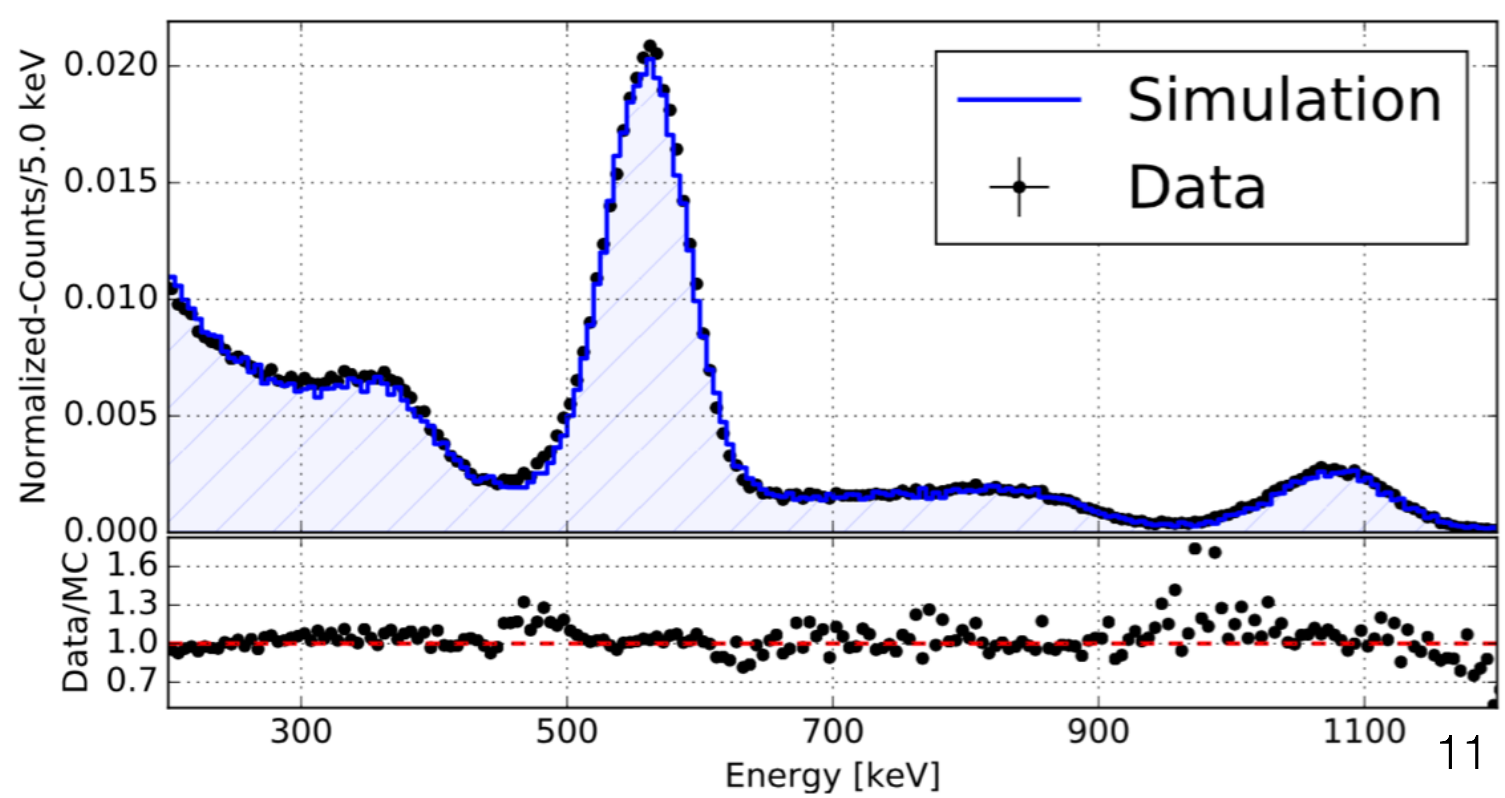
results from a 10x10 cm^2 prototype tile

Test cell:

- 30 X and 30 Y channels
- 3 mm readout pitch
- PMT provides the trigger
- 3.3 cm drift @ 936 kV/cm
- 16 us maximal drift time
- ^{207}Bi source (570 and 1064 keV)

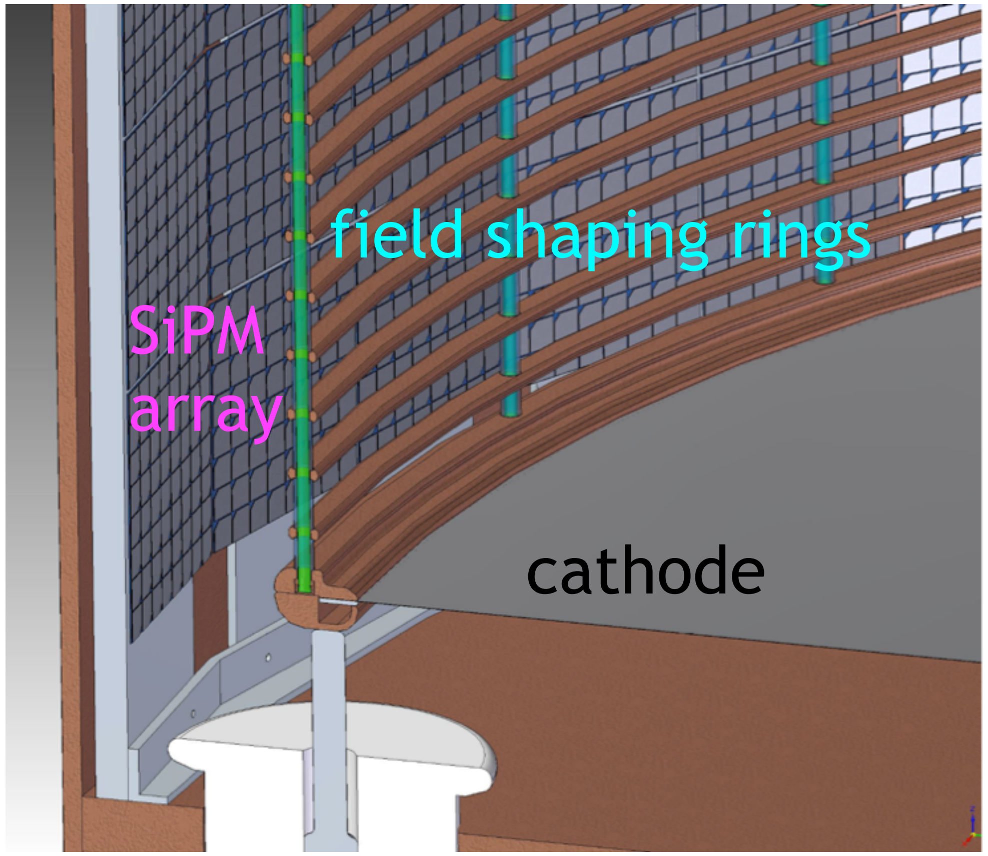


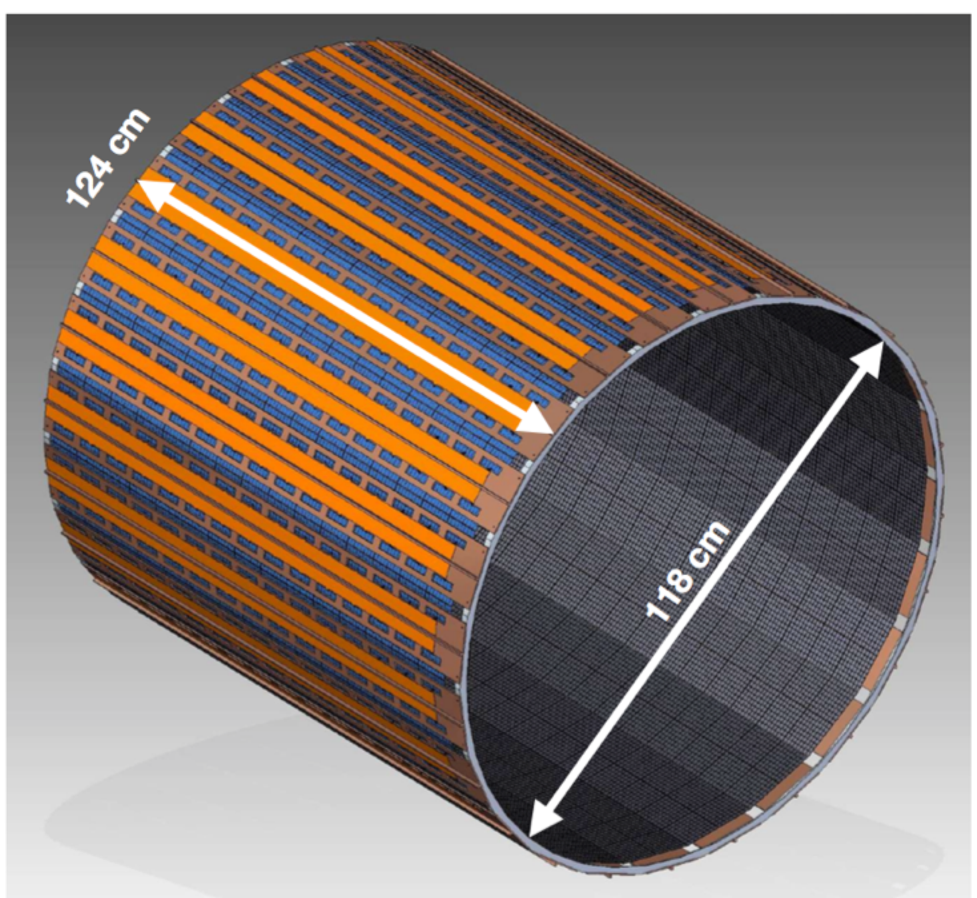
- σ/E=5.5% at 570 keV
- consistent with the literature



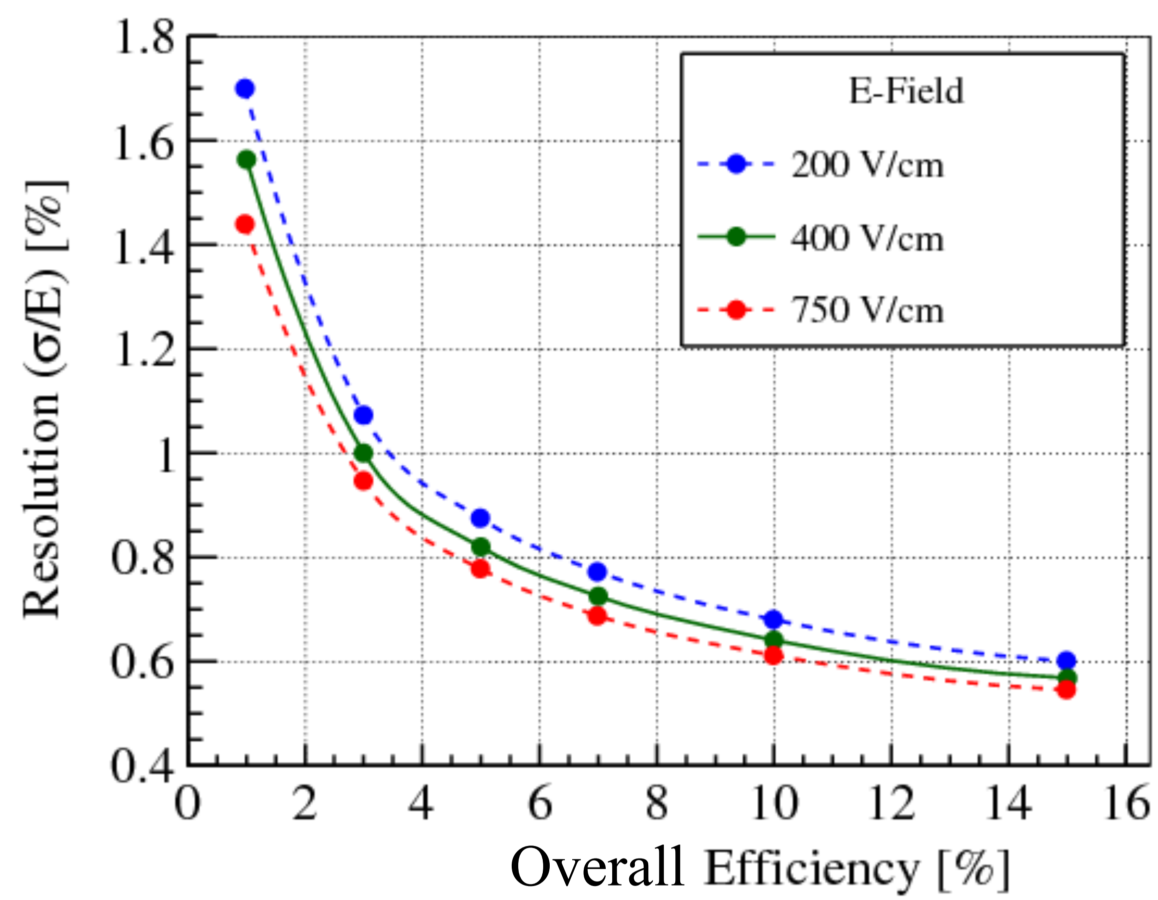
nEXO (M. Jewell et al.)
"Characterization of an Ionization Readout Tile for nEXO",
JINST 13 P01006 (2018)

nEXO light readout





- ~4m^2 of VUV-sensitive SiPMs
- Provide t_0 information
- meeting the 1% resolution goal:
  1. photo detection efficiency of SiPM (PDE)>15%
  2. photon transport efficiency (PTE)>20%
  3. overall efficiency (PDE*PTE)>3%

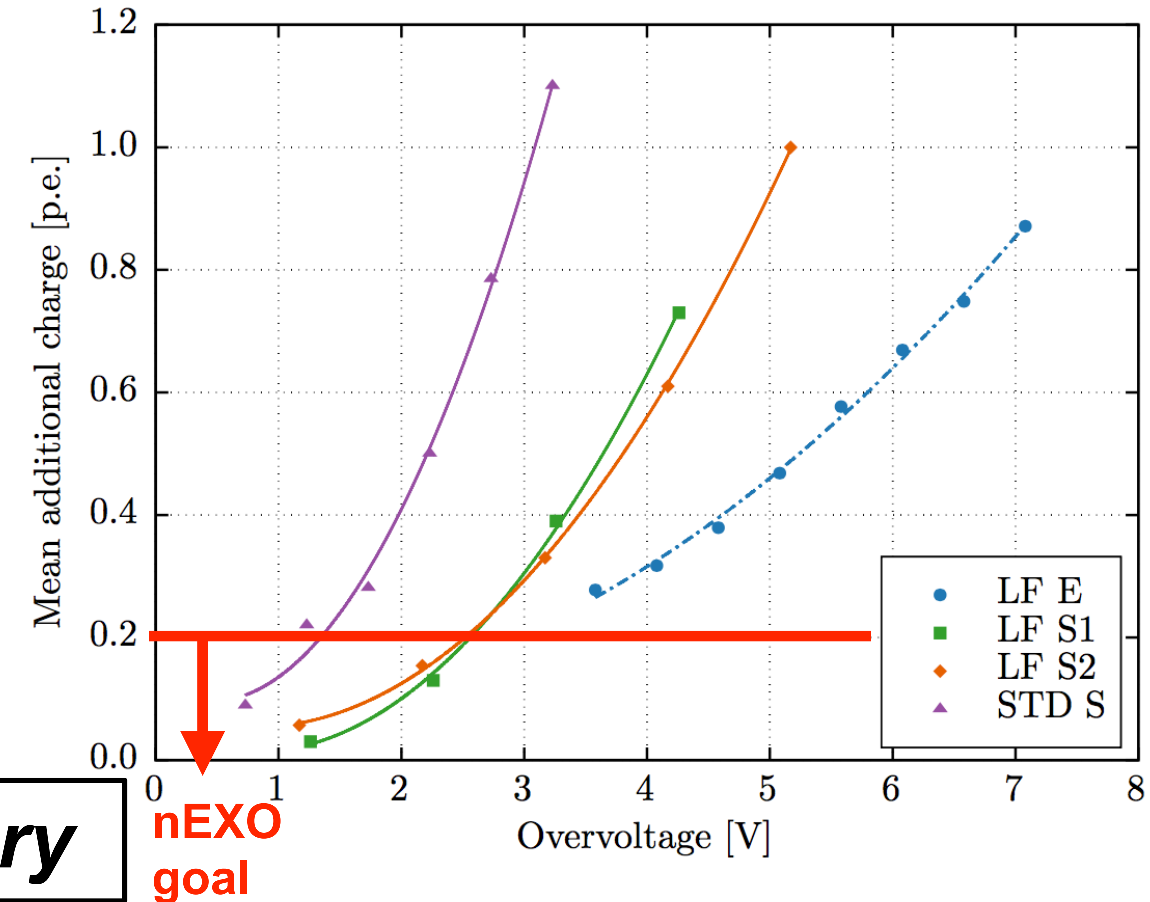


"nEXO Pre-Conceptual Design Report", arXiv:1805.11142

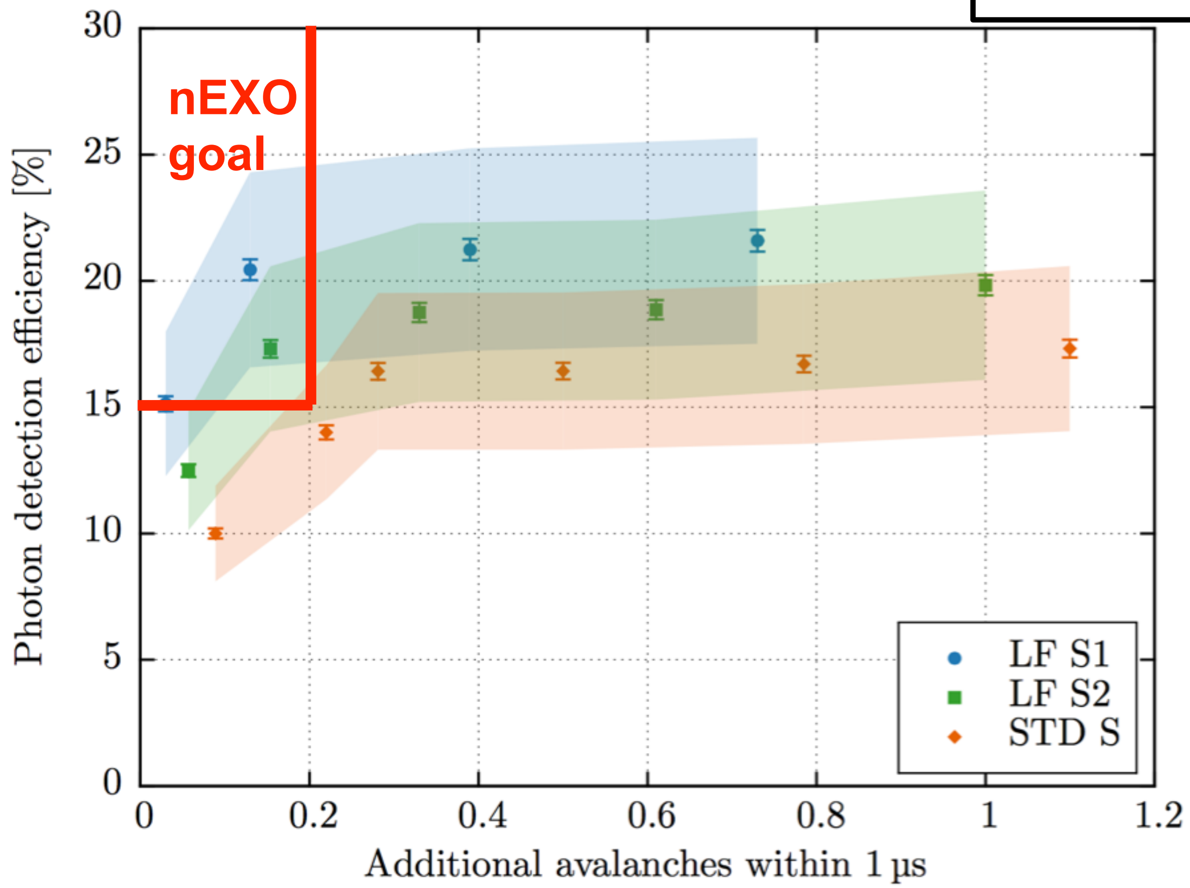
Characterisation on SiPMs for nEXO

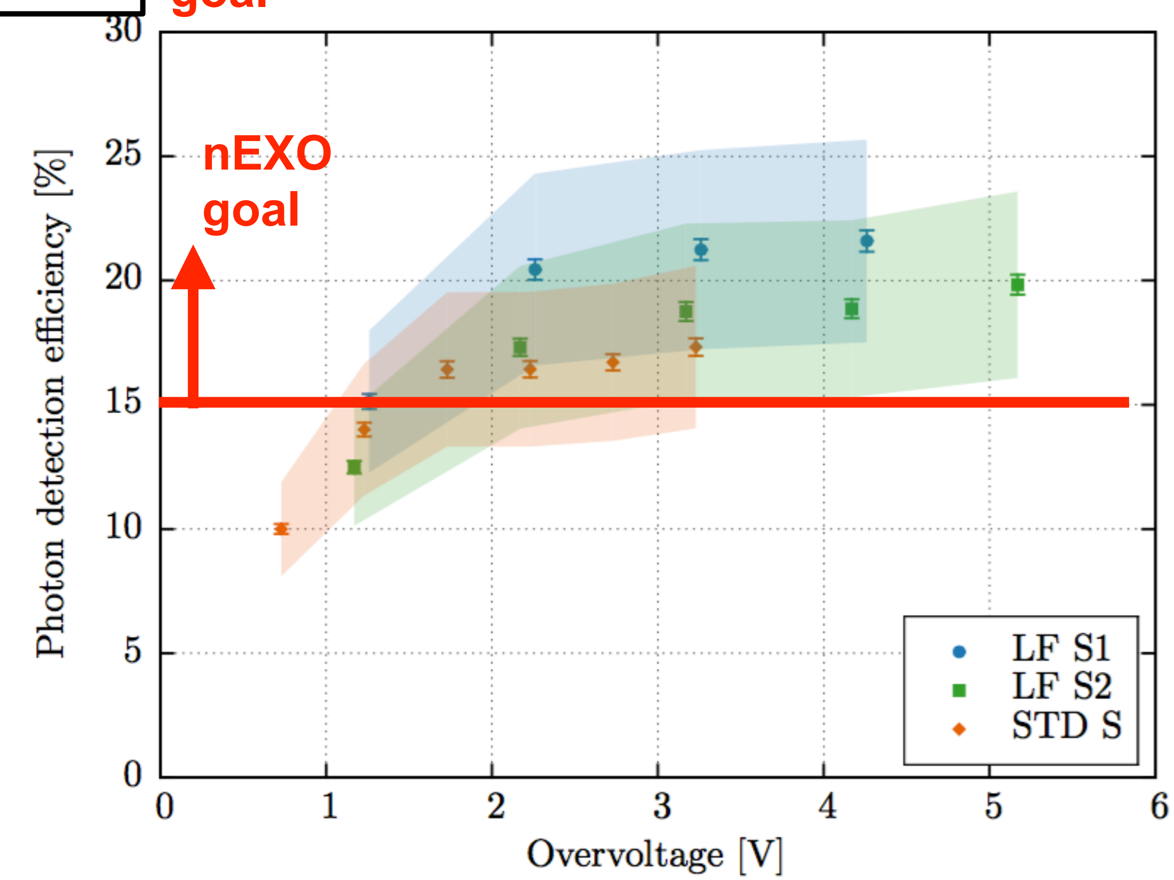
Requirements:

- Dark count rate < 50 Hz/mm2
- Correlated avalanche rate < 20%
- Noise < 0.1 pe
- Capacitance < 50 pF/mm2
- Unit area > 1 cm2



Preliminary



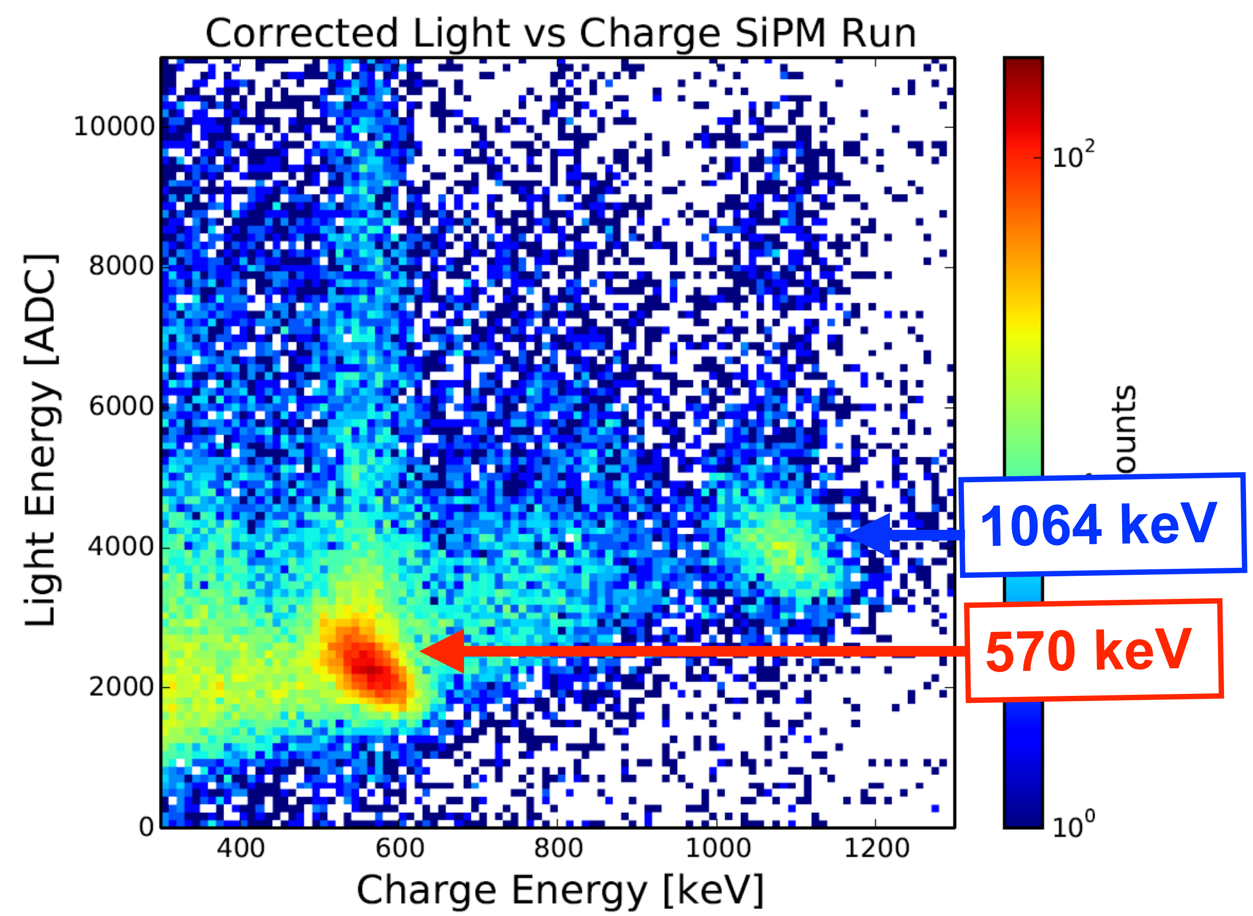


to be submitted to IEEE TRANSACTIONS

combining charge and light readout

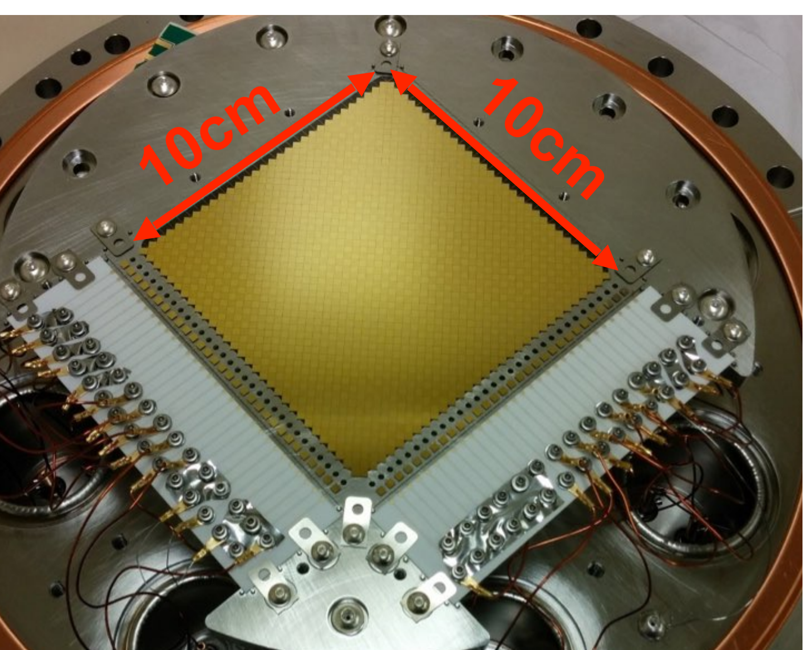
Test cell:

- ^{207}Bi source (570 and 1064 keV)
- 30 X and 30 Y charge channels
- 24 1x1 cm^2 SiPMs readout in pairs

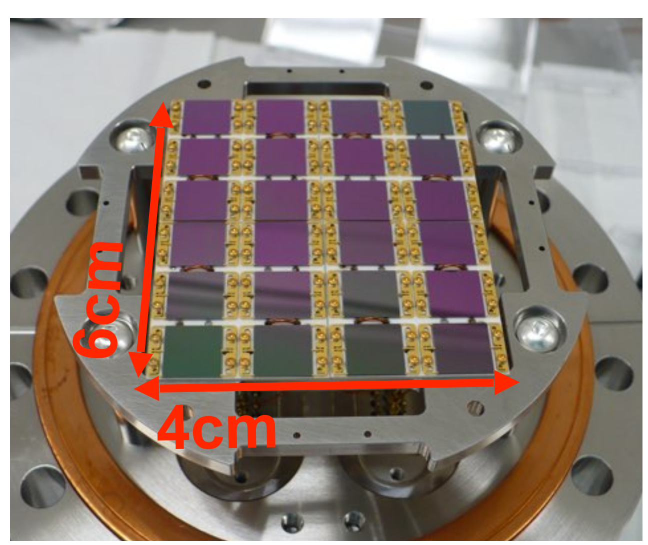


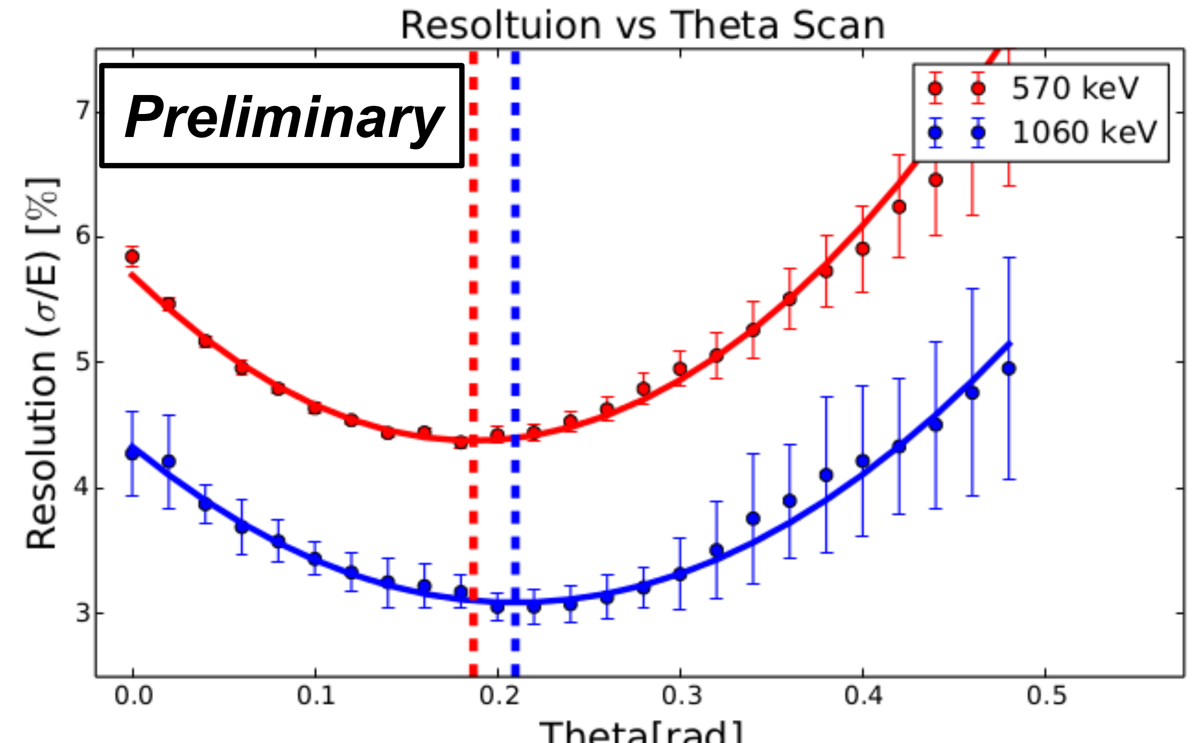
resolution improved from 5.8% to 4.6% at 570 keV peak

charge tile:



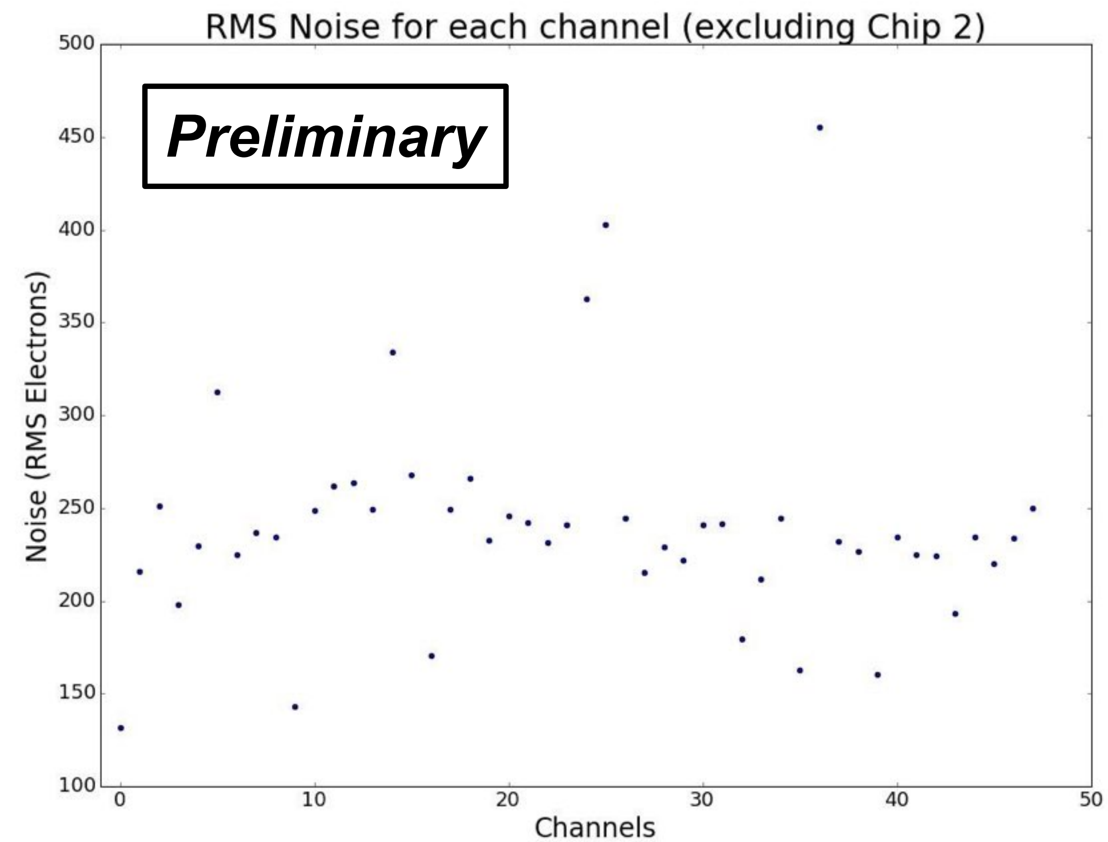
SiPM array:

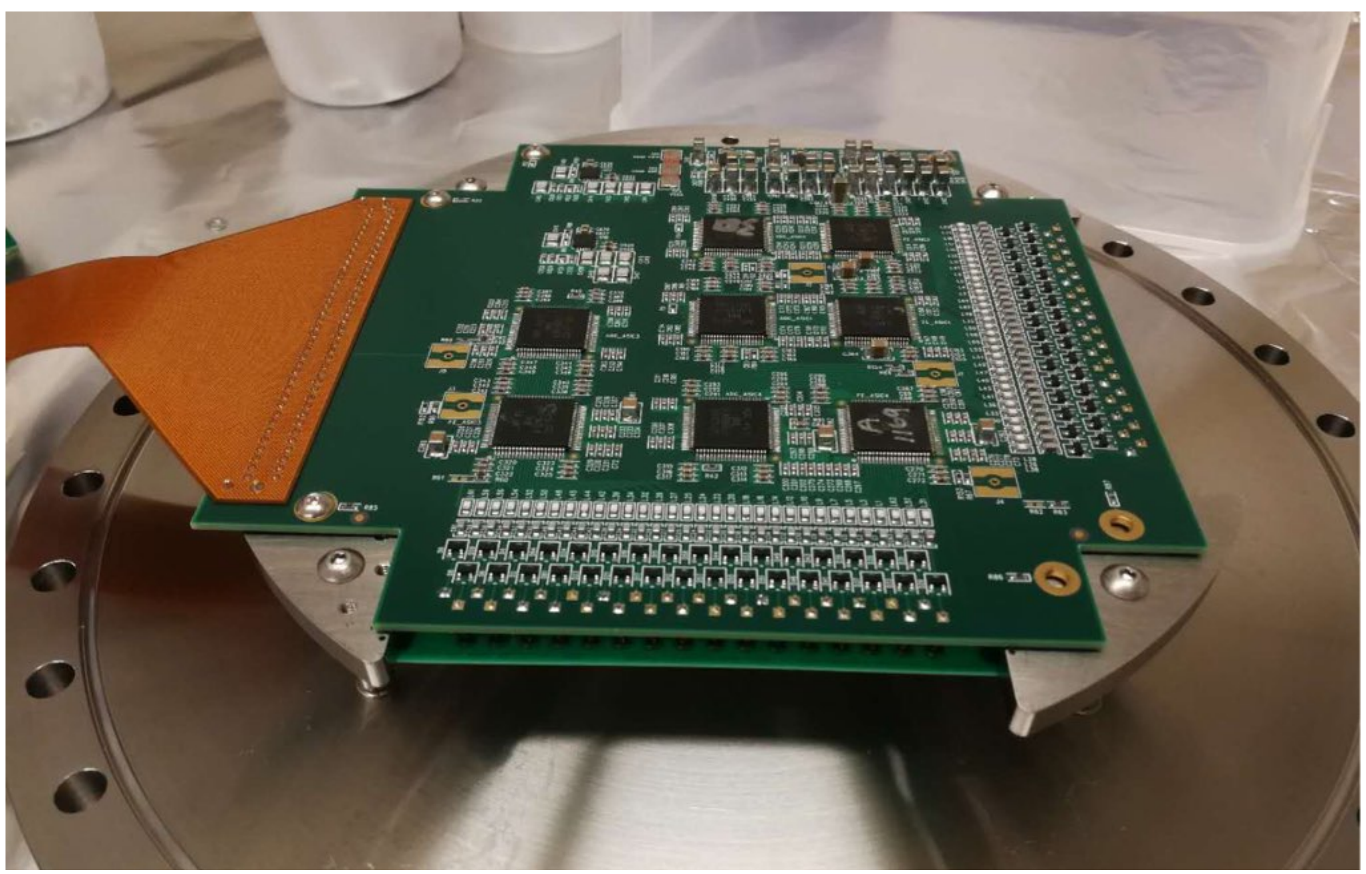


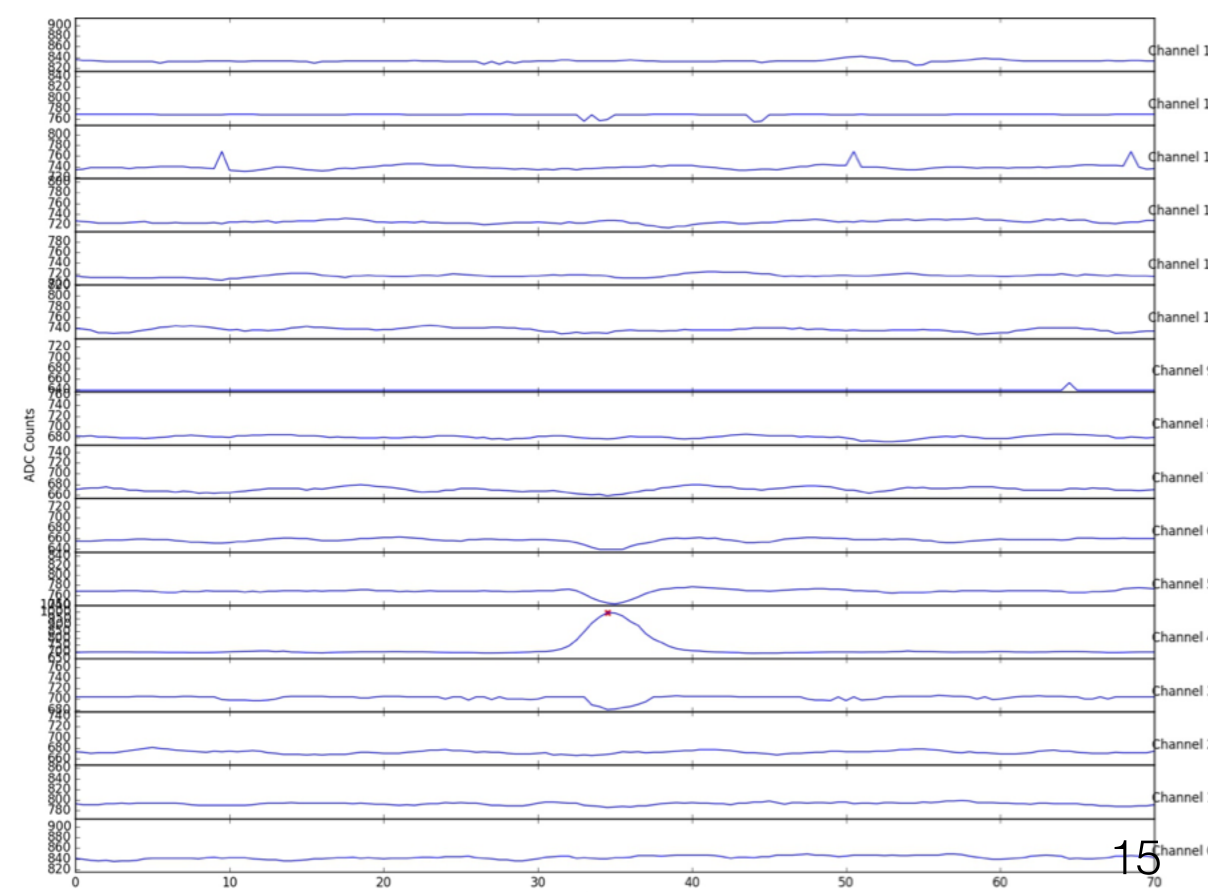


In-LXe cold electronics

- cold ASICs working inside LXe
  - ➡ designed initially for LAr TPCs (BNL)
  - ➡ 16 ch per chip
  - ➡ selectable gains@4.7, 7.8, 14, or 25 mV/fC
  - ➡ selectable peaking time@0.5, 1, 2, or 3 us
- ~ 240 e^- ENC noise achieved inside LXe
- analysis on-going

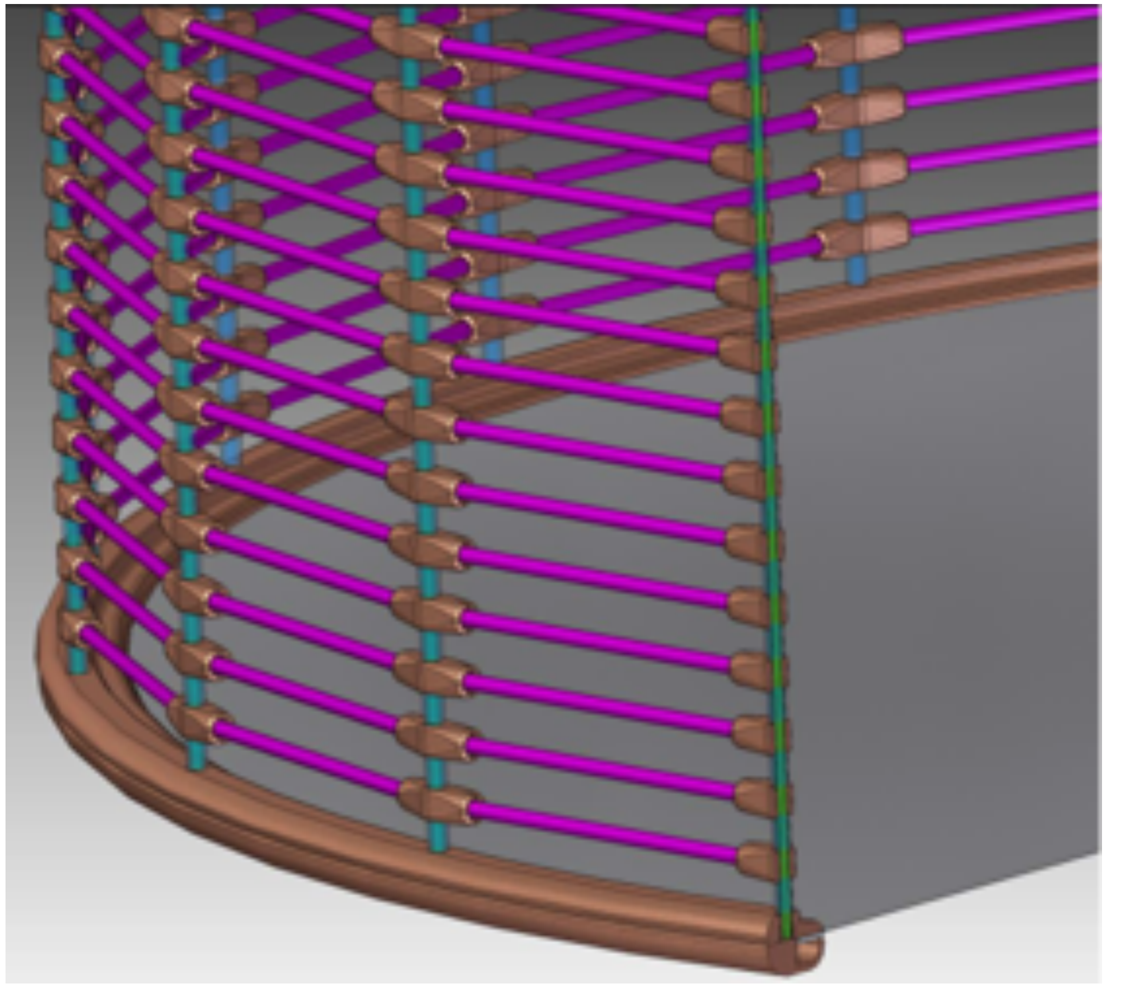




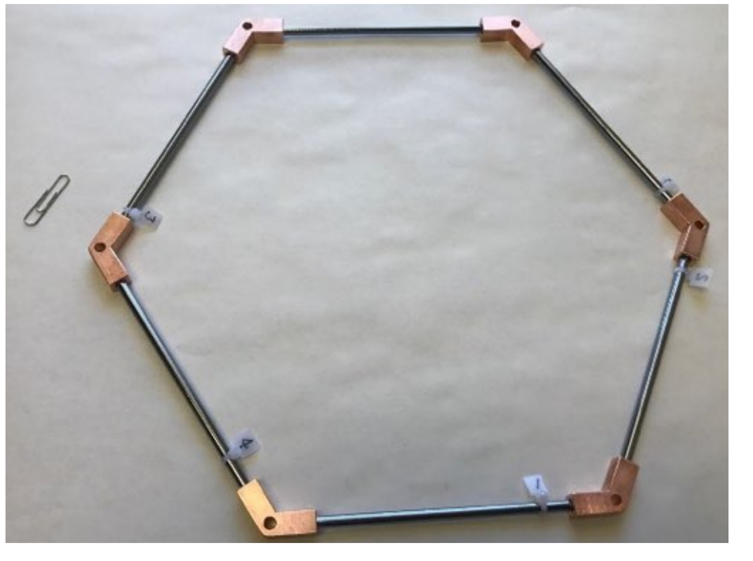


High voltage R&D

- Charge collection requires a stable HV
- Energy resolution improves with HV
- The scale up dramatically increases the electrostatic stored energy.
- A mitigation scheme is being considered.
- Resistive (and radio-pure) components is the optimal solution.
- Modelling and materials selection



Ideas:
- High-resistivity Si field shaping rings to limit spark current
- Reflective coating of cathode and field-shaping rings

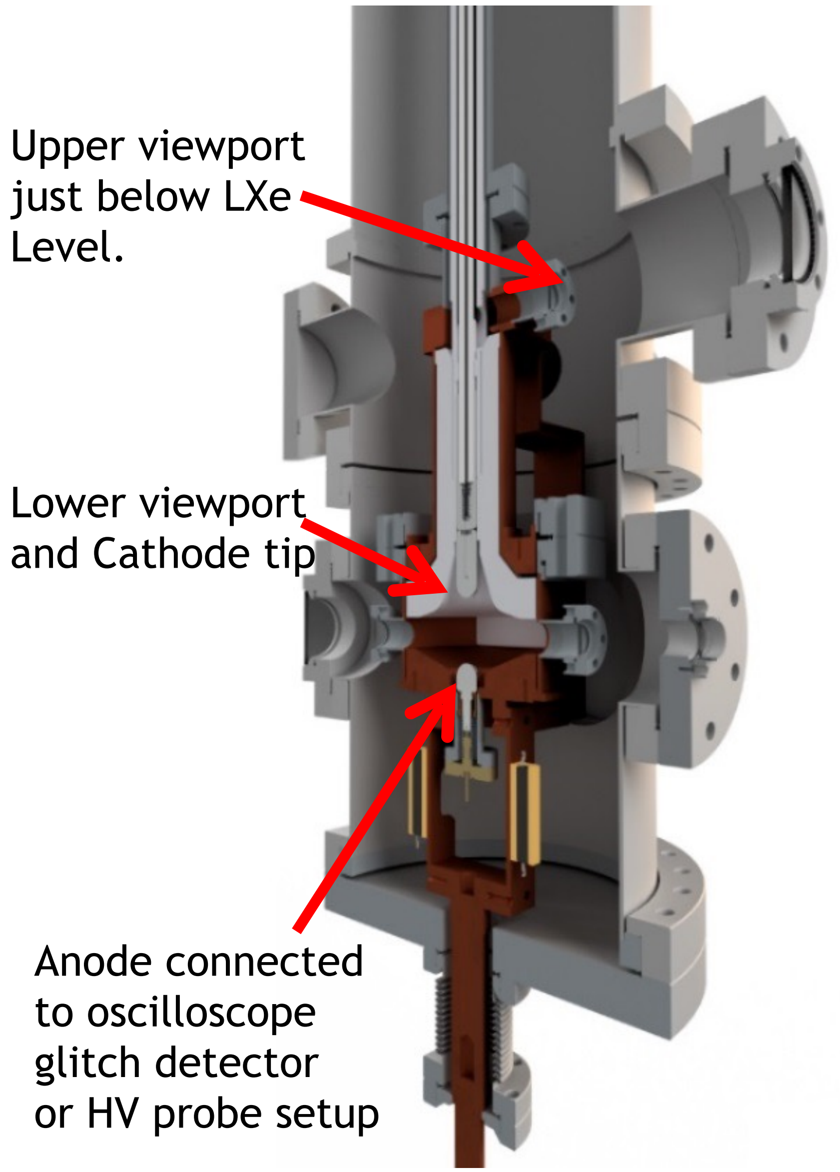


High voltage R&D test setups

30L LXe HV test setup at **Carleton U.** with cryogenic cameras

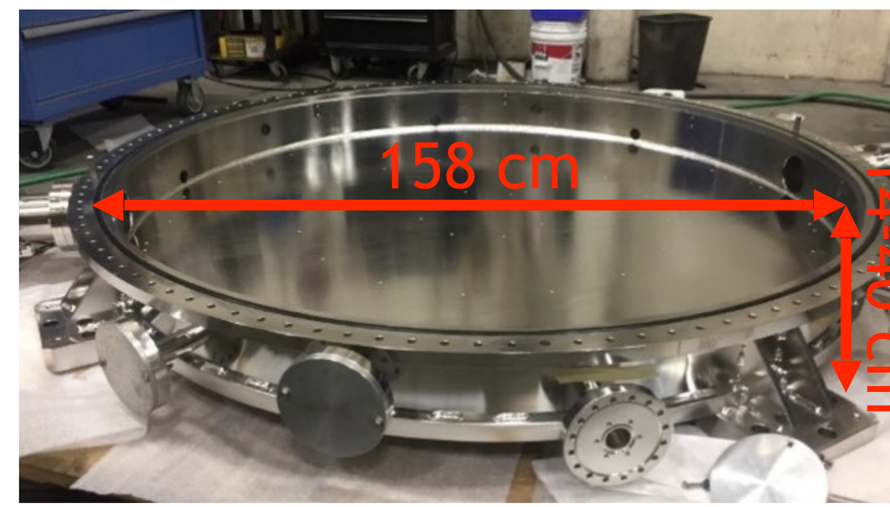
HV tests of ~30cm scale geometries

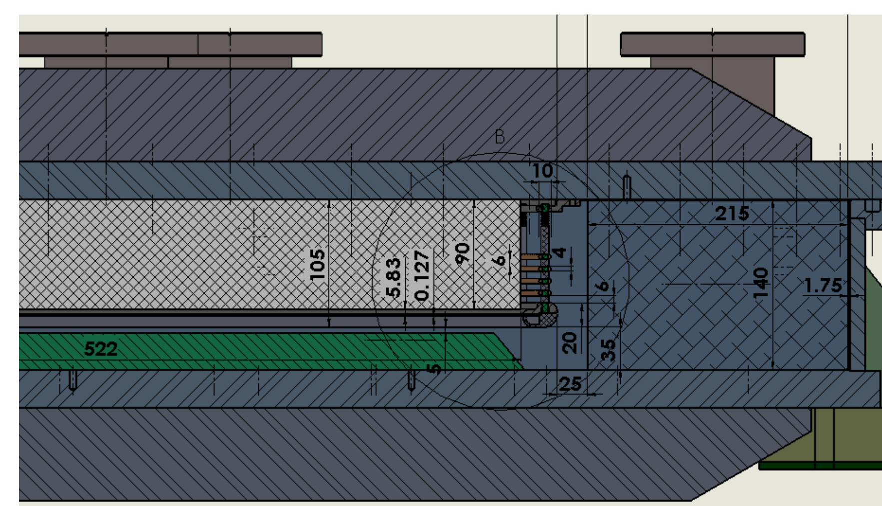
400 cc LXe HV cell at **SLAC**



Test of breakdown voltage in LXe for different small size geometries

800 kg LXe setup at **LLNL** to test full size parts (under development)





HV tests in LXe for different full-nEXO diameter size geometries

Summary

- nEXO is a planned 5-ton liquid xenon detector with 90% ^{136}Xe
- The sensitivity at 90% C.L. on ^{136}Xe $0\nu\beta\beta$ $T_{1/2}$ is $\mathcal{O}(10^{28})$ years, covering the entire inverted hierarchy region
- This converts to 5.7–17.7 meV sensitivity on Majorana mass
- Various R&D on charge and light readout, HV has been performed, demonstrating the detection principle of nEXO

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University of Bern, Switzerland — J-L Vuilleumier
Brookhaven National Laboratory, Upton NY, USA — M Chiu, G Giacomini, V Radeka, E Raguzin, S Rescia, T Tsang
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