Preliminary measurement of the germanium ionization yield

First studies of the new silicon crystal detectors

Ricochet experiment

PhD day – 23/04/2026

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About Quenching (ionization yield)

Goal of the study → Measure the **Quenching on Germanium**

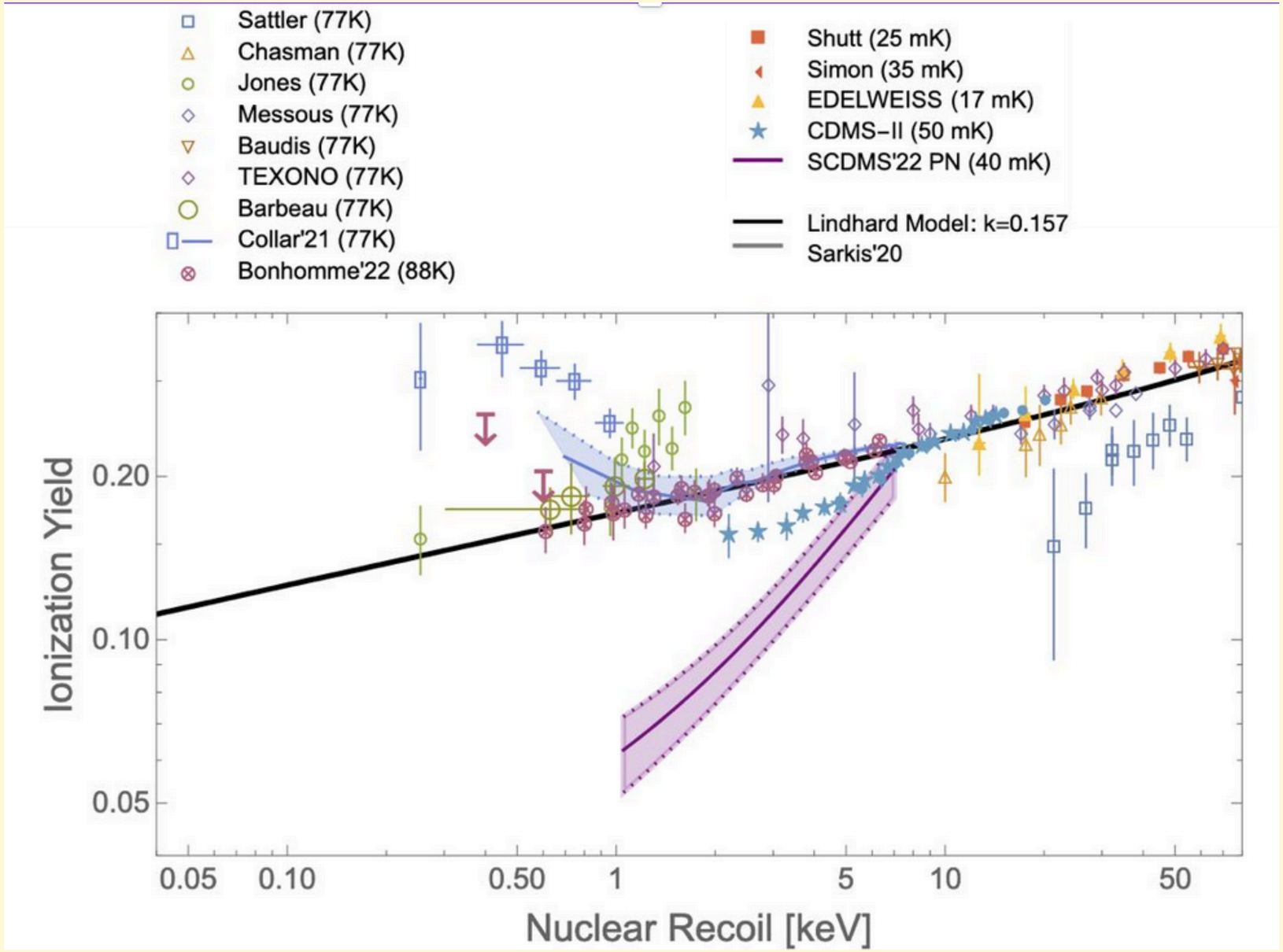
$$Q_{NR} = \frac{E_{i,NR}}{E_{r,NR}}$$

Strategy → we have **Ei** and **Eh** ⇨ we have **Er** ⇨ we have **Q**!

Method →
We use **RUN014 Cf data** (a lot of NR)
We do **Er slices** and look at the data histogram on each slice

Be careful of... →
We must take into account:
Heat Only (HO), Nuclear Recoils (NR), Surface events (betas), multiple scattering!

State of the art of the Quenching measurement



Two approaches

1. **Analytical model**

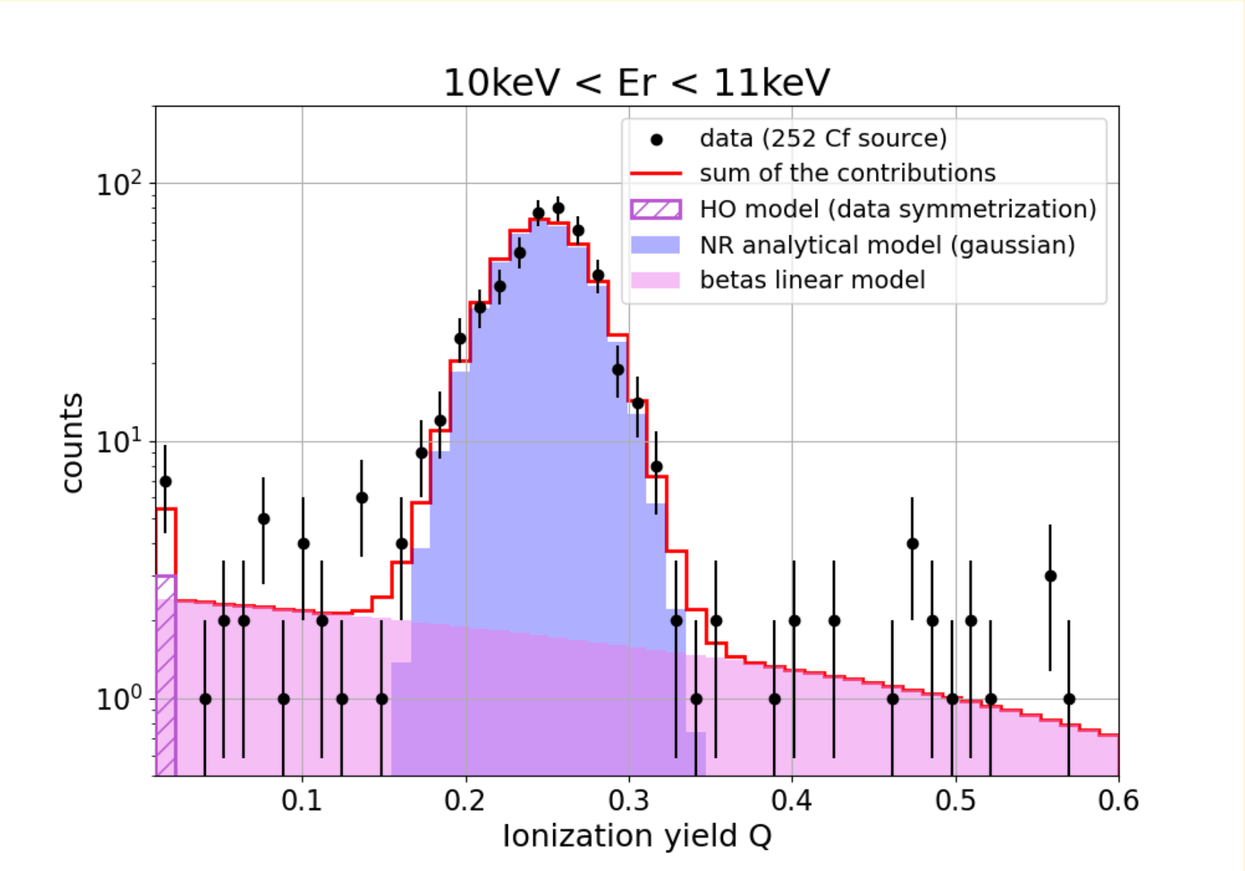
Summing the **contributions** (HO,NR,betas)

2. **Model running simulations**

Using an algorithm called **MPS** developed by the group

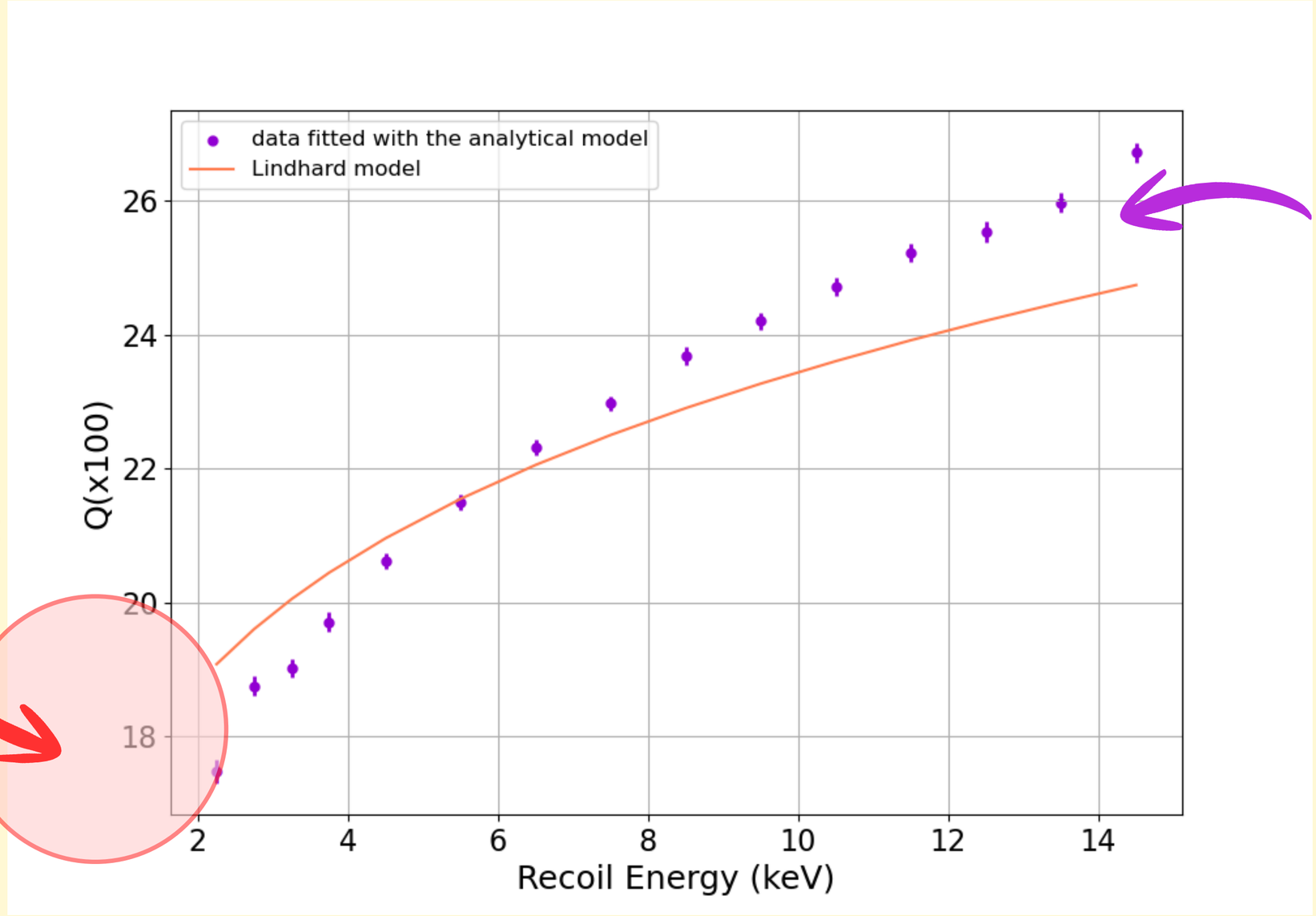
Analytical model

$$N_{tot} = Gauss(A_G, \mu, \sigma) + HO + Lin(A_L, \alpha)$$



→ Minimizing a Poissonian **Likelihood**, we find the **Q value that fits better the data**

Q vs Er



Results include only statistical uncertainties

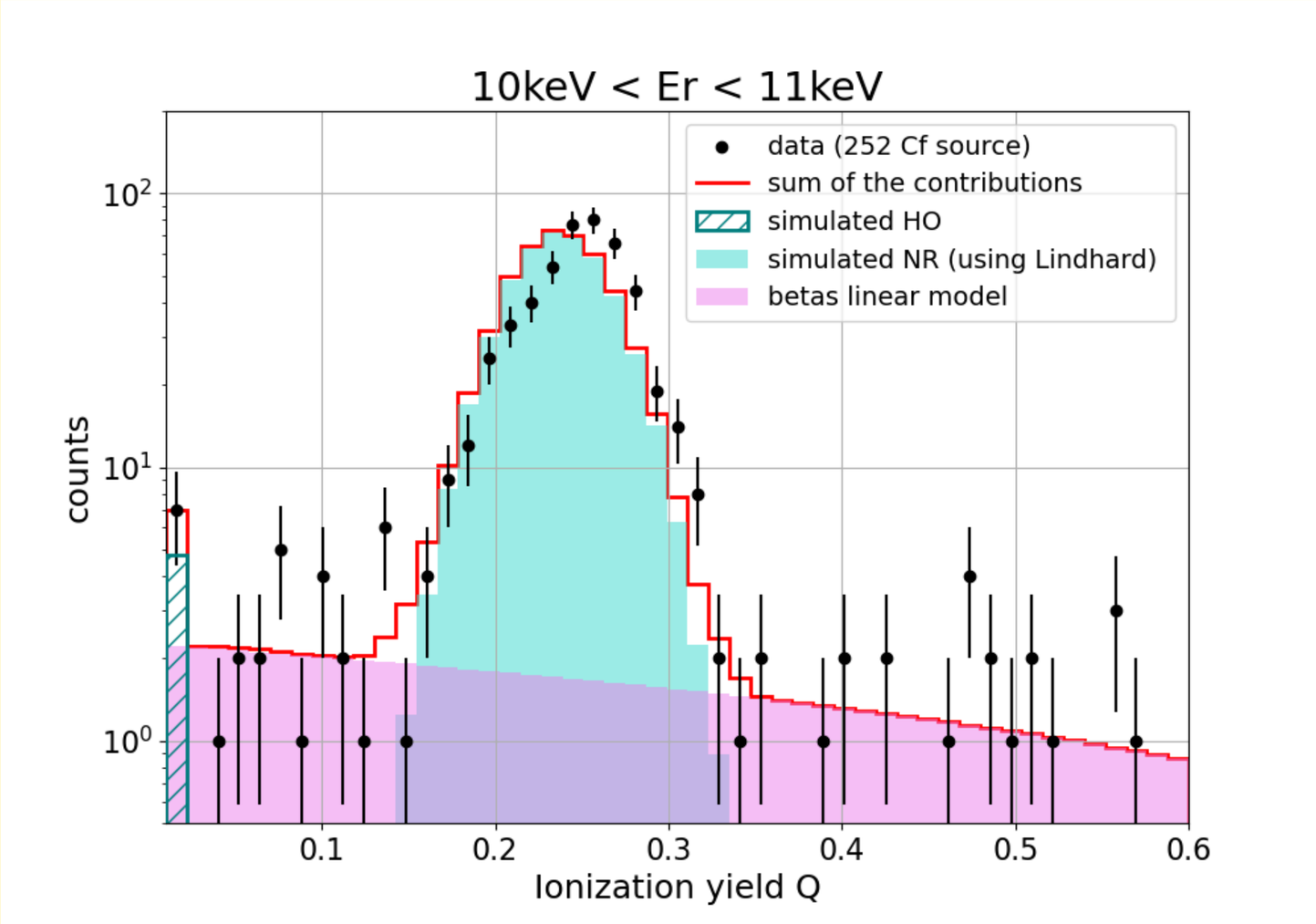
0-2 keV region: ongoing study

MPS model running simulations

- We **simulate events following Lindhard** model
- We make a **Q scan** in order to find **the best fitting Q value**
- We may include **multiple scattering**

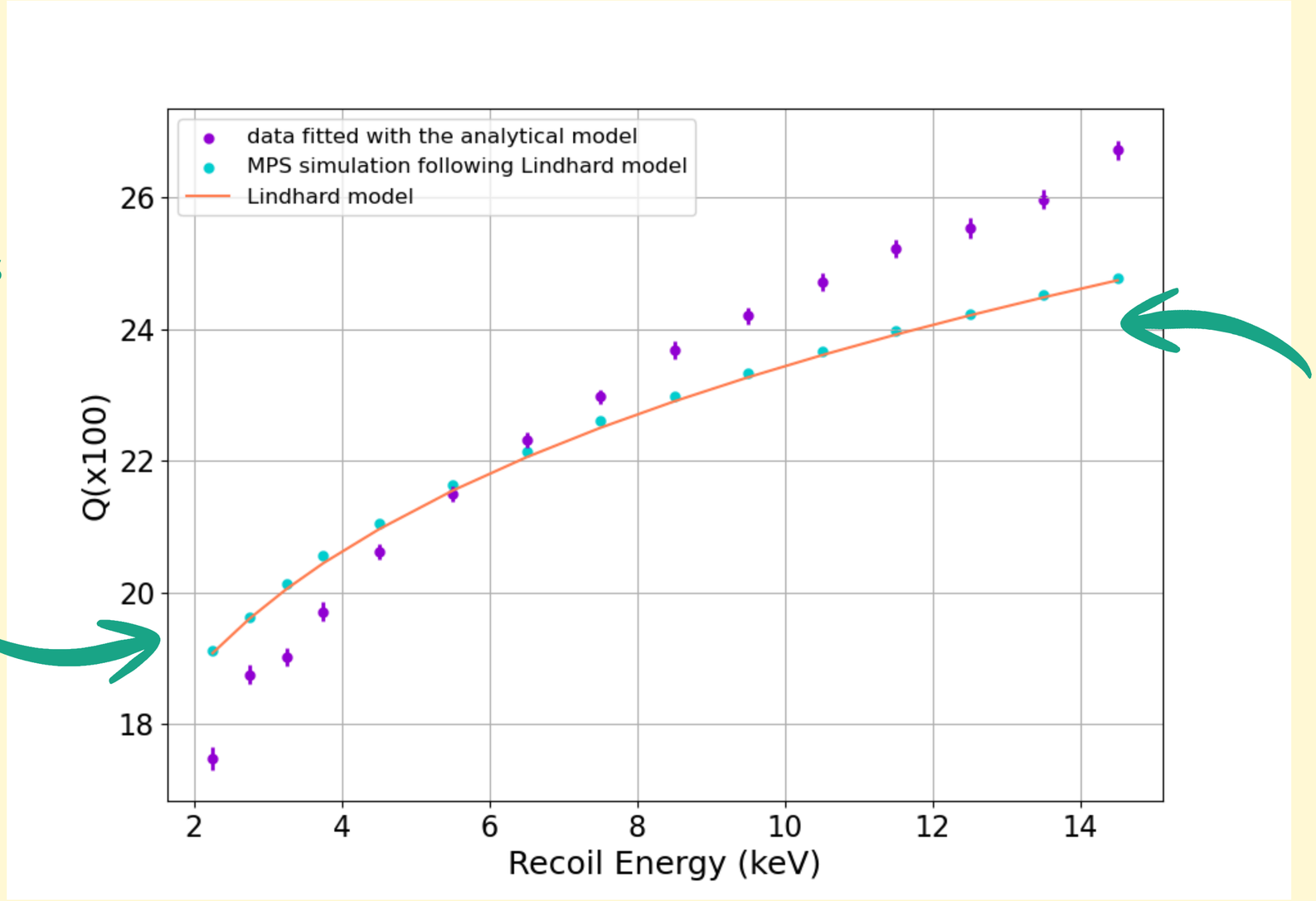
MPS simulations following Lindhard

simulated NR, simulated HO, linear model for betas



Q vs Er

The simulated events follow the Lindhard model: **there is no reconstruction bias at these recoil energies**



MPS simulation with Lindhard are **not fitting well the data**

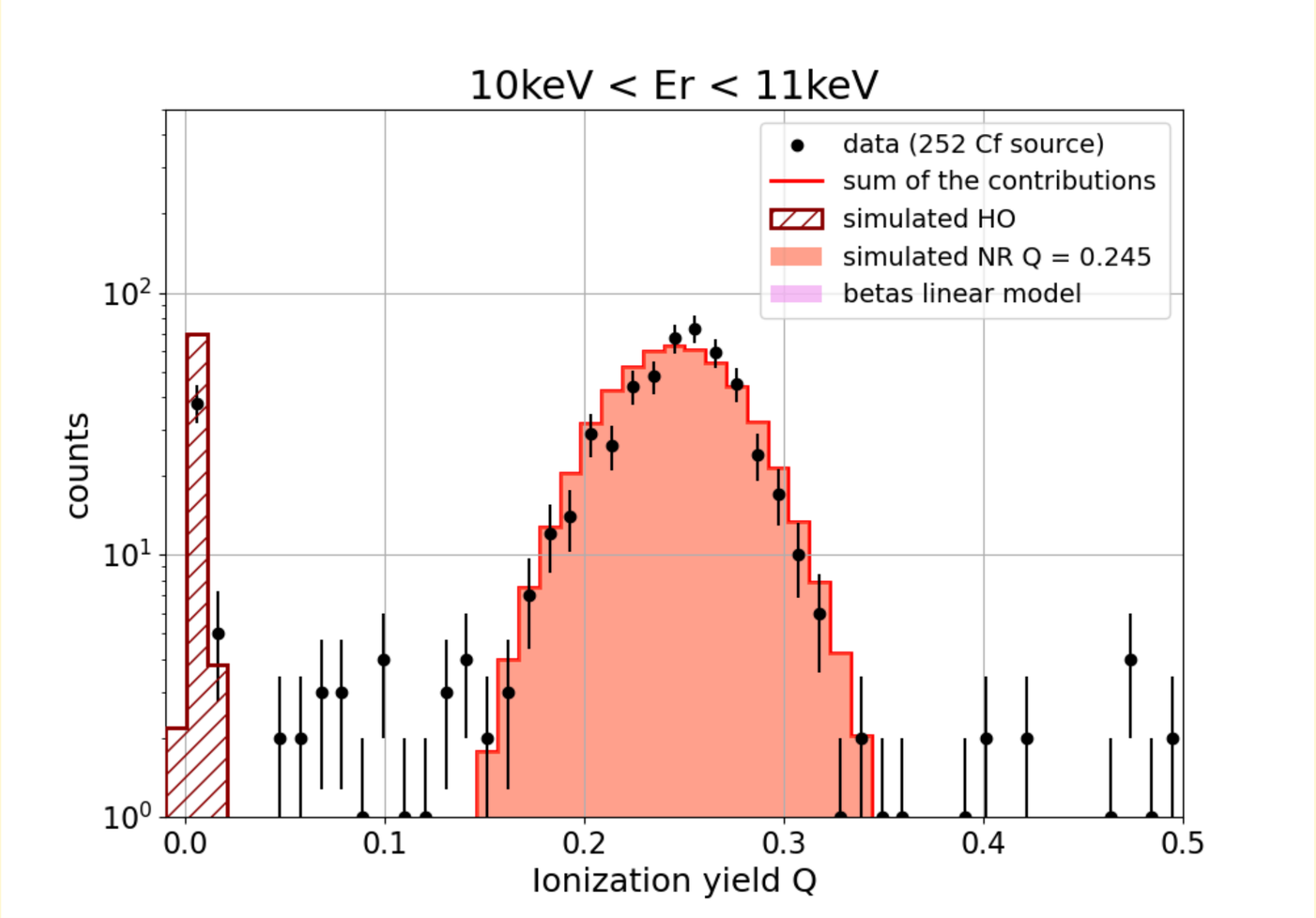
let's do a scan over Q values for Er each slice!

MPS model running simulations

- We **simulate events following Lindhard** model
- We make a **Q scan** in order to find **the best fitting Q value**
- We may include **multiple scattering**

Example of the 10-11 keV slices

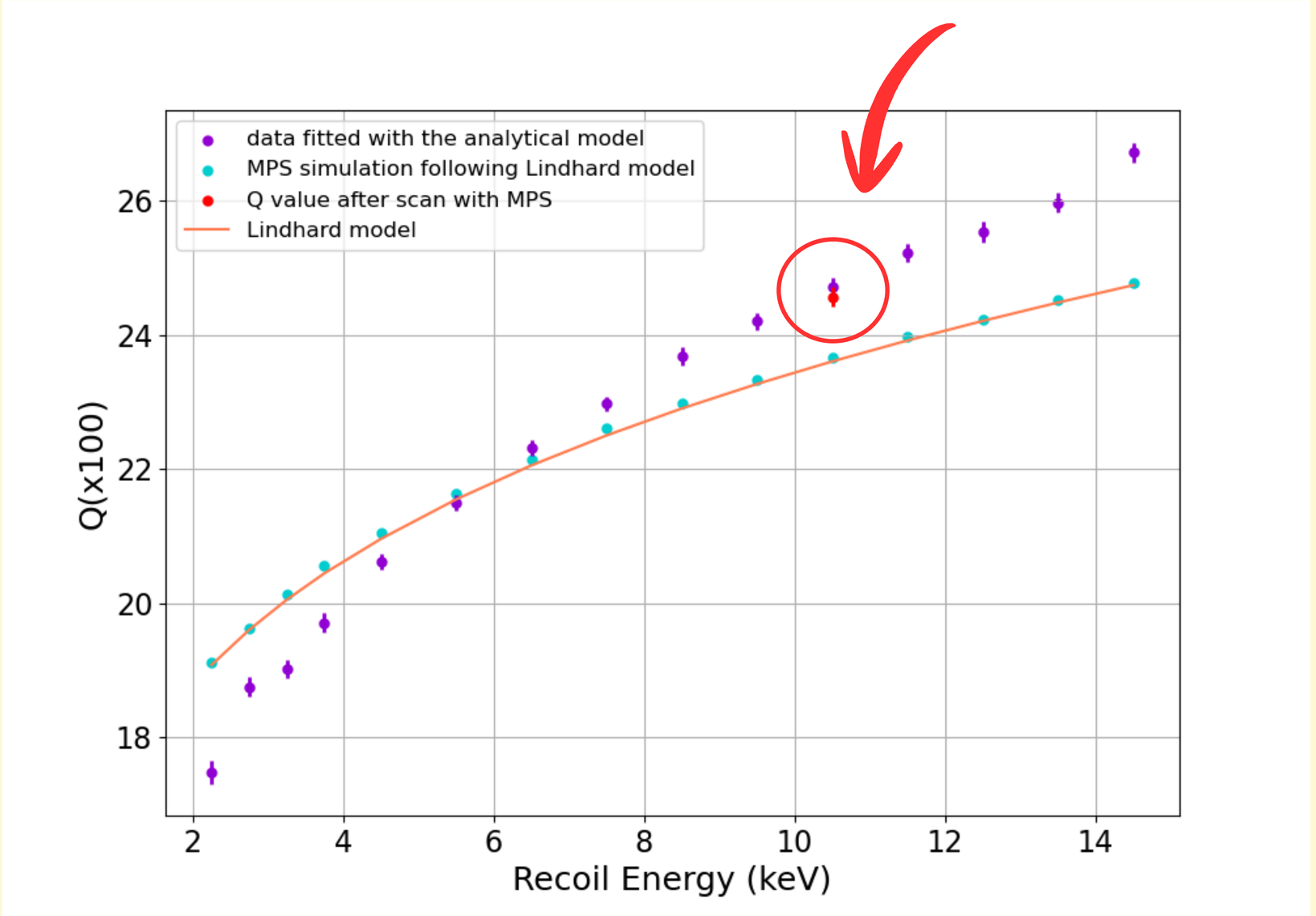
For each Er slice, we simulate events with MPS **fixing the Q value** and we do that **for a set of Q values**



Q(10-11) = 0.244 +/- 0.002

Q vs Er

A new point!
fitting better the data



MPS model running simulations

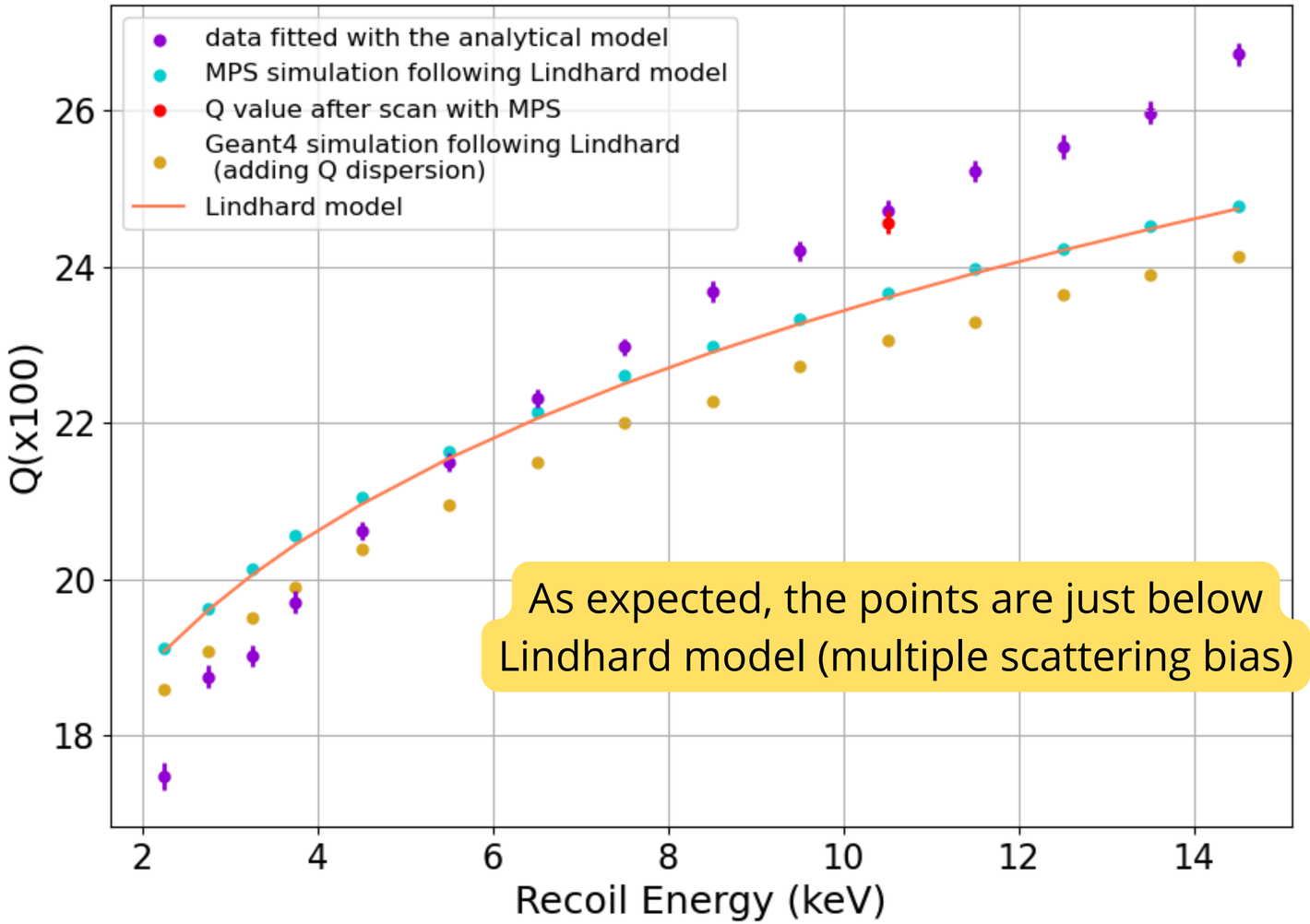
- We **simulate events following Lindhard** model
- We make a **Q scan** in order to find **the best fitting Q value**
- We may include **multiple scattering**

Now what about the multiple scattering contribution?

In a detector, a particle can sometimes do **more than one recoil**.
But **the detector is not able to record separately the energies** coming from different recoils (not enough time between the collisions)...
Then we get just **one Er for a multiple recoil event**.

The **quenching computed with the energies coming from multiple scattering is lower** than the one we would have for a single collision.

Q vs Er



As expected, the points are just below Lindhard model (multiple scattering bias)

More exciting things to come!

The goal is to have a **full model simulated with MPS including the multiple recoils without assuming Lindhard!**

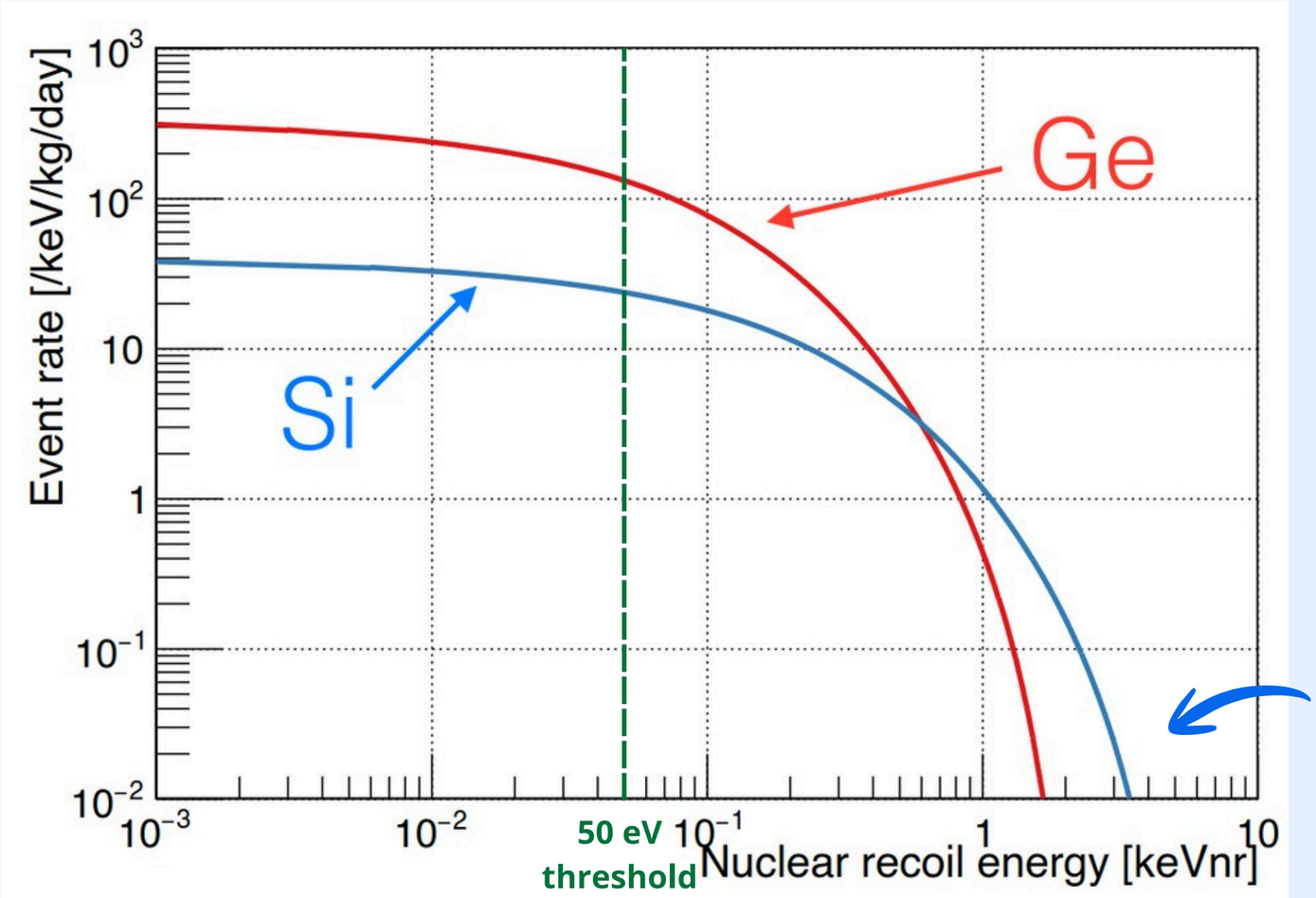
The region **below 2 keV is an ongoing study** (maybe the most interesting part!)

Development of new detectors in Silicon and preliminary analysis

Why do we want to use Silicon?

Standard model CENNS spectra for Ge and Si

lower rate than Ge



but higher maximum Er than Ge

→ Possible **comparison of the 2 materials** to crosscheck the results: $\sigma \propto N^2$

How do we use Silicon as a new material for our detectors?

We want to operate the new detectors similarly as the Ge ones

We might take into account some **differences between Si and Ge**

How do we use Silicon as a new material for our detectors?

We want to operate the new detectors similarly as the Ge ones

We might take into account some **differences between Si and Ge**

1. **Si density < Ge density**
   For the same crystal size: $m_{Ge} \simeq 40$ g / $m_{Si} \simeq 17$ g

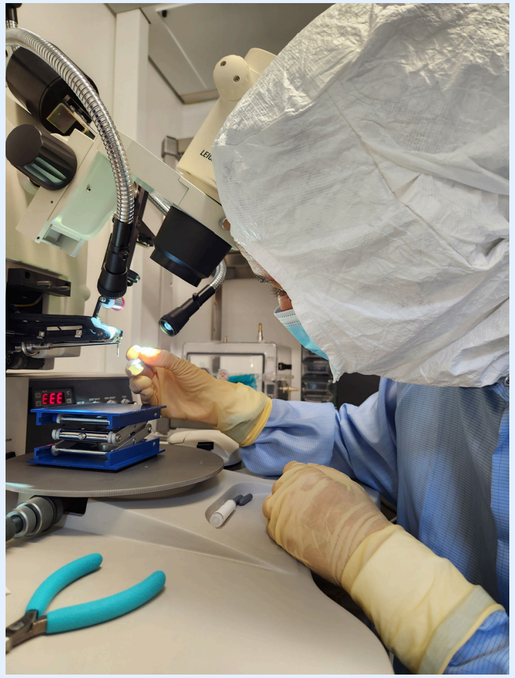
2. **The pair creation energies** are not the same:
   $\epsilon_{Ge} = 3$ eV / $\epsilon_{Si} = 3.8$ eV

3. **Calibration: we can't activate Si** as we do with Ge!
   We use sources put in the copper holder next to the crystal with defined peaks:
   - **Fe(55) source** = a doublet (**5.89 keV,6.4 keV**)
   - **Am(241) source** = **60 keV**

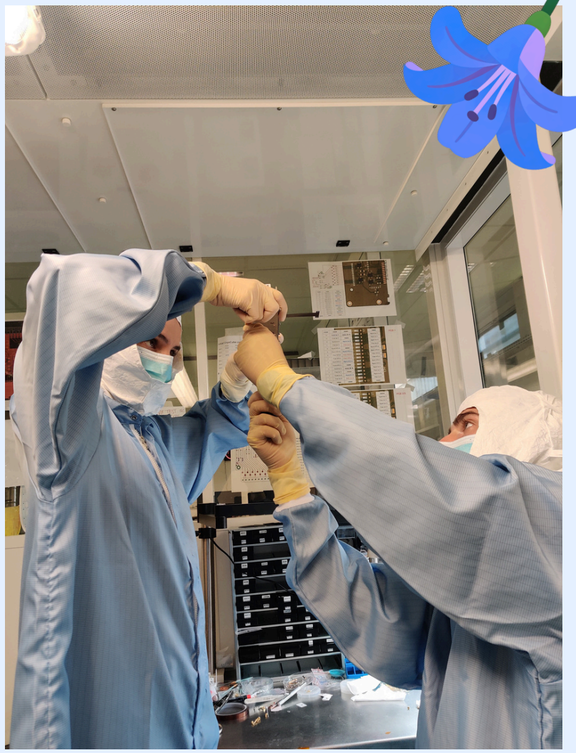
⚠ Fe source produces surface events (problem of charge collection)! not so good for calibration

We use 2 Si planar detectors

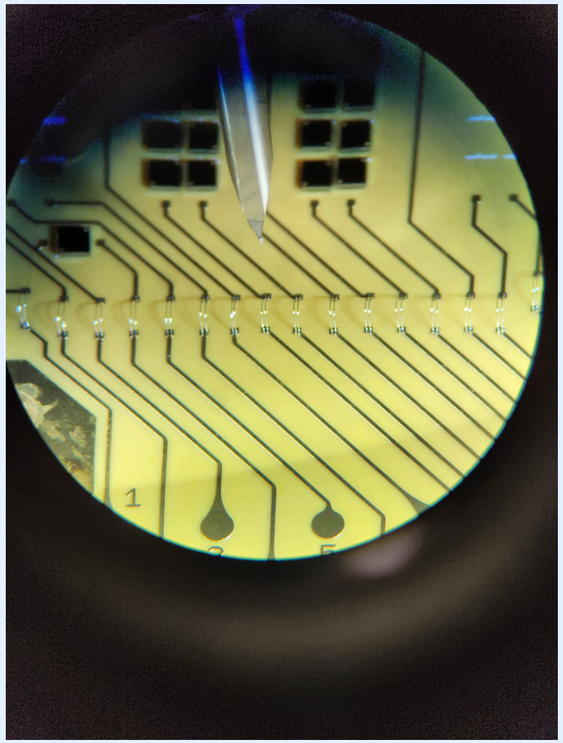
Some pics about the development of our new detectors



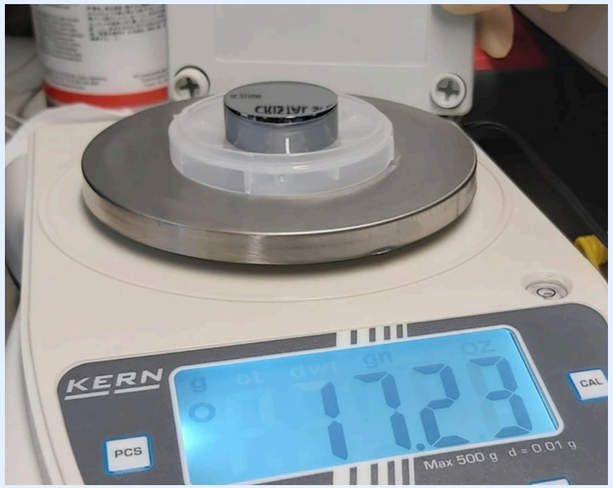
Working hard to make them perfect…

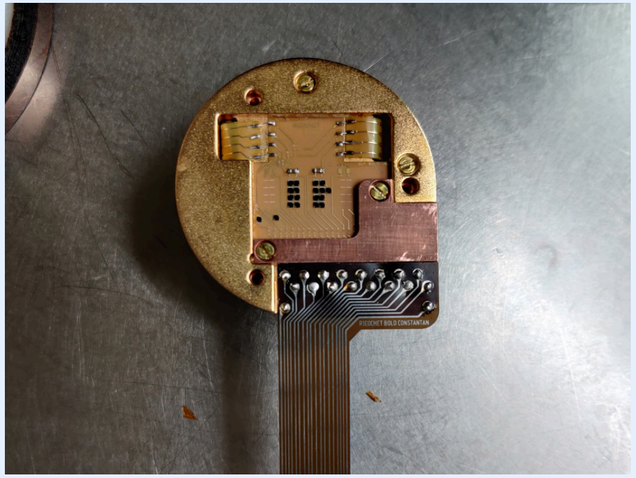


So bright and beautiful!



Here is PLSI01 (Sidonie)!





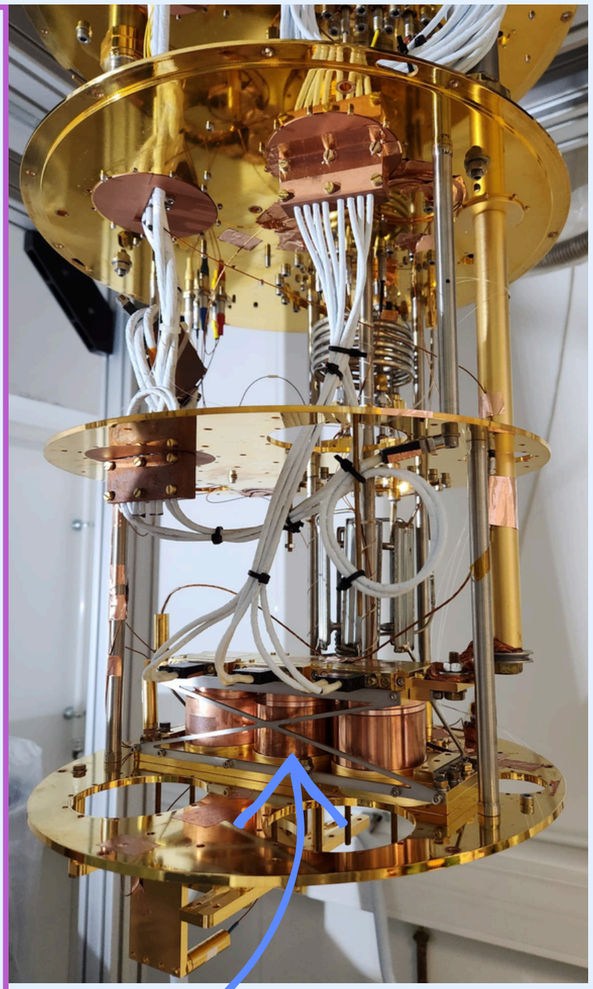
Now let's go into more details…

And PLSI02 (Simone) is over there!

2 Si planar detectors for the RUN141: PLSI01, PLSI02

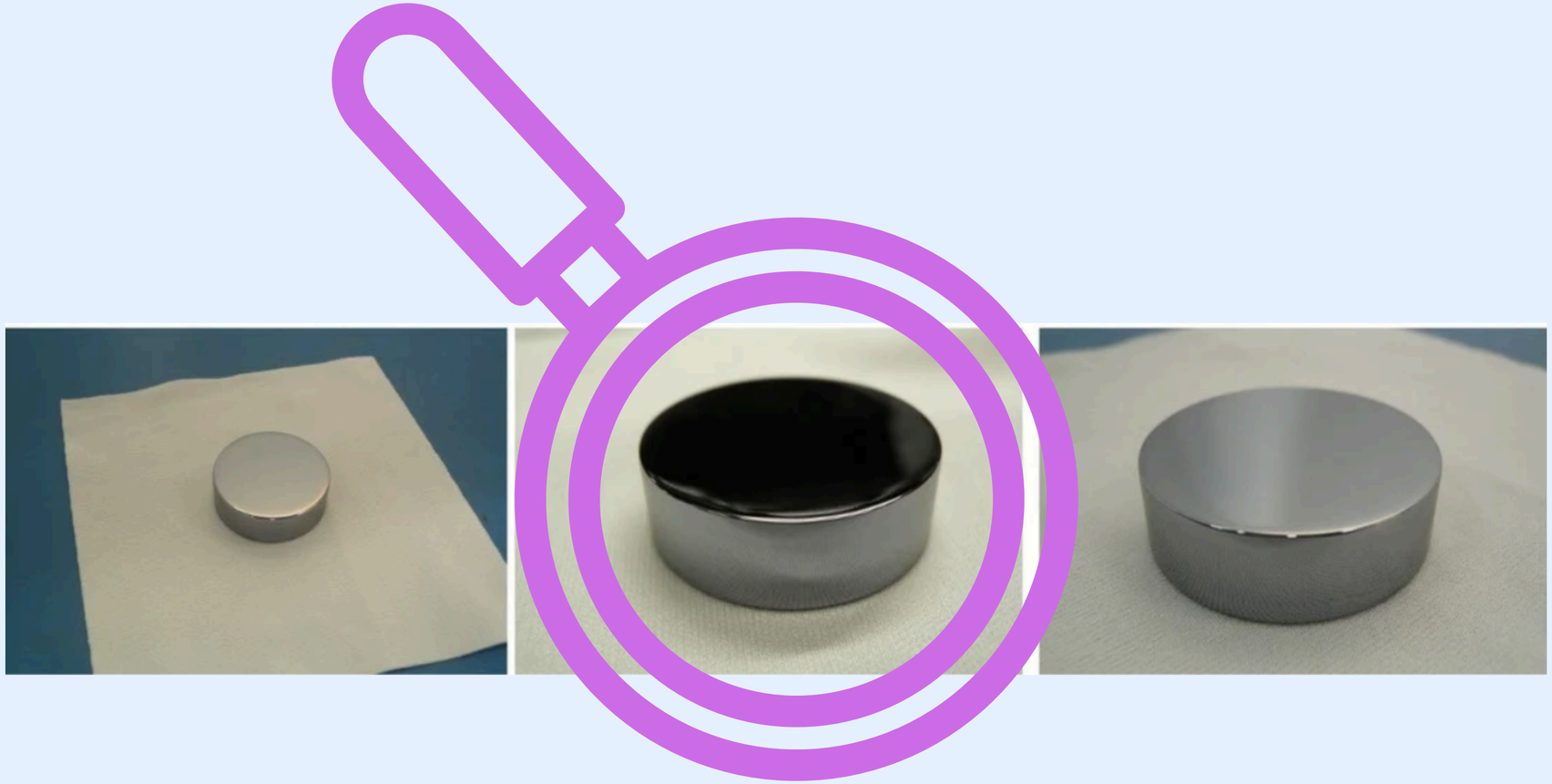
PLSI01:
- ★ T=21 mK
- ★ heat channel ✓ reso = 150 eV
- ★ two ionization channels ✓ reso = 80 eV

PLSI02:
- ★ T=21 mK
- ★ heat channel ✓ reso = 150 eV
- ★ two ionization channels but less performant ✓ reso = 130 eV



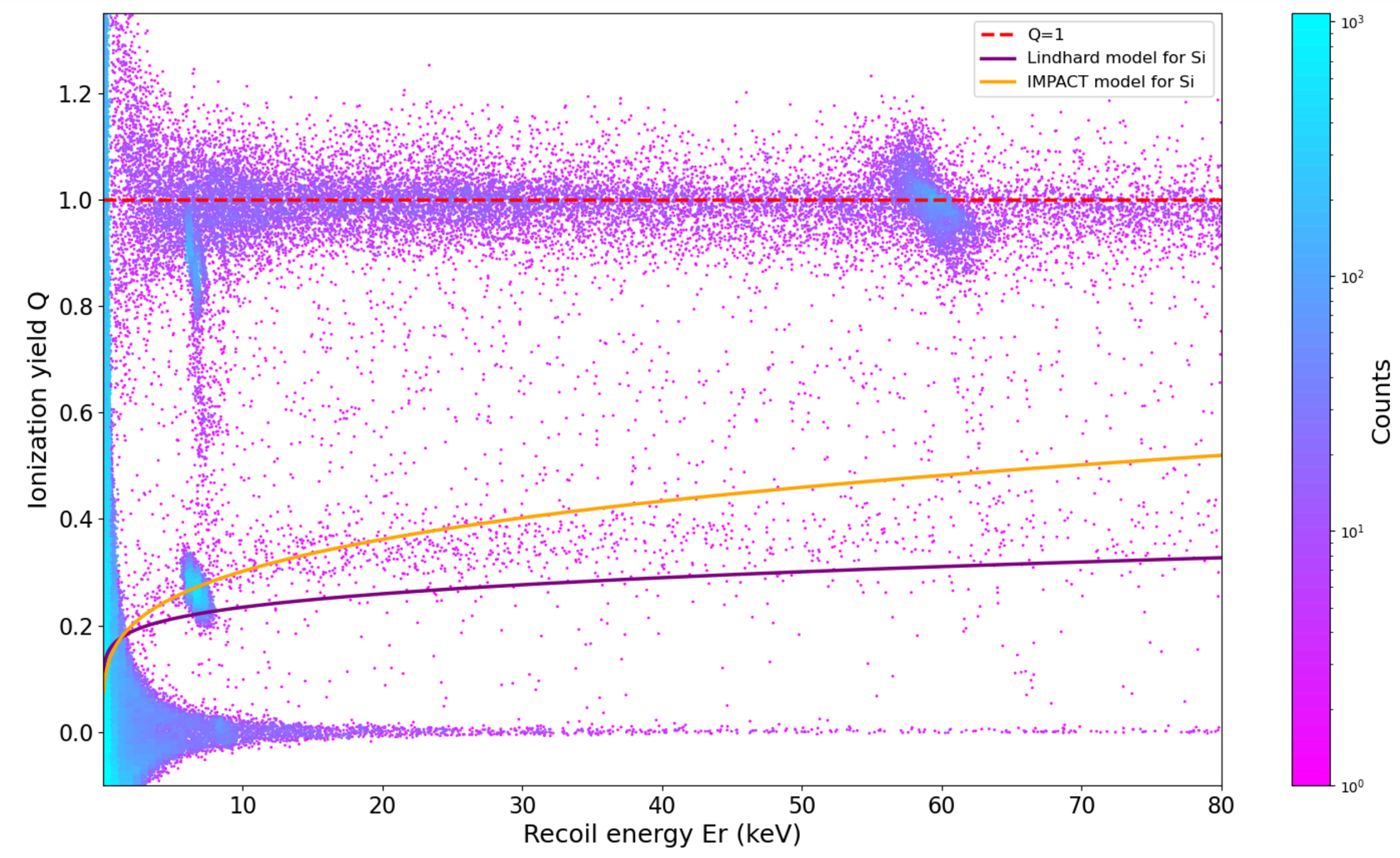
PLSi01 and PLSi02 were put in the LIO cryostat in Lyon
+ a laser!

PLSI01 preliminary analysis on RUN141



Choosing the bias between the electrodes V = -7 V

‘Q vs Er’ plot



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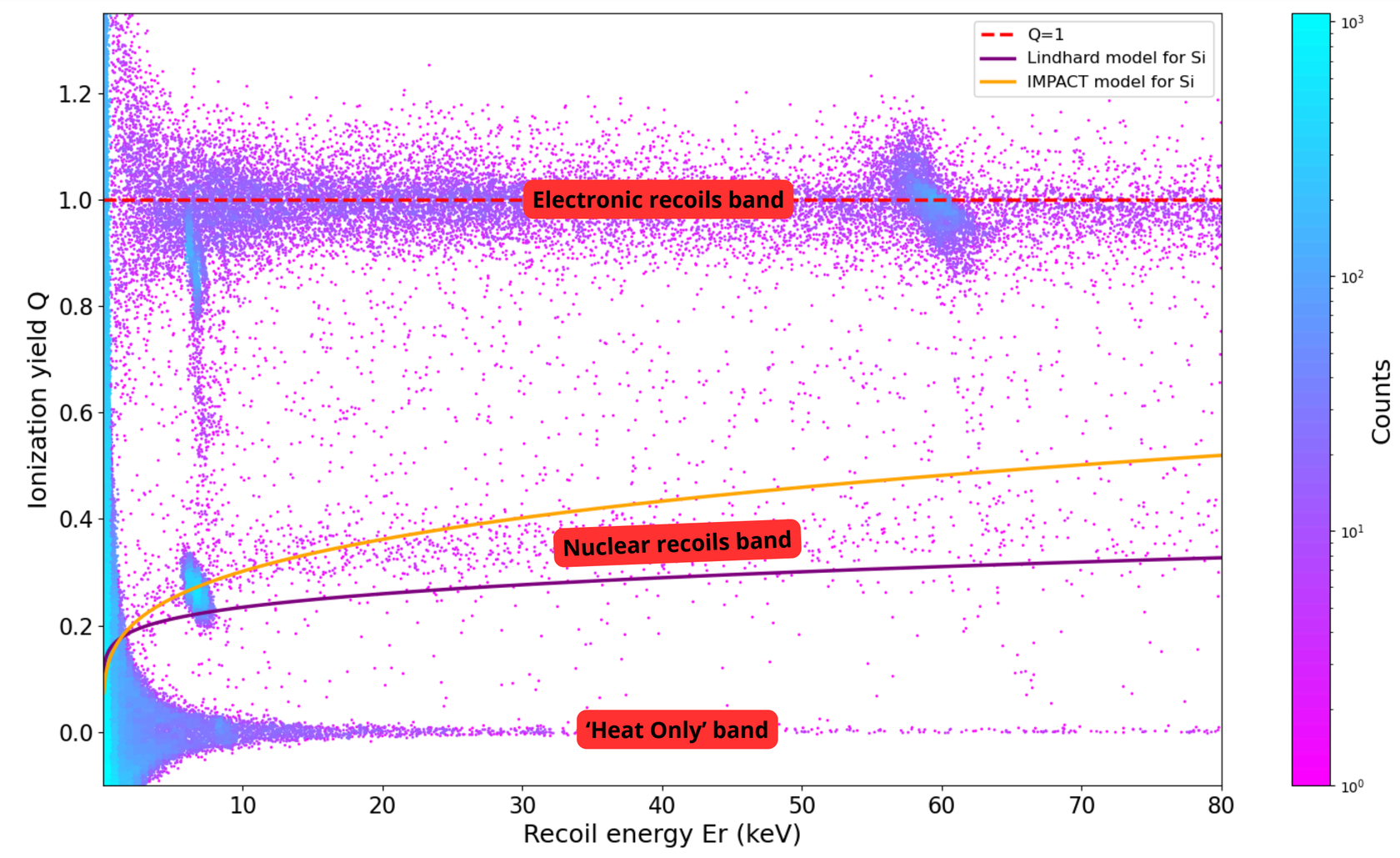

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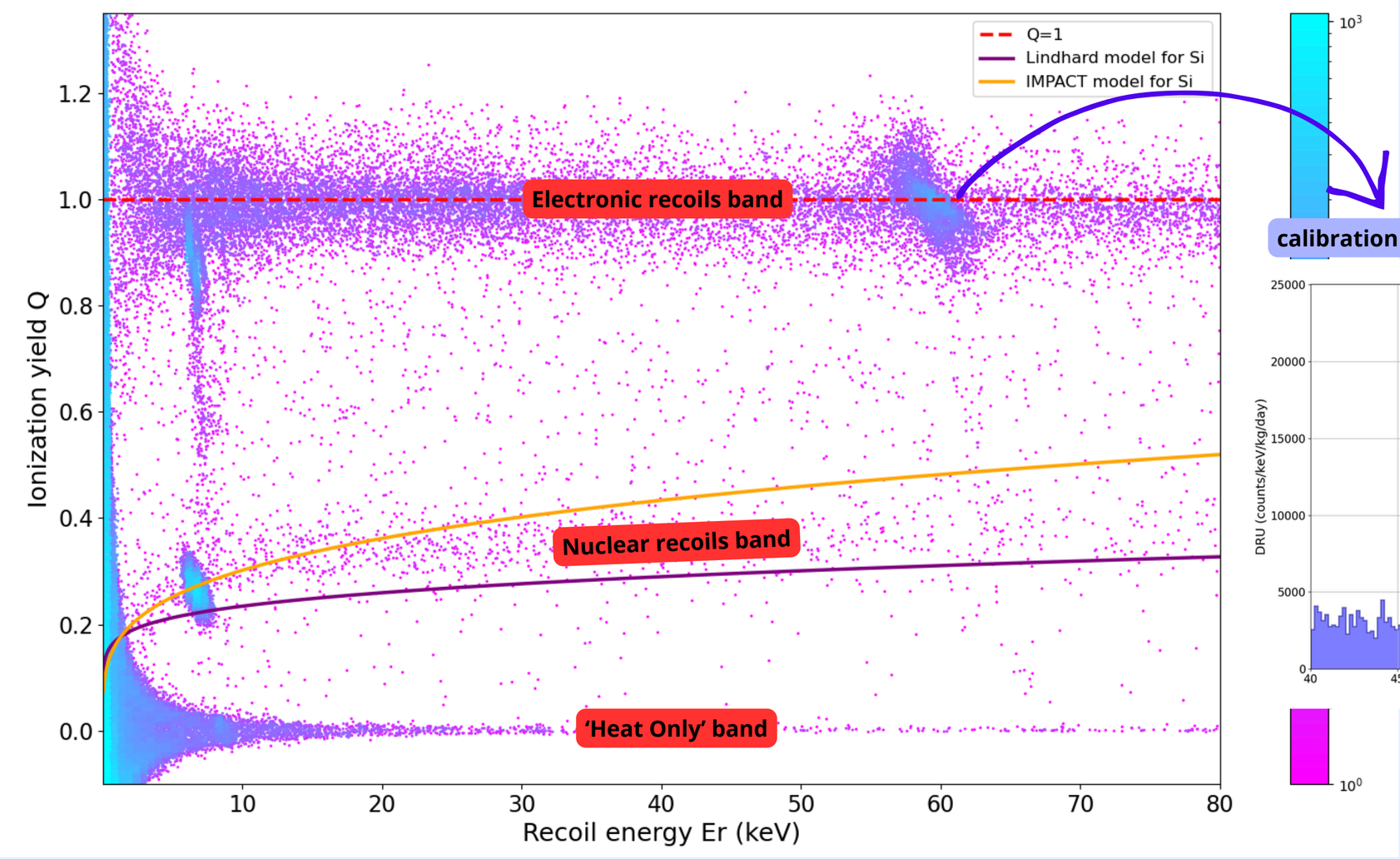
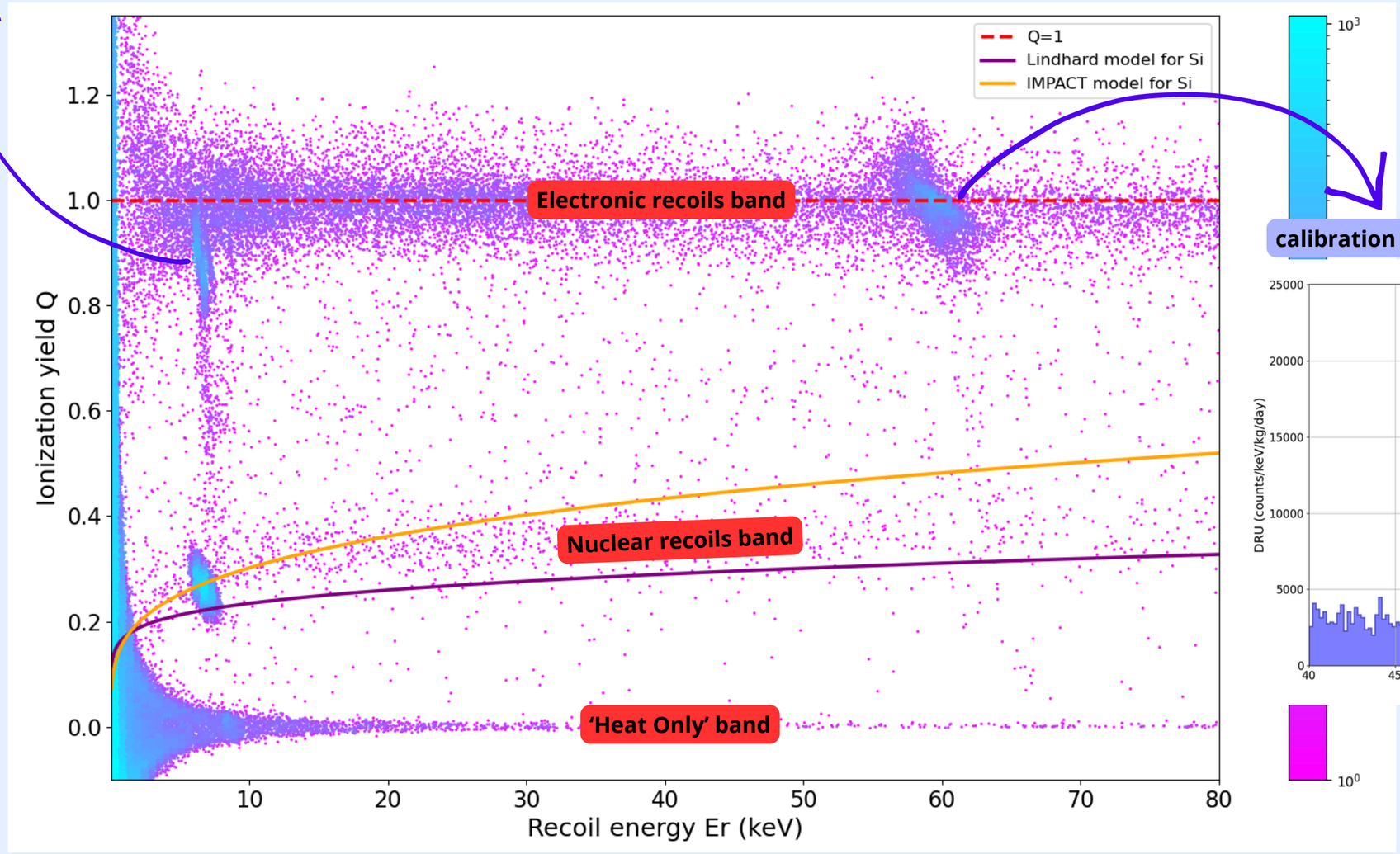


calibration with an Am(241) source having a peak at 59.5 keV

Choosing the bias between the electrodes V = -7 V

‘Q vs Er’ plot

Fe peak, surface events, then Q=0.88<1



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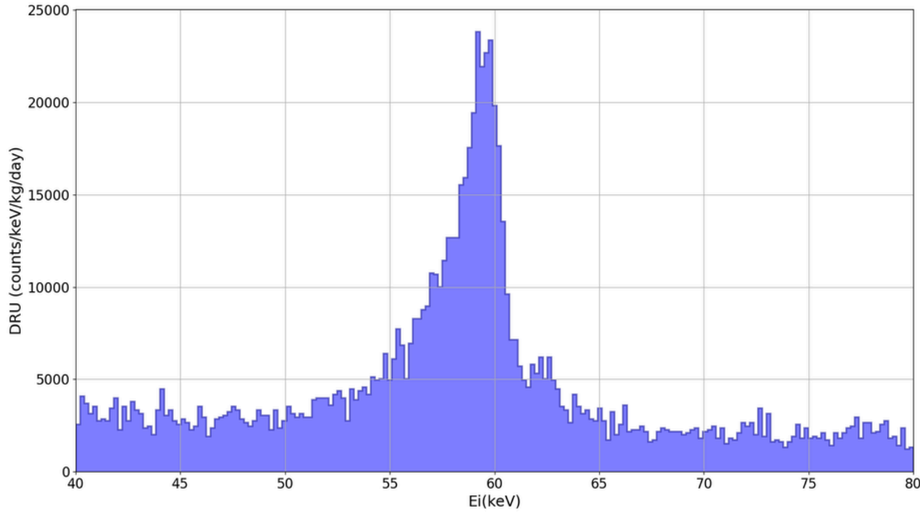

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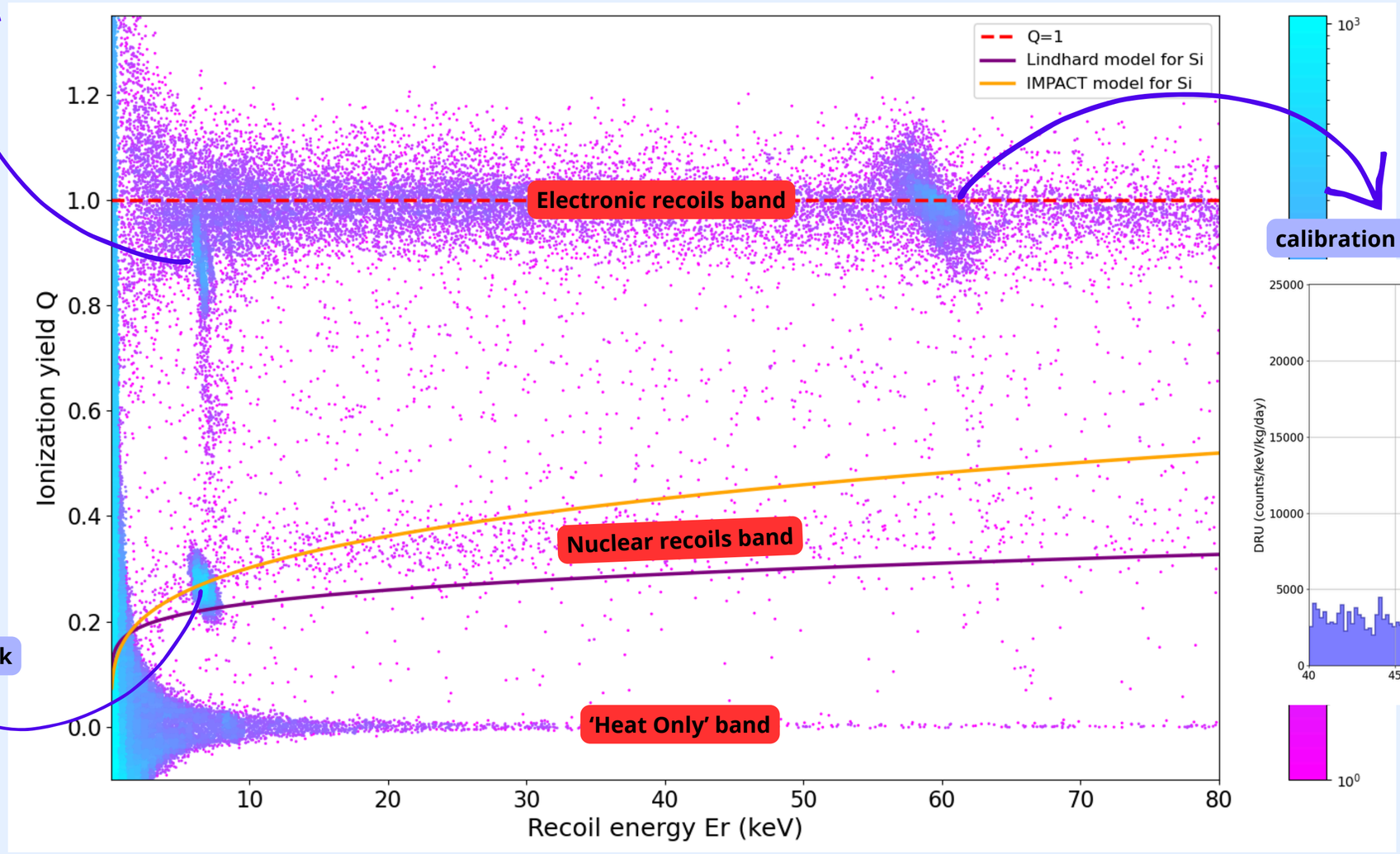
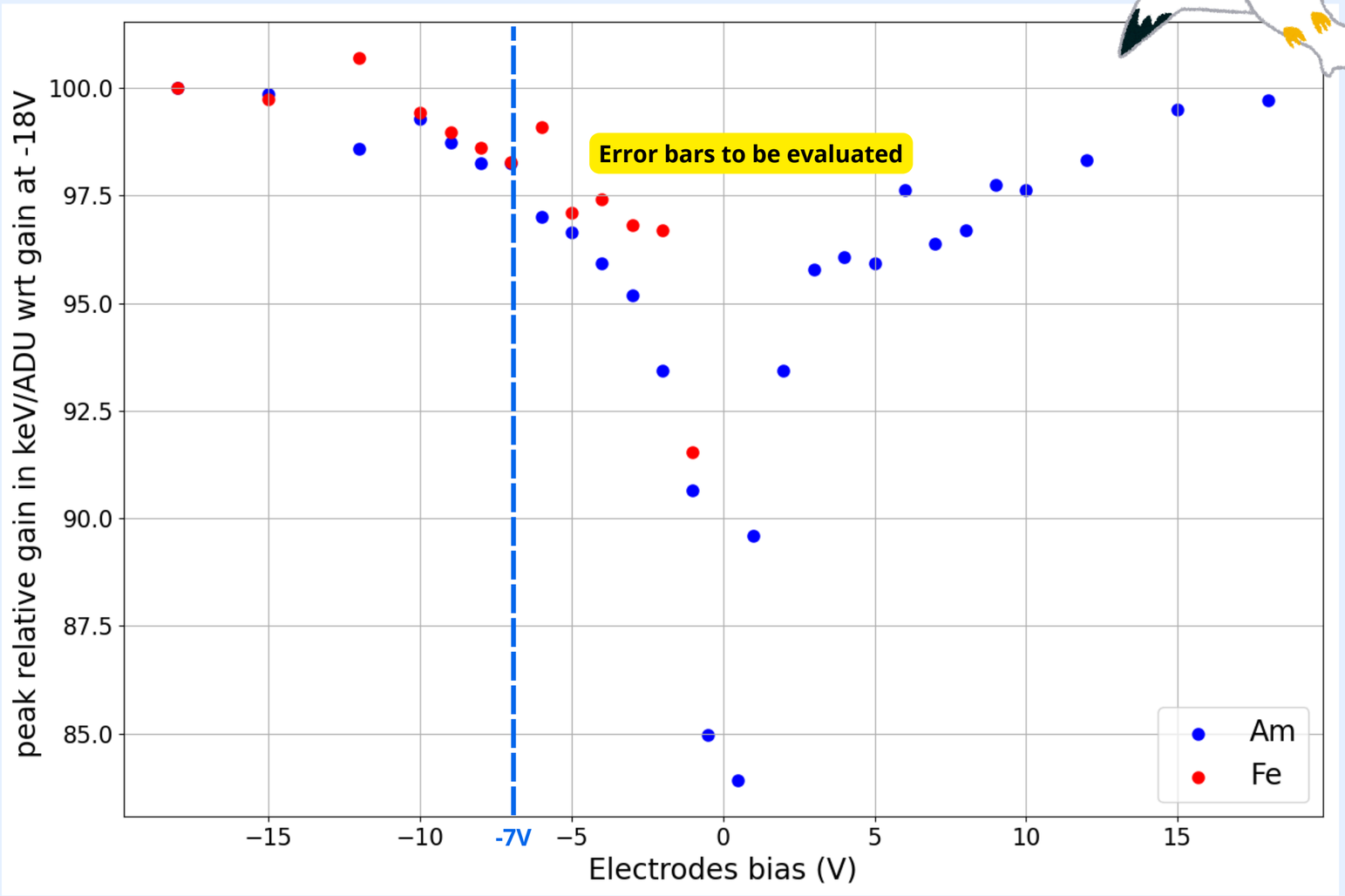


Laser peak

calibration with an Am(241) source having a peak at 59.5 keV

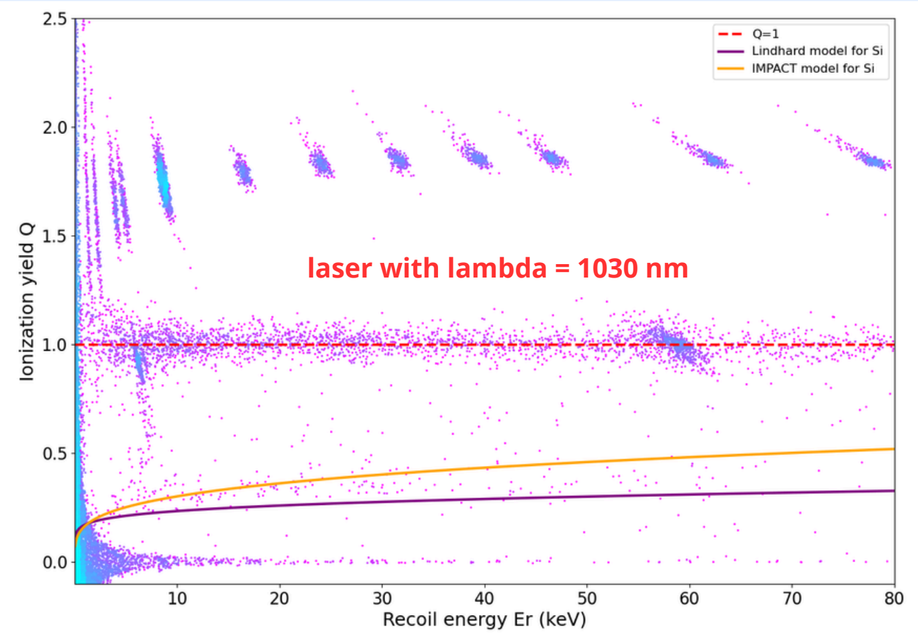
Charge collection depending on the bias between the electrodes?

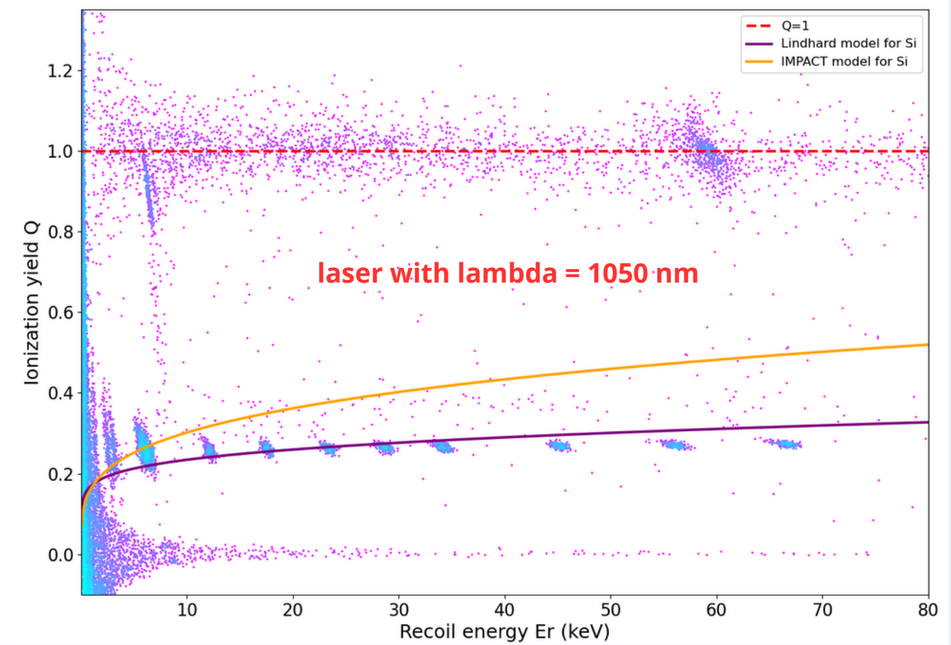
The “seagull” plot

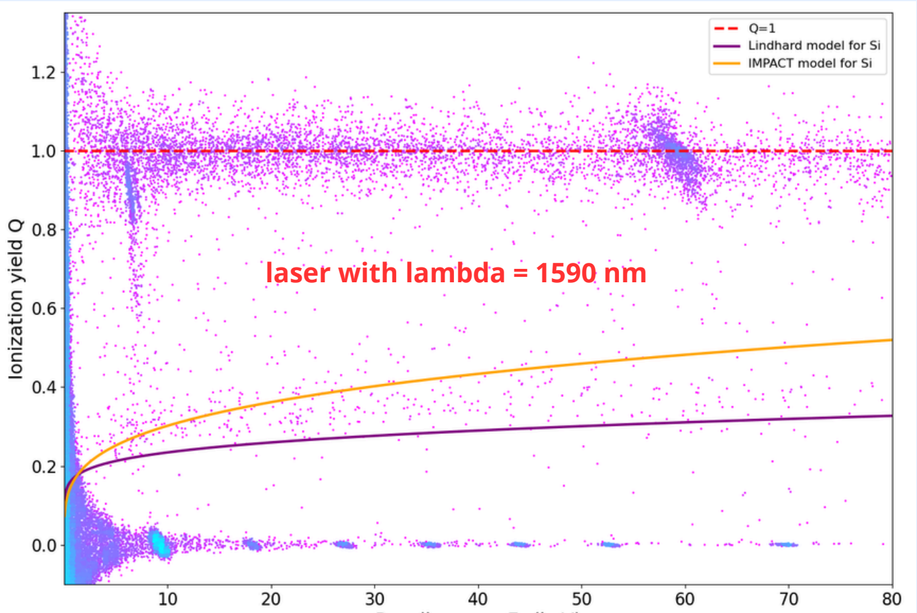


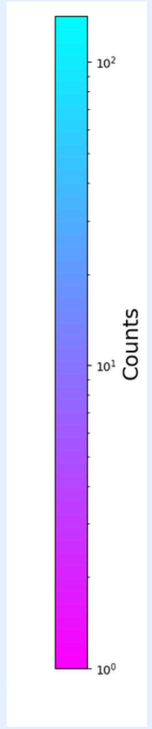
Laser scan

Si is a semiconductor with a gap at 1060 nm



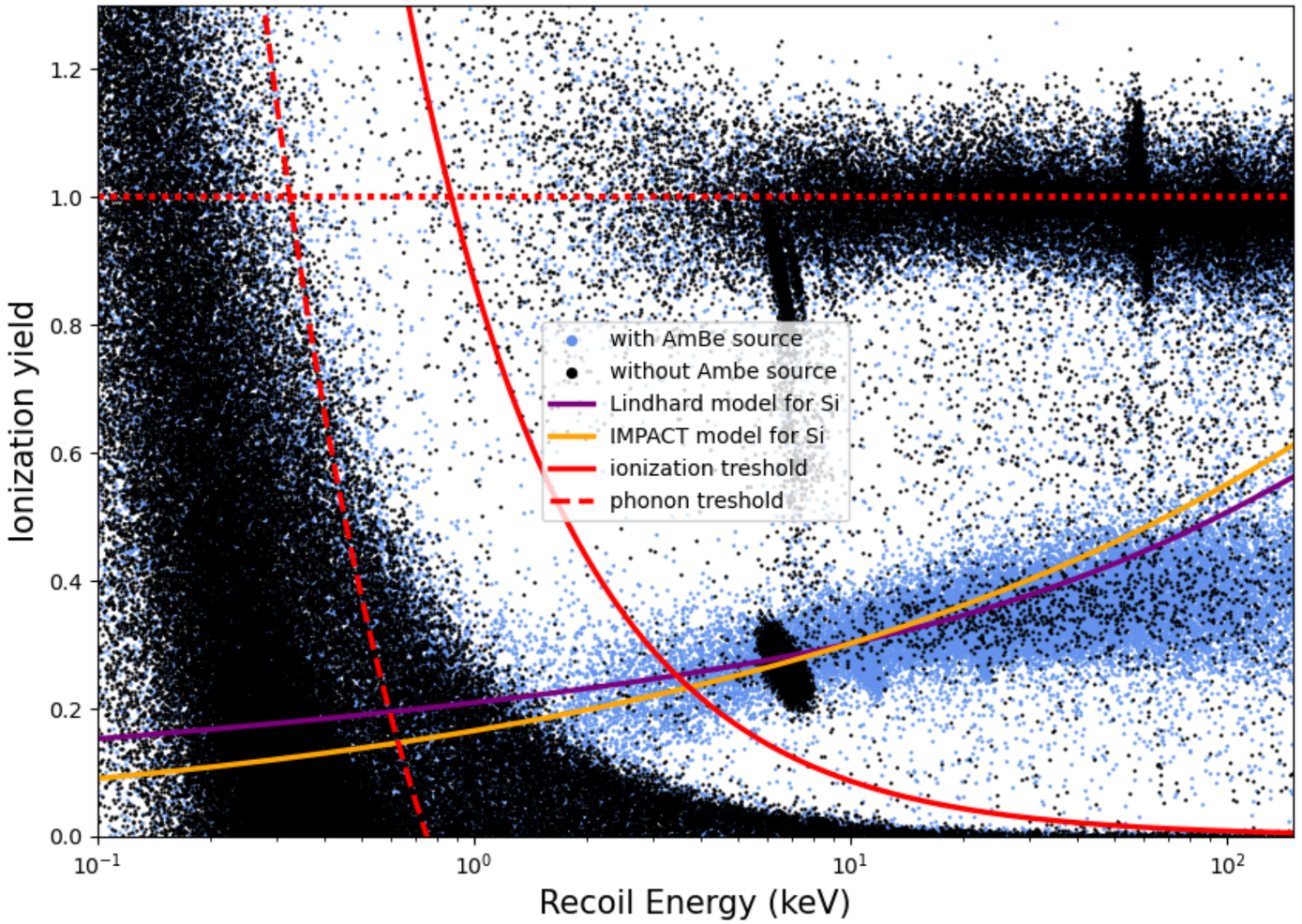






Neutron source (AmBe) to see the nuclear recoils band

‘Q vs Er’ plot



But this is just the beginning...

- More analysis on the way, may go for a **paper** on it
- **4 new crystals** have been ordered for FID design (Mirion Technologie)
- We may go for **more massive detectors** in the future
- A **future phase** for Ricochet including Germanium and Silicon crystals!

Stay tuned!

Thank you!

Ricochet experiment

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