



GE21 Foil Production and Quality Control

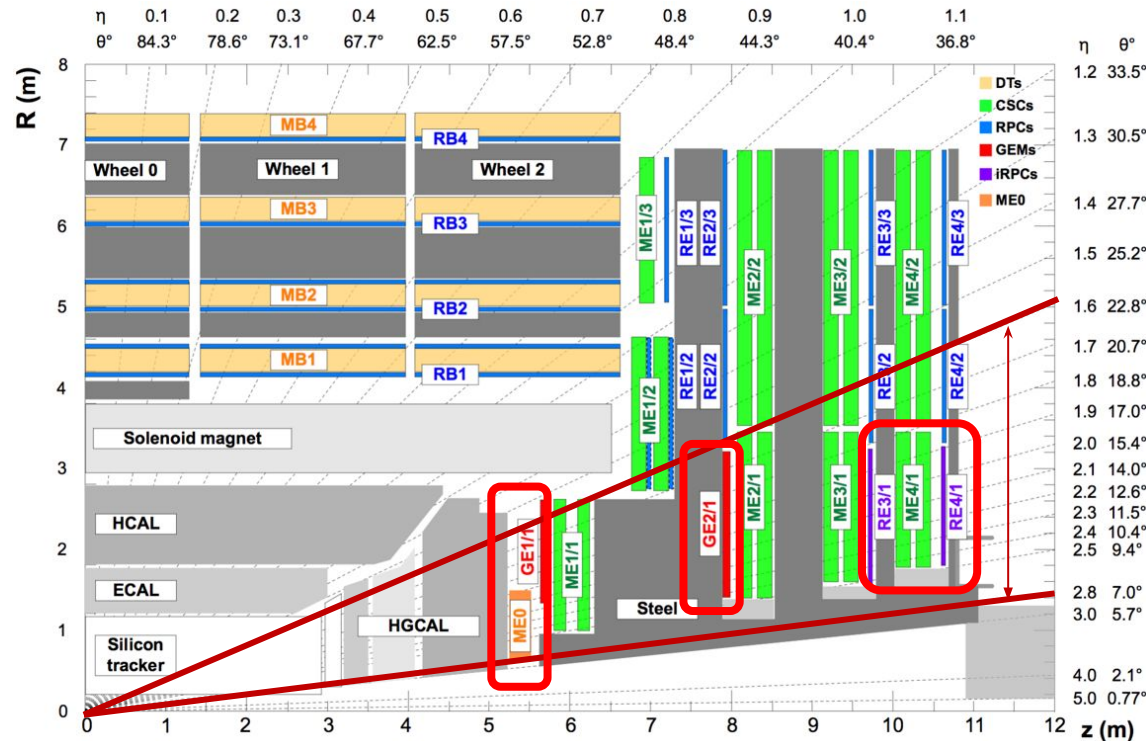
2022 CPLUOS detector mini-workshop, May 13

Prof. Inkyu Park

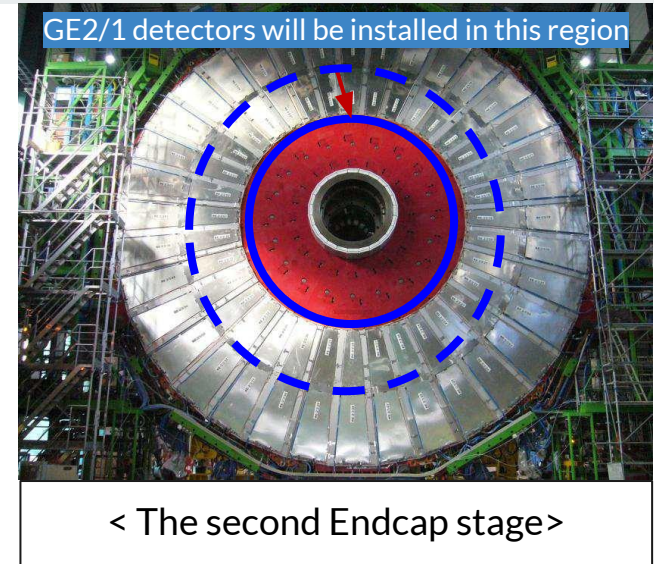
Natural Science Research Institute, University of Seoul

Presenting on behalf of the Korea-CMS

CMS Muon Detector Upgrade in Phase 2

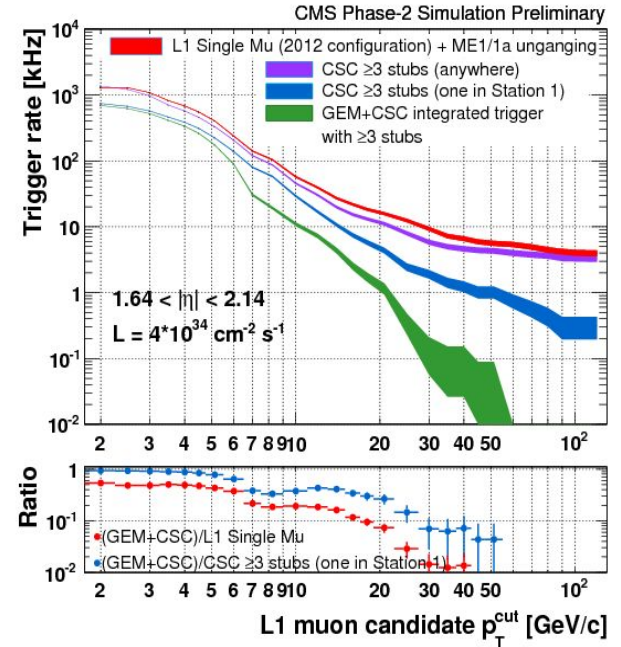
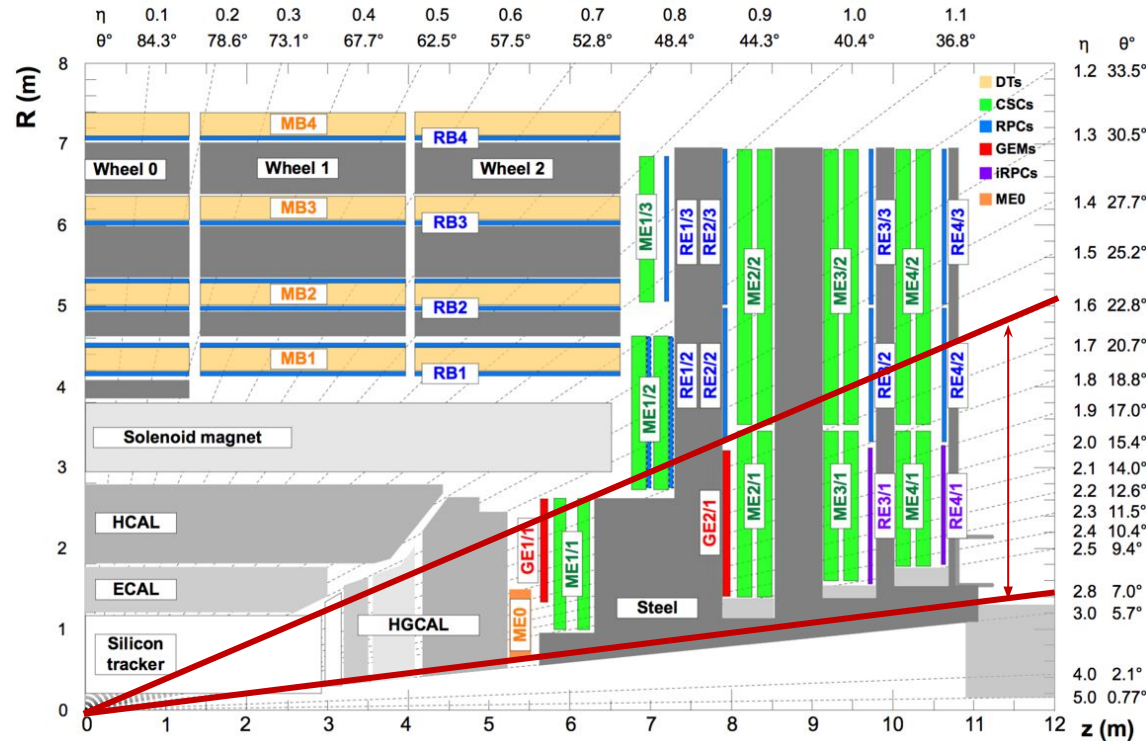


G(Detector) E(Endcap) 2(Stage 1~4) 1(Ring 1~3)



The muon detector upgrade will preserve and enhance the performance of the CMS muon system in the **Forward and High eta** (1.6~2.8) region by installing new forward muon detectors such as GEM (ME0, GE1/1, GE2/1) and iRPC (RE3/1, RE4/1) in the Phase 2.

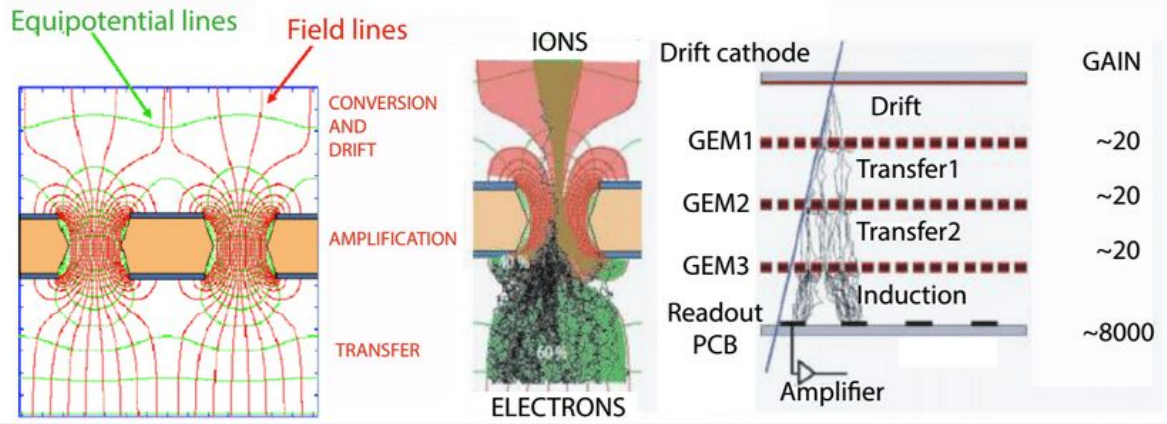
CMS Muon Detector Upgrade in Phase 2



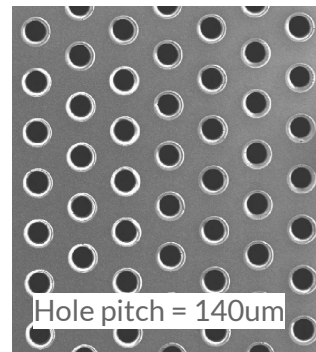
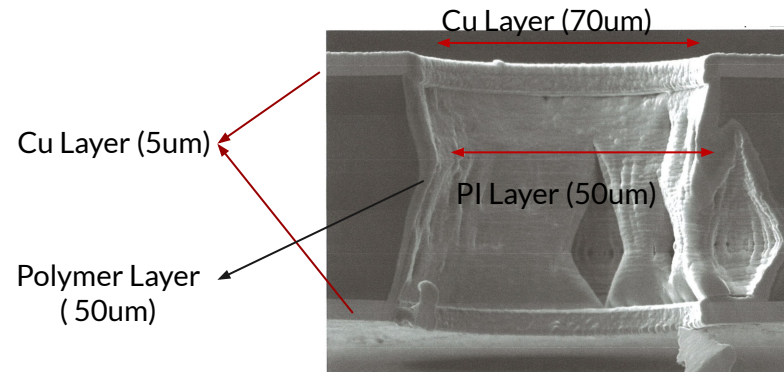
L1 muon trigger rate at a luminosity of $4 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ as a function of p_T cut. Adding a GEM detector greatly reduces the trigger rate in the low P_T cut.

<https://cds.cern.ch/record/2714892/files/CMS-TDR-021.pdf>

CMS GE2/1 GEM Detector

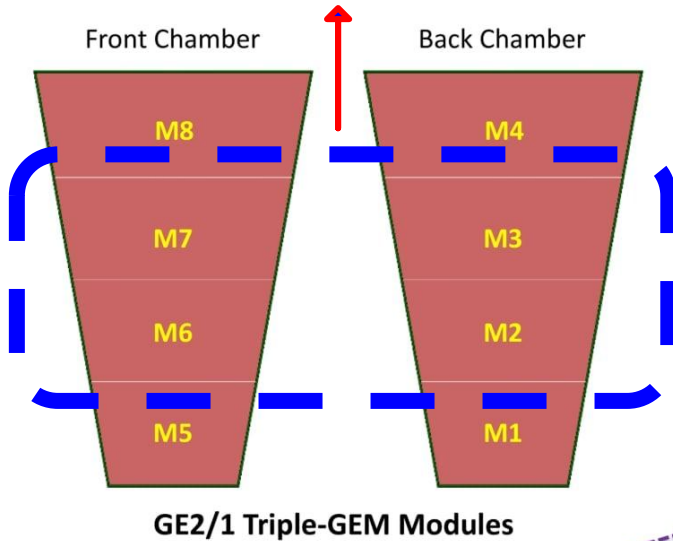


- The CMS GEM detector consisting of three foils with 3/1/2/1 mm gaps . (GEM1, GEM2, and GEM3)
- This triple layer structure can expect a Gain amplified by about 8,000 times.
- Ions that are sufficiently accelerated in the drift section pass through the foil holes where the strong electric field, producing a large number of electrons by the avalanche effect.

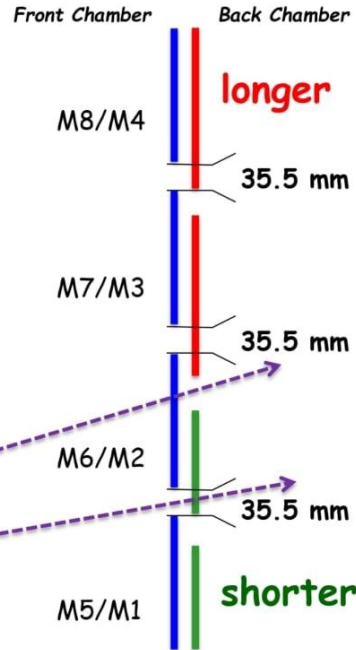


CMS GE2/1 GEM Detector

Produce by Mecaro company



GE2/1 Superchamber



I.P.

- The GE2/1 station consists of 36 Superchamber.
- One Superchamber combined with Front & Back Chambers.
- The chambers consist of eight different modules type. (M1 ~ M8)
- The GE2/1 will be installing in the back of first disk (YE1).
- It will be installed to cover the High eta region $1.6 < |h| < 2.4$.
- 20 degrees wide.



Brief History of GEM project

Brief History of GEM project



< MOU signing ceremony on April 15.2019 >



Brief History of GEM project

Memorandum of Understanding (MoU) for Korea-CMS Contributions to the Phase-2 GEM Detector Upgrades

Considering that:

- The CMS Collaboration (CMS in the following) has prepared and presented the **Phase-2 Upgrade of the CMS Muon Detectors - Technical Design Report** (cf. CERN-LHCC-2017-012).
- CMS has submitted a Technical Design report for the Phase-2 Upgrade of the Muon System with GEM Detectors and the CMS TDR 2017-16 has been approved.
- The CMS Korea Institutes (hereinafter referred to as KCMS) have been participating in the construction of GEM chambers at CERN for the Muon GEM upgrade.

It is agreed that:

- KCMS shall provide GEM foils for GE2/1 chamber construction as below:
 - 114 volume production foils for each GE2/1 M2, M3, M6, and M7 modules. This volume production shall be considered as an in-kind contribution of 839.0 kCHF (= 1.84 kCHF/foil x 114 foils x 4 types)
 - One pair of GE2/1 photolithography masks for each GE2/1 M2, M3, M6, and M7 modules. This will be considered as an in-kind contribution of 158.4 kCHF (= 39.6 kCHF/pair x 4 types).
- KCMS shall produce GEM foils for ME0 chamber construction as below:
 - 666 foils for ME0. This will be considered as an in-kind contribution of 1'225.4 kCHF (= 1.84 kCHF/foils x 666 foils)
 - One pair of ME0 photolithography masks. This will be considered as an in-kind contribution of 39.6 kCHF.
- Therefore, the total contribution from KCMS to Phase-2 GEM Detector Upgrades shall be recognized as 2'262.4 kCHF (whereas the original KCMS TDR commitment is 1'066 kCHF).
- It is understood that the technical specifications and technology transfer of GEM foils has been already communicated via document (Agreement KR2148 /KT/TE/144L)
- The CMS GEM Project Manager will be responsible for providing the infrastructure and the facilities necessary to assemble and test the chambers at the 904 site and subsequent installation in CMS.

❖ Considering that:

The CMS Collaboration (CMS in the following) has prepared and presented the Phase II Upgrade of the CMS Muon Detectors - Technical Design Report (cf. CERN-LHCC-2017-012).

CMS has submitted a Technical Design report for the **Phase-II Upgrade of the Muon System with GEM Detectors** and the CMS TDR 2017-16 has been approved.

The CMS Korea Institute (KCMS in the following) has been participating in the construction of GEM chambers at CERN for the Muon GEM upgrade.

Brief History of GEM project

Memorandum of Understanding (MoU) for Korea-CMS Contributions to the Phase-2 GEM Detector Upgrades

Considering that:

- The CMS Collaboration (CMS in the following) has prepared and presented the **Phase-2 Upgrade of the CMS Muon Detectors - Technical Design Report** (cf. CERN-LHCC-2017-012).
- CMS has submitted a Technical Design report for the Phase-2 Upgrade of the Muon System with GEM Detectors and the CMS TDR 2017-16 has been approved.
- The CMS Korea Institutes (hereinafter referred to as KCMS) have been participating in the construction of GEM chambers at CERN for the Muon GEM upgrade.

It is agreed that:

- KCMS shall provide GEM foils for GE2/1 chamber construction as below:
 - 114 volume production foils for each GE2/1 M2, M3, M6, and M7 modules. This volume production shall be considered as an in-kind contribution of 839.0 kCHF (= 1.84 kCHF/foil x 114 foils x 4 types)
 - One pair of GE2/1 photolithography masks for each GE2/1 M2, M3, M6, and M7 modules. This will be considered as an in-kind contribution of 158.4 kCHF (= 39.6 kCHF/pair x 4 types).
- KCMS shall produce GEM foils for ME0 chamber construction as below:
 - 666 foils for ME0. This will be considered as an in-kind contribution of 1'225.4 kCHF (= 1.84 kCHF/foils x 666 foils)
 - One pair of ME0 photolithography masks. This will be considered as an in-kind contribution of 39.6 kCHF.
- Therefore, the total contribution from KCMS to Phase-2 GEM Detector Upgrades shall be recognized as 2'262.4 kCHF (whereas the original KCMS TDR commitment is 1'066 kCHF).
- It is understood that the technical specifications and technology transfer of GEM foils has been already communicated via document (Agreement KR2148 /KT/TE/144L)
- The CMS GEM Project Manager will be responsible for providing the infrastructure and the facilities necessary to assemble and test the chambers at the 904 site and subsequent installation in CMS.

◆ It is agreed that:

KCMS shall provide GEM foils for GE21 chamber construction as below:
114 foils for each GE21 M2, M3, M6, M7 modules. This volume production shall be considered as an in-kind contribution of **839.0 kCHF** (= 1.84 kCHF/foil x 114 foils x 4 types), **1 pair of GE21 masks** for each GE21 M2, M3, M6, M7 modules. This will be considered as an in-kind contribution of **158.4 kCHF** (= 36.9 kCHF/pair x 4 types).

KCMS shall produce GEM foils for ME0 chamber construction as below:
666 foils for ME0. This will be considered as an in-kind contribution of **1225.4 kCHF** (= 1.84 kCHF/foils x 666 foils), **1 pair of ME0 masks.** This will be considered as an in-kind contribution of **39.6 kCHF.**

Thus, the total contributions from KCMS shall be valued at **2,262.4 kCHF.** This in-kind contribution will be specially recognized (or accounted) in contrast to the original KCMS's TDR commitment of **1,066 kCHF.**

It is understood that the technical specifications and technology transfer of GEM foils has been already communicated via document (Agreement KR2148 /KT/TE/144L)

The CMS GEM Project manager will be responsible for providing the infrastructure and the facilities necessary to assemble and test the chambers at the 904 site and subsequent installation in CMS.

The present Memorandum of Understanding should be considered as an extension to the original CMS Construction MoU and its upgrade amendments (RRB CMS-D 98-31) and it has the same conditions of applicability.

Brief History of GEM project

[회의록]

회의일시	2019. 9. 30. 월 16:00 - 18:00
회의장소	서울대 호암교수회관 메이플룸
참석자	서울대: 양운기 교수, 윤인석 박사, 한승주 실장 시립대: 박인규 교수, 박성호 수석, 정영근 팀장 메카로: 정태성 사장, 김근우 이사

3. 메카로 계약 관련

- 1) 총 물량 496장은 4회에 나눠 계약을 체결하고 납품한다.
 - ① 1회 31장 x 4회=124장
 - ② 단가: 1,935,483원(VAT 및 배송료 포함)
- 2) 총 124장은 2억 4천만 원(VAT 및 UPS 배송료 포함)에 계약하되, 수율이 높아지면 추가로 더 생산하고, 수율이 낮아지더라도 헤럴티는 없는 것으로 한다. 주후 계약에는 전년도의 수율을 고려하여 계약한다.
- 3) 초반 생산 물량을 적게 하고 점차 물량을 늘리는 방식으로 M2, M3, M6, M7을 각 10장씩 생산해서 우선 CERN에 배송하여 실제 적용해보는 방식으로 진행한다.
- 4) 첫째 생산 물량을 못 맞추더라도 4년에 걸쳐 총 생산 물량을 맞추는 방식으로 진행한다.
- 5) 최종 계약조건: 2019년도 계약을 체결하고, 2020년 납품하며, 선금금 50%를 먼저 지급한다.

◆ KCMS - MECARO contract for production

총 물량 496장 4회에 나눠 계약 체결

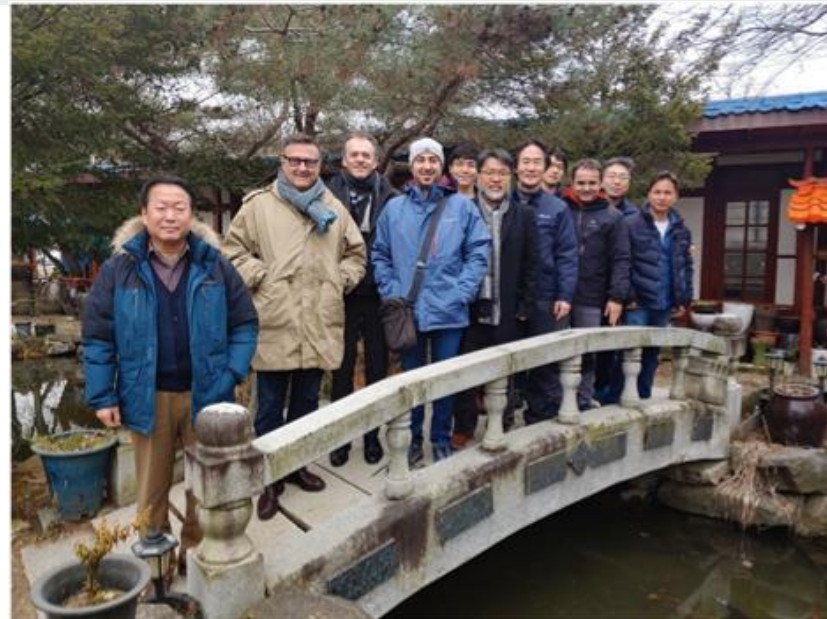
1회 31장씩 4회 생산하여 124장

M2, M3, M6, M7을 각 10장씩 생산하여 우선 CERN에 배송, 실제 적용해본다.

4년에 걸쳐 총 생산 물량을 맞춘다.

2019년 계약 체결, 2020년 납품, 선금금 50%를 먼저 지급

Brief History of GEM project



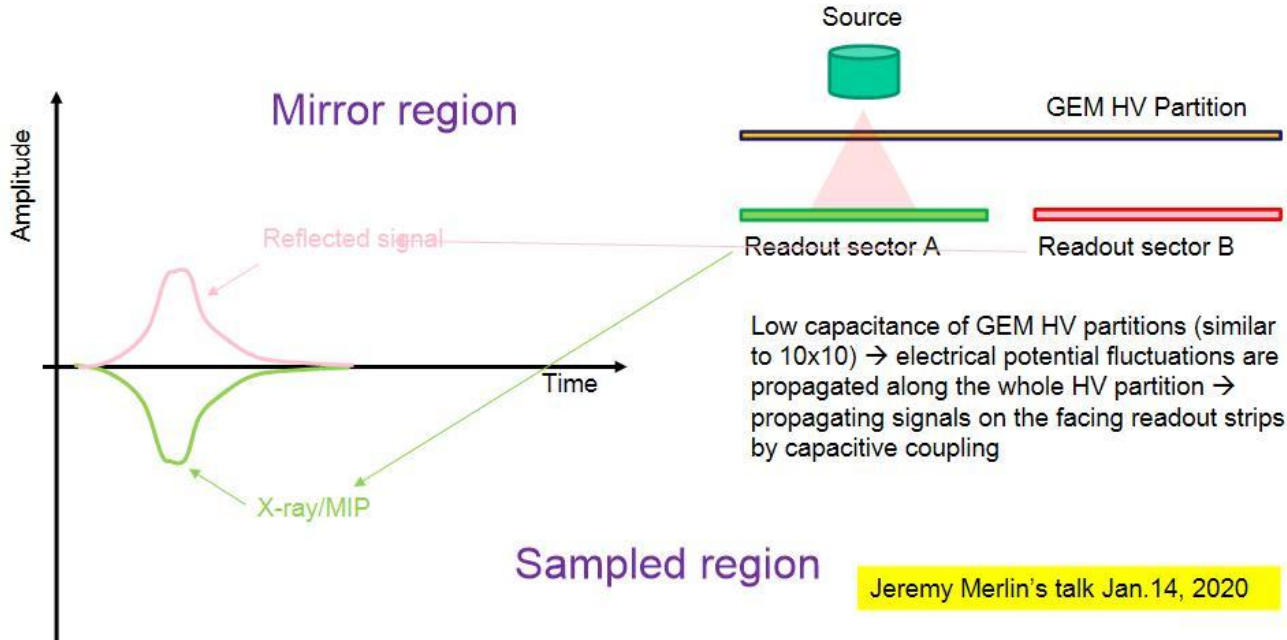
< MECARO Production line tour at 20~22 Jan.2020 >

Brief History of GEM project

- ❖ Double polarity issue

This problem was found Dec. 2019, reported in Jan. 2020

Redesigned the mask, and it decided on Dec.2020. -> Remade the masks for M2, M3, M6, M7.



https://indico.cern.ch/event/834058/contributions/3495290/attachments/1881377/3099966/Double_Segmented_GEM_foils_Report_FFallavollita_20190507.pdf

https://indico.cern.ch/event/875842/contributions/3690838/attachments/1973386/3283409/MBianco_Foils_Design_Status.pdf

Jeremy Merlin's talk Jan.14, 2020

Brief History of GEM project

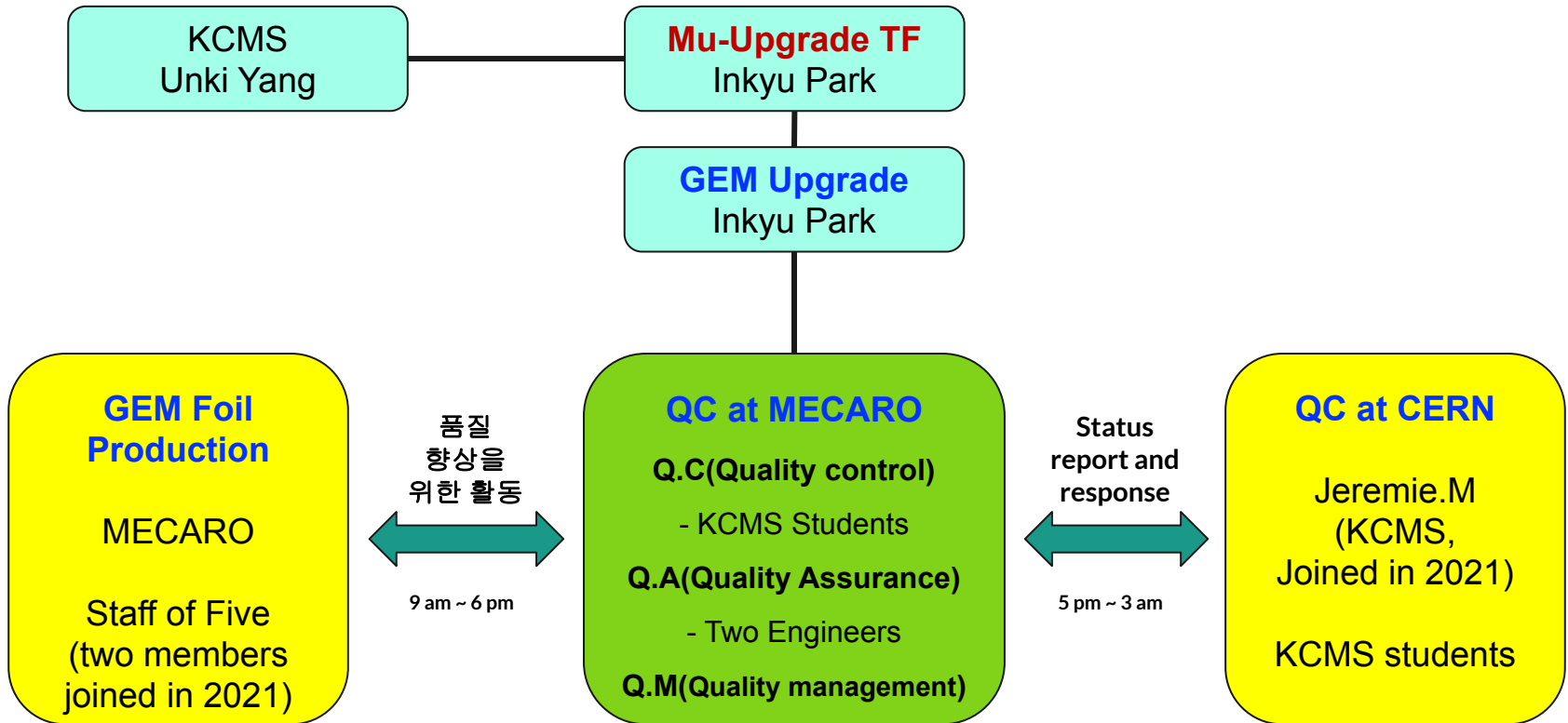
- ❖ M2 type foils production started at Feb.2021
- ❖ Sixty foils, including foils for aging chamber, were officially delivered in July





GE2/1 QC activity

GE2/1 KCMS QC activity



GE2/1 KCMS QC activity

◆ QC Activities @ MECARO

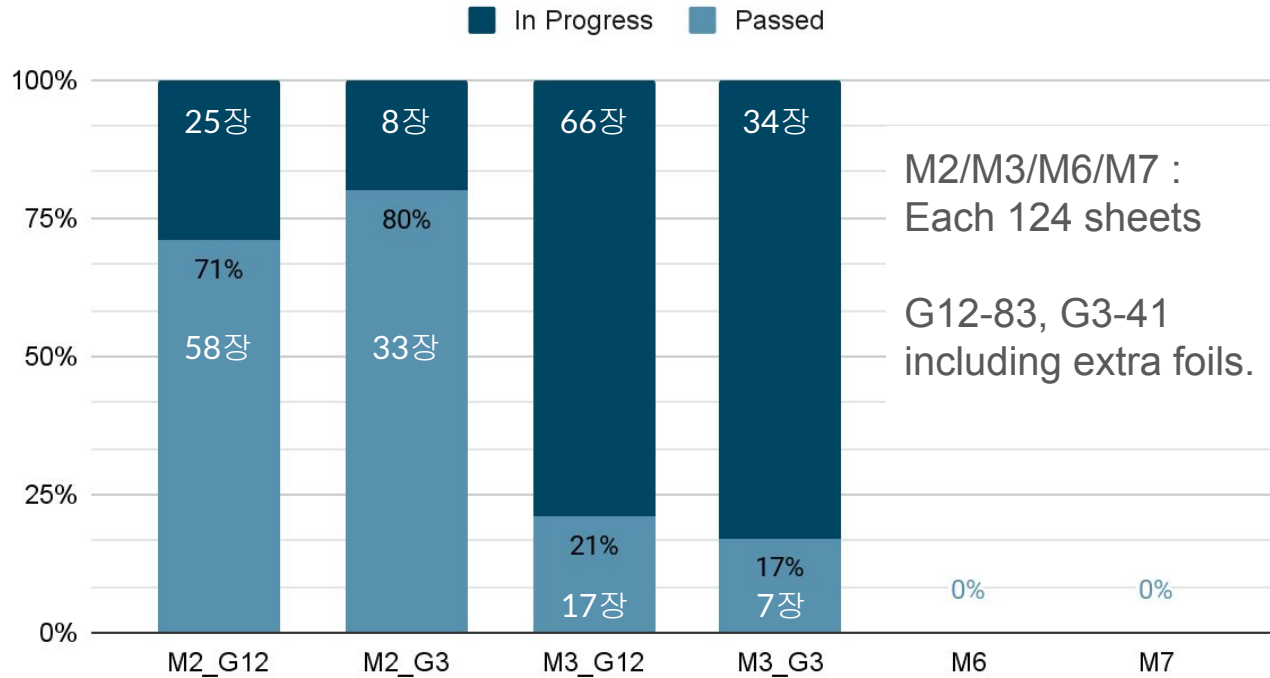
- Location : MECARO Eumseong Office
- Beginning date : March 2nd. 2021
- Total 30 weeks

- Manpower : 4 Universities, 12 graduate students
- Local Manager : 1 Researcher and 2 Engineers(UOS)
- **Five QC steps progress and Packing**
- 250 foils were tested, 115 foils were passed



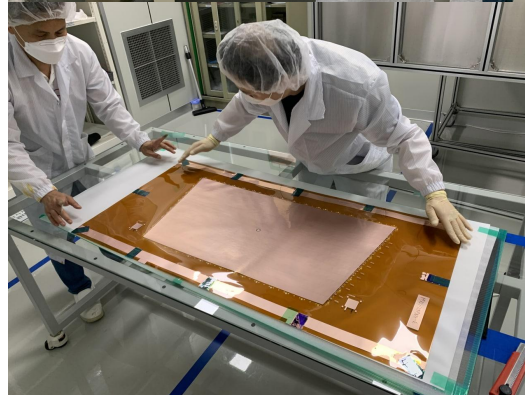
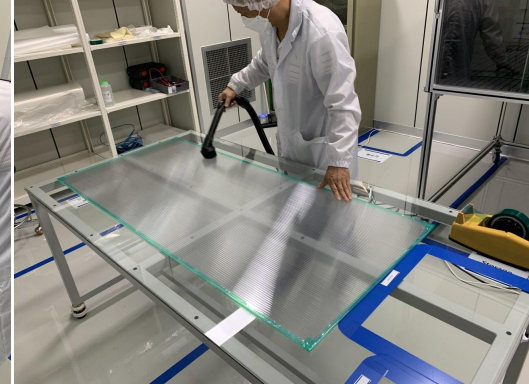
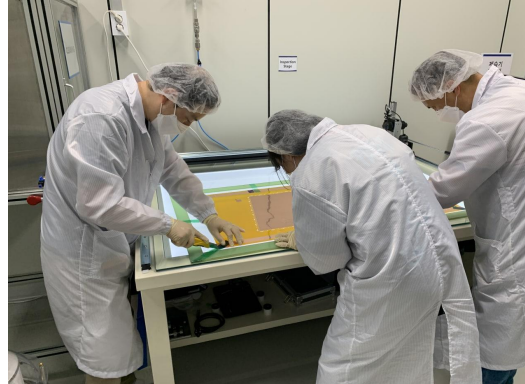
GE2/1 KCMS QC activity

CMS GEM GE2/1 Foils Production Status



GE2/1 KCMS QC activity

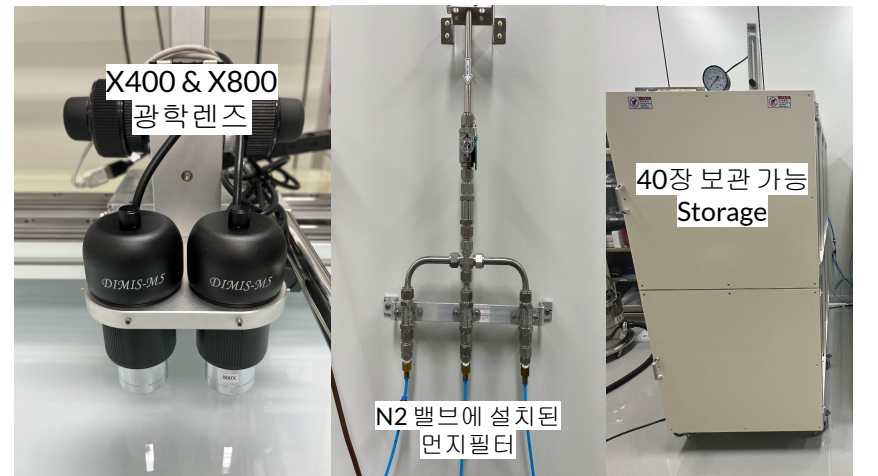
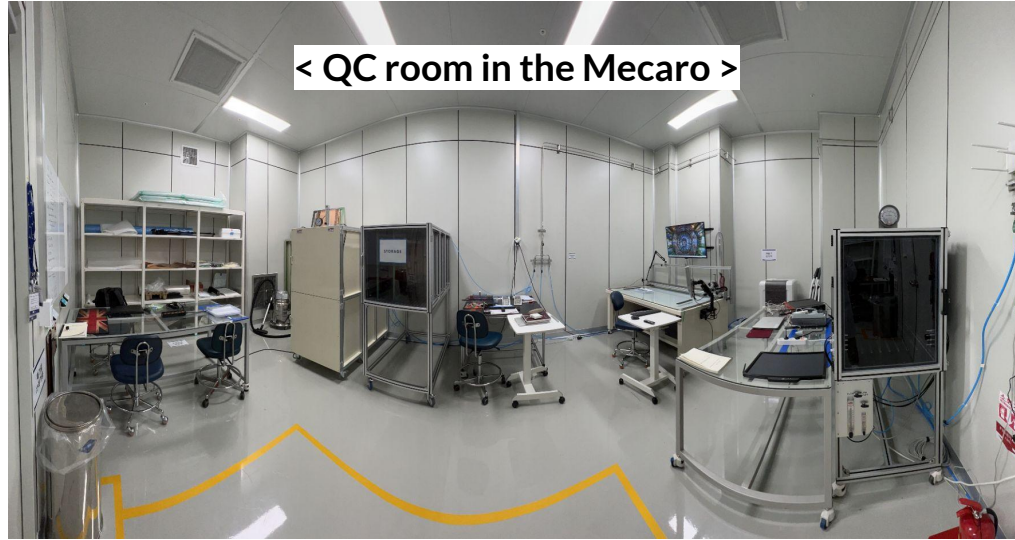
❖ Shipping equipment and parts | Packing



GE2/1 KCMS QC activity

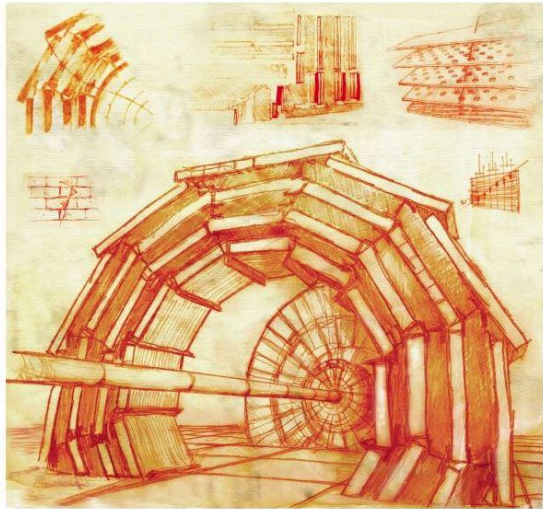
❖ Investment and upgrade of quality control facilities.

< QC room in the Mecaro >



< 참고로 사용 중이던 공간을 QC 공간으로 이용 중임. 온습도 조절 및 먼지 유입 방지를 위해 양압 유지 및 클린룸 운영. 원활한 QC 활동을 위해 설비에 대한 업그레이드 작업을 진행하였음. >

GE2/1 KCMS QC activity



LOT_2
CMS GEM GE2/1 M2 type Foils
QC2 Reports

Written by KCMS QC2 Members
Date May. 17. 2021

QC2 Status

KIM Seulgi & KANG Dayoung
University of Seoul

Seulgi & Dayoung

19th Aug 2021 ~

1

GEM Foils Produce at the MECARO Company



Overview

Mecaro company produces Four different types (M2, M3, M6, and M7) of foil and provide it to CMS-GEM group.



Type

Double Mask Method (CERN-Sing Mask Method)

Foil type : **G12** and **G3** of Double segments type

G12 : Drift side - 10 Mohm | Readout Board side - 100 Kohm

G3 : Drift side - 10 Mohm | Readout Board side - 0 ohm



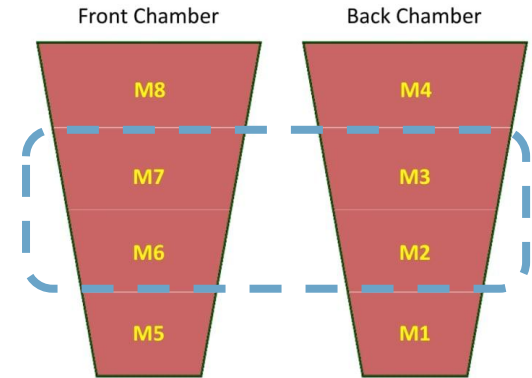
Quantity

M2 / M3 / M6 / M7 : Each 124 sheets including extra foils

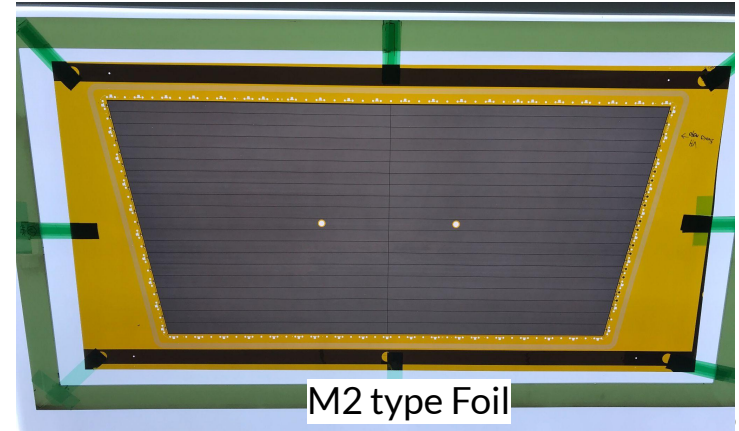
G12 : 72 sheets + 11 extra sheets

G3 : 36 sheets + 5 extra sheets

Total : 496 sheets



GE2/1 Triple-GEM Modules



GEM Foils Produce at the MECARO Company



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Mecaro company produces Four different types (M2, M3, M6, and M7) of foil and provide it to CMS-GEM group.



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Quantity

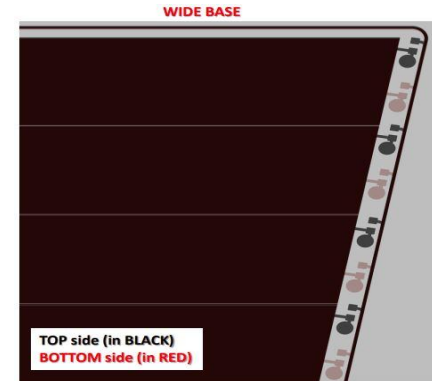
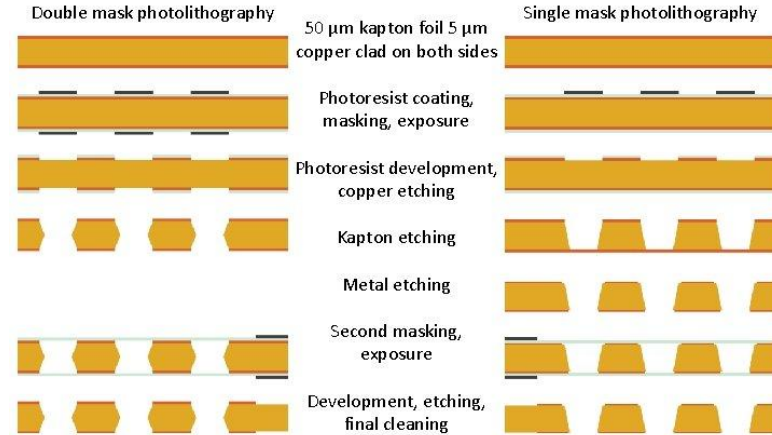
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Total : 496 sheets

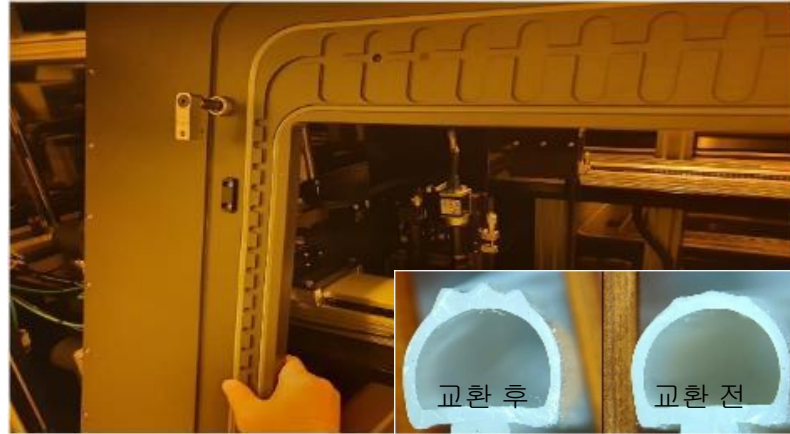
Double mask vs. single mask



GEM Foils Produce at the MECARO Company

❖ The issues of production equipment

- Develop/Etching machine, Exposure unit ... etc

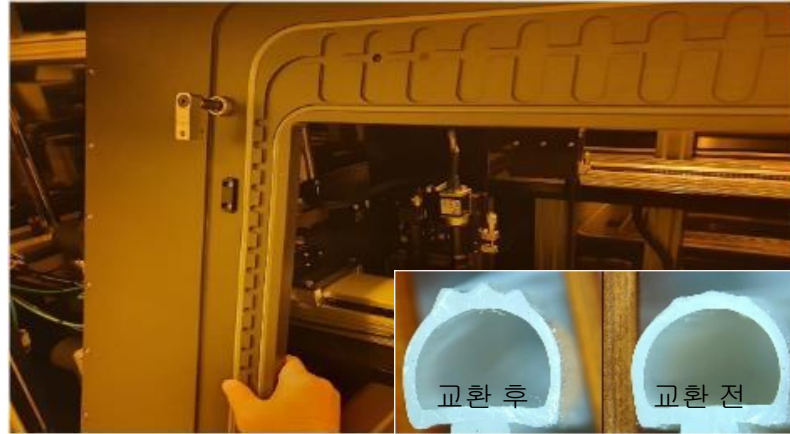
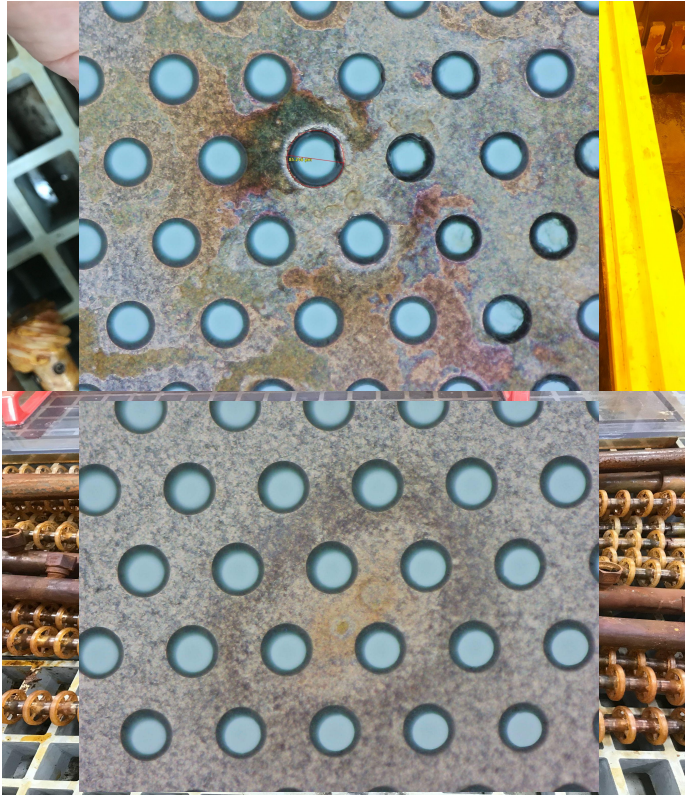


- 케미칼 사용에 따른 장비의 노후화 및 잦은 파손 발생
 - 유지 보수를 위한 예비 물품 확보 필요함
- 노광기 제작 후 4년 경과. 이로 인한 지속적 문제 발생
 - 노광기 제작 업체 폐사, 유지 보수를 위한 현 유지보수업체와의 관계 유지
 - Mask 피로 누적으로 인한 파손

GEM Foils Produce at the MECARO Company

❖ The issues of production equipment

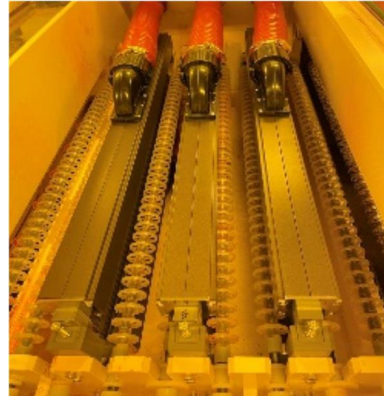
- Develop/Etching machine, Exposure unit ... etc



- 케미칼 사용에 따른 장비의 노후화 및 잦은 파손 발생
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GEM Foils Produce at the MECARO Company

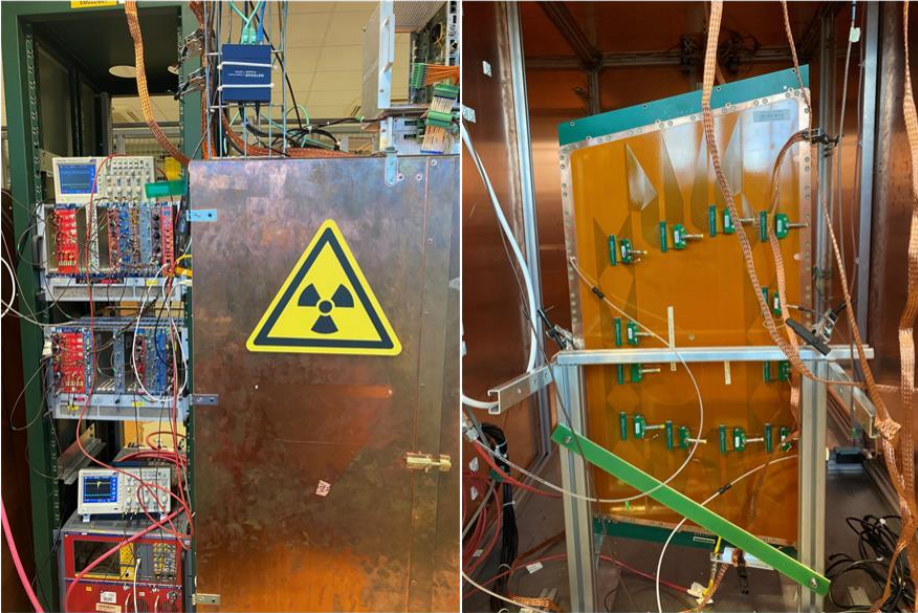
- ❖ MECARO 지원을 위한 예비 및 교체 부품 구매



At CERN

QC in the Muon Detector site

Korean students were dispatched to participate in QC activities.



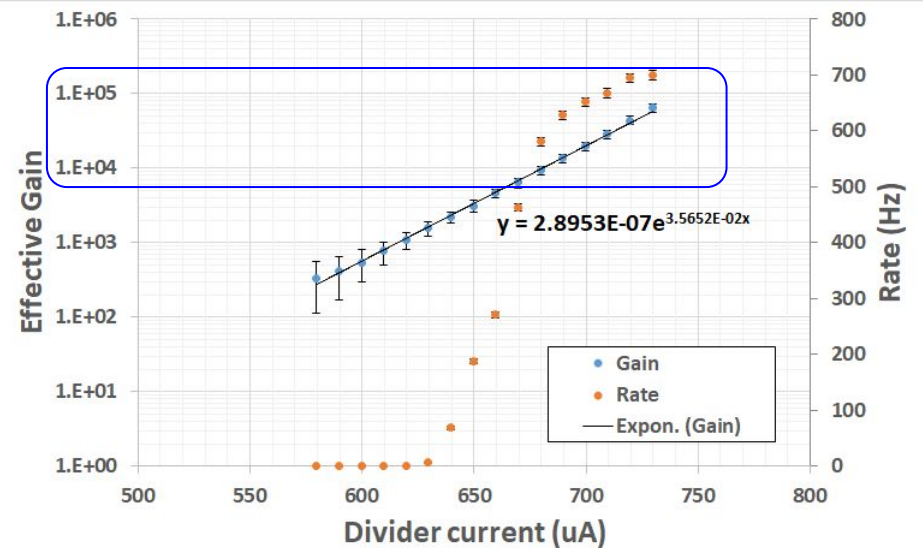
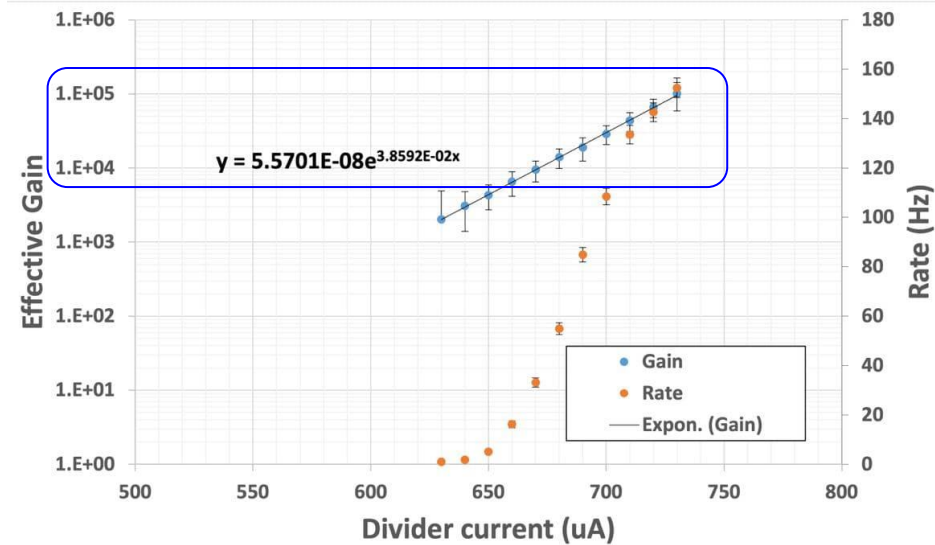
< It shows QC activities in the clean room at CERN >
They proceed with the same QC2 process
as QC2 conducted in Korea.

< It shows QC5 Gain measurement bench in the 904 site at CERN >
Seulgi Kim(UoS) has decided to work as a QC5 manager.

At CERN

QC5 Gain Measurement

Compare the results for Eff.Gain

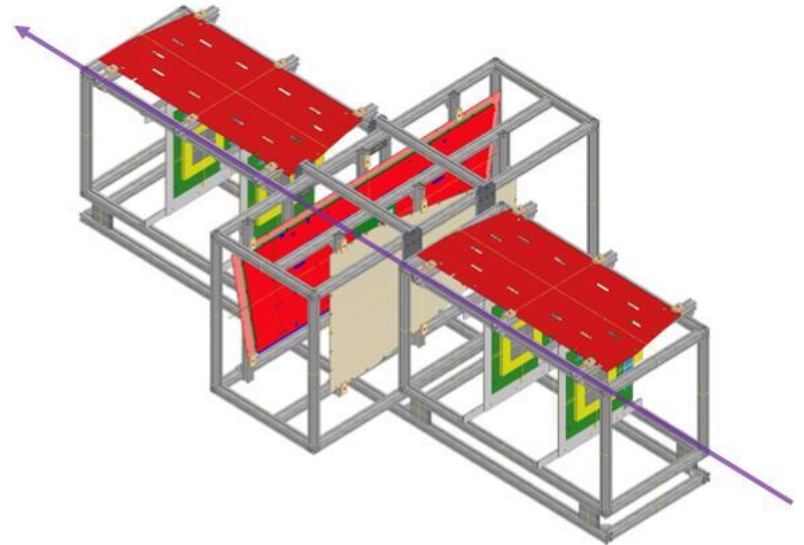


< These plots show the variation of Eff.Gain and Rate of M1-0001 (Left) and M2-0001 (Right) detector as a function of divider current
The Eff.Gain measurement results of detector assembled with M2 type foils manufactured in Mecaro and detector assembled with M1 type foils manufactured in CERN show satisfactory performance >

Test Beam Activities

- ❖ Efficiency & Resolution study for GE21 (M1) & ME0
 - Setup
 - Beam: muon (80 GeV/c)
 - Tracking: 4 10×10 cm² GEM chambers

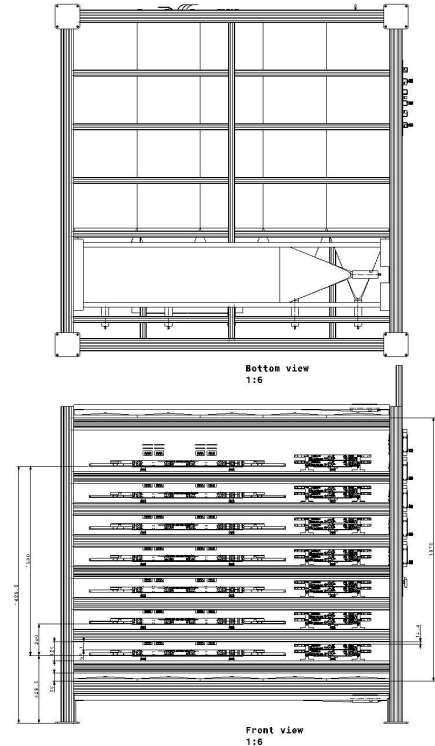
- ❖ First data taking
 - Yechan Kang (UoS)
 - Antonello Pellecchia (INFN Bari)



At CERN

QC8 Analysis Software Development

- ❖ QC8: Cosmic test
- ❖ GE2/1 QC8 Analysis SW is under development
 - Simulation is ready
 - Track reconstruction script is under construction
- ❖ Analysis team
 - Yechan Kang(UoS)
 - Seulgi Kim(UoS)
 - Manuel Rodriguez (U. Antioquia)
 - Daniel Estrada (U. Antioquia)





CMS Experiment at the LHC, CERN
Data recorded: 2018-Jul-08 19:55:40.193536 GMT
Run / Event / LS: 319347 / 36141749 / 46

A 3D visualization of a particle detector, likely the CMS detector at the LHC. The detector is shown in a perspective view, with various components and structures visible. The background is a light gray, and the detector components are rendered in various colors, including blue, green, orange, and purple. A central orange starburst pattern is visible, representing a particle collision event. The text 'THANK YOU FOR YOUR ATTENTION' is overlaid in the center of the image.

**THANK YOU
FOR YOUR ATTENTION**

GEM Foils QC by Korea-CMS



GEM Foils Quality Control (QC) : The Korea-CMS (KCMS) performs QC activities to select **High quality** foil that meets the specifications and send it to the CMS-GEM group.

Graduate students of 10 universities are participate. Based on QC activities, we are working with Mecaro company to produce more improved quality foil.



< The photo shows a QC lab located in Eumseong-gun, MECARO >

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- QC Stage -

