



Nuclear *E*mulsions for *W*IMP Search - *d*irectional *m*easurement



Alexandra Scholz, Sebastian Münkel
Gran Sasso HandsOn September 2023

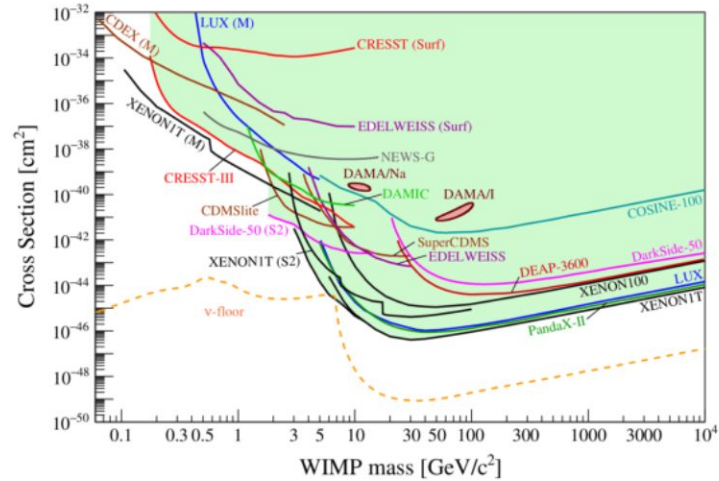
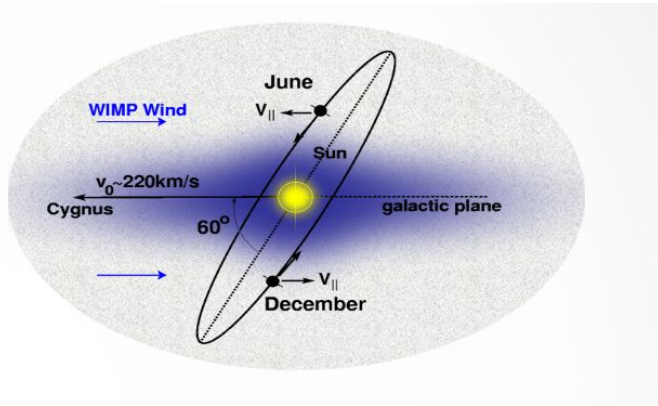


UNIVERSITÀ
DEGLI STUDI
DELL'AQUILA

SFB 125B



Directionality in Dark Matter Searches



- unique possibility to overcome the “neutrino floor” (coherent neutrino scattering)
- helpful in understanding the DM model

Directionality in Dark Matter Searches

- Typical nuclear recoil energies: 1 - 100 keV (WIMP masses: 10 GeV - 10 TeV)
- Required spatial accuracy:
 1. Solid detectors: sub- μm domain \rightarrow high resolution
 2. gaseous detectors: sub-mm domain \rightarrow large volume, low pressure
- solid target: would allow to explore lower cross-sections (in the region of direct search experiments)
- challenge: short track length $O(100 \text{ nm})$

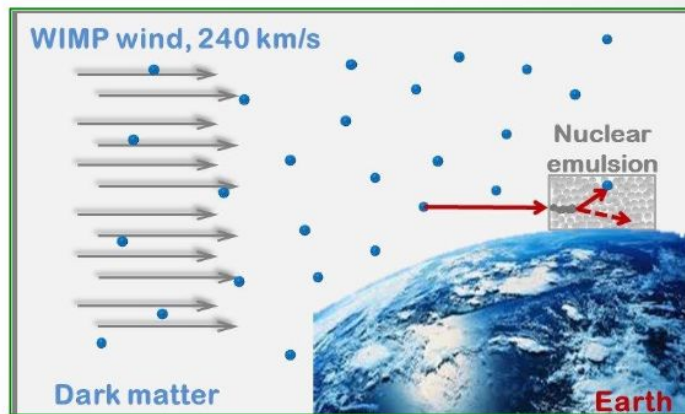


Nuclear Emulsion based detector

NEWSdm – Nuclear Emulsion WIMP Search with Directional Measurement

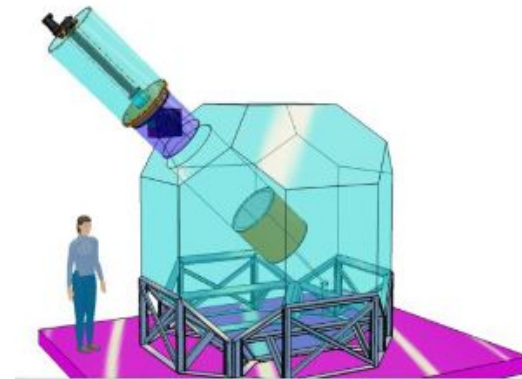
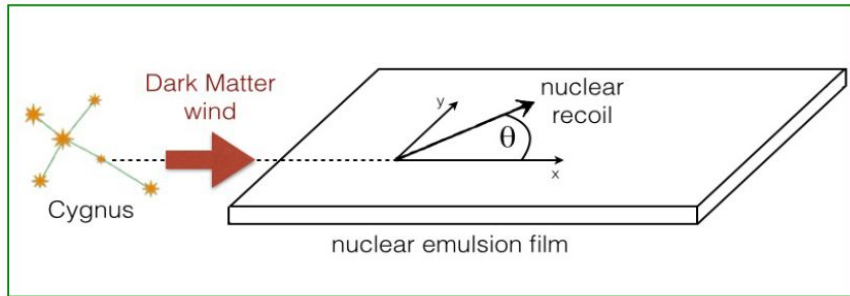
Mission: measure the direction of WIMP-induced nuclear recoils with nuclear emulsions acting as target and tracking detector at the same time

Location: Gran Sasso Underground Laboratory



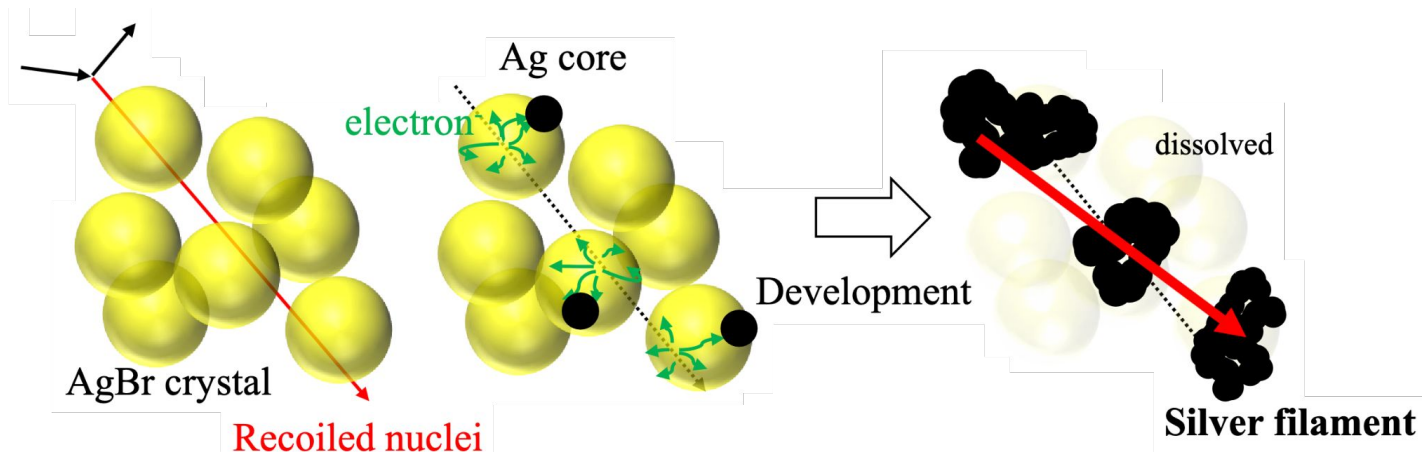
NEWSdm-Principle

- Bulk of nuclear emulsion films with nanometric grain (NIT)
- Background reduction by placing detector underground and shield against natural radioactivity
- Emulsion films paced on equatorial telescope keeping detector at a fixed orientation



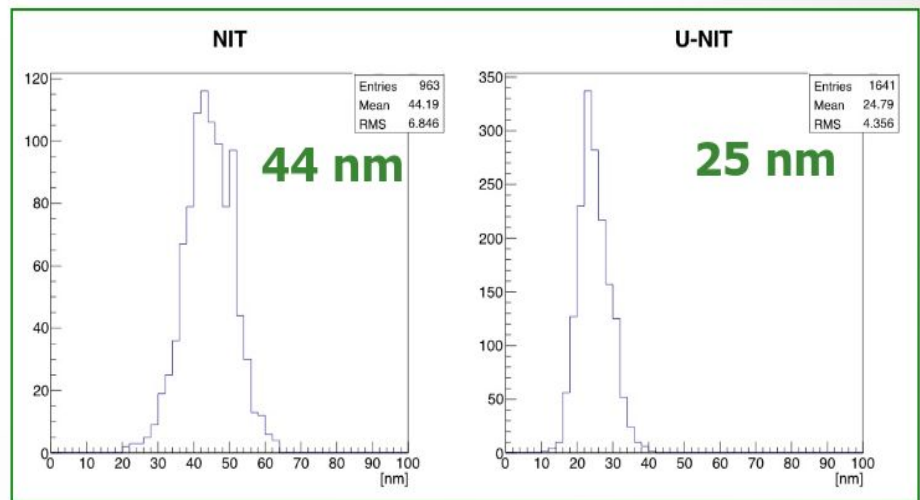
Nuclear Emulsion-Detection Principle

- Made of AgBr crystals in organic gelatine
- Passing charged particle → formation of latent image
- Development makes silver grains visible



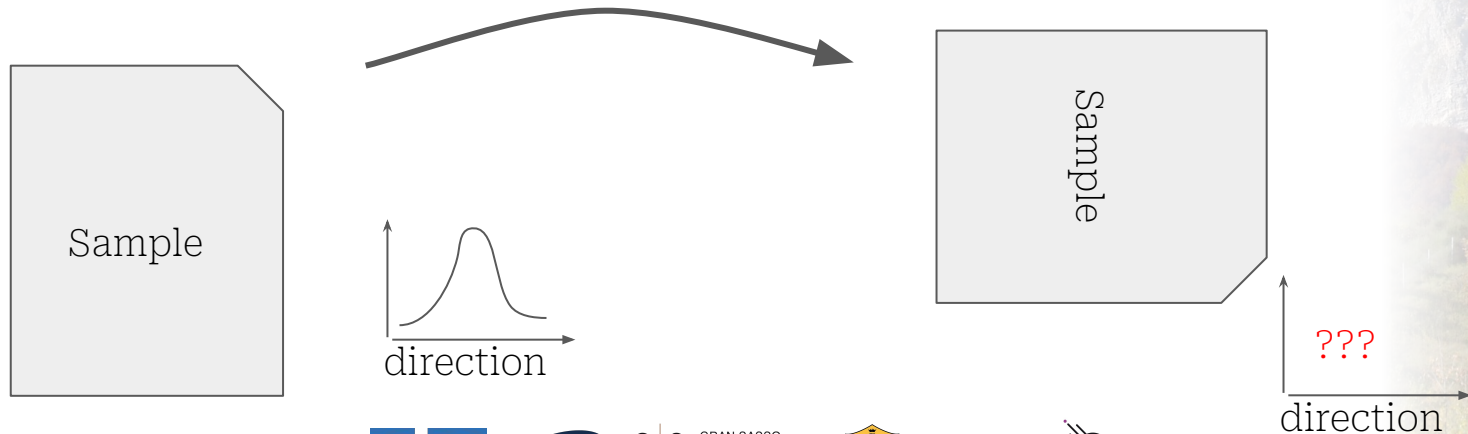
Nuclear Emulsion-Nano Imaging Tracker (NIT)

- Standard emulsions: crystal size between $0.1\mu\text{m}$ - $1\mu\text{m}$
→ not suitable for DM search
- New emulsion films: NIT with crystal size of 44.2
→ reconstruction of trajectories with path lengths shorter than 100 nm possible
→ need microscopes with enough resolution



Biases in Directional Measurements

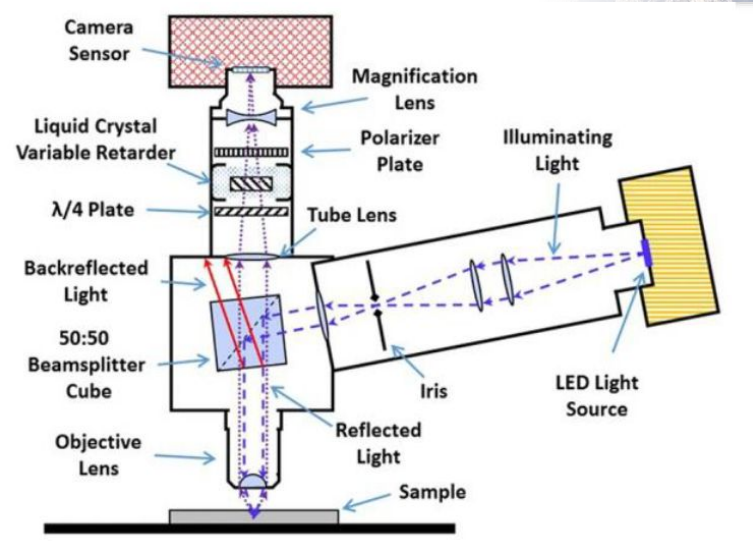
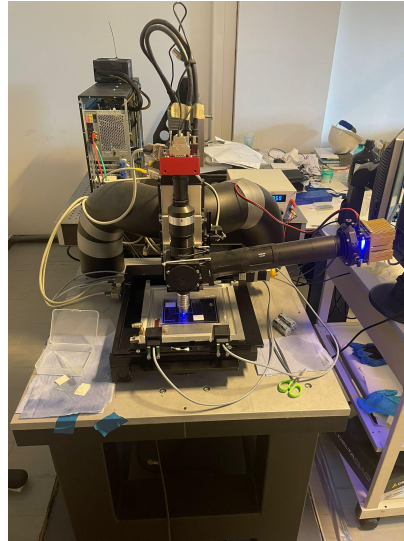
- realistic measurement to perform
- achievable scope for HandsOn
- very relevant for NEWS_{dm}
- 2mm x 2mm sample area



Biases in Directional Measurements

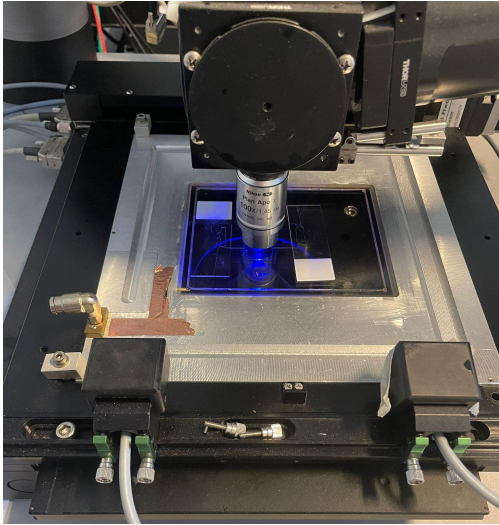
Experimental Setup:

- 100 keV carbon ions in NIT
- read out with optical scanning system



Biases in Directional Measurements

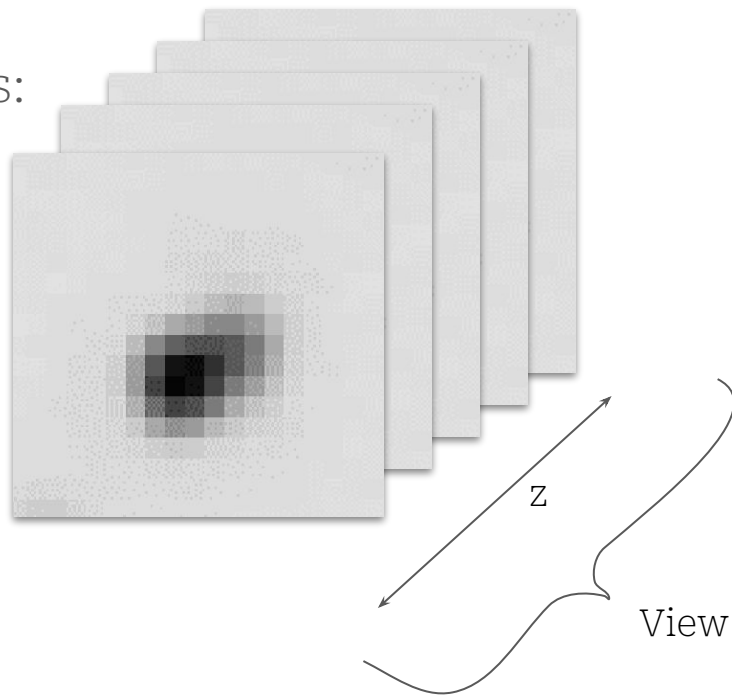
Data acquisition:



- $\sim 70\mu\text{m} \times 50\mu\text{m}$ views
- stop and go path around the desired surface ($2\text{mm} \times 2\text{mm}$)
- automatic cover glass detection
- data preprocessing:
images \rightarrow stacks of clusters
 \rightarrow grains \rightarrow microtracks

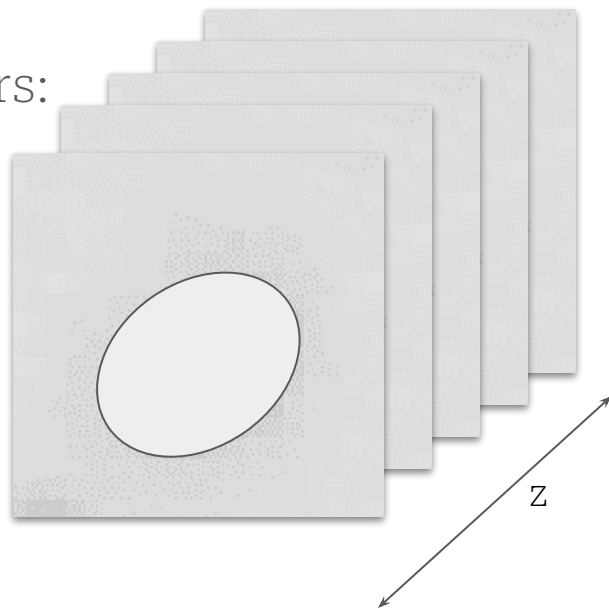
Clusters, Grains and Microtracks

Images:



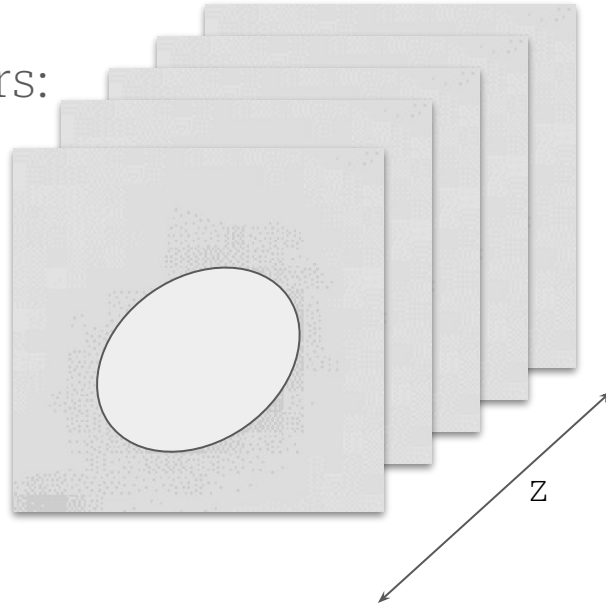
Clusters, Grains and Microtracks

Clusters:



Clusters, Grains and Microtracks

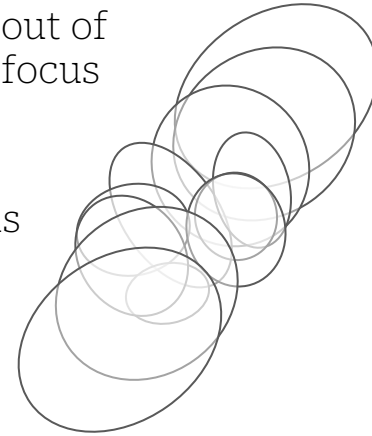
Clusters:



out of focus

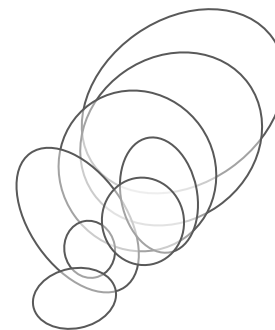
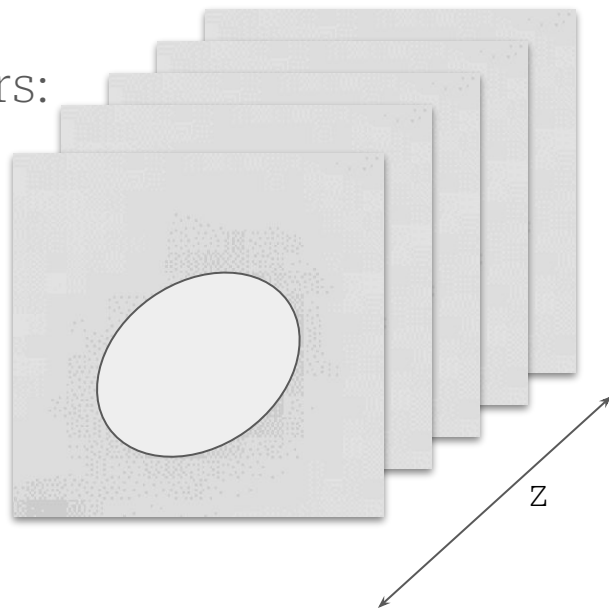
in focus

out of focus



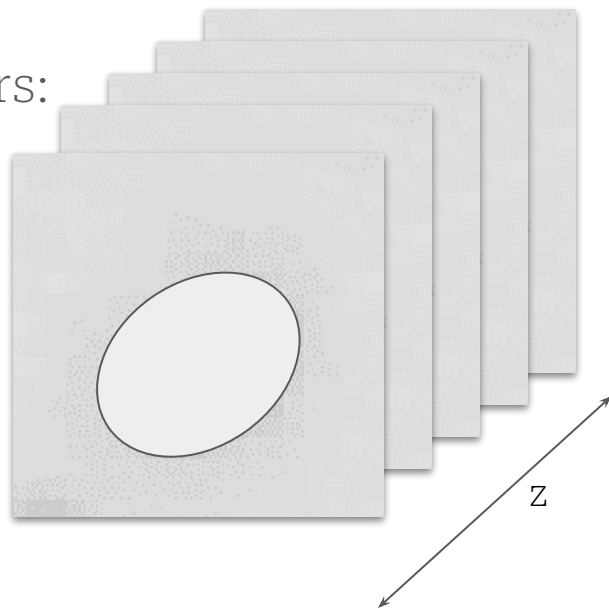
Clusters, Grains and Microtracks

Clusters:

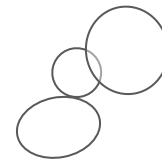


Clusters, Grains and Microtracks

Clusters:

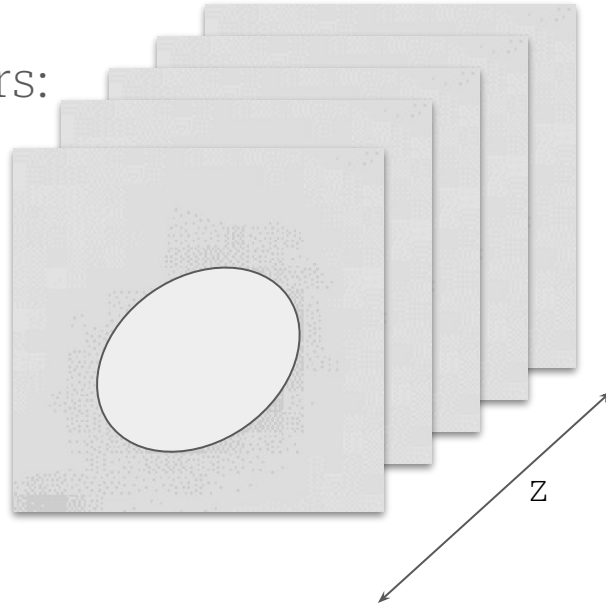


Grains:



Clusters, Grains and Microtracks

Clusters:



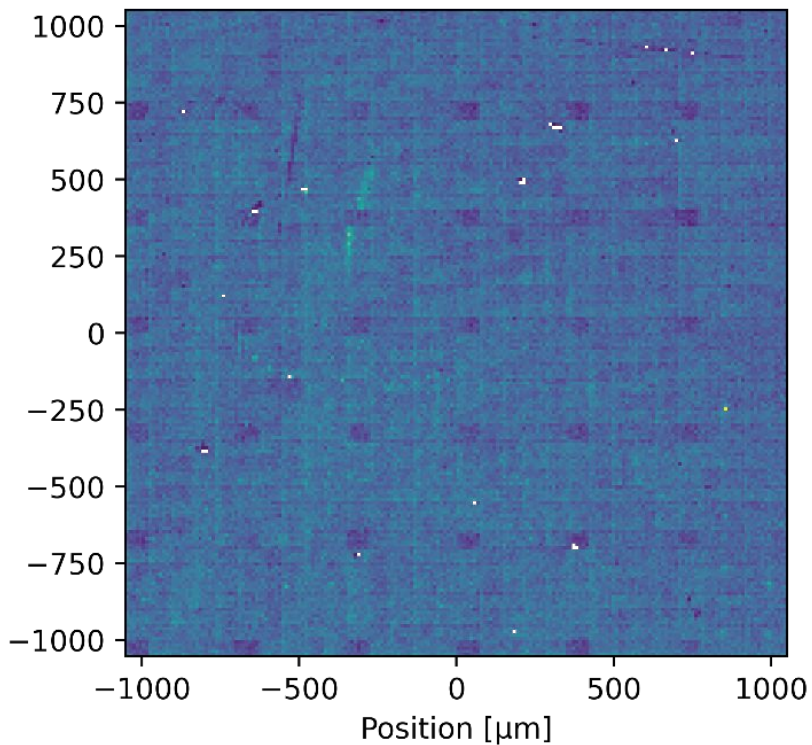
Grains:



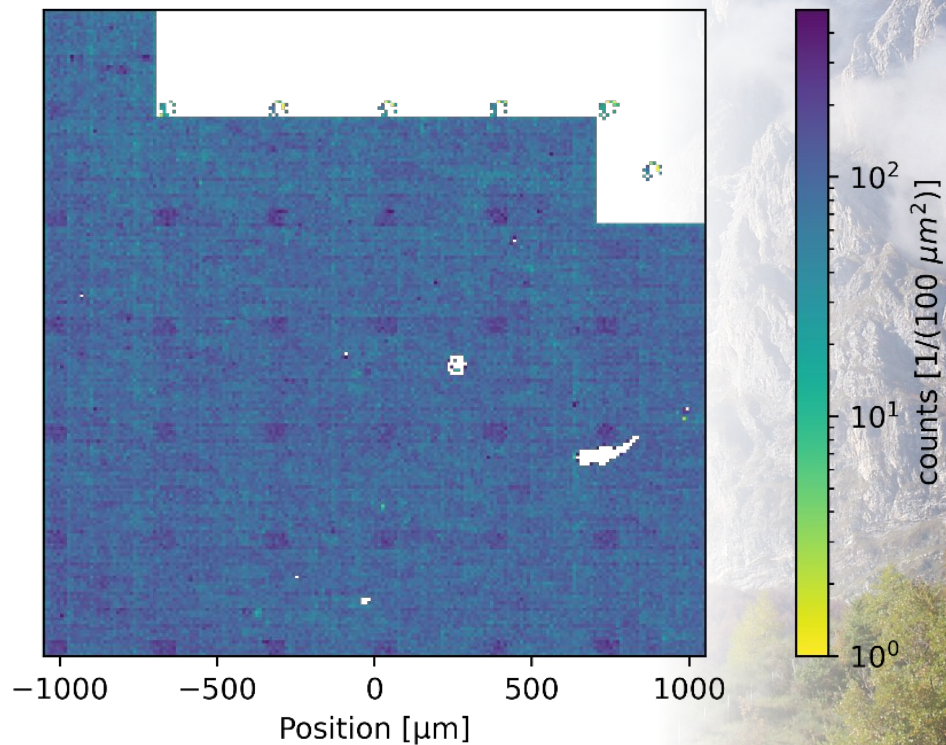
Microtrack:



Clusters (scan 00)

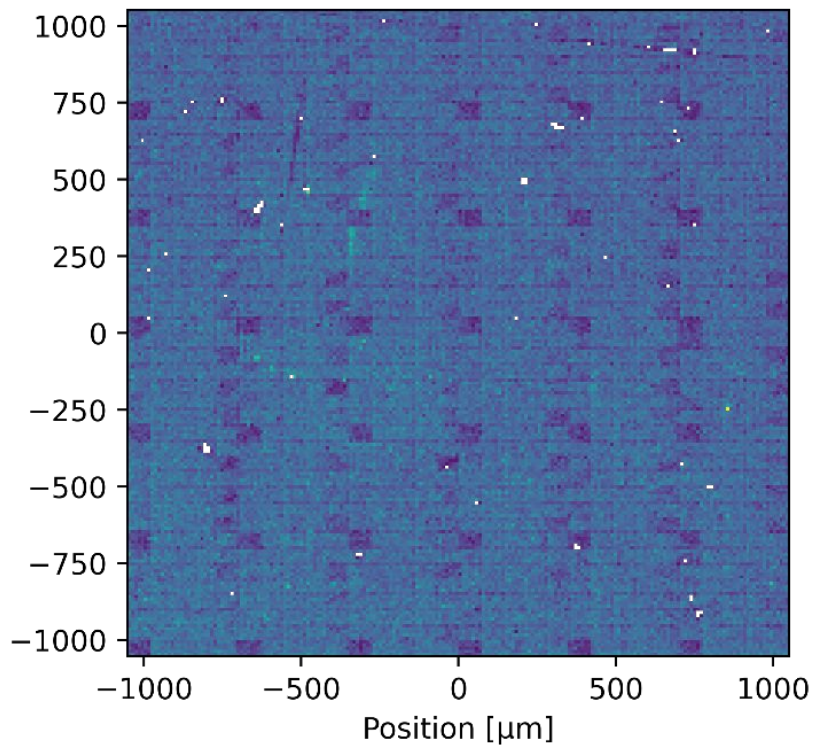


Clusters (scan 90)

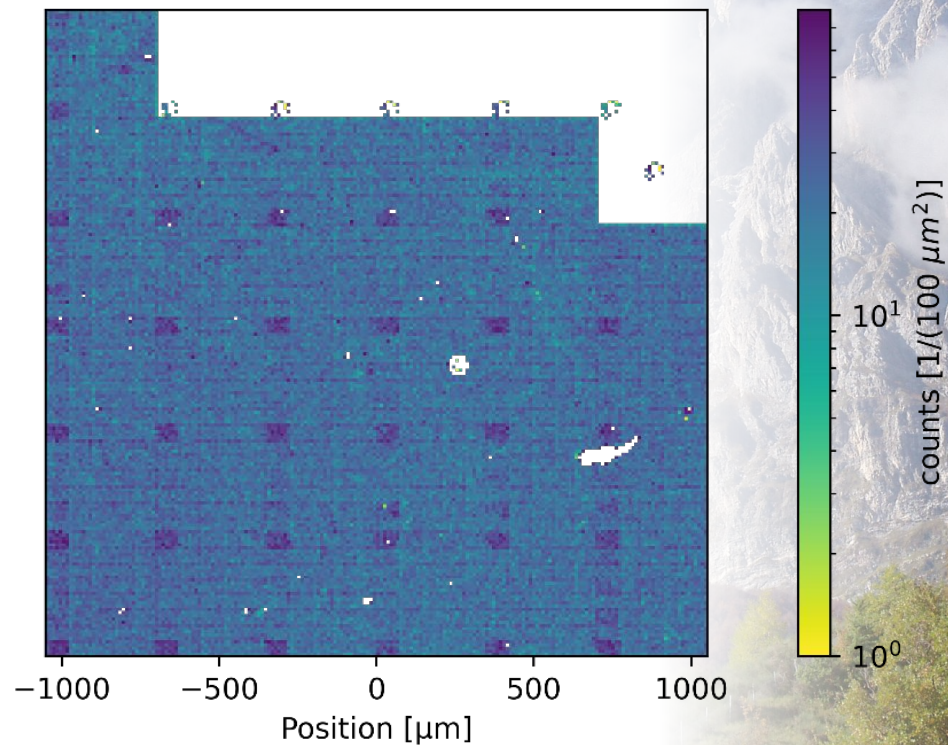


Clusters

Grains (scan 00)

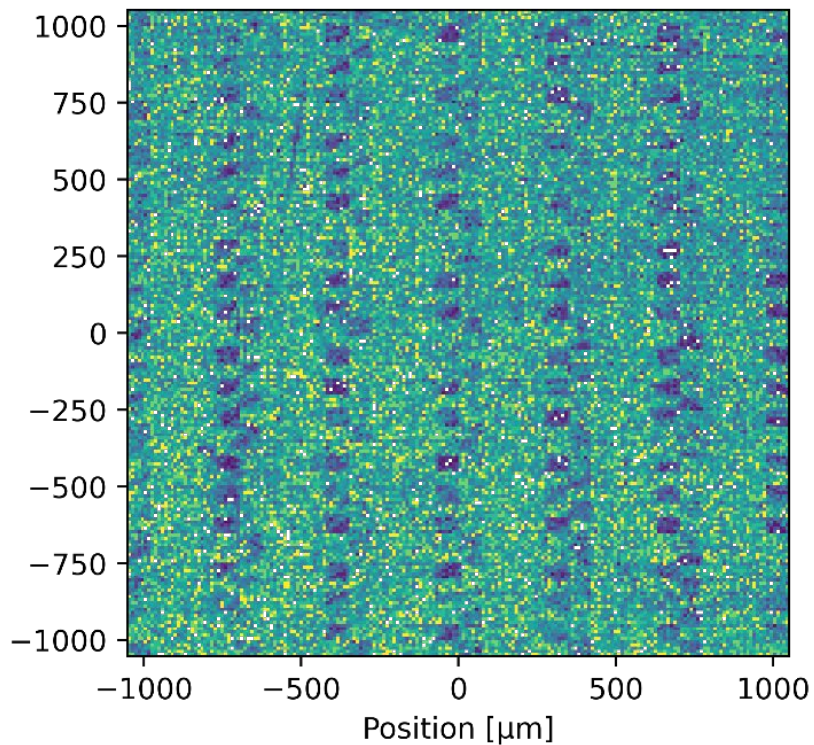


Grains (scan 90)

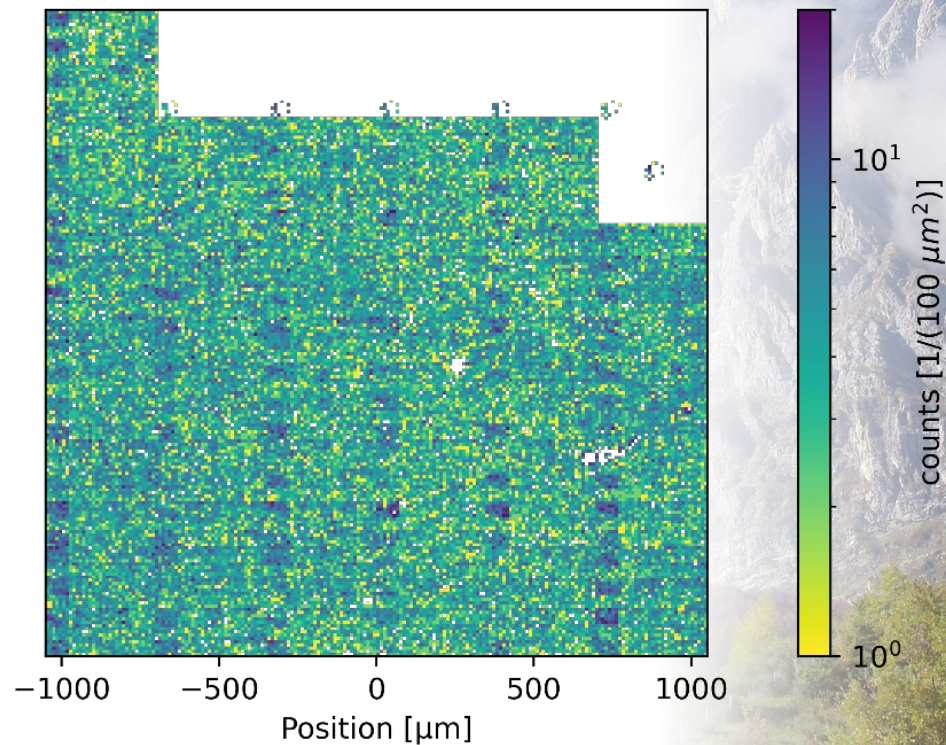


Grains

Microtracks (scan 00)

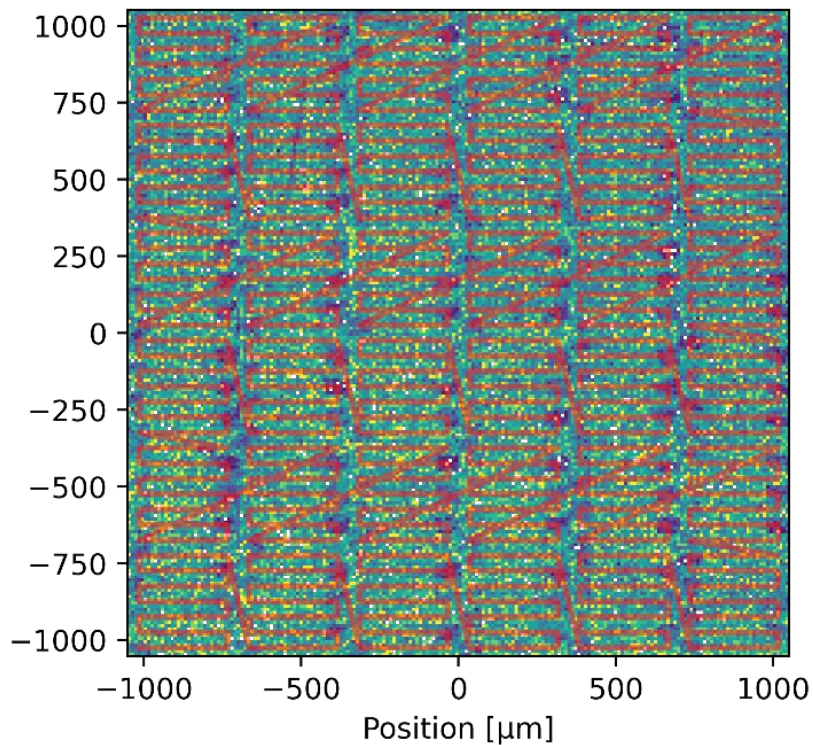


Microtracks (scan 90)

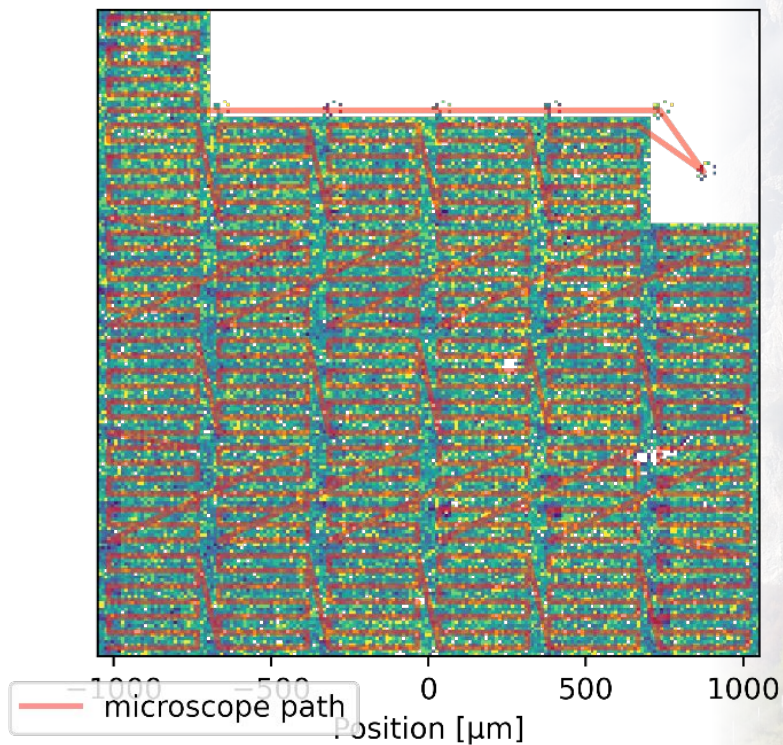


Microtracks

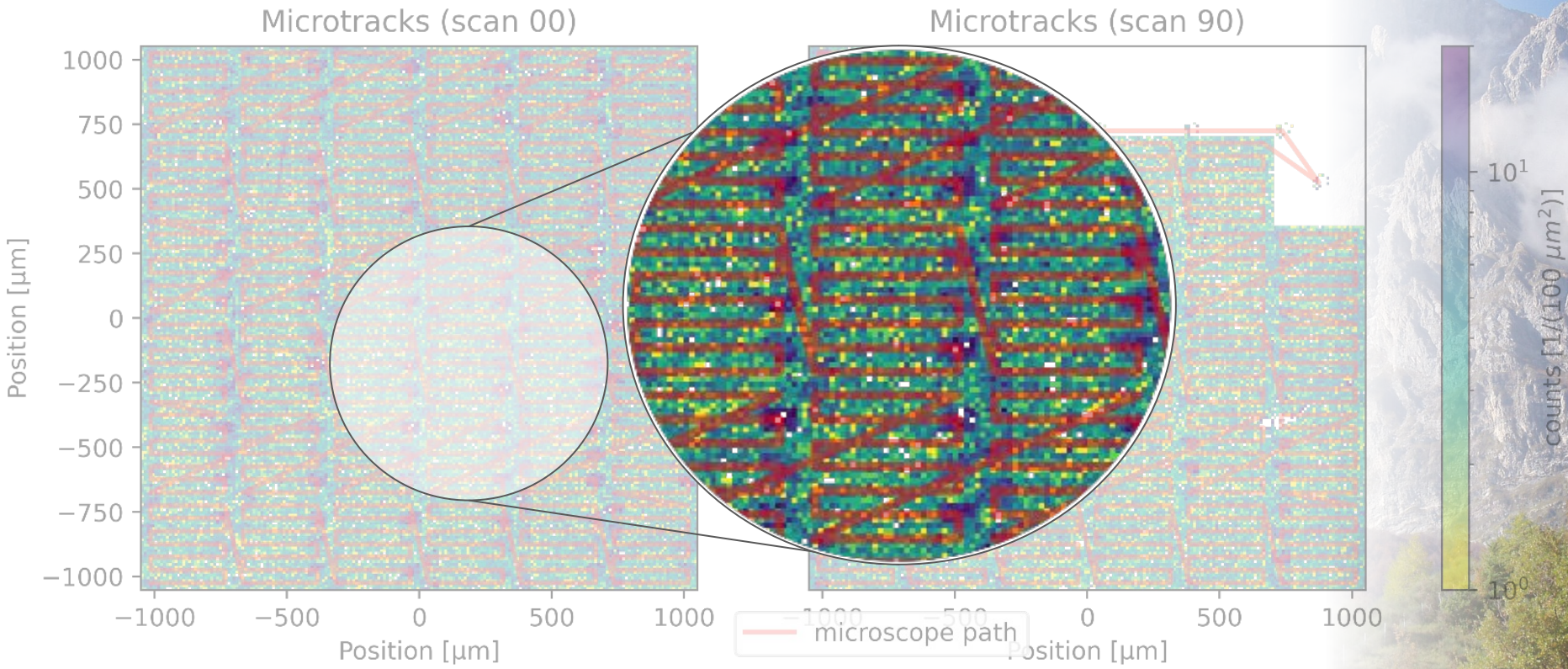
Microtracks (scan 00)



Microtracks (scan 90)

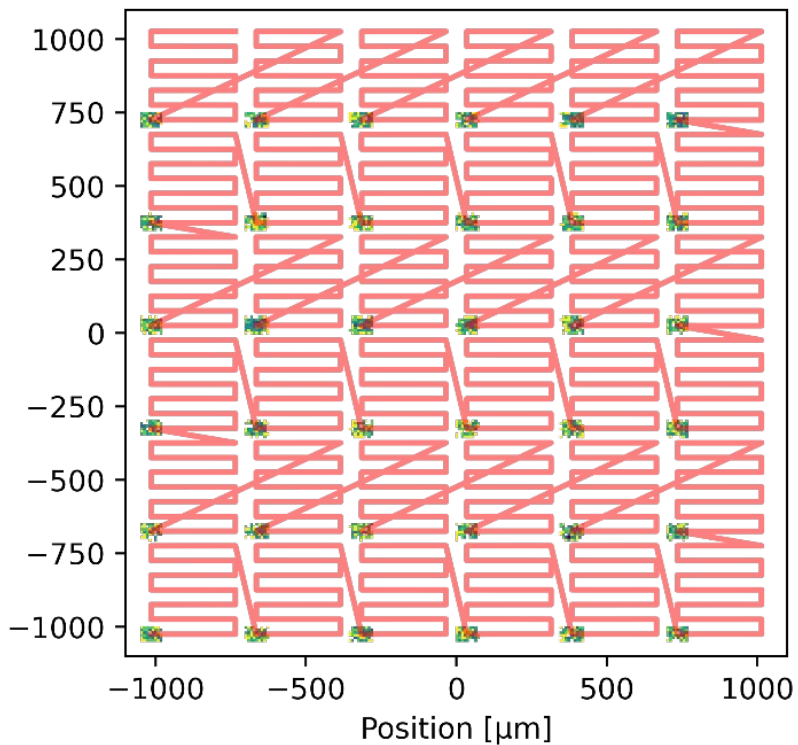


Microtracks, with microscope path

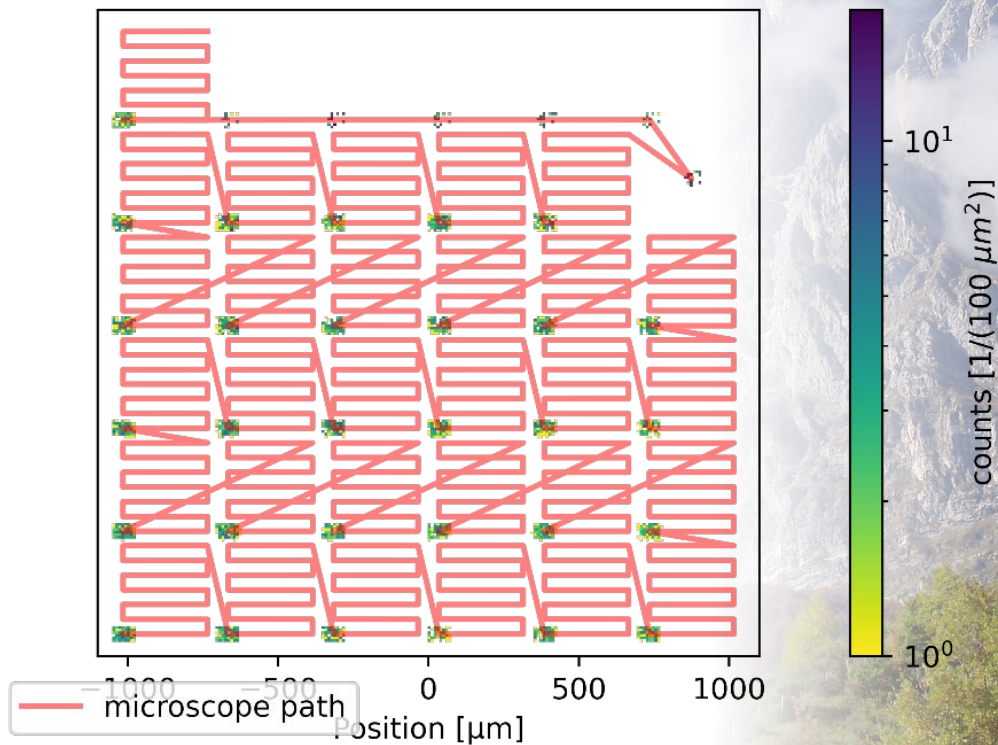


Microtracks, with microscope path

Microtracks (scan 00)

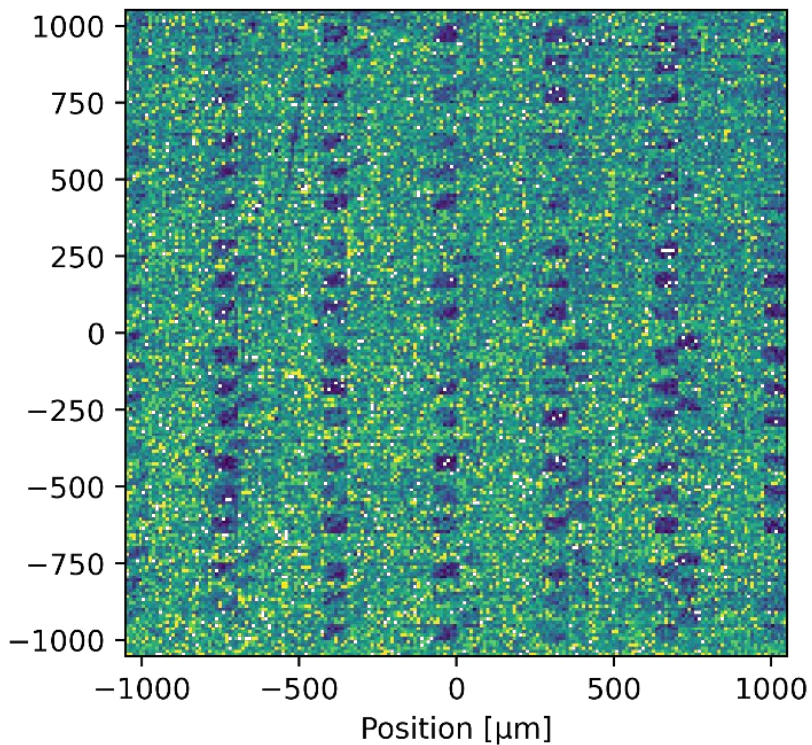


Microtracks (scan 90)

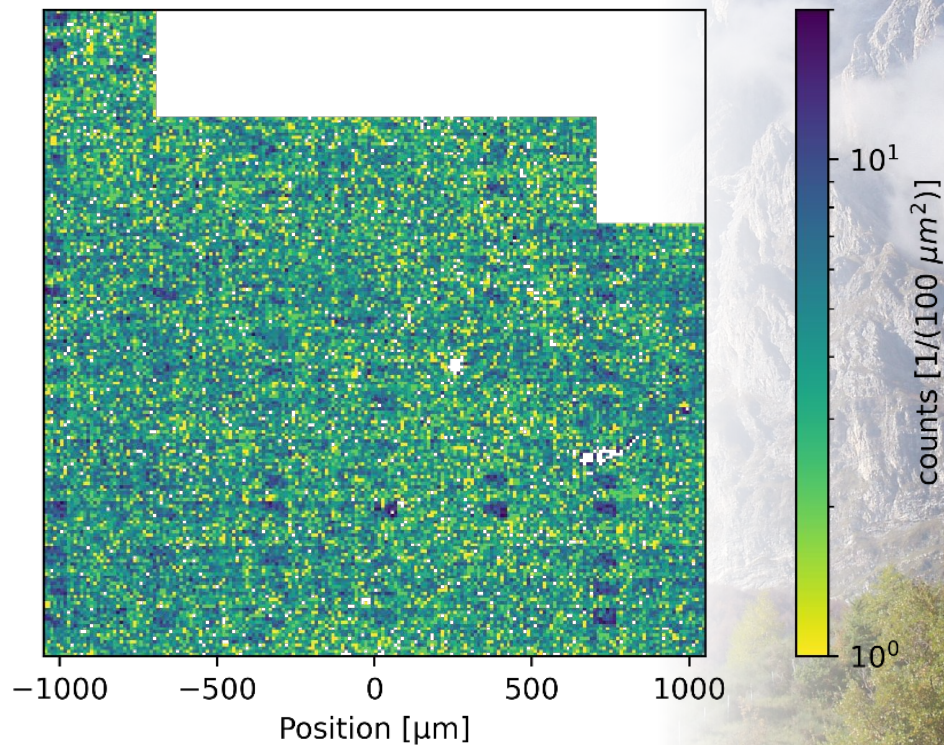


Microscope path, flagged views

Microtracks (scan 00) with flag cut

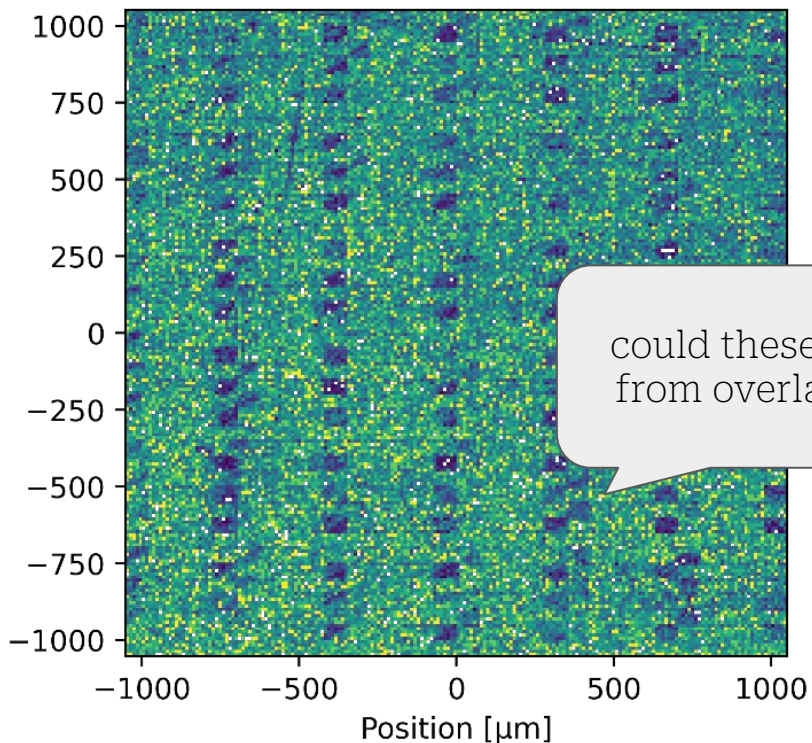


Microtracks (scan 90) with flag cut

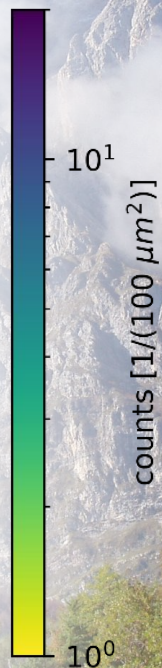
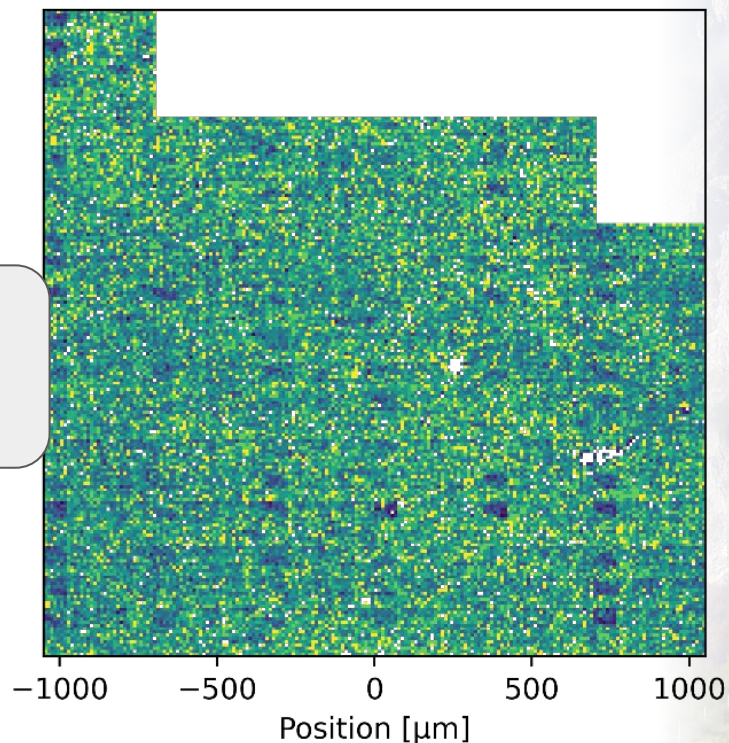


Microtracks, cuts: flagged views

Microtracks (scan 00) with flag cut



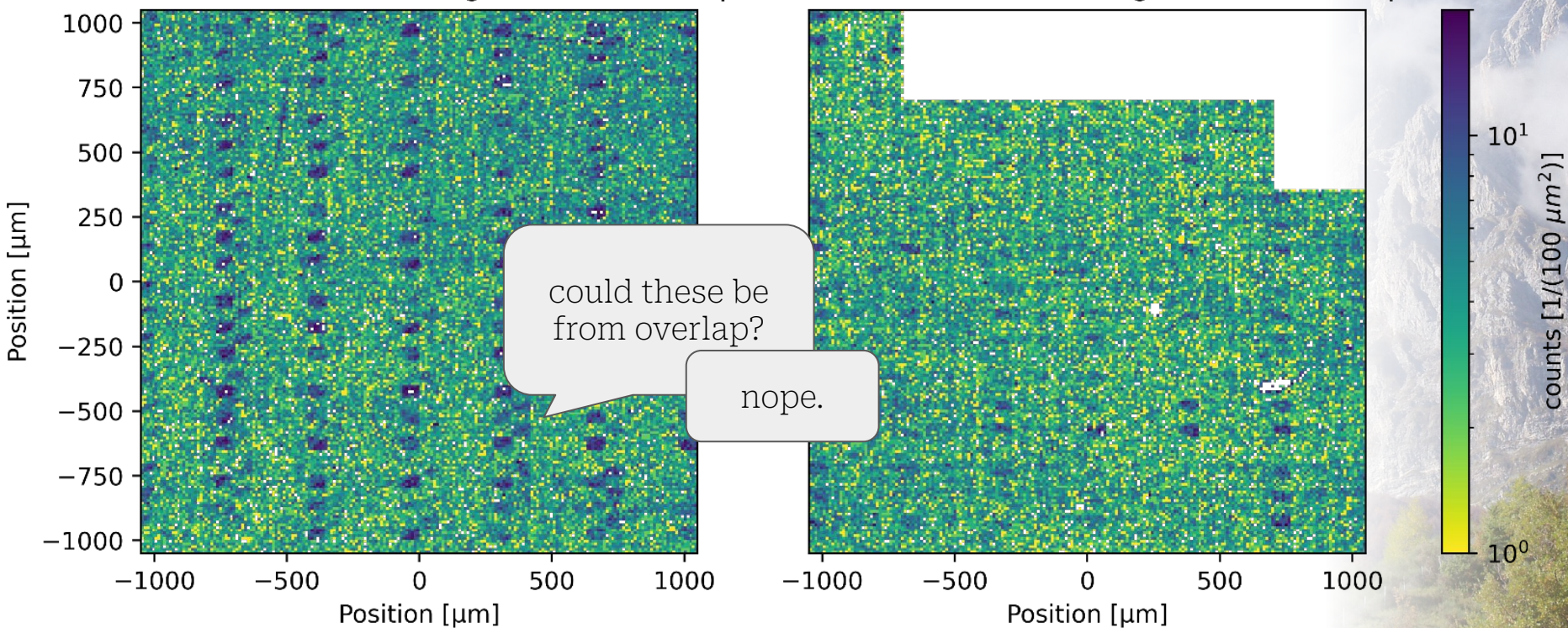
Microtracks (scan 90) with flag cut



Microtracks, cuts: flagged views

Microtracks (scan 00) flag cut + no overlap

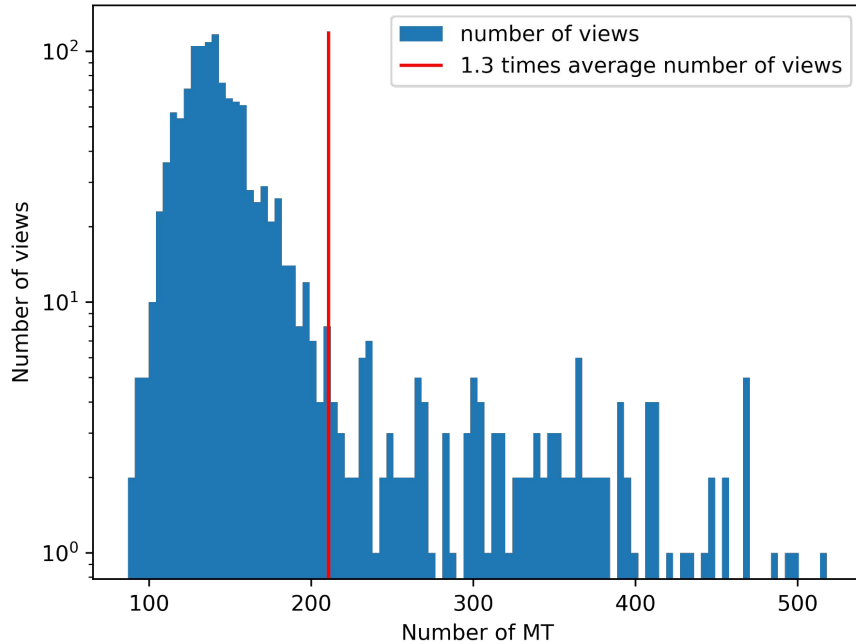
Microtracks (scan 90) flag cut + no overlap



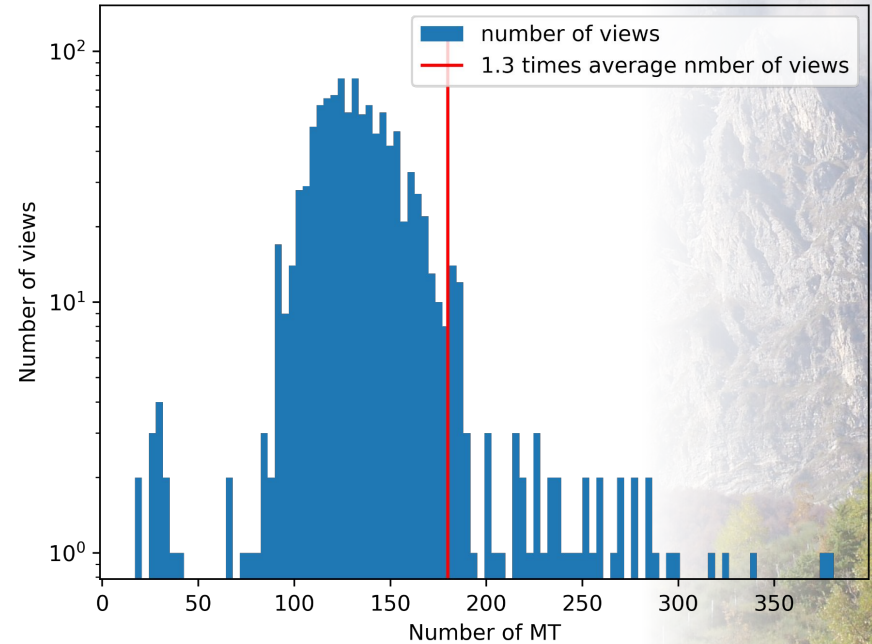
Microtracks, cuts: flagged views, overlap

Thanks to Asada for figuring out the root issue!

Number of Views for MTs (Scan 00 deg)

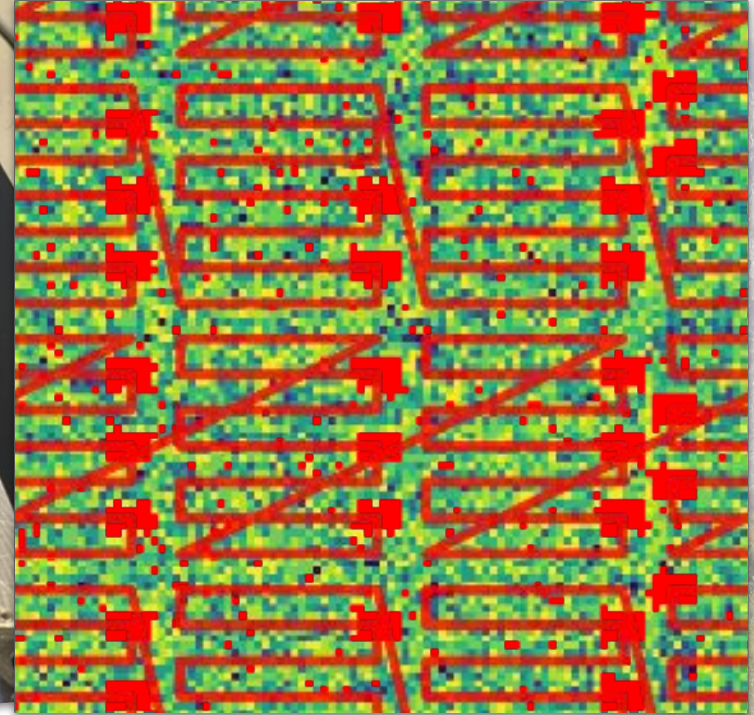
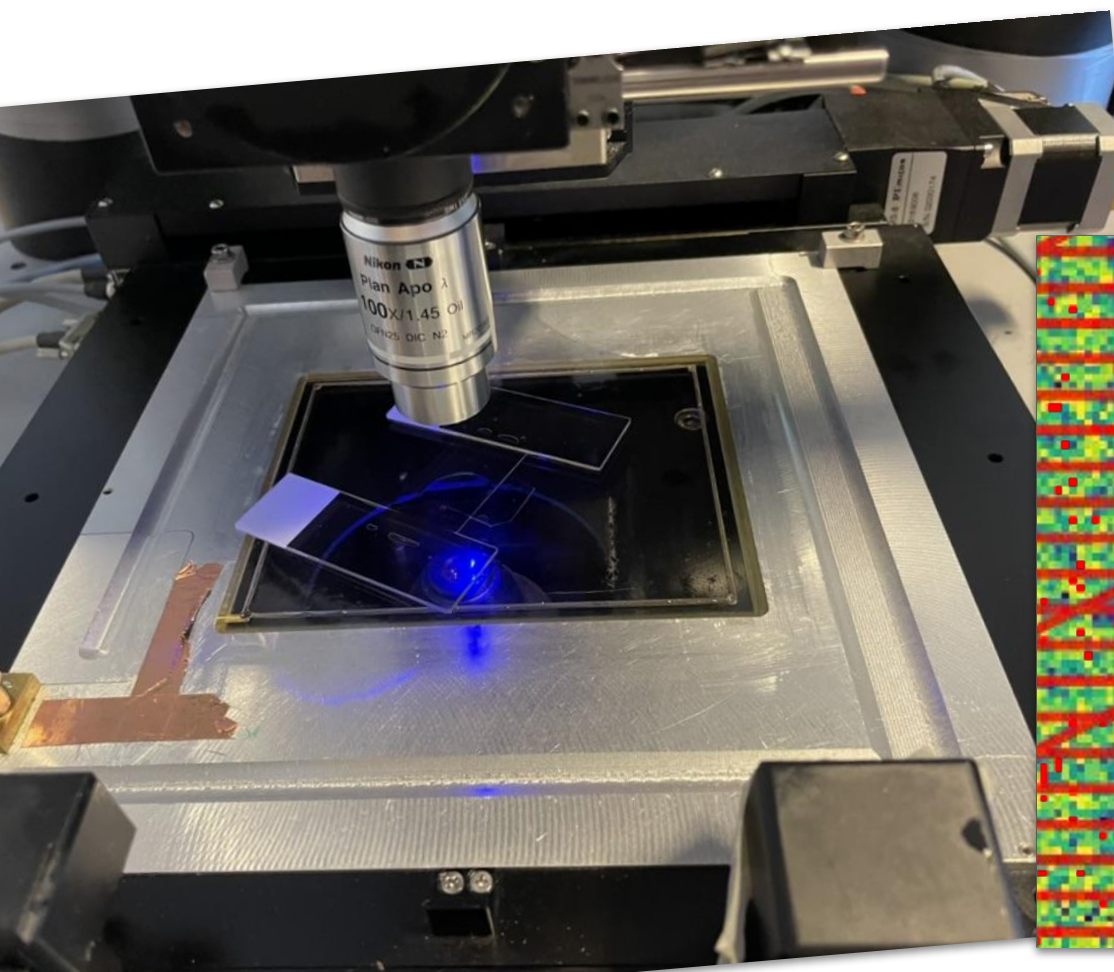


Number of Views for MTs (Scan 90 deg)

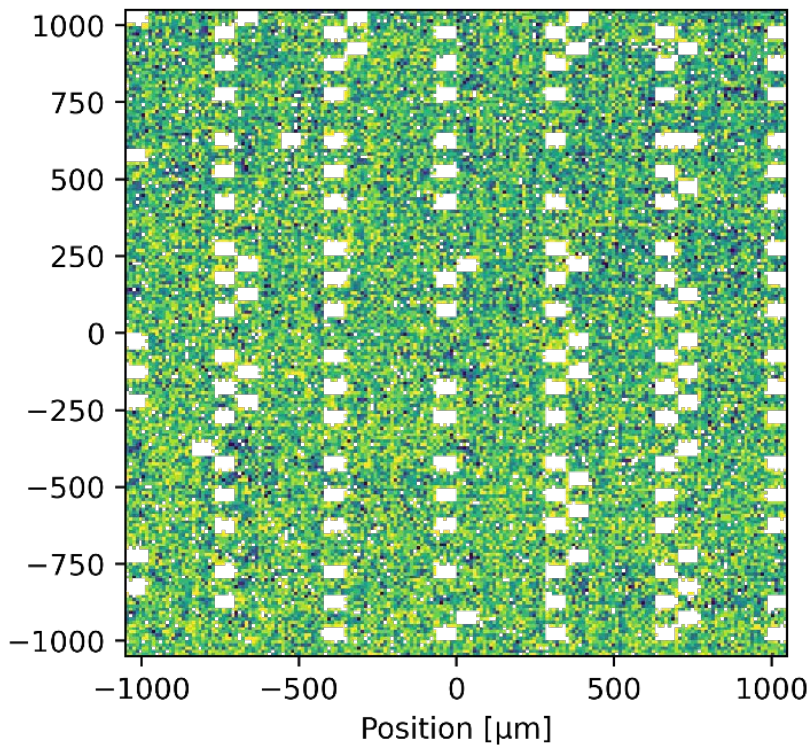


Distribution of microtracks across views

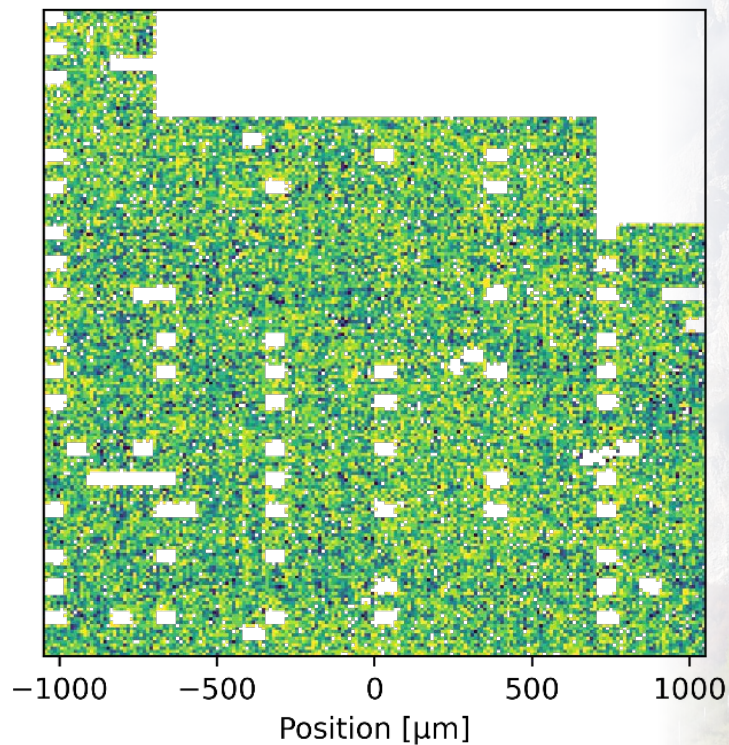
Thanks to Asada for figuring out the root issue!



Microtracks (scan 00) full cuts



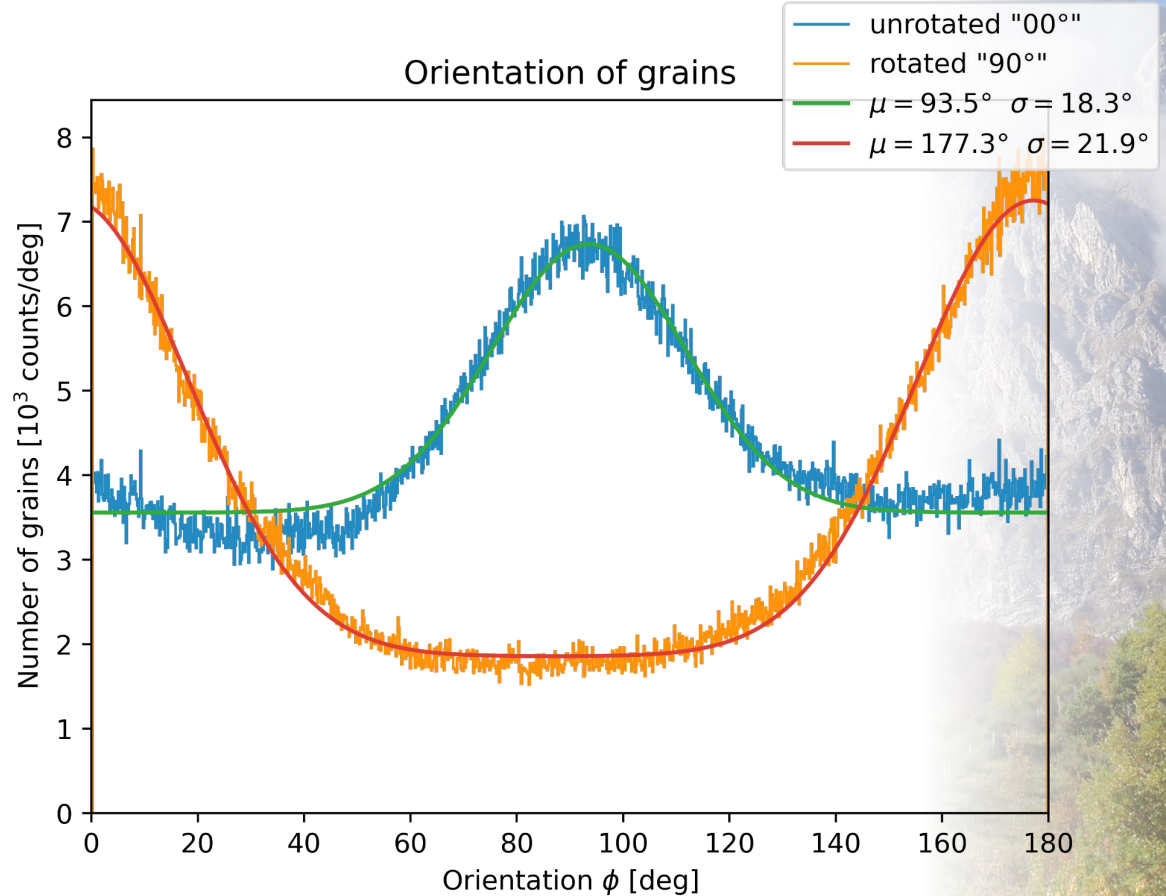
Microtracks (scan 90) full cuts



Microtracks, cuts: flags, overlap, overshoot

Data Analysis

- simple model:
Gaussian + flat bkg
- results match expectations
- seemingly negligible impact of microscope on directionality

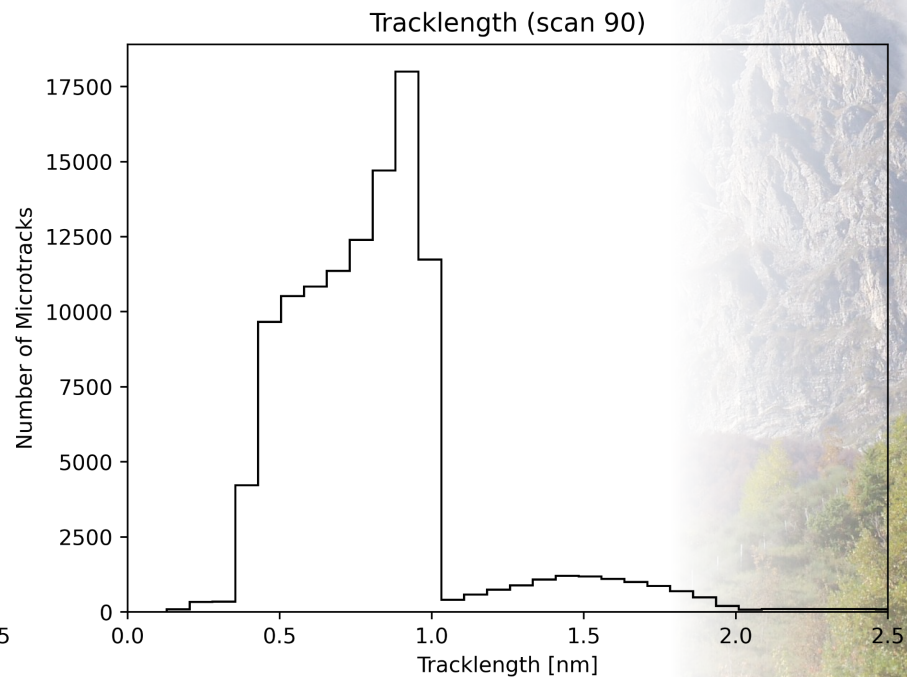
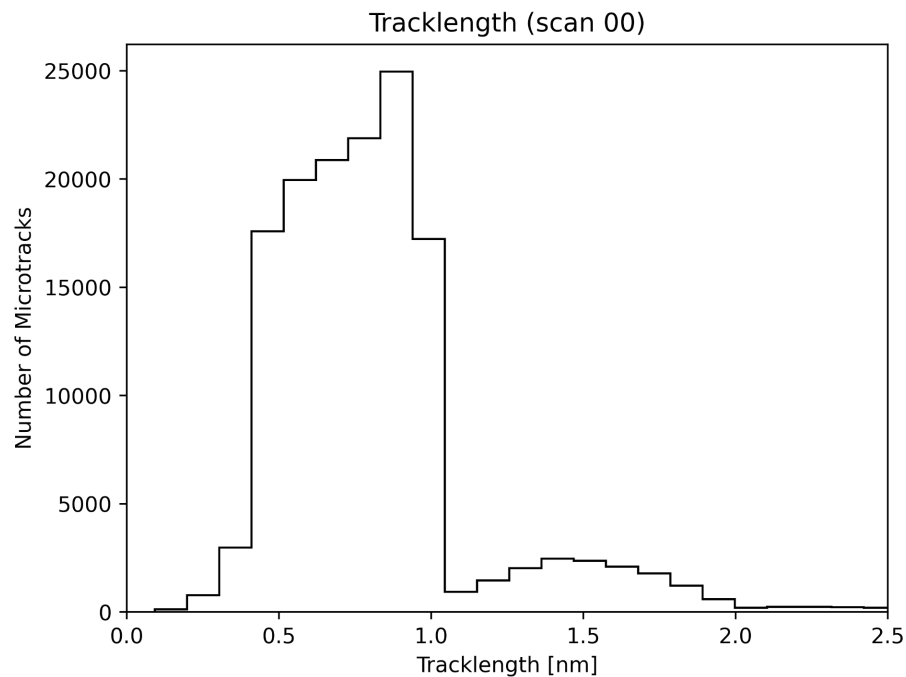


Further variables to examine

- track length
→ energy deposition
- expect exponential decay

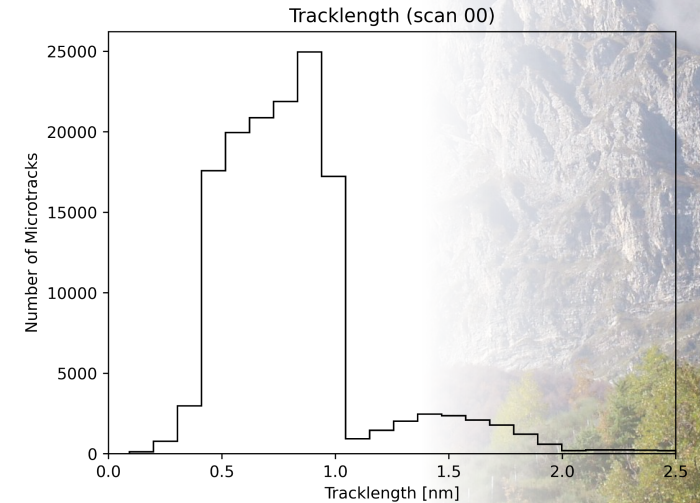


Further variables to examine



Further variables to examine

- track length
 - energy deposition
- expect exponential decay
 - not very well supported by this “raw” data
 - requires more complex cuts/model
- would require more time, but instead we went to get our *HandsOn* some of our own emulsions!
(see pictures in a few slides)



Summary

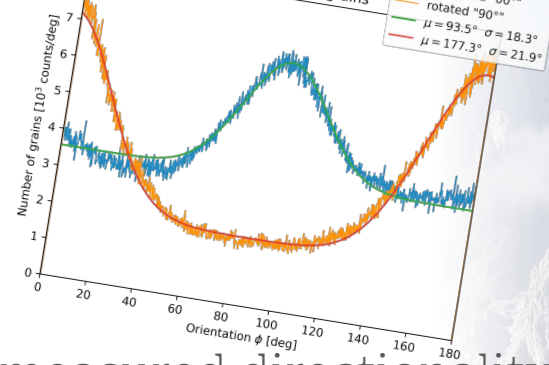
Biases in directional measurement

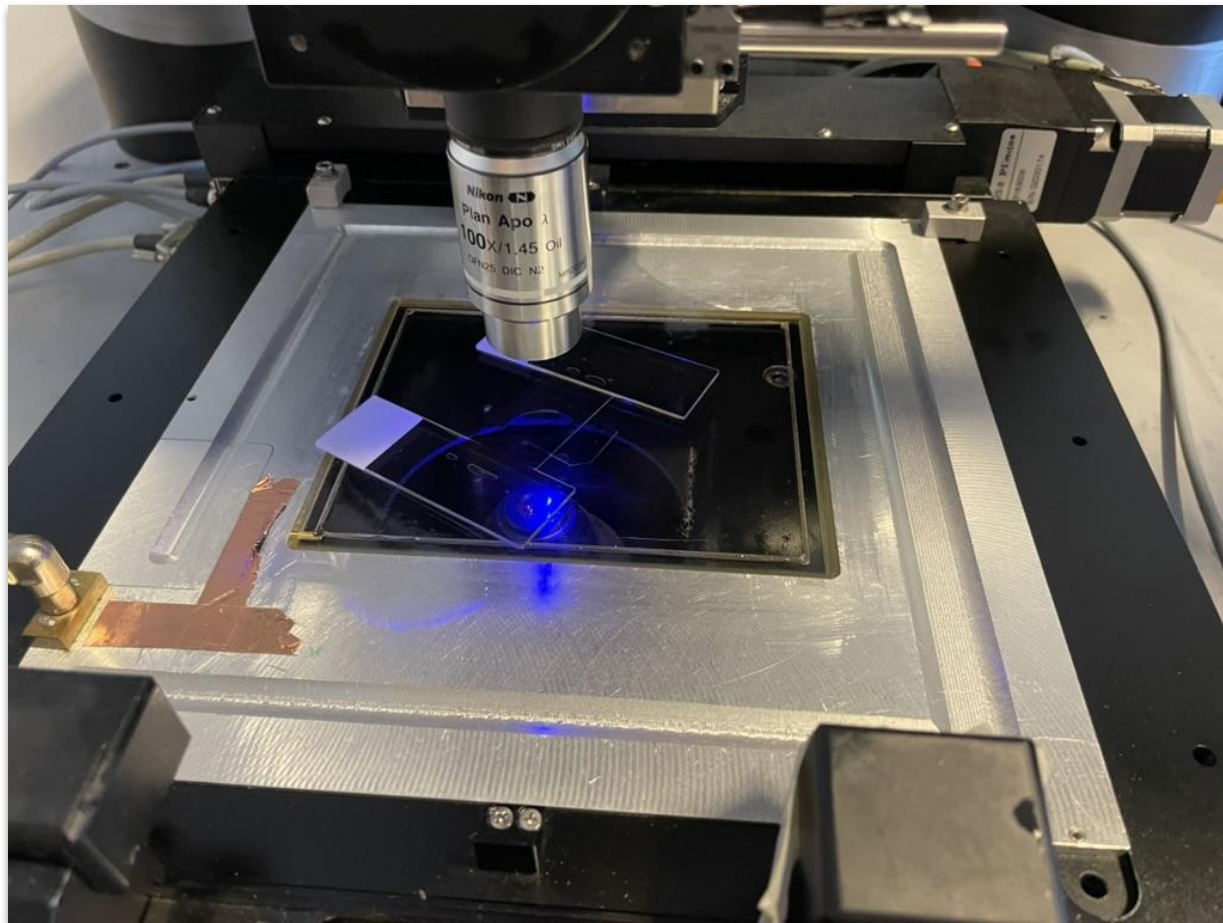
- minimal impact of experimental setup on measured directionality
- in general a flat bkg model is insufficient to fully explain obsv.

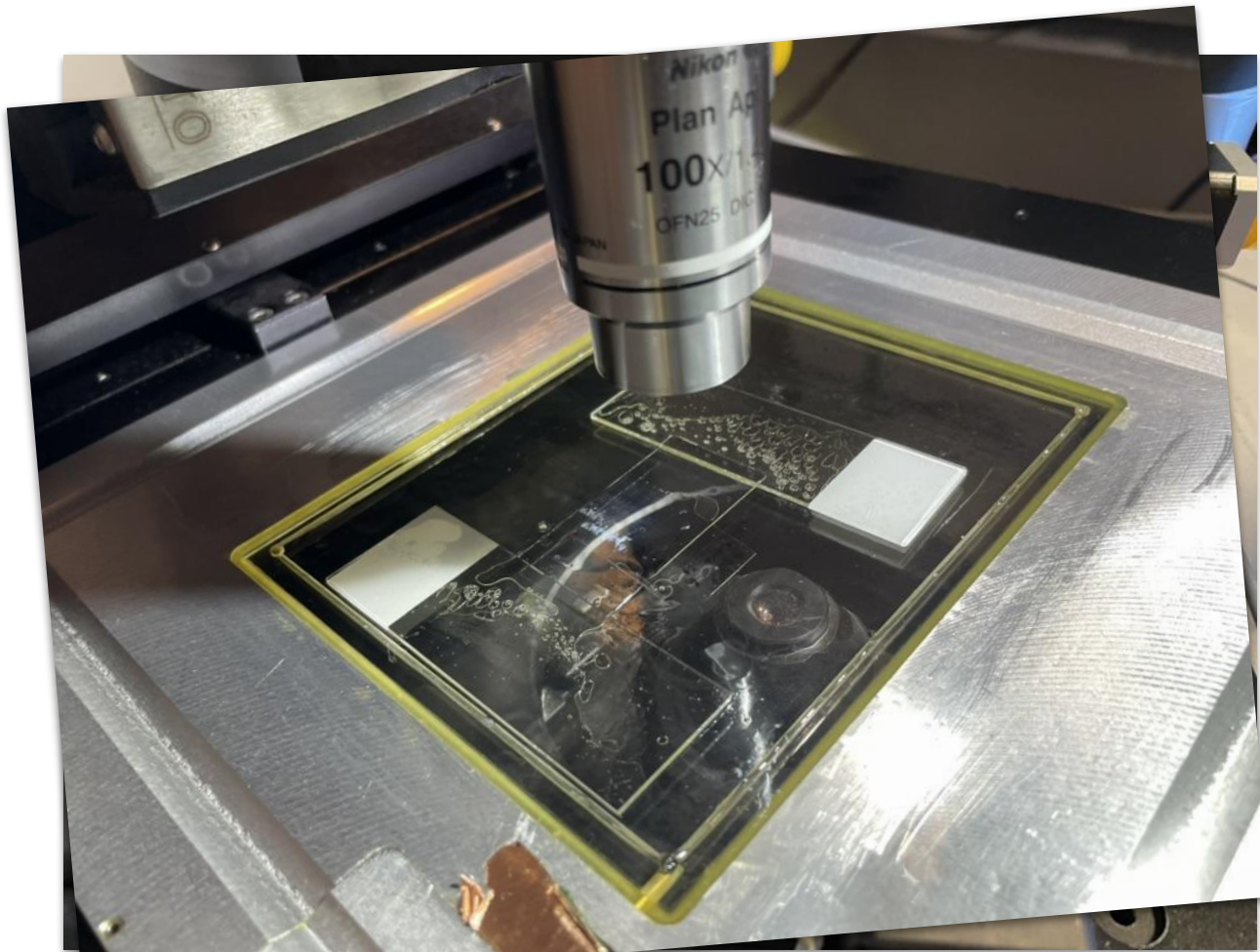
Nuclear emulsions in general

- excellent spatial resolution
- low cost
- high dependence of cleanliness in production for rare event search

Huge thanks to Valeri, Asada, Nicola and Andrey!

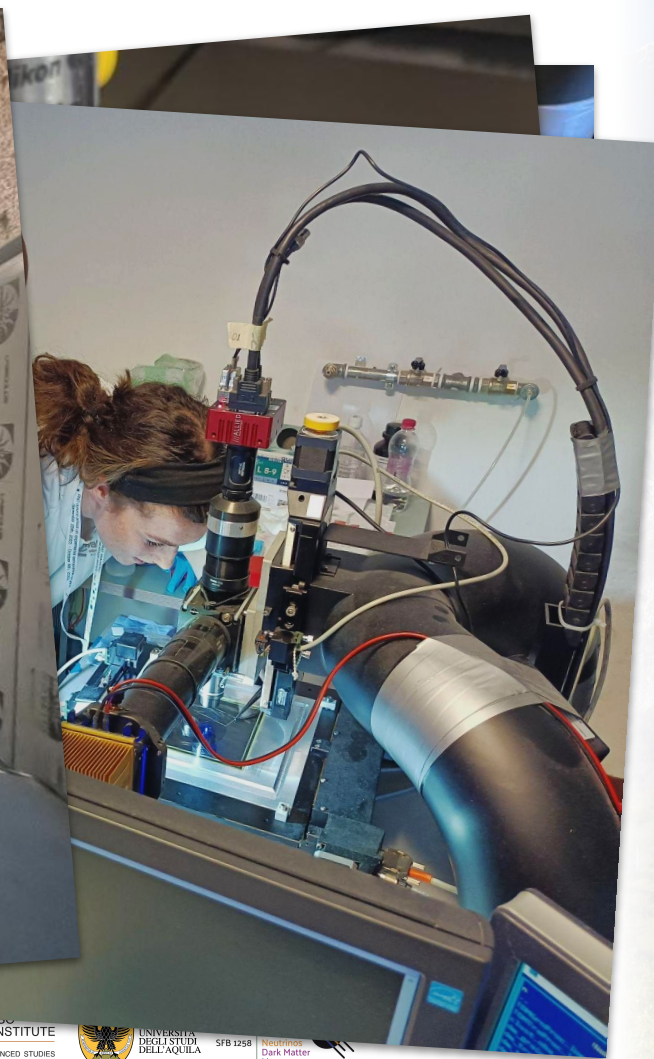








Alexandra Scholz, Sebastian Munkel
Gran Sasso HandsOn September 2023





Alexandra Scholz, Sebastian Munkel
Gran Sasso HandsOn September 2023



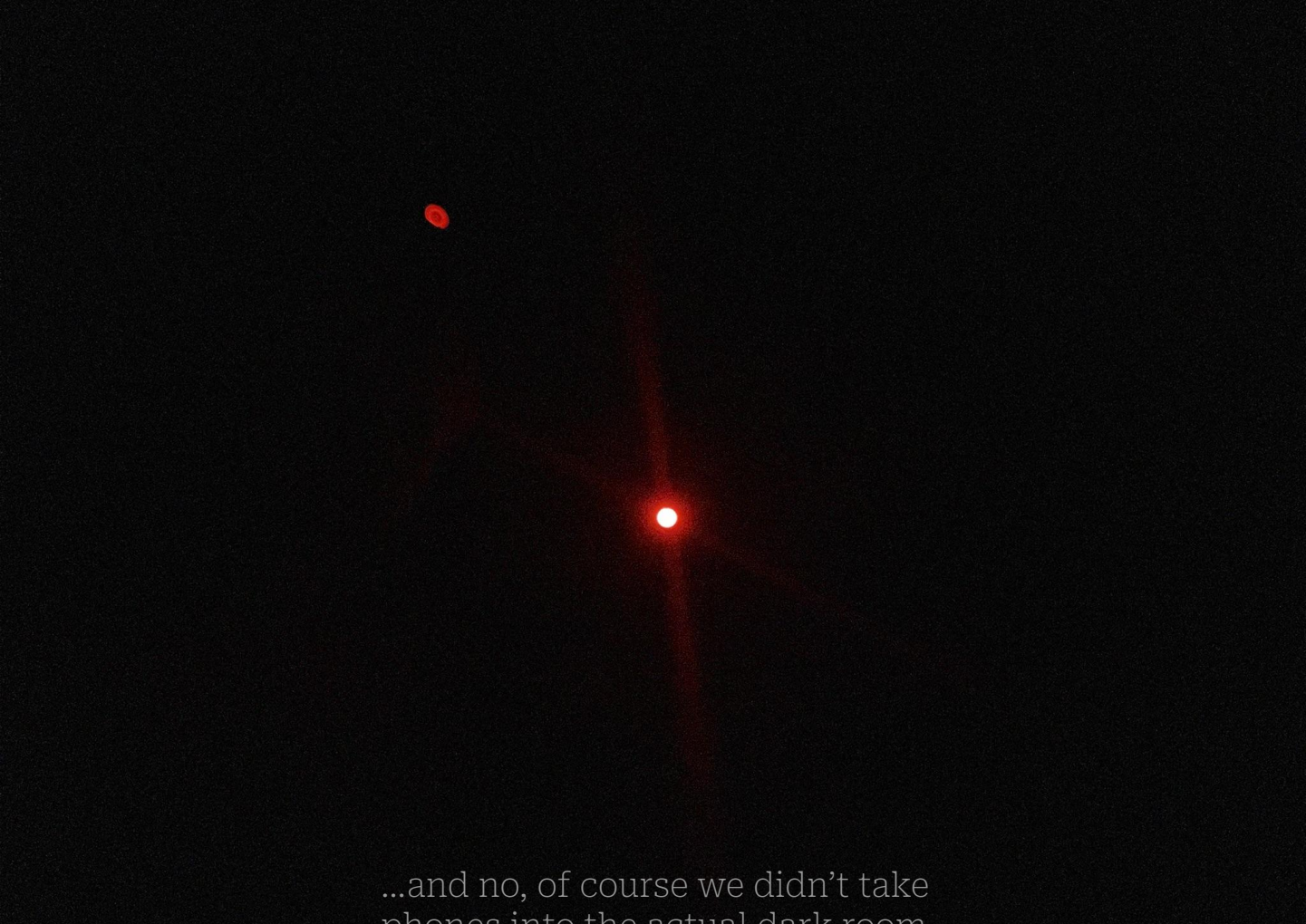
SFB 1258





Alexandra Scholz, Sebastian Munkel
Gran Sasso HandsOn September 2023





...and no, of course we didn't take phones into the actual dark room

Sources :

- https://indico.cern.ch/event/1025480/contributions/4456995/attachments/2298287/3908796/2021_08_25_DiCrescenzo_NEWSdm.pdf
- https://agenda.infn.it/event/28874/contributions/169106/attachments/94657/129883/2022-07-09_ICHEP_2022_NEWSdm_v2.pdf
- <https://arxiv.org/pdf/1604.04199.pdf>
- <https://iopscience.iop.org/article/10.1088/1361-6633/ac5754/pdf>

