Time Projection Chamber

이 효 상
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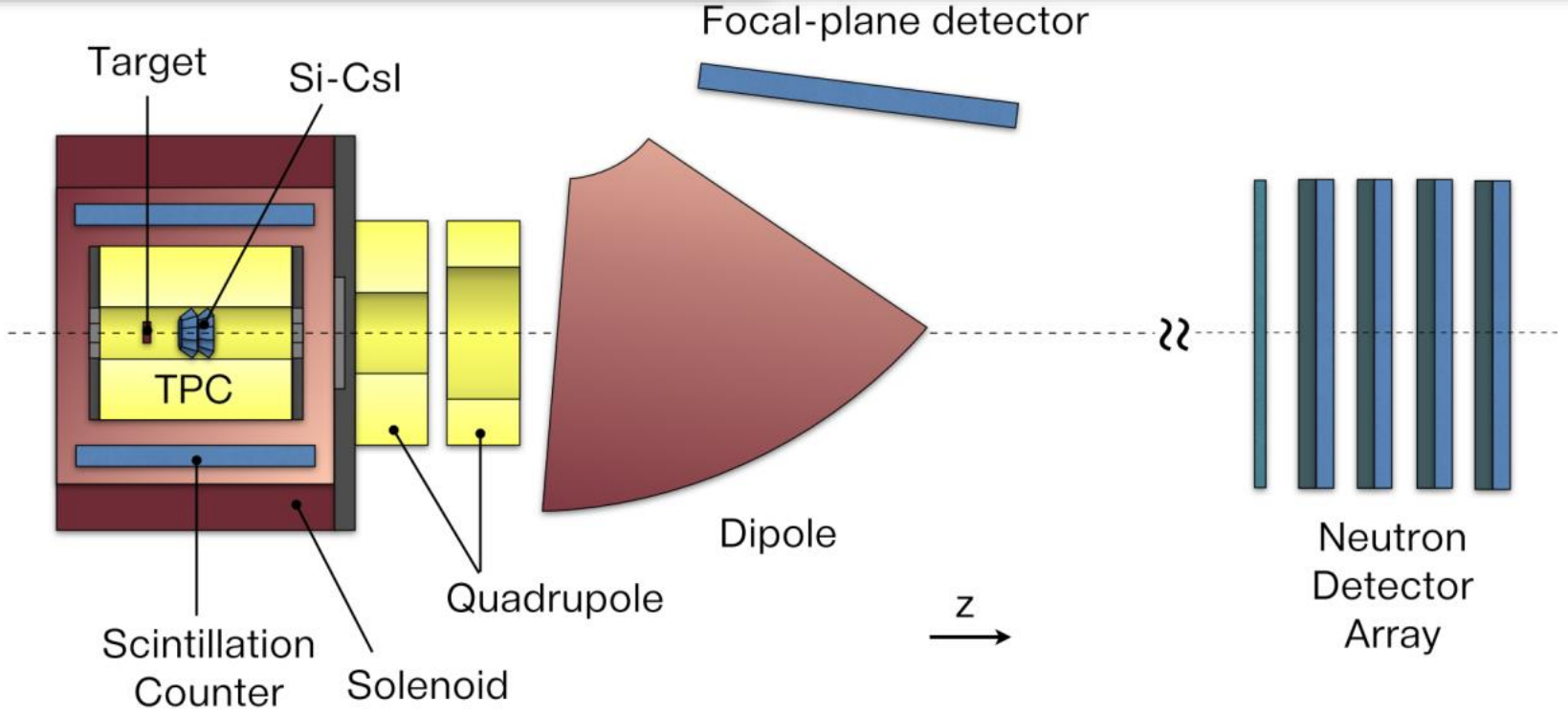
2014.12.08

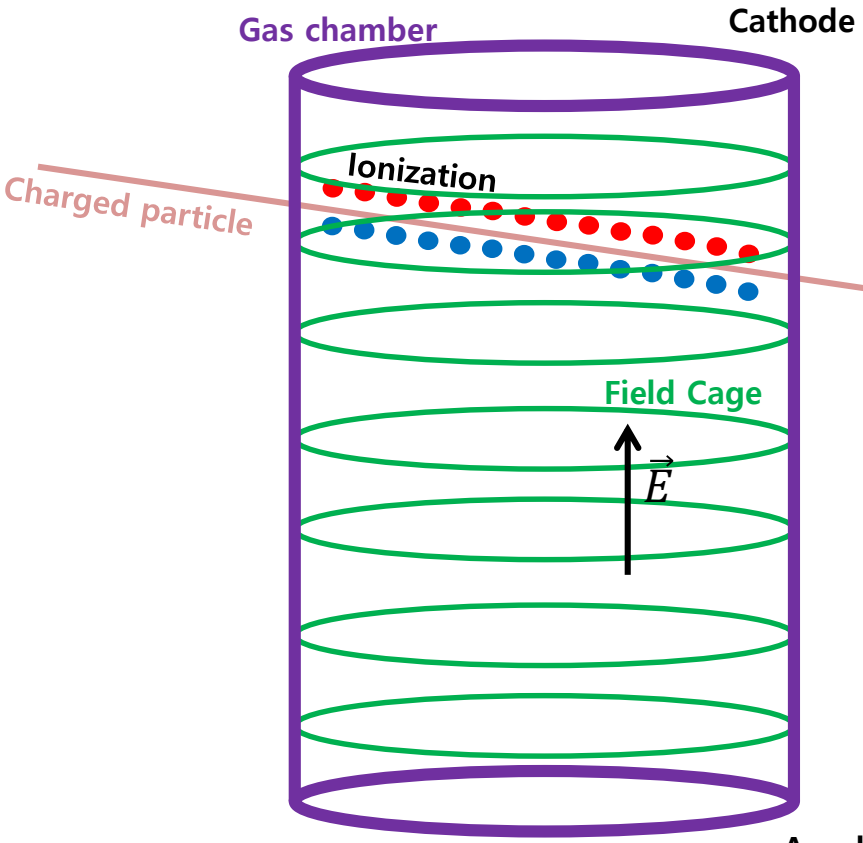
LAMPS High Energy



✓ **LAMPS High Energy**
- heavy ion collisions
- to study the symmetry energy in the EoS of nuclear matter
- designed to cover wide acceptance range
  with high detection efficiency and accuracy of charged particles and neutrons

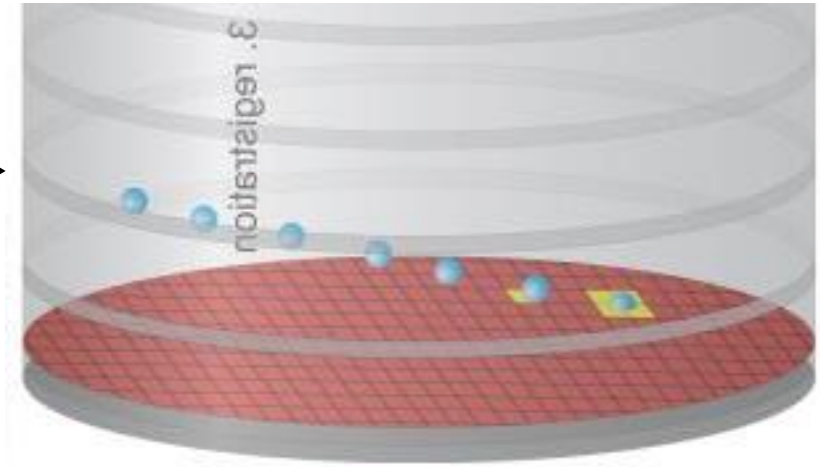
✓ **Time Projection Chamber (TPC)**
- main detector for tracking of particles
- inside of Solenoid magnet
- complete information of charged particle trajectory

Working principle of Time Projection Chamber

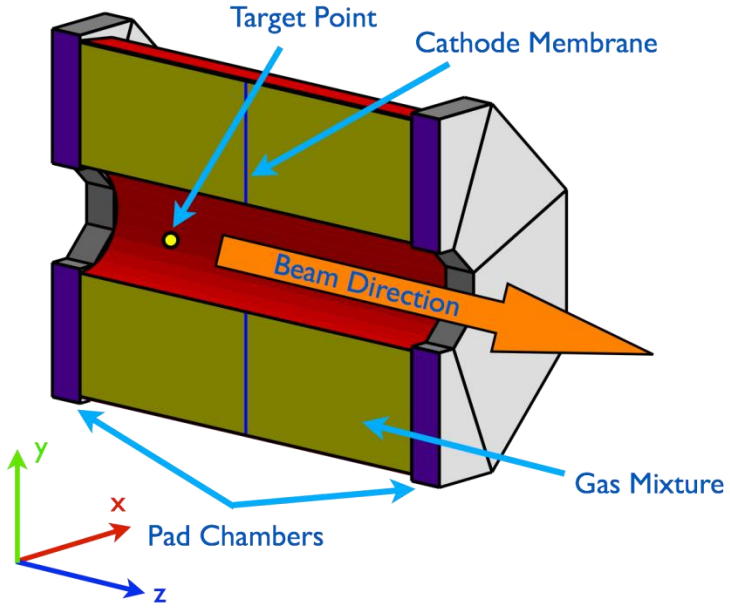


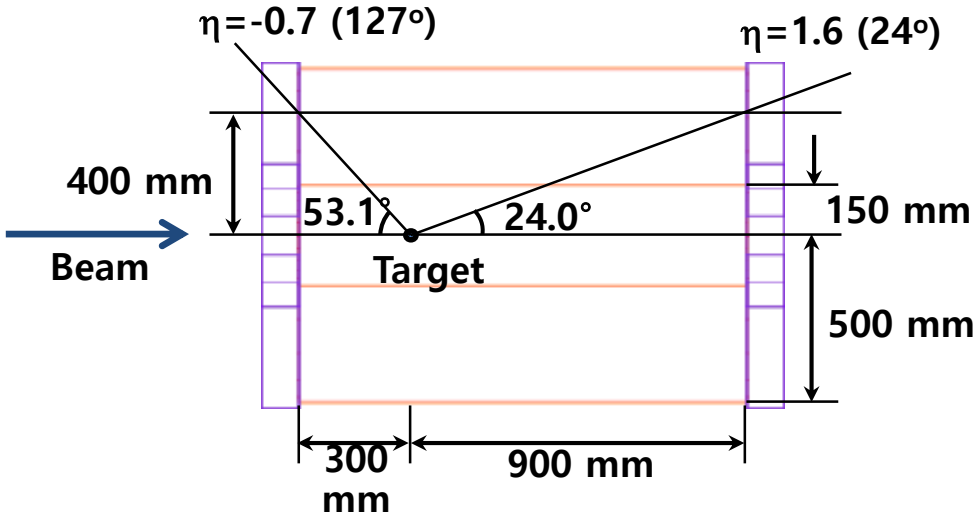
- **Gas chamber**
  - gas ionization
  - → ion + electron
- **Field Cage**
  - homogeneous high electric field
  - conducting rings
  - → electron drift
- **Anode**
  - segmented PAD : x-y position
  - drift time : z position
  - → 3D tracking

Anode →



LAMPS TPC

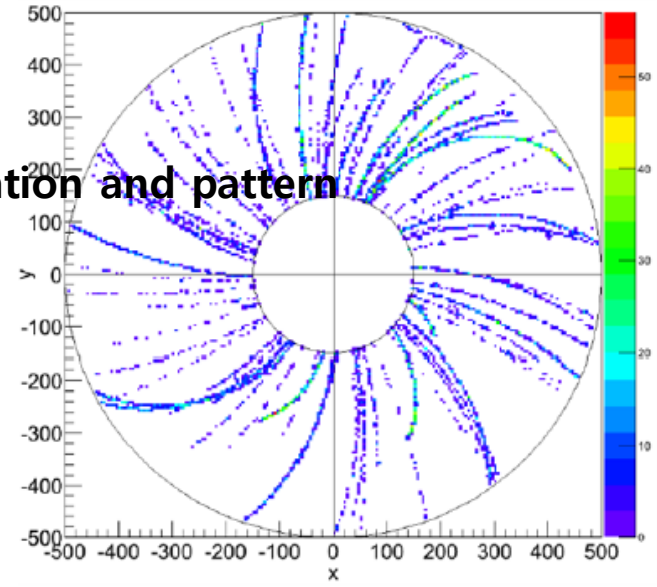




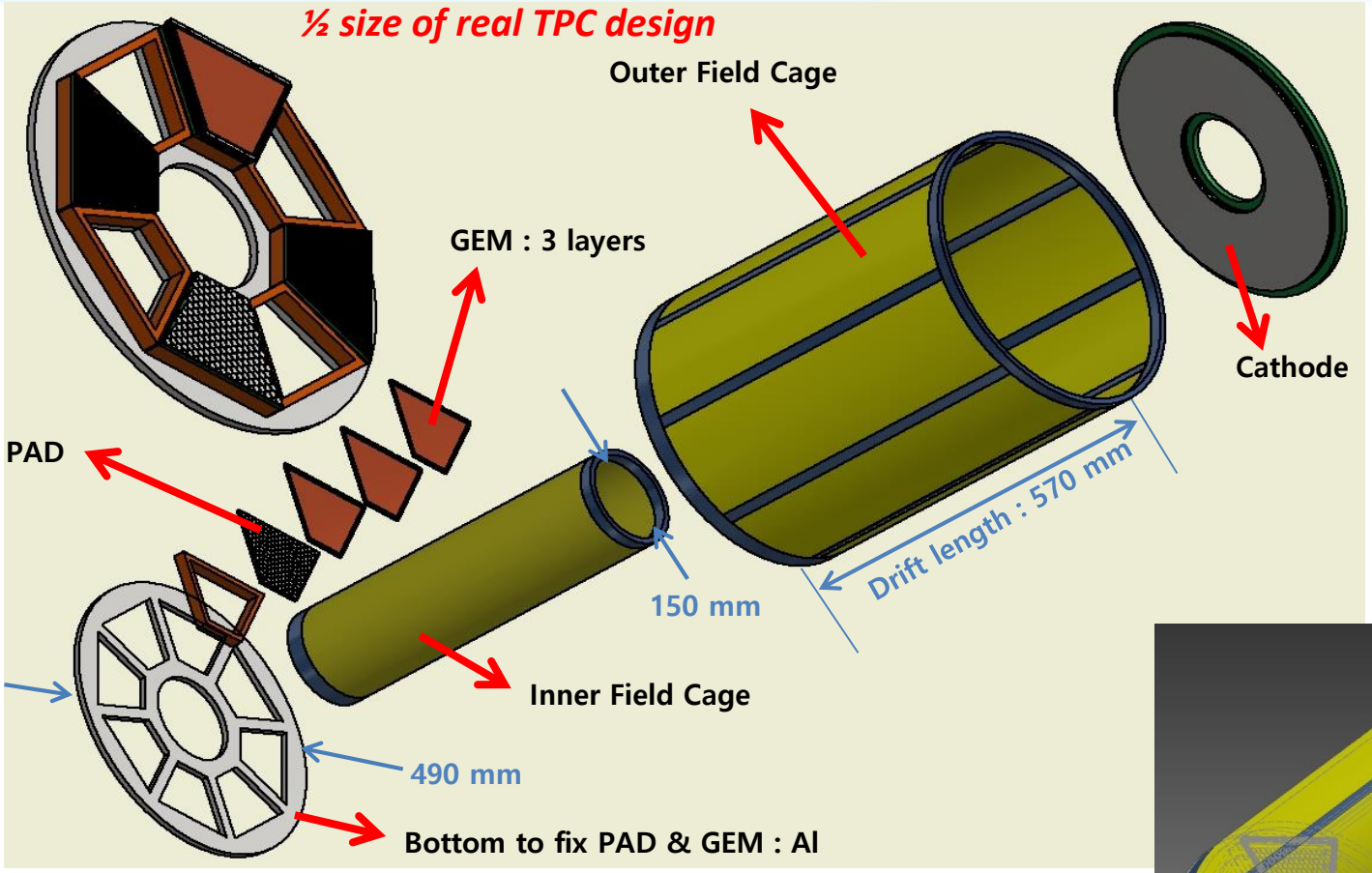
- Target : 30cm away from the center

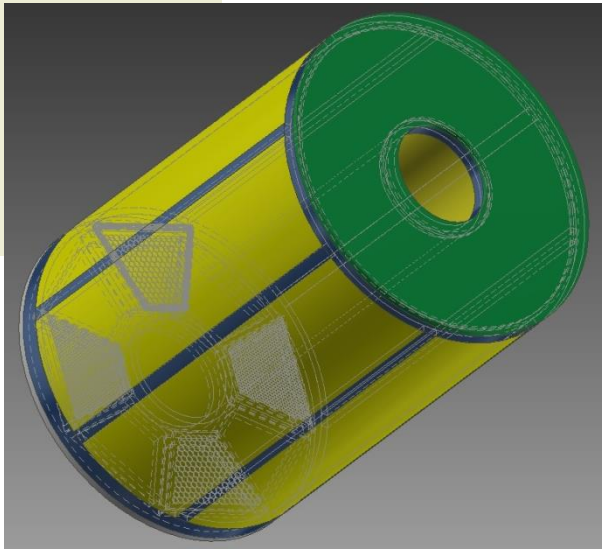
Key Points of TPC development

- Detection range : -0.7(127°) ~ 1.6(24°)
  - ✓ Gas Electron Multiplier (GEM) : max size, installation and pattern
- Drift length : 60cm (x2)
  - ✓ PAD : shape and pattern – hexagon shape
- Volume : 857L
  - ✓ Field Cage : uniform field by Cu strip
- Cathode Membrane
  - ✓ Body : light material (G10) and honeycomb
- Amplified by Gas Electron Multiplier (GEM)
  - ✓ Electronics : GET system
- Both side readout PAD



Prototype TPC



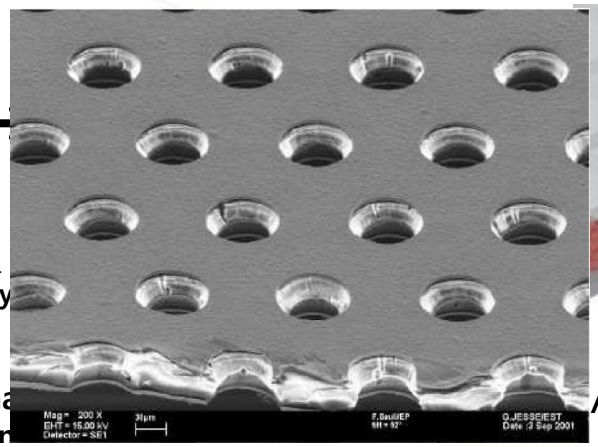


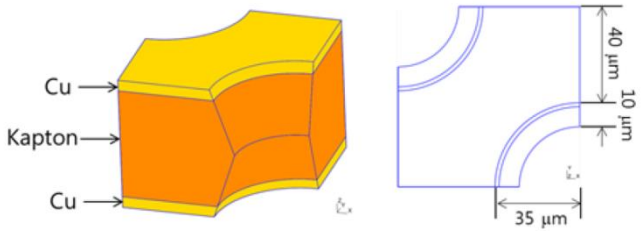
Concept of prototype TPC for LAMPS

- Optimized design & fabrication method : 1/2 size of real TPC (1/8 volume)
  Honeycomb body for gas chamber
- PAD : Hexagon shape
  Test with 5mm & 2.5mm
- GEM : Test with large size & specific shape
- Field cage : Uniform electric field by cu strip
- DAQ : r-COBO system
- Analysis : Development of reconstruction algorism

Gas Electron Multiplier (GEM)

Gas Electron Multiplier



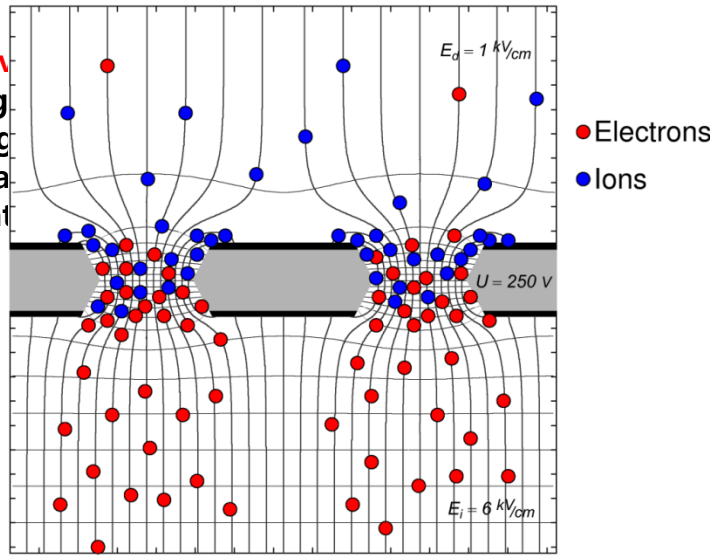


prima /cm

→ n

Disadv

1. Sig
2. Hig tha
3. Gat

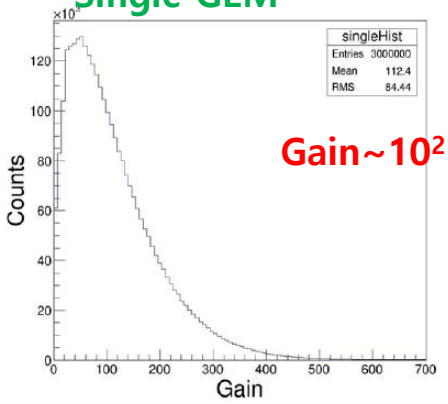


Advantages of GEM

1. No wires to break
2. Prevent positive ions
3. Uniform electric field
4. High gain
5. Narrow signal

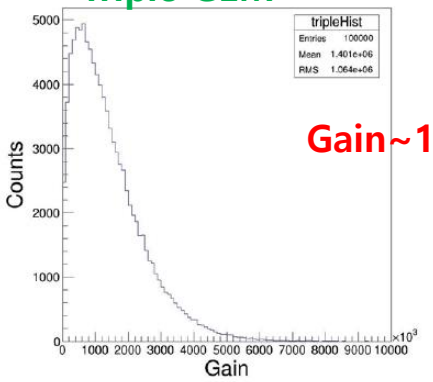
Garfield++ simulation

Single GEM



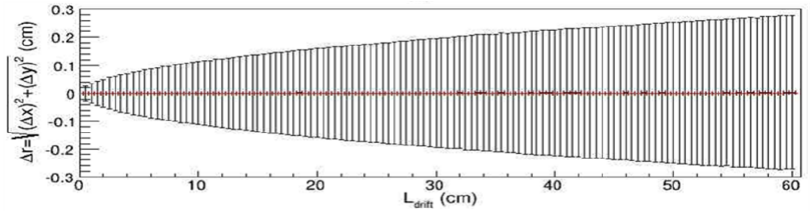
Gain~10^2

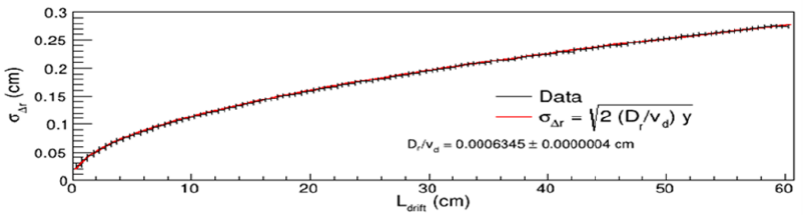
Triple GEM



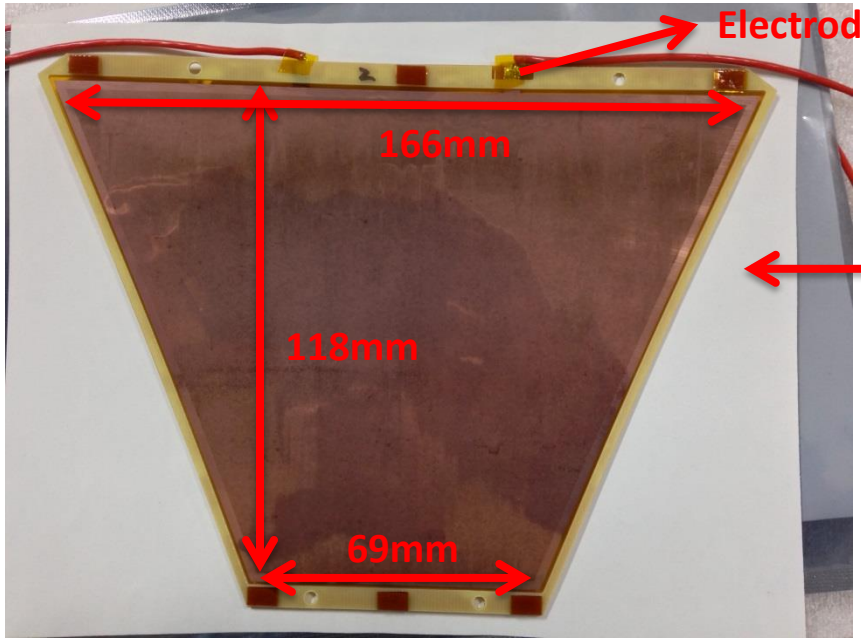
Gain~10^6

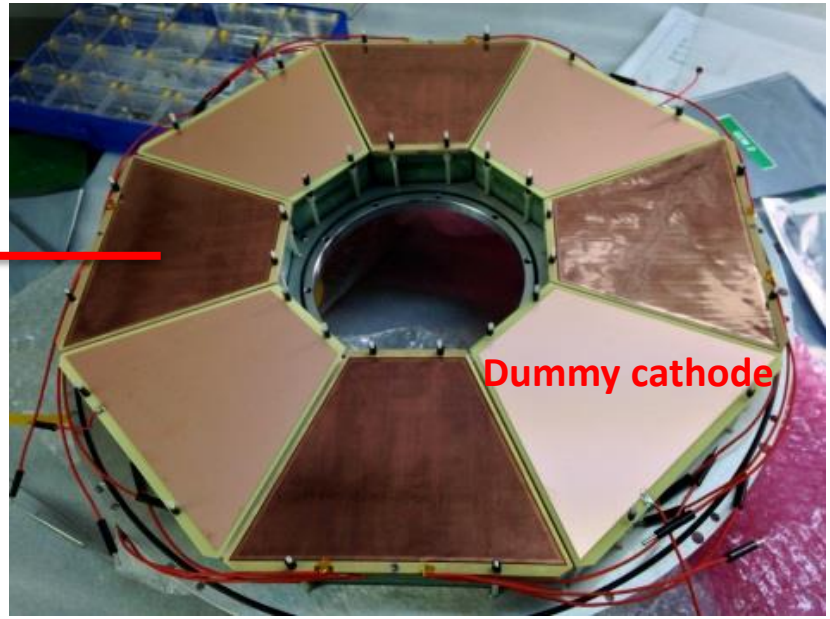
Triple GEM TPC gas gain diffusion simulation



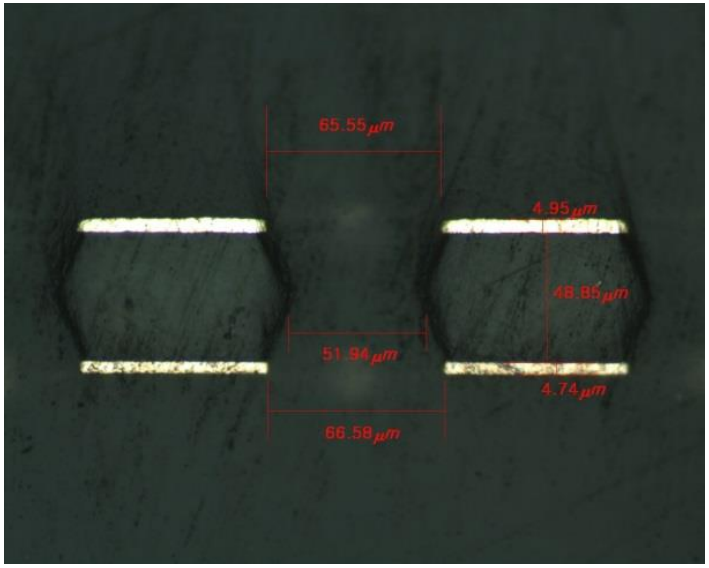


Gas Electon Multiplier (GEM)





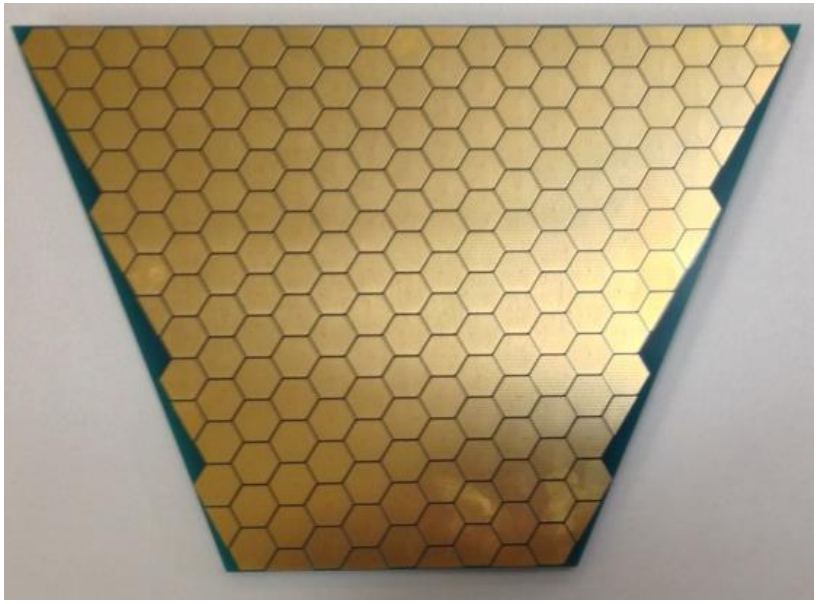
- Trapezoidal shape
- 50μm thickness
- 160x120 mm²
- 3 layers for each PAD



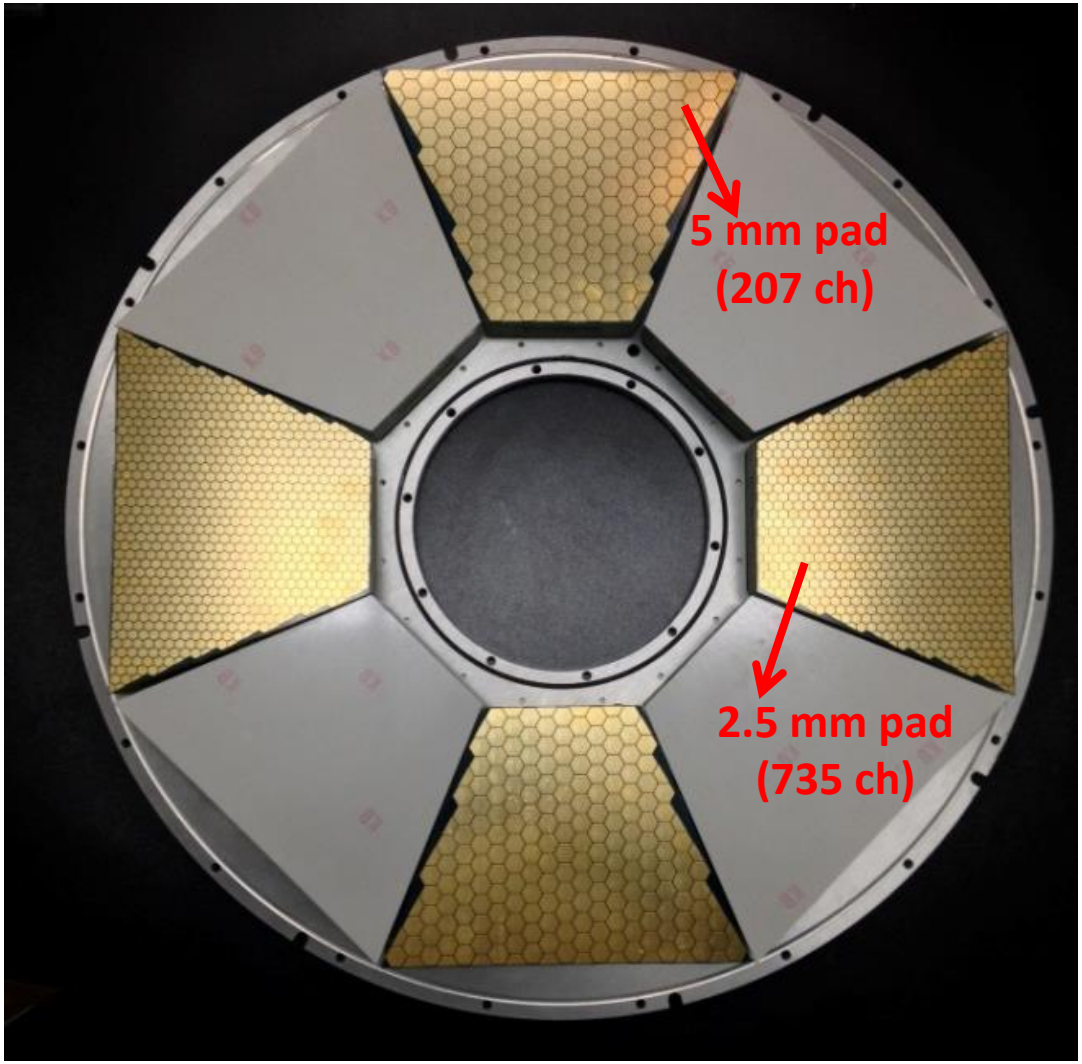
PAD

- Hexagonal shape : 5mm & 2.5mm
- 500 μm gap between two pads
- Multi-layer PCB board
- Trapezoidal (or Octant) shape PCB
- 4 layers PCB
- 16 pin SMD type connector

  (1.27mm pitch)



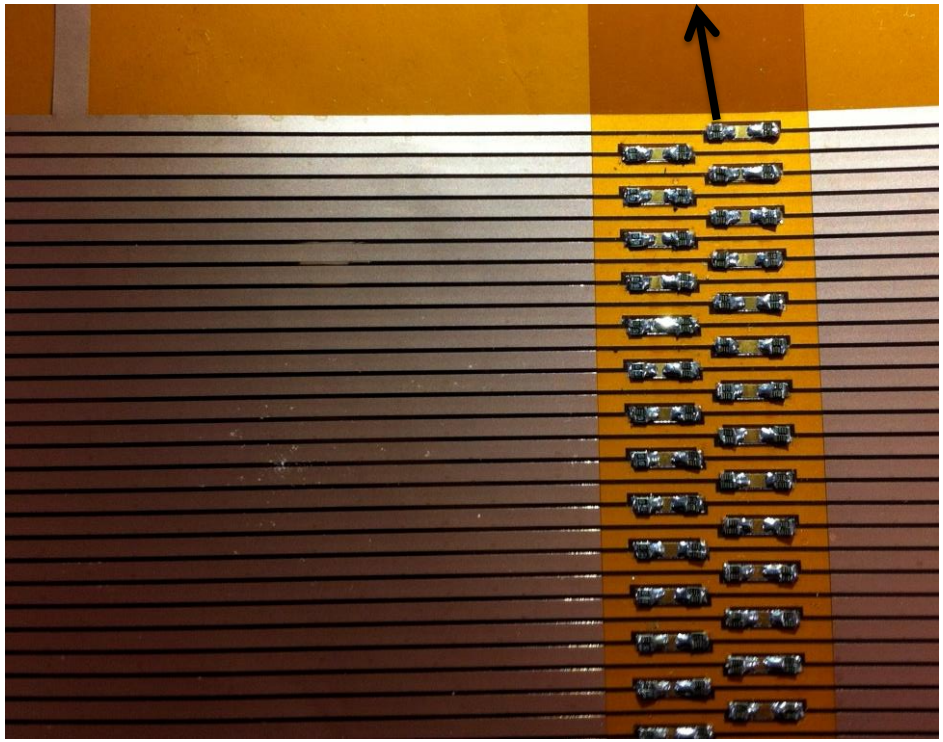
Trapezoidal (or Octant) shape PCB



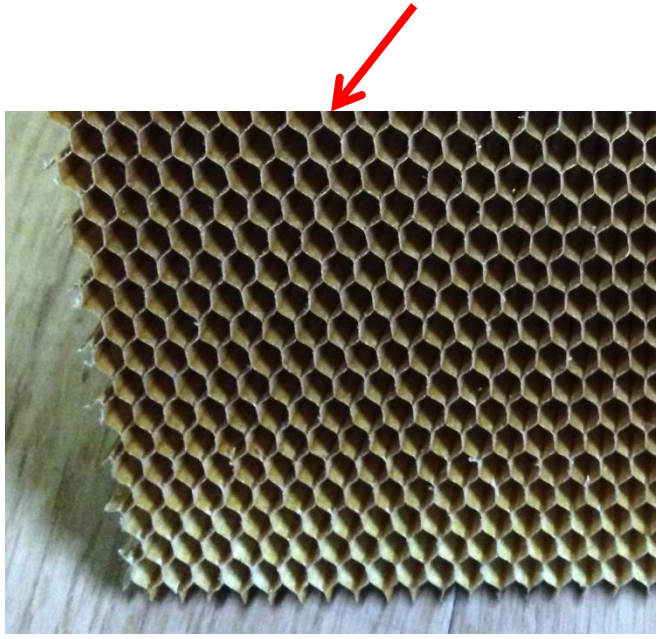
Field Cage

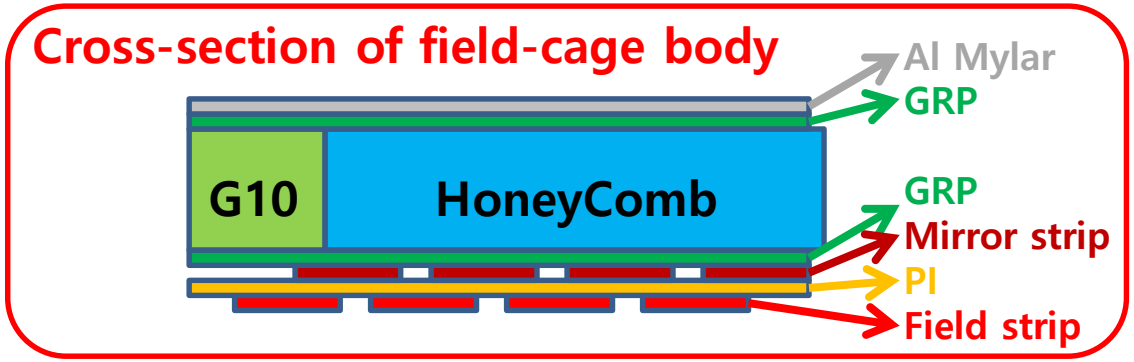
- 35 um thick and 2 mm wide Cu strips
- 0.5 mm gap between neighboring strips
- Mirror strips on the back
- 1 MΩ resistors with 0.1% var.

1MOhm resistor(0.1%)



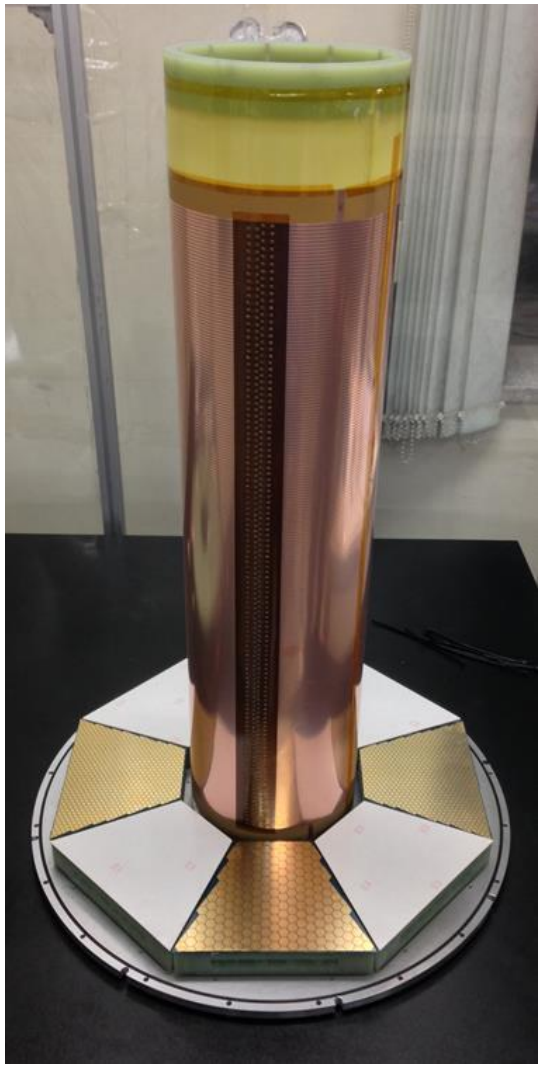
- TPC body: G10 + Aramid honeycomb



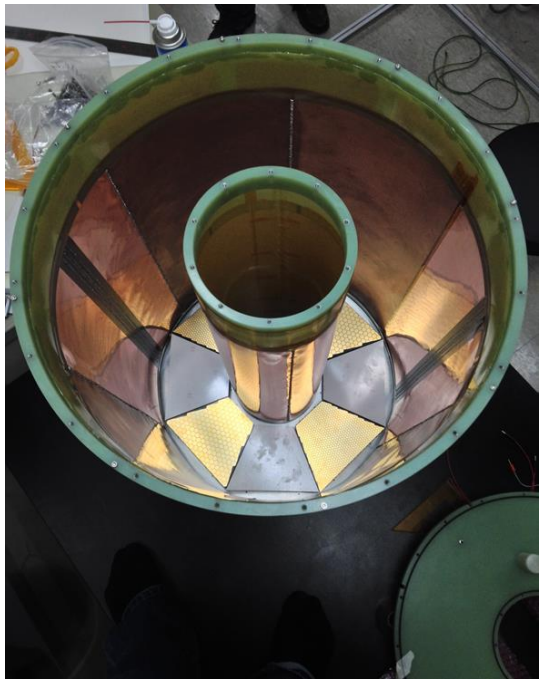


Assembling

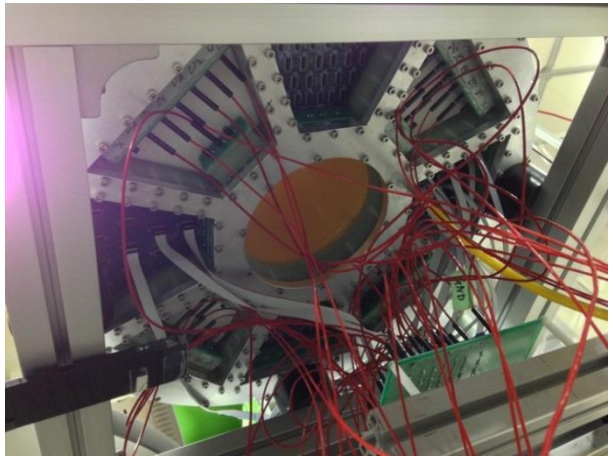
Inner Field Cage install



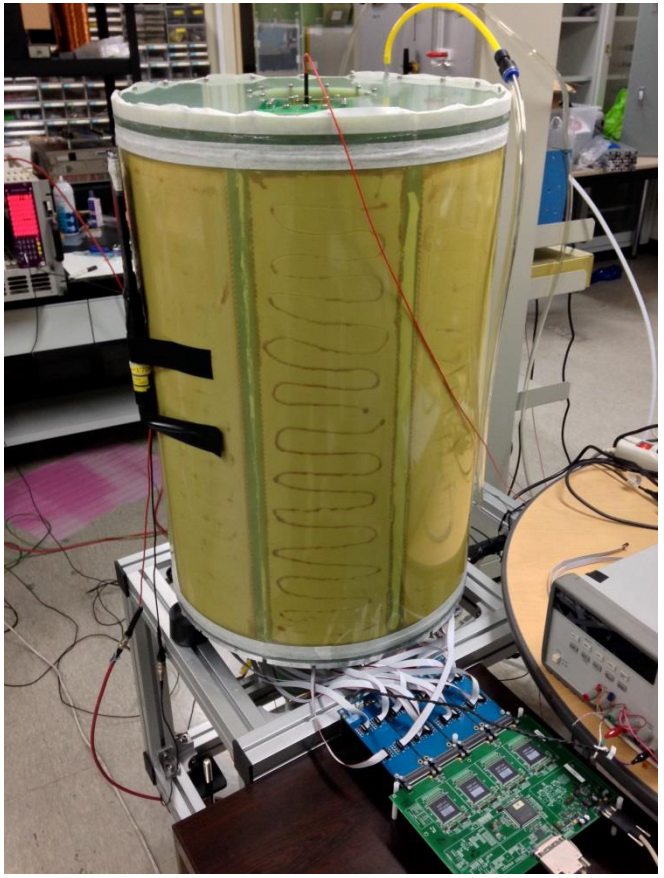
Outer Field Cage install



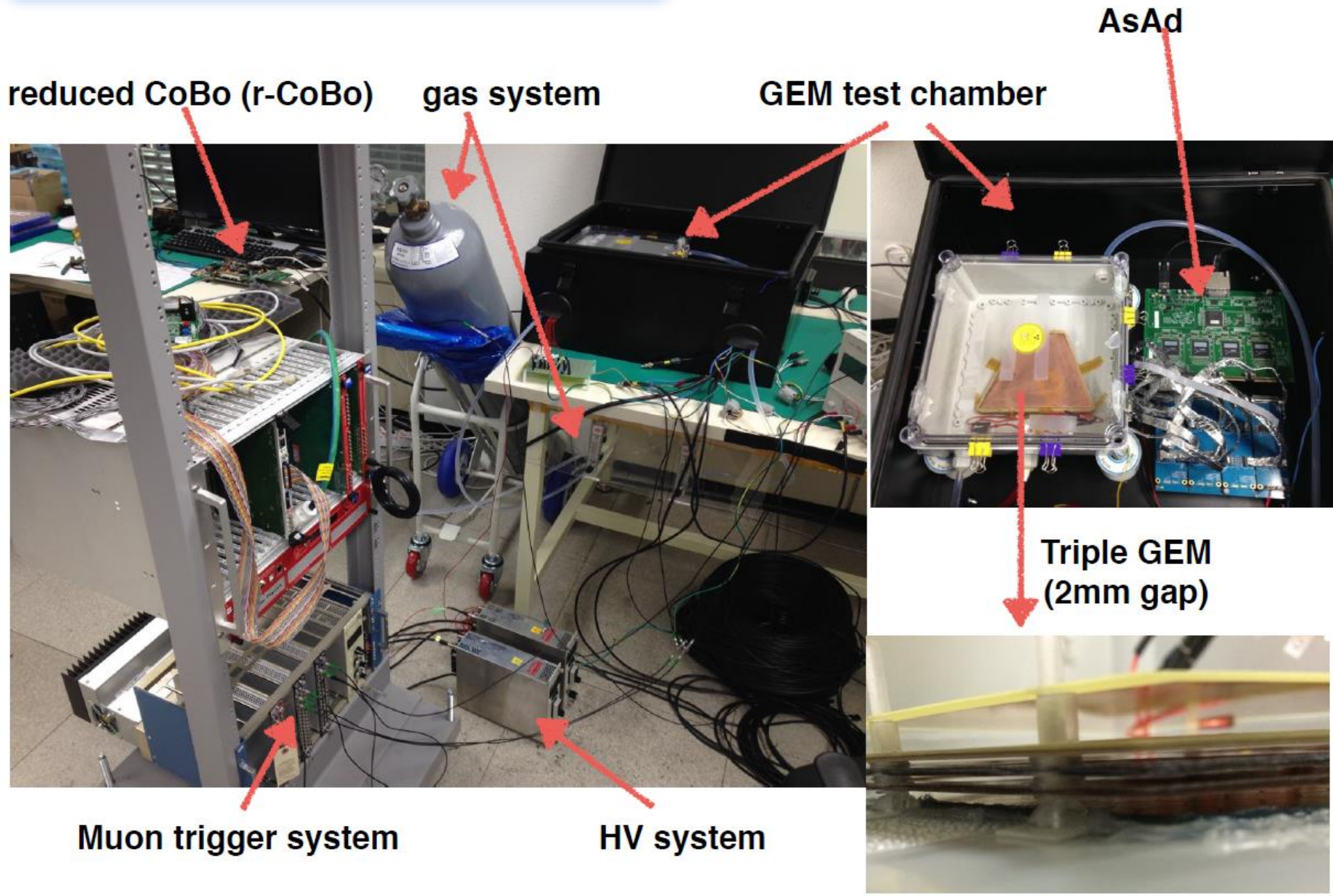
Prototype TPC : back



Prototype TPC

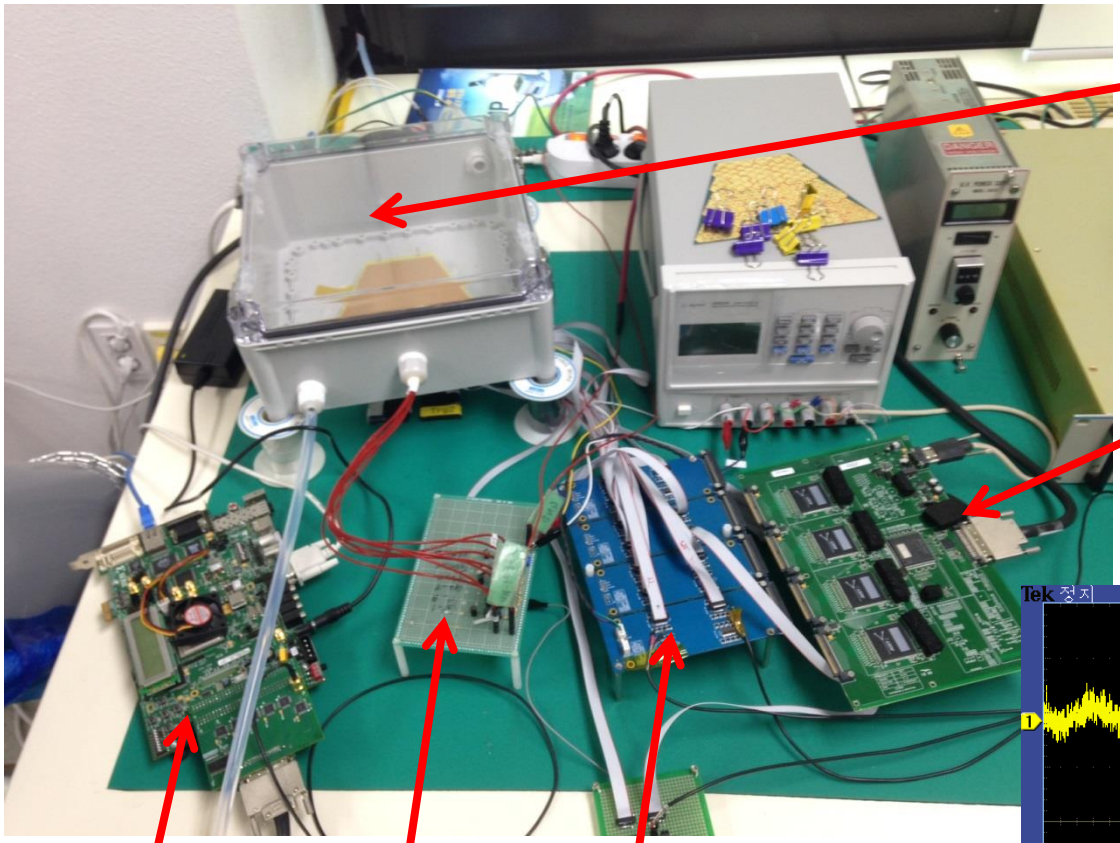


GEM test system



GEM test system

Single section test setup



Single section test box
- 1PAD + 3GEM + cathode

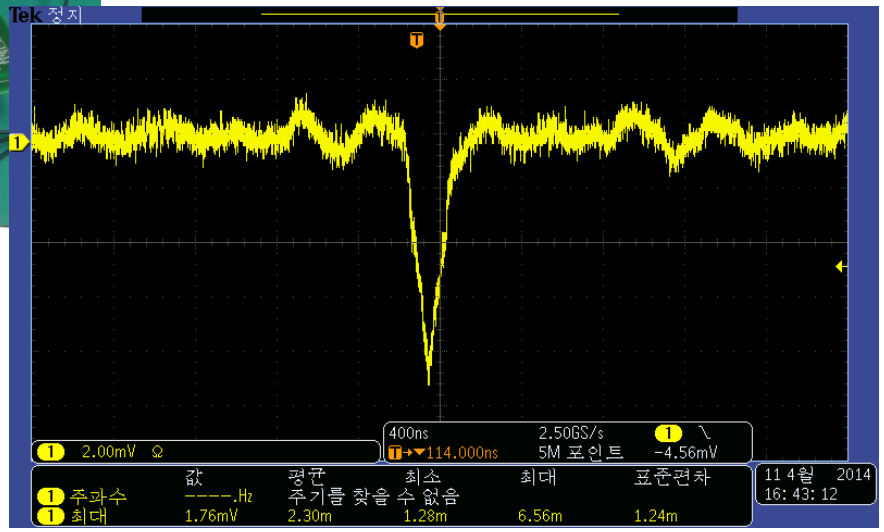
AsAd

r-CoBo

HV divider

ZAP

Oscilloscope signal from PAD



Source : Co60, Cs137

Test plan

- ✓ GET system test
- ✓ Cosmic-ray muon test
- ✓ Source test : Fe55

AGET system

GET system

TPC

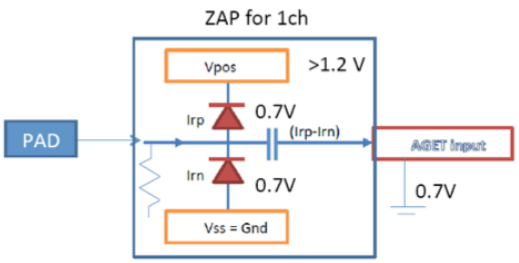
ZAP

AsAd

CoBo

PC

● ZAP board : to protect AGET chip in AsAd board



✓ 2nd version ZAP

✓ BAV99 chip : small signal diode

● ASAD : AGET Support for Analog to Digital

A(Asic)GET chip

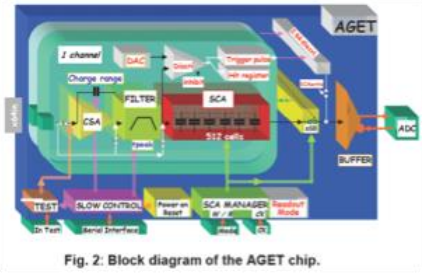


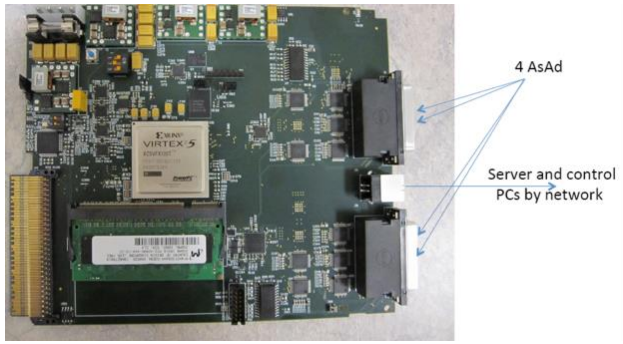
Fig. 2: Block diagram of the AGET chip.

✓4 AGET (256 ch) in 1 AsAd

✓12 bit ADC

✓Pulsar

● COBO : Collection BOard



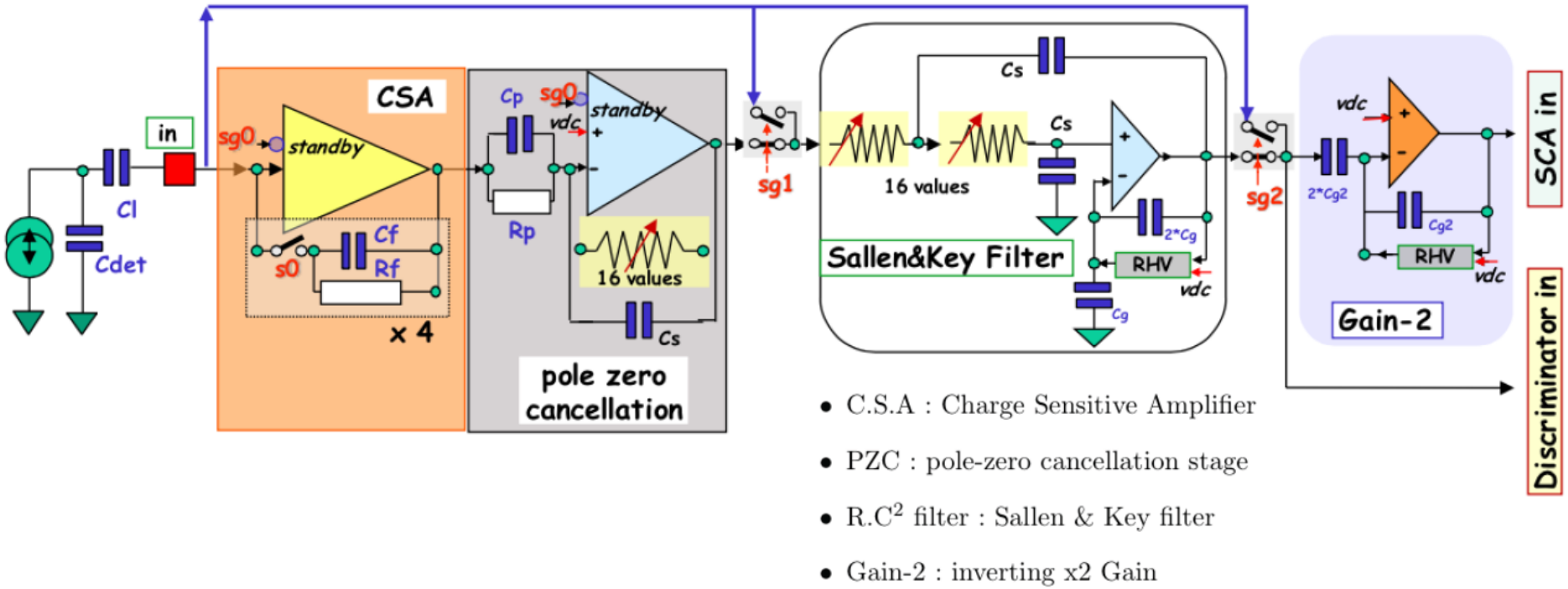
✓Digital data from AsAd

✓Zero suppression

✓Network transfer to PC

✓4 AsAd controlled by 1 COBO

AGET system

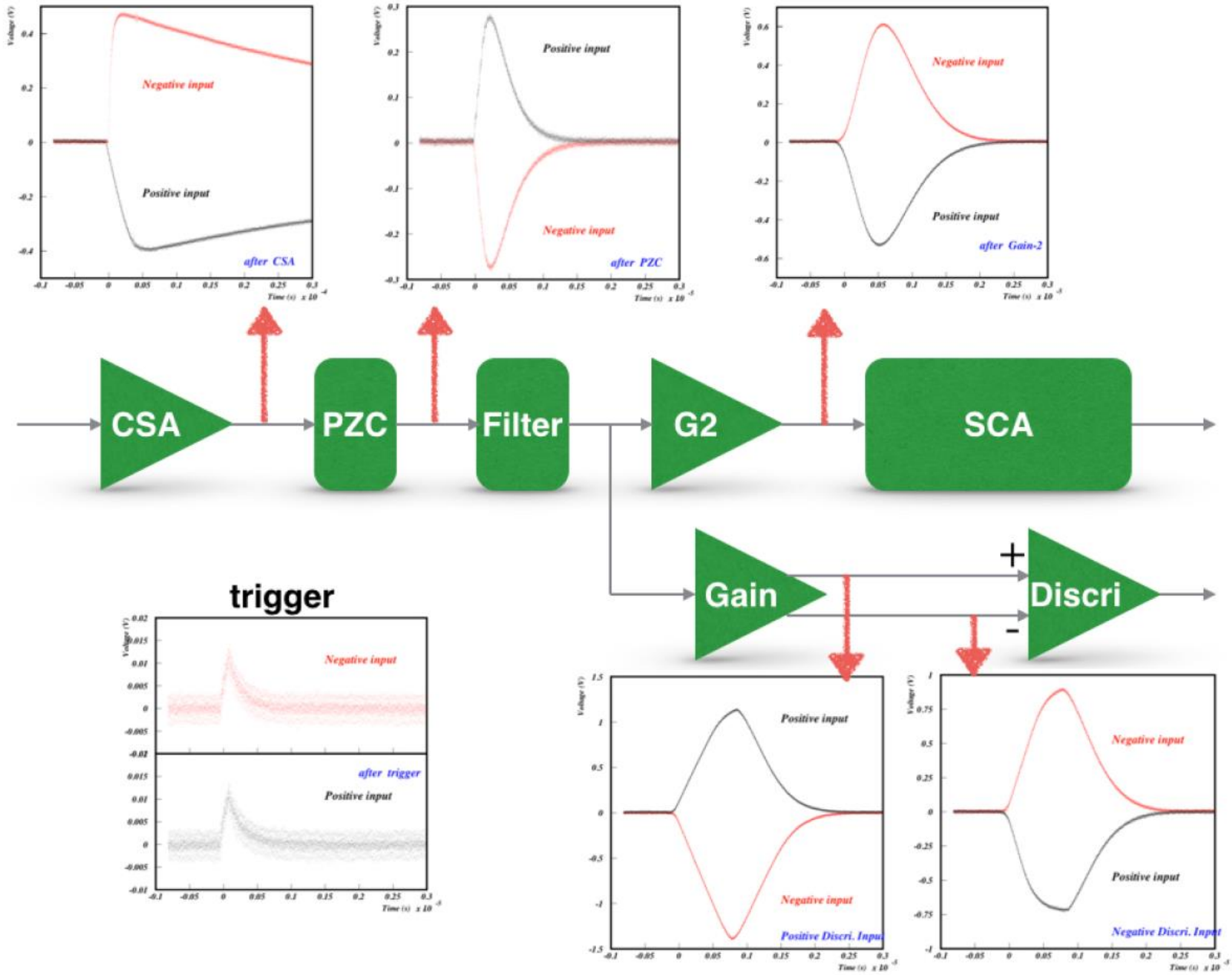


- C.S.A : Charge Sensitive Amplifier
- PZC : pole-zero cancellation stage
- R.C^2 filter : Sallen & Key filter
- Gain-2 : inverting x2 Gain

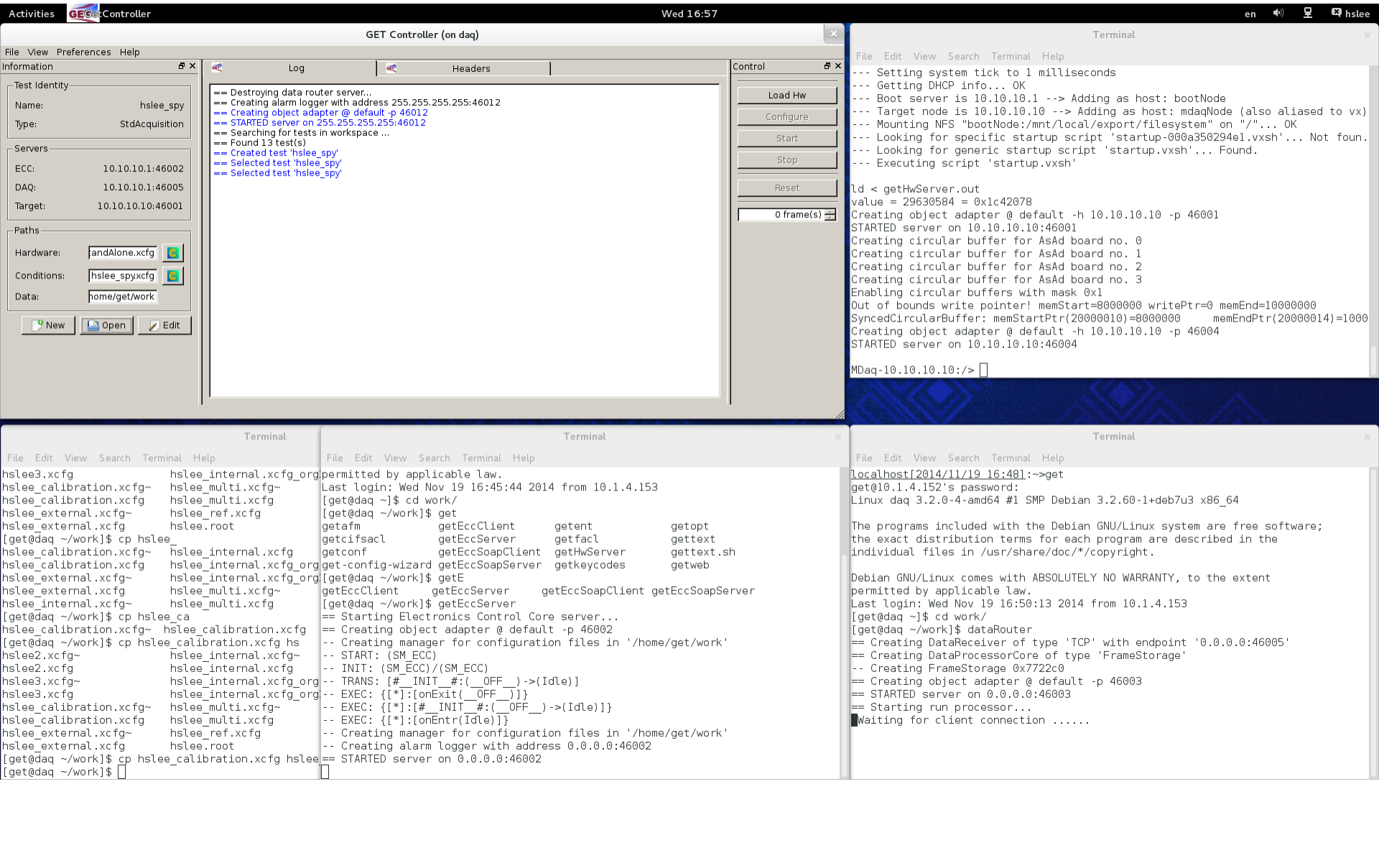
Parameter	Value
Polarity of detector signal	Negative or Positive
channels number	64
External Preamplifier	Yes, access to the filter or SCA input (external CSA)
Charge measurement	
Input dynamic range	120fC, 240fC, 1pC, 10pC
Gain	Adjustable per channel
Output dynamic range	2Vp-p(differential)
I.N.L	< 2%
Resolution	< 850e- (Gain:120fC, Peaking Time:200ns, Cinput<30pF)
Sampling	
Peaking time	50ns to 1μs (16 values)
SCA time bin number	512 or 2x256cells
Sampling Frequency	1 MHz to 100 MHz

Multiplicity	
Multiplicity signal	Analog OR of 64 discriminator outputs
Input dynamic range	5% or 17.5% of input channel input charge range
I.N.L	< 5%
Threshold value	7-bit DAC
	(3-bit + polarity bit) common DAC + 4-bit DAC/channel
Readout	
Readout frequency	25MHz
Channel Readout mode	Hit, selected or all
SCA Readout mode	1 to 512 cells
Test	
calibration	1 channel among 64, 1 external test capacitor (2)
test	1 channel among 64, internal test capacitor
functional	1 to 64(68) channels, 1 internal test capacitor per channel
Counting rate	< 1kHz
Power consumption	< 10 mW/channel 3.3V

AGET system


Negative input
Positive input
after CSA
Positive input
Negative input
after PZC
Negative input
Positive input
after Gain-2
CSA
PZC
Filter
G2
SCA
Gain
+
-
Discri
trigger
Negative input
after trigger
Positive input
Positive input
Negative input
Positive Discri. Input
Negative input
Positive input
Negative Discri. Input

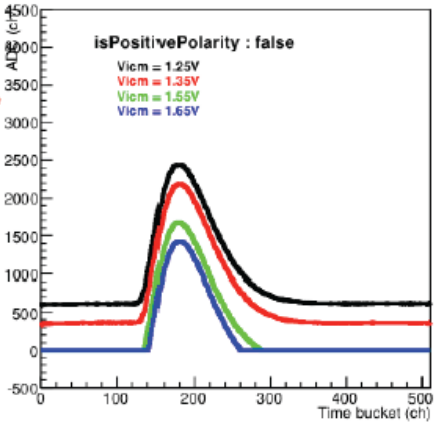
AGET system

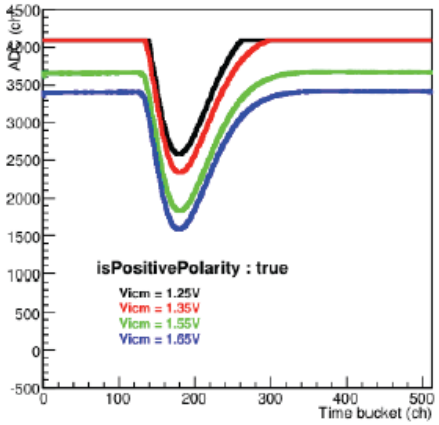

Activities
GetController
Wed 16:57
en
hslee
GET Controller (on daq)
File View Preferences Help
Information
Test Identity
Name: hslee_spy
Type: StdAcquisition
Servers
ECC: 10.10.10.1:46002
DAQ: 10.10.10.1:46005
Target: 10.10.10.10:46001
Paths
Hardware: tandAlone.xcfg
Conditions: hslee_spy.xcfg
Data: home/get/work
New
Open
Edit
Log
Headers
== Destroying data router server...
== Creating alarm logger with address 255.255.255.255:46012
== Creating object adapter @ default -p 46012
== STARTED server on 255.255.255.255:46012
== Searching for tests in workspace ...
== Found 13 test(s)
== Created test 'hslee_spy'
== Selected test 'hslee_spy'
== Selected test 'hslee_spy'
Control
Load Hw
Configure
Start
Stop
Reset
0 frame(s)
Terminal
File Edit View Search Terminal Help
--- Setting system tick to 1 milliseconds
--- Getting DHCP info... OK
--- Boot server is 10.10.10.1 --> Adding as host: bootNode
--- Target node is 10.10.10.10 --> Adding as host: mdaqNode (also aliased to vx)
--- Mounting NFS "bootNode:/mnt/local/export/filesystem" on "/"... OK
--- Looking for specific startup script 'startup-000a350294e1.vxsh'... Not foun.
--- Looking for generic startup script 'startup.vxsh'... Found.
--- Executing script 'startup.vxsh'
ld < getHwServer.out
value = 29630584 = 0x1c42078
Creating object adapter @ default -h 10.10.10.10 -p 46001
STARTED server on 10.10.10.10:46001
Creating circular buffer for AsAd board no. 0
Creating circular buffer for AsAd board no. 1
Creating circular buffer for AsAd board no. 2
Creating circular buffer for AsAd board no. 3
Enabling circular buffers with mask 0x1
Out of bounds write pointer! memStart=8000000 writePtr=0 memEnd=10000000
SyncedCircularBuffer: memStartPtr(20000010)=8000000 memEndPtr(20000014)=1000
Creating object adapter @ default -h 10.10.10.10 -p 46004
STARTED server on 10.10.10.10:46004
MDaq-10.10.10.10:/>
Terminal
File Edit View Search Terminal Help
hslee3.xcfg hslee_internal.xcfg_org
hslee_calibration.xcfg~ hslee_multi.xcfg~
hslee_calibration.xcfg hslee_multi.xcfg
hslee_external.xcfg~ hslee_ref.xcfg
hslee_external.xcfg hslee.root
[get@daq ~/work]$ cp hslee_
hslee_calibration.xcfg~ hslee_internal.xcfg
hslee_calibration.xcfg hslee_internal.xcfg_org
hslee_external.xcfg~ hslee_internal.xcfg_org
hslee_external.xcfg hslee_multi.xcfg~
hslee_internal.xcfg~ hslee_multi.xcfg
[get@daq ~/work]$ cp hslee_ca
hslee_calibration.xcfg~ hslee_calibration.xcfg
[get@daq ~/work]$ cp hslee_calibration.xcfg hs
hslee2.xcfg~ hslee_internal.xcfg~
hslee2.xcfg hslee_internal.xcfg
hslee3.xcfg~ hslee_internal.xcfg_org
hslee3.xcfg hslee_internal.xcfg_org
hslee_calibration.xcfg~ hslee_multi.xcfg~
hslee_calibration.xcfg hslee_multi.xcfg
hslee_external.xcfg~ hslee_ref.xcfg
hslee_external.xcfg hslee.root
[get@daq ~/work]$ cp hslee_calibration.xcfg hslee
[get@daq ~/work]$
Terminal
File Edit View Search Terminal Help
permitted by applicable law.
Last login: Wed Nov 19 16:45:44 2014 from 10.1.4.153
[get@daq ~]$ cd work/
[get@daq ~/work]$ get
getafm getEccClient getent getopt
getcifsacl getEccServer getfacl gettext
getconf getEccSoapClient getHwServer gettext.sh
get-config-wizard getEccSoapServer getkeycodes getweb
[get@daq ~/work]$ getE
getEccClient getEccServer getEccSoapClient getEccSoapServer
[get@daq ~/work]$ getEccServer
== Starting Electronics Control Core server...
== Creating object adapter @ default -p 46002
-- Creating manager for configuration files in '/home/get/work'
-- START: (SM_ECC)
-- INIT: (SM_ECC)/(SM_ECC)
-- TRANS: [#__INIT__#:(__OFF__)->(Idle)]
-- EXEC: {[*]:[onExit(__OFF__)]}
-- EXEC: {[*]:[#__INIT__#:(__OFF__)->(Idle)]}
-- EXEC: {[*]:[onEntr(Idle)]}
-- Creating manager for configuration files in '/home/get/work'
-- Creating alarm logger with address 0.0.0.0:46002
== STARTED server on 0.0.0.0:46002
Terminal
File Edit View Search Terminal Help
localhost[2014/11/19 16:48]:~>get
get@10.1.4.152's password:
Linux daq 3.2.0-4-amd64 #1 SMP Debian 3.2.60-1+deb7u3 x86_64
The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.
Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Wed Nov 19 16:50:13 2014 from 10.1.4.153
[get@daq ~]$ cd work/
[get@daq ~/work]$ dataRouter
== Creating DataReceiver of type 'TCP' with endpoint '0.0.0.0:46005'
== Creating DataProcessorCore of type 'FrameStorage'
-- Creating FrameStorage 0x7722c0
== Creating object adapter @ default -p 46003
== STARTED server on 0.0.0.0:46003
== Starting run processor...
Waiting for client connection ......

AGET test

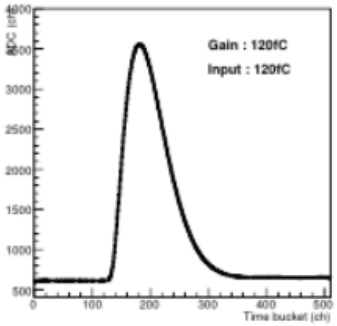
Parameter	Value
Channel number	64
Detector signal polarity	Negative or Positive
External preamplifier	Access to the filter or SCA input
Counting rate	< 1 kHz
Power consumption	< 10 mW/channel at 3.3 V
Charge measurement	
Input dynamic range	120 fC, 240 fC, 1 pC, 10 pC
Gain	Adjustable per channel
Output dynamic range	2 V p-p (differential)
I. N. L.	< 2%
Resolution	< 850 e^- (Gain: 120 fC, Peaking Time: 200 ns, C_{input} < 30 pF)
Sampling	
Peaking time	50 ns to 1 μs (16 values)
SCA time bin number	512 or 2×256 cells
Sampling frequency	1 MHz to 100 MHz
Multiplicity	
Multiplicity signal	Analog ≪ OR ≫ of 64 discriminator outputs
Input dynamic range	5% of input charge range
I. N. L.	< 5%
Threshold value	4-bit DAC/channel + (3-bit + polarity bit) common DAC
Readout	
Readout frequency	25 MHz
Readout mode	Hit, specific or 64
SCA readout mode	1 to 512 cells
Test	
Calibration	1 channel among 61, 1 external test capacitor
Test	1 channel among 61, 1 internal test capacitor (1 among 4)
Functional	1 to 64(68) channels, 1 internal test capacitor/channel

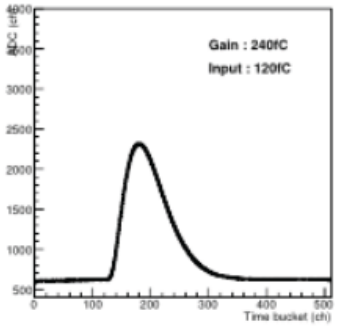
Polarity - negative or positive

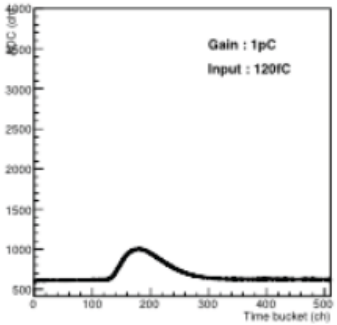


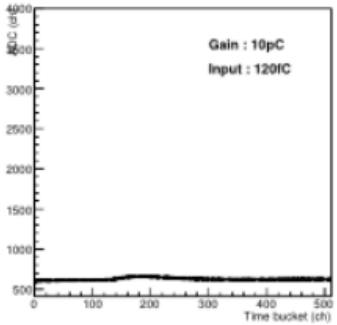


Dynamic range - 120fC, 240fC, 1pC, 10pC









AGET test

Parameter	Value
Channel number	64
Detector signal polarity	Negative or Positive
External preamplifier	Access to the filter or SCA input
Counting rate	< 1 kHz
Power consumption	< 10 mW/channel at 3.3 V
Charge measurement	
Input dynamic range	120 fC, 240 fC, 1 pC, 10 pC
Gain	Adjustable per channel
Output dynamic range	2 V p-p (differential)
I. N. L.	< 2%
Resolution	< 850 e^- (Gain: 120 fC, Peaking Time: 200 ns, C_{input} < 30 pF)
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Multiplicity signal	Analog ≪ OR ≫ of 64 discriminator outputs
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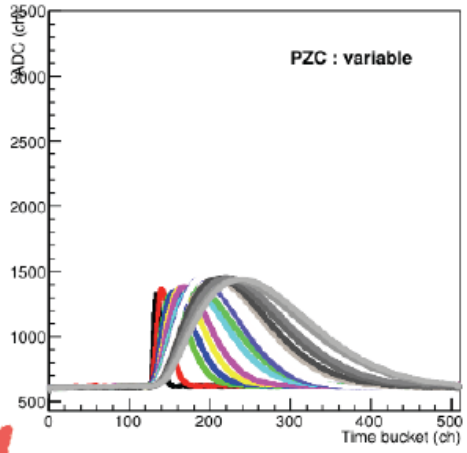
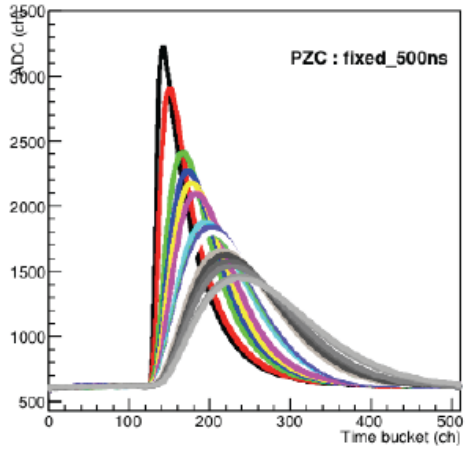
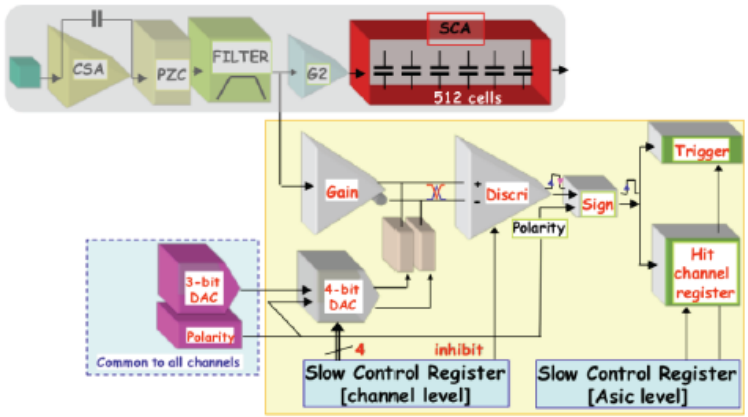
Threshold value	4-bit DAC/channel + (3-bit + polarity bit) common DAC
Readout	
Readout frequency	25 MHz
Readout mode	Hit, specific or 64
SCA readout mode	1 to 512 cells
Test	
Calibration	1 channel among 61, 1 external test capacitor
Test	1 channel among 61, 1 internal test capacitor (1 among 4)
Functional	1 to 64(68) channels, 1 internal test capacitor/channel

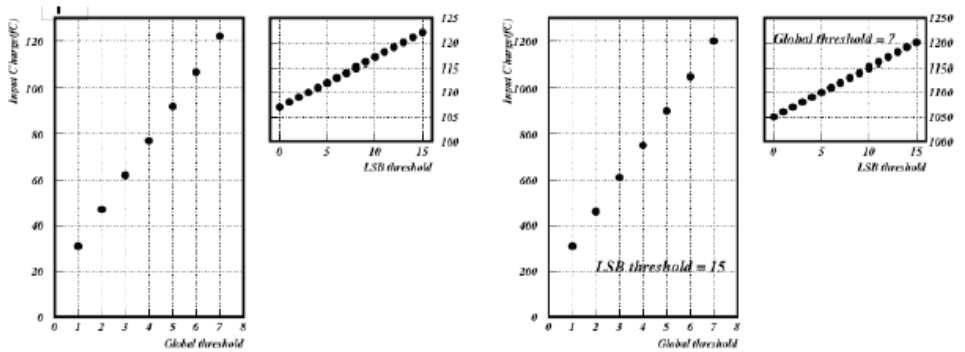
Peaking time - 50s to 1us (16 values)





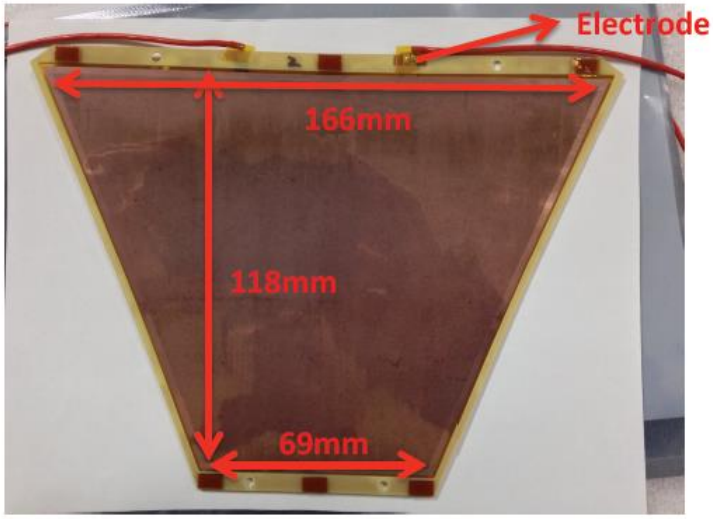
Threshold





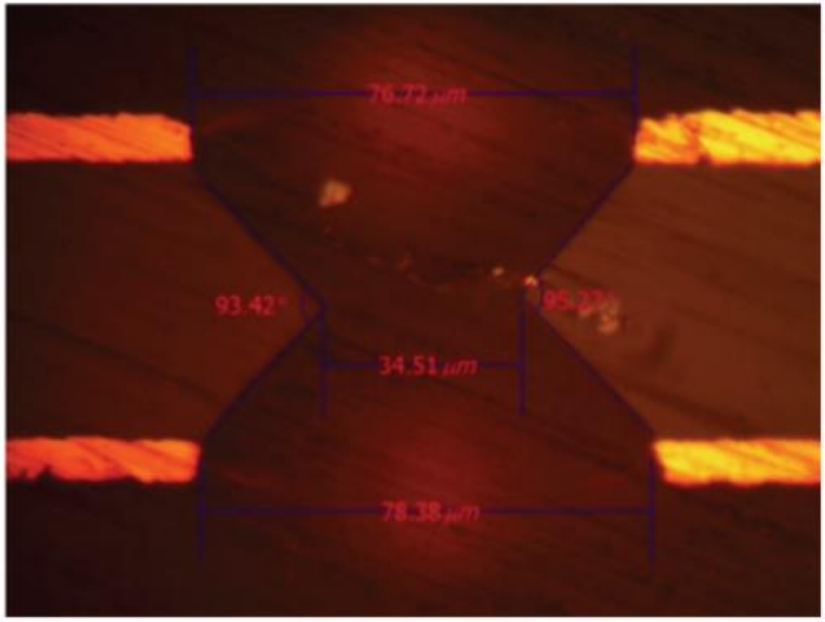
GEM test

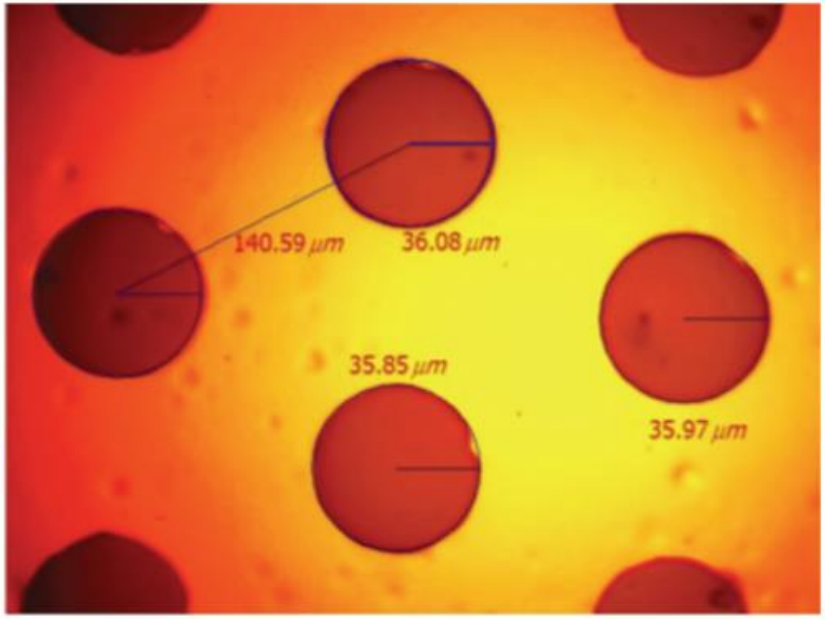
GEM



Test list

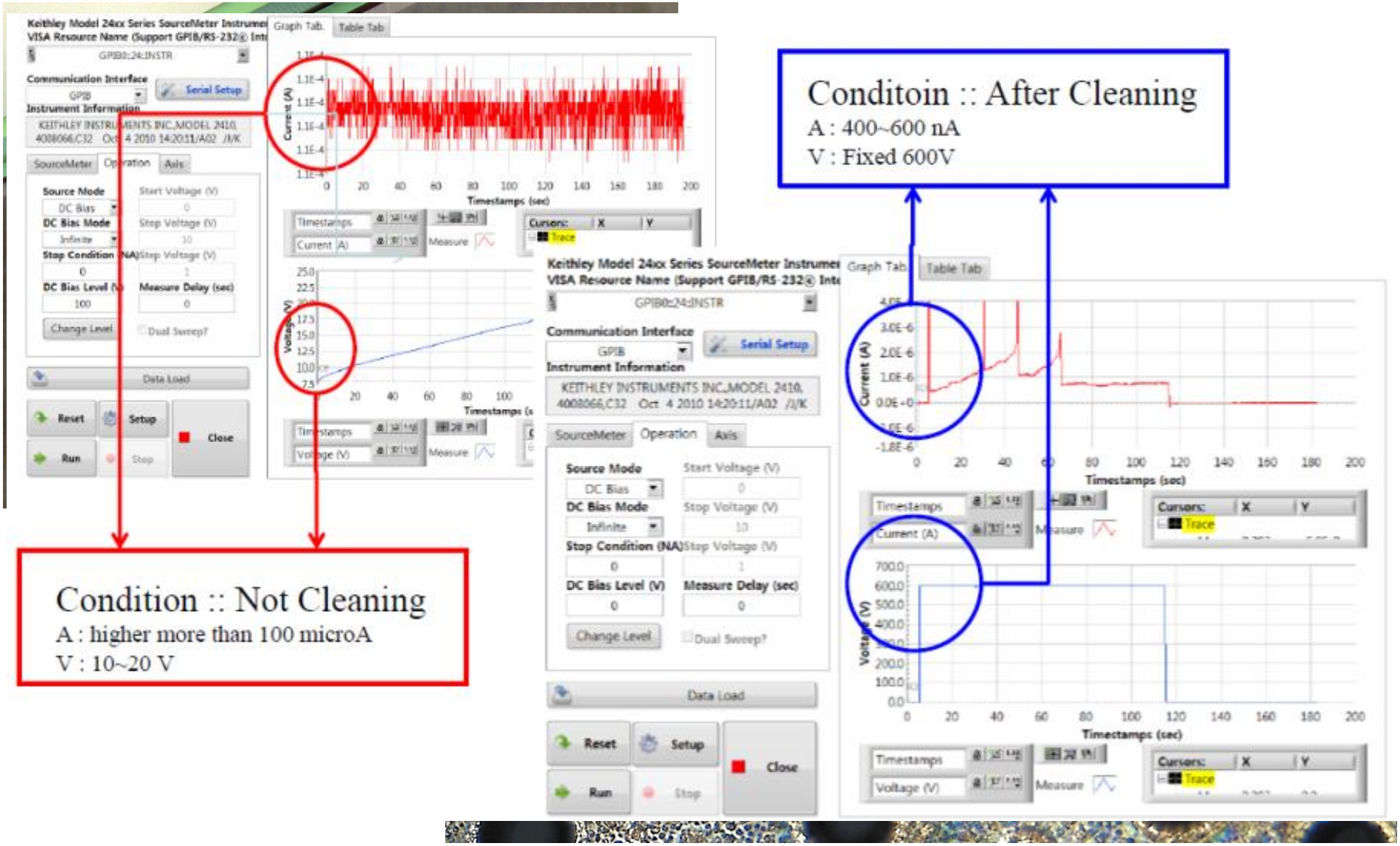
- Leakage Current
- Cosmic-ray muon
- Fe55 source



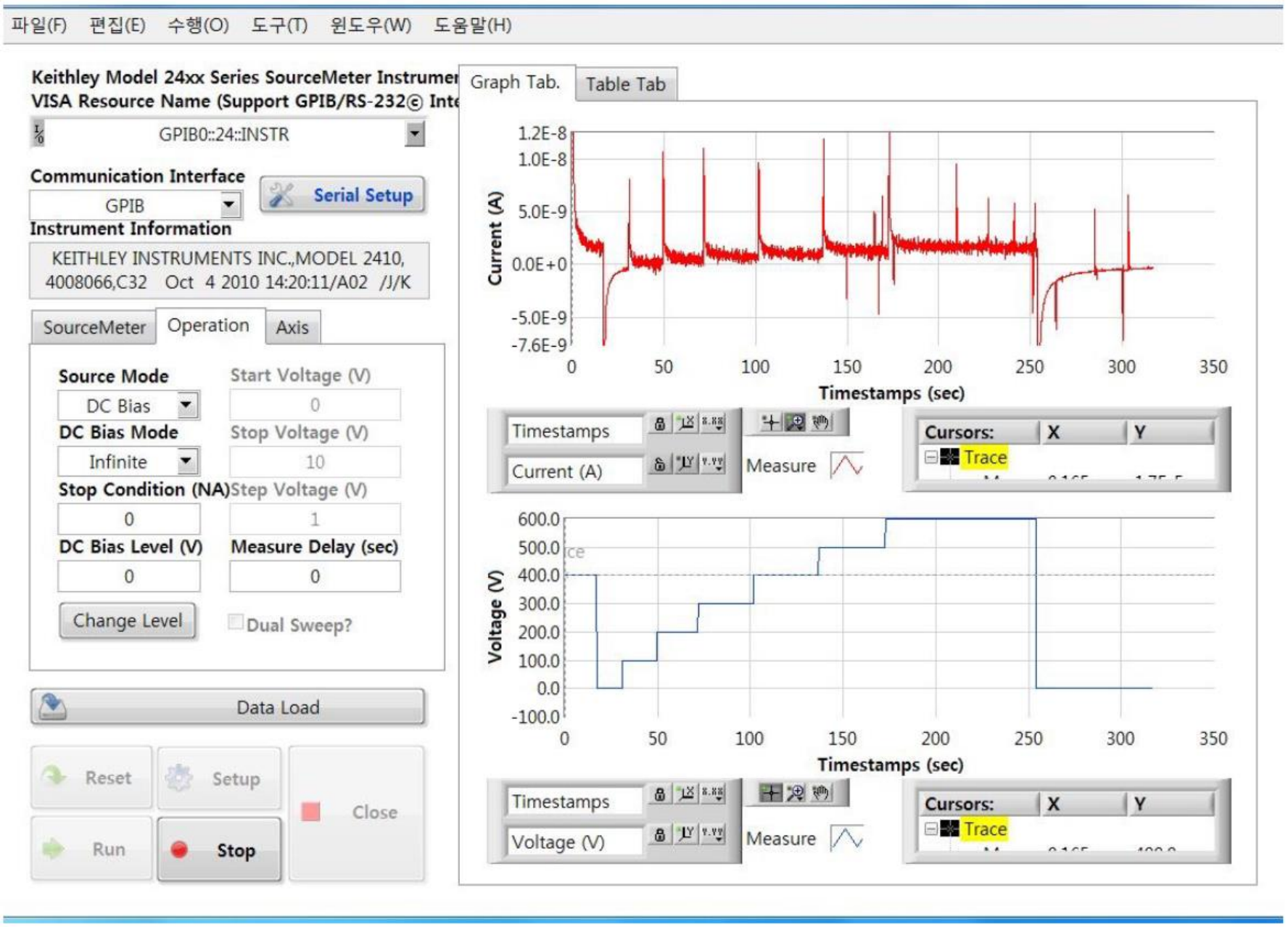


GEM test

GEM problem
Leakage current test before/after cleaning

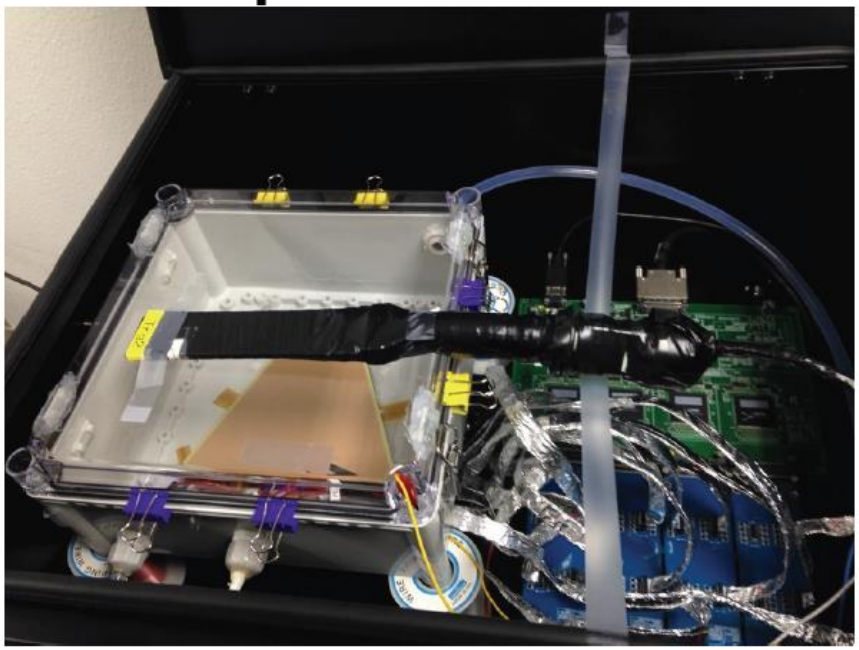


GEM test

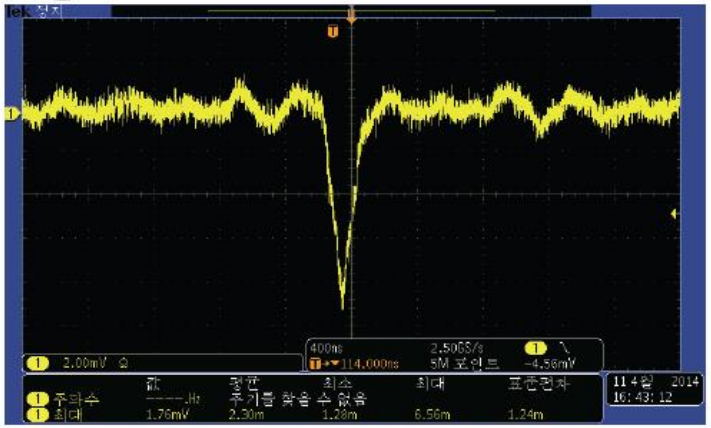

파일(F) 편집(E) 수행(O) 도구(T) 윈도우(W) 도움말(H)
Keithley Model 24xx Series SourceMeter Instrumer
VISA Resource Name (Support GPIB/RS-232ⓒ Inte
GPIB0::24::INSTR
Communication Interface
GPIB
Serial Setup
Instrument Information
KEITHLEY INSTRUMENTS INC.,MODEL 2410,
4008066,C32 Oct 4 2010 14:20:11/A02 /J/K
SourceMeter
Operation
Axis
Source Mode
DC Bias
Start Voltage (V)
0
DC Bias Mode
Infinite
Stop Voltage (V)
10
Stop Condition (NA)
0
Step Voltage (V)
1
DC Bias Level (V)
0
Measure Delay (sec)
0
Change Level
Dual Sweep?
Data Load
Reset
Setup
Close
Run
Stop
Graph Tab.
Table Tab
1.2E-8
1.0E-8
5.0E-9
0.0E+0
-5.0E-9
-7.6E-9
Current (A)
0
50
100
150
200
250
300
350
Timestamps (sec)
Timestamps
Current (A)
Measure
Cursors:
X
Y
Trace
600.0
500.0
400.0
300.0
200.0
100.0
0.0
-100.0
Voltage (V)
Timestamps (sec)
Timestamps
Voltage (V)
Measure
Cursors:
X
Y
Trace

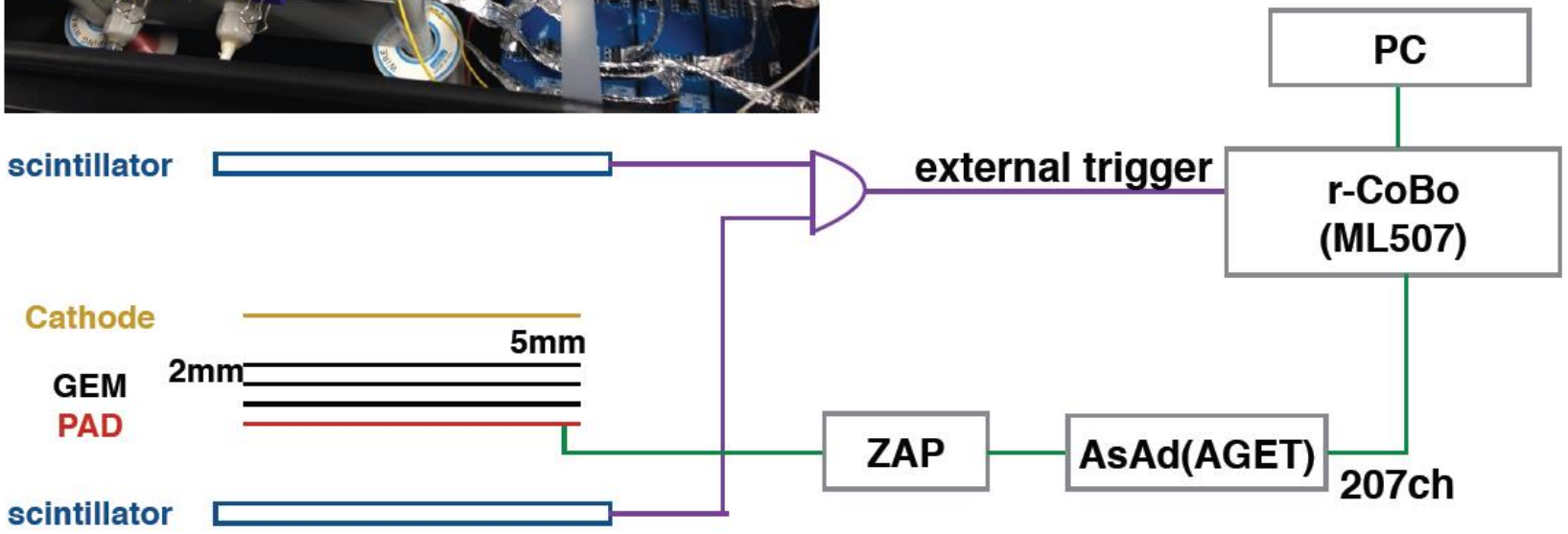
GEM test - Test setup

Test setup

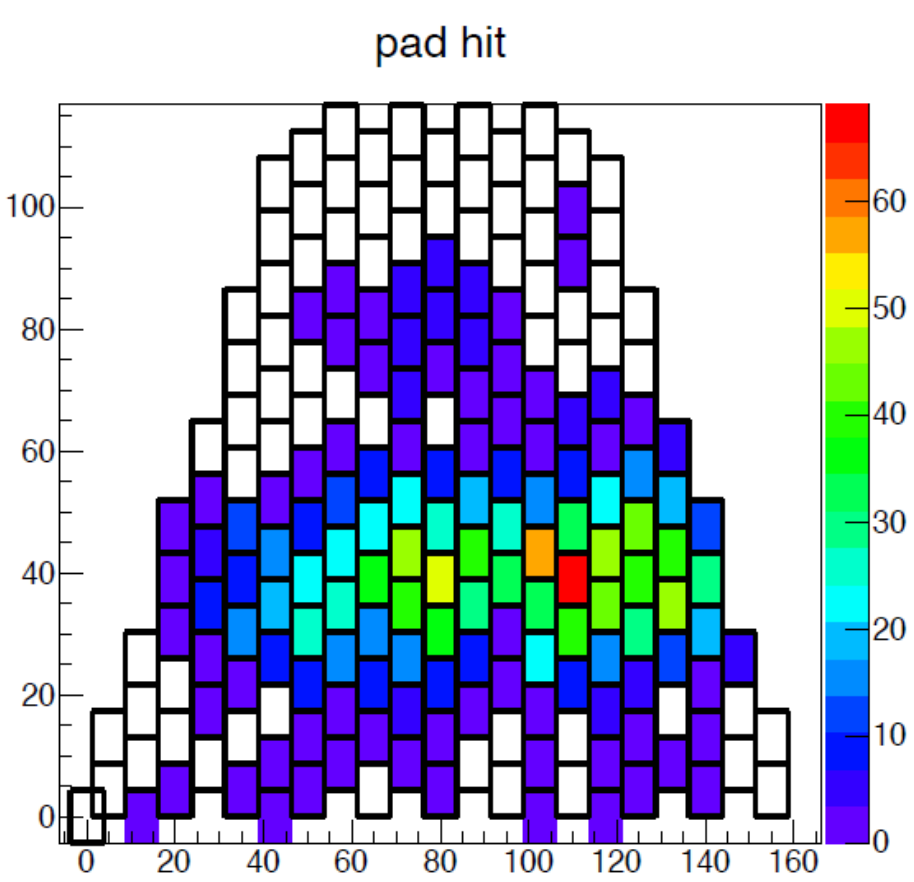


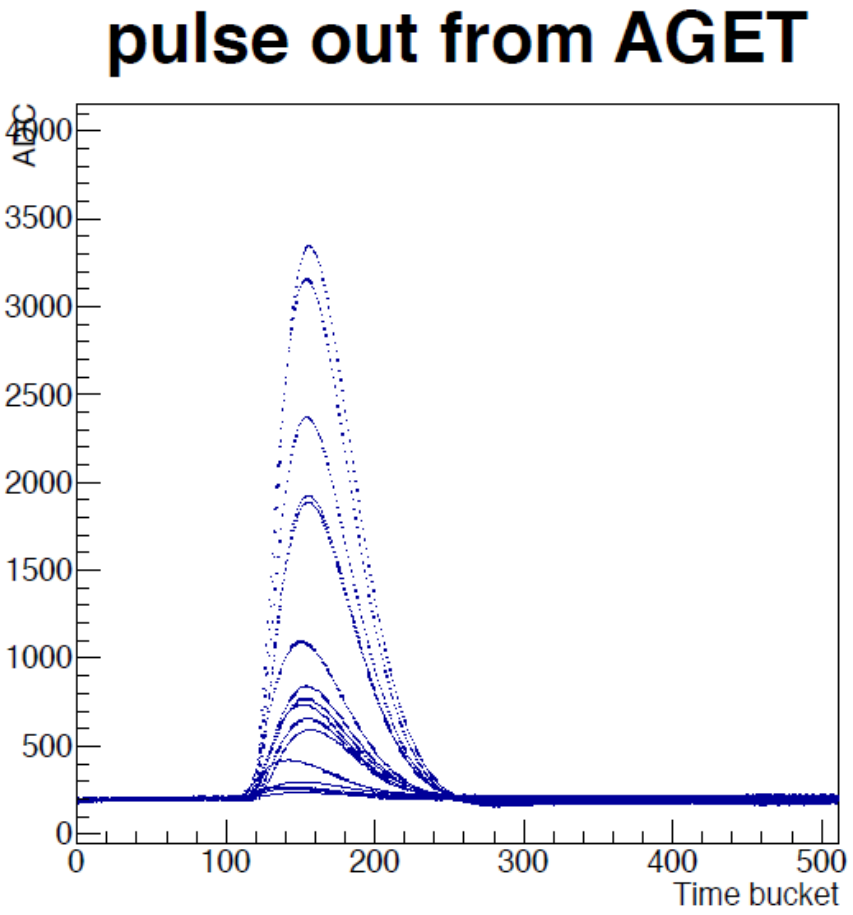
Signal from PAD





GEM test

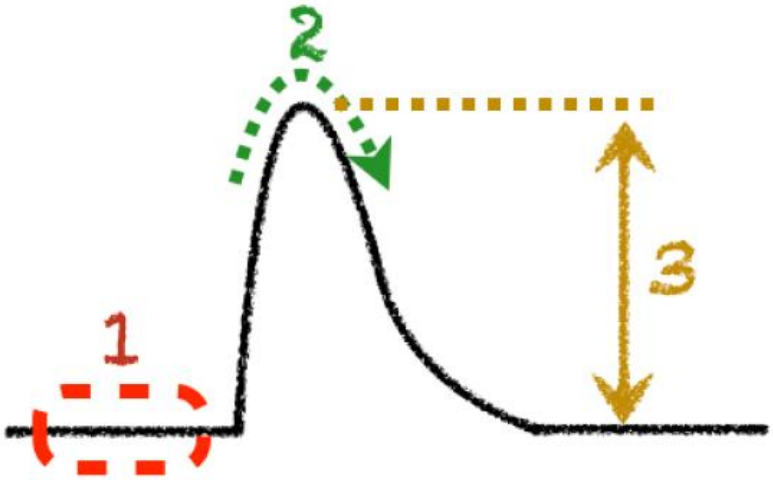

pad hit
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
60
50
40
30
20
10
0

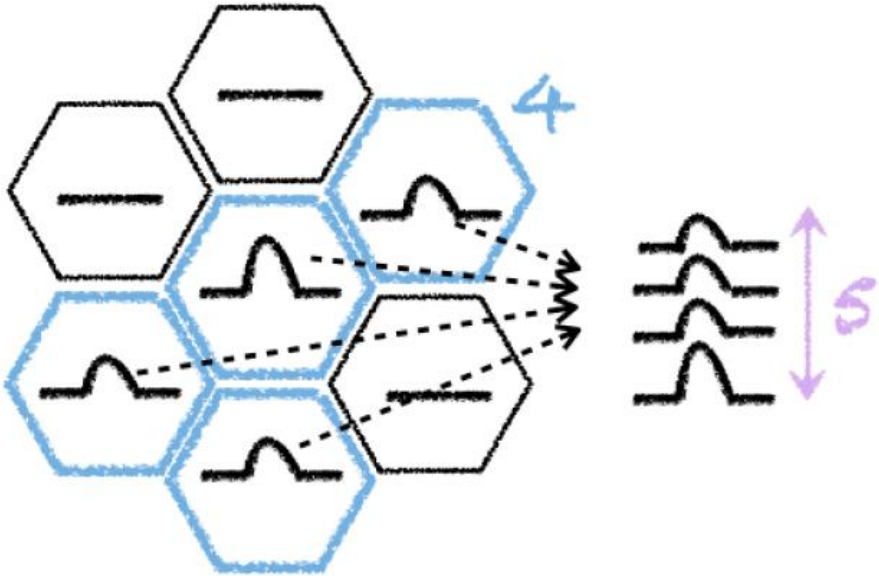

pulse out from AGET
ADC
4000
3500
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
Time bucket

GEM test

Analysis flow

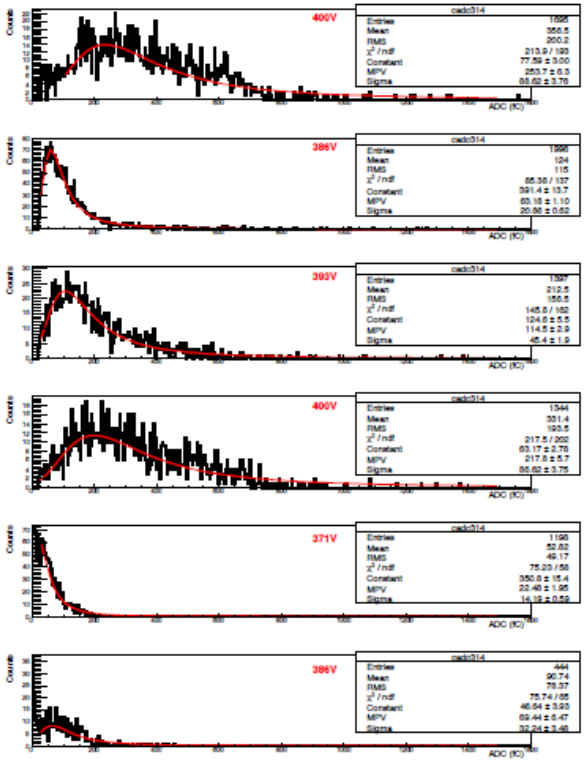
1. pedestal
2. pulse searching
3. pulse height
4. clustering
5. ADC



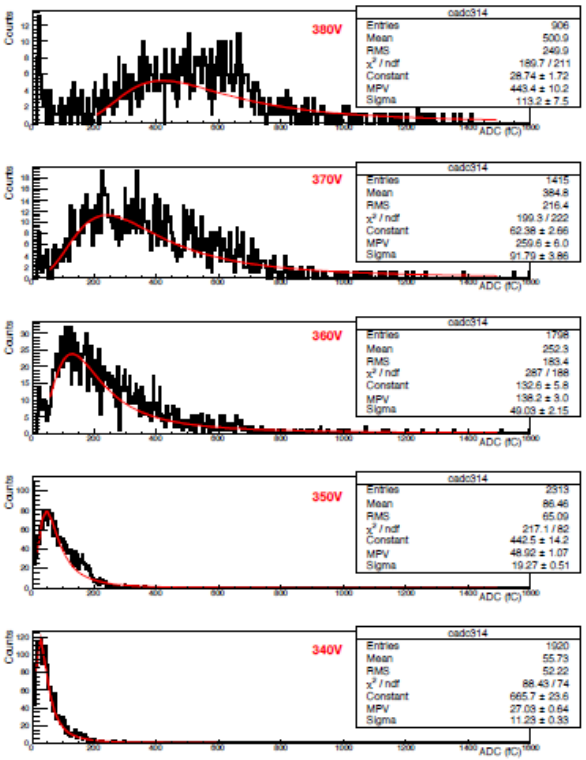


GEM test

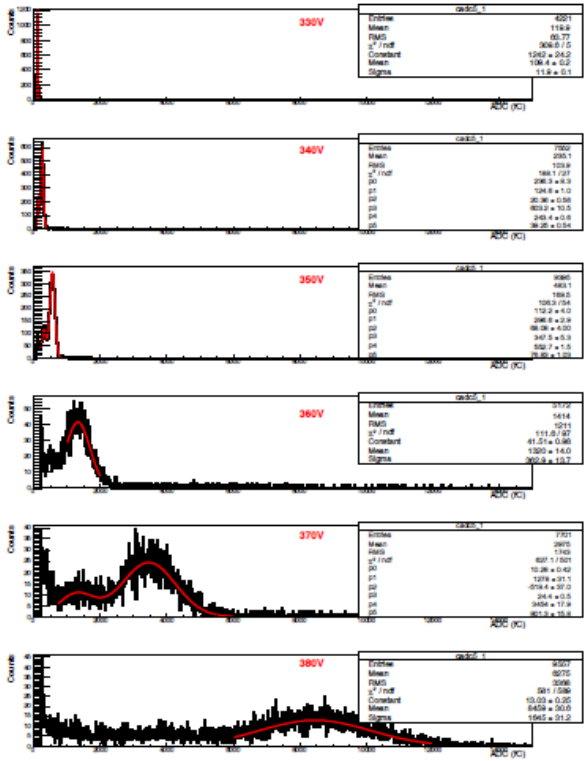
GEM1(UplusLab) - muon



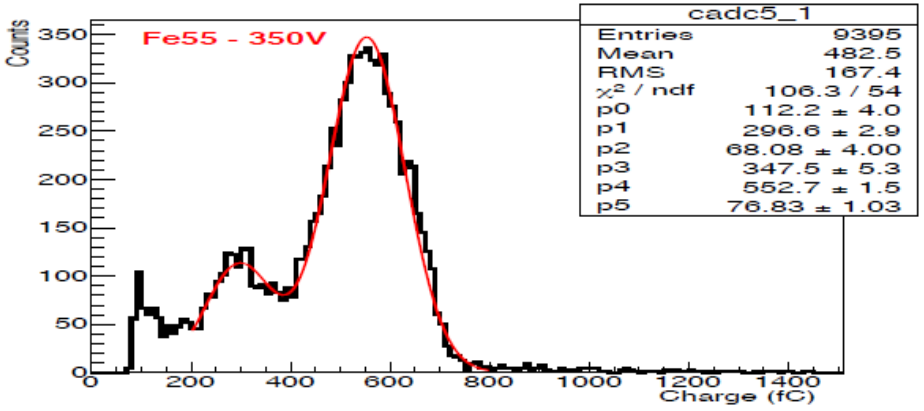
GEM2(Mecharonics) - muon



GEM2(Mecharonics) - Fe55



Fe55 ADC distribution



GEM test

$$\text{Gain} = \frac{\#\text{ of collected electron on PAD}}{\#\text{ of produced electron}}$$

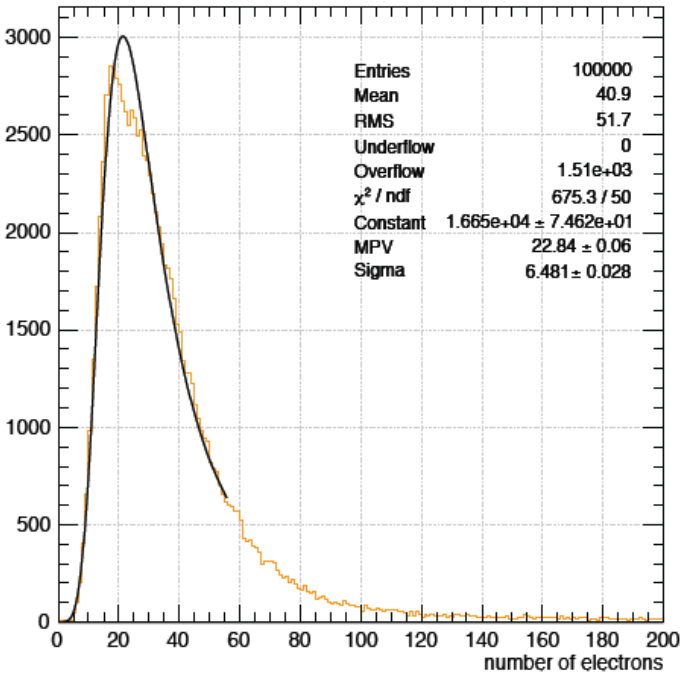
# of collected electron on PAD : from MIP peak (charge)

# of produced electron : from garfield++ (# of electron x (1.602x10E-19C))

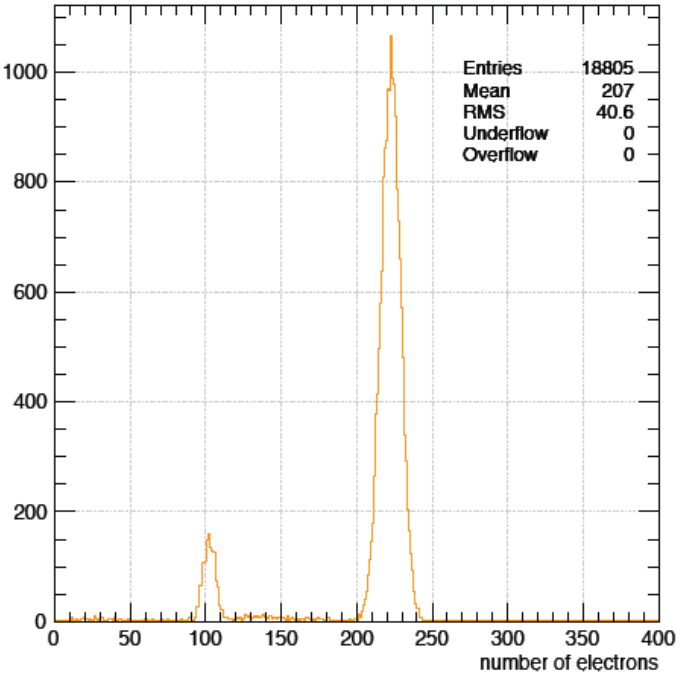
http://garfieldpp.web.cern.ch/garfieldpp/examples/heed/

(Calculation of charged particle ionization using Heed)

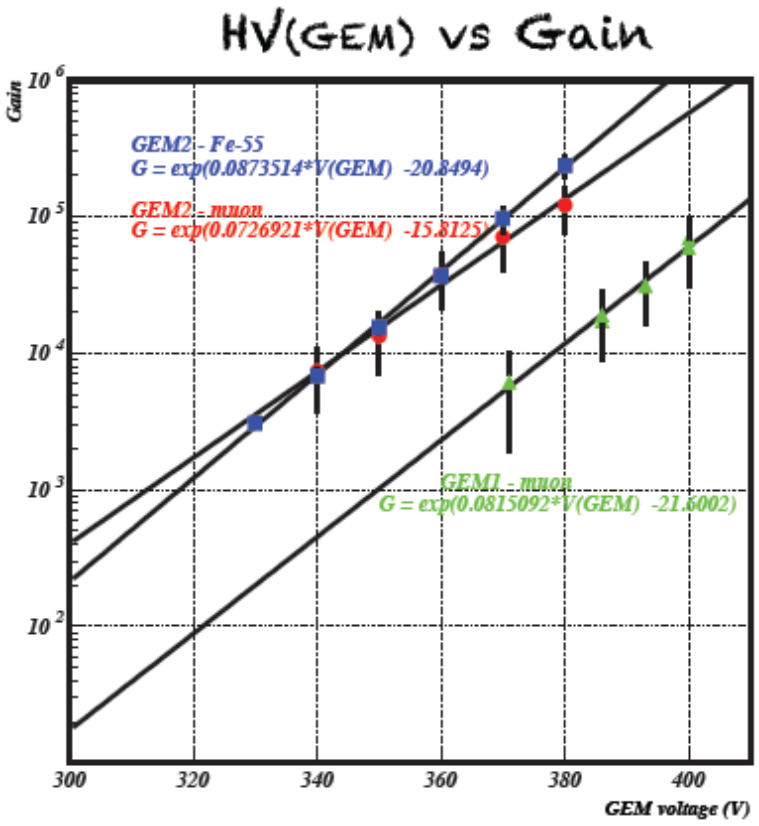
Muon

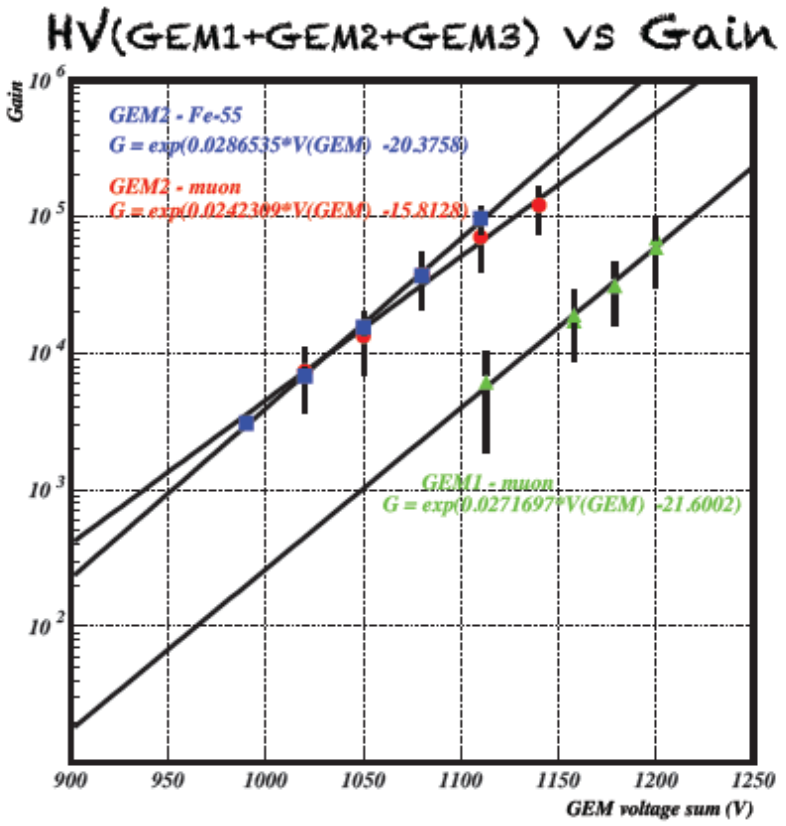


Fe55



GEM test


HV(GEM) vs Gain
Gain
GEM2 - Fe-55
G = exp(0.0873514*V(GEM) -20.8494)
GEM2 - muon
G = exp(0.0726921*V(GEM) -15.8125)
GEM1 - muon
G = exp(0.0815092*V(GEM) -21.6002)
GEM voltage (V)


HV(GEM1+GEM2+GEM3) vs Gain
Gain
GEM2 - Fe-55
G = exp(0.0286535*V(GEM) -20.3758)
GEM2 - muon
G = exp(0.0242309*V(GEM) -15.8128)
GEM1 - muon
G = exp(0.0271697*V(GEM) -21.6002)
GEM voltage sum (V)

Summary

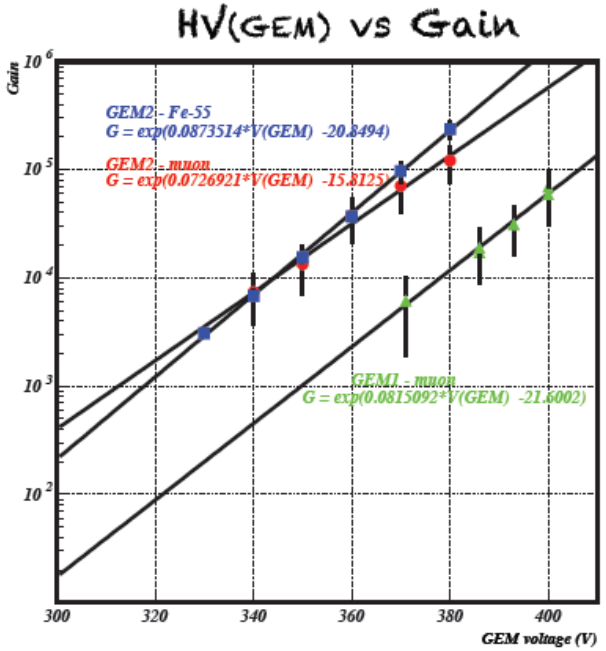
- **Time Projection Chamber (TPC)**
  - main detector for tracking of particles
  - complete information of charged particle trajectory
  - Target : 30cm away from the center
  - Detection range : -0.7(127°) ~ 1.6(24°)
  - Drift length : 60cm (x2)
  - Cathode Membrane
  - Amplified by Gas Electron Multiplier (GEM)
  - Both side readout PAD

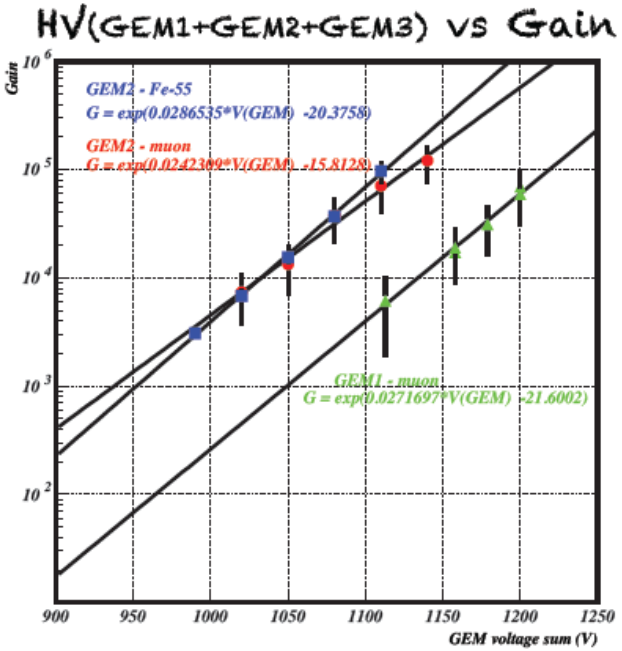
- **Concept of prototype TPC for LAMPS**
  - Optimized design & fabrication method : 1/2 size of real TPC (1/8 volume), Honeycomb body for gas chamber
  - PAD : Hexagon shape with 5mm & 2.5mm
  - GEM : Test with large size & specific shape
  - Field cage : Uniform electric field by Cu strip
  - DAQ : r-CoBo system
  - Analysis : Development of reconstruction algorism

- **Current status**
  - GET system study
  - Single section GEM & PAD test with source & cosmic-ray
  - long time test

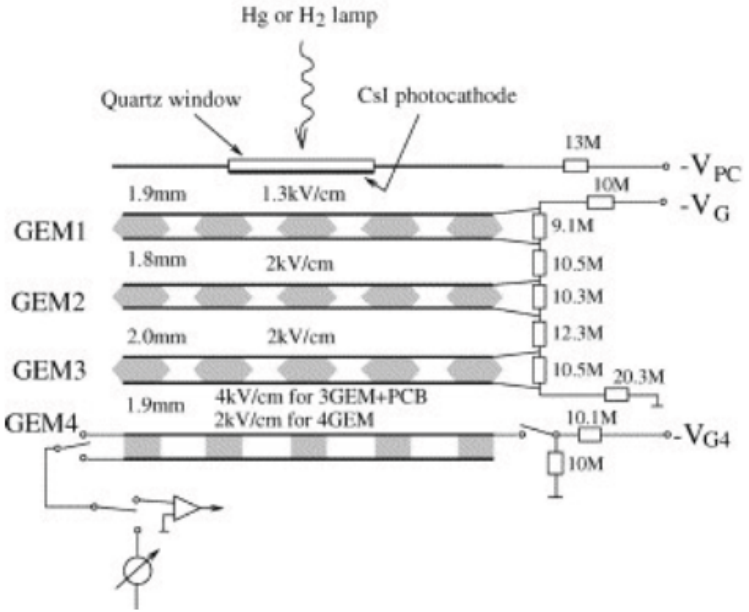
Backup

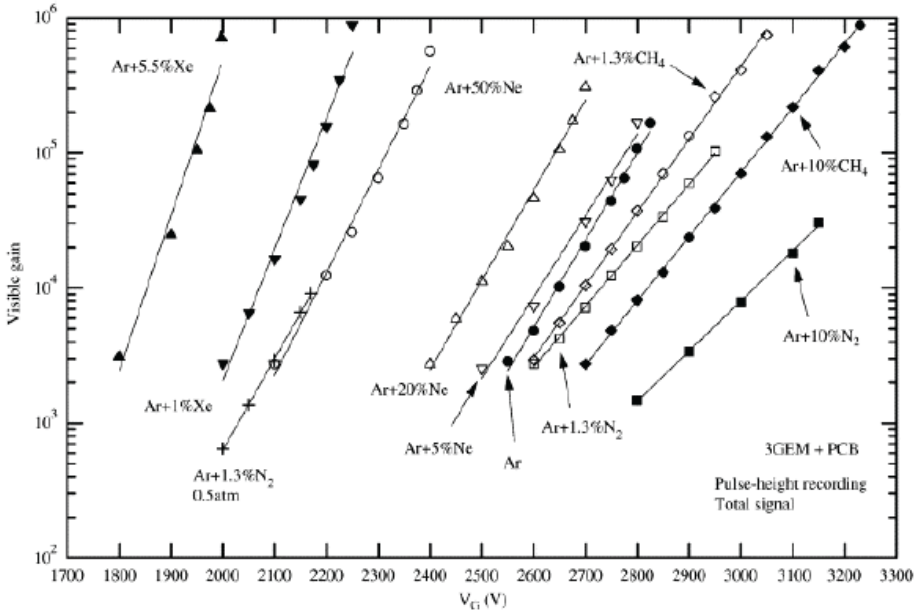
GEM test - Gain



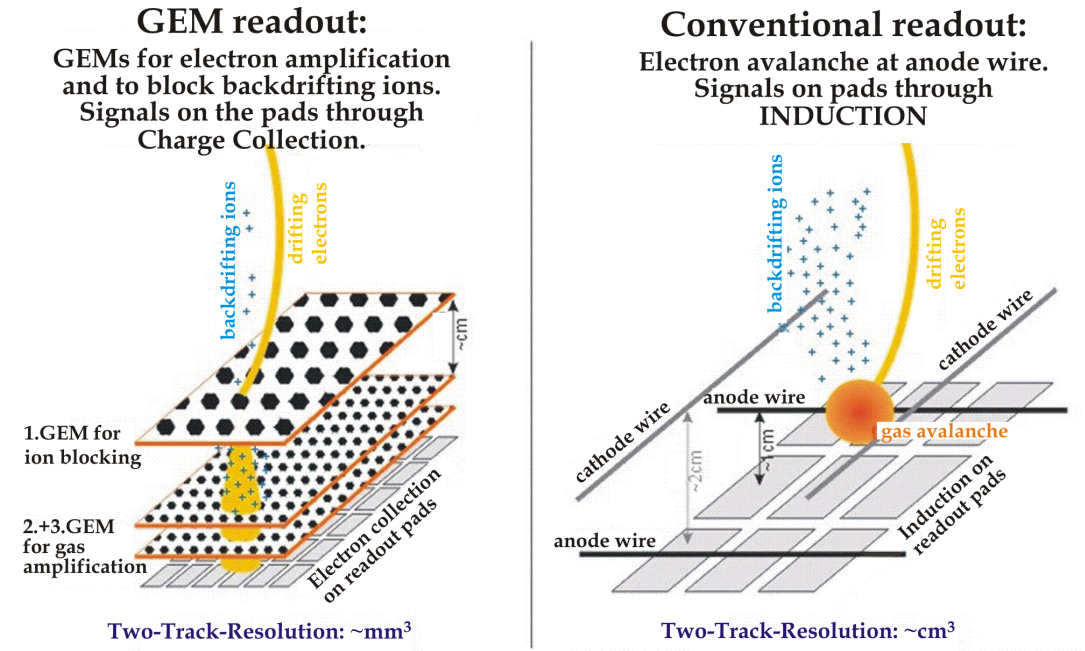


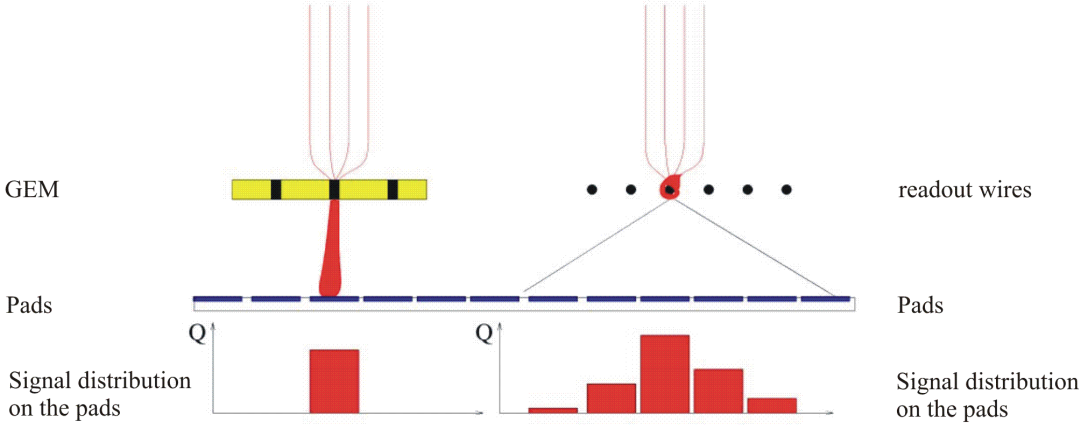
- A. Buzulutskov et al, NIMA443(2000)164

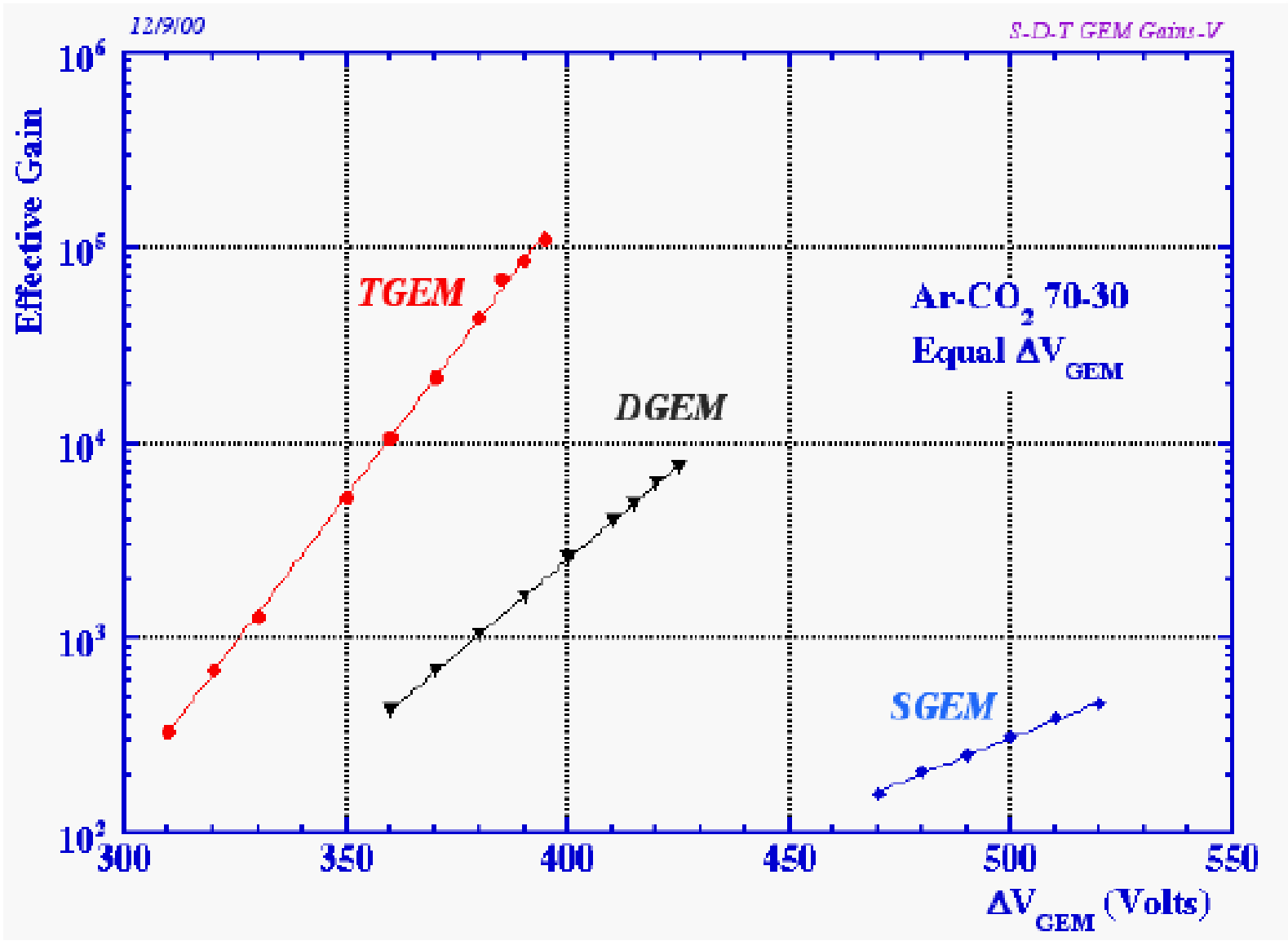




GEM? Wire?


GEM readout:
GEMs for electron amplification and to block backdrifting ions. Signals on the pads through Charge Collection.
backdrifting ions
drifting electrons
~cm
1.GEM for ion blocking
2.+3.GEM for gas amplification
Electron collection on readout pads
Two-Track-Resolution: ~mm³
Conventional readout:
Electron avalanche at anode wire. Signals on pads through INDUCTION
backdrifting ions
drifting electrons
cathode wire
anode wire
gas avalanche
~1cm
~2cm
cathode wire
anode wire
Induction on readout pads
Two-Track-Resolution: ~cm³


GEM
readout wires
Pads
Pads
Q
Q
Signal distribution on the pads
Signal distribution on the pads


12/9/00
S-D-T GEM Gains-V
Effective Gain
10^6
10^5
10^4
10^3
10^2
TGEM
DGEM
SGEM
Ar-CO_2 70-30
Equal ΔV_{GEM}
300
350
400
450
500
550
ΔV_{GEM} (Volts)

GET system

Parameter	Value
Channel number	64
Detector signal polarity	Negative or Positive
External preamplifier	Access to the filter or SCA input
Counting rate	< 1 kHz
Power consumption	< 10 mW/channel at 3.3 V
Charge measurement	
Input dynamic range	120 fC, 240 fC, 1 pC, 10 pC
Gain	Adjustable per channel
Output dynamic range	2 V p-p (differential)
I. N. L.	< 2%
Resolution	< 850 e^- (Gain: 120 fC, Peaking Time: 200 ns, C_{input} < 30 pF)
Sampling	
Peaking time	50 ns to 1 μs (16 values)
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Multiplicity signal	Analog ≪ OR ≫ of 64 discriminator outputs
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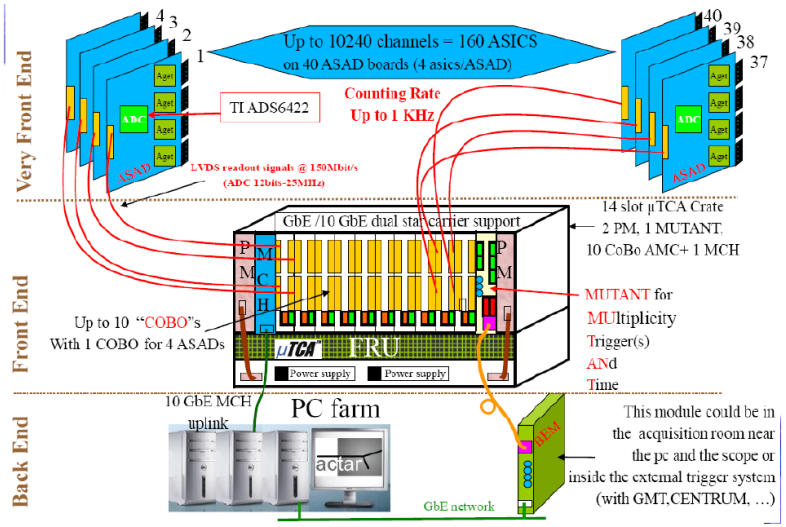
I. N. L.	< 5%
Threshold value	4-bit DAC/channel + (3-bit + polarity bit) common DAC
Readout	
Readout frequency	25 MHz
Readout mode	Hit, specific or 64
SCA readout mode	1 to 512 cells
Test	
Calibration	1 channel among 61, 1 external test capacitor
Test	1 channel among 61, 1 internal test capacitor (1 among 4)
Functional	1 to 64(68) channels, 1 internal test capacitor/channel

GET for 1µTCA

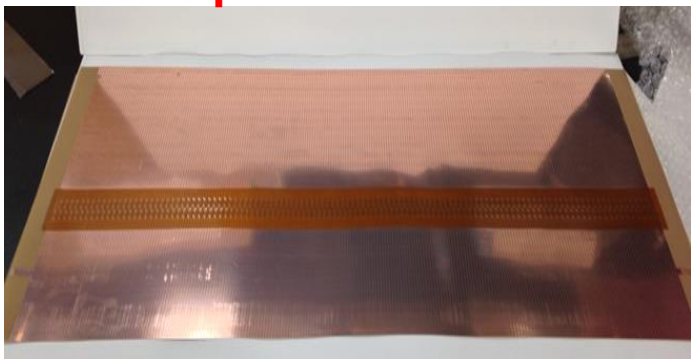


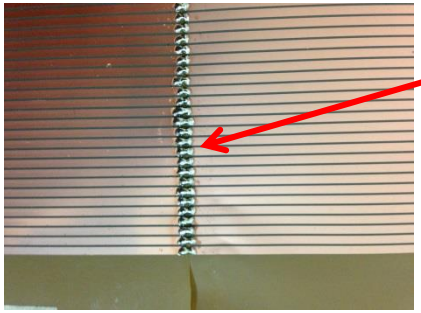
- 1 ASAD : 4GET → 256ch
- 1 COBO : 4ASAD →1024ch
- 1 uTCA : 10COBO → 10240ch

- 5mm size PAD
  : ~11000ch x 2 → 2~3 uTCA
- 2.5mm size PAD
  : ~44000ch x 2 → 8~9 uTCA

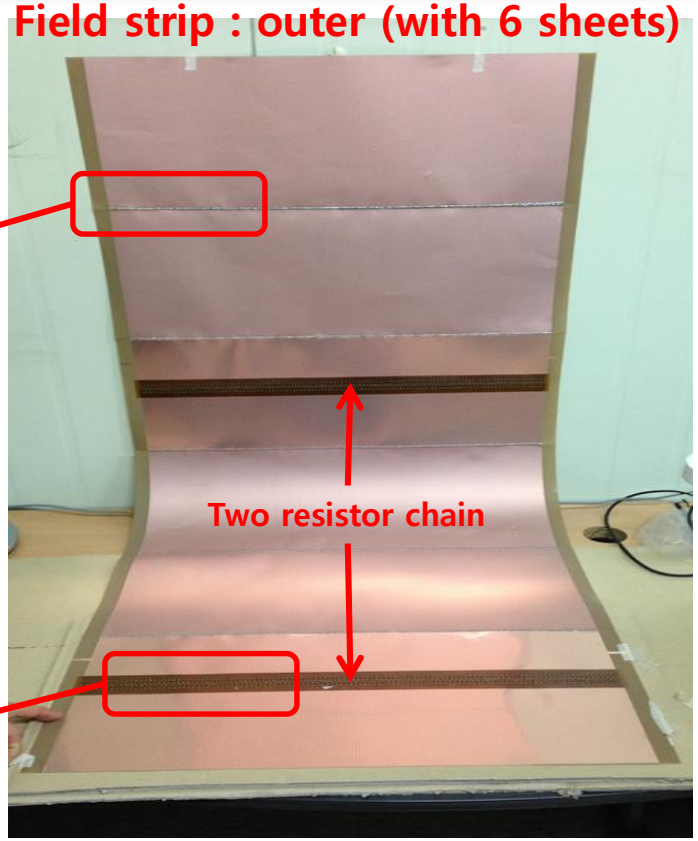
Field Cage

Field strip sheet with resistor pattern

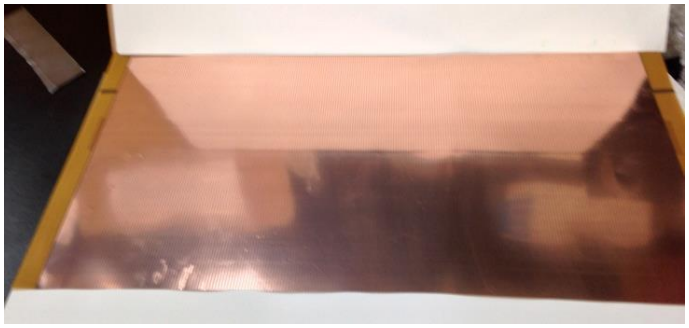


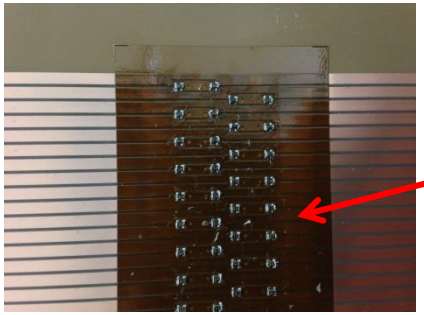


Field strip : outer (with 6 sheets)

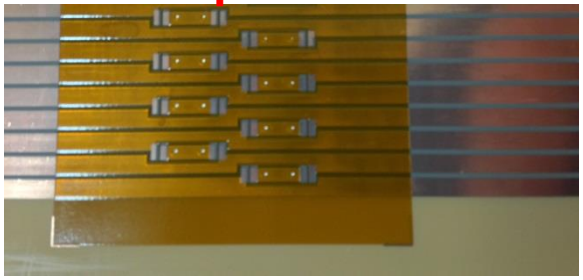


Field strip sheet without resistor pattern





resistor pattern

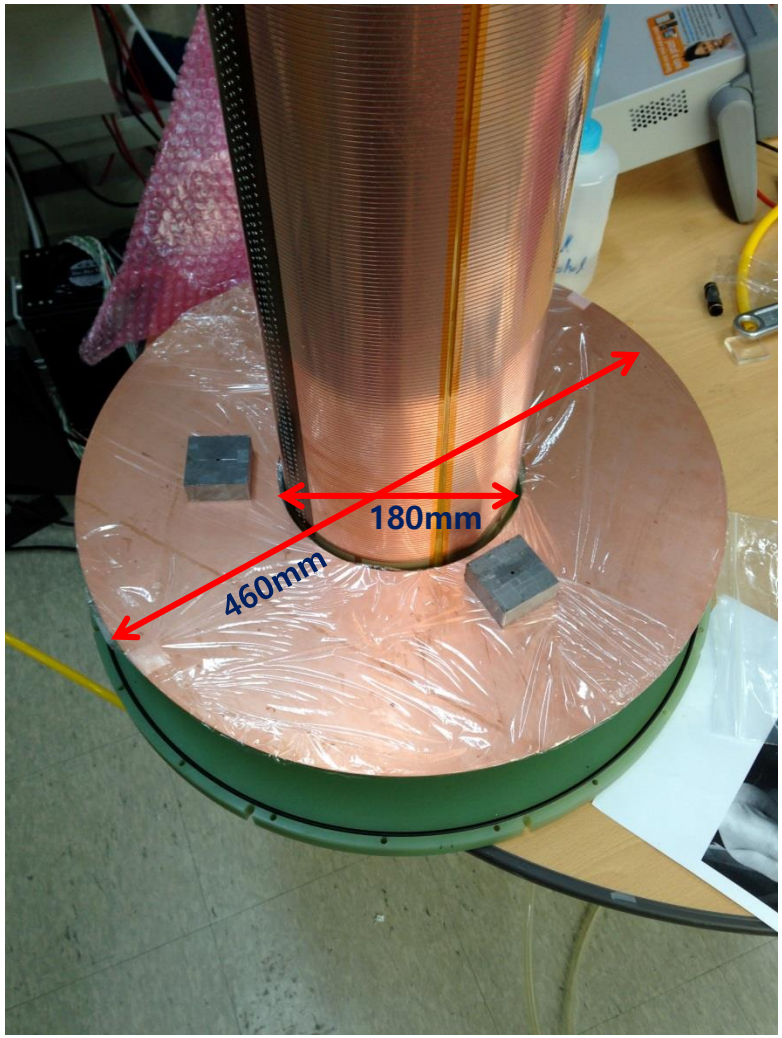


electrode

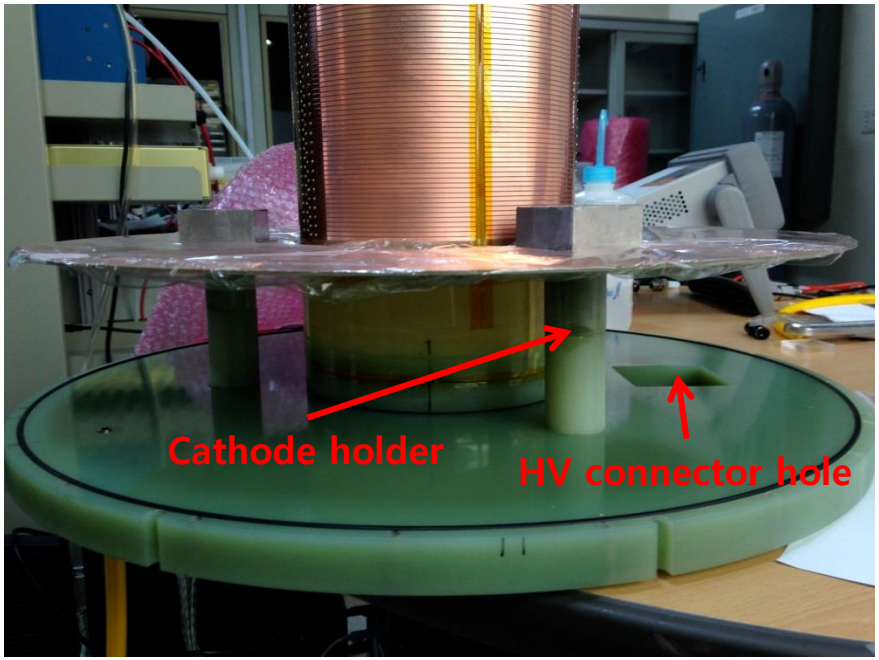
Field strip : inner (with 2 sheets)

Cathode

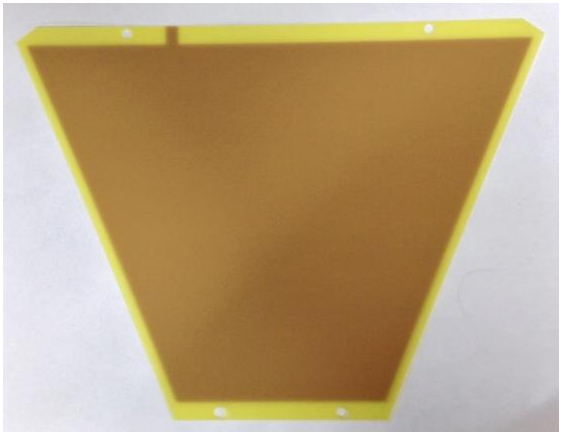
Cathode



Cathode holder

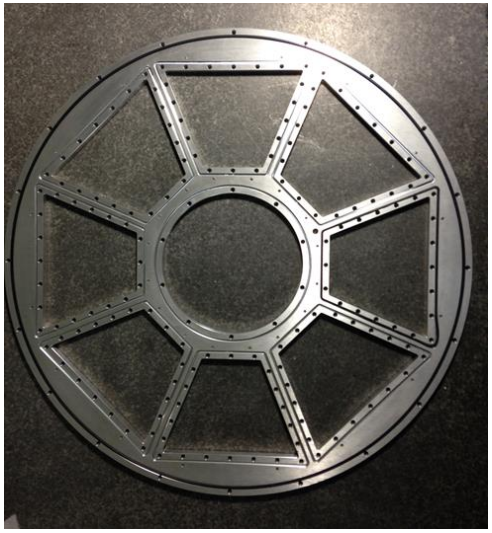


Dummy cathode

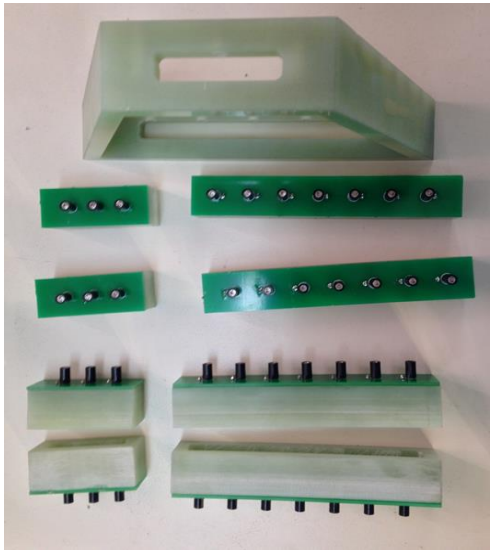


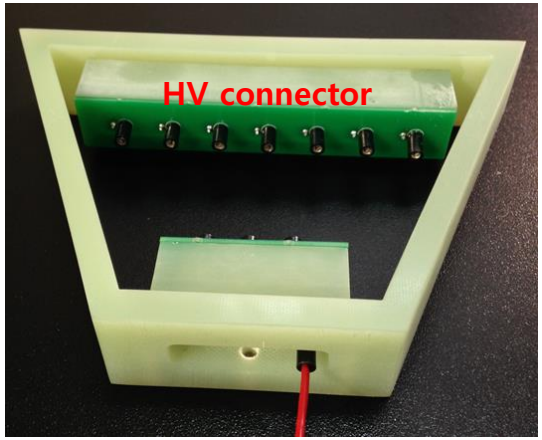
Assembling

TPC bottom frame : Al

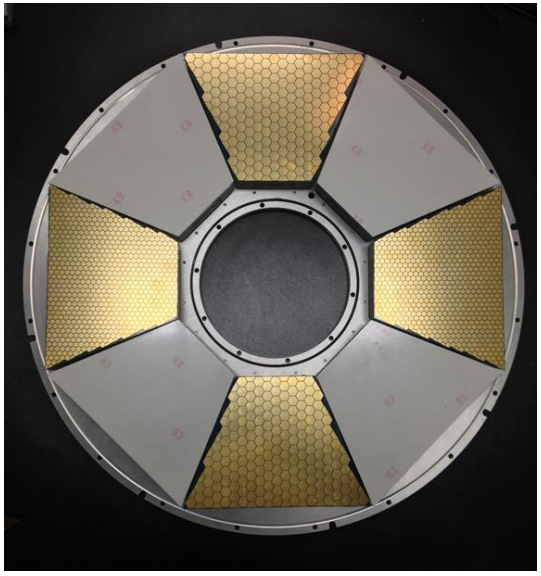


PAD frame (G10) & HV connector

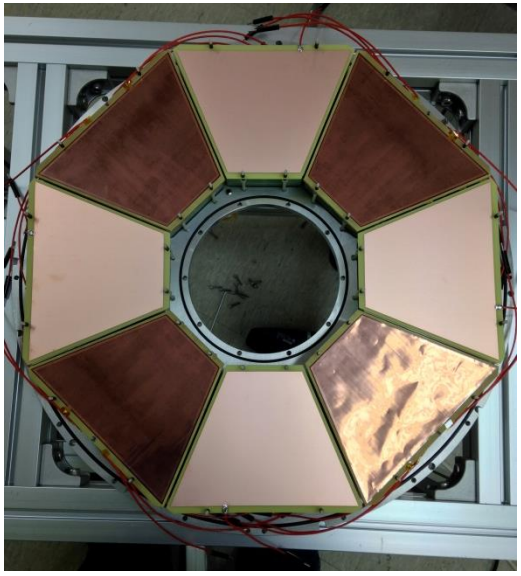




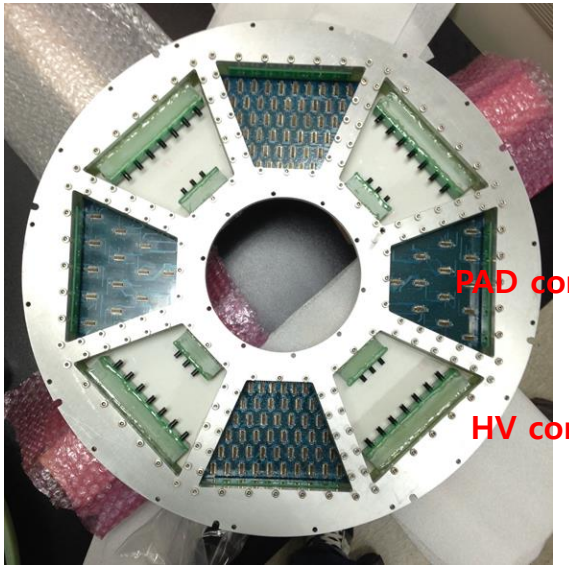
TPC bottom with PAD



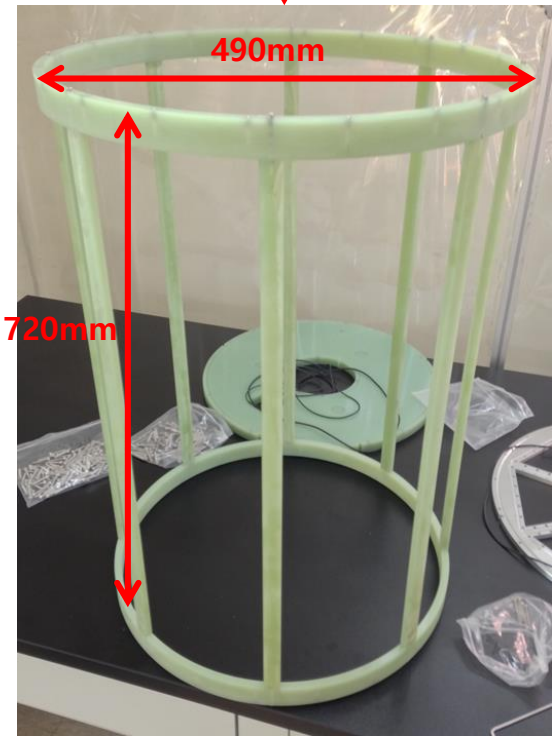
TPC bottom
with PAD + GEM + dummy cathode



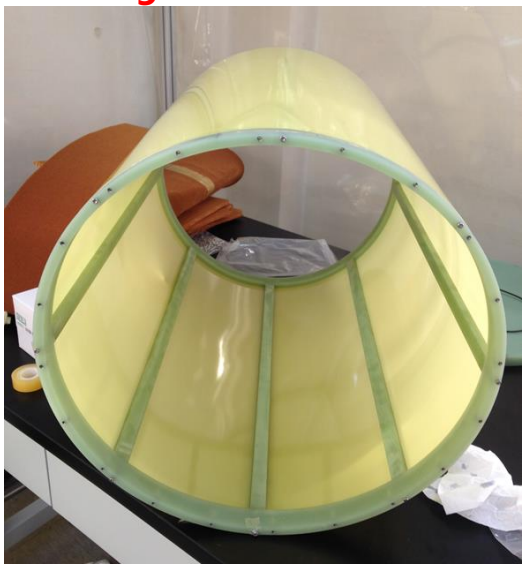
TPC bottom back



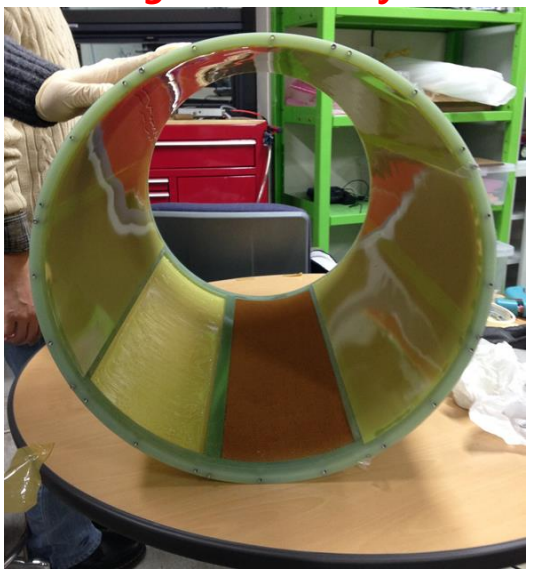
G10 frame for Field Cage



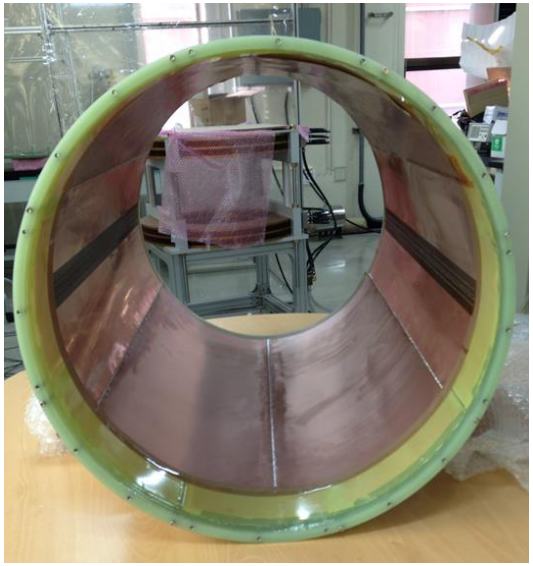
Field Cage with G10 sheet



Field Cage with honeycomb



Field Cage with field strip



Inner Field Cage