Joint Institute for Nuclear Research

The Liquid Scintillator Track Detector

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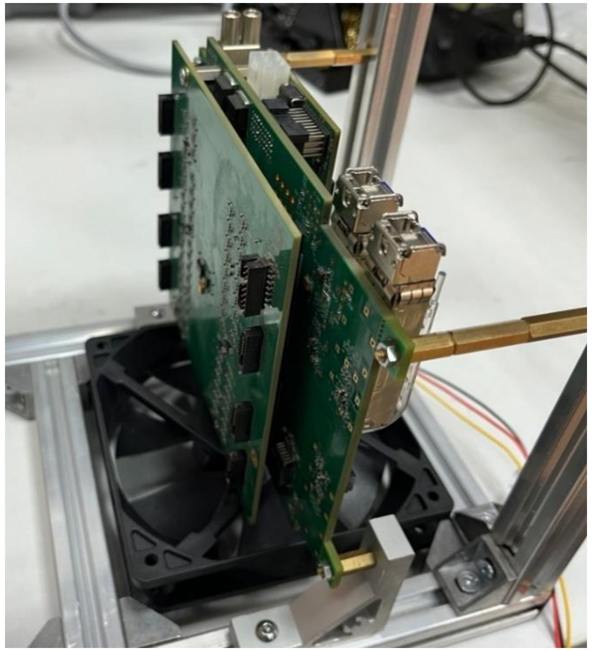
Introduction

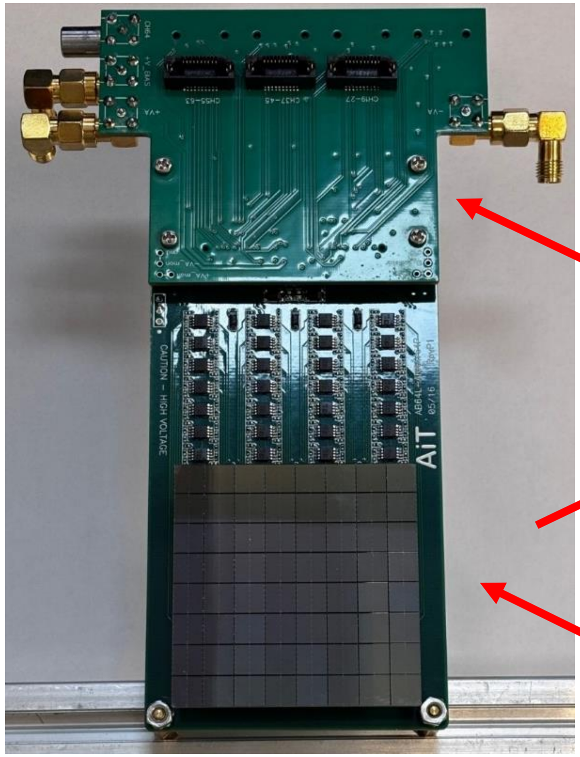
The idea of developing a track scintillator detector was proposed by **Igor Golutvin**. The main idea was to create a modern 4π detector based on liquid xenon (LXe), similar in principle to bubble chamber. At the initial stage, it is planned to develop a single-phase LXe detector with active volume of ∼1 liter. It was assumed that the particle track would be detected by «photographing» scintillation light using silicon photomultiplier (SiPM) arrays.

This report includes the process of developing a track scintillator detector using plastic and liquid scintillators. During the work a two-arm track scintillator detector based on SiPM matrices has been developed and tested. A 0.5 liter volume liquid scintillator prototype detector also has been developed and tested using the same technique.

A two-arm 128-channel track detector

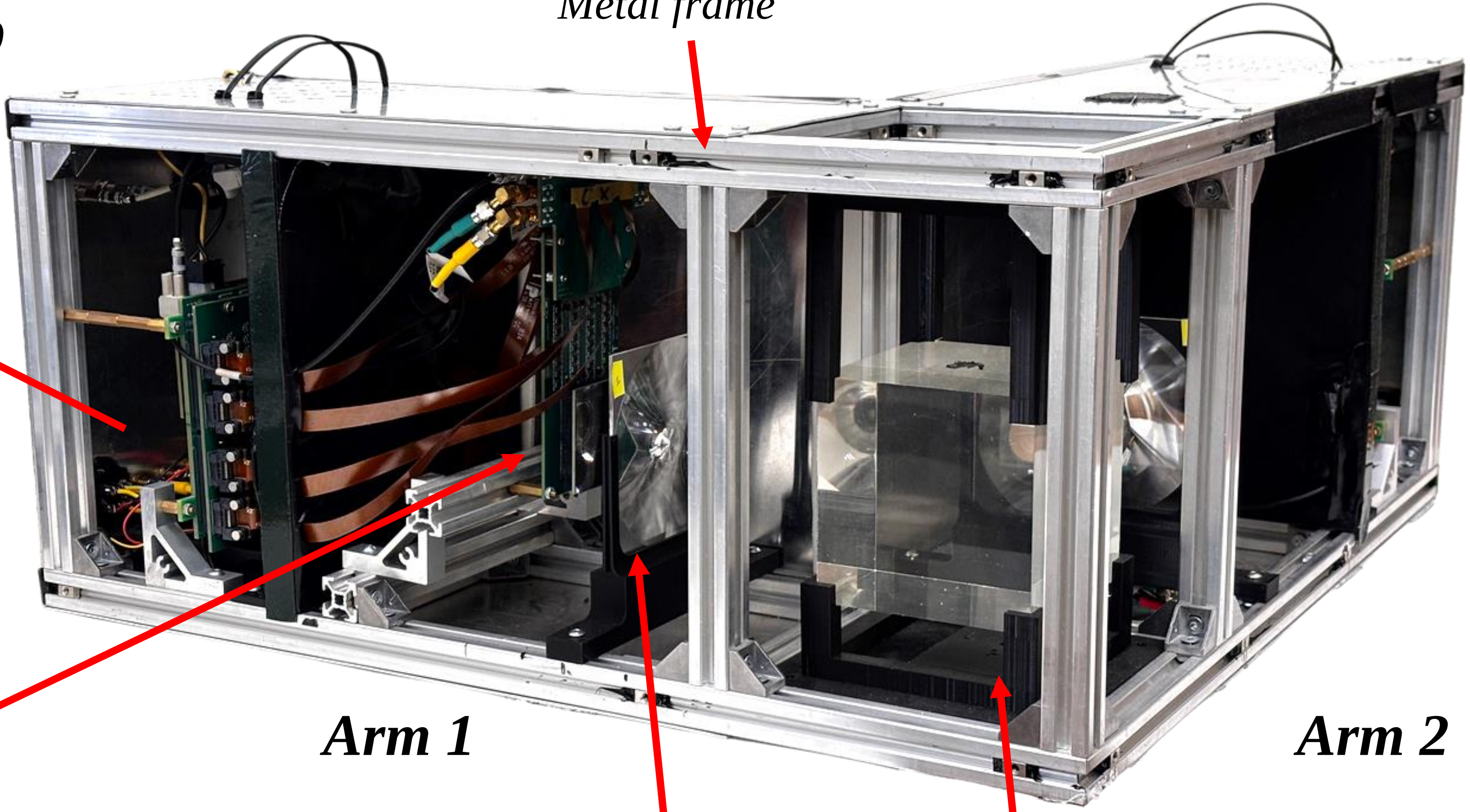


64-channel ADC
ADC64s2 (JINR)



Adapter board for integration with ADC64s2

64-channel SiPM matrix Onsemi Sensl ArrayJ-60035-64P-PCB install on base board



Metal frame

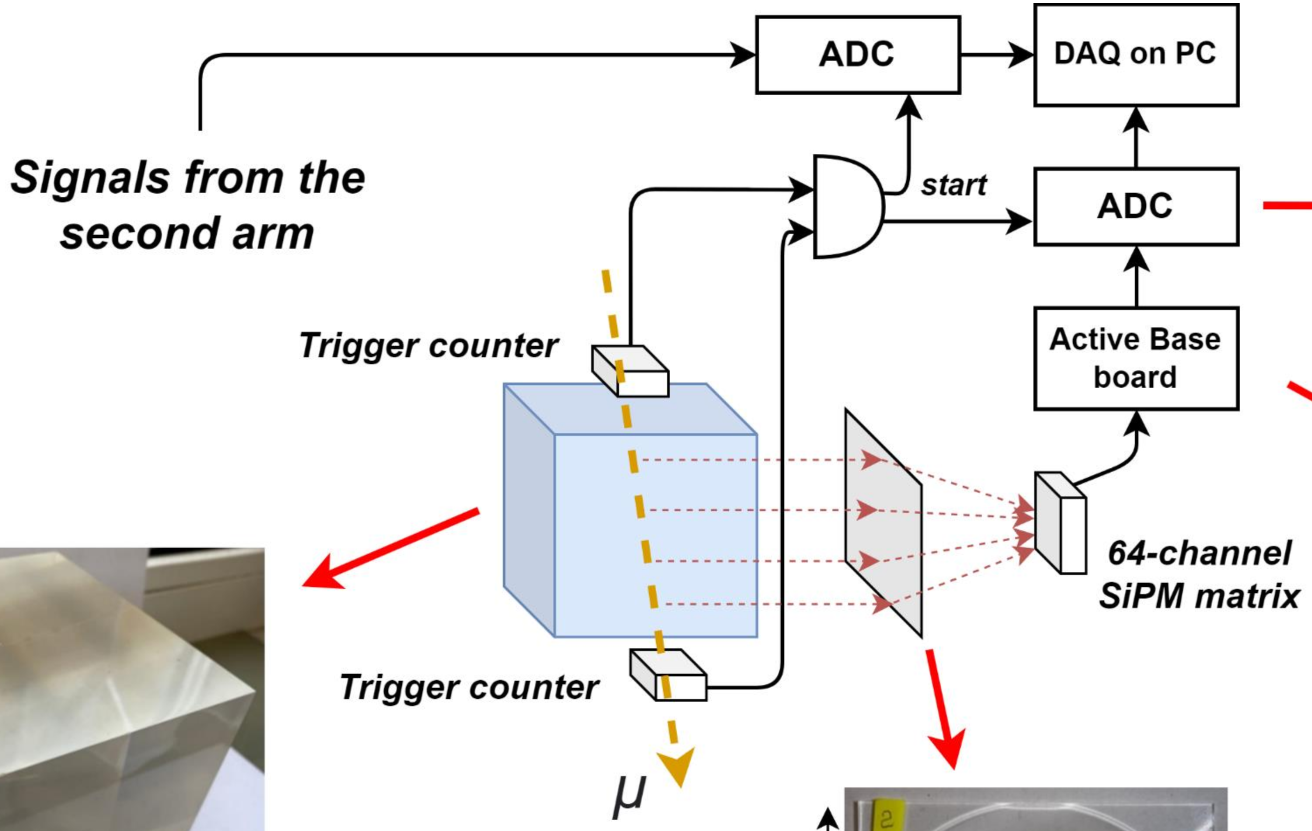
Arm 1

Arm 2

Fresnel lens

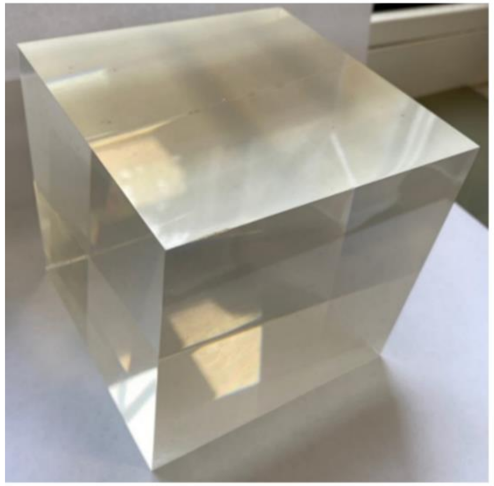
Plastic scintillator

The block diagram of 128-channel track detector

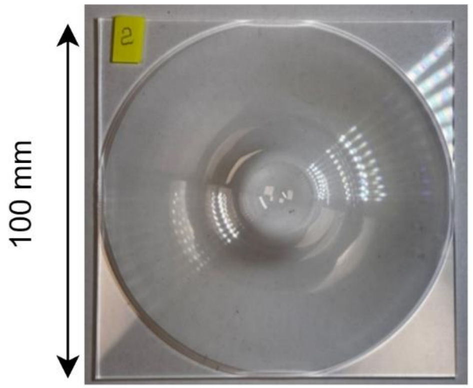


64-channel ADC

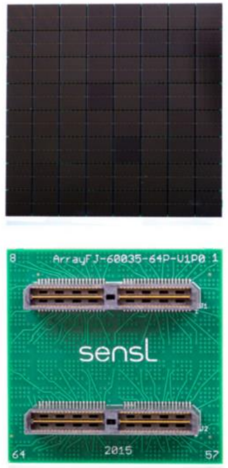
https://afi.jinr.ru/ADC64s2



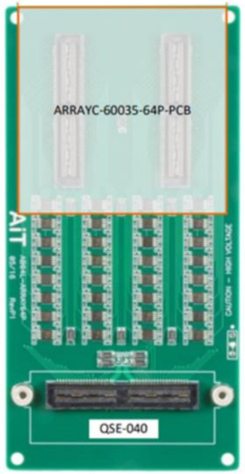
Cubic scintillator
$100 \times 100 \times 100$ mm^3
(material: polystyrene)



Short-focus Fresnel lens (F = 20 mm)

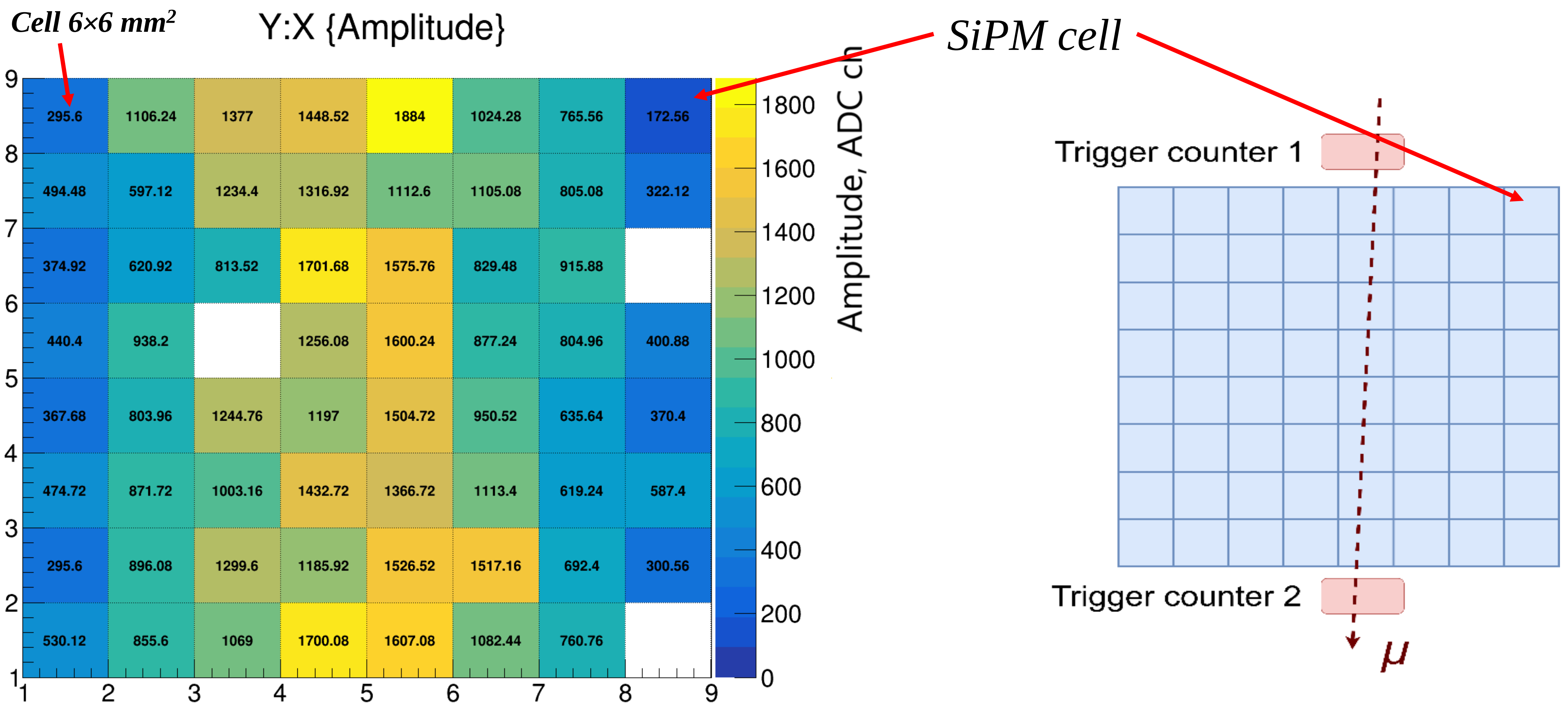


ArrayJ-60035-64P-PCB



AB64L-ARRAY64P

Signal in direct contact between the SiPM matrix and the scintillator (without lens)

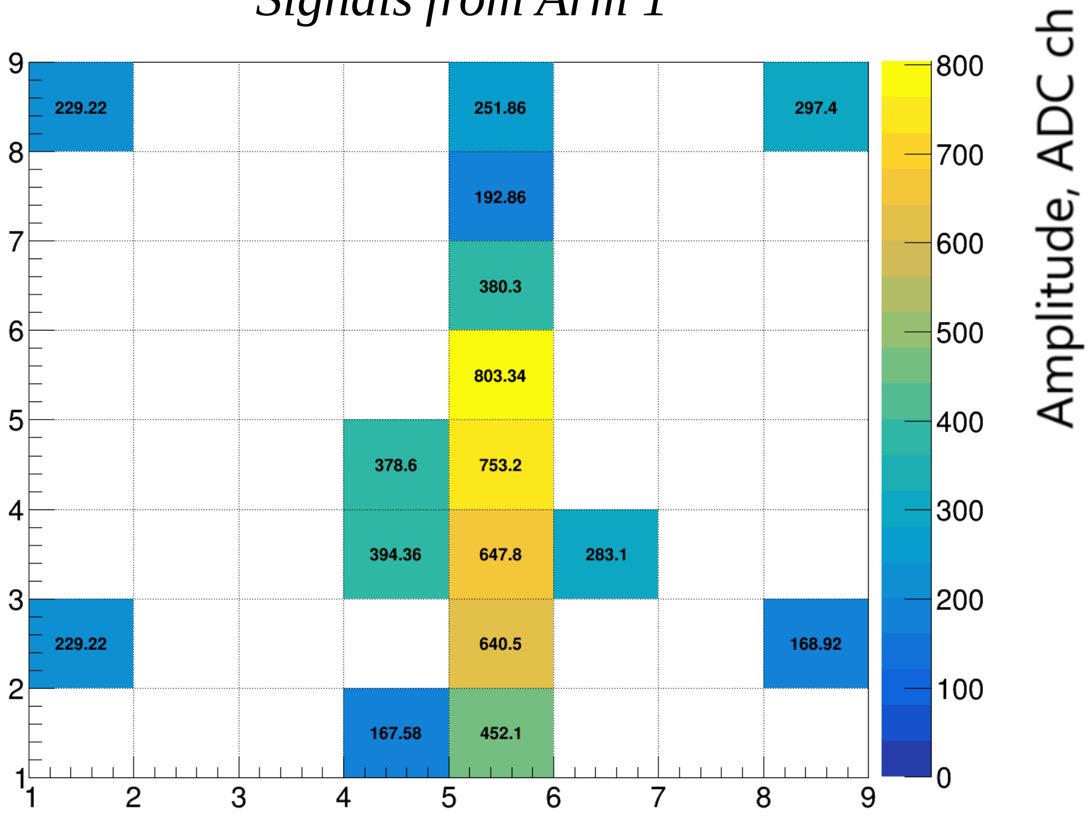


Signal from the vertical passage of a cosmic muon in direct contact of SiPM matrix with scintillator is not clearly. It is necessary to use lenses.

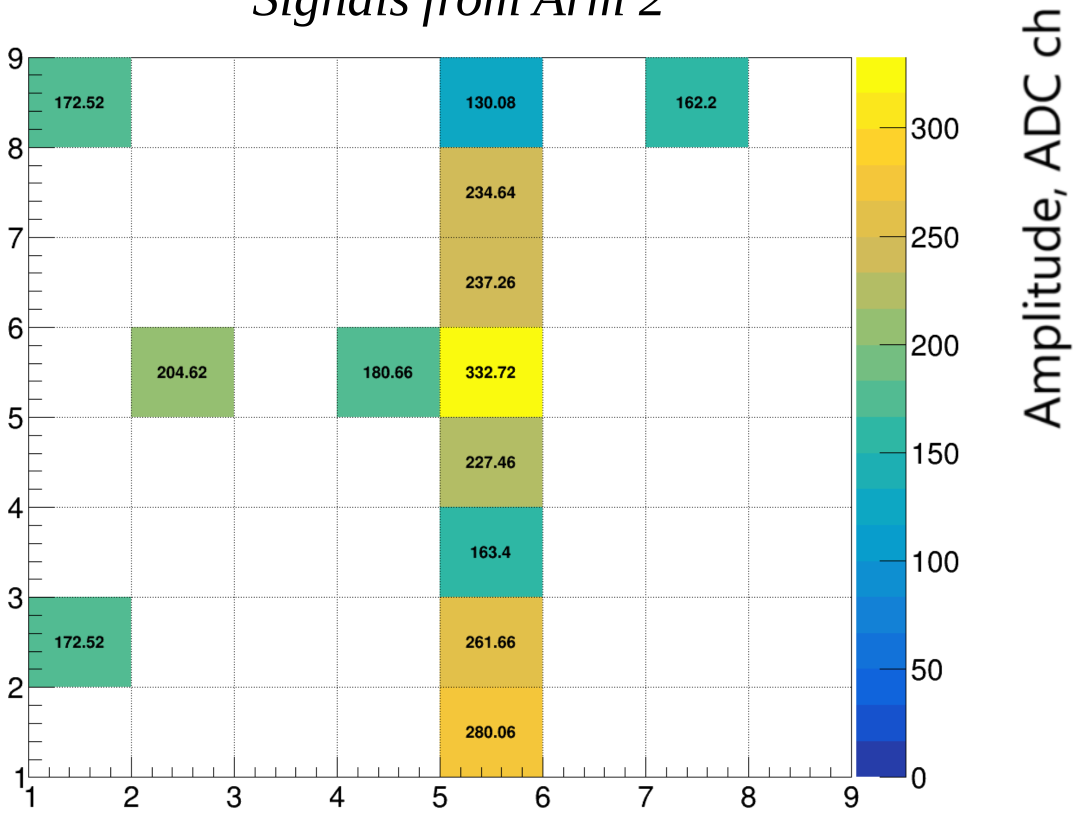
Two 10×10×8 mm³ scintillation counters selected area under study

Muon tracks obtained by short-focus Fresnel lens

Signals from Arm 1



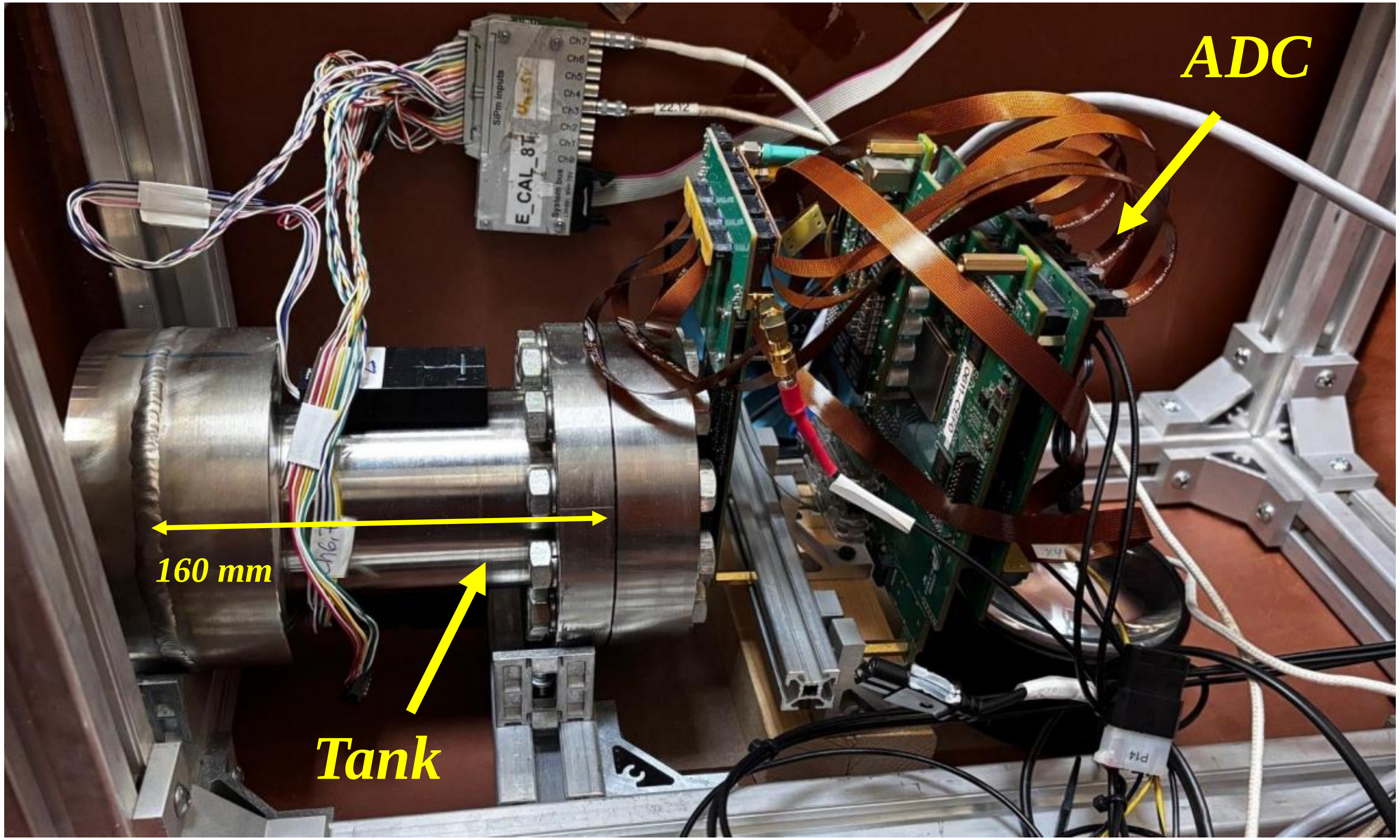
Signals from Arm 2

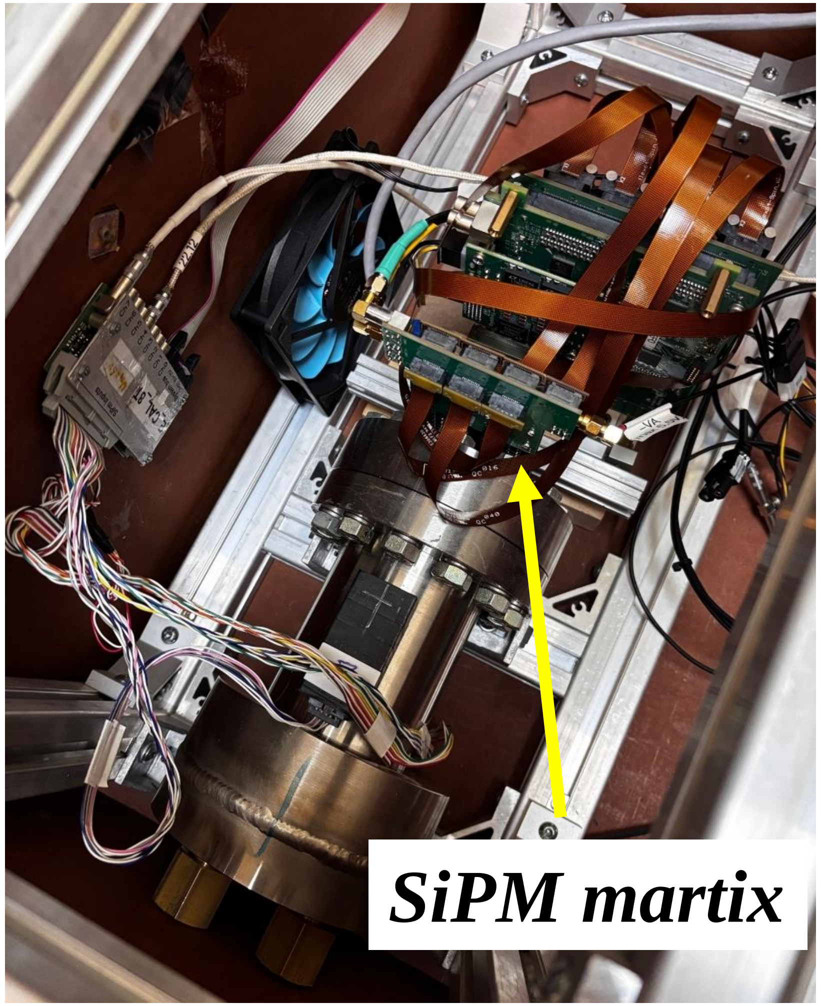


2D reconstruction of muon track by signal from trigger

The spatial resolution in the case using SiPM matrices with 6×6 mm^2 cell sensitive area and Fresnel lenses with focus length of F = 20 mm is $\boldsymbol{\sigma_x}$ **= 2.1 mm**. In this case, we have well-recognized tracks.

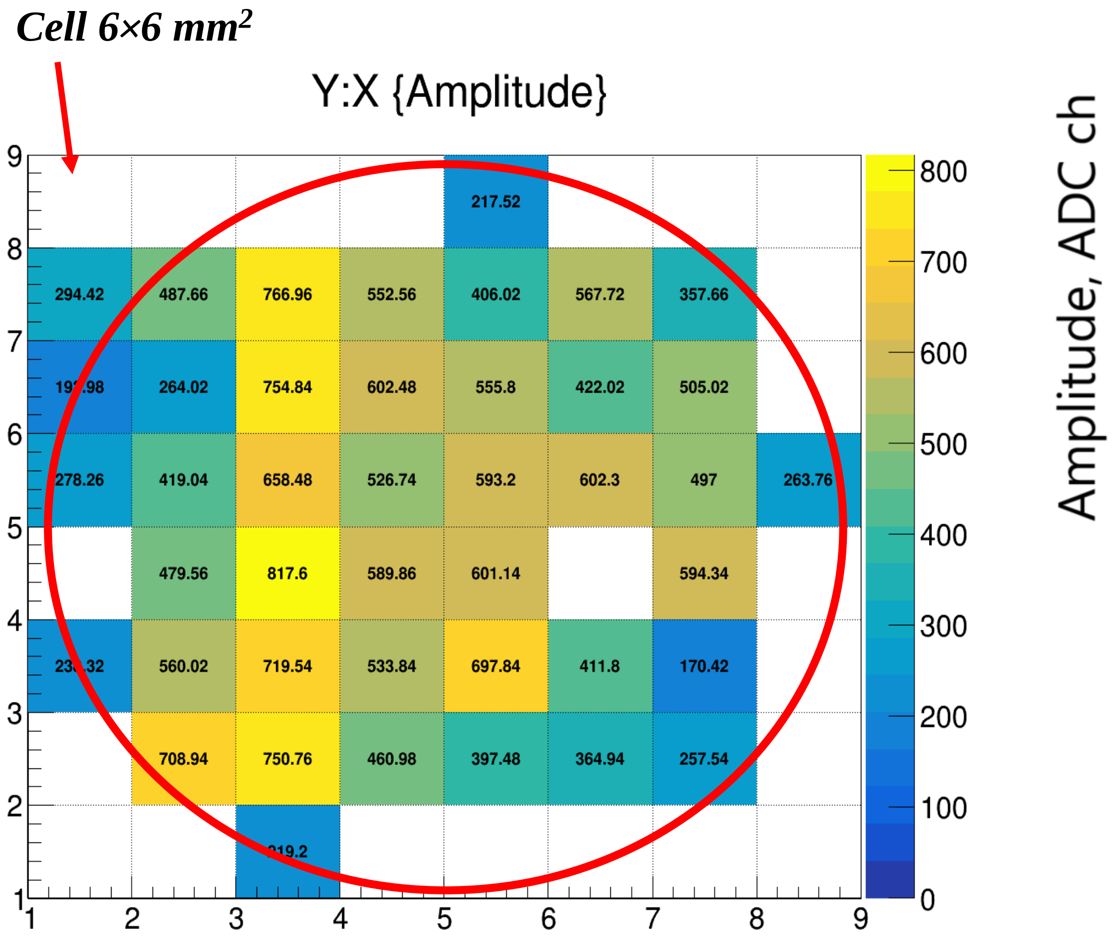
A liquid scintillator track prototype detector

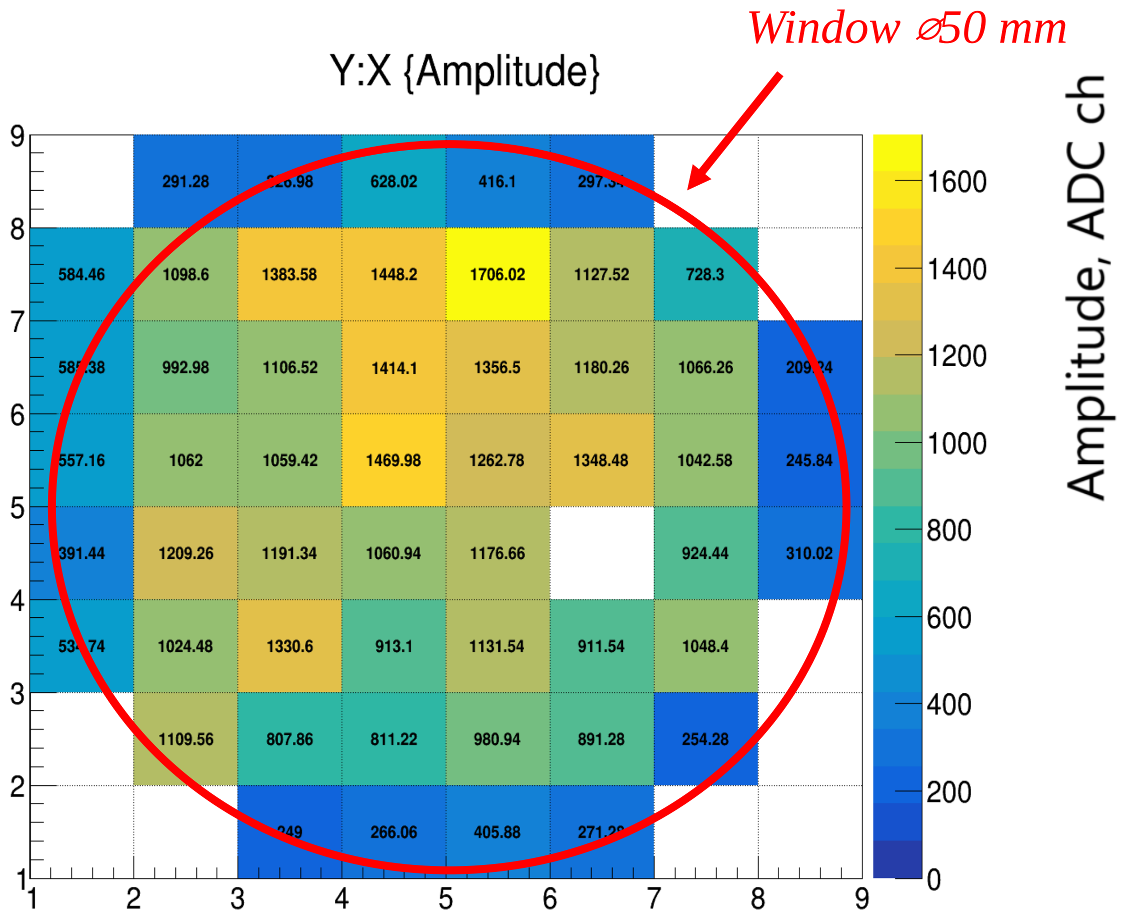




Liquid scintillator prototype detector : 0.5 liter volume cylindrical tank with window (scintillator is LAB (Linear Alkyl Benzene) + 0.5% PPO + 0.025% POPOP, LY ~8500 photons/MeV). The tank is made of 1 cm steel and is designed for high pressures.

Signal in direct contact with liquid scintillator detector prototype

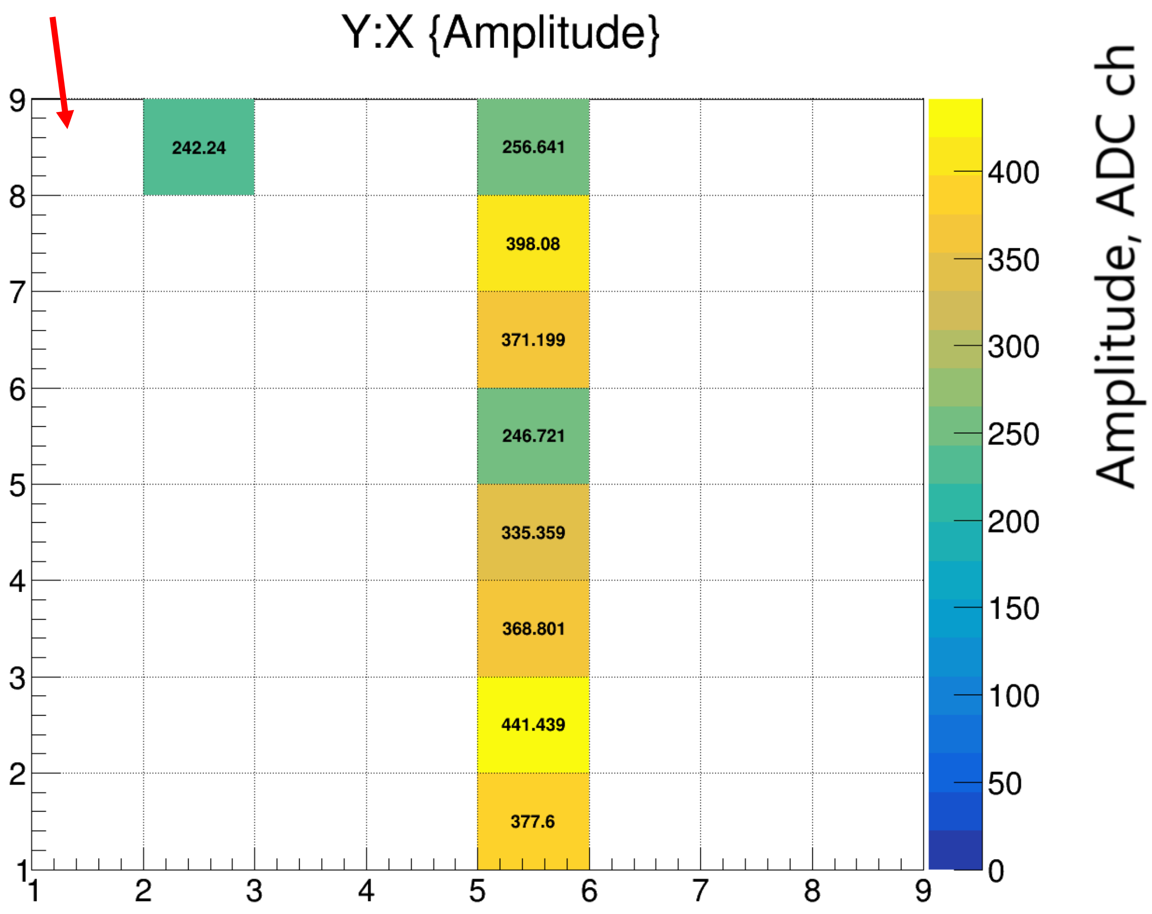


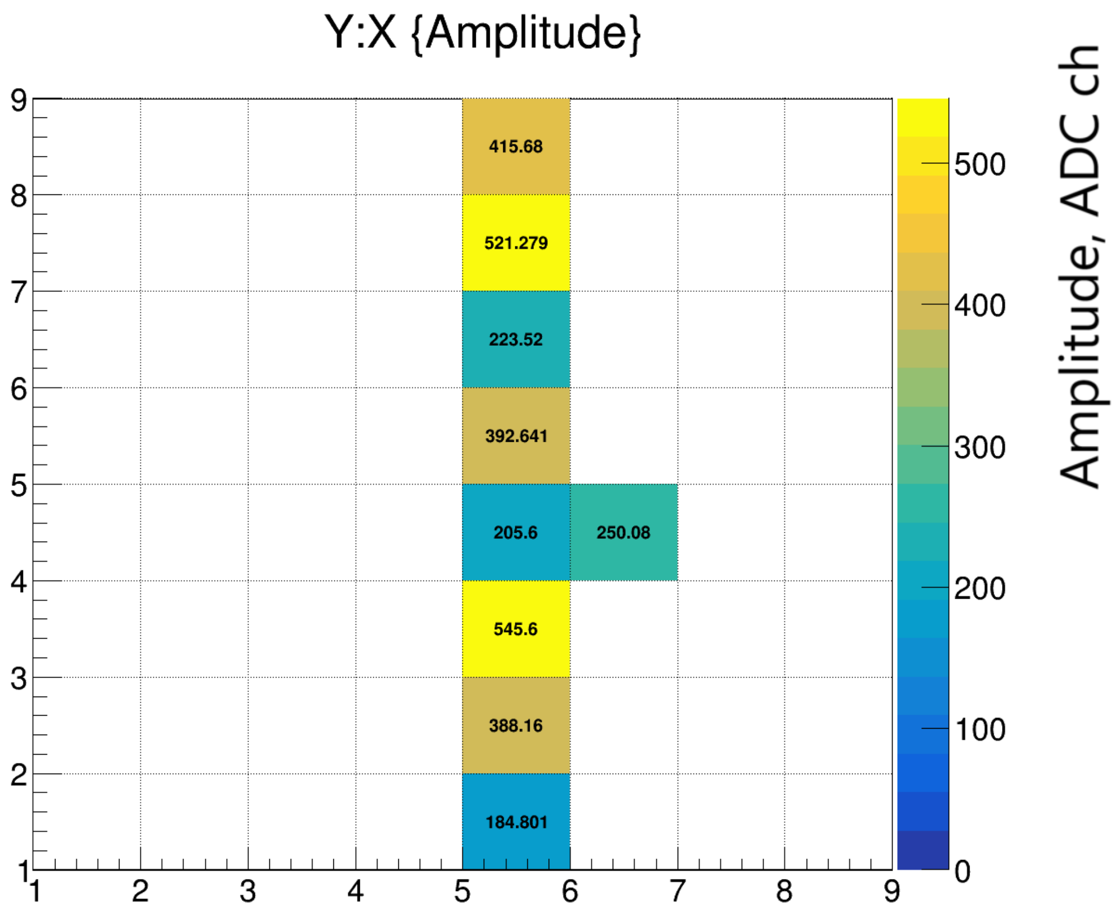


Signals from liquid scintillator in direct contact of SiPM matrix with window of the tank (without lens)

Muon tracks using short-focus Fresnel lens

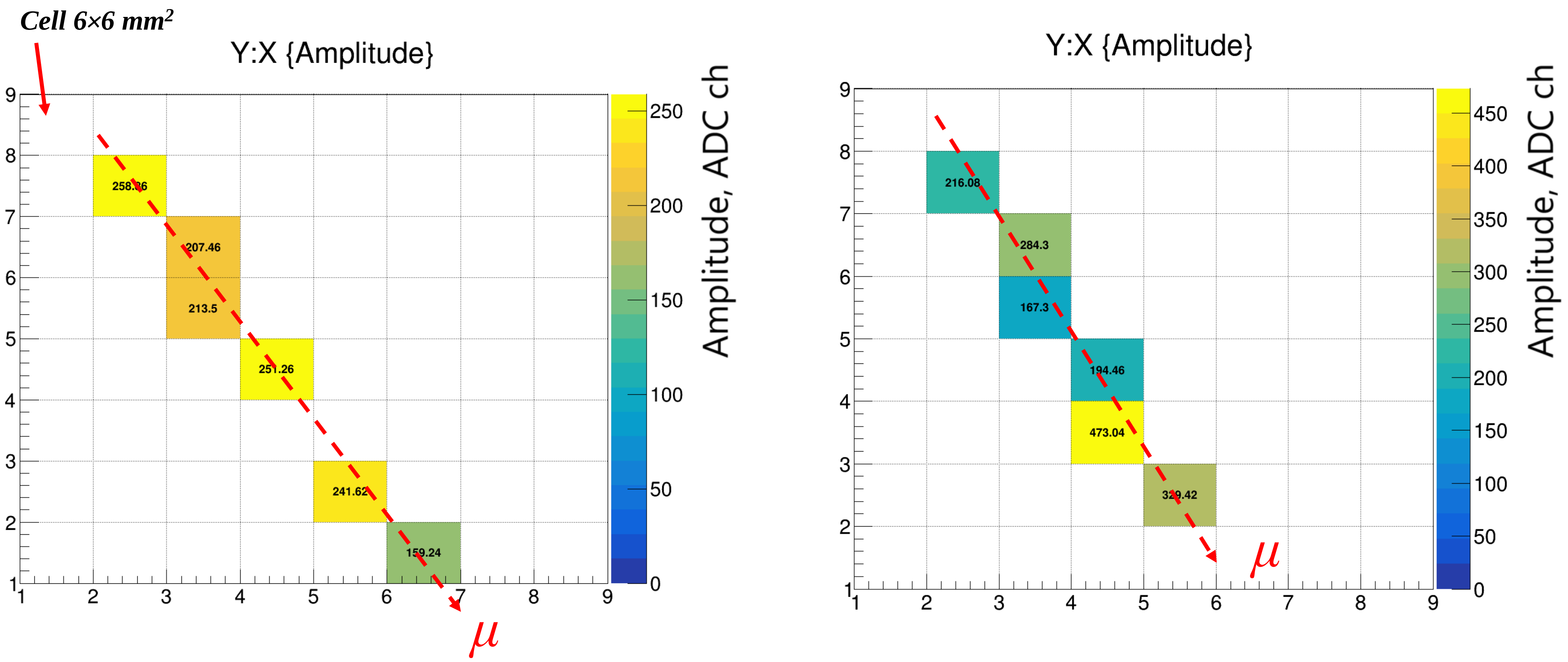
Cell 6×6 mm²





Muon tracks in a liquid scintillator with vertical trigger counters position

Muon tracks using short-focus Fresnel lens



Tracks in a liquid scintillator with trigger counters positioned at an angle of ~40° relative to the vertical

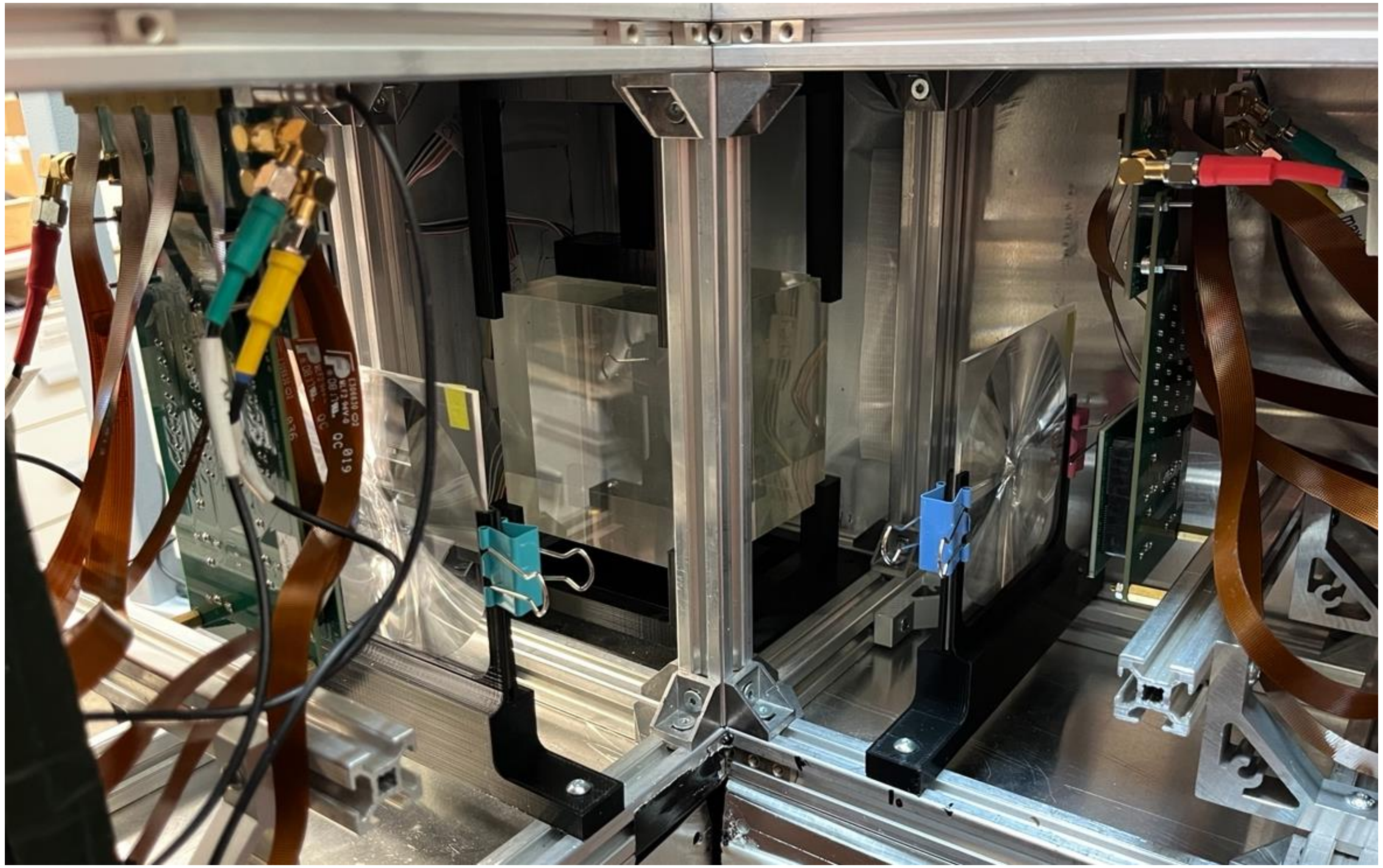
Conclusion

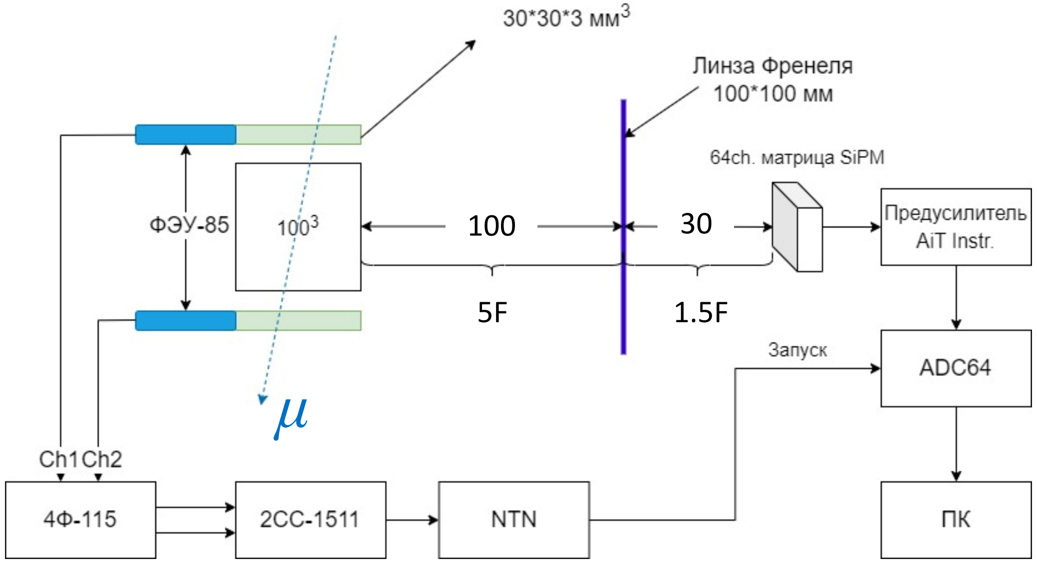
- A two-arm 128-channel track detector based on *SiPM* matrices has been developed. A plastic scintillator is used as the active media of the detector.
- The detector was tested on the cosmic rays. A spatial resolution of 2.1 mm was obtained.
- A 64-channel prototype detector based on a 0.5 liter volume liquid scintillator (LAB) has also been developed.
- In both cases, well-recognized muon tracks have been obtained.
- In the future, it is planned to carry out measurements with liquid xenon (LXe).

Thank you for your attention!

Backup slides

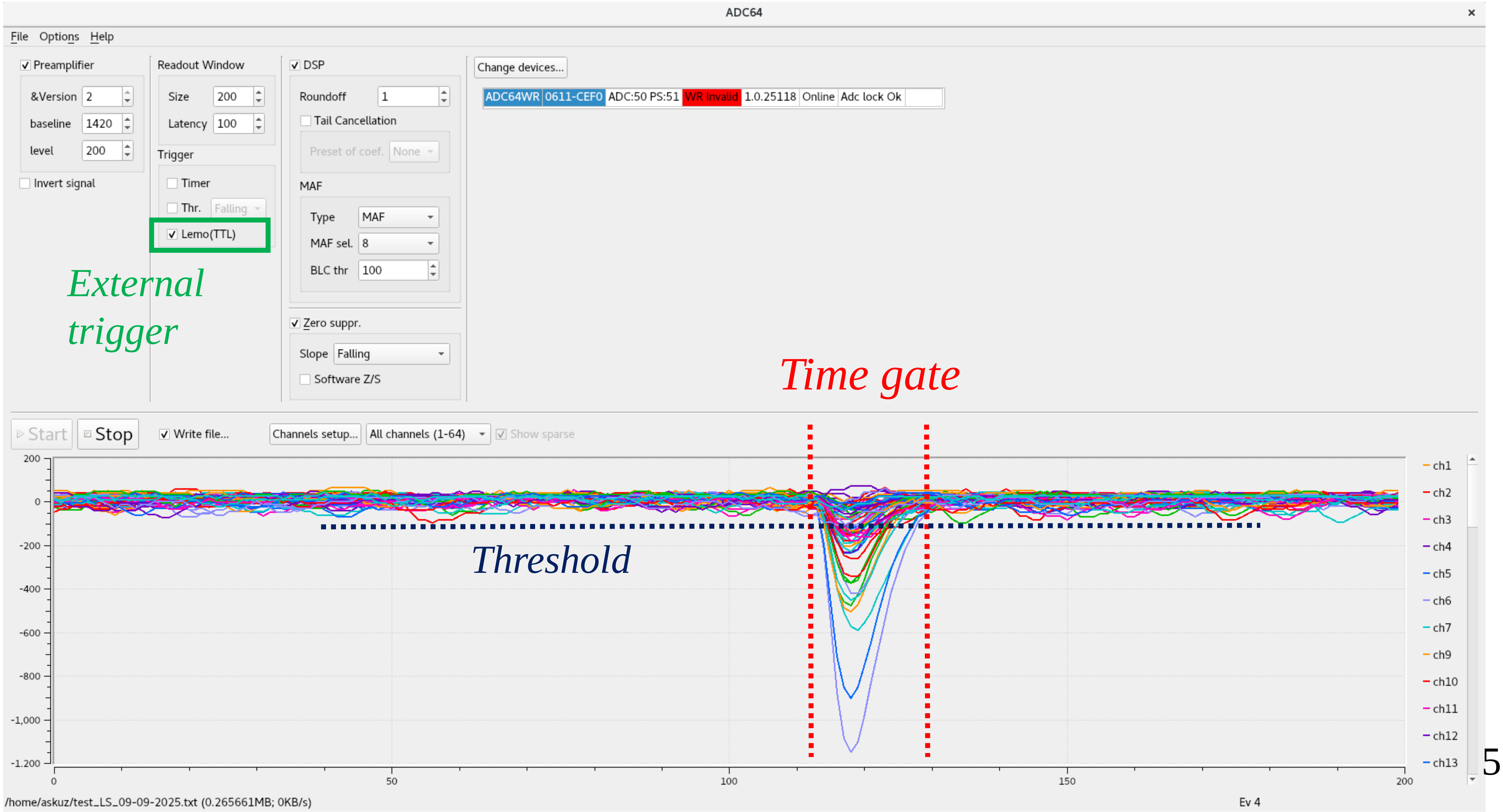
The block diagram of 128-channel detector measurements



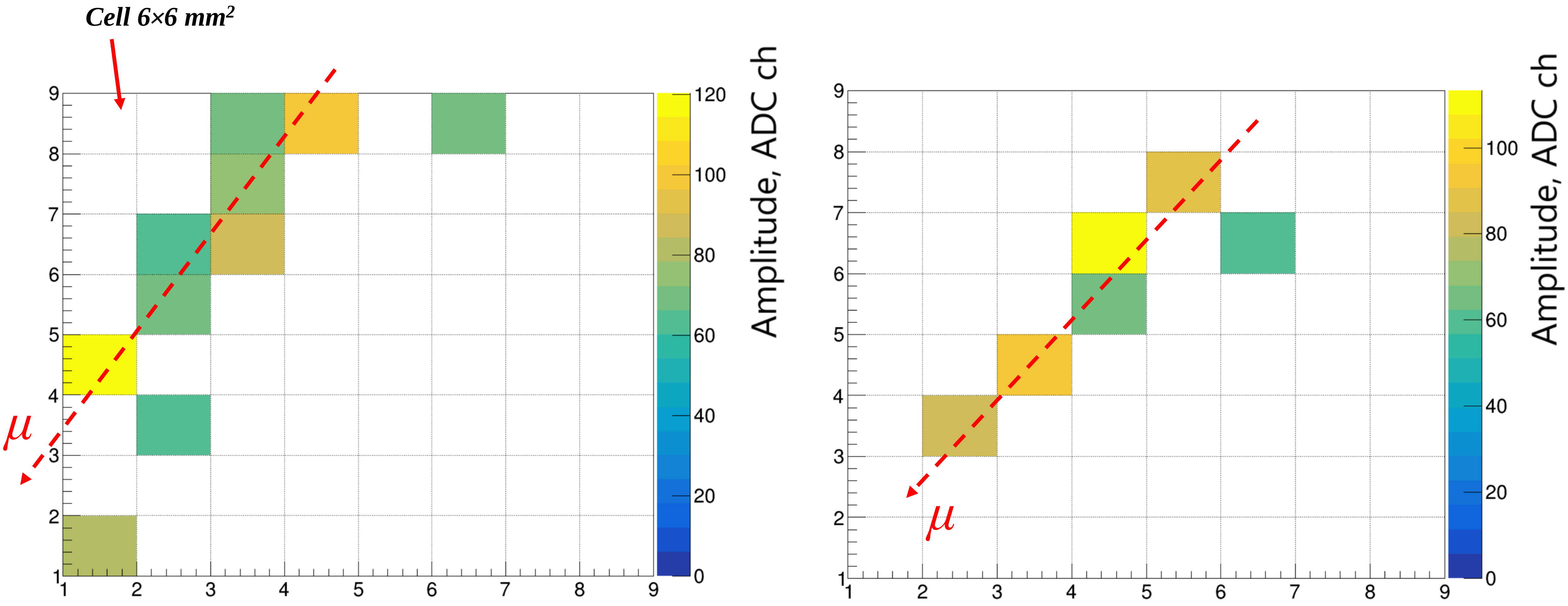


** Focus length (F) of Fresnel lens is 20 mm*

Detected signals in DAQ and analysis conditions

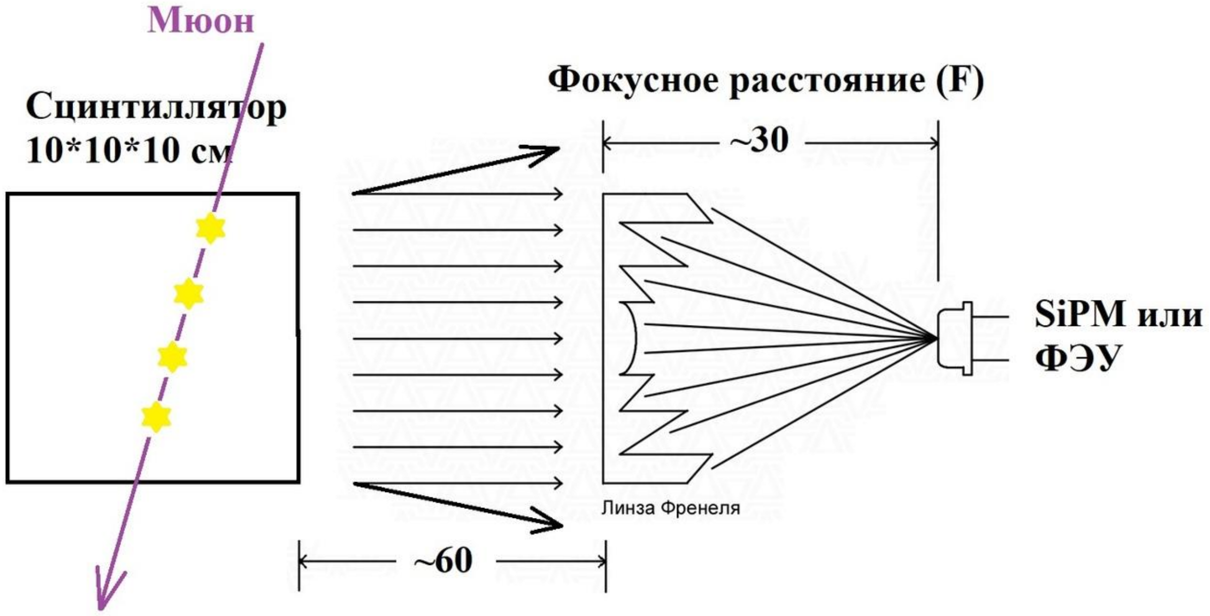


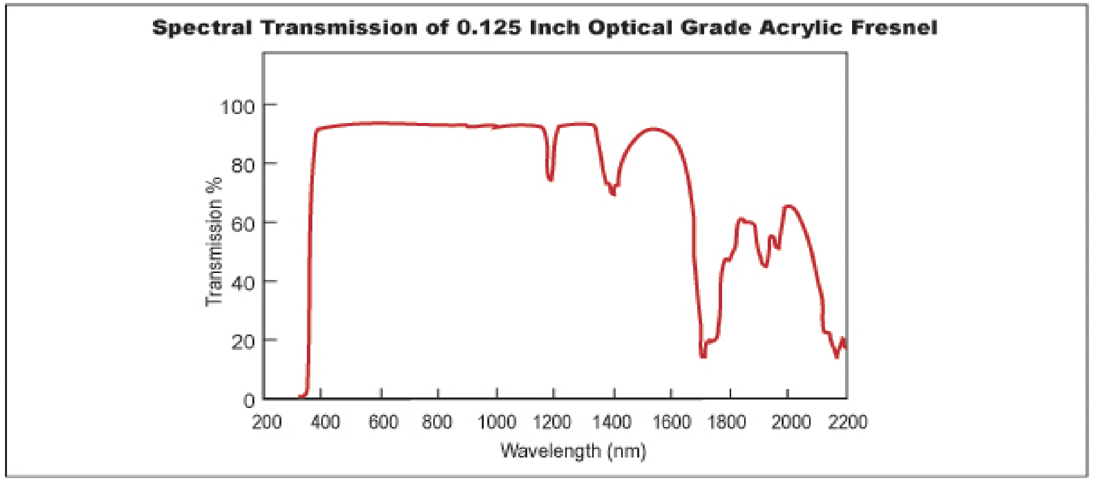
Muon tracks using glass lens with focus 130 mm

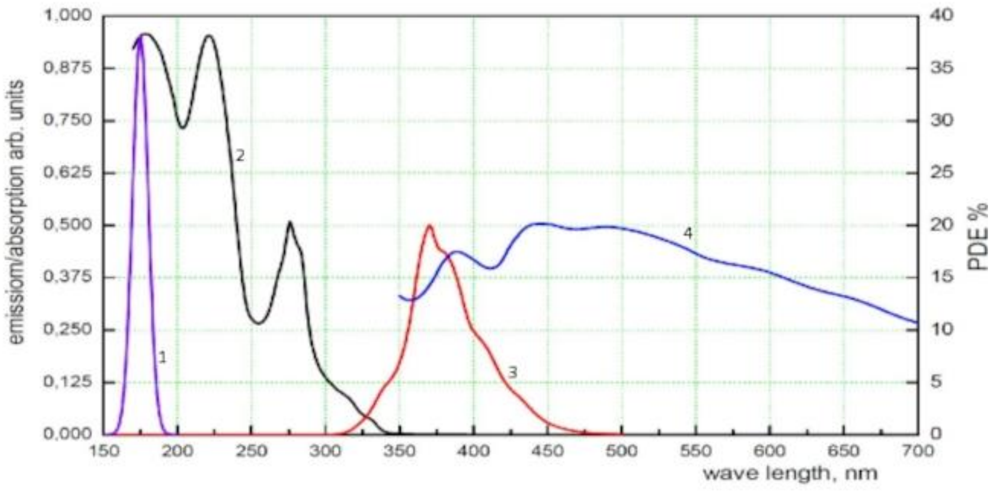


The amplitude of the signals is much smaller than in the case of using short-focus Fresnel lenses.

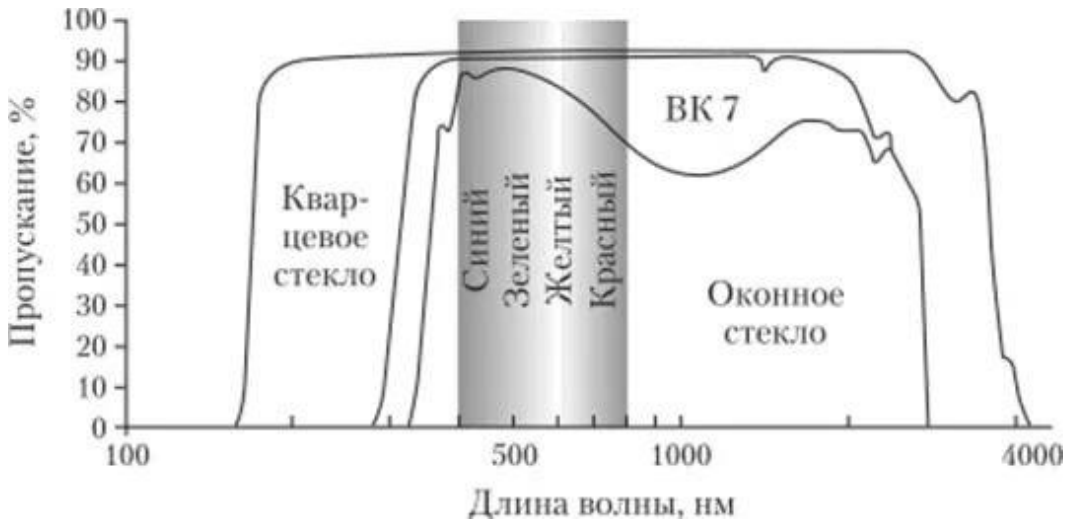
The operation principle of Fresnel lens



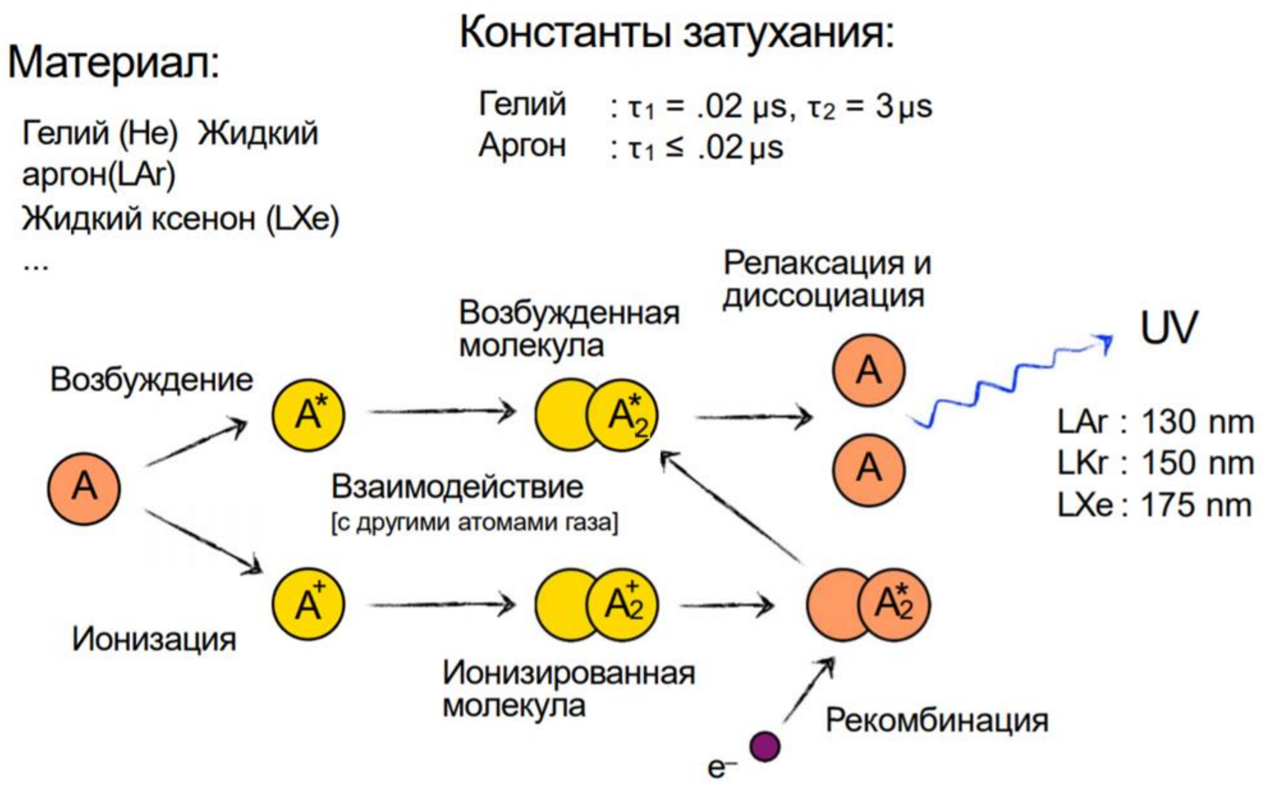




Emission spectrum of liquid xenon (1), absorption (2) and emission (3) spectra of p- terphenyl, PDE of CPTA (4)



Scintillations in liquid noble gases



Scintillator	Form	Density, g/cm^3	Refractive index	Emission wavelength, nm	Decay time, ns	Photons / MeV
Liquid xenon LXe	Liquid	3.1	~ 1.69	170	3, 20	4×10^4
LS baes on LAB	Liquid	~ 1	~ 1.5	~ 430	2÷5	~ 8.5×10^3
Polystyrene (JINR)	Solid	~ 1	~ 1.58	425	2÷4	1×10^4

The operation principle of two-phase LXe detectors

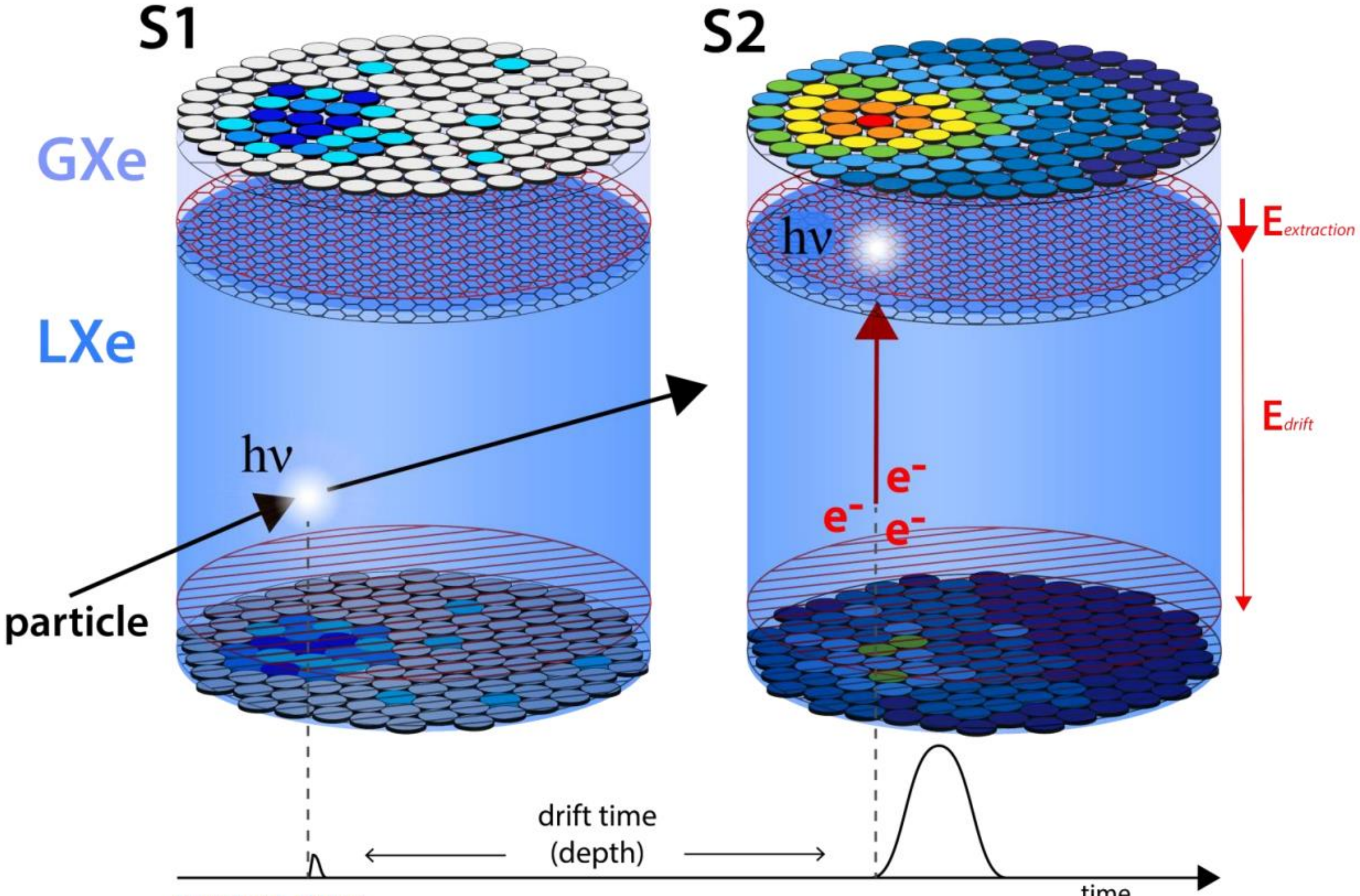
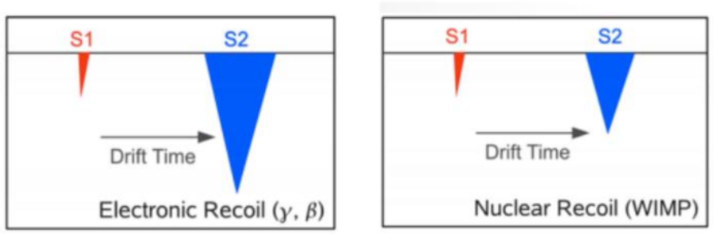


Figure from L. Althüser

Basic parameters:

- Dual-phase xenon TPC: liquid (Lxe) + gas (GXe)
- Energy reconstruction
- 3D event reconstruction
- Event discrimination (electronic recoil vs nuclear recoil)



- Present volume is about 12 tons of xenon (total)
- Number of channels is about 250÷500
- Spatial resolution is about several cm