Status of GEM foil industrialization

- **GEM foil production in Korea (95% of the presentation)**
  on behalf of Inkyu Park

- **First steps in India : Larval stages (5% of the presentation)**

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Status of industrialization of GEM foil production in Korea

June 19, 2014 @ RD51 Mini-workshop

Inkyu PARK for the KCMS-GEM team
Dept. of Physics, University of Seoul

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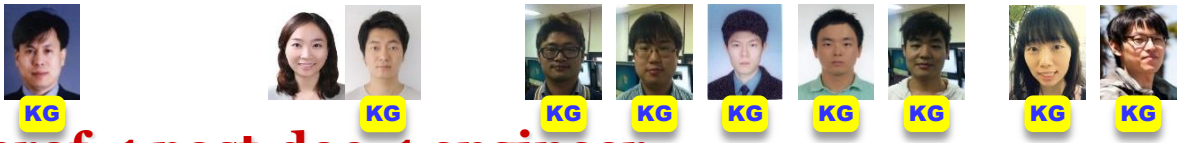
1. **Introduction to Korea-GEM team**
2. A brief history of KGEM foil production
3. Status of GEM foil production
4. Other GEM related R&Ds
5. Things to do

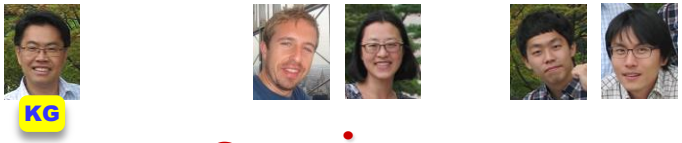
KCMS GEM members

- Korea CMS GEM TF: 3 universities+ 1 company
  - We are the biggest sub-group in KCMS.
    - Univ. of Seoul: 1 prof, 2 post-docs, 5 students, 2 staffs

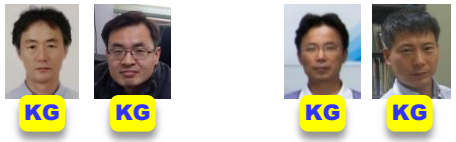


    - Chonbuk Univ.: 1 prof, 1 post-doc, 1 engineer

    - Seoul Nat'l Univ.: 1 prof, 2 post-docs, 2 students



    - Mecharonics: 2 managers, 2 engineers, some technicians



Production site

GEM foil production site: Mecharonics

- Founded in 2000, semiconductor parts manufacturer in Korea
  - Main products: heater block, chemical precursor, etc.

- Head Quarter & Production Facility
- Clean room : 1000 m^2

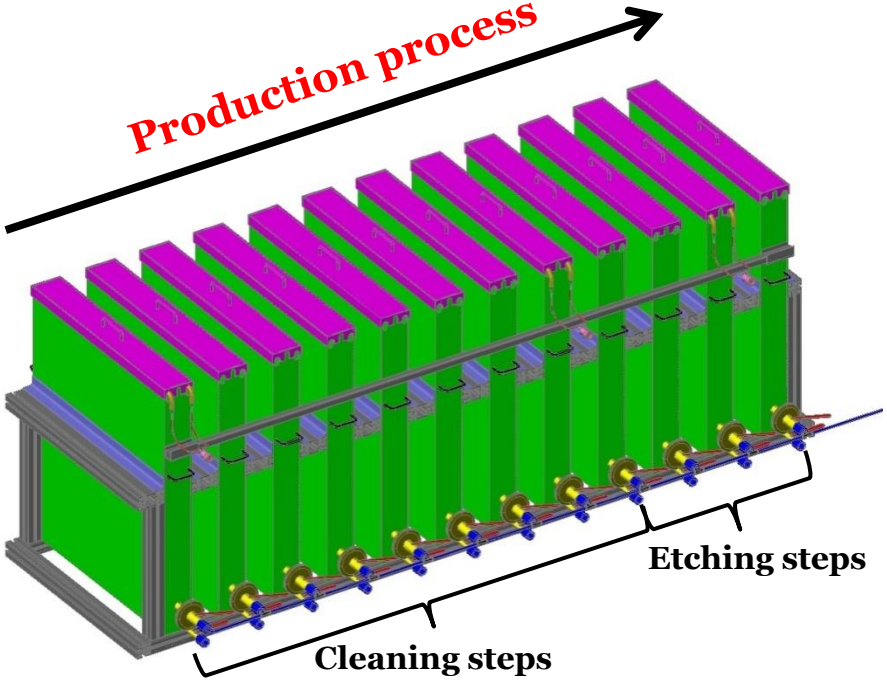
- R&D and Production Facility
- Clean room : 1300 m^2
- **GEM foil production site is here!**

Production site at Mecharonics (1/3)

- Old test production facility for R&D
  - Only for manual production of 10x10 (up to 30x30) GEM foil
    - Replaced with a new test production system

Production site at Mecharonics (2/3)

- New production facility for the small-size GEM foil
  - Up to 55cm x 55 cm

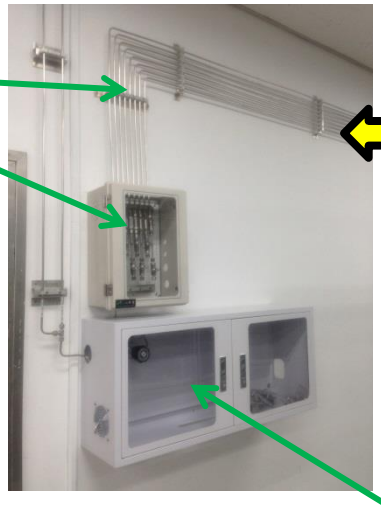


Production site at Mecharonics (3/3)

- Production room for the large-size GEM foil
  - Can produce up to 1.2m x 50cm
    - same configuration as the small-size facility, but bigger dimension

GEM R&D site at UOS (1/2)

8 gas pipes from gas depository
8 gas filter (40-60 μm) with 8 main valves



Gas depository

Area of detector lab ~70 m²
1 air filter on the ceiling

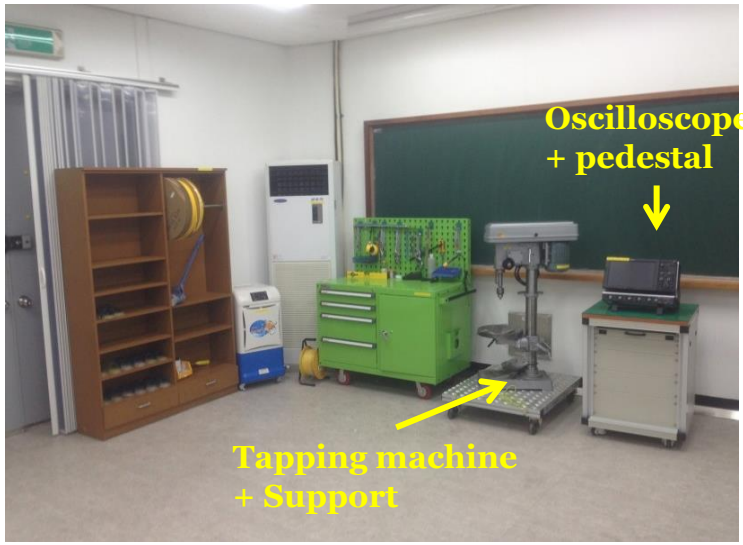
2 tables for detector test

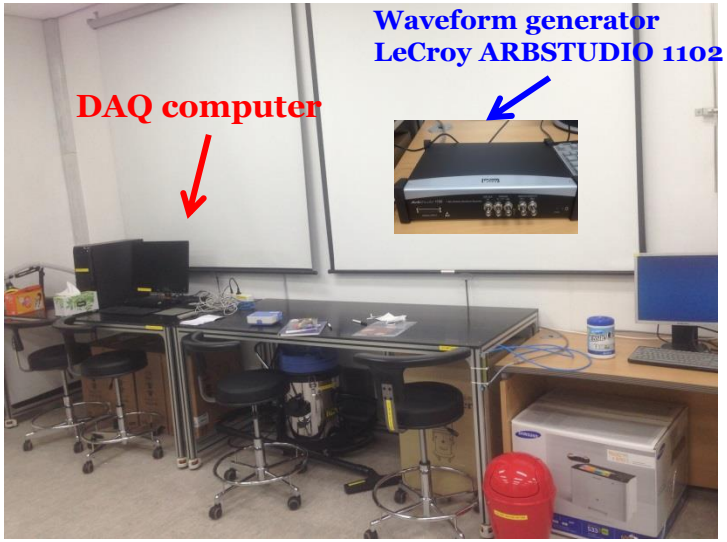
regulator for N_2

Clean room
3.5 m x 4 m x 2.5 m(H)
4 clean filter (class 1)

1 air-conditioner (19-25 ℃) and 1 dehumindifier (40-60 %)

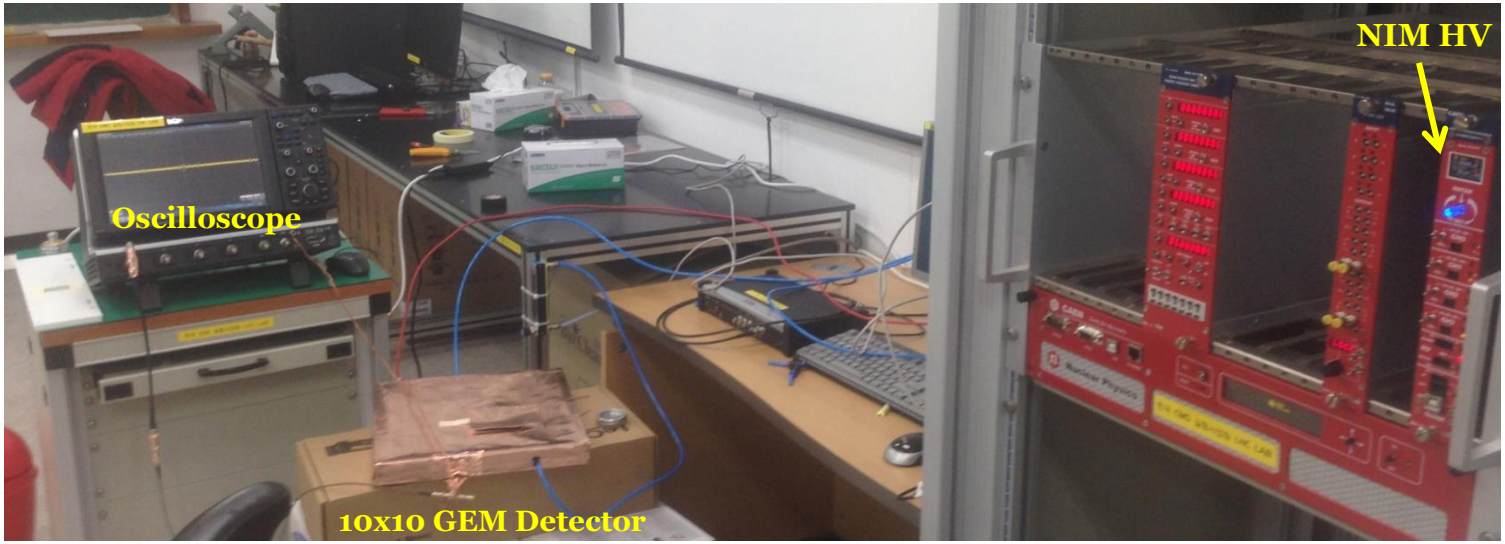
GEM R&D site at UOS (2/2)





Upgrade of Lab

Operational test of prototype GEM detector at Uinversity of Seoul



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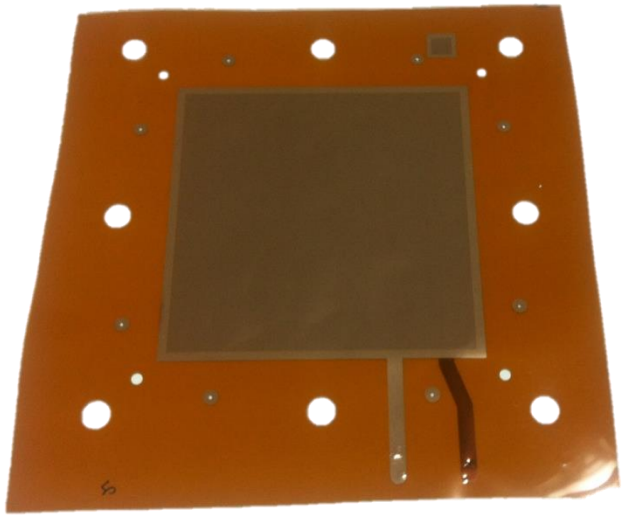
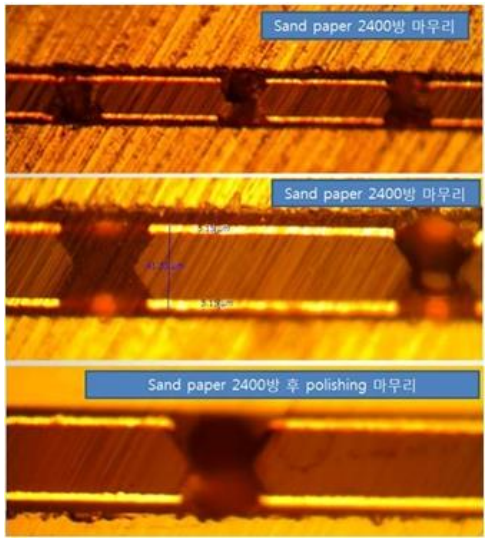
Very first production in 2012

- A very first version of GEM was produced (2012/11)
  - We started by our own method w/o Tech transfer from CERN
    - Step1: Cu lithography & etching
    - Step2: PI etching
      - own recipe for FCCL, etchant, etching condition (**major know-how)





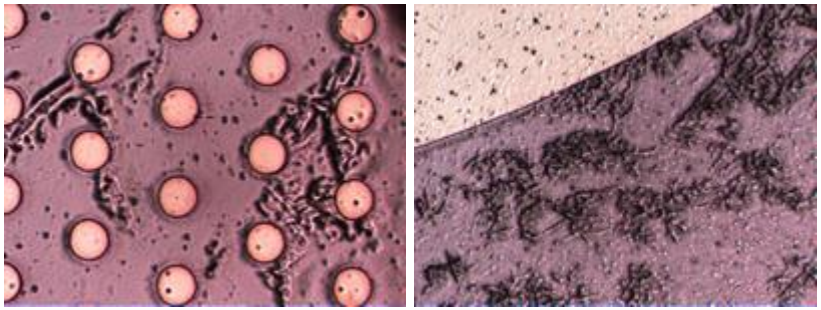
Good news: Symmetric PI etching condition was obtained
- Bad news: Some degree of side etch problem were seen

Those hard times in spring 2013

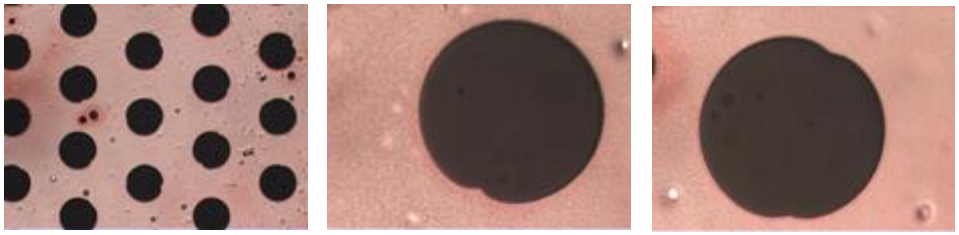
Cu etching

- We faced many different unexpected obstacles in the beginning.
  - Packing issue: stain

  - Cu surface defect



  - Irregular shape



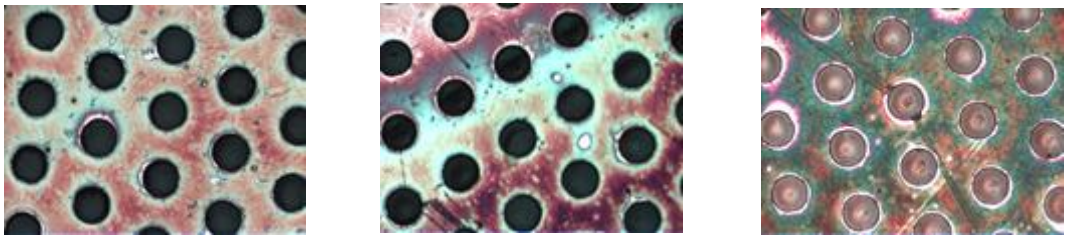
Finding the best etching recipe!

- R&D for 3 months to find the best etchant
  - Function of etchant composition, temperature, etching time

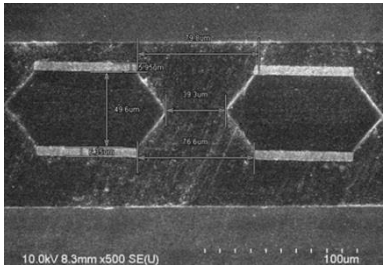
PI etching

etching time

Cu damage

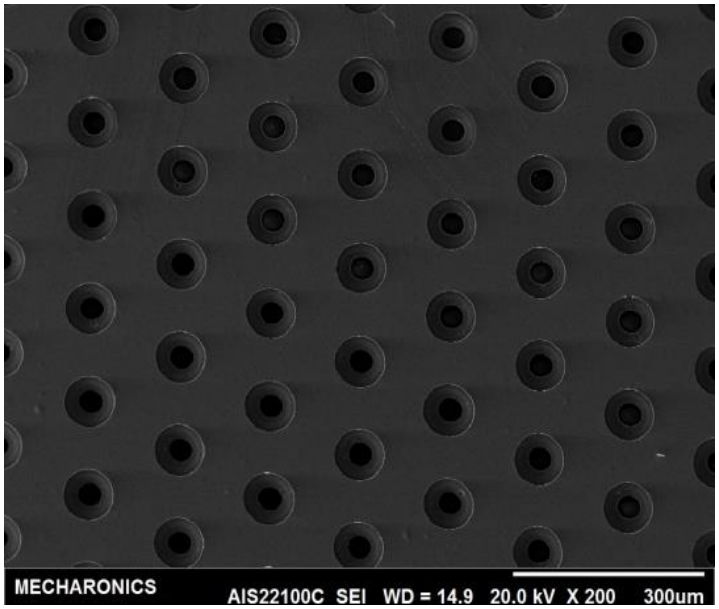


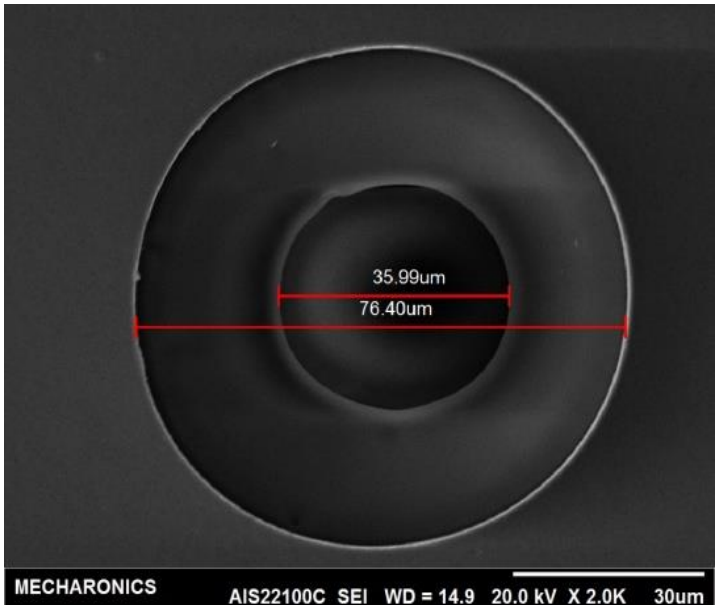
  - Finally we found the optimal PI etching condition in May. 2013

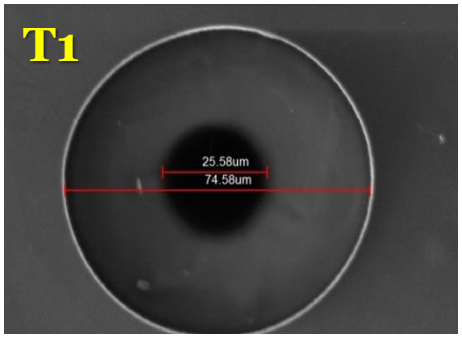


SEM images

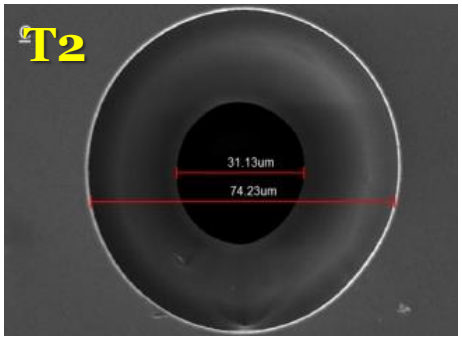
- We can control the PI hole shape & size!



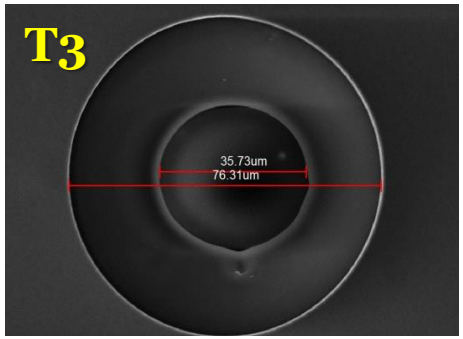




Condition A, 26μm



Condition B, 31μm



Condition C, 36μm

Getting HD GEM structure!

- KCMS & Mecharonics finally made the precision GEM foil ever produced!!
  - well received by CERN DG & CMS CB

한국 中企가 만든 부품
힉스입자 찾는데 쓴다

메카트로닉스 부품 공급

세계 과학계의 이목이 집중된 '힉스(Higgs) 입자'를 찾는 장치에 국내 중소기업 부품이 사용된다. 경기 광명시 송탄산업단지에 있는 메카트로닉스는 힉스 입자 연구를 하고 있는 유럽입자물리연구소(CERN)와 대형강입자가속기(LHC·Large Hadron Collider)에 들어가는 부품을 납품하기로 최근 계약을 체결했다. 국내 기업이 CERN에 LHC 부품을 공급하는 것은 이번이 처음이다.

이재정 메카트로닉스 사장은 "지난 4월 한국 물리학회 참석차 방문한 CERN의 롤프 호이어 소장과 물리학자들이 우리가 만든 부품을 보고 놀라움을 표시했다"며 "그 즉시 계약 체결이 추진됐다"고 밝혔다. 이 사장

이재정 대표

해 힉스 입자를 찾고 있다.

메카트로닉스가 공급하는 제품은 LHC에서 빛의 속도로 양성자를 충돌시키면서 나오는 입자를 확인하는 'GEM 검출기'에 사용되는 '쌤 포일(GEM foil)'이다. 이 부품은 얇은 박막에 정교한 구멍을 뚫어 입자를 수십 배로 증폭시켜 쉽게 검출할 수 있도록 한다.

CERN은 쌤 포일의 원천 기술을 보유하고 있지만 정교하게 제작할 수 있는 역량이 부족하다. 이 때문에 특허 임대를 통해 제품을 공급받는 방식을 취한다.

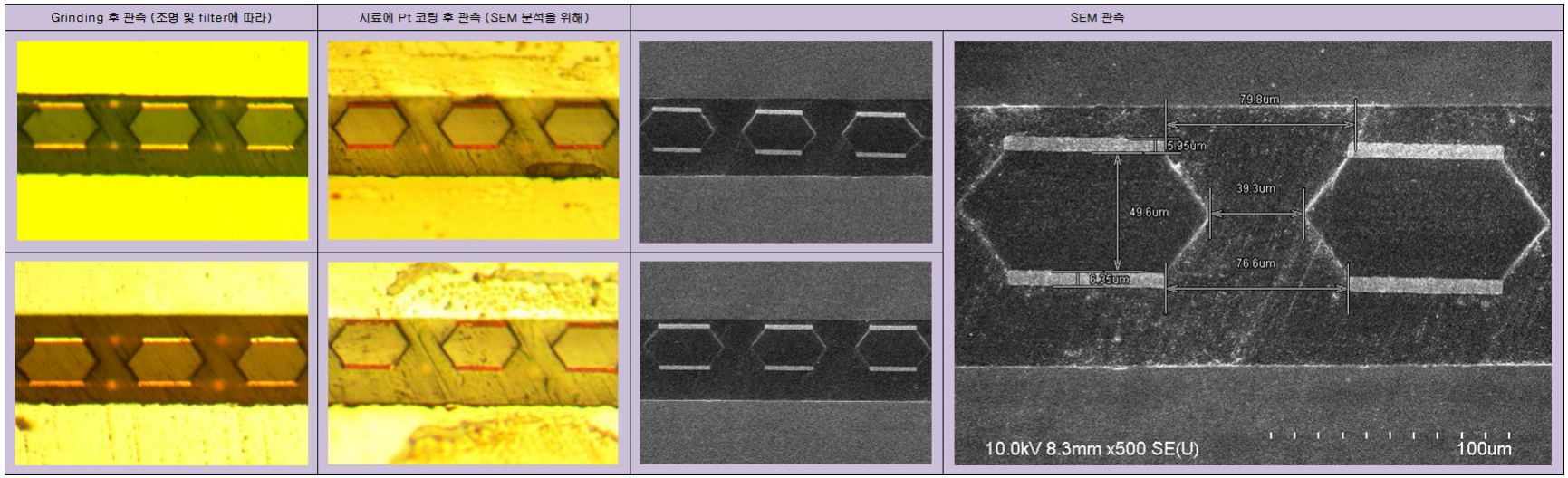
CERN은 한국의 반도체 공정기술이 뛰어나다는 점에 착안해 한국-[illegible]력사업으로 힉스 입[illegible]하고 있는 박인규 서[illegible]과 교수에게 의뢰했[illegible]분 끝에 메카트로닉스[illegible]한국 기업이 GEM 검[illegible]쌤 포일을 생산한다[illegible]할 만한 일"이라며 [illegible]진도 국제공동연구에 [illegible]립적인 역할을 할 수 [illegible]고 의미를 부여했다.

김미연 기자

매일경제

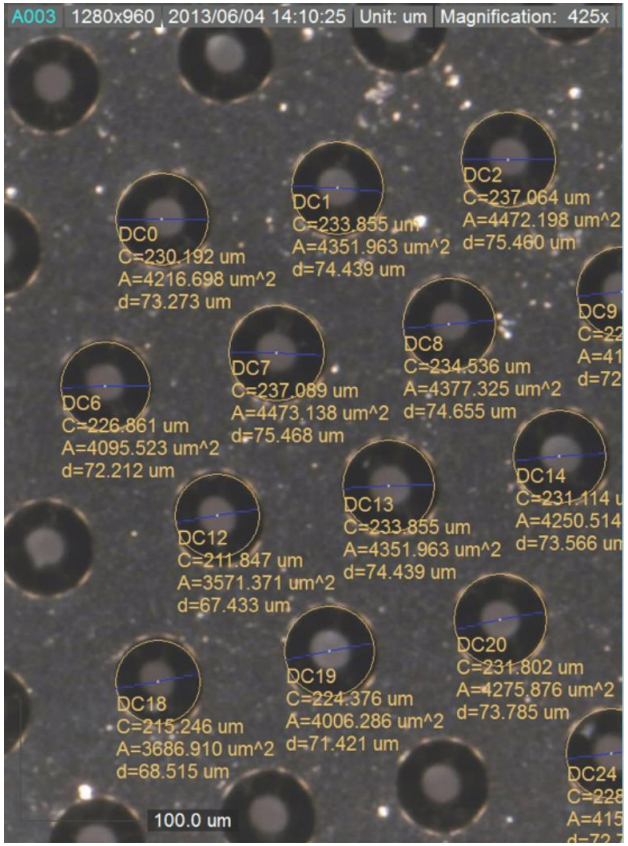
Best cross-sectional view ever achieved.

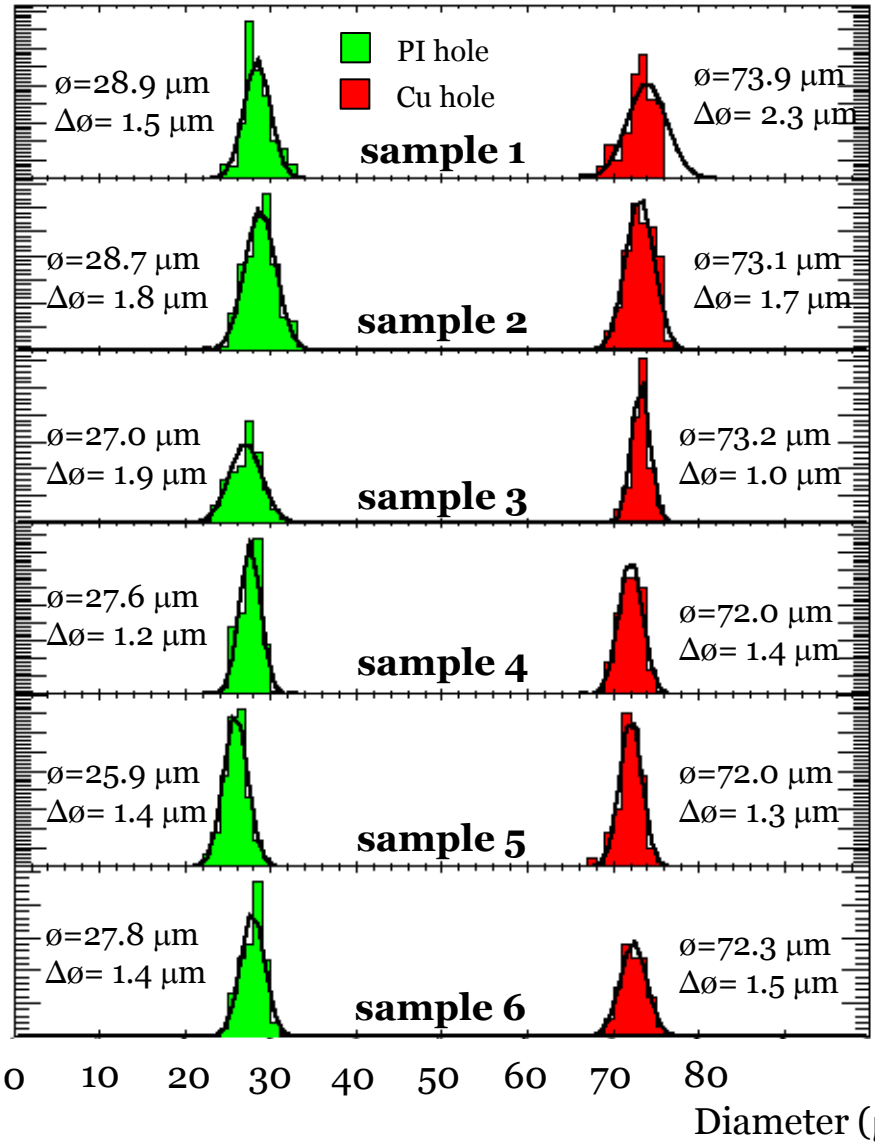
- **High Definition GEM**



Hole size uniformity

- very uniform, $\sigma < 2\mu m$
  - presented in MPGD 2013



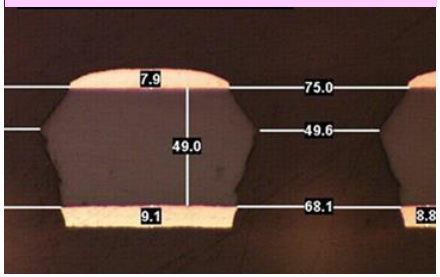


HD-GEM produced

- Seeing is believing. But a question?
  - Does HD-GEM perform better?
    - Cu & PI hole shapes do matter with gain?

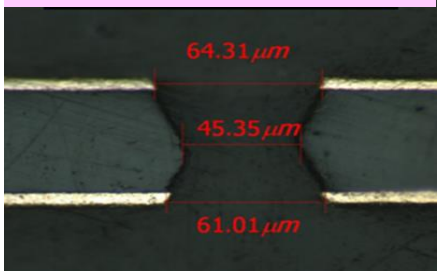
CERN technology

CERN



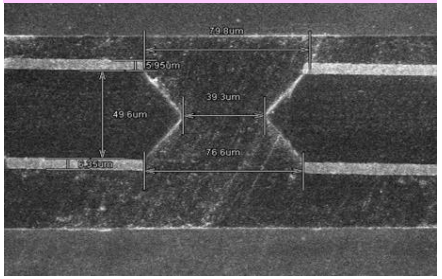
CERN tech / Korea made

Nflex-UPlus



KCMS & Mecha technology

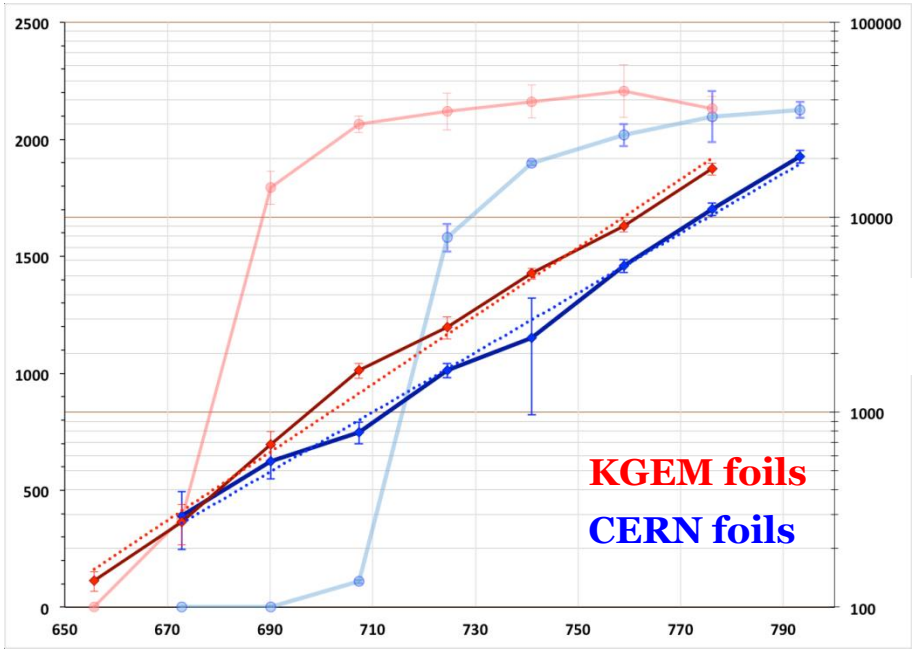
Mecharonics



- Is it worth to produce HD-GEM?
  - Benefits in gain, efficiency, resolutions, are expected.
    - But how much?
    - Cost effective?

CERN-GEM vs KCMS-GEM

- A good news from CERN (2014/02/17)
  - Two 10x10 GEM detectors were built for gain test.
    - One with CERN foils and the other with KGEM foils.
  - Roughly twice bigger gain was achieved
    - GEANT4 simulation is undertaken (see the following section)



Source: 55Fe (2-3MBq)
Gas: Ar/CO2 (70:30)
Gaps: 3/2/2/2 (Ceramic Divider)
+300kΩ HV filter

A Christmas card for CERN

- Just before the Christmas 2013, we made a very first version of Large-GEM ($100cm \times 50cm$)
  - We sent a Christmas card to CMS-GEM team

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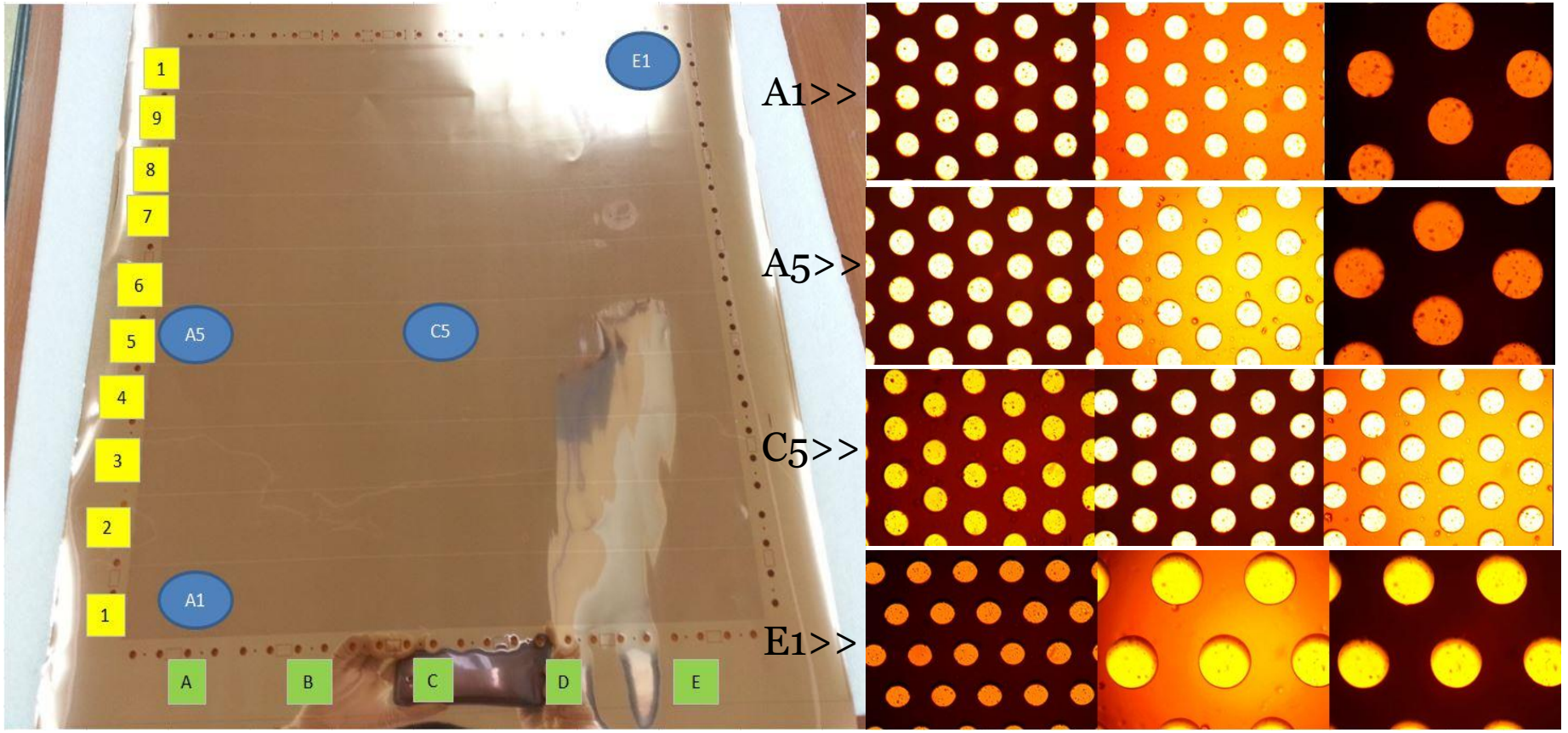
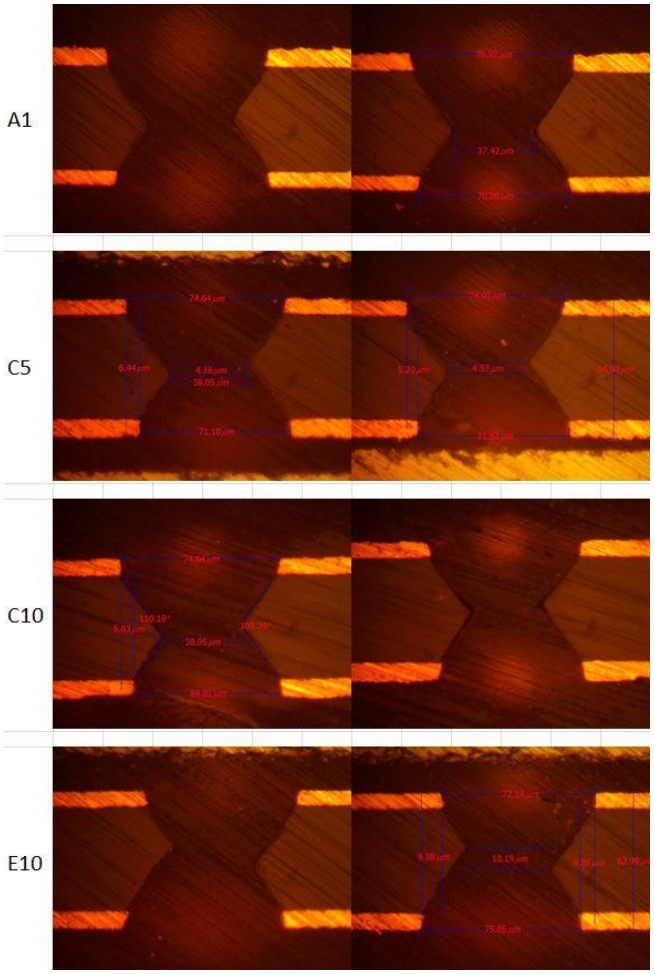
30 x 30 GEM is being tested

- Our newly produced 30x30 GEM are at CERN now.
  - Hole shapes are all O.K. as in the 10cm x 10cm foil case.
    - some minor misalignments exist.



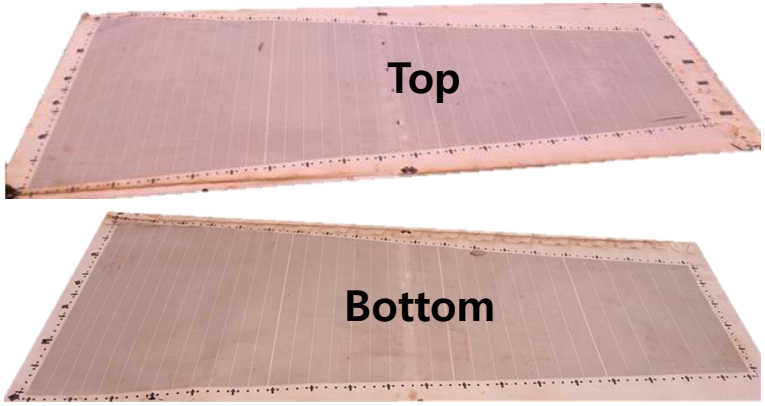
30 x 30 foil: inspection result

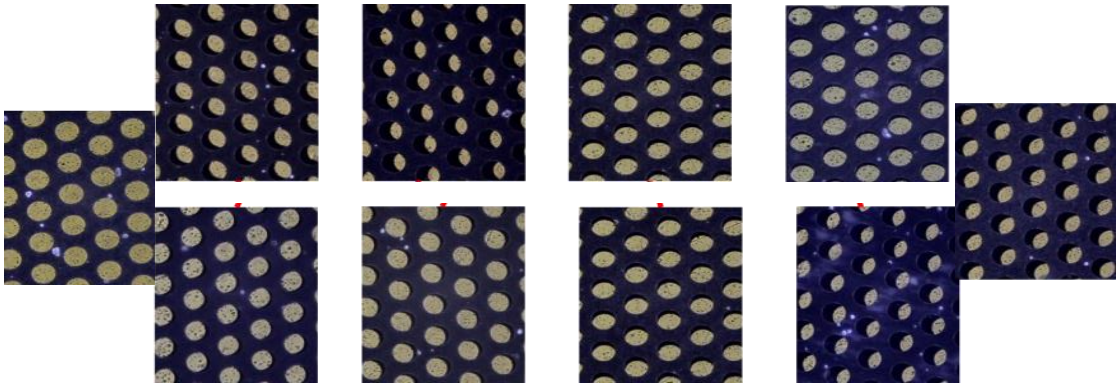
- Near the edge-most side, there are some minor misalignments
  - Production was done by film mask
  - Can be easily fixed by
    - Further alignment or glass mask



Large size GEM foil production

- Avery first large size GEM foil was produced in 2013.
  - Double side copper lithography (Using double-mask method)
  - No Q/C was done, but misalignments up to 30μm were found





- For Large size GEM foil production,
  - We need the glass mask for better alignment and we do need to buy a large size photo lithography machine (~ 1M$)
    - This is a huge investment and it may need some bureaucratic arrangement between KCMS and our FA.

Current status of GEM foil production

- **We have created various sizes of GEM foils so far.**
  - **We plan to produce some other dimensions too**

Dimension	Foil production	Gain test
$5 \times 5\ cm^2$	done	-
$10 \times 10\ cm^2$	done	done
$20 \times 20\ cm^2$	-	-
$30 \times 30\ cm^2$	Done	being tested at CERN now
$50 \times 50\ cm^2$	Planned in mid 2014	-
$100 \times 50\ cm^2$	Test production done	-

  - **We plan to focus on the large size GEM foil production after the 30 x 30 detector gain test.**

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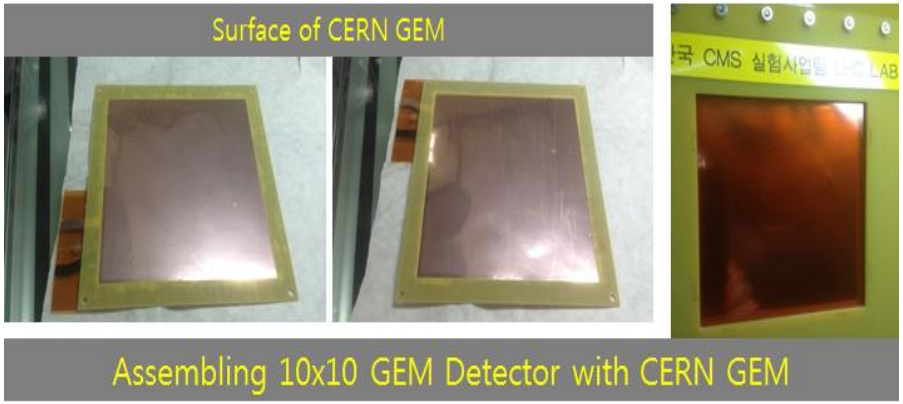
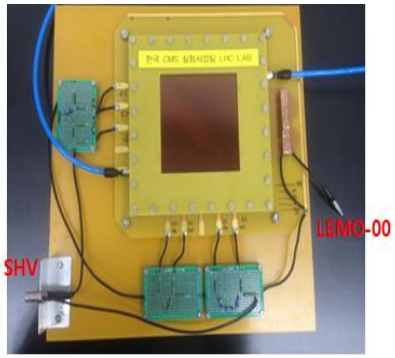
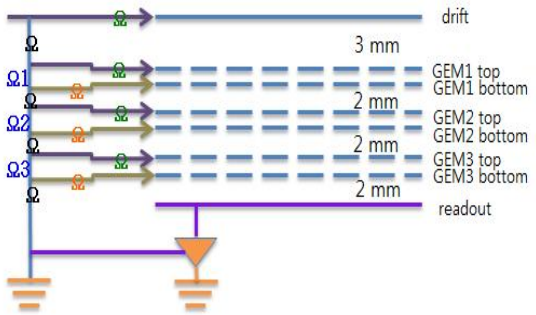
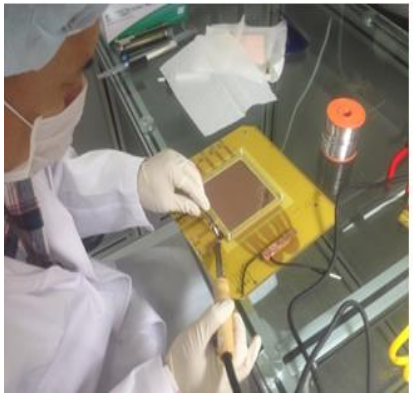
Detector construction at UOS

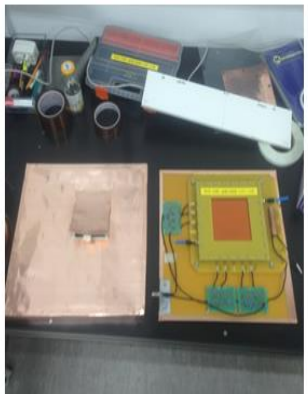
- We have successfully built a first 10x10 prototype GEM chamber in Korea

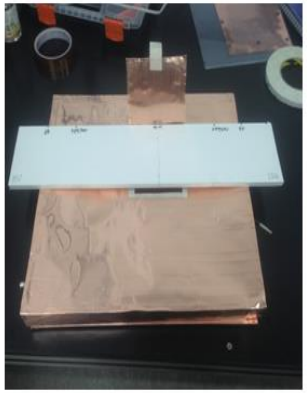






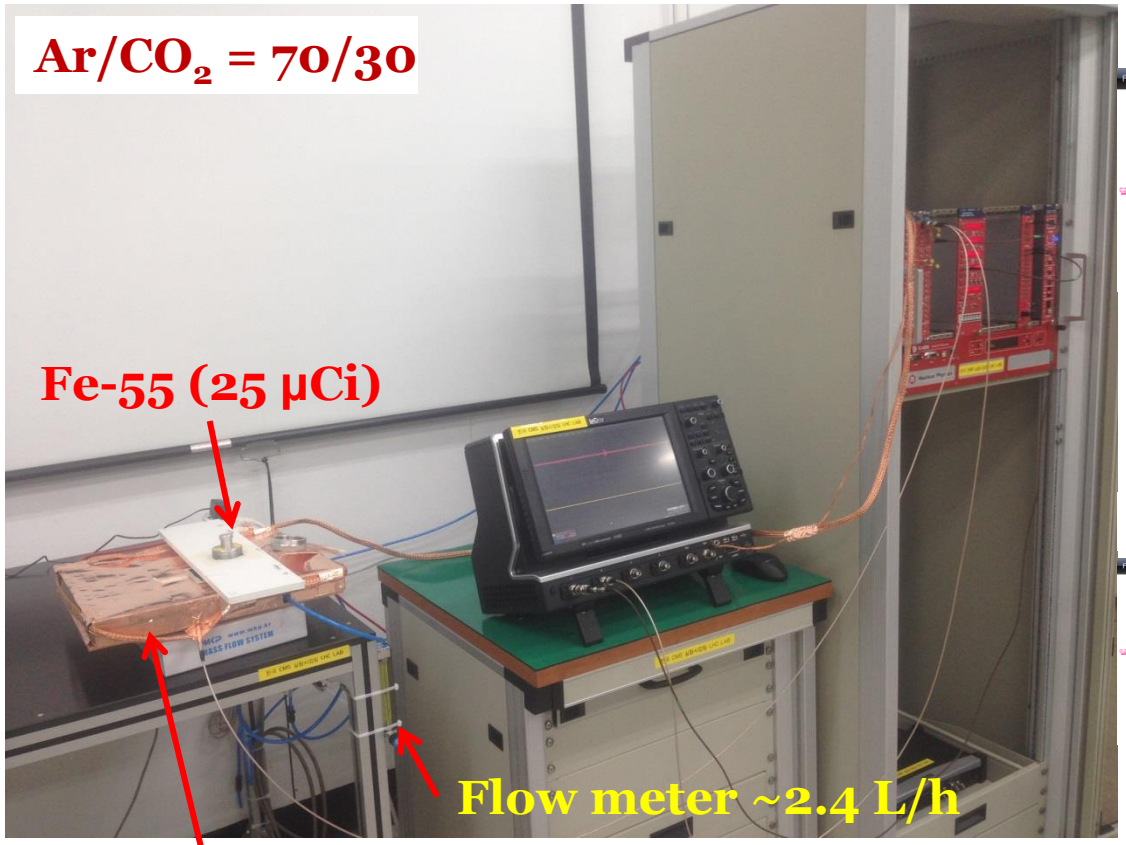




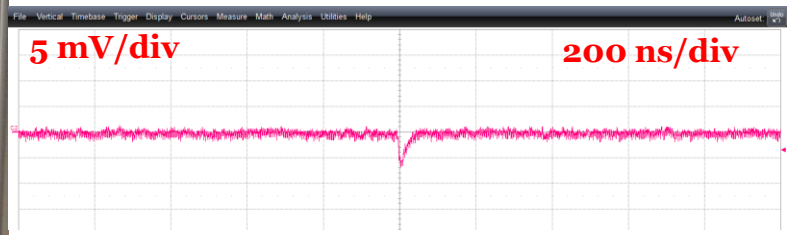


Detector construction at UOS

- Operational test of prototype GEM detector at University of Seoul (Korea)

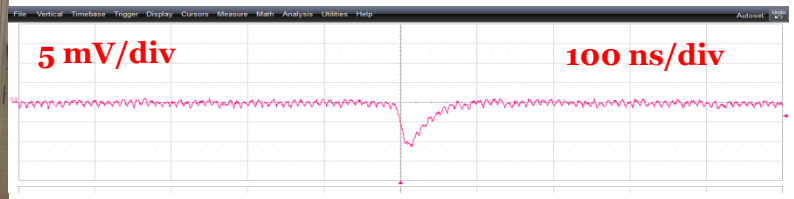


V_{drift} = -3800 V (I_{total} = 706.45 μA)



Rate and pulse height are increased.

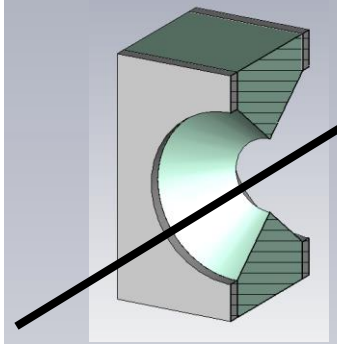
V_{drift} = -4000 V (I_{total} = 745.6 μA)

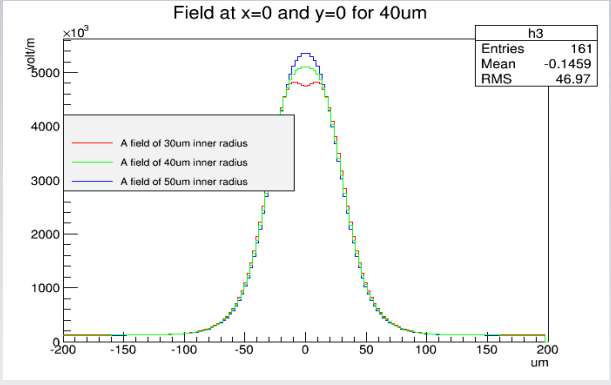


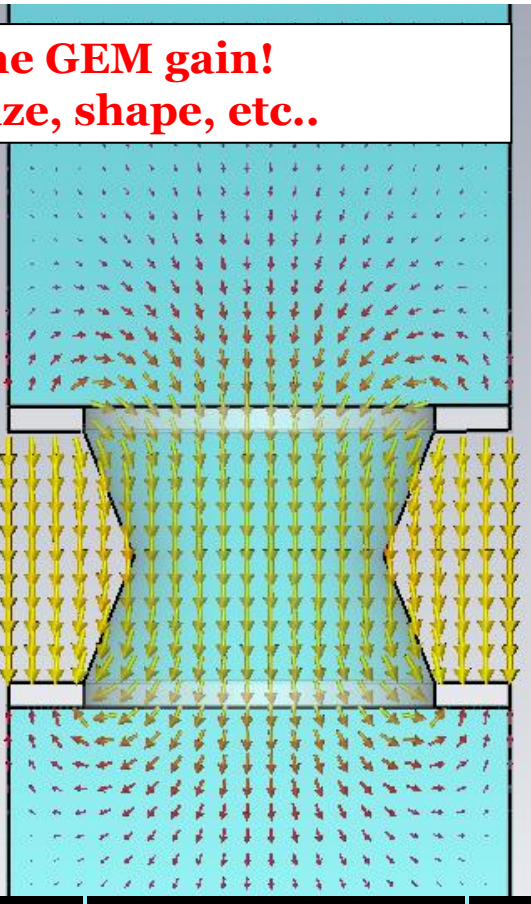
We see that our detector works!

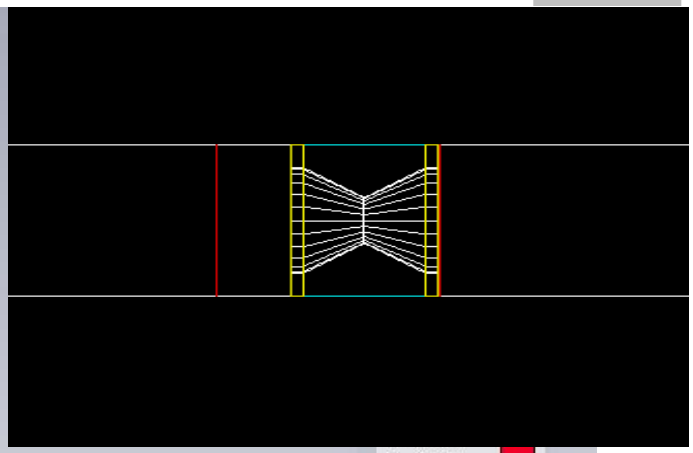
GEANT4 simulation

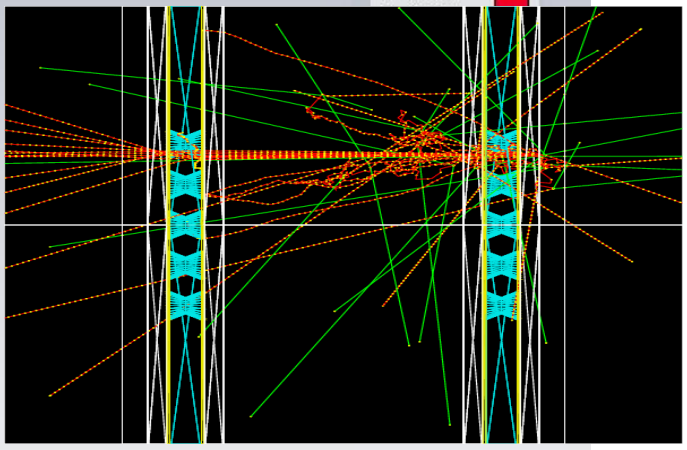
Motivation: Understanding the GEM gain!
→ vary Cu hole size, PI hole size, shape, etc..

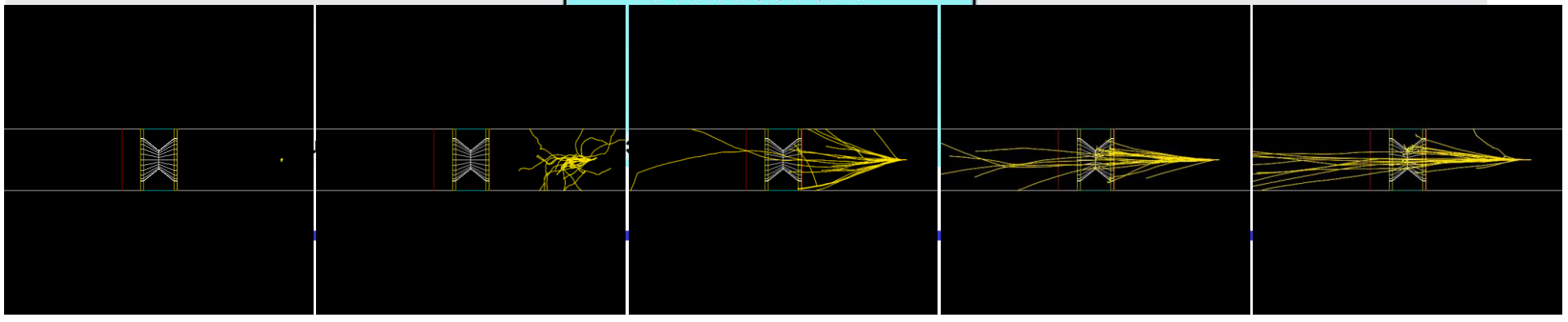












Contents

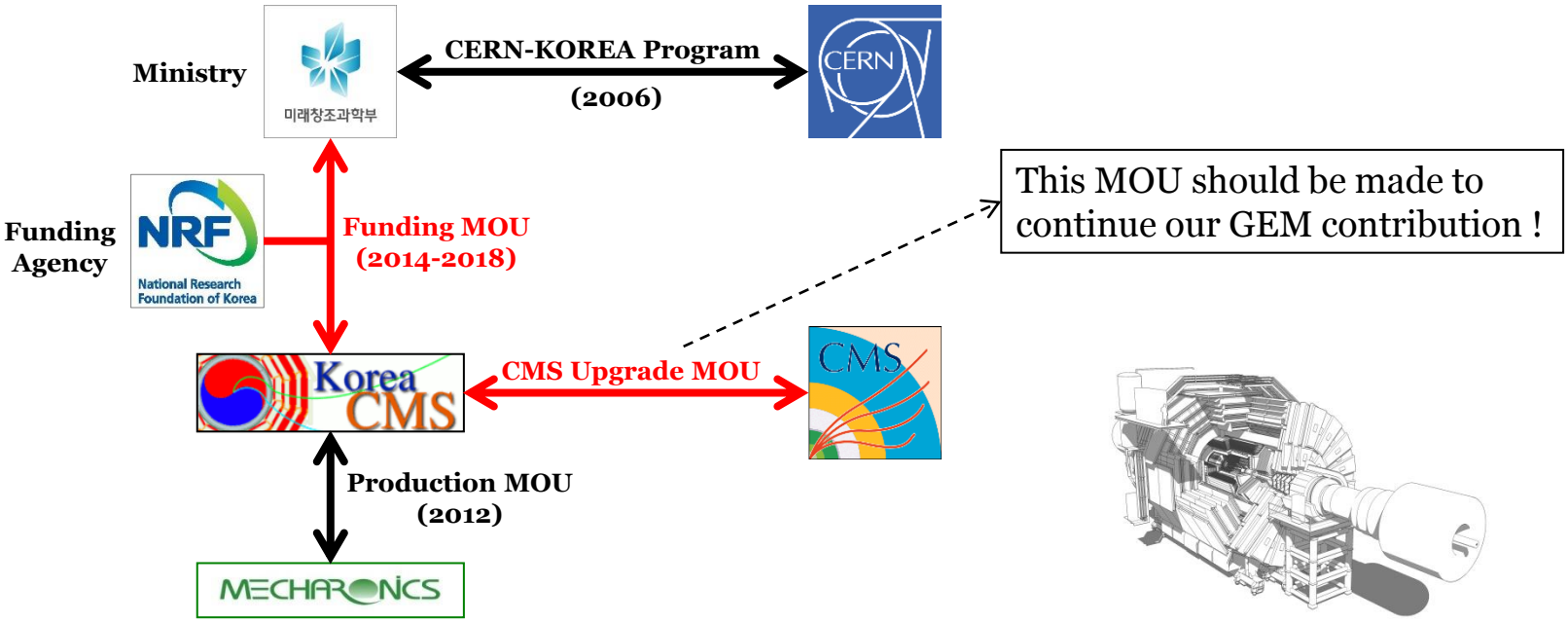
1. Introduction to Korea-GEM team
2. A brief history of KGEM foil production
3. Status of GEM foil production
4. Other GEM related R&Ds
5. Things to do

Summary

- KCMS GEM TF → So far extremely successful
  - GEM & H/W team
    - High definition GEM produced (10 x 10), twice gain achieved.
    - 30 x 30 GEM foils were produced and they are under test now at CERN
    - We will focus on the large size GEM foil production in 2014
  - TDR & S/W team + Physics team
    - We made many achievements for TDR (Trigger, SW, ED, Physics)
    - We launched a GEANT4 simulation program to understand the GEM performance in microscopic view point.
- For large size GEM foil production, we need a further investment which can be doable upon some administrative works between KCMS and our FA.

Remarks

- **We do need to start some management works NOW for the CMS LS2 upgrade participation officially.**
  - **Our goal is to make all MOUs signed during the CERN-Korea Committee in Oct. 2014**
    - **Red lines are to be signed.**



Industrialization of GEM foil development in India

- **NPD-BARC, Mumbai &**
- **Micropack, Bangalore**

Company Brief

mp

- 100% privately owned Indian company.
- Focus on fabrication of bare PCBs for aerospace and defence
- Strategy to focus on small volume / high mix segment
- Factory is located at Jigani Industrial Area, in Bangalore, in 10 acres of land with a built-up manufacturing area of 60000 Square feet.
- Installed capacity of 30000 Square meters per annum.
- 170 employees, all technically qualified and trained to handle specialized processes.
- Presently manufacturing multilayer PCBs up to 30 layers.
- Fabricates approximately 450-500 designs every month including 300-350 fresh designs.
- In-house facility for all operations

www.micro-pack.com

Discussions at CERN

mp

- **Thin Polyimide GEM foil technology introduced to Micropack by NPD-BARC team in Aug 2013**
- **Visited CERN , Geneva on 15th Nov 2013**
- **Discussions with**
  Dr. Rui De Oliveira
  Dr. Andrey Marinov
  Dr. Tim Tsarfati, Technology Transfer Officer
- **TOT agreement terms agreed by Micropack**
- **2 year road map as per the TOT finalised in December 13**

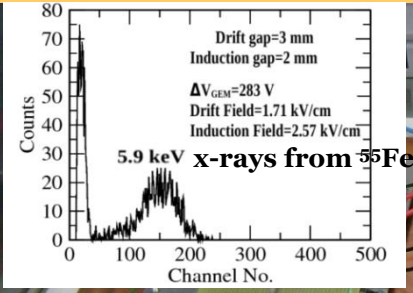
MICROPACK ROADMAP

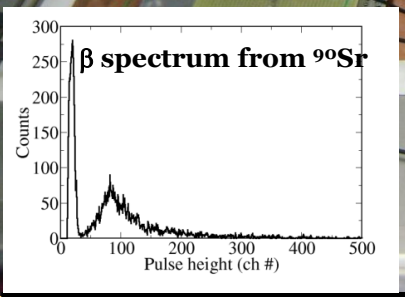
S.No.	Item	1Q		2Q			3Q			4Q			1Q			2Q			3Q			4Q		
		2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
1	**License Agreement**																							
2	**100 x 100 Fabrication and QC Validation**																							
	- Rebuild equipments/utility for GEM Foil																							
	- Prepare raw materials(FCCL, mixed chemicals)																							
	- develop the ***prototype***																							
	- QC validate the prototype @COMPANY																							
	- QC validate the prototype @COMPANY																							
3	**100 x 100 Routine and standard production , 300 x 300 R&D**																							
	- ***100 x 100 routine*** & standard production																							
	- develop the ***prototype of 300 x 300***																							
	- QC validate the prototype @COMPANY/CERN																							
4	**300 x 300 Routine and standard production , 500 x 500 R&D**																							
	- ***300 x 300 routine*** & standard production																							
	- develop the ***prototype of 500 x 500***																							
	- QC validate the prototype @COMPANY/CERN																							

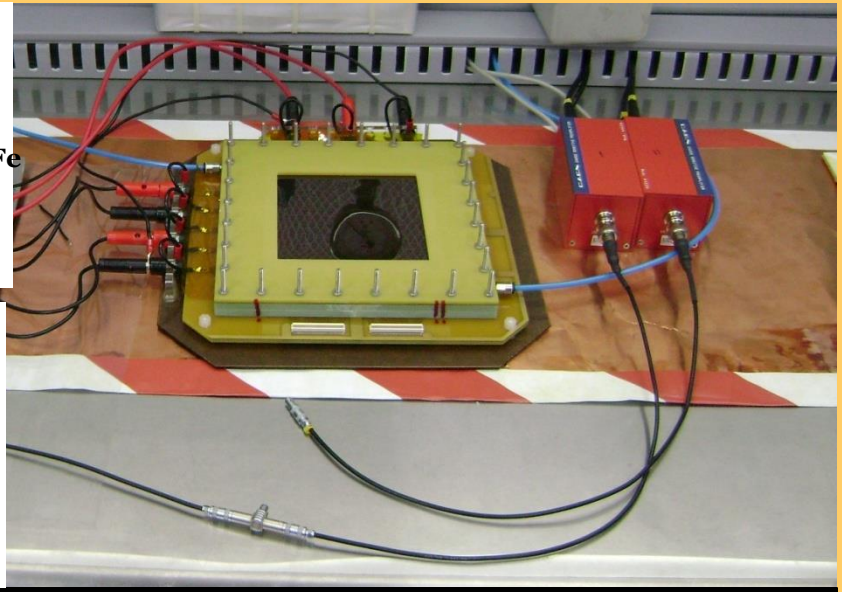
Delayed for want of raw materials

The existing Laminar Air Flow Table (class 100) and the adjoining area being expand ed and will be provided with a gradient from class 10,000 to class 1,000 for assembly of GEMs at NPD-BARC

Three channel gas mixing system for Ar, CO_2 and CF_4 with MFCs for a 5 lph flow already exists in the lab. CF_4 yet to be procured







Testing of a Single GEM with voltage divider and P-10 gas : NPD-BARC : 2012

@ NPD-BARC : 2012

The existing space (shown with RE42 bottom gap for RE4 upgrade of CMS) being converted to GEM testing table with x-ray source and shielding

RE4/2 Bottom gap under leak and spacer test

Shielding

Laminated plyboard : Lead : Aluminum :: 20 mm : 1 mm : 3 mm

Dimensions : 2.5 m x 1.3 m x 1.0 m

X-ray gun

AMPTEK with Gold target

Commissioning by Sept 2014

@ NPD-BARC : 2014

Industrialization of GEM foil development in India

- ToT signed and agreed between CERN and Micropack Ltd., India : Jan 2014
- Difficulties in procuring the Cu clad polymide and the photoresist
- Waiting for arrival of Cu clad polymide foils from CERN via BARC
- Augmentation of resources for trial runs for the first 10 cm x 10 cm GEM foil
- Mask with 70 μm diameter holes at 140 μm pitch, getting ready
- First 10 cm x 10 cm GEM foil may roll out by third/fourth quarter of 2014
- Meeting between BARC and Micropack personnels next month to freeze the Action Plan
- Rui from CERN visiting Micropack and BARC in October 2014.