Cryogenic Detectors & associated instrumentation.

- IN2P3, Massive Detector R&D Overview -

- Journée R&T IN2P3 -

IPHC 06-08 Nov 20213 *https://indico.in2p3.fr/event/29132/*

Alex Juillard IP2I

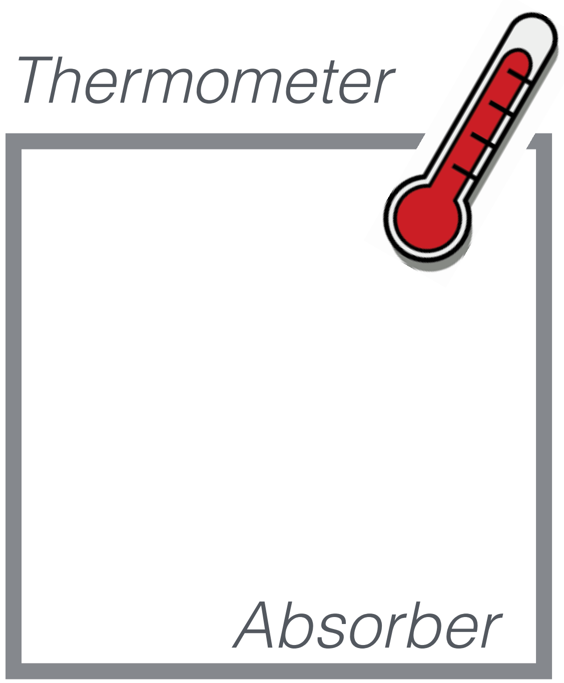
contribution from APC, IP2I, LPSC, IJCLab & Institut Néel

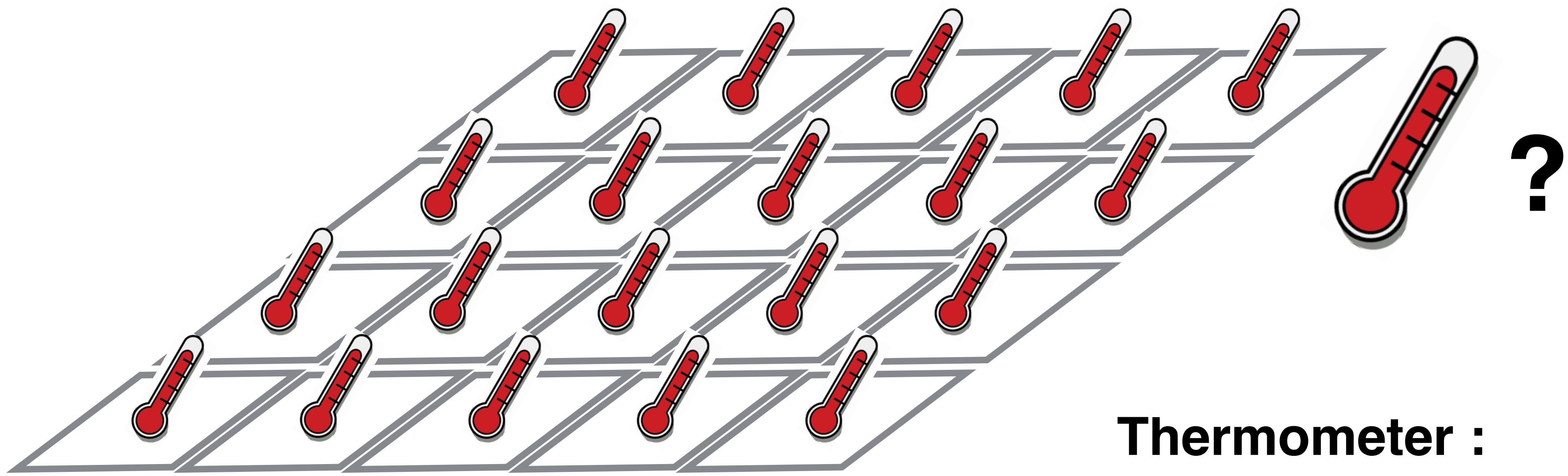
IN2P3
Institut national de physique nucléaire
et de physique des particules

LES 2 INFINIS
LYON

- **Cryogenic Detector ?**
  - basics
- **Science application w/ massive detector**
  (with IN2P3 involvement)
  - $0\nu\beta\beta$
  - Dark Matter
  - CEνNS
- **Ongoing Project R&D** & next generation experiments
  - massive bolometer
- **Conclusion**

Cryogenic Detector ??





« massive » Bolometer:

- ~ g ➙ ~ kg
- Some of the fabrication step done *«by hand»*
- Particle detection « one by one »
- Main application :
  Rare event detection
  - Dark Matter
  - $0\nu\beta\beta$
  - CEνNS

Matrice de Bolomètre :

- 1 ➙ 100k « pixels »
- Some of the fabrication step done *«collectively»*
- Particle detection « one by one » or by flux
- Main application :
  Astro
  - Sub-mm (50-600 Ghz)
  - X

see A. Catalano for KIDs matrix detectors

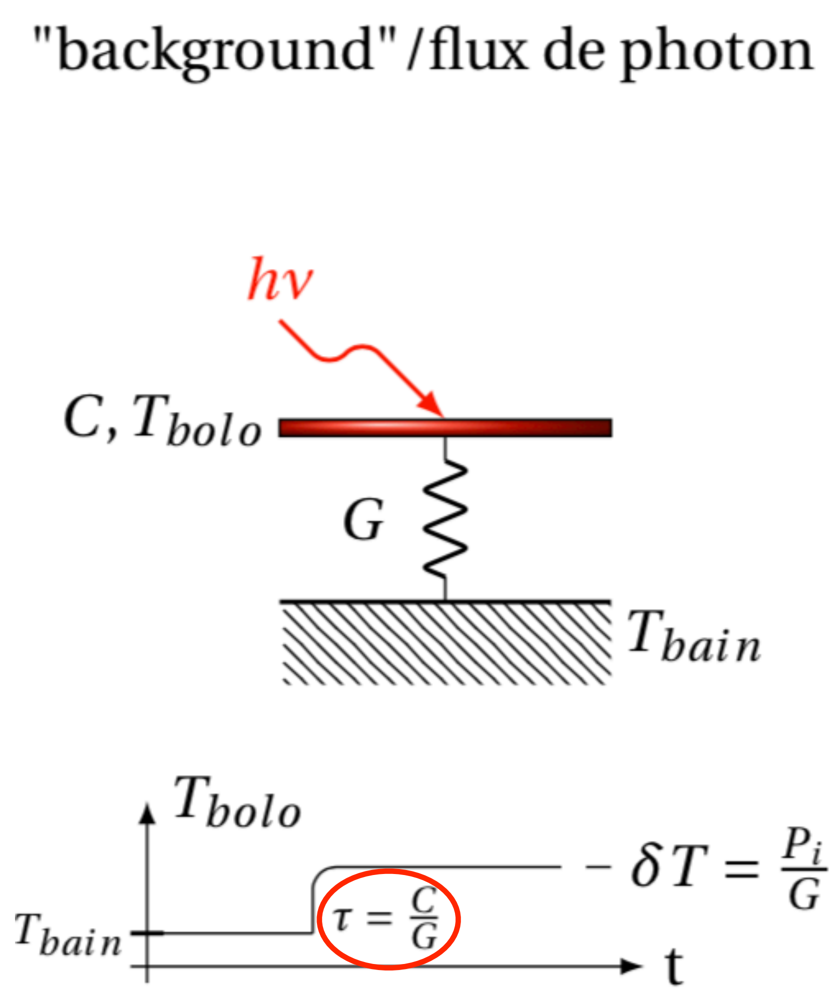
Thermometer :

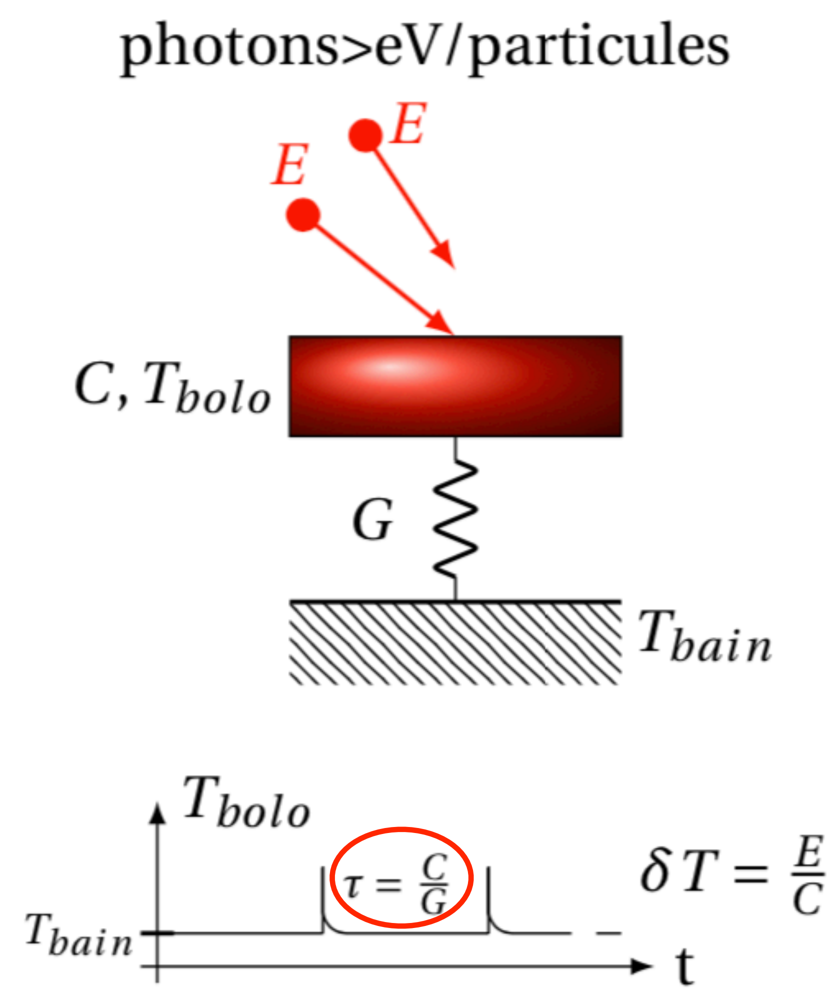
- T ➙ measurable value
- Resistive
  - superconductor
  - Metal InsulatorTransition
- Magnetic
- w/ out of equilibrium mediator
  - Copper pairs in SC material :
  - Kinetic Inductance vs dN_{qp}
  - Out of equilibrium phonon can brake Cooper Pairs

Link with Quantum sensor

Cryogenic Detector ??

D. Prêle DRTBT 2018





« Bolometer » Mode

- ✦ Response ~ C/G
- ✦ NEP = $\sqrt{4k_BT^2G}$ [W/√Hz]

« Calorimeter » Mode

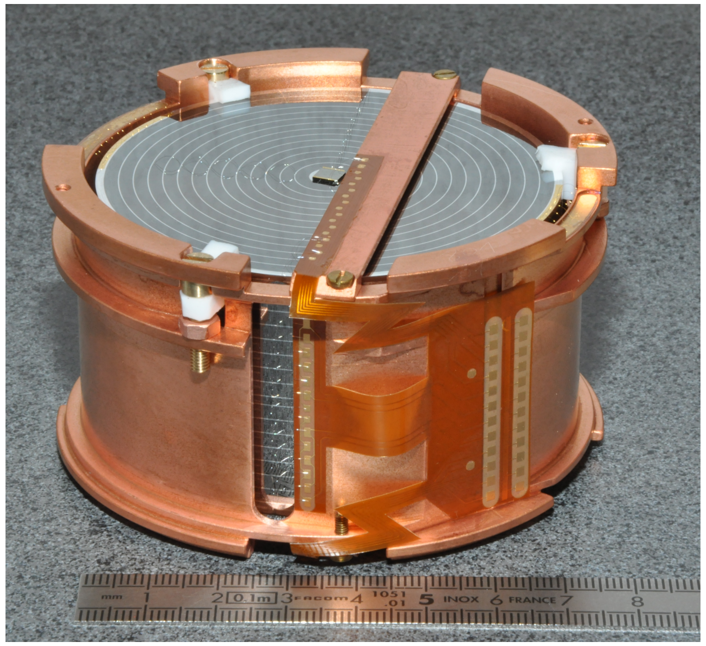
- ✦ Decay ~ C/G
- ✦ $\delta E = \sqrt{4k_BT^2C}$ [J]

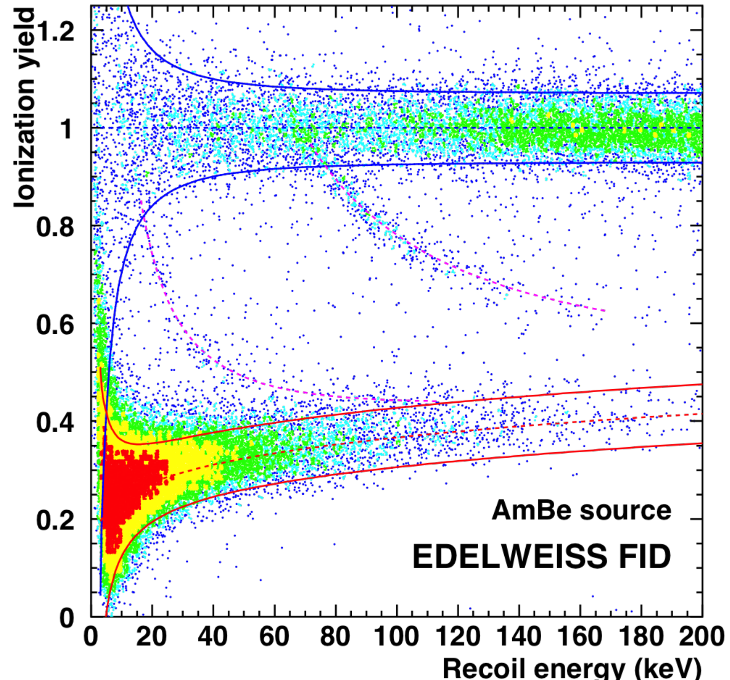
Low Temperature → Sensitivity ↗ & Noise ↘

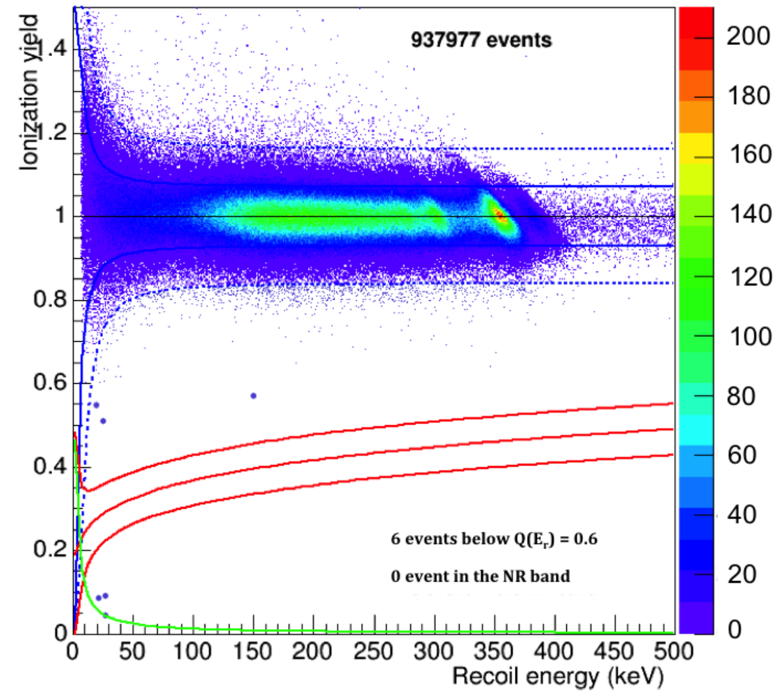
T_{bath} ~10 mK - 300 mK

R&D = absorber + thermometer + electronics (Z adaptation, gain, readout) + cryo environment

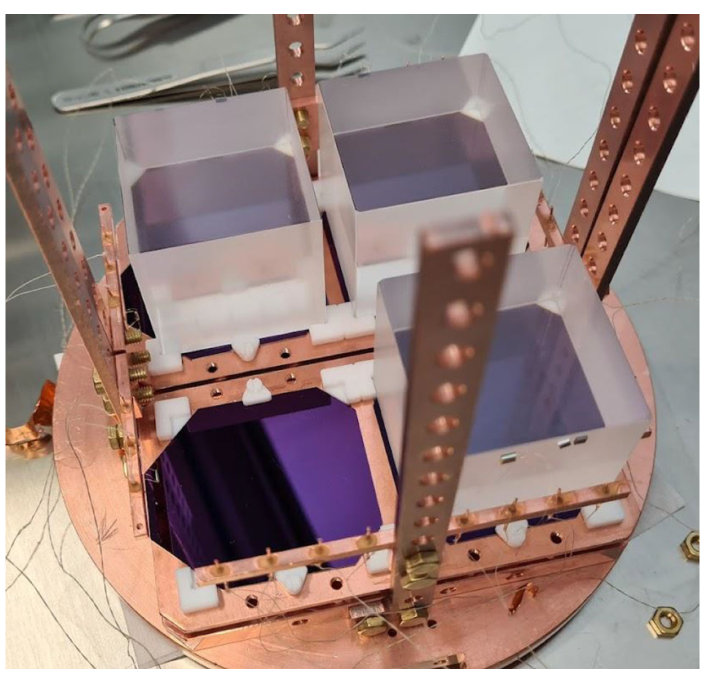
Cryogenic Detector : why ??

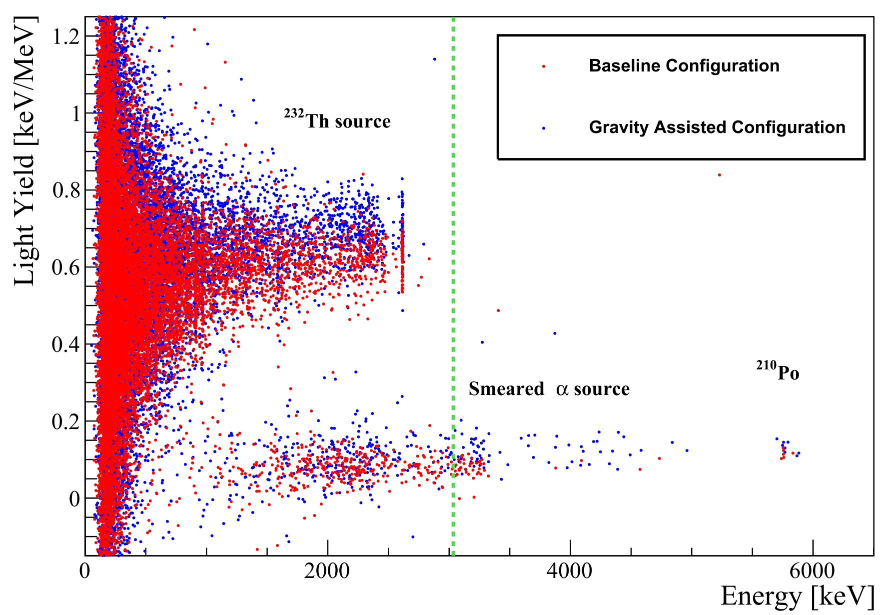






EDELWEISS-III ; **2017** *JINST* 12 P08010





CUPID ; Eur. Phys. J. C (**2022**) 82:810

Double readout cryogenic detectors allows for an **evt-by-evt background rejection** :

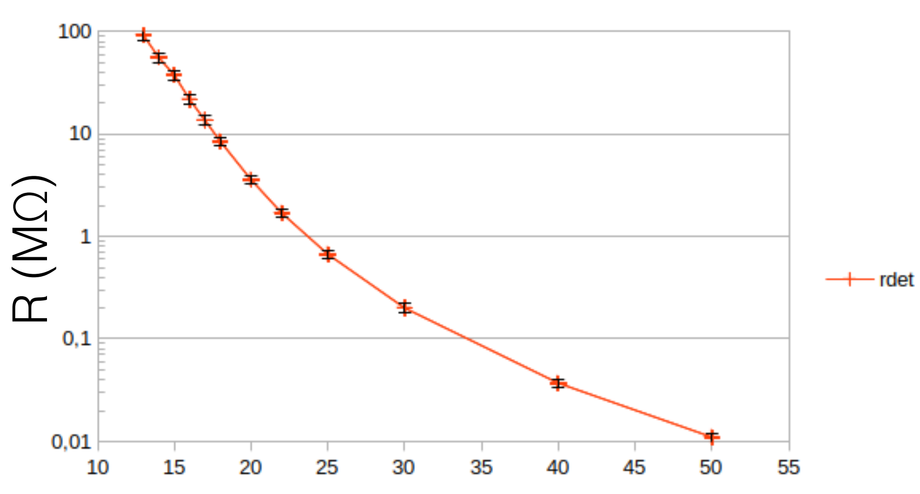
- ✦ **Heat and Ionization on Ge** detector :
  - ➡ Elec. Recoil / **Nuclear Recoil discrimination**
  - ➡ **Heat only** event **rejection**
  - ➡ **surface event rejection**
- ✦ **Heat and Light** on different crystal
  - ➡ **α background rejection**

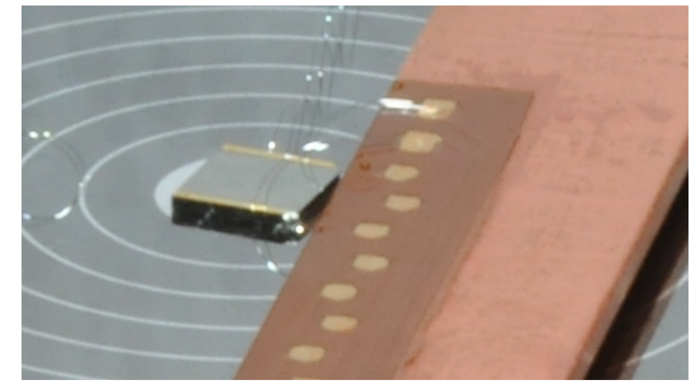
R&D : Ge-NTD thermal sensors

Ge-NTD **(IJCLab, IP2I)**

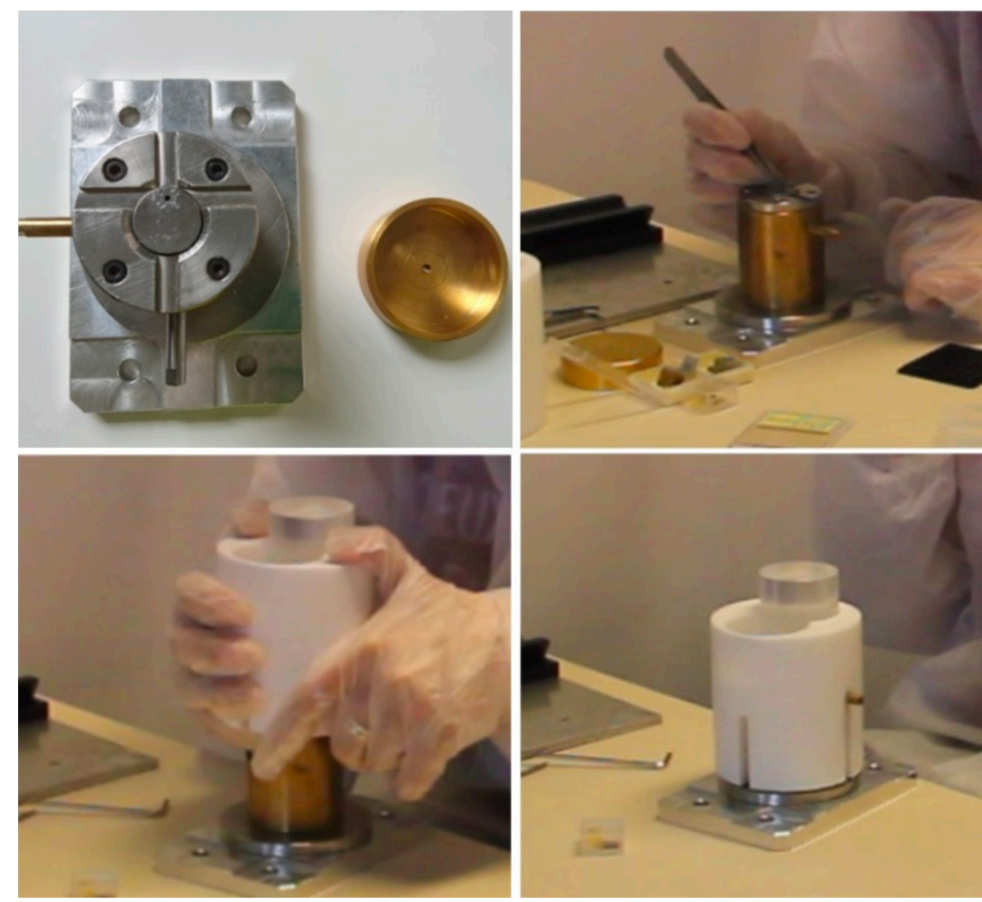
Neutron doped semiconductor. Near Metal Insulator Transition.

- ✦ NTD production on french reactor feasible in France
- ✦ Production (2015) during the LUMINEU ANR (CSNSM - CEA)
- ✦ No new production planed. Contact w/ other producer.
- ✦ **R&D : Optimization**
  - cutting, electrodes metallization. Gluing.
  - Massive test for selection and extra noise measurement
  - **need = few 1000s of NTDs over the next decade**



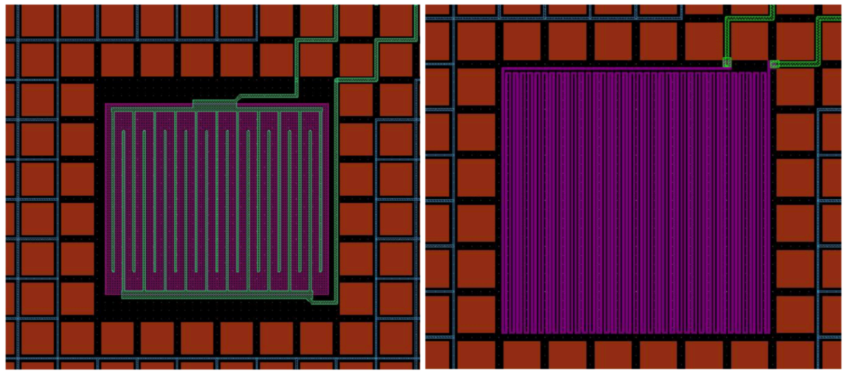


EDELWEISS FID800 det.



Eur. Phys. J. C **80**, 44 (2020)

R&D : NbSi thermal sensor



Low Impedance High Impedance

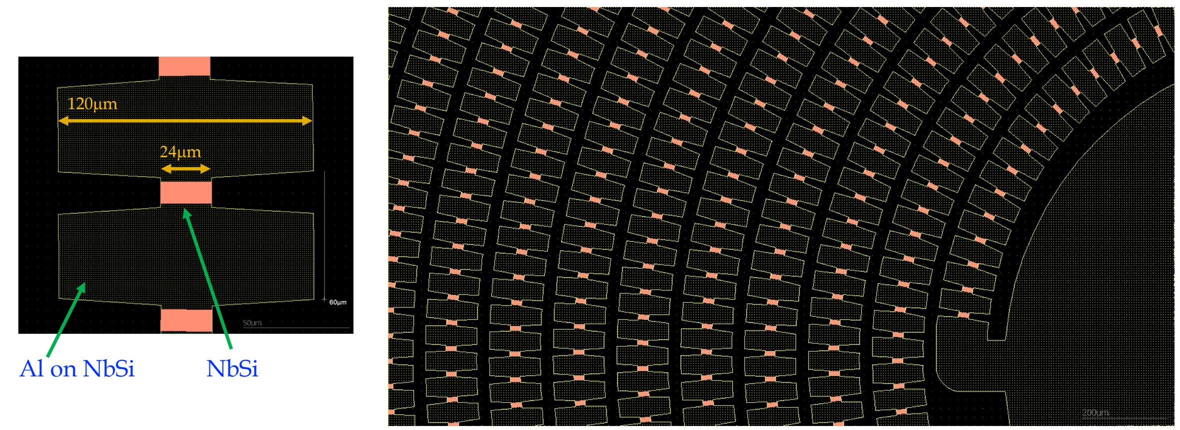
Nb_xSi_{1-x} (IJCLab)

Alloy near the Metal Insulator Transition or superconductor

- ✦ > 20 years of development. Co-evap of thin film.
- ✦ Best result in the superconducting mode (high or low Z)
- ✦ **Micro-lithography** (CNRS/C2N) for both **detectors matrices** (QUBIC) **and massive bolometers** (EDELWEISS, CryoSEL, TINY).
- ✦ **R&D :**
  - Specific heat minimization ➙ Phonon traps
  - Low threshold « metastable »state for heat only event discrimination (**Superconducting Single-Electron Device** -SSED-, CryoSEL ANR project)
  -

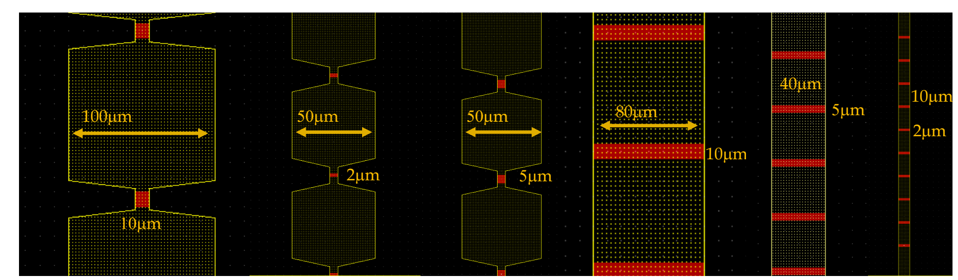
The NbSi phonon-trap design

17000 NbSi-Al cells in series to form a spiral

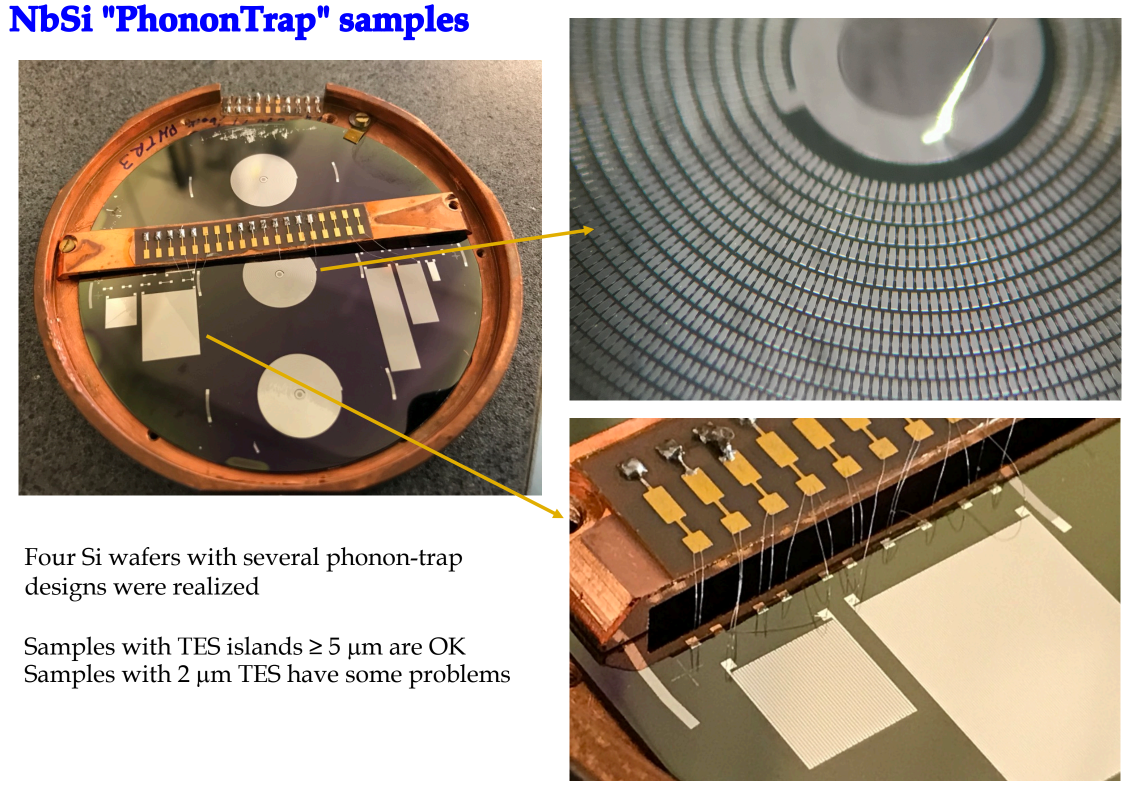


Other tested designs …

10 µm, 5 µm and 2 µm TES



NbSi "PhononTrap" samples



Four Si wafers with several phonon-trap designs were realized

Samples with TES islands ≥ 5 µm are OK
Samples with 2 µm TES have some problems

Stefanos Marnieros & IJCLab

R&D on Massive Bolometer

3 major scientific goals (All are rare events search) :

- **$0\nu2\beta$** (double beta desintegration w/o neutrino emission) :

  Prepare the future of CUORE = **CUPID**

  ➡ **CUPID-Mo** @ LSM is **a major input for CUPID**

  ➡ Goal = 1 ton of detector with bkg discrimination

- **Dark Matter** « crisis » : no direct detection so far + no new physics at LHC

  ➡ « near death » of the « standard » GeV-TeV SUSY WIMPs candidate.

  ➡ Focus on low mass and ALPs (Axion Like Particle)

  ➡ EDELWEISS-SubGeV, **TESSERACT** proposal @ LSM

- **Search of New Physics** with precision **CEνNS** **(Coherent Elastic neutrino-nucleus scattering)** measurement near nuclear reactor

  ➡ **Push the discrimination** at very low threshold

  ✓ **RICOCHET** (installation started @ ILL reactor)

  ➡ **background rejection with cryogenic active vetos**

  ✓ **Nucleus** @ Chooz reactor

- Many other application:

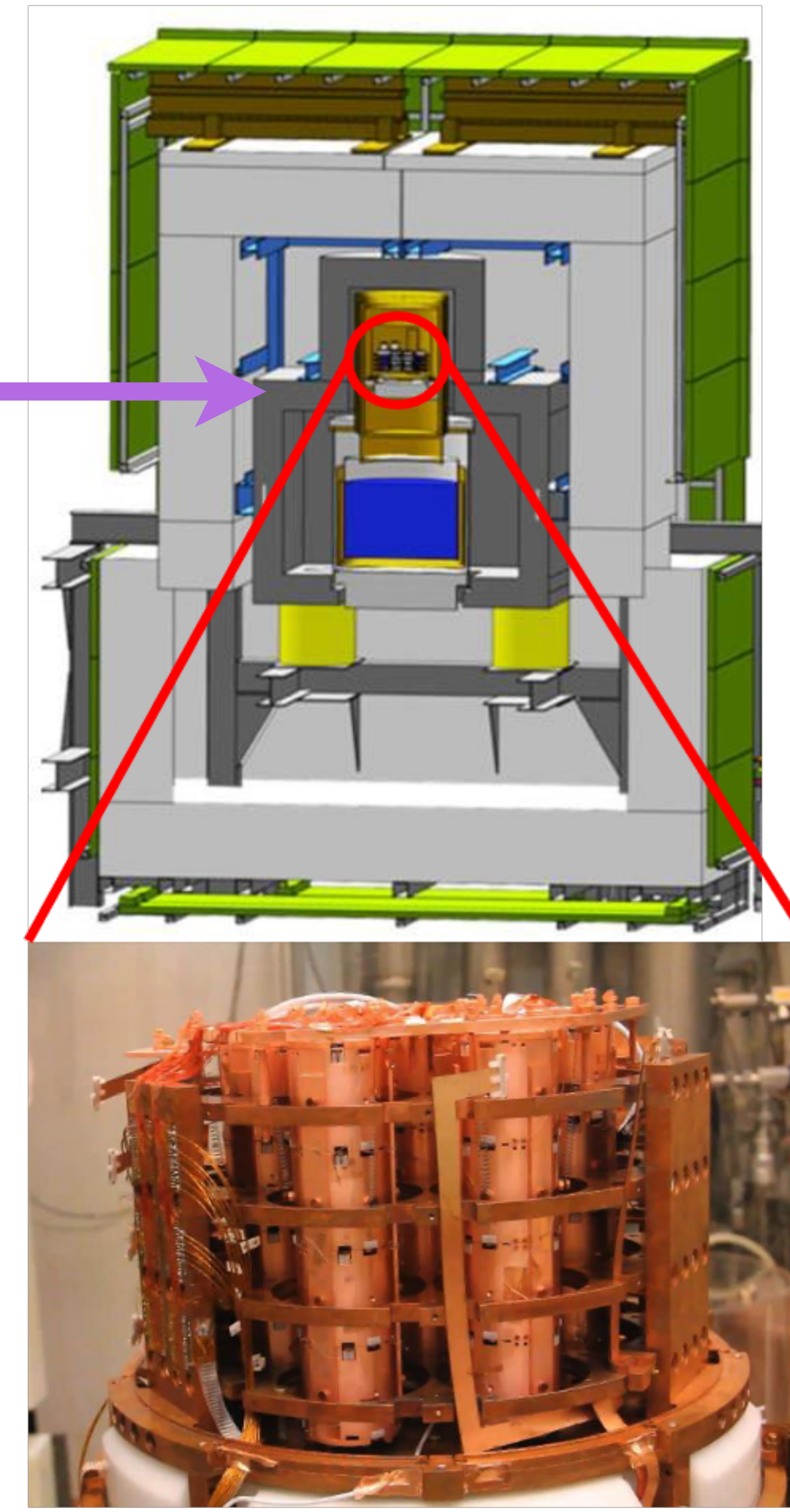
  ➡ Fast neutron spectroscopy, rare decay observation, metrology, etc.

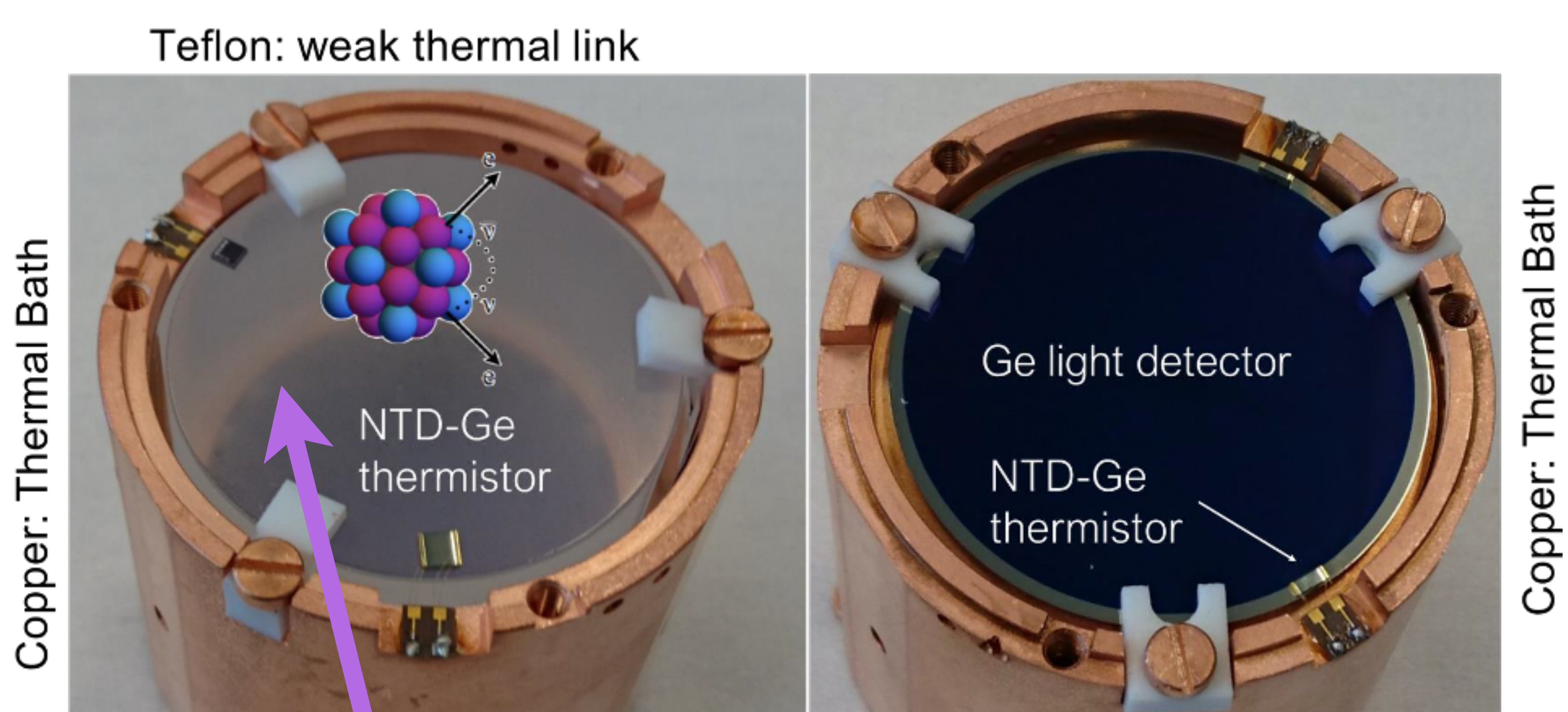
CUPID-Mo @ LSM [EPJC 83, 675 (2023), PRL162501 (2023)]

✦ IJCLab, IP2I + CEA

✦ **Pilot ββ experiment** based on scintillating bolometers with NTD readout

- **20x Li_2MoO_4** crystals coupled to Ge light detectors
- Data taking at **LSM in EDELWEISS cryostat (2018-20)**
- **Best worldwide results** on ββ decay of ^{100}Mo
- Demonstrator of the **CUPID technology (see next slide)**





Li_2Mo_4 crystal enriched in ^{100}Mo (99%)
210 g – cylinders ø44 mm x 45mm
2.1 kg of ^{100}Mo

CUPID (CUORE Upgrade with Particle Identification)

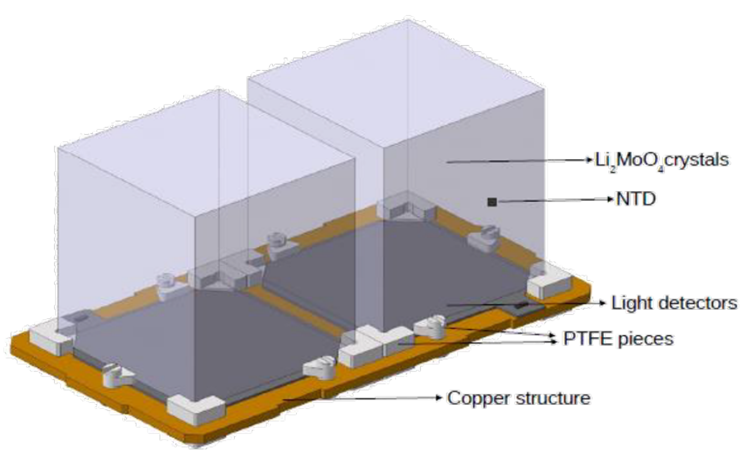
[EPJC 82, 810 (2022), JINST 18, P06033 (2023)]

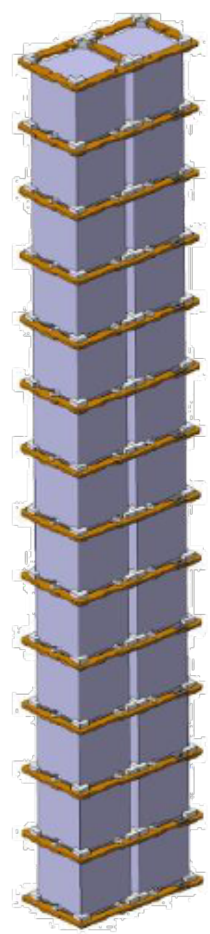
✦ IJCLab, IP2I + CEA

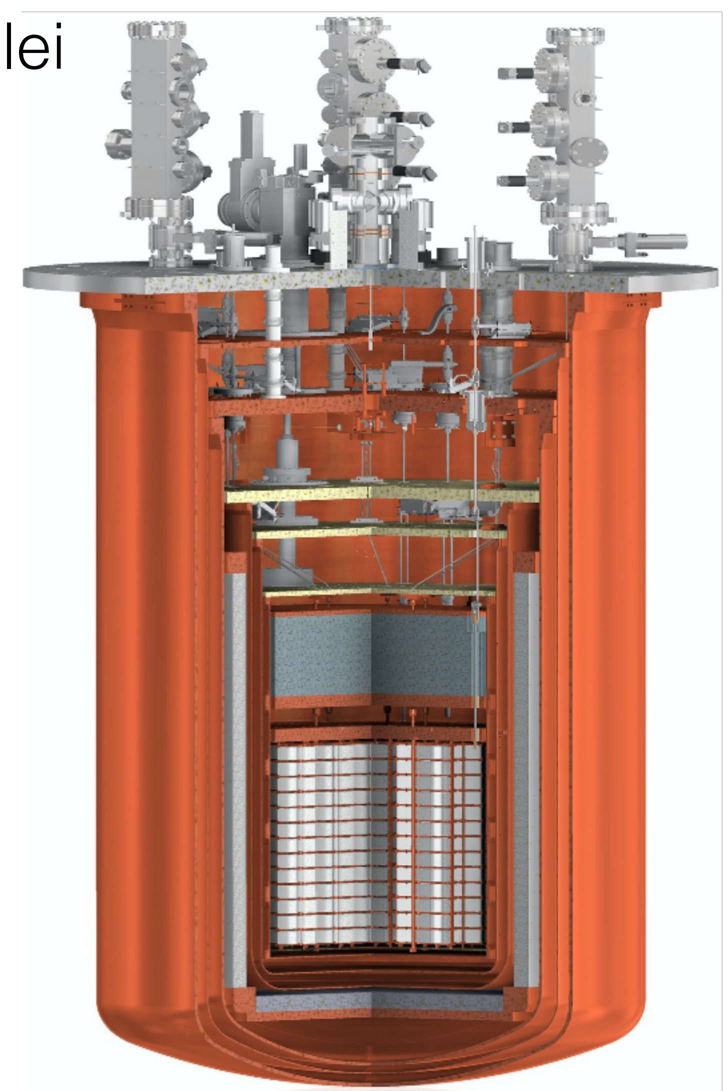
✦ **One of the 3 next-generation ββ experiments** selected by the US and EU funding agencies (CUPID, LEGEND, nEXO)

- **170 people & 33 institutions**
- Exploit **CUORE infrastructure** (Gran Sasso) with **CUPID-Mo technology**
- **Single module**: $Li_2{}^{100}MoO_4$ 45×45x45 mm **~ 280 g**
- 57 towers of 14 floors with 2 crystals each - **1596 crystals**
- **~240 kg of ^{100}Mo** with >95% enrichment ~1.6×10^{27} ^{100}Mo nuclei
- **Bolometric Ge light detectors as in CUPID-Mo**

✦ **Data taking > 2030**







2 X 14 x 57 = 1596

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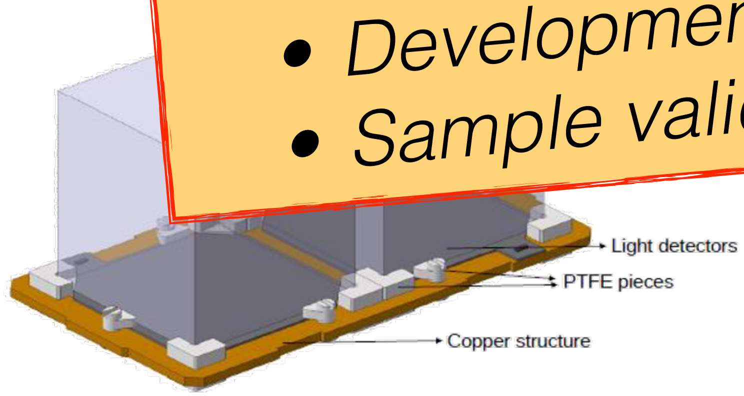
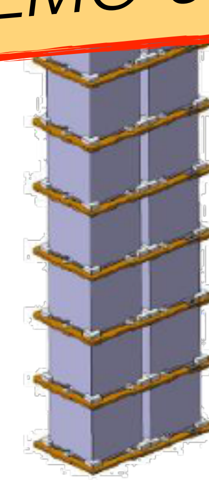
- **Single module**: $Li_2{}^{100}MoO_4$ 45×45x45 mm **~ 280 g**
- 57 towers of 14 floors with
- **~240**
- **Bolo**

✦ **Data tak**

Numerous IN2P3 (& IRFU) tasks:

- *Light detectors*
- *Transportation and storage of the towers*
- *Part of NTD sensor characterization*
- *Part of radioactivity measurements*
- *Alternative heater production, based on Pd meander on Si*
- *Development of LMO crystals in France*
- *Sample validation of LMO crystals*





2 X 14 x 57 = 1596

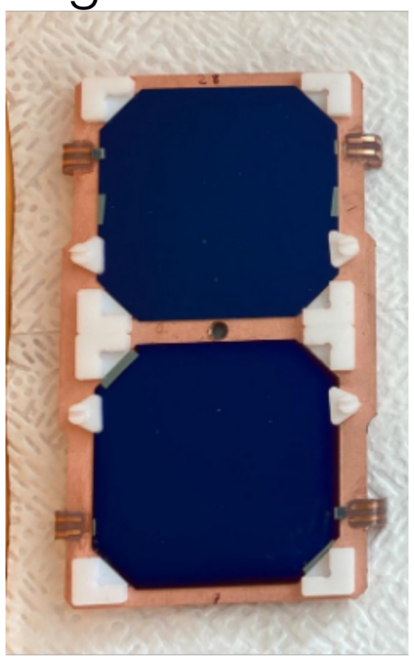
R&D : CUPID (CUORE Upgrade with Particle Identification)

CUPID Prototype Tower : ANR CUPID1 2022-25 + R&T IN2P3

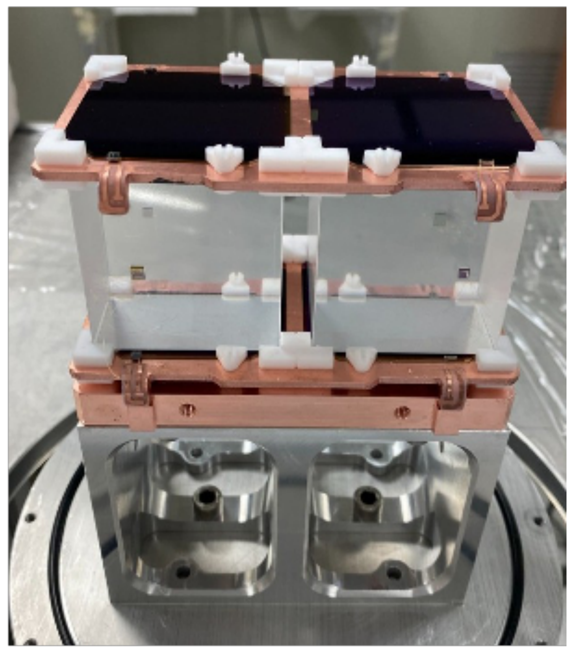
✦ **Assembly in IJCLab and Gran Sasso**

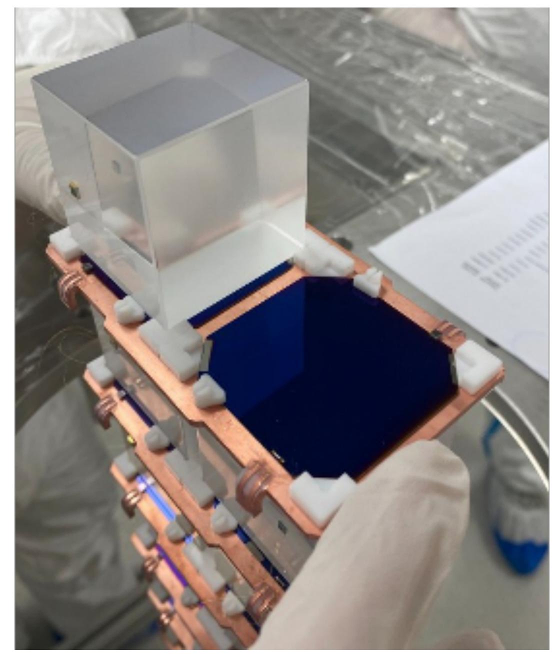
- **To be tested Mid-2024** in Cuoricino Cryostat @ Gran Sasso

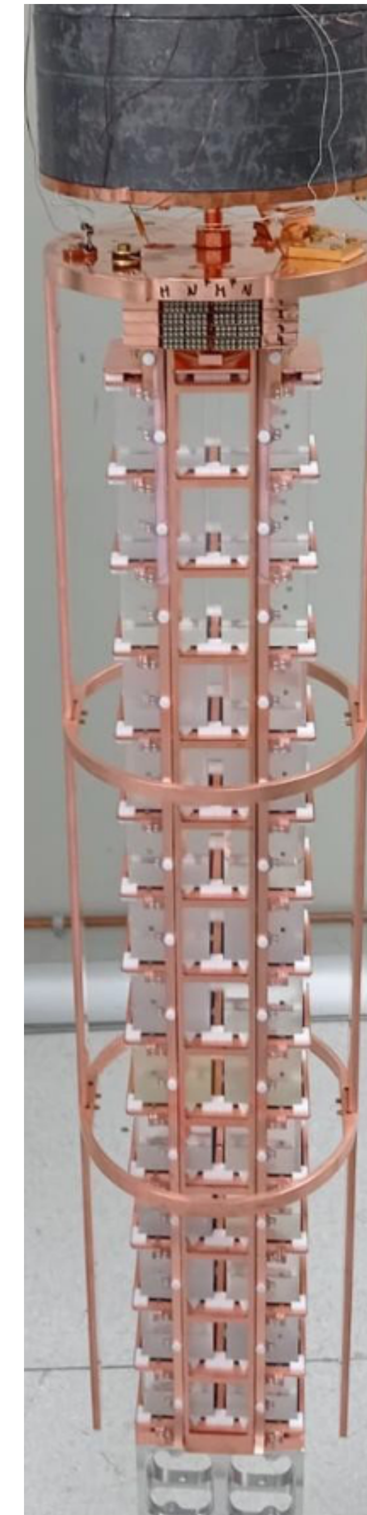
Light Detector



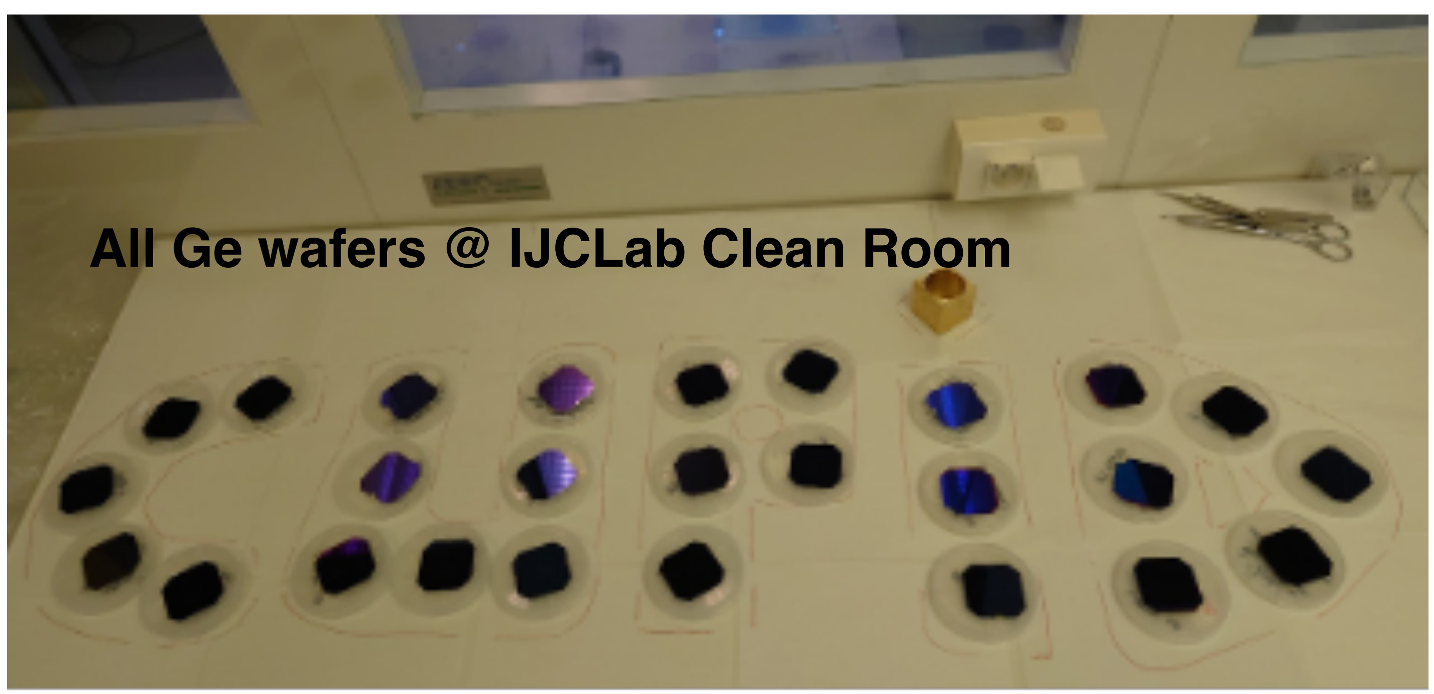
Tower Construction







CUPID Tower @ GS (2022)



R&D : CUPID (CUORE Upgrade with Particle Identification)

CUPID Prototype Tower : ANR CUPID1 2022-25 + R&T IN2P3

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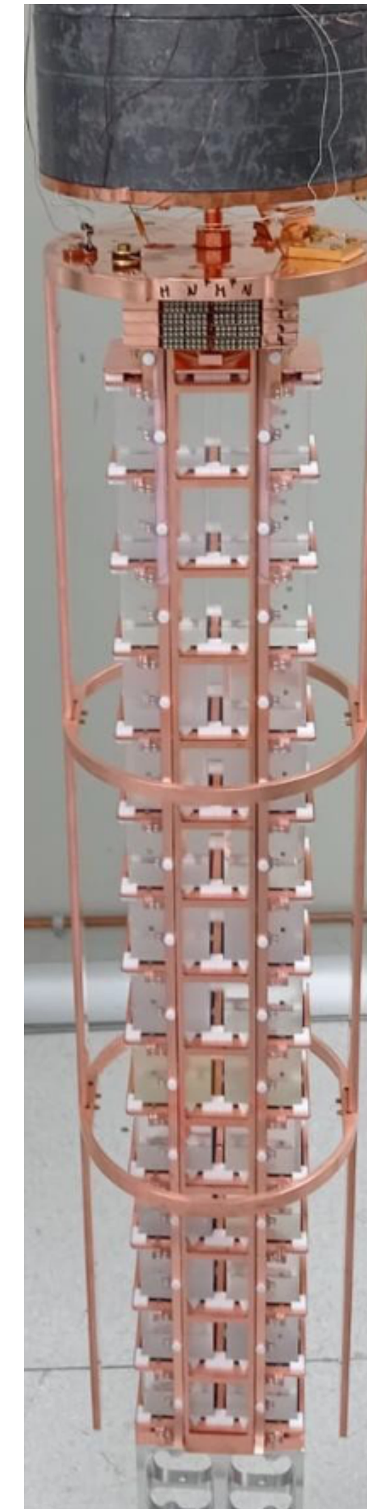
Light Detector

Tower Construction

IN2P3 (& IRFU) tasks:

- *SiO coating of 50% of the light detectors*
- *gluing (NTD and heater) of LMOs and light detectors*
- *pre-test of light detectors at IJCLab (& IP2I ?)*
- *participation to the tower assembly @ Gran Sasso*

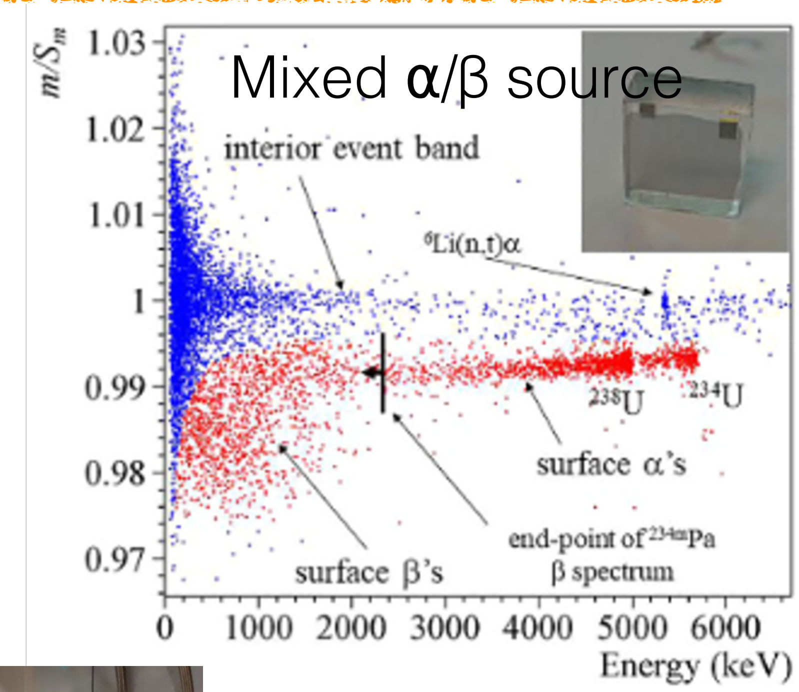


CUPID Tower @ GS (2022)

CUPID related R&D : CROSS (2018-24)

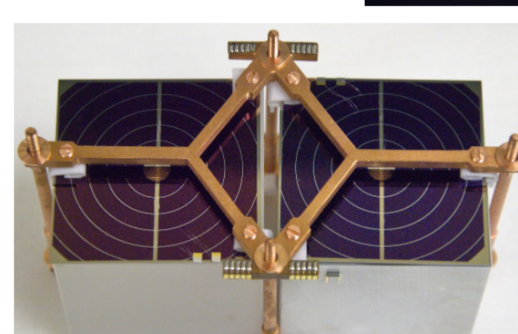
[Appl. Phys. Lett. 118, 184105 (2021), Appl. Phys. Lett. 118, 184105 (2021)]

- **Reject surface events by PSD assisted by metal film coating**
  - Proof of concept achieved with small prototypes
  - Both **surface α's and β's** are **separated from bulk events**

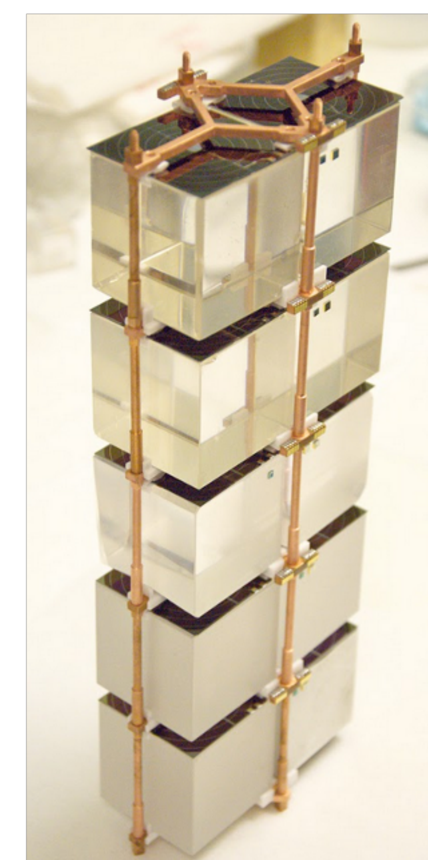


- **Technology demonstrator**
  - ~ 5 kg of ^{100}Mo shared in ~36 x Li_2MoO_4 crystals (+ 6x $^{130}TeO_2$ crystals)
  - **Dedicated cryostat** @ Canfranc underground laboratory

- **Redundancy**
  - surface sensitivity
  - scintillation light detection
  - Improved Light detectors
    - ➡ enhanced by Neganov-Trofimov-Luke technology : **demonstrated**
    - ➡ Now **CUPID baseline**



Prototype CROSS Tower

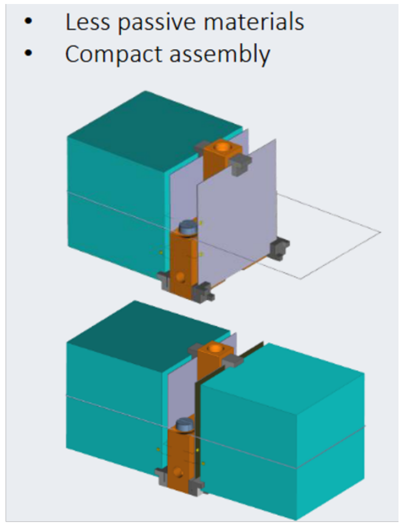


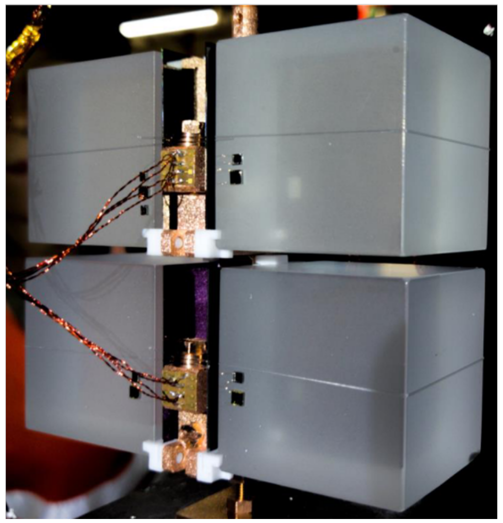
CUPID related R&D : BINGO (2020-26)

[arXiv.2301.06946, arxiv.2204.14161]

✦ Three innovations to reject background in **ββ** decay experiments based on Li_2MoO_4 and TeO_2

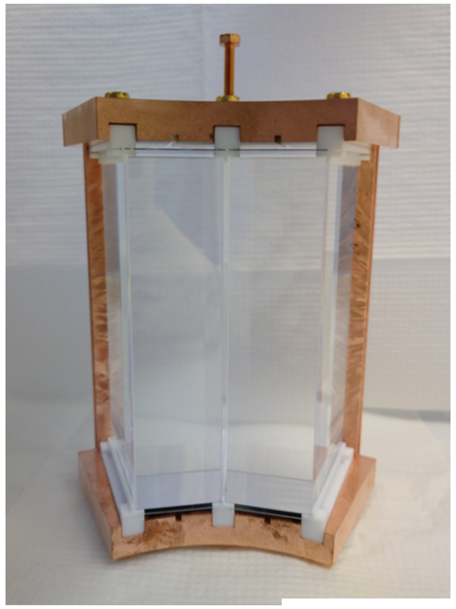
- **Revolutionary assembly** to reject surface background
  ➡ The light detector shields the passive materials





- **Enhanced-sensitivity** light detectors (Neganov-Trofimov-Luke) **(see next slide)**

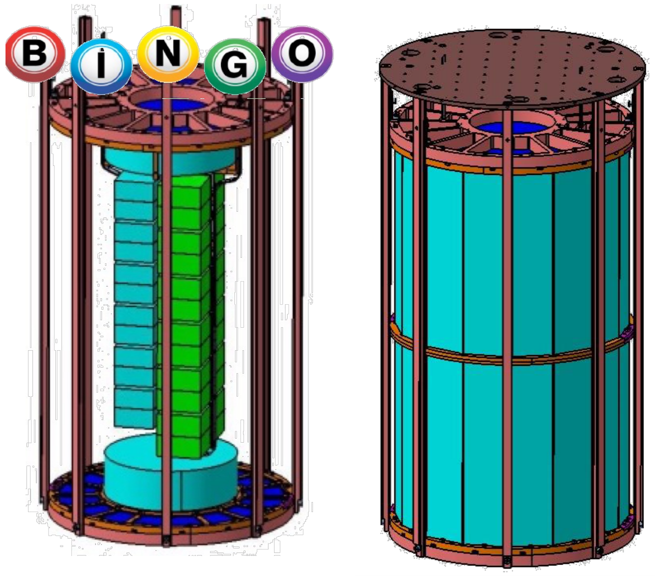
- **Internal veto** (ultrapure BGO/$ZnWO_4$ scintillators)
  ➡ mitigate **γ** background in TeO_2



VETO prototype
BGO scintillators

✦ BINGO demonstrator at LSM

- **Dedicated cryostat :** installation in 2024 in part of the EDELWEISS space (now dismantled) @ LSM

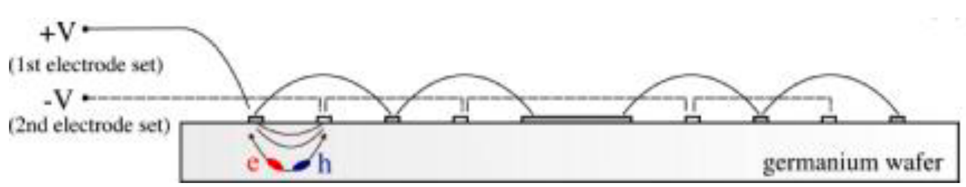


CUPID related R&D : BINGO (2020-26)

[arXiv.2301.06946, arxiv.2204.14161]

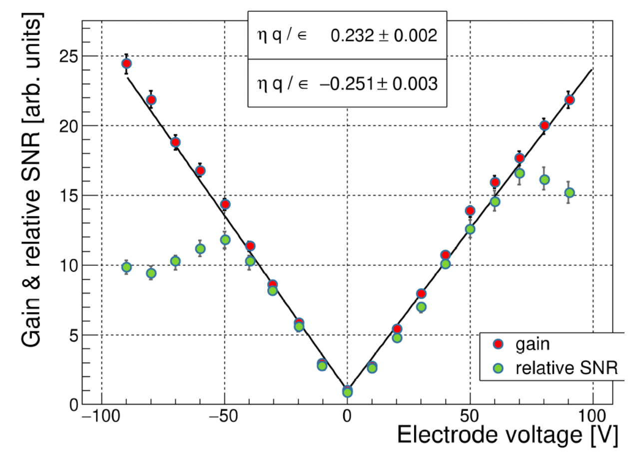
BINGO - Technology demonstration NTL

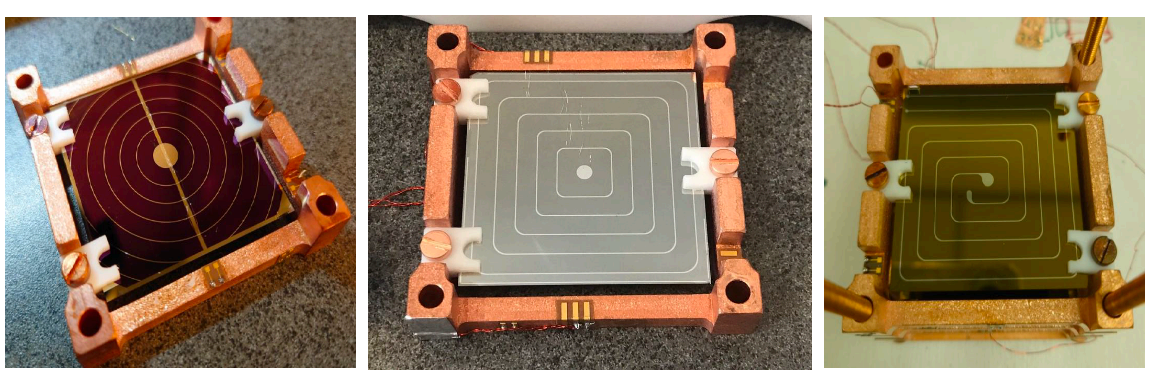
NTL assisted light detectors
Original design: 1 sided Electrode deposition, circular, typical operation voltage 50 to 100V

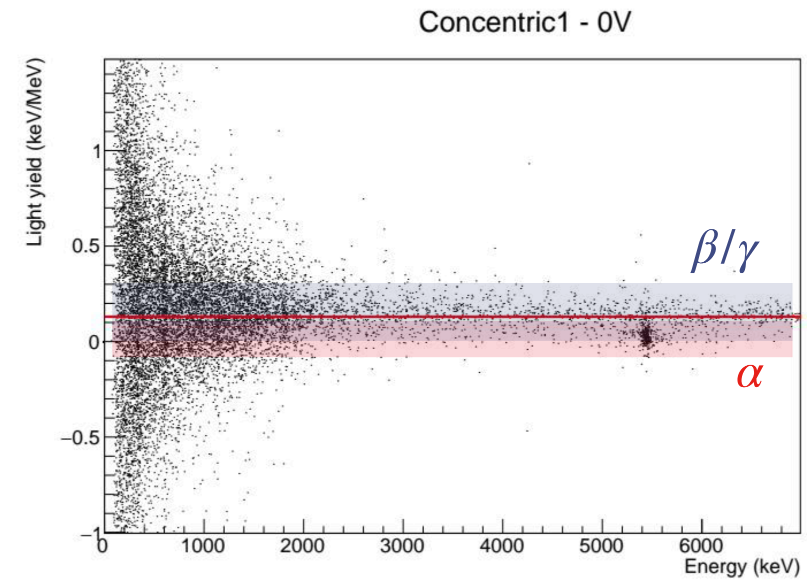


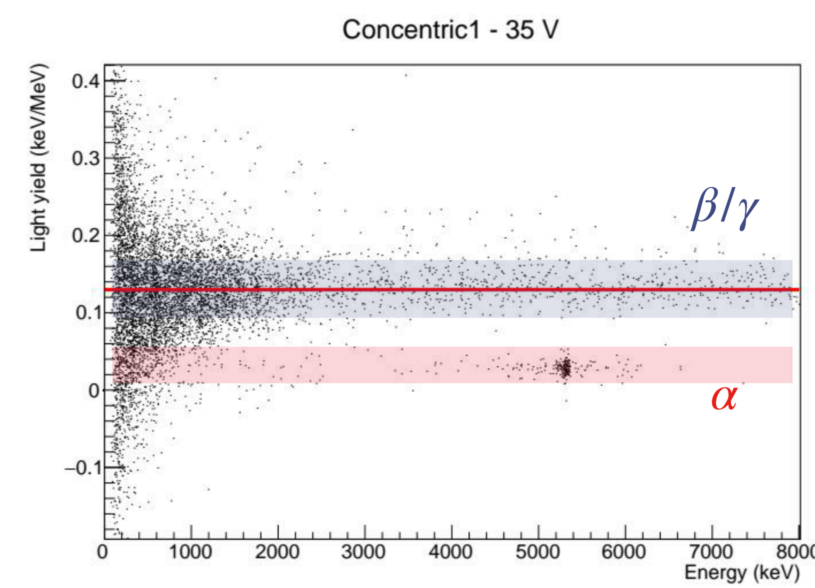
$$E_{tot} = E_0 \left(1 + \frac{q \cdot V_{el} \cdot \eta}{\epsilon}\right)$$

NIM A 940 (2019) 320









Ongoing work:
Optimisations for CUPID/BINGO: Square and trapezoidal geometries, two-sided LDs, optimised voltage & operation, minimize loss from charge trapping η

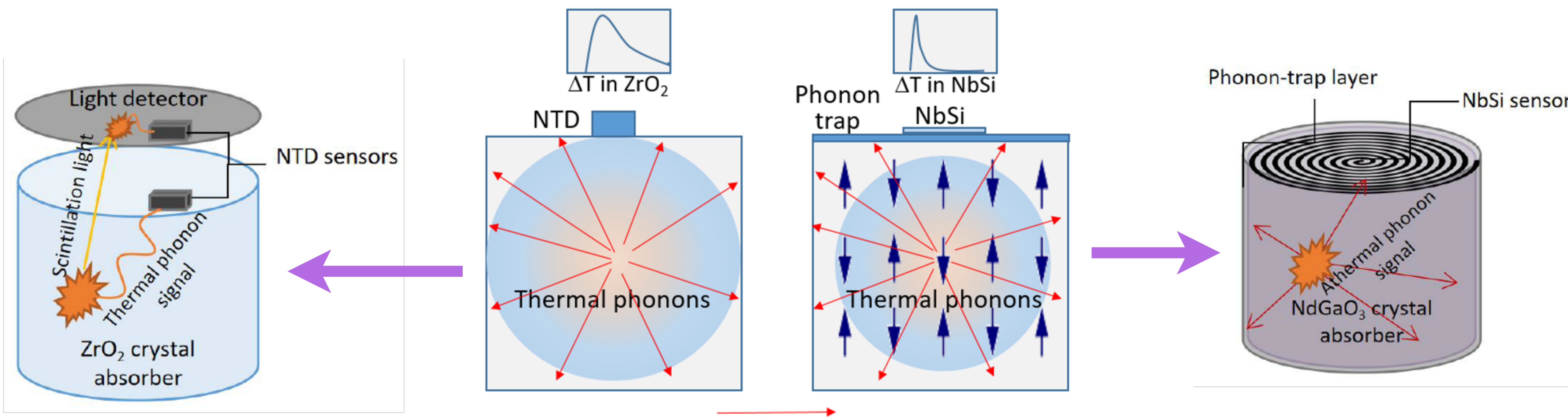
CUPID related R&D : TINY (2023-29)

✦ Development of bolometric detectors containing **the most promising ββ isotopes** ^{96}Zr and ^{150}Nd

- Main challenge in Nd-based compounds: high specific heat from magnetism
- detect phonons before thermalization

✦ **TINY objective**: develop a demonstrator with a 2 kg mass detector distributed in a few elements for each isotope

- New **dedicated cryostat** @ Saclay **(**installation in 2025) for R&D
- demonstrator tested in CROSS or BINGO Cryostat



Classical scintillating **bolometers** with **thermal signals**

ZrO_2

Dielectric diamagnetic

Athermal phonons

$NdGaO_3$

Antiferromagnetic order

Ricochet @ ILL

Precise Measurement of a known signal
IP2I, IJCLab, LPSC, I. Néel, ILL

- ✦ US-France-Russia collab.
  - ➡ 2 detectors technology
- ✦ Change of philosophy wrt Dark Matter
- ✦ **CEνNS measurement for MeV ν** (measured in 2018 @ 30 MeV)
- ✦ Specifications goals for french techno.
  - **1 kg Ge (27*38g) (18 for the 1rst phase)**
  - **20 eV ioni + 10eV chal (10* better than EDWIII)**
- ✦ some of the R&D (HEMT transistors) common w/ EDELWEISS
- ✦ CENNS erc funding (2019-24)
- ✦ Ricochet ANR funding (2021-25)

60 MW reactor @ ILL / Grenoble

- ✦ Ricochet installation **started in 2022**
- ✦ **5-10 years program**

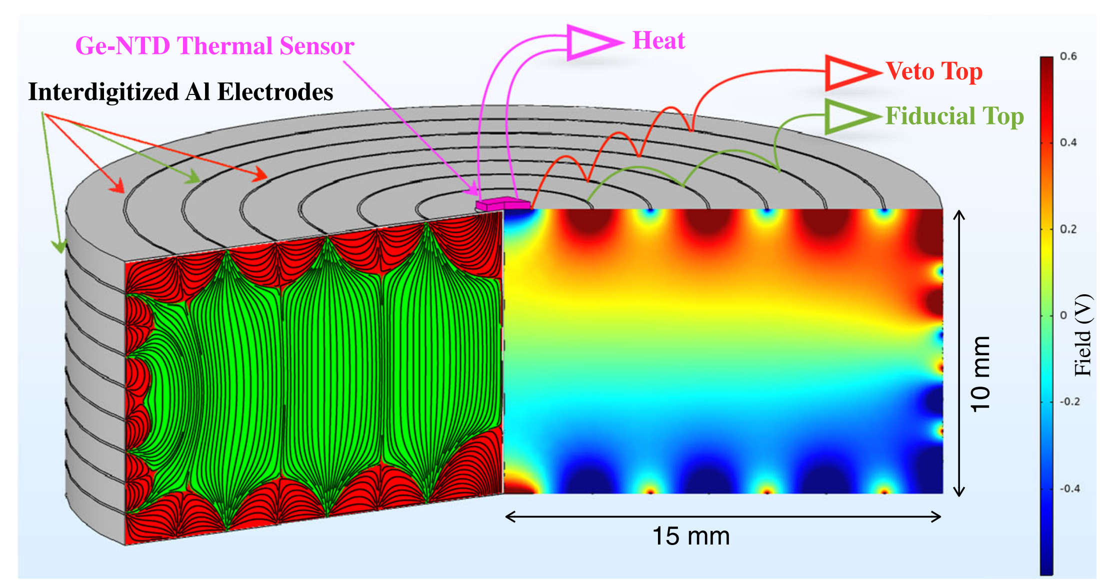


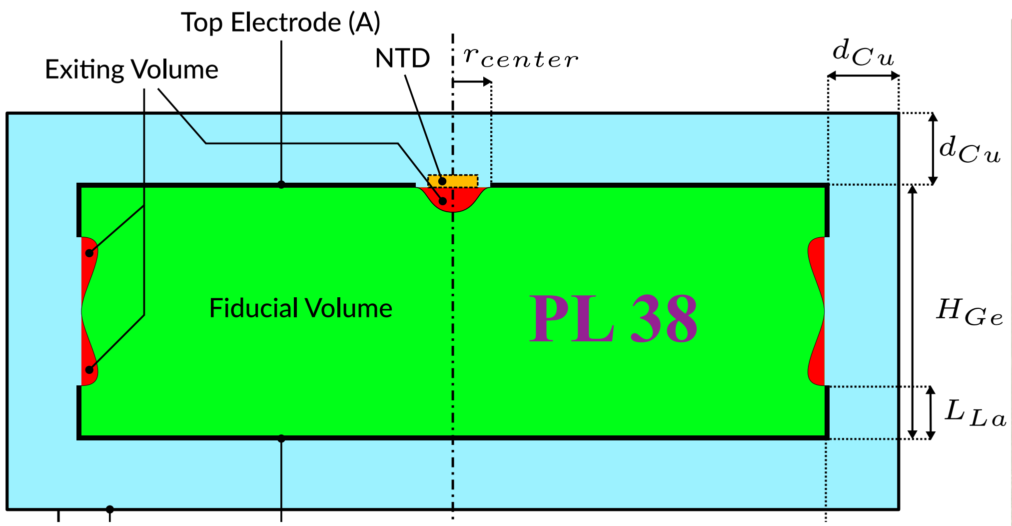
Fig. 6 Electrostatic simulation of a Full Inter-Digitized electrodes scheme on a 38 g germanium crystal ($\Phi = 30$ g, h = 10 mm). The crystal is surrounded at 2 mm distance by a chassis connected to the ground (not shown). The capacitance of the 4 electrodes with respect to the ground is about 20 pF (Color figure online.)

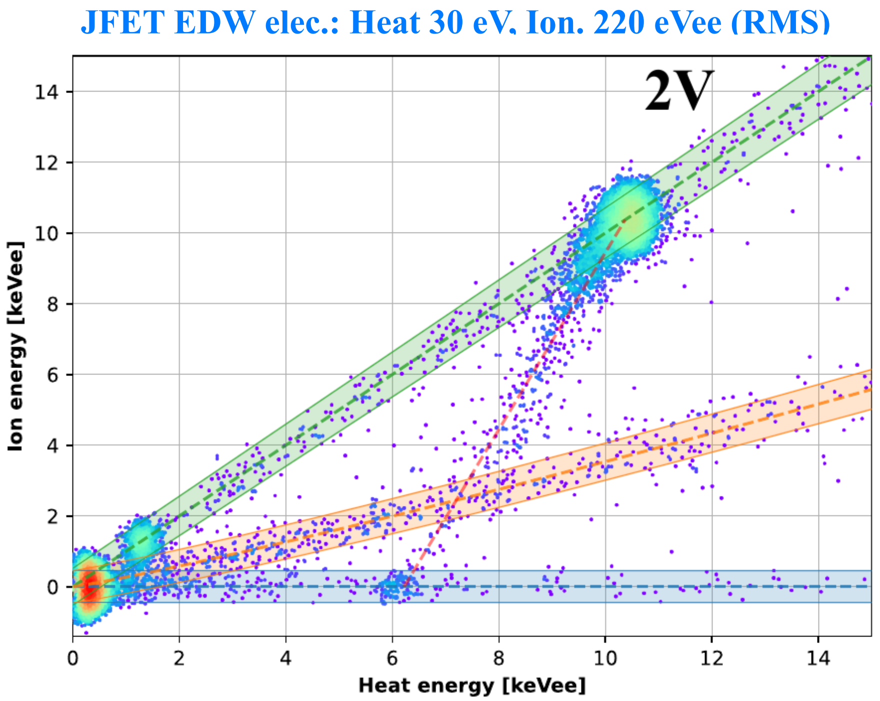
ArXiv 1909.02879

Ricochet R&D : detector geometry optimization

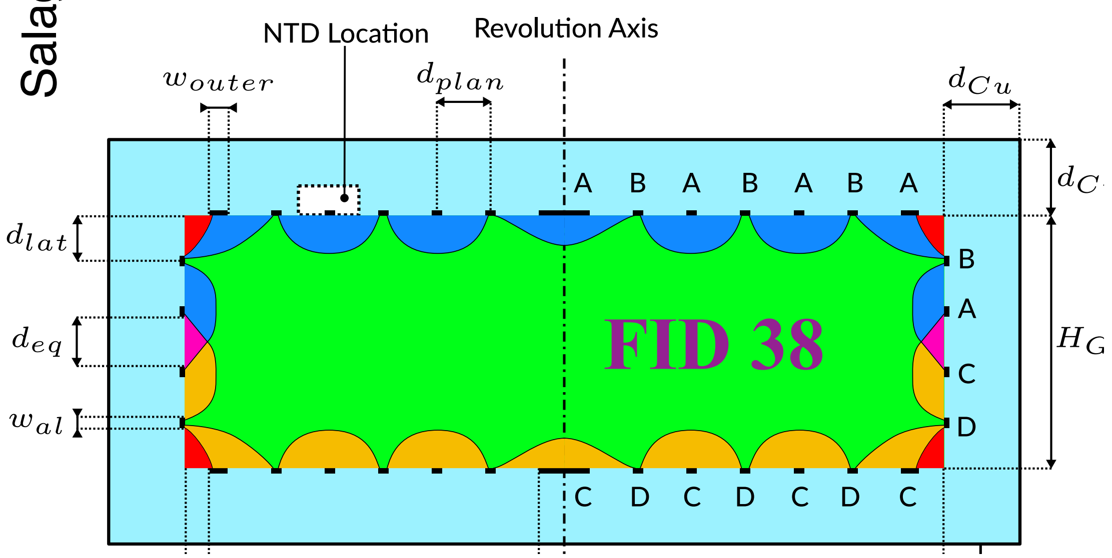
Low-Voltage approach for optimal particle identification

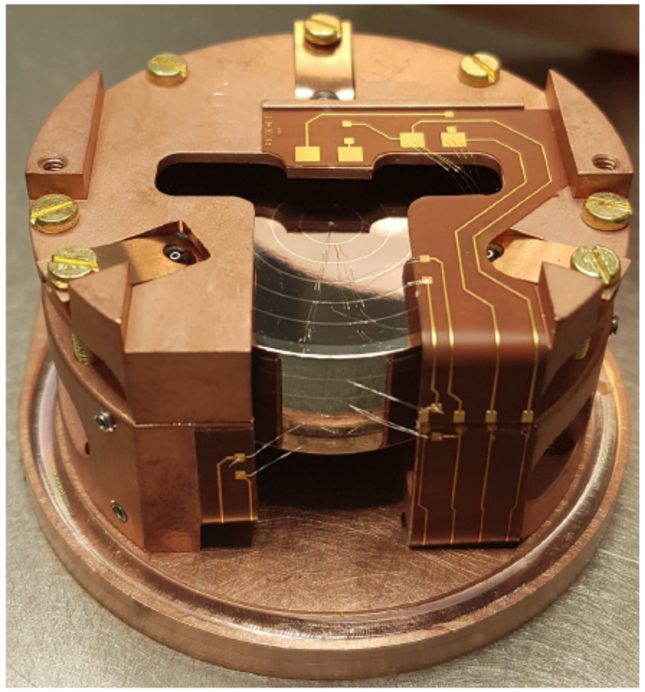
Salagnac & al: arXiv:2111.12438

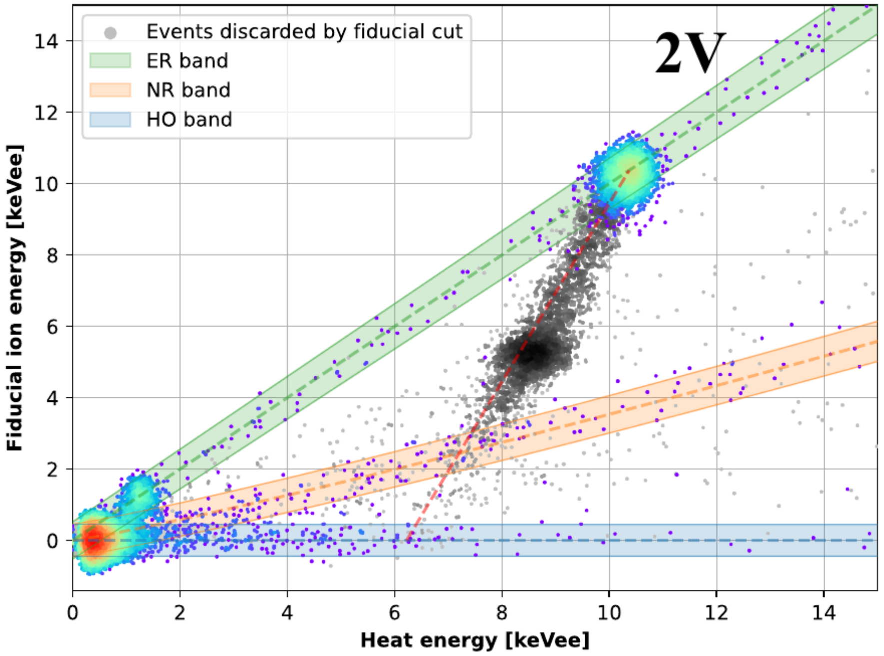




- Incomplete charge coll. **< 10%**
- Fiducial volume: **98.6 %**
- Surface event rejection: **NO**
- Total capacitance: **15 pF**

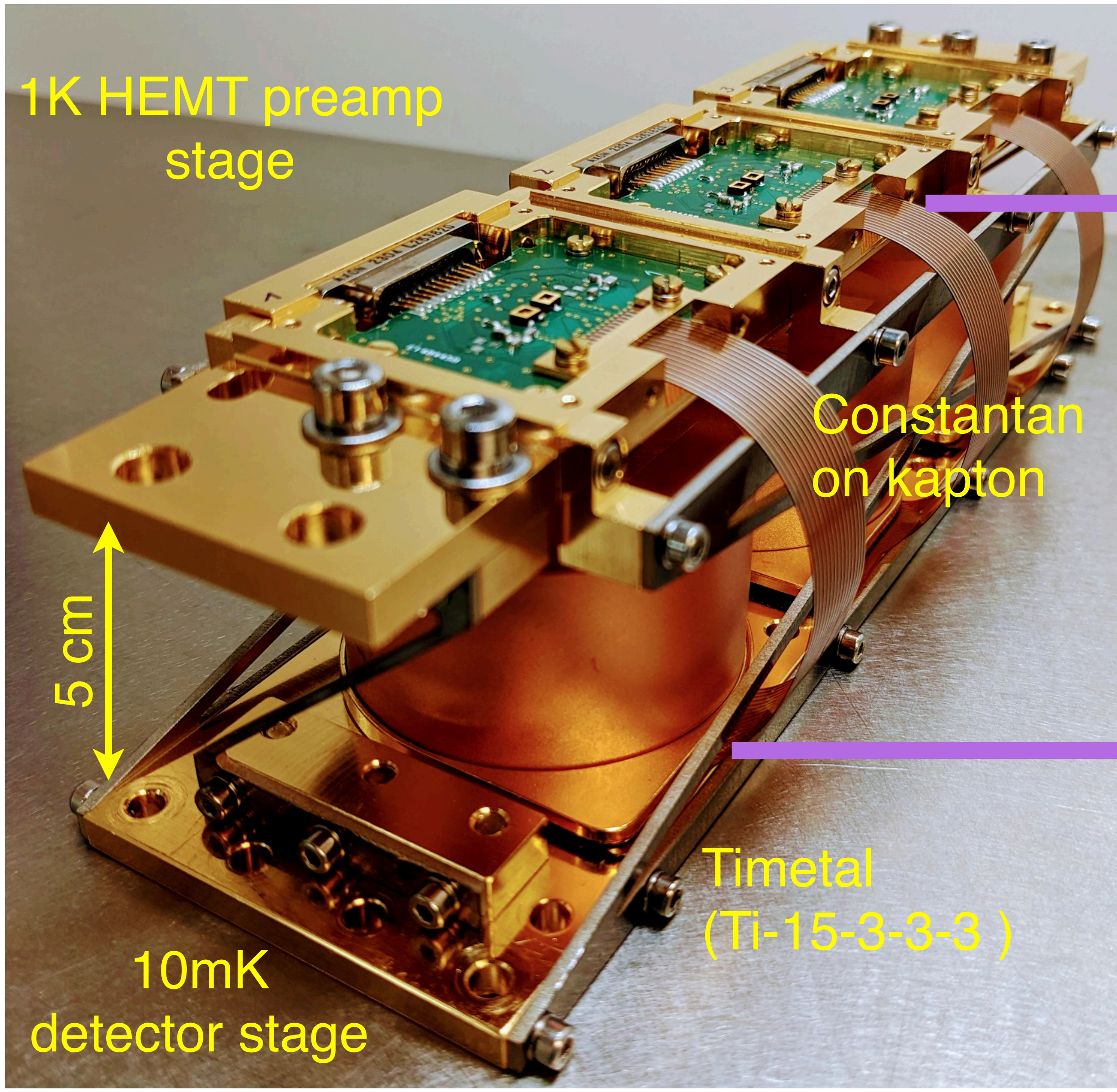


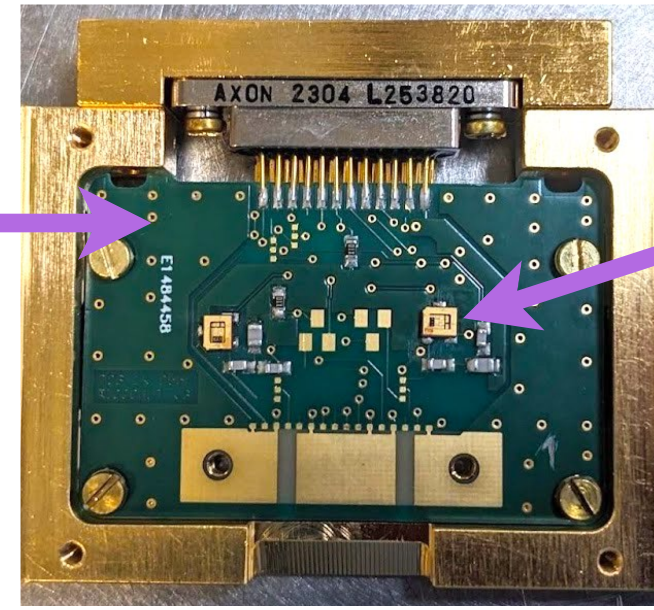




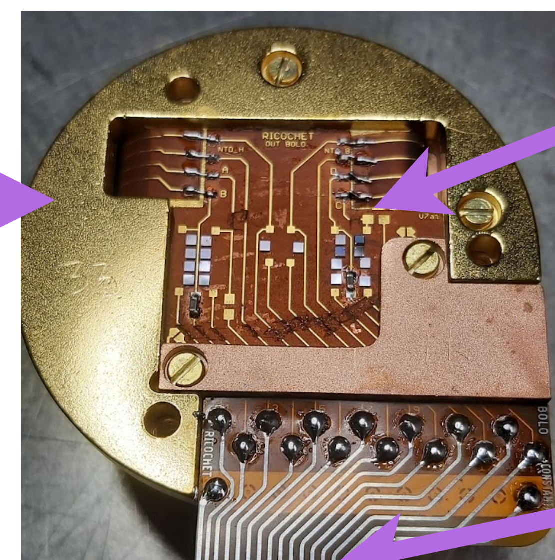
- Incomplete charge coll. **< 1%**
- Fiducial volume: **62 %**
- Surface event rejection: **YES**
- Total capacitance: **18 pF**

Ricochet R&D : 1K cold elec & 1K-10mK interface optimization





✦ **HEMT** (High electron Mobility Transistor) **@ 1K** to replace the standard Si-JFET working at 100K



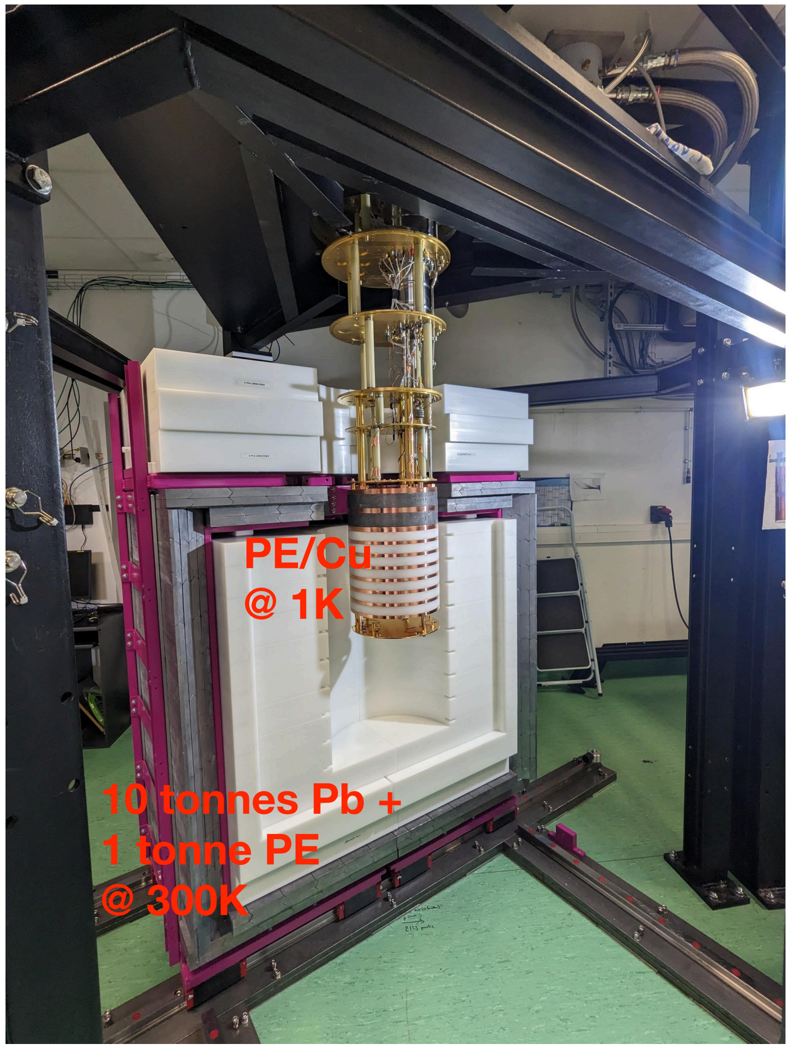
✦ Bias and feedback resistor **placed at 10mK** to minimize the thermal noise

✦ 35 μm contantan tracks on 100 μm kapton foil for the 10mK-1K path

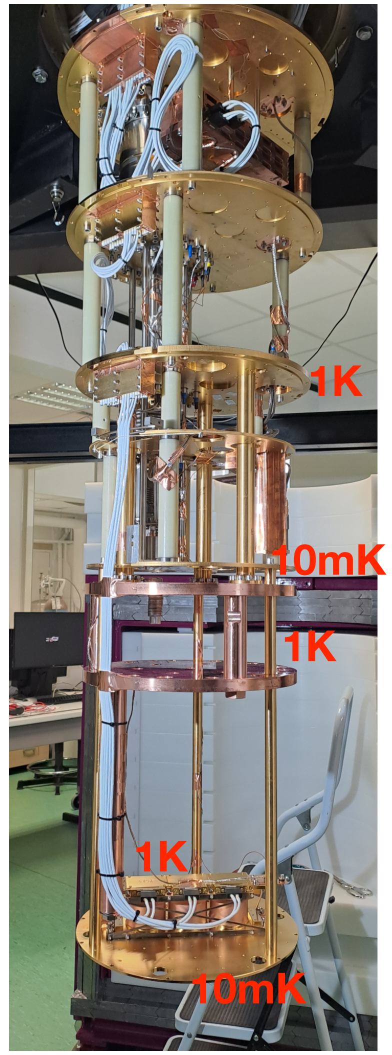
✦ Intense work on the 1K HEMT based cold elec and 1K-10mK interface :

- **Mitigate stray capacitance** (ionization reso)
- **Mitigate heat load** on 10mK stage
  - ➡ low HEMT bias dissipation
  - ➡ Use of special material for the 1K-10mK mechanics
- **Mitigate Johnson noise** of FB and and bias resistor

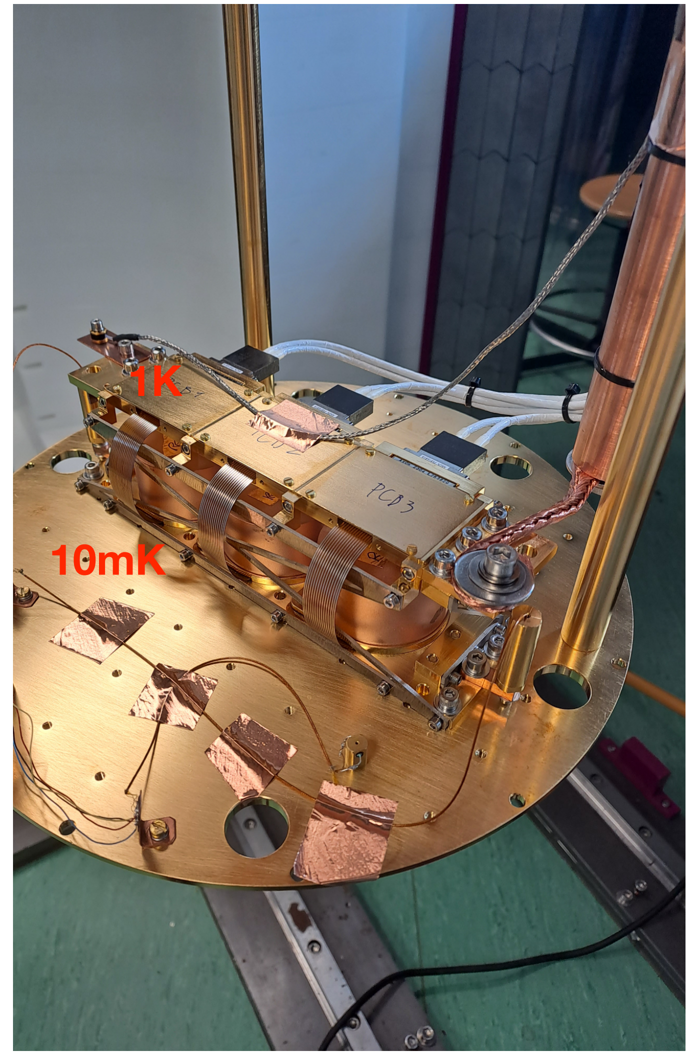
Ricochet R&D : MiniCryoCube demonstrator @ IP2I



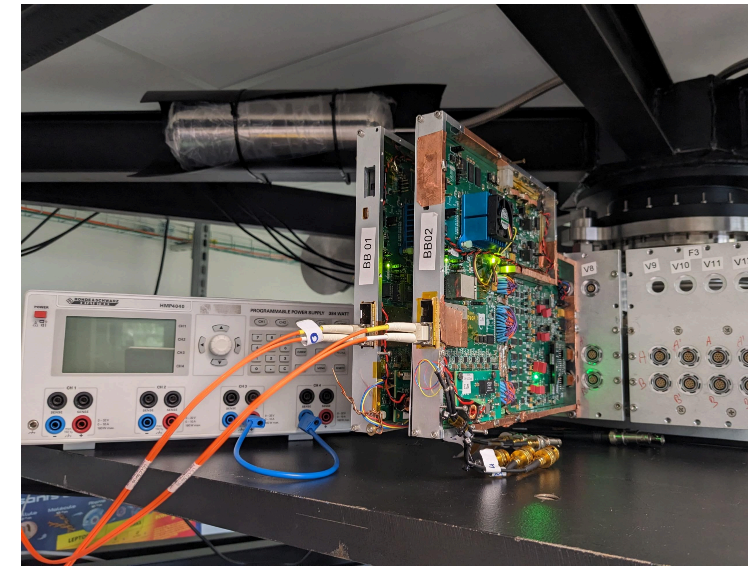
Ricochet cryostat w/ full shielding

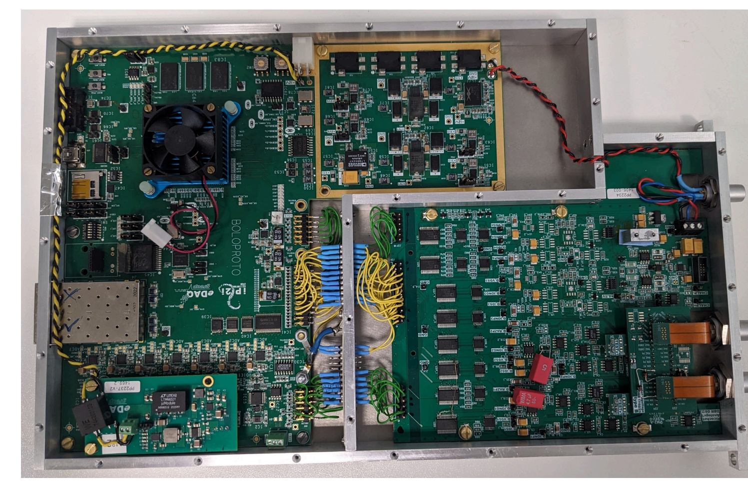


w/o 1K shielding



MiniCryoCube on its remote 10mK plate (45cm)



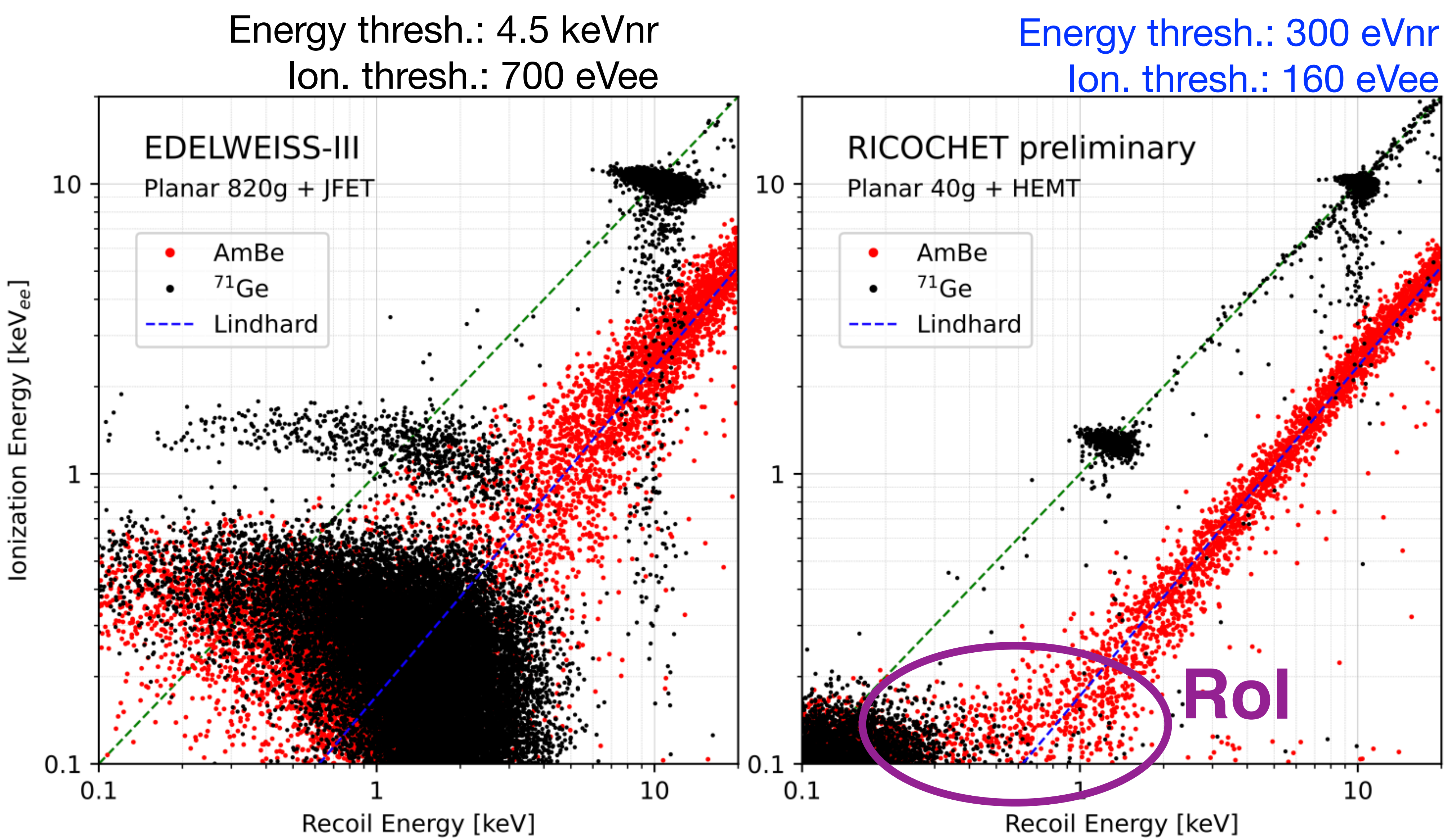


Ricochet Bolometer Box Analog + Numerical

✦ Aug-Oct 2023 @ IP2I :

First tests of a MiniCryoCube array in the Ricochet cryostat operated at Lyon **with its dedicated 300K electronics** for **dual heat/ionisation measurement**

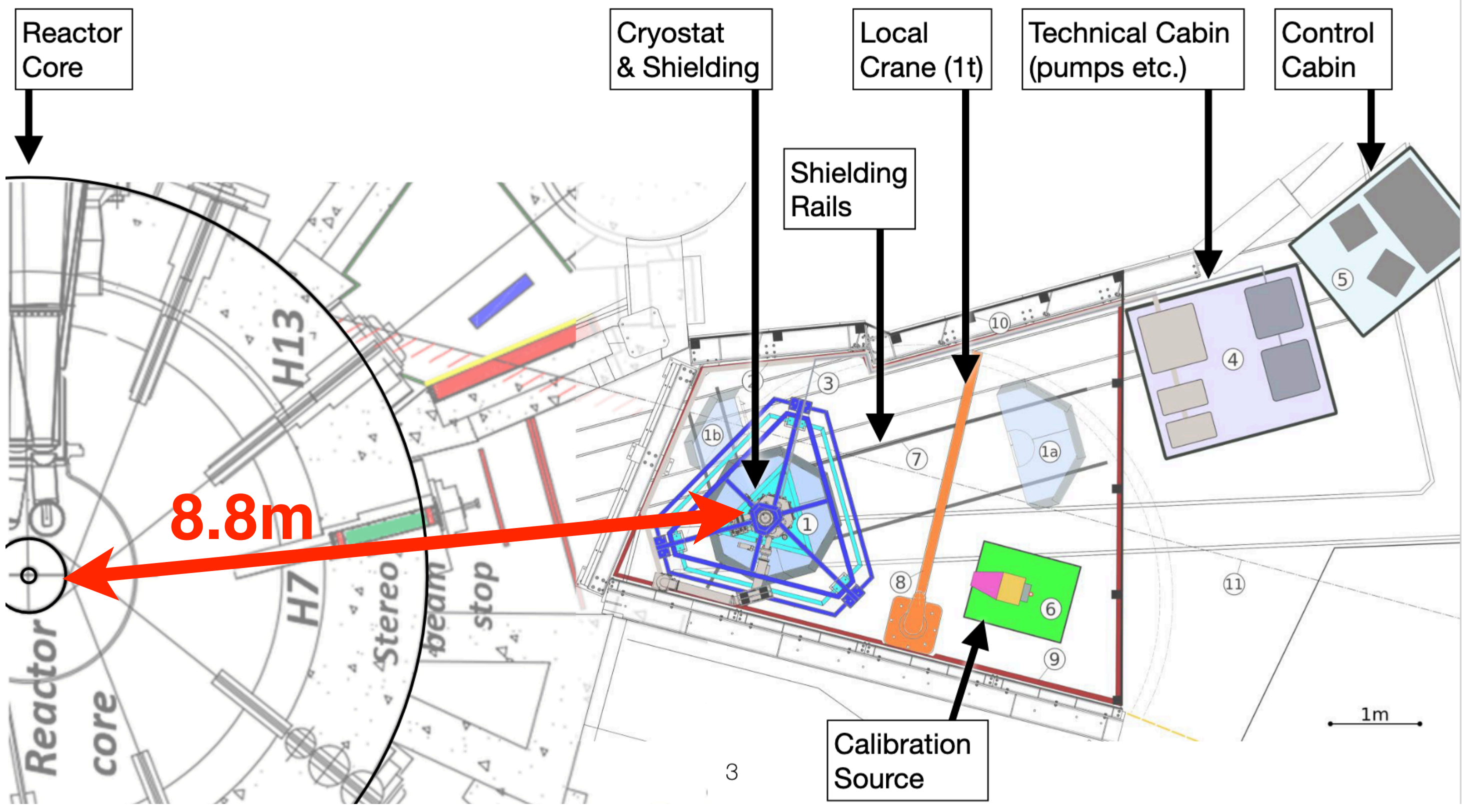
Ricochet R&D : MiniCryoCube demonstrator @ IP2I

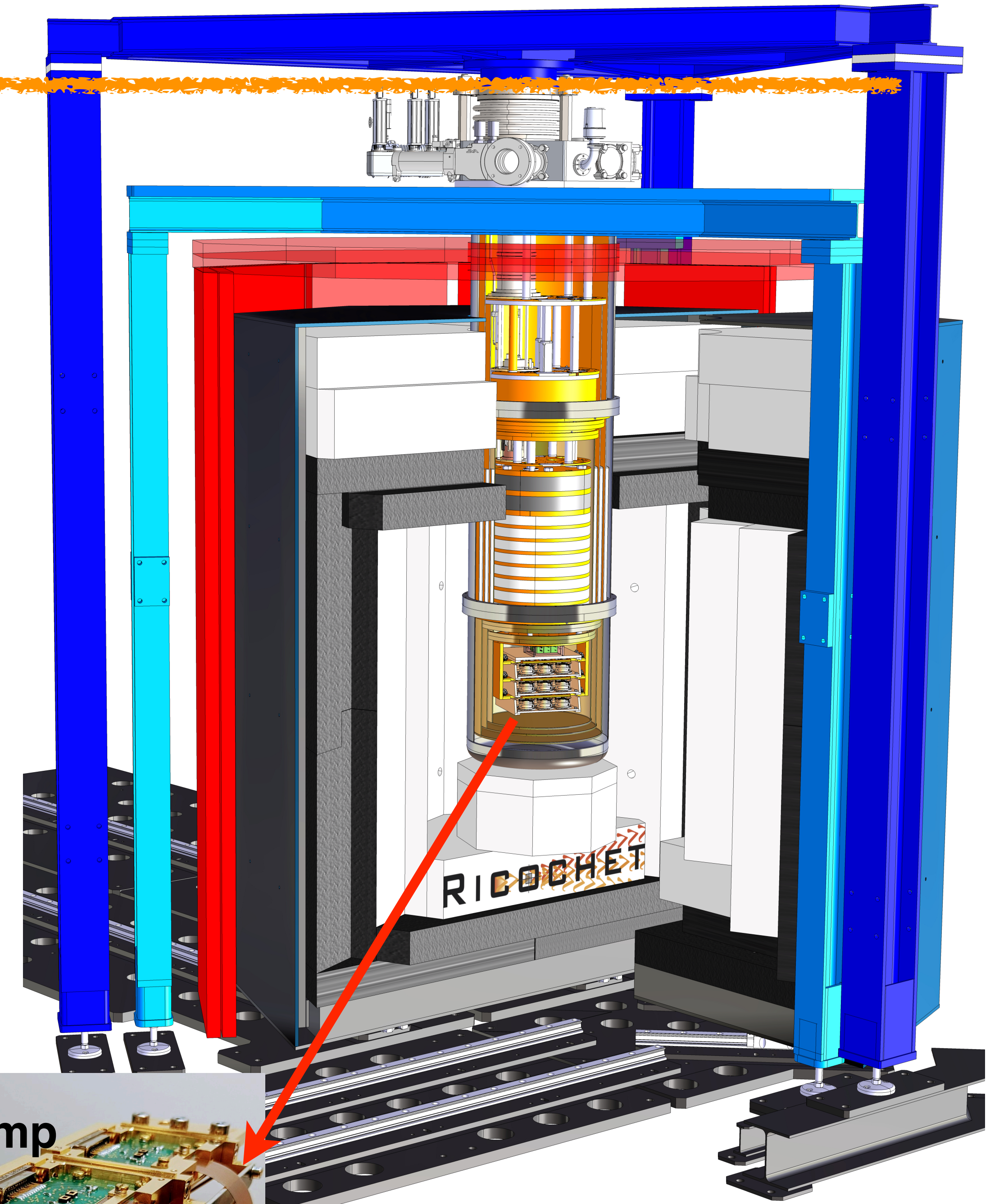


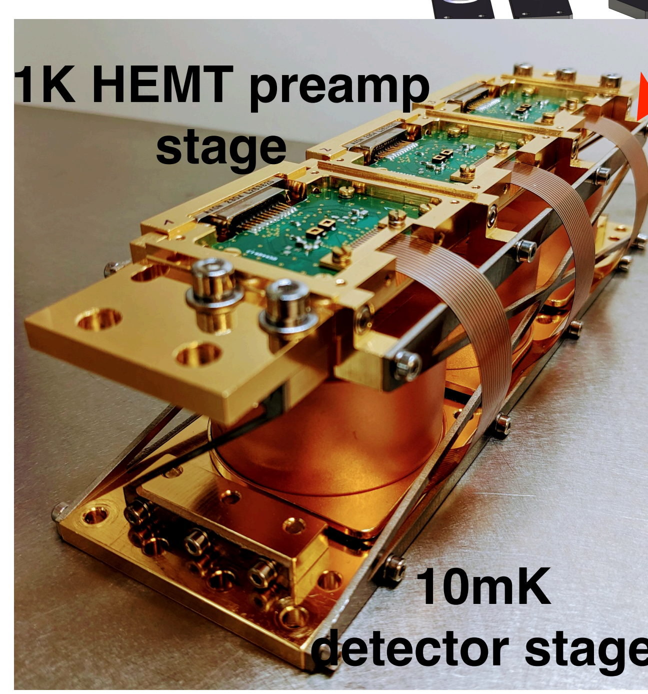
Presented at: TAUP2023, IDM2023, Nobel Symposium 2023 (NS-182 « Dark Matter »)

- ✦ ER/NR discrimination **threshold** has been improved **by about one order of magnitude w.r.t EDW** and SuperCDMS
- ✦ **Ricochet can** now **probe reactor neutrinos (CEvNS)** (and equiv. 3 GeV WIMP with highly efficient LEE and ER rejection)
  - ➡ Ricochet resolution goals: 10 eV (heat) + 20 eVee (ionisation)
  - ➡ factor of ~2 still missing

Ricochet : Installation @ ILL

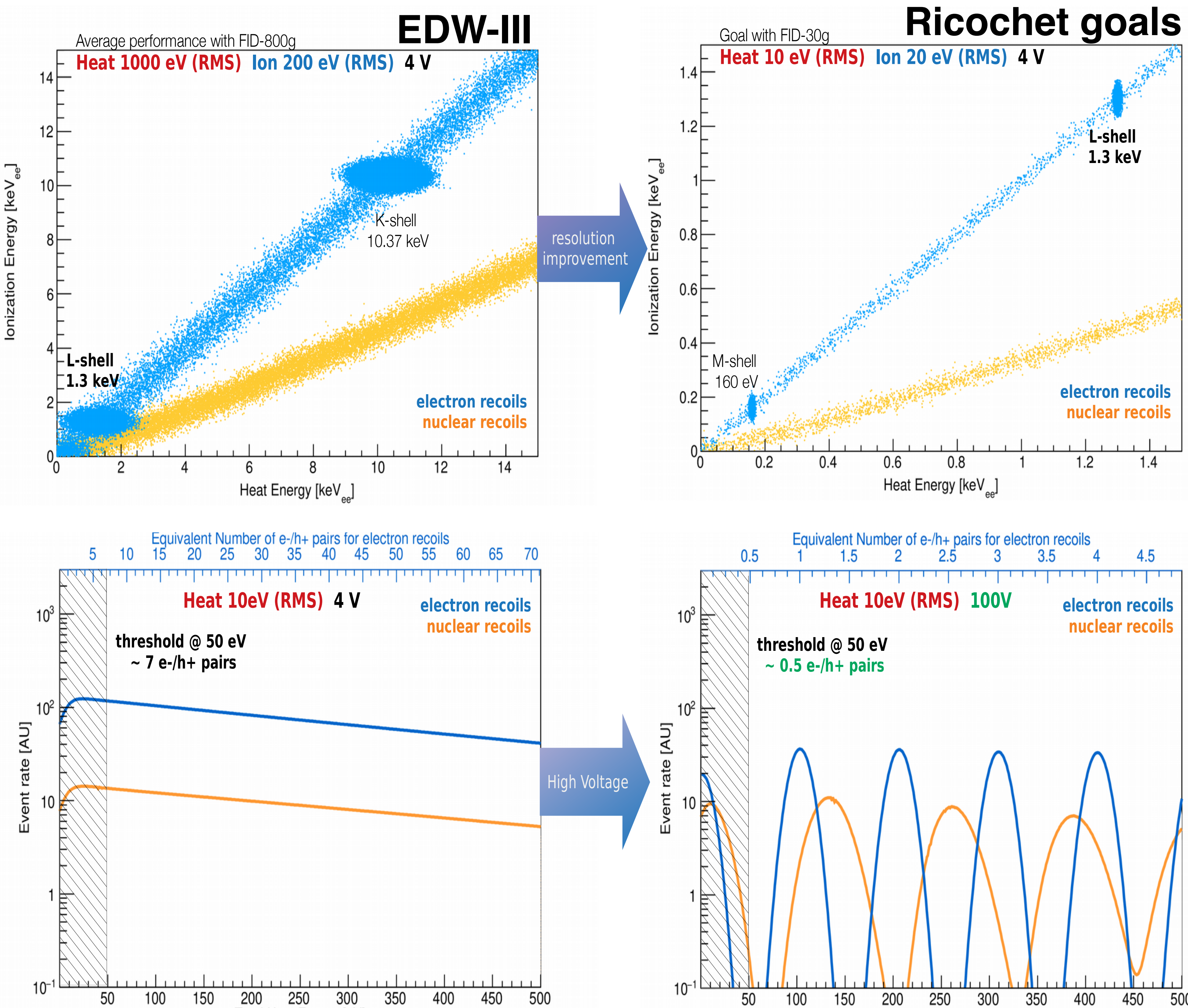






RICOCHET cryostat moving on Nov 20th 2023 !

Low Mass Dark Matter : 2 complementary modes



Low Voltage mode
Part. ID + Fid

$$E_{total} = E_{recoil} + E_{luke} = E_{recoil} + \frac{1}{3\ \mathrm{eV}} E_{ion} \Delta V$$

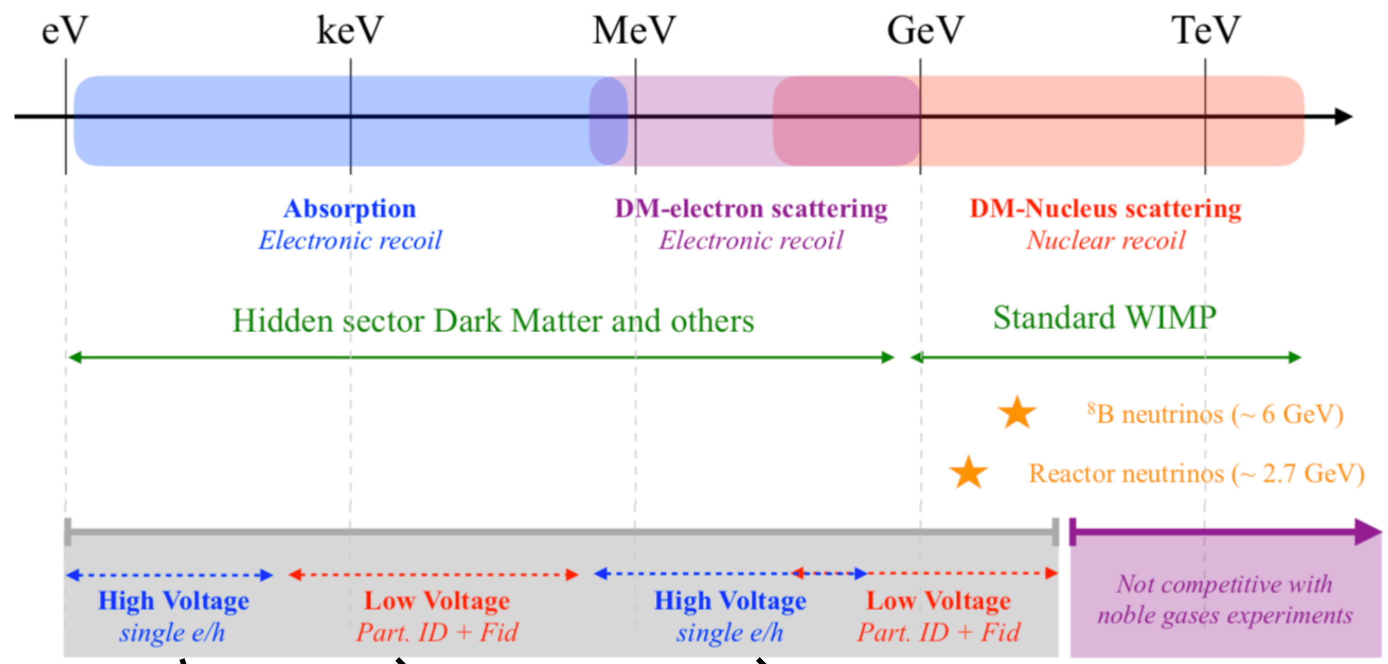
High Voltage mode
single e/h - No PID

Low Mass Dark Matter : 2 complementary modes

« small is beautiful ! »

- ✦ No observation of « standard » WIMPs (M> few GeV) w/ interaction rate < 1 evt/ton.year !
- ✦ Cryogenic detector no more competitive in this region
- ✦ **Focus at low mass** (resolution & threshold)
- ✦ If DM = Sub-GeV WIMPs then there are a lot of them !
  - **1 kg of good detector is competive**
- ✦ Axion & ALPs : **Electronic Recoils**
  - **main background = Heat Only excess at low E**
- ✦ **R&D goals:** IPNL IJCLab LPSC (+ CEA)
  - HV withstand (w/o current leakage) for Luke Neganov « **boost** »
  - Discrimination down to a single **e-/h+ pair**
  - **New transistor technology**
    - ➡ Si-JFET ➛ **HEMT** (C2N/CNRS)
- ✦ **> 10 years program**

✦ **Coming experiments could use part of the EDELWEISS space (now dismantled) @ LSM**



« HEMT » R&D common w/ Ricochet

CryoSEL @LSM (On BINGO cryostat)

Luke Neganov « boost », single pair sensitivity

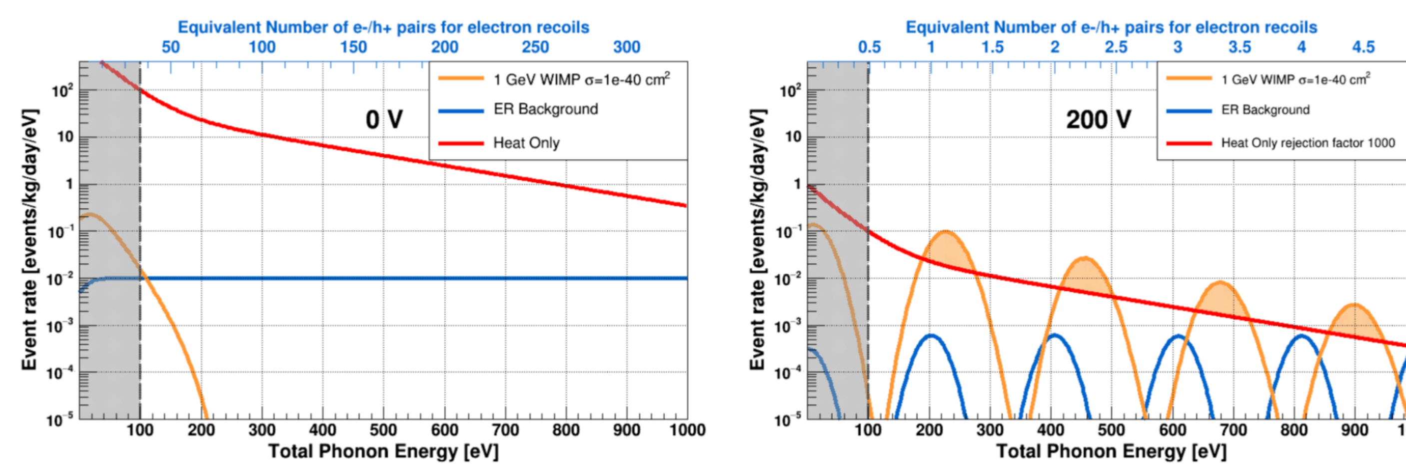
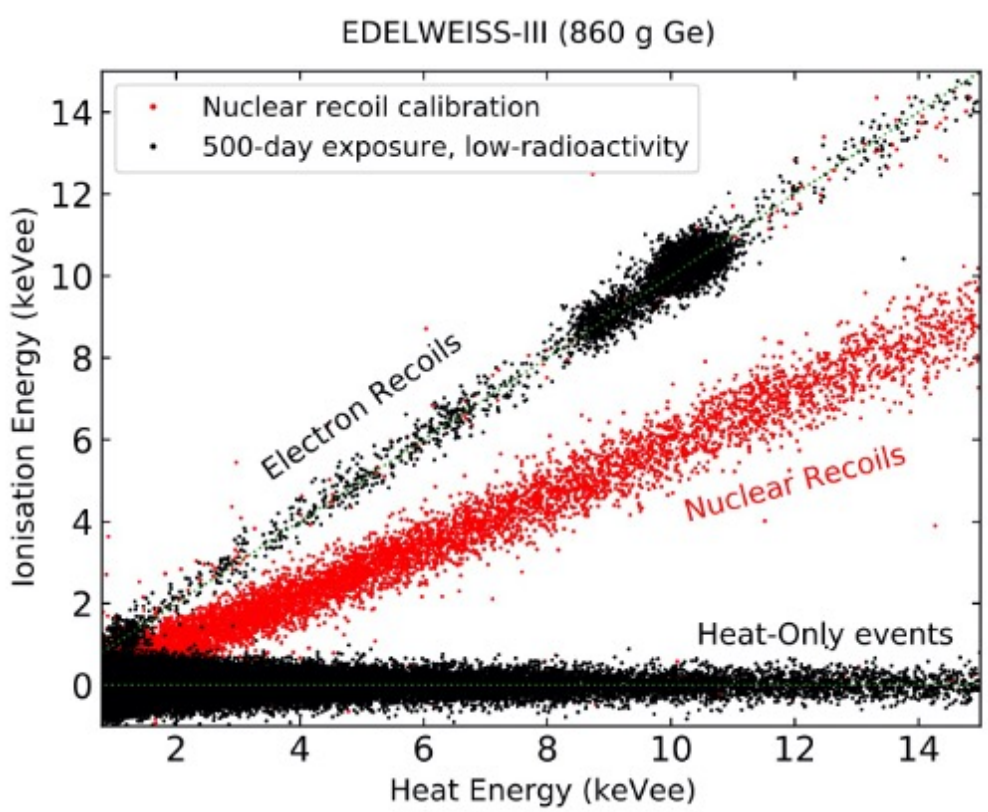


Figure 1: Response of the CRYOSEL detector operated at 0 V (left) and 200 V (right). Orange: expected NR signal for a 1 GeV/c² WIMP with a scattering cross-section of 10^{-40} cm². The blue and red lines correspond to the ER and heat-only backgrounds observed in EDELWEISS detectors. The shape of the NR response is sensitive to the actual quenching factor and straggling effects for this type of interaction. In right panel a rejection factor of 1000 is considered for HO events.

Low Mass Dark Matter : Low Energy Excess (LEE), Heat only (HO) events

✦ **Low Voltage :**

- despite large EDELWEISS-III large target mass (20 kg Ge) and excellent ER/NR separation, **results limited by large HO population**

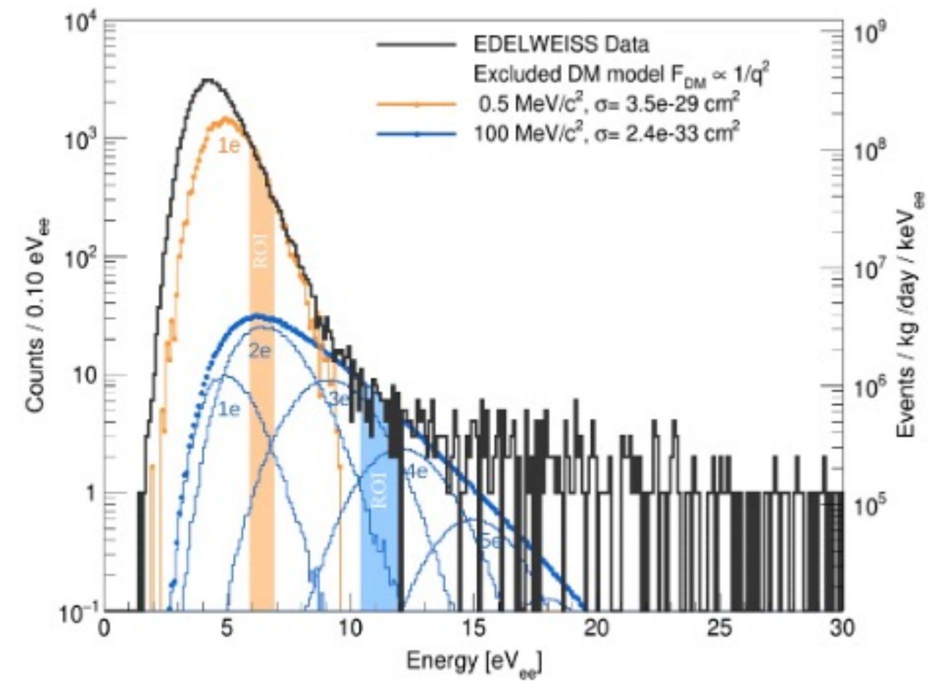


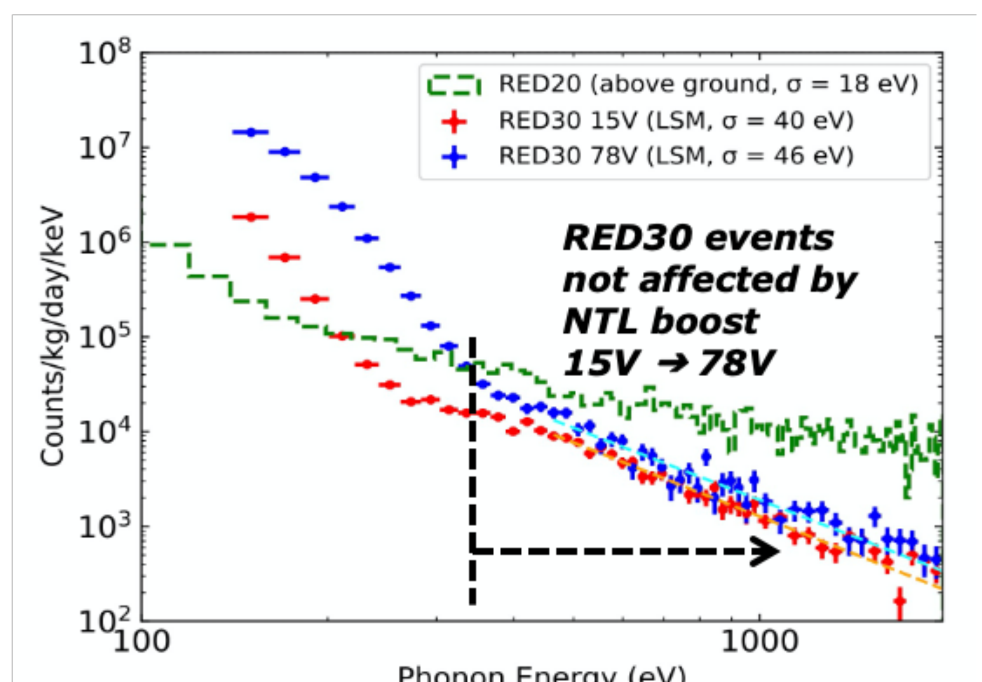
✦ **Only Heat only ? :**

- **HO nature confirmed** by absence of NTL boost from 15V to 78V

✦ **High Voltage :**

- despite σ =0.53 e$^-$ resolution on 33g @ 78V, r**esults also limited by HO**

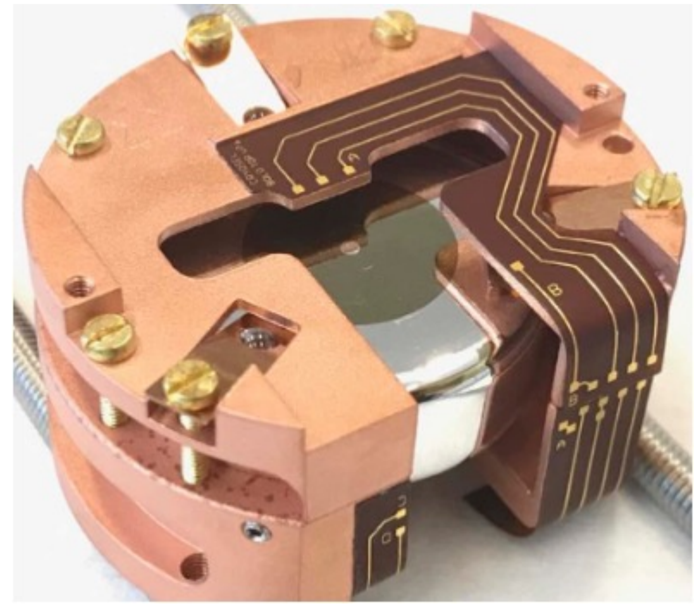


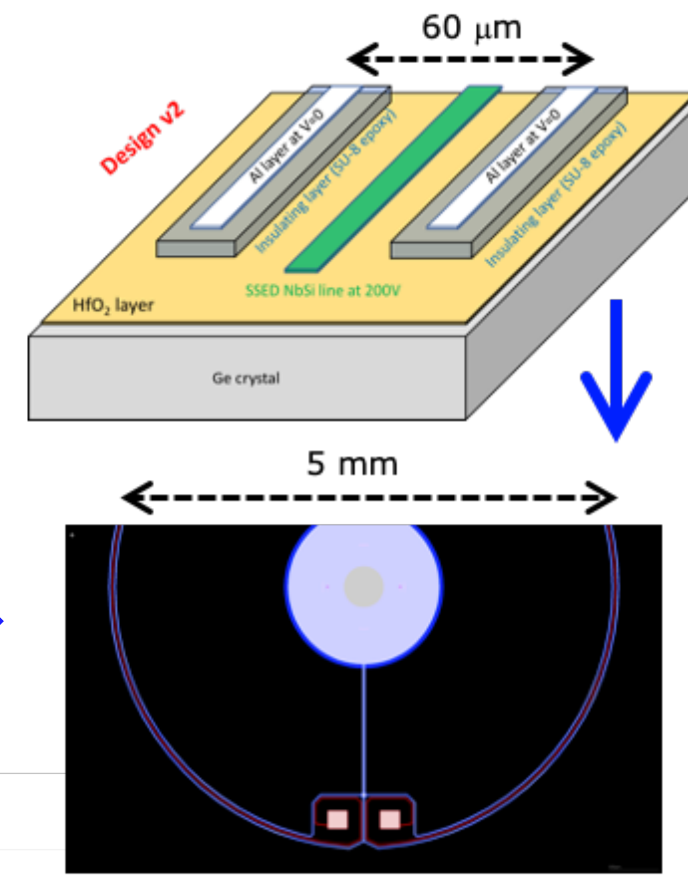


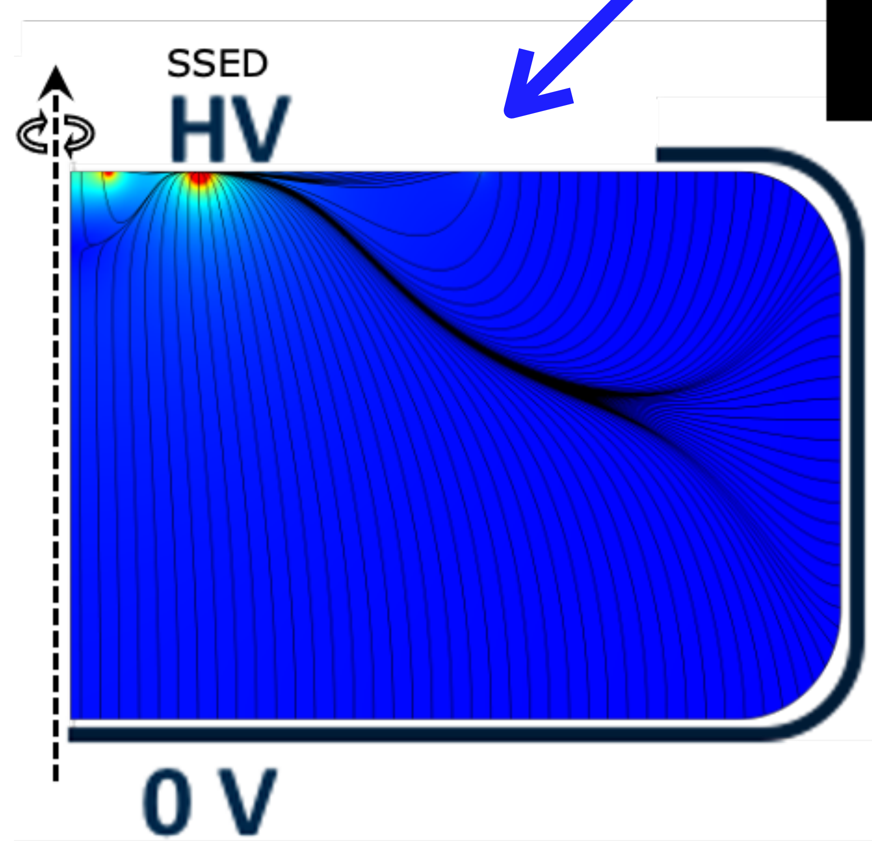
Low Mass Dark Matter : CryoSEL project

✦CryoSEL : ANR 2022-25

- 40 g Ge crystal
- Phonon sensor = **single NbSi strip** (10 µm wide) forming a 5 mm-wide circle
- **Use this small film as Point-Contact-like electrode** of HV detector
- NTD glued on large enveloping electrode (high-resolution NTL-amplified heat measurement)
- **NbSi operated as SSED (Superconducting Single-Electron Detector)**
- Detector kept well below Tc so that SSED is only triggered by large bursts of primary NTL phonons from high-field region just in front of it
- **Most HeatOnly will not trigger SSED**

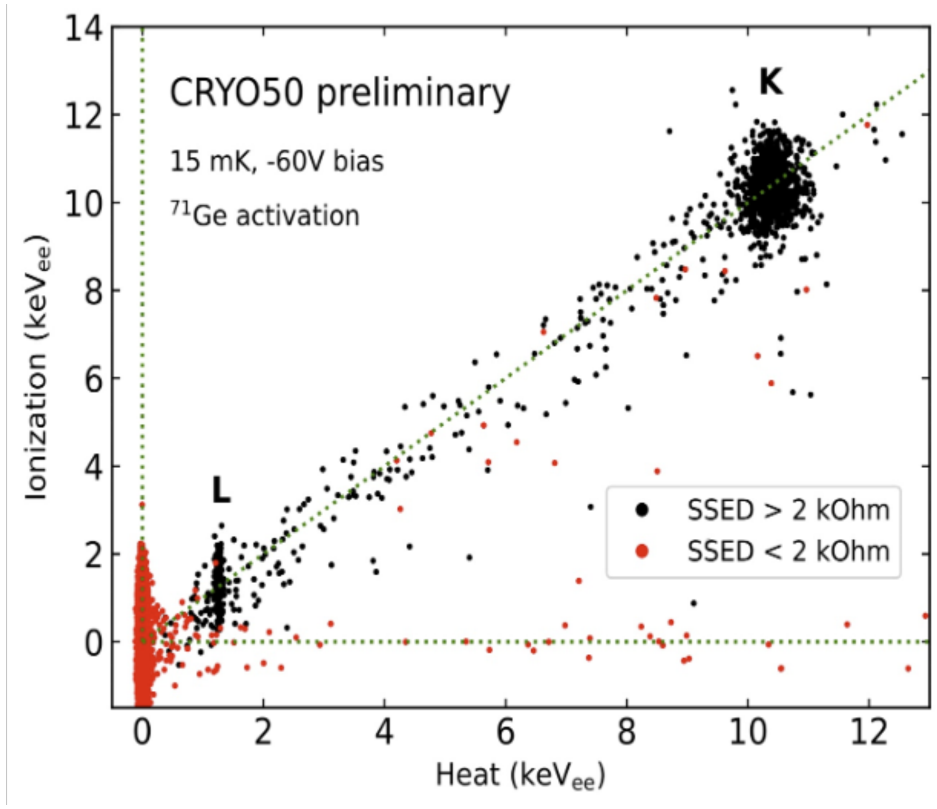


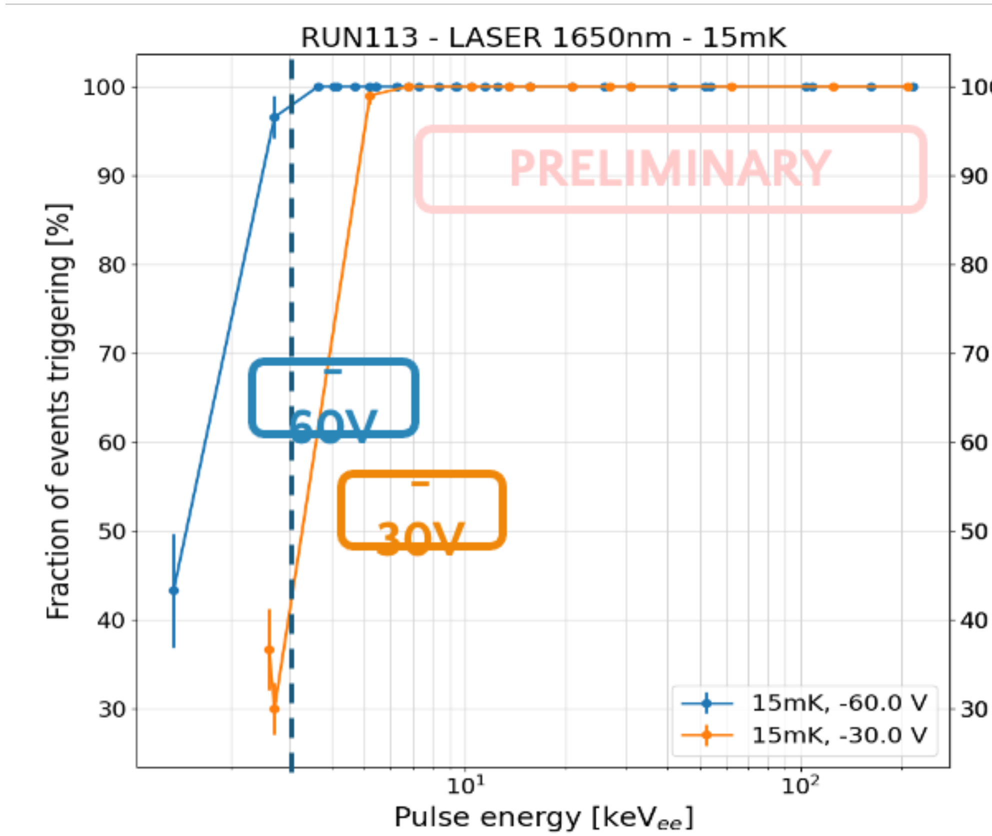




Low Mass Dark Matter : CryoSEL project

- ✦ **CryoSEL :**
  - Operation of **SSED as NTL phonon "tag"**: 5σ thresh = 1.250 kΩ
  - With laser pulses, **~100% trigger at 2.6 keVee @ 60V**
  - Tag operation confirmed by K+L+HO ionization vs NTD data
  - Threshold still far from goal → **improvements to come** from film with **increased phonon efficiency**, from **increased bias** and **from reduced Tc**

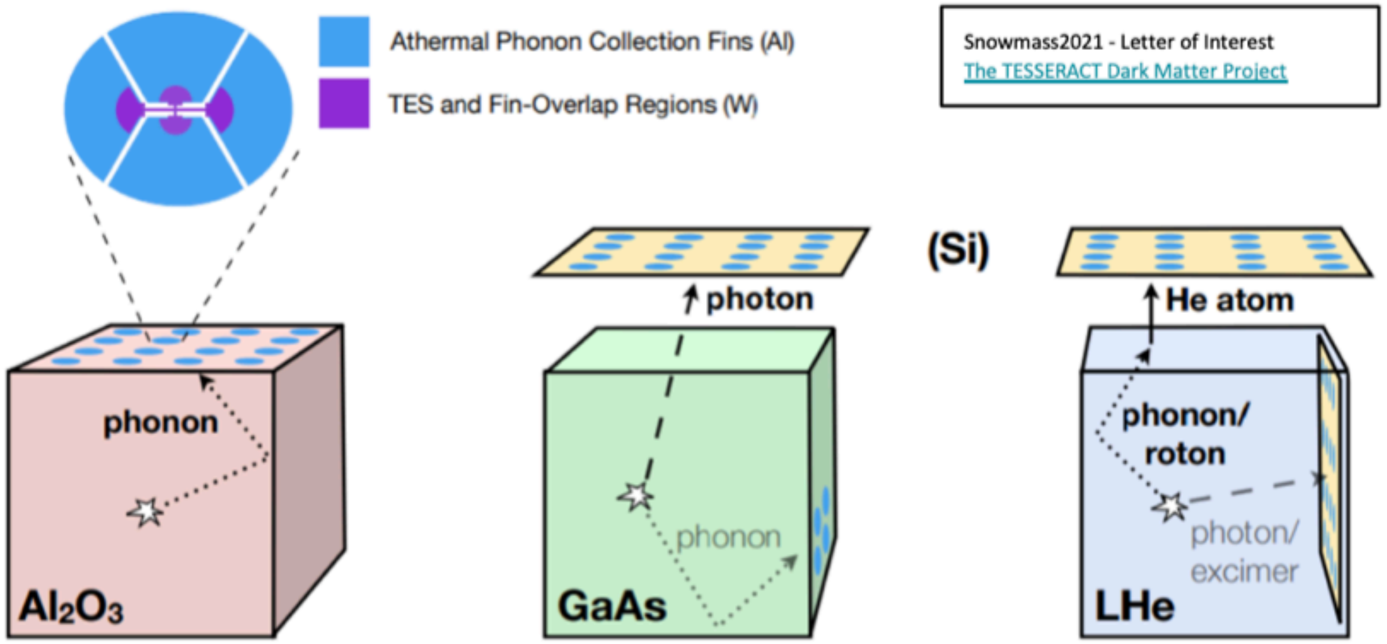




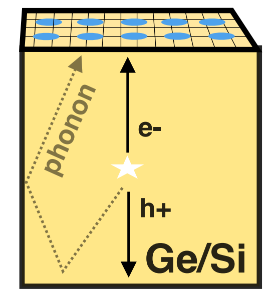
TESSERACT : Proposal experiment @ LSM

Transition Edge Sensors with Sub-Ev Resolution And Cryogenic Targets

Snowmass2021 - Letter of Interest
The TESSERACT Dark Matter Project



- DOE Funding for R&D and project development began in June 2020 (Dark Matter New Initiative)
- One experimental design, and different target materials with complementary DM sensitivity, all using TES
- Includes **SPICE** (**Al_2O_3** and **GaAs**) and **HeRALD** (**LHe**)
- **~40 people from 8 institutions**
- Actively searching for an underground lab

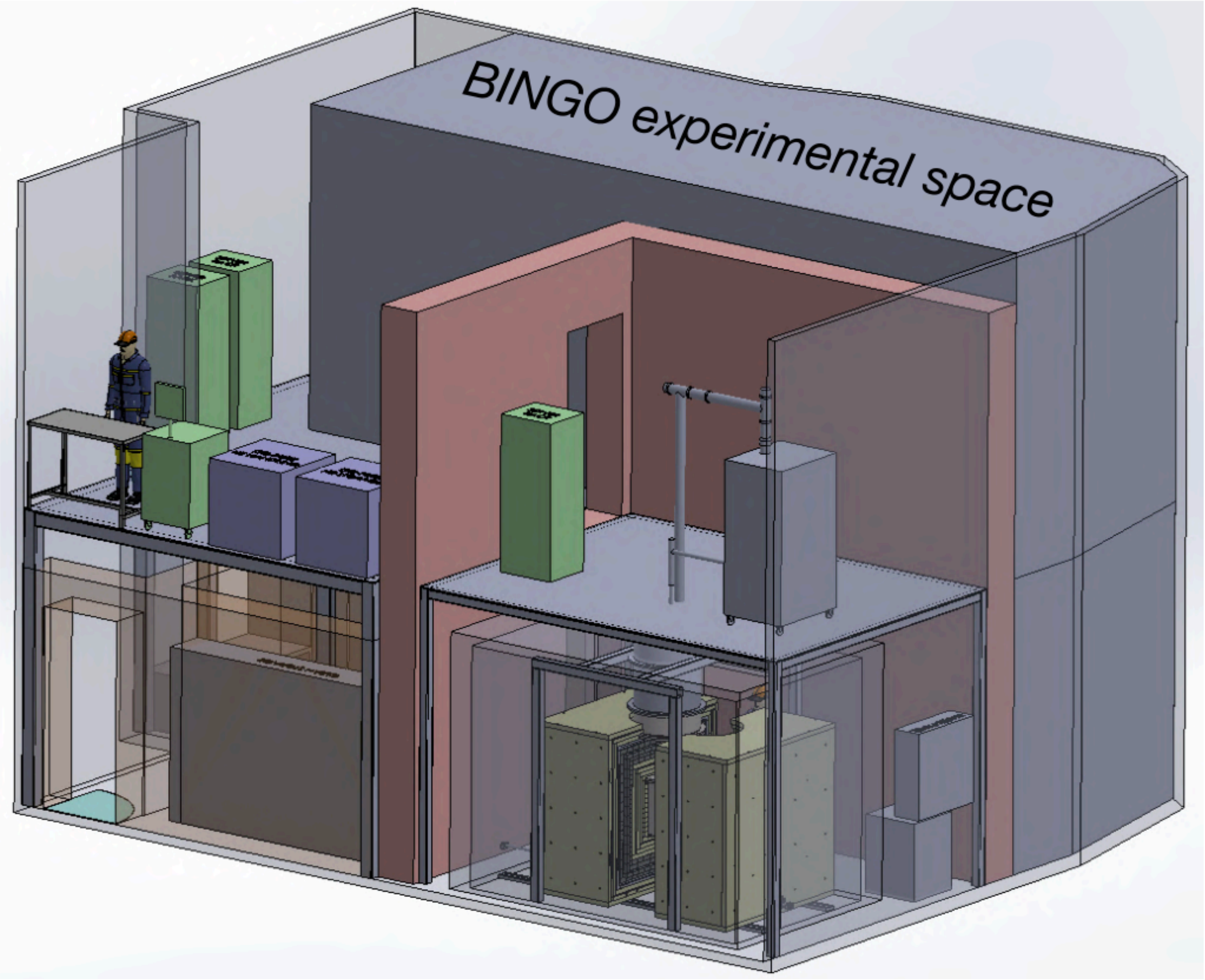


TESSERACT @ LSM proposal:

- Benefit from EDW+Ricochet+CUPID Ge bolometer expertise and low-background cryogenic experience to:
  1. **Add the French** semiconductor **Ge bolometer** technology (**both LV and HV mode**) to the TESSERACT science program
  2. **Deploy** the future TESSERACT **experiment at LSM**
- Achieve leading light DM sensitivities on short time scales
- Benefit from exchange of technologies with US partners

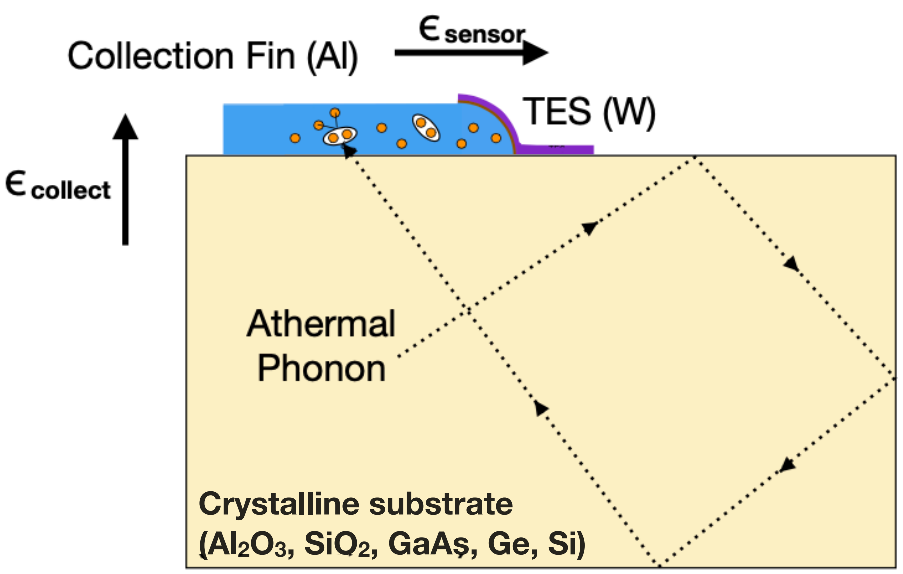
TESSERACT : Proposal experiment @ LSM

EDELWEISS room at LSM (May 2023)



- Potential **TESSERACT** layout in Modane accommodating the BINGO cryostat **in the former EDELWEISS space**
  - **Work ongoing between US and IN2P3 TESSERACT partners**
- **Ideally two cryostats** would be needed tom combine short (R&D) and long (DM search) cycles simultaneously
- Significant emphasis on vibrational and EM noise suppression
- Integration of dedicated low energy NR and ER calibration sources

TESSERACT : New generation TES sensors

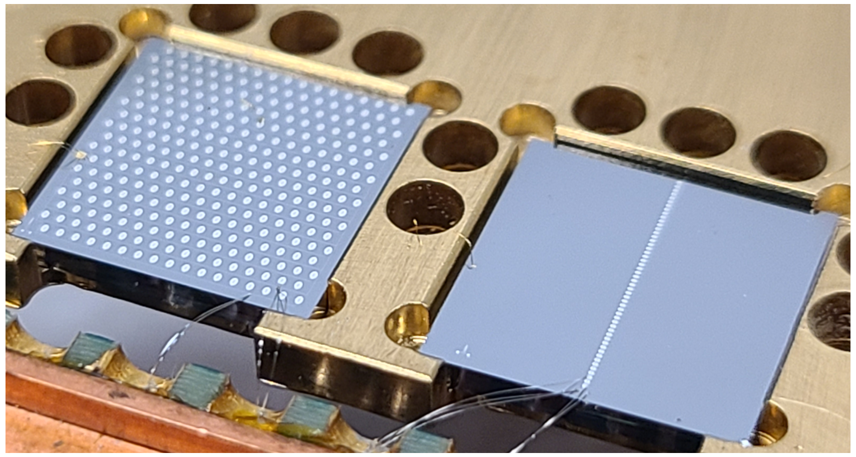


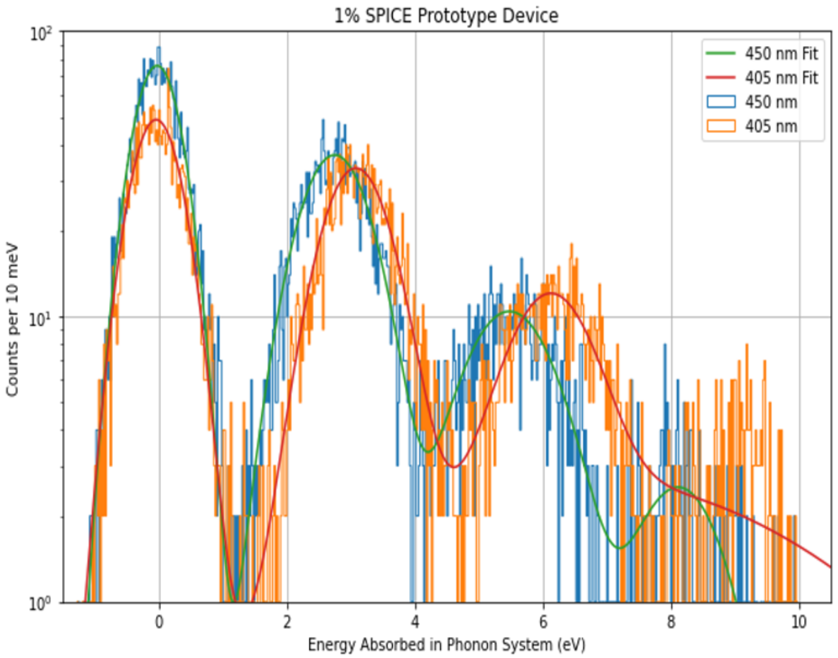
$$\sigma_E \sim \frac{\sqrt{4k_bT_c^2G(\tau_{collect}+\tau_{sensor})}}{\epsilon_{collect}\epsilon_{sensor}}$$

$$\sigma_E \propto V_{det}^{1/2}T_c^3$$

Energy threshold **decreases w/ detector mass**

Energy threshold **decreases very quickly w/ Tc**





- **273 meV (RMS) leading to eV-scale threshold already achieved** with a 0.2g Si detector and Tc = 50 mK
- Targeted Tc around 15-20 mK recently achieved

  ~100 meV threshold achievable on 1 cm^3 crystals
- **Next challenge:** parasitic power (vibrations, EMI, IR photons) needs to be <aW to fully reach TES sensitivity

TESSERACT

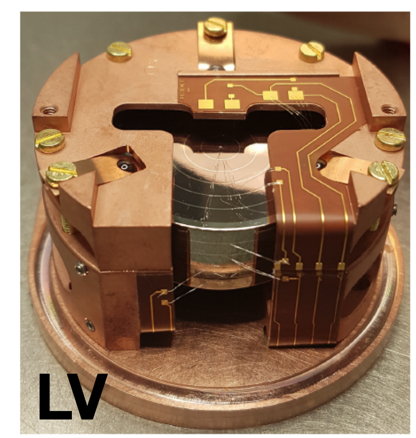
TESSERACT @ LSM: summary

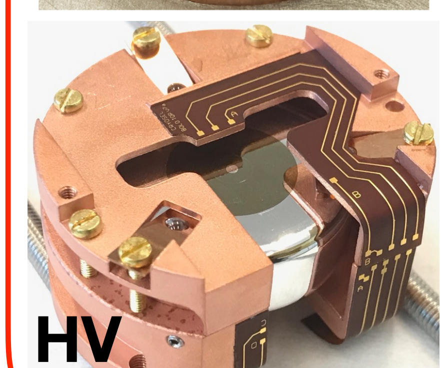
All detector technologies will be using:

1. athermal phonon TES with sub-eV energy thresholds,
2. drastically mitigated LEE (under intense investigation),
3. and payloads between 10g to 100g

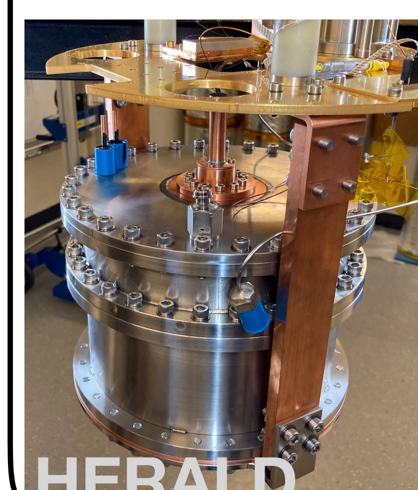
	Target	Search type	Mass range	LEE rejection	Particle ID
SPICE ***Polar crystals***	Al_2O_3, SiO_2	ERDM	100 meV - MeV	Dual TES channel	None
SPICE ***Scintillator***	GaAs	NRDM/ ERDM	eV - MeV MeV - GeV	Phonon/ photon coïncidence	Dual Phonon-photon readout
HERALD	He	NRDM	MeV - GeV	Multiple He4/ photon detector	Pulse shape discrimination
Semicon. ***High V***	**Ge, Si**	**ERDM**	**eV - MeV**	**SSED**	**None**
Semicon. ***Low V***	**Ge, Si, C**	**NRDM**	**MeV - GeV**	**Phonon/ Ionization coincidence**	**Dual phonon-ionisation readout**

IN2P3





SPICE



Conclusion

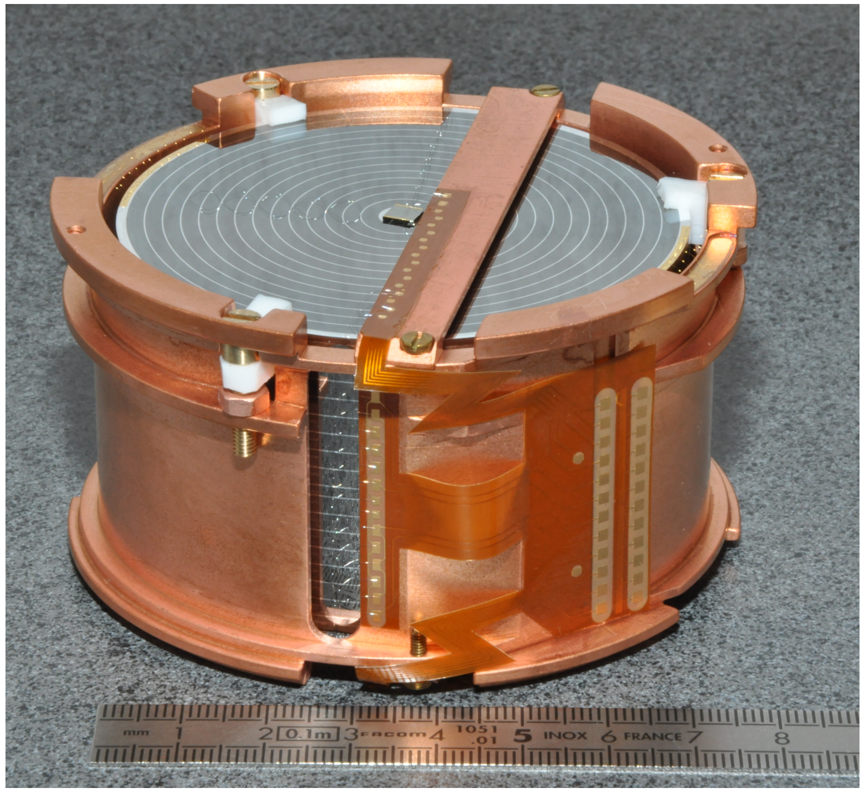
- ✦ **Cryogenic** massive **detectors** have reached maturity and **are integrated into complex instruments and demanding sites** (underground labs, nuclear reactors)
- ✦ **Few well identified projects with high IN2P3 contributions** over the next decades
- ✦ Proposal for a **new Dark Matter Search experiment @ LSM**
  - ➡ see Tesseract talk @ CS IN2P3 « Recherche directe de matière noire » - 23 Oct 2023 https://indico.in2p3.fr/event/31015/
- ✦ Many other projects not mentioned here

for a more general review w/ bolometer matrix see
Réunion GDR DI2I 10–12 juil. 2023 SUBATECH, Nantes
https://indico.in2p3.fr/event/29808/contributions/126565/

+

ANF DRTBT2024 (Detection de Rayonnement à Très Basse Température)
Aussois 24-29 Mars 2024

Ex. of instrument : EDELWEISS-III



36 * FID-800

- **Ge 820 g**
- High impedance Ge-NTD thermometer (neutron doped Ge crystals)
- 4 sets of Al electrodes for charge collection
  - Simultaneous measurement of **ionization & heat**
  - Background active rejection

Running 2013-2022

- **10mK Cryostat** + 40 tons of shielding (PE + Pb) @ LSM
- **3000 coax. cables (6 km)**
- **350 Si-JFET transistors@ 120K**
- 36*2 « Bolometers Boxes » @ 300K

R&D : CUPID

CUPID

CUORE Upgrade with Particle Identification

- ✦ 30 institut., 100s of people
- ✦ Long **process of R&D selection**
  - *https://arxiv.org/abs/1504.03612*
- ✦ French R&D (**CUPID-Mo**, IJCLab-IP2I + CEA) **selected as the CUPID baseline**
  - *https://arxiv.org/abs/1907.09376*
  - *Luke Neganov Ge **Light detectors will be produced by IJCLab***
- ✦ dedicated « small » underground R&D project : CROSS, BINGO ERC project
- ✦ **lots to be done over the next 3 decades**

https://arxiv.org/abs/1712.07995

Parameter	CUPID	CUPID-reach	CUPID-1T
Crystal	$Li_2{}^{100}MoO_4$	$Li_2{}^{100}MoO_4$	$Li_2{}^{100}MoO_4$
Detector mass (kg)	472	472	1871
^{100}Mo mass (kg)	253	253	1000
Energy resolution FWHM (keV)	5	5	5
Background index (counts/(keV kg y))	10^{-4}	2×10^{-5}	5×10^{-6}
Containment efficiency	79%	79%	79%
Selection efficiency	90%	90%	90%
Livetime (years)	10	10	10
Half-life exclusion sensitivity (90% C.L.)	1.5×10^{27} y	2.3×10^{27} y	9.2×10^{27} y
Half-life discovery sensitivity (3σ)	1.1×10^{27} y	2×10^{27} y	8×10^{27} y
exclusion sensitivity (90% C.L.)	10–17 meV	8.2–14 meV	4.1–6.8 meV
discovery sensitivity (3σ)	12–20 meV	8.8–15 meV	4.4–7.3 meV

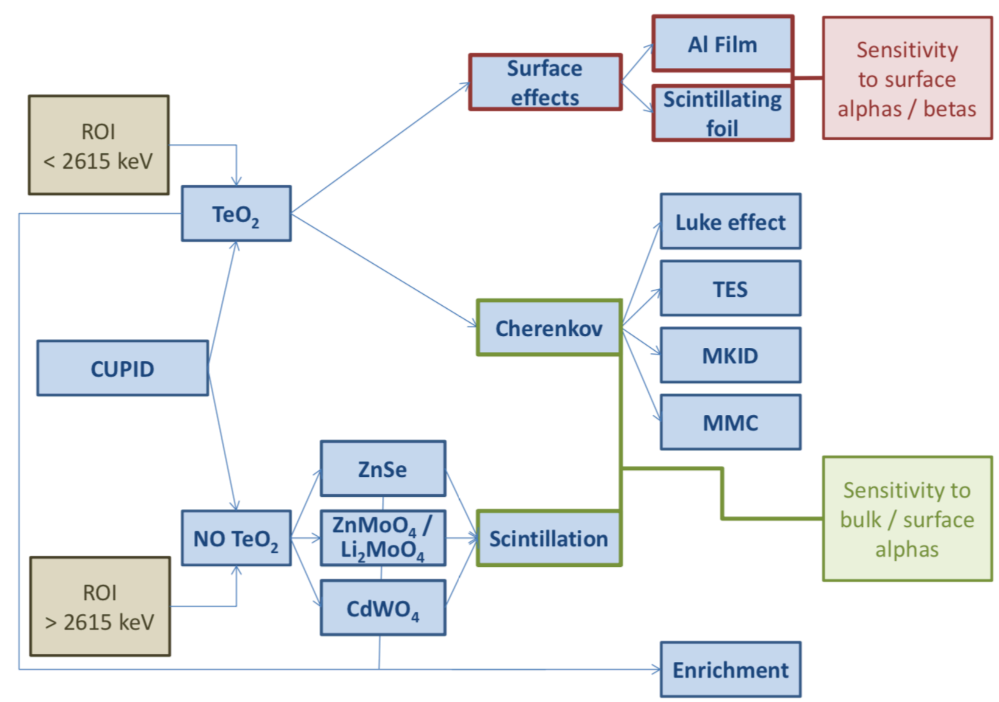
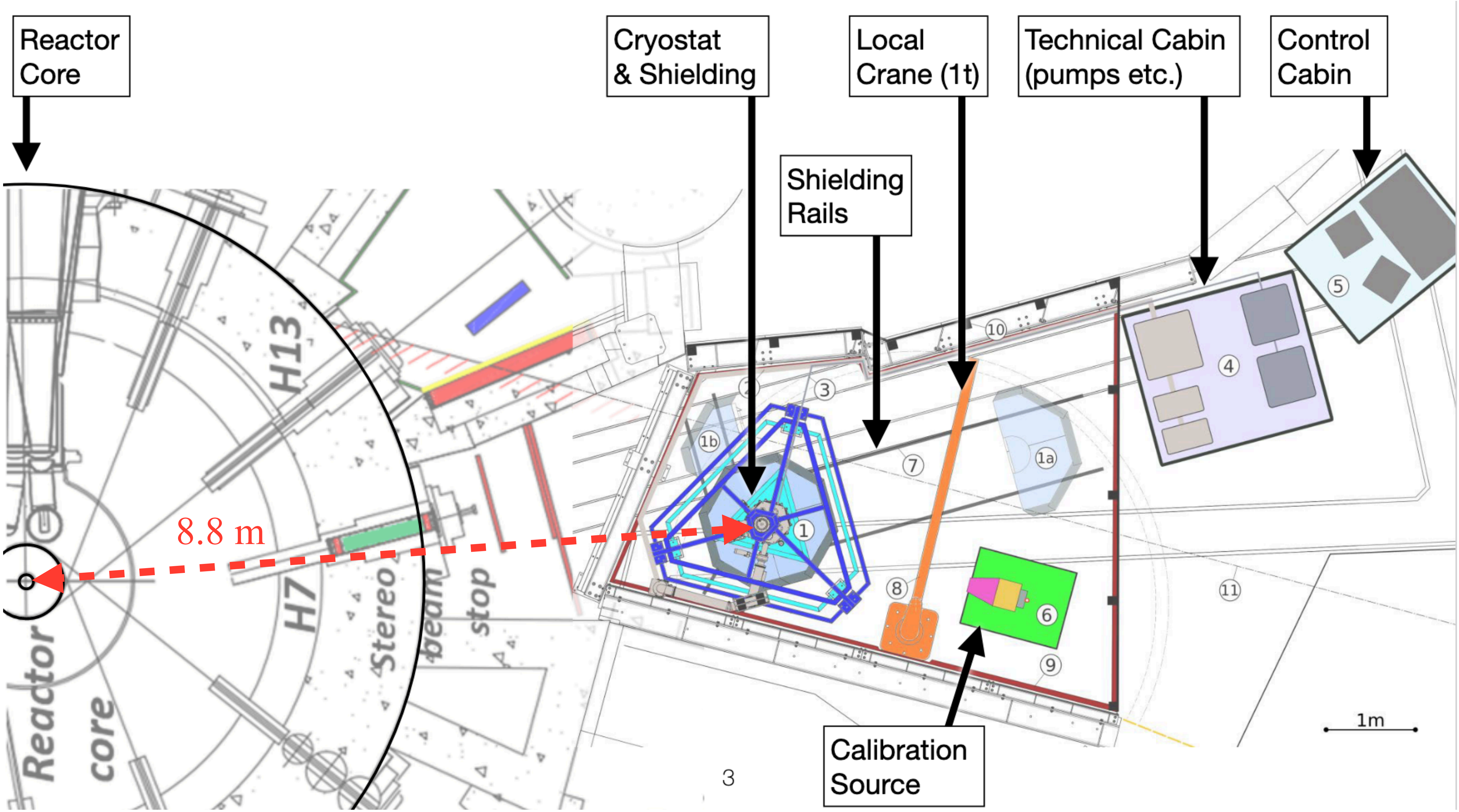


FIG. 1: Scheme of the R&D detector activities for CUPID

https://arxiv.org/abs/1504.03612

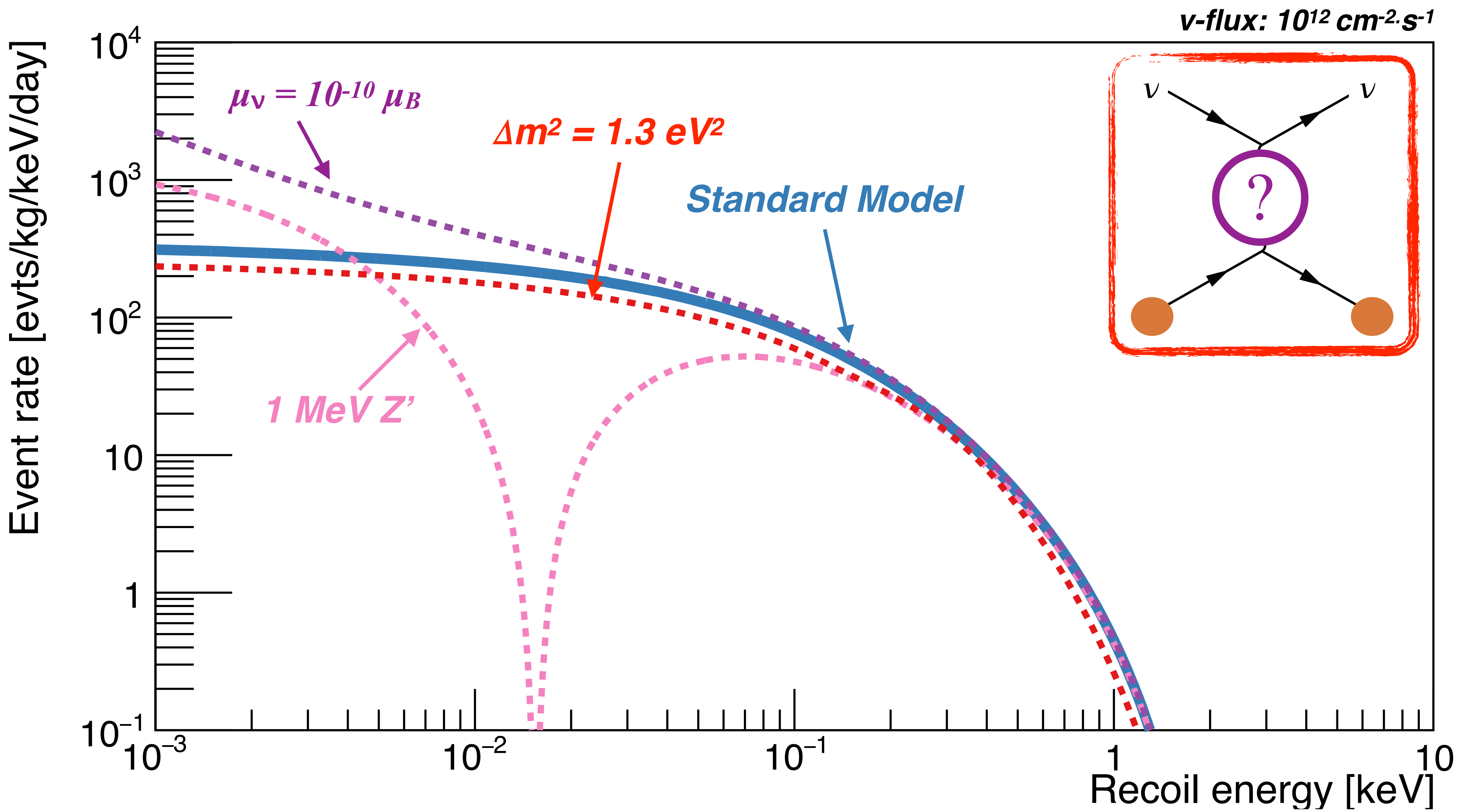
RICOCHET: *A future low-energy neutrino observatory*



Ricochet integration at ILL started

RICOCHET: *Searching for new physics with CENNS*

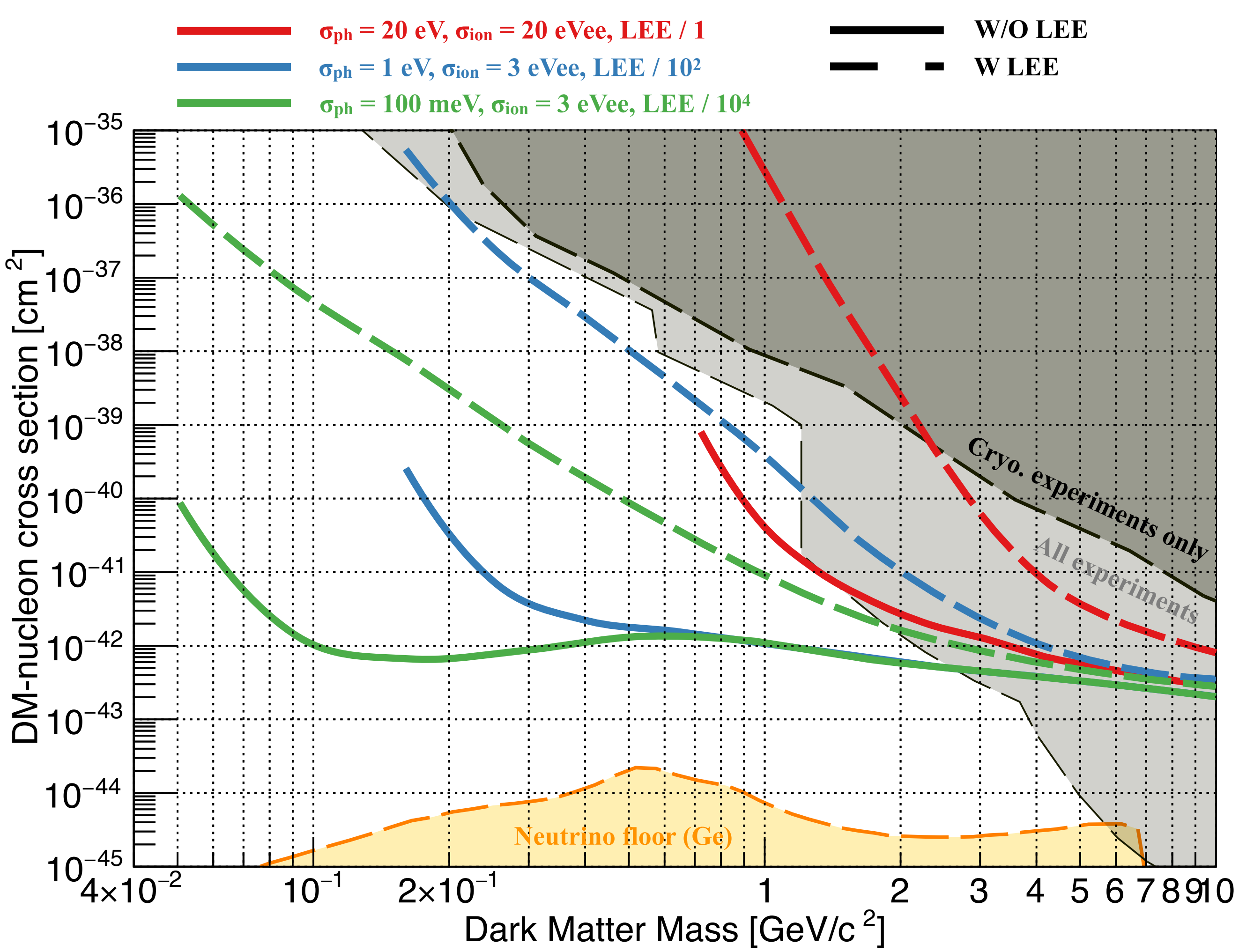
Recoil energy distribution



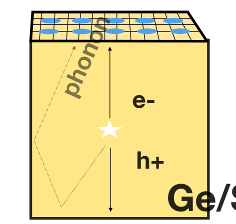
J. Billard, J. Johnston and B. Kavanagh, JCAP (2018)

New physics signatures will arise at the lowest energies
Calls for very low-energy thresholds: O(10) eV

TESSERACT@LSM: *Ge/Si semiconductors*



TESSERACT back. model = 10 DRU gamma + other backgrounds from EDW-III



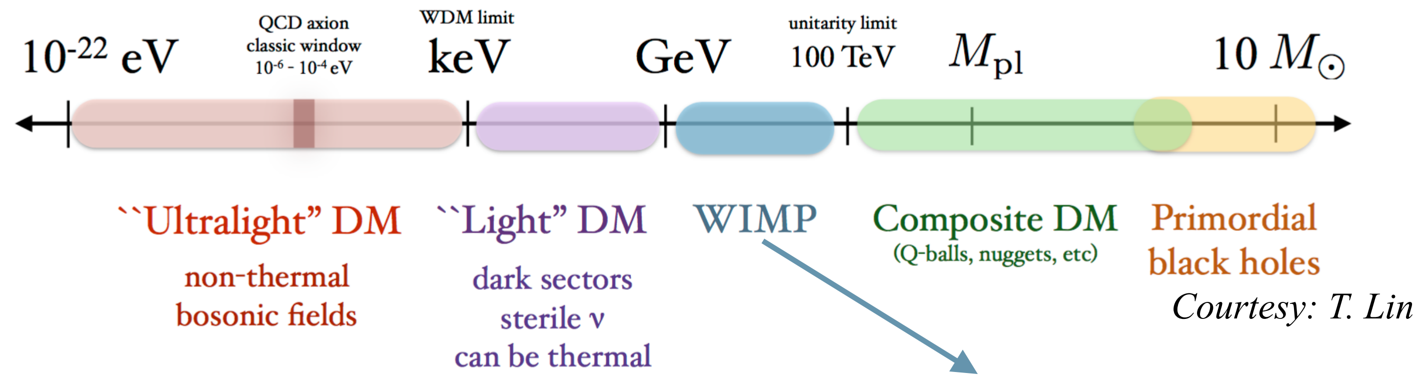
The LV technology in TESSERACT will allow to vastly extend the NRDM searches down to 100 MeV with particle ID and LEE rejection in a region of the parameter space inaccessible to non-cryogenic experiments

Tesseract @ CS IN2P3 - 23 Oct 2023
https://indico.in2p3.fr/event/31015/

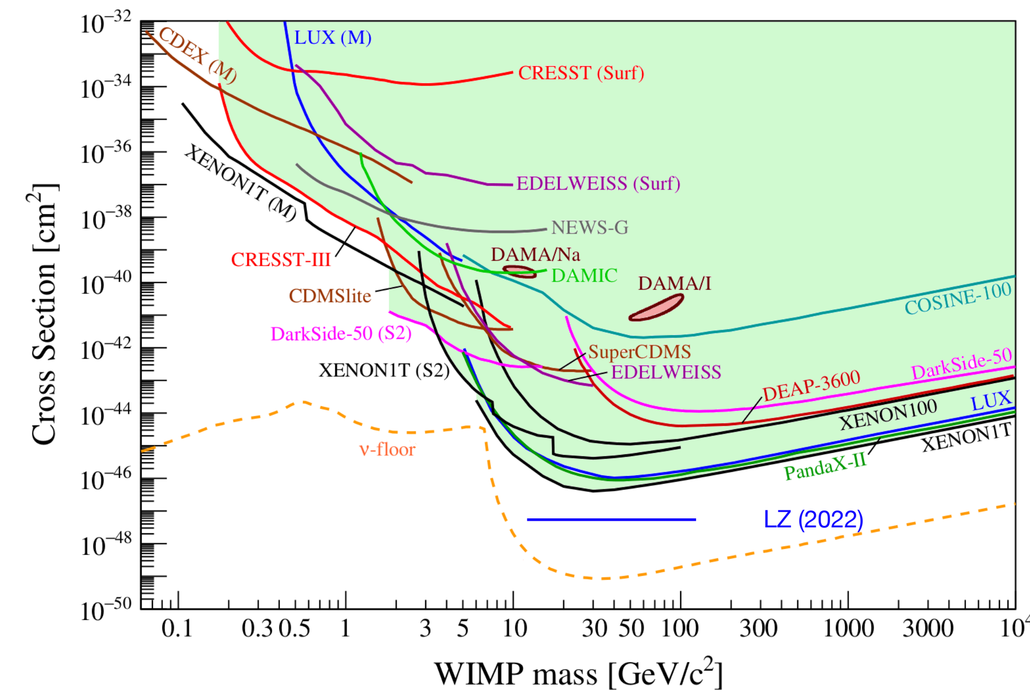
TESSERACT@LSM: Dark Matter Candidates

TESSERACT

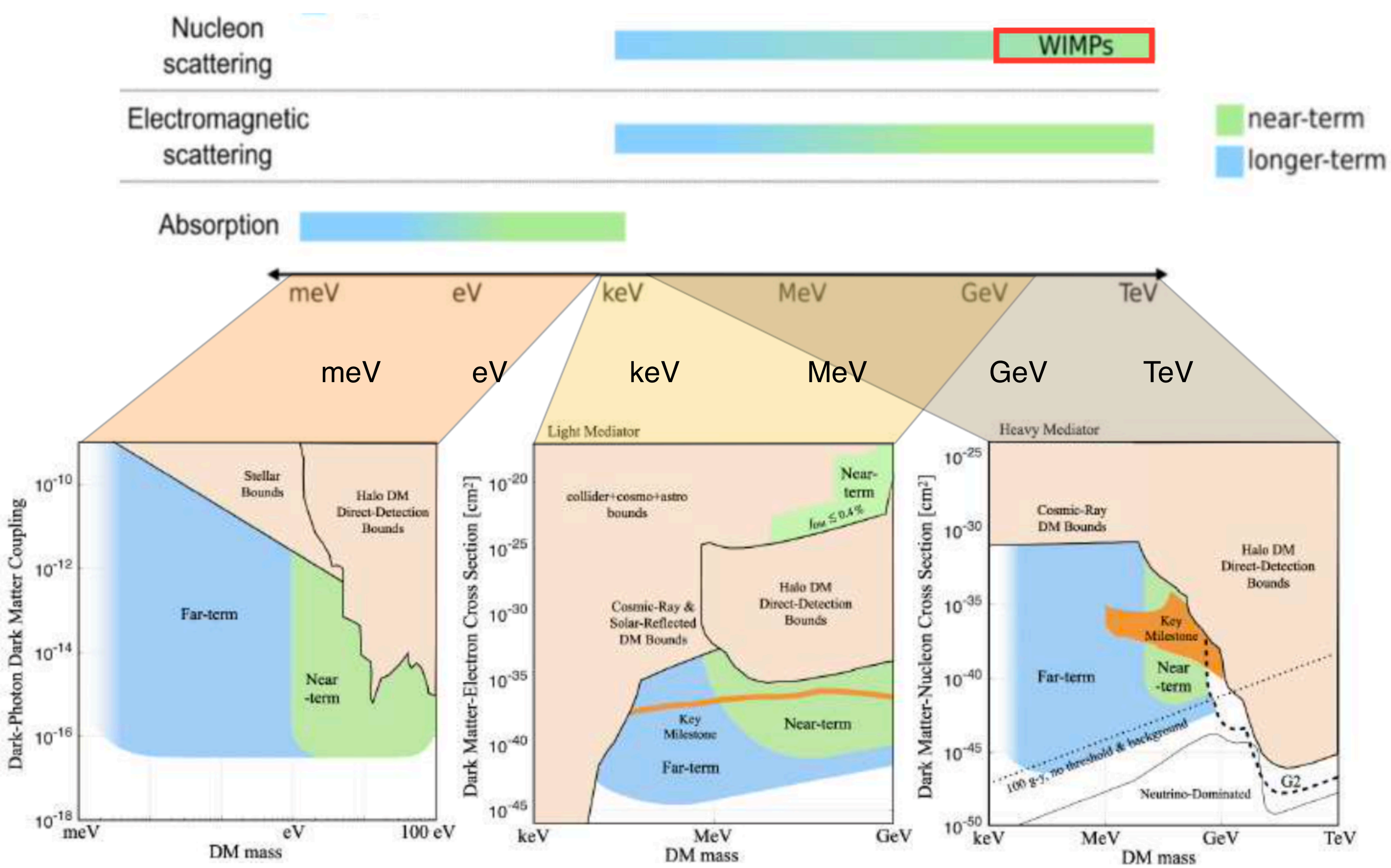
Dark matter candidate:
About 50 orders of magnitude in mass (assuming it is an elementary particle)



- Focus of DM searches for the last decades has been on axion DM (ueV - meV) and the standard WIMP (10 GeV - TeV)
- The standard WIMP case « *was* » highly motivated thanks to the so-called WIMP miracle and the SUSY predictions
- After few decades, still no DM signal and ongoing or planned ton-scale experiments (LZ, XENON-nT, DarkSide-20k, DARWIN, ARGO,…) are approaching the neutrino limit
- **Need for new experiments with broader DM mass range and increased sensitivity to more DM interactions !**



TESSERACT@LSM: Dark Matter Search Range



TESSERACT: Extending the Dark Matter mass search window from meV-to-GeV with ultra low-threshold cryogenic detectors with multiple targets and particle identification capabilities

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