Recent Results on Micropattern Gas Detectors

First Hand Experience with the Gas Electron Multipliers (GEM)

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4/24/02
MultiWire Proportional Chamber (MWPC)
Micro-Strip Gas Chamber (MSGC)

- gas mixture: Ne(40%)-DME(60%)
- cathode: 93 μm
- anode: 7 μm
- coating: 1 μm
- thickness: 0.8 μm
- pitch: 200 μm

A.Oed, ILL 1988
R.Bellazzini et al, Pisa INFN 1989
F.Udo et al, NIKHEF 1989
Micro-Strip Gas Chamber
Micro-Gap Chamber (MGC)

R. Bellazzini, 1993

Small gap chamber

D. Contardo et al., 1997
Electric Field and Signal Waveform Comparison

**Electric field**

MWPC

-200

0

200

-1200 -800 -400 0 400 800 1200 μm

MSGC

120

80

40

0

-300 -200 -100 0 100 200 300 μm

MGC

60

40

20

0

-120 -60 0 60 120 μm

**Signals**

- Change (mV or ab/A)

- Time (ns)

- Curves (Anode, Cathode, etc.)
Compteur a Trou (CAT)


MICROCAT

Micro MEsh GAseous Structure (Micromegas)

Conversions gap 3 mm
Amplification gap 100 µm
Anode Strips (V=0)

Drift Electrode (HV1)
Micromesh (HV2)

E1 1kV/cm
E2 100kV/cm

Conversions GAP (3mm)
E_{drift} 1-5kV/cm
E_{amplification} 30-50kV/cm

Mesh Pitch 50µm
Mesh Thickness 3µm

G.Charpak, Y.Giomataris, 1992
MICROMEGAS

Large MICROMEGAS (40x40cm²) for COMPASS

5.4keV Energy Resolution = 16% FWHM

Positive ion Feedback

Y. Giomataris, F. Kunne, F. Jeanneau, P. Mangeot
Micro-groove detector

R.Bellazzini, 1997 (INFN, Piza)

WELL detector

R. Bellazzini, 1997
Micro-wire detector

B. Adeva et al., 1998
Micro-dot chamber

Micro-Pin Array

Gain

Cathode Voltage

P. Rehak et al. 1999

S. Biagi, 1993

Ar - DME
GEM Fabrication

PATTERNING:

MASK
PHOTORESIST
Exposure to light

DEVELOPMENT:

Photoresist Curing
Etching in Na₂CO₃

METAL ETCHING:

Etching in FeCl₃

KAPTON ETCHING:

Etching in ethylene-diamine
(1,2 diaminoethane)
H₂NCH₂-CH₂NH₂

(from Hoch, Kadyk)
Electron Multiplication Process

CONVERSION AND DRIFT

AMPLIFICATION

TRANSFER

from Archana SHARMA
Electron Multiplication Process

from Ulrich Moosbrugger
Characteristics of Micropattern Gaseous Detectors

Pros

- Spatial resolution
- Rate capability
- Energy resolution
- Time resolution

Cons

- Discharges induced by heavily ionizing particles
- Aging
Applications of the GEM

Large Area Tracking

C. Altunbas, et al., CONSTRUCTION, TEST AND COMMISSIONING OF THE TRIPLE-GEM TRACKING DETECTOR FOR COMPASS
CERN-EP/2002-008
Two Dimensional Readout of the GEM

Projective Readout

8 keV X-ray absorption image of a bat
Image size ~ 6 cm x 3.5 cm

GEM foils and pads

fabricated at the CERN PCB workshop

GEM foil

50 μm

140 μm

GEM pads

2.54 mm pitch hexagons and strips
An event

Ar CO₂ (90:10)
HQV810 preamps
Scan over entire pad – charge sharing

100 mm circles centred at pin hole locations during scan

With P10 gas:
- cloud size 550 mm
- x,y standard deviations: ~70 mm
**Other Applications of the GEM**

*Scintillating Gems*

Coupling the GEM to a CCD to record the fluorescence light from the GEM avalanche.

**Alpha particle tracks:**

**Proton & triton tracks**
from neutron & He3 interaction

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Other Applications of the GEM

CASCADE Neutron Detector

Multi-layer boron coated GEM for neutron detection

\[ ^{10}\text{B} + \text{n} \rightarrow ^{7}\text{Li} \ (0.84\text{MeV}) + ^{4}\text{He} (1.47\text{MeV}) + ^{\gamma} \ (0.48\text{meV}) \]

Other Applications of the GEM

GEM Photomultiplier

Multi-stage (3-4) GEM coupled to transmissive or reflective CsI photo cathode


Other Applications of the GEM

GEM Imager with Pixel Readout

Ultrafast imaging of soft X-rays for plasma diagnostics


X-ray polarimetry

R. Bellazzini, et al., X-Ray Polarimetry with a Micropattern Gas Detector with Pixel Read-Out, presented at the 2001 Nuclear Science Symposium
Double GEM Detector Schematic Cross Section
(with resistive divider)

HG

1MΩ

3mm

15% Vw

3.8MΩ

Upper GEM

2.4MΩ

Drift Region

10MΩ

10MΩ

Transfer Region

10MΩ

150µm

3.8MΩ

Lower GEM

2.4MΩ

Induction Region

10MΩ

200µm

HV

Anode Strip Plane

VGEM\sim 15\% Vw
Normalized Anode Spectra vs HV

5.4 keV collimated x-ray, Ar+20% CO2.

Pulse Height

2.7kV
2.8kV
2.9kV
3kV
3.1kV
3.2kV
3.3kV
Effective Gas Gain of the Double GEM Detector

Ar+20% CO₂, 5.4 keV x-rays (~1mm², 2kHz), \(E_d=1\, \text{kV/cm}, E_t=4\, \text{kV/cm}, E_i=5\, \text{kV/cm}\)
Energy Resolution of the Double GEM Detector

Ar+20% CO₂, 5.4 keV x-rays (~1mm², 2kHz), E₀=1kV/cm, Eₜ=4kV/cm, Eᵢ=5kV/cm

Voltage Across One GEM [volt]

Relative Width of the Photo Peak [%]

Equal voltages on both GEMs

Lower GEM @440V
Energy Resolution of the Double GEM Detector

Ar+20% CO₂, 5.4 keV x-rays (~1mm², 2kHz), \( V_{\text{GEM1}} = 280V, \ V_{\text{GEM2}} = 450V, \ E_t = 4kV/cm, \ E_i = 4kV/cm \)
Electron Transfer vs. Drift Field

Ar+20% CO₂, 5.4 keV x-rays (~1mm², 2kHz), $V_{GEM1}=280V$, $V_{GEM2}=450V$, $E_t=4kV/cm$, $E_i=4kV/cm$
Anode Charge vs. Transfer Field

Ar+20% CO₂, 5.4 keV x-rays (~1mm², 2kHz), E_d=500 V/cm, E_i=4 kV/cm

![Graph showing the relationship between anode charge and transfer field for different GEM voltages.]

- Blue line: V_GEM₁ = 420 V, V_GEM₂ = 420 V
- Red line: V_GEM₁ = 280 V, V_GEM₂ = 450 V
Electron Transfer vs. Transfer Field

Ar+20% CO₂, 5.4 keV x-rays (~1mm², 2kHz), Ed=500V/cm, Ei=4kV/cm

"Transfer Efficiency" [%]

V_{GEM1}=280V, V_{GEM2}=450V
Double GEM Detector Schematic Cross Section
(with resistive divider)

Entrance Window

3mm

50µm

2mm

2mm

1MΩ

10MΩ

10MΩ

10MΩ

10MΩ

10MΩ

10MΩ

10MΩ

10MΩ

10MΩ

3.8MΩ

3.8MΩ

3.8MΩ

2.4MΩ

2.4MΩ

2.4MΩ

3.8MΩ

3.8MΩ

3.8MΩ

V_{GEM} \sim 15\% V_W

Drift Region

Transfer Region

Induction Region

Upper GEM

150µm

Lower GEM

400µm

Anode Strip Plane
Pulse Height Spectra of 4 Adjacent Anode Strips
5.4 keV, Ar+20%CO₂, V_{GEM}~490, Q_A~0.45\,pC, FWHM~16.5%
Pulse Height Spectra from 4 Adjacent Anode Strips

(-0.4mm pitch). The x-ray beam was stepped at 100µm intervals.
Most Probable Pulse Height vs X-ray Position

A set of 4 adjacent strips 0.4mm pitch
Initial Charging Up of the GEM

Ar+20% CO₂, 5.4 keV x-rays (~1mm², 4kHz), Qa~0.025pC

\[ E_{\text{GEM}1} = 260V, \quad V_{\text{GEM}2} = 440V, \quad E_d = 200V/cm, \quad E_t = 4kV/cm, \quad E_i = 5kV/cm \]
Double GEM Gas Gain Uniformity
Collimated 5.4keV x-ray, at 2mmx2mm grid, 9cmx9cm area
Double GEM Gas Gain Uniformity
Collimated 5.4keV x-ray, at 1mmx1mm grid, 9cmx9cm area
Gas Gain Uniformity of the Double GEM
Gas Gain Variation around a Damaged Spot
The x-ray beam was stepped at 1mm intervals along the middle of a 1.6mm wide anode strip. At each x-ray position, the photo peak height was recorded together with the time of exposure. Each segment in this plot lasted about 5-6 minutes. It seems that at most positions on the detector, the pulse height decreases with time at this photon rate (4kHz over 0.1mmx0.5?mm area).
Average Photo Peak Height vs Position

Average pulse height between 3 and 5~6 minutes of exposure @4kHz
Scans Along the Strip Length at 1mm Intervals

5.4 keV x-rays, 0.1pC, 2kHz, Ar+20% CO₂
(each curve is shifted up by 5%)
Pulse Height vs X-ray Flux

x-ray flux of 0.5, 1, 2, 4, 2, 1, 0.5 kHz, @0.1pC

- Normal incidence
- Inclined beam
Gas Gain vs Flux

Ar+20% CO₂, 5.4 keV x-rays (~1 mm², 2 kHz), $E_d=1$ kV/cm, $E_t=4$ kV/cm, $E_i=5$ kV/cm, $Q_a=0.2$ pC
Lifetime and Energy Resolution

Ar+20% CO₂ gas flow stopped, HV increased twice during the measurement (equivalent to a factor of 4 increase in gain). FWHM derived from fitted gaussian curve.