

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

Content

Introduction

- PICOSEC Micromegas
- Test beam setup

April/May 2023 test beam campaign

- Detector prototypes
- Photocathode studies
- Electronics
- Gas studies

Plans for July 2023 test beam





1	•	•	•	•	+	•	•	•	•		
ł	•	•	•	•	*	•	•	•		*	ŀ
1			+	+		•			*		
10	•	•	•	•	•	•	•	·	·	•	
ï	÷.	•	·	•	•	•	•	•	•	+	ľ
![•	÷	·	•	+	•	•	•	•	+	١.
I	•	•	*		+	•			+	+	
1	۰.		•		+	•	•			٠	
I	1		•	•	•	÷	•	•	•	•	
T			•	•			•	•	•		1

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 \rightarrow <u>Now we want to push the limits</u>

Test beam campaign

Experimental setup

- Infrastructure:
 - → tracking/timing/triggering telescope: GEMs + MCP PMTs
 - → Devices Under Test: Multipad + Single Channel + Saclay Chamber
 - \rightarrow flammable gas mixture: Ne:CF₄:C₂H₆ (80:10:10)



Beam type: CERN SPS H4 beam line,

80 GeV muon beam

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 Csl 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 $82M\Omega$ 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

 $\mu RWELL$

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



100 334.0 7 - Hits 448.0 6 - Hits 388.0 5 - Hits 355.0 4 - Hits 164.0 3 - Hits 451.0 17 - Hits 533.0 16 - Hits 491.0 15 - Hits 422.0 14 - Hits 509.0 13 - Hits 80 280.0 25 - Hits 521.0 24 - Hits 459.0 23 - Hits 505.0 28 - Hits 2389.0 282.0 27 - Hits 22 - Hits 29 - Hits 458.0 472.0 535.0 36 - Hits 496.0 35 - Hits 648.0 673.0 501.0 60 39 - Hits 38 - Hits 37 - Hits 34 - Hits 33 - Hits 32 - Hits 503.0 49 - Hits 567.0 48 - Hits 770.0 45 - Hits 681.0 44 - Hits 444.0 741.0 47 - Hits 46 - Hits 43 - Hits 41 - Hits 42 - Hits 349.0 455.0 615.0 810.0 891.0 649.0 475.0 40 59 - Hits 58 - Hits 57 - Hits 56 - Hits 55 - Hits 54 - Hits 53 - Hits 52 - Hits 362.0 798.0 1040.0 1117.0 1693.0 1534.0 1430.0 603.0 413.0 0 - Hits 69 - Hits 68 - Hits 67 - Hits 66 - Hits 65 - Hits 64 - Hits 63 - Hits 62 - Hits 259.0 10 - Hits 871.0 78 - Hits 1433.0 76 - Hits 1591.0 75 - Hits 1205.0 73 - Hits 496.0 79 - Hits 1009.0 795.0 72 - Hits 393.0 71 - Hits 20 74 - Hite 77 - Hits 704.0 1091.0 1101.0 1141.0 1006.0 88 - Hits B7 - Hits 86 - Hits 85 - Hits 84 - Hits 83 - Hits 82 - Hits 391.0 761.0 1028.0 862.0 95 - Hits 982.0 493.0 93 - Hits 369.0 91 - Hits 0 98 - Hits 97 - Hits 96 - Hits 94 - Hits 92 - Hits

40

X position (mm)

60

80

Y position (mm)

0

20

Hitmap Multipad Picosec

100



7-pad resistive Detectors Under Test

- Multi-Pad Prototypes
 - Hexagonal pads ø 1cm
 - MgF2 crystal
 - Csl 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 \rightarrow 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



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



uRWELL Pi 0.05 Charged particle Cherenkov radiator: MgF₂ -0.05 Photocathode: Cr (3 nm) + Csl (18 nm) -0.1 Drift gap (100-200 µm): pre-amplification E₁ -0.15 Mesh (bulk Micormegas) E_2 -0.2 First operation of µRWELL Picosec continueration in beam test -0.25 Anode +H\ -0.3 High gain and stable operation achieved -0.35 -0.4 Preamplifier 0 Slower rising time of electron peak observed compared to Micromegas

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

MM4 300A/380C



2Gauss BEAM 2023 Apr RUN 147 Pool2 DUT:C2 REF:C1 (d = 4.0 mm) ² / NDE = 103.6 / 80 RAW his Gauss combined Gauss 1 μ = 6.014 ns \pm 3.962 ps Gauss 2 $\sigma_{\rm c} = 78.4 \text{ ps} \pm 9.352 \text{ ps}$ 25 $\sigma_{e} = 217.7 \text{ ps} \pm 147.155$ $\sigma_{\rm tot}$ = 112.4 ps RMS_{tot} = 92.3 ps 20 5.8 5.9 6 6.1 6.2 6.3





μRWELL



K. Gnanvo

Picolarge $10M\Omega$ CsI photocathode - capacitive sharing



Pad multiplicity





Signal amplitude (sum)



X/Y residuals



Performance studies

B4C photocathodes

Gas comparison

Csl

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



2D amplitude map



Amplitude distribution



Efficiency map

35

30

25

20

20

25

ŝ

Time resolution <20ps

5.82



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



Gas mixture comparison



Res vs Amp

0.15

0.2

Time difference, ns

0.3

0

0.2

RAW hist

Gauss 1

Gauss 2

0.4

Gauss combined

160

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



D. Fiorina (INFN-PV)

Readout electronics

Oscilloscope - SAMPIC comparison with MCPs

FastIC

Oscilloscope - SAMPIC comparison with MCPs

1200

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

Oscilloscope 10GS/s

RAW signal 0.3 0.2 8 0.1 -0.1 200 400 600 800 1000 1200 Time, ns Sigmoid fit result 0.4 0.3 B 0.2 235 235.5 236 236.5 237 237.5 238 Time ns



0.1 0.236.6 236.8 237 237.2 237.4 237.6 237.8 238 238.2 238.4 238.6 Time.ns

2Gauss BEAM 2023 Apr RUN 125 Pool3 DUT:C4 REF:C1 (ϕ = 4.0 mm)



SAMPIC 8.4GS/s

MM

MM fit



125 SAMPIC DUT:ch102 - Pad 41

120

100

80

60

40

20

0

0.1 0.2 0.3

e-peak amplitude μ = 0.3919 V U_{max} = 0.3674 V

0.4 0.5 0.6 0.7

Signal amplitude. V





FastIC Analogue to binary conversion



L. Scharenberg

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/

100.0%/

Input signal

Shaper Output

Timing-OR

Ch Out

Time scale: 100 ns

Auto

Picosec and FastIC for the April2023 test beam

FastIC board in the lab







Exemplary waveform (from other run)



07 May 2023

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)