Field emission for liquid xenon purification in next generation liquid xenon detectors

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INTRODUCTION

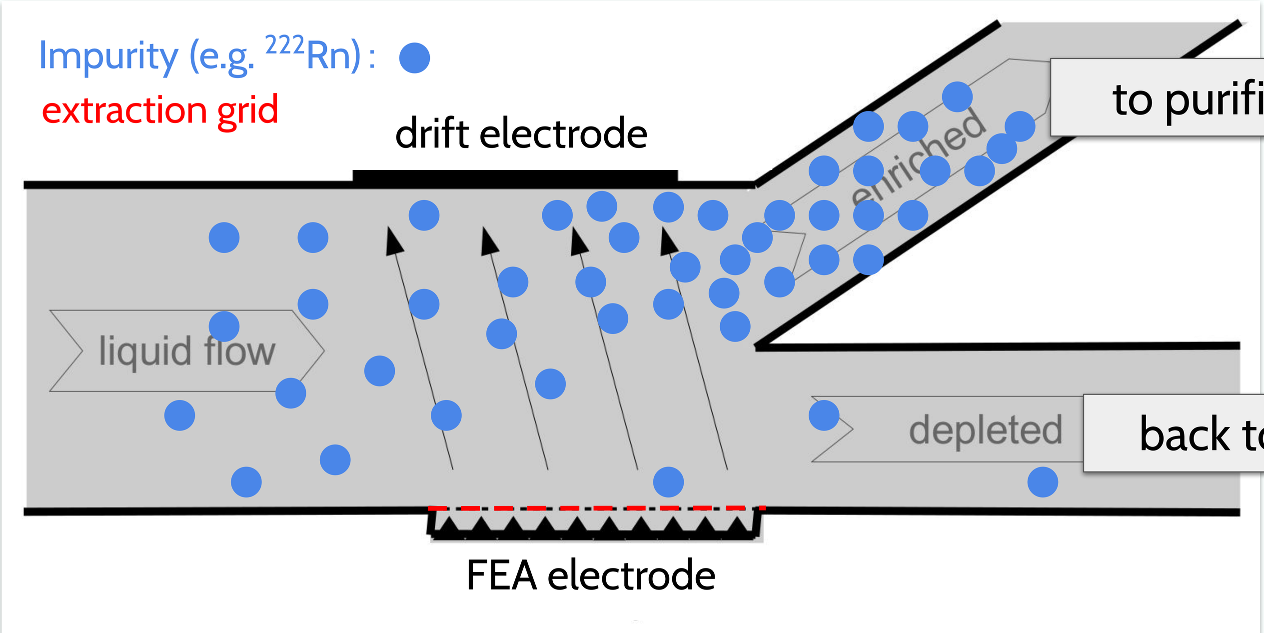
Radon is the main impurity in the current liquid xenon based detectors. We have methods that consists on distillation for example to get rid of ^{222}Rn. However, next generation detector will require higher purification rate, which will not be satisfied by using only the current purification methods.

What we want to do ultimately:

- use field emission arrays (FEAs) to inject electron/hole current into LXe.
  → electron/hole will then attach to Rn so that we can drift it inside the liquid and remove it

Objective of the first tests:

- observe current injection using FEA
- see what happens to tips after current discharge



FEAs

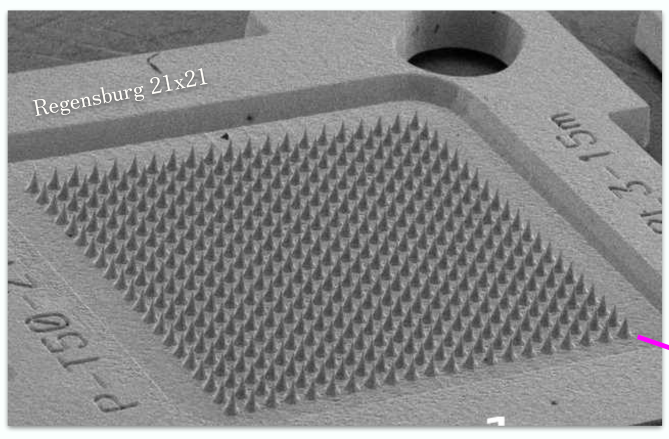
We are using FEAs provided by Prof. Rupert's group from OTH-Regensburg University. Some properties of FEAs:

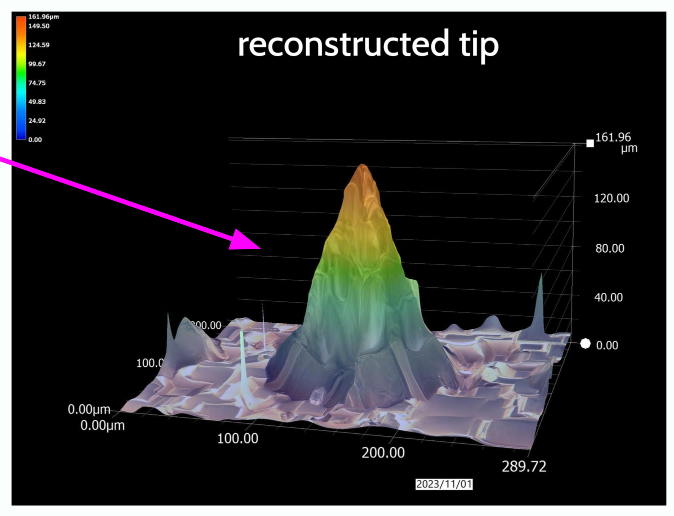
- made of silicon (n-doped)
- they were laser "chiseled" (both tips and grid) with this machine

The imaging of the tips were conducted using the scanning electron microscope (SEM) and the Keyence digital optical microscope (VHX) with 3D reconstruction software. Explained in Xiaoxin's poster #21

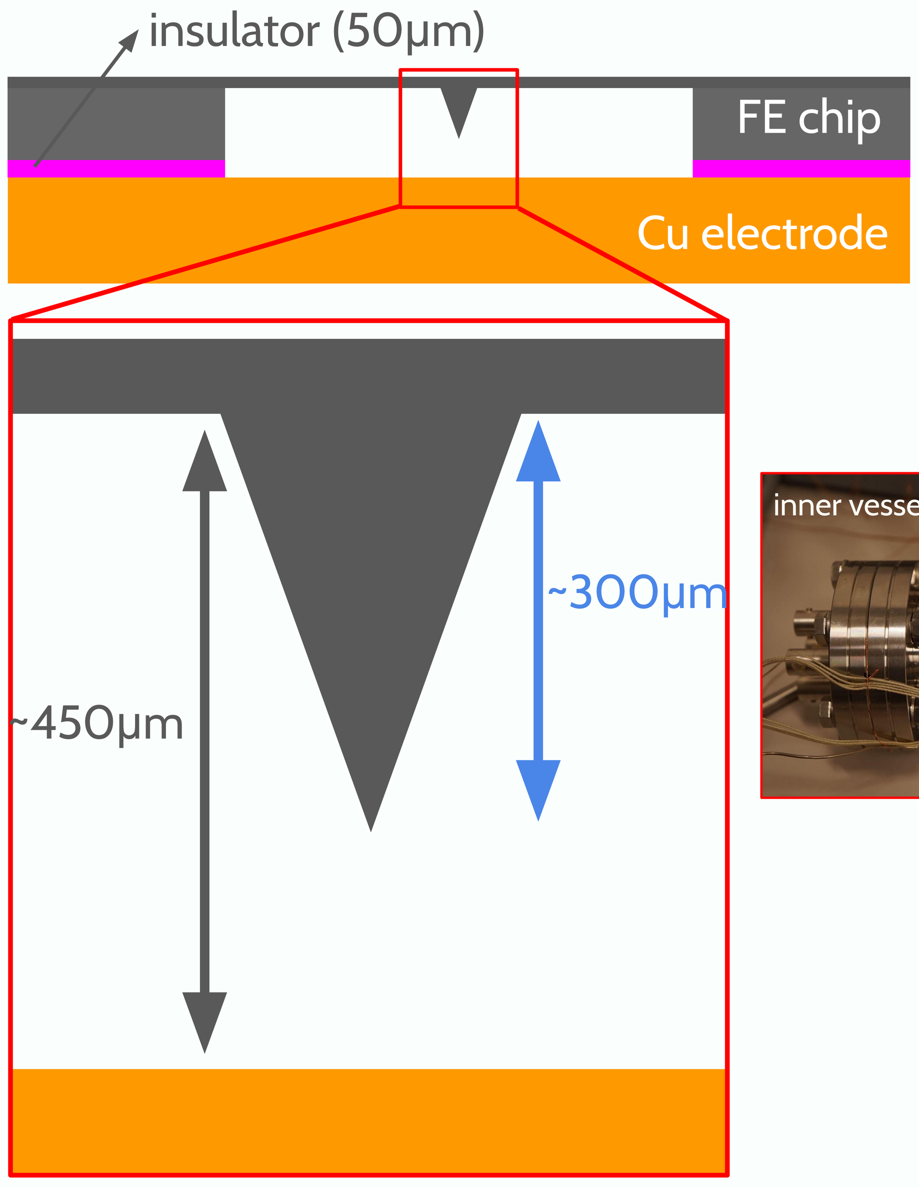
The experiment that this poster is based on was conducted using single-tip FE chips, meaning that each chip has only ONE tip. This allows:

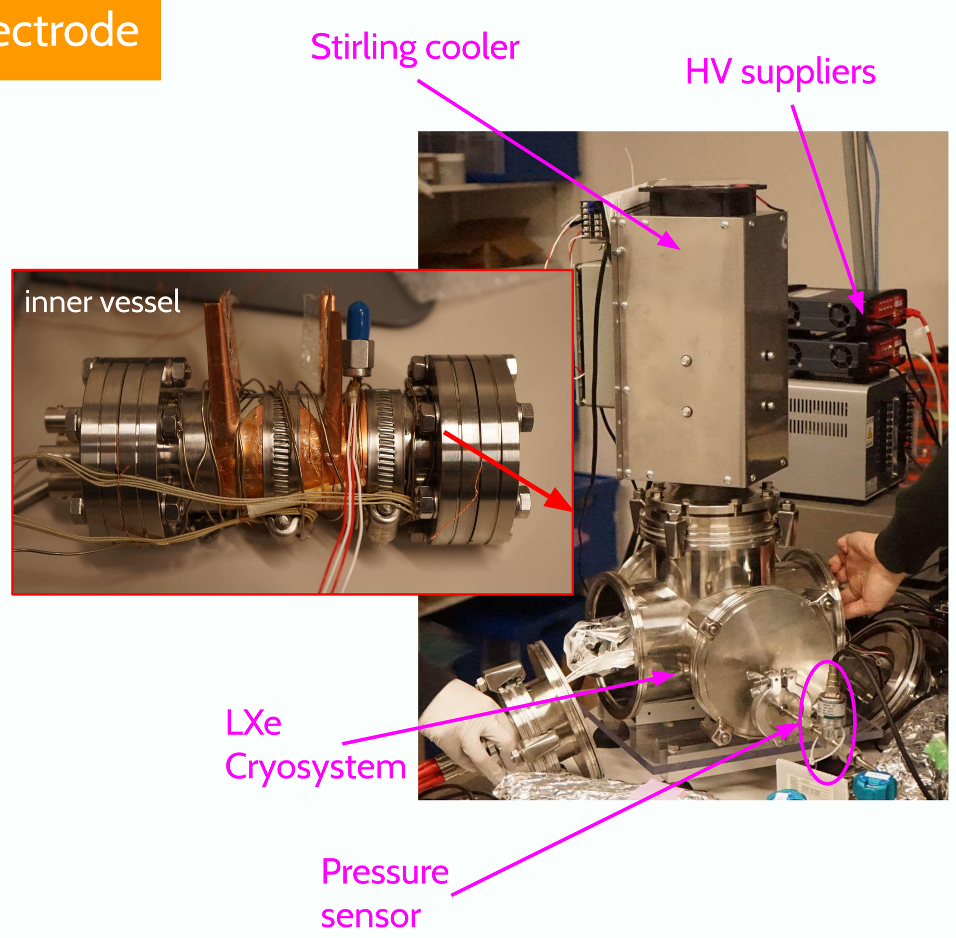
- attribute the current to the tip
- study the limits (total charge/highest current) of one tip





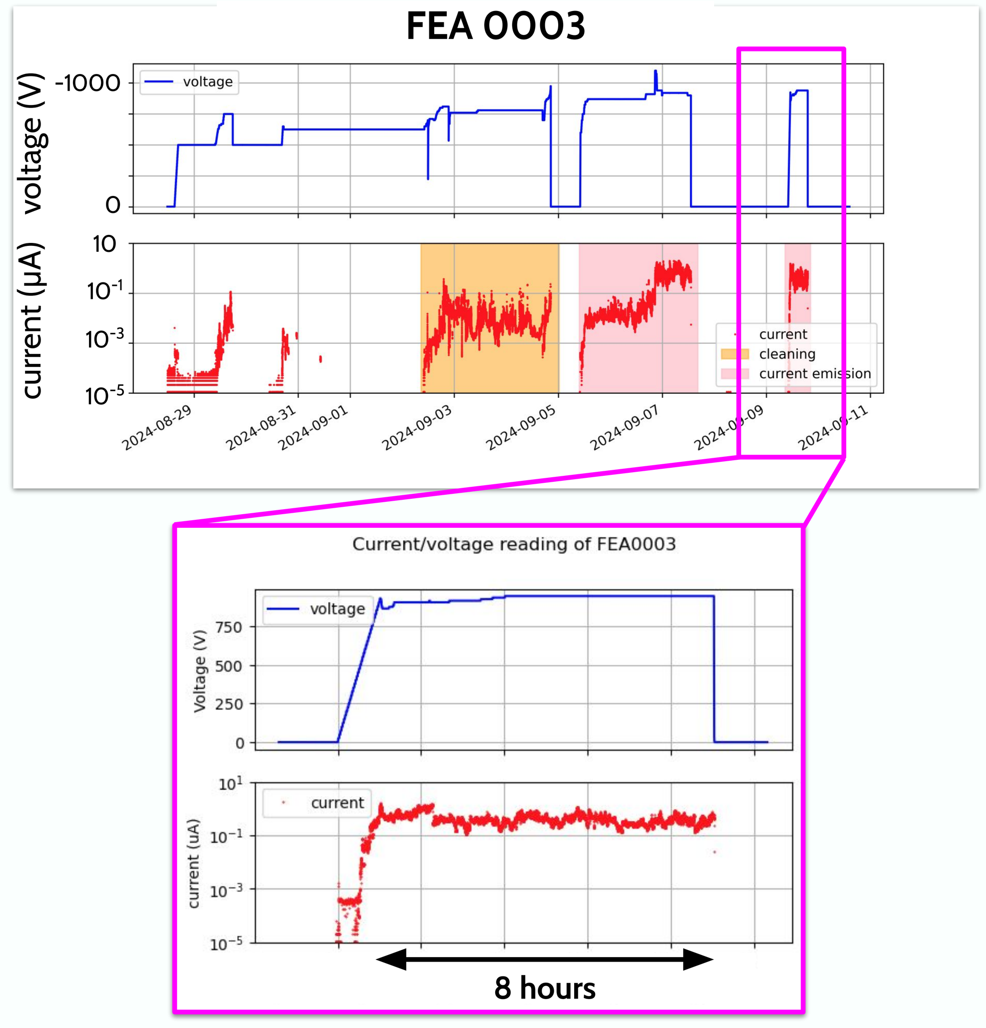
FE CHIP SETUP





RESULT

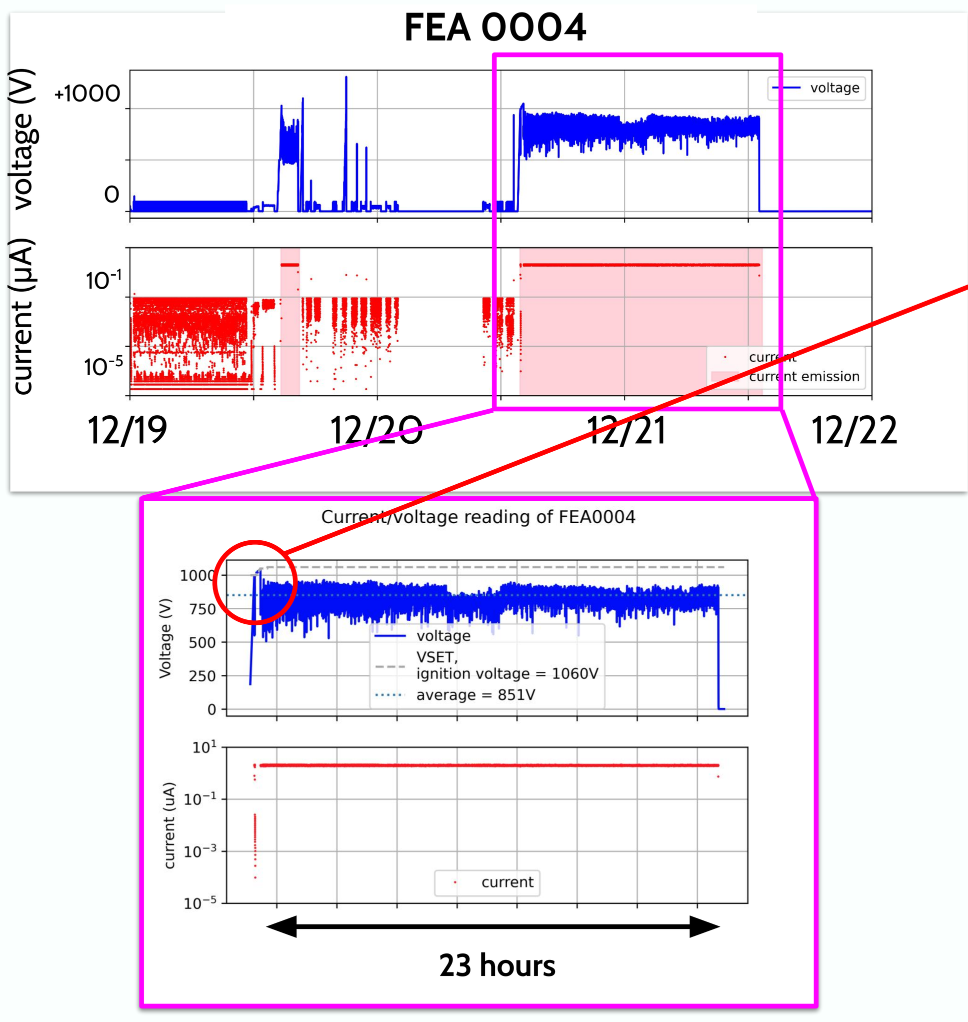
VACUUM CONDITIONING:



one of the main cleaning procedures, we can see in the yellow background a current with larger fluctuation, whereas in the red background regions, the current is more stable. One example of a stable current of 9 hours is shown in pink.

This procedure allows us to burn-off contaminants stick in the tip, adjust the shape of the tip and rip-off the oxidation layer.

LIQUID XENON RUN:



In liquid xenon, we observed currents being "activated" at voltages from 800V~1400V depending on the FEAs.

The "activation" was observed for the first time and its mechanism is still under investigation.

SEE XIAOXIN' POSTER #21 FOR IMAGES OF THE TIPS BEFORE AND AFTER THE TEST!!!

CONCLUSION & FUTURE PLANS

- both electrons & holes successfully emitted in liquid xenon
- newly observed:
  - fuzz & outgrowth (Xiaoxin poster #21)
  - "activation" of current

Near future:

- Test leak current (ongoing)
- FEA stability: order 1 year operation?
  - 1x1 FE chips → do they stabilize??
  - 21x21 FEAs → more current with less degradation
  - copper as bulk material → heat & electric conductivity

Far future:

→ Rn drifting test

References

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[2] Arii, Kiyomitsu, and Werner Schmidt. 1984. "Current Injection and Light Emission in Liquid Argon and Xenon in a Divergent Electric Field." IEEE Transactions on Electrical Insulation EI-19 (1): 16–23. https://doi.org/10.1109/TEI.1984.298728.

[3] Hausladen, M., P. Buchner, M. Bartl, M. Bachmann, and R. Schreiner. 2024. "Integrated Multichip Field Emission Electron Source Fabricated by Laser-Micromachining and MEMS Technology." Journal of Vacuum Science & Technology B 42 (1): 012201. https://doi.org/10.1116/6.0003233.

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