Next Steps for Electron Detection with TESs

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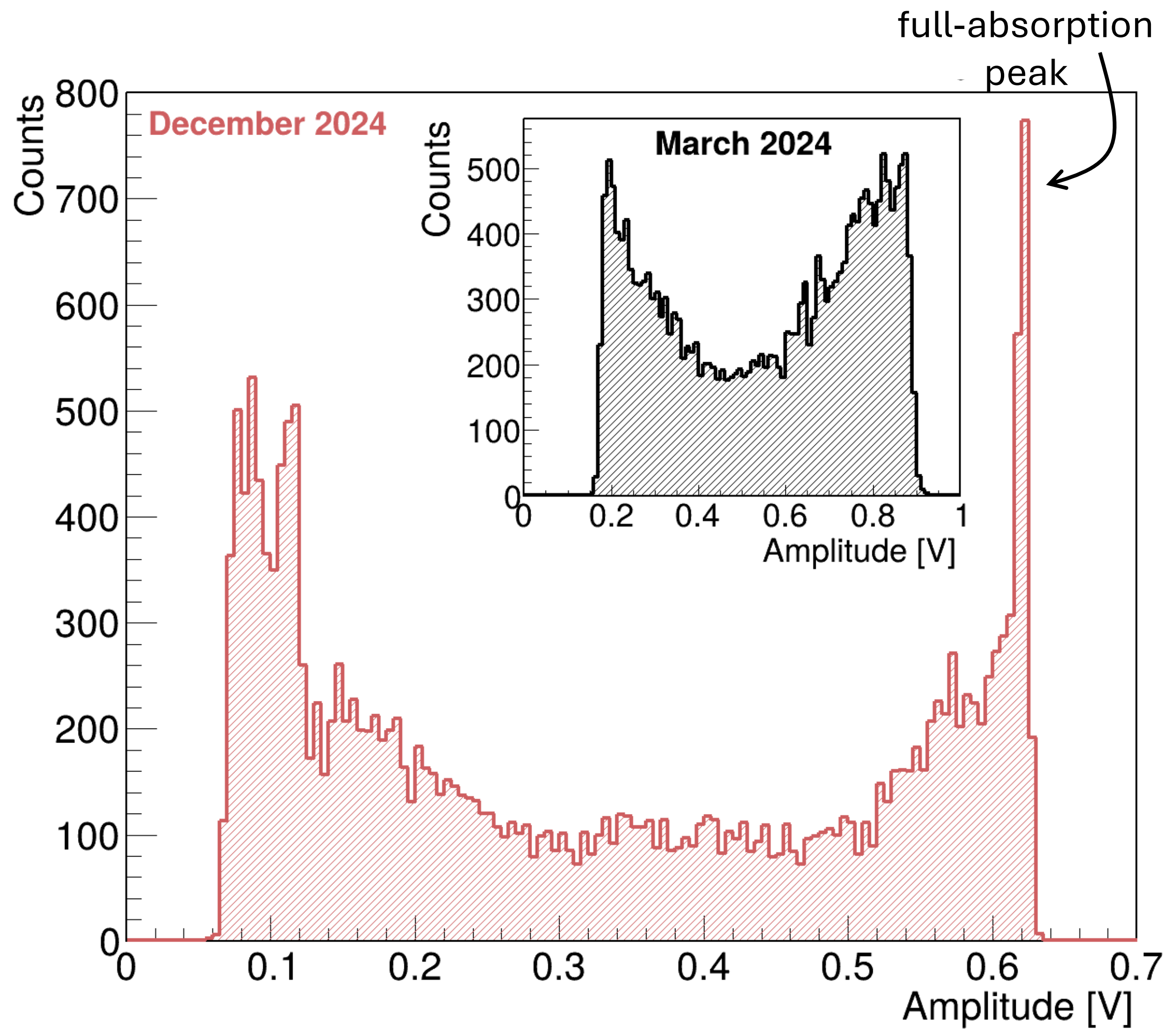
INRiM Istituto Nazionale di Ricerca Metrologica
Roma Tre Università degli Studi
INFN Istituto Nazionale di Fisica Nucleare

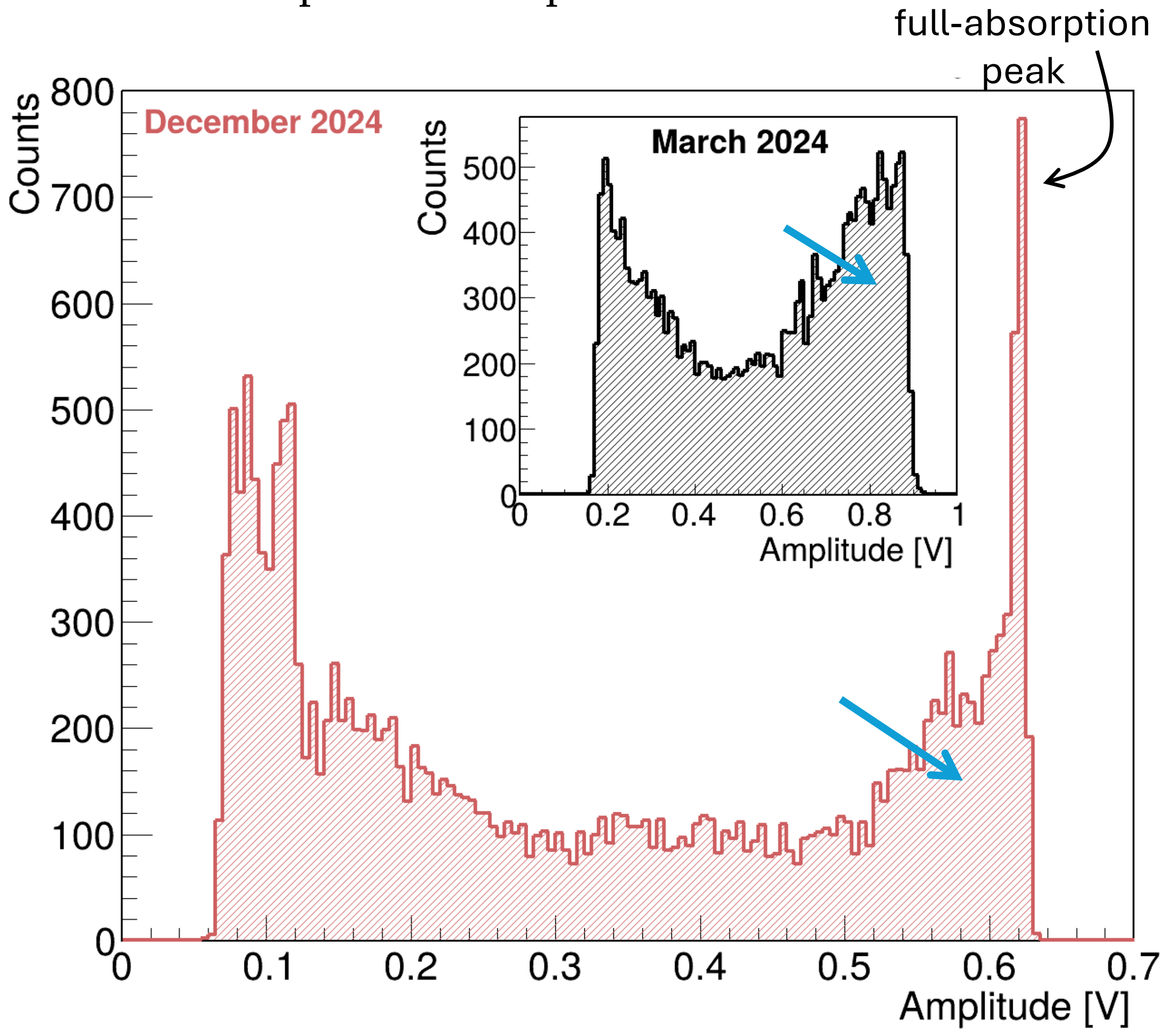
Where We Are

Setup Changes ⇒ Promising Results



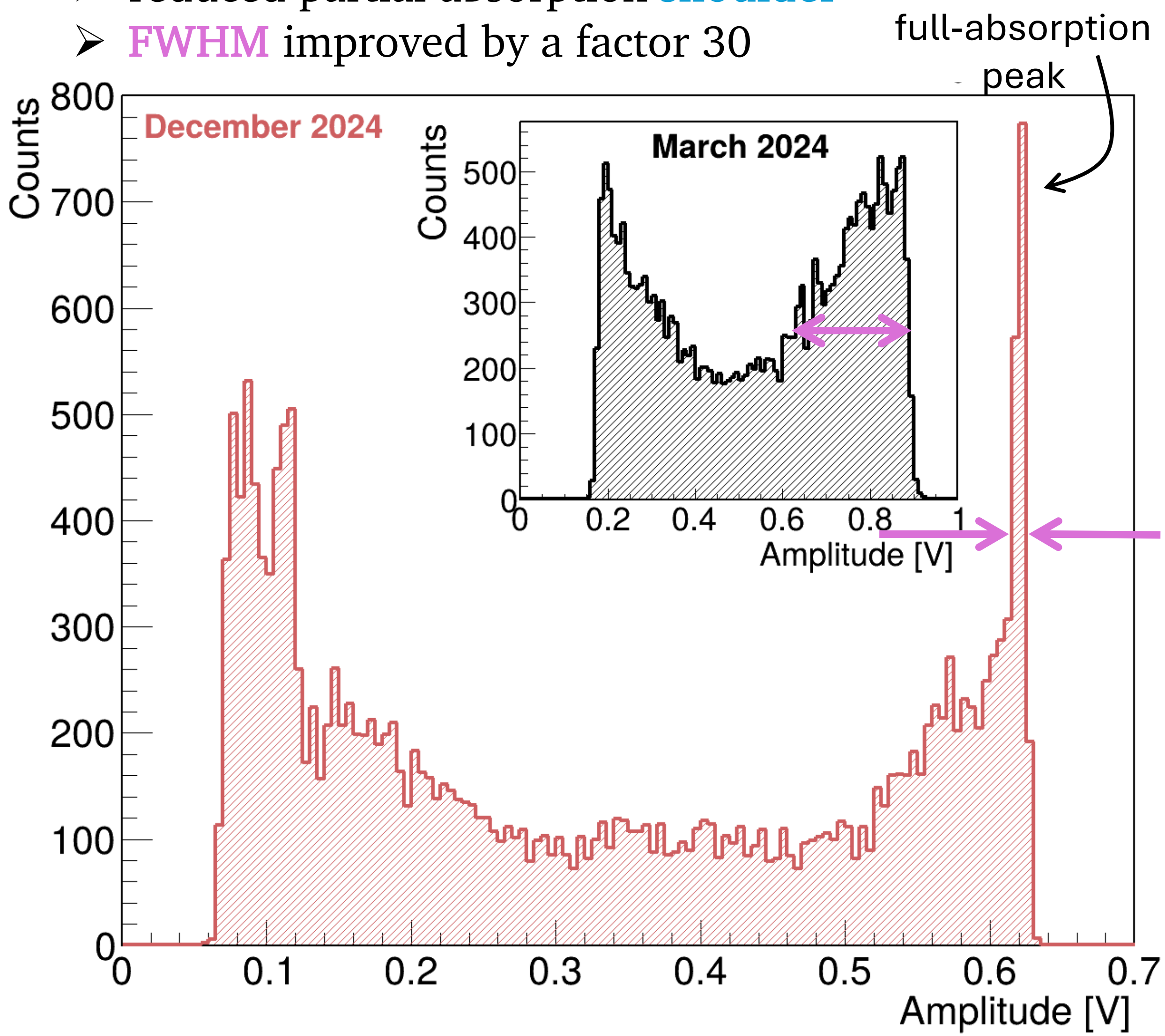
Setup Changes ⇒ Promising Results

- reduced partial absorption **shoulder**



Setup Changes ⇒ Promising Results

- reduced partial absorption shoulder
- FWHM improved by a factor 30



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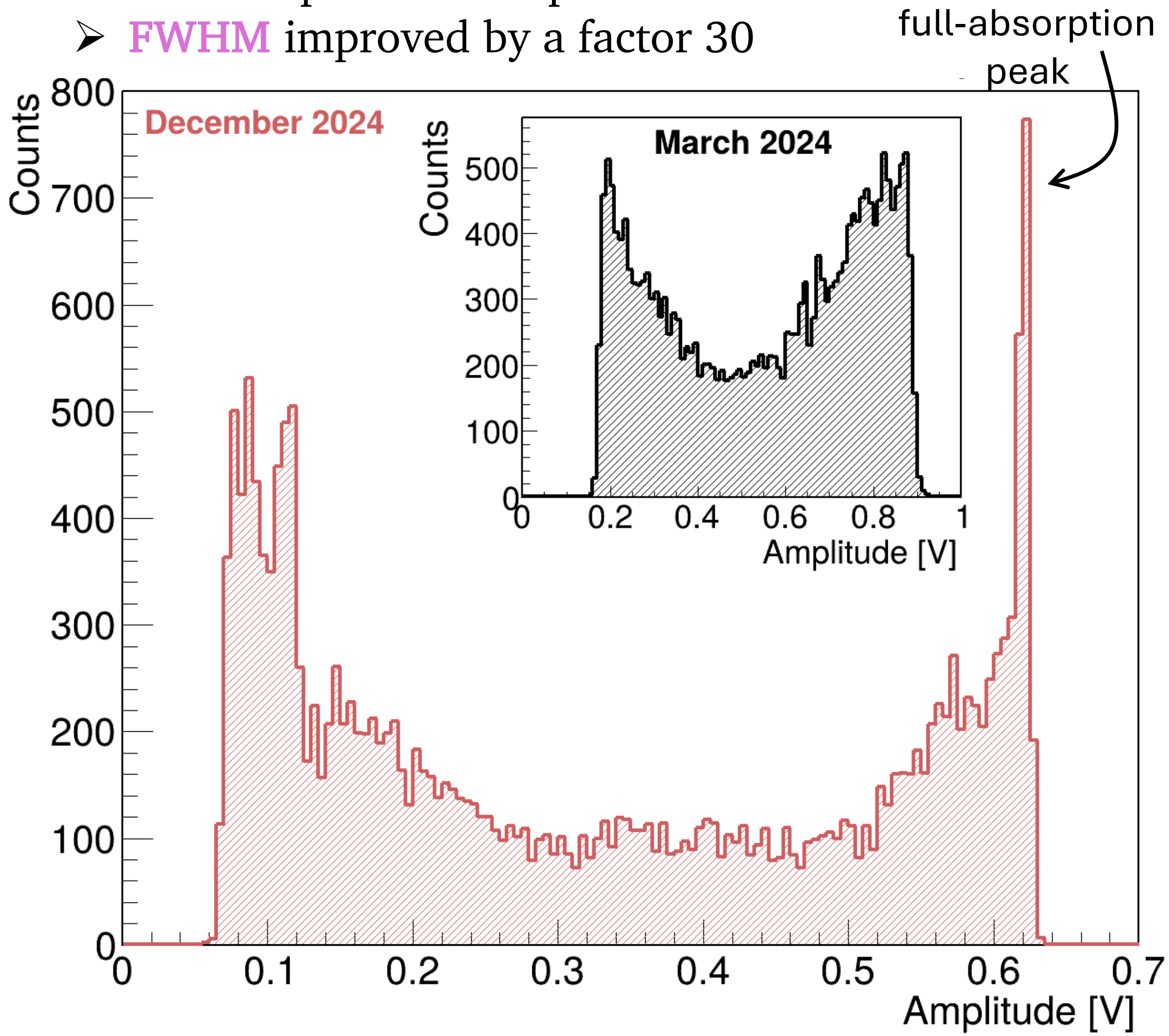
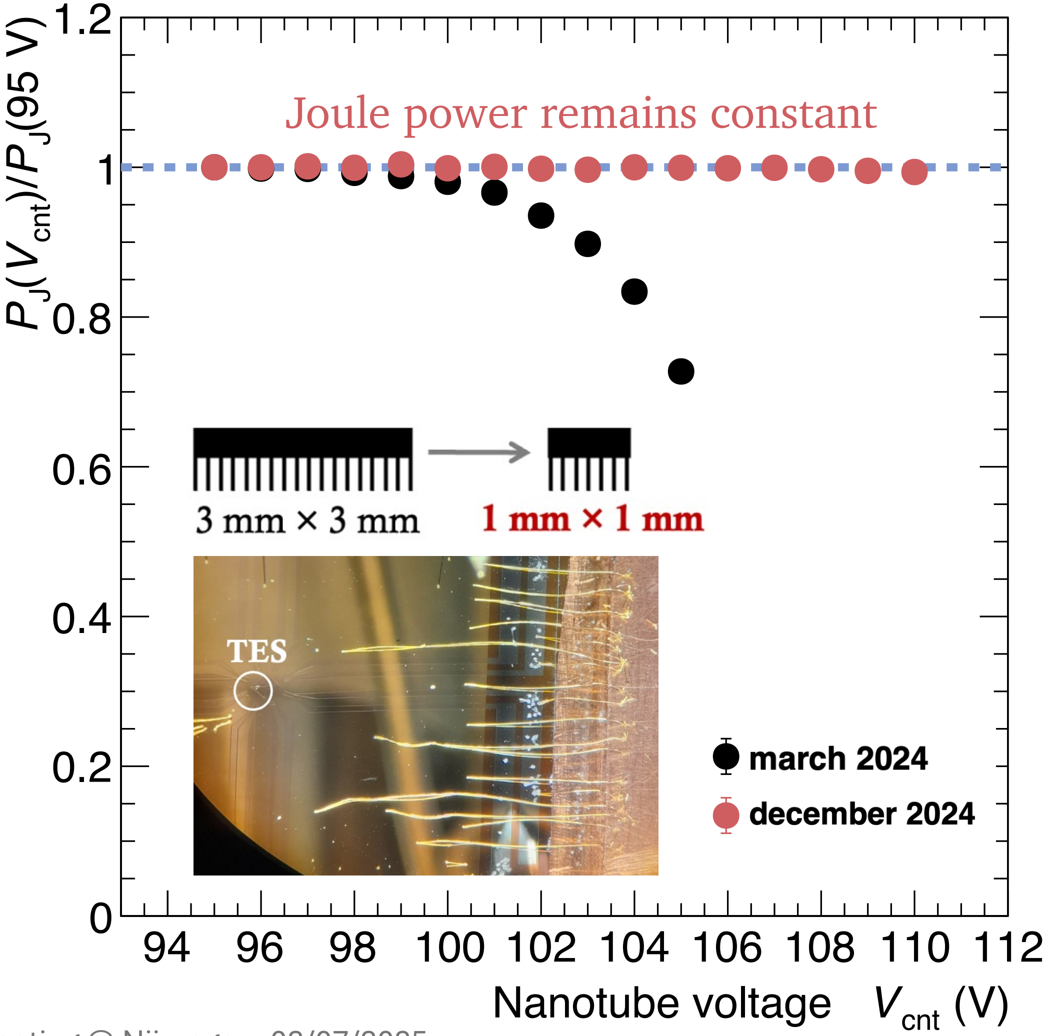
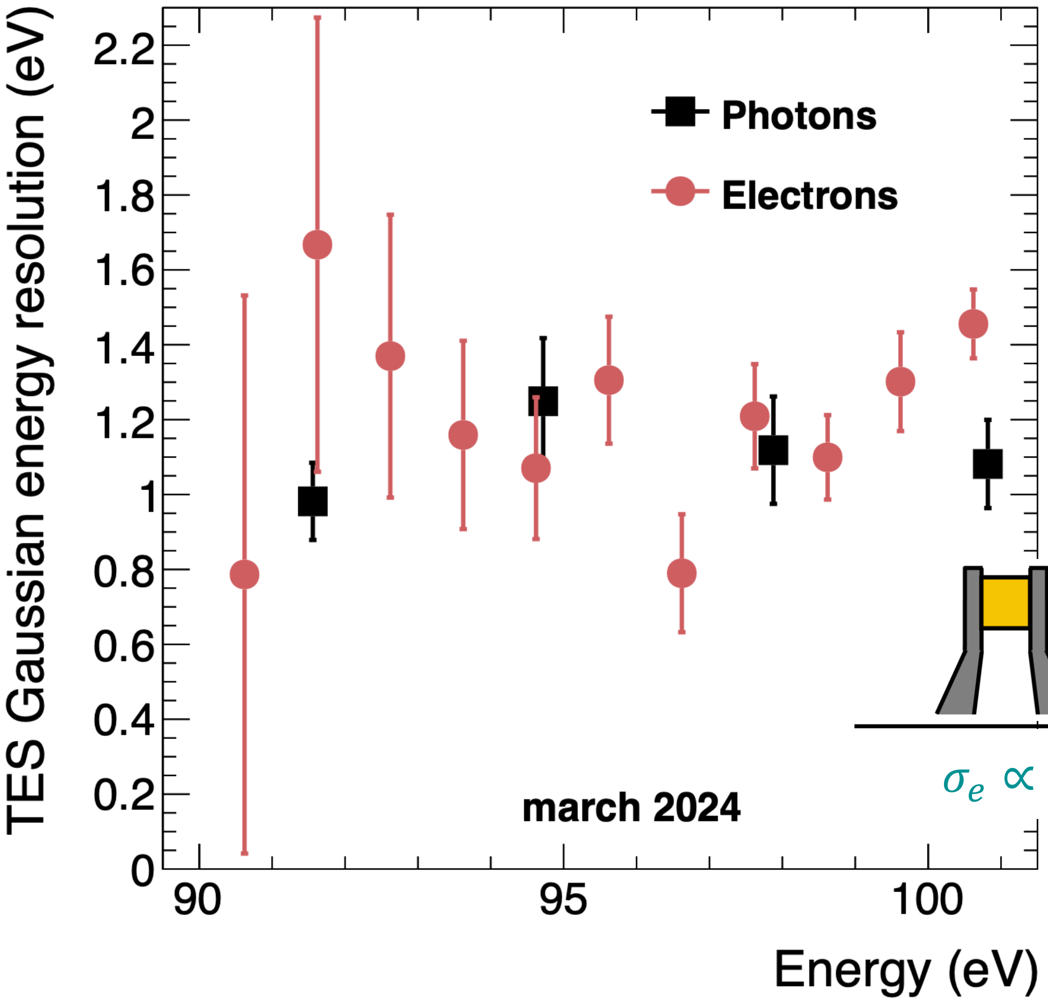


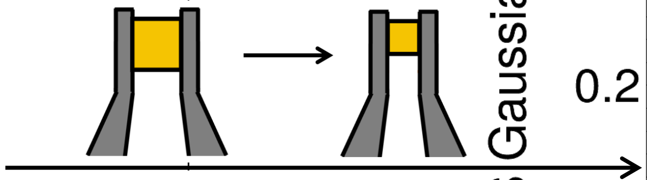
- no more heating of the setup → **fixed working point** for all electron energies



Energy Resolution Better than Expected

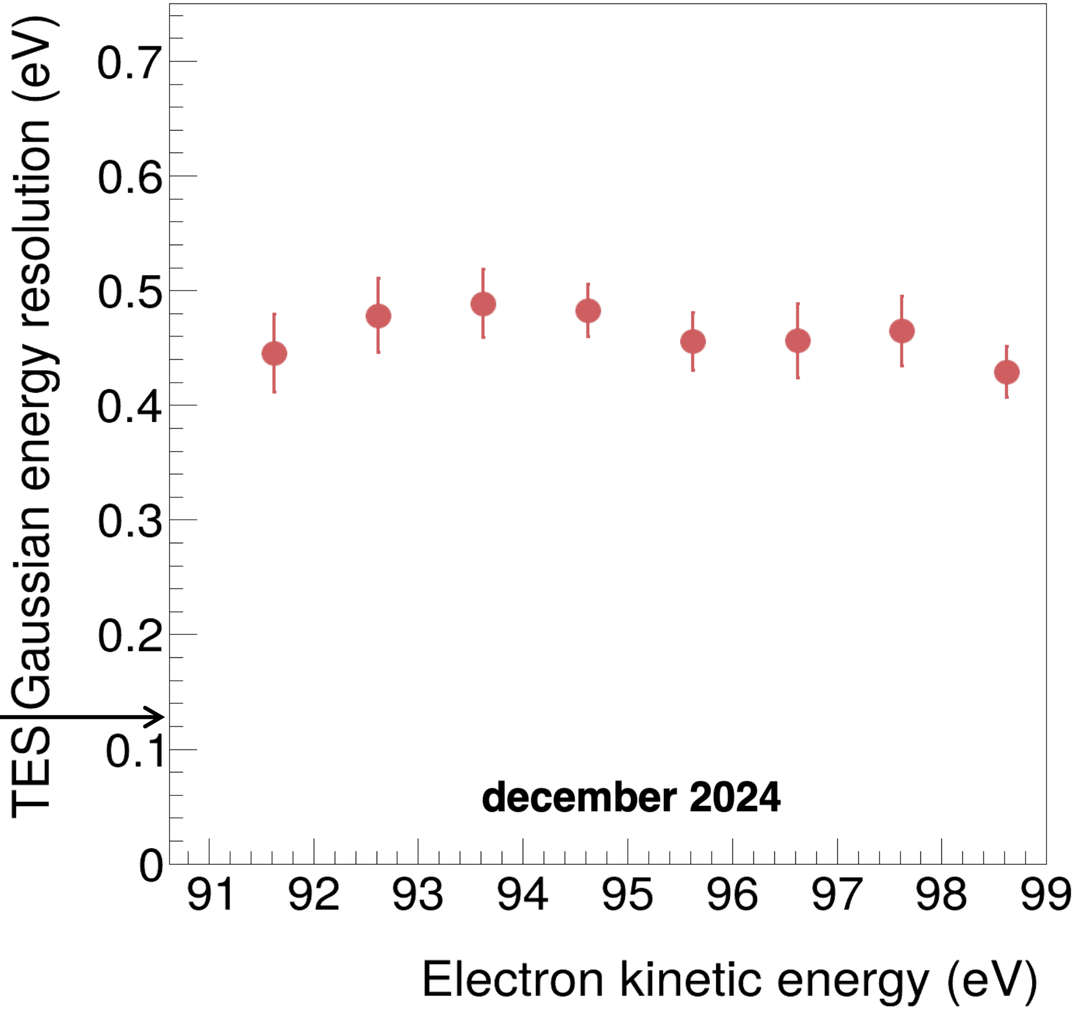
- compatible energy resolution between **photons** and **electrons**





$\sigma_e \propto \sqrt{Area_{TES}}$

- optical calibration will be performed soon to compare photon resolution



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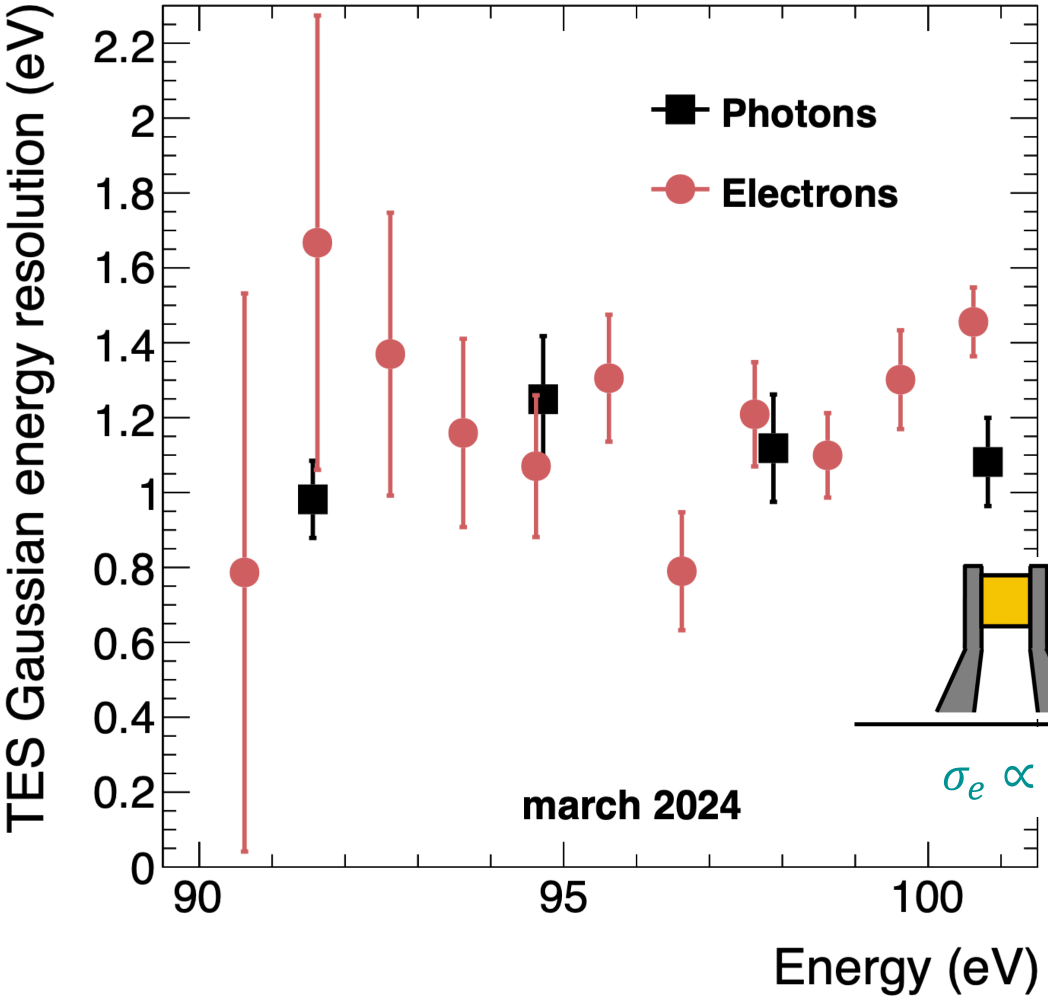

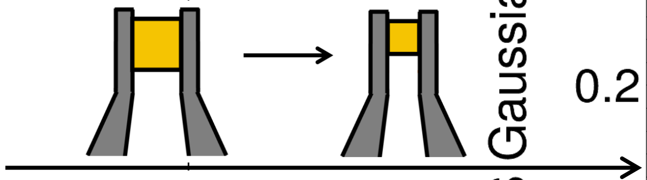

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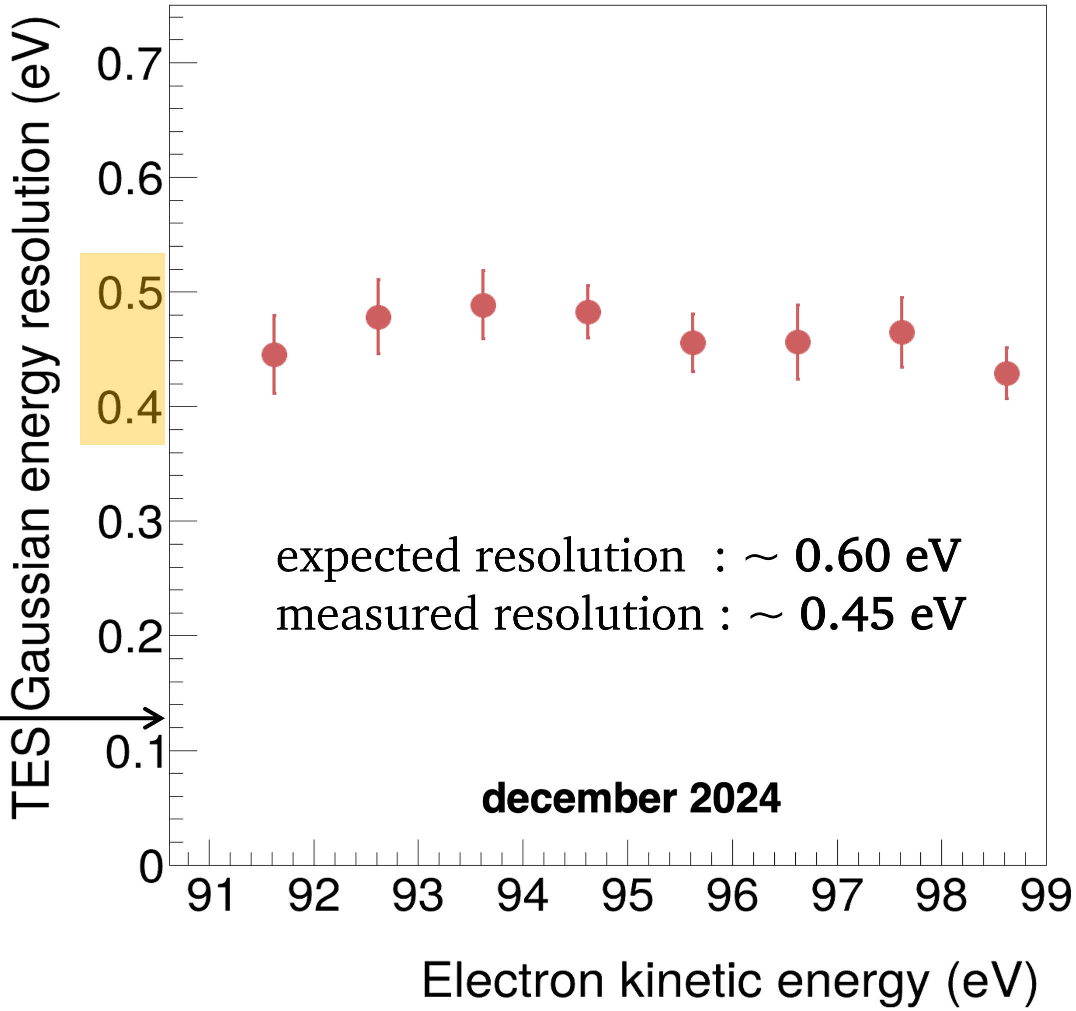

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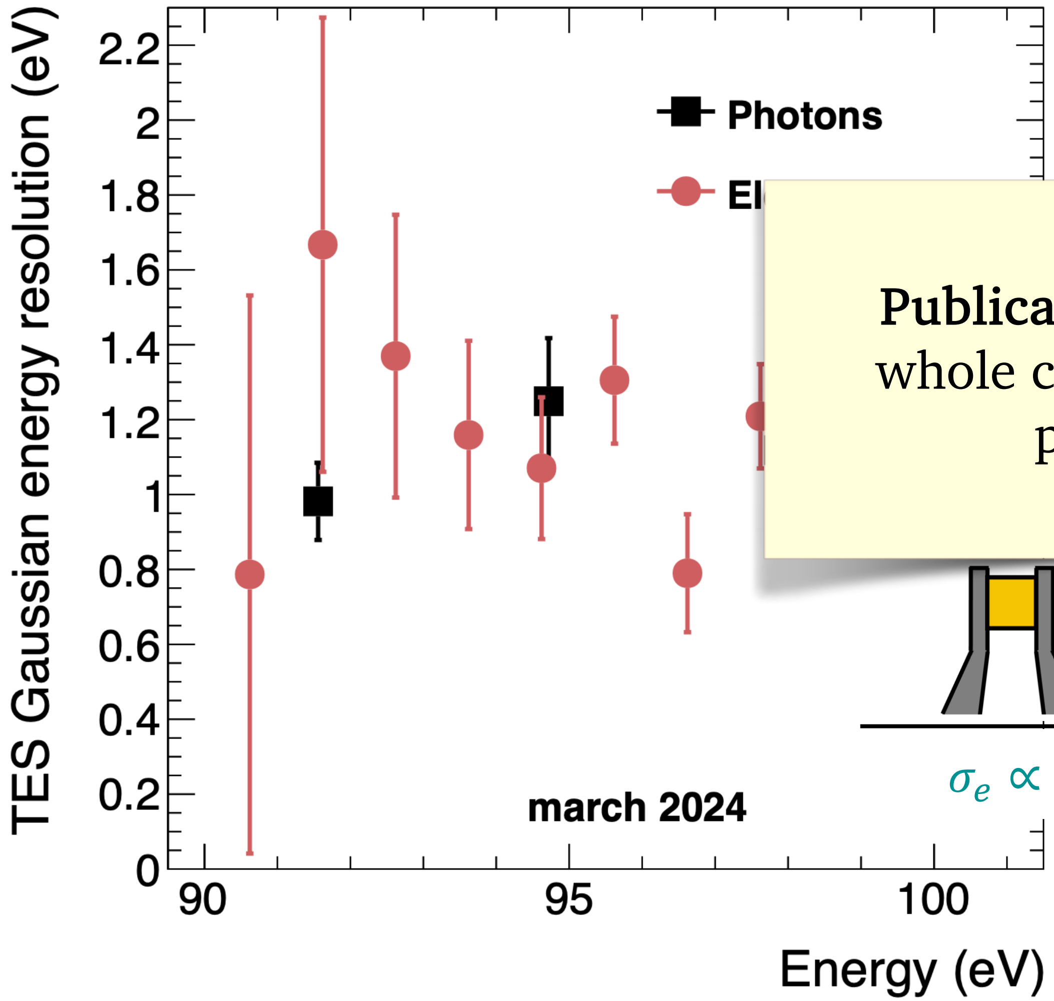

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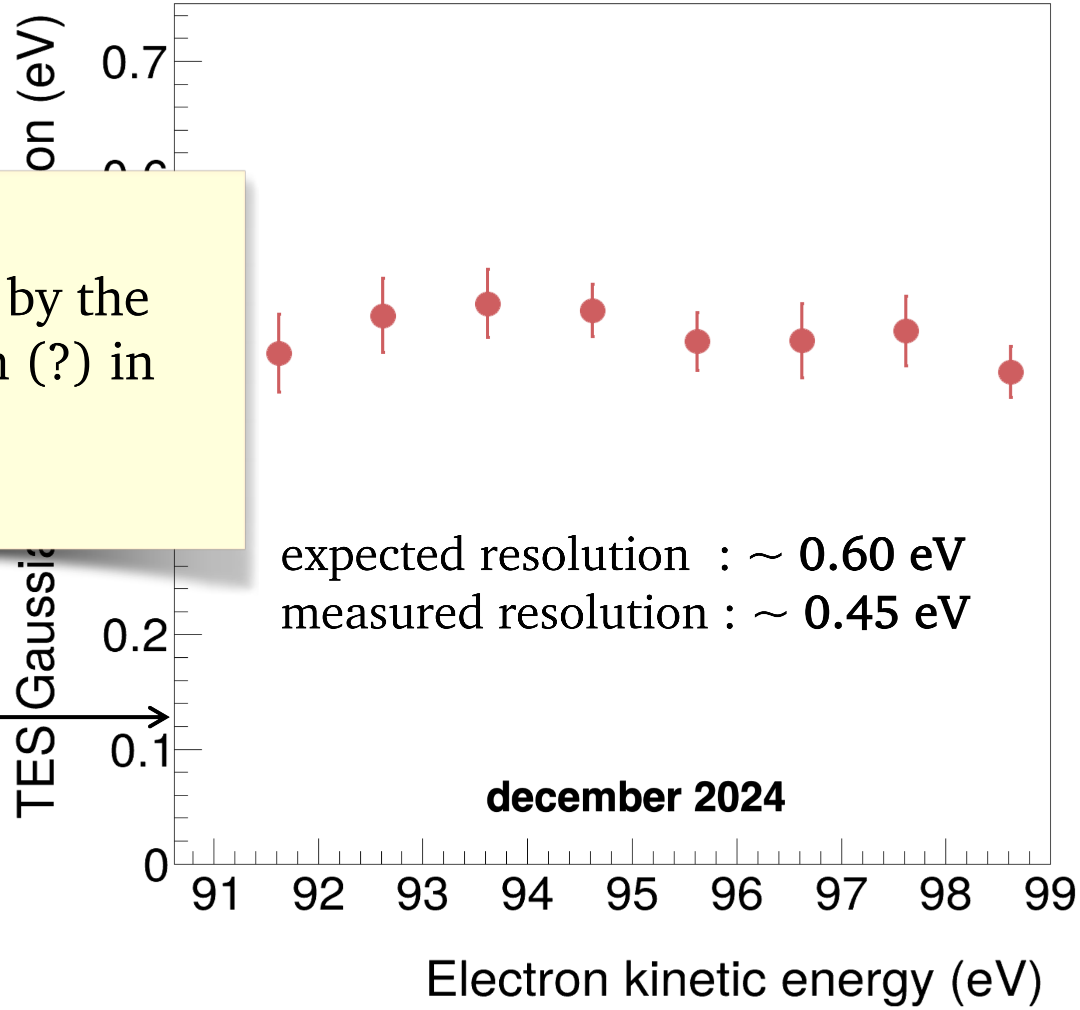
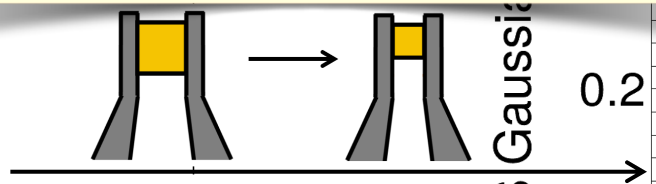


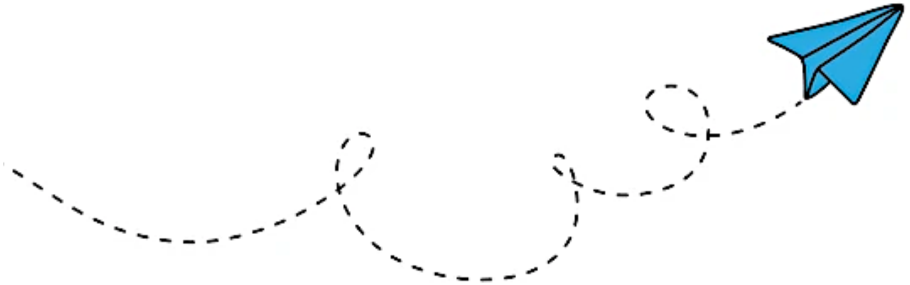
Publication signed by the whole collaboration (?) in preparation!



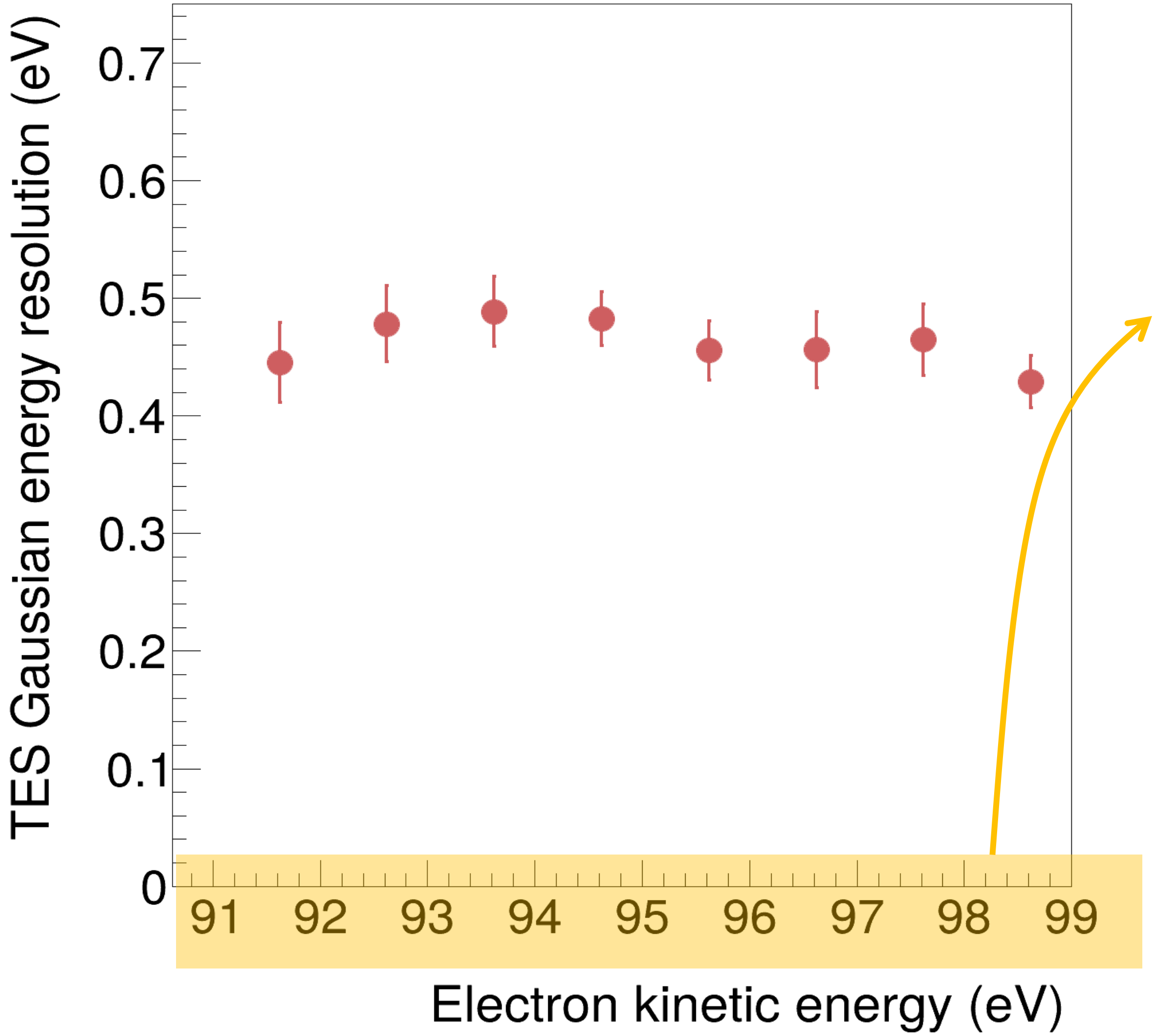
$\sigma_e \propto \sqrt{Area_{TES}}$

expected resolution : ~ **0.60 eV**
measured resolution : ~ **0.45 eV**

Where Are We Going?



Problem 1: Lower the Energies

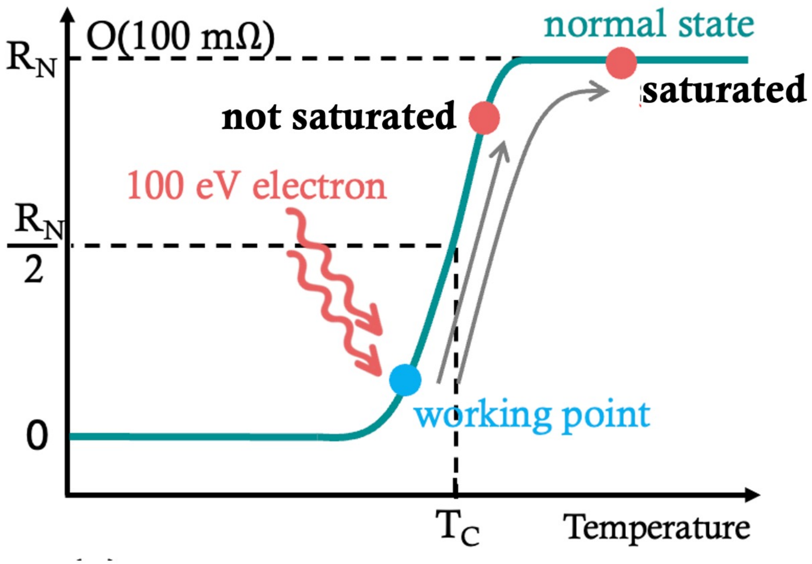


electron nominal energy:

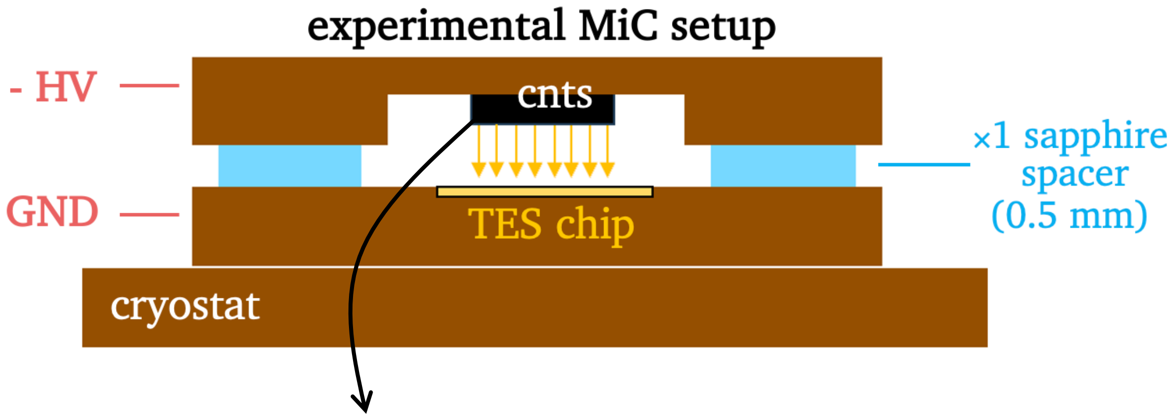
$\boldsymbol{E_e} = eV_{\text{cnt}} - \varphi_{\text{tes}} = eV_{\text{cnt}} - 4.4\ \text{eV}$

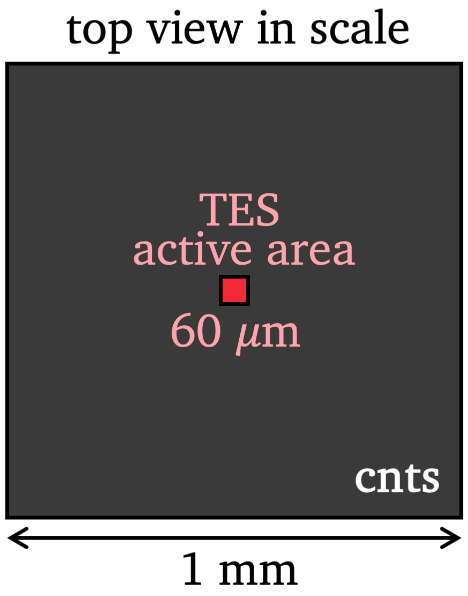
limitation due to field emission threshold voltage

- energies are too high for the **PTOLEMY goal** of **10 eV**
- TES **saturation** at ~ 100 eV electrons → we are too close



Problem 2: Undesidered Partial Absorptions



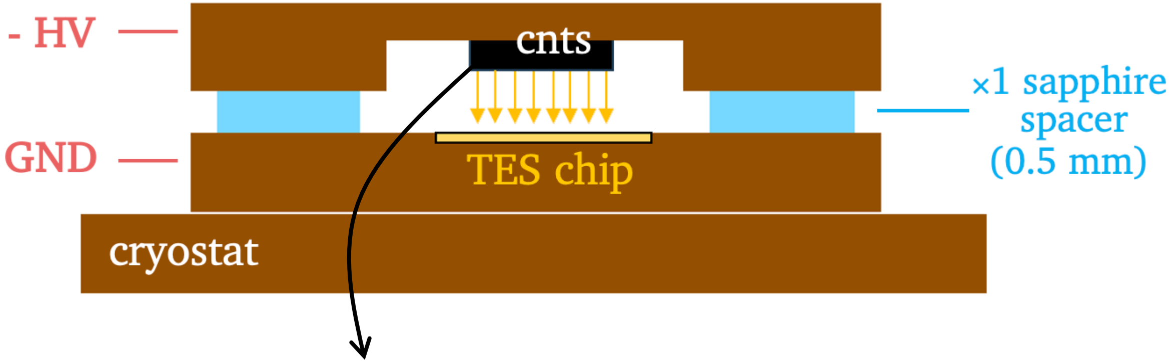


around the TES there are elastic scatterings, anelastic scatterings, secondary electrons...

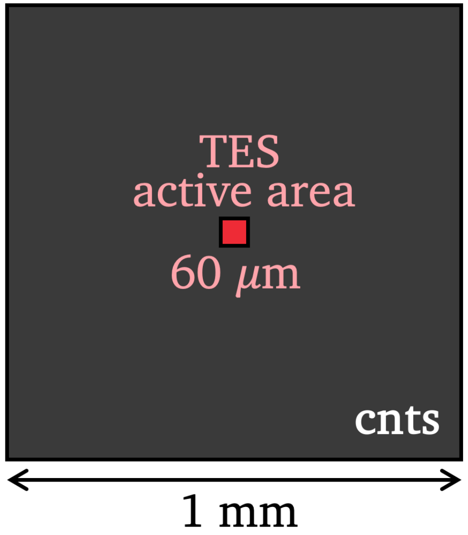
CNTs surface ≫ TES active area

Problem 2: Undesidered Partial Absorptions

experimental MiC setup



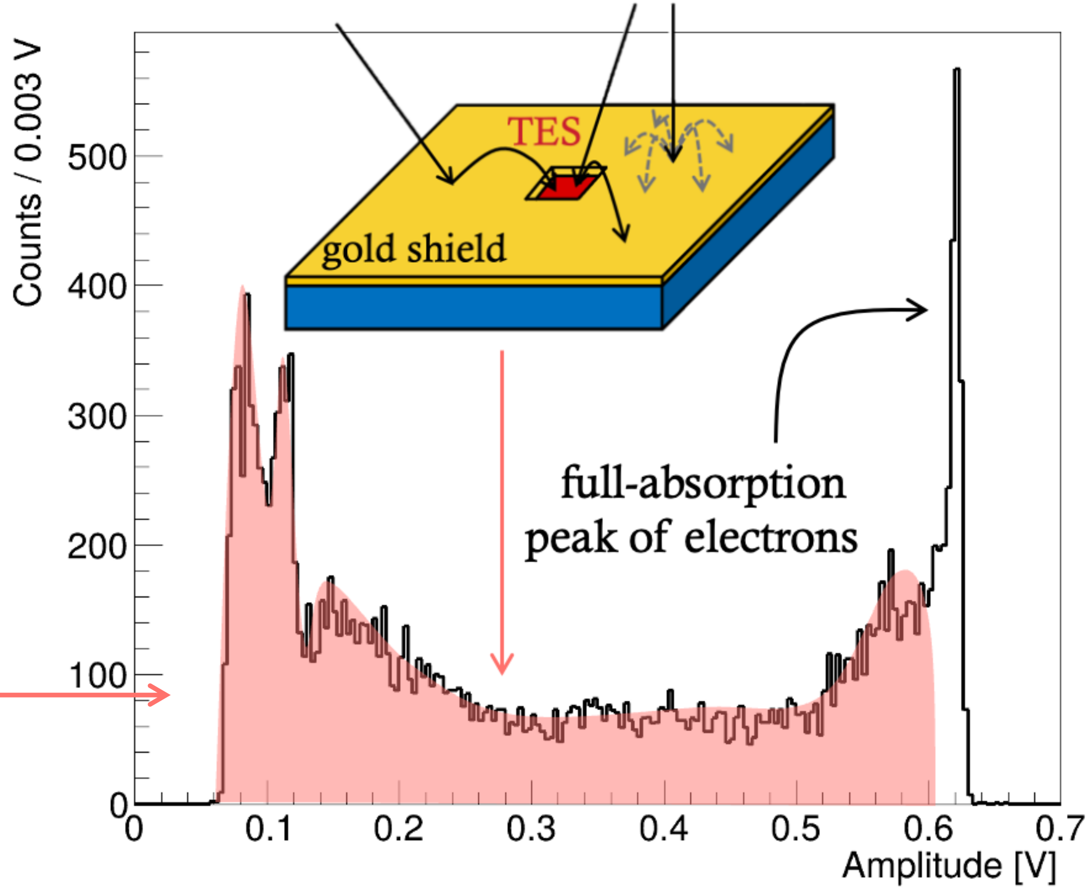
top view in scale



around the TES there are elastic scatterings, anelastic scatterings, secondary electrons...

do they justify this?

ideal spectrum of monochromatic electrons: one Gaussian full-absorption peak



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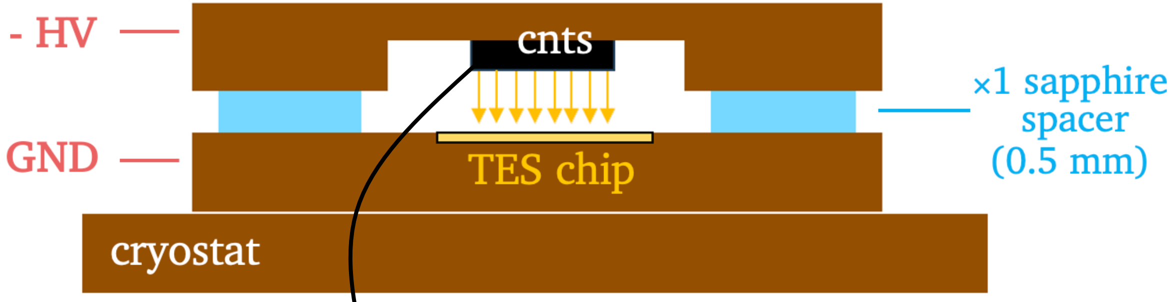

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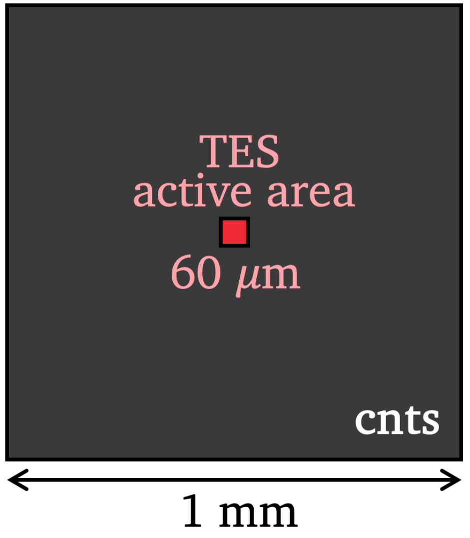

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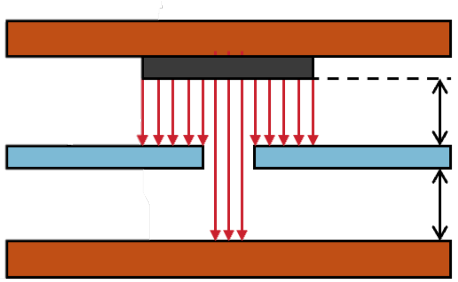

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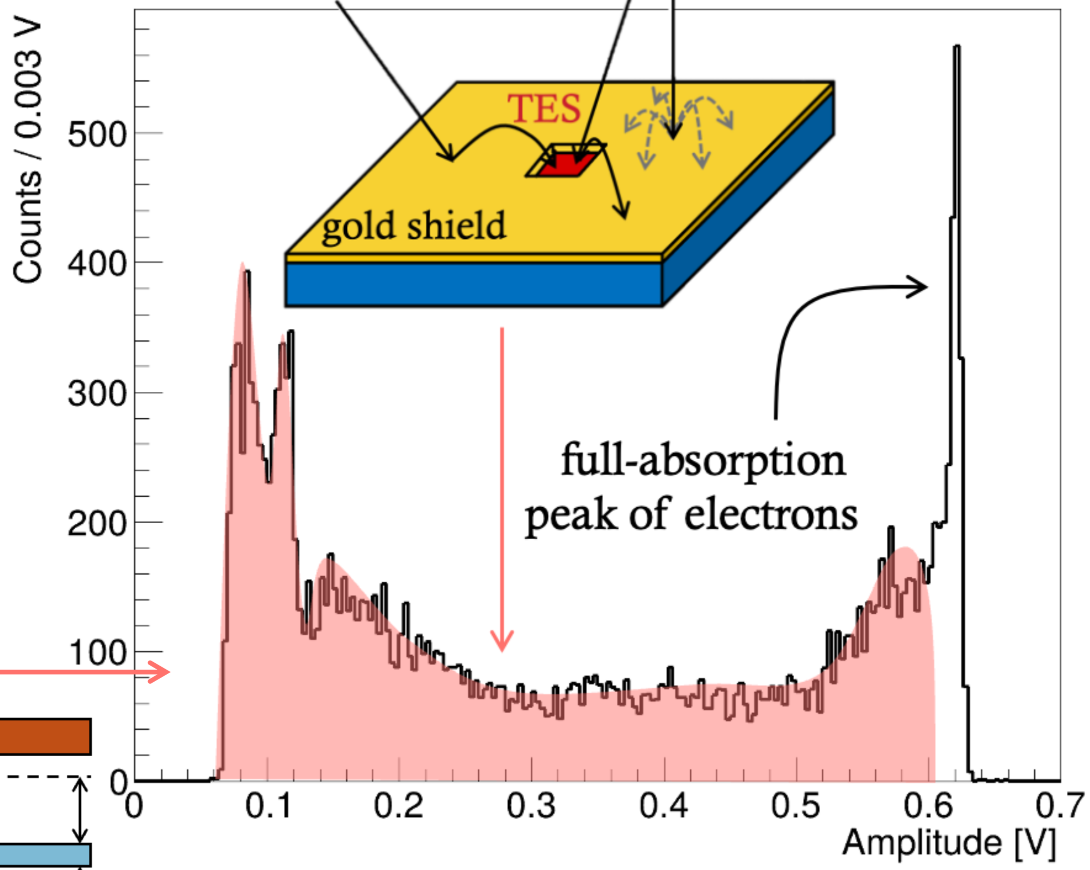
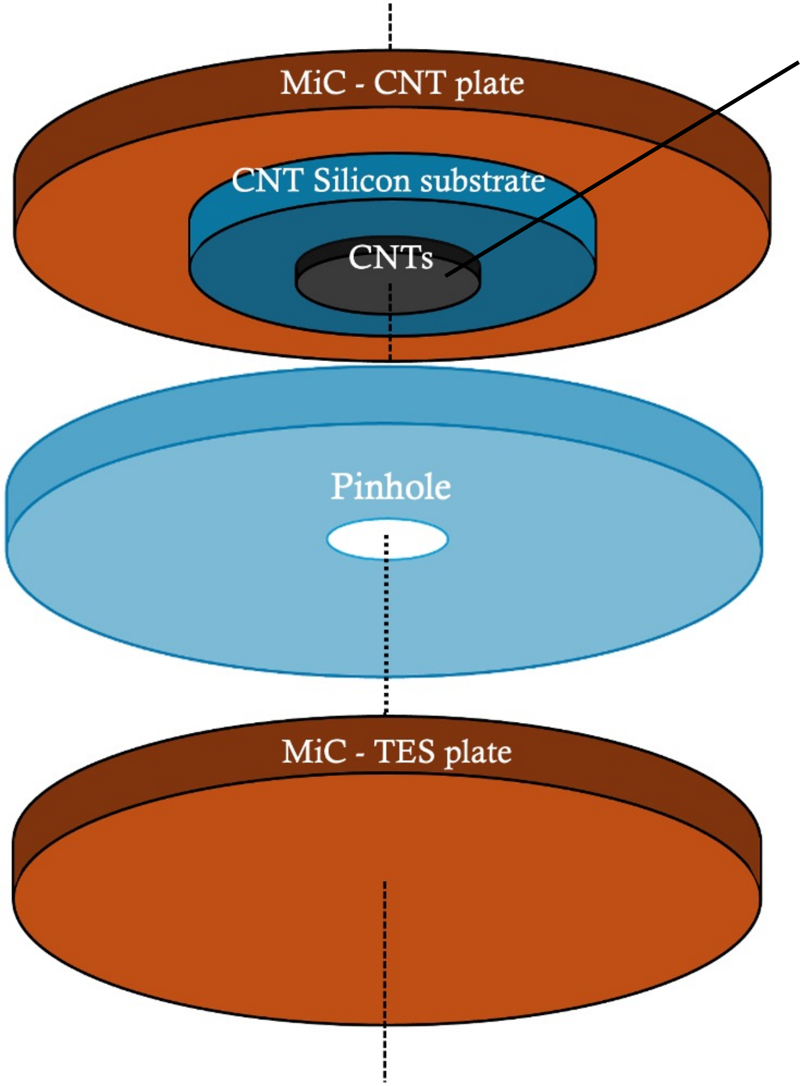


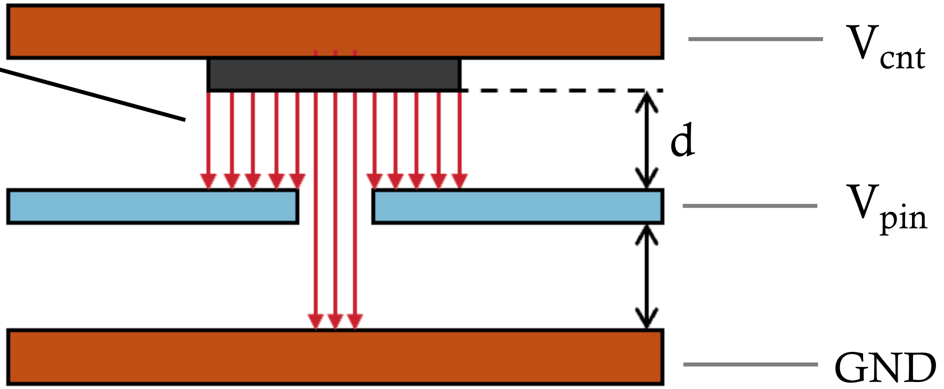
PINHOLE to manage both problems

SIMION to Simulate Electric Field

Geometry of simulations:



electrons generated @ 0 eV on surface of CNTs



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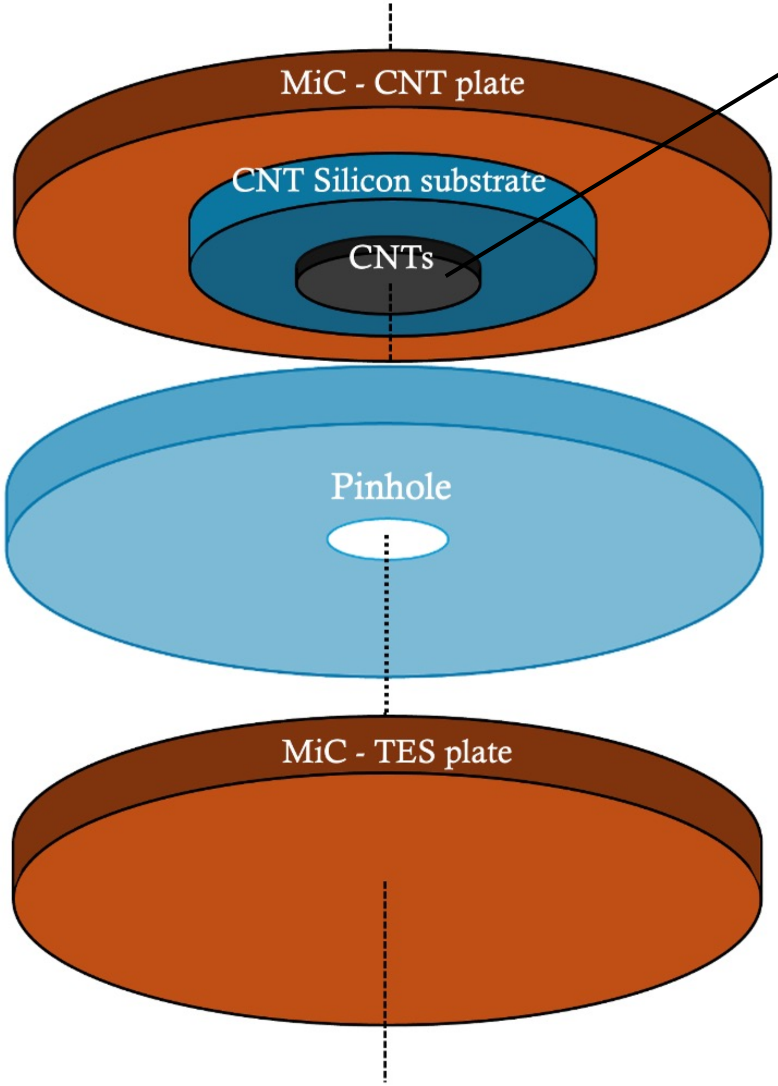

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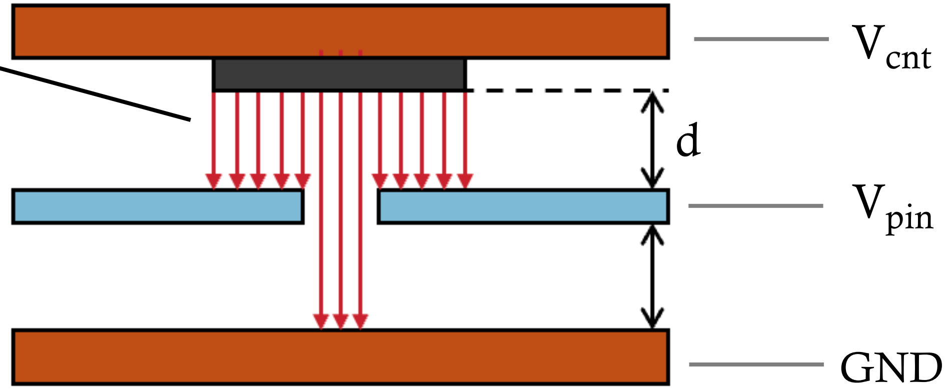
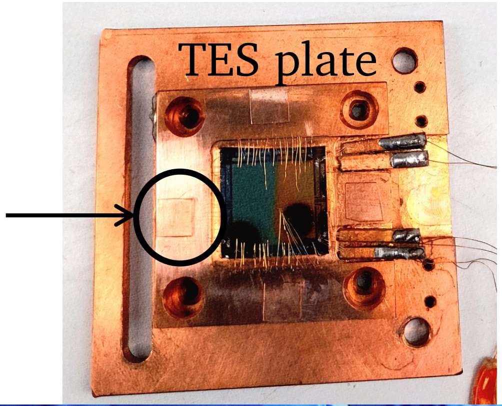


Parameters to change

- size of the pinhole (diameter)
- distances between electrodes (sapphire spacers between plates)

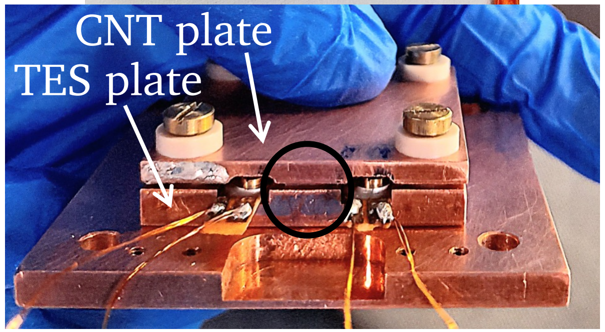


parallel-plate capacitor geometry:

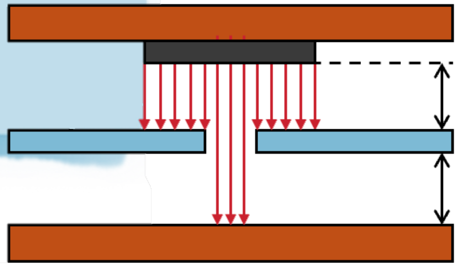
$$\vec{E} = V/d$$

$$\downarrow$$

$$\vec{E}_{thr} = (V_{cnt} - V_{pin})/d$$



ENERGY TUNABILITY with PINHOLE



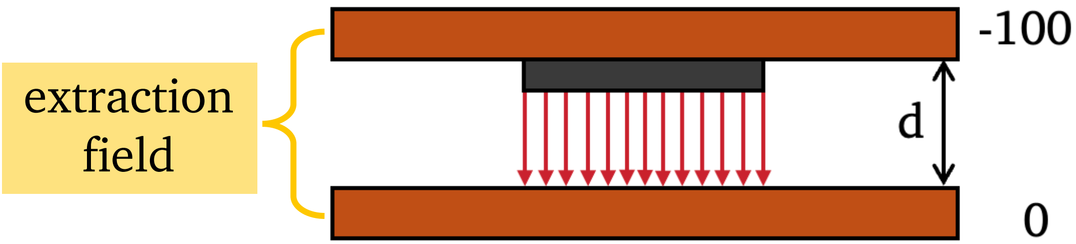
Pinhole Used as Decelerator

- to generate field emission $\Delta V = -100\ V\ @\ d = 600\ \mu m$; final kinetic energy of electrons is $K_e = e \cdot V_{cnt}$

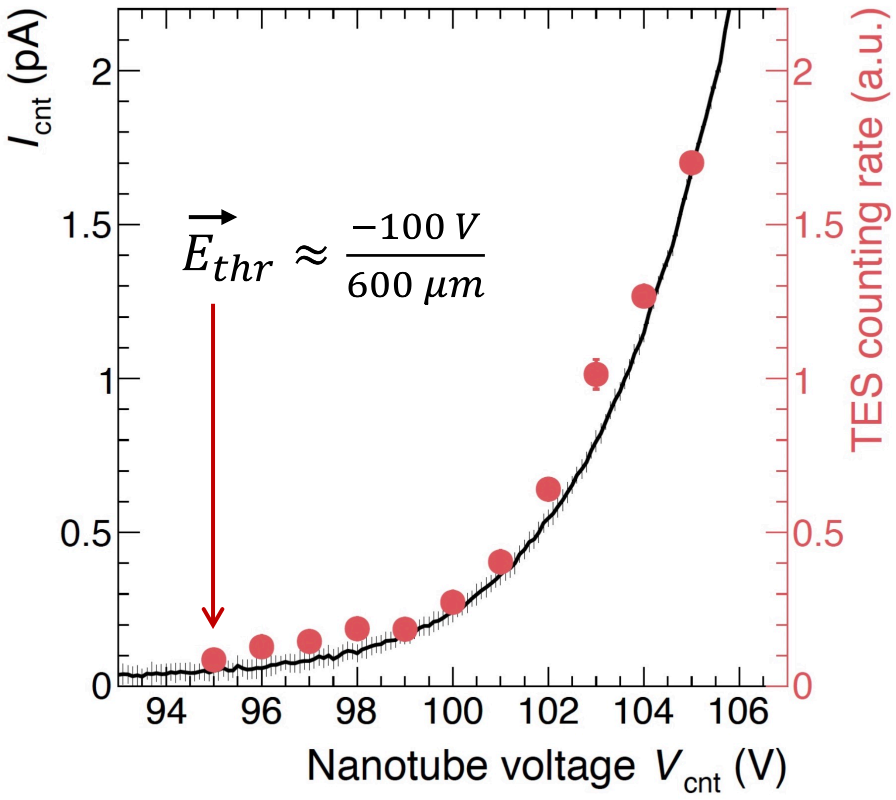
OLD SETUP

$\Delta V = -100\ V - 0\ V = -100\ V$

$K_e = 100\ eV$



$\vec{E} \propto energy \propto i_{cnt}$



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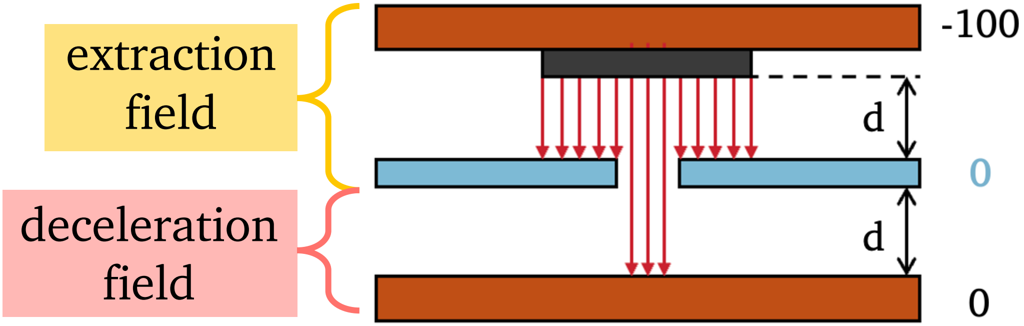
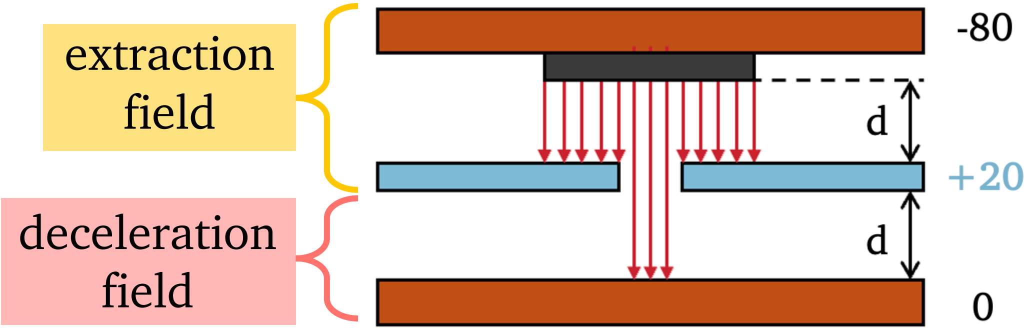
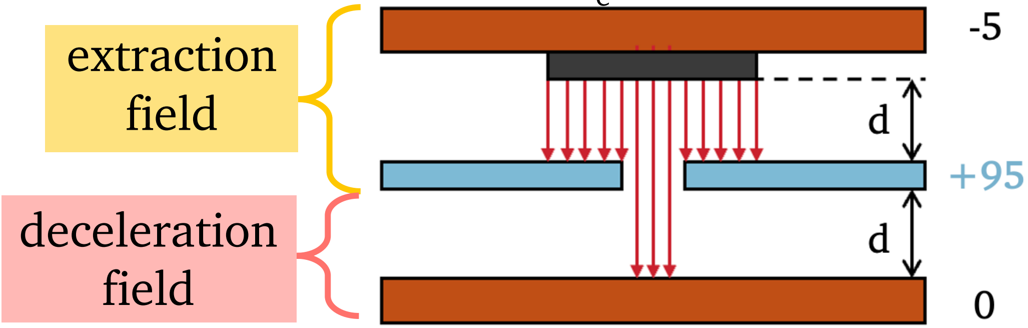


$\Delta V = -80\ \mathrm{V} - 20\ \mathrm{V} = -100\ \mathrm{V}$
$K_e = 80\ \mathrm{eV}$



$\Delta V = -5\ \mathrm{V} - 95\ \mathrm{V} = -100\ \mathrm{V}$
$K_e = 5\ \mathrm{eV}$



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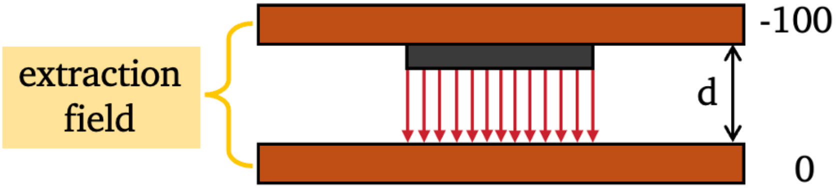

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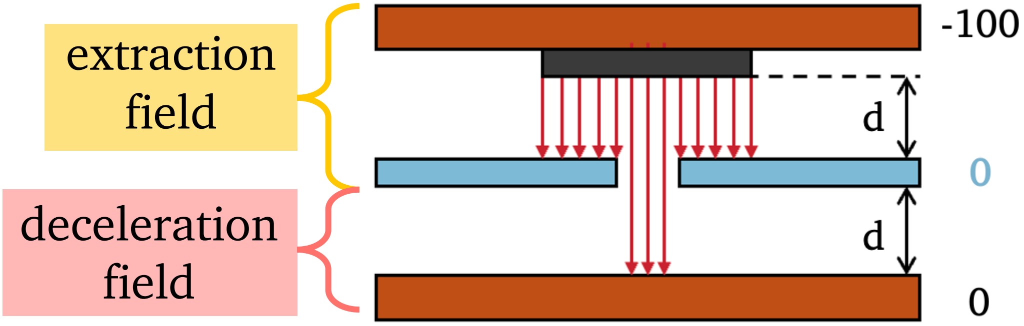

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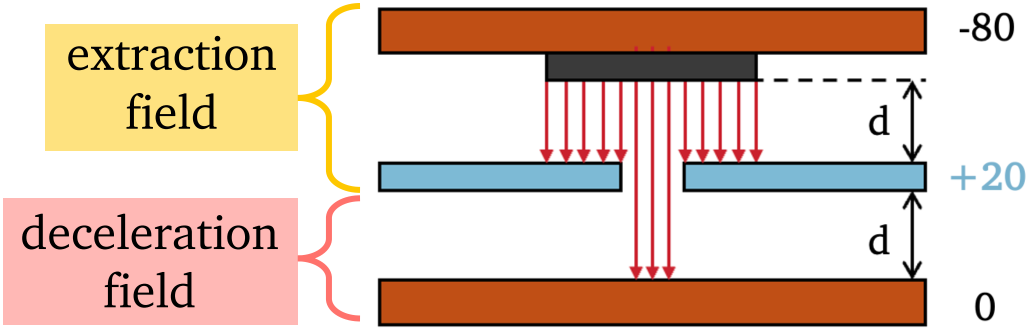

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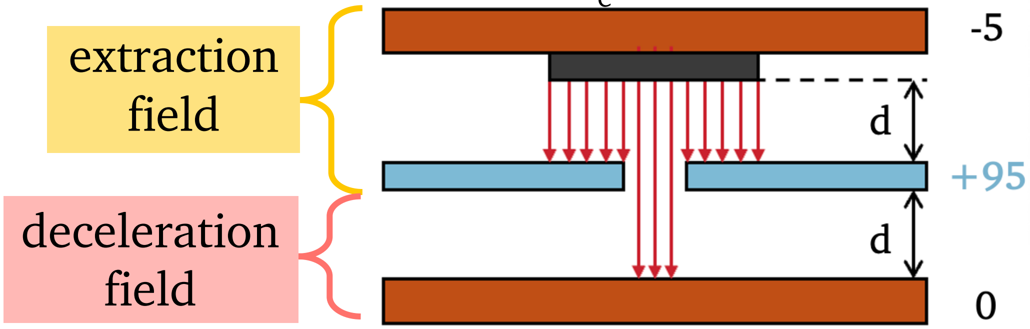
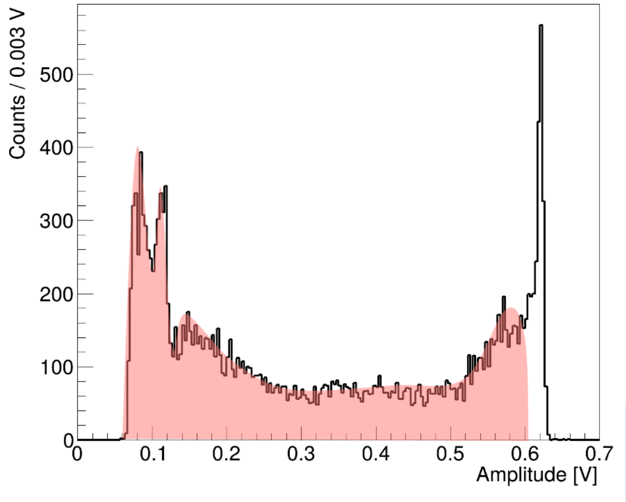


we can select voltages that:

✓ achieve field emission **threshold**

✓ **tune** the electron final energy

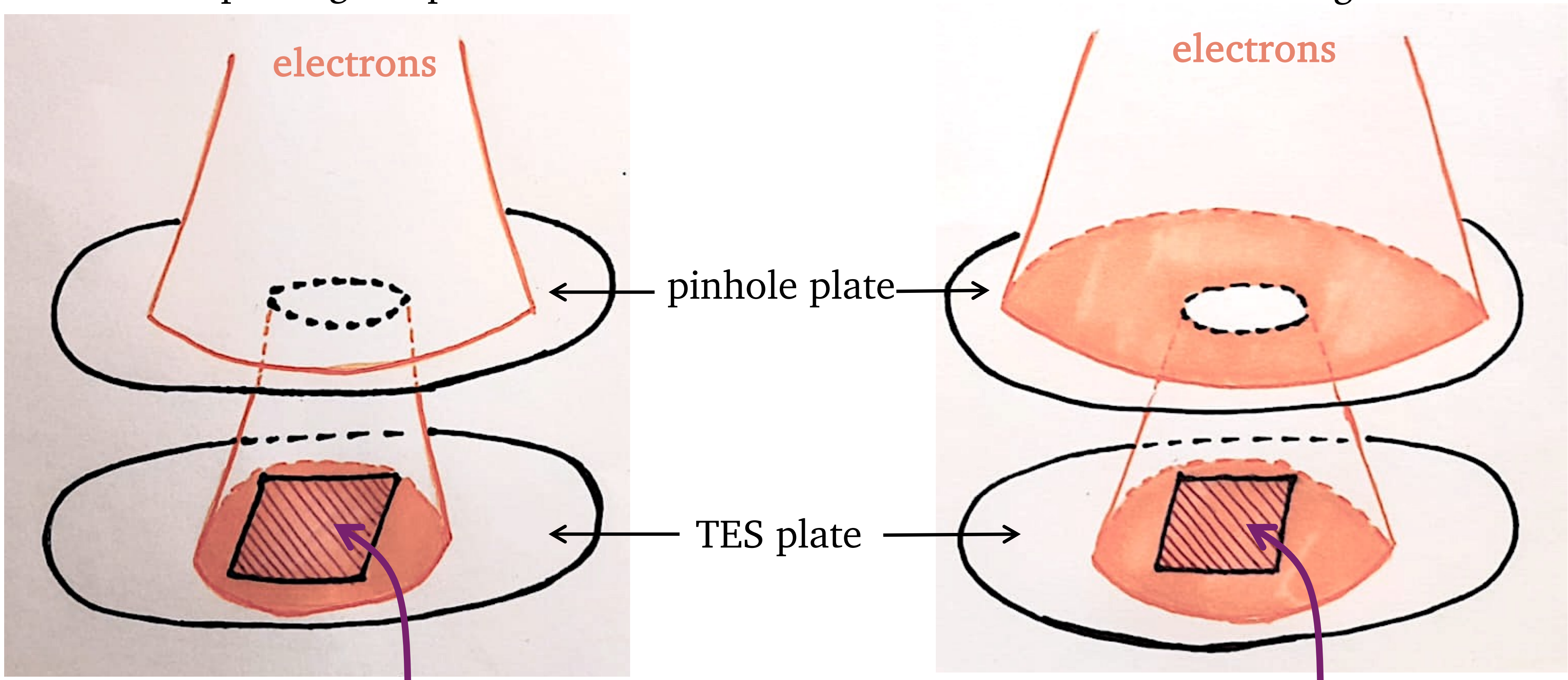


ELECTRON FOCALIZATION on TES with PINHOLE

Two Different Figures of Merit

How many electrons hit the TES out of the ones passing the pinhole?

How many electrons hit the TES out of the all the electrons generated?



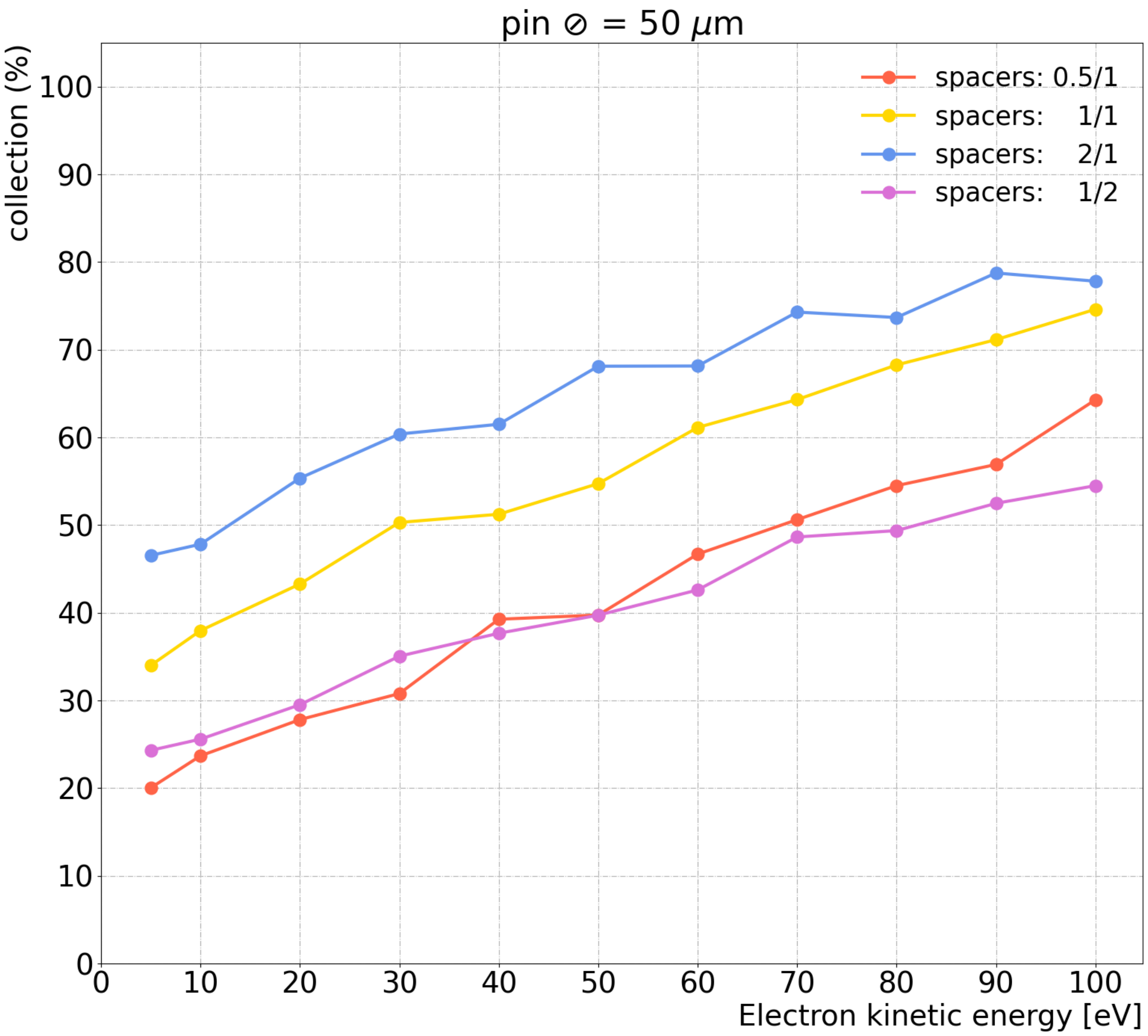
$$c = \frac{\textit{hits inside TES}}{\textit{total hits on the MiC plate}}$$

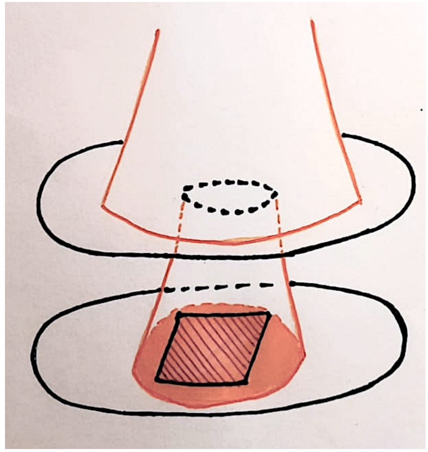
collection parameter

$$r = \frac{\textit{hits inside TES}}{\textit{all events generated}}$$

rate parameter

Collection (%) in the Useful Energy Range





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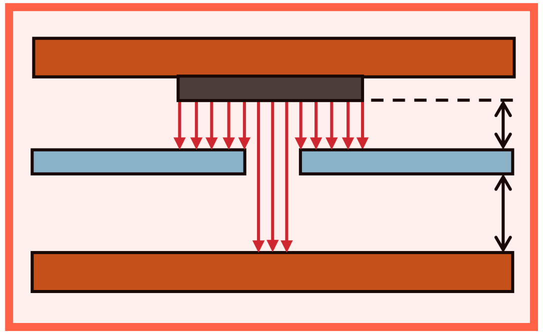

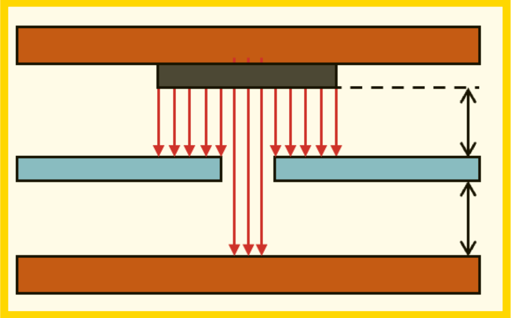

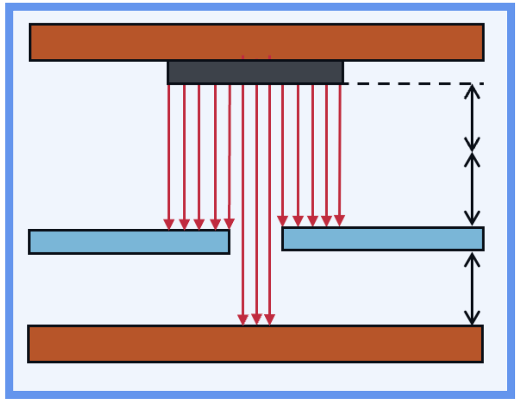

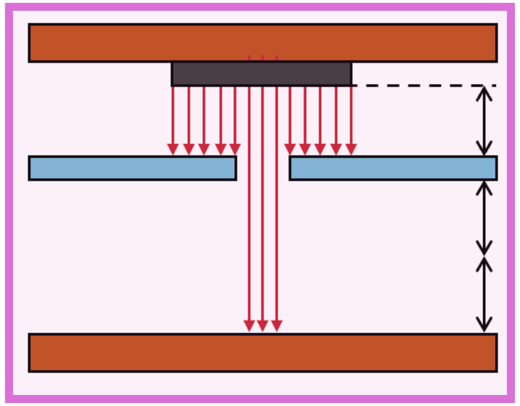

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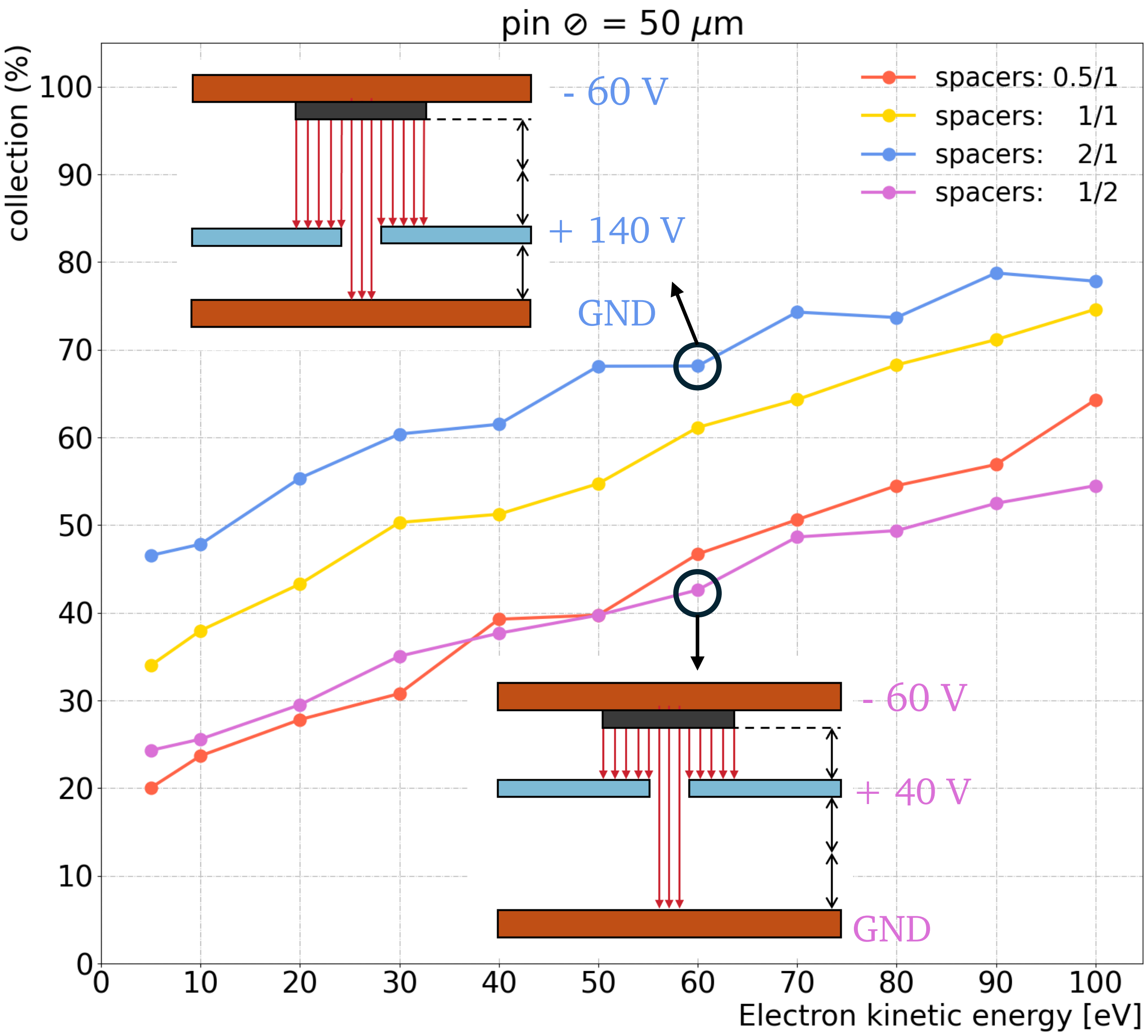

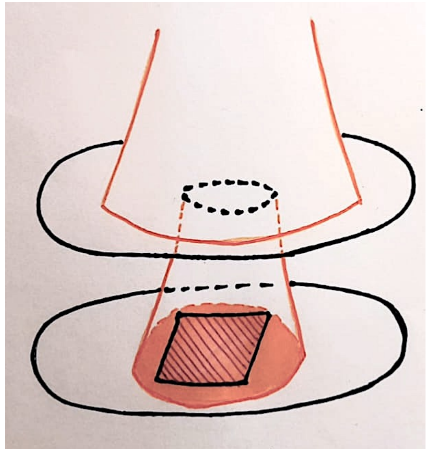

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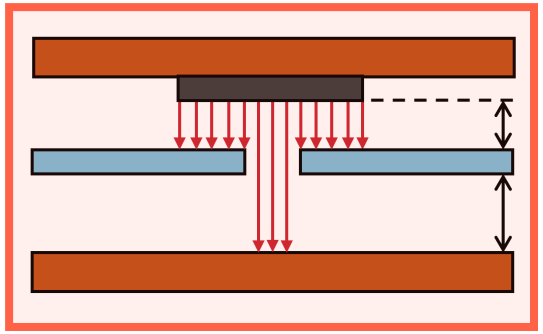

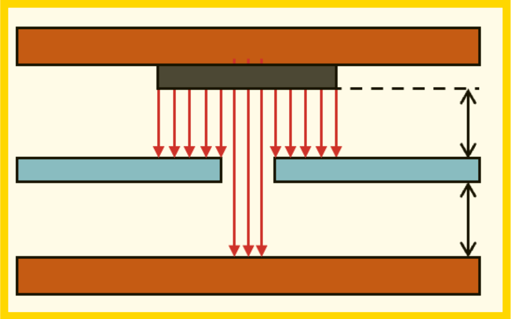

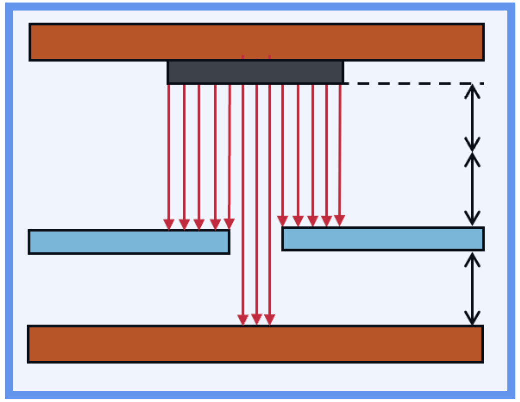

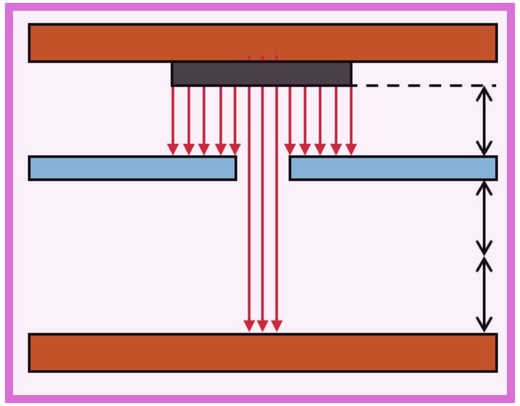

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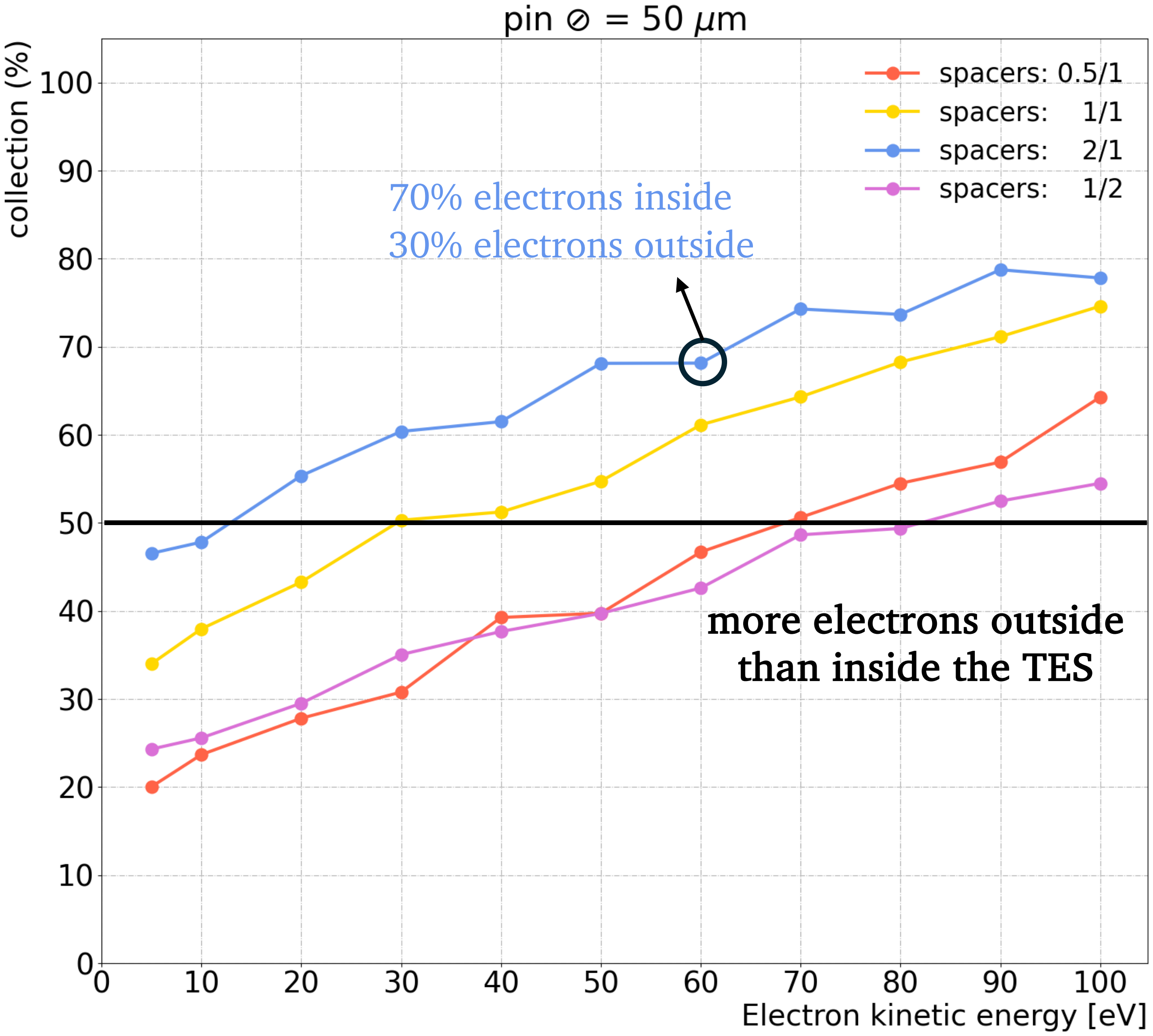
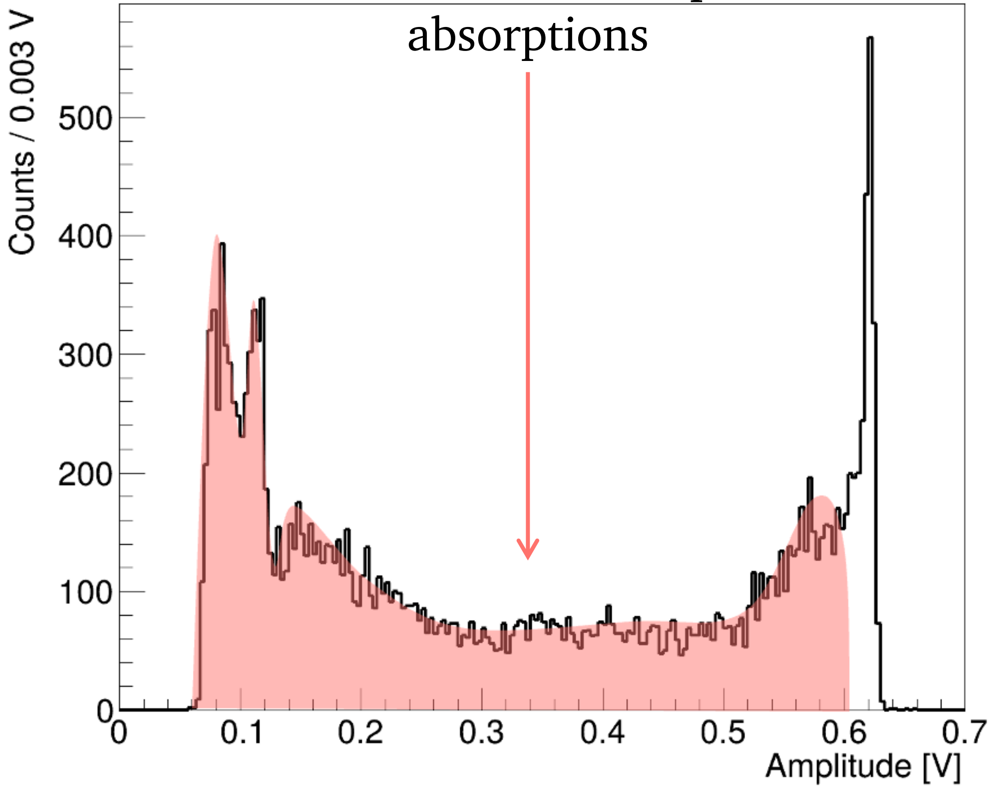
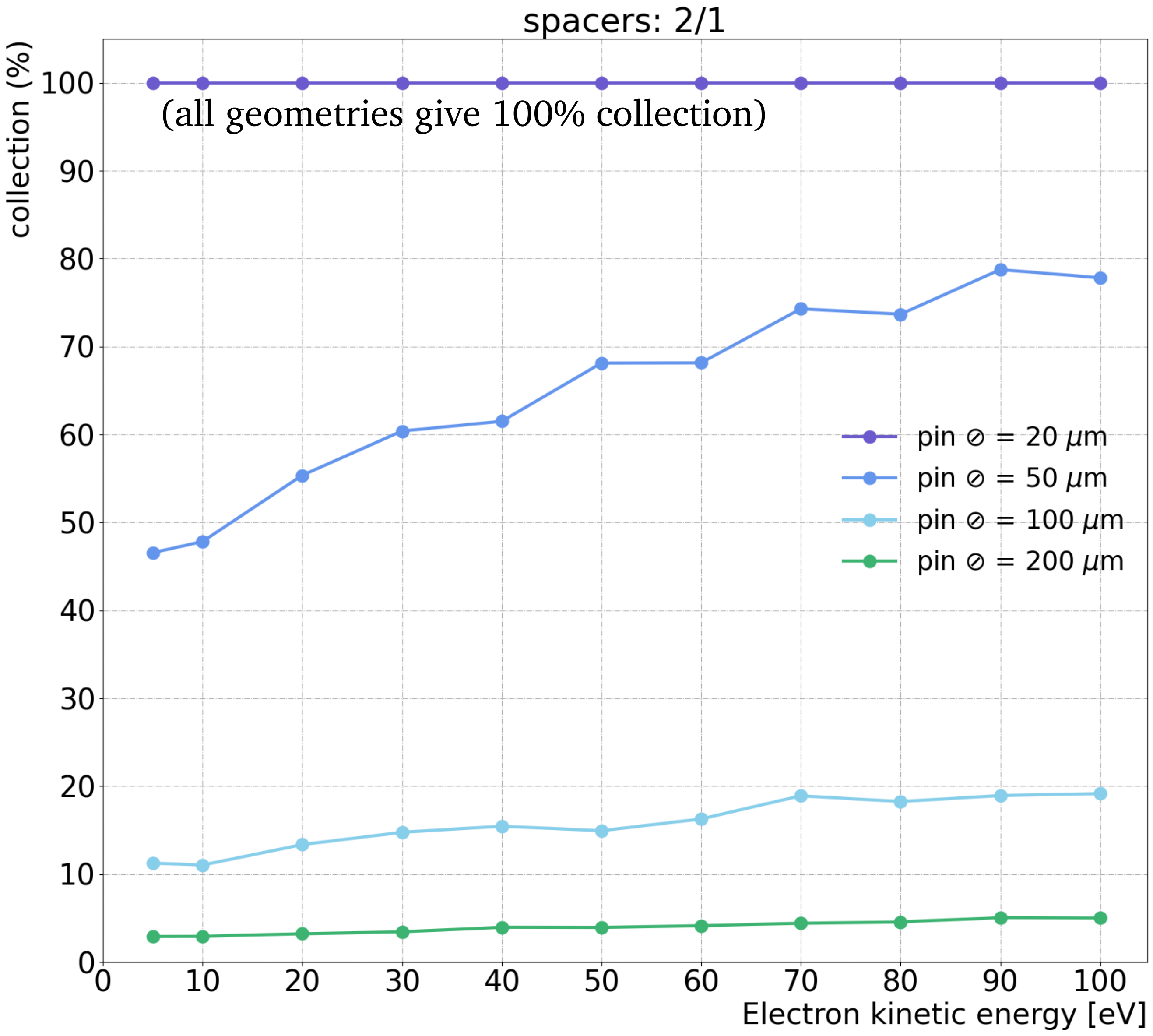


$$c = \frac{\textit{hits inside TES}}{\textit{total hits on the MiC plate}}$$

all the electrons missing the TES contribute to the partial absorptions



How Pinhole Size Affects Collection (%)



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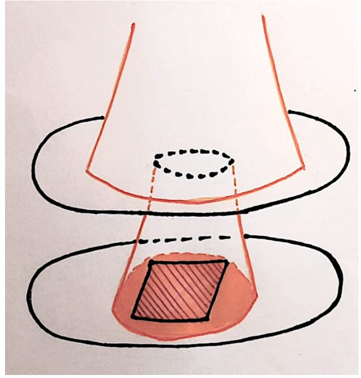
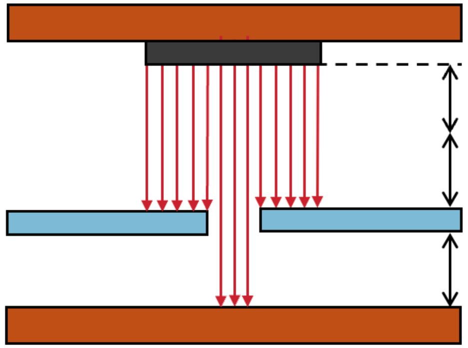
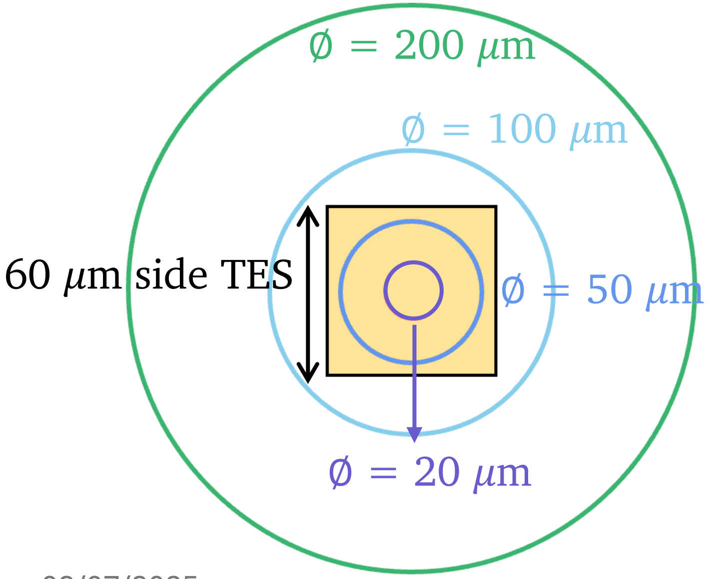


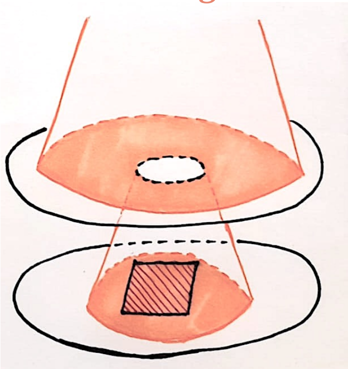


in scale proportions:

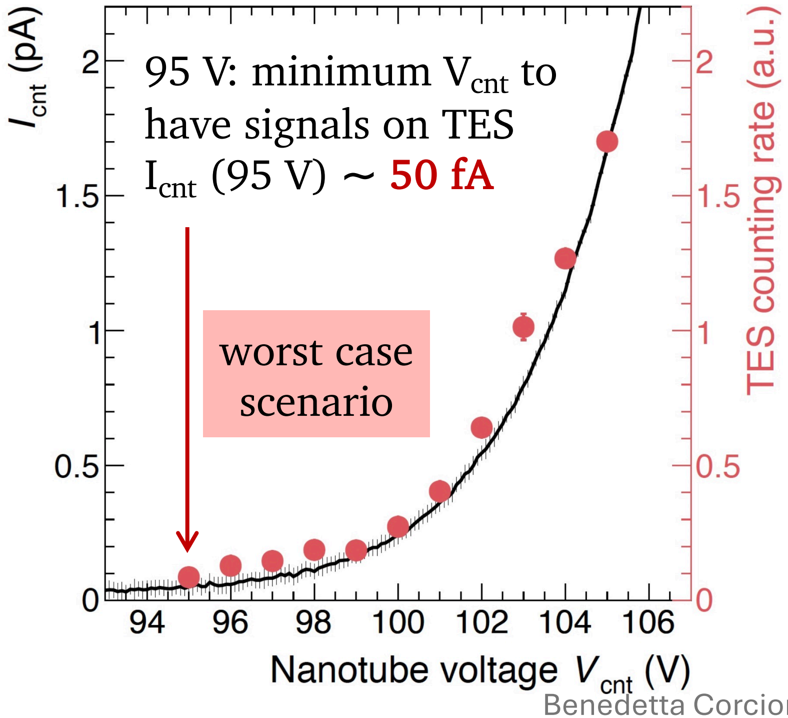


Possible Rate of Signals on TES

$$r = \frac{\textit{hits inside TES}}{\textit{all events generated}}$$

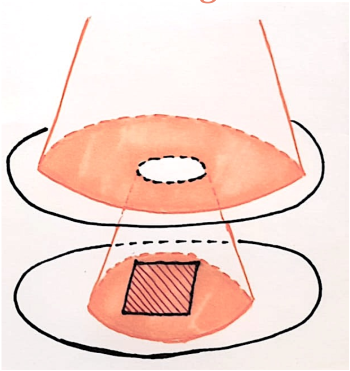


- I_{cnt} and TES counting rate **comparison**
- 10 times smaller CNTs: requirement of total emitted current ~ **5 fA** (= total rate of **30 kHz**)
- r parameter rescaled by such reference rate



Possible Rate of Signals on TES

$$r = \frac{\textit{hits inside TES}}{\textit{all events generated}}$$



- I_{cnt} and TES counting rate **comparison**
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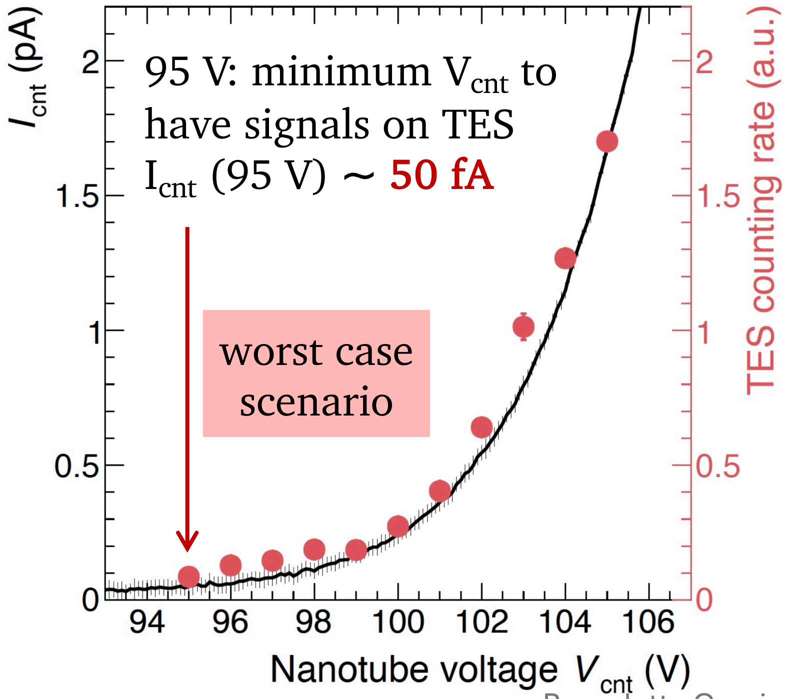
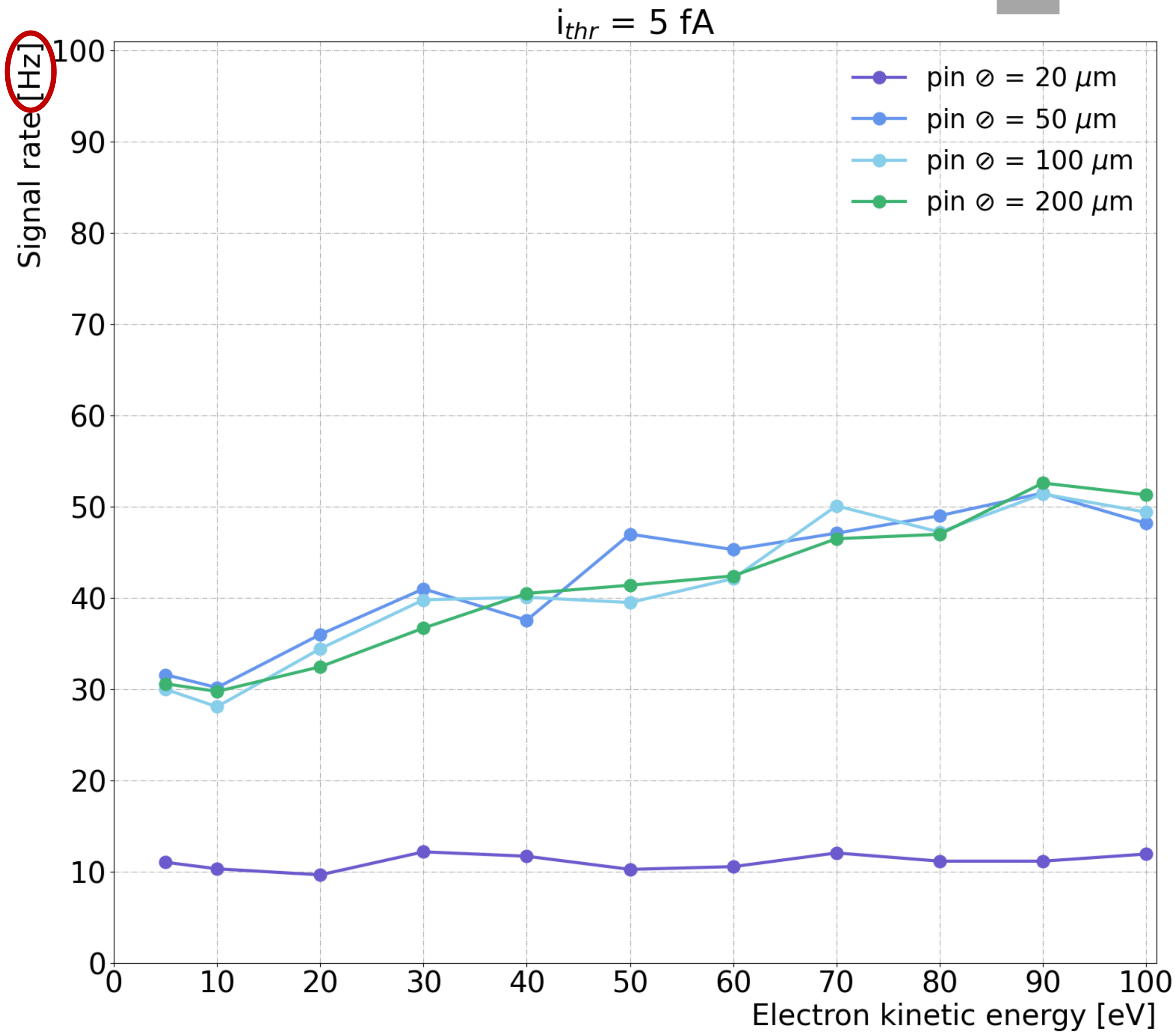
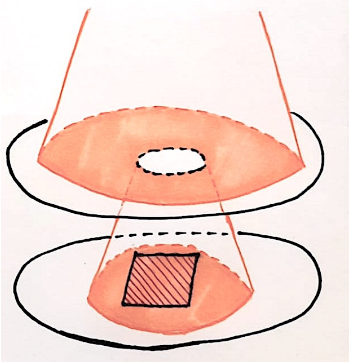




Possible Rate of Signals on TES

$$r = \frac{\textit{hits inside TES}}{\textit{all events generated}}$$



- I_{cnt} and TES counting rate **comparison**
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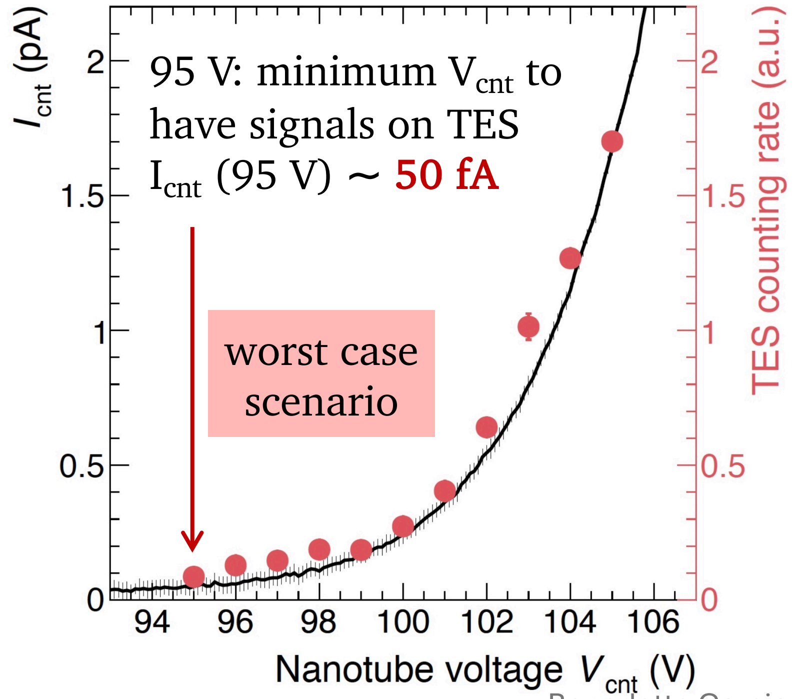
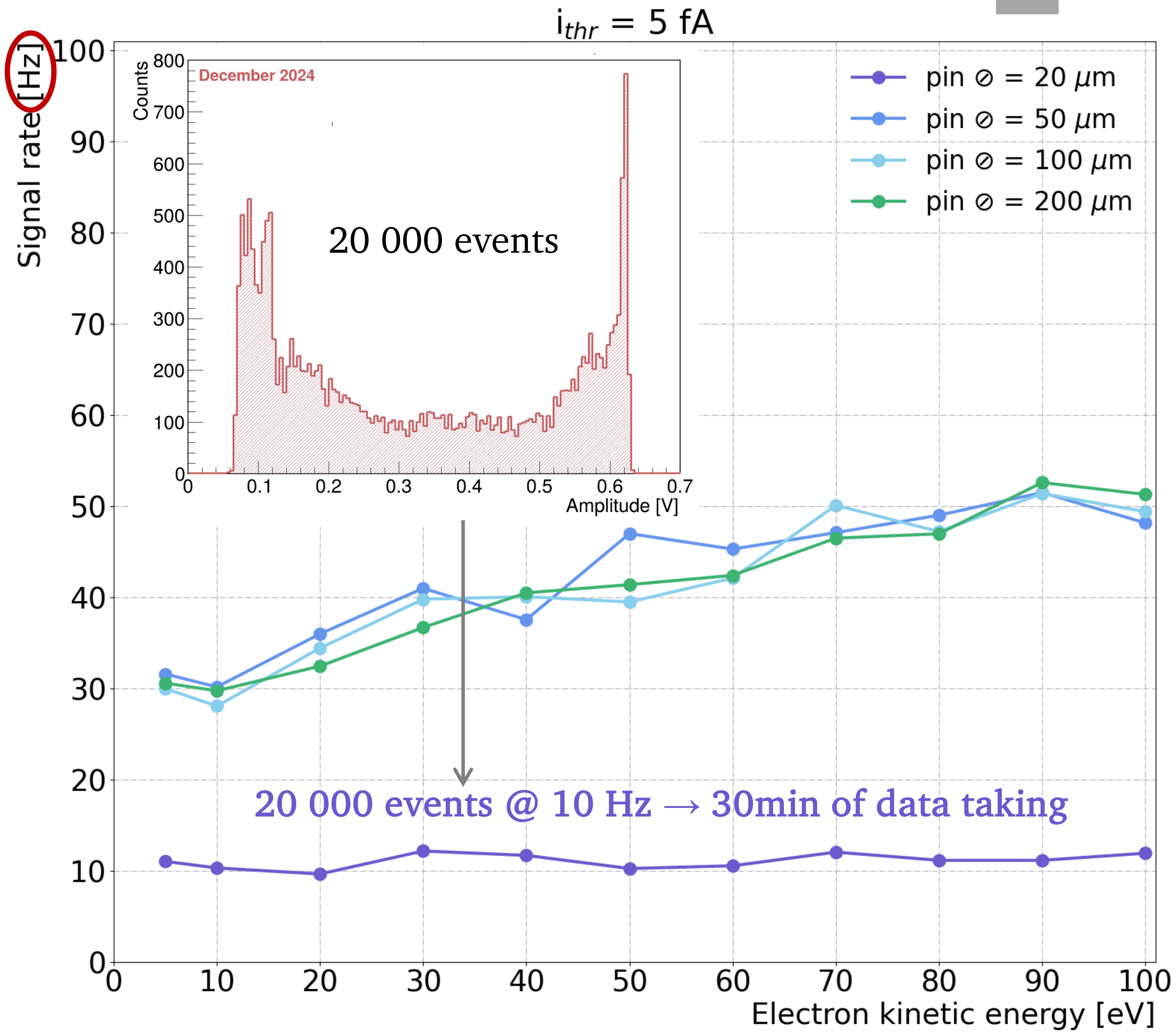


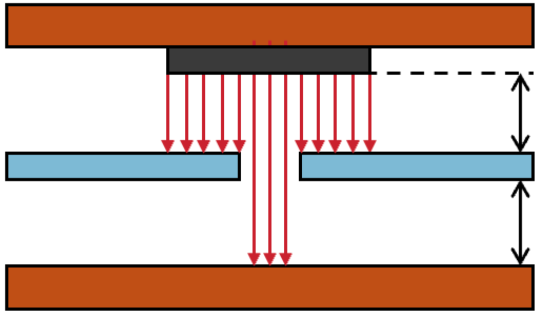


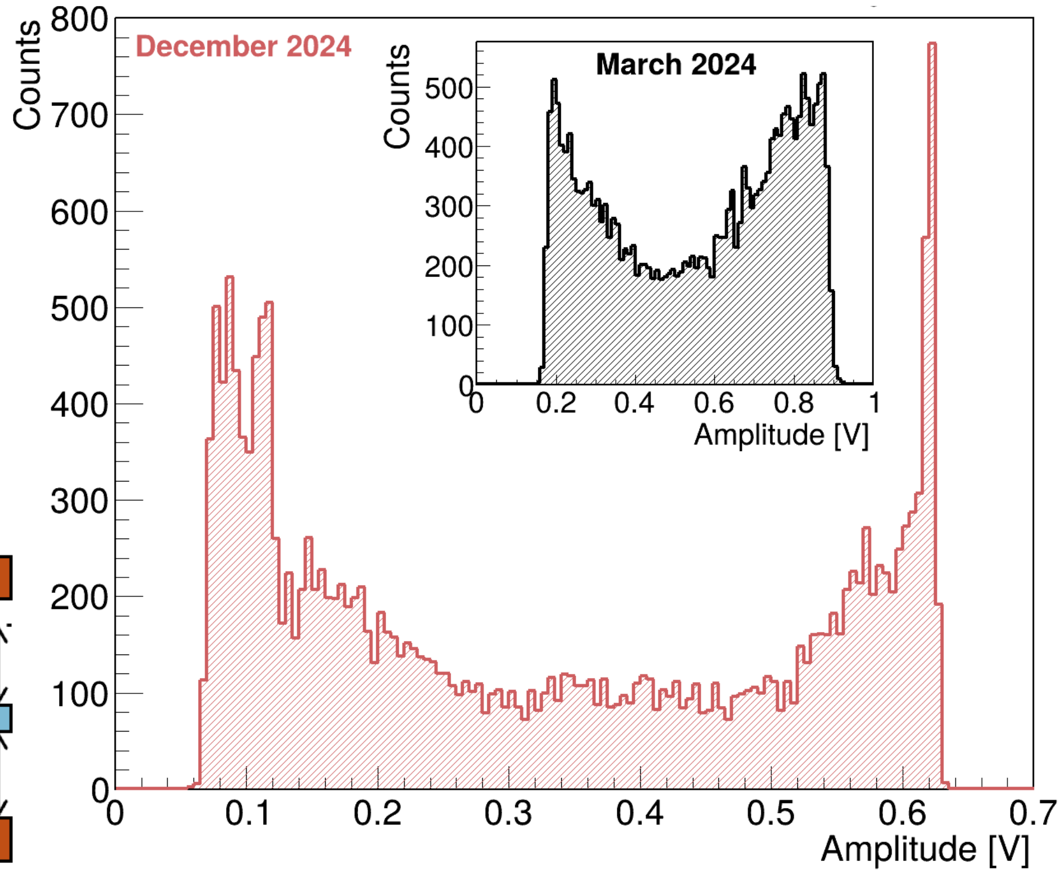
Conclusions

- **article** in preparation signed by all collaboration (?) on latest results (shown by Federico)

- simulations on **pinhole** to:
  1) lower energy of electrons → pinhole as **decelerator**
  2) send electrons on TES only → pinhole **stops** part of the electrons missing the TES

- **Ø = 20 μm pinhole** optimizes electron collection on TES and signal rate is acceptable





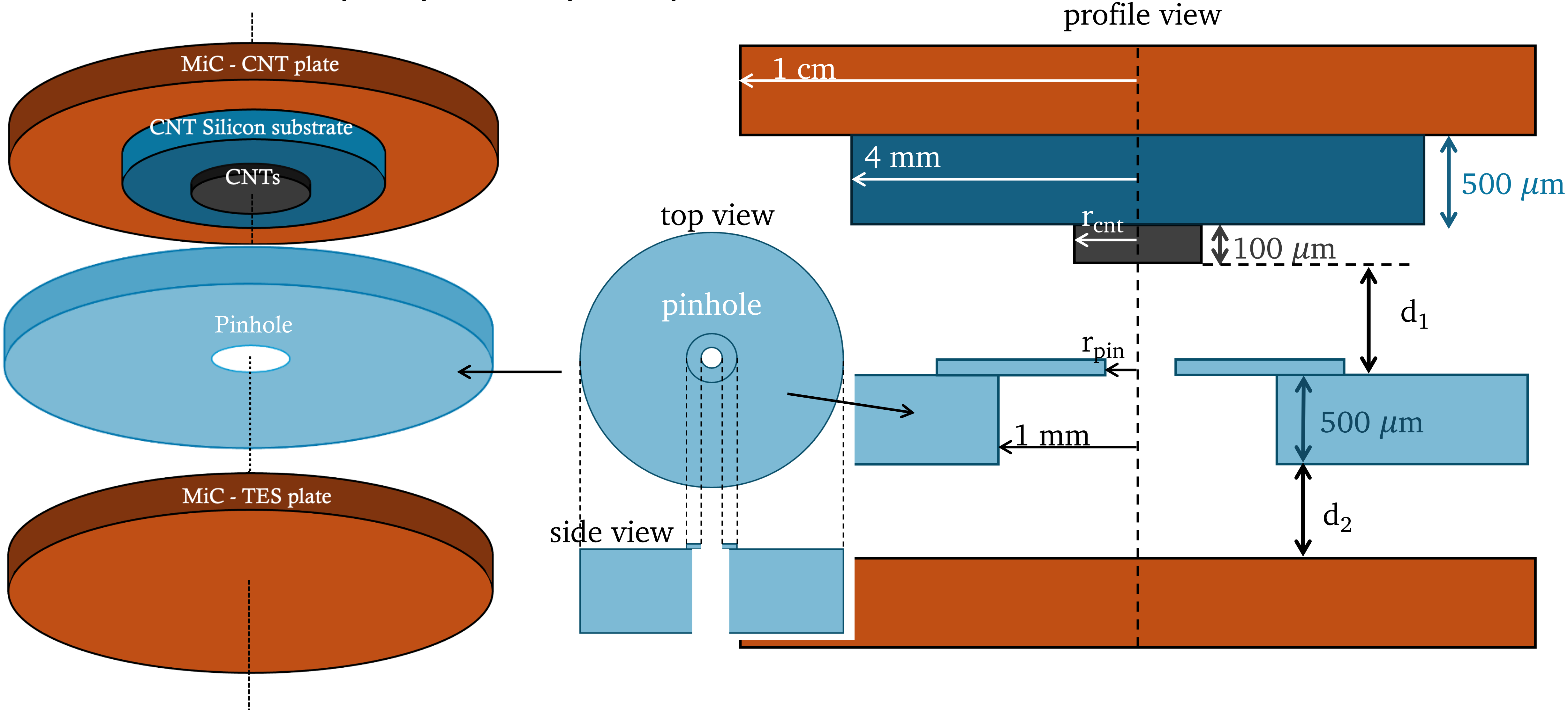
Thank you for your attention!

Backup Slides

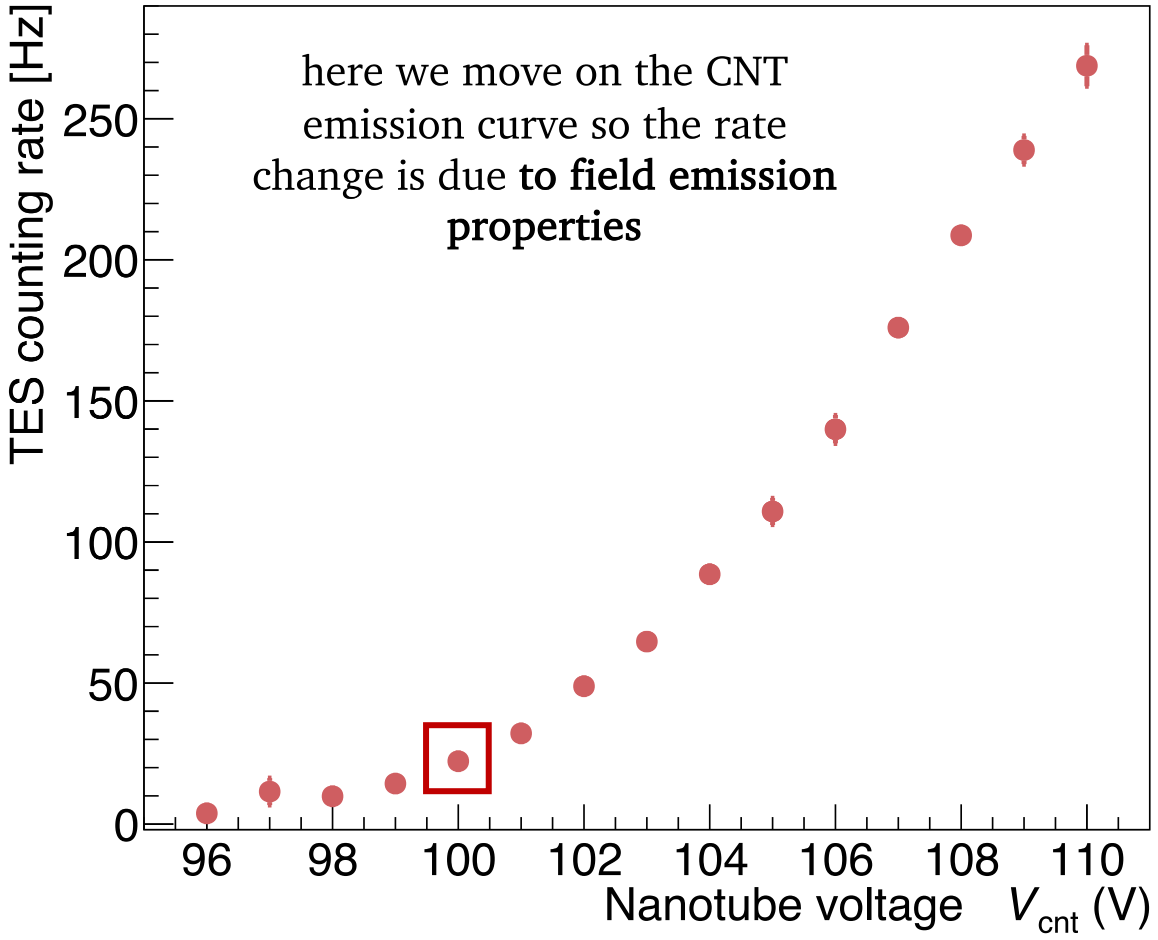
Some Numbers on Simulations

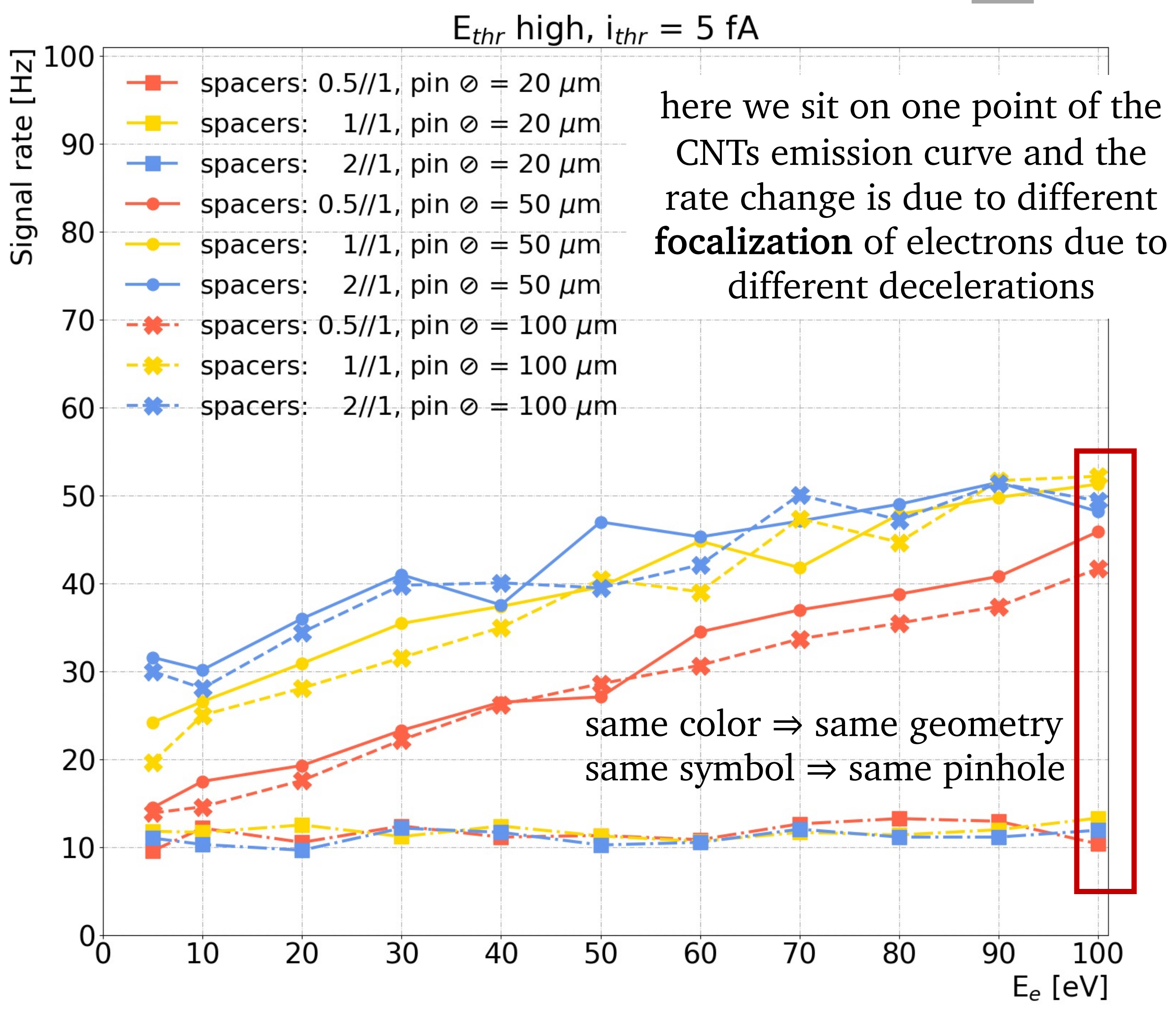
A

- SIMION works more easily on cylindrical symmetry

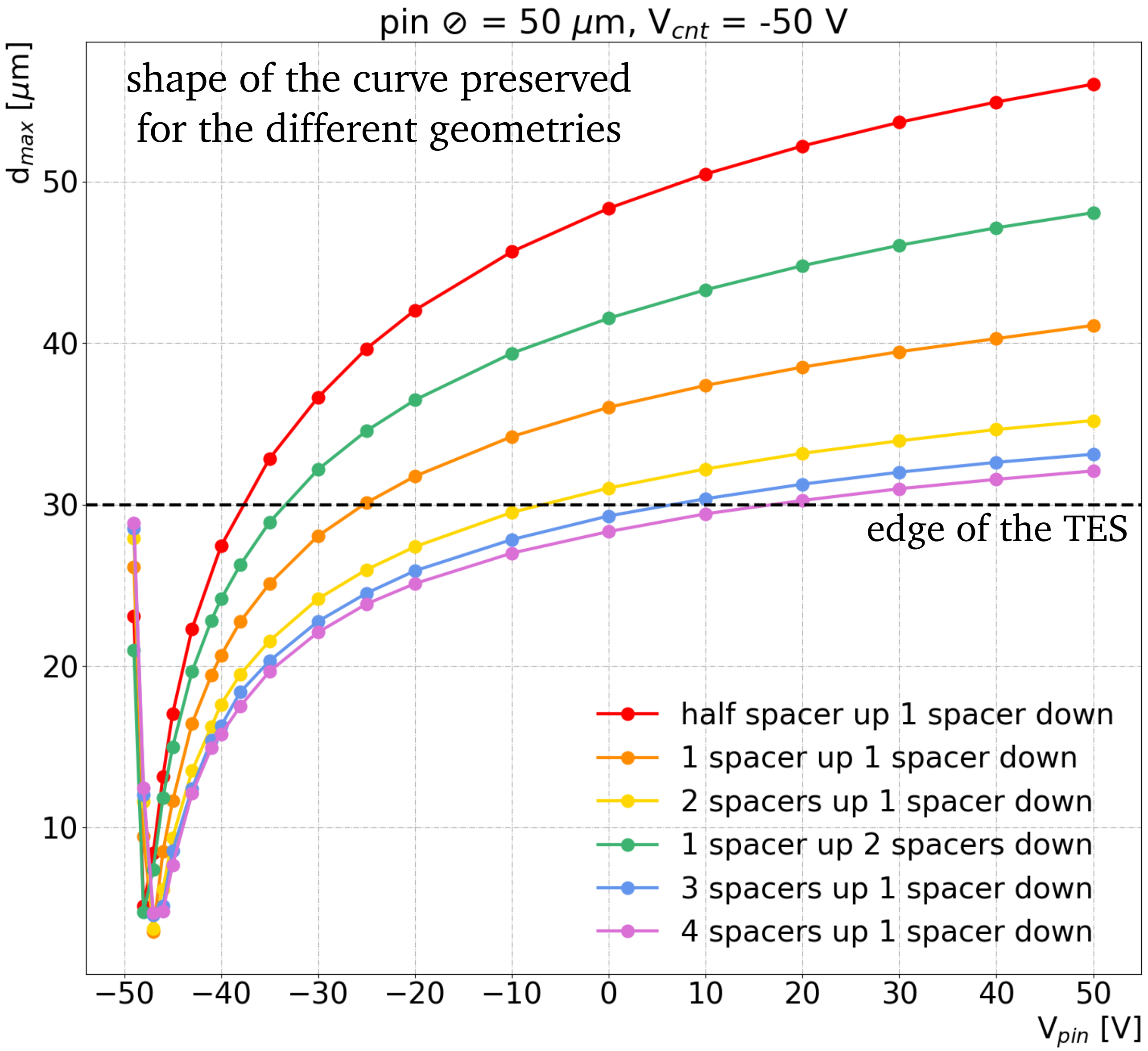


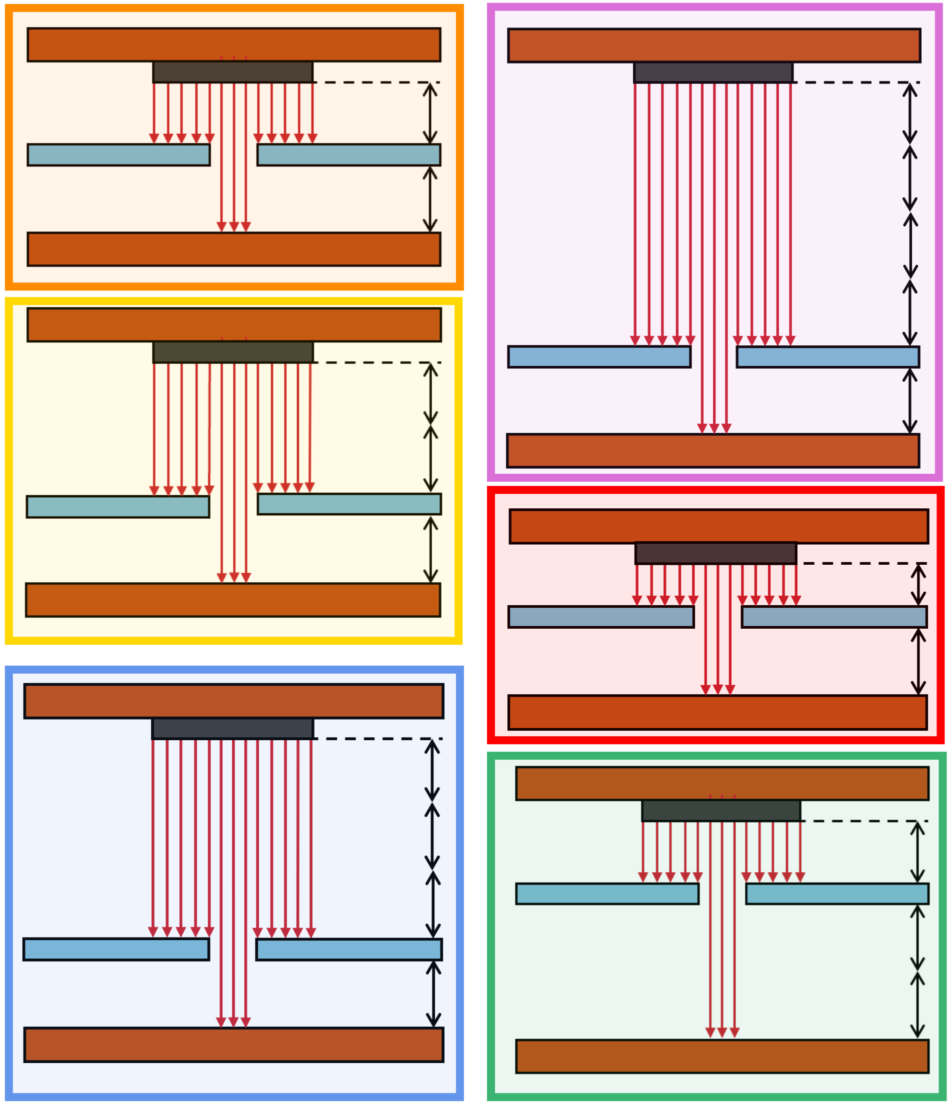
Possible Rate of Signals on TES





Focalization Curves of the Setups





Geometries tested

1 spacer = 500 microns