PICOSEC Micromegas

Overview of April 23 RD51 test beam campaign
& plans for July test beam

F.M. Brunbauer, PICOSEC Micromegas collaboration, CERN GDD lab

RD51 Collaboration Meeting - WG7 - June 2023

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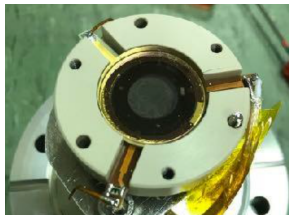
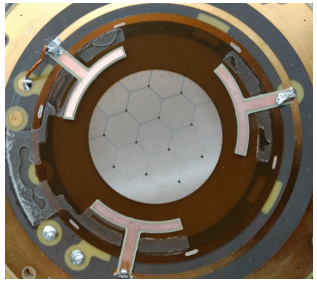
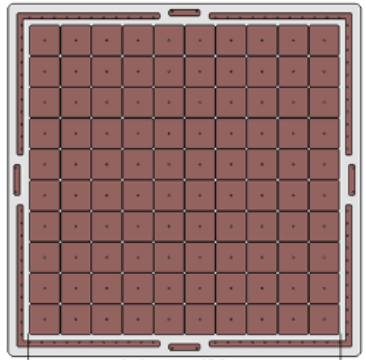
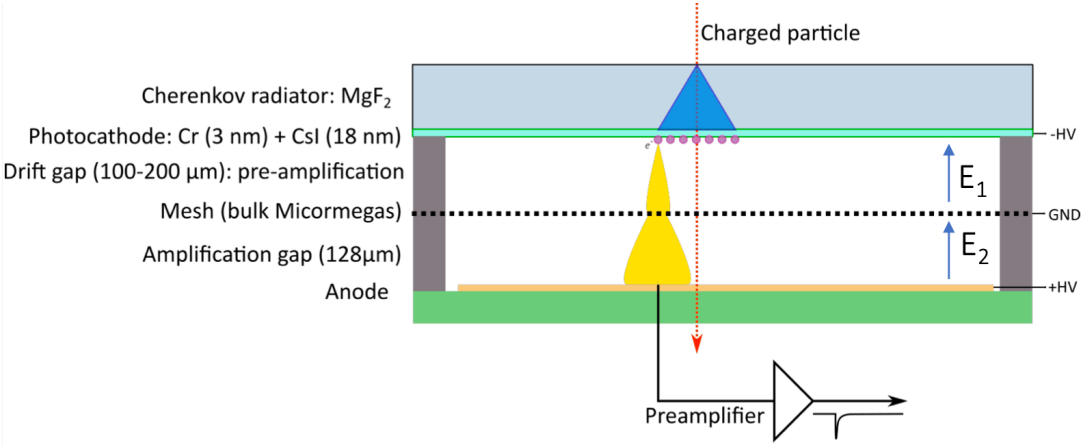
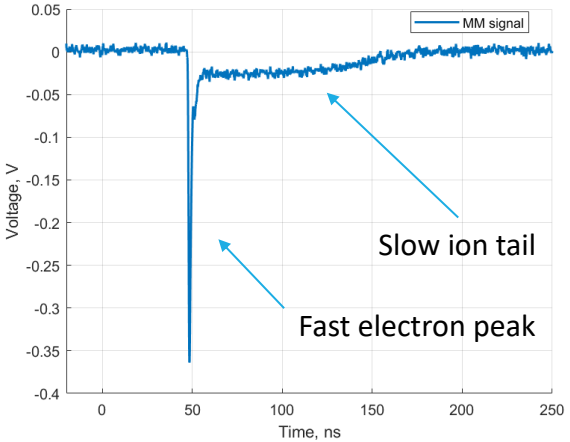




PICOSEC Micromegas

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>

Test beam campaign

Experimental setup

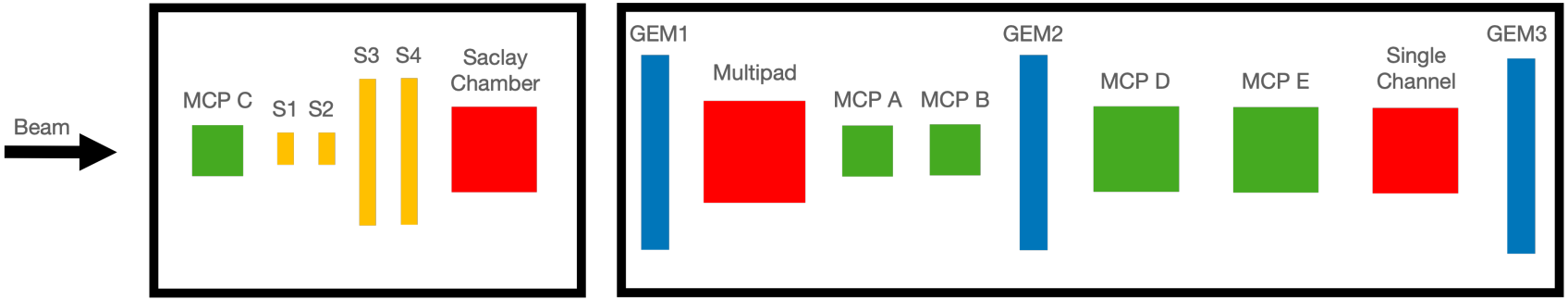
Beam type: CERN SPS H4 beam line, 80 GeV muon beam

- **Infrastructure:**

  → **tracking**/**timing**/**triggering** telescope: **GEMs** + **MCP PMTs**

  → **Devices Under Test:** Multipad + Single Channel + Saclay Chamber

  → flammable gas mixture: Ne:CF_4:C_2H_6 (80:10:10)



April/May 2023 test beam campaign

Detector prototypes

10x10 Multipad detector
- SAMPIC readout for uniformity check

Picolarge (Saclay): 7 pad resistive prototype
- 10MΩ resistivity
- 200kΩ resistivity
- 10MΩ resistivity (capacitive sharing)

μRWELL - single pad
- Timing test CsI sealed

SinglePad (Saclay) -
- Thin gap (120μm) - Voltage scan & timing

Performance studies

High rate operation - pion beam
- Single pad resistive + non resistive detector - sealed - 82MΩ - B4C

Photocathode studies
- Single pad resistive detector - sealed - 82MΩ - B4C
- Diamond secondary emitter

Gas studies (INFN-PV)
- Ne-isobutane
- Ar/CO2
- Ar/CO2/Isobutane

Readout
- SAMPIC vs oscilloscope
- FastIC ASIC

Detector prototypes

10x10 SAMPIC readout

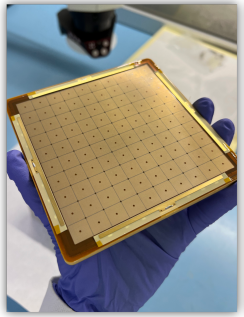
Picolarge

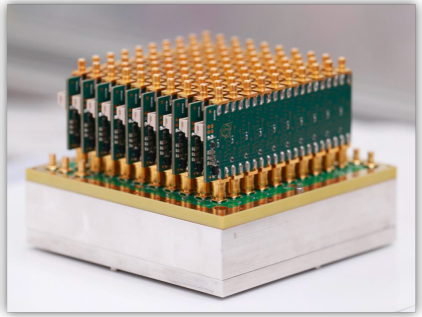
μRWELL

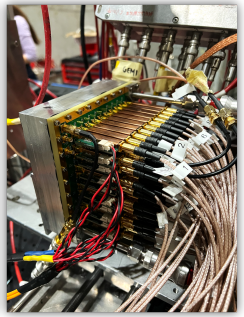
SAMPIC MM1 ThinGap Non-resistive

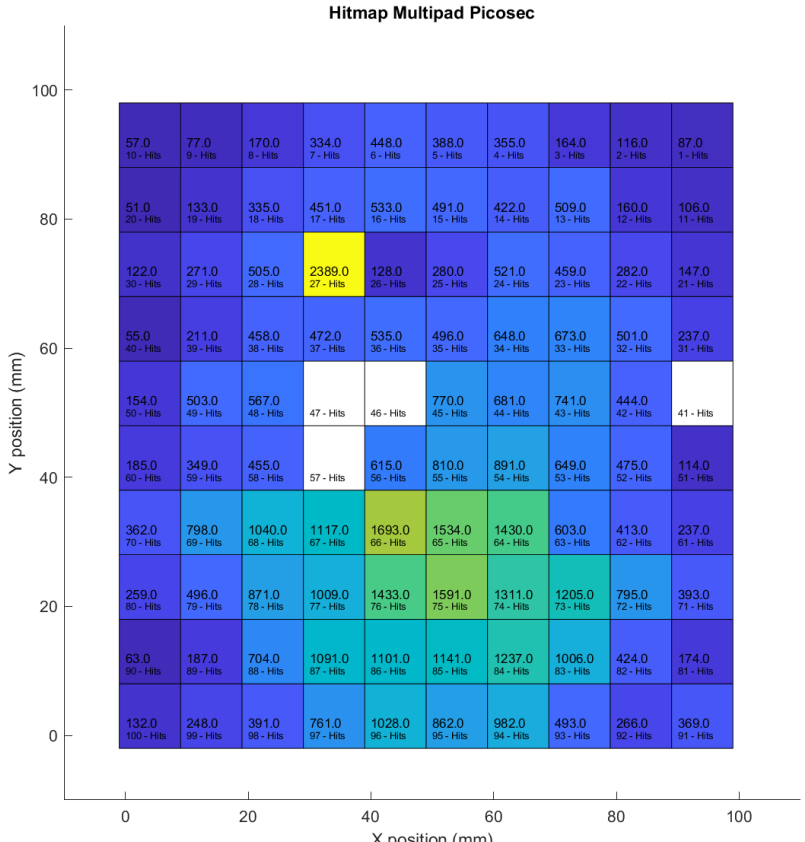
Free running

pads 46,47,57 missing (known to be problem on detector), pad 41 missing (to check), pad 27 noisy





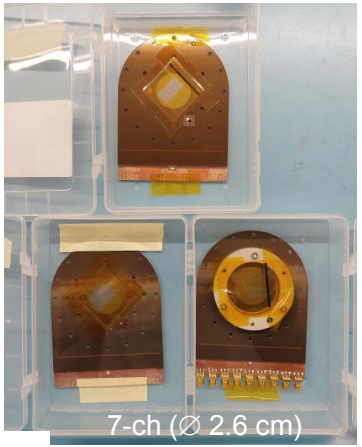


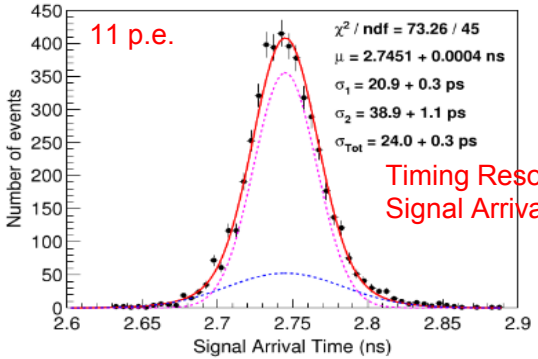


7-pad resistive Detectors Under Test

- 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

uRWELL Picosec

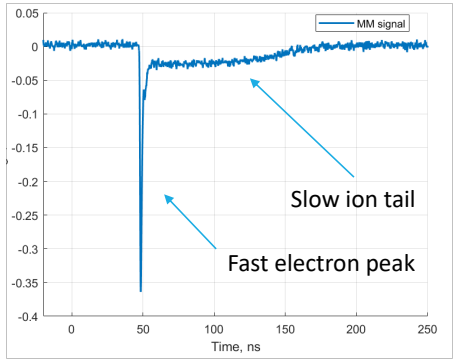
First operation of μRWELL Picosec configuration in beam test

High gain and stable operation achieved

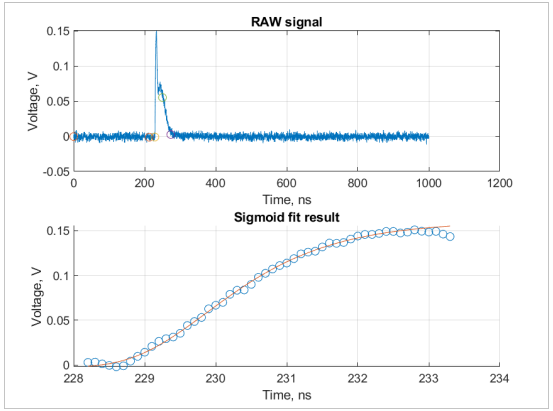
Slower rising time of electron peak observed compared to Micromegas

Will investigate different geometries (capacitance / pitch) in upcoming beam

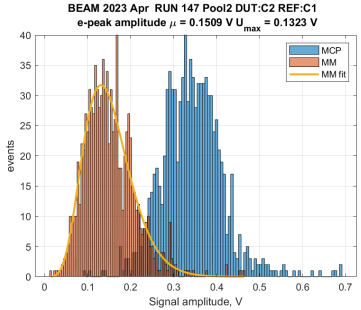
Micromegas

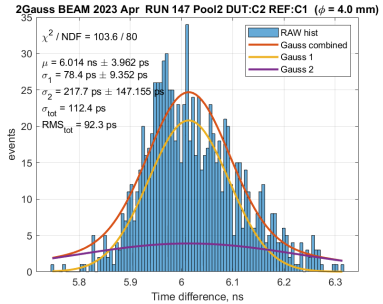


μRWELL



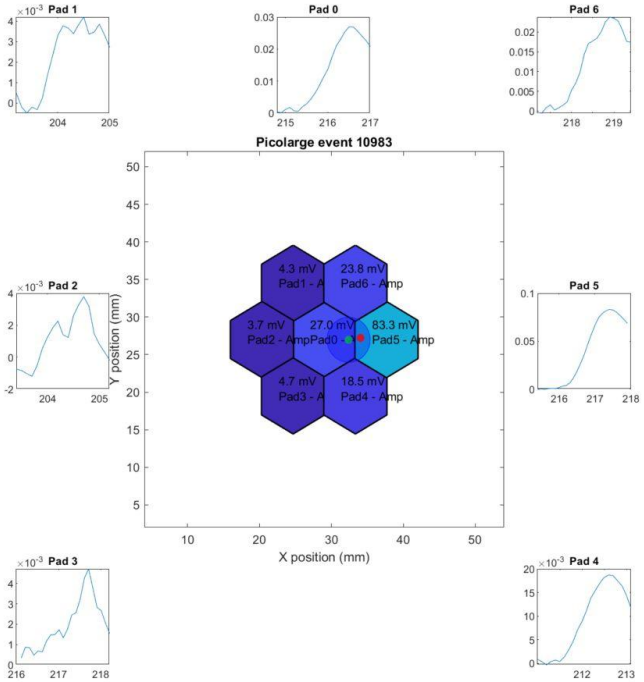
MM4 300A/380C



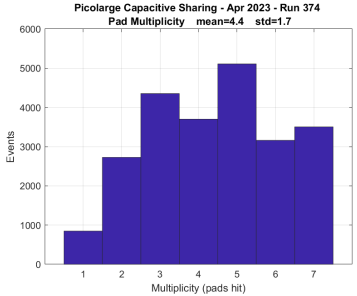


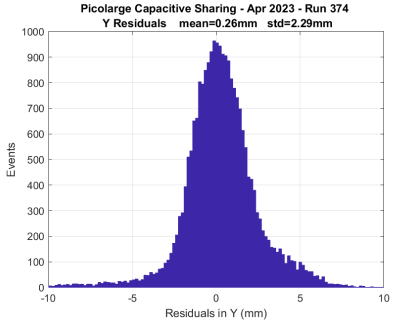
K. Gnanvo

Picolarge 10MΩ CsI photocathode - capacitive sharing

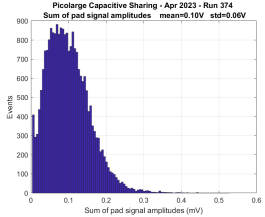


Pad multiplicity

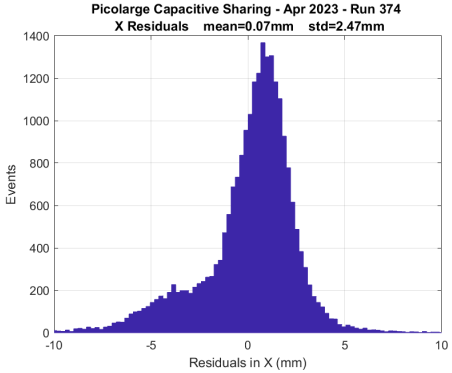




Signal amplitude (sum)



X/Y residuals



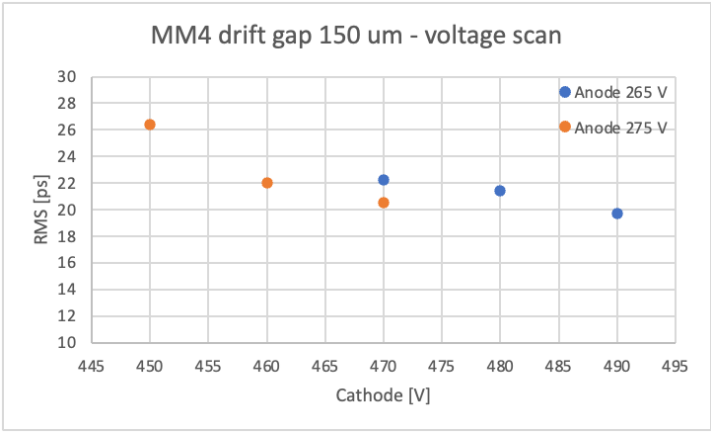
Performance studies

B4C photocathodes

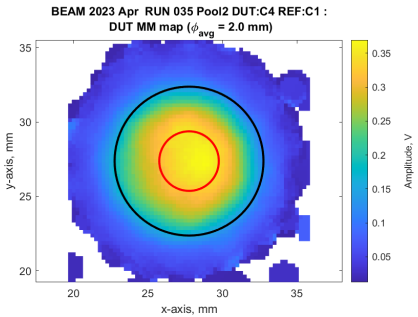
Gas comparison

CsI

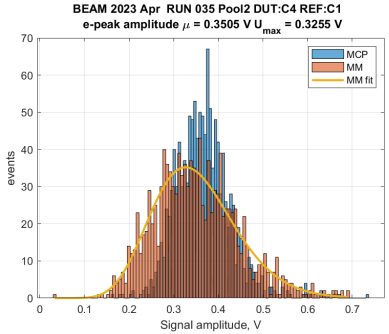
Single pad detector, sealed operation
82M resistive Micromegas, 150µm preampfification gap



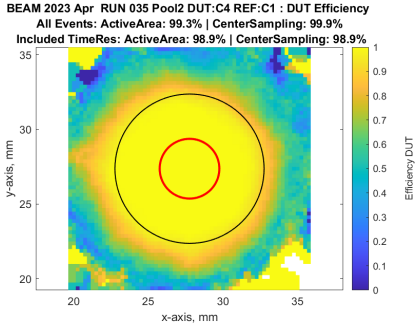
2D amplitude map



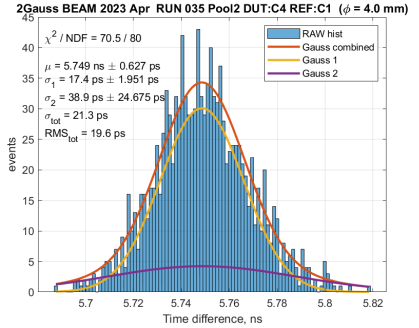
Amplitude distribution



Efficiency map



Time resolution <20ps

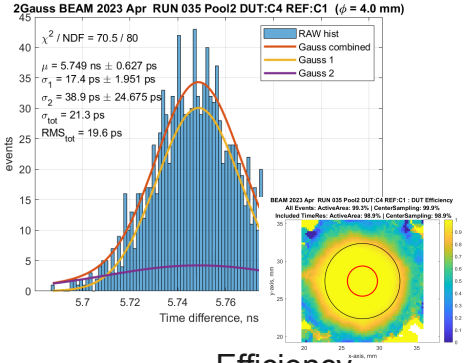


Comparison CsI vs. B4C photocathodes

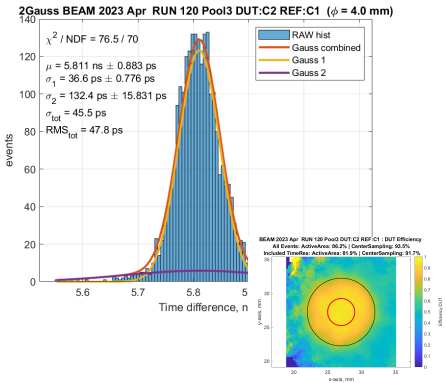
Single pad detector, sealed operation
82M resistive Micromegas, 150µm preampfification gap

Observed worse performance (timing/amplitude) with all studied B4C thicknesses compared to previous (2022) tests of same photocathodes
-> to be repeated with new depositions

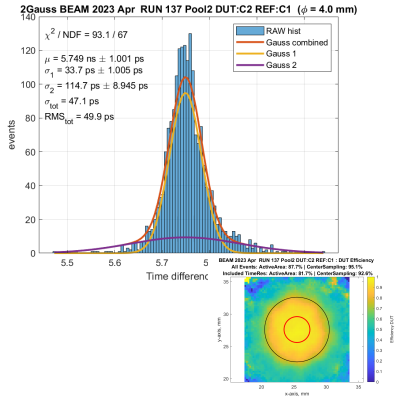
CsI



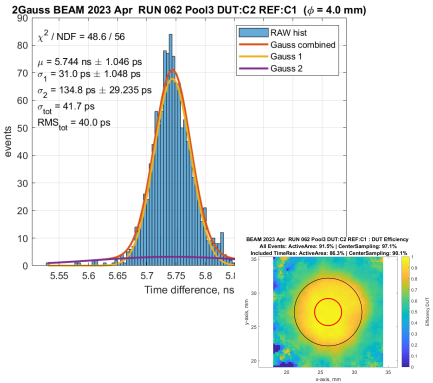
6nm B4C



10nm B4C

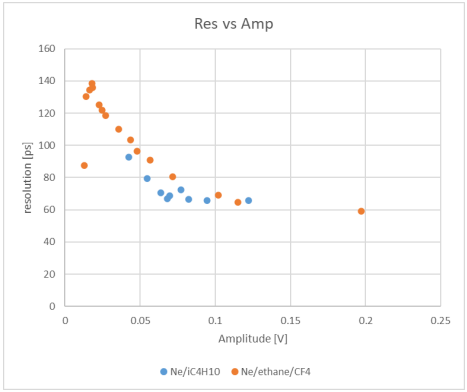


12nm B4C



Gas mixture comparison

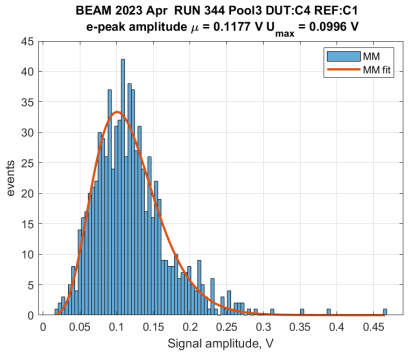
Sealed detector with degradation after some hours

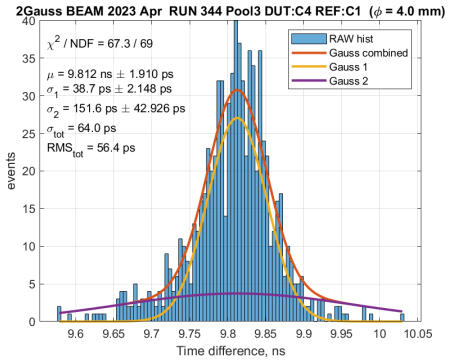


Comparison at Similar Gain

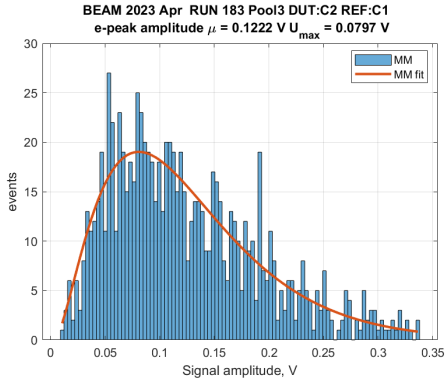
Time resolution 15% higher

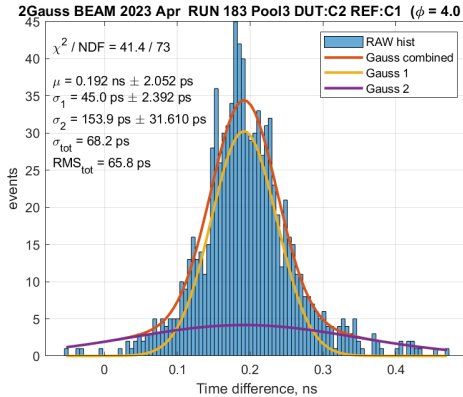
Standard mixture:
Ne/ethane/CF4 (80/10/10%)
540/275V





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





D. Fiorina (INFN-PV)

Readout electronics

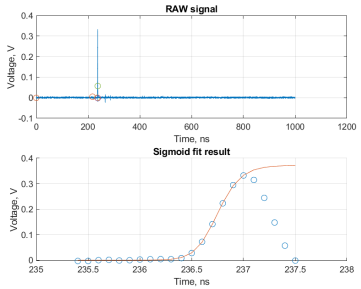
Oscilloscope - SAMPIC comparison with MCPs

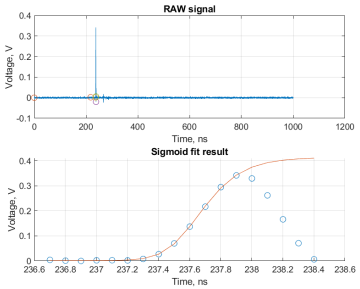
FastIC

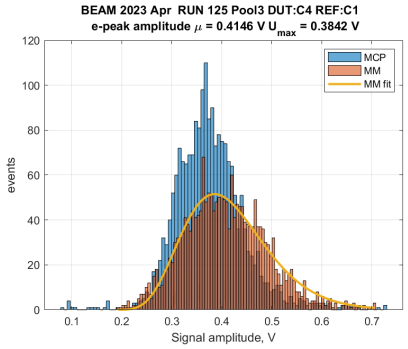
Oscilloscope - SAMPIC comparison with MCPs

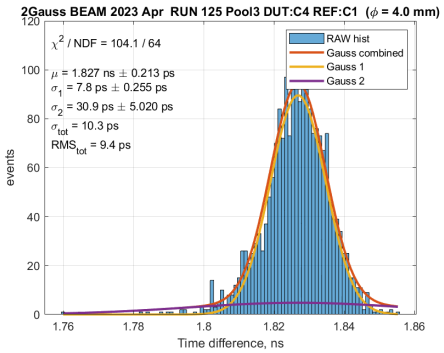
MCP1 double split (3200V, movable stage) vs. MCP2 (3100V, single split)

Oscilloscope 10GS/s

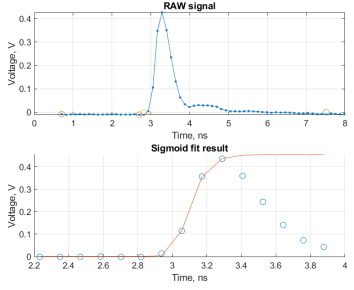


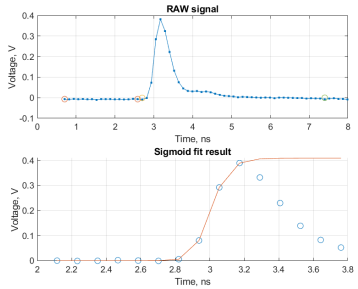


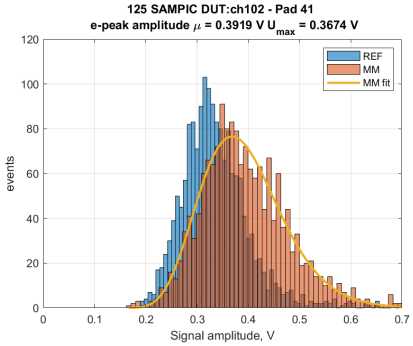


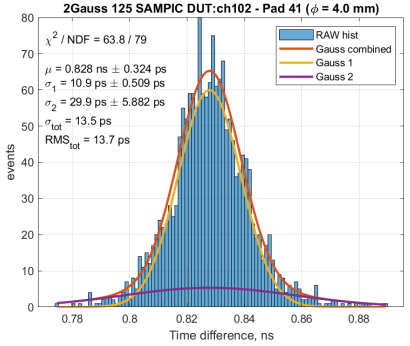


SAMPIC 8.4GS/s



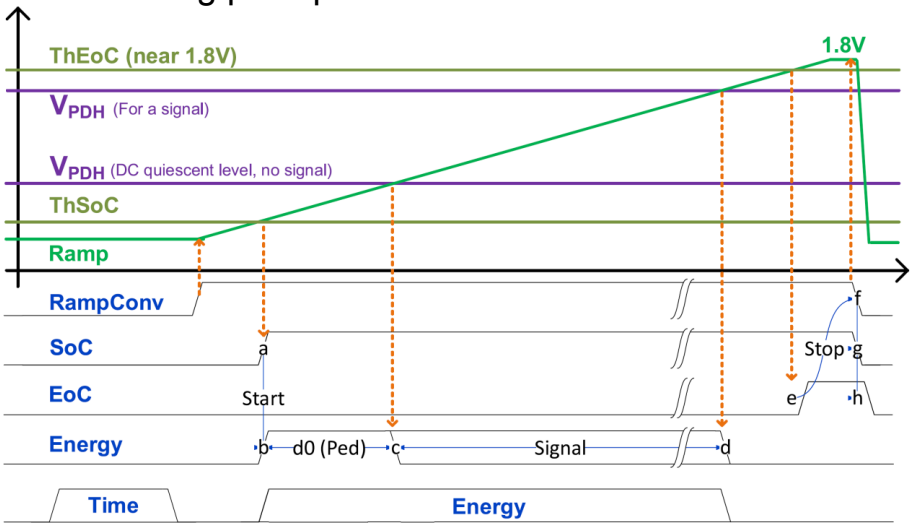


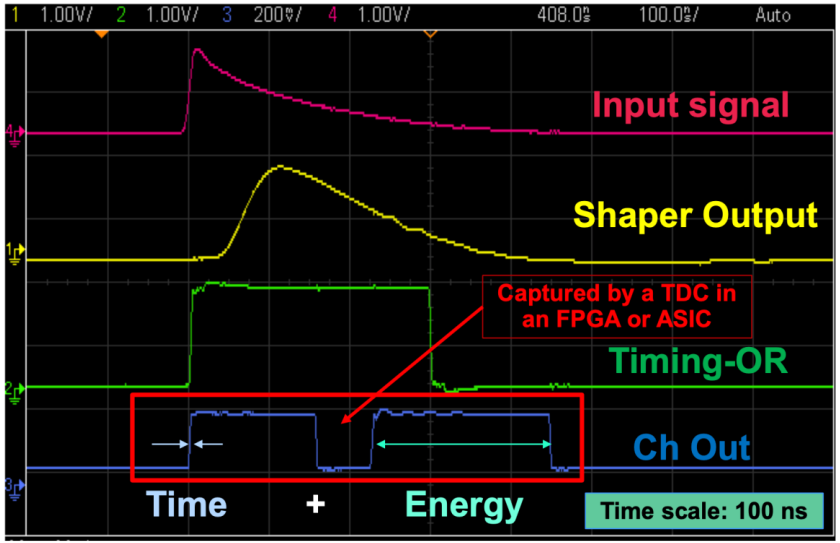




FastIC
Analogue to binary conversion

Working principle identical to HRFlexToT ASIC





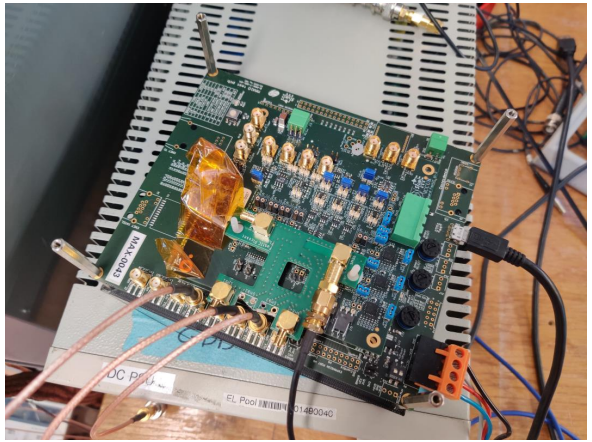
L. Scharenberg

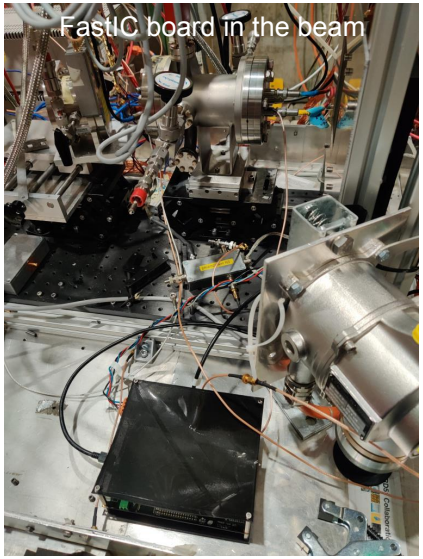
22 April 2023

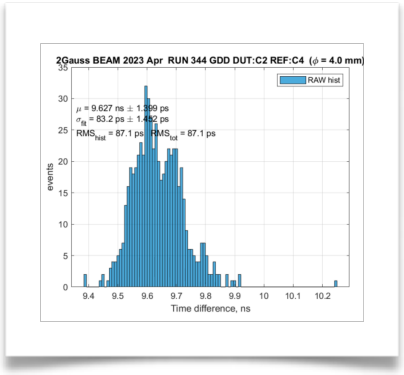
Left: IEEE Trans. Radiat. Plasma Med. Sci. 6 (2022) 51, https://doi.org/10.1109/TRPMS.2021.3066426
Right: https://agenda.infn.it/event/28667/contributions/167717/

Picosec and FastIC for the April2023 test beam

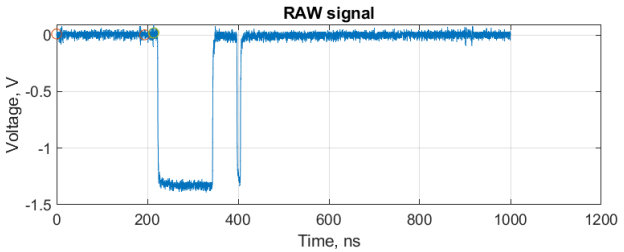
FastIC board in the lab







Exemplary waveform (from other run)



L. Scharenberg

Plans for July test beam period

Detector prototypes

10x10 Multipad detector (USTC)
- Timing performance
- Uniformity check

Picolarge (CEA Saclay): 7 pad resistive prototype
- Spatial resolution measurements
- μRWELL Picolarge?
- Tilted detector - signal sharing

μRWELL - single pad (JLab)
- Multiple detector geometries with different capacitances and varying pitch

New single pad detector?

Performance studies

Electron beam (CEA Saclay, AUTH)
- Dedicated setup - resistive detector - robust photocathode

Pion beam operation of resistive prototypes?

Photocathode studies (CERN, CEA Saclay, USTC)
- DLC photocathodes deposited at ESS
- New B4C photocathode to verify previous measurements (CEA Saclay)
- Large B4C/DLC photocathode in 10x10 detector (USTC/ CERN)?
- Nanostructure photocathodes (Zagreb)?

Gas studies (INFN-PV)
- Improved gas comparison with sealed chamber

Readout
- FastIC ASIC timing measurements with timing and energy branch readout - offline timewalk correction
- FastIC + SAMPIC ?
- New electronics test (USTC)