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# Study and development of new detectors for the search of light dark matter with EDELWEISS

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**Why** we need dark matter and **what** supports its existence

## 03 Our biggest challenge

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**Spoiler :**  
It is not even detecting dark matter yet



→ Back-up slide !

## 02 EDELWEISS & direct detection

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**How** we plan on detecting dark matter particles

## 04 A glimpse of hope ?

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✨ my thesis ✨



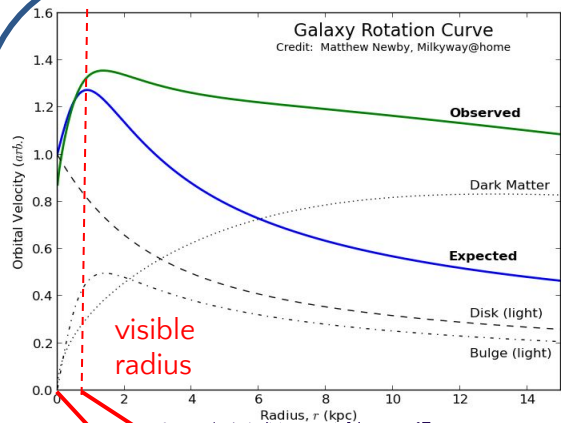


01

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The problem of  
dark matter

# 01. Facts supporting the existence of dark matter

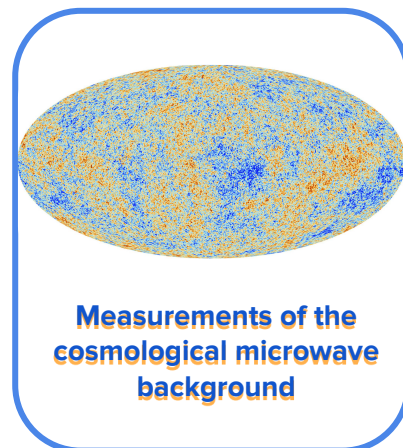
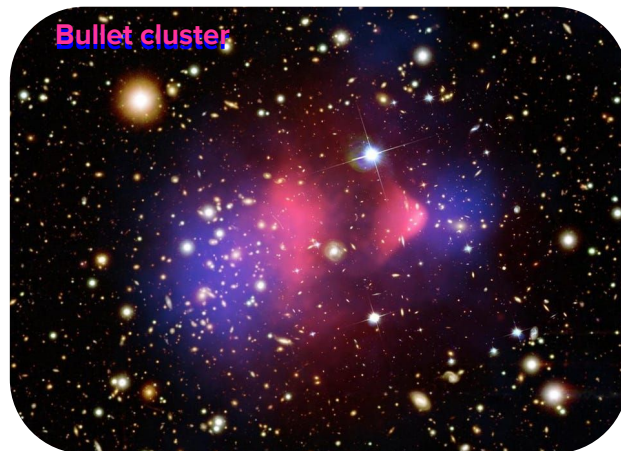
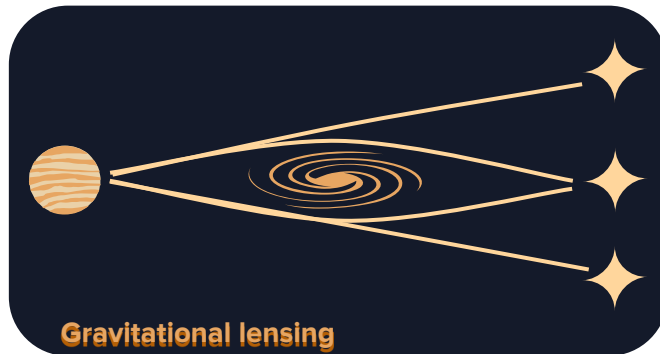


$v - \text{const}$

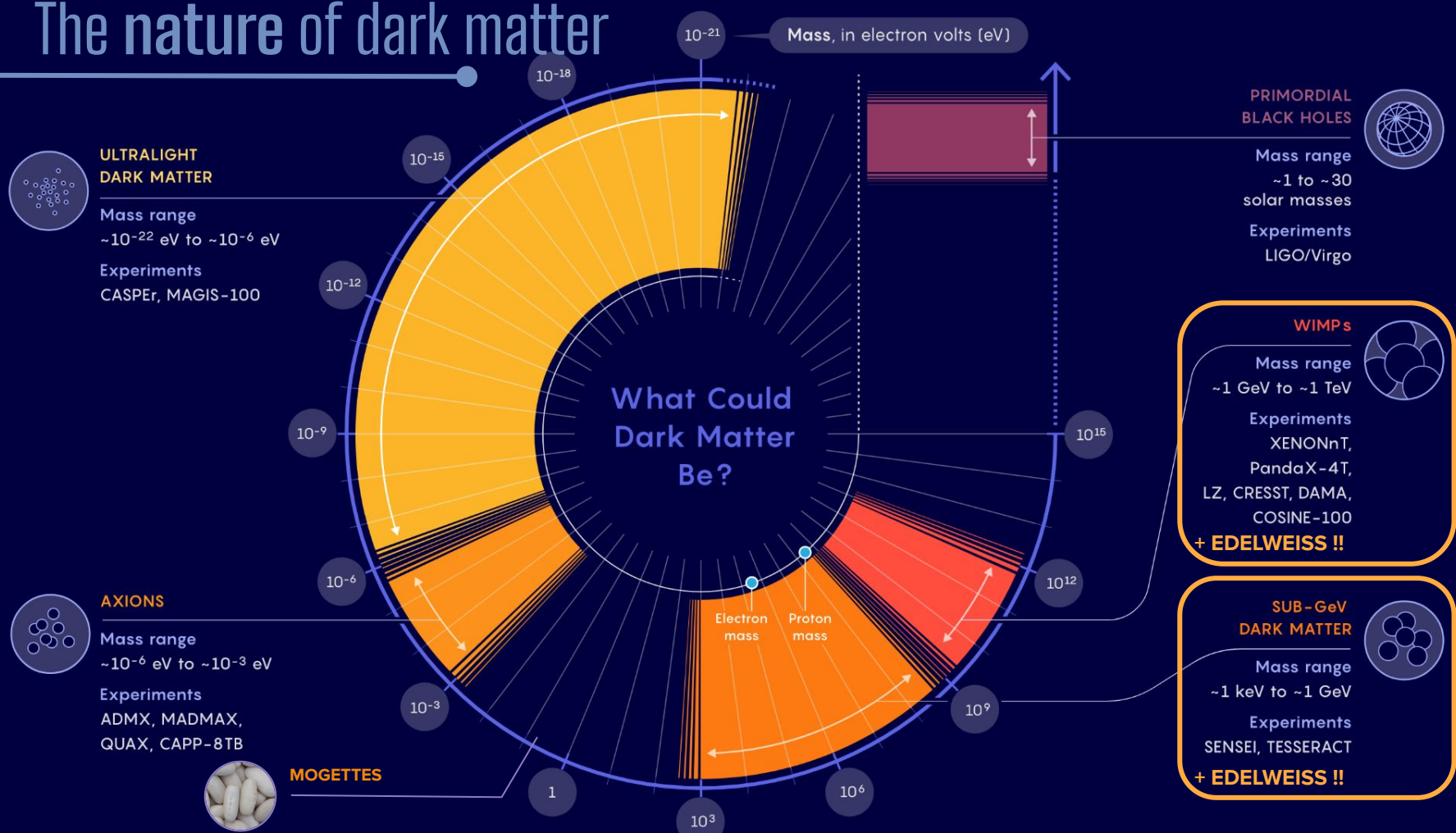
$v \propto 1/\sqrt{r}$

dark matter?

Galaxy rotation curve



# 01. The nature of dark matter

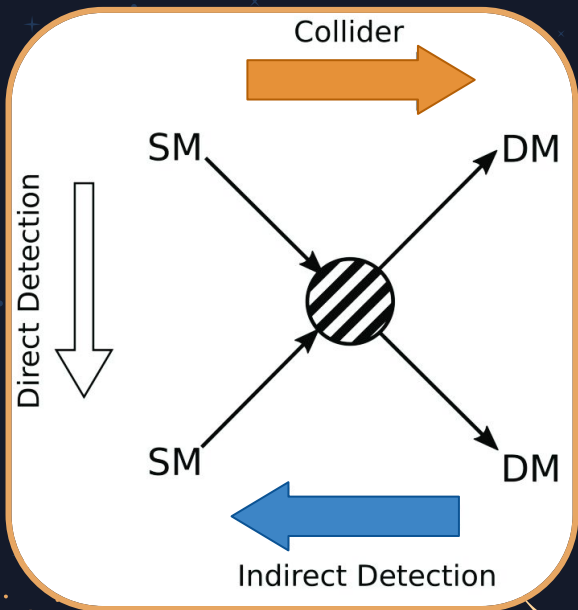


# 01. Ok, but, what do we know about dark matter ?

- Formation of large structures, “bottom-up” mechanism
  - **COLD**, hence **NON-RELATIVISTIC**
- N-body simulations + non-relativistic
  - **MASSIVE**
- Have not been detected yet
  - **WEAK INTERACTION** w/ baryonic matter
  - **NEUTRAL** in charge (EM interaction)
  - **NEUTRAL** in color (strong interaction)
- Gravitational effects visible in galaxies/galaxy clusters
  - **STABLE** at the scale of the Universe

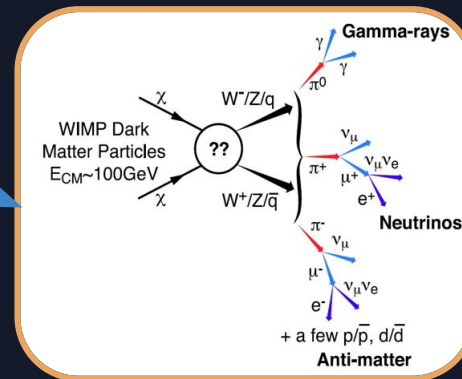
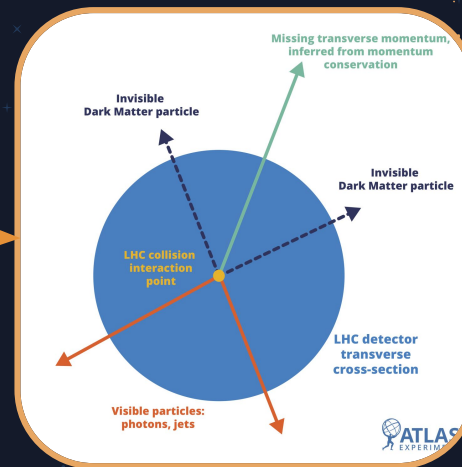
# 01. Detecting dark matter particles

- Production in collider
- Indirect detection
- Direct detection



Make it!

Break it!



02

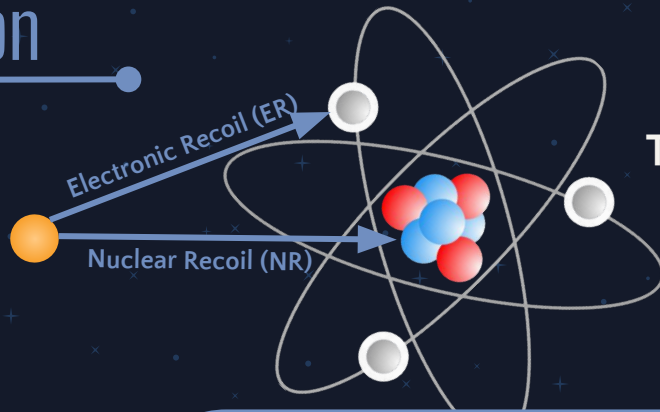
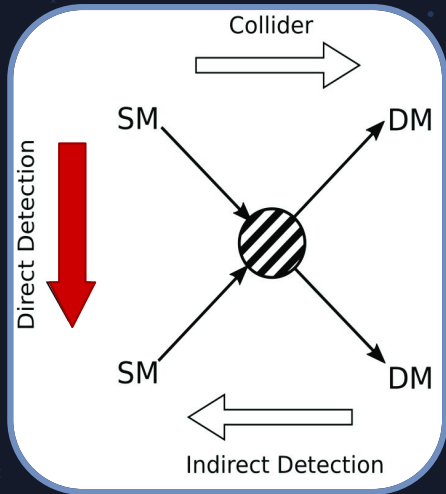
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EDELWEISS  
& direct detection





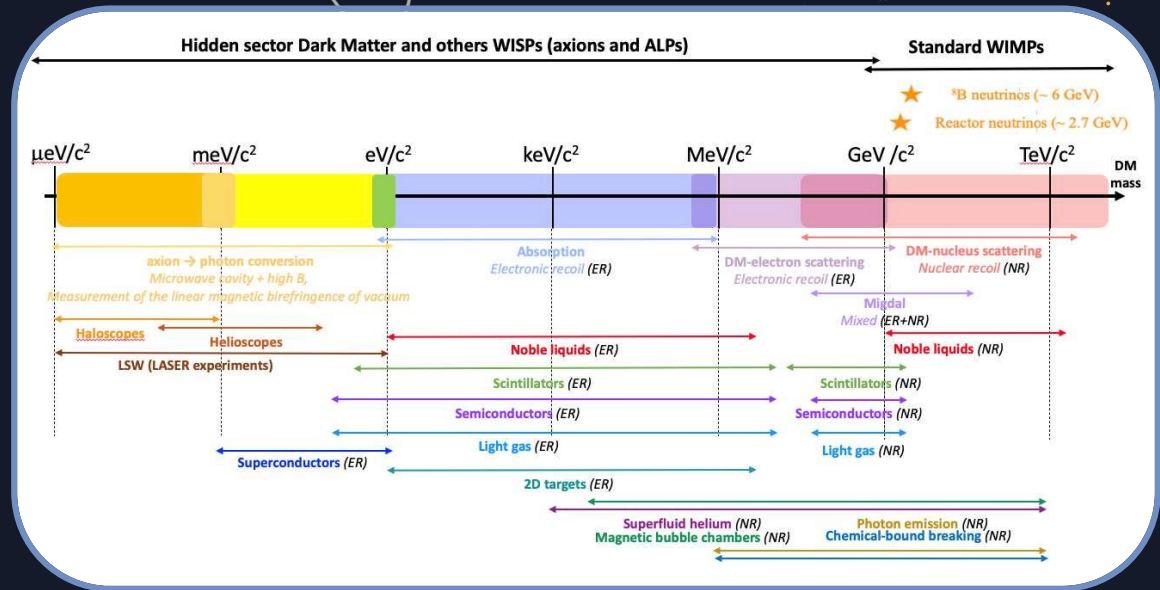
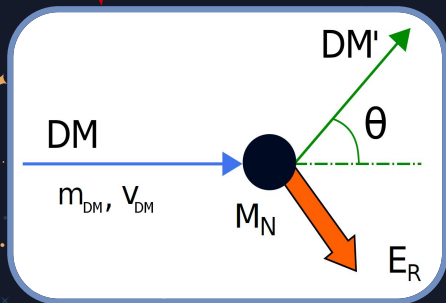
# 02. Direct detection



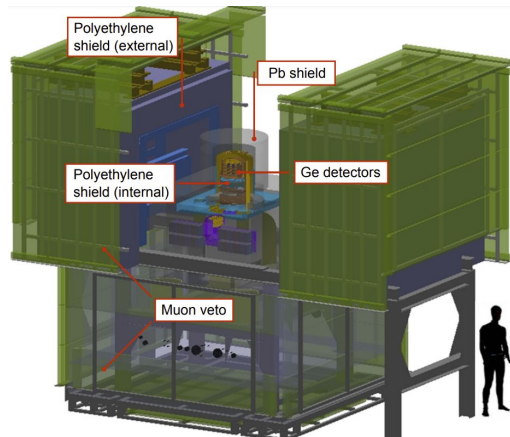
The interactions can produce :

- motion  $\rightarrow$  heat
- ionization  $\rightarrow$   $e^-/h^+$  pairs
- excitation  $\rightarrow$  scintillation

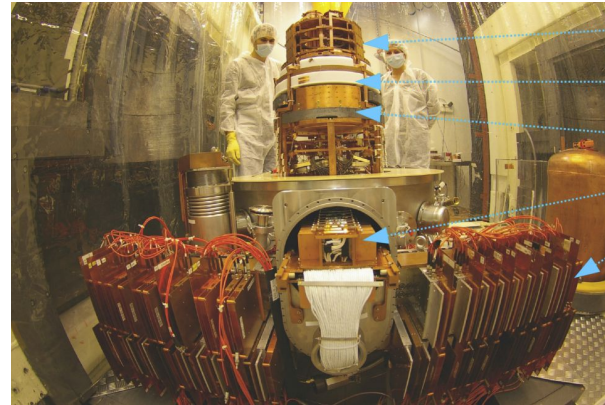
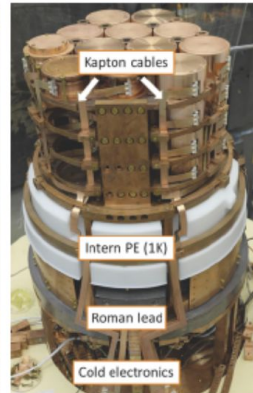
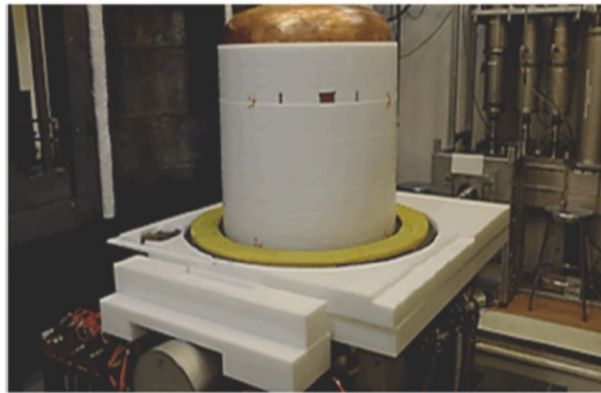
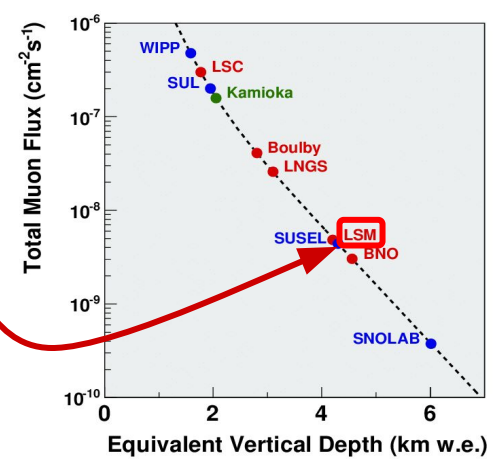
Shake it !



# 02. EDELWEISS-III setup at LSM



- LSM (*Laboratoire Souterrain de Modane*): deepest site in Europe, 4800 m.w.e,  $5 \mu\text{m}^2/\text{day}$
- Clean room + deradonized air
- PE and lead shielding
- Selection of radiopure materials
- Operated - 20mK
- Largest array (20kg) of cryo detectors for DM search!
- [IINST 12 P08010 \(2017\)](#)



- detector chamber
- internal PE shield at 1 K
- internal lead shield at 1 K
- FET boxes at 100 K
- Bolometer boxes at 300 K

EDW-III currently being dismantled after 15 years of good and loyal service 🕊️🕊️ :'(



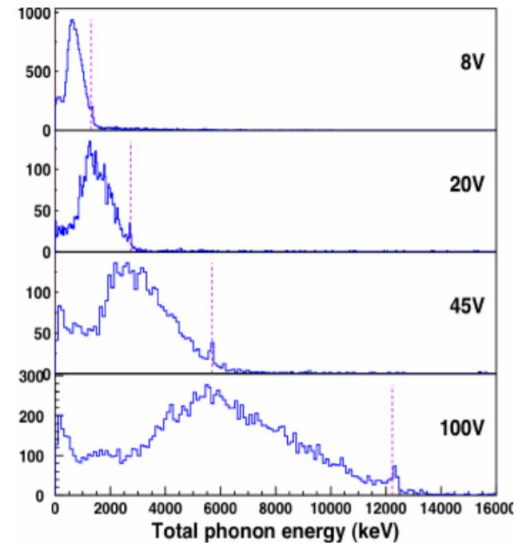
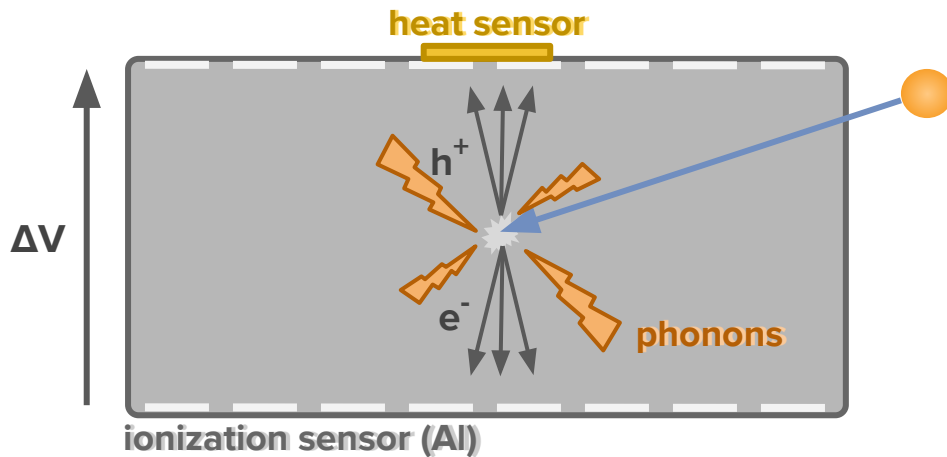
# 02. Direct detection at EDELWEISS

- Double measurement : **heat & ionization**
- Ge semiconductor cylindrical crystals (4 → 800g)
- Operated at cryogenic temperature -15mK

$$E_{heat} = E_{recoil} + E_{Luke} = E_{recoil} + N_p \Delta V$$

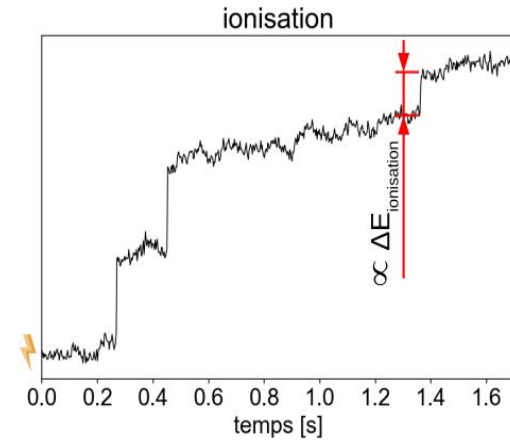
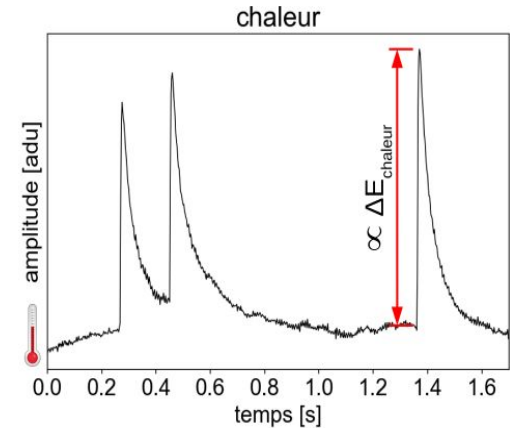
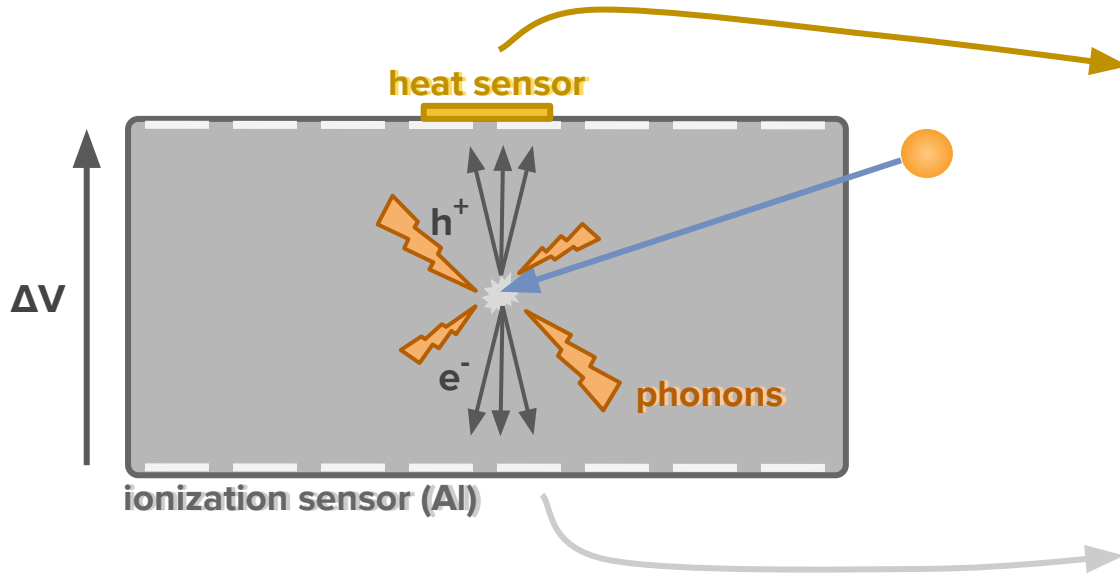
NTL boost

$$E_{heat} = E_{recoil} \left( 1 + \frac{\Delta V}{\epsilon} \right) \text{ particle-ID dependent}$$

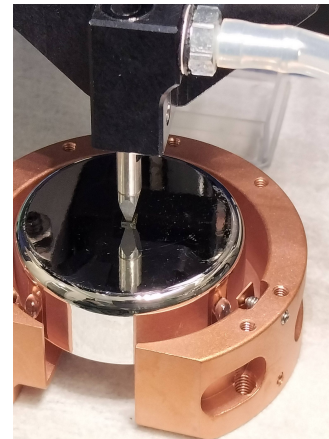
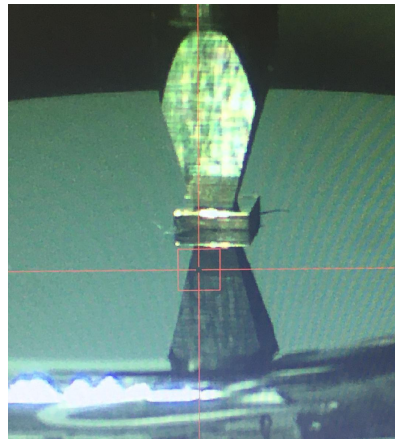
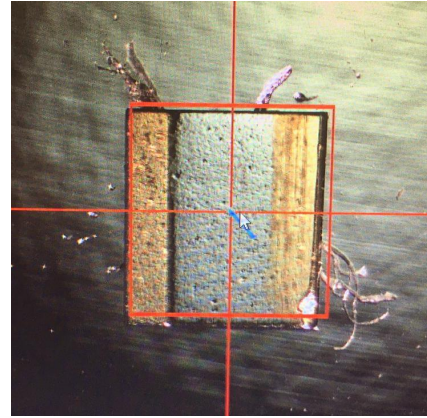
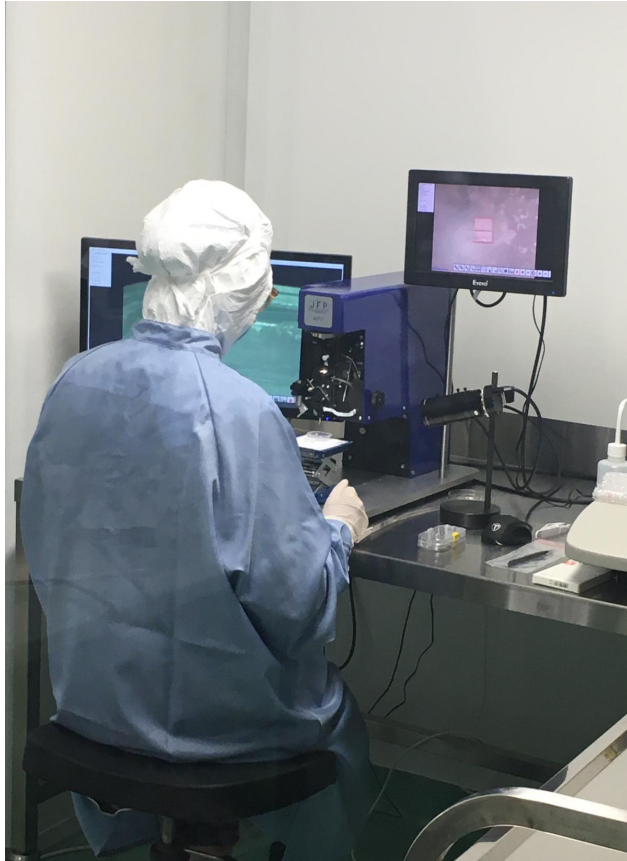


# 02. Direct detection at EDELWEISS

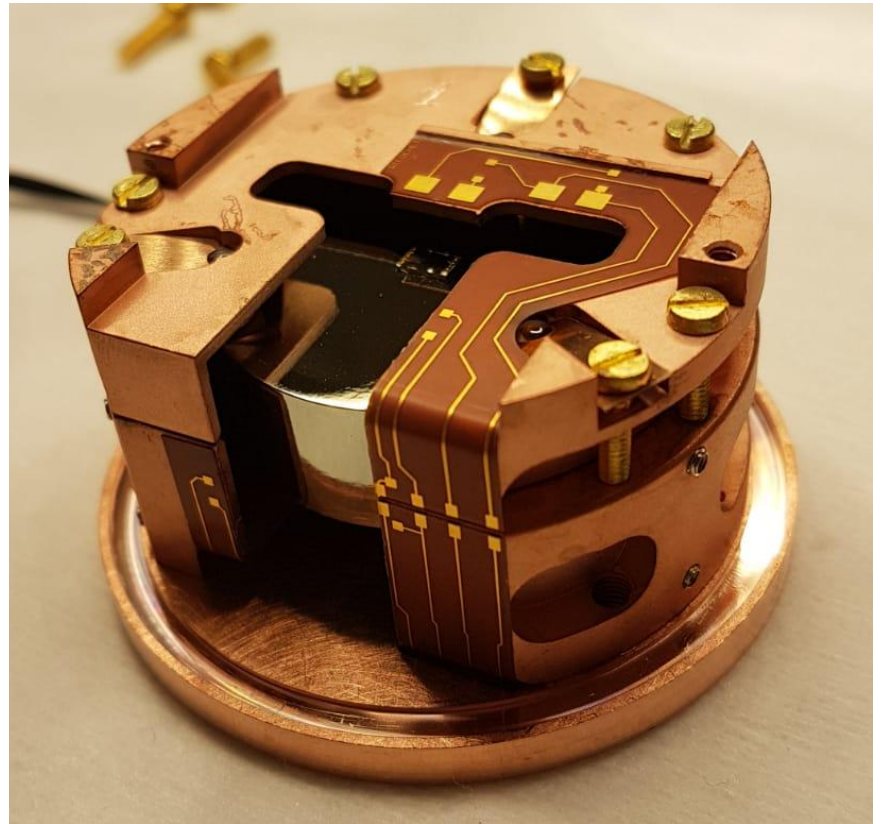
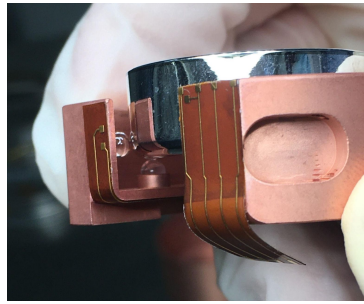
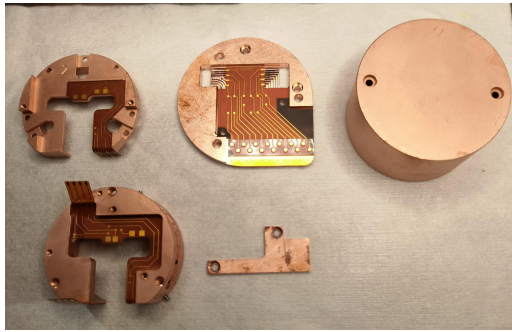
- Double measurement : **heat & ionization**
- Ge semiconductor cylindrical crystals (4 → 800g)
- Operated at cryogenic temperature -15mK



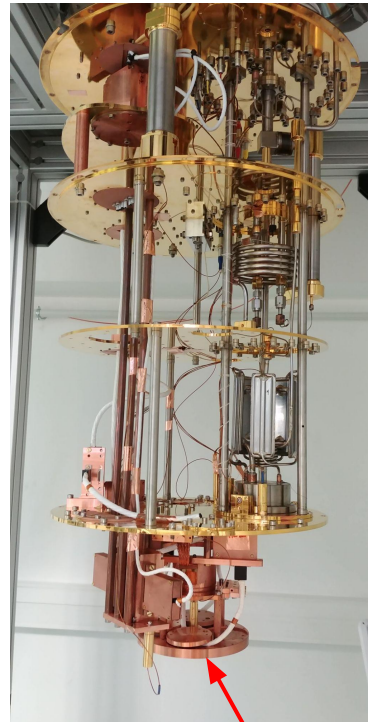
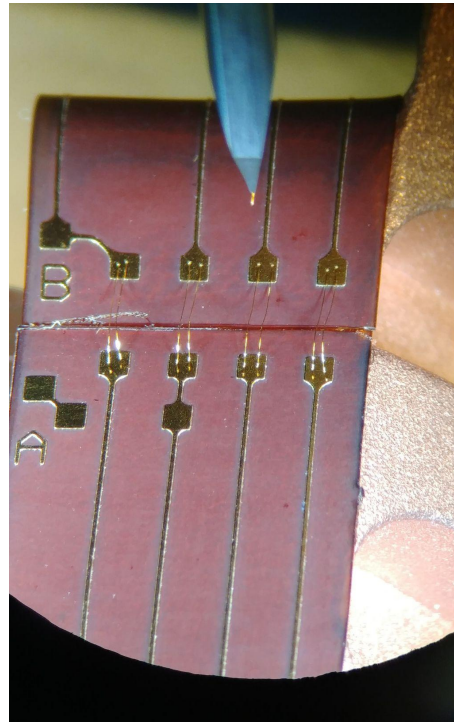
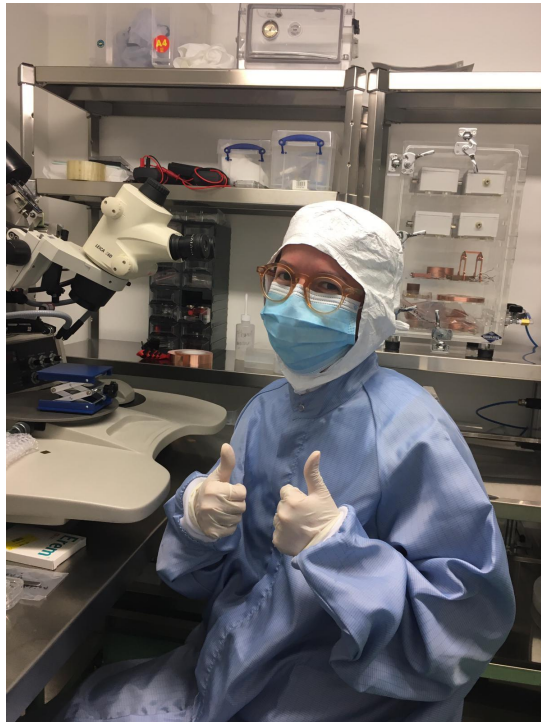
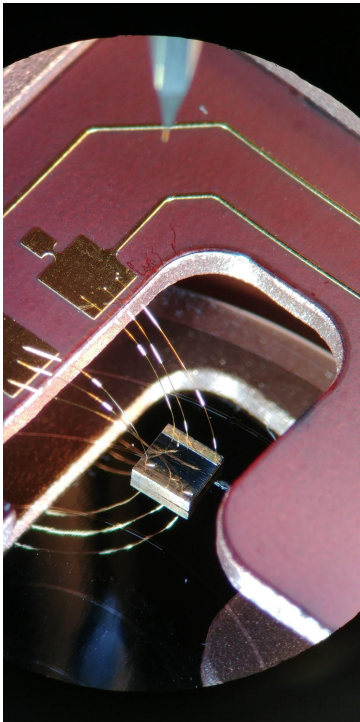
## 02. Getting detectors ready at IP2I, *gluing*



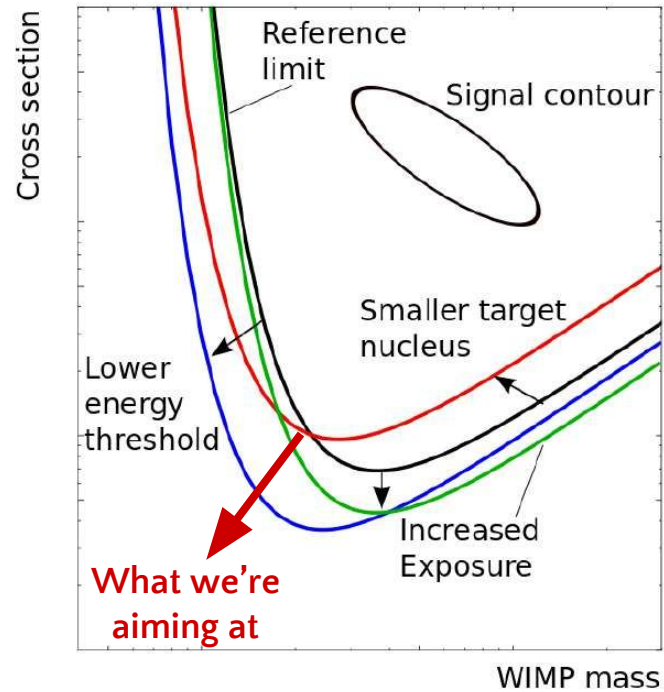
## 02. Getting detectors ready at IP2I, *setting-up*



## 02. Getting detectors ready at IP2I, *bonding*



## 02. Some of EDW results

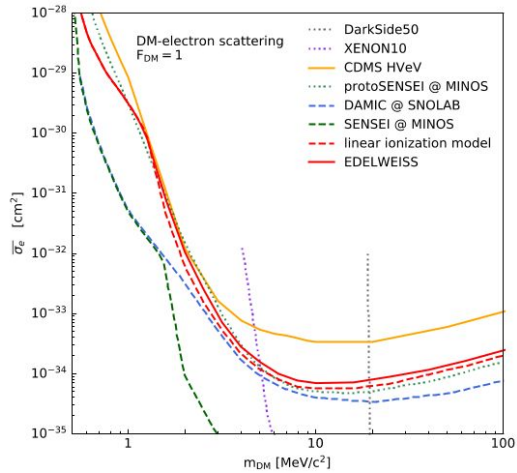


[Phys. Rev. Lett. 125, 141301 \(2020\)](#)

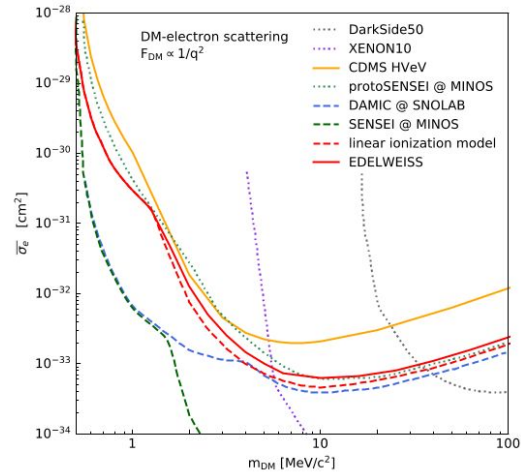


# 02. Some of EDW results

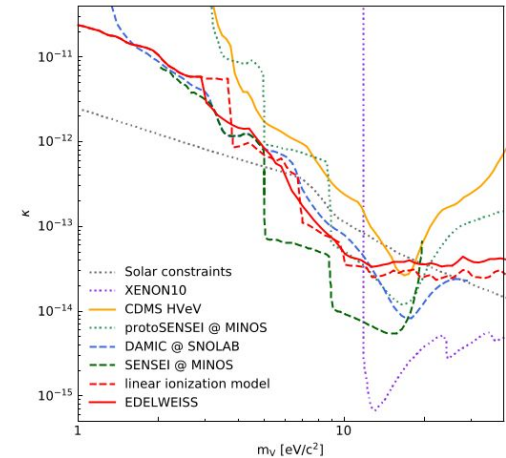
## DMES with heavy mediator



## DMES with light mediator



## DP

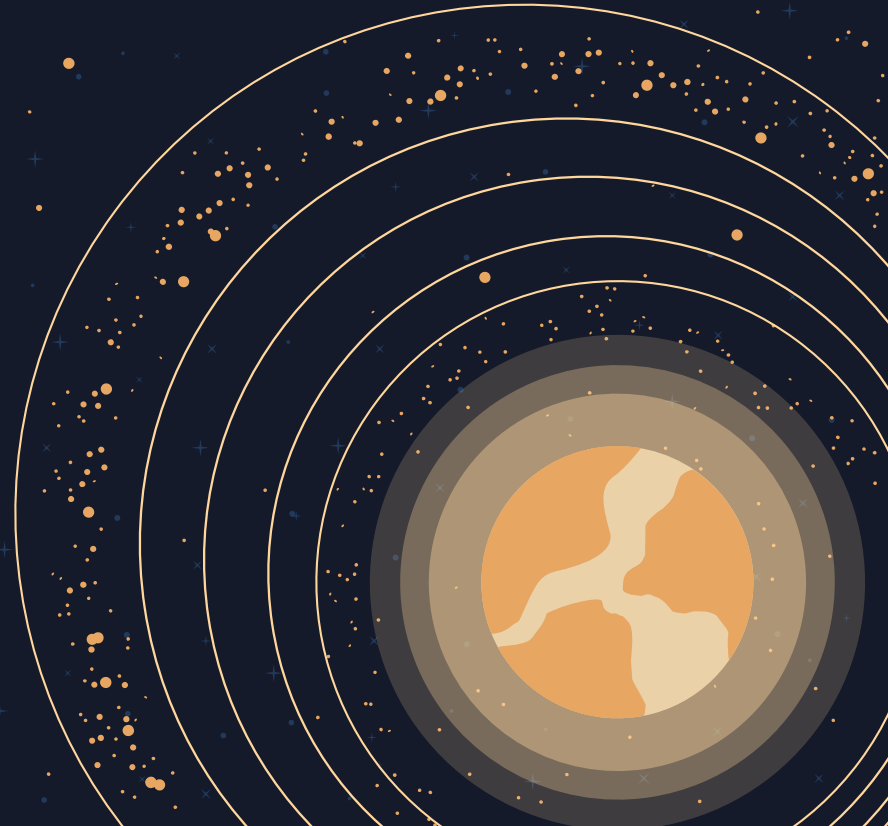


[Phys. Rev. Lett. 125, 141301 \(2020\)](#)

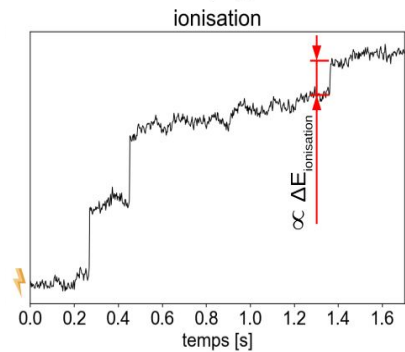
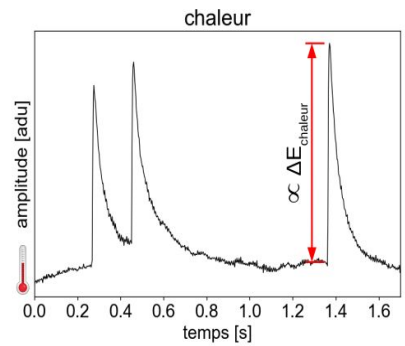
# 03

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Our biggest  
challenge

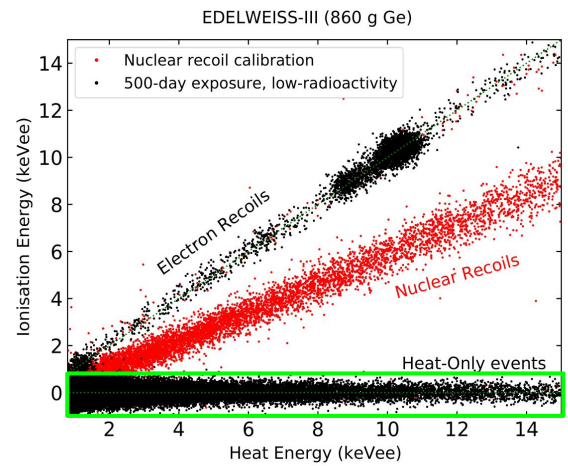
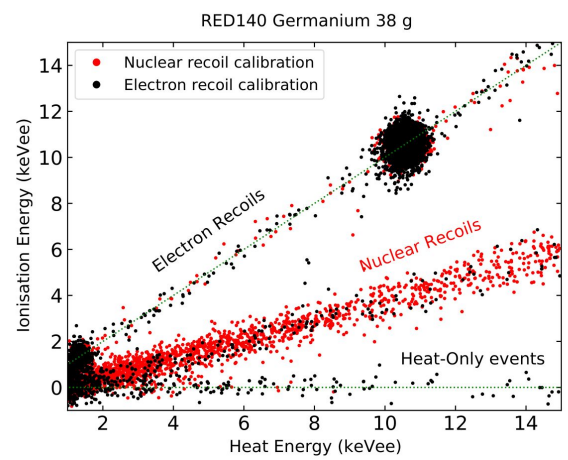
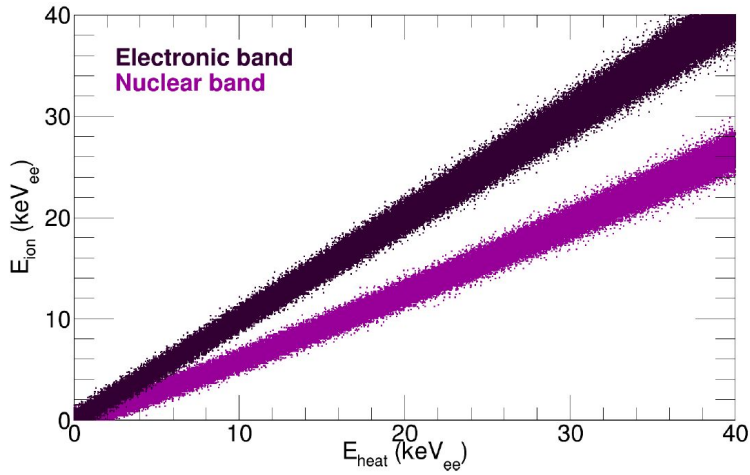
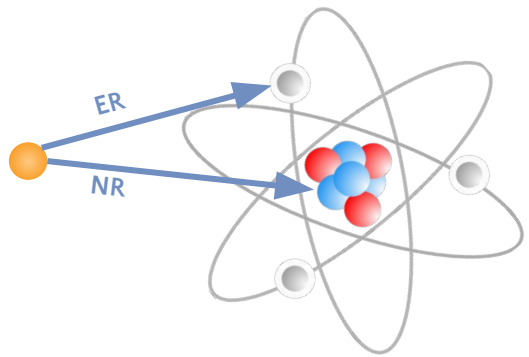


# 03. As I said, no dark matter yet...



Quenching :

$$\frac{\Delta E_{\text{ion}}}{\Delta E_{\text{heat}}} = Q$$



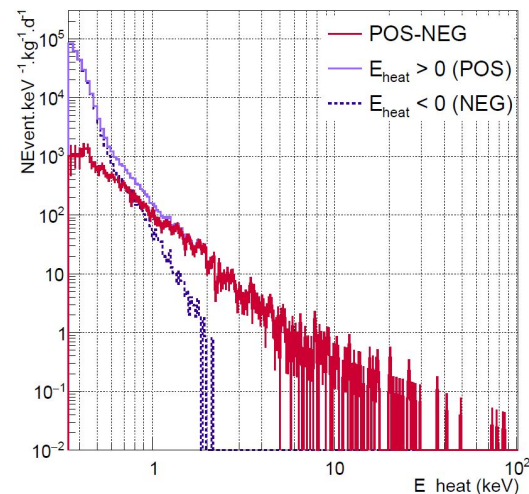
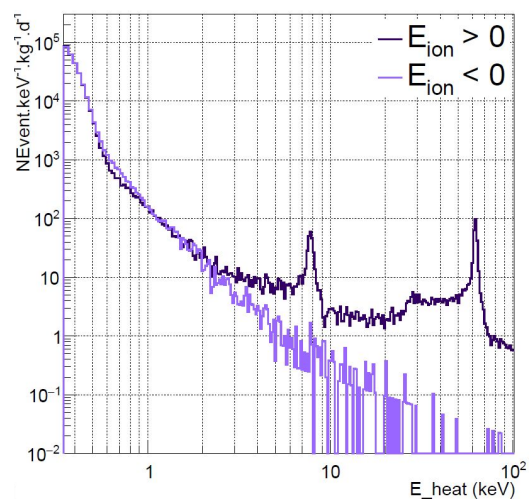
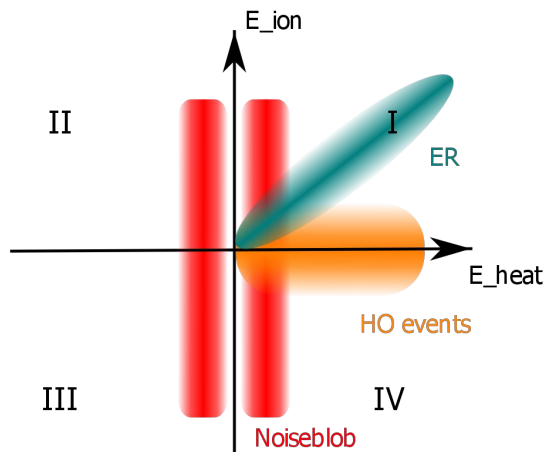
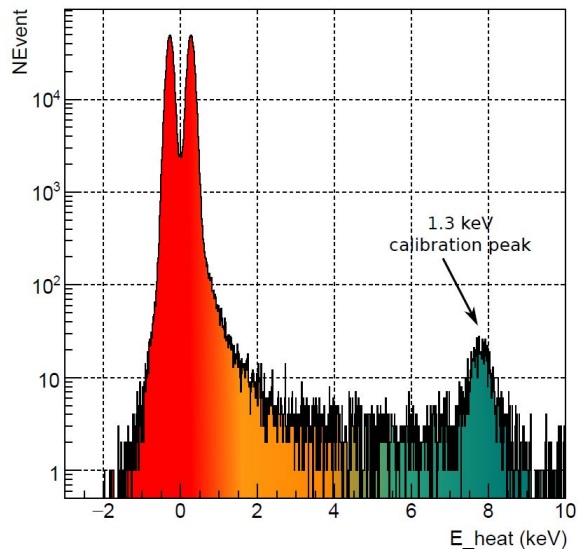
# 03. We don't know, Jim.

But we do know that,

→ no production of charges

→  $E_{\text{ion}} = 0$  eV!

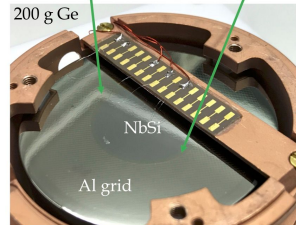
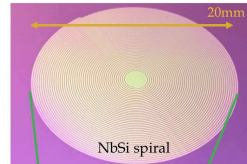
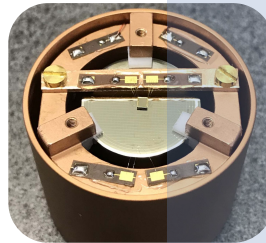
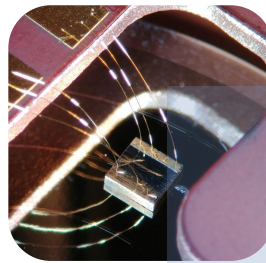
→ Isolate HO!



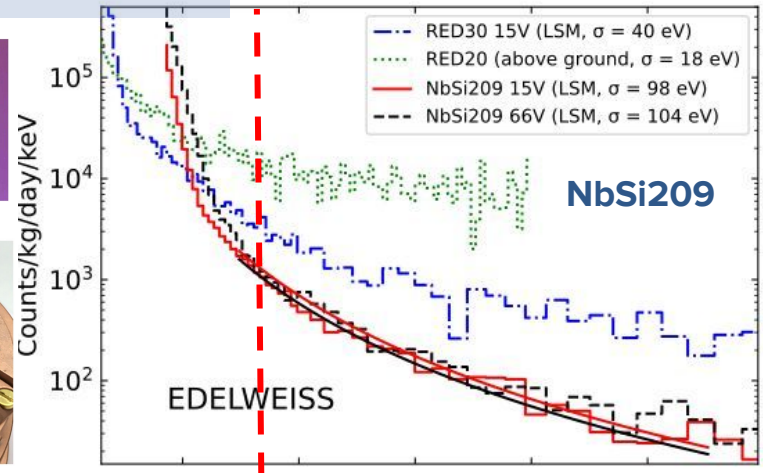
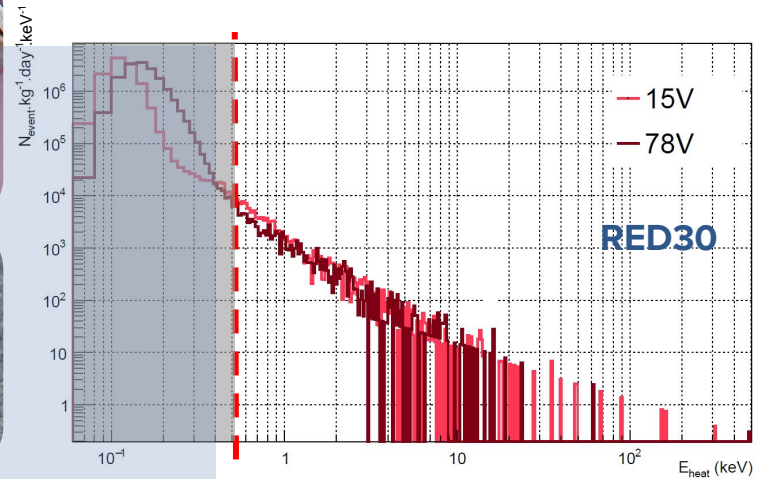
# 03. We don't know, Jim.

But we do know that,

- no production of charges
- not affected by NTL boost !



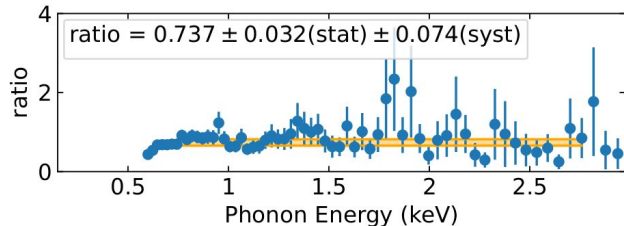
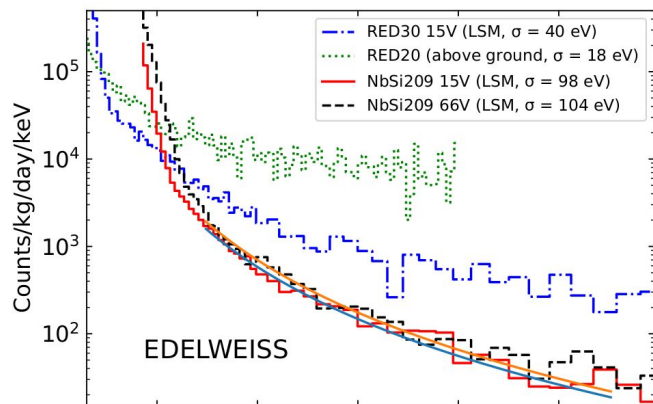
→ = DRU (Daily Rate Unit)



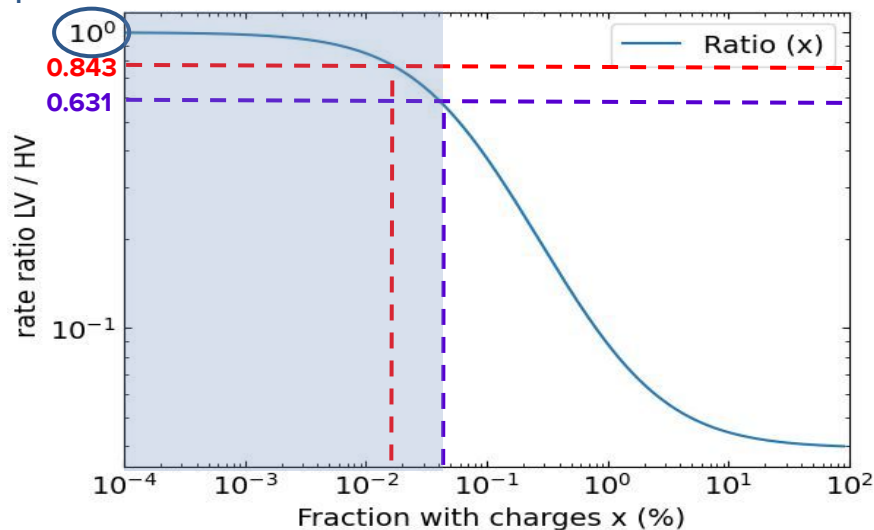
# 03. We don't know, Jim.

But we do know that,

- no production of charges
- not affected by NTL boost !



perfect ratio



- Worst case scenario (ratio = 0.631) :
- fraction of events producing charges = 0.04%.
- we managed to create a HO spectrum !
- [Phys. Rev. D 106, 062004 \(2022\)](#)



04

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A glimpse of  
hope ?

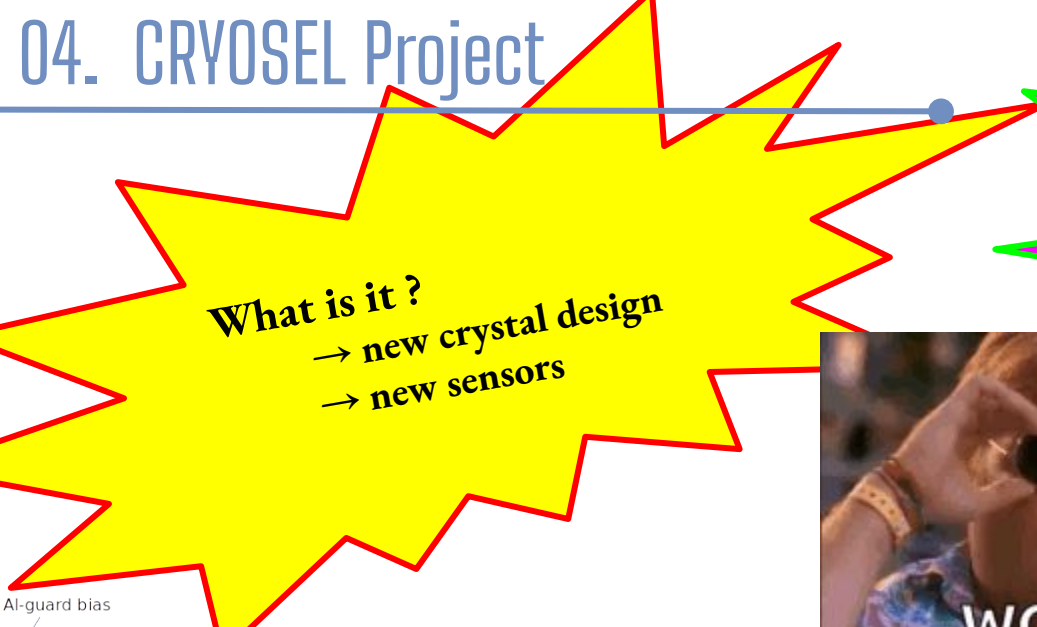


What if...

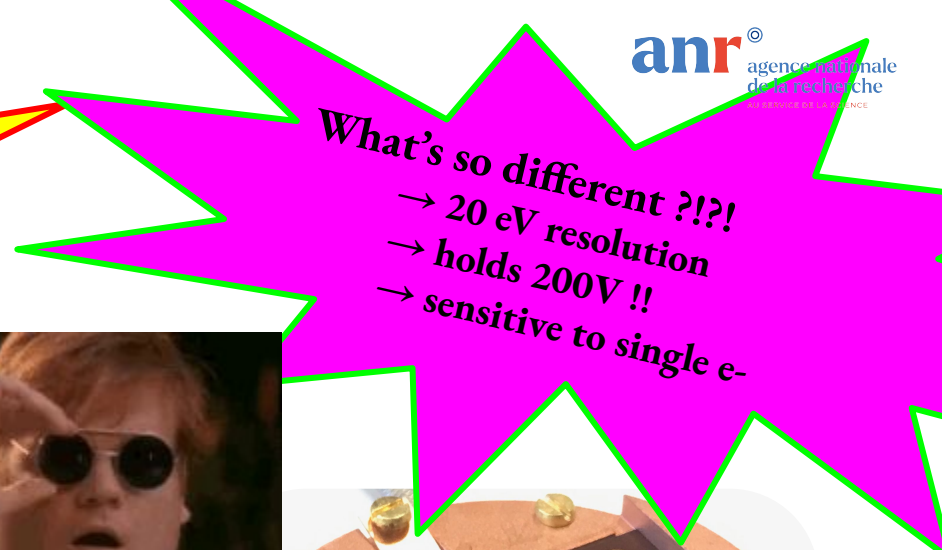
We could completely  
get rid of this  
population ???







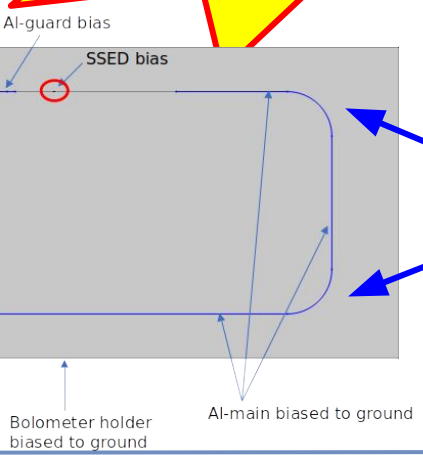
**What is it ?**  
→ new crystal design  
→ new sensors



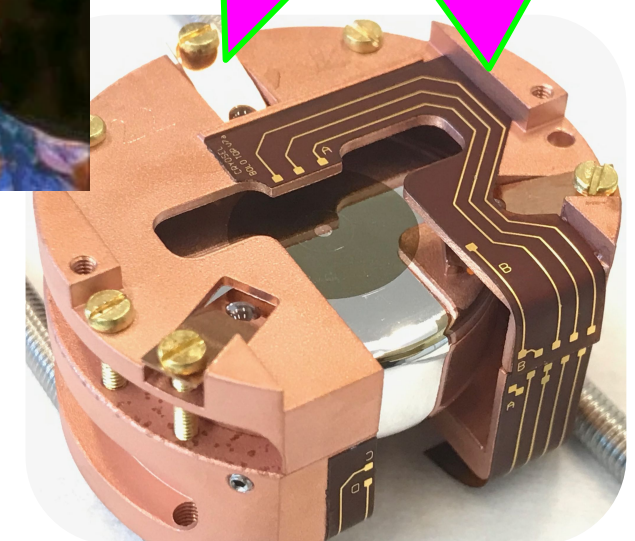
**What's so different ???**  
→ 20 eV resolution  
→ holds 200V !!  
→ sensitive to single e-



WOW

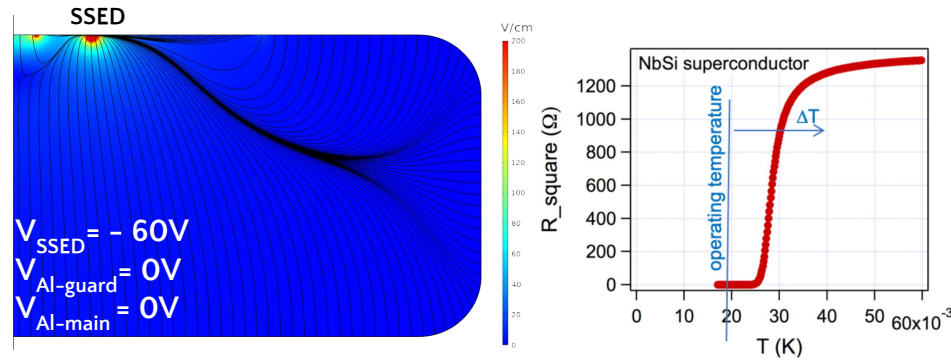


**double rounded shape !**

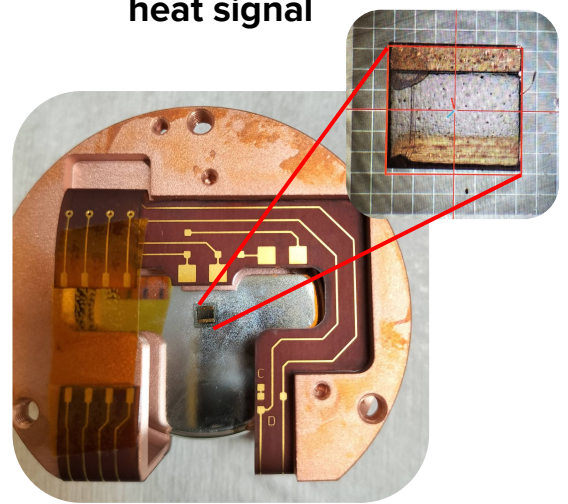


# 04. CRYOSEL Project

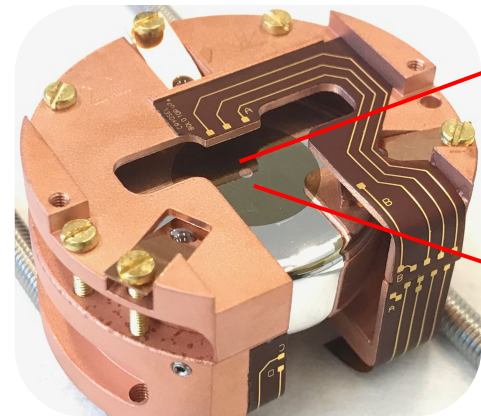
- 40g Ge detector,  $\sigma_{\text{phonon}} = 20 \text{ eV}$ , 200 V bias,
- new sensor design : **SSED**  
“Superconducting Single Electron Device”



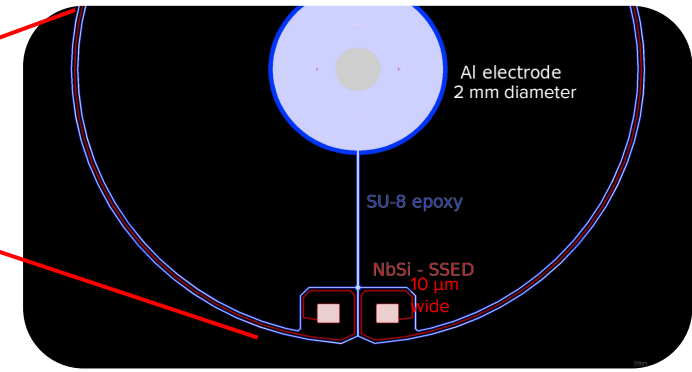
heat signal



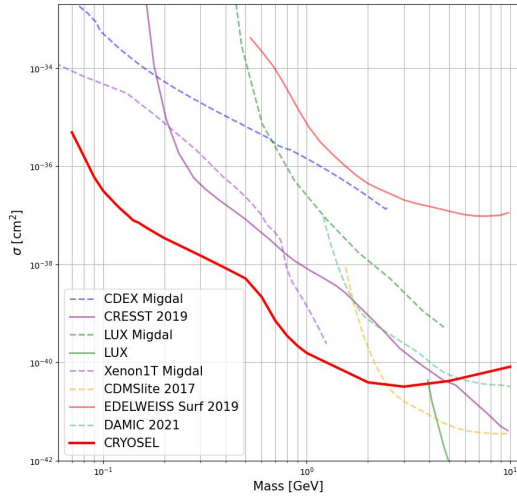
ionization signal



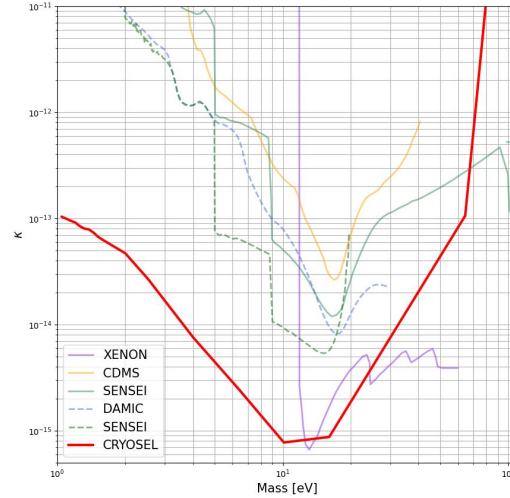
SSED signal



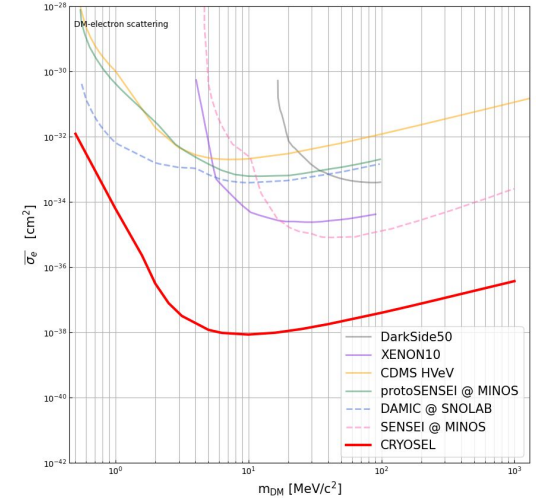
## WIMP (1 kg.d)



## DP (1 kg.d)

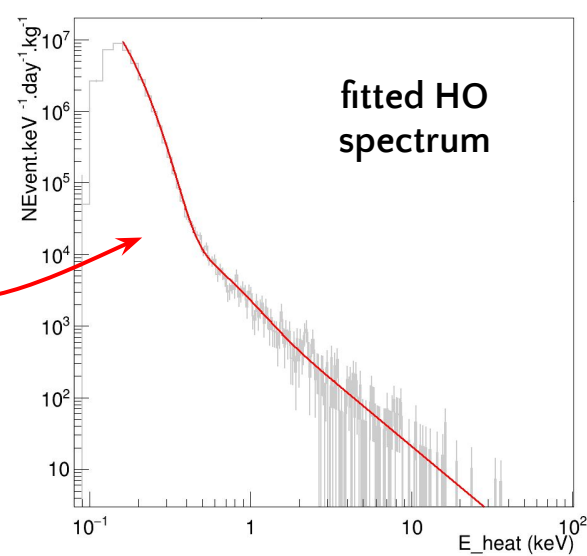


## DMES (1 kg.d)

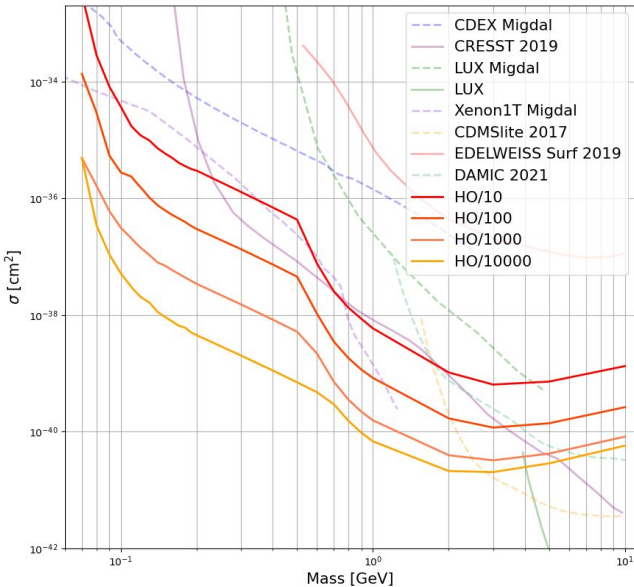


# 04. Modelling HO

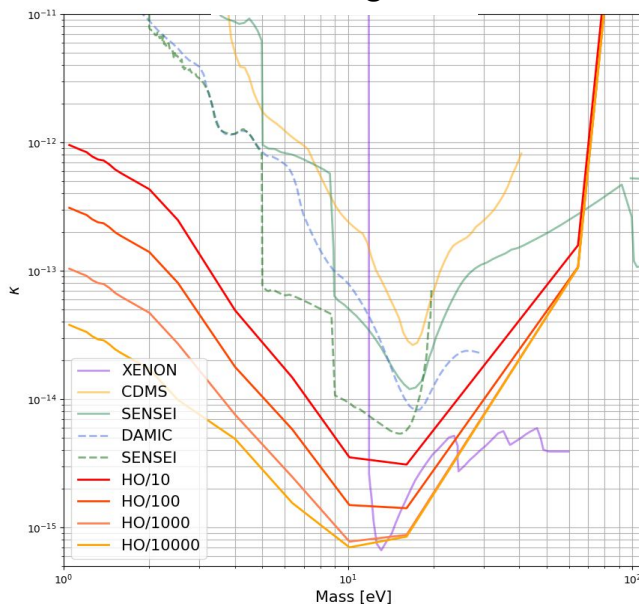
From isolated HO spectrum :  
 $f(E_r) = p_0 * e^{p_1 * E_r} + p_2 * e^{p_3 * E_r} + p_4 * E_r^{p_5}$



WIMP (1 kg.d)

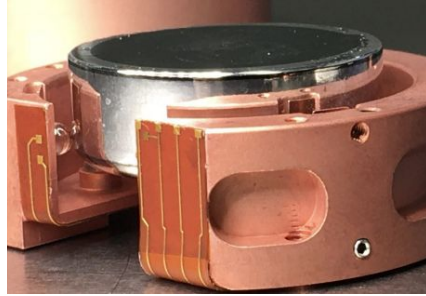


DP (1 kg.d)

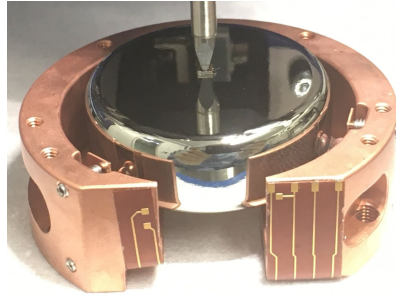


& into the simulation program

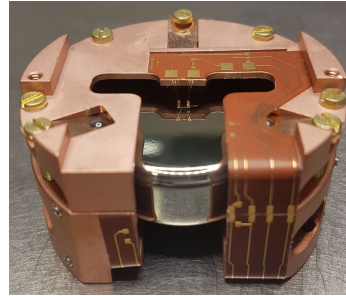
# 04. CRYOSEL detectors



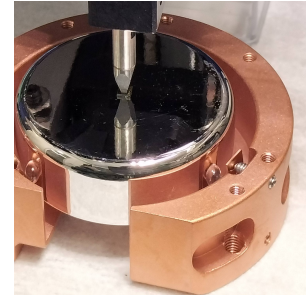
CRYO10



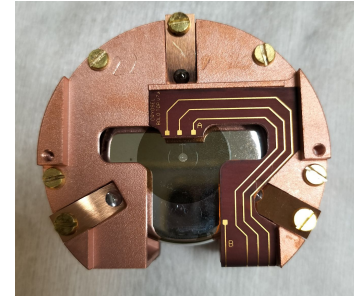
CRYO20



CRYO30



CRYO40



CRYO50

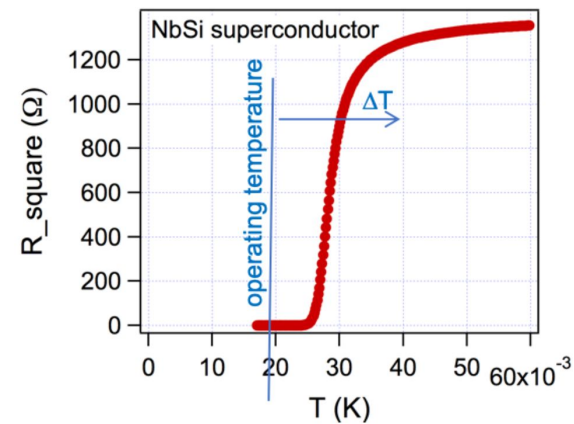
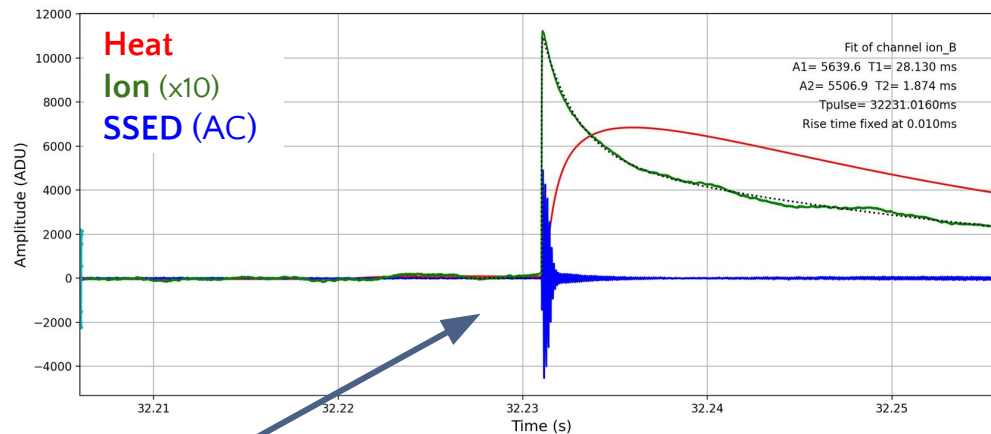
Test design & charge  
collection w/ Al  
electrodes

Test different *crystal*  
design

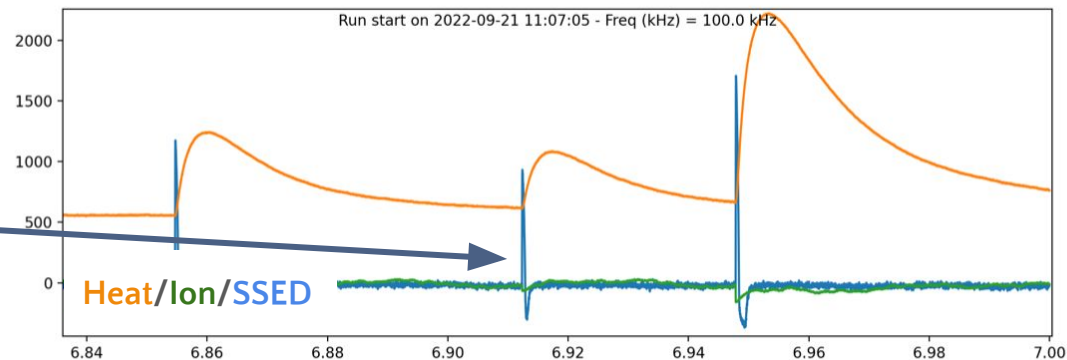
Test different *electrodes*  
design

# 04. CRYO50 first preliminary results

→ 30mn, T=16.4mK, V=-60V



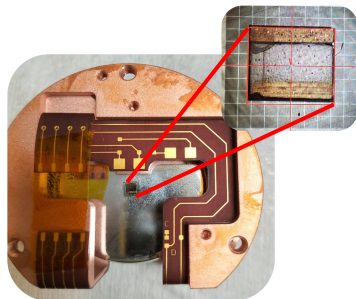
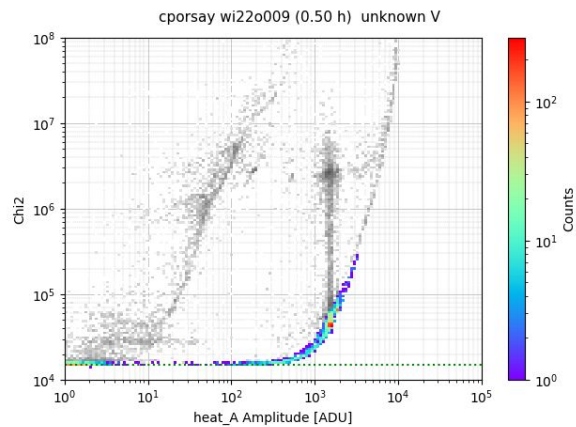
SSED signal in coincidence with heat & ion !!



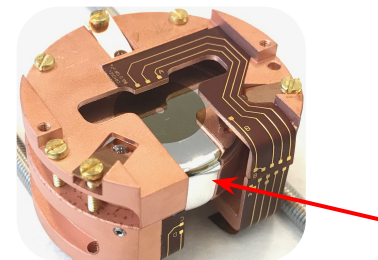
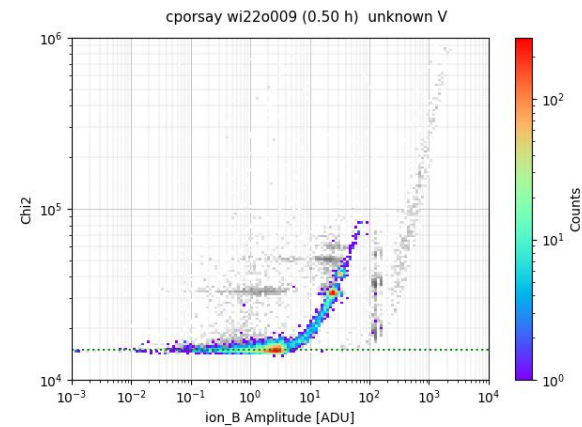
# 04. CRYO50 first preliminary results


→ 30mn,  $T=16.4\text{mK}$ ,  $V=-60\text{V}$

## heat channel



## ionization channel B $V = 0\text{V}$ (collects $e^-$ )





# Conclusion & Perspectives



# Conclusion & Perspectives

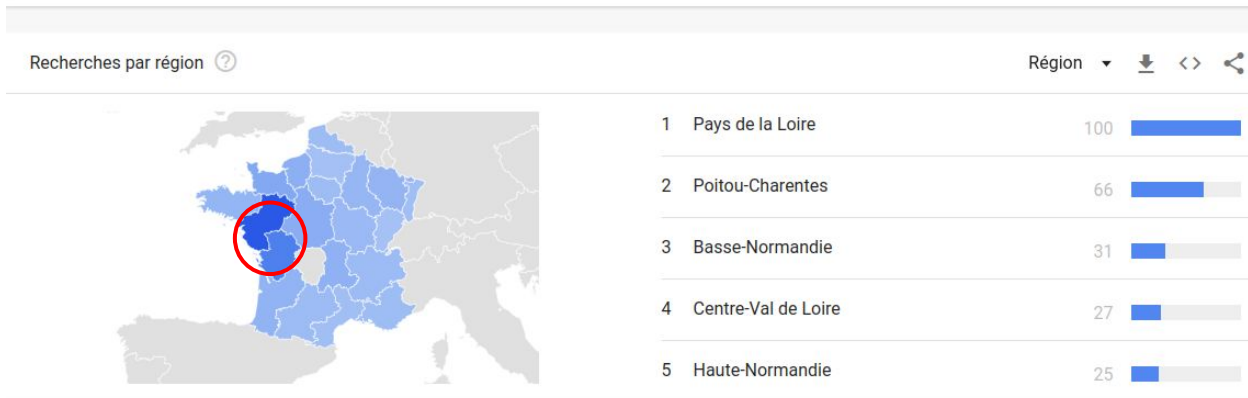
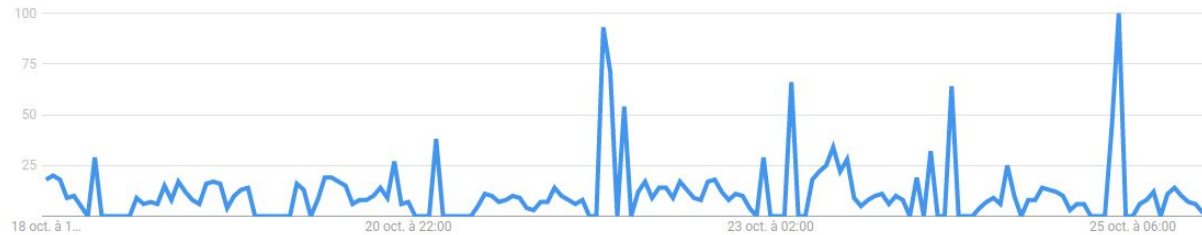
- More and more knowledge about HO bkg (*for lack of other things...*)
- Really exciting perspectives for CRYOSEL !
  - First transitions of SSED, very promising technology !
- Need to study detector behaviour in details
  - Problem with template ?
  - Strange ion signal
  - Look at the SSED signal !!
    - Any (non-)coincidence with the other signals ?
    - Towards no heat-only events ??
- New design prototype ?
- And so many other things...



→ Installation at LSM w/  
BINGO in 2023 (hopefully)



# Giving mogette the fame it deserves ✨



Thank you for your attention !