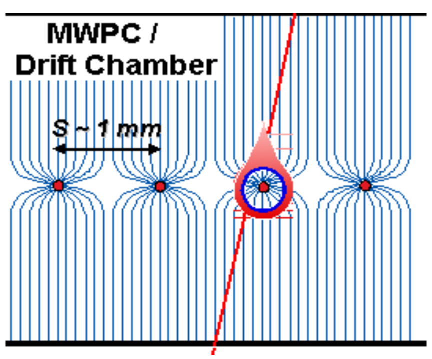
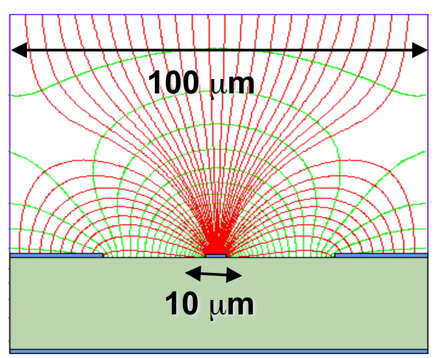
Application of Highly Resistive Material to Particle Detection

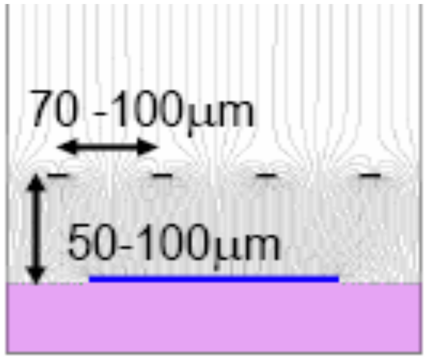
Sung Keun Park
Korea Univ., UCDavis

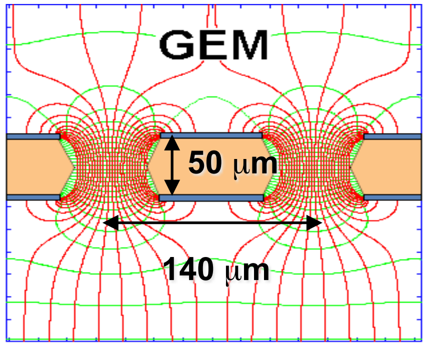
New Trends after Wire Detectors

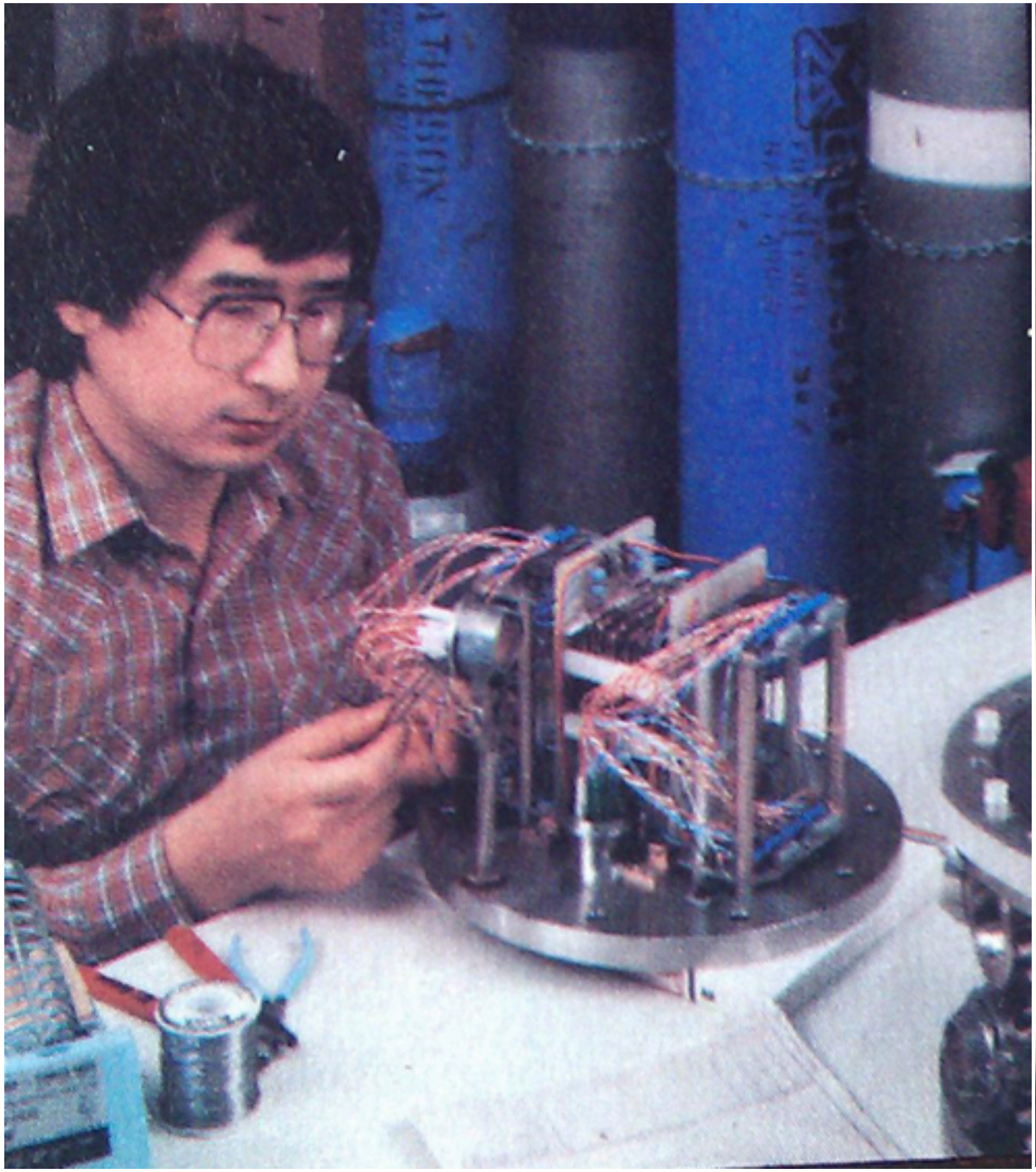
- Resistive Plate Chambers (RPCs)--Good time resolution
- Variation of RPCs (mRPC, gRPC)--Fast timing, High rate capability
- Micropattern Gas Detectors (MPGDs)--Good spatial resolution
- Variation of MPGDs (GEM, MICROMEGAS)--High rate + Spatial resolution

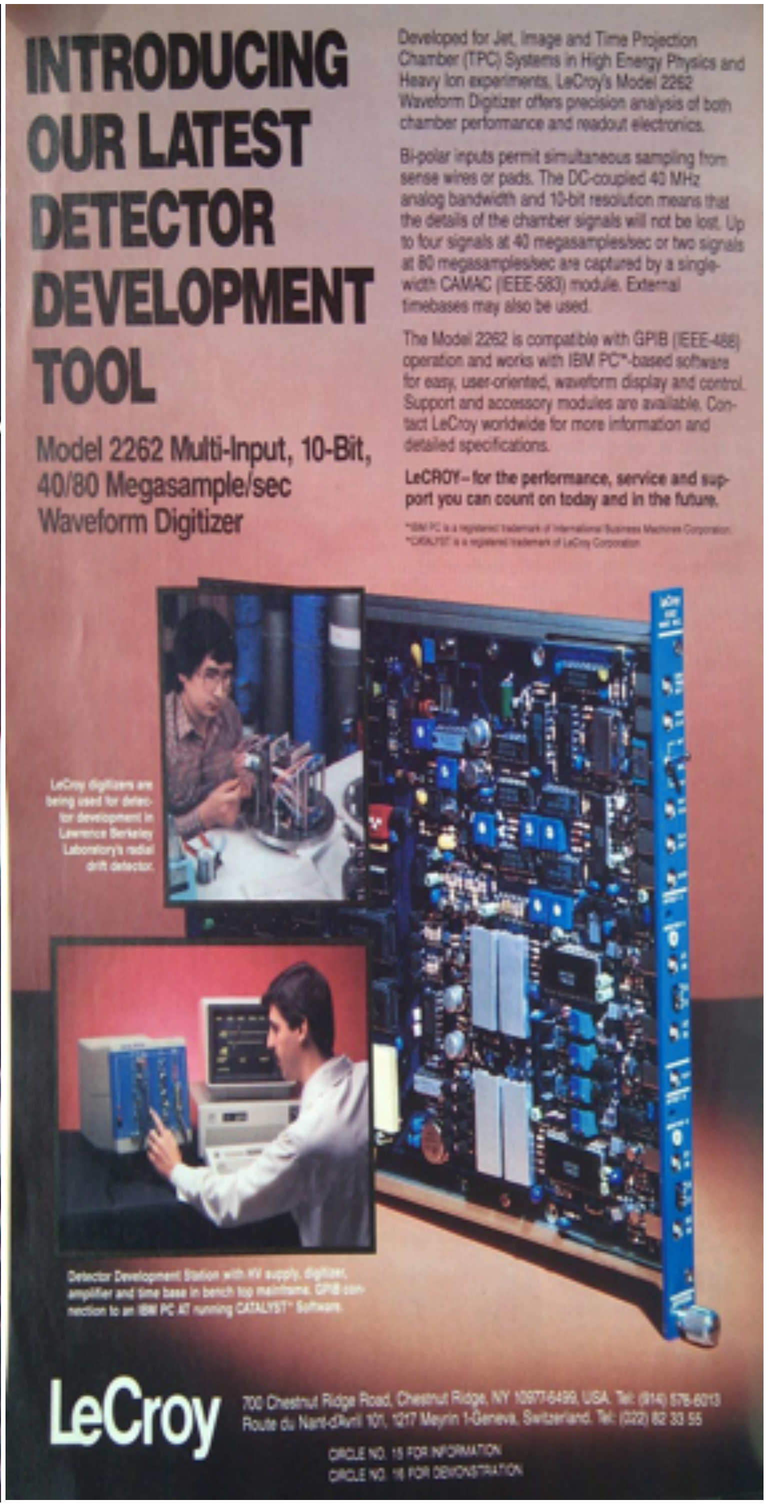








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Model 2262 Multi-Input, 10-Bit, 40/80 Megasample/sec Waveform Digitizer
Developed for Jet, Image and Time Projection Chamber (TPC) Systems in High Energy Physics and Heavy Ion experiments, LeCroy's Model 2262 Waveform Digitizer offers precision analysis of both chamber performance and readout electronics.
Bi-polar inputs permit simultaneous sampling from sense wires or pads. The DC-coupled 40 MHz analog bandwidth and 10-bit resolution means that the details of the chamber signals will not be lost. Up to four signals at 40 megasamples/sec or two signals at 80 megasamples/sec are captured by a single-width CAMAC (IEEE-583) module. External timebases may also be used.
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CIRCLE NO. 15 FOR INFORMATION
CIRCLE NO. 16 FOR DEMONSTRATION

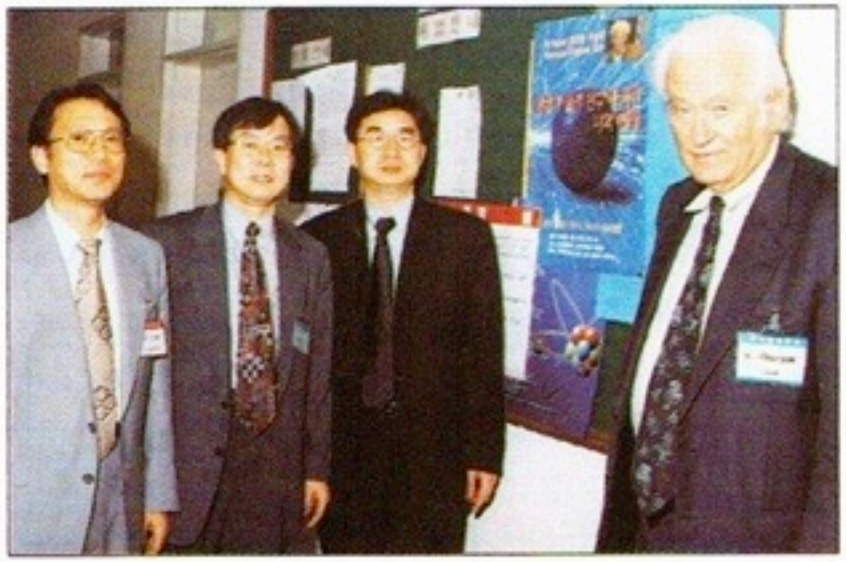
collaboration between CERN and the regional feature in a forthcoming issue. Working Group should soon be available.

KODEL establishes Korea as major physics player

Marking the emergence of Korea as a major player on the world physics scene, the Korea Detector Laboratory (KODEL) was established this year under director Sung Keun Park of Korea University, Seoul. Its aim is to carry out research and development for high-energy physics detectors and international high-energy physics programmes, and to provide the infrastructure for the ever-increasing scope of major international high-energy physics projects.

About 11 Korean universities have links with KODEL and participate in the research at Brookhaven, CERN, DESY (Hamburg), Fermilab, GSI (Darmstadt), and KEK (Japan).

A guest of honour at the KODEL opening ceremony was 1992 Physics Nobel prize-winner Georges Charpak of CERN. His lecture was televised throughout the country.



Georges Charpak (right) at the new Korea Detector Laboratory (KODEL) with (right to left) KODEL director Sung Keun Park, Kwangsouk Sim and Juntaek Rhee.

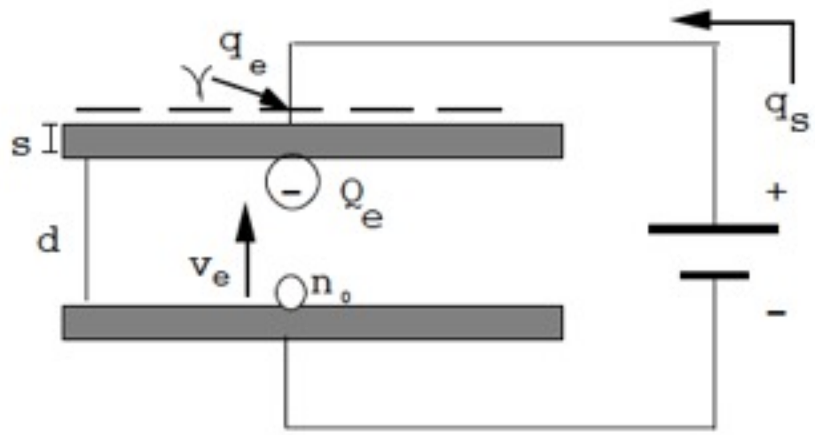
While at KODEL, Charpak stressed the importance of research and development for high-energy physics detectors in Korea, and Korea's collaboration with CERN in the LHC Collider project.

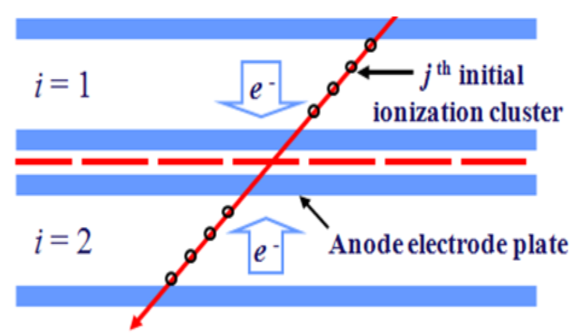
At a news conference Charpak affirmed that present economic problems could be alleviated by higher investment in basic research to provide a solid foundation for future technological advancement.

Charpak also met with the Korean Prime Minister, the Minister of Science and Technology and the Minister of Information and Communication, and gave a talk to the Korean Physical Society entitled "Recent advances on gaseous detectors and their applications for medicine and biology", a subject for which his enthusiasm never wavers.

KODEL produces prototypes of forward resistive plate chamber for the CMS detector at the LHC and is obtaining very encouraging results. It will be the main Korean laboratory for mass production of these units.

Principle of Operation of RPC





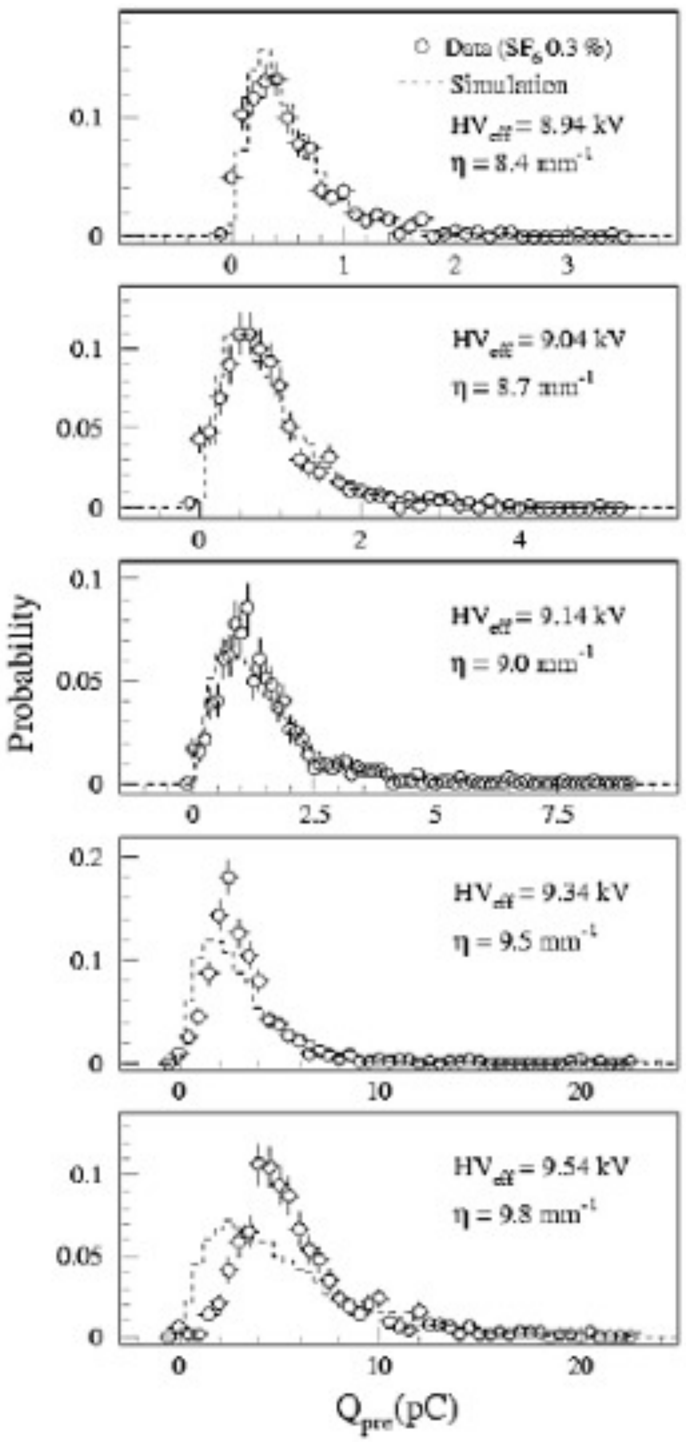
$$q_e = \sum_{i=1}^{2}\sum_{j=1} \frac{q_{el}}{\eta d} n_{0ij} M_{ij} k [e^{\eta(d-x_{ij})} - 1]$$

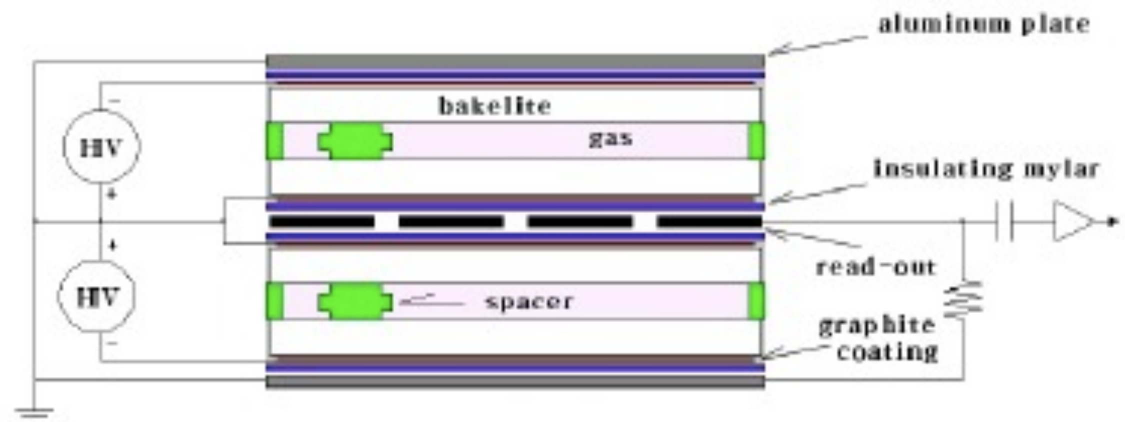
$$dn = n\eta dx$$
$$n = n_0 e^{\eta x}$$
$$\Rightarrow \frac{\eta}{p} = A e^{(-B\frac{p}{E})}$$

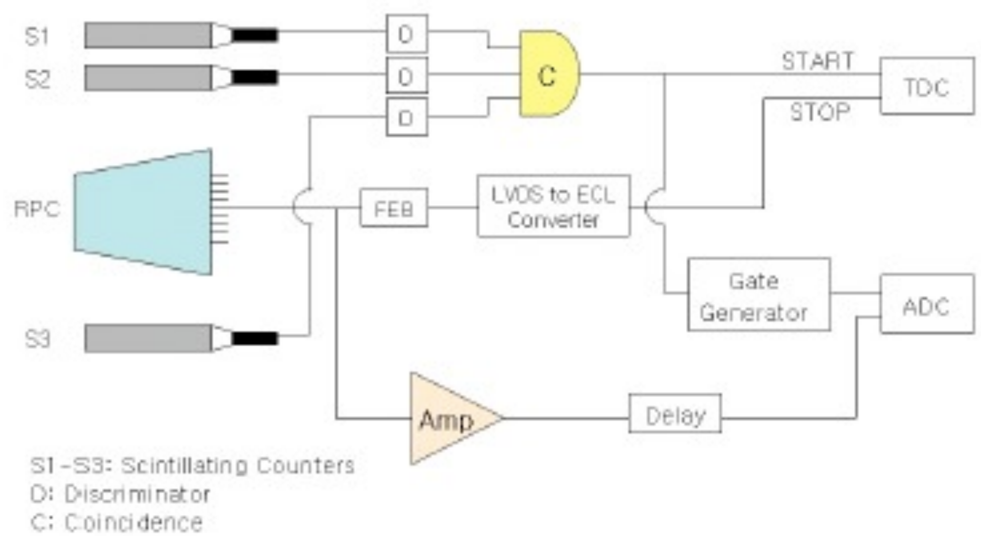
$$< q_e > = 2\sum_{j=1} \frac{q_{el}}{\eta d} \mu k e^{\eta d} \left(\frac{\lambda}{\lambda + \eta}\right)^j$$

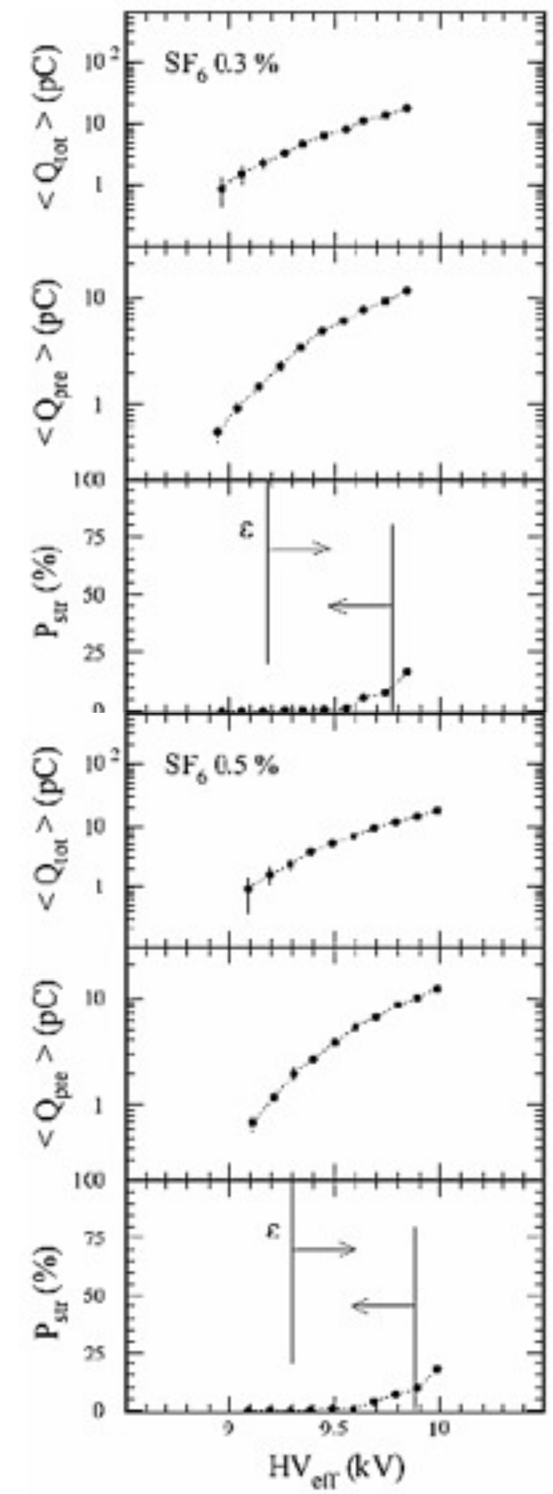
- n_0 : initial size of clusters(electrons)
- n : size of of clusters(electrons)
- $\eta = \alpha - \beta$: effective Townsend coefficient
- β : attachment coefficient
- E : effective field
- P : gas pressure
- A, B : constants in Korff's approximation
- q_e : induced charge at signal pick-up strip
- μ : avarage initial size of clusters
- q_{el} : electron's charge
- d : gap width
- M : gain fluctuation factor
- $k = (\varepsilon_r d/s) / (\varepsilon_r d/s+2)$
- λ : average cluster density

Comparison of Model with Data









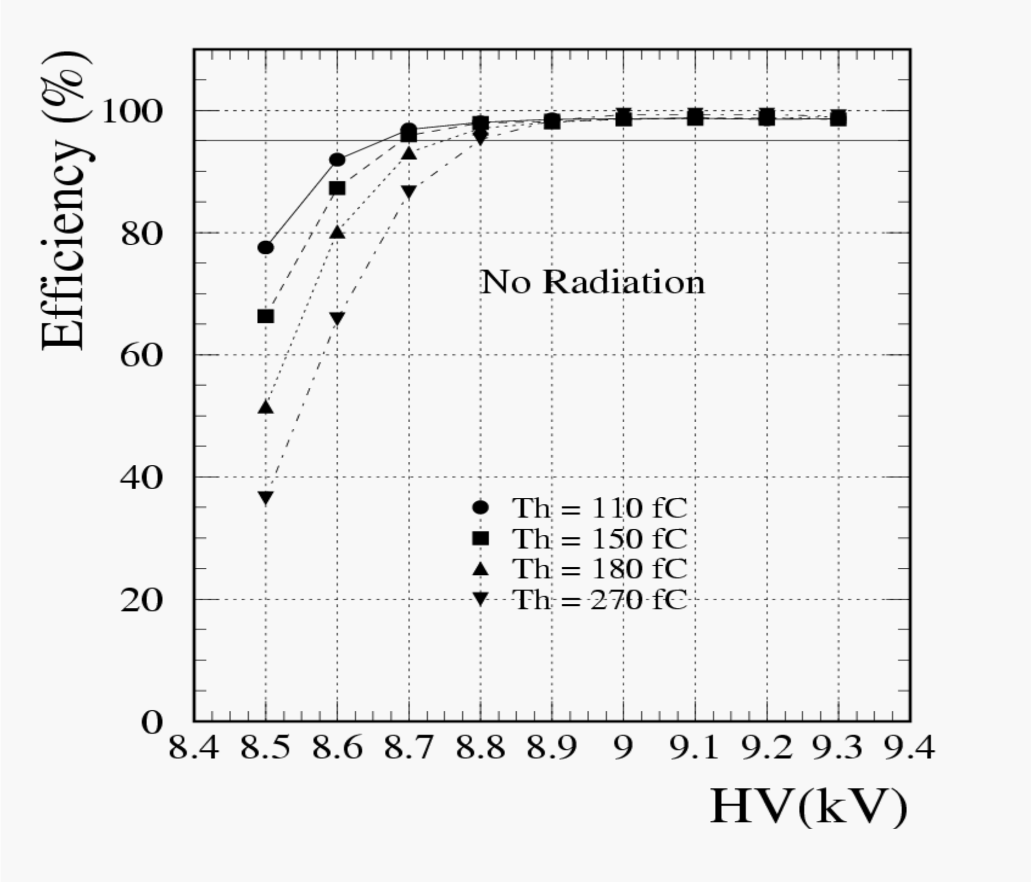
JKPS, Vol. 45, 2004, page1490-1499

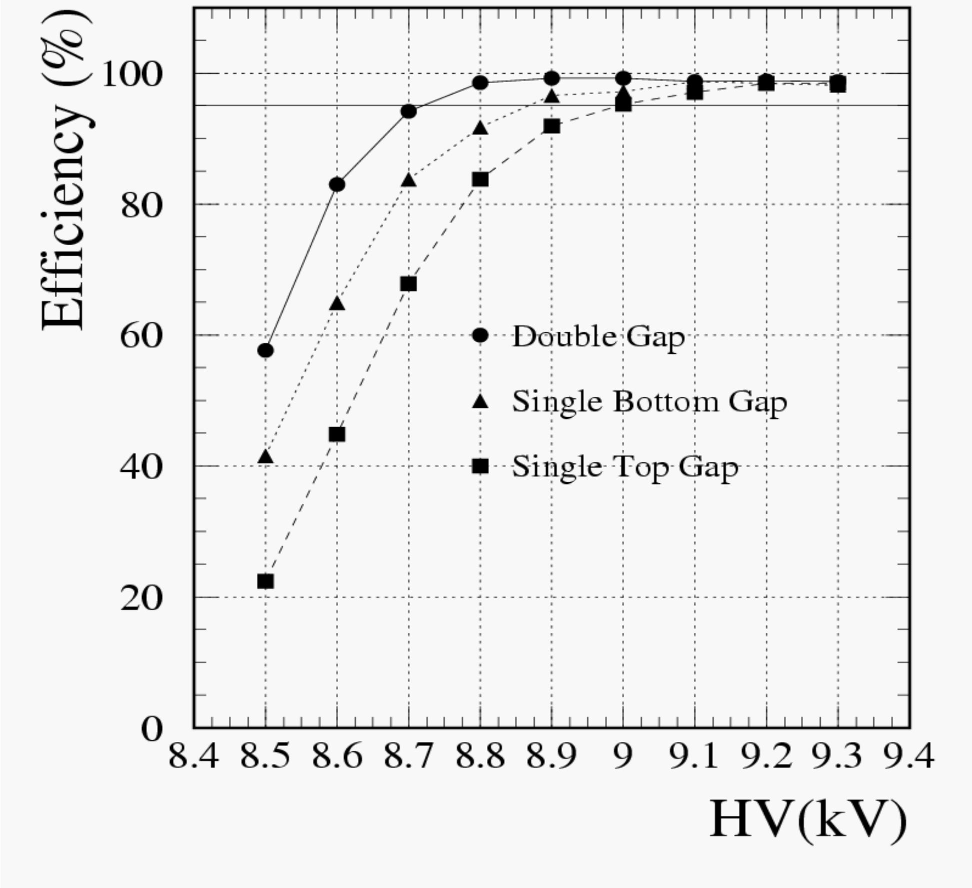
RPCs as Muon Trigger Detectors

Experiment	Operating mode	# gaps	Gap width(mm)	Electrodes material, $\rho(\Omega cm)$	Gas mixture (%)	Readout
BaBar	Streamer	1	2	Oiled bak, $10^{11} \sim 10^{12}$	$60Ar/35C_2H_2F_4/5C_4H_{10}$	strips xy
Belle	Streamer	2	2	glass, $10^{12} \sim 10^{13}$	$30Ar/62C_2H_2F_4/8C_4H_{10}$	strips xy
ALICE TRI	Streamer	1	2	oiled bak., $\approx 3 \times 10^9$	$51Ar/41C_2H_2F_4/7C_4H_{10}/1SF_6$	strips xy
ATLAS	Prop.	1	2	oiled bak., $\approx 10^{10}$	$96.7C_2H_2F_4/3C_4H_{10}/0.3SF_6$	strips xy
CMS	Prop.	2	2	oiled bak., $\approx 10^{10}$	$96C_2H_2F_4/3.5C_4H_{10}/0.5SF_6$	strips x
STAR	Prop.	5	0.22	glass, $\approx 10^{13}$	$95C_2H_2F_4/5C_4H_{10}$	pads
ALICE TOF	Prop.	10	0.25	glass, $10^{12} \sim 10^{13}$	$90C_2H_2F_4/5C_4H_{10}/5SF_6$	pads

CMS RPC requirements

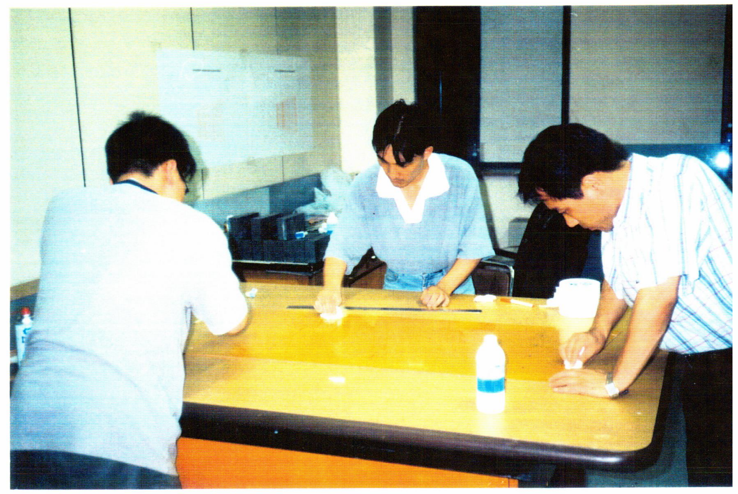
Categories	Requirements
Time Resolution	~1ns
Efficiency	>95%
Rate Capability	~2kHz/cm2
Noise Rate	0.5 ~ 5 Hz/cm2
Strip Multiplicity	1.5 ~ 3.0
Mean Avalanche Charge	2.5 ~ 5 pC
Charge Threshold	200fC
Resistivity	1~6 x10^10 ohm cm





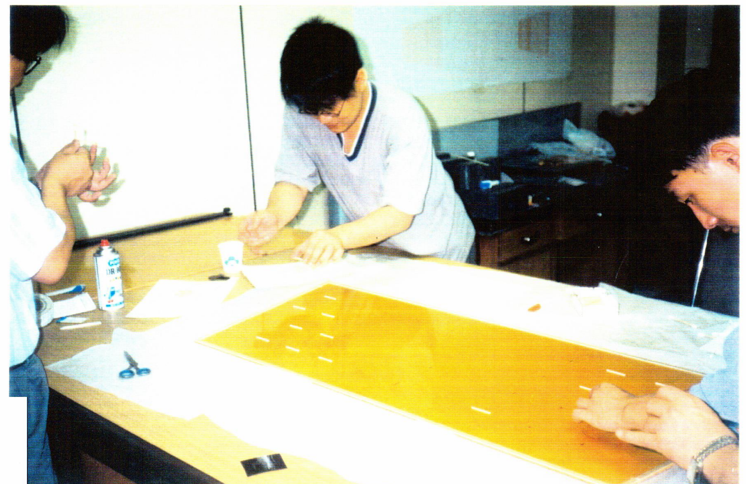
NIMA **508**, 147 (2003)

CMS FRPC Prototype in 1998

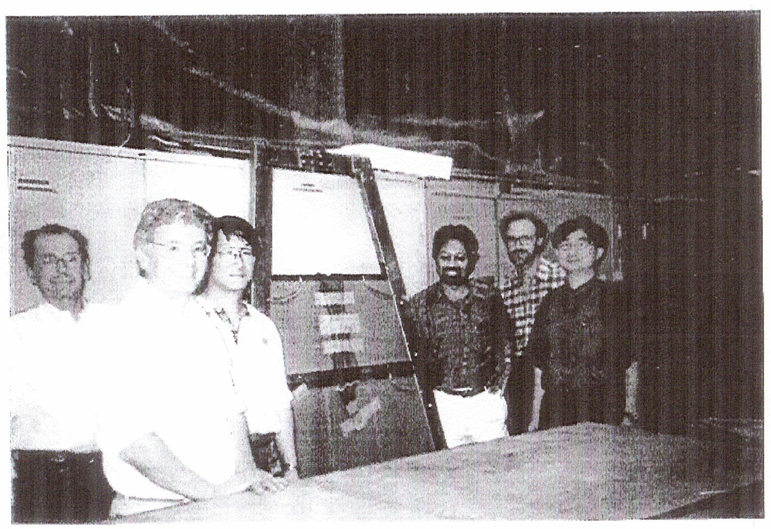





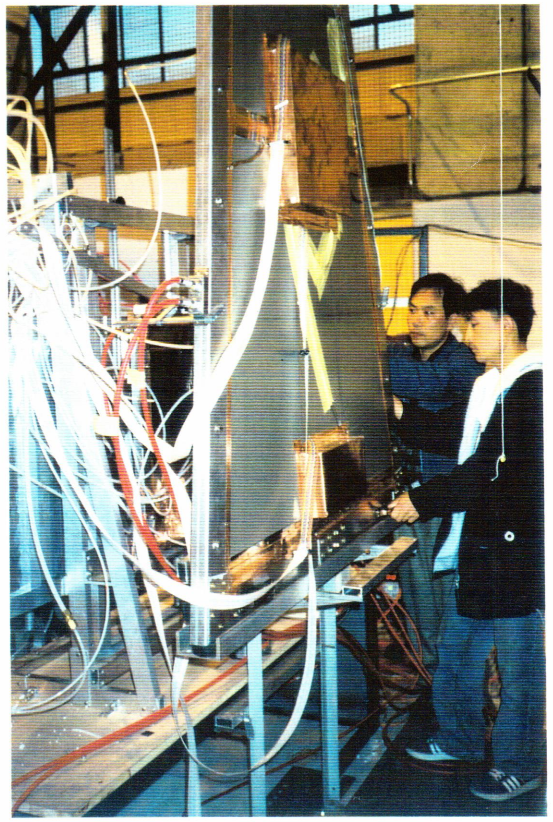
CMS FRPC Prototype

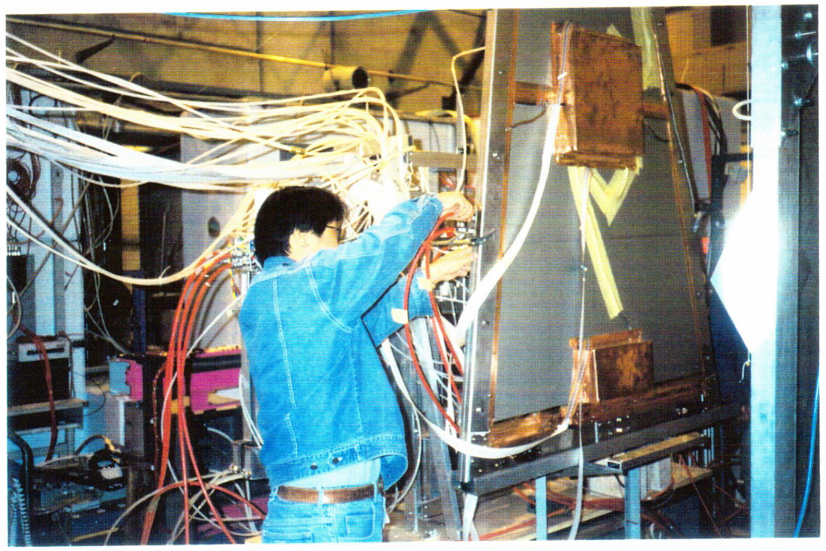


MF2-1 Beam Test(1998)



CERN Beam Test at GIF in 1998



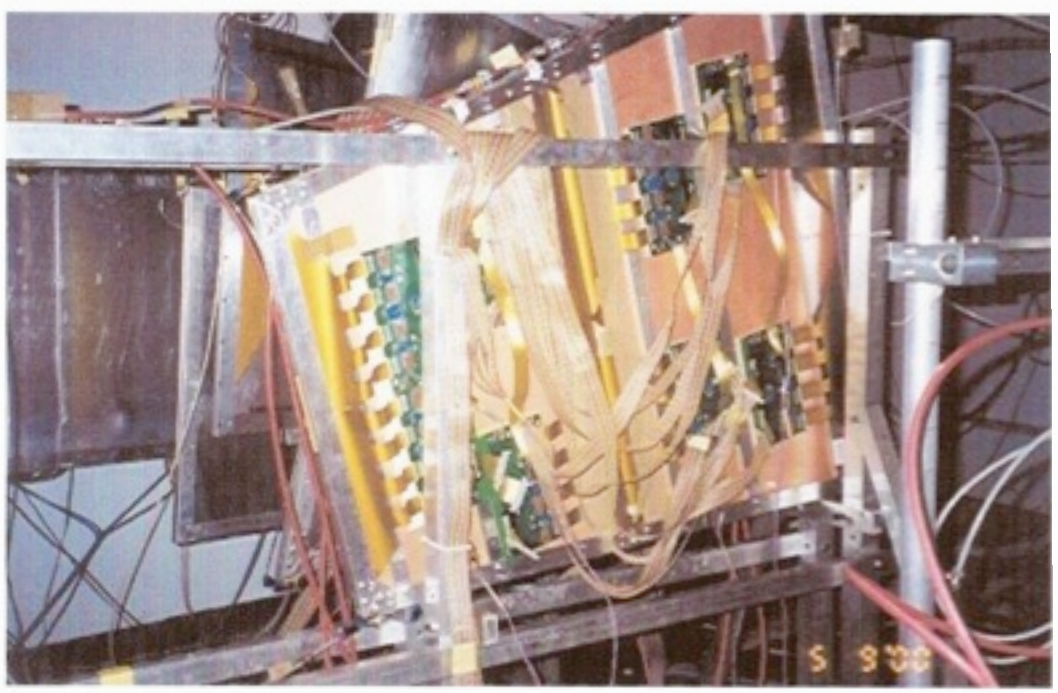


More Prototypes for CMS FRPC in 1999

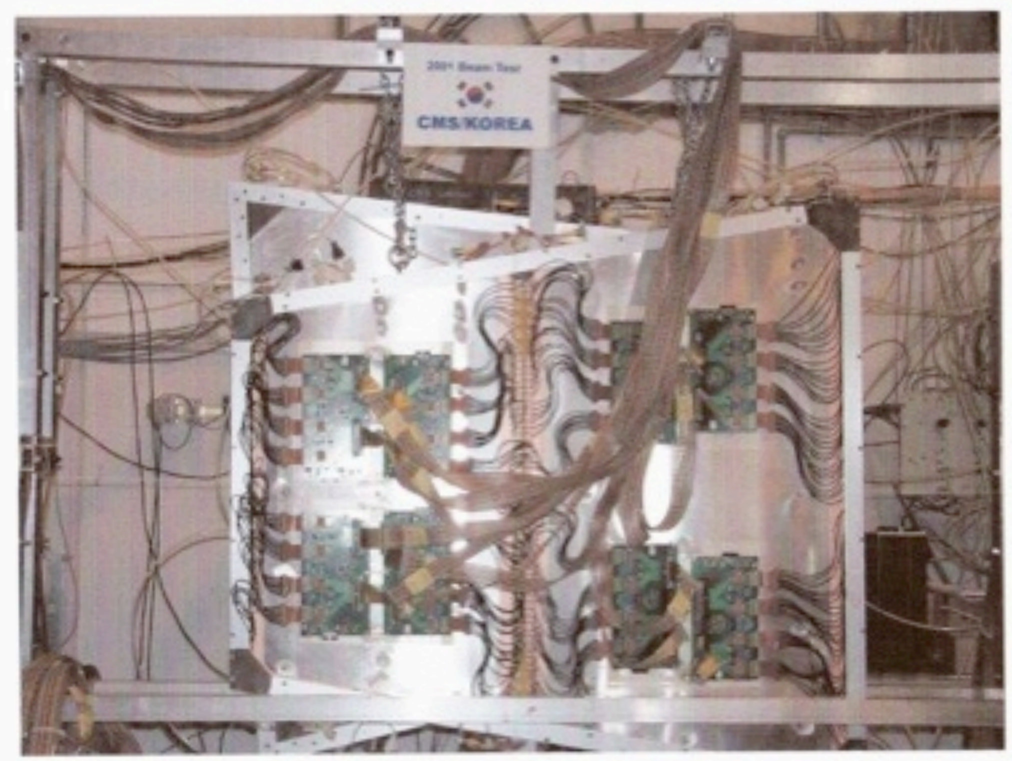
RPC : Beam Test at CERN(2001)

MF2-2 Beam Test(1999)

RPC : Beam Test at CERN (2000)



RPC : Beam Test at CERN(2001)



CMS FRPC for the Gamma Ray Image

Gamma ray transmission imaging detectors using a double gap resistive plate chamber ☆

S. Park, S.H. Ahn, B. Hong, S.J. Hong, T.I. Kang, T.J. Kim, K.S. Lee*, J.K. Lim, D.H. Moon, J.K. Oh, W.J. Park, M.S. Ryu, K.S. Sim

NIMA, 533 (2004) 144-148

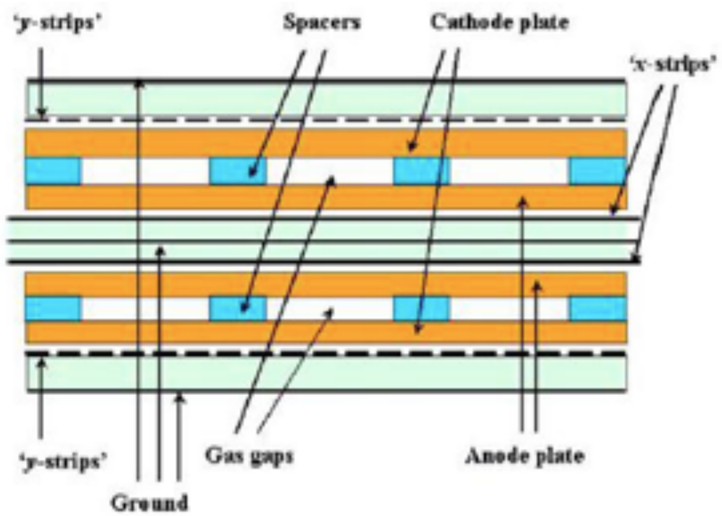
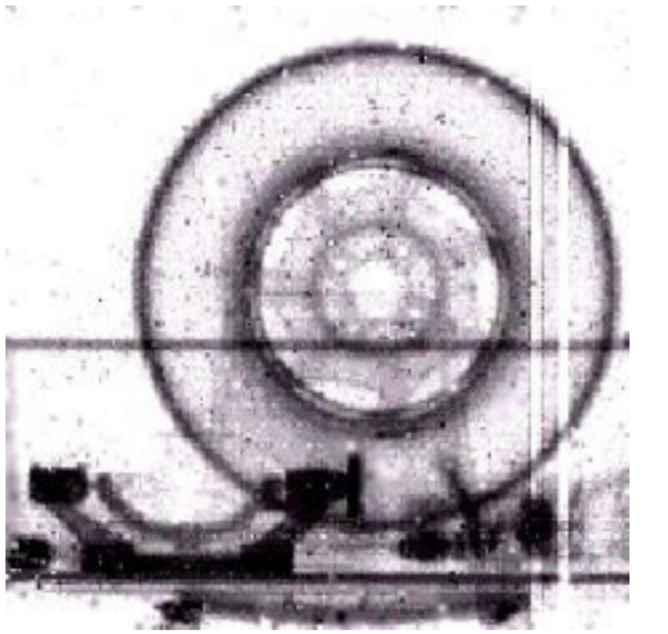


Fig. 3. Cross-sectional view of the double gap RPC with two-dimensional read-out strips.

Fig. 2. 2 mm double gap RPC manufactured for the gamma ray transmission images.



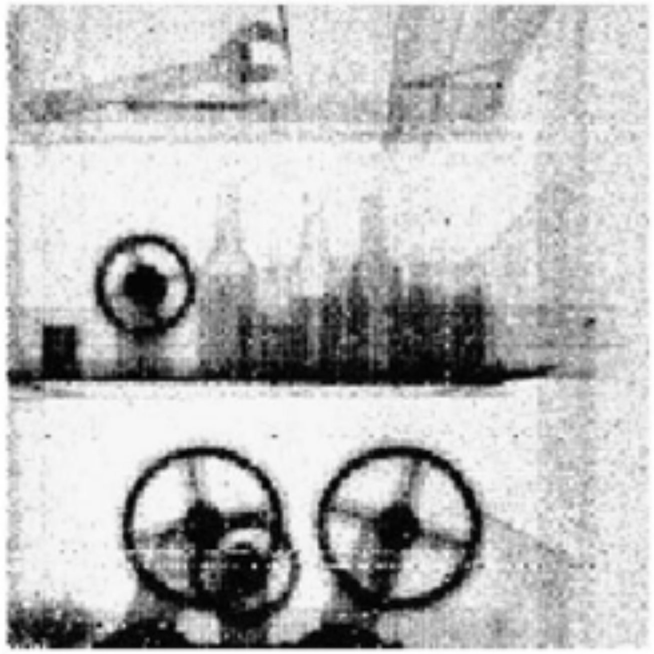


Fig. 6. Gamma ray transmission images for objects in a 0.5 mm thick stainless steel cabinet.

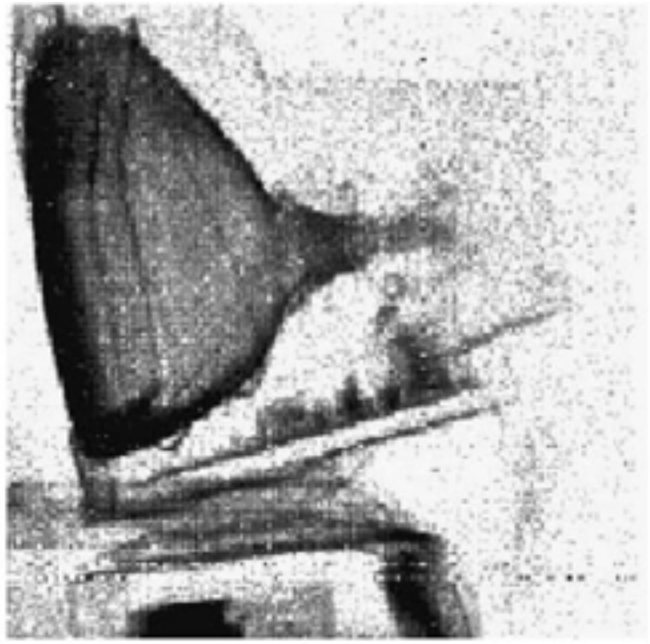
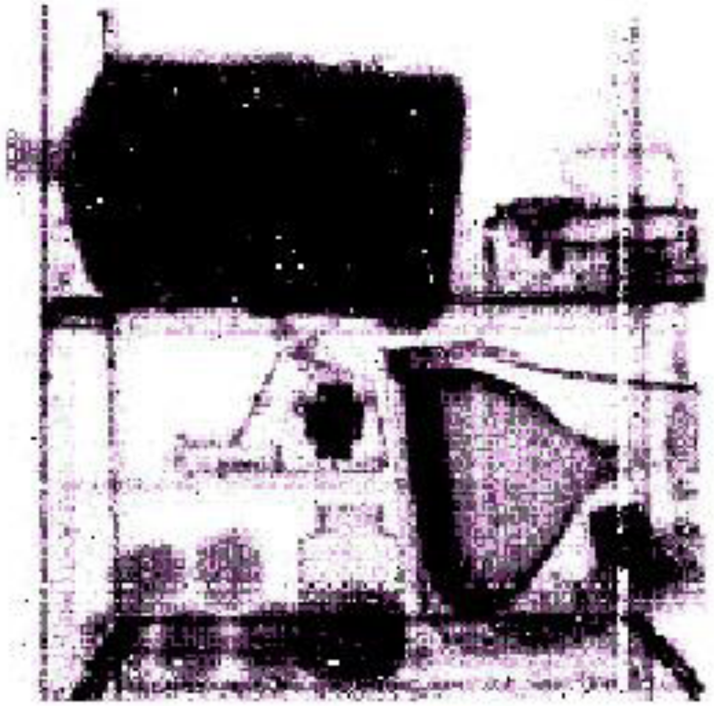
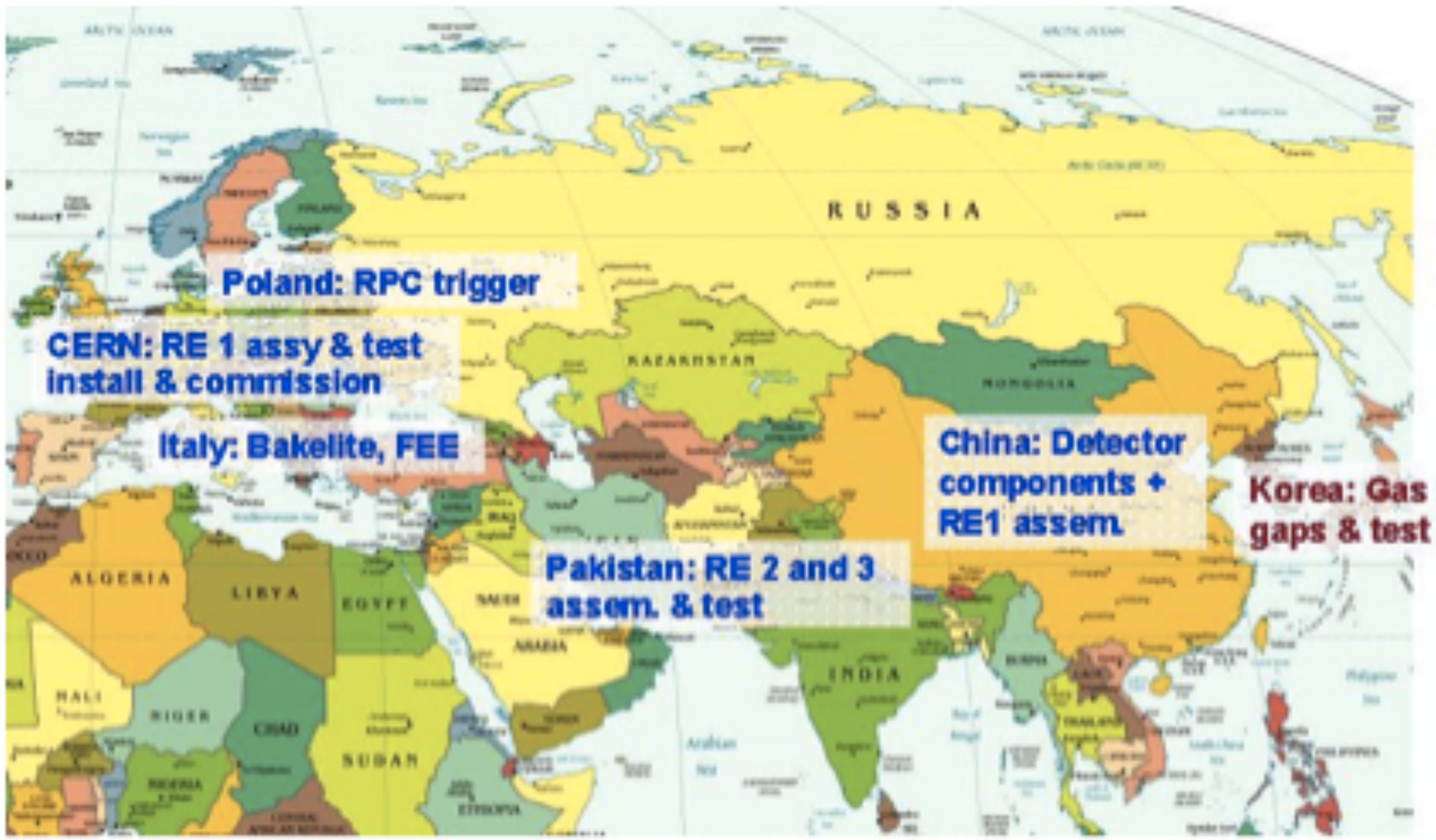


Fig. 7. Gamma ray transmission image for the computer monitor.



Collaboration works for the Forward RPCs

Korea, Belgium, CERN, China, India, Italy, Pakistan, Poland, Russia …



7

3. Collaboration for the Forward RPC upgrades

Korean Group :

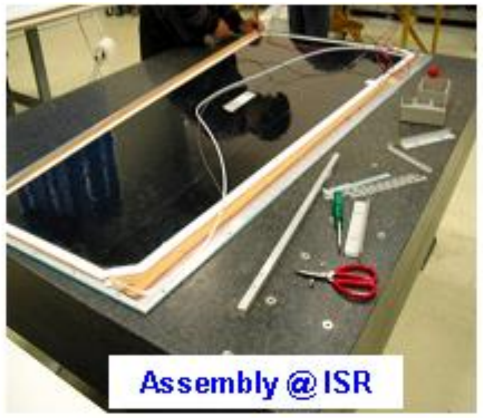
1. Production and the tests for RPCs gaps (Phase I)
2. Participation of the detector assem. for high η RPCs

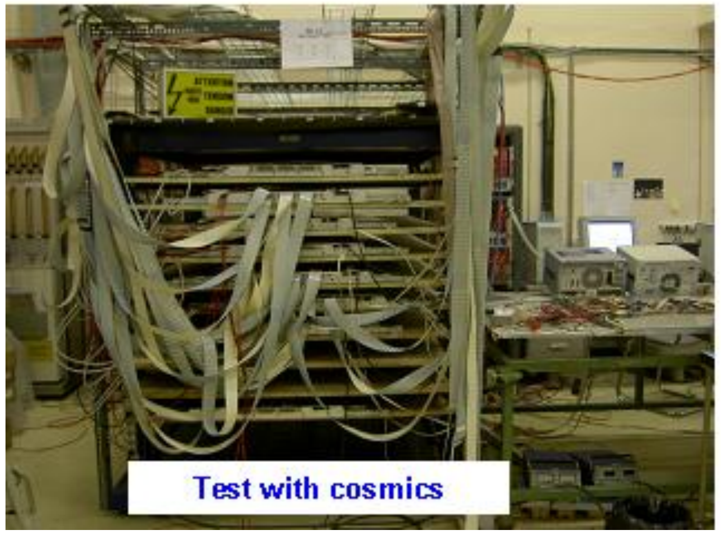
Will use the current detector production site and the facilities in Korea University (used for the previous production for the RE).

26

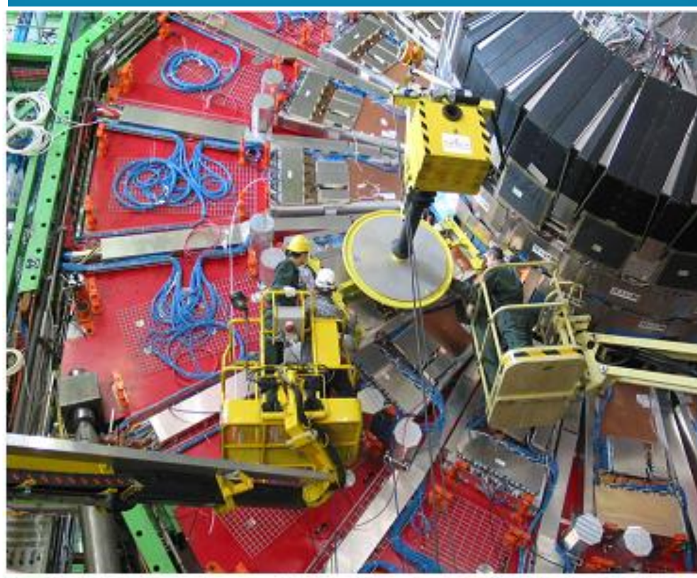
At CERN

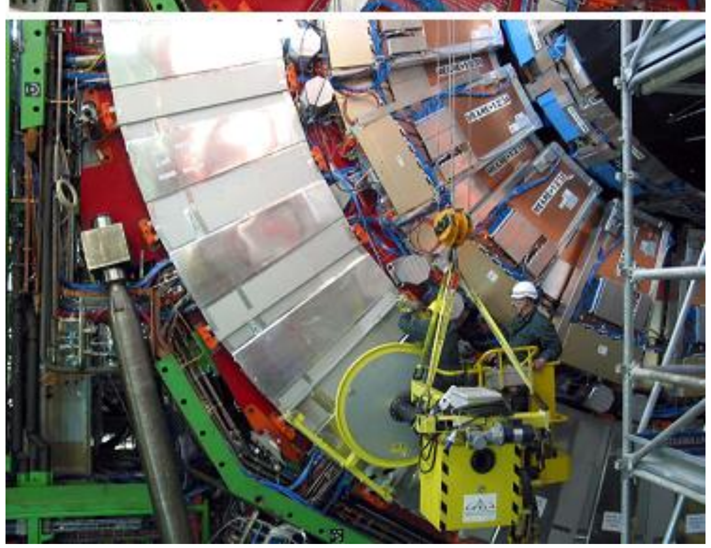
Cosmic tests for the new RPCs at the site in the ISR (used for the previous detector assembly and tests)





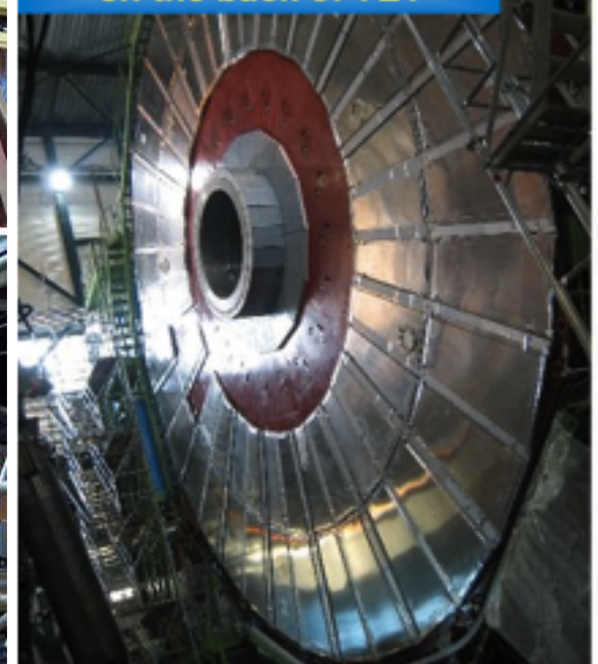
RE1 in η < 1.6
RE1/2 & RE1/3 : 144 RPCs



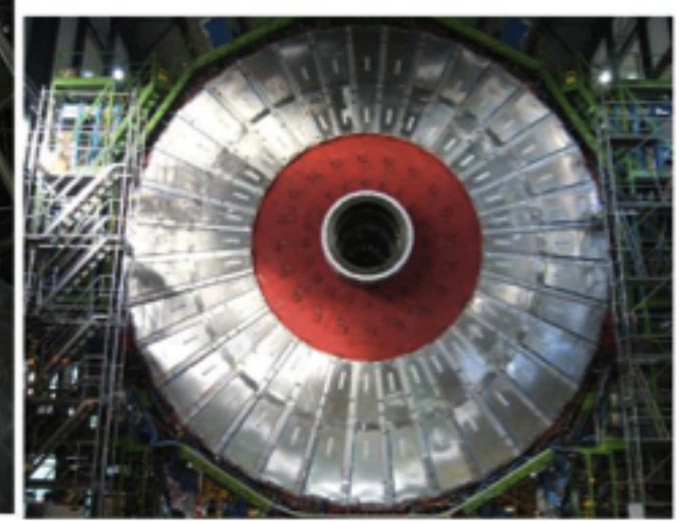


RE2 in η < 1.6
RE2/2, RE2/3, RE3/2, RE3/3 288 RPCs

RE2/2 & RE2/3
on the back of YE1



RE3/2 & RE3/3
on the back of YE3

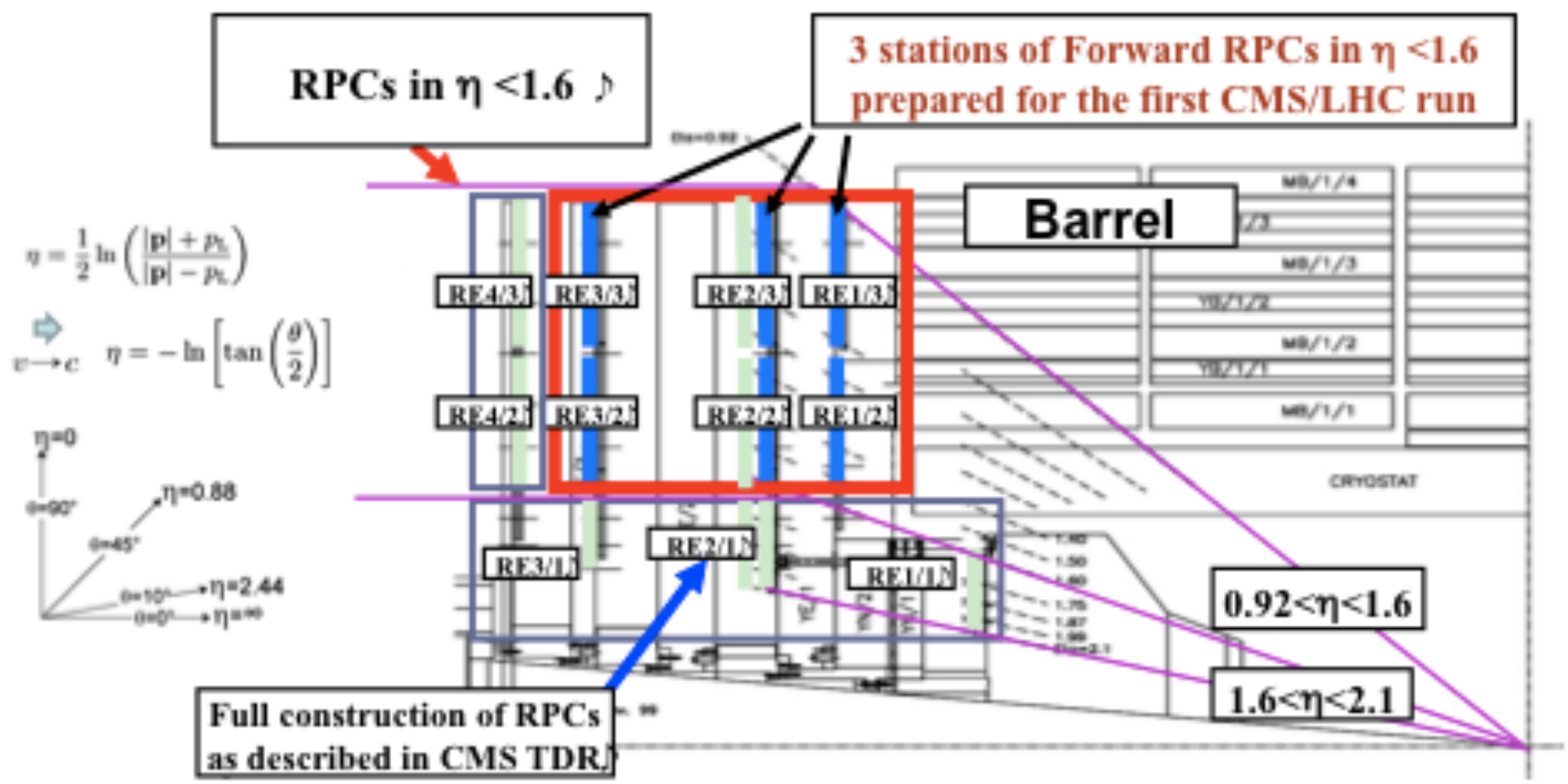


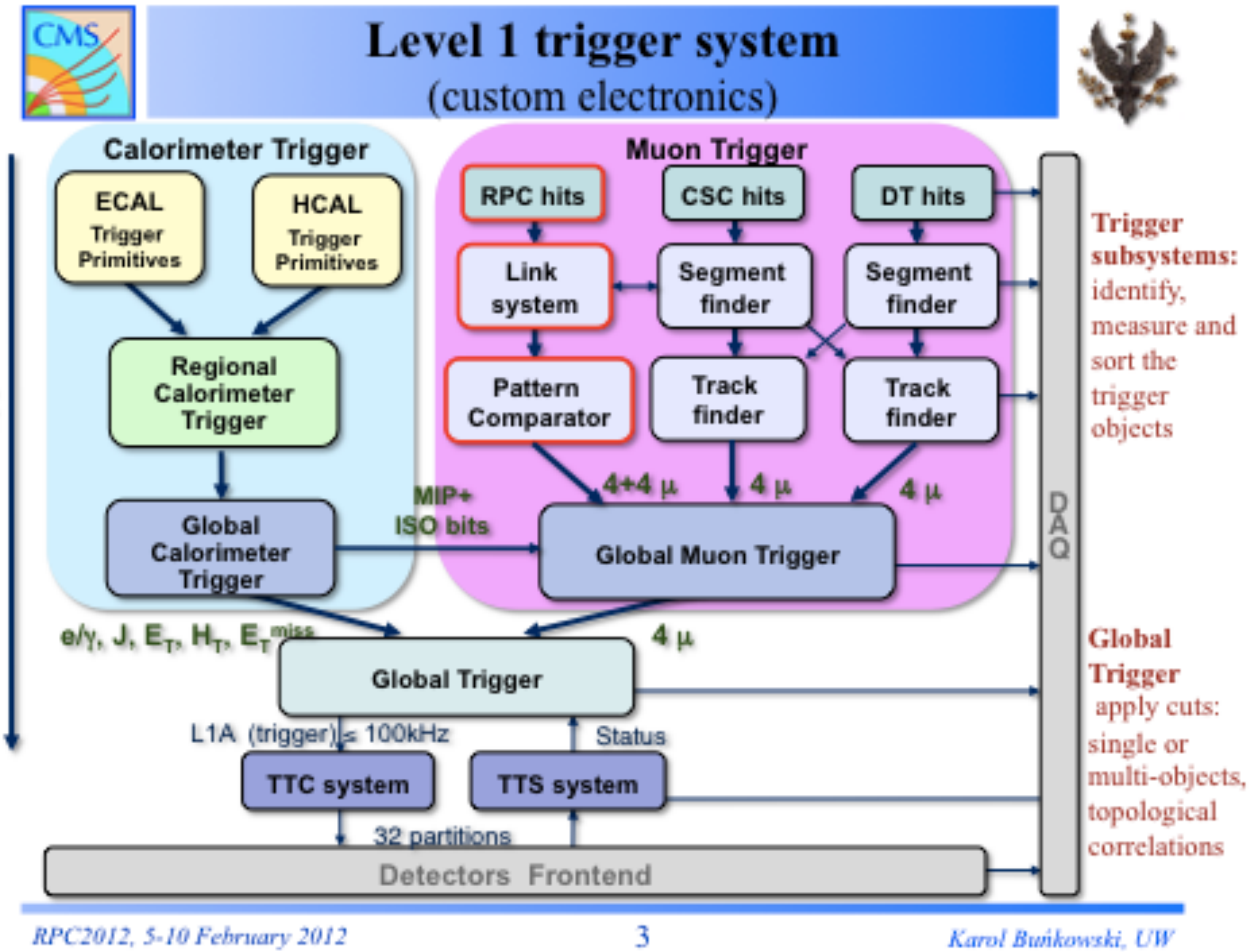
Current CMS RPC System

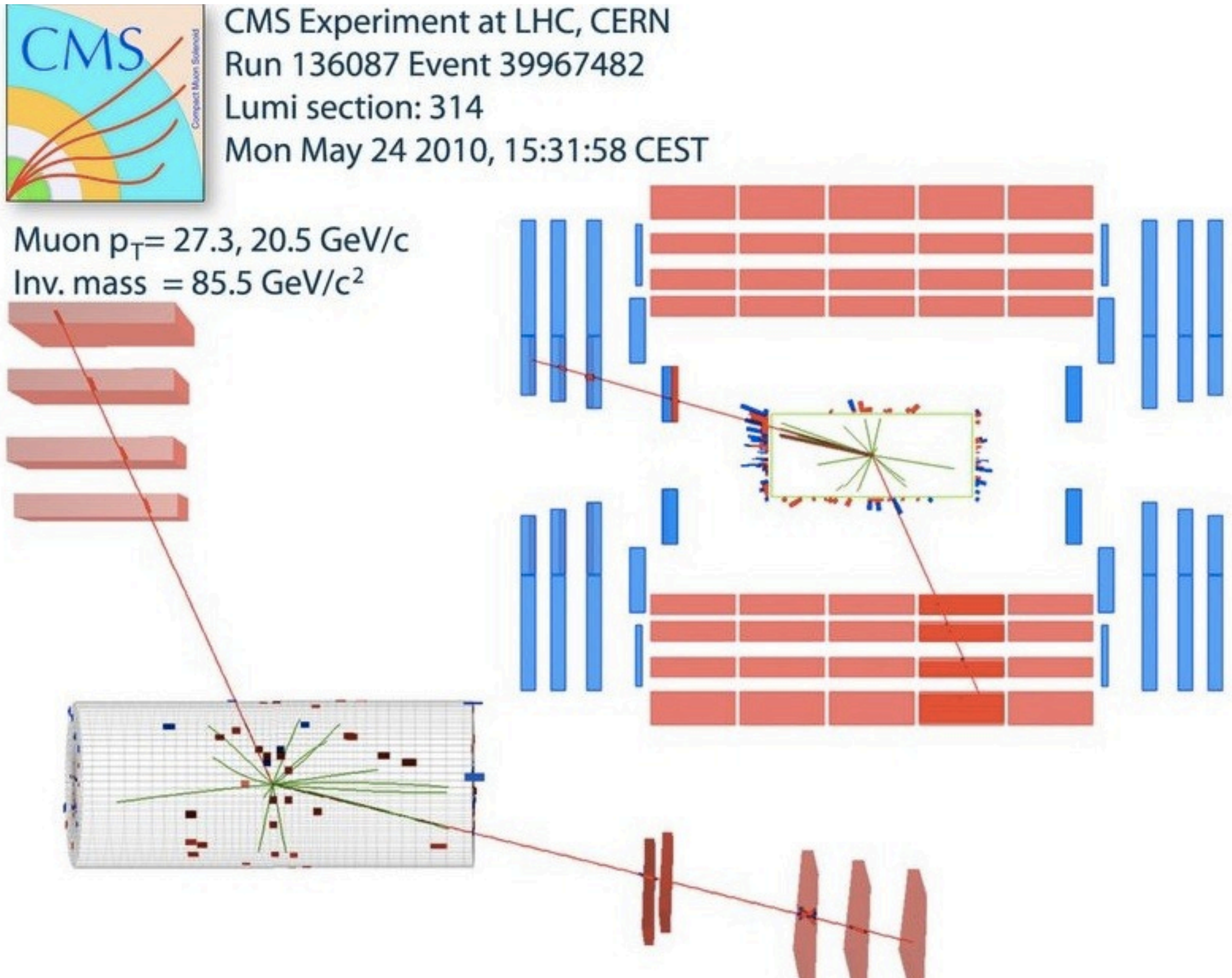
- ▶ **RPCs System for the Compact Muon Solenoid (CMS/TDR LHCC/CERN 97-32)**
  - RPCs in Barrel + Forwards cover η < 2.1
  - The angular coverage ~ 3 π

- ▶ **Barrel RPCs**
  - 6 stations (layers)
  - Fully covering up to η = 0.8
  - Partially covering up to η = ~ 1.2

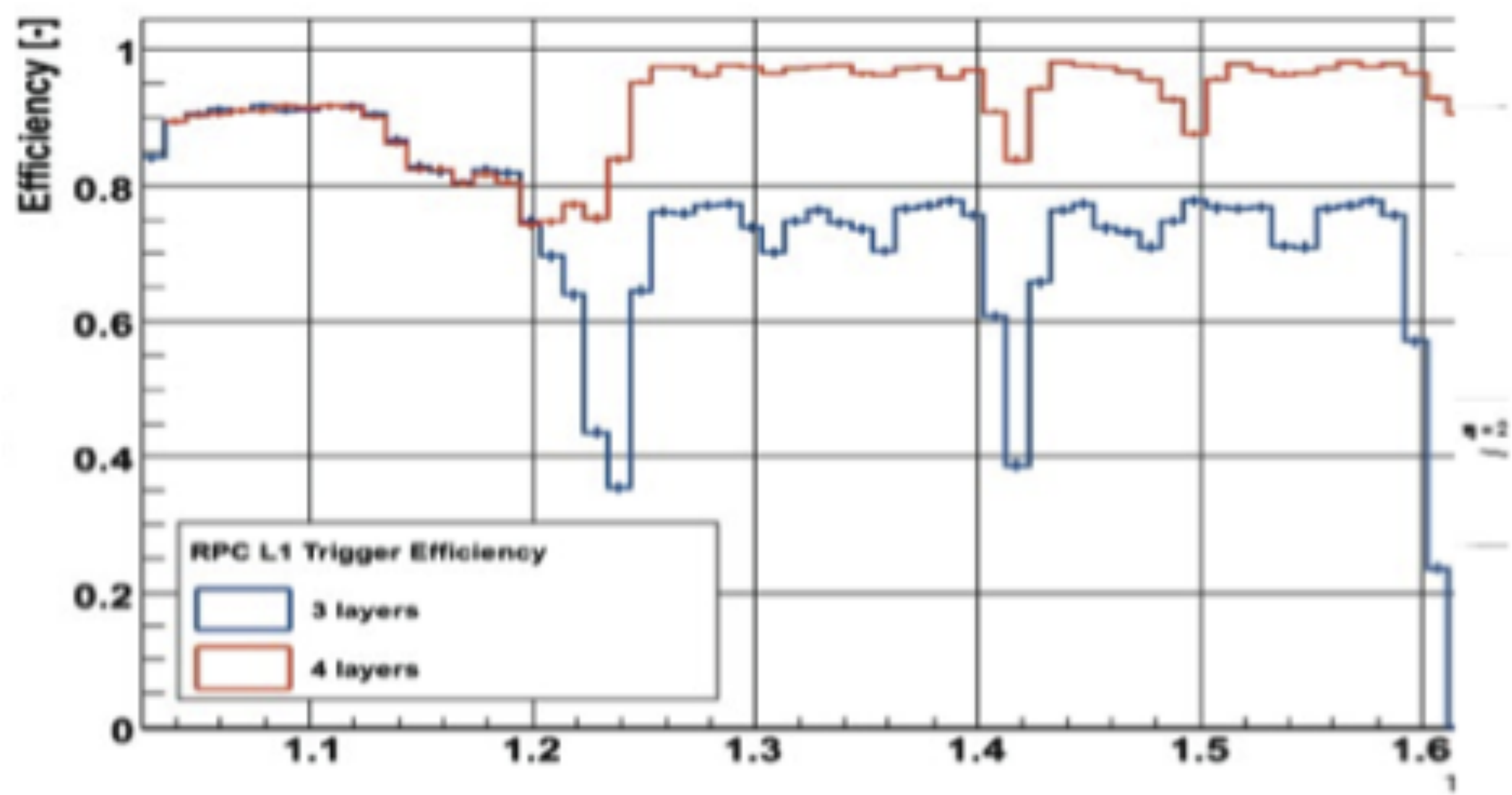
- ▶ **Forward RPCs**
  - 2 wings (RE+, RE-)
  - 4 stations (RE1, RE2, RE3, RE4) in each wing
  - Covering 0.92 < η <2.1



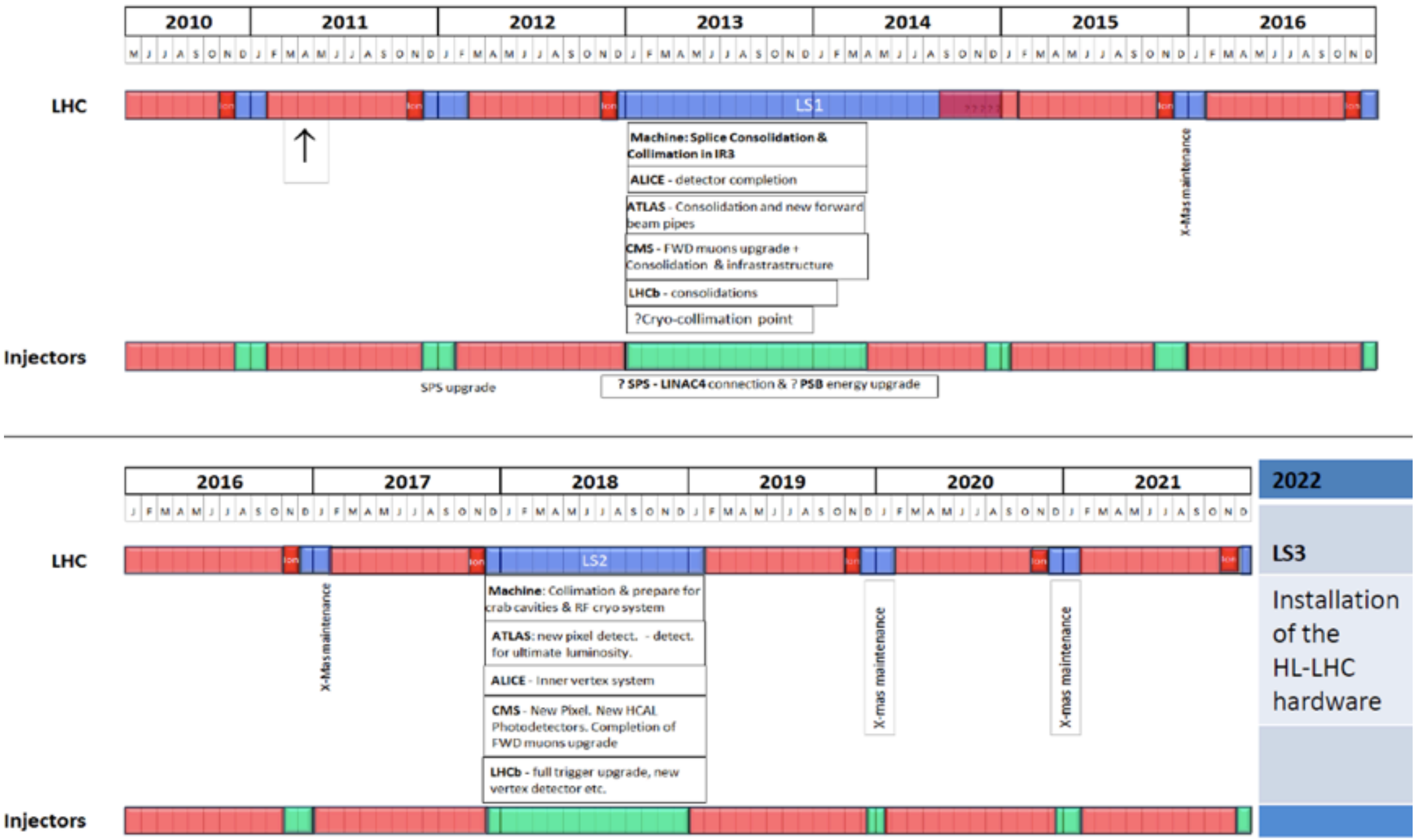

Level 1 trigger system
(custom electronics)
CMS
Calorimeter Trigger
ECAL
Trigger Primitives
HCAL
Trigger Primitives
Regional Calorimeter Trigger
Global Calorimeter Trigger
Muon Trigger
RPC hits
CSC hits
DT hits
Link system
Segment finder
Segment finder
Pattern Comparator
Track finder
Track finder
4+4 μ
4 μ
4 μ
MIP+ ISO bits
Global Muon Trigger
e/γ, J, E_T, H_T, E_T^miss
4 μ
Global Trigger
L1A (trigger) ≤ 100kHz
Status
TTC system
TTS system
32 partitions
Detectors Frontend
40 MHz pipeline
DAQ
Trigger subsystems: identify, measure and sort the trigger objects
Global Trigger apply cuts: single or multi-objects, topological correlations
RPC2012, 5-10 February 2012
3
Karol Buńkowski, UW


CMS Experiment at LHC, CERN
Run 136087 Event 39967482
Lumi section: 314
Mon May 24 2010, 15:31:58 CEST
Muon p_T= 27.3, 20.5 GeV/c
Inv. mass = 85.5 GeV/c^2

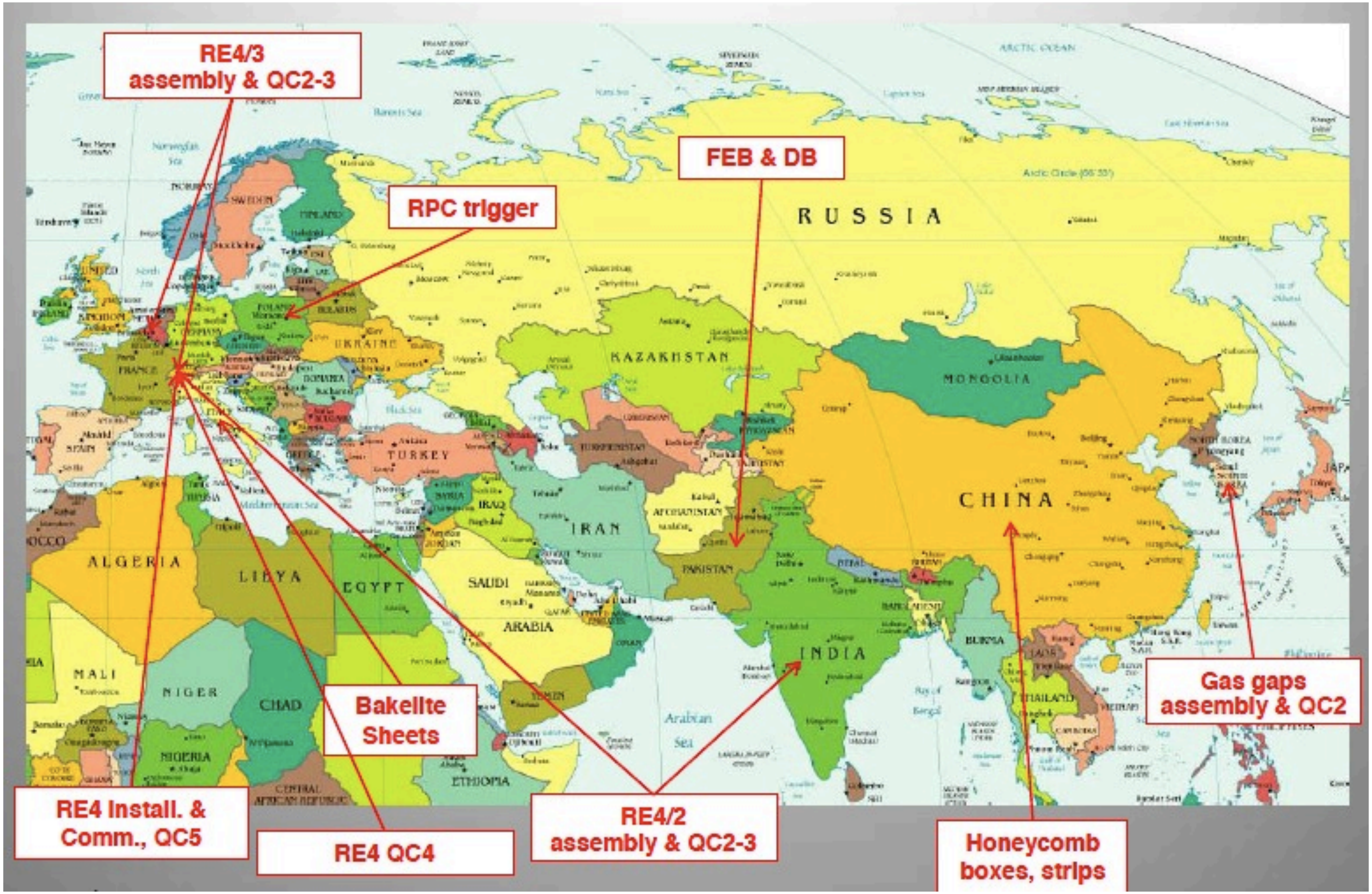
Upgrade Trigger improvements



LHC Long Shutdown Plan



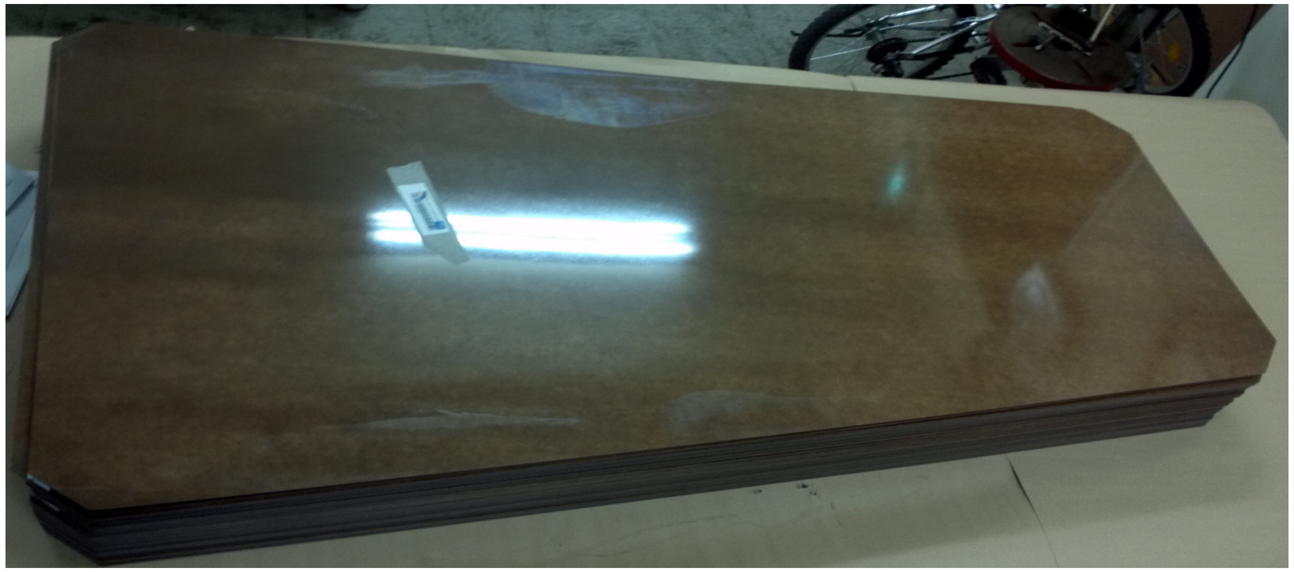
Forward RPC Upgrade Project



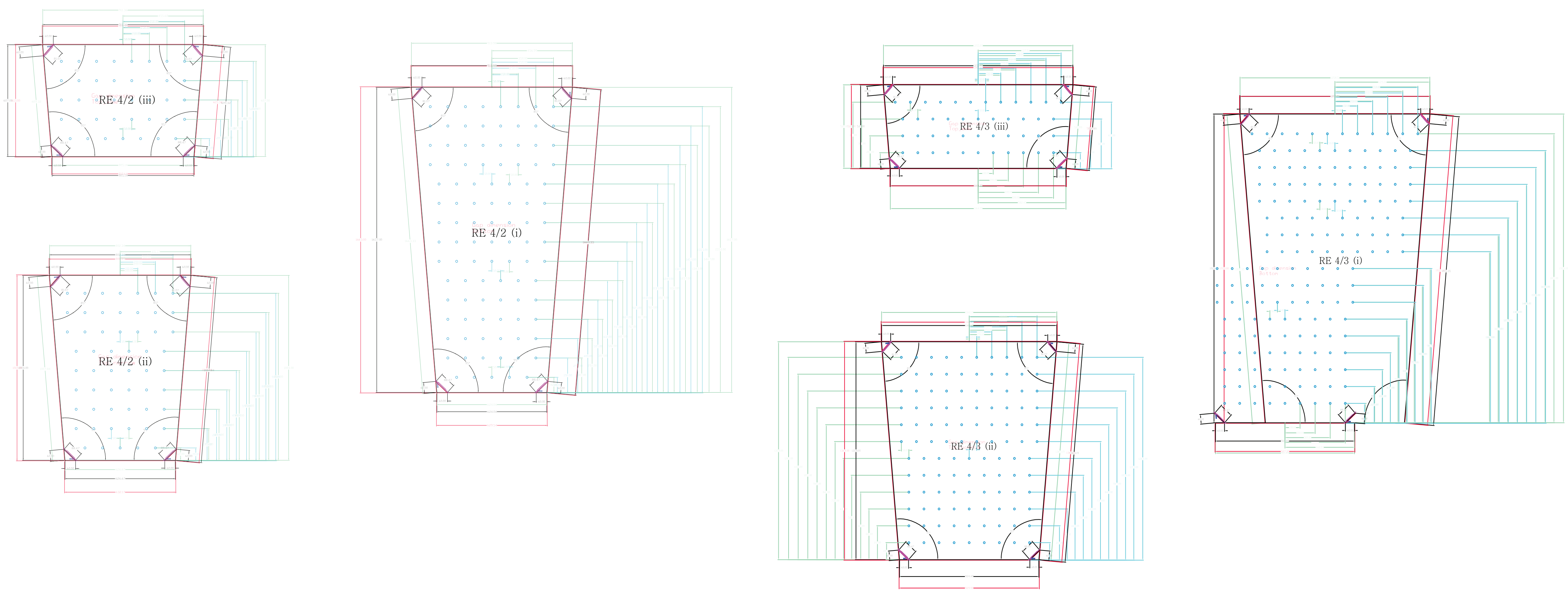
GAP Production for Upgrade at KODEL

HPL arrived at KODEL

HPL for RE4/2 CMS FRPC



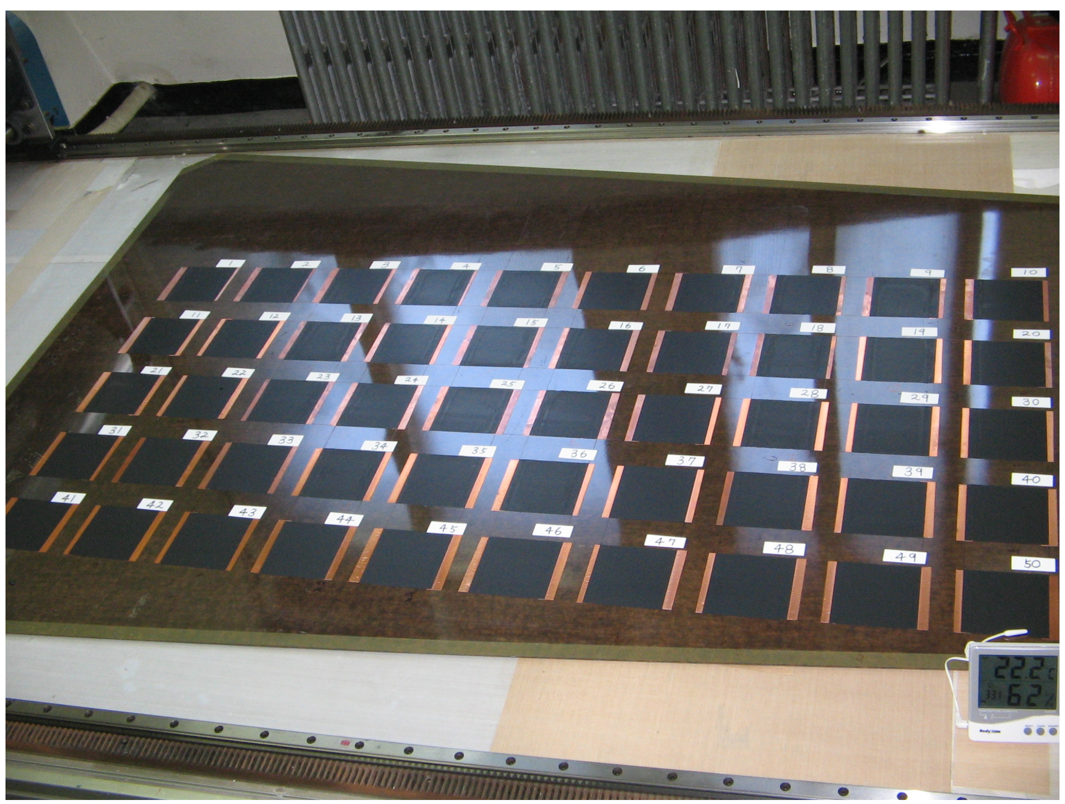
RE4/2 and RE4/3 CMS FRPC Dimensions

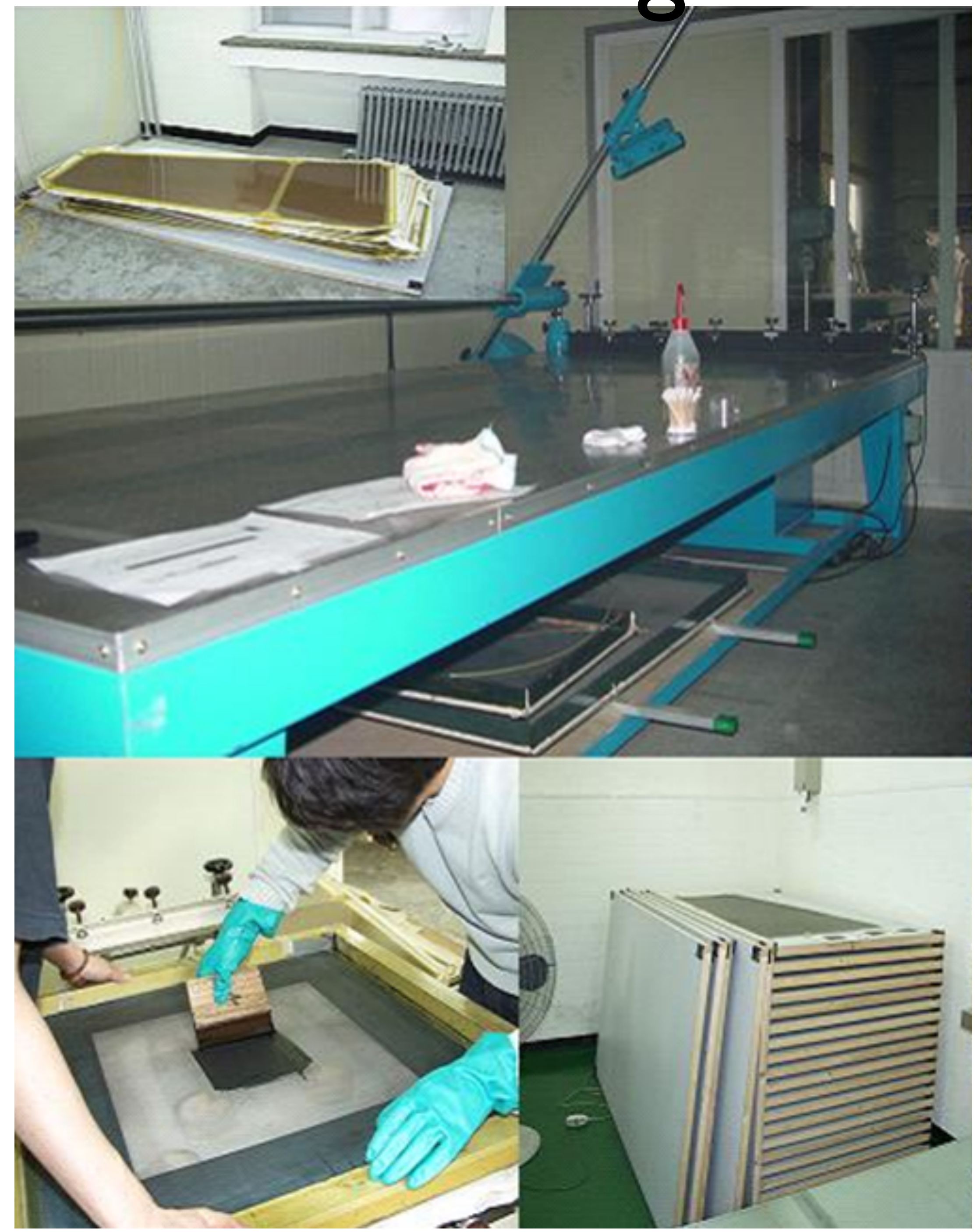


Electrodes from Silkscreen Coating

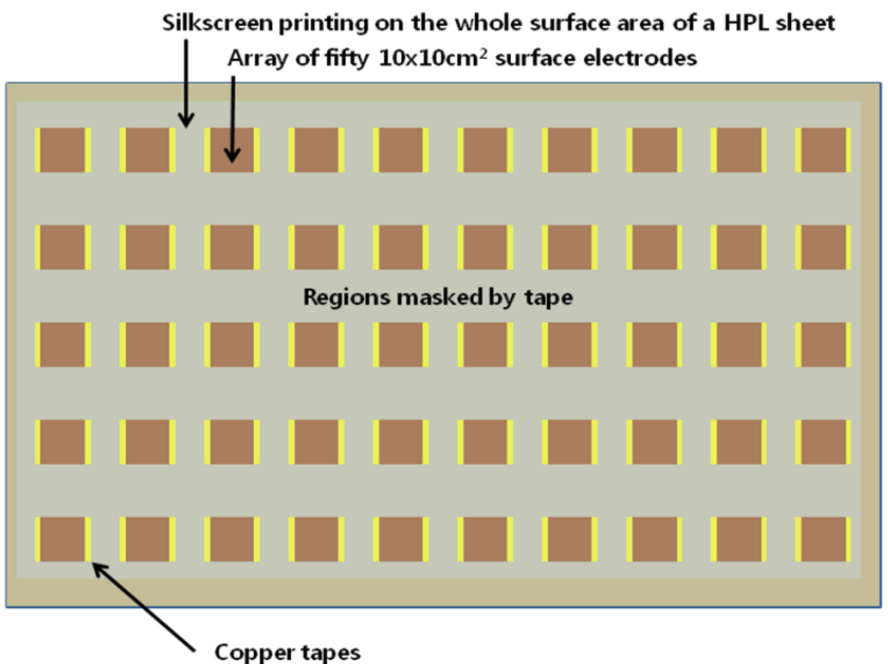
Applying the same procedures and tools used for the CMS Forward RPCs

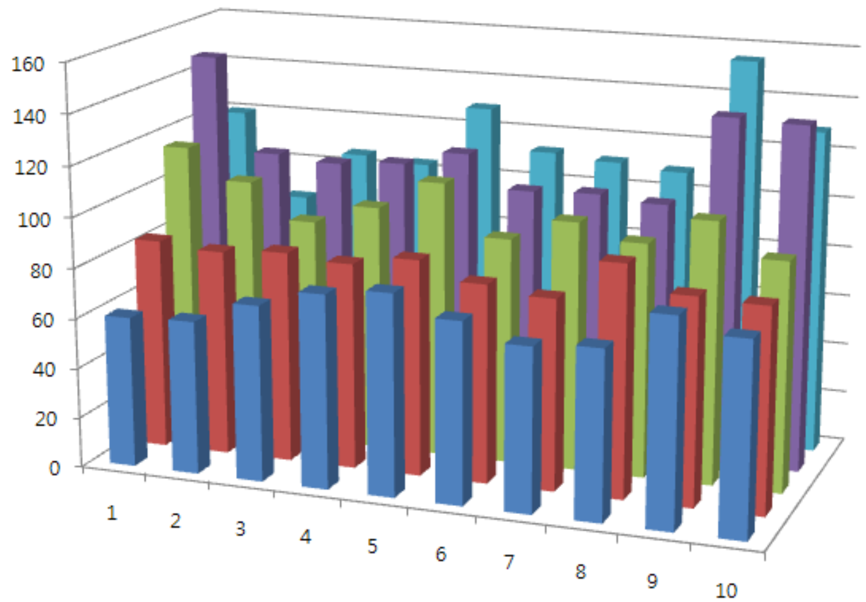
1. **Graphite coating for RPC electrodes**
   - Silkscreen method
   - Surface resistivity of electrode ranges from 50 to 200 kΩ/square



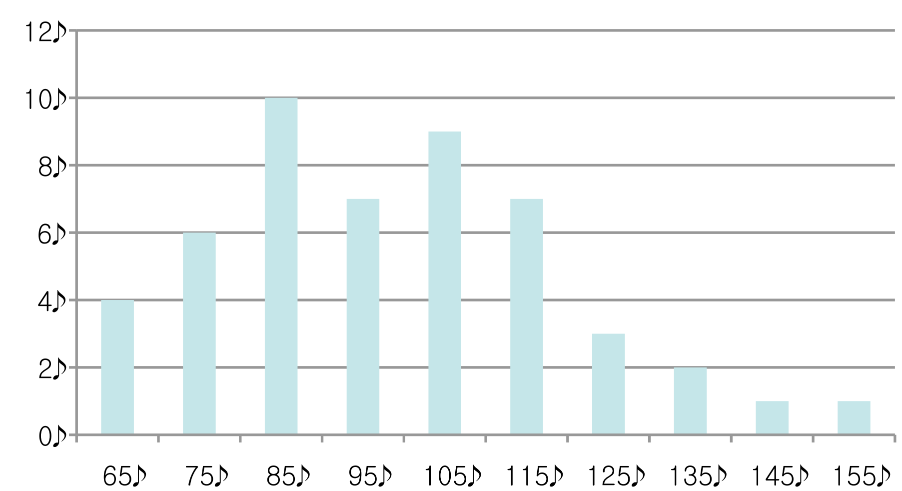


Uniformity of the Surface Resistivity





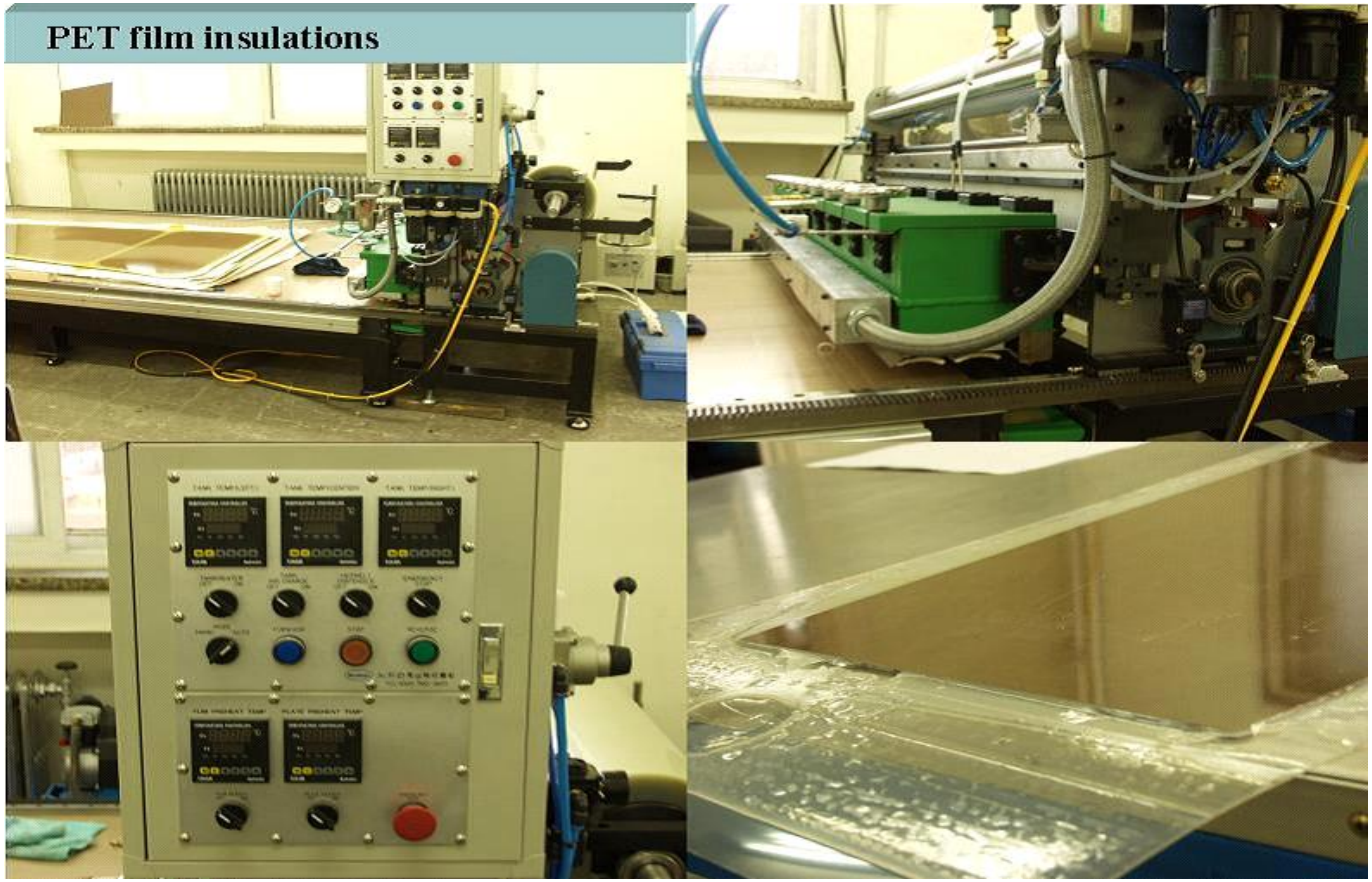
Ave. = 97.42 kOhm♪
Sigma = 21.84 kOhm♪



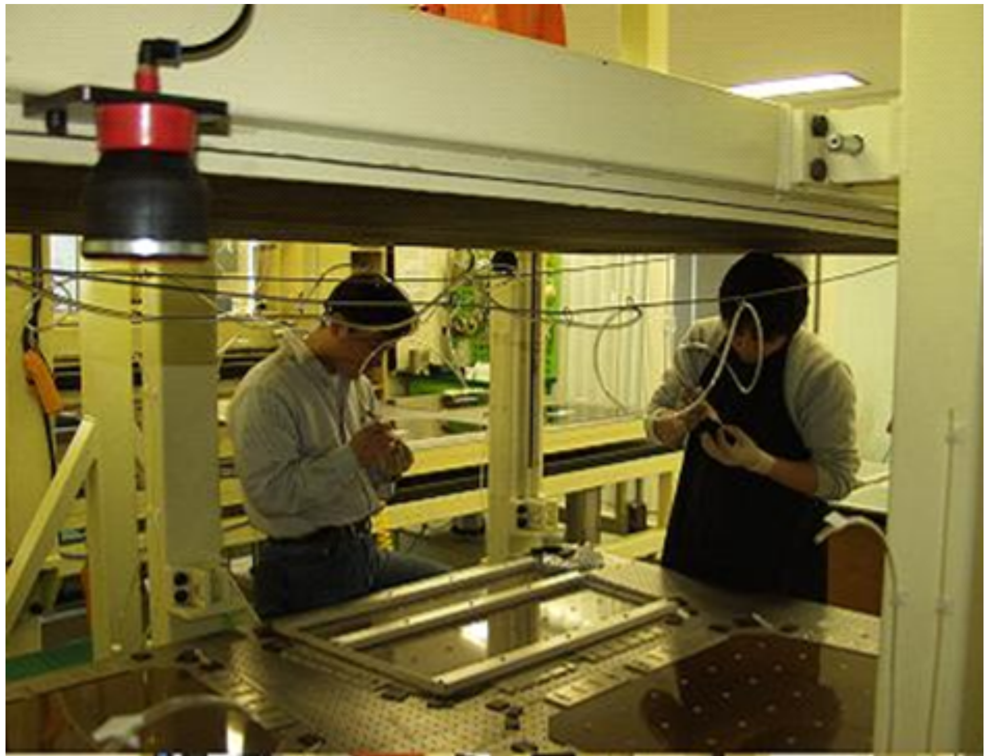
Electrodes Coated with Graphite

PET film coating for protection of graphite electrodes

- 1 layer of 200 micron PET film, Ethylene Vinyl Acetate base glue



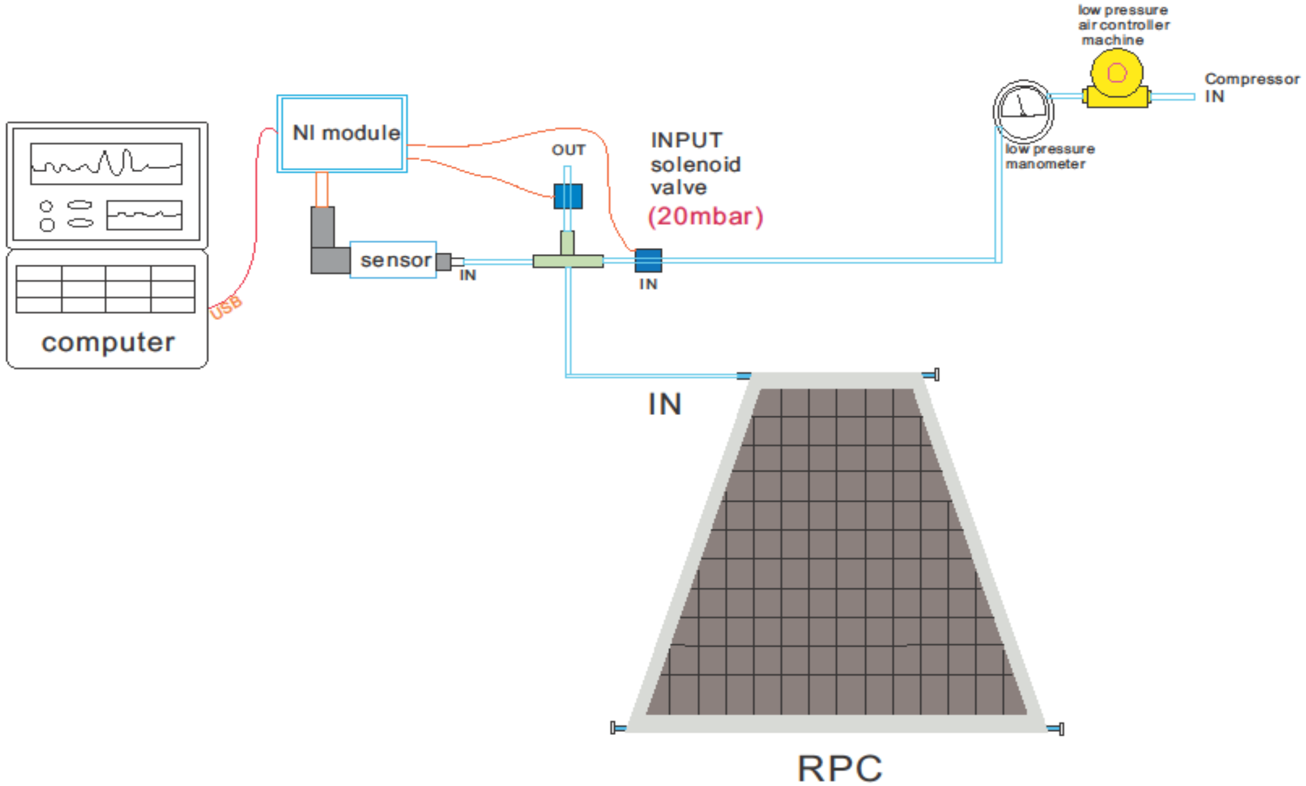
Gap Assembly



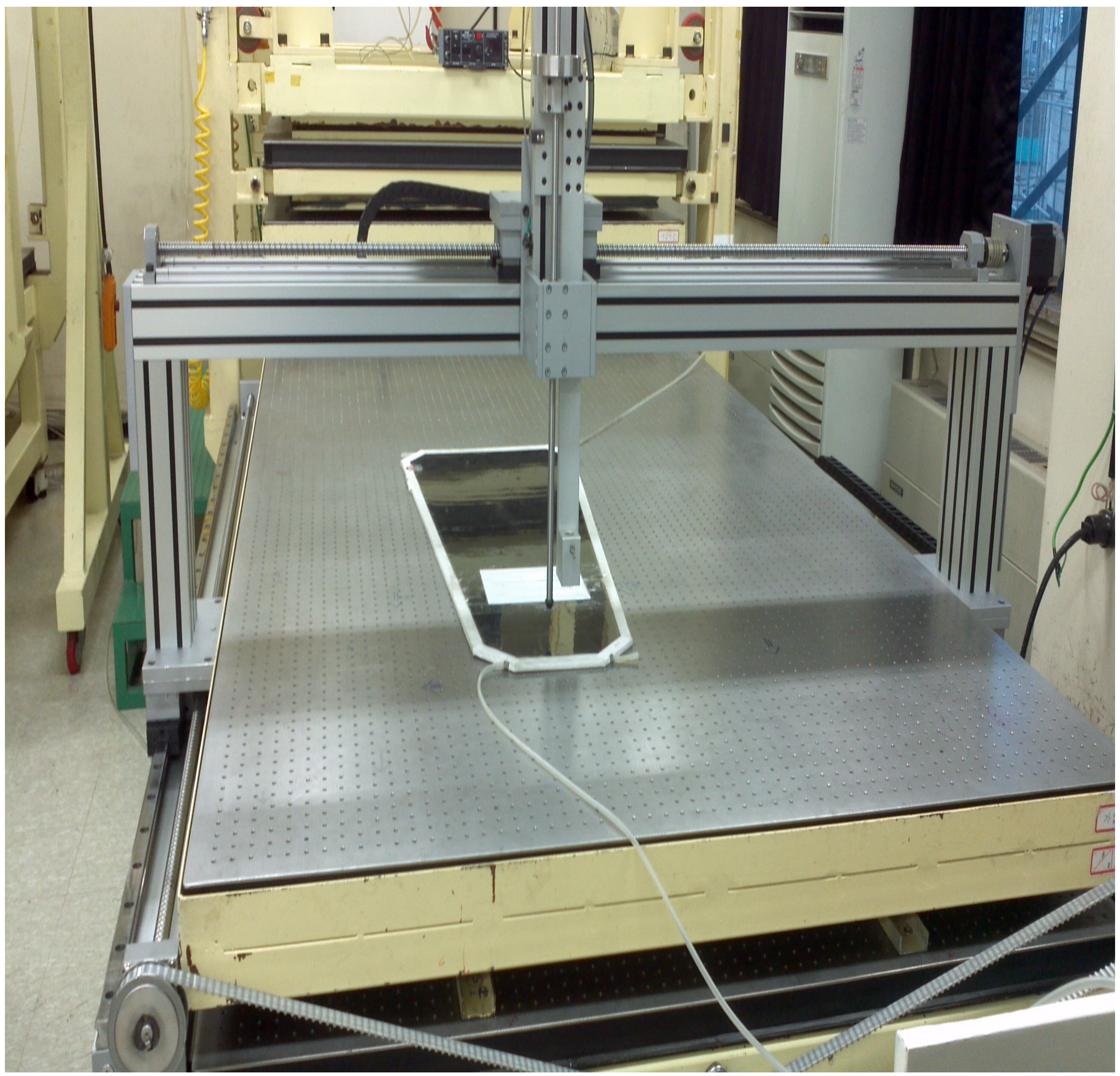
3. Gap assembly

- multi-layered metric tables and shelves
  for the assembly and glue curing
- Glue curing time : **24 hours**
- Glue : DP460, 3M production
- Selection of spacers : **2 mm +/- 20 μm**
- Use spacer jigs for the location of spacers
  Accuracy of positions < 1 mm

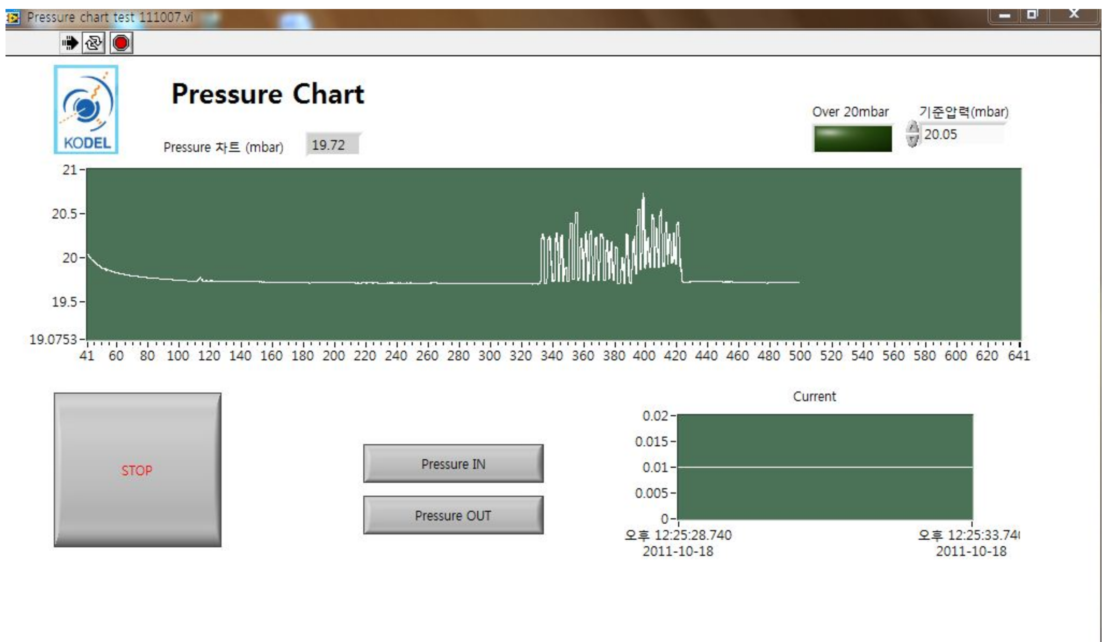
Leakage and Pressure Test

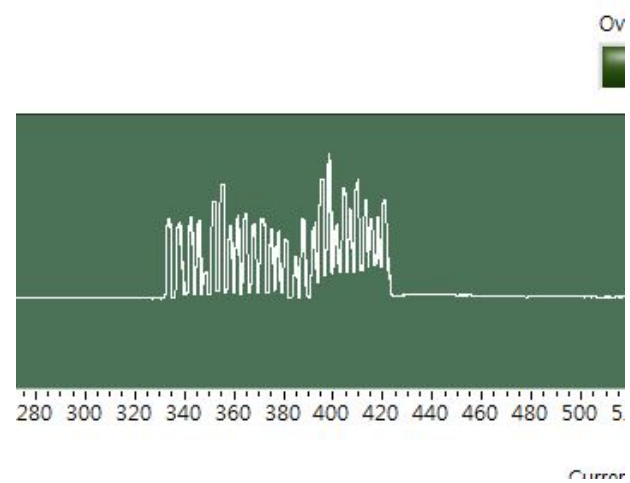


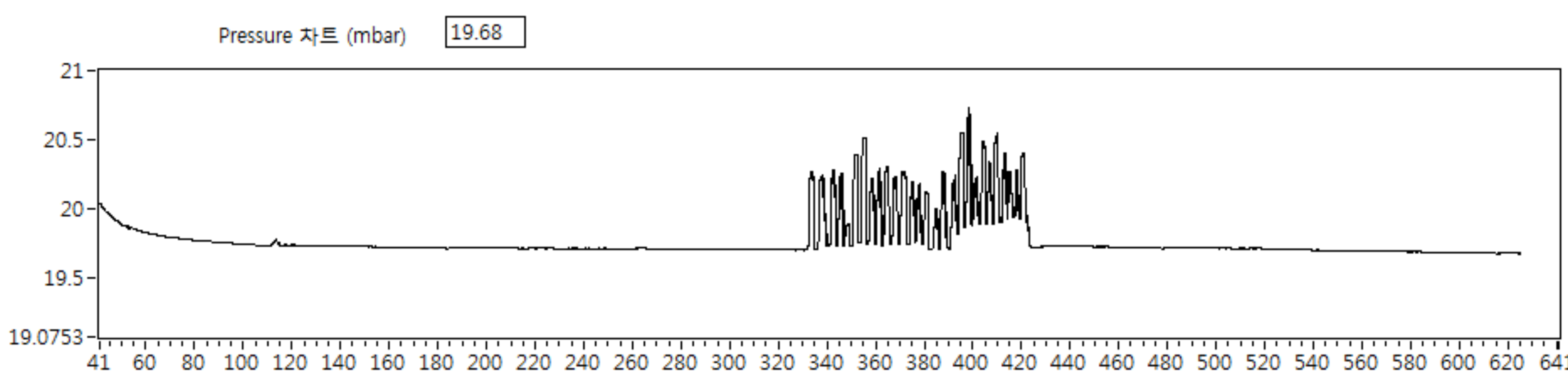
KODEL Robot Checking Leakage and Spacers



Pressure Test Results from KODEL Robot







KODEL

QC steps

Leak

Pop spacers

1. Leak test (maxi. *p* drops allowed:
   0.2 ~ 0.4 hPa with +20 hPa
2. Pop spacer test (no pop spacer allowed)

Gap code	HPL code (GND)	HPL code (HV)
Kodel-CMS-RE4-2-B121		

1. Visual inspections		Good	Not good	Description of the problem
	Bar code label	O		N/A
	Gas inlet and outlet pipes	O		N/A
	Edges and gas corner piece	O		N/A
	HPL (HV)	O		Minor scratches
	HPL (GND)	O		N/A
	HV cable	O		N/A
	GND cable	O		N/A
	Graphite (HV) quality & surf. value (kΩ)	O		N/A
	Graphite (GND) quality & surf. value (kΩ)	O		N/A
	PET coating (HV)	O		Some bubbles bubbles on edges
	PET coating (GND)	O		N/A

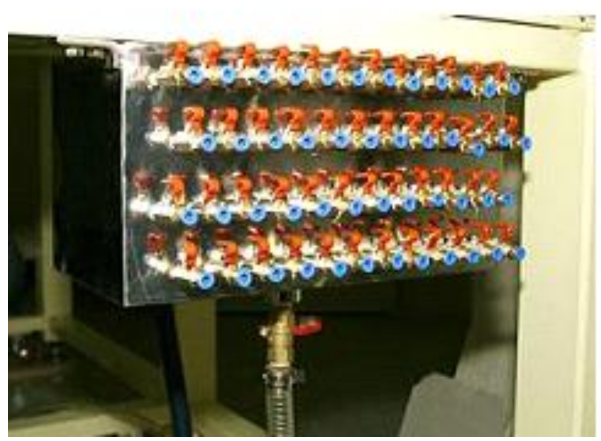
Cen1	Cen2	Edge1	Edge2	Mean	Allowed range	
85	67	121	132	101	Minimum	50
Cen1	Cen2	Edge1	Edge2	Mean	Maximum	200
64	102	147	126	111		

2. Leak Test	require 2 mins to reach	an equilibrium			Leak Limits Allowed					
Time (mins)	Pressure drop (hPa)	0.11	Certified	O	RE4/2 TW	RE4/2 TN	RE4/2 BT	RE4/3 TW	RE4/3 TN	RE4/3 BT
10			Not certified		0.2 hPa	0.2 hPa	0.3 hPa	0.2 hPa	0.3 hPa	0.4 hPa

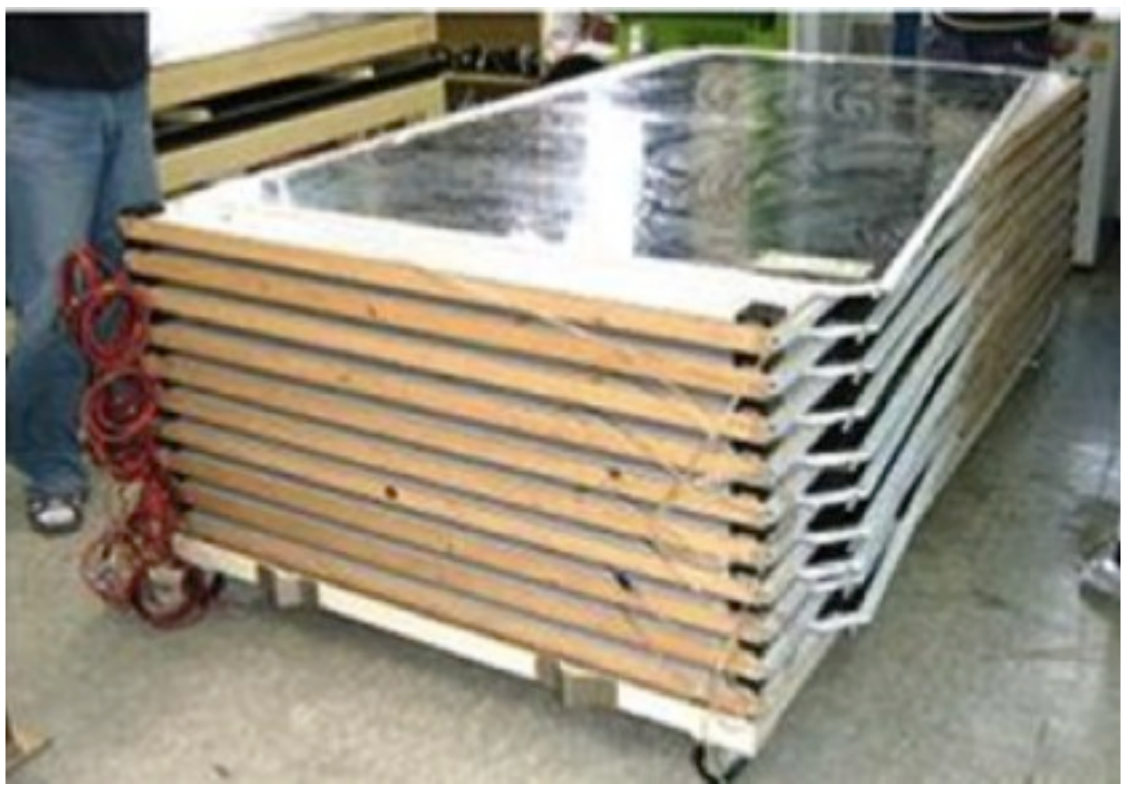
3. Pop spacers	Number of spacers	Number of popped spacers	Largest shift (hPa)	# of pop spacers allowed	0	Certified	O
	120	0	1.1	Shift allowed	3 hPa	Not certified	

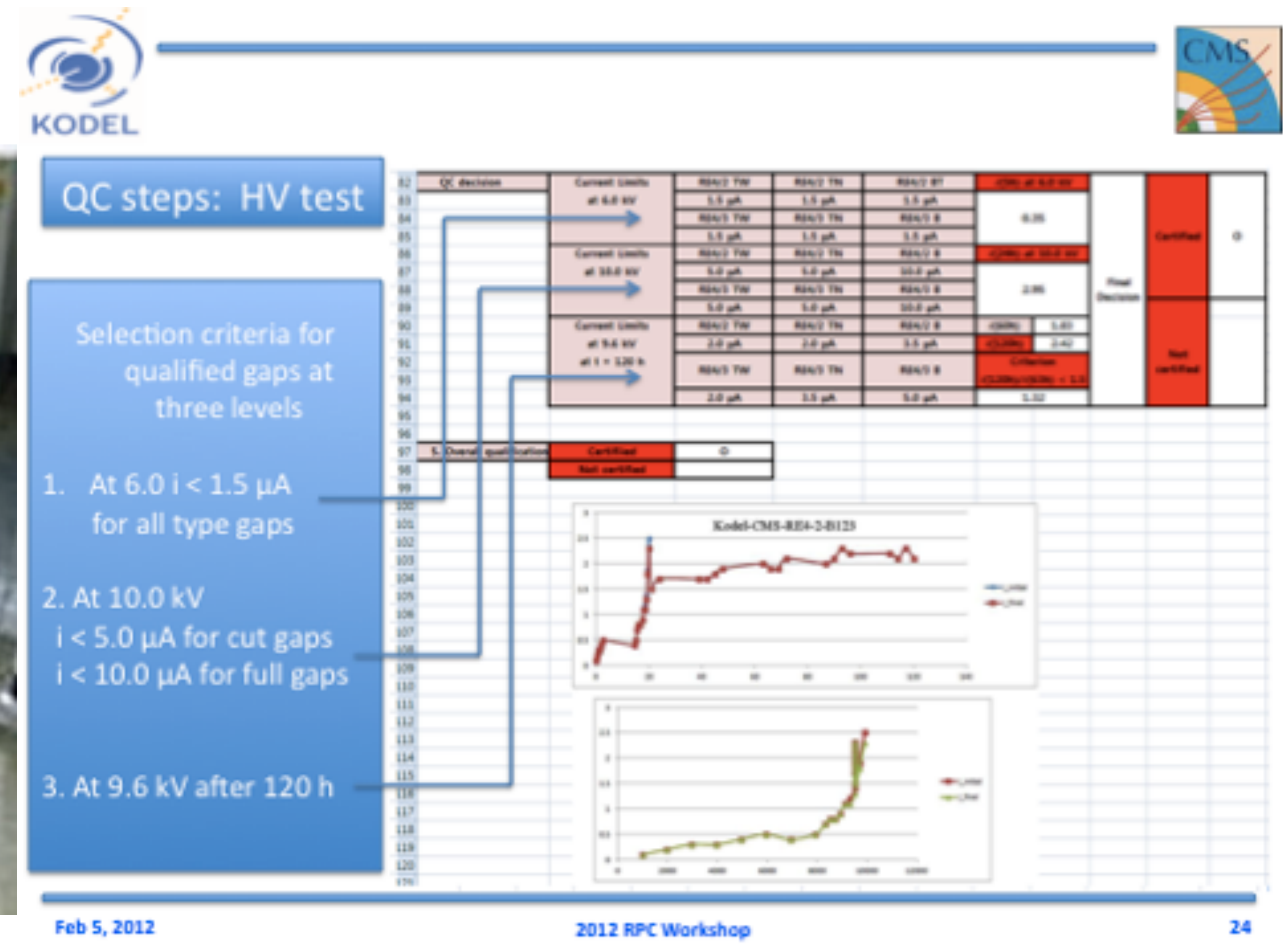
Oiling for curing noises

- Linseed oil + heptane
  (Ratio : 40 % + 60 %)
- Polymerization with air
  Rate : 60 – 100 liter/h/gap
  Period : 72 – 96 hours
  Humidity : 40%



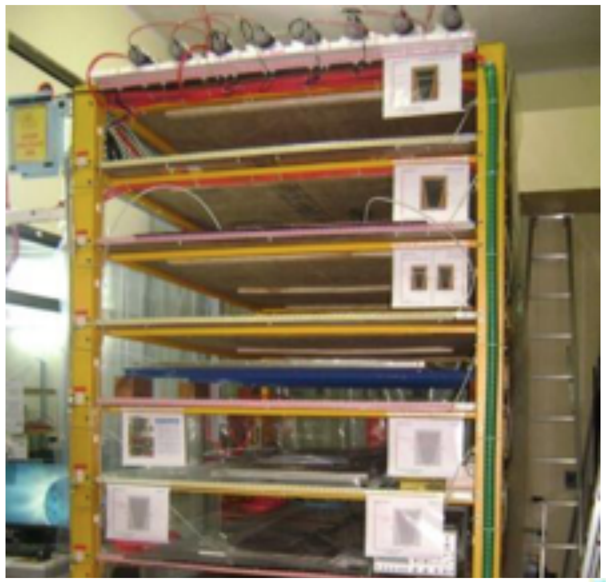
120-hour HV test
(gas circulation is not included)

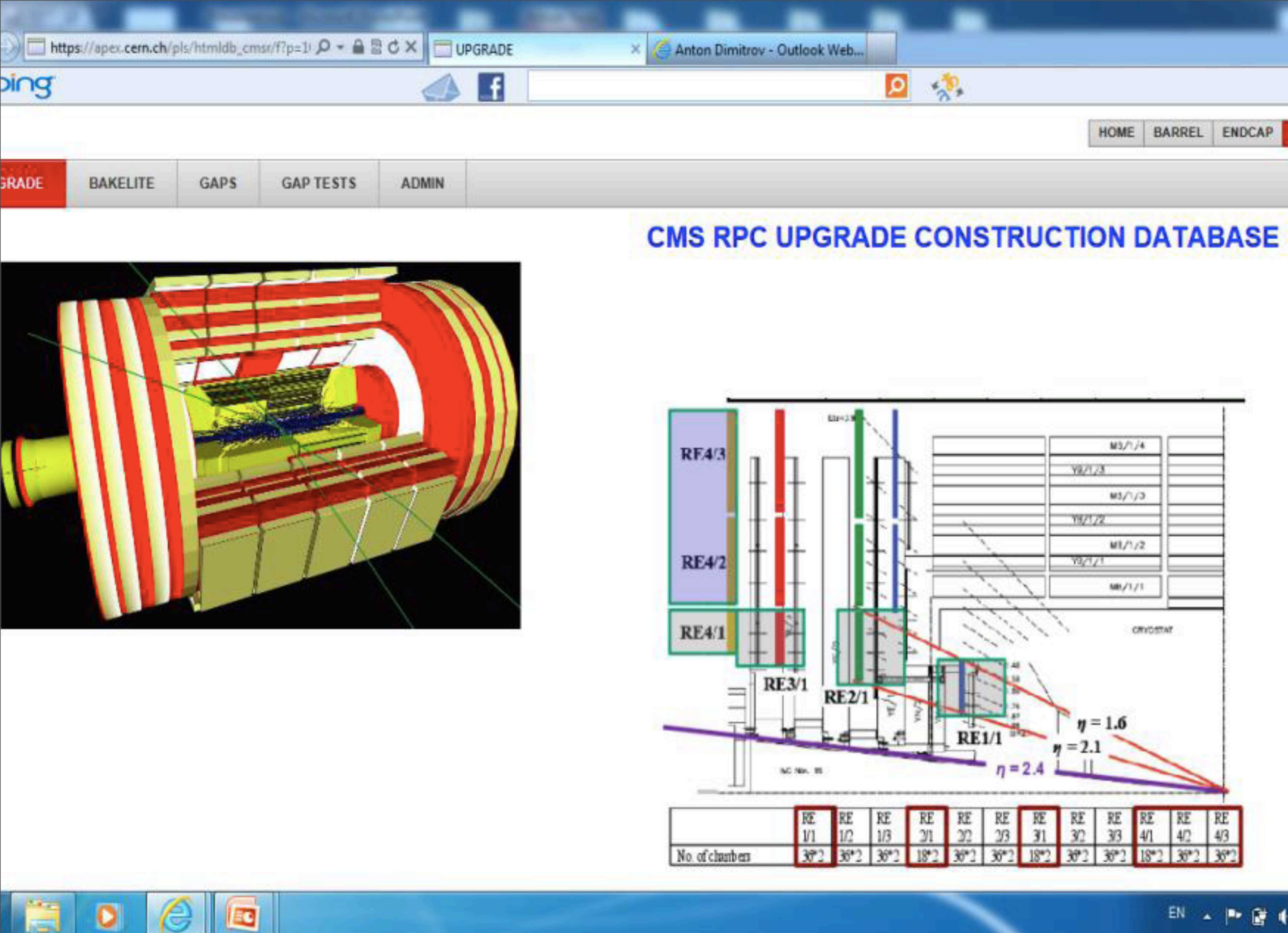




Packing and Shipping from KODEL

Three Assembly Sites




https://apex.cern.ch/pls/htmldb_cmsr/f?p=1
UPGRADE
Anton Dimitrov - Outlook Web...
HOME
BARREL
ENDCAP
GRADE
BAKELITE
GAPS
GAP TESTS
ADMIN
CMS RPC UPGRADE CONSTRUCTION DATABASE
RE4/3
RE4/2
RE4/1
RE3/1
RE2/1
RE1/1
CRYOSTAT
η = 1.6
η = 2.1
η = 2.4
RE 1/1 36*2
RE 1/2 36*2
RE 1/3 36*2
RE 2/1 18*2
RE 2/2 36*2
RE 2/3 36*2
RE 3/1 18*2
RE 3/2 36*2
RE 3/3 36*2
RE 4/1 18*2
RE 4/2 36*2
RE 4/3 36*2
No. of chambers
EN

Limits of Current Double-Gap RPCs

For 2-gap RPCs, aging study with an intensive gamma rate > 3 kHz cm^{-2}
→ The high gamma rate caused **Fast Degradation** of gaps
(H. C. Kim *et al.*, NIM A602 (2009) 771)

Table 1: Rates at CMS and ATLAS muon trigger

Parameter	LHC	HL-LHC
s	14TeV	14TeV
L	$10^{34}/cm^2s$	$10^{35}/cm^2s$
bunch spacing	25ns	12.5ns
interactions/crossing	≈ 12	≈ 62
$dN/d\eta$ crossing	75	375
CMS particle flux 1st muon layer $\eta \approx 2.4$	$\approx 1kHz/cm^2$	$\approx 10kHz/cm^2$
CMS particle flux 1st muon layer $\eta \approx 2.4$	$\approx 1kHz/cm^2$	$\approx 10kHz/cm^2$
ATLAS particle flux 1st muon layer $\eta \approx 2.4$	$\approx 1 - 10kHz/cm^2$	$\approx 1 - 15kHz/cm^2$
ATLAS particle flux 1st muon layer $\eta \approx 2.4$	$\approx 1 - 10kHz/cm^2$	$\approx 1 - 15kHz/cm^2$

Forward Region	Rates Hz/cm^2 LHC (10^{34} cm^2/s)	High Luminosity LHC 2.3 x LHC	(10^{35}cm^2/s) Phase II
RB	30	Few 100	kHz (tbc)
RE 1, 2, 3,4 $\eta < 1.6$	30	Few 100	kHz (tbc)
Expected Charge in 10 years	0.05 C/cm^2	0.15 C/cm^2	~ C/cm^2
RE 1,2,3,4 $\eta > 1.6$	500Hz ~ kHz	Few kHz	Few 10s kHz
Total Expected Charge in 10 years	(0.05-1) C/cm^2	few C/cm^2	Several C/cm^2

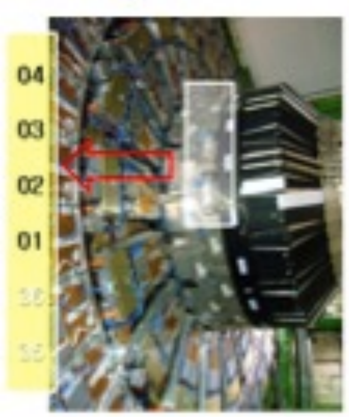
From Archana's talk

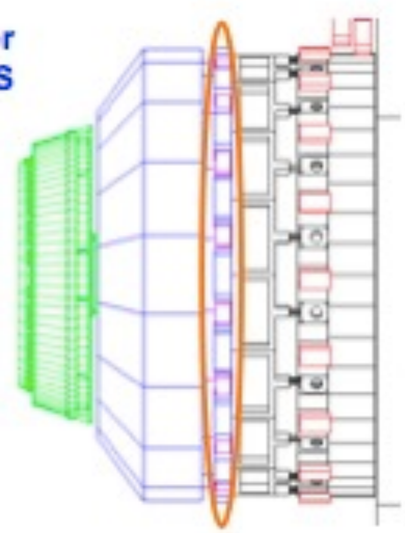
R&D for High Rates

RE1/1 RPCs for high-η triggers

▶ **72 RE1/1 RPCs at YE1 :**
- High priority among RPCs in $1.6 < \eta < 2.1$
- Advantage of RE1/1 : RPCs closest to *pp* collision vertex with presence of strong magnetic fields.
- Expect an effective rejection of the beam-related backgrounds (Gammas, neutrons, charged pions...) for the muon triggers.

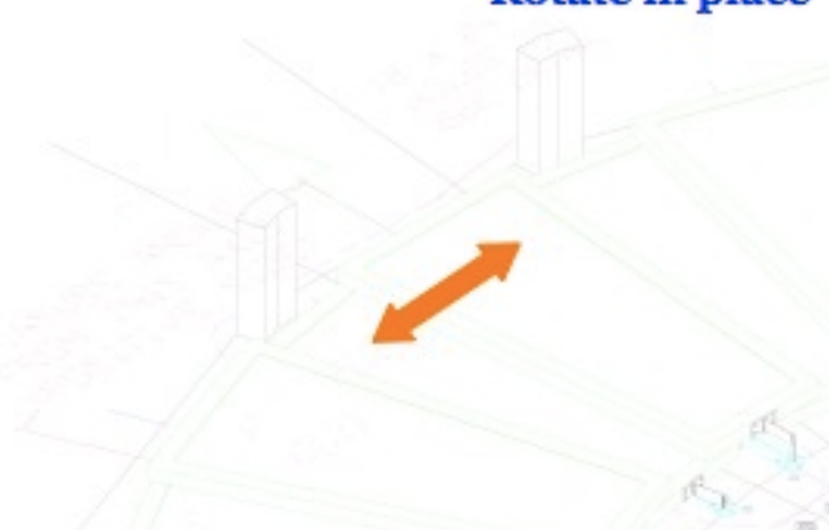
Have to insert trigger detectors in the CMS end-cap noses





Insert via rails

Rotate in place



1) Standard 2-gap phenolic RPC: first six RE1/1 RPCs in CMS

Phenolic plate (~$10^{10}\Omega$cm) instead of glass (~$10^{13}\Omega$cm)

Expected maximum rate : 300 ~ 400 Hz/cm^2 @ $L = 10^{34}$ cm^2 s^{-1}

1. Standard procedure for the detector manufacture
2. Cosmic ray test for the detector quality assurance

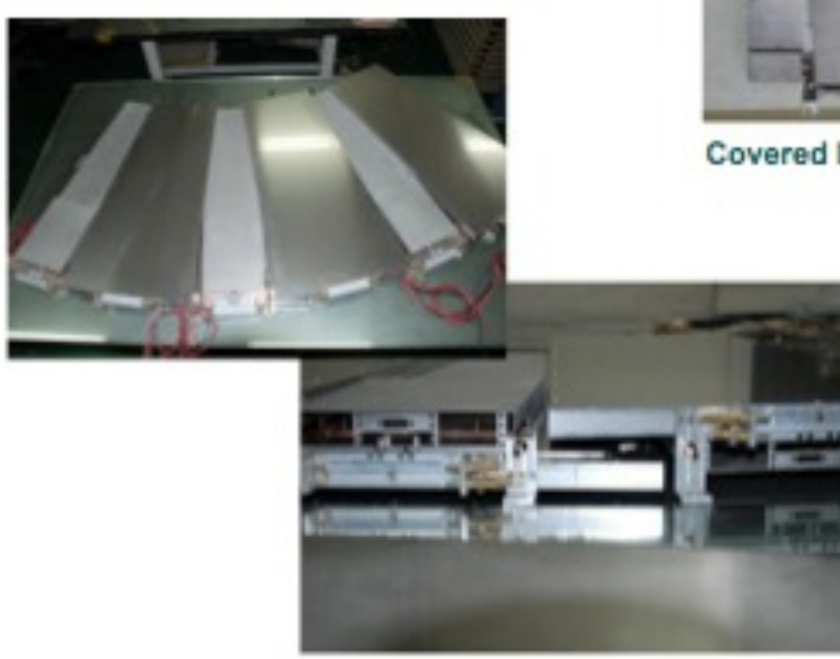
First 2-gap RE1/1 Detector at ISR

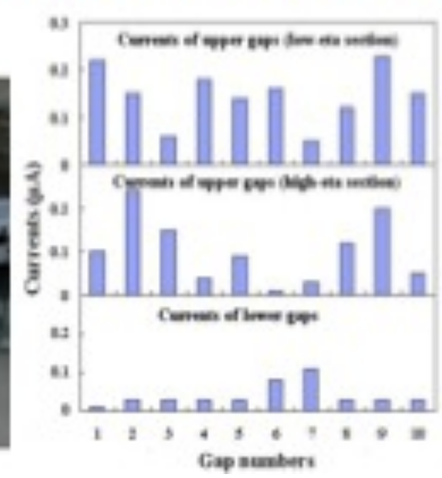
Covered by shielding box

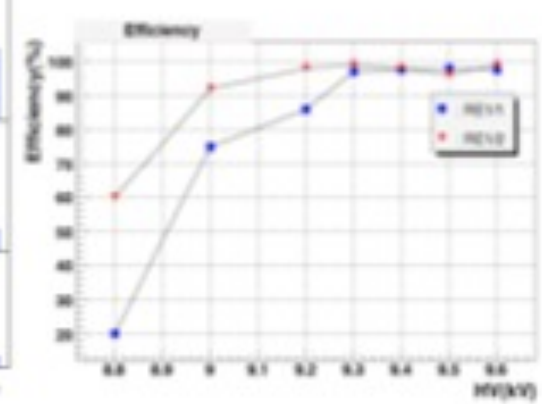
FEB flat cable layout

Signal cable layout

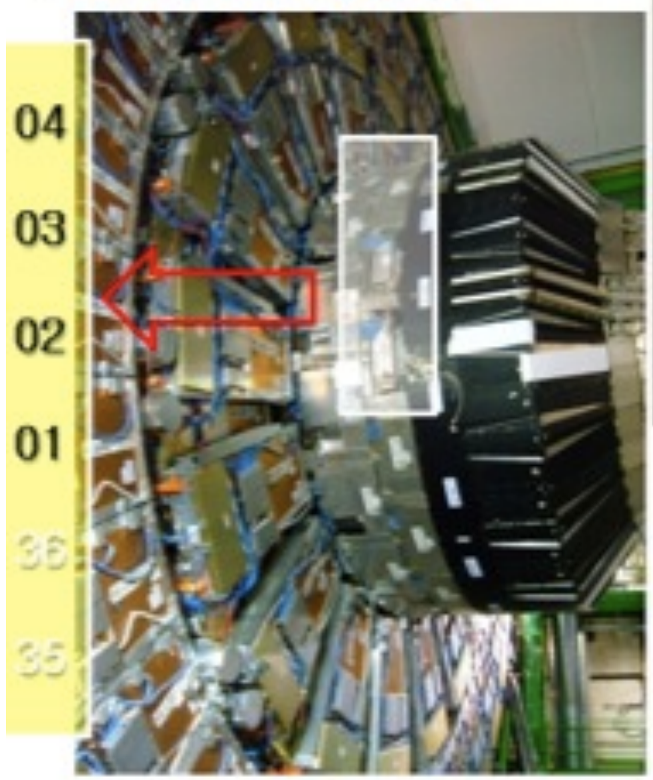
Configuration of 6 RE1/1 RPCs in a 60 degree sector

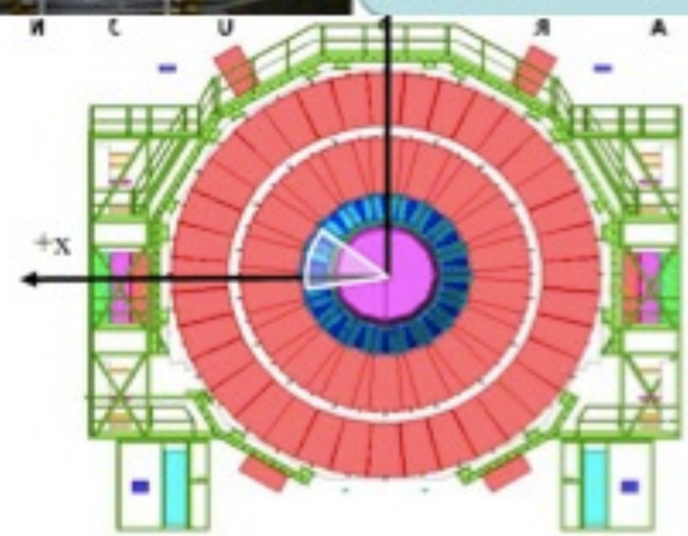






4 RE1/1 RPC module installed in the CMS nose-cone (2009)





Multi-Gap RPC R&D

R & D of HPL multi-gap RPCs

Direction → Smaller detector charges

1. **To reduce aging at high rate background**
2. **To enhance high rate capability**

Higher rate capability ← lower avalanche charge
- **Rate capability ~ 1/ ρ**
- **Smaller q_e → higher rate capability (actually related to Q_e)**

Typical glass multi-gap RPCs
- **q_e < 1 pC (~ 0.5 pC)**
- **$\rho = 10^{12} \sim 10^{13}\ \Omega$ cm for normal glass**
  $= 10^{9} \sim 10^{10}\ \Omega$ cm (ceramic & low res. glass)

Then, what if multi-gap RPCs with high-pressure laminated (HPL) plates ?
- **q_e ~ 1 pC**
- **Phenolic HPL → $\rho = 10^{10} \sim 10^{11}\ \Omega$ cm**
- **Oiling required to reduce noises**

2. Constructions of prototype detectors

Detector structures

Oiled Phenolic Multigap Panel-type RPCs for CMS high-η triggers

Panel-shape multigap RPCs

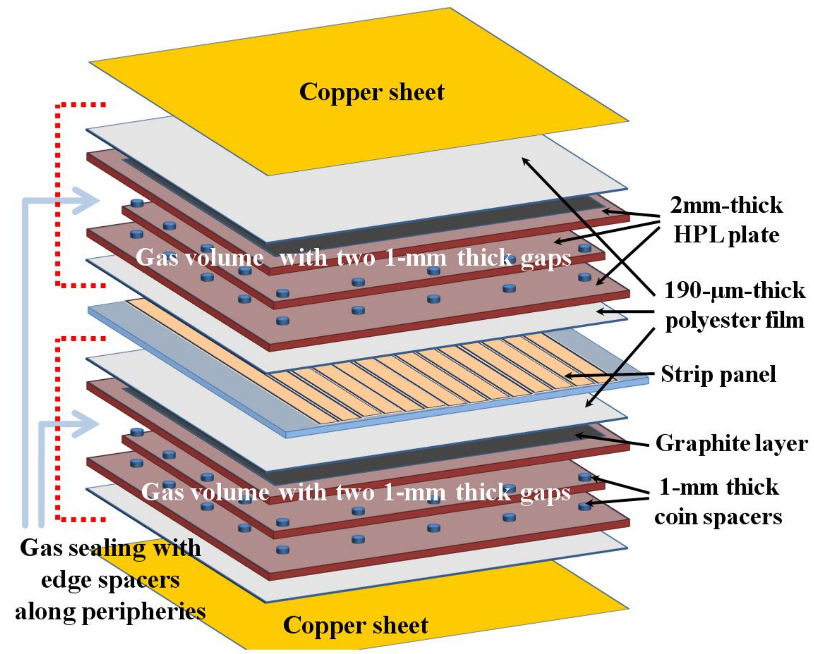
~ Two separated gas envelopes + a strip panel
Each gas envelope ~ 2 gaps in 4-gap RPCs
3 gaps in 6-gap RPCs

Prototype detectors

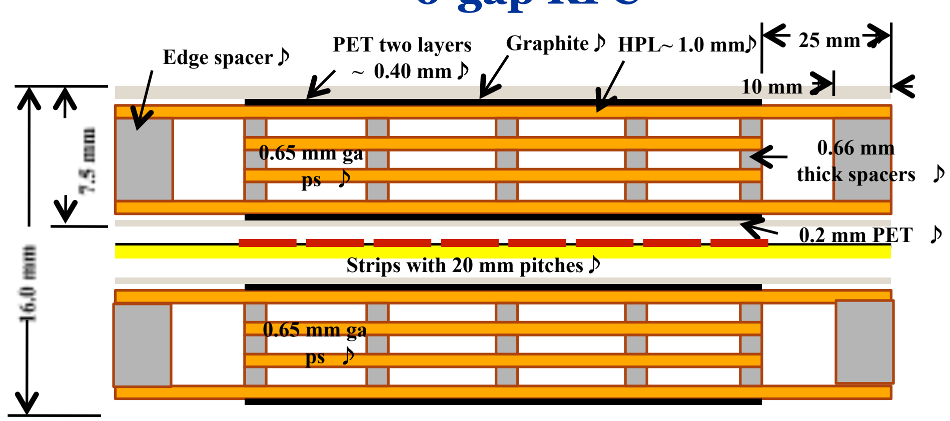
4-gap RPC: 45 x 45 cm^2 (active area)
- HPL : 2 mm
- Coin spacers : 1000 ± 10 μm (Polycarbonate)
- Strip pitch = 27 mm

6-gap RPC: 15 x 29 cm^2 (active area)
- HPL : 1 mm
- Coin spacers : 660 ± 10 μm (Polycarbonate)
- Strip pitch = 20 mm

4-gap RPC



6-gap RPC



Gas mixture

95.7% $C_2H_2F_4$ + 3.5% iC_4H_{10} + 0.5% SF_6 + 0.3% water vapor in mass ratio

Flow rates ~ 1.8 l/h

Gamma rays source

200-mCi ^{137}Cs (born in Nov. 2001)

- 5.5 GBq for the 4-gap RPC test (2011)
- 5.8 GBq for the 6-gap RPC test (2009)

Mean distance ~ 45 cm

- Max. gamma-rates in the test

1.50 kHz cm^{-2} for 4-gap RPC

N_γ = 145 kHz cm^{-2}

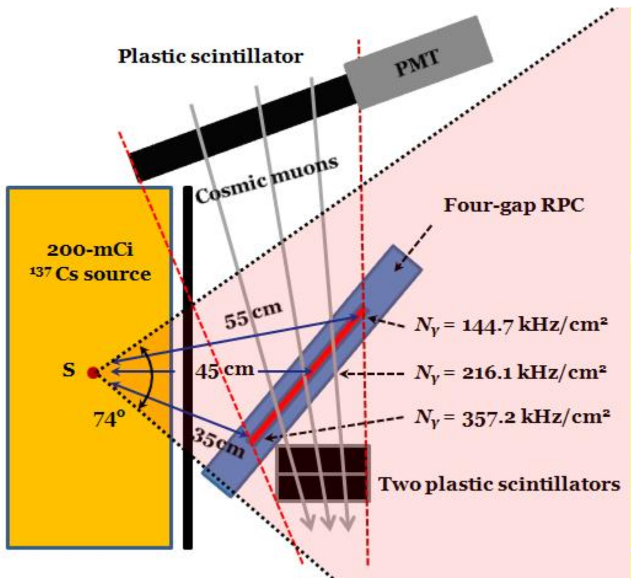
ε_γ = 0.0103

2.02 kHz cm^{-2} for 6-gap RPC

N_γ = 152 kHz cm^{-2}

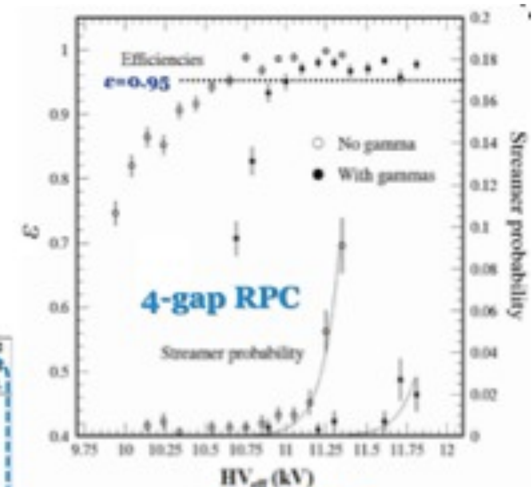
ε_γ = 0.0133

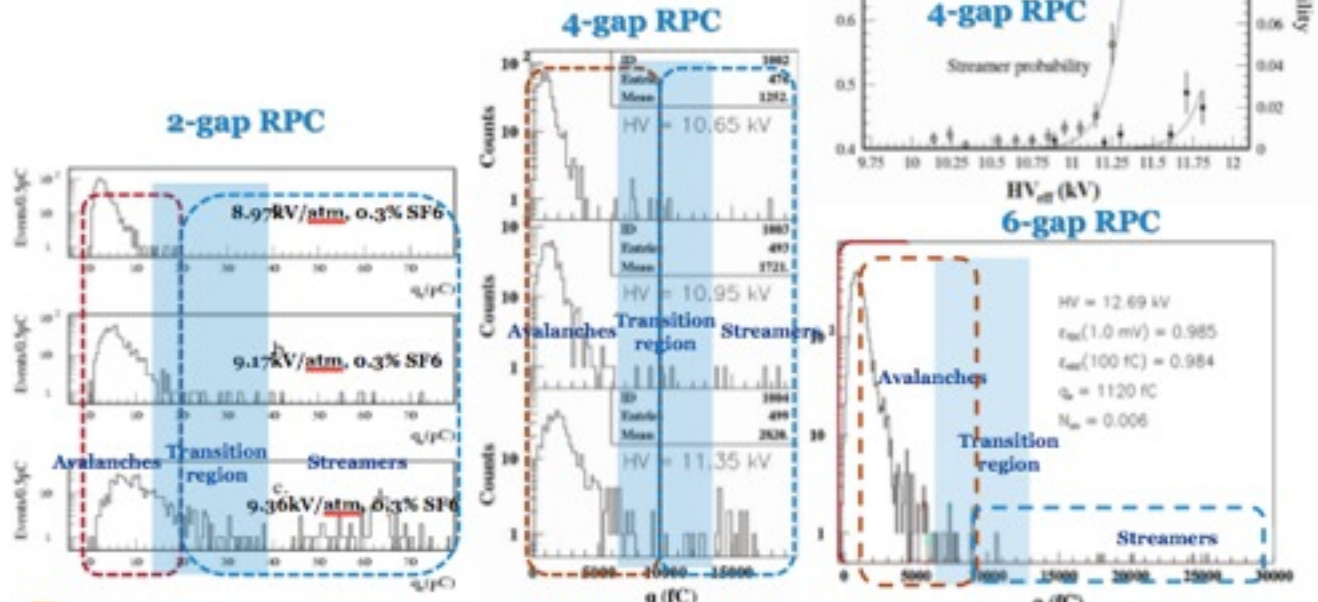
Cosmic muon test without gammas



Avalanche pulse limit

- For 2-gap RPCs
  - q_c < 10 pC for CMS Barrel RPCs
  - q_c < 20 pC for CMS Forward RPCs (no termination)
- For 4-gap RPCs: q_c < 10 pC (no termination)
- For 6-gap RPCs: q_c < 5 pC (no termination)



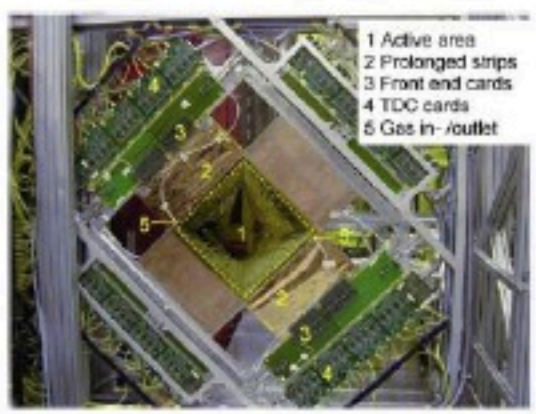


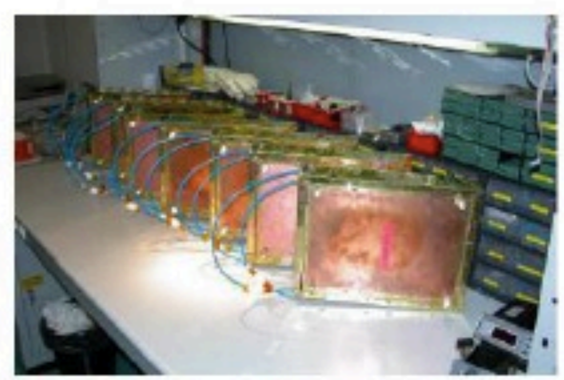
	2-gap RPCs	4-gap RPCs	6-gap RPCs
Each gap thickness	2.0 mm	1.0 mm	0.66 mm
Total gap thickness	4.0 mm	4.0 mm	4.0 mm
$\langle q_c \rangle$ at ~ mid of plateau	4.0 pC (Thr~200 fC)	1.5 pC (Thr~150 fC)	0.9 pC (Thr~100 fC)
Type of resistive plates	HPL	HPL	HPL
Thickness of HPL	2.0 mm	2.0 mm	1.0 mm
Resistivity of HPL	1 ~ 6 x10^{10} Ωcm (for CMS)	~ 10^{10} Ωcm (Italian HPL)	~ 10^{11} Ωcm (Korean HPL)

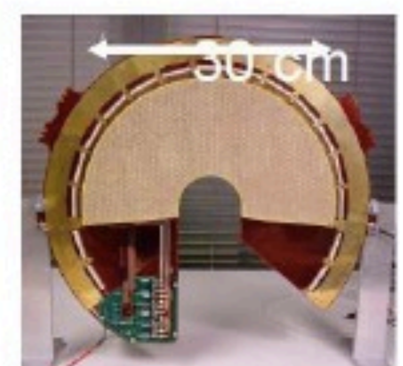
MPGD in Running Experiments

Exp.	#	Type	Readout	# of ch.	Size (cm²)	Gas	σ_{space} (μm)	σ_{time} (ns)	ε (%)
COMPASS	22	GEM	2-D strips	1536	31×31	Ar/CO_2 (70/30)	70	12	>97
	12	MM	1-D strips	1024	40×40	$Ne/C_2H_6/CF_4$ (80/10/10)	90	9	>97
LHCb	24	GEM	pads	192	10×24	$Ar/CO_2/CF_4$ (45/15/40)		4.5	>97
TOTEM	40	GEM	pads + strips	1536 + 256	30 × 20	Ar/CO_2 (70/30)	~70 (θ)		>92

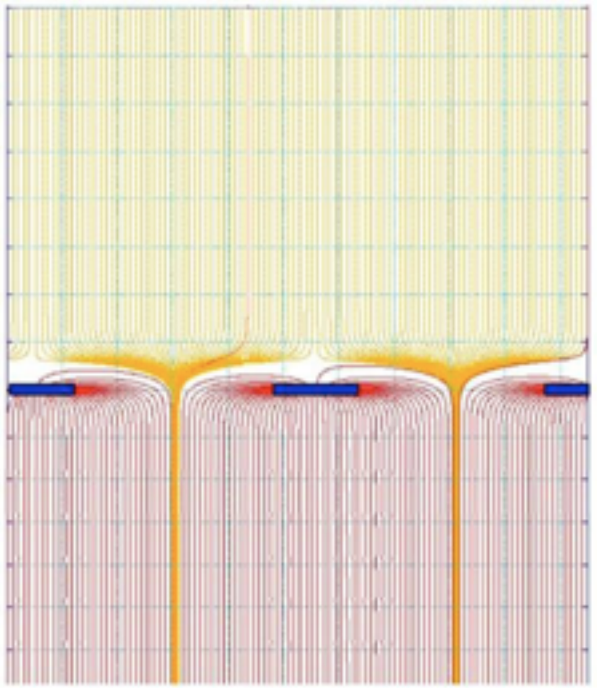
also CAST, NA48, PHENIX ...

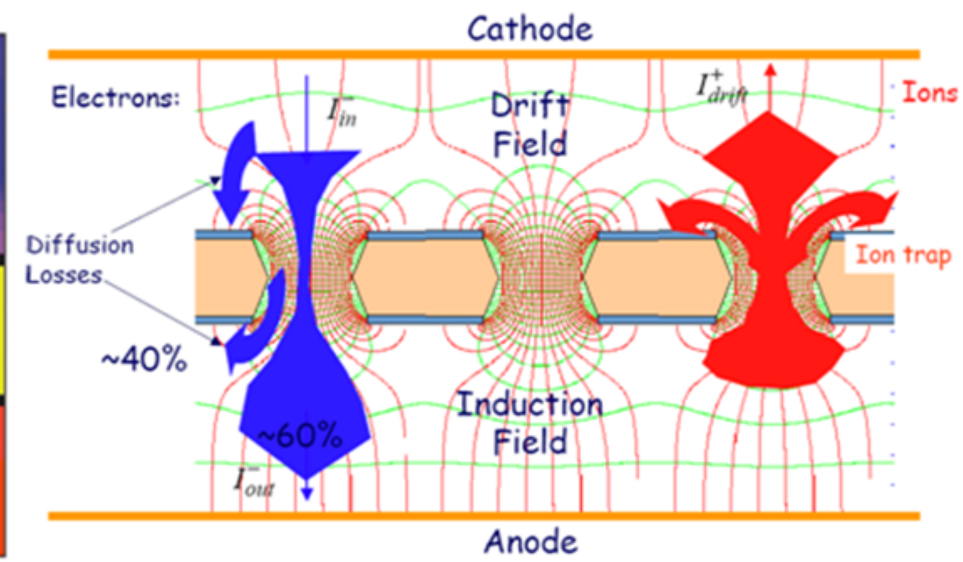


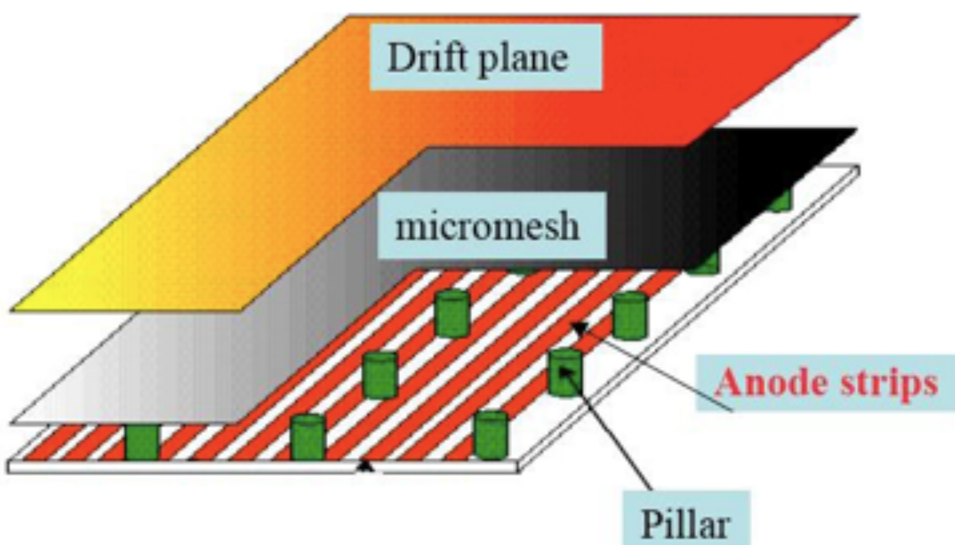




Micromegas and GEM



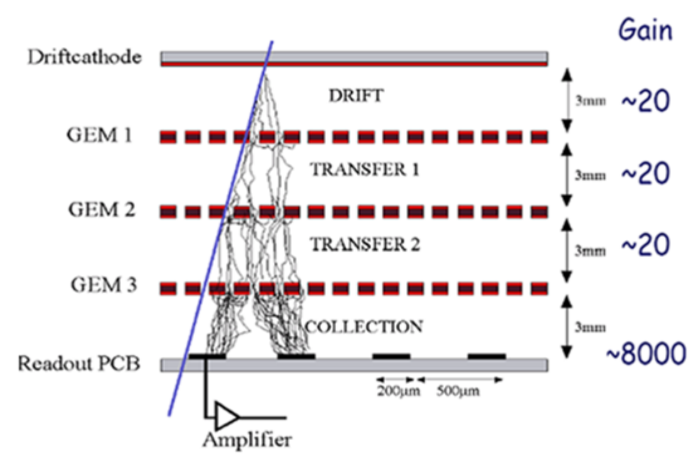


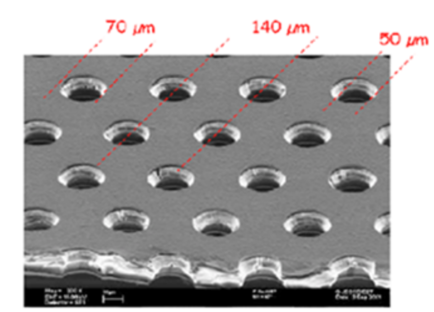


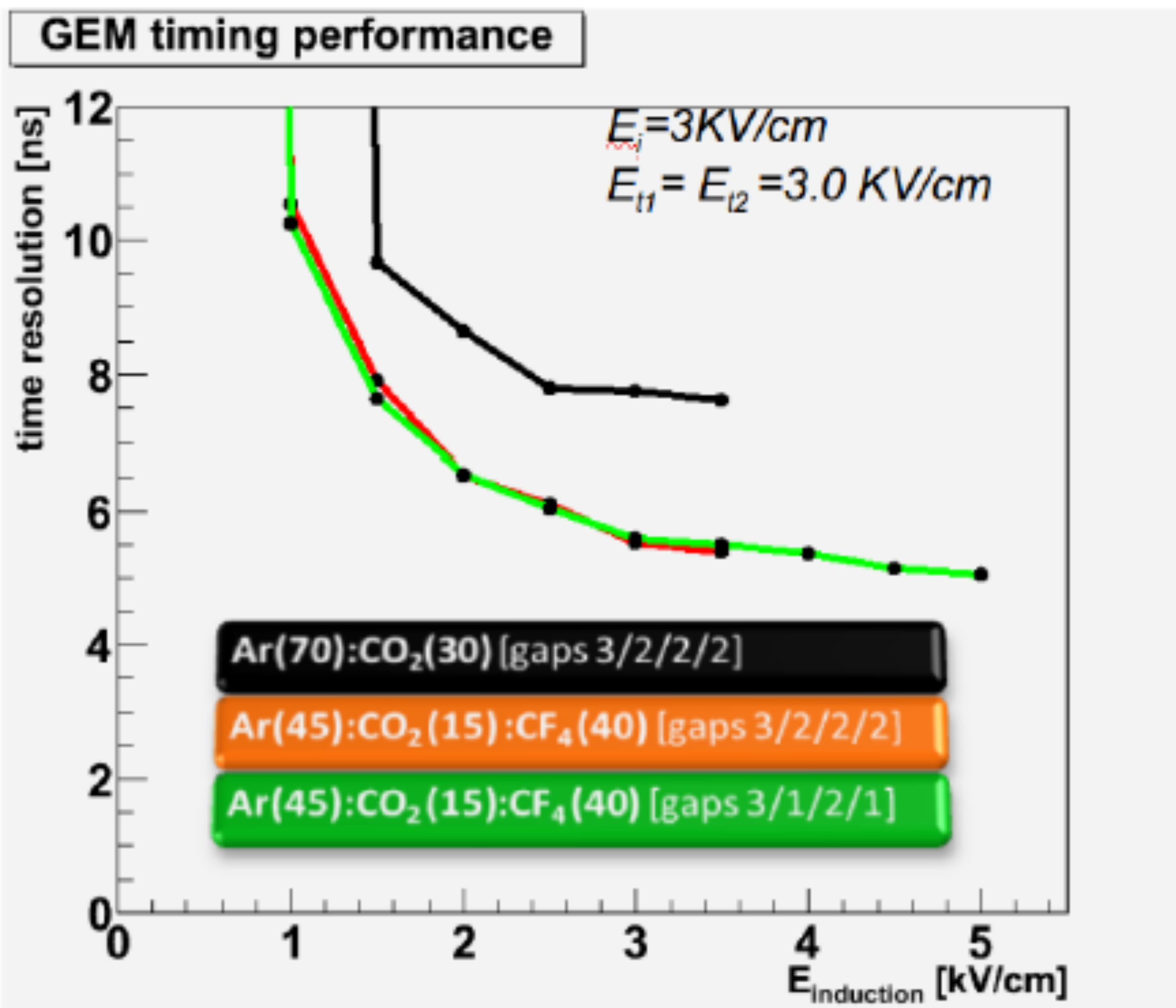
Basic structure

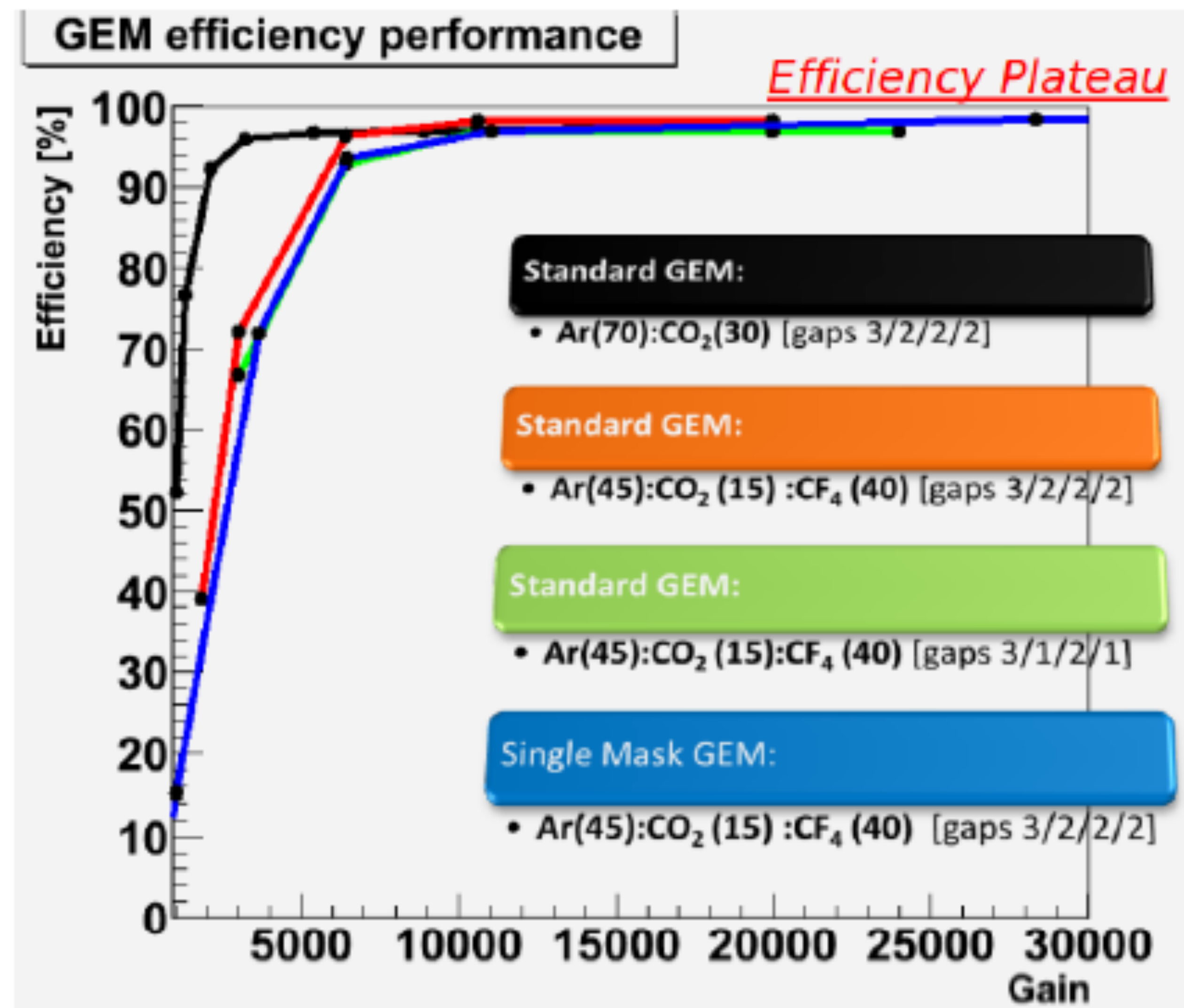
2 ~ 3 GEM plates : for the amplification of X-ray signals

Two dim. microstrips (~ 100 ㎛ spacing : to pickup the avalanche images)






GEM timing performance
E_i=3KV/cm
E_{t1} = E_{t2} =3.0 KV/cm
time resolution [ns]
12
10
8
6
4
2
0
0
1
2
3
4
5
$E_{induction}$ [kV/cm]
Ar(70):CO_2(30) [gaps 3/2/2/2]
Ar(45):CO_2(15):CF_4(40) [gaps 3/2/2/2]
Ar(45):CO_2(15):CF_4(40) [gaps 3/1/2/1]


GEM efficiency performance
Efficiency Plateau
Efficiency [%]
100
90
80
70
60
50
40
30
20
10
0
5000
10000
15000
20000
25000
30000
Gain
Standard GEM:
• Ar(70):CO_2(30) [gaps 3/2/2/2]
Standard GEM:
• Ar(45):CO_2 (15) :CF_4 (40) [gaps 3/2/2/2]
Standard GEM:
• Ar(45):CO_2 (15):CF_4 (40) [gaps 3/1/2/1]
Single Mask GEM:
• Ar(45):CO_2 (15) :CF_4 (40) [gaps 3/2/2/2]

NewFlex Visit

GEM Production

Test Condition

1) Base Material

: **Nippon Mining & Metals, Kaneka PI, NPI 2MIL 5um Cu**

2) Cr Layer Remove

: Potassium Permanganate, 65℃, 1min (65g/L)

3) PI Etchant

: Ethylene Diamine55%, Water 45%, 70g/L KOH

: Temperature : 64~66℃

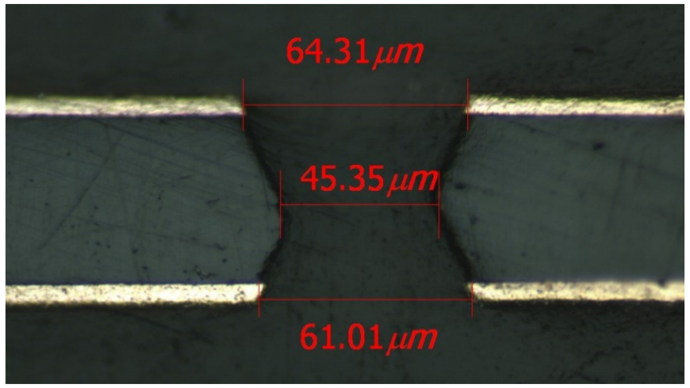
: Treatment time : 140sec

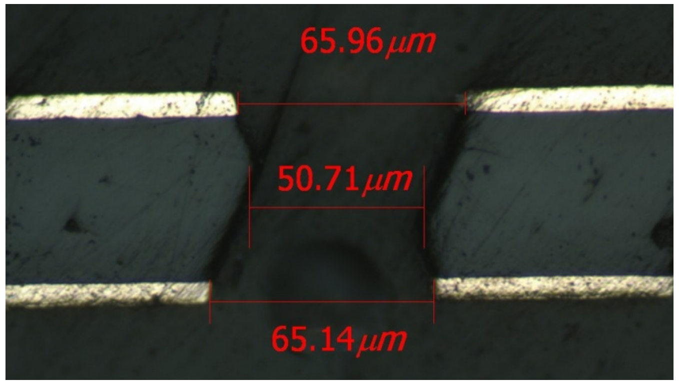
Specification

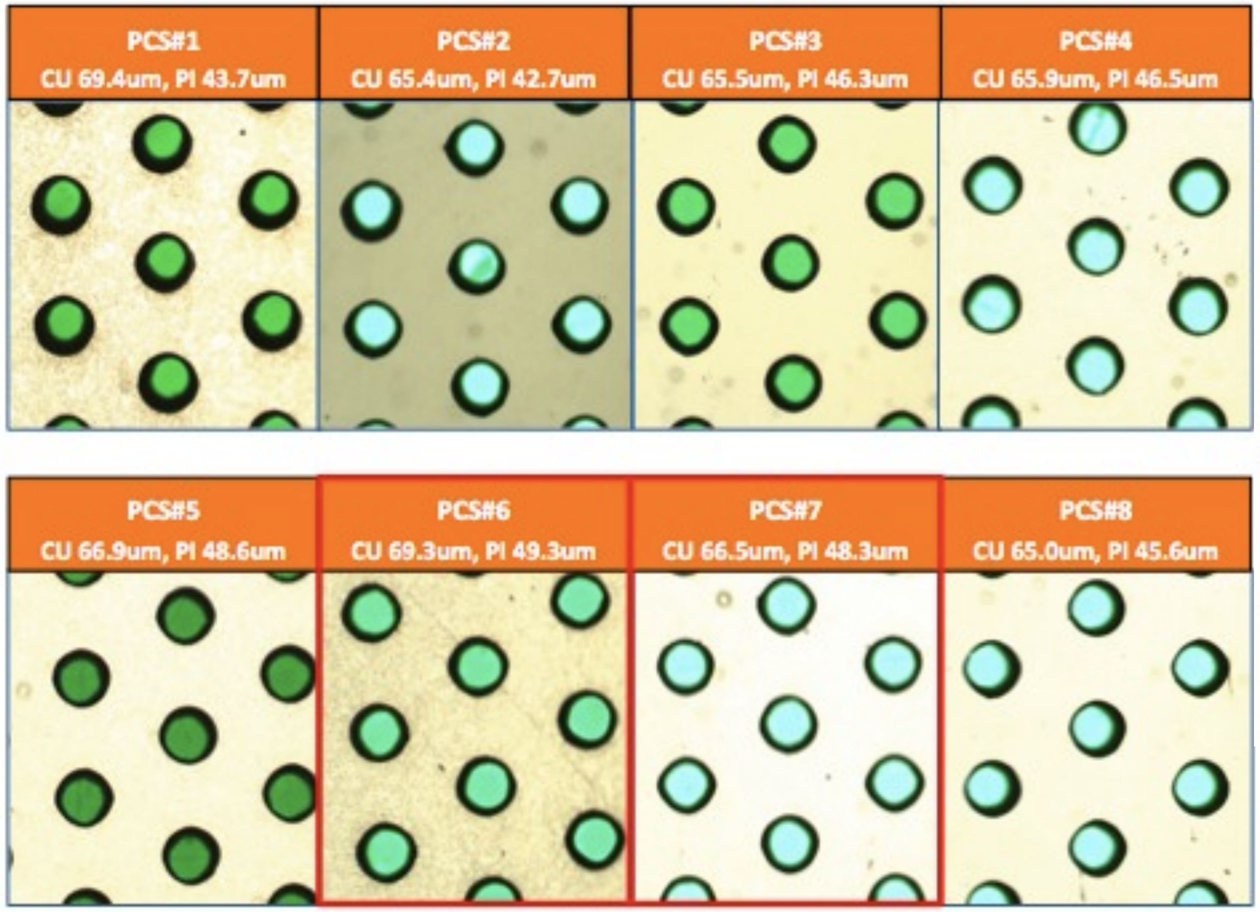
1) Cu Diameter : 70±5um

2) Uniformity : ±2um (Panel 내)

2) PI Diameter : 55±5um



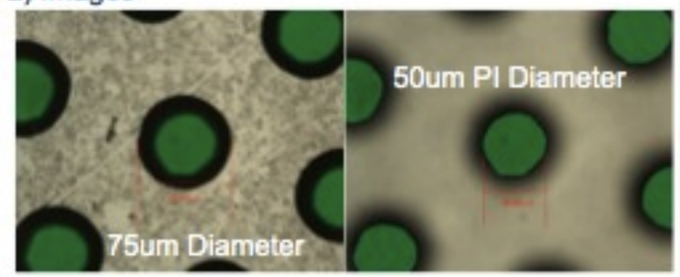




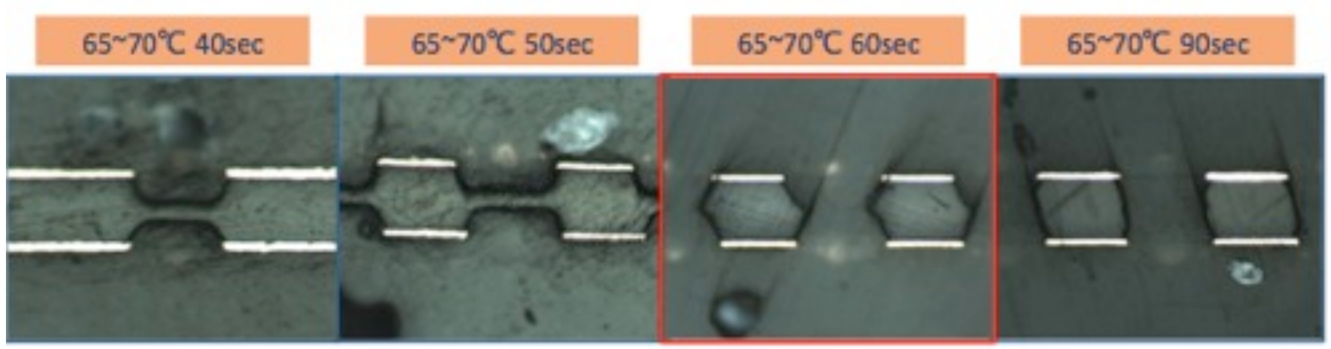
1) Best Results

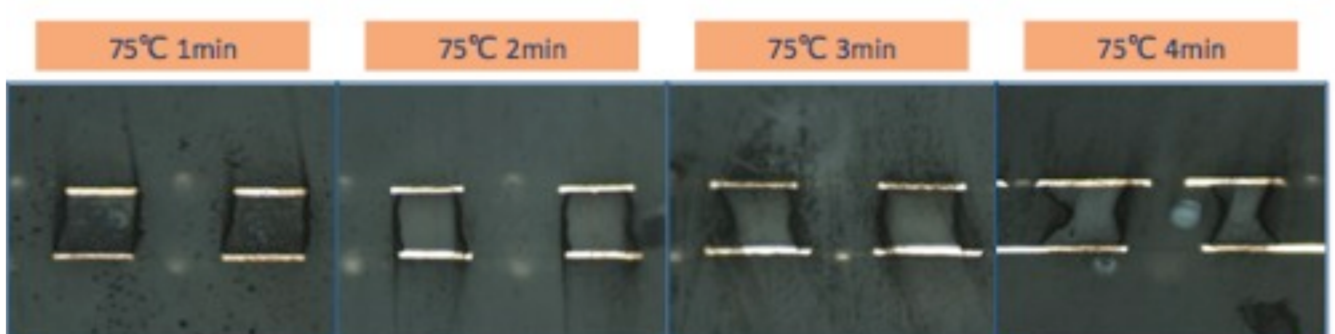
: 70℃ 1min

2) Images

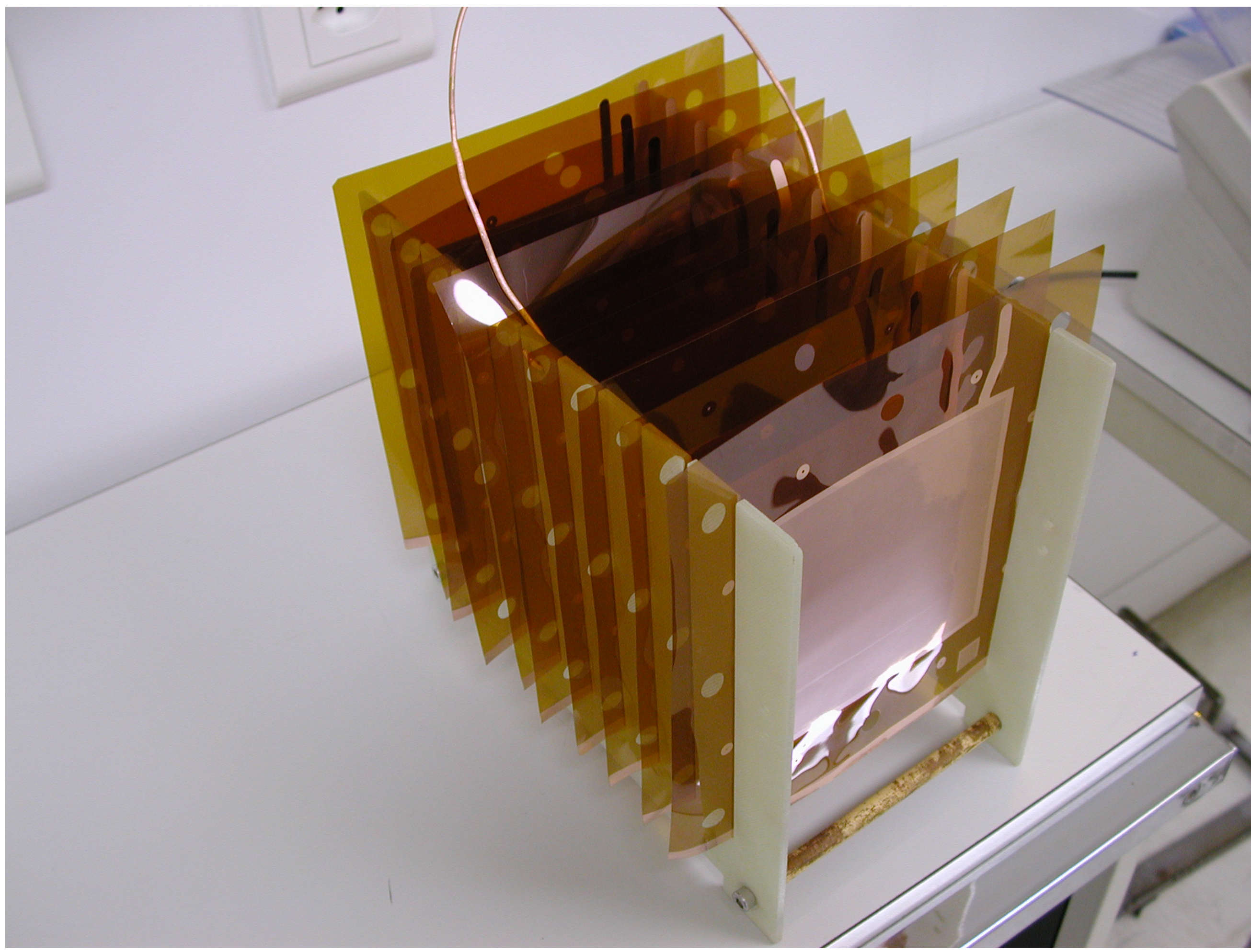


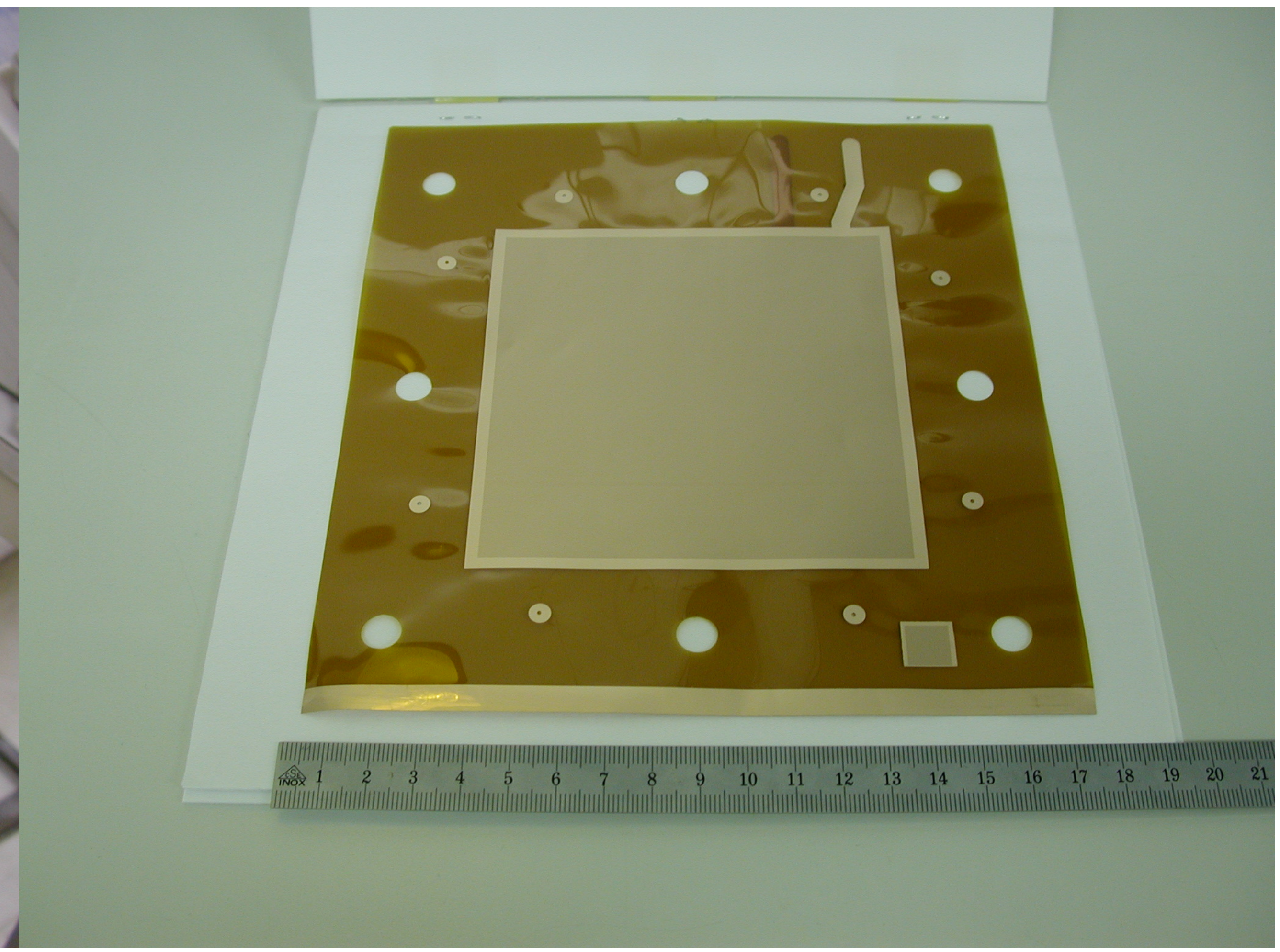
3) Sectional Images

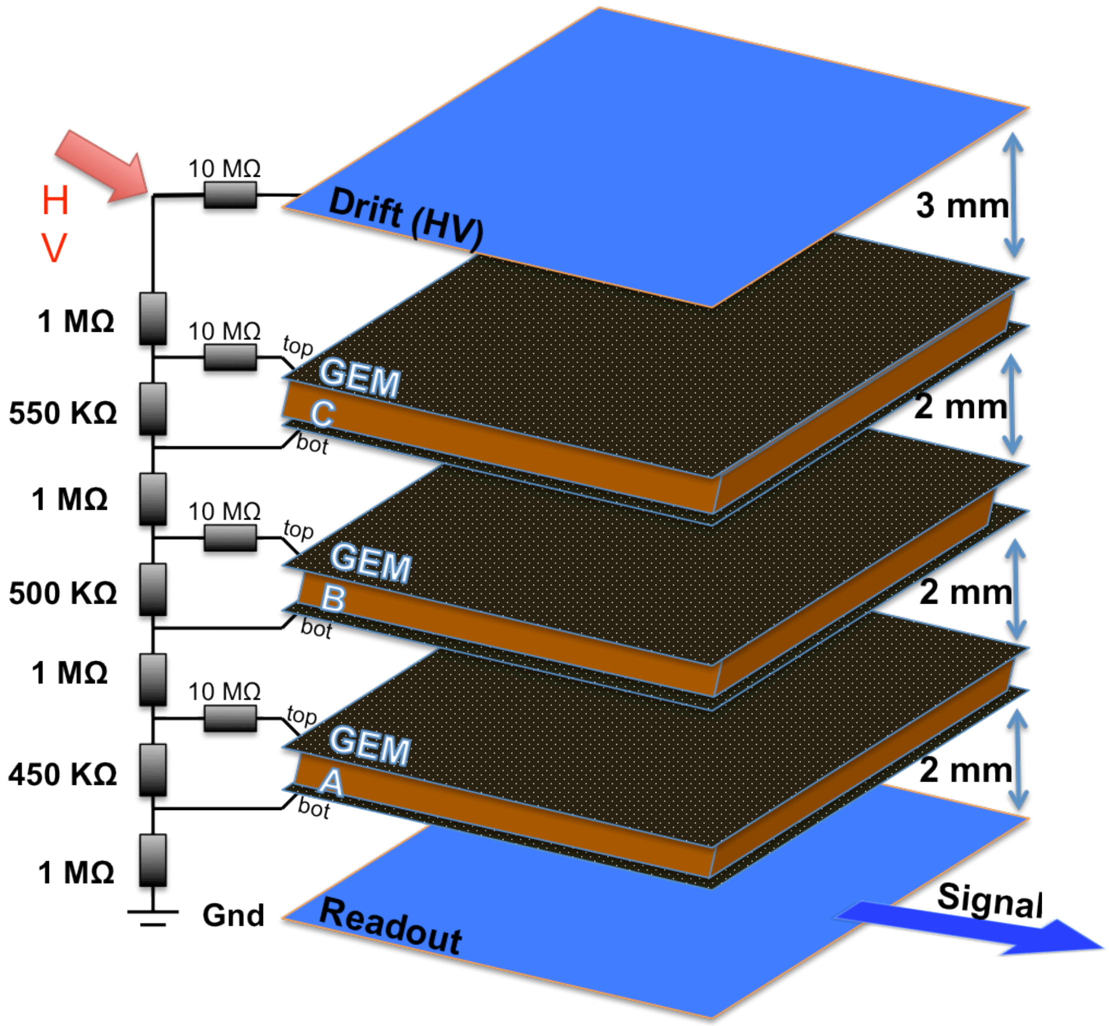


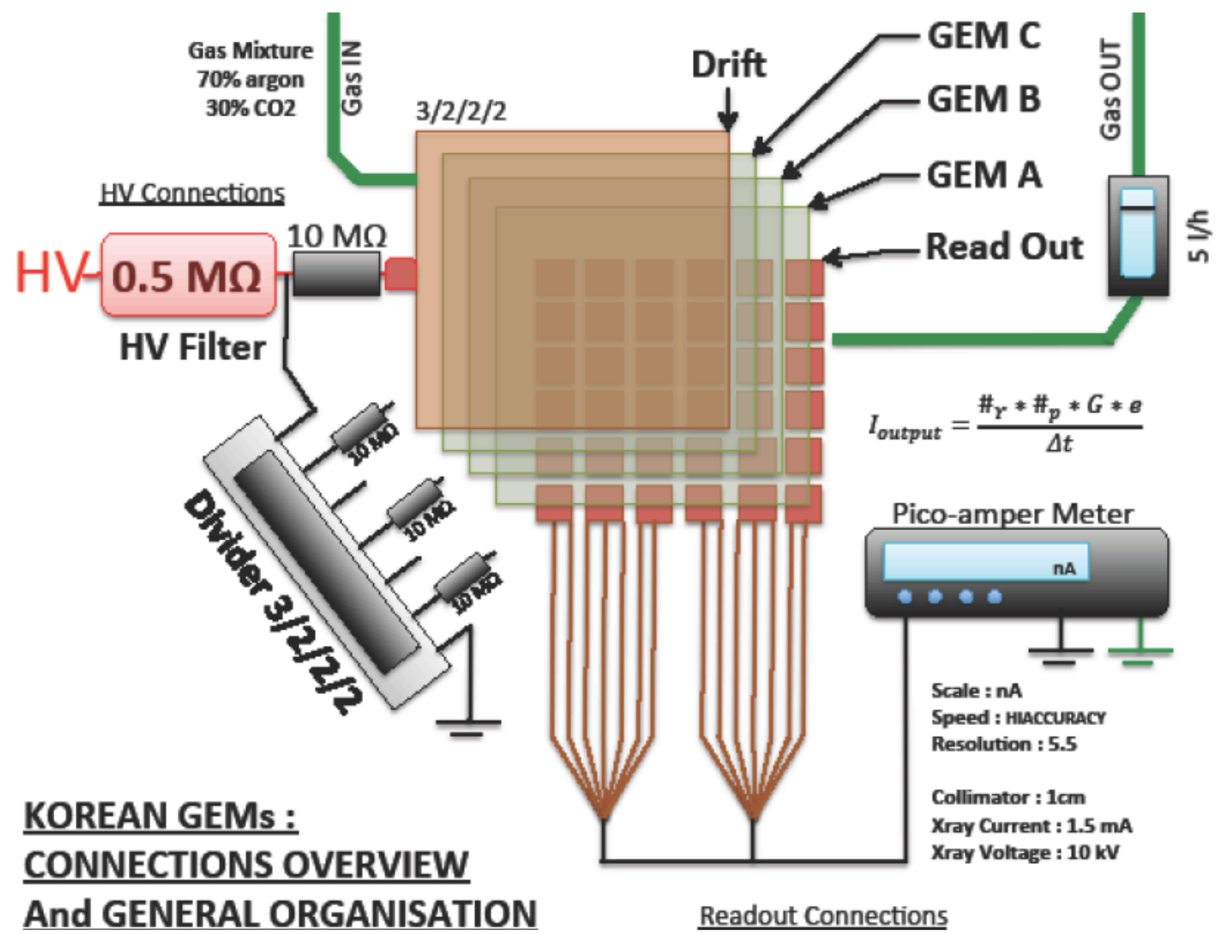


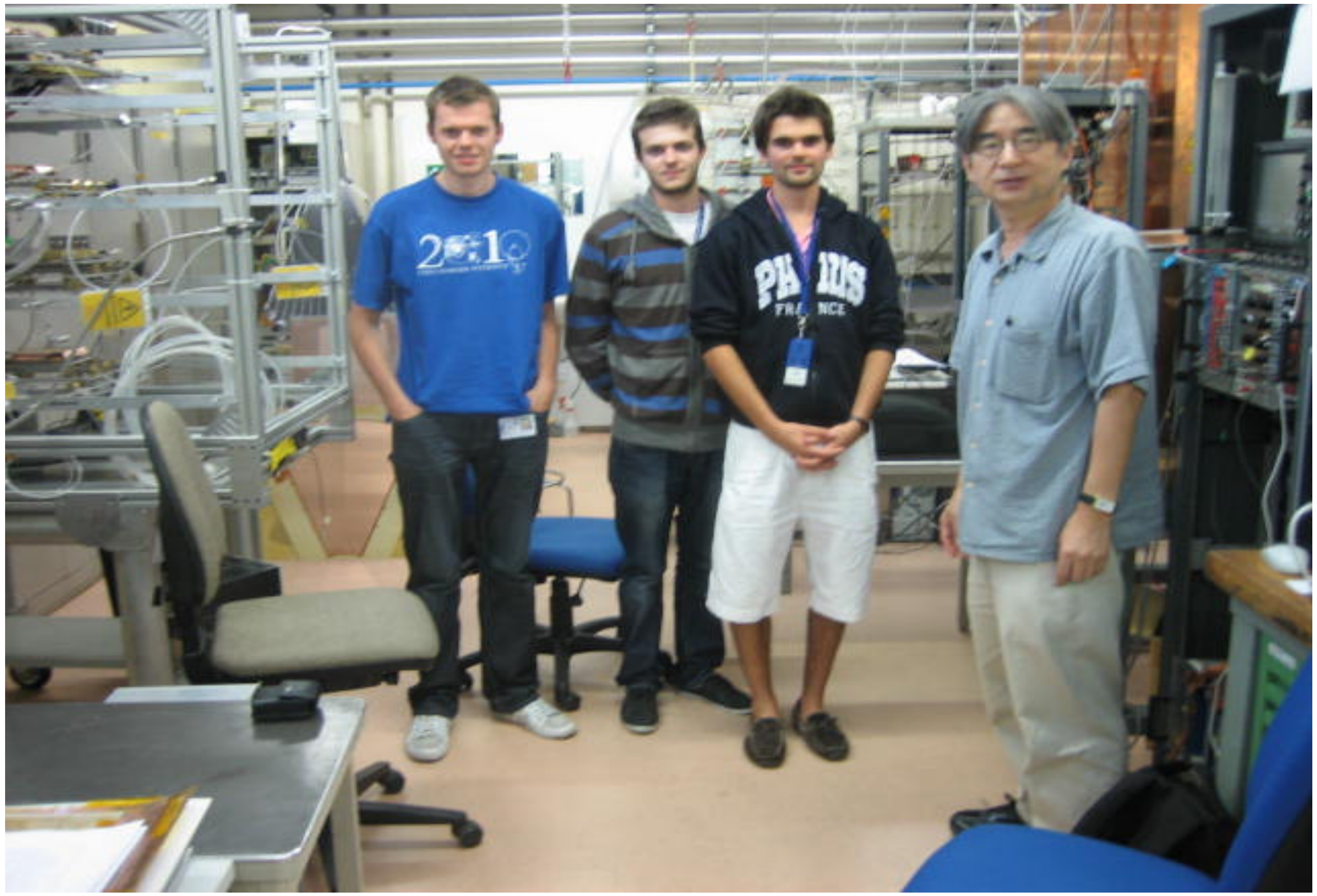
GEM Production





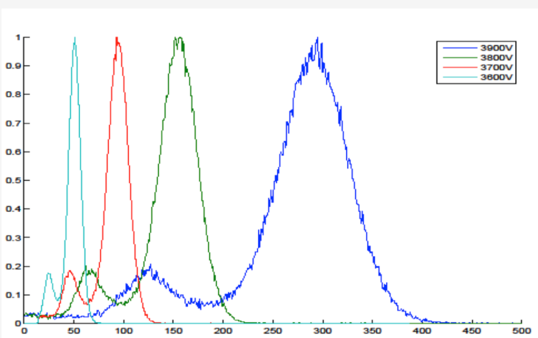

H
V
10 MΩ
Drift (HV)
3 mm
1 MΩ
10 MΩ
top
GEM
C
bot
2 mm
550 KΩ
1 MΩ
10 MΩ
top
GEM
B
bot
2 mm
500 KΩ
1 MΩ
10 MΩ
top
GEM
A
bot
2 mm
450 KΩ
1 MΩ
Gnd
Readout
Signal

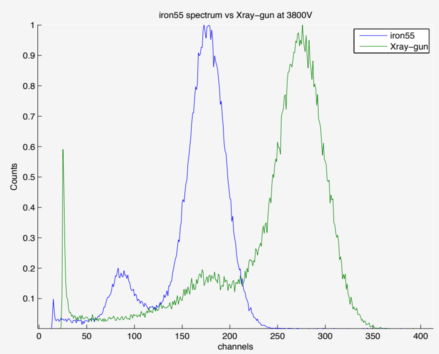

Gas Mixture
70% argon
30% CO2
Gas IN
3/2/2/2
Drift
GEM C
GEM B
GEM A
Read Out
Gas OUT
5 l/h
HV Connections
10 MΩ
HV
0.5 MΩ
HV Filter
10 MΩ
10 MΩ
10 MΩ
Divider 3/2/2/2
$I_{output} = \frac{\#_r * \#_p * G * e}{\Delta t}$
Pico-amper Meter
nA
Scale : nA
Speed : HIACCURACY
Resolution : 5.5
Collimator : 1cm
Xray Current : 1.5 mA
Xray Voltage : 10 kV
KOREAN GEMs :
CONNECTIONS OVERVIEW
And GENERAL ORGANISATION
Readout Connections

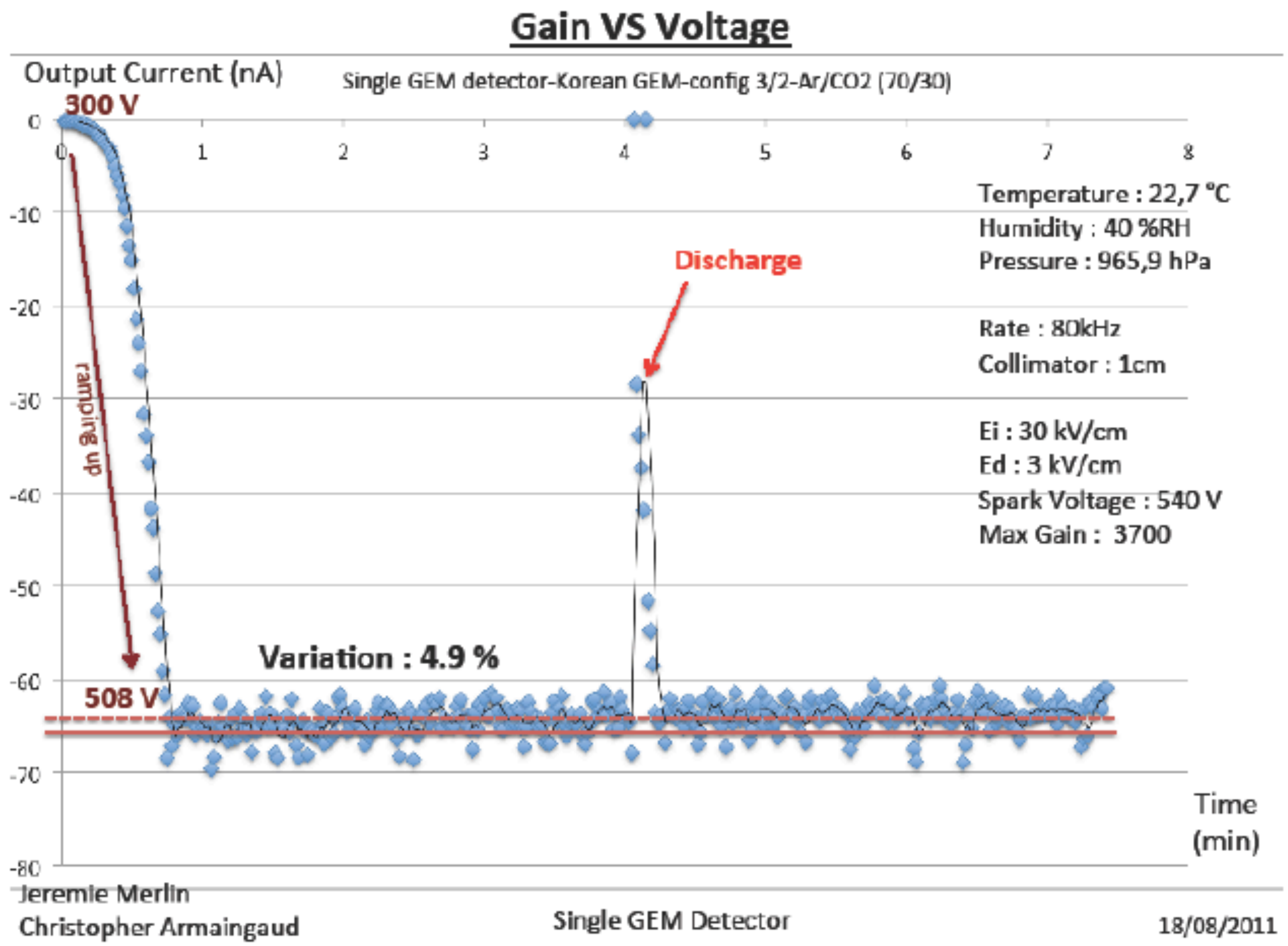


Xray Gen (Cu) / Iron 55

Iron 55 : Spectrum and Count Rate

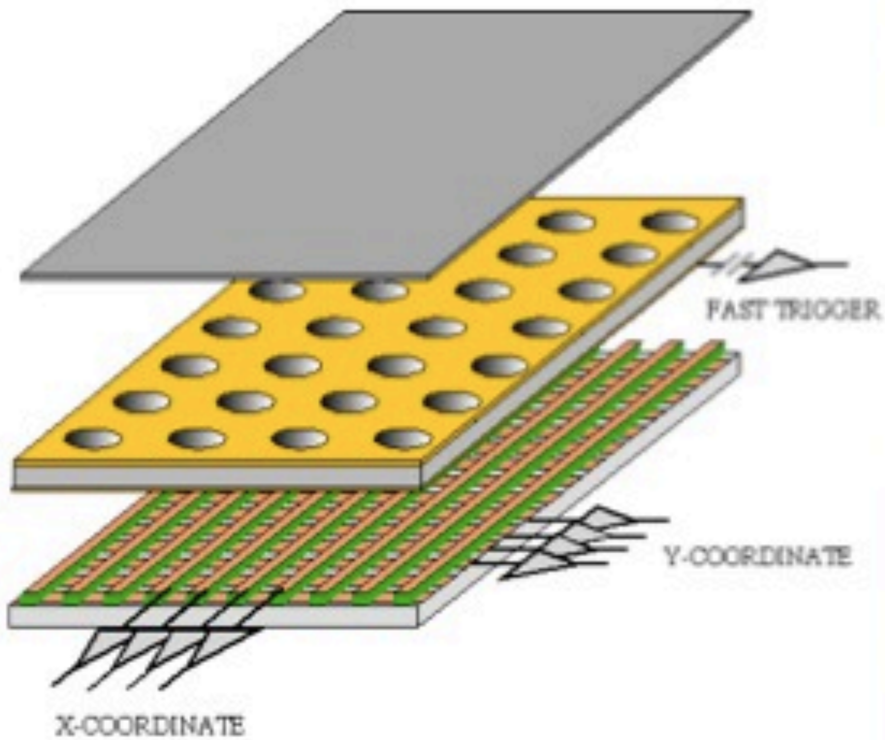






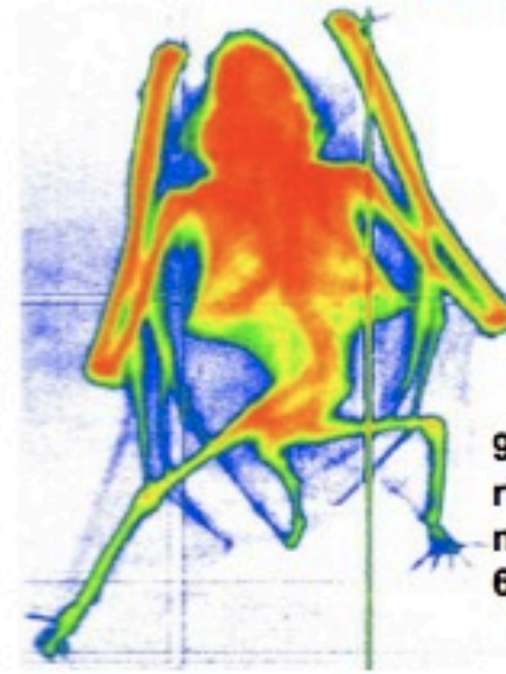
GEM Application Potential

Using the lower GEM signal, the readout can be self-triggered with energy discrimination:



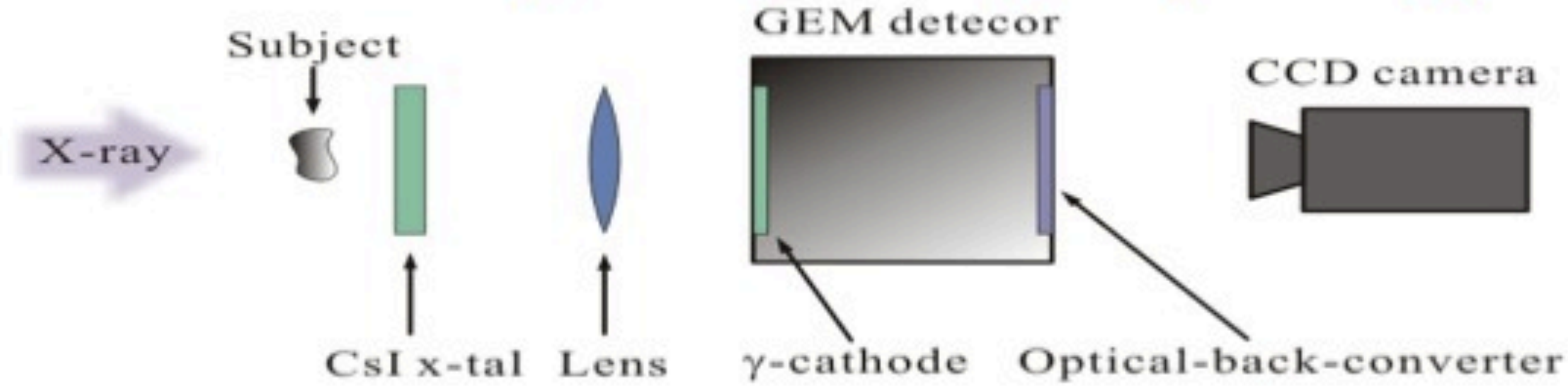
A. Bressan et al,
Nucl. Instr. and Meth. A 425(1999)254
F. Sauli, Nucl. Instr. and Meth.A 461(2001)47

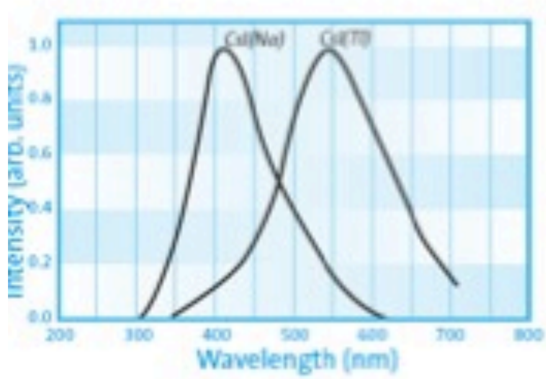
FAST X-RAY IMAGING

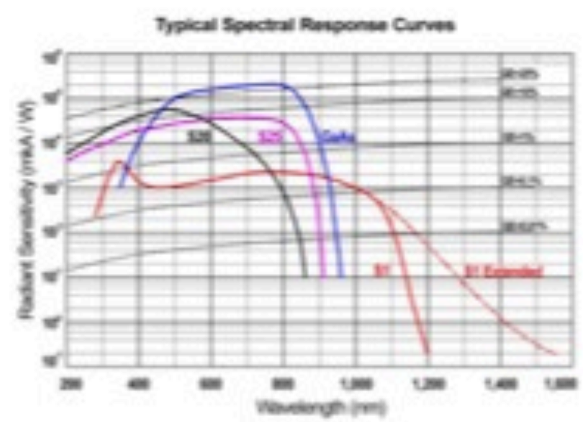


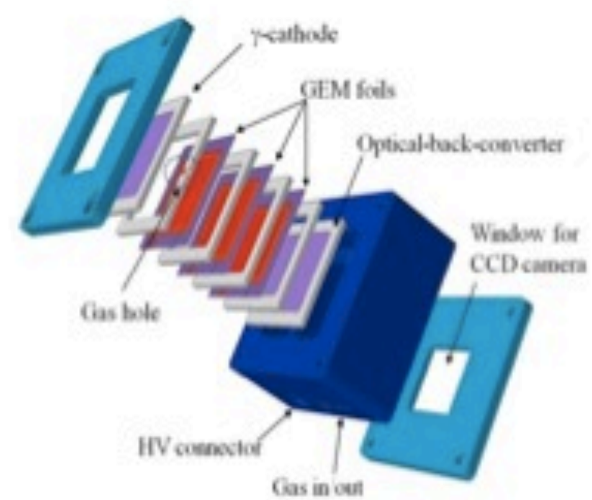
9 keV absorption radiography of a small mammal (image size ~ 60 x 30 mm^2)

GEM Image Amplifier (GIA) Design









Scintillator:CsI
Σ-20 photo-converter
Optical-back-converter:

Conclusions

1. Lessons from the past invaluable
2. Value the students participation
3. We were hungry and foolish.
4. We are ready to move to upscope.
5. We will be in the high eta area.