

# Status of the 3" x3 Demonstrator

16/01/2025 – BULLKID-DM Meeting – Pisa

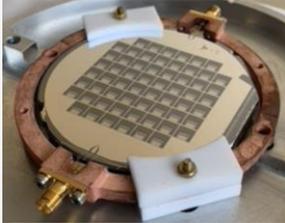
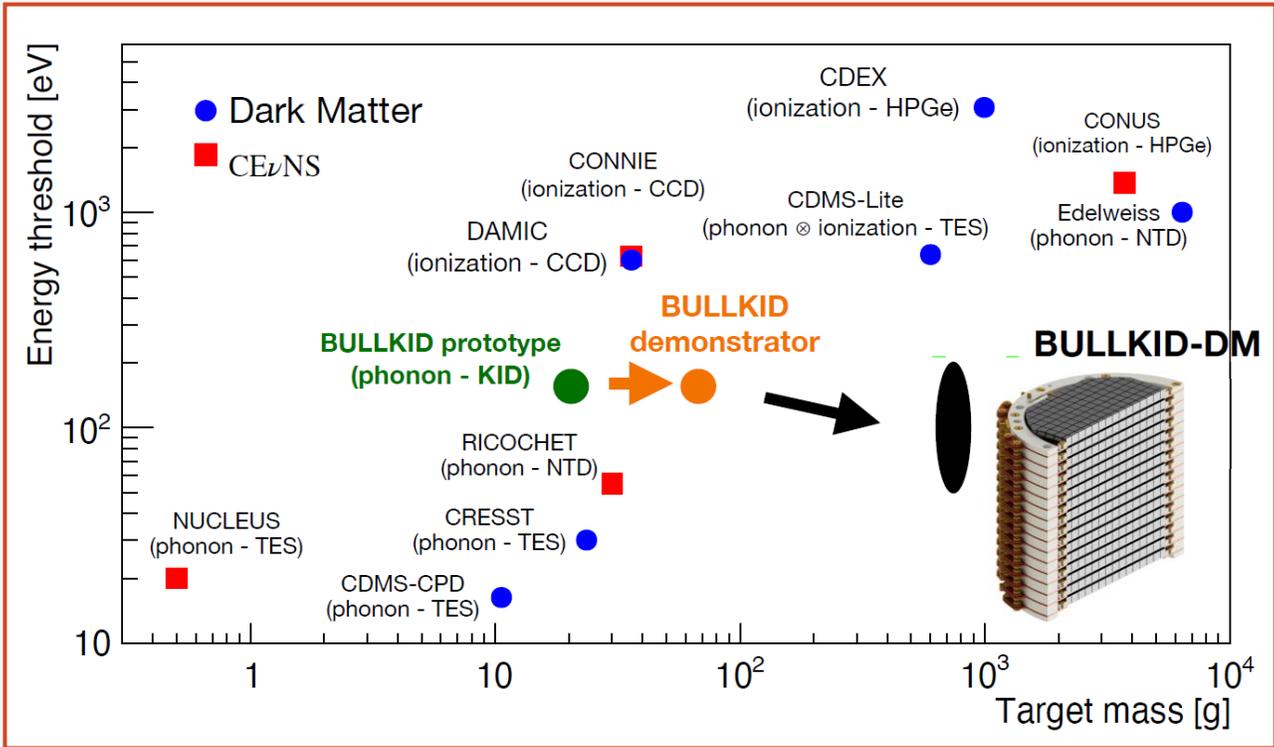
Daniele Delicato *for the BULLKID collaboration*



SAPIENZA  
UNIVERSITÀ DI ROMA

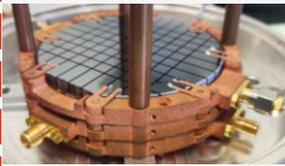


# Project goal



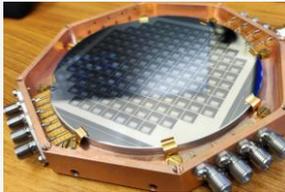
## Prototype - 20 g / 60 dice

single 3" wafer  
concluded in 2023



## Demonstrator - 60 g / 180 dice

3-layer stack of 3" wafers  
operations ongoing



## R&D on large wafer 50 g / 145 dice

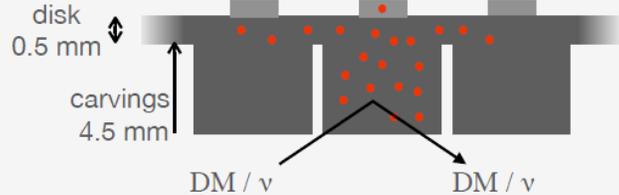
single 100 mm wafer first operations  
fall 2024



## BULLKID-DM - 800 g / 2300 dice

16-layer stack of 100 mm wafers  
commissioning in 2026 at Sapienza U.  
Fiducial mass: 600g

- Threshold (ongoing R&Ds):
1. Replace Al with Al-Ti-Al KIDs: 5x inductance
  2. Deeper carvings for higher phonon focussing

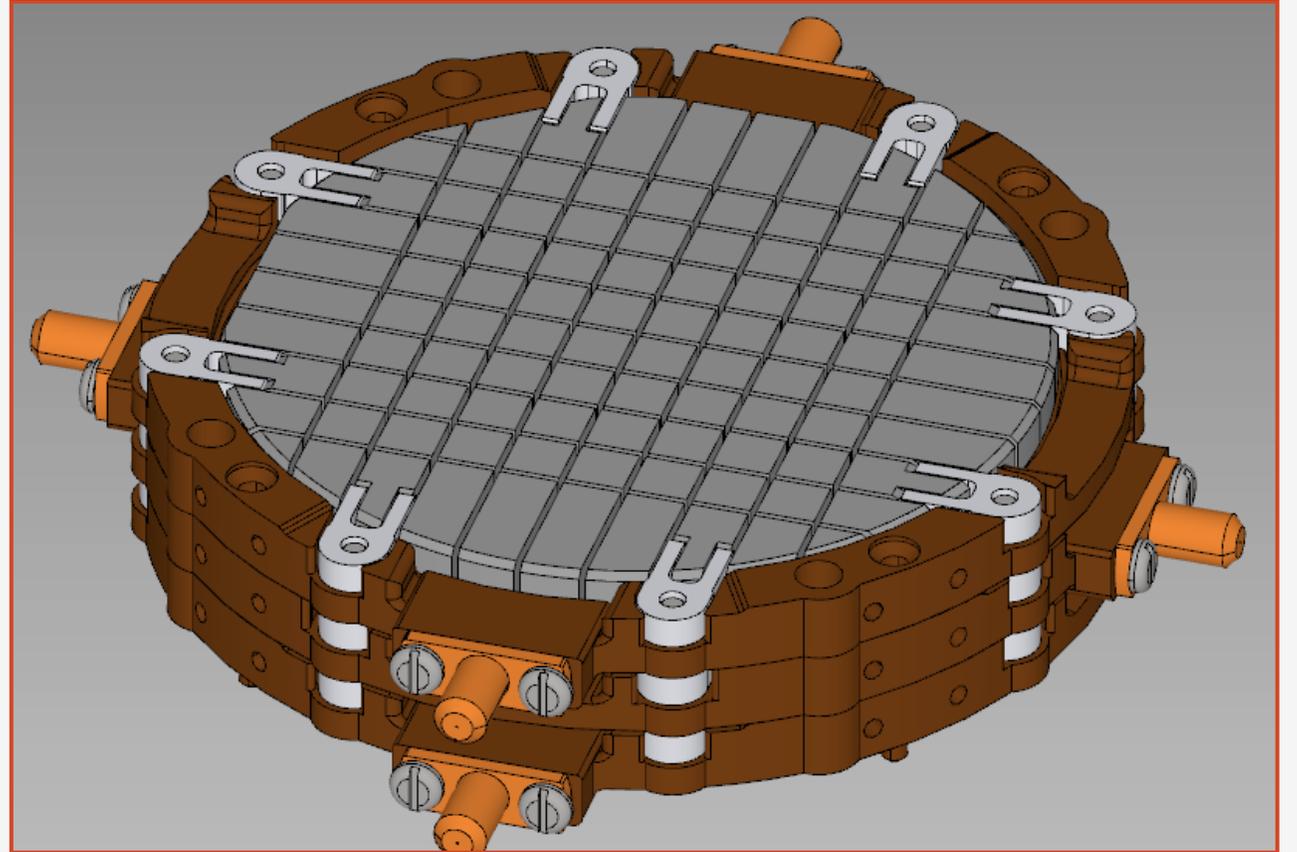


# Setup of a first 3 wafer demonstrator

---

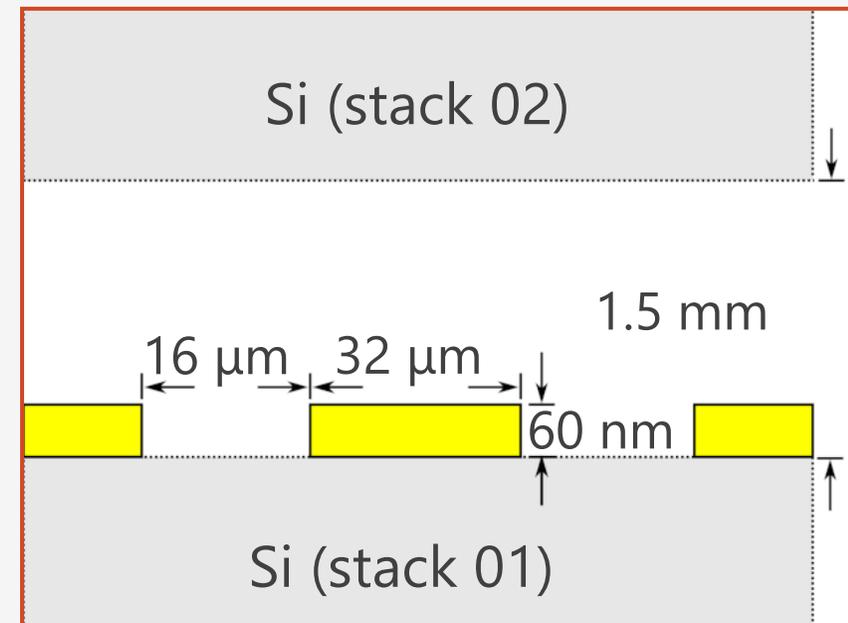
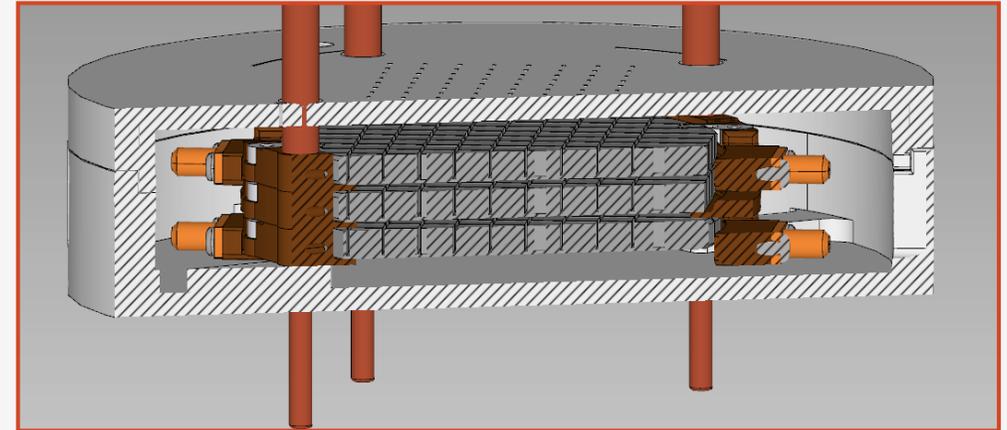
## **3 inch demonstrator:**

- 3x 3inch wafers
- Identical lithography (60nm Al) with 60 KIDs per unit
- Total instrumented mass of 61.2g
- Three independent readout lines
- Passive shielding (PB + ??)



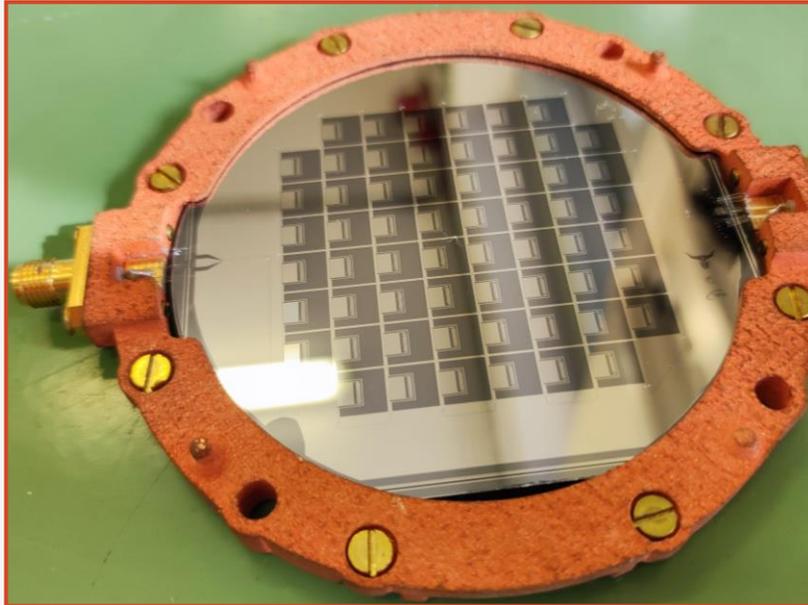
# Goals of a first 3 wafer demonstrator

- **Thermalization** of the wafers via the copper structure
- **Electrical coupling** not compromised by proximity among wafers
- **Energy threshold** on par with earlier prototypes
- **Scale readout and analysis** to simultaneously measure multiple wafers
- **Background** in a shielded environment **flat and lower than  $10^5$  dru**



# Current prototype of the 3 wafer demonstrator

---

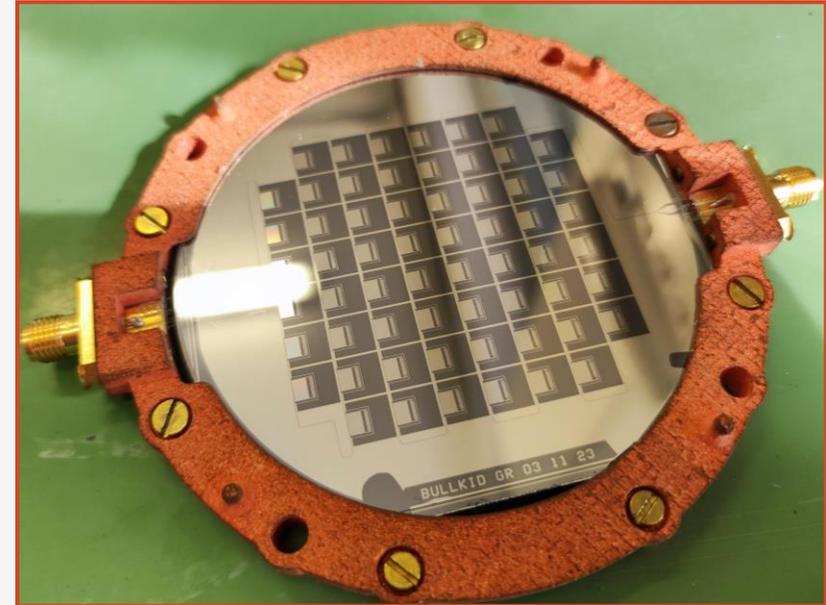


## **Stack-01: 60nm Al**

40 working pixels out of 60

Quality factor (median): 185k

Coupling Q factor (median): 190k



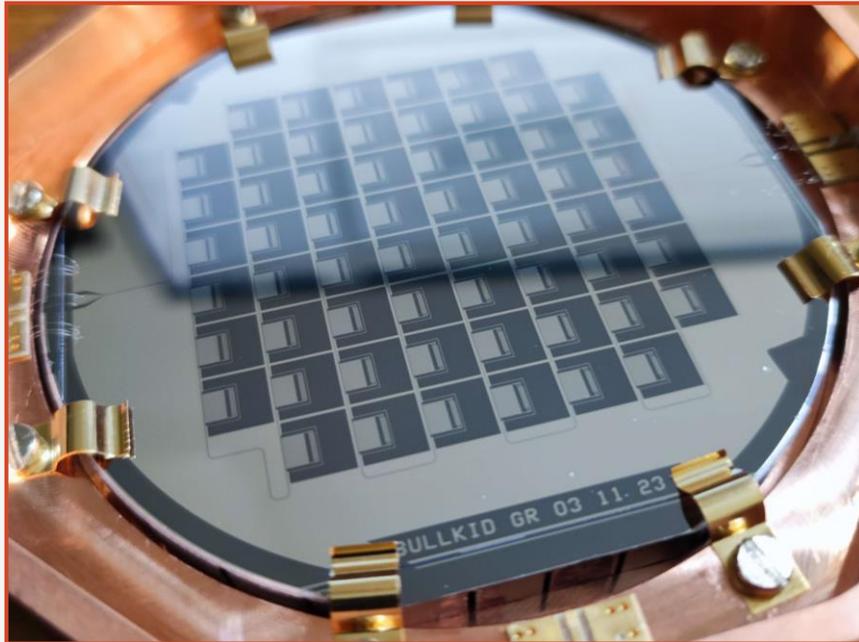
## **Stack-02: 90nm Al**

44 working pixels out of 60

Quality factor (median): 80k

Coupling Q factor (median): 140k

# Fabrication status of two additional stack elements: STACK-03

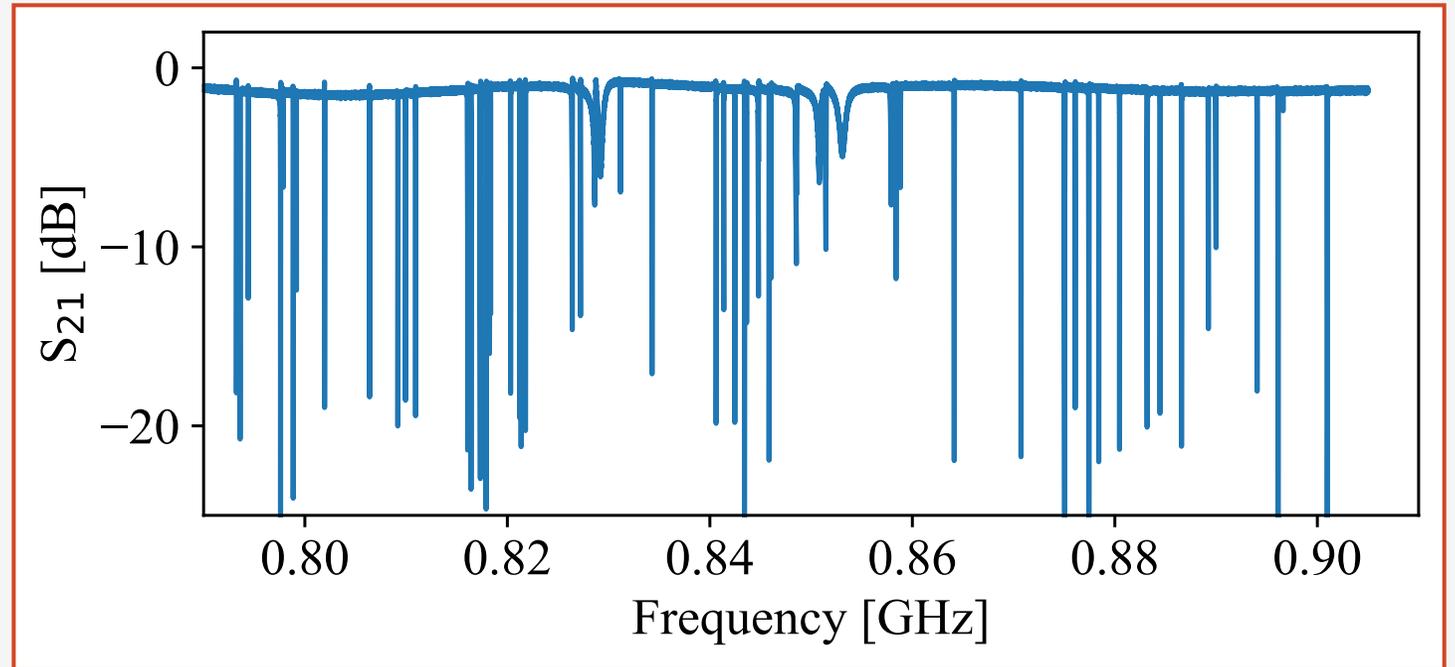


## Stack-03: 60nm Al

55 working pixels out of 60

Quality factor (median): 90k

Coupling Q factor (median): 110k

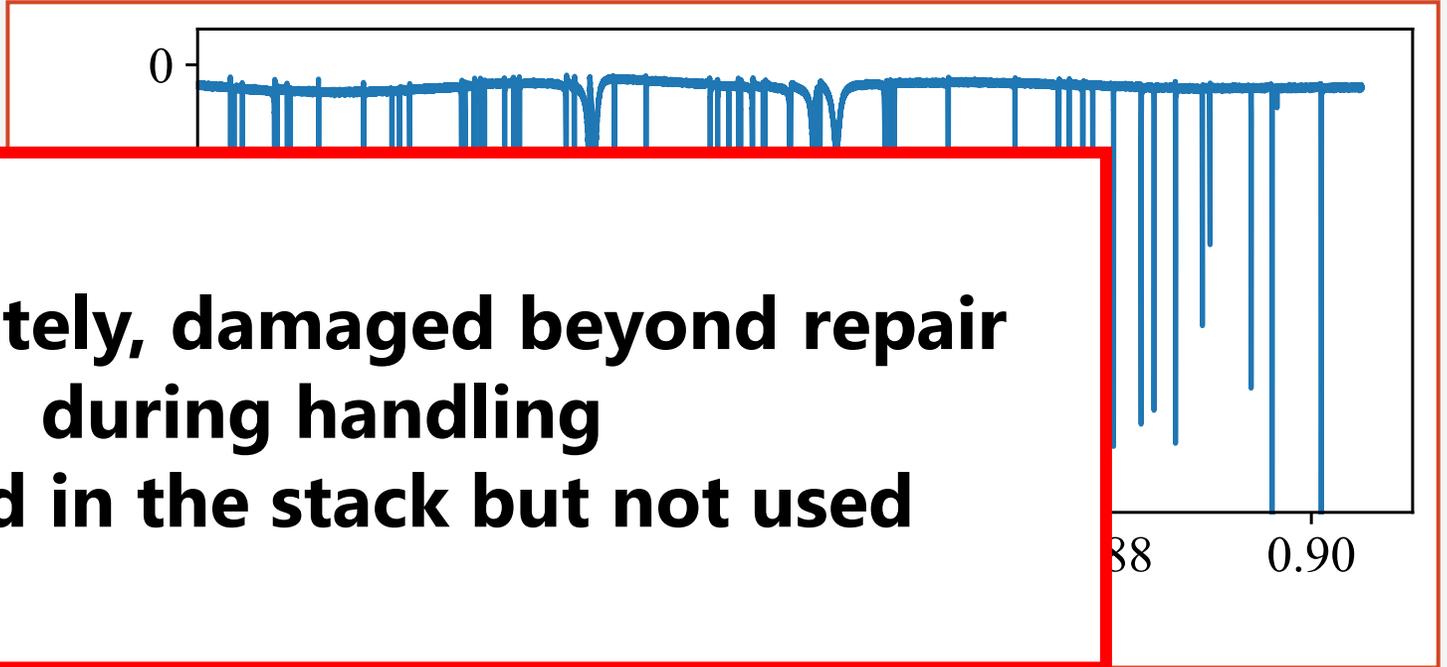


Preliminary test in Grenoble

Concerto2-60 @ 130mK

Single wafer configuration

# Fabrication status of two additional stack elements: STACK-03



**Unfortunately, damaged beyond repair during handling**  
**Installed in the stack but not used**

**Stack-03: 60nm**

55 working pixels out of 60

Quality factor (median): 90k

Coupling Q factor (median): 110k

Preliminary test in Grenoble

Concerto2-60 @ 130mK

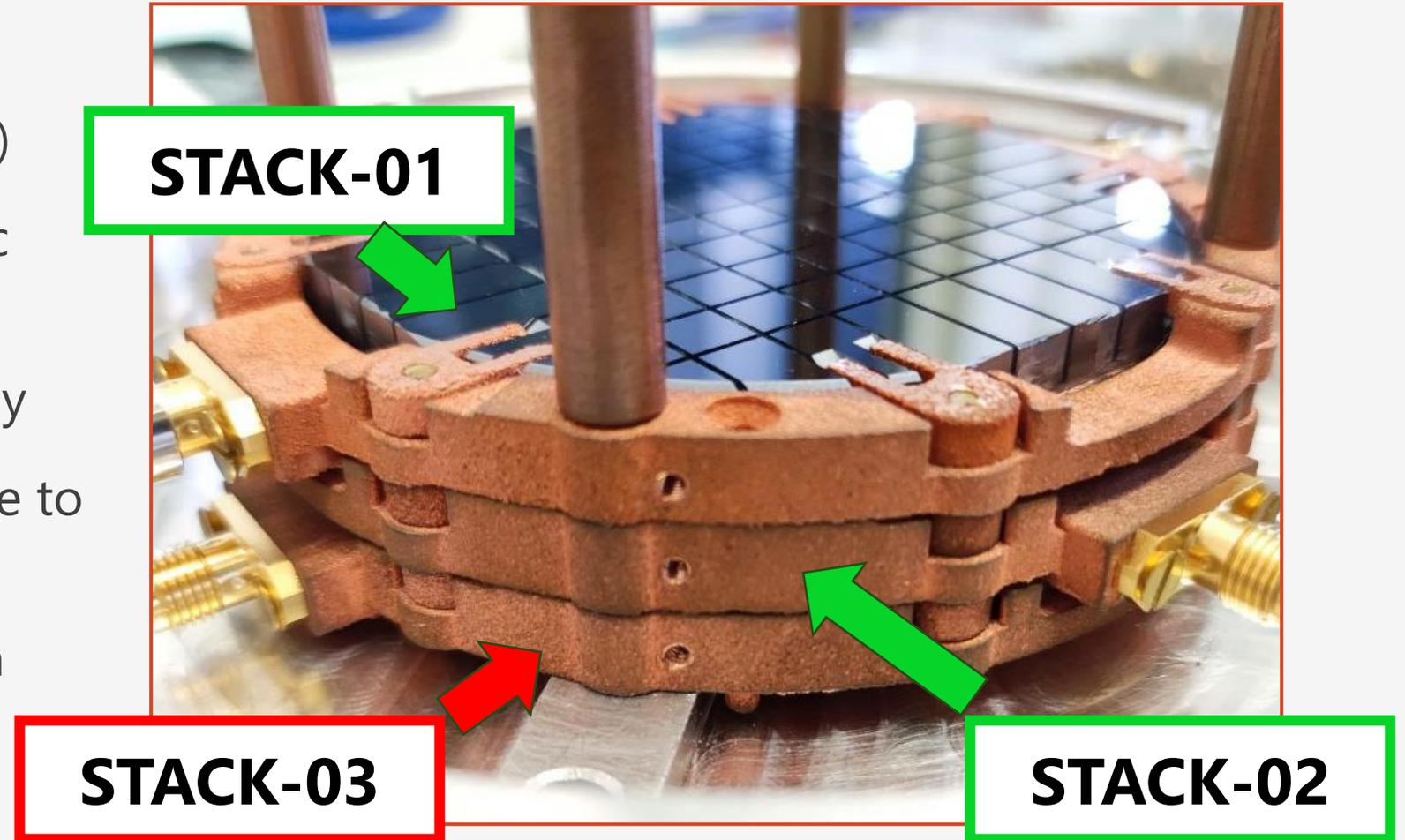
Single wafer configuration

# Current prototype of the 3 wafer demonstrator

---

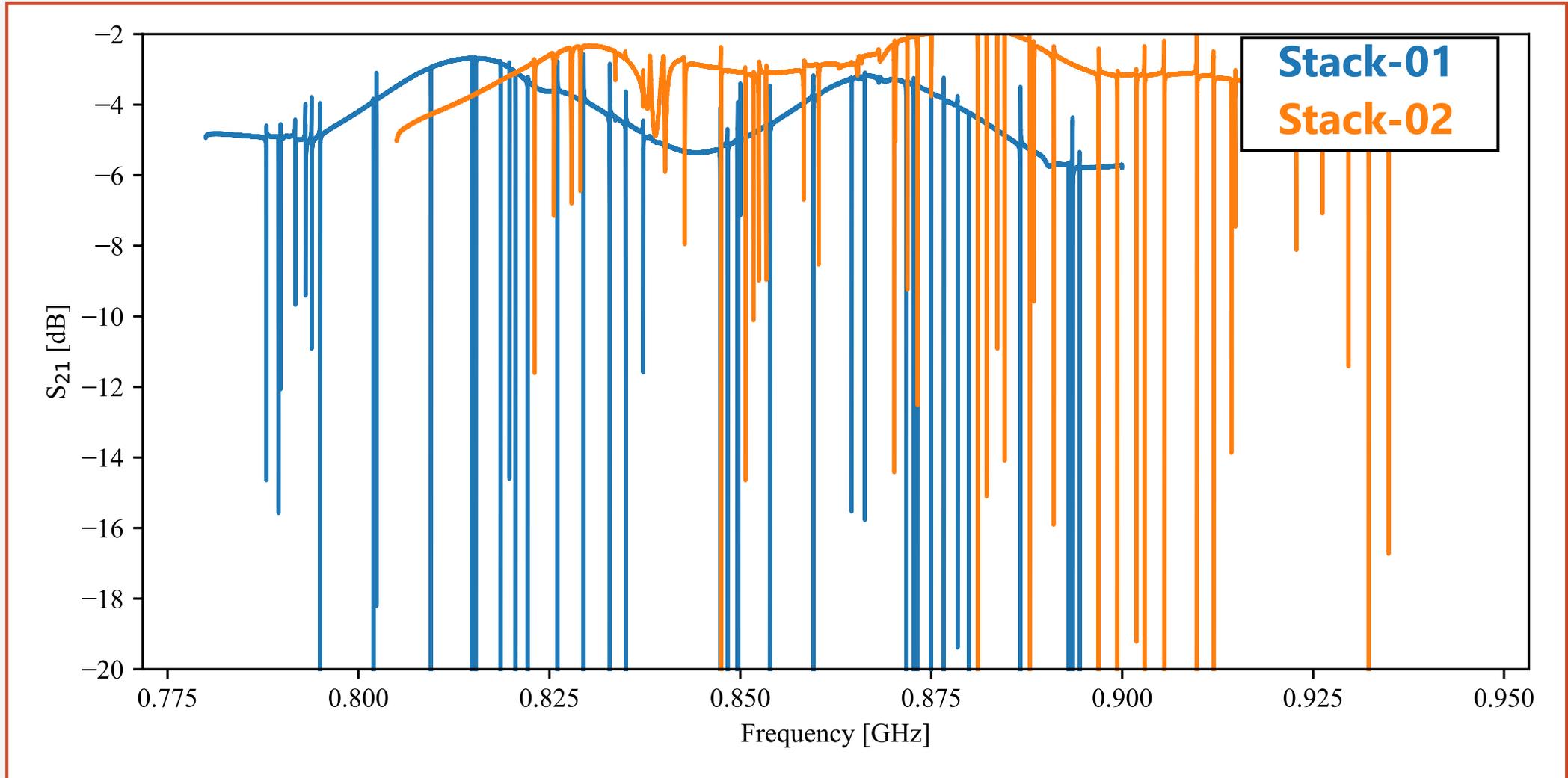
## Current prototype:

- 3x 3inch wafers (2 functional)
- Slightly different lithographic process to ease fabrication
- Two RF lines read sequentially
- Pixel uniformity is limited due to production difficulties
- Setup ready in our cryolab in Rome

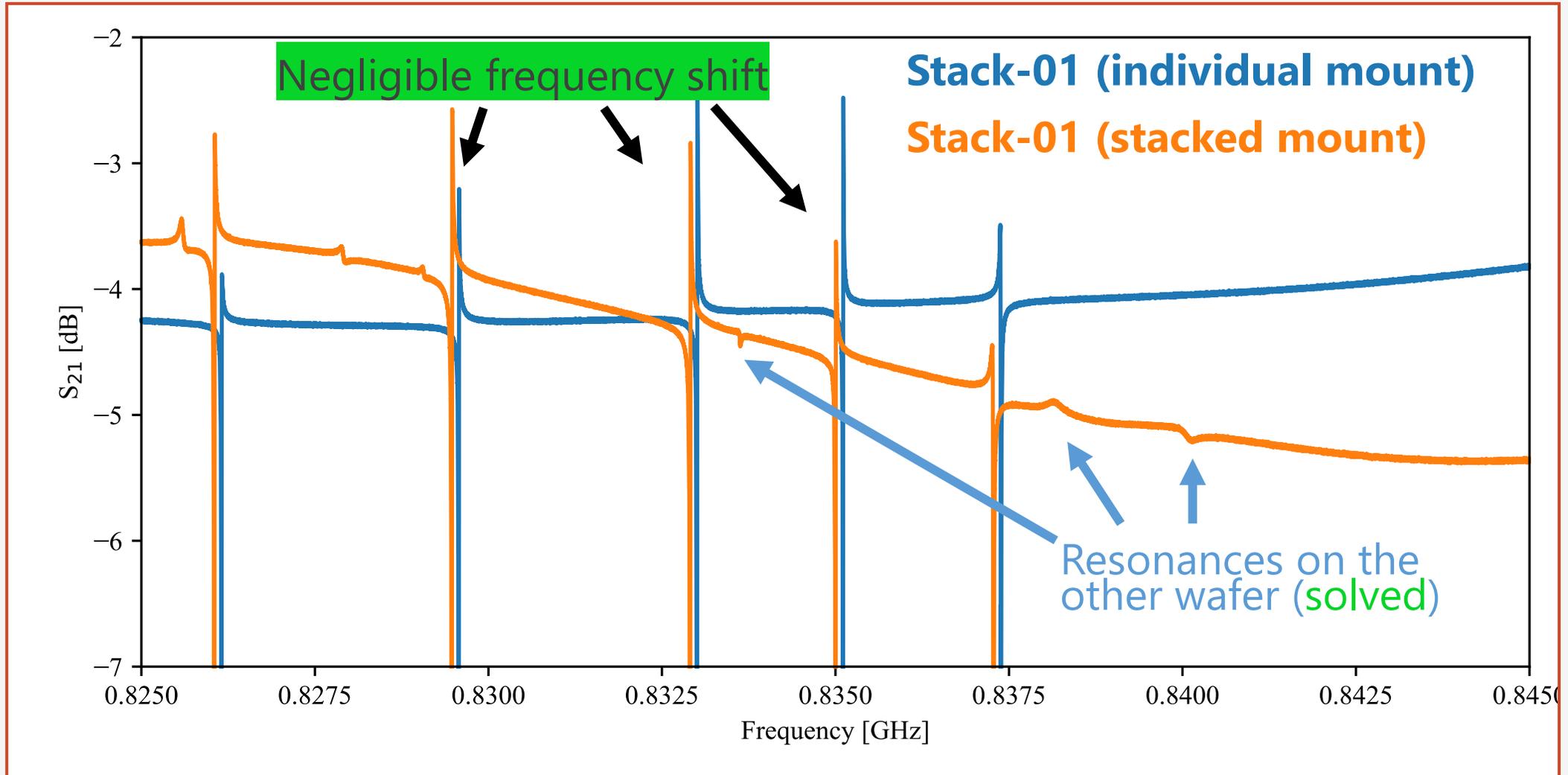


# Thermalization and electrical coupling

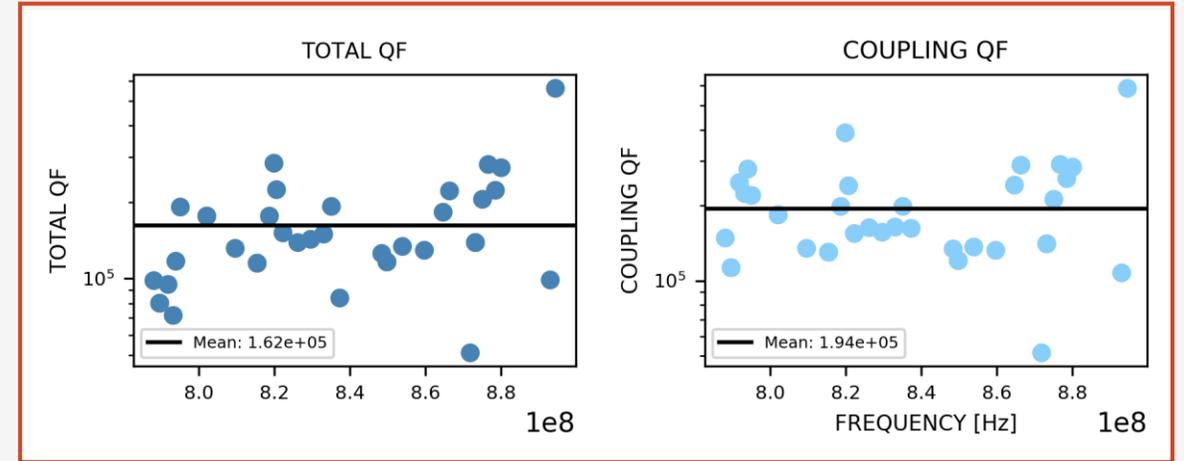
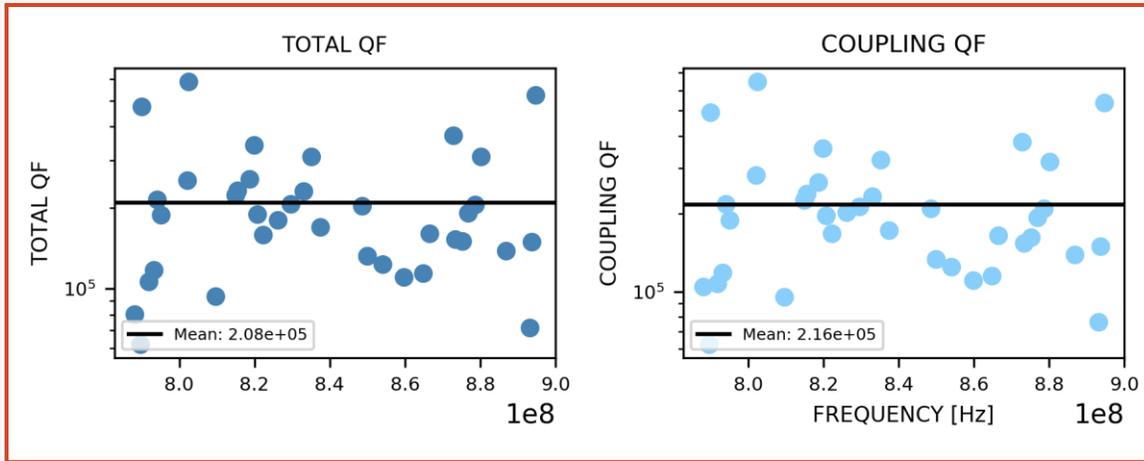
- Holding structure: **thermalization** OK
- **Resonance depth and  $Q_i$**  OK



# Thermalization and electrical coupling



# Thermalization and electrical coupling: Q factor comparison



## Stack-01: Individual mounting

Quality factor (median): 185k

Coupling Q factor (median): 190k

- Electrical behaviour **OK**

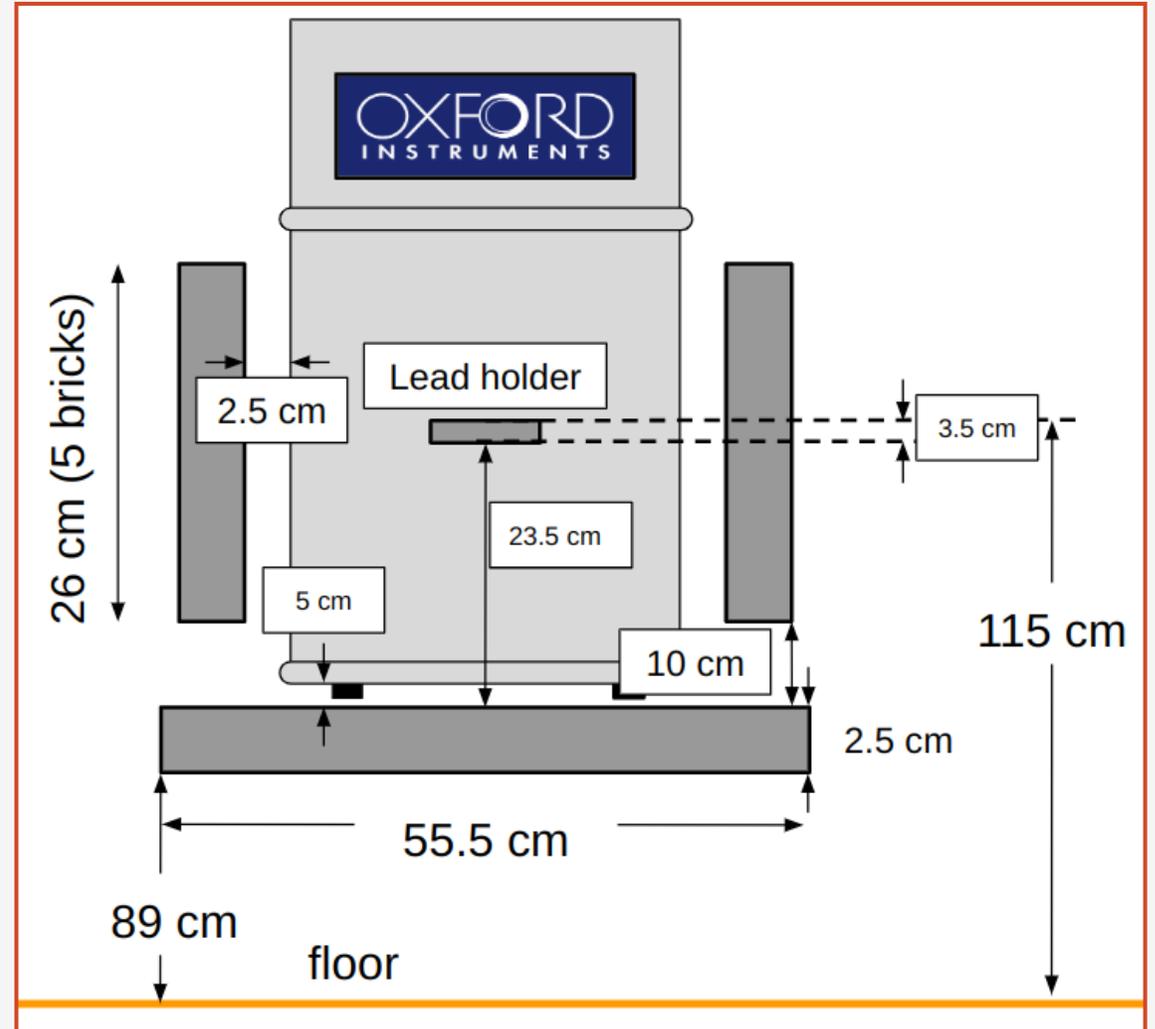
- Coupling **Qc** and impedance mismatch **minimally impacted**

## Stack-01: Stacked mounting

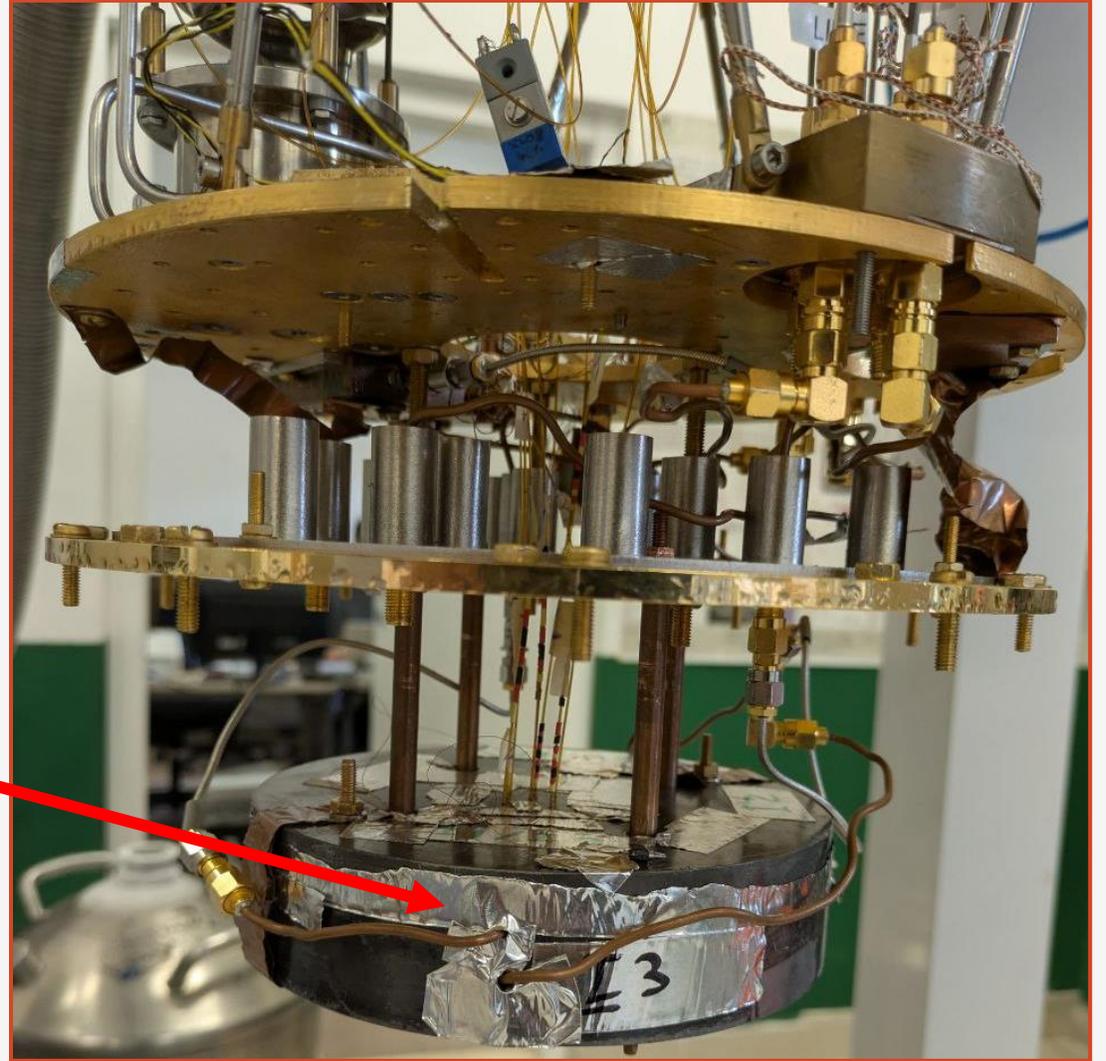
Quality factor (median): 140k

Coupling Q factor (median): 160k

# Preliminary results above ground: shielded background



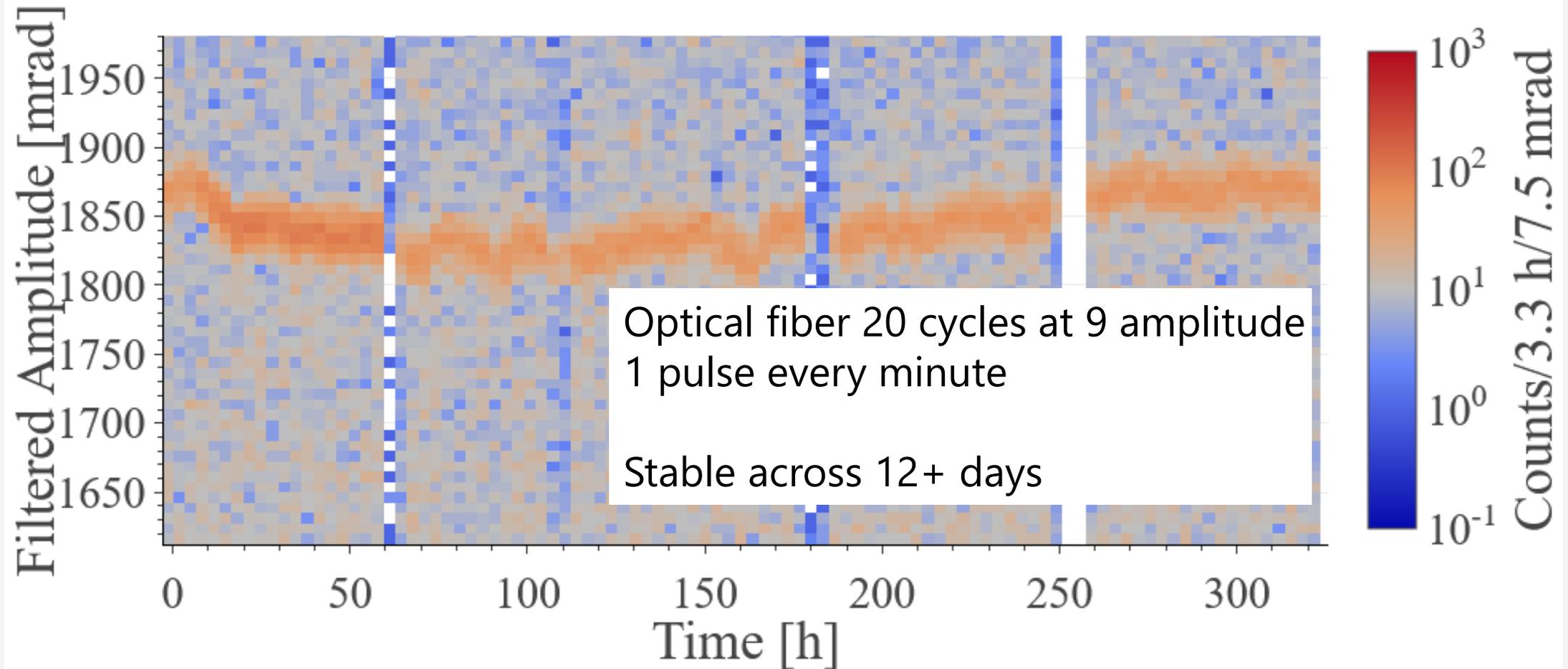
# Preliminary results above ground: shielded background





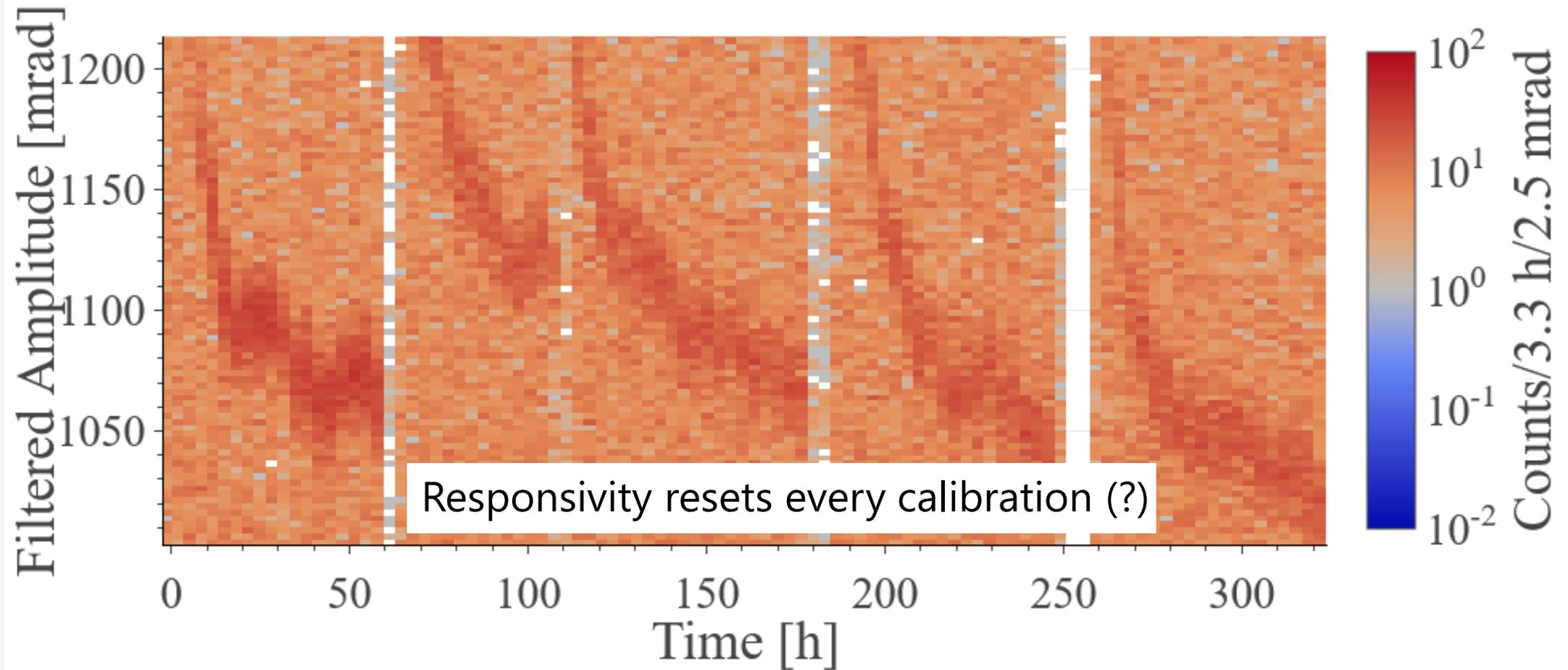
# Master of stable cluster, KID-11

## Control LED stability KID-11



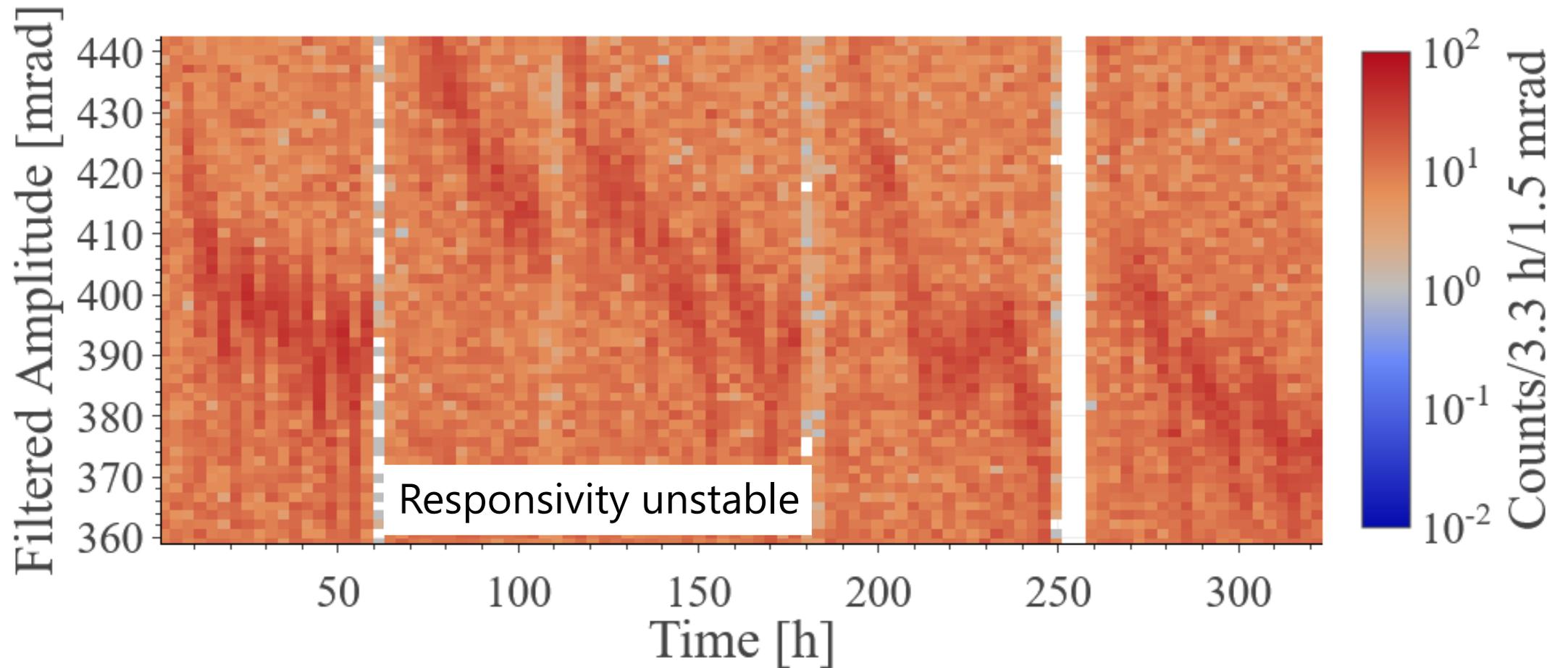
# Master of unstable cluster, KID-9

## Control LED stability KID-9

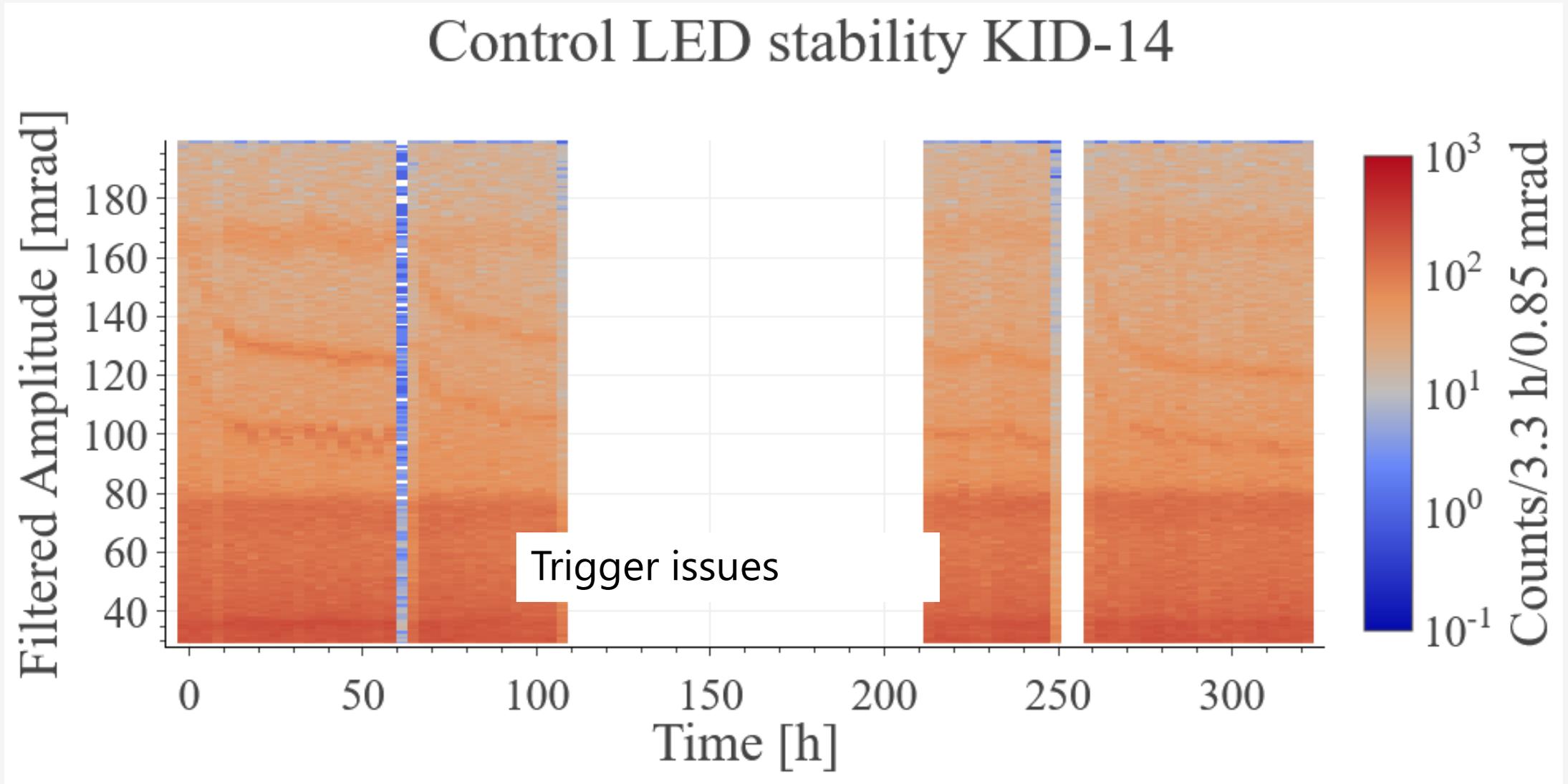


# Master of unstable cluster, KID-13

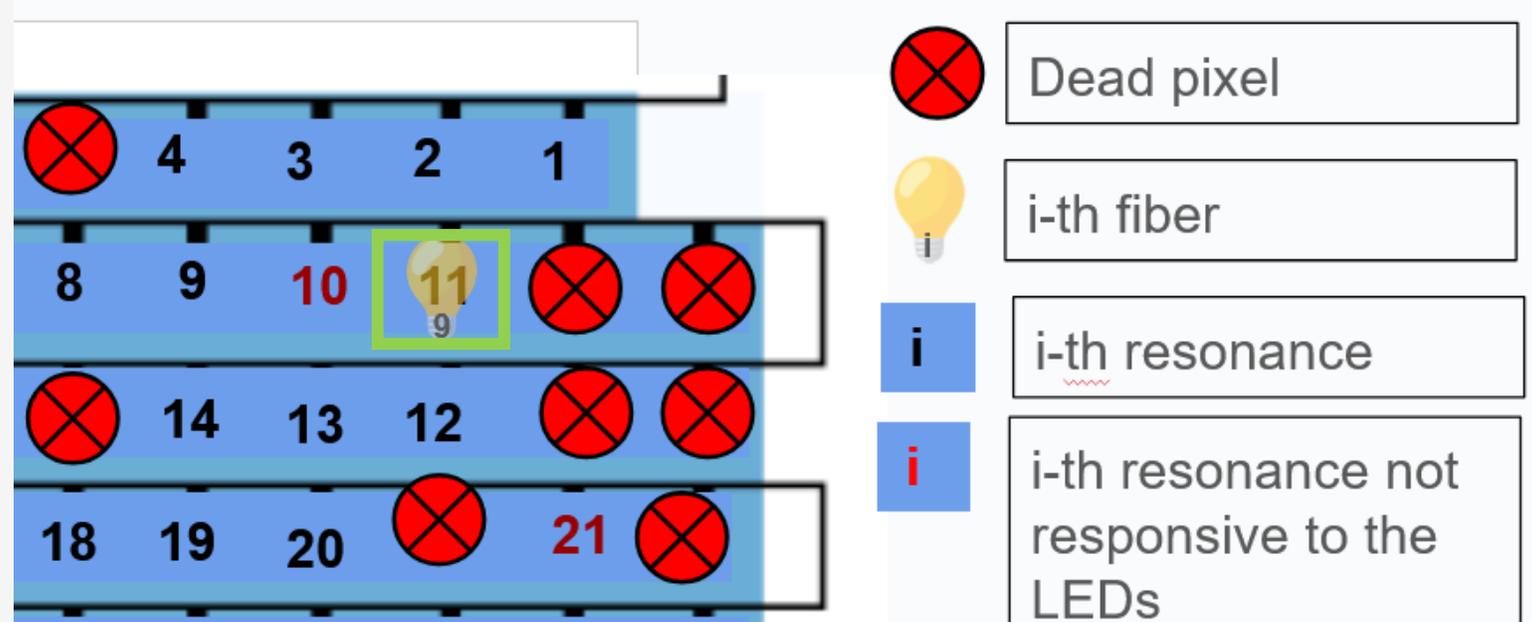
## Control LED stability KID-13



# Master of unstable cluster, KID-14



# Background acquired with cluster 11



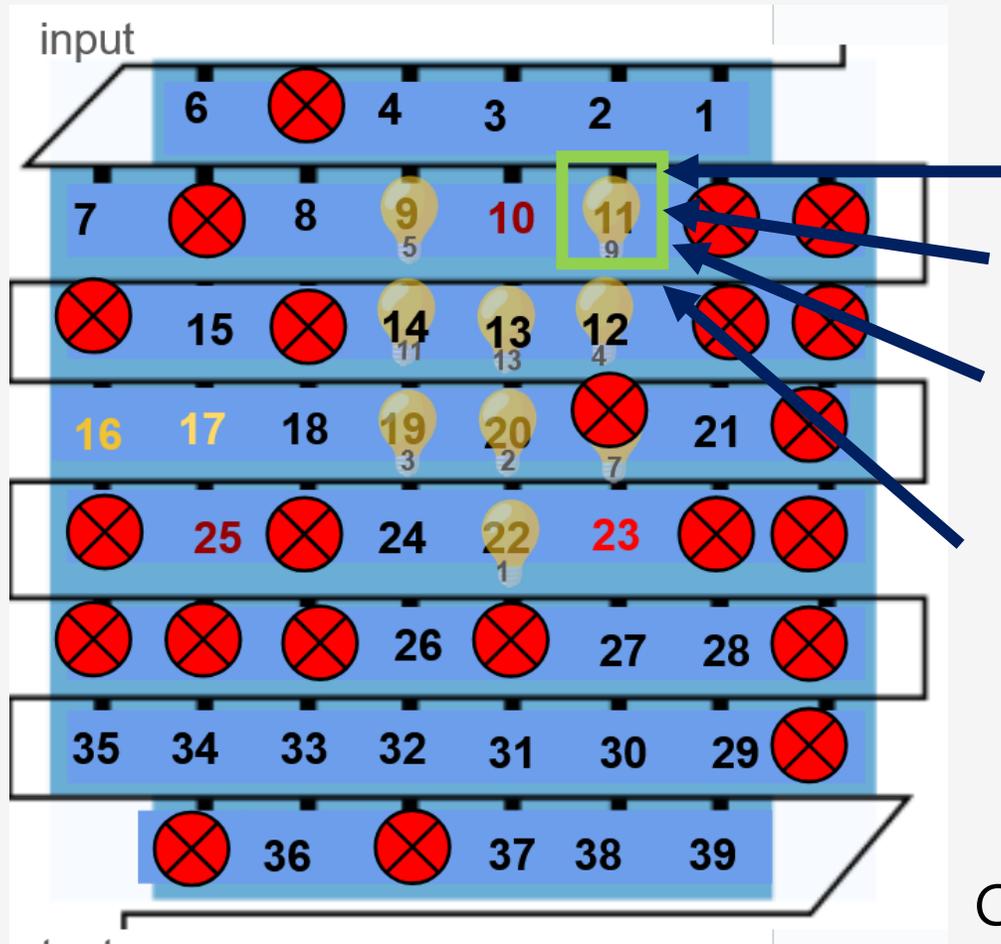
Resolution **KID-11**:  $54 \pm 2$  eV @  $35 \pm 1$  mrad/keV

Single 0.34g die vetoed by **13 neighbours**

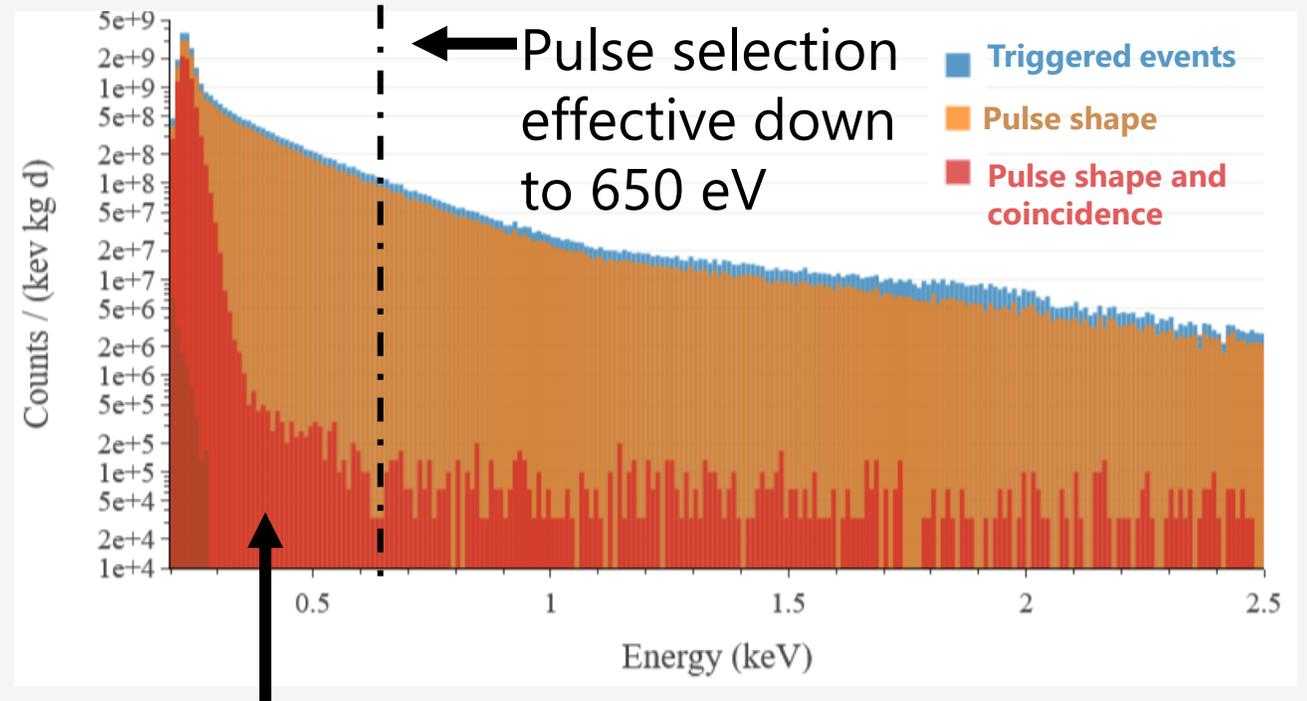
Total exposure: 267.5h

**External and internal lead shield**

# Limited discrimination power, KID-11

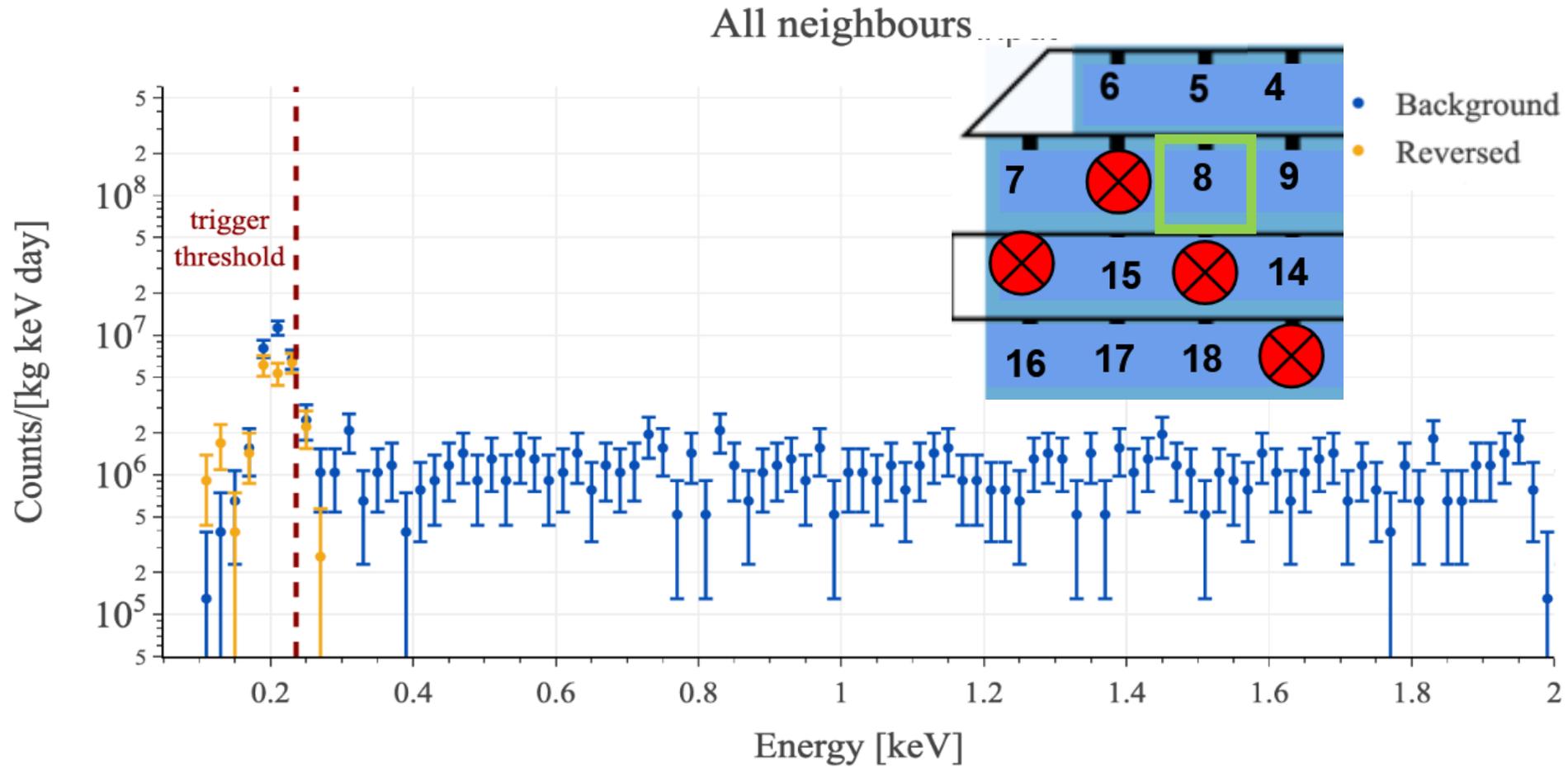


(Many!) missing pixels **do not allow vetoing from some directions**

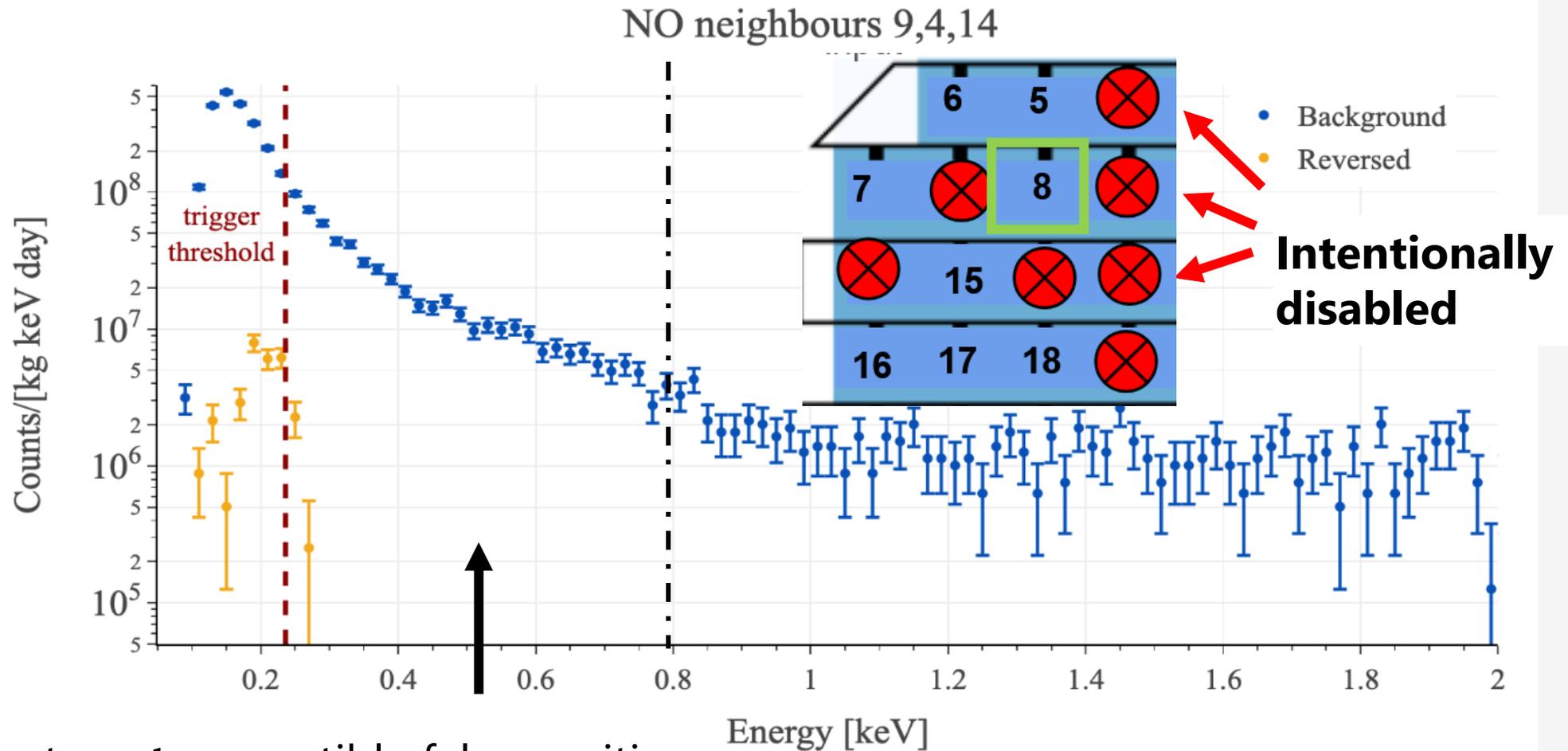


Counts **not** compatible with noise false positives

# Unshielded background, full discrimination



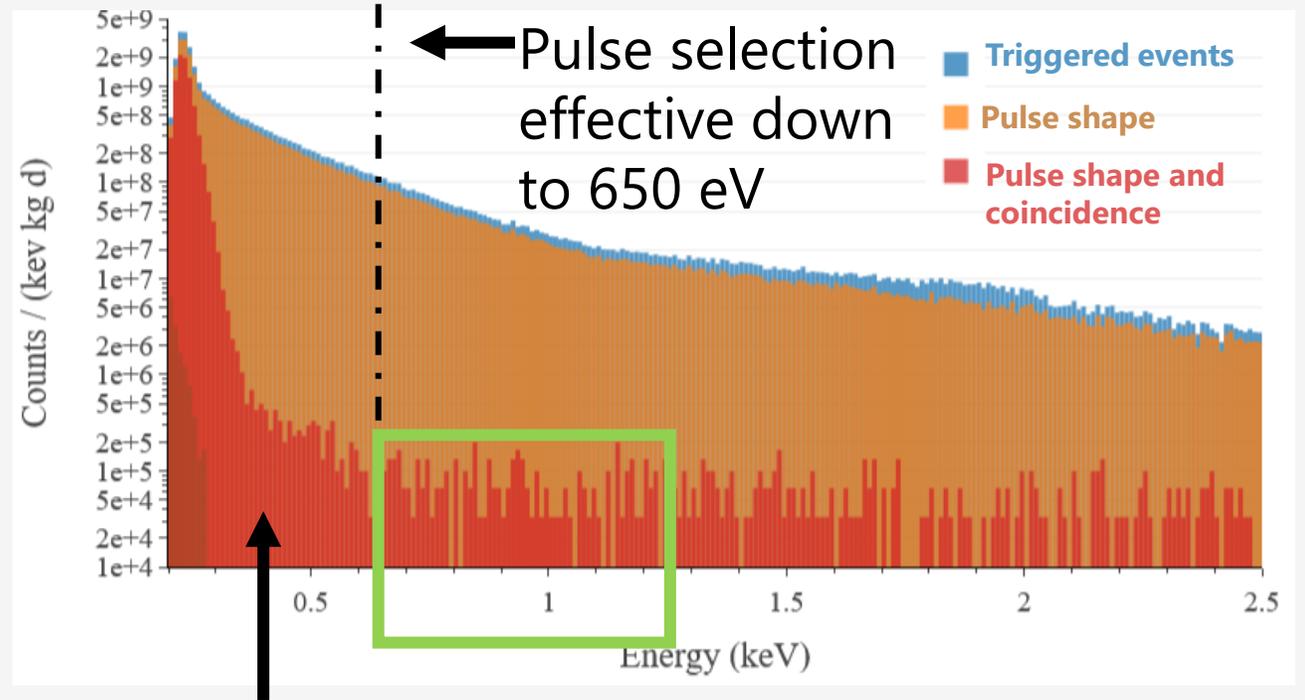
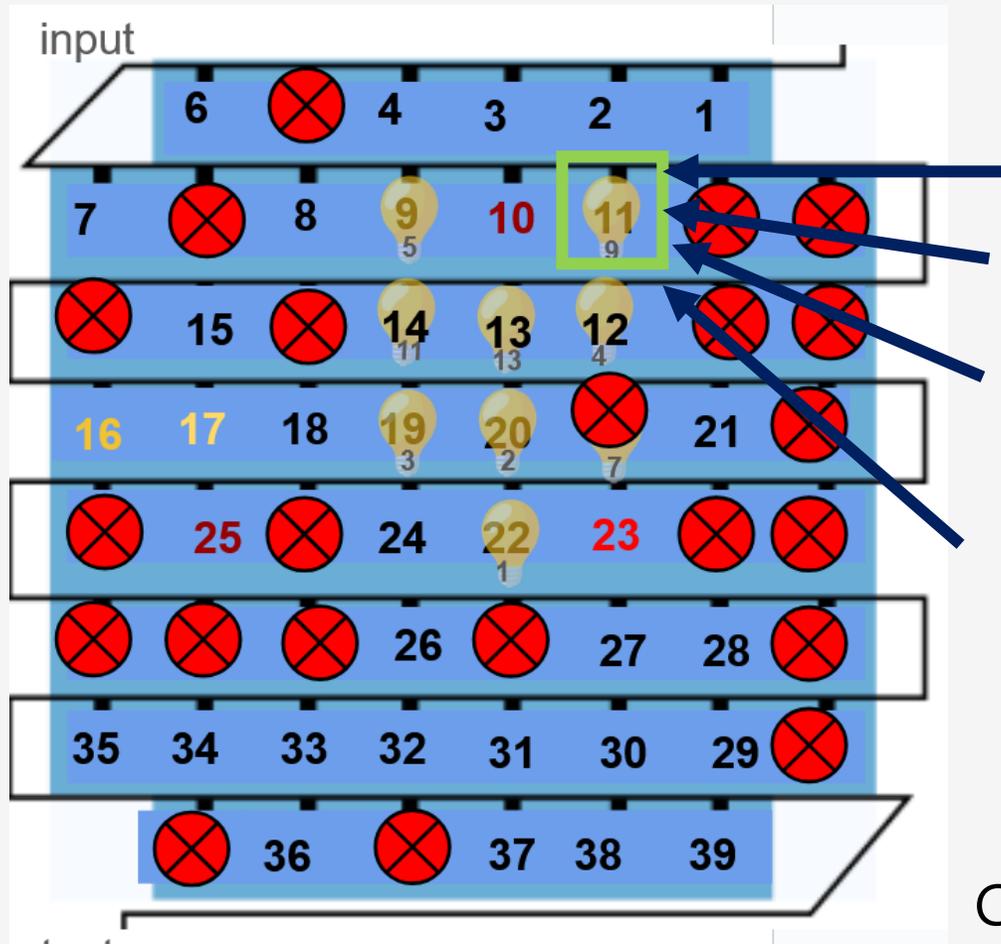
# Emulation of limited discrimination power



Counts **not** compatible false positives

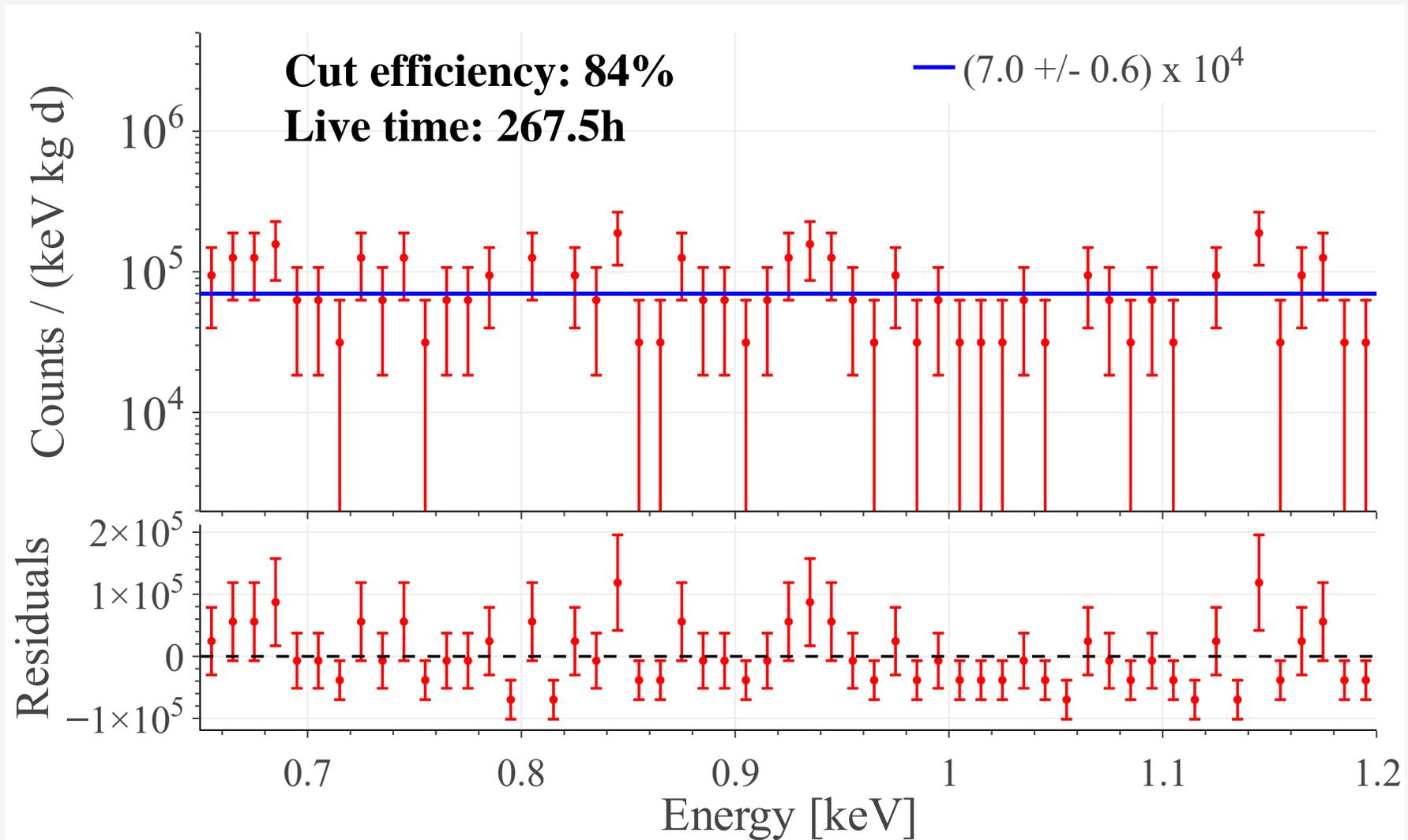
# Limited discrimination power, KID-11

(Many!) missing pixels **do not allow vetoing from some directions**

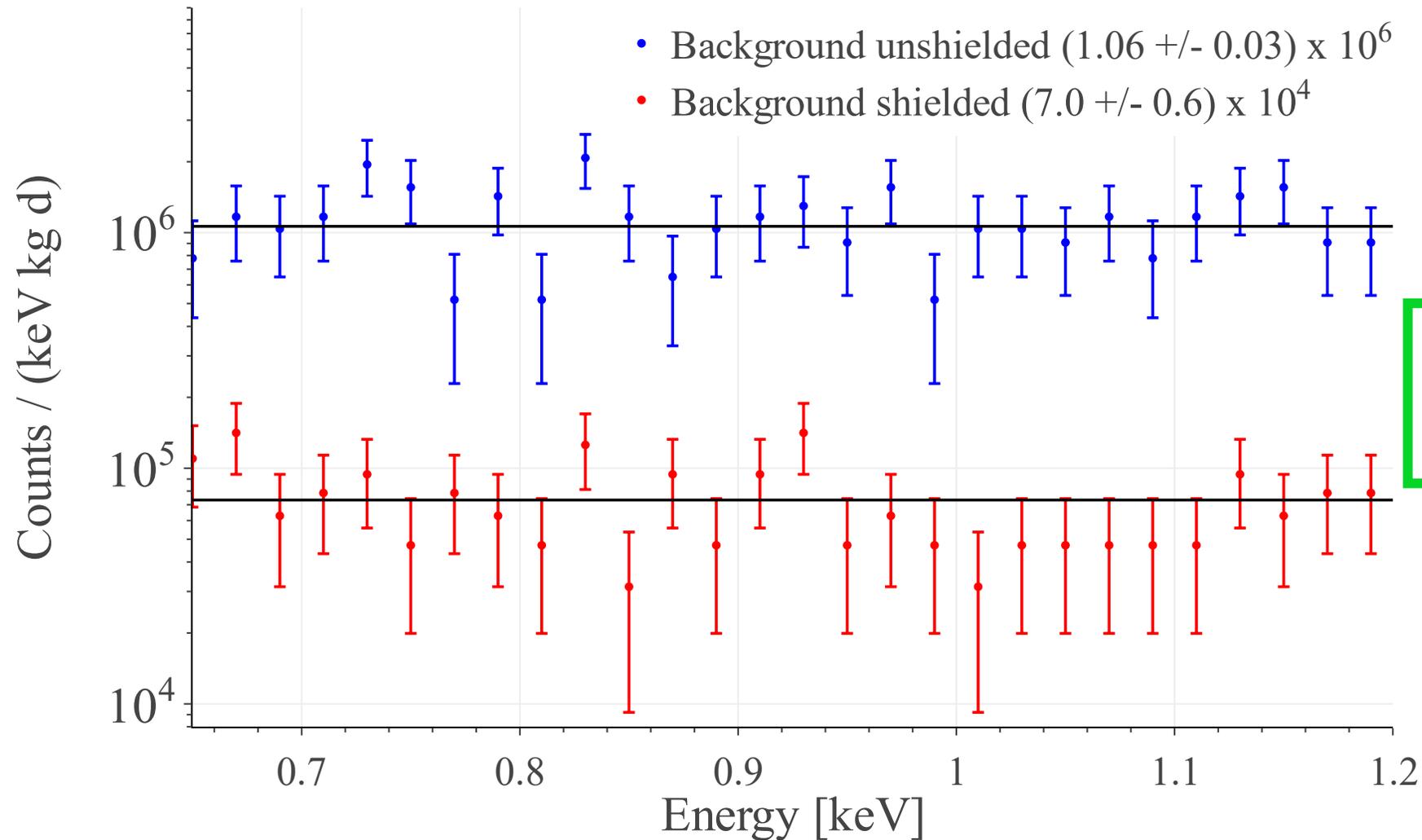


Counts **not** compatible with noise false positives

# Background of stable cluster, KID-11



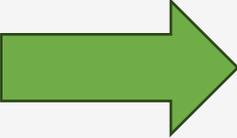
# Background shielded vs unshielded STACK-01



**Reduction by  
a factor  $15 \pm 2$**

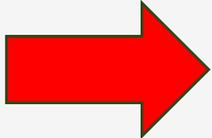
# Status of the BULLKID 3" demonstrator

---

- **Thermalization** of the wafers via the copper structure 
  - **Electrical coupling** not compromised by proximity among wafers 
  - **Energy threshold** on par with earlier prototypes
  - **Scale readout and analysis** to simultaneously measure multiple wafers
  - **Background** in a shielded environment **flat and lower than  $10^5$  dru**
- **Deep resonances**
  - Typical  **$Q_i > 1M$**
  - **Negligible** effect on  **$Q_c$**
  - **Negligible impedance mismatch**
  - **Very weak** coupling with resonators on different wafers

# Status of the BULLKID 3" demonstrator

---

- **Thermalization** of the wafers via the copper structure
  - **Electrical coupling** not compromised by proximity among wafers
  - **Energy threshold** on par with earlier prototypes
  - **Scale readout and analysis** to simultaneously measure multiple wafers
  - **Background** in a shielded environment **flat and lower than  $10^5$  dru**
- 
- **So far unable to reproduce the original responsivity**
  - **Not** an intrinsic problem with stacking
  - **Dirty / Low quality wafers** are a limiting factor

# Status of the BULLKID 3" demonstrator

---

- **Thermalization** of the wafers via the copper structure
  - **Electrical coupling** not compromised by proximity among wafers
  - **Energy threshold** on par with earlier prototypes
  - **Scale readout and analysis** to simultaneously measure multiple wafers
  - **Background** in a shielded environment **flat and lower than  $10^5$  dru**
- 
- **Work in progress, so far 4 clusters (14 pixels)**  
For more see talks of
    - T. Muscheid on electronics
    - M. Cappelli on the analysis pipeline

# Status of the BULLKID 3" demonstrator

---

- **Thermalization** of the wafers via the copper structure
- **Electrical coupling** not compromised by proximity among wafers
- **Energy threshold** on par with earlier prototypes
- **Scale readout and analysis** to simultaneously measure multiple wafers
- **Background** in a shielded environment **flat and lower than  $10^5$  dru**



## From the CDR:

For the time being we plan to repeat the measurement with a mild lead shield at Sapienza U. before the end of the year (the maximum amount of lead is limited to a few kg by the load that the current cryostat can sustain). This shield is expected to reduce the background by a factor close to 50, below  $10^5$  DRU.

## Flat background $< 10^5$ dru demonstrated

- Above ground
- Passive internal and external Pb shields

## To probe background $< 650$ eV

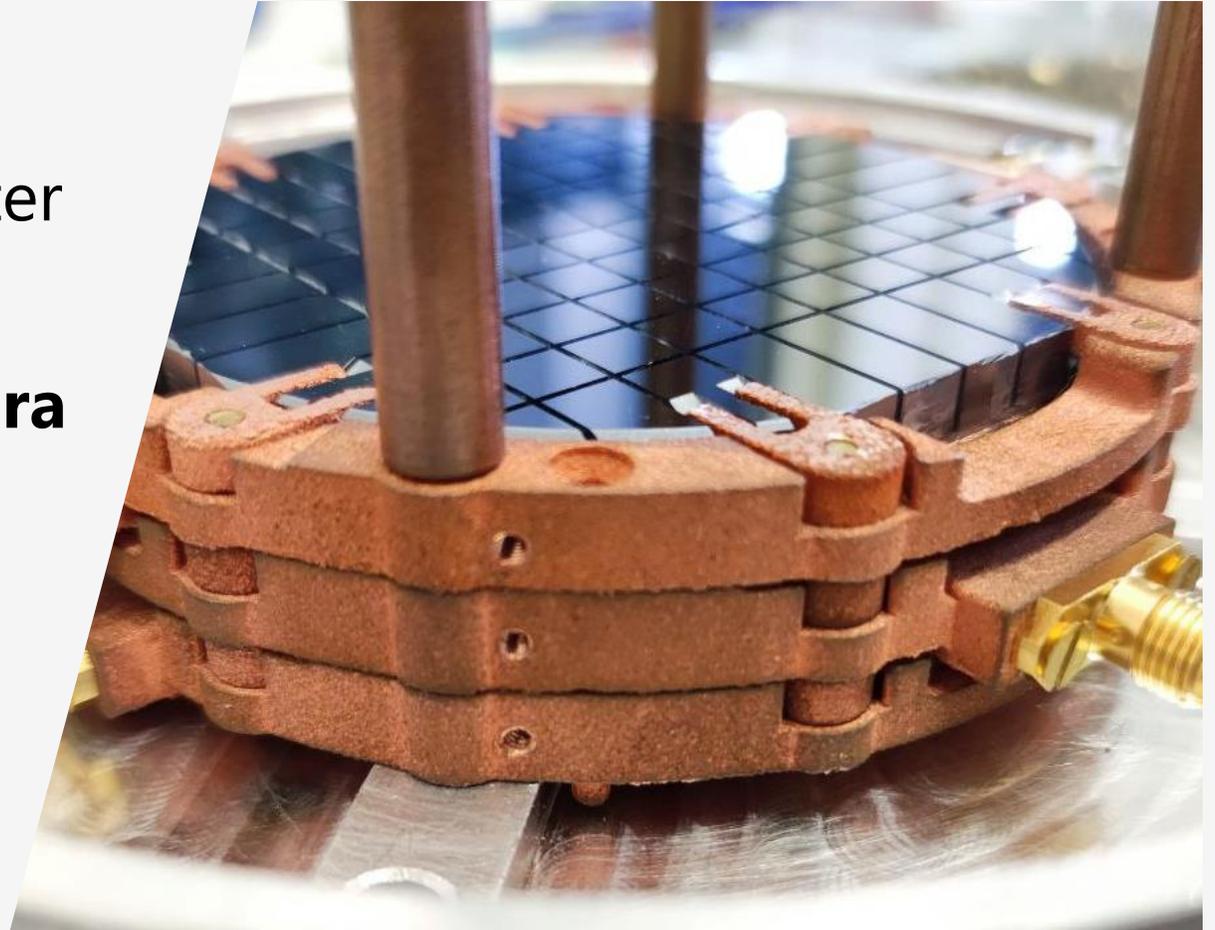
- Lower threshold
- More active pixels
- Overall better samples

## Status of the BULLKID 3" demonstrator: next steps

---

Swap out low quality arrays for better performing ones

- **3 diced wafers ready from Ferrara**
- **Fabrication in Grenoble soon**



# (Extra) Low energy background analysis, cuts

---

