A search for short range interactions with Mössbauer spectroscopy

LBNL, May 7th 2026

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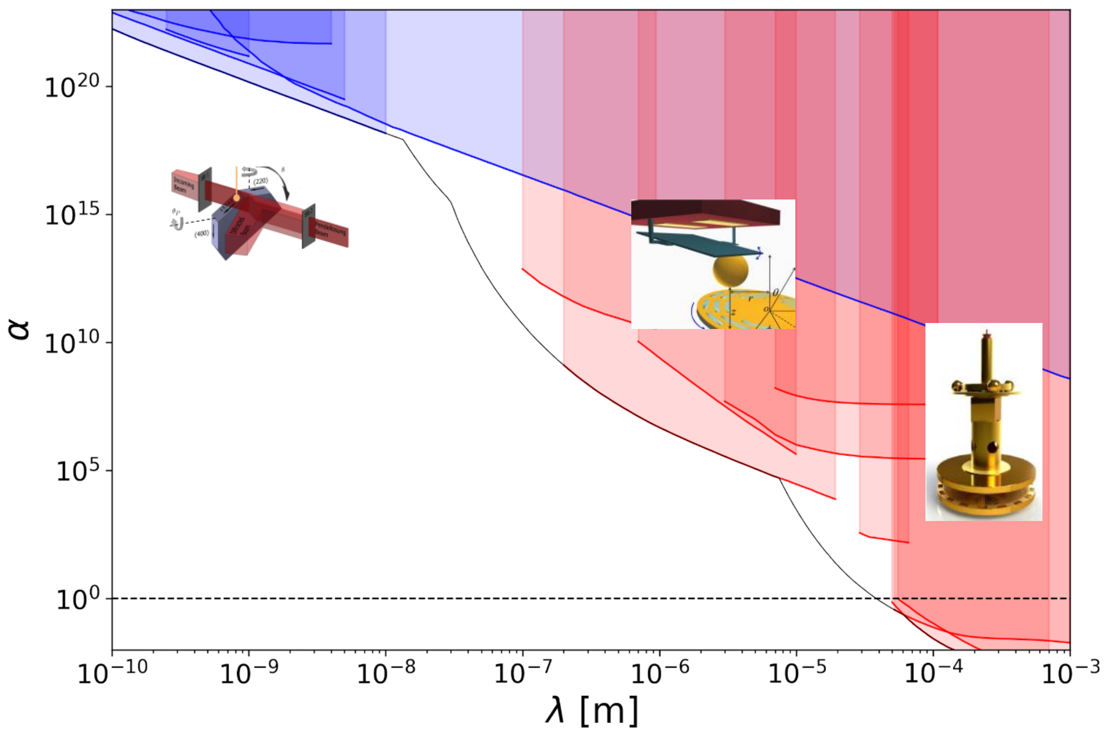
Stanford University

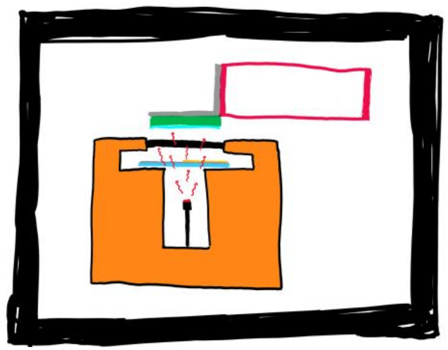
New interactions are usually be mapped to yukawa type potential (scaled to Newtonian gravity)

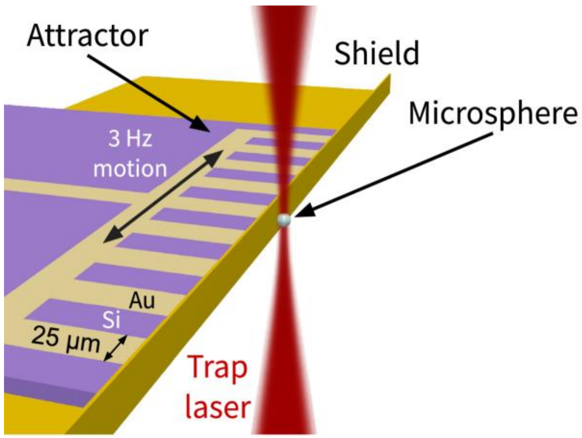
$$V(r) = \frac{GMm}{r}(1 + \alpha e^{-\frac{d}{\lambda}})$$



Short range interaction experiments in the Gratta group at Stanford

xenon1g





1-10 nm

10-500 nm

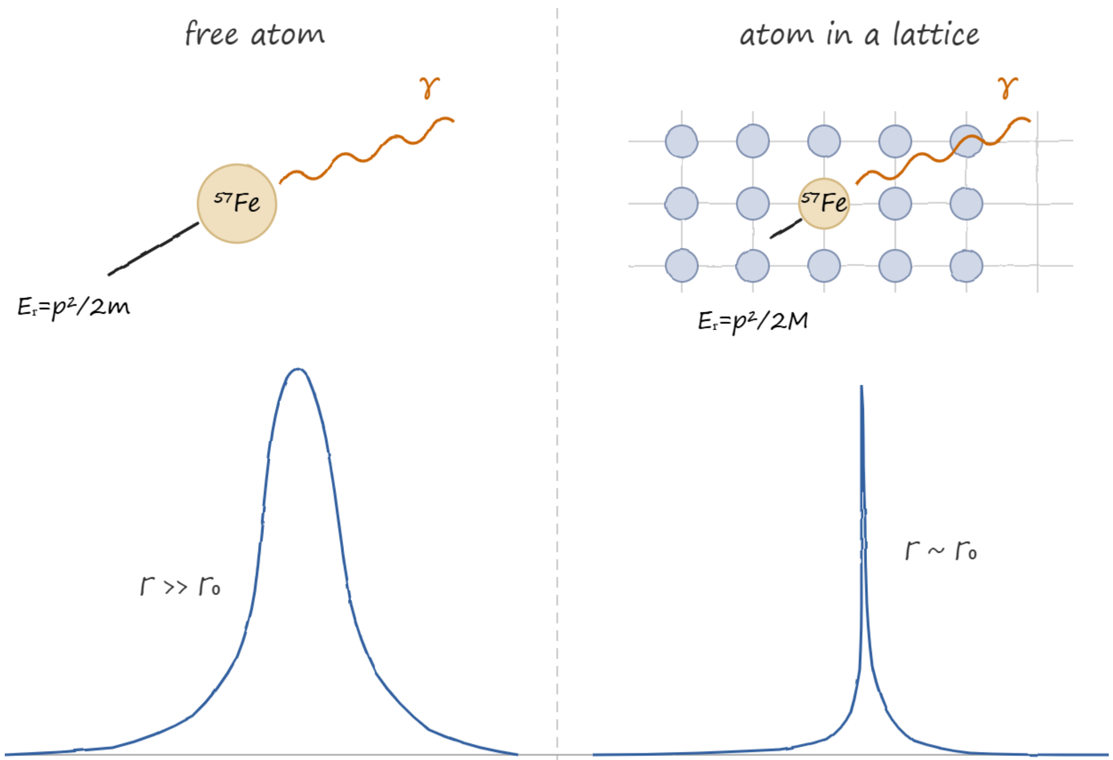
1-100 um

What we know for sure is that there is not a lack of models for new interactions!

$$\mathcal{L} \supset y_q \phi \bar{q} q + \frac{\phi}{f_\gamma} F^2_{\mu\nu} + \frac{\phi}{f_g} G^2_{\mu\nu} + \frac{\tilde{h}_{\mu\nu}}{f_T} F^{\mu}{}_{\sigma} F^{\nu\sigma} + g \phi h^2$$

Gratta *et al.* PRD 102 (2020)

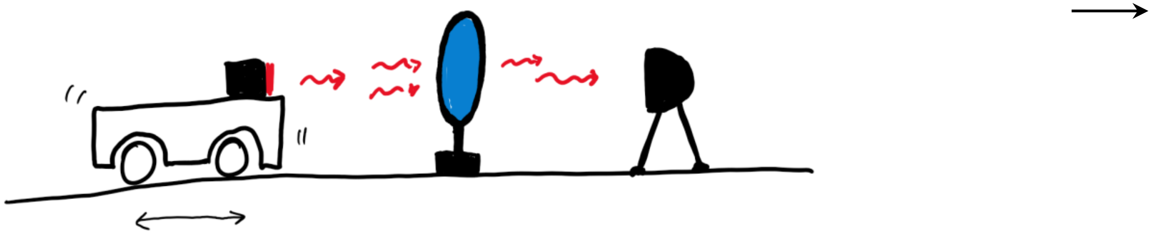
A special nuclear transition: its recoilless!



Mössbauer, Z. Naturforsch. 14A, 211 (1959)

Pound and Rebka, PRL 4

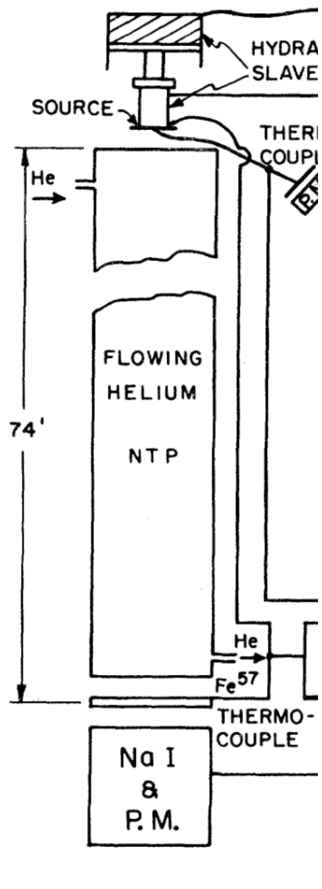
The line is so narrow that adding 1mm/s puts it out of resonance!

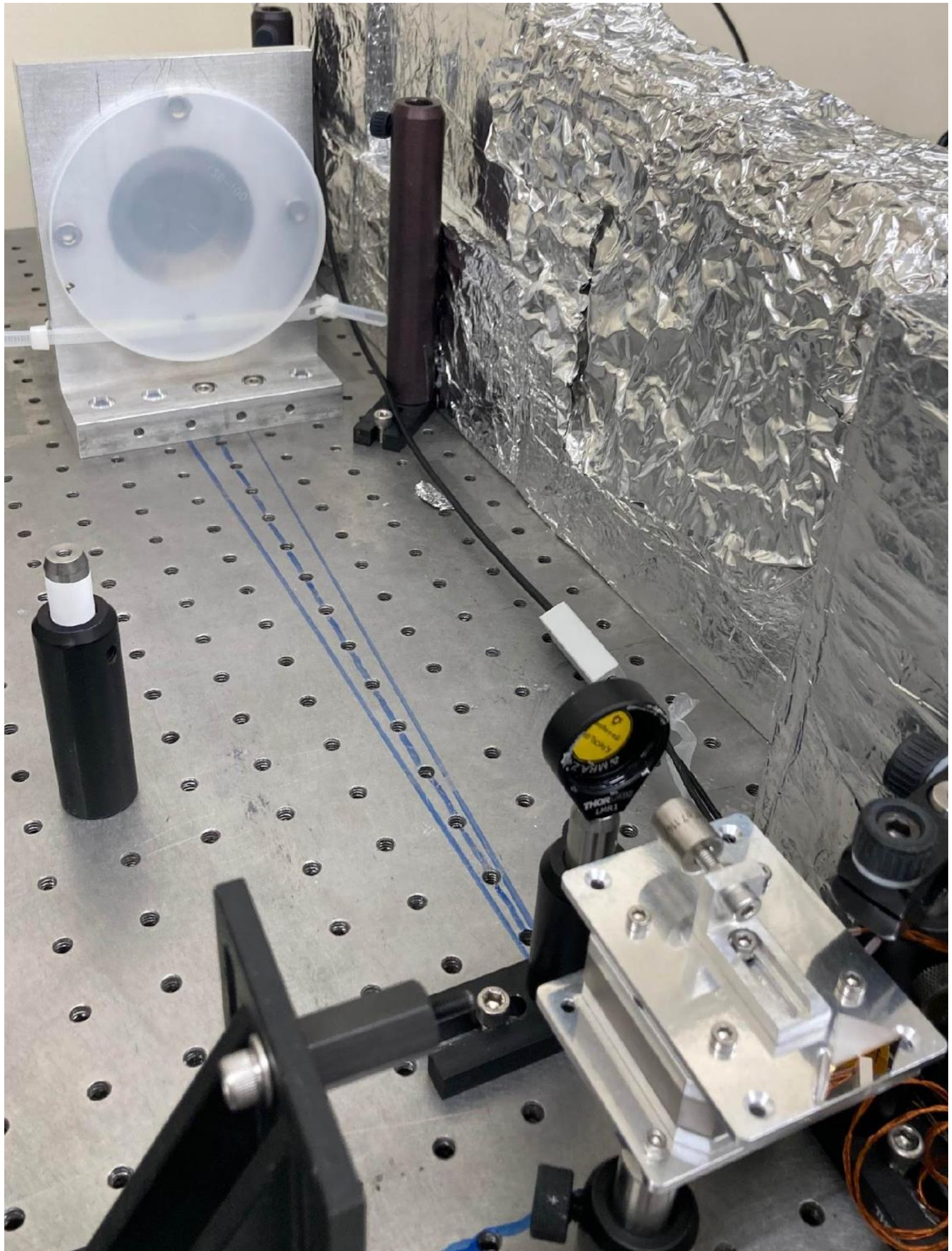


The Mossbauer effect was used to measure

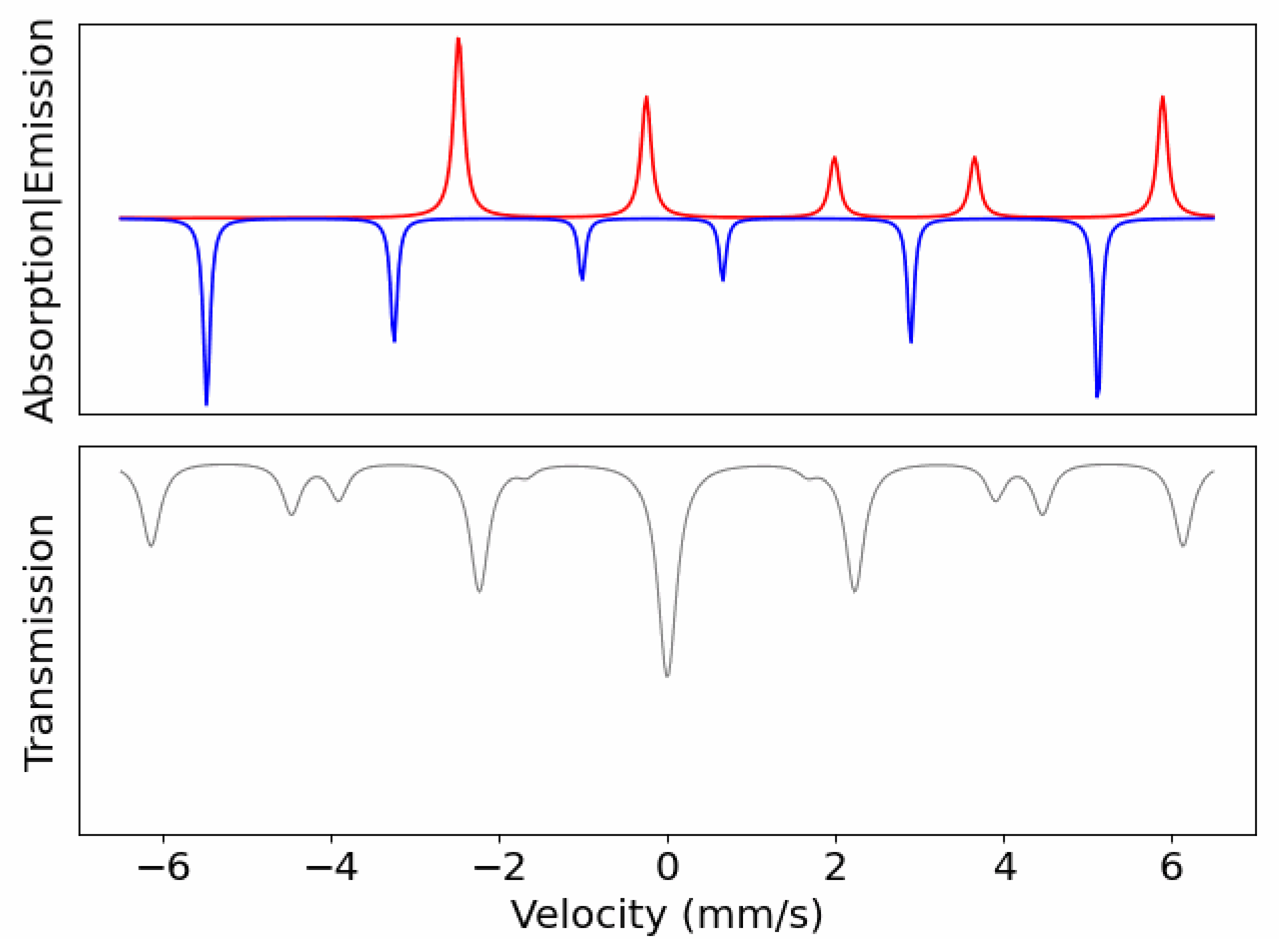
“The apparent weight of photons”

Pound and Rebka, PRL 4
(1960)



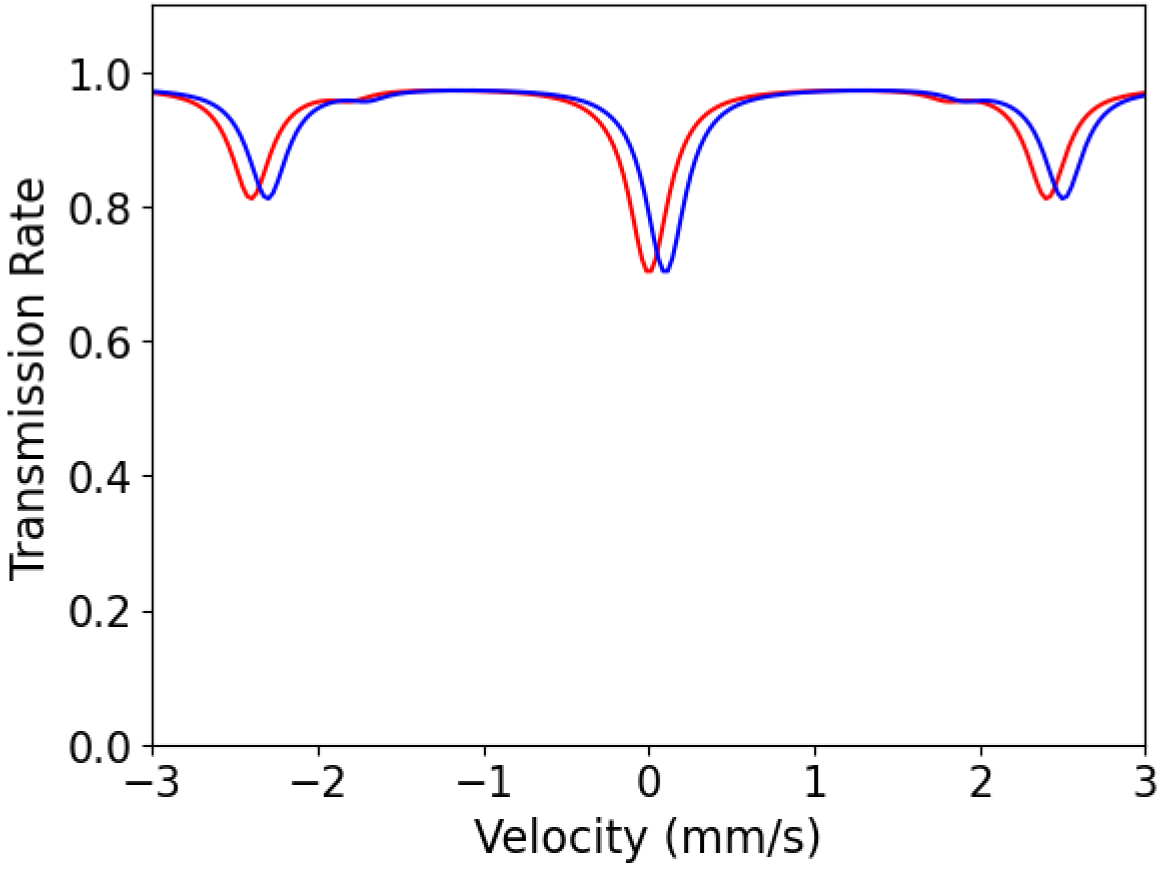


The true spectrum is more complicated!

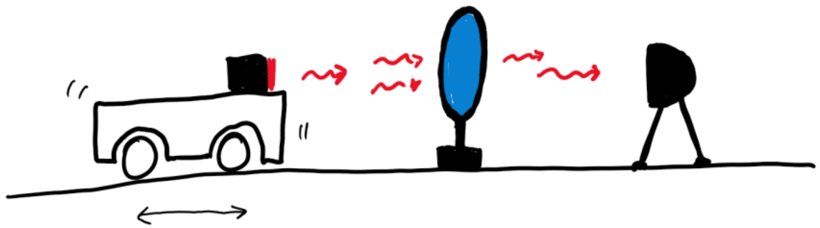


The energy sensitivity depends on contrast, linewidth and photon rate

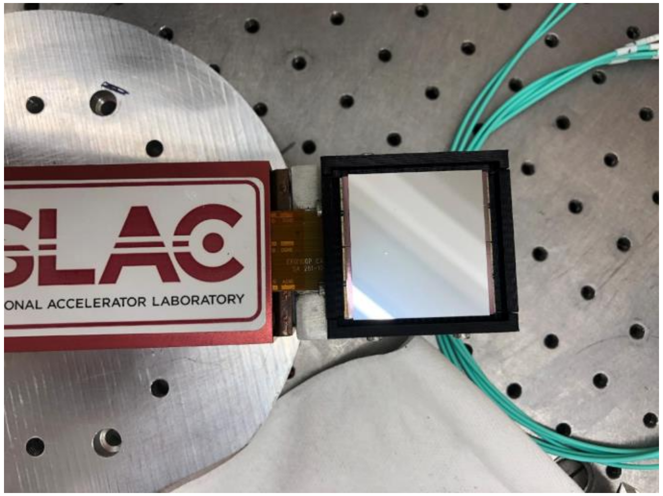
$$\delta E_{min} = \frac{T(v_0)}{2\sqrt{n}} \left| \frac{dT}{dv} \right|_{v_0}^{-1} \sim \frac{T(v_0)\,\Gamma}{2\sqrt{n}C}$$



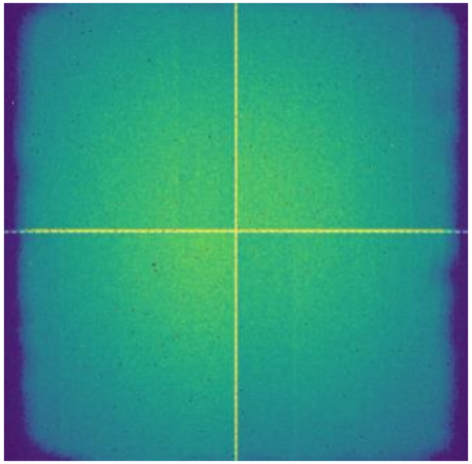
But how are we actually going to probe short range interactions?

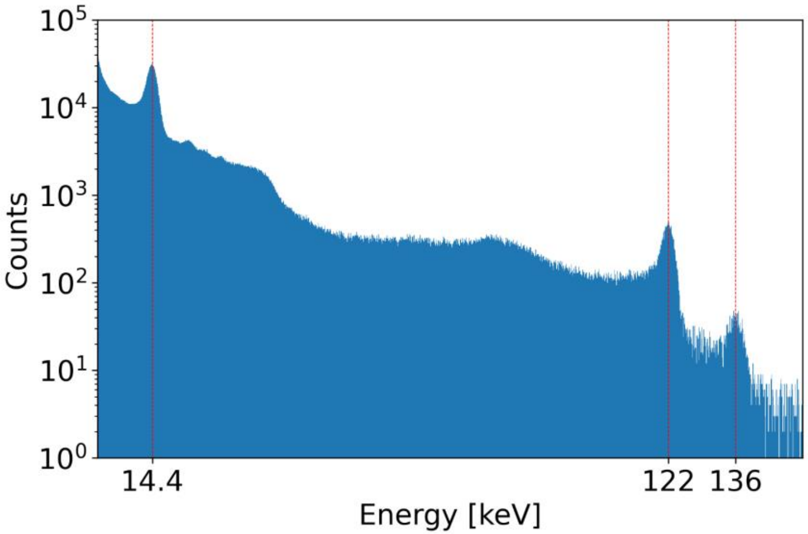


epix10ka xray camera form SLAC



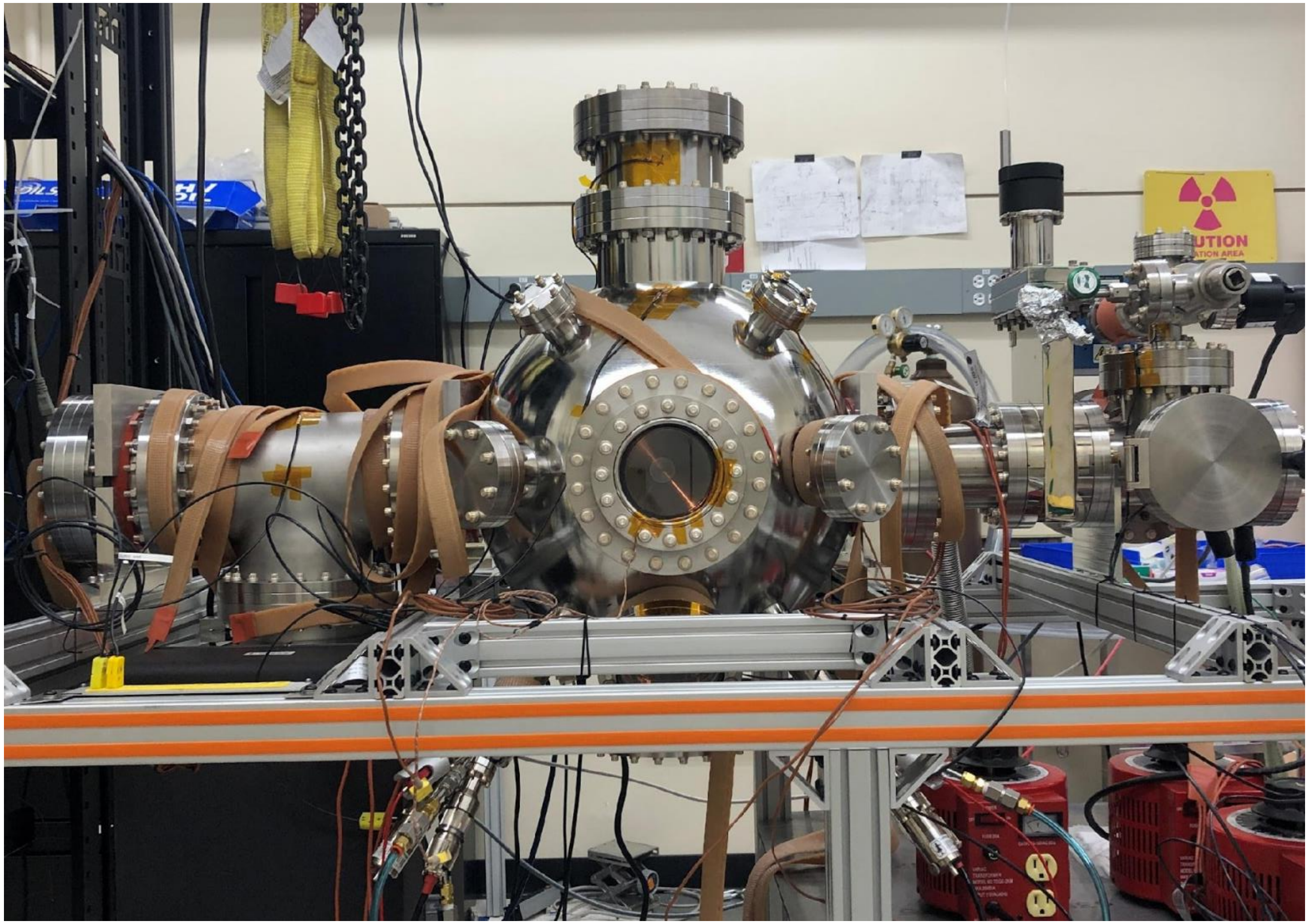
- $352\ x\ 384\ pixels$
- $1\ kHz$ framerate
- $500\ \mu m\ Si\ \rightarrow$ 75% efficiency at 14.4 keV

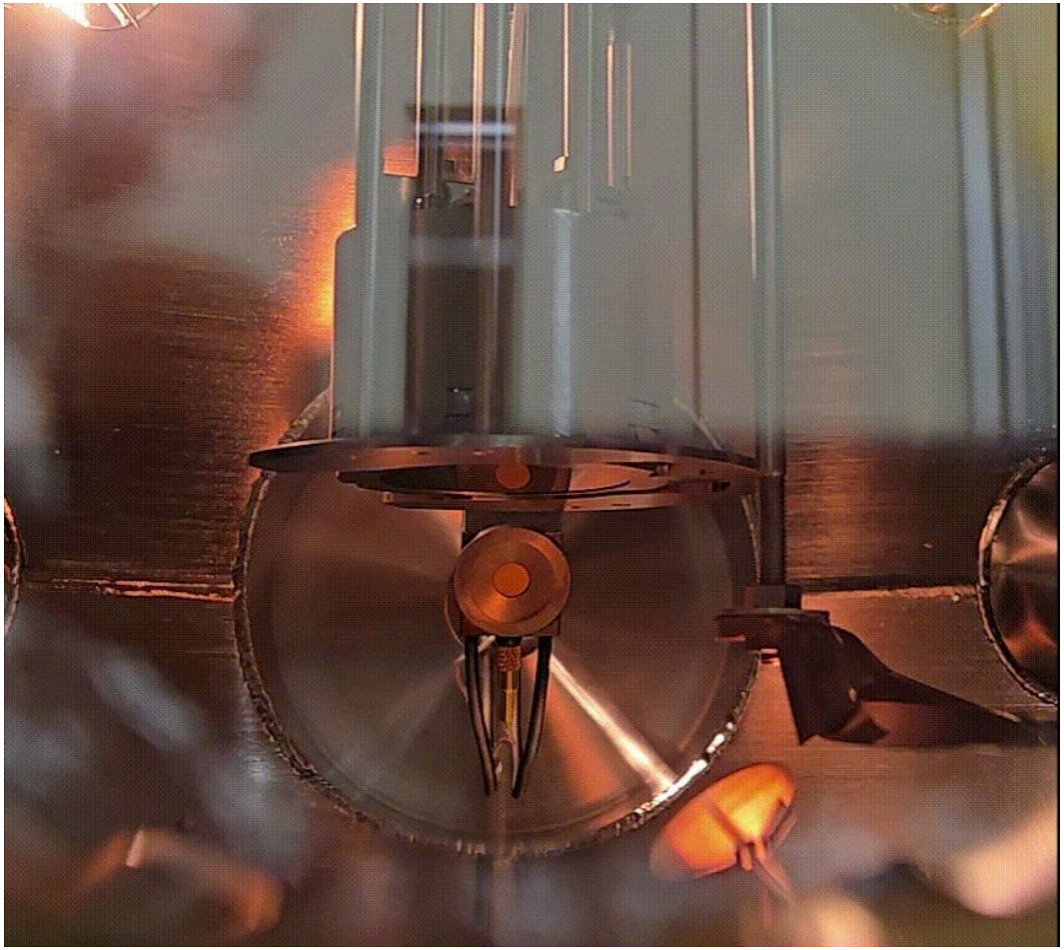


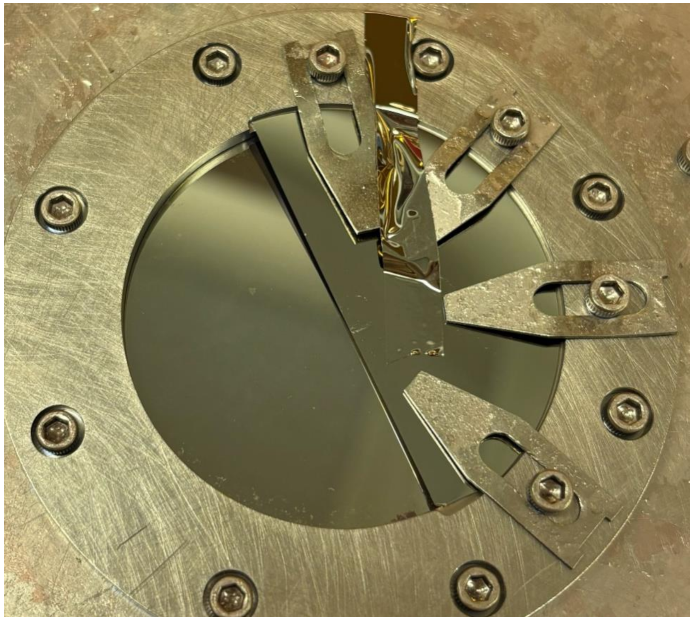


Nishimura *et al.*, AIP *Conf. Proc.*,1741

Fe57 is expensive so we made our own evaporator



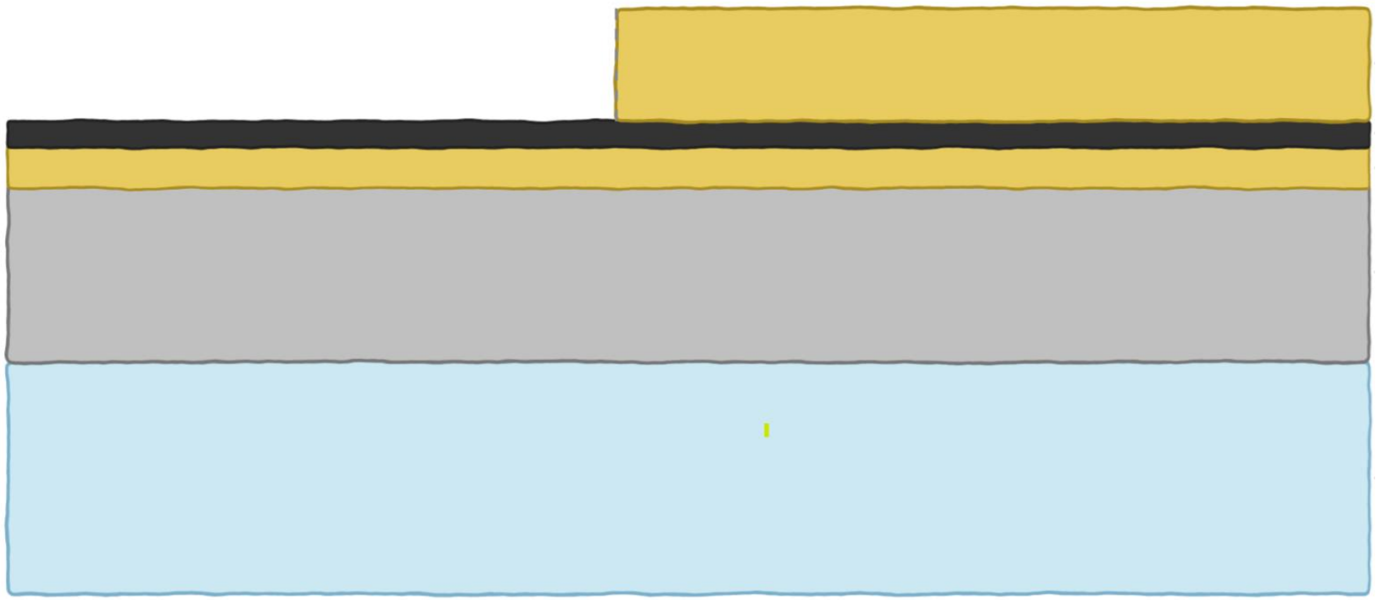




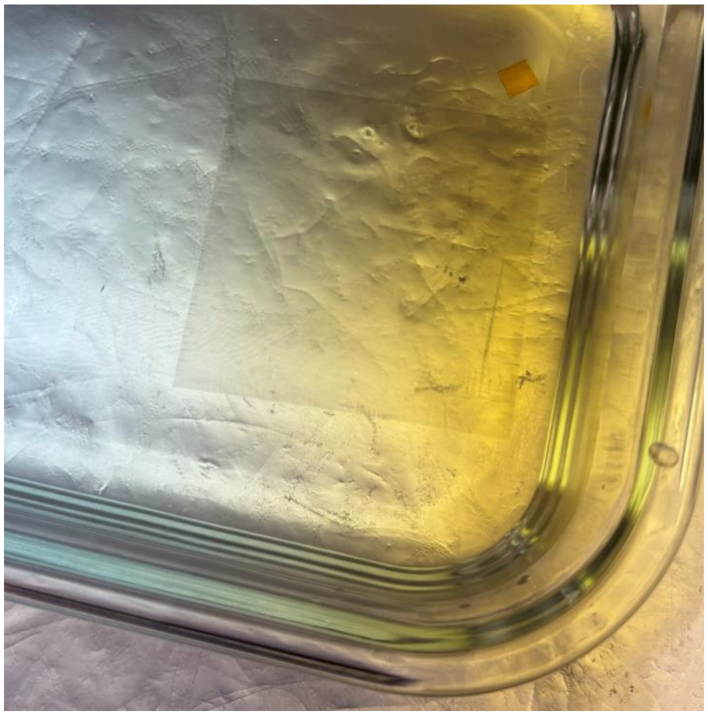
An energy shift of $10^{-15} eV$ is equivalent to:

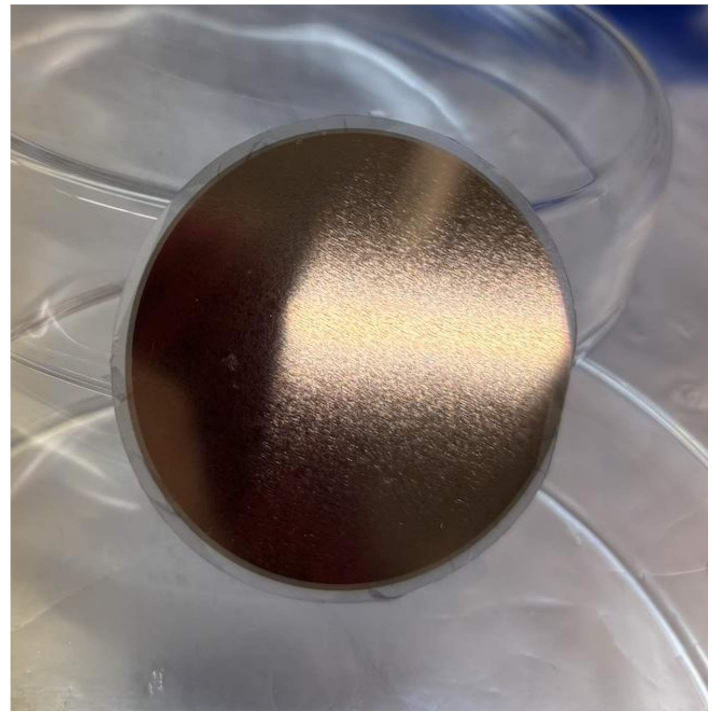
- Temperature $\Delta E \sim 10^{-11} \left(\frac{T}{300K}\right)^3 \; eV/K$ $\boxed{0.1\; mK}$
- Casimir $\Delta E \sim 3 \cdot 10^{-15} \left(\frac{10\; nm}{d}\right)^4 \; eV$ $\boxed{20\; nm}$
- Magnetic $\Delta E \ll 10^{-8} \; eV/T$ $\boxed{50\; nT}$
- Pressure $\Delta E \sim 10^{-10} \; eV/GPa$ $\boxed{10\; \mathrm{k}Pa}$

Across the size of the sample (2iches)!

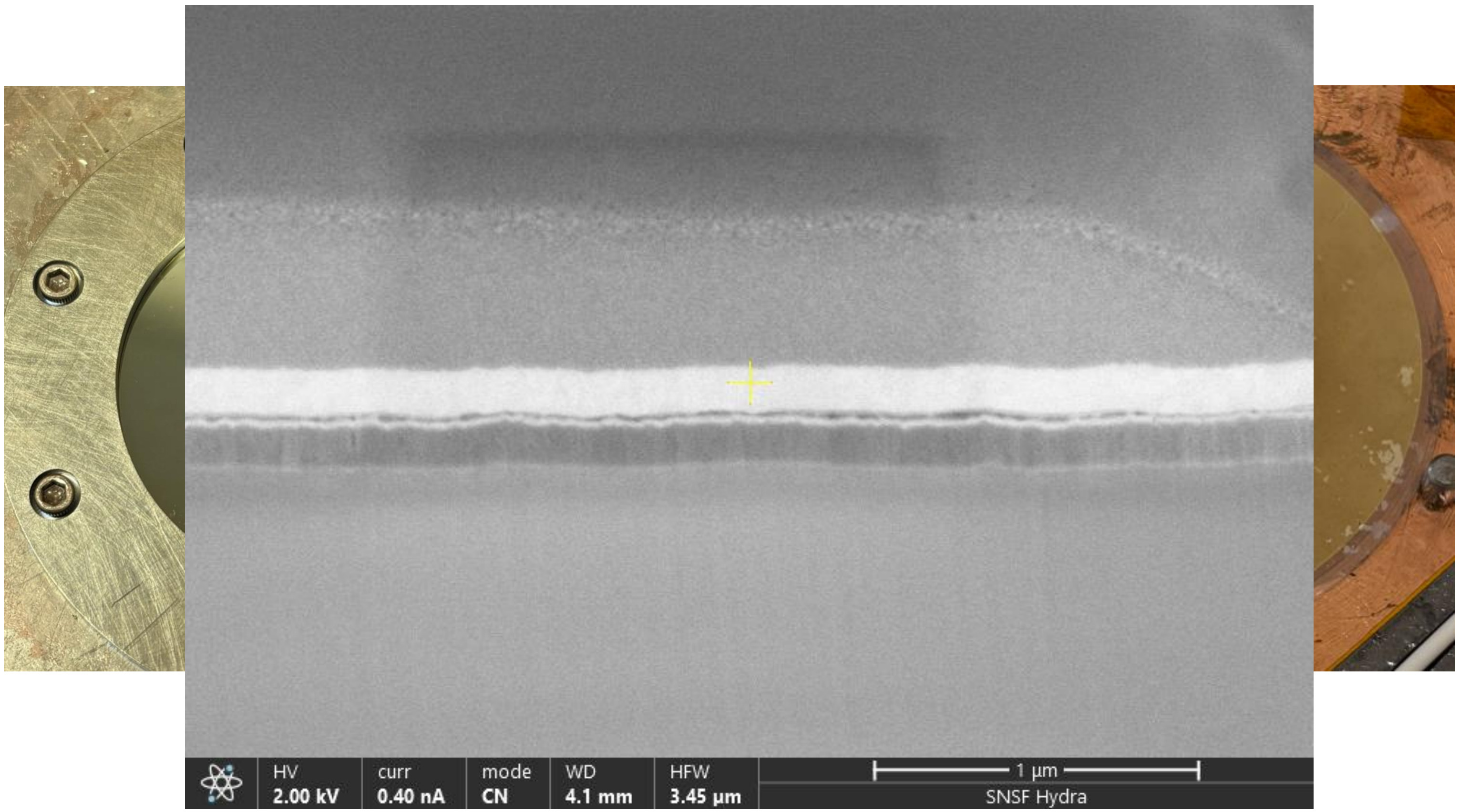


We use graphene sheets to attenuate possible surface stress form lattice mismatch

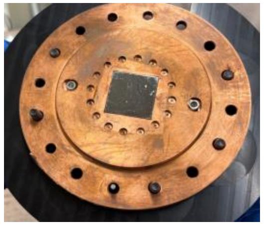


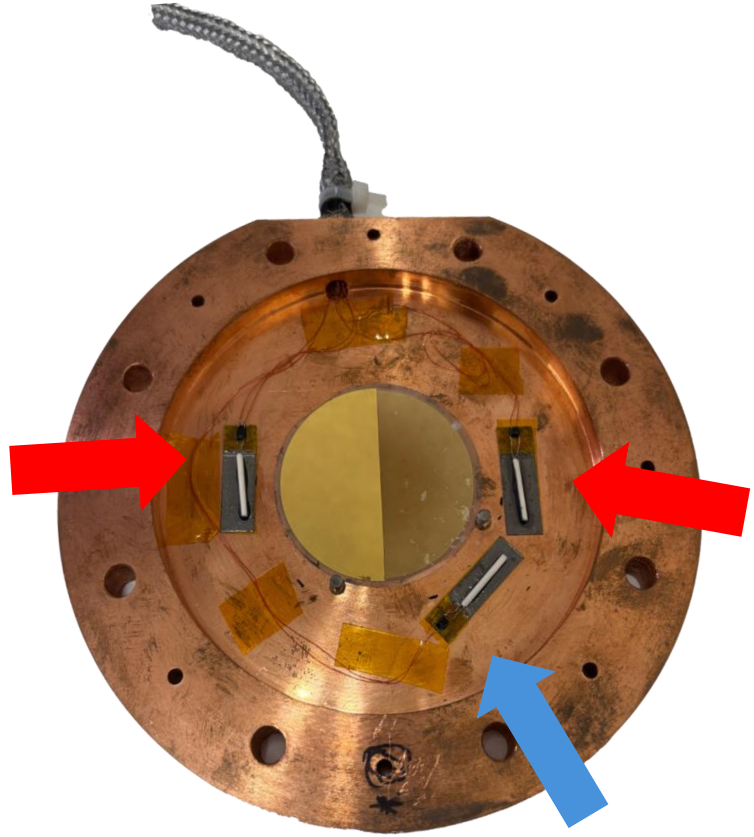


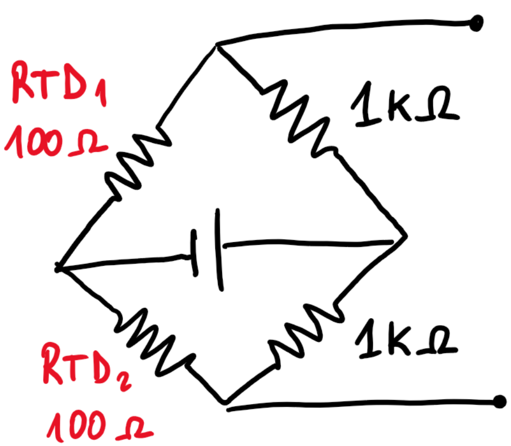
…and the gold is deposited on half of the sample

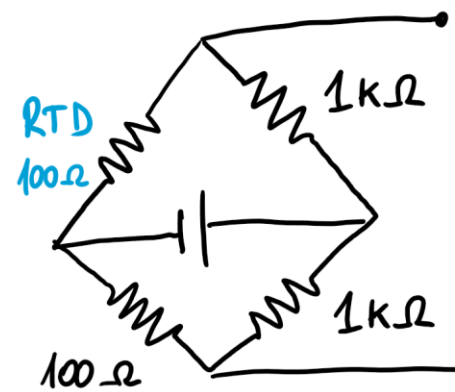


A temperature difference of 0.1 mk corresponds to $\Delta E \sim 10^{-15} eV$

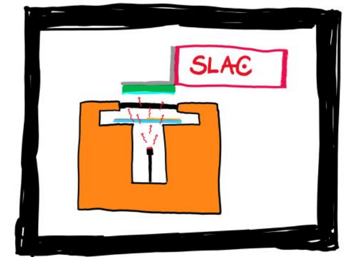


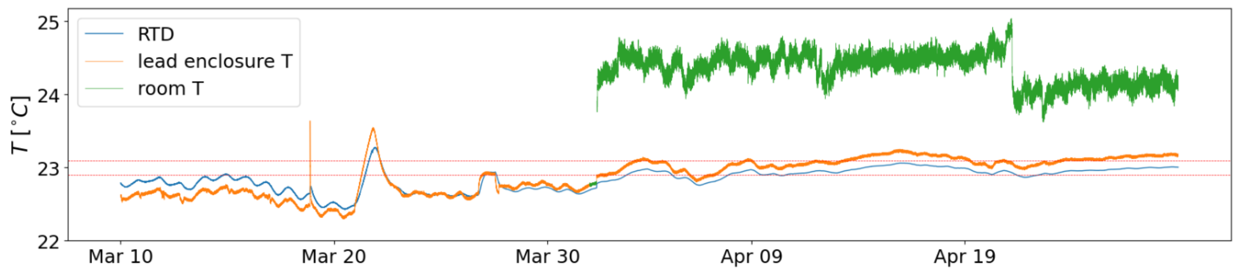


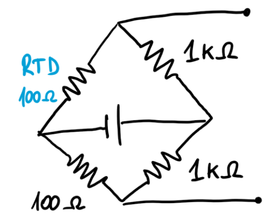

RTD1
100 Ω
1KΩ
1KΩ
RTD2
100 Ω

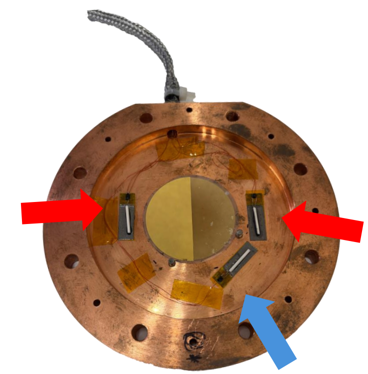

RTD
100Ω
1KΩ
1KΩ
100 Ω

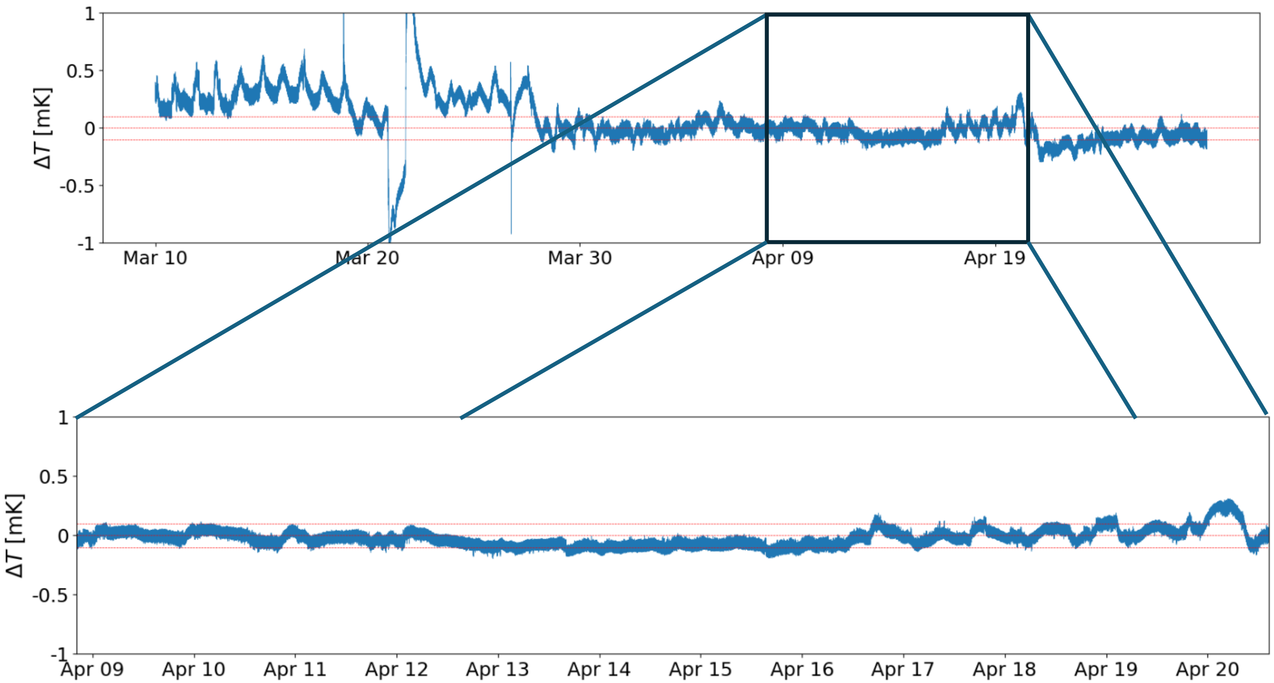
Temperature difference is stabilized to less than 0.2 mK!

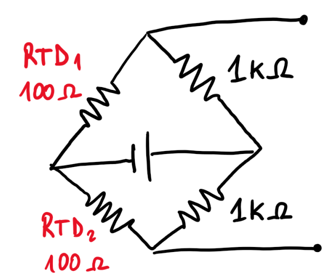


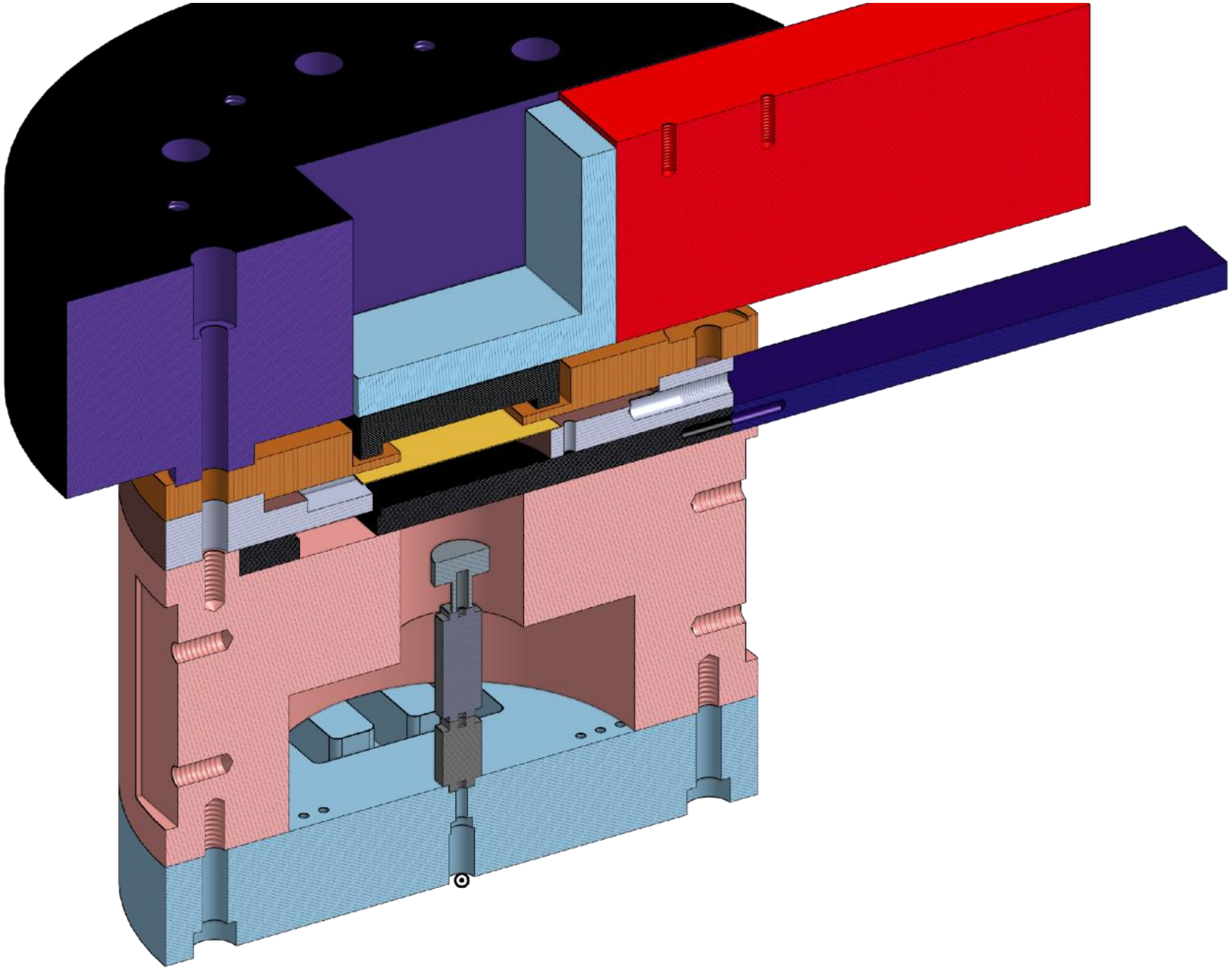


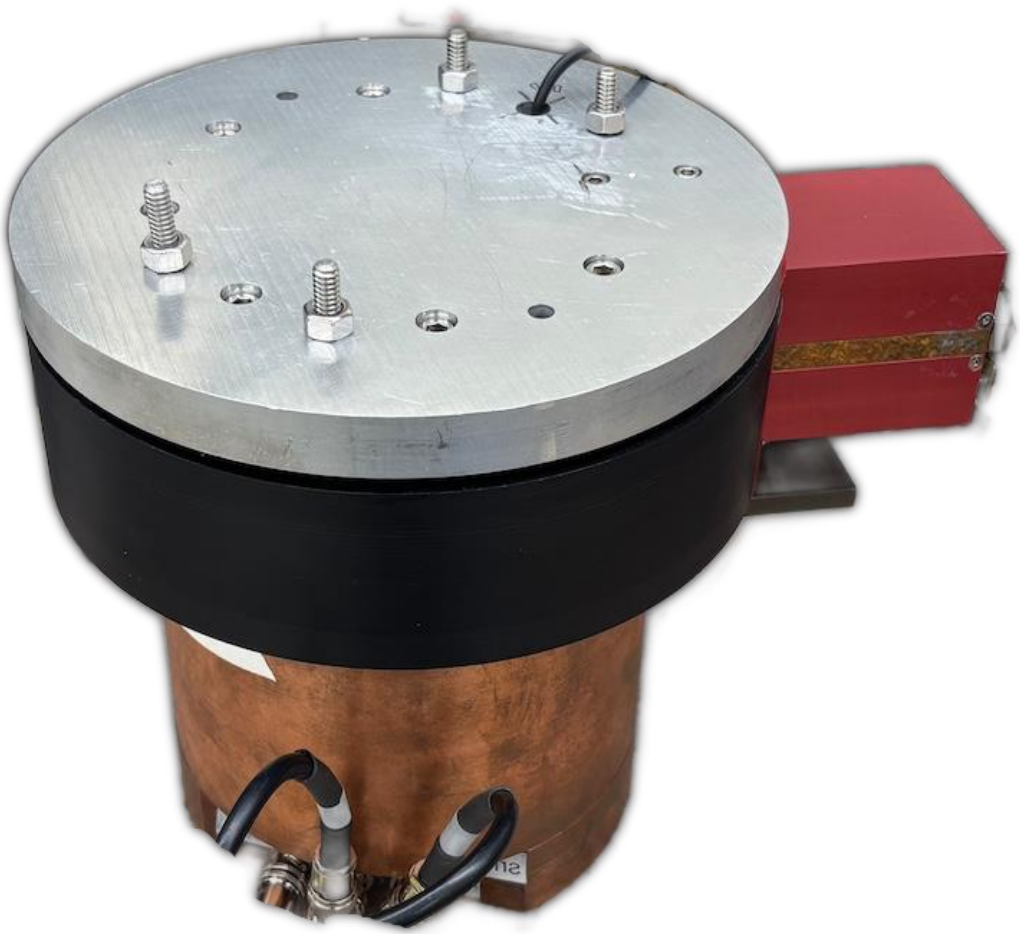




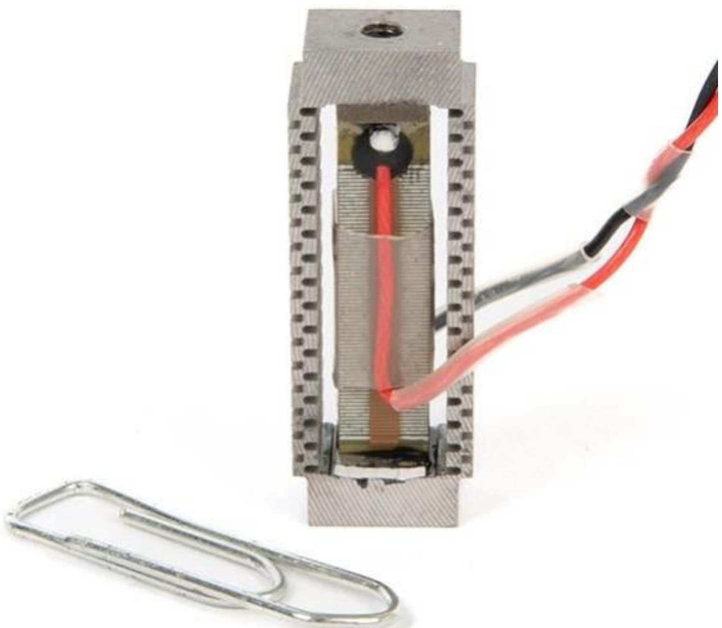


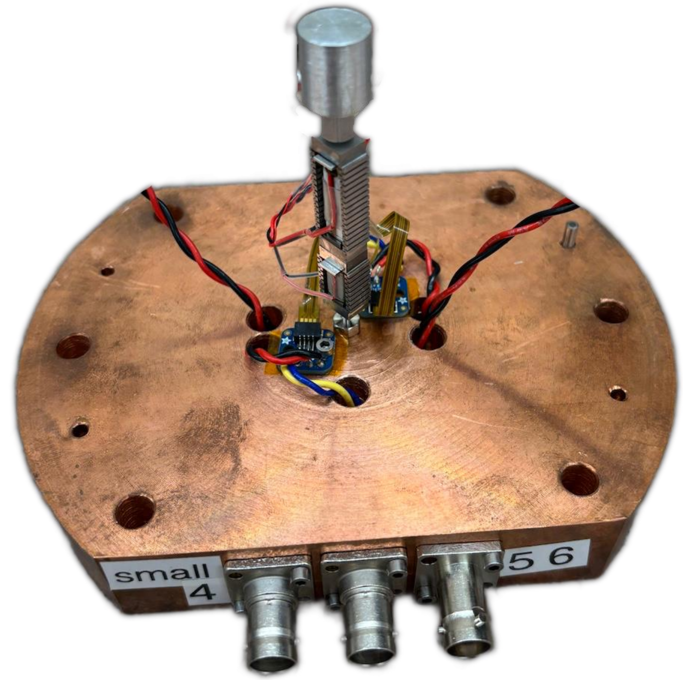




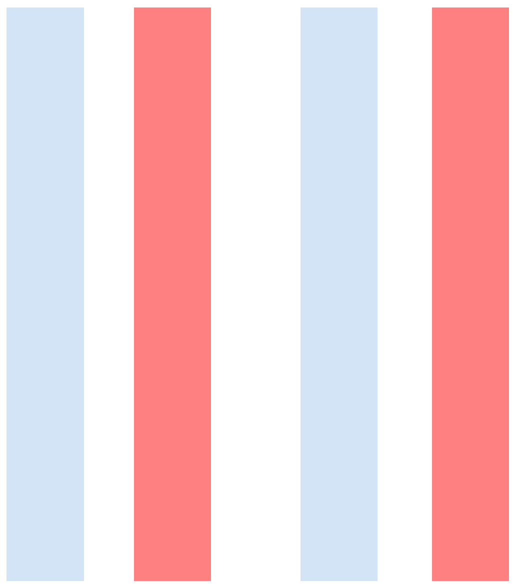


We move the source at $0.1mm/s$ with $10\ pm/s$ precision!





We measure at 2 fixed points



$A \sim 150\, nm$

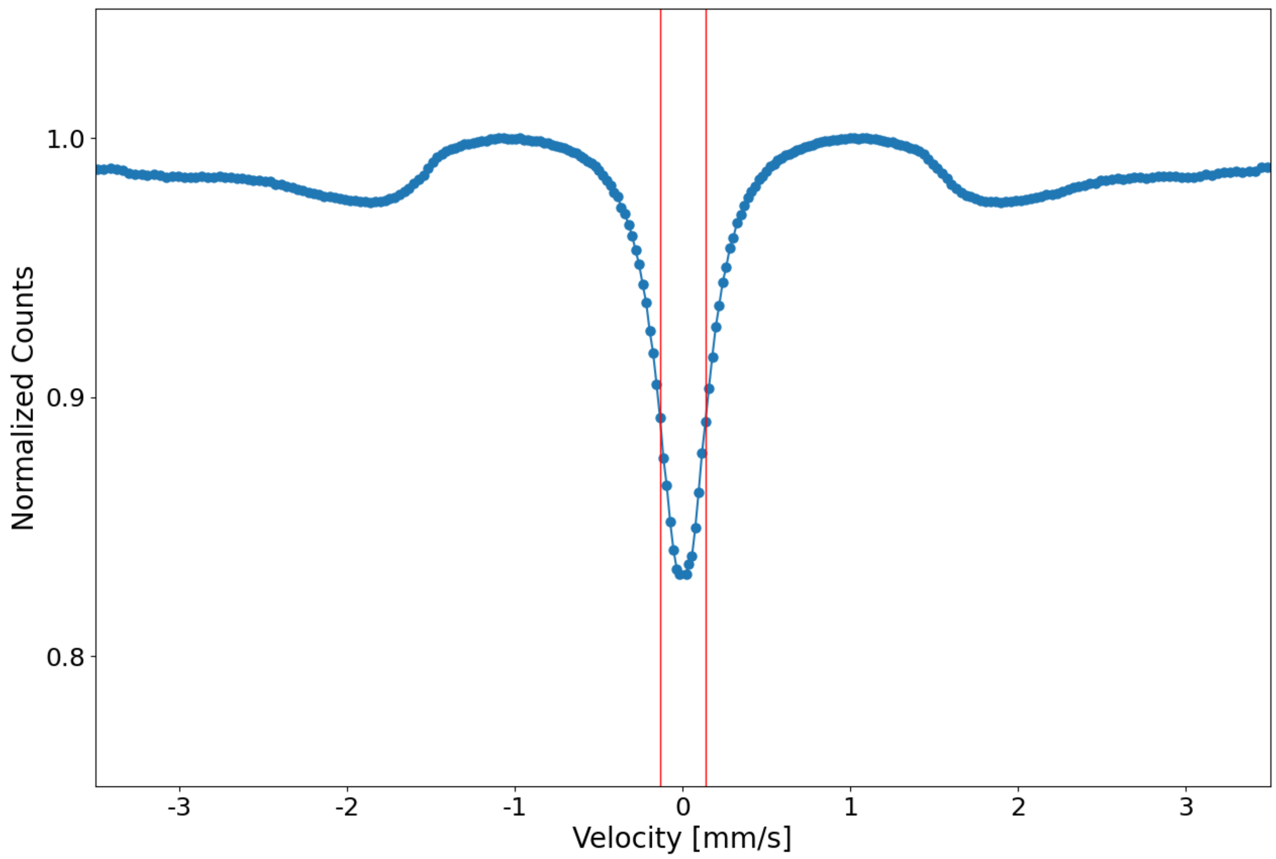
$f = 200\, Hz$

$v_{max} = 2\pi\, A\, f = 0.18\, mm/s$

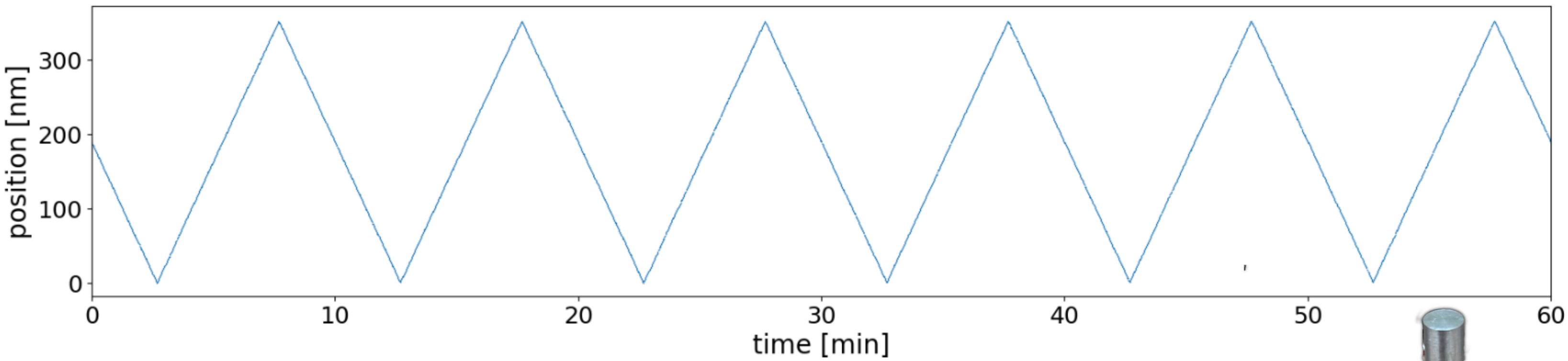
$\tau_{exp} = 1.6\, ms$

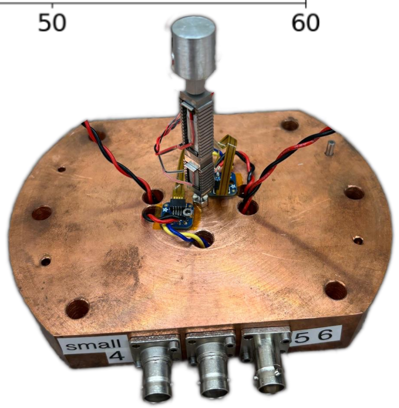
Pound and Rebka, PRL 4

Varying the amplitude we scan the velocity



for sensitivity calibration we inject a signal of 1 nm/s (1e-13 ev)

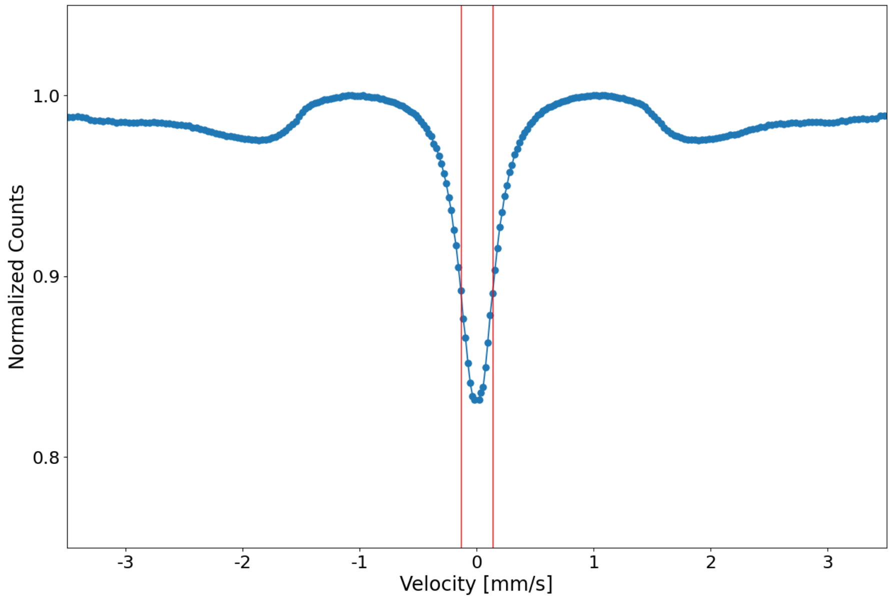




The energy sensitivity depends on contrast, linewidth and rate

$$\delta E_{min} = \frac{T(v_0)}{2\sqrt{n}} \left| \frac{dT}{dv} \right|_{v_0}^{-1} \sim \frac{T(v_0)\,\Gamma}{2\sqrt{n}C}$$

$$= 2 \cdot 10^{-14}\ eV$$

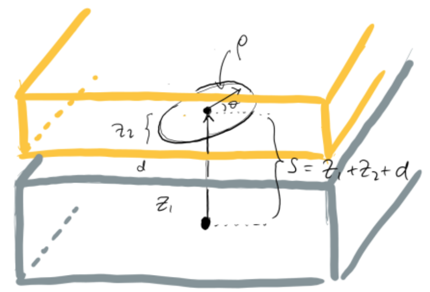


$$\Gamma = 0.24\ \mathrm{mm/s} = 1.2 \cdot 10^{-8}\ eV$$

$$C = 0.18$$

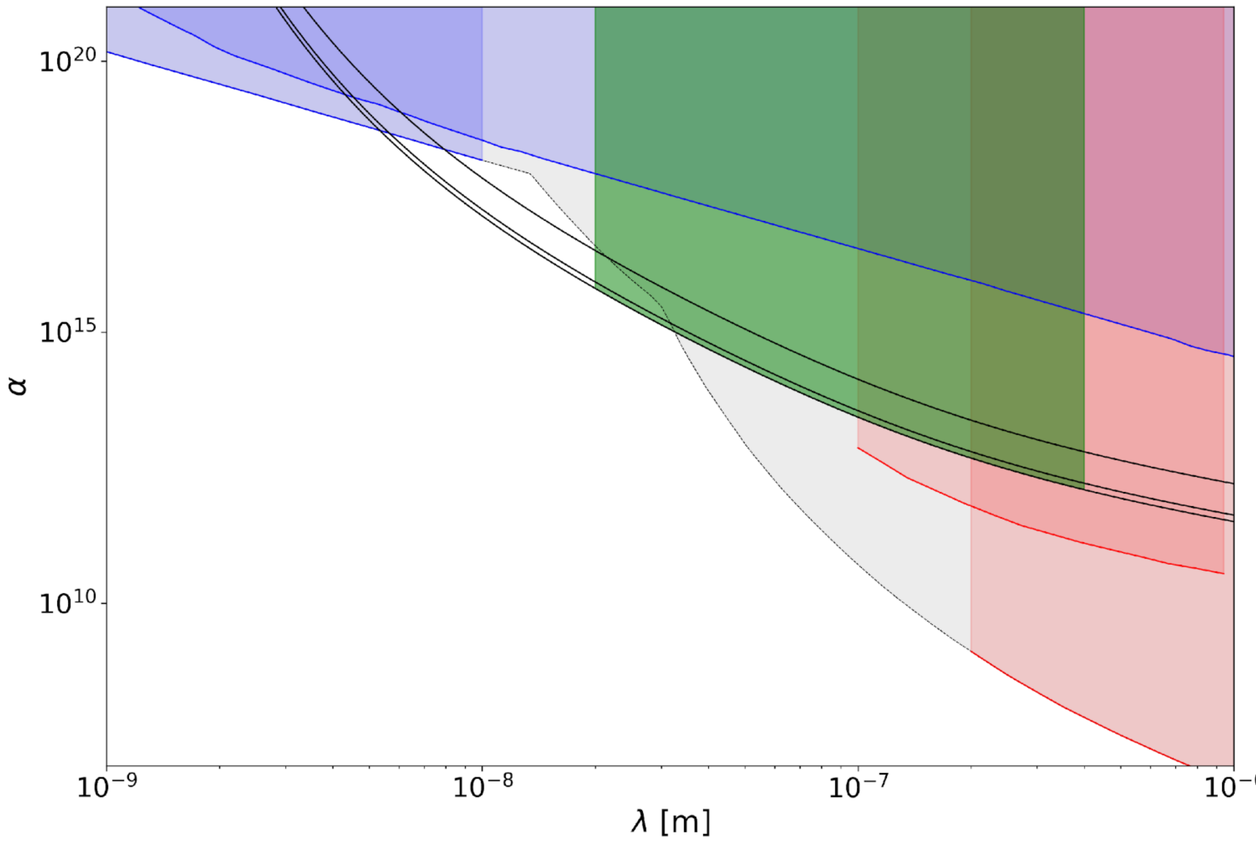
$$n = 4 \cdot 10^{12}\ per\ side\ (100\ days\ at\ 0.25\ M\ events/second)$$

the reach in parameter space depends on sensitivity, geometry and model



$$\alpha(\lambda) = C_{model} \frac{\delta E_{min} t_{Fe} \, e^{-d/\lambda}}{n_{Au} \lambda^3 (1 - e^{-t_{Fe}/\lambda})(1 - e^{-t_{Au}/\lambda})}$$

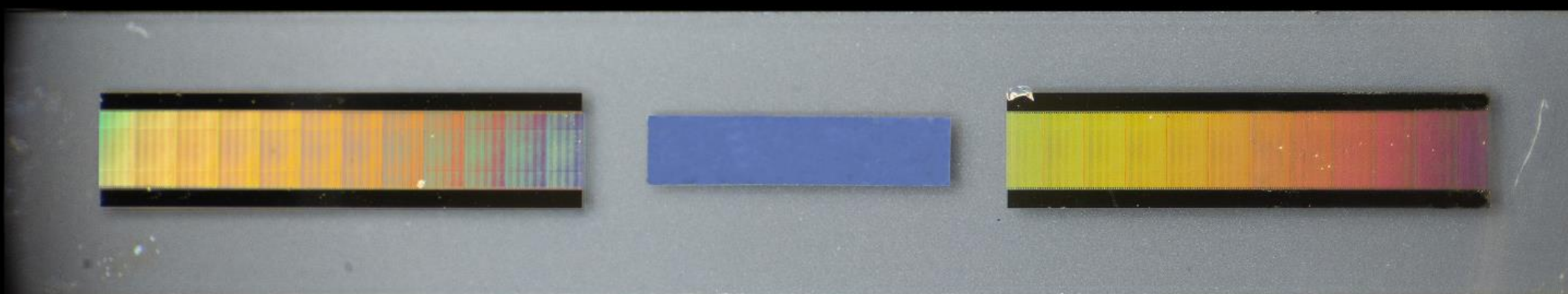
With a projected sensitivity of $2 \cdot 10^{-14}\ eV$,



"Tantalum181 has a natural linewidth of $10^{-10}eV$, that is 50 times narrower!"

Saul Balcarcel-Salazar

Coupling of a nuclear resonance to a surface acoustic wave



Nazeeri *et al.* PRL 136 18 (2026)

Thank you!

Saul Balcarcel-
Salazar

Albert
Nazeeri

Giorgio Gratta

Chiara Brandenstein

Chengjie
Jia

LELAND STANFORD JUNIOR UNIVERSITY 1891

SLAC NATIONAL ACCELERATOR LABORATORY

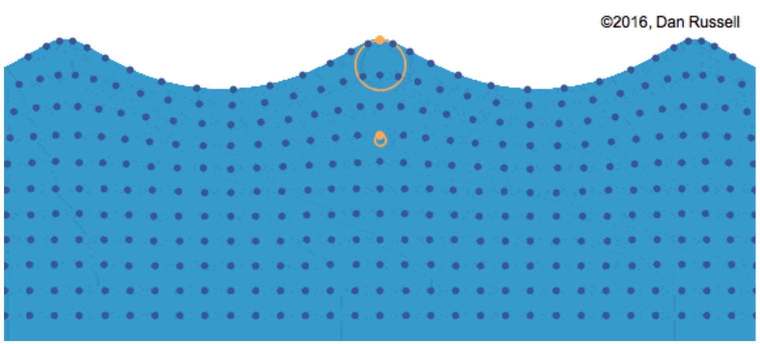
SIMONS FOUNDATION

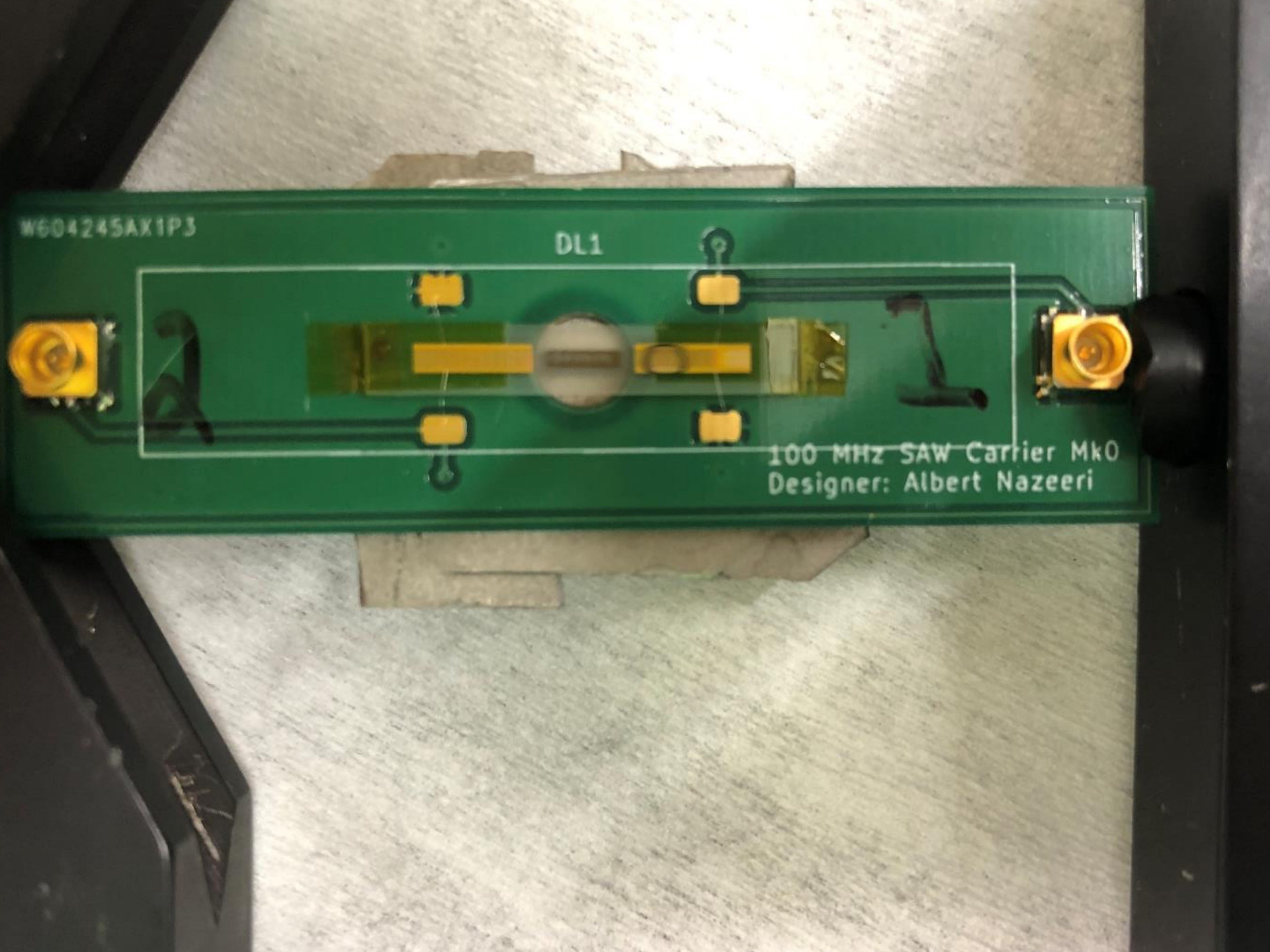
GORDON AND BETTY MOORE FOUNDATION

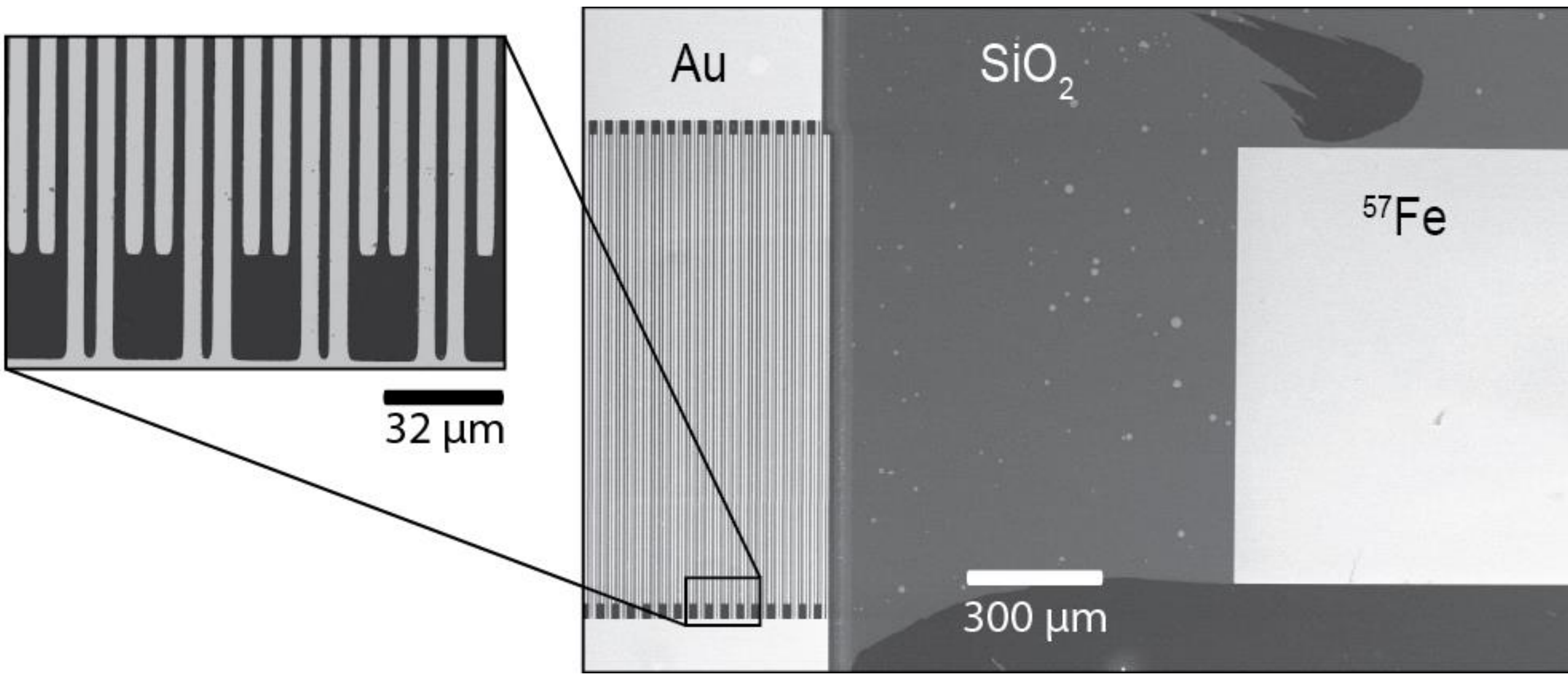
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH UNITED STATES AIR FORCE

a voltage signal drives (surface acoustic) waves on the surface of a solid

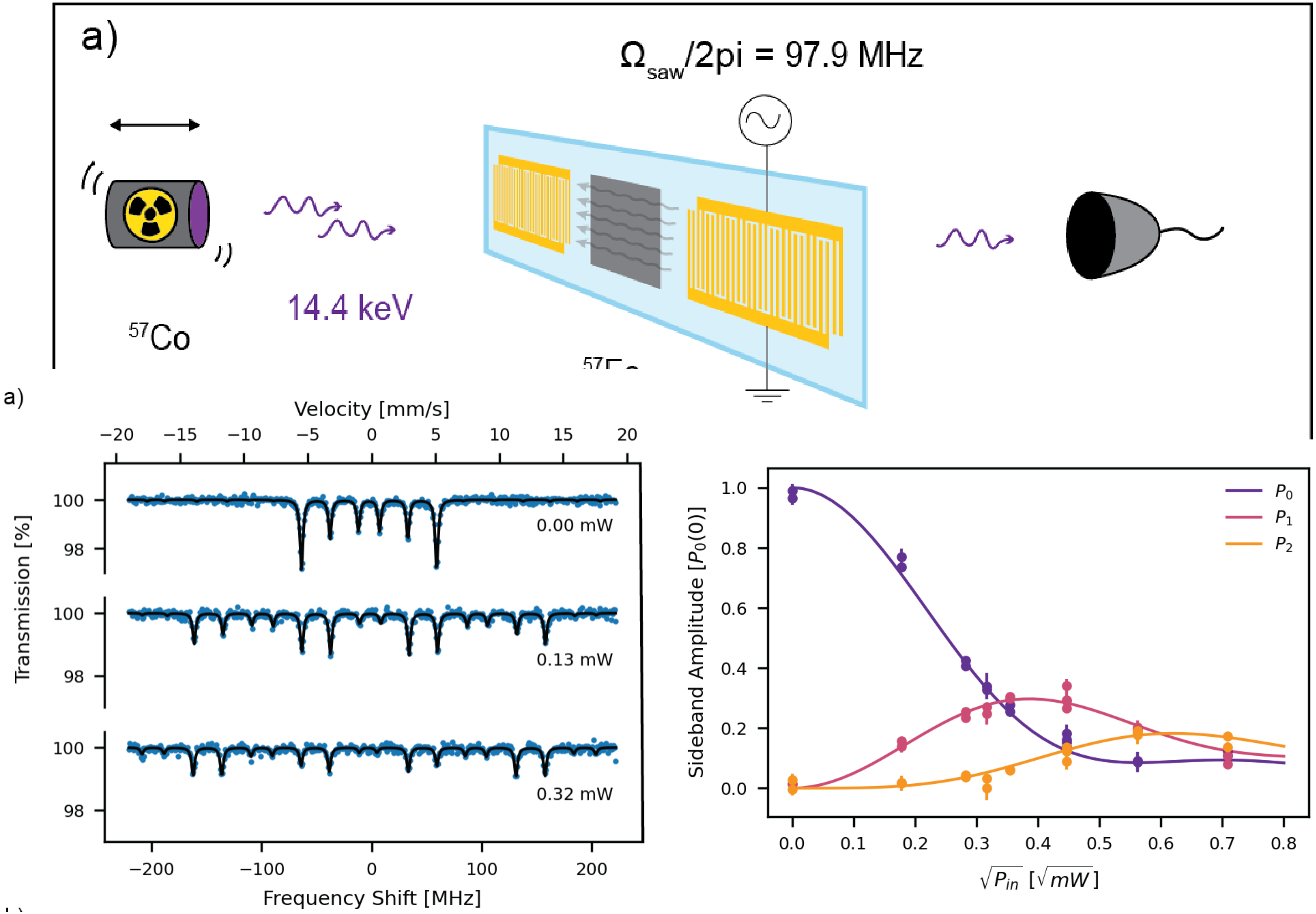
$$f = \frac{v_s}{\lambda}$$




W60424SAX1P3
DL1
100 MHz SAW Carrier Mk0
Designer: Albert Nazeeri

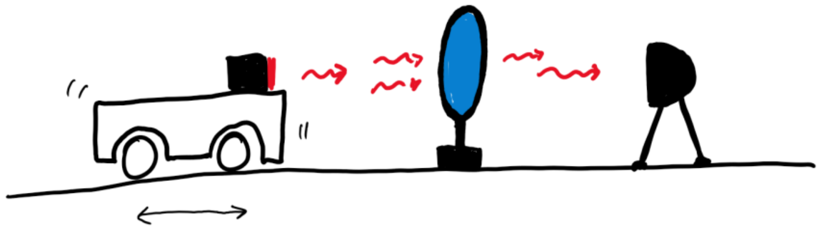


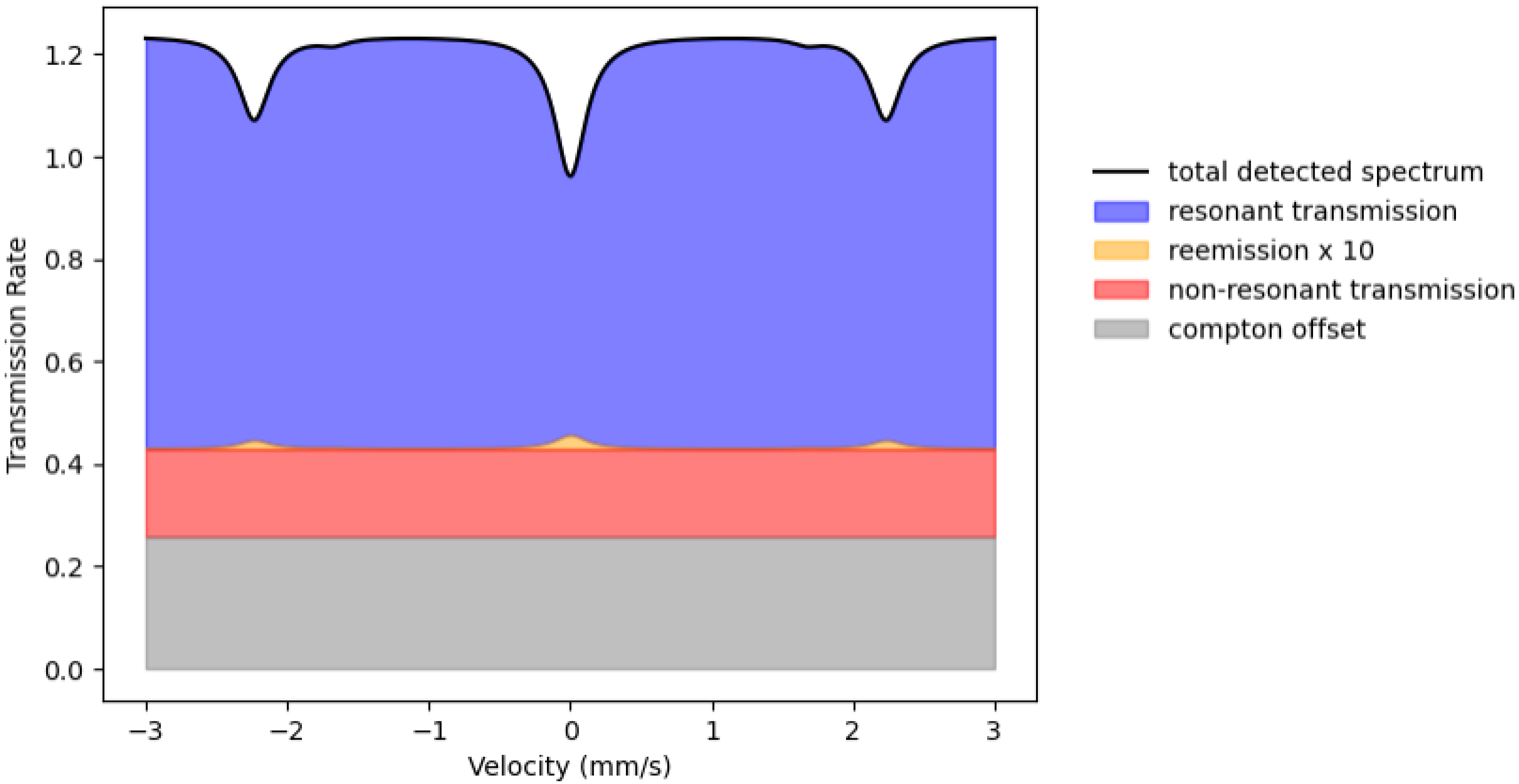
32 µm
Au
SiO2
57Fe
300 µm



a)
Ωsaw/2pi = 97.9 MHz
14.4 keV
57Co
a)
Velocity [mm/s]
−20 −15 −10 −5 0 5 10 15 20
Transmission [%]
100
98
0.00 mW
0.13 mW
0.32 mW
−200 −100 0 100 200
Frequency Shift [MHz]
Sideband Amplitude [P0(0)]
1.0 0.8 0.6 0.4 0.2 0.0
P0
P1
P2
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
√Pin [√mW]

The line is so narrow that adding 1mm/s puts it out of resonance!





1.2
1.0
0.8
0.6
0.4
0.2
0.0
Transmission Rate
−3
−2
−1
0
1
2
3
Velocity (mm/s)
total detected spectrum
resonant transmission
reemission x 10
non-resonant transmission
compton offset