Detection system for muography applications
~ design and testing ~

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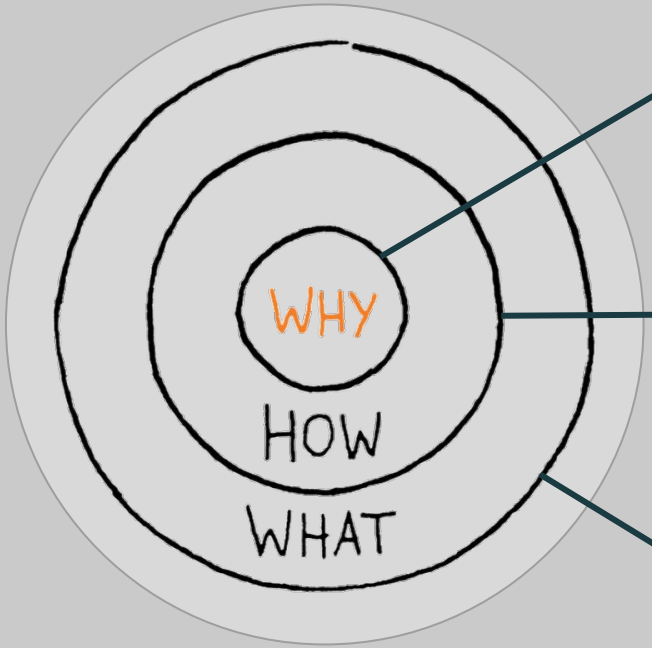


Evaluate angular density distribution

Atmospheric muons

Muography

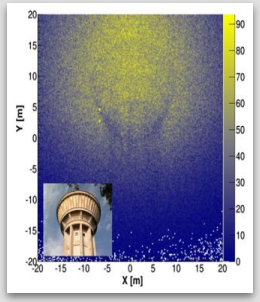
Muon radiography
= transmission/absorbtion muography

Muon tomography
= deviation muography

Muon radiography

- based on muon flux attenuation (inelastic collisions with atomic electrons)
- records the direction and counts the number of muons **after** crossing a given structure

only one detector



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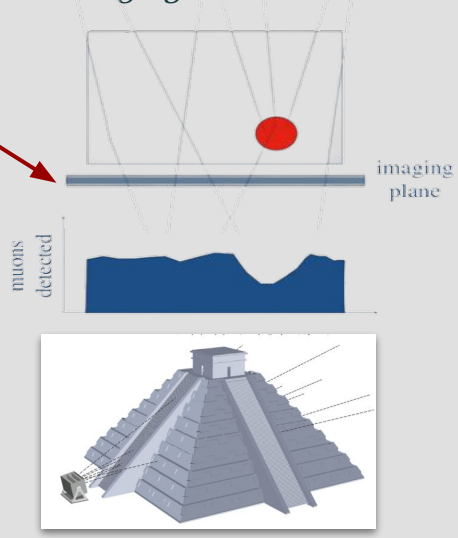

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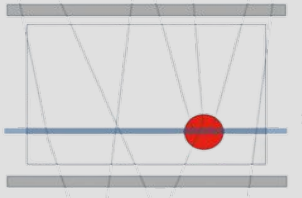
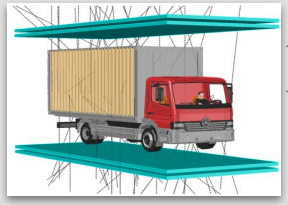
Applications: geological, archaeological and subsoil prospecting applications in civil and mining fields.

Muon tomography

- based on angular deflection of incident muon direction (elastic scattering on nuclei)
- records the direction and counts the number of muons both **before** and **after** crossing a given structure





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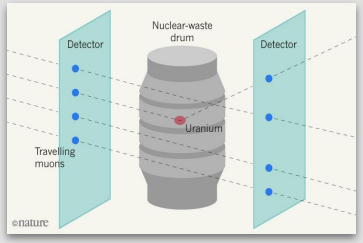
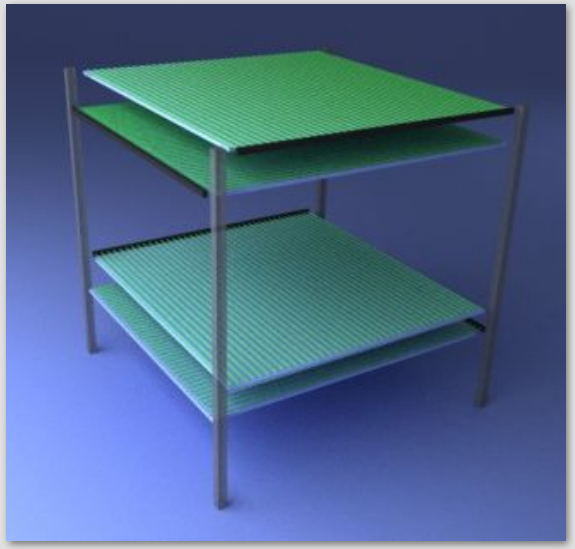


Nature 557, 620-621 (2018)

Applications: nuclear security, transport control

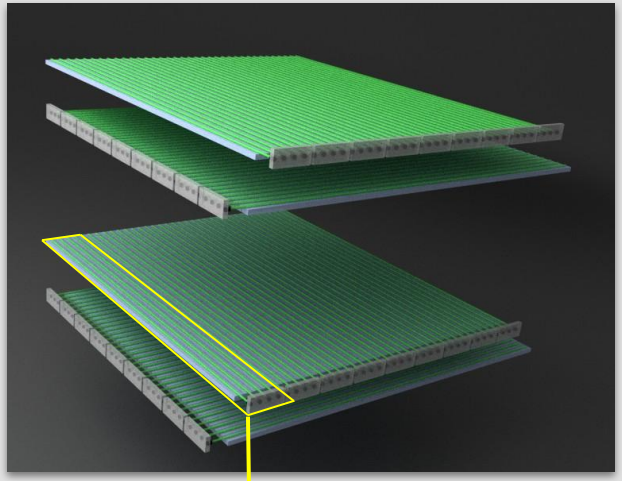
SHOGUN - Scintillator HOdoscope for Geophysical and UNderground applications



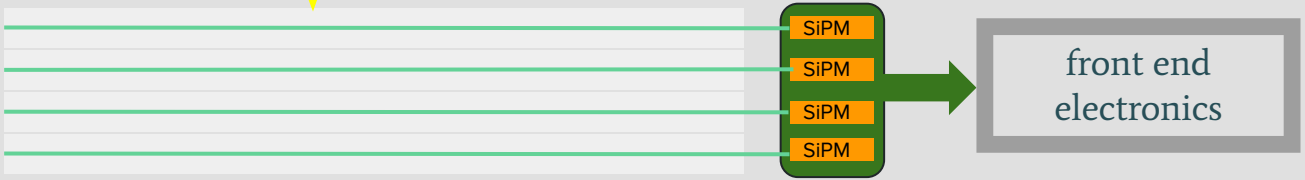
- absorption/transmission muography
- plastic bar scintillators
- SiPM devices
- trajectory information
- developed at IFIN-HH, Magurele, Romania within the Astroparticle Physics Group

SHOGUN - Scintillator HOdoscope for Geophysical and UNderground applications

3D representation



- 935 cm^2 active surface
- 36 plastic scintillator strips per layer
- 4 layers with orthogonal scintillators
- one optic fiber on each plastic scintillator
- collected light is readout by a SiPM device for each plastic bar
- 1296 pixels on each layer
- spatial resolution : 2.5 x 2.5 cm^2
- coincidence condition between the planes



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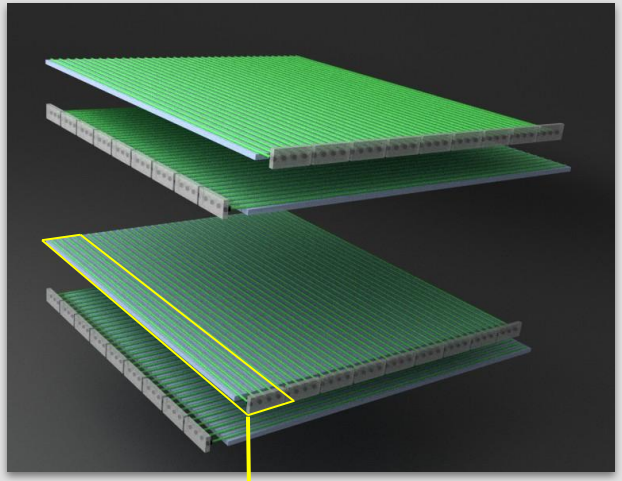

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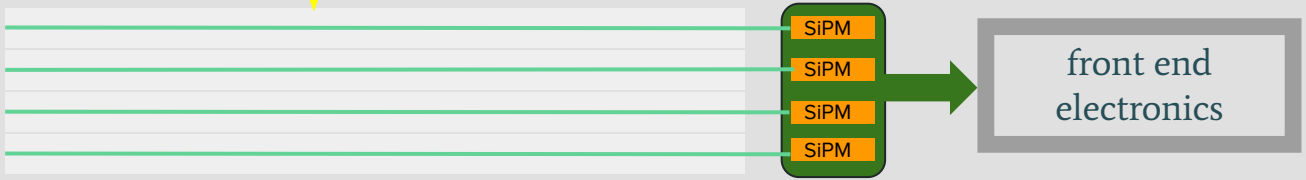
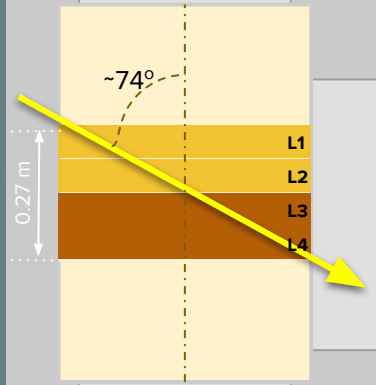


MUON TRACKING

By increasing the distance between detection planes
- angular resolution is improving
- maximum solid angle is reducing

! useful when the object of interest is small and well located

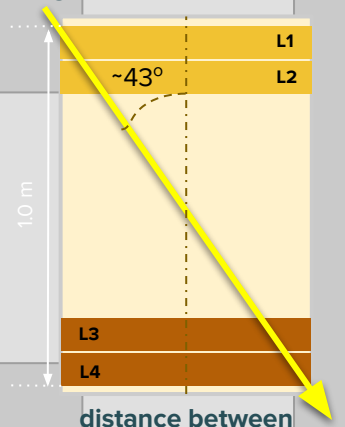
solid angle: 4.55 Sr
angular resolution: 97.9 mrad



minimum distance between the planes 9 cm

Spatial resolution for a distance of 1 km
- 98 m for an angular resolution of 98 mrad
- 17 m for an angular resolution of 17 mrad
- 8 m for an angular resolution of 8 mrad

solid angle: 1.66 Sr
angular resolution: 17 mrad



distance between the planes 73 cm

- the customizable spatial configuration makes the detector suitable for various application cases

3. Tests on the basic unit

SiPM

SiPM

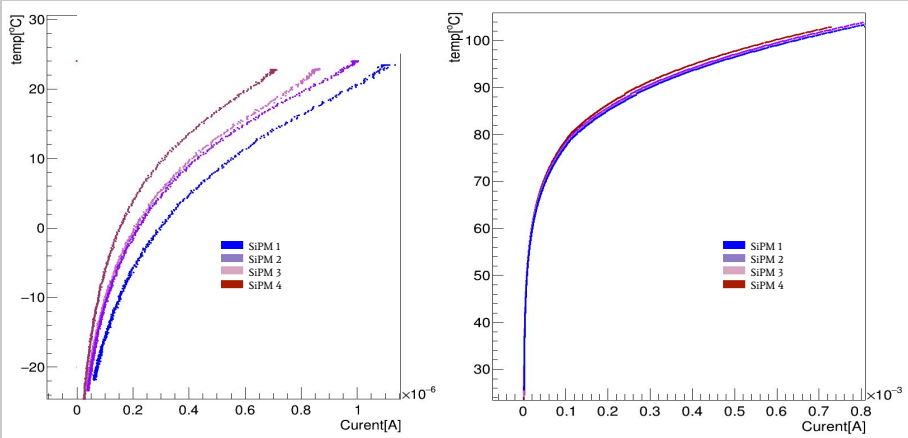
Basic unit

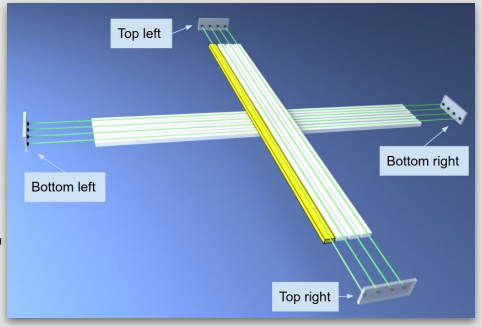
- scintillator bar with optical fiber waveguide
- two SiPM devices collecting the light signal at both ends of the fiber

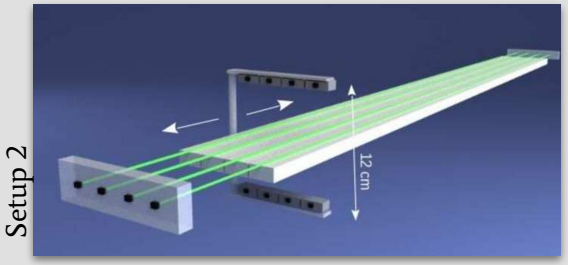
What we inspected

- signal propagation
- data acquisition
- time of flight
- temperature dependence

Temperature dependence of SiPM current for 4 different devices. Left: temperature was lowered from 24°C to -25°C. Right: temperature was raised from 24°C to over 100°C



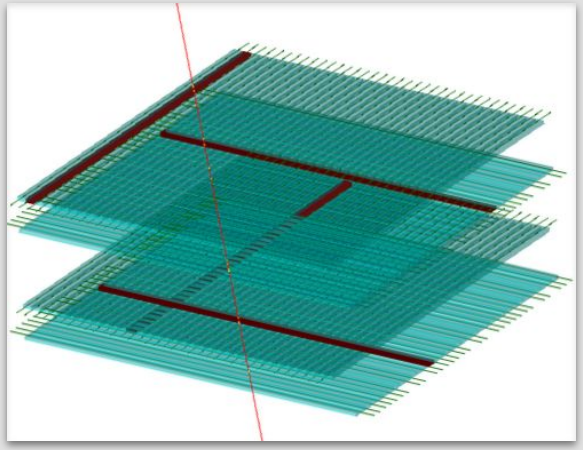




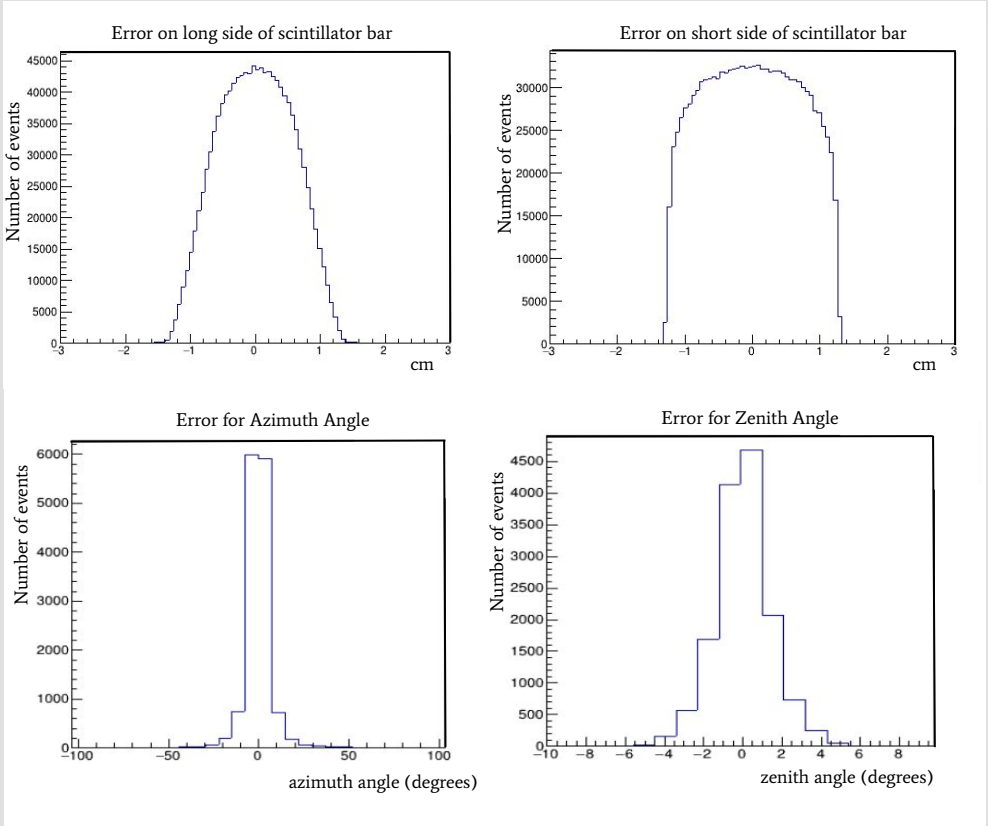
Results:

- At constant temperature, bias voltage and threshold, differences of up to 40% were observed between the counting rates of the SiPM devices utilised in the tests
- results are reported in *Balaceanu A. et al, Characterization of the basic unit in a multi-channel SiPM muography detector using cosmic muons* (in press at NIMA)

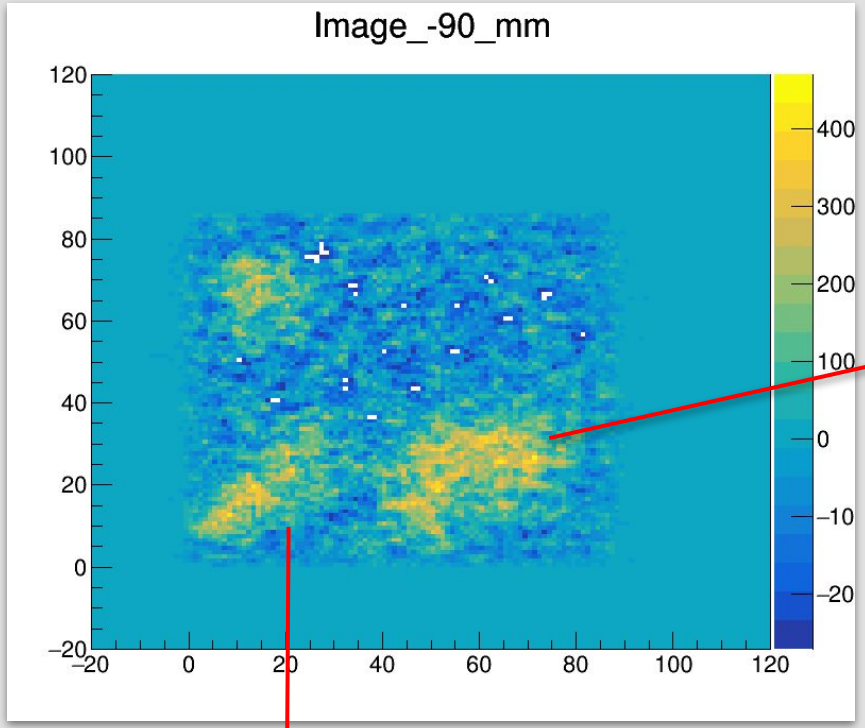
4. Preliminary reconstruction algorithm

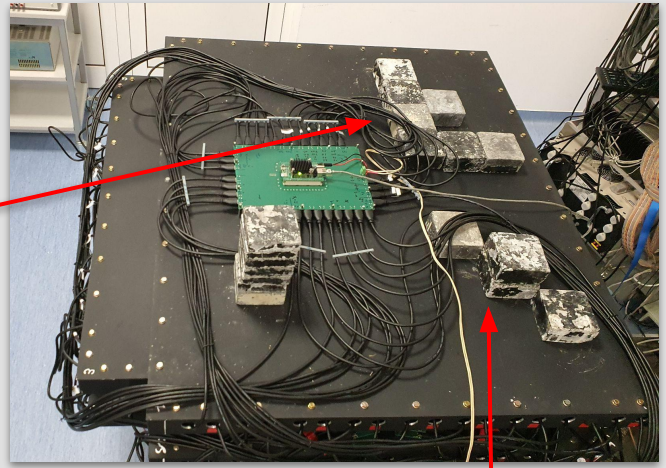


- trajectory reconstruction on simulation data
- position error < ± 2.5 cm on x and y axes



- the reconstruction algorithm makes a projection of trajectory points on different heights above the detector
- looking at reconstruction for different heights, we observe that the image is focusing as the presumed height is approaching the real one





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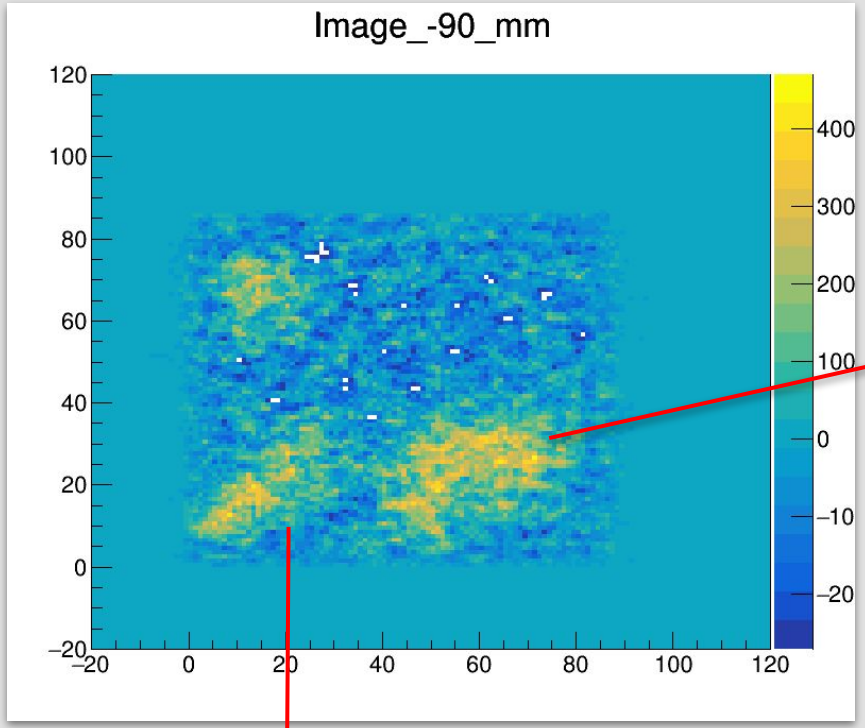

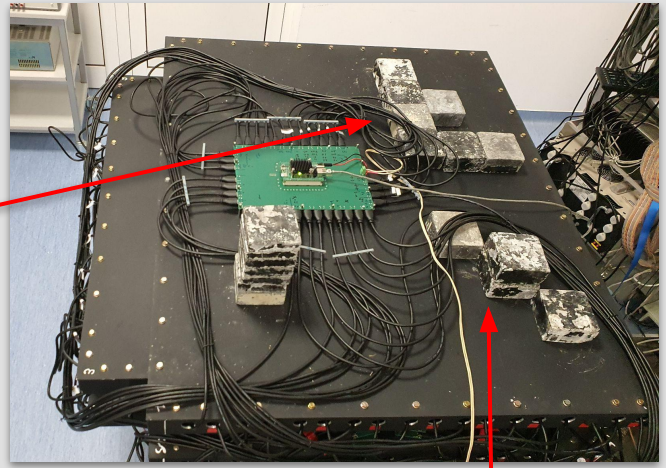

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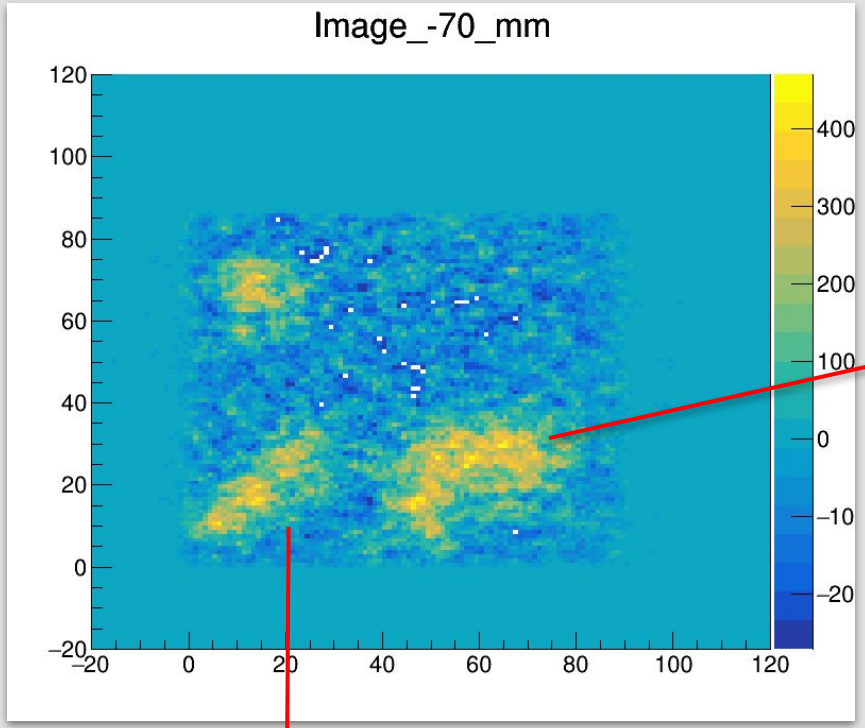

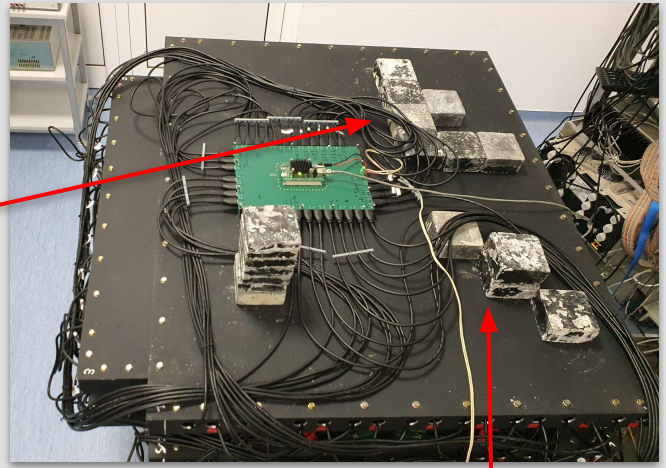

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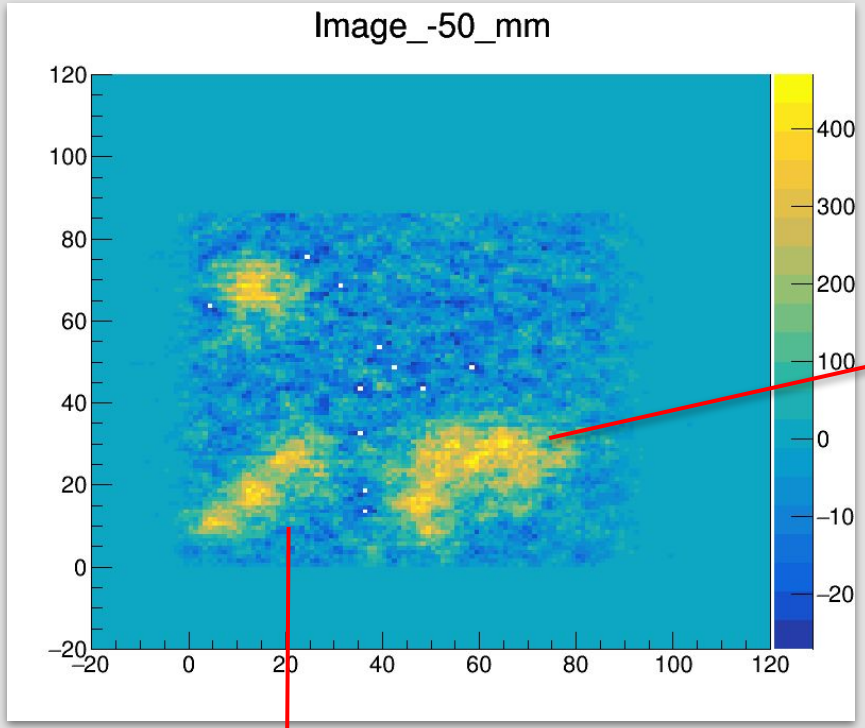

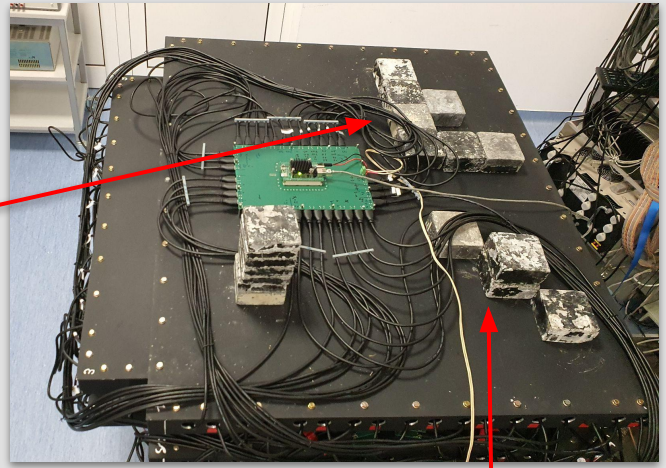

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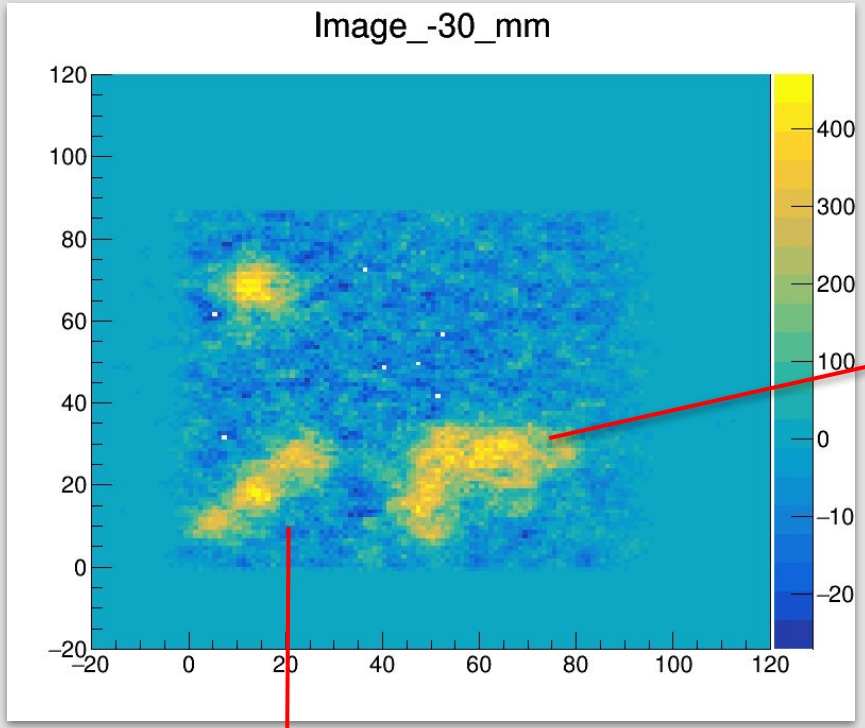

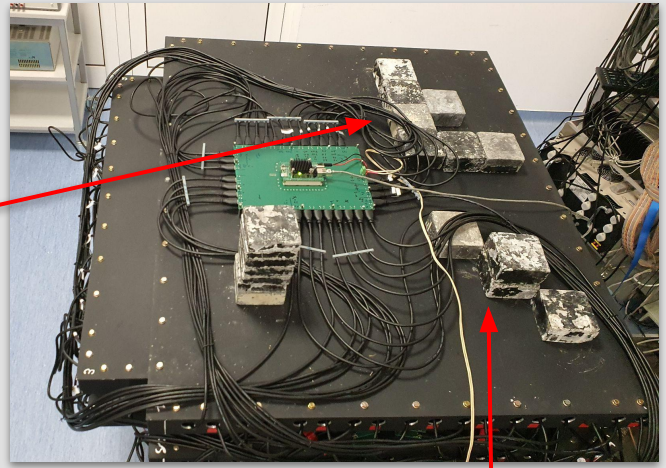

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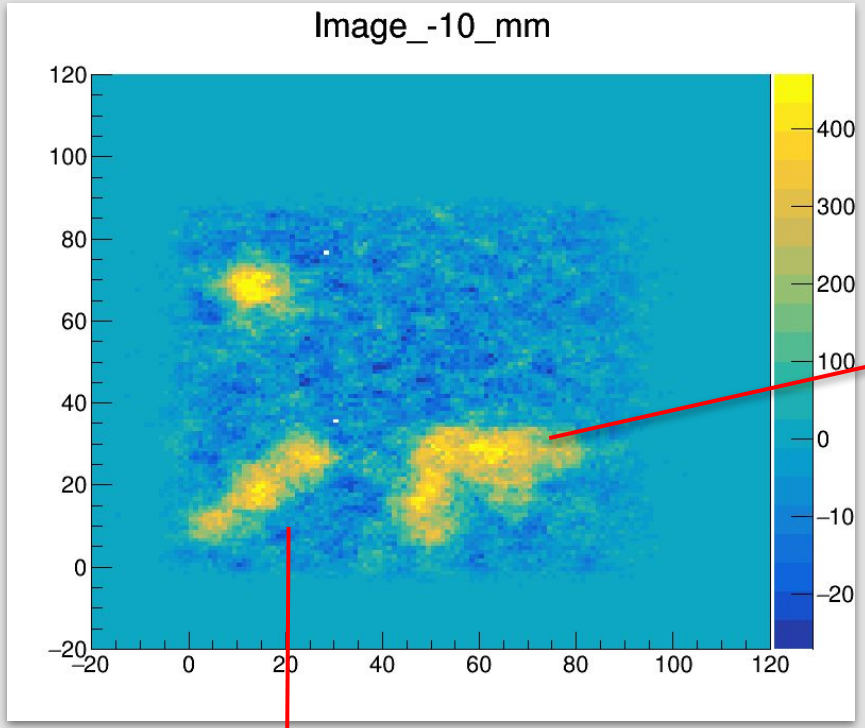

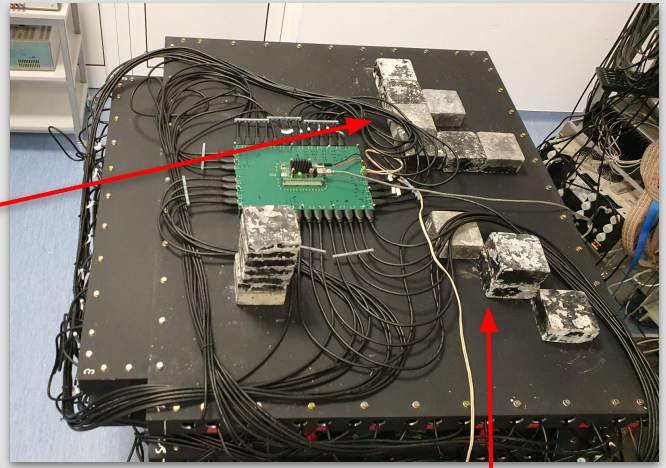

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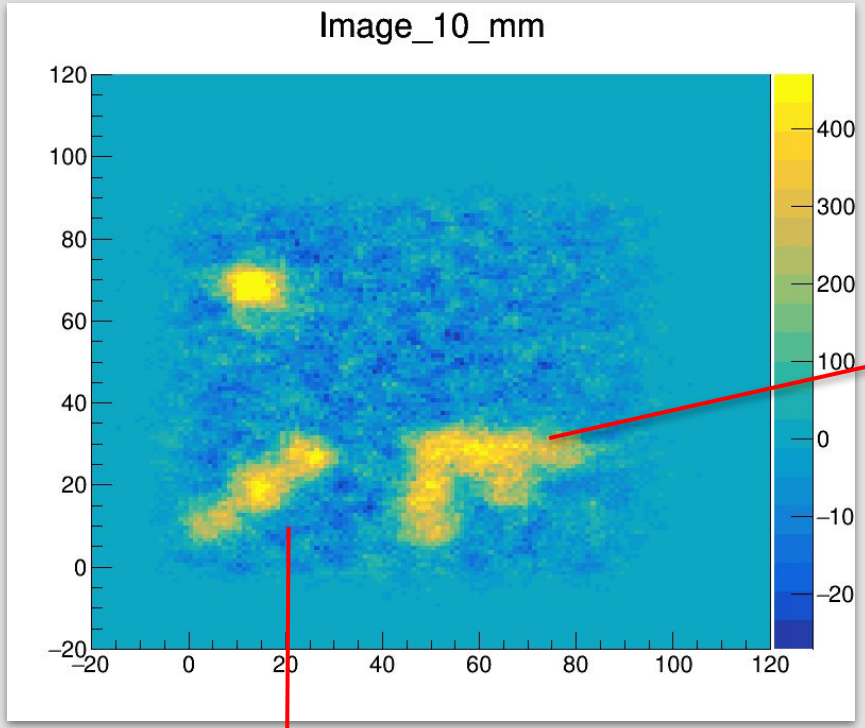

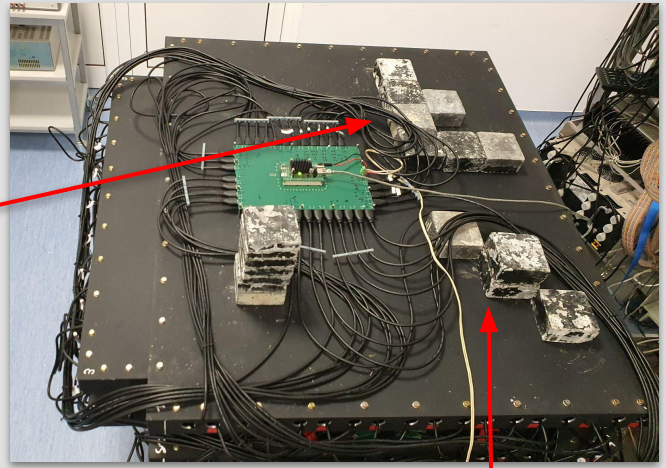

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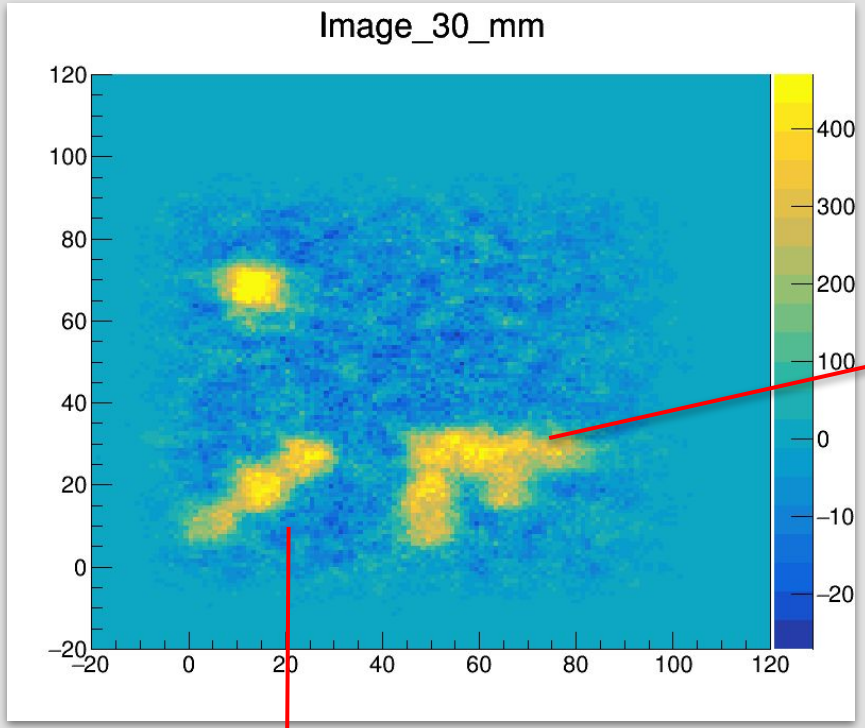

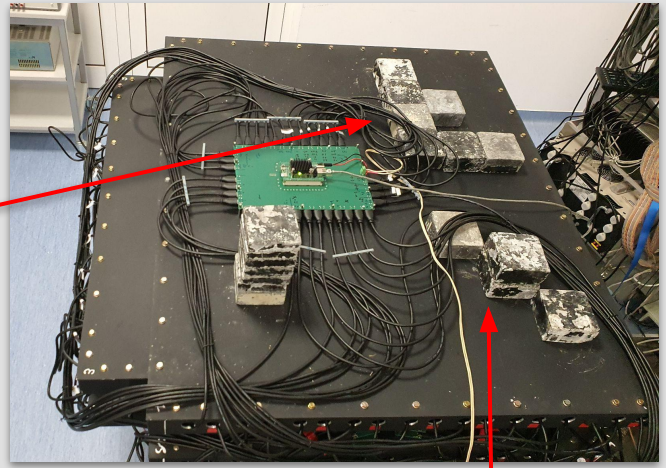

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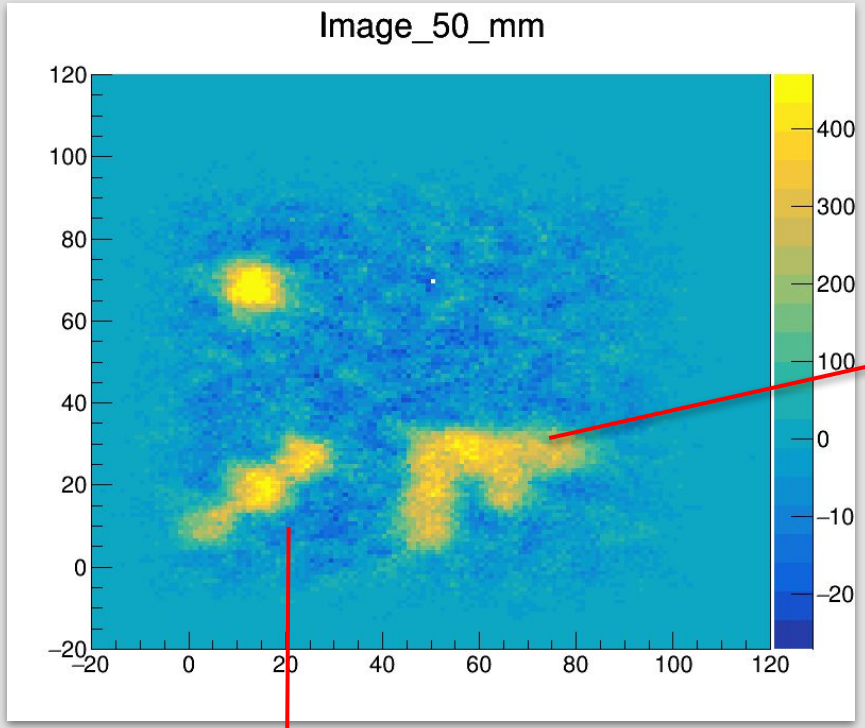

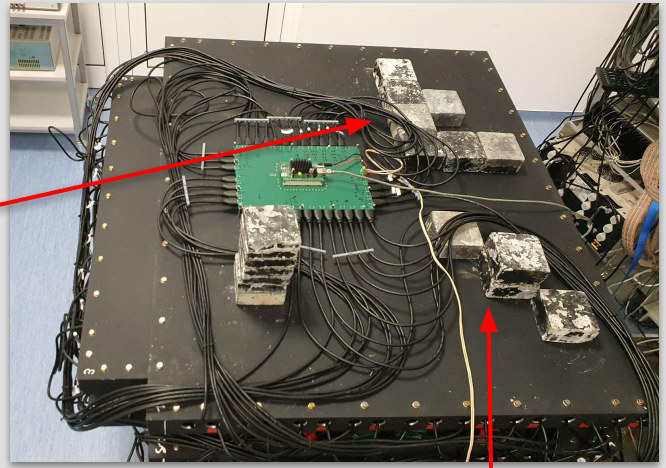

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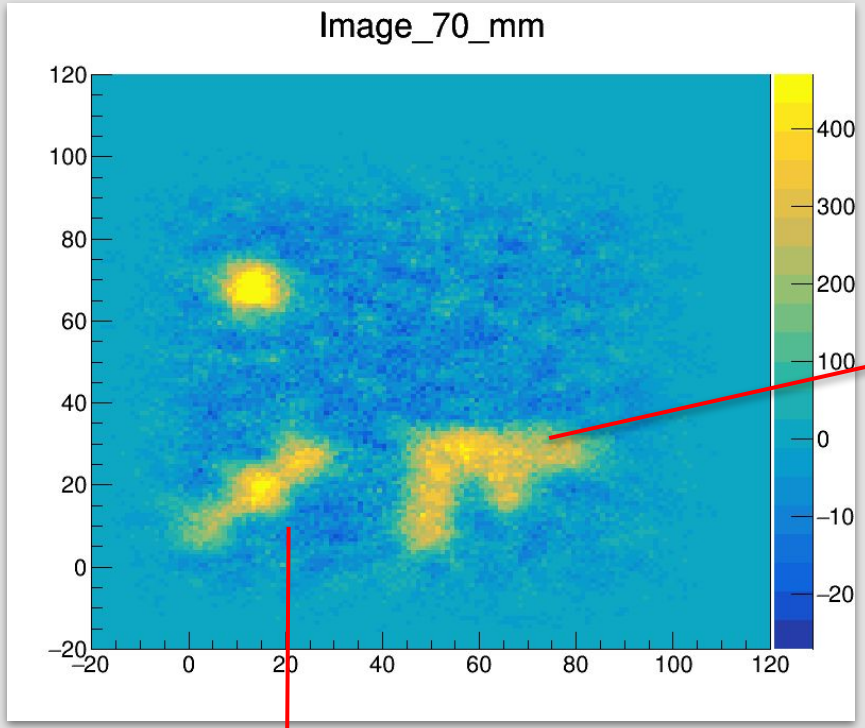

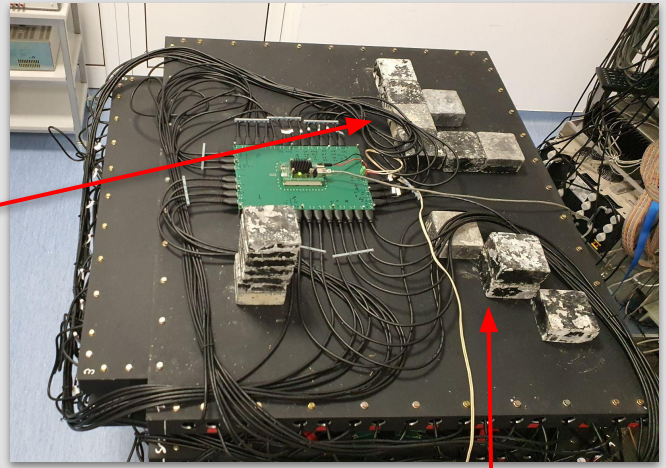

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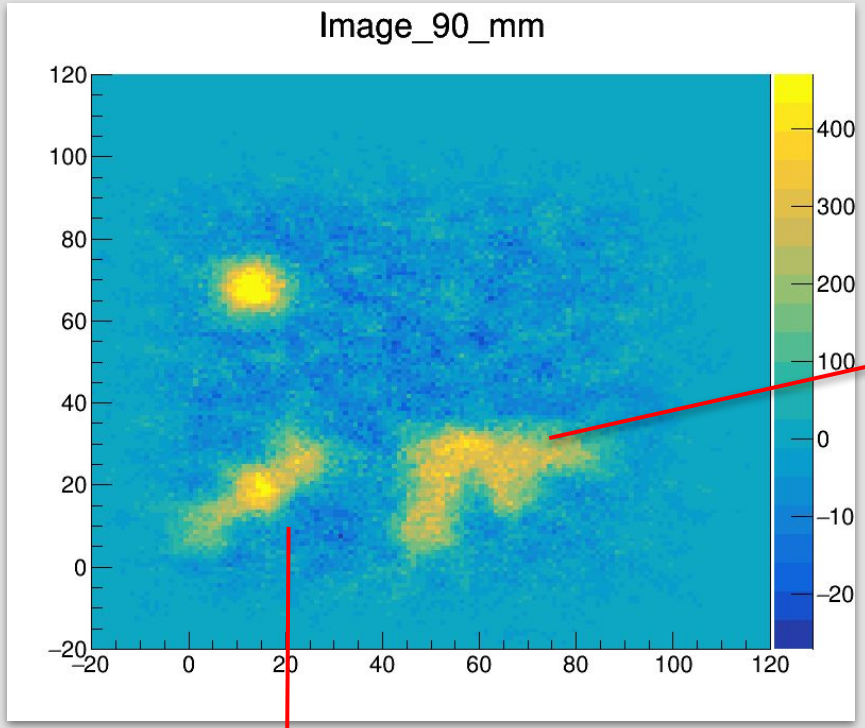

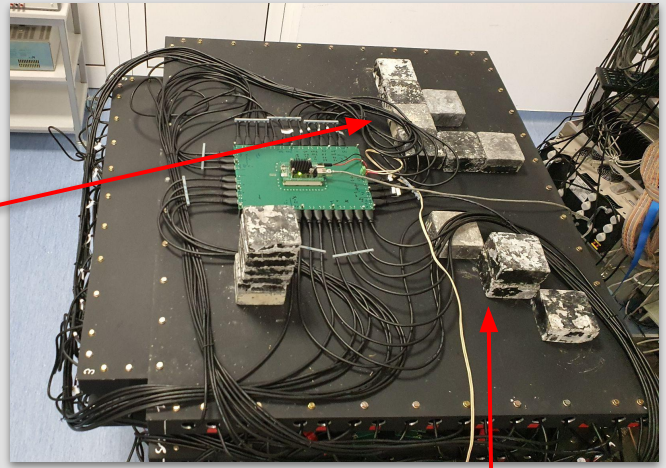

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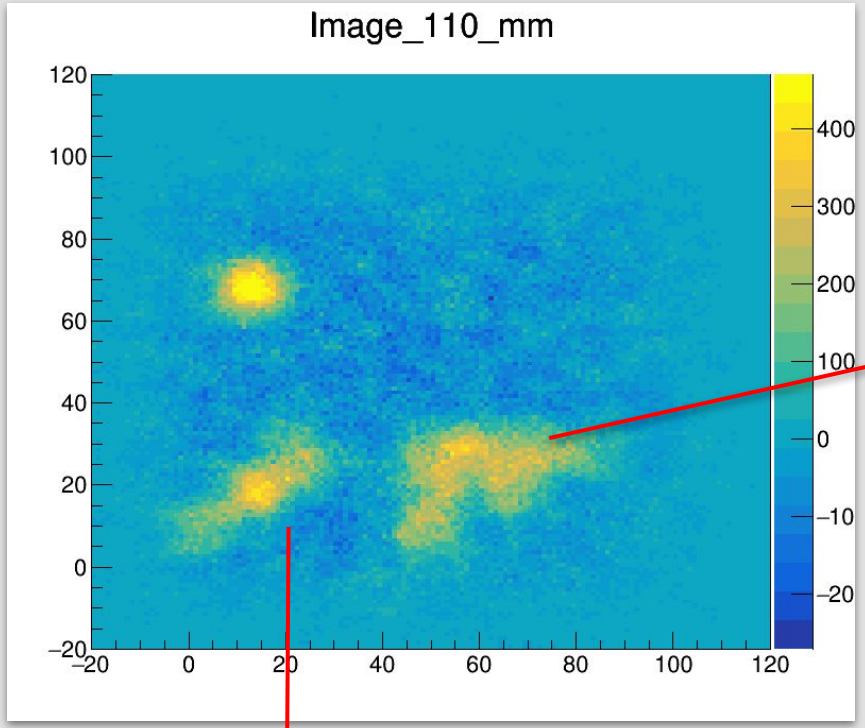

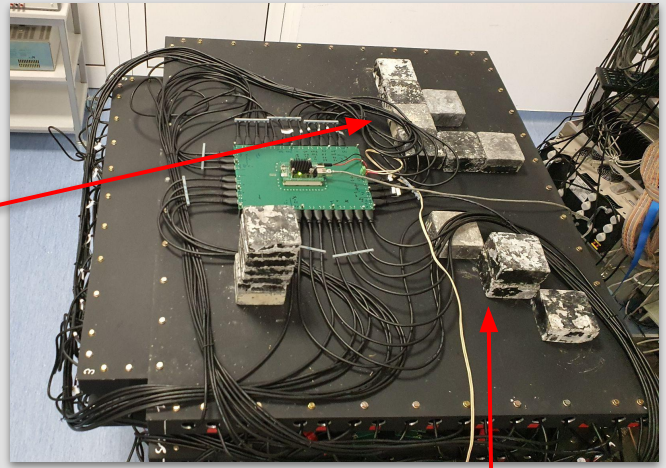

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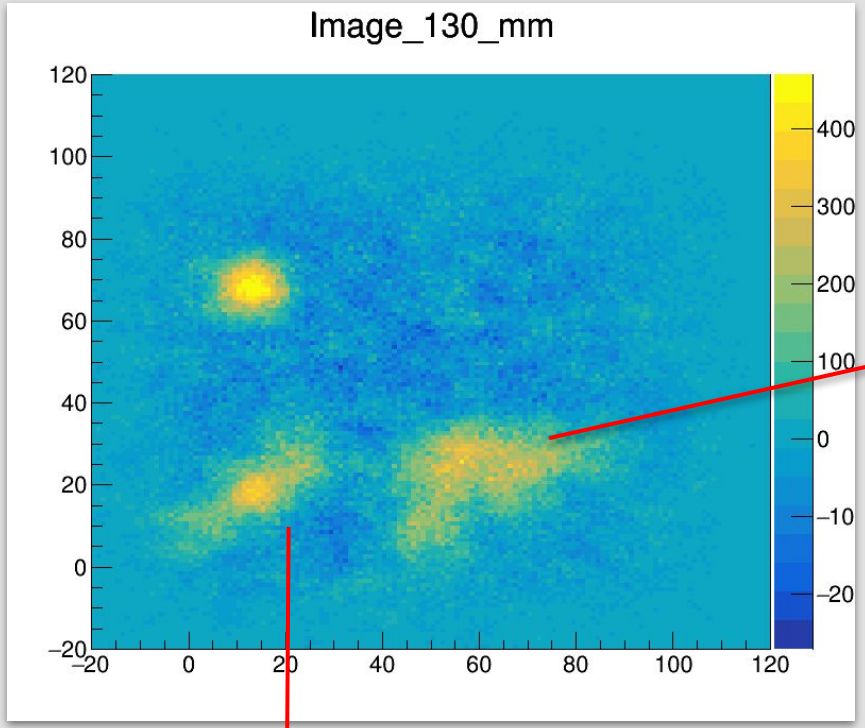

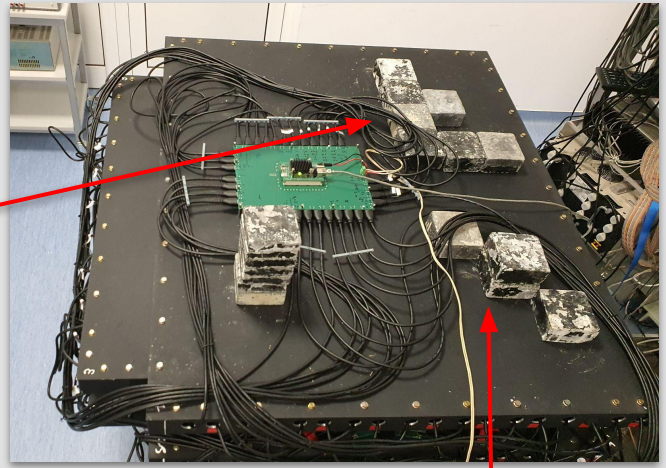

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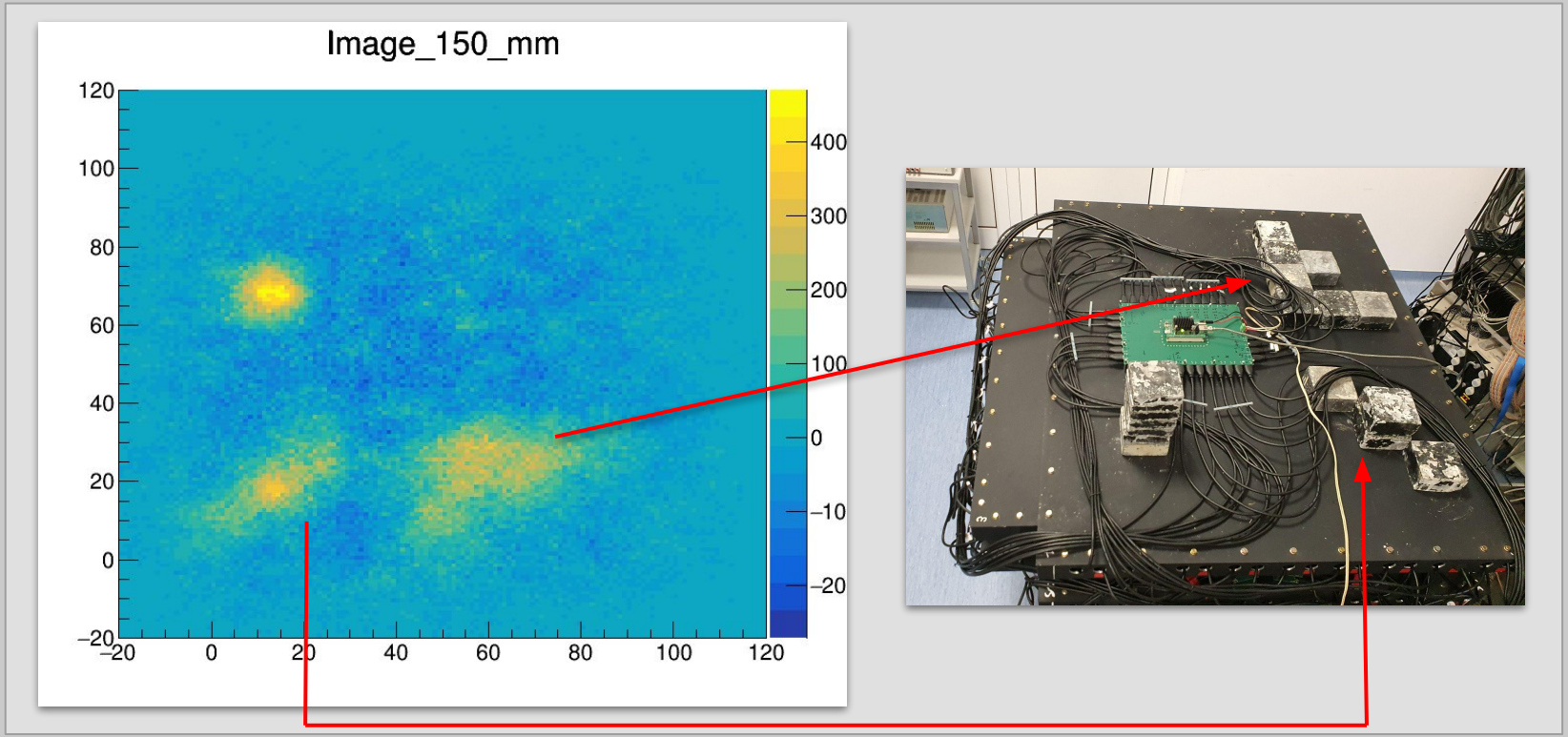

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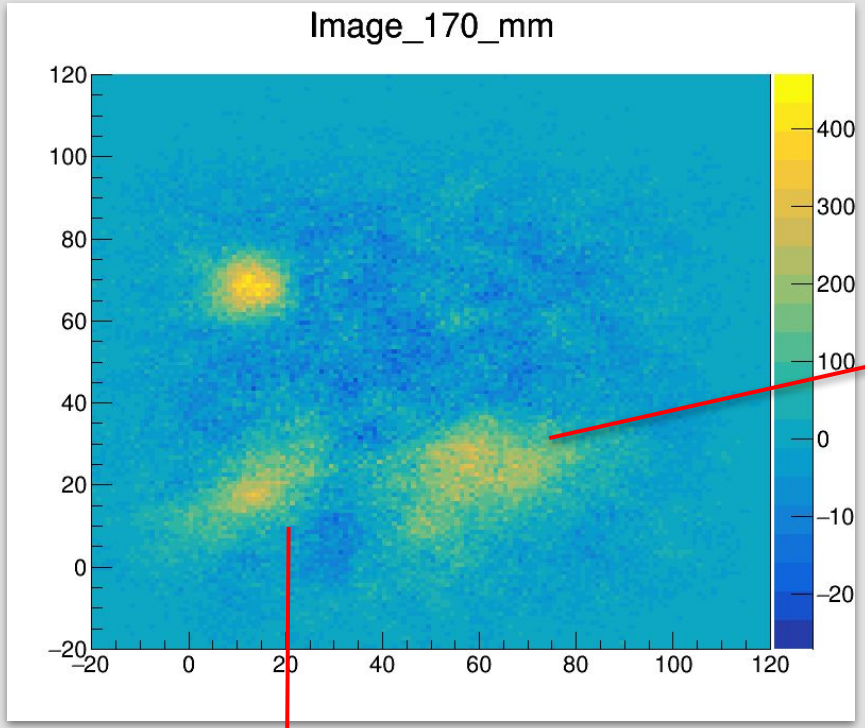

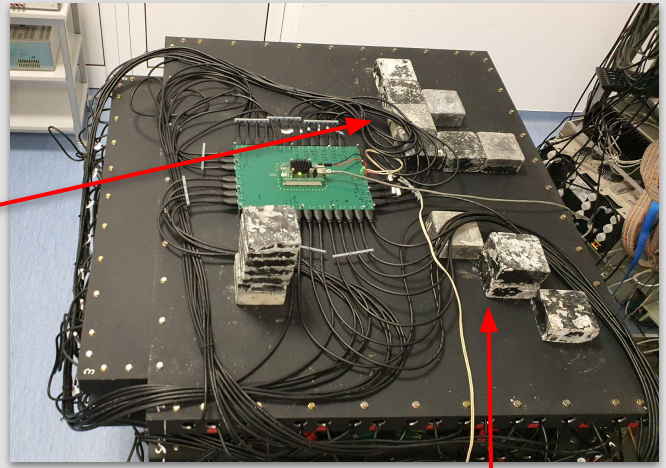

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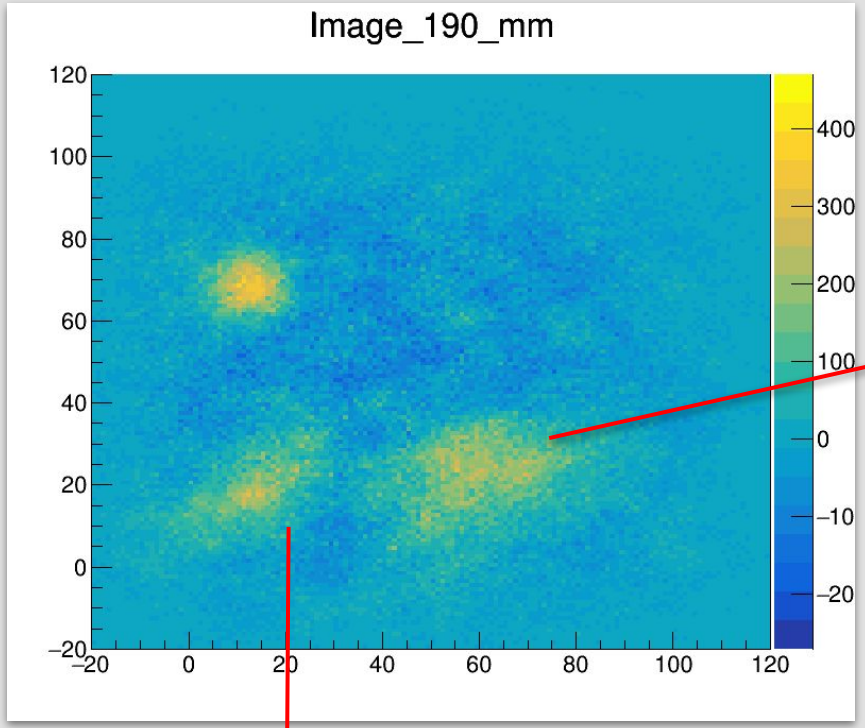

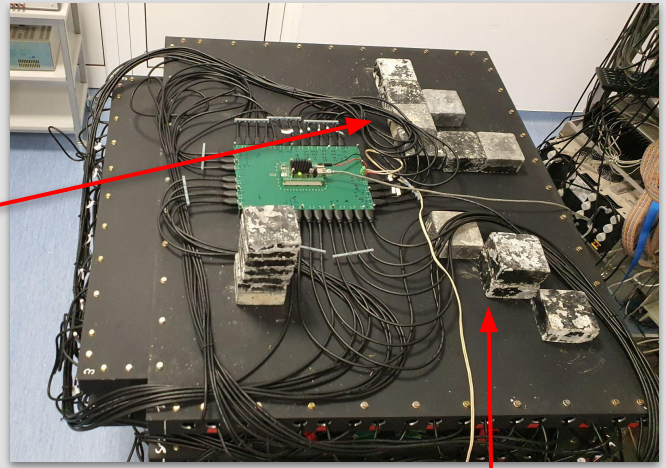

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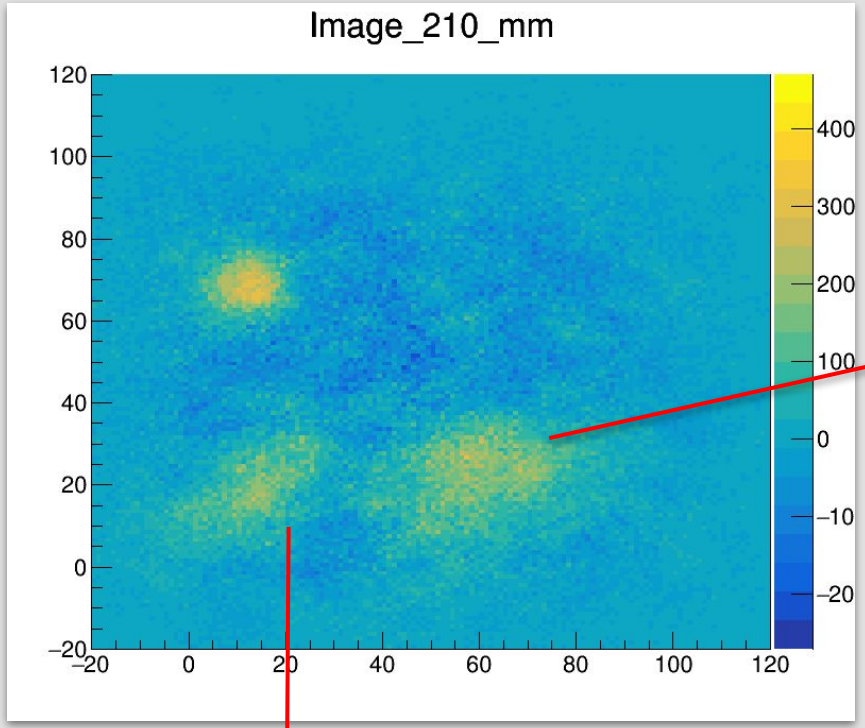

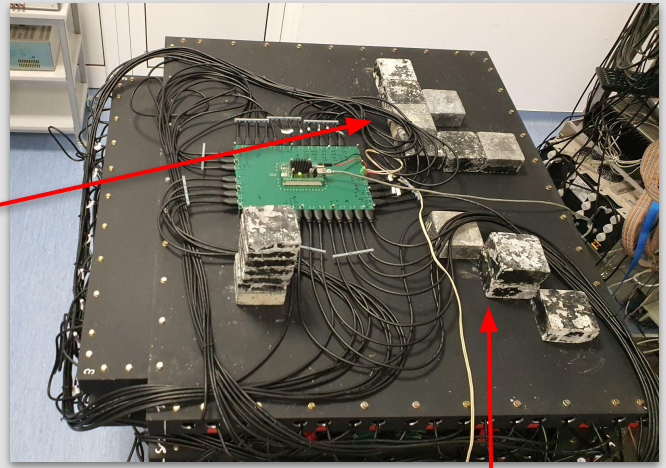

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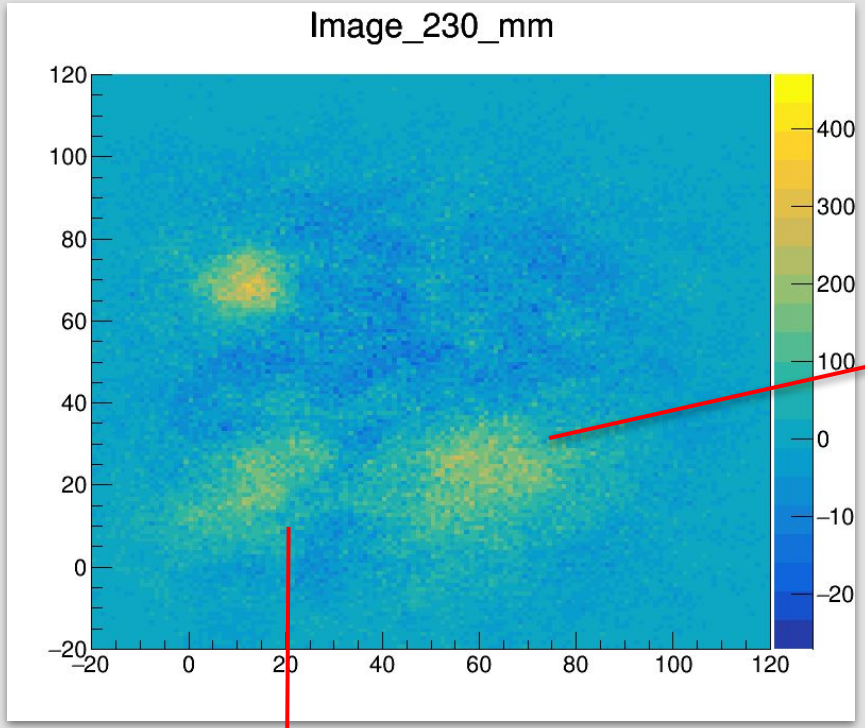

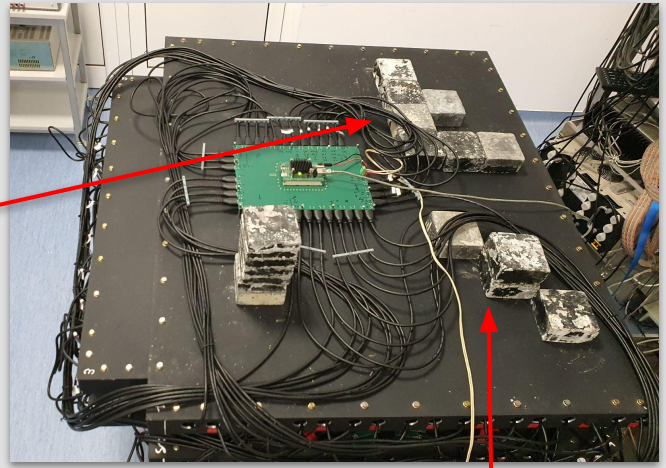

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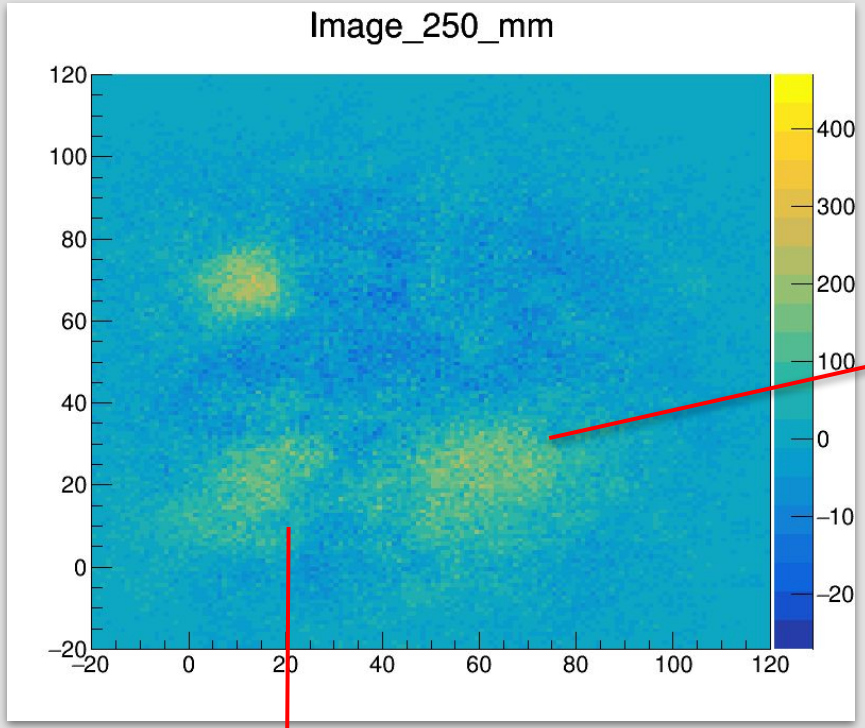

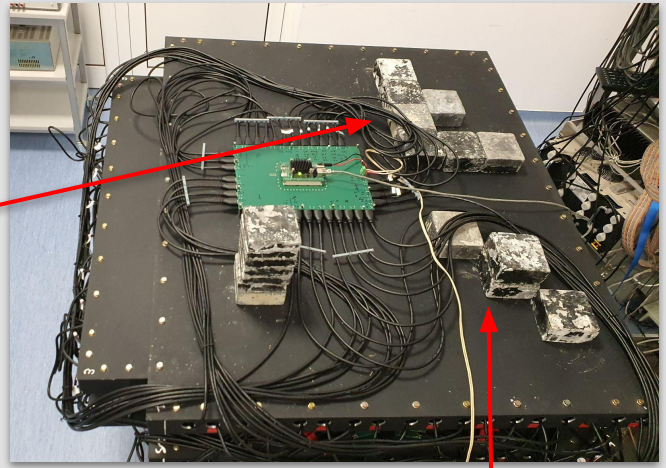

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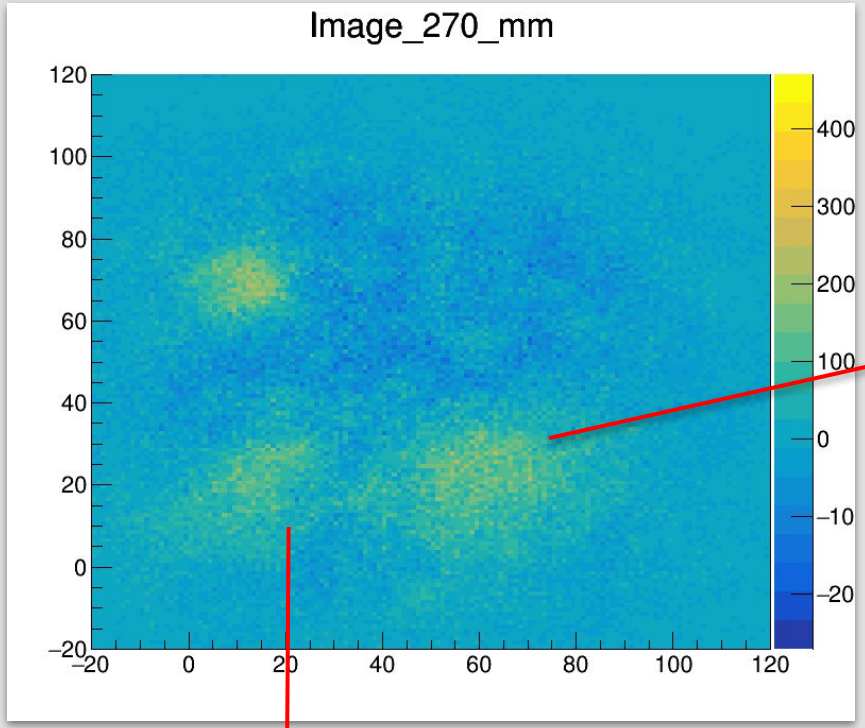

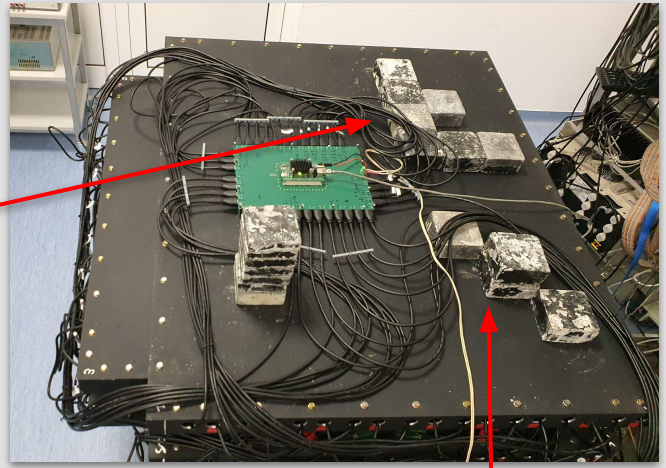

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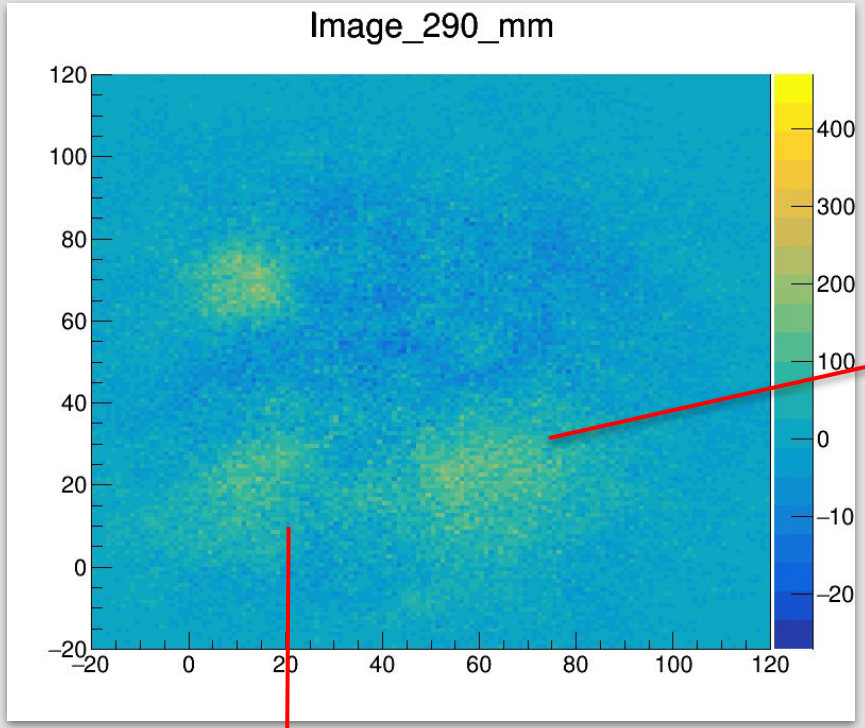

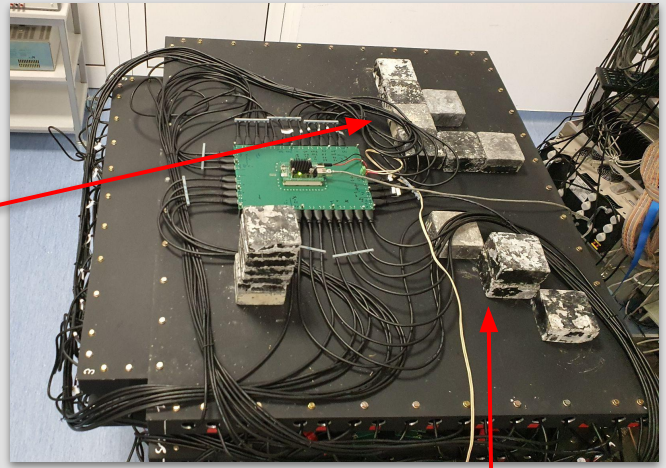

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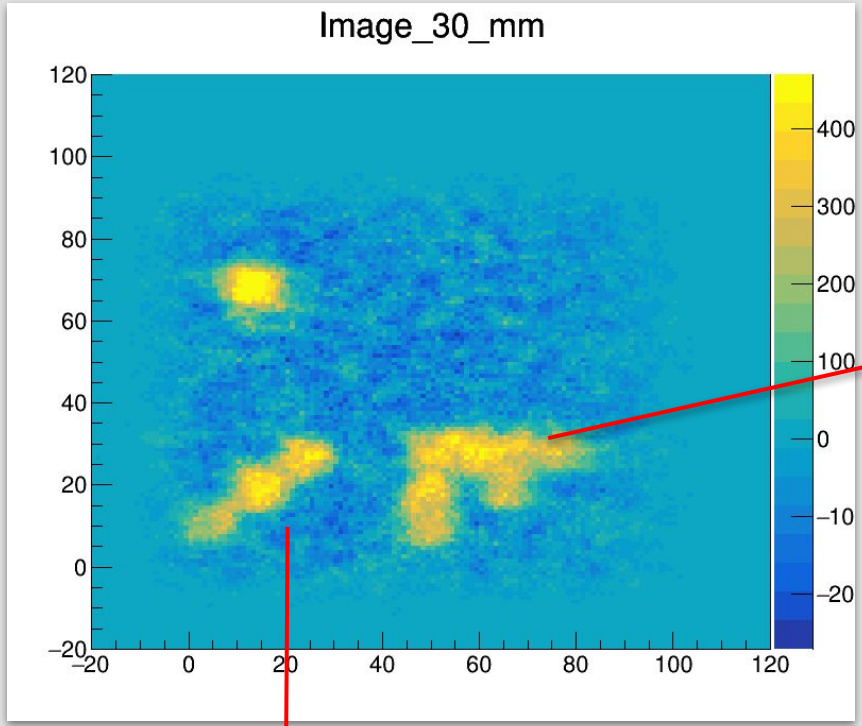

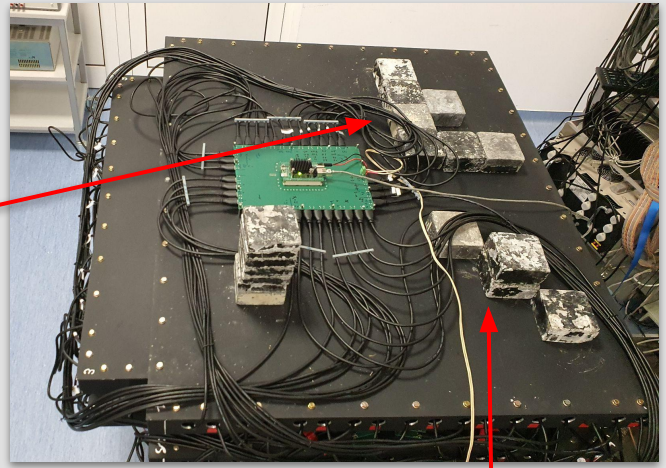

CONCLUSIONS

- detector has been tested in our lab
- trajectory reconstruction algorithm has minimal errors
- reconstruction method was applied on a basic set up and the results are in agreement with the predictions

OUTLOOK

- measurement campaigns for various applications
  - geophysical
  - archeological
  - mine safety
- develop and test other reconstruction methods
- automatic temperature stabilisation of SiPM response

Thank you for your attention!

Beware of the muons! They are constantly scanning you!