

**PSI**



# Muon Trigger Detector for the PSI muEDM experiment

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

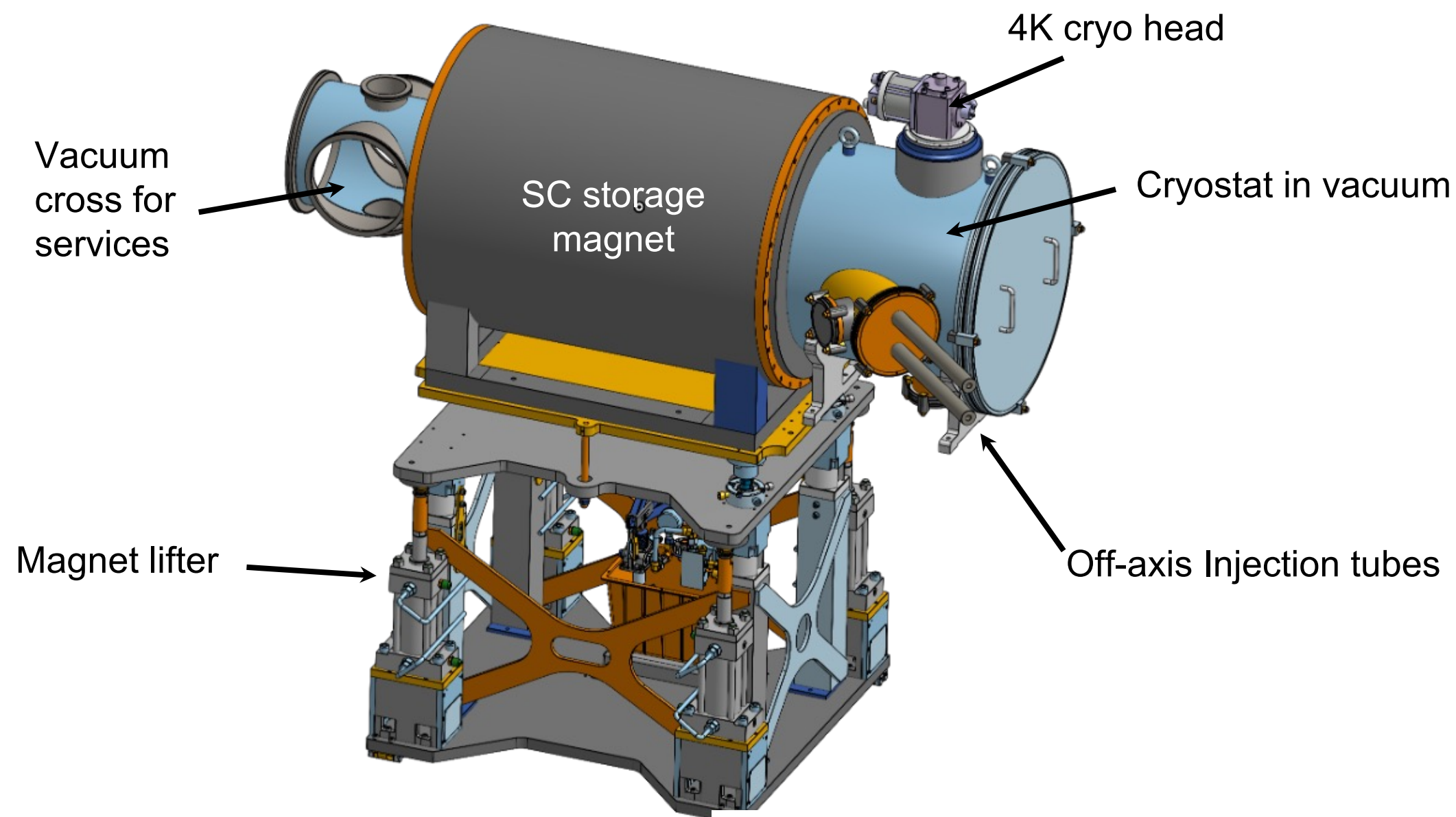
**Muon Trigger Detector Development Team:**  
Tianqi Hu, Xingyun Huang, Kim Siang Khaw,  
Jun Kai Ng and Guan Ming Wong (with strong  
support from the PSI muon group)



李政道研究所  
TSUNG-DAO LEE INSTITUTE

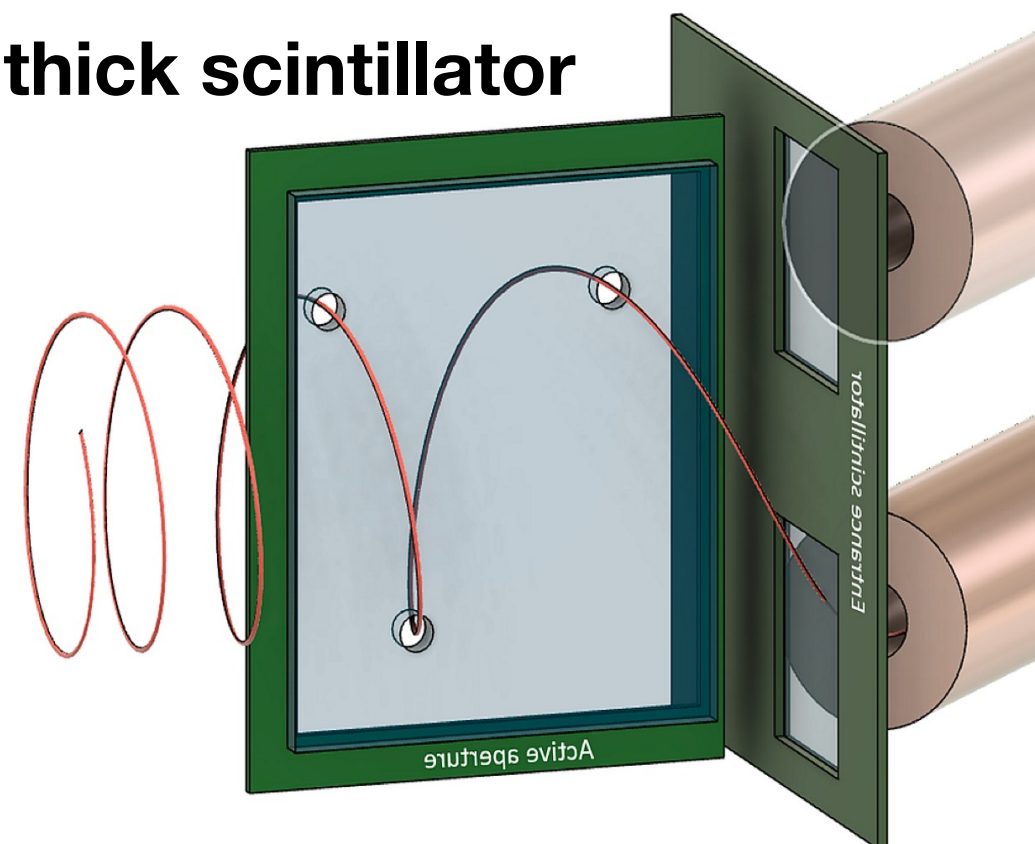


# Overview of the muon trigger detector



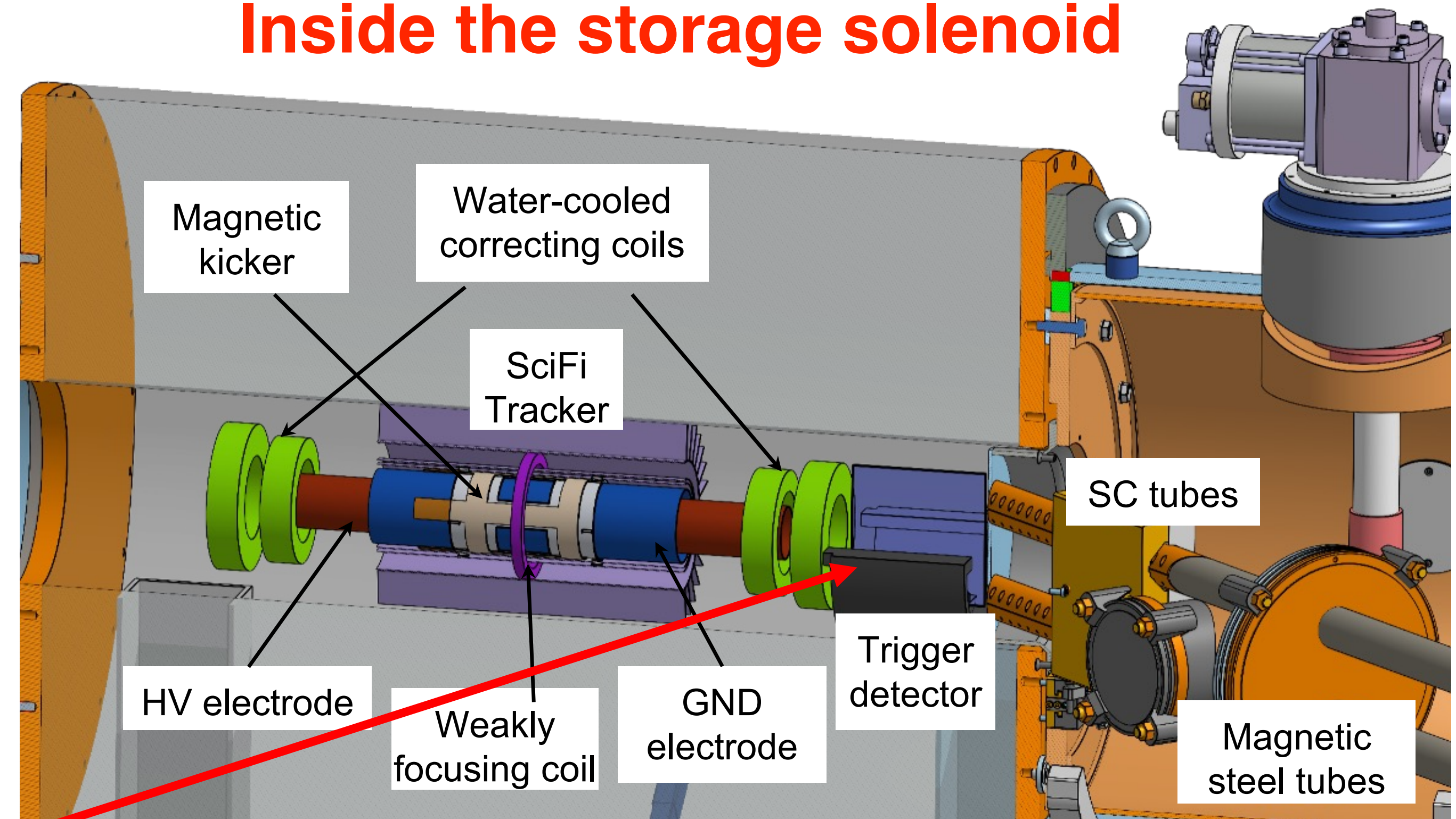
5 mm thick scintillator

Conceptual design



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

## Inside the storage solenoid

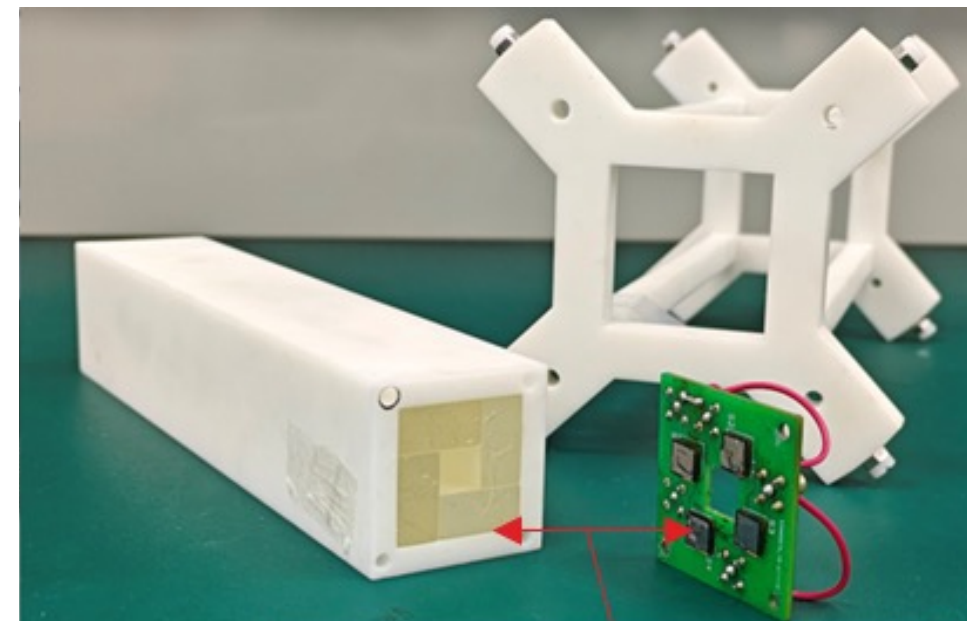
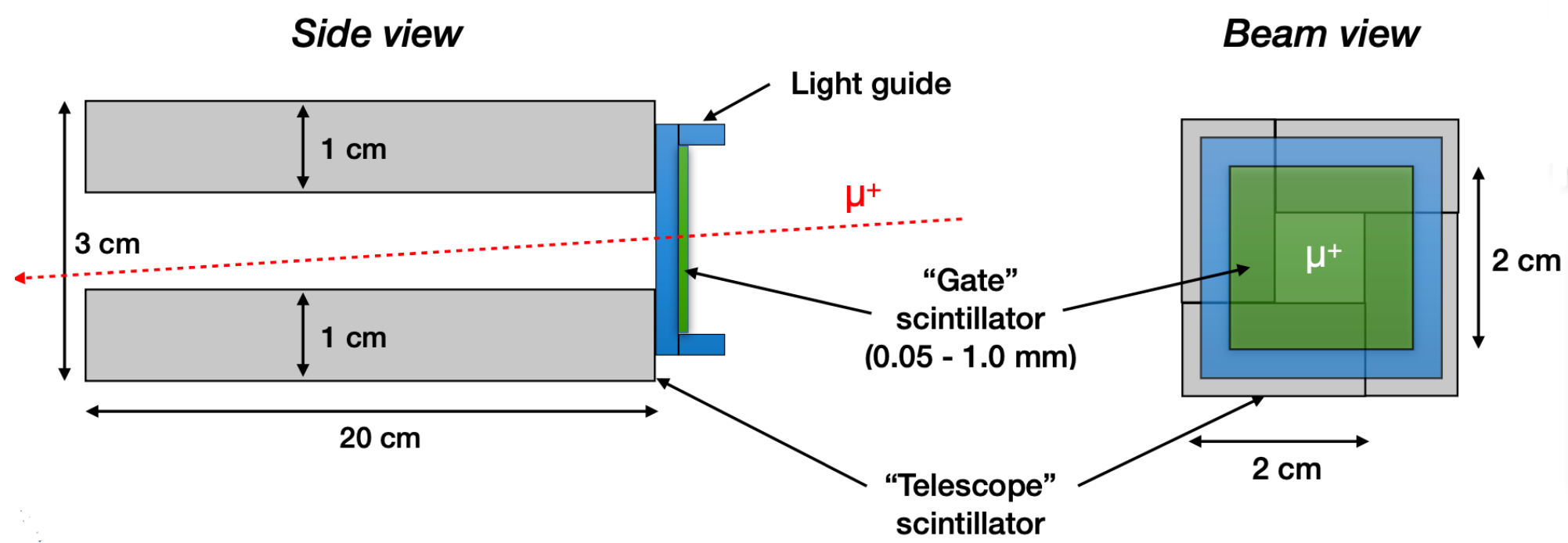


### Main requirements:

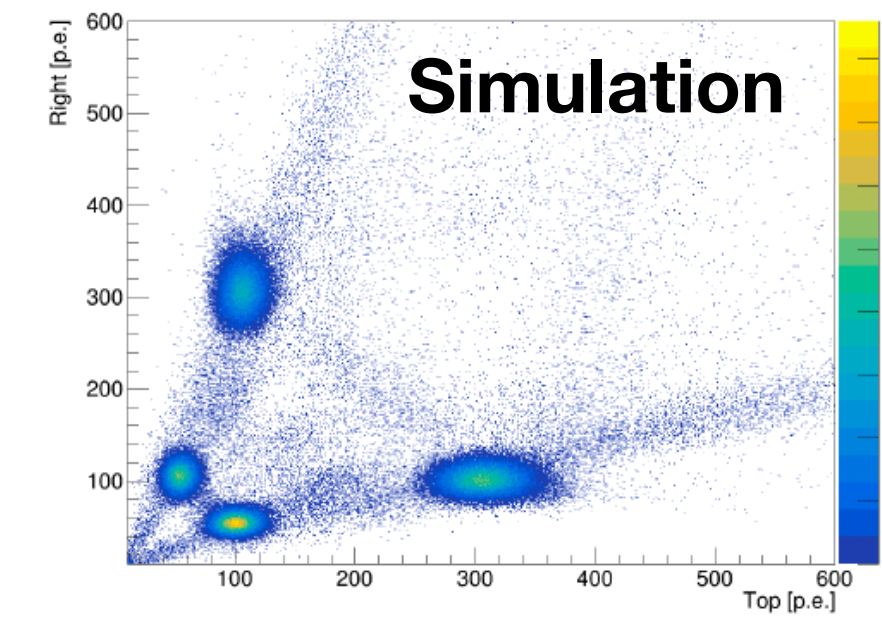
- Detects incoming muon while minimizing scattering
- Generates trigger signals for “storable” muons (~2%) (reject out of acceptance muons)
- < 25 ns signal delay from muon detection to HV switch for the magnetic kicker

# Proof of concept experiment in 2022

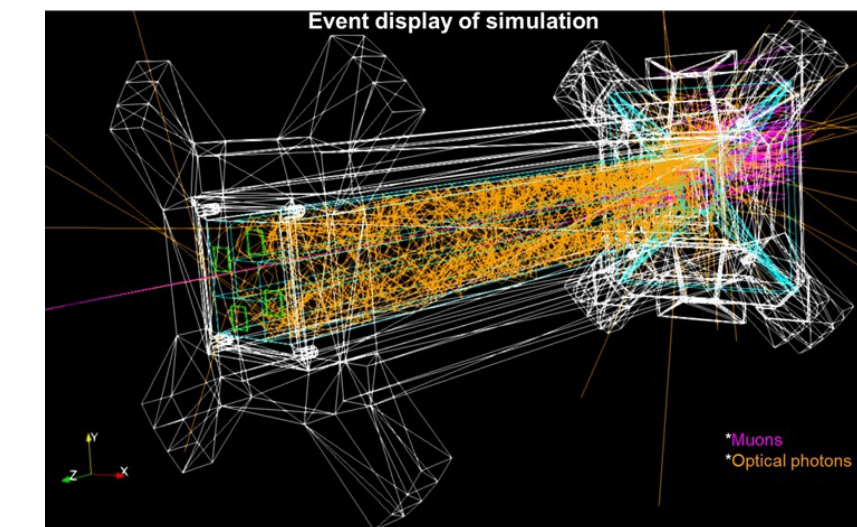
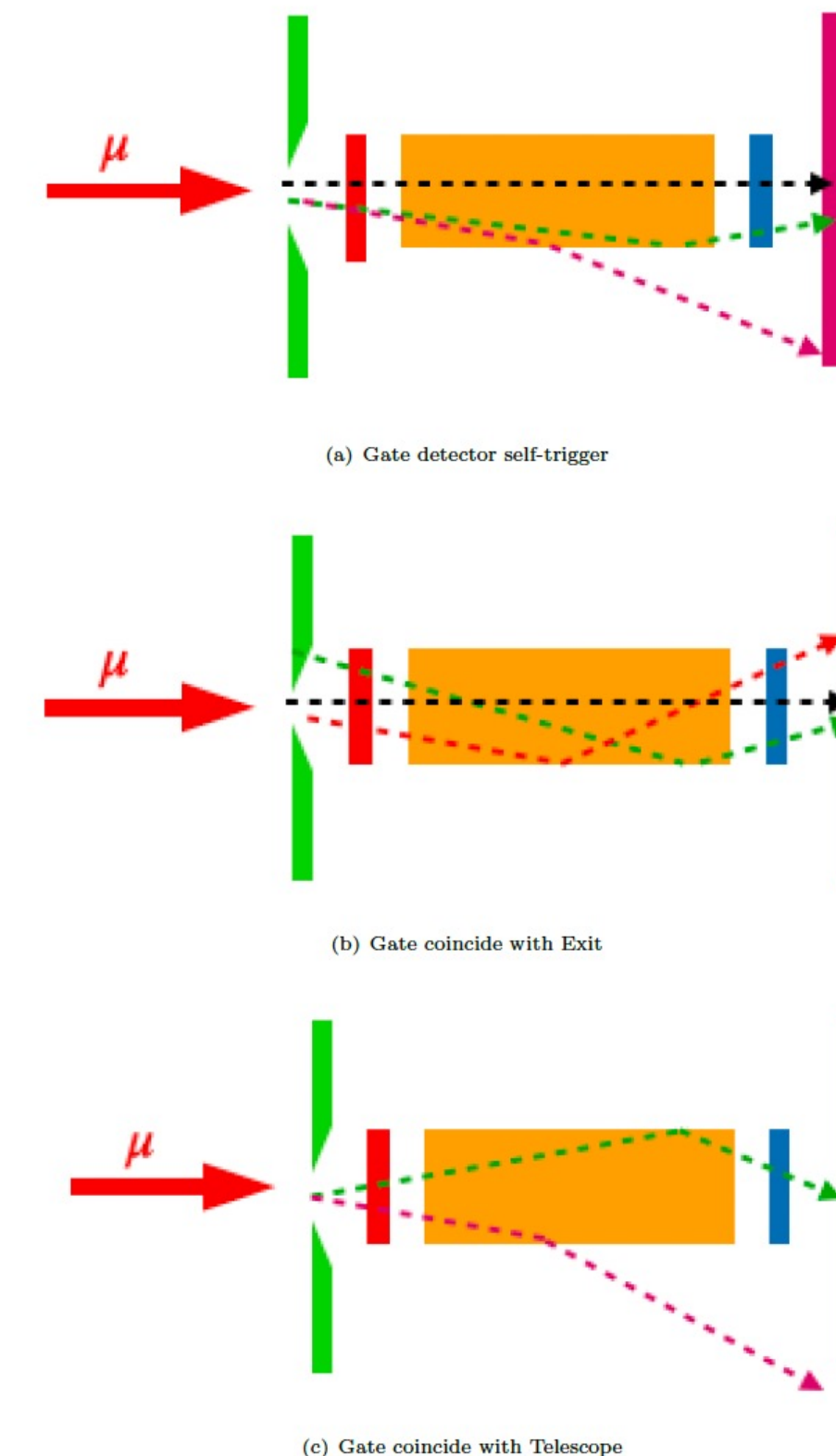
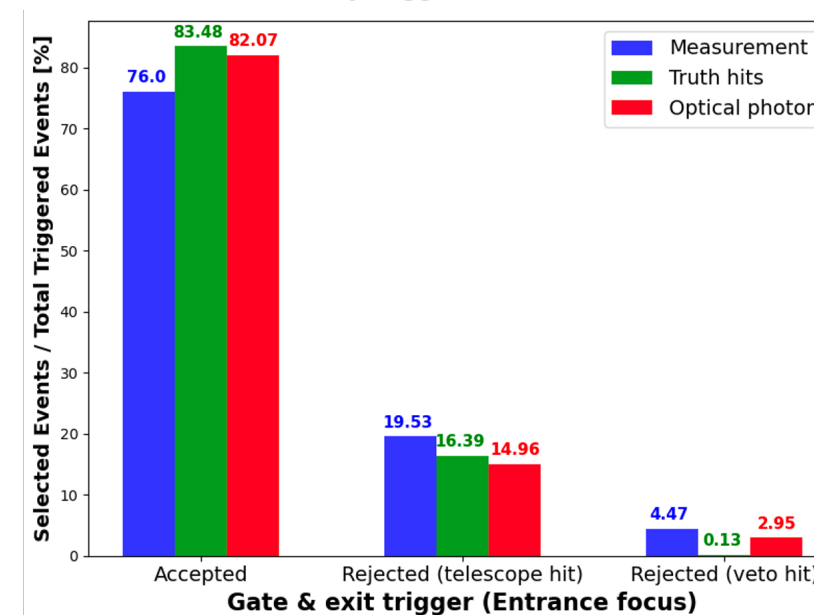
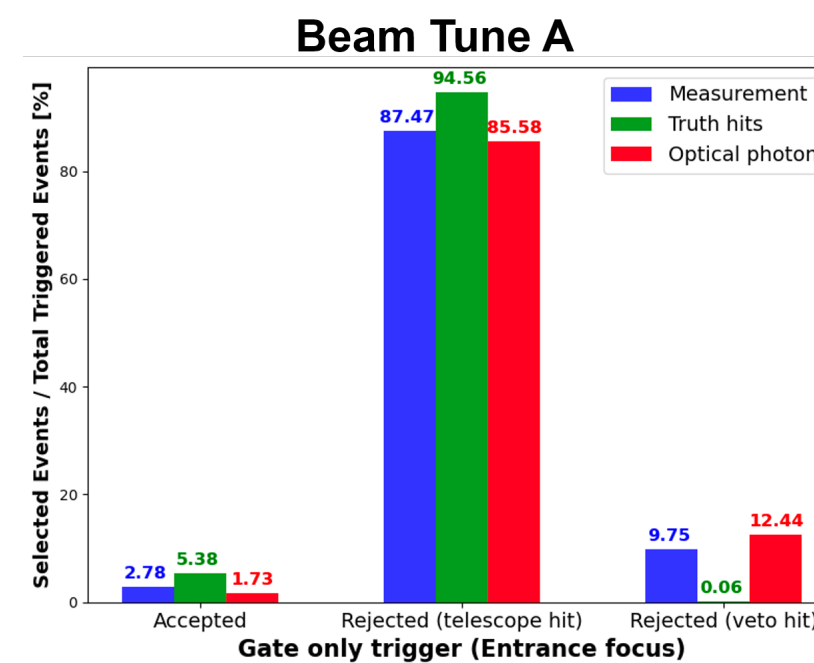
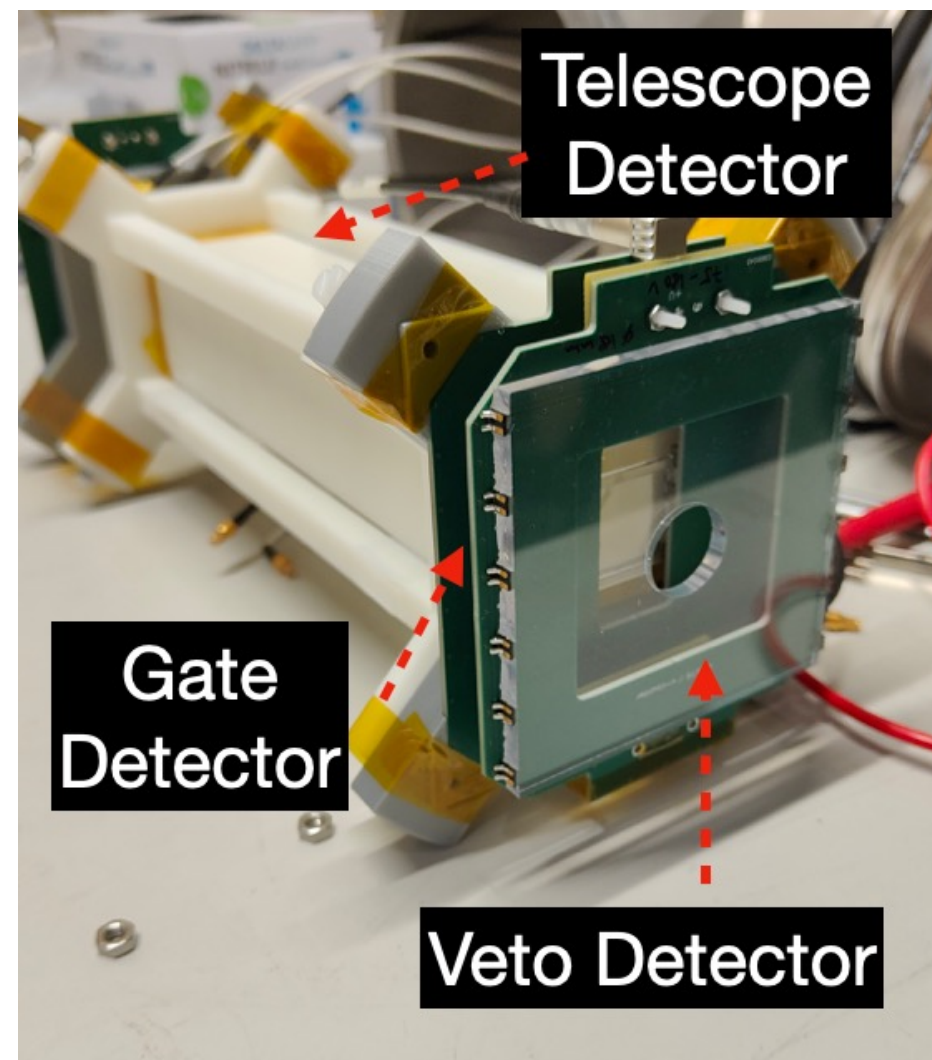
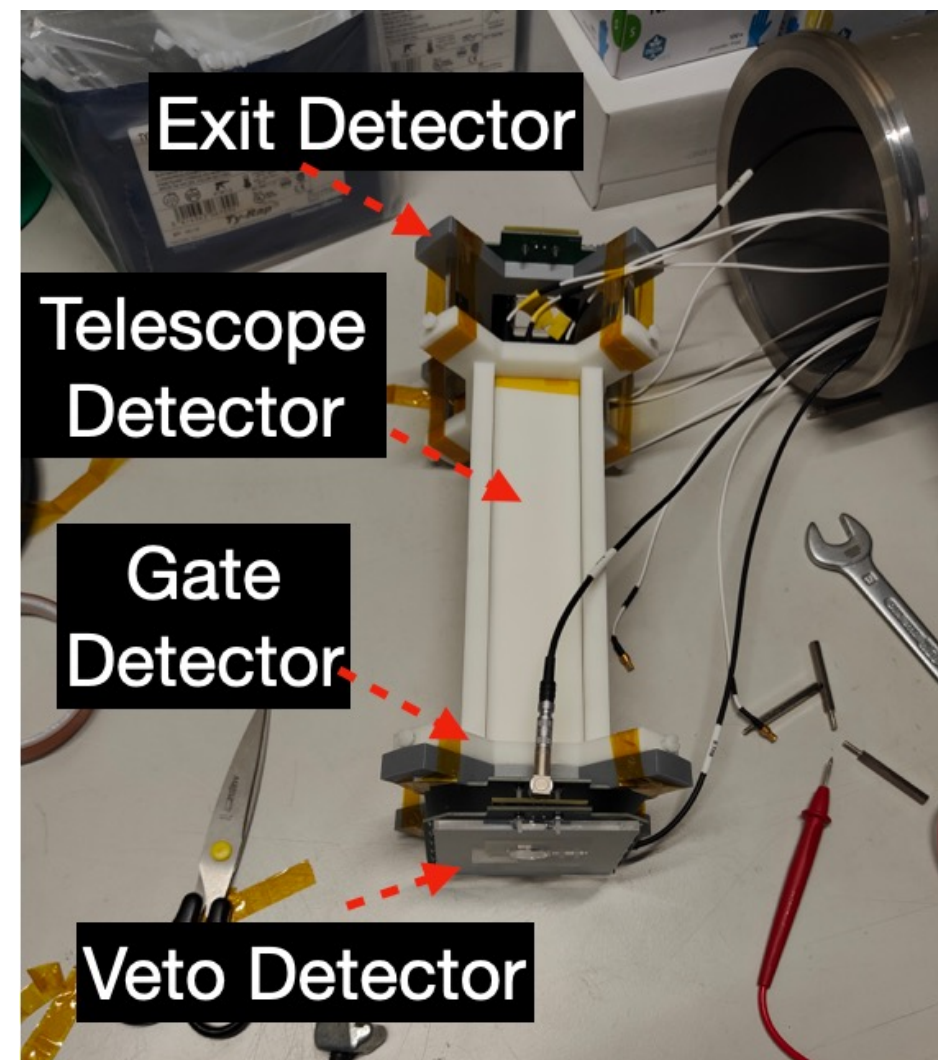
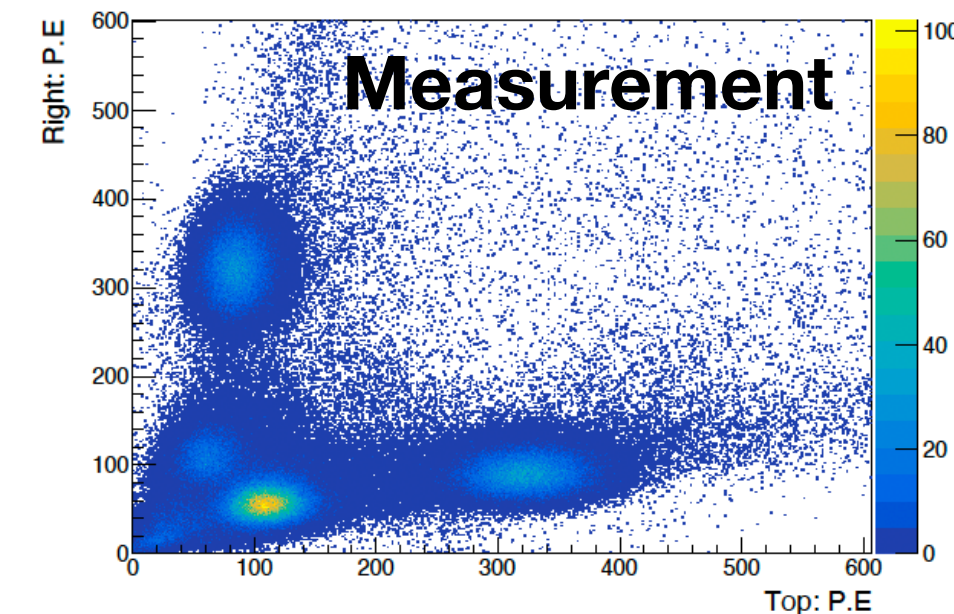
## Beam Test at PSI in 2022 to test the idea (no magnetic field)



Right vs Top (Adjacent Channels)

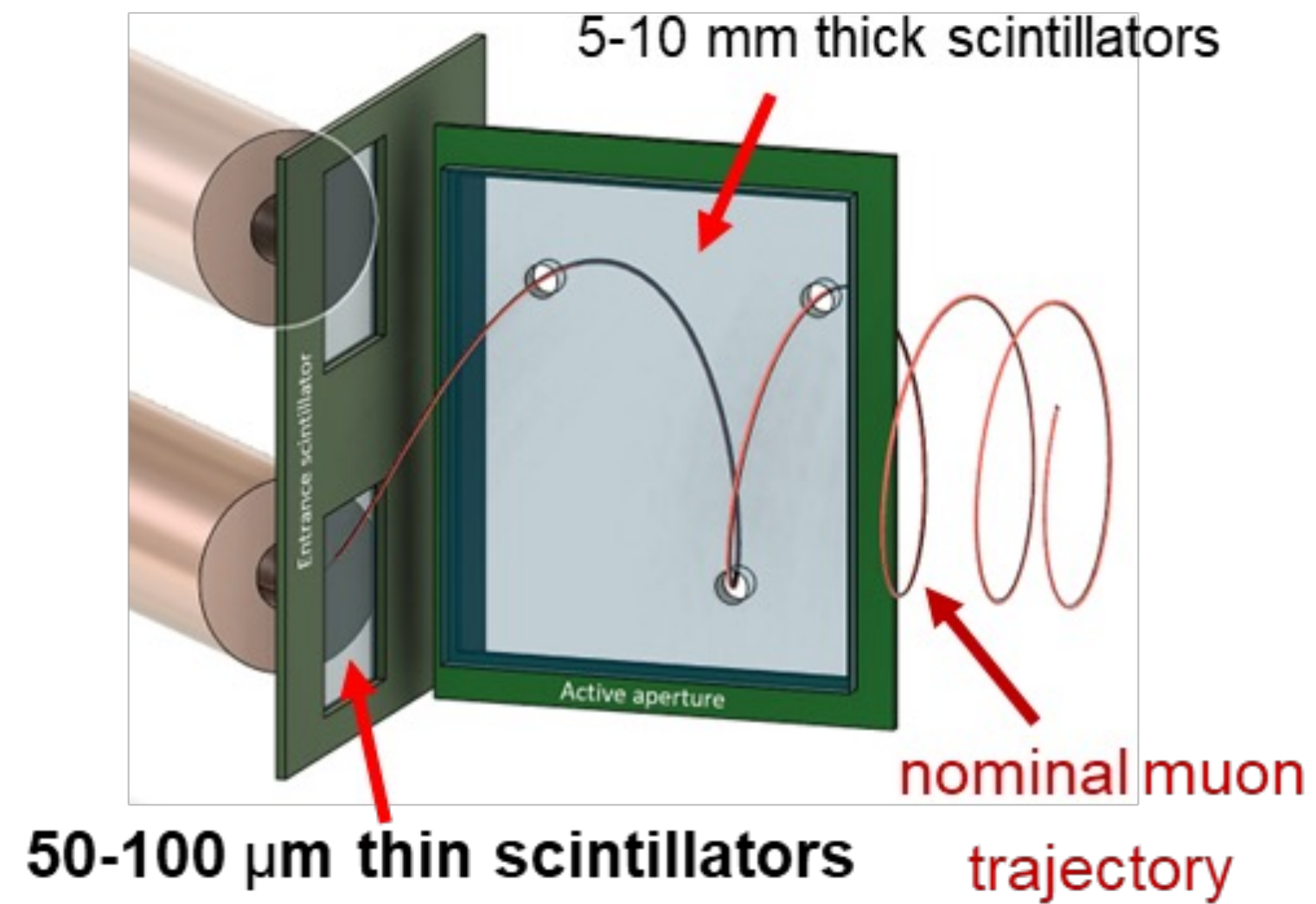


Right VS Top (Adjacent Channels)



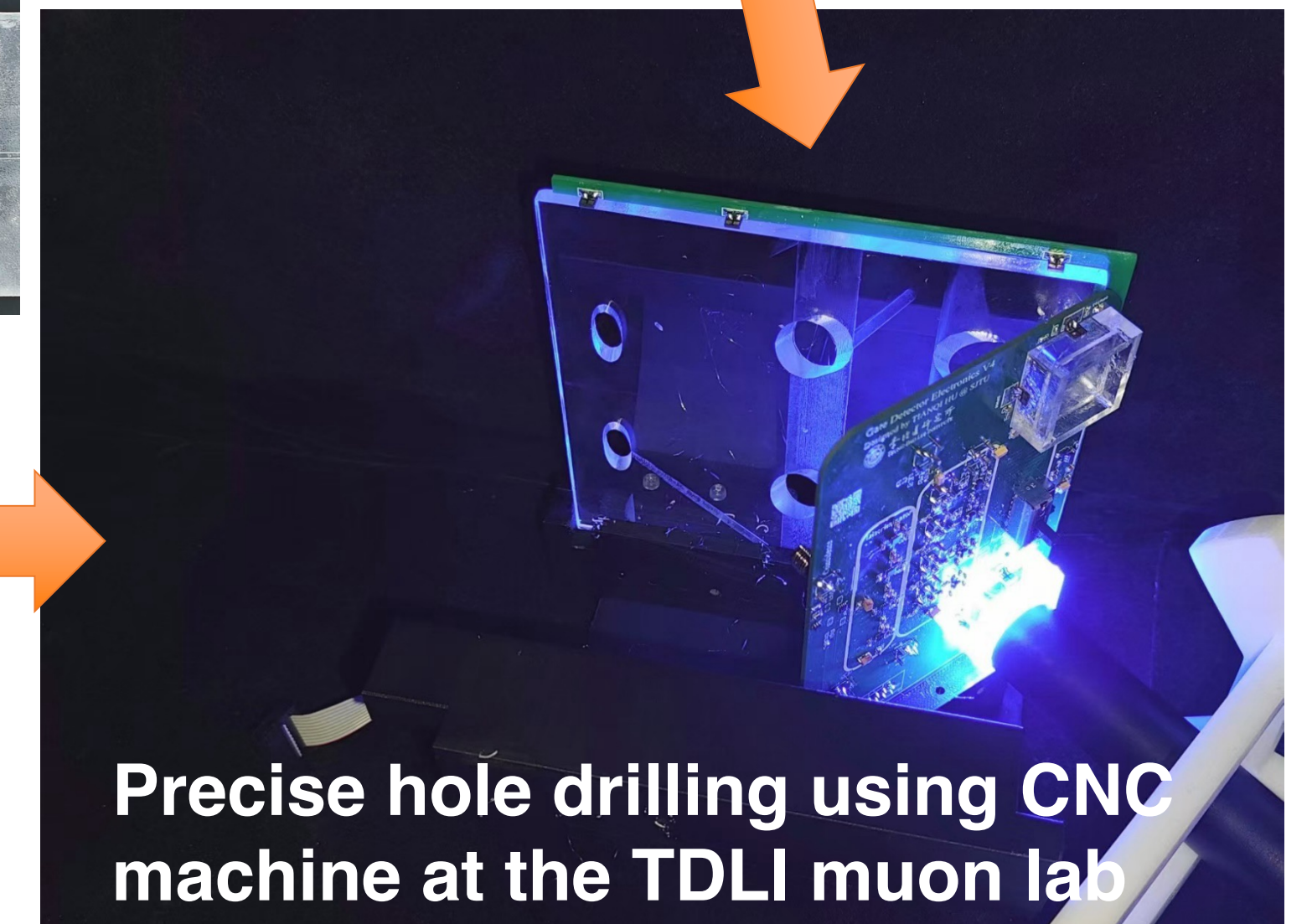
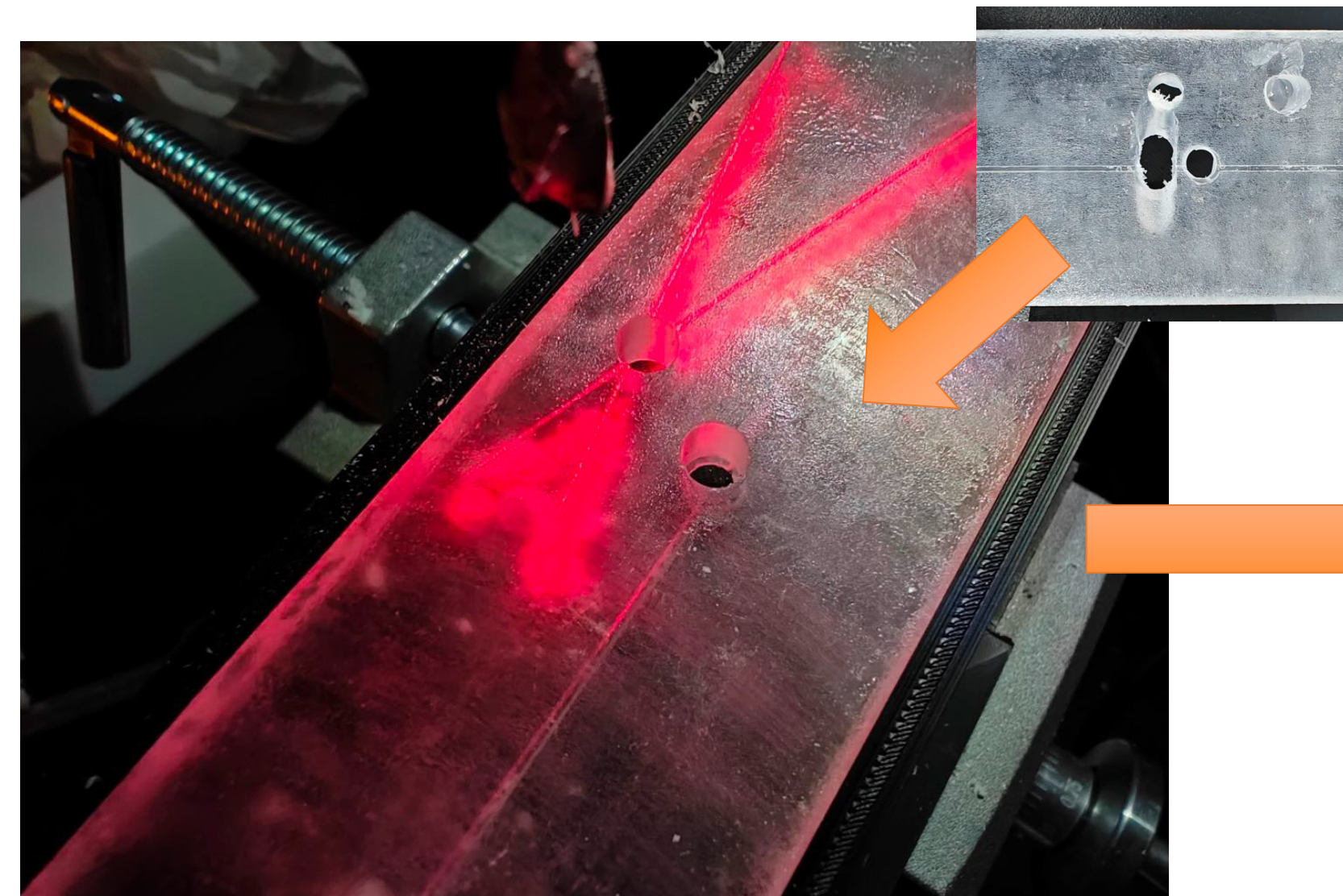
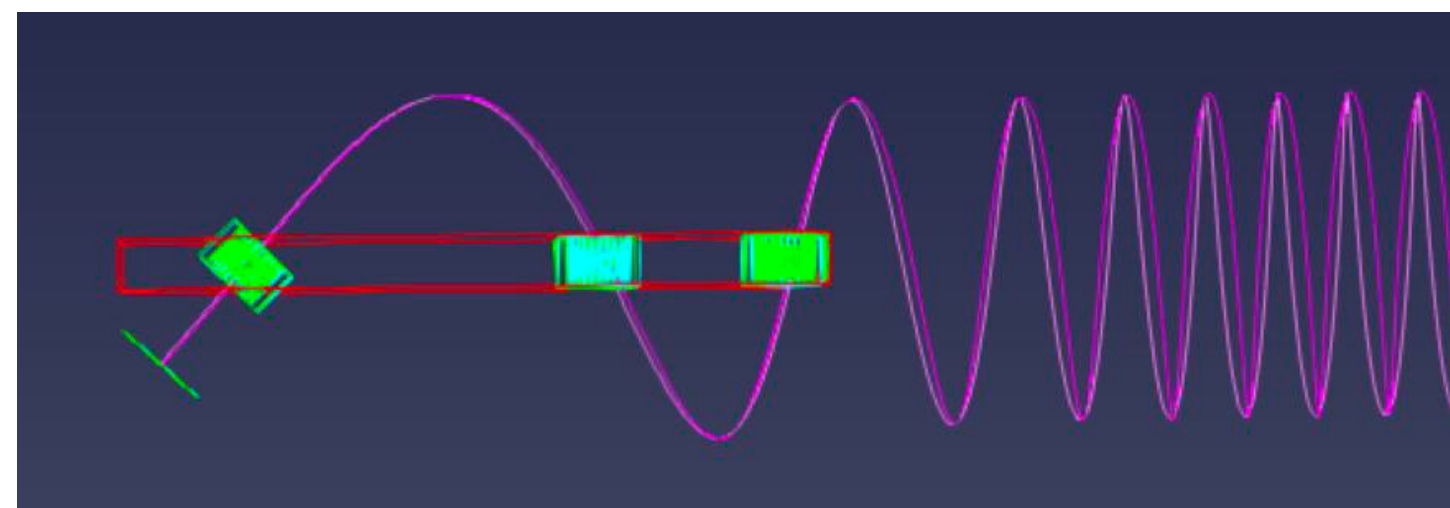
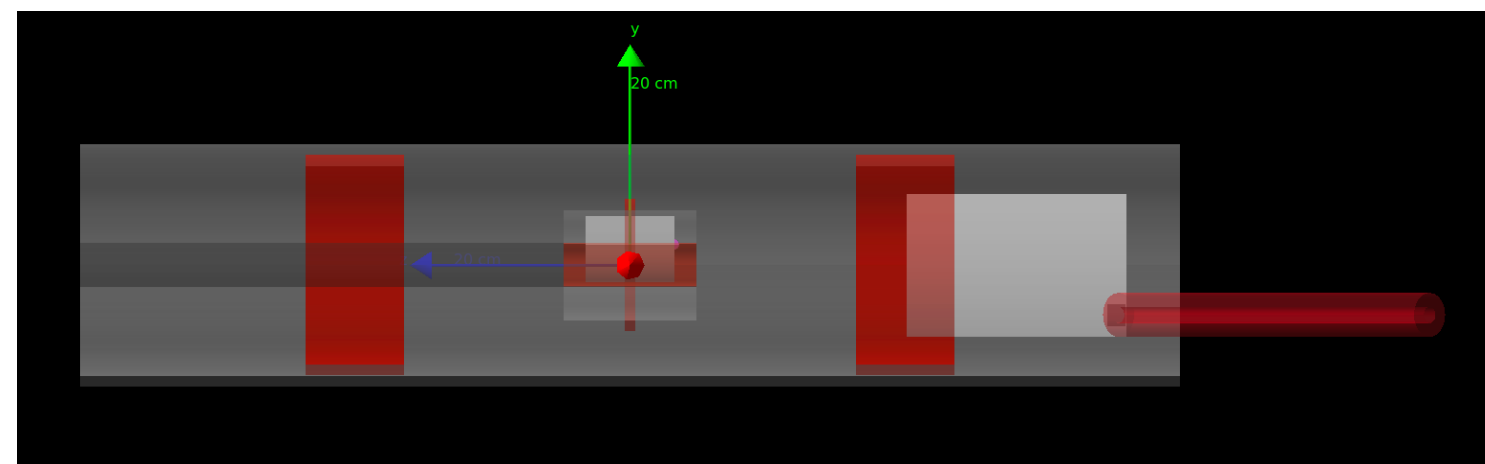
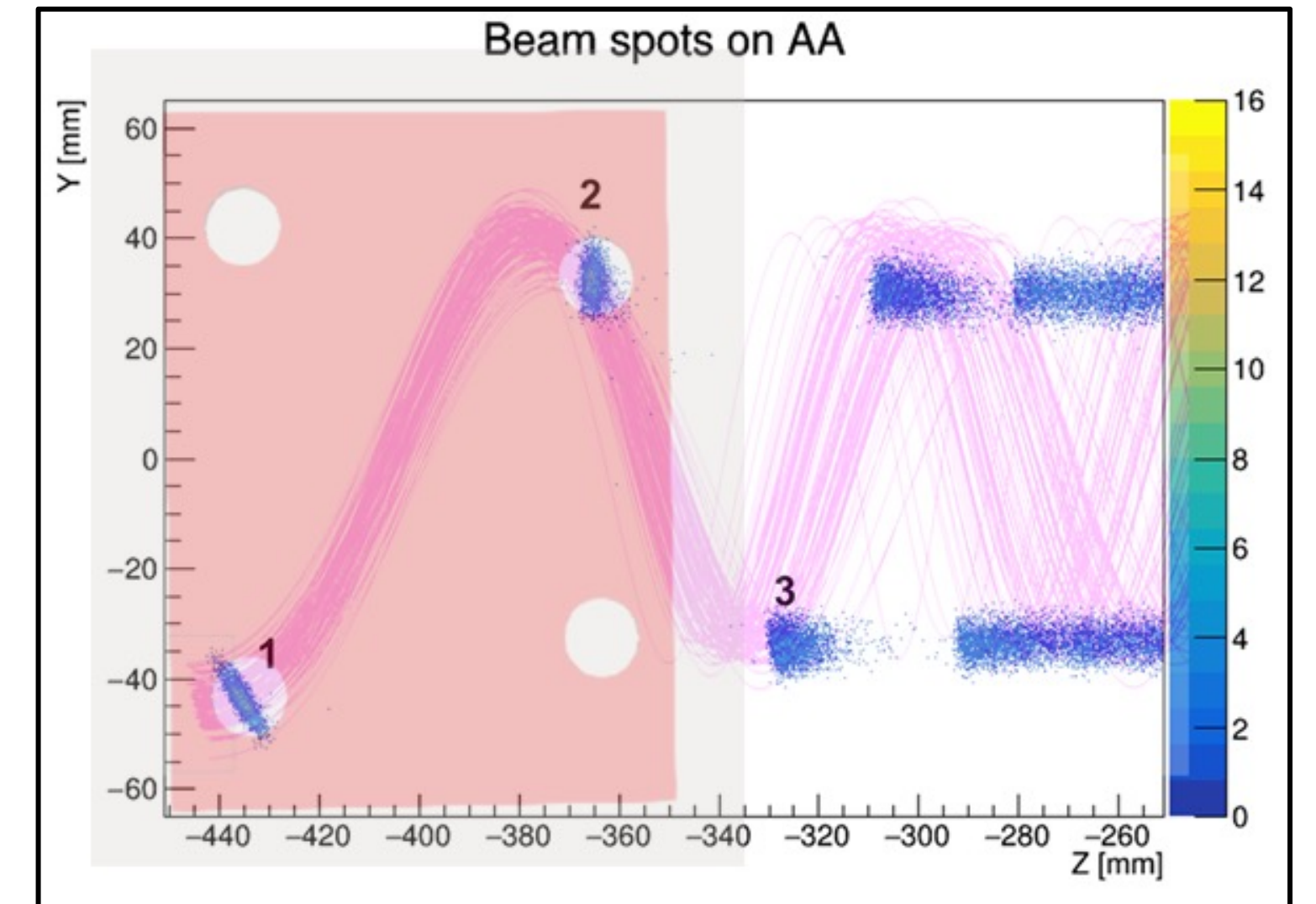
Event topologies were reproduced following the activation of optical photon processes in Geant4.

# Detector design and development

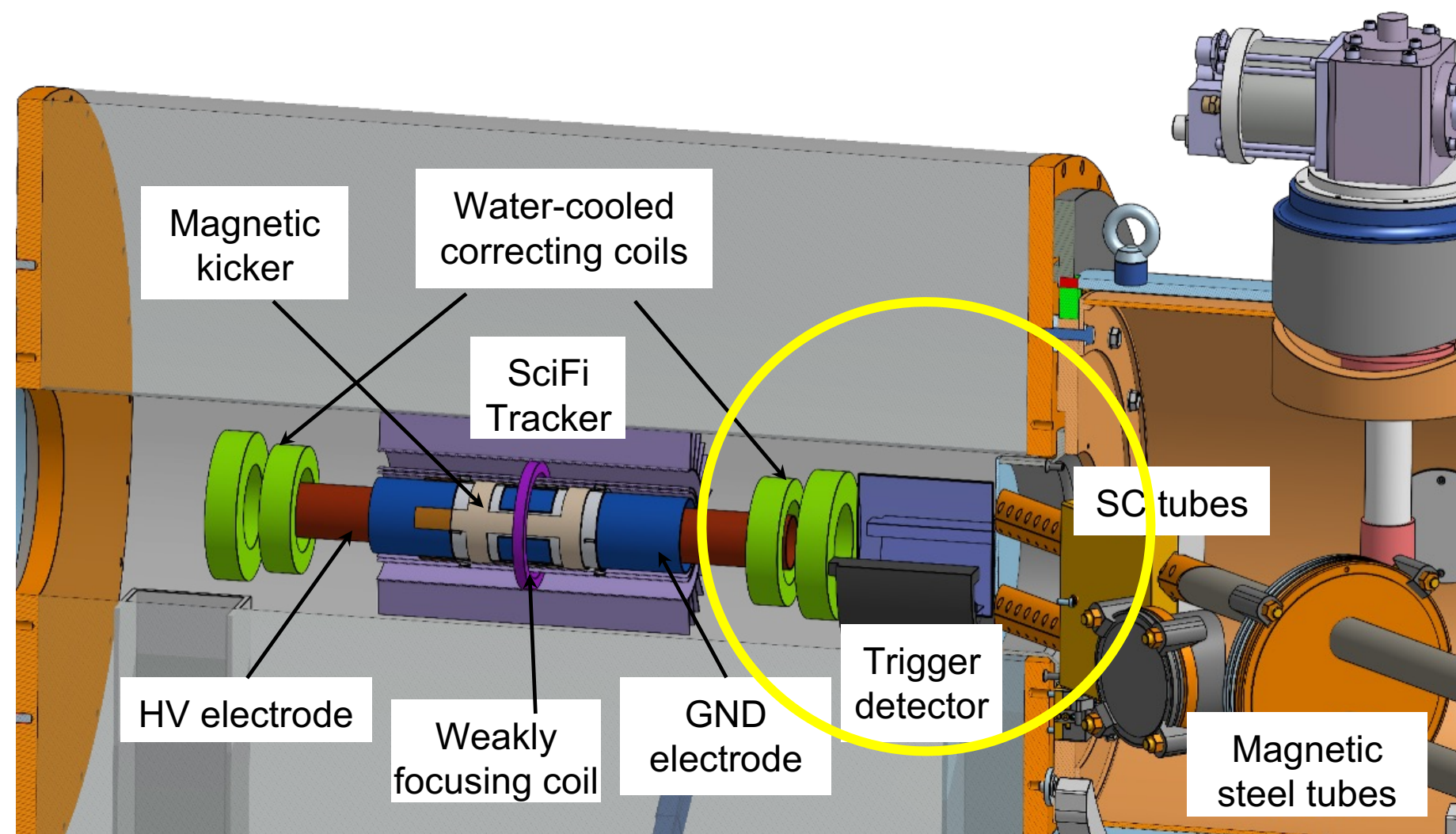


Using G4beamline and musrSim models to:

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

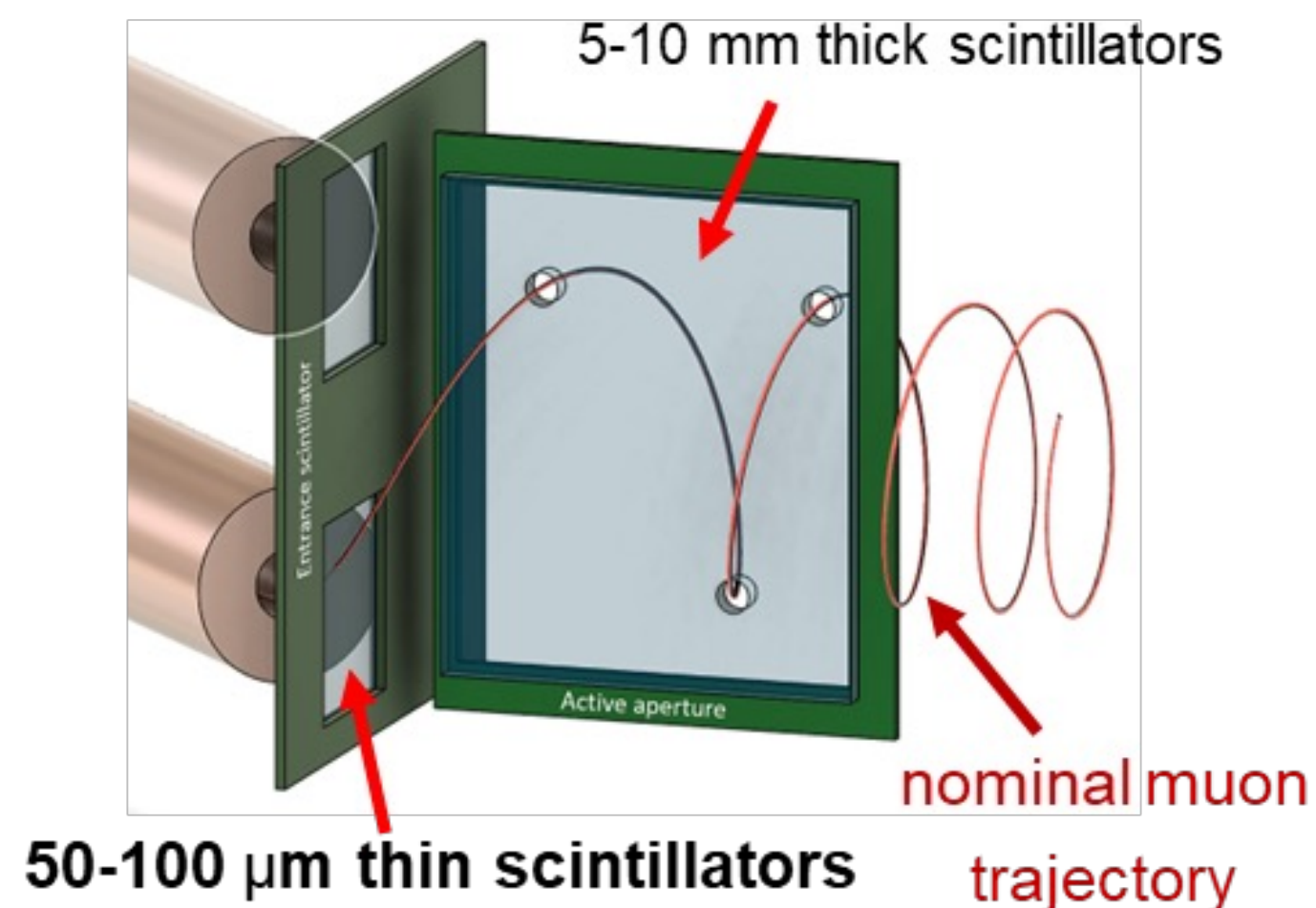
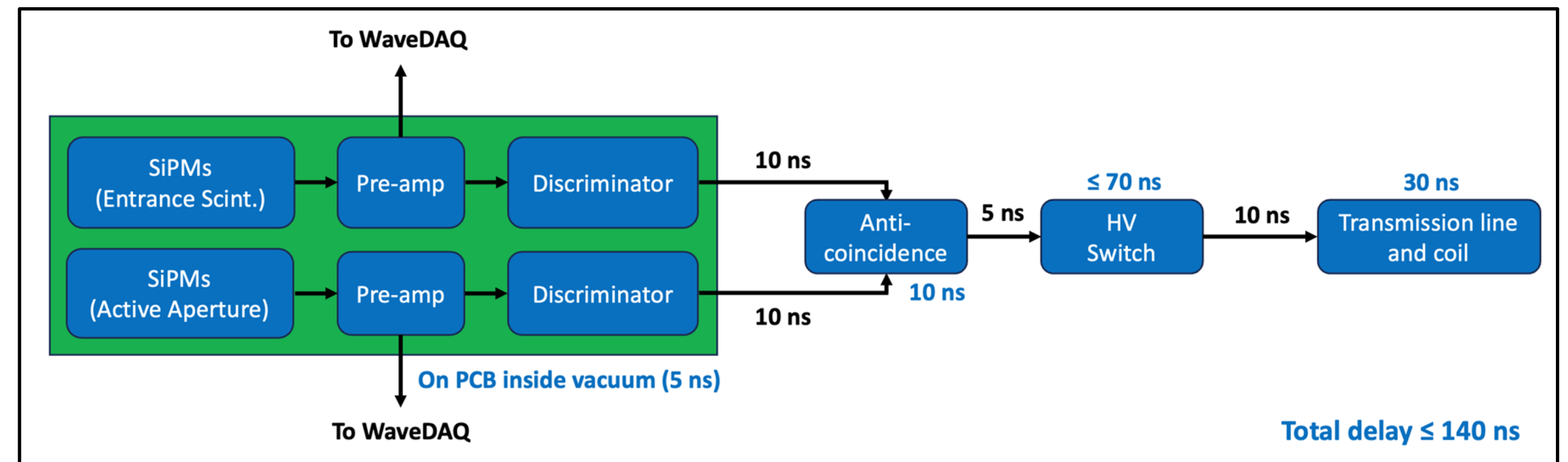


# Fast trigger for the magnetic kicker



Fast electronics design to satisfy strict timing requirements

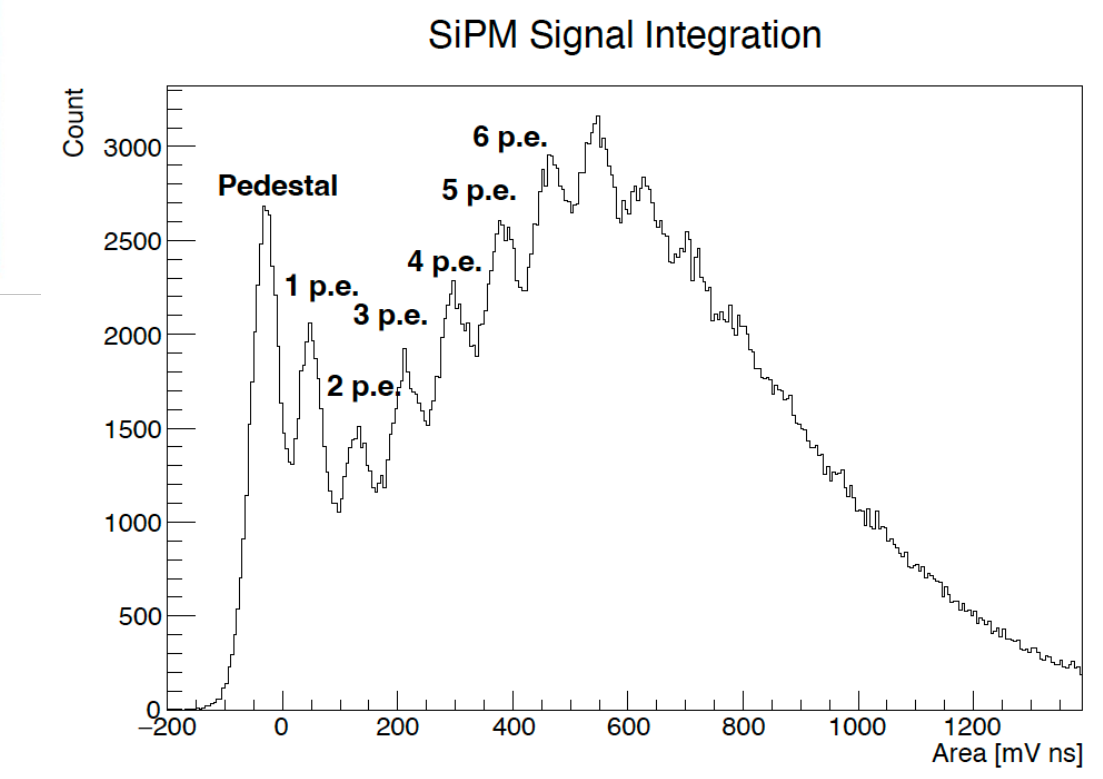
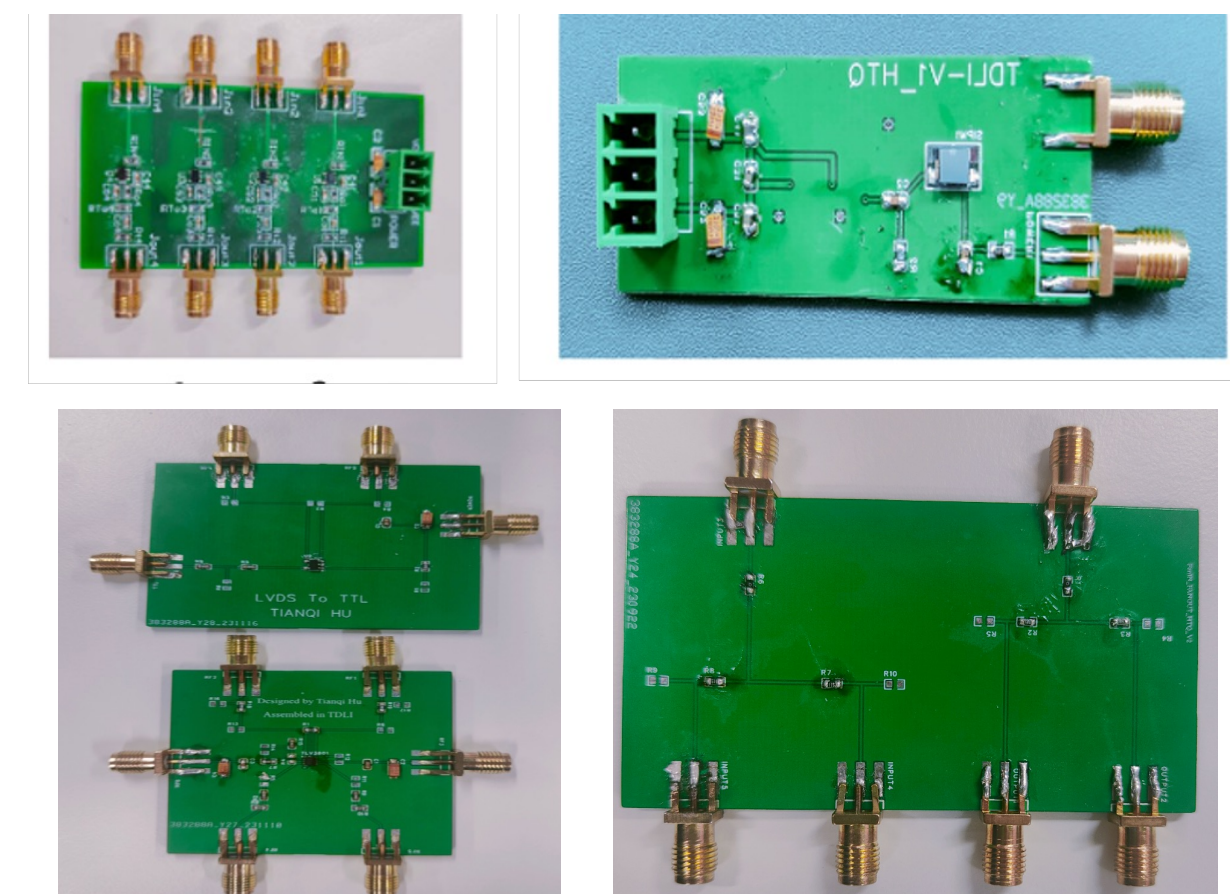
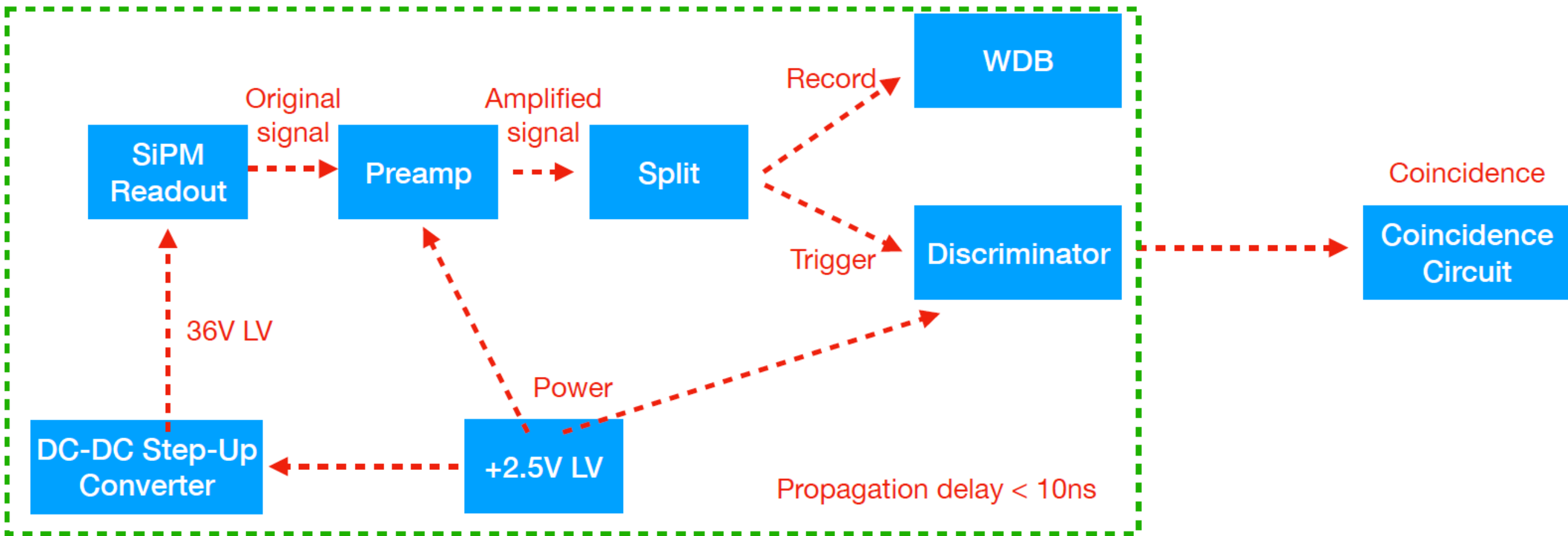
- CAEN products/WaveDAQ have delays  $> 10$  ns
- systematically searching for all fast chips on the market for each functionality



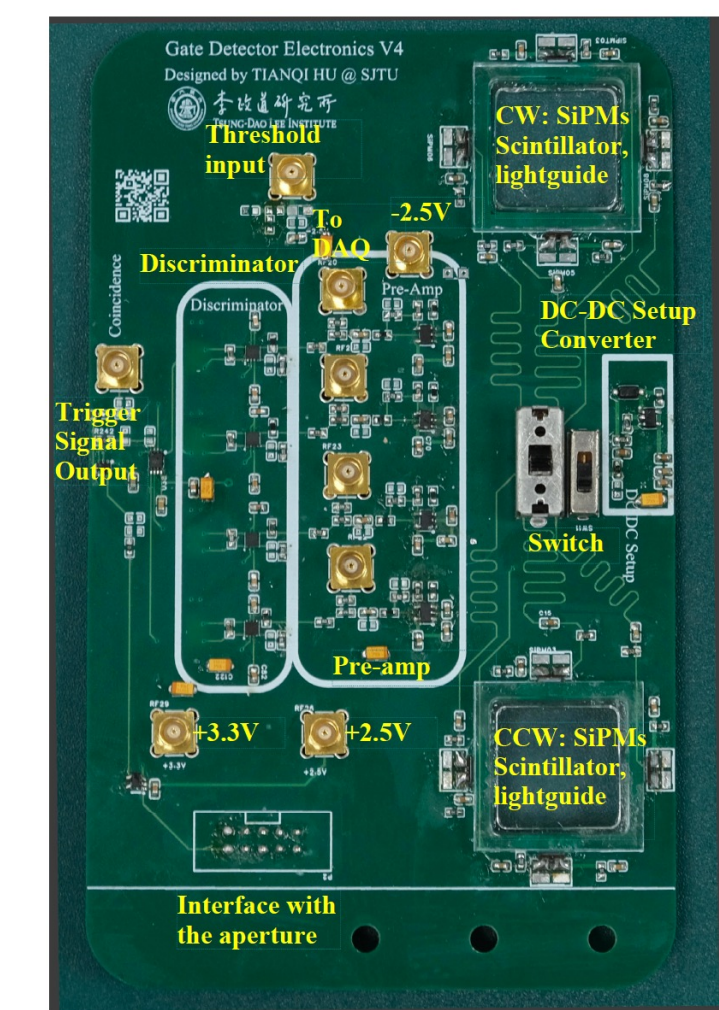
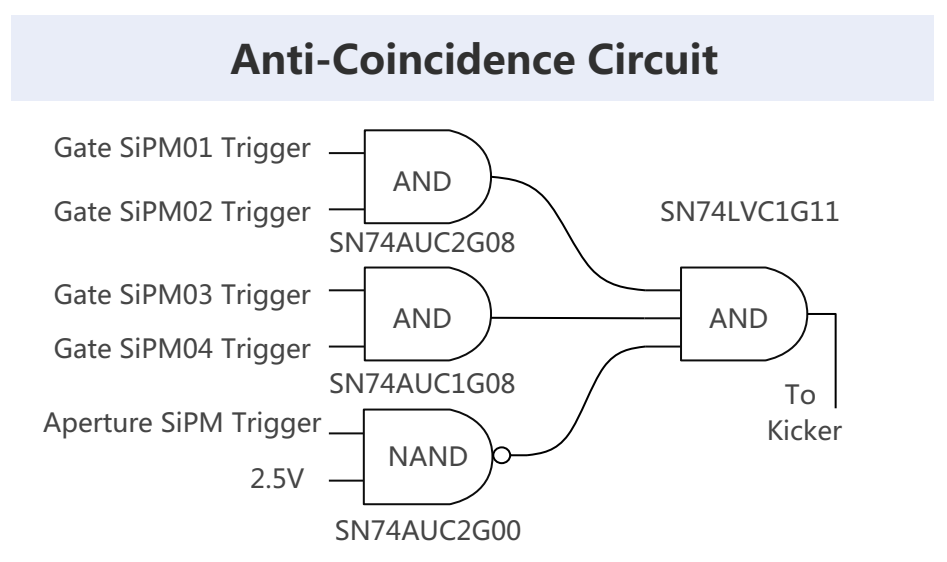
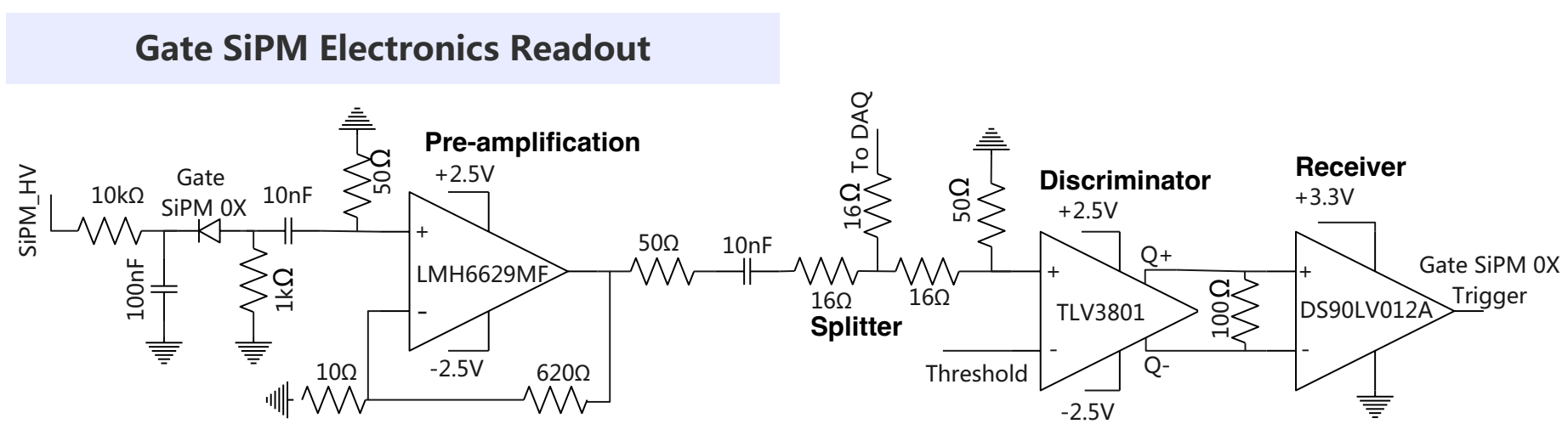
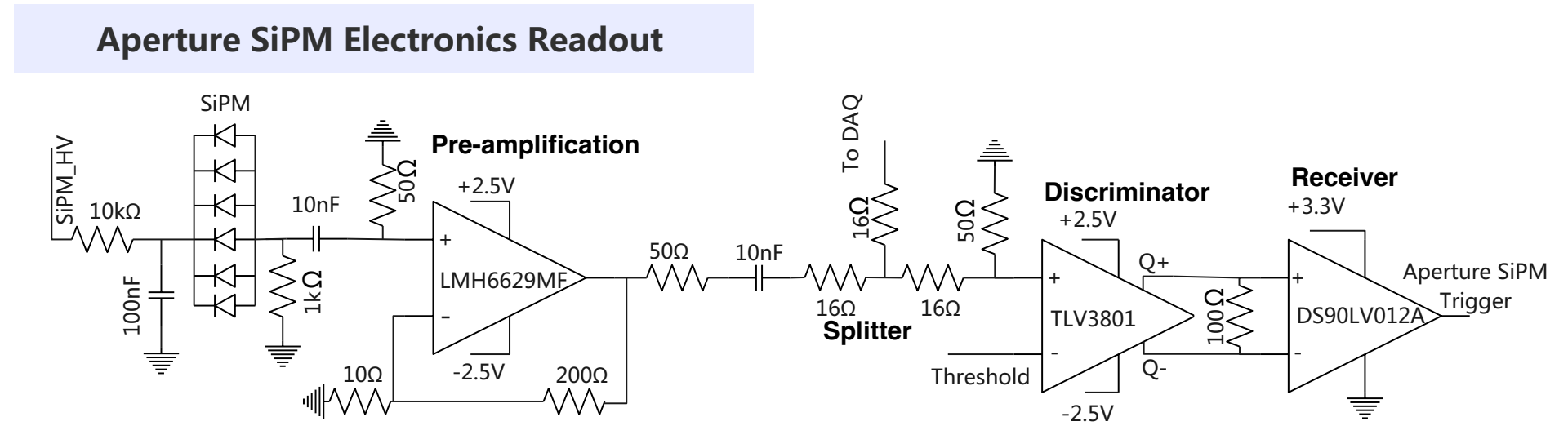
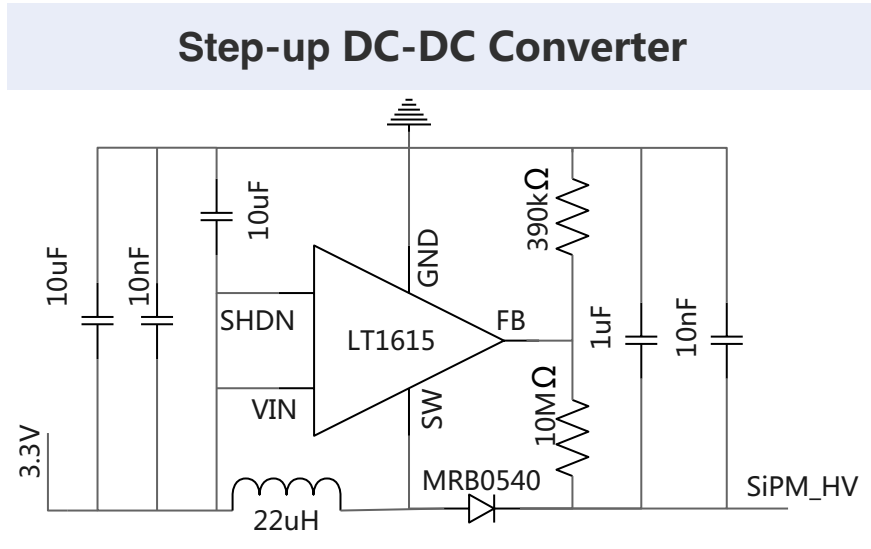
Particles	Average Energy deposition(MeV)	Photons per SiPM	Average Photons per SiPM	Pre-amp(mV) (20dB)	Split Out (mV)
Positron	0.017	<3	0.6	<12	<4
Muon	0.190	5~9	6	20~36	7~12
Pion	0.307	8~12	9	32~48	11~16

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

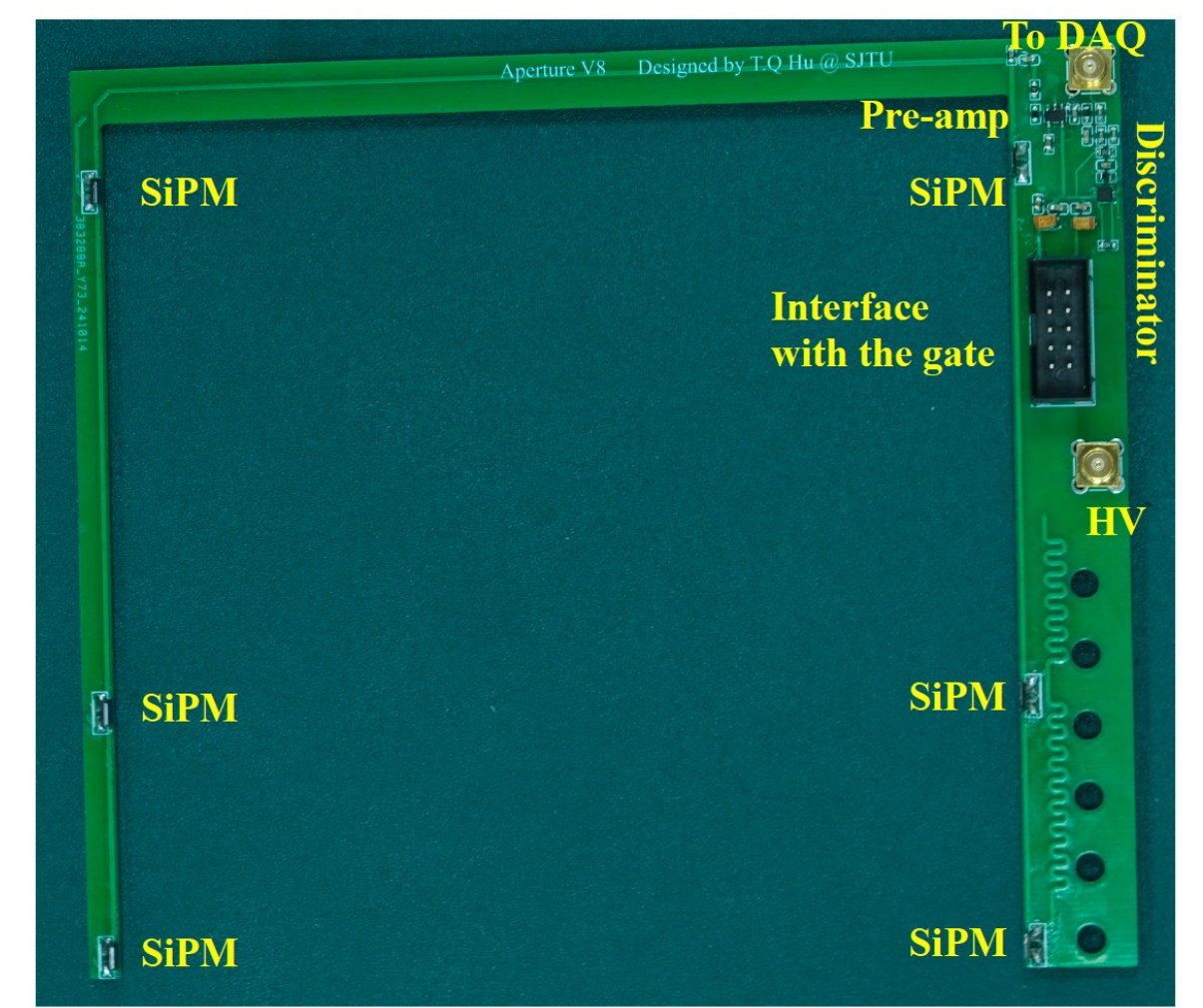
# Electronic design and fabrication



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

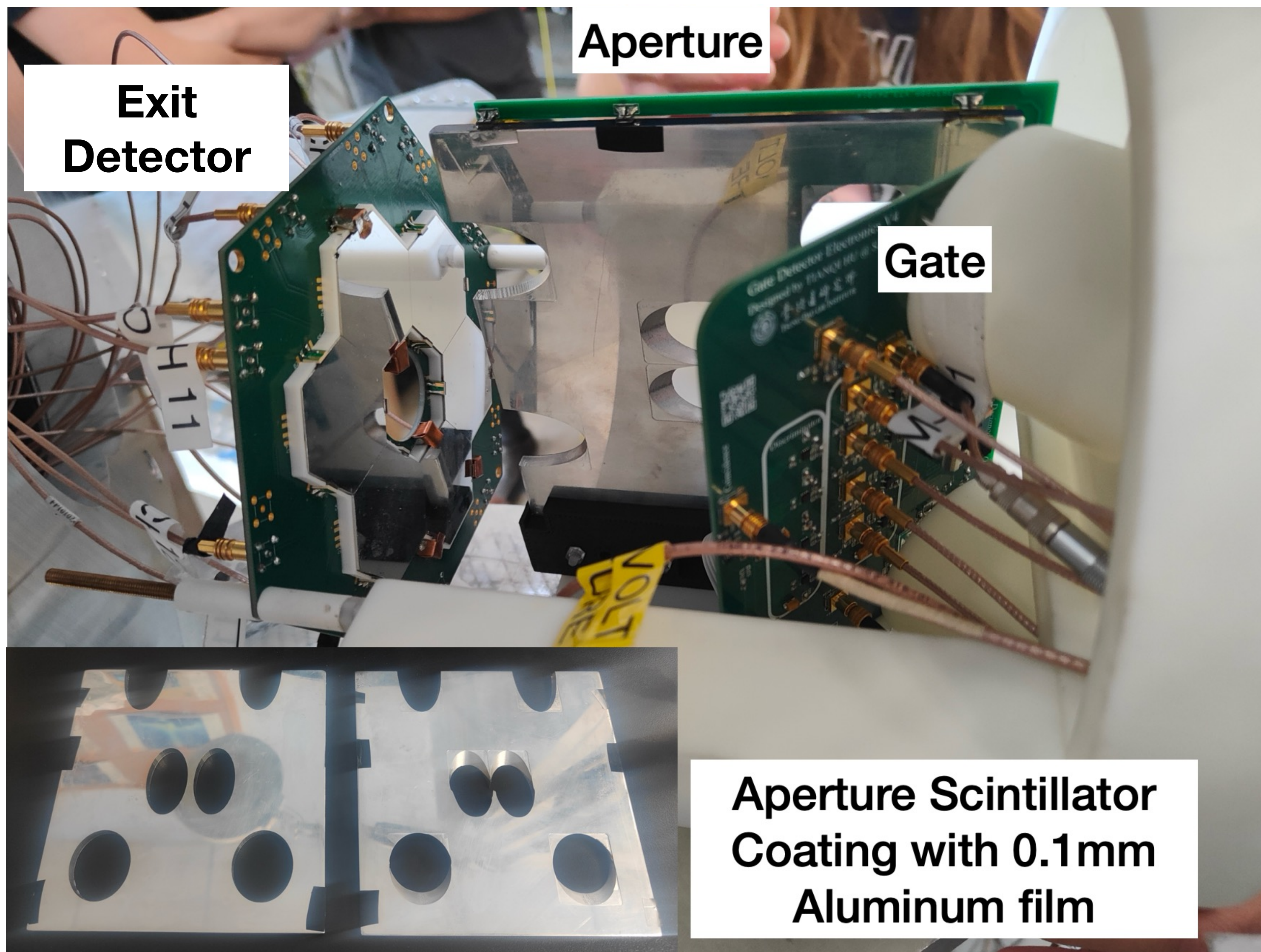


**Gate PCB**



**Aperture PCB**

# Beam time @ PSI in Oct/Nov 2024



## Tested 3D spiral injection

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

## Characterized Trigger Detector

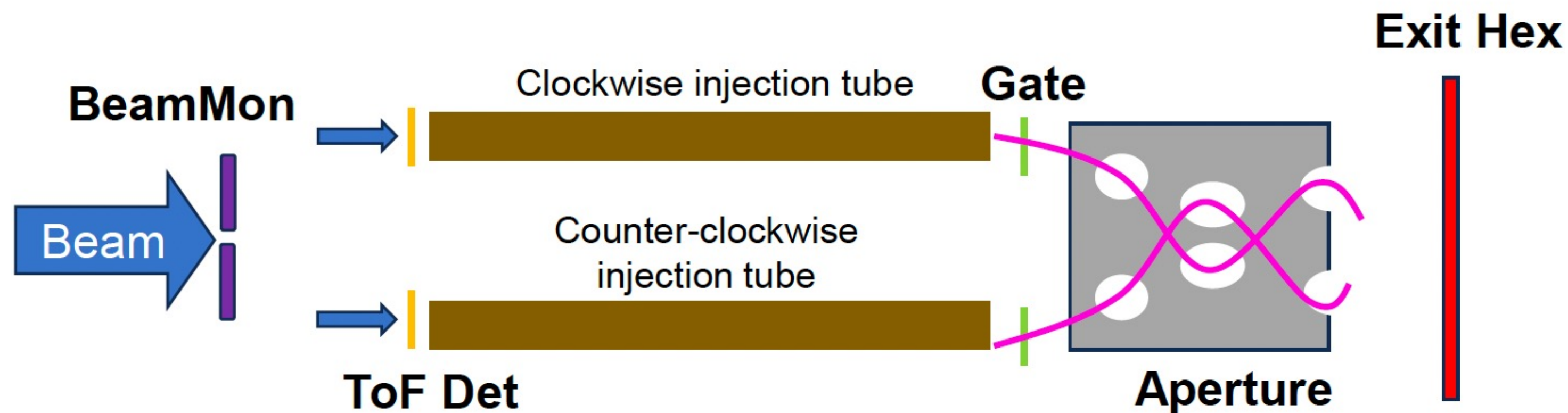
- Performance of fast electronics readout
- Acceptance rate and rejection rate
- Induced background studies



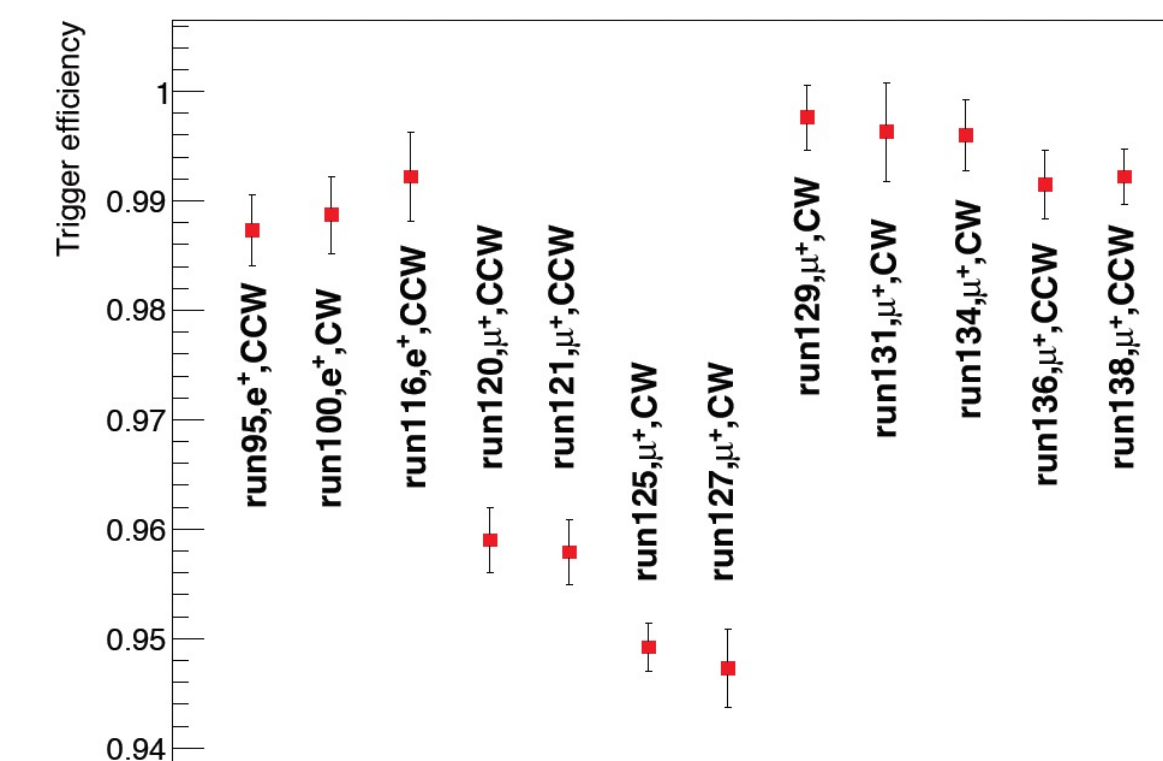
# Preliminary results

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

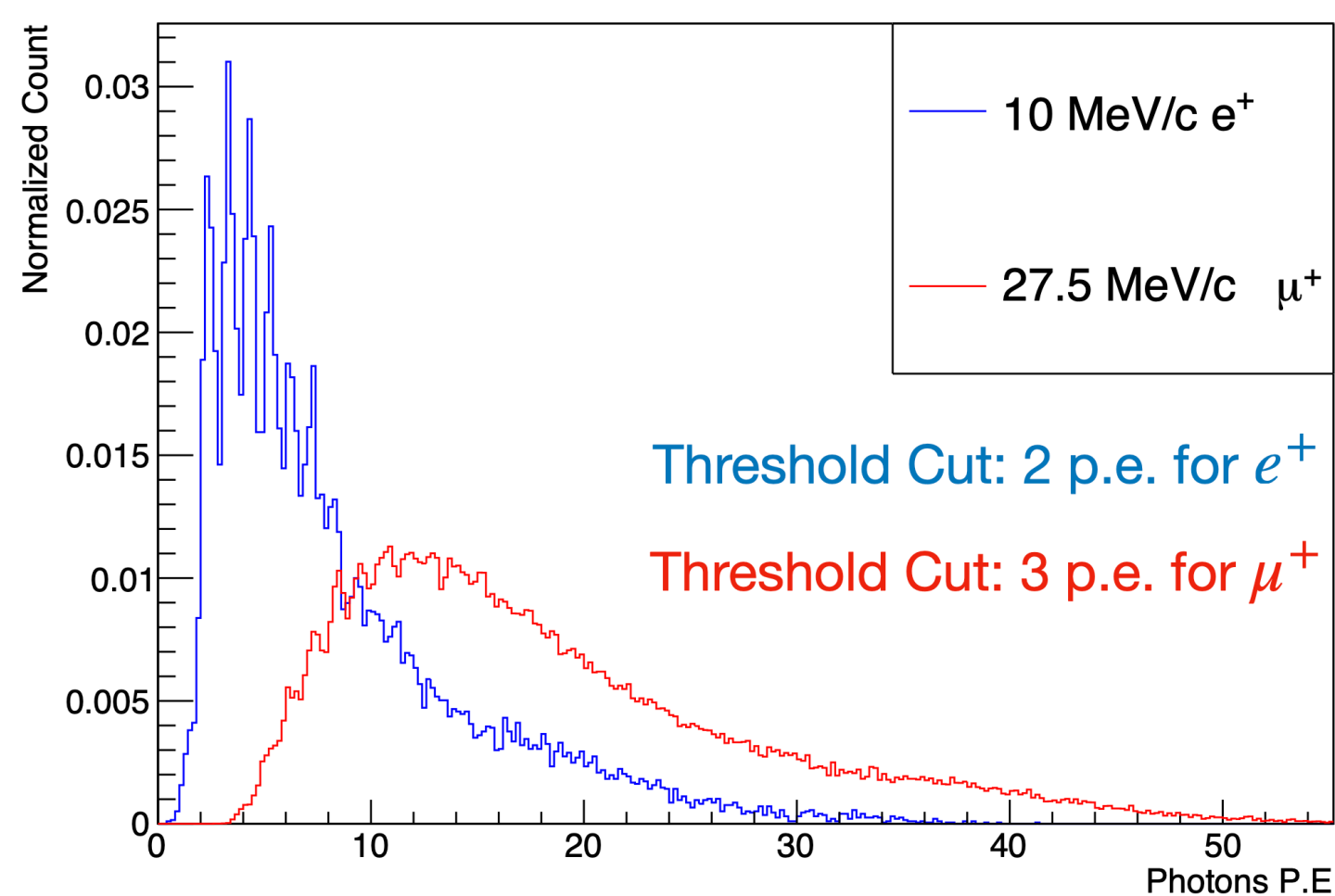
## Scheme of detectors



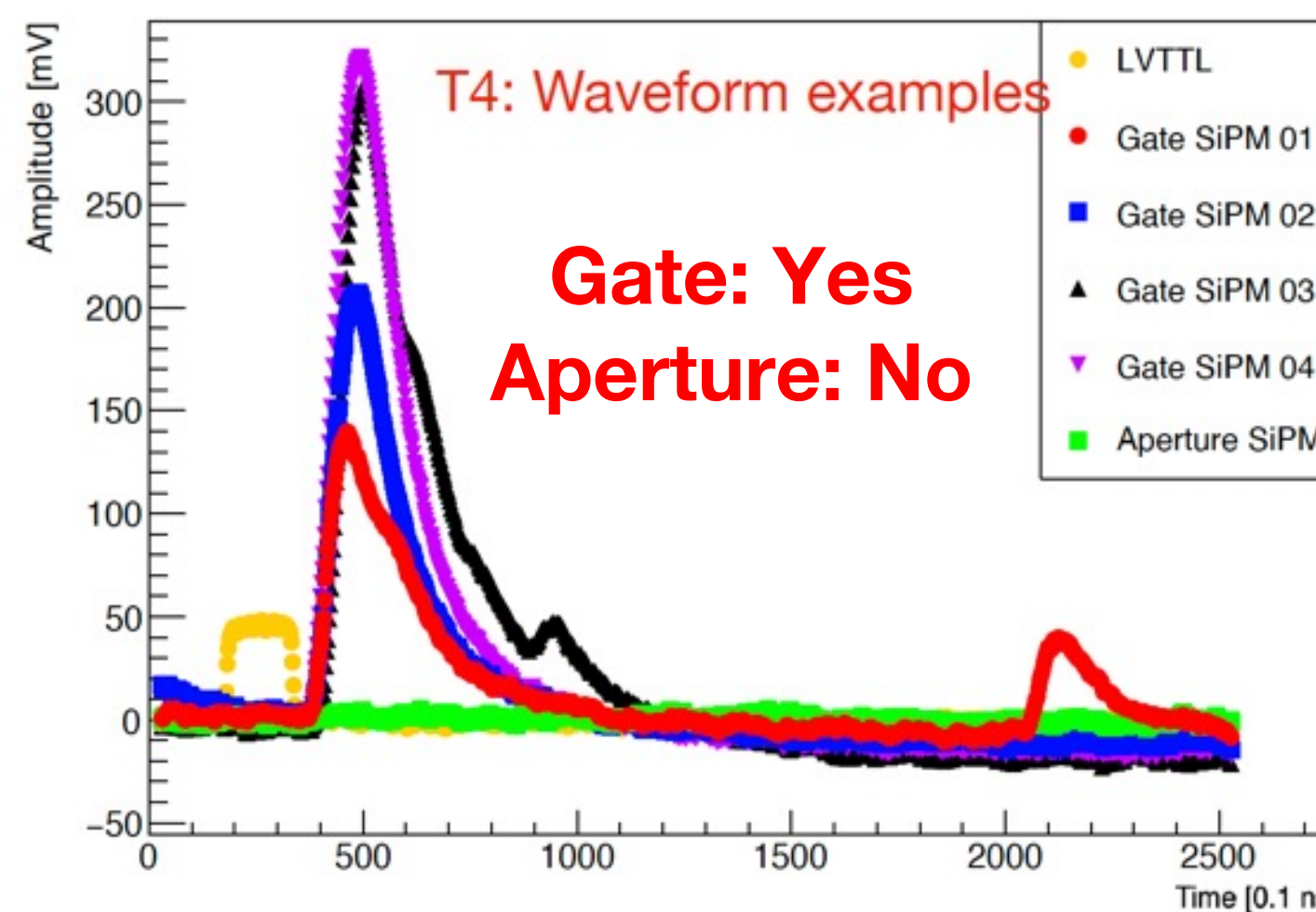
Trigger efficiency at the anti-coincidence



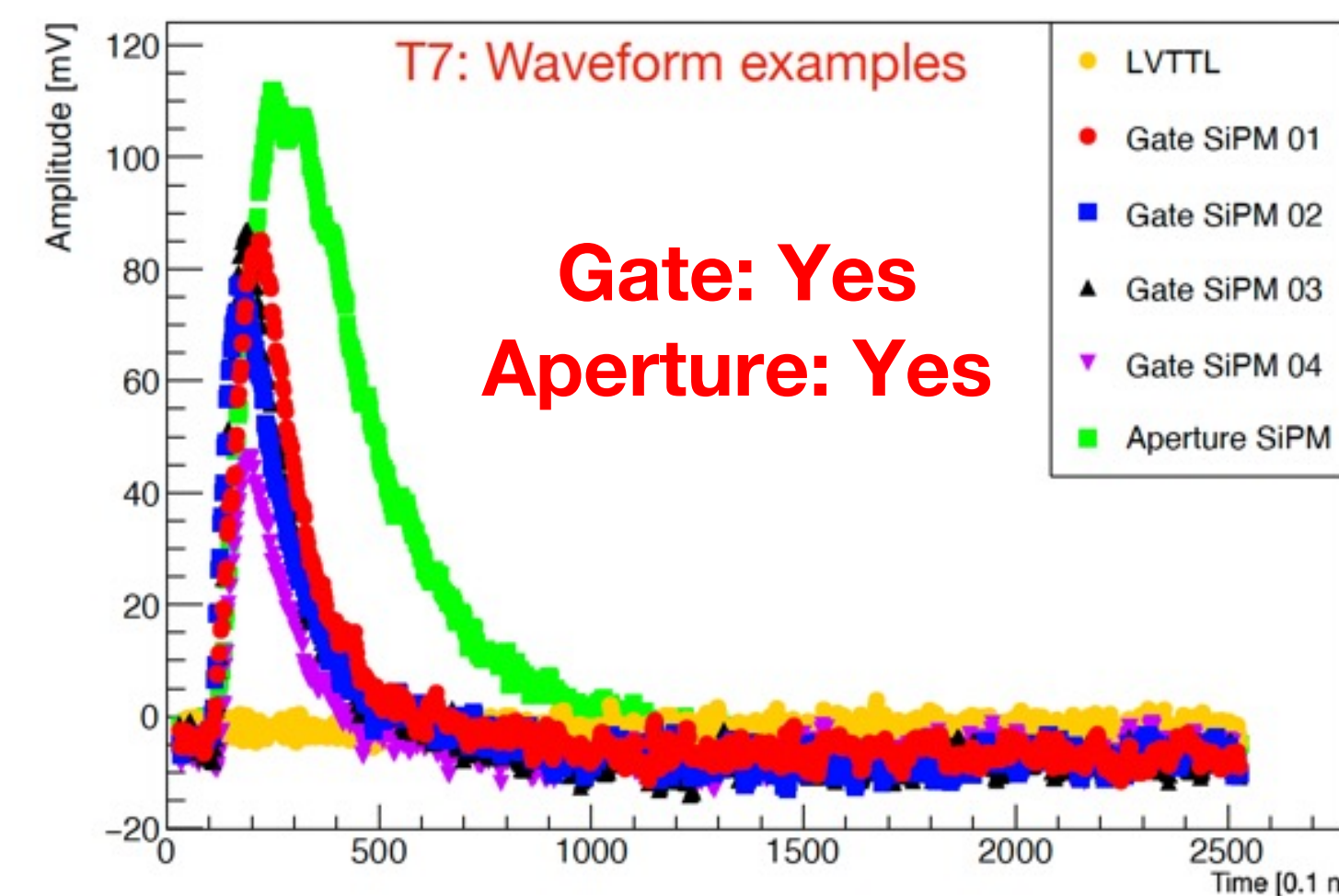
Photons Received by SiPM per event



Response to different particles



A good muon (with TTL signal)

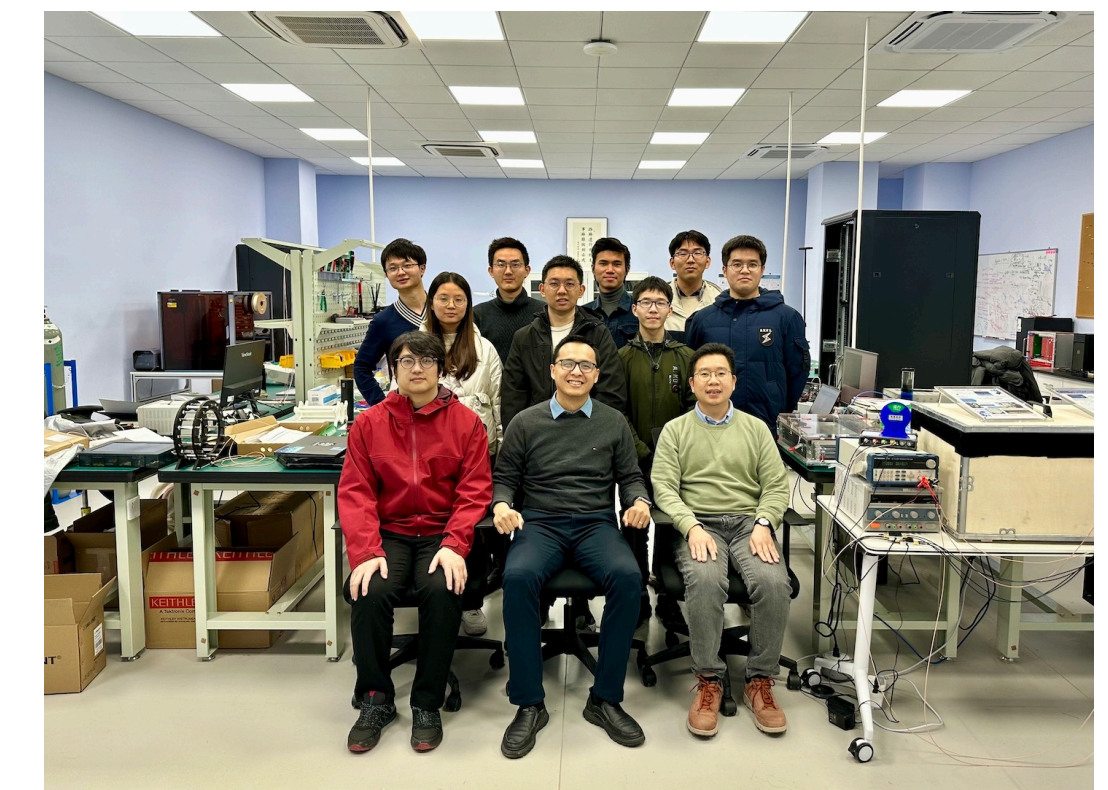
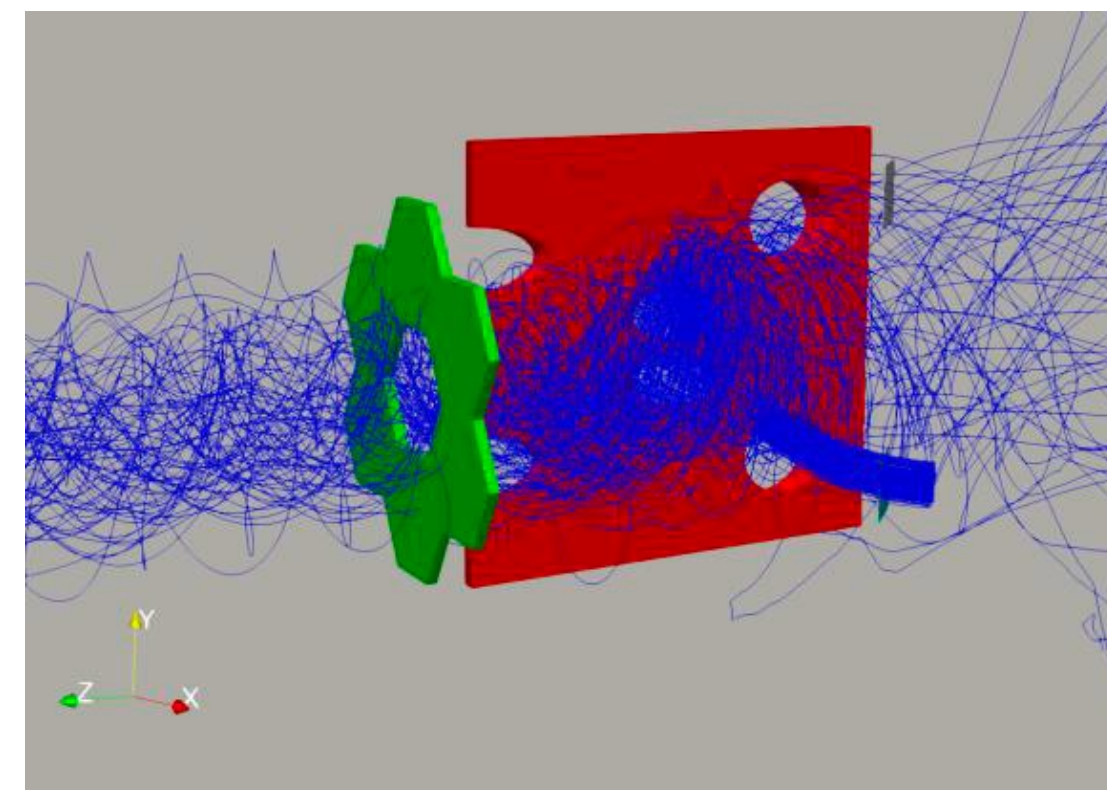
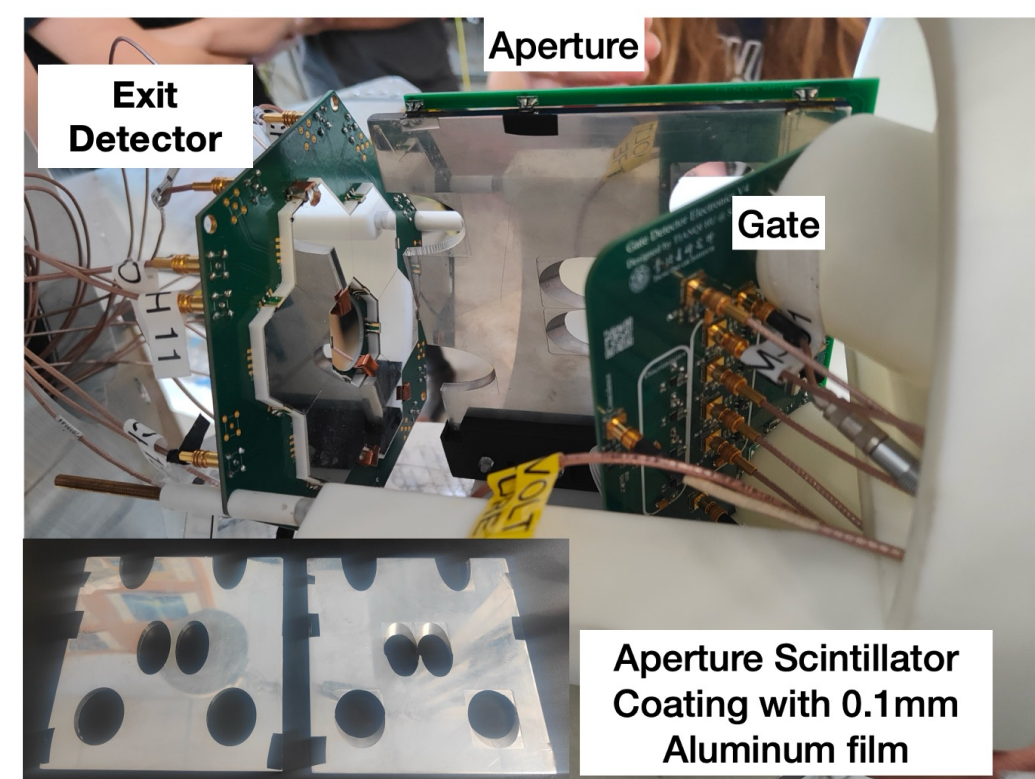
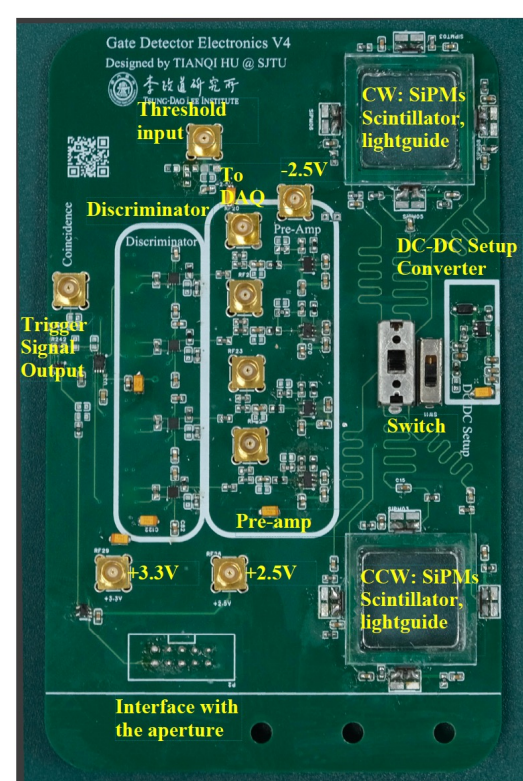


A "bad" muon (without TTL signal)



# Summary and outlook

- The Muon Trigger Detector is a vital part of the experiment, providing the trigger signal to the magnetic kicker for storable muons.
- The choice of plastic scintillator, SiPM, and custom PCB technology is backed by the successful beam tests conducted at PSI in 2022 and 2024
- Analysis and simulation on-going to finalize the Test Beam 2024 results
- Another round of revisions will take place before the permanent installation of the detector for the commissioning and physics run of the experiment in 2026.



# 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