Recent developments on Micro-Pattern Gaseous Detectors

Micromegas

GEM

THGEM

MHSP

Ingrid

Matteo Alfonsi (CERN)
Outline

• Introduction on MPGD
• GEM and MicroMegas
• Latest developments
• Large Area detectors
• RD51 collaboration
Limitations on MWPC

Space charge build-up at high particle rate, due to slow motion of ions, results in a deformation of the field, leading to e.g. a reduction of gain or a distortion of the drift paths.

GAIN DROP ABOVE $\sim 10^4$ mm$^{-2}$ s$^{-1}$

From F. Sauli presentation at TIPP09
Micro Strip Gas Chambers (1)


Small pitch (~100 $\mu$m between anodic and cathodic strips):
- fast ion collection on cathodic strips
- resolution ~ 50 $\mu$m, two-track resolution ~ 500 $\mu$m
- high rate capability ~ $10^6$ mm$^{-2}$ s$^{-1}$

Micro Strip Gas Chambers (2)

- MSGC can discharge in hostile environment, due to the higher field present at the strip edges close to the interface with the insulating substrate.

- Discharges can heavily damage the strips.

- Special modifications, such as resistive substrate or passivation of the edges, can solve the problem (see R. Bellazzini et al., Nucl. Instr. and Meth. A 457 (2001) 22.)
Micro-Pattern Gaseous Detectors

Produced with standard photolithographic process

From F. Sauli presentation at RD51 collaboration meeting at NIKHEF - 2008
Gas Electron Multiplier

In a Gas Electron Multiplier (GEM), holes act as multiplication channels for gaseous detectors.

GEM foils can be cascaded:

a Triple-GEM detector is built by inserting three GEM foils between two planar electrodes, which act as the drift cathode and the readout anode.
GEM: rate capability, discharges studies

- RATE CAPABILITY
  No gain loss up to ~3 MHz mm$^{-2}$


MICRO MEsh GAseous Structure

A thin mesh very close (50 - 150 μm) to the anode defines the multiplication gap.
Insulating pillars sustain the mesh.

MICROMEGAS performance

Excellent energy and spatial resolution can be obtained with the suitable gas mixture and proper geometry.

**Good energy resolution**


**Excellent single electron resolution**

**Micromegas**

Spatial resolution $\sigma \sim 12 \mu m$
Current and future trends on MPGD

- COMPASS
- NA48 / KABES
- CAST (CERN Axial Solar Telescope)
- nTOF (neutron beam profiles)
- Laser MegaJoule
- DEMIN (inertial confinement fusion)
- Picollo (in-core neutron measurement)
- T2K Time Projection Chamber
- Linear Collider TPC (?)
- ATLAS Muon System Upgrade (?)
- LHCb Muon Detector
- TOTEM Telescope
- HBD (Hadron Blind Detector)
- Cascade neutron detection
- NA49 - upgrade
- X-Ray Polarimeter (XEUS)
- GEM TPC for LEGs, BoNuS
- Linear Collider TPC (?)
- KLOE2 vertex detector (?)
Latest developments
Cylindrical GEM detectors

L. Ropelewski, Vienna Instr. Conf. 2007

Bulk-Micromegas

- Micromegas is produced together with the readout board

Read-out board
Laminated Photoimageable coverlay
Stretched mesh on frame
Laminated Photoimageable coverlay
Exposure Development + cure

Bulk-Micromegas for T2K TPC (A. Delbart at TIPP09)

ENERGY RESOLUTION ON $^{55}$Fe:

$\sigma \sim 9.2\%$

GAIN UNIFORMITY: ~ 2% RMS
Photodetection with THGEM

- Thicker version of GEM, realized on standard PCB, usually by mechanical perforation
- CsI deposited on top electrode
- “Closed geometry” photo-detector:
  - Suppression of photon feedback
- Reduction of ion feedback

See E. Rocco’s talk
**MPGD with resistive electrodes**

**RESISTIVE ANODE:**
CHARGE DISPERSION READOUT


**RETGEM: RESISTIVE ELECTRODE THICK GEM**

RESISTIVE FOIL
GLUE
PADS
PCB
MESH

**GAIN OF RETGEM IN VARIOUS GASES:**


**POSITION ACCURACY ~ 50μm**

Ar CF4 Iso (95:3:2)
B = 5T

**GAIN**

Voltage (V)

Gain
Integration MPGD + electronics

- MPGD built directly over the silicon pixel readout chip.
- Single electron detection due to high gain and small pixel size.
- A resistive silicon layer over the active chip protects for discharges induced by α particles.

H. Van der Graaf
Large Area detectors
Single mask GEM technique

- **No masks alignment problem** (as in double mask technique):
  - Maximum size: 450mm (due to raw material) x 100 meters!
- Holes profiles are conical
- On-going effort for the quality improvement
- On-going studies on the effects of "conicality" w.r.t. a cylindrical shape

Raw material

Single side copper patterning

Chemical polyimide etching

Chemical copper reduction
Single mask technique & foil splicing: first prototype

The limit in width (~45 cm) due to the available material is overcome “splicing” together two foils, with a ~3 mm wide local efficiency loss.

Large THGEM, Large Micromegas

600x600mm² THGEM@ INFN Trieste

For COMPASS RICH upgrade

2000x1000mm² stretched mesh

For ATLAS Muon system upgrade

The stretched micromegas mesh on its frame

R. De Oliveira, RD51 Meeting (Jan. 2009)
Summary and..

• MPGD are nowadays well-established technologies
• New structures are under developments, as well as new studies to increase the maximum size of such detectors

Such R&D projects can take advantages by the sharing of the resources and the infrastructures, and many groups joined in an international collaboration...
RD51: development of MPGD technologies

Collaboration of ~60 institutes worldwide.
Approved by CERN’s Research Board December 5, 2008

“RD51 aims at facilitating the development of advanced gas-avalanche detector technologies and associated electronic-readout systems, for applications in basic and applied research.”

Collaboration Board Chair: Silvia Dalla Torre
Spokesman: Leszek Ropelewski, Maxim Titov

Workshops:
Amsterdam April 16-18, 2008 http://indico.cern.ch/conferenceDisplay.py?confId=25069
RD51 organization

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**Objectives**
- Design optimization
- Development of new geometries and techniques
- Common test standards
- Characterization and understanding of physical phenomena in MPGD
- Evaluation and optimization for specific applications
- Development of common software and documentation for MPGD simulations
- Readout electronics optimization and integration with MPGD detectors
- Development of cost-effective technologies and industrialization
- Sharing of common infrastructure for detector characterization

**Tasks**
- Large Area MPGDs
- Common Test Standards
- Tracking and Triggering
- Photonic Detection
- Calorimetry
- Cryogenic Detectors
- X-Ray and Neutron Imaging
- Astrophysical Physics Applications
- Medical Applications
- Study of Avalanche Statistics
- Algorithms
- FE electronics requirements definition
- General Purpose Pixel Chip
- Large Area Systems with Pixel Readout
- Portable Multi-Channel System
- Discharge Protection Strategies
- Common Production Facility
- Testbeam Facility
- Collaboration with Industrial Partners
- Irradiation Facility
- Industrialization

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IFAE - Bari 16/04/2009

M. Alfonsi (CERN)
Backup slides
MPGD in HEP now

• Micromegas and triple-GEM detectors in COMPASS experiment at CERN are taking data since several years without change of performance

• Two LHC experiments, LHCb and TOTEM, include triple-GEM detectors in the apparatus

Time resolution of a LHCb GEM station, composed by two triple-GEM chambers in OR, used by level-0 trigger

TOTEM T2 telescope
The electric field at the edge of the strips is strongly affected by the resistivity of the support:

\[ \rho = 10^{15} \, \Omega \text{ cm} \]

Very large signal observed in the charge spectrum, due to ionization very close to cathodic strips edges.
