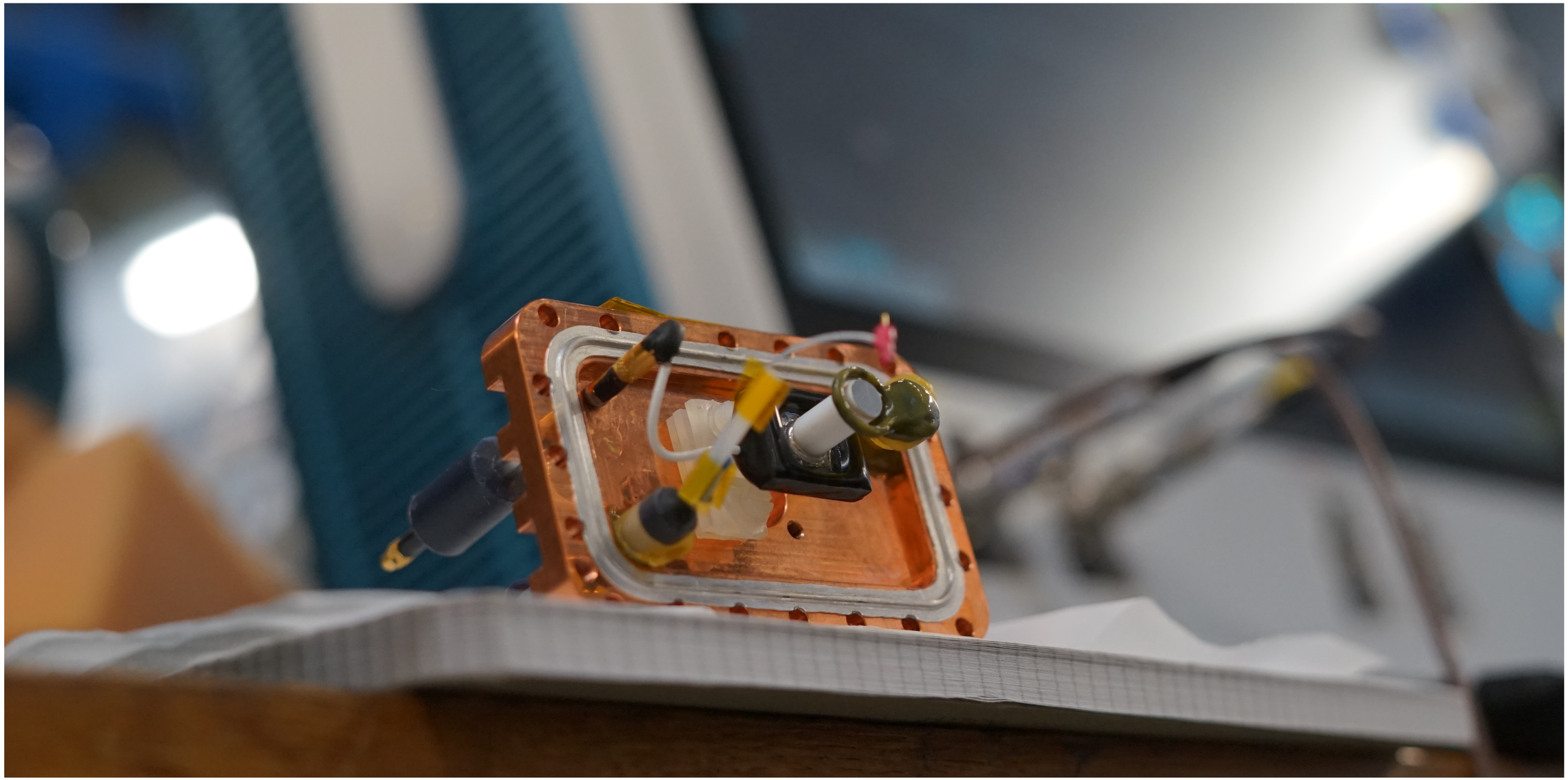
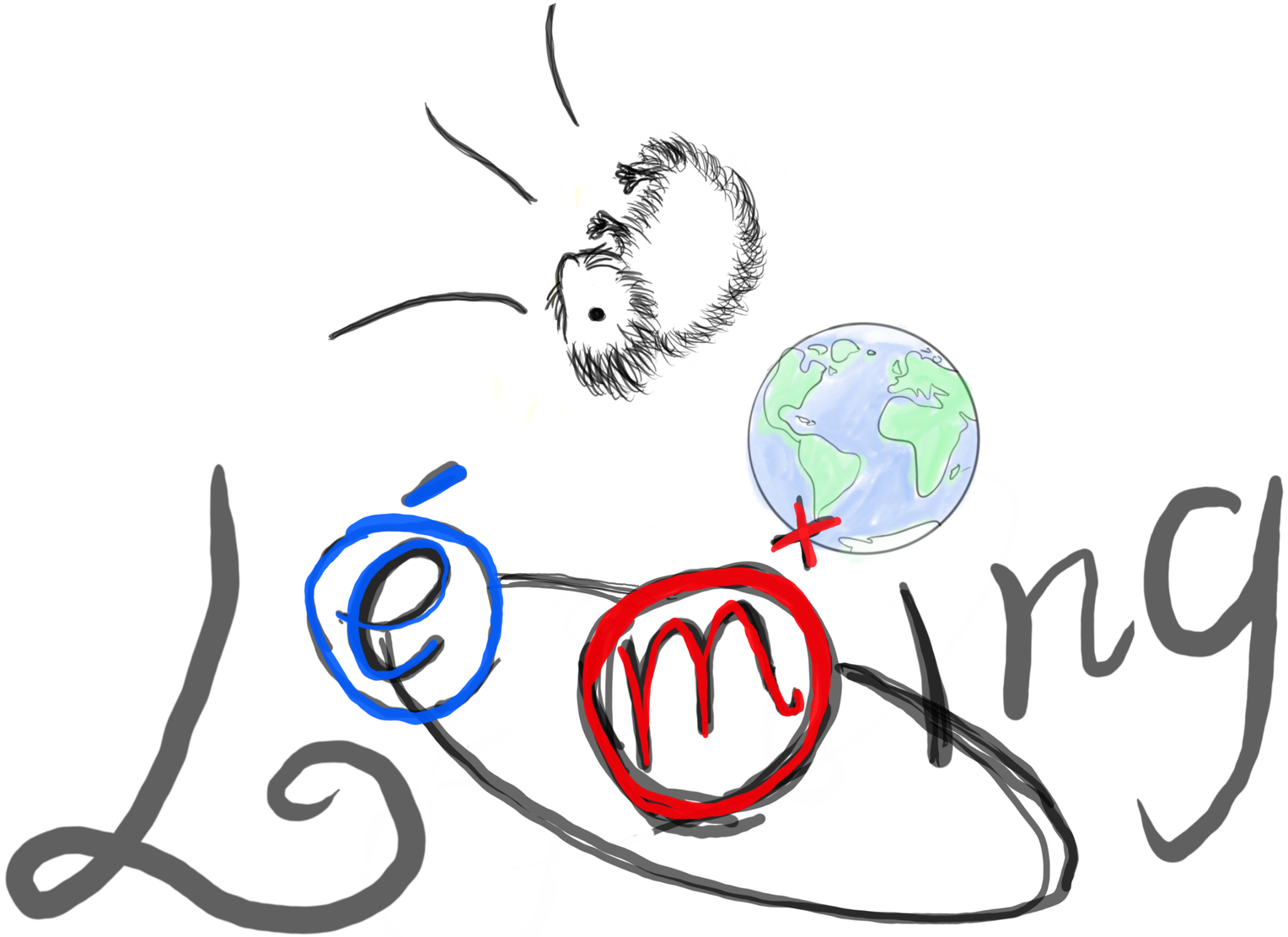


Atomic electron detector for the LEMING experiment

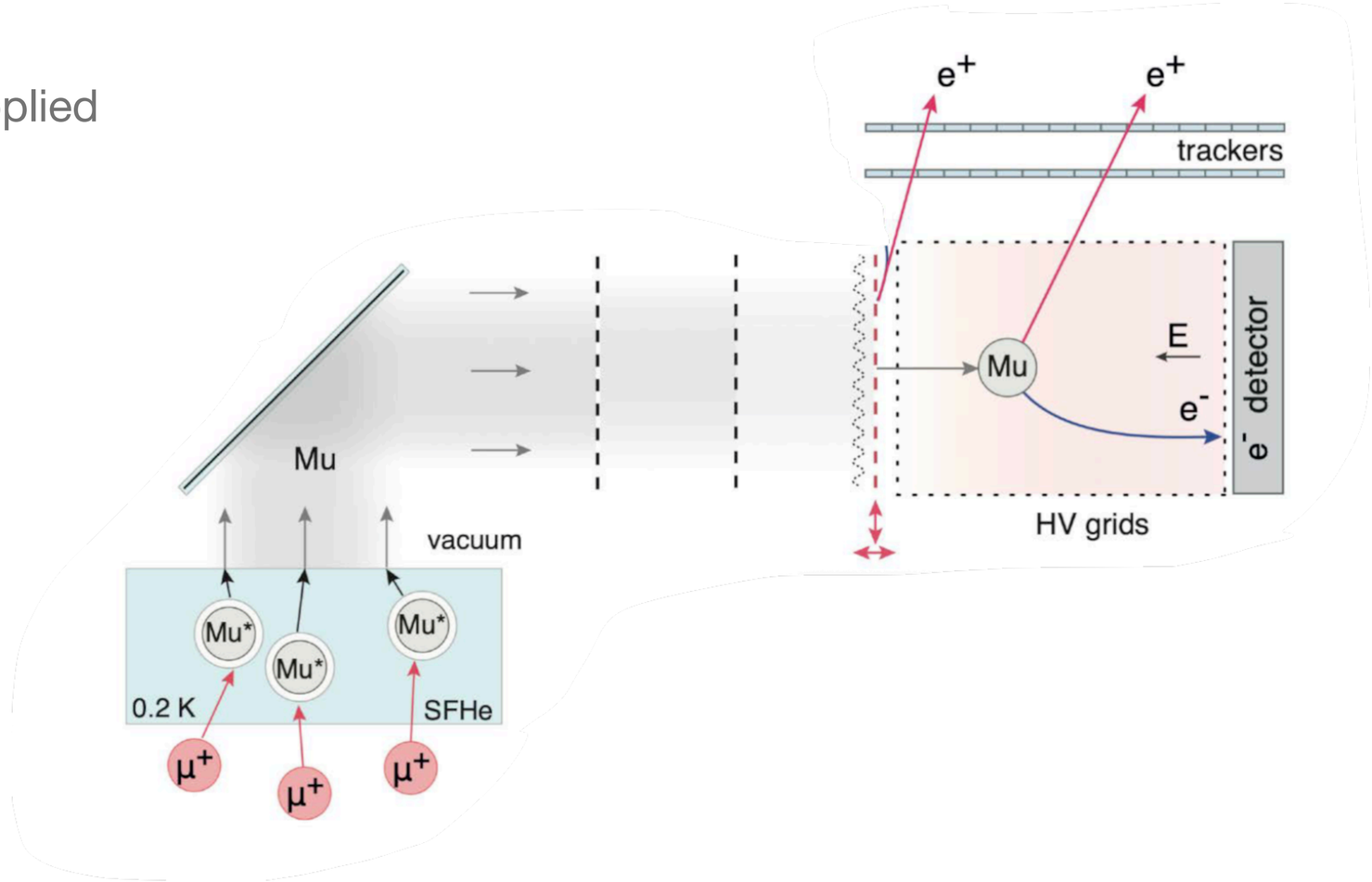
Paul Wegmann - CHIPP winter school 2023



LEptons in Muonium INteracting with Gravity

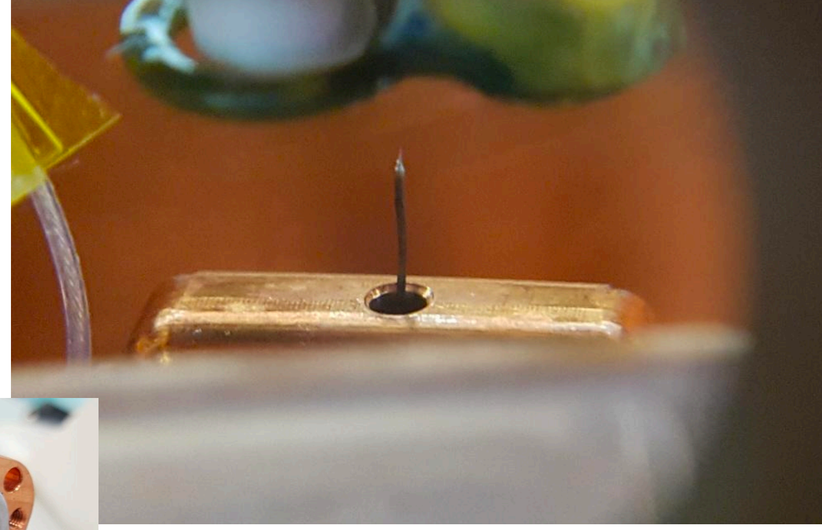
Experimental Challenges

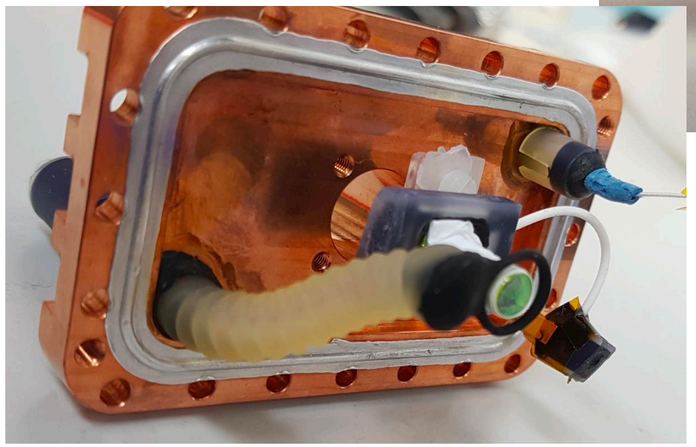
- Superfluid Helium (SFHe)
  - Limits High voltage which can be applied
    - Need low threshold detector
  - Detector needs to work below 1K
- Coincidence measurement
  - Need fast signal
- High counting rates
  - Need fast reset time

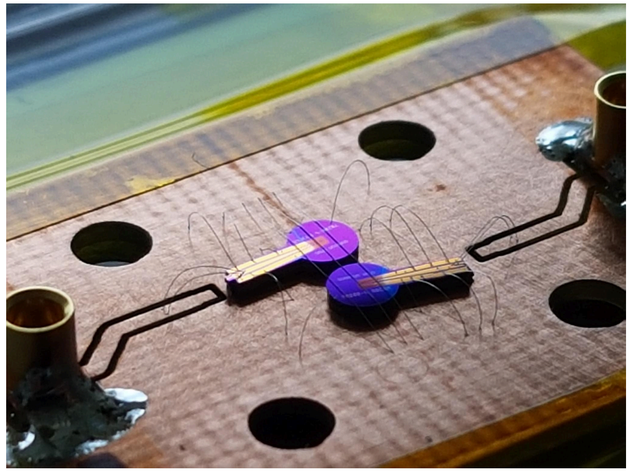


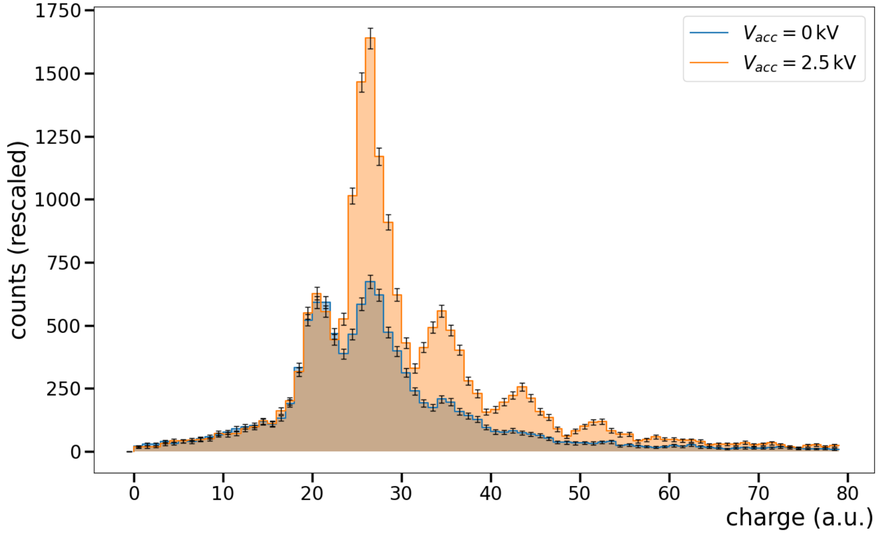
My work

- Figure out a reproducible electron source in the cold (and ideally) in SFHe
  - Field emission tip (FET)
- Testing alternative scintillators:
  - Perovskite nanocrystals, measured sensitivity down to 2.5kV
- Testing alternative detector designs:
  - Superconducting nanowires









Thanks for your Attention!

I’m happy to take Questions

Backup slides

Schematic components for a gravity experiment

Interferometer

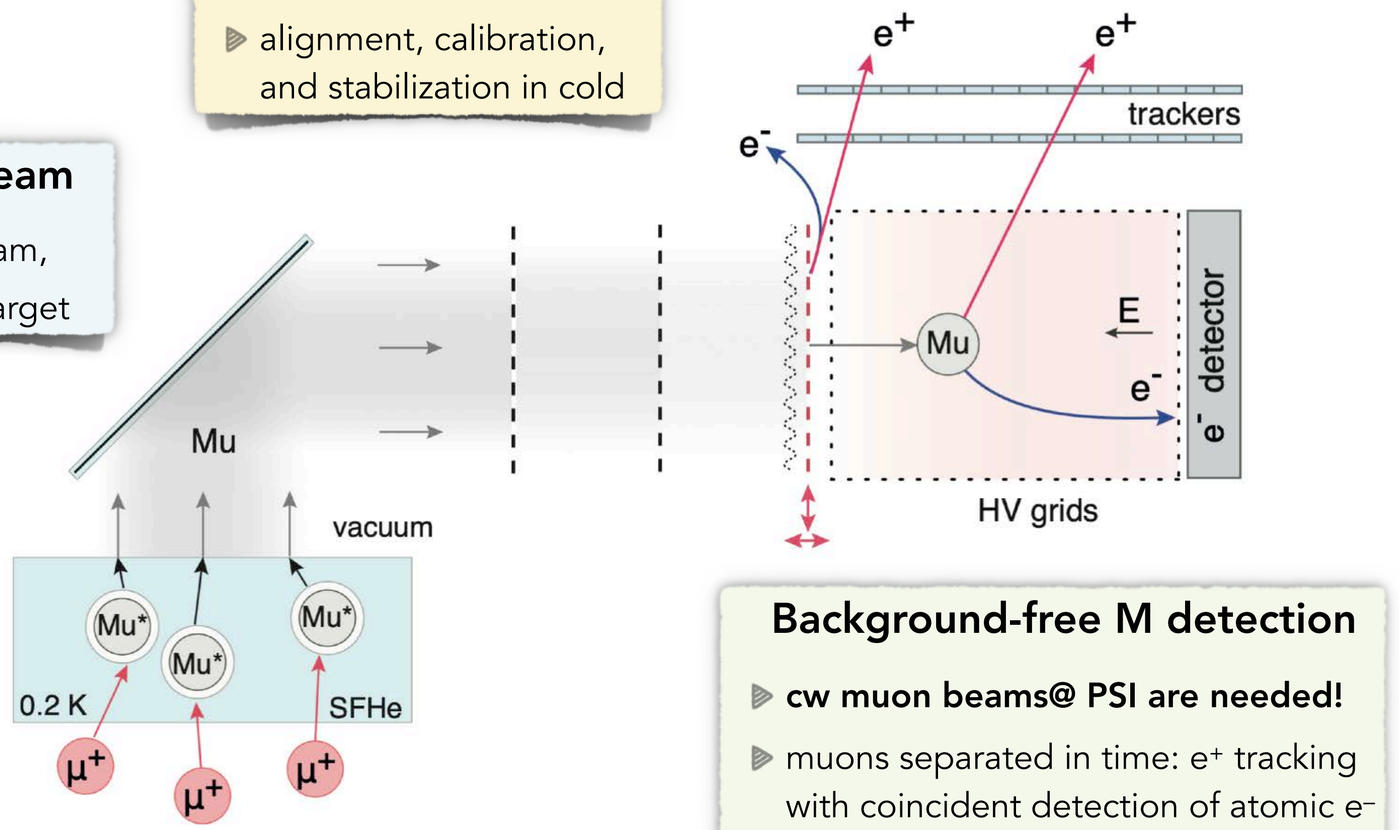
- nm-precise fabrication over few mm aperture
- alignment, calibration, and stabilization in cold

Horizontal M beam

- reflection of Mu beam,
- OR: vertical SFHe target

$\mu^+ \rightarrow$ vacuum M conversion

- efficient M production
- fast diffusion to surface
- efficient vacuum emission

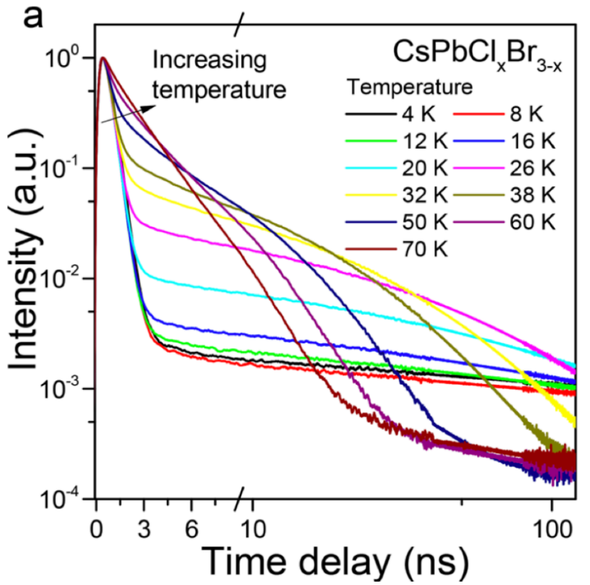


Background-free M detection

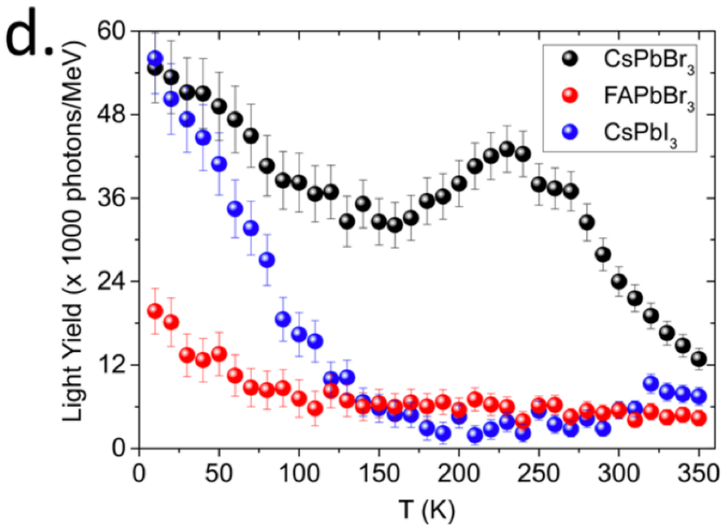
- **cw muon beams@ PSI are needed!**
- muons separated in time: e^+ tracking with coincident detection of atomic e^-
- high overall efficiency and low background in cryogenic setup

Perovskites

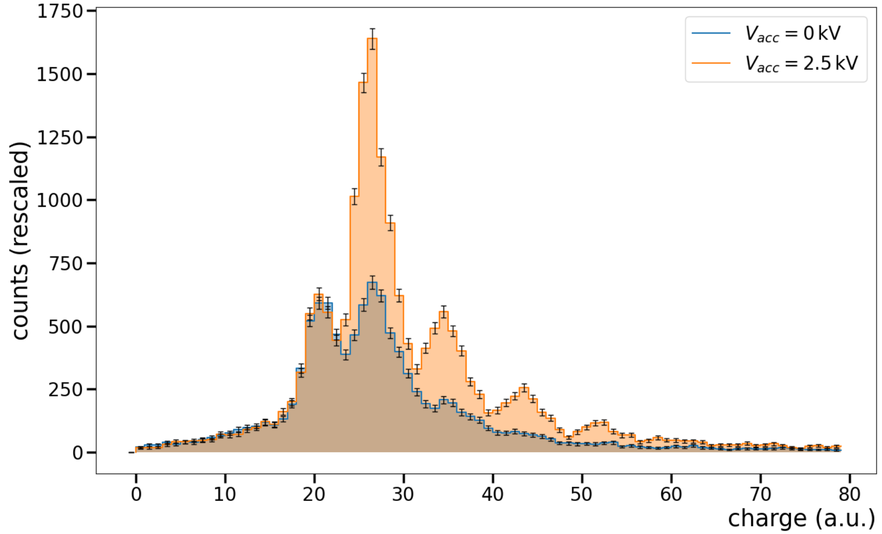
- Interesting because:
  - Improvement in the cold
  - High light yield
  - Fast signal
  - Could be deposited directly onto detector
- Tested:
  - Room temperature with electron gun
  - At 77K with secondary electrons
- Open questions:
  - Afterglow?
  - Performance at ~2K?



Chen, Lan, et al. "Composition-dependent energy splitting between bright and dark excitons in lead halide perovskite nanocrystals." *Nano Letters* 18.3 (2018): 2074-2080.



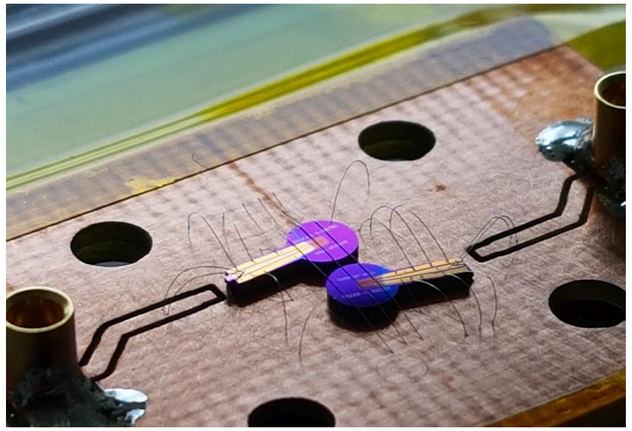
Maddalena, Francesco, et al. "Deterministic light yield, fast scintillation, and microcolumn structures in lead halide perovskite nanocrystals." *The Journal of Physical Chemistry C* 125.25 (2021): 14082-14088.

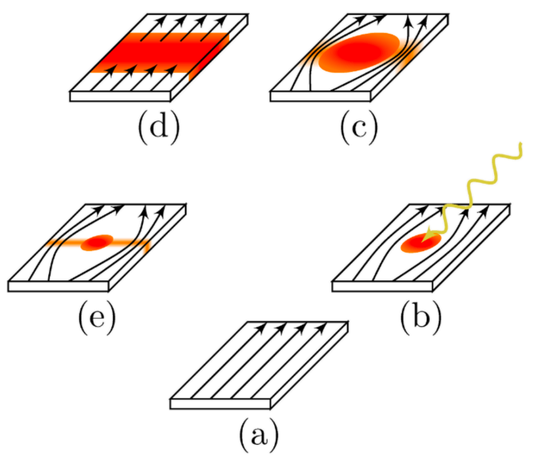


Measurement at 77K with secondary electrons

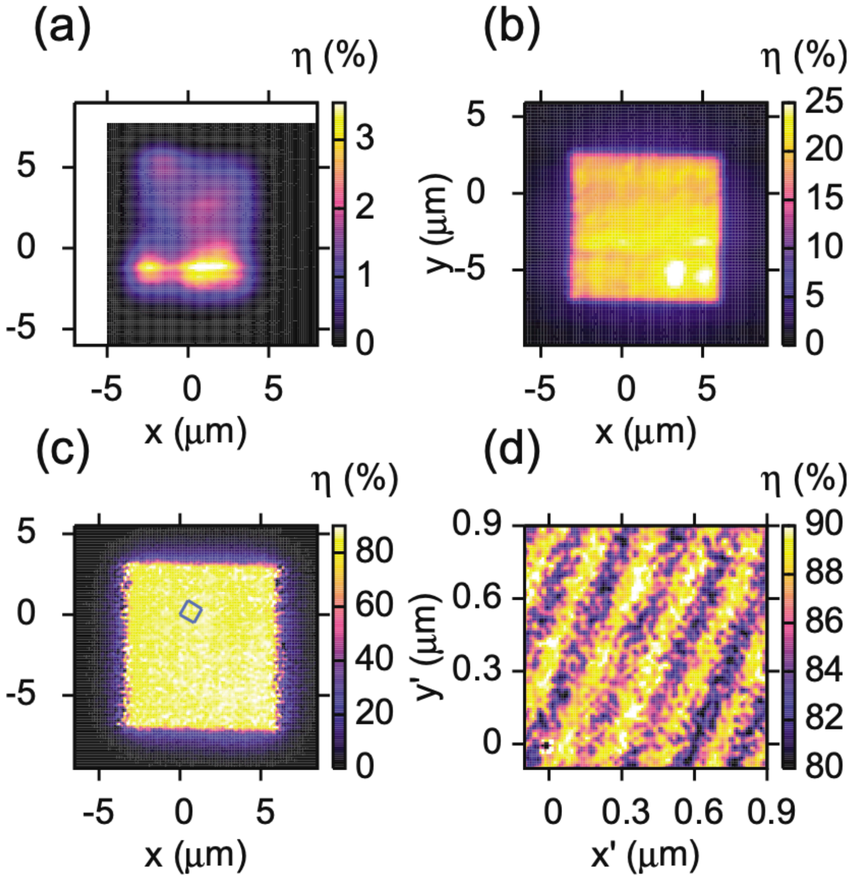
Superconducting Nanowires

- Interesting because:
  - High detection efficiencies
  - Fast rates
- Open questions:
  - Sensitive areas?
  - Charge accumulation?





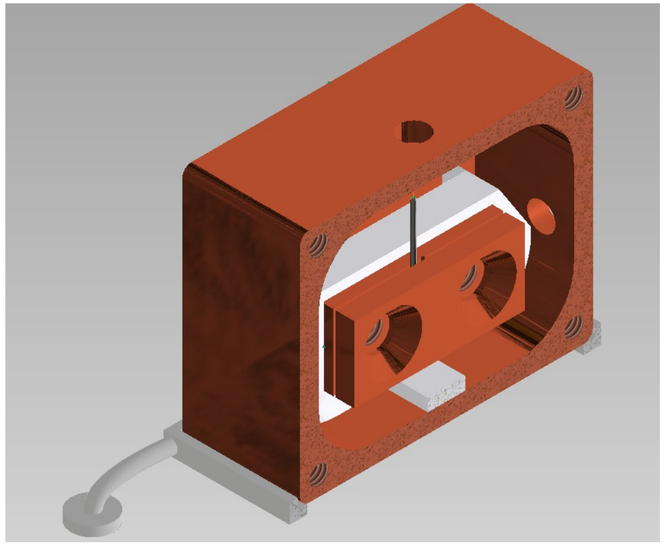
Tomas Polakovic et al. “Unconventional Applications of Superconducting Nanowire Single Photon Detectors”. In: *Nanomaterials* 10.6 (2020). ISSN: 2079-4991. DOI: 10.3390/nano10061198. URL: https://www.mdpi.com/2079-4991/10/6/ 1198.

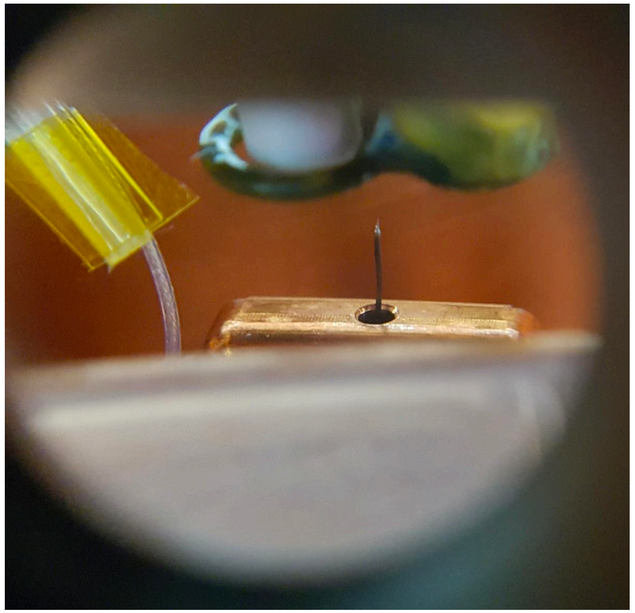


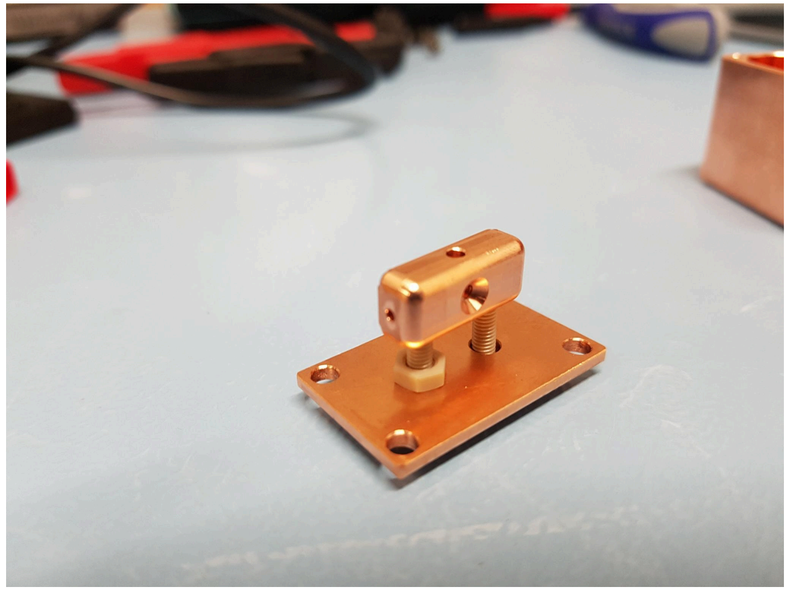
Rosticher, Michael, et al. "A high efficiency superconducting nanowire single electron detector." *Applied Physics Letters* 97.18 (2010): 183106.

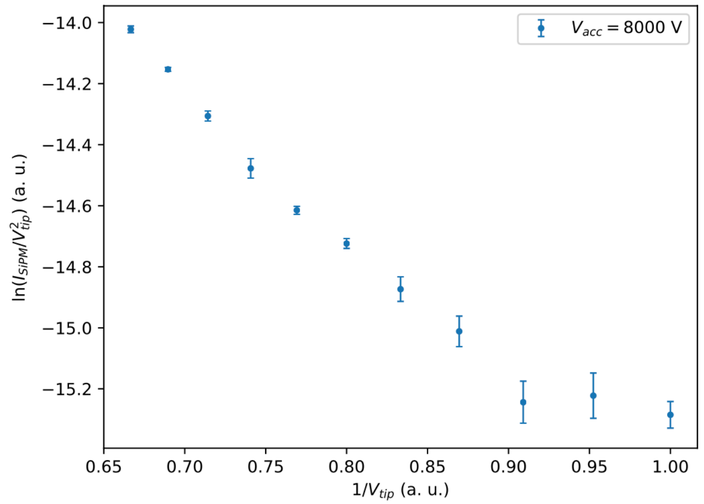
Field emission tip (FET)

- For having an electron source in the cold
  - Already tested at 2K
- Open question:
  - Works in SFHe?
  - Reproducible measurements?
    - Contamination on tip?
- Planned:
  - More reproducible setup?:
    - New design
    - Etched FET









Fowler-Nordheim plot of FET at 2.3K