



**PSI**



# Muon Trigger Detector for the PSI muEDM experiment

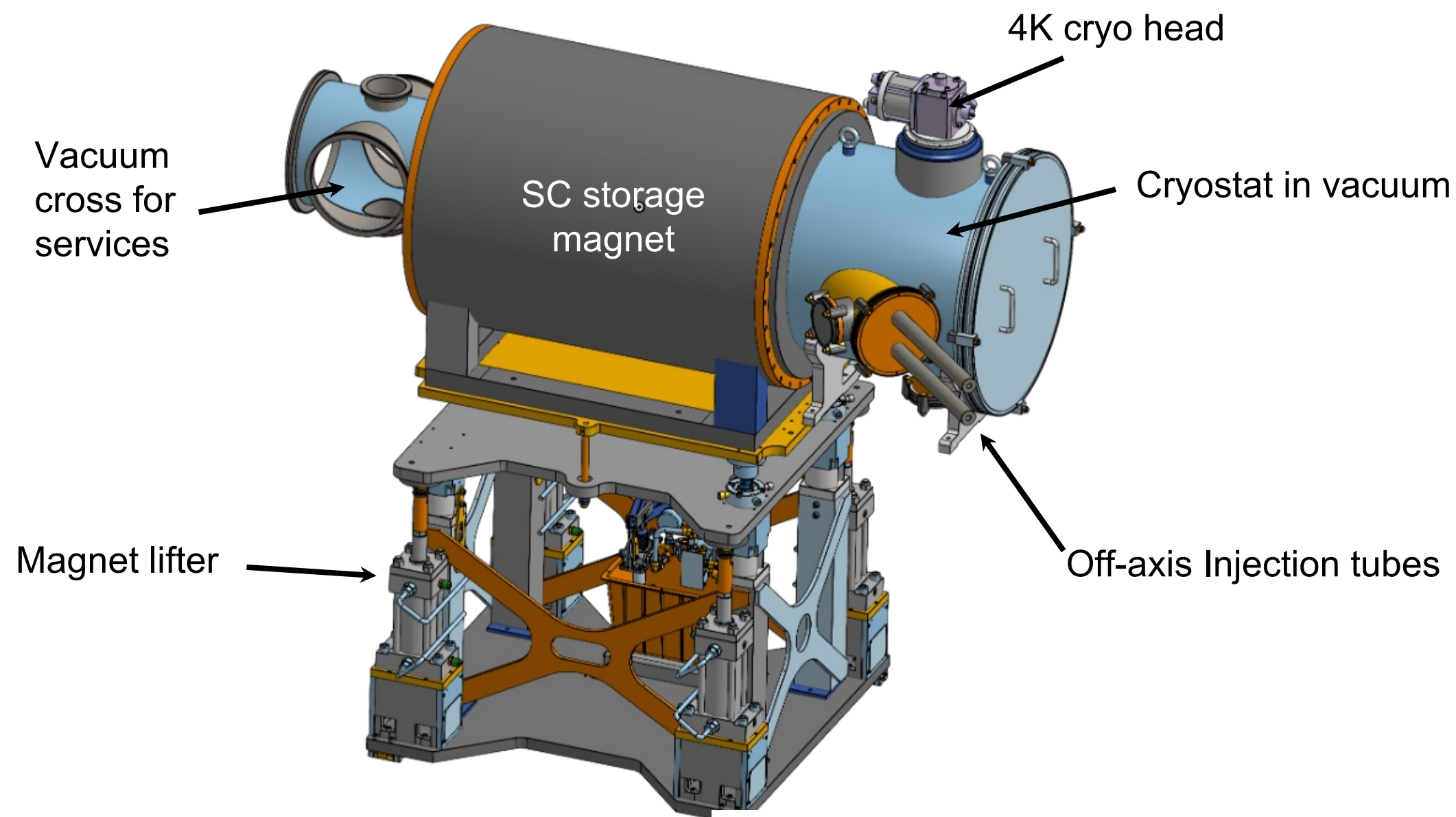
**Kim Siang Khaw**  
**muEDM BVR review @ PSI**  
**10 Feb 2025**

**Muon Trigger Detector Development Team:**  
Tianqi Hu, Xingyun Huang, Kim Siang Khaw,  
and Guan Ming Wong (with strong support  
from the PSI group)



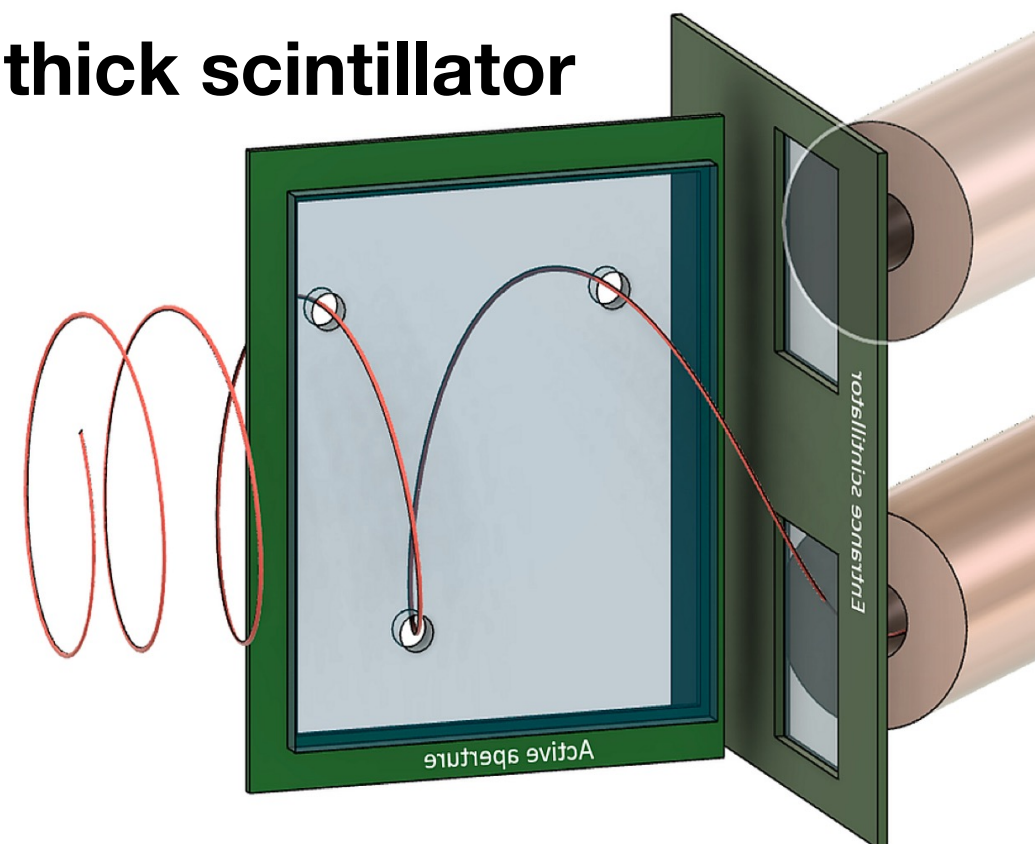
李政道研究所  
TSUNG-DAO LEE INSTITUTE

# Overview of the muon trigger detector



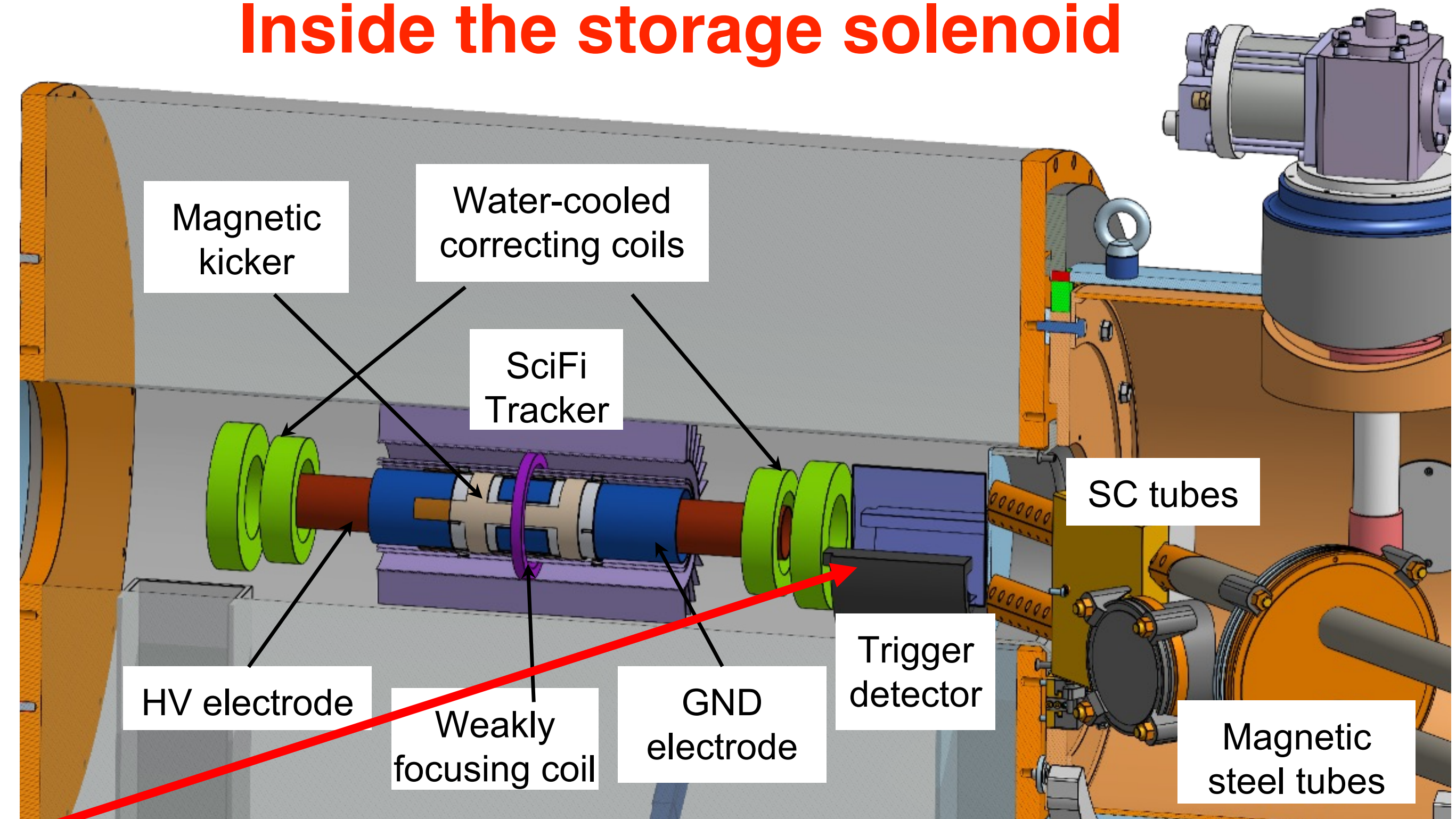
5 mm thick scintillator

Conceptual design



100  $\mu\text{m}$  thin scintillators

## Inside the storage solenoid

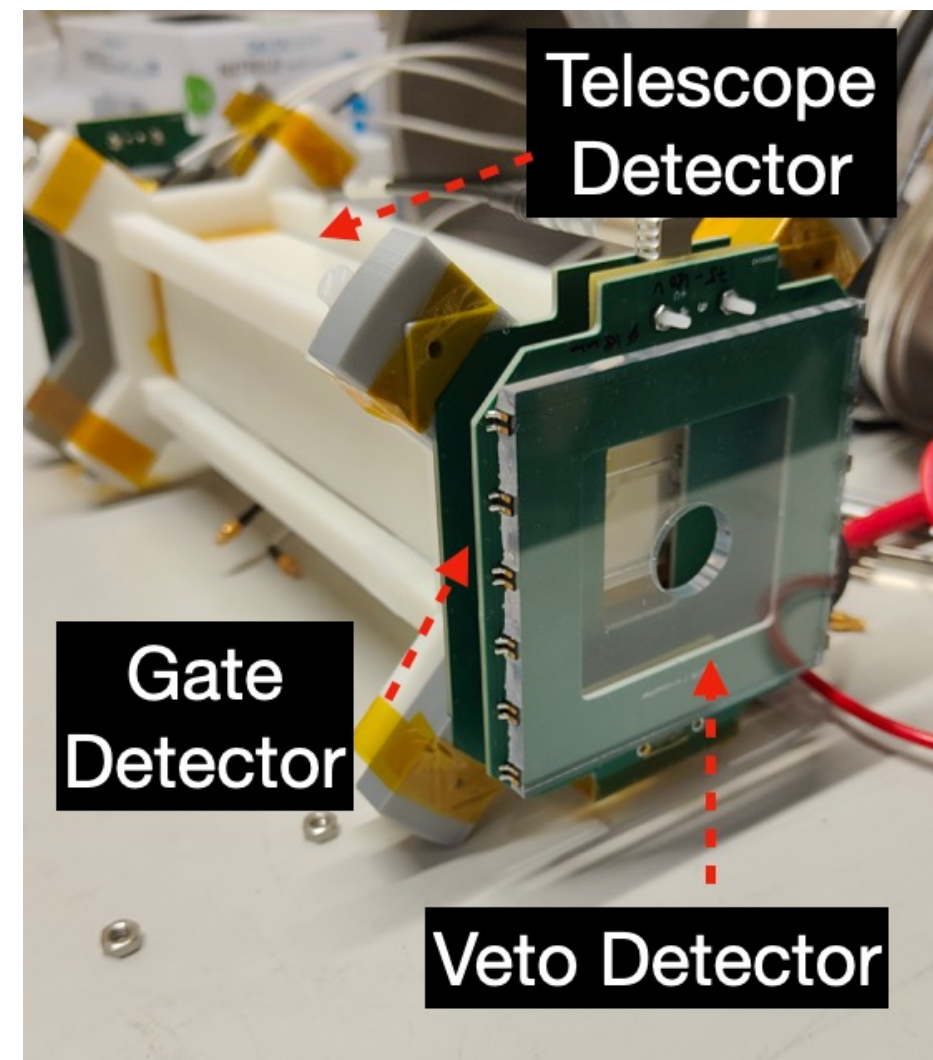
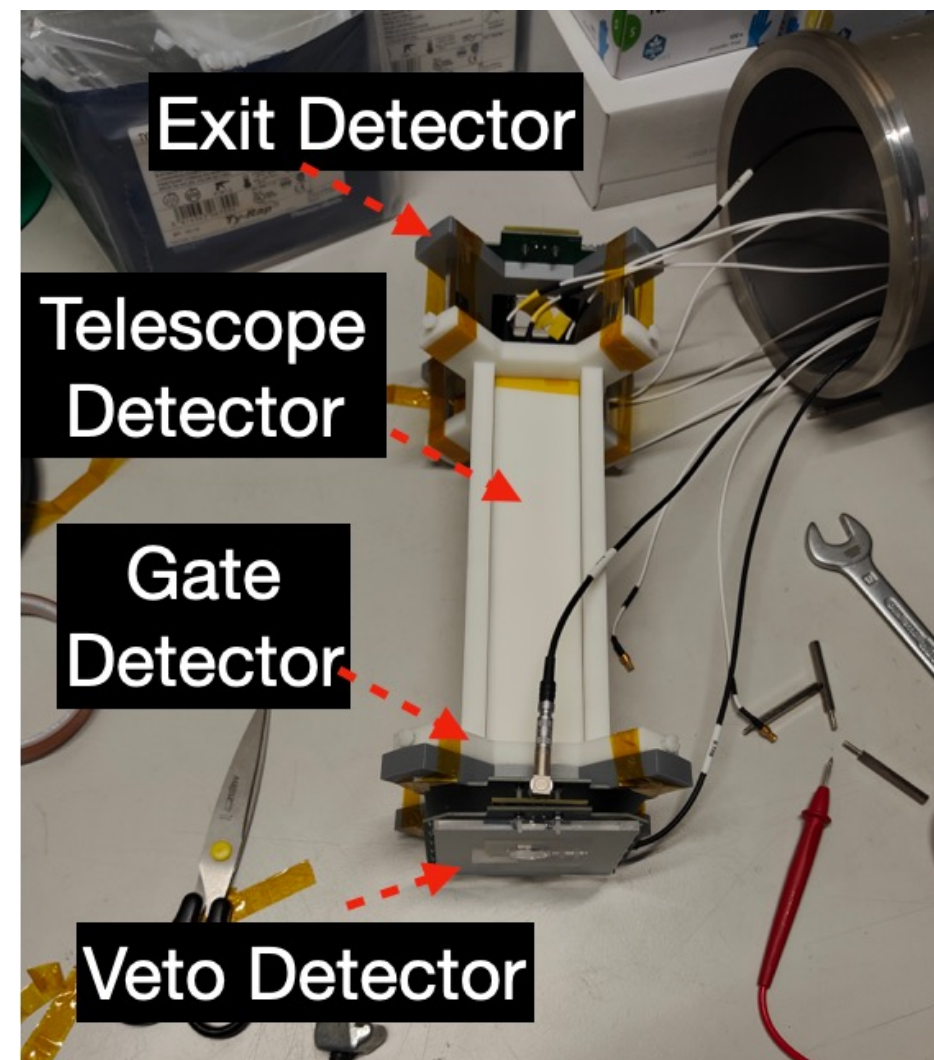
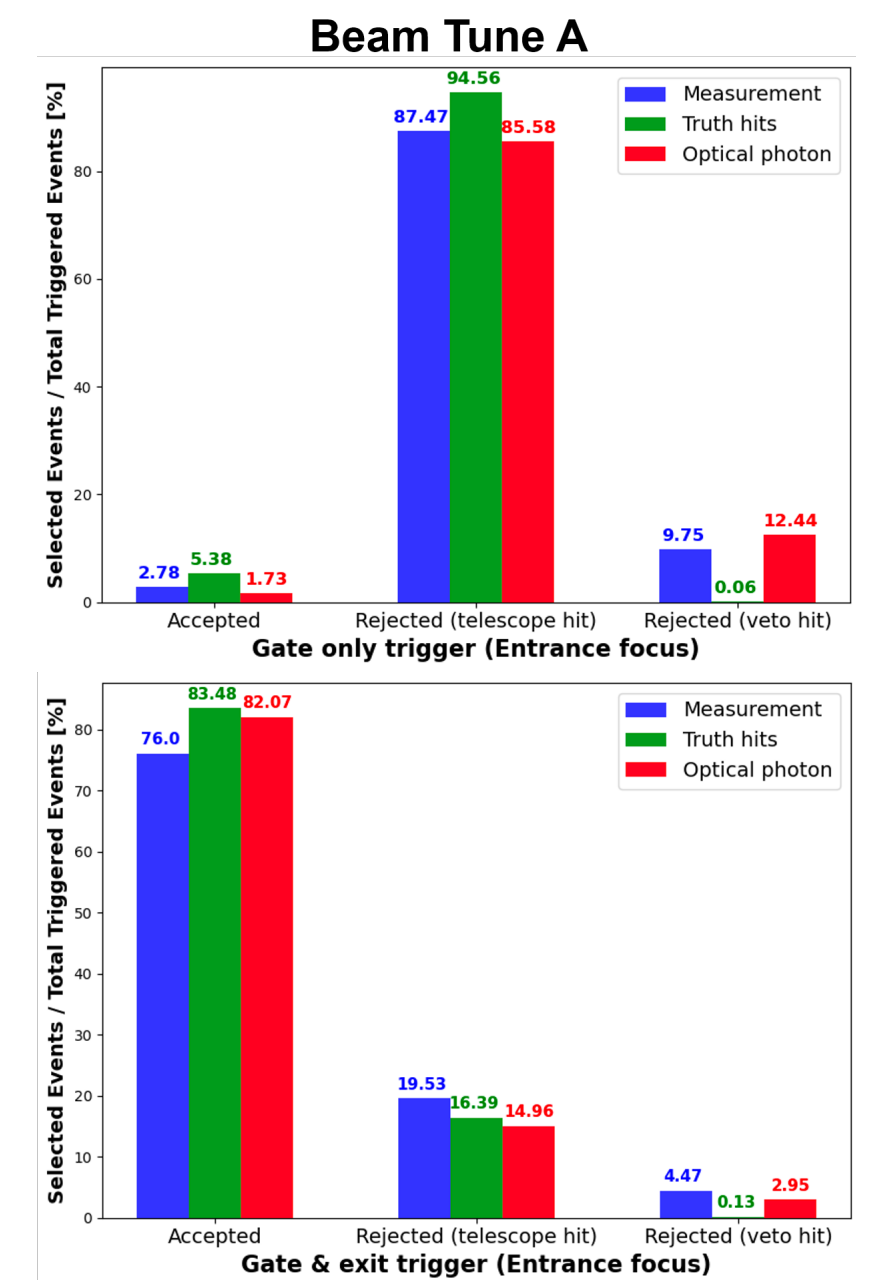
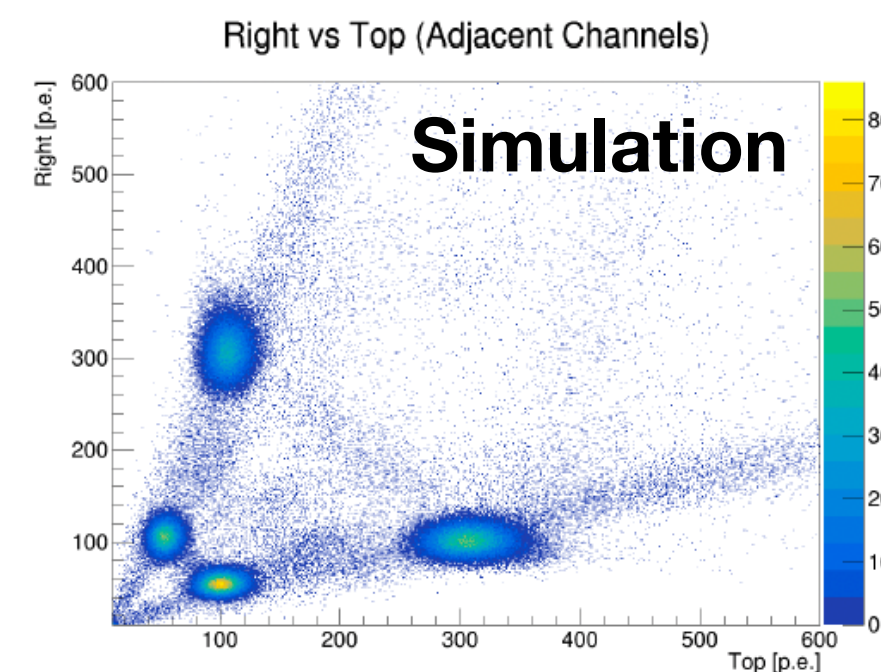
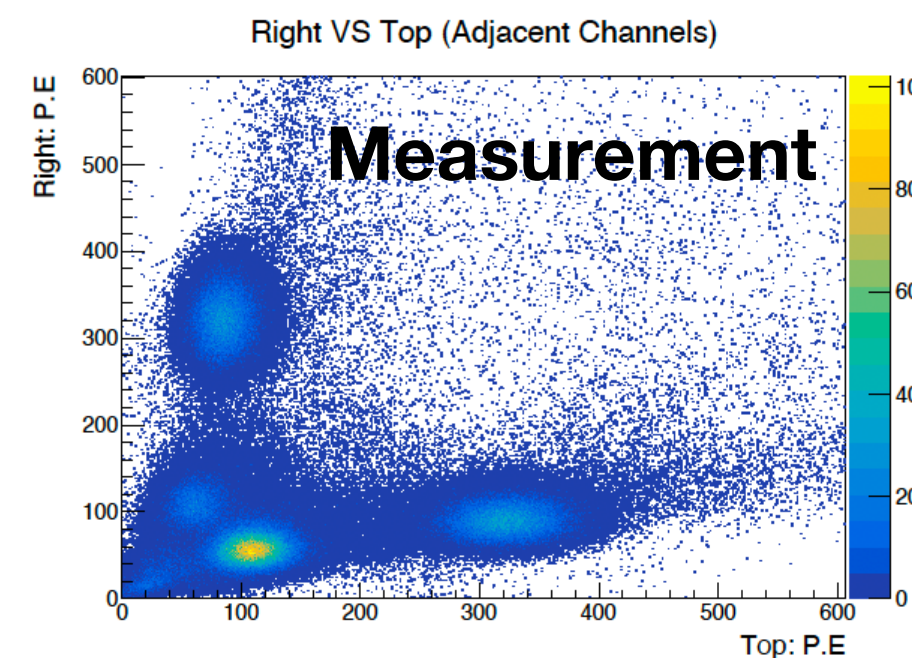
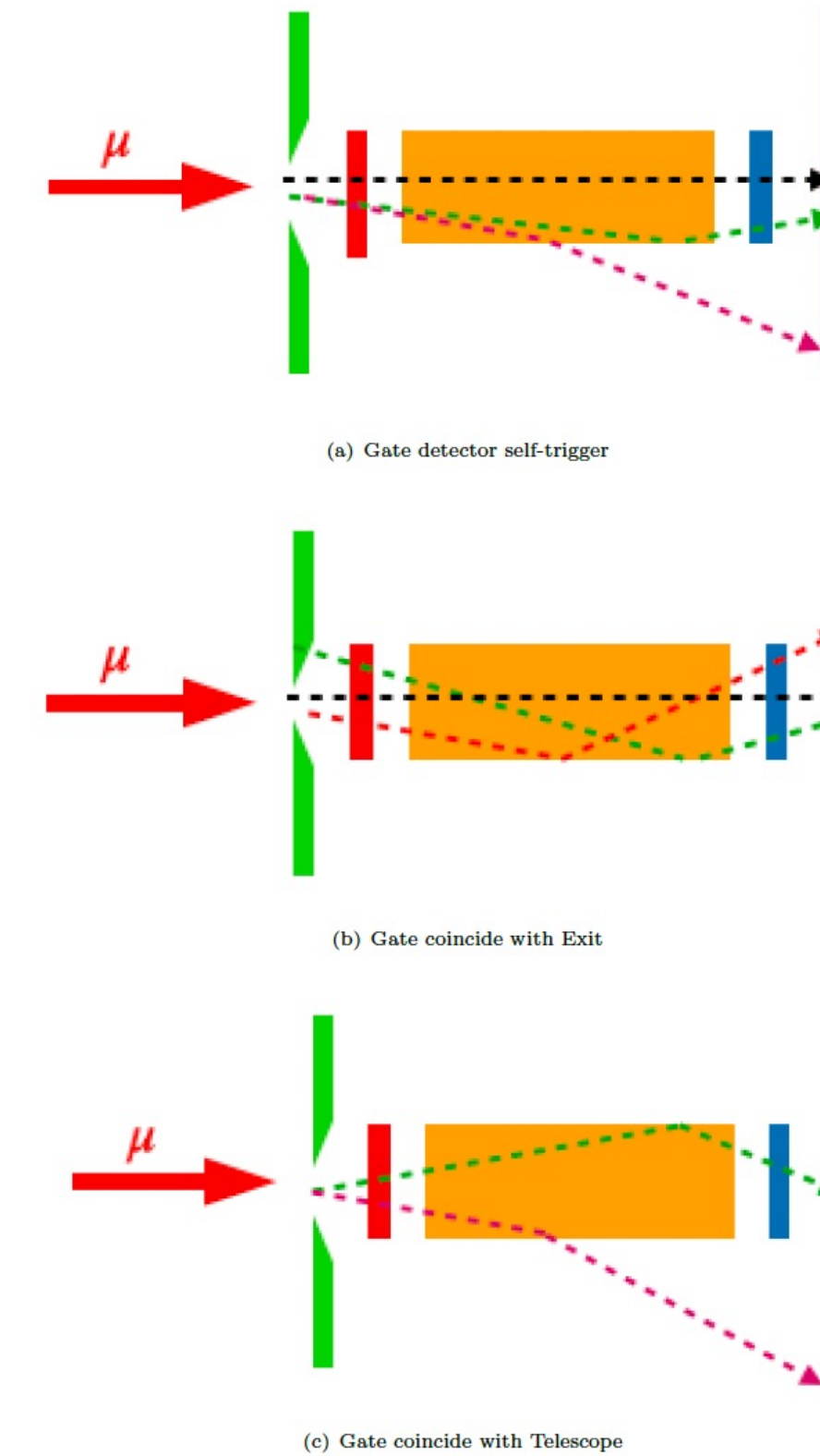
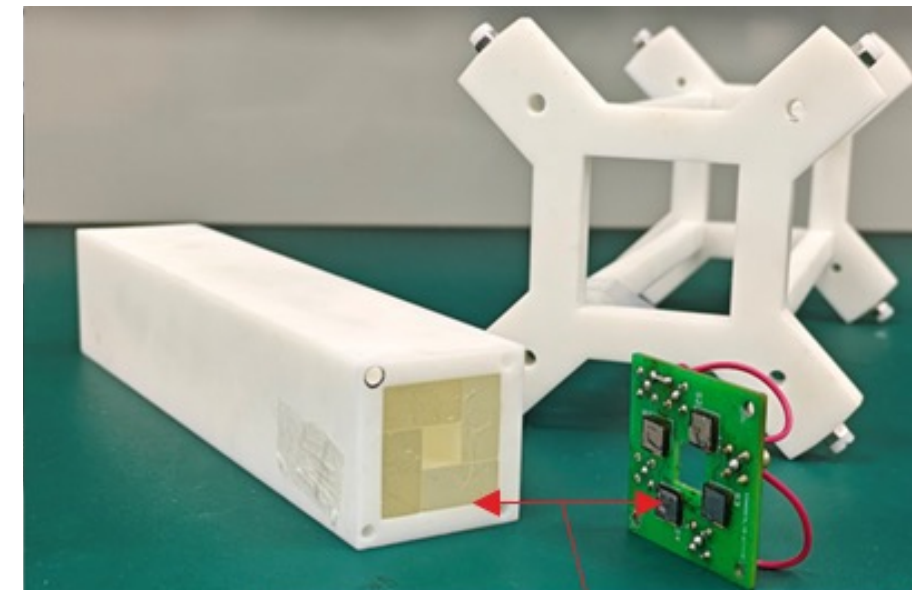
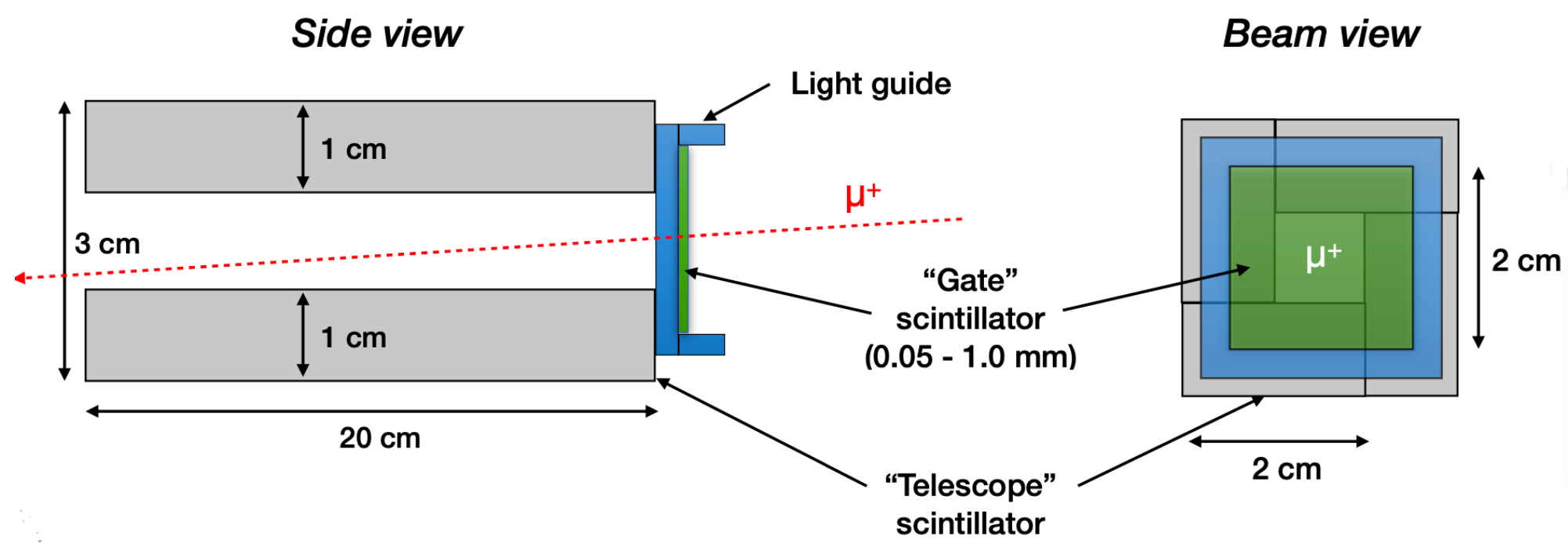
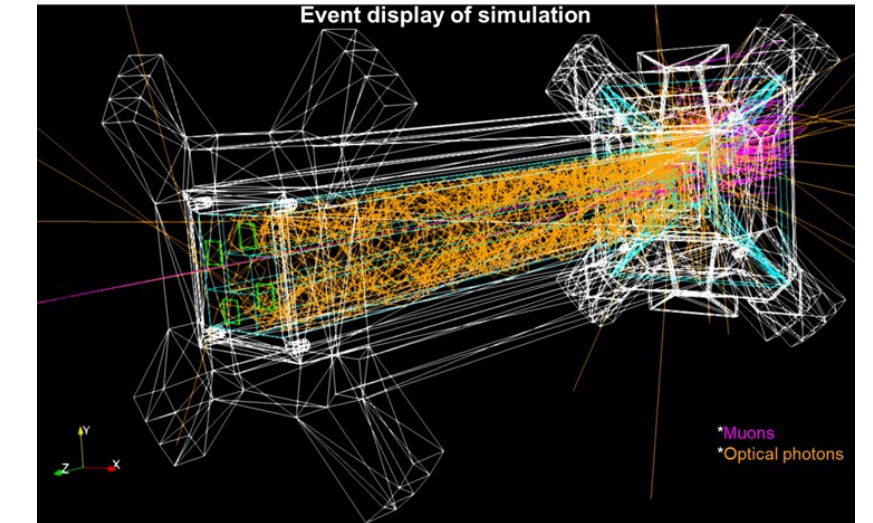


### Main requirements:

- Detects incoming muon while minimizing scattering
- Generates trigger signals for “storable” muons (reject out of acceptance muons)
- $< 25$  ns signal delay from muon detection to HV switch for the magnetic kicker

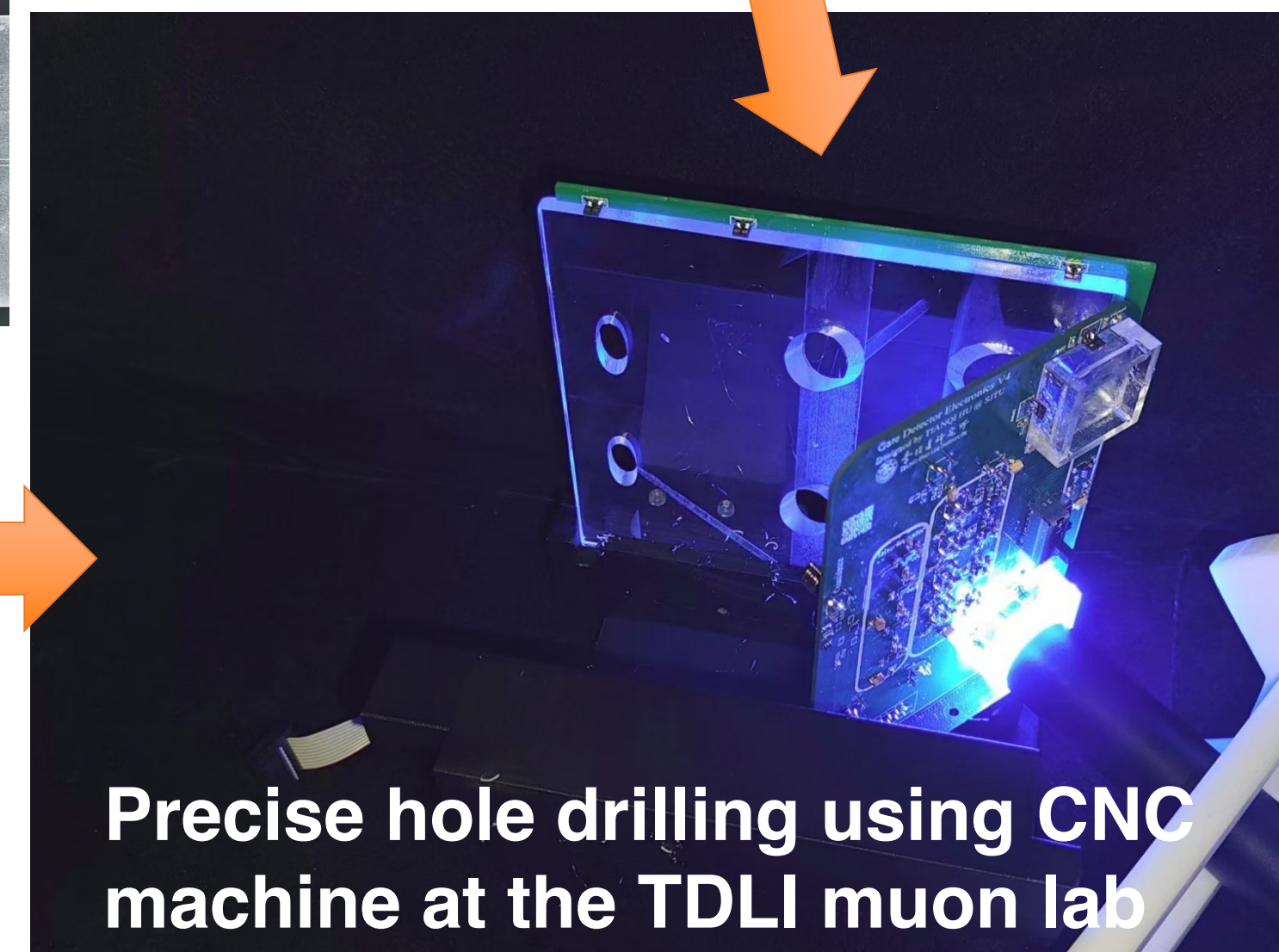
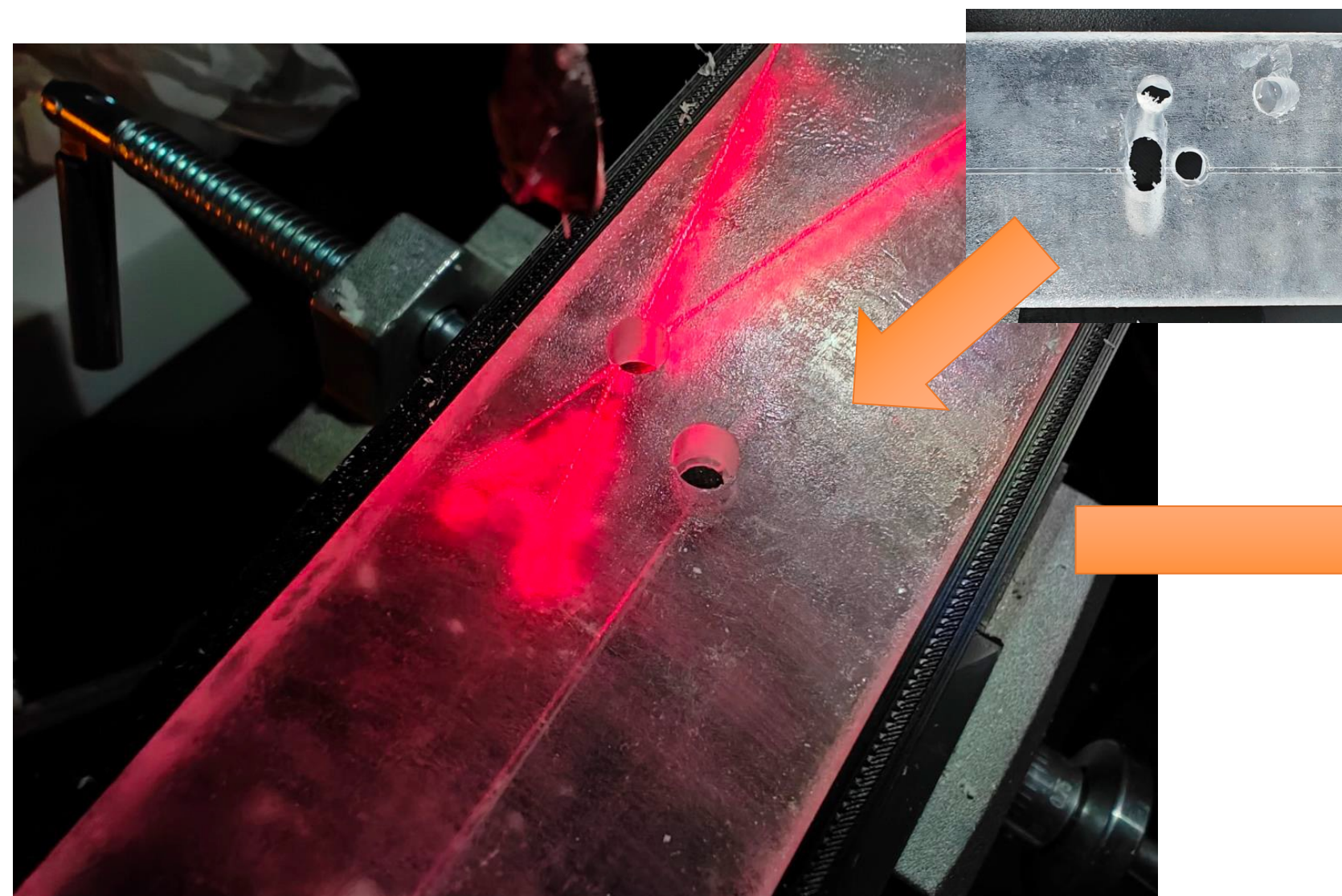
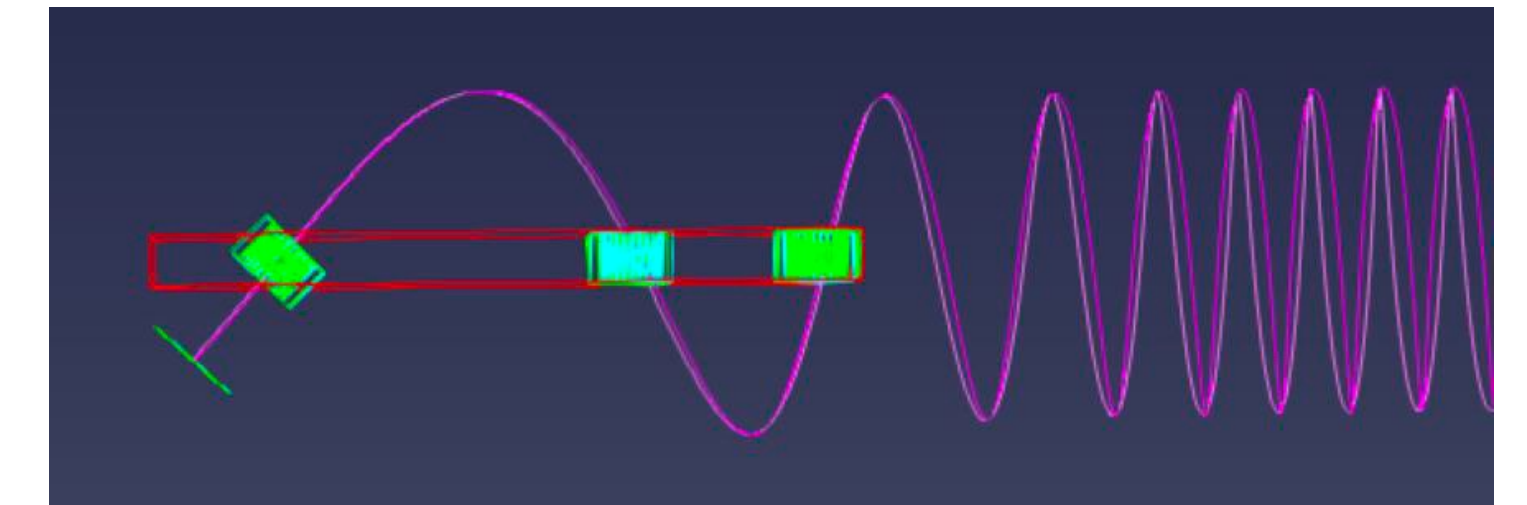
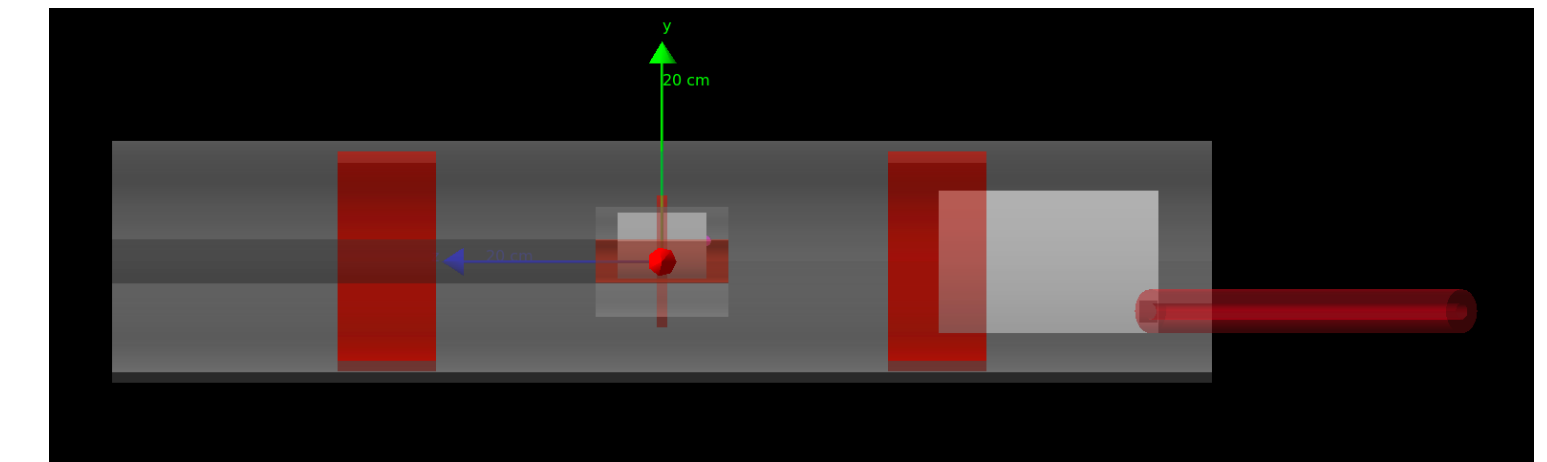
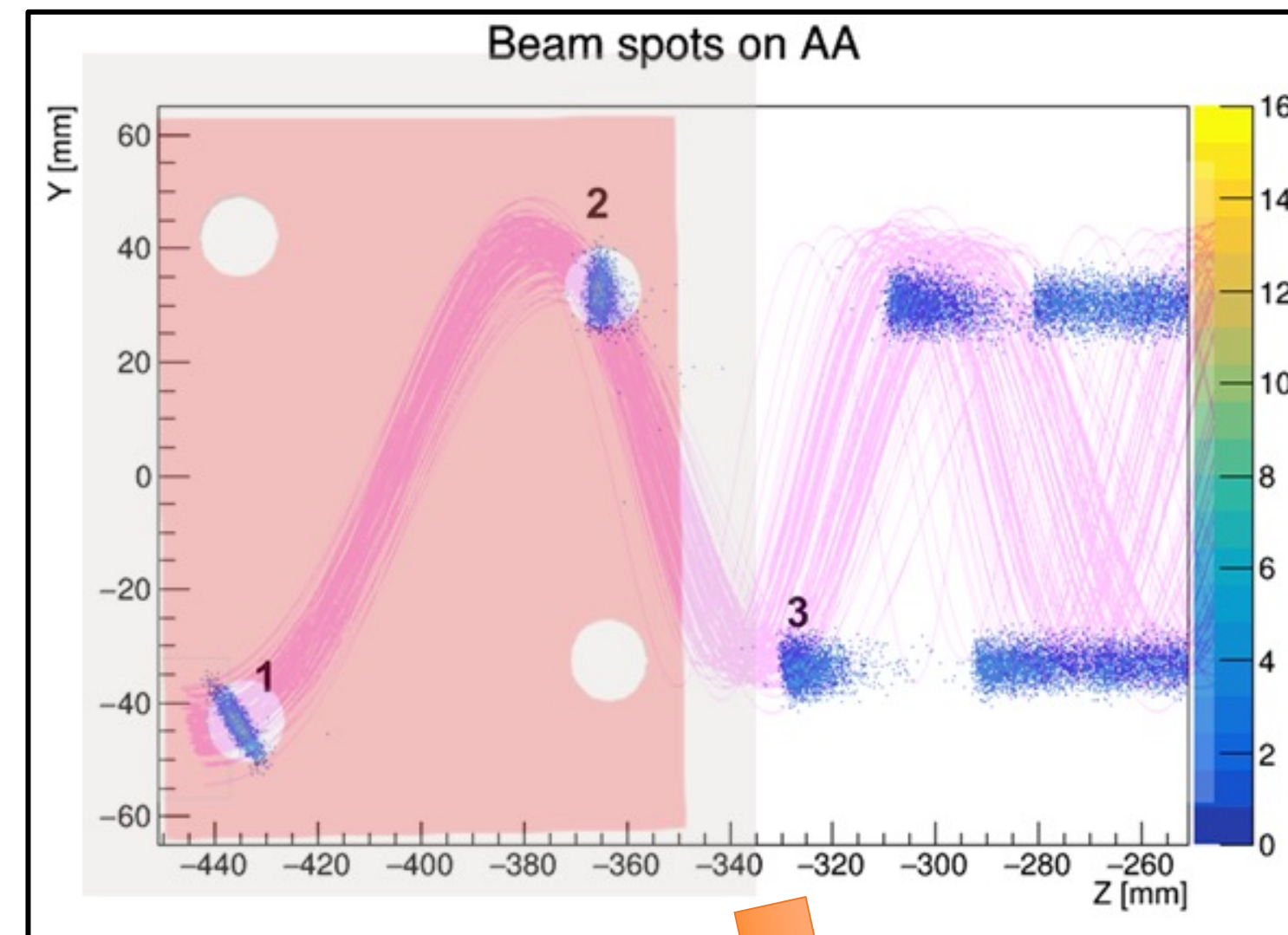
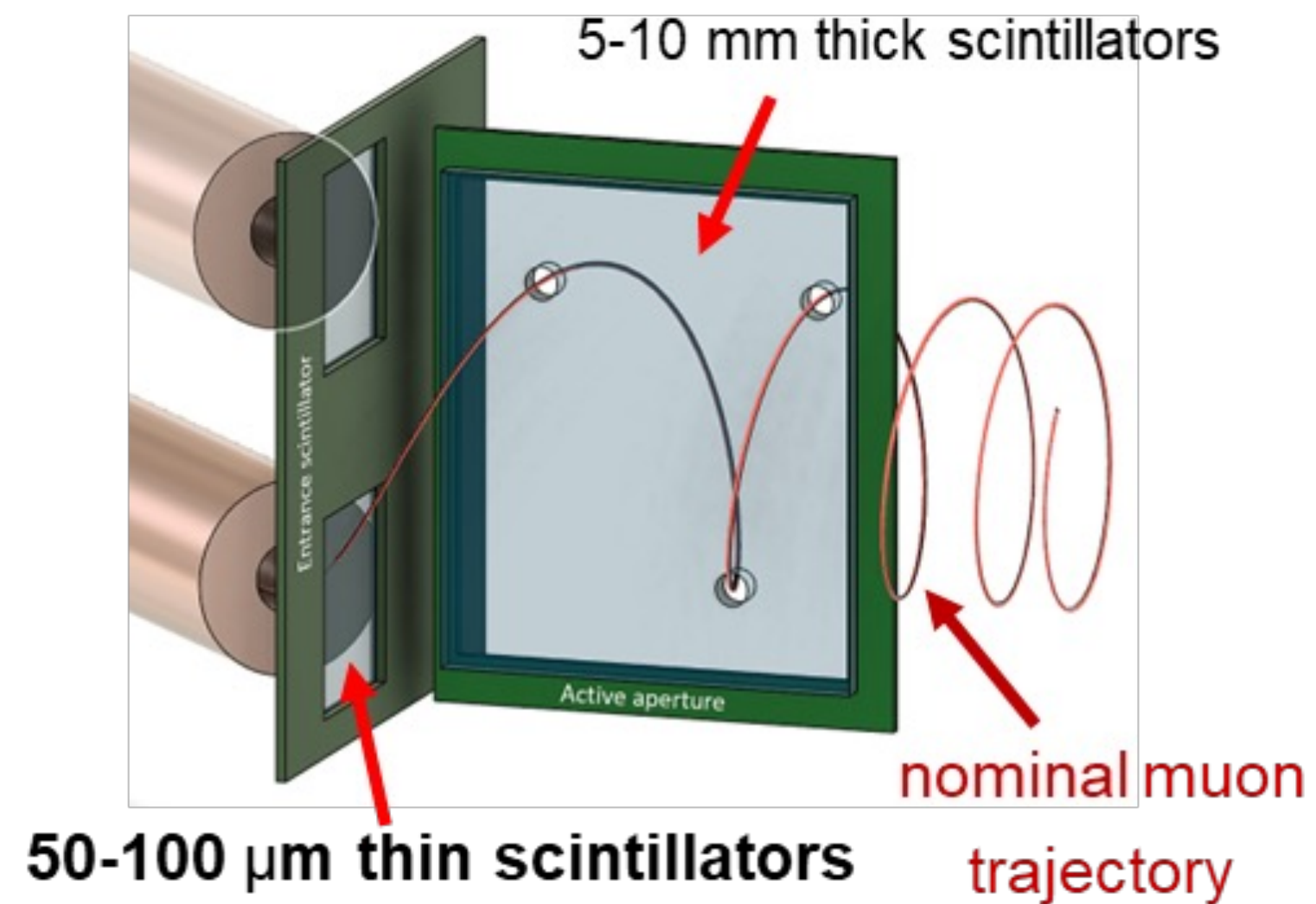
# Proof of concept experiment in 2022

## Beam Test at PSI in 2022 to test the idea (no magnetic field)



Reproduced event topologies after activating the optical photon processes in Geant4

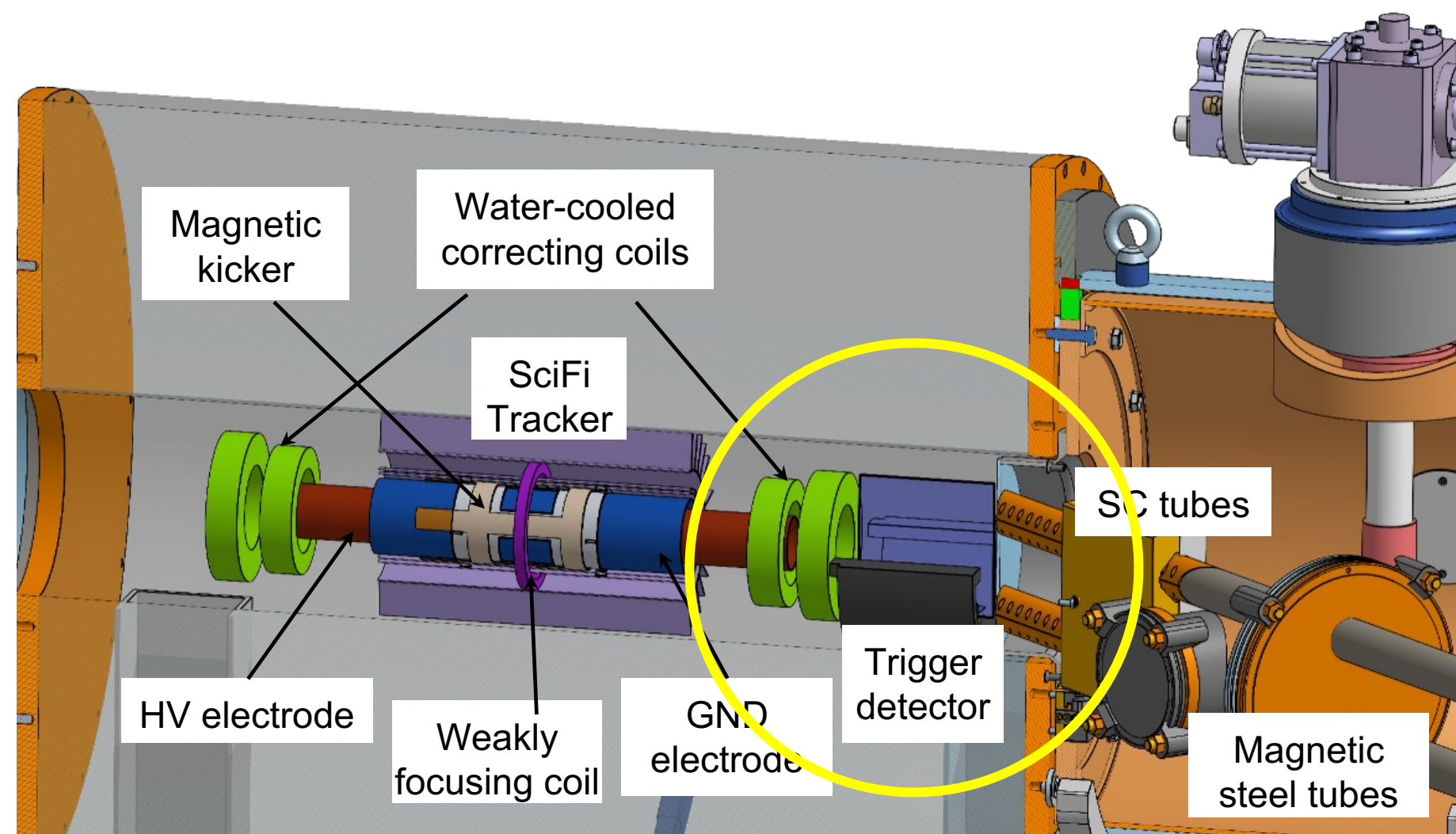
# Detector design and development



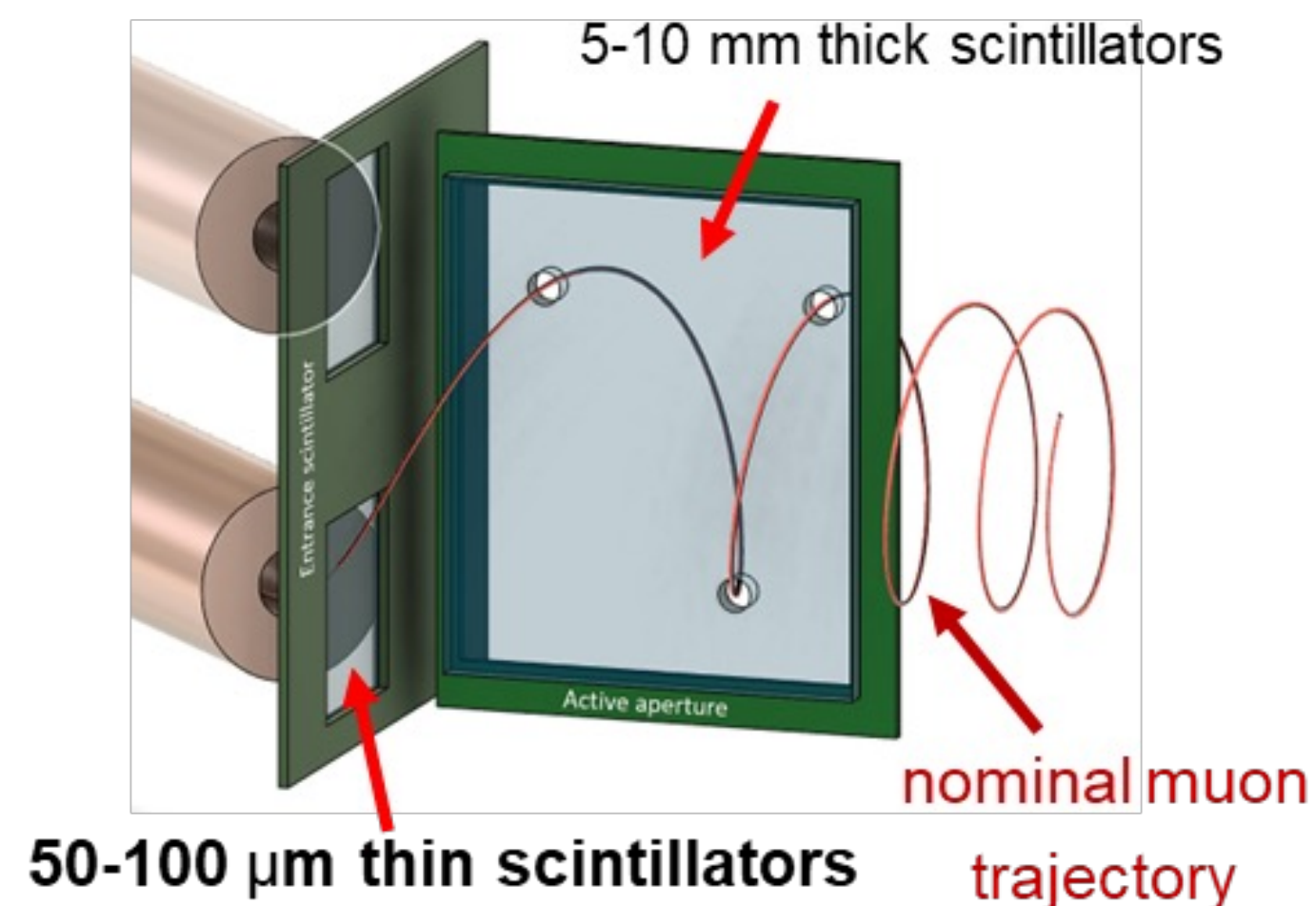
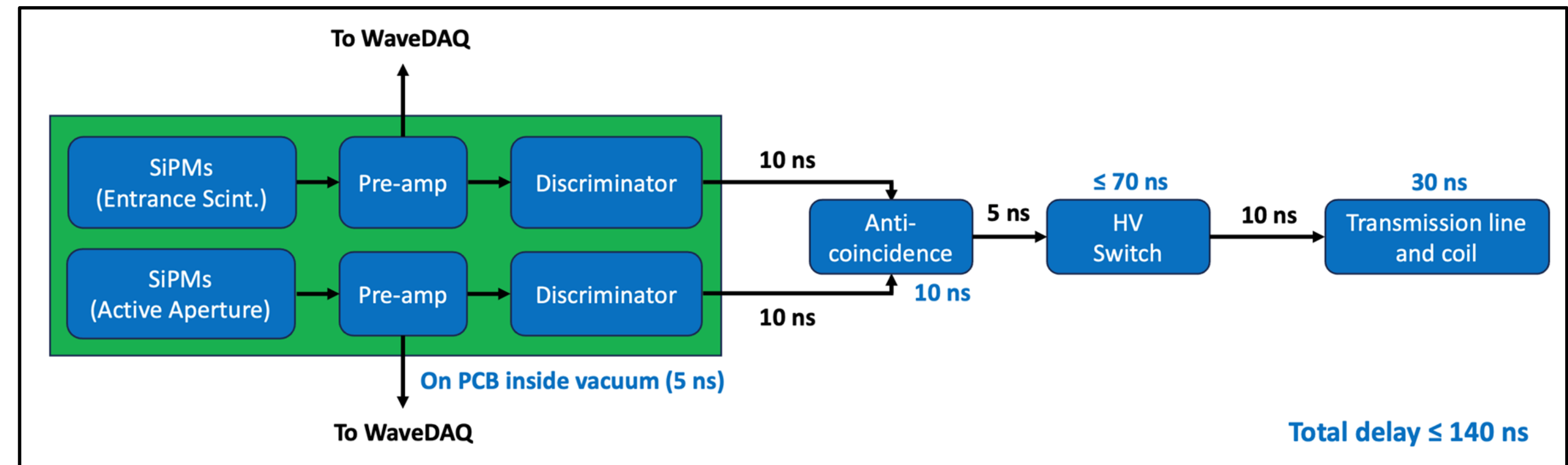
Using G4beamline and musrSim models to:

- 1) Optimize detector geometry to maximize storage fraction
- 2) Optimize SiPM readout locations to maximize photon collection efficiency

# Fast trigger for the magnetic kicker



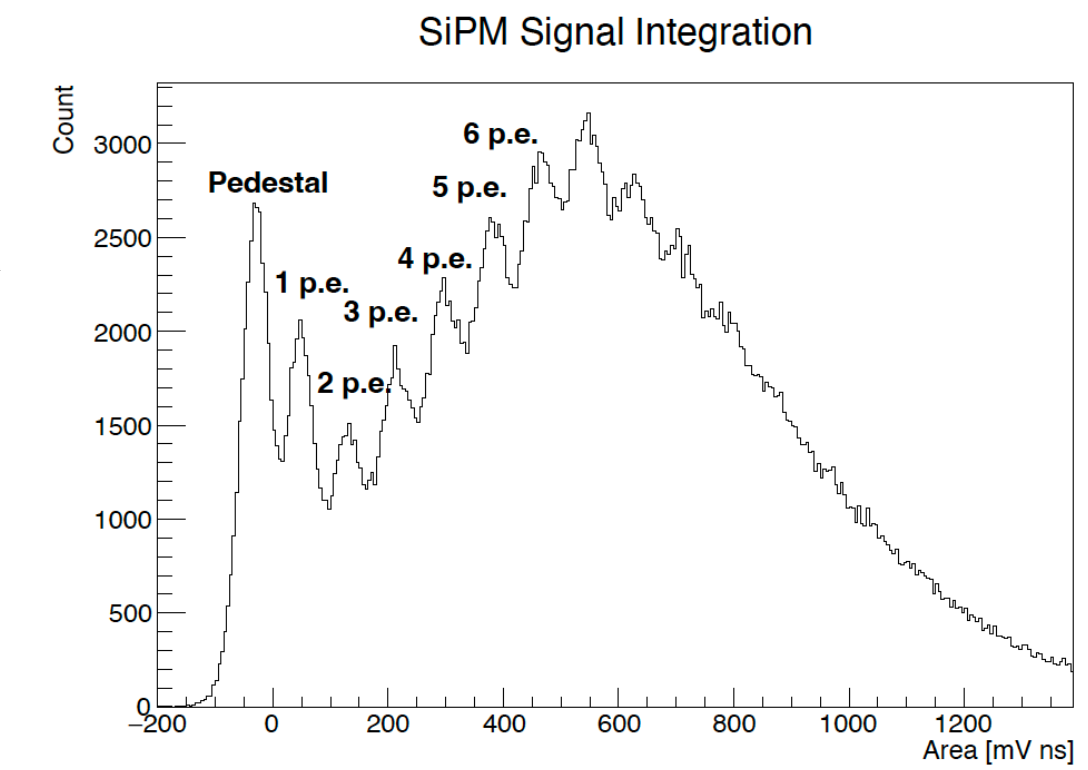
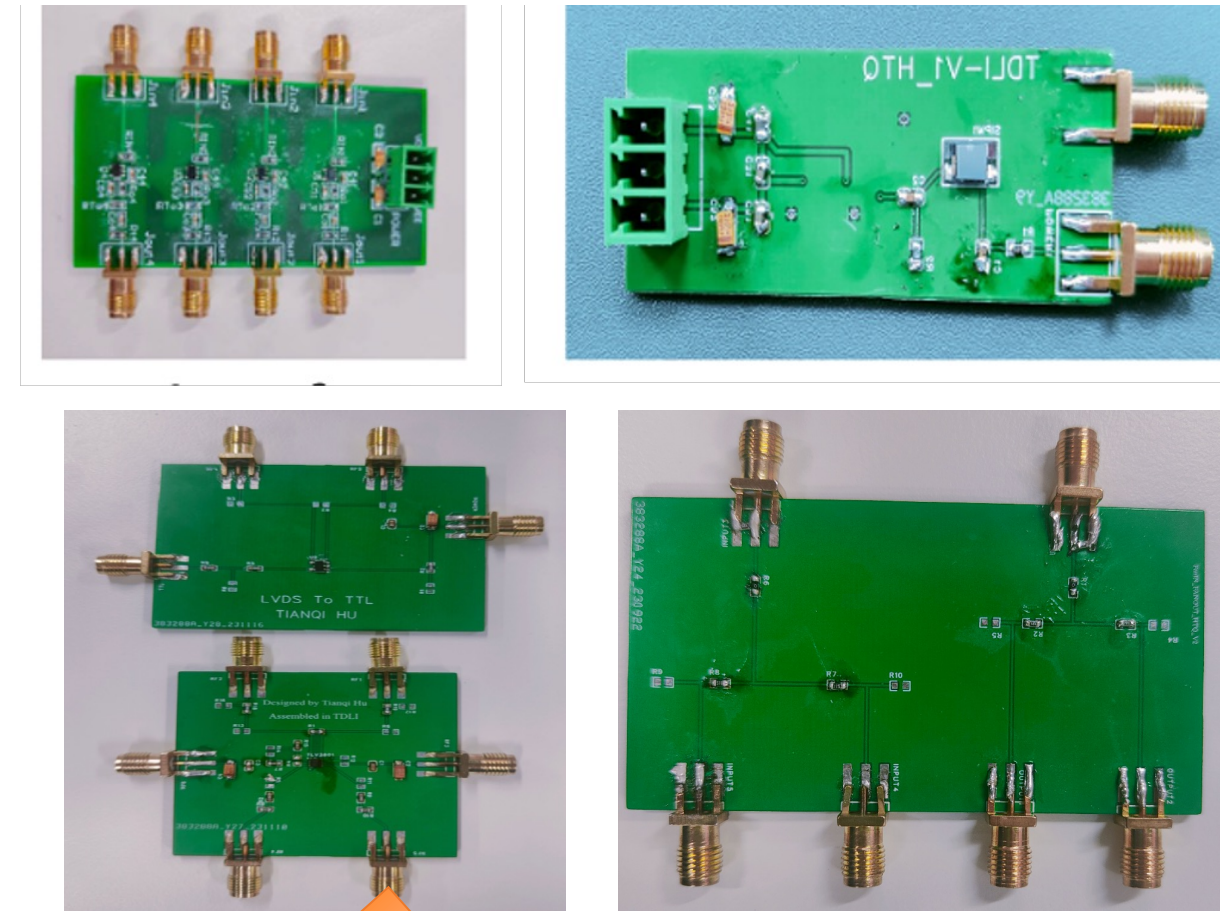
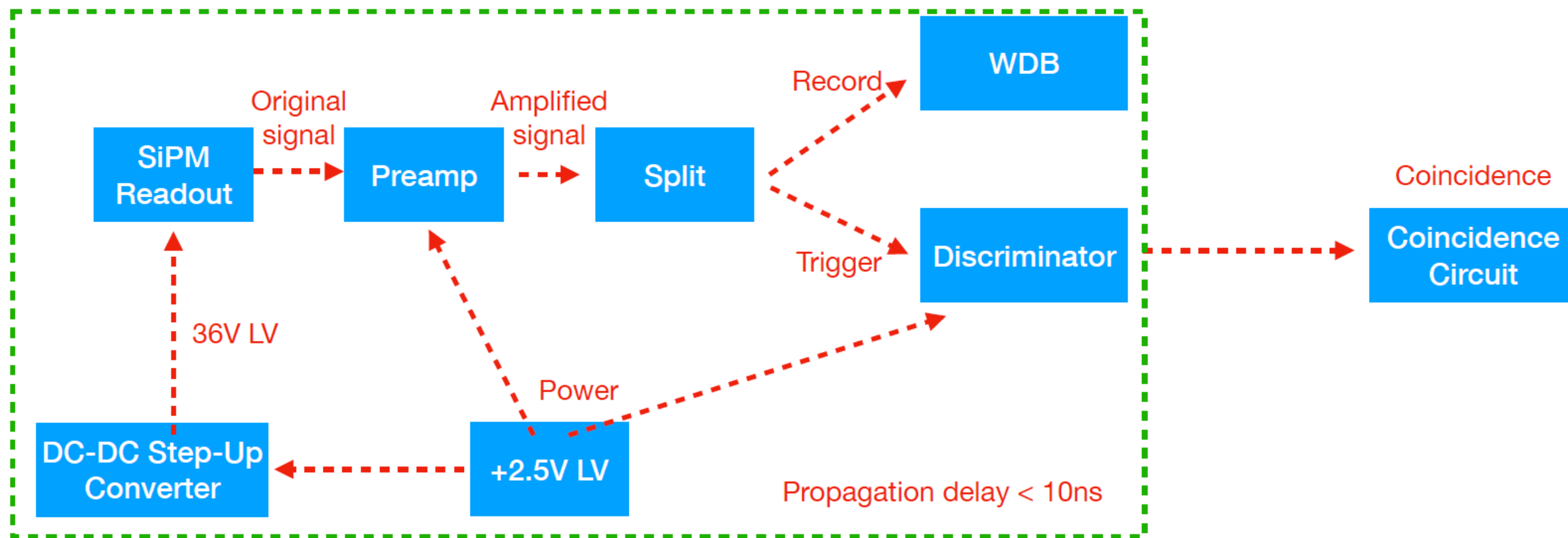
**Fast electronics design to satisfy stringent timing requirements (procured the fastest chips on the market)**



Particles	Average Energy deposition(MeV)	Photons per SiPM	Average Photons per SiPM	Pre-amp(mV) (20dB)	Split Out (mV)
Positron	0.017	<3	0.6	<12	<4
Muon	0.190	5~9	6	20~36	7~12
Pion	0.307	8~12	9	32~48	11~16

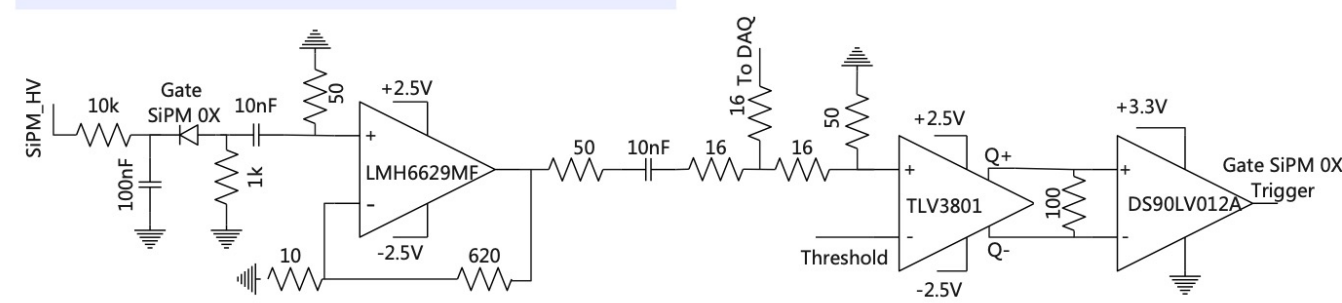
**Detector response to various particle species drives the electronic design**

# Electronic design and fabrication

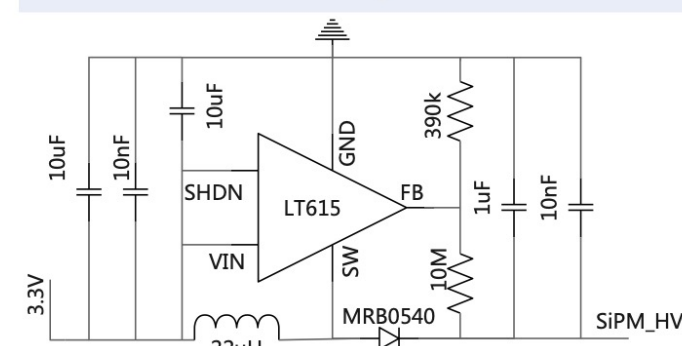


**Tested every component before integrating them into a single PCB**

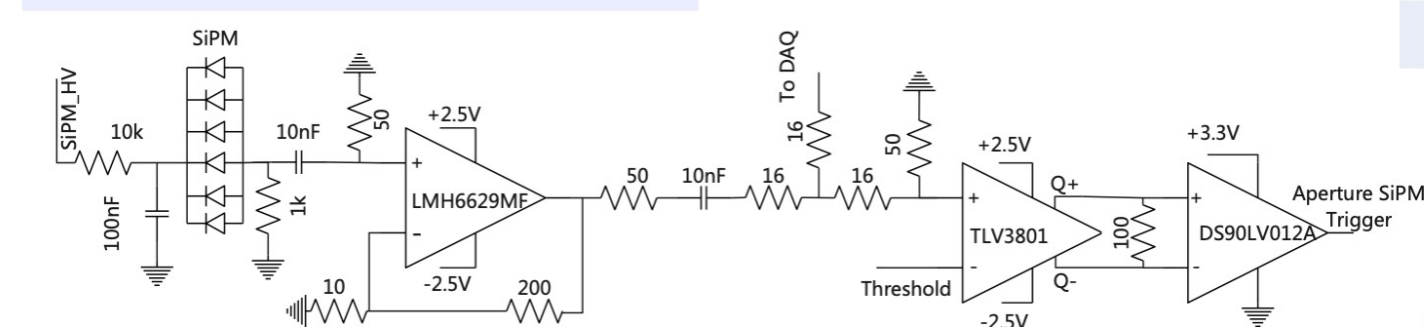
Gate SiPM Electronics Readout



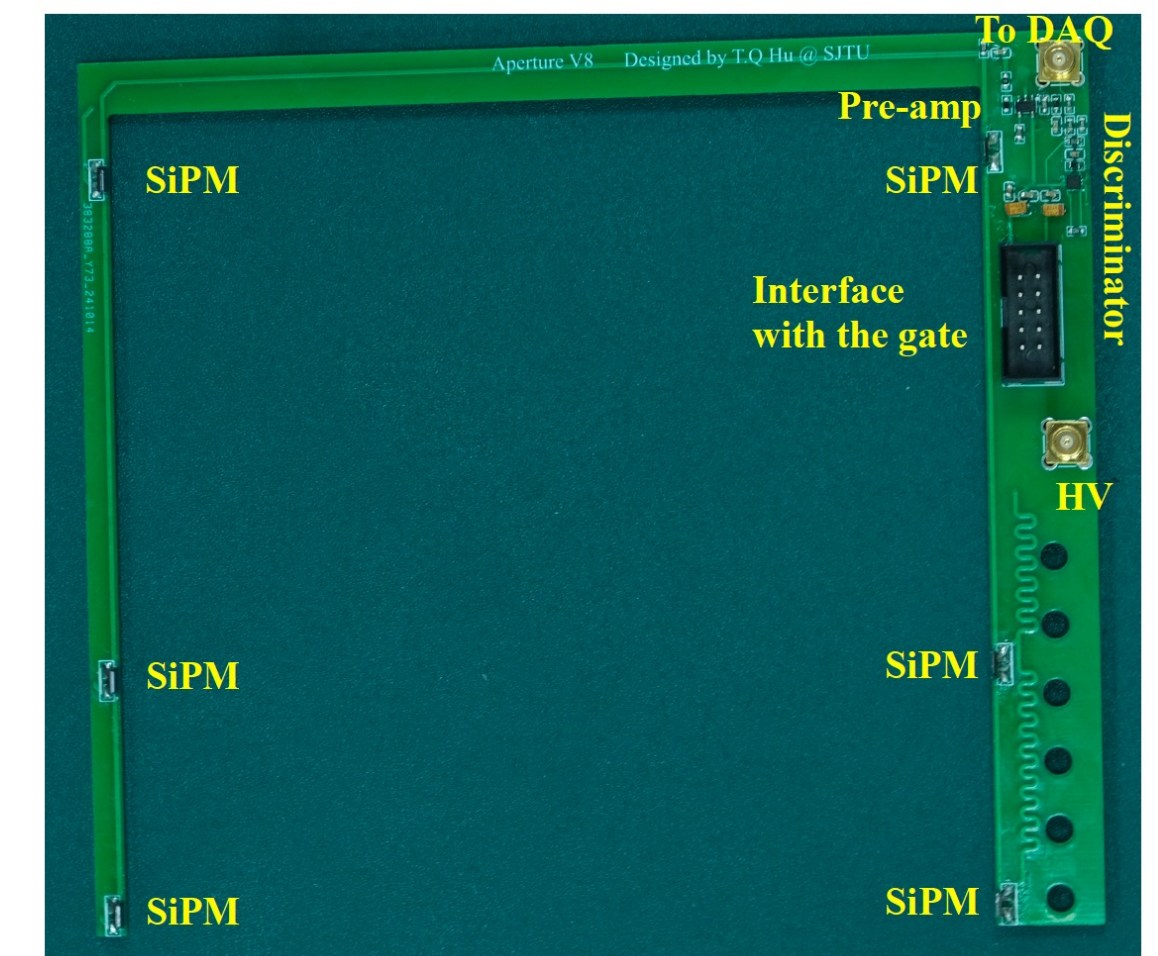
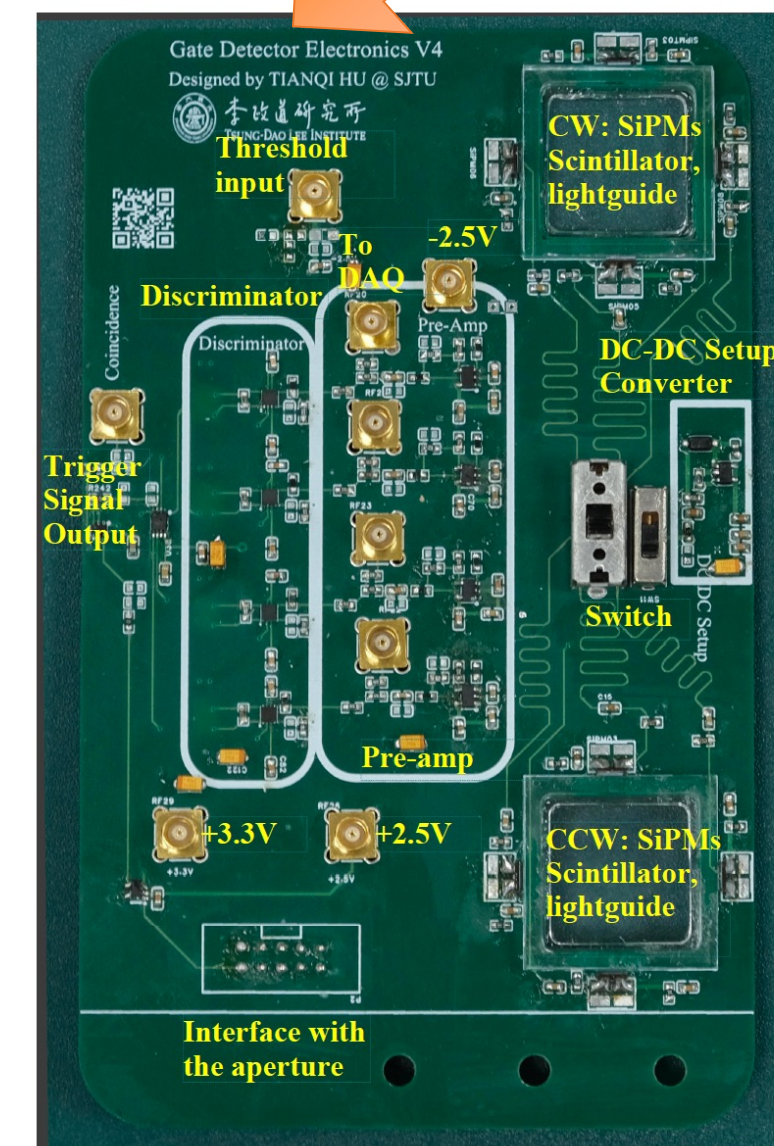
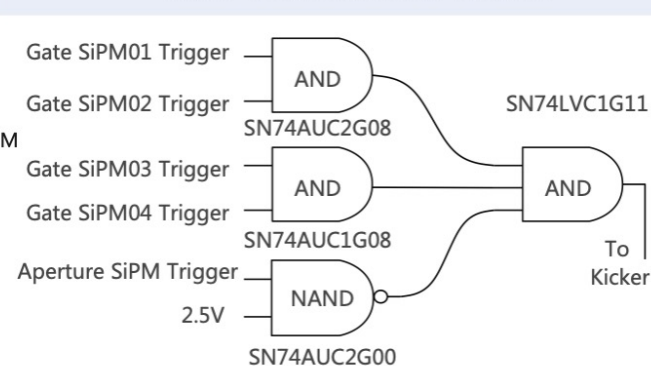
DC-DC Setup Converter



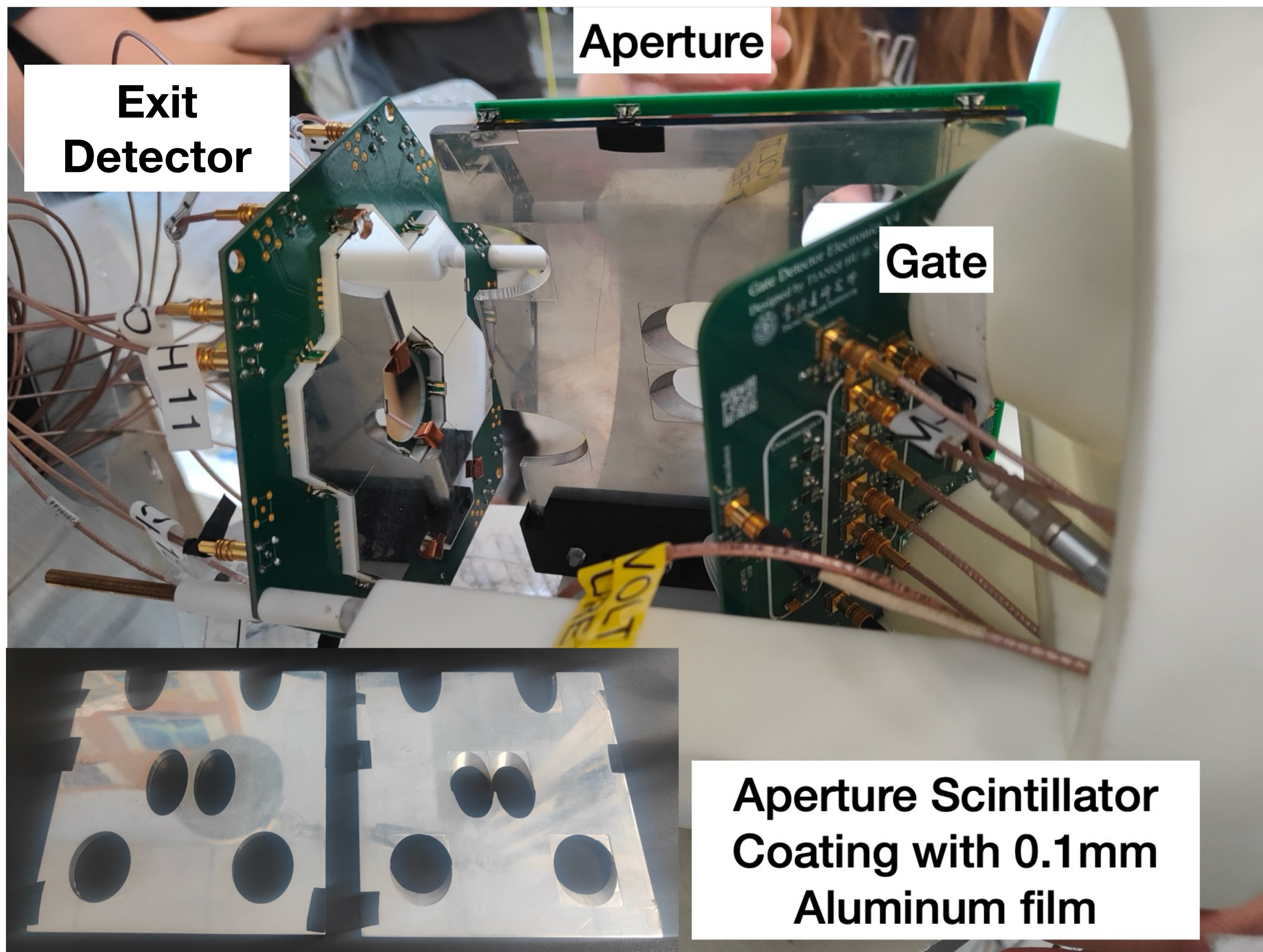
Aperture SiPM Electronics Readout



Anti-Coincidence Circuit



# Beam time @ PSI in Oct/Nov 2024



## Test 3D spiral injection

- Clockwise (CW) and counter-clockwise (CCW) injection
- Momentum control when switching between CW and CCW injection

## Characterize Trigger Detector

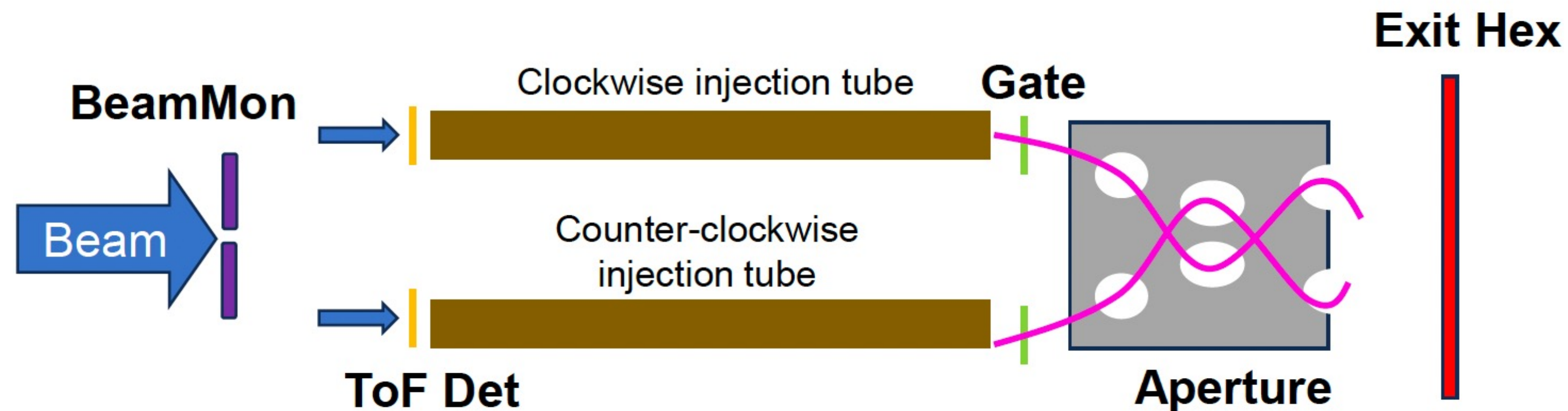
- Performance of fast electronics readout
- Acceptance rate and rejection rate
- Induced background studies



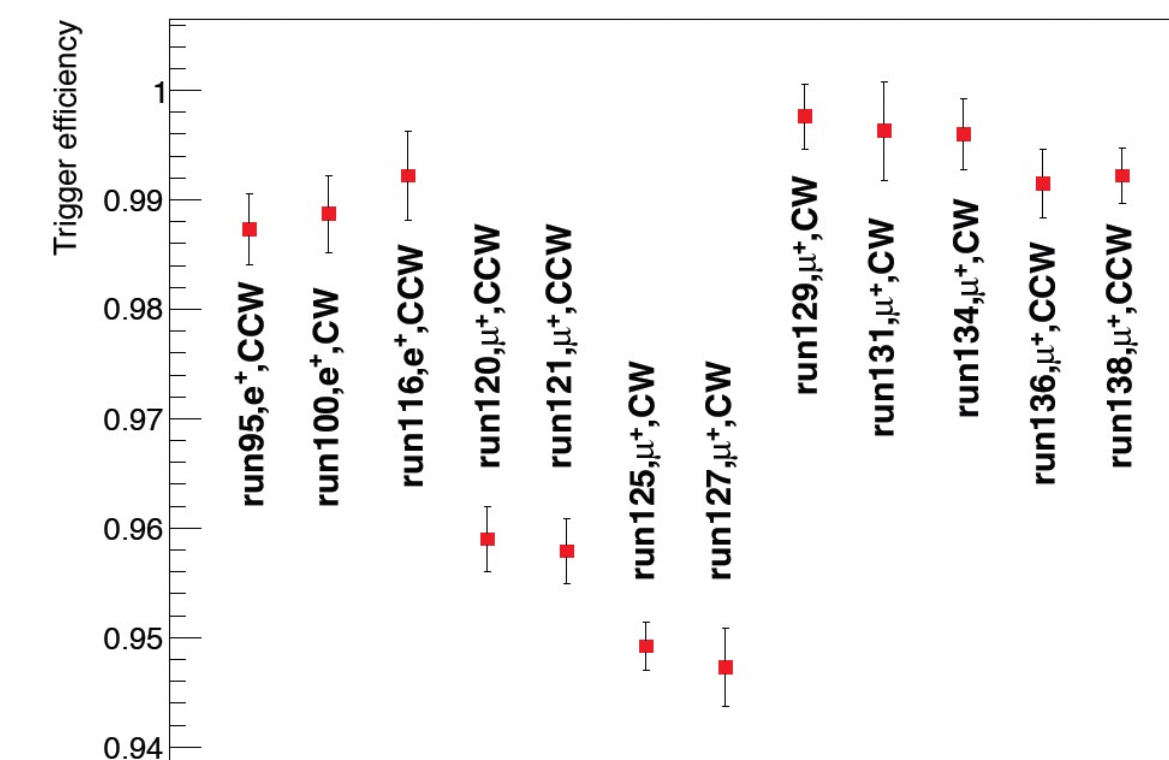
# Preliminary results

**Analysis ongoing,  
preliminary results show  
> 95% signal efficiency**

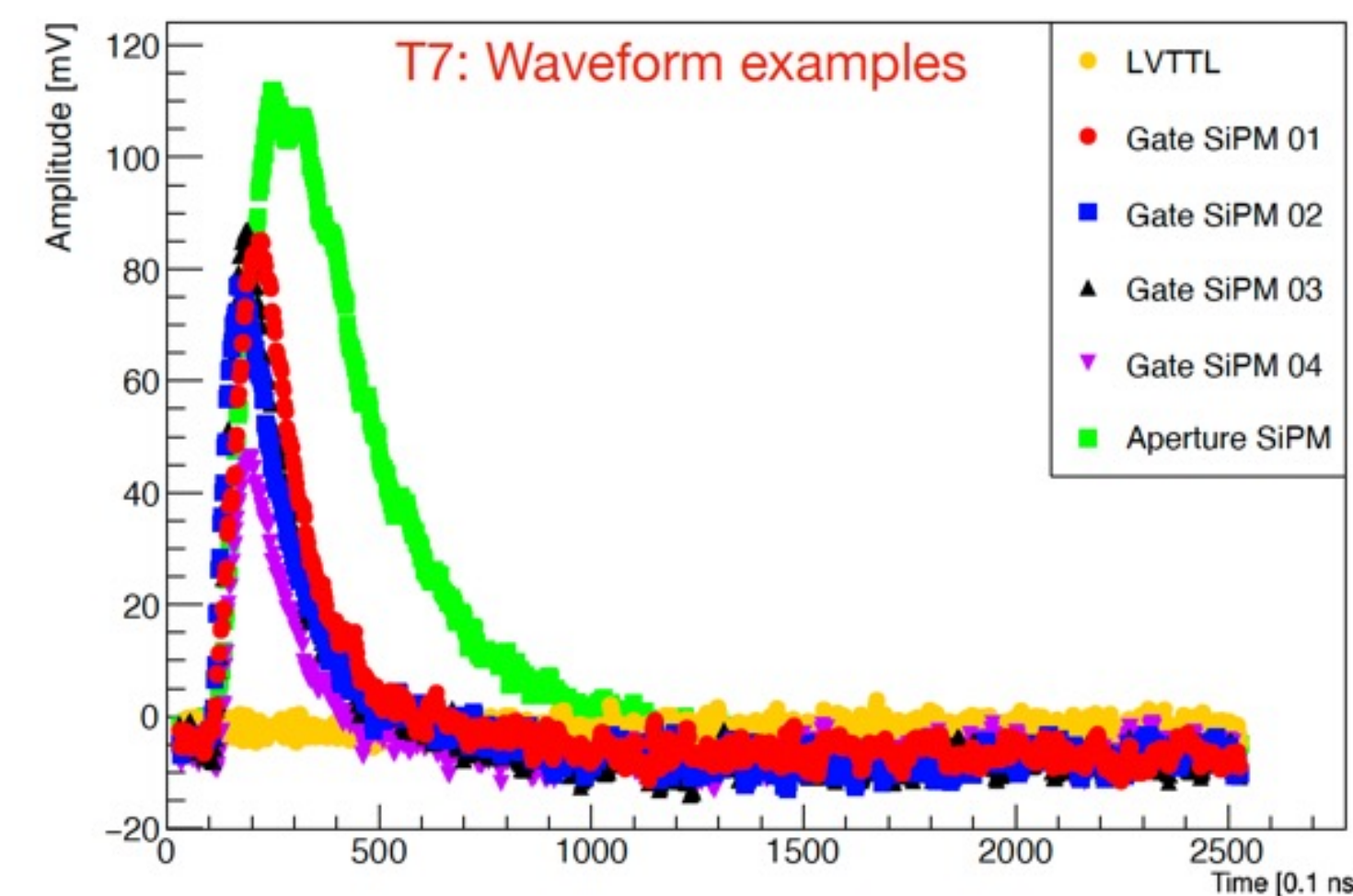
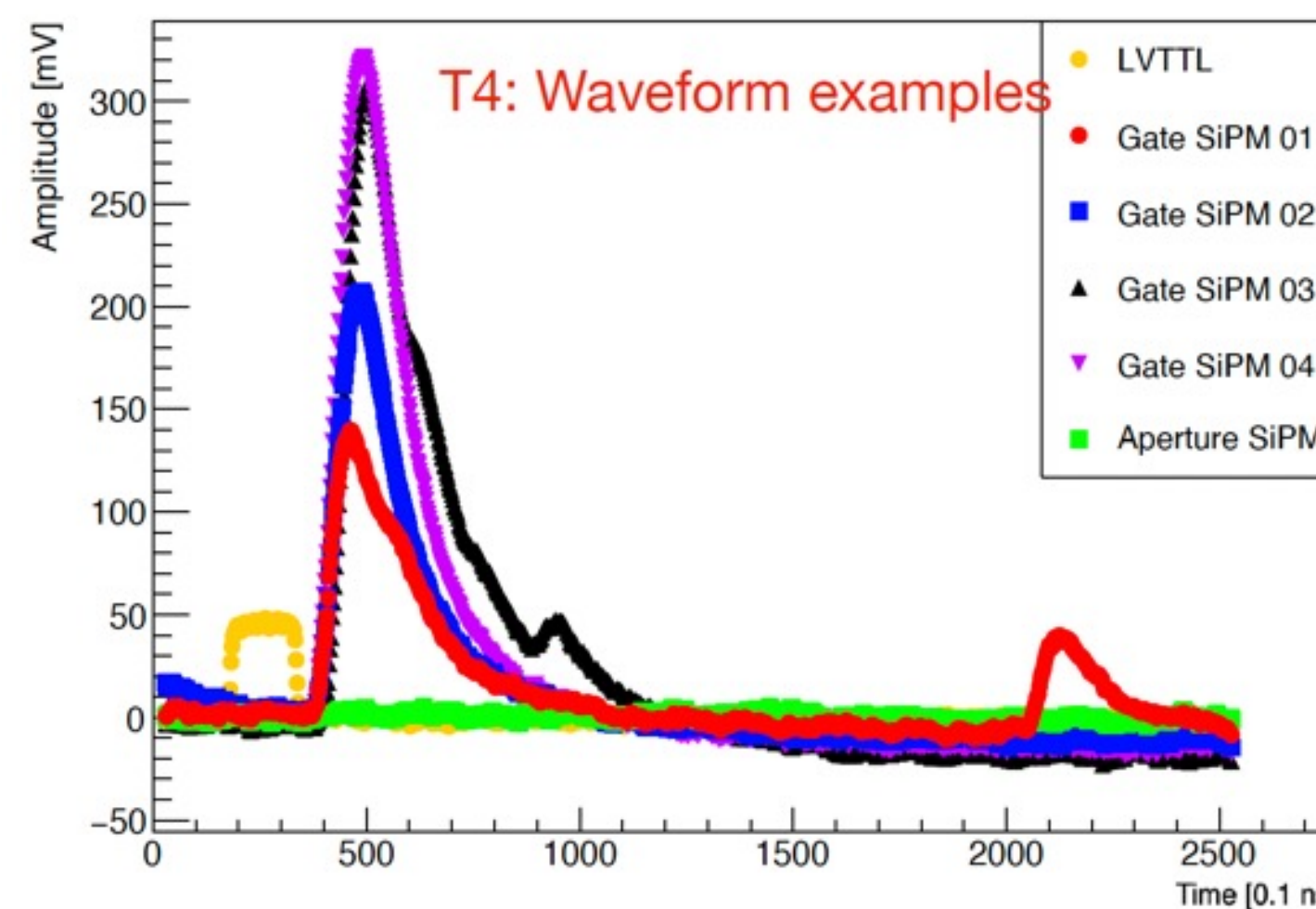
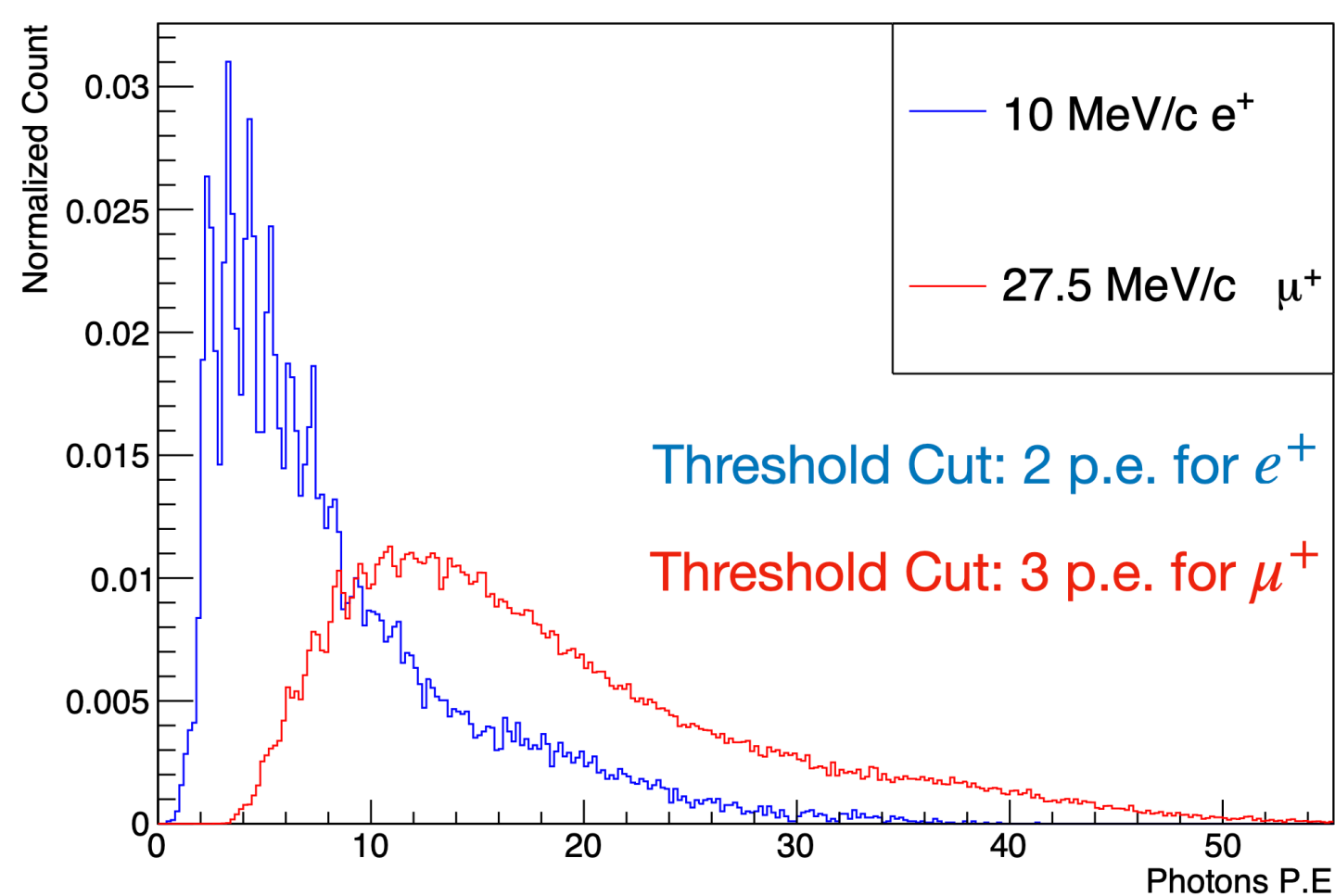
## Scheme of detectors



Trigger efficiency at the anti-coincidence



Photons Received by SiPM per event



Response to different species

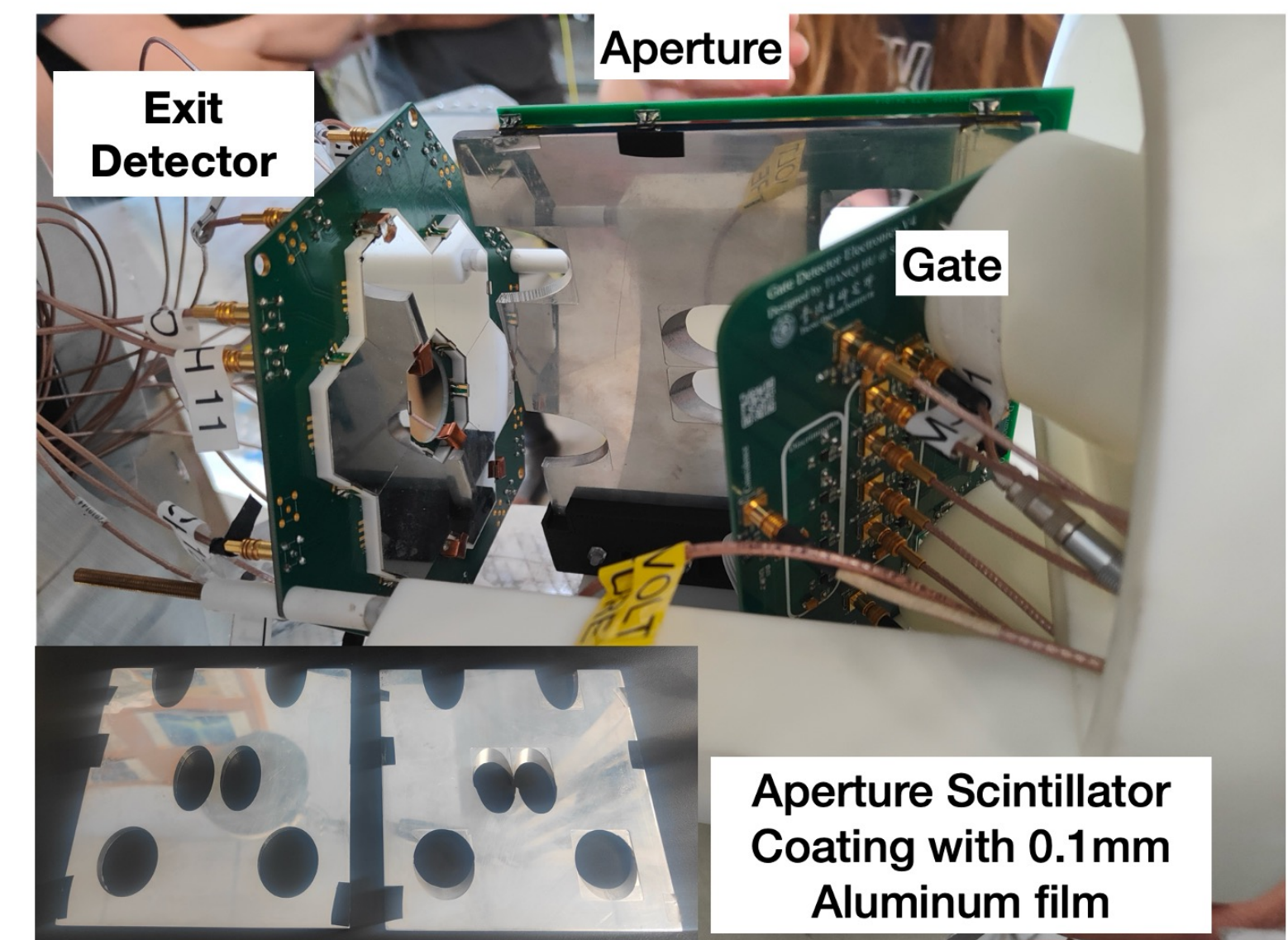
A good muon (with TTL signal)

A "bad" muon (without TTL signal)



# Summary and outlook

- The Muon Trigger Detector is a crucial component of the experiment, supplying the trigger signal to the magnetic kicker for storable muons.
- The selection of plastic scintillator + SiPM + custom PCB technology is supported by the successful beam tests conducted at PSI in 2022 and 2024
- A further round of revisions will occur before the permanent installation of the detector in the storage solenoid.



# Talks and Publications



- Talks

- MIP 2023, MIP 2024, NuFact 2023, NuFact 2024

- Publications

- The muon trigger detector for the PSI muEDM experiment: design, simulation and beam test results (to be submitted to Nuclear Science and Techniques)
- Development of Fast Front-End Electronics for the Muon Trigger Detector in the PSI muEDM Experiment (to be submitted to IEEE Transactions on Nuclear Science)
- Beam test performance of a prototype muon trigger detector for the PSI muEDM experiment, arXiv:[2501.01546](https://arxiv.org/abs/2501.01546) (submitted to RDTM for review)
- Research and development of a muon entrance trigger for the muEDM experiment at PSI, Nucl. Part. Phys. Proc. 346 (2024) 58-62