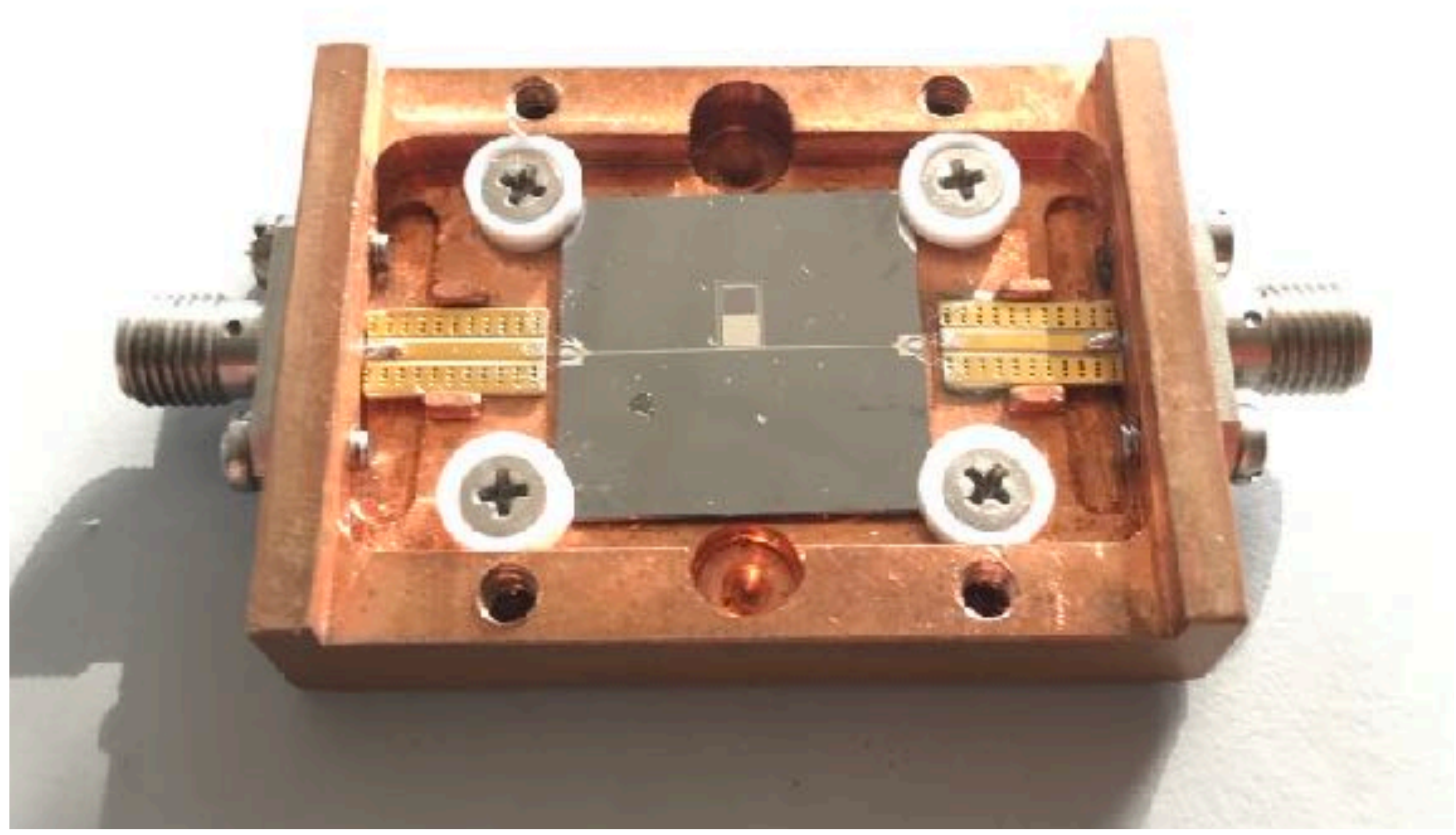
GAGG VETO UPDATES

Digest meeting 2025/05/14

Tommaso Lari

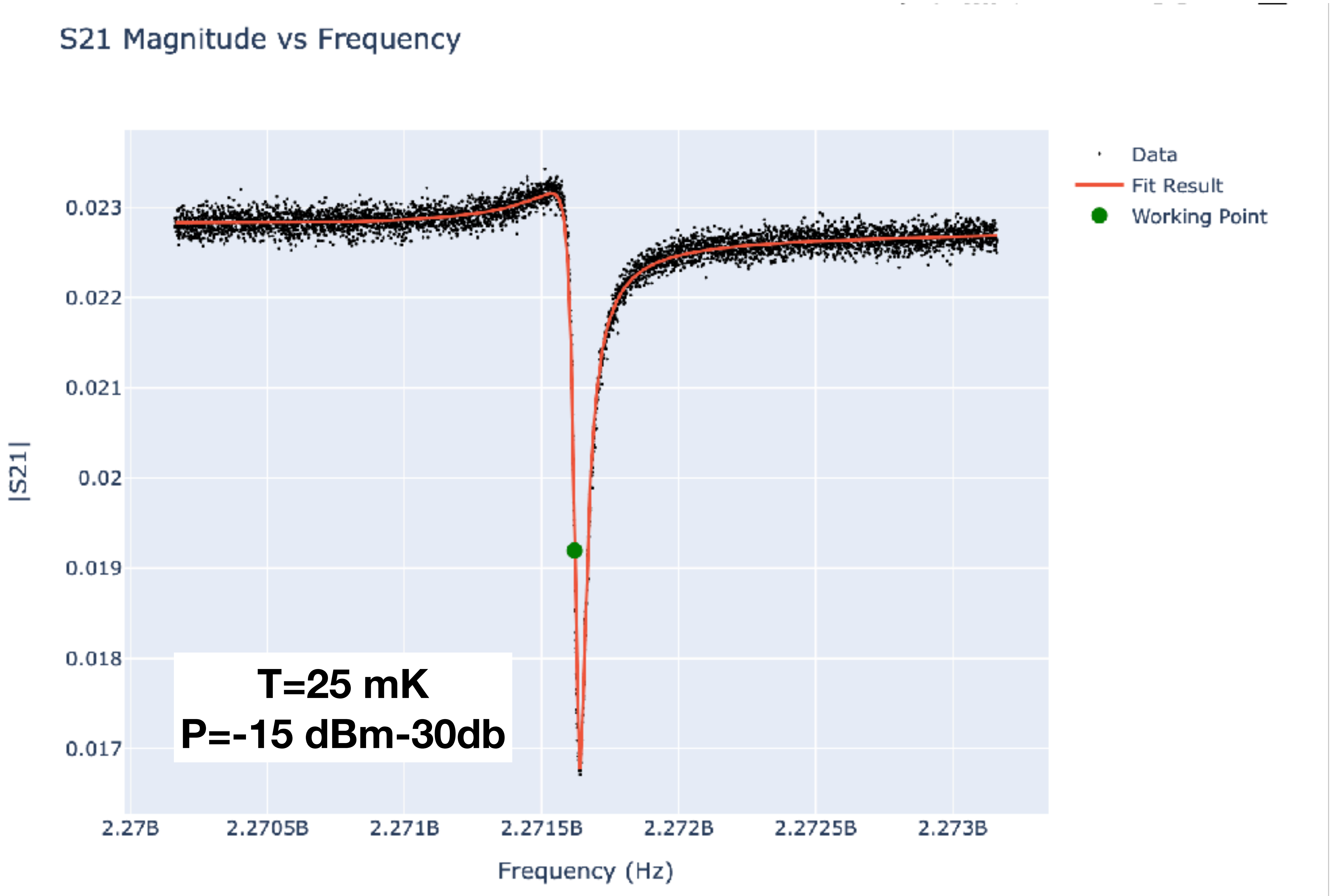
Cooldown #1:

- **KID based light detector from Roma Sapienza**
- **2x2 cm Si wafer**
- **AlTiAl KID**



- **Detector blind enclosed in the holder**
- **S21 scan using VNA**

KID resonance observed



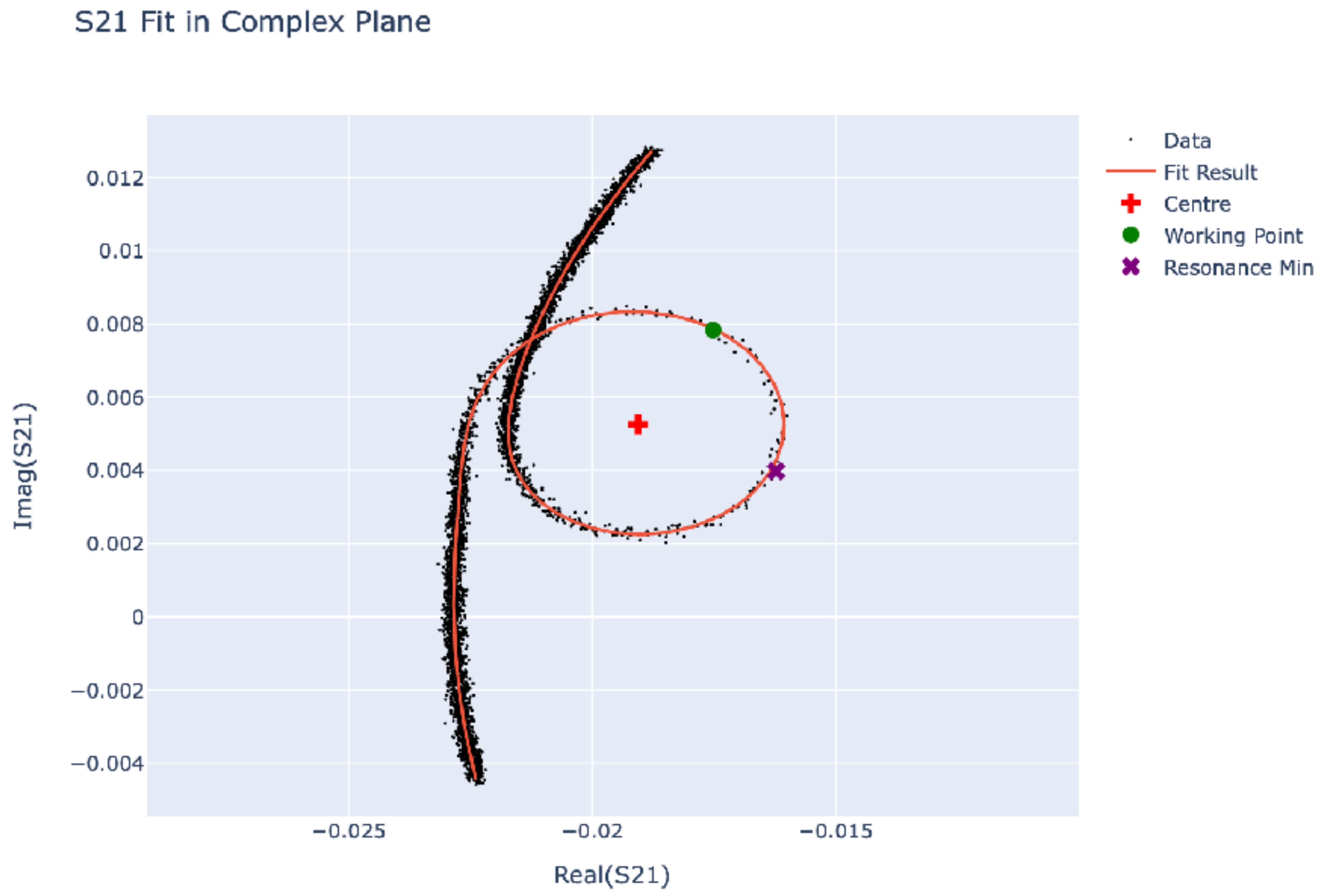
Cooldown #1:

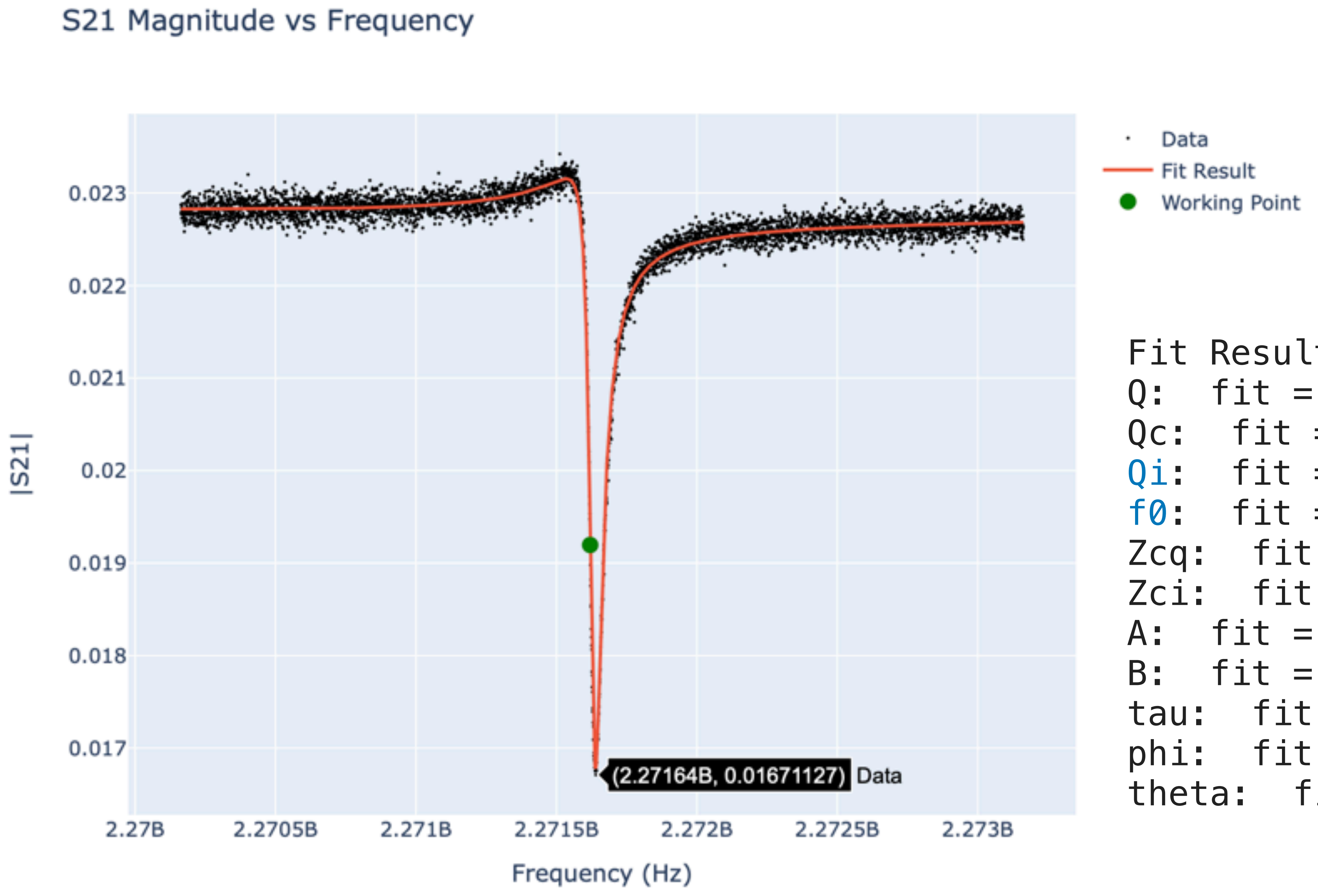
- **Fit Resonator Parameters:**

$$S_{21}(x) = Z + \left(A\cos(-2\pi x\tau) + iB\sin(-2\pi x\tau)\right) e^{-i\phi}\left(1 - \left(\frac{Q}{Q_c}e^{i\theta}\right)\cdot\frac{\cos(\theta)}{1+2ix}\right)$$

Casali, Nicola, et al. "Characterization of the KID-based light detectors of CALDER." *Journal of Low Temperature Physics* 184 (2016): 142-147.

- **Resonator parameters: Q,Qc,f_0**
- **Transmission line and amplifiers: Z, A,B,τ,ϕ**
- **Impedance mismatch: θ**
- **Optimal parameters found minimizing the χ^2 in the I-Q plane**
- **Working point and center of resonator circle**



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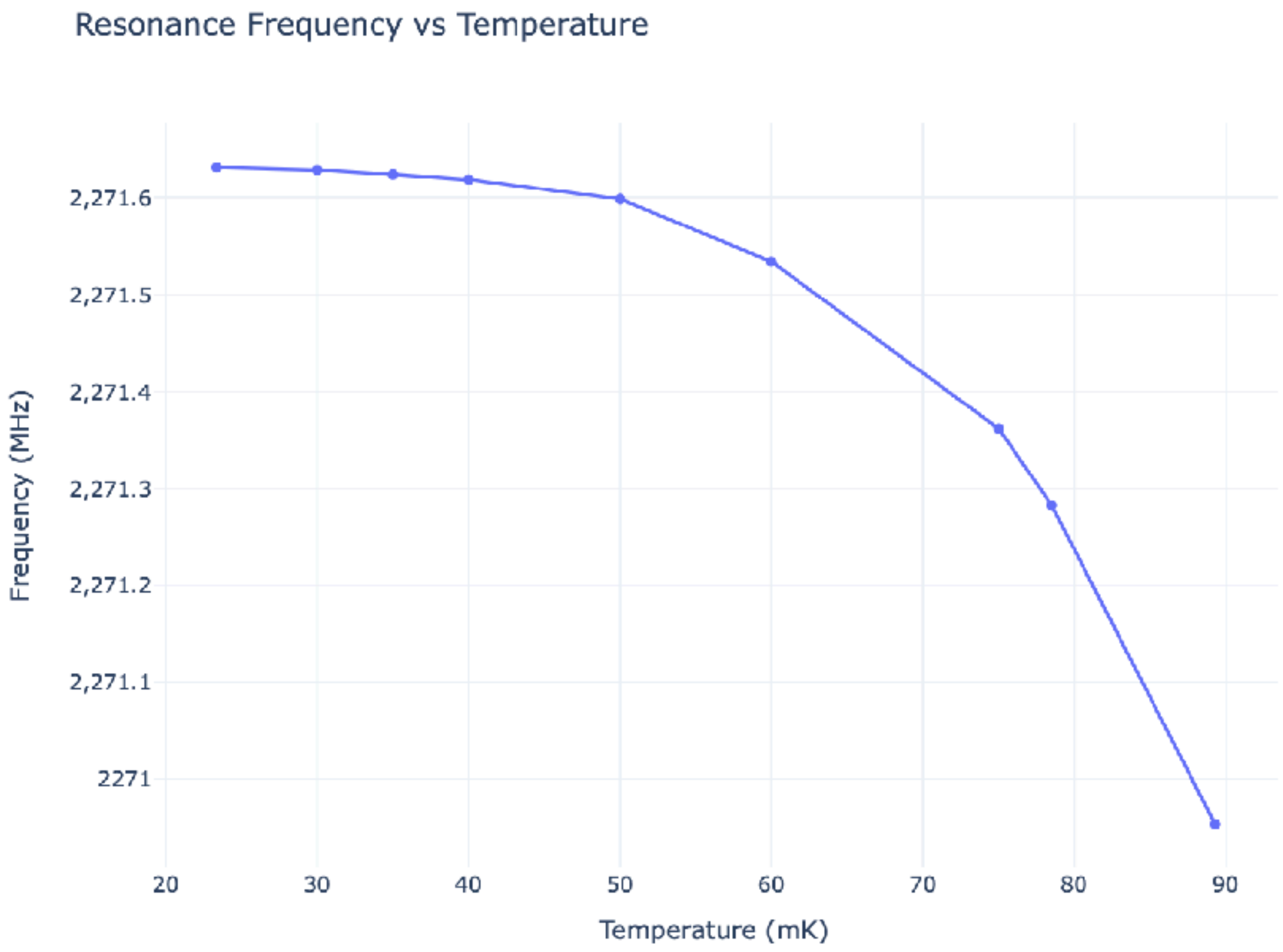
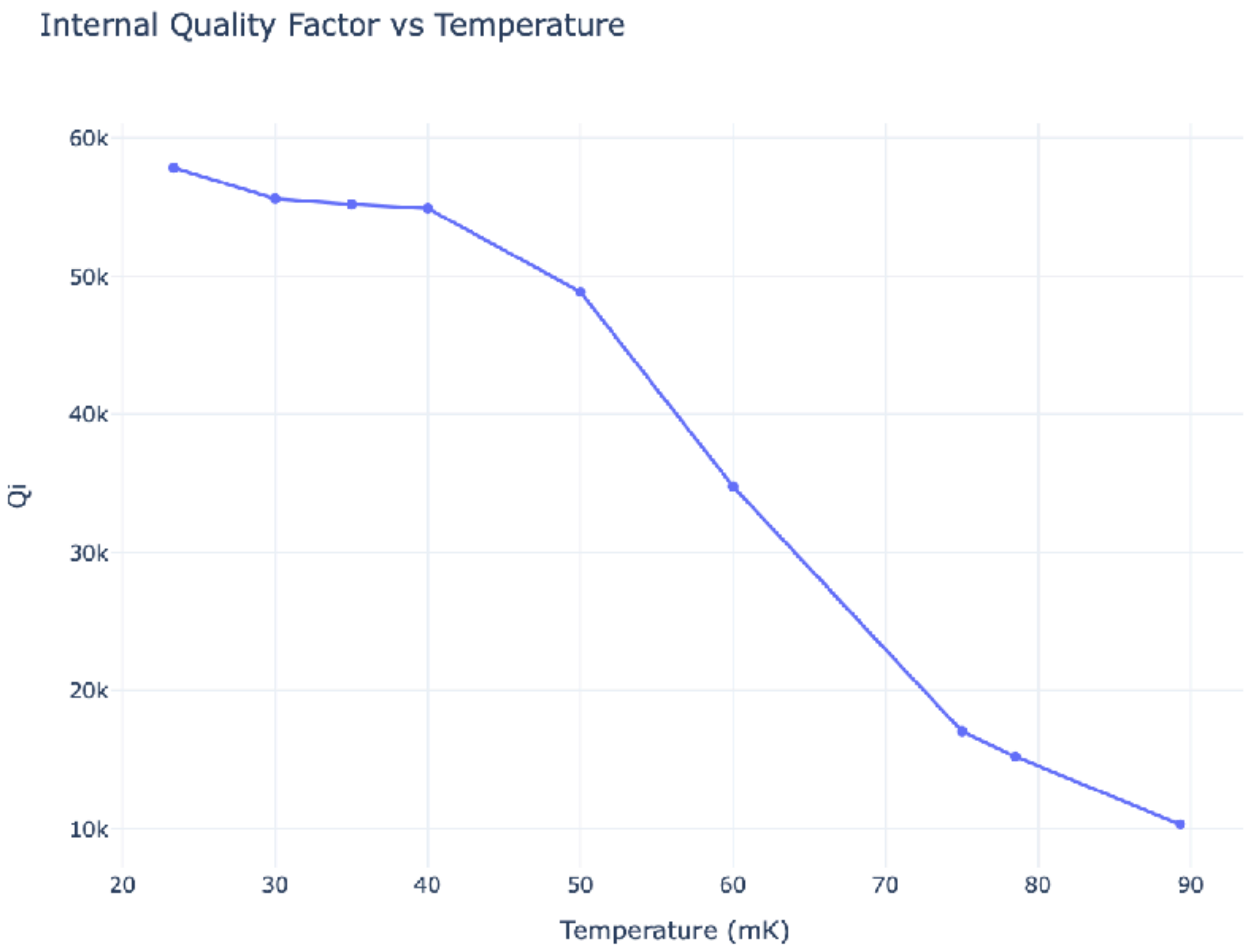
Fit Results:
Q:  fit = 40262.6
Qc:  fit = 132526
Qi:  fit = 57832.7
f0:  fit = 2.27163e+09
Zcq:  fit = 0.00105825
Zci:  fit = −0.000249464
A:  fit = 0.0238145
B:  fit = 0.0234521
tau:  fit = 0.00232336
phi:  fit = 3.3347
theta:  fit = 0.490679
```

Cooldown #1:

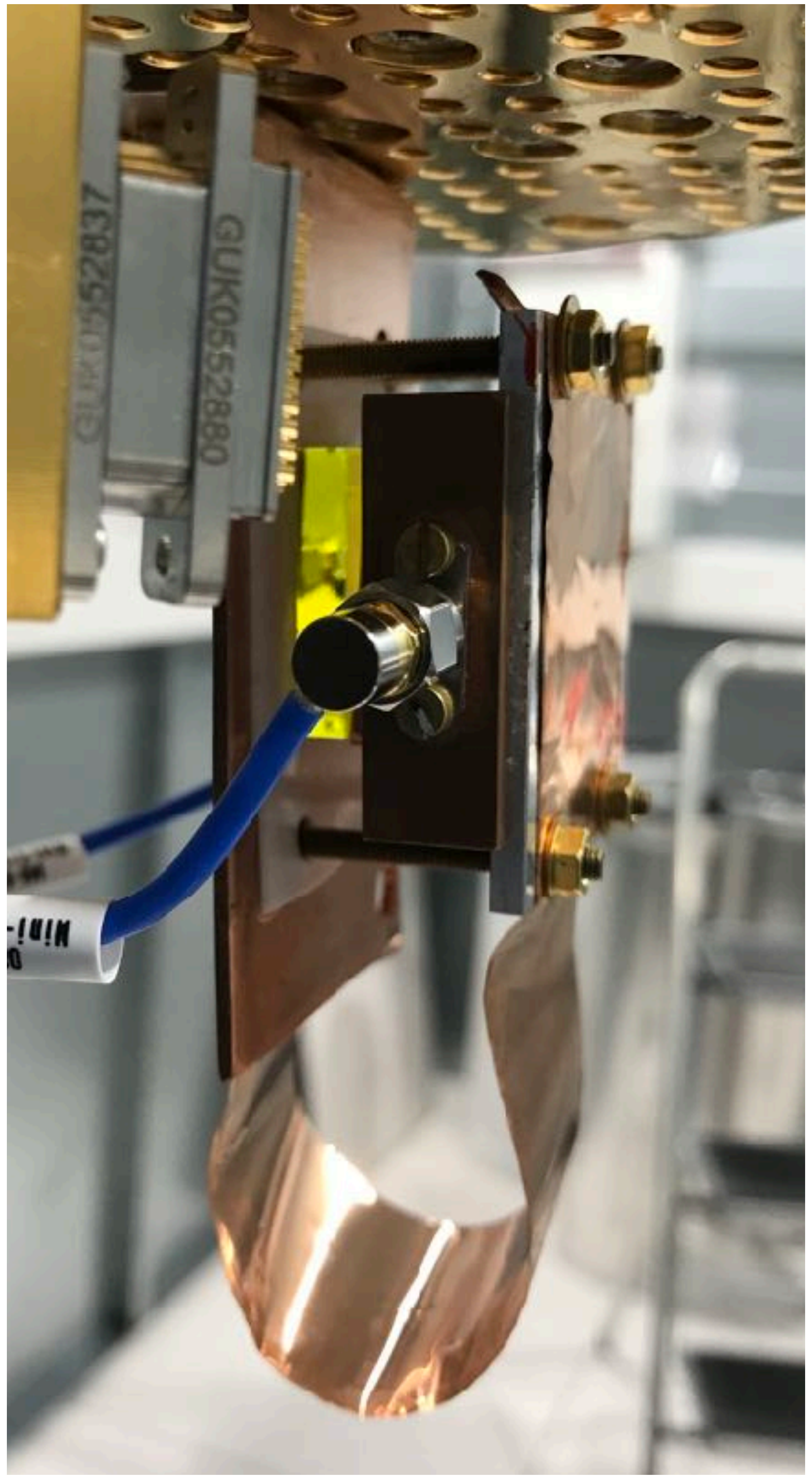


Resonance Frequency vs Temperature
Frequency (MHz)
2,271.6
2,271.5
2,271.4
2,271.3
2,271.2
2,271.1
2271
20
30
40
50
60
70
80
90
Temperature (mK)

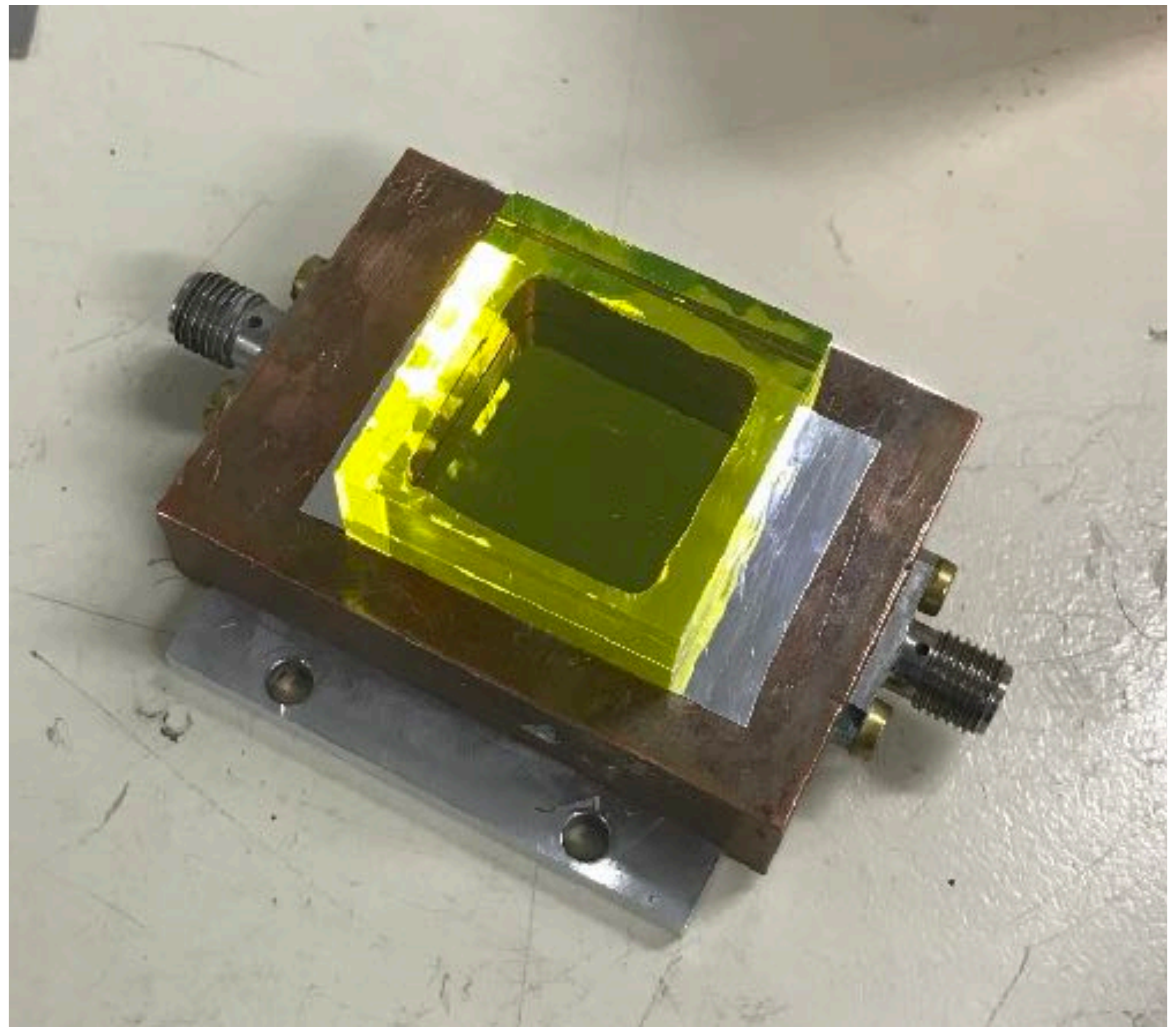


Internal Quality Factor vs Temperature
Qi
60k
50k
40k
30k
20k
10k
20
30
40
50
60
70
80
90
Temperature (mK)

Cooldown #2:



- **Test of the KID light sensor coupled to GAGG Crystal**

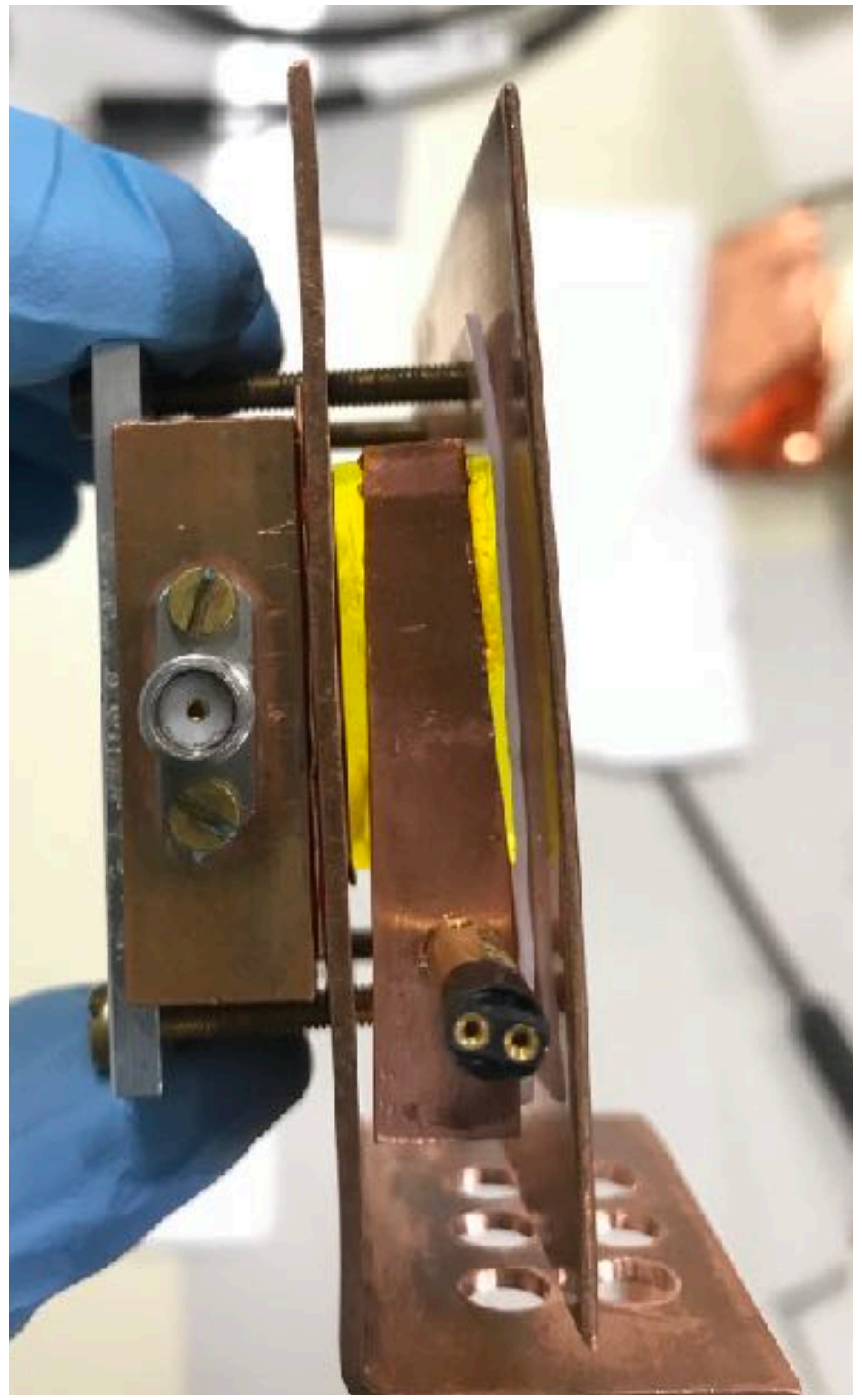


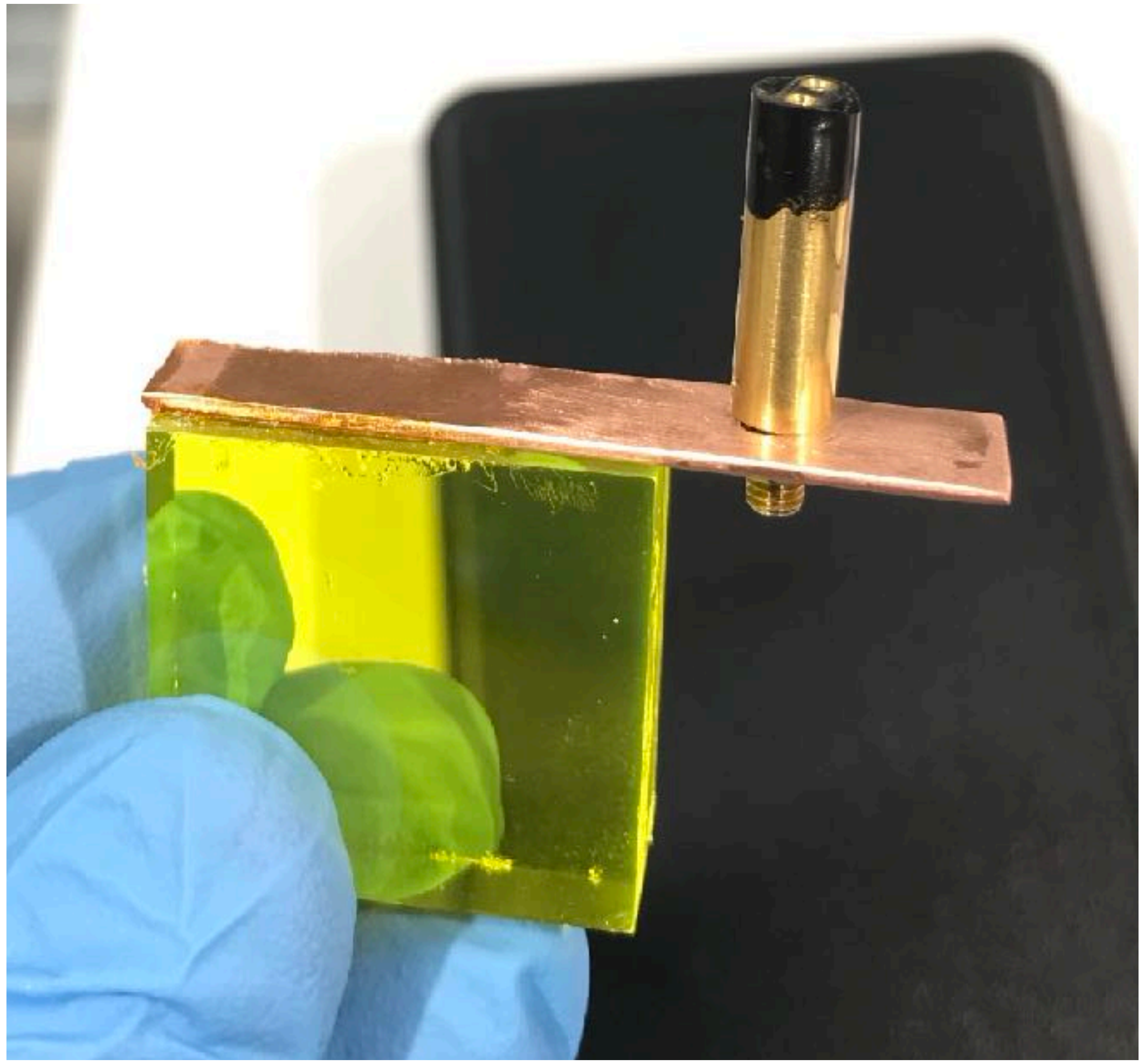
Set Up:
1. **Set up is mounted on a Cu main support attached to the MXC plate**
2. **Detector faced to a 2..5x2.5x1 GAGG crystal**
3. **4 screws hold the sandwich composed of the GAGG and the detector holder.**
4. **A 1 mm thick Teflon sheet is placed between the GAGG crystal and the copper plate to prevent mechanical damage to the crystal.**
5. **A copper foil is used to establish thermal contact between the detector holder and the main copper support**

KID resonance NOT observed

- **Thermalization?**
- **GAGG magnetic properties?**

Cooldown #3:

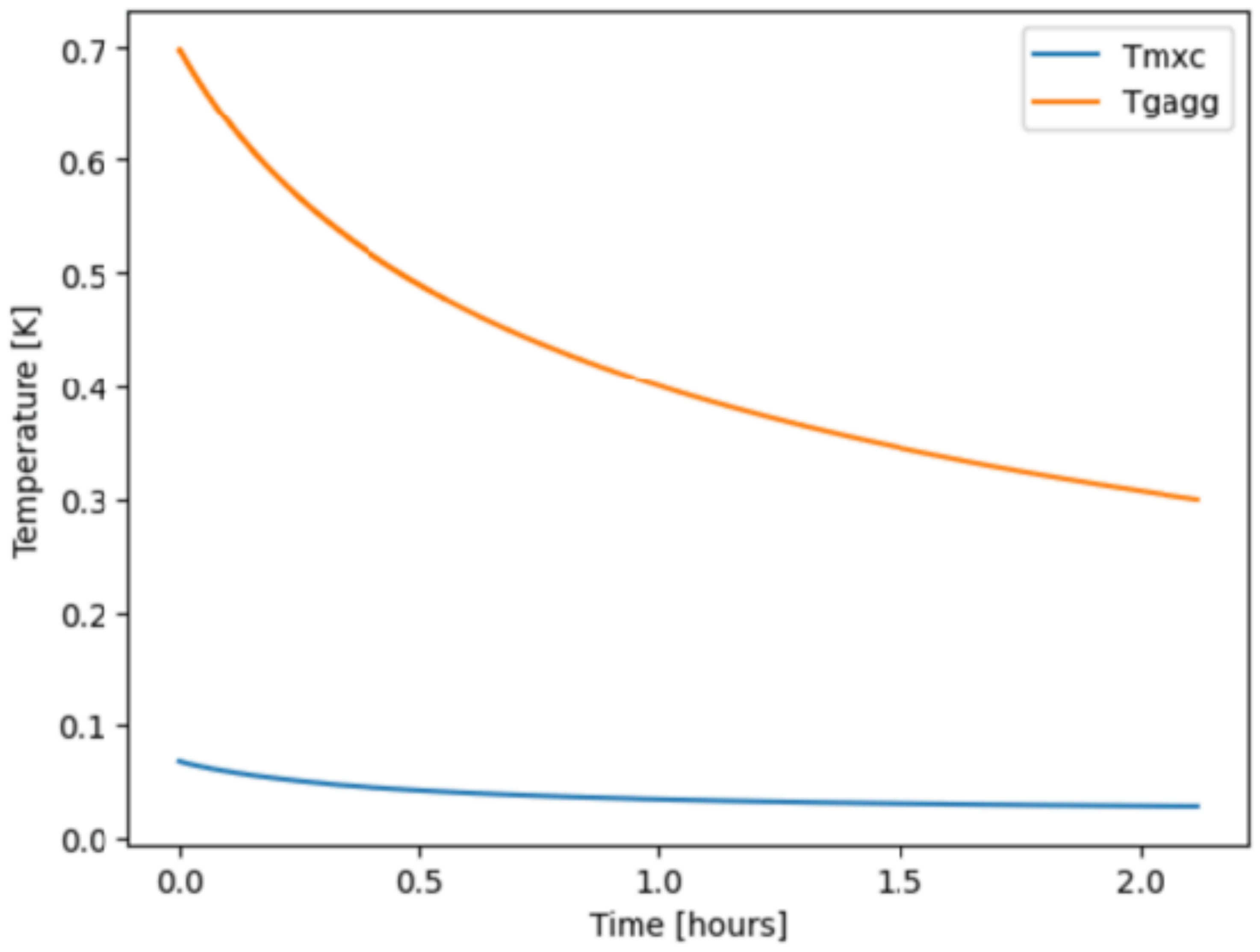


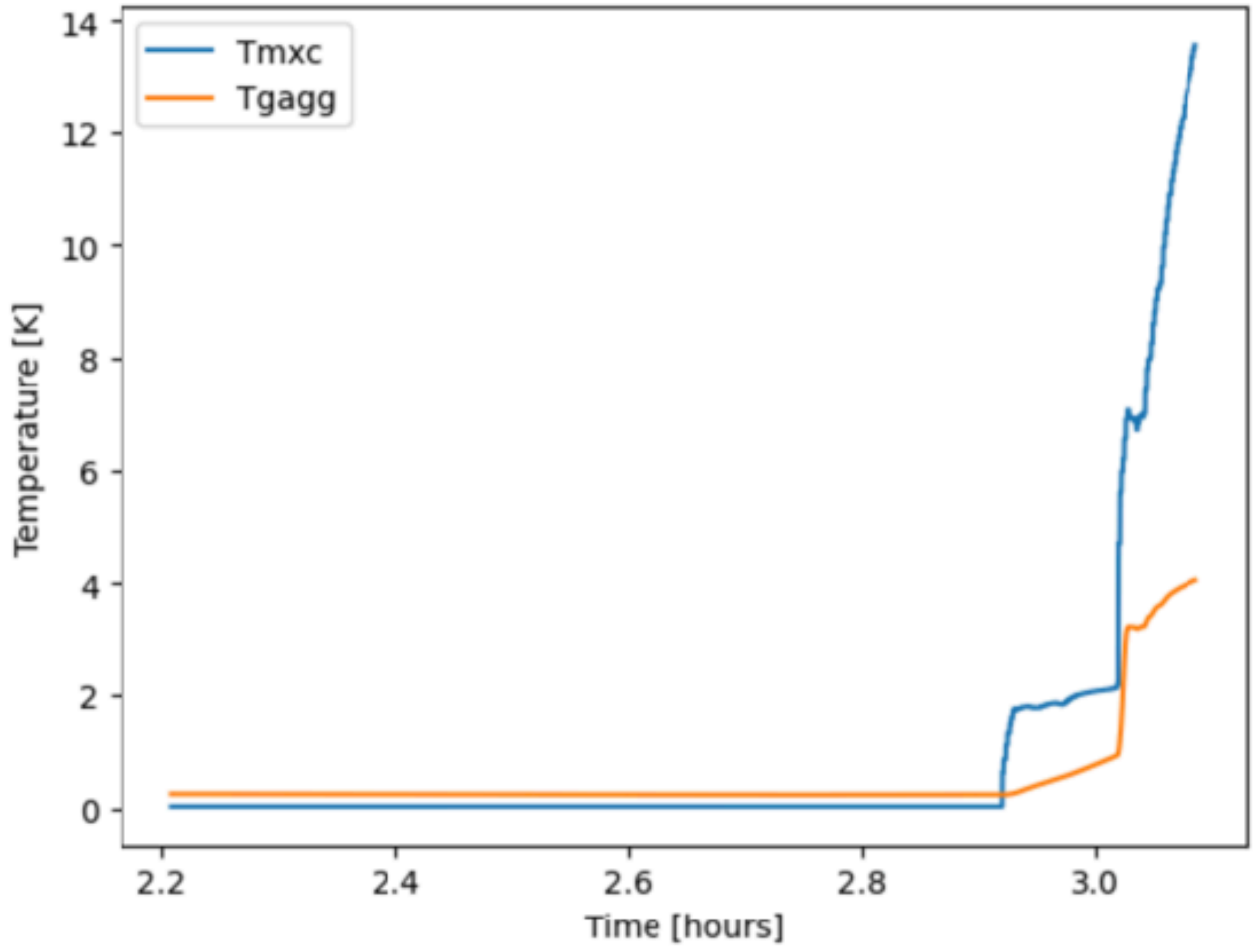


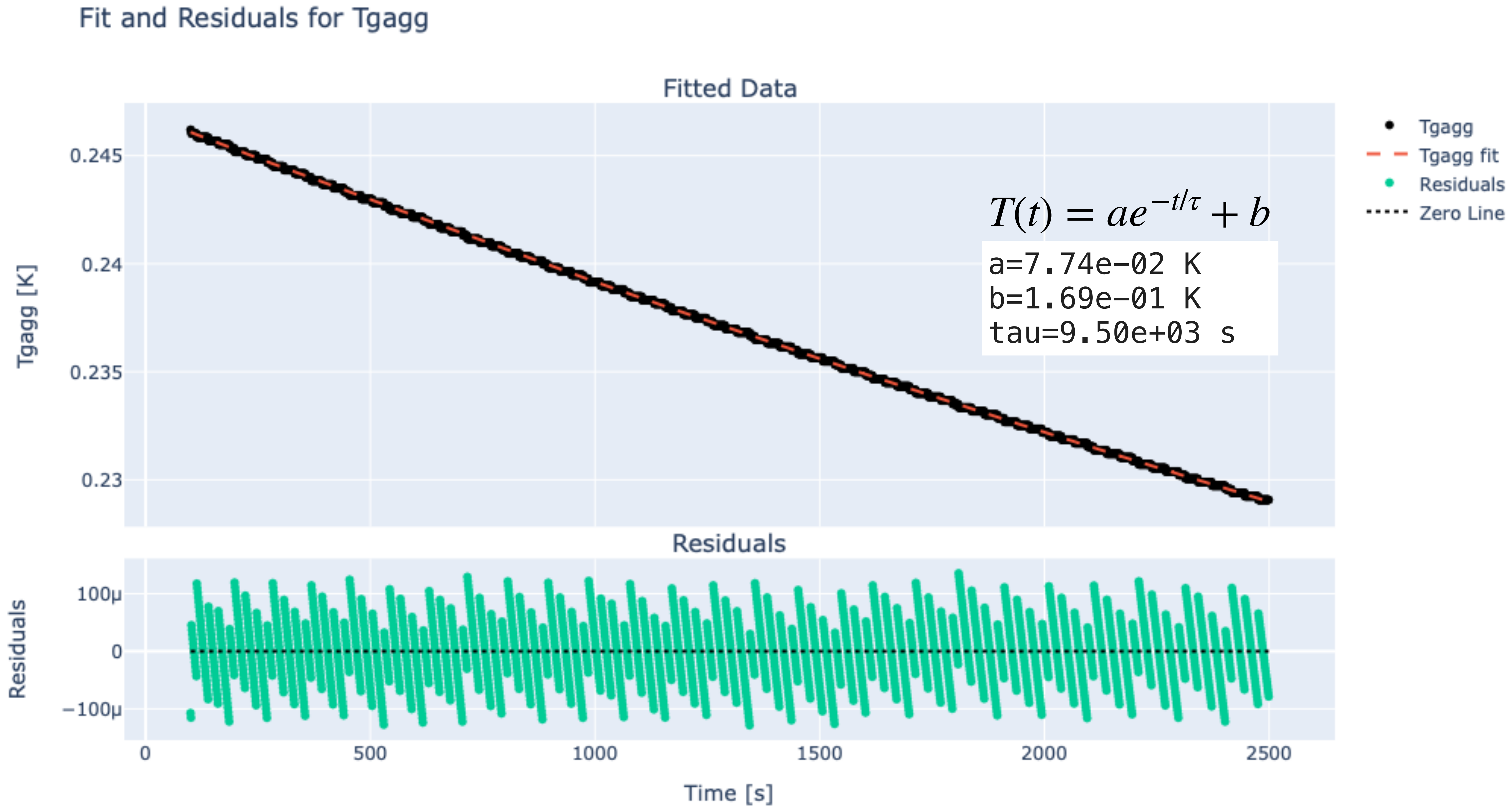
Goals:
- Verify **GAGG thermalization:**
- **Verify** that **the detector** is still working

Set Up:
- **Detector blind** and thermalized on the main copper support
- A RuOx 10K **thermometer** is in contact with the **GAGG** crystal
- The thermometer is fixed on a Cu support attached to GAGG crystal using GE varnish glue.

Cooldown #3:







Results:

- **GAGG Thermalizes but it is slow, compared to the MXC temperature**
- **Lowest temperature** ~ 230 **mK**
- **Thermalization time constant** $\sim$**2.63 hours from 0.245 mK to 0.230 mK**

KID resonance NOT observed

Simulations:

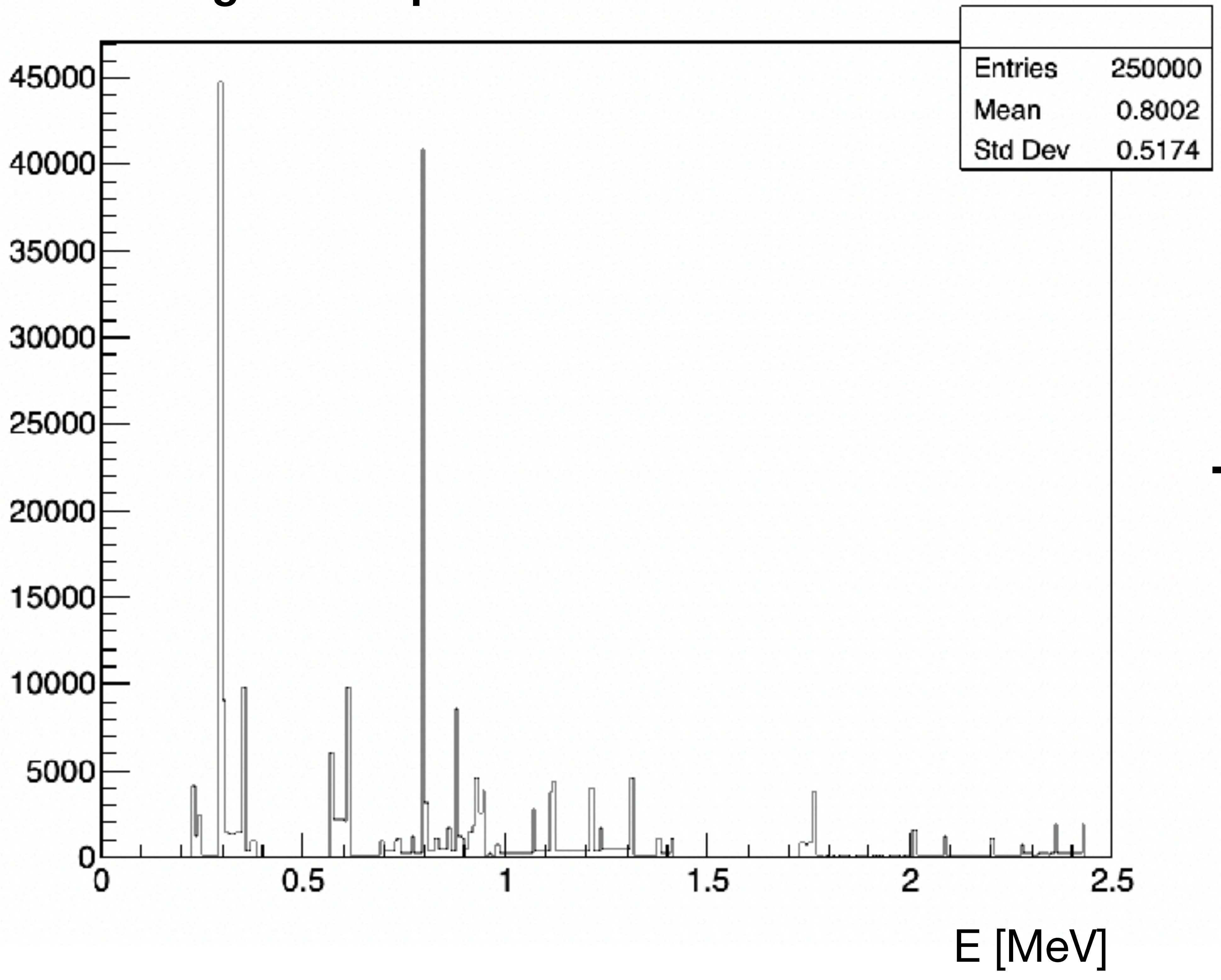
Results of GSO sample contamination form LNGS

- ^{238}U 550-165 ppb
- ^{232}Th <200 ppb
- ^{39}K 10-5 ppm → ^{40}K 1.28 ppb

Simulations:

- Gamma lines form U,Th and K decay chain:
- http://www.lnhb.fr/Laraweb/
- Considered only gamma lines with intensity > 2.5% and Energy >200 keV
- 6.5 cm thick Veto (worst case) or about 130 kg of GSO
- 10^7 events generated in the veto volume
- Count gammas that escape the veto and reach bullkid detector

^{238}U gamma spectrum



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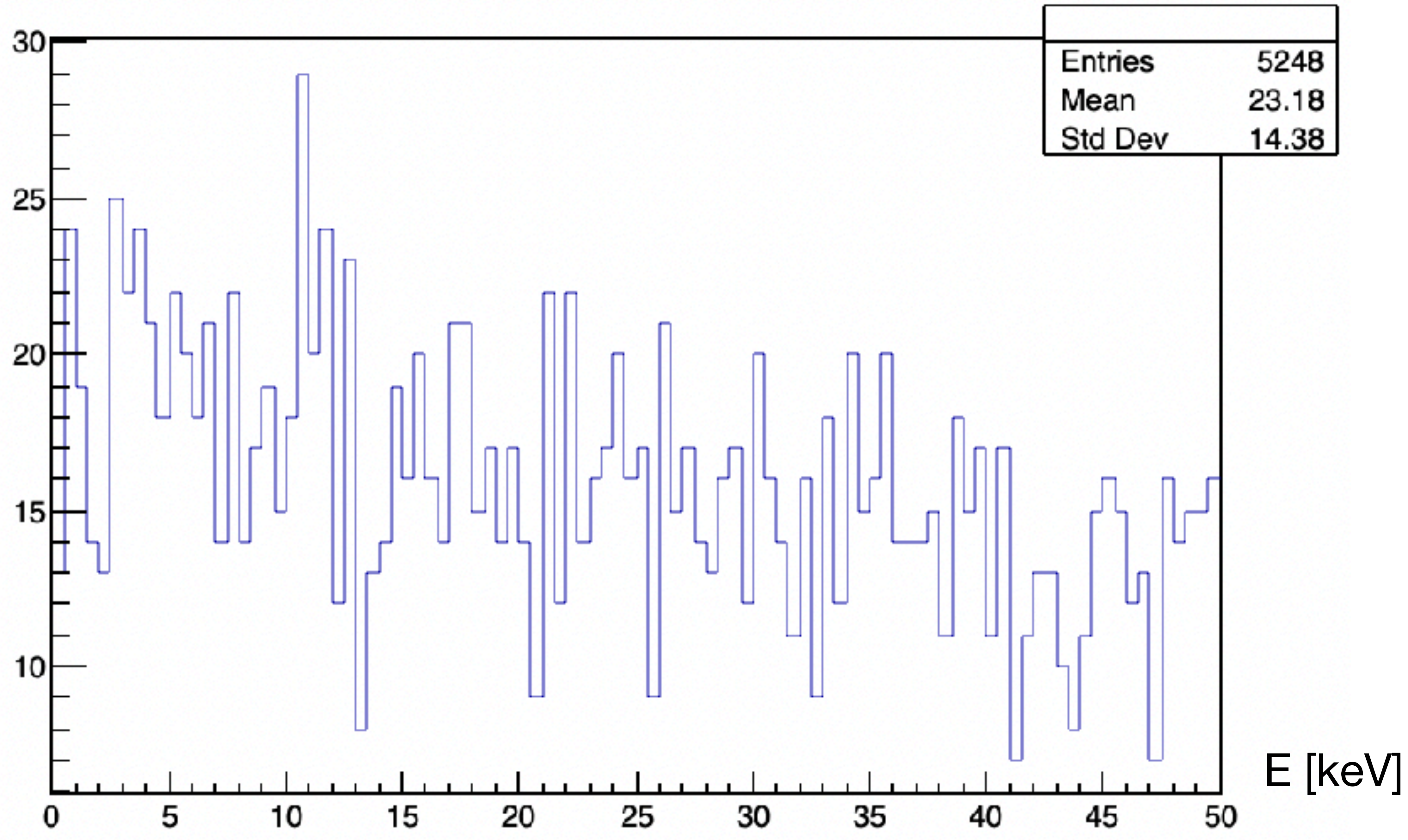
Events in BULLKID Detector



Cuts: Veto Th=50 keV, 1 die only, no events in the wafer border

Simulations:

Results:

- **Output of the simulations: Suppression Factor s=(Event in BULLKID ROI [0.2-16]keV)/Generated events**
- **Different veto materials GAGG/BGO/GSO assuming the same contamination of the GSO sample**

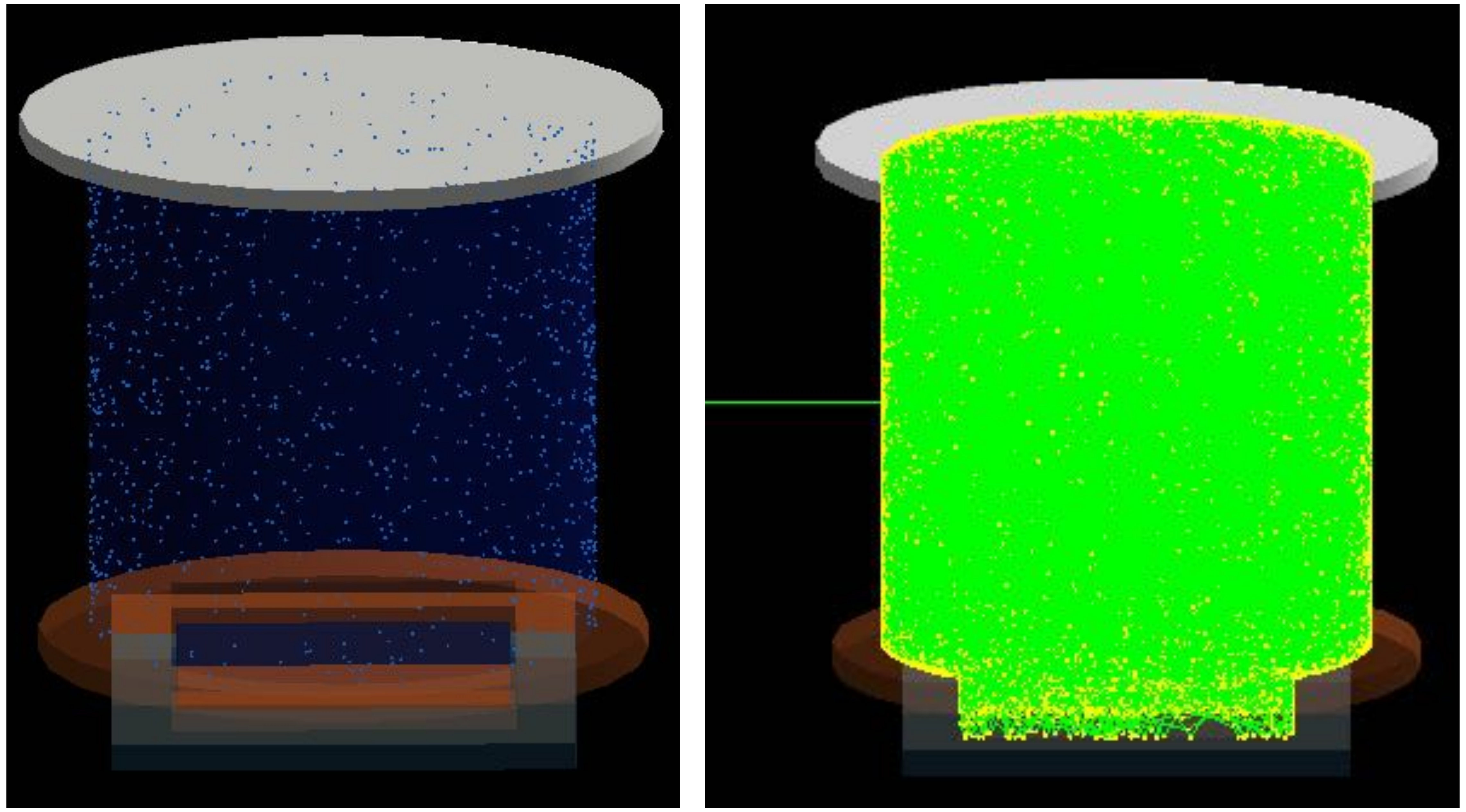
Suppression Factor	238U	232Th	40K
BGO	5.4e-5	4.6e-5	5.2e-5
GSO	5.9e-5	5.4e-5	5.2e-5
GAGG	5.8e-5	5.9e-5	6.9e-5

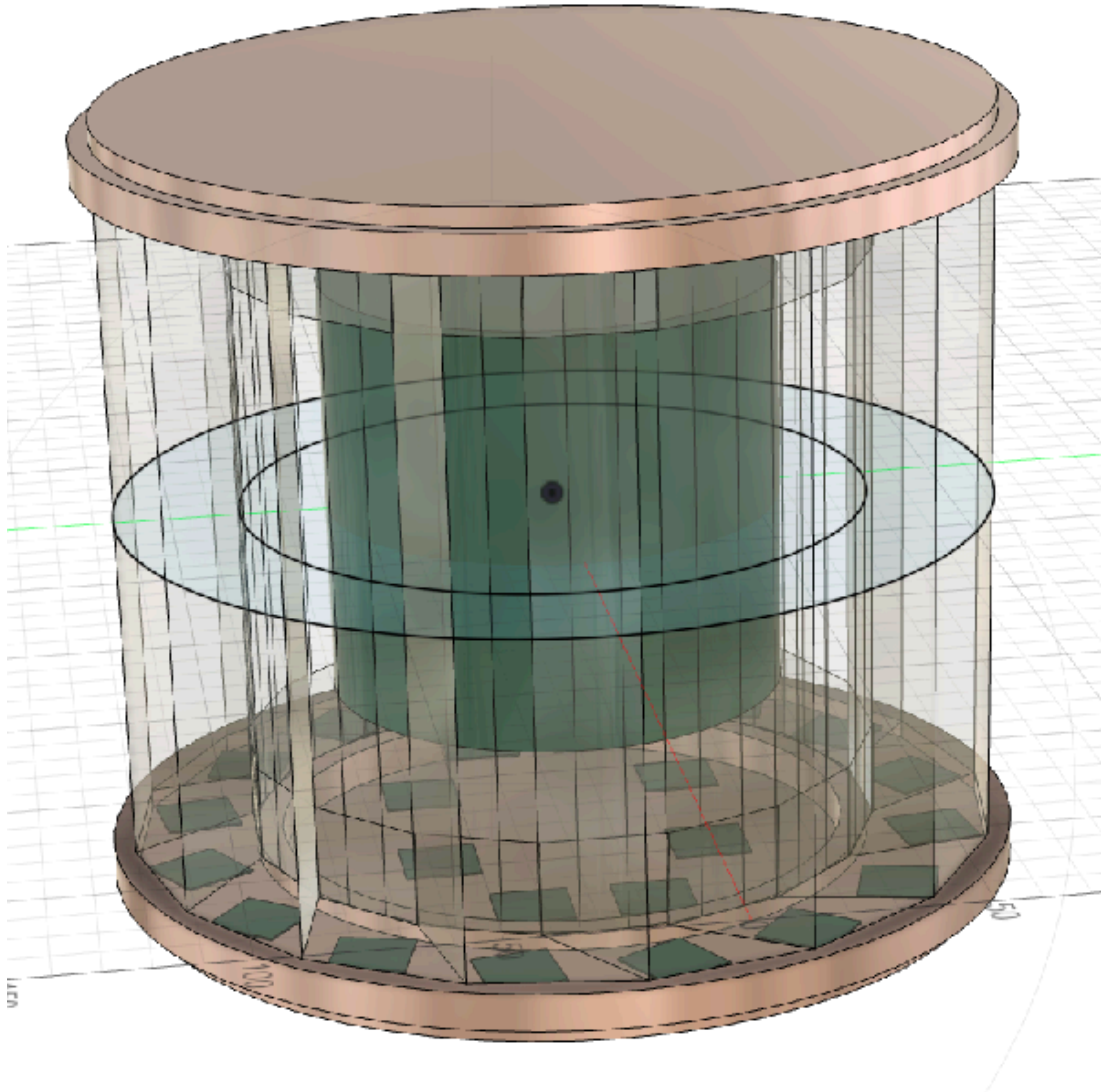
Isotope	Concentration [ppb]	Activity [Bq/kg]	Rate BULLKID [dru]	Rate BULLKID Active Veto [dru]	Concentration for 1 dru [ppb]	Activity for 1 dru [mBq/kg]
238 U	550	40	6.24e3	2.54e3	0,217	15.74
232 Th	200	2.8	3.73e2	1.52e2	1.317	18.5
40 K	1.28	3.42e-3	5.27	2.10	0.61	16.28

- **Need to take into account crystals radio-purity**
- **Crystals Radio-purity requirements obtained from simulations**

Simulations:

NEXT STEPS:





Simulation of optical photons transportation and signal formation in KID sensor in BGO set-up (developed by Matteo del Gallo)

- Use this working package to simulate the set-up of the future veto tests
- Extend the model to simulate a realistic veto with multiple crystal tiles and sensors

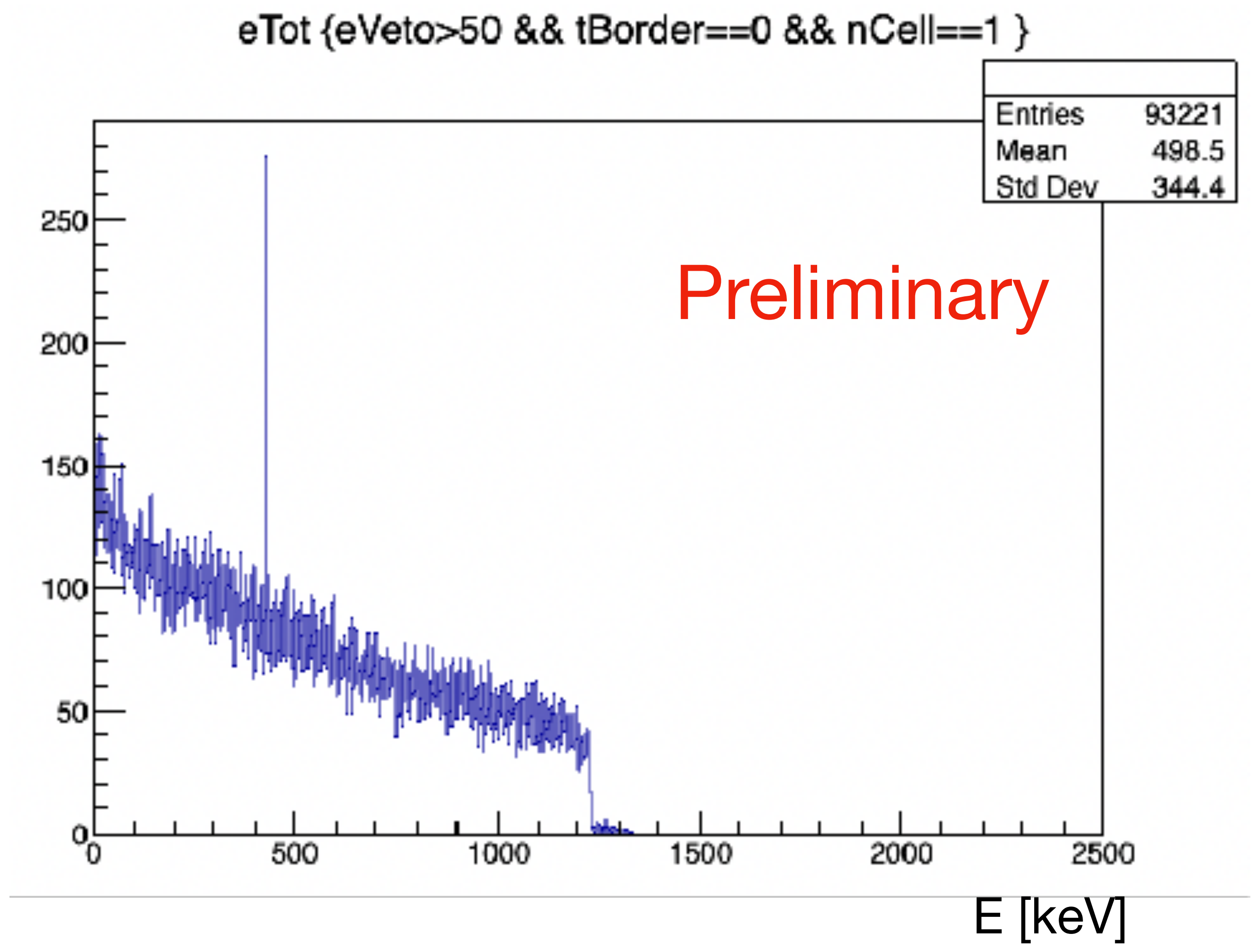
Calibration:

BRAINSTORMING:

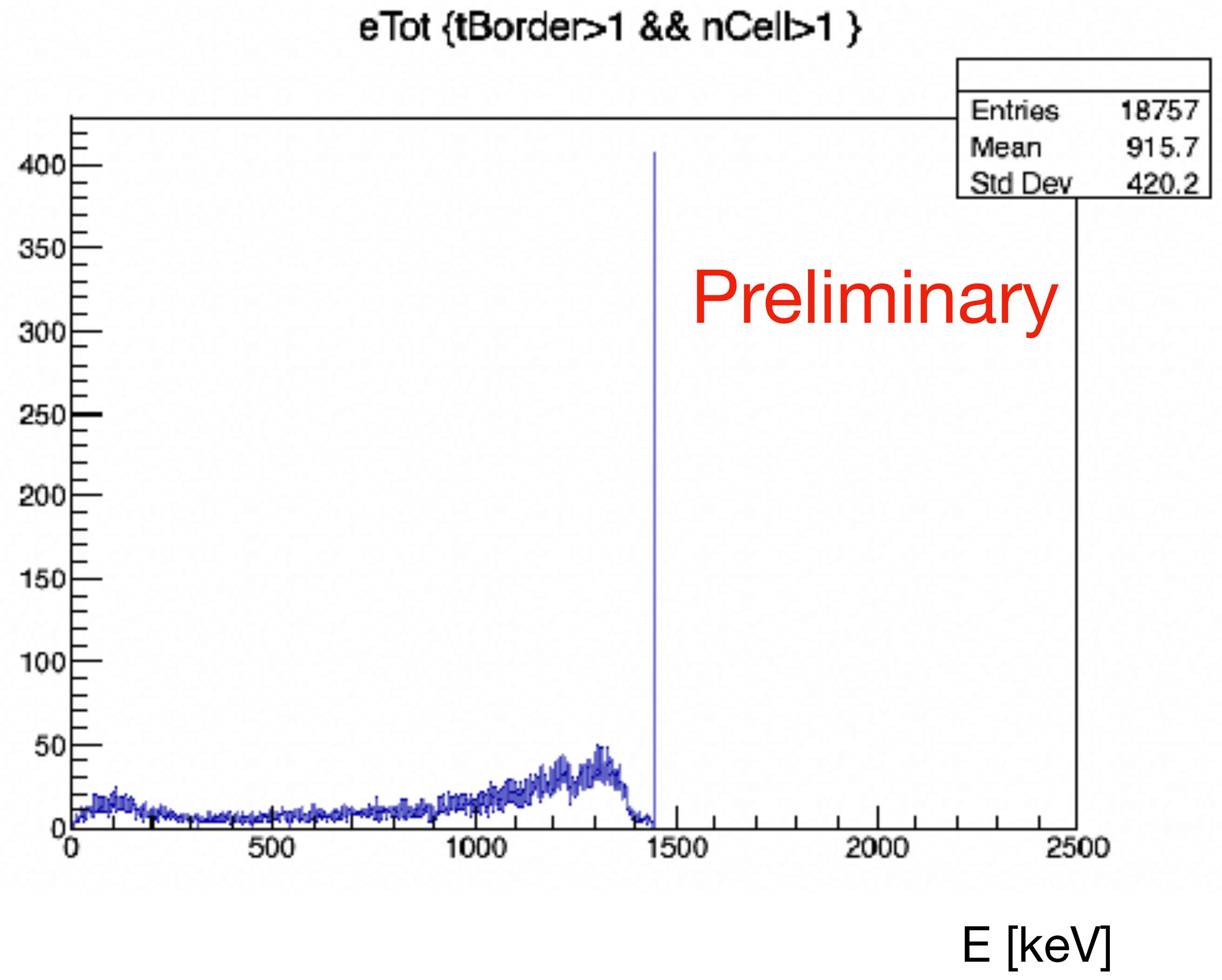
1. **^{192}Ir wires:**
   - **Available because used in medical application**
   - **Gamma and Xray Lines [11-612] keV**
2. **Background Events:**
   - **We aim to almost zero events in the ROI and applying selection cuts (1 die only, no event in the border)**
   - **Relaxing or Inverting the cuts, maybe, it is possible to exploit some features in the background spectrum outside the ROI**
   - **Use coincidence with the veto**
   - **To be validated using simulations**
3. **^{241}Am "inside" an instrumented material:**
   - **Use ~60 keV Xray to calibrate BULLKID**
   - **Easy to tag events thanks to alpha emission →minimal background in the ROI**
   - **To be validated using simulations**

Gamma Spectrum of 192 Ir

Energy (keV)	Intensity (%)	Type	Origin*	Levels Start*	Levels End*
11.6 (-)	3.96 (6)	X_L	Pt		
65.123 (-)	2.66 (5)	$X_{K\alpha2}$	Pt		
66.833 (-)	4.55 (8)	$X_{K\alpha1}$	Pt		
205.79430 (9)	3.34 (4)	γ	Os-192	1	0
295.95650 (15)	28.72 (14)	γ	Pt-192	2	1
308.45507 (17)	29.68 (15)	γ	Pt-192	4	2
316.50618 (17)	82.75 (21)	γ	Pt-192	1	0
468.0688 (3)	47.81 (24)	γ	Pt-192	3	1
484.5751 (4)	3.189 (24)	γ	Os-192	4	1
588.5810 (7)	4.517 (22)	γ	Pt-192	5	2
604.41105 (25)	8.20 (4)	γ	Pt-192	4	1
612.4621 (3)	5.34 (8)	γ	Pt-192	2	0



^{40}K background



^{40}K background