

# Large Area GEM Production at Peking University



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On behalf of CMS Muon Group

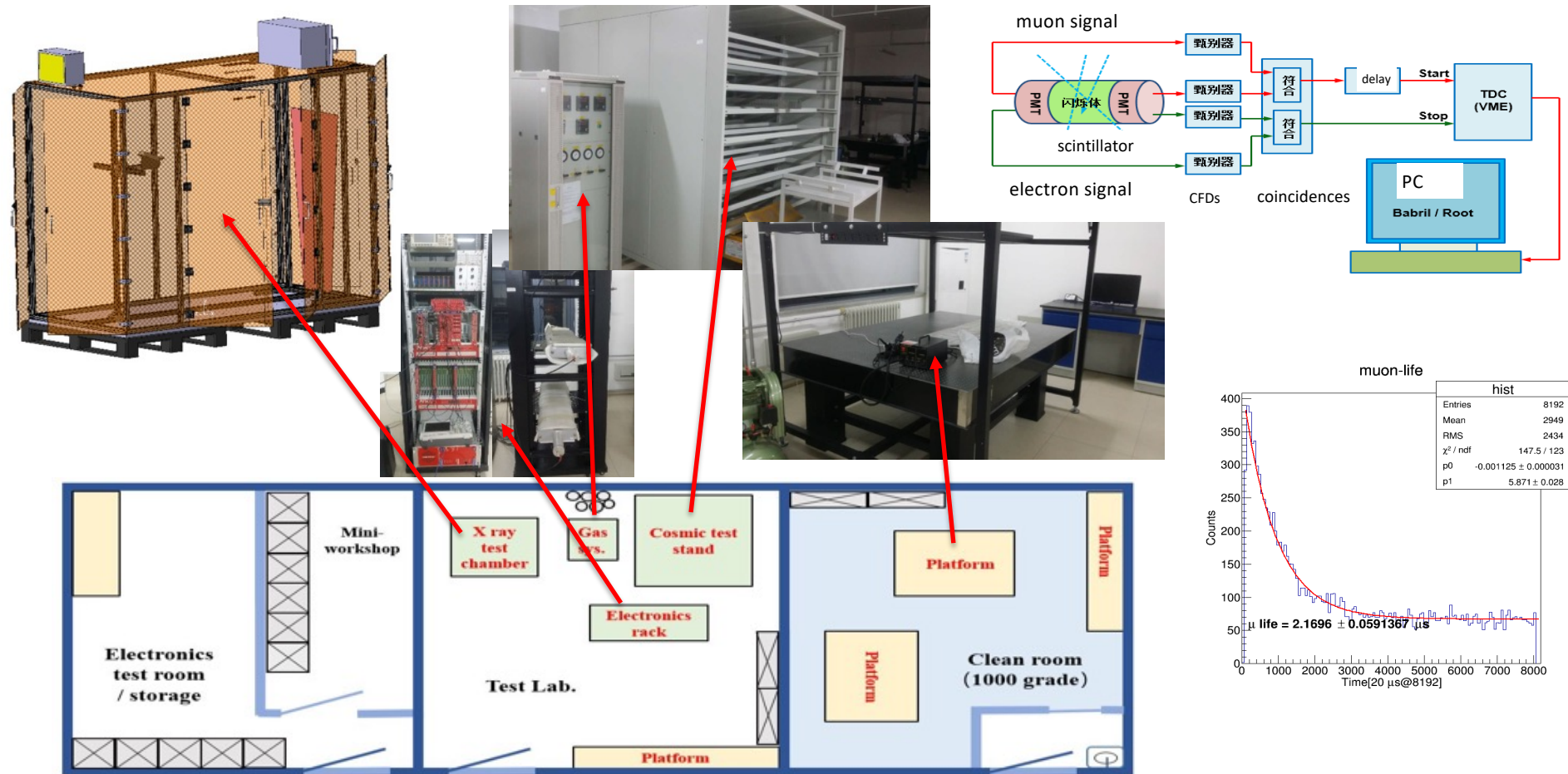
CEPC workshop, Hangzhou, 2024.10.25

# Outline

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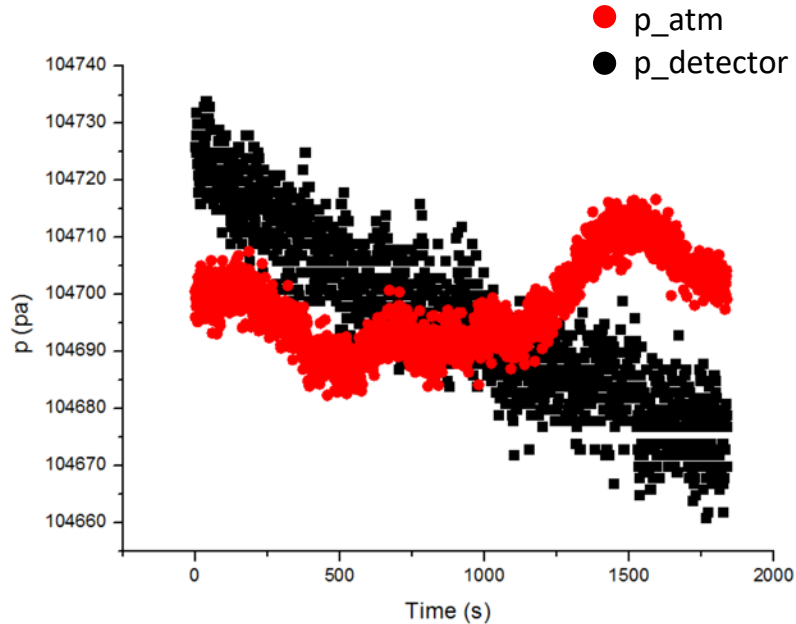
- PKU-HEP local lab development and setups
- CMS Phase-II GEM upgrade projects and PKU tasks
- Large area GEM assembly and QC tests
  - GE2/1 M5 production and QC tests
  - ME0 production and QC tests
- Summary and Outlook

# PKU-HEP Lab development: layout and facilities

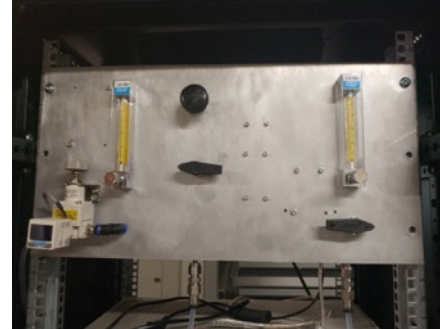


# PKU-HEP Lab set up: Gas Leak Test

Gas Leak Test platform established and verified with a RPC:



gas leak test result with a glass RPC detector

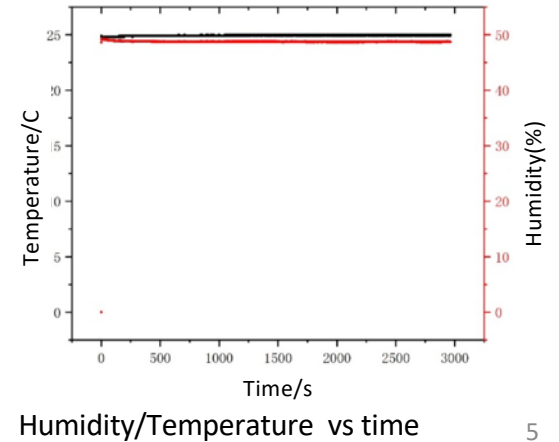
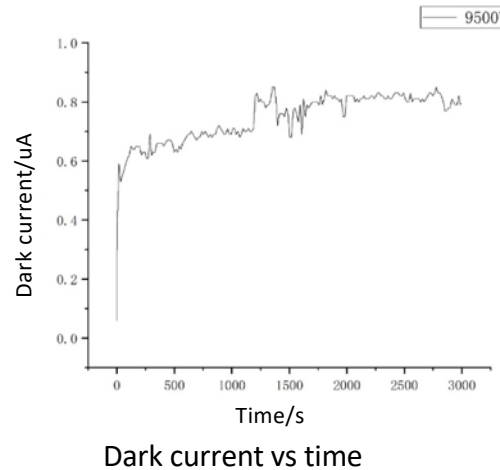
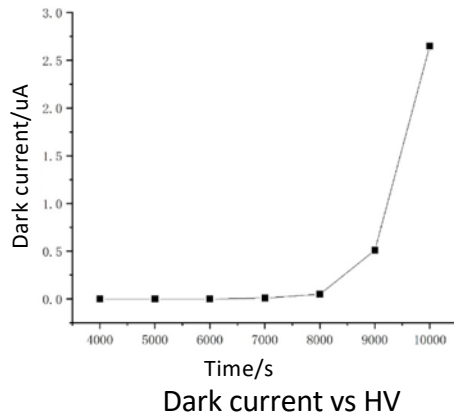
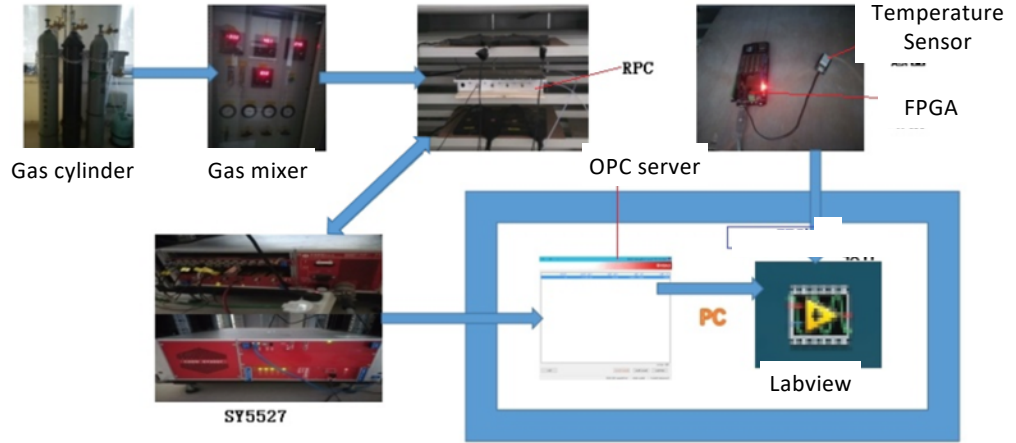


Front and back panel of the updated leak test system

Arduino  
+  
BMP085  
+  
BME280

# PKU-HEP Lab set up: I-V and H/T Test

- A system for automatically monitoring was established using LABVIEW
- The system was functionally tested using a RPC detector.



# PKU-HEP Lab test stands



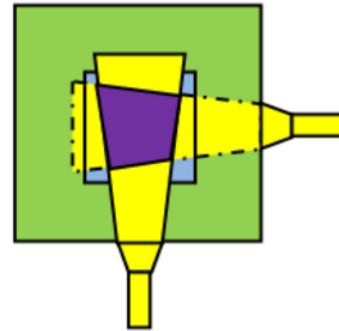
Picoammeter



3-d trail

X-ray shielding room  
With a three-dimensional movable trail inside  
to fix the chamber for testing

## Cosmic test stand

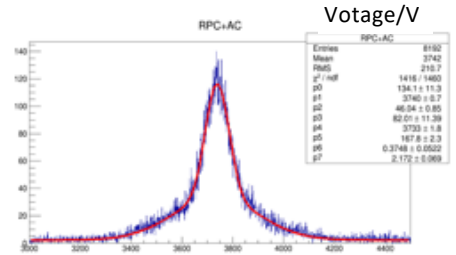
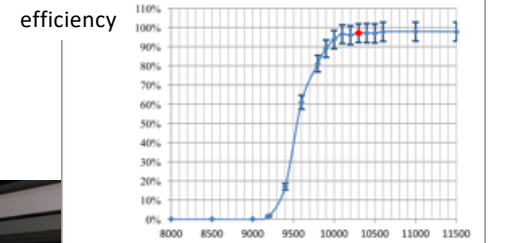


Scintillator trigger

A cosmic ray test stand built with a scintillators as trigger and a glass RPC as test object

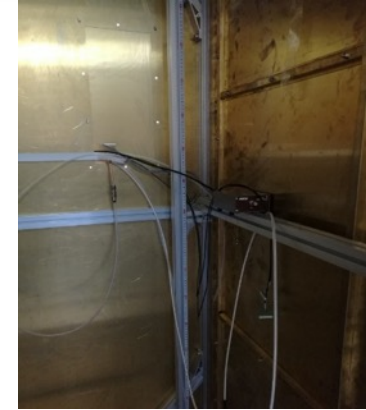


Testing RPC at the cosmic stand

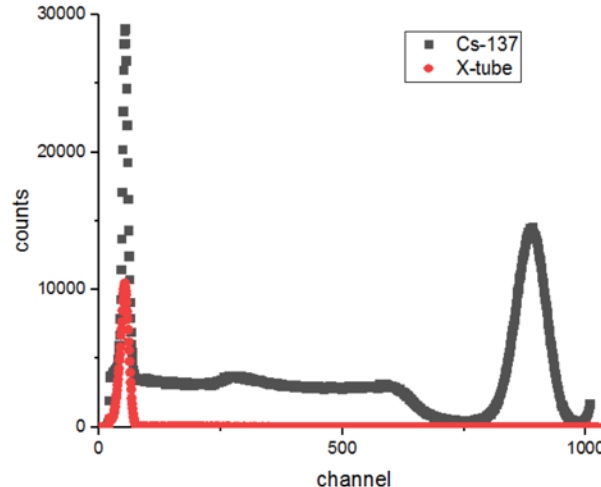


Time resolution

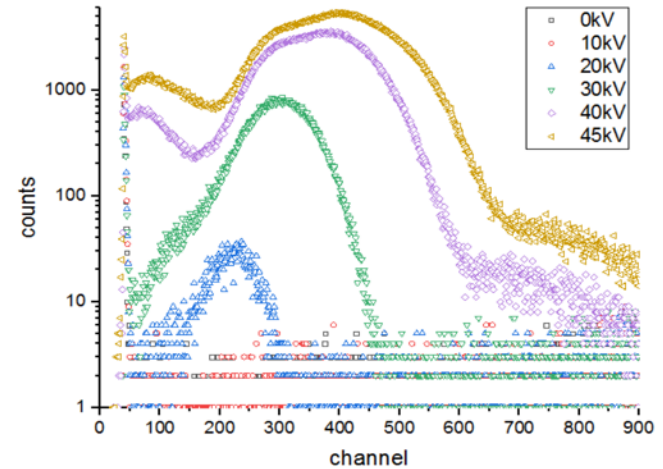
# X-ray test chamber



Target: Ag  
Tube Voltage: 0-50kV  
Tube Current: 0-1mA  
Max Power: 50W

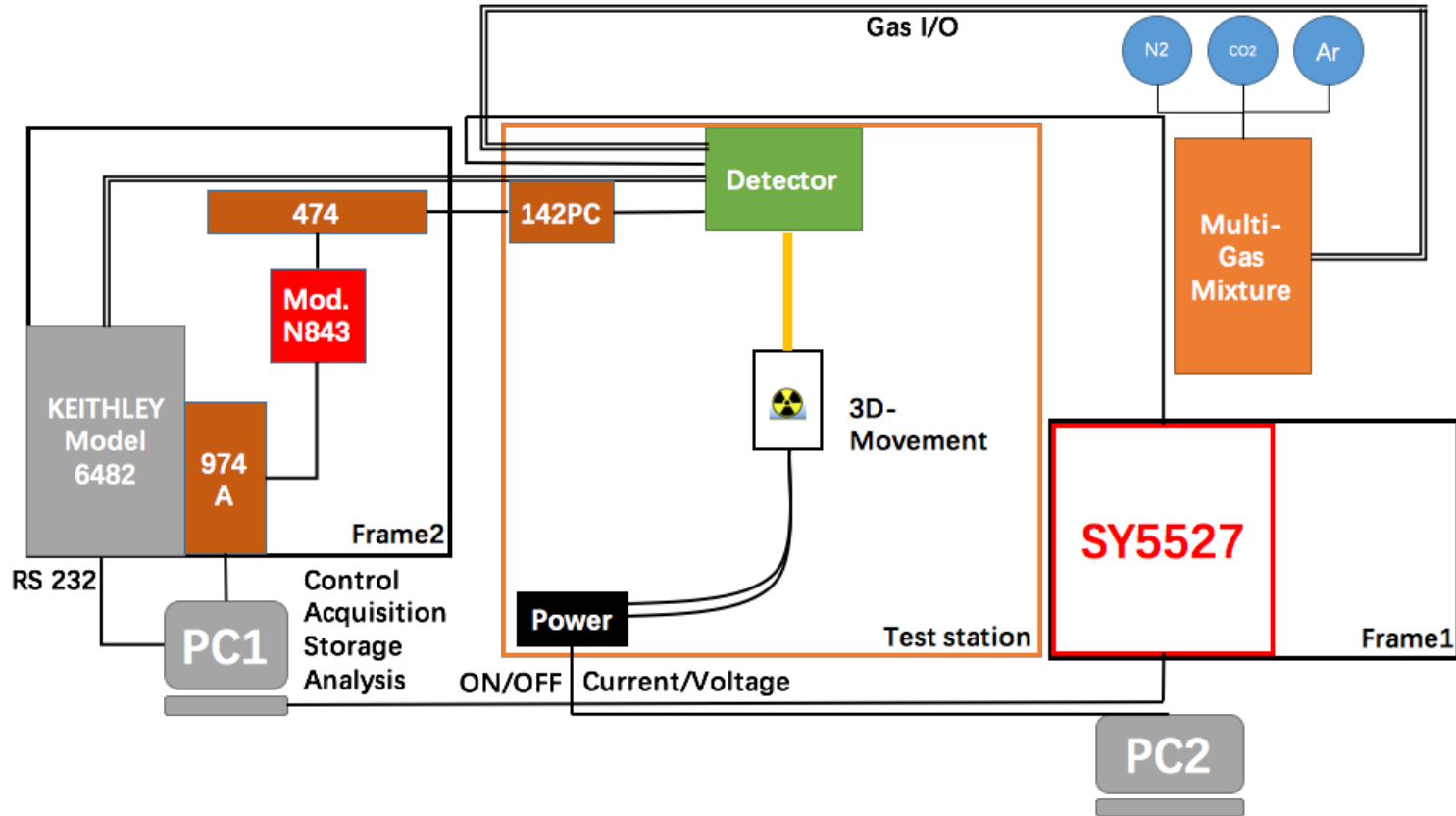


Energy spectrum of X-ray tube with 40kV compared to Cs-137



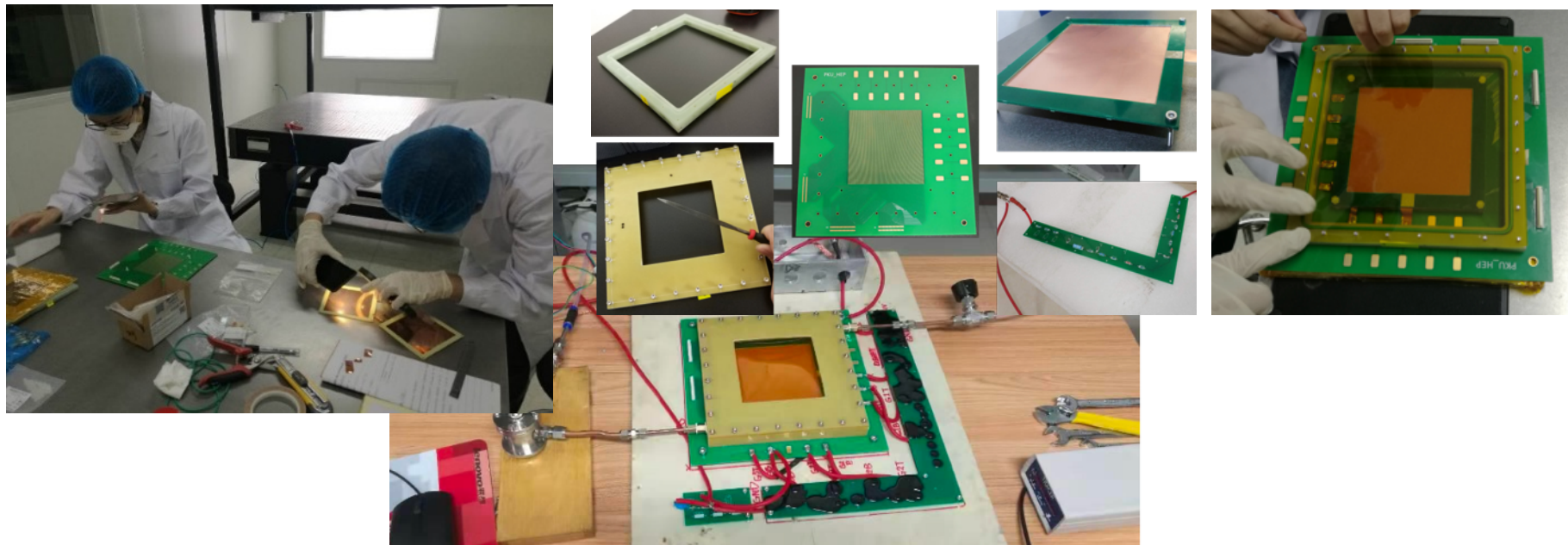
Energy spectrum of X-ray tube at different voltage

# Lab set up: effective gain test scheme





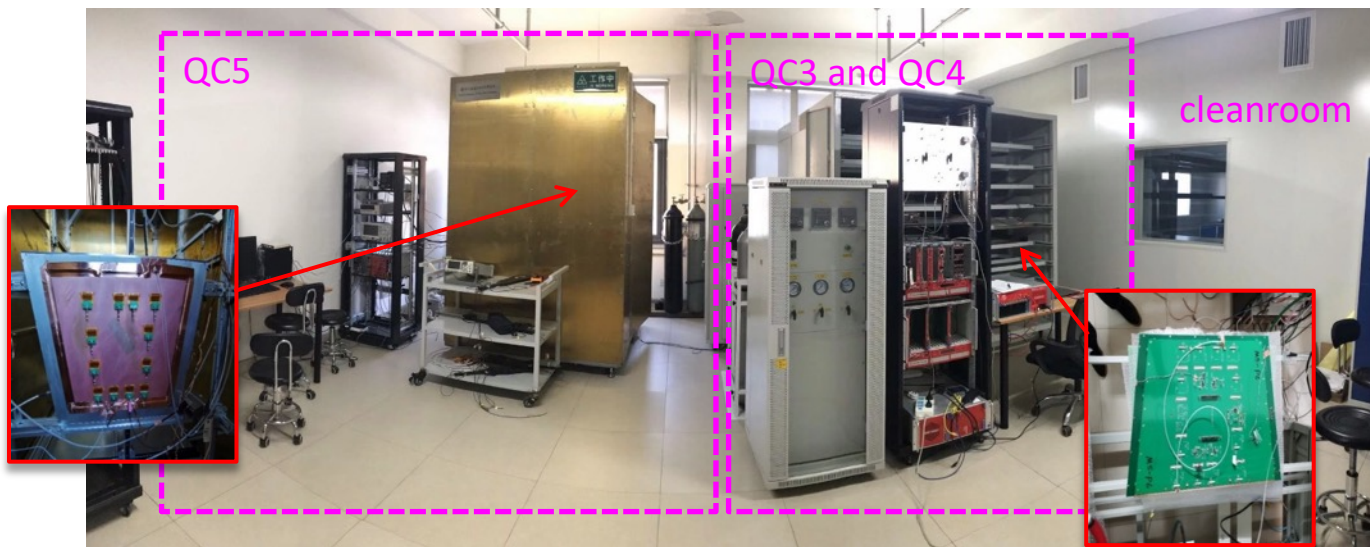
# Design and Test of a 10x10cm<sup>2</sup> GEM detector



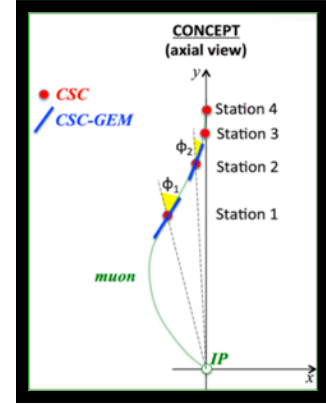
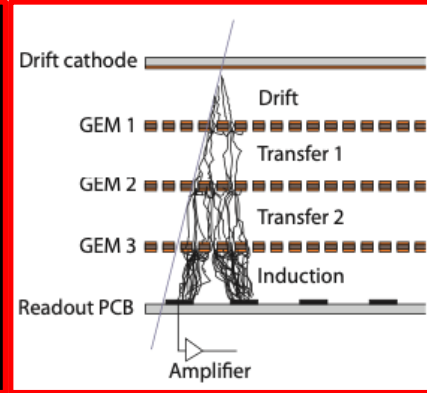
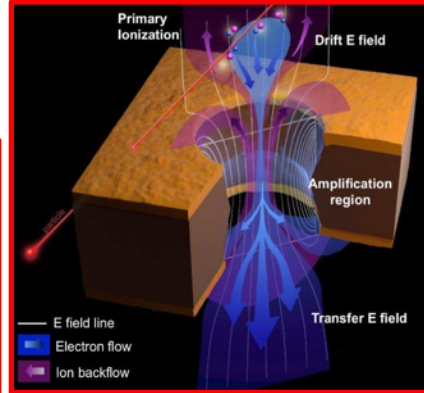
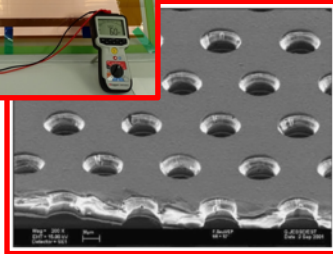
- GEM foil from CERN MPT workshop
- Readout board, drift board, frame and high-voltage distributor designed and manufactured locally
- Mastered relevant technologies
- Made preparations for CMS GEM assembly site certification

# The certified set up for GEM assembly and test

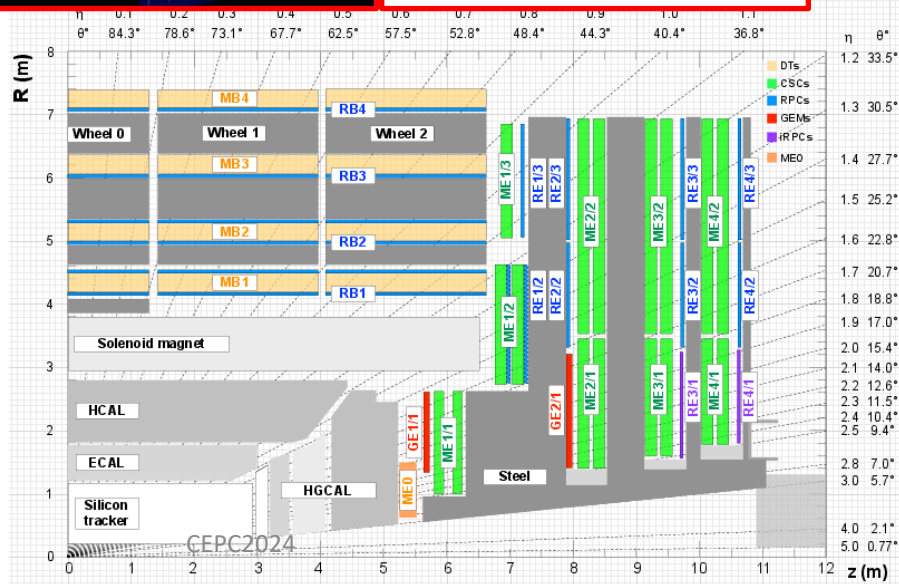
- Some assembled chambers are sent from CERN for testing procedures
- The final CMS GEM assembly site certification was achieved in 2021-22



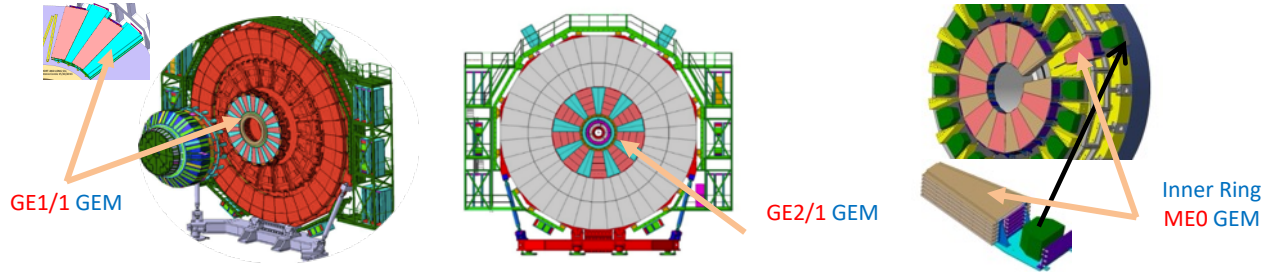
# CMS phase-II GEM upgrade projects



- The use of GEM technology in the endcap muon station will help to maintain or even improve the forward muon triggering and reconstruction in the region  $|\eta| > 1.6$  in the phase of high luminosity.



# Project overview and PKU contributions

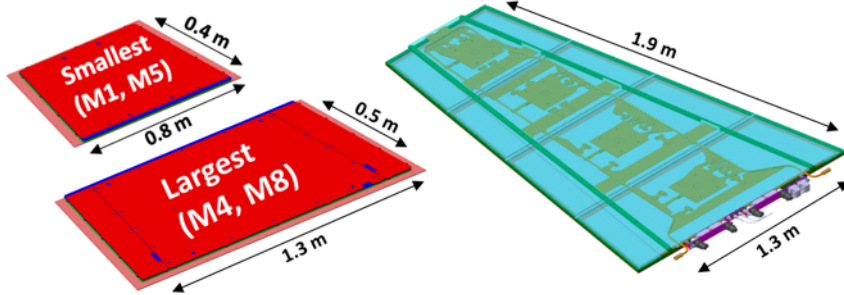


	GE1/1	GE2/1	ME0
Numbers*	288 (=2×36×4)	288 (=2×18×8)	216 (=2×18×6)
CMS-China Tasks (Led by PKU)	Production and test of all electronic boards(GEB) Participate assembly, test and commissioning at CERN	Design, production and test of all electronic boards(GEB) Assembly and QC of ~1/8 GEM detectors at PKU, Participate assembly, test and commissioning at CERN Production of external frames, mechanical structures, etc	Design, production and test of all electronic boards(GEB) , Assembly and QC of ~1/5 GEM detectors at PKU, Participate assembly, test and commissioning at CERN Production of external frames, mechanical structures, etc

\* (Total number= #endcap×#module/endcap×#/module)

# GEM detector design: GE2/1 and ME0

- Both are using triple-GEM technology
- The full GE2/1 system: 72 chambers (36 per end-cap)
  - 4 triple-GEM modules per chamber = 288 modules in total
  - The chambers are arranged in two layers
- Two different types of chambers
  - On-Yoke= FRONT-type (module types M1-M4)
  - Off-Yoke= BACK-type (module types M5-M8)

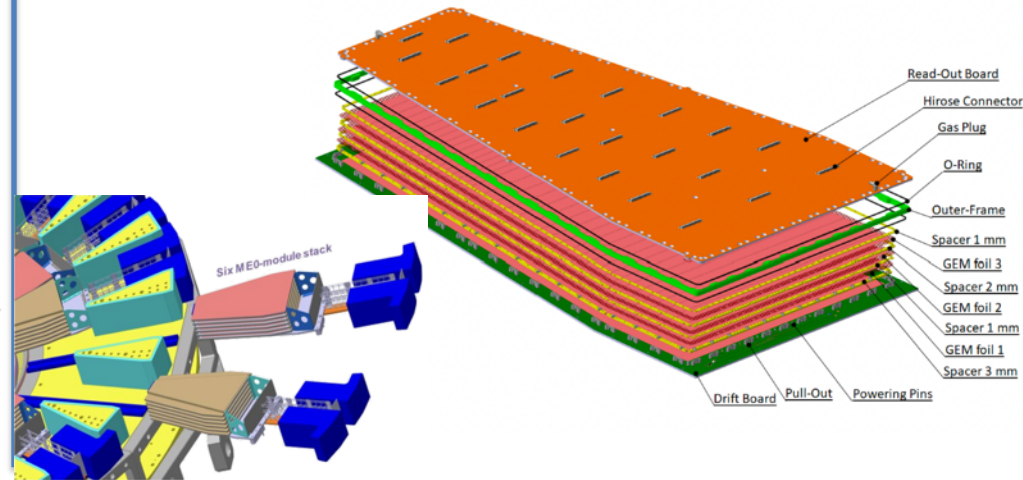


8 slightly different triple-GEM modules (M1 to M8)

2024/10/25

Off-Yoke (M1 to M4) and On-Yoke (M5 to M8) chambers

- ME0 system: 216 chambers (108 per end-cap)
  - 6 triple-GEM modules per stack
  - 18 stacks per endcap
- Harsh environment and limited space
  - Rate Capability:  $>150\text{kHz/cm}^2$
  - Longevity: Need to survive integrated charge up to  $7.9\text{C/cm}^2$ .



CEPC2024



# GEM assembly and test schemes

**CERN**

QC 1: material inspection

QC 2: GEM foils test (fast + long)

**Production sites  
(e.g. PKU)**

QC 2: GEM foils test (fast)

Assembly preparation + Assembly

QC 3: gas leak test

QC 4: HV test

QC 5: gas gain calibration

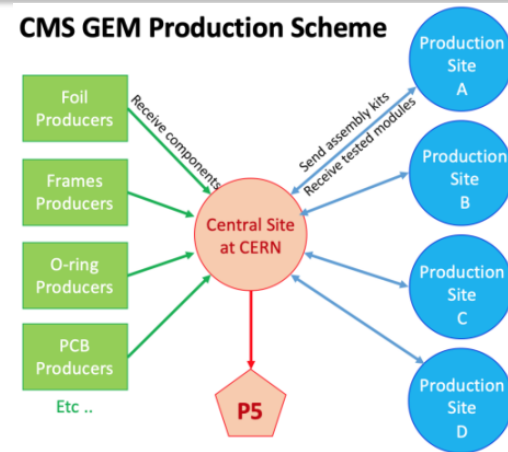
**CERN**

QC 6: HV stability test

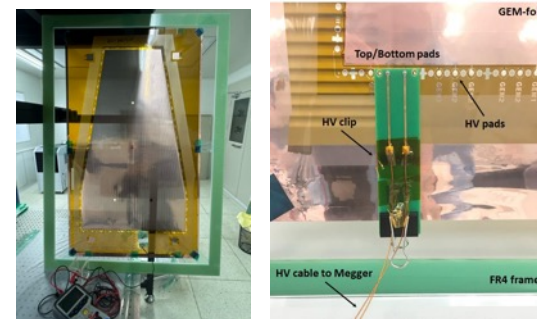
QC 7: electronics connectivity test

QC 8: cosmic ray test

## CMS GEM Production Scheme



QC2 (ME0 chamber)



short impedance test

# GE2/1 M5 assembly at PKU lab(2022-23)

GEM探测器组装步骤

01 清洗有机玻璃罩前盖板	33 在GEMstack上放置上屏有机玻璃保护板(注意准直)。按上屏两个角上两个螺钉
02 插入内板蒙罩导针	34 拧上中心支撑杆螺钉(不要太紧)
03 插入前置第一屏内板架(3mm厚)。T-nuts接口朝上。朝外。盒边缘上标记孔数目与板数一致	35 拧上读板边板螺钉(除了盒边缘上两个预锁固定螺钉)
04 放置中心支撑杆和3mm厚盖	36 拆除GEM Stack上有机玻璃保护板边沿外的GEM读板边沿部分
05 在G1 GEM读板边沿去胶GEM2和GEM3高压接触点	37 清洗读板板(观察读板push-out是否有损坏)
06 清洗G1 GEM读板	38 把读板移离有机玻璃板螺钉固定安装在平台前置板前板上
07 用Megger测试G1 GEM读板	39 把读板GEM Stack 绝缘导针
08 放置G1 GEM读板 准直针对准读板边沿孔。可稍稍调工具调整导针方向使穿入	40 把GEM Stack移动到读板上。注意准直
09 拆卸G1 GEM读板中心板松脱螺母。移除读板	41 在前置板安装push-out驱动螺钉(安装位置同一侧。不要太紧)
10 用绝缘纸贴G1 GEM读板边沿。对蒙罩人员同时操作(至少一个接触点)	42 松开前置板螺母。移除读板准直架同一边盖空。从底下两拉板板字架孔push-out安装螺钉
11 用Megger测试G1 GEM读板。并在有机玻璃罩前置板接触点测试G1 GEM读板	43 把读板板放回原位位置。两侧固定
12 在中心支撑杆放置1mm厚盖	44 拧上前置板保护板上固定螺母。在准直架安装好内板架螺钉
13 在G2 GEM读板上放置第二屏内板架(1mm厚)。T-nuts接口朝外	45 用12mm拉板板字架字架孔push-out驱动螺钉。拉紧GEM Stack
14 在G2 GEM读板边沿去胶GEM1和GEM3高压接触点	46 清洗前置板盖了O型圈的边沿。放置。塞在GEM Stack
15 清洗G2 GEM读板	47 用绝缘纸贴GEM读板边沿GEM读板
16 用Megger测试G2 GEM读板	48 清洗读板出。检查气嘴
17 放置G2 GEM读板 准直针对准读板边沿孔。可稍稍调工具调整导针方向使穿入	49 取下保护中心孔螺钉。移除保护板
18 拆卸G2 GEM读板中心板松脱螺母。移除读板	50 把读板移动到GEM Stack上。注意准直
19 用绝缘纸贴G2 GEM读板边沿。对蒙罩人员同时操作(至少一个接触点)	51 拧上读出板上中心支撑杆螺钉
20 用Megger测试G2 GEM读板。并在有机玻璃罩前置板接触点测试GEM1和GEM2	52 拧上读出板边沿push-out安装螺钉(每个push-out上两个螺钉可安装架空)
21 在中心支撑杆放置2mm厚盖	53 用1.2mm拉板板字架孔向有螺钉(注意不要有弯曲)
22 在有机玻璃罩上插T-nuts。再工具再平	54 用绝缘纸贴GEM读板边沿GEM读板
23 在G2 GEM读板上放置第三屏内板架(2mm厚)。T-nuts接口朝上。朝外	55 插上连接两个气嘴的保护气嘴
24 在G3 GEM读板边沿去胶GEM1和GEM2高压接触点	
25 清洗G3 GEM读板	
26 用Megger测试G3 GEM读板	
27 放置G3 GEM读板 准直针对准读板边沿孔。可稍稍调工具调整导针方向使穿入	
28 拆卸G3 GEM读板中心板松脱螺母。移除读板	
29 用绝缘纸贴G3 GEM读板边沿。对蒙罩人员同时操作(至少一个接触点)	
30 用Megger测试G3 GEM读板。并在有机玻璃罩前置板接触点测试三屏GEM读板	
31 在中心支撑杆放置1mm厚盖	
32 在G3 GEM读板上放置第四屏内板架(1mm厚。无T-nuts接口)	

## Assembly check list

- 注意事项
- 如果螺钉很紧时，不要先拧到每个螺钉，要协同拧上。如果拧不动，
    - 螺钉上涂些润滑油(尽量少涂)
    - Push-out上涂些润滑油(但需谨慎)
    - 是否有点有问题(要谨慎)
  - 要放轻的动作。
    - 如果拧不动时，但仍拧不上，可能孔内残留金属碎屑。
    - 试一试使用止血钳将其拆出来。
  - 操作中心孔螺钉。移动上屏有机玻璃保护板时要特别小心。不要碰到GEM读板。
  - 气嘴要插到位。



Clean and test GEM foils



Make up GEM stack



Mount readout board



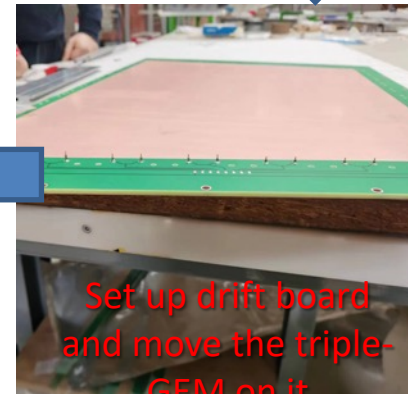
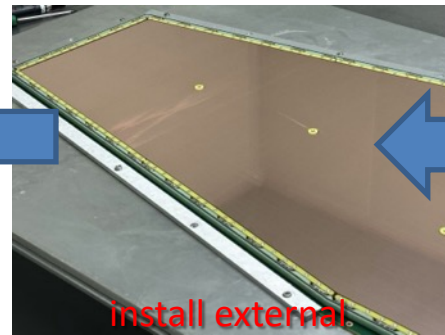
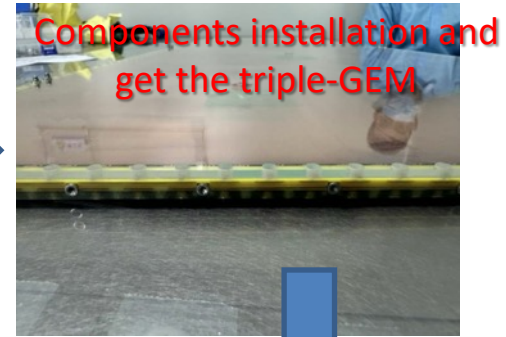
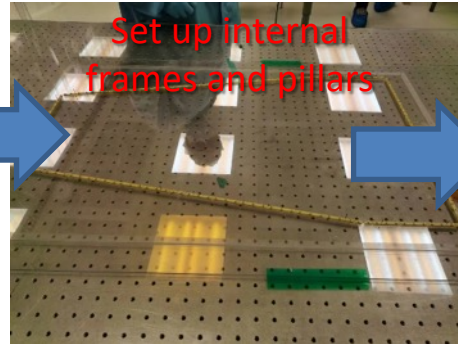
Mount GEM stack on drift board



Closure, Done!

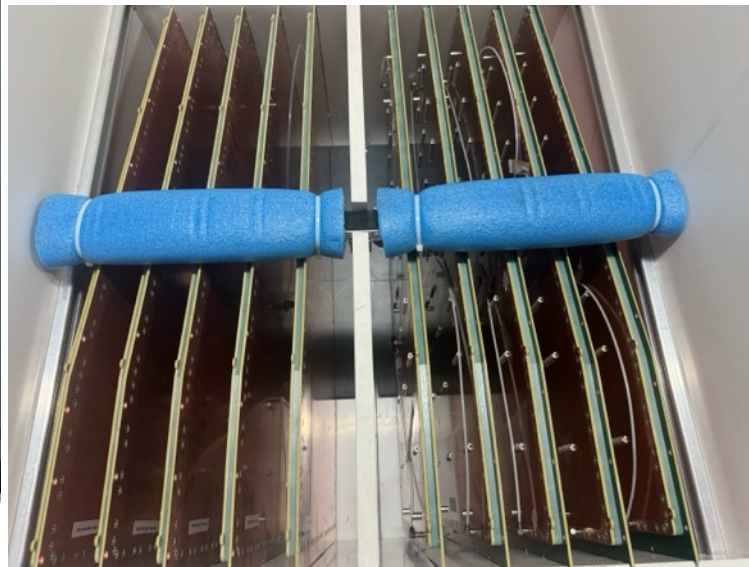
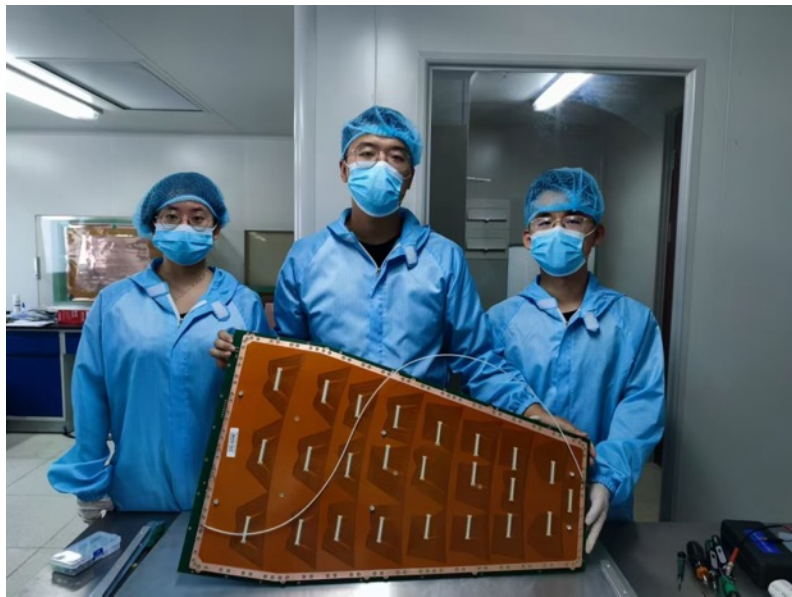


# 1<sup>st</sup> batch of 10 ME0 assembly(Aug-Oct, 2024)



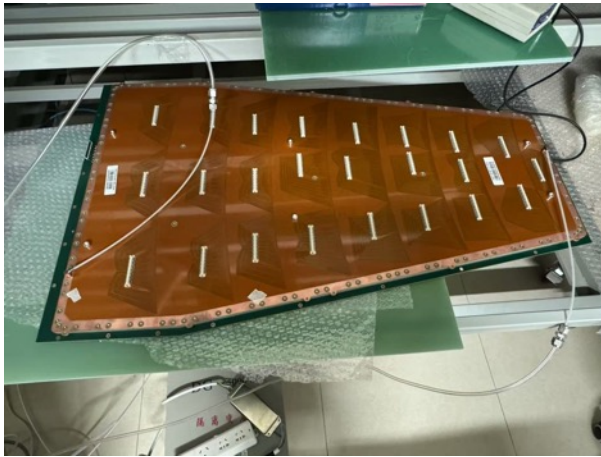
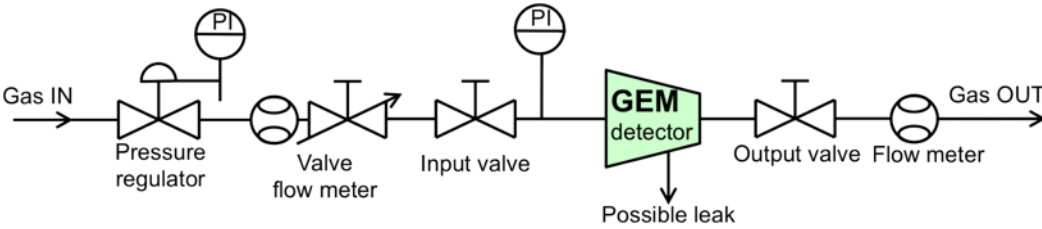
# ME0 assembly : 1st batch of 10 chambers

- Assembly and QC test of the first batch of ME0 is completed.
- All the ME0 GEMs will be sent back to CERN for further testing.
- Preparation for the next batch of ME0 is going on.

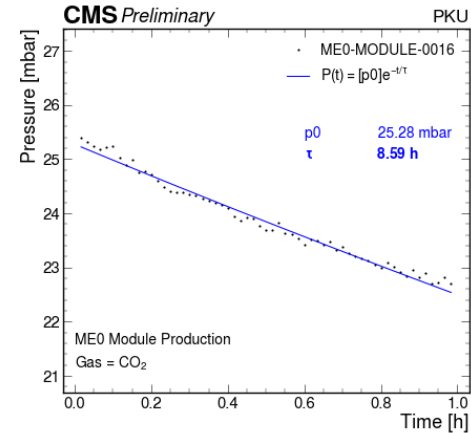


# QC of assembled ME0: gas leakage

QC3  
gas leak test

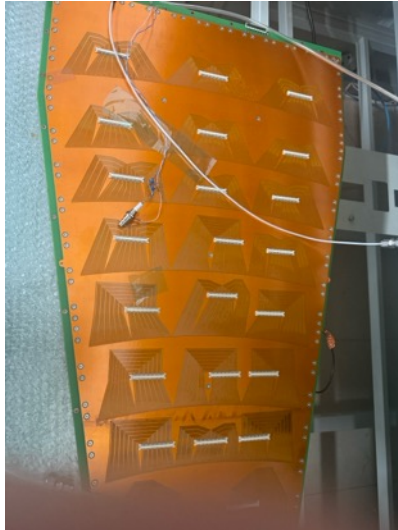
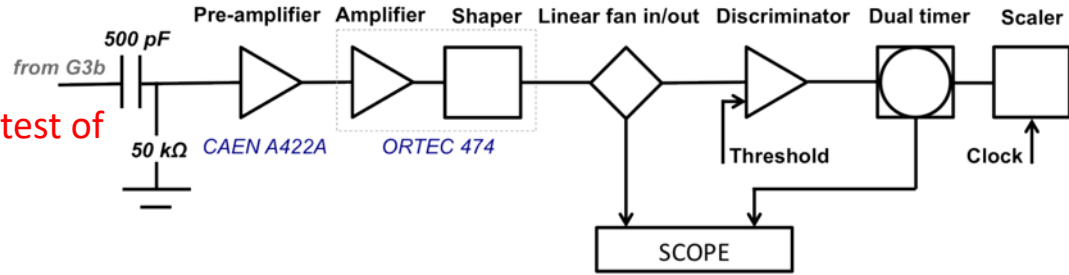


test result

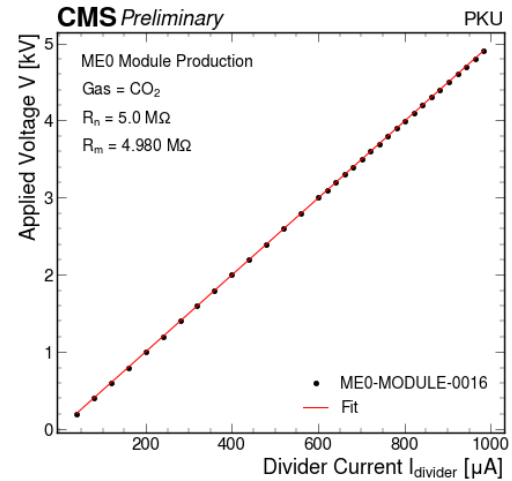


# QC of assembled ME0: I-V

QC4  
linearity test of  
the HV

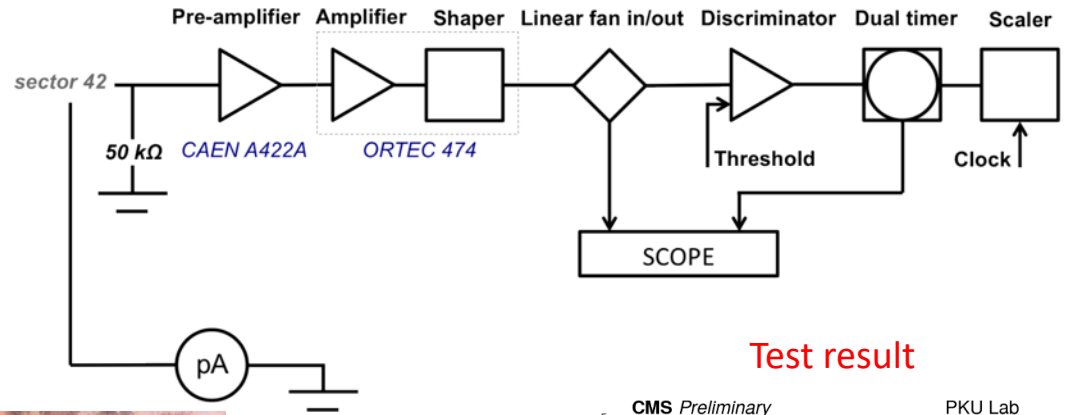


Test result

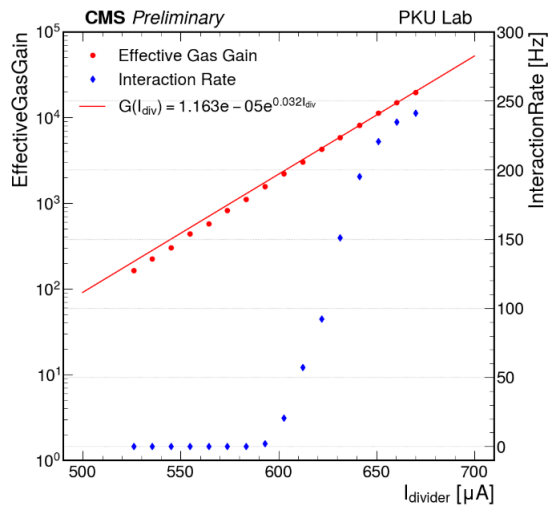
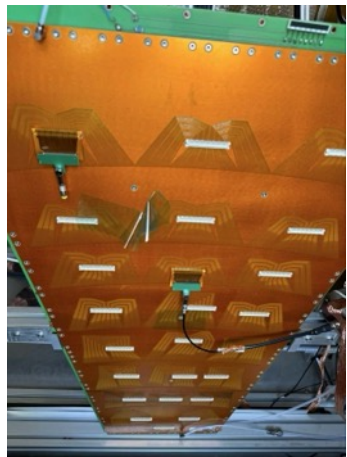


# QC of assembled ME0: effective gas gain

QC5  
effective gas gain test  
with X-ray



Test result



# Summary and outlook

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- To match the CMS Phase-II GEM upgrade projects, a local GEM lab has been set up in PKU and certified as one of CMS-GEM production sites.
- Several batches of GE2/1 M5 and ME0 chambers have been successfully assembled and tested.
- Beyond CMS upgrade, there are some other related activities on gaseous detectors at PKU
  - Muon tomography with RPCs and GEMs
  - TPC as active target for nuclear reaction studies
  - Searching for exotic dark matter and beyond: PKMu [proposal](#)
  - ...