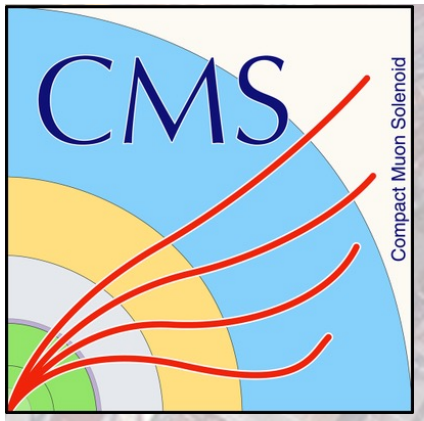

GEM Chamber Assembly and Test for CMS ME0 Upgrade at Peking University

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Peking University

CLHCP 2024, Qingdao

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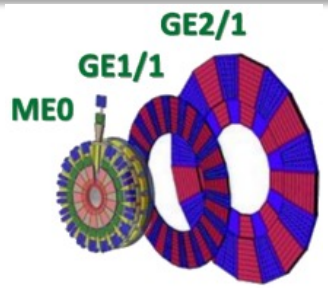
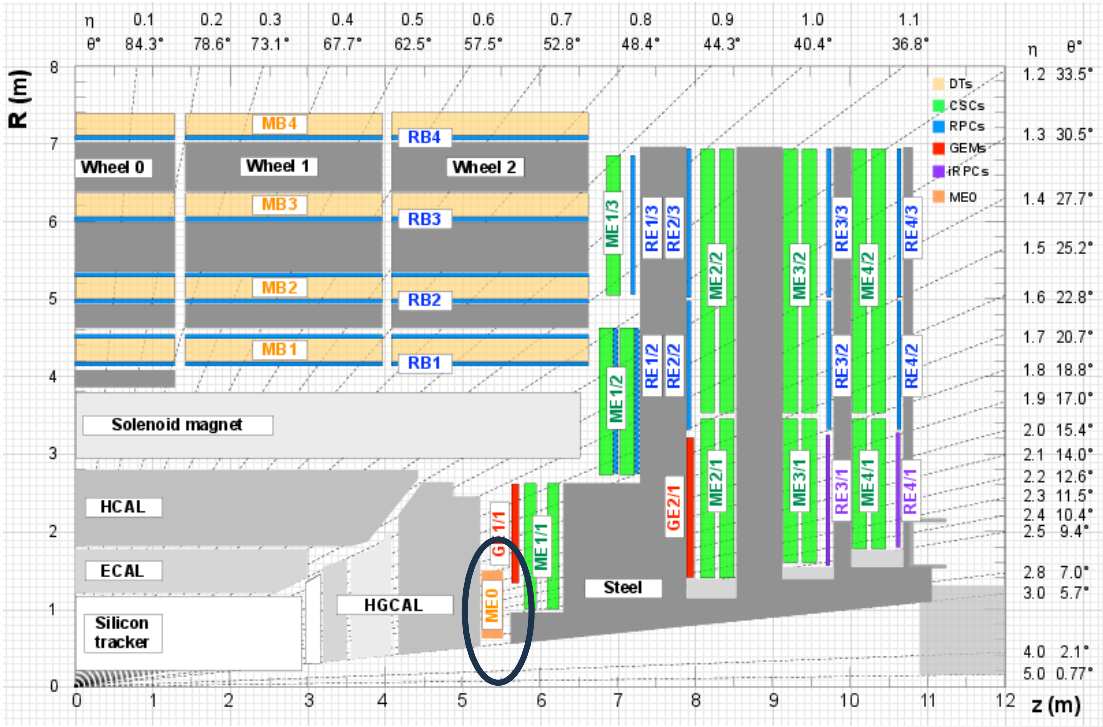
Contents

1.Overview of CMS ME0 GEM upgrade project

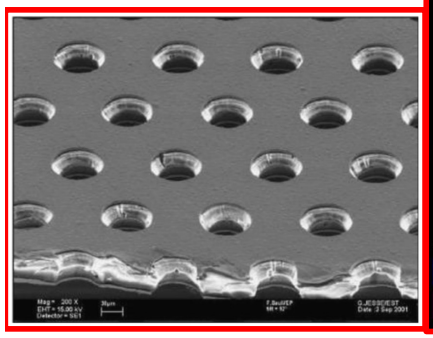
- *The Large Hadron Collider (LHC) is being improved to higher instantaneous luminosity. To maintain the detector's sensitivity to electroweak scale physics, an upgrade of the detector is necessary.*

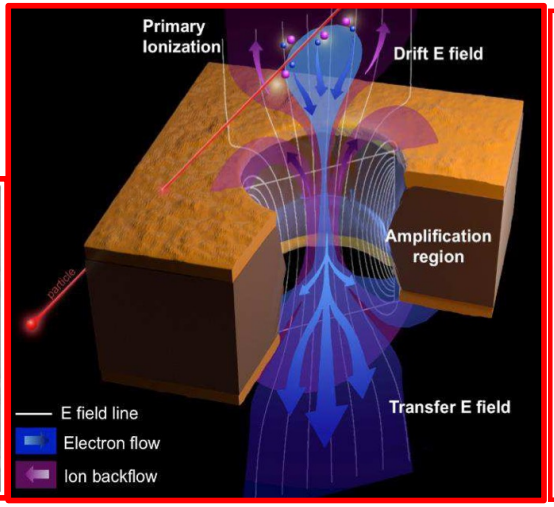


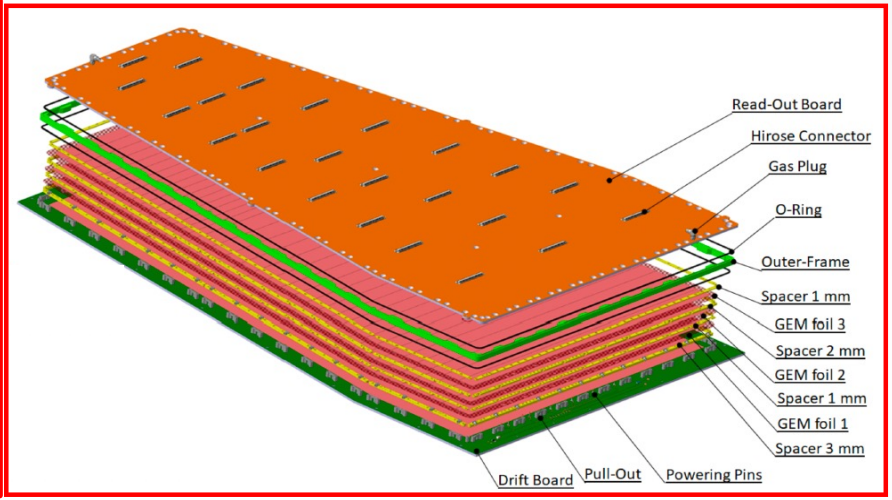
- The gas electron multiplier (GEM) in the endcap muon station will help to maintain or even improve the forward muon triggering and reconstruction.
- The ME0 is closer to the beam ($2.0<\eta<2.8$)
  - **Rate Capability**: >150kHz/cm^2 (much more central than GE2/1 & GE1/1: a few kHz/cm^2)
  - **Longevity**: Survive harsh radiation environment: 7.9C/cm^2



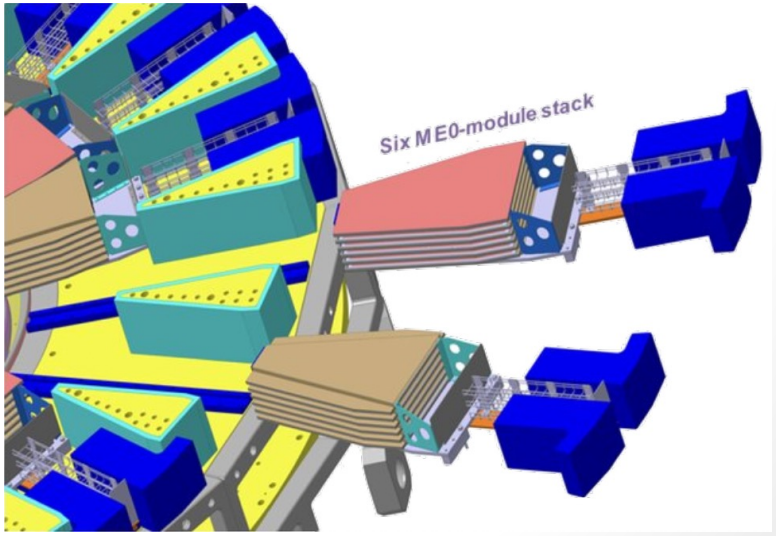
CMS GEM detector design







- The full system: 216 ME0 chambers (108 per end-cap)
  - 6 triple-GEM modules per stack
  - 18 stacks per endcap
- Performance Expectations
  - **97% module efficiency**
  - **Timing Resolution:**8-10ns
  - **Gain Uniformity**: ≤15%
  - **Space Resolution:**<500µrad



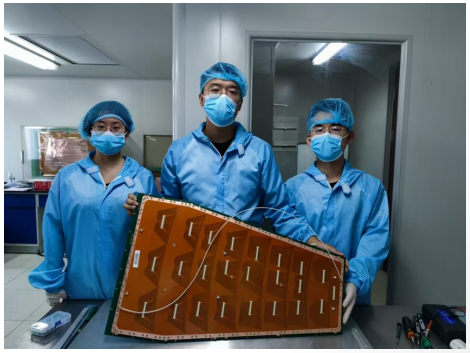
Timeline of ME0 GEM Assembly

- **Vendors**
  - Manufacturing of the detector components
  - Shipment to CERN
- **Central Site (at CERN)**
  - Material inspection (QC1/QC2)
  - Pre-assembly work
  - Preparation of assembly kits
  - Shipment to/back from production sites
- **Production Sites**
  - Module assembly
  - QC2-QC5 tests
  - Data Base updates

Timeline

1st	2nd	3rd	4th & 5th	6th
Jul-Sep 2024	Oct-Dec 2024	Feb-Apr 2025	2025	2026

CERN,
Bari,
Frascati,
PKU(10 modules)



First ME0 module assembled at PKU

2. 1st batch of 10 GEM assembly and test at PKU

CERN

- QC 1: material inspection
- QC 2: GEM foils test (fast + long)

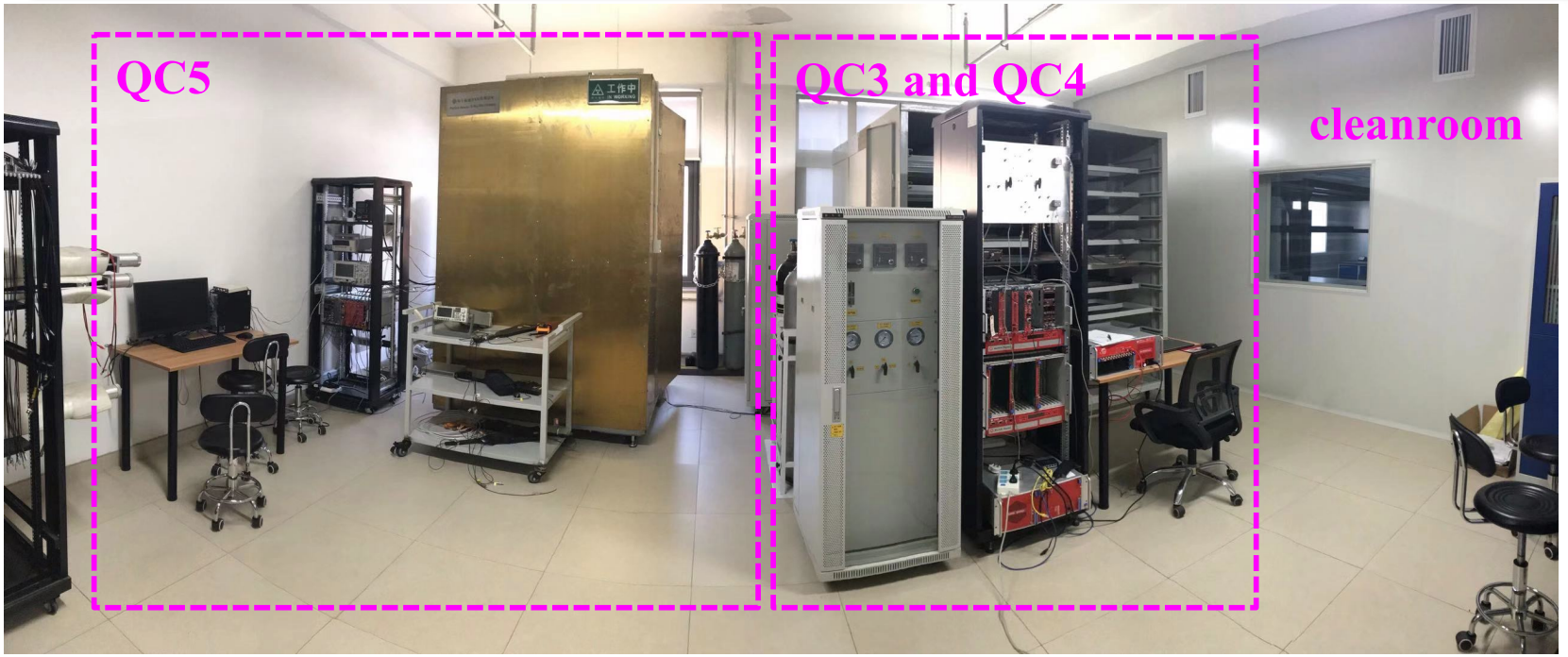
Production sites (e.g. PKU)

- QC 2: GEM foils test (fast)
- Assembly preparation + Assembly
- QC 3: gas leak test
- QC 4: HV test
- QC 5: gas gain calibration

CERN

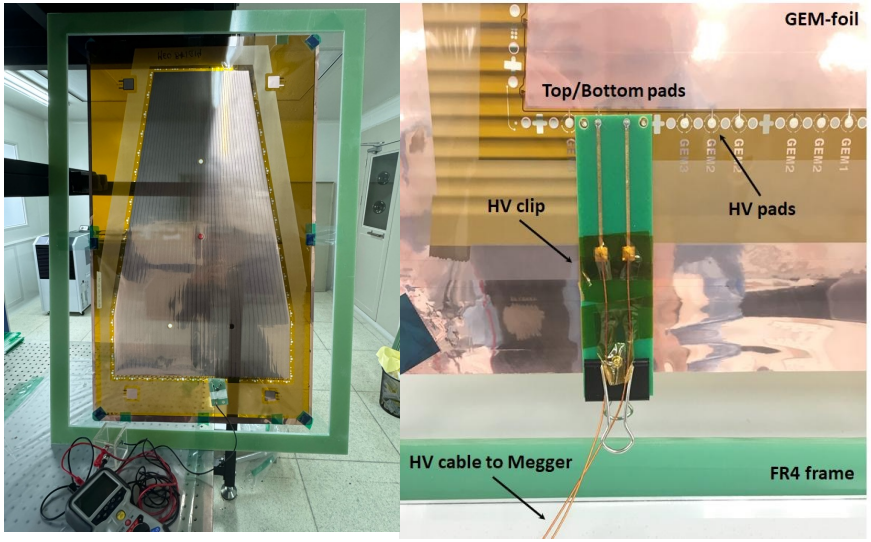
- QC 6: HV stability test
- QC 7: electronics connectivity test
- QC 8: cosmic ray test

Workshop at PKU



QC2 Fast Impedance Test

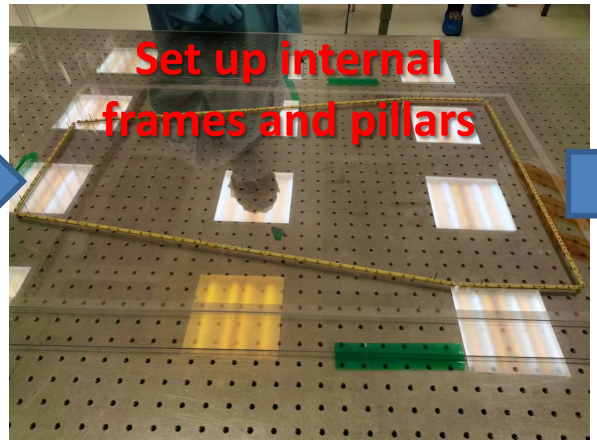
QC2



Test the impedance of the foil by the Megger connected to the HV pads beside the foil. If there's a short on the foil, use an electrostatic scroll to clean where the spark is.

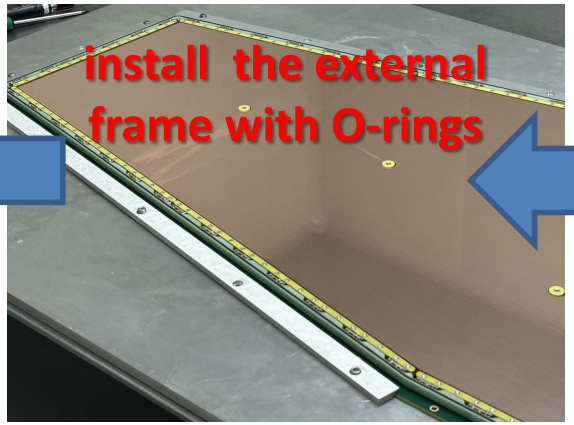
Assembly

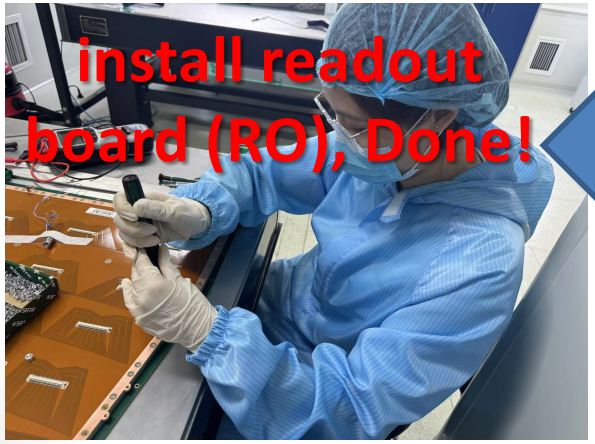

Clean the foil


Set up internal
frames and pillars

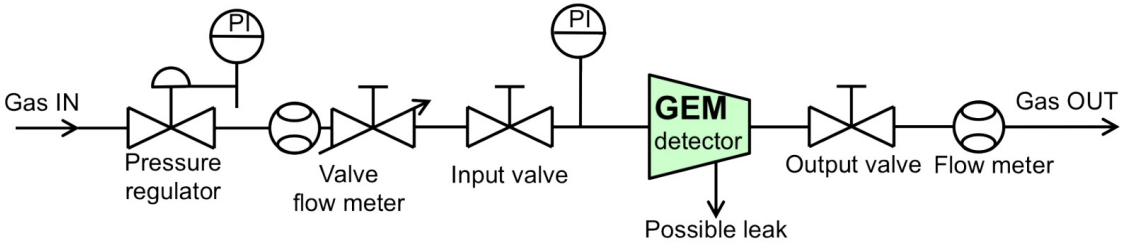

Components installation and
get the triple-GEM

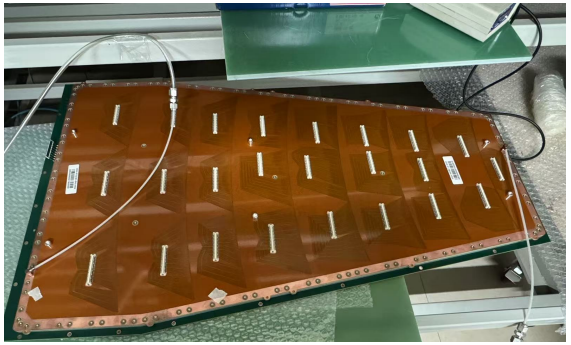

Set up drift board (DB)
and move the triple-
GEM on it


install the external
frame with O-rings


install readout
board (RO), Done!

QC3 Gas Leak Test

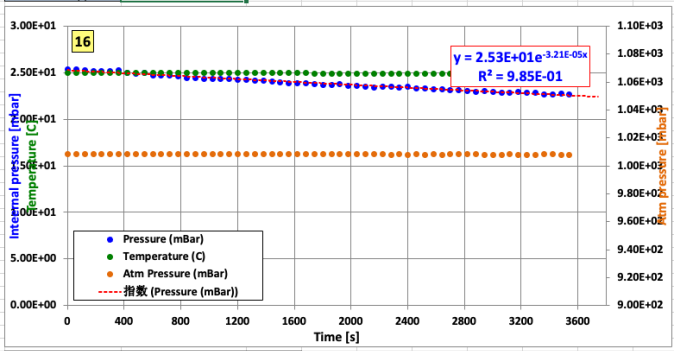




record

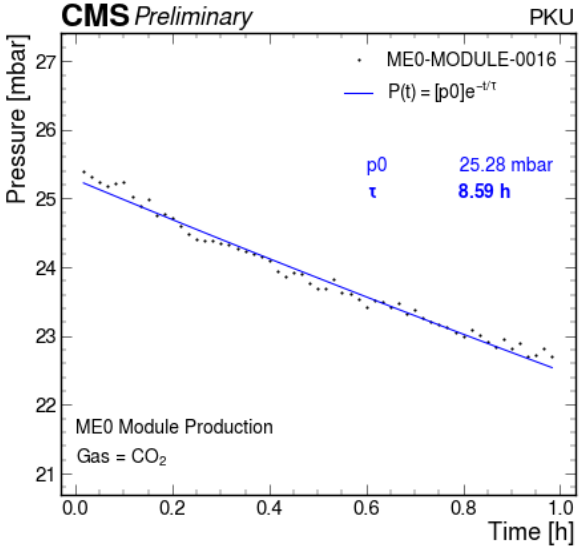
Time	Seconds	Pressure (mBar)	Temperature (C)	Atm Pressure (mBar)
11:46:24	0.00	2.54E+01	2.50E+01	1.01E+03
11:47:24	60.00	2.54E+01	2.50E+01	1.01E+03
11:48:24	120.00	2.53E+01	2.50E+01	1.01E+03
11:49:24	180.00	2.52E+01	2.50E+01	1.01E+03
11:50:24	240.00	2.52E+01	2.50E+01	1.01E+03
11:51:24	300.00	2.52E+01	2.50E+01	1.01E+03
11:52:24	360.00	2.52E+01	2.51E+01	1.01E+03
11:53:24	420.00	2.50E+01	2.51E+01	1.01E+03
11:54:24	480.00	2.49E+01	2.50E+01	1.01E+03
11:55:24	540.00	2.50E+01	2.51E+01	1.01E+03
11:56:24	600.00	2.48E+01	2.50E+01	1.01E+03
11:57:24	660.00	2.48E+01	2.50E+01	1.01E+03
11:58:24	720.00	2.47E+01	2.50E+01	1.01E+03
11:59:24	780.00	2.46E+01	2.50E+01	1.01E+03
12:00:24	840.01	2.45E+01	2.50E+01	1.01E+03
12:01:24	900.01	2.44E+01	2.50E+01	1.01E+03
12:02:24	960.00	2.44E+01	2.50E+01	1.01E+03
12:03:24	1020.01	2.44E+01	2.50E+01	1.01E+03
12:04:24	1080.01	2.44E+01	2.50E+01	1.01E+03
12:05:24	1140.01	2.43E+01	2.50E+01	1.01E+03
12:06:24	1200.01	2.43E+01	2.50E+01	1.01E+03
12:07:24	1260.01	2.42E+01	2.50E+01	1.01E+03
12:08:24	1320.01	2.42E+01	2.50E+01	1.01E+03
12:09:24	1380.01	2.42E+01	2.50E+01	1.01E+03
12:10:24	1440.01	2.41E+01	2.50E+01	1.01E+03
12:11:24	1500.01	2.39E+01	2.50E+01	1.01E+03
12:12:24	1560.01	2.39E+01	2.50E+01	1.01E+03
12:13:24	1620.01	2.39E+01	2.50E+01	1.01E+03
12:14:24	1680.01	2.39E+01	2.50E+01	1.01E+03
12:15:24	1740.01	2.38E+01	2.50E+01	1.01E+03
12:16:24	1800.01	2.37E+01	2.50E+01	1.01E+03
12:17:24	1860.01	2.37E+01	2.50E+01	1.01E+03
12:18:24	1920.01	2.36E+01	2.50E+01	1.01E+03
12:19:24	1980.01	2.36E+01	2.50E+01	1.01E+03
12:20:24	2040.01	2.36E+01	2.50E+01	1.01E+03
12:21:24	2100.01	2.35E+01	2.49E+01	1.01E+03
12:22:24	2160.01	2.34E+01	2.49E+01	1.01E+03
12:23:24	2220.01	2.35E+01	2.49E+01	1.01E+03
12:24:24	2280.01	2.35E+01	2.49E+01	1.01E+03
12:25:24	2340.01	2.34E+01	2.49E+01	1.01E+03

Date	5/9/2024
Name	hjm
Detector ID	16
Duration (h)	1



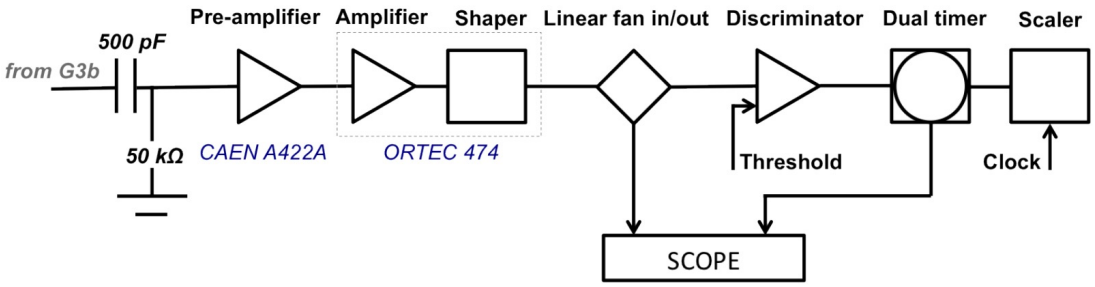
Summary		Error
Temperature (C)	24.96133333	0.060013
Atm Pressure (mBar)	1008.3492	0.0982939
Initial pressure (mBar)	25.4103	
Final pressure (mBar)	22.8231	
Duration (h)	1	
Leak rate (mBar/h)	2.5872	
Exponential fit P0	25.28485046	
Exponential P1	-3.22461E-05	

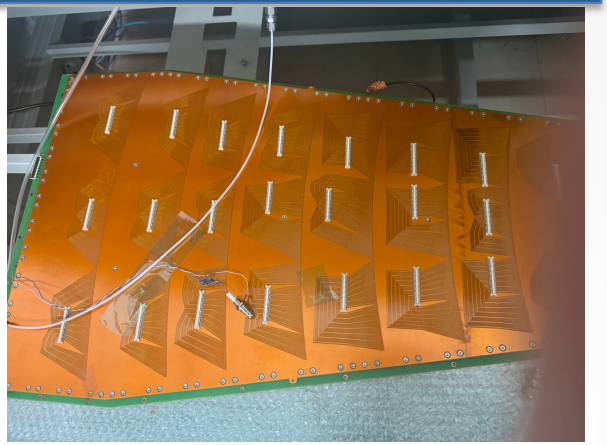
result



criteria: pressure decrease < 7mbar/h

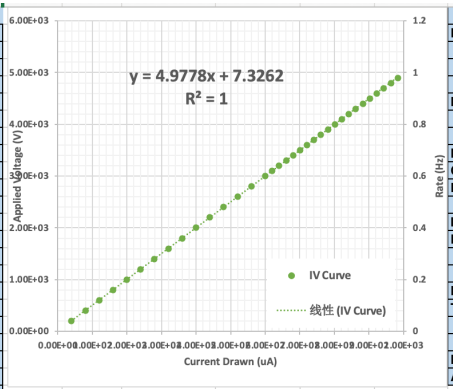
QC4 Linearity Test of the HV

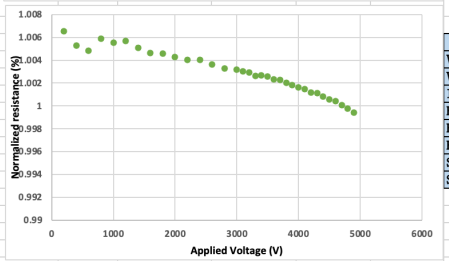




record

QC4 HV test				
Vmon	Iset	Imon	R calc	R norm
(V)	(uA)	(uA)	(Mohm)	(Mohm)
2.00E+02	40.16064	######	5.01256294	1.0065387
3.99E+02	80.32129	######	5.00627371	1.0052758
5.99E+02	120.4819	######	5.00417723	1.0048549
8.00E+02	160.6426	######	5.00939831	1.0059033
9.99E+02	200.8032	######	5.0075188	1.0055259
1.20E+03	240.9639	######	5.00835073	1.0056929
1.40E+03	281.1245	######	5.0053647	1.0050933
1.60E+03	321.2851	######	5.00312882	1.0046443
1.80E+03	361.4458	######	5.00277993	1.0045743
2.00E+03	401.6064	######	5.00125078	1.0042672
2.20E+03	441.7671	######	5.00000007	1.0040161
2.40E+03	481.9277	######	5.00000006	1.0040161
2.60E+03	522.0884	######	4.99807692	1.0036299
2.80E+03	562.249	######	4.99642974	1.0032991
3.00E+03	602.4096	######	4.99583552	1.0031798
3.10E+03	622.49	######	4.99516422	1.003045
3.20E+03	642.5703	######	4.99453552	1.0029188
3.30E+03	662.6506	######	4.99318819	1.0026482
3.40E+03	682.7309	######	4.99338907	1.0026886
3.50E+03	702.8112	######	4.99286538	1.0025834
3.60E+03	722.8916	######	4.99167822	1.002345
3.70E+03	742.9719	######	4.99122942	1.0022549
3.80E+03	763.0522	######	4.99014706	1.0020376
3.90E+03	783.1325	######	4.98912194	1.0018317
4.00E+03	803.2129	######	4.98814885	1.0016363
4.10E+03	823.2932	######	4.98722324	1.0014505
4.20E+03	843.3735	######	4.98574822	1.0011543
4.30E+03	863.4538	######	4.98550395	1.0011052
4.40E+03	883.5341	######	4.98413598	1.0008305
4.50E+03	903.6145	######	4.98283126	1.0005685
4.60E+03	923.6948	######	4.98212351	1.0004264
4.70E+03	943.7751	######	4.98038995	1.0000783
4.80E+03	963.8554	######	4.97872776	0.9997445
4.90E+03	983.9357	######	4.97713659	0.999425

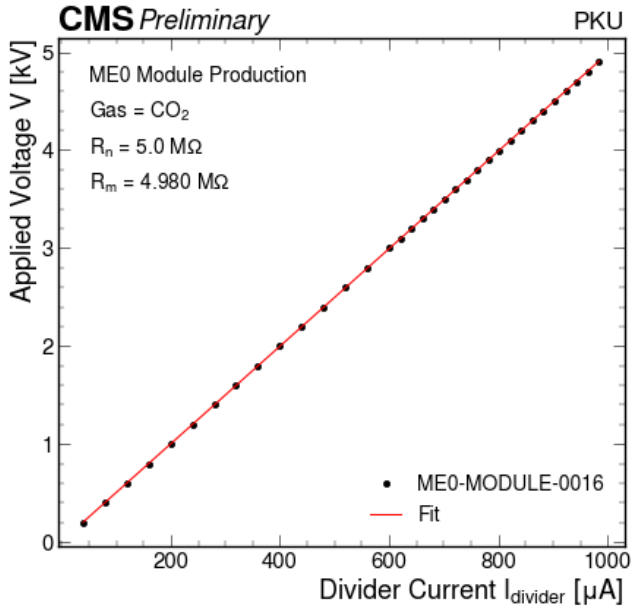




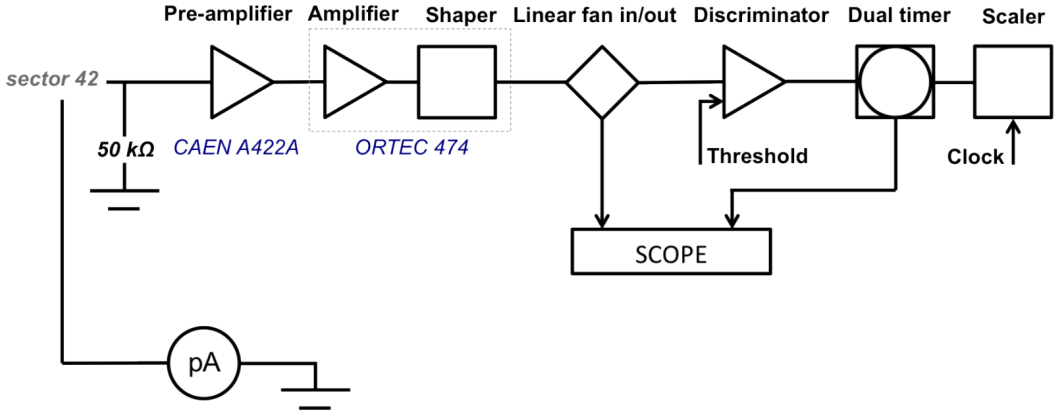
HV Circuit	
R_Equiv (Mohm)	4.98
Preamplifier	
Make & Model	User Provides
	User Provides
Amplifier	
Make & Model	User Provides
Coarse Gain	User Provides
Fine Gain	User Provides
Int. Time (ns)	User Provides
Diff Time (ns)	User Provides
Discriminator	
Make & Model	User Provides
Threshold (mV)	User Provides
Scalar	
Make & Model	User Provides
Acquisition Time (s)	User Provides

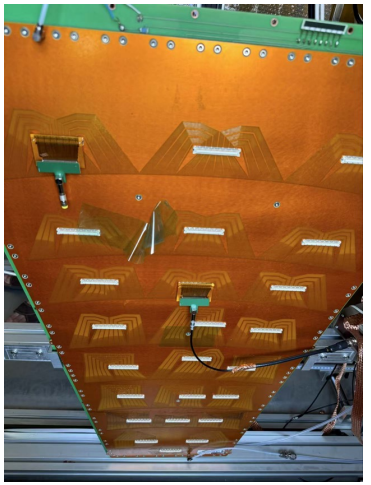
Summary	
V_Max (V)	4898
Vdrift_Max (V)	4625.269887
I_Max (uA)	984.099976
R_Equ_MSRD (Mohm)	4.98
R_Equ_Slope (Mohm)	4.977780748
R_Diff (%)	0.044563296
SPR_Signal_Rate (H	#VALUE!
SPR_Signal_Rate_Er	#VALUE!

result



QC5(stage1) effective gas gain test with X-ray

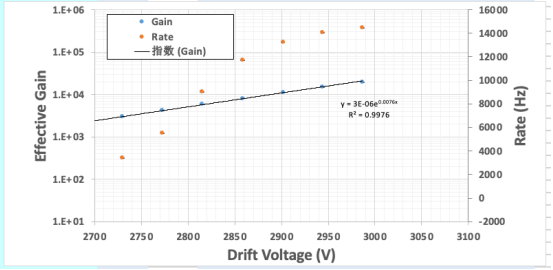




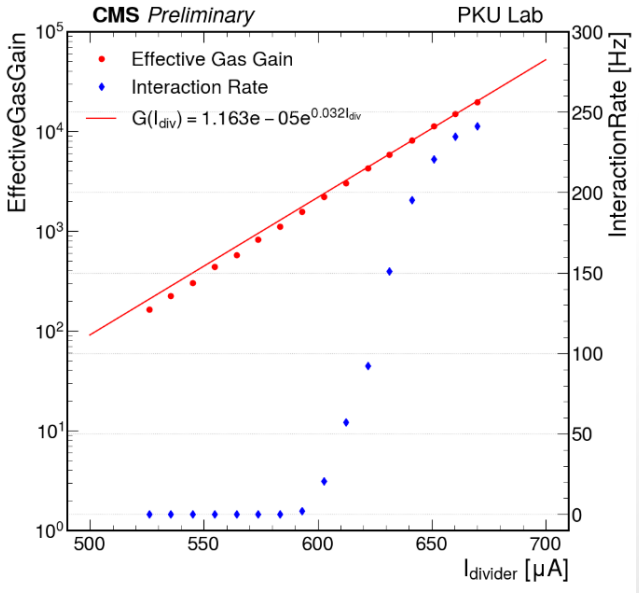
record

QC5 Effective gain

	Environment					For Measuring Rate				For Measuring Current				
	Vmon	Imon	Time	Pressure	Temp	Source Off Counts	Source On Counts	Err		Source Off Current	Err	Source On Current	Err	
	(V)	(uA)	(HH:MM)	(mbar)	(Deg C)	(N)	(N)	(N)		(A)	(A)	(A)	(A)	
Ar/CO2:70/30 Range	3.50E+03	7.02E+02		1017	26.1	22	4.690416	868408	931.8841	-4.56E-11	2.73E-12	-9.88E-09	5.19E-11	
	3.45E+03	6.92E+02				8	2.828427	844661	919.0544	-3.72E-11	3.10E-12	-7.63E-09	3.65E-11	
	3.40E+03	6.82E+02				4	2	794895	891.5688	-3.92E-11	2.78E-12	-5.70E-09	2.32E-11	
	3.35E+03	6.72E+02				2	1.414214	703277	838.6161	-3.25E-11	3.44E-12	-4.13E-09	1.93E-11	
	3.30E+03	6.61E+02				2	1.414214	543368	737.138	-3.33E-11	2.73E-12	-2.98E-09	1.35E-11	
	3.25E+03	6.51E+02				0	0	332713	576.8128	-3.50E-11	2.80E-12	-2.18E-09	7.96E-12	
	3.20E+03	6.41E+02				5	2.236068	206383	454.294	-3.13E-11	2.59E-12	-1.55E-09	6.99E-12	
	3.15E+03	6.31E+02				1	1	74182	272.3637	-3.50E-11	2.57E-12	-1.14E-09	4.99E-12	
	3.10E+03	6.21E+02				1	1	7796	88.29496	-3.48E-11	2.53E-12	-8.30E-10	4.49E-12	
	3.05E+03	6.11E+02				118	10.86278	642	25.33772	-3.38E-11	2.57E-12	-5.94E-10	4.41E-12	
	3.00E+03	6.01E+02				0	0	117	10.81665	-3.18E-11	2.39E-12	-4.46E-10	3.04E-12	
	2.95E+03	5.91E+02				0	0	60	7.745967	-3.44E-11	2.46E-12	-3.25E-10	3.45E-12	
	2.90E+03	5.81E+02				0	0	55	7.416198	-2.95E-11	2.35E-12	-2.51E-10	2.61E-12	
	2.85E+03	5.71E+02				17	4.123106	54	7.348469	-3.57E-11	2.27E-12	-1.87E-10	2.34E-12	
	2.80E+03	5.61E+02				115	10.72381	69	8.306624	-3.56E-11	2.35E-12	-1.49E-10	2.20E-12	
	2.75E+03	5.51E+02				0	0	63	7.937254	-3.21E-11	2.45E-12	-1.14E-10	2.65E-12	

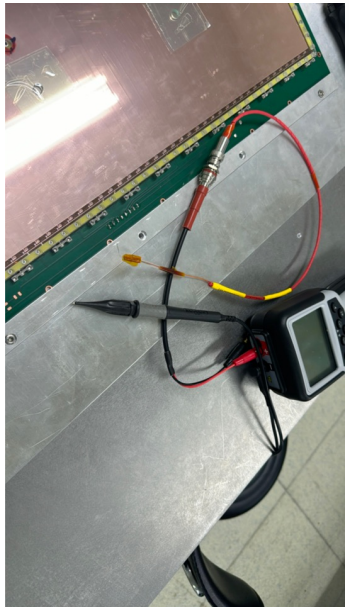


result



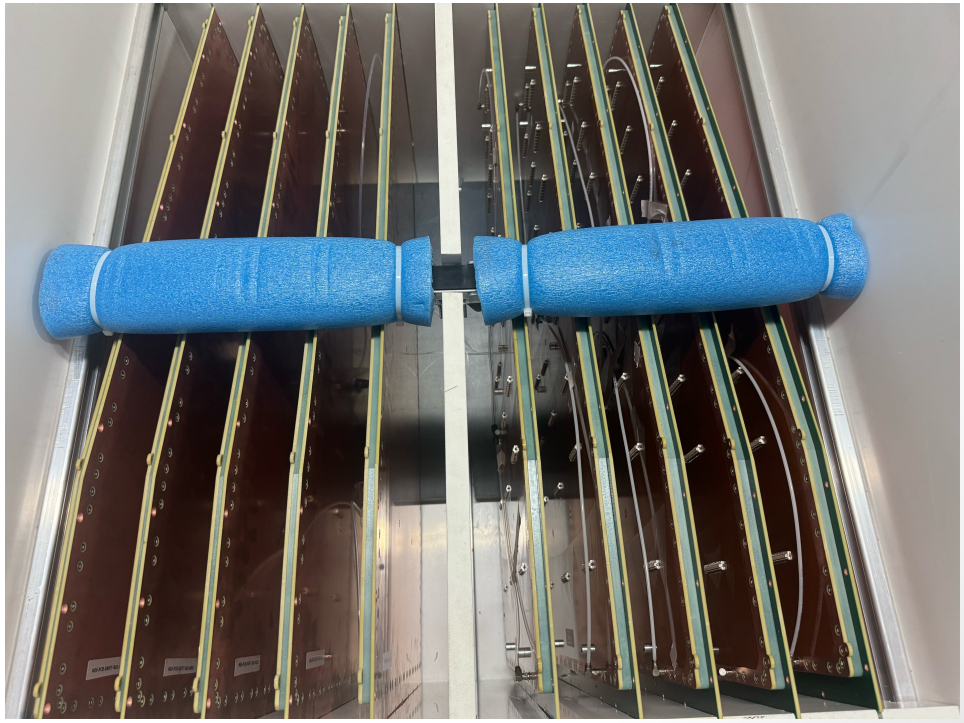
Resolution of Issues

- Short after the assembly
  - It is likely that the dust has fallen onto the foil
  - If the short is on the 3rd foil (close to the RB), remove the RB and use a scroll to clean the foil
  - If the short is on the 1st or 2nd foil, remove the RB and DB, then use a hook to apply a HV on the sector where the short is.
- Gas leak
  - Use a mini-tracer to confirm where the gas leak is
  - Replace the screw with the gasket
  - Apply more AB glue around the gas nozzle
- Screw strip
  - If only one screw in a pair strips, remove the RB and DB, and throw the pull-out where the screw connected
  - If both the screws in a pair strip, remove the RB and DB, and use a drill to destroy the cap of the screw



Summary

- The assembly of the first batch of ME0 at PKU is completed.
- All the ME0 GEM modules have passed the QCs and will be sent back to CERN for further testing.
- Preparation for the next batch of ME0 is going on.



End

Thank you

Backup