

# ***Status of CMS GEM production in Korea***

***RD51 @ CERN***

***Feb. 22, 2016***

***Presented by Archana Sharma***

***for***

***Inkyu PARK on behalf of the Korea CMS***

***Dept. of Physics, University of Seoul***

**KCMS-MECARO consortium**



[www.mecaro.com](http://www.mecaro.com)

Address : 103-14, Sandan-ro, Pyeongtaek-si, Gyeonggi-do, Korea(Mogok-dong 439-5)

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**\*Founded in 1999**

## Mission

We do a key role in the high-tech industry with the products containing a unique technology and soul. We exist to improve our quality of life.



## Core Value

To do our best with passion in all areas and constantly innovate based on positive and creative thoughts.



## Vision

Happy company does not have a retirement

Through continuous self-development and ownership, we will be with you to the end responsibly.



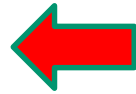
### ● GEM(Gas Electron Multiplier) 검출기

- Ar, Ne, He 등의 기체를 광-전자 변환체로 X-선으로부터 전자들을 생성시킨 후 GEM foil을 통해 전자를 증폭하여 이를 수집하는 영상 검출기
- 기존 검출기 대비 simple한 구조에 높은 효율, 의료/국방/보안/산업용 등 다양한 응용분야에 적용가능
- CERN(유럽원자핵공동연구소)의 입자가속기 경착용 부품으로 납품중



## ❑ Semiconductor parts manufacturer in Korea.

– Products: Heater block, Chemical Precursor, GEM foil etc.



- Head Quarter & Production Facility
- Clean room : 1000 m<sup>2</sup>



- R&D and Production Facility
- Clean room : 1300 m<sup>2</sup>
- **R&D for GEM foil production**





Test production R&D lab for small size GEM



Test production R&D lab for large size GEM

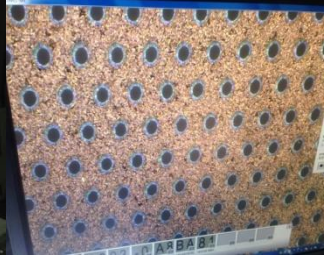
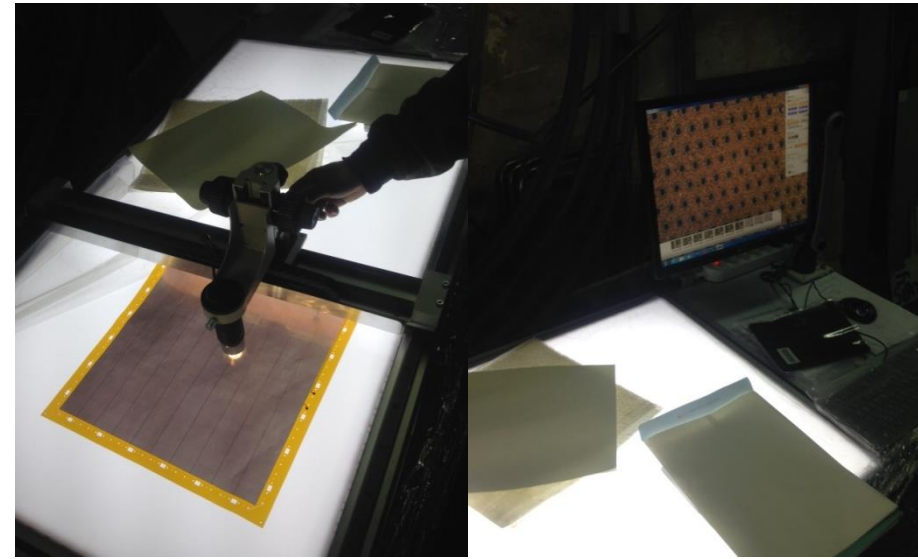


Real production machine for large size GEM



GE11  
for CMS

## Optical Inspection System



Hole inspection  
x400

Inner holes  
x1200

Outer holes  
x1200

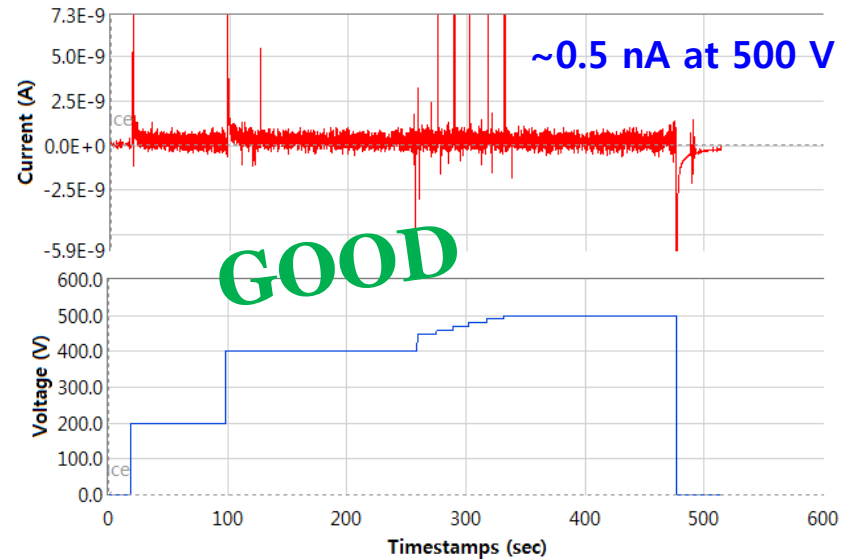
## Leakage Current Measurement System



DAQ Laptop

KEITHLEY  
2410 PS

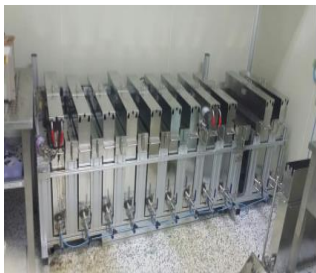
N<sub>2</sub> box & GEM





## 2013-2014

Wet station for GEM  
(up to 50x50 cm<sup>2</sup>)

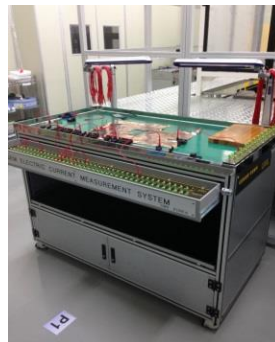


Wet station for mass production



## 2014-2015

Current measurement



Optical inspection

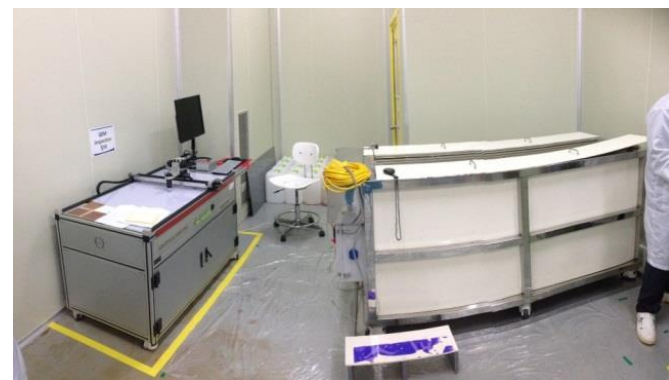
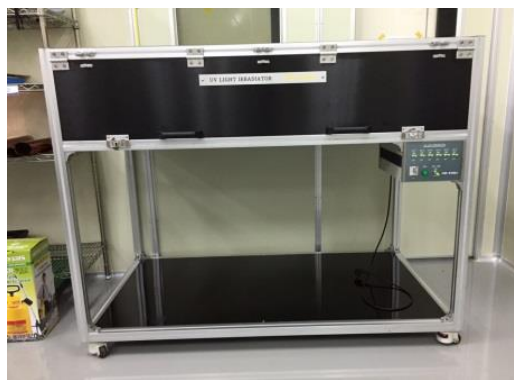


## 2015-2016

Etching/cleaning bath for Large GEMs



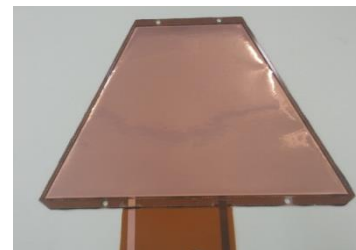
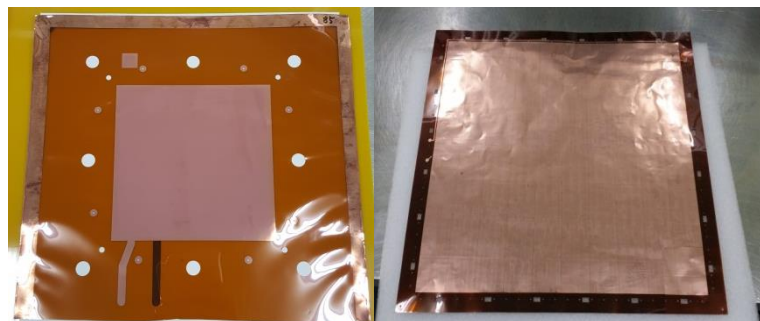
UV systems for removing DFR



# **Production status**

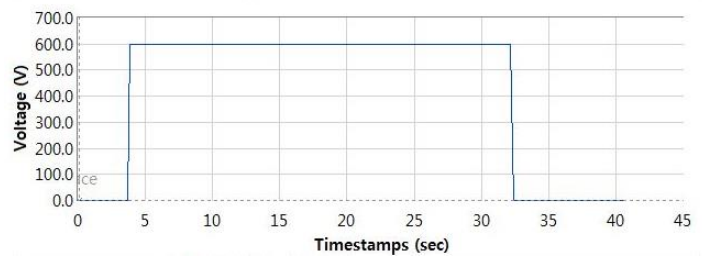
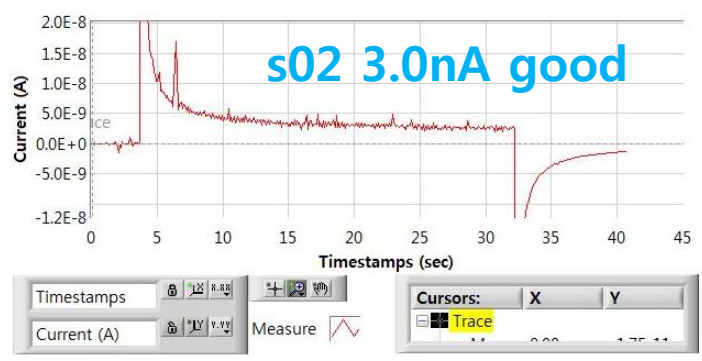
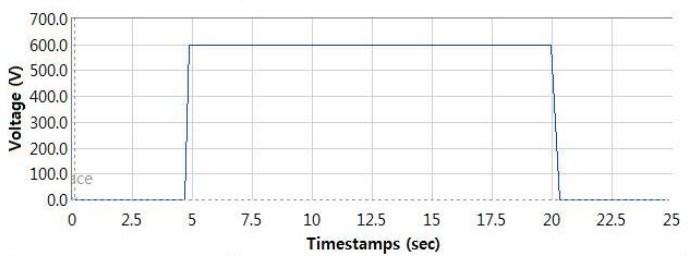
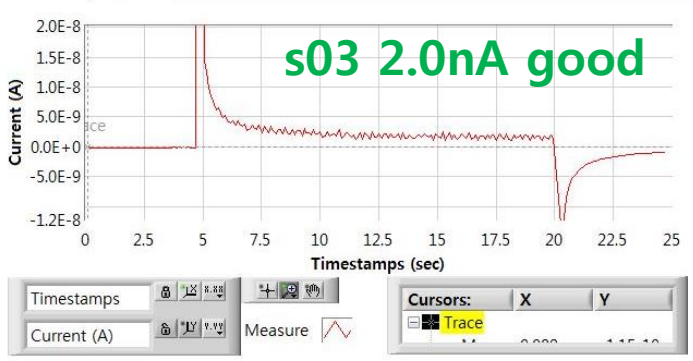


- ❑ Small size GEM (10x10 cm<sup>2</sup>)
  - Mass production phase since 2015
    - capability: ~2000 foils/year
- ❑ Mid-size GEM (30x30 cm<sup>2</sup>)
  - Order-based production MECARO
  - 5 + 5 under test
- ❑ Large size GEM (50x100 cm<sup>2</sup>)
  - Still R&D phase (almost done)
    - Chemistry is different frm CERN
  - Hole shape; single mask foil source is KANEKA
    - Utilizing PI+LsMTRON FCCL middle cut
  - For the CMS upgrade (GE11)
    - Capability: ~500 GEM foils by 2017
- ❑ Custom design GEM
  - IBS LAMPS project : 10 x 20 cm<sup>2</sup>
    - Produced & shipped
  - KU-KEK: GEM-TPC 10 x 20 cm<sup>2</sup>



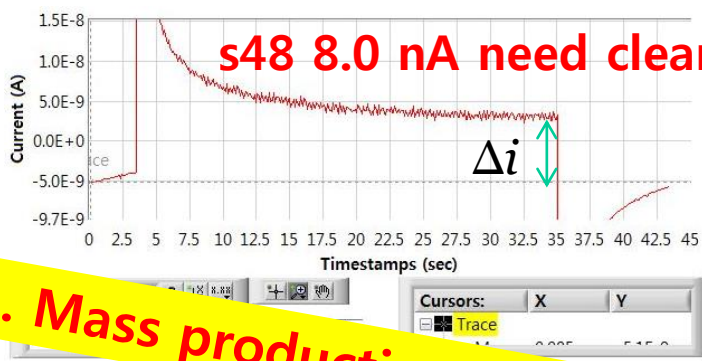
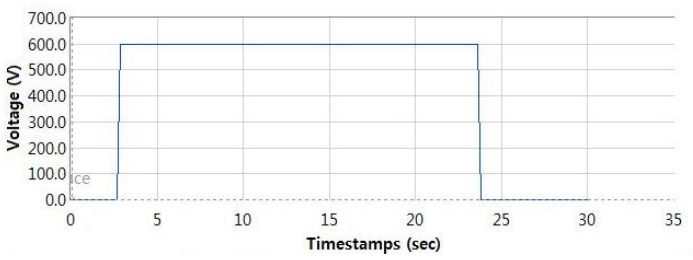
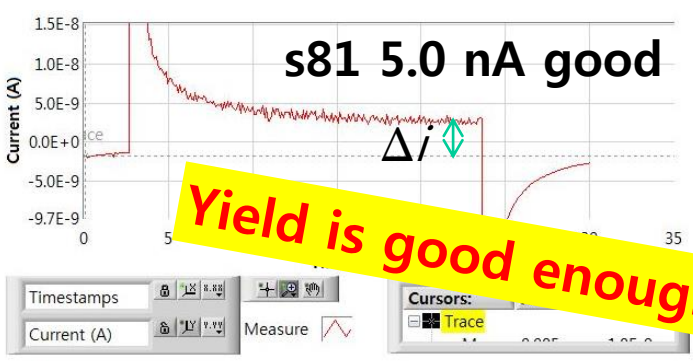


# Mass production of small size GEM Mecaro-50 RH%



## Leakage current ( $\Delta i$ )

- s01 3.5 nA good
- s02 3.0 nA good
- s03 2.0 nA good
- s04 4.0 nA good
- s05 5.0 nA good
- s06 3.5 nA good
- s07 3.5 nA good
- s08 2.0 nA good
- s09 2.5 nA good
- s10 4.0 nA good
- ...



- s31 3.0 nA good
- s39 5.0 nA good
- s41 5.0 nA good
- s42 2.0 nA good
- s43 3.5 nA good
- s44 5.0 nA good
- s45 5.0 nA good
- s46 5.0 nA good
- s48 8.0 nA need clean
- s49 4.0 nA good
- ...

- s81 5.0 nA good
- s82 3.0 nA good
- s83 3.0 nA good
- s84 3.0 nA good
- s85 3.5 nA good
- ...

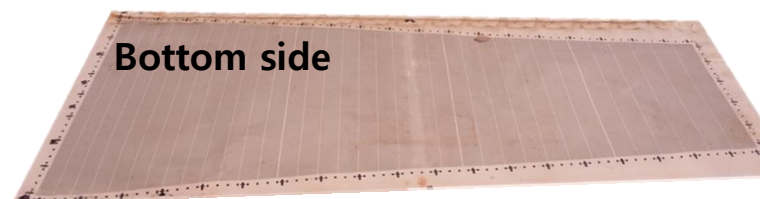
**Yield is good enough. Mass production stage.**

# **Status of Large GEM foil production**

□ 2013: A very first GE11 foil was produced by the double-side etching method

– Mask misalignments  $\sim 10\mu\text{m}$

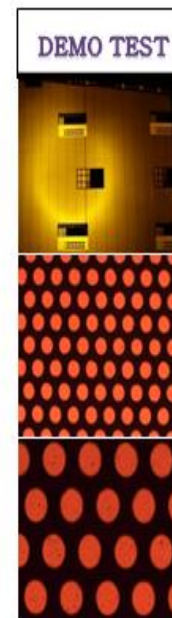
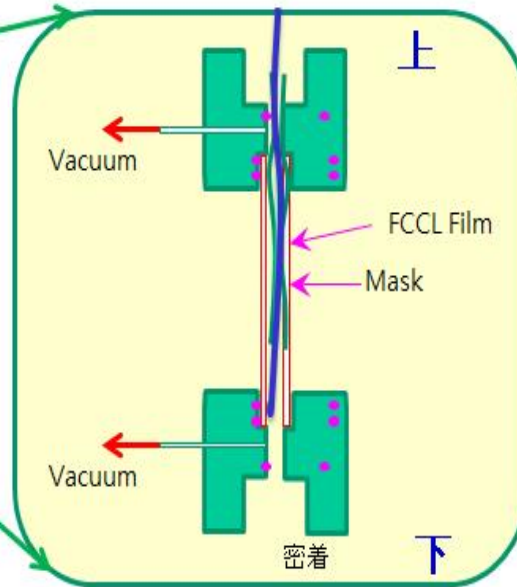
- Thus, we concluded that we needed a finer mask alignment tool.





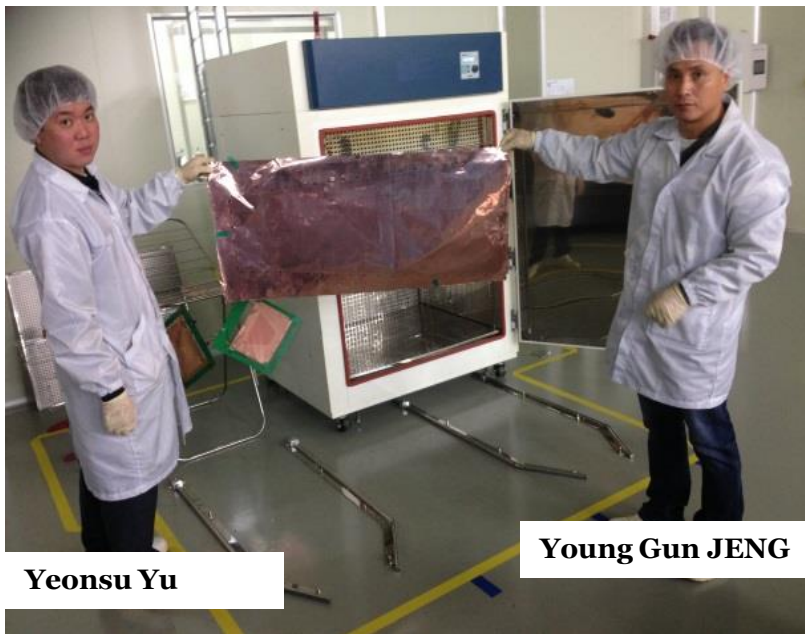
- A successful GE11 production was done.
  - By using a high definition bi-polar lithography machine with the alignment precision of  $\sim 1\mu\text{m}$  (Japanese optics company)
  - However, the machine price  $\sim 1$  million dollars! KCMS wanted to buy this machine anyway, if the CMS management was willing to consider the investment as the in-kind contribution of Korea  $\rightarrow$  But, denied.
  - We hold the procedure to purchase the machine.

Double-mask Cu lithography in 2014



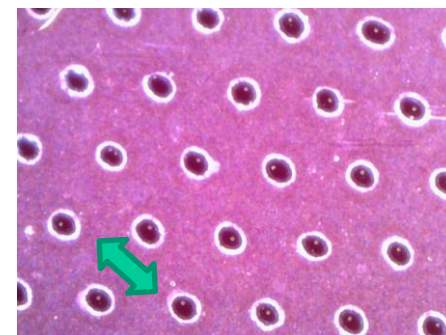
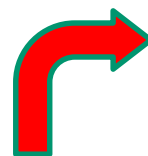
□ Thus, we started the single-side etching method in 2015, as followed in CMS

– The production seemed to be quite straightforward, and well progressed.



Yeonsu Yu

Young Gun JENG



The production qualities were not stable over the productions. The PI hole shapes were not uniform over the GE11 area for some production. → serious yield cut.

# Plans & remarks

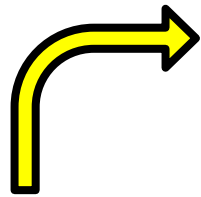
- ❑ To overcome the current obstacle (PI dependence), we have to return back to the double-side method.
- The double-side method doesn't suffer from the irregular PI etching shape problem (Both Cu holes on top and bottom are circular).
  - Again, everything becomes a money issue. But now, the CMS management may agree to purchase the machines as the in-kind contribution of Korea. → Then, we'll buy the following machines using KCMS funds. (See the next page)
    - Rough estimation of the total investment ~ about 300KCHF.



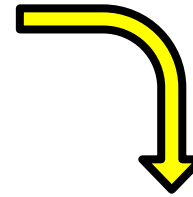
Big \$\$\$ investment is needed, but they are crucial for mass production of GE11



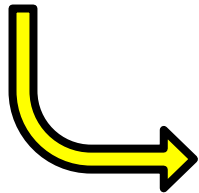
DFR coating system



Cu etching



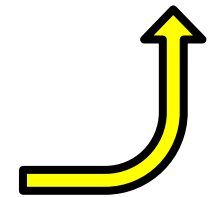
Oven for dry



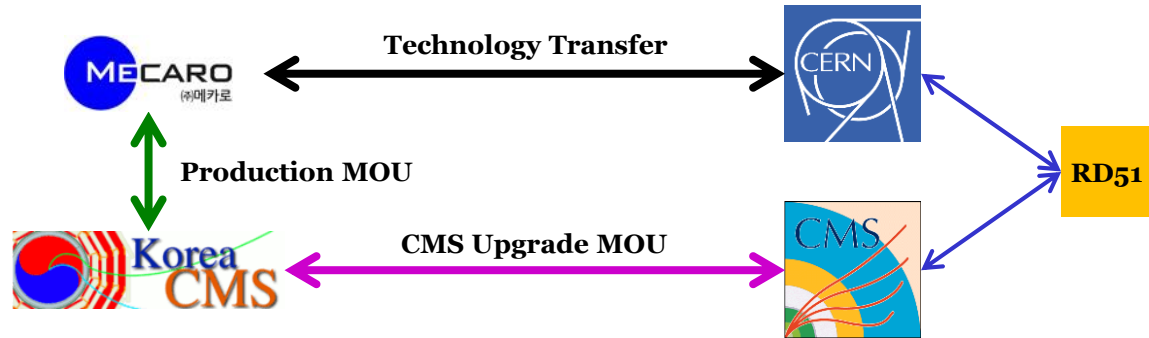
Lithography system



Development of DFR



## □ Work flow



## □ KCMS GEM TF → Very successful

### – Small size GEM foil

- 10x10 cm<sup>2</sup> : mass production ready (by the double-side method)

### – Mid-size GEM foil

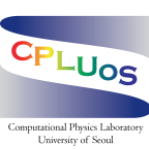
- 30x30 cm<sup>2</sup> : production upon request (by the double-side method)

### – Large size GEM foil

#### • GE11 production:

- Using single-side method: doable, but hole shape uniformity is not good
- Using double-side method: recommended, but the machine cost is high (additional 300kCHF needed)

**Backup slides**



# Test results of 10x10 and 30x30 GEMs produced by KCMS&MECARO

**Min Sang RYU**

on behalf of the Korea CMS GEM R&D team

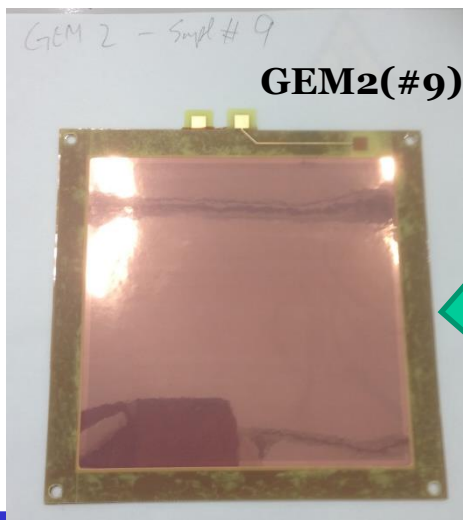
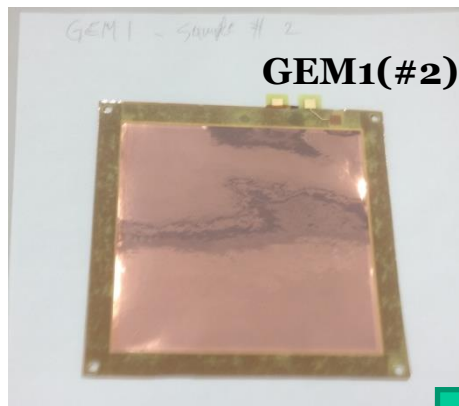
University of Seoul (UoS)



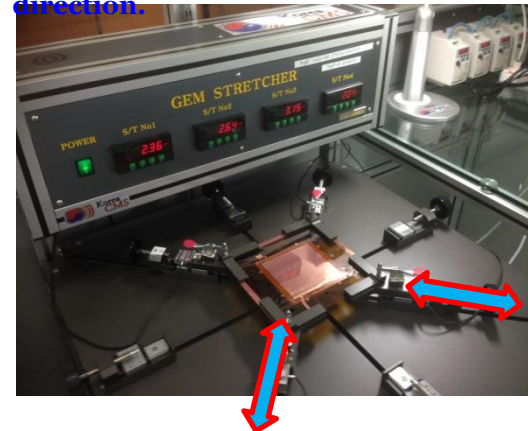
# 2DxID with GEM1(#2), GEM2(#9), GEM3(#10) at LHC lab

GEM test in LHC lab in UoS

Customized DAQ program with K2410 SMU



GEMs are stretched about  $4-7 \text{ N/cm}^2$  summed with values in opposite direction.



Typical stretching tension  $\sim 5-10 \text{ N/cm}$

GEM3(#10) is on the stretcher now (2016.03.09), we designed and fabricated.



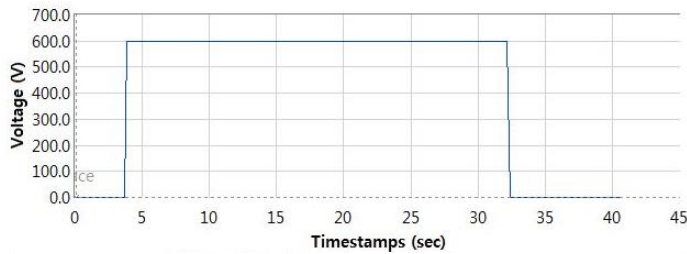
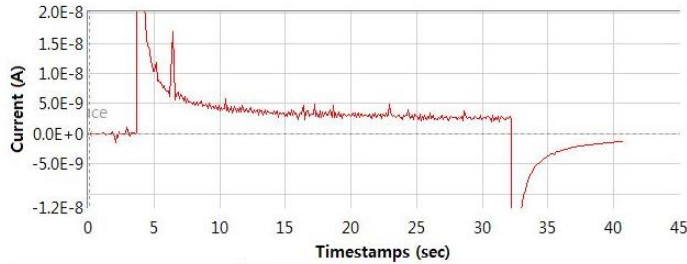
# Leakage current of GEM from MECARO (2015)

Leakage current ( $\Delta i$ )



sample #2 → s2 on the right list

3 nA @ 600V with 18.3 °C and ~52 % humidity

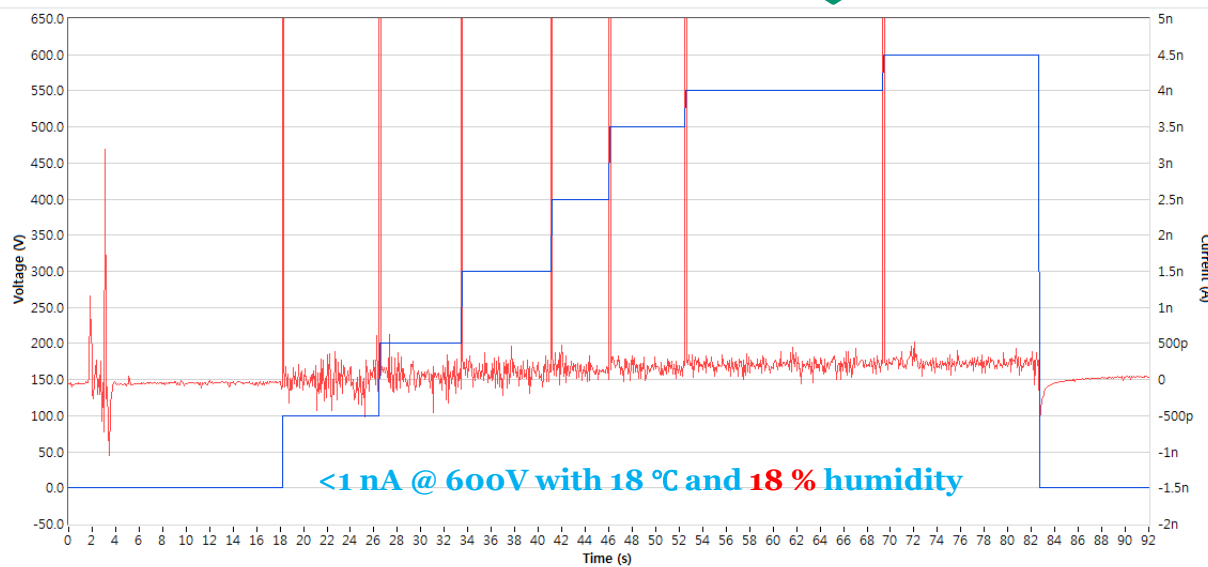


TEST in MECARO  
(August 2015)

TEST at Univ. of Seoul (UoS)  
in Korea (March 2016)

- ★ s1 3.5 nA good
- s2 3 nA good
- s3 2 nA good
- s4 4 nA good
- s5 5 nA good
  
- s6 3.5 nA good
- s7 3.5 nA good
- s8 2 nA good
- ★ s9 2.5 nA good
- s10 4 nA good
  
- s31 3 nA good
- s39 5 nA good
- s41 5 nA good
- ★ s42 2 nA good
- s43 3.5 nA good
  
- s44 5 nA good
- s45 5 nA good
- s46 5 nA good
- ★ s48 8 nA need to clean
- s49 4 nA good
  
- s81 5 nA good
- s82 3 nA good
- s83 3 nA good
- s84 3 nA good
- s85 3.5 nA good

<1 nA @ 600V with 18 °C and 18 % humidity



★ s1 and s48 used for  
GEM stretcher, we've  
designed.

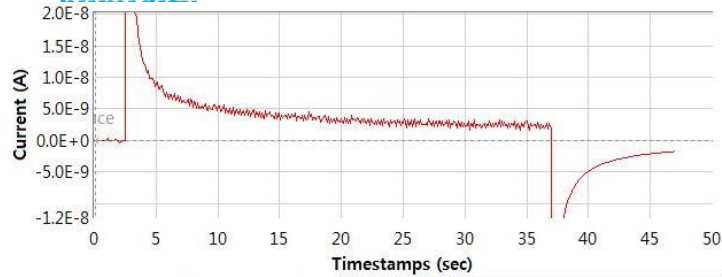
# Leakage current of GEM from MECARO (2015)

Leakage current ( $\Delta i$ )

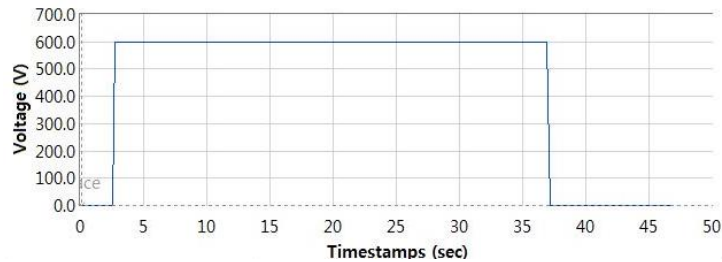
서울시립대학교  
UNIVERSITY OF SEOUL

sample #9 → s9 on the right list

2.5 nA @ 600V with 18.3 °C and ~52 %



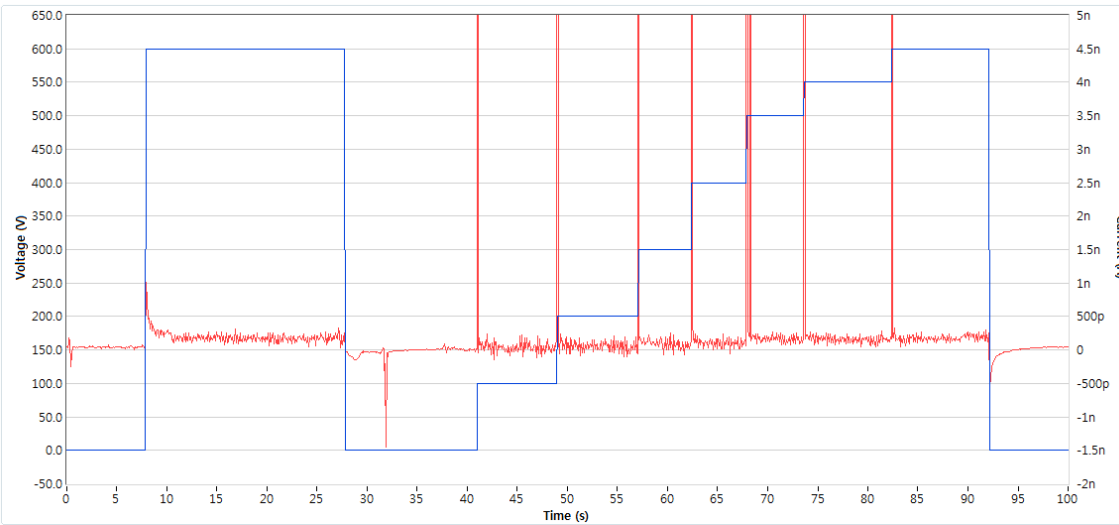
TEST in  
MECARO  
(August 2015)



TEST at UoS in Korea  
(March 2016)



<1 nA @ 600V with 18 °C and 18 % humidity



★ s1 3.5 nA good  
s2 3 nA good  
s3 2 nA good  
s4 4 nA good  
s5 5 nA good

s6 3.5 nA good  
s7 3.5 nA good  
s8 2 nA good  
★ s9 2.5 nA good  
s10 4 nA good

s31 3 nA good  
s39 5 nA good  
s41 5 nA good  
s42 2 nA good  
s43 3.5 nA good

s44 5 nA good  
s45 5 nA good  
s46 5 nA good

★ s48 8 nA need to clean  
s49 4 nA good

s81 5 nA good  
s82 3 nA good  
s83 3 nA good  
s84 3 nA good  
s85 3.5 nA good

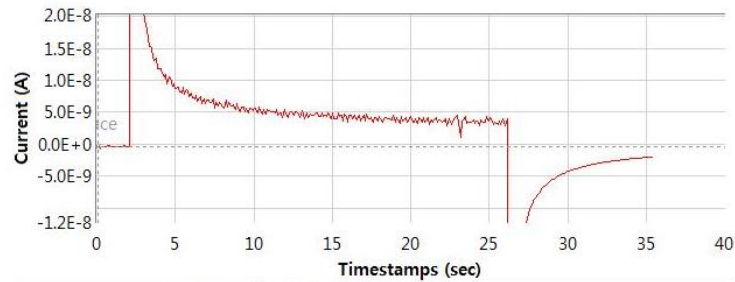
★ s1 and s48 used for  
GEM stretcher, we've  
designed.

# Leakage current of GEM from MECARO (2015)

Leakage current ( $\Delta i$ )

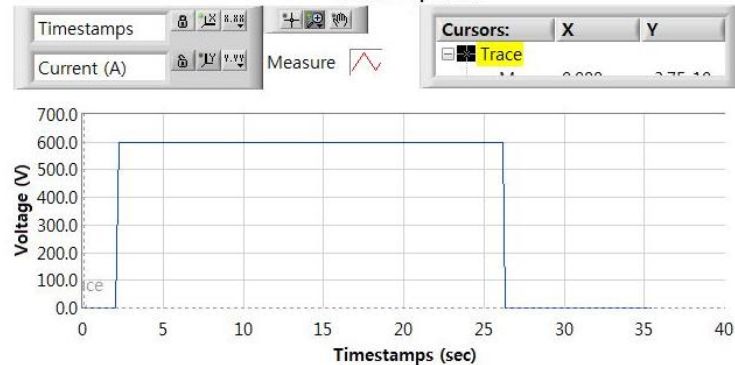
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UNIVERSITY OF SEOUL

**sample #10** → s10 on the right  
list @ 600V with 18.3 °C and 52 % humidity



TEST in MECARO  
(August 2015)

- ★ s1 3.5 nA good
- s2 3 nA good
- s3 2 nA good
- s4 4 nA good
- s5 5 nA good
- s6 3.5 nA good
- s7 3.5 nA good
- s8 2 nA good
- ★ s9 2.5 nA good
- ★ s10 4 nA good



TEST at UoS in Korea  
(March 2016)

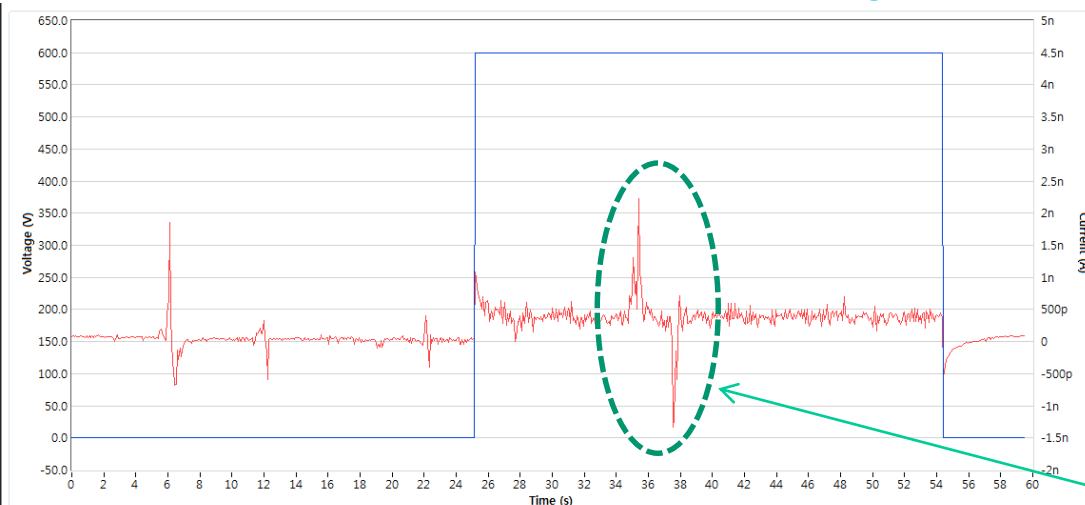
- s31 3 nA good
- s39 5 nA good
- s41 5 nA good
- ★ s42 2 nA good
- s43 3.5 nA good

- s44 5 nA good
- s45 5 nA good
- s46 5 nA good

- ★ s48 8 nA need to clean
- s49 4 nA good

<1 nA @ 600V with 18 °C and 18 % humidity

- s81 5 nA good
- ★ s82 3 nA good
- ★ s83 3 nA good
- ★ s84 3 nA good
- ★ s85 3.5 nA good



★ s1 and s48 used for GEM stretcher, we've designed.

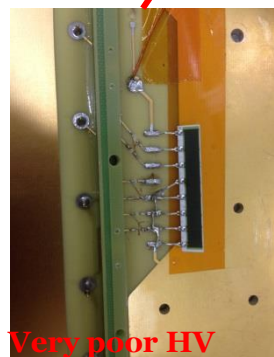
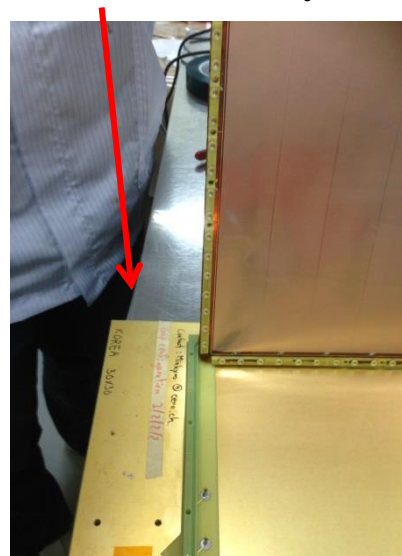
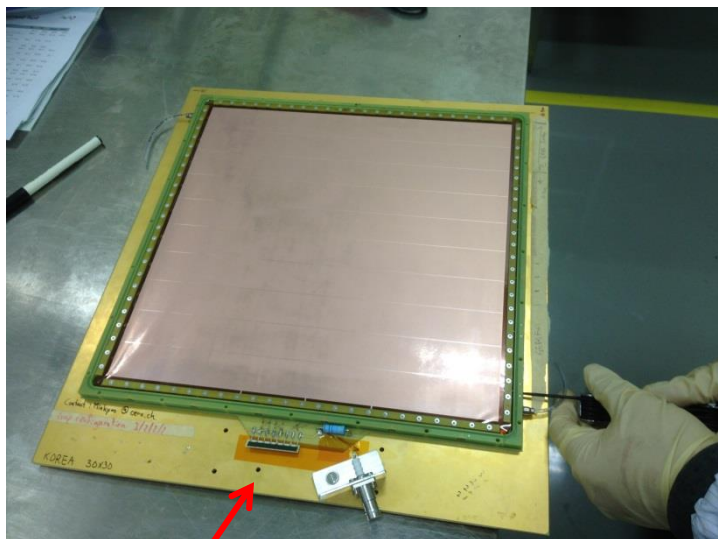
It is due to the noise from static



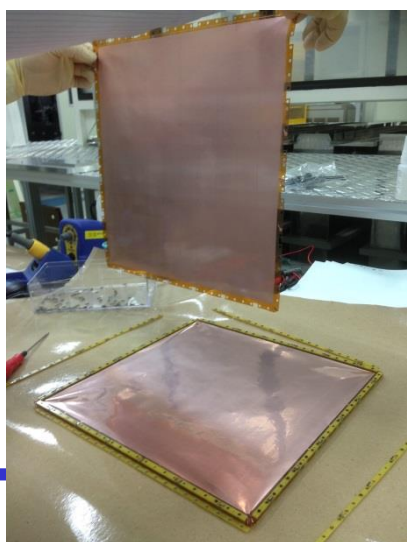
# 30x30 GEM detector with MECARO GEMs (FCCL from 3M)

Open Detector in Dec 2015

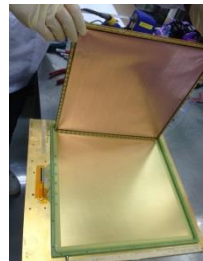
Bad sector check by message on the board



Very poor HV connection by customized ceramic resistance ???

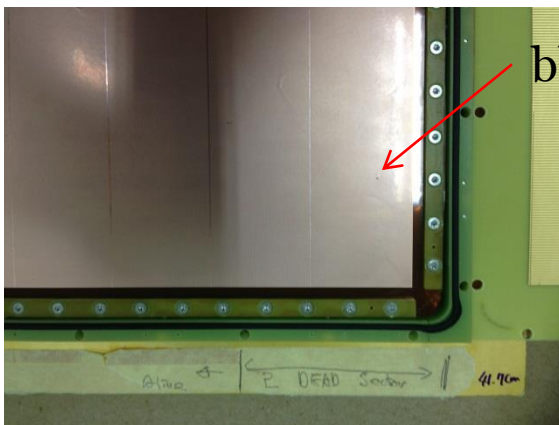


# Leakage current of GEM (30x30 cm<sup>2</sup>) from MECARO (3M) in Dec 2015



It was tested at CERN in 2015 but there was bad sectors.

Holes ??

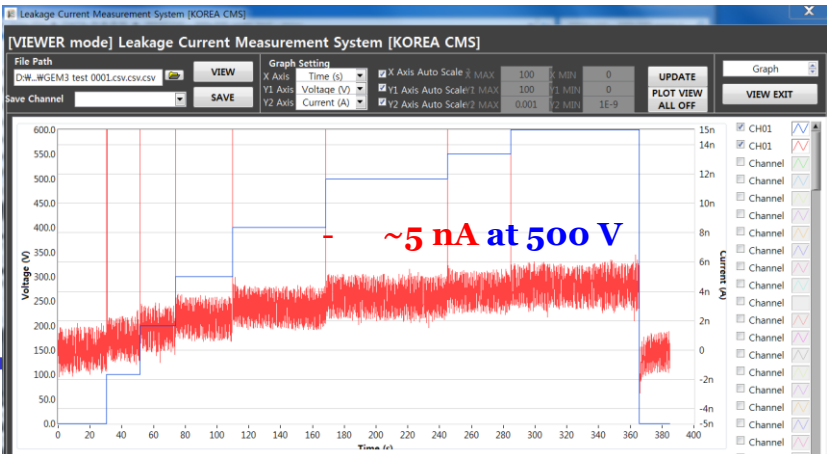
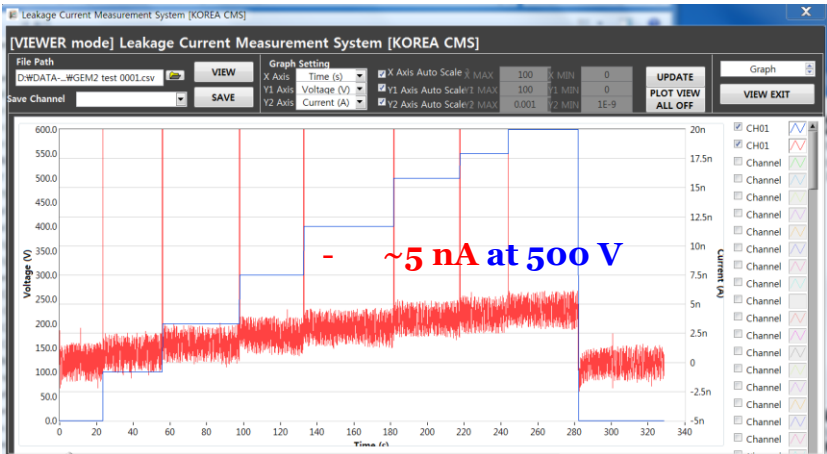
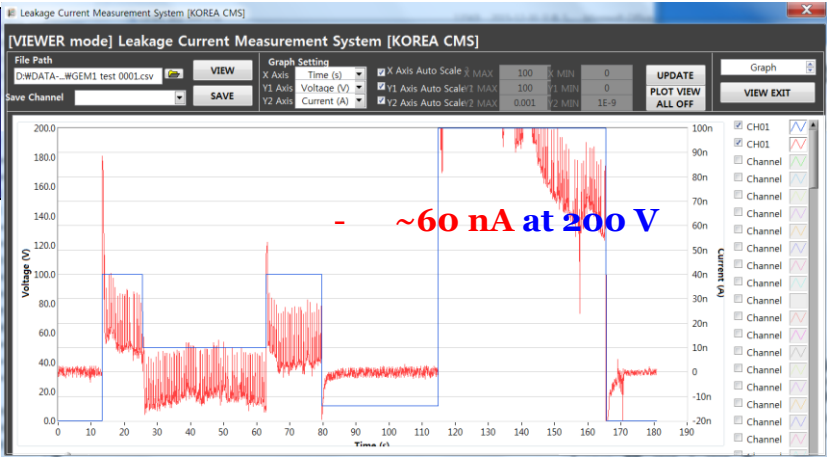
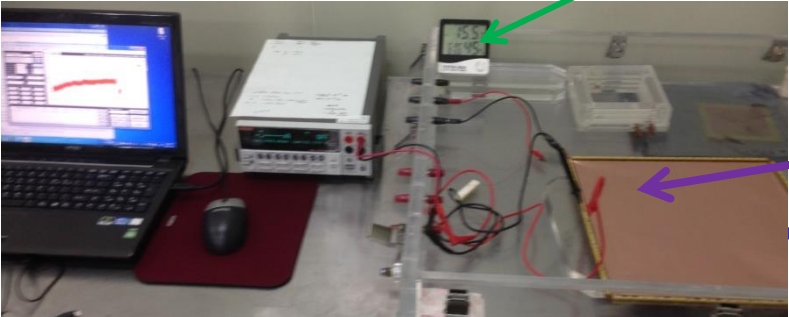


black dot at GEM1

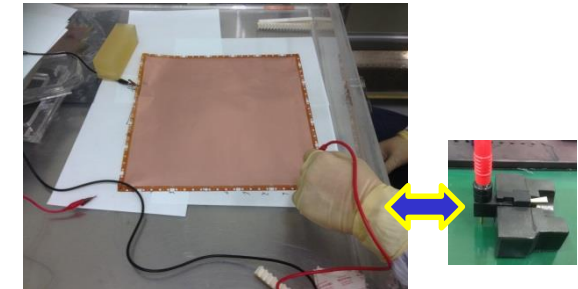
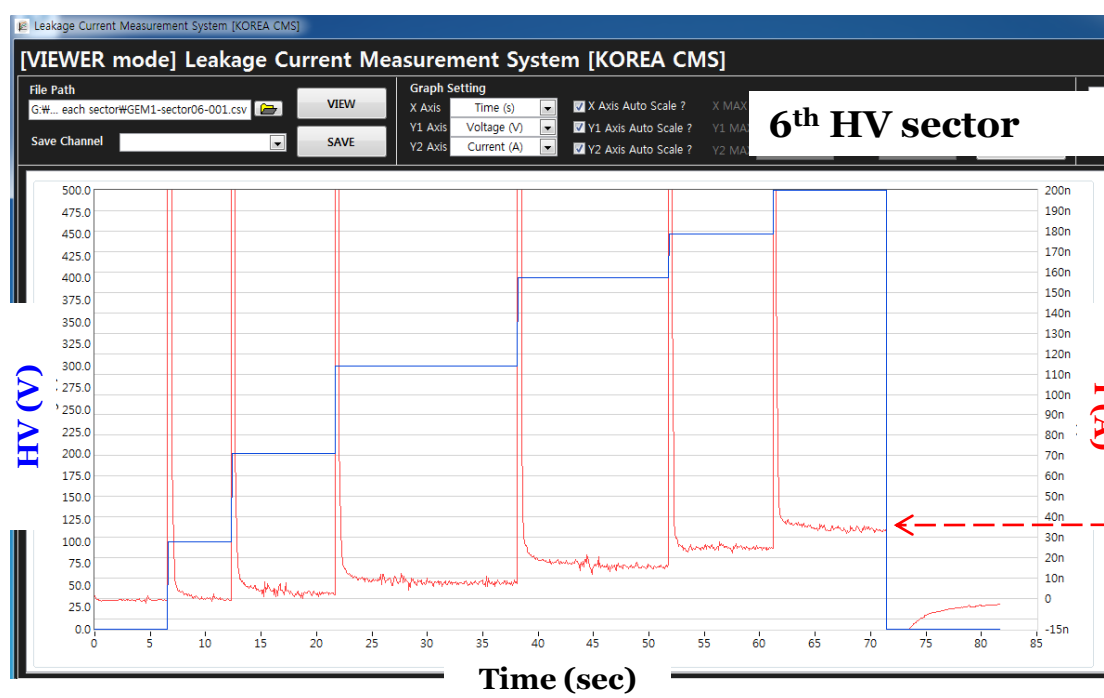
GEM2&3 are OK.

## TEST SETUP (MECARO)

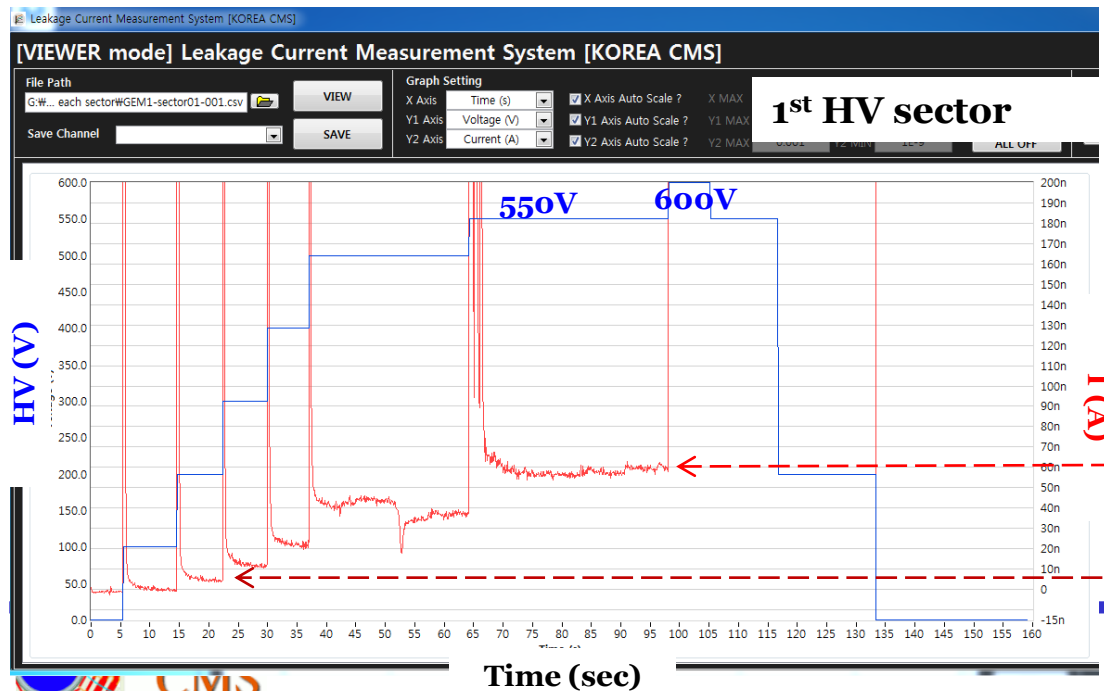
15.5 °C  
45 % humidity



# Leakage current of GEM1 (30x30 cm<sup>2</sup>) from MECARO (3M) in Jan 2016



- Leakage current at 500V: **20-50 nA** for each HV sectors



- Similar pattern
- **~60 nA at 550 V**
- **Damaged at 600 V**

**GEM1 showed ~60 nA at 200 V.**



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