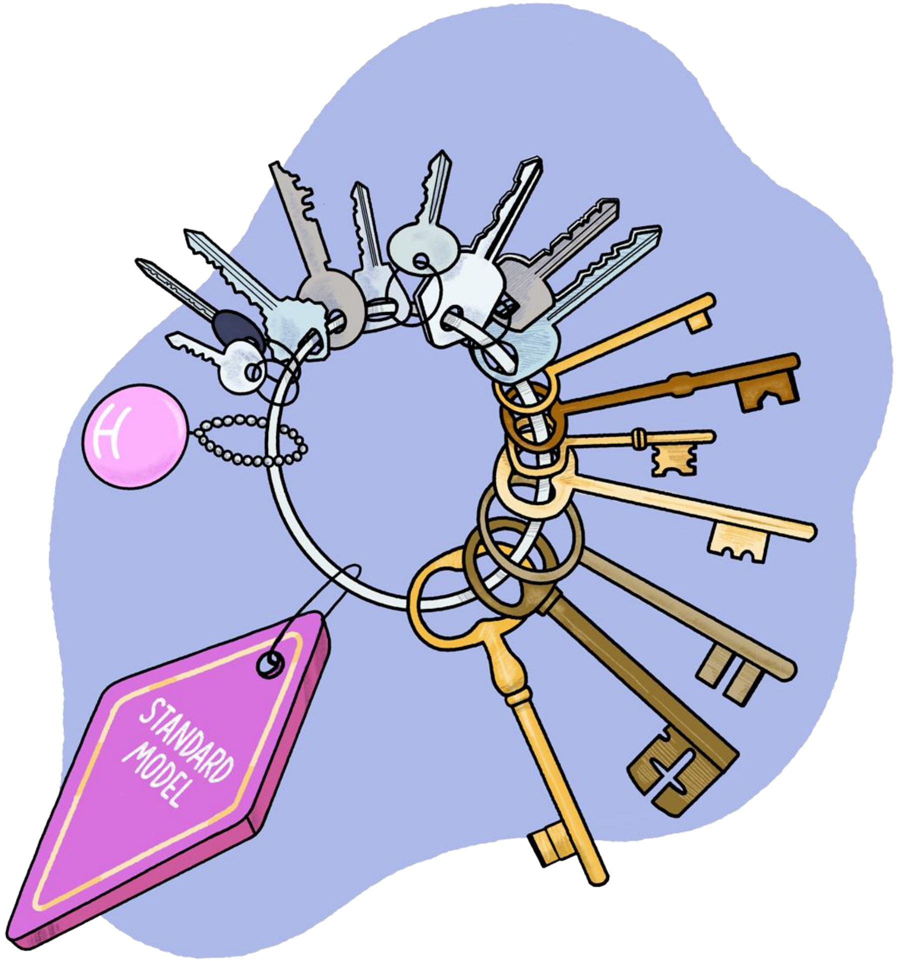
Superconducting Array for Low-Energy Radiation (SALER)

Driss GUILLET
for the SALER collaboration
LPC Caen

I. Introduction and Motivations

Beta decay to probe BSM physics

- Standard Model provides the most robust predictions to date



Artwork by Sandbox Studio

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- Standard Model provides the most robust predictions to date
- **Weak interactions studies** are especially interesting for BSM searches
- **Beta decay is competitive,** with several probes for high precision measurements

Artwork by Sandbox Studio

Probing CKM matrix unitarity

- Study beta decay spectra **to test CKM matrix unitarity**

$$\begin{pmatrix} d \\ s \\ b \end{pmatrix}_w = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}_m$$

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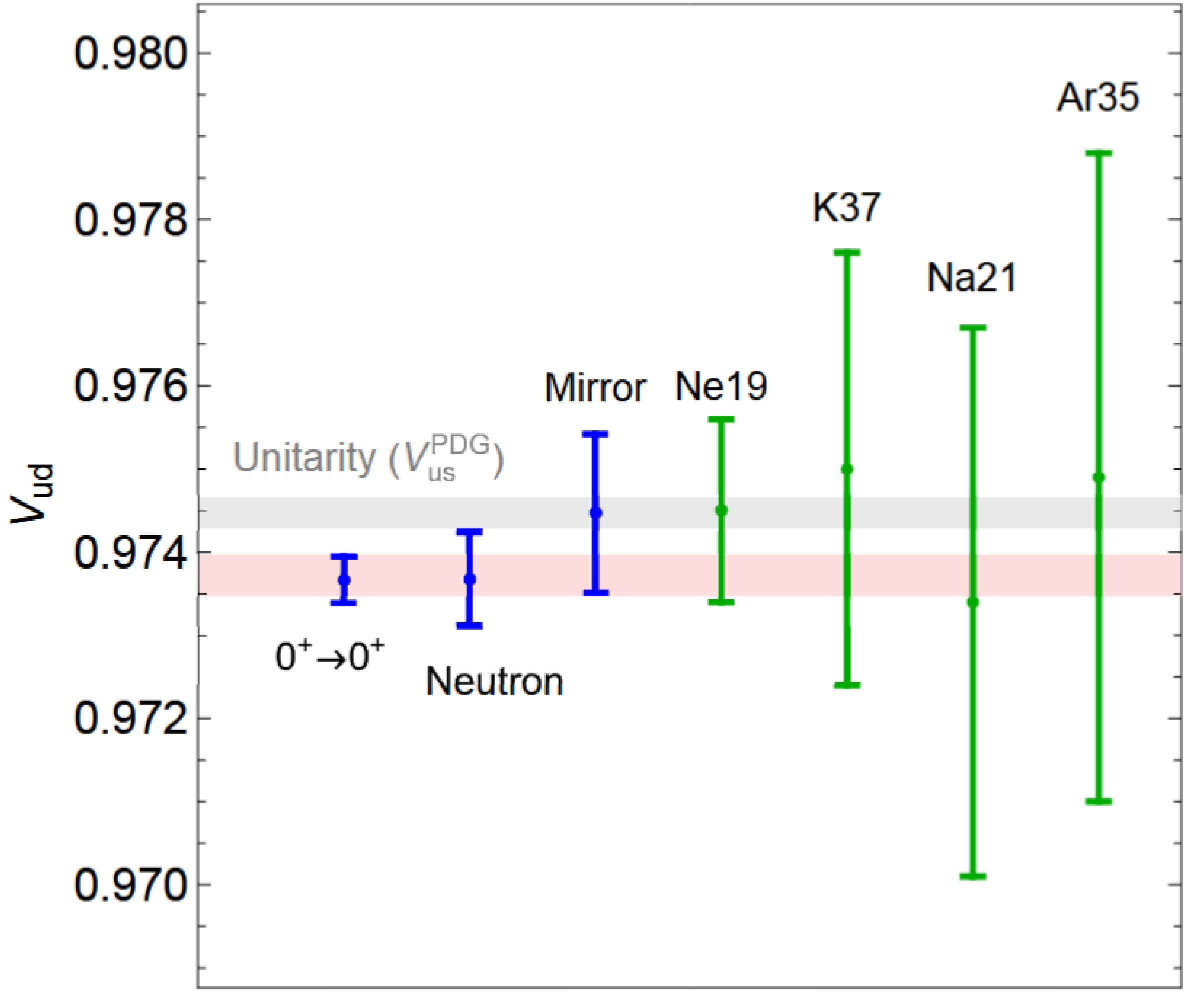
~ 0.973 $\sim 10^{-5}$

Probing CKM matrix unitarity

- Study beta decay spectra **to test CKM matrix unitarity**
- Largest element in the row : V_{ud}
- 1σ deviation from unitarity



Adam Falkowski, Martín González-Alonso and Oscar Naviliat-Cuncicc, 2021

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$$a_{\beta\nu}\approx\frac{1-\rho^2/3}{1+\rho^2}$$

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- Recoil spectrum sensitive to α
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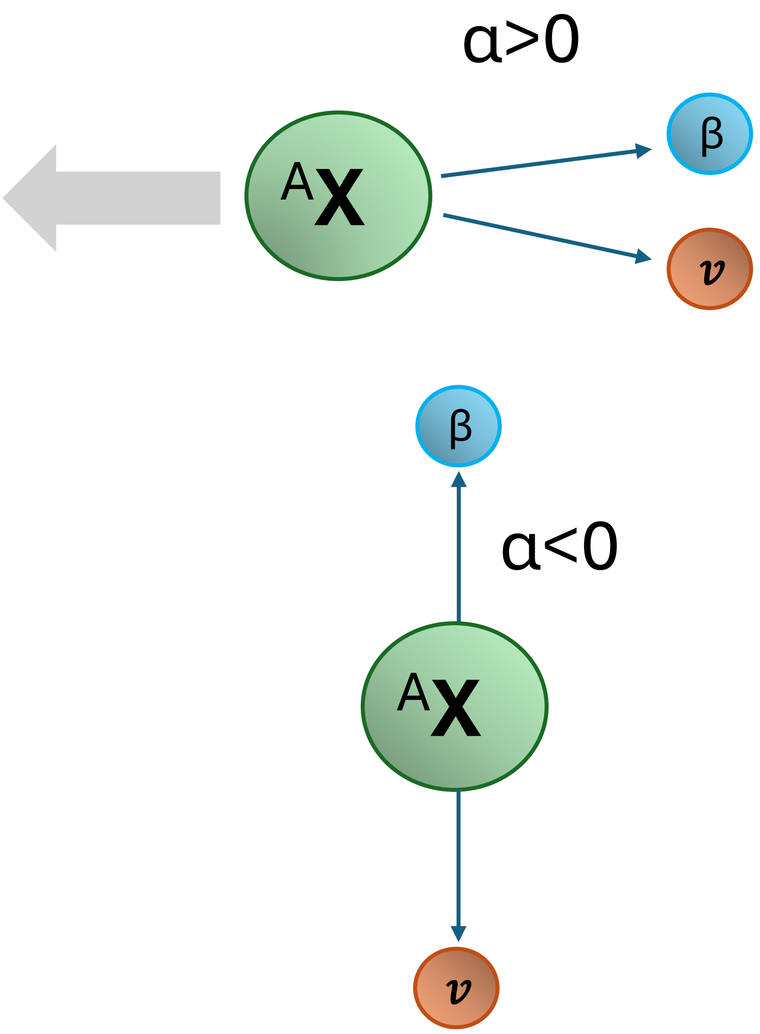

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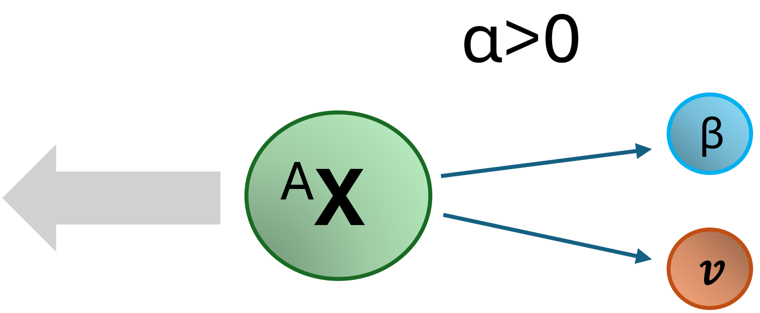

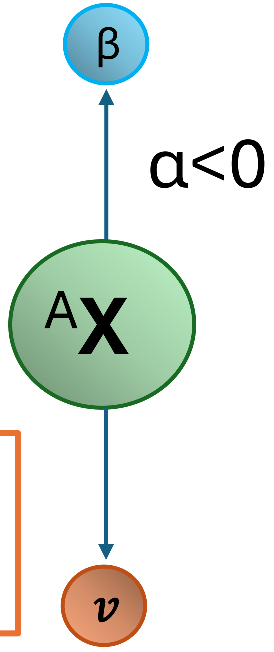

eV-scale spectrum
$\sim 100\ eV$

II. Superconducting Tunnel Junctions

Superconducting Tunnel Junctions (STJ)

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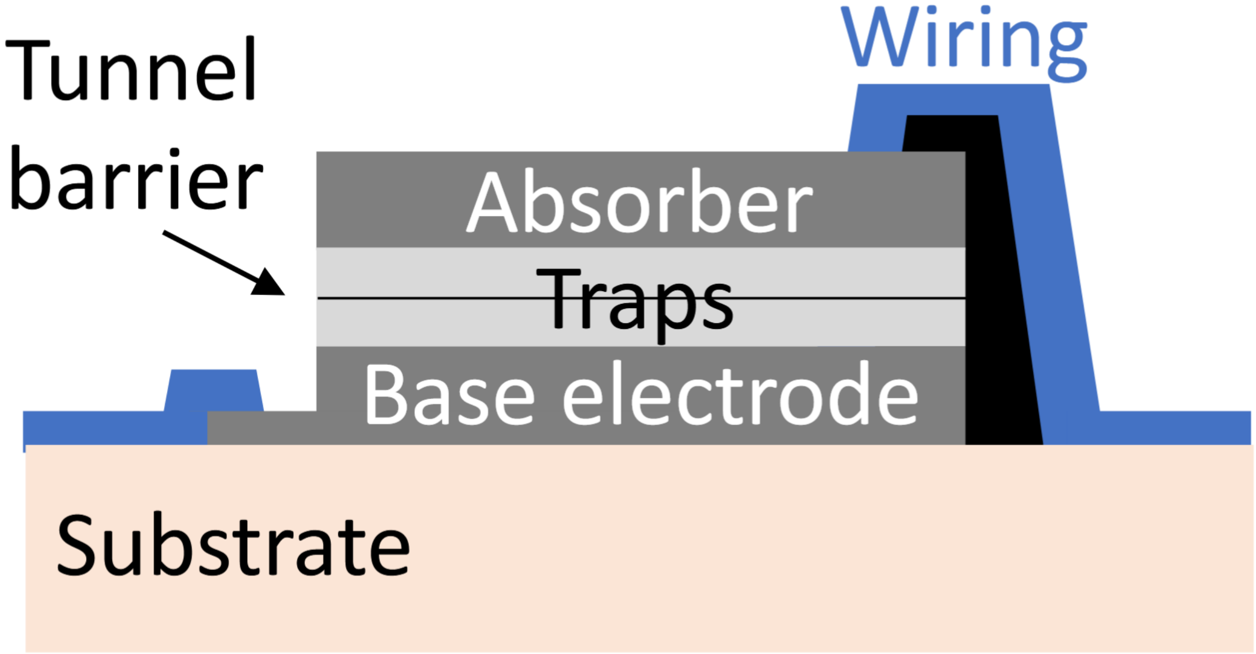

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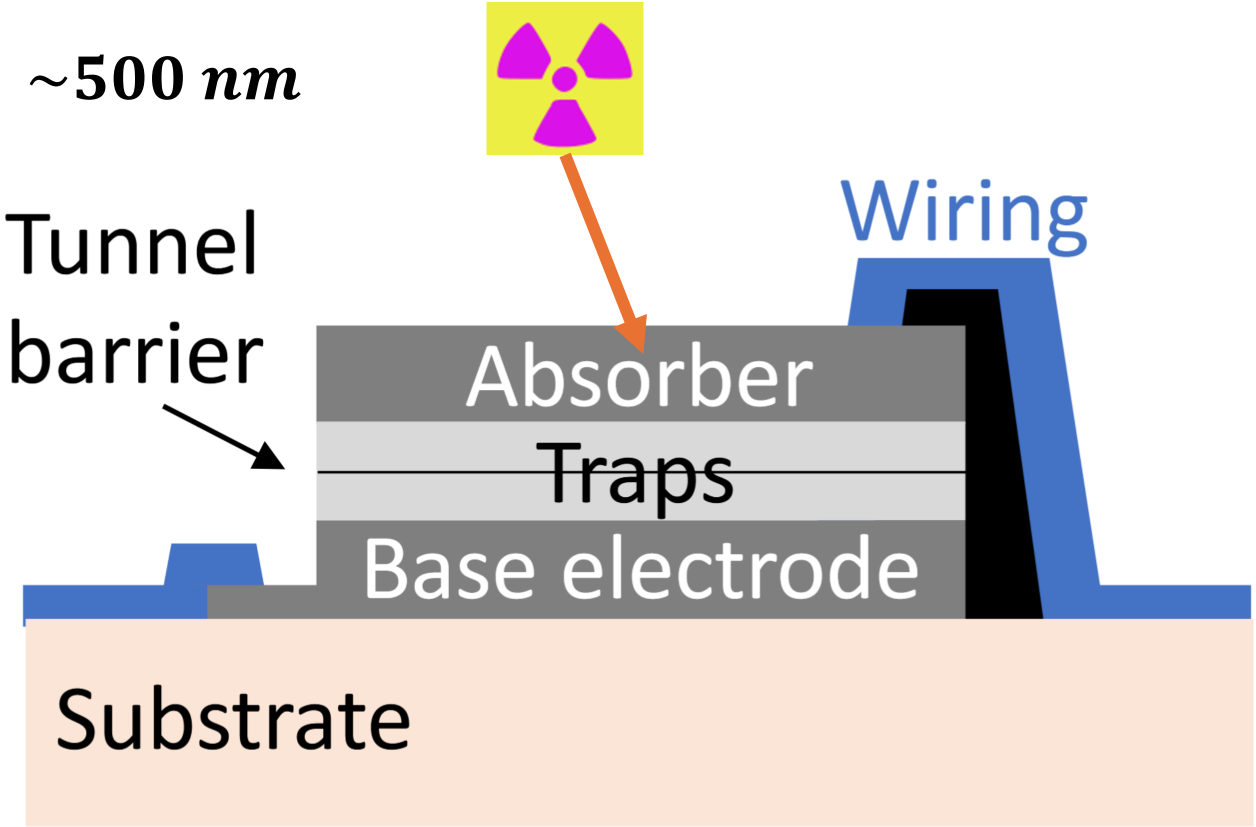

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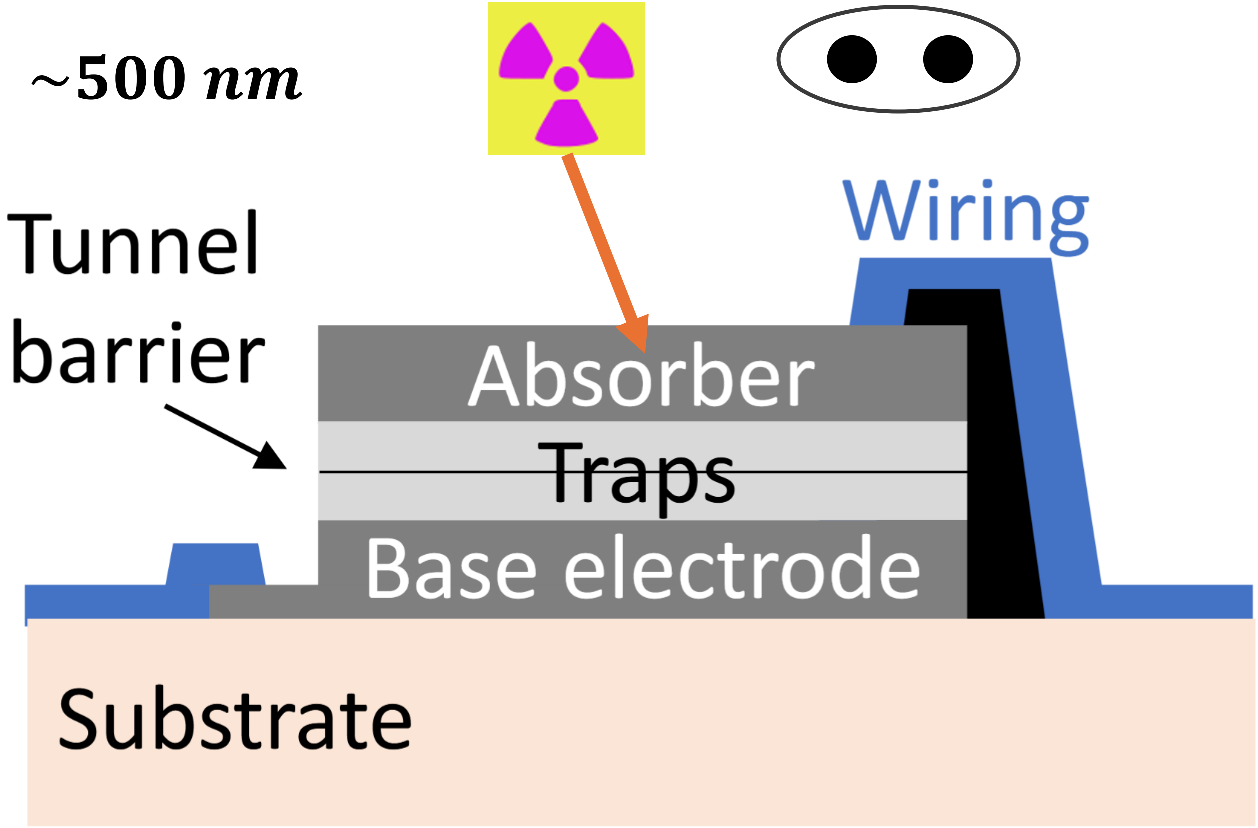

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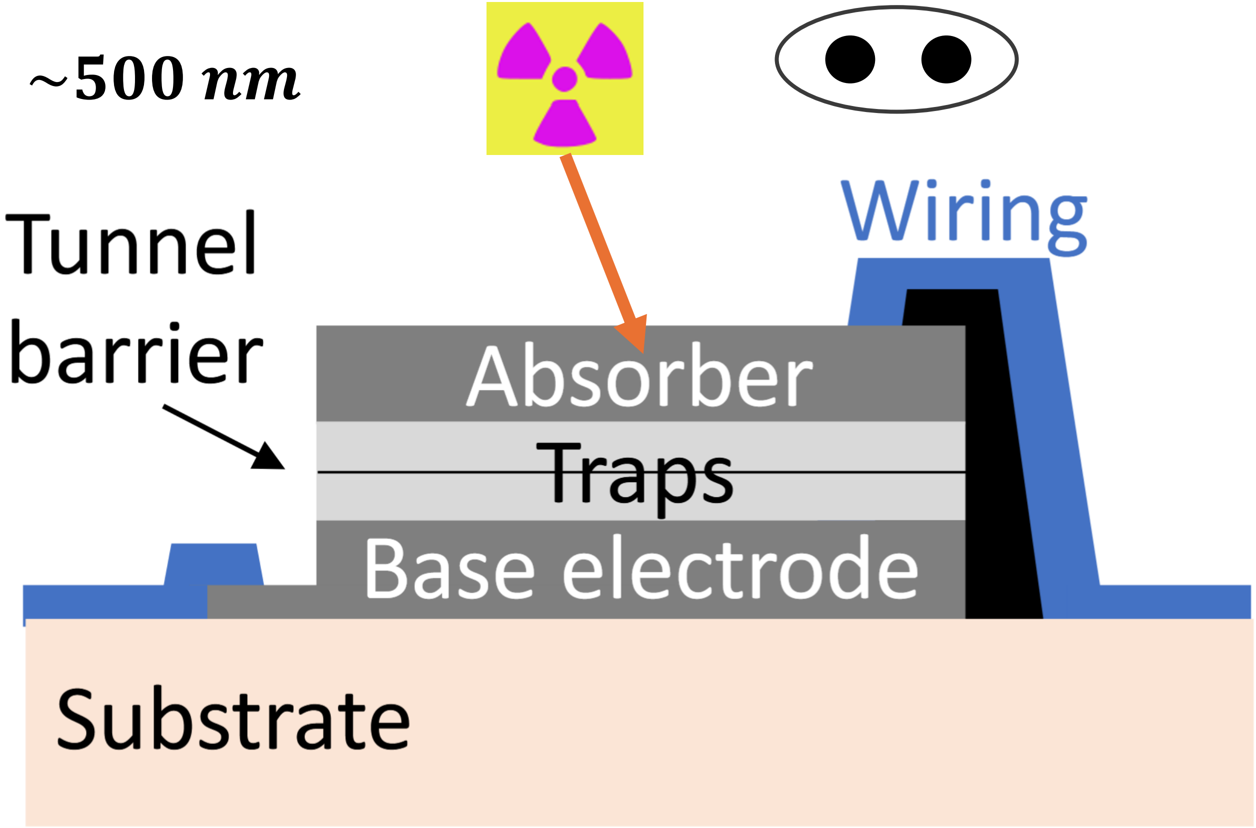

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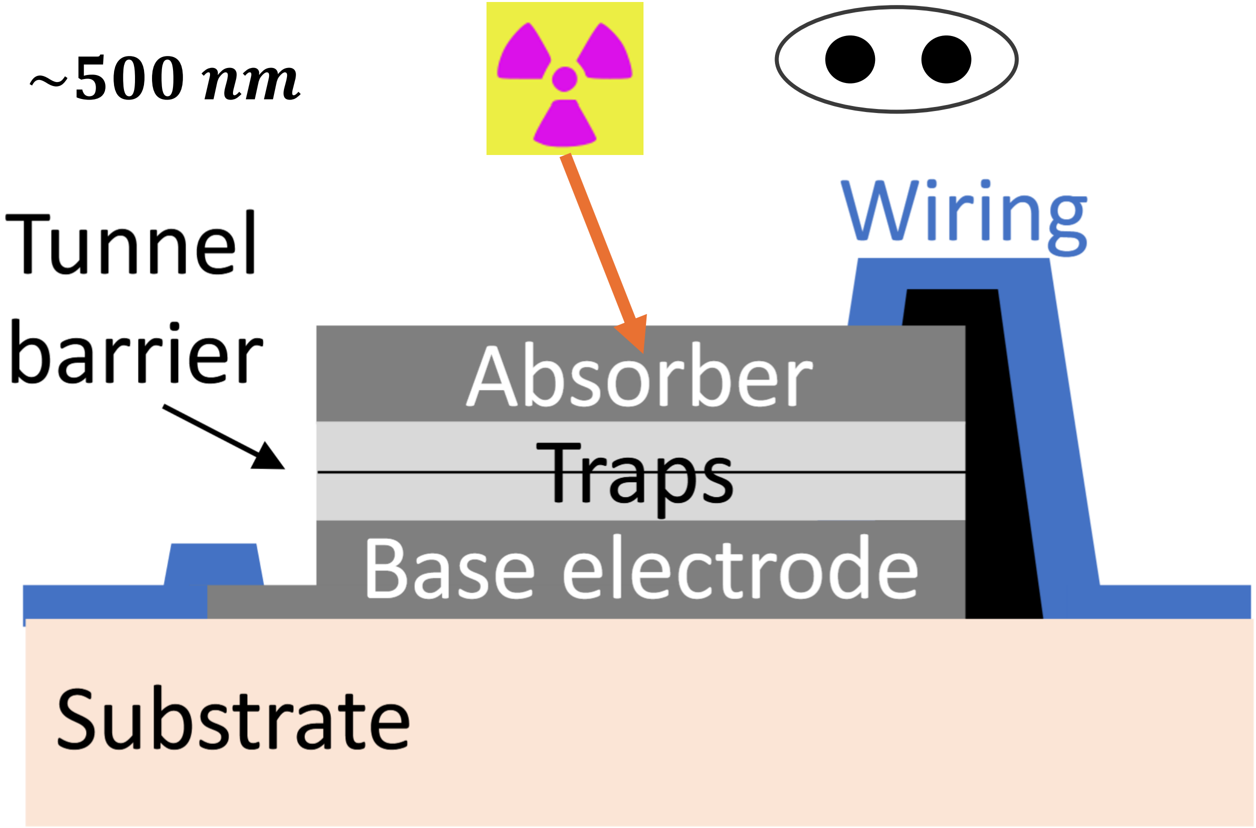

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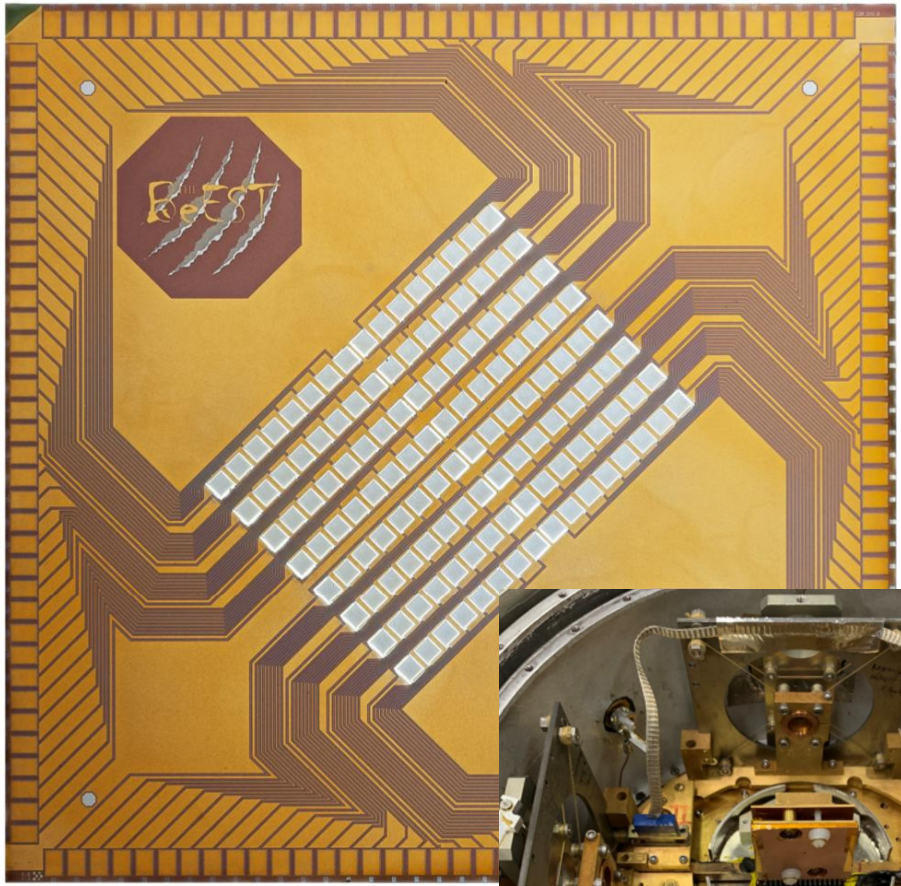
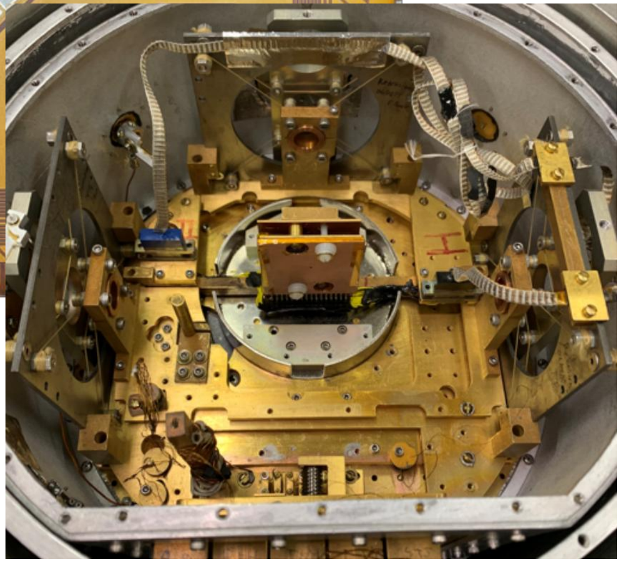


128-pixel STJ



Cooled to 40 mK
(ADR)

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BeEST experiment

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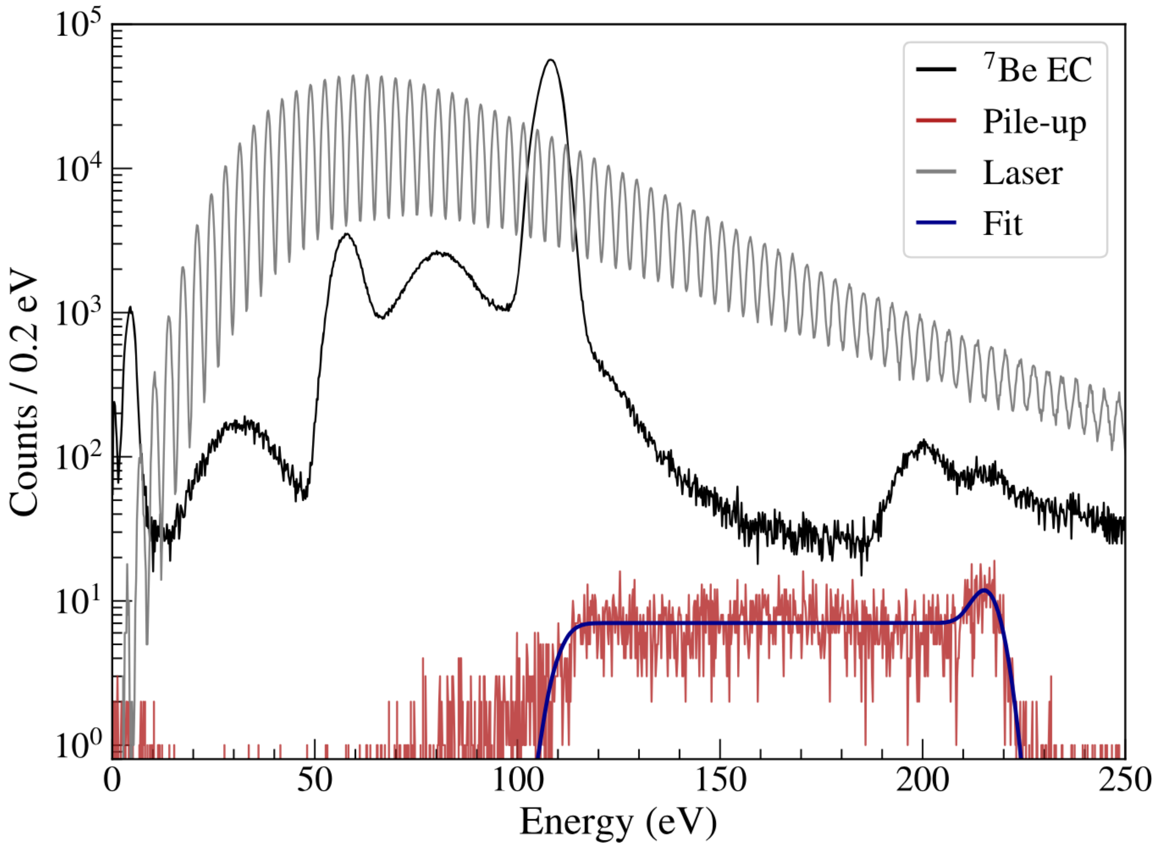

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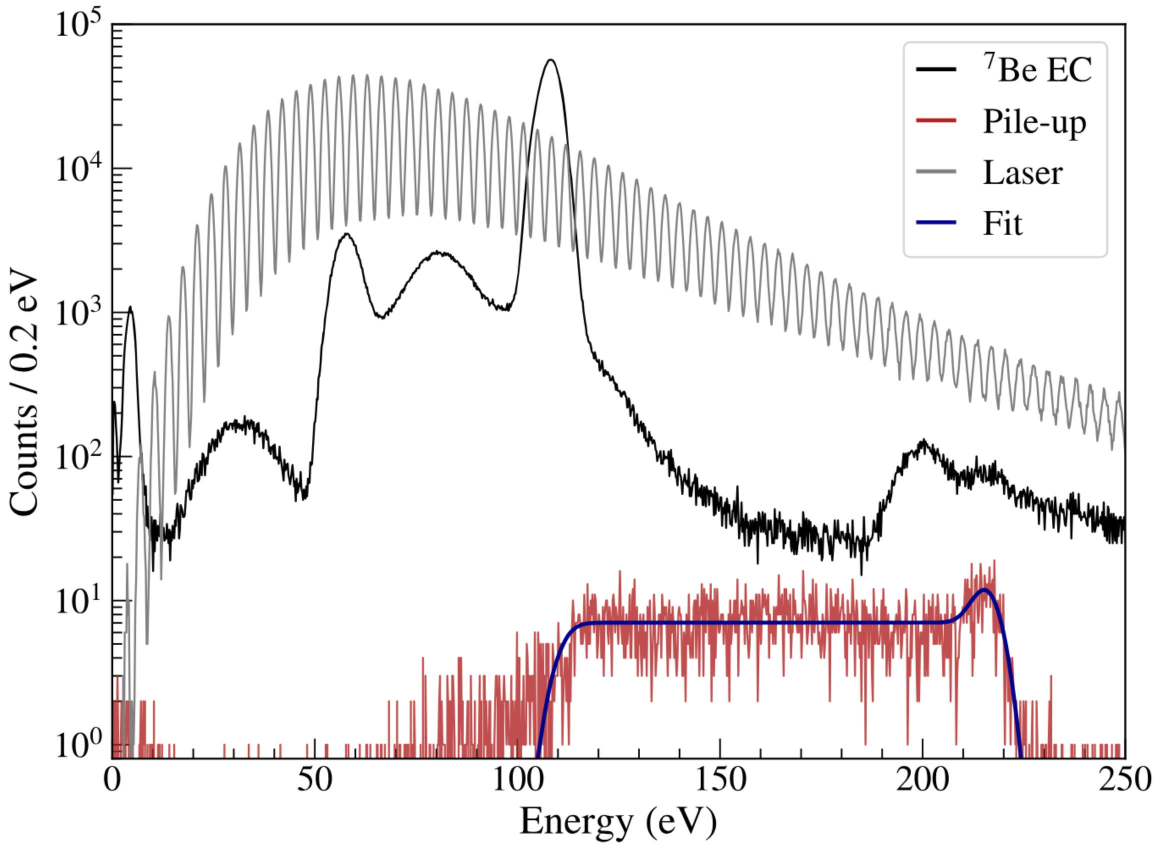

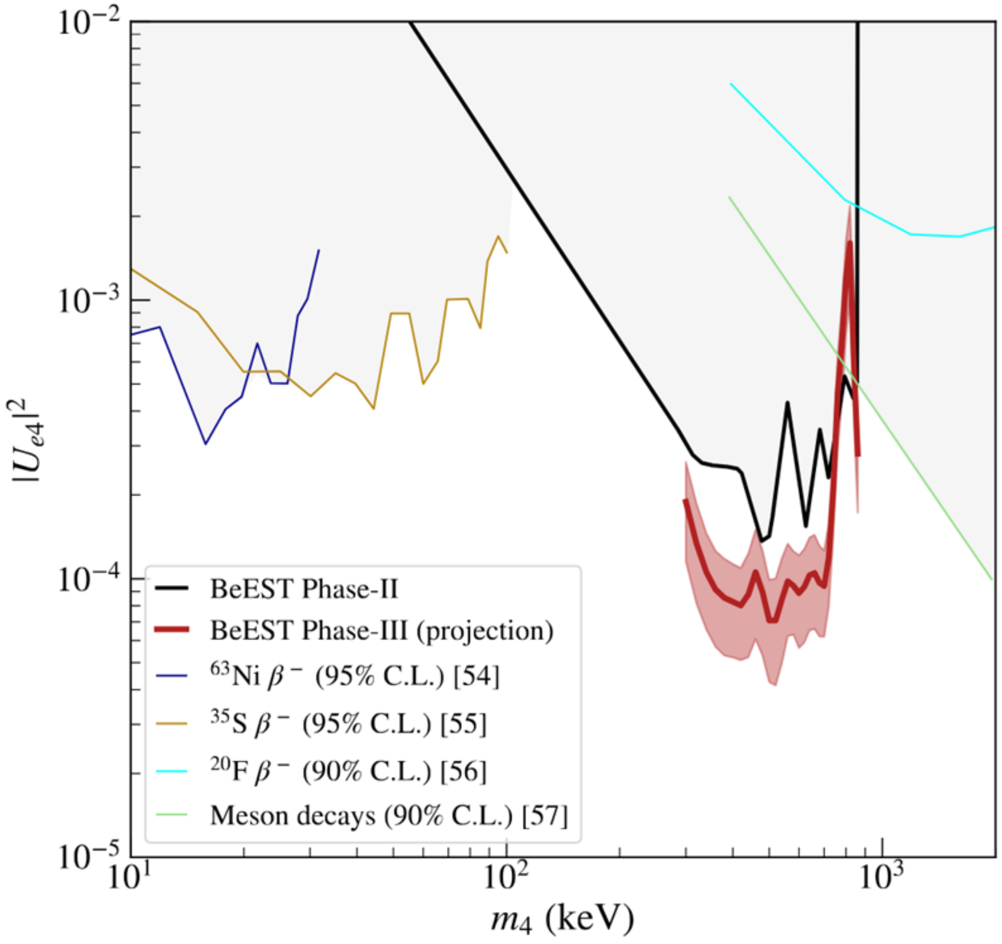

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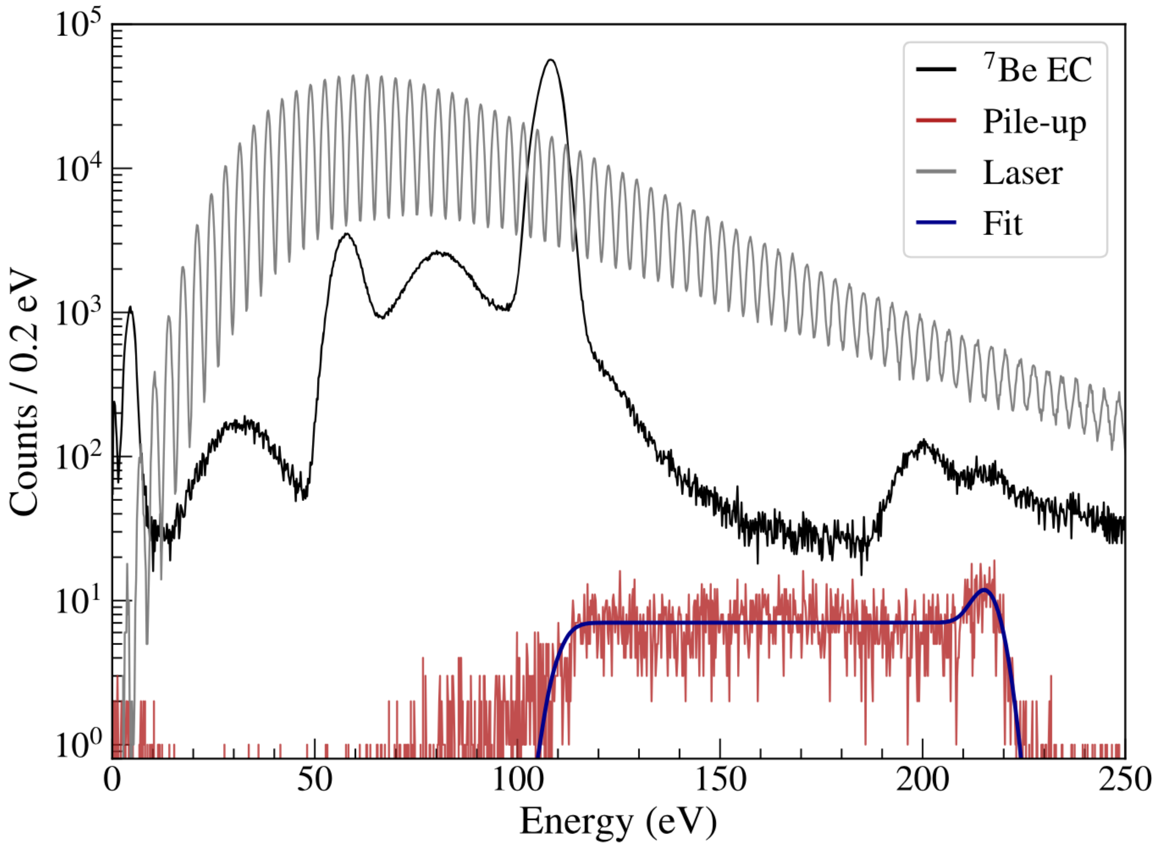

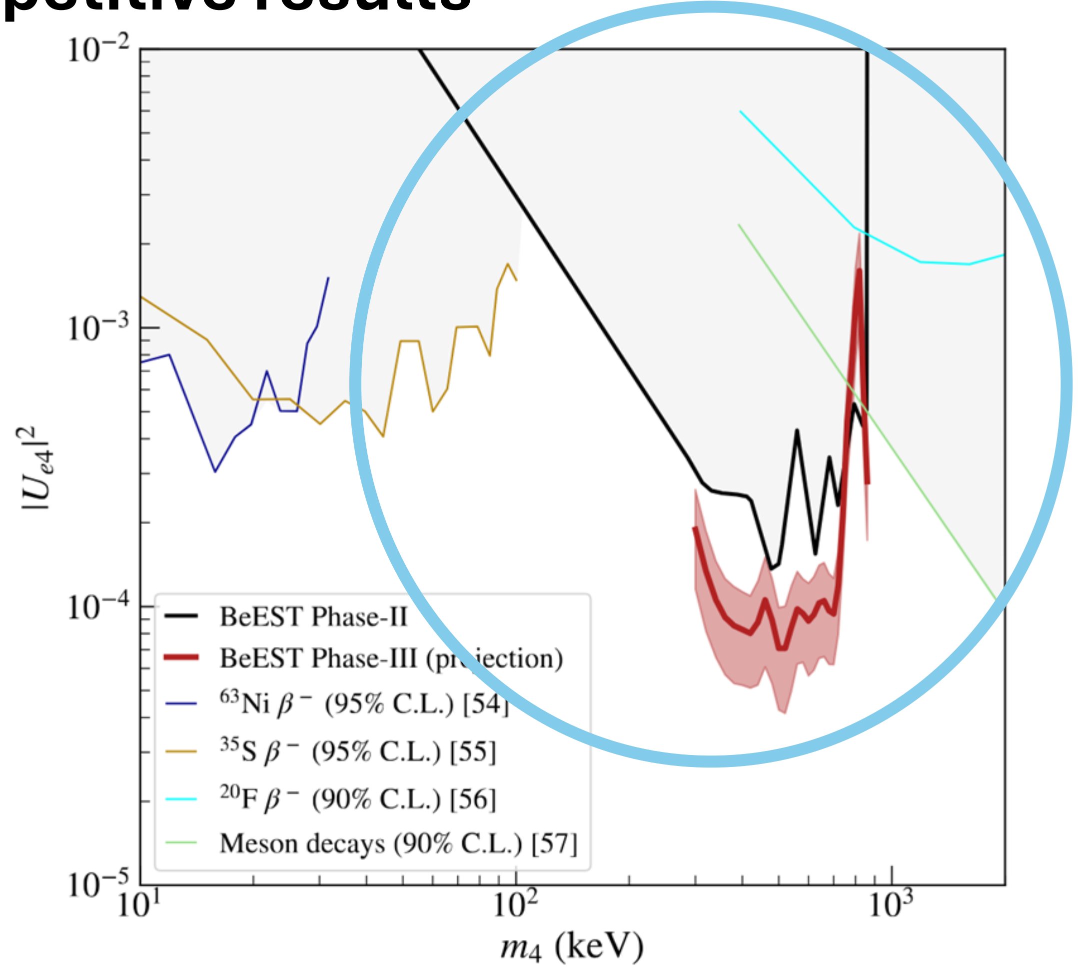

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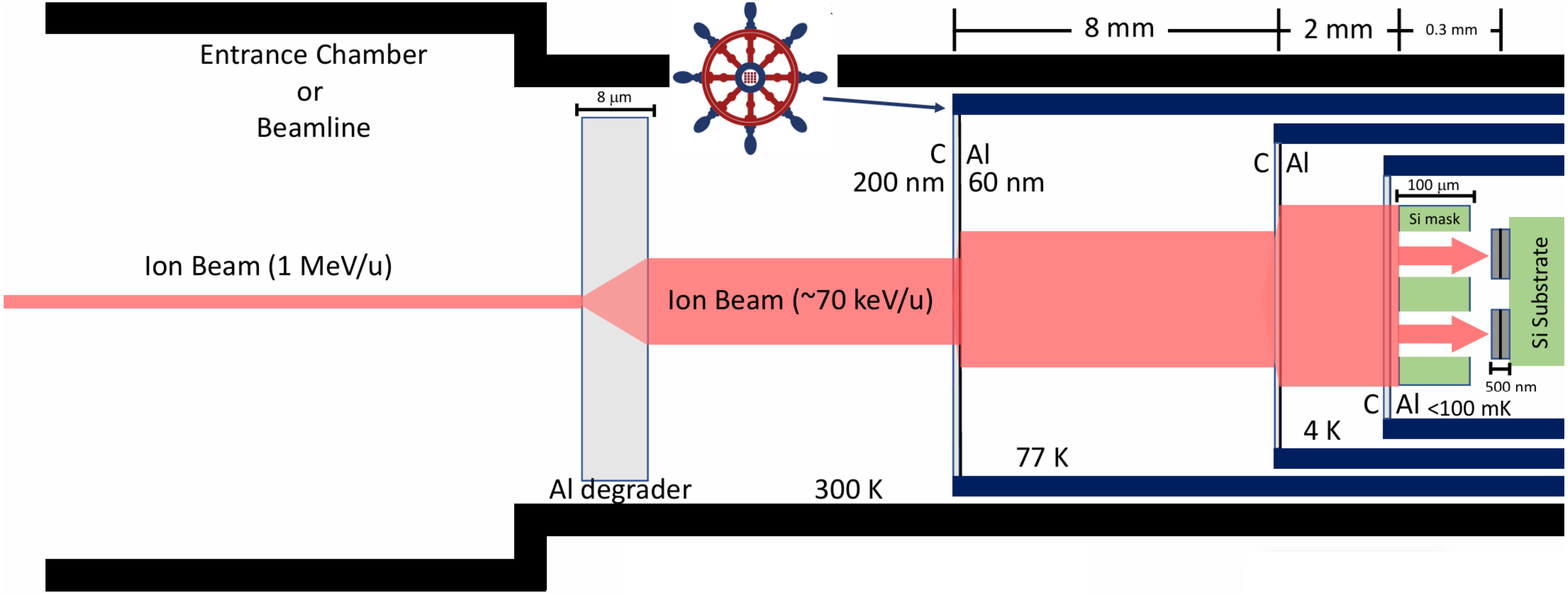
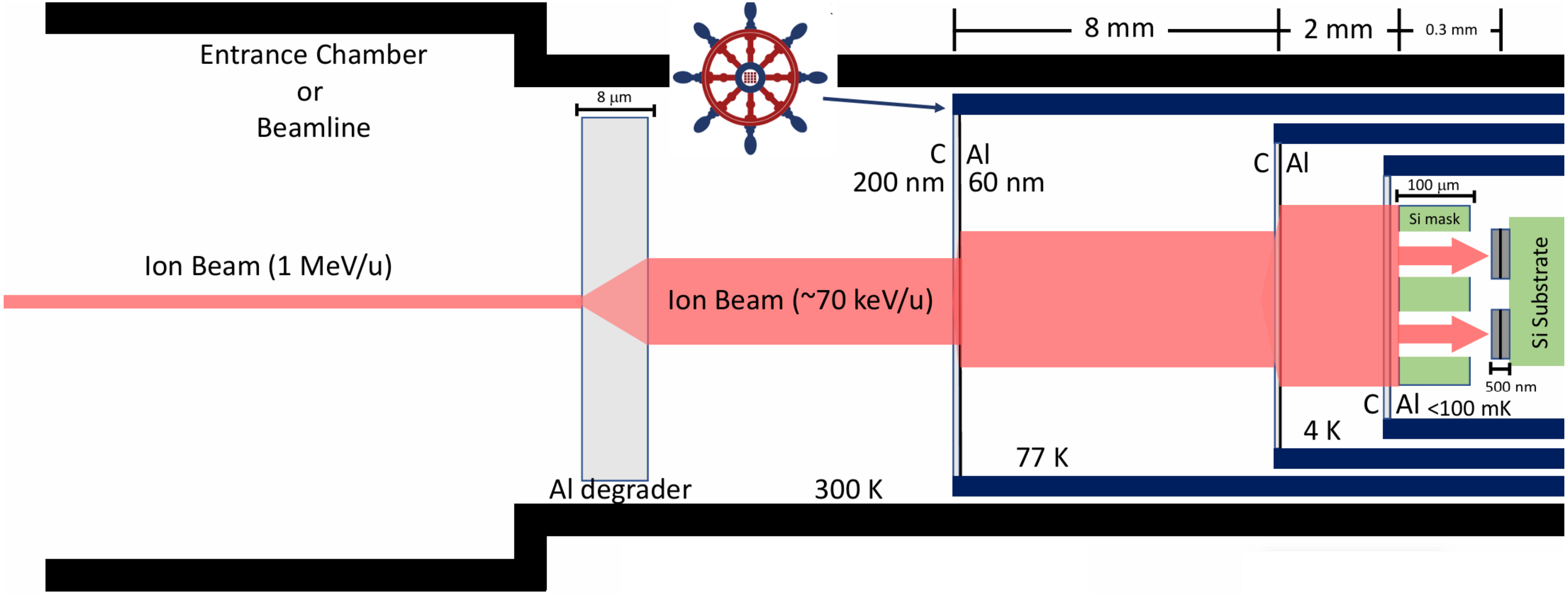
- Aim of the SALER experiment based at FRIB
- **With mirror decays for ρ : ^{11}C and ^{19}Ne**

III. SALER Set up

SALER Experiment

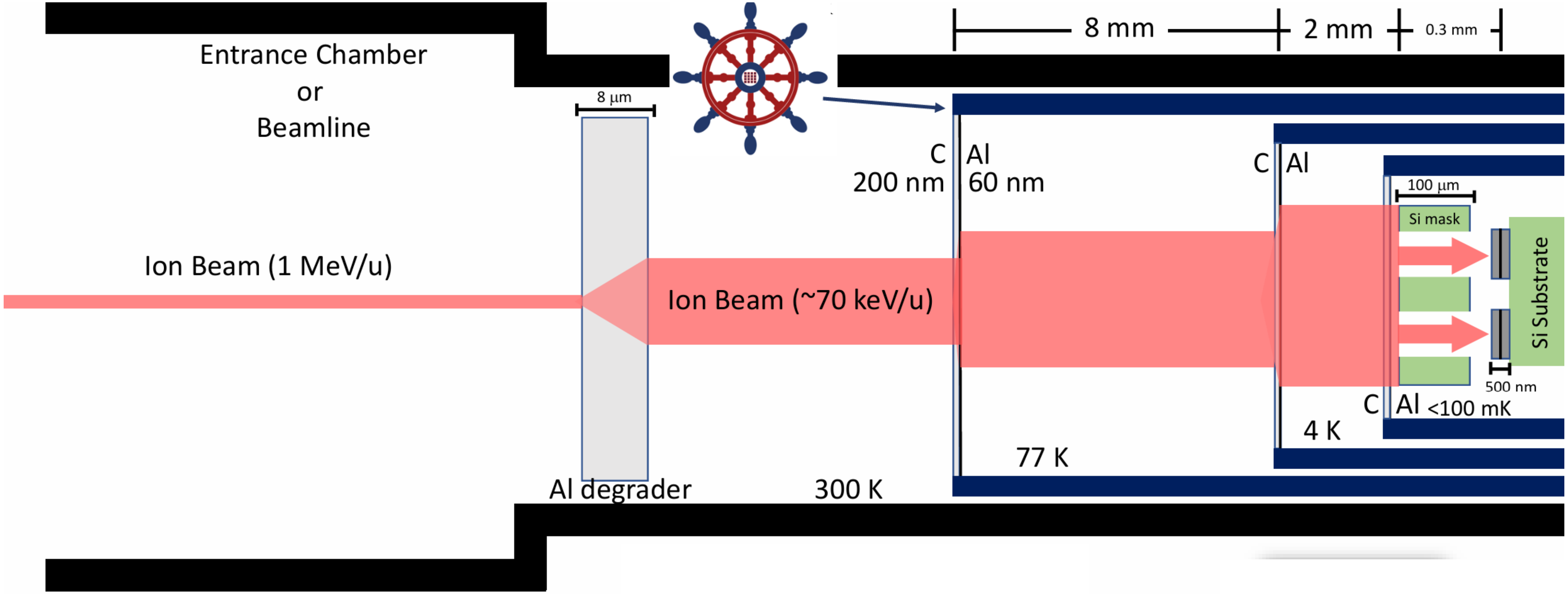


SALER Experiment



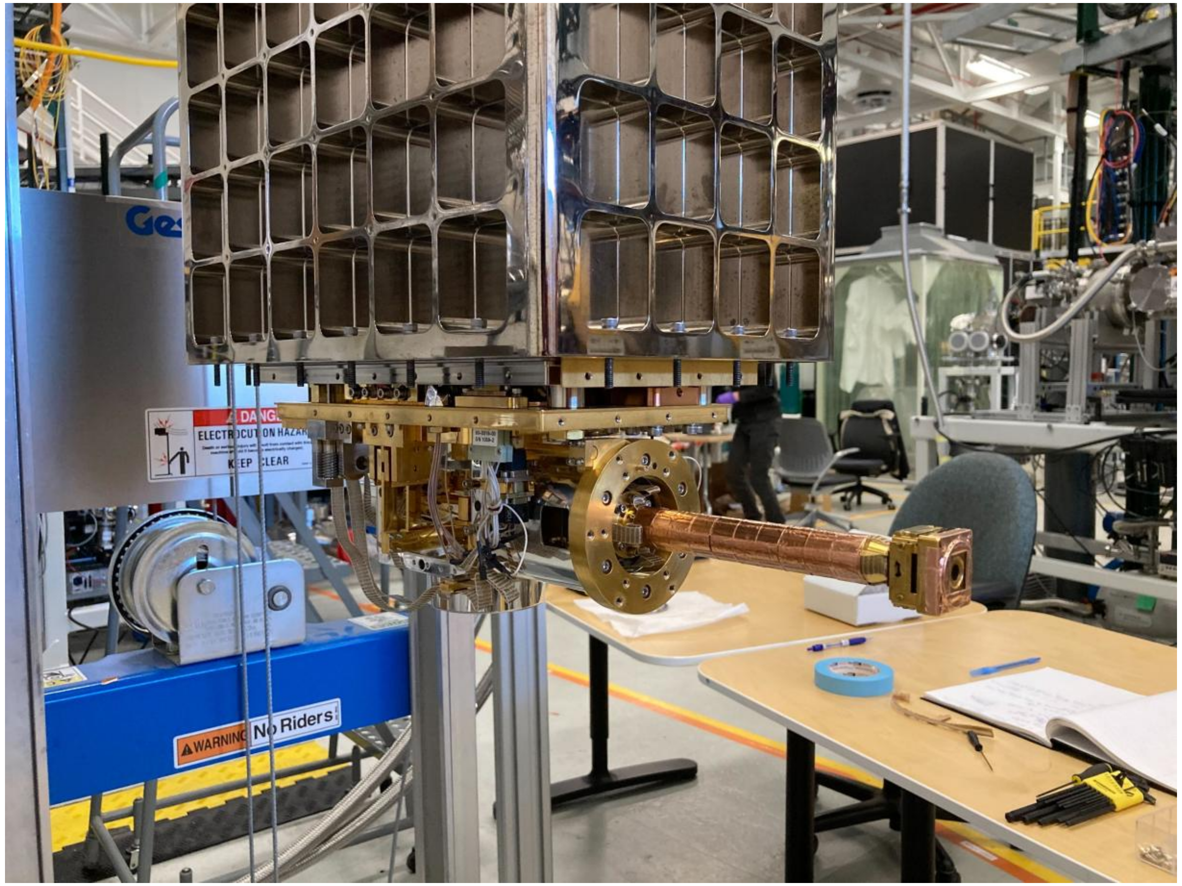
Stable beam commissionning in April/May !

SALER Experiment



Dress rehearsal /testing calibration procedure last week !

Unshielded device



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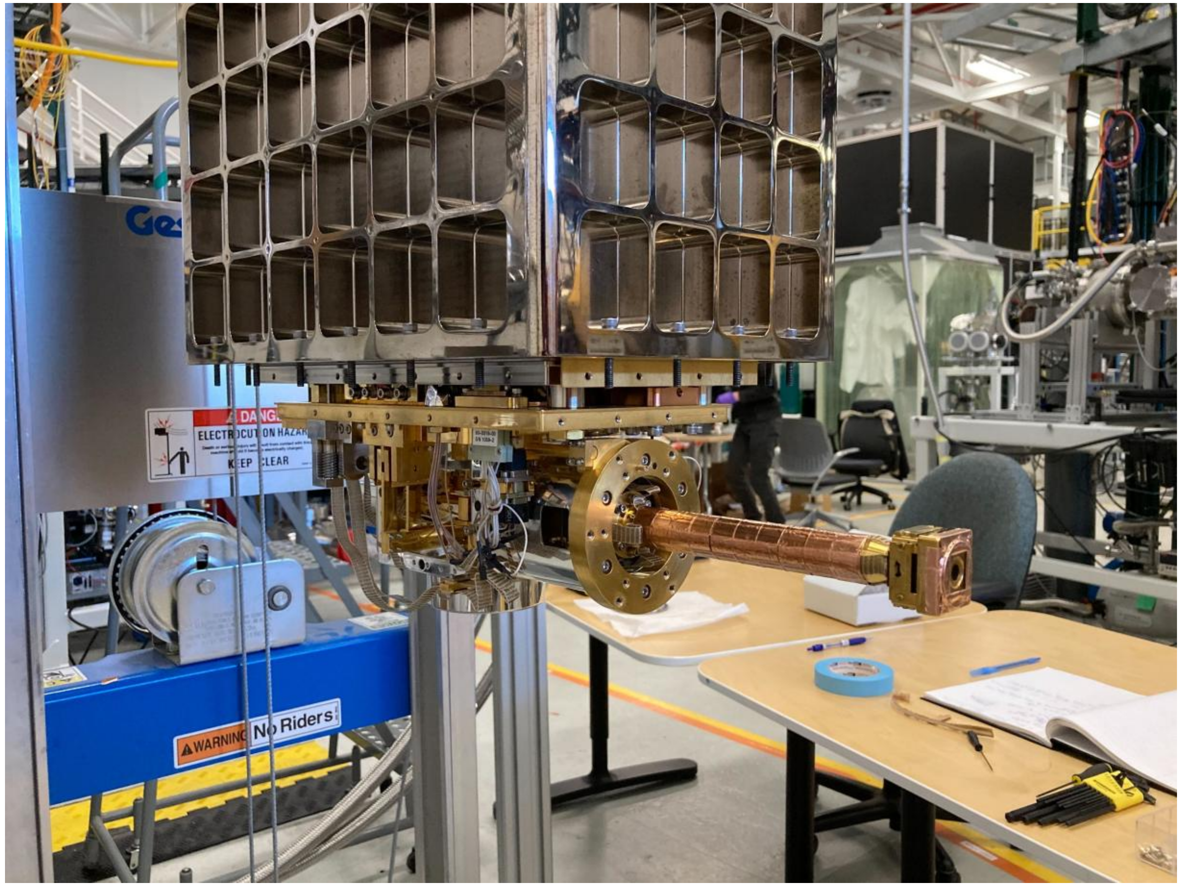

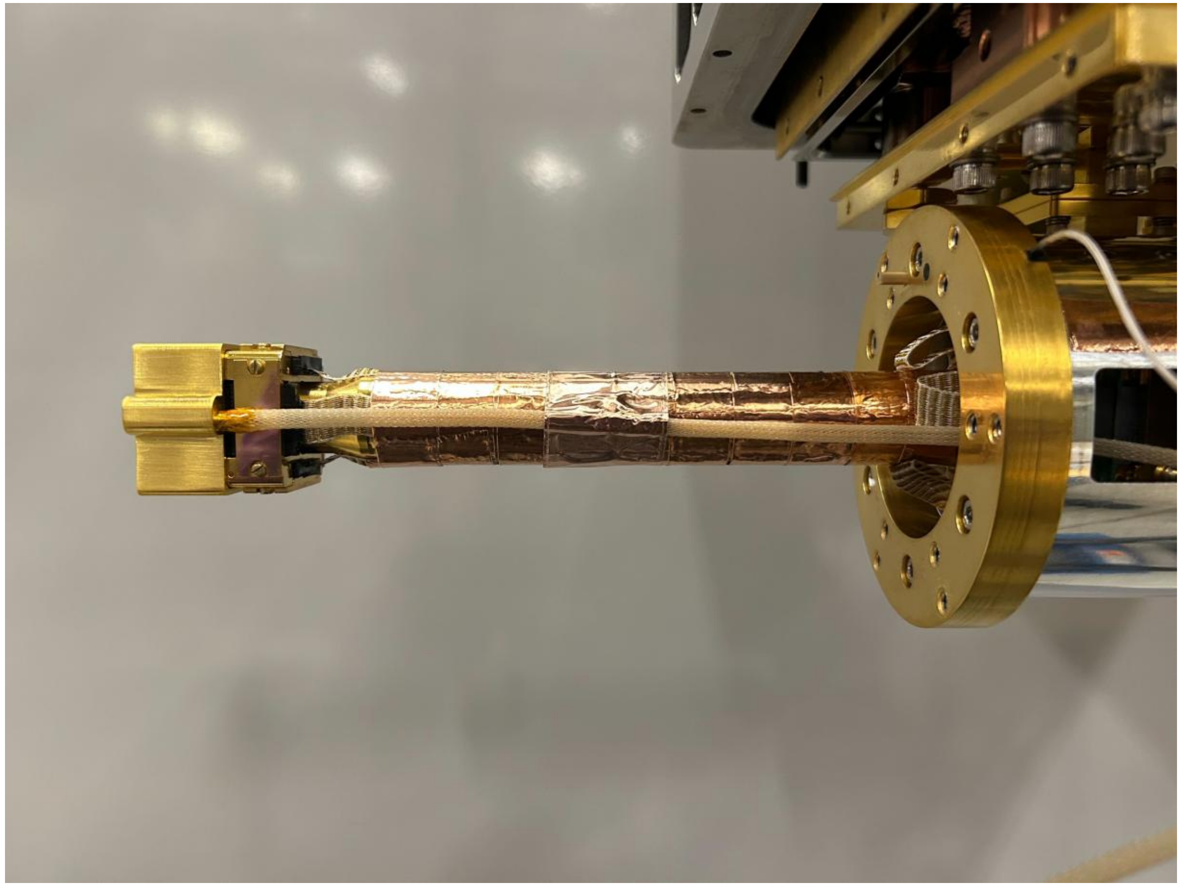

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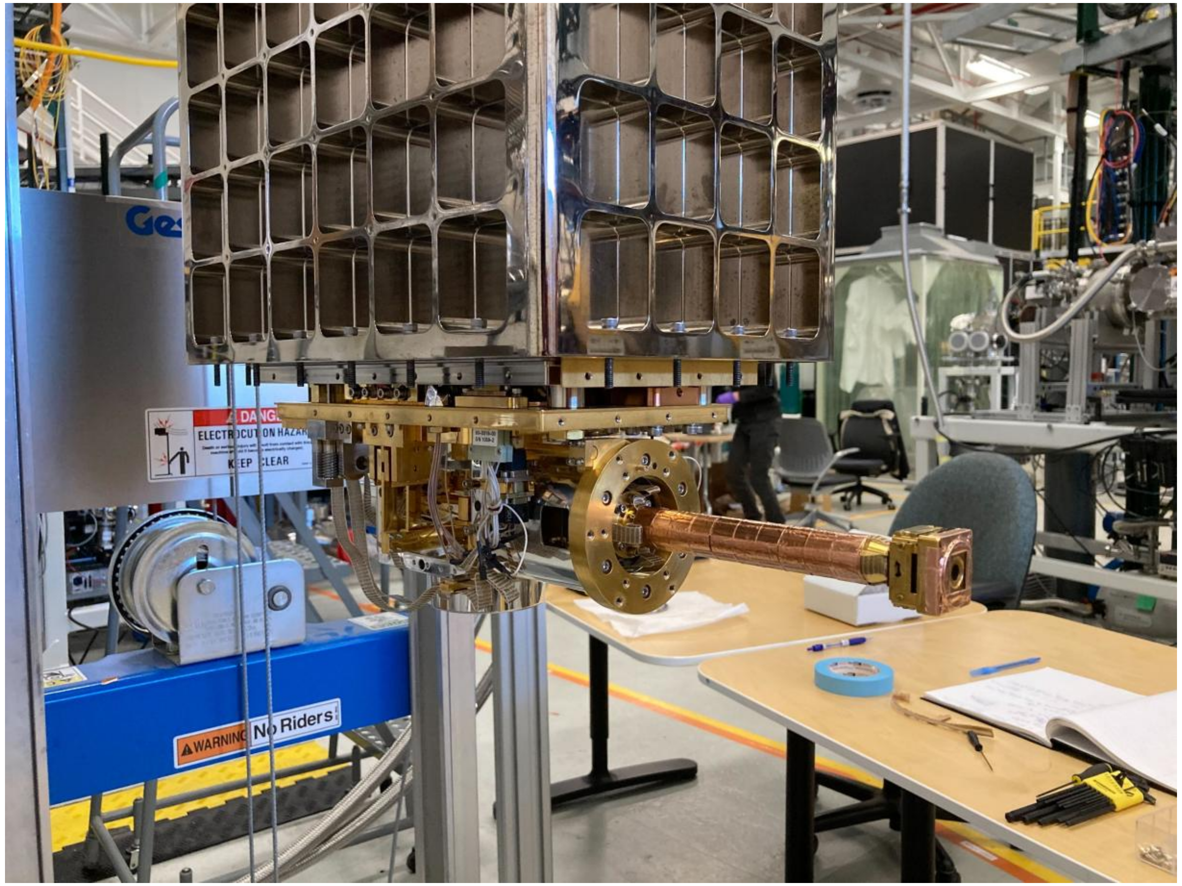

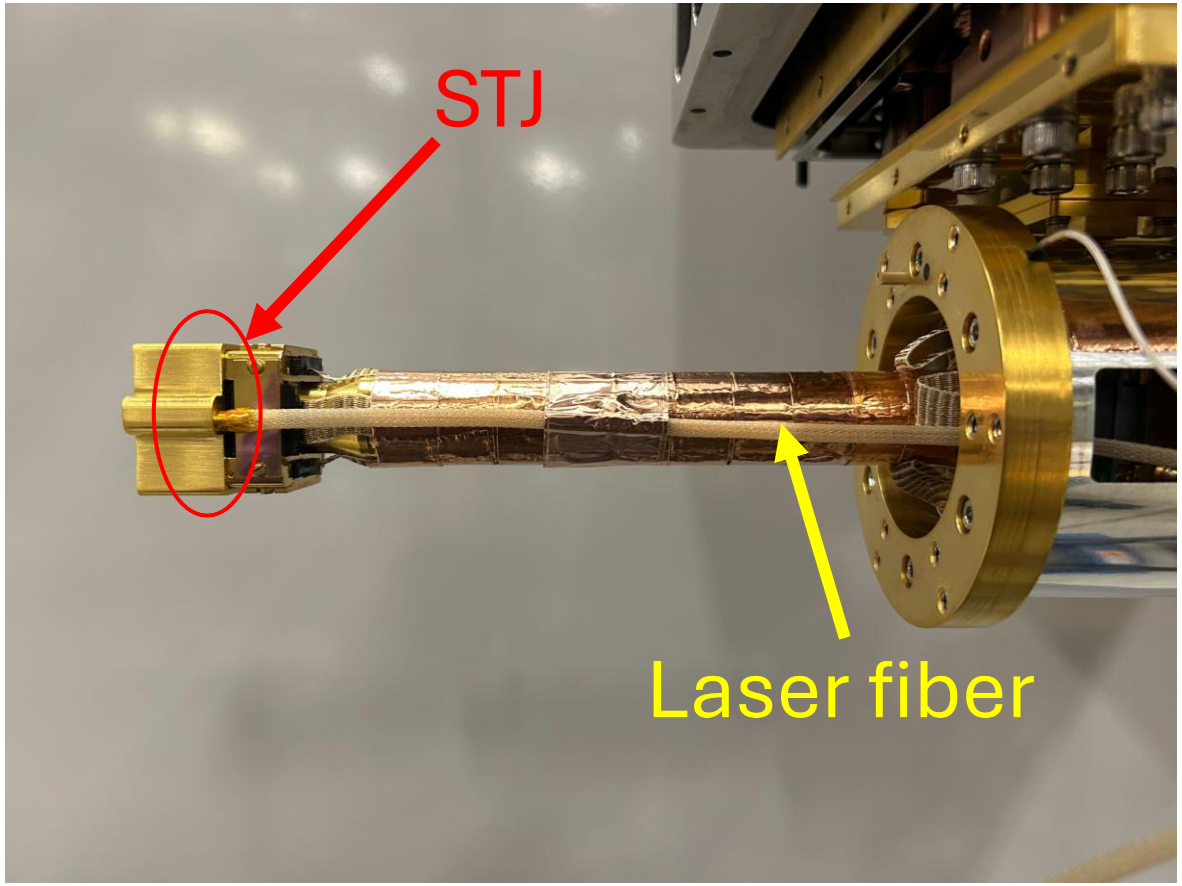

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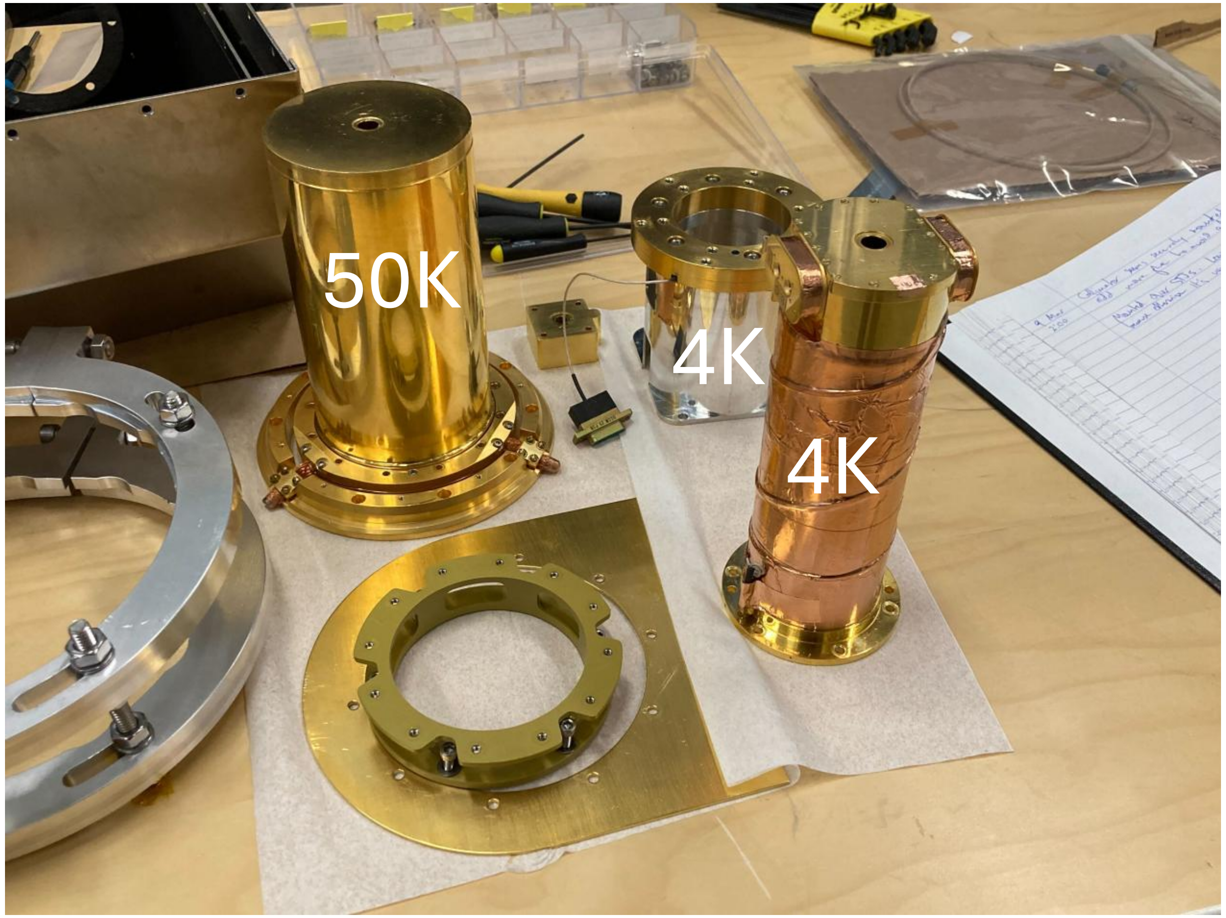

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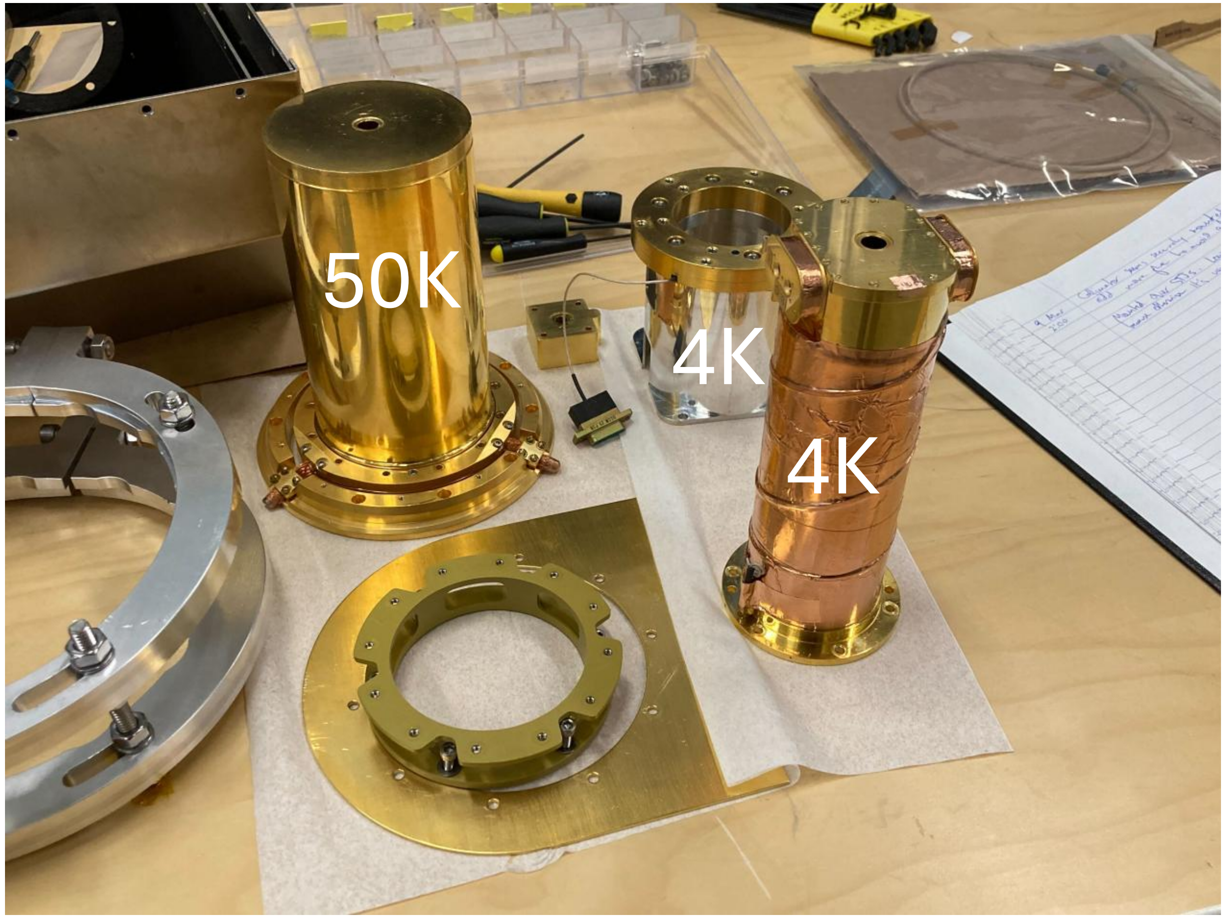

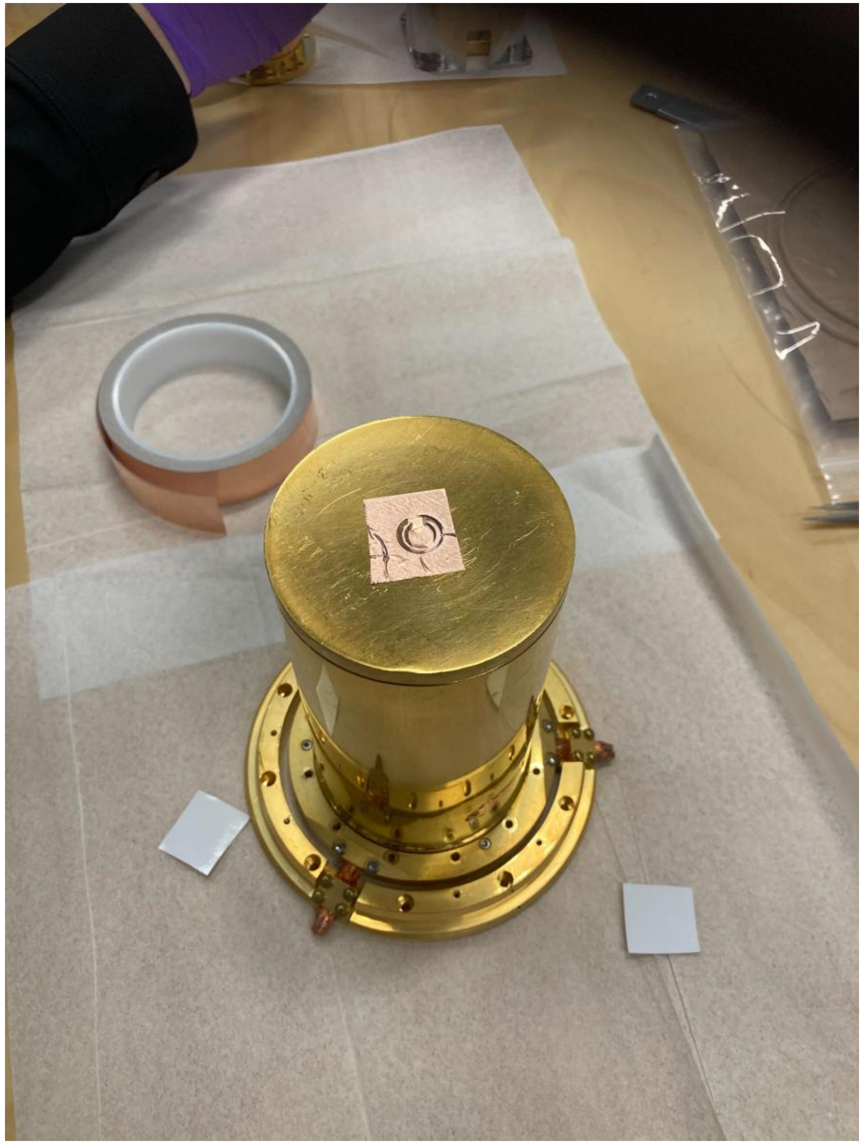

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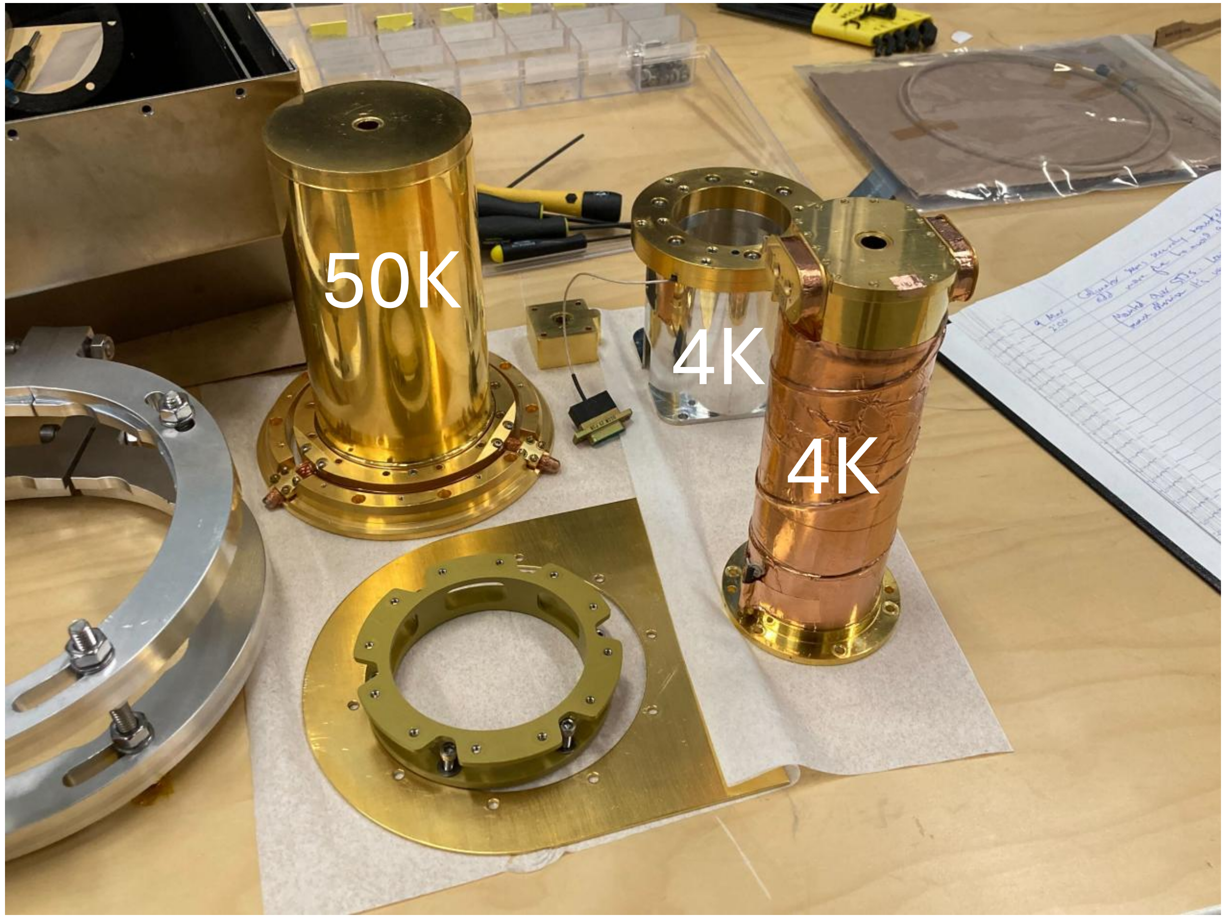
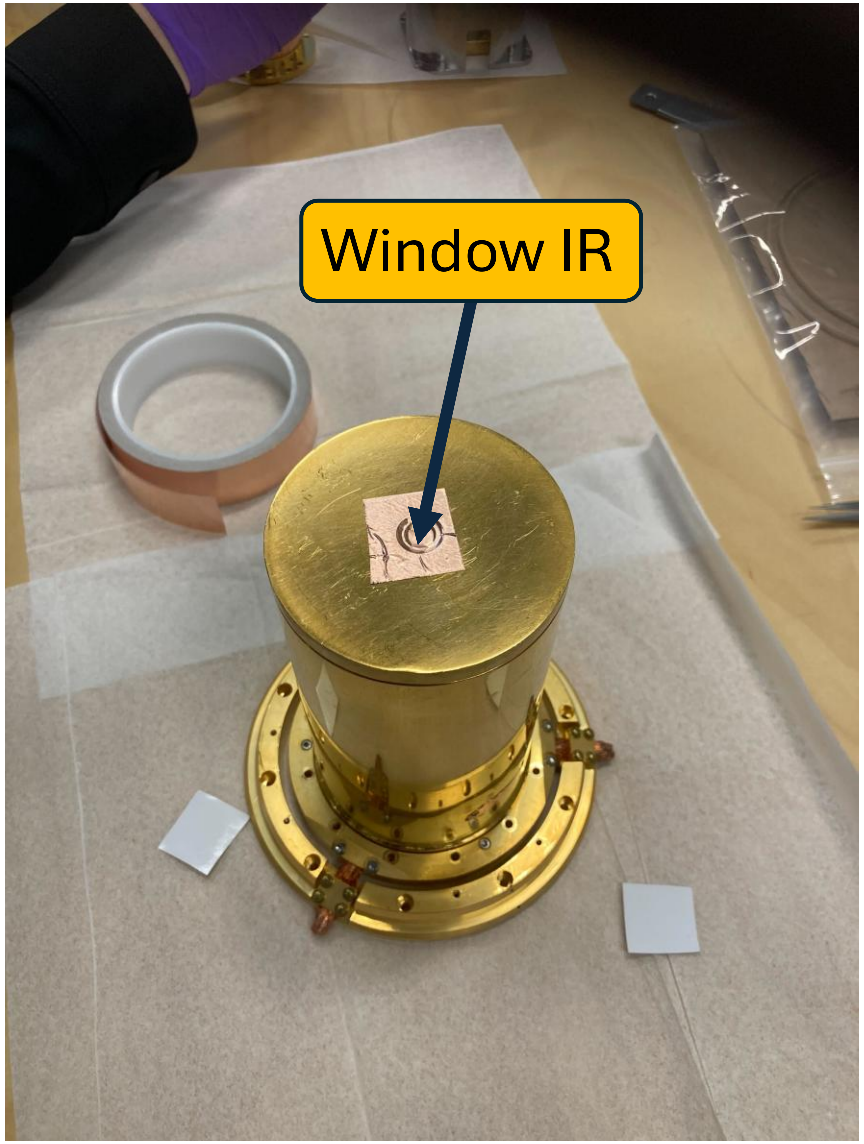
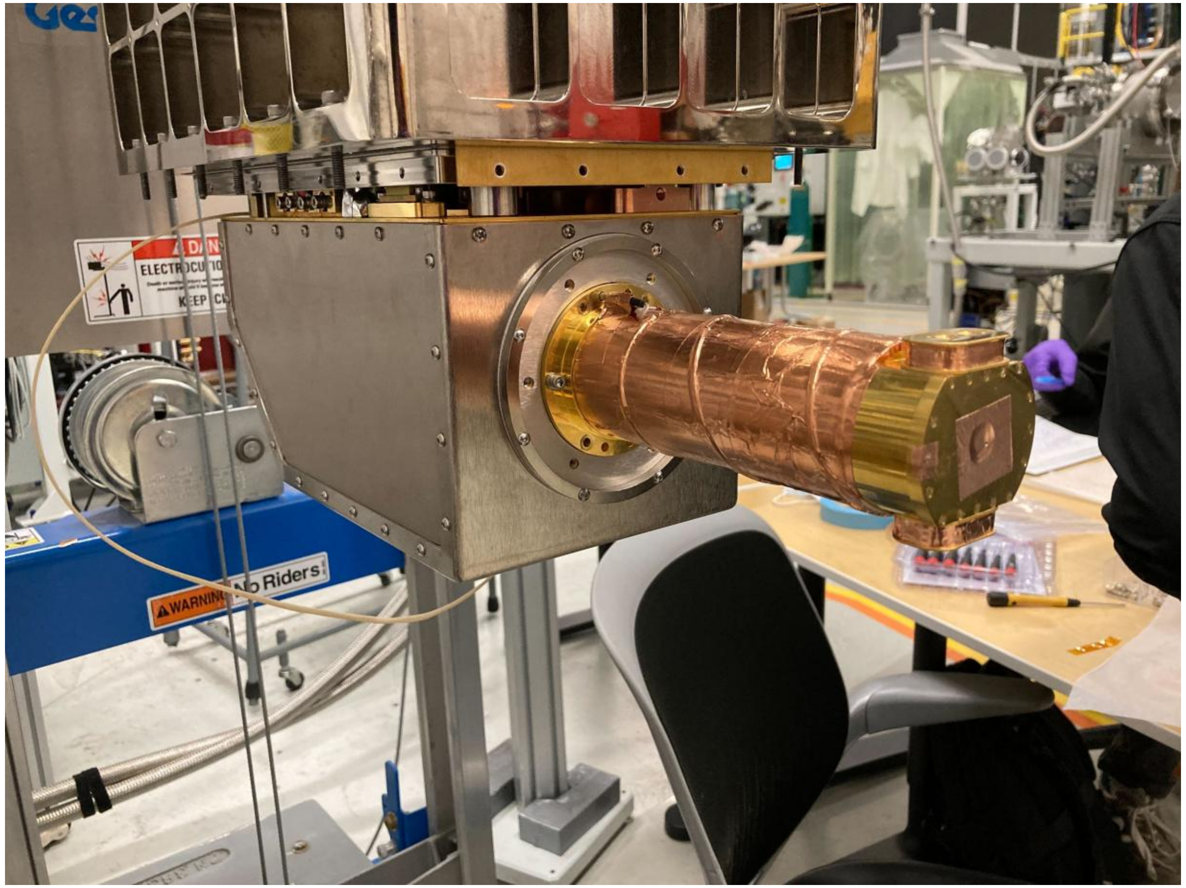




Assembling

With the 4K shield



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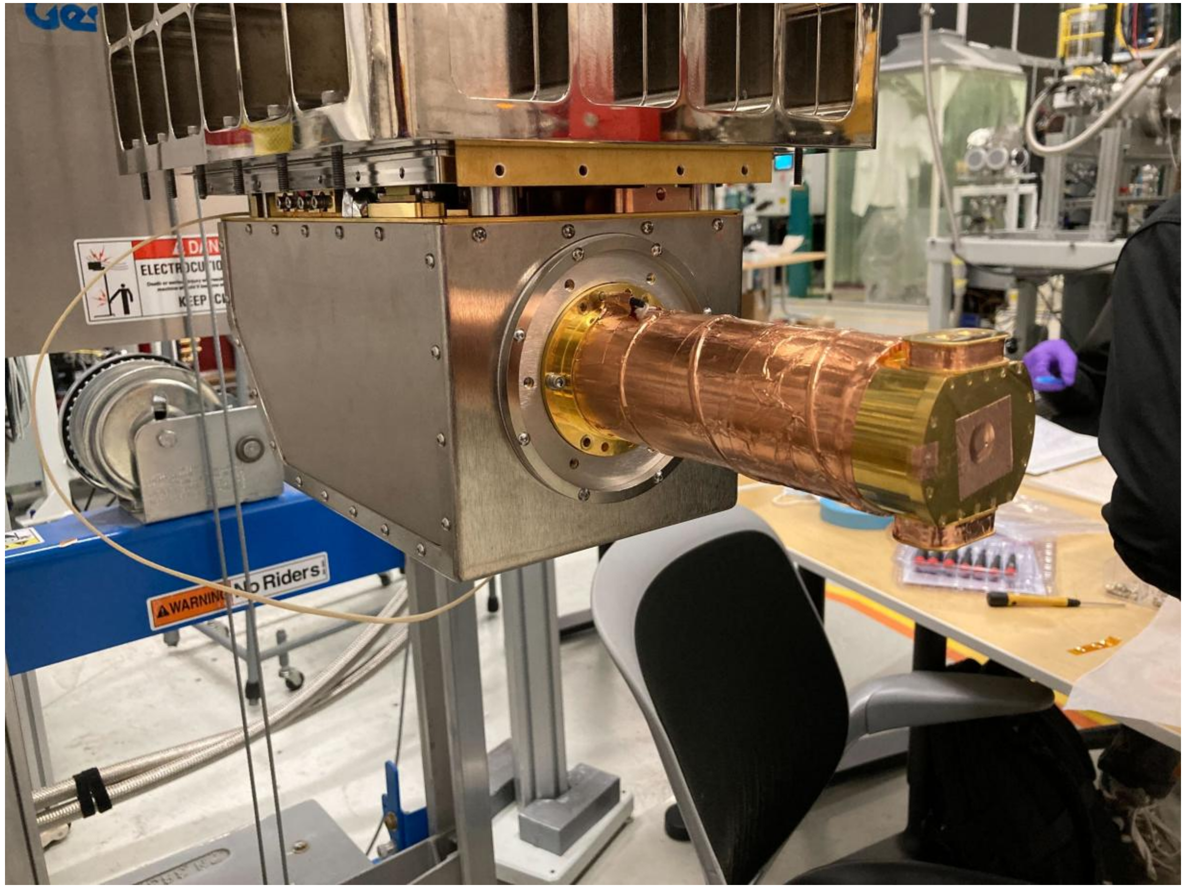
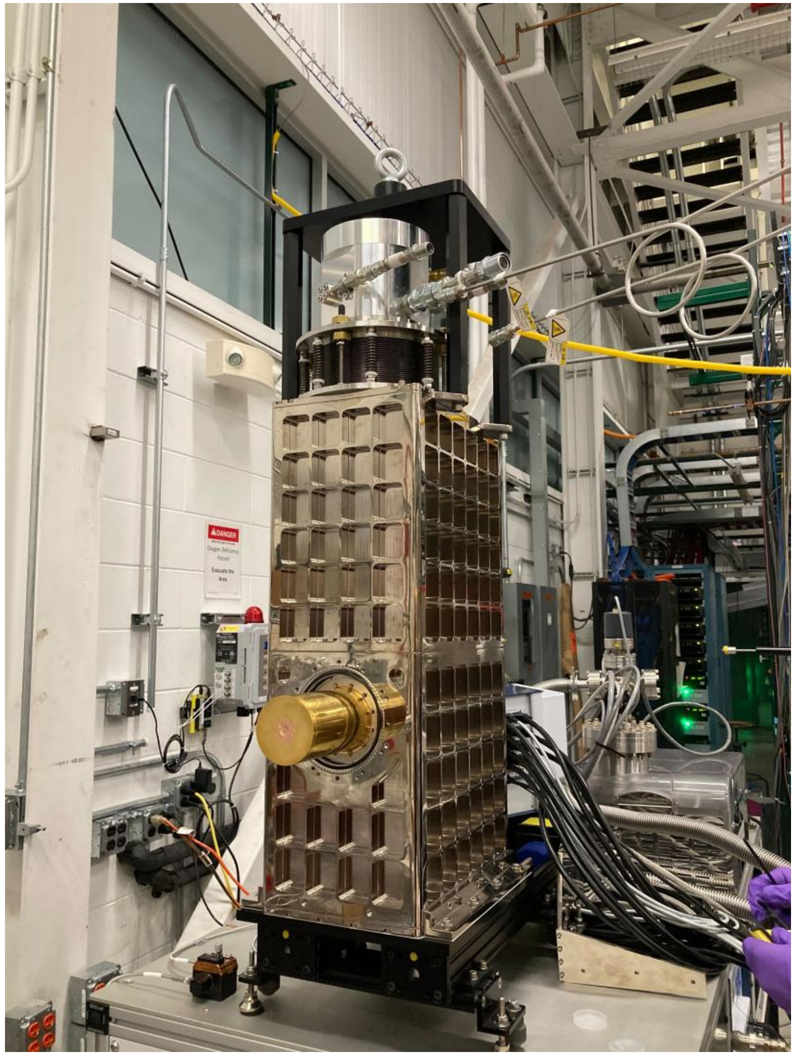
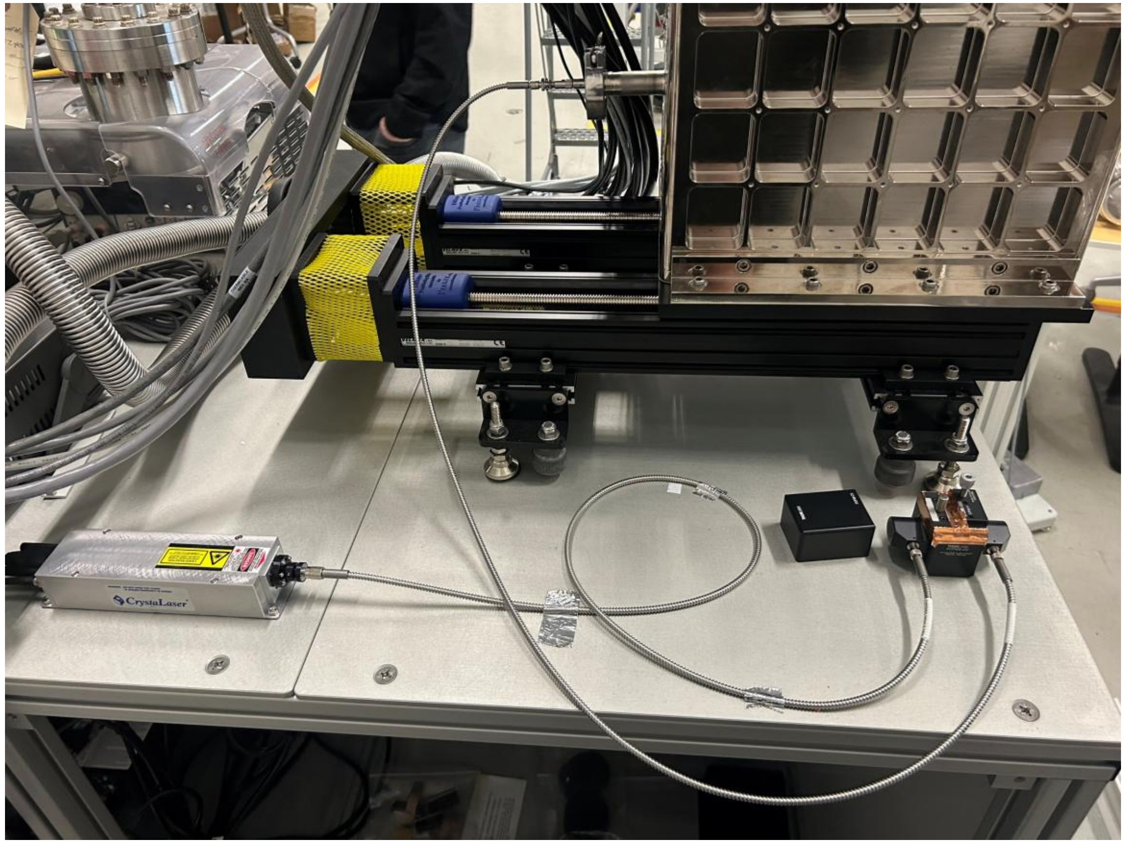


With the 50K shield



Laser calibration

262 nm laser – 4.7 eV



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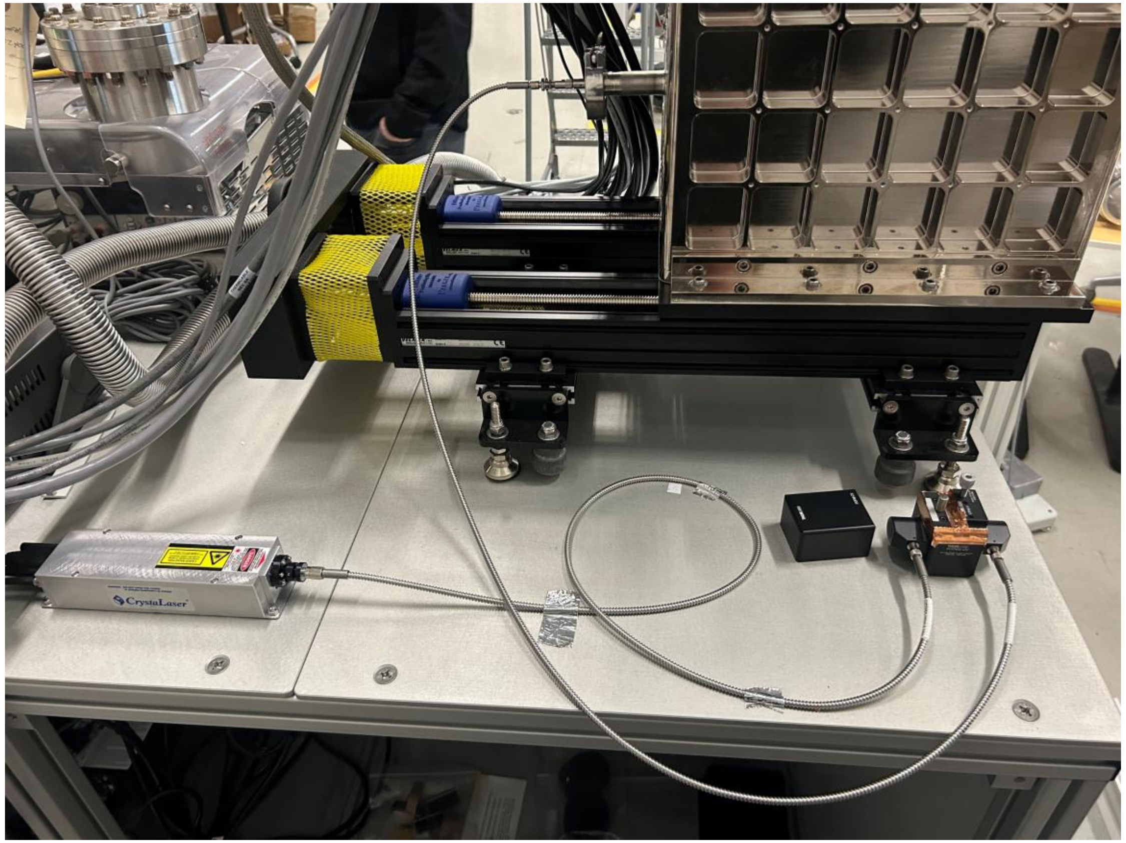
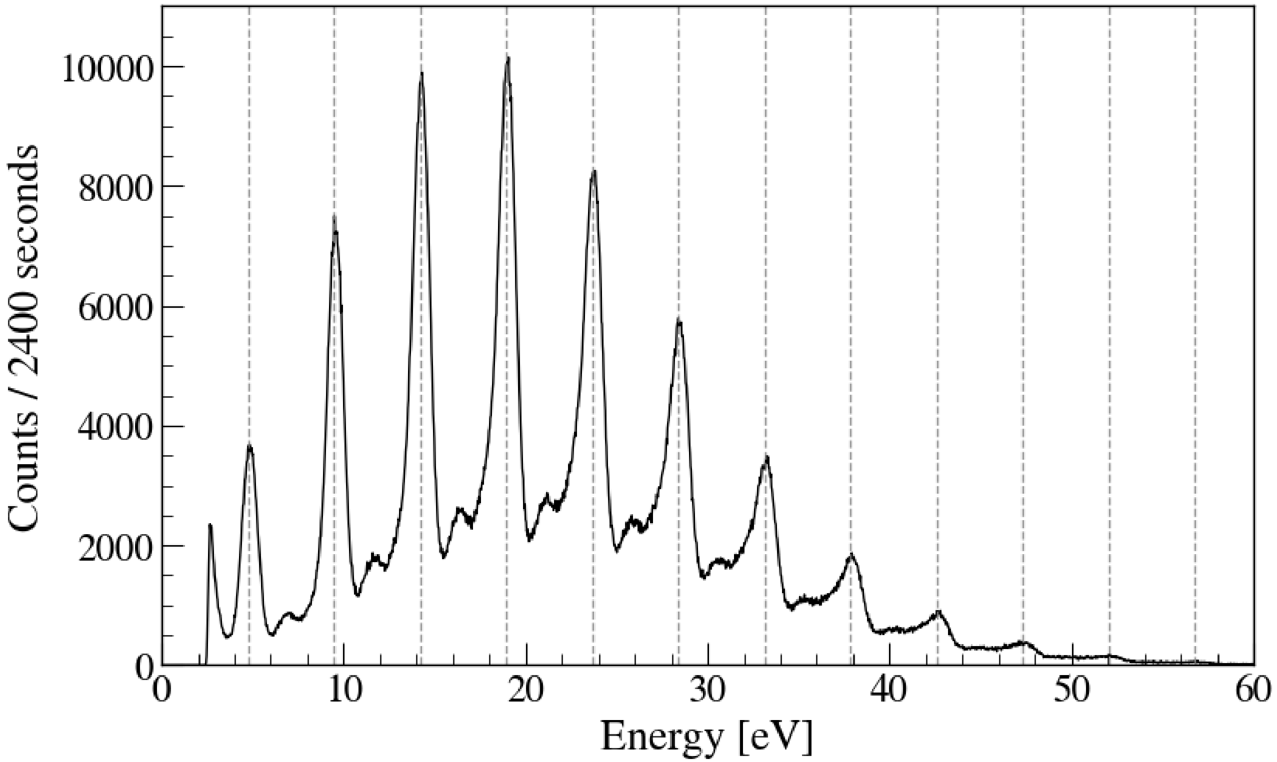


Spectrum for one pixel



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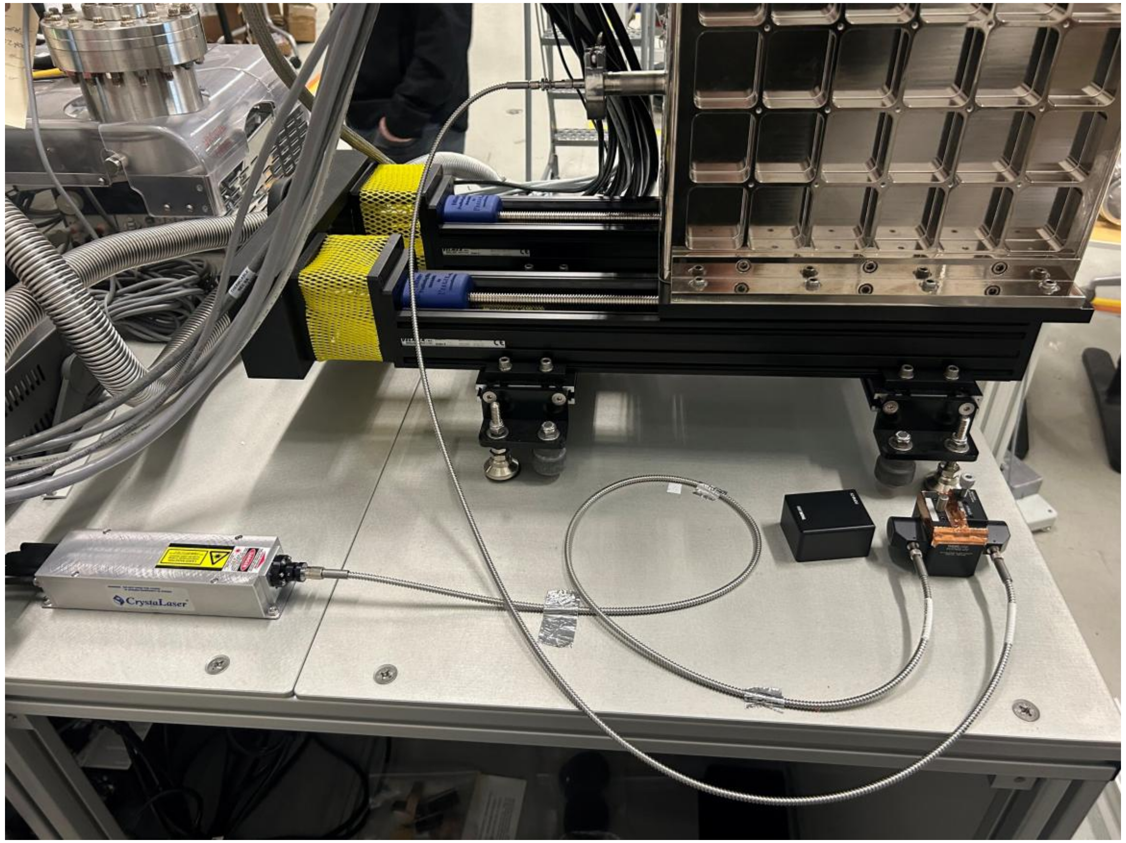

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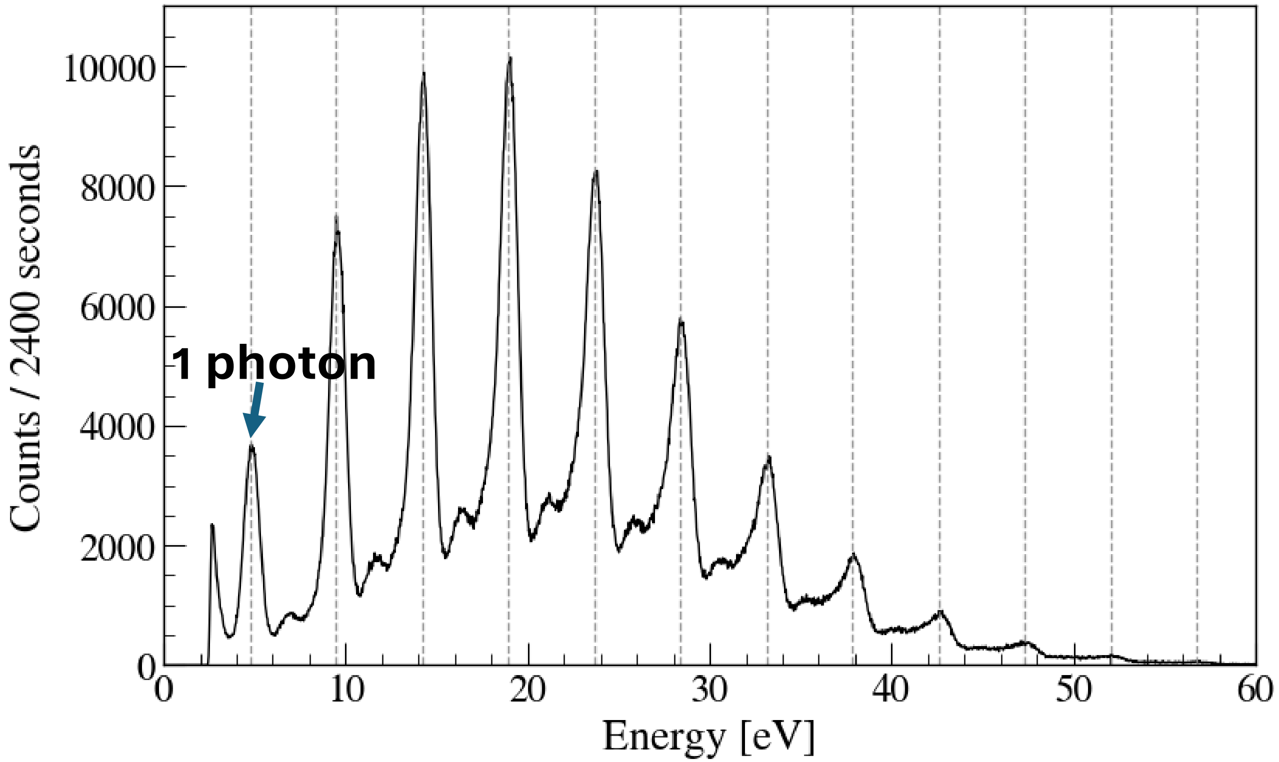

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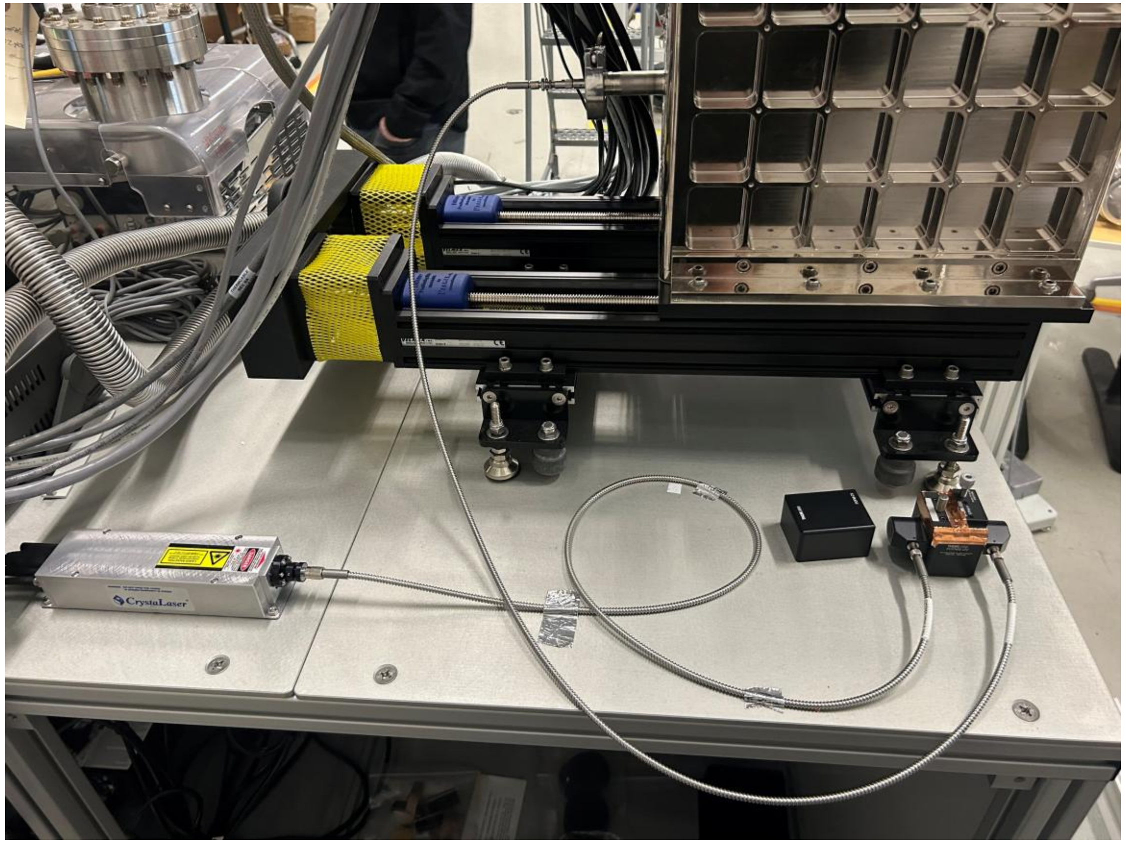

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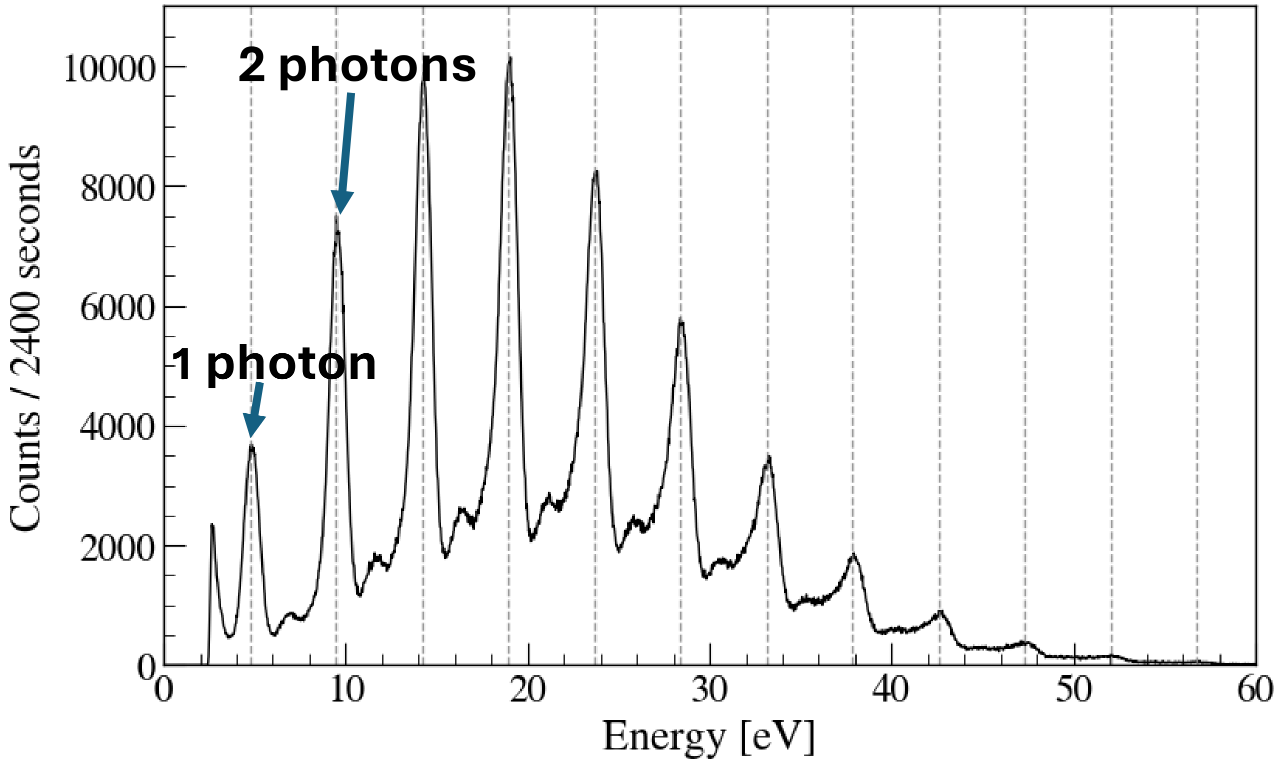

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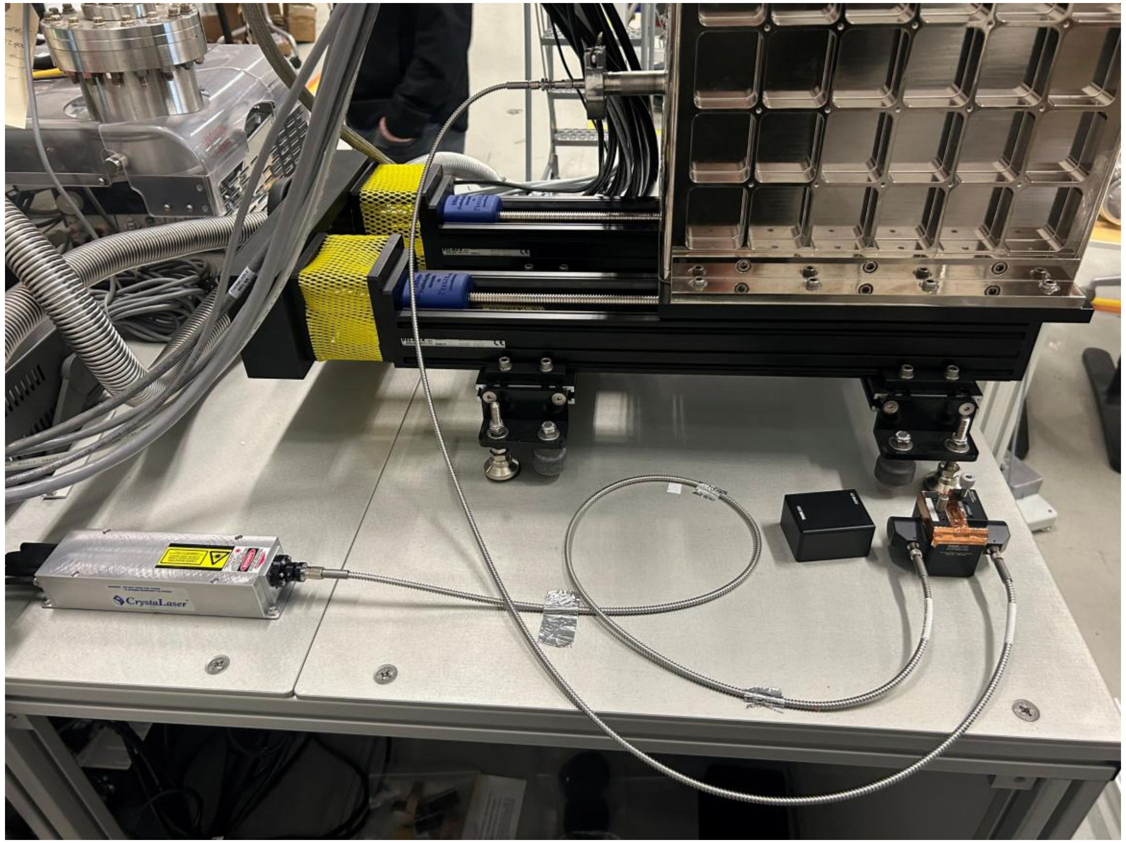

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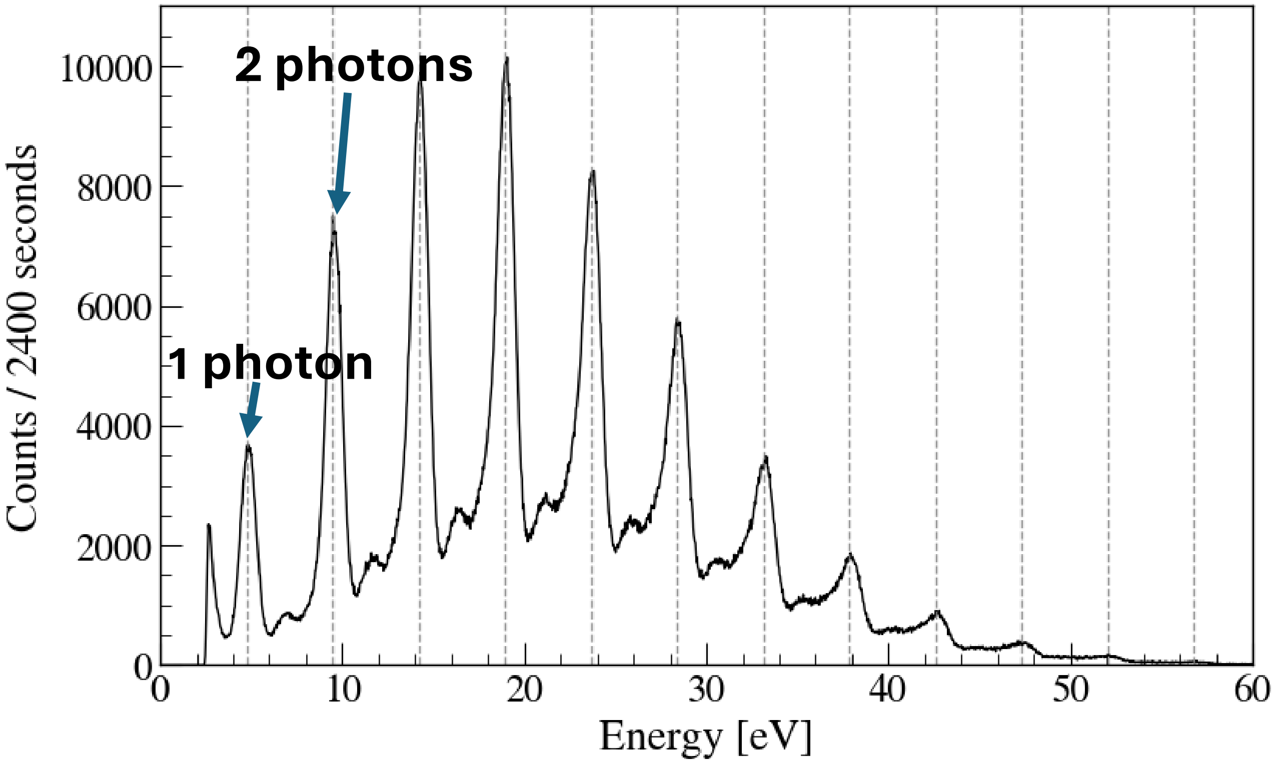

Best one : 1.25 eV FWHM !

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Conclusion and outlook

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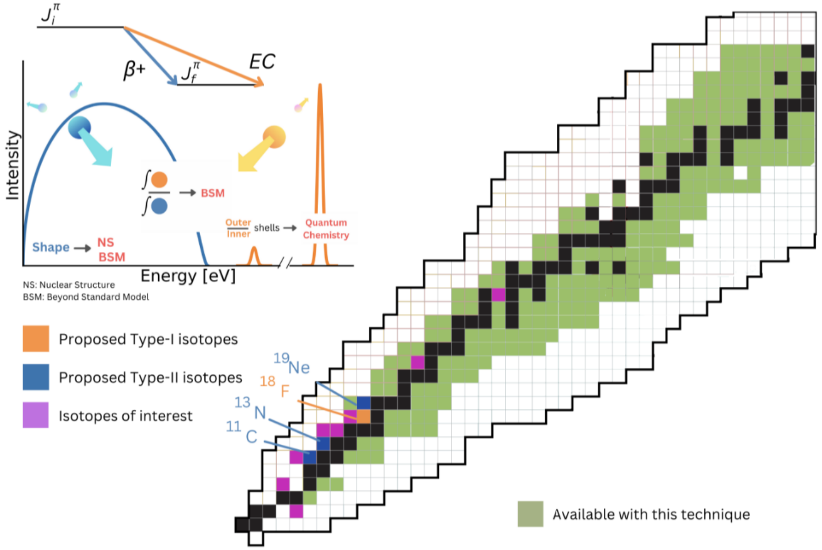
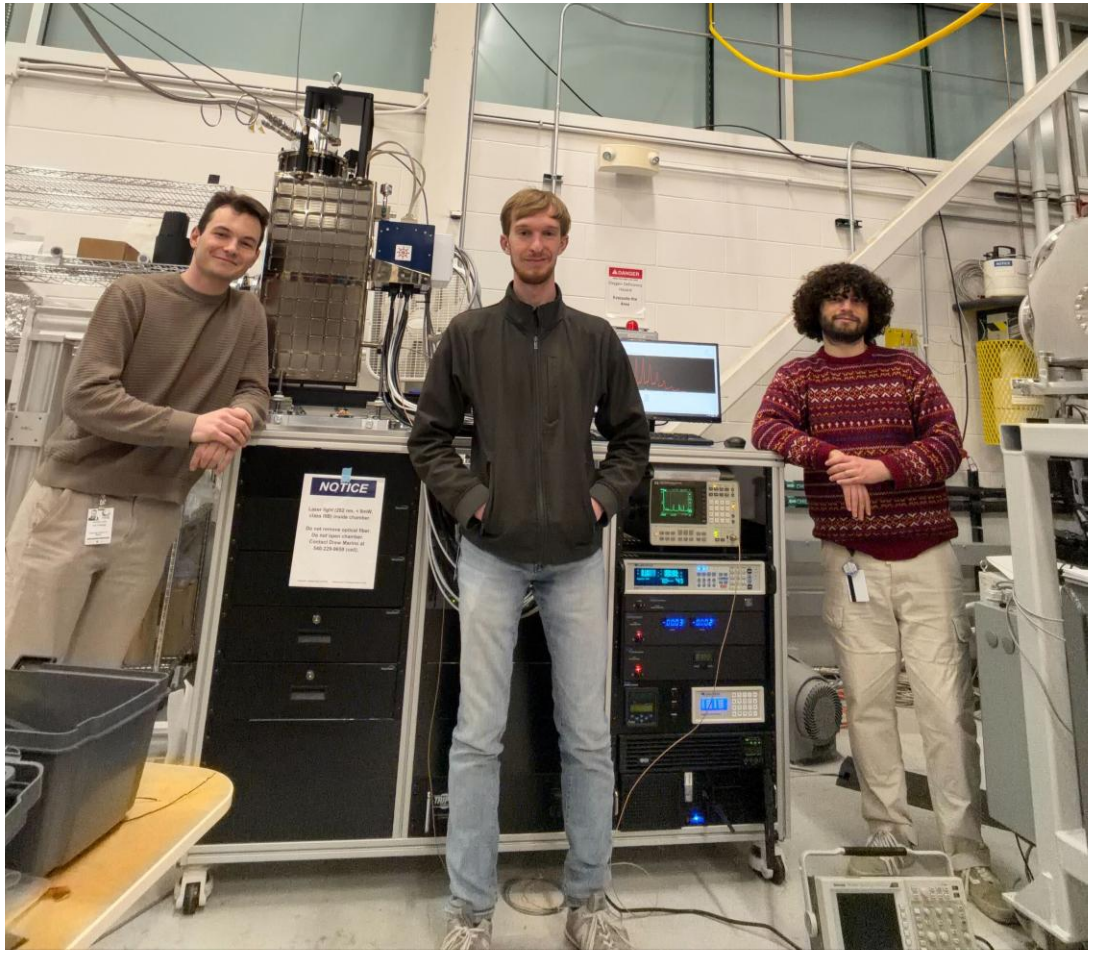
- Pave the way for ASGARD (at DESIR)



Collaboration



MINES
SCHOOL OF MINES 1874 COLORADO

LPC CAEN

Lawrence Livermore National Laboratory

FRIB

U.S. DEPARTMENT of ENERGY | Office of Science

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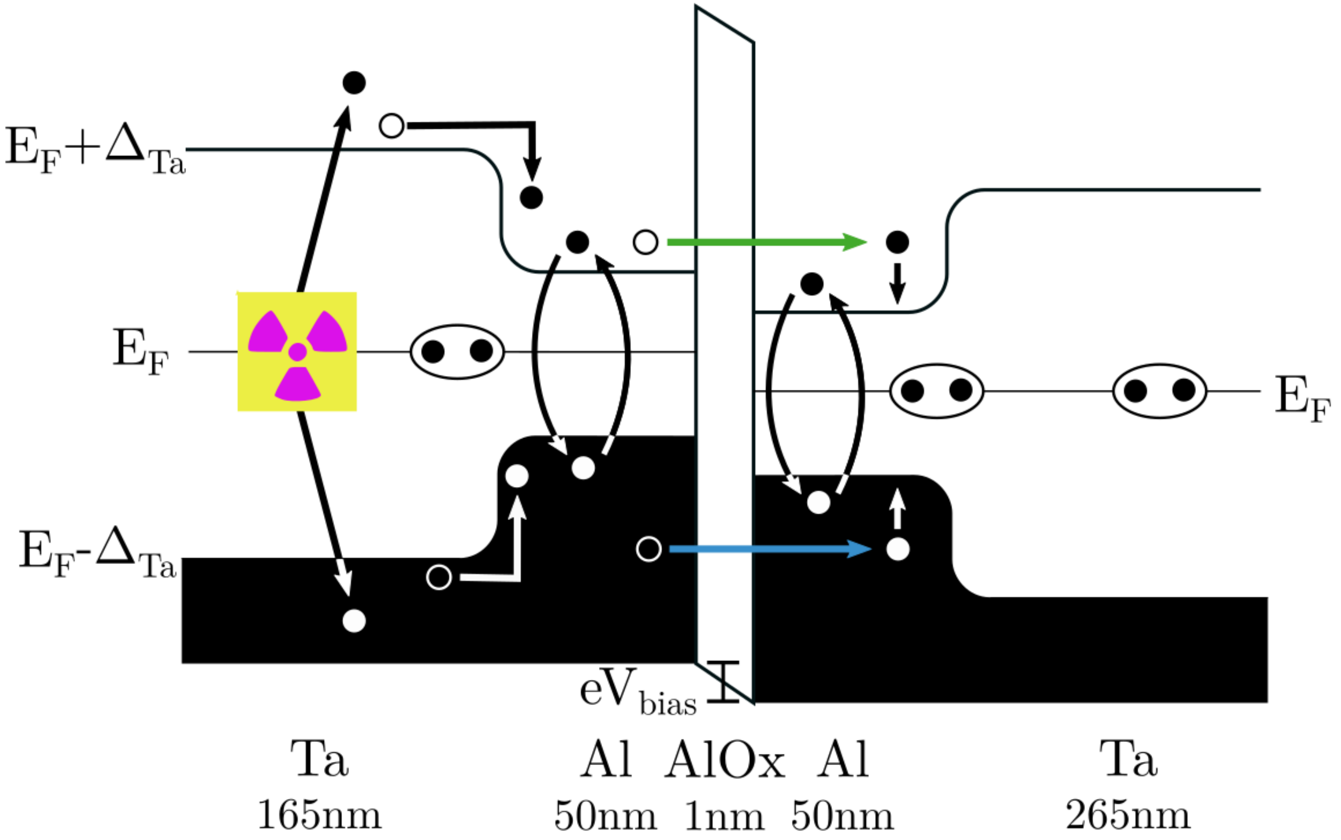
Thanks for listening !

Back-up

Superconducting Tunnel Junctions

- Five layers detector : absorber, trapping layer, biased insulator, trapping layer and final layer

- Onset of superconductivity : formation of Cooper pairs



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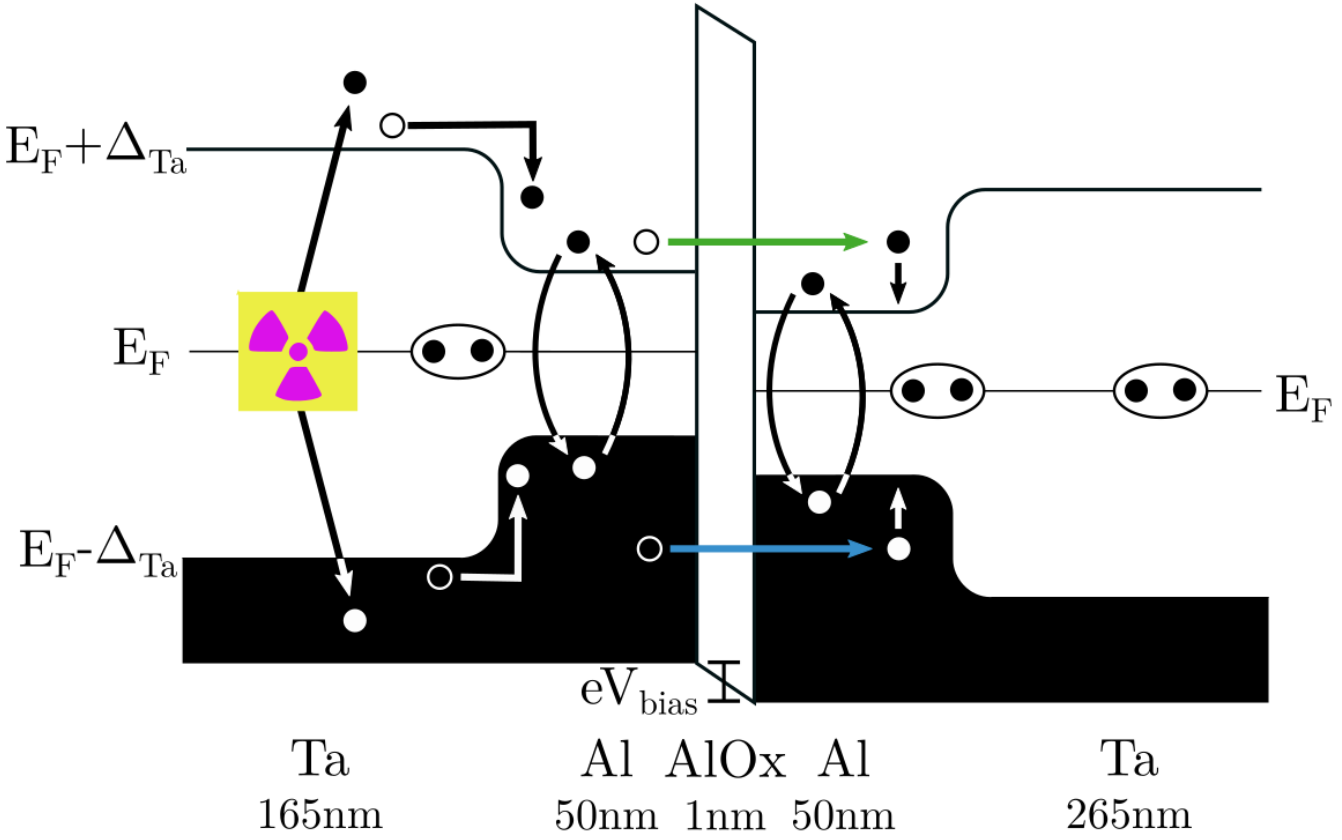

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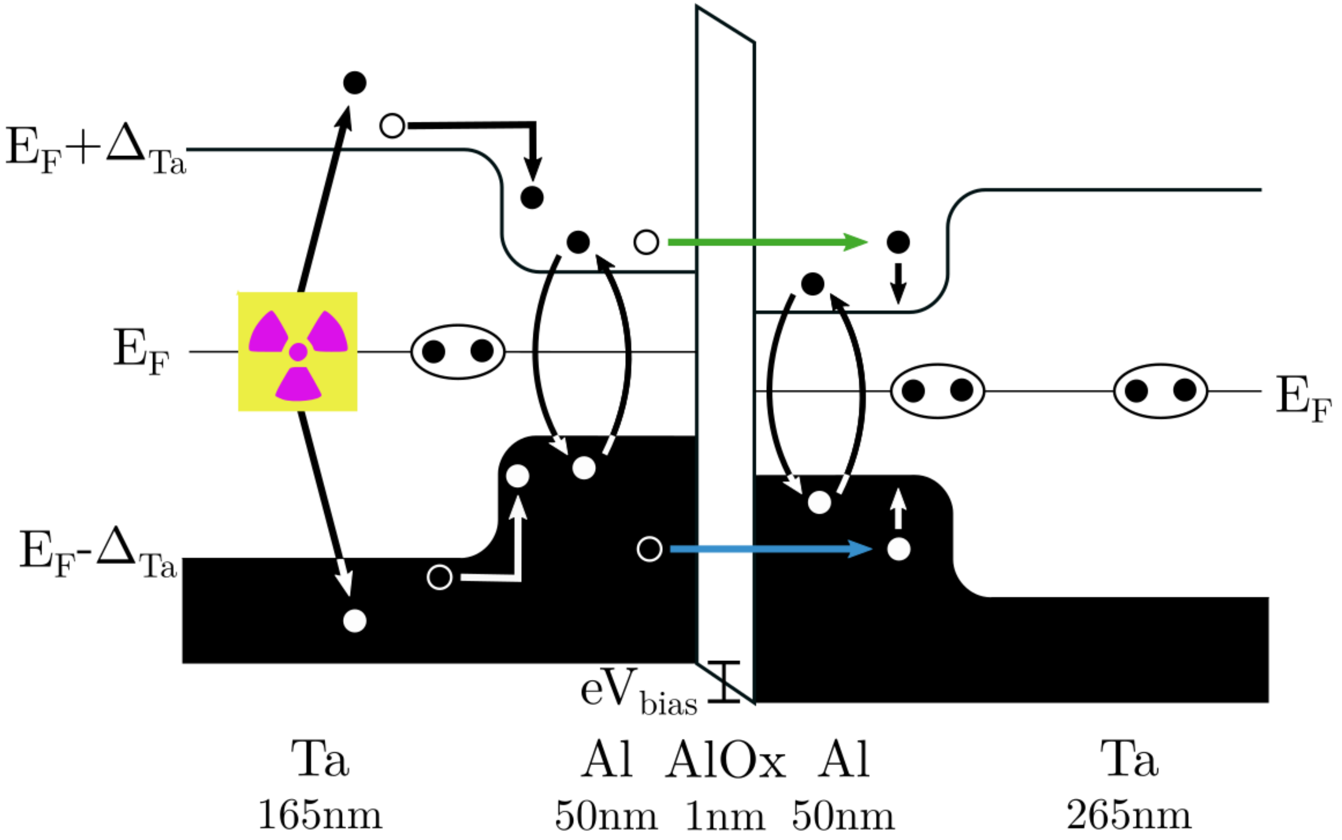
- **Measuring the tunneling current to recompose the momentum of the nucleus**



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About BeEST results

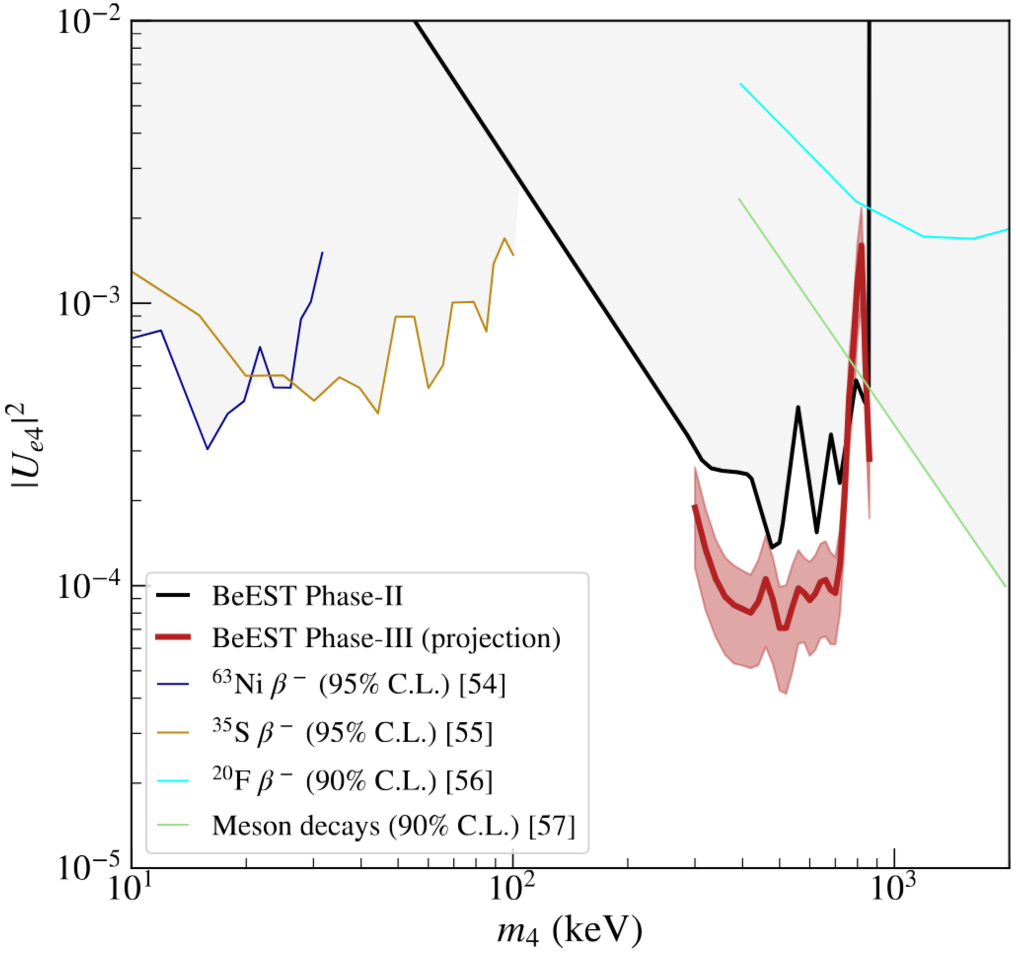


FIG. 25. Projected sensitivity for the BeEST Phase-III with 1σ uncertainty band. Only the statistical considerations were made. Previous limits are shown in gray shaded regions [54–58].

Stastical Uncertainties (from Andrew Marino's poster)

Species	δV_{ud} $\delta\rho$ only $[10^{-4}]$	δV_{ud} All uncertainties $[10^{-4}]$
n	5.7	6.6
^{3}H	95	95
^{11}C	78	8.2
^{13}N	6.9	8.7
^{15}O	5.2	8.5
^{17}F	3.8	5.8
^{19}Ne	2.6	4.1

Beta decay spectrum

$$\frac{d\Gamma}{dE_e d\Omega_\nu d\Omega_e} = \frac{G_F^2 F}{(2\pi)^5} p_e q^2 \left(1 + a_{\beta\nu}\frac{\mathbf{p_e}\cdot\mathbf{p}_\nu}{E_e E_\nu} + b\frac{m_e}{E_e} + \ldots\right)$$

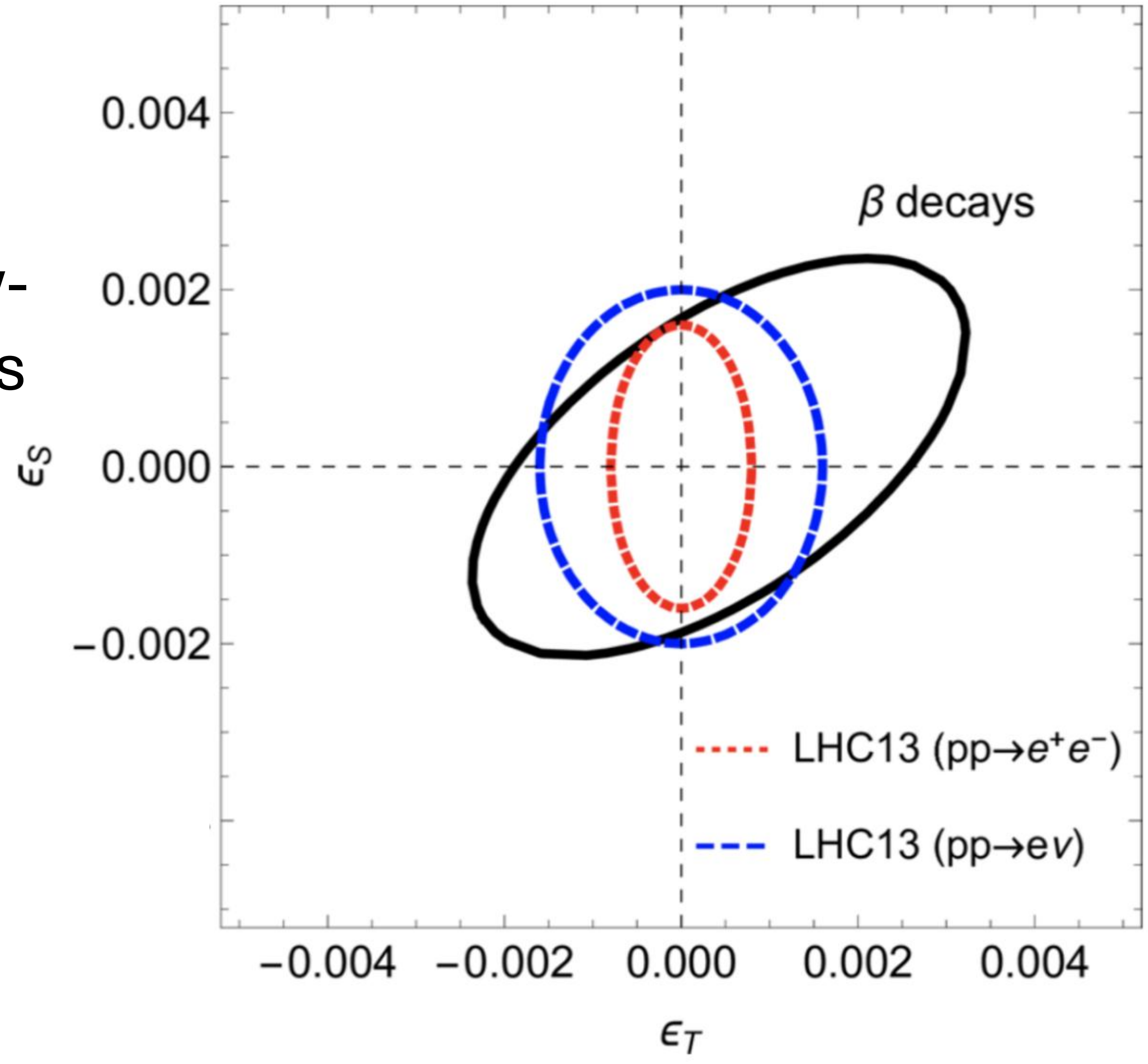
Integrate the angles

$$\frac{d\Gamma}{dE_f} \simeq$$

$$\frac{G_F^2}{4\pi^3} E_f \{ I^{110} + bI^{010} + \frac{a}{2}\left(p_f^2 I^{000} - I^{002} - I^{020}\right)$$
$$+ \alpha Z \left(I^{21-1} + \frac{a}{2}\left(p_f^2 I^{10-1} - I^{101} - I^{12-1}\right)\right)\}$$

Beta decay to probe BSM physics

- High precision measurements at low-energies → explore TeV-scale physics
- **In the search of exotic currents for the Standard Model, beta decay is competitive with LHC**



Extension of SM Lagrangian (V.Dumenil)

$$\mathcal{L}_{eff} = -\frac{G_F \tilde{V}_{ud}}{\sqrt{2}} \Big\{ \bar{e}\gamma_\mu \nu_L \cdot \bar{u}\gamma^\mu [C_V - (C_A - 2\epsilon_R)\gamma^5] d + \epsilon_S \bar{e}\nu_L \cdot \bar{u}d$$
$$-\epsilon_P \bar{e}\nu_L \cdot \bar{u}\gamma^5 d + \epsilon_T \bar{e}\sigma_{\mu\nu}\nu_L \cdot \bar{u}\sigma^{\mu\nu}(1-\gamma^5)d \Big\}$$

ϵ_i correspond to Right, Scalar, Pseudo-scalar and Tensor contribution respectively

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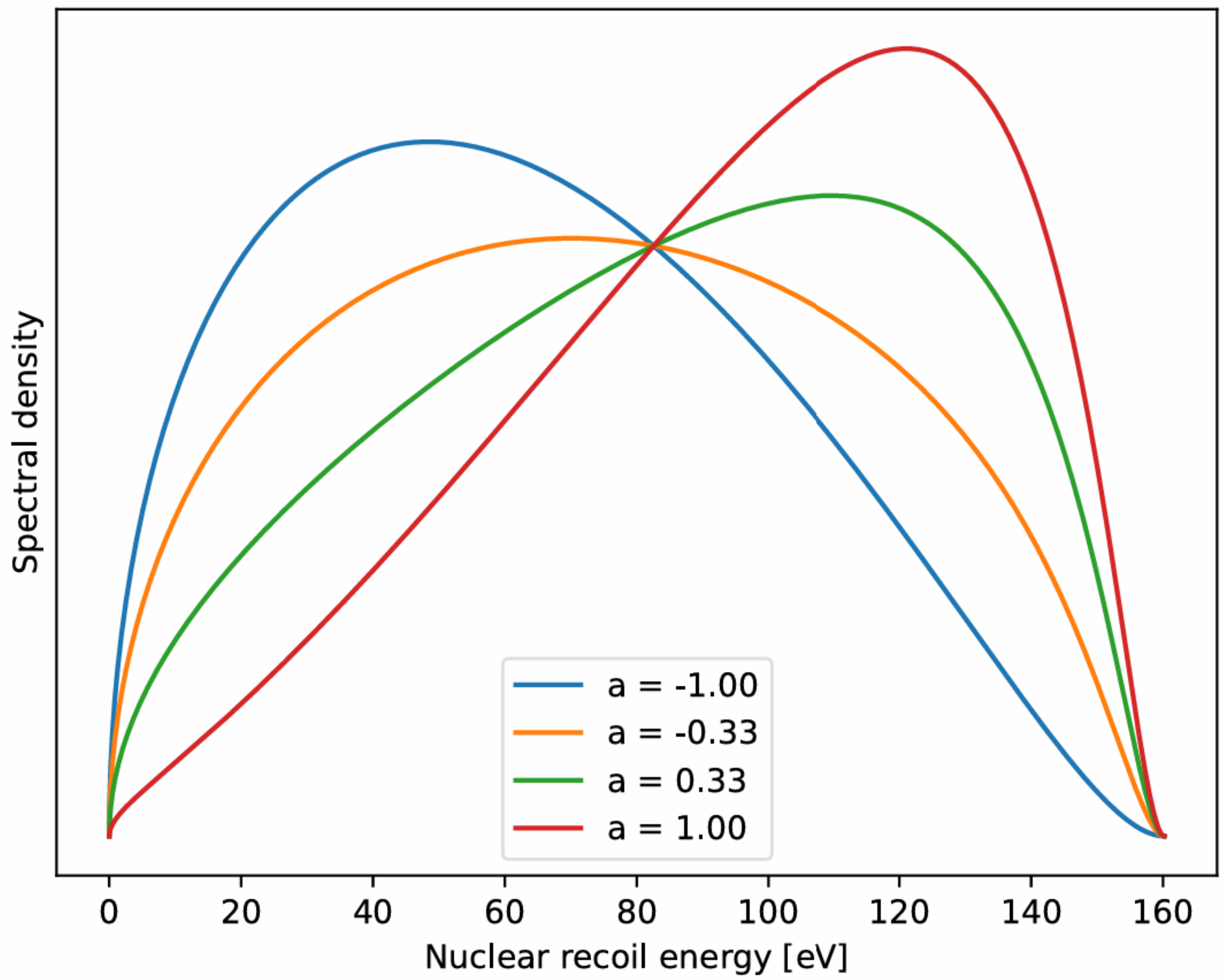
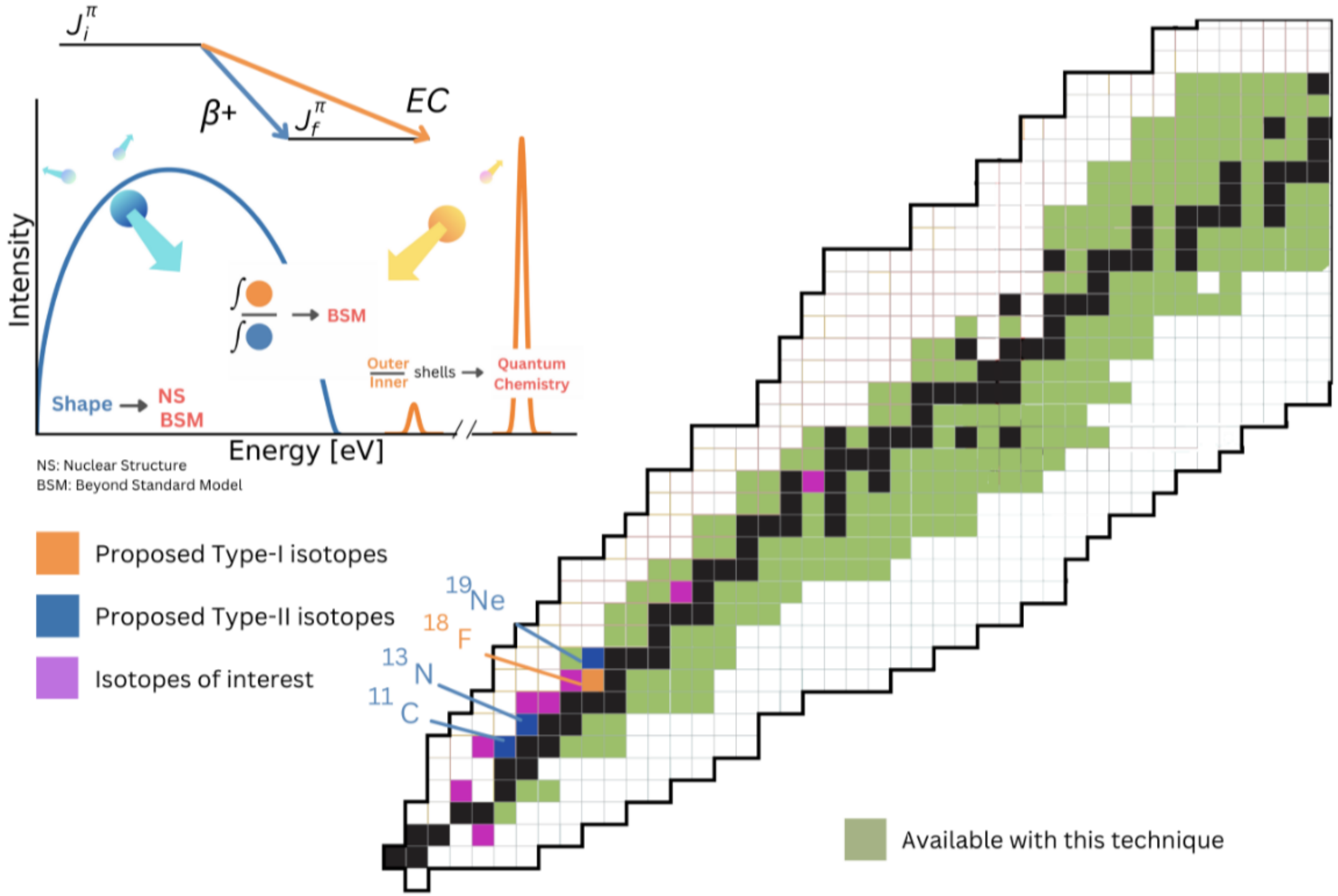
Effects on the recoil spectrum



ASGARD

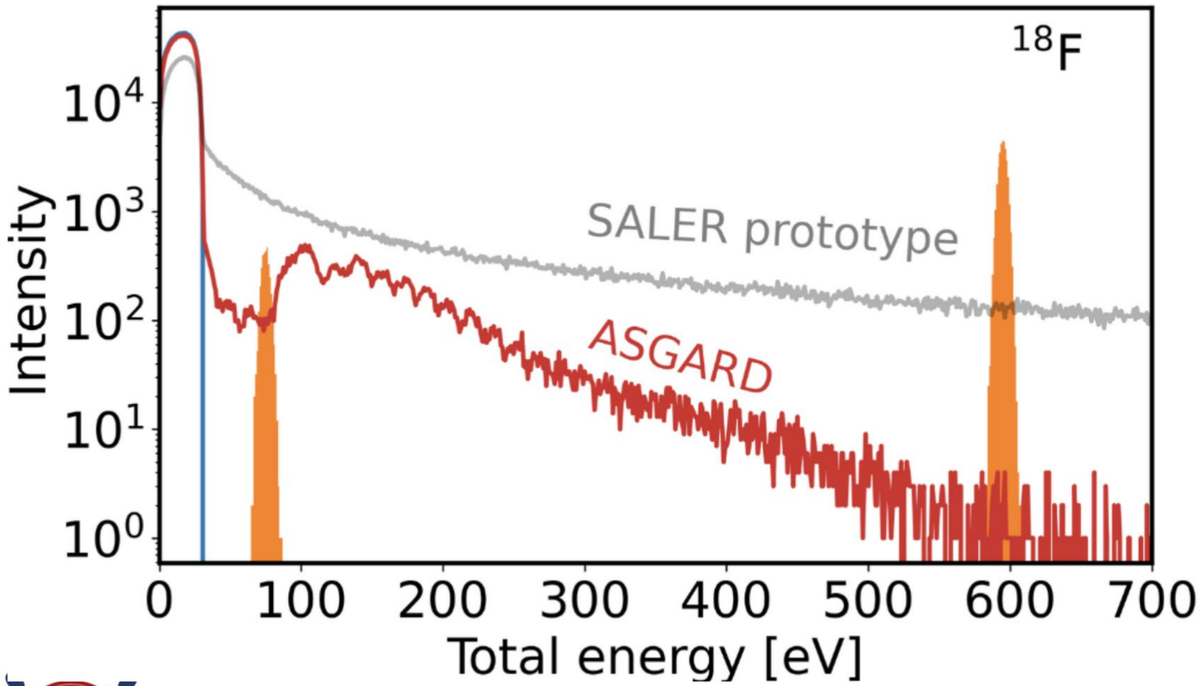


J_i^π
$\beta+$
J_f^π
EC
Intensity
BSM
Outer
Inner
shells
Quantum
Chemistry
Shape
NS
BSM
Energy [eV]
NS: Nuclear Structure
BSM: Beyond Standard Model
Proposed Type-I isotopes
Proposed Type-II isotopes
Isotopes of interest
19 Ne
18 F
13 N
11 C
Available with this technique

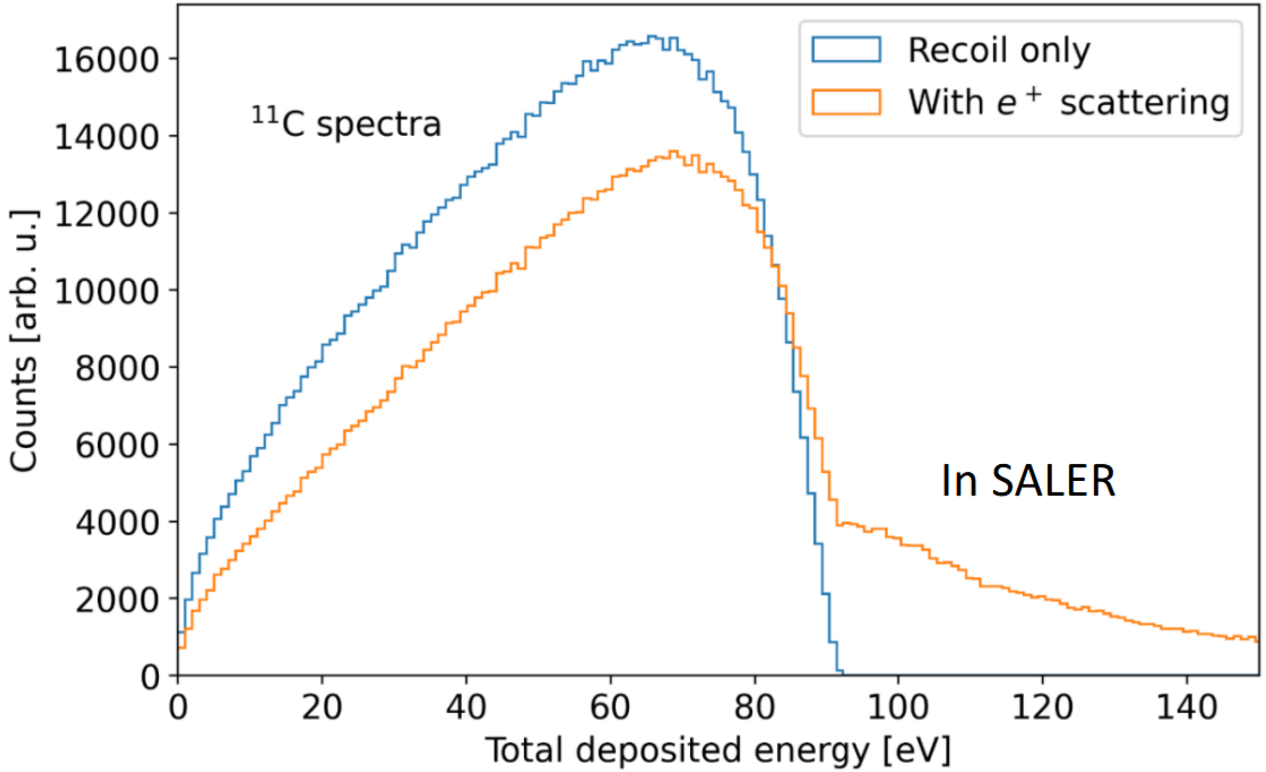
What about fierz interference term ?

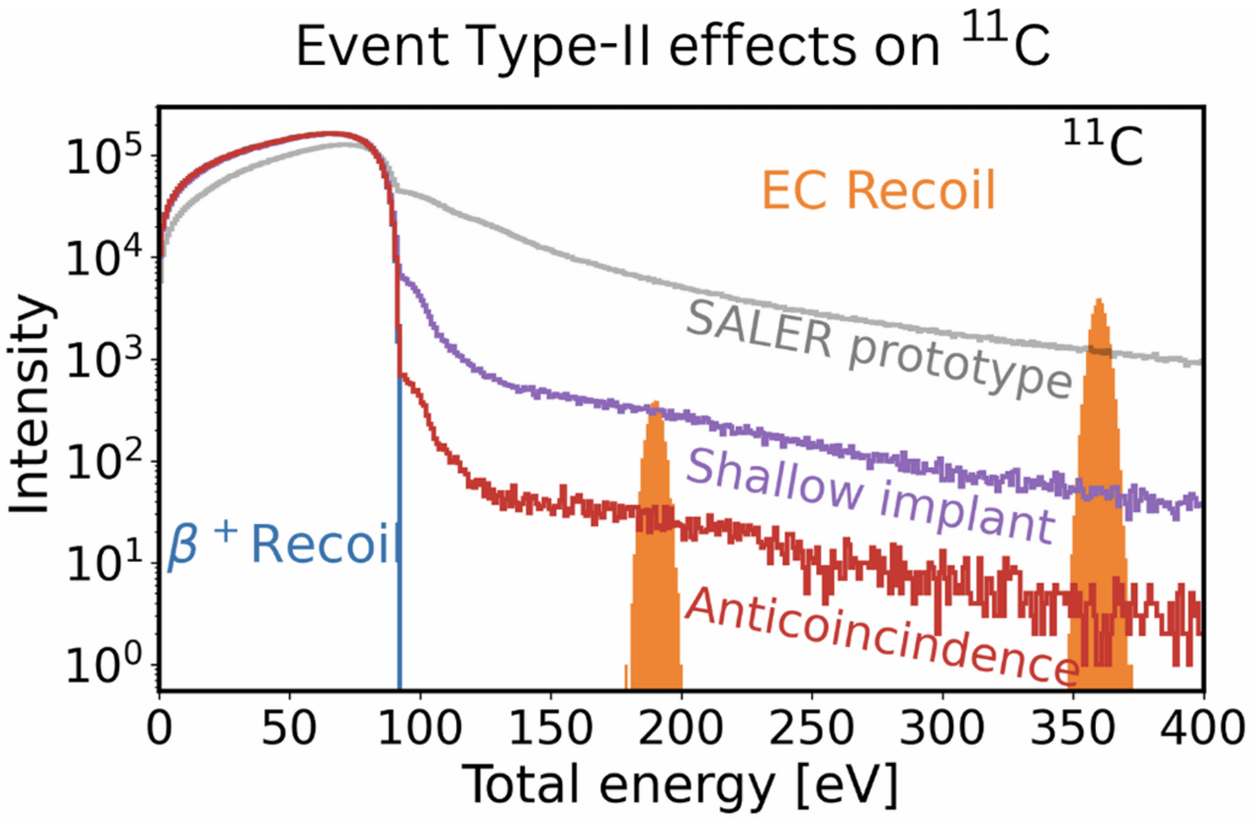
$$\frac{\lambda_{EC}}{\lambda_{\beta+}} = \sum_{x=K,L,\ldots} \frac{f_x}{f_{\beta+}} \left[\frac{1 + b_F m_e / E_x}{1 - b_F m_e / \overline{E}} \right] (1 + 0.001 \times \delta_{\text{theory}})$$

Event Type-III effects on ^{18}F

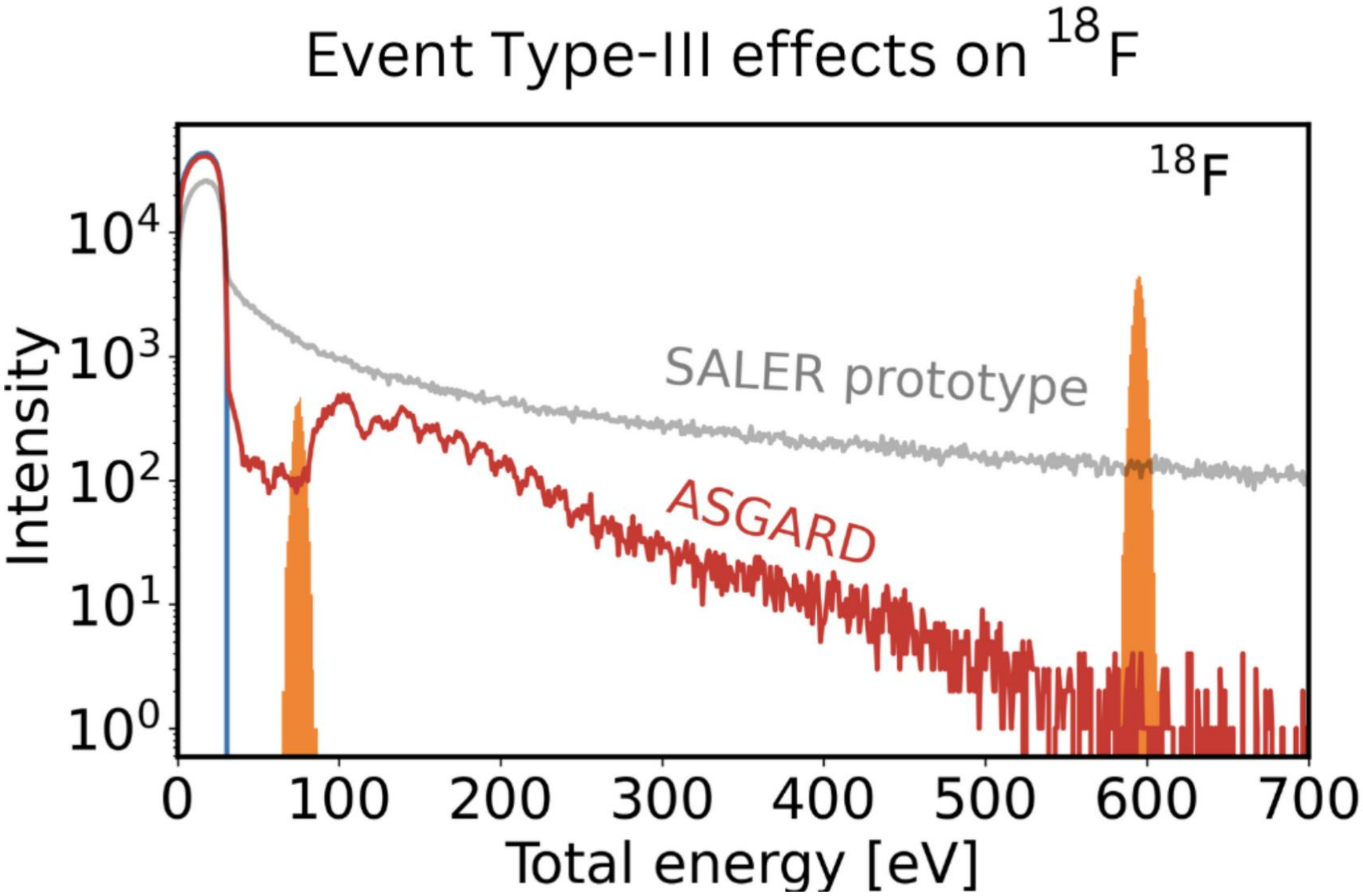


Material effects

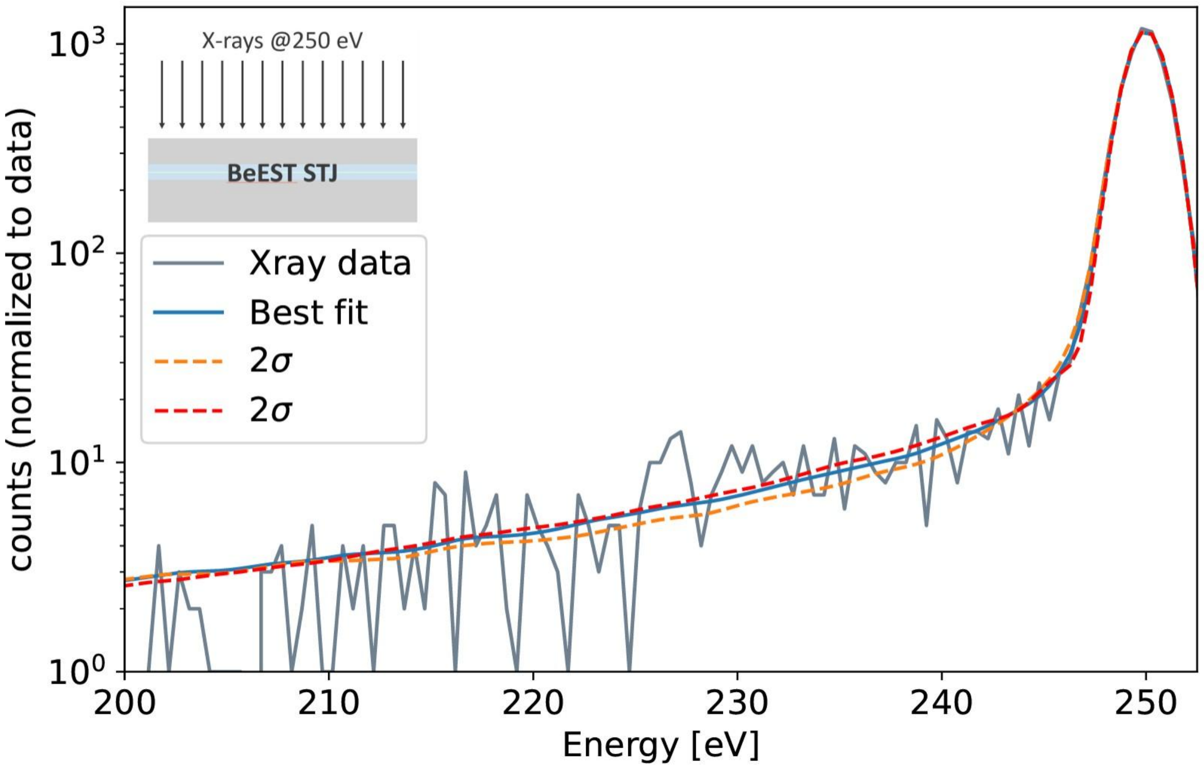


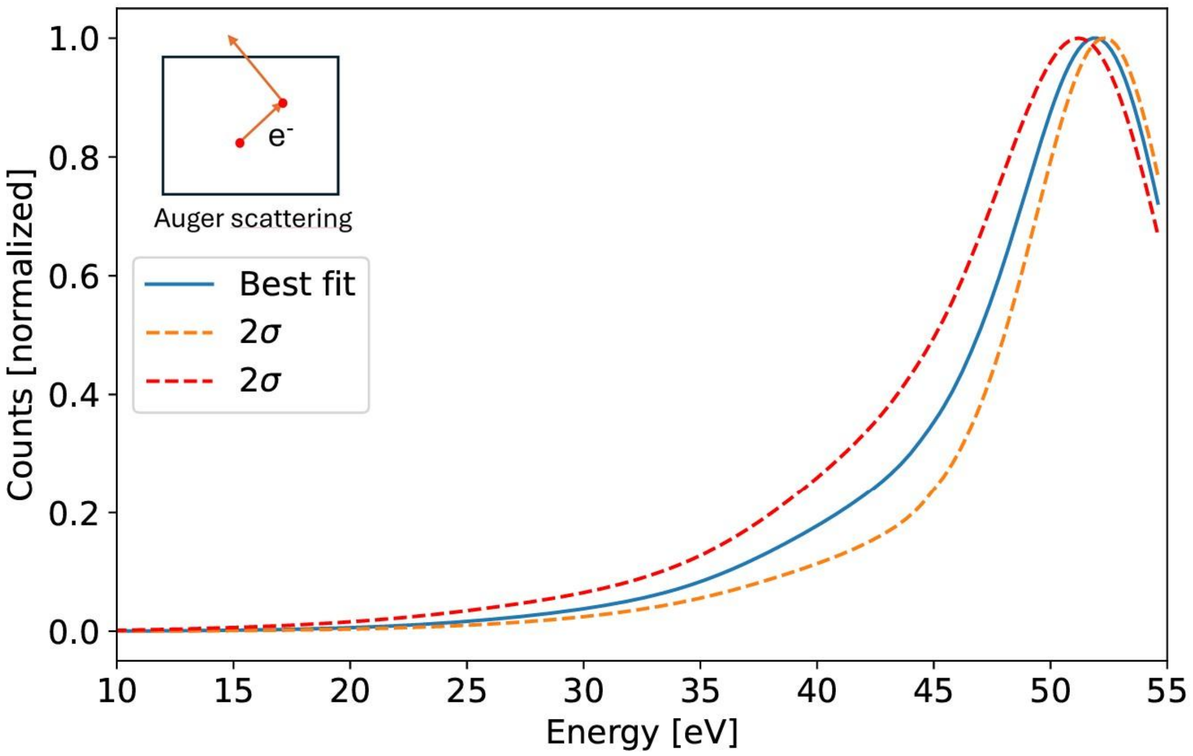


The importance of background

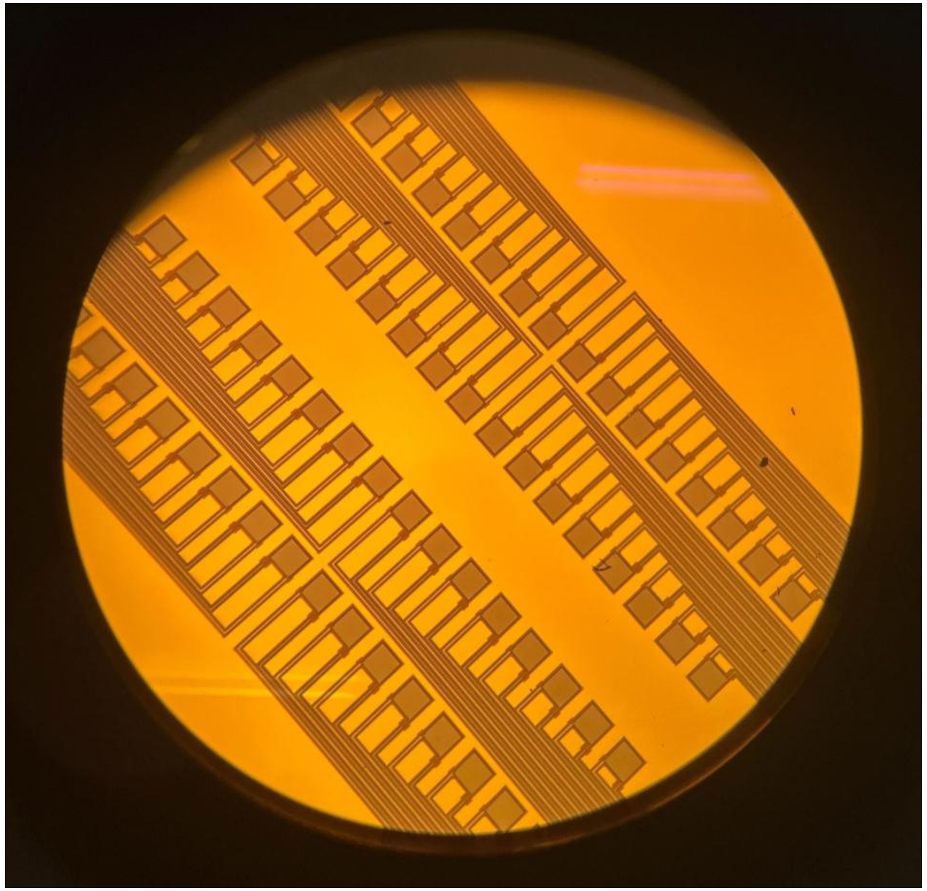


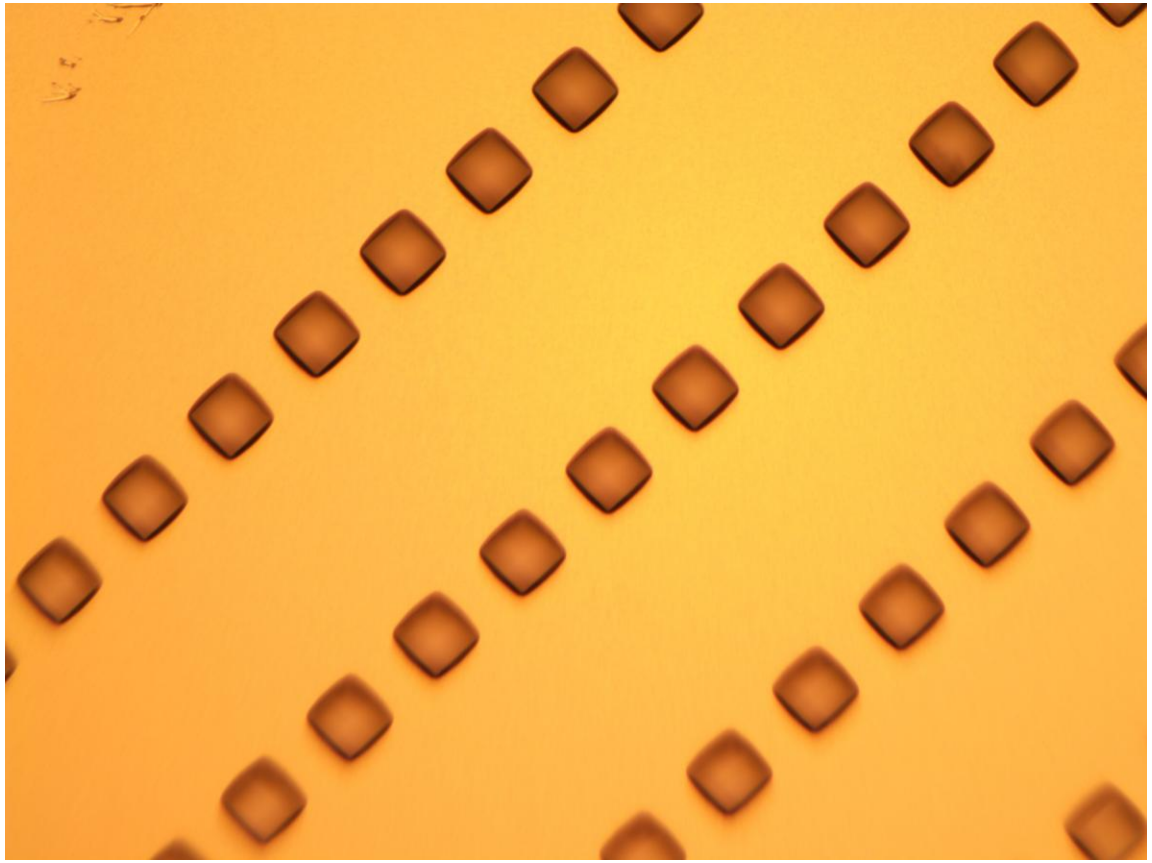
Elastic cross-section studies



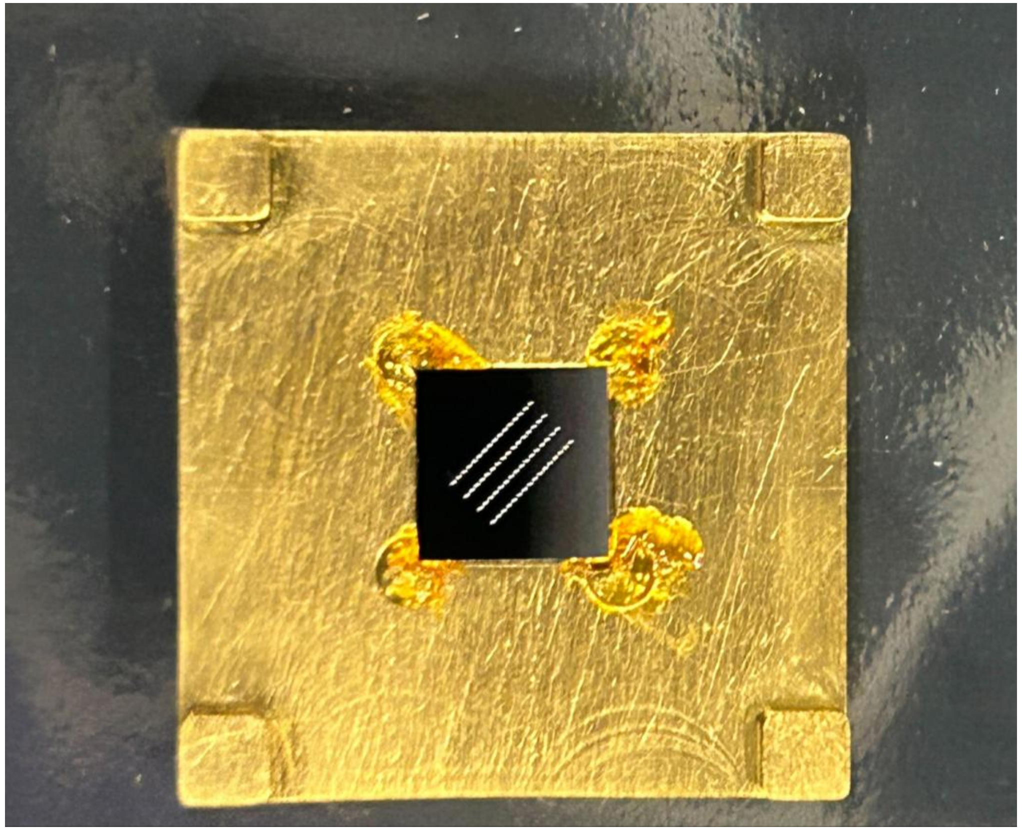


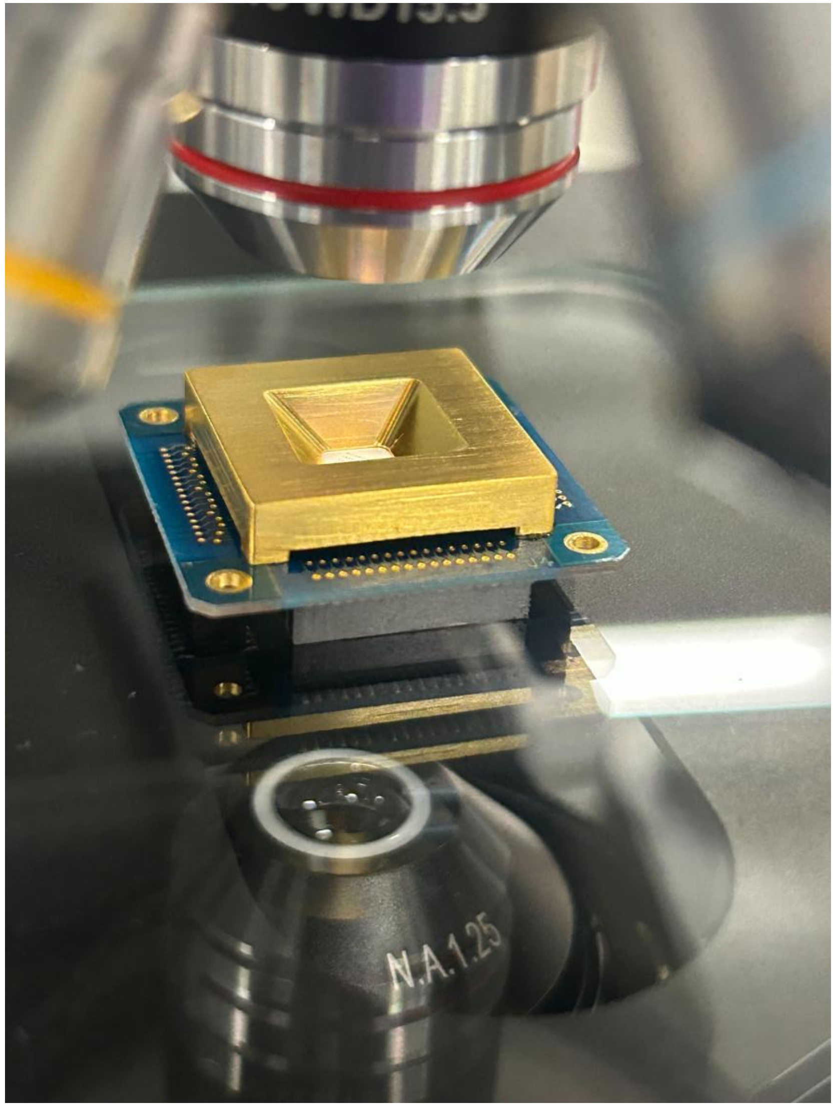
STJs for SALER



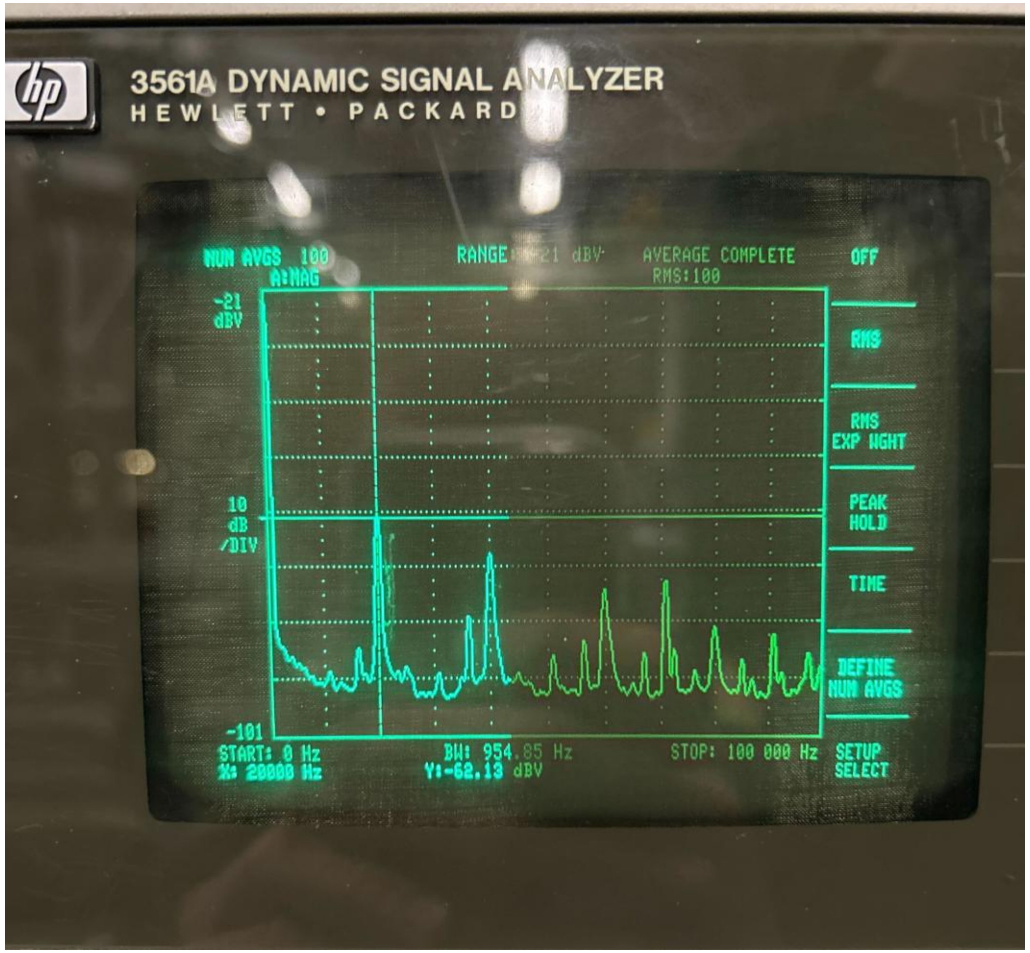


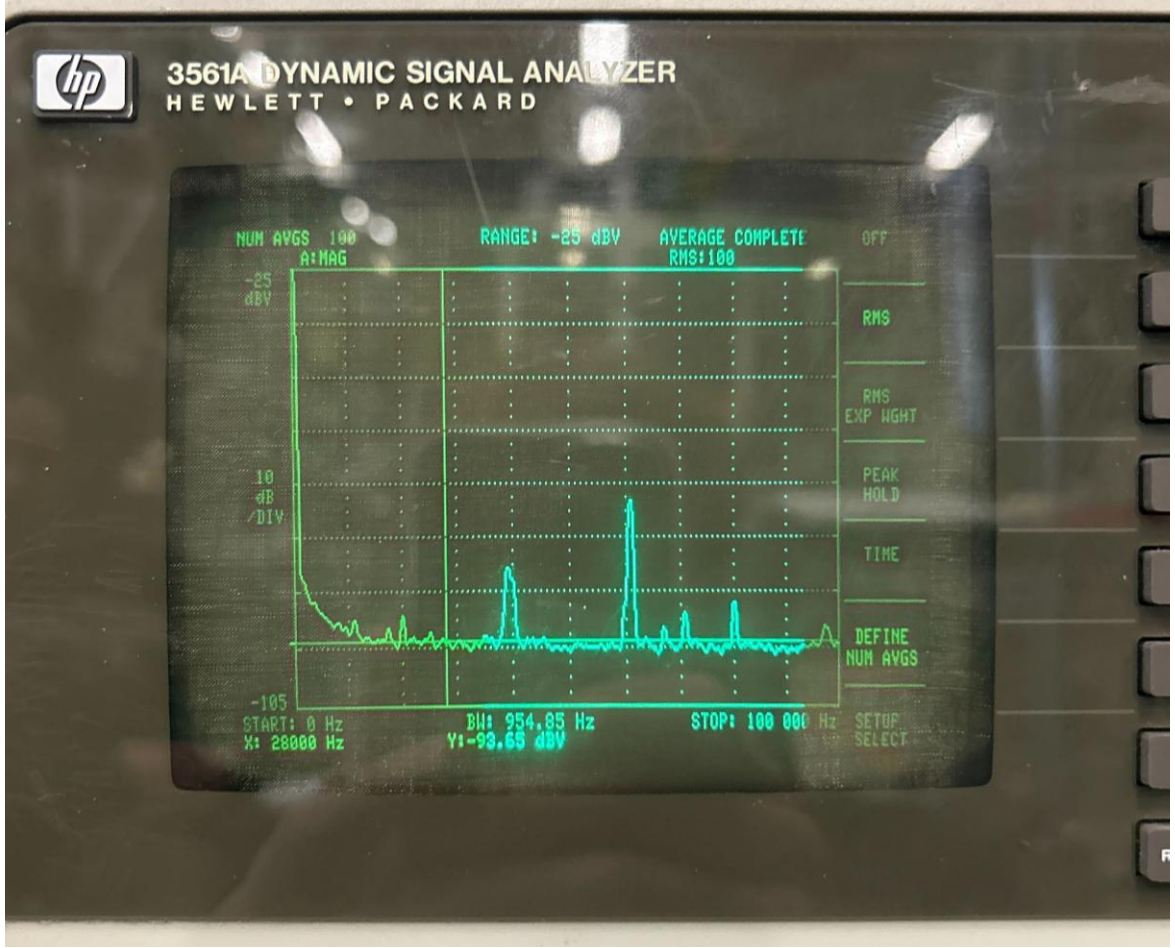
STJs for SALER





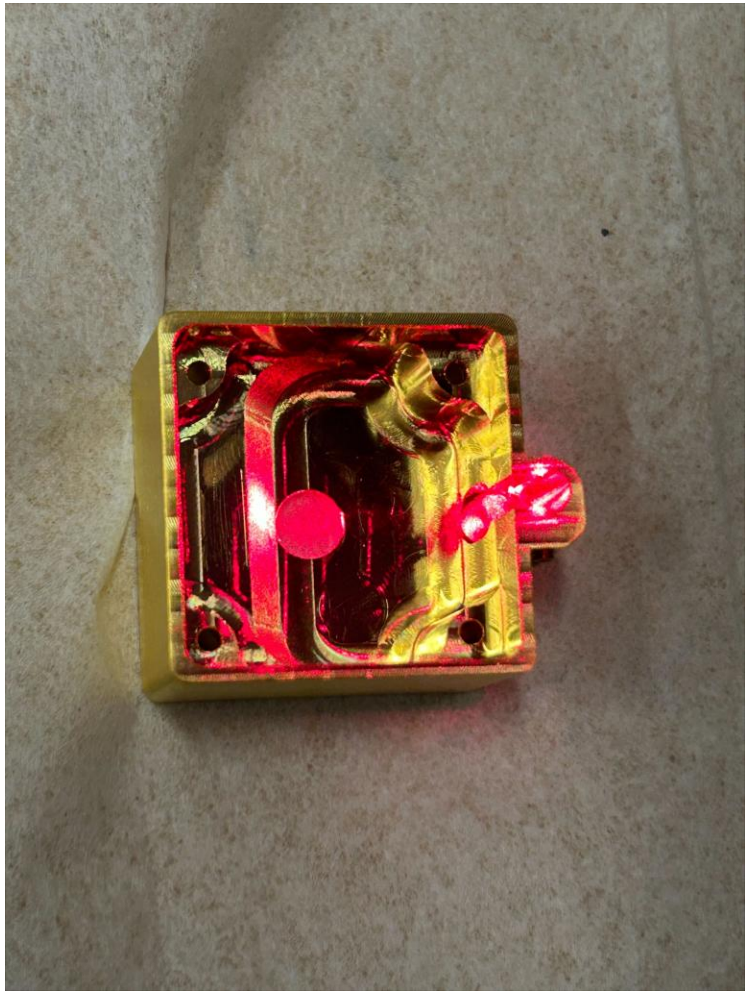
Electronic pickup

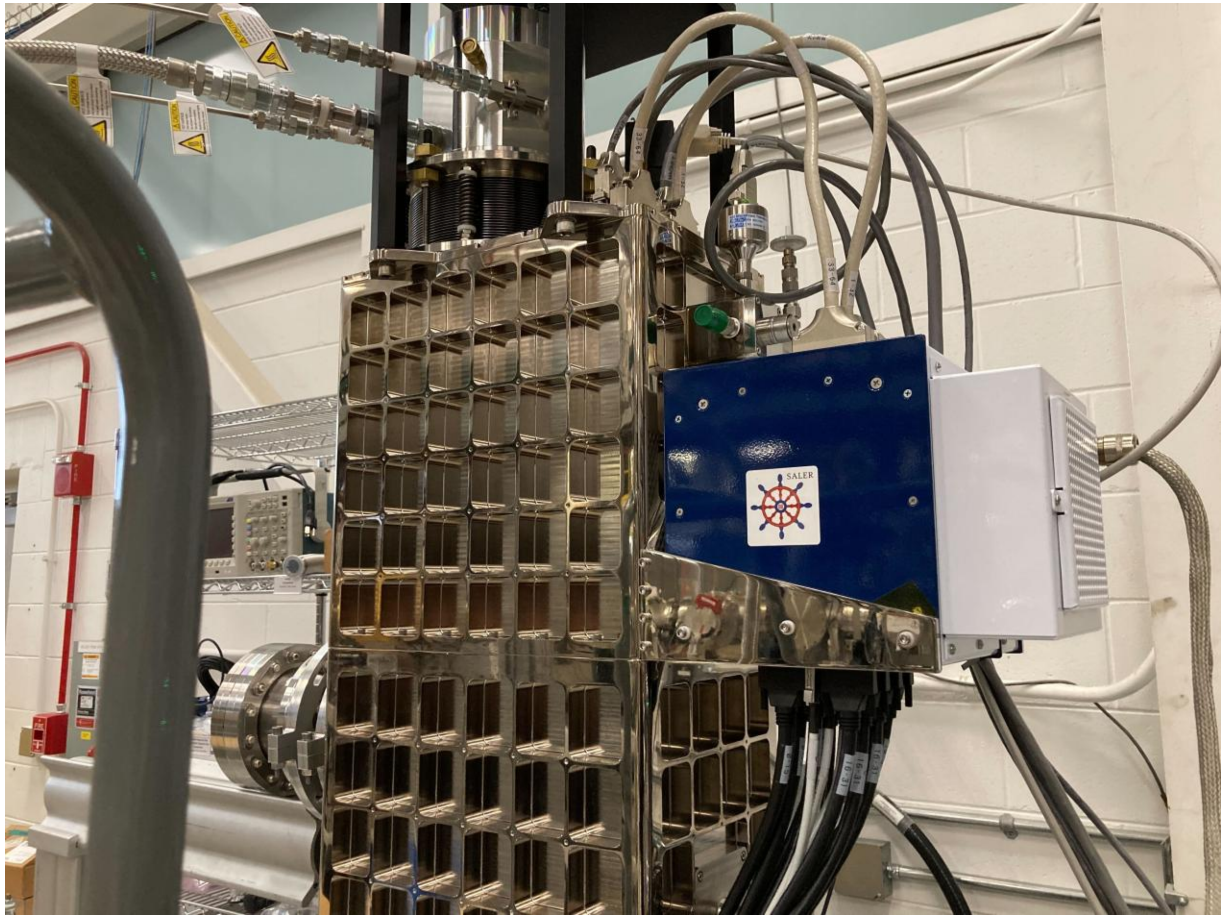




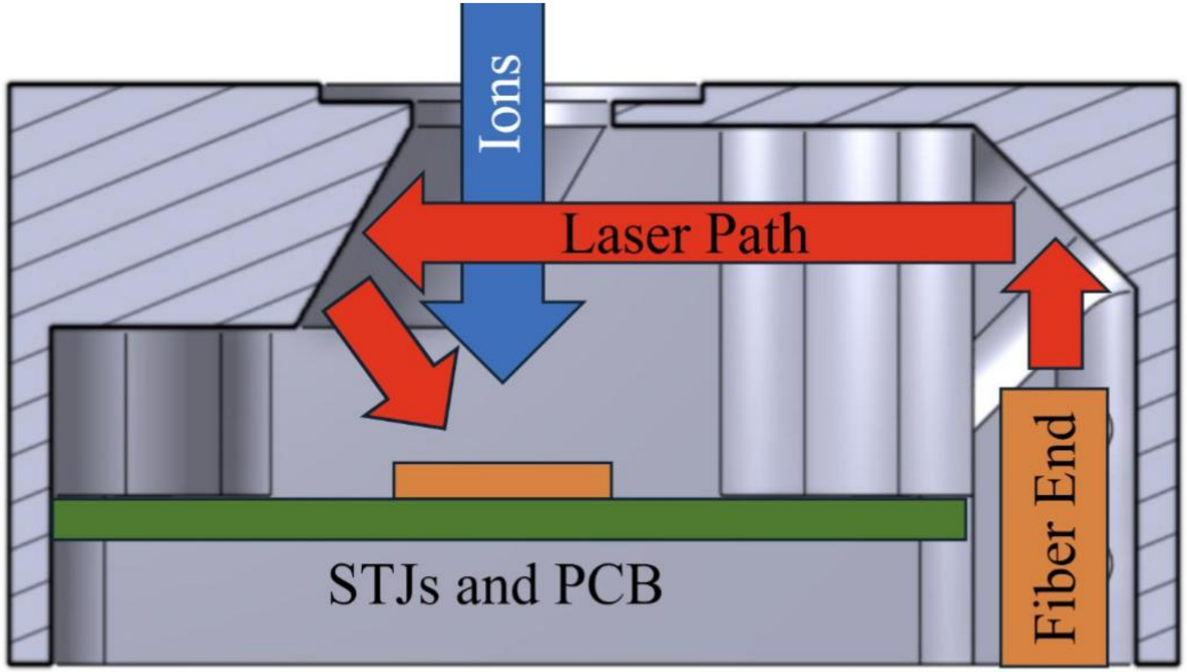
20 kHz noise

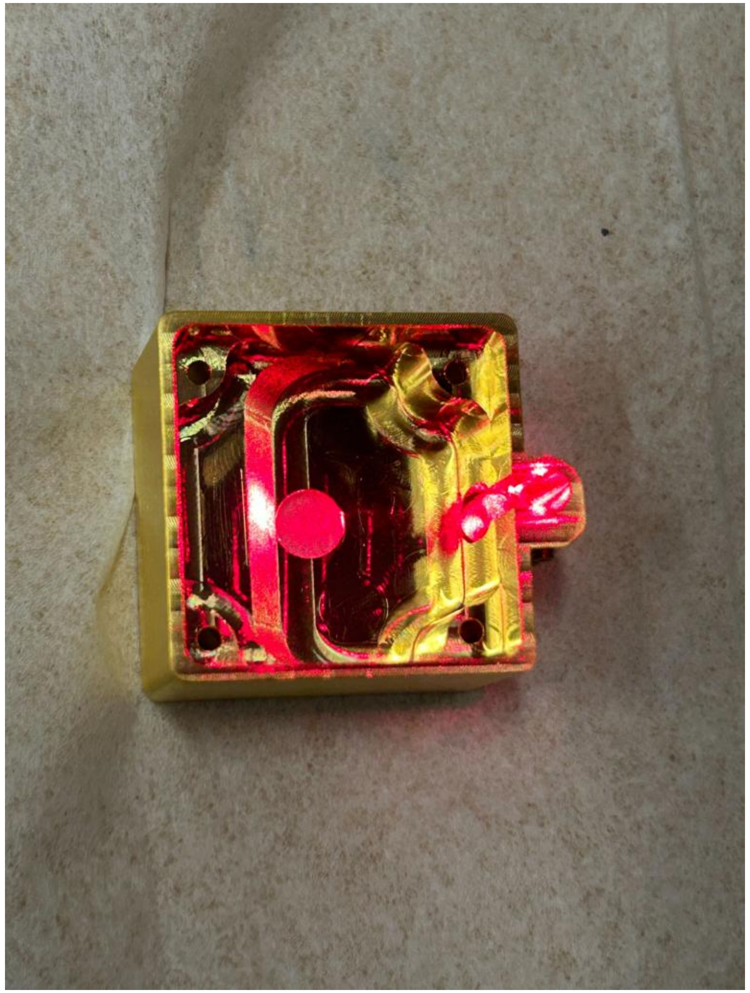
Additional photos



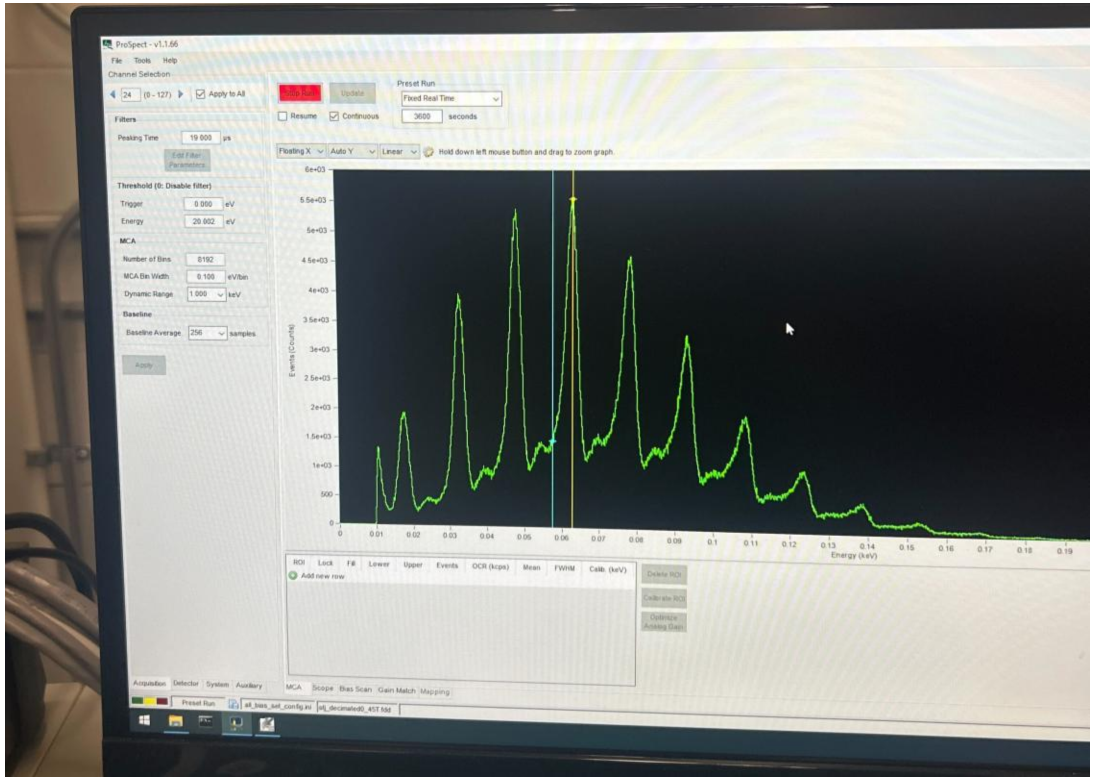


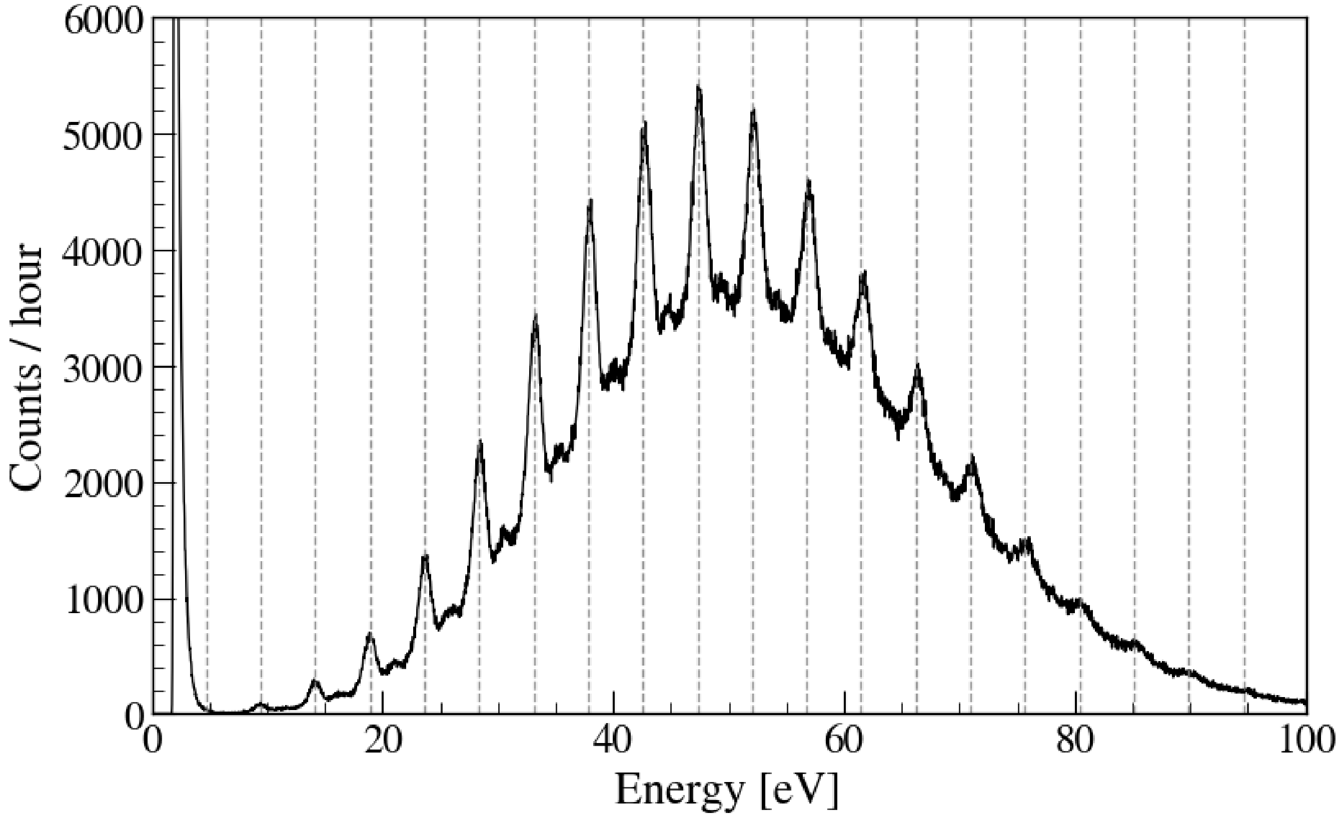
Laser calibration





Additional laser photos





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STJs masks