

Results of QC of large size GEM detector based on Korean GEM foil for future upgrades of the CMS muon system



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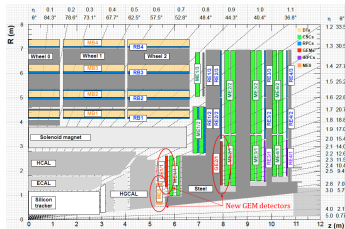
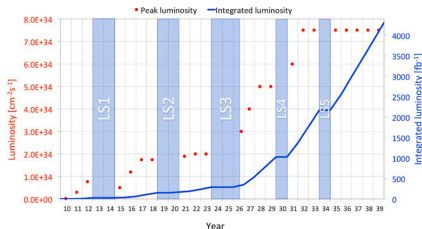
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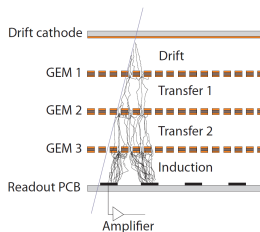
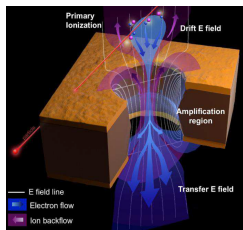


The CMS Phase-II muon detector upgrade



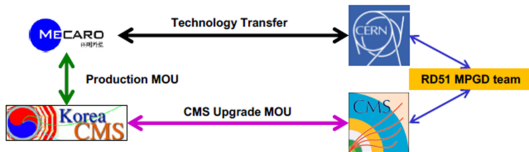
- As luminosity upgrade of LHC is scheduled, detector capability should be upgraded to maintain trigger performances.
- Detectors based on GEM technology, GE1/1, GE2/1, and ME0, are planned to be installed.
 - TDR of CMS Phase-II muon detector upgrade [for detail](#).

GEM detector technology





- Avalanche occurs at micro holes which are filled with high density electric fields.
- Why GEM technology is chosen for the CMS Phase-II upgrade?
 - High rate capability.
 - Hardness to radiation.
 - Thin.


KCMS & Mecaro consortium




- KCMS has made the consortium with Mecaro to produce large size GEM foil since 2012.
 - The current supply of GEM foil can't satisfy the demand.
 - To be a second supplier for the CMS Phase-II upgrade.
- Mecaro produces GEM foil with double-mask technique.
 - Inner(outer) hole diameter = 50(70) μm , pitch = 140 μm .
 - Production rate: 10 foils/week.
 - Maximum producible foil size: 1300mm \times 610mm.

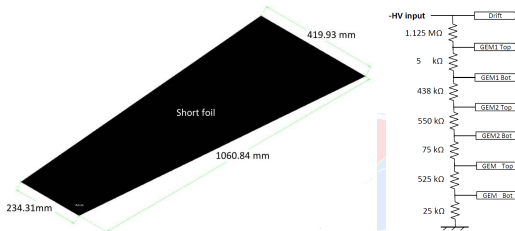
Single-mask & double-mask comparison

	Single-mask	Double-mask
Production process		
Production speed	Slow	Fast
Necessity of mask alignment	No (film)	Crucial (glass)
Cost of necessary machines	Cheap	Expensive
Hole shape	Asymmetric	Symmetric


- Mecaro alignment capability: residual misalignment $< 3\mu\text{m}$.
- Inkyu's talk  for the detail of GEM foil production at Mecaro.

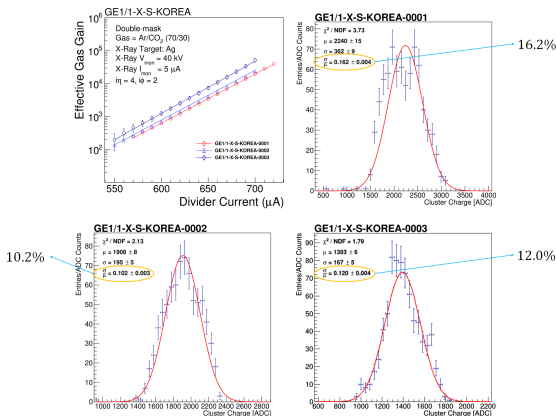
Foil quality validation with CMS GE1/1 detector

- To validate the quality of Mecaro foils, three CMS GE1/1 detectors  are assembled with Mecaro foils.
- Triple GEM detector with mechanical foil stretching. Single line HV with voltage divider.
- Validation of cleaning capability of Mecaro is still ongoing.
 - For proper operation, Mecaro foils should be cleaned again at CERN.
- Once cleaned again, Mecaro foils work well.



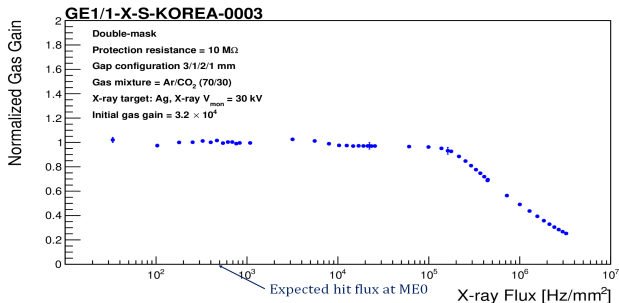
Gain and its uniformity

- Gain: $2 - 5 \times 10^4$ at $700\mu A$, gain variance: 10.2 – 16.2%
 - Consistent with the results of the detectors based CERN foils .




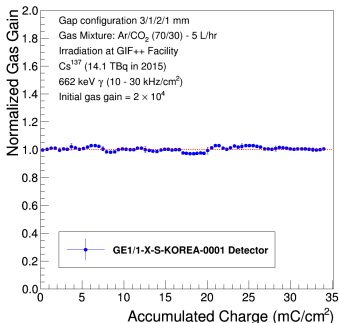
Rate capability

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



Radiation hardness

- No gain degradation due to aging is observed up to $34\text{mC}/\text{cm}^2$.
 - It corresponds to 113 years of GE2/1 and 1.2 years of ME0 detector operation at HL-LHC.
- Yonghoon's poster  for detail.



Conclusion & Summary

- KCMS & Mecaro consortium produces large size GEM foil with double-mask technique for the CMS Phase-II muon detector upgrade.
- Foil quality validation is ongoing by assembling CMS GE1/1 detectors and measuring properties.
- Once foils are cleaned again at CERN, Mecaro foils work fine in terms of gain, gain uniformity, rate capability and radiation hardness.
- Foil cleaning capability of Mecaro is being reviewed now.
- KCMS & Mecaro consortium will contribute to not only the CMS Phase-II muon upgrade but also other experiments by supplying the large size GEM foils.

