First results from BULLKID

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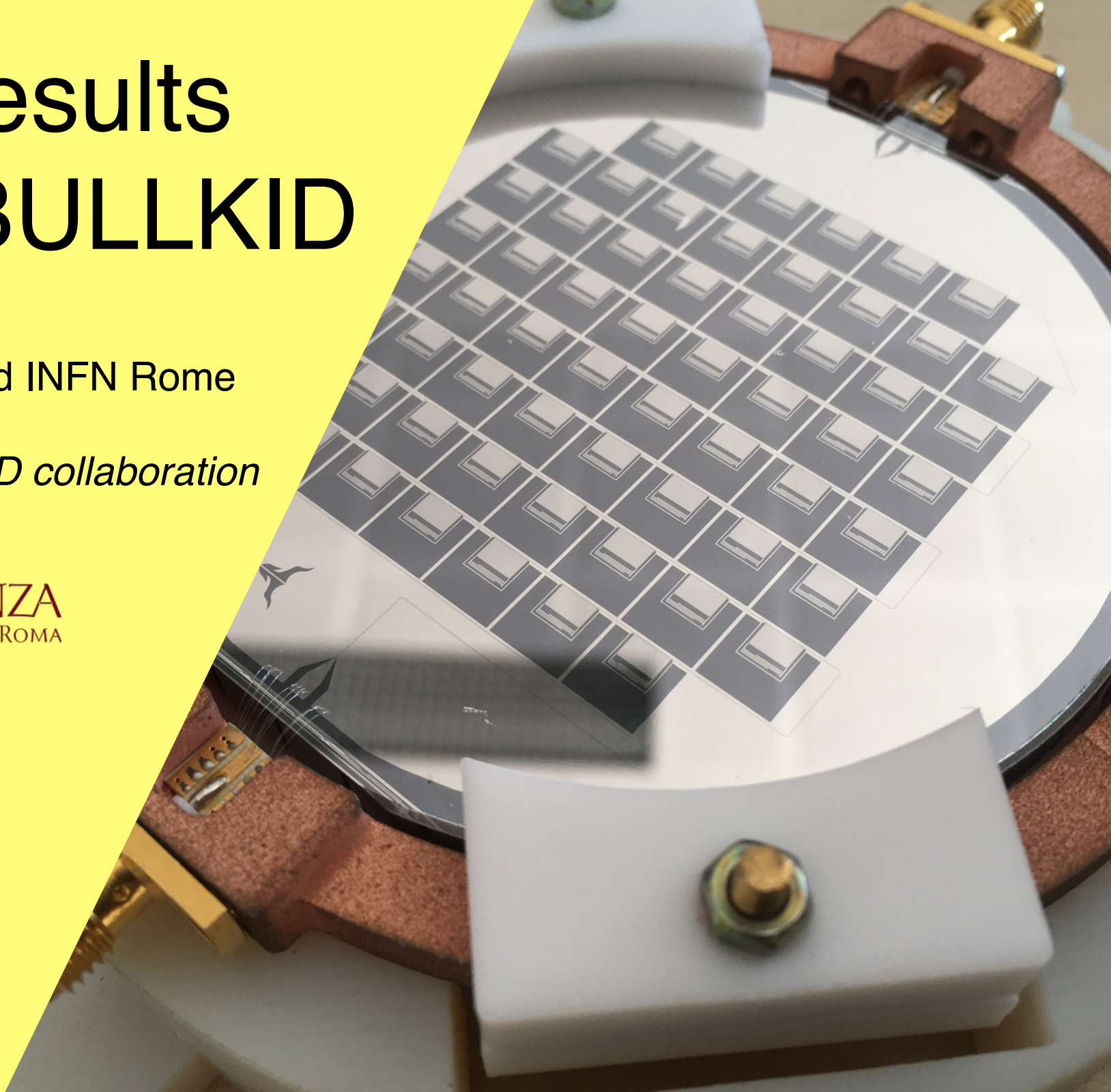
for the BULLKID collaboration

SAPIENZA
UNIVERSITÀ DI ROMA

INFN
Istituto Nazionale di Fisica Nucleare

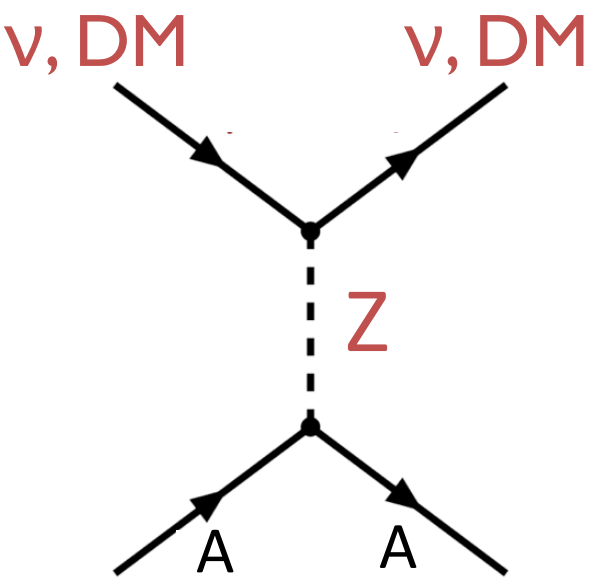
Magnificent 7's
2021



Objective

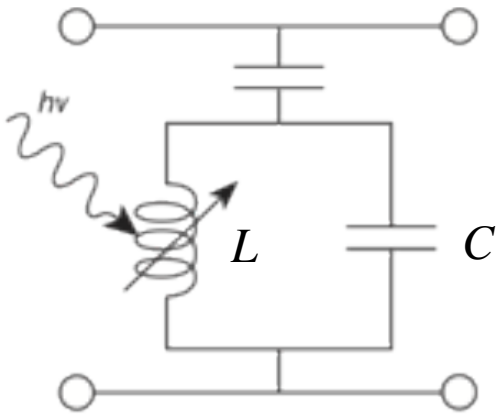
- Create an innovative cryogenic nuclear recoil detector for:
  - Coherent elastic neutrino-nucleus scattering scattering (CEvNS),
  - GeV/sub-GeV Dark Matter.

- Detector specifications:
  - Phonon sensors (not quenched),
  - Energy threshold < 200 eV_{nr},
  - Silicon and/or germanium target,
  - Target mass ~ 1 kg,
  - High segmentation.



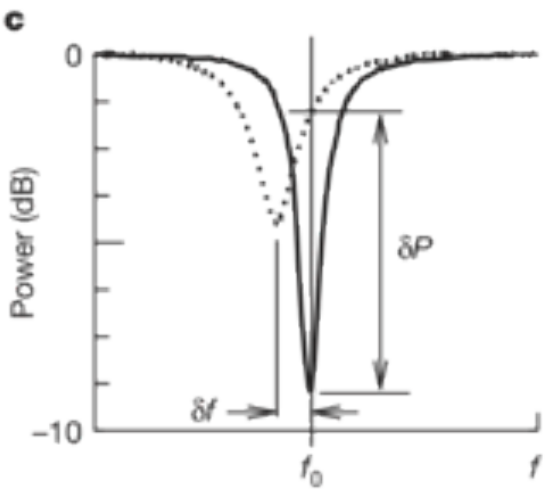
Kinetic Inductance Detectors

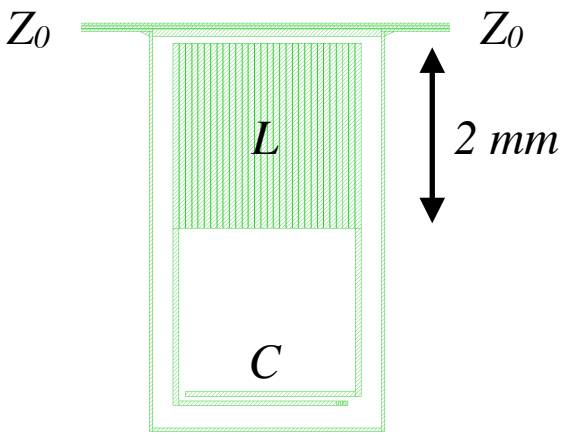
Day et al., Nature 425 (2003) 817



Cooper pairs breaking in a superconductor changes its inductance (*L*).
Probe *L* with high quality factor (*Q*) LC circuit.

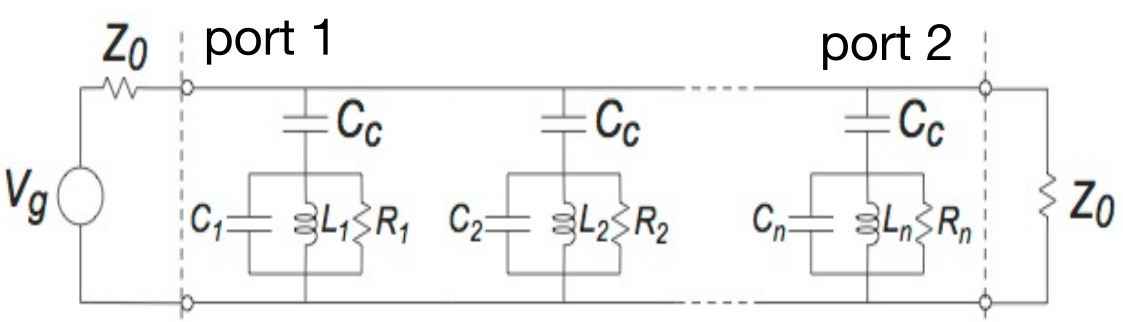
Signal: amplitude and phase shift of the wave transmitted past the resonator

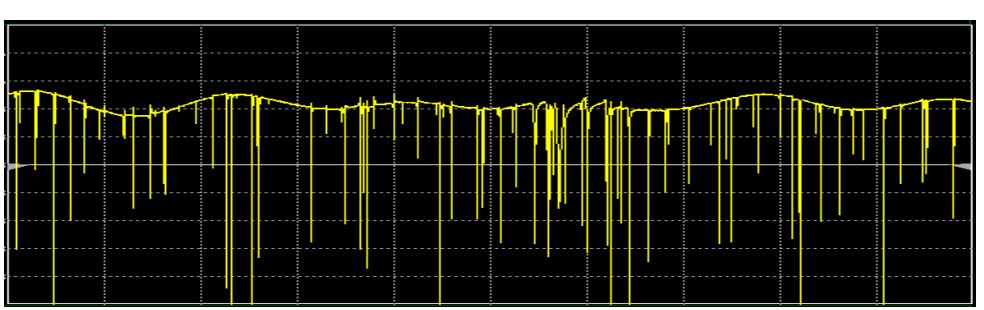




Actual implementation: meandered inductor (*L*), closed on a capacitor (*C*) and coupled to a feedline with impedance Z_0

Multiplexing: different resonators coupled to the same feedline with slightly different resonant frequencies. Resonant frequency tuned via the capacitor pattern of the circuit.



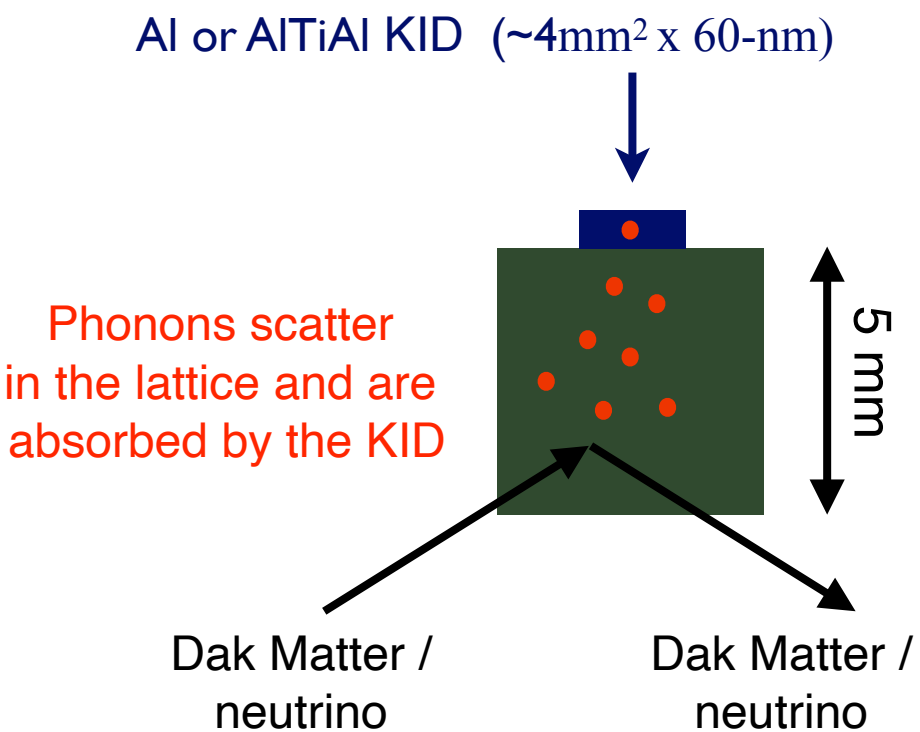


1.5 GHz 1.7 GHz

BULLKID concept

Phonon mediation:

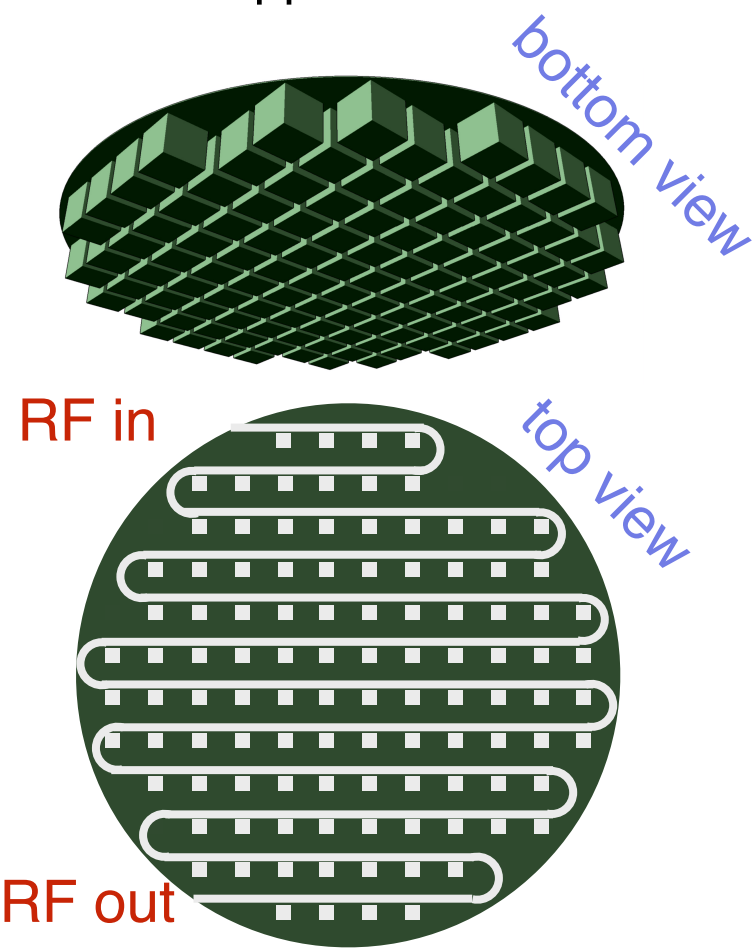
detect phonons created by nuclear recoils in a silicon absorber



Volume and sensor mux:

carve several absorbers in a thick silicon wafer

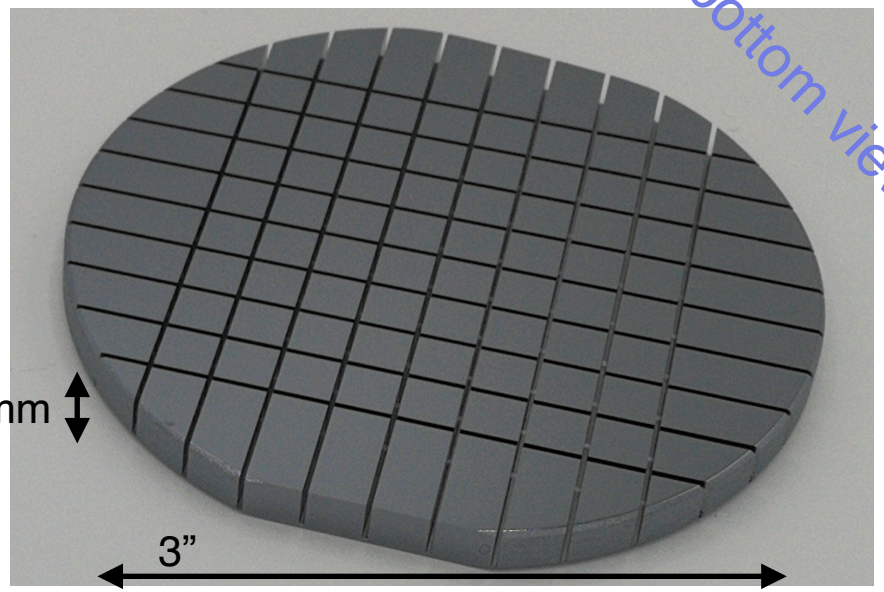
multiplexed KID array on opposite surface

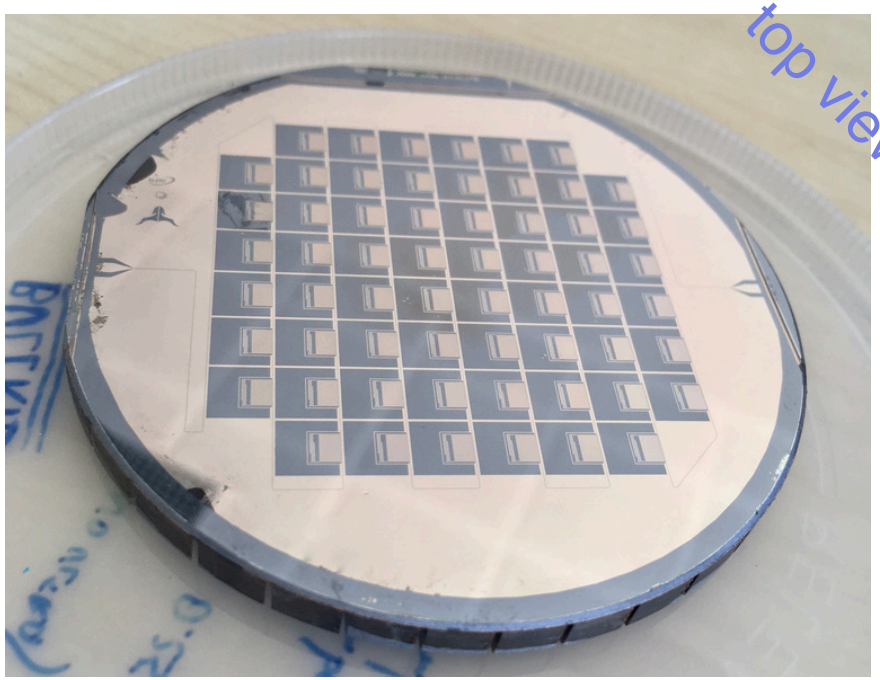


Idea first presented at Mag 7's '18, Chicago

First prototype

- 60 dices read by multiplexed aluminum KIDs
- *Dice volume:* 5.5x5.5x4.5 mm^3
- *Surface thickness:* 0.5 mm
- *Dice mass:* 0.31 g
- *Total active mass:* 19 g

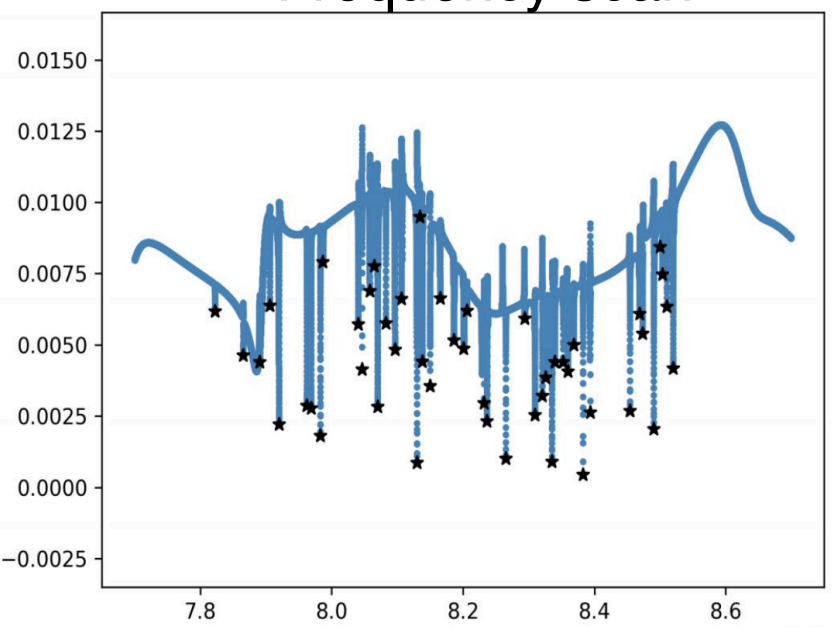




First results

see poster of D. Delicato

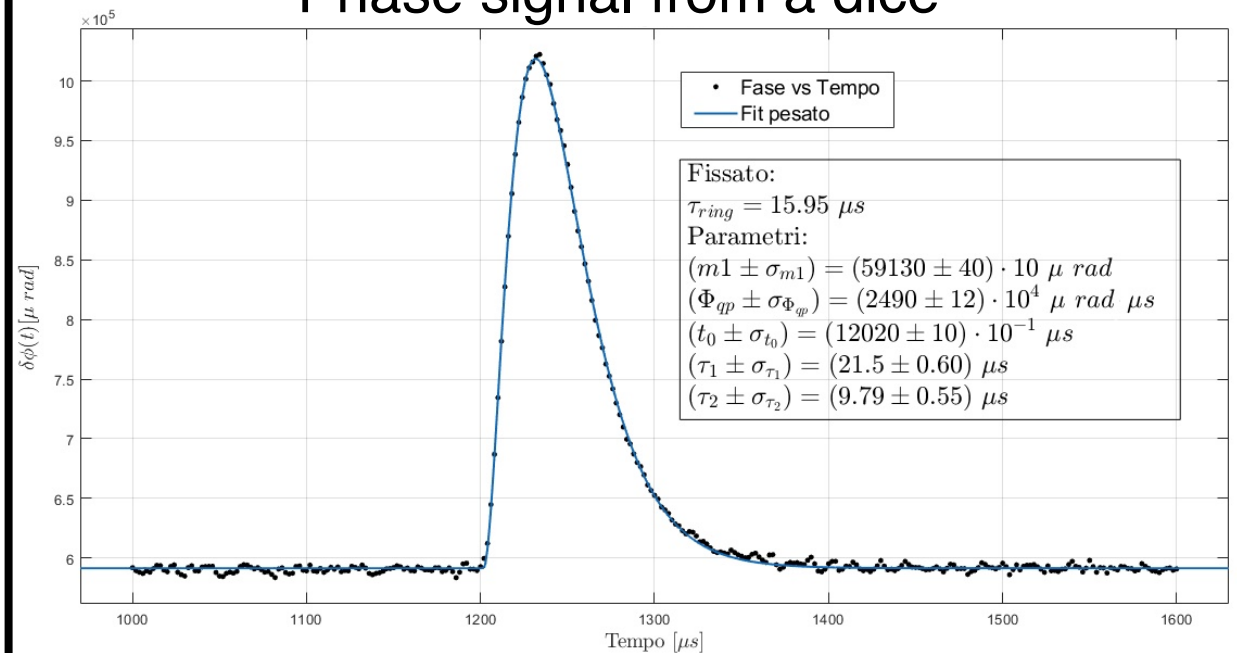
Frequency scan



Frequency [10^8 Hz]

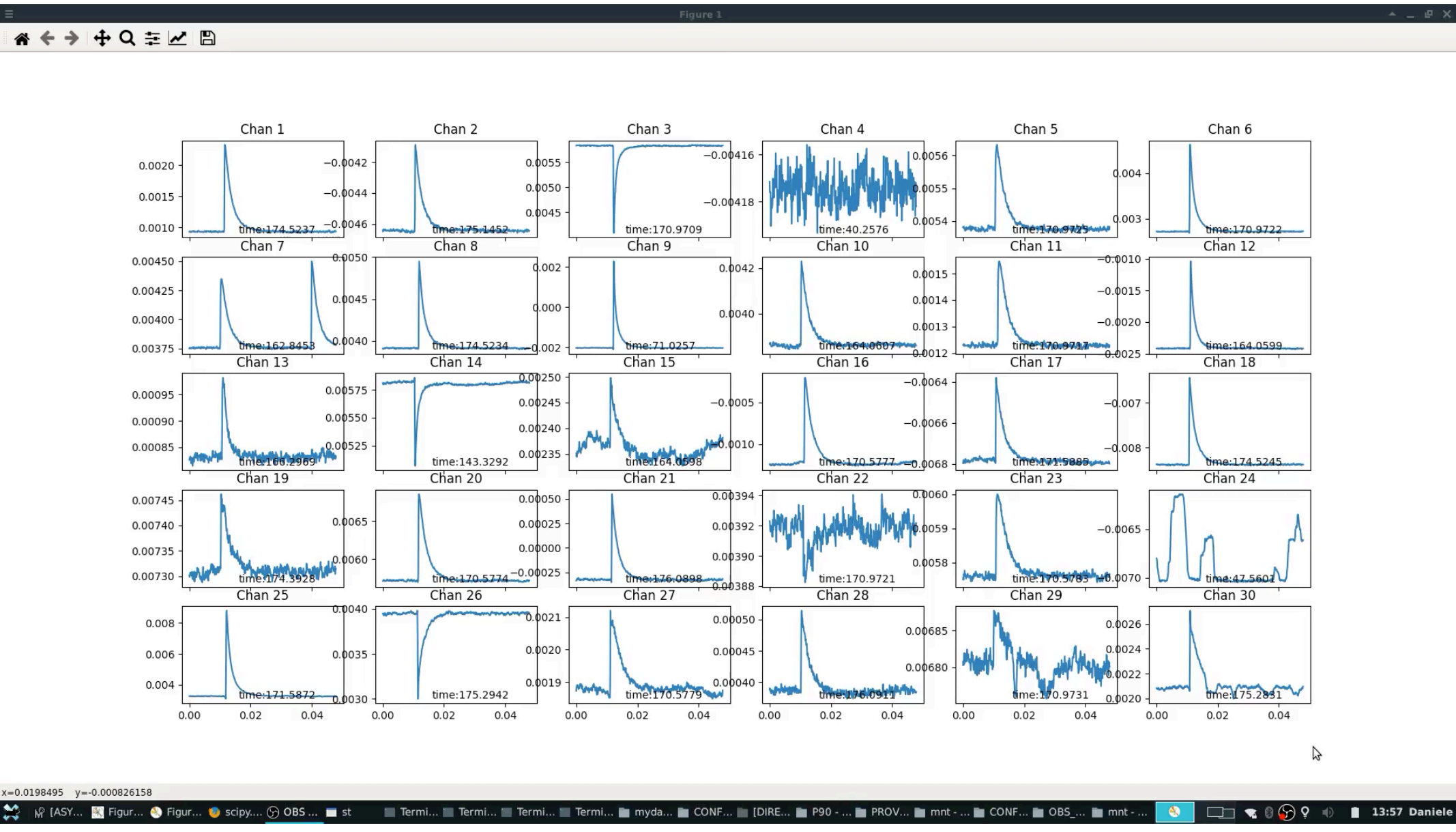
- 50/60 resonators alive
- Average Q: 2 10^4
  (5x lower than expected)
- Frequencies
  (20% lower than expected)

Phase signal from a dice



- Phonon efficiency: O(10%)
  (as expected).
- Recombination of quasiparticles: 20 µs
  (10x lower than expected)
- Phonon x-talk from nearby dice: ~25%
  (as expected)
- Energy resolution: ~ 100 eV
  (as expected, very encouraging!)

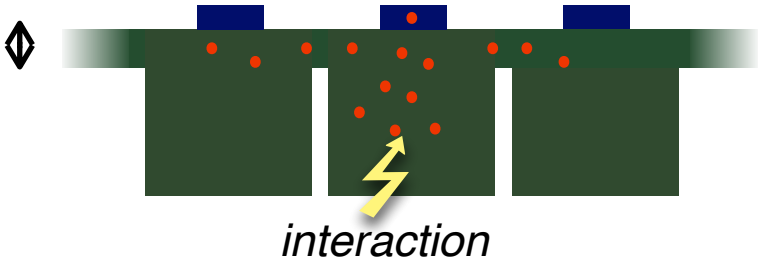
Multiplexing

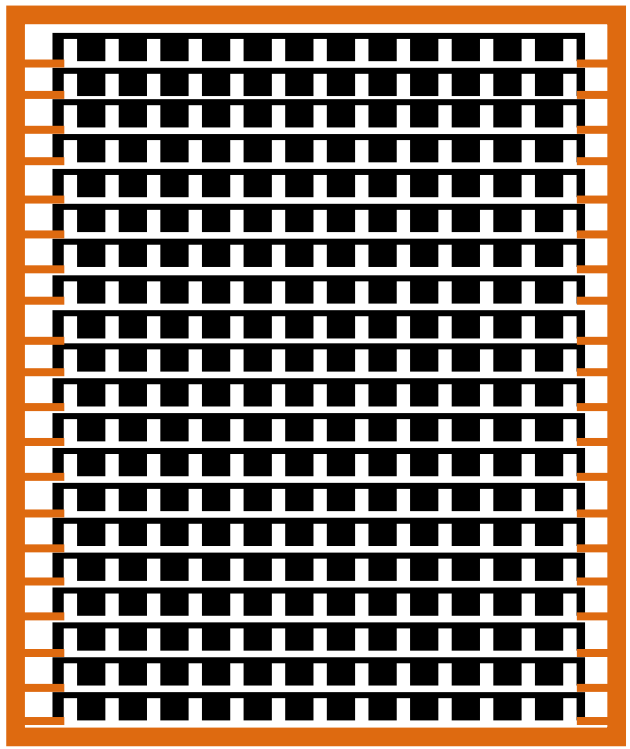


Next goals

Short term (months):

- Improve uniformity of the response
- Improve the resolution below 50 eV
  by moving from Aluminum to AlTiAl KIDs:
  25 eV already demonstrated in CALDER
  (SUST 31 (2018) 075002)



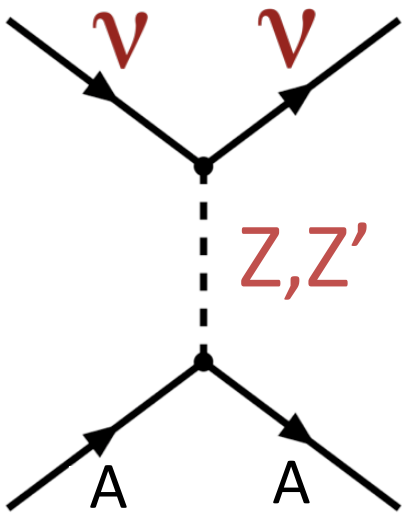


✓ fully active, no dead material
✓ high segmentation
✓ fiducial volume

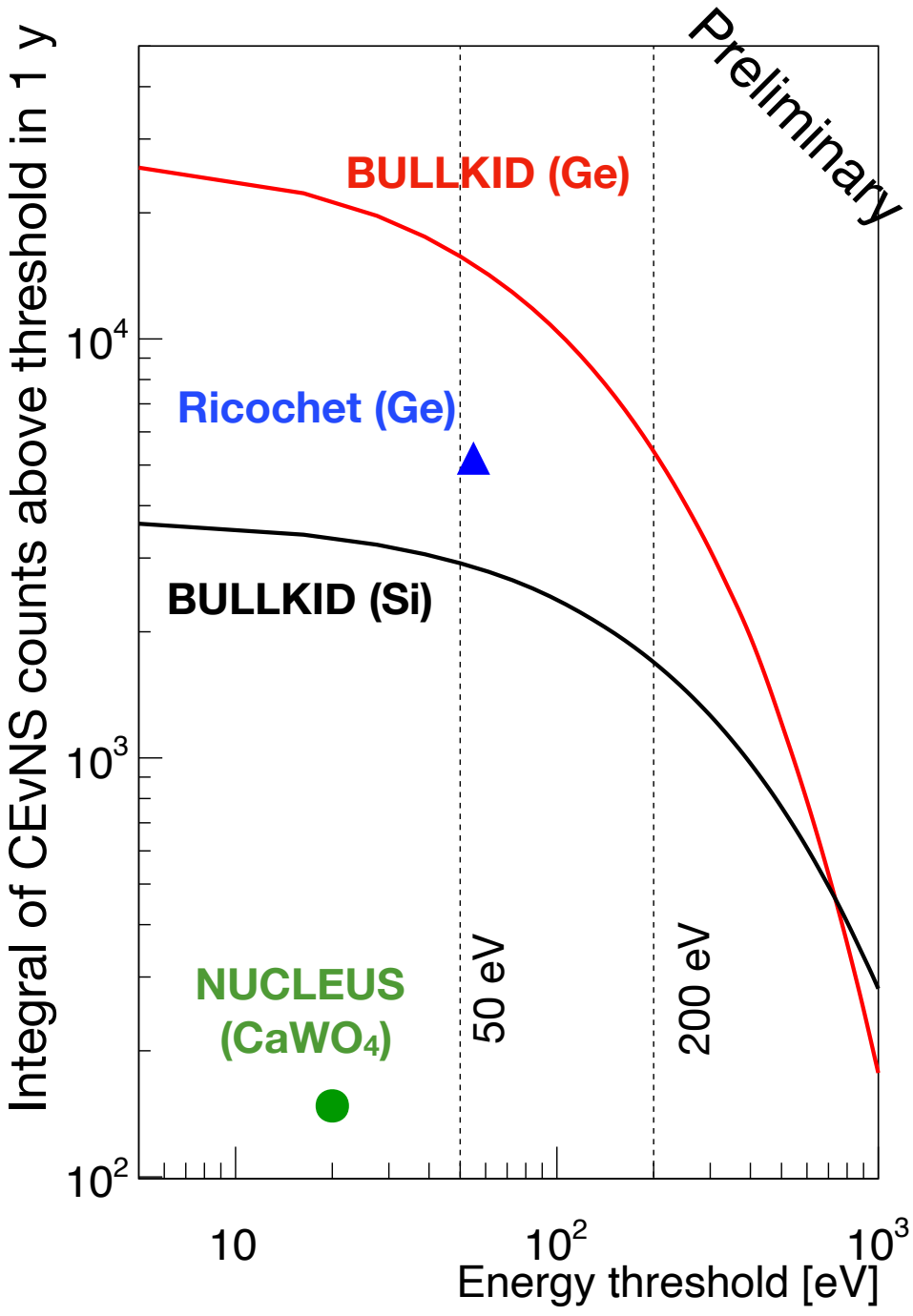
Long term (2 years):

- Try to reduce the surface thickness from 0.5 mm to 0.3 mm (reduces phonon x-talk)
- Move from 3” to 4” wafers to increase the number of dices
- In parallel apply the technology to germanium
- Start building a stack of wafers

CEvNS signal



- 250 cm^3
  - 0.58 kg of silicon
  - 1.33 kg of germanium
- Assuming the same site as NUCLEUS (Chooz nuclear plant)



Collaboration

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Activities are ramping up, we welcome new collaborators!!!