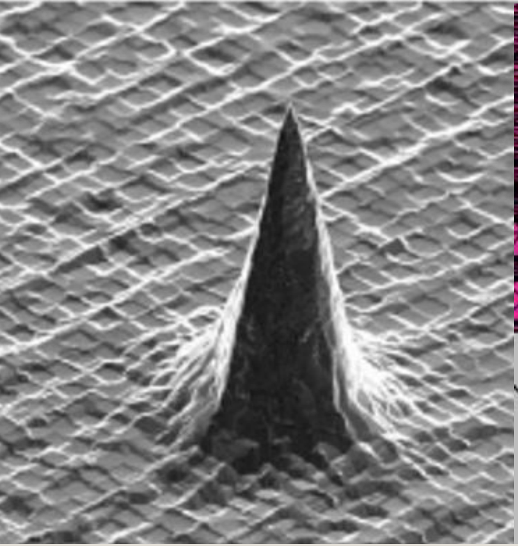
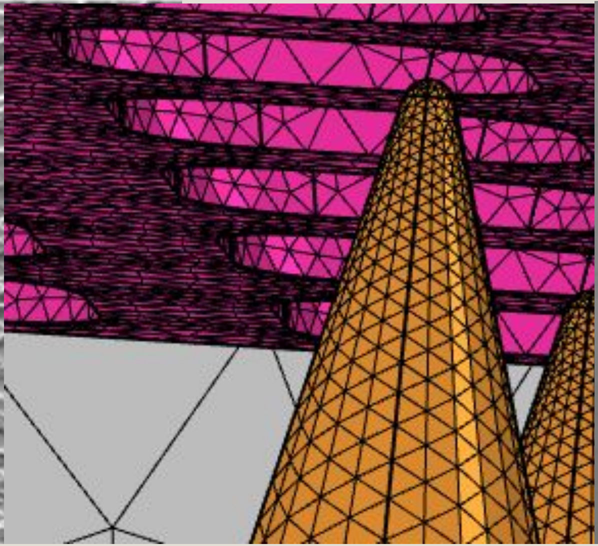
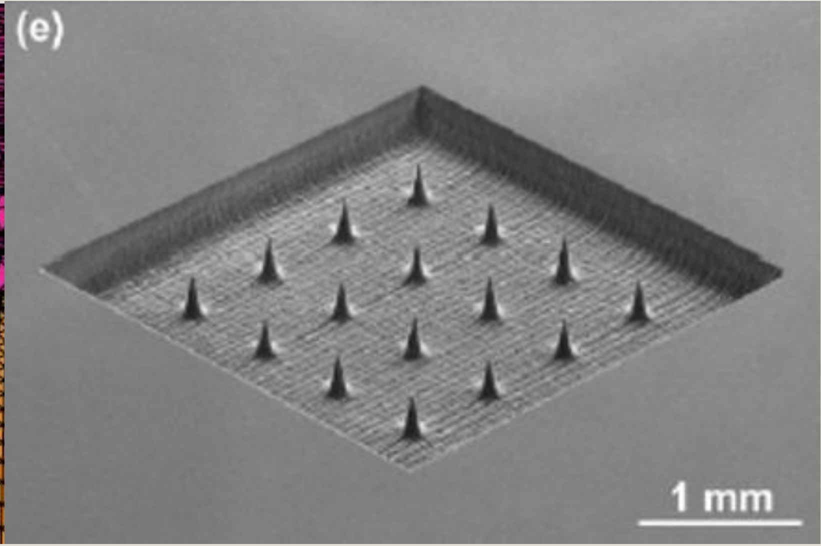






Romain Gaïor

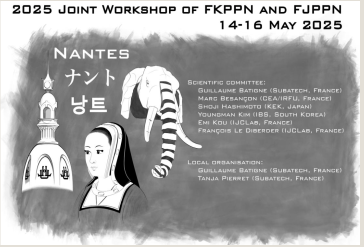
LPNHE

2025/05/15
TYL/FJPPN workshop
Nantes

K. Martens
M. Yamashita
C. Ishikawa
X. Wang

Prof R. Schreiner
M. Hausladen

Prof C. Weinheimer



Fea In XE Detector

Scientific context

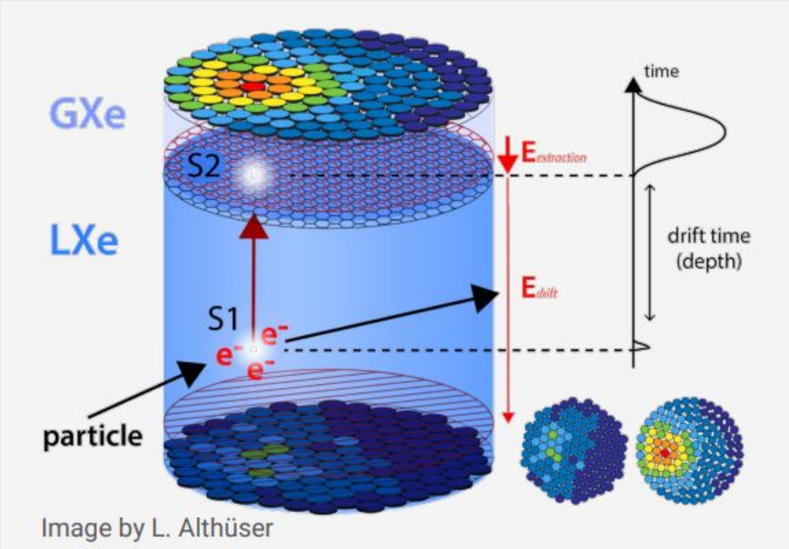
<u>XLZD</u>: Next generation LXe Experiment (50-100 tons) for **rare event searches** (Dark Matter, neutrinos, 0vBB)

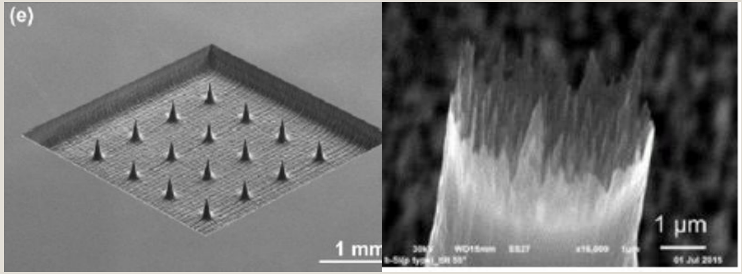
<u>(some)Problematics with large detectors</u>

- Radioactive purity: need for faster **purification** methods (Radon)
- Electrodes for **2nd scintillation**:
  Mechanical issues, resolution, spurious charge

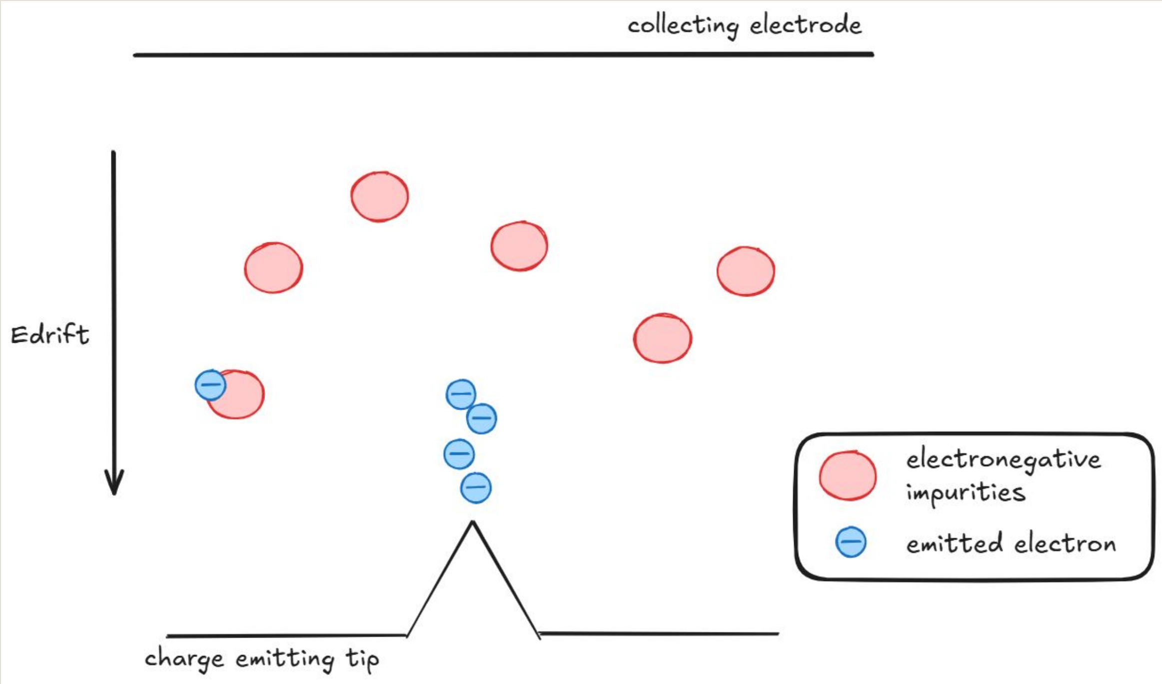
<u>FEA: Microscopic Conductive structure</u>

- **Large electric field** site
- Various shape / material (Cu, Si) / fabrication method
- Used in industry in vacuum

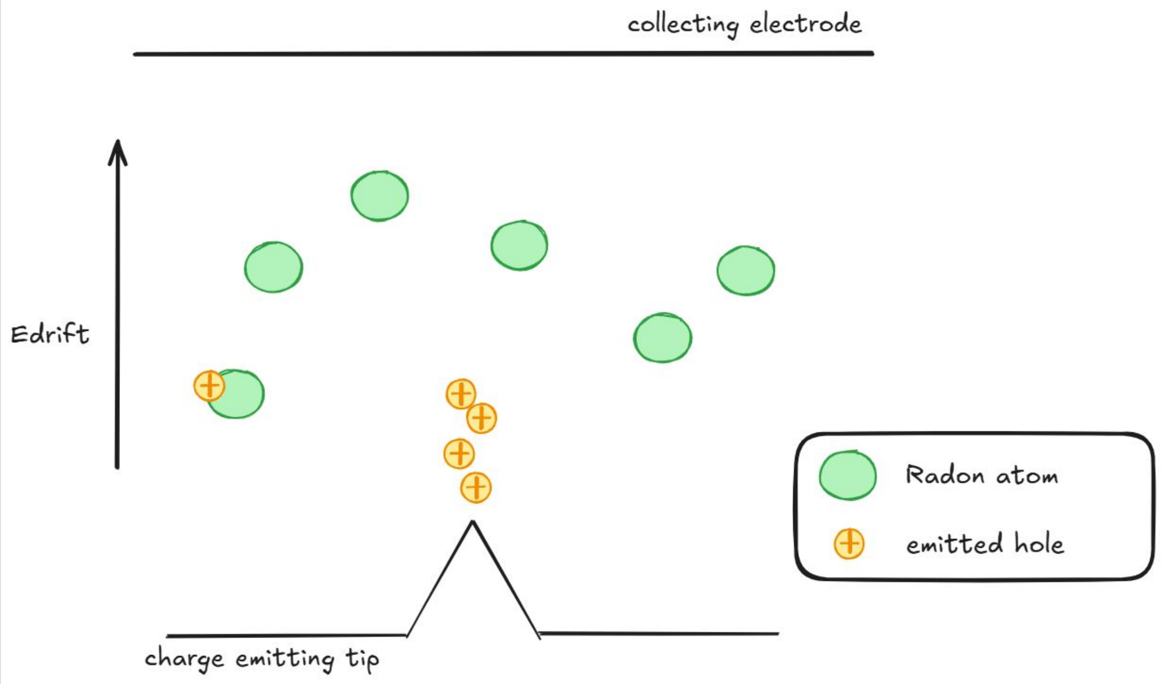




PURIFICATION

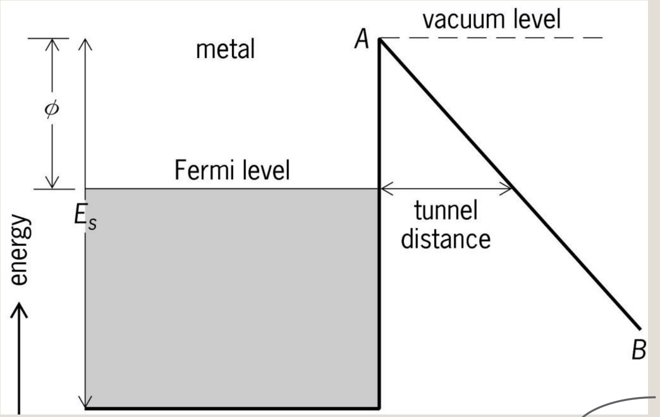


PURIFICATION



Field effect charge emission

Fowler-Nordheim tunneling (~1930)



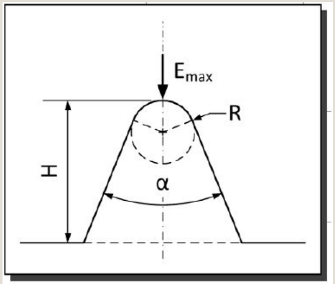
~ 10^9V/m

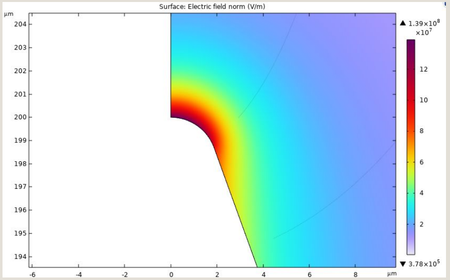
$$j = \frac{q^3}{2\pi h} \cdot \frac{\sqrt{\mu}}{(\phi + \mu)\sqrt{\phi}} \cdot F_l^2 \exp\left(-\frac{4\kappa\phi^{3/2}}{3qF_l}\right)$$

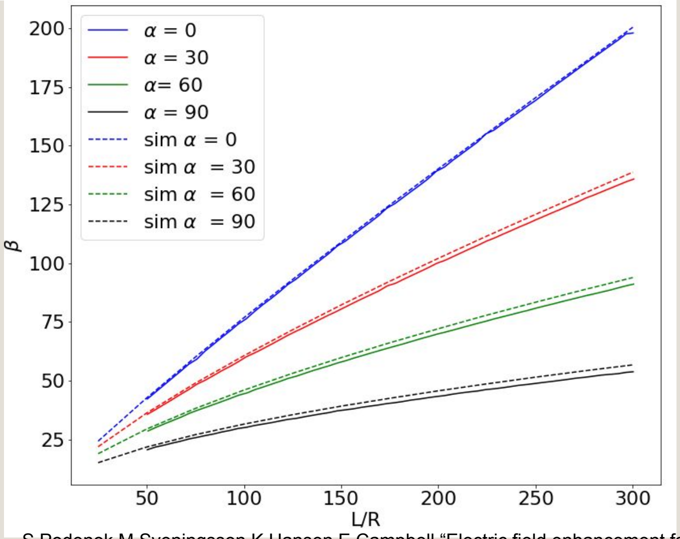
F_l=Electric surface field

Very high local field required

Field enhancement β





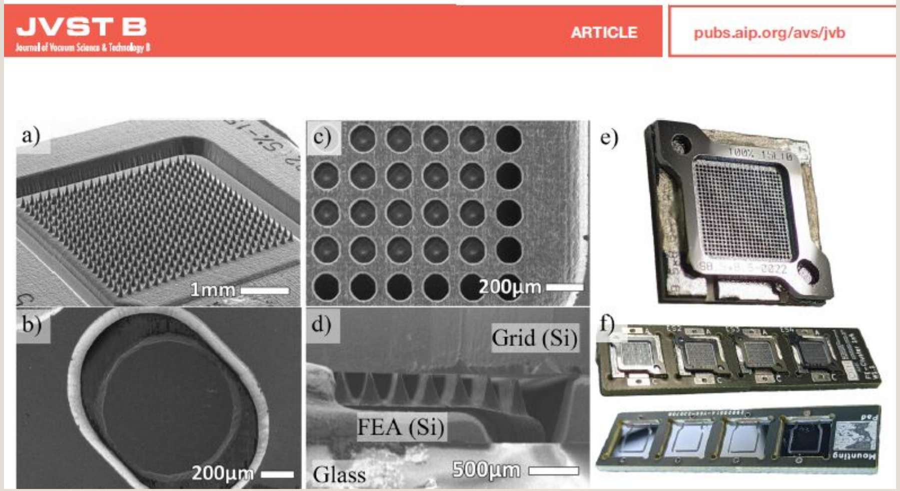


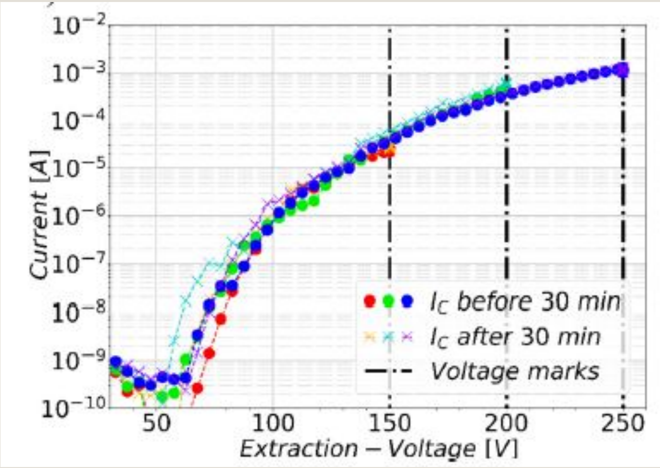
S.Podenok,M.Sveningsson,K.Hansen,E.Campbell,“Electric field enhancement factor around a metallic,end-capped cylinder”,NANO1(1),S.87-93(2006).

Charge emission in vacuum

Result from OTH in Vacuum

Hausladen *et al.* DOI: 10.1116/6.0003233

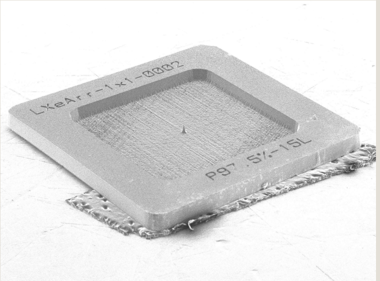


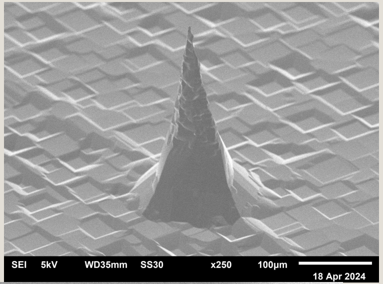


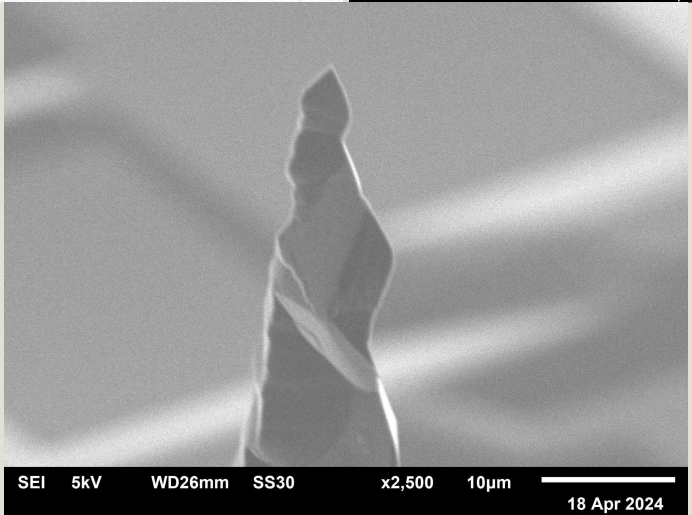
- Silicon laser micromachined tip array of 21x21
- Onset current of ~70V
- Stable current obtained
- Current distributed evenly over the array

Single tip in LXe

Tip for LXe tests



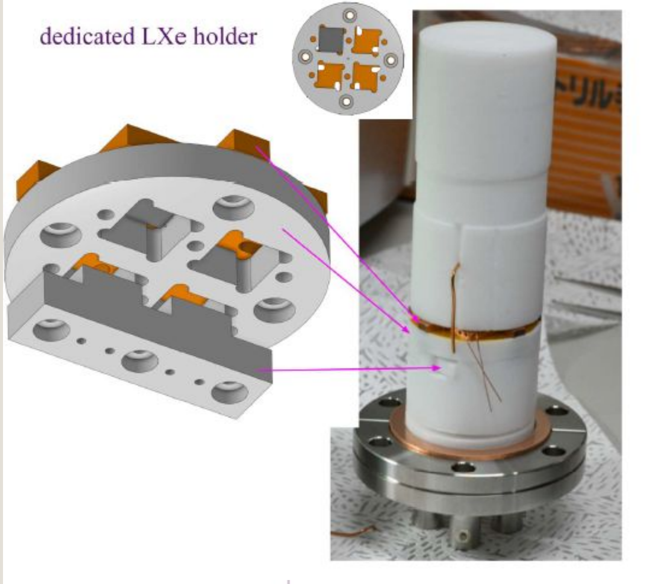




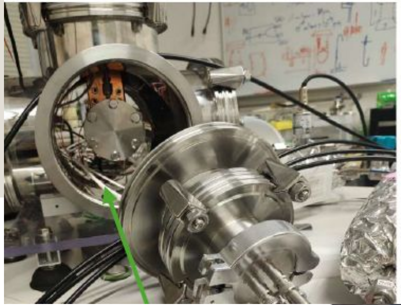
- We took first measurement in 2023 with a 21x21 array
  → Emission but hard to interpret
- Going back to 1 single tip
- First "conditioning" in vacuum
  → smoothens the surface

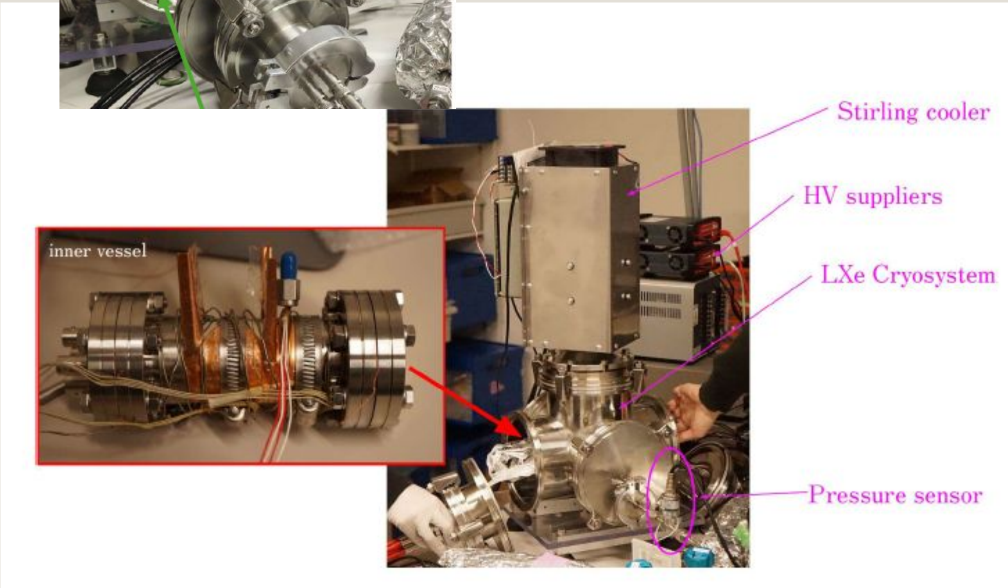
Single tip in LXe

Inner vessel



Cryogenic Setup

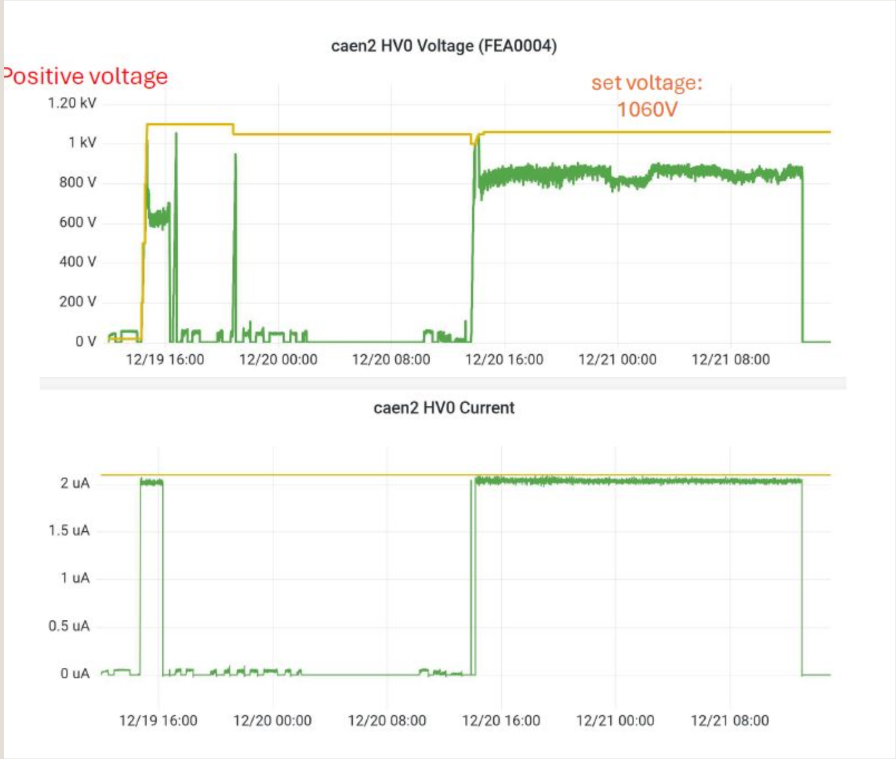


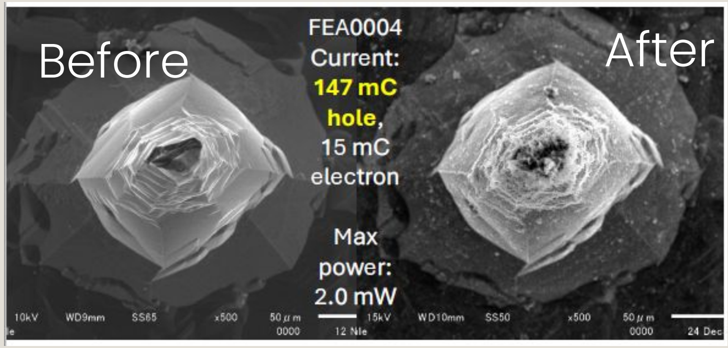


C. Ishikawa & X. Wang

Results

Electron AND Hole emission observed !



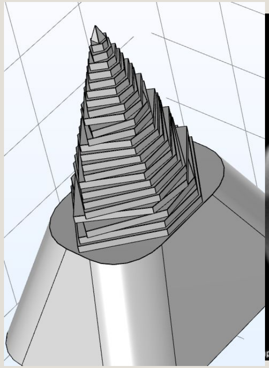


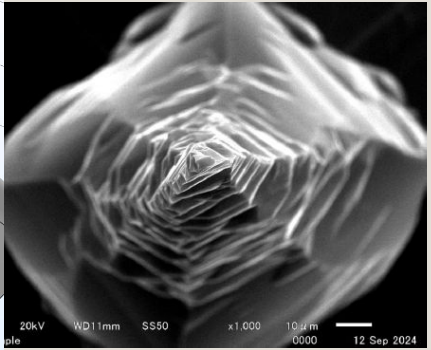
- Established procedure to obtain stable emission
- Change of tip structure observed to be understood
- Effect of coating ?

C. Ishikawa & X. Wang

Plans

- Experience building up on the tip conditioning
- Work on simulations is ongoing
- Distribute emission over an array
- Measure attachment to radon with a dedicated experiment →





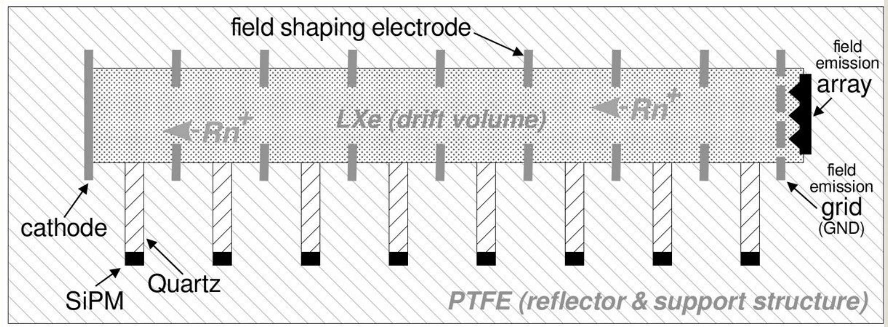
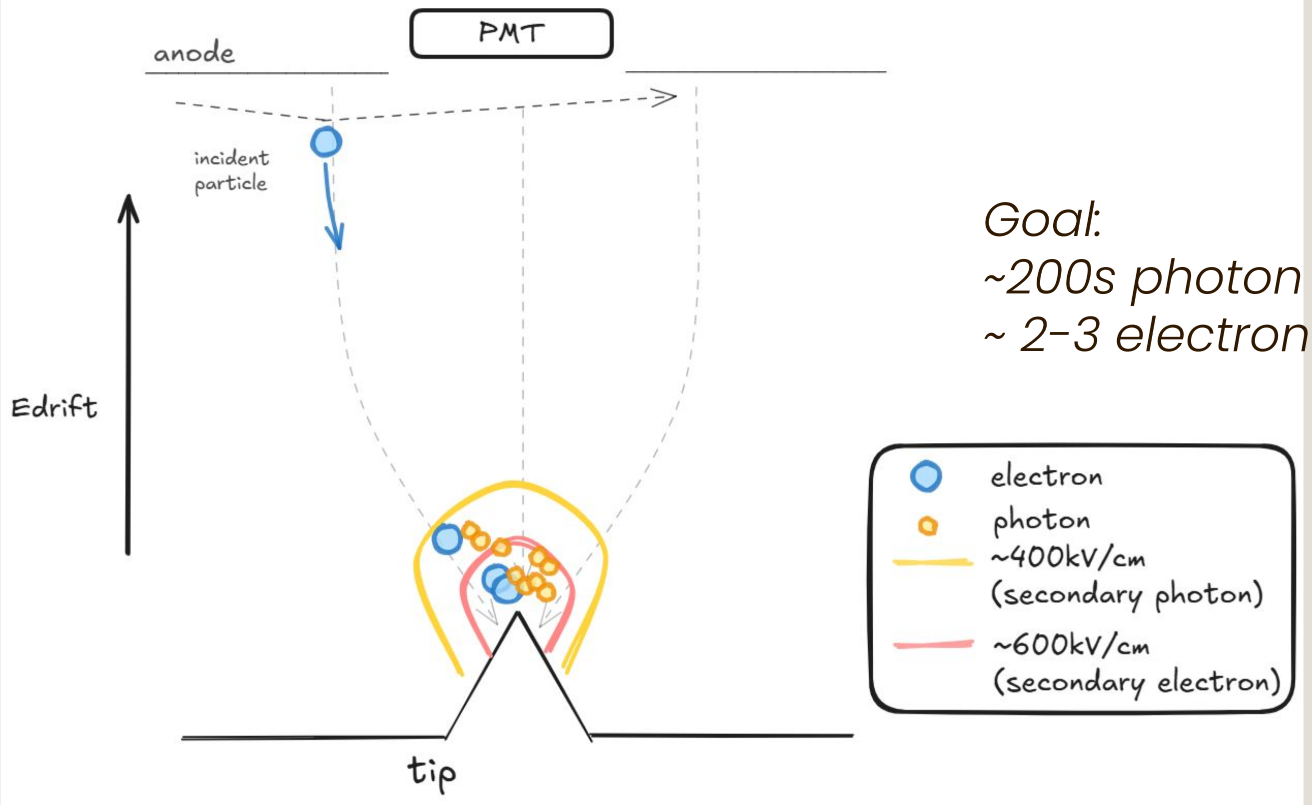


Fig. 1 Schematic of LXe drift volume

K. Martens credit

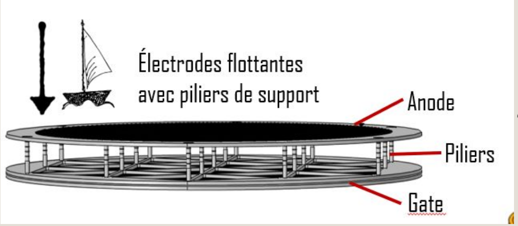
Secondary scintillation



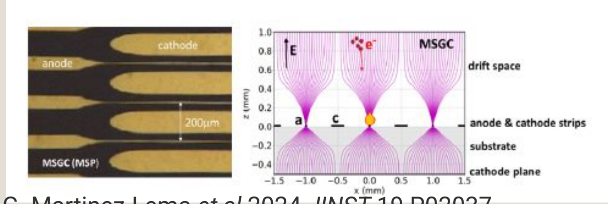
Goal:
~200s photon
~ 2-3 electron

Electrode R&Ds

Double phase "Floating electrodes"

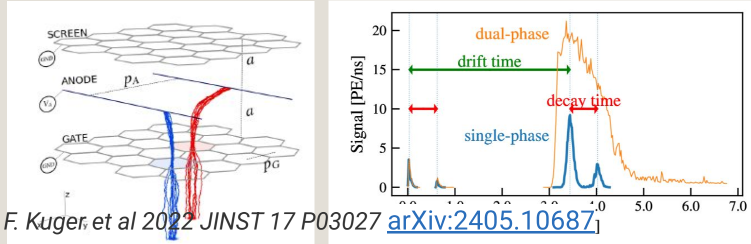


Single phase Microstrips



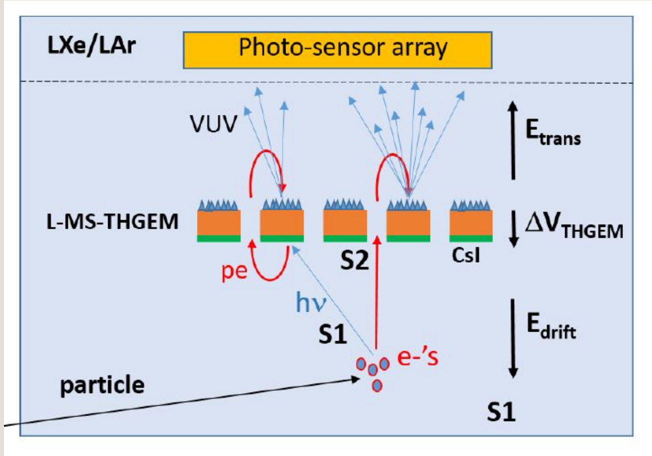
G. Martinez-Lema *et al* 2024 *JINST* 19 P02037

Single phase with wire



F. Kuger et al 2022 JINST 17 P03027 arXiv:2405.10687

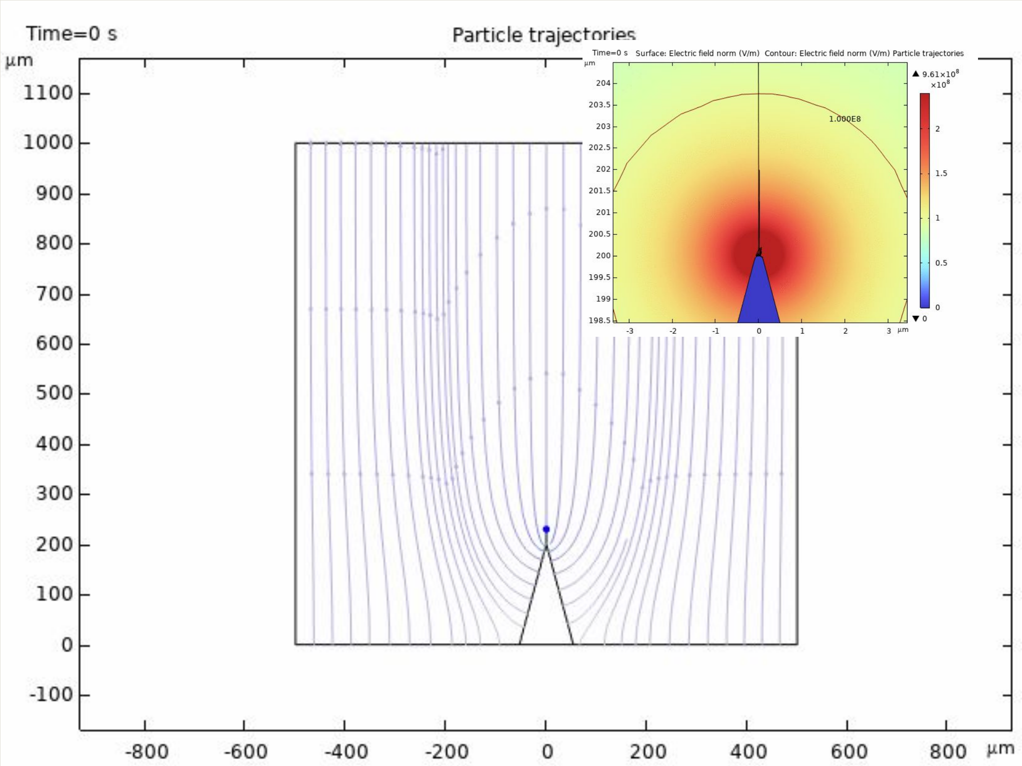
Single phase with micro/nano structure



A. Breskin 2022 *JINST* 17 P08002 / arXiv:2203.01774

- **No liquid - gas interface**
- **No electrode sagging**
- **No delayed electrons**
- **Cleaner S2 signal**
- **Large local electric field**
- **Not as studied as double phase for rare event searches**

Secondary scintillation simulation



1. E-field simulation
2. Electron tracking
3. Emission simulation

$$\Delta N_e = N_e \theta_0 \exp\left(-\frac{\theta_1}{E(\vec{x}, V_A, d_w) - \theta_2}\right)\Delta\vec{x},$$

$$\Delta N_\gamma = N_e \theta_3 (E(\vec{x}, V_A, d_w) - \theta_4)\Delta\vec{x},$$

θ_2 = 400 kV/cm

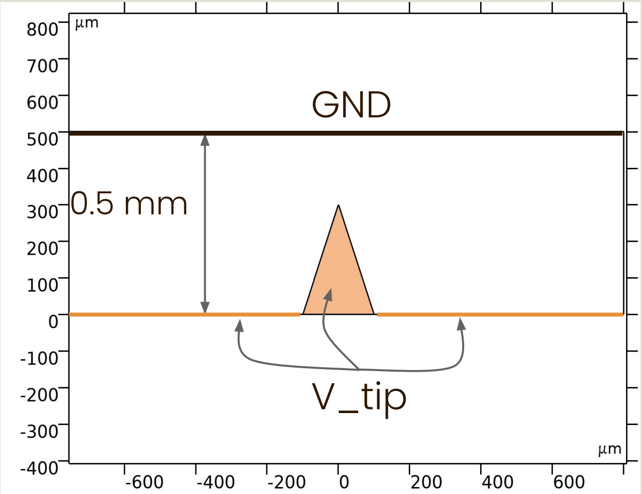
θ_4 = 600 kV/cm

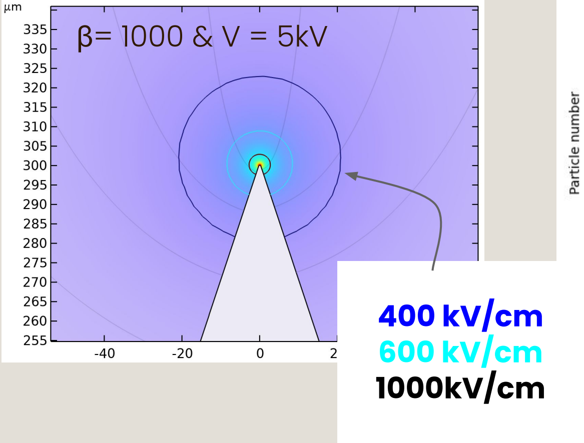
arXiv:1408.6206v3 / E Aprile *et al* 2014 *JINST* 9 P11012

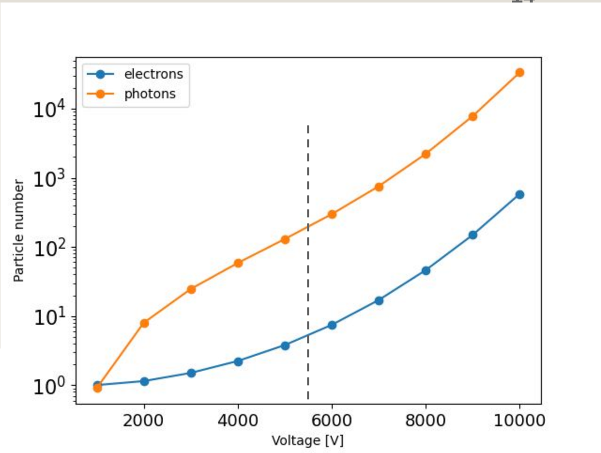
→ Started with full COMSOL

→ Now Emission with python code

Simple geometry



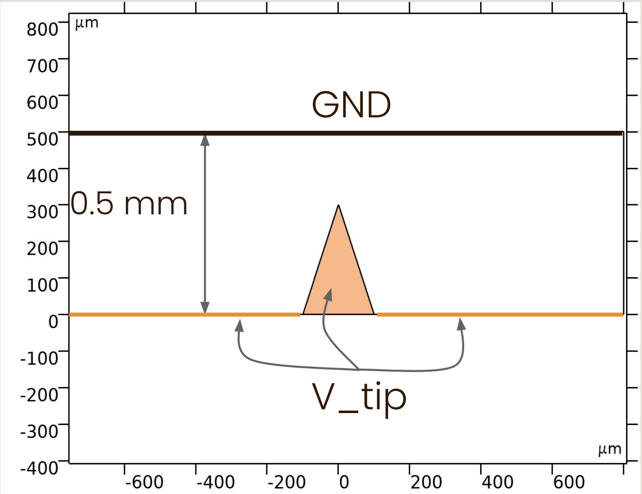


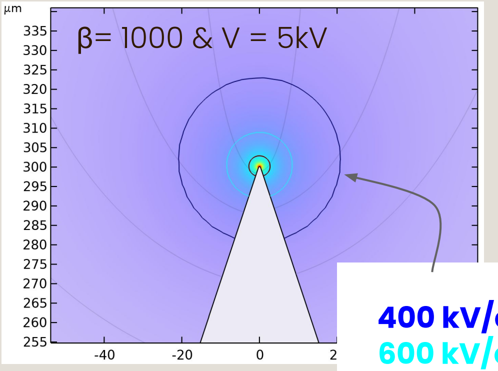


- Number of electron vs photon
- Charge emission ?

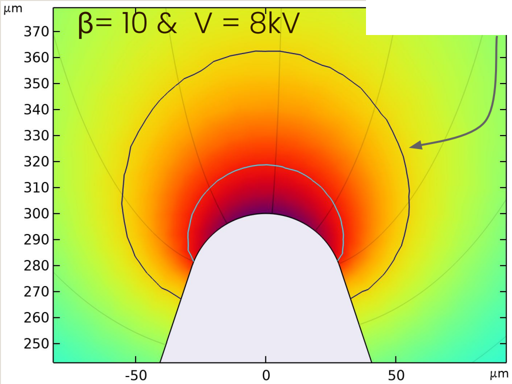
→ Need a smaller enhancement factor

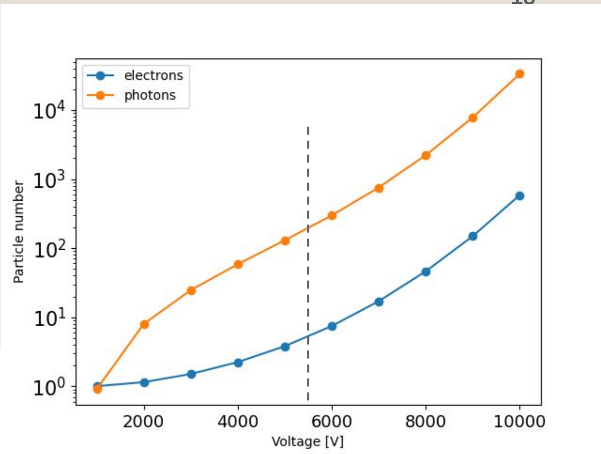
Simple geometry

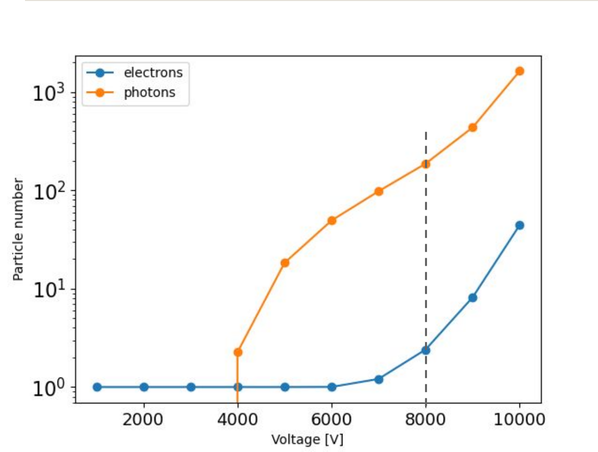




400 kV/cm
600 kV/cm
1000kV/cm





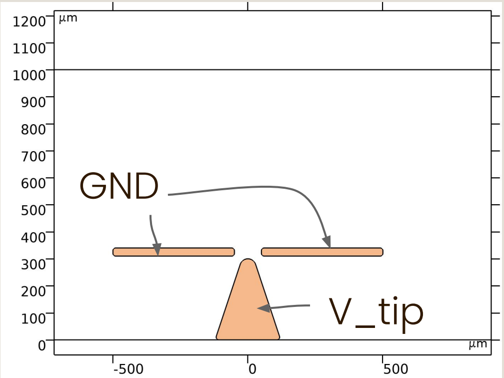


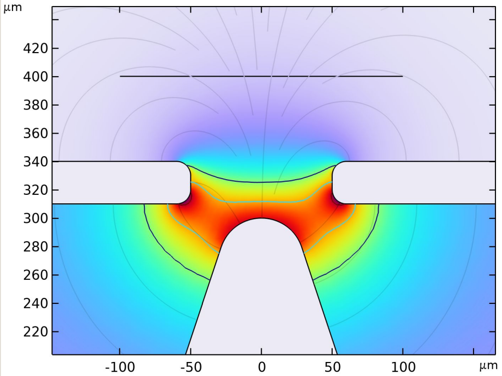
- Number of electron vs photon
- Charge emission ?

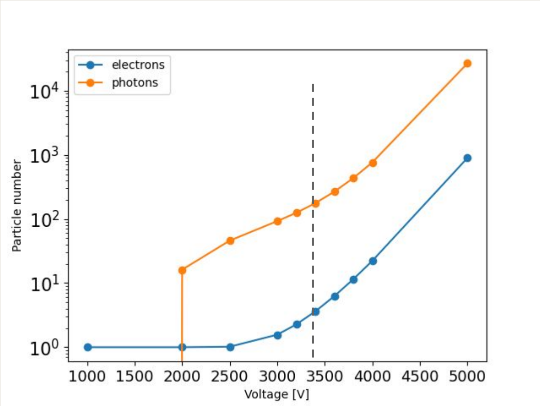
→ Need a smaller enhancement factor

Many possibilities

Gated FEA

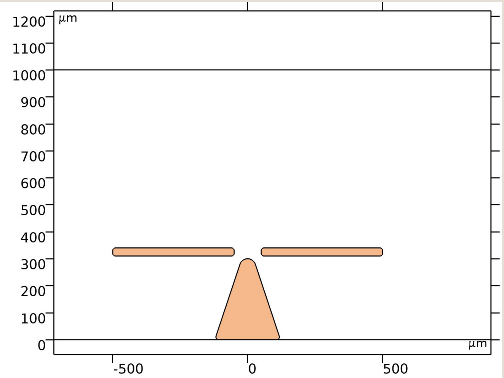


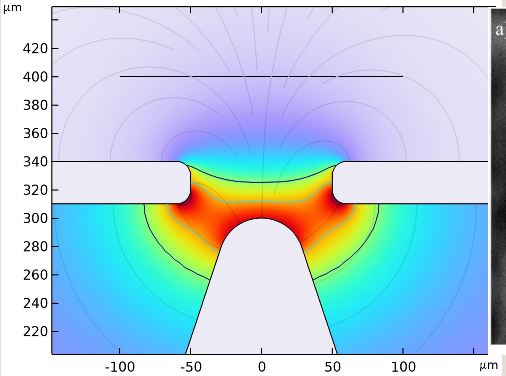


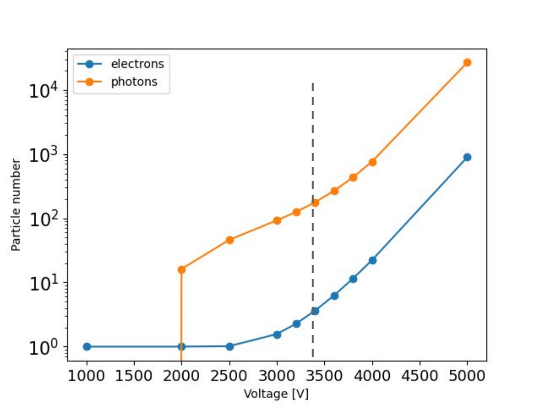


Many possibilities

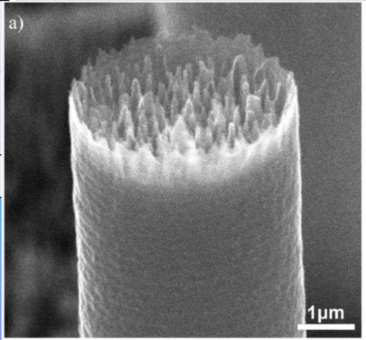
Gated FEA

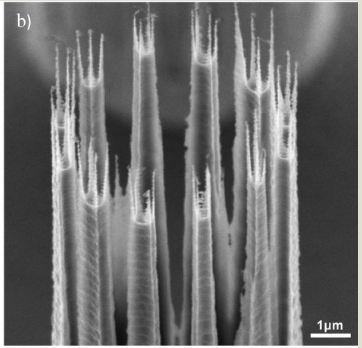






Various geometry





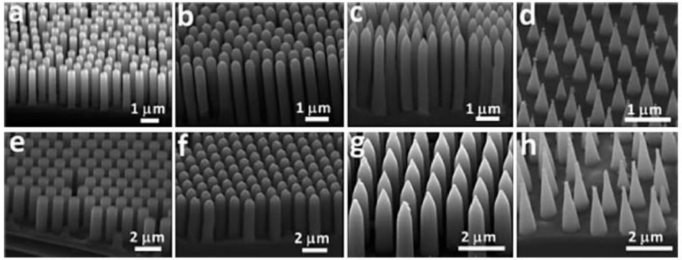
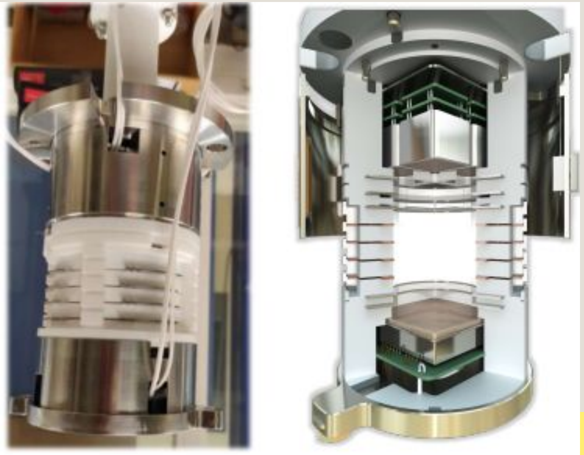


Figure 14. SEM images of highly regular (a and e) nanopillar, (b and f) nanorod, (c and g) nanopencil, and (d and h) nanocone Si arrays, produced by wet-etching. (Reproduced from ref. [81] with permission from the authors and the Royal Society of Chemistry).

Plans



- Explore / optimize geometries with simulation
  - among existing ones
  - discuss feasibility if not existing

- Test simulation with experiment
  → Xelab@LPNHE is now an option

- Measure performance of these structures

Budget request

- **1 trip France→ Japan**:
  Work on the charge emission setup
  Acquire experience on tip conditioning

- **1 trip Japan→ France**:
  Work on the secondary scintillation setup
  Profit of the Xelab facility

THANK YOU !