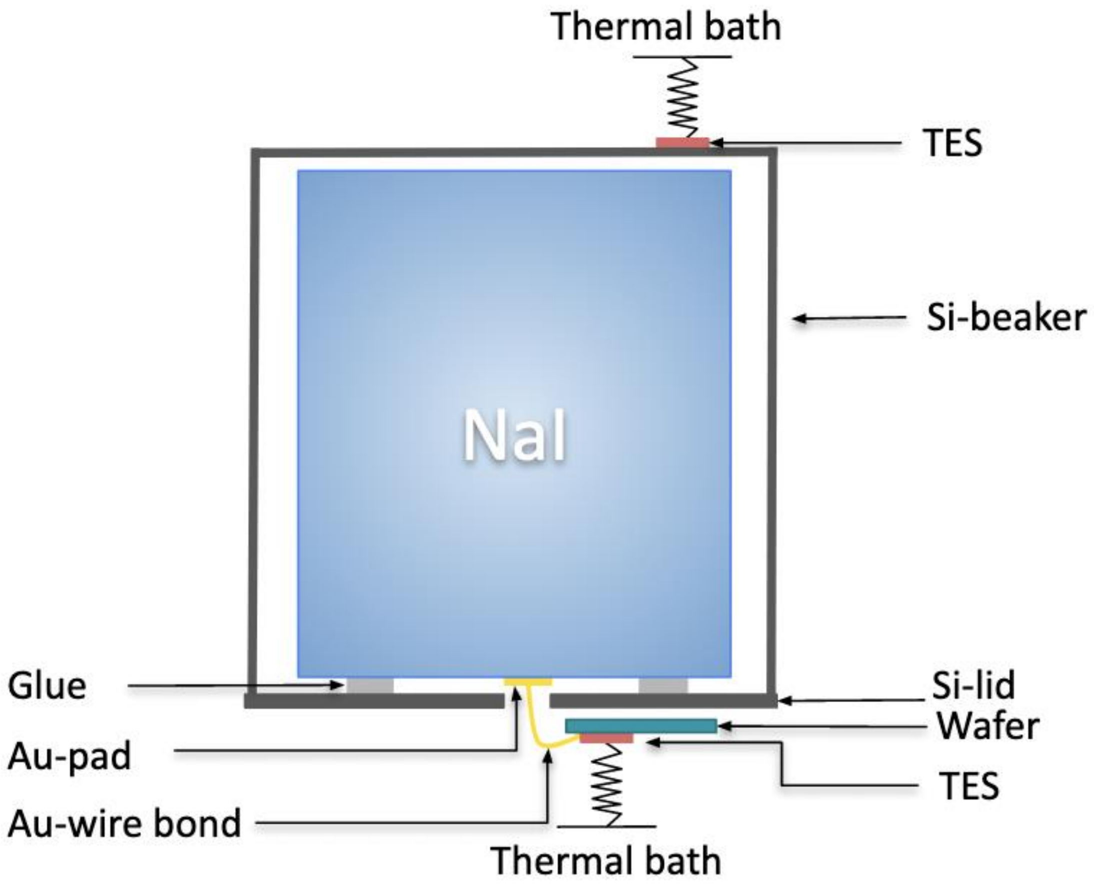
Optimization of the remoTES design using silicon absorber

- SMuK DPG 2023, March 20th to 24th
- Speaker: Kumrie Shera

COSINUS: **C**ryogenic **O**bservatory for **SI**gnals seen in **N**ext generation **U**nderground **S**earches

- Direct dark matter search experiment operating NaI as cryogenic calorimeter
- NaI is a very good scintillator
- Two channel readout: phonon signal and light signal by using transition edge sensors (TES)



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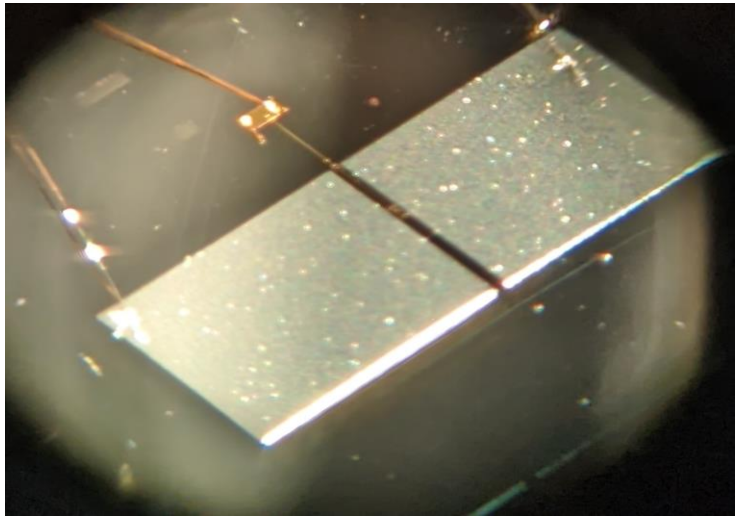
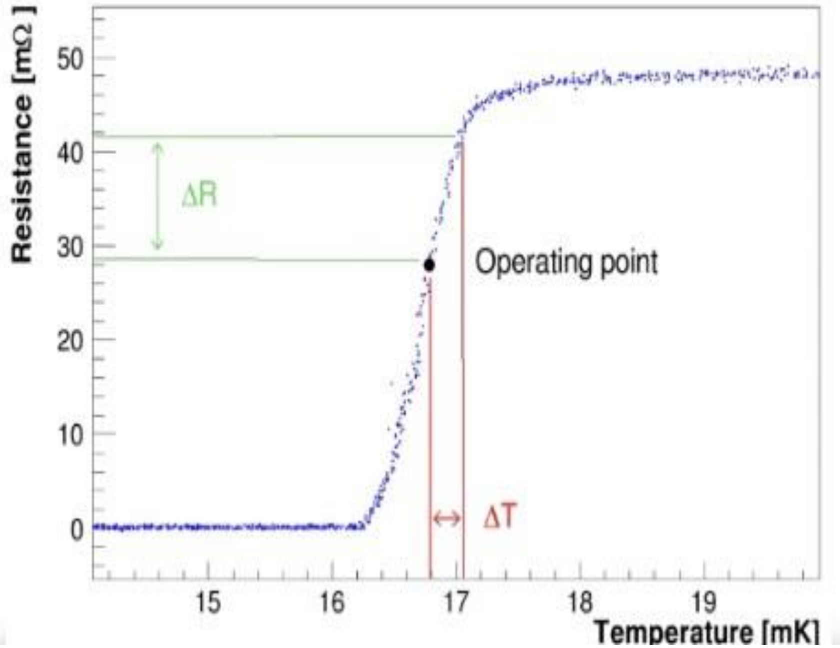
Transition Edge Sensor (TES)



- Sensors made of superconducting thin film ($T_c = 15\ mK$) used to measure the temperature increase (phonons) in the order of ~μK
- Operated in the transition from normal conducting to the superconducting phase
- Small increase in the temperature ΔT (μK) leads to a significant change in the resistance ΔΩ (mΩ)



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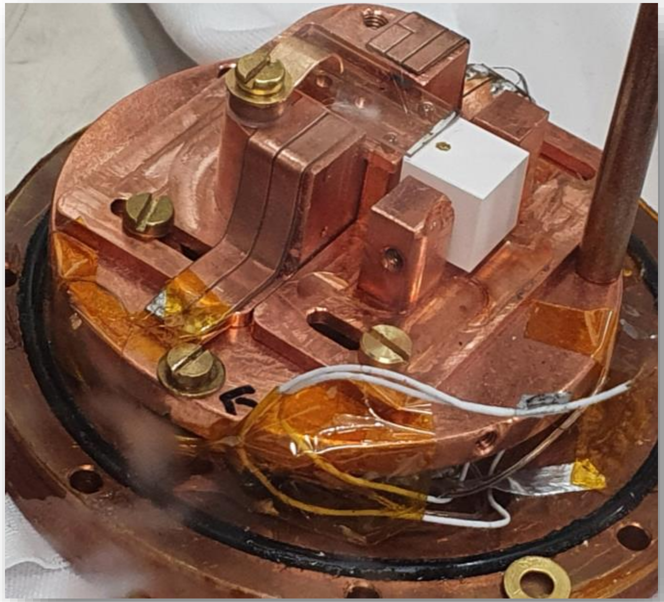
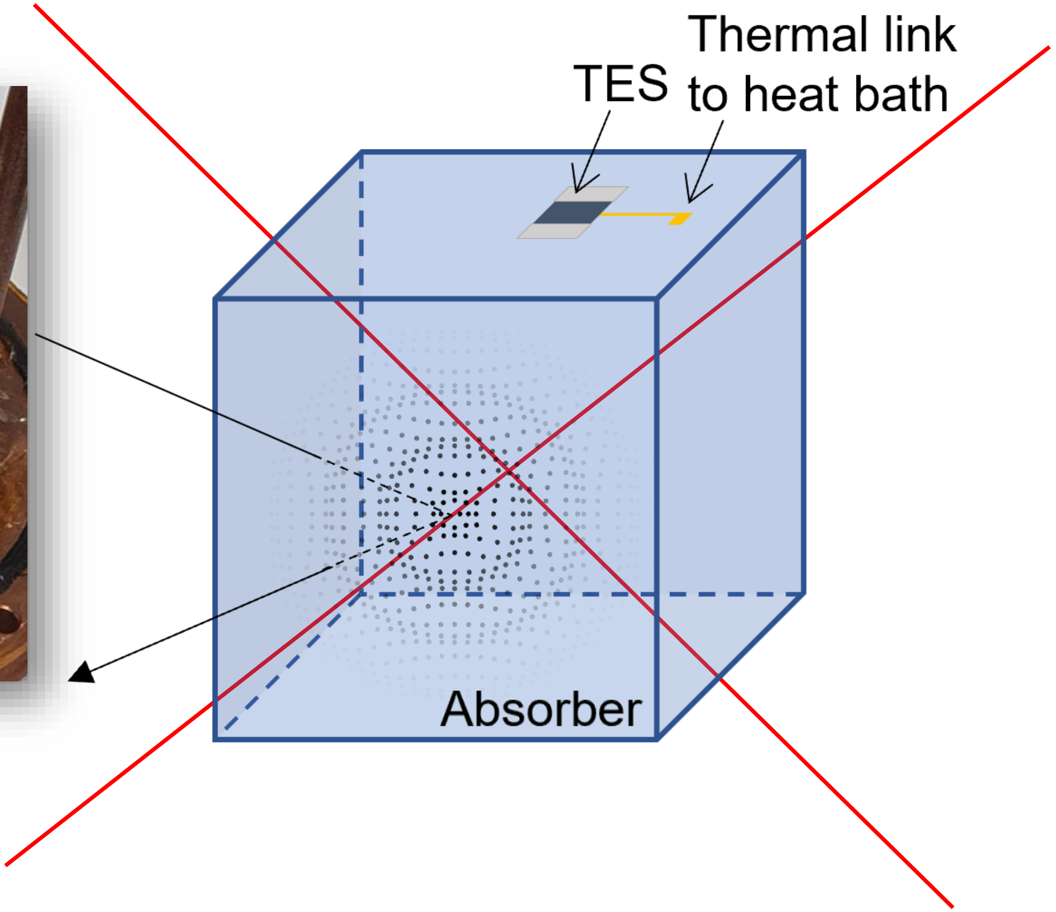
TES and NaI

- NaI: Hygroscopic and low melting point





Can NOT survive the fabrication process

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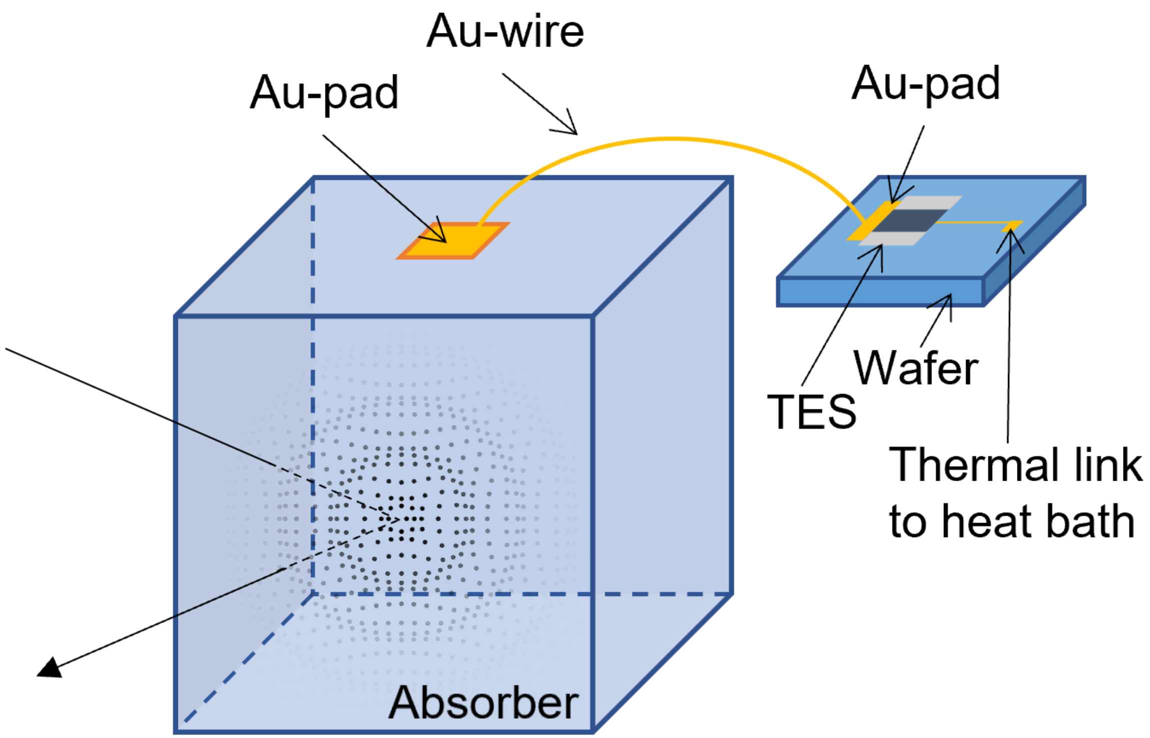
remoTES design

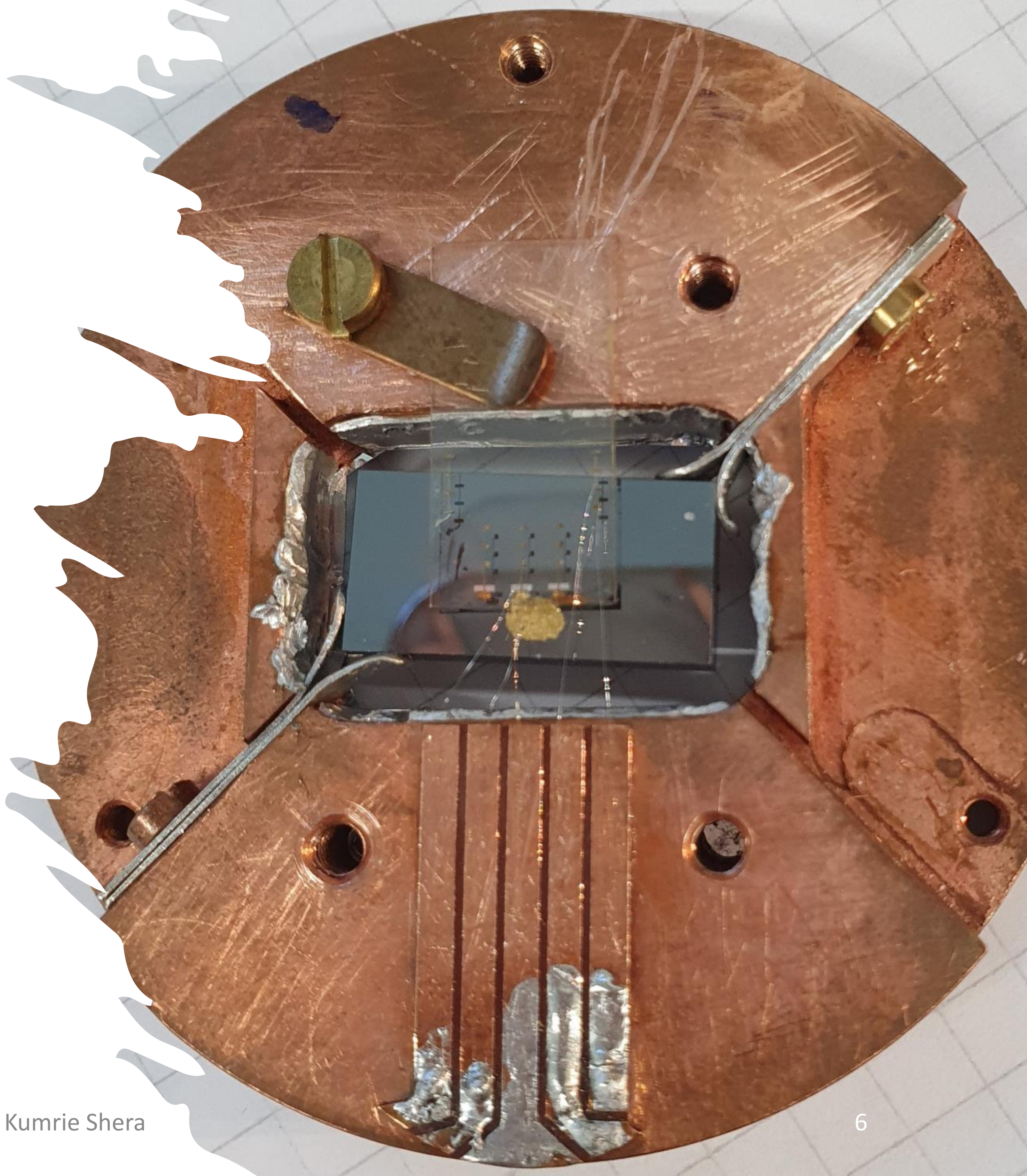
- First theoretically proposed by Matt Pyle and colleagues in 2015 arXiv:1503.01200
- TES deposited on a separate wafer
- Connected to the crystal via an Au-pad and an Au bond wire
- COSINUS provided the first experimental implementation of this specific design

https://doi.org/10.1016/j.nima.2022.167532

- NaI is not subjected to the fabrication process of TES
- Opens the possibility to use other NaI-like crystals as cryogenic calorimeters



Optimization studies of remoTES using Si crystal as benchmark



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Optimization studies of remoTES using Si crystal as benchmark

Overview of the different detector setups			
Run	**Detector**	**Characteristics**	
1	Φ	1 μm glued Au-pad	Wedge-bond
2	Elektra	200nm sputtered Au-pad	Ball-bond
	Olympia	8 μm glued Au-pad	Ball-bond
3	Elektra´	200nm sputtered Au-pad	2nd ball-bond
	Olympia´	8 μm glued Au-pad	Removal of Au-bridge

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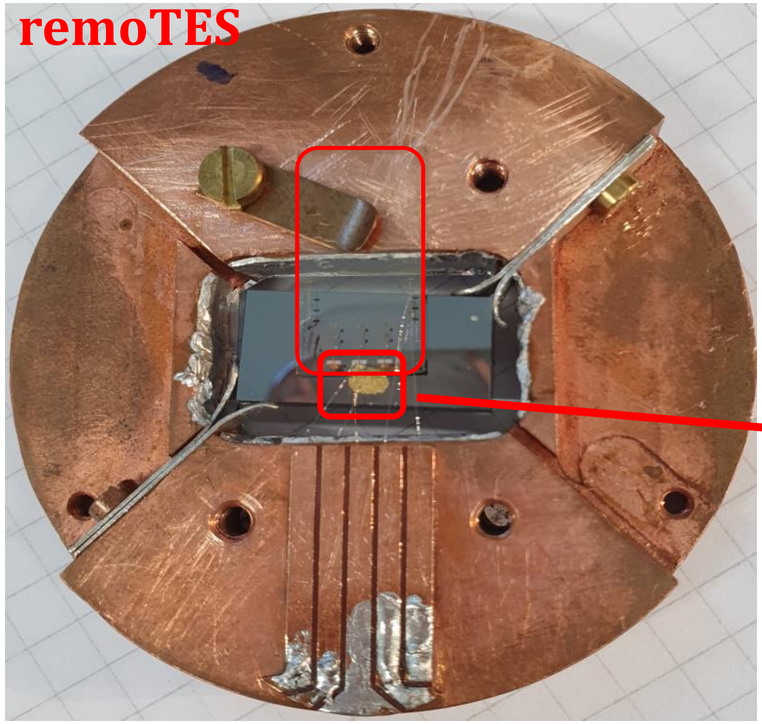
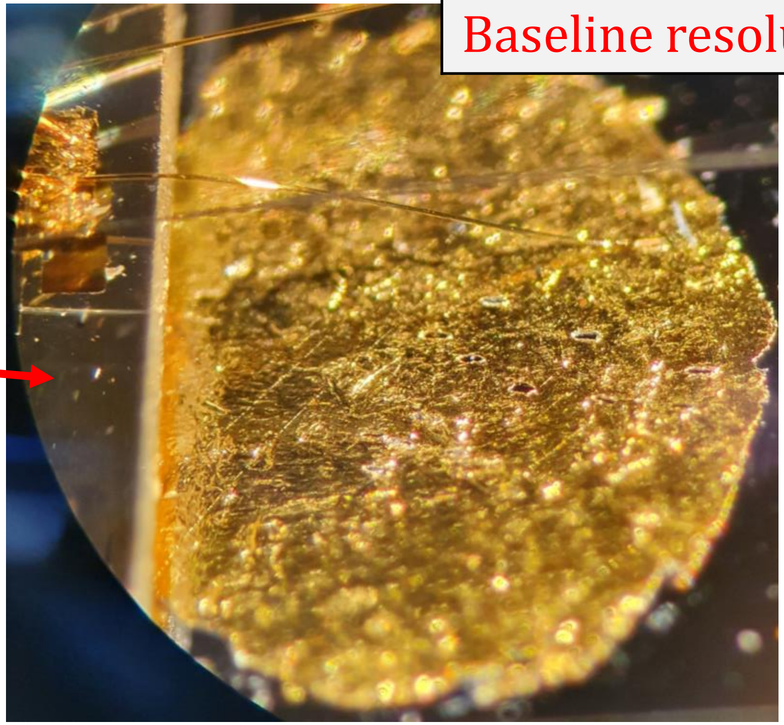
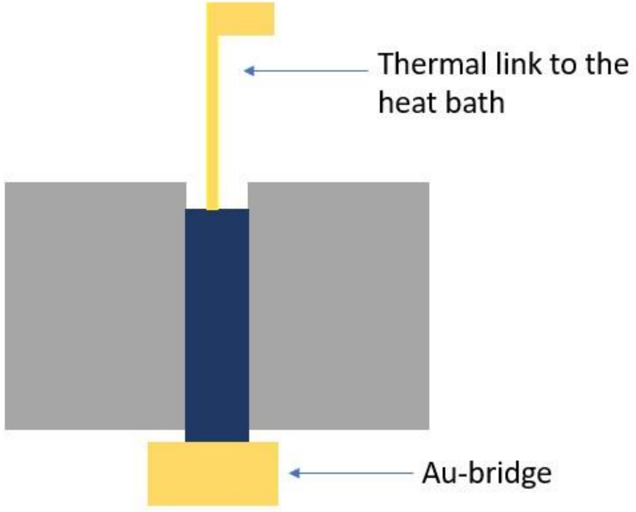
Optimization studies of remoTES using Si crystal as benchmark

Detector Φ

Absorber	Si (20×10×5 mm^3)
Au-pad	1 μm thick (glued)
Au-wire	17 μm thick (wedge-bond)
TES	W-TES on Al_2O_3
Baseline resolution	434 eV







Schematic representation of the TES on the wafer

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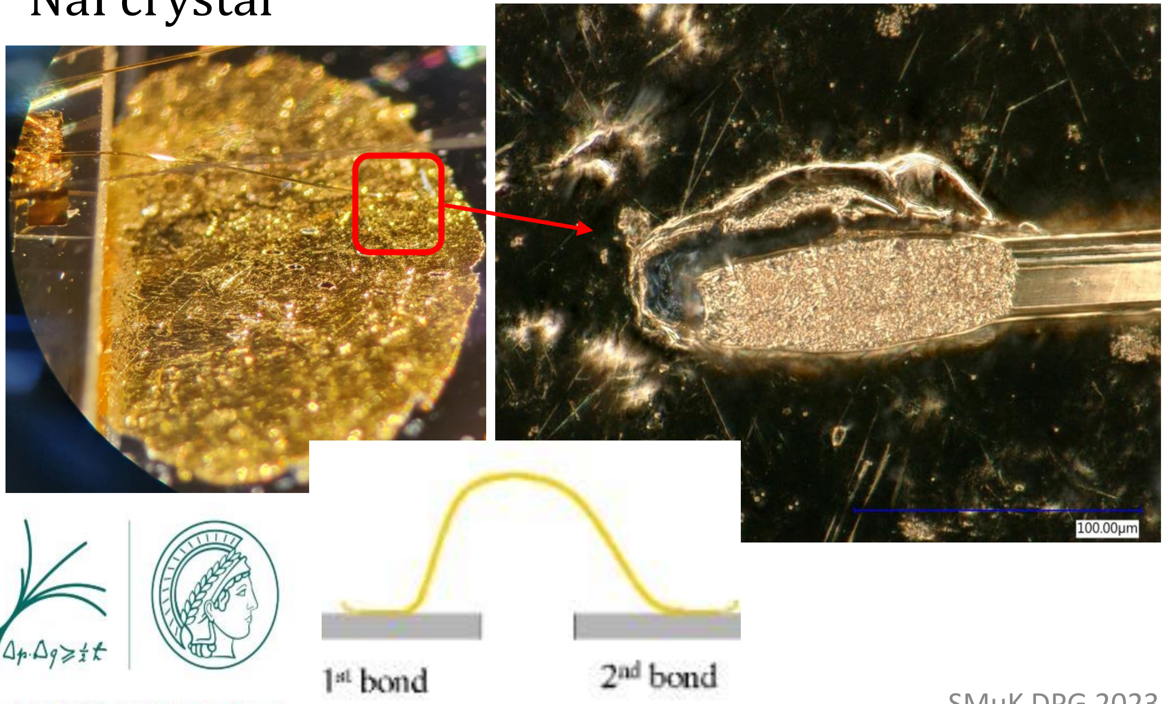
Optimization studies of remoTES using Si crystal as benchmark

Wedge- bond on 1µm thick Au-foil

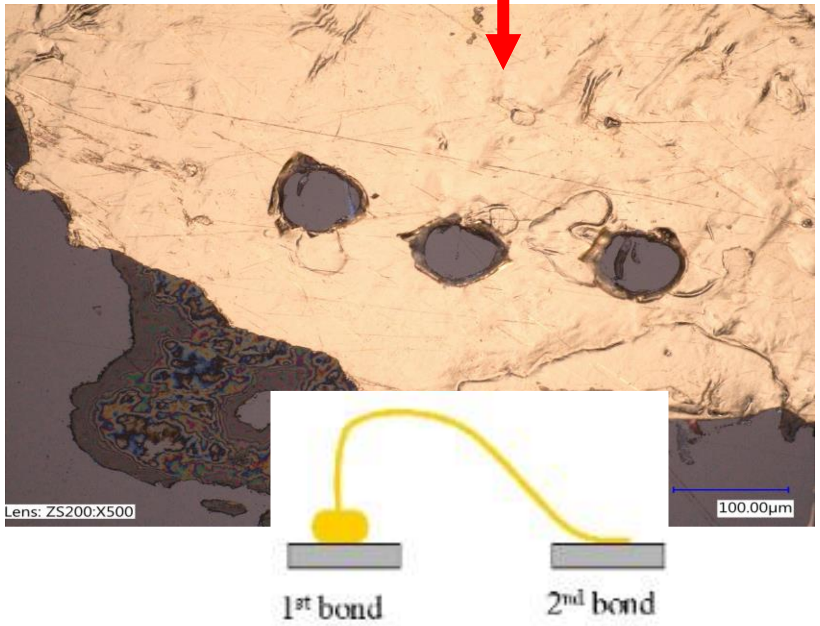
- Wedge bond detaches from Au-pad → not the entire Au-Pad area available for phonon collection
- It affects the Au-pad quality
- Bad thermal conductance
- Wedge-bond uses force →might cause cracks on the NaI crystal



Alternative: Ball-bond

- Improved thermal conductance
- Less destructive for NaI crystal

For direct comparison with previous detector setup a **ball-bond** on **1µm** thick Au-foil was tried. Not successful



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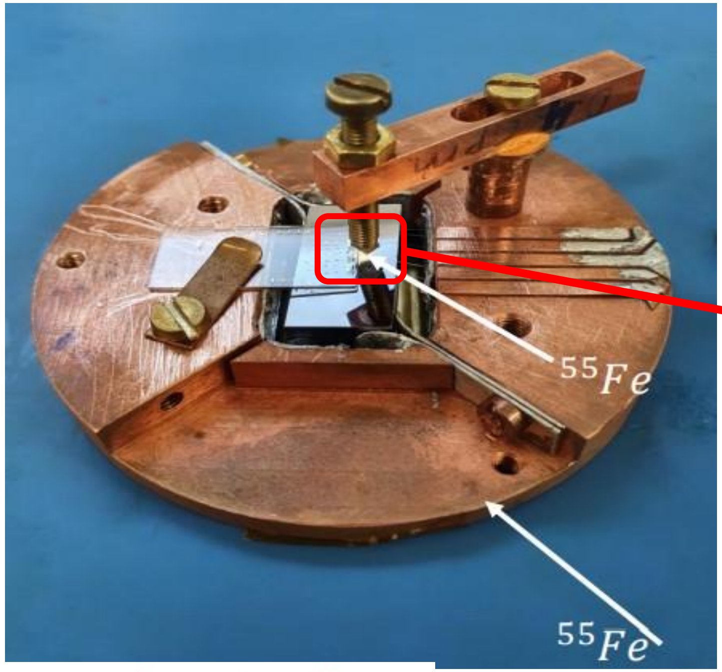
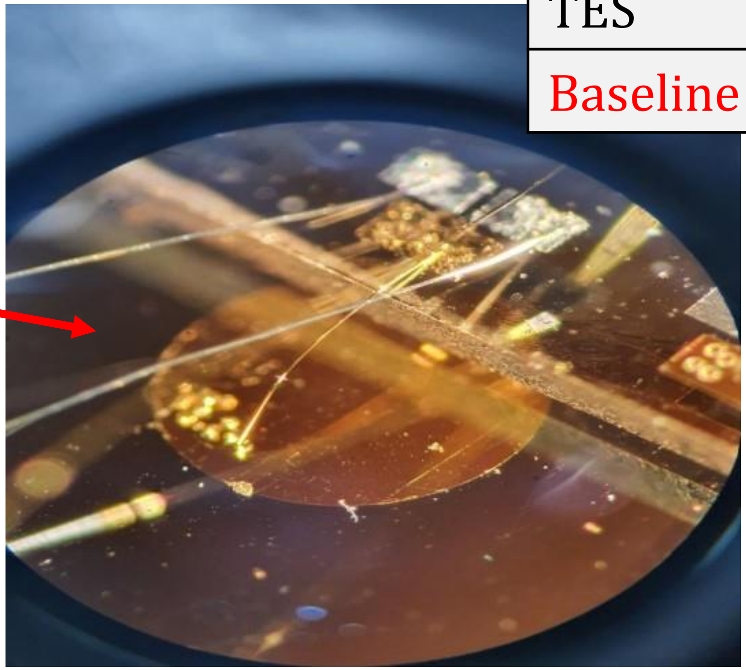
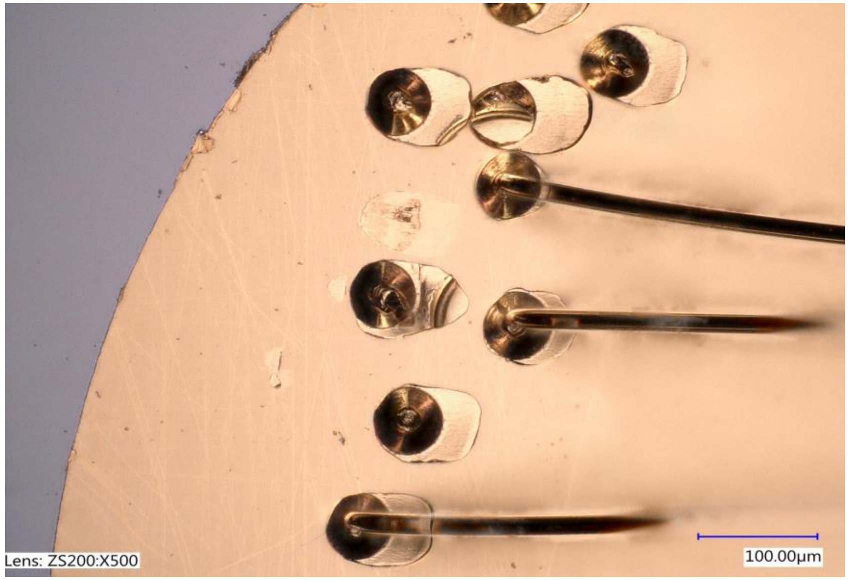
Optimization studies of remoTES using Si crystal as benchmark

Detector Elektra

Absorber	Si (20×10×5 mm^3)
Au-pad	200 nm thick (sputtered)
Au-wire	25µm thick (ball-bond)
TES	W-TES on Al_2O_3
Baseline resolution	132 eV







Ball-bonds on sputtered Au-pad

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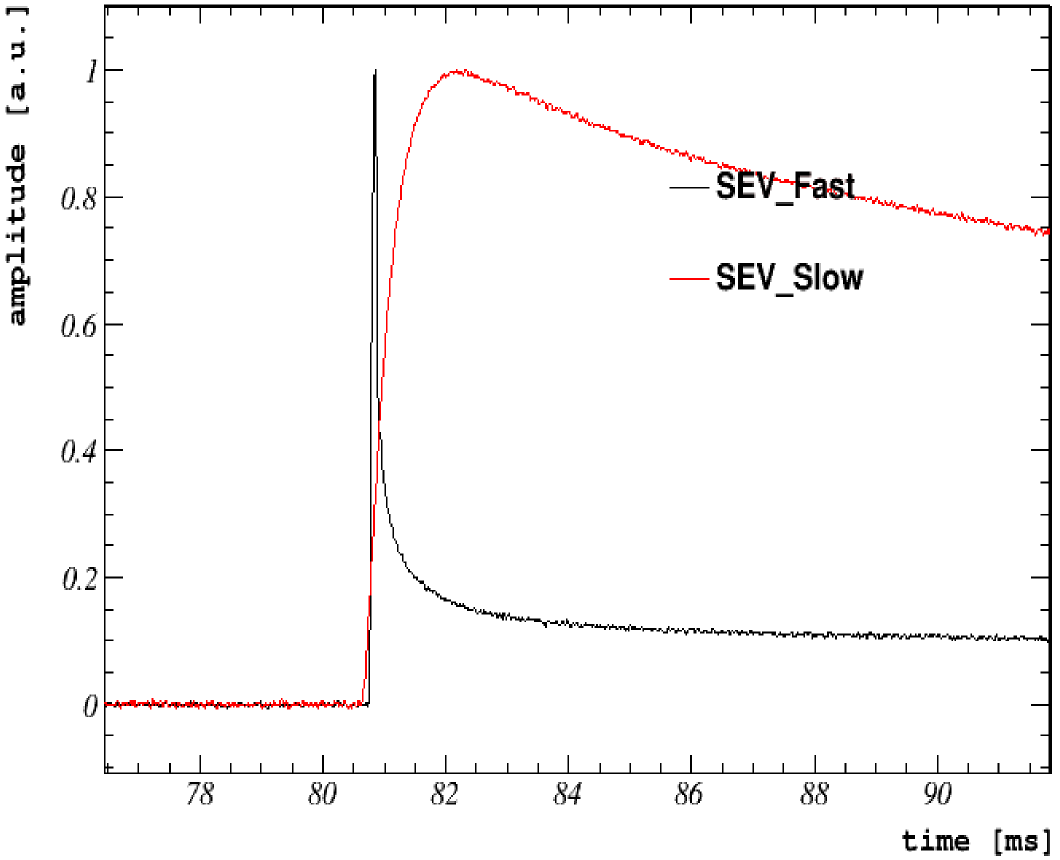
Optimization studies of remoTES using Si crystal as benchmark

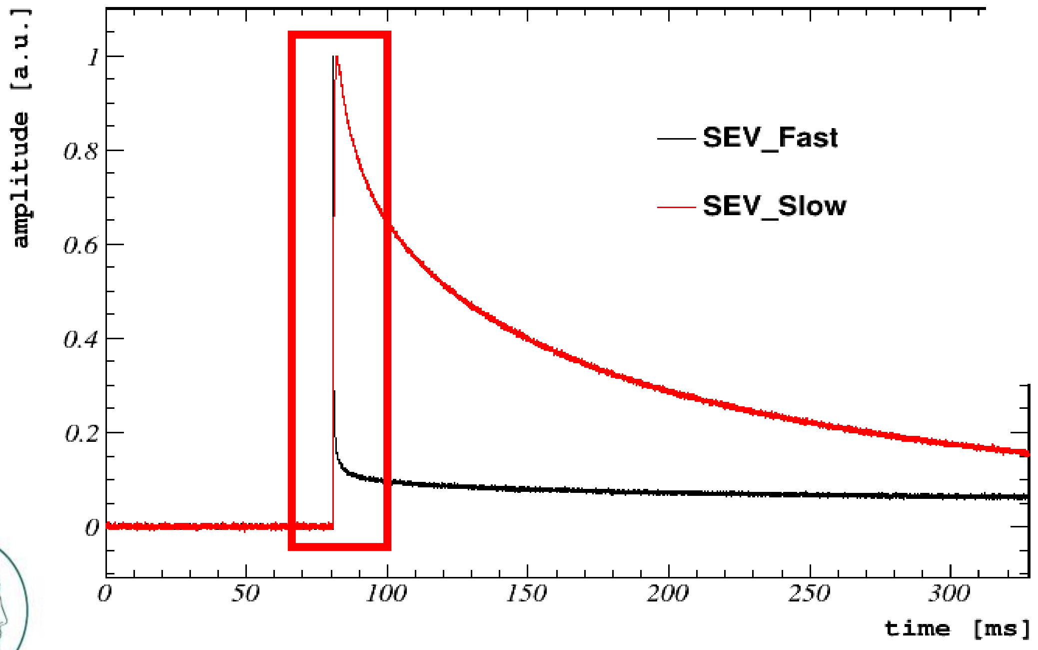
Detector Elektra

- Two different event classes

a. Slow events (slow rise time)

b. Fast events (fast rise time)





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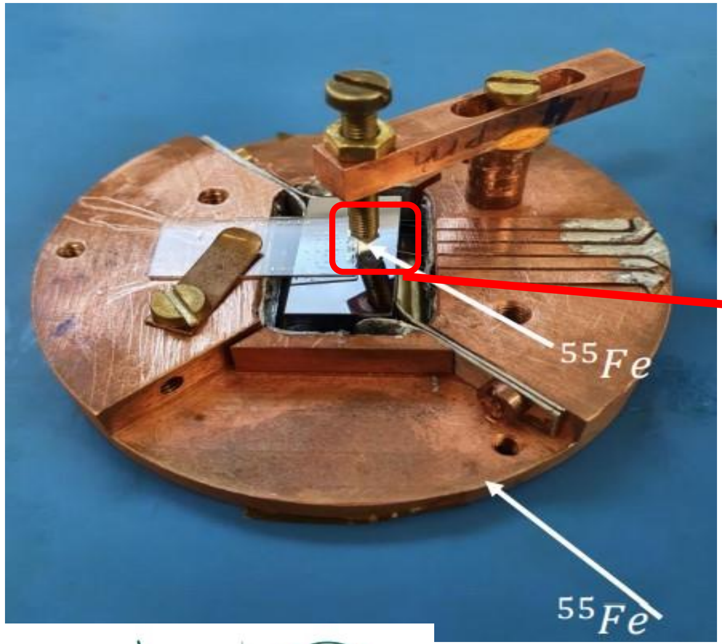
Optimization studies of remoTES using Si crystal as benchmark

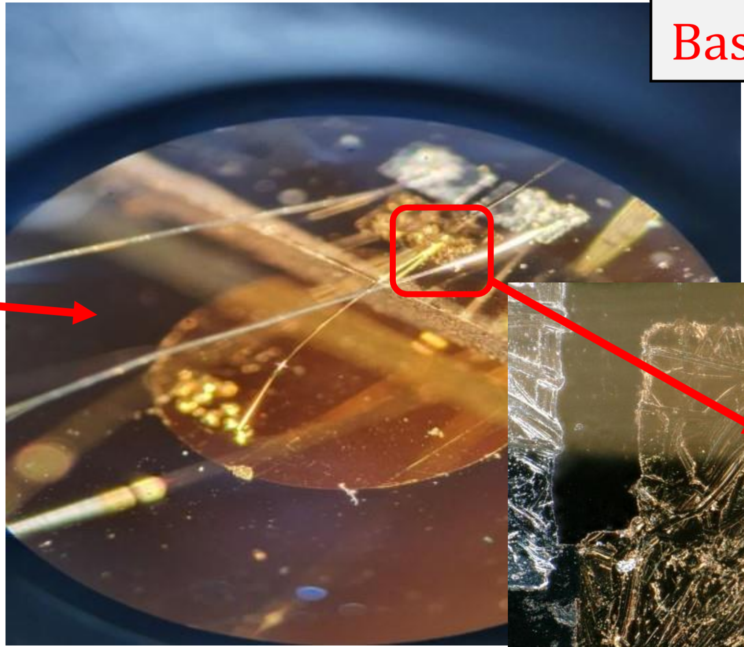
Detector Elektra´

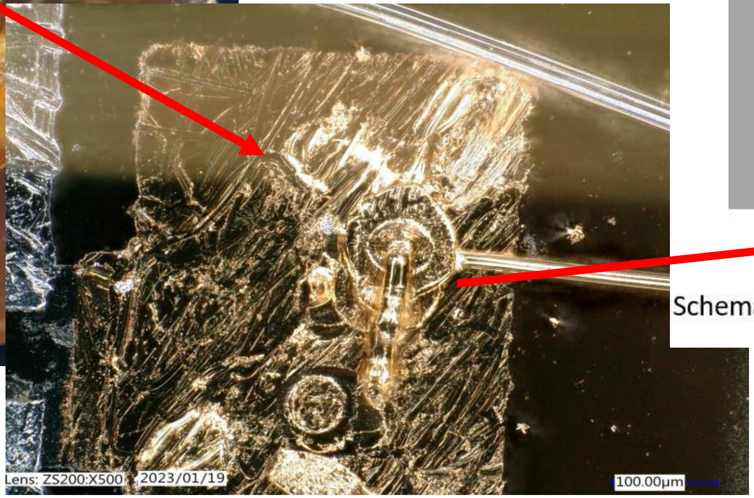
Modification: 2^{nd} ball-bond

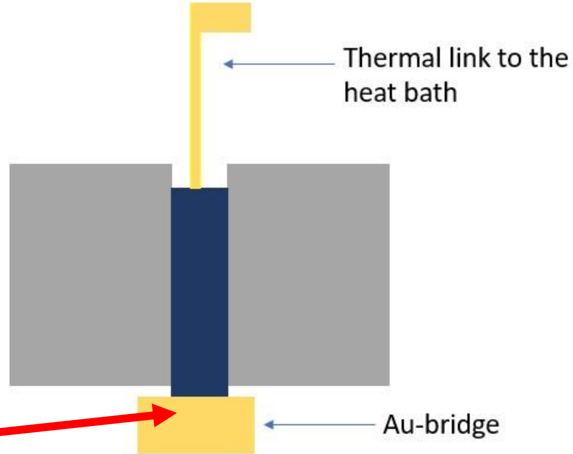
- Better thermal conductance

Absorber	Si ($20{\times}10{\times}5\ mm^3$)
Au-pad	200 nm thick (sputtered)
Au-wire	25µm thick (ball-bond)
TES	W-TES on Al_2O_3
Baseline resolution	139 eV









Schematic representation of the TES on the wafer

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Optimization studies of remoTES using Si crystal as benchmark

Detector Elektra´

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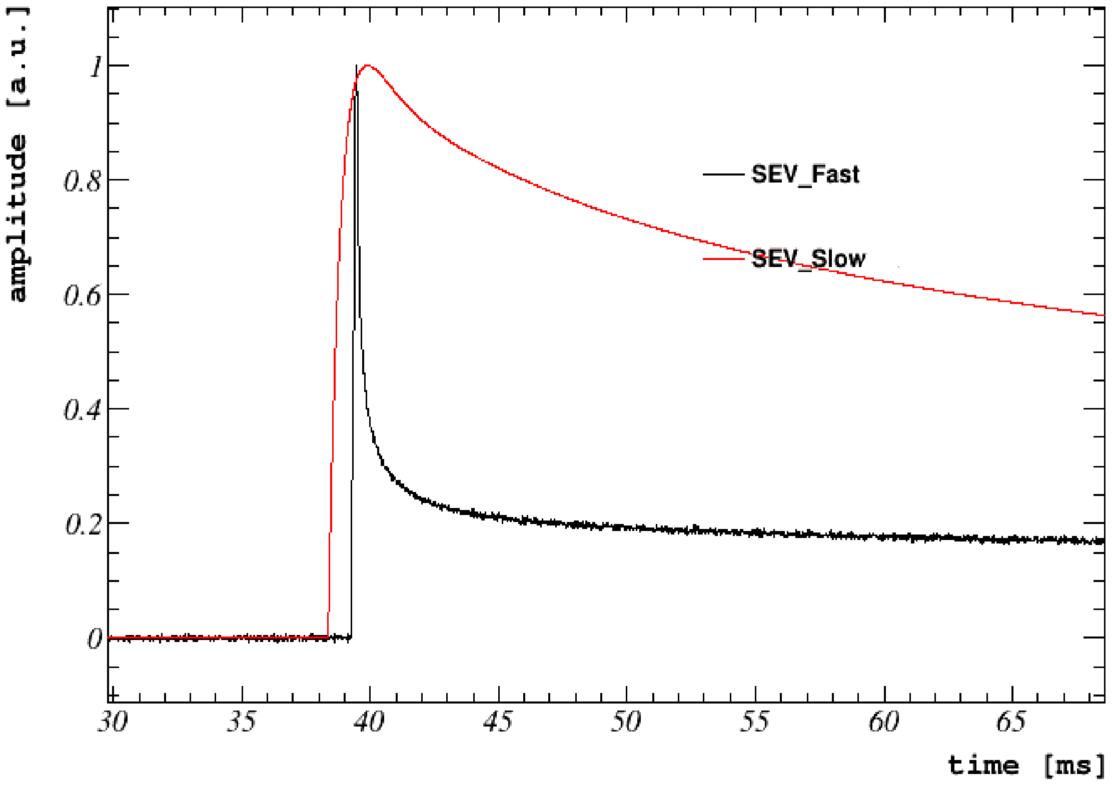

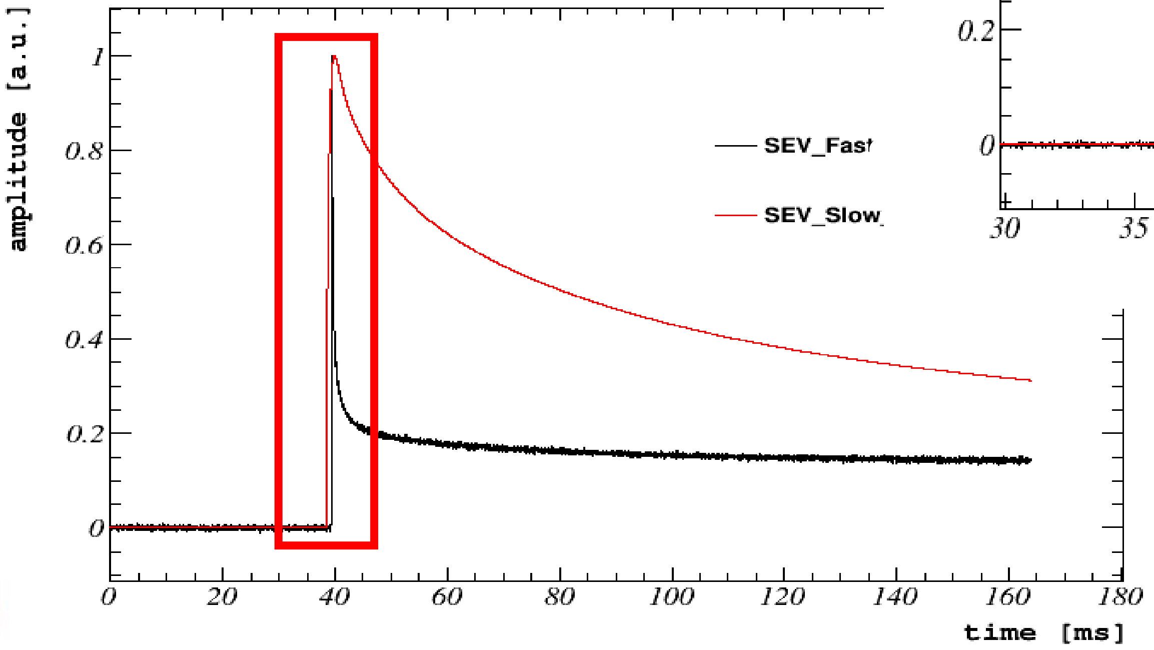

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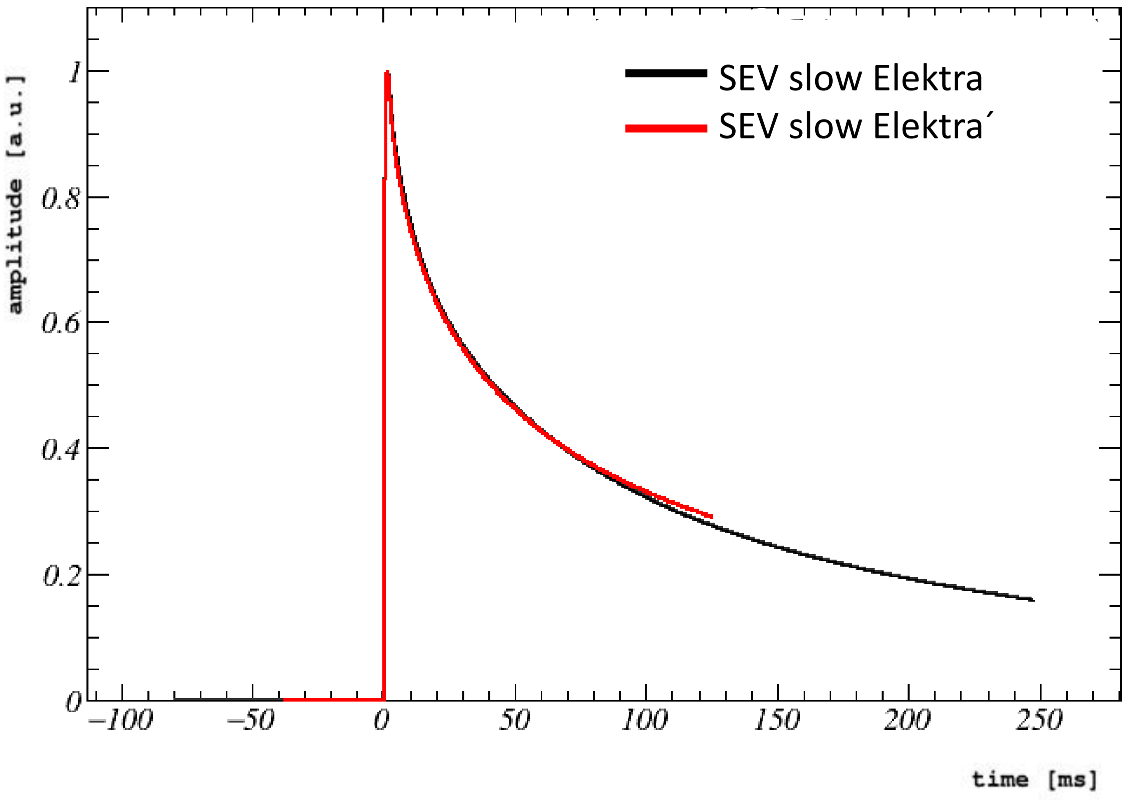
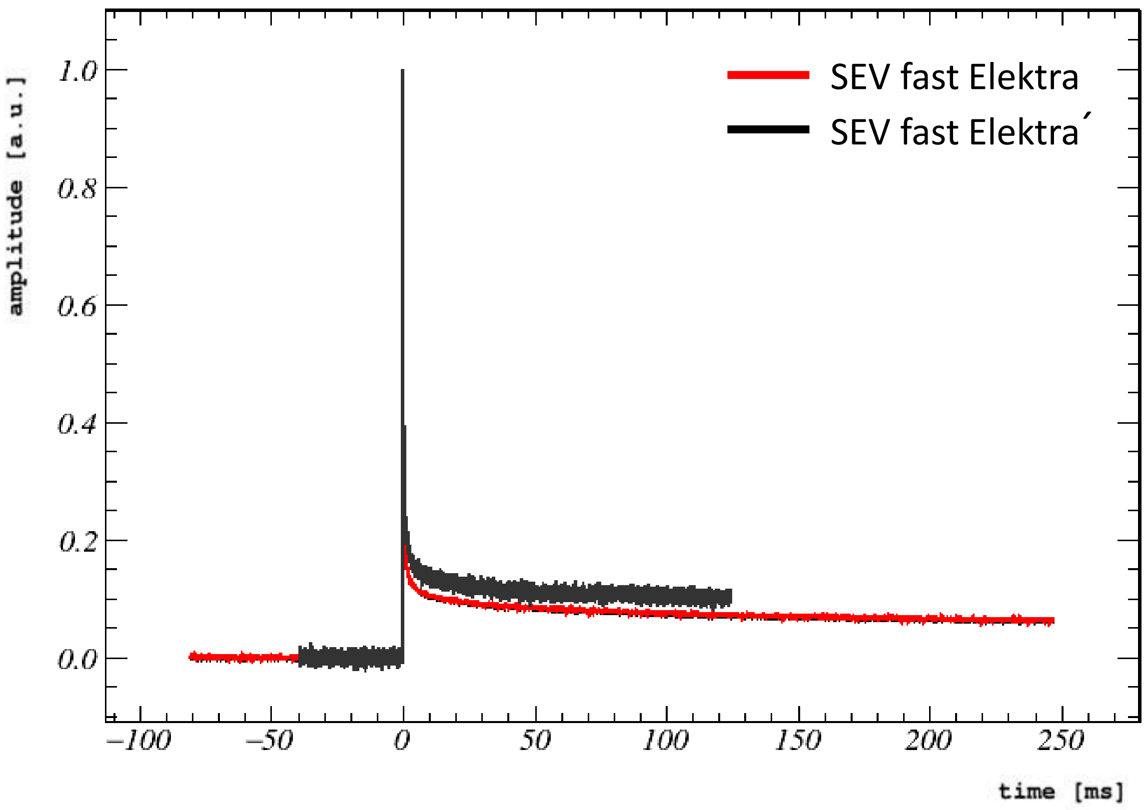
Comparison of the pulse shapes between detector setup Elektra and Elektra´





No essential difference between the pulse shapes of the two different detector setups Elektra and Elektra´.

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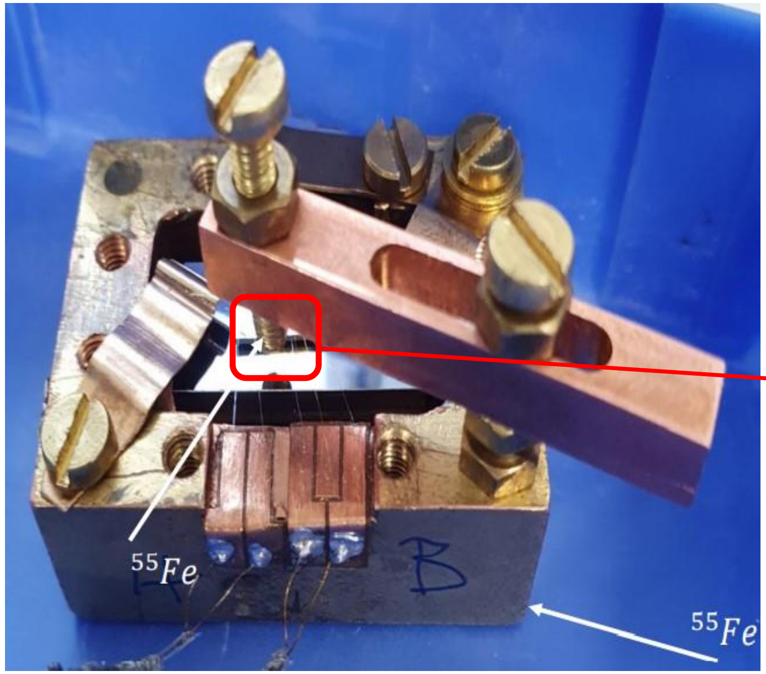
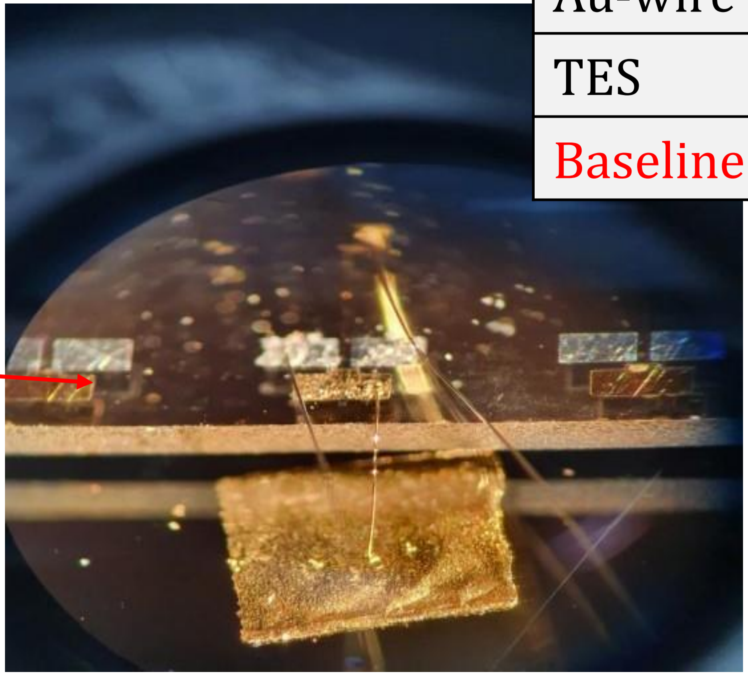
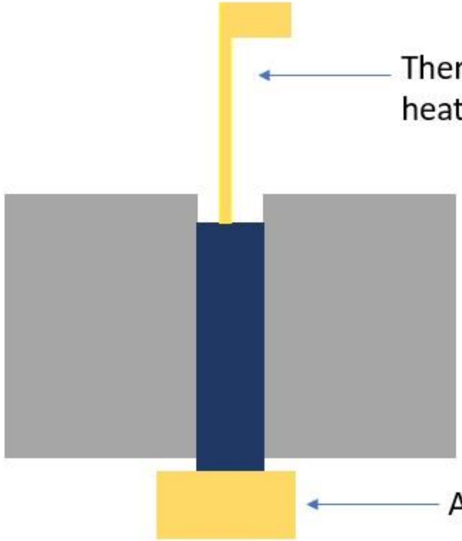
Optimization studies of remoTES using Si crystal as benchmark

Detector Olympia

Absorber	Si (20×10×5 mm^3)
Au-pad	8 µm thick (glued)
Au-wire	25µm thick (ball-bond)
TES	W-TES on Al_2O_3
Baseline resolution	82 eV







Schematic representation of the TES on the wafer

Conclusions:

- Ball-bond improves the baseline resolution
- At this point we are not limited by the heat capacity

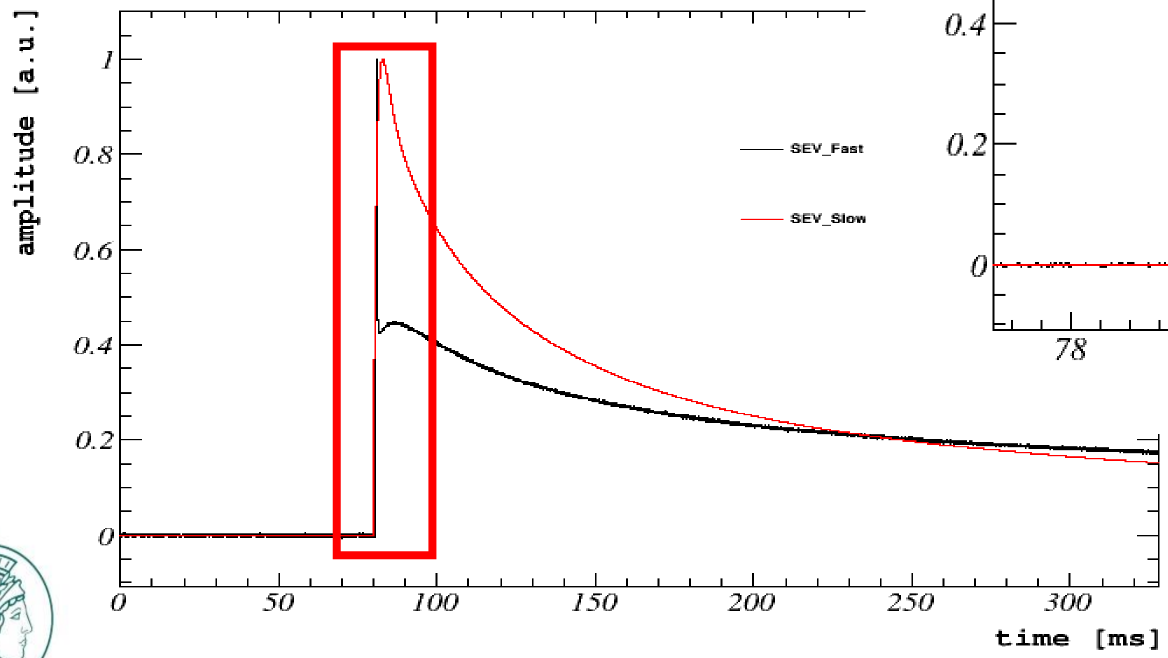
Optimization studies of remoTES using Si crystal as benchmark

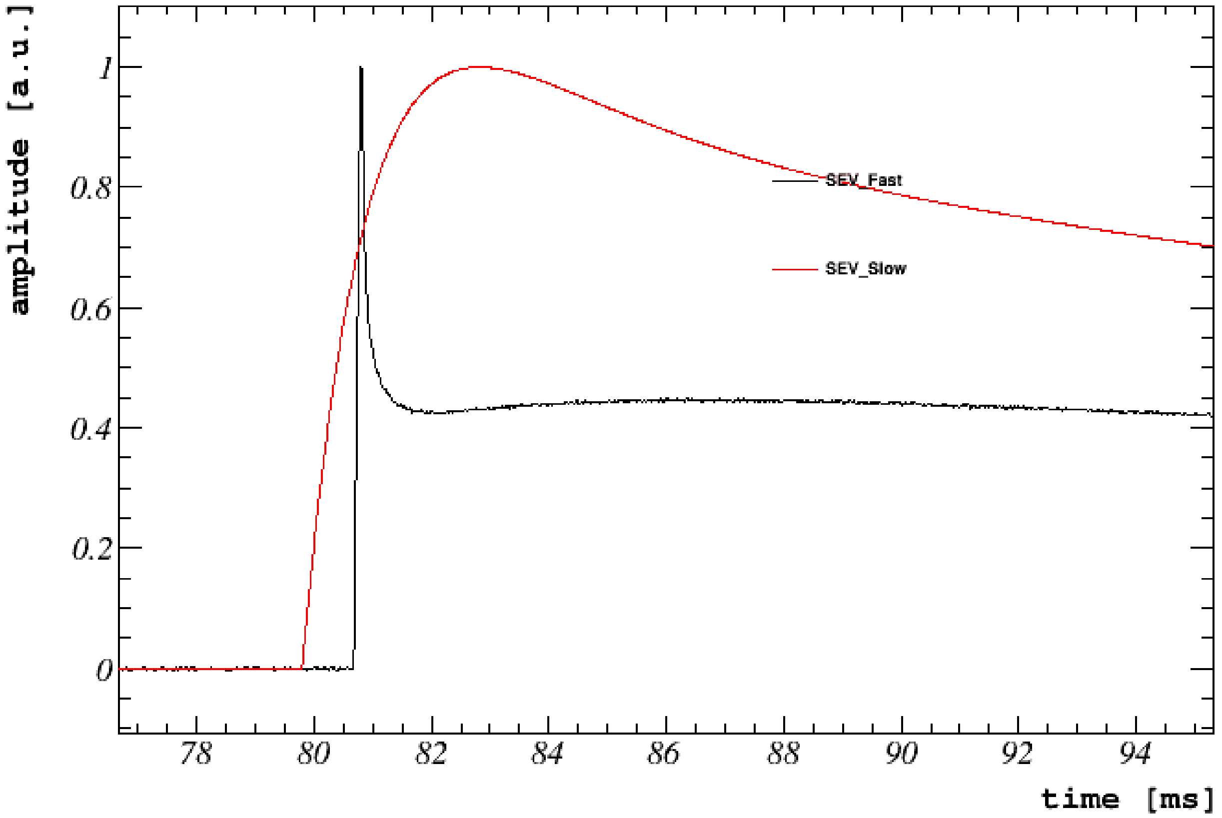
Detector Olympia

- Two different event classes

a. Slow events (slow rise time)

b. Fast events (fast rise time)





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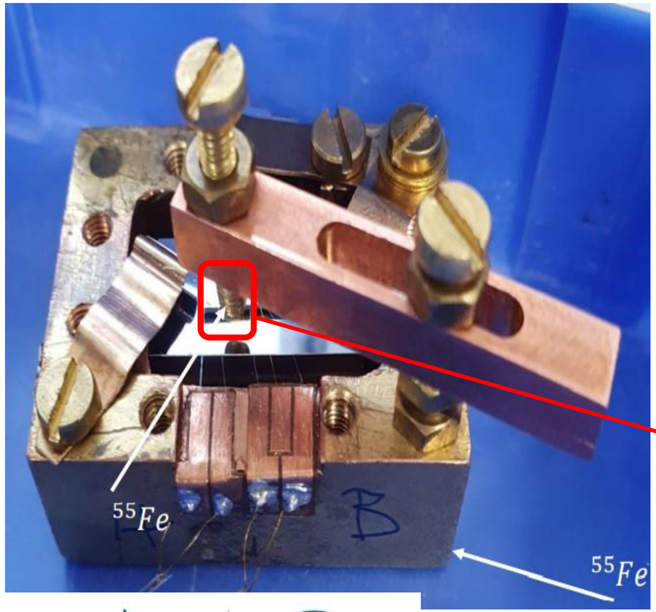
Optimization studies of remoTES using Si crystal as benchmark

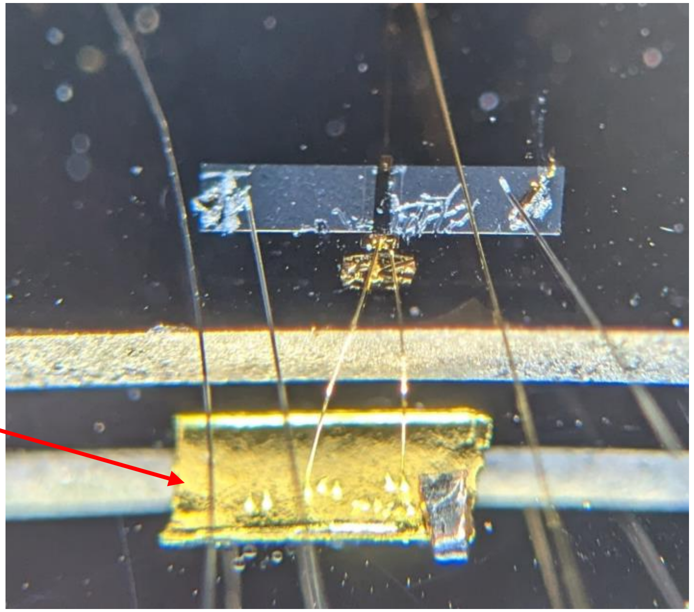
Detector Olympia´

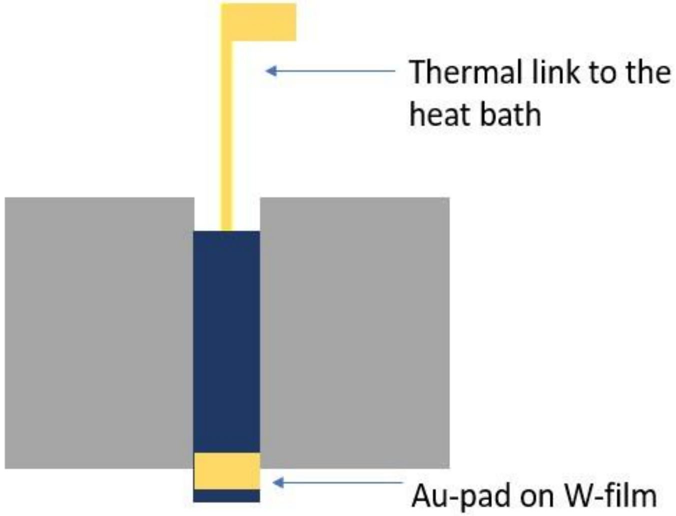
Modification: No Au-bridge

- Au-bridge might be a bottleneck for the transmission of the signal

Absorber	Si (20×10×5 mm^3)
Au-pad	8 µm thick (glued)
Au-wire	25µm thick (ball bond)
TES	W-TES on Al_2O_3
Baseline resolution	800eV







Schematic representation of the TES on the wafer

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Optimization studies of remoTES using Si crystal as benchmark

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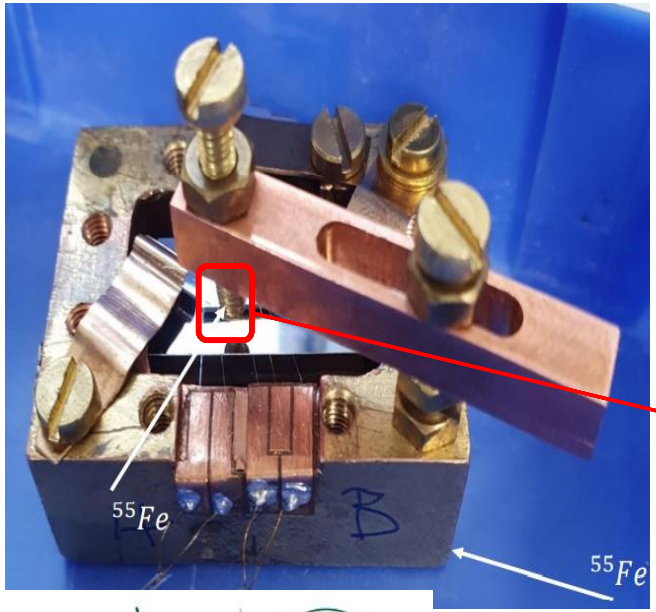
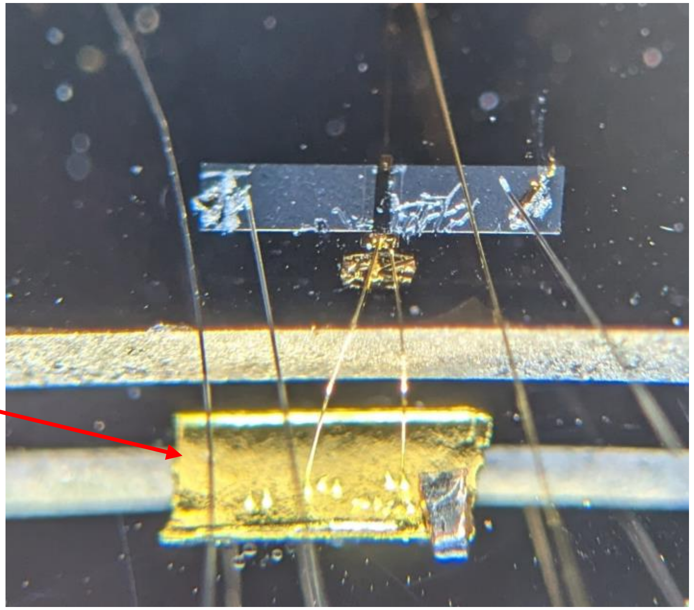
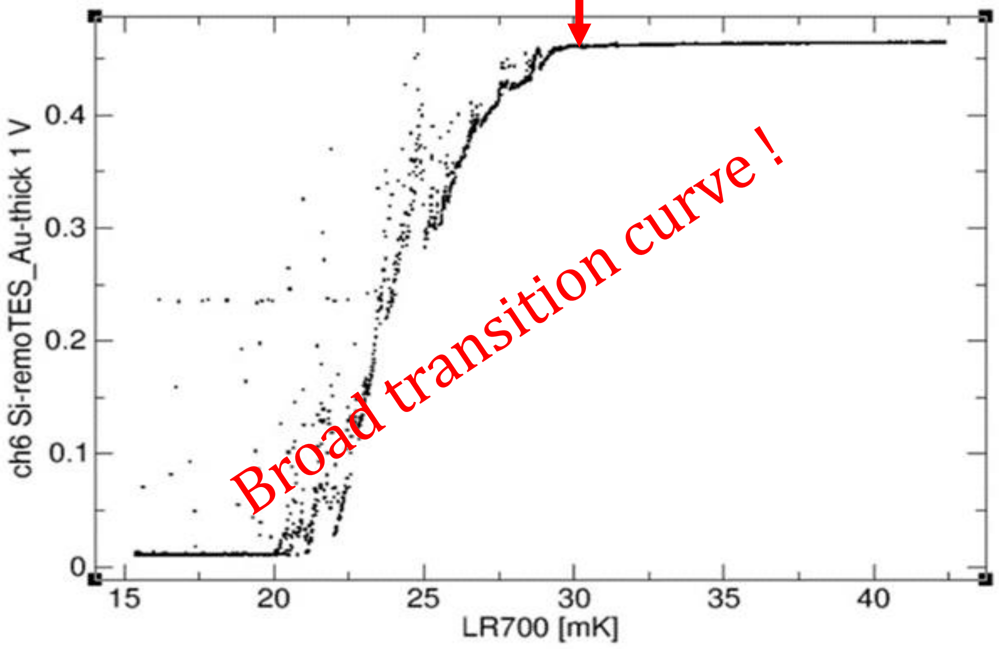






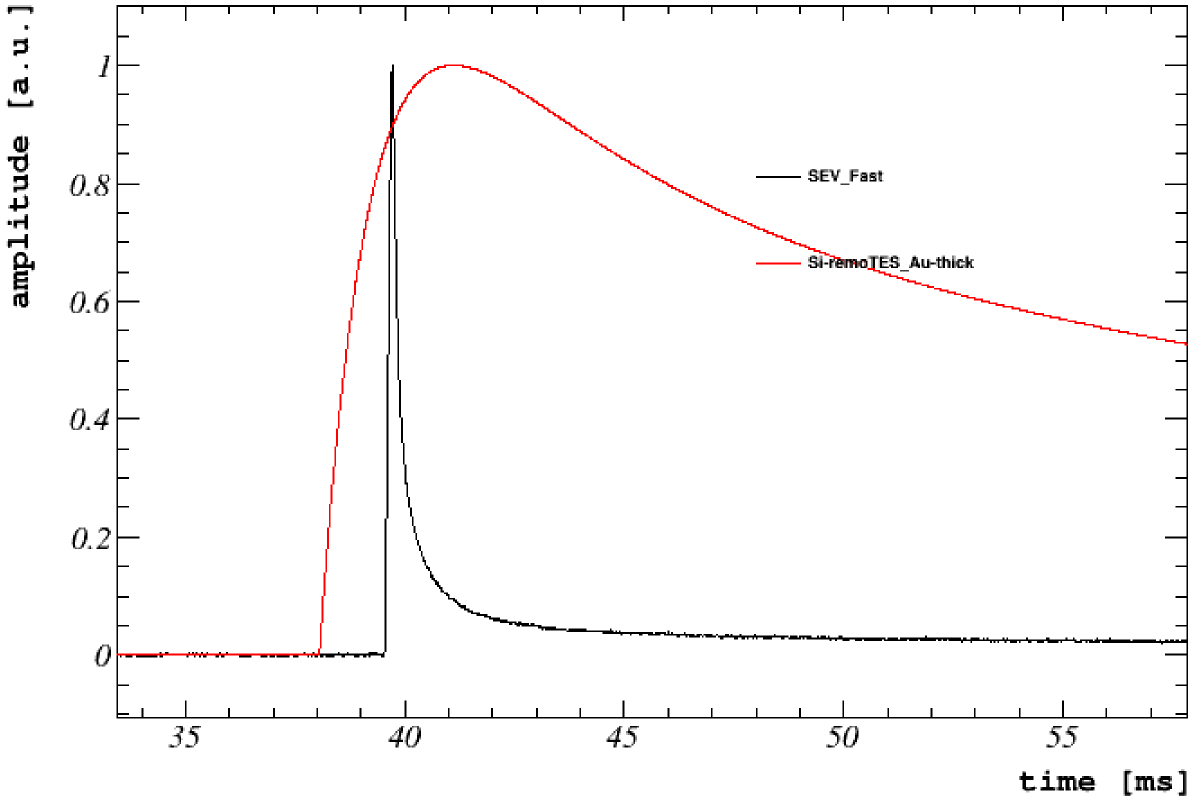
Optimization studies of remoTES using Si crystal as benchmark

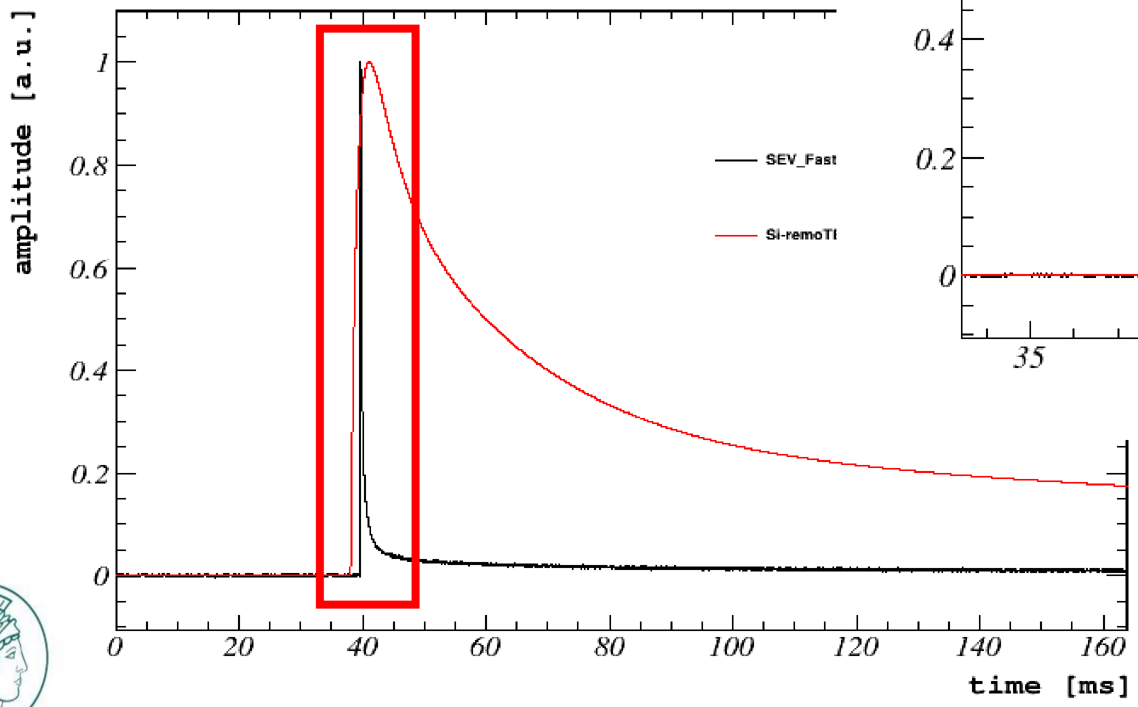
Detector Olympia´

- Two different event classes

a. Slow events (slow rise time)

b. Fast events (fast rise time)





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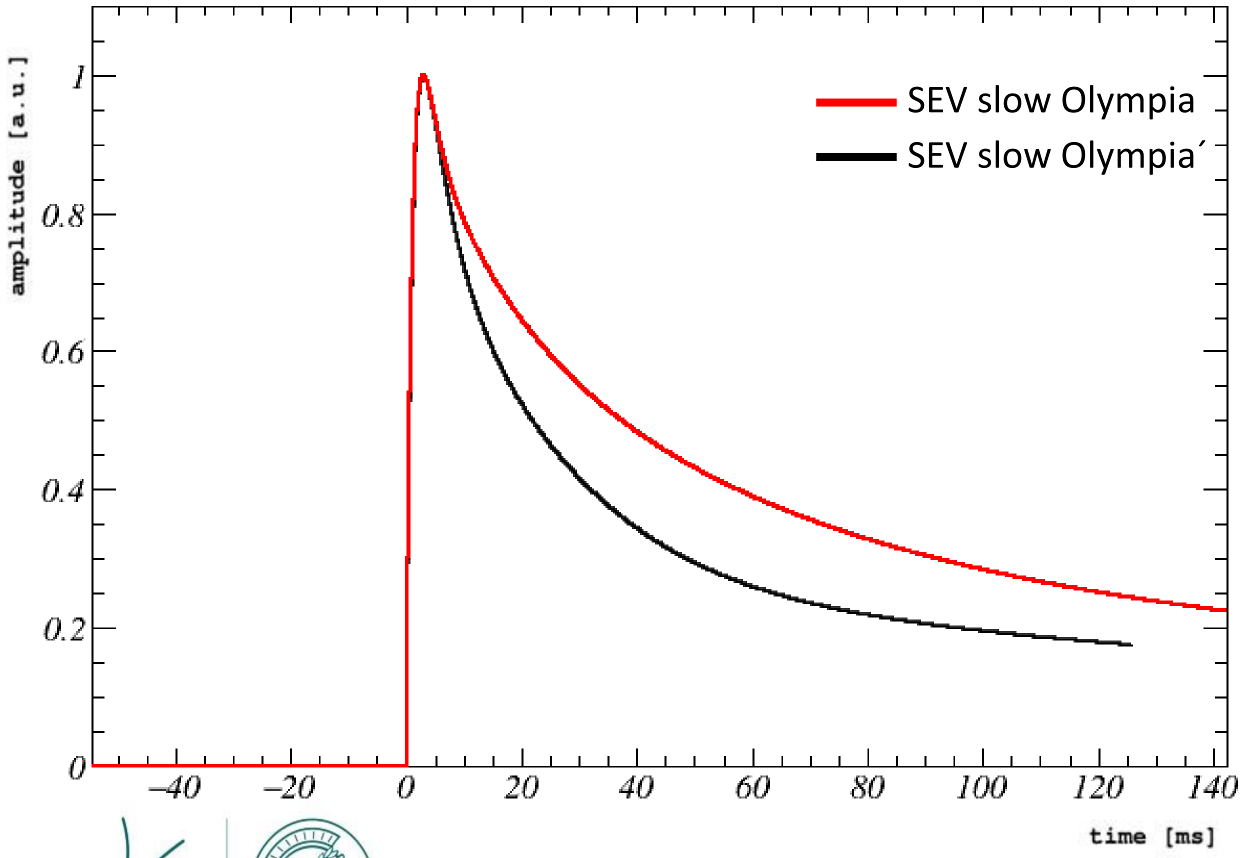
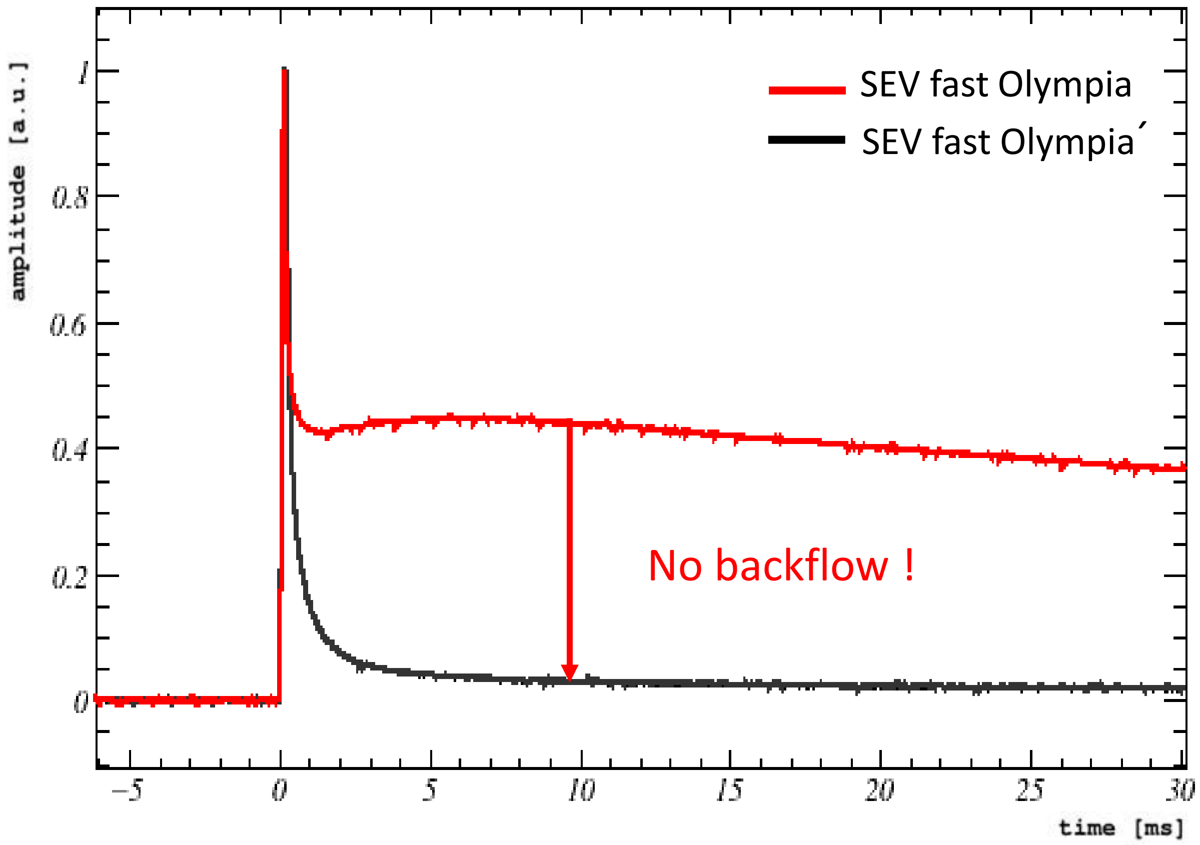
Comparison of the pulse shapes between detector setup Olympia and Olympia´

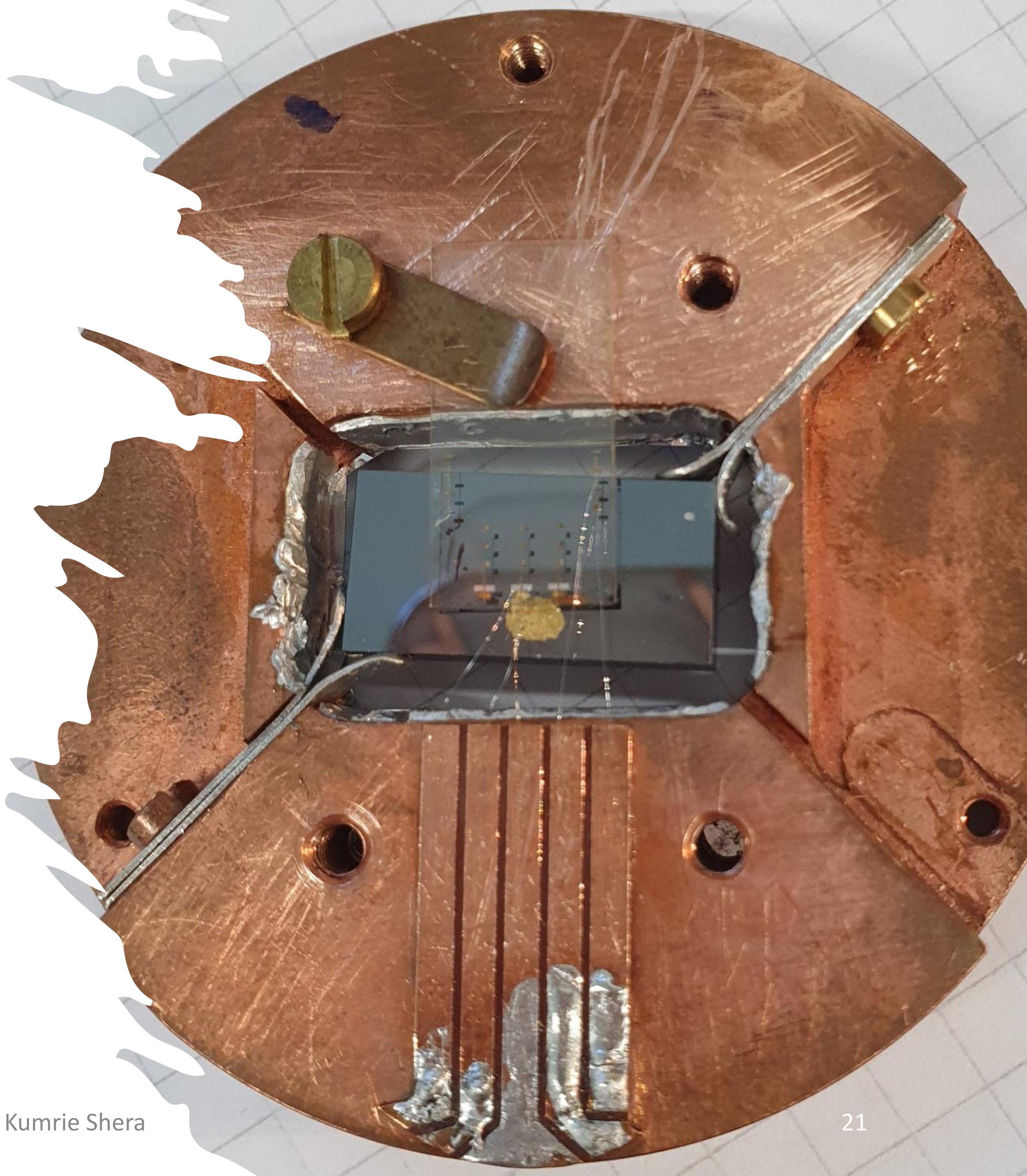




Further measurements are planned !

Summary

- Ball-bond improves the performance of the remoTES
- Heat capacity is not limiting at this point the performance
- The removal of the Au-bridge seems to be promising for optimize the performance



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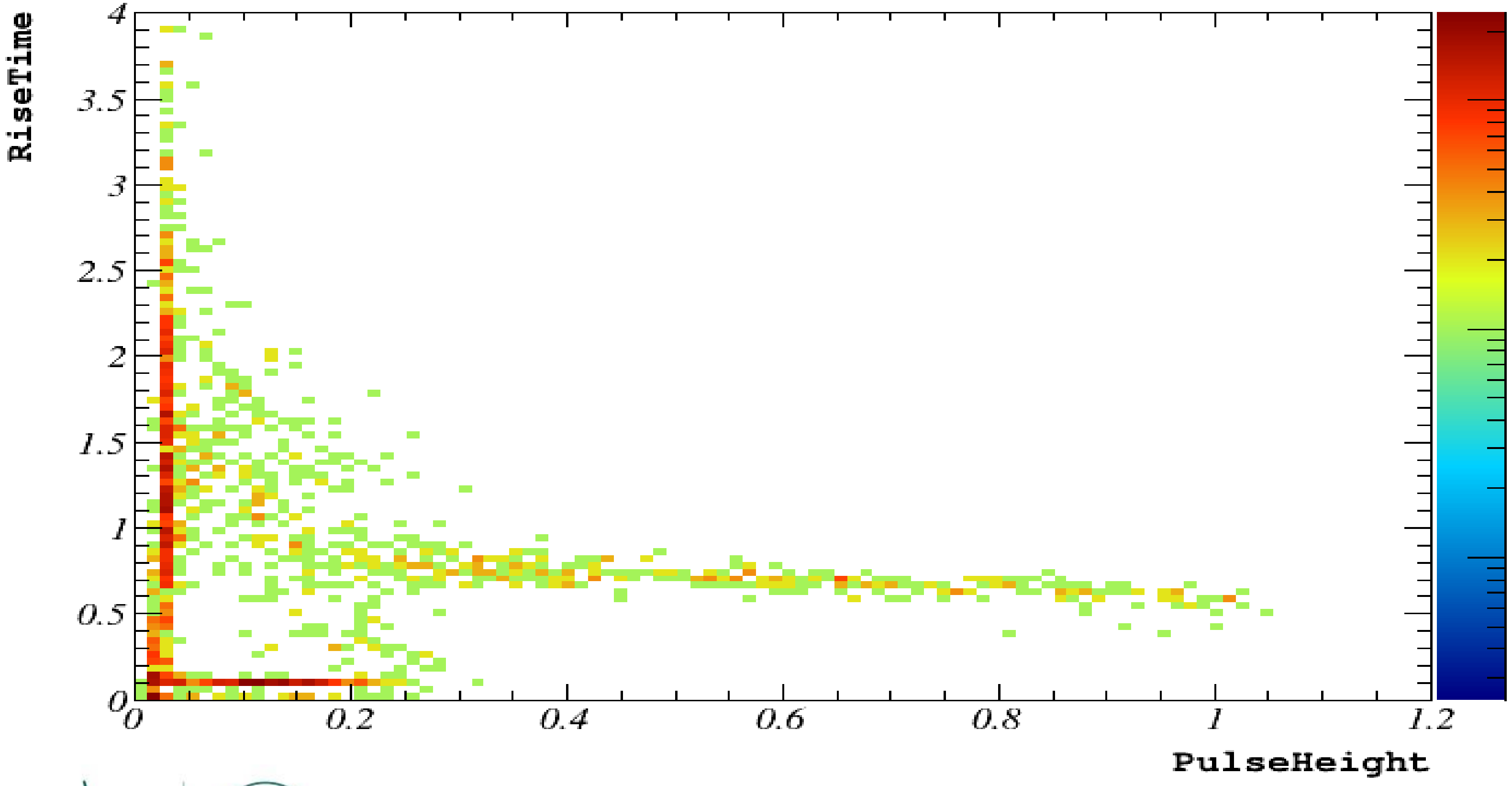
Thank you !

Backup slides

A way to identify different event classes



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