PICOSEC Micromegas

Plans for 2024 test beam campaigns

https://picosec-mm.web.cern.ch/

F.M. Brunbauer
on behalf of PICOSEC Micromegas collaboration, CERN GDD lab
with slides from M. Lisowska, A. Kallitsopoulou and many others

DRD1 Collaboration Meeting - WG7 - Jan 2024

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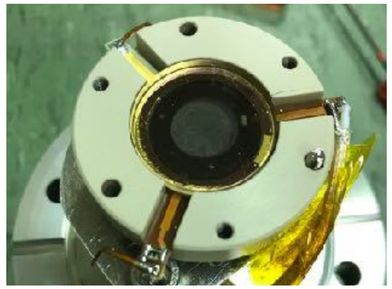
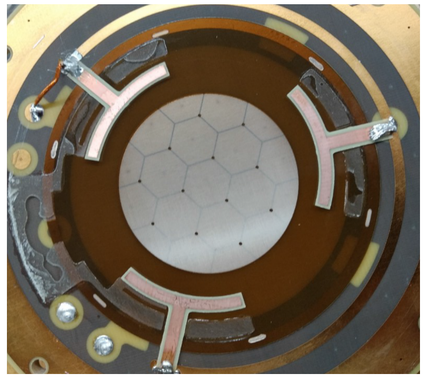
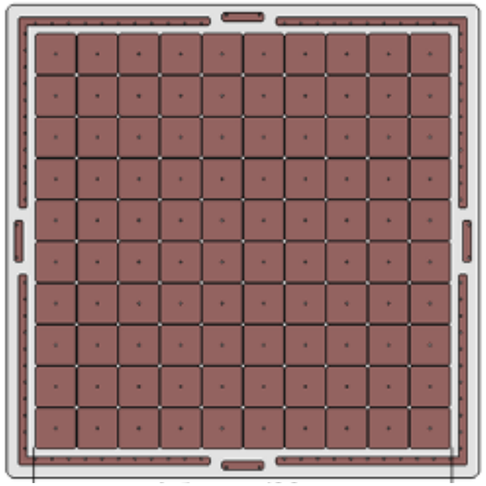
- PICOSEC Micromegas
- Test beam setup

Plans for 2024 test beam campaigns

- Detector prototypes
- Performance studies (photocathodes, gas)
- Scalable readout



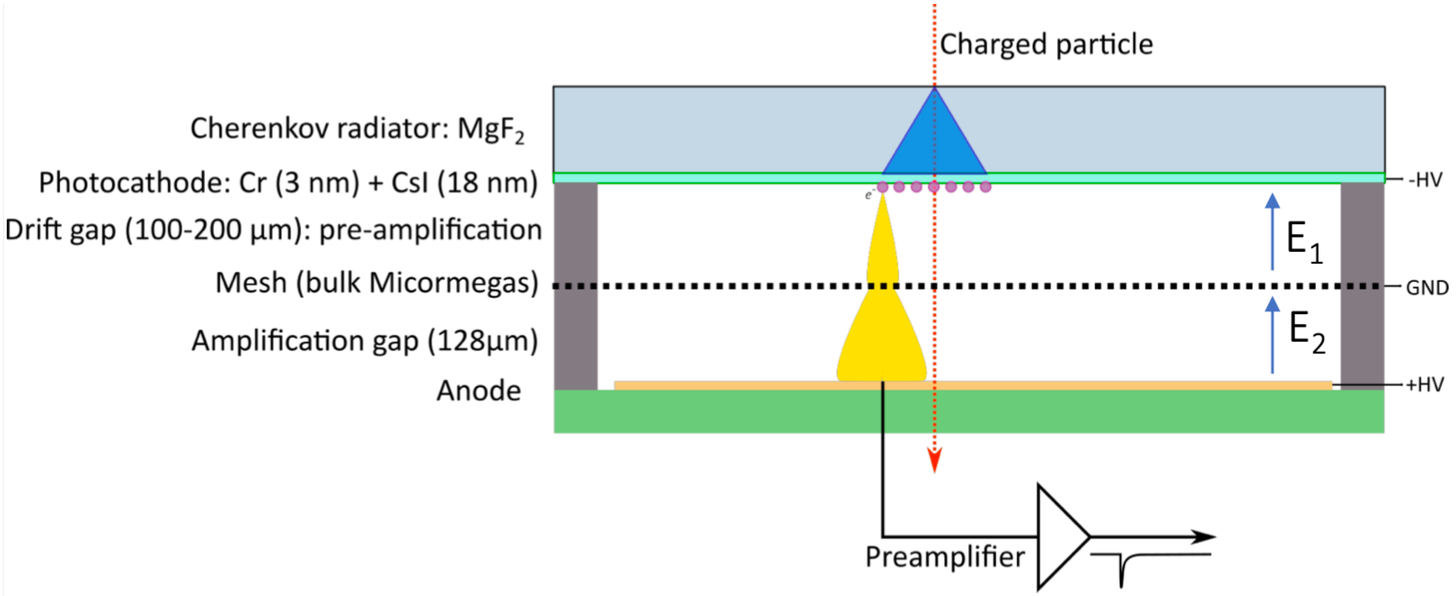


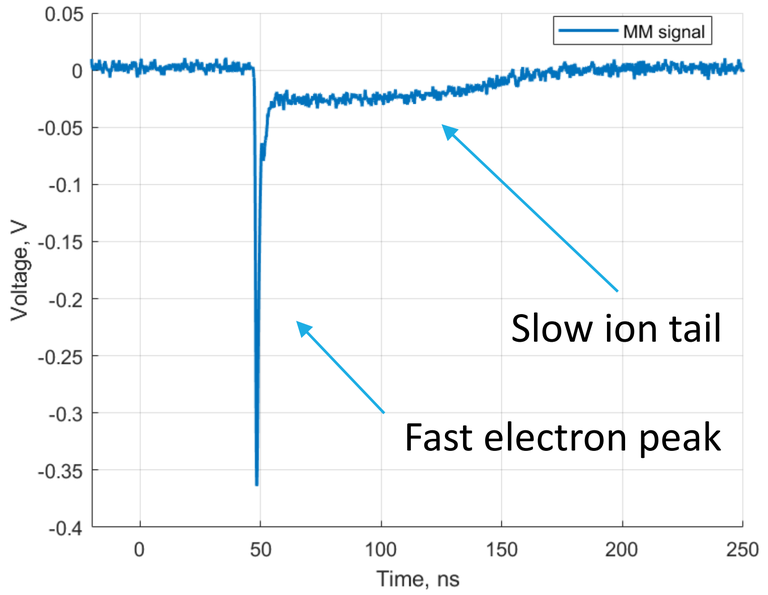


PICOSEC Micromegas

Introduction

- **PICOSEC Micromegas collaboration:** Gaseous detector with time resolution tens of picoseconds





J. Bortfeldt et al., NIM A, 903, 317-325 (2018)

- First single pad prototypes demonstrated time resolution below 25 ps → <u>Now we want to push the limits</u>

2024 test beam campaign

Detector prototypes

10x10 Multipad detector
- B4C photocathode
- Multi-module integration
- µRWELL PICOSEC
- (High-rate resistive Micromegas)

Picolarge (Saclay): 7 pad resistive prototype
- Different resistivities
- Readout with dedicated preamp cards and direct connection to SAMPIC WTDC
- Low material budget detectors

µRWELL - single pad
- Timing tests of prototypes with improved signal routing

SinglePad (RBI)
- Resistive MM (15mm)
- Non-resistive 10 mm prototype for readout optimization
- (Electroformed mesh)
- (High granularity)

Performance studies

Photocathode studies
- Uniformity of 10x10 B4C photocathode
- DLC photocathodes produced at MPT workshop
- Nanodiamond photocathodes

Gas studies (INFN-PV)
- Studies of alternative gas mixtures without CF4

Readout
- Multipad readout with FastIC
- (FastIC+ ASIC - when available)

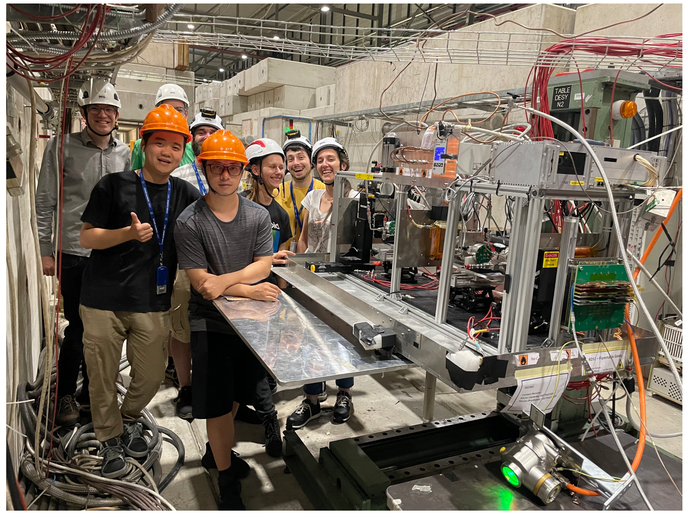
2024 test beam campaign

Collected plans to participate from PICOSEC MM collaboration members

Participating institutes

- 5-6 institutes planning to come for at least one test beam period
- Focus on summer period
- Some participations to be confirmed / some remote participation

Will participate in all (three) test beam periods



	A	B	C	D
1	TEAMs	**Beam period of interest**		
2		ril/May?	July?	August/September?
3		?	?	?
4		YES/NO/MAYBE (3 persons)	YES/NO/MAYBE (3 persons)	YES/NO/MAYBE (3 persons)
5	AUTH			
6	GDD	YES (2 persons)	YES (3 persons)	YES (3 persons)
7	HIP			
8	JLAB	YES (2 persons)	YES / MAYBE (2 people)	MAYBE / YES (2 people)
9	PAVIA	YES (2 persons)	YES (2 persons)	MAYBE (2 persons)
10	SACLAY	MAYBE(1 person)	YES (2 persons)	YES (1 person)
11	SBU			
12	USTC	MAYBE(1 person)	YES (2 persons)	MAYBE (2 persons)
13	ZAGREB		YES(1 person)	
14	Add...			
15	Minicactus (Saclay)	MAYBE (2 persons)	YES (2 persons)	MAYBE (2 persons)
16		**Availability to help on measurements or analysis (local/remote)**		
17				
18		April/May	July	August/September
19		YES/NO/MAYBE (1 person)	YES/NO/MAYBE (1 person)	YES/NO/MAYBE (1 person)
20	AUTH			
21	GDD	YES	YES	YES
22	HIP			
23	JLAB	YES	YES / MAYBE (1 person)	MAYBE / YES (1 person)
24	PAVIA	YES	YES	MAYBE
25	SACLAY	YES (remote)	YES	YES
26	SBU			
27	USTC	YES/MAYBE	YES	

"MS 365 on Cloud" app content area

PICOSEC Testbeam

PICOSEC test beam

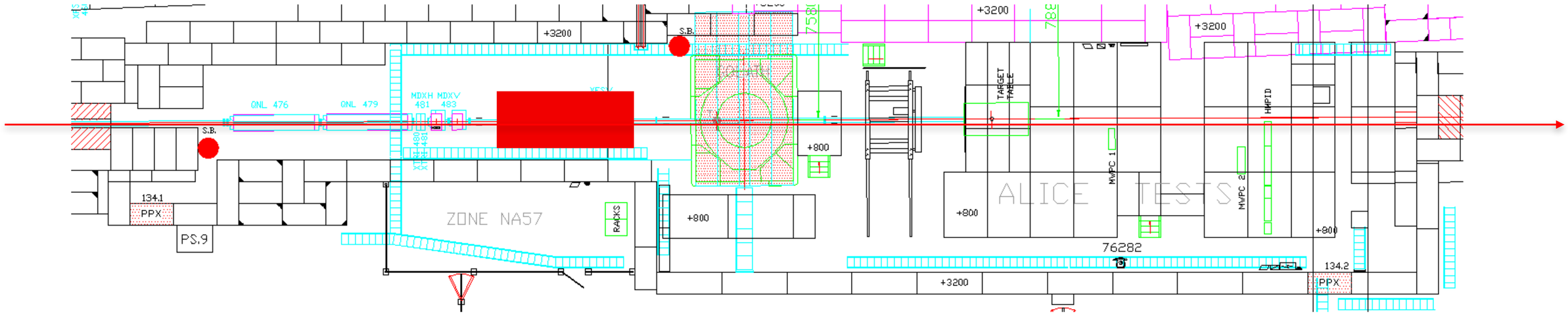
Tracking and timing setup

Data acquisition

Data analysis

Tools

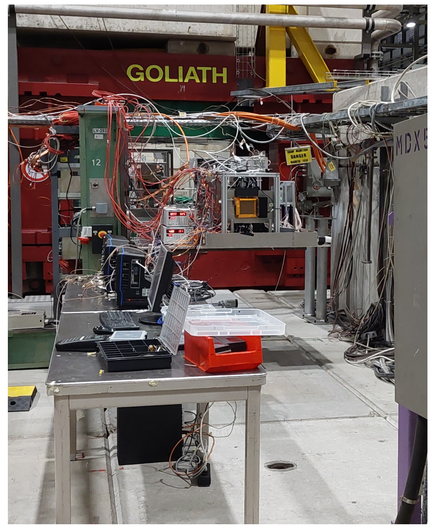
PICOSEC in SPS H4



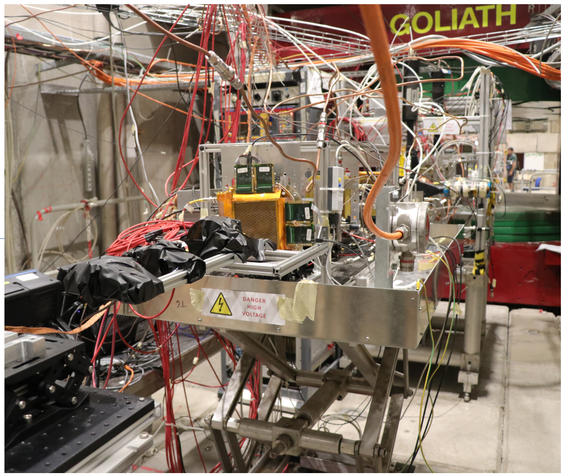
Particle Beams @ CERN SPS H4 Beamline

Muons (80-150 GeV): 8cm diameter of beam - muons/spill (measured rate ~kHz/)
MIP timing tests of single and multipad detectors, uniformity measurements of 10x10 prototypes

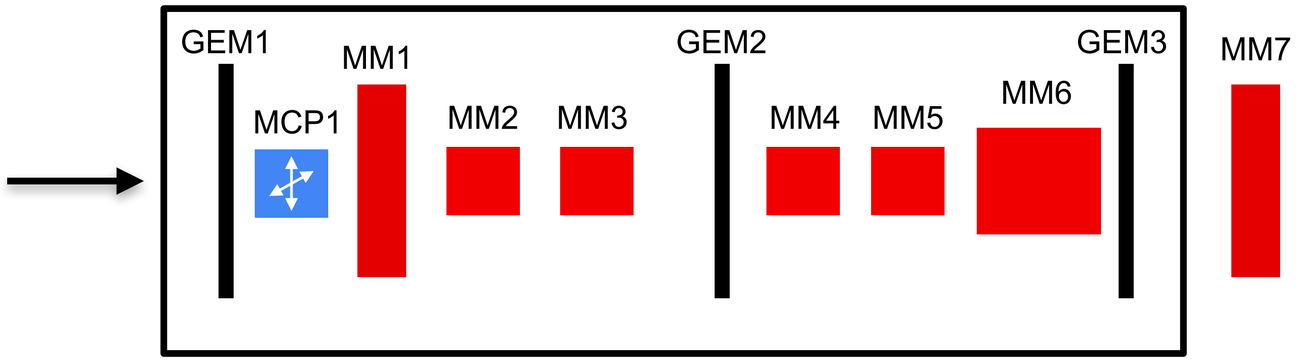
Pions of 80 GeV: Beam size 2.3x1.6cm - rate ~MHz - high rate operation
Electron beam (30 GeV) - 1MHz/cm^2 - operation in shower conditions

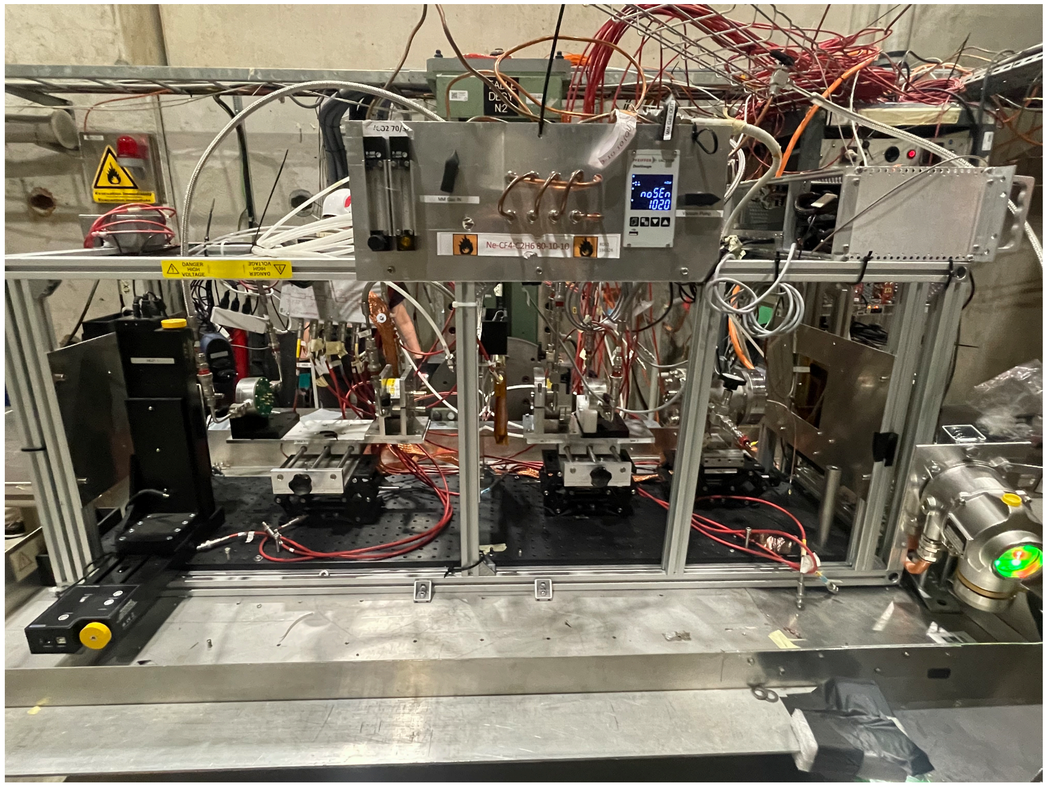


PICOSEC setup - baseline



Tracking and timing telescope





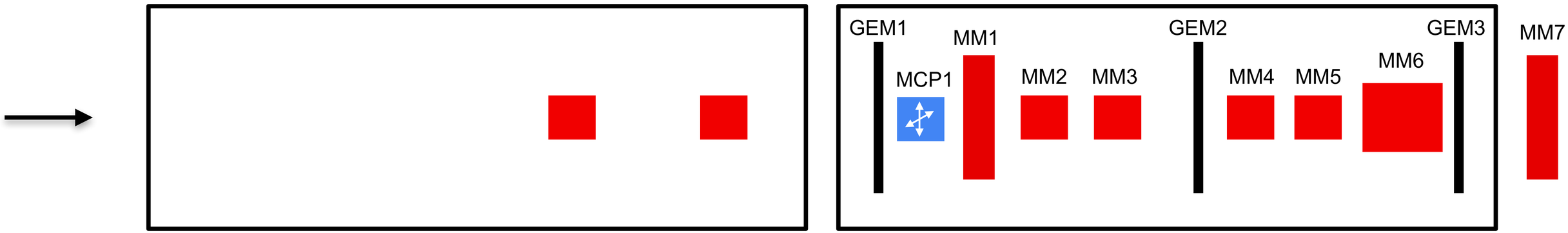
Tracking: 3 triple- GEMs for tracking: 10x10cm^2, SRS readout

Timing: MCP-PMT, 10mm active area, <8ps time resolution
Scanning of MCP-PMT to cover 10x10cm^2

DUTs: up to 7 detectors including single pad, multipad, sealed detector

PICOSEC setup

Additional telescope to support more DUTs,
using same tracking & time reference



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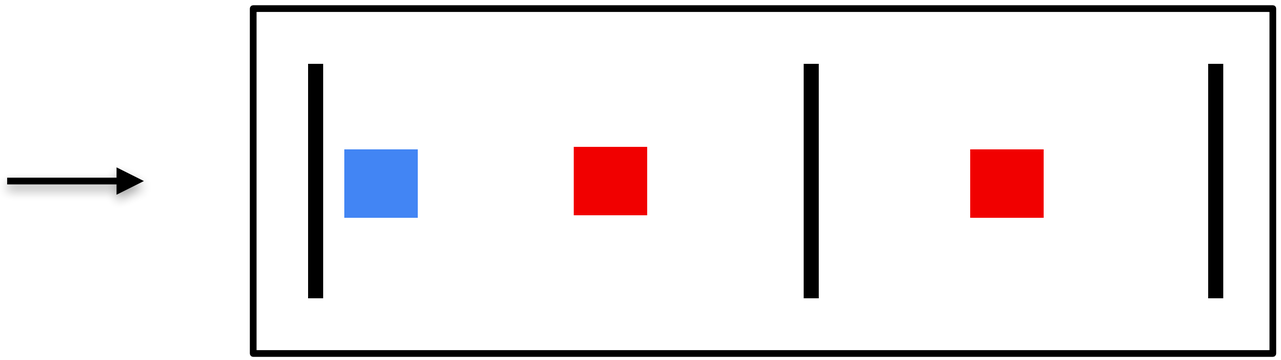
Timing: MCP-PMT, 10mm active area, <8ps time resolution
Scanning of MCP-PMT to cover 10x10cm^2

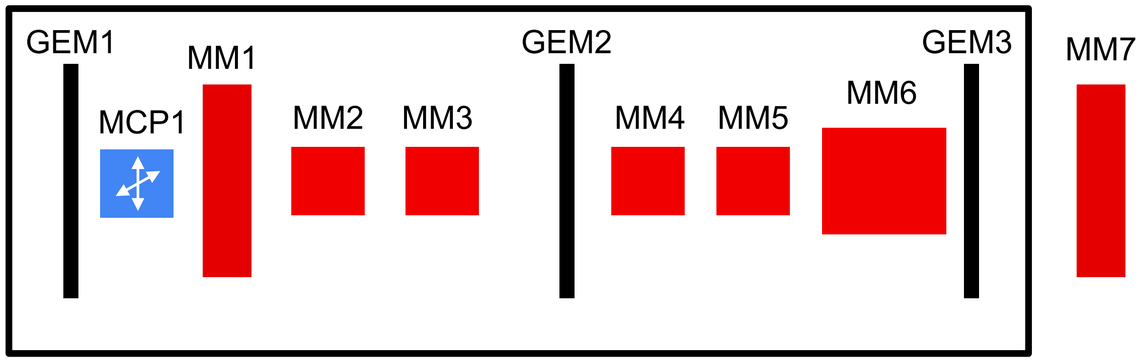
DUTs: up to 7 detectors including single pad, multipad, sealed detector

PICOSEC setup

Extension with new independent JLab telescope for μRWELL studies



Currently in design/construction



Tracking: 3 triple- GEMs for tracking: 10x10cm^2, SRS readout

Timing: MCP-PMT, 10mm active area, <8ps time resolution
Scanning of MCP-PMT to cover 10x10cm^2

DUTs: up to 7 detectors including single pad, multipad, sealed detector

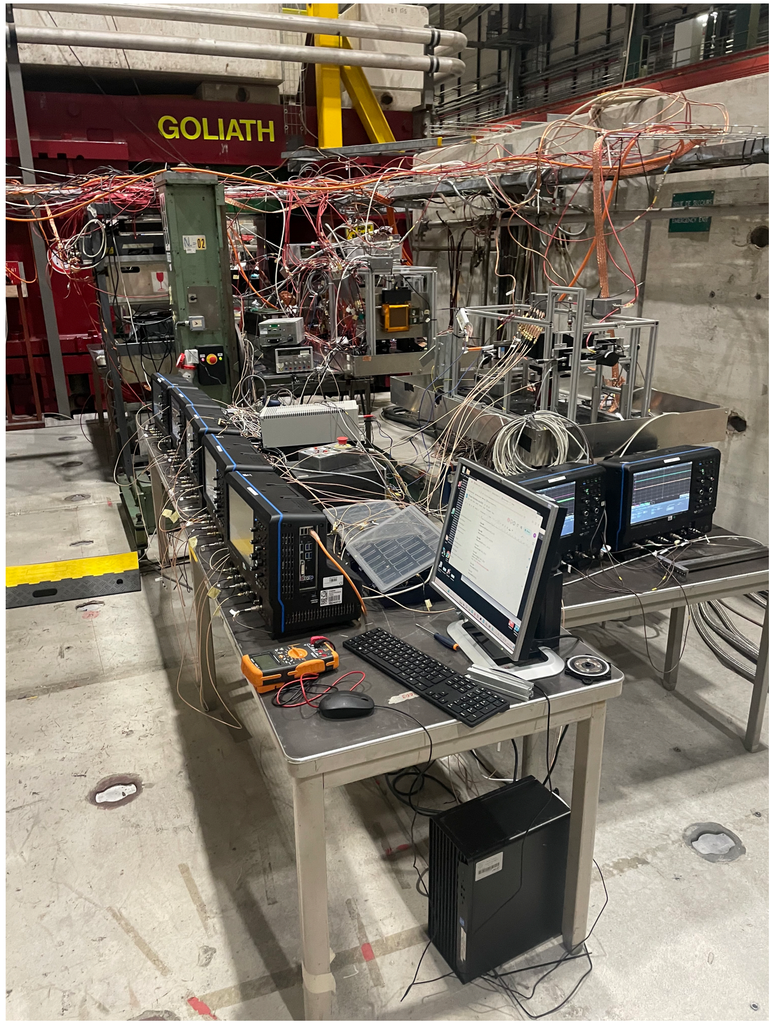
Data acquisition

Tracking: SRS readout, Date + Amore
anamicon recontruction software (J. Bortfeldt)

Acquisition with oscilloscopes (rented from CERN ePool)

Multi-channel acquisition with SAMPIC WTDC (crate system with 128CH)

All data collected on EOS (dedicated project with >35TB



Data analysis

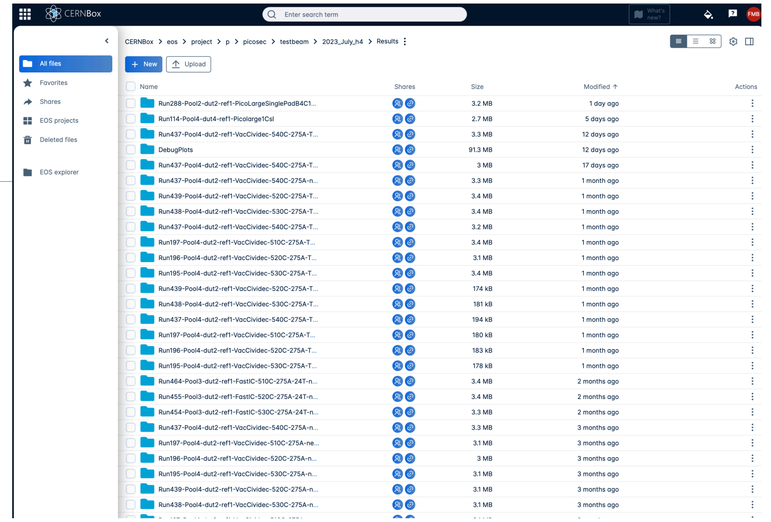
Reconstruction code from Spyros Tzamarias et al. (AUTh)

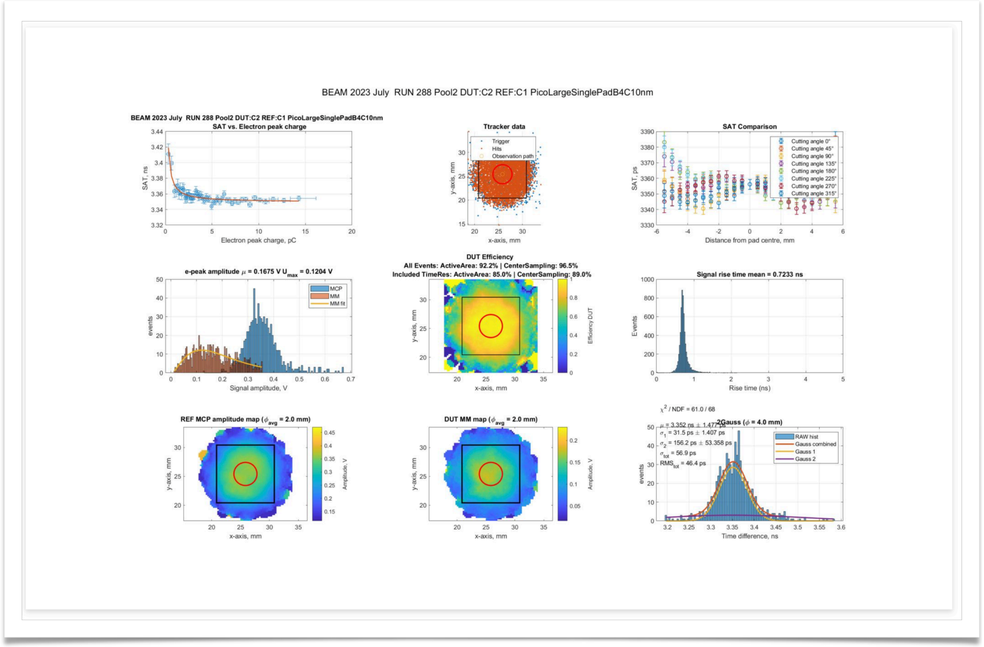
Ported to Matlab (A. Utrobicic et al.) for immediate analysis of acquired data during beam periods

Matlab analysis code used by institutes in collaboration and continuously extended

During test beam periods, batch Matlab analysis running on several computer producing standardised monitoring plots

Read/write directly from mounted EOS folder
Access through CERNbox

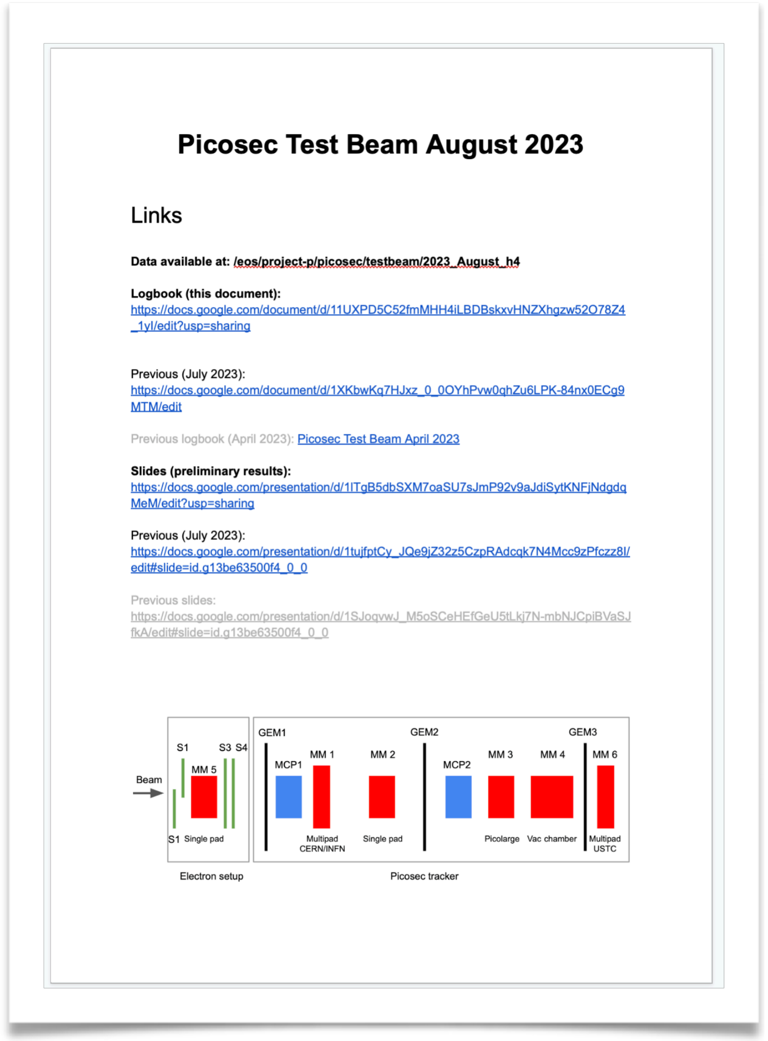




Logbook / shared slides

Shared Google Document used as test beam logbook

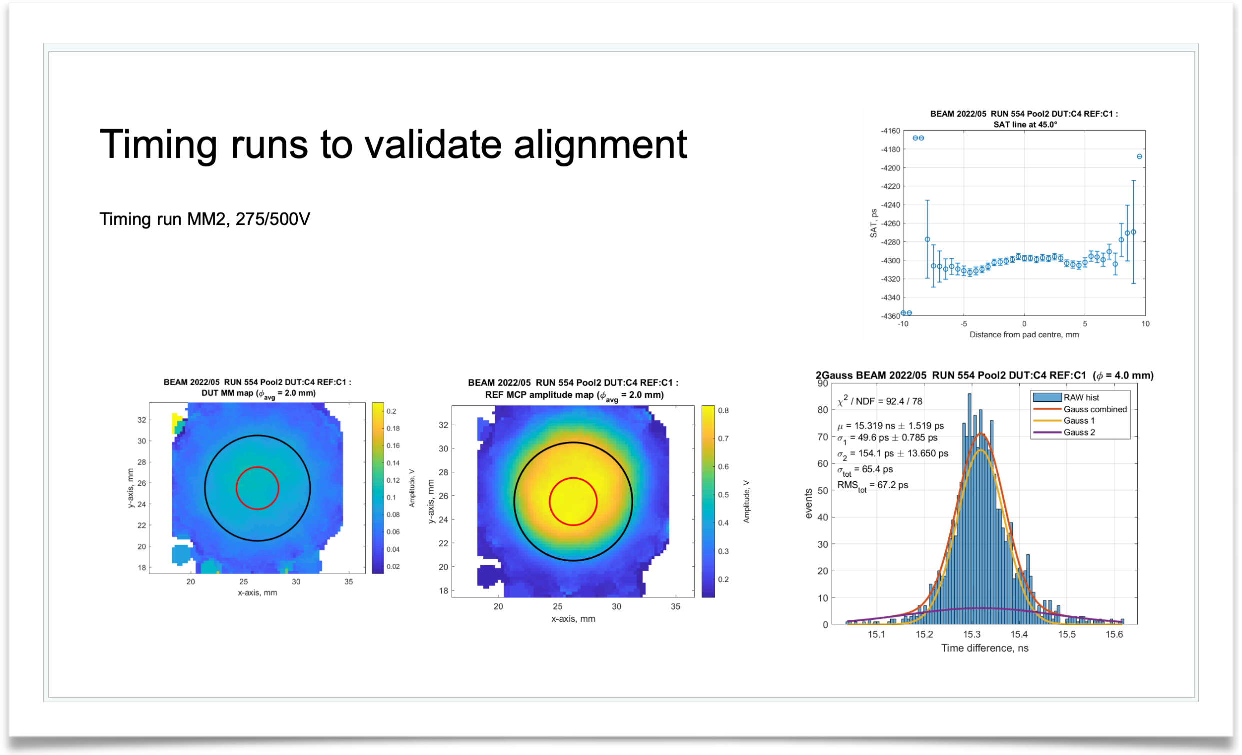
Access by all participating groups (local/remote)
Access from control room & beam area (tracking of ToDo items)
Automatic saving/versions (no risk to lose info)
Store information from one beam period to next (references)
Store run info



>70 page document per beam

Shared Google Slides

Collect analysis performed during beam
Discussion and guiding of subsequent measurements
Access by all participating groups (local/remote)



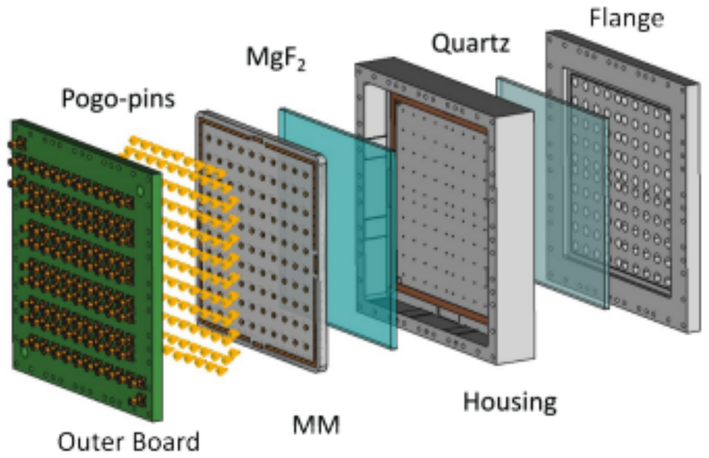
Planned studies

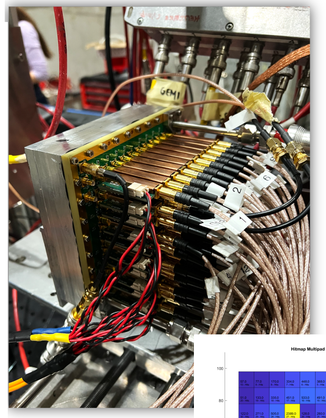
Detector prototypes and integration

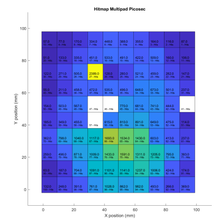
Multipad modules

Previously tested 100CH detector prototype

Readout with dedicated preamps and SAMPIC

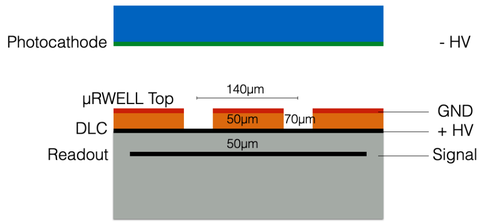






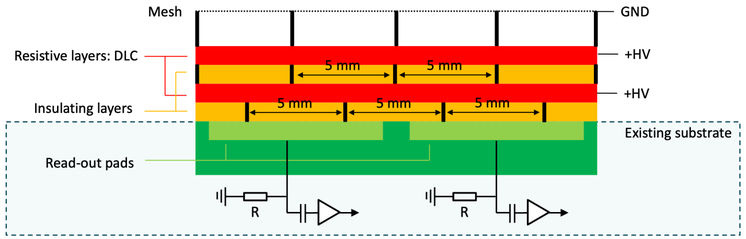
New 10x10 µRWELL Picosec

Based on experience with single pad µRWELL geometries



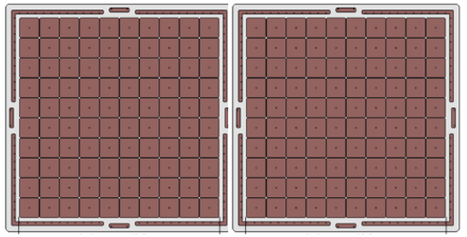
New prototypes in preparation

Vertical charge evacuation with double DLC layers



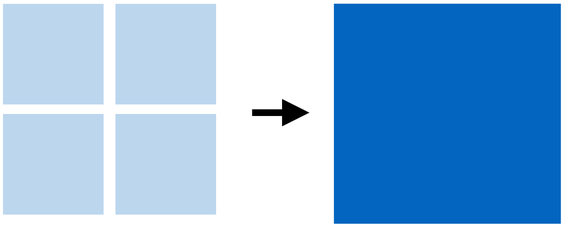
Combination of two prototypes

Operate two prototypes together



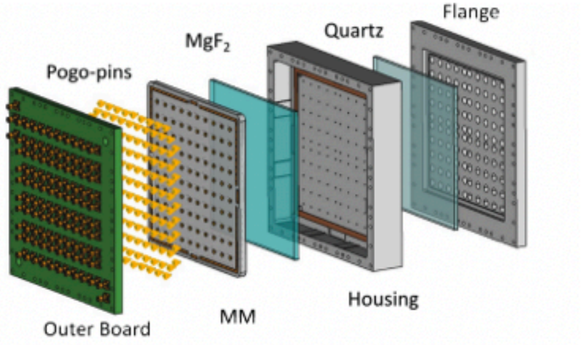
20cm x 20cm detector

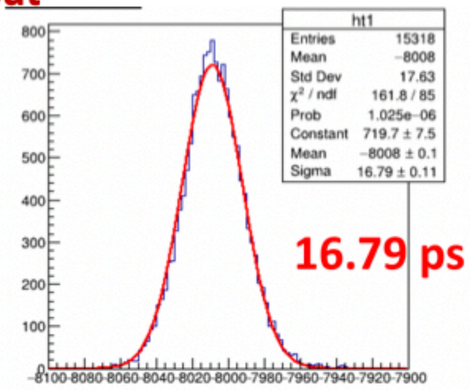
2x2 array of MgF2 radiators, common amplification stage



Ensure the planarity

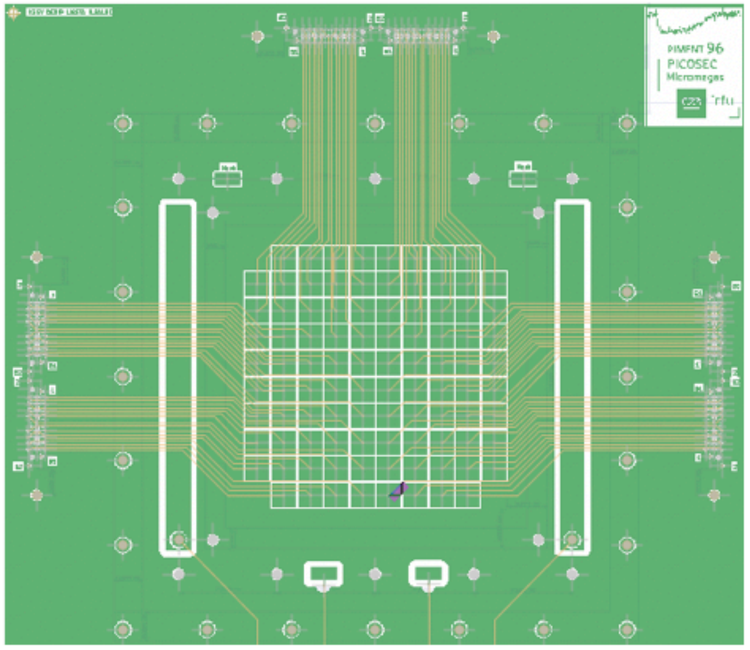
- **Rigid, ceramic-core PCB for the MM readout**





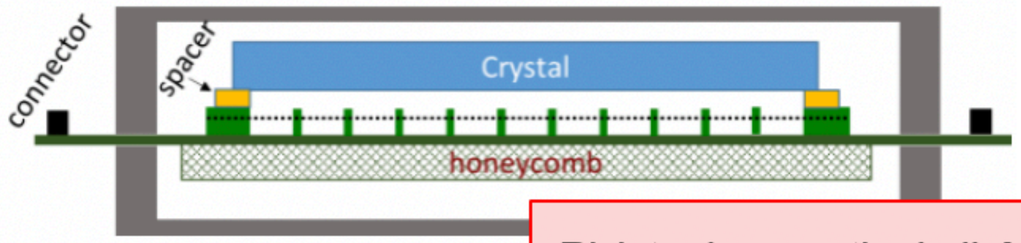
Ready and operational from CERN-GDD Group

NEW design From CEA Saclay



- 96 pad prototype
- Develop custom-made amp. cards in 6 x 16 connector groups compatible for SAMPIC digitization

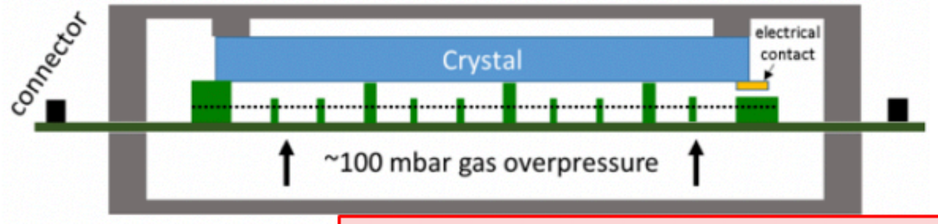
- **The ATLAS NSW Approach**



Risk to damage the bulk MM

- **Advantage:**
  - Low material budget on the detector
  - Allow the fabrication of large flat boards

- **Longer pillars MM module**
  - Pressed against Cherenkov radiator

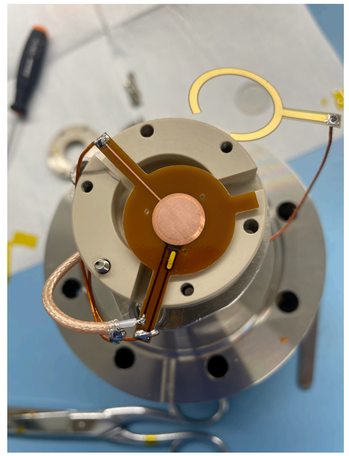


Risk to damage the photocathode

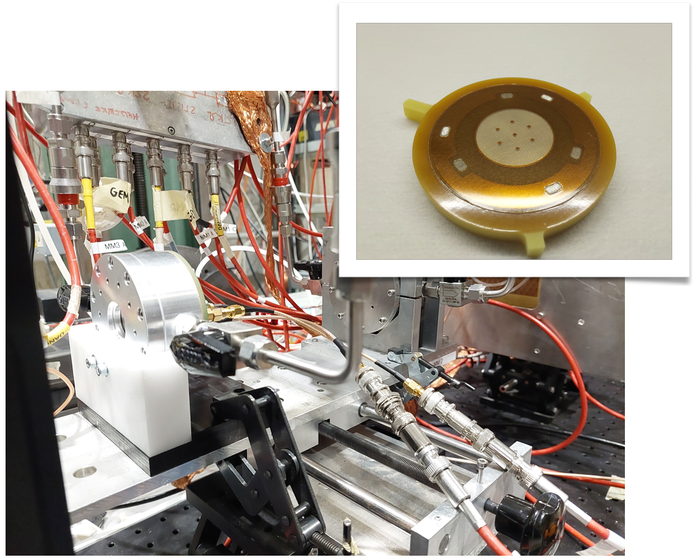
Single-pad prototypes

Use of new single-pad detector assemblies designed by RBI-Zagreb

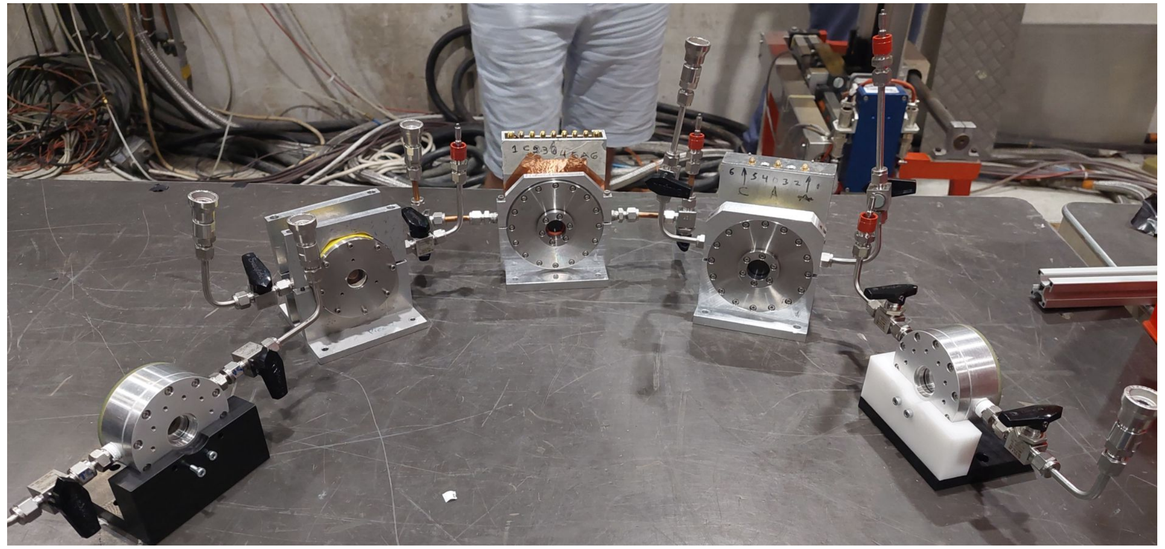
- Performance optimisation: Single pad thin gap - detector+readout chain optimization (12-bit digitisation, variable gain amplifier to increase SNR)
- Comparative studies (photocathodes, gases, μRWELL geometries)
- New resistive MM in production
- Detailed μRWELL tests



μRWELL prototype



Single pad RBI-Zagreb



Single-pad vessels

Planned studies

Alternative photocathodes

Alternative gases

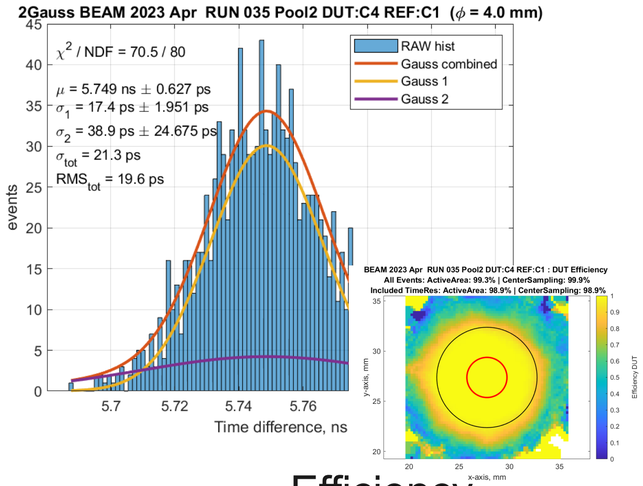
Resistive detectors

2024 test beam campaign

Photocathodes

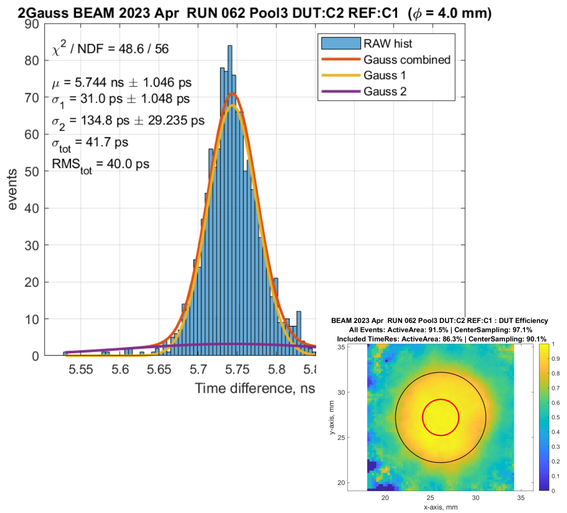
- CsI
- B4C
- DLC
- Nanodiamonds

CsI



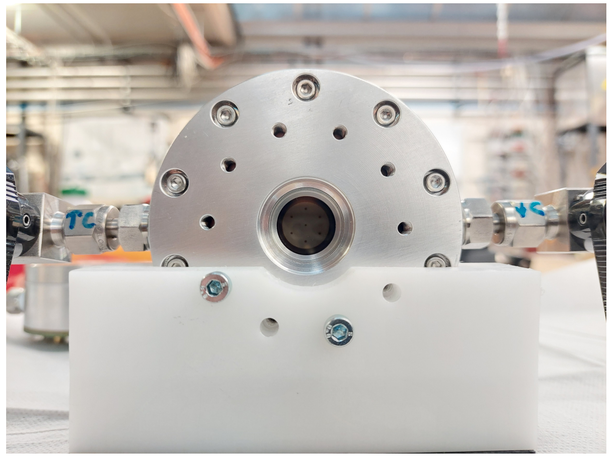
Efficiency

12nm B4C



- B4C and DLC depositions at USTC before beam
- B4C depositors (1inch) at Saclay before beam
- DLC samples prepared at CERN MPT workshop
- **CsI depositions at CERN: 1inch and 10x10cm**
- Nanodiamond samples existing to be tested

- Groups purchase/prepare substrates
- Shared depositions
- Sharing photocathode samples (1inch) to evaluate in different prototypes



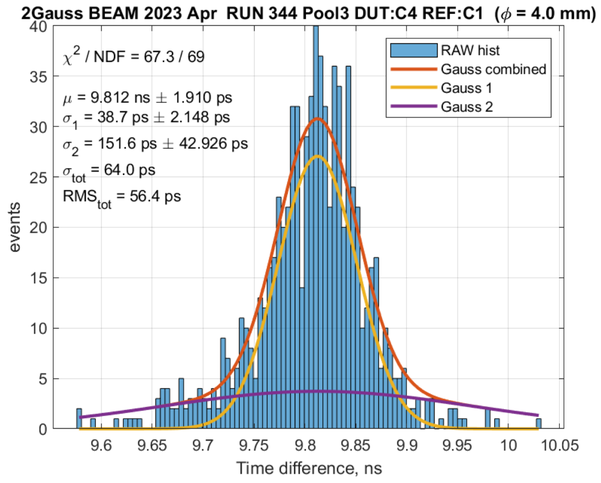
2024 test beam campaign

Gas requirements

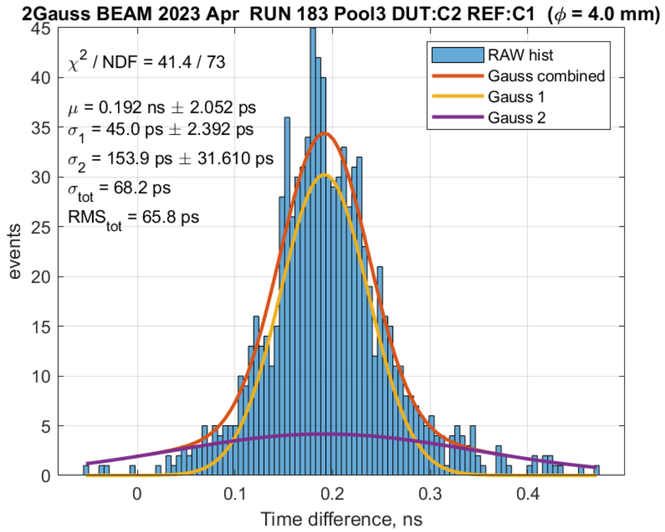
- **Ne-CF4-C2H6 80-10-10 flushed**
- **Ne/CO2**
- **Isobutane?**

- Sealed operation (filled in GDD lab)
- Sealed operation (other mixtures - isobutane?)

Standard mixture:
Ne/ethane/CF4 (80/10/10%)
540/275V



Alternative gas mixture:
Ne/iC4H10 (94/6%)
450/300

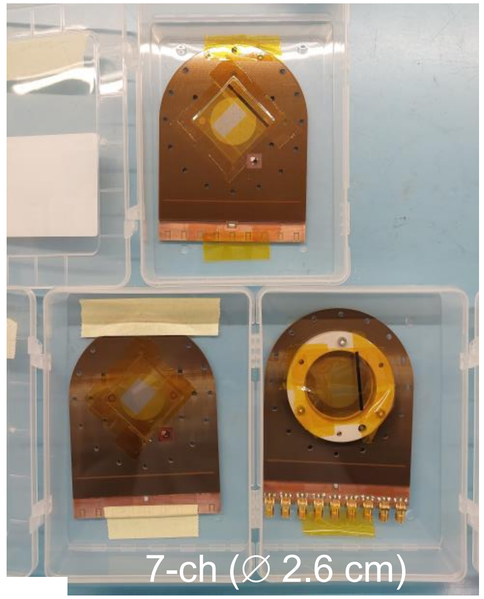


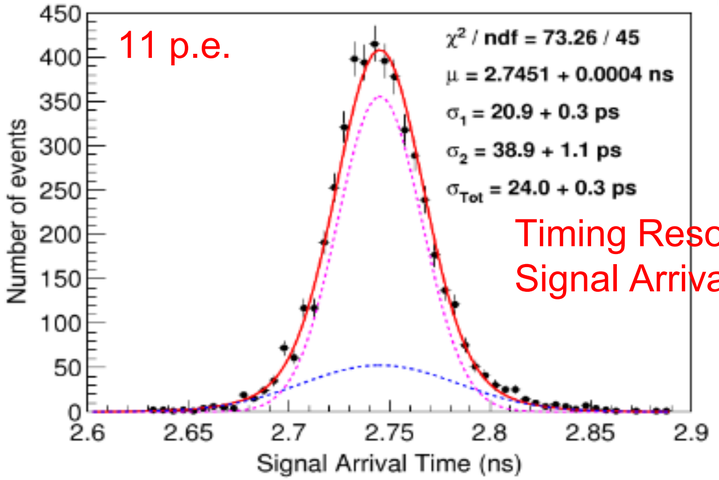
D. Fiorina (INFN-PV)

7-pad resistive Detectors Under Test

- Multi-Pad Prototypes
  - Hexagonal pads ø 1cm
  - MgF2 crystal
  - CsI photocathode

- Measurements of interest focus on Timing properties & Robust Prototypes
  - Different resistivity values (10 MΩ, 200kΩ)
  - Different resistivity layer architectures (resistive & capacitive sharing)
  - Voltage scans → Stable operation voltage at a high rate
  - Timing runs on individual pads
  - Long scan for uniformity map on amplitude and timing
  - Signal Sharing
  - Tilted detector relative to beam direction in 45 and 35 degrees
  - Effectively spatial resolution studies





Timing Resolution → RMS of Signal Arrival Time Distribution

J.Borteldt, et al. *"PICOSEC: Charged particle timing at sub-25 picosecond precision with a Micromegas based detector"*, Nuc. Instrum. Meth. A (2021)https://doi.org/10.1016/j.nima.2018.04.033

Planned studies

Readout chain

Scalable readout electronics

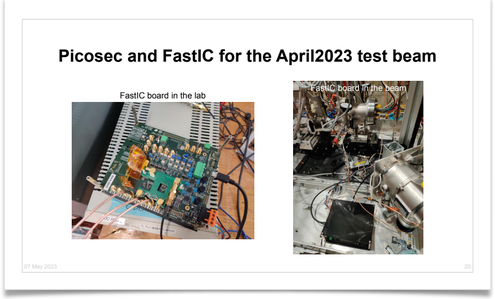
Scalable readout chain

Different approaches for scalable readout electronics to equip tileable detector modules

- Custom pre-amp cards + SAMPIC WTDC
- Custom preamplifiers + FPGA
- Integration of precise timing ASICs

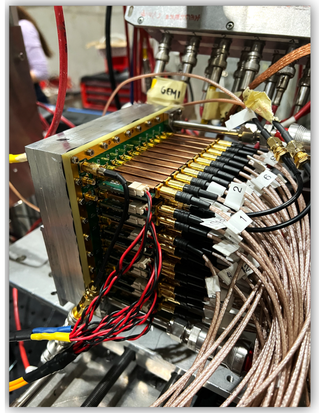
FastIC+TDC

If available, try new FastIC+TDC ASIC building on experience with FastIC



Multi-module readout

Preamp cards + SAMPIC WTDC

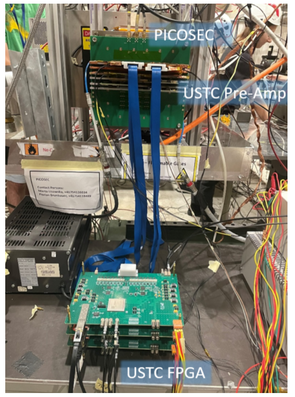


Integration of preamplifiers on detector

Test on single-pad detector

Custom readout electronics + FPGA

Readout of 20x20 Picosec



Test beam period planning

Plans for test beam periods

	Period 1	Period 2	Period 3
Beam requirements	**Muon,** pion	**Muon,** pion	**Muon,** pion, electron
Space / trackers	2 trackers (each on DESY table)	1-2 trackers (each on DESY table)	1-2 trackers (each on DESY table)
Gas	Ne/CF4/Ethane + mixtures (sealed)	Ne/CF4/Ethane + mixtures (sealed)	Ne/CF4/Ethane + mixtures (sealed)
Prototypes	up to 6 single pad, 3x 10x10 detectors, 1x 20x20 detector	up to 6 single pad, 3x 10x10 detectors, 1x 20x20 detector	up to 6 single pad, 3x 10x10 detectors
Measurements	Single-pad measurements + long scan during nights	Single-pad measurements + long scan during nights	Single-pad measurements + long scan during nights + dedicated electron beam shifts