Readout of a TPC using the Medipix2 CMOS pixel sensor

(detection of single electrons on a direct pixel segmented anode)

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Ioannis Giomataris            Joop Rovenkamp
Arnaud Giganon                Max Chefdeville
Goals

• Gas multiplication GEM or Micromegas foil(s)
• Charge collection with granularity matching primary ionisation cluster spread
• Needs sufficiently low diffusion gas
• \(\text{d}E/\text{d}x\) using cluster counting?  
  \(\rightarrow\) M. Hauschild

• Proof of principle based on existing Medipix2 readout chip
Our GEM-equipped TPC
We have constructed a small test TPC equipped with three GEM foils which can be read out by means of the MEDIPIX2 CMOS pixel sensor. The GEM foils were obtained from the CERN/Sauli/GEM group; hole-to-hole distance (hexagonal geometry): 140 µm, hole diameter 85 µm, fiducial surface 100 mm x 100 mm, thickness 50 µm. The drift volume (vol. 100x100x100 mm³) is surrounded by square wire loops, spaced 6.3 mm, put at decreasing potential. Three GEM foils are placed 7.4 mm behind the plane of the bottom wire loop; the distance between GEM foils is 1.6 mm. The anode plane, at ground potential, is 6.6 mm below the third GEM foil.
Drift length: 100 mm
Distance between GEMs: 1.6/2.6 mm
Distance bottom GEM/MEDIPIX: 6.6 mm

Drift Space

GEM foils

MediPix CMOS pixel sensor
Brass spacer block
Printed circuit board
Aluminium base plate

Medipix2: 256 x 256 pixels
55 µm x 55 µm
area 14 x 14 mm²
each pixel: low-noise preamp, discriminator, two threshold DAC, 13-bit counter, communication logic
First events, recorded on March 29, 2003!
Drift space irradiated with $^{55}$Fe quanta

Not immediately understood. Now we do: conversion source $\sim$0.3 mm, defocussing GEM $\sim$0.5 mm, diffusion in driftspace $\sim$1.5 mm
Feb 9, 2004

Ar/Isobutane  95/5

Fiducial field:  
14 x 14 mm²

Collected ionisation in 14 x 14 x 100 mm³ during exposure time

LCWS 2004 Paris

90Sr source; exposed 0.01 s
With Paul Colas & Ioannis Giomataris: MediPix2 & Micromegas

55Fe

Cathode (drift) plane

Micromegas

Baseplate

MediPix2 pixel sensor
Brass spacer block
Printed circuit board
Aluminum base plate

Drift space: 15 mm

Very strong E-field above (CMOS) MediPix!

21 April 2004

LCWS 2004 Paris
Pixel Pitch: 55 x 55 µm²
Bump Bond pad: 25 µm octagonal
75 % surface: passivation SiN
New Pixel Pad: 45 x 45 µm²

Insulating surface was 75 %
Reduced to 20 %
Friday 13 (!) Feb 2004: signals from a $^{55}$Fe source (220 e- per photon); 300 $\mu$m x 500 $\mu$m clouds as expected

The Medipix CMOS chip faces an electric field of 350 V/50 $\mu$m

$= 7$ kV/mm !!

Ar/Isobutane 95/5

We always knew, but never saw: the conversion of $^{55}$Fe quanta in Ar gas
New trial: March 30 - April 2

try to see single electrons from cosmic muons (MIPs)

• New Medipix
• New Micromegas  (holds >500 V over 50 µm in ….)
• He/Isobutane 80/20  (gas gain 10,000 – 20,000)
• Pixel preamp threshold: ~3000 e⁻
• Required gain: 5,000 – 10,000

…… it works!
He/Isobutane
80/20
Modified MediPix

31 March 2004
He/Isobutane
80/20
Modified MediPix

31 March 2004
He/Isobutane
80/20
Modified MediPix

31 March 2004
He/Isobutane 80/20
Non Modified MediPix

Amaricium Source

1 April 2004

21 April 2004
He/Isobutane
80/20
Modified MediPix

31 March 2004
He/Isobutane
80/20
Modified MediPix

31 March 2004
Data analysis cosmics ongoing ……

Modified Medipix

Non-modified Medipix
Example of a track reconstructed

(very preliminary)

This track:
• #hits = 24
• #clusters = 11
• length (3d) = 16.8 mm
• 1.4 e⁻/mm; 0.65 cl./mm

On average:
• 1.7 e⁻/mm; 0.5 cl./mm
• Proof of principle done!
• Can reach sufficiently high gas gains in He based gases (will try other ones)
• The Medipix2 chip can withstand strong E-fields (100kV/cm!)
• Accidental discharges destroy chip immediately (we broke 4 chips in 4 days!)
  Need protection!
• Analysis in progress: single electron efficiency, #clusters and #e− per mm and
  comparison with expectations

Plans for coming weeks:
• Add cosmic trigger; Medipix2 can not be triggered, but can run in “stop” mode
• Try other gases: Ar/Isobutane 80/20
  He/CF4 80/20
• Single electron efficiency vs HV

Later this year beam tests (dE/dx (?): e−, µ, π, …
A lot of work ahead:

• Form collaboration to develop TimePix CMOS pixel chip (add time stamping); submit costs ~150 kEuro for 6 wafers. YOU ARE WELCOME TO JOIN and ADD Euros/$s/Yens

• Develop discharge protection

• At NIKHEF/Mesa+: try to integrate Micromegas and pixel sensor by ‘post-wafer’ processing: InGrid → TimePixGrid

• Lots of simulations to study TPC performance in view of single electron detection: JOIN IN, no Euros needed
Backup slides
In the base plate of the chamber, a hole was cut out for the MEDIPIX2 chip: its pixel surface was flush with the (anode plane) base plate plane. The MEDIPIX2 chip contains 256 x 256 square pixels with pitch 55 µm x 55 µm giving a total fiducial sensitive area of 14.08 mm x 14.08 mm. Each pixel is equipped with a low-noise charge preamp, discriminator, two threshold DACs, a 13-bit counter and communication logic.

Since a triggering system had not been implemented, we operated the MEDIPIX2 sensor by enabling the counters manually, and stop the counting after a pre-set time interval (0.1 - 10 s). After that, the counts of each pixel are read out.

<table>
<thead>
<tr>
<th></th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Drifter</td>
<td>5700 V</td>
</tr>
<tr>
<td>Bottom Drifter</td>
<td>3473 V</td>
</tr>
<tr>
<td>Top GEM 1</td>
<td>2813 V</td>
</tr>
<tr>
<td>Bottom GEM 1</td>
<td>2462 V</td>
</tr>
<tr>
<td>Top GEM 2</td>
<td>1876 V</td>
</tr>
<tr>
<td>Bottom GEM 2</td>
<td>1524 V</td>
</tr>
<tr>
<td>Top GEM 3</td>
<td>938 V</td>
</tr>
<tr>
<td>Bottom GEM 3</td>
<td>586 V</td>
</tr>
</tbody>
</table>

Drift length: 100 mm
Distance between GEMs: 1.6/2.6 mm
Distance bottom GEM/MEDIPIX: 6.6 mm
\[
\text{Prob}(n) = \frac{1}{G} \cdot e^{-n/G}
\]

\[
\text{Eff} = e^{-n/G}
\]

\text{n: threshold setting (\#e-)}

\text{G: Gas amplification}