TESSERACT

TESSERACT @ LSM

A proposal for a new generation light DM search cryogenic experiment in Modane

J. Billard (IP2I) and S. Scorza (LPSC)

on Behalf of the TESSERACT collaboration and interested IN2P3 partners

Paris Michel-Ange

CS IN2P3, October 23rd, 2023

TESSERACT

J. Billard

Light dark matter science motivation and detection challenges
TESSERACT@LSM proposal and design drivers
Cryogenic detector technologies and projected sensitivities

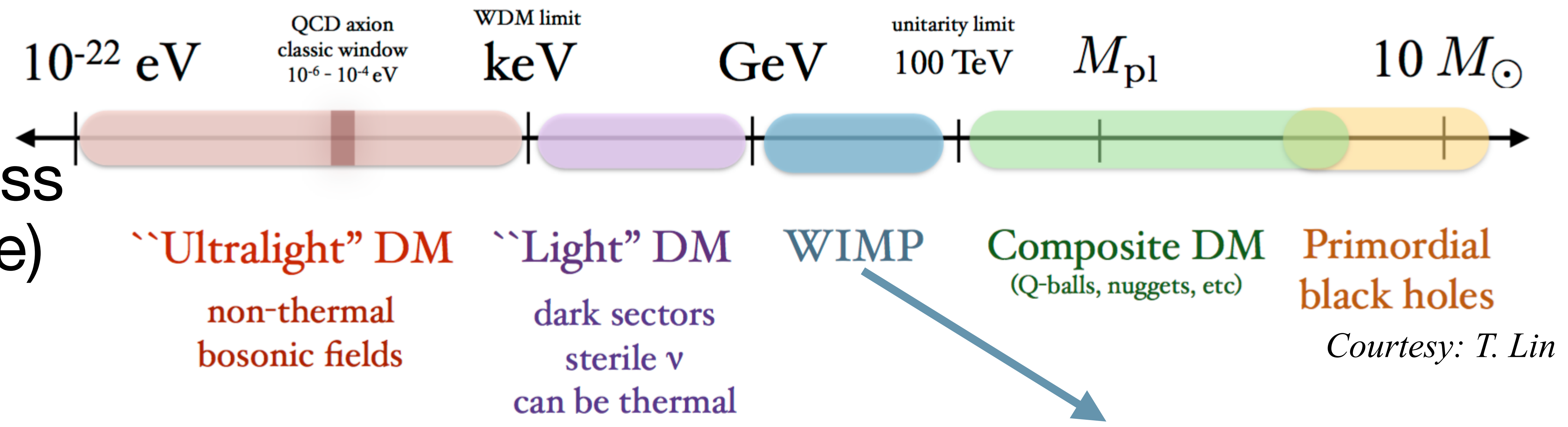
S. Scorza

Testing Facilities
Background Consideration
The Underground Modane Laboratory (LSM)
Integration at LSM
WBS Structure
Budget

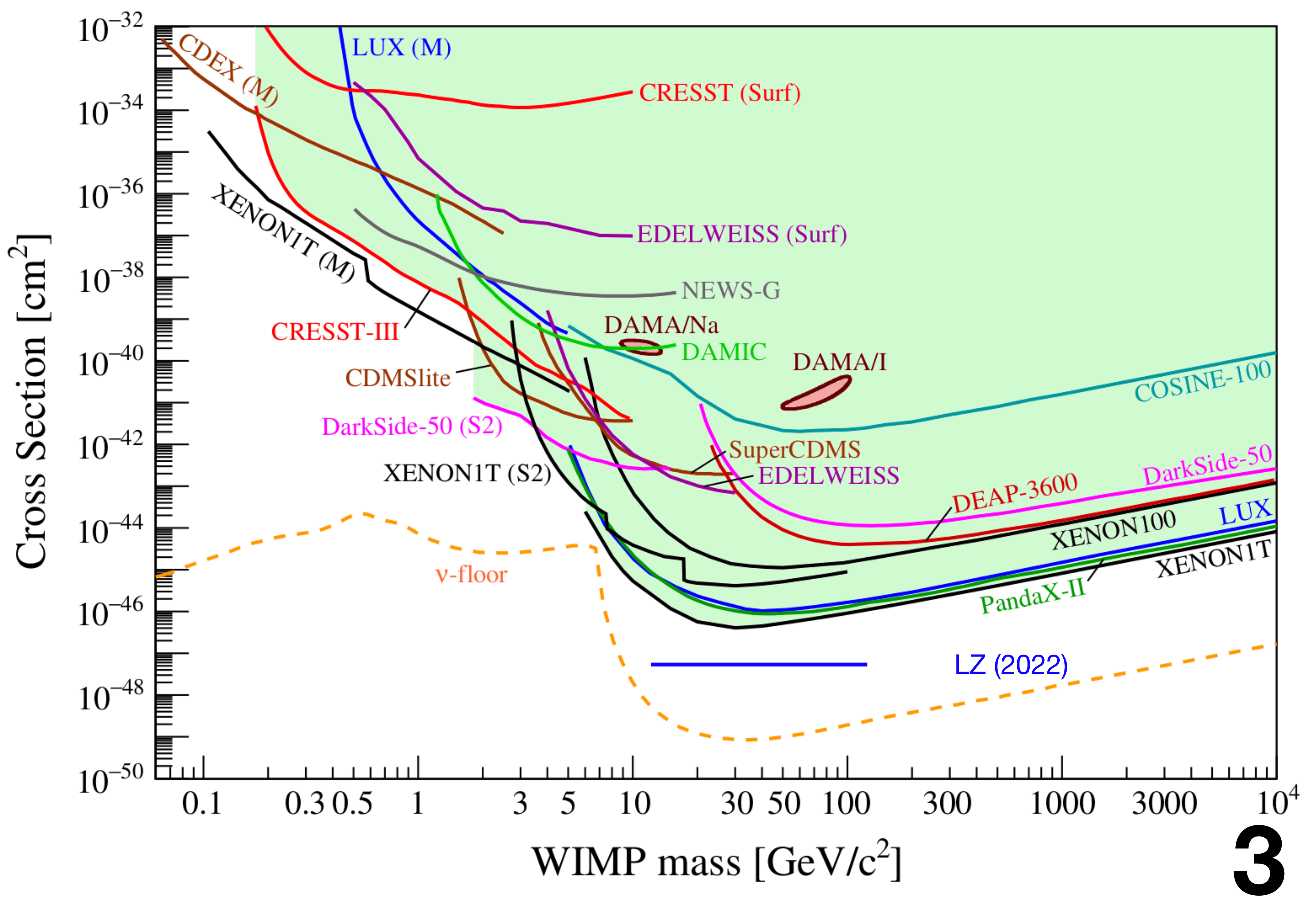
TESSERACT@LSM: Dark Matter Candidates

Dark matter candidate:

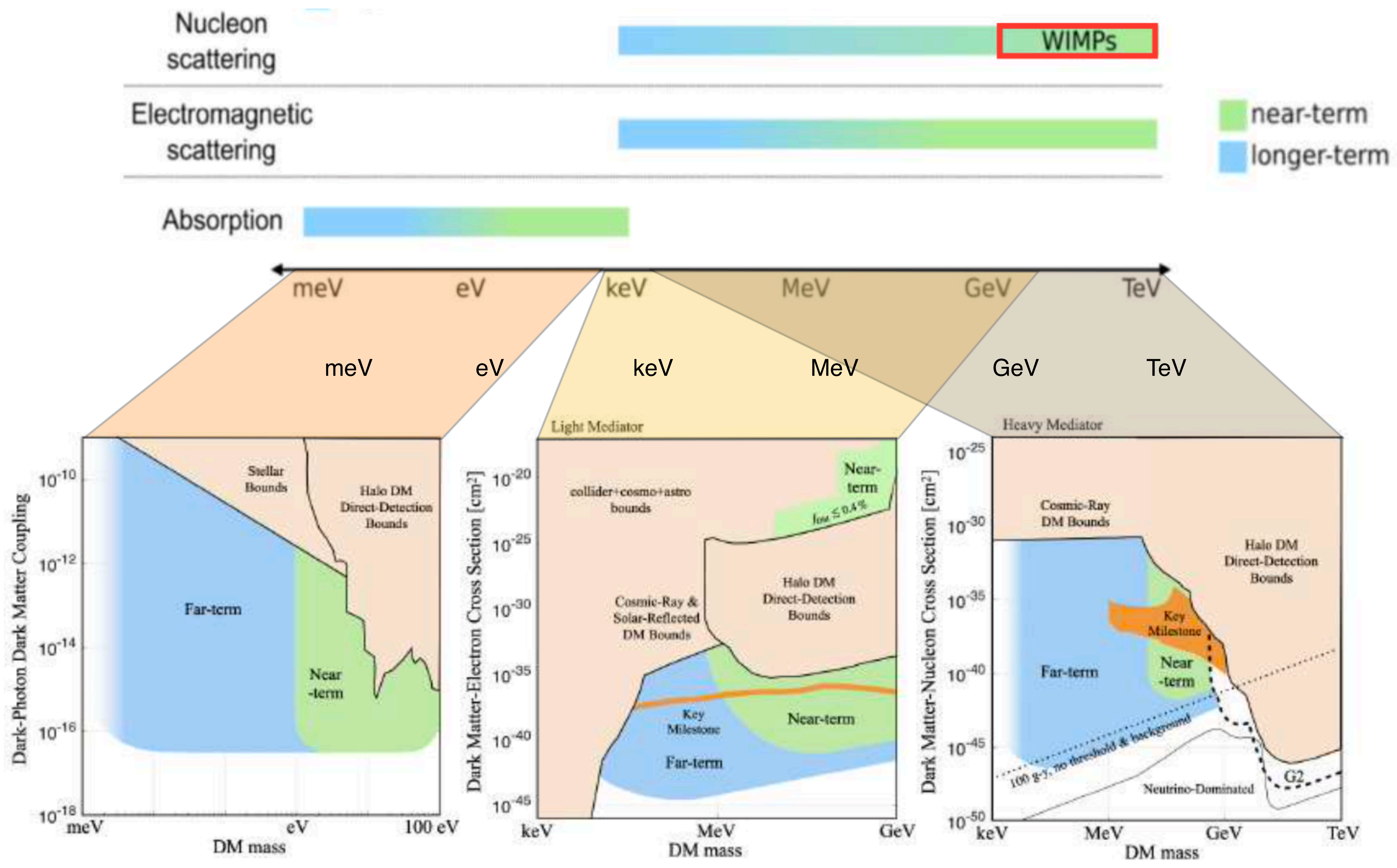
About 50 orders of magnitude in mass (assuming it is an elementary particle)



- 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

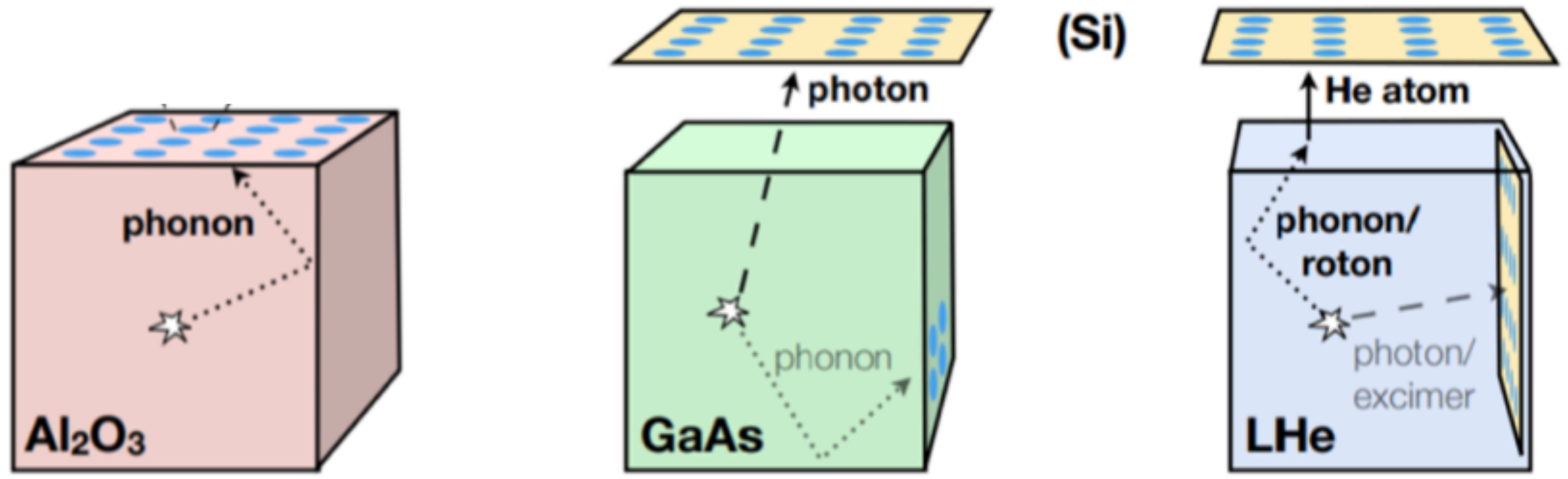


TESSERACT: Extending the Dark Matter mass search window from meV-to-GeV with ultra low-threshold cryogenic detectors with multiple targets and particle identification capabilities

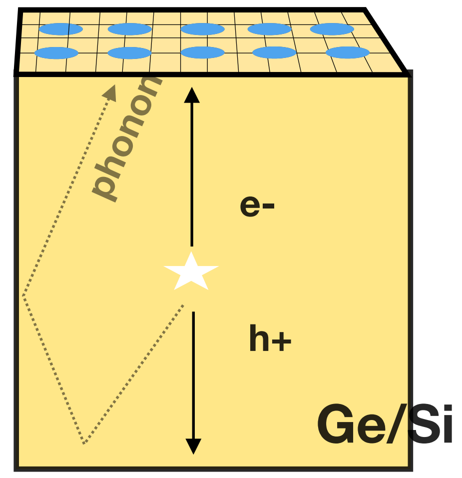
iP2i LES 2 INFINIS LYON
LPSC GRENOBLE | MODANE
IJCLab Irène Joliot-Curie
cnrs

TESSERACT@LSM: Proposal experiment at LSM

Transition Edge Sensors with Sub-Ev Resolution And Cryogenic Targets



- 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**

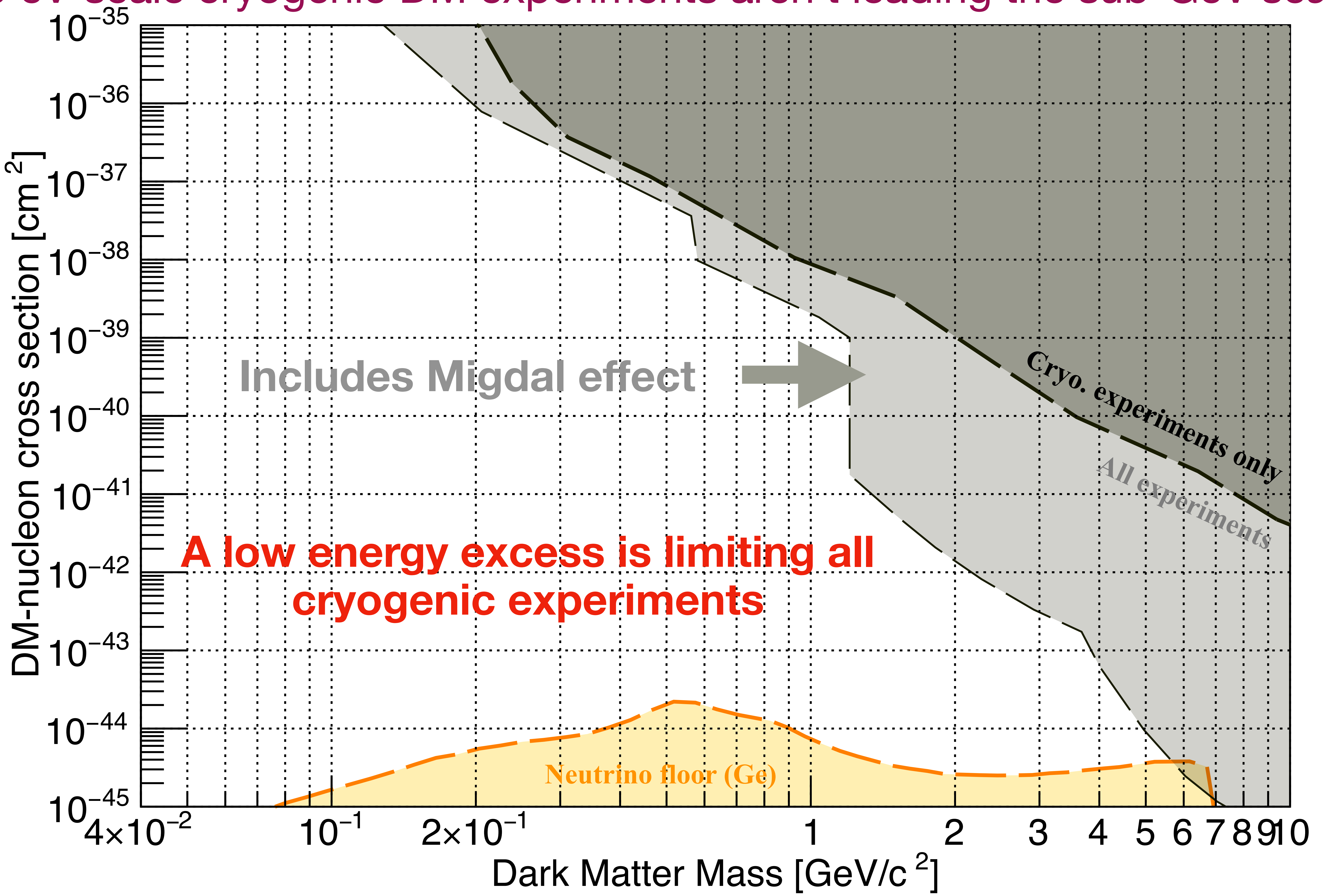


TESSERACT @ LSM proposal:

- Benefit from EDW+Ricochet+CUPID Ge bolometer expertise and low-background cryogenic setup experience to:
  1. **Add the French semiconductor Ge bolometer technology 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

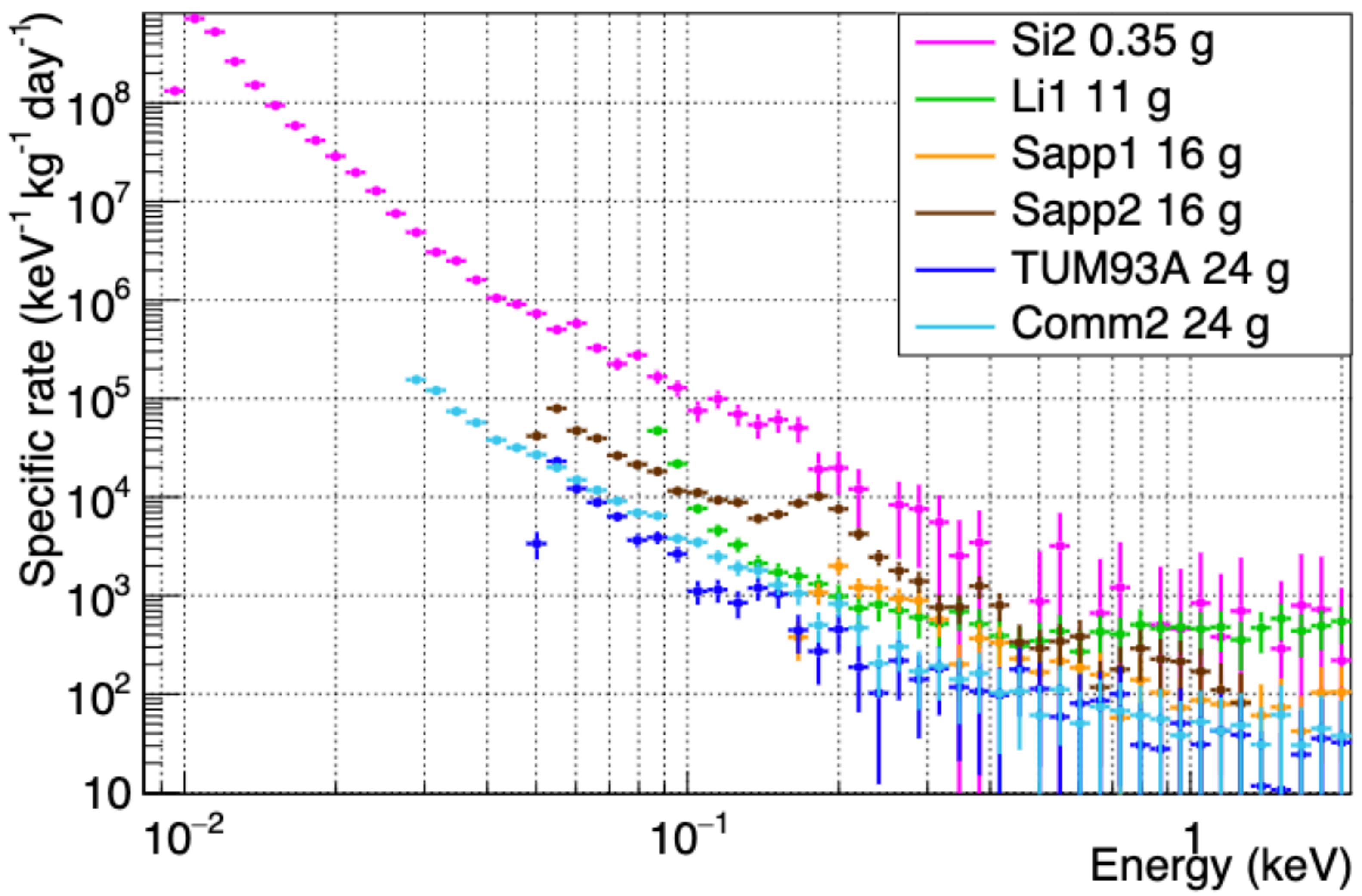
TESSERACT@LSM: State of the art (low-mass NRDM)

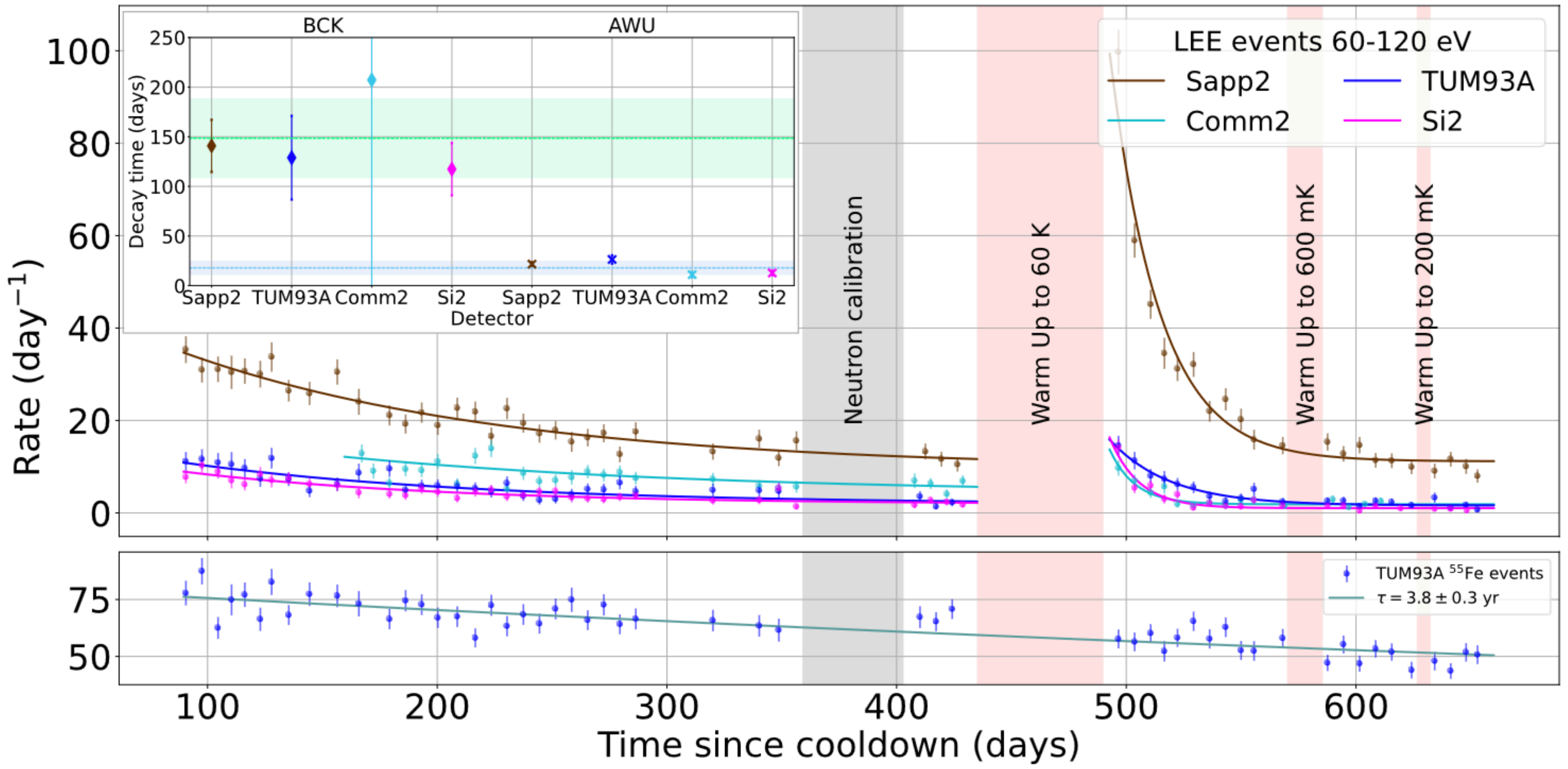
Why 100 eV-scale cryogenic DM experiments aren't leading the sub-GeV search region ?



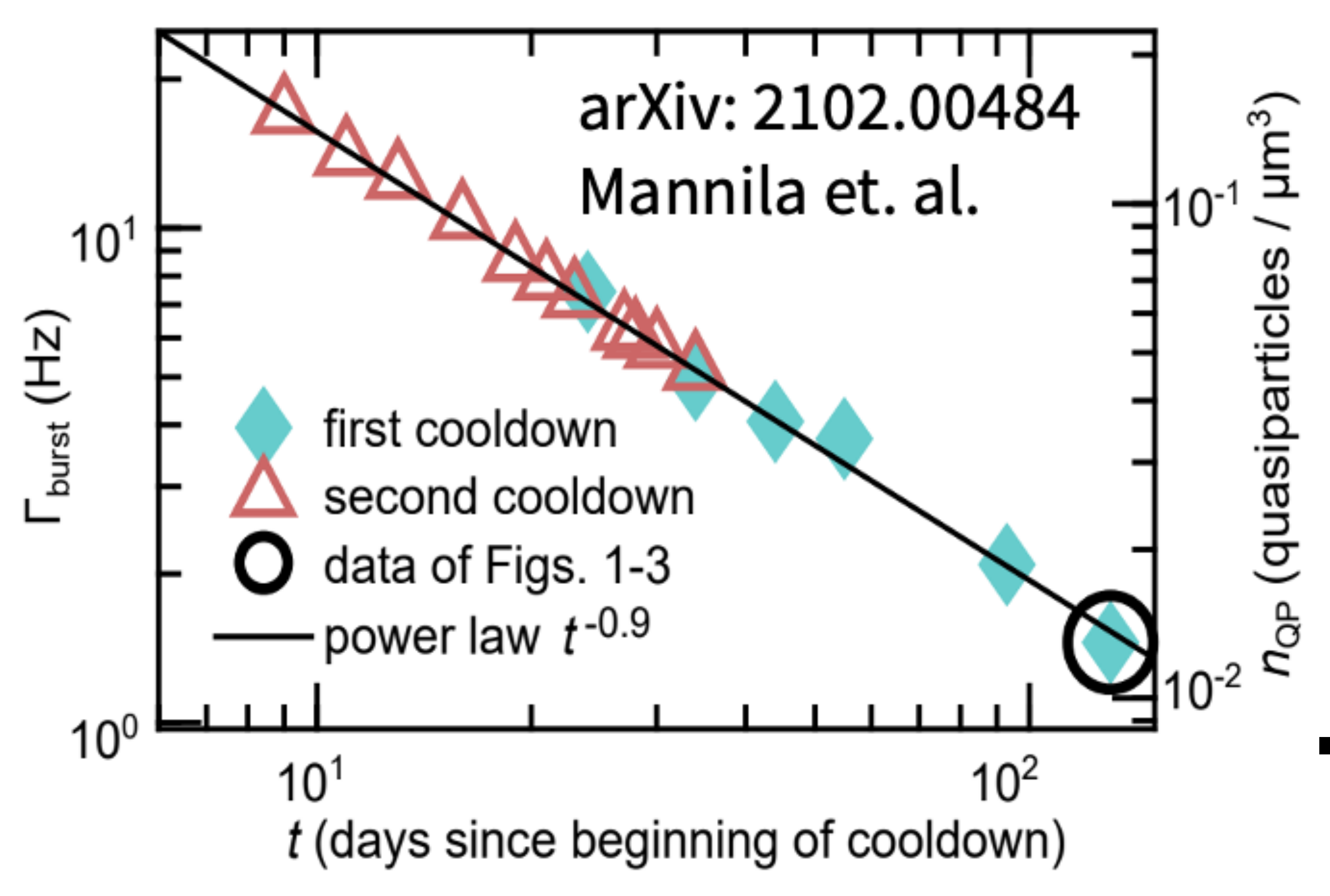
TESSERACT@LSM: Low-E excess

CRESST collaboration, SciPost Phys.Proc. 12 (2023) 013



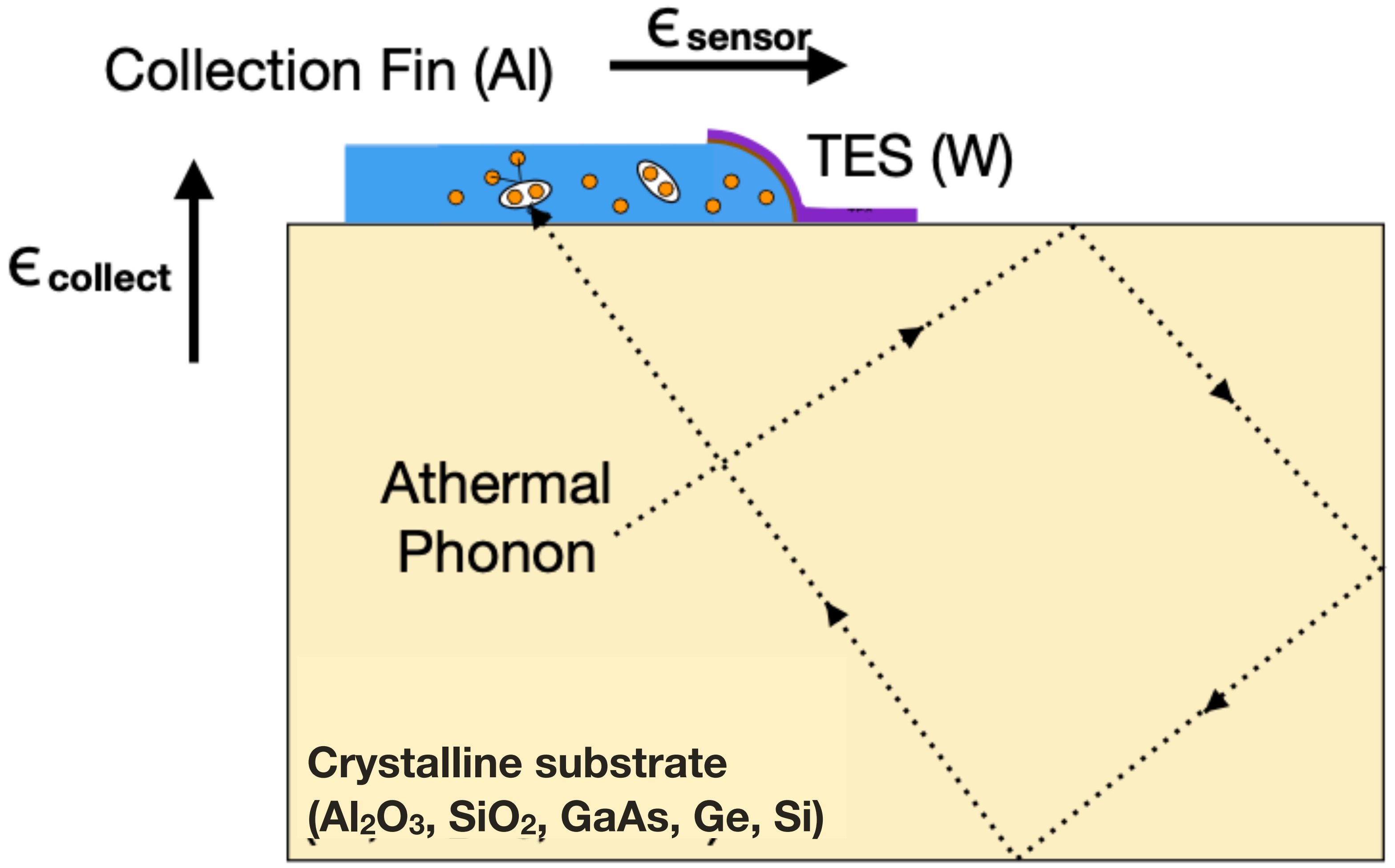


- Currently, all cryogenic experiments which have reached sub-100 eV thresholds are seeing such an excess limiting their DM reach
- LEE characteristics: **time dependent**, non-ionising, mostly independent of sites, dependence with holders/vibrations (?)
- Design driver of TESSERACT: *1) find the origin of the LEE to mitigate it*, and *2) develop detector technologies that can reject it*
- Possible connection to anomalously short coherence time in Q-bits partially due to high and **decreasing over time** quasiparticle density => ***Behaves like the LEE !***



TESSERACT: New generation TES phonon sensors

TES based athermal phonon sensor technology:

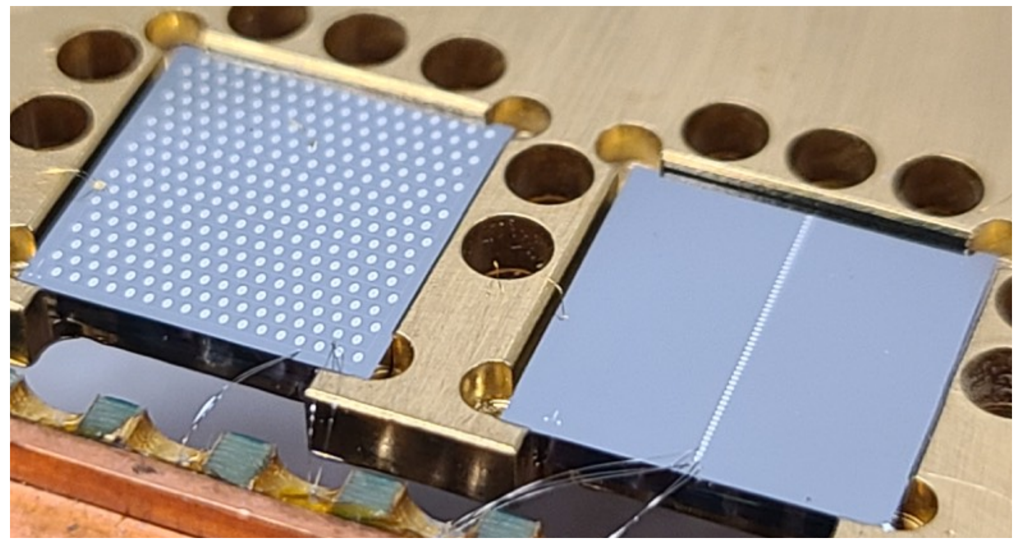


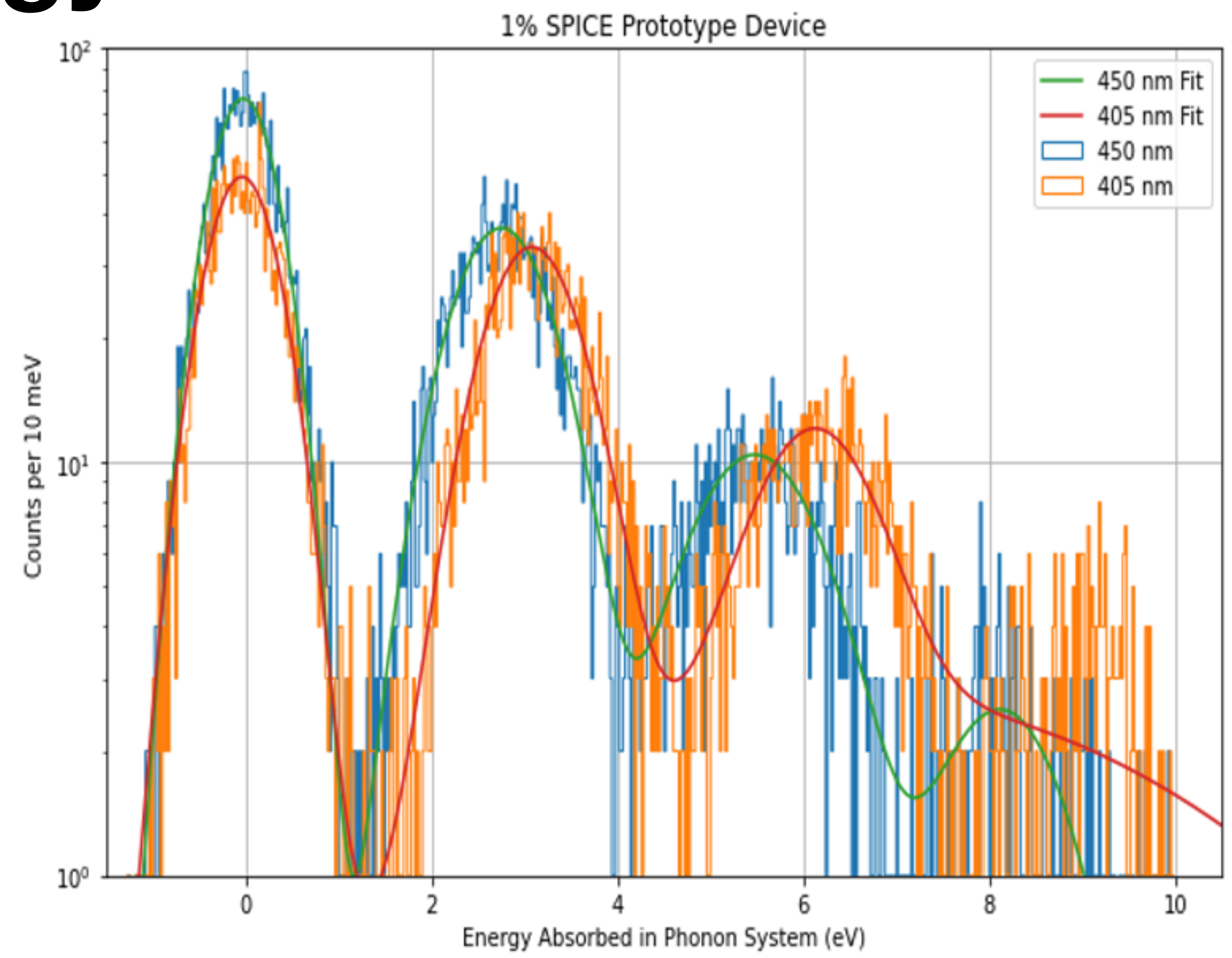
$$\sigma_E \sim \frac{\sqrt{4k_b T_c^2 G(\tau_{collect} + \tau_{sensor})}}{\epsilon_{collect}\epsilon_{sensor}}$$

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

Energy threshold decreases with detector mass

Energy threshold decreases very quickly with Tc



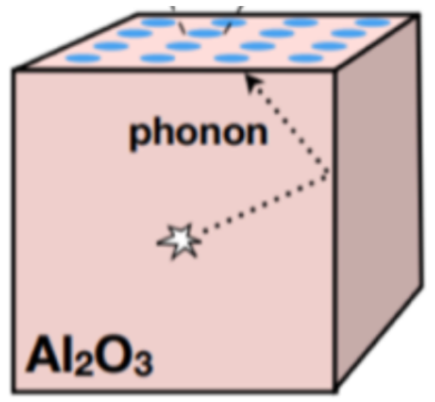


- **273 meV (RMS) leading to eV-scale threshold already achieved** with a 0.2g Si detector and Tc = 50 mK
- Targeted Tc around 15-20 mK recently achieved

  ~100 meV threshold achievable on 1 cm³ crystals

- **Next challenge:** parasitic power (vibrations, EMI, IR photons) needs to be <aW to fully reach TES sensitivity

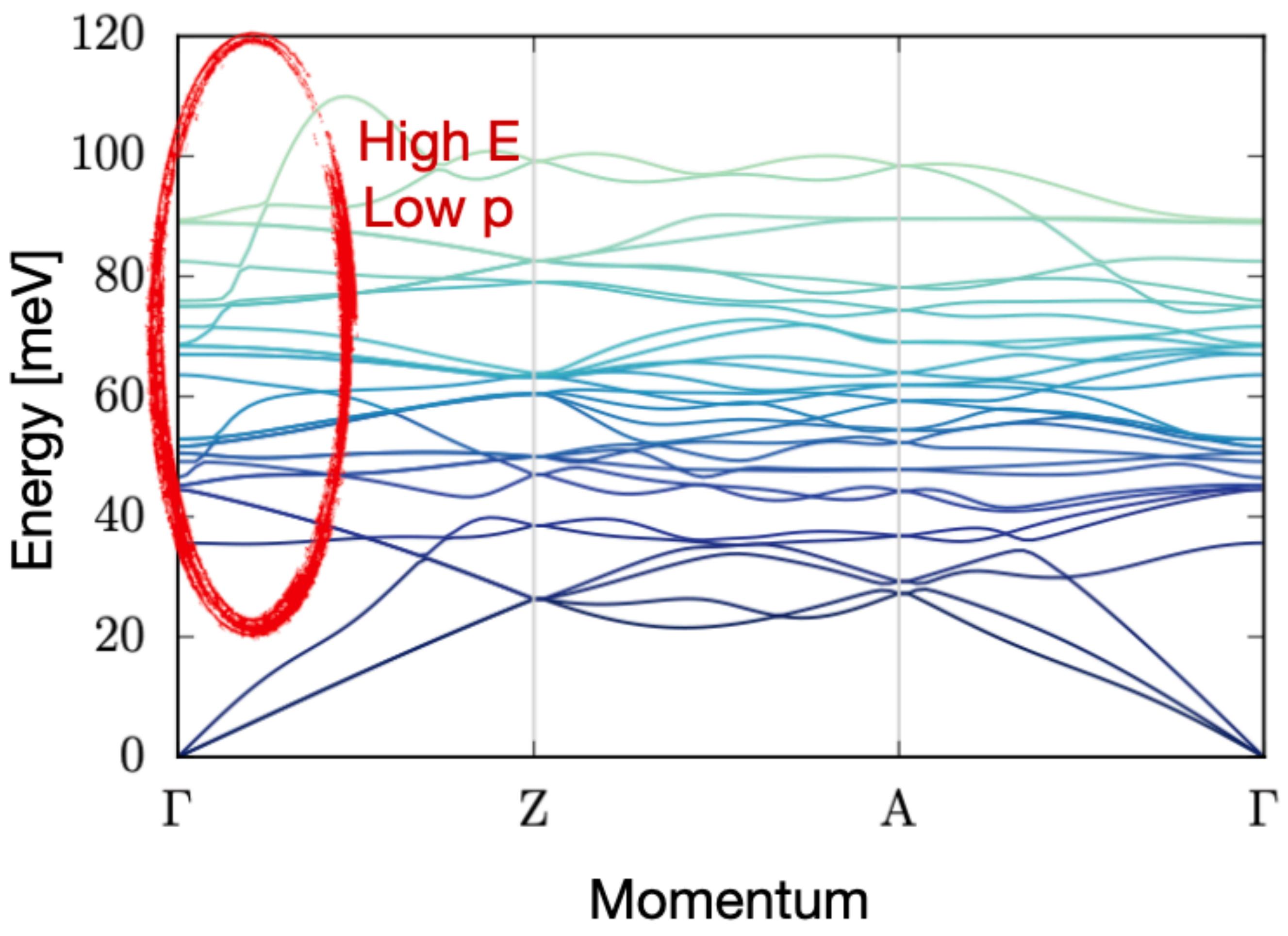
TESSERACT@LSM: SPICE



Sub-eV Polar Interactions Cryogenic Experiment: Al_2O_3

1. **Sapphire supports many optical phonon modes.**
   (phonons with a high energy:momentum ratio)

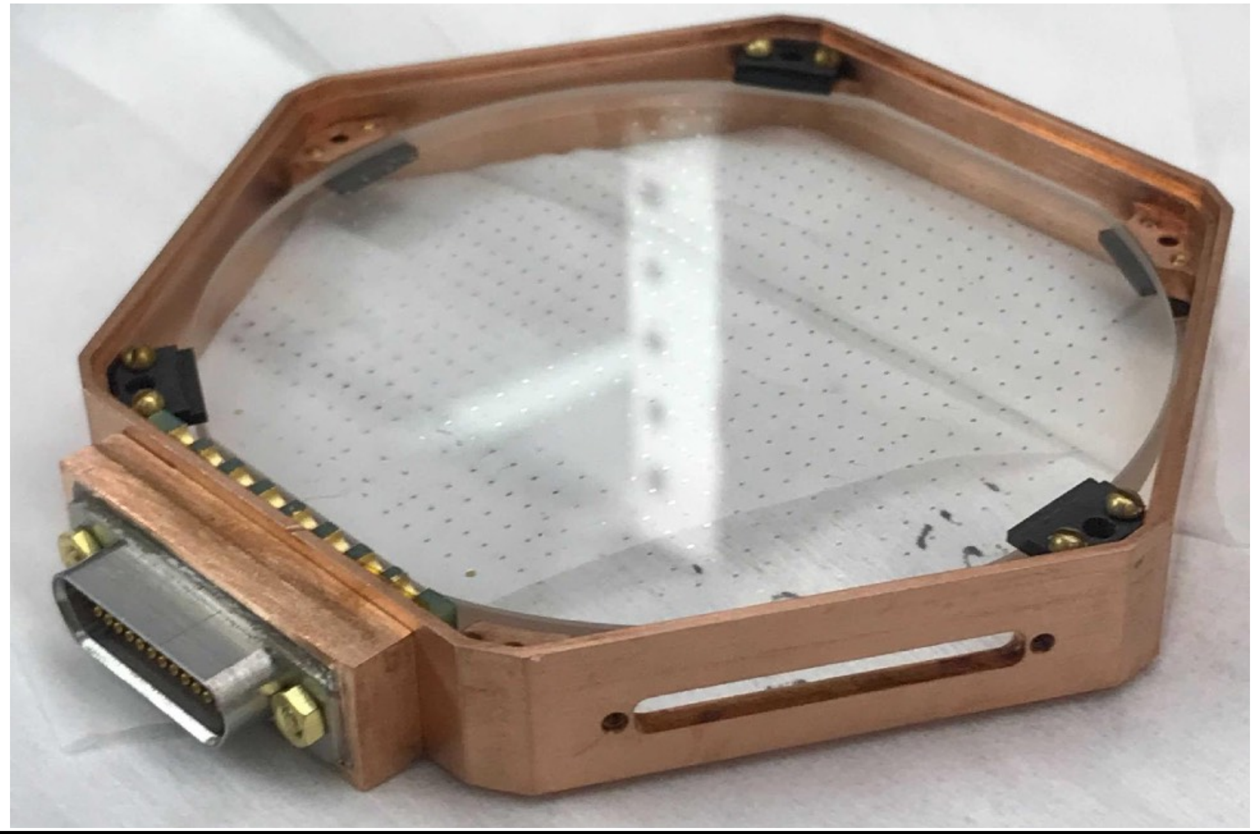
   Instead thinking about 'kicking an atom' we now think about recoiling off the lattice, and 'exciting a phonon'.
   Optical phonons are kinematically well-matched to low-mass dark matter (similar effective mass)



2. **Sapphire is a polar crystal**
   (couples well to E&M-like inputs)

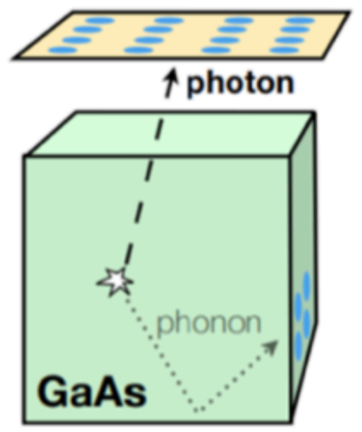
   Allows to extend DM scattering searches via light dark photon down to keV masses **not accessible** to any other target materials
   Possibility to extend further down to 100-meV (eV) DM masses thanks to absorption on phonon (electron)

   LEE mitigation: Use of two TES channels

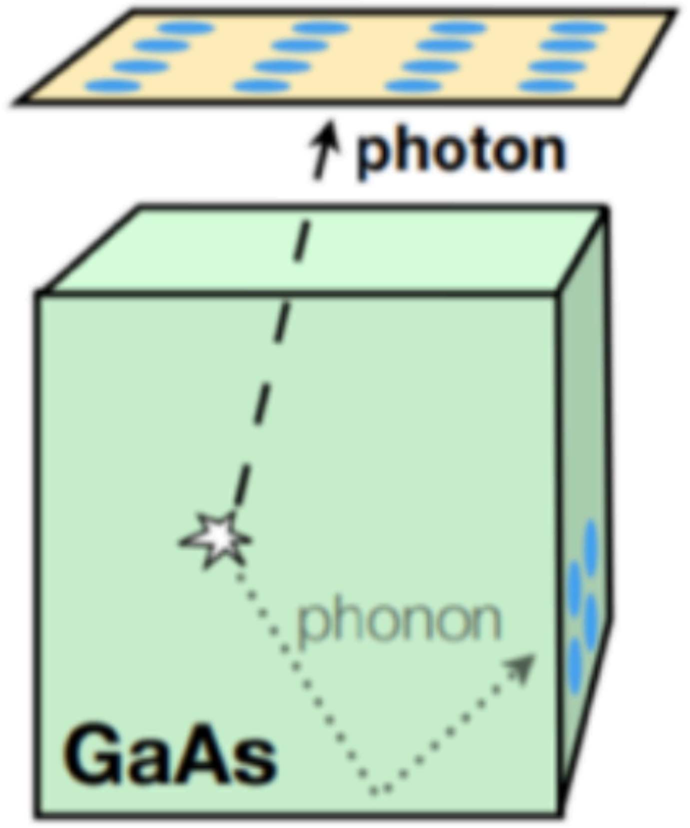


TESSERACT iP2i LPSC IJCLab Irène Joliot-Curie cnrs

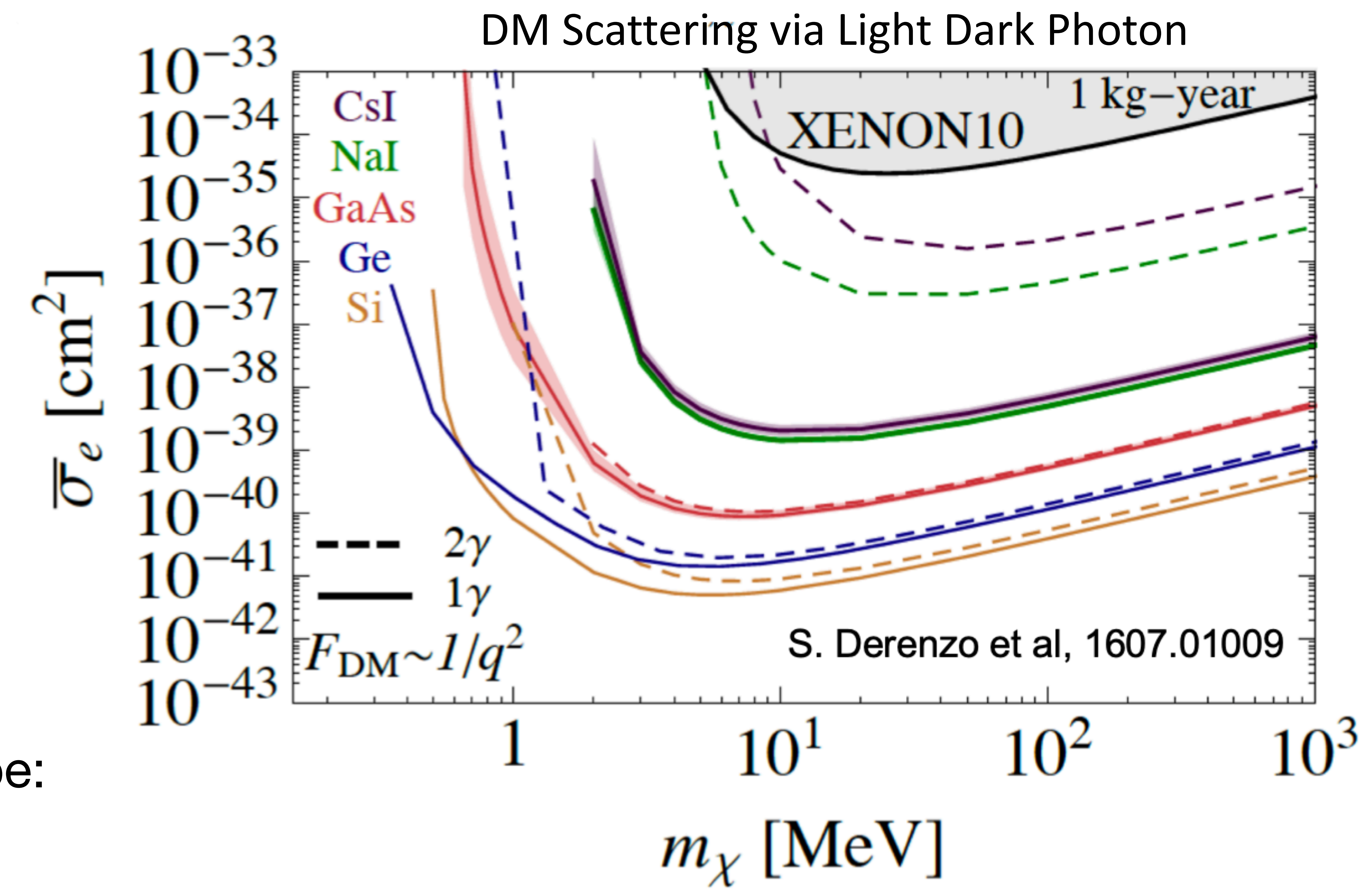
TESSERACT@LSM: SPICE



Sub-eV Polar Interactions Cryogenic Experiment: GaAs

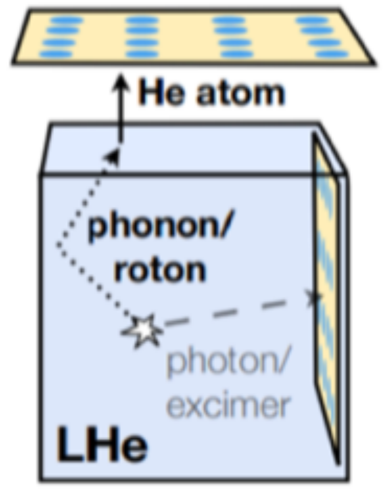


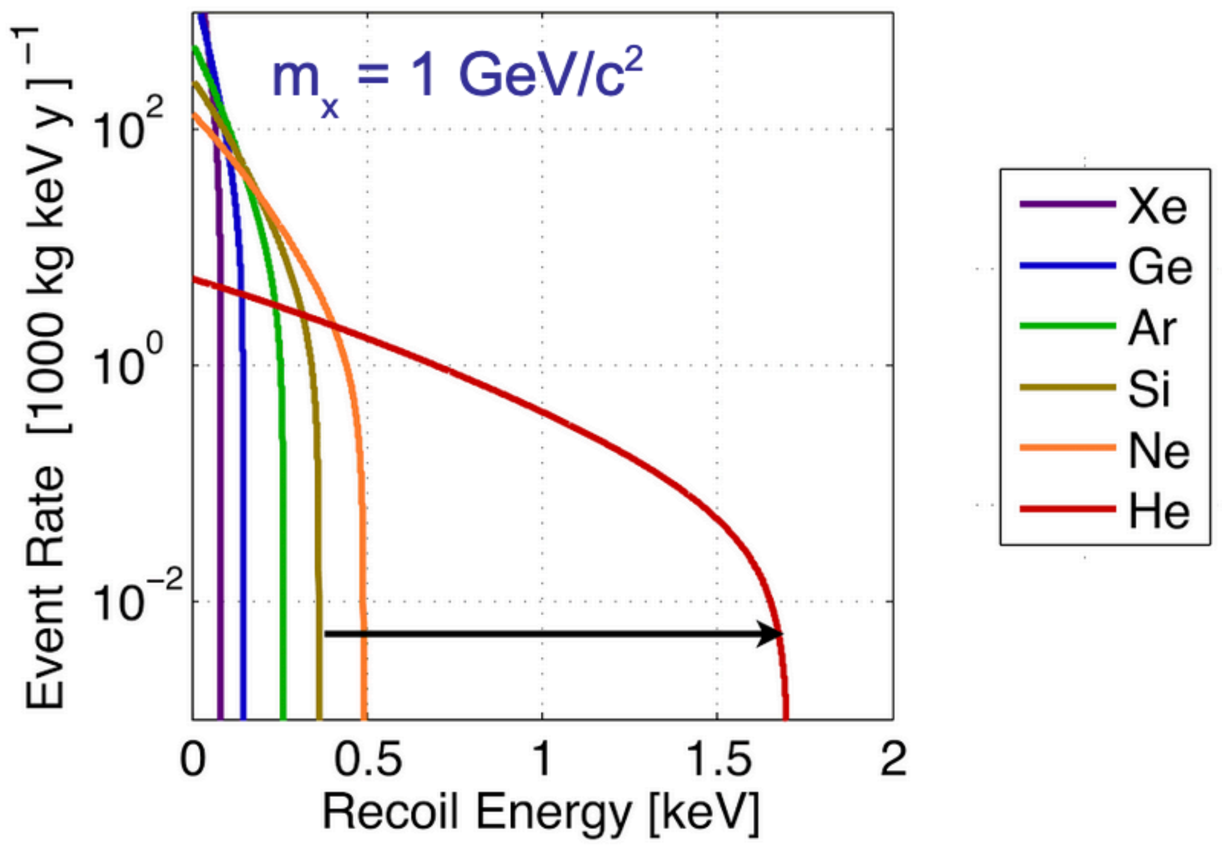
- GaAs has very high scintillation yield (125 ph/keV, arxiv:1904.09362),
- GaAs has a similar ERDM sensitivity than Ge/Si and similarly allows for **control of the backgrounds**:
  - photon:phonon ratio depends on the recoiling particle type: NR/ER discrimination (~10 eV scale)
  - photon/phonon coïncidence in two separate sensors: instrumental background rejection (LEE) (~eV scale)

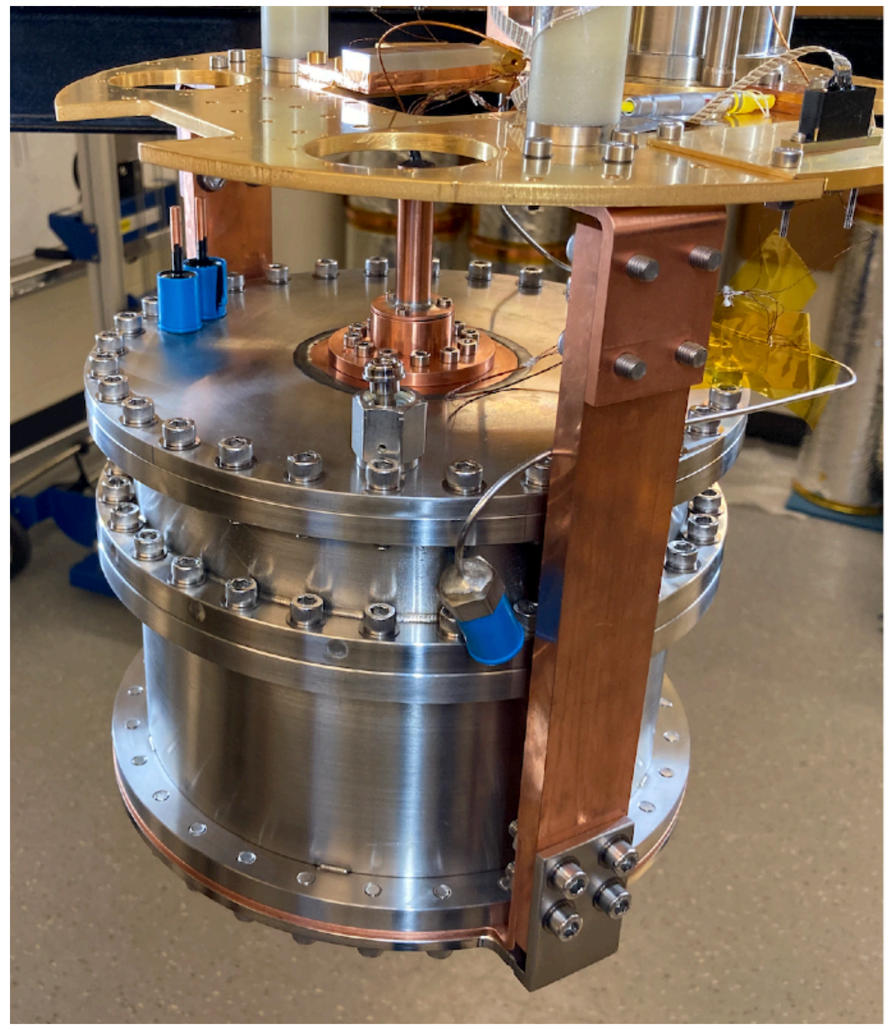


TESSERACT@LSM: HeRALD

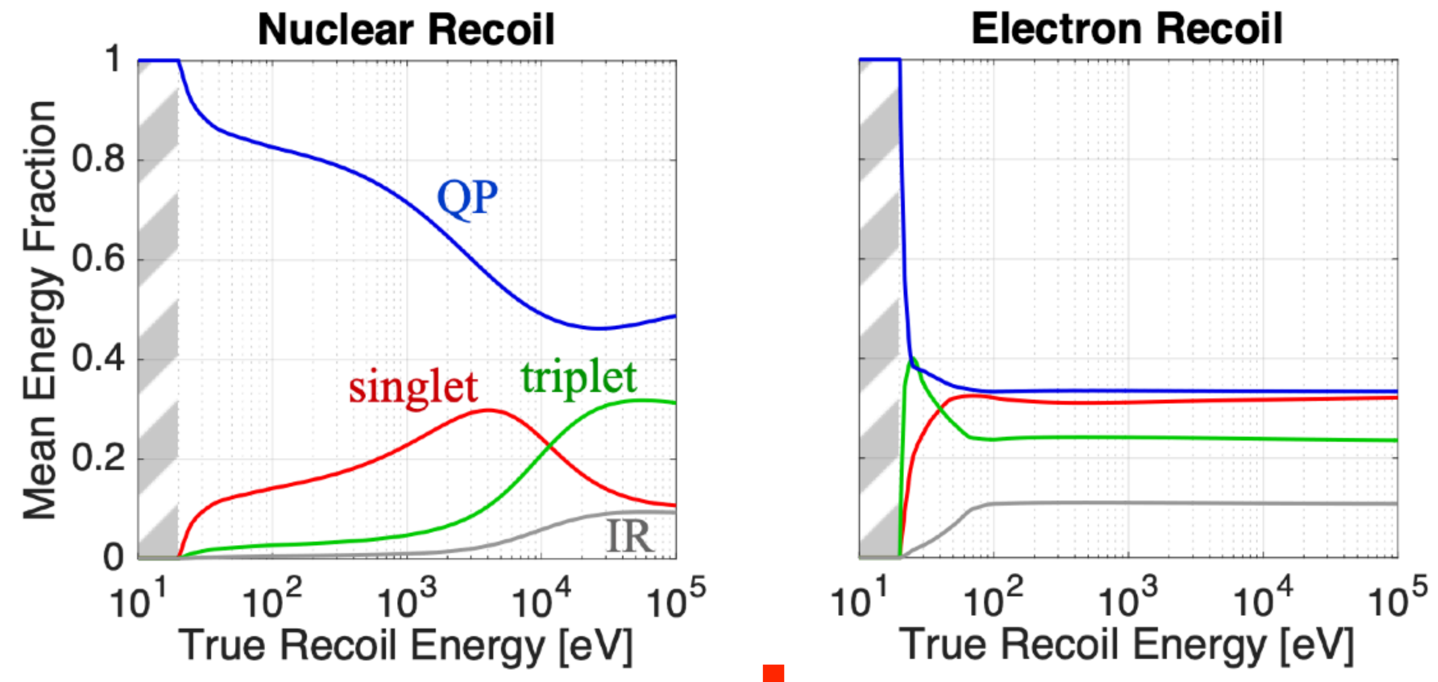
Helium Roton Apparatus for Light Dark matter

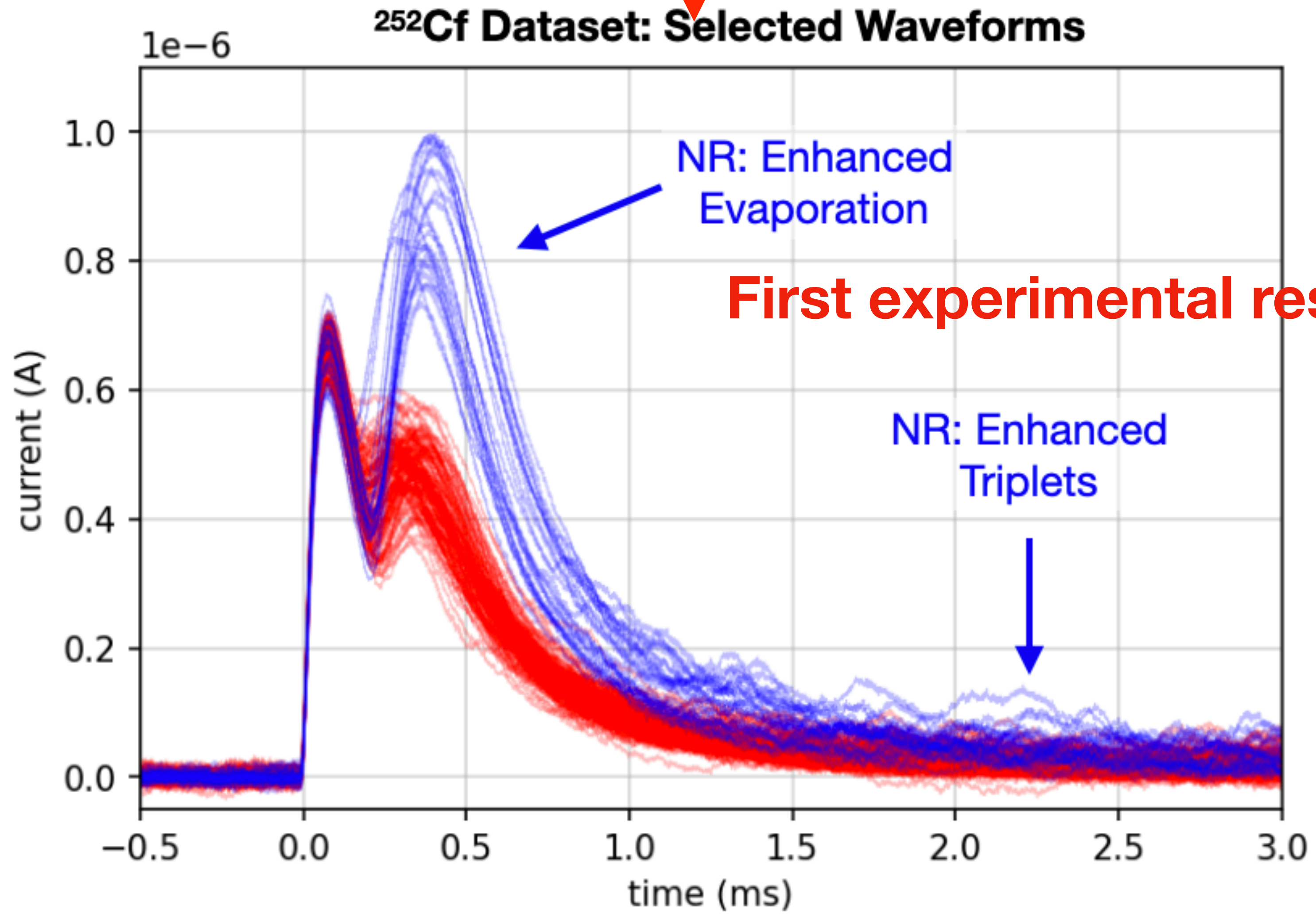






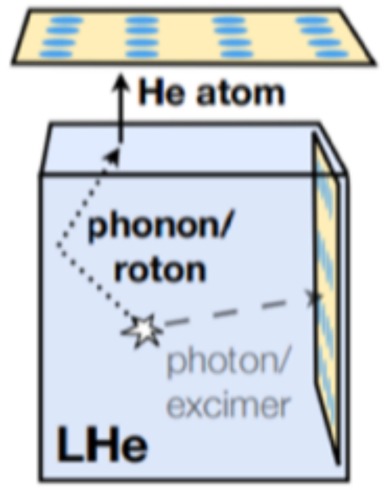
R. Anthony-Petersen et al., arXiv:2307.11877





- Well kinetically matched to GeV-scale DM
- Easy to purify, intrinsically radio pure
- Monolithic and scalable
- LHe cell operated at 20-50 mK with wafer-like cryogenic detectors with TES suspended in vacuum
  - UV/IR photons and **He atoms** from qp induced evaporation
- **First evidence of ER/NR discrimination @10 keV**
- **Already achieved ~170 eV threshold on He recoils (300 MeV DM)**

TESSERACT@LSM: HeRALD

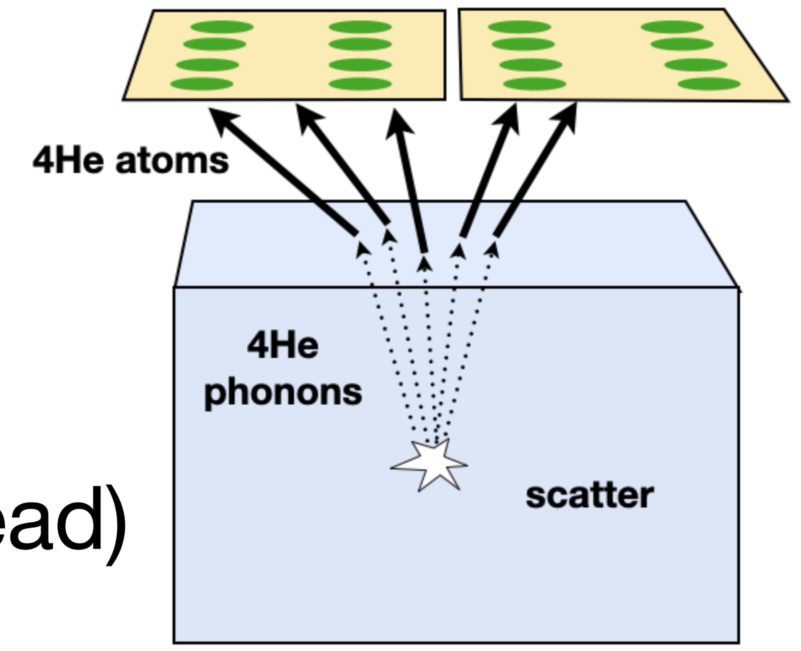


Helium Roton Apparatus for Light Dark matter

^{4}He is unique in two ways:

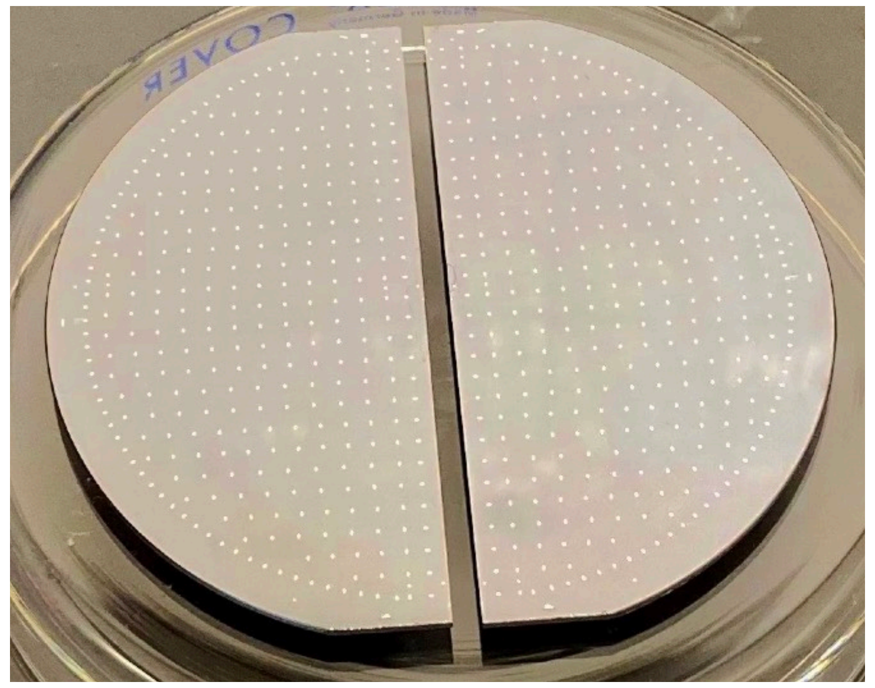
1. **Target material (4He) close to a macroscopic quantum ground state, with no defects/stress/etc.**
   Superfluid 4He is nearly unique among bulk target materials in this regard

2. **Quantum evaporation allows for robust coincidence-based selection of target events at sub-eV scales**
   Events in calorimetry: single-channel (vacuum gaps mean no shared phonons)
   Events in 4He: always multiple channel (evaporated atoms have large angular spread)

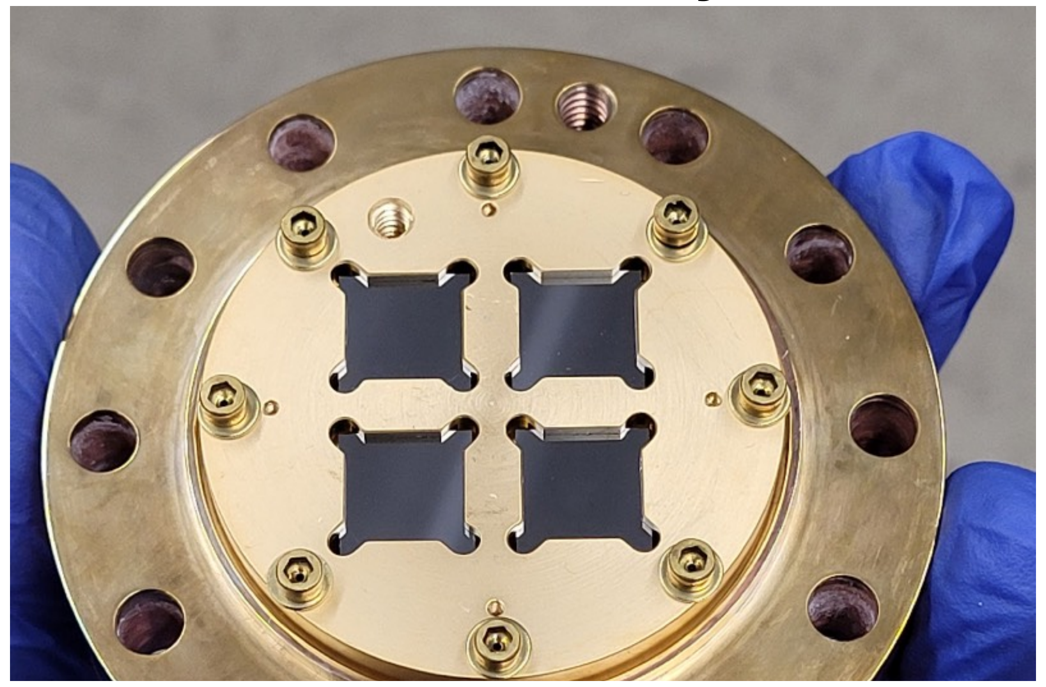


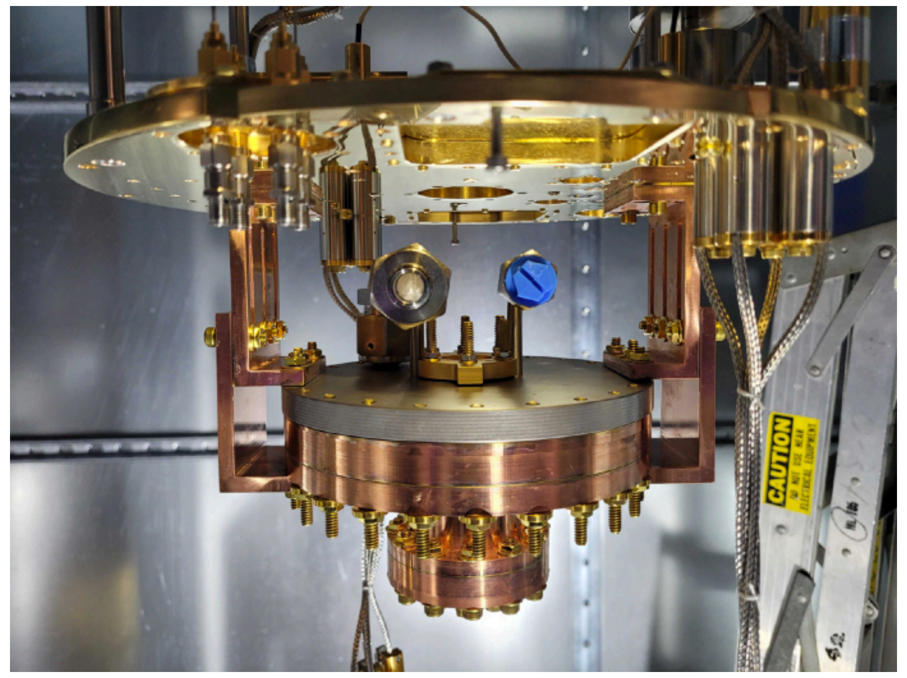
→ Near-term HeRALD plans all involve multi-channel evaporation readout and testing the above strategy

2-Channel Array for HeRALD v0.1 @UMass (3-inch)



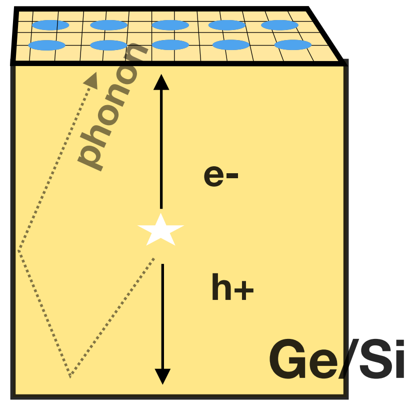
4-Channel Array for HeRALD v0.2 @LBNL (4x 1cm^2)

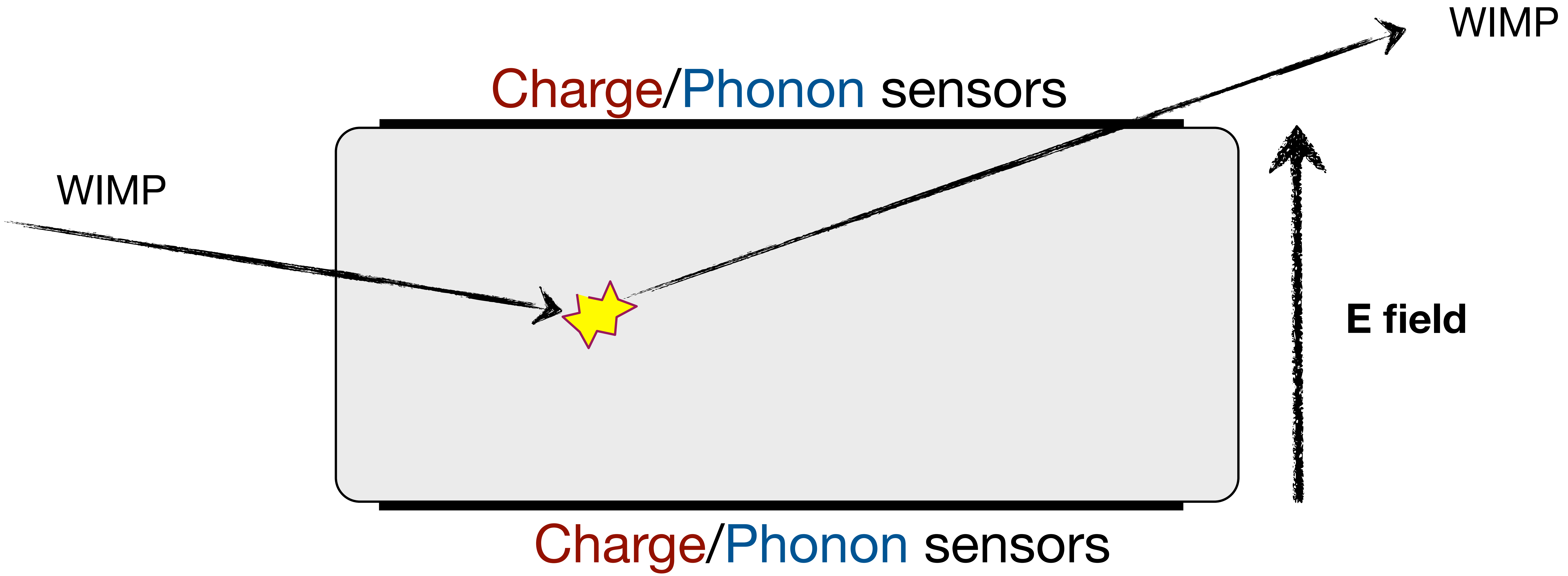




TESSERACT@LSM: Ge/Si semiconductors

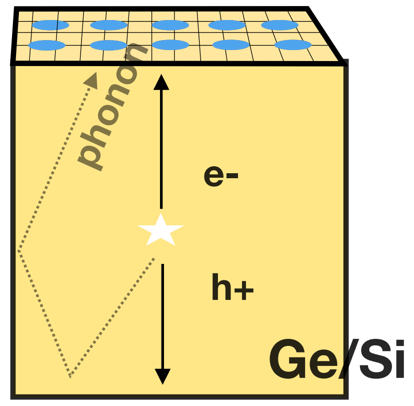
Introduction to the dual heat and ionization readout:

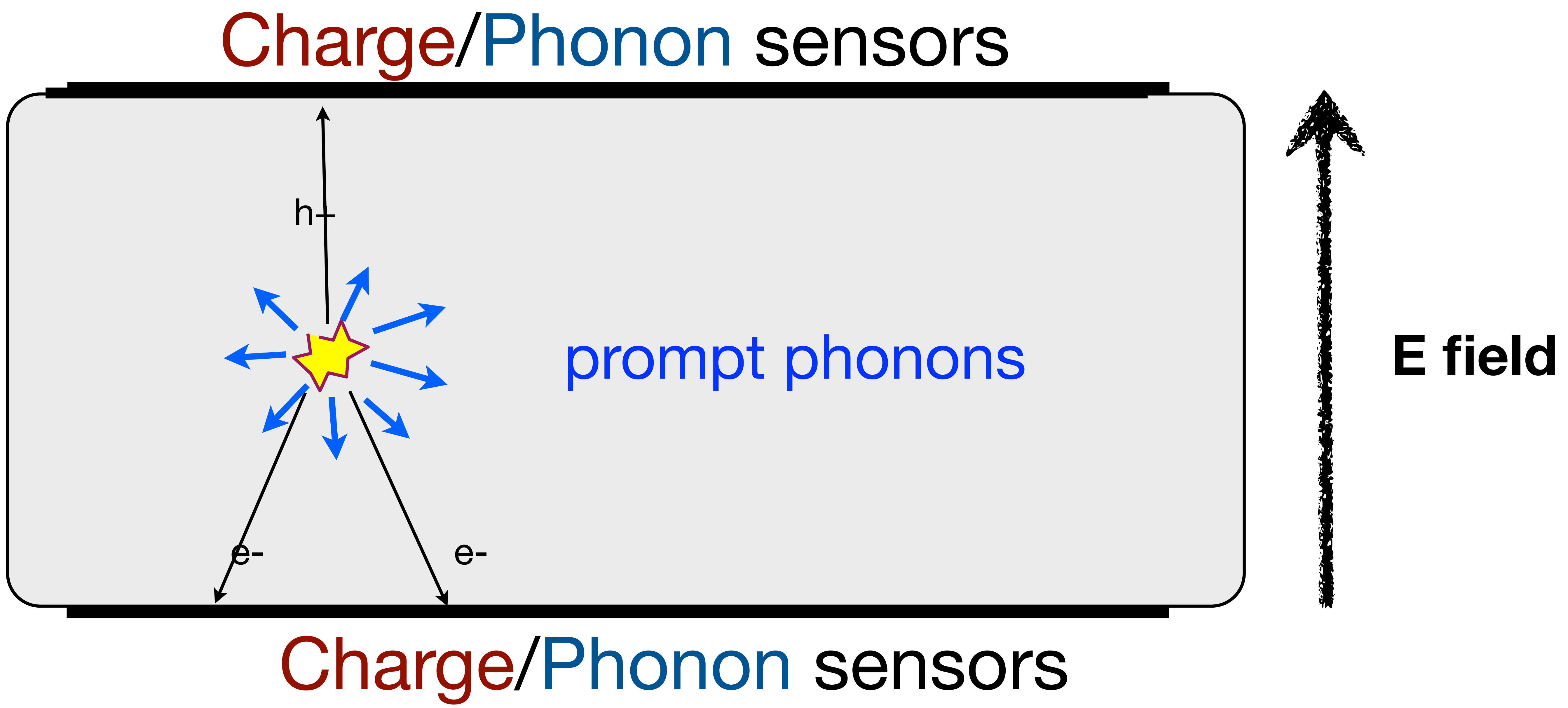




TESSERACT@LSM: Ge/Si semiconductors

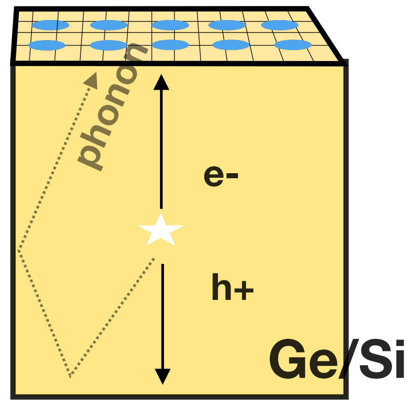
Introduction to the dual heat and ionization readout:





TESSERACT@LSM: Ge/Si semiconductors

Introduction to the dual heat and ionization readout:



Charge/Phonon sensors

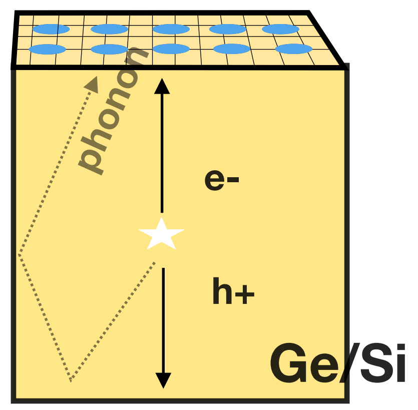
Charge/Phonon sensors

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

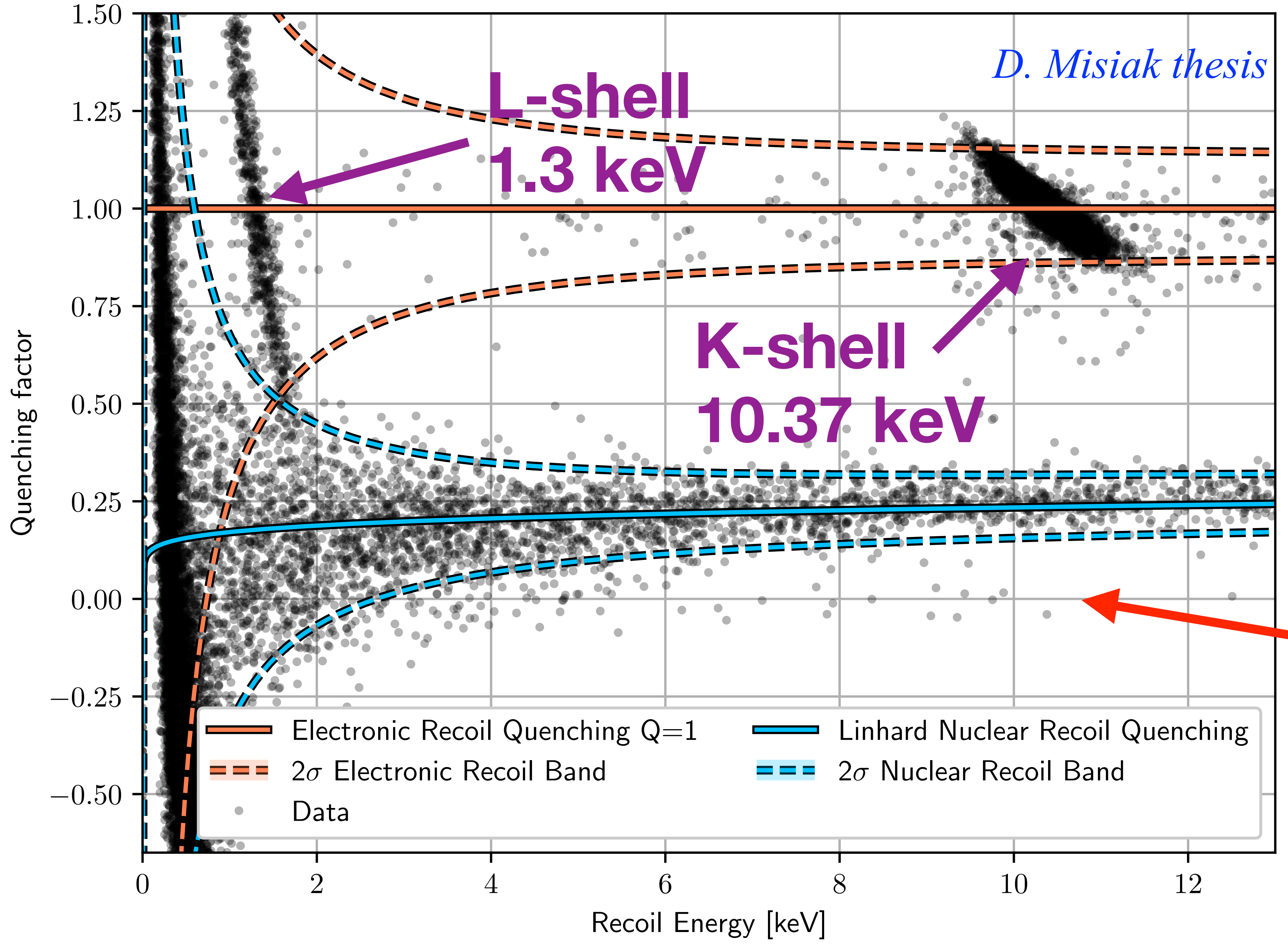
iP2i LES 2 INFINIS LYON
LPSC GRENOBLE | MODANE
IJCLab Irène Joliot-Curie
cnrs

TESSERACT@LSM: Ge/Si semiconductors

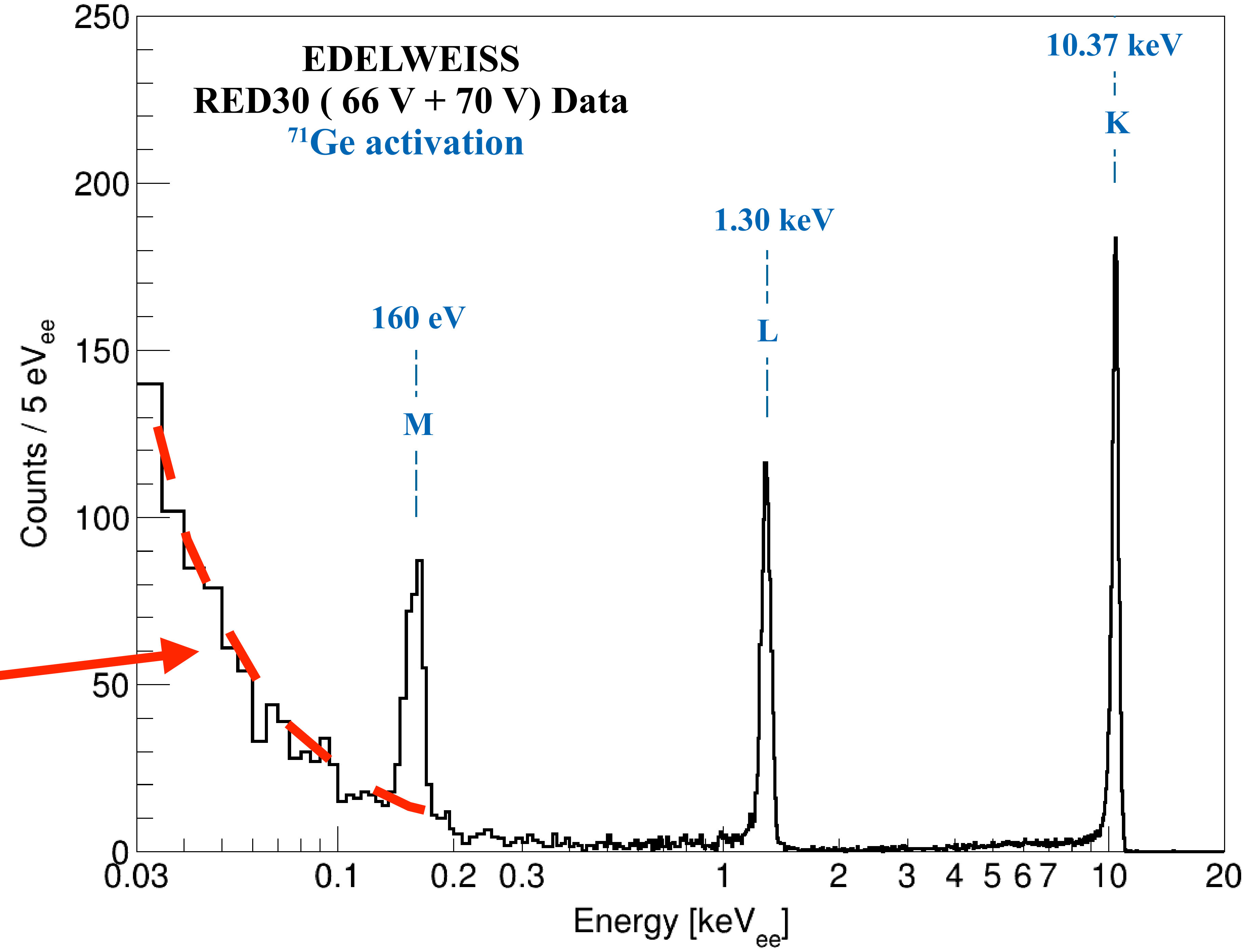
$$E_{total} = E_{recoil} + E_{luke} = E_{recoil} + \frac{1}{3\,eV} E_{ion} \Delta V$$



Low Voltage mode
Part. ID + Fid



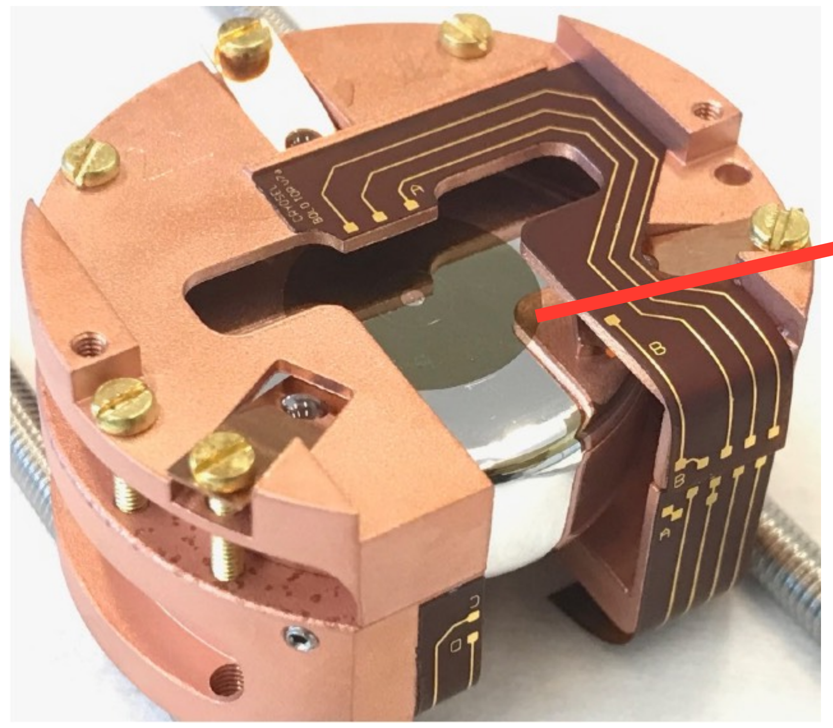
High Voltage mode
single e/h - No PID

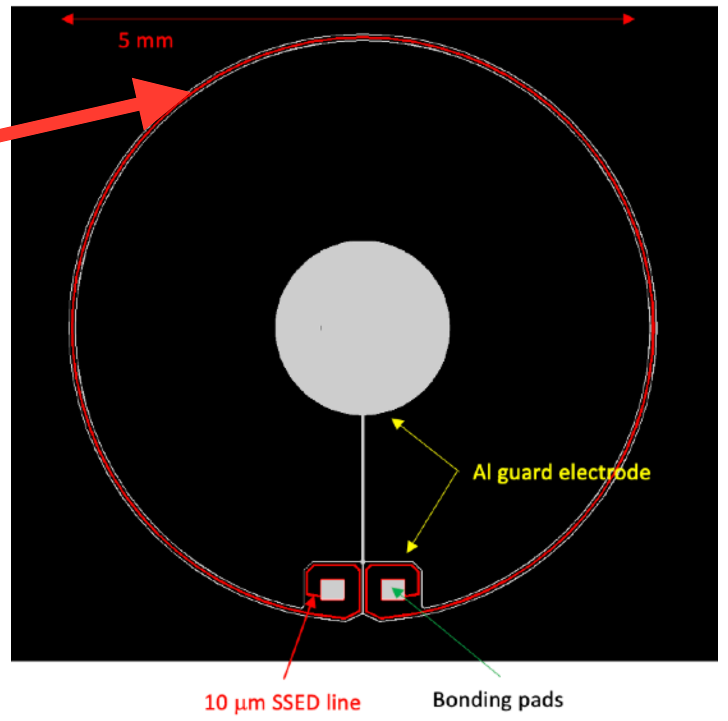


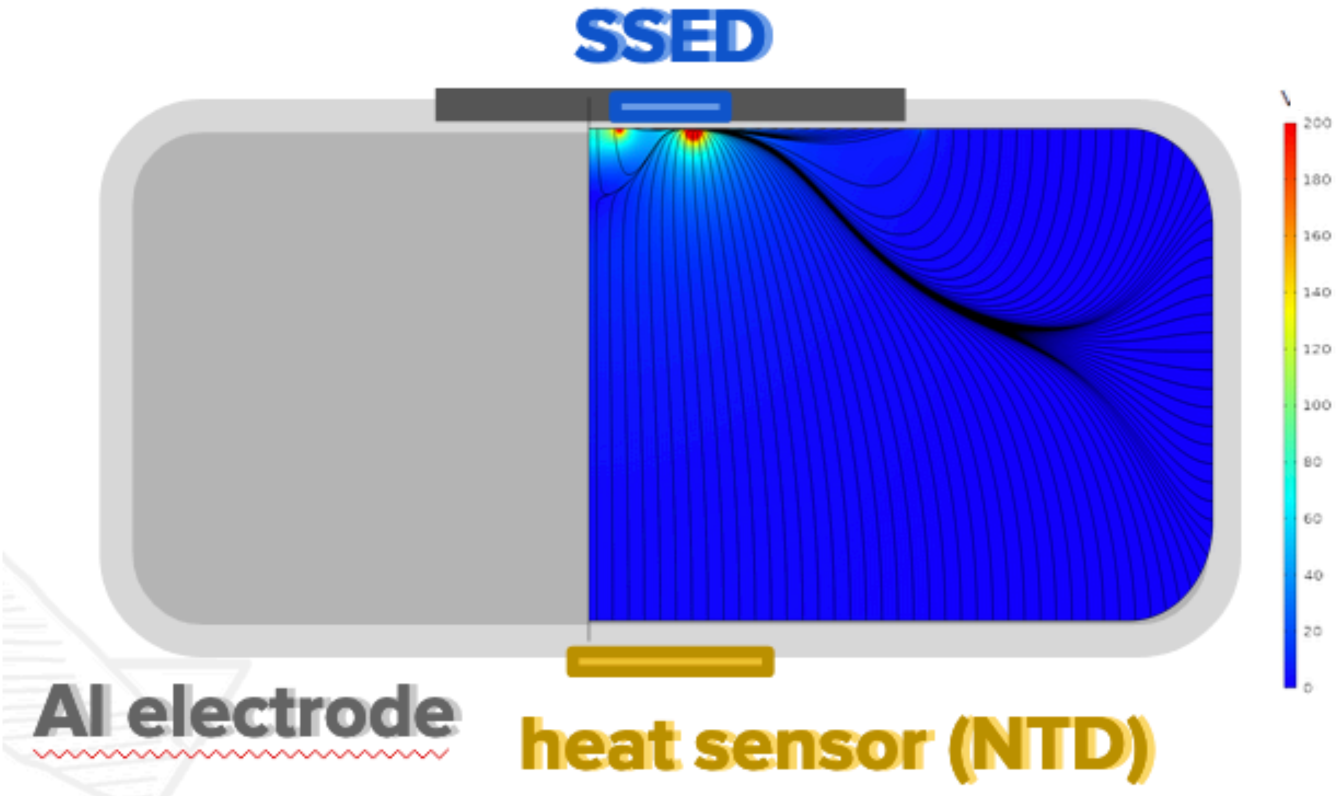
LEE

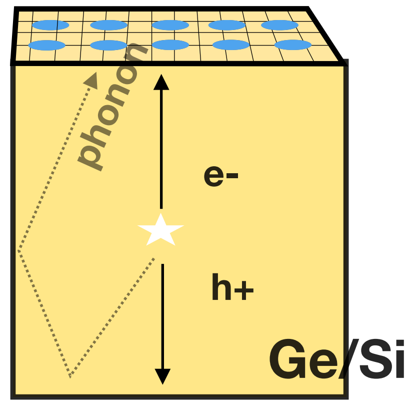
TESSERACT@LSM: Ge/Si semiconductors

High-Voltage approach for optimal ERDM sensitivity





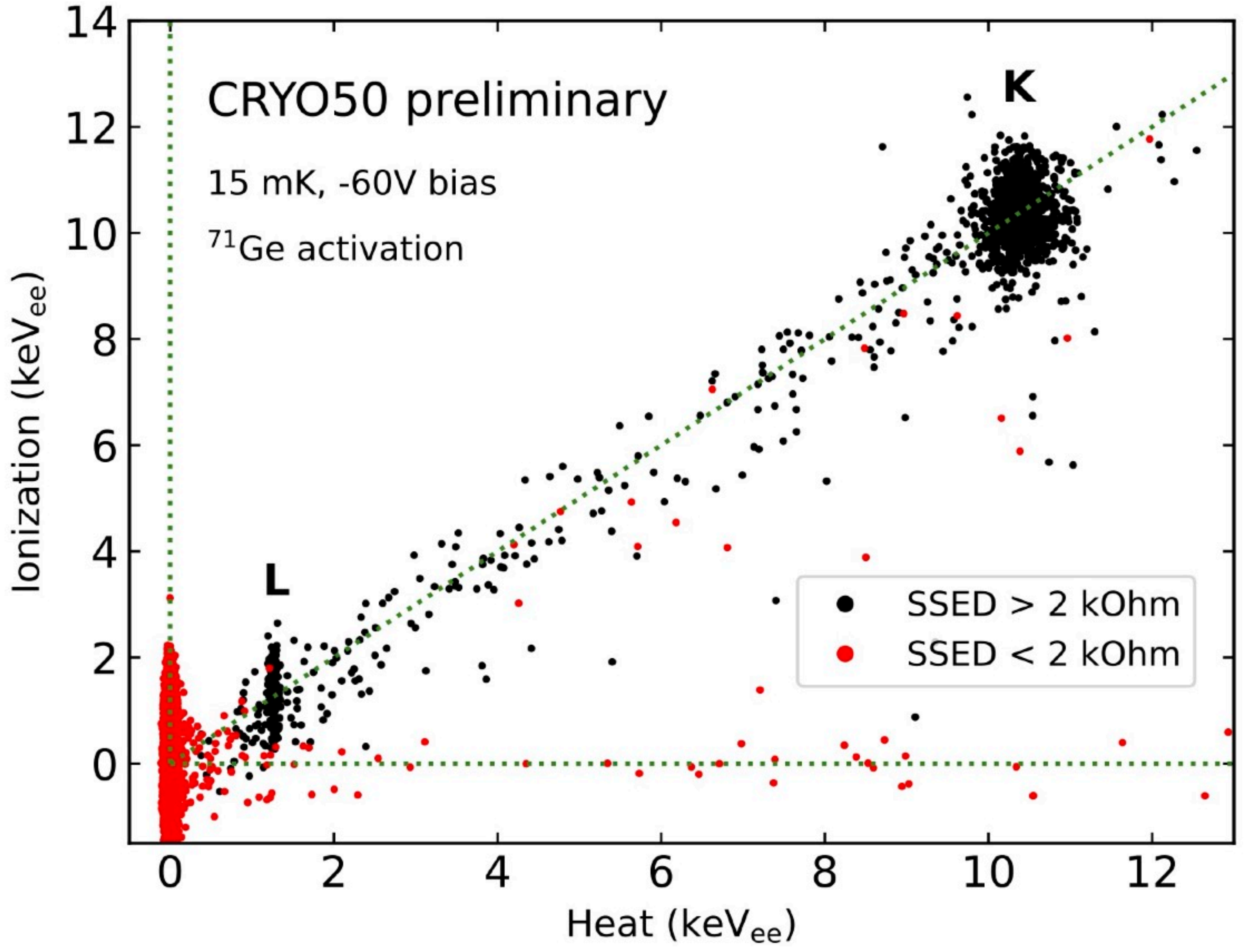




CRYOSEL performance goals: 200 V bias + single e-h sensitivity + SSED LEE tagging efficiency > 1000

First R&D results shown at TAUP2023:

- Stable operation up to 60 V
- Confirmation that first NbSi SSED acts as efficient LEE veto
- New prototype currently being tested with significantly improved performance

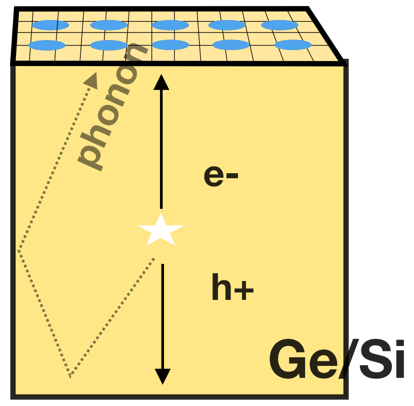


For TESSERACT:

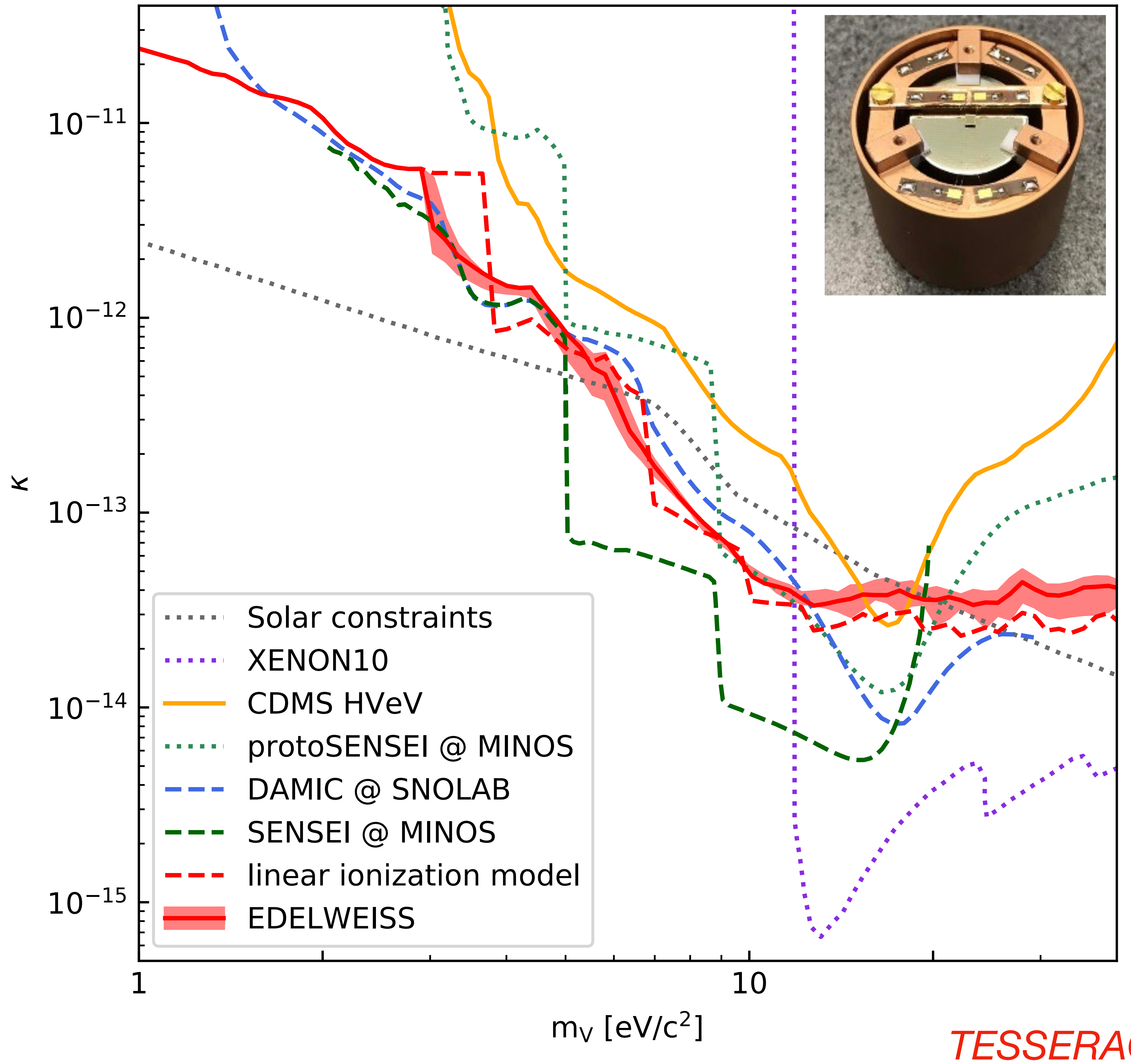
- Switch to low-imp. TES for sub-eV SSED energy threshold
- High control of IR backgrounds and charge leakage
- LEE discrimination down single e-h pair
- **Exquisite sensitivities to ERDM with LEE discrimination**

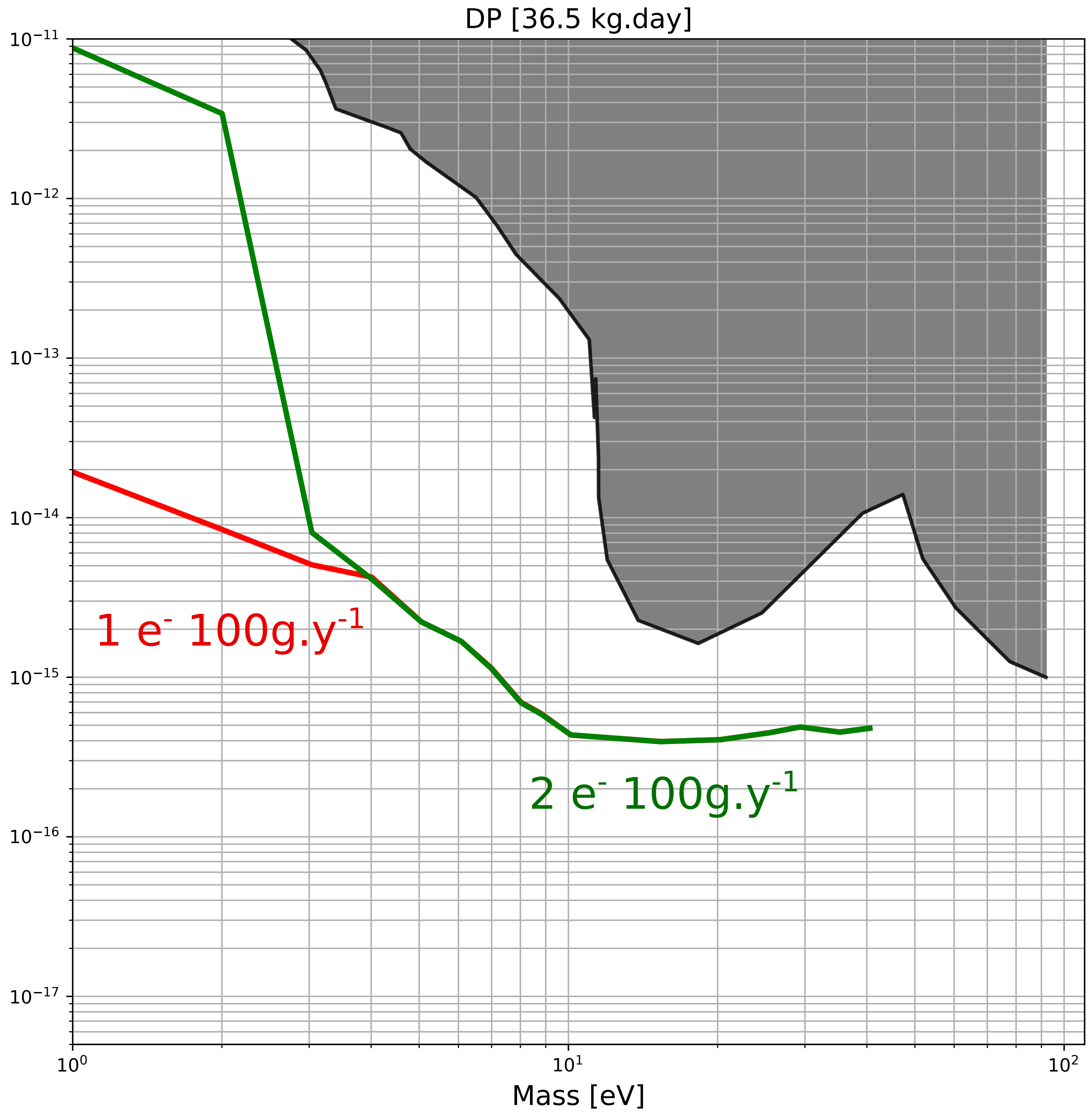
TESSERACT@LSM: Ge/Si semiconductors

High-Voltage approach for optimal ERDM sensitivity



EDELWEISS collaboration, PRL 125, 141401 (2020)





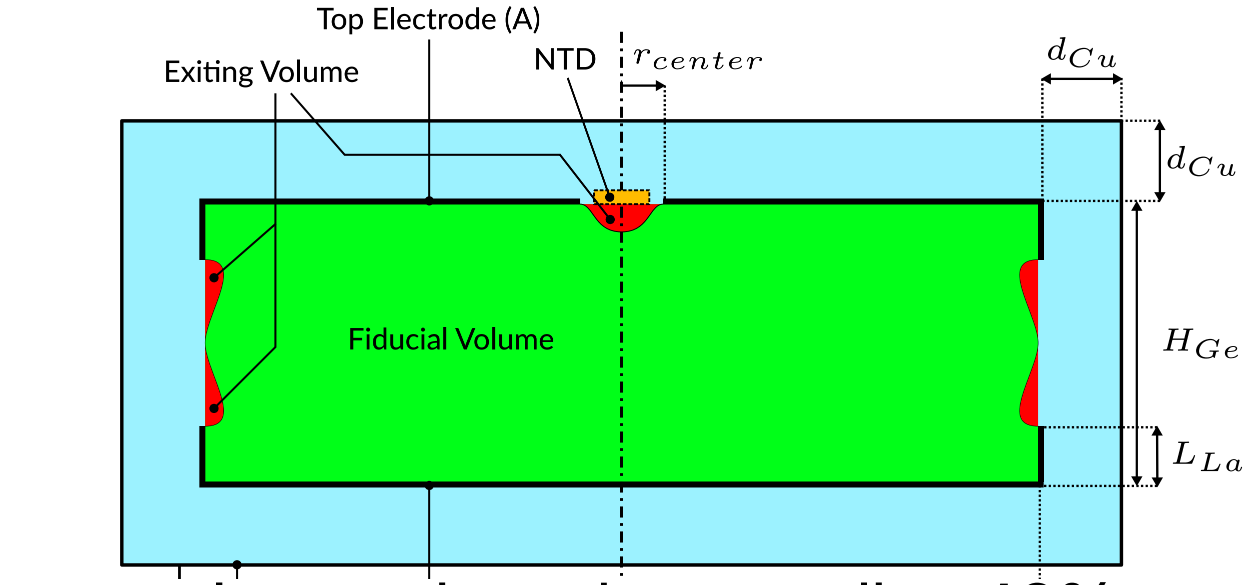
TESSERACT back. model = 10 DRU gamma + other backgrounds from EDW-III

- In 2020 EDELWEISS-III achieved one of the best ERDM sensitivity with sub-electron energy resolution with a 33 g Ge crystal operated at 78 V
- The HV technology (SSED + TES + 200V) in TESSERACT will allow to achieve orders of magnitude improved sensitivities

TESSERACT@LSM: Ge/Si semiconductors

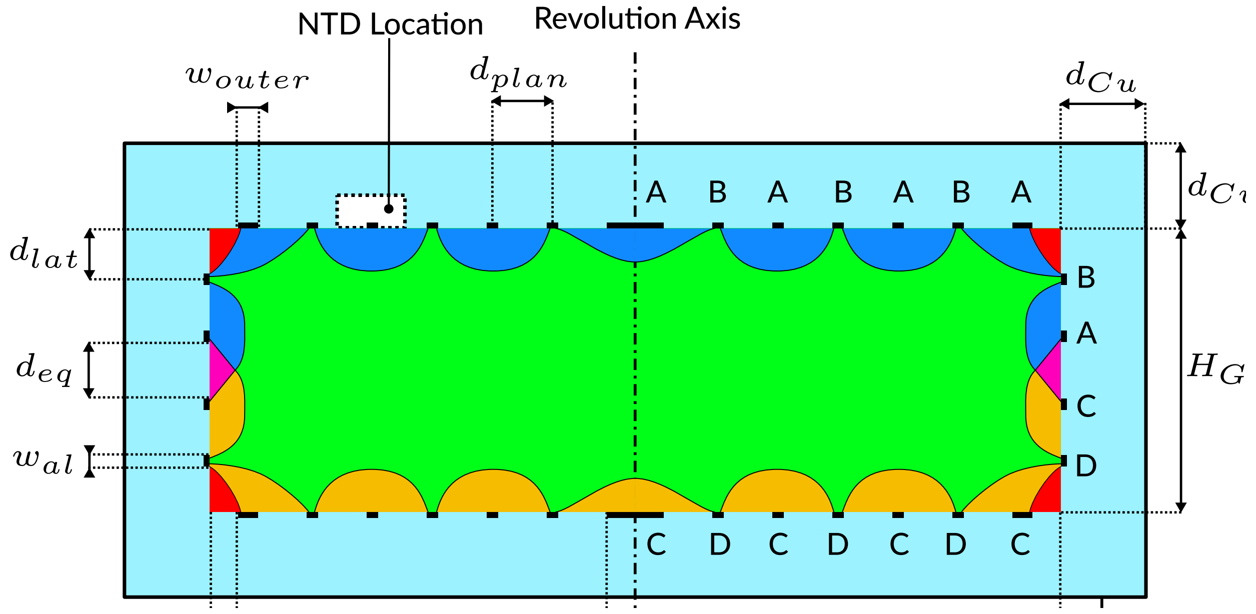
Low-Voltage approach for optimal particle identification (Ricochet style bolometers)

PL 38



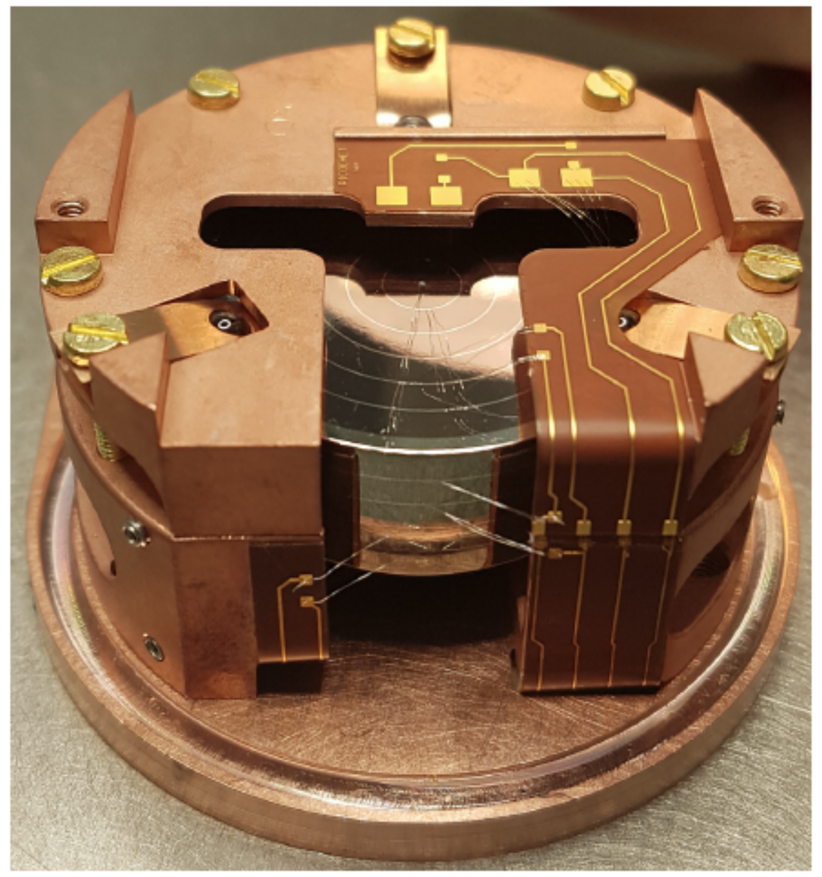
- Incomplete charge coll. **< 10%**
- Fiducial volume: **98.6 %**
- Surface event rejection: **NO**
- Total capacitance: **15 pF**

FID 38

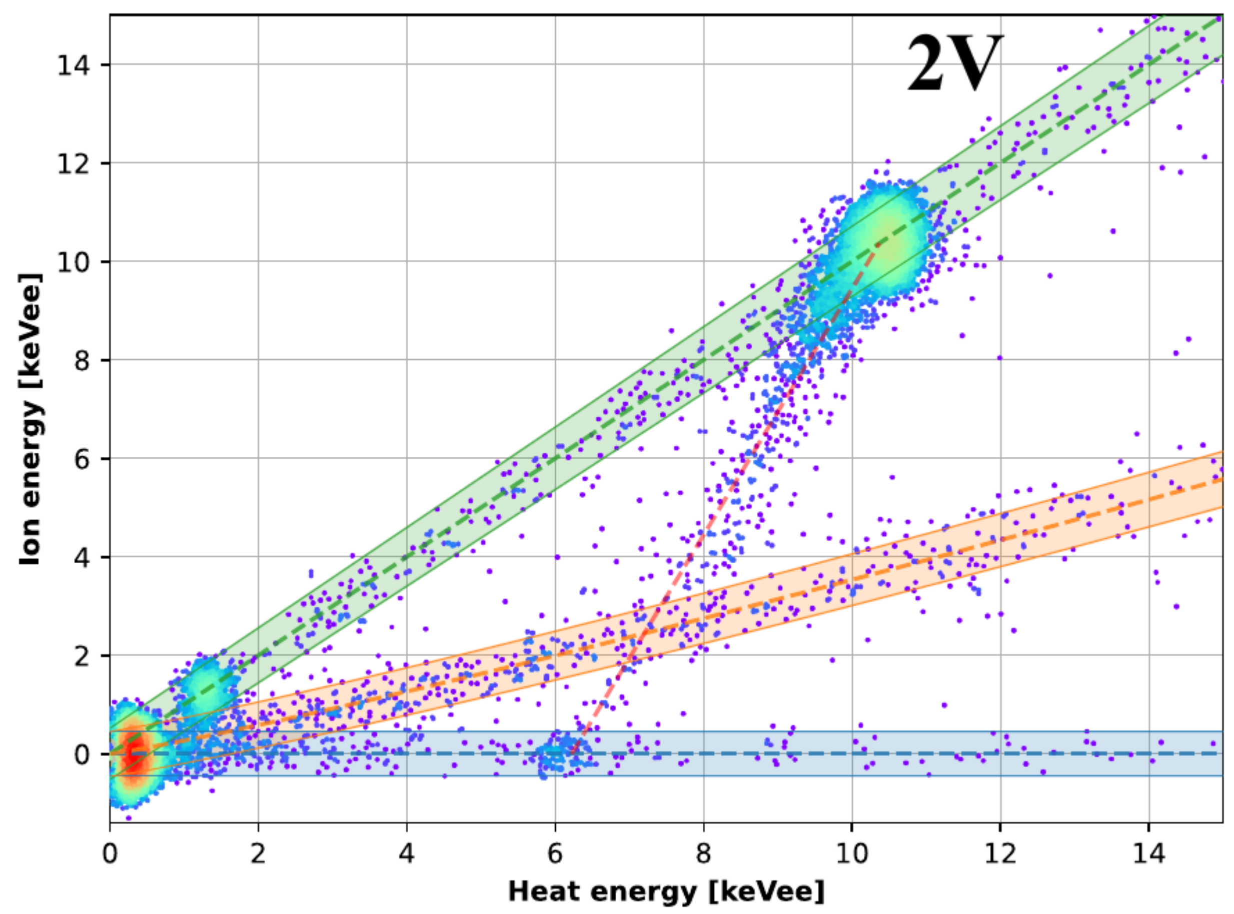


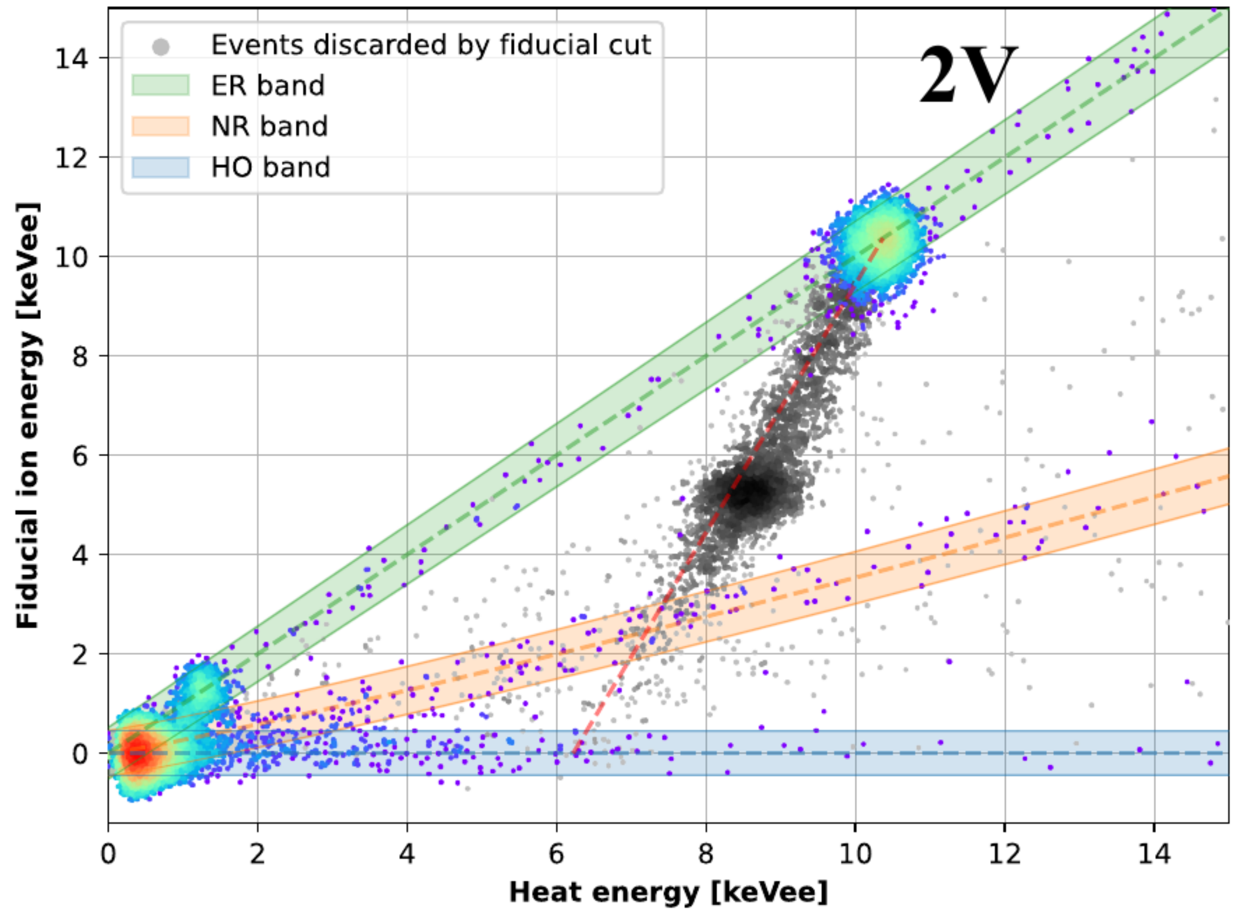
- Incomplete charge coll. **< 1%**
- Fiducial volume: **62 %**
- Surface event rejection: **YES**
- Total capacitance: **18 pF**

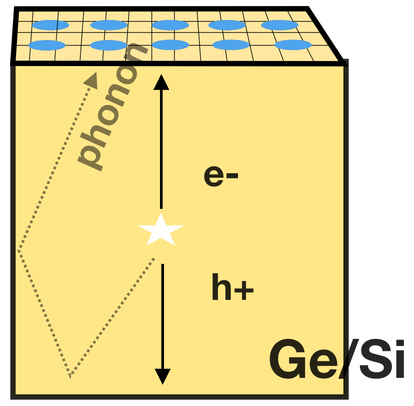
Salagnac & al: arXiv:2111.12438



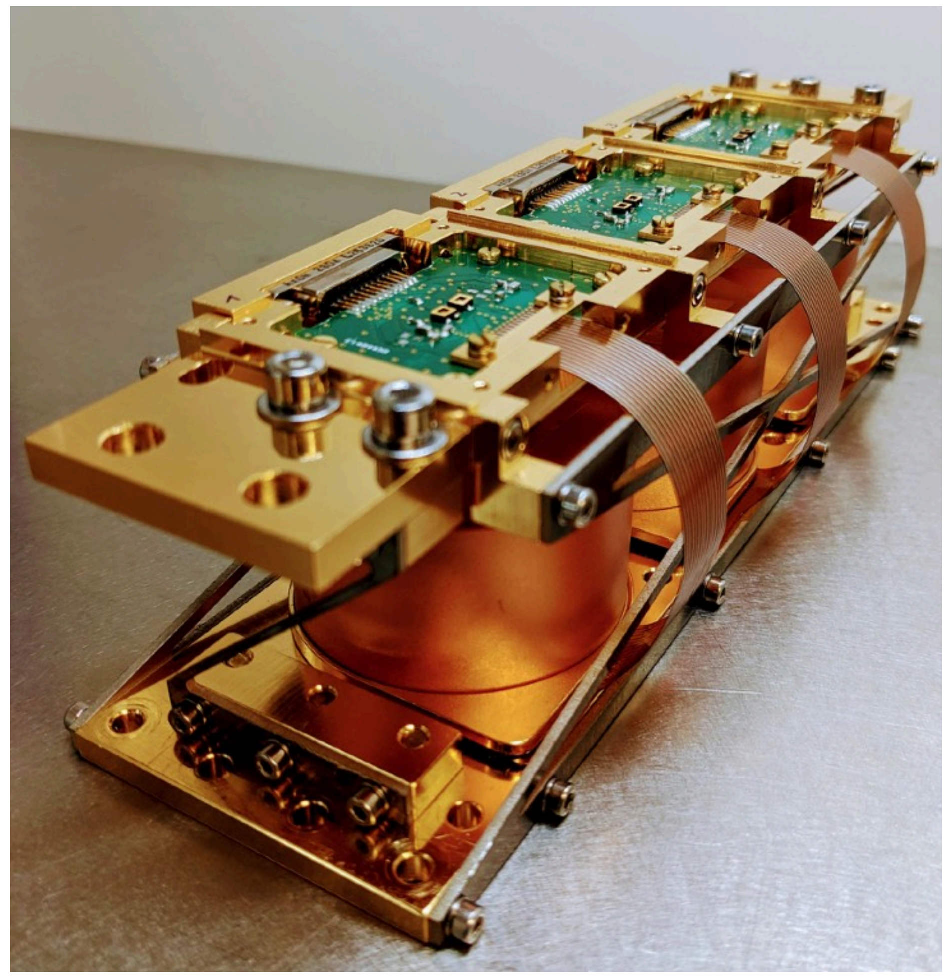
JFET EDW elec.: Heat 30 eV, **Ion. 220 eVee** (RMS)

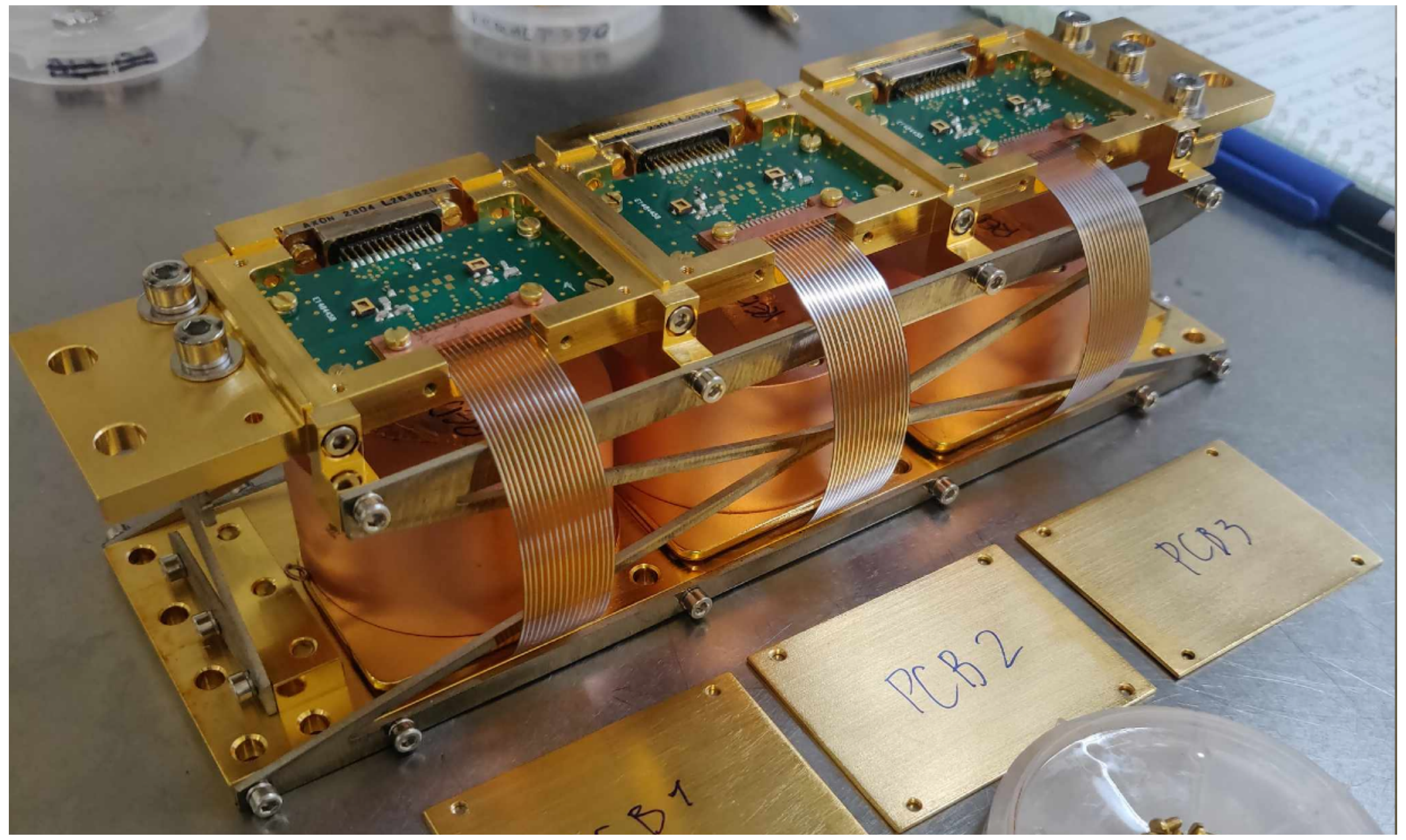


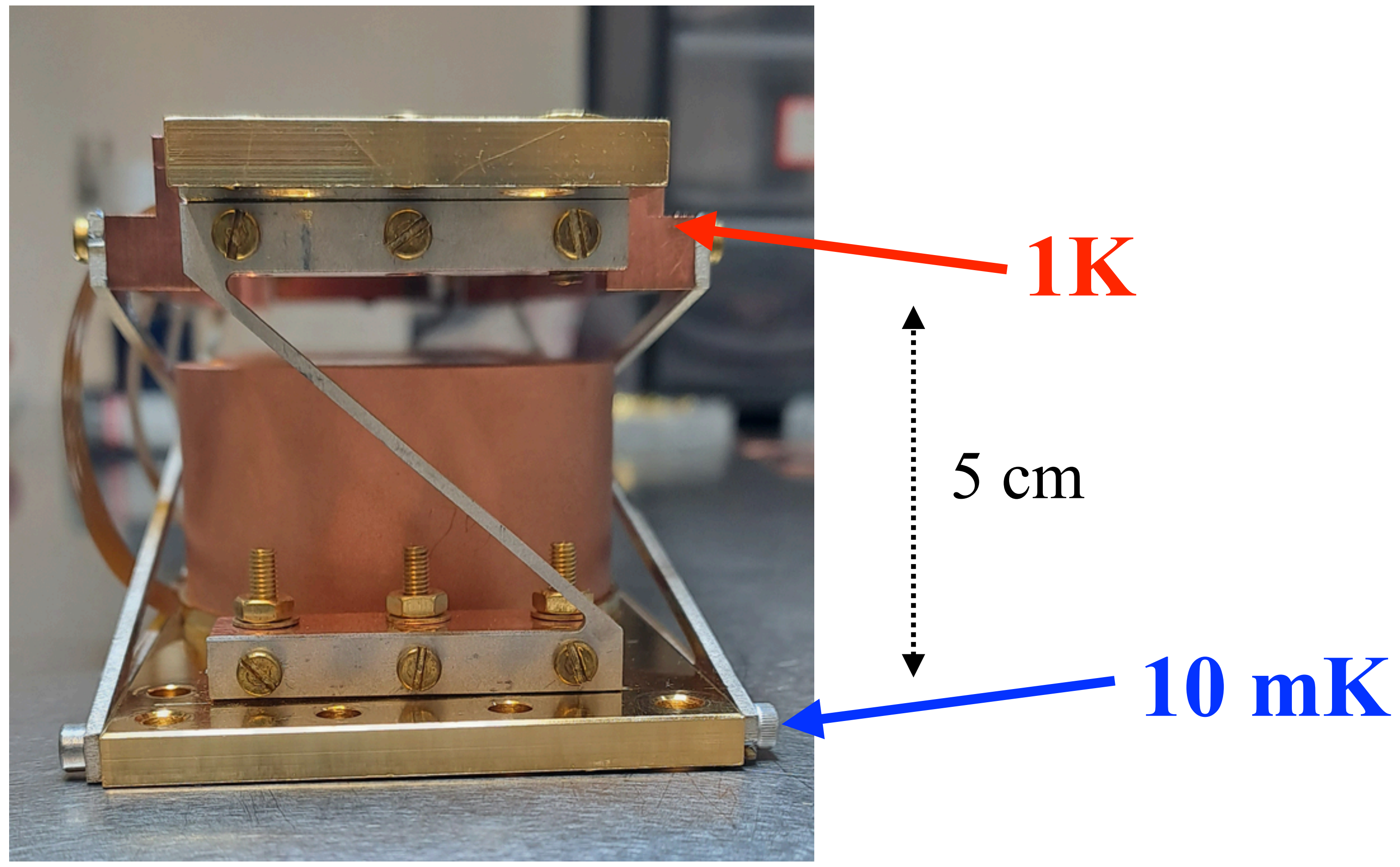


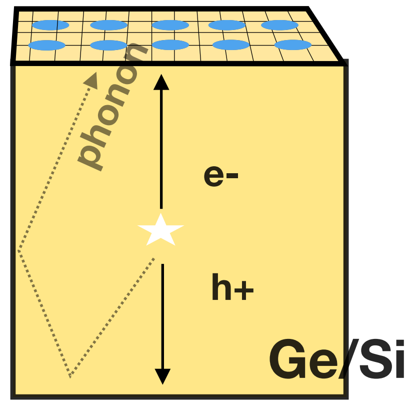


TESSERACT@LSM: Ge/Si semiconductors



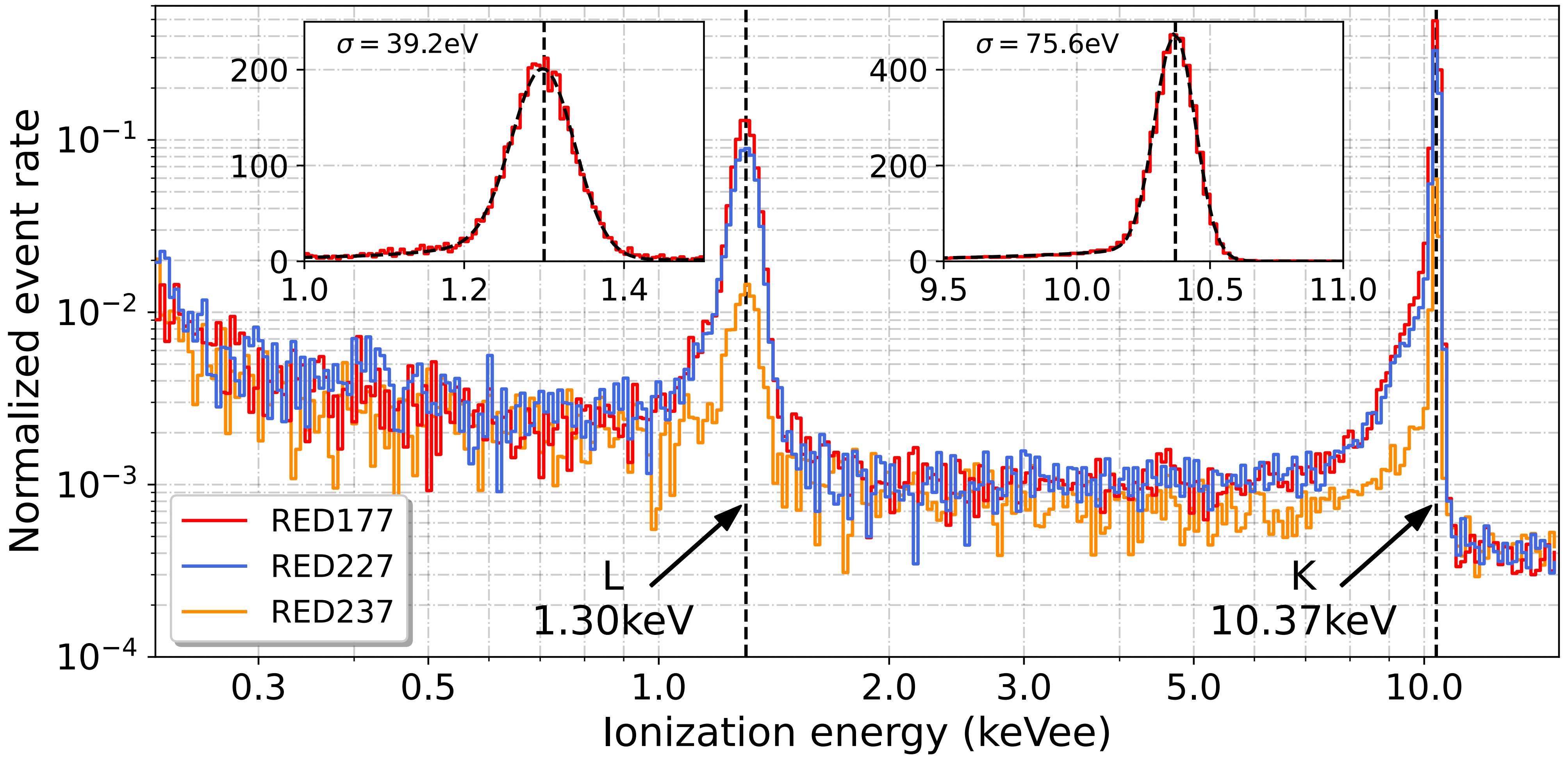




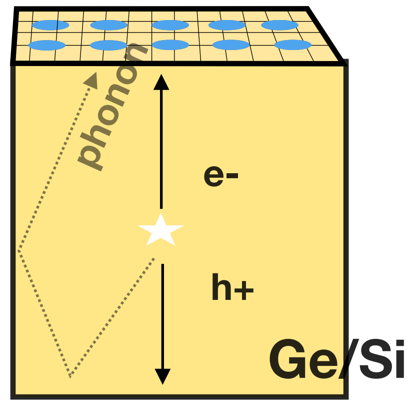


- **Mini-CryoCube:** 3 bolometers @ 10 mK with their HEMT preamplifiers @ 1K only 5 cm above (~1 uW total heat load)
- 30 eVee ionisation resolution achieved on all three detectors
- Factor of 7 and 11 improvement w.r.t to previously achieved resolution in EDW/CDMS and similar to best HPGe @ 77K
- **Reaching over the Heat Only (LEE) wall!**
- Next step: dual heat/ionisation measurement

Ricochet coll., *arXiv:2306.00166*

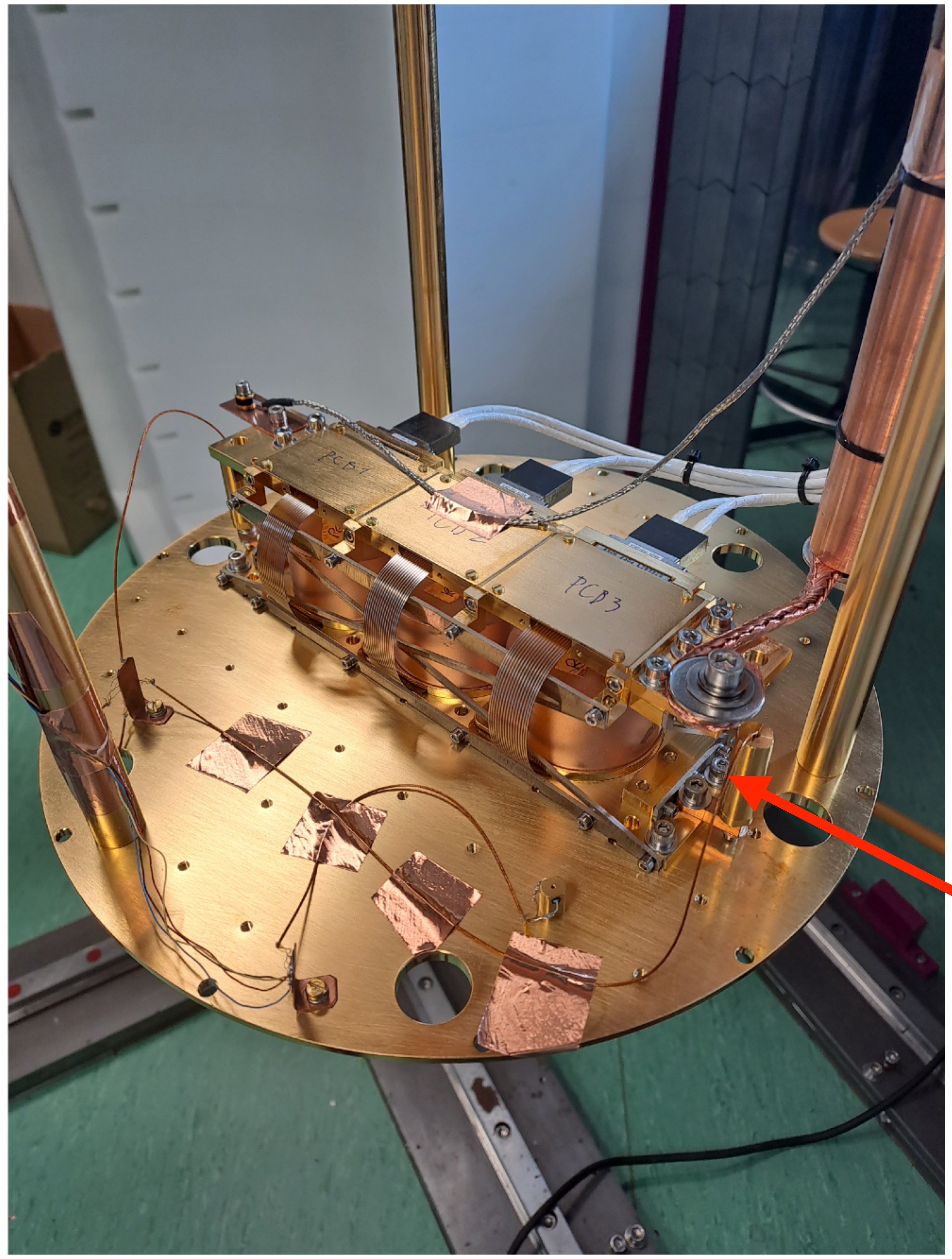


TESSERACT@LSM: Ge/Si semiconductors

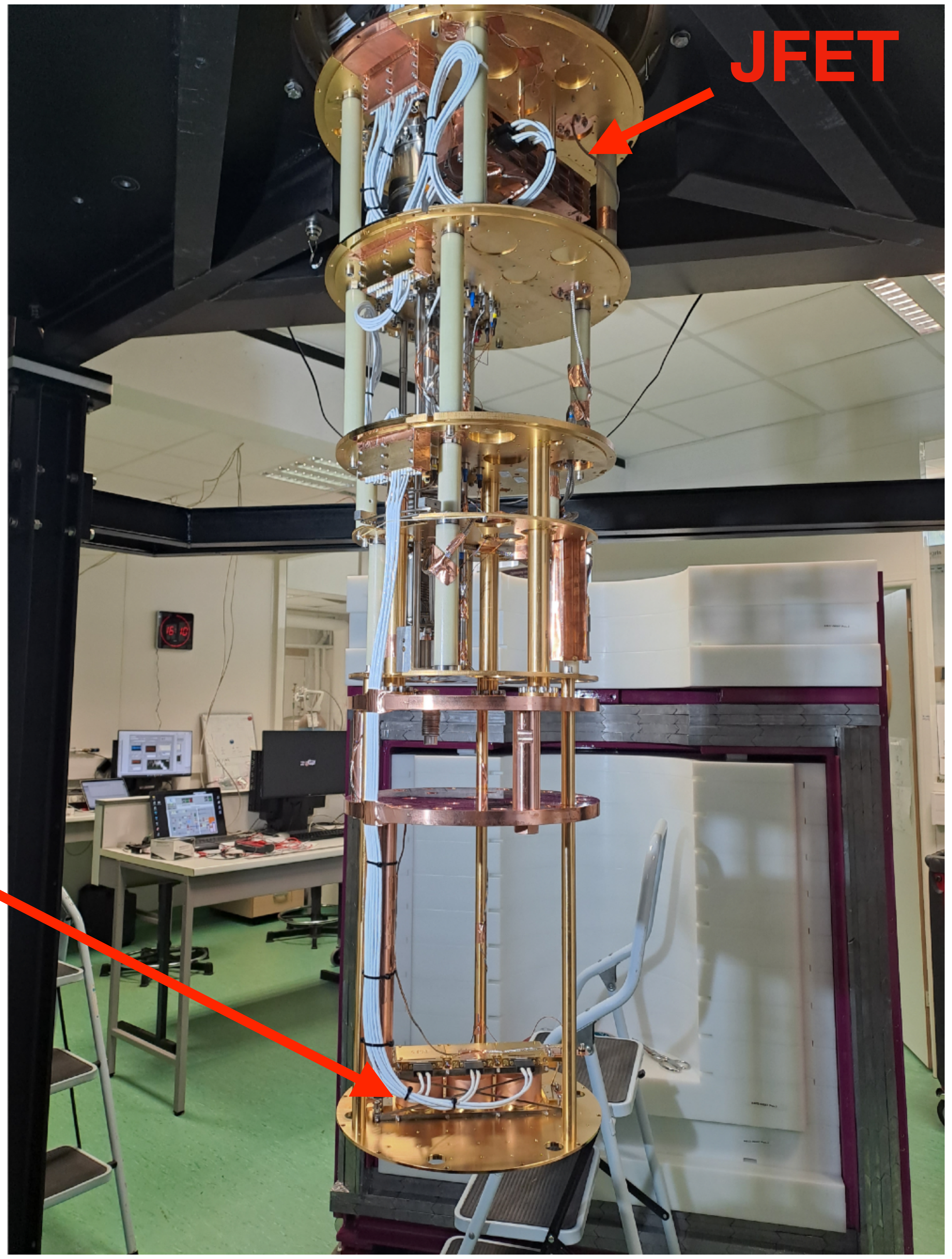


Ricochet bolometer box
Analog + Numerical

Detectors on a remote
10 mK plate (43 cm)



Ricochet cryostat without
internal shielding

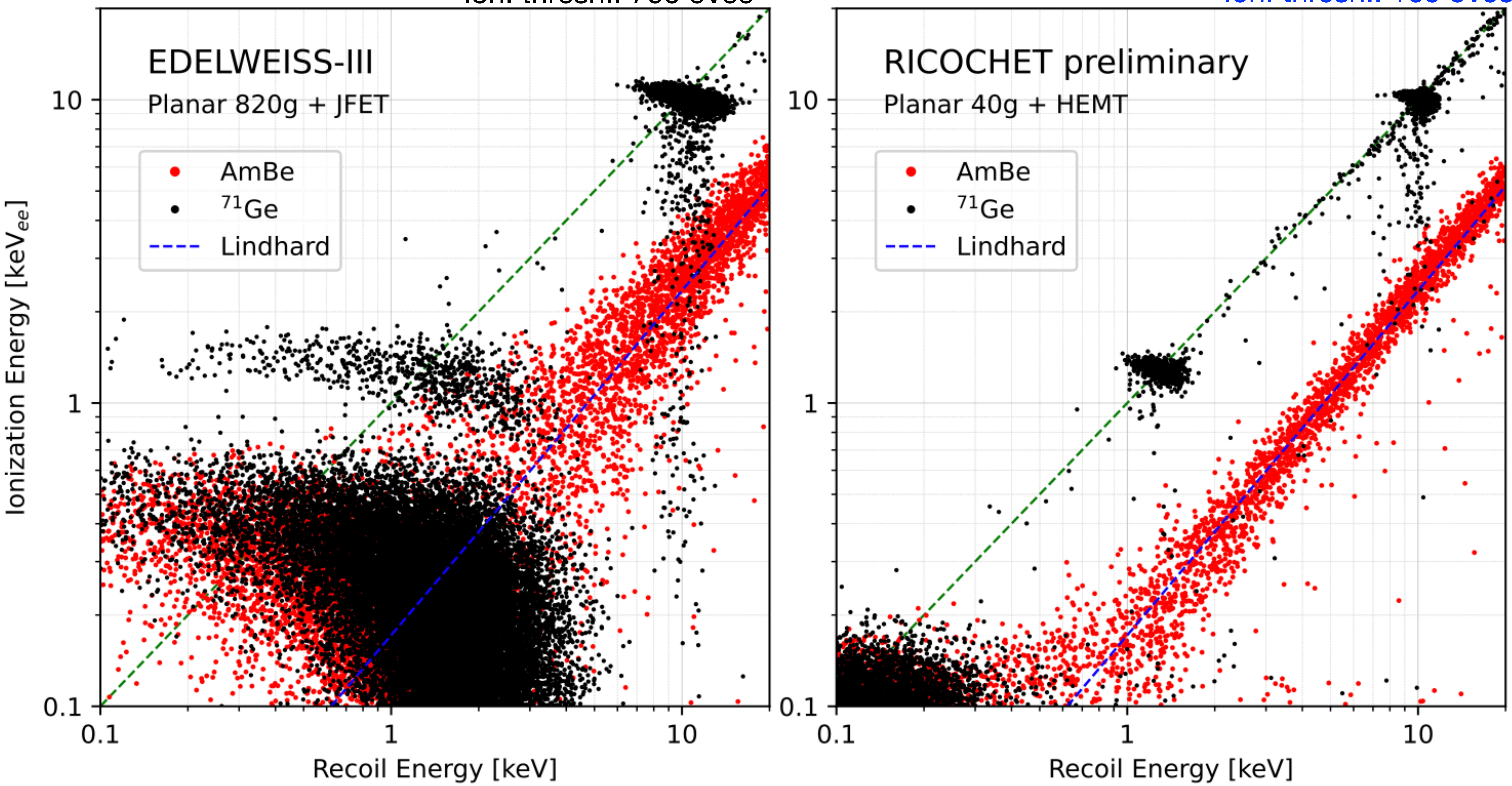


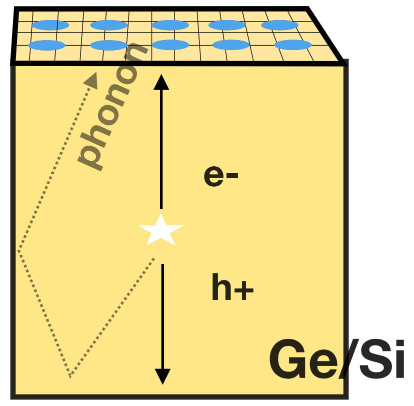
First test of a MiniCryoCube array in the Ricochet cryostat operated at Lyon with its dedicated electronics for dual heat/ionisation measurement

TESSERACT@LSM: Ge/Si semiconductors

Energy thresh.: 4.5 keVnr
Ion. thresh.: 700 eVee

Energy thresh.: 300 eVnr
Ion. thresh.: 160 eVee





- 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

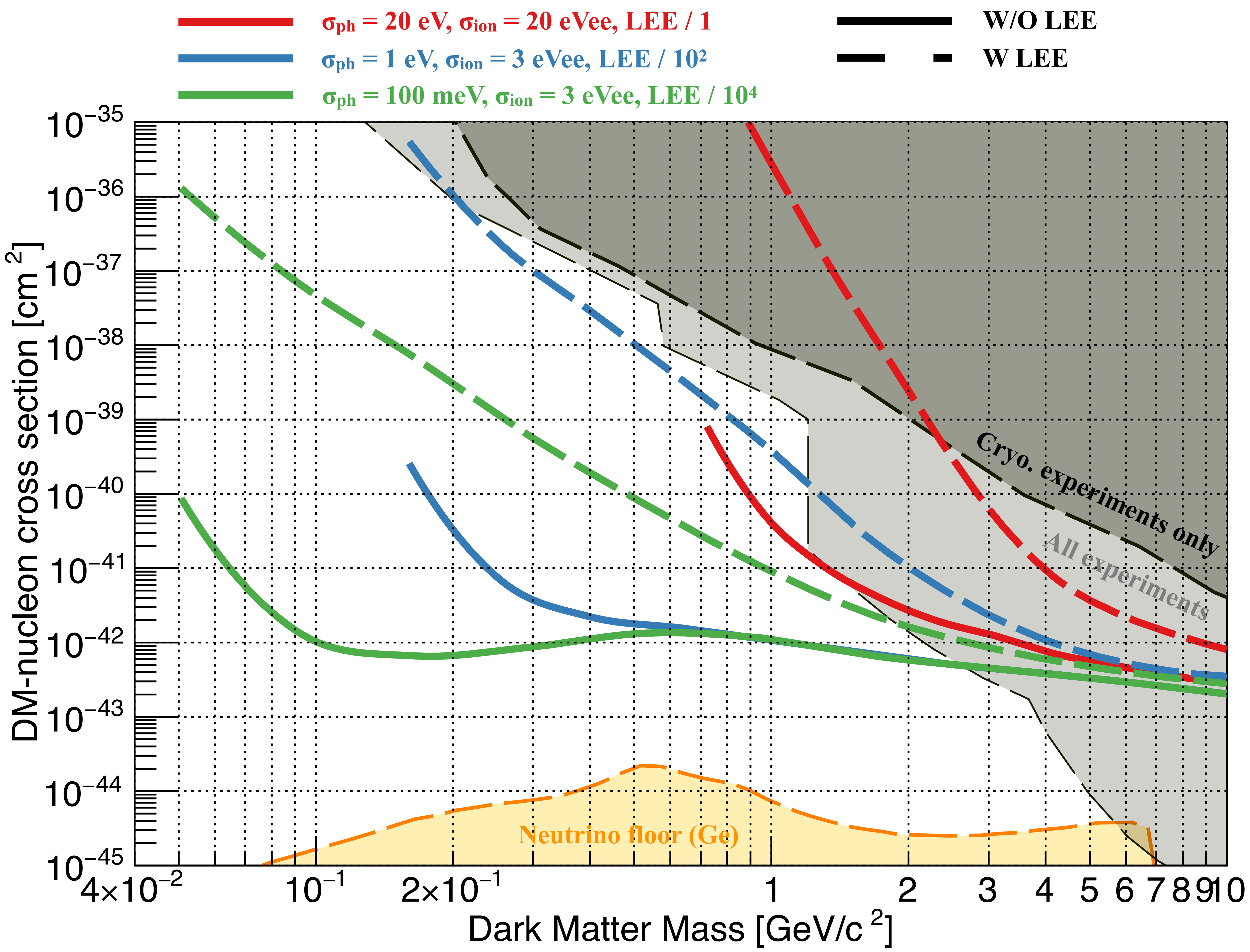
Ricochet resolution goals: 20 eV (heat) + 20 eVee (ionisation) - *almost achieved (by a factor of ~2)*

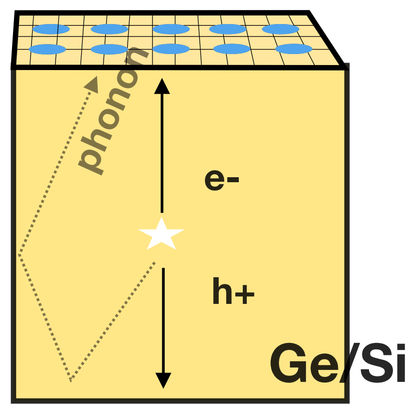
For TESSERACT:

- Switch to TES for sub-eV heat energy threshold and reduced LEE, and aiming for 3-6 eVee ion. resolution
- ER/NR identification down to 10s of eVnr + LEE discrimination down to 50 eVnr (Lindhard)
- Ideal for low-mass NRDM with PID

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

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

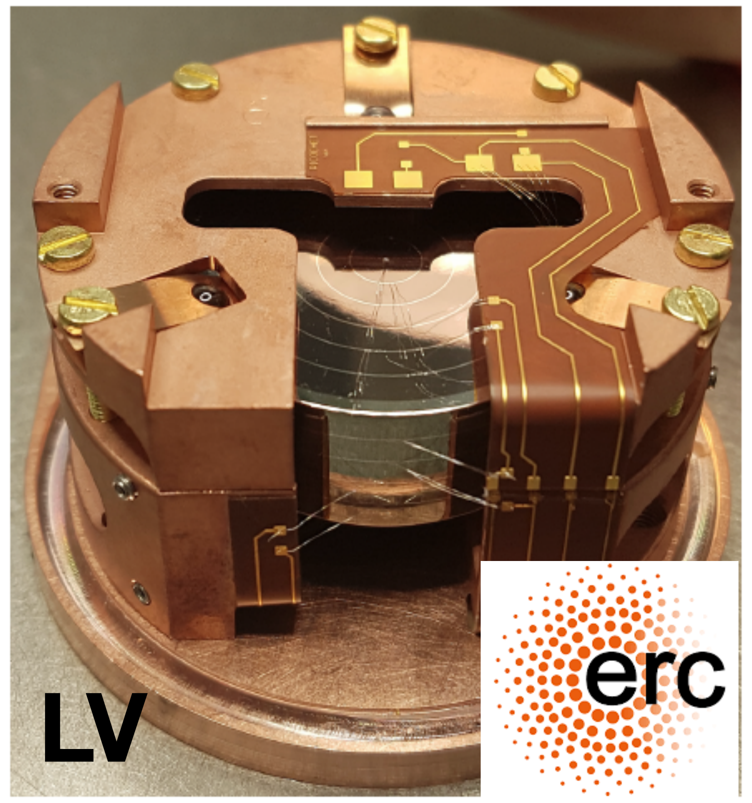
TESSERACT@LSM: Detector technology summary

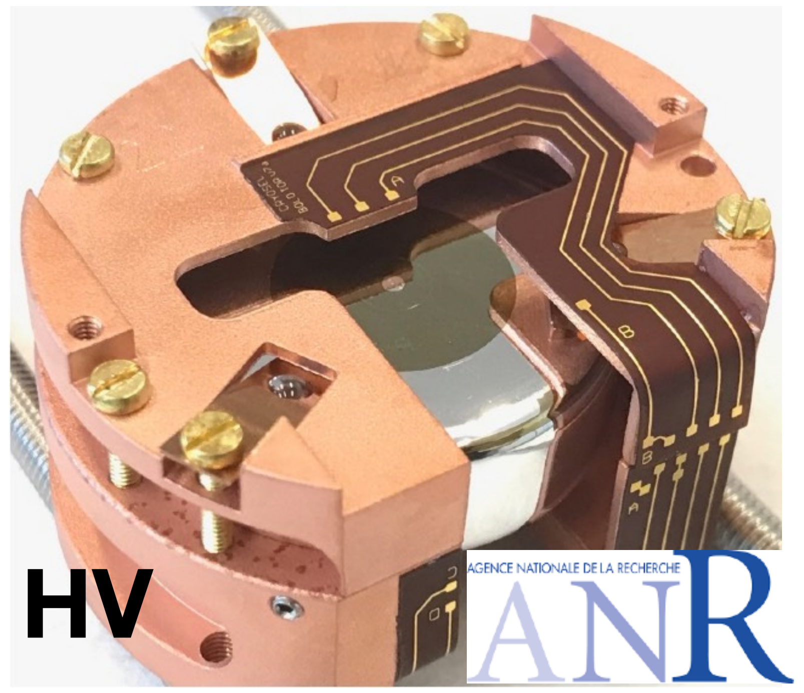
All detector technologies will be using:

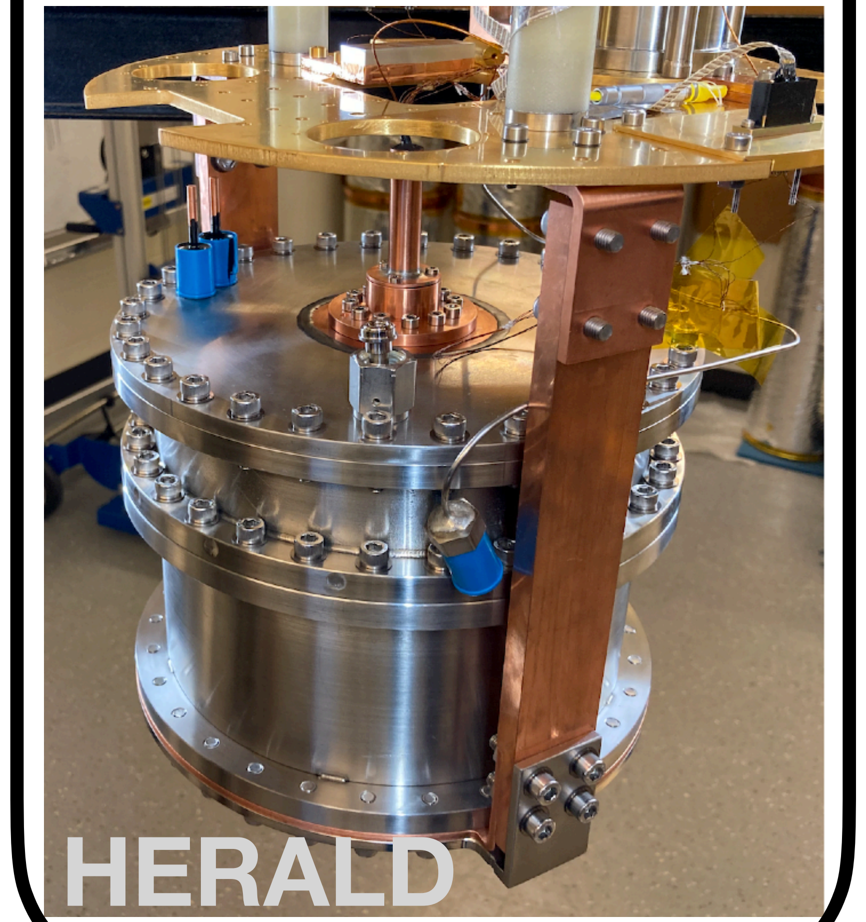
1. athermal phonon TES with sub-eV energy thresholds,
2. drastically mitigated LEE (under intense investigation),
3. and payloads between 10g to 100g

	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 *LHe*	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







TESSERACT

J. Billard

Light dark matter science motivation and detection challenges
TESSERACT@LSM proposal and design drivers
Cryogenic detector technologies and projected sensitivities

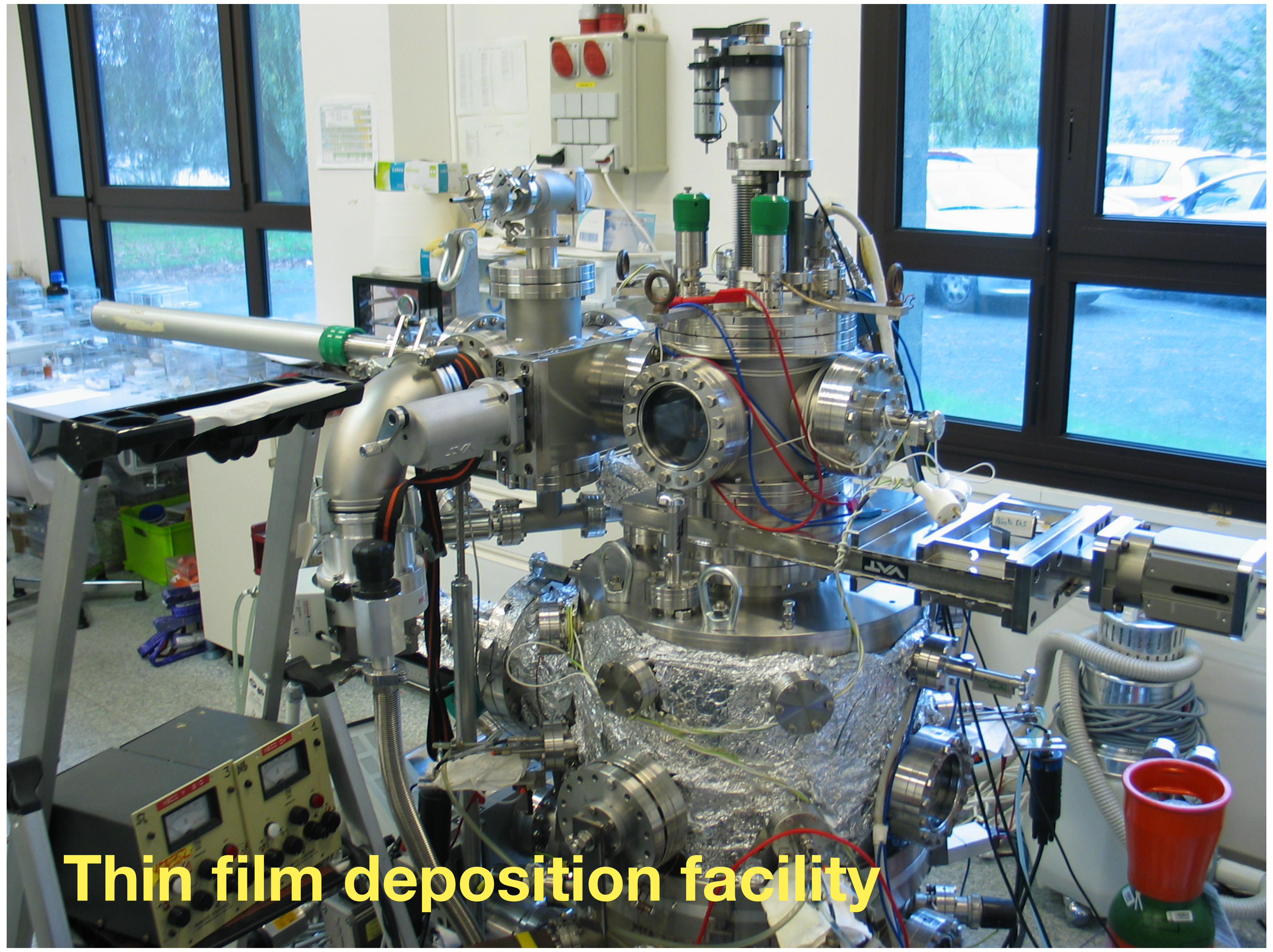
S. Scorza

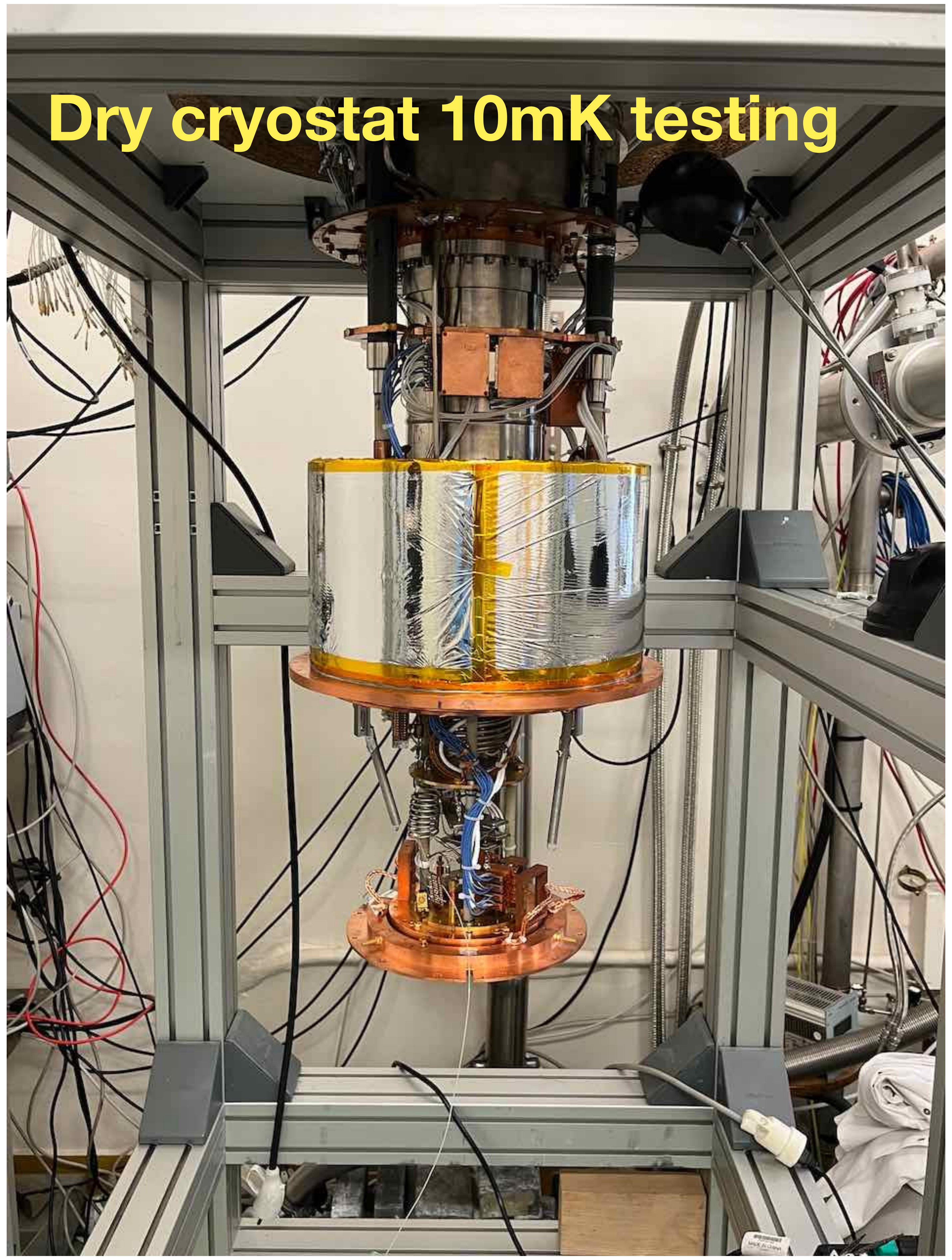
Testing Facilities
Background Consideration
The Underground Modane Laboratory (LSM)
Integration at LSM
WBS Structure
Budget

TESSERACT@LSM: IJCLab detector development platform

The **Cryogenic Quantum Detectors platform** at IJCLab is tailored to cryogenic detectors development, fabrication and testing.

- Intense R&D on low T detectors and innovative sensors
- Responsible for the detector manufacturing of several projects (EDELWEISS, CUPID, RICOCHET, QUBIC, X-ray microcalorimeters…)
- Will fully support the TESSERACT semiconductor R&D and detector fabrication





TESSERACT@LSM: A new test facility at IP2I

Outer shielding:
- PE: 30 cm (1 ton)
- Pb: 10 cm (9 tons)

CRYORED cryogenic platform in Lyon (IP2I) with a background budget of 200 DRU (NR and ER) @ 1 keV

Ricochet cryostat moves to ILL by end-2023 and will be replaced by a **new cryostat** dedicated to CRYORED

<u>To support:</u> Ricochet,TESSERACT, future R&D programs, detector fabrication and testing, and achieve « **surface science** » (e.g. calibration, SIDM, …)

Background Considerations

Cosmic rays &
cosmogenic activation
of detector/shielding materials

Natural radioactivity (^{238}U, ^{232}Th, ^{40}K):
γ, e^-, n, α, β

Ultimately: neutrino fog

Minimizing Background

Go deep underground

Fewer cosmic rays to produce neutrons. Neutrons produce nuclear recoils as WIMPs

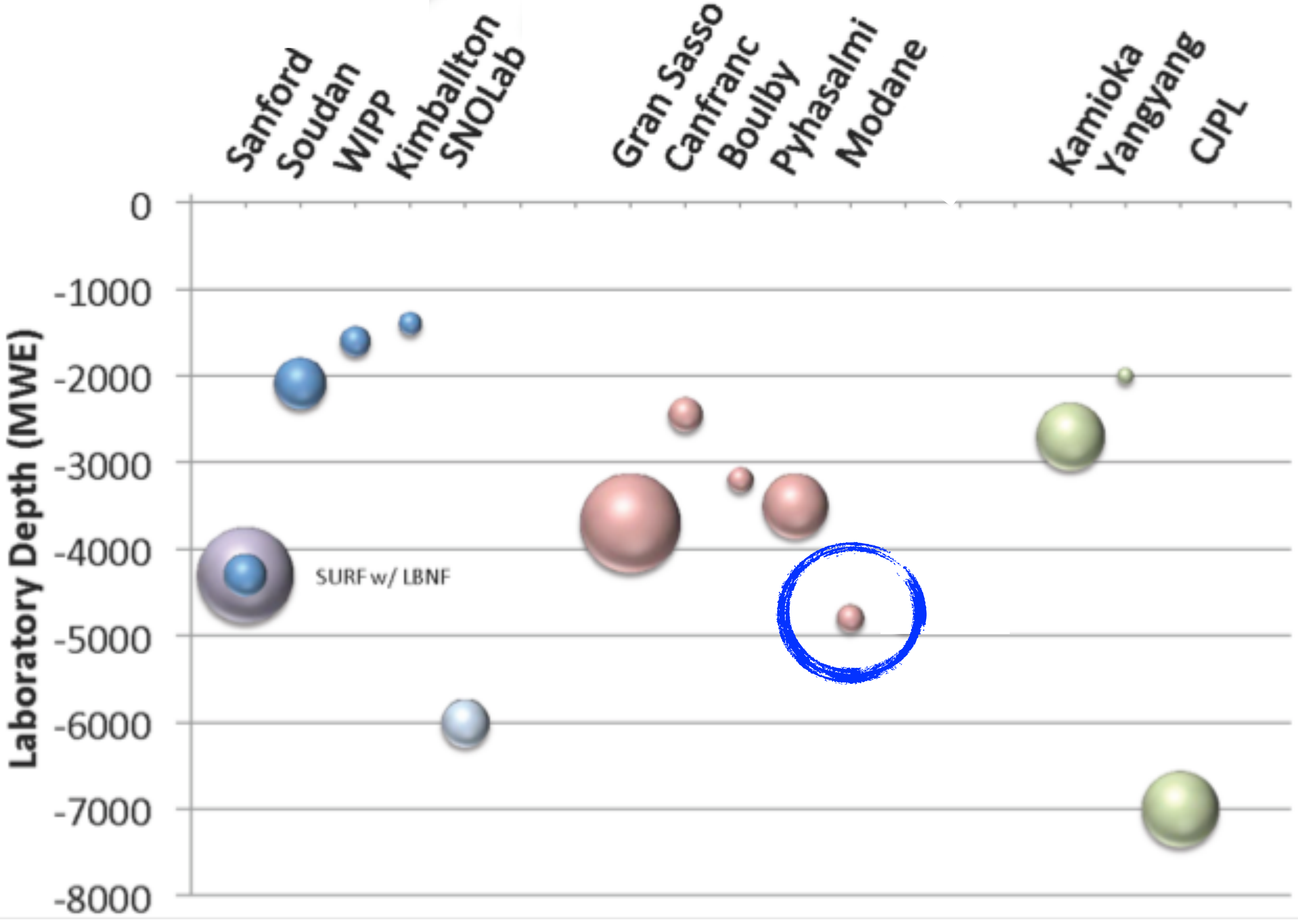
Passive/Active shielding

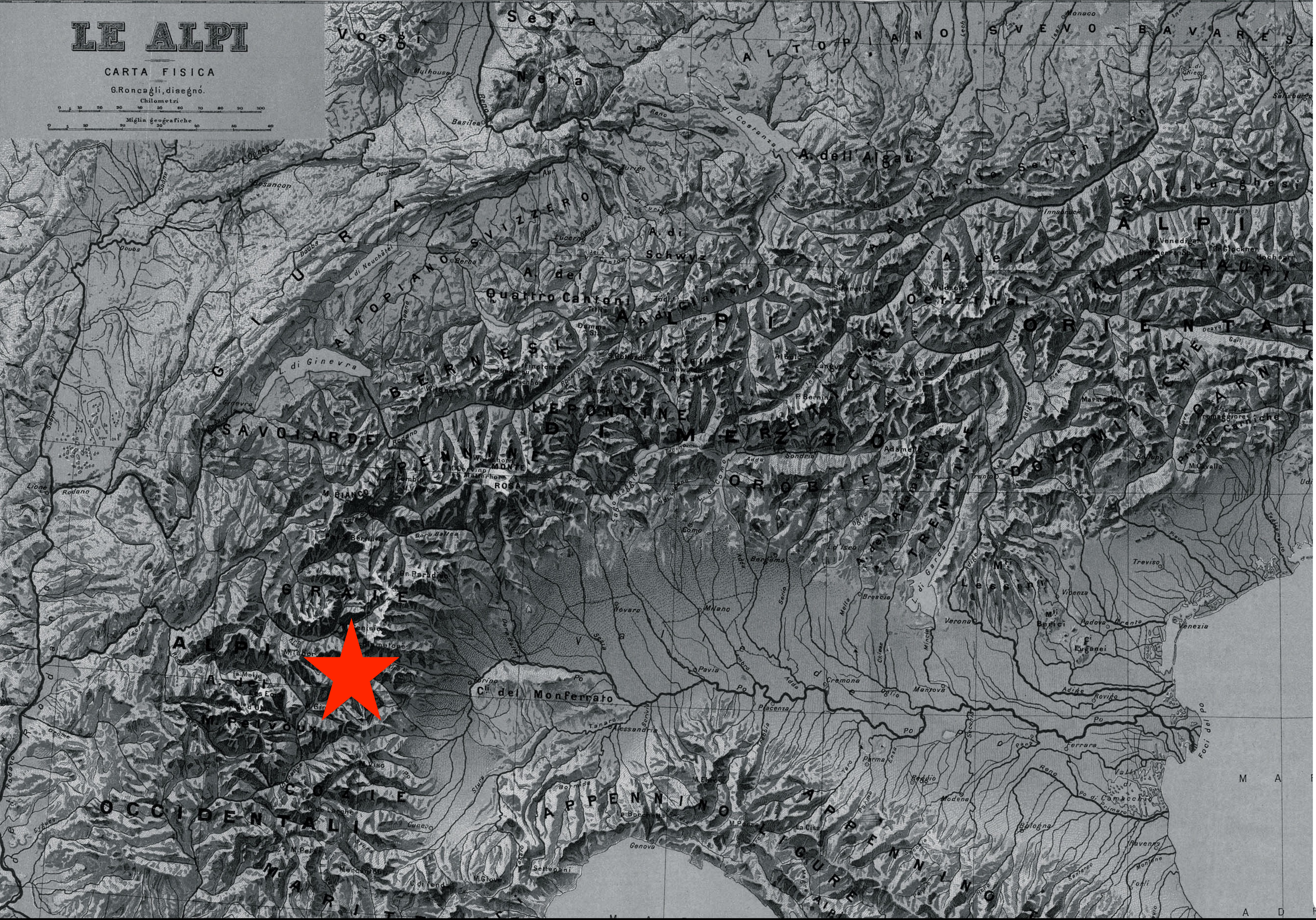
Reduce backgrounds from natural (^{238}U, ^{232}Th, ^{40}K) radioactivity

Material screening and assay, and cleaning techniques

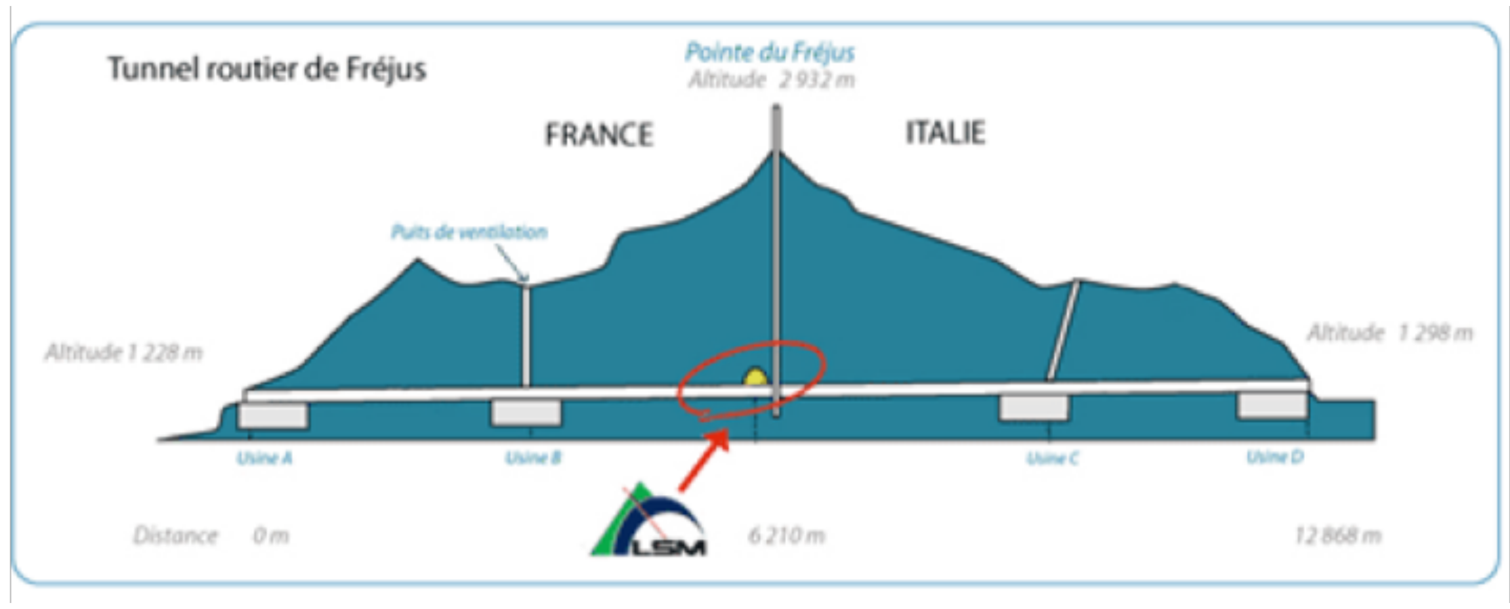
The Modane Underground Laboratory

- Deepest underground laboratory in Europe
- Easy access via highway tunnel
- Muon flux 5 times smaller than other European underground labs
- Surface 400m²

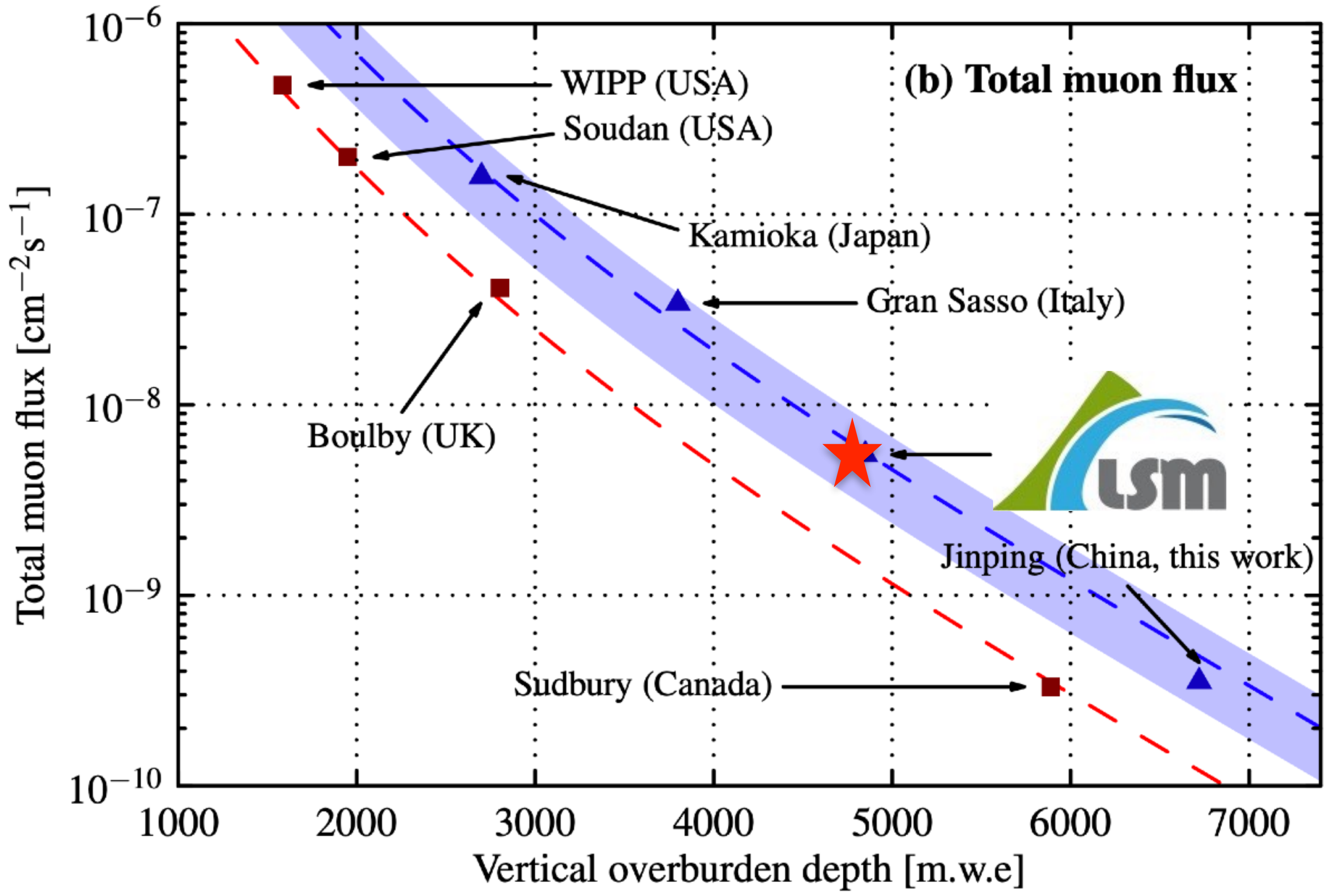




LSM
@ Frejus tunnel



Guo et al., arXiv:2007.15925v2

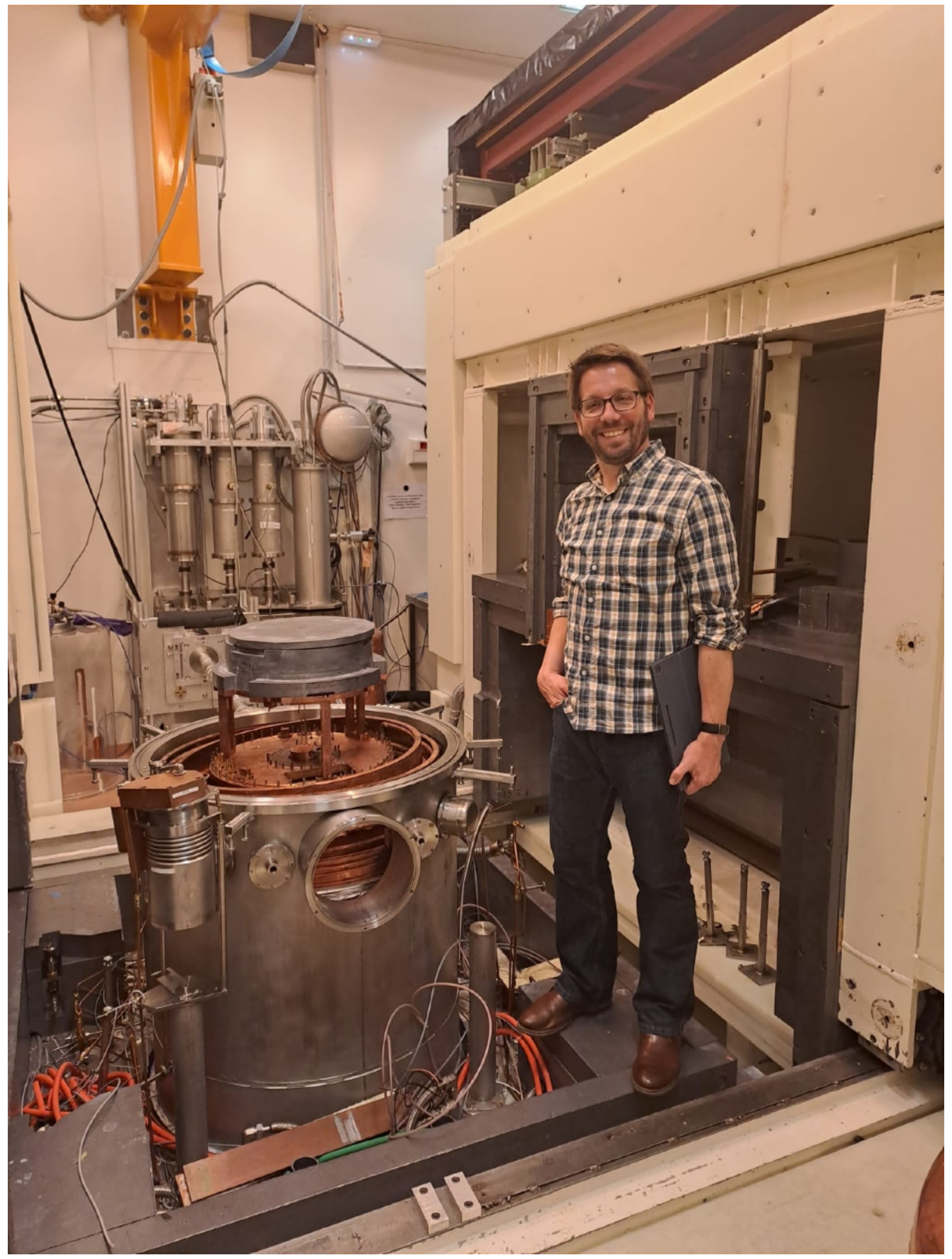


iP2i LES 2 INFINIS LYON
LPSC GRENOBLE | MODANE
IJCLab Irène Joliot-Curie
cnrs

The Modane Underground Laboratory

TESSERACT

D. McKinsey January 2022



B. Penning March 2023

Discussions with TESSERACT started in January 2022 during Dan McKinsey' sabbatical at IP2I Lyon (Jan - Jun 2022)

Two meetings with TESSERACT executive board to discuss collaboration opportunities with IN2P3 partners (Fall 2022)

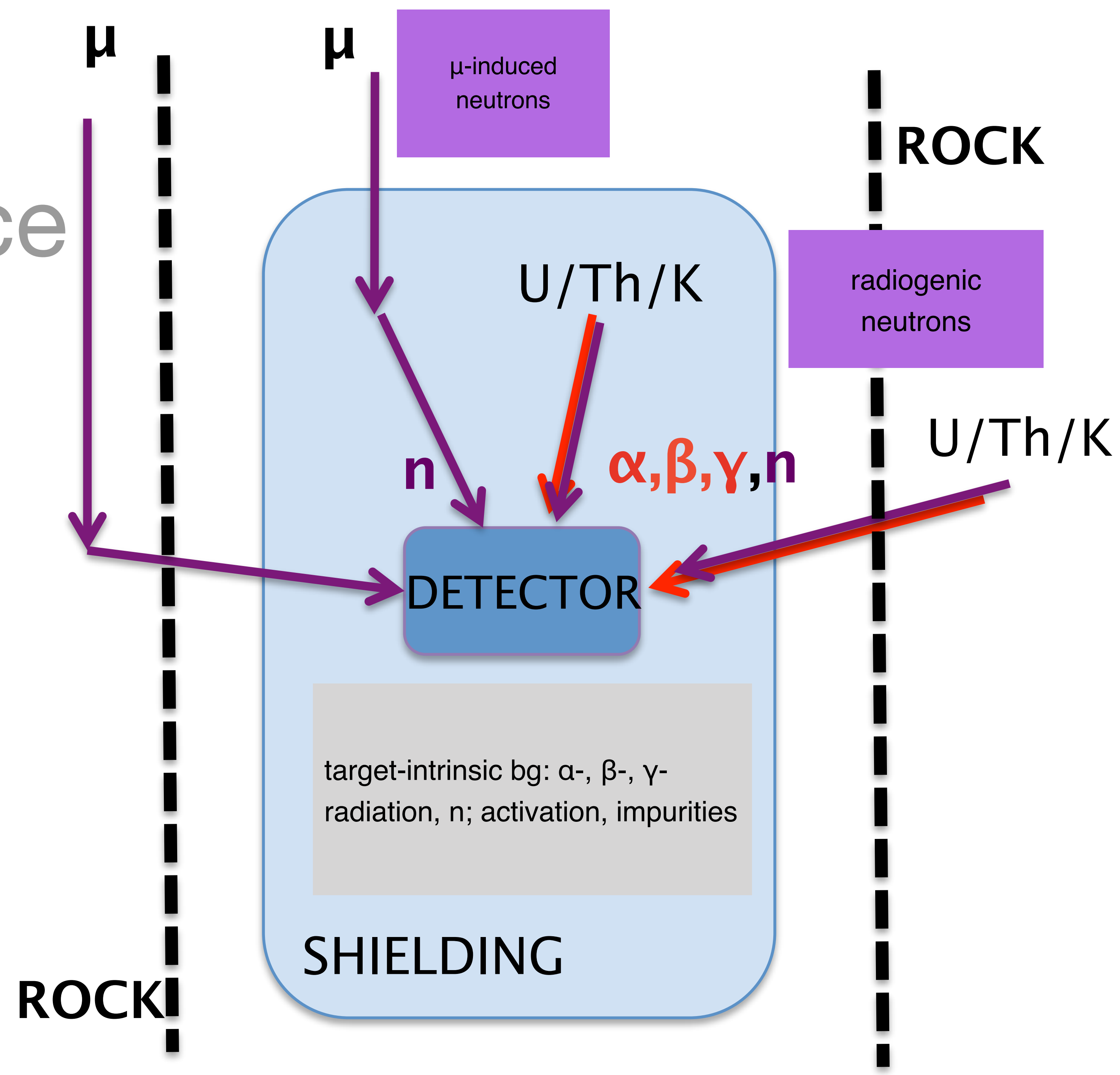
IN2P3 directorate visit US partners and DOE representatives at UC Berkeley (April 2023)

Since spring 2023: bilateral weekly project management meetings between US and French partners

Minimizing Background

Go deep underground
Fewer cosmic rays to produce neutrons. Neutrons produce nuclear recoils as WIMPs

Passive/Active shielding
Reduce backgrounds from natural (^{238}U, ^{232}Th, ^{40}K) radioactivity

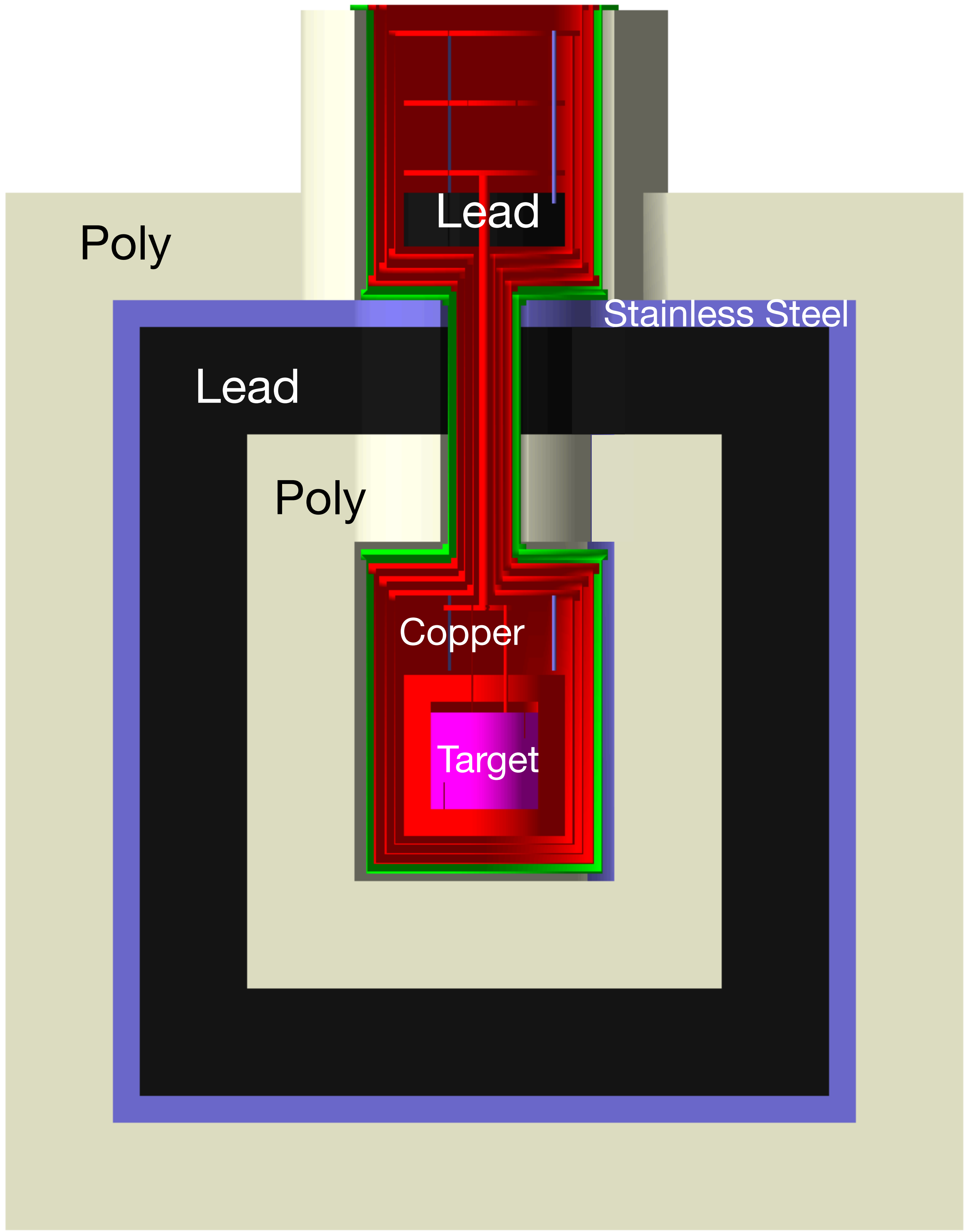


Material screening and assay, and cleaning techniques

Shielding Design

Final shielding design from iterations of different geometries

- Neck like structure will prevent line of sight backgrounds
- No Poly at mixing temperature plate for ease of cooling down and future improvements



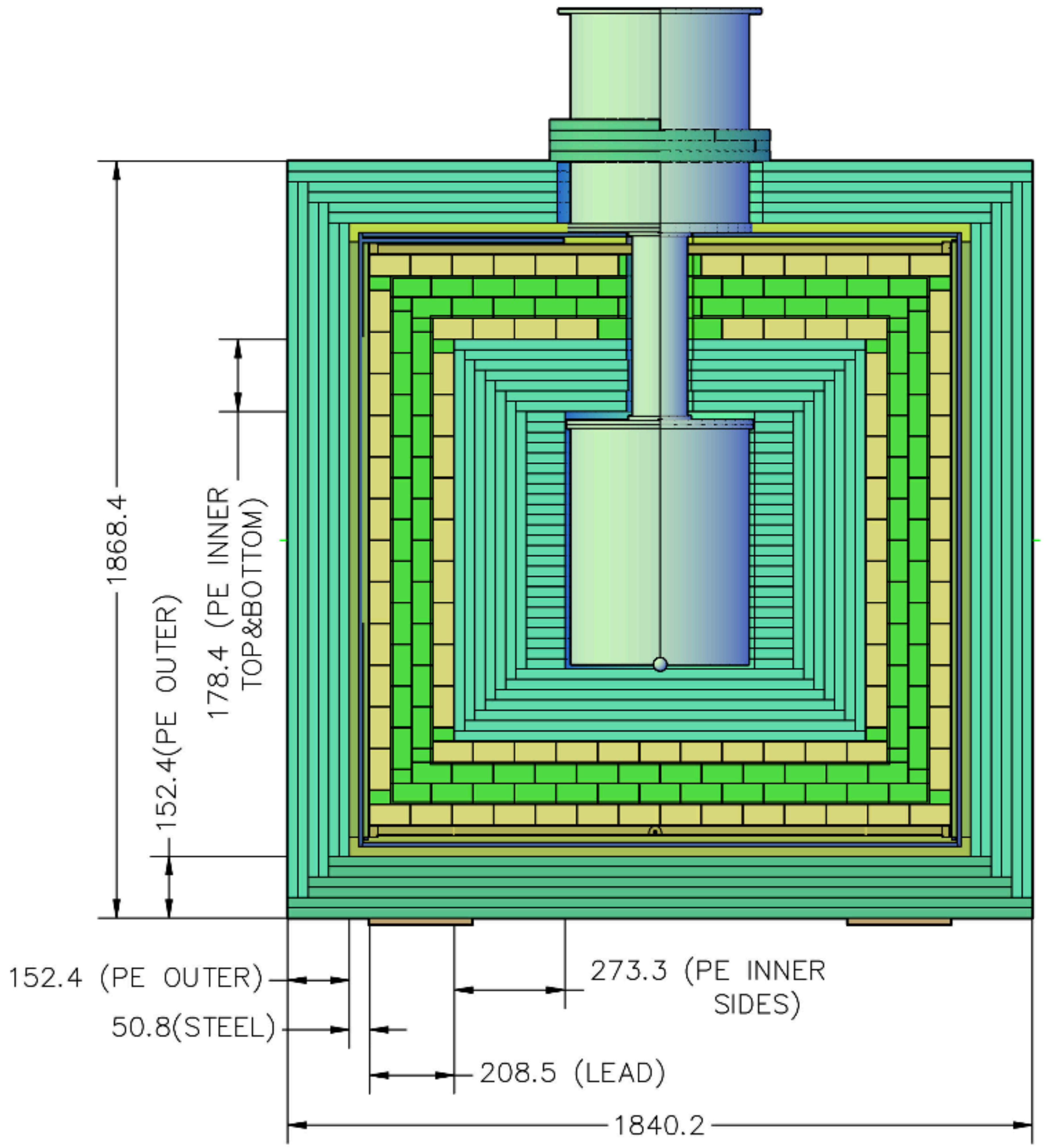
Shielding Design

Final shielding design from iterations of different geometries

The shielding is designed to be assembled from the bottom up and the outside inwards.

All single pieces are small enough to be easily moved into the experimental hall.

Cleaning and sealing the lead at suitable facilities at the surface to minimize risk and waste production underground.



iP2i LES 2 INFINIS LYON
LPSC GRENOBLE | MODANE
IJCLab Irène Joliot-Curie
cnrs

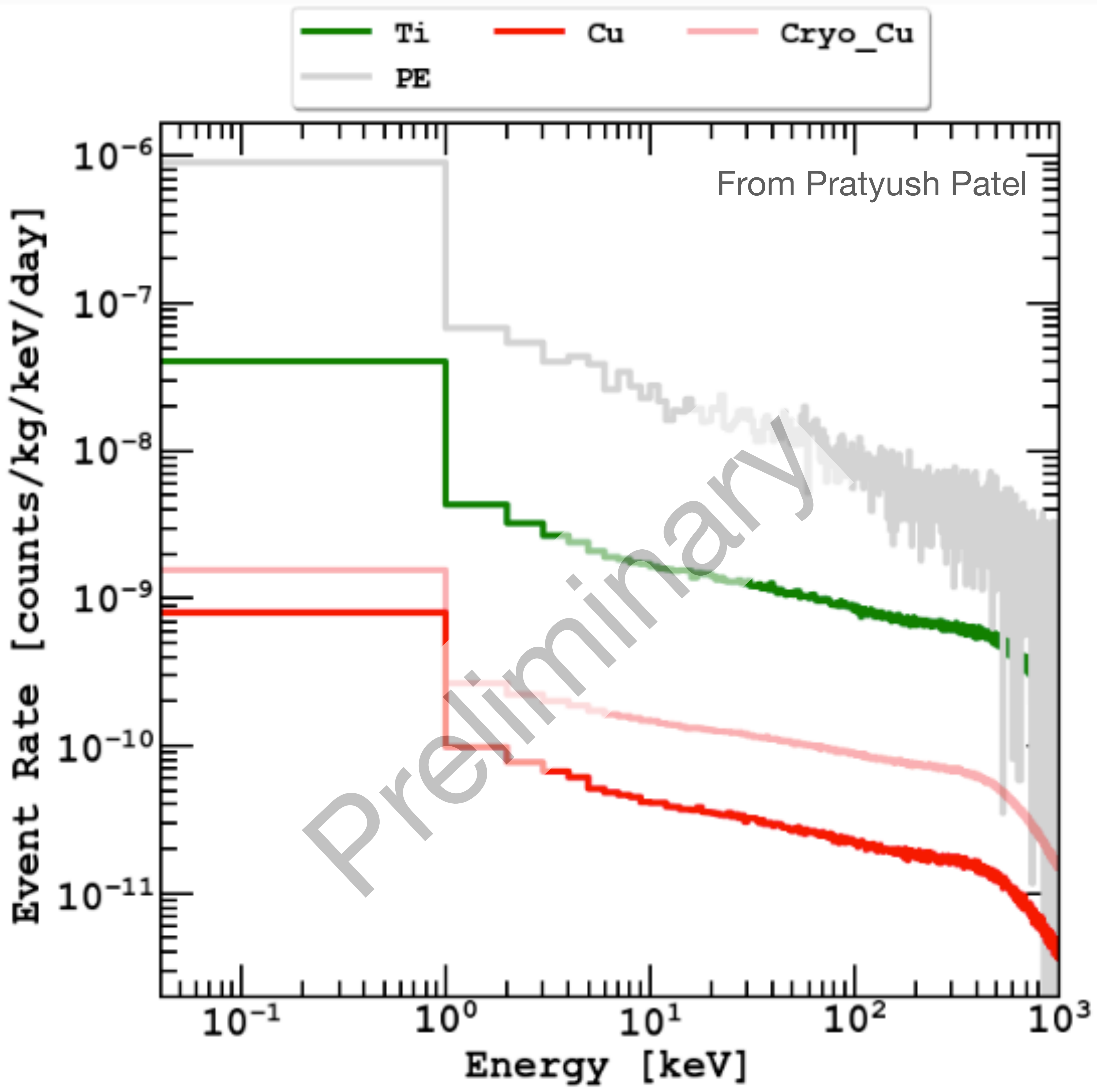
Initial Simulations Internal radioactivity

TESSERACT

External neutron sources

Titanium, stainless steel, polyethylene, copper

The rate for neutron internal backgrounds is almost negligible



Initial Simulations Internal radioactivity

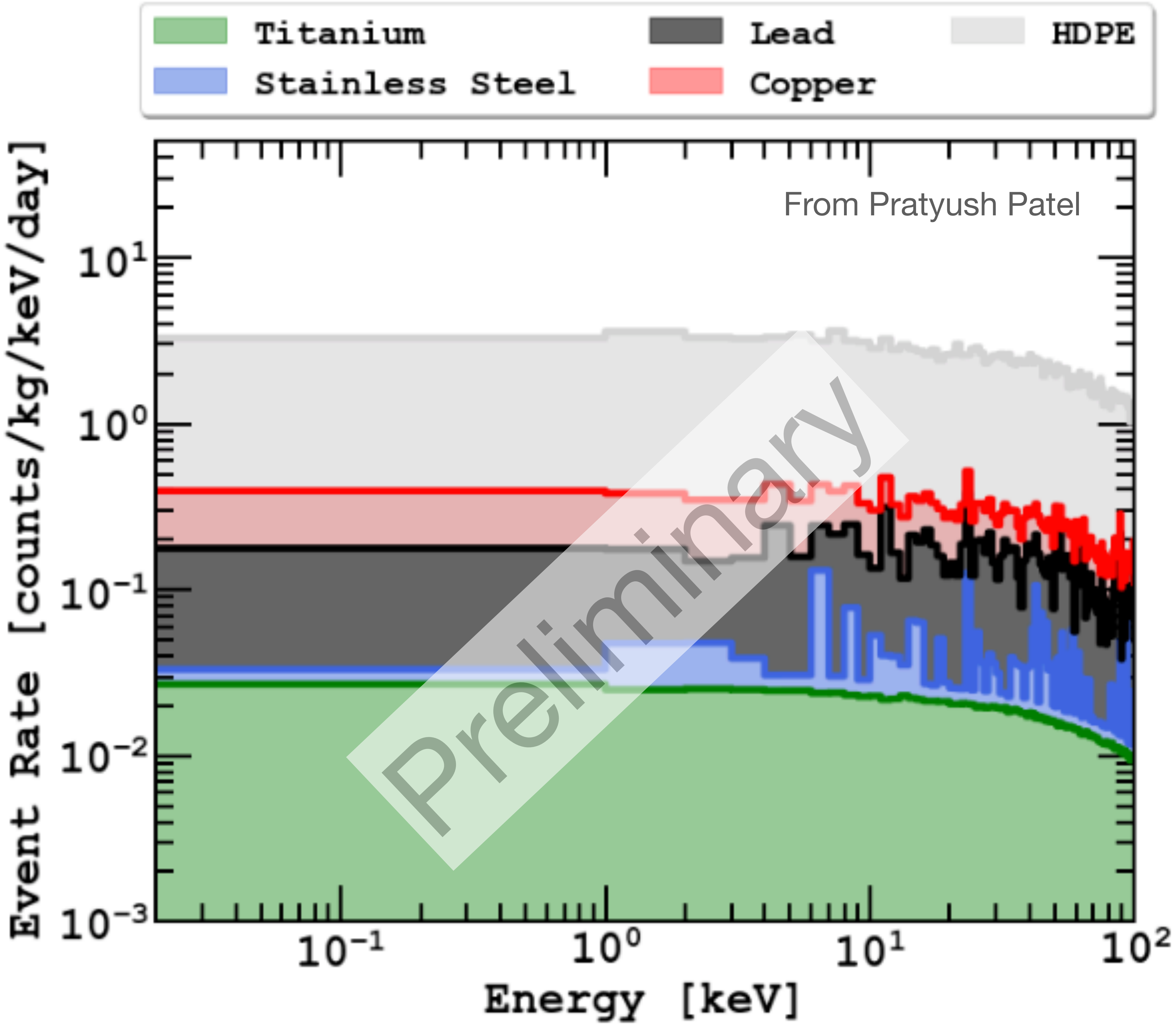
TESSERACT

External gamma sources

Copper, polyethylene, lead, titanium, stainless steel all from EDELWEISS published data

The rate for internal backgrounds is dominant, 3DRU in He target

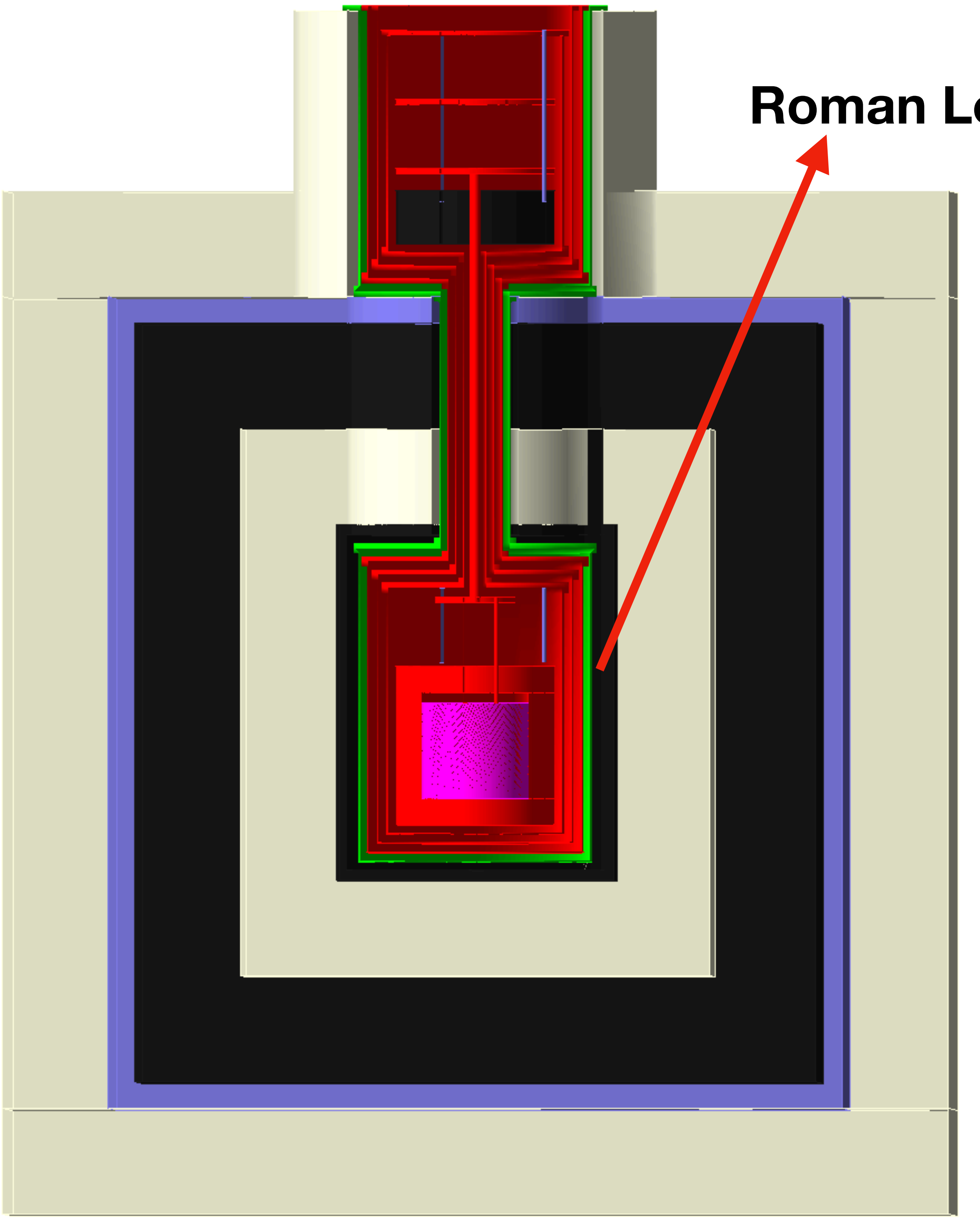
Plan to have a inner layer of high-z materials, likely roman lead or copper.



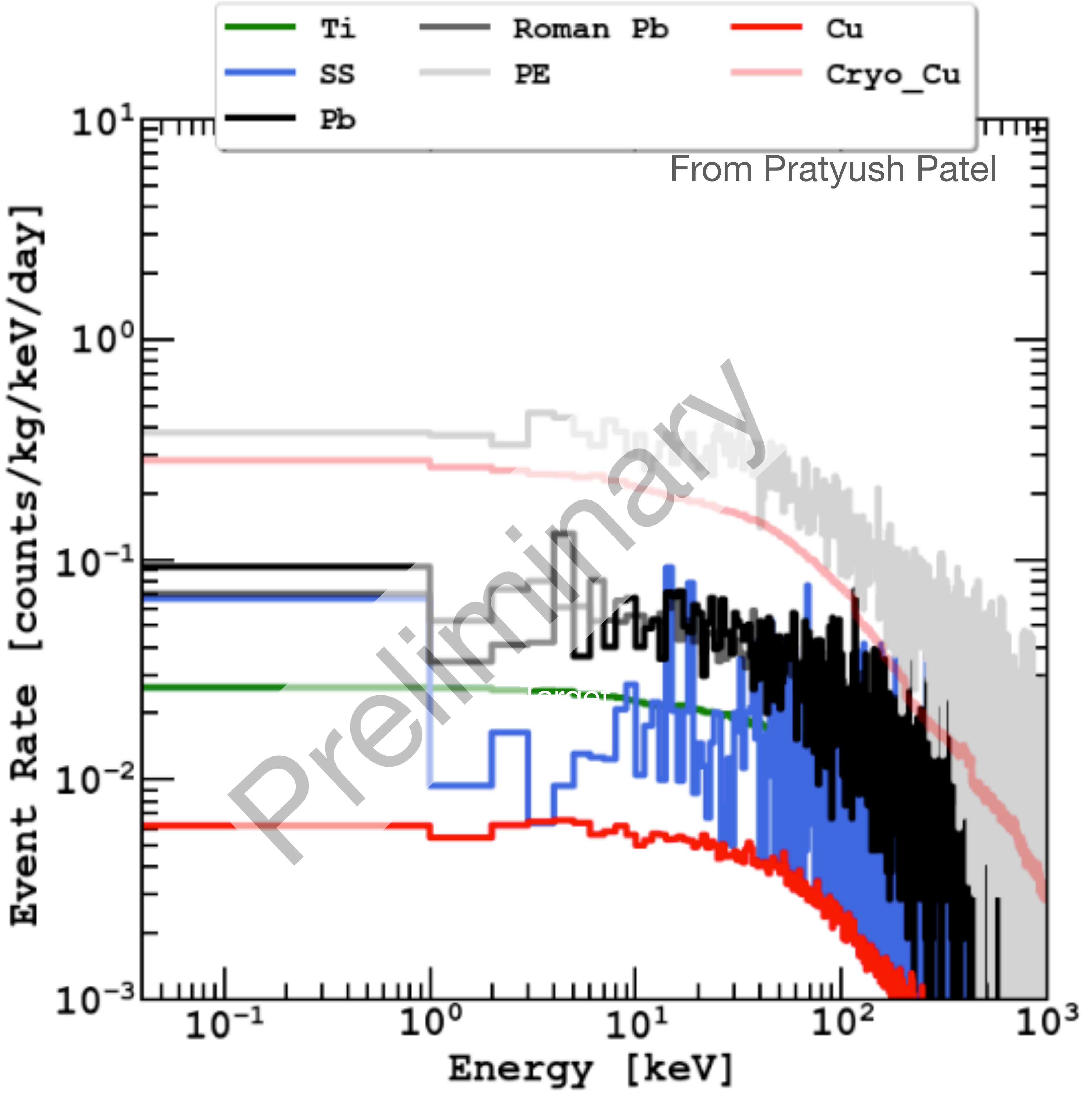
iP2i LES 2 INFINIS LYON
LPSC GRENOBLE | MODANE
IJCLab Irène Joliot-Curie
cnrs

Initial Simulations Internal radioactivity

External gamma sources



An additional internal roman lead shield of ~5cm, brings gamma internal budget down to <1 DRU



Minimizing Background

Go deep underground

Fewer cosmic rays to produce neutrons. Neutrons produce nuclear recoils as WIMPs

Passive/Active shielding

Reduce backgrounds from natural (^{238}U, ^{232}Th, ^{40}K) radioactivity

Material screening and assay, and cleaning techniques

radiopurity.org

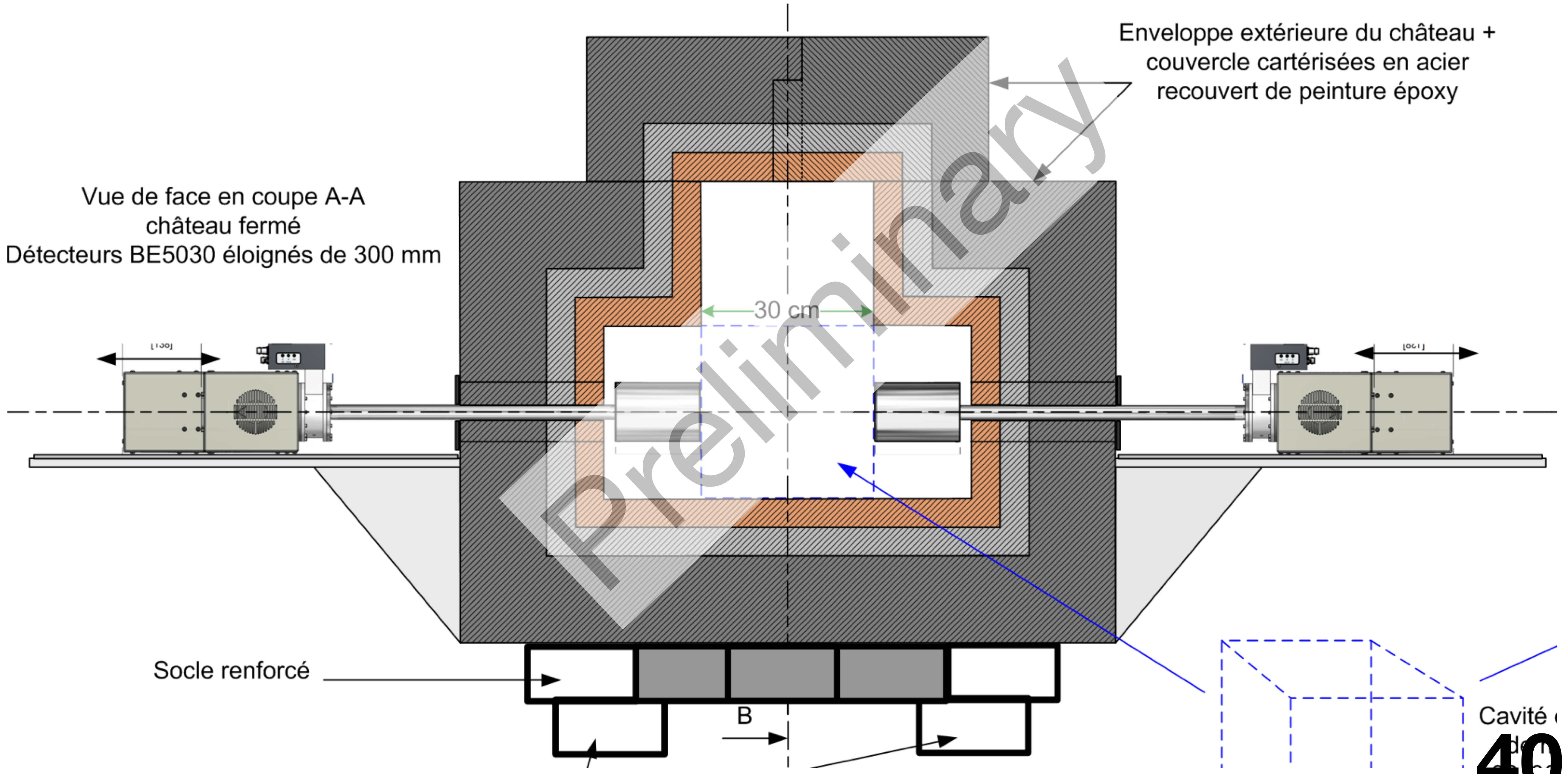
Screening and Assay

Private instance

radiopurity.org

Gamma Bulk

- Gentiane @LSM (available for EDELWEISS since Nov 1997)
- Dual BEGe



Surface contamination

- XIA UltraLo-1800

TESSERACT: Integration at LSM

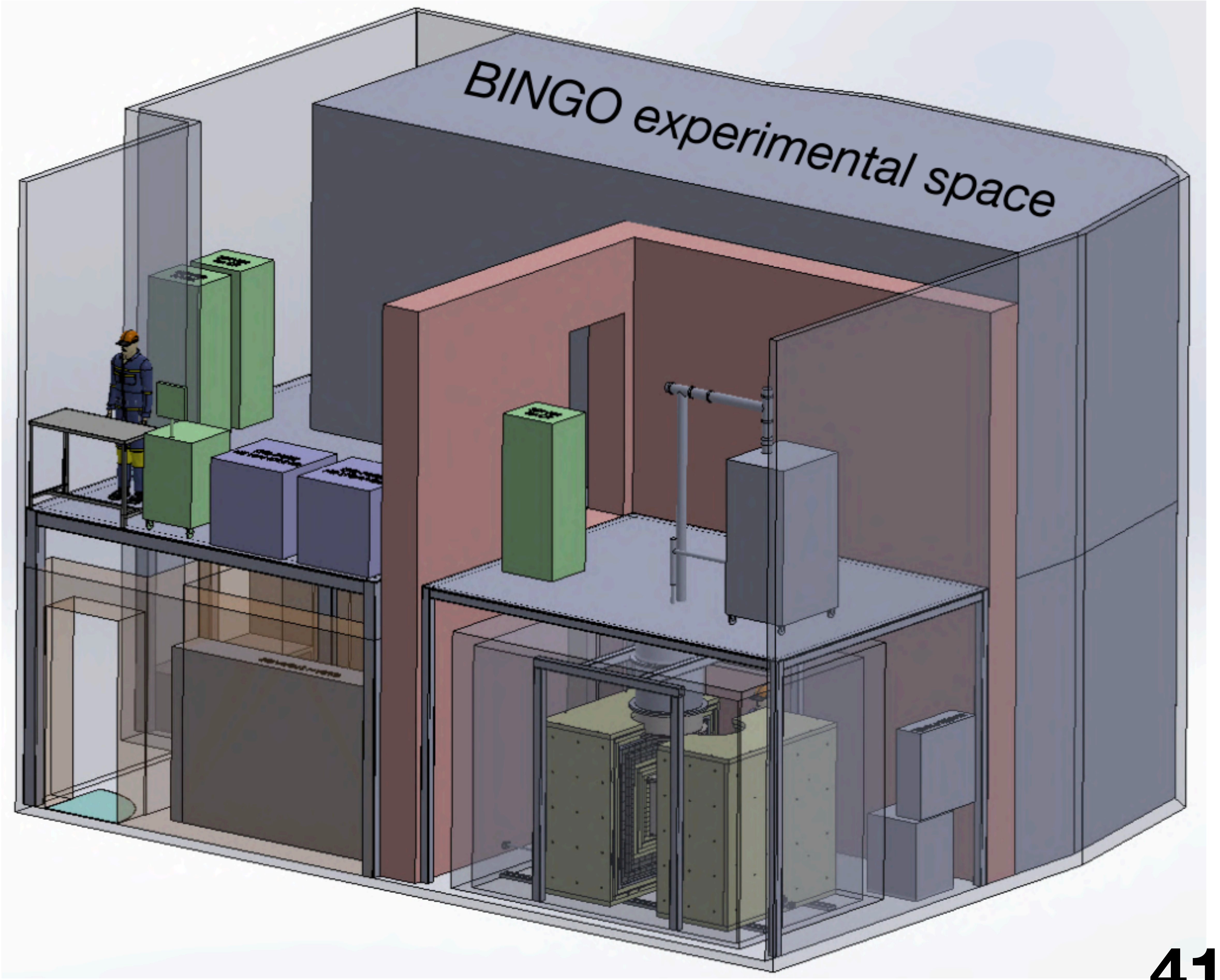
- Two copies of the setup, for enabling both:
    1) underground R&D and detector optimisation
    2) DM science data taking in parallel

- Each detector technologies is designed to achieve major breakthrough in short time scales (few months) hence allowing fast turnarounds

- The two setups could be (ideally) in the same underground lab or not

- Installation of 1st cryostat at LSM in the next 3 years may be feasible (depending on resources & availability) AND timely for the TESSERACT collaboration.

- Choice of site(s) still in discussion in US, and there significant support in the US collaboration to consider LSM —> **ongoing discussions on the LSM setup**



TESSERACT: WBS

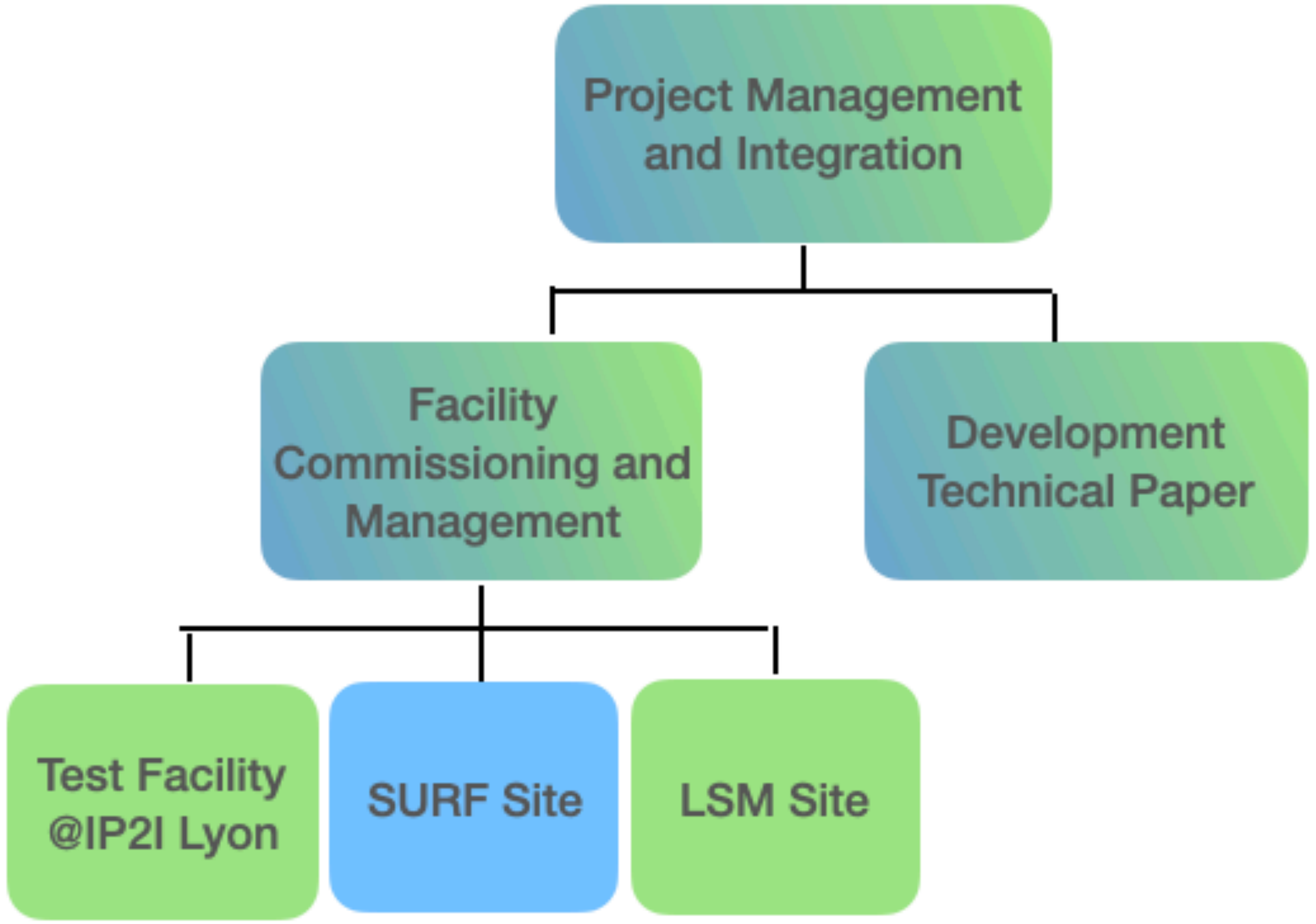
Structure in evolution

The success of EDELWEISS has shown that the IN2P3 cryogenic detector groups have had, in the past, the strength and expertise to manage a leading role in the installation and exploitation of a major low-background cryogenic facility at LSM.

Most tasks will be shared among US and French laboratories, with significant overlap and collaborations.
Depending on the allocation of resources that will be decided by the directions of their respective laboratories, the French group are proposing to take the lead in several tasks

TESSERACT: WBS

Structure in evolution

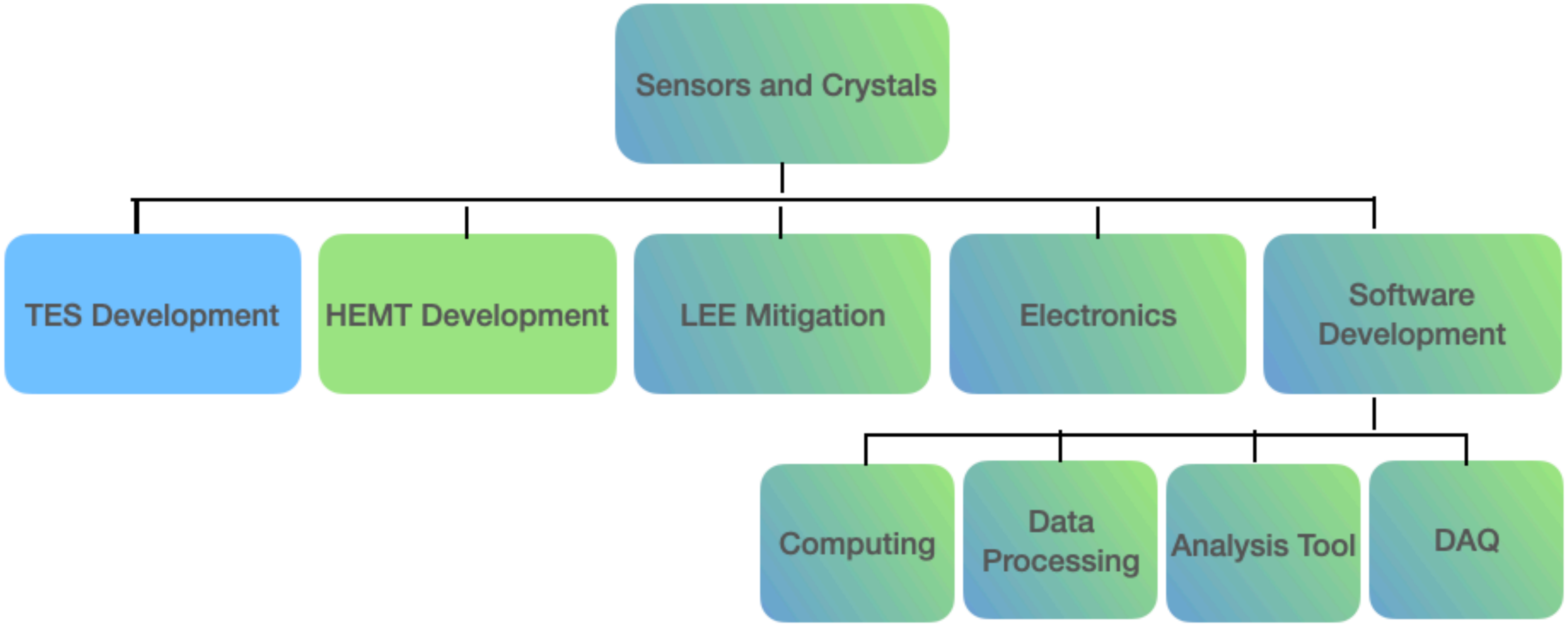


Project Management and Integration: Test Facility at IP2I Lyon coordinated by IP2I as it will involve its CRYORED low-background cryogenic test facility, but most tests will require a strong collaborations with the LPSC and IJCLab groups to build on the expertise gained in the operation of EDELWEISS and RICOCHET detectors.

Project Management and Integration: LSM Site: the LPSC group intends to have a leading role in the underground integration of the TESSERACT experiment, while the IP2I and IJCLab will bring their EDELWEISS expertise.

TESSERACT: WBS

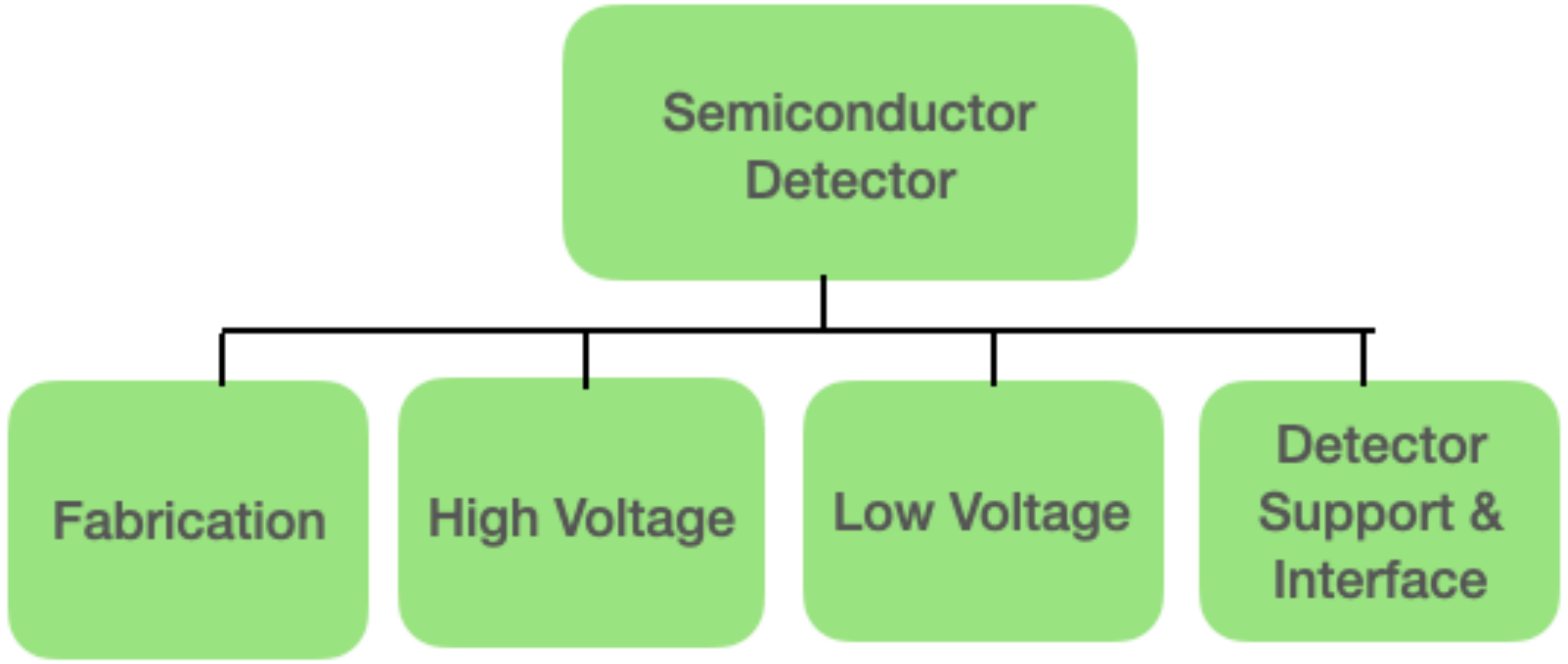
Structure in evolution



Sensors and Crystals: HEMT Development
IP2I would continue to coordinate this activity started in the context of the RICOCHET collaboration.

TESSERACT: WBS

Structure in evolution



Semiconductor Detector: Fabrication: The IJCLab cryogenic detector fabrication facility will be the main infrastructure for the realization of the TESSERACT semiconductor devices. Strong collaboration is planned to combine the single-charge HEMT read-out design with the athermal phonon sub-eV threshold TES. The "high voltage" and "low voltage" detector prototypes will be systematically tested and optimized at the IJCLab and IP2I cryogenic test facilities.

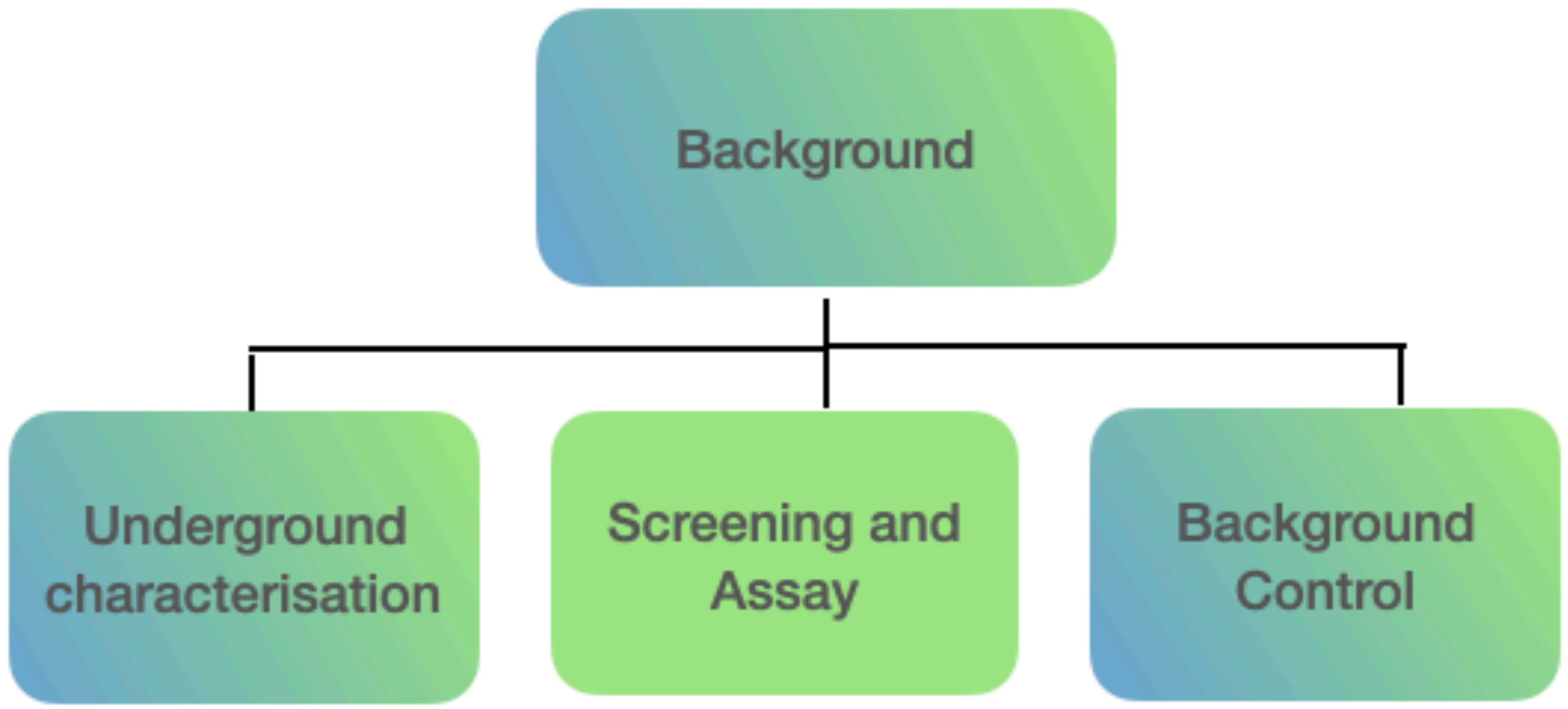
Semiconductor Detector: Detector Support and Interface: IP2I intends to coordinate this task as in RICOCHET. This integration work, crucial for detector performance, involves the mitigation of vibrations and microphonics as well as the optimisation of the very-front-end electronics in the sub-K environment.

Semiconductor Detector: High Voltage IJCLab will continue to coordinate the R&D on HV detector technology as in the context of the Cryosel-ANR program.

Semiconductor Detector: Low Voltage IP2I will continue to coordinate the development of this program as in the context of RICOCHET.

TESSERACT: WBS

Structure in evolution



Background: Underground Characterization
The LPSC intends to coordinate this task, in continuation of its leadership role in this activity for the RICOCHET experiment. In addition to the background budget assessment, it will develop cleanliness and dust exposure protocols.

Background: Screening and Assay
The LPSC, with its strong connexion to the LSM screening infrastructure at LSM, intends to coordinate this activity that involves its BEGe and XIA detectors. IP2I will contribute via its involvement with the Gentiane HPGe.

TESSERACT: Budget

- **TESSERACT is already an existing and funded pre-project from the DOE** dark matter new initiatives program. It started in 2020 and **has already received so far 1.3 M-EUR in funds for equipment**, materials, engineering, and project management. The total pre-project budget from the DOE, *i.e. excluding ressources needed to build TESSERACT at LSM*, **is expected to reach 2.8 M-EUR by 2025**.

- TESSERACT at LSM project, including the addition of the French IN2P3 detector technology to the TESSERACT payload and science reach, **a total budget of 3.5 M-EUR is required.**

TESSERACT: Budget

Budget split

1.5 M EUR: Cryostat (700kEUR), shielding (400kEUR) and cleanroom/clean storage/wirebonders/workspaces (400kEUR). *For the second TESSERACT cryostat, that could come at later times, require additional funds and space at LSM would be required.*

2 M EUR: Detector R&D, including lab and infrastructure upgrades, in the initial period of the project (2024-2026)

- **Significant infrastructure upgrades and new equipment for the IN2P3 laboratories essential to the project (1 M-EUR):** equipment for radiopurity assay at LPSC, upgrade of IJCLab fabrication and cryogenic test facility and finalisation of the cryogenic test facility at IP2I

- **Detector materials and consumables related to the construction of the semiconducting detector arrays (1 M-EUR):** Ge Crystals, HEMT developments, SQUID electronics, various electronic components, materials and fabrication costs

TESSERACT: Resources

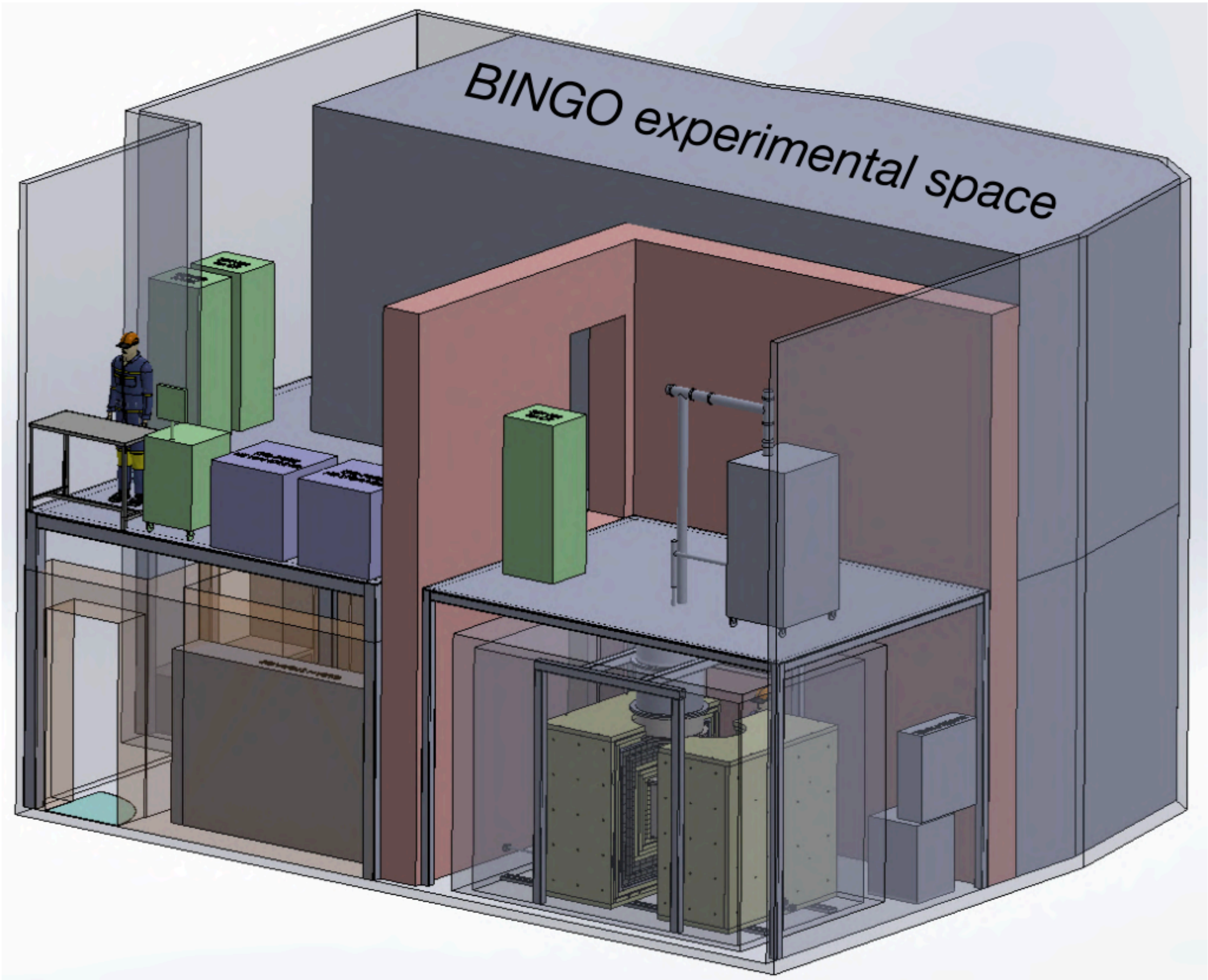
- Full HR requirements for the French part of the project has to be defined and validated but they can be estimated to be comparable to the French contributions to EDELWEISS or RICOCHET ***(approx. 20 people, 10 FTE)***
- Benefit from the recent strengthening of the LPSC research group ***(1 DR + 1 CR)***
- Care now should be taken to provide an **appropriate technical support** for the new experimental structures at LPSC/LSM
- To ensure the maximal impact of the French groups in TESSERACT, together with the continuing efforts on both Ricochet and CUPID, the 2024 HR request of IP2I and IJCLAB include:
  - ***A CR at IP2I*** for detector developments and light DM science output
  - ***A IR at IJCLab*** to ensure the growing demand on fabrication (in particular for the French-designed CUPID light detectors) and the development of new detectors

TESSERACT: Conclusion

TESSERACT@Modane:

Extending the Dark Matter mass search window from meV-to-GeV with ultra low-threshold cryogenic detectors with multiple targets and particle identification and LEE rejection capabilities with two identical cryogenic setups installed in the ultra-low background environment from the LSM

- ***Unique opportunity to build the next leading cryogenic light DM experiment at LSM, featuring French bolometer technology, benefiting from decades of experience from EDELWEISS, CUPID, and Ricochet***
- High level discussions are ongoing between IN2P3 and DOE for a joint TESSERACT collaboration and implementation at LSM
- TESSERACT is now a so-called IN2P3 master project allowing for direct CNRS fundings and ressources:
  - One IN2P3 TESSERACT postdoc position at LPSC
  - One IN2P3 international PhD thesis grant at IP2I to start in the Fall 2023
- French partners are currently actively looking for fundings to start building TESSERACT at LSM by the horizon 2026

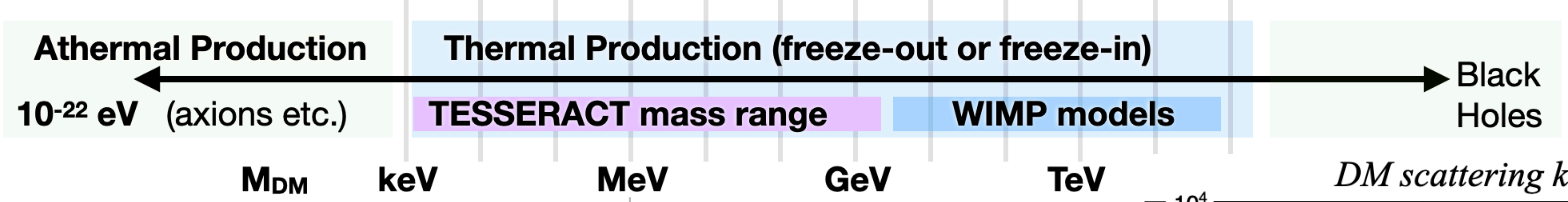


TESSERACT

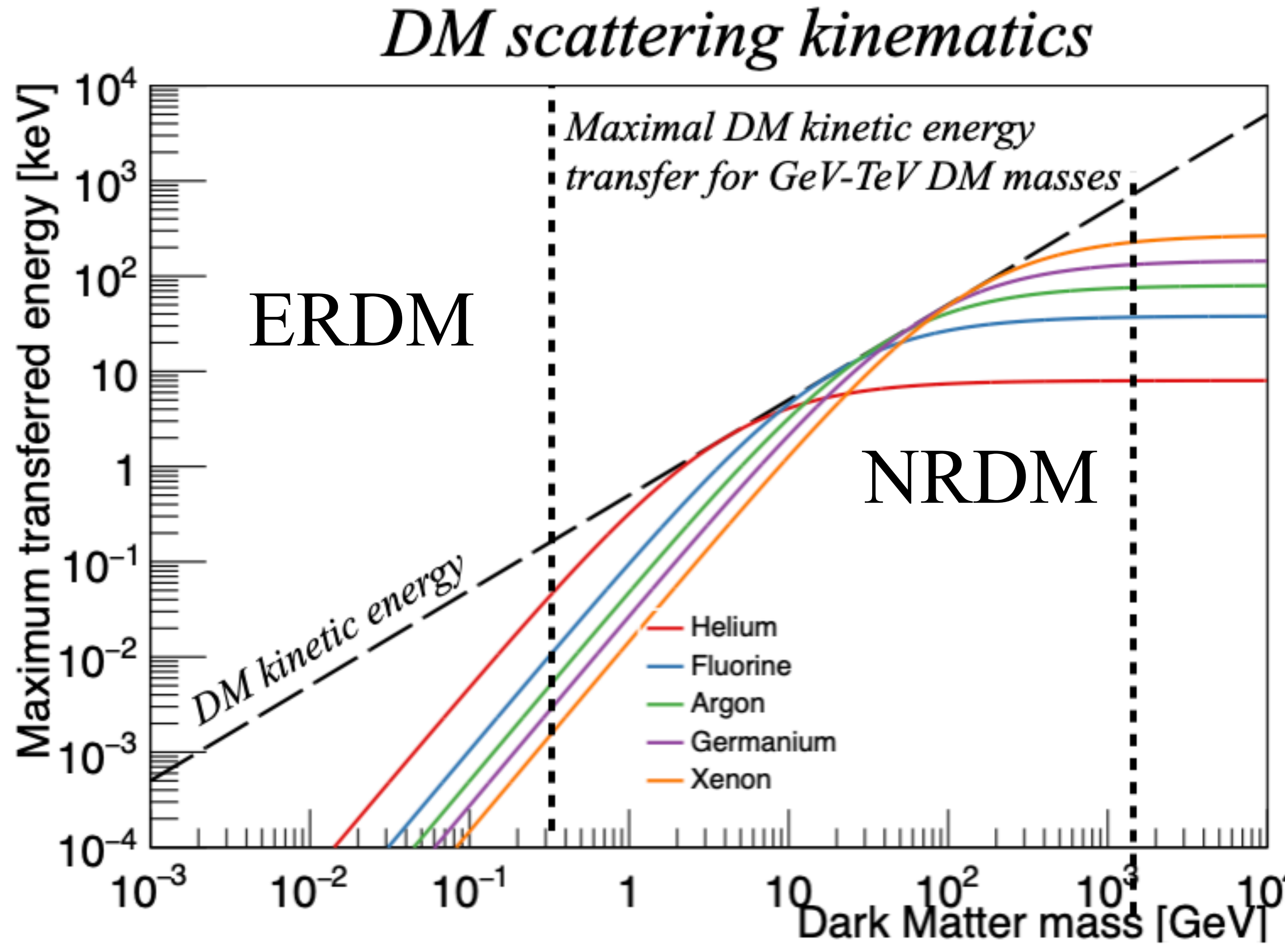
That's all Folks!

TESSERACT: keV-GeV « light » Dark Matter

- Consistent with simple thermal production after inflation (like other massive particles)
- Typically requires a new force mediator too, not just the DM particle.
- Direct detection searches via electron scattering (ERDM) or nuclear scattering (NRDM)



	keV	MeV	GeV
Nuclear recoil end-point:	~neV	~meV	~keV
Electronic recoil end-point:	~meV	~eV	~keV



- eV-scale thresholds already demonstrated
- meV-scale threshold under intense R&D
- **Bonus:** Extend the DM search window to ultra-light DM (10meV-scale masses) thanks to DM absorption on electron/phonons

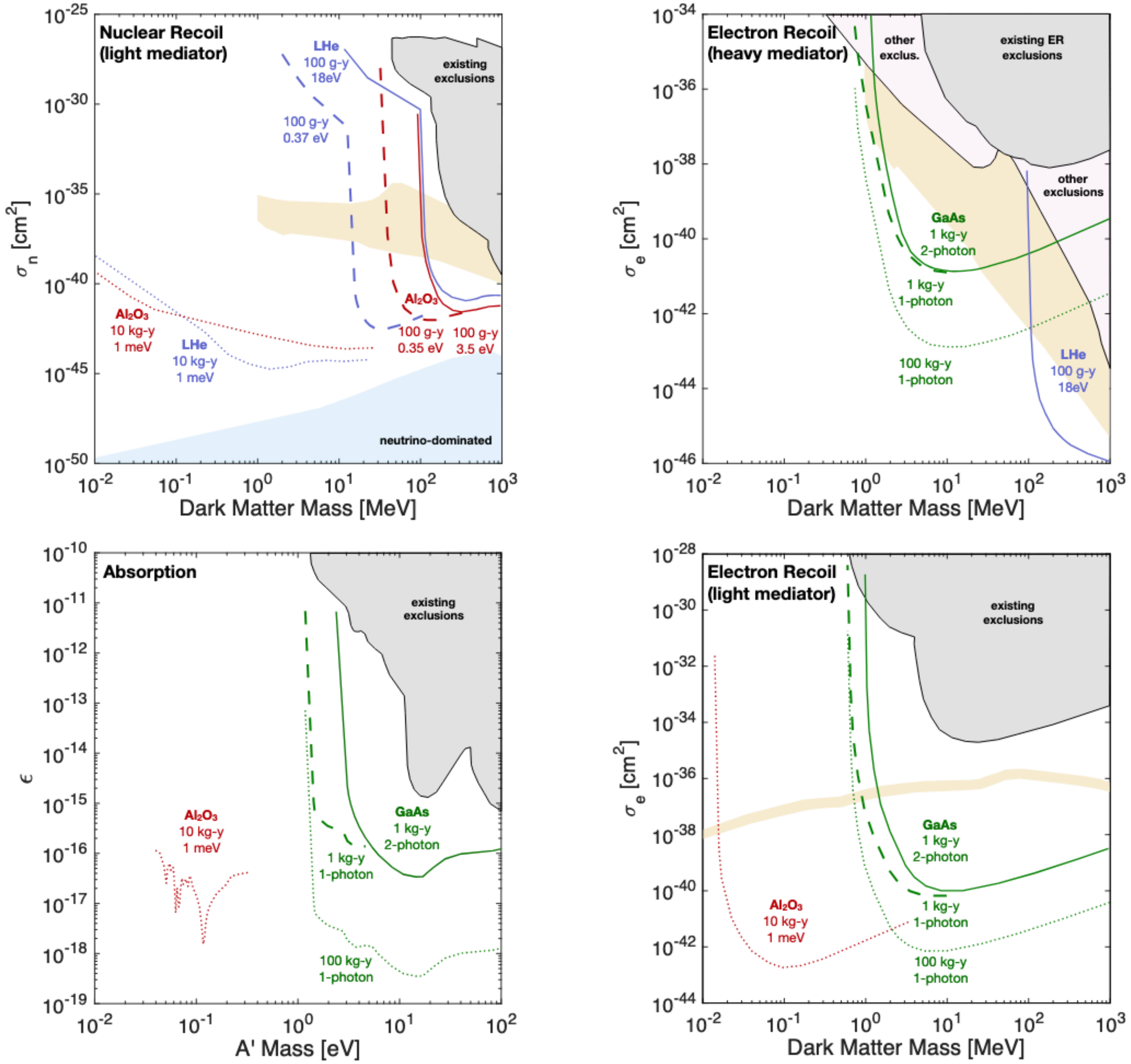
TESSERACT: SWOT

	Helpful to achieving the objective	**Harmful** to achieving the objective
Internal origin attributes of the organization	**Strengths** • Only DM direct detection project aiming for meV-scale energy thresholds combined with particle identification and low-energy excess discrimination capabilities • Only project optimised for both NRDM and ERDM searches, using several targets: He, SiO2, Al2O3, GaAs, Ge, Si, and Diamond, to efficiently probe DM candidates over the meV-to-GeV mass scale • All partners have decades of experience in direct detection searches from EDELWEISS, SuperCDMS, LUX, and LZ. • *Most of the required technical specifications for a first DM phase have been accomplished*	**Weaknesses** • A national source of budget supporting the TESSERACT at LSM project has to be identified in France to both join the collaboration and build the experiment in Modane • At this stage, the French contribution and hosting of the TESSERACT experiment at LSM is only a proposal still awaiting approval for personnel and resources
External origin attributes of the environment	**Opportunities** • Hosting TESSERACT at LSM would significantly contribute to its scientific reputation and strengthen the joint astroparticle physics program between IN2P3 and the DOE • The decommissioning of the EDELWEISS experiment allows for a timely installation of the first TESSERACT cryostat. Additional space would become available in the coming years for the second cryostat • Mutually beneficial transfers of cryogenic detector technologies between US and France. • Creation of a new DM group at LPSC	**Threats** • Not getting fundings for TESSERACT at LSM could simply delay the project or, in the worse case, push the TESSERACT collaboration to go for another underground site • As with all project with significant R&D, there is always risk in developing the technology with delays or to never achieve the targeted ultimate performance. • Light DM direct detection is an extremely competitive field of research among which TESSERACT needs to be ahead

TESSERACT: Projection SPIDE/HeRALD

TESSERACT

Snowmass2021 - Letter of Interest
The TESSERACT Dark Matter Project



TES sensitivity:

Solid — Achieved

Dashed — Targeted

Dotted — Ultimate