IMAGING WITH MICROPATTERN GAS DETECTORS

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MODERN GASEOUS DETECTORS: POWERFUL TOOLS FOR RADIATION DETECTION AND LOCALIZATION IN PARTICLE PHYSICS, BASED ON THE MULTIWIRE PROPORTIONAL CHAMBER (Georges Charpak, 1967)
TWO-DIMENSIONAL LOCALIZATION FROM SIGNALS INDUCED ON CATHODE PLANES (Charpak & Fabio Sauli, ~1973)

LOW-DOSE DIGITAL RADIOGRAPHY WITH MWPC: CHARPAK’S HAND (2002):
PATTERN DETECTORS IN PARTICLE PHYSICS: TIME PROJECTION CHAMBER
POWERFUL, THREE-DIMENSIONAL IMAGING OF COMPLEX EVENTS

ALEPH TPC, CERN 1990-2001
MWPC LIMITATIONS

DIFFICULT TO BUILD (THIN WIRES)
POOR TWO-TRACK RESOLUTION (~ 5 mm)

THE GAIN DECREASES WITH DETECTED FLUX
(POSITIVE IONS SPACE CHARGE):

[Graph showing the relationship between relative gain and rate (mm$^2$ s$^{-1}$).]

$10^4$ mm$^2$ s$^{-1}$
FIRST MICRO-PATTERN GAS DETECTORS

MICROSTRIP GAS CHAMBERS (Anton Oed, ~1990)
THIN METAL STRIPS ON GLASS SUBSTRATE:

COMPACT, LIGHT CONSTRUCTION
VERY HIGH RATE CAPABILITY:

SPACE ACCURACY ≈ 50 µm
TWO-TRACK RESOLUTION ≈ 100 µm

BUT... TOO FRAGILE
EFFECT OF A DISCHARGE:

NEW MICROPATTERN GAS DETECTORS

MICROMEGAS: THIN-GAP PARALLEL PLATE COUNTER

MICROMEGAS

POSITION ACCURACY (100 µm PITCH STRIPS):

\[ \sigma / \sqrt{2} = 12 \, \mu m \]


TIME RESOLUTION (ISOCHRONOUS ELECTRONS):

\[ 0.77 \, \text{ns rms} \]

NEW MICROPATTERN GAS DETECTORS

GAS ELECTRON MULTIPLIER (GEM)
THIN METAL-COATED POLYMER FOIL WITH HIGH DENSITY OF HOLES:

50 µm Kapton, 5 µm Copper
70 µm holes at 140 µm pitch:

F. Sauli, Nucl. Instr. and Meth. A386(1997)531
GEM: WIDER AVALANCHE, FAST ELECTRON SIGNAL ONLY

GEMs CAN BE CASCADED: MULTI-STAGE AMPLIFICATION

IONS

ELECTRONS

SENSITIVE VOLUME

HIGHER SAFE GAINS!

30 ns

10 ns ( ~ 1 mm)
**RADIATION-INDUCED BREAKDOWN**

**DISCHARGE PROBABILITY IN HADRON BEAMS:**

**TRIPLE GEM:**

- **G=10000**

  ![Graph showing discharge probability for Ar/CO₂ (70/30) with no discharges observed at G=10⁴.]

  @ GAIN 10⁴
  DISCHARGE PROBABILITY < 10⁻¹²


**MICROMEGAS:**

- **DISCHARGE PROBABILITY ~ 10⁻⁶**

  ![Graph showing discharge probability for various gases with GAIN 10⁴.]

  D. Thers et al, Nucl. Instr. and Meth. A469(2001)133
MICROMEGAS COMPASS SPECTROMETER AT CERN:
12 PLANES IN 3 STATIONS X, Y, U, V
40x40 cm² ACTIVE
350 µm STRIPS - DIGITAL READOUT

SPACE RESOLUTION:
70 µm rms

TIME RESOLUTION:
9 ns rms

GEM DETECTORS FOR COMPASS

22 TRIPLE-GEM CHAMBERS
31x31 cm² ACTIVE
2-D CHARGE READOUT

SPACE RESOLUTION:

TIME RESOLUTION (FROM 3-BIN FIT):

GEM DETECTOR FOR TOTEM
CERN-HELSINKI (IN CONSTRUCTION)

HALF-MOON SHAPED

M. Bozzo et al, IEEE NSS 2004 Conf. Records

CERN PROTOTYPE

CYLINDRICAL GEM DETECTORS:

RADIAL DRIFT CHAMBER (BONUS, JLAB):

H. Fenker, JLAB (2006)
PHOTON DETECTION WITH GEM

REFLECTIVE CsI PHOTOCATHODE

EDrift ~ 0

FURTHER MULTIPLICATION

MULTIPLE GEM DETECTORS:
VERY HIGH GAIN ( > 10^5) FOR SINGLE
PHOTON DETECTION AND LOCALIZATION

HEXABOARD PAD READOUT

HEXAGONAL PADS PLANE, 500 μm PITCH

PAD ROWS INTERCONNECTED ALONG THREE DIRECTIONS:


FAST RICH (2 ns resolution)
GEM FOR X-RAY IMAGING

ENERGY SIGNAL ON LOWER GEM ELECTRODE, POSITION INFORMATION FROM ANODE STRIPS:

X-RAY ABSORPTION RADIOGRAPHY OF A SMALL MAMMAL:

A. Bressan et al, Nucl. Instr. And Meth. A199)254
CASCADE: NEUTRON IMAGING

$^{10}$B - COATED MULTI-GEM DETECTOR

M. Klein et al
The CASCADE project
http://pi1.physi.uni-heidelberg.de/physi/cascade/

DETECTION EFFICIENCY vs NEUTRON WAVELENGTH:

NEUTRON ABSORPTION IMAGE:
PORTAL IMAGING: VERY HIGH RATE GAMMA RAYS DETECTION
ROYAL INSTITUTE OF TECHNOLOGY AND KAROLINSKA HOSPITAL (STOCKHOLM)

COMBINED MULTILAYER DETECTOR FOR LOW ENERGY DIAGNOSTIC RADIOGRAPHY AND HIGH ENERGY PORTAL IMAGING:

GAS CONVERTER (30-50 keV)

GEM+SOLID CONVERTER (MeV)

FAST READOUT ELECTRONICS: CHARGE INTEGRATION ON PADS

ACTIVE ELECTRONICS (OUTSIDE RADIATION FIELD)

CHARGE COLLECTION PADS
100 PIXELS 1.27x1.27 mm² PER CARD

DETECTOR

50 CARDS

5000 PIXELS

Fig. 2. The electronic readout board consists of edge-plated FECs stacked together to a 2D-surface of pixels. The prototype shown in the picture has 50 FECs with 100 pads each.

PORTAL IMAGING: FAST FRAME READOUT

TIME-RESOLVED NEWTON’S PENDULUM IMAGE AT 40 keV
10 ms INTEGRATION, 70 FRAMES PER SECOND

QuickTime™ and a Cinepak decompressor are needed to see this picture.
X-RAY POLARIMETER: TRACKING THE PHOTOELECTRON DIRECTION
MICRO-GEM DETECTOR WITH PAD READOUT

DEDICATED CMOS READOUT
80 µm PITCH HEXAGONAL PADS:

5 KeV PHOTOELECTRON:

1 mm²

R. Bellazzini et al,
THE ULTIMATE MPGD: INTEGRATED PIXEL ELECTRONICS READOUT

MEDIPLEX 2: 256x256 PIXELS
55 µm x 55 µm

- Digital readout: preamp / discriminator
- Two DAC thresholds (low, high)
- Noise RMS ~ 150 e^-/channel


M. Titov, Como conference 2005
COSMIC RAY TRACK: SINGLE ELECTRON DETECTION

MEDIPIX - GEM

3xGEM

MEDIPIX

PRIMARY IONIZATION CLUSTERS:

A. Bamberger et al, IEEE NSS (Puerto Rico 2005)
THE END OF THIS TALK...

BUT HOPEFULLY NOT OF INTERESTING DEVELOPMENTS!