Quality validation on Mecaro GEM foils and CMS GE2/1 foils production plans

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1 Overall Info. about GEM foil production @ Mecaro

- KCMS & Mecaro consortium have been created to be a second supplier of large size GEM foils for the phase-2 upgrade of CMS.
  - Three batches of test production of CMS GE1/1 foils for quality validation.
  - One batches of test production of CMS GE2/1 M7 foils for quality validation.

- The validations show promising results.
  - Hole geometry & uniformity, gain & gain uniformity, rate capability, discharge prob. and radiation hardness were measured with Mecaro foils.
  - After validation is finished, mass production of CMS GE2/1 foils will be started.
1 Overall Info. about GEM foil production @ Mecaro

• Mecaro produces GEM foils with double mask technique.
  - Thanks to the double mask technique and automated machines, production rate is fast~10 foils/week.
  - Residual misalignment < 3 μm
  - Foil up to 1300 mm × 610 mm (machine size 1379mm × 813mm) is producible.

• Standard geometry: diameter of Cu (PI) hole=70 (50) μm, pitch= 140 μm
  - Symmetrically biconical hole.
Three stations of GEM detectors will be installed to maintain L1 muon trigger performance after HL-LHC.

- GE1/1: assembly almost done. will be installed during LS2
- GE2/1: assembly scheduled to be done before 2022. will be installed during LS3.
- ME0: assembly scheduled to be done before 2024. will be installed during LS3.
2 CMS GEM upgrade plan – GE1/1, GE2/1, ME0

- Mecaro foils will be used to build GE2/1 and ME0.
  - M2, M3, M6, and M7 of GE2/1.

- Mecaro foil quality validation is ongoing with GE1/1.
  - The larger foils, the harder to be produced.
  - If Mecaro shows capability to produce GE1/1 well, we can think Mecaro can produce GE2/1 and ME0 also.
3 Quality validation with CMS GE1/1

- PI hole diameter: \(49.04 \pm 0.79 \mu m\),
- Cu hole diameter: \(70.24 \pm 0.91 \mu m\).
- Well calibrated manual microscope. 450 holes

- Hole uniformity with automatic CCD scanner by Matt Posik, Temple Univ.
- Not so well calibrated.

Private communication, Matt Posik, Temple Univ.

Cross section of Mecaro GE1/1 foil

Calibration wasn’t correctly done. 1.2 times over measured.
3 Quality validation with CMS GE1/1

- Cleanliness of foils: “CMS QC2-Long”
  - Impedance > 120 GΩ @ 600 V, RH<7% for 6 h wo/ sparks.
  - Mecaro foils are clean enough to pass the QC2-Long now.

- Actually, we had issue on foil cleaning at first.
  - Foil became short or sparked.
  - After we updated cleaning solution, the issue has been resolved.

- Then, chamber with Mecaro foils has been assembled.
  - Gain, gain uniformity, rate capability, radiation hardness and discharge Prob.
  - Results are quite promising.
3 Quality validation with CMS GE1/1

• Gain: $2 - 5 \times 10^4$ at 700 $\mu$A (operating voltage), gain variance: 10.2-16.2 %
  - Consistent with the results of the detectors with CERN foils.
3 Quality validation with CMS GE1/1

- Gain remains stable x-ray flux up to $1 \times 10^5 Hz/mm^2$.
  - Enough capability for the phase-2 upgrade.
  - Gain drops at very high flux because of voltage drop at protection resistor.

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**GE1/1-X-S-KOREA-0003**

- Double-mask
- Protection resistance = 10 MΩ
- Gap configuration 3/1/2/1 mm
- Gas mixture = Ar/CO₂ (70/30)
- X-ray target: Ag, X-ray $V_{\text{mon}} = 30$ kV
- Initial gas gain = $3.2 \times 10^4$

![Graph showing the relationship between X-ray Flux and Normalized Gas Gain. The expected maximum hit flux at ME0 is indicated.](image)
3 Quality validation with CMS GE1/1

- No gain degradation due to aging is observed up to $34 \text{ mC/cm}^2$.
  - It corresponds to 113 years of GE2/1 and 1.2 years ME0 operation at HL-LHC.
  - CMS requires 30 years. So far, so good.
3 Quality validation with CMS GE1/1

- Probability of discharge induced by $\alpha$ from $^{241}Am$.
  - Special chamber with holes to let $\alpha$ enter detector.
  - Promising result has been obtained.

![Signal shape of discharge induced by $\alpha$](image1)

![Discharge Prob. Vs. Gain, 5.5 MeV $\alpha$](image2)

*Not approved yet*
4 CMS GE2/1 M7 production and QC results

- As validation is being proceeded well, Mecaro is considered to be capable of producing GE2/1 foils.

- GE2/1 M7 foils has been produced and delivered on 23th, Oct. 2018.
  - Cleanliness test (QC2-Long); foils have passed QC2-Long smoothly.
  - Several hole diameter measured; diameters of PI holes were measured to be slightly smaller.
  ⇒ PI etchant and etching processes will be reviewed.
  - Due to delayed production of RO, chamber assembly hasn’t been done yet.
5 Further production plans

- Test production of CMS GE2/1 M2, M3, M6 will be done until Feb.
  - Full CMS GE2/1 assembly and final validation should be done by Mar. 2019.

- Mass production
  - After test production for validation over, mass production should be started immediately.
  - First 24 pieces of each four modules should be delivered until Aug., 2019.
  - In total, 114 pieces of each four modules will be produced to build 38 CMS GE2/1 detectors (=36+1(test bench)+1(spare)).
  - After GE2/1 production over, ME0 production will be started.

- Mecaro is being ready for mass production.
6 Summary

• Mecaro produces large size GEM foils for CMS phase-2 upgrade.

• Quality validation is ongoing with CMS GE1/1 chamber.
  - Promising results were obtained.

• Mecaro produced CMS GE2/1 M7 foils for validation.
  - Foils has passed QC2-Long smoothly.
  - Other modules will be produced until Feb. 2019.

• Mass production for GE2/1 assembly will start from Mar. 2019.
  - 114 foils of each four modules will be produced by Mecaro.
Back up
## 1 Overall Info. about GEM foil production @ Mecaro

<table>
<thead>
<tr>
<th></th>
<th>Single mask</th>
<th>Double mask</th>
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</thead>
<tbody>
<tr>
<td><strong>Production method</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mask alignment</strong></td>
<td>No need (film)</td>
<td>Crucial (glass)</td>
</tr>
<tr>
<td><strong>Cost of necessary machines</strong></td>
<td>Cheep</td>
<td>Expensive</td>
</tr>
<tr>
<td><strong>Foil size</strong></td>
<td>No limit</td>
<td>Limited by machine</td>
</tr>
<tr>
<td><strong>Production process</strong></td>
<td>Complicated</td>
<td>Simple</td>
</tr>
<tr>
<td><strong>Production time</strong></td>
<td>Long</td>
<td>Short</td>
</tr>
<tr>
<td><strong>Labor cost</strong></td>
<td>Expensive</td>
<td>Cheep</td>
</tr>
<tr>
<td><strong>Robustness to FCCL quality</strong></td>
<td>Vulnerable</td>
<td>Robust</td>
</tr>
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