Development and Integration of the Forward Spectator Detector for the CBM Experiment at FAIR

13th Beam Telescopes and Test Beams Workshop

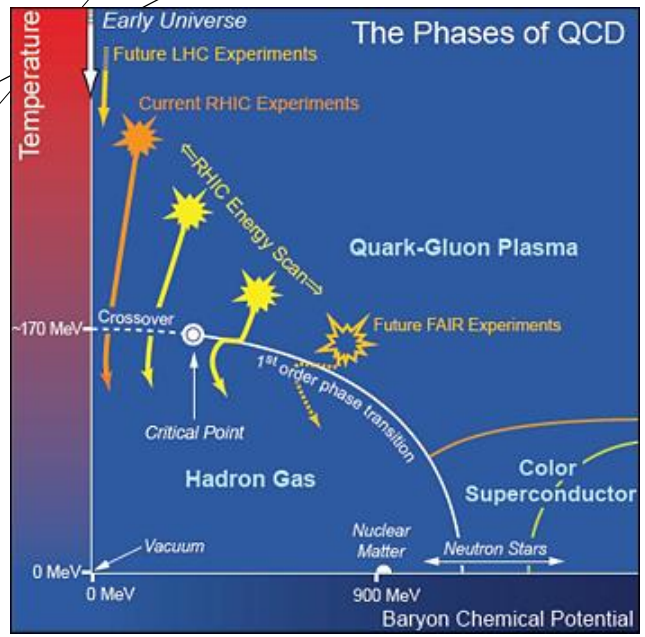
Otari Javakhishvili
Czech Technical University in Prague

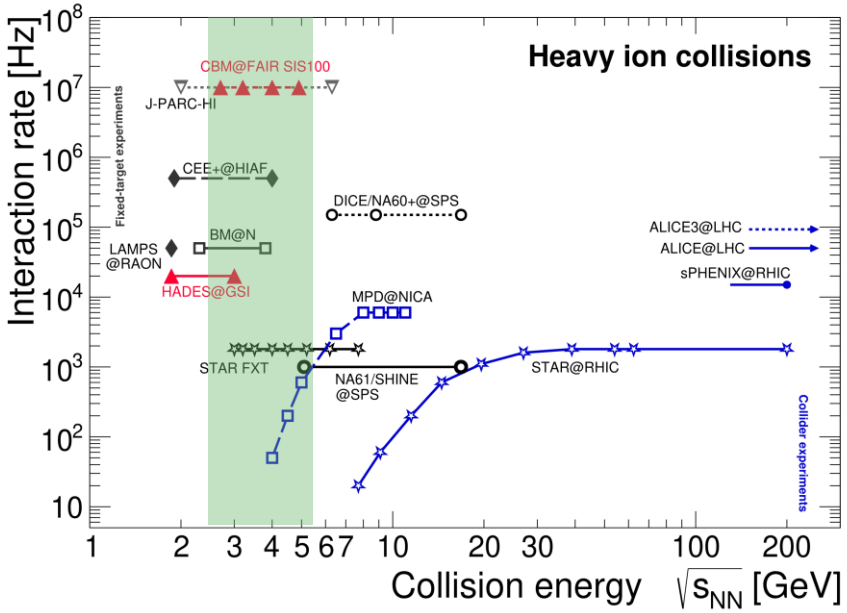
23.05.2025

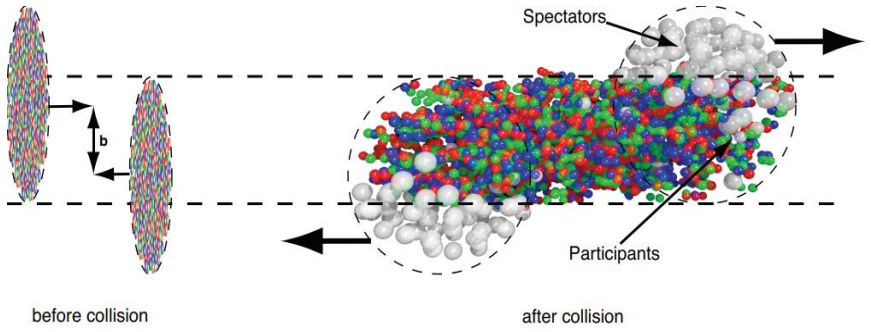
OUTLINE

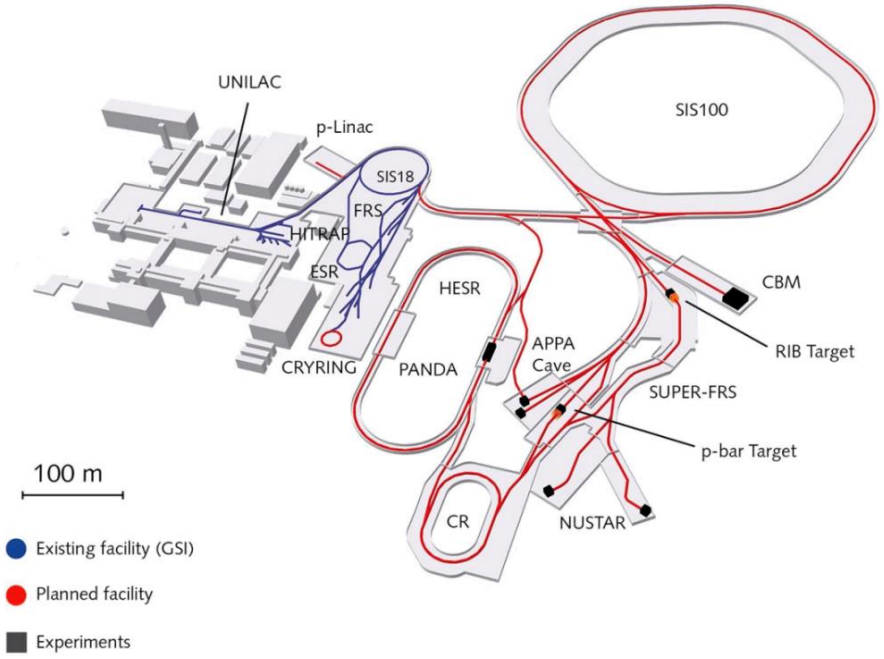
- Introduction
- Design and Concept
- Readout System
- Prototyping and Testing
- Future Plans
- Conclusions

INTRODUCTION



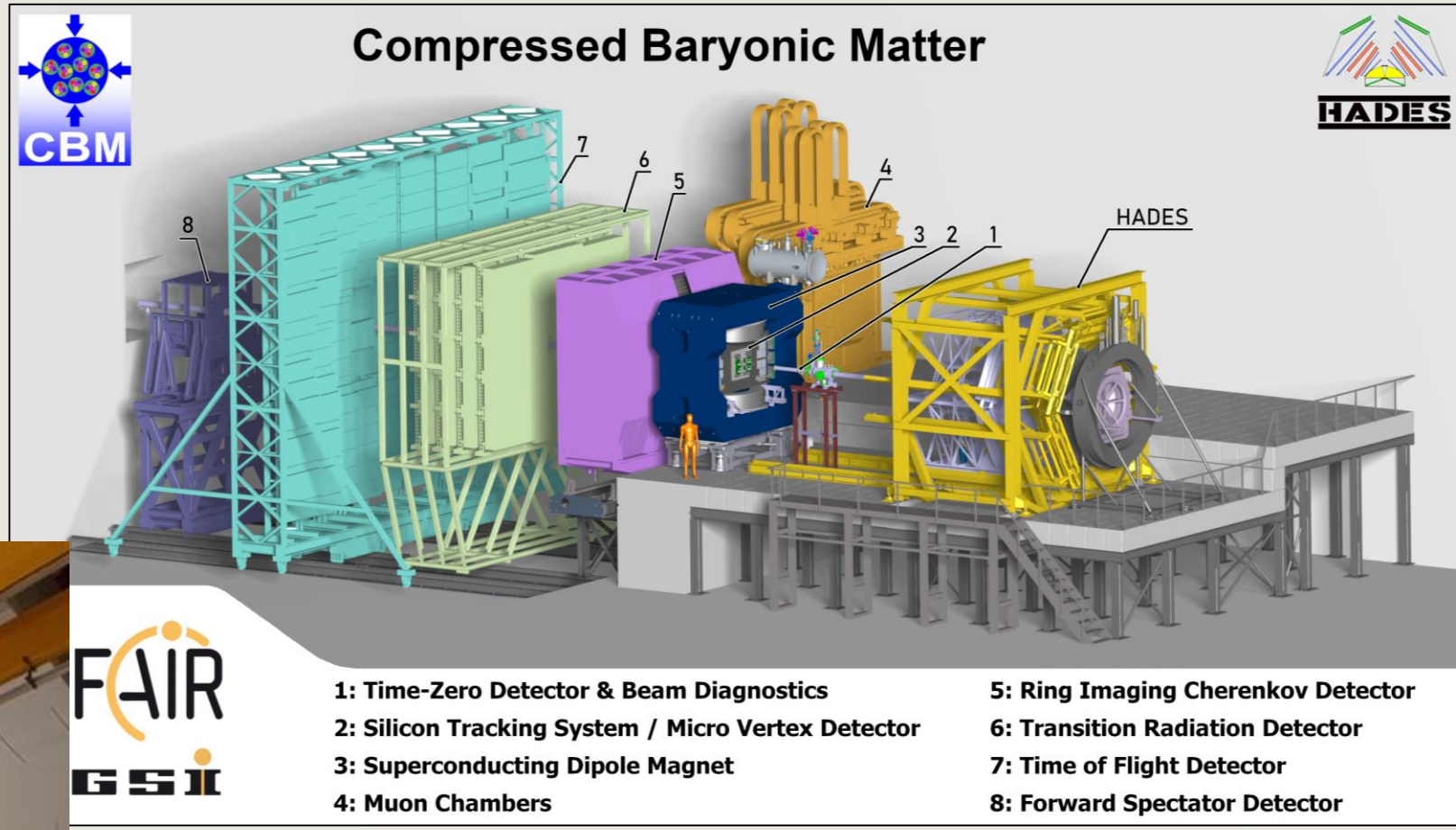






- **CBM Experiment**
  - Investigates the behavior of matter in high-energy nuclear collisions
  - Seeks to understand how matter behaves under extreme density and temperature conditions
- **Purpose of the Forward Spectator Detector (FSD)**
  - Detects spectator nucleons to measure collision centrality
    - Spectators are non-interacting protons and neutrons
    - Travel in the forward direction after collisions
  - Provides information for reconstructing the event plane
  - Helps analyze the geometry and dynamics of the collision

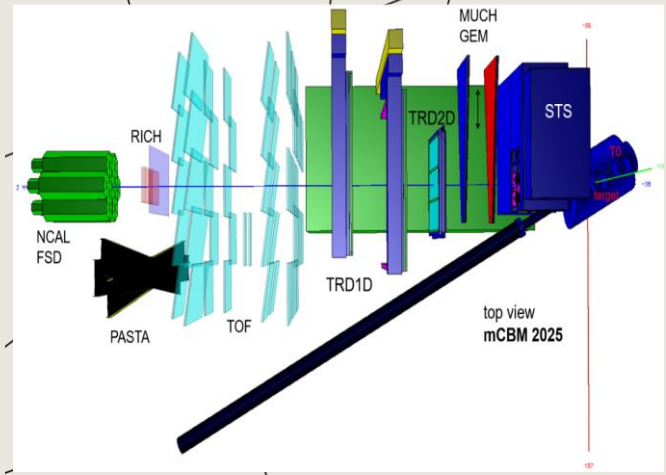
SIS100
CRYO 2
APPA
cave
CBM
S-FRS
NUSTAR HEB
NUSTAR LEB


Compressed Baryonic Matter
CBM
HADES
8
7
6
5
4
3
2
1
HADES
FAIR
GSI
1: Time-Zero Detector & Beam Diagnostics
2: Silicon Tracking System / Micro Vertex Detector
3: Superconducting Dipole Magnet
4: Muon Chambers
5: Ring Imaging Cherenkov Detector
6: Transition Radiation Detector
7: Time of Flight Detector
8: Forward Spectator Detector

CBM
Compressed Baryonic Matter
FAIR
GSI

mCBM Setup

Full system test with SIS18 beam

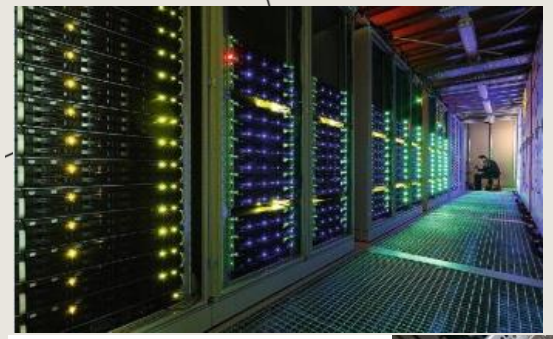


Free-streaming readout implemented and commissioned

Connection scheme, hardware, and achieved occupancies close to the final CBM DAQ

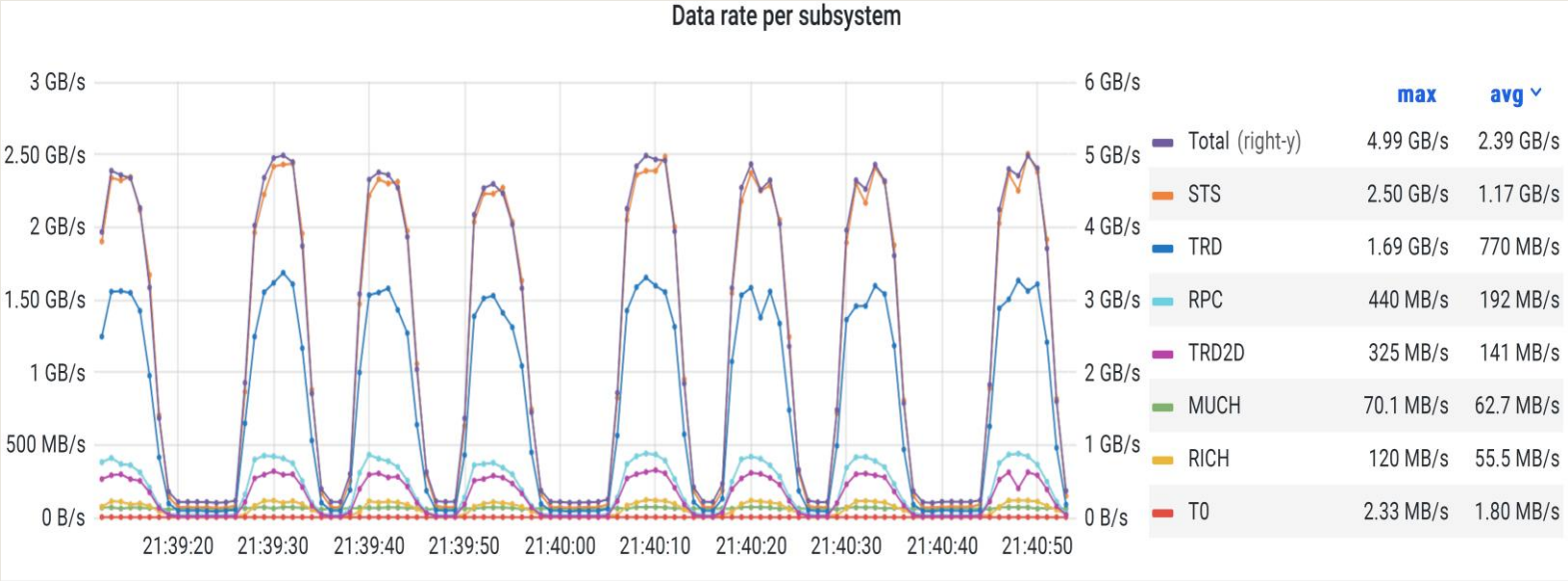
Can be scaled towards full CBM

High-rate capabilities demonstrated up to 10 MHz



GSI Green IT Cube

mCBM DAQ with CRIs (prototype for CBM) in an entry node

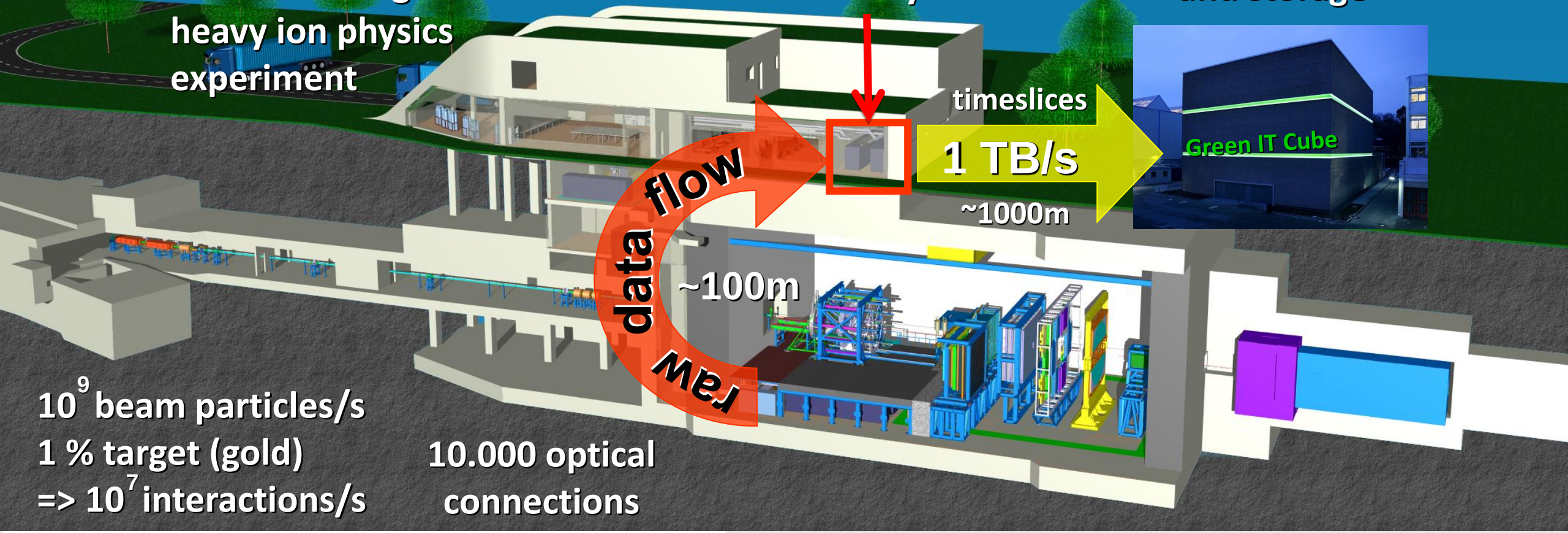


2028

CBM: a fixed target, high interaction rate, free-streaming heavy ion physics experiment

DAQ room: data pre-processing on FLES entry nodes

Green IT Cube: online event selection and storage

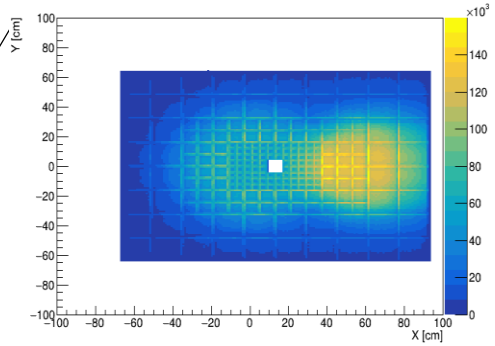


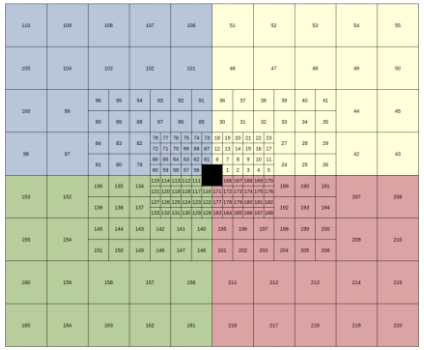
10^9 beam particles/s
1 % target (gold)
=> 10^7 interactions/s

10.000 optical connections

DESIGN AND CONCEPT

Modular design for easy maintenance





Detector size (cm):
160 x 128 x 10

Modules:
Small: 4x4 cm^2
Medium: 8x8 cm^2
Large: 16x16 cm^2

Based on PMT and Plastic scintillators (similar to HADES forward wall)

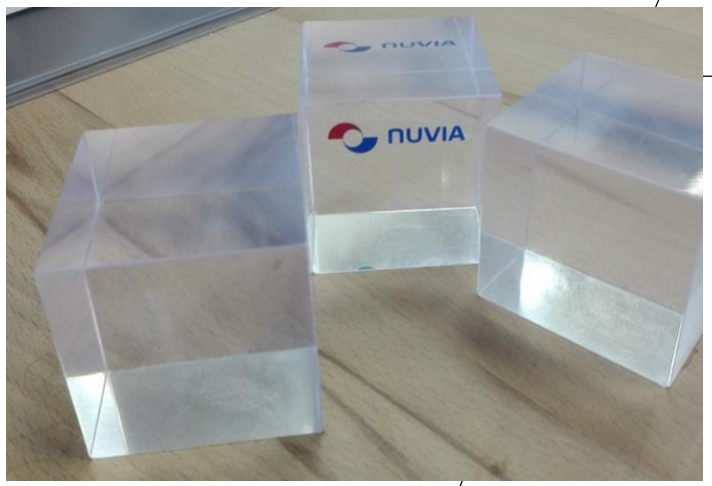
Material choice:

- plastic scintillator

  - not very radiation hard, easily replaceable

  - Local producer Nuvia (part Saint-Gobain)
    - Custom tuning of scintillator properties
    - Mechanical and optical processing
    - Cooperation in radiation hardness tests

- LYSO crystal (offered from Jedi experiment)
  - 3x3 cm
  - central part, possible to anneal
  - need to consider in simulations

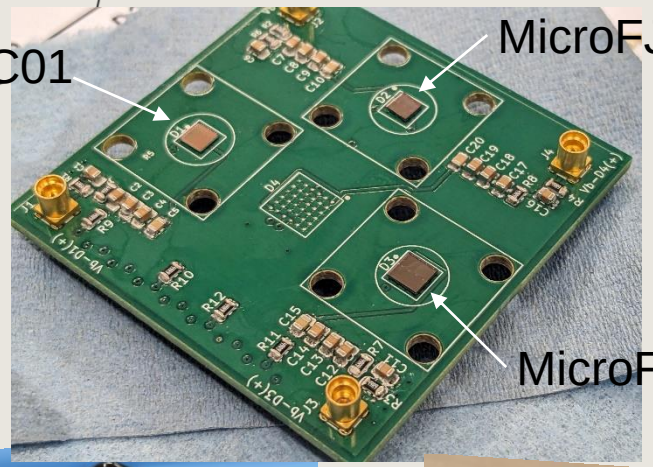


LIGHT SIGNAL DETECTION

LIGHT DETECTION DEVICES

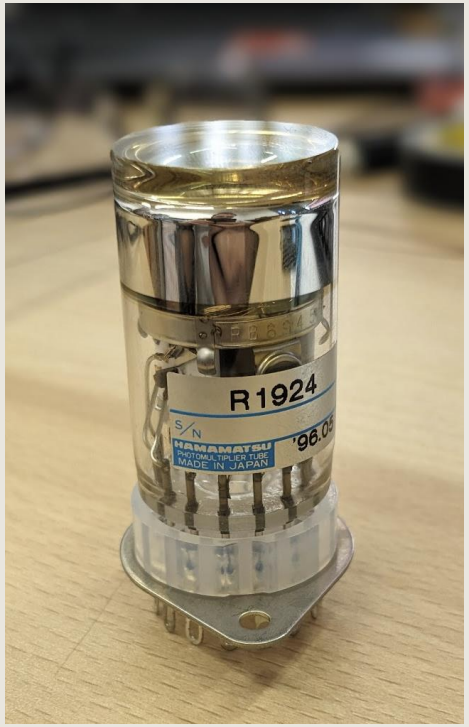
SIPMs

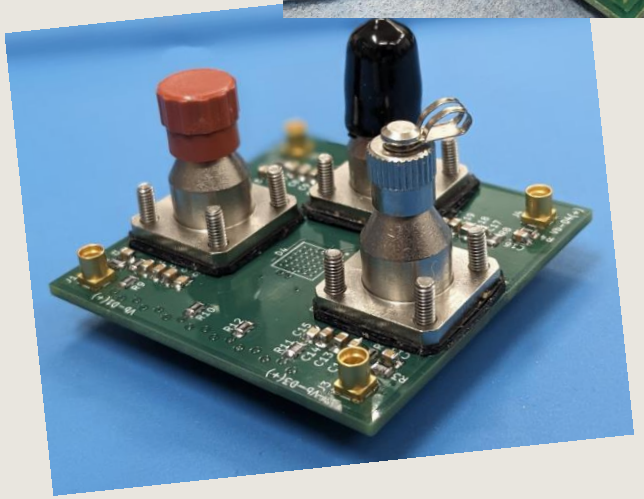
- Broadcom S4K33C01
- Onsemi MicroFJ30035
- Onsemi MicroFJ40035

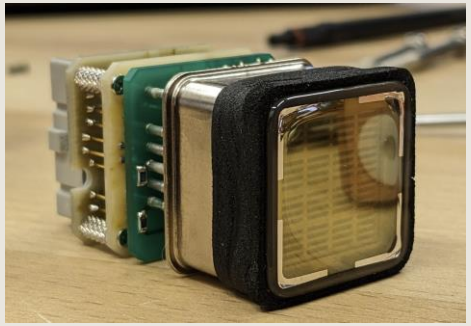


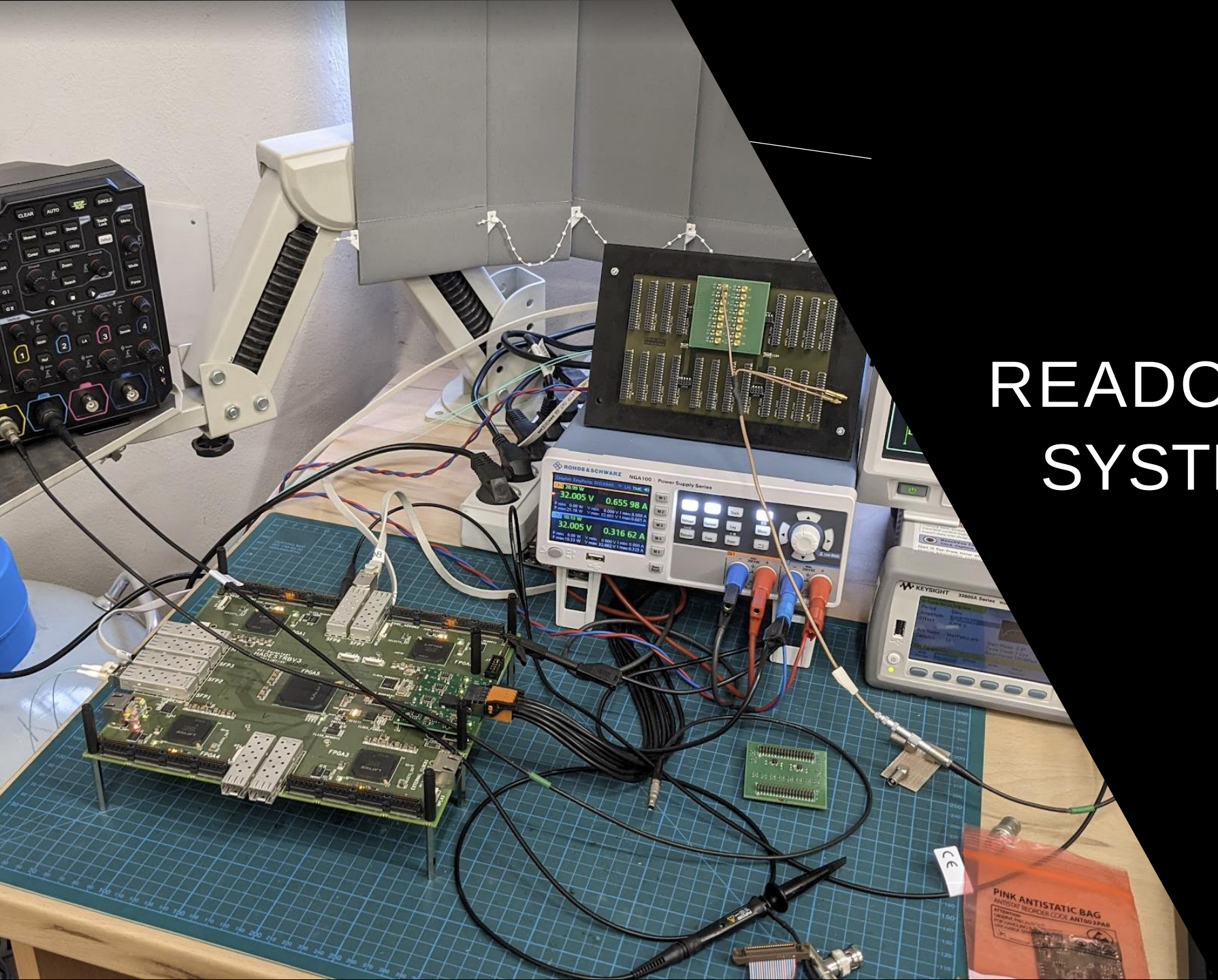
PMTs

- Siemens XP2020
- HAMAMATSU R8900
- HAMAMATSU R1924





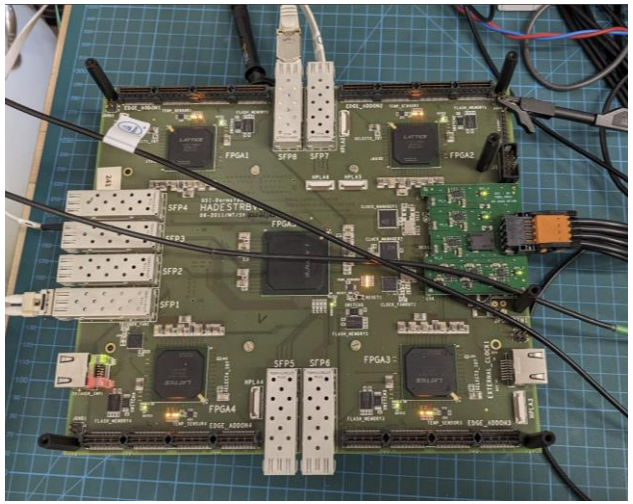




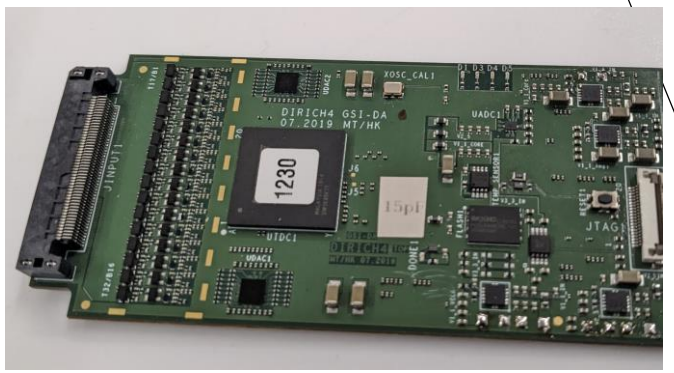
READOUT SYSTEM

CURRENTLY IN USE:

TRB3, Dirich4 - Readout system developed in GSI. Well tested, used in other experiments

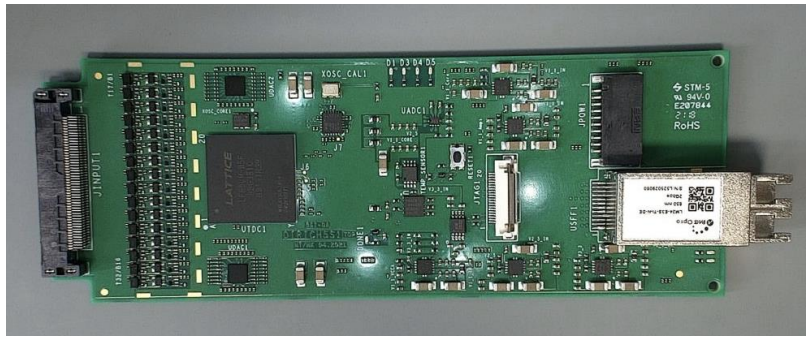


TRB + DIRICH



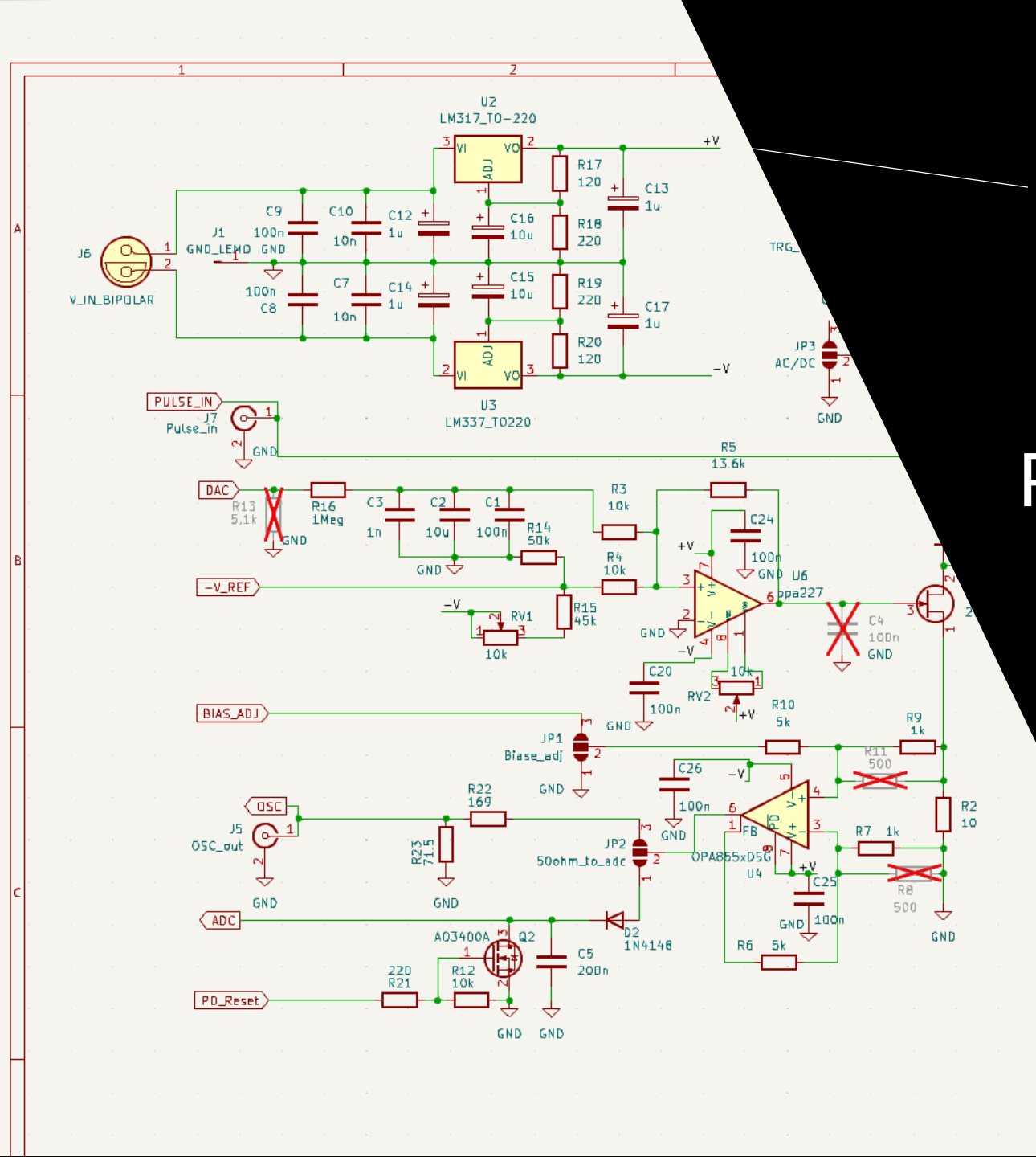
NEW ALTERNATIVES

DIRICH 5 standalone



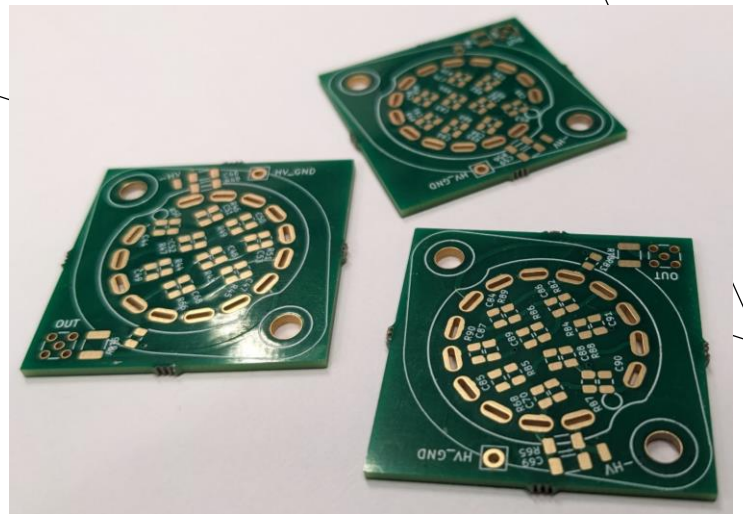
DIRICH 5 Dogma

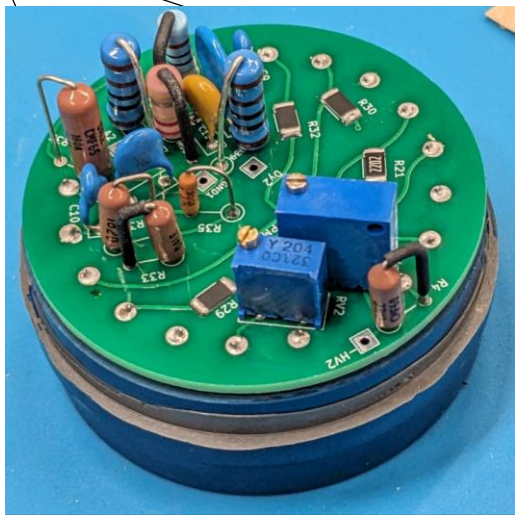
http://trb.gsi.de/

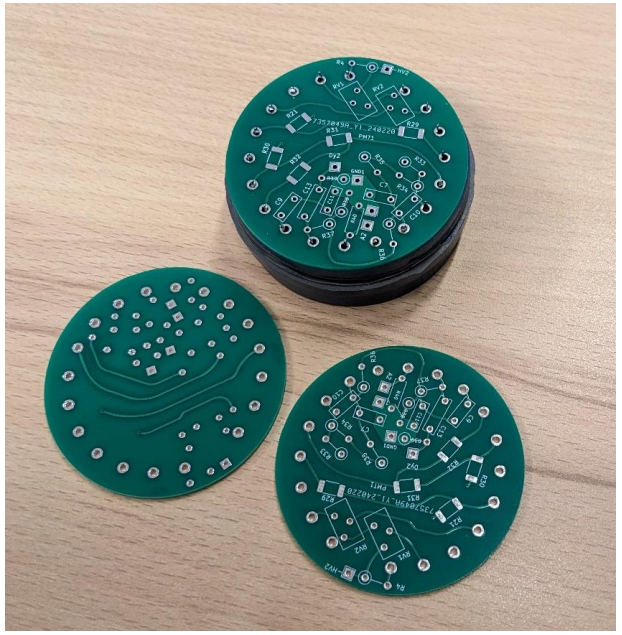


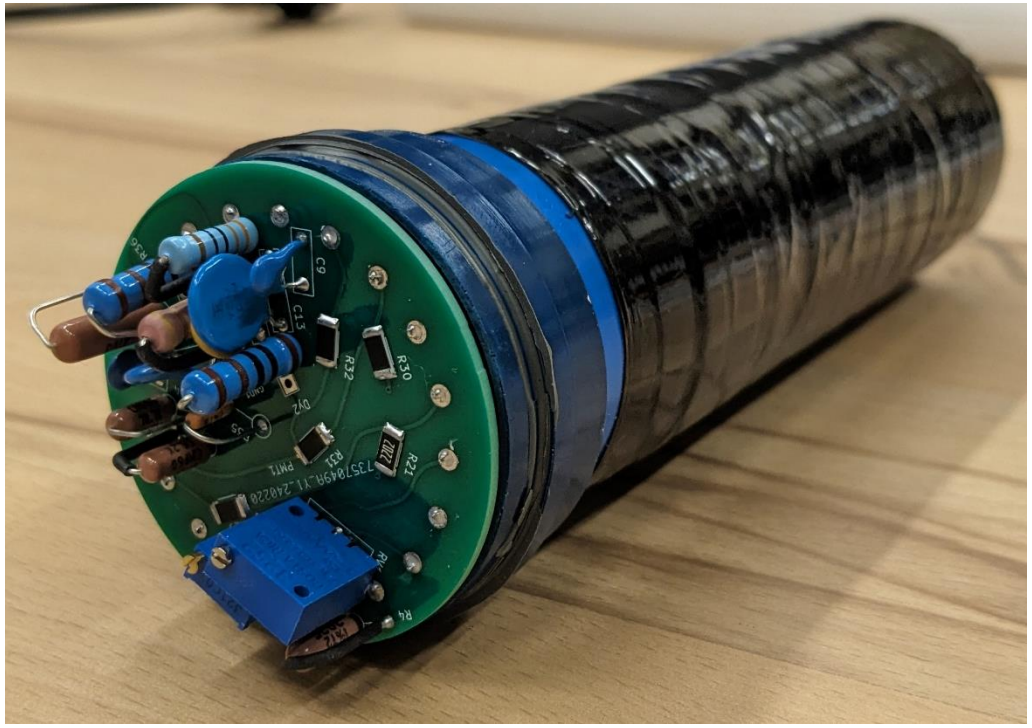
PROTOTYPING and TESTING

NEW PMT BASE



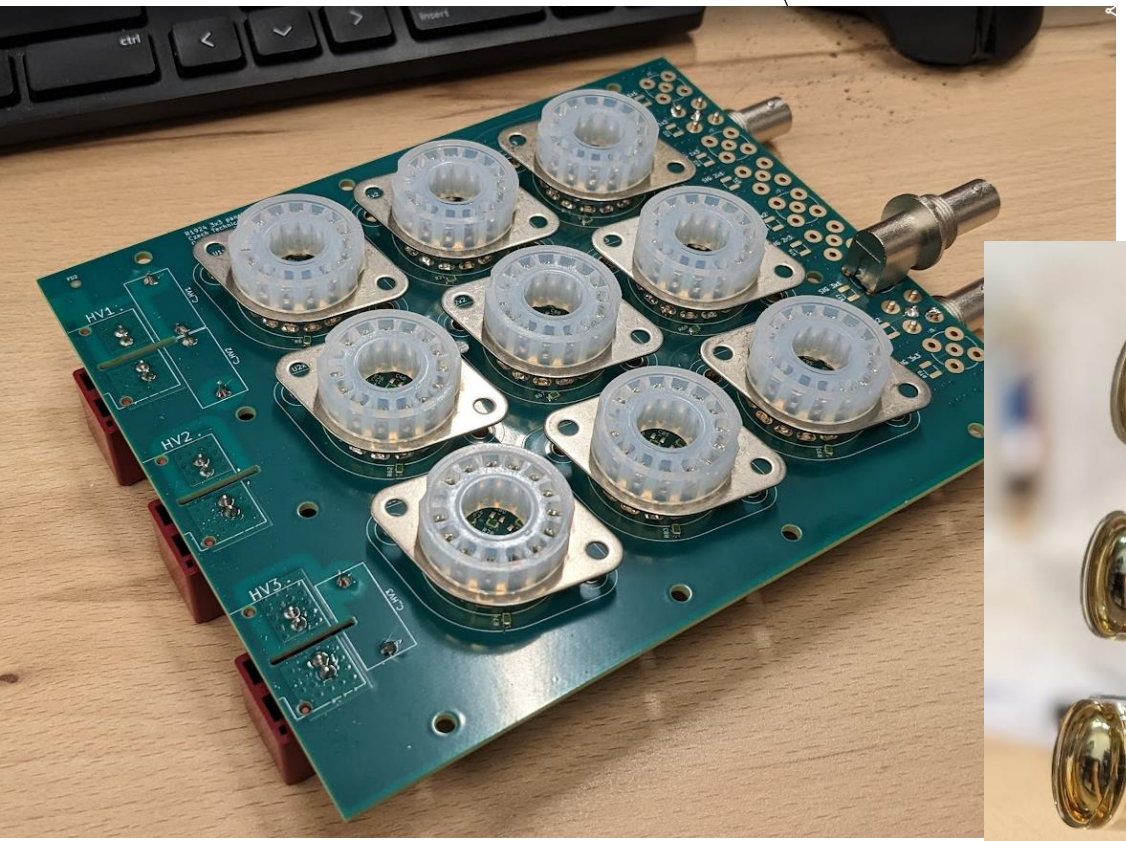


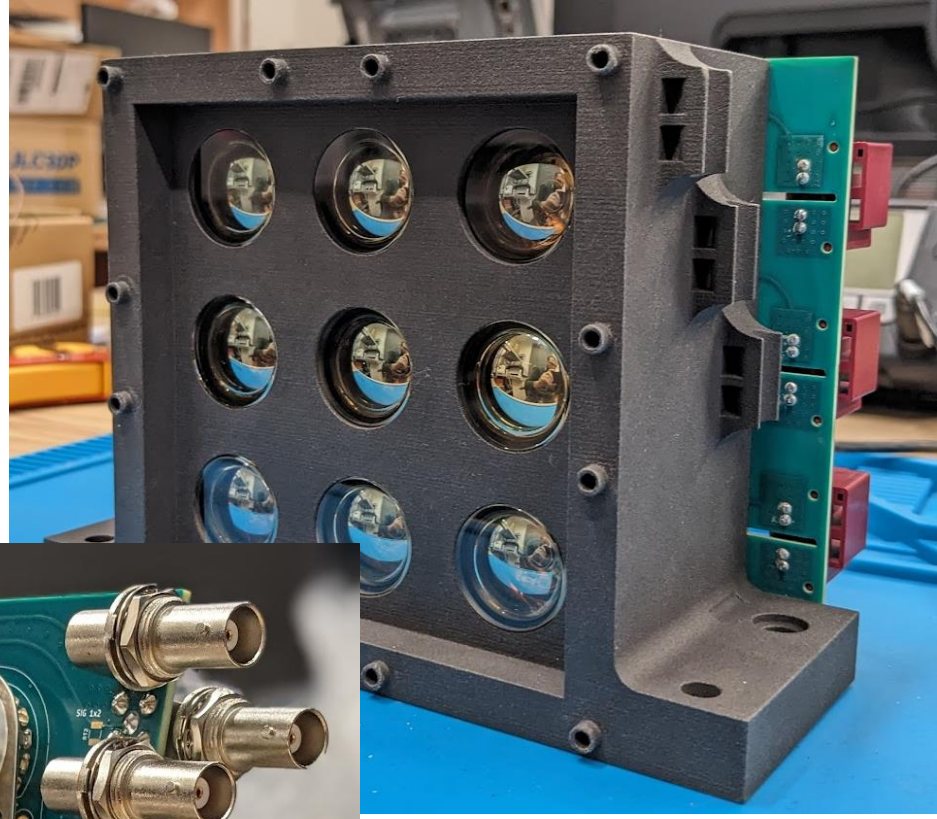


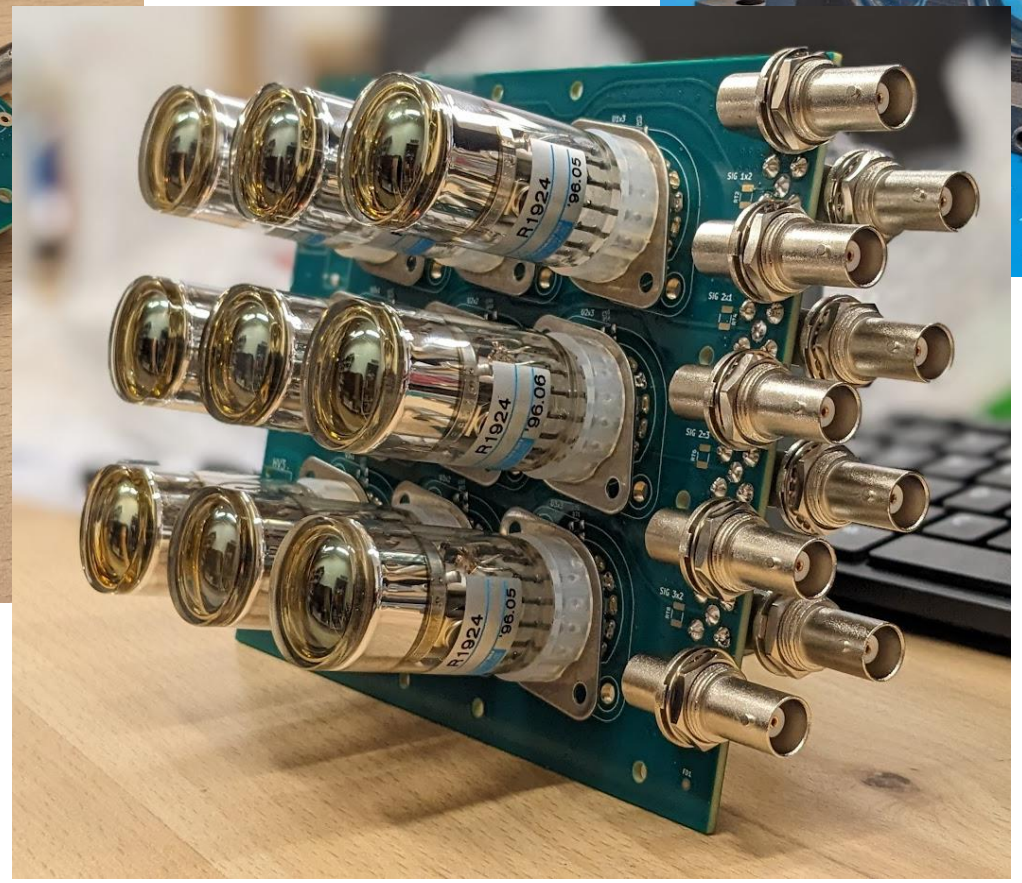


Several new designs. Optimized for timing, fast readout and power dissipation and small footprint

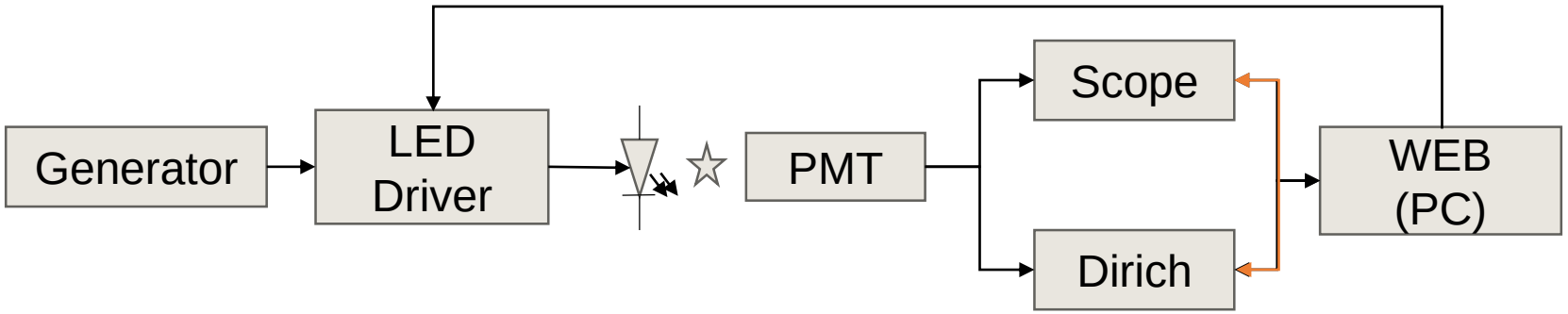
NEW TEST SYSTEM

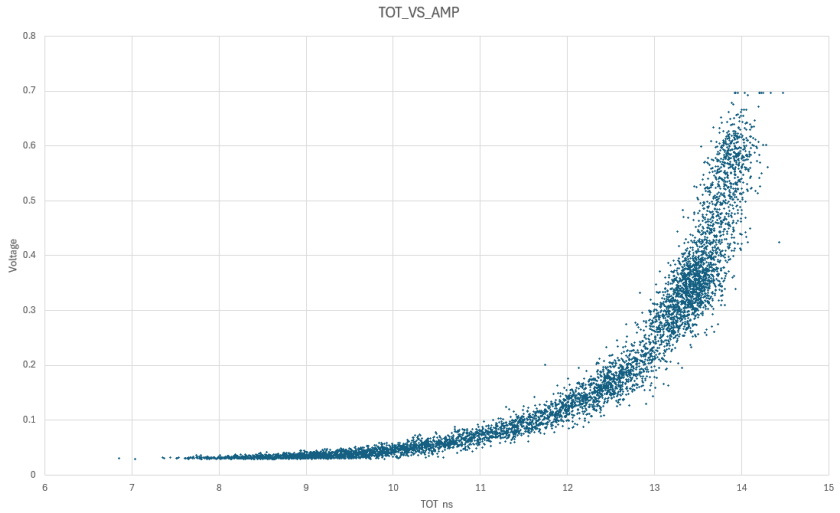




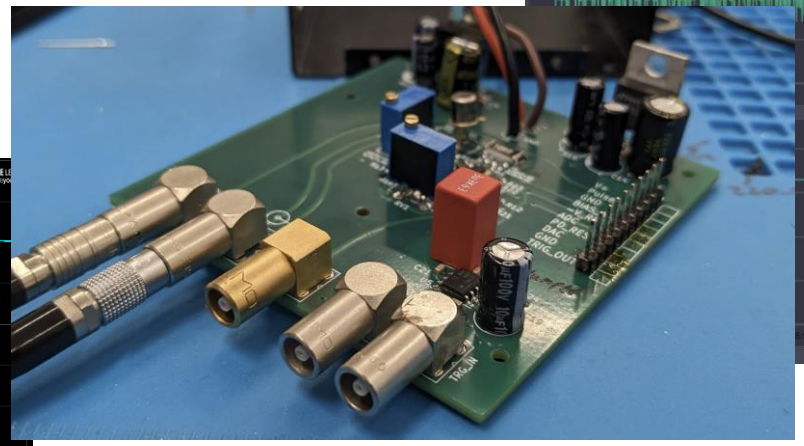


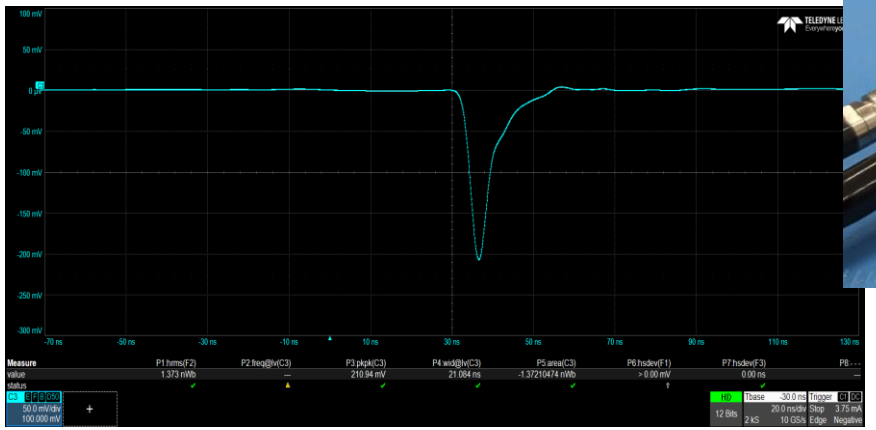
ADJUSTABLE LED DRIVER



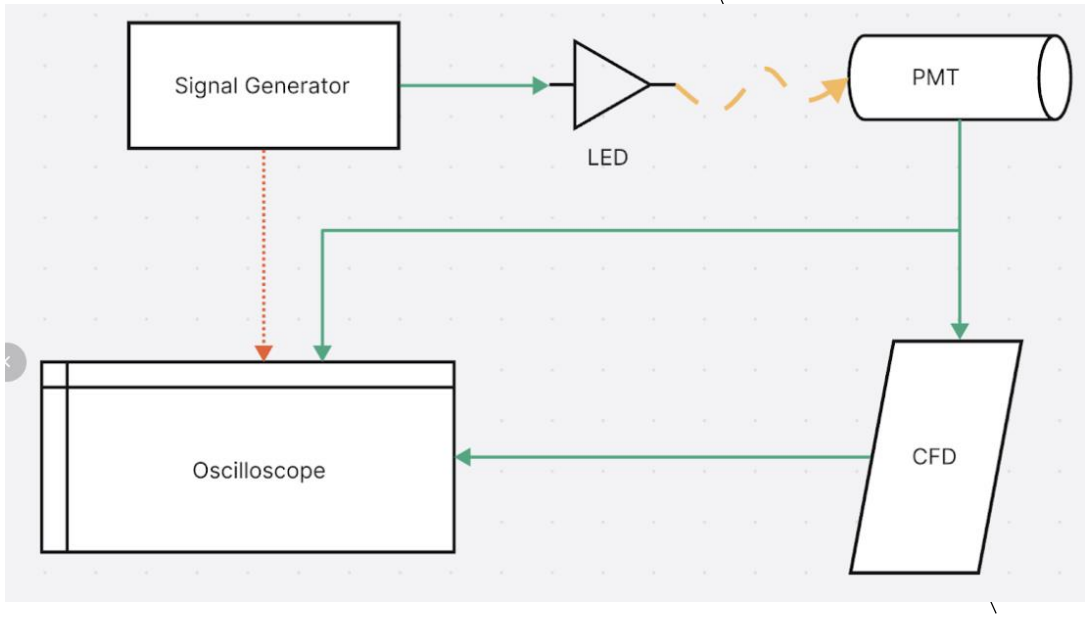


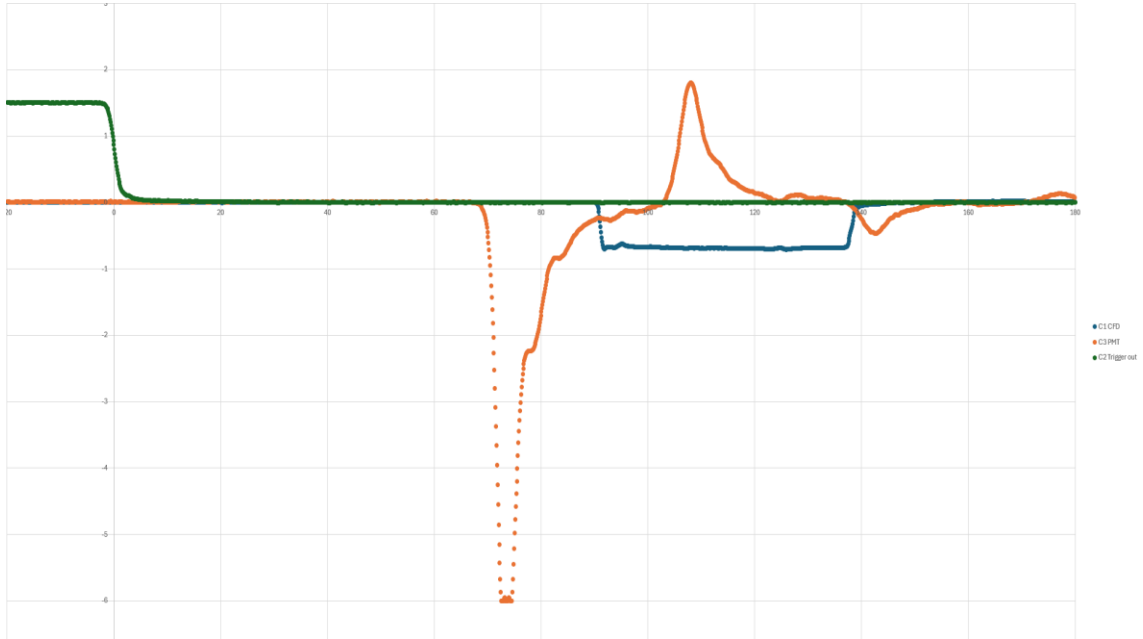
- Web controlled
- Current adjustment 1.5-50mA
- Current monitoring (OSC_out or average current measurement
- Trigger in/out

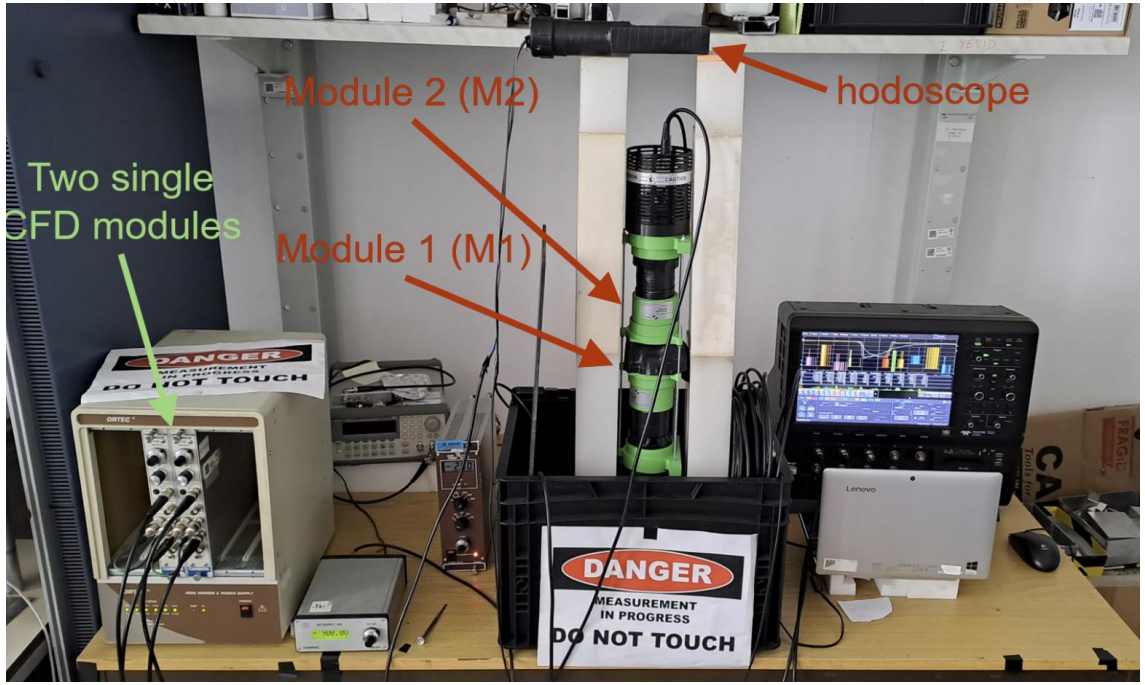




PMT time resolution

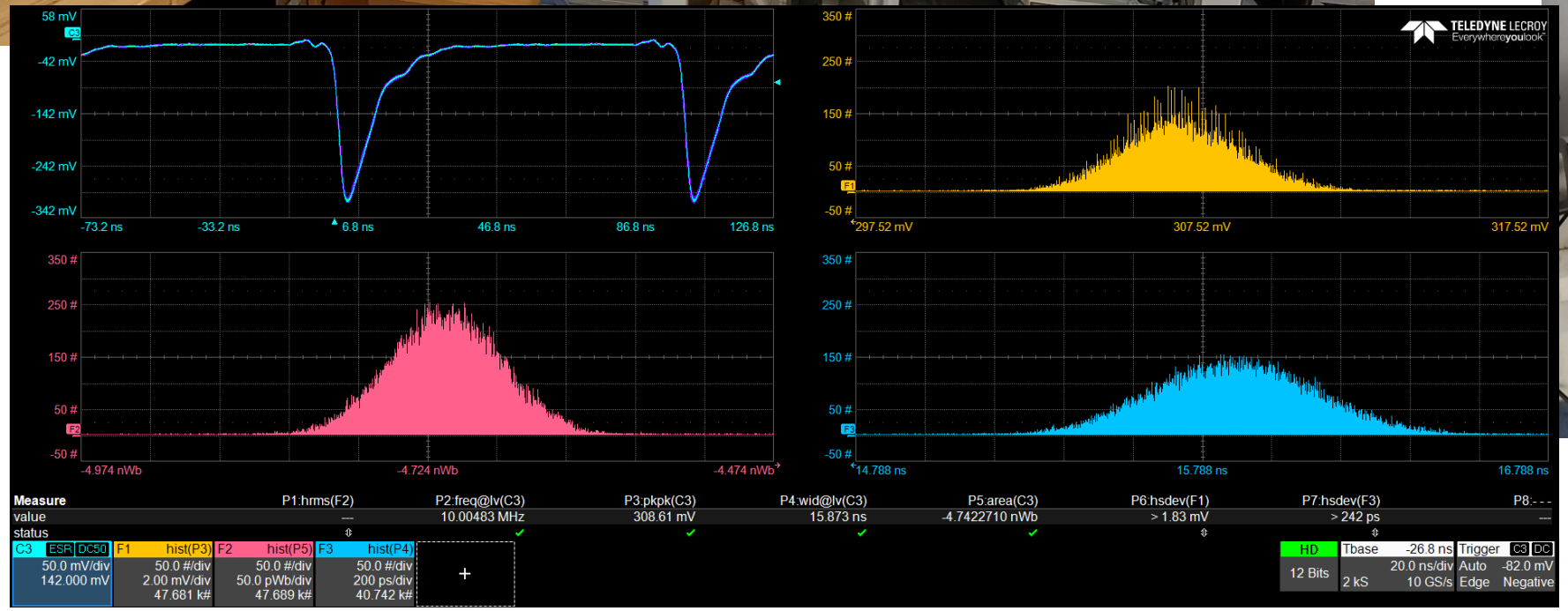






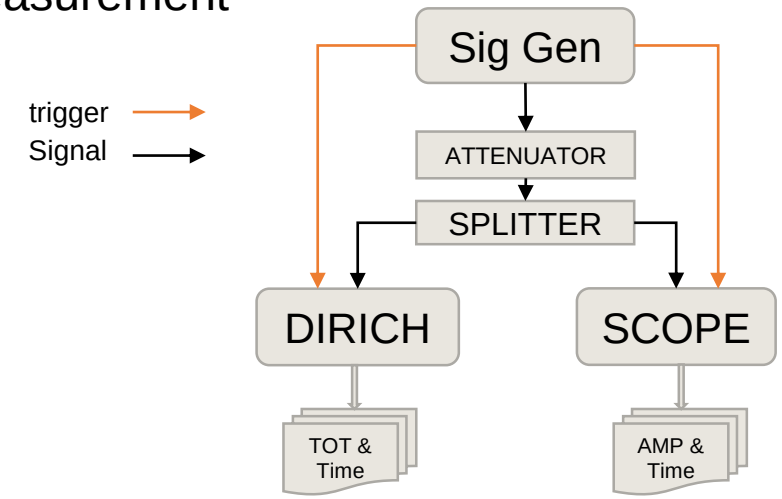
Lab tests
XP2020 ≈ 150ps
R1924 ≈ 300ps
System error ≈ 50ps

Cosmic tests with double xp2020 with scintillators showed ≈ 560ps which corresponds to ≈ 167ps of single module time resolution

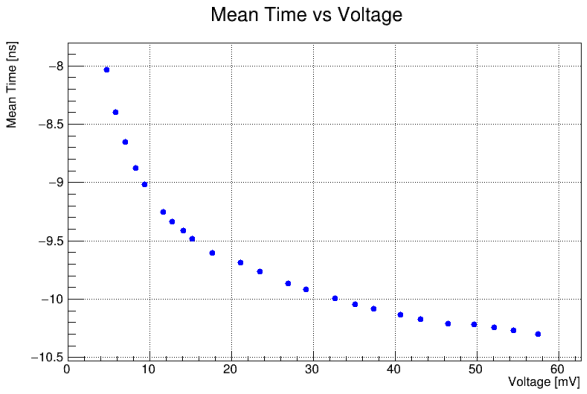


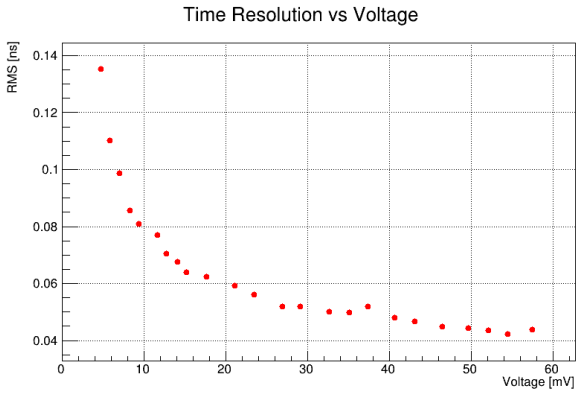
Ongoing tests with cosmics

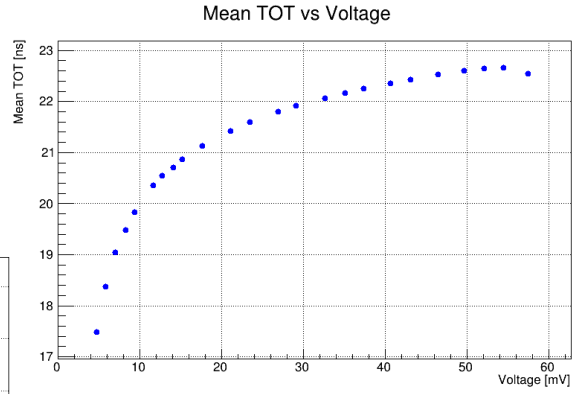
Time walk measurement

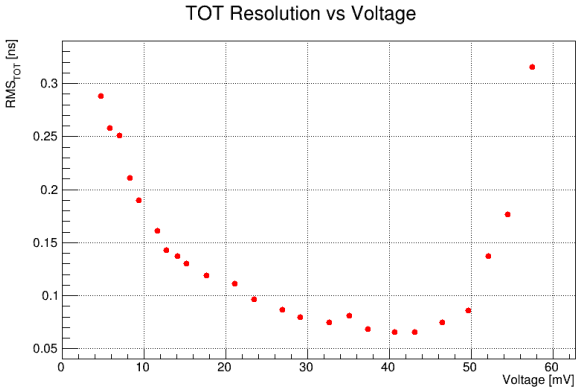


CH2

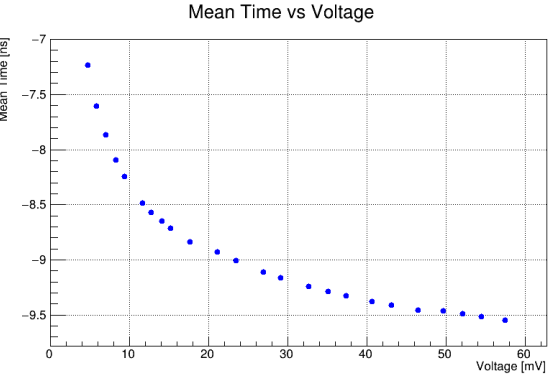


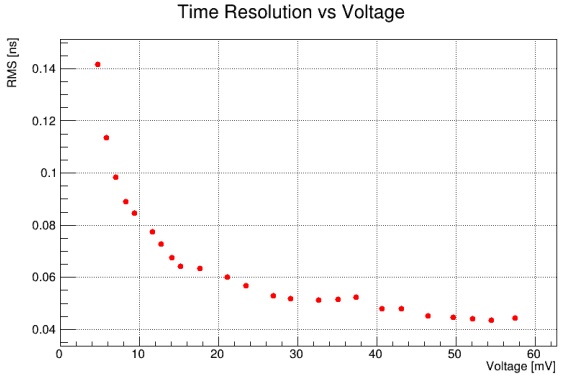


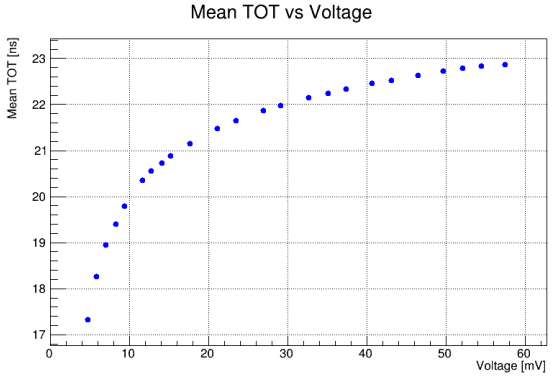


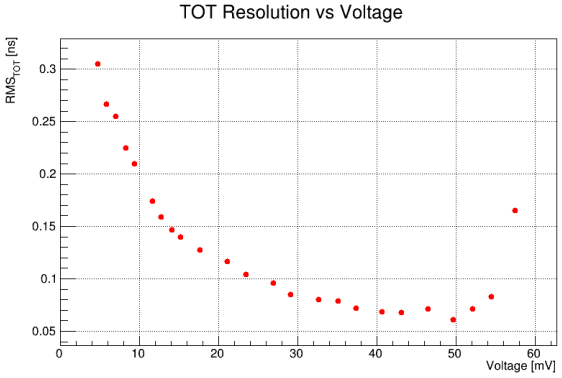


CH3

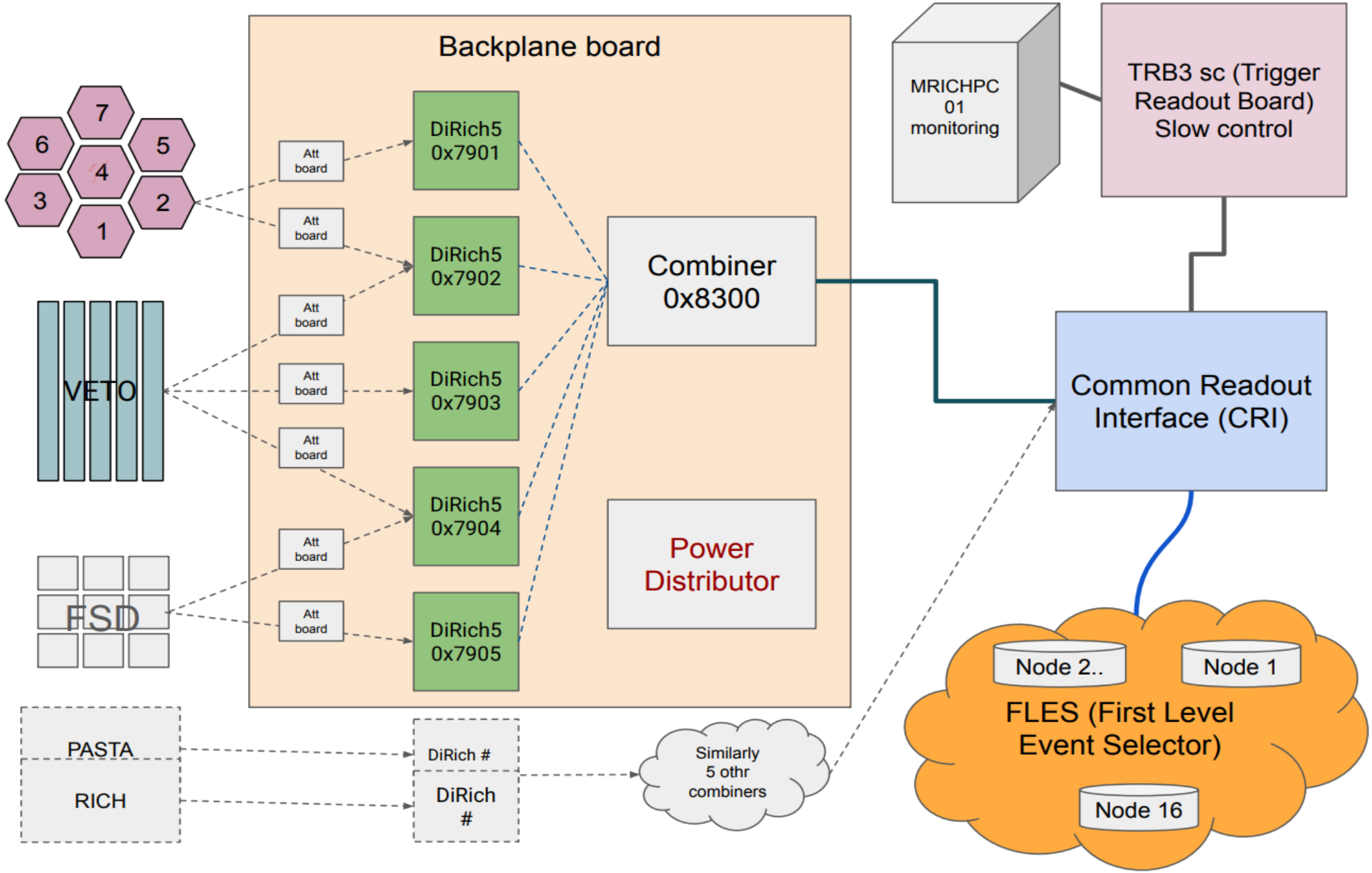




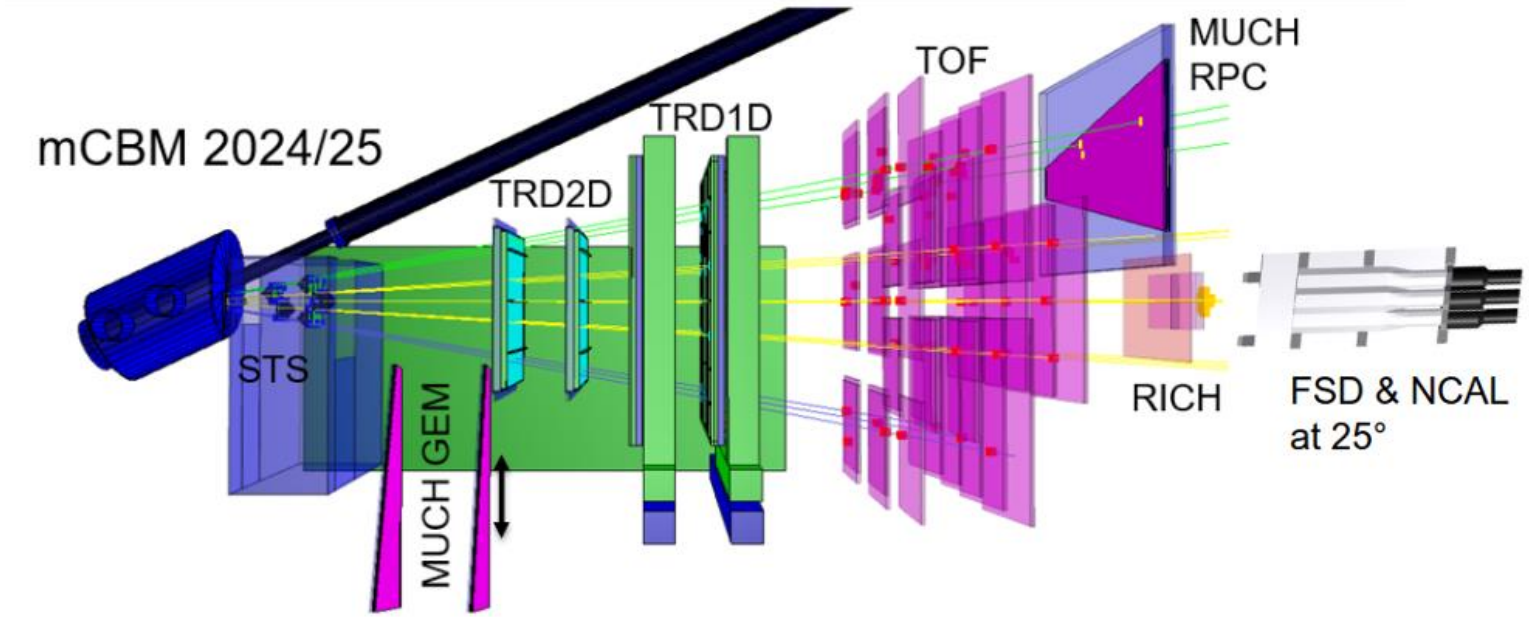


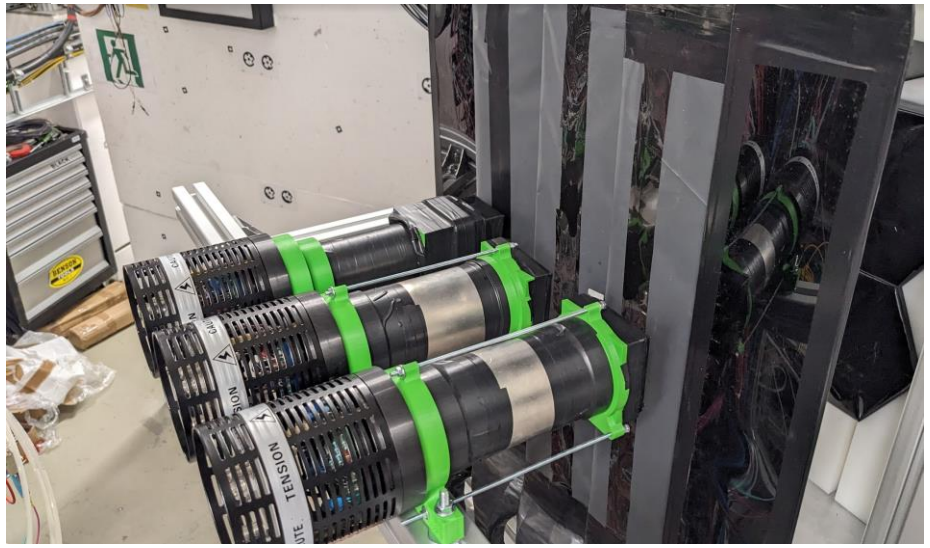


FSD, NCAL, VETO DAQ Flowchart

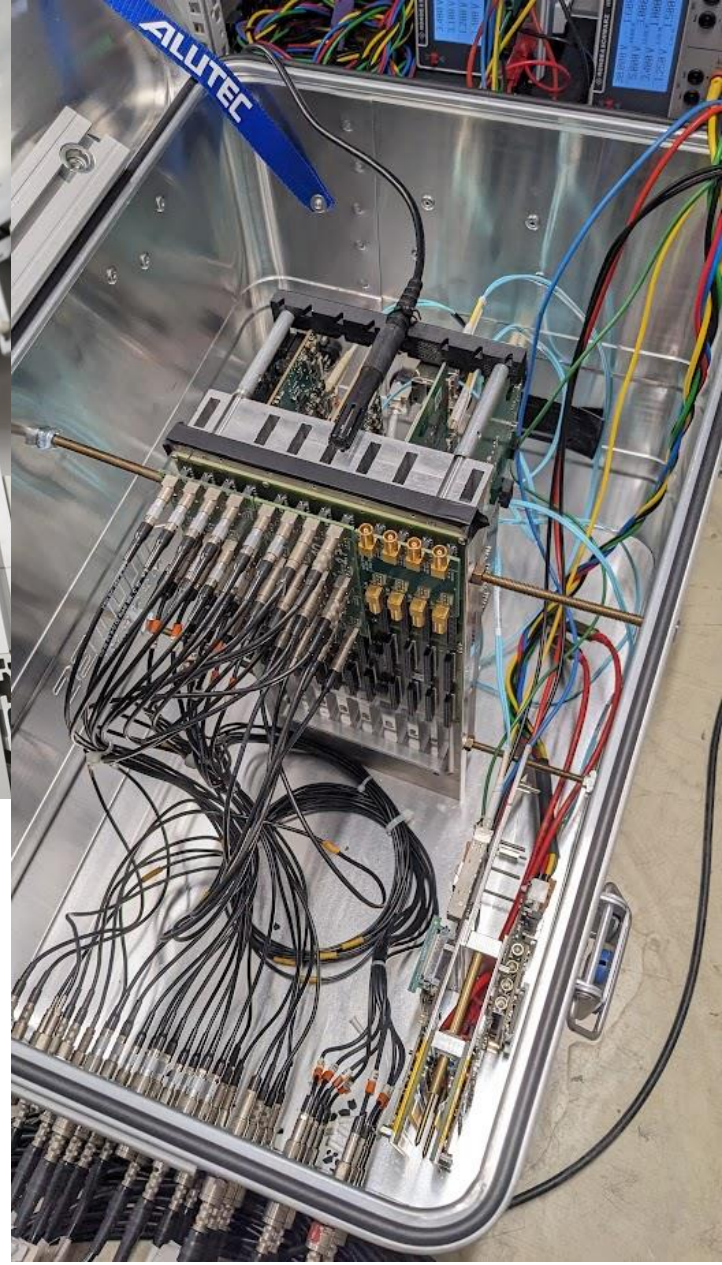


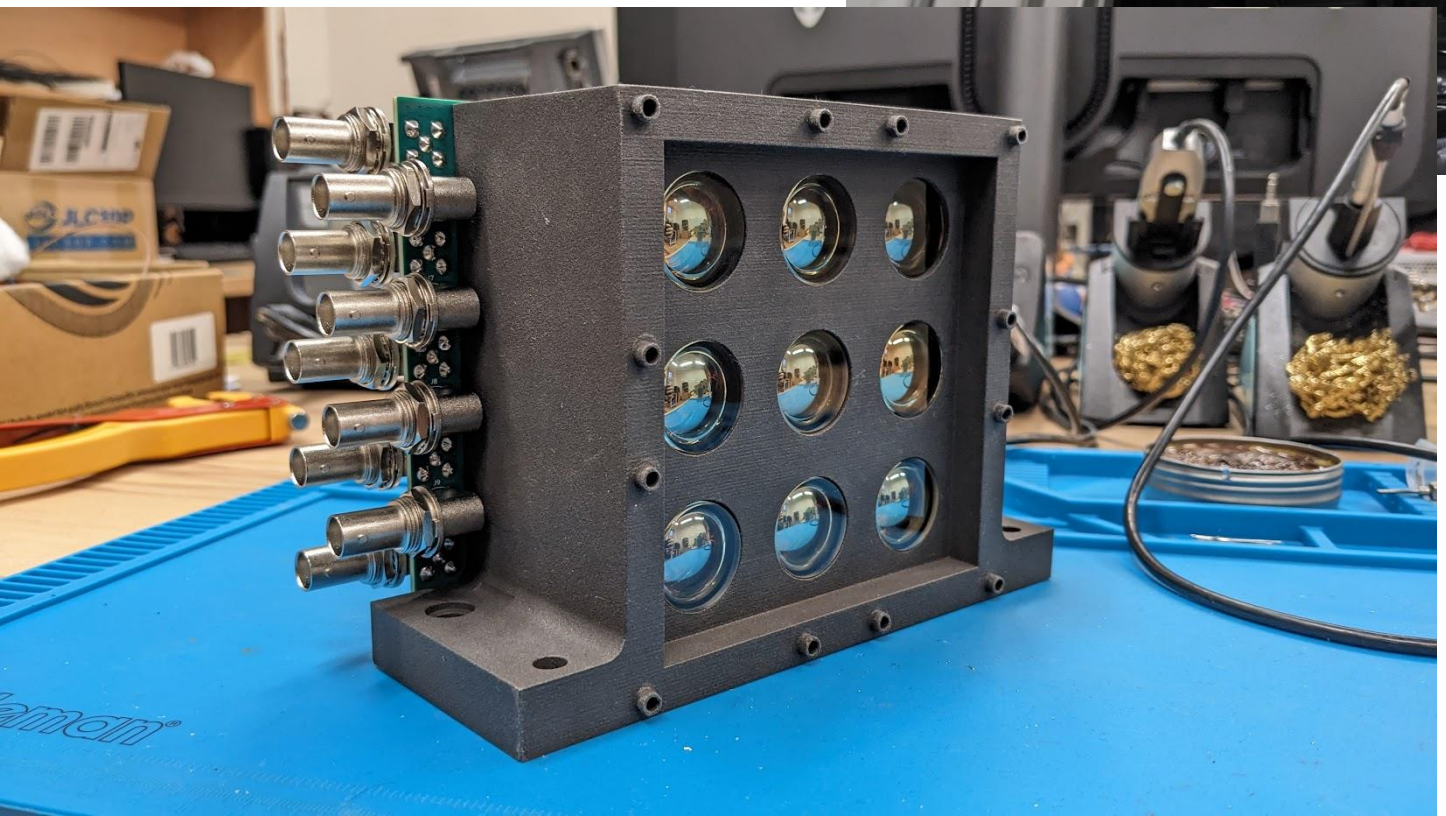
FSD in mCBM


mCBM 2024/25
STS
MUCH GEM
TRD2D
TRD1D
TOF
MUCH
RPC
RICH
FSD & NCAL
at 25°



mCBM test setup





SUMMARY

- Basic concept and outline of the detector has been created using well tested GSI in-house technology for readout
  - Several versions of optimized dividers has been created and are tested
    - Dedicated lab test bench has been created to test and characterize the PMTs + readout system
      - First test measurements has been already done in the lab. The system performs as expected
        - First several modules are installed in mCBM experiment

FUTURE PLANS

- Further study and simulate the detector to determine final granularity and geometry
  - Test the performance of the modules and electronics (timing, charge resolution, power dissipation, high-speed readout and long-term stability and radiation hardness)
    - Analyze the data from mCBM test runs and check the performance of the new voltage divider
      - Assemble test setup, integrate it in mCBM system and test the system in the most realistic way
        - Further test Dirich system including new versions

Thank You