Update on Small-Pad Micromegas rate capability as a function of irradiated area

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Small PAD resistive MICROMEGAS prototypes

Two classes of prototypes: Pad-Patterned (PAD-P) and uniform layer DLC (two techniques: standard and Sequential Build Up produced with copper clad DLC)

Pad readout electrodes

768 readout Pad matrix on 4.8x4.8 cm$^2$ active area.

Customized sparks suppression resistive layout


DLC type and its latter version SBU (SCHEME 2)

Brief recap:

- [https://indico.cern.ch/event/843711/contributions/3591285/attachments/1930604/3197497/Camerlingo_22_10_2019_RD51.pdf](https://indico.cern.ch/event/843711/contributions/3591285/attachments/1930604/3197497/Camerlingo_22_10_2019_RD51.pdf)
  - Compared results between the small-PAD resistive Micromegas prototypes with PAD-P spark suppression layer and DLC spark suppression layer in term of rate capability up to 120 MHz/cm²;
  - Preliminary results on the Exposure area dependence (Areas < 4 cm²);
  - Summary of advantages of each spark suppression layer (Back-up);

- **Today**
  - Scan in amplification voltage (different gain factors)
  - Continuation of studies on exposure area dependence (Areas > 4 cm² and lower rate range < 30 MHz/cm²);
  - Updates on the test campaign of the detectors @PSI (Full areas and < 200 kHz/cm²)
SCAN in Amplification voltage (< 0.5 MHz/cm² rate range)

Gain measurement in RD51 LAB: with $^{55}\text{Fe}$ and Xray(Cu target) sources and 0.79 cm² exposed area, (93:7)%Ar:CO$_2$;

- To set the working amplification voltages for which the detectors have the same gain at low rates;

The ohmic voltage drops on the resistive layers are negligible in this range while the charging-up effects are already visible in PAD-P prototype.

PAD-P require an ampl. voltage + (20-30) V respect to DLC20-6mm (effect of several contributions not completely quantified)
SCAN in Amplification voltage (rate range of interest)

Gain measurement in RD51 LAB: Xray(Cu target) sources and 0.79 cm$^2$ exposed area, (93:7)%Ar:CO$_2$;

PAD-P: Charging-up effect is more severe for increasing rate/cm$^2$ (rel drop ~16% from 1 MHz/cm$^2$ to 10 MHz/cm$^2$ at 530 V). The ohmic voltage drop for the individual pads still negligible in this range, too.

DLC-20: The ohmic voltage drop on the resistive DLC plane is significant in this range (rel drop ~12% from 1 MHz/cm$^2$ to 10 MHz/cm$^2$ at 510 V).
Dependence on the exposed area: PAD-P (updated)

Previous investigated areas

New studies

New studies confirm that PAD-P gain is independent on the exposed area.
Exposure area dependence: DLC20-6mm (updated)

DLC series: DLC50 and DLC20 have two different vias pitches in the active area

As already observed in DLC50 for \{0.071, 0.79, 3.61\} cm² areas and also in DLC20, the voltage drop depends on the exposed area for area < 3.6 cm² (10 times the area defined by the grounding vias pitches);

New studies: the gain drops in DLC20-6mm do not scale for areas > 3.6 cm² square. It is comparable for 3.69 cm² and 9 cm² areas.
SBU2 and DLC20 were almost at same distance from the beam focus and irradiated with comparable incident rate.

Estimated from the current acquired from the mesh

Also the gain measurements with pions confirmed the previous results with 55Fe/X-rays.

(93:7)%Ar:CO₂

129.6 kHz/cm²
126 kHz/cm²
108.4 kHz/cm²
104.7 kHz/cm²

Gain

Amplification voltage (V)

11/02/2020
DLC-series: Spark events

A second DLC series (SBU) was realized to improve the robustness of DLC to suppress sparks. Therefore, a part of the test beam was dedicated to DLC spark studies.

Three examples (acquired setting the max investigated gain for each detector):

- **DLC20** has both DLC foils with ~20 MOhm/sq;
- **SBU internal DLC**: 30 MOhm/sq;
- **SBU External DLC** is only 5 MOhm/sq (possible cause of instabilities);

DLC20 is more stable than SBU (contrary to our SBU construction goals).

**REMINDER:**
- **SBU1 505 V**
  - G = 8.7 k
  - R = 108.4 kHz/cm²

- **SBU2 495 HV**
  - G = 6.3 k
  - R = 129.6 kHz/cm²

### Sample Data

<table>
<thead>
<tr>
<th>Detector</th>
<th>Gain (k)</th>
<th>Resistance (kHz/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBU1 505 V</td>
<td>8.7</td>
<td>108.4</td>
</tr>
<tr>
<td>SBU2 495 HV</td>
<td>6.3</td>
<td>129.6</td>
</tr>
</tbody>
</table>
DLC: discharge counting (preliminary)

Sparks rate was evaluated for each voltage change and in different time intervals.

Spark criterium (preliminary): >30% increase of instantaneous current;

<table>
<thead>
<tr>
<th>500 V (G~7.5k)</th>
<th>Inc rate (kHz/cm²)</th>
<th>sparks/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLC20</td>
<td>126</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>SBU1</td>
<td>108.4</td>
<td>~ 0.07</td>
</tr>
<tr>
<td>SBU2 (495 V)</td>
<td>129.6</td>
<td>&gt; 0.1</td>
</tr>
</tbody>
</table>

DLC20 is the most robust among the DLC series, despite to the constructive improvement of SBUs.
PADP: discharge counting (preliminary)

G = 8.8 k
R = 104.7 kHz/cm²

Inc rate (kHz/cm²) sparks/s

<table>
<thead>
<tr>
<th>Voltage (V)</th>
<th>Inc Rate (kHz/cm²)</th>
<th>Sparks/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>527 V (G~ 7.5k)</td>
<td>104.7</td>
<td>&lt; 0.02</td>
</tr>
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</table>

PAD-P confirmed to be the most robust prototype

Same criterion of the spark counting
Conclusions

All the prototypes (PADP and DLC series) show a < 10% gain drop:

- **PAD-P**: in the interest range (1 MHz/cm²; 10 MHz/cm²) for all the investigated cases;
- **DLC20**: in the interest range (1 MHz/cm²; 10 MHz/cm²) for the area 0.79 cm² and ampl. voltage < 520 V. Other cases the range stops at 7-8 MHz/cm² (STILL ACCEPTABLE);

• We investigated the dependence on the exposed area up to 50 MHz/cm²:

  - **PAD-P**: PAD-P gain is not affected by the dimension of the exposed area thanks to its segmented layout;
  - **DLC20-6mm**: the voltage drops do not increase when the exposed area is larger than a threshold area;

• Current-time trends and discharge studies (confirming the observations in lab):
  - **DLC** and **DLC-SBU** prototypes show some instabilities with moderate discharges up to a gain of about 6000.
  - **PAD-P** is VERY STABLE and show no-sparks up to a gain above 10000.
Thank you for the attention
Back-up
Current trend in full time window
Relative Gain

Direct info on voltage drop and rate capability; (threshold value on deviation from the low rate value: 10%)

\[
\begin{align*}
\text{DLC50 } G_0 &= (6.07 \pm 0.10) \times 10^3 \\
\text{DLC20 } G_0 &= (6.95 \pm 0.08) \times 10^3 \\
\text{SBU2 } G_0 &= (6.12 \pm 0.04) \times 10^3 \\
\text{PADP } G_0 &= (5.05 \pm 0.16) \times 10^3
\end{align*}
\]

Area: 0.79 cm\(^2\)
Summary on **PAD-P scheme (1):**

Good **rate capability** at rate higher than 10 MHz cm\(^{-2}\), **current/cm\(^2\) vs rate** independent from area, discrete **spatial resolution** on the precision coordinate, low **energy resolution** and **currents as function of time** affected by charging-up effects.

![Graph](attachment:image.png)

**55Fe spectrum**

- **Entries** = 25083
- **Mean** = 0.015 ± 0.001
- **Std Dev** = 0.211 ± 0.001
- **Constant** = 2563.058 ± 20.660
- **Sigma** = 0.190 ± 0.001

**FWHM Peak** = 48%

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8 keV (Cu target) Xrays
Good rate capability up to-10 MHz cm\(^{-2}\), mesh current does not scale linearly with the spot size, better spatial resolution on precision coordinate, better energy resolution and no (or very little) charging up in currents as function of time.
Proton beam current on target
In exit of the target: positive pion with 300 MeV/c as max momentum (and 7% of proton contamination) in continuum
Fig 3 gives the measured particle fluxes for the standard beam-line tune as a function of momentum with an uncertainty of 10\% at the peak of the yield curves. The flux of muons is 100 times smaller than the corresponding pion flux at momenta around 300 MeV/c, and falls more slowly than for the pions toward low momenta. Since πM1 is the only beam line with a vacuum system separated from the proton-channel vacuum by a thin window, there are no “surface” muons available.

<table>
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<th>Table 1: Characteristics of the πM1 beam line</th>
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<td>Momentum range</td>
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<td>Solide angle</td>
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<td>Momentum acceptance (FWHM)</td>
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<td>Momentum resolution</td>
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<td>Dispersion at focal plane</td>
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<td>Spot size on target (FWHM)</td>
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<td></td>
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<tr>
<td>Angular Divergence on target (FWHM)</td>
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