Designing and testing a phonon-mediated Kinetic Inductance Detector with phonon-funneling volume

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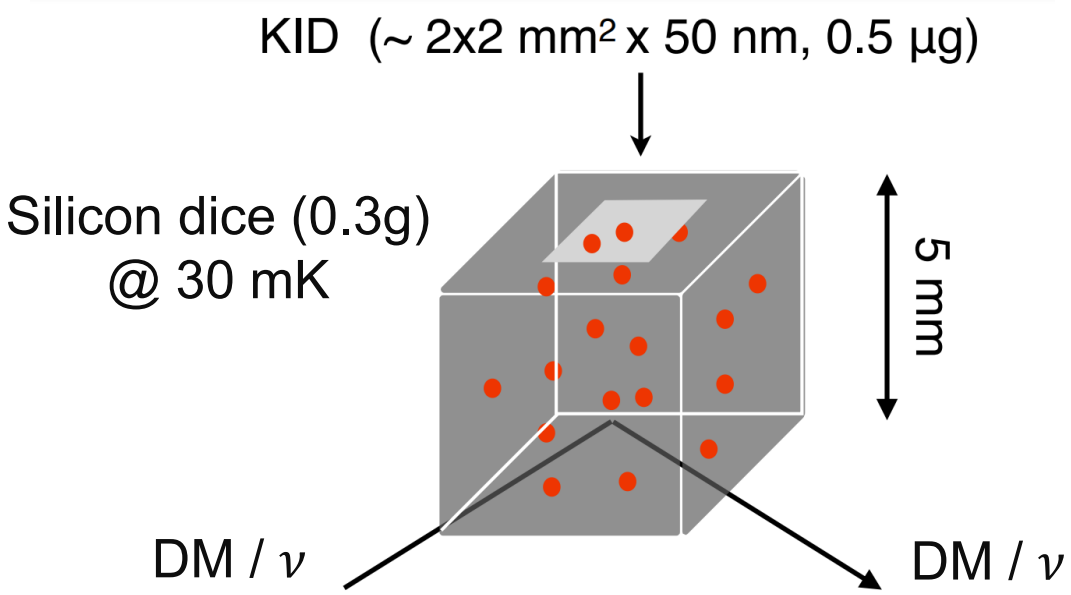
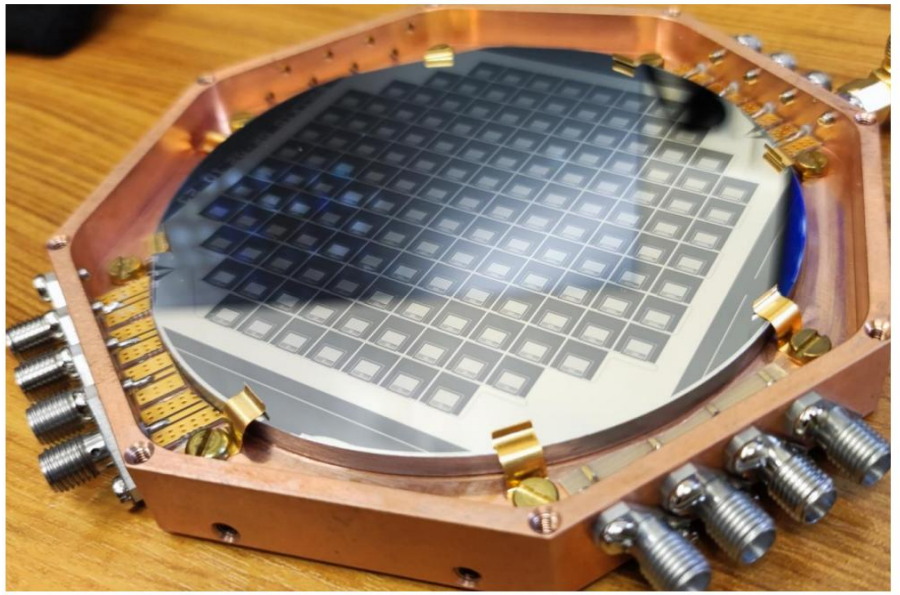
Phonon-mediated KIDs: the BULLKID project

- **BULLKID** detector → **Light Dark Matter** search or **Coherent Elastic Neutrino-Nucleus Scattering** measurements.
- **Silicon** dice target sensed with Kinetic Inductance Detectors (**KID**s).
- Low energy threshold needed (~ $\mathcal{O}$ **(0.1−1) keV**).



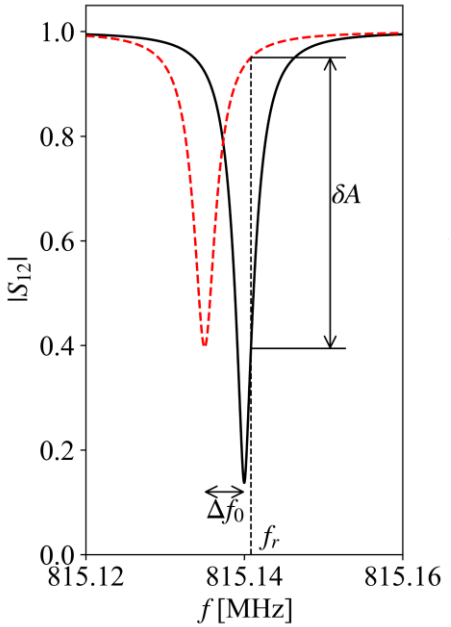


KID: the working principle

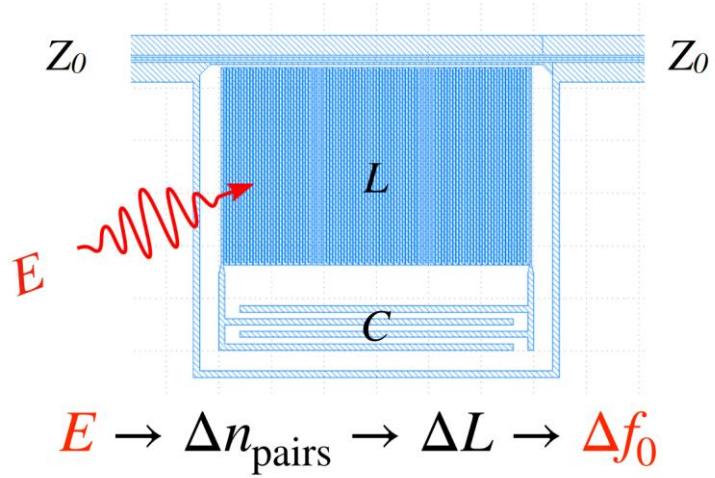
- **RLC superconducting** resonator coupled to a feed-line:

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \qquad L = L_k + L_g$$

Kinetic Inductance: motion of Cooper Pairs in the superconductor



1. Phonons break Copper Pairs (**CP**) and Quasi-Particles (**QP**) released.
2. Change of the Kinetic Inductance $\boldsymbol{\Delta L}$.
3. Shift of the resonance frequency $\boldsymbol{\Delta f_0}$.

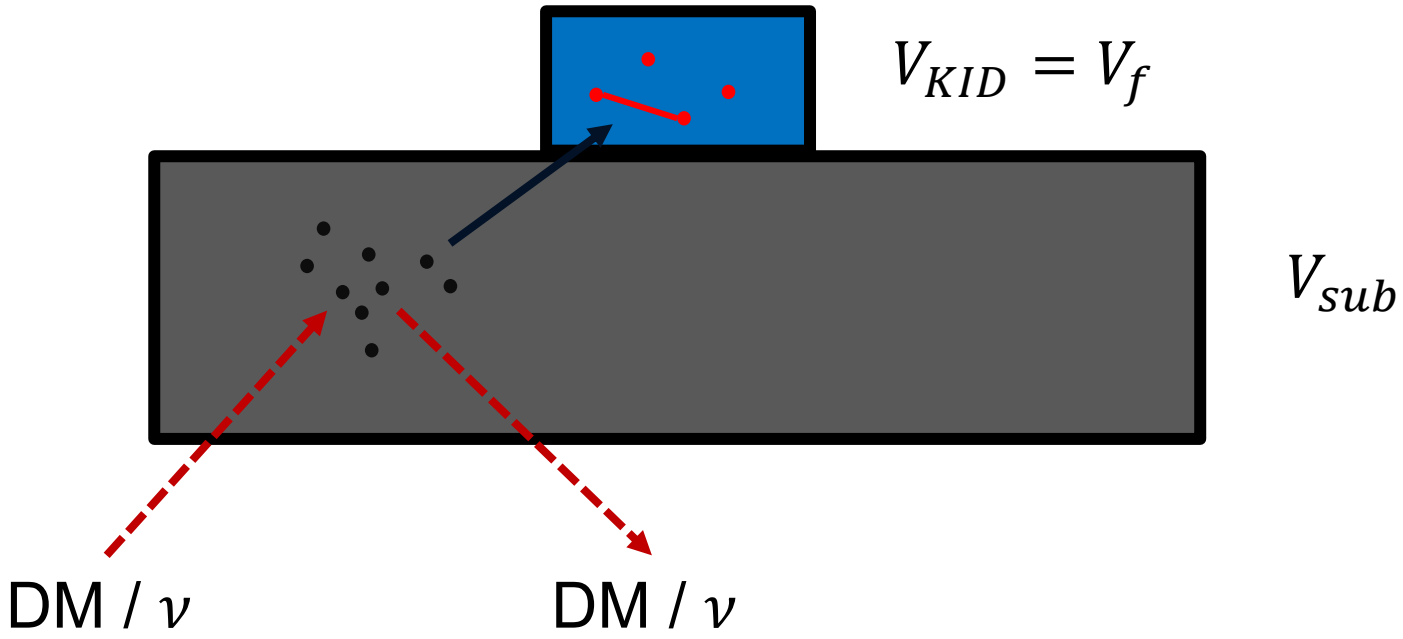


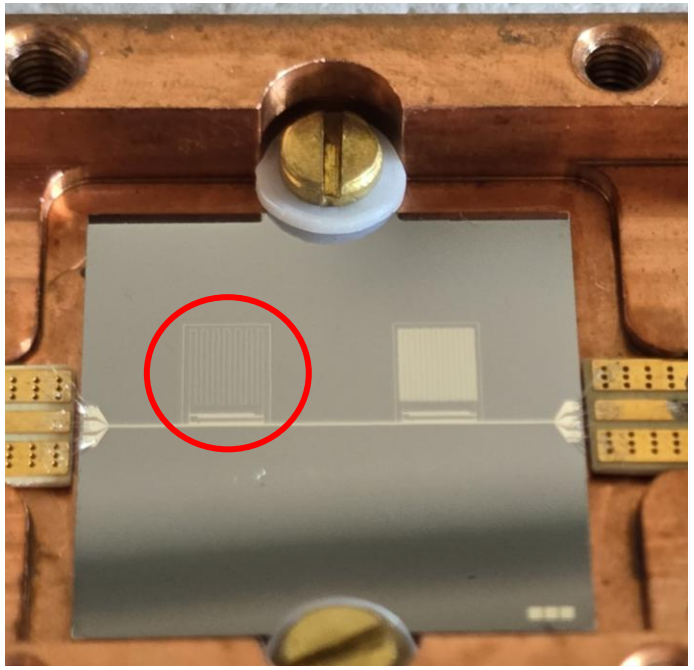
How to improve ?

- **Phonon collection efficiency η** plays a key role for detector **responsivity**, energy **resolution** and **threshold.**

- You may want to maximize the phonon collection volume.

Active sensor volume V_{KID} **coincides** with phonon collection volume V_f

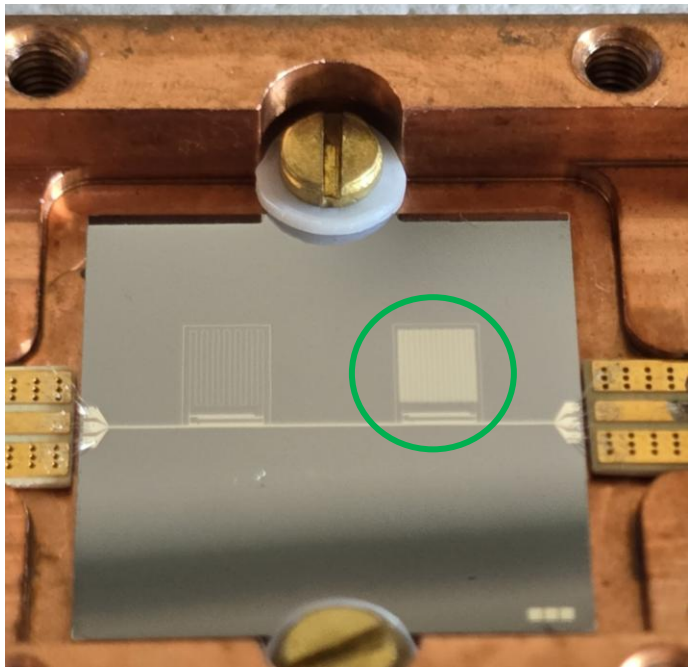


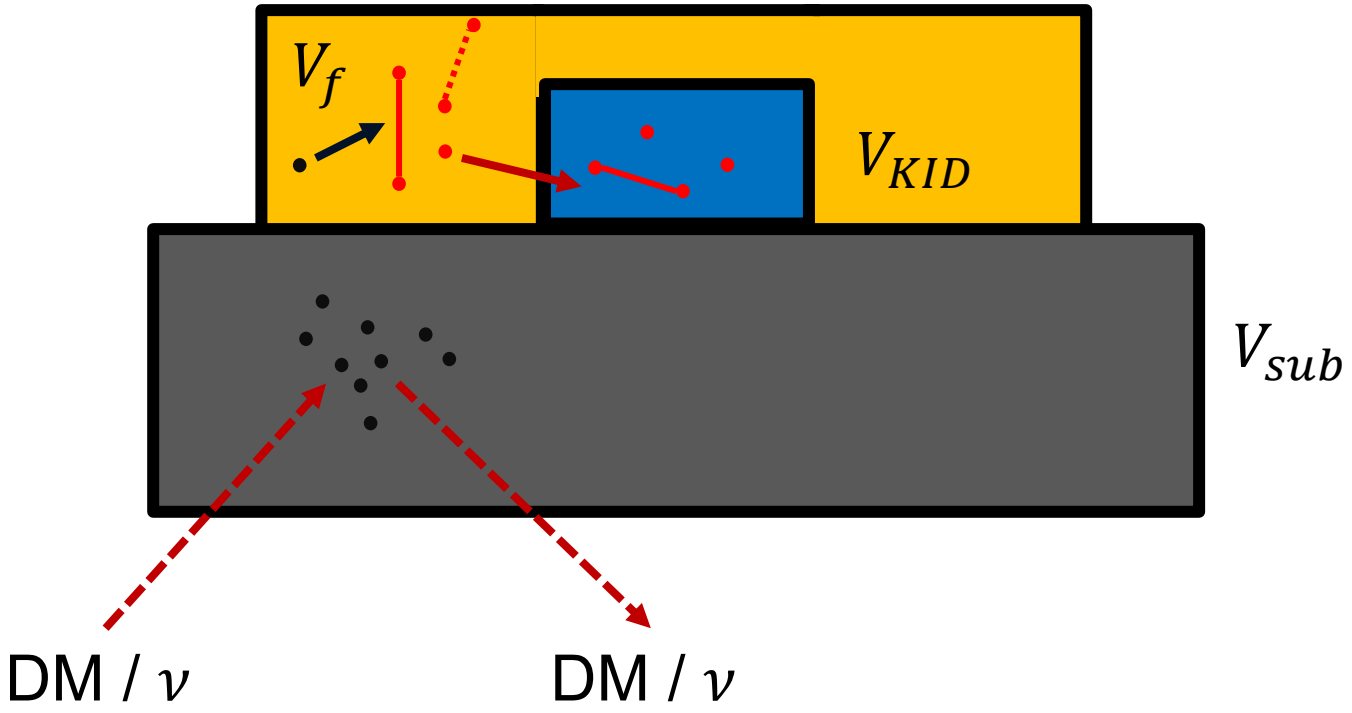


A possible way: Funnell-KID

- Large collection phonon structures surrounding the KID (funnells).
- Funnels in Al and KID in trilayer Al/Ti/Al with different superconductive gaps Δ_0.

Active sensor volume V_{KID} **separated** from phonon collection volume V_f



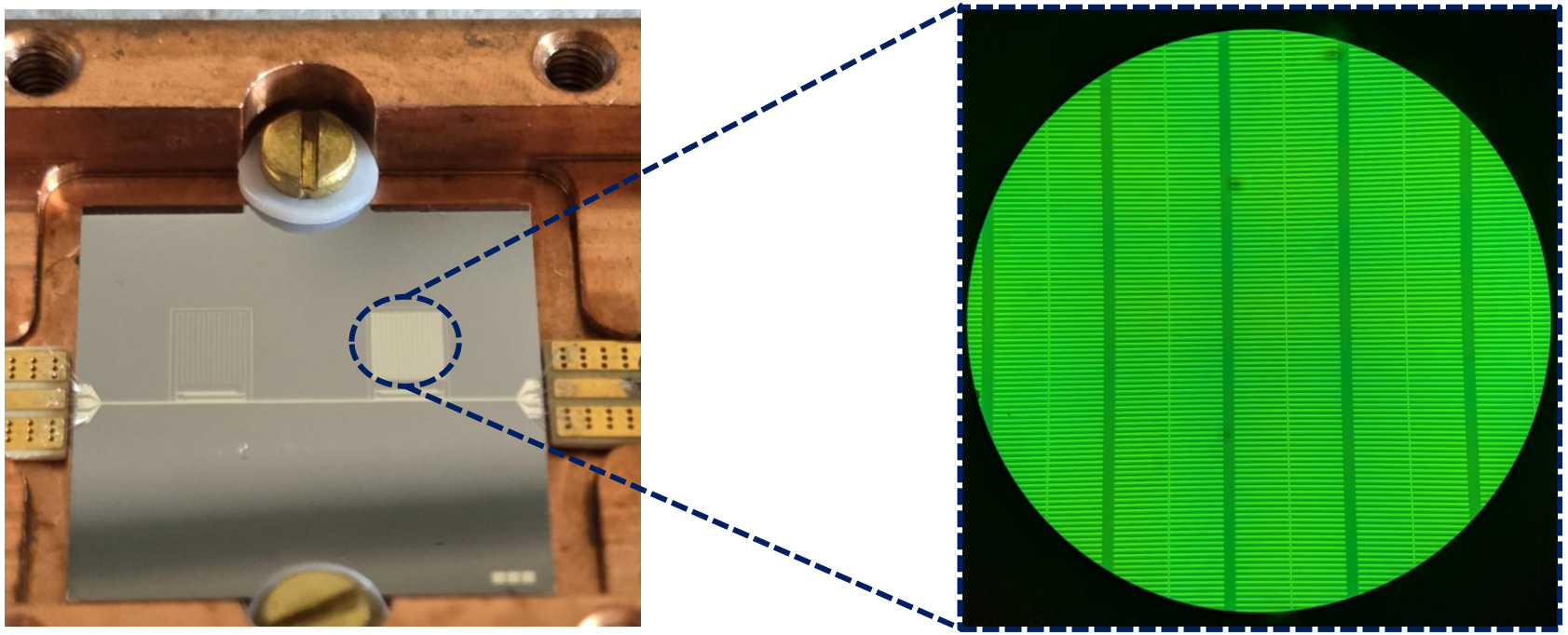


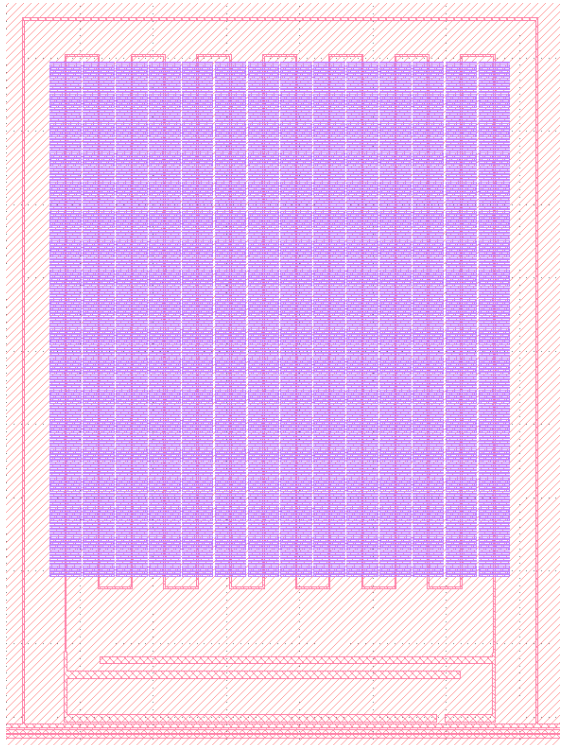
A possible way: Funnell-KID

Responsivity $\rightarrow \frac{df_r}{dE} = \frac{\eta}{V_{KID}\Delta_0^2} \frac{\alpha S_2(\omega,T) f_r}{4N_0}$

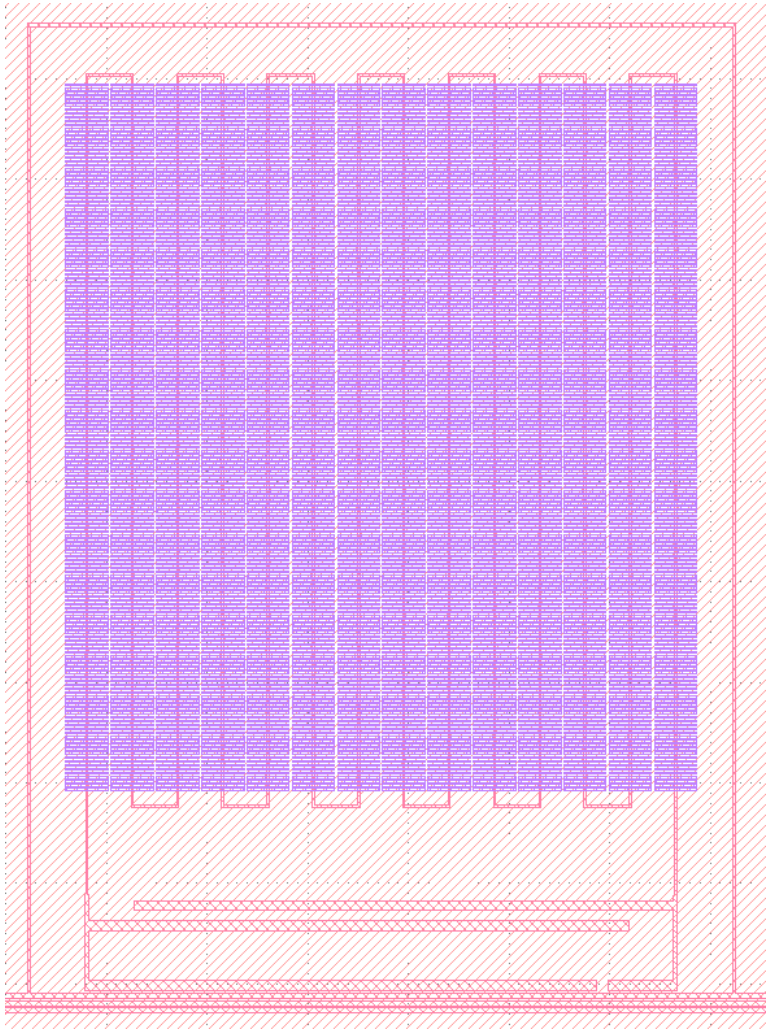
Resolution $\rightarrow \sigma_E \propto \Delta_0 \frac{\sqrt{V_{KID}}}{V_f}$

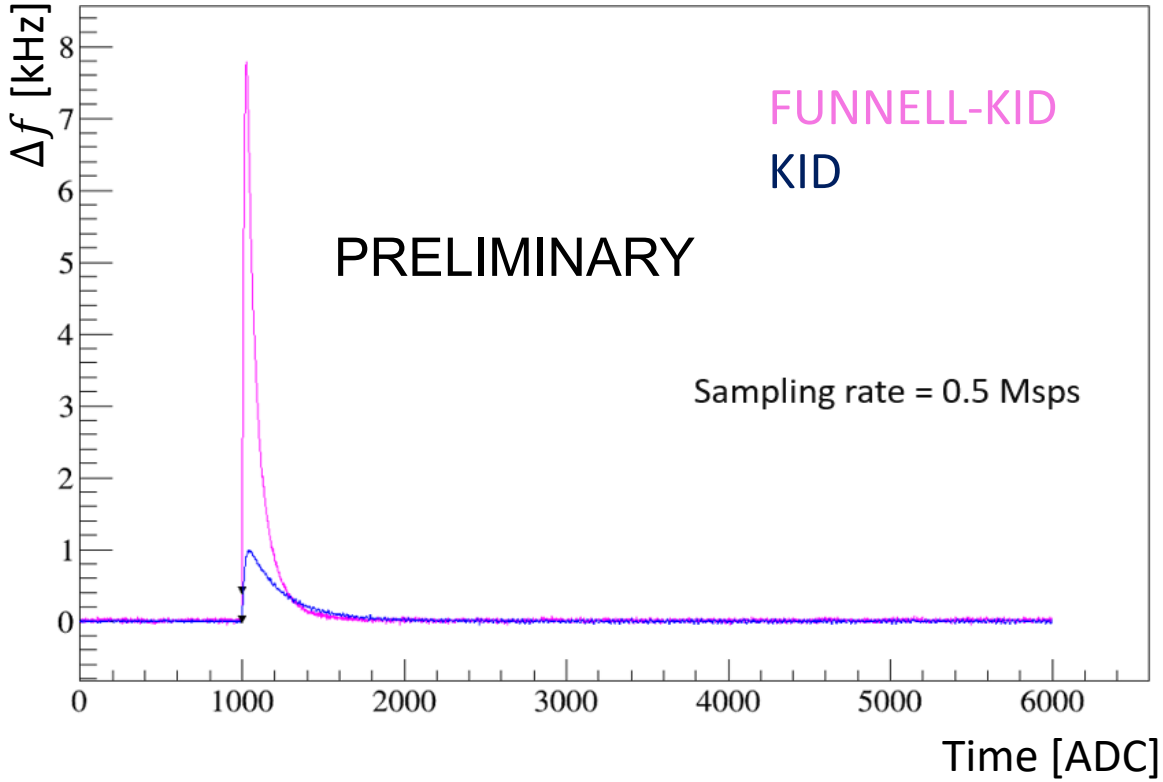
Separation allows for **large collection structure** and **mild active sensor volumes** at the same time





Design and preliminary tests.





- Currently, a **more responsive** signal and stable behavior were observed.

Thanks for the attention

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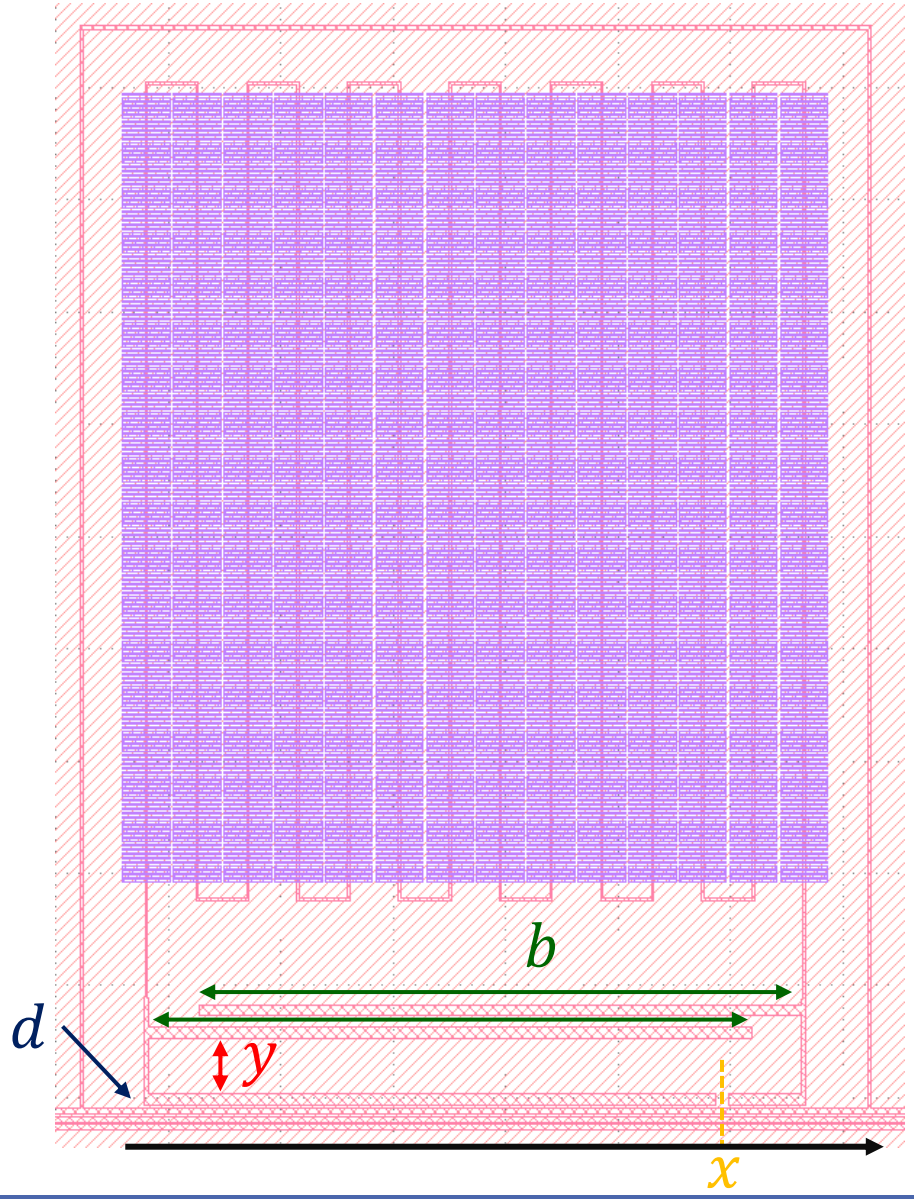

- Simulations performed with **SONNET** software to predict f_r, α and Q.
- We can design KIDs with different geometries.
- L_k is matched a 1.4 pH/sq.