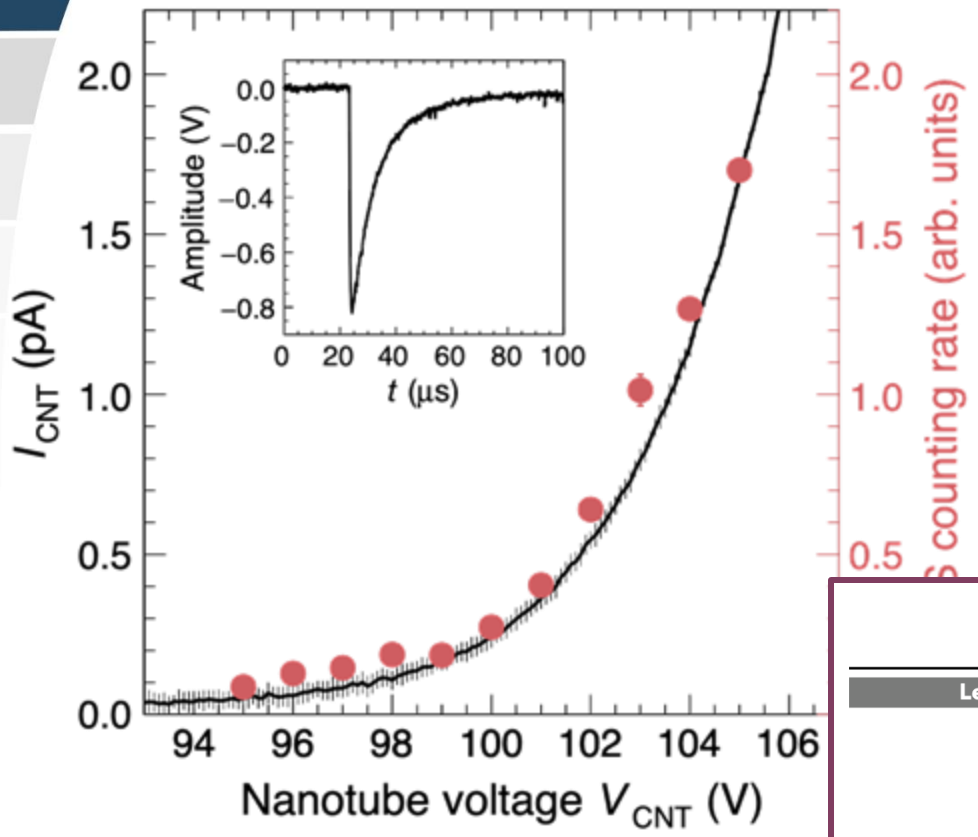
Recap of the recent upgrades on electron detection setup with TESs

Federico Malnati
Alice Apponi, Benedetta Corcione, Hobey Garrone, Eugenio Monticone, Francesco Pandolfi, Carlo Pepe, Mauro Rajteri, Alessandro Ruocco

Nijmegen, 2nd June 2025

INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA
www.inrim.it
Politecnico di Torino
SAPIENZA UNIVERSITÀ DI ROMA
INFN Istituto Nazionale di Fisica Nucleare
ROMA TRE UNIVERSITÀ DEGLI STUDI
Centro Nacional de Microelectrónica

One year ago…



PHYSICAL REVIEW APPLIED **22,** L041007 (2024)

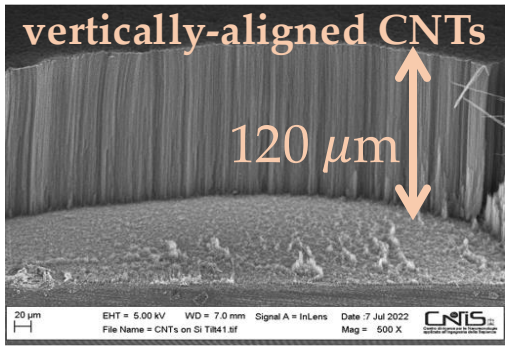
Letter

Detection of low-energy electrons with transition-edge sensors

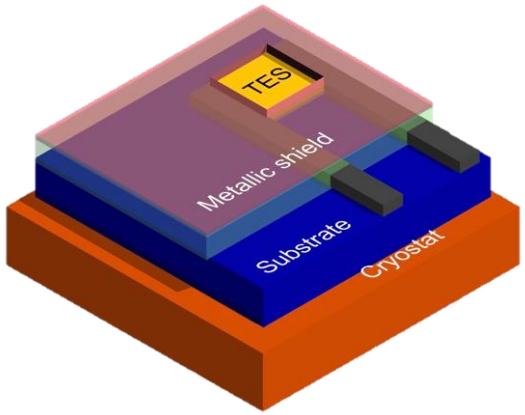
Carlo Pepe,[1,2] Benedetta Corcione,[3,4] Francesco Pandolfi,[4,*] Hobey Garrone,[1,2] Eugenio Monticone,[1] Ilaria Rago,[4] Gianluca Cavoto,[3,4] Alice Apponi,[5] Alessandro Ruocco,[5] Federico Malnati,[6] Danilo Serazio,[1] and Mauro Rajteri[1]

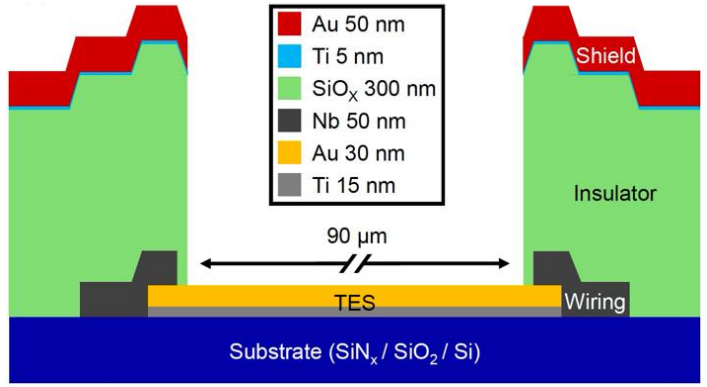
INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

MiC setup (Pollica, 2024)

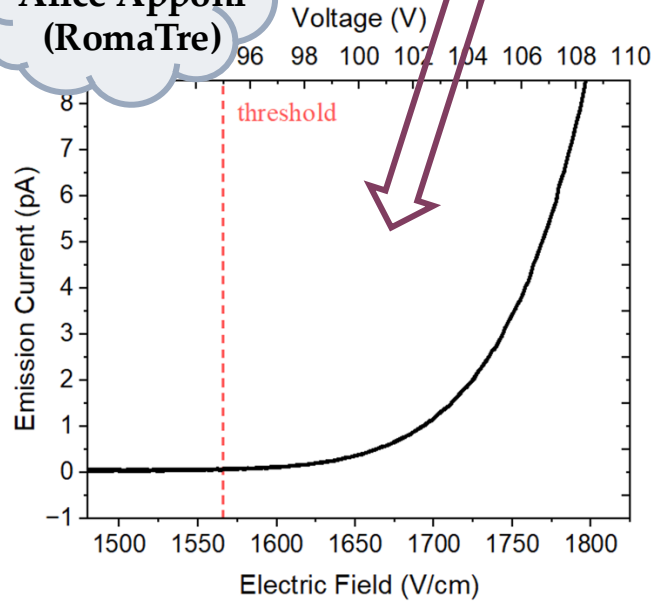


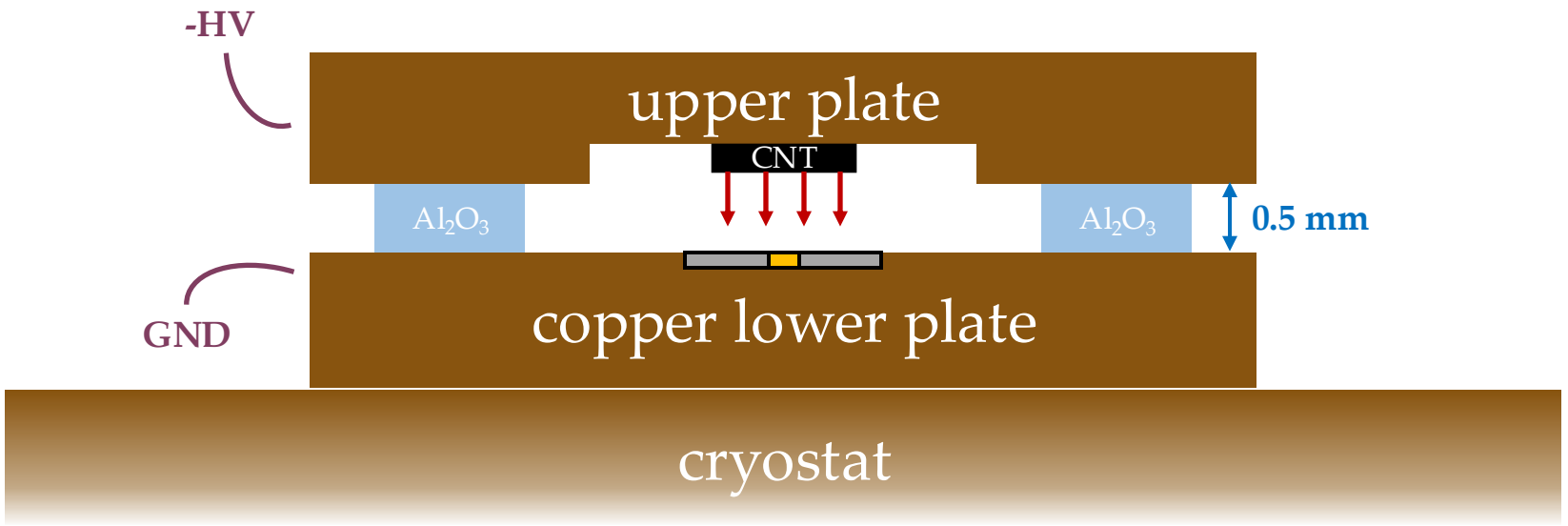
Fabricated at QR Lab - INRiM (Turin)





original idea by **Alice Apponi (RomaTre)**

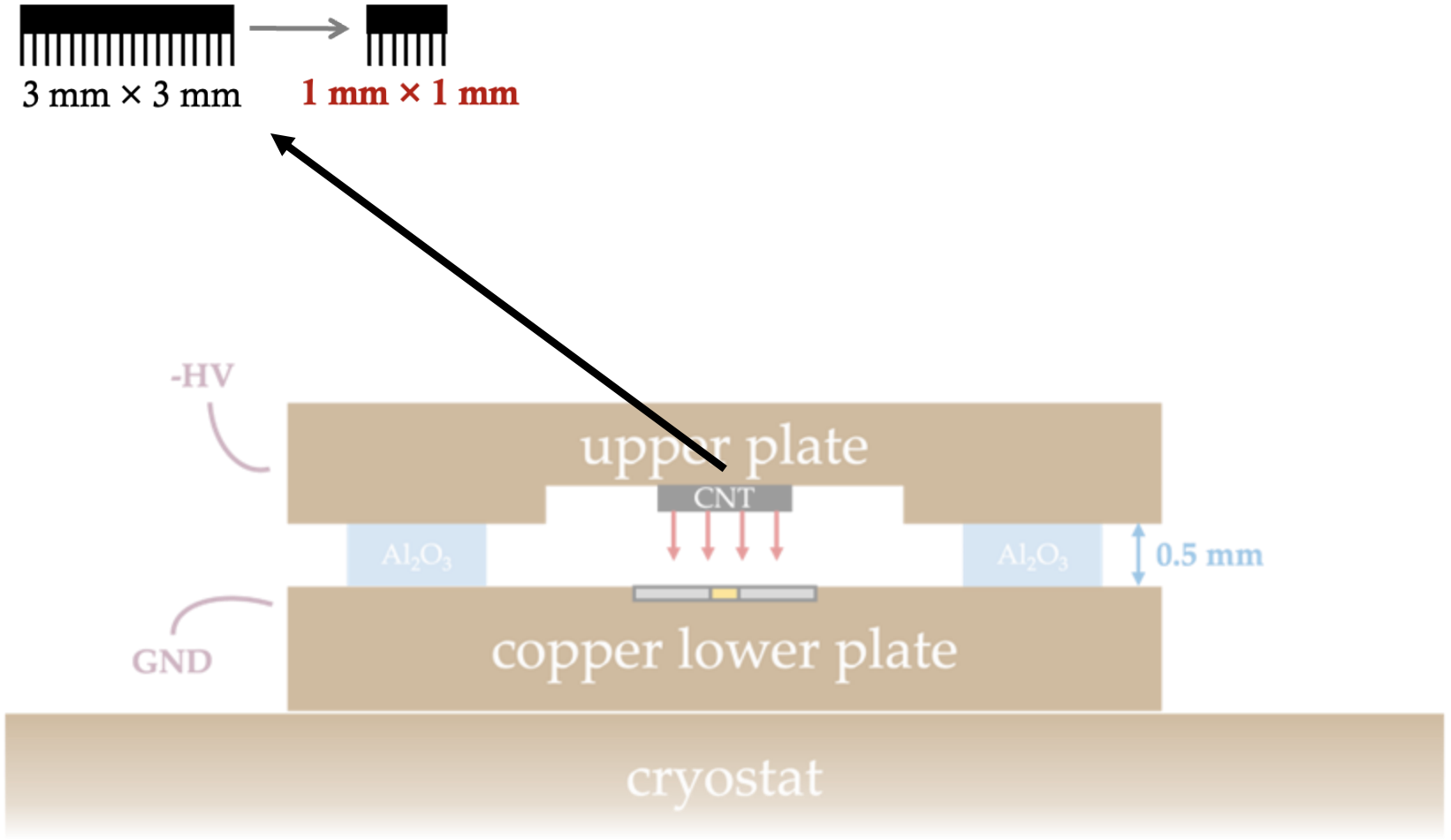




INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

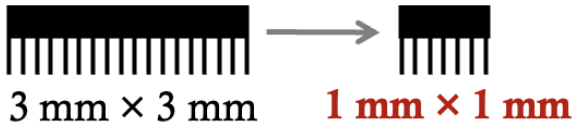
Some differences (Dec 24 – Jan 25)

1) CNTs reduced to send less electrons on the shield

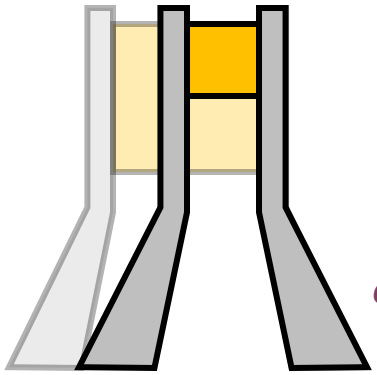


Some differences (Dec 24 – Jan 25)

1) CNTs reduced to send less electrons on the shield



2) smaller TES area

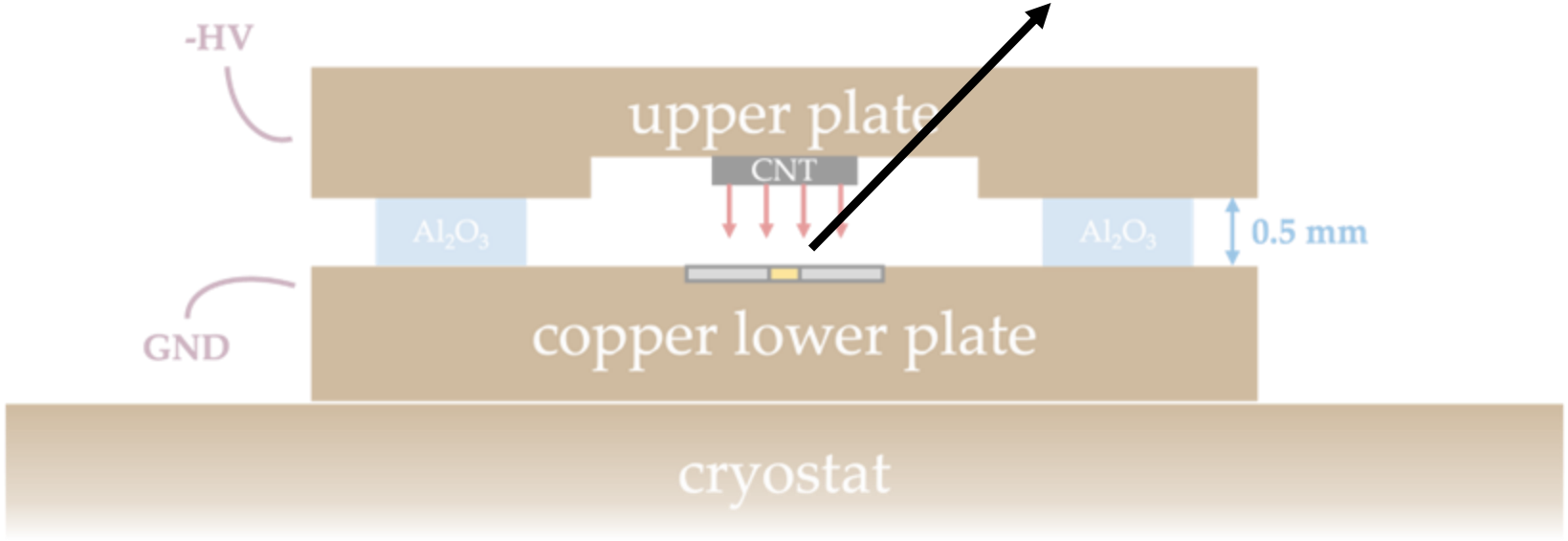


100 μm x 100 μm

⇩

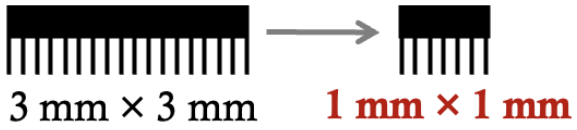
60 μm x 60 μm

$\sigma_e \propto \sqrt{Area}$ → 40% improvement

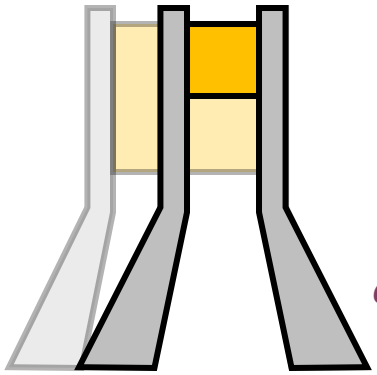


Some differences (Dec 24 – Jan 25)

1) CNTs reduced to send less electrons on the shield



2) smaller TES area

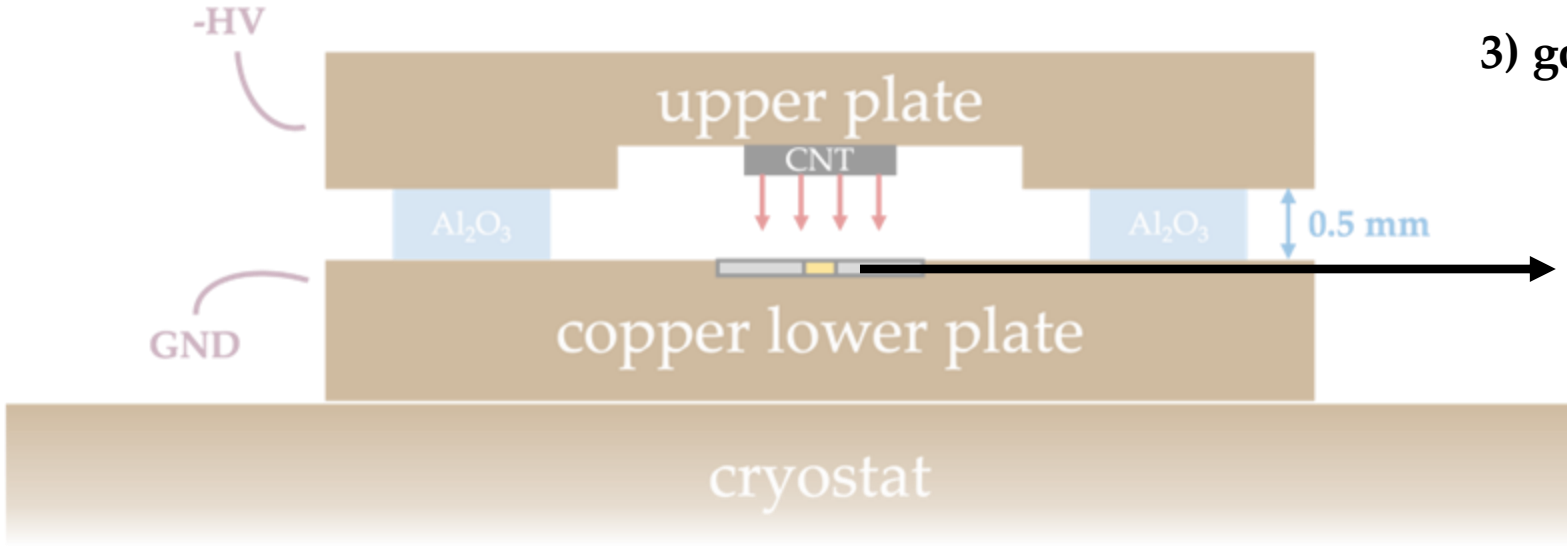


100 μm x 100 μm

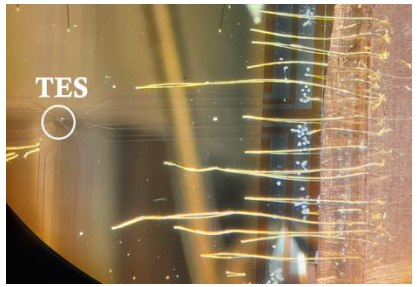
⇩

60 μm x 60 μm

$\sigma_e \propto \sqrt{Area}$ → 40% improvement

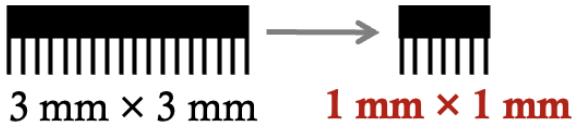


3) gold wire bondings

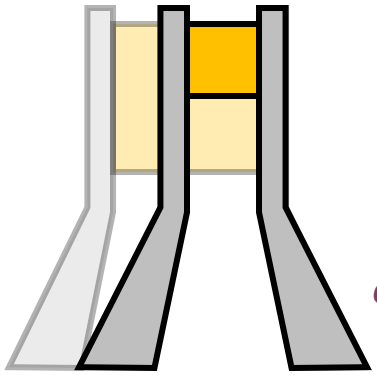


Some differences (Dec 24 – Jan 25)

1) CNTs reduced to send less electrons on the shield



2) smaller TES area



100 μm x 100 μm

⇩

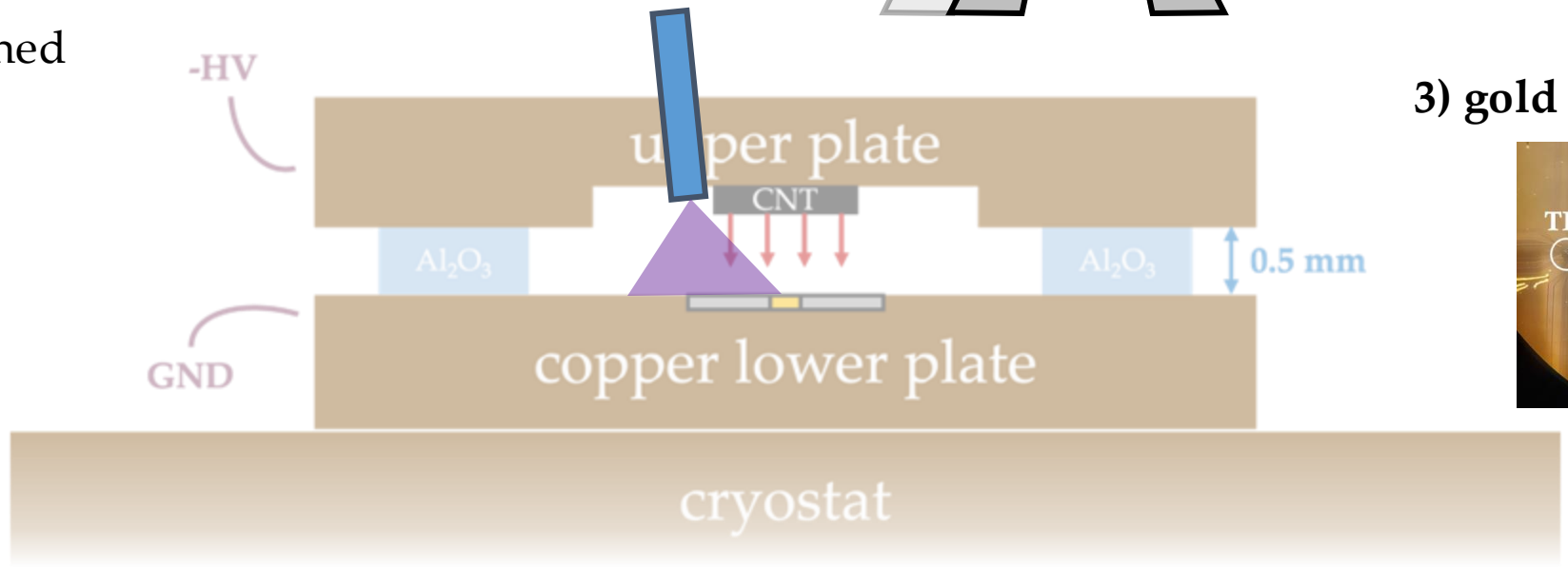
60 μm x 60 μm

$\sigma_e \propto \sqrt{Area}$ → 40% improvement

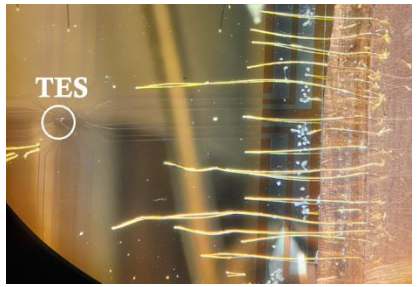
4) Optical fiber added for low E calibration

Not really aligned

E_{ph} = 3.06 eV



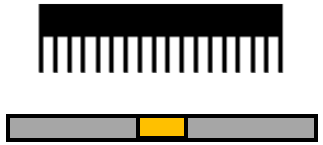
3) gold wire bondings

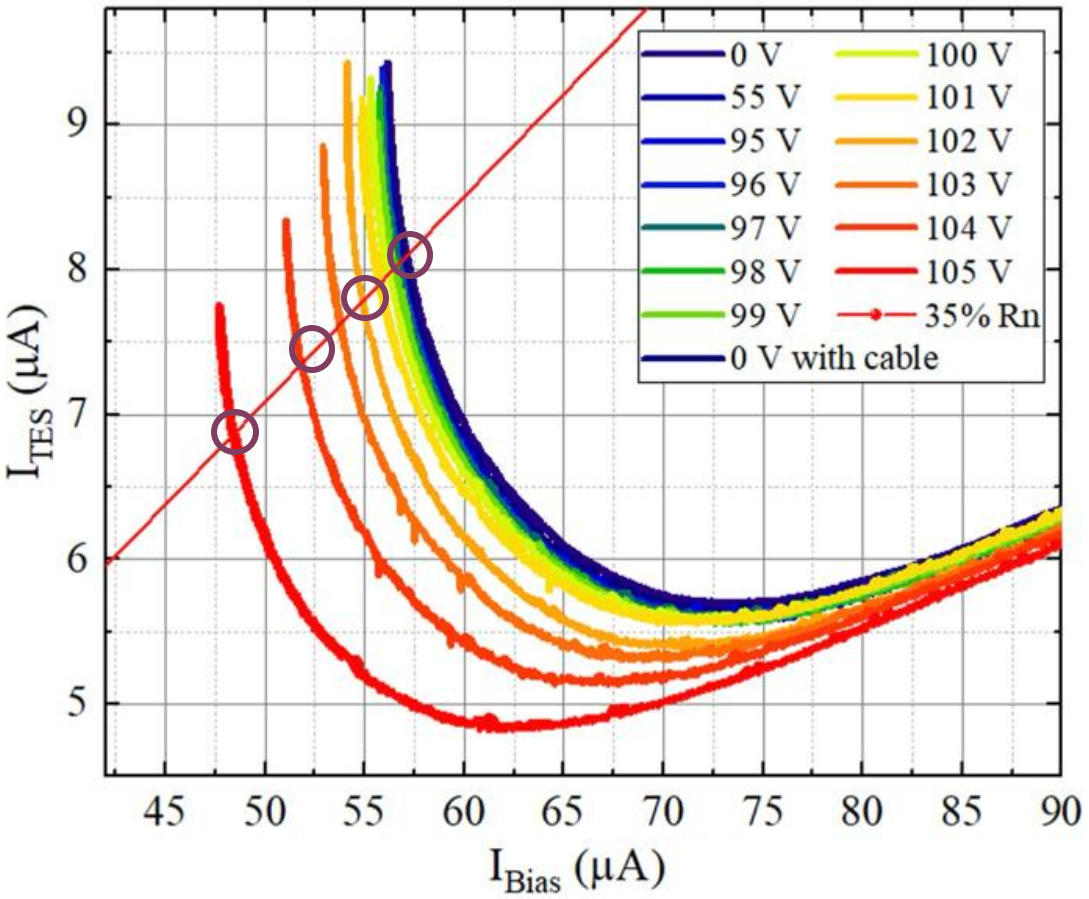


INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

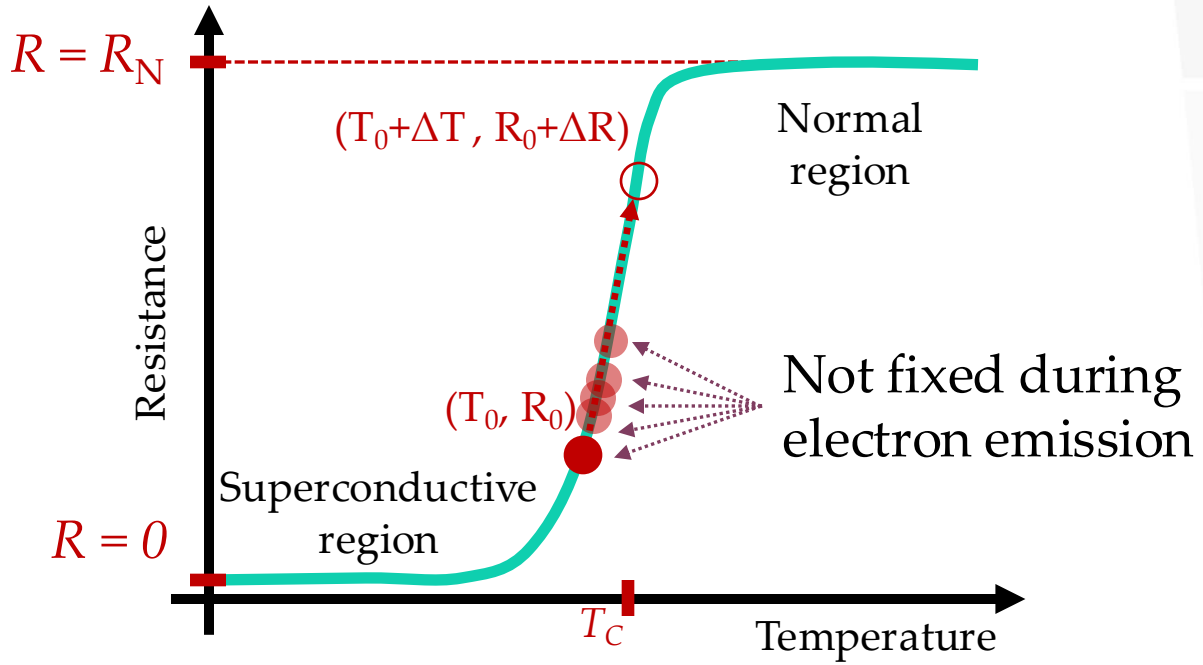
What did we obtain?

- **Stabilization of TES working point**





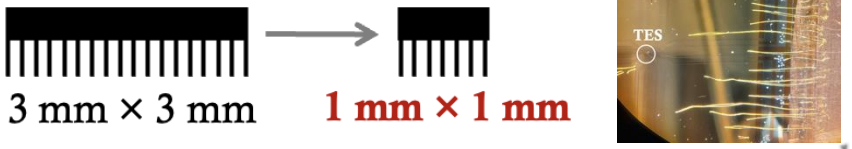
Typically expressed as a percentage of R_N

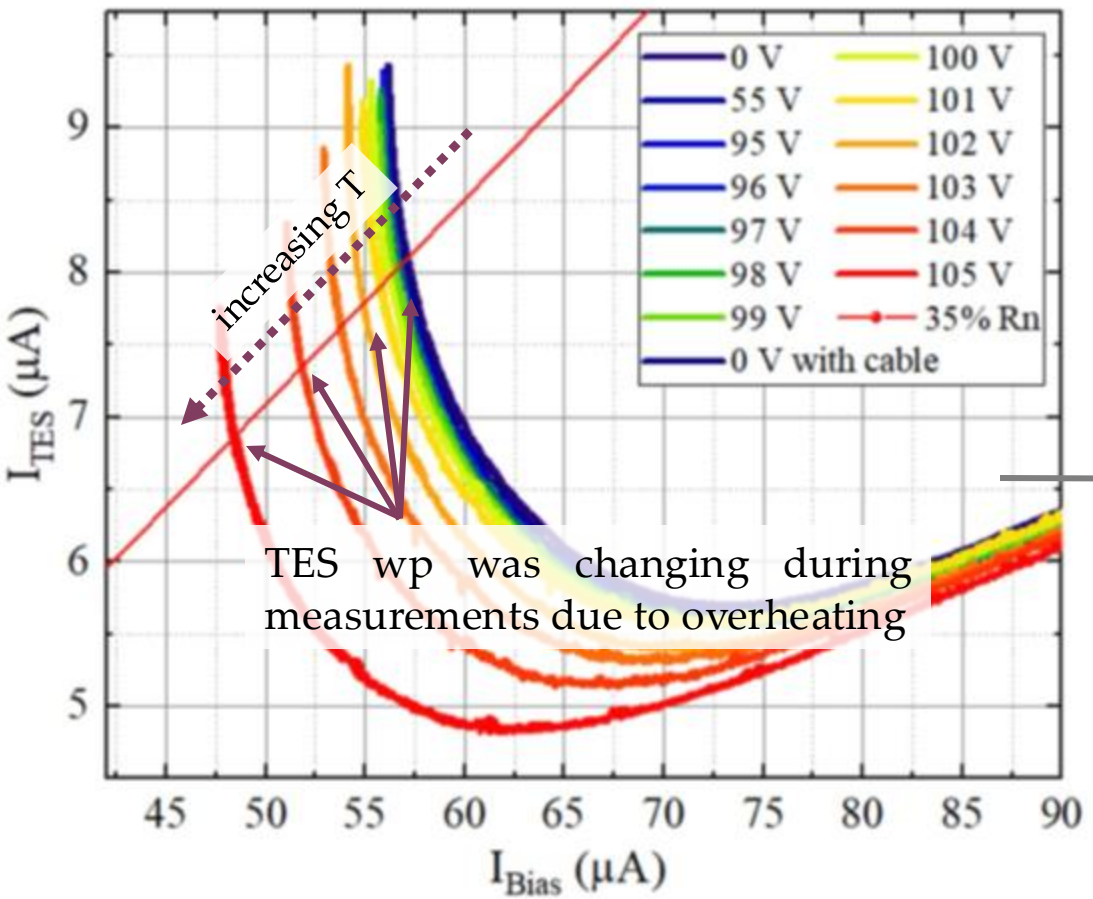


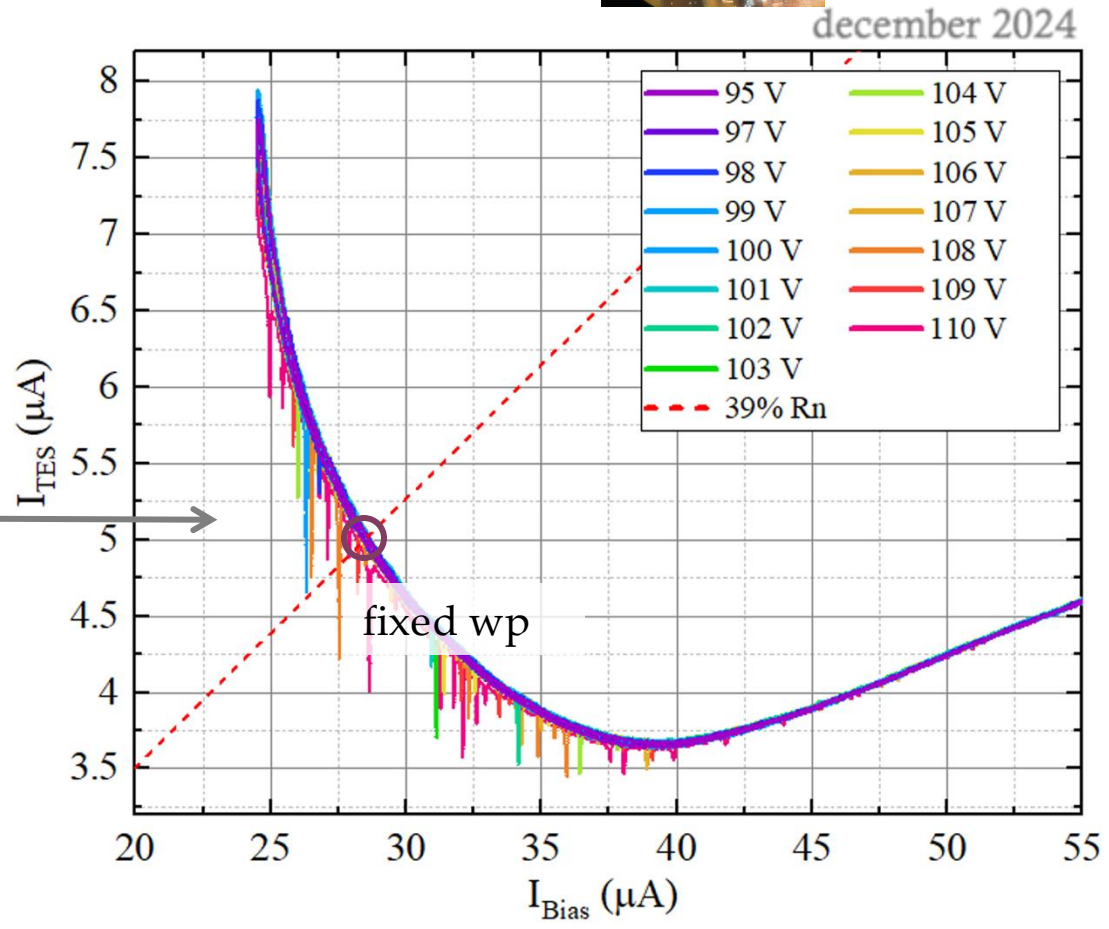
INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

What did we achieve?

- **Stabilization of TES working point**



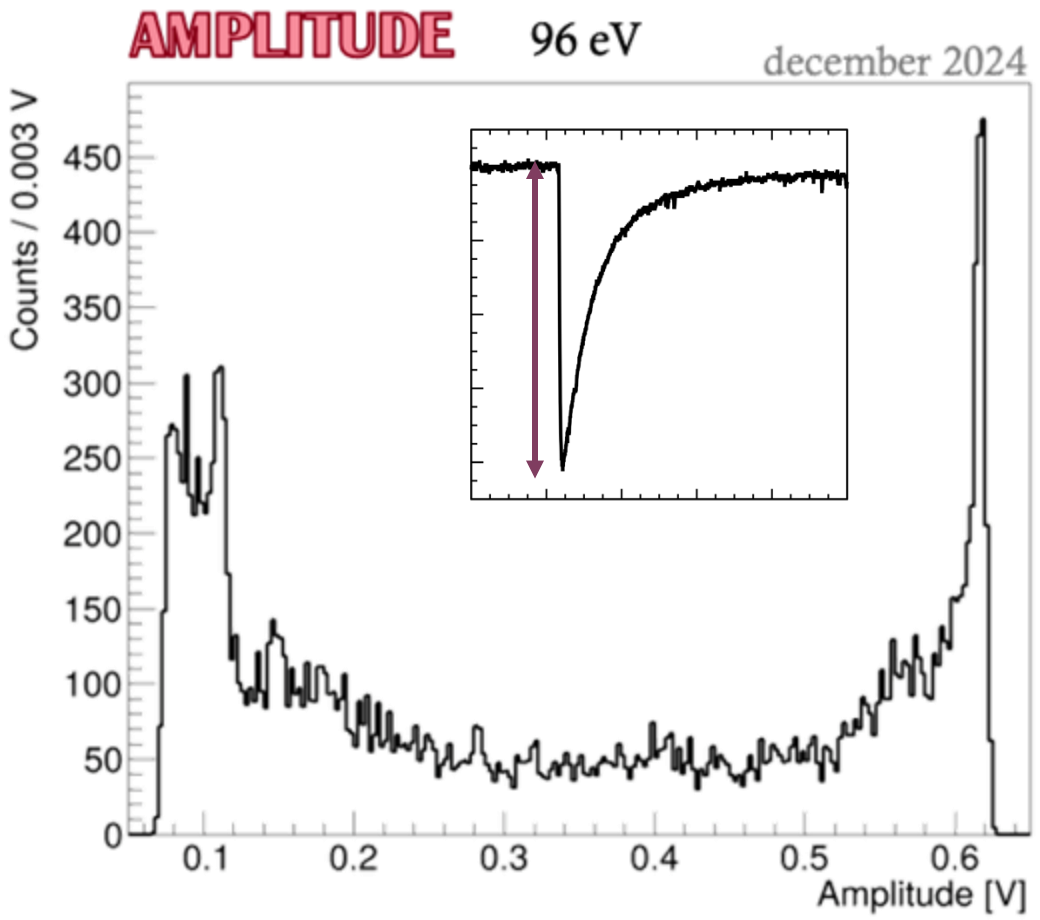


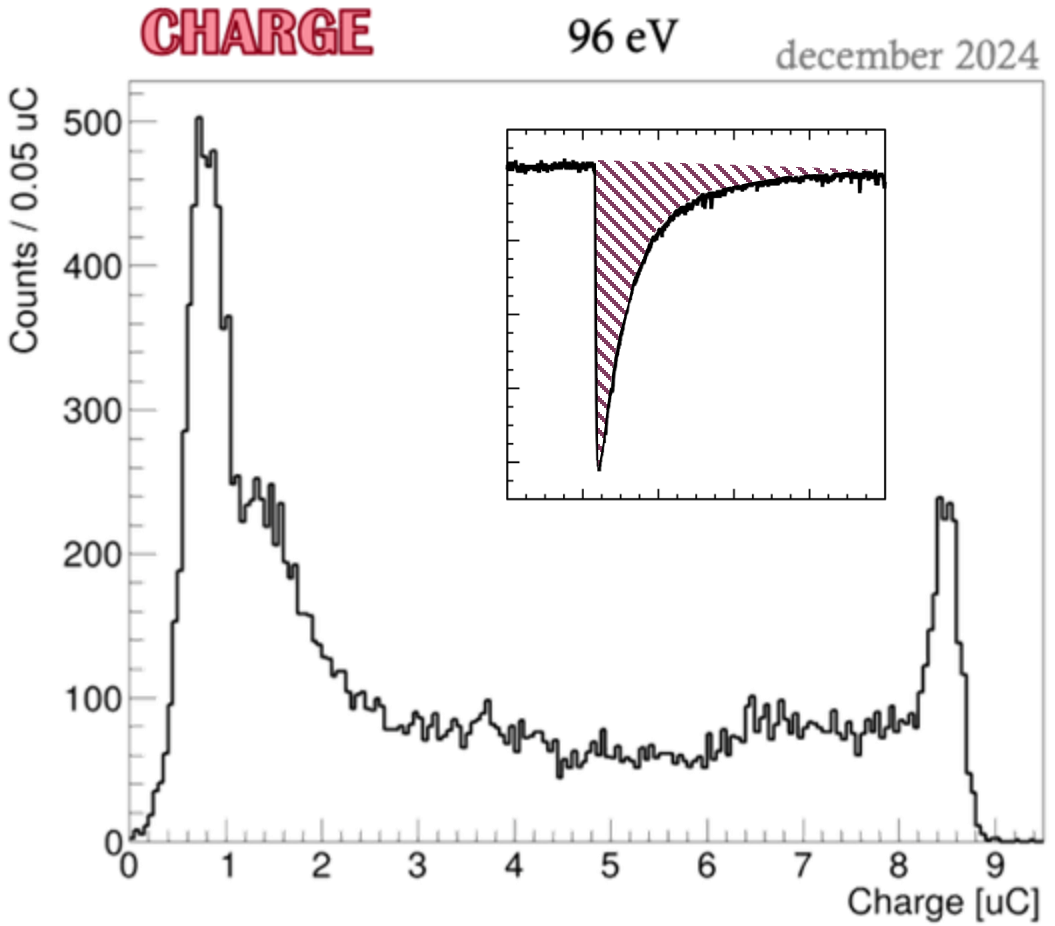


INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

What did we achieve?

- **More defined histogram shape**

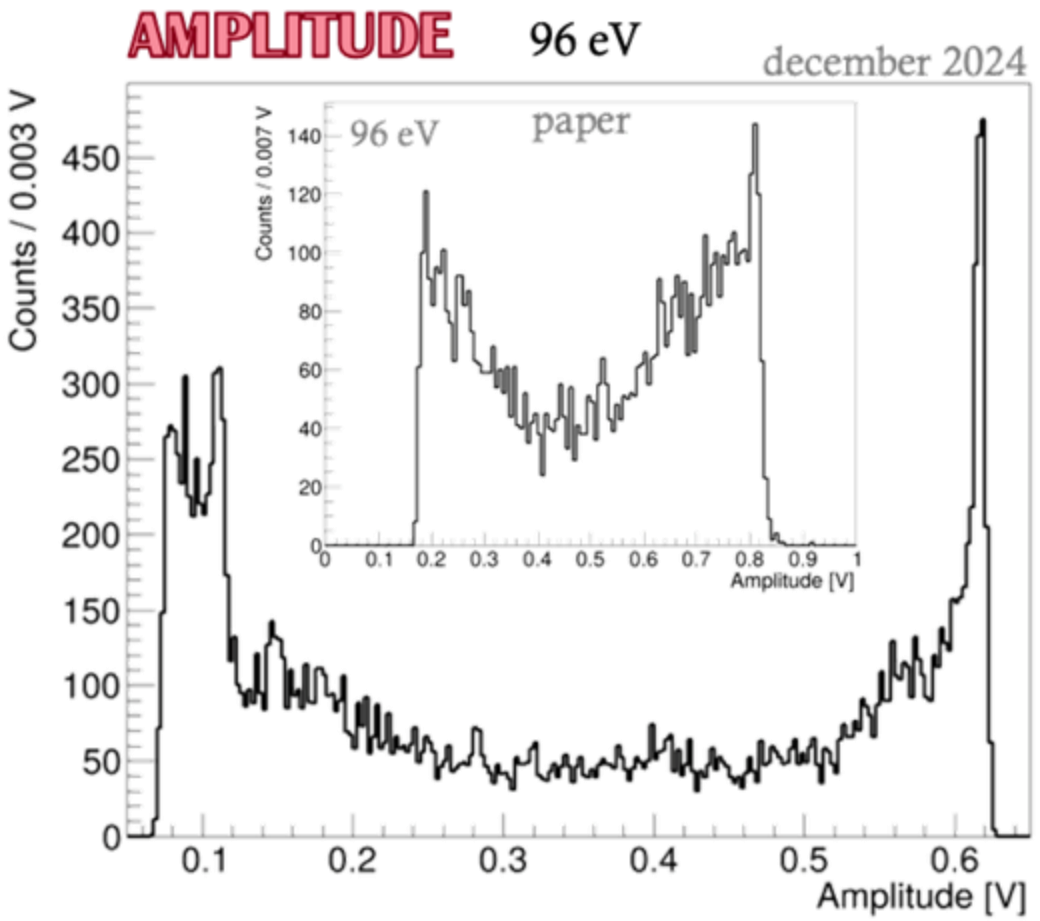


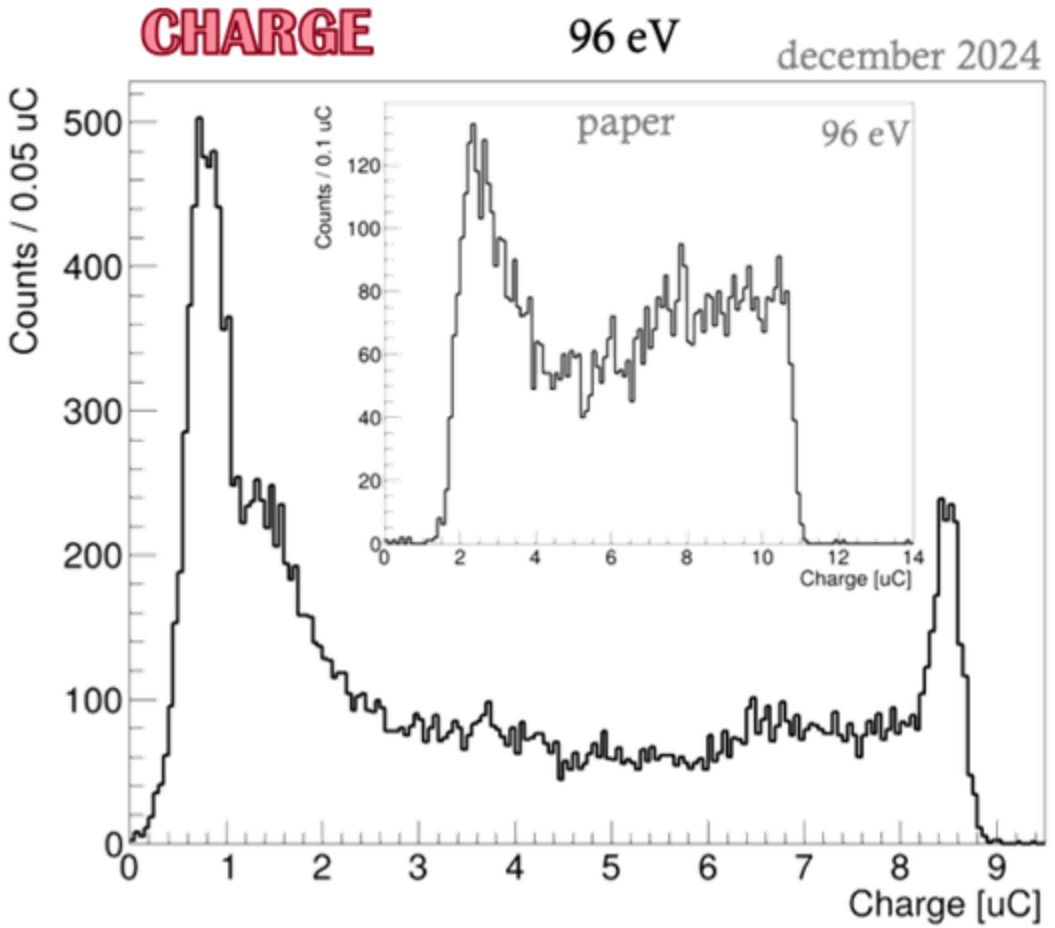


INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

What did we achieve?

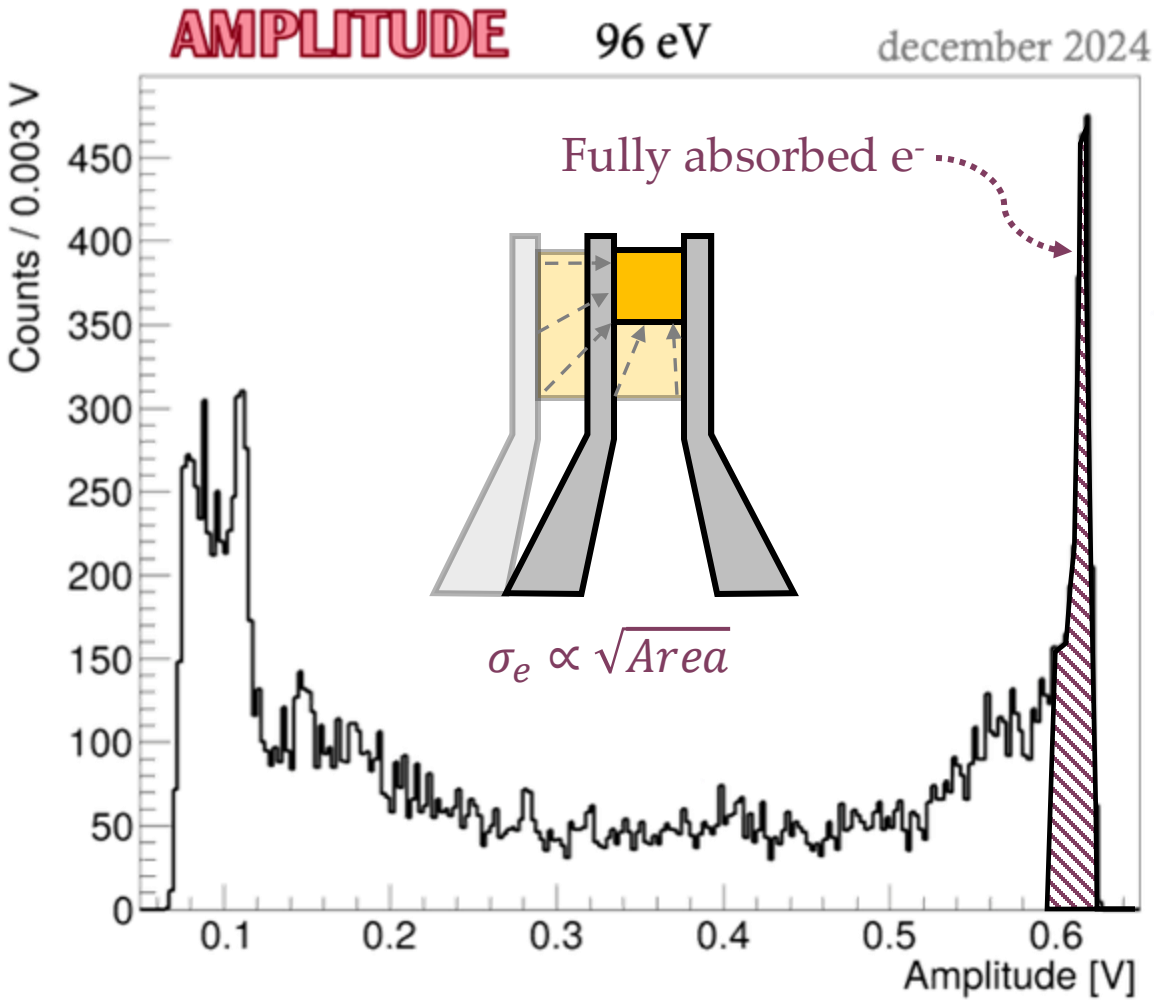
- **More defined histogram shape**

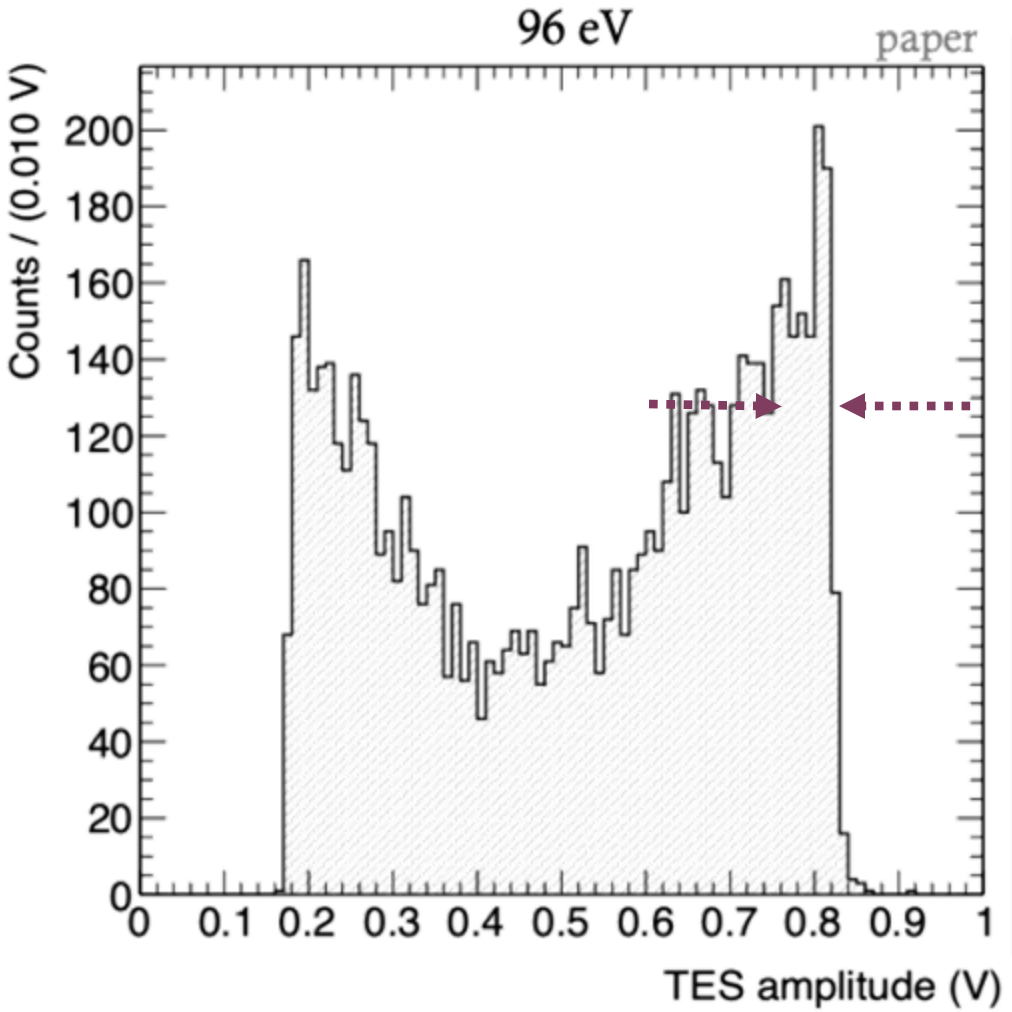




INRiM
ISTITUTO NAZIONALE
DI RICERCA METROLOGICA

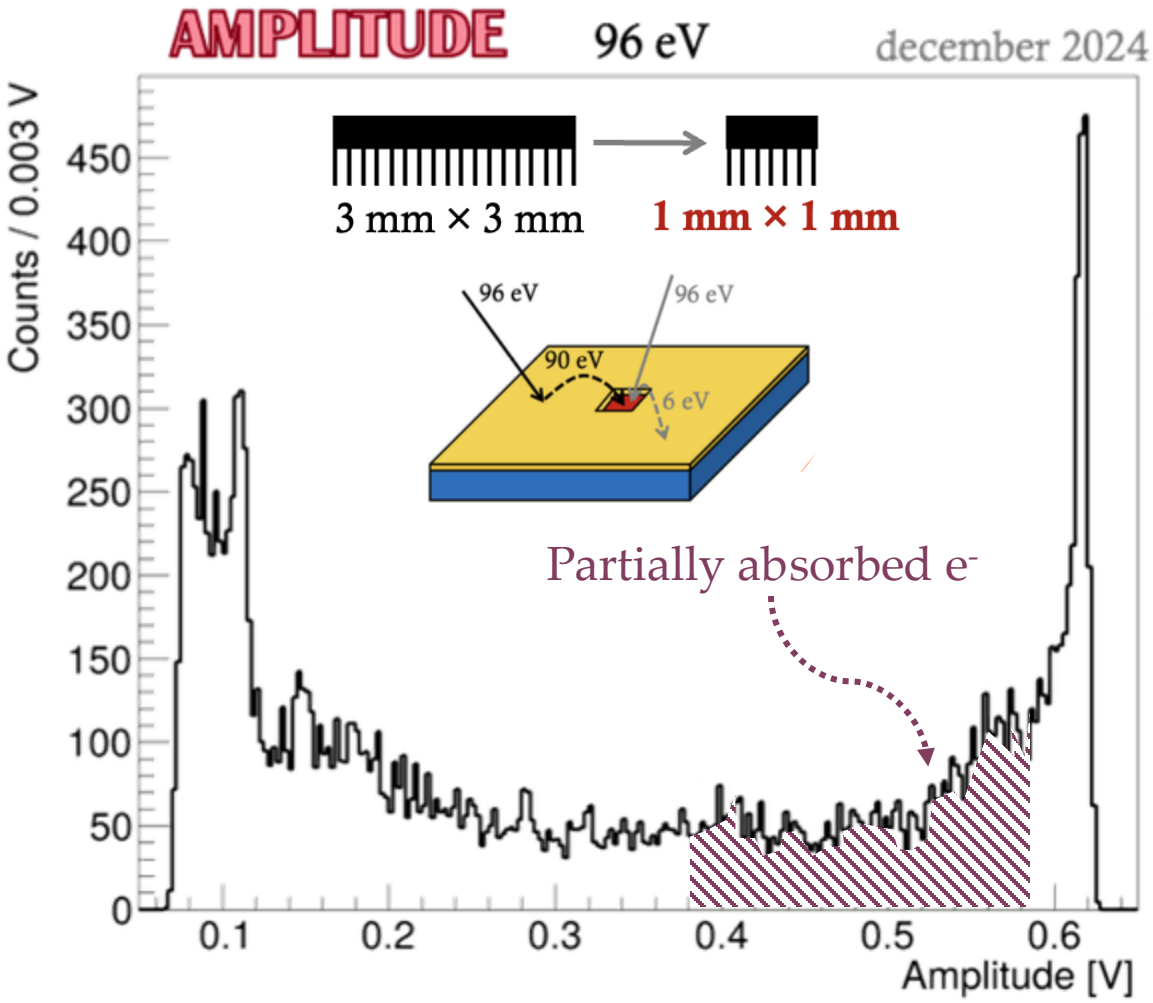
Amplitude High-energy peak resolution improved

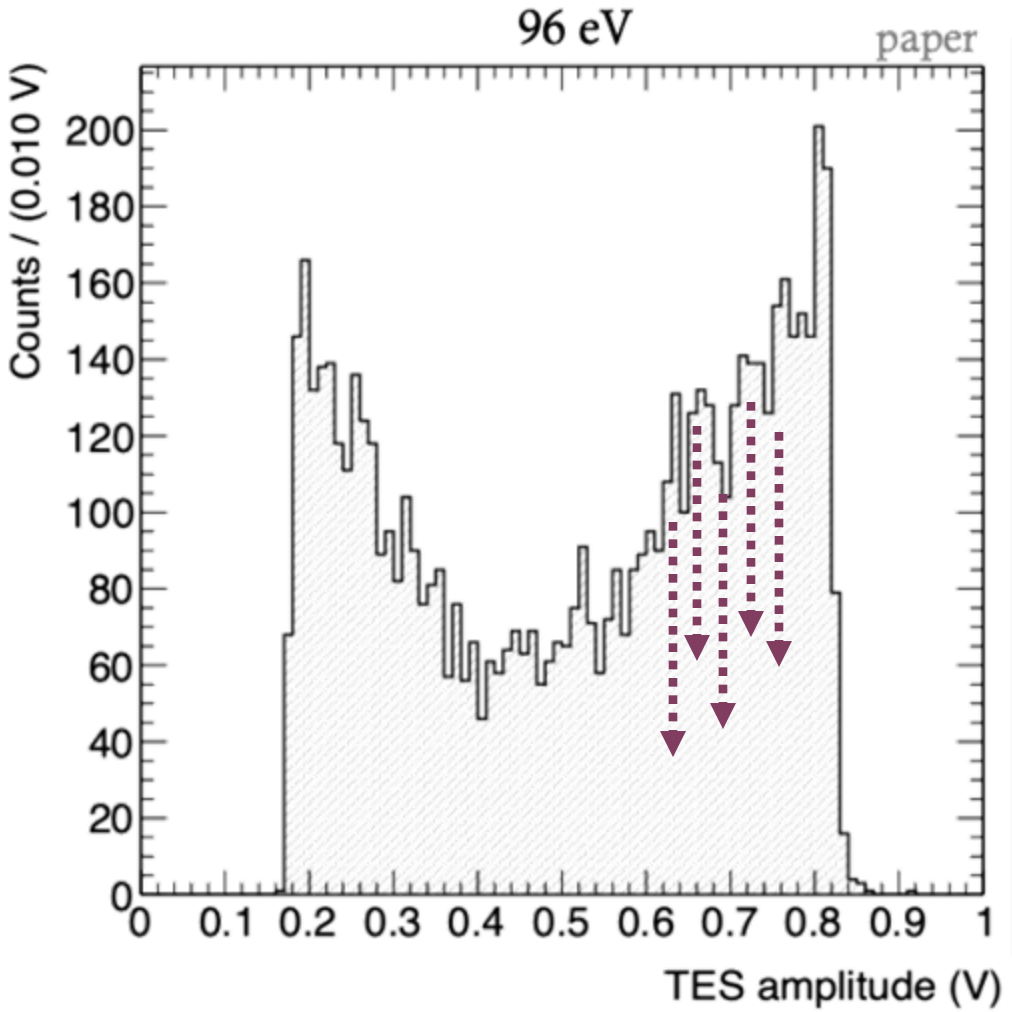




INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

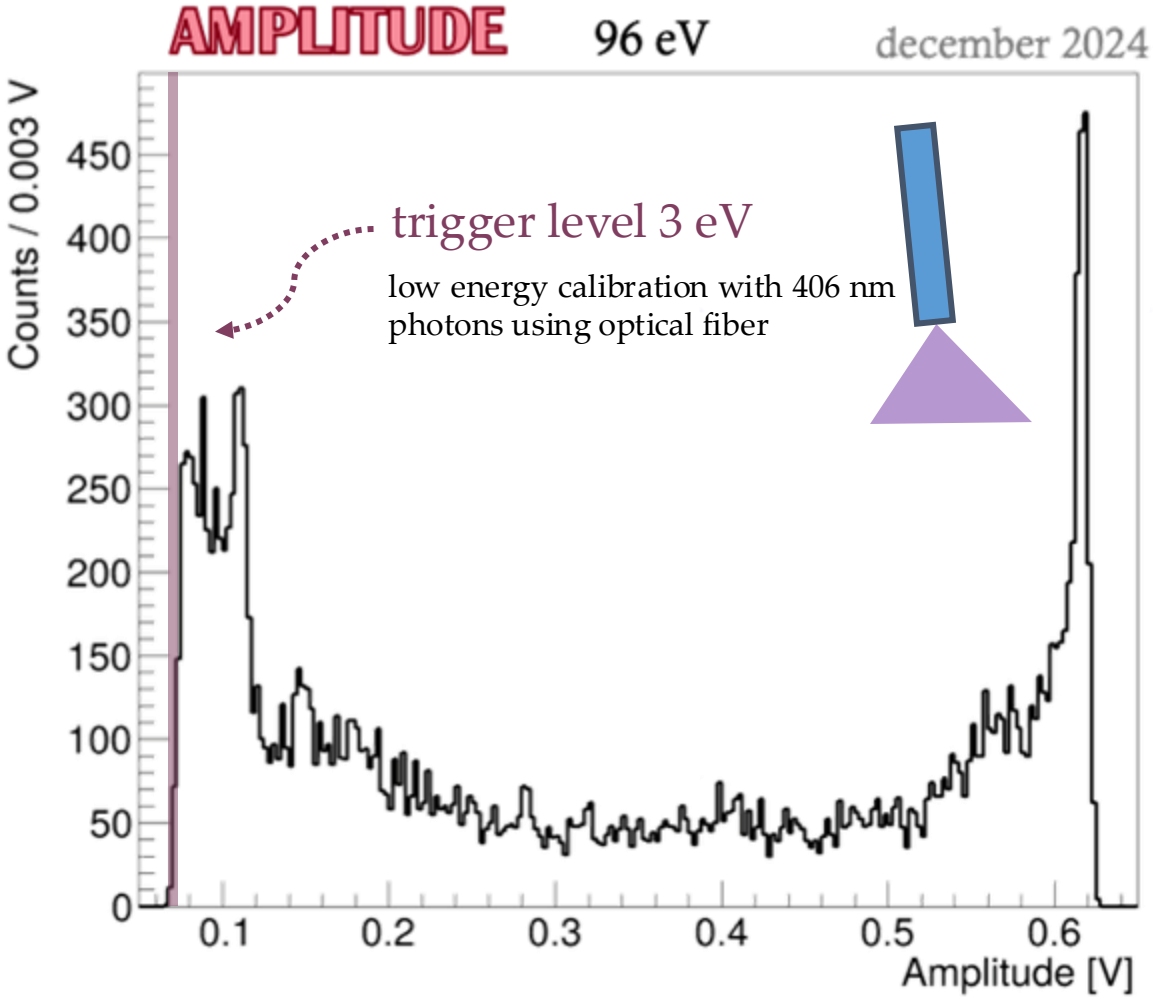
Left tail reduced

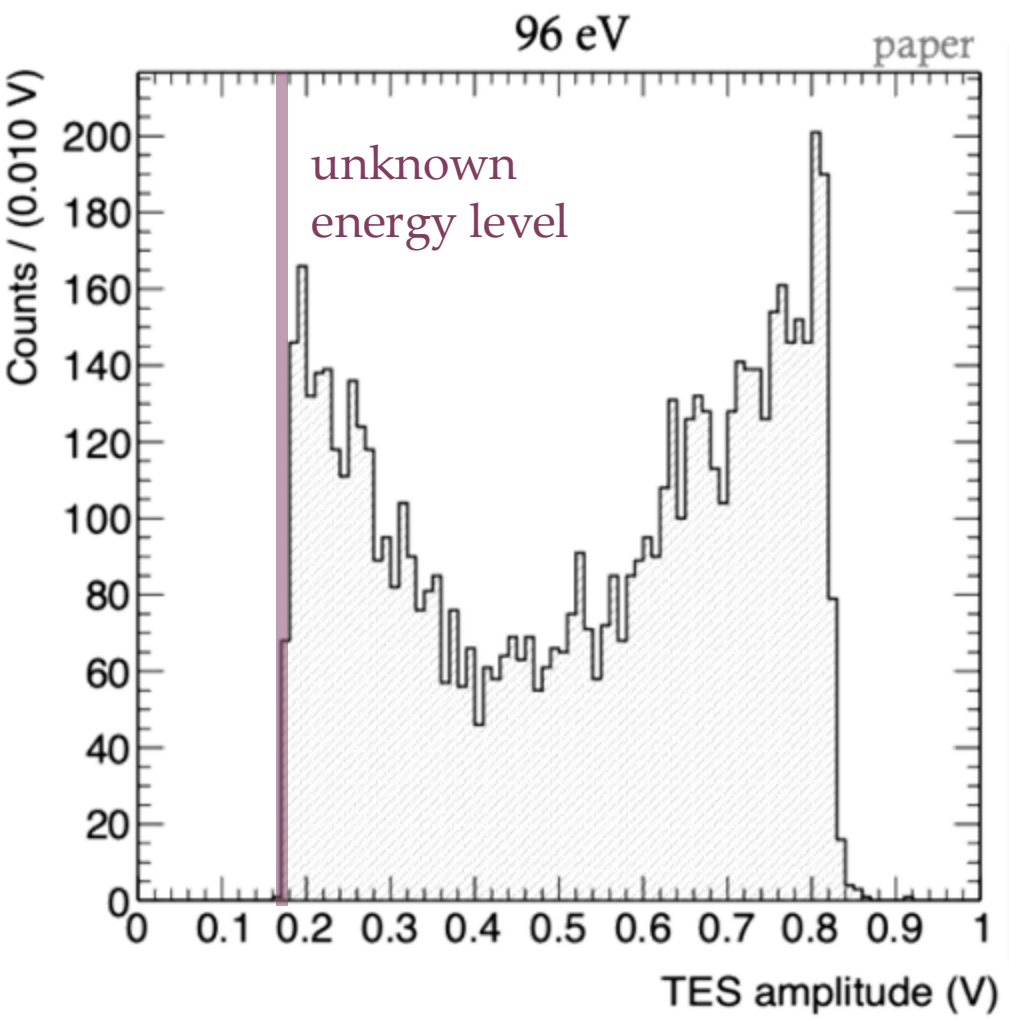




INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

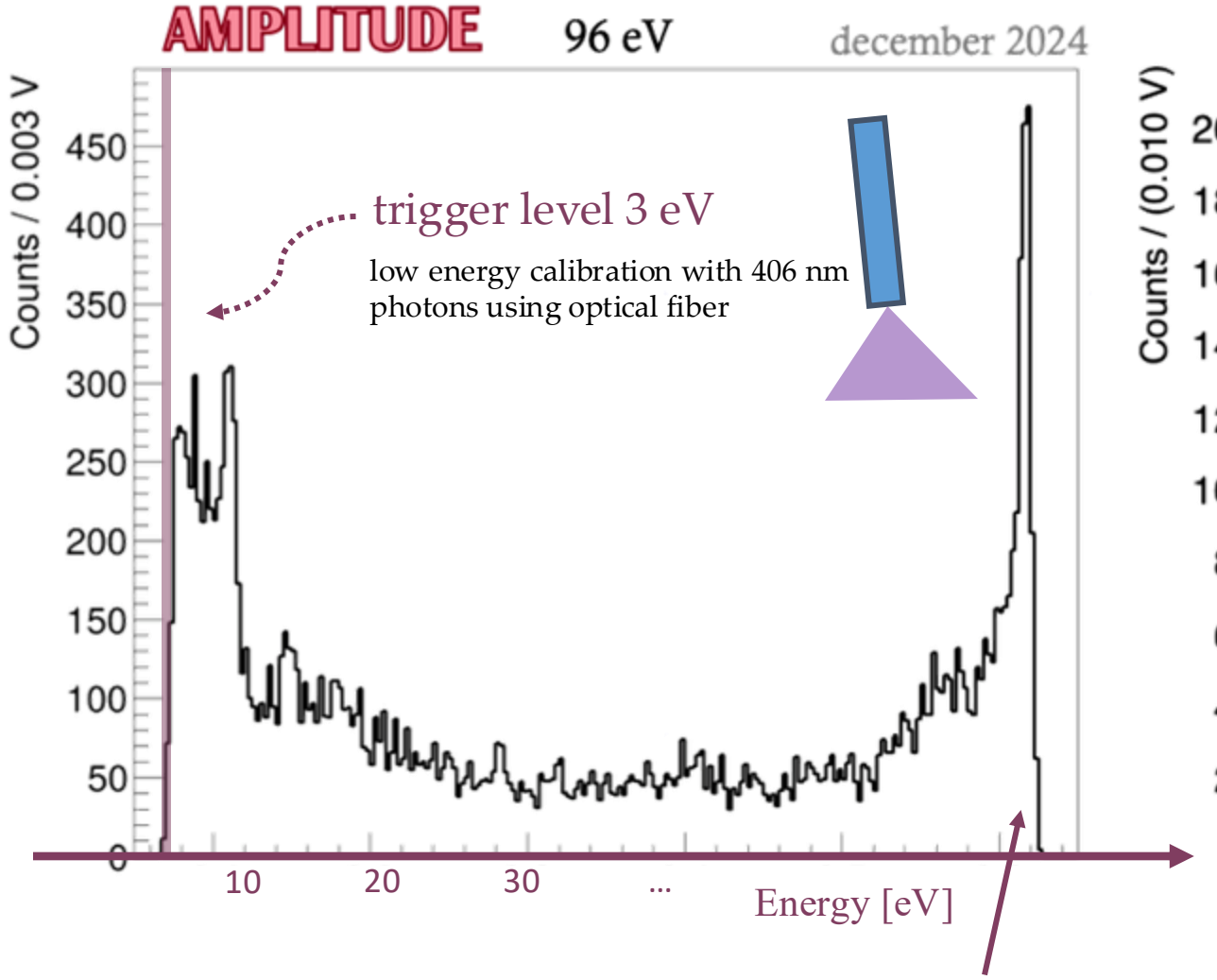
A known energy level

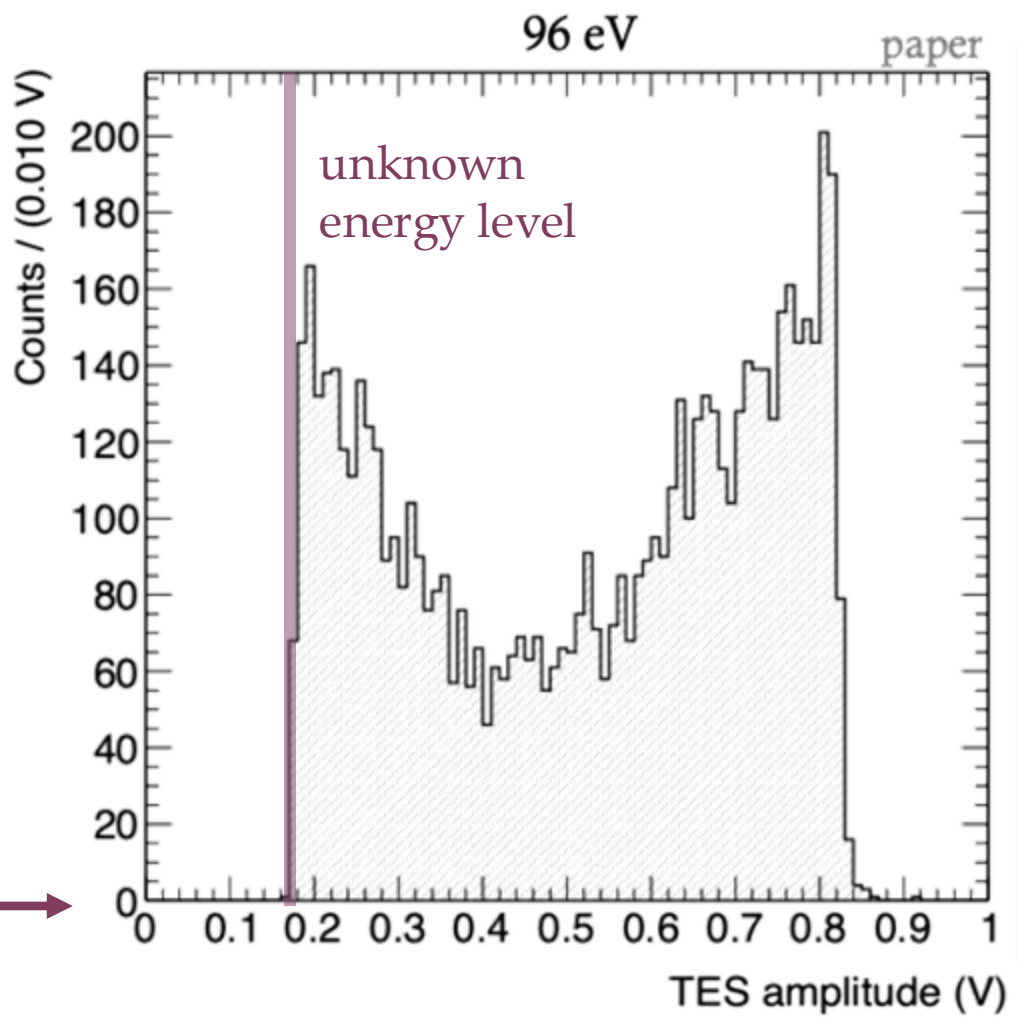




INRiM
ISTITUTO NAZIONALE
DI RICERCA METROLOGICA

A known energy level

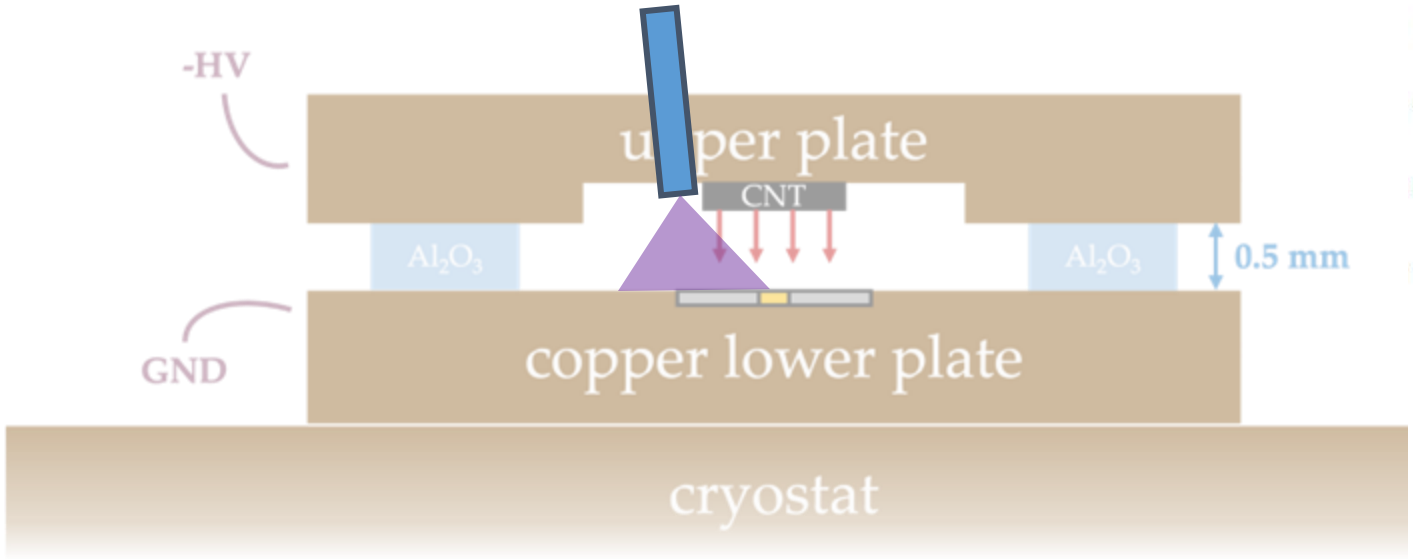


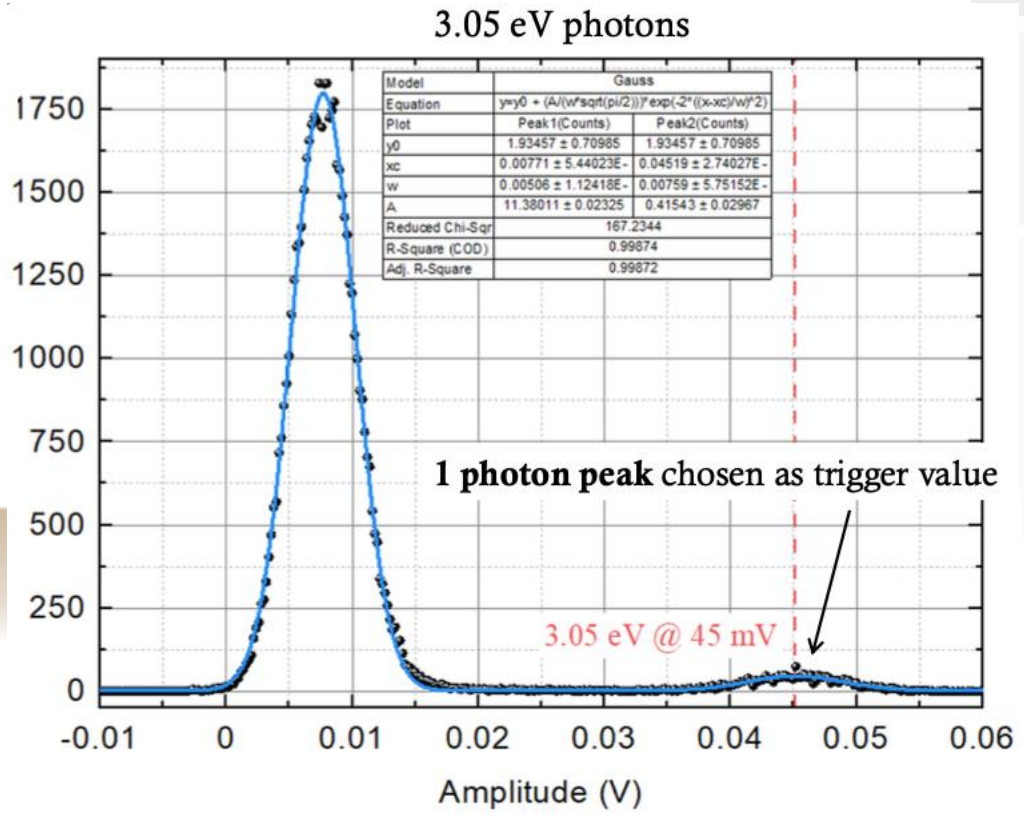


INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

Energy calibration with photons

Due to misalignment of the fiber, it was NOT possible to calibrate the TES in the full range





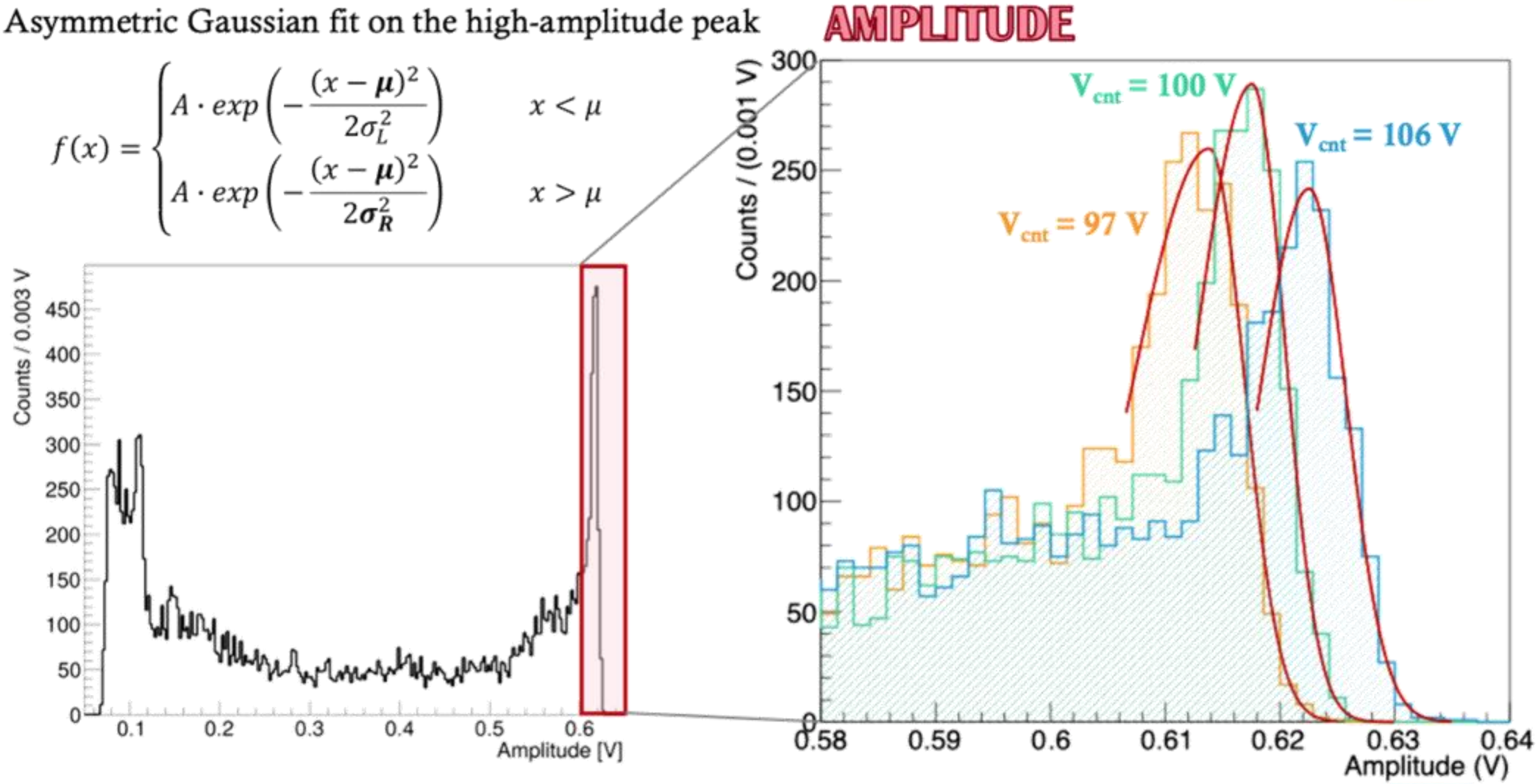
Sending more photons/pulse was heating up the TES

INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

The sharper the peak the easier the fit…

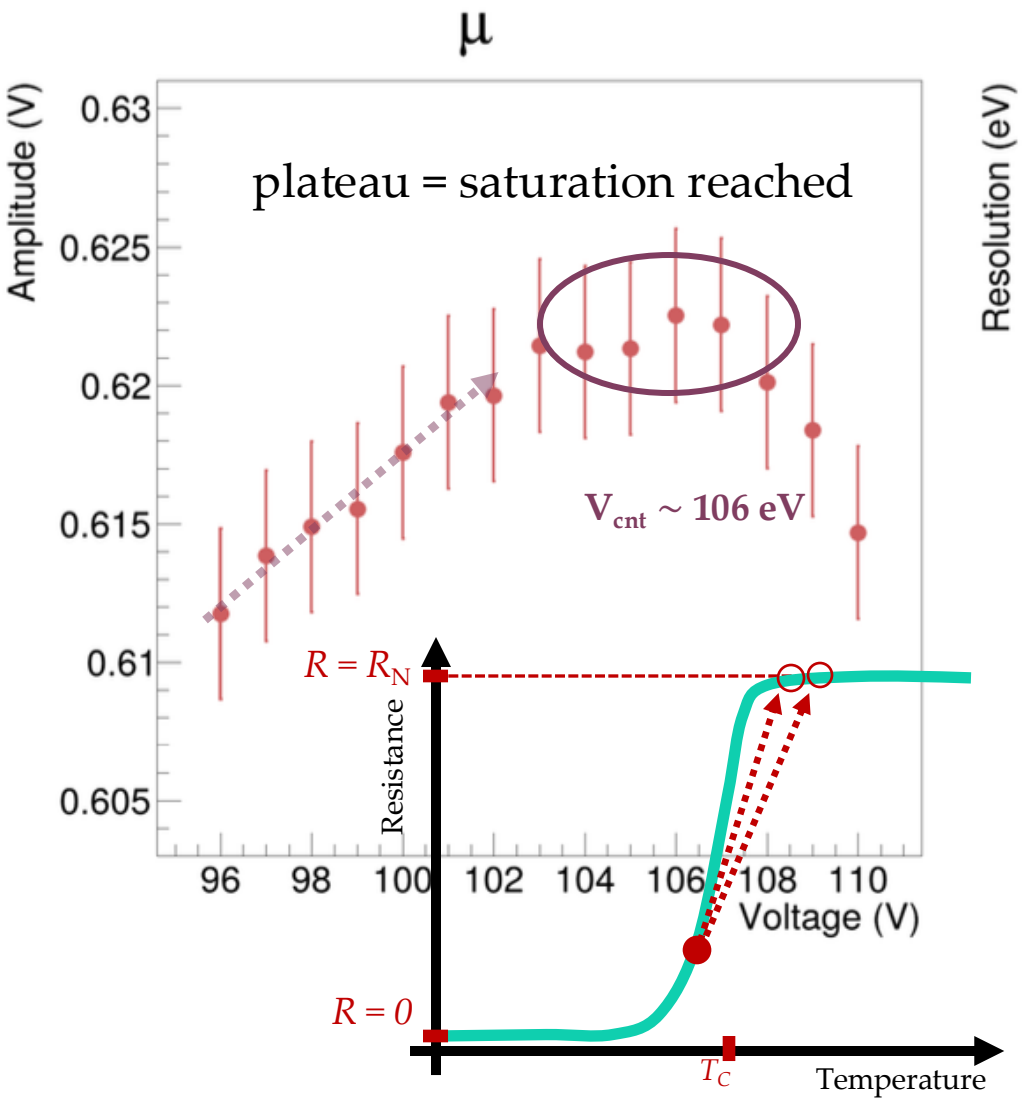
- Asymmetric Gaussian fit on the high-amplitude peak

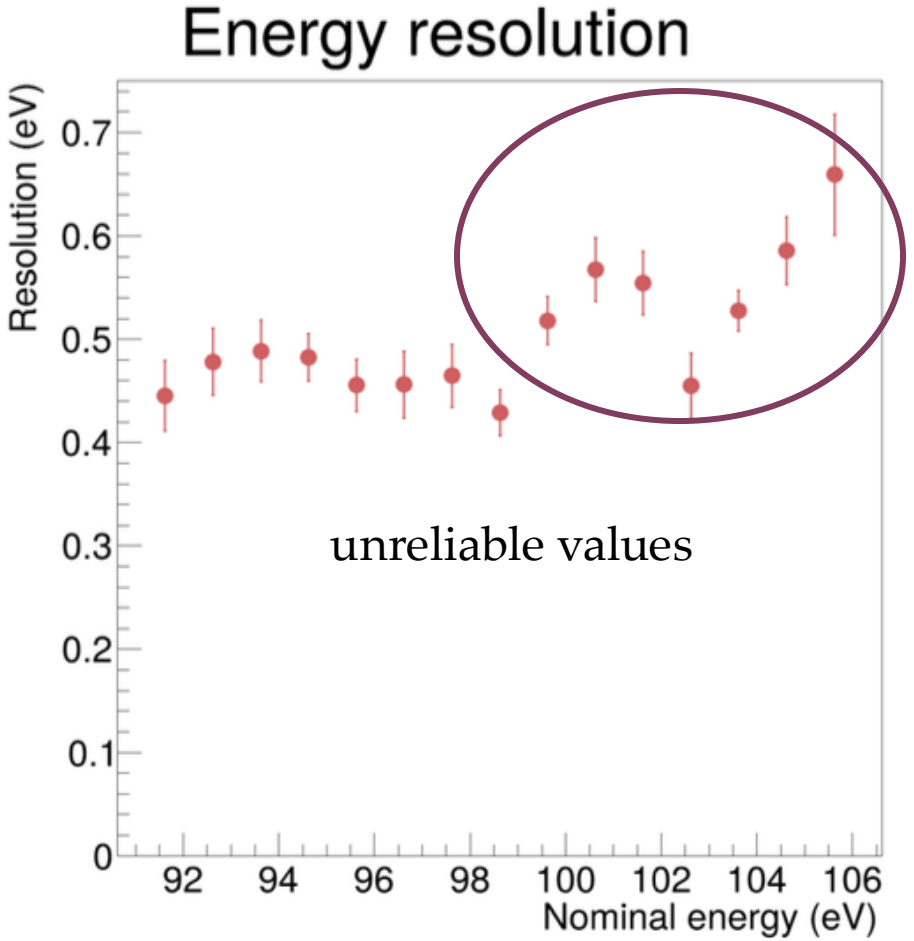
$$f(x) = \begin{cases} A \cdot exp\left(-\frac{(x-\mu)^2}{2\sigma_L^2}\right) & x < \mu \\ A \cdot exp\left(-\frac{(x-\mu)^2}{2\sigma_R^2}\right) & x > \mu \end{cases}$$



INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

Saturation energy & Energy resolution





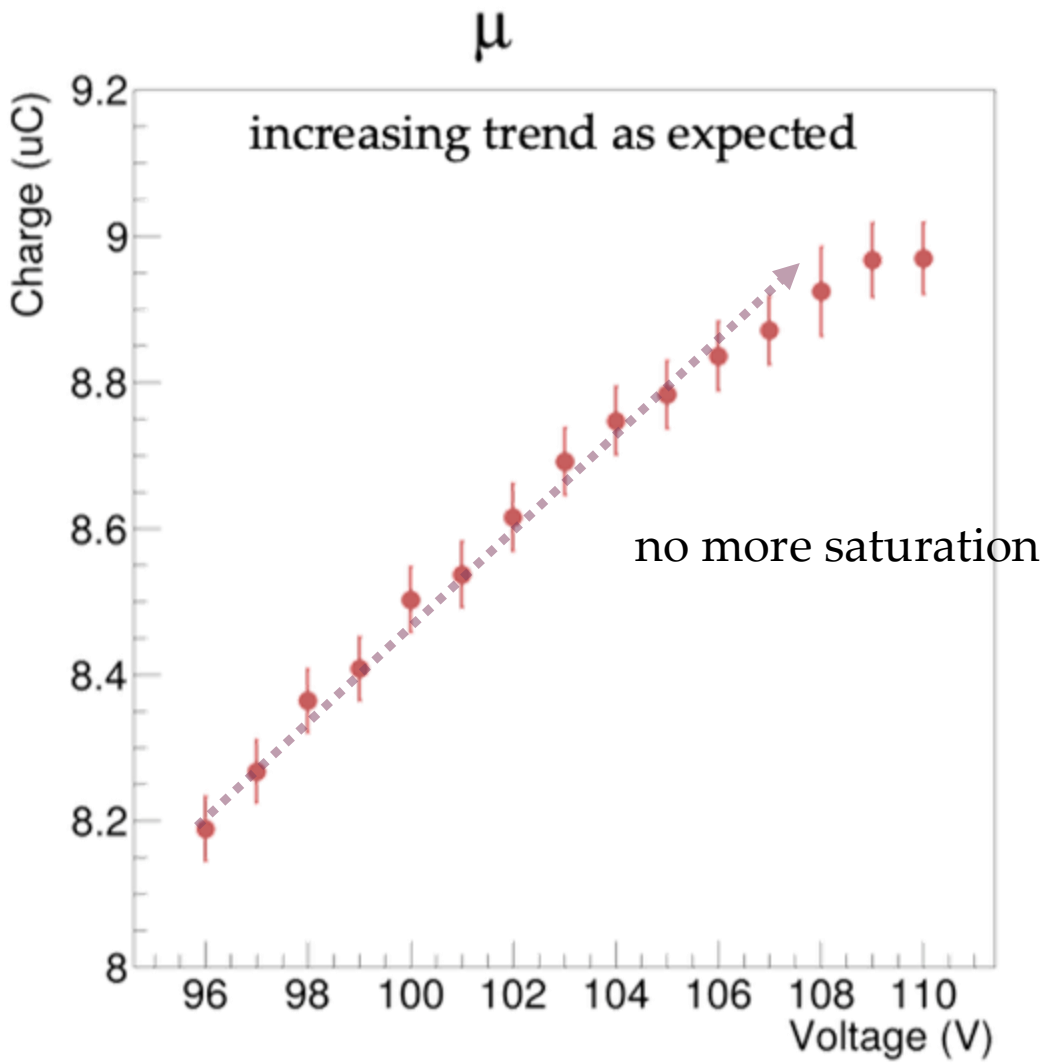
$$\sigma_e(E) = \frac{\sigma_R}{\mu} E_e$$

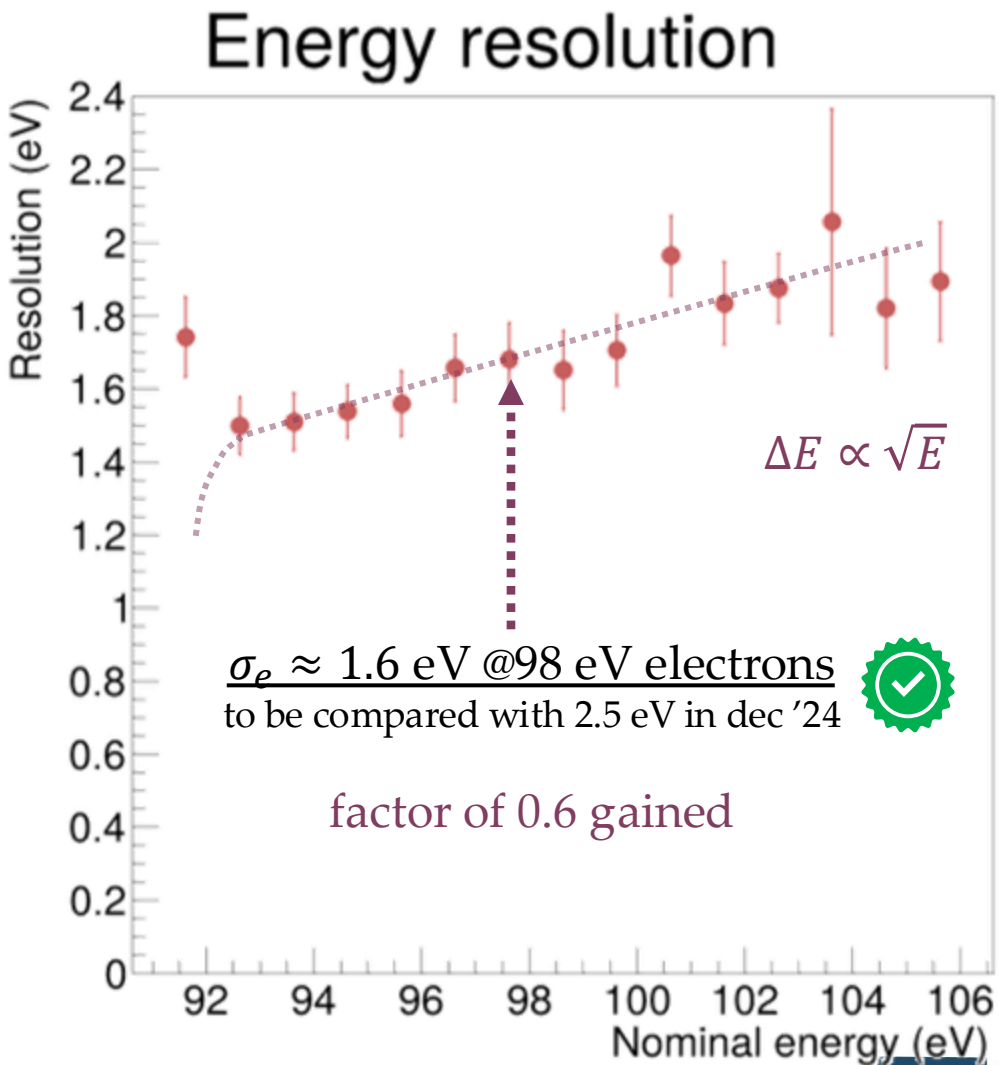
E_e is the electron nominal energy

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

INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

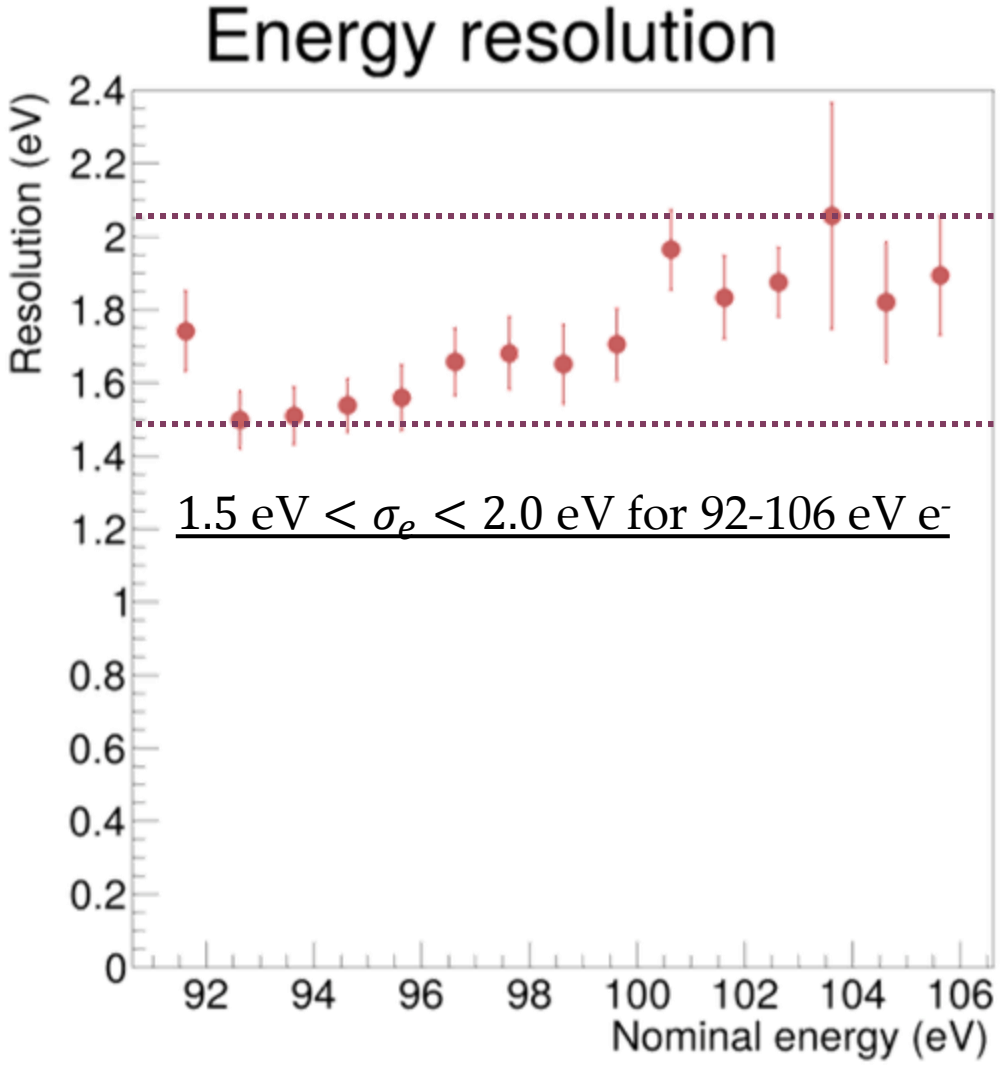
Calculation repeated with **charge** distribution





INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

Some conjectures on resolution



- In terms of charge, we showed:

$$\frac{\text{resolution as Dec '24}}{\text{resolution as paper}} \sim 0.6$$

- Let's impose this ratio in "conserved" also in terms of amplitude:

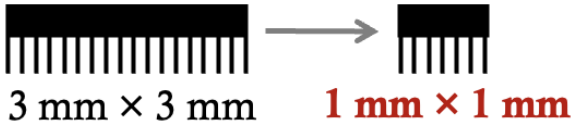
$$0.6 = \frac{\text{resolution as Dec '24}}{\text{resolution as paper (1 eV)}}$$

⇨ $\sigma_e \sim 0.6$ for 92-106 eV electrons

40% improvement!

Conclusions

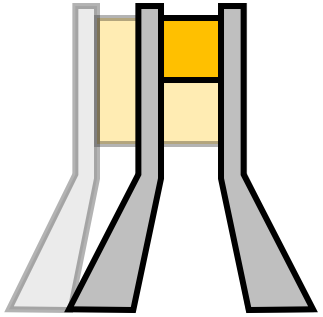
- Reduction of CNTs



Stable working point

Left tail of high energy peak reduced

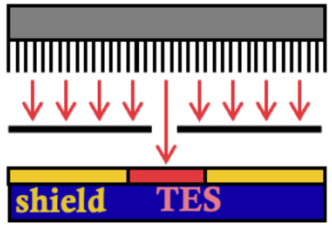
- Smaller TES active area



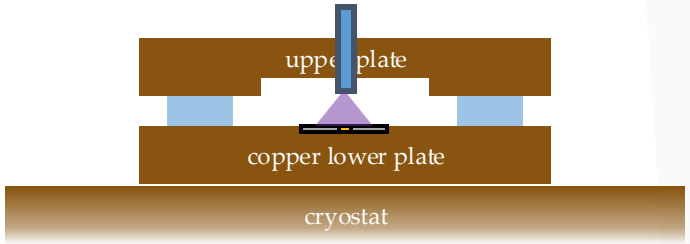
Enhanced energy resolution on charge

40% improvement expected* on amplitude

- Further reduction of CNTs chip area



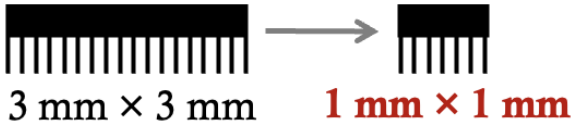
- *A posteriori* TES high-energy calibration with photons



INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

Conclusions

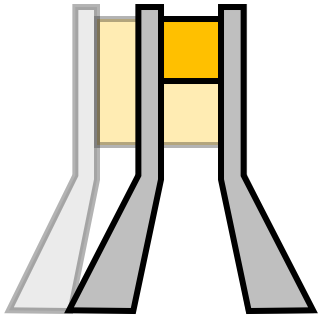
- Reduction of CNTs



Stable working point

Left tail of high energy peak reduced

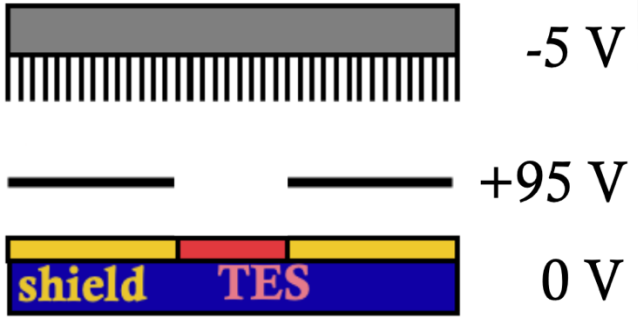
- Smaller TES active area



Enhanced energy resolution on charge

40% improvement expected* on amplitude

- Further reduction of CNTs chip area
- *A posteriori* TES high-energy calibration with photons
- Lowering electron energy using decelerating plate



INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

Thank you for your attention!