The nEXO TPC: High Voltage Design R&D

Andrea Pocar‡ and **Peter C. Rowson**§ *(for the nEXO Collaboration)*

‡ Department of Physics and ACFI, University of Massachusetts, Amherst, MA, USA

§ SLAC National Accelerator Laboratory, Menlo Park, CA, USA

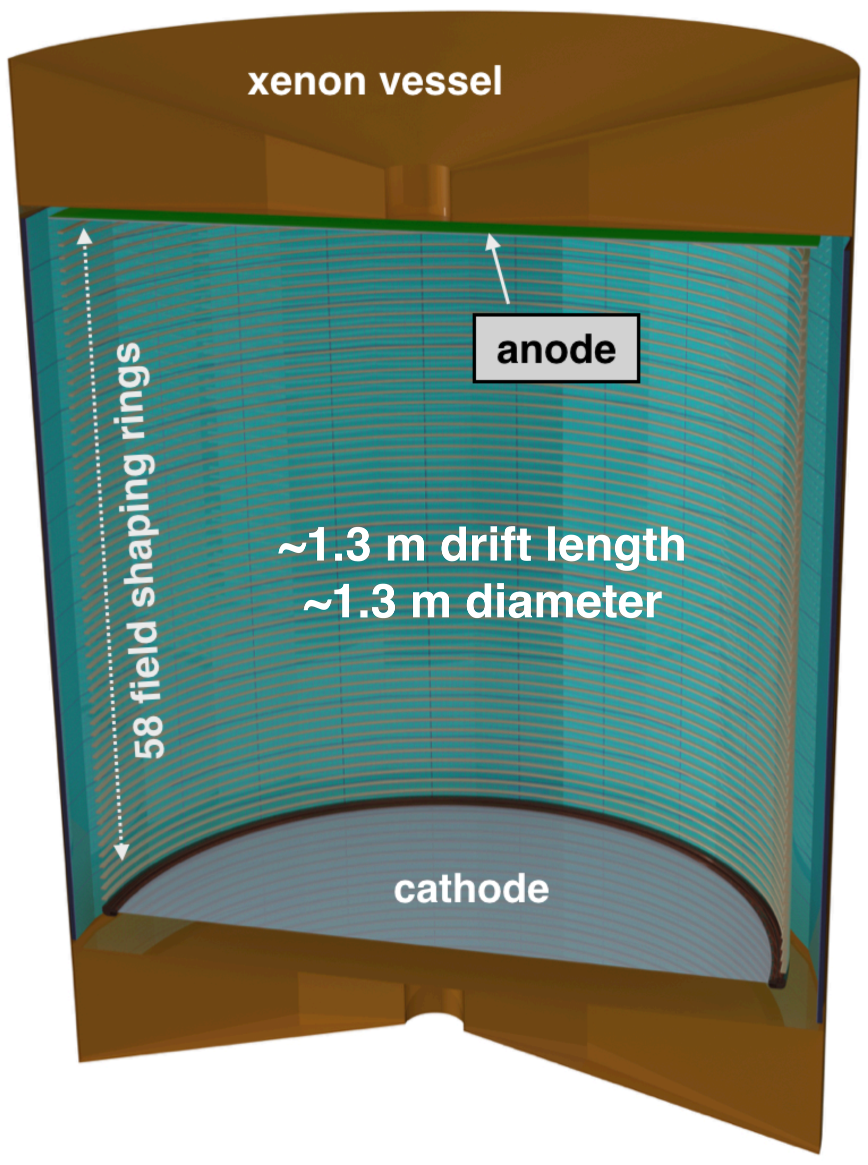
Neutrino XXXVIII — 4-9 June, 2018
Heidelberg, Germany

The nEXO Time Projection Chamber

The tonne-scale nEXO experiment will search for neutrino-less double beta ($0\nu\beta\beta$) decay of xenon-136 in five tonnes of enriched liquid xenon (90% ^{136}Xe) instrumented as a single-drift Time Projection Chamber (TPC) equipped with scintillation light readout. A follow-up to the successful EXO-200 experiment, nEXO is projected to reach a sensitivity $T_{1/2}^{0\nu\beta\beta}$ (^{136}Xe) ~ 10^{28} years in ten years. [1,2]

The nEXO TPC features:

- Grid-less charge collection anode 'tiles' with crossed, metal strips deposited on fused silica wafers.[3]
- Thin, tensioned cathode plane.
- Optically open, lightweight field shaping electrode structure.
- Long (~130 cm) sapphire tensioning rods, threaded through the field rings. Sapphire or fused silica spacers between the rings also work as potential grading resistors.
- Reflecting electrodes and internal surfaces, where possible.
- Array of VUV-sensitive SiPMs (~4 m²) on the cylindrical barrel. [4]
- In-xenon, low noise cryogenic front-end electronics (charge and light).
- Minimal use of plastics for maximal xenon chemical purity.



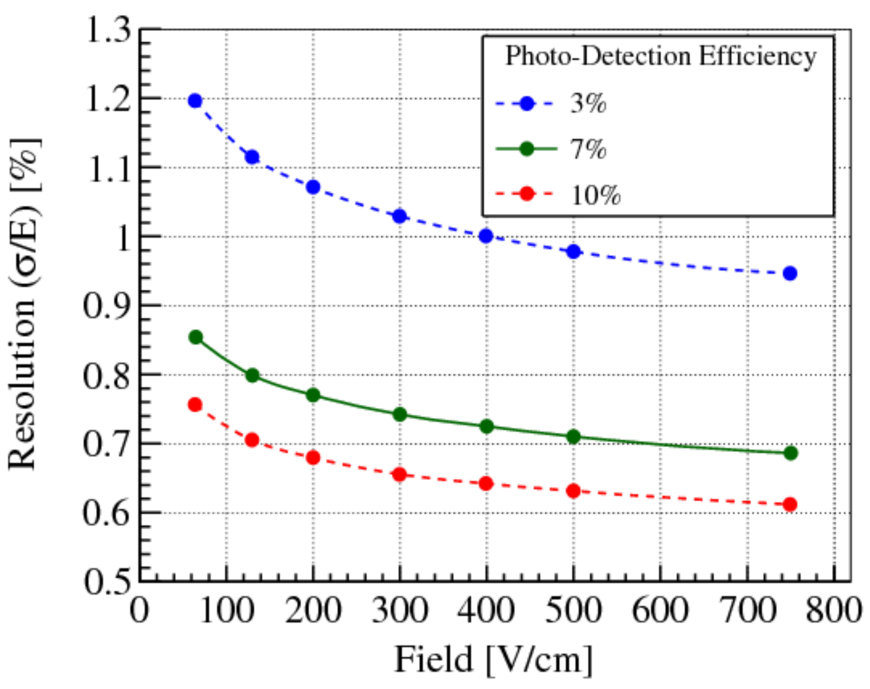
- Ultra-low radioactivity, thin copper vessel.

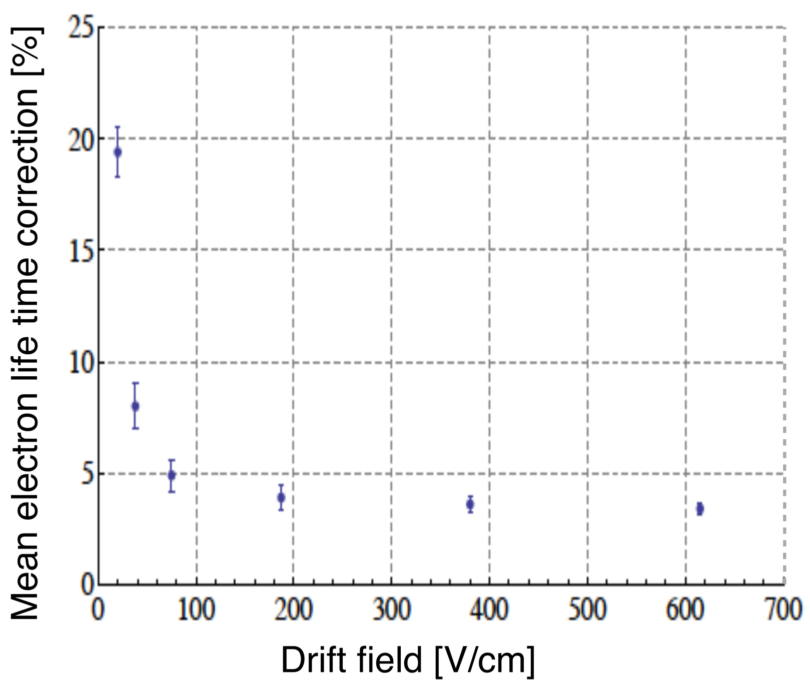
High Voltage requirements for nEXO

In nEXO, ionization drifts to the charge detector at the anode under an electric field established applying negative HV to the cathode. The nEXO TPC's benchmark drift field is 400 V/cm, the same as EXO-200 Phase I [5] (currently EXO-200 runs at 600 V/cm)). This corresponds to a cathode potential of -50 kV. Given recurring problems encountered by LXe TPC's in reaching their design HV [6], an engineering safety factor of two is currently assumed, for a cathode potential of -100 kV. Safe and efficient HV design is one of the most challenging engineering constraints for nEXO.

A lower drift field would bring the following pros and cons:

- Reduce the ionization resolution and, to a lesser extent, total (charge+light) energy resolution (significant below ~100 V/cm).
- Increase electron loss due to impurities in the LXe (<100 V/cm).
- Enhance the effects of stray electric fields in the TPC.
- Mitigate standoff requirements, allowing one to increase the size of the TPC field cage and the fully instrumented LXe volume.
- Reduce the risk of potentially damaging spark accidents

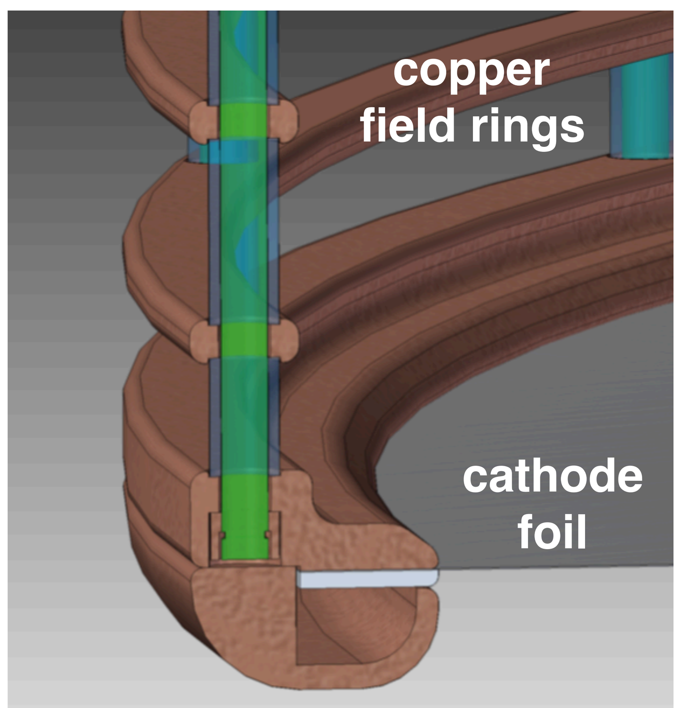




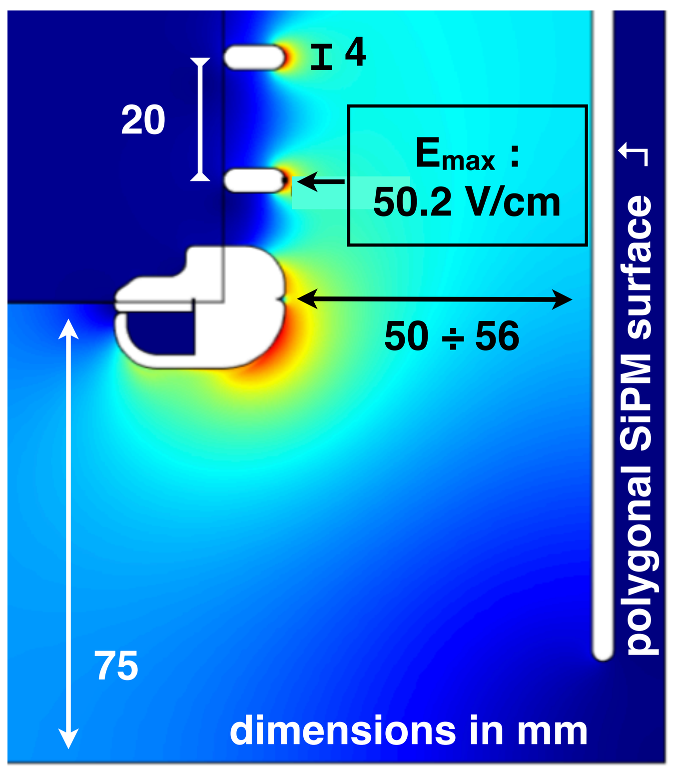
✦ The drift field effects listed above vary slowly, as does the sensitivity increase from an incrementally larger TPC

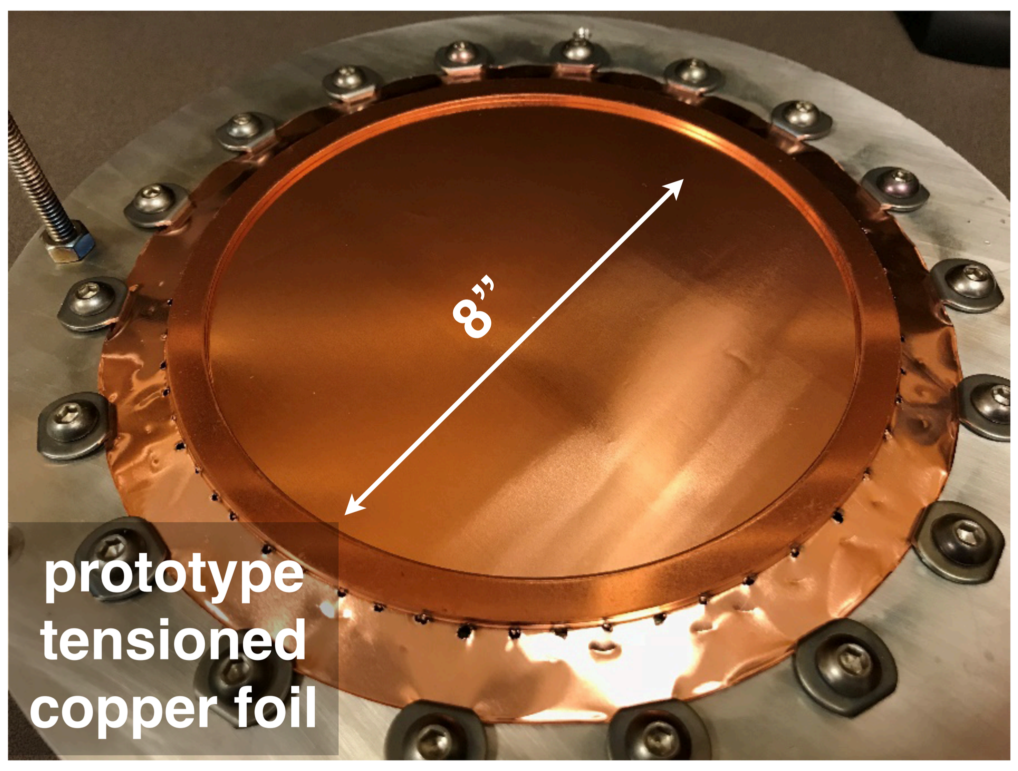
✦ The optimization of the nEXO drift field and TPC dimensions will be performed that considers their trade-offs. Input will come from ongoing R&D work and more refined detector simulations.

The nEXO 'conductive' TPC design



- The current design uses:
  - 58 copper field shaping rings
  - A tensioned metal (Cu or P-bronze) foil welded or epoxied to an a ring
- The highest electric fields in the TPC are in proximity of the cathode.
- The electrode profiles and the standoff distances to ground are studied with COMSOL electrostatic simulations.





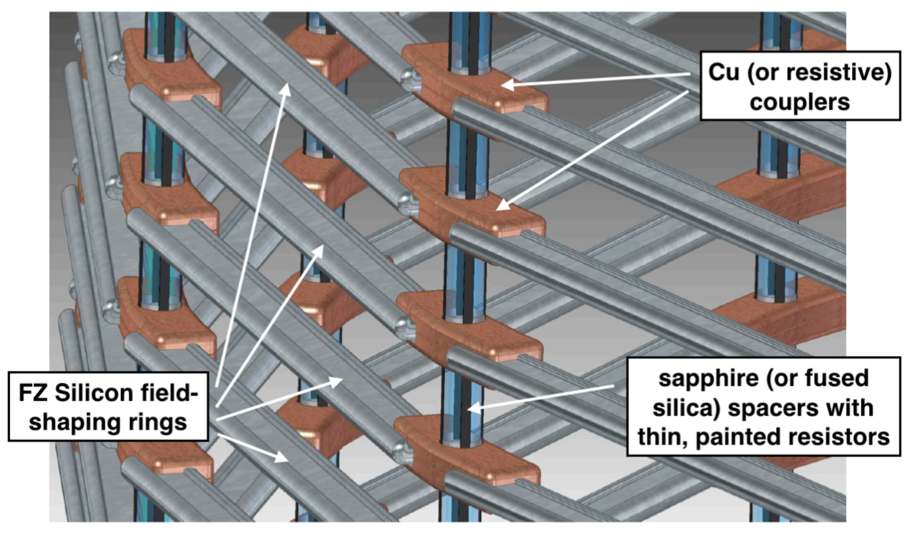
Alternative cathode solutions are being considered with the goal of minimizing the intrinsic radioactivity of this component and allowing tagging of the decays of radon daughters that drift onto it:

- Thin, aluminized mylar, that allows α-particles to traverse it.
- Stretched mesh membrane (like in EXO-200 [7]).
- Scintillating cathode film.

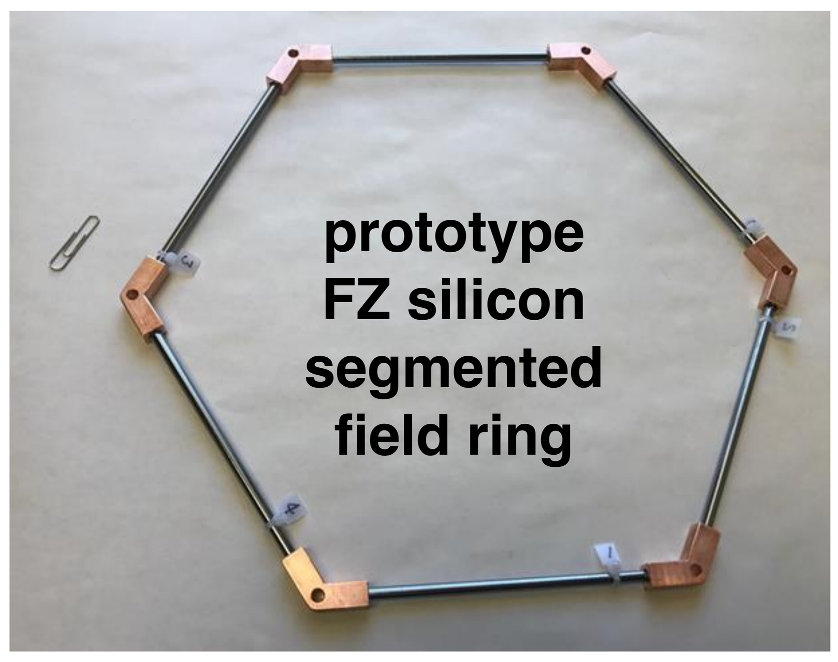
HV risk mitigation: 'resistive' design

High Voltage protection for nEXO has two different aspects:

1. Small 'glitches' (few 10s mV) on the HV as seen in EXO-200, if frequent enough, could hinder TPC operation (as observed in EXO-200 at excessive cathode voltages).
2. Spark discharge of the TPC stored energy (a few Joule) could be catastrophic for the integrity of the in-xenon electronics and the SiPMs.



Novel high resistivity TPC electrodes, in particular segmented field rings made of intrinsic float-zone (FZ) silicon, are being investigated.



- FZ silicon was tested with resistivity of 80 kΩ-cm, and is one of the most radio-clean solids ever assayed.
- A resistive cathode design is yet to be developed, as sufficiently radio-clean resistive films have still to be found.
- Prototype and final TPC elements will be tested in LXe for HV performance in several nEXO test facilities of different sizes.

Bibliography

[1] J.B. Albert et.al. arXiv:1710.05075 (t.a. PRC)
[2] nEXO Collaboration, arXiv:1805.11142
[3] M. Jewell et al., JINST 13, P01006 (2018)
[4] I. Ostrovskiy et al., IEEE-TNS 62, 1825 (2015)
[5] EXO-200 Collab., Nature 510, 229 (2014)
[6] B. Rebel et al., JINST 9, T08004 (2014)
[7] M. Auger et al., JINST 7, P05010 (2012)

The nEXO R&D is supported by: DoE Office of Science, NSF, and LDRD programs at LLNL, ORNL, BNL, and PNNL (US); NSERC, CFI, FRQNT, and NRC (Canada); CAS and ISTP (China); IBS (Korea); RFBR (Russia); SNF (Switzerland).

(***contact information** — Andrea Pocar, pocar@umass.edu and Peter C. Rowson, rowson@slac.stanford.edu*)