The COMPASS experiment gets its new hybrid pixelized Micromegas detectors for high particle flux

Damien Neyret
CEA Saclay IRFU/SPhN

MicroPattern Gaseous Detectors conference 2015
13/10/2015

New pixelized Micromegas detector project
Pixelized read-out and discharge impact reduction
Preliminary performance during 2015 run
The COMPASS experiment gets its new hybrid pixelized Micromegas for high particle flux

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CEA DSM Irfu

13 October 2015

The COMPASS experiment at CERN

Muon or hadron beams on fixed target
2 spectrometers for small and large angles
Taking data from 2002 for nucleon structure studies
High statistic experiment (30kHz trigger rate)
Micromegas just after the target

Absorber after the target for Drell-Yan physics

Polarized target $^6$LiD, NH$_3$

L = 4.10$^7$/s

Muon or hadron beams on fixed target
2 spectrometers for small and large angles
Taking data from 2002 for nucleon structure studies
High statistic experiment (30kHz trigger rate)
Micromegas just after the target
Old COMPASS Micromegas detectors

COMPASS Micromegas detectors

First Micromegas detectors installed in particle physics experiment (since 2001-2002)

Light board sandwich with 40x40 cm² active area

Good performance: 70-100 µm and 10 ns resolutions

Light gas mixture Ne + 10% C₂H₆ + 10% CF₄ to limit discharge rate

Blind center to reduce electronics occupation

Low-noise electronics using SFE16 chips (threshold ~ 4000 e⁻)
New pixelized Micromegas project

Motivations

New COMPASS study phase in 2015-2018 with high flux muon (DVCS) and hadron beams (Drell-Yan)

Tracking at very small angle with same material budget

Discharge impact reduction at high beam flux

Main objectives of the project

Detectors active in beam area with pixel read-out

Less discharge → stand 5 times higher flux

Integrated electronics (APV25 chips)

Robustness improved with bulk technology

Same active area (40x40cm²) as present MM
Impact of low angle tracking on DVCS measurement


Study on large kinematic domain in particular at low muon scattering angle

Insufficient track detection at low angle would lead to loose statistic in important part of the domain

DVCS kinematic domain

Study by Eric Fuchey

DVCS event number ratio without/with active pixel area (Monte-Carlo)
The COMPASS experiment gets its new hybrid pixelized Micromegas for high particle flux.

5 cm

80 cm

40 cm

Active area

Too high flux for strips

Expected particle flux $> 100$kHz/mm$^2$
→ $> 500$kHz/channel if strip read-out
→ $> 10\%$ electronics inefficiency

Rectangular pixels

Keep spatial resolution in perpendicular dimension (400µm pitch like strips)
1280 pixels + 1280 strips
APV front-end electronics for pixelized MM

Design from TUM Munich

*Used in other COMPASS detectors (RICH, pixelGEMs,...)*

**APV cards**

*APV25-S1 chips for amplification and analog multiplexing*

*Very integrated, 128 channels/chip*

*Specific changes done for MM read-out (protection circuit)*

**ADC boards**

*Digitalize analog signals from APV chips*

**HGeSiCa VME cards**

*Data concentration and trigger distribution*
Selected solutions to reduce the impact of discharges

**Resistive Micromegas**

*Other resistive schemes not fully adapted for pixels*

**Buried resistors** scheme proposed in 2010 by R. de Oliveira et al.

**Hybrid Micromegas with 1 GEM foil**

*Preamplification with a GEM foil (gain 10-20)*

*Micromegas stage at lower gain → fewer discharge*

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*drift electrode*

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*GEM*

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*μ-mesh*

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*gain 10-20*
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**Hybrid detectors**

*Important reduction (>10) of discharge probabilities compared to standard MM*

Common studies in 2009-2010 on small size detectors (6x10 cm² active area) with CLAS12 Saclay group in the framework of the RD51 collaboration

**Resistive detector**

*No visible discharge as their amplitude are too small to be detected*

CERN PS

~1 GeV

pion beam

M. Vandenbroucke

G. Charles

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Discharge rates with high flux hadron beam

Hadron 2012 data taking at COMPASS, pion beam

Standard MM with reduced gain

Resistive detector

Hybrid detectors
Discharge rates with high flux hadron beam

Mesh current on station 1 placed just after target + absorber

High current due to amplification of low momentum particles

No large discharge visible on new detectors

Drell-Yan 2015 data taking, pion beam
MM board production

Choice of MM+GEM hybrid detection

- Better spatial and time resolutions than for resistive detector
- No solution yet for serial production of buried resistor boards

MM technology transfer to industry

- Collaboration between IRFU and CIREA / ELVIA group (french PCB producer) since 2011, partner on « SPLAM » ANR agency funding
- ELVIA masters bulk technology since mid-2012, producing 40x40 cm² active area prototypes since then
Production and installation of 12 detectors + spares

Challenges for the production

- Large size PCB with very thin design in the pixel area (60µm thin strips with 60µm insulation)
- Gluing of 200 µm thin PCB – 4 mm Rohacell foam sandwich

Production of bulk boards at ELVIA company

- Took place from end 2014 to September, peak production 2 boards every 2 weeks
- Cf. poster

Installation at CERN

- 3 stations of 4 planes (X, Y, U, V), station 1 was already equipped in 2014 with prototypes of pixelized MM
- Station 2 installed in April, station 3 in May
- Station 1 equipped with final detectors in June
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14 October 2015

PixelMM efficiencies at low \( \mu \) flux

All magnets on

Station 1

Very preliminary
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13 October 2015

PixelMM efficiencies at low $\mu$ flux

All magnets on Station 2

Very preliminary
PixelIMM efficiencies at low $\mu$ flux

All magnets on Station 3

Effectiveness:
- Strips 3X: Eff = 99.0%
- Strips 3Y: Eff = 99.4%
- Strips 3U: Eff = 98.5%
- Strips 3V: Eff = 98.8%

Very preliminary
PixelIMM efficiencies at high intensity hadron beam

Station 1

Very preliminary
PixelMM efficiencies at high intensity hadron beam

Station 2

**Strips 2X**
Eff = 96.5%

**Strips 2Y**
Eff = 97.6%

**Strips 2U**
Eff = 96.5%

**Strips 2V**
Eff = 97.9%

**Pixels 2X**
Eff = 94.2%

**Pixels 2Y**
Eff = 95.6%

**Pixels 2U**
Eff = 96.2%

**Pixels 2V**
Eff = 97.1%

Very preliminary
PixelMM efficiencies at high intensity hadron beam

Station 3

Strips 3X

Eff = 97.7 %

Strips 3Y

Eff = 98.4 %

Strips 3U

Eff = 96.9 %

Strips 3V

Eff = 97.5 %

Very preliminary

Pixels 3X

Eff = 96.5 %

Pixels 3Y

Eff = 97.0 %

Pixels 3U

Eff = 83.3 %

Pixels 3V

Eff = 96.0 %
Pixel MM spatial residuals at low $\mu$ flux

All magnets on

Station 1

Strips 1X
\[ \sigma_{\text{residual}} = 103 \, \mu\text{m} \]
\[ \sigma_1 = 67 \, \mu\text{m} \]

Strips 1Y
\[ \sigma_{\text{residual}} = 90 \, \mu\text{m} \]
\[ \sigma_1 = 63 \, \mu\text{m} \]

Strips 1U
\[ \sigma_{\text{residual}} = 104 \, \mu\text{m} \]
\[ \sigma_1 = 71 \, \mu\text{m} \]

Strips 1V
\[ \sigma_{\text{residual}} = 100 \, \mu\text{m} \]
\[ \sigma_1 = 71 \, \mu\text{m} \]

Very preliminary

Pixels 1X
\[ \sigma_{\text{residual}} = 116 \, \mu\text{m} \]
\[ \sigma_1 = 67 \, \mu\text{m} \]

Pixels 1Y
\[ \sigma_{\text{residual}} = 107 \, \mu\text{m} \]
\[ \sigma_1 = 61 \, \mu\text{m} \]

Pixels 1U
\[ \sigma_{\text{residual}} = 128 \, \mu\text{m} \]
\[ \sigma_1 = 64 \, \mu\text{m} \]

Pixels 1V
\[ \sigma_{\text{residual}} = 133 \, \mu\text{m} \]
\[ \sigma_1 = 69 \, \mu\text{m} \]
Pixel MM spatial residuals at low $\mu$ flux

All magnets on

Station 2

Strips 2X

$\sigma_{\text{residual}} = 128 \ \mu m$
$\sigma_1 = 84 \ \mu m$

Strips 2Y

$\sigma_{\text{residual}} = 97 \ \mu m$
$\sigma_1 = 65 \ \mu m$

Strips 2U

$\sigma_{\text{residual}} = 99 \ \mu m$
$\sigma_1 = 77 \ \mu m$

Strips 2V

$\sigma_{\text{residual}} = 88 \ \mu m$
$\sigma_1 = 69 \ \mu m$

Pixels 2X

$\sigma_{\text{residual}} = 117 \ \mu m$
$\sigma_1 = 77 \ \mu m$

Pixels 2Y

$\sigma_{\text{residual}} = 99 \ \mu m$
$\sigma_1 = 59 \ \mu m$

Pixels 2U

$\sigma_{\text{residual}} = 102 \ \mu m$
$\sigma_1 = 67 \ \mu m$

Pixels 2V

$\sigma_{\text{residual}} = 102 \ \mu m$
$\sigma_1 = 65 \ \mu m$

Very preliminary
Pixel MM spatial residuals at low $\mu$ flux

All magnets on Station 3

Strips 3X

$\sigma_{\text{residual}} = 202 \, \mu m$

$\sigma_1 = 169 \, \mu m$

Strips 3Y

$\sigma_{\text{residual}} = 79 \, \mu m$

$\sigma_1 = 60 \, \mu m$

Strips 3U

$\sigma_{\text{residual}} = 140 \, \mu m$

$\sigma_1 = 118 \, \mu m$

Strips 3V

$\sigma_{\text{residual}} = 117 \, \mu m$

$\sigma_1 = 99 \, \mu m$

Very preliminary

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**PixelMM spatial residuals vs position at low $\mu$ flux**

### All magnets on

<table>
<thead>
<tr>
<th>$\Delta U$ vs $U_{track}$ strip</th>
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### Station 3

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### Strips only

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### Very preliminary

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### U ($\perp$ strips) (cm)

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### V ($\parallel$ strips) (cm)

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Pixel MM spatial residuals at high hadron flux

Station 1

Very preliminary

Strips 1X

\[ \sigma_{\text{residual}} = 109 \, \mu m \]
\[ \sigma_1 = 78 \, \mu m \]

Strips 1Y

\[ \sigma_{\text{residual}} = 127 \, \mu m \]
\[ \sigma_1 = 107 \, \mu m \]

Strips 1U

\[ \sigma_{\text{residual}} = 132 \, \mu m \]
\[ \sigma_1 = 101 \, \mu m \]

Strips 1V

\[ \sigma_{\text{residual}} = 145 \, \mu m \]
\[ \sigma_1 = 108 \, \mu m \]

Pixels 1X

\[ \sigma_{\text{residual}} = 96 \, \mu m \]
\[ \sigma_1 = 71 \, \mu m \]

Pixels 1Y

\[ \sigma_{\text{residual}} = 100 \, \mu m \]
\[ \sigma_1 = 74 \, \mu m \]

Pixels 1U

\[ \sigma_{\text{residual}} = 2483 \, \mu m \]
\[ \sigma_1 = 105 \, \mu m \]

Pixels 1V

\[ \sigma_{\text{residual}} = 123 \, \mu m \]
\[ \sigma_1 = 123 \, \mu m \]
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Station 2

PixelMM spatial residuals vs position at high hadron flux

Very preliminary
Pixel MM spatial residuals at high hadron flux

Station 3

**Strips 3X**

\[ \sigma_{\text{residual}} = 214 \, \mu m \]
\[ \sigma_1 = 188 \, \mu m \]

**Strips 3Y**

\[ \sigma_{\text{residual}} = 126 \, \mu m \]
\[ \sigma_1 = 92 \, \mu m \]

**Strips 3U**

\[ \sigma_{\text{residual}} = 11060 \, \mu m \]
\[ \sigma_1 = 205 \, \mu m \]

**Strips 3V**

\[ \sigma_{\text{residual}} = 146 \, \mu m \]
\[ \sigma_1 = 118 \, \mu m \]

**Pixels 3X**

\[ \sigma_{\text{residual}} = 185 \, \mu m \]
\[ \sigma_1 = 35 \, \mu m \]

**Pixels 3Y**

\[ \sigma_{\text{residual}} = 94 \, \mu m \]
\[ \sigma_1 = 63 \, \mu m \]

**Pixels 3U**

\[ \sigma_{\text{residual}} = 157 \, \mu m \]
\[ \sigma_1 = 115 \, \mu m \]

**Pixels 3V**

\[ \sigma_{\text{residual}} = 131 \, \mu m \]
\[ \sigma_1 = 101 \, \mu m \]

Very preliminary
PixelMM spatial residuals vs position at high hadron flux

Station 3

Very preliminary
Conclusions

New COMPASS detectors installed and working
- Good performances: efficiencies and spatial resolutions
- Preliminary results, further works to be done to complete them
- No result on time resolution yet for 2015 run, require more calibration work

Hybrid Micromegas+GEM detectors proven to be very promising concept
- Discharge rate strongly decreased at high intensity hadron beam, without efficiency loss
- Performance as good as or better than old classic Micromegas

Buried resistor MM boards promising but further studies required
- Complicated structure, R&D necessary for serial production of such boards
- Good efficiency and spatial resolution, but bad time resolution, origin not understood