Performance Evaluation of Plastic Scintillator-Based Calorimeter Modules for Neutron Detection in the mCBM Experiment

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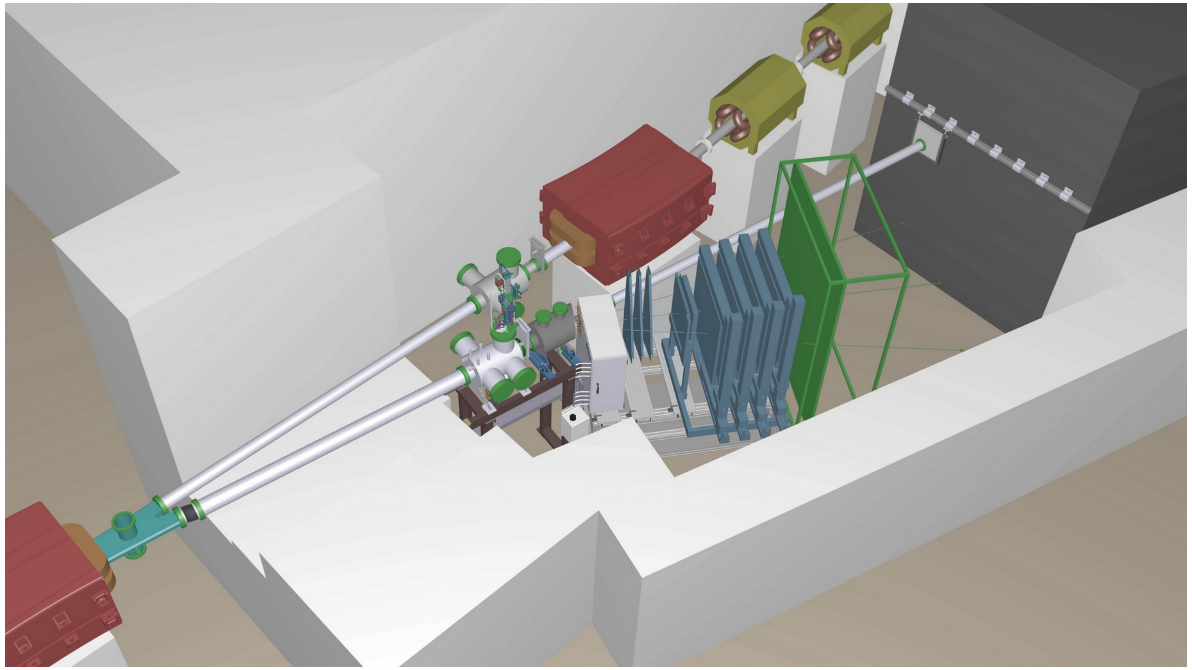
Introduction – Neutron Detection at mCBM

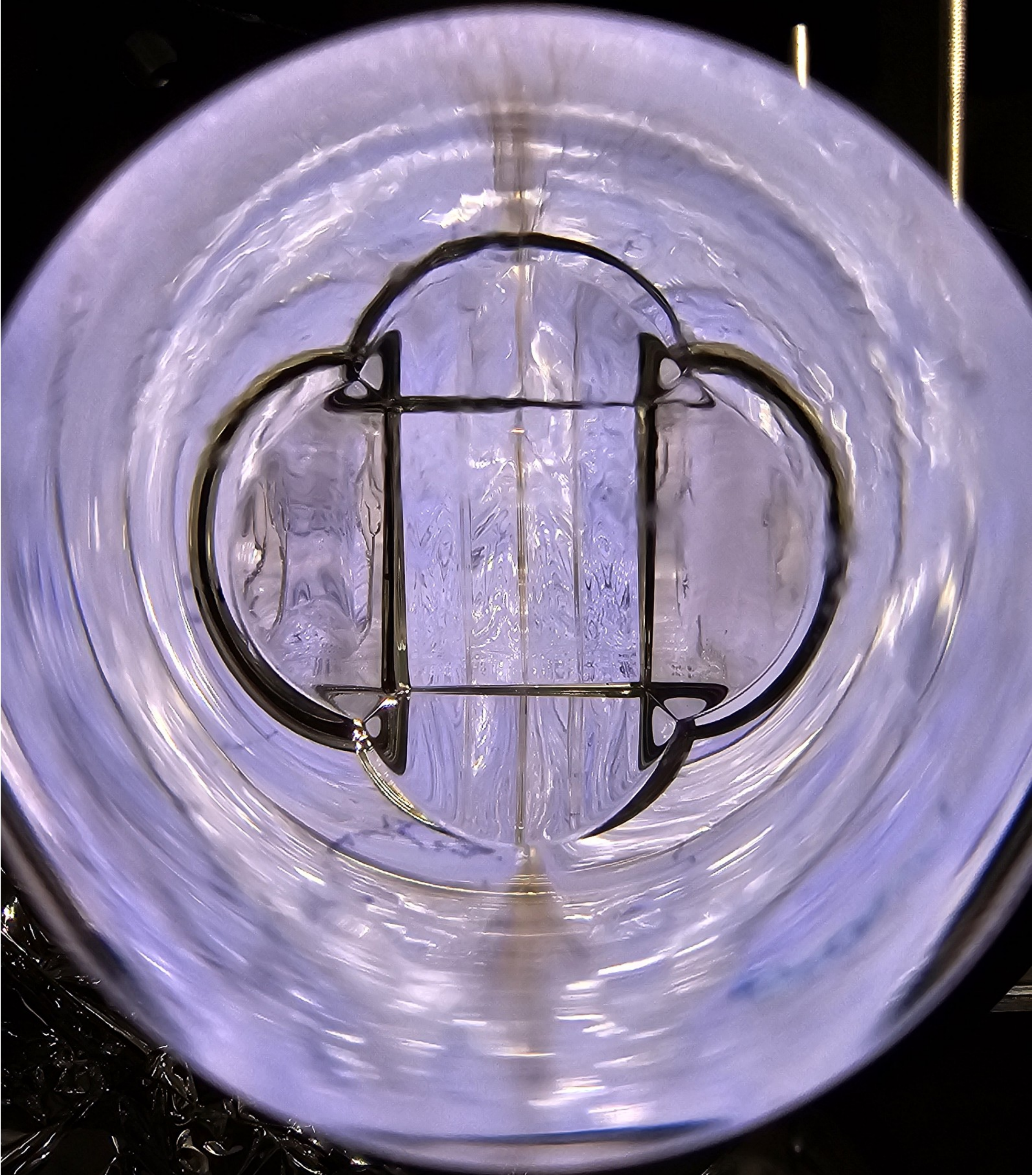
Ph.D. Project - Neutron Detection at mCBM, SIS18 CBM, GSI FAIR

- Neutrons don't possess charge, therefore don't interact with EM force. Neutrons are less likely to interact with the matter

- Previous reaction channel at 2.7GeV/c momentum resulted 40% efficiency on neutron detection using same systems [1]

- Improved Forward Spectator Detector (FSD) determination of collision centrality and collective flow [2]



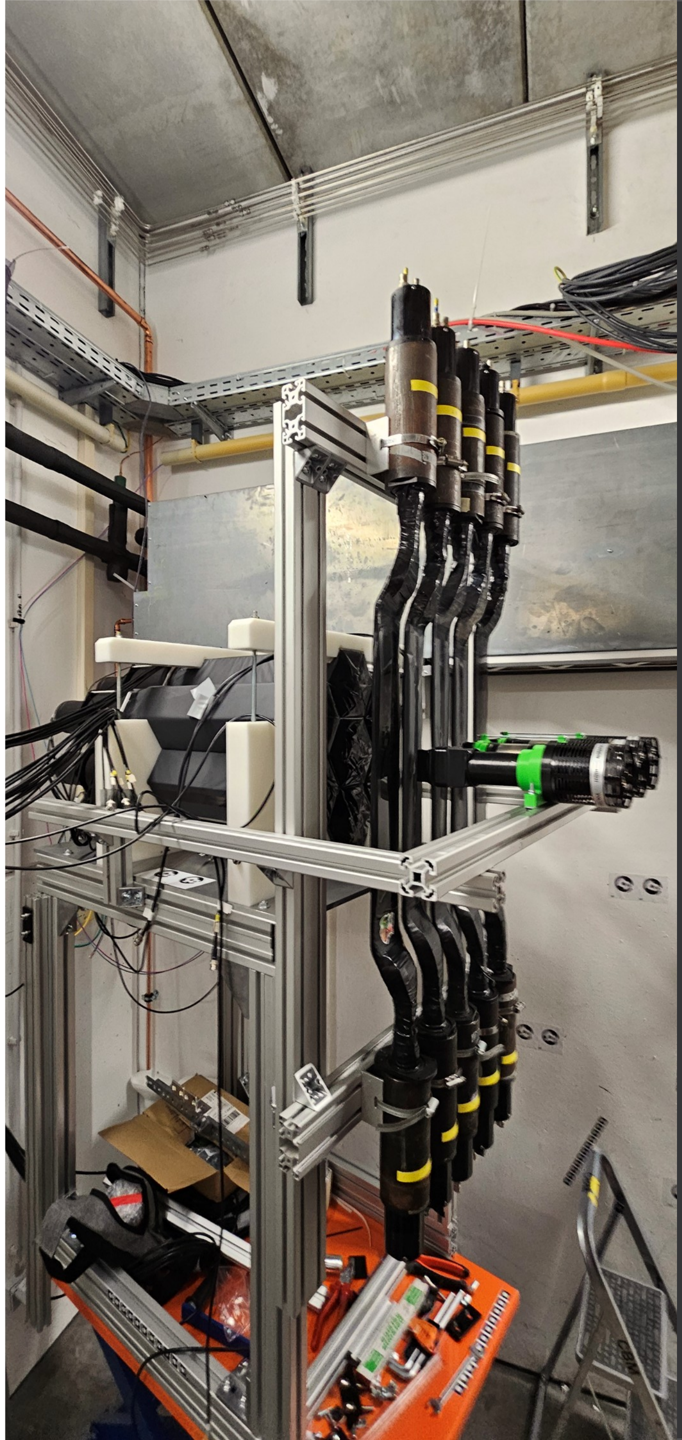


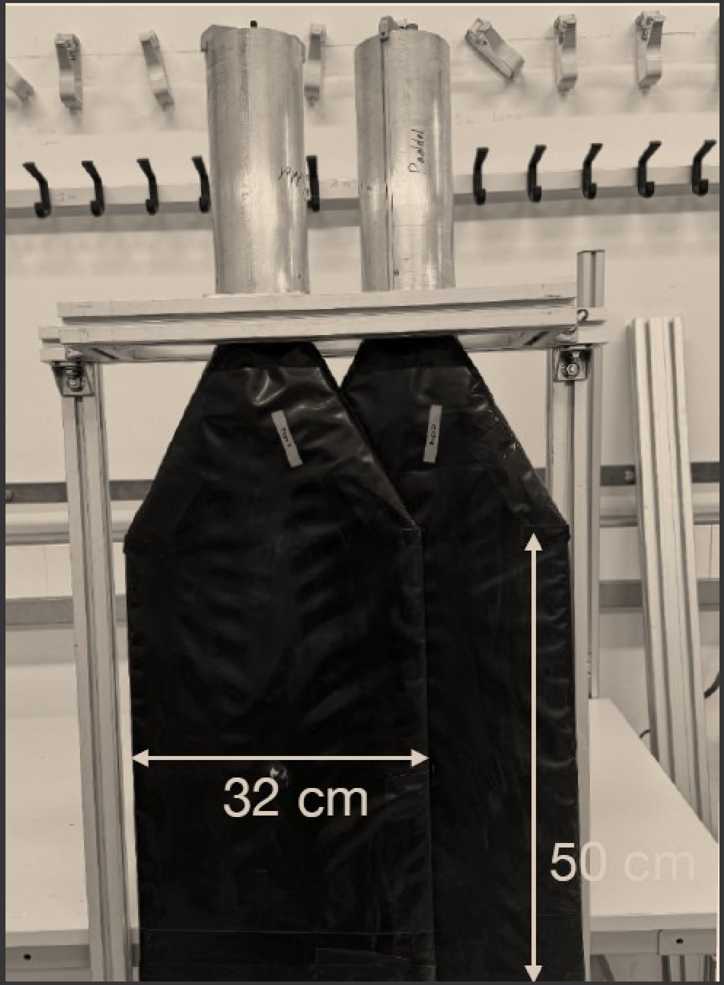
Objectives

- Detector Design and Development: For mCBM experiment two identical detectors need to be designed, each consisting of 7 identical neutron detection modules, one placed behind FSD close to the beam for high multiplicities and the other behind TOF further away for track reconstruction
- PP simulations in Geant4
- Installation and Integration: Devices need to be mounted inside the mCBM cave, one behind FSD. DAQ systems need to be selected and integrated with the mCBM environment
- System Calibration and Testing
- Data Acquisition during Beamtime(s) 2024 on…
- Data Analysis and Interpretation

Hardware at mCBM

- NCAL – Neutron Calorimeter Detector
- VETOs plates
- FSD – Forward Spectator detector




32 cm
50 cm

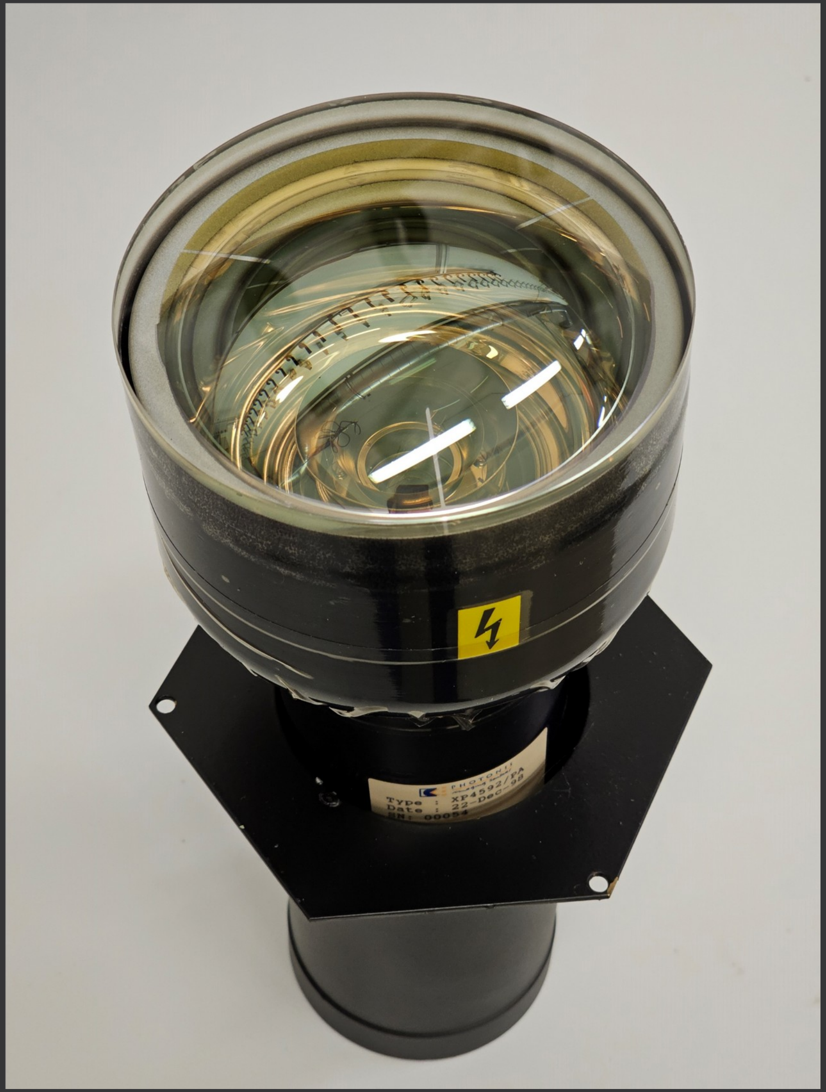
Hardware – Module

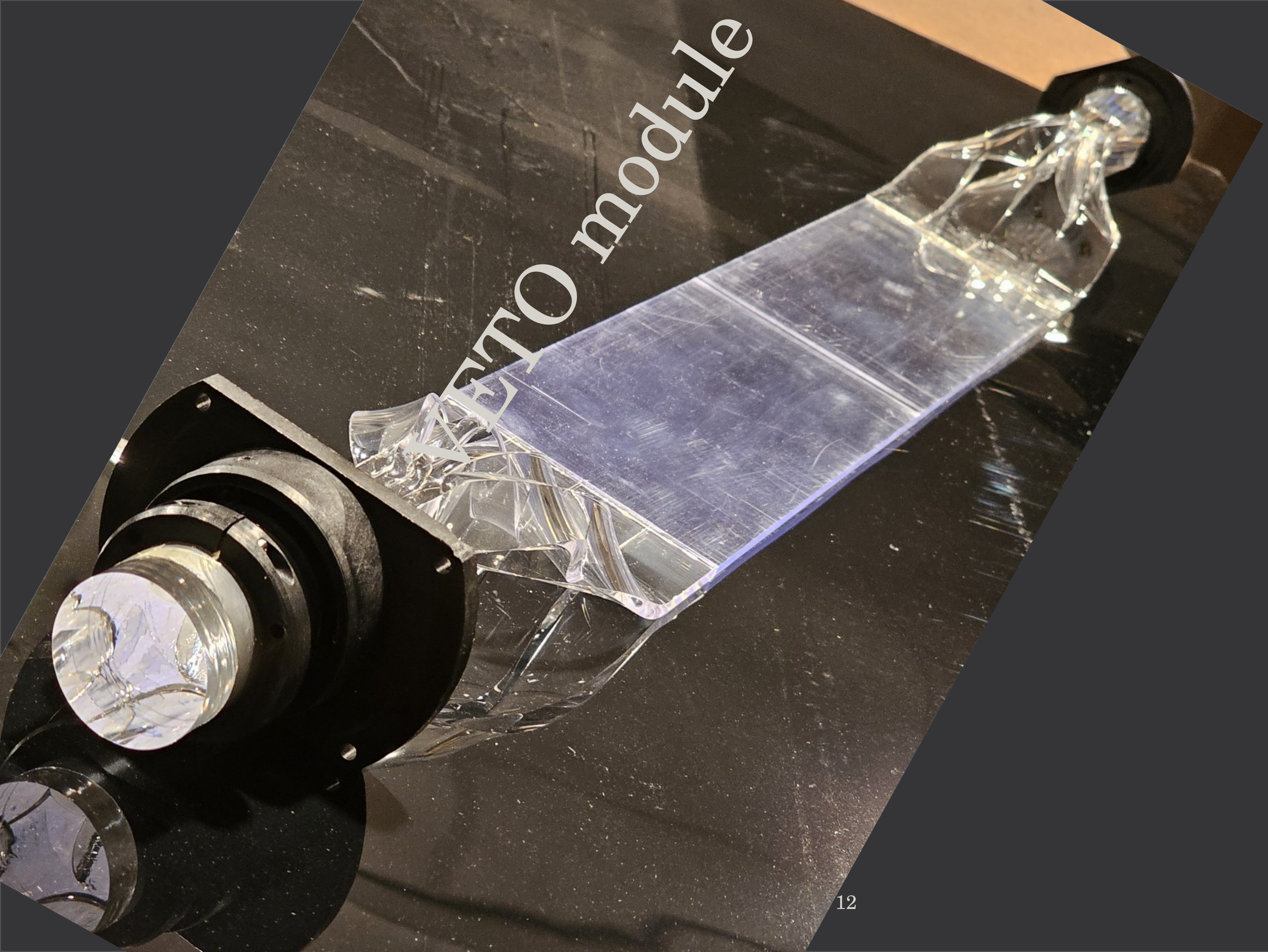
- Plastic scintillator BC-416 - hexagonal shape with a side length of about 8cm and a length of 45 cm resulting in an area of about 1200 cm2

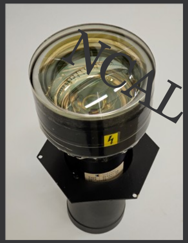
- Photomultiplier Photonics XP4592/PA - outer diameter of about 130 mm

- Assembly:
  - Scintillator wrapped in several layers of light-insulating tape
  - Silicon based gel used in between the PMT and scintillator contact
  - Scintillator and PMT fixed together using plastic ring and outer metal frame

NCAL module




VETO module

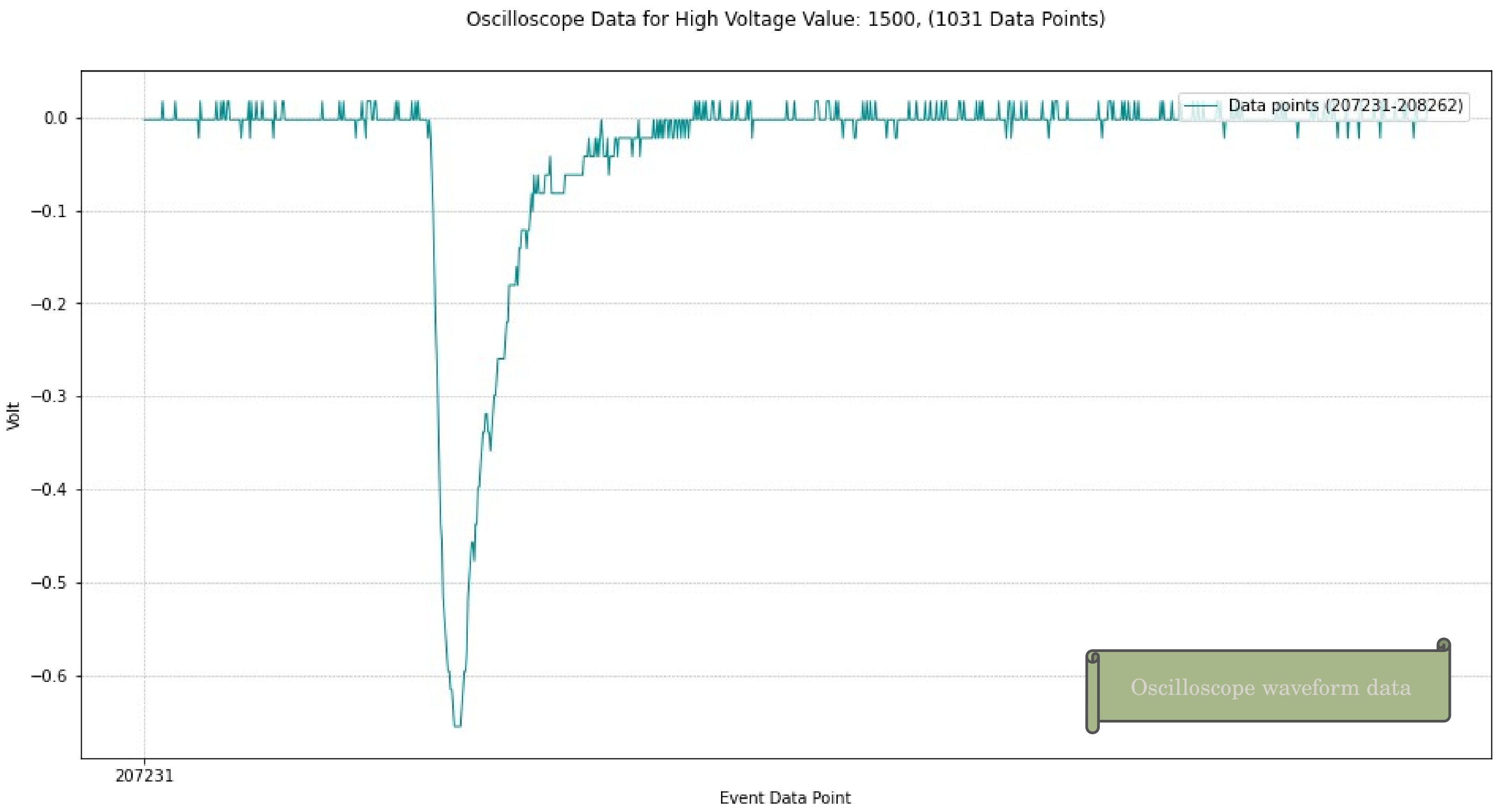



NCAL module

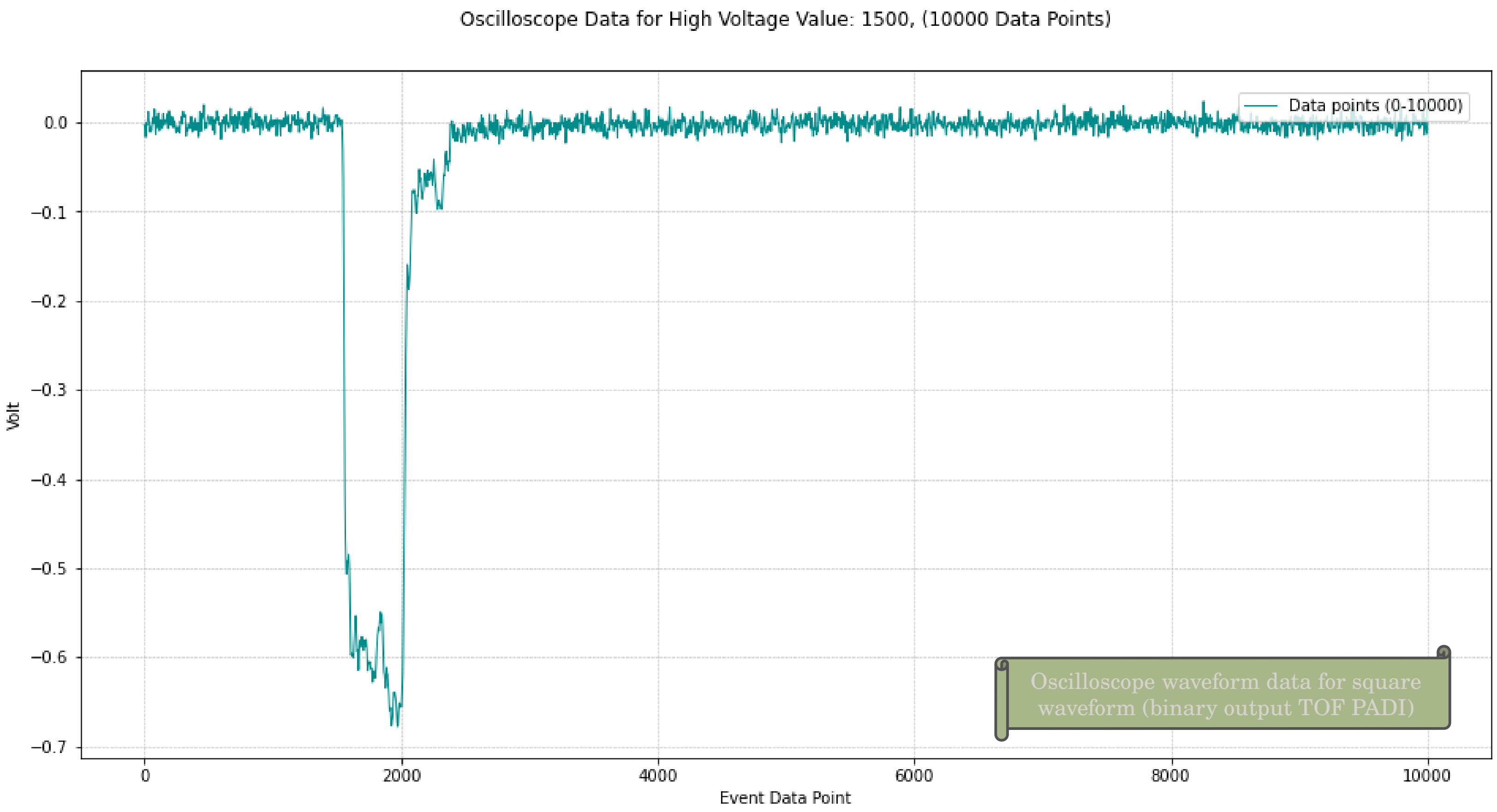
DAQ - Readout System Selection

- Two Candidates: DiRich & TOF PADI
- Both measure time over threshold (TOT)
- Objective is to measure energy of a particle and to choose the most suitable device for the task
- Two independent readout tests have been set up in Wuppertal and at GSI using Neutron Detector modules

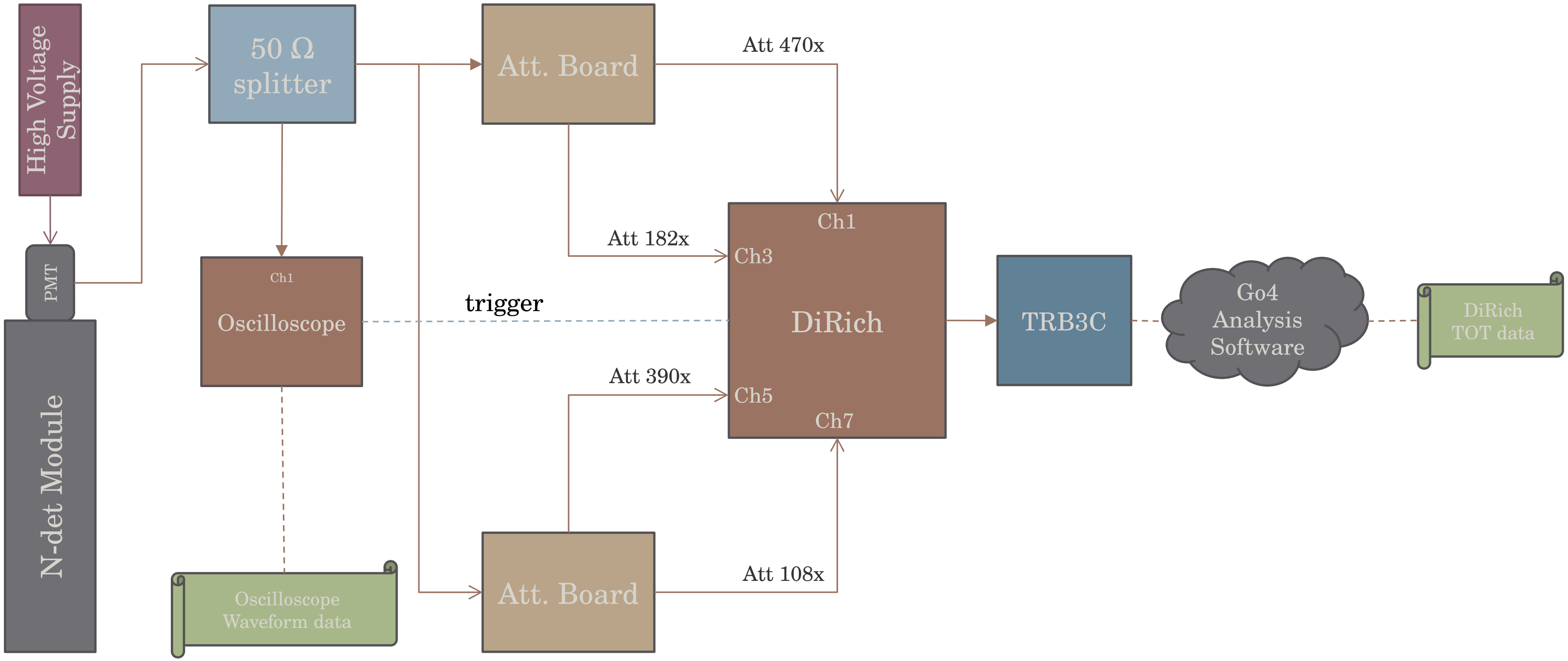
DiRich tests – Plots



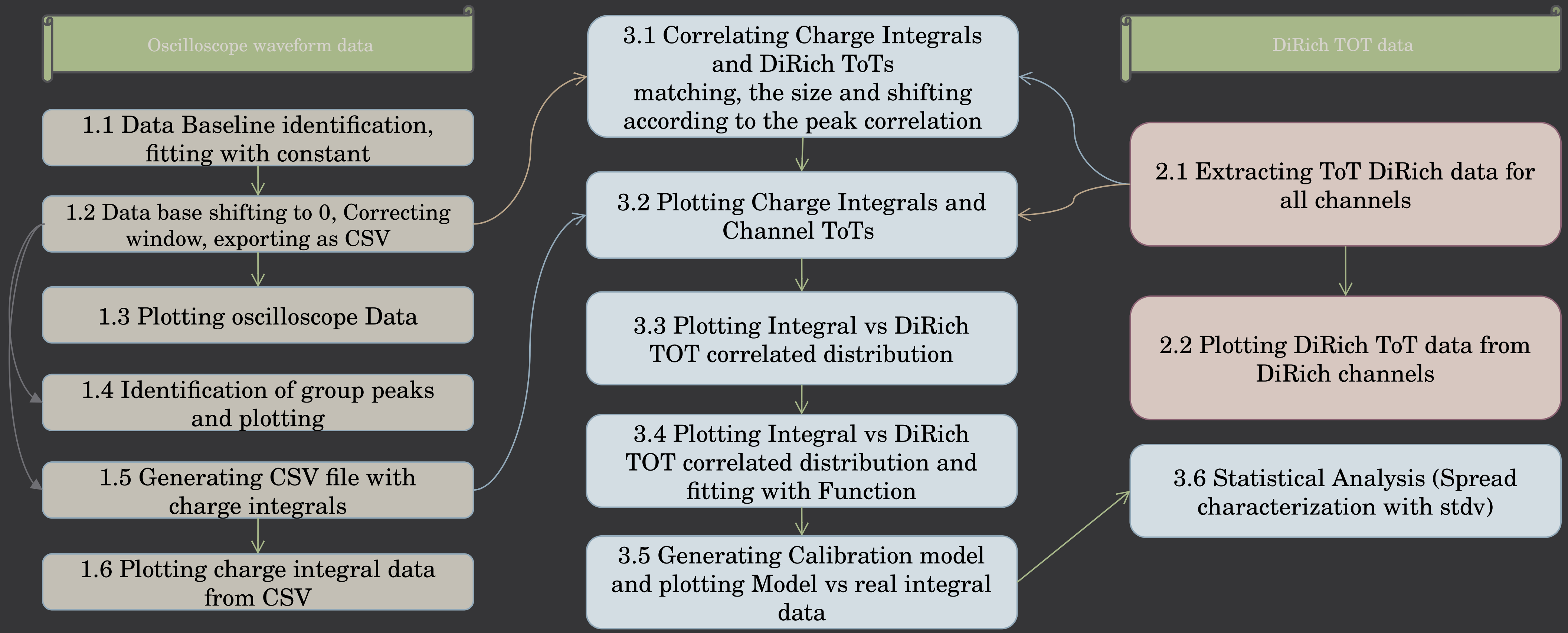
DiRich tests – Plots



DiRich tests - setup

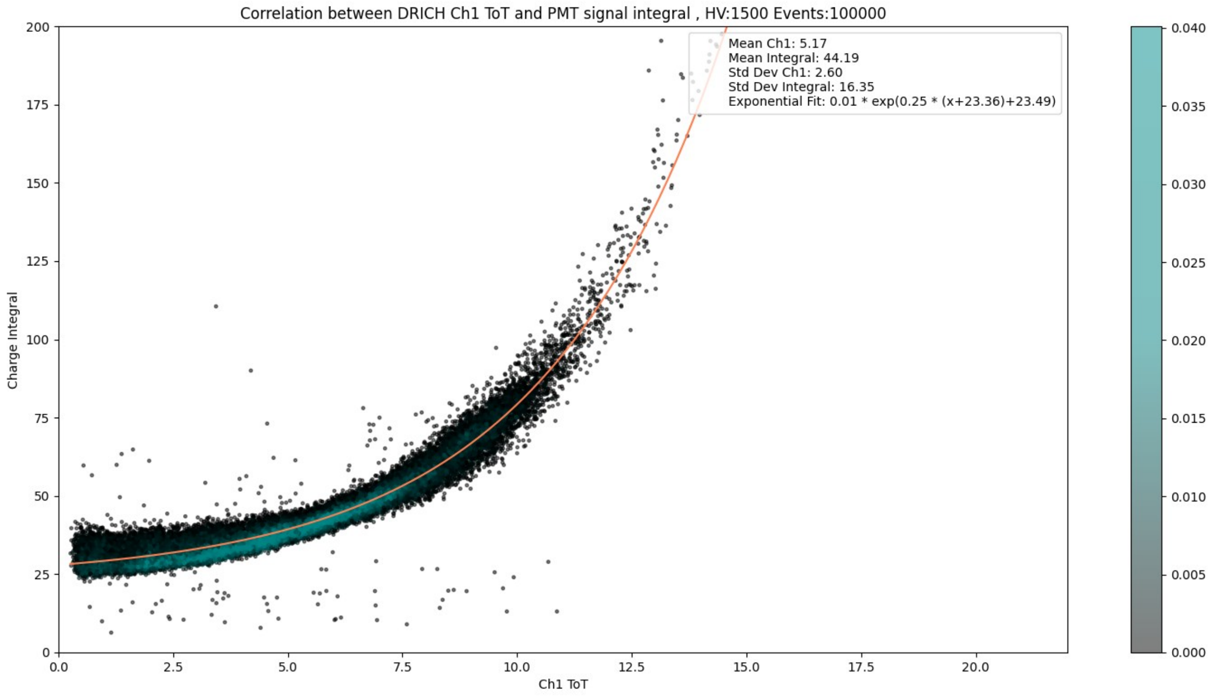


DiRich tests – Analysis tree



DiRich tests – Plots

3.4 Plotting Integral vs DiRich TOT correlated distribution and fitting with Function



DiRich tests – Plots

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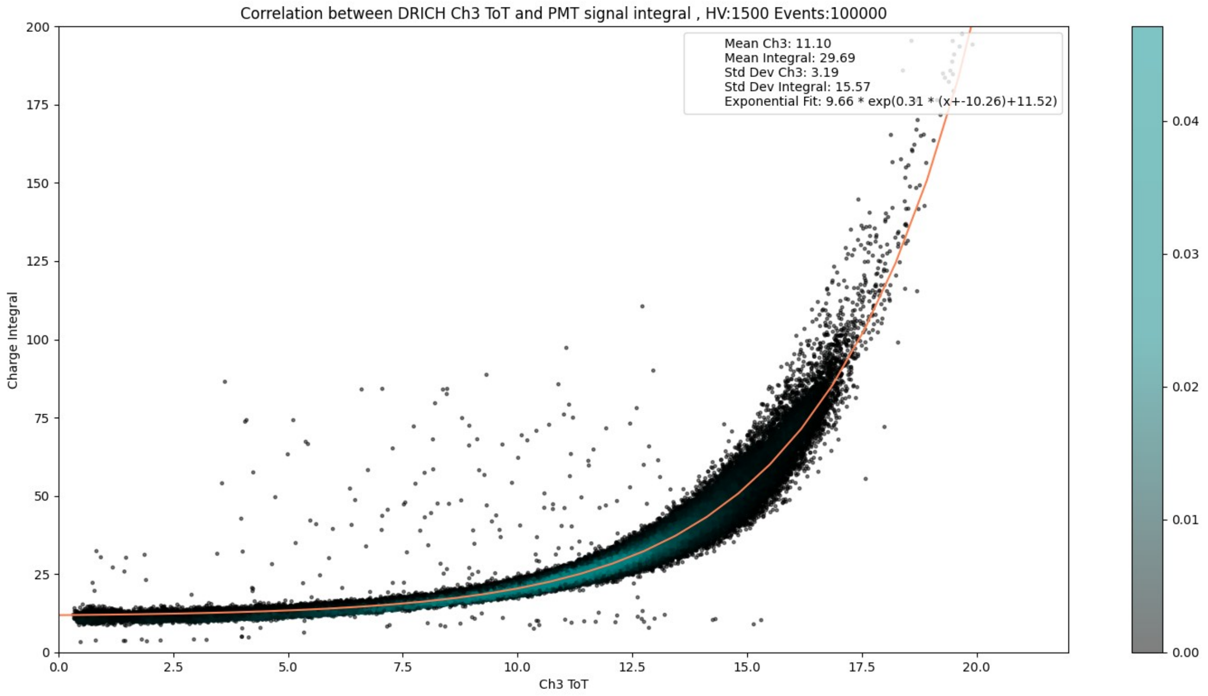

DiRich tests – Plots

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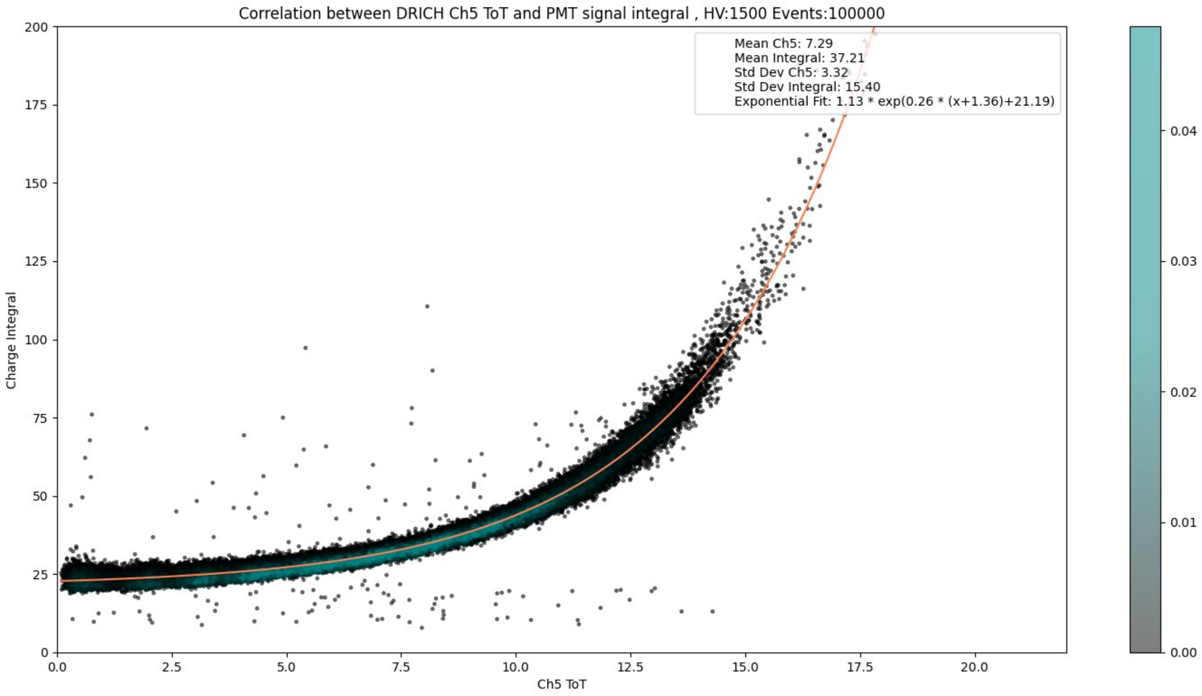

DiRich tests – Plots

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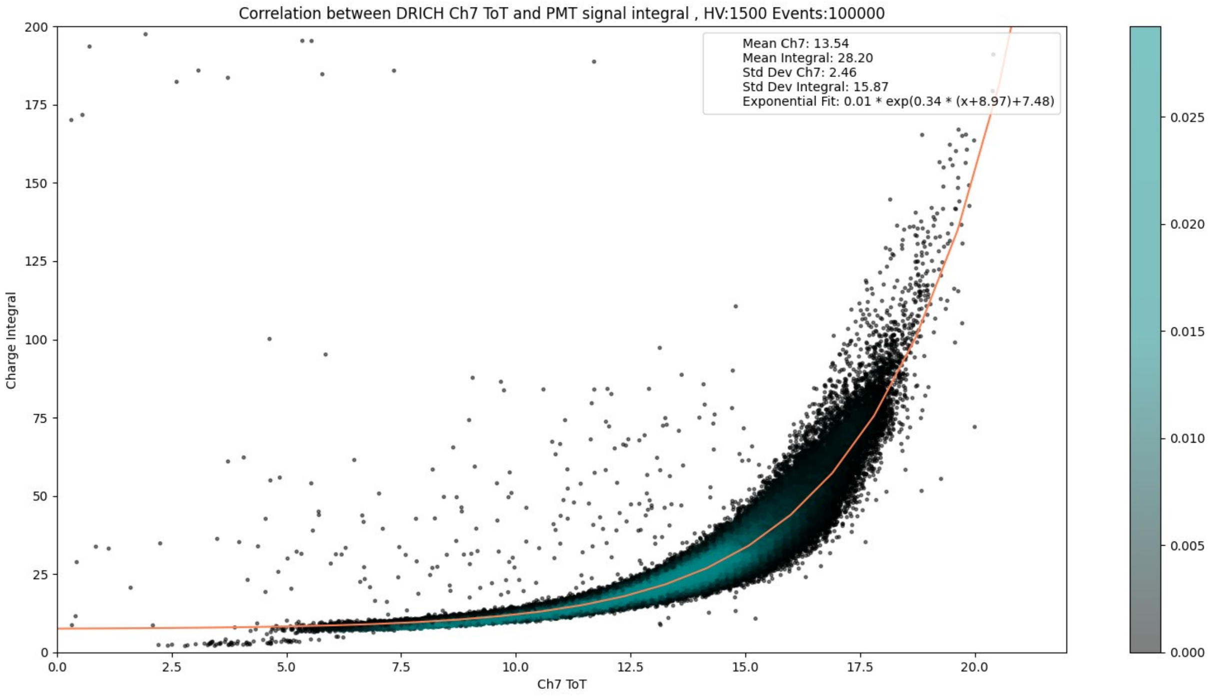
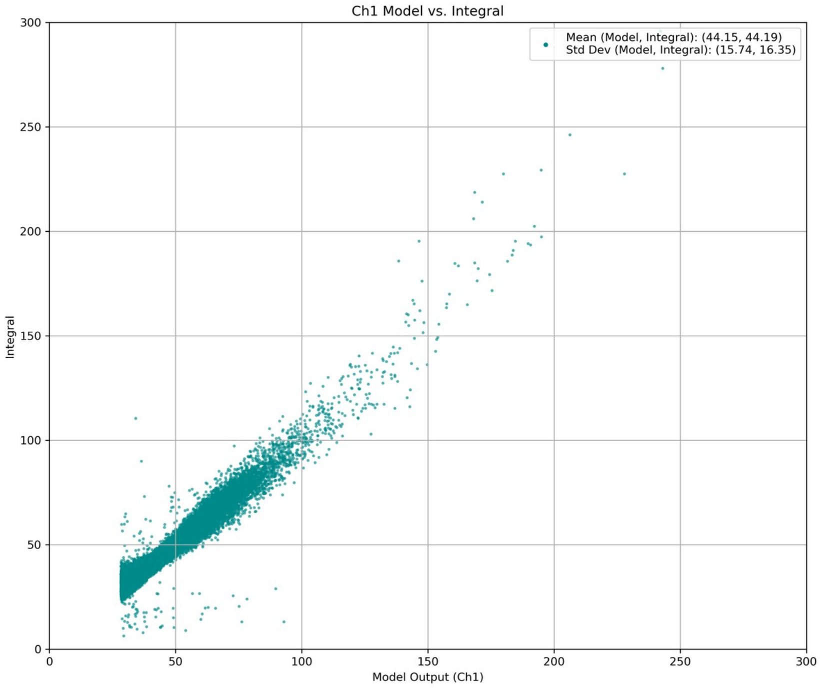
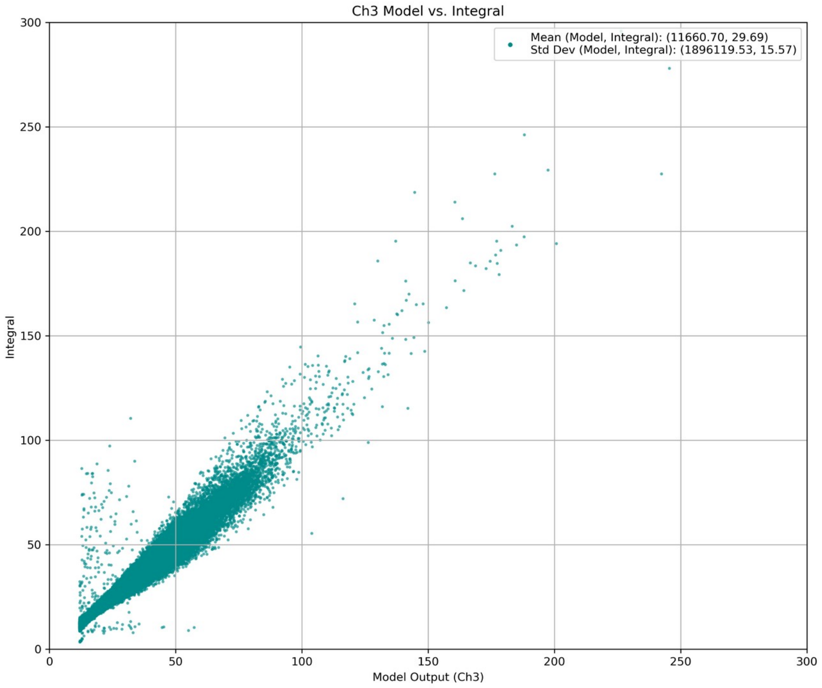


DiRich tests – Plots

3.5 Generating calibration model and plotting model vs real integral data





DiRich tests – Plots

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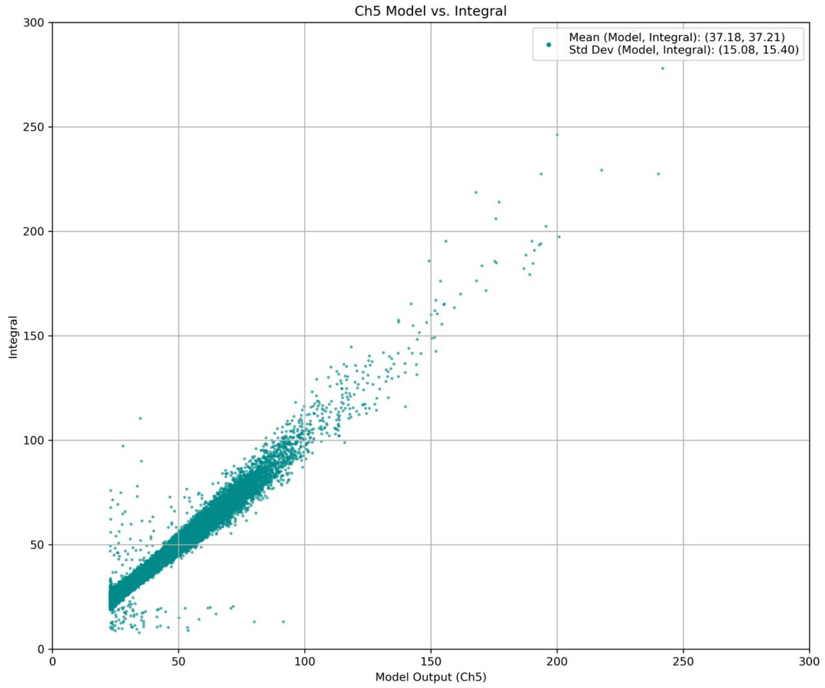
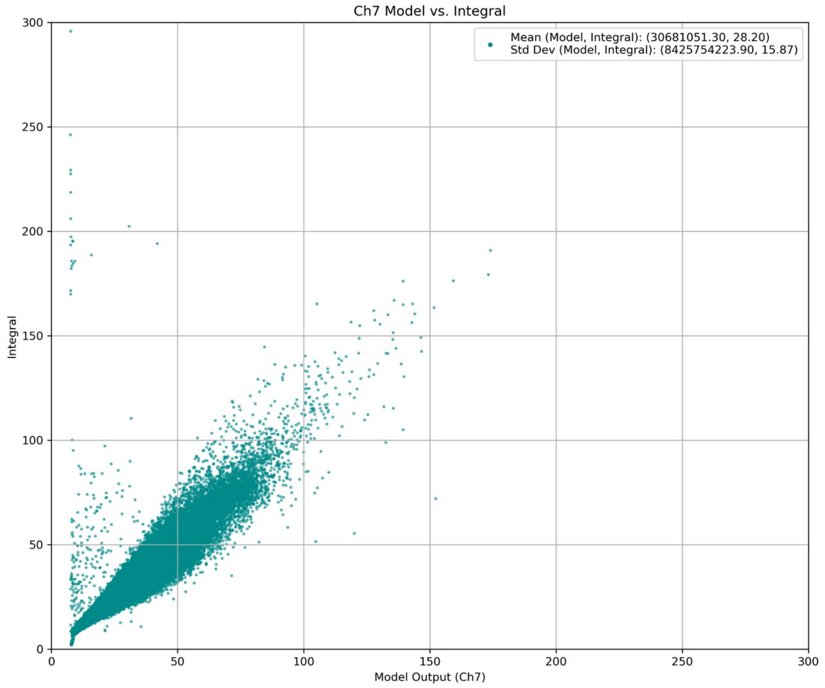
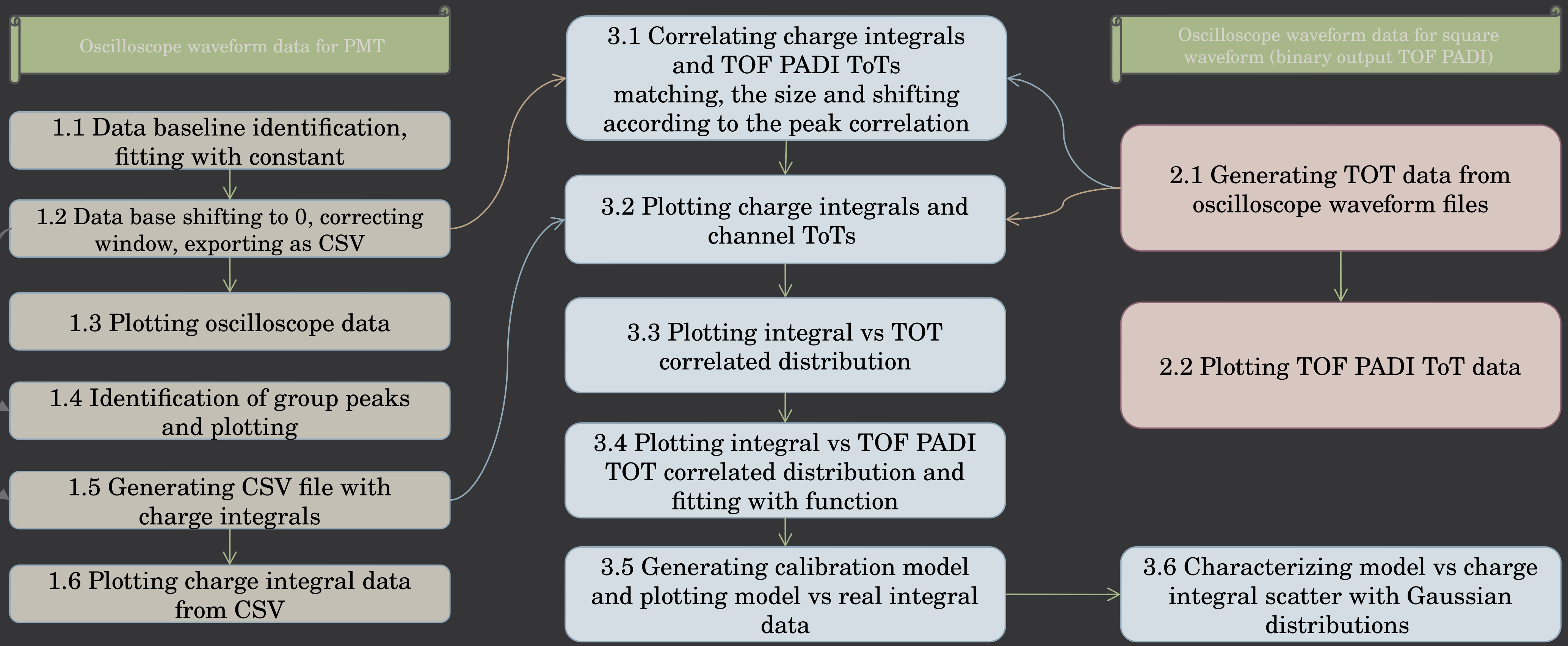
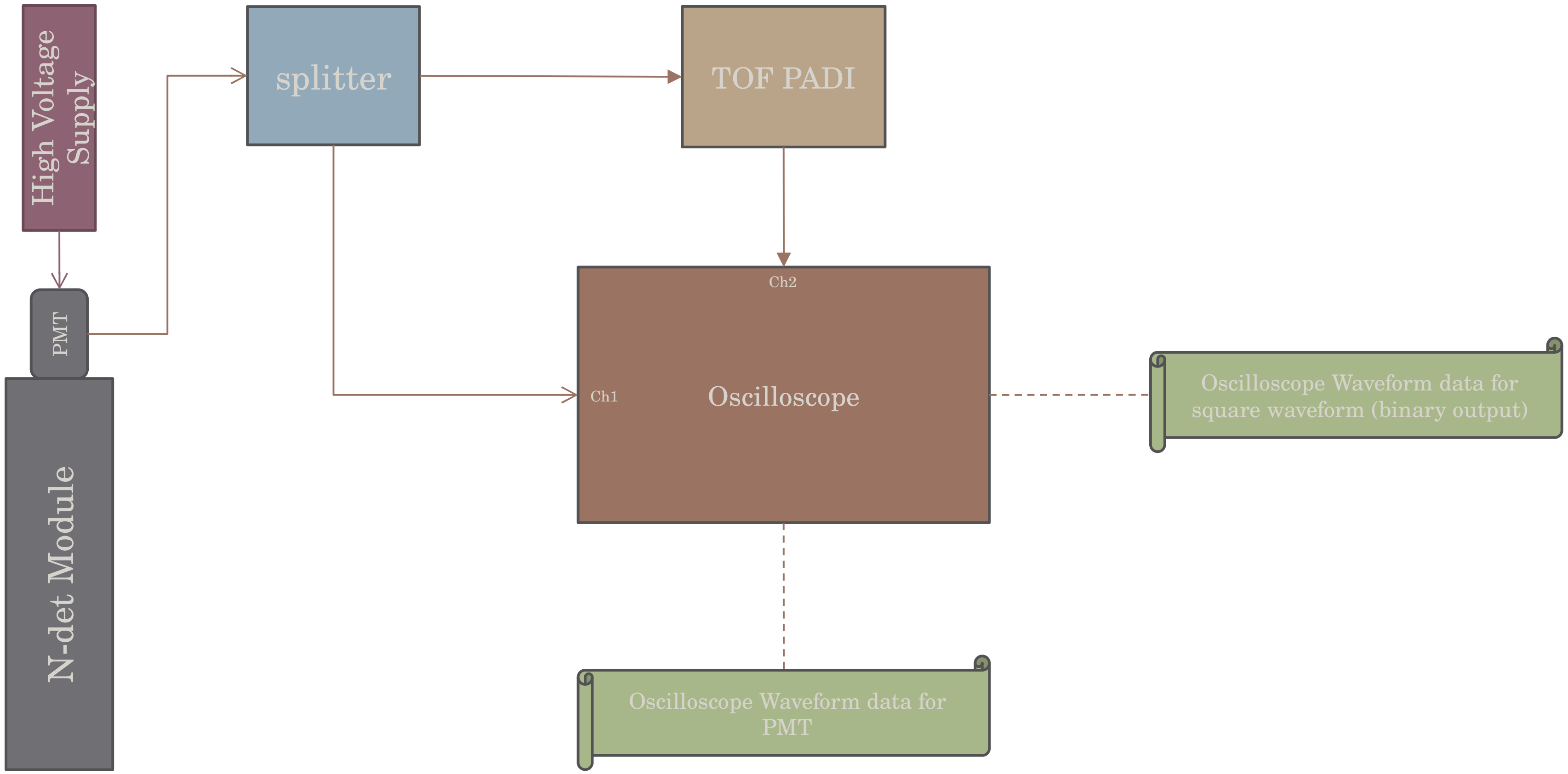




TOF PADI tests – Analysis tree

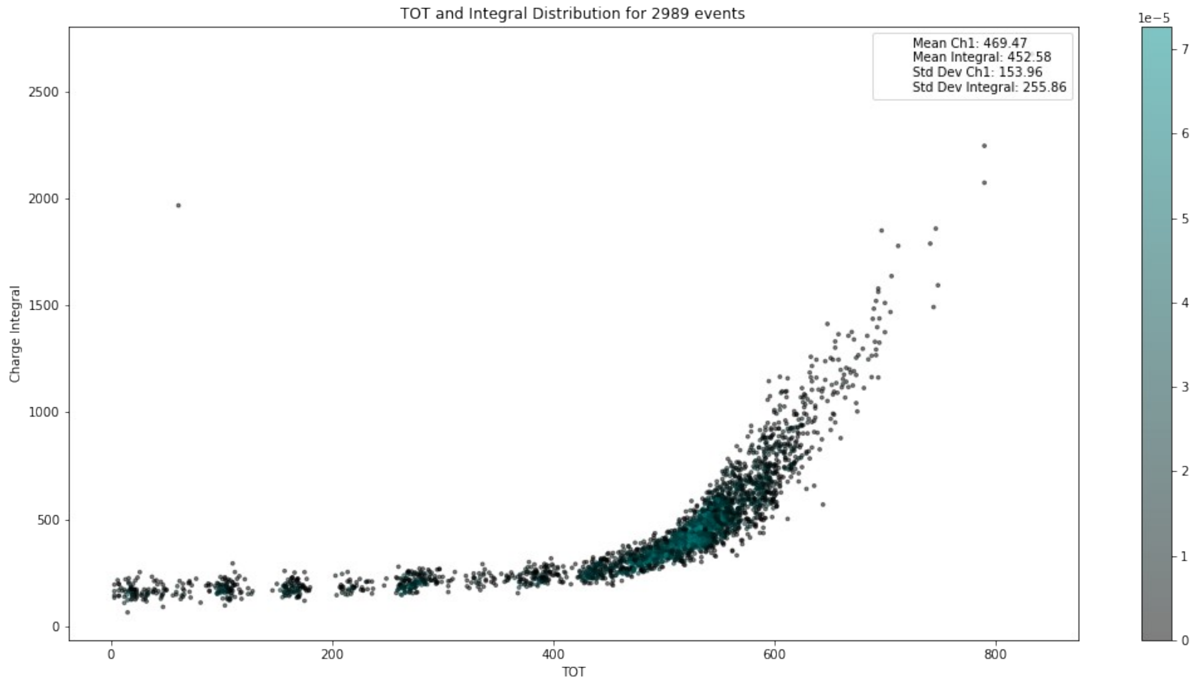


TOF PADI tests - setup

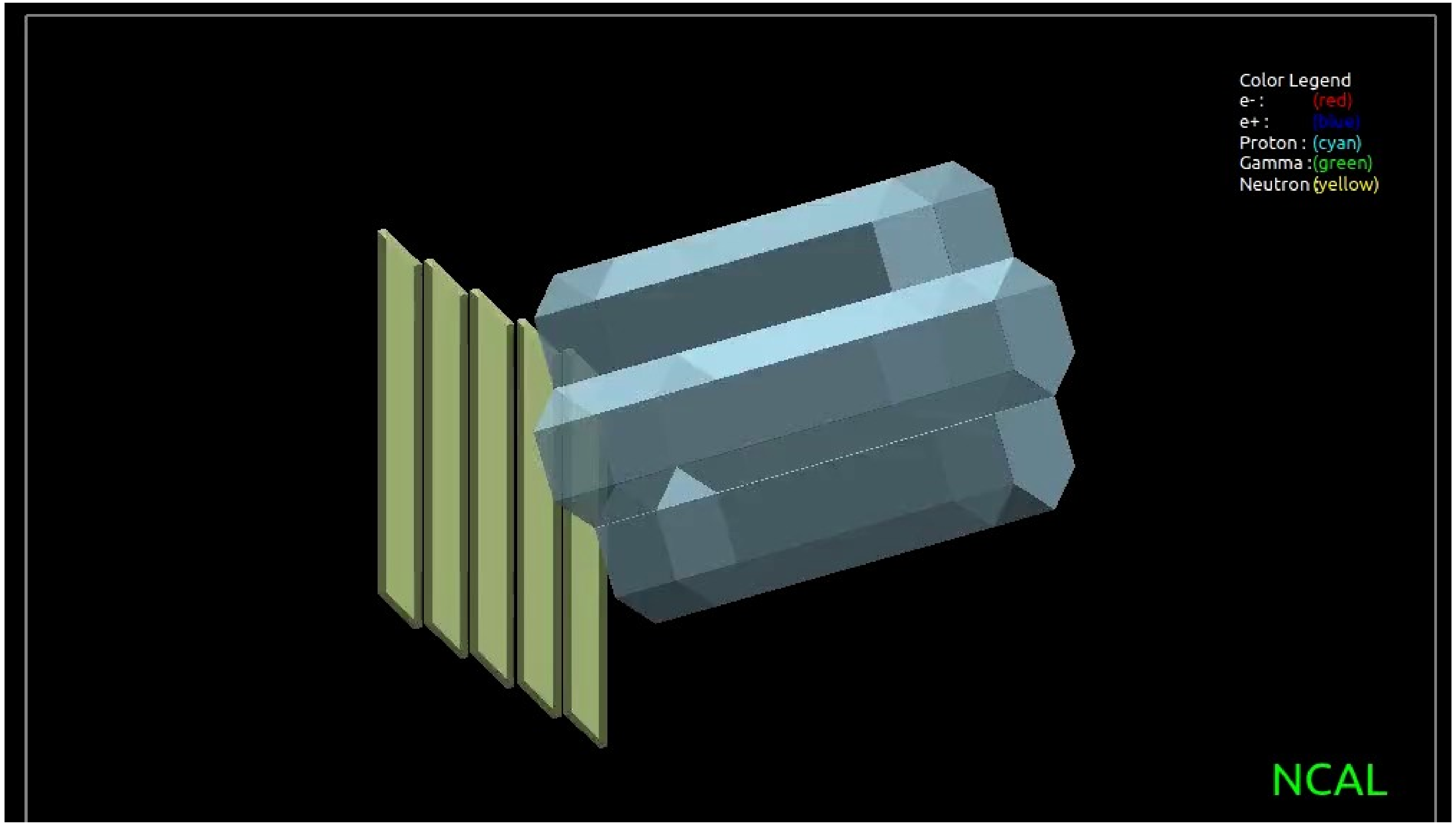


TOF tests – Plots

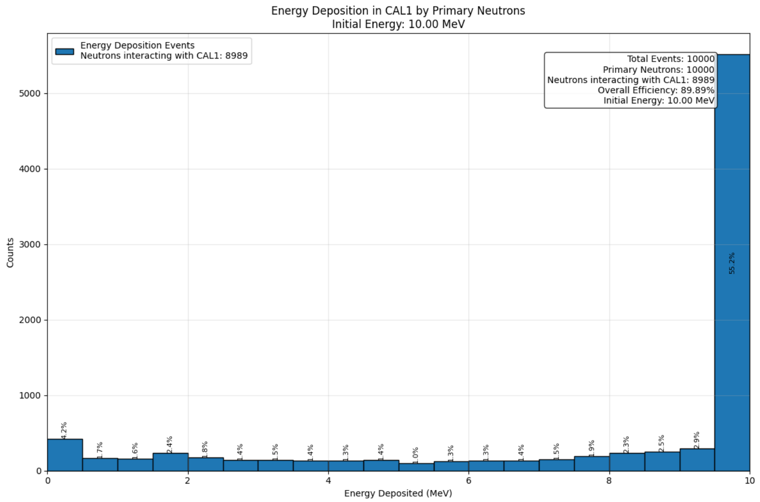
3.3 Plotting integral vs TOT correlated distribution

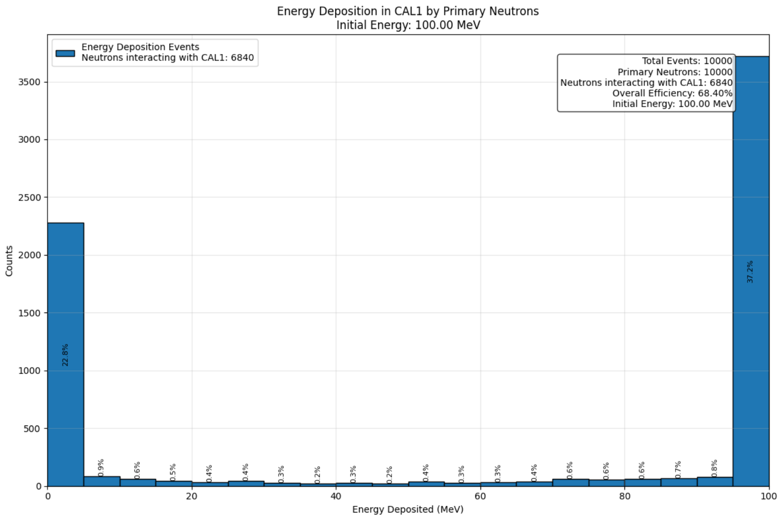


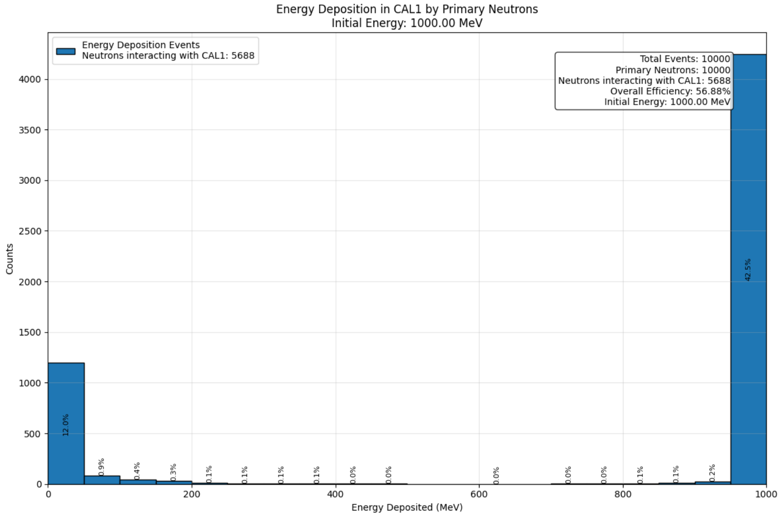
Geant4 Simulations

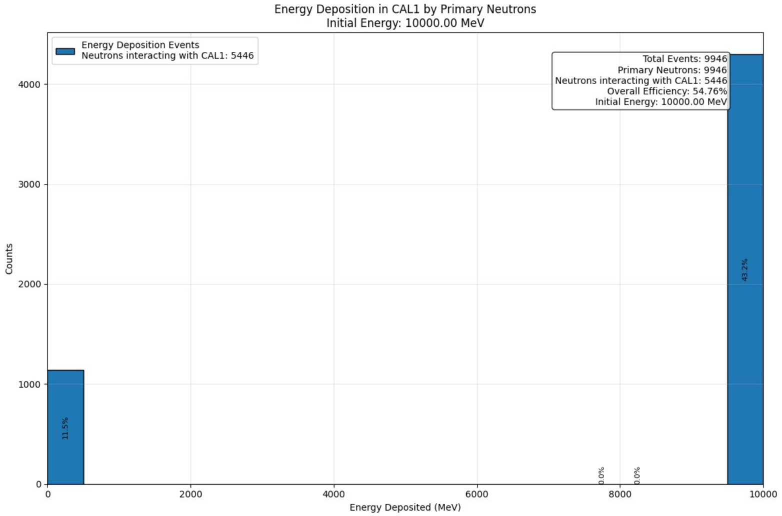


Geant4 – Neutron hits

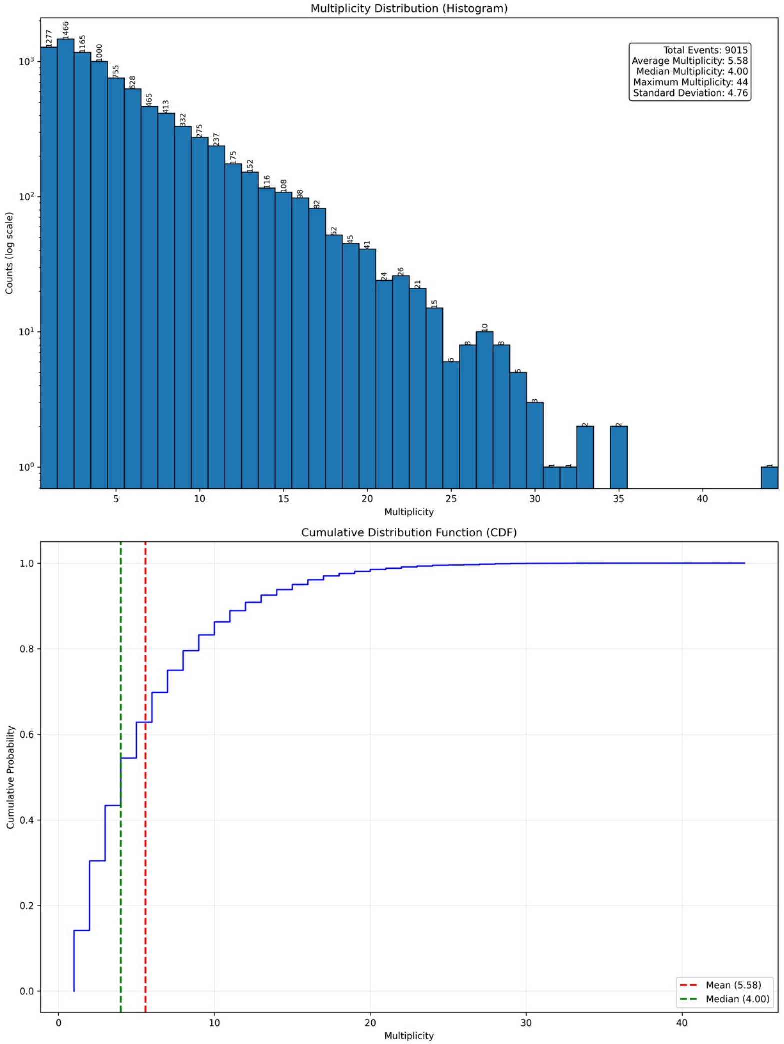


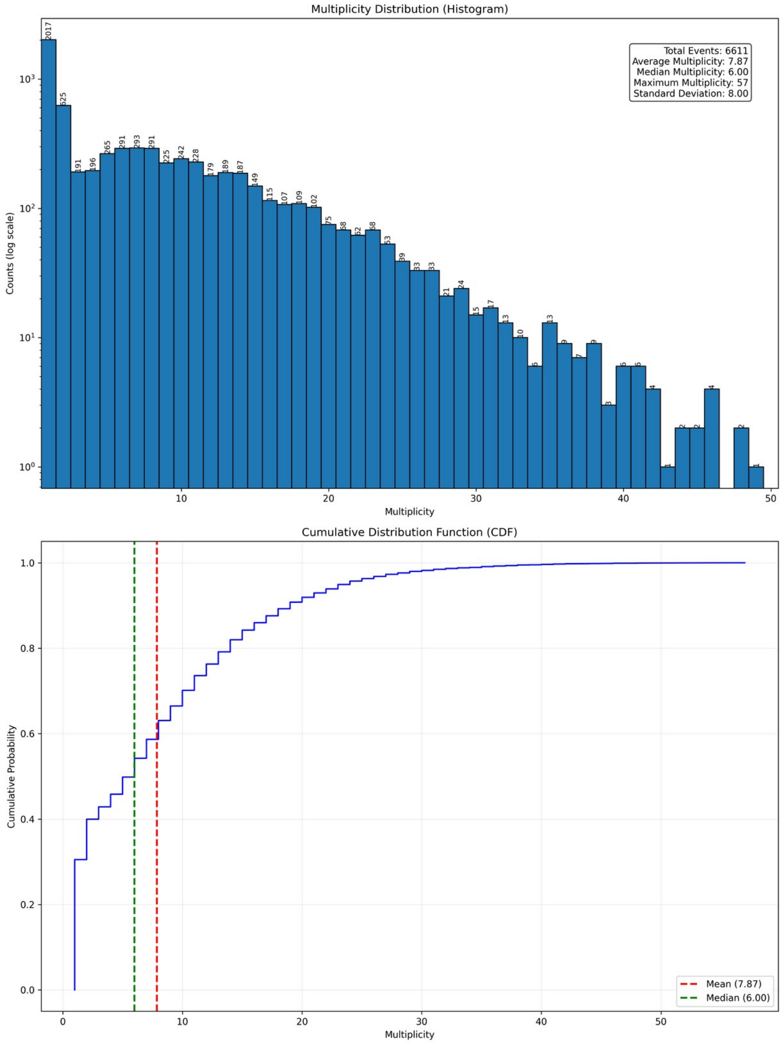




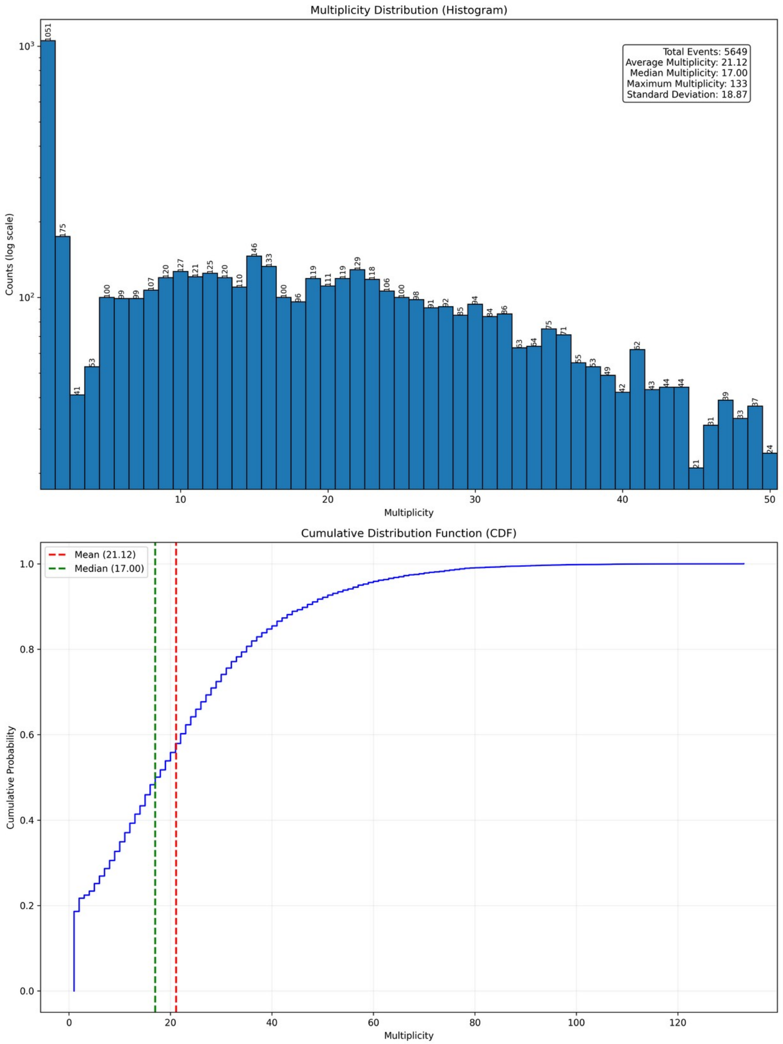


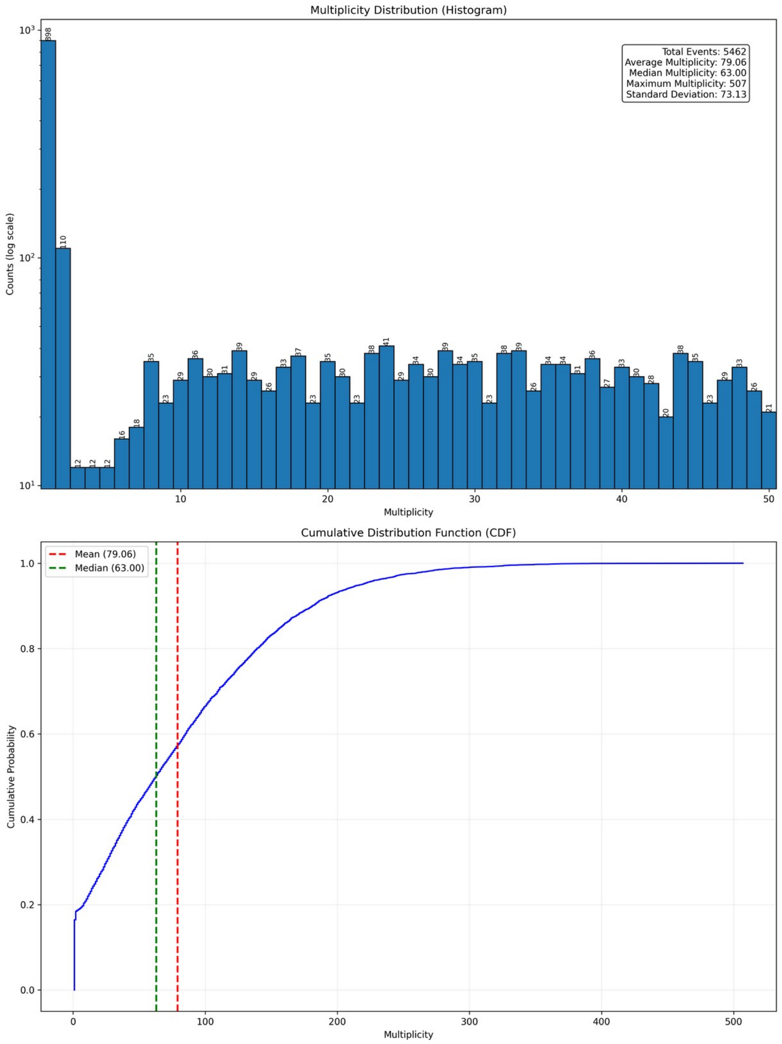
Geant4 – Multiplicity



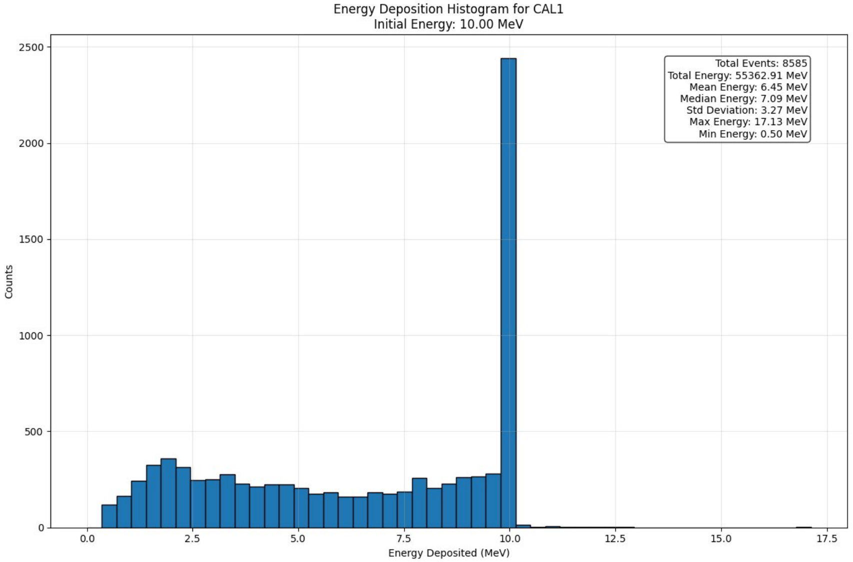


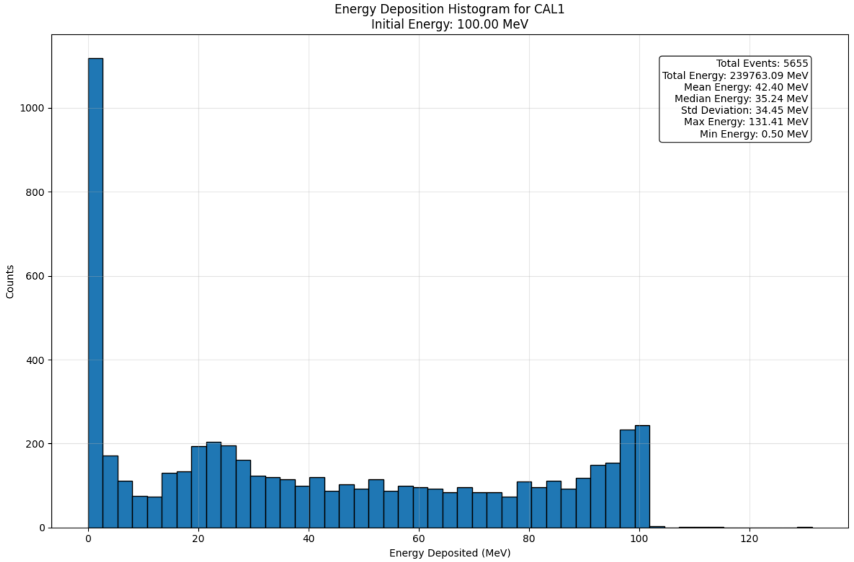
Geant4 – Multiplicity

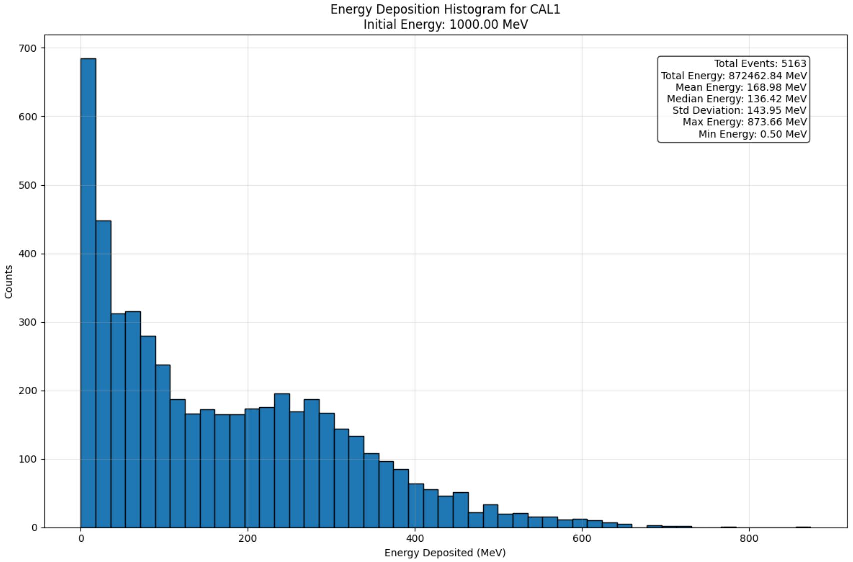


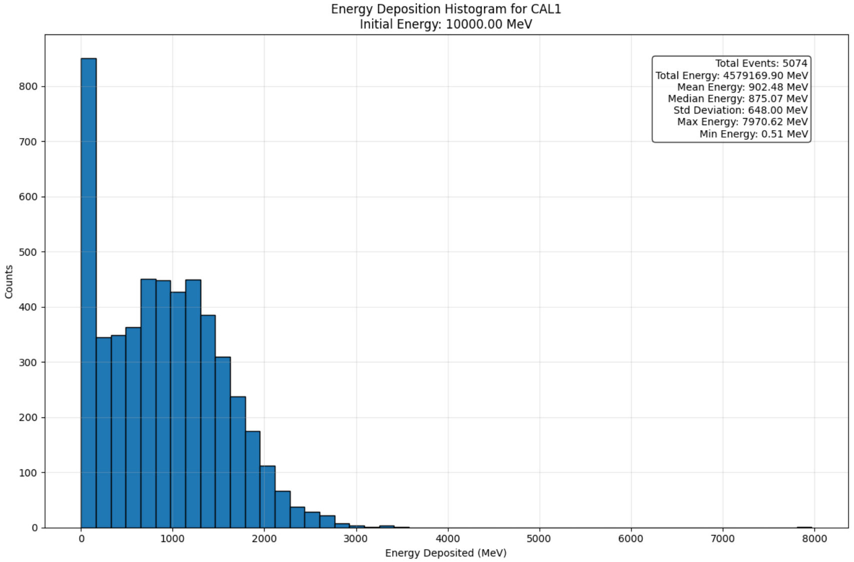


Central Module Energy Depositions

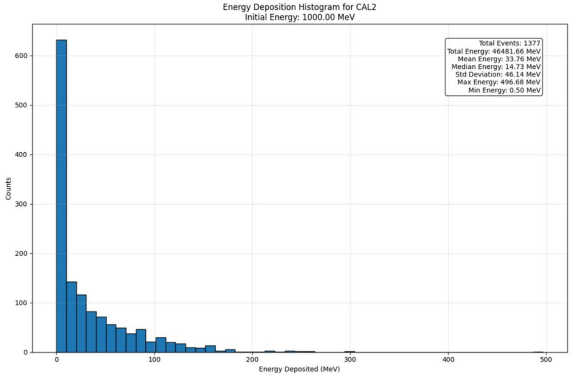


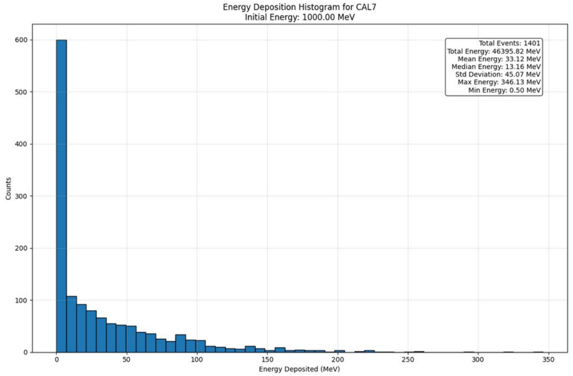


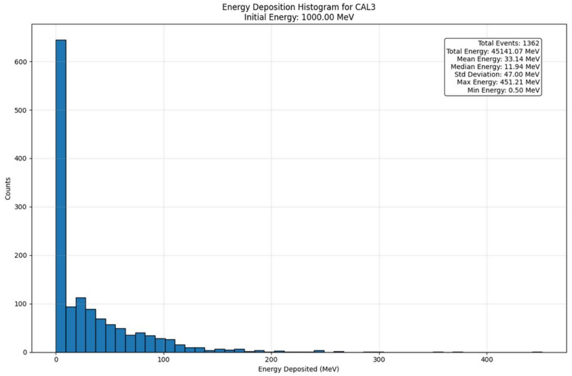


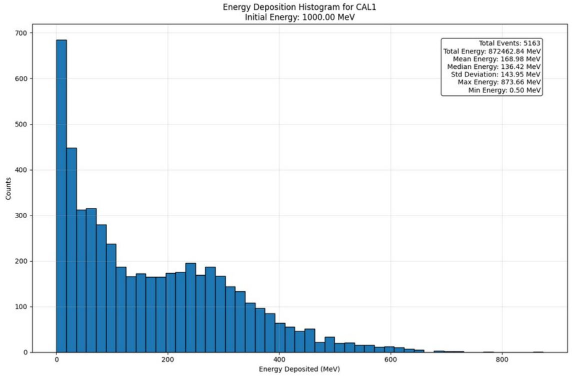


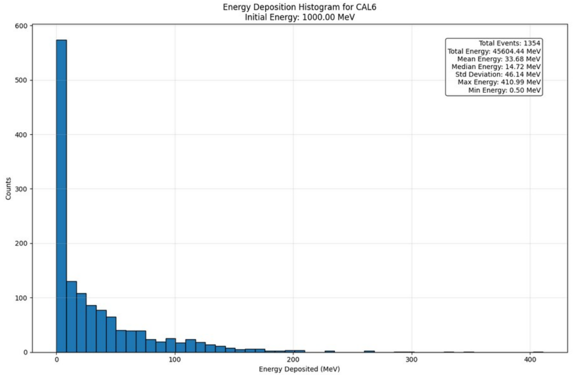
All Module Energy Depositions – 1 GeV

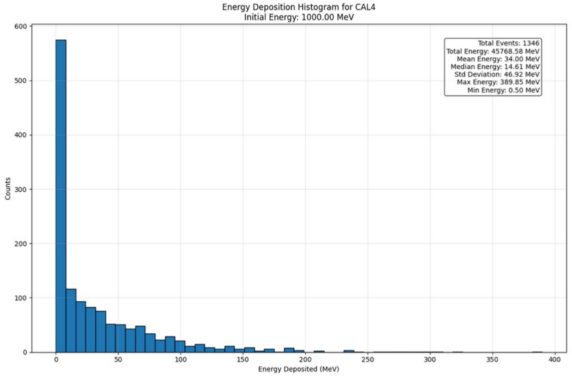


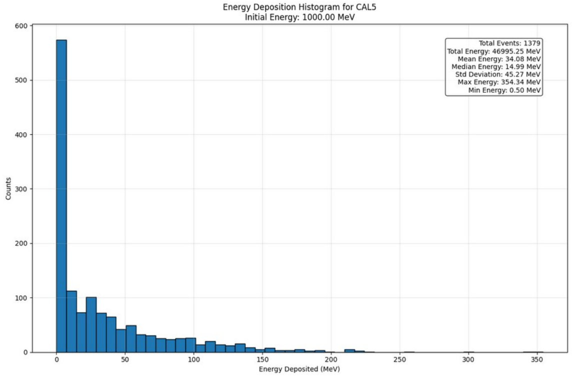




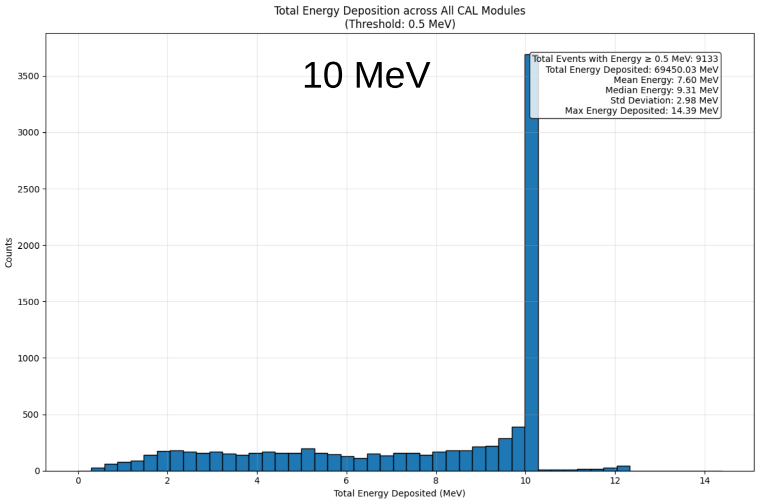


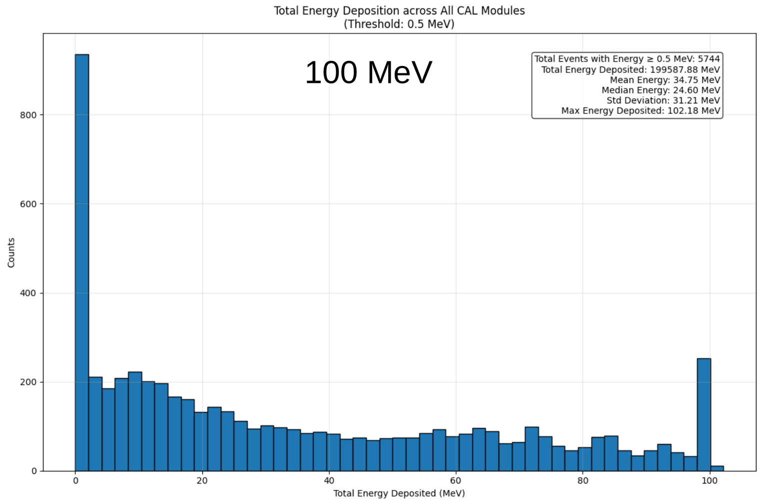


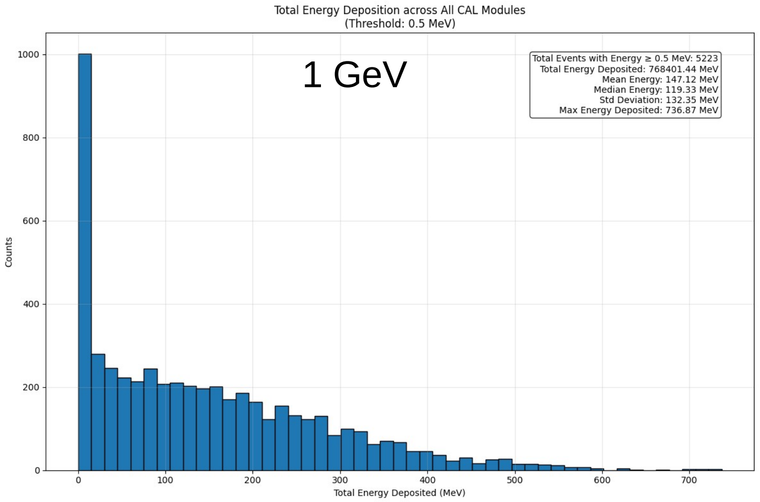


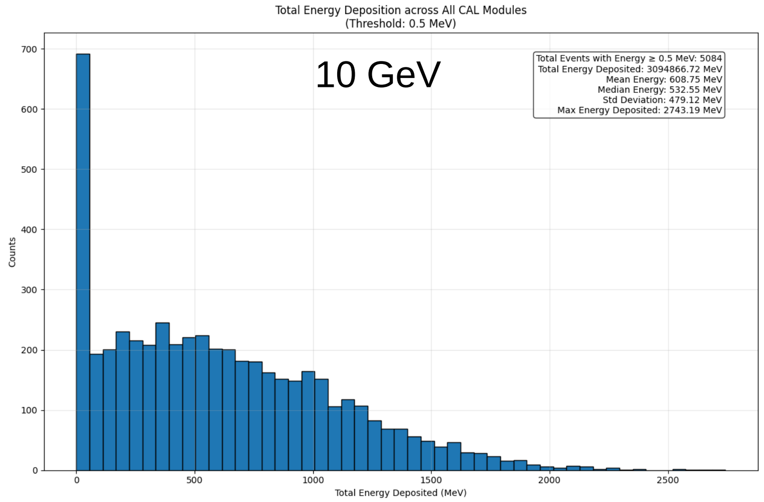


Total Energy Depositions

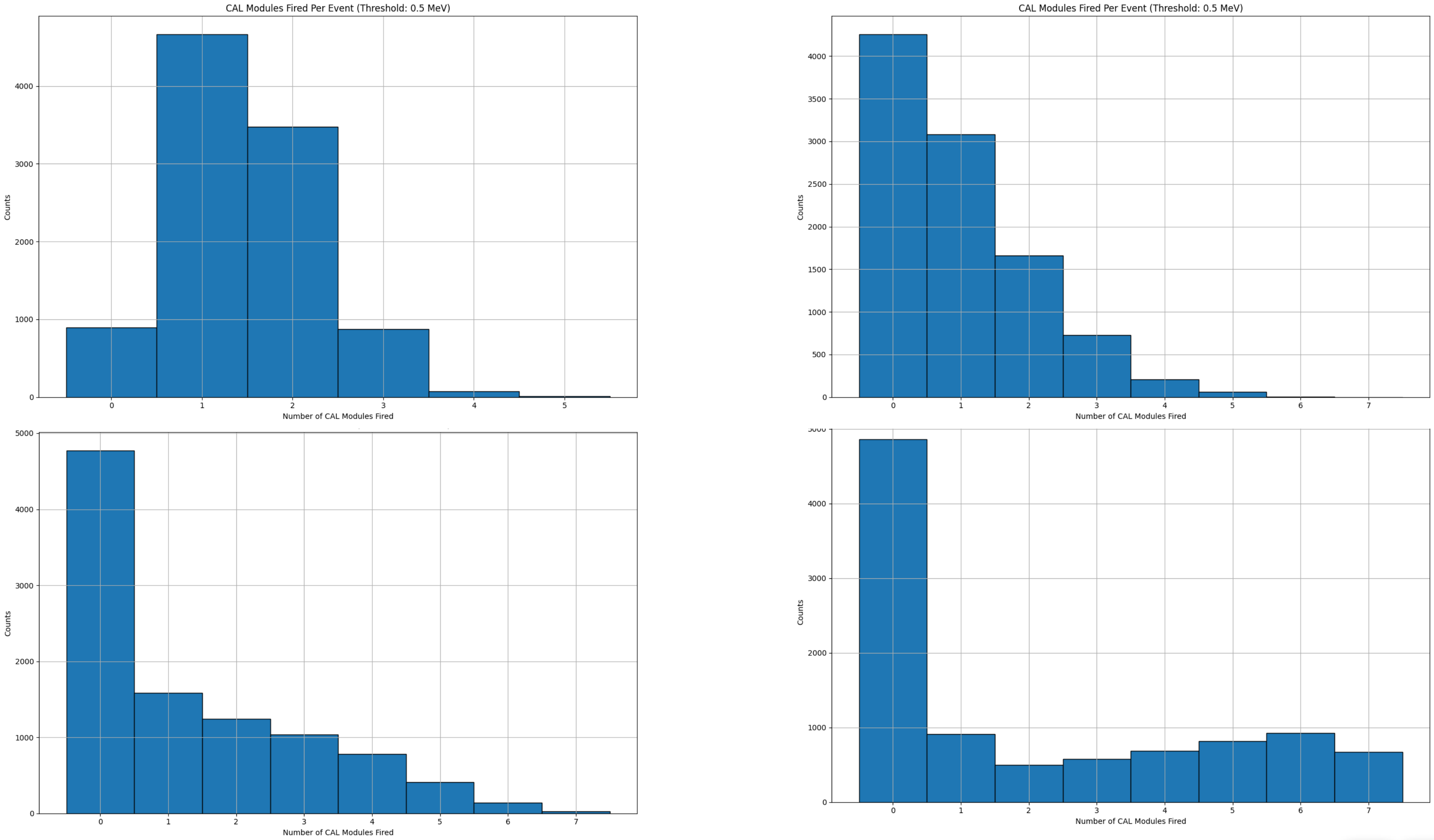








Modules Firing per Event



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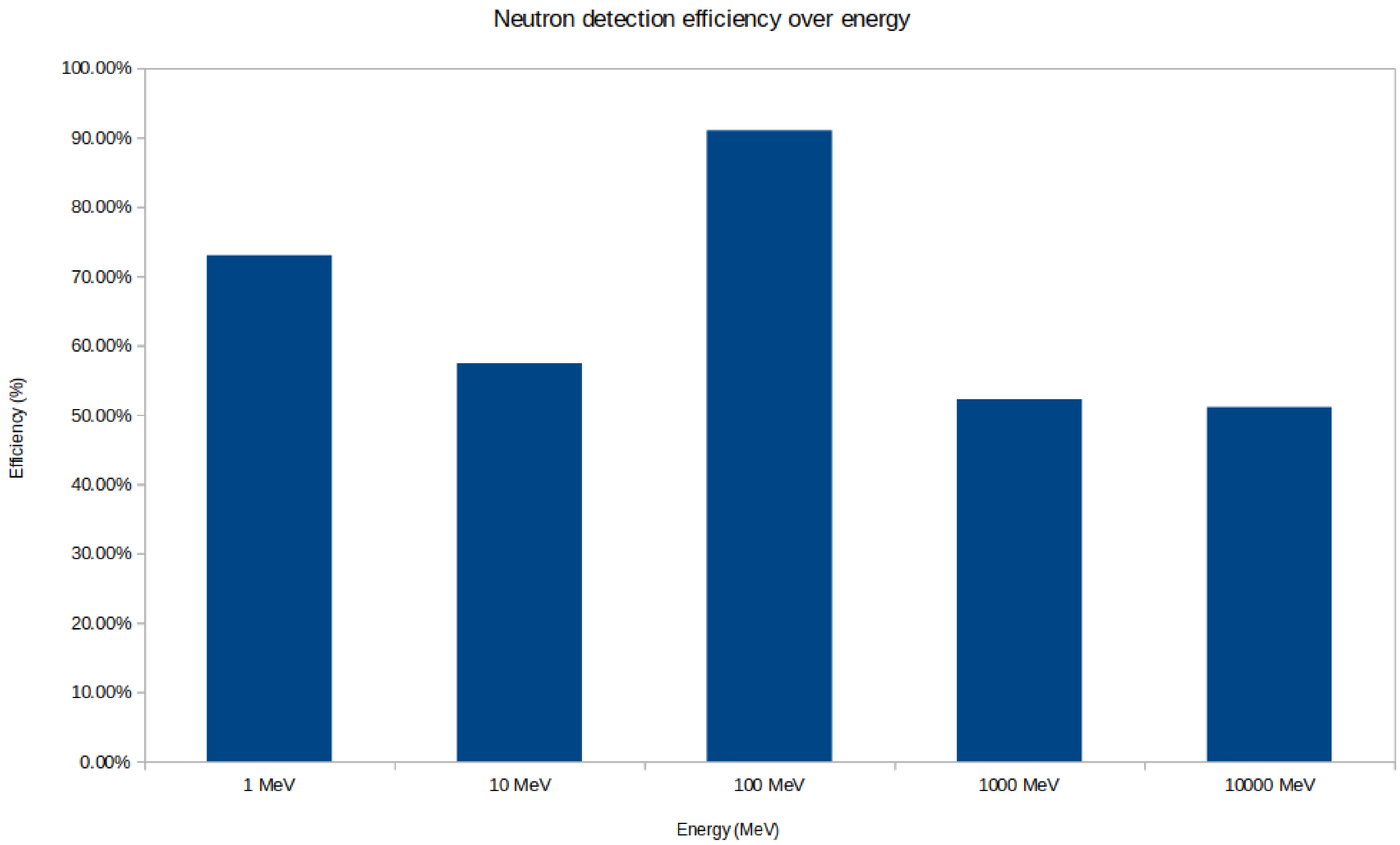
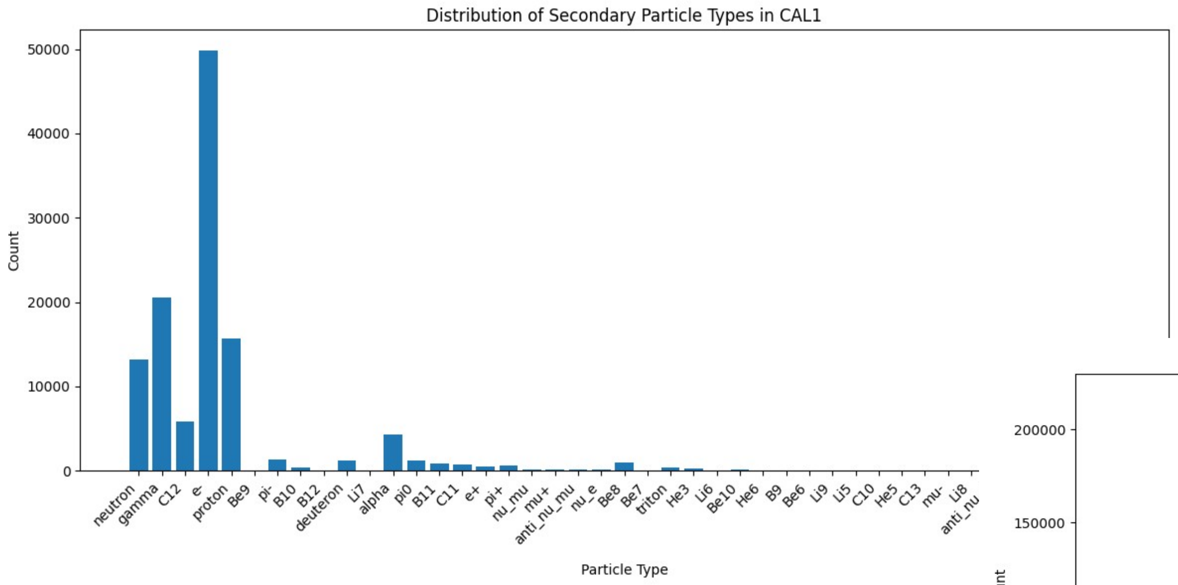
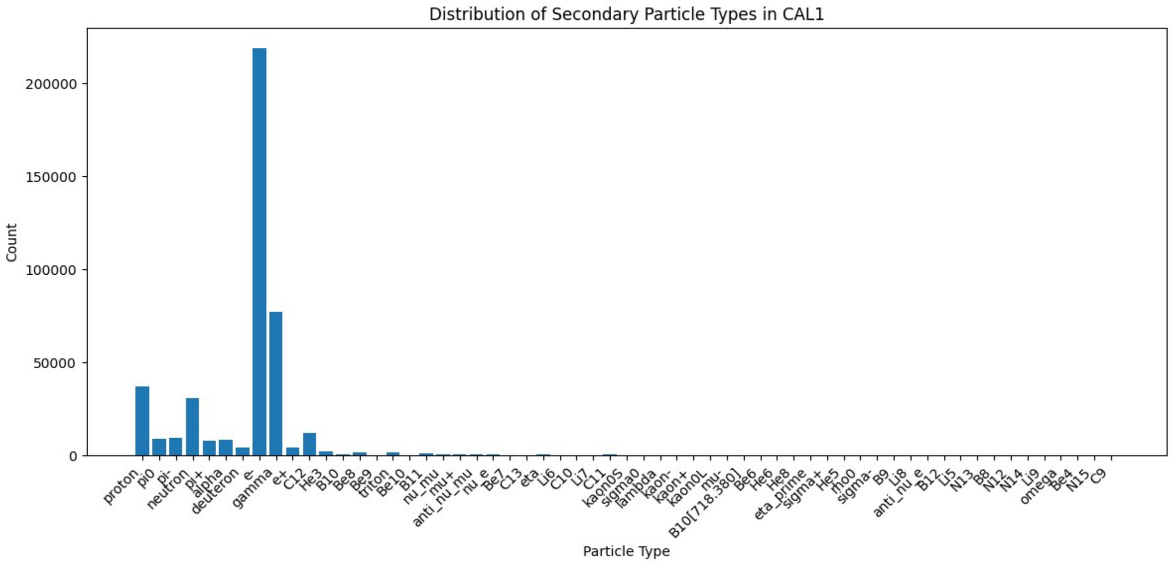


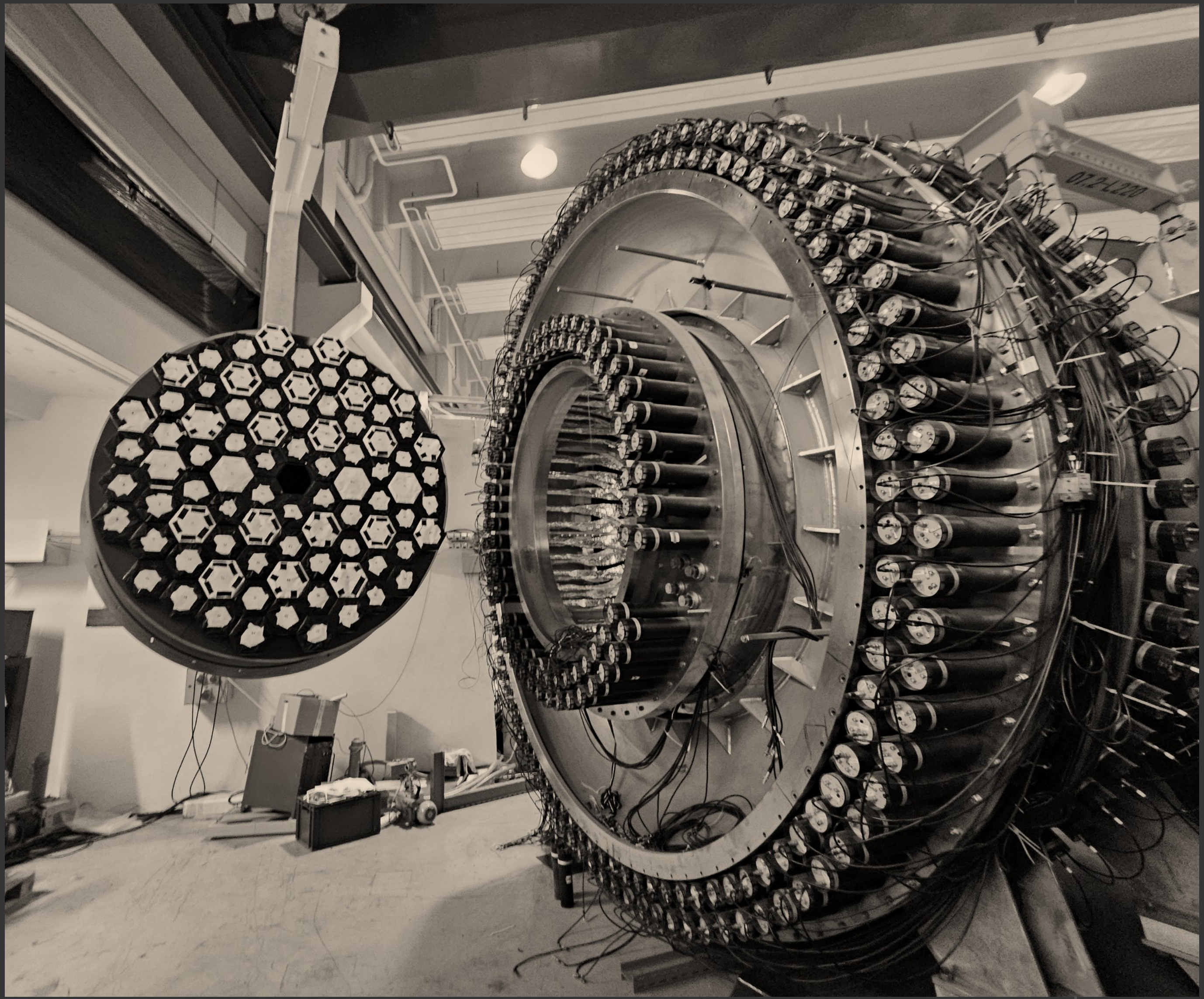
Geant4 – Particles produced





Summary

- 16 Modules have been removed from the 20+ ton detector TOF at COSY
- Two systems each consisting of 7 modules have been assembled mounted on the movable and height adjustable crates
- Both detectors have been transported to GSI and with upgraded VETO modules now are located in/near mCBM cave
- Data acquisition system selection in progress…
  - Two candidates: DiRich & TOF PADI
  - Single modules set up for readout tests in Wuppertal for DiRich and at GSI for PADI
- Geant4 Simulations …
- Beamtime data-taking and analysis



Outlook

- Completing selection process of readout systems and making a decision
- pp Geant4 simulations
- Calibration at CANAM, CZR cyclotron facility
- Detector commissioning
- Data taking on upcoming beamtimes
- Analysis, conclusions

Questions, Suggestions, Comments
Thank you for your attention!

References

1. E. Roderburg, IKP annual report 2011.
2. D. Grzonka, et al., Preparation of test modules for neutron detection at mCBM, 2023
3. J. Kreß, PhD thesis, University Tübingen, 2003.