Ricochet Progress and Status

Enectali Figueroa-Feliciano*

Magnificent CEvNS 2021

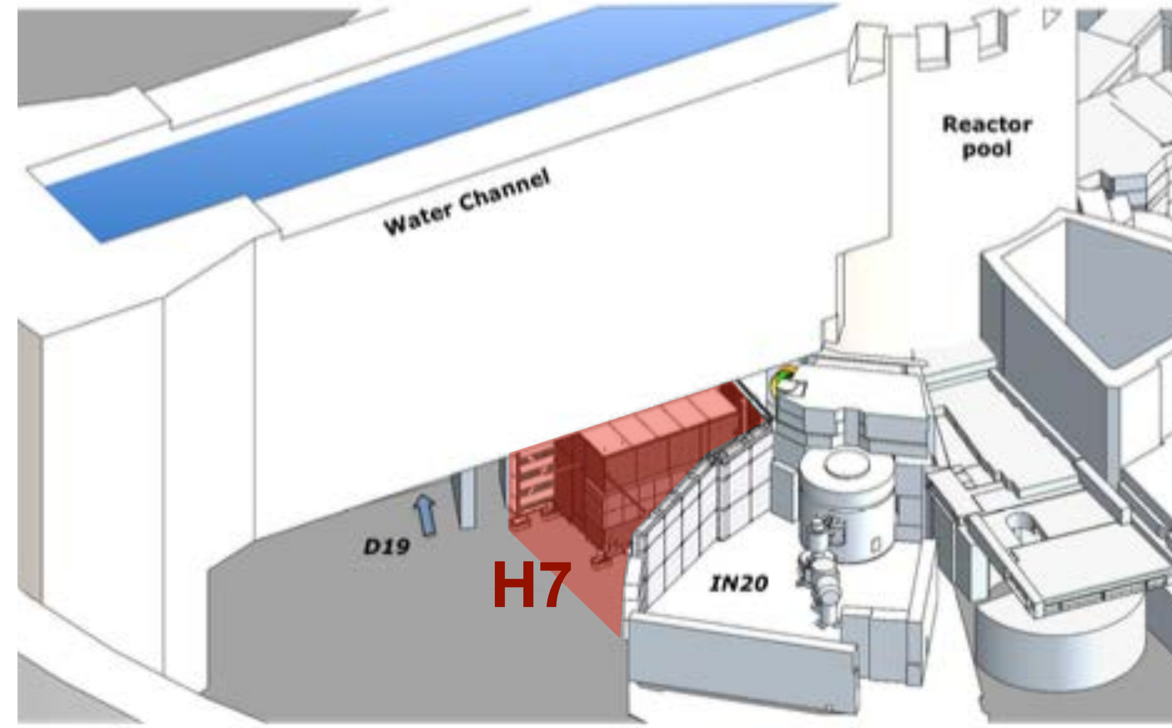
*Thanks to Scott Hertel for Slides

Experiment Site: Institut Laue Langevin (ILL) research reactor

58 MW nominal thermal power

Total neutrino flux: ~1x10^{19} ν/s

Convenient on/off modulation
(3 to 4 cycles per year)



Utilizing ILL experiment site “H7”
(Former location of STEREO experiment)

8.8m distance to core

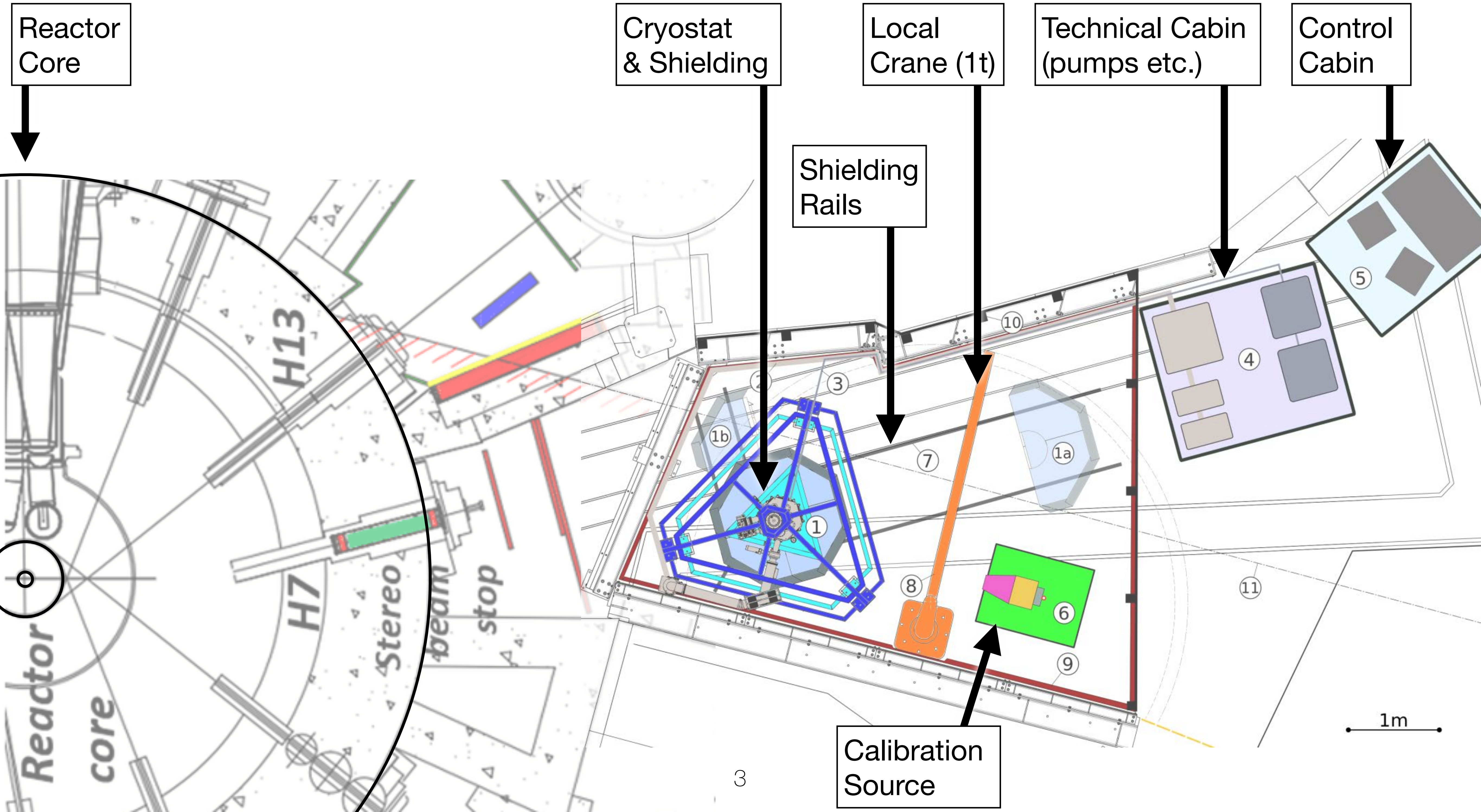
12.8 evts/day/kg   (above 50eV threshold)

~15 m.w.e.   (water channel overhead)

Future: Possible later stage at Novovorenezh NPP
Higher flux (~6x) with greater overburden (~3x)

Infrastructure and Integration at H7 Site

Layout in final design stage

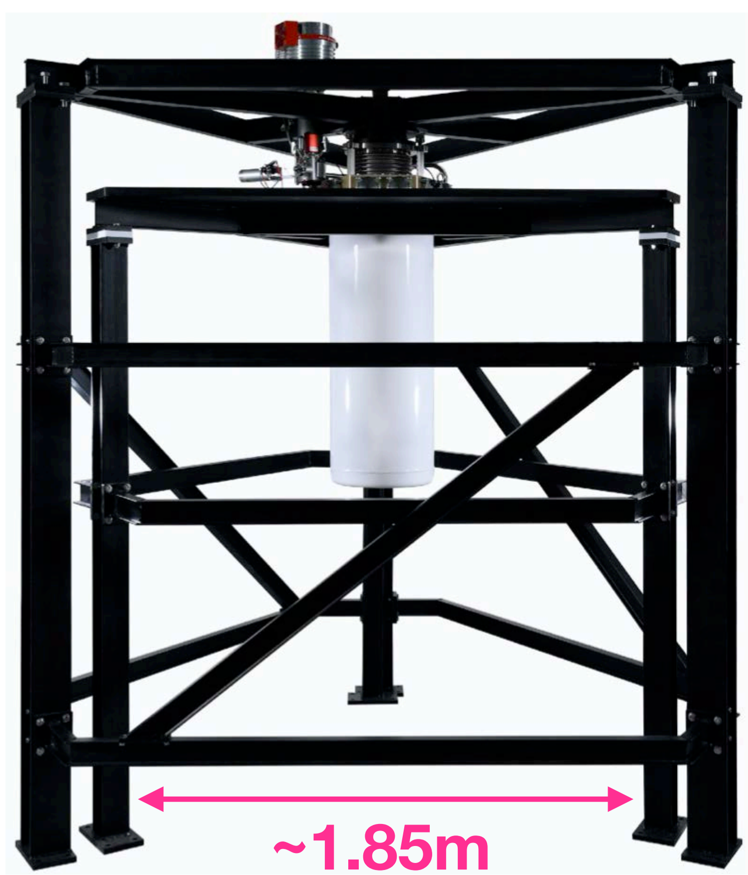


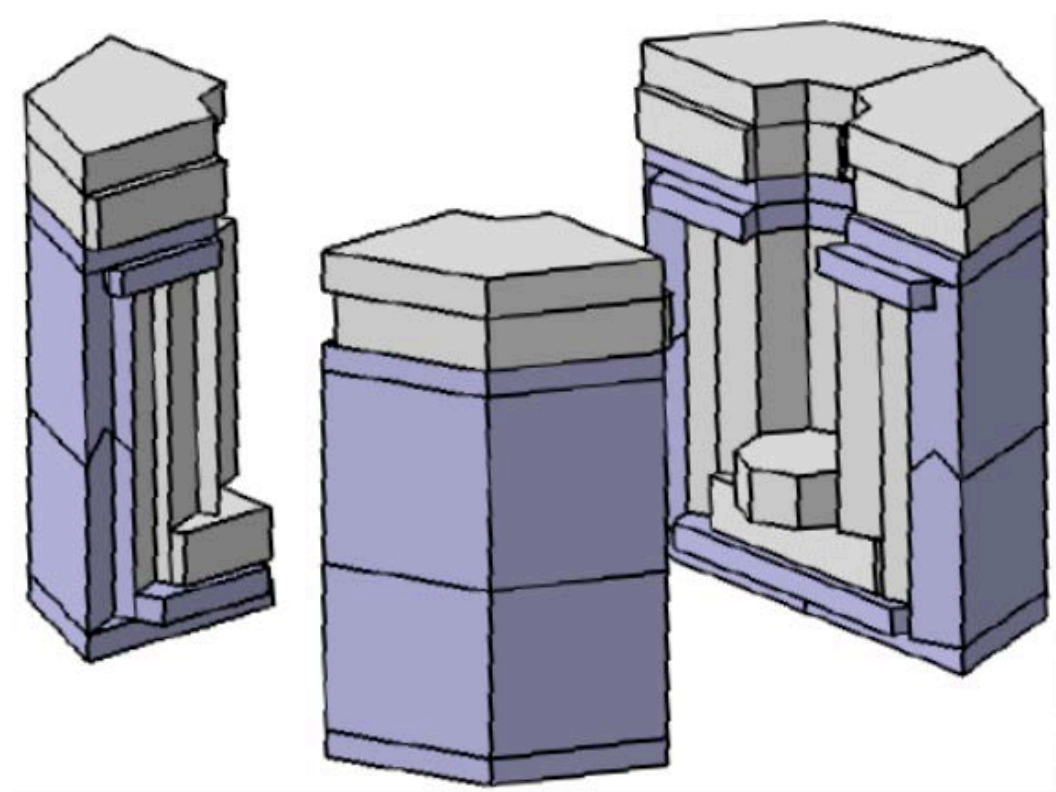
Cryostat & Shielding

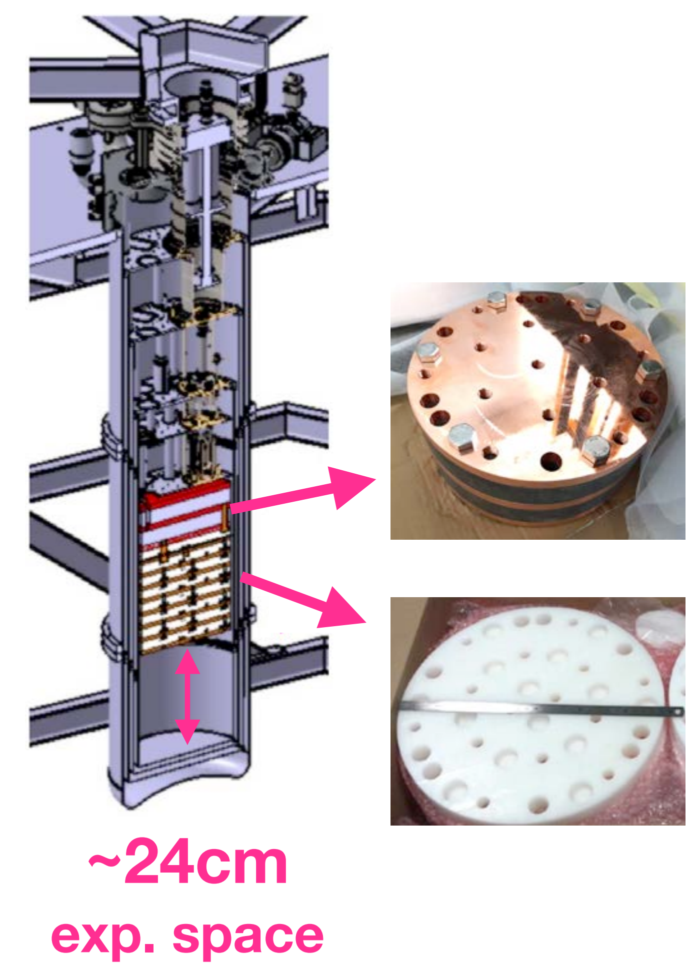
Cryoconcept HEXA-DRY 200
Ultra-quiet technology
Low radioactivity materials
Frame accomodates shielding

External Shielding
Pb outer layer (20cm, 20t)
Polyethylene inner layer (35cm, 2t)

Cold Shielding @1K
Pb/Cu (15 cm)
Poly/Cu (30 cm)
150 kg total







Expected backgrounds

Two-pronged effort:

1) Campaign of Geant4 Simulations
Radiogenic, Reactogenic, Cosmogenic…

2) Campaign of Onsite Measurements
Gammas measured using HPGe detector
Fast neutrons measured using a 3He tube
Thermal neutrons measured using a BF3 counter
Cosmic muons measured using GERDA panels

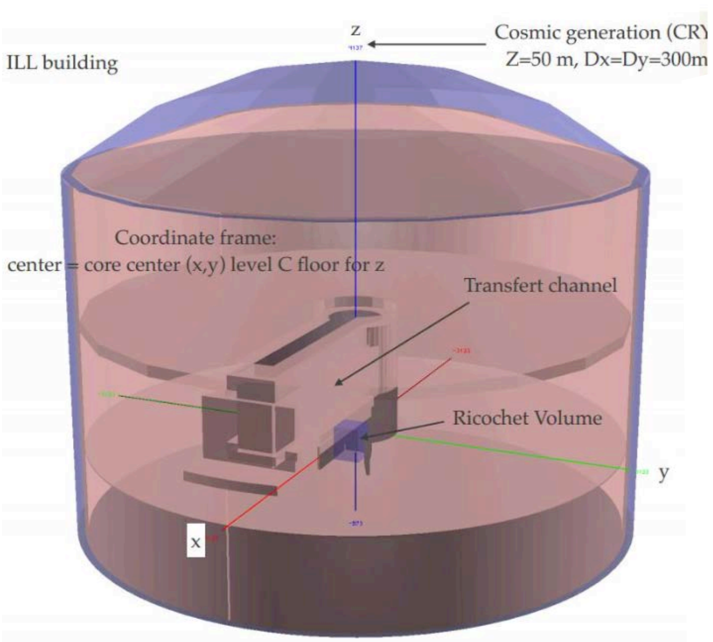
Combined results:

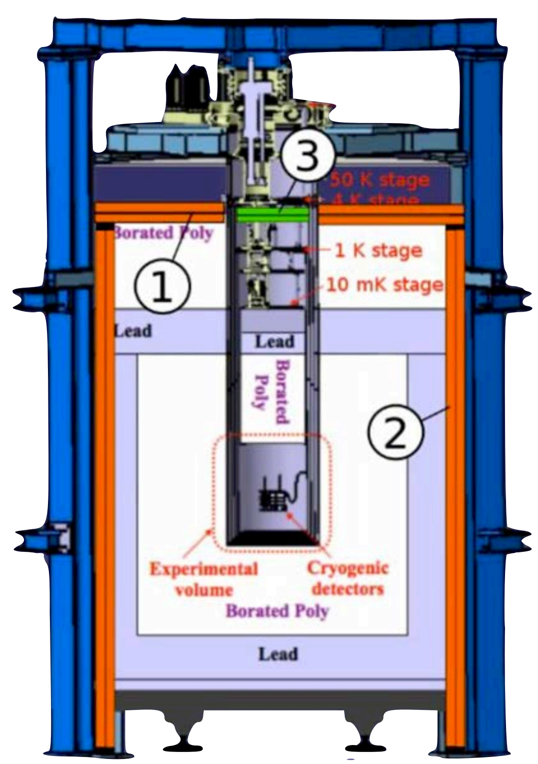
ER: ~30 evts/day/kg
NR: 5-13 evts/day/kg

Background goals are achievable.

NR rate sensitive to muon veto coverage, still in design.

Reactogenic neutrons are negligible.





Orange: prelim. 300K μ-veto geom.
Green: prelim. cold μ-veto (4K)

Electronic recoil rates in [50eV, 1keV] energy range (in evts/day/kg)				
	Cosmogenic	Reactogenic	Total	Goal
(I) No shielding	260 ± 5	4365 ± 301	4265 ± 301	—
(II) Shielding	175 ± 4		201 ± 5	—
(III) Shielding + μ-veto	7 ± 1	26 ± 2	33 ± 2	100
(IV) Shielding + full cover. μ-veto	0.6 ± 0.2		27 ± 2	100

Nuclear recoil rates in [50eV, 1keV] energy range (in evts/day/kg)				
	Cosmogenic	Reactogenic	Total	Goal
(I) No shielding	1554 ± 12	53853 ± 544	55407 ± 545	—
(II) Shielding	37 ± 2		38 ± 2	—
(III) Shielding + μ-veto	12 ± 1	0.8 ± 0.1	13 ± 1	5
(IV) Shielding + full cover. μ-veto	4 ± 1		5 ± 1	5

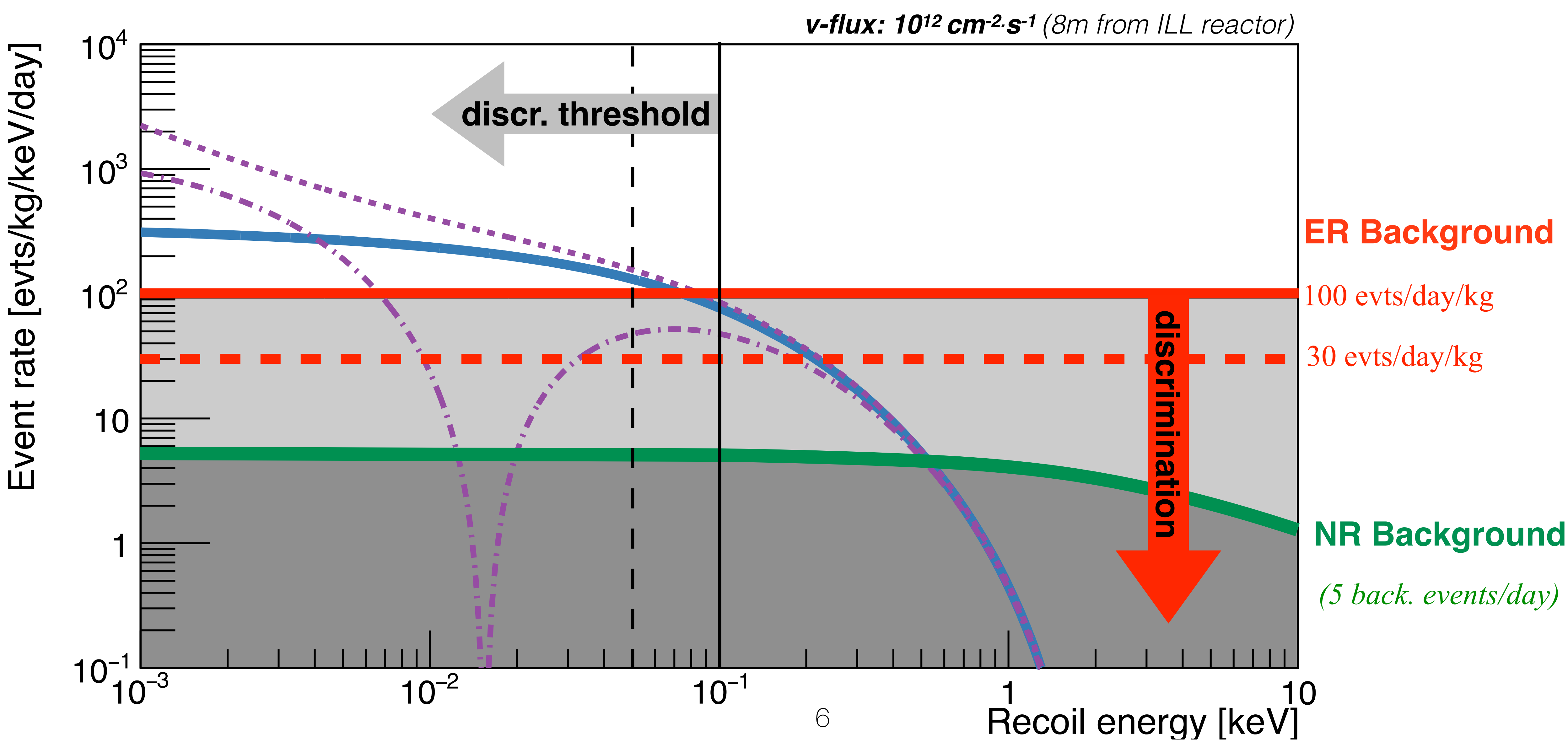
Ricochet Detector Requirements and Goals

Key requirement: ER/NR discrimination (aiming for ~10^3)

Threshold *with discrimination*: <100eV (aiming for 50eV)

~1 kg target mass

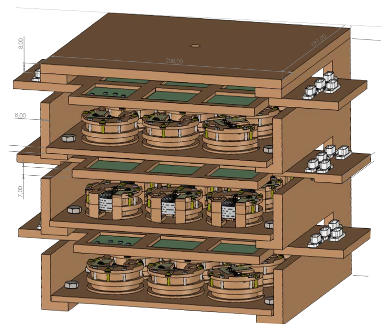
Target complementarity (different nuclei)

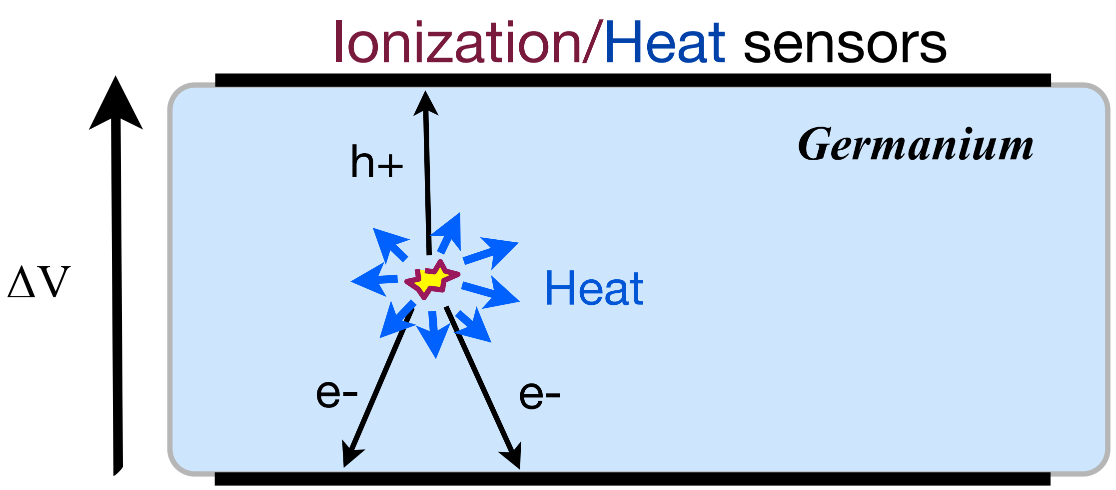


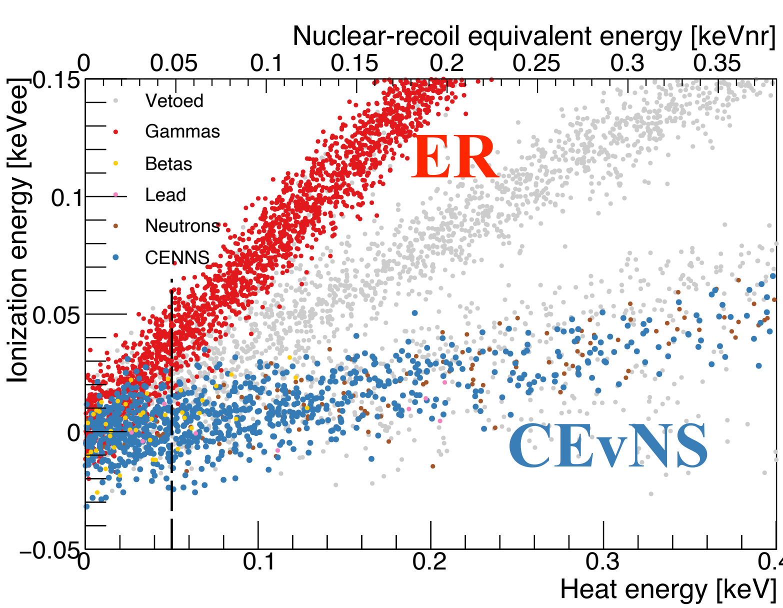
Ricochet Detector Technologies

Two complementary target nuclei (Ge and Zn).
Two complementary approaches to NR/ER discrimination.
Baseline plan accomodates simultaneous operation of both technologies.

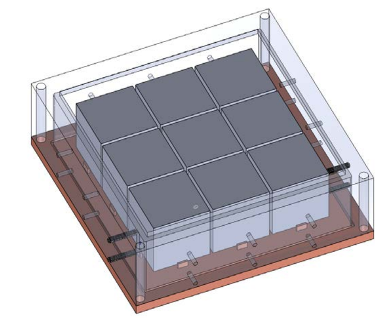
"CryoCube" (See poster P4-4)
Ionization+Heat in Ge
Sensors: NTDs and HEMTs

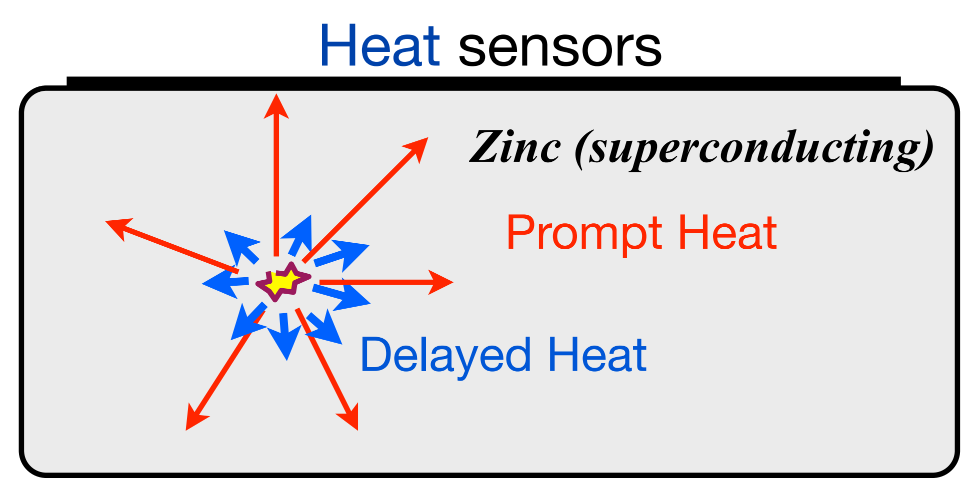


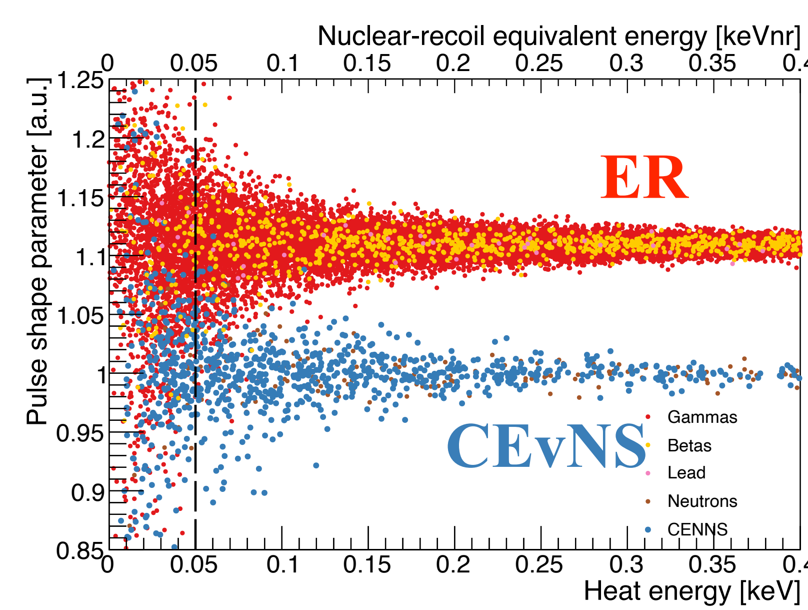




"Q-Array"
Heat Pulse Timing in Zn
Sensors: TESs



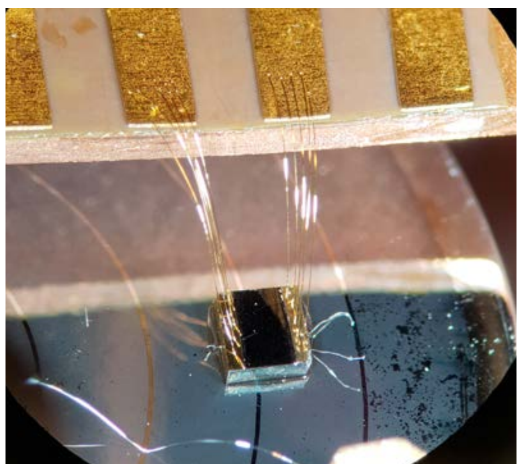


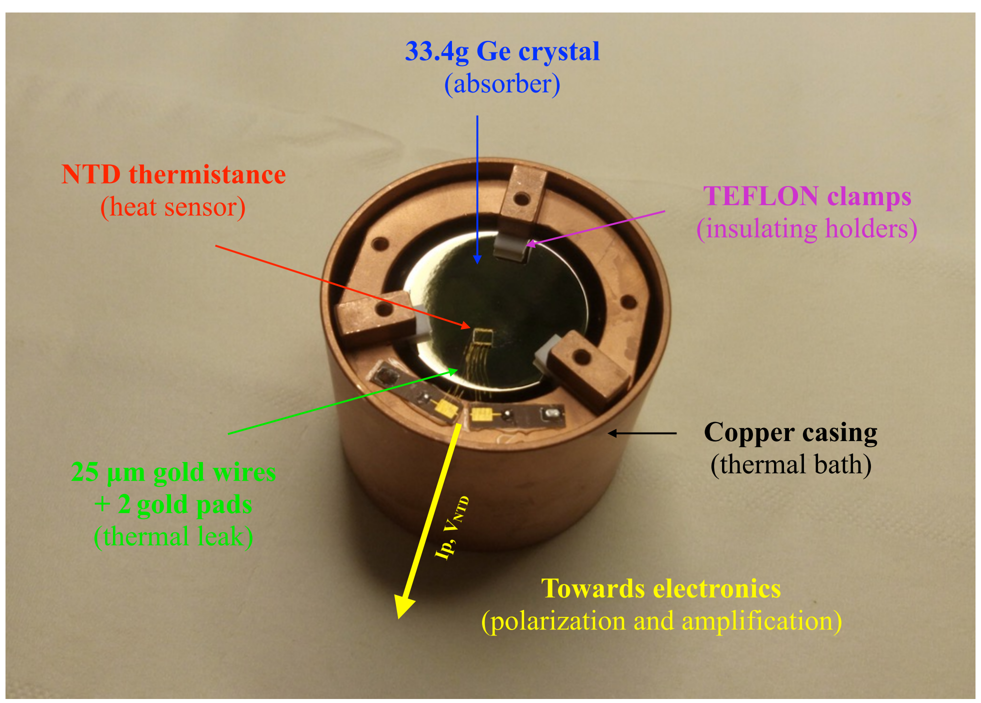


CryoCube development: Heat Channel Optimization

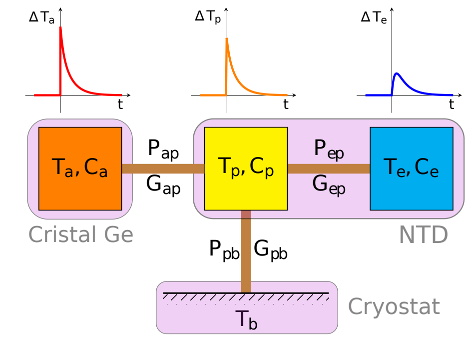
Single-channel NTD Readout

Detectors produced at
IJCLab - CEA/Saclay - IP2I
(EDELWEISS/Ricochet Synergy)

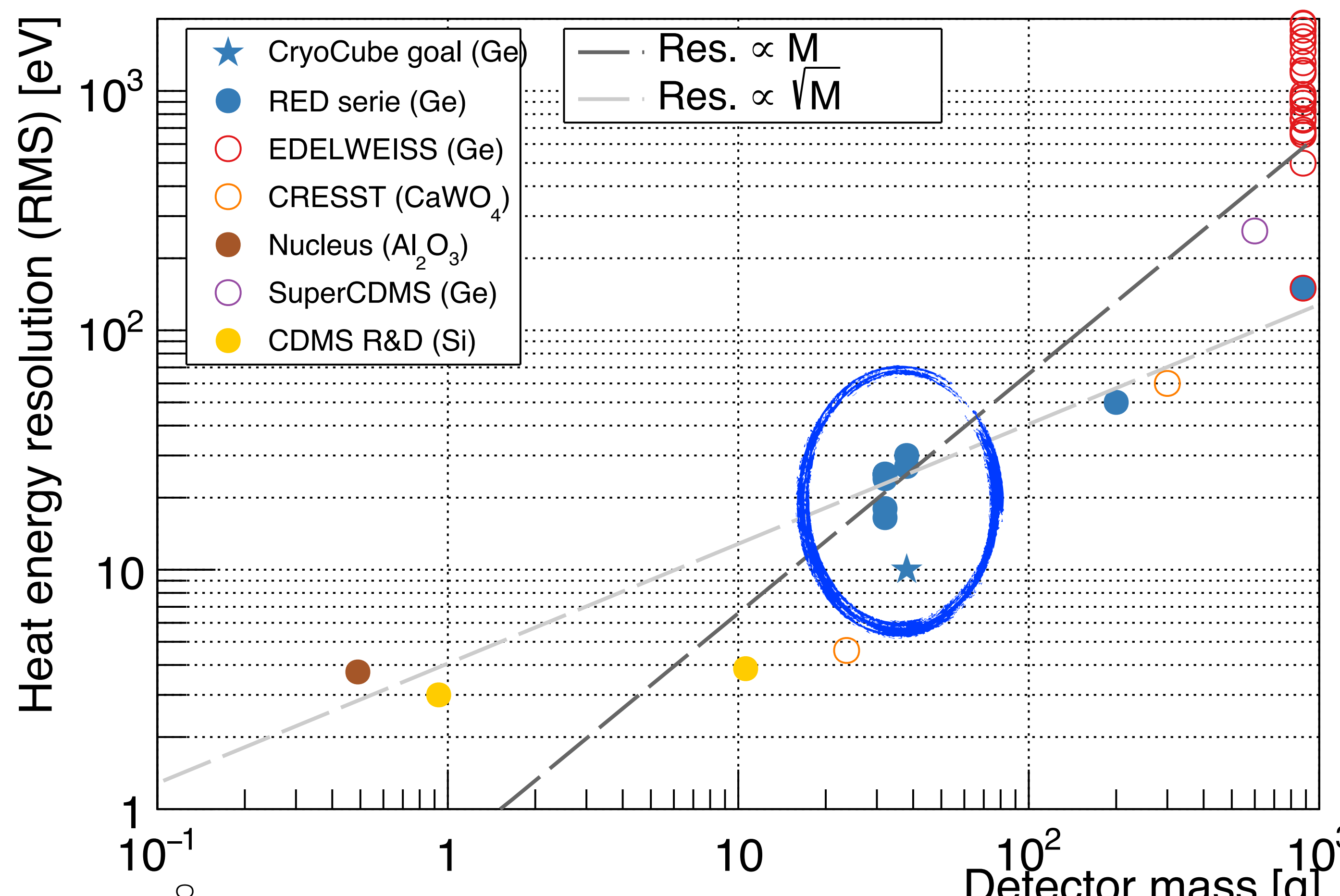




Data constrains thermal model in three ways:
- -steady state (thermal conductivities)
- -time domain (heat capacities)
- -frequency domain (noise sources)



Achieved 22eV RMS (average of five Ge detectors)
Excellent "resolution to mass" ratio



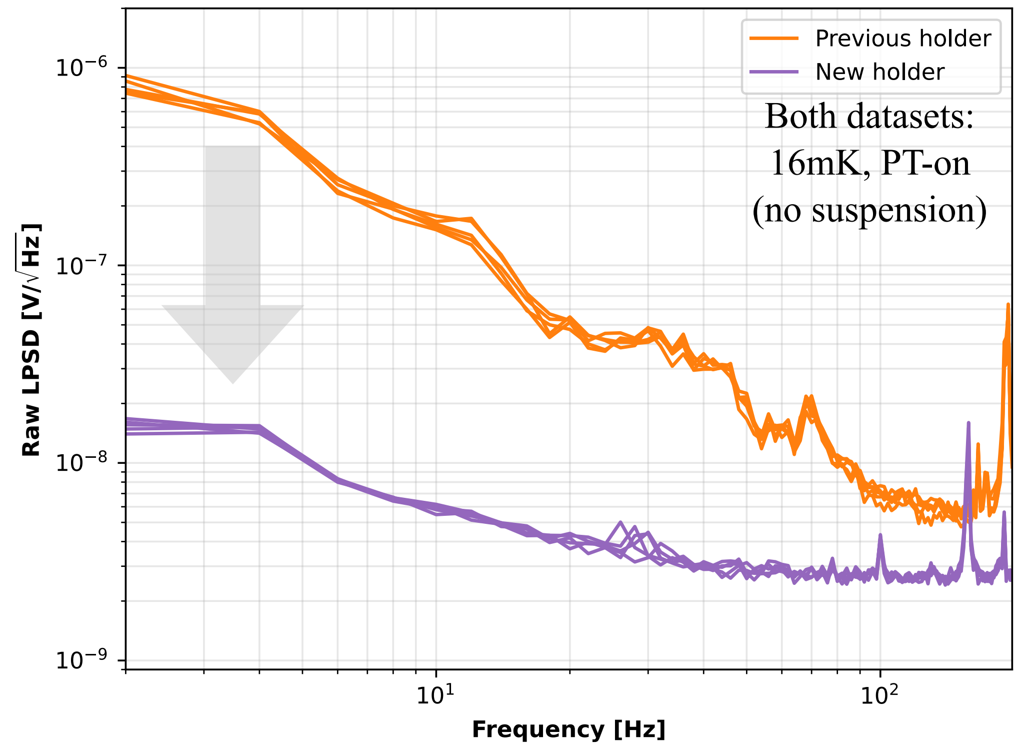
CryoCube development: Holder Optimization

New Holder shows significant noise reduction

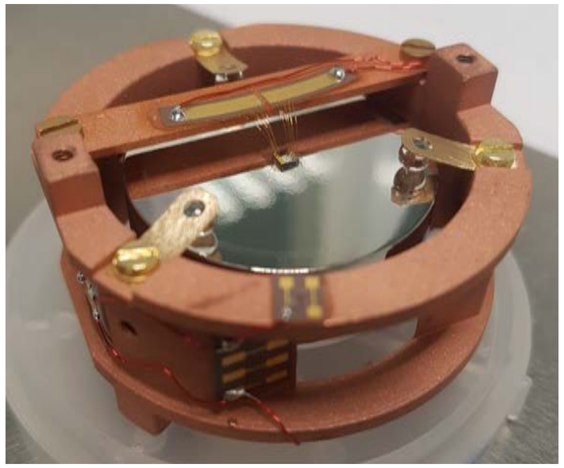
~2 orders of magnitude reduction at 1Hz
(consistent for 3 migrated detectors)

Opens possibility of avoiding cryogenic suspension

Ongoing topic of R&D

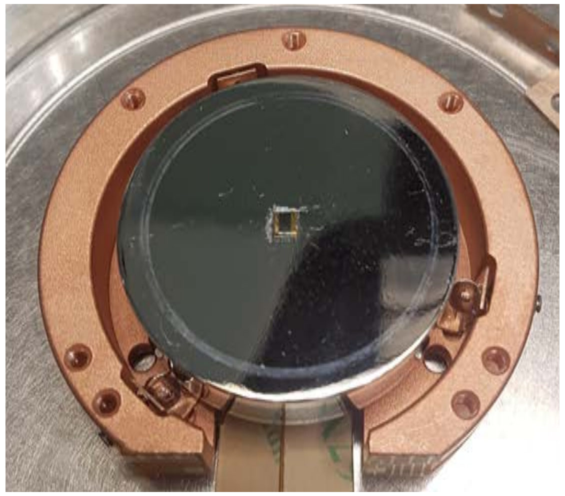


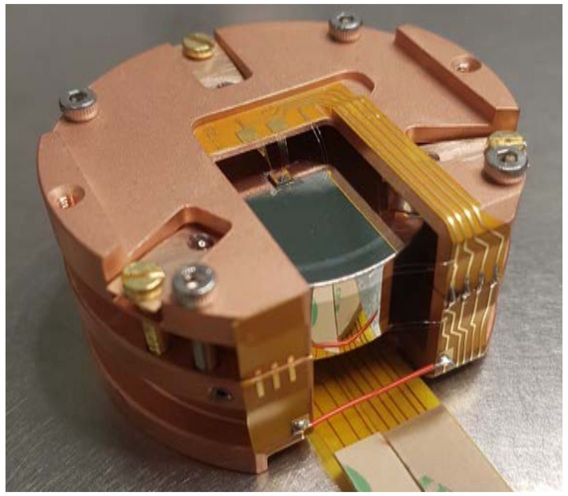
Previous Holder
3 sapphire balls + 3 TEFLON clamps



Holder Migration
(same detector)

New Holder
9 sapphire balls + dedicated kapton

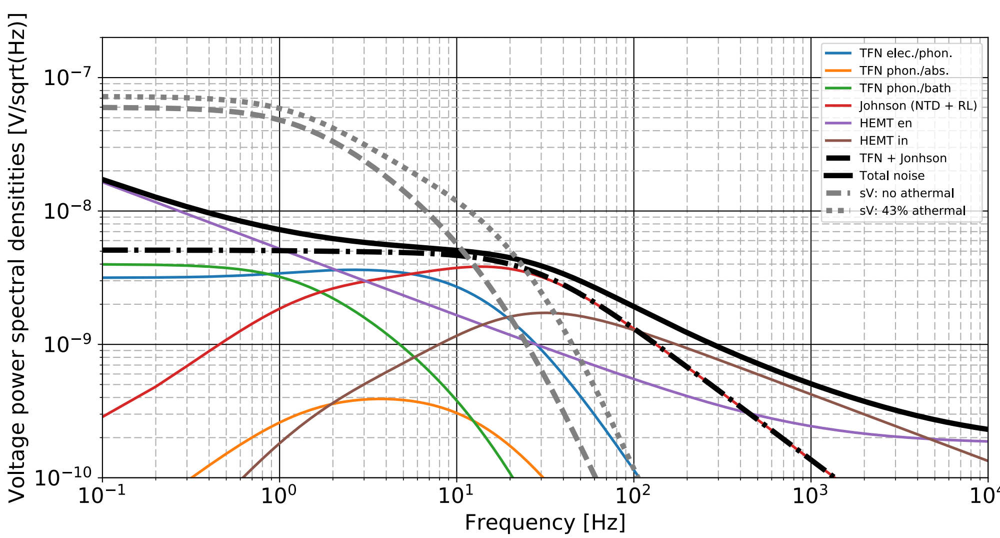




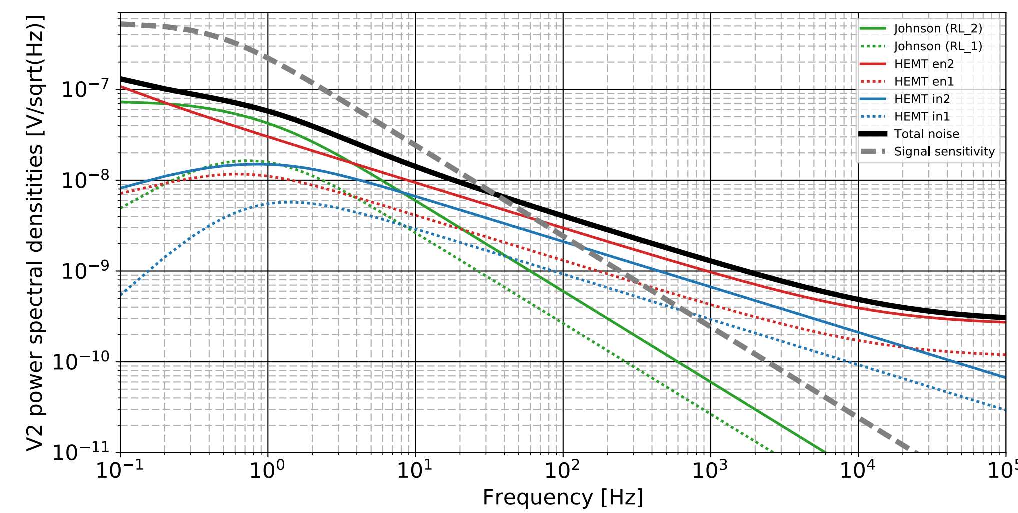
CryoCube development: HEMT-based readout

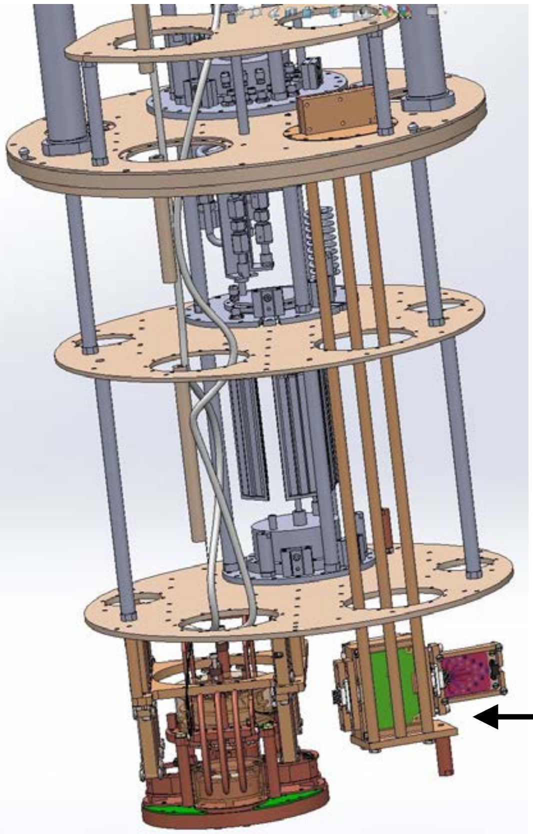
Upgrade to HEMT electronics: Strong focus of ongoing CryoCube R&D   Dedicated poster: P4-10

Heat (currently at ~22eV RMS)
Expect to reach goal of **10eV**

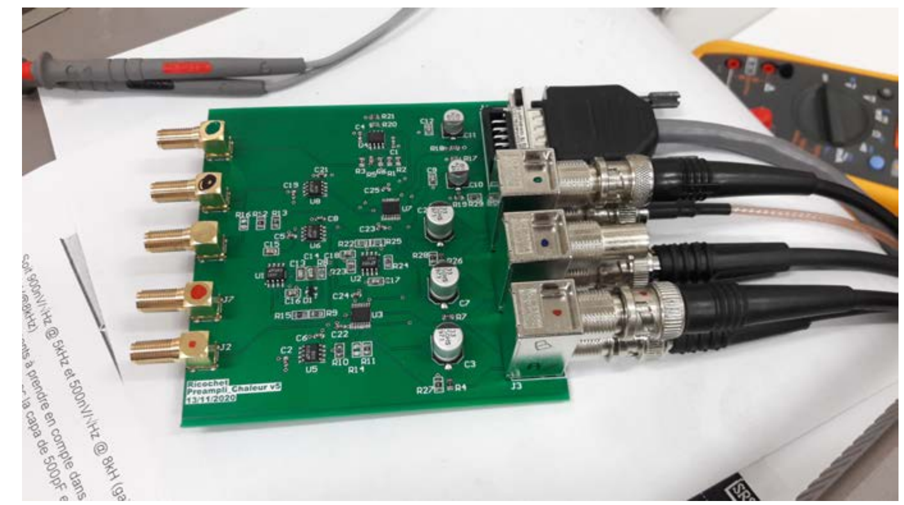


Charge (currently at ~200eV RMS)
Expect to reach goal of **20eV**





HEMTs, cold+warm electronics, and DAQ all being developed in collaboration in Institut Néel, LPSC, and IP2I



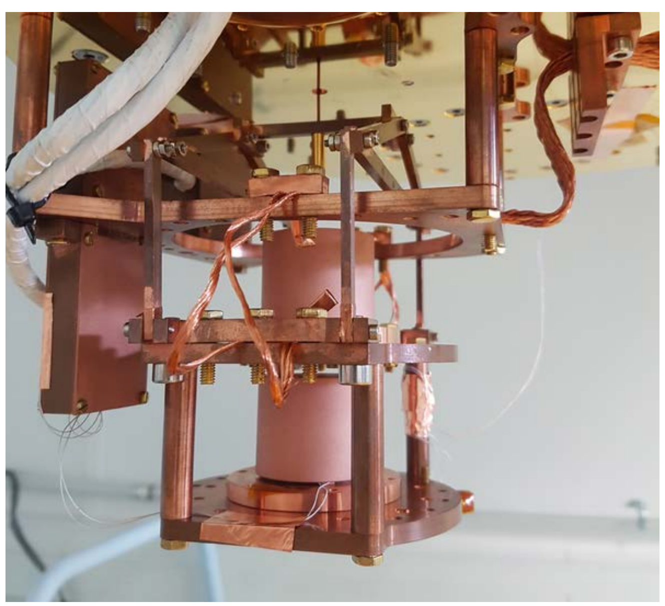
test stand @IP2I
HEMT preamplifiers at 1K

CryoCube development: Research Path

Pathfinder

~60 g payload, JFET readout

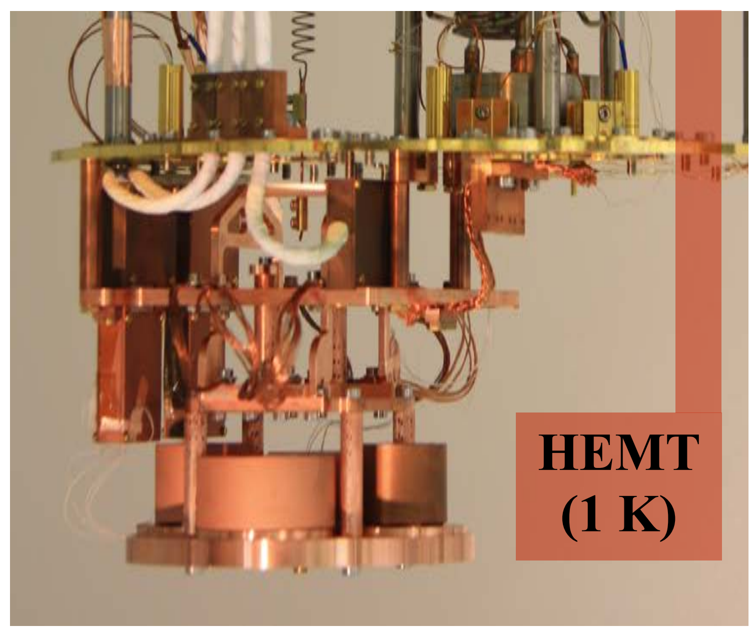
R. Maisonobe et al., JINST **2018**



Demonstrator

~200 g payload
HEMT readout on 1K finger

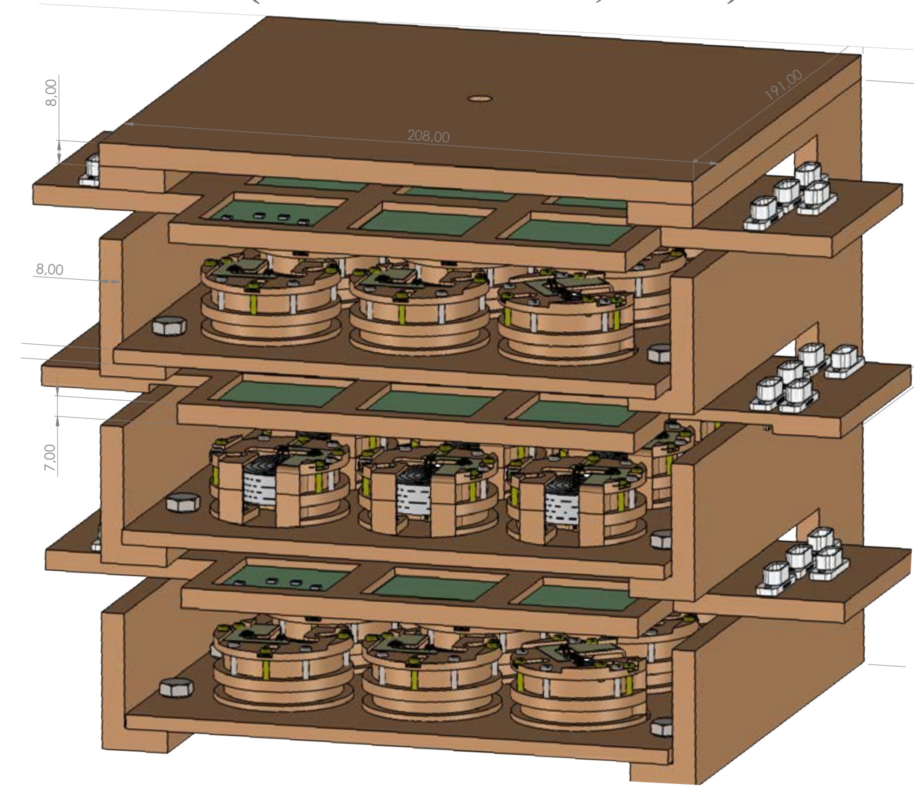
(Ongoing)



3x3x3 CryoCube

1kg payload
integrated HEMT readout

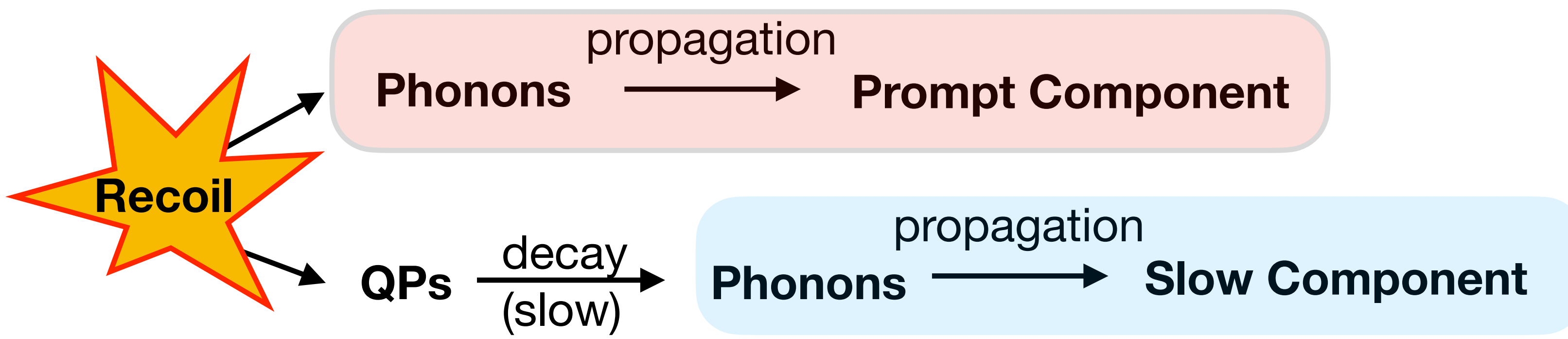
(to be delivered, 2022)



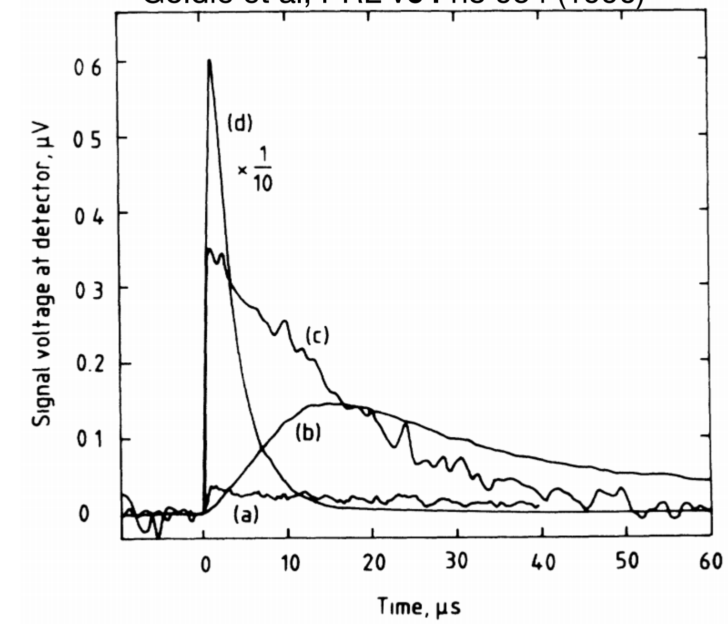
Q-Array development: Overview

Superconductors as Discriminating Target Materials

Recoil produces two excitation types: Phonons and Quasiparticles



Goldie et al, PRL v**64** n8 954 (1990)



Result: **Phonon pulse shape dependent on QP microphysics at the recoil site.**

Plausible that ER:NR differences may arise…
 …. but ER/NR discr. still open question

Compared to CryoCube: “high risk high reward”

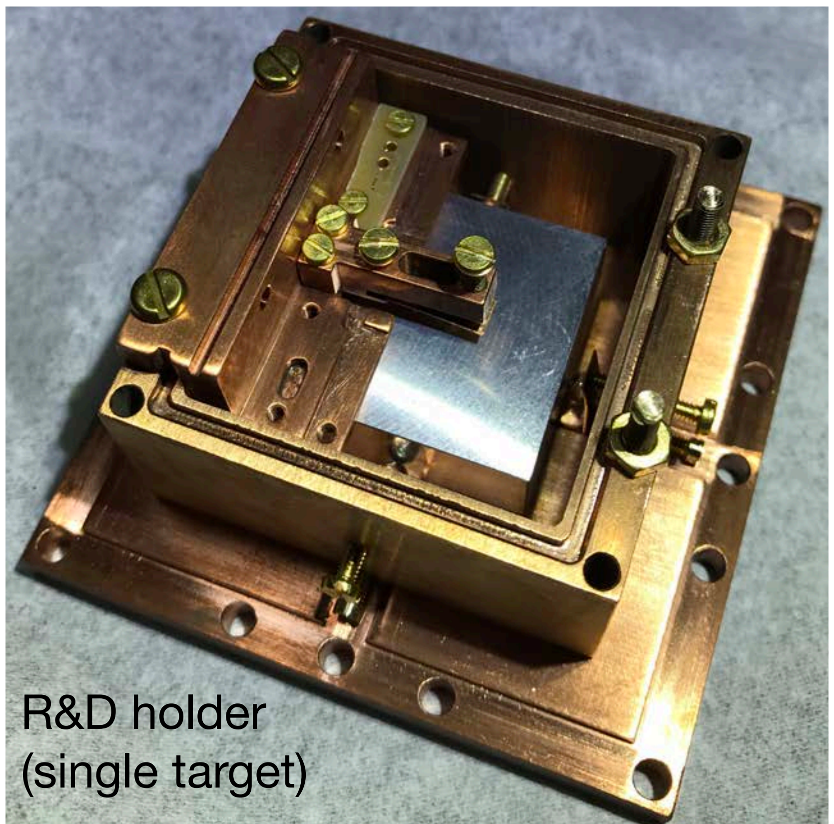
Q-Array baseline target material: Zn
      Convenient Tc (850 mK), relatively high-Z, can grow crystal

Initial production of Zn crystals by RMD (right)
Two Au pads (with and without ZnO barrier)

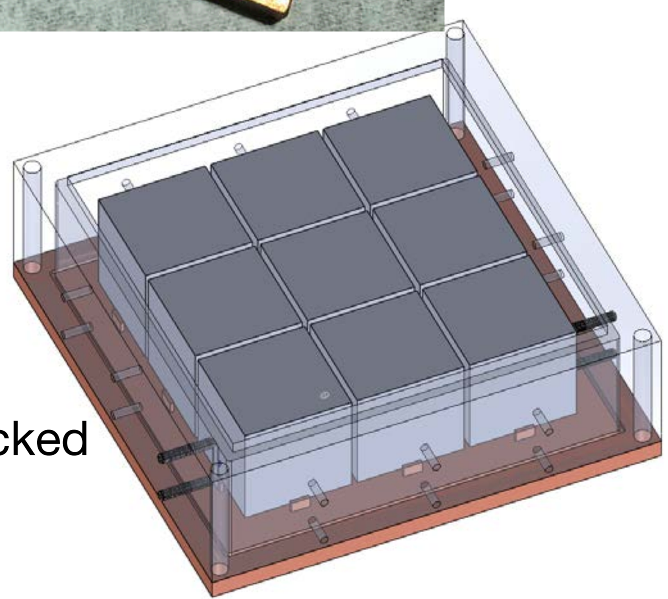
Q-Array development: Overview

Holder Design
(Amherst)

Reproduce optimizations from CryoCube Holder
Adapt to close-packed rectangular geometries
(simpler in that capacitance is irrelevant)



R&D holder
(single target)



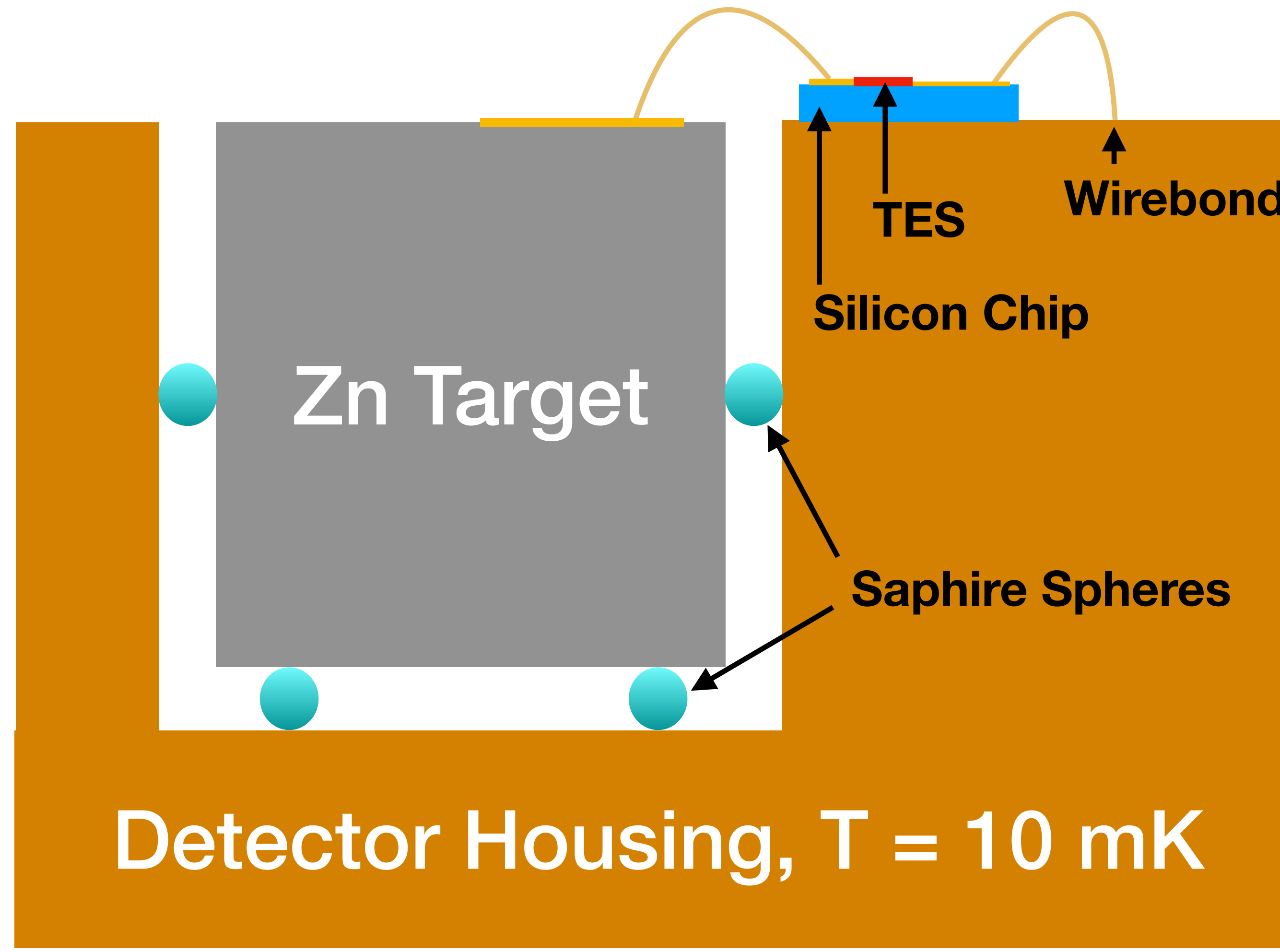
Q-Array at ILL:
3x3 and close-packed

TES-based Readout

First: Phonon transport to Au pad on target
-> conversion to e-system in normal metal

Then: Thermal transport through Au structures and TES

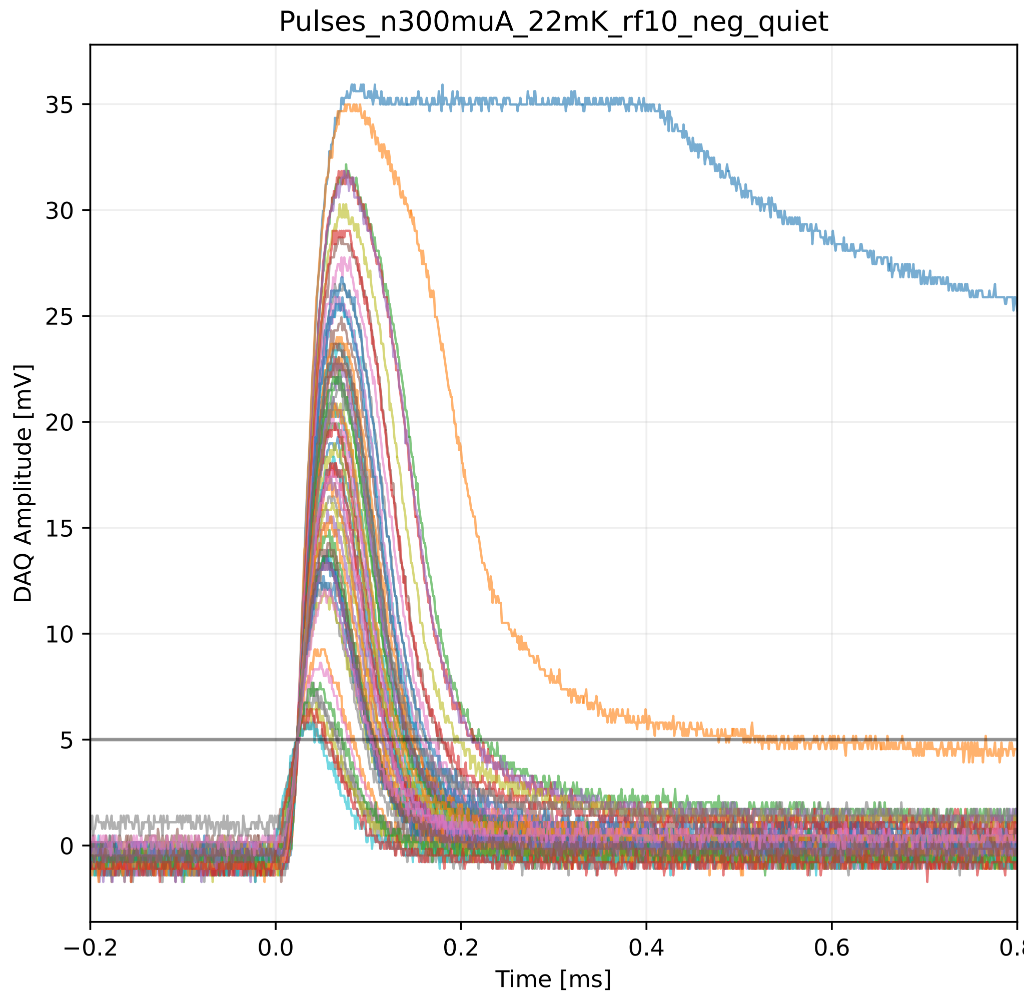
Allows for a low threshold, plus great ease of fabrication.

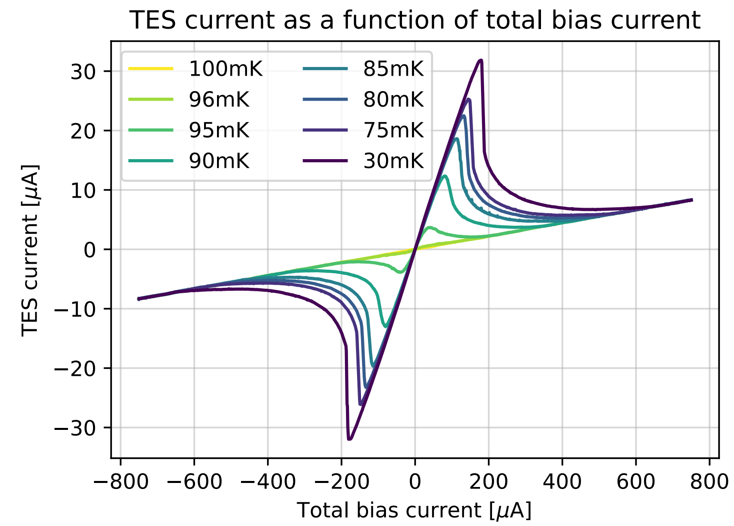


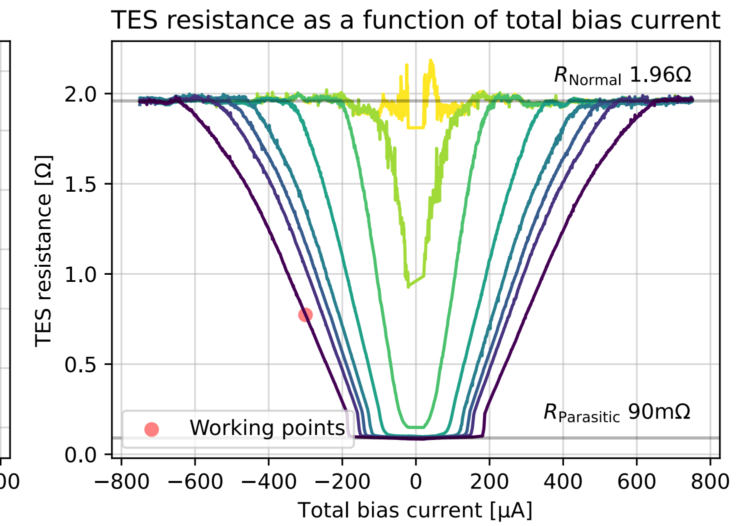
Q-Array V1 Results

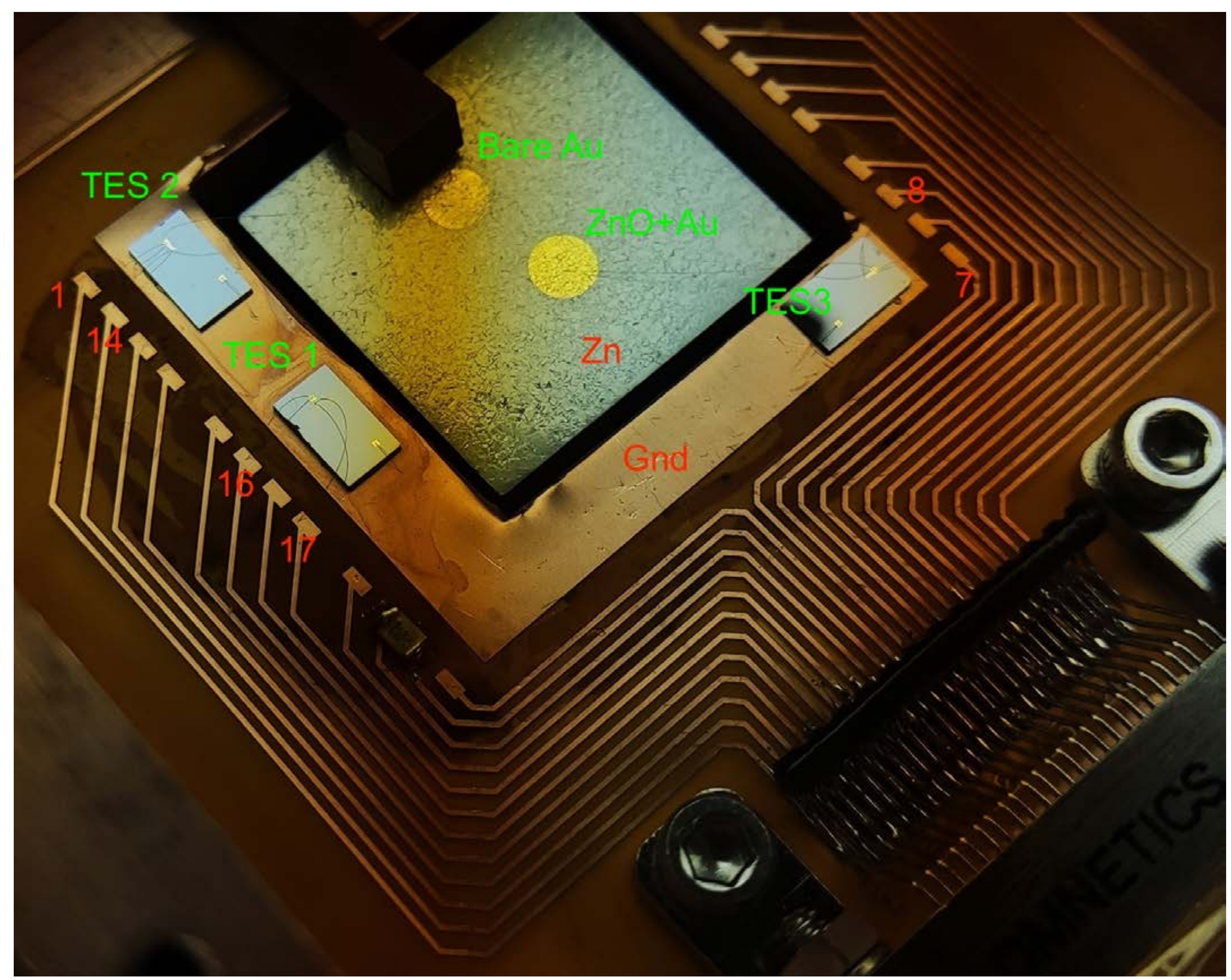
Detector Operation

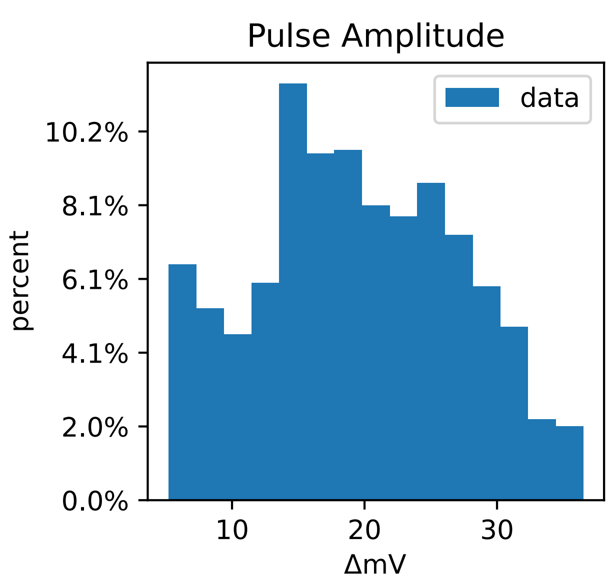
(MIT)

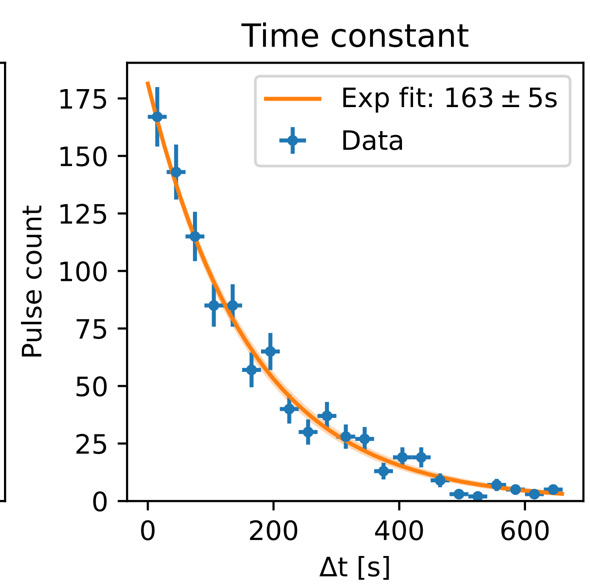










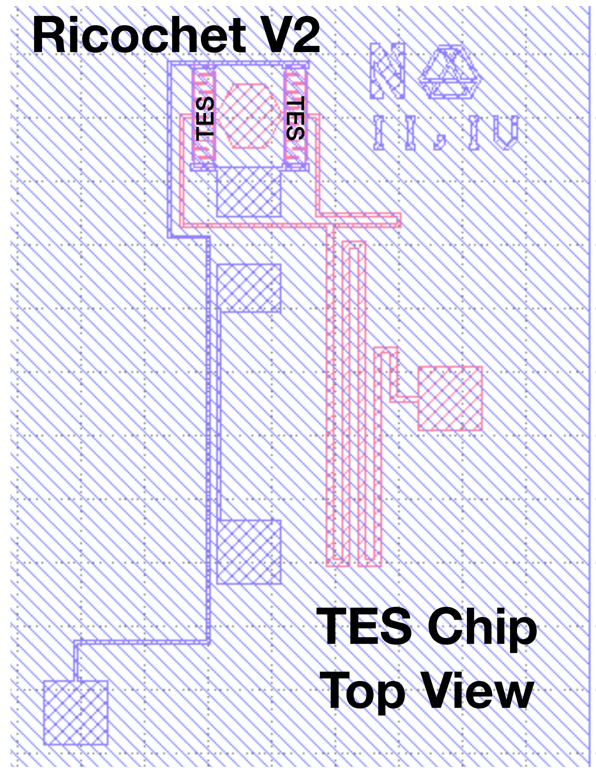


Q-Array V2 in Fabrication Now

Thermal chip design
(Northwestern)

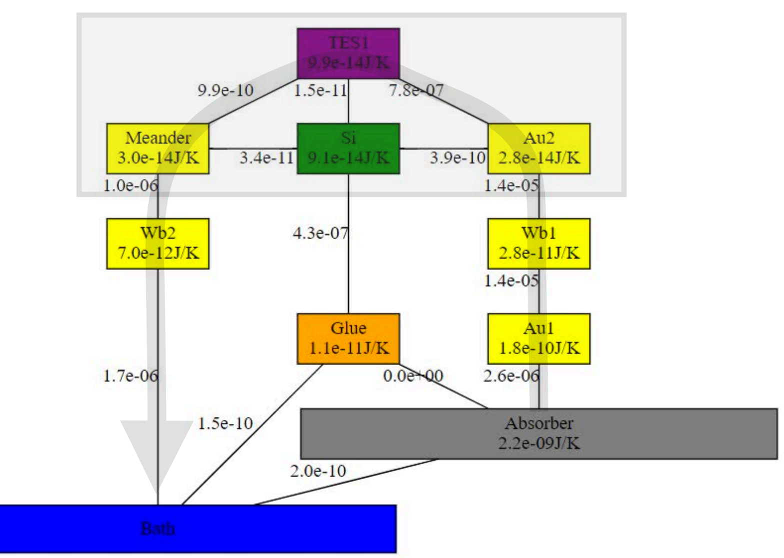
Key parameter: Au meander length
(sets G from TES to bath)
Model motivates few-mm meander.

Predict 10-20eV RMS on 41g Zn target
(~100ms falltime)

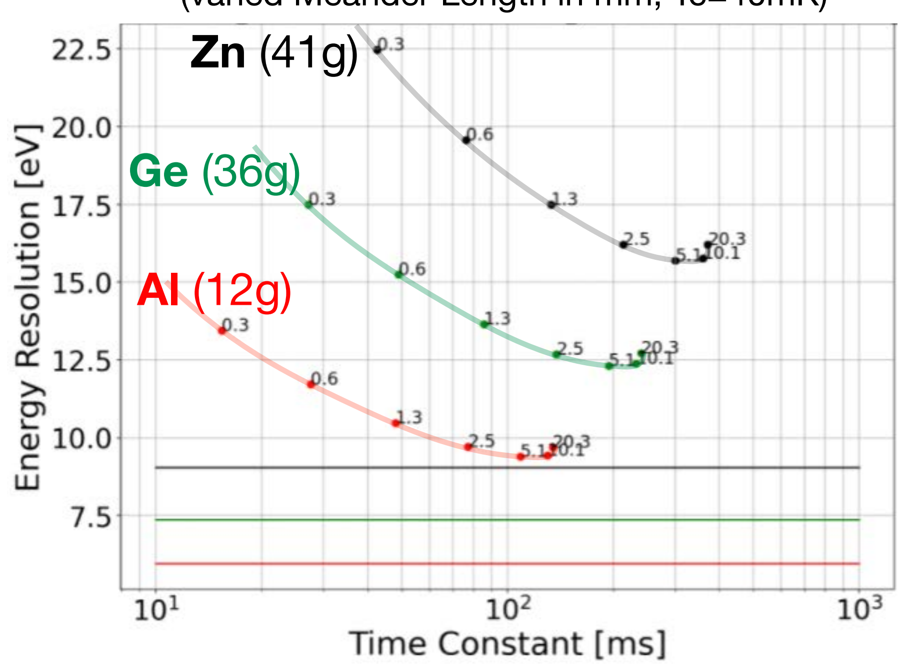


Wafer Deposition in Progress
(Argonne)
Al/Mn TES detectors
Tc target = 40 mK

Expect First Results by end of Year!



Predicted Resolution and Falltime
(varied Meander Length in mm, Tc=40mK)



Gold Deposition on Targets
Si Demonstrated
Ge / Zn next

Summary and Timeline

An exciting past year,
and only more exciting in the future!