Status of the 2D MWPC detector for China Spallation Neutron Source (CSNS)

Huirong QI

Institute of High Energy Physics
Chinese Academy of Sciences

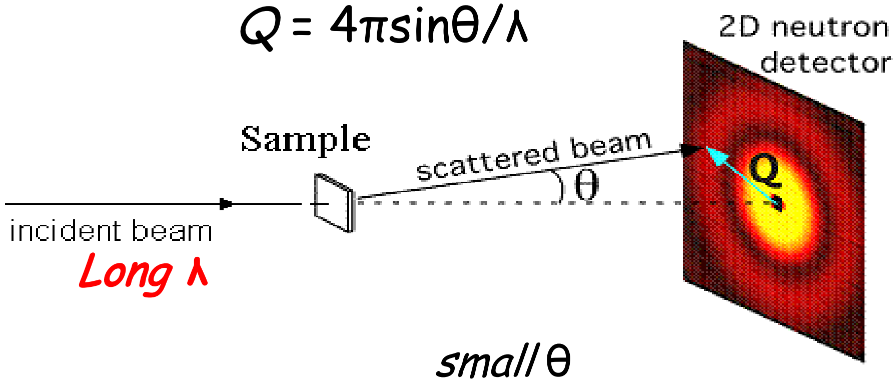
Overview

- Requiremtns of neutron detector
- MWPC prototype R&D
- 8.0atm 2D MWPC detector
- Summary

Requirements

- Developed the two-dimensional gas detectors for China Spallation Neutron Source
- An alternate detector as the 3He tube for MR
- Both better the position resolution and the high efficiency
- Position resolution: <2mm
- 2D imaging function: 200mm×200mm(Approximately)
- High gas pressure : (5.5atm)^3He+(2.5atm)C_3H_8
- Work stable: ~6 Years

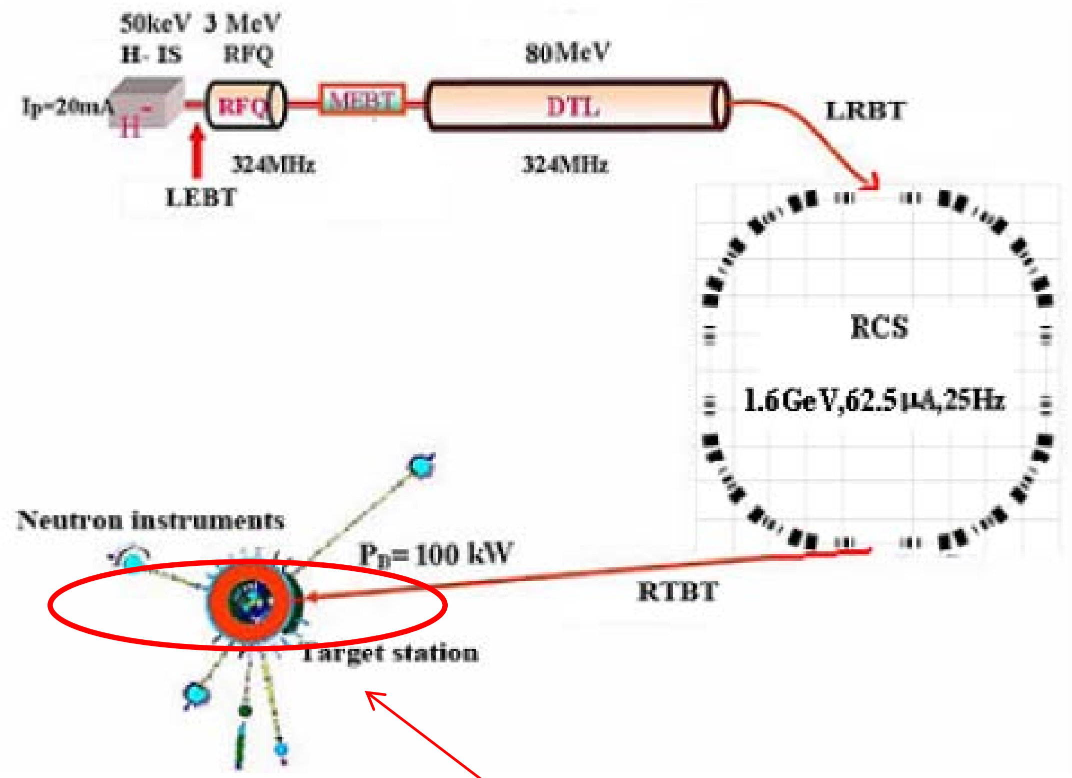
$Q = 4\pi \sin\theta / \lambda$



small θ

Design of neutron detectors in CSNS

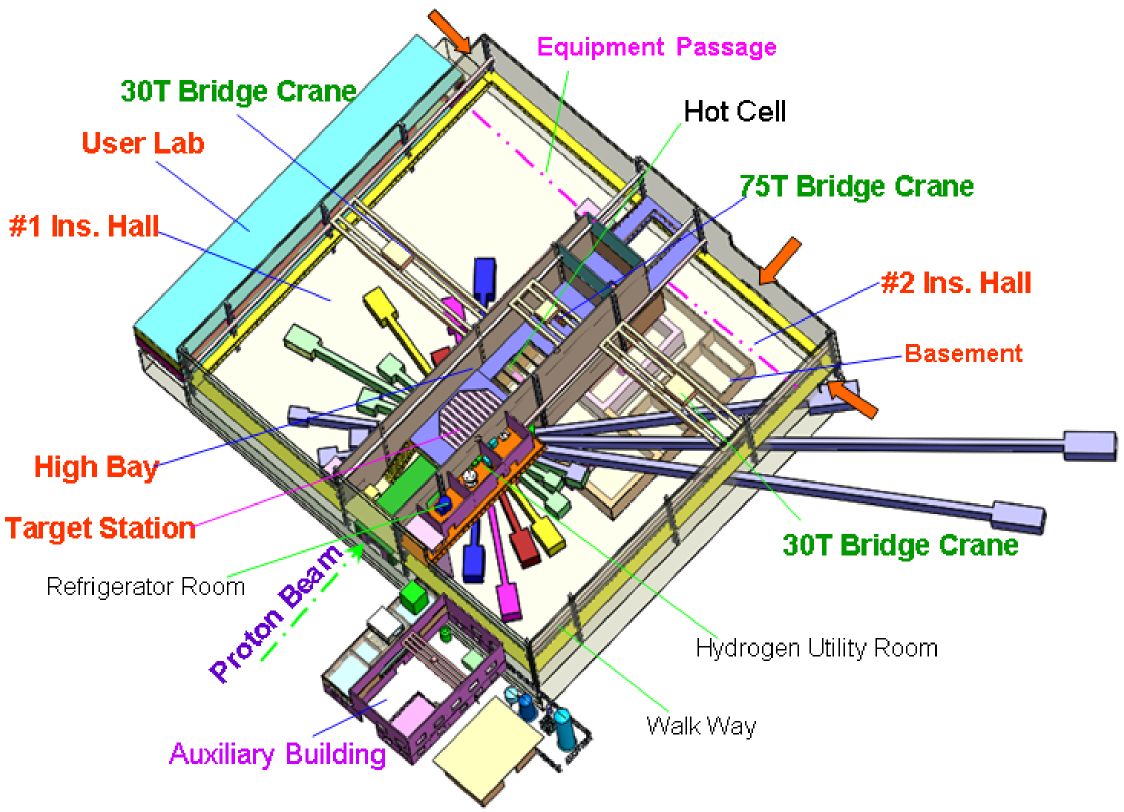
Project Phase	I	II
Beam Power on target [kW]	100	500
Proton energy [GeV]	1.6	1.6
Average beam current [μ A]	62.5	312.5
Pulse repetition rate [Hz]	25	25
Linac energy [MeV]	80	250
Linac type	DTL	+Spoke
Linac RF frequency [MHz]	324	324
Macropulse. ave current [mA]	15	40
Macropulse duty factor	1.0	1.7
RCS circumference [m]	228	228
RCS harmonic number	2	2
RCS Acceptance [πmm-mrad]	540	540
Target Material	Tungsten	Tungsten

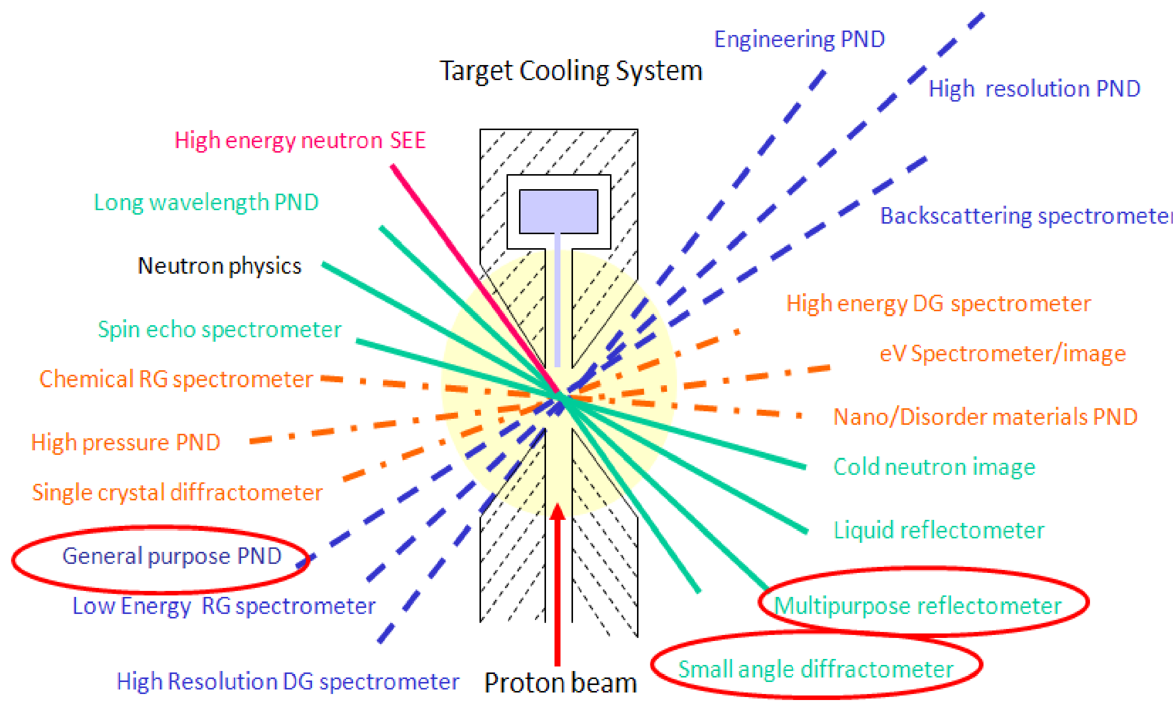


Detector in here

Main parameters of CSNS in Dongguan, China

Design of neutron detectors in CSNS





Instruments at Phase I:

3 neutron instruments, but with most potential users

- GPPD:
  General purpose to determine crystallographic and magnetic structures
- SANS: Rapid characteristic check for nano-scale materials
- MR (Multipurpose Reflectometer): Interface structure for films

Instruments at Phase I

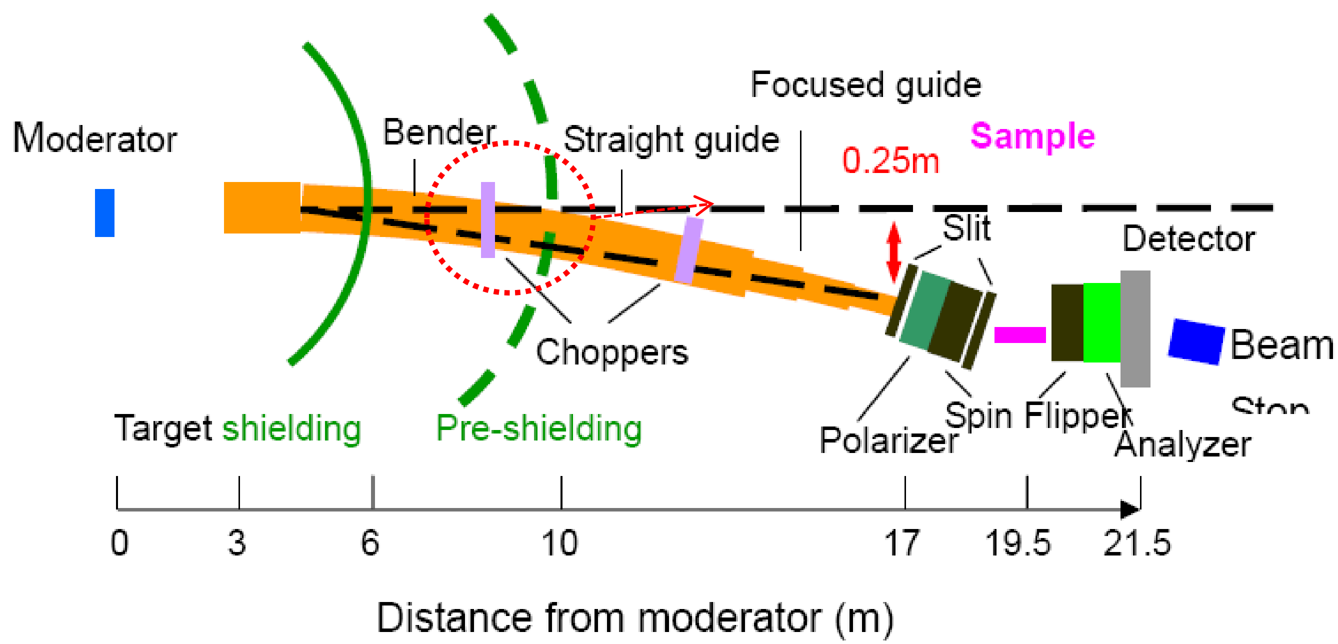
Instrument requirements

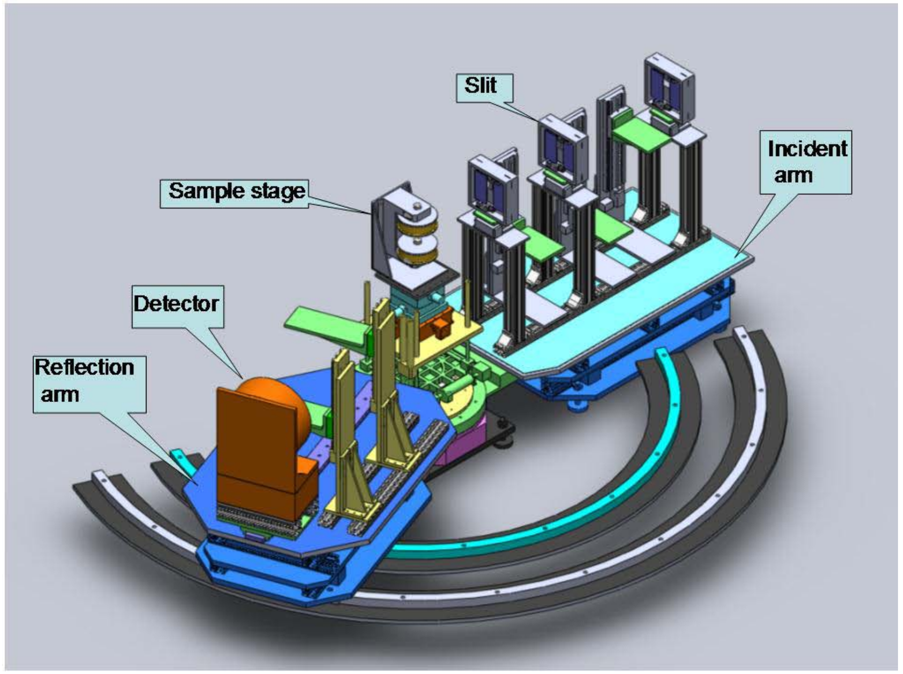
Instrument	Active area	Pixel area (cm^2)	Neutron capture efficiency(%)	Time resolution (μs)
GPPD	**$4m^2$** **$2m^2$**	**0.5×5.0** **2.5×2.5**	**50%@2Å** **80%@2Å**	**1@2Å, 10@10Å** **1@2Å, 10@10Å**
MR **Multi-purpose Reflectometer**	**20cm×20cm**	**0.2×0.2**	**50%@2Å**	**1@2Å, 10@10Å**
SANS Small Angle Neutron Spectrometer	**100cm×100cm**	**0.8×0.8**	**50%@2Å**	**1@2Å, 10@10Å**

Detector Selections

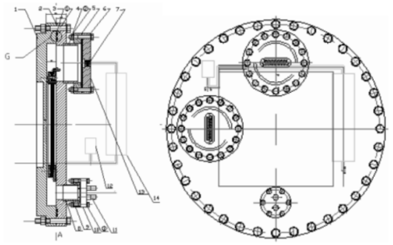
Instrument	Detector selection
GPPD	**^3He filled 100 cm×2.5 cm Linear position sensitive detectors** **0.5cm*5cm Shifting Scintillator Neutron Detector**
MR	**Multiwire proportional chamber**
SANS	**^3He filled 100 cm×0.8 cm Linear position sensitive detectors**

Design of 2D Detector





Moderator	**Coupled LH_2 (20 K)**
Bandwidth（Δλ）	**7.3 Å**
Guide	**Bender+Sraight+Taper** **40×60 → 20×30 mm²**
Choppers	**3**
Flux at sample	**3.8 × 10^7 n/s·cm²**
$L_{MS} + L_{SD}$	**19.5 + 2 m**
Sample table	**6-axis movements**
Polarizer/analyzer	**Supermirror type**
Detector	**2D position-sensitive detector** **resolution: 2 mm**

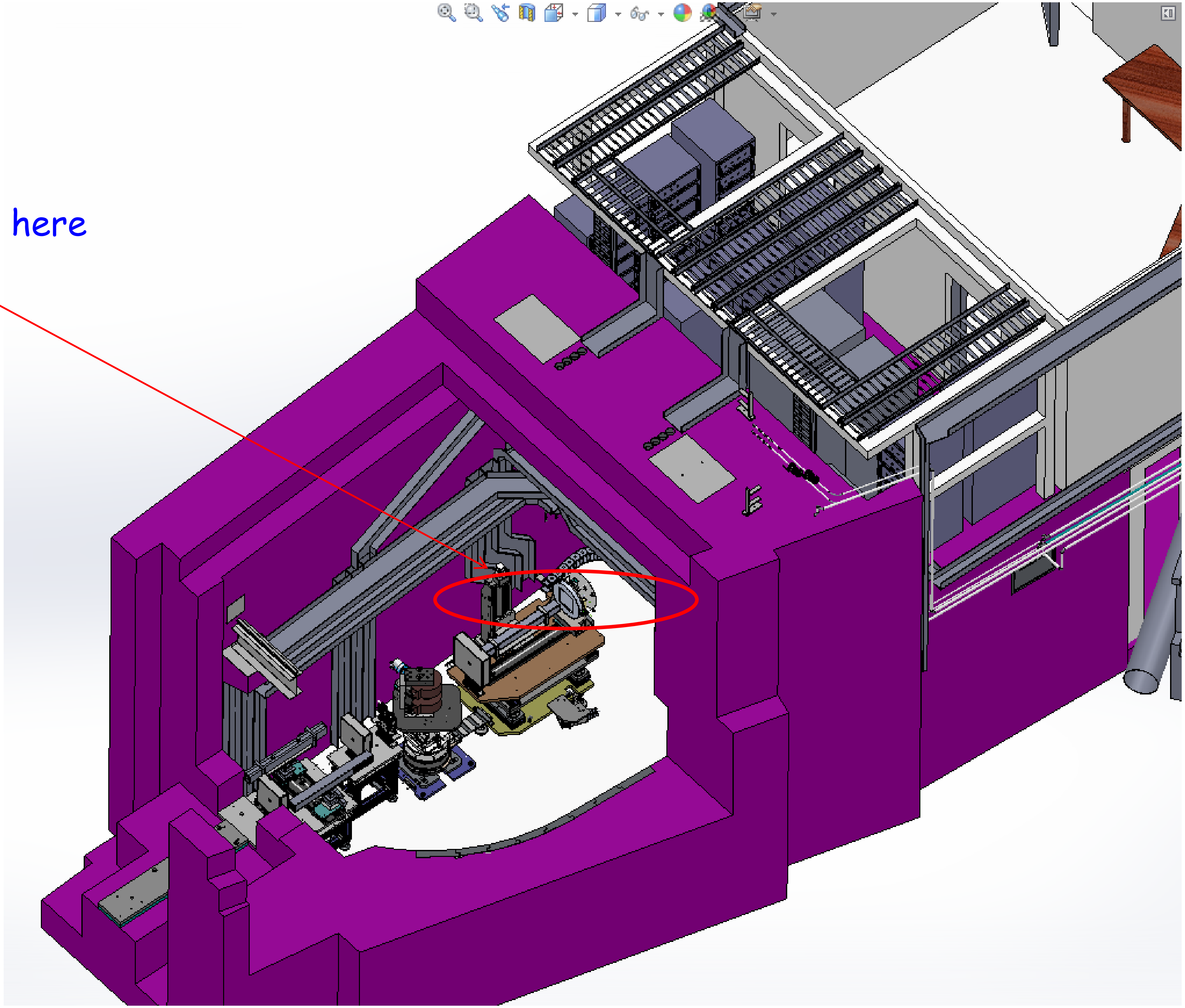


200mm*200mm MWPC

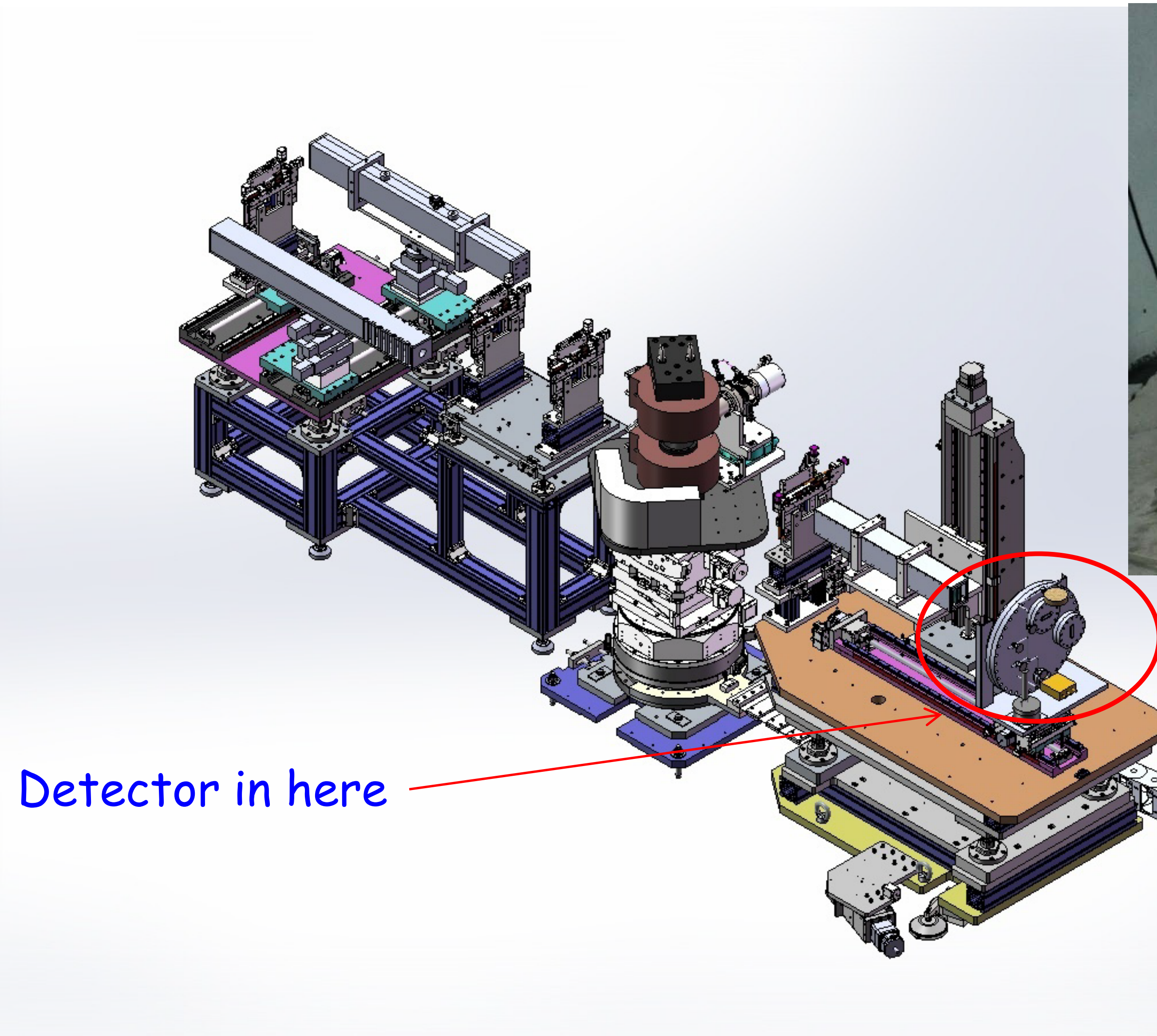
Active area	20cm×20cm
Pixel size	2mm*2mm
Number of electronic channels	200 （X： 100， Y： 100）
Gas	(5.5atm)^3He＋(2.5atm)C_3H_8
Detection efficiency	50% @2Å

Site in CSNS

Detector in here



Site in CSNS in April



Update photo in CSNS

Principle of the neutron Detector

n + ^{3}He → p + ^{3}H + 764 keV → ~25,000-30,000 electron-ion pairs

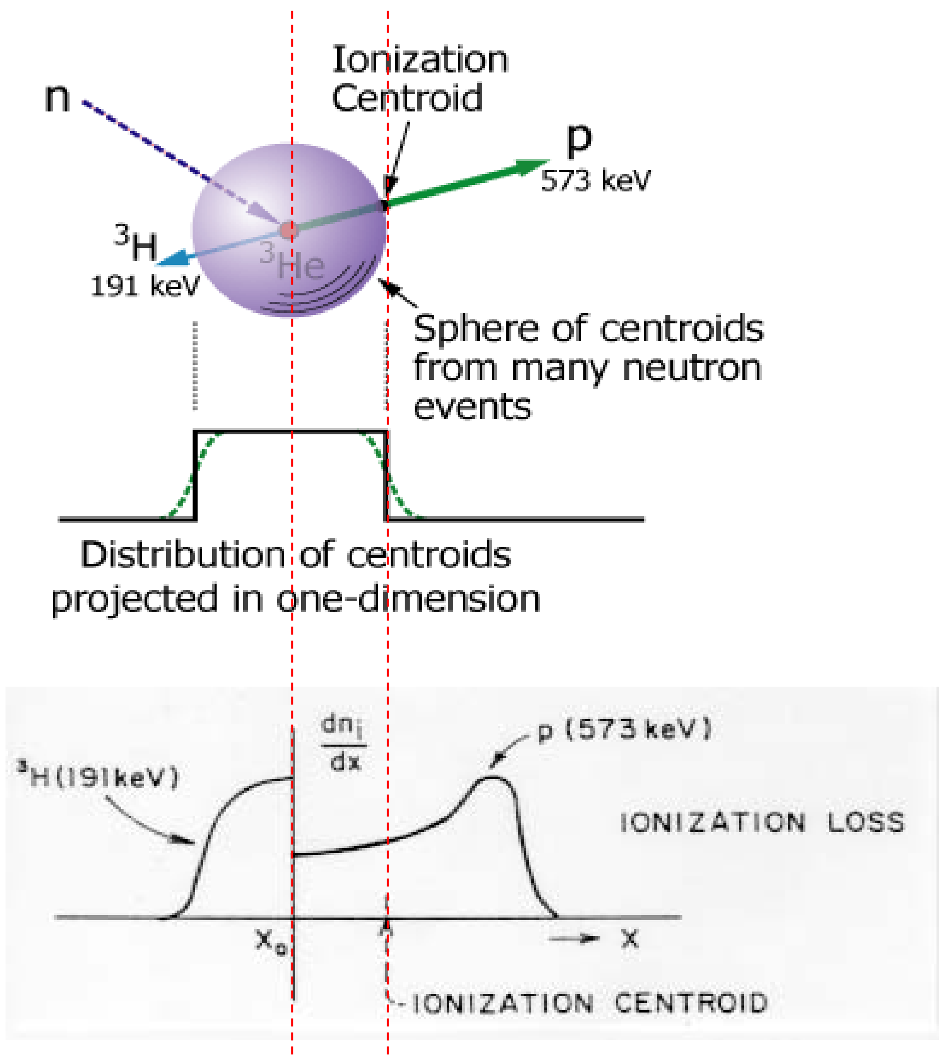


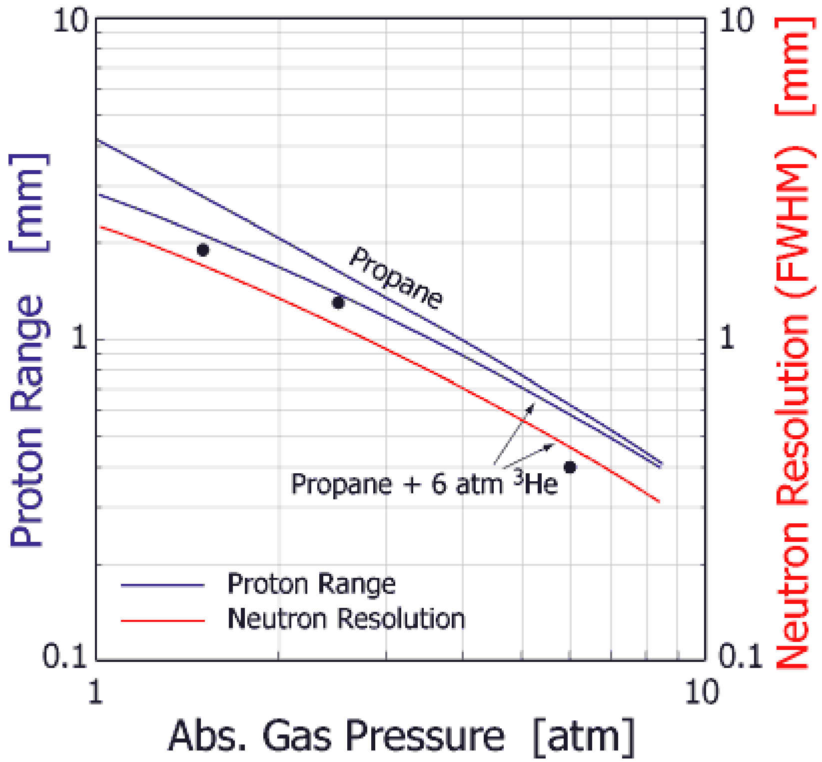
Diagram of the neutron detector

Let R_P = Proton Range

Centroid ~ 0.42 R_P from conversion point

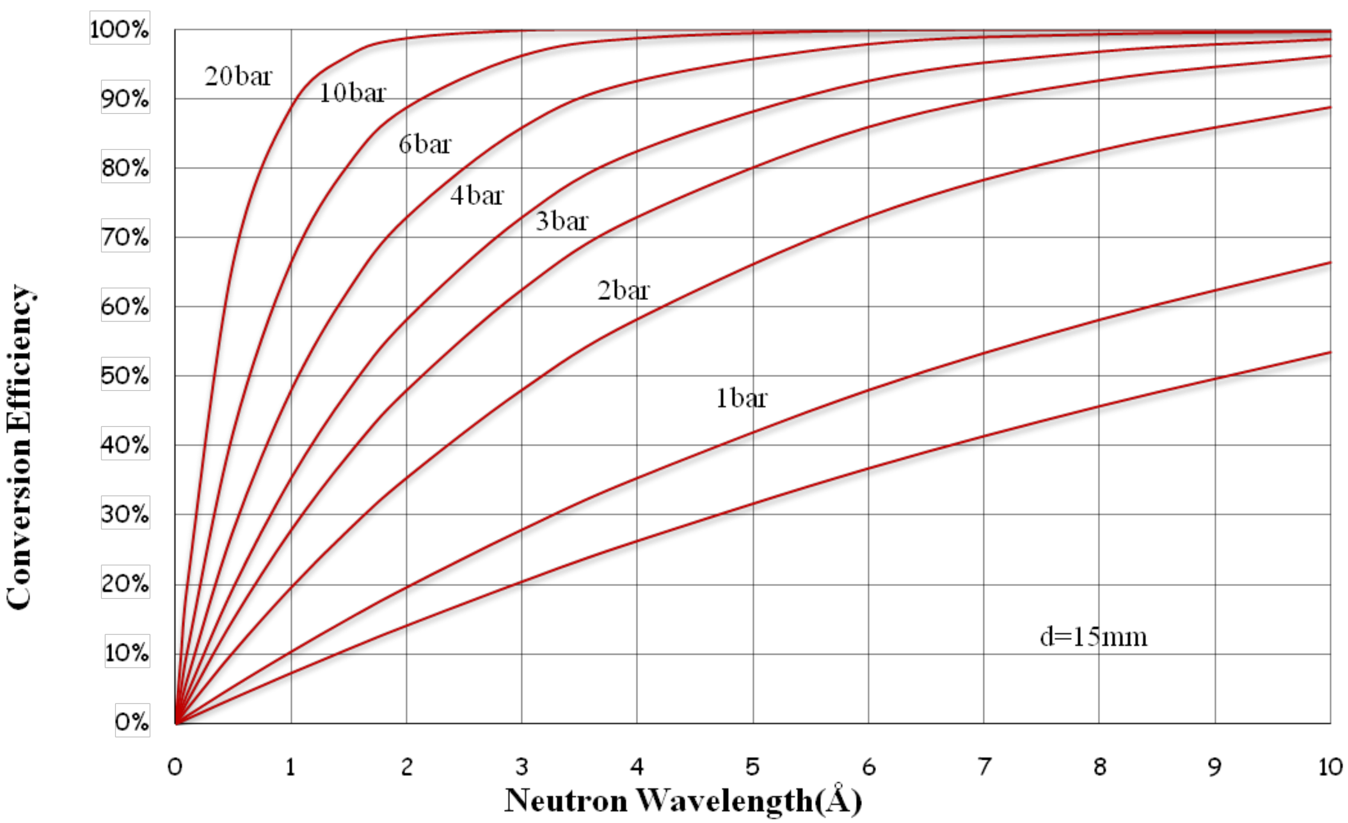
Therefore, FWHM ~ 0.84 R_P

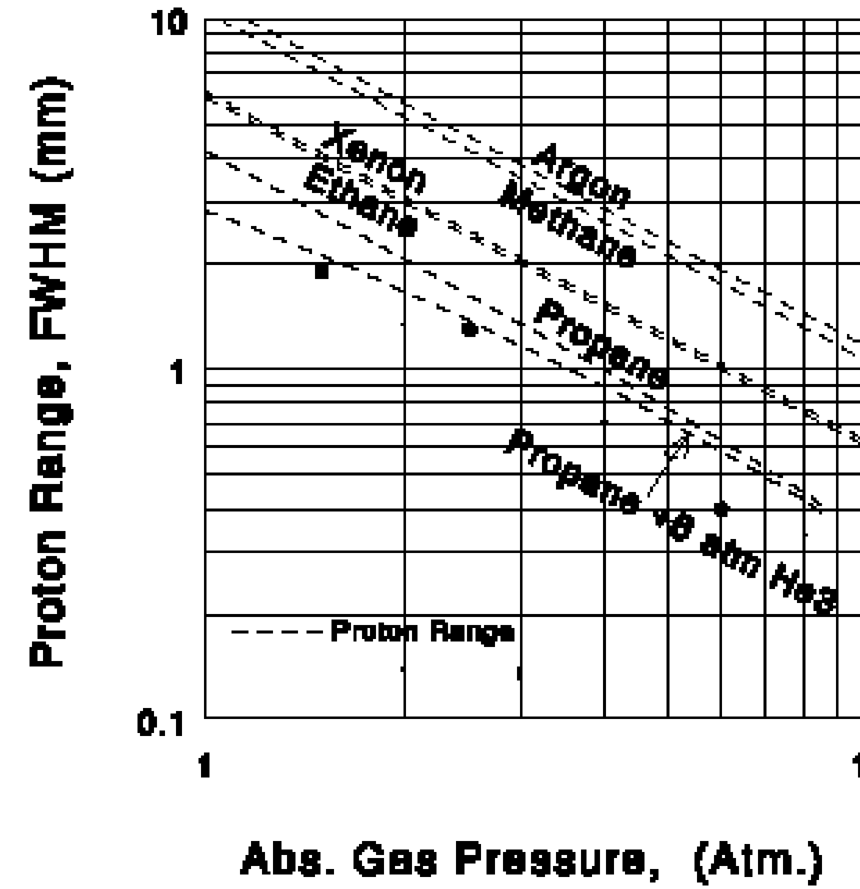
R_P ~ 4.2 mm in 1 atm. Propane



Range in the mixture gas by Proton

Working gas

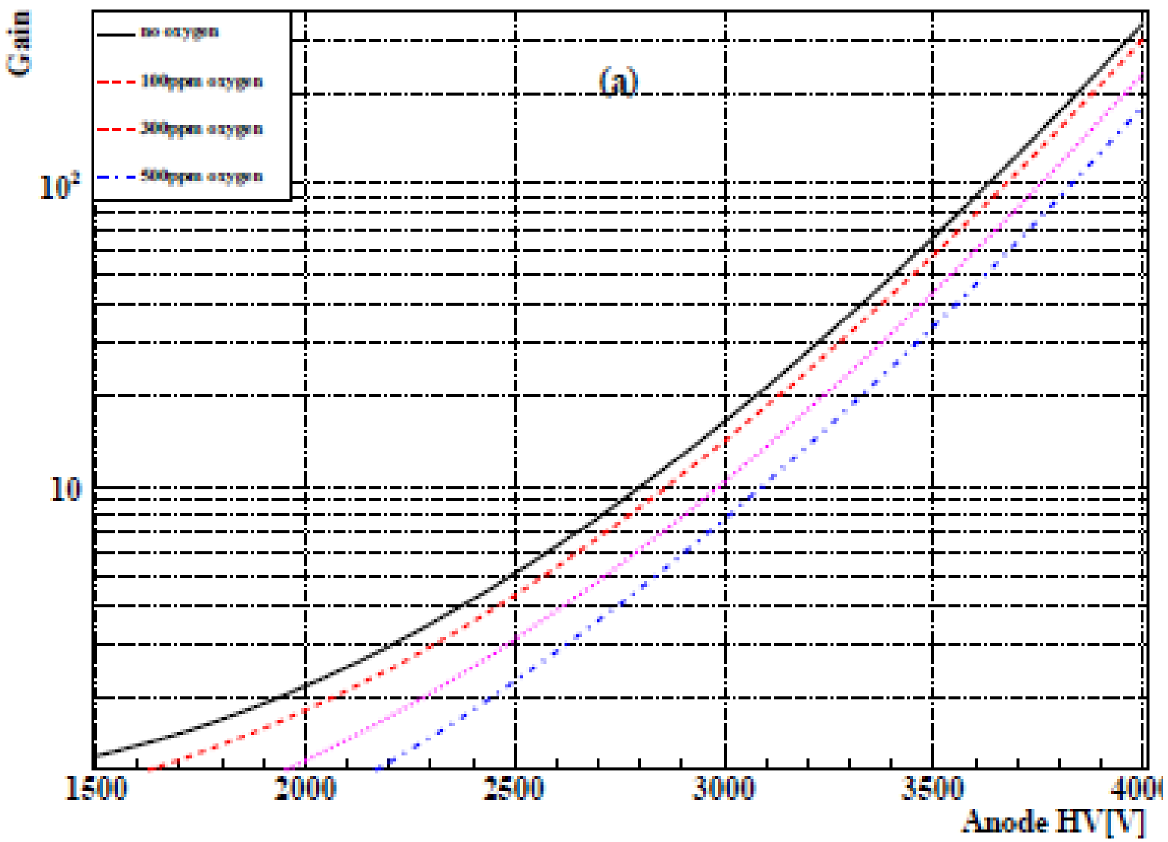


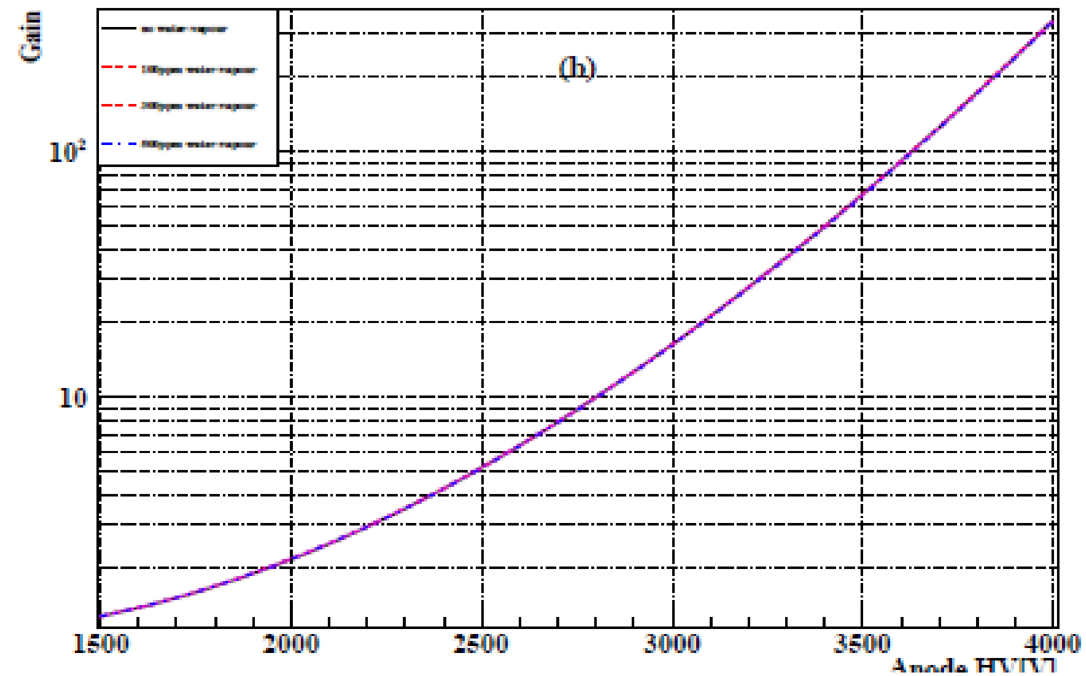


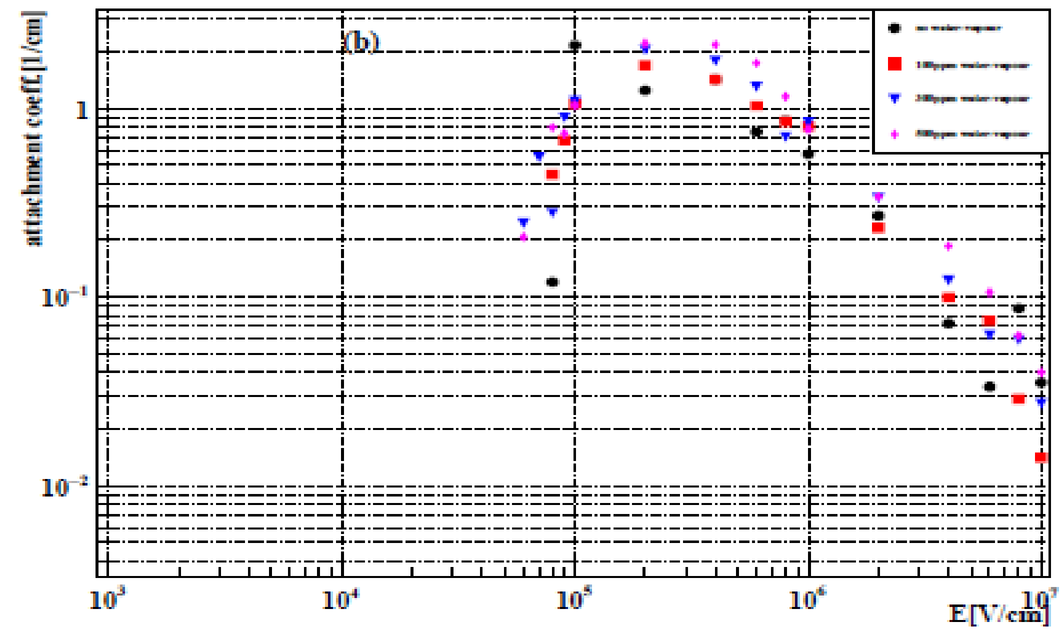
3He(6atm)
detection efficiency 70%@ 2Å

The stopping gas has two roles. First it reduces the path length of the electrons for a good position resolution and minimizes the wall effects. Secondly, in an environment of high photon background, it has a low sensitivity to gamma and X-rays. So, we used C_3H_8(2.5atm) as the stopping gas.

Gas purification -Simulation





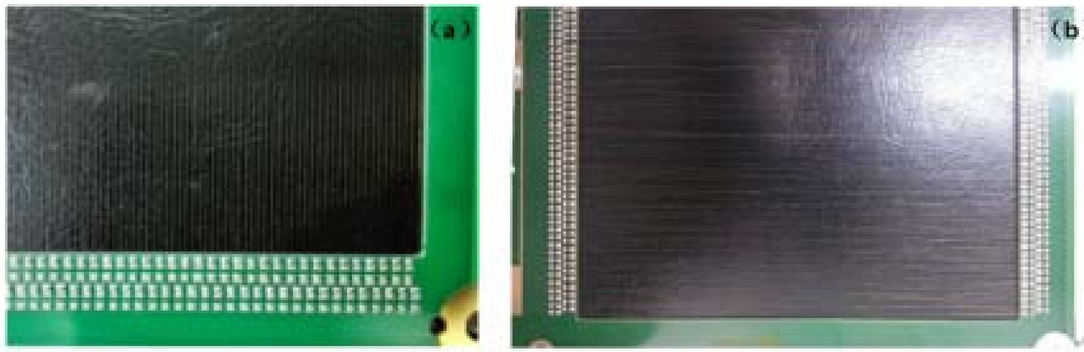


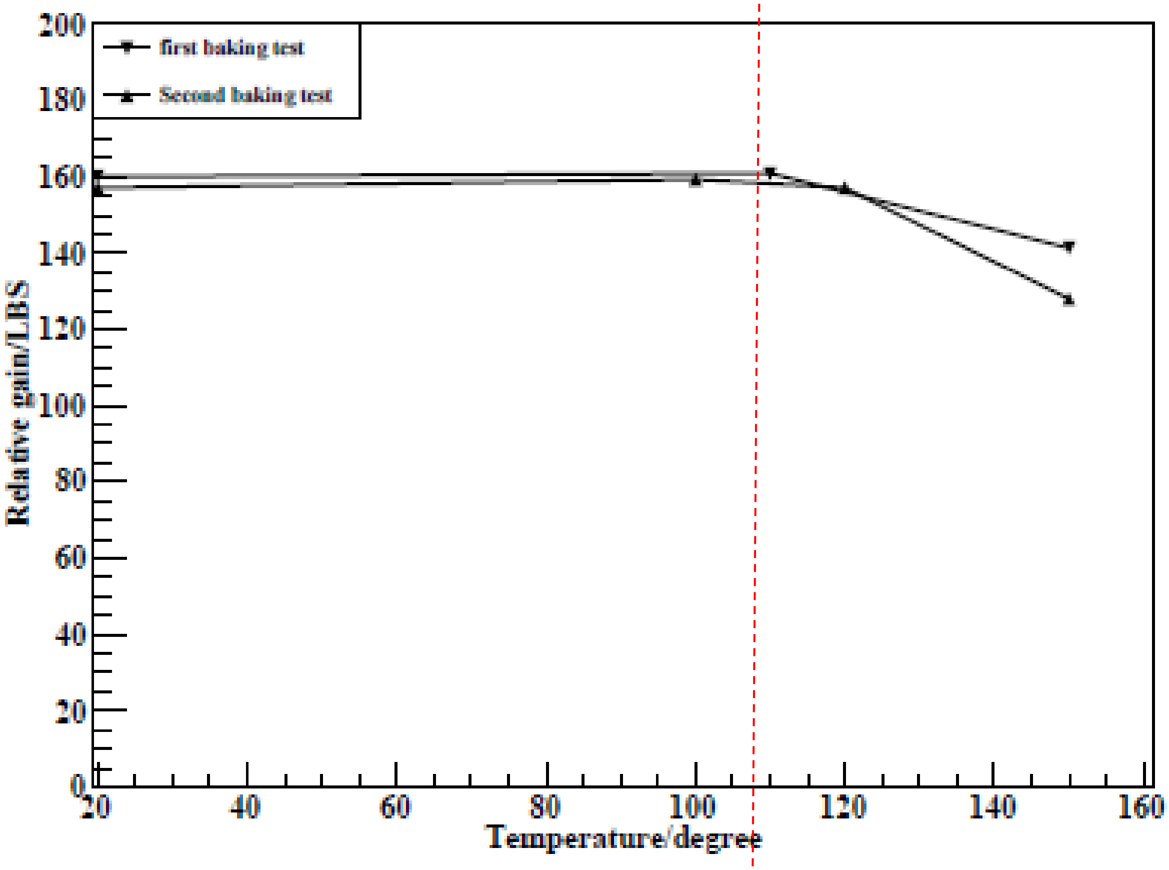
The gas gain for different amount of oxygen impurity

/O_2

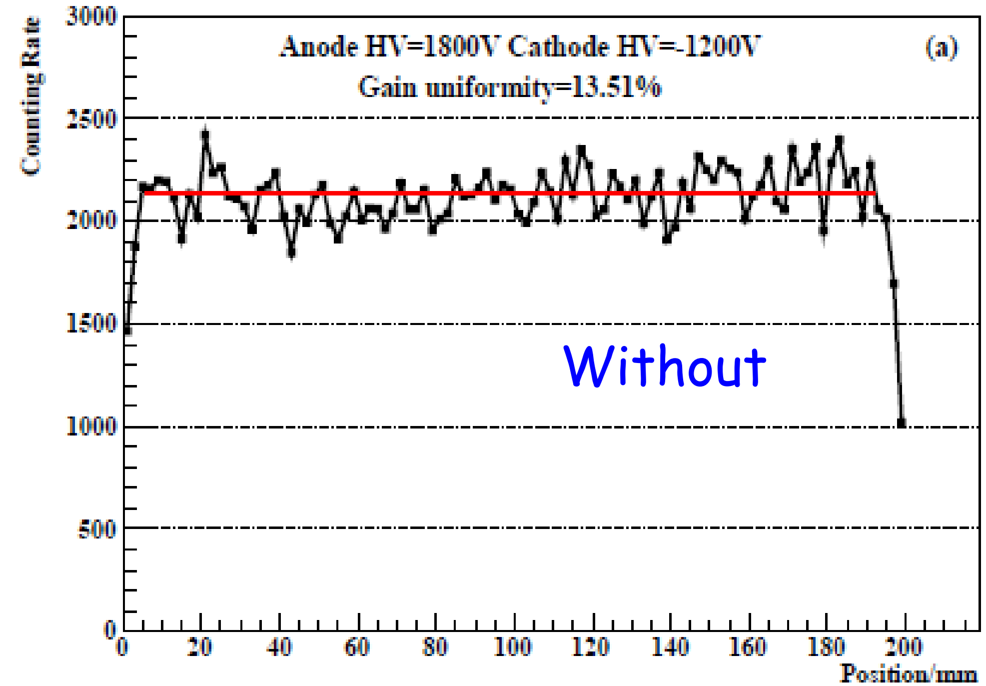
The gas gain and attachment for different amount of water vapour impurity /H_2O

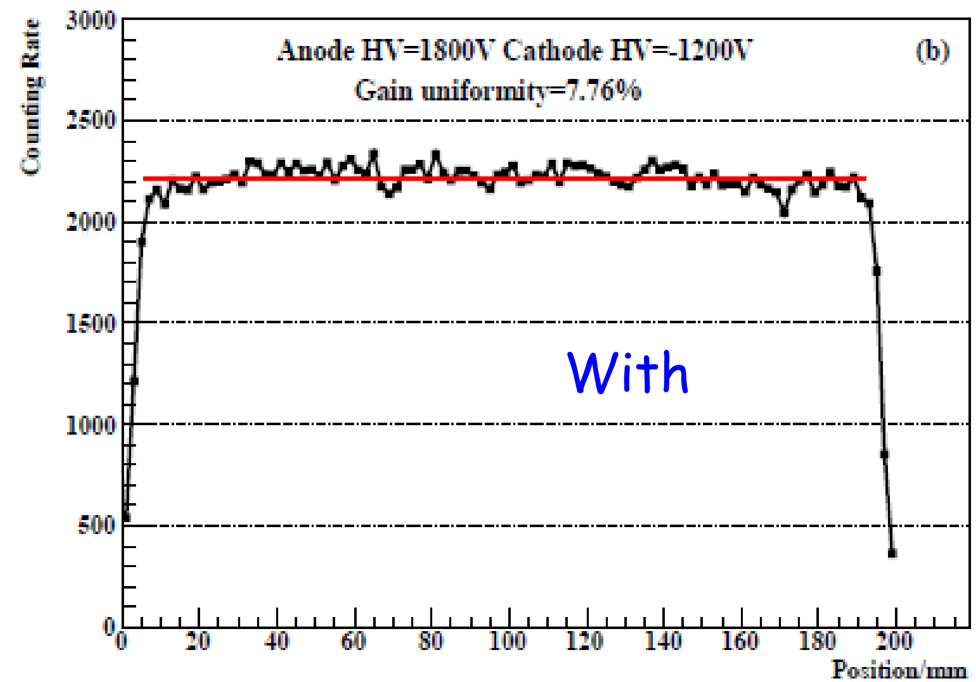
Heating clearing procedure





The relative gain as a function of heating temperature

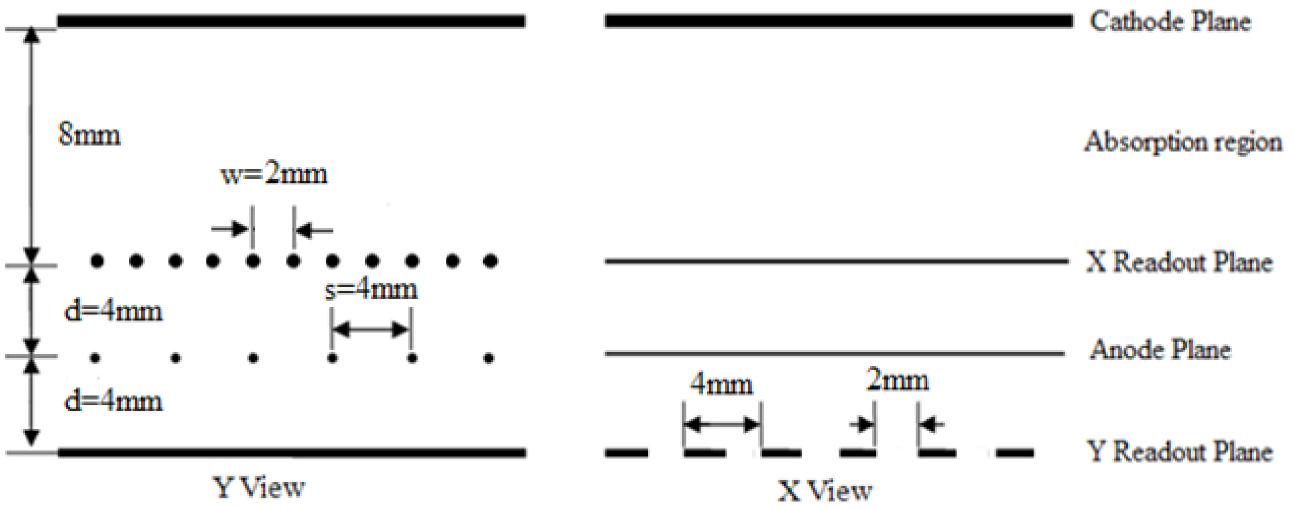


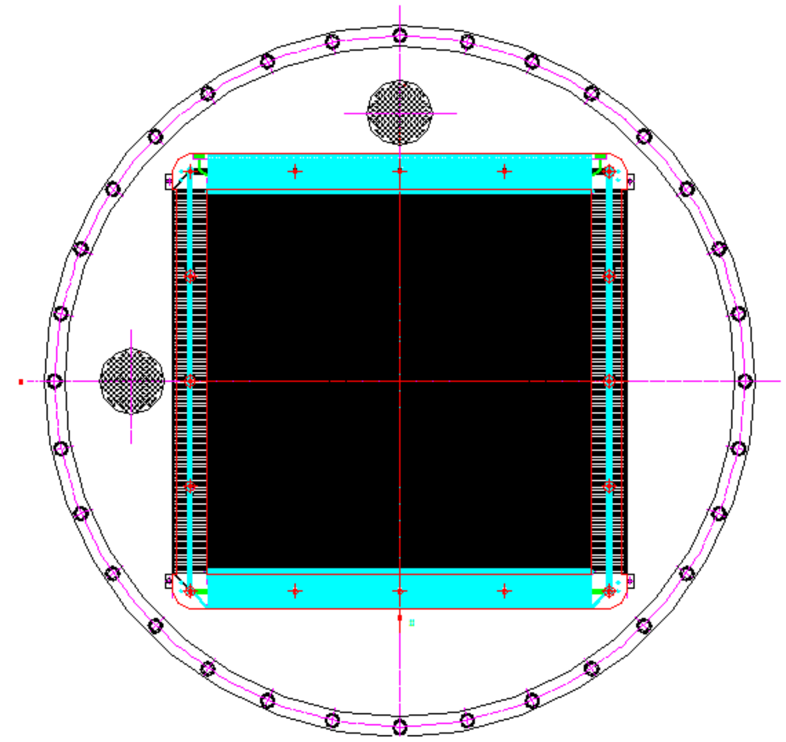


The gain uniformity of detector at the condition w/o heating 100 degree

Geometry of the detector

- Pitch of Anode wire: 4 mm
- Anode wire: 15μm
- Anode Wire Tension: 25g
- Pitch of the Readout wire: 2mm
- Readout wire: 50μm
- Readout Wire Tension: 40g
- Space of the Anode Plane and the Readout Plane: 4 mm
- Space of the Drift Region: ~8 mm





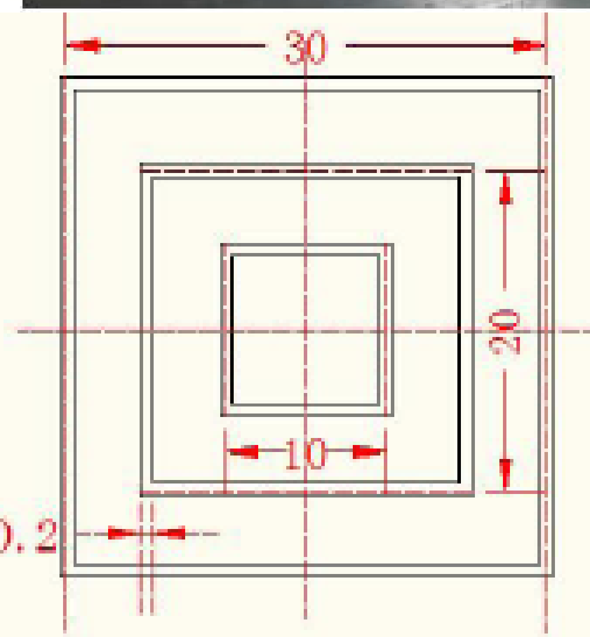
Schematic diagram of the detector

Optimization of the Geometry

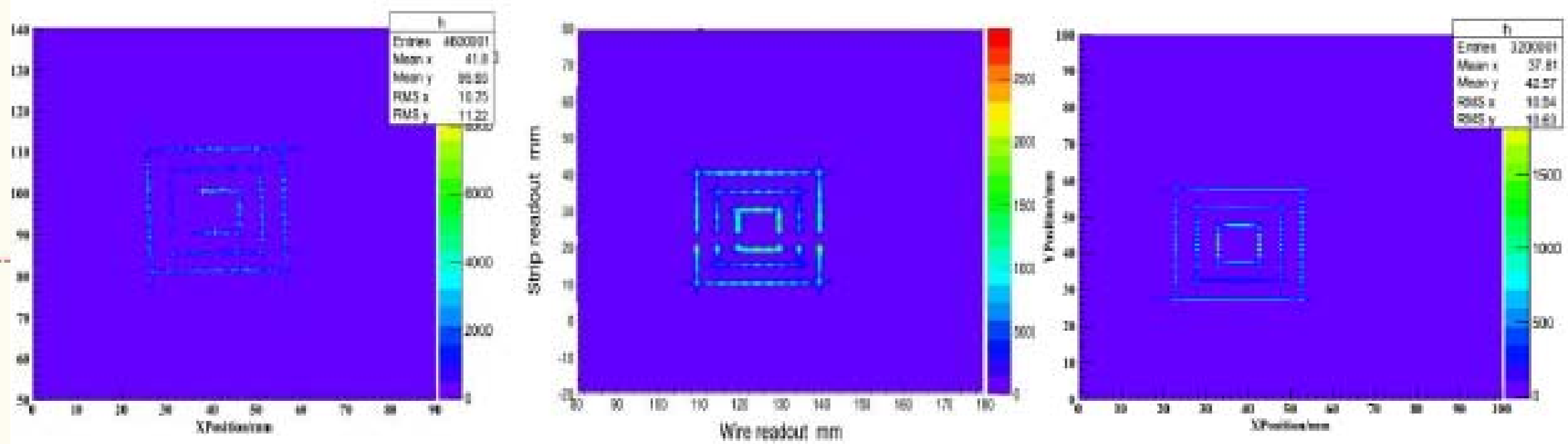
$$x = \frac{\sum (Q_i - b_i) x_i}{\sum (Q_i - b_i)}.$$

	A	B	C
Pitch of anode wire	2mm	1.5mm	1.5mm
Pitch of readout wire	4mm	4mm	2mm
Channels of readout	184	184	234
Working voltage	1750V~2050V	2150V~2450V	2230V~2530V

Selection of the Structure-B



Collimator

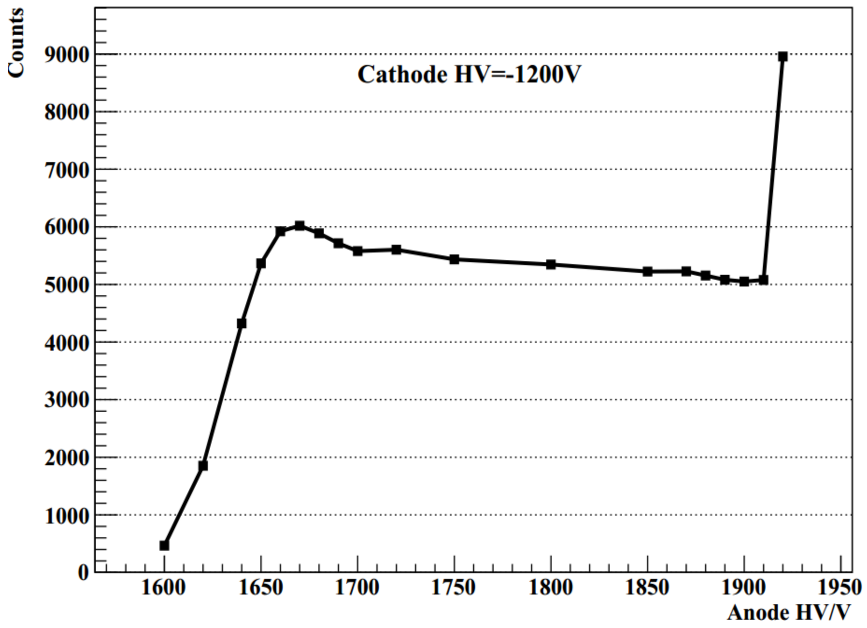


(a) (b) (c)

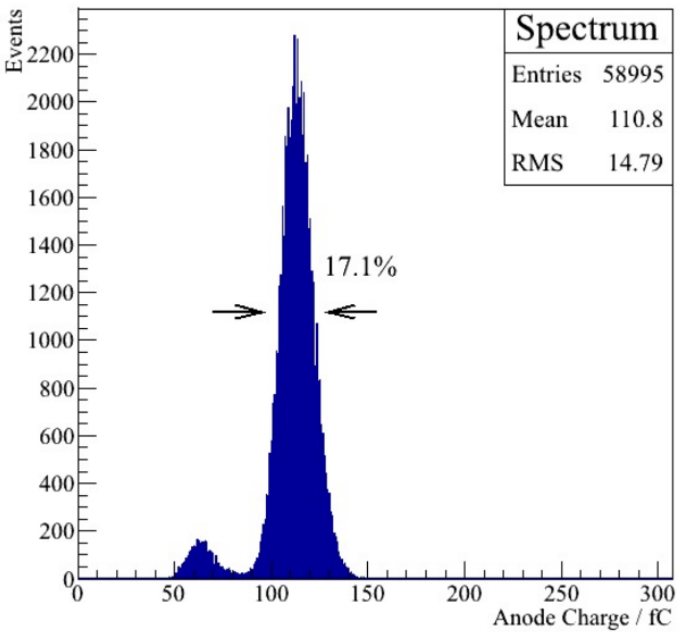
The imaging of three kinds of structure detector with center of gravity method.

Status of the MWPC Detector Prototype

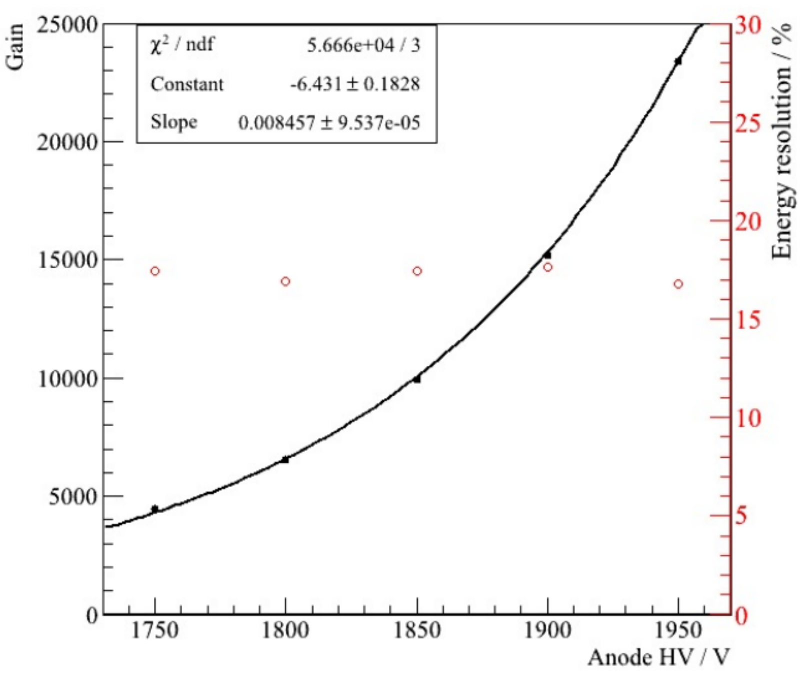
- 55Fe X-rays
- Working Gas:Ar/CO2 (90/10)
- Length of plateau : ~300 V
- Energy Resolution: 17.1%
- Uniformity test



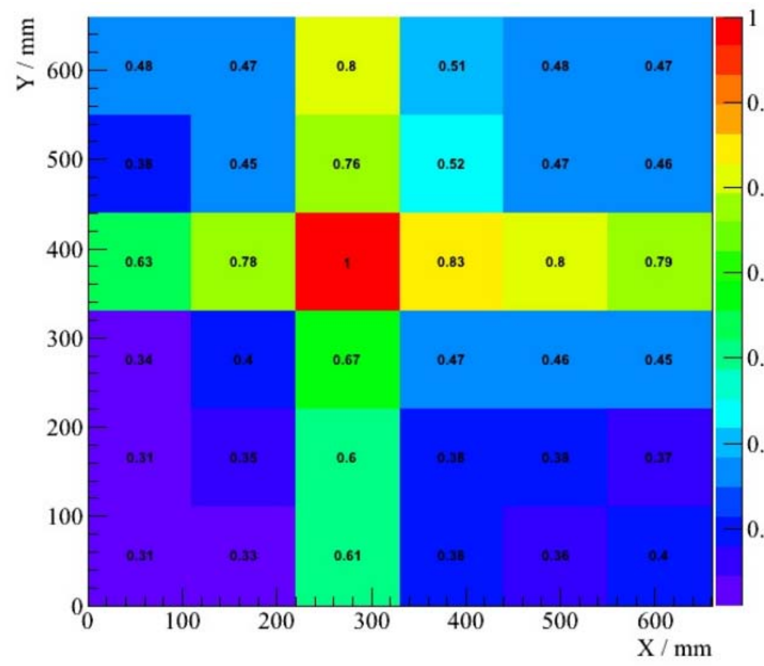
Plateau



Spectrum of Fe55 X-ray



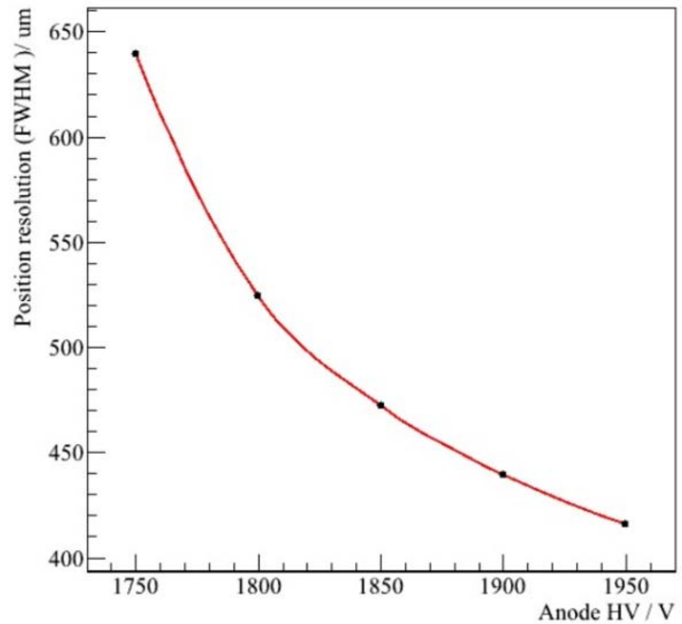
Gain and Energy Resolution



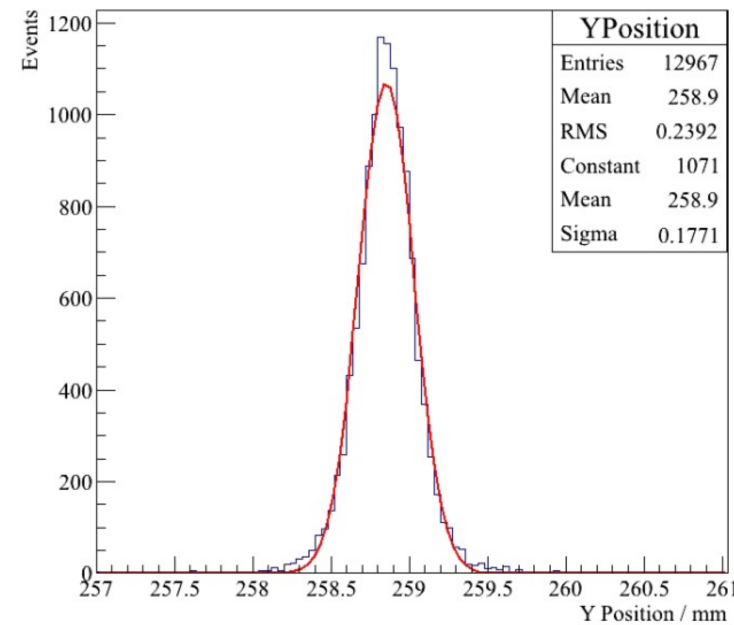
Uniformity test

MWPC Detector Prototype

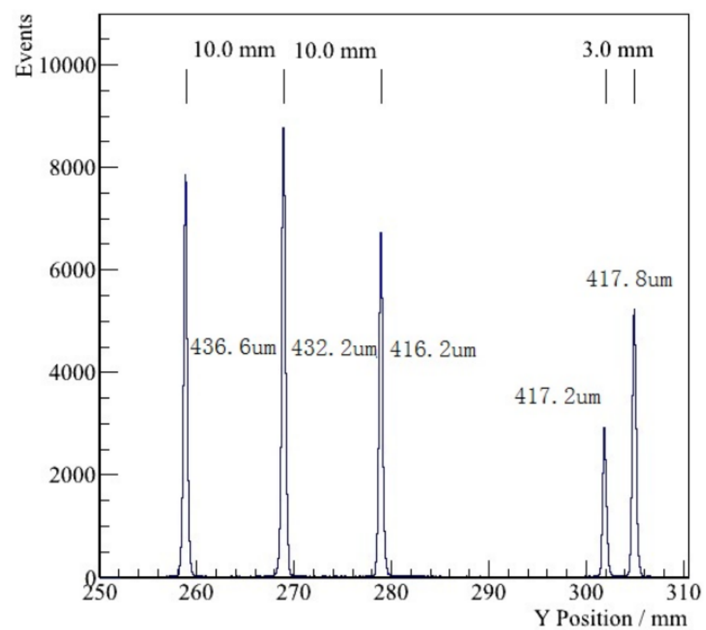
- Best performance of higher working voltage
- Position Resolution: 416 μm
- Uniformity of the position resolution at the different postion
- Image of the hole using the Fe55 X-ray



Position Resolution VS High voltage



Position Resolution



Position Resolution

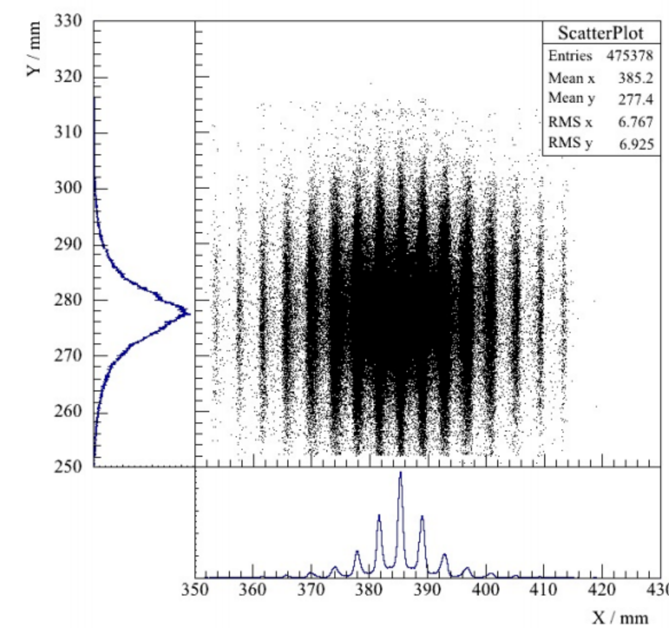
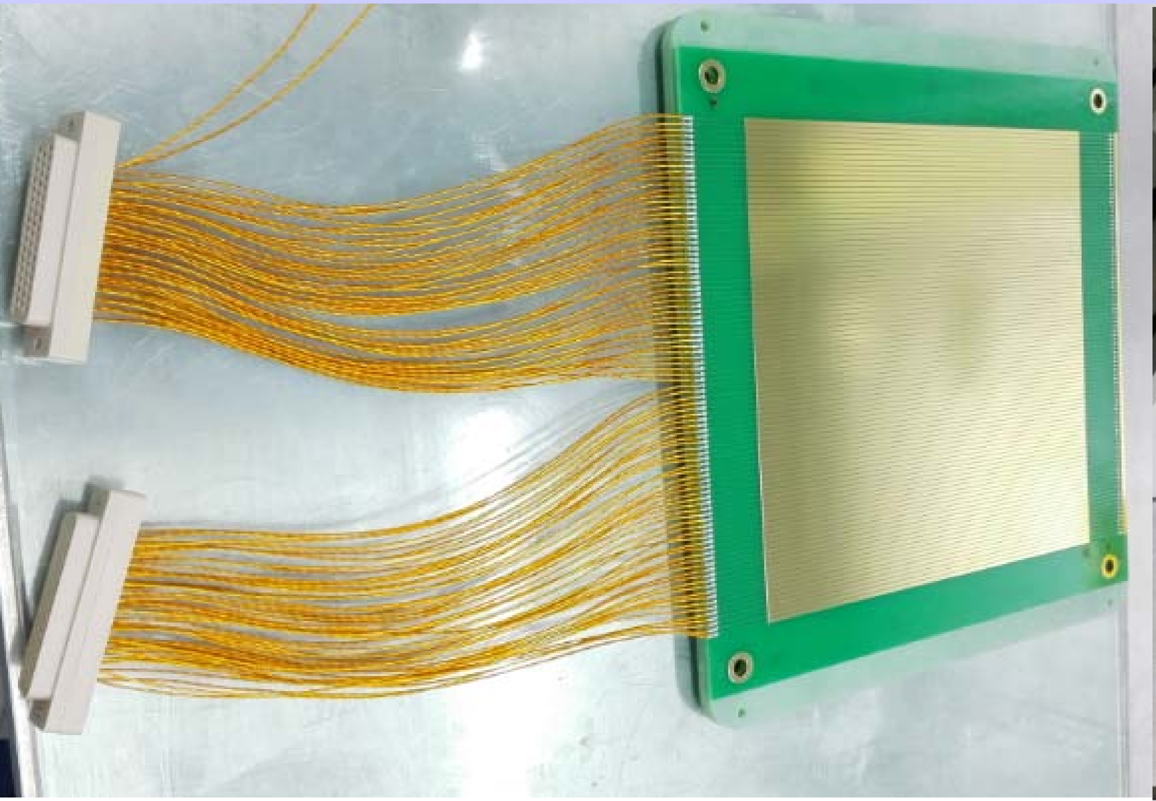
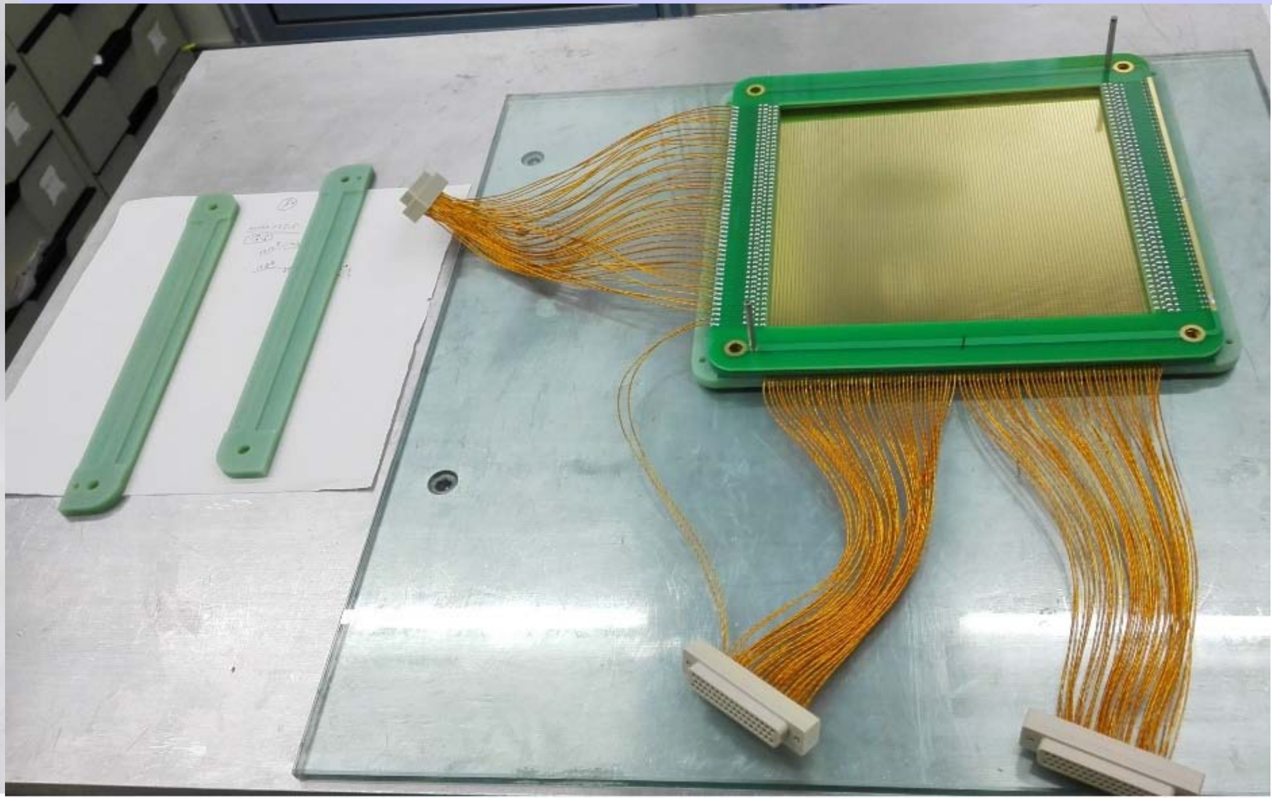


Image of hole

Optimization of the wire detector





Photos of the wire detector

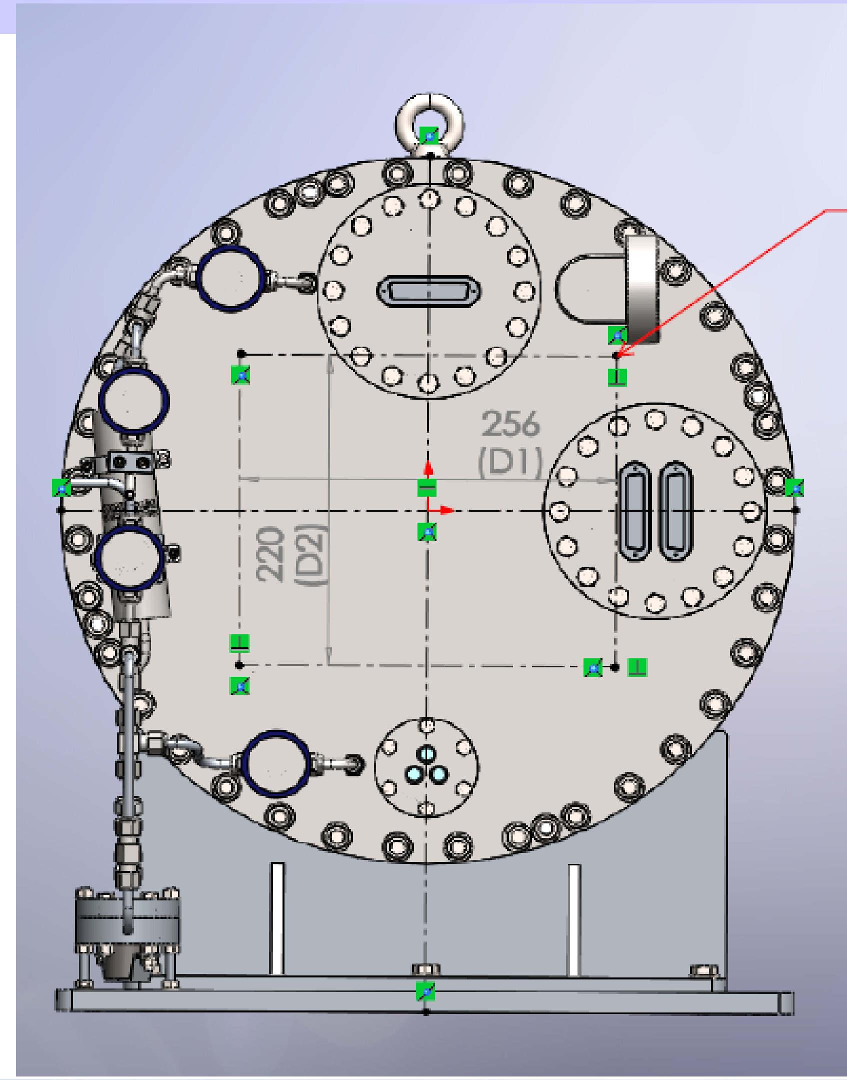
	Set-1	Set-2	Set-3	Set-4
Working voltage of anode wire/V	**2150**	**2150**	**2150**	**2150**
Plateau curve/V	**1740~2100**	**1700~2030**	**1650~1990**	**1650~1910**
length of the plateau curve/V	**360**	**330**	**340**	**260**
Linear of Gain	**16.5%**	**13.5%**	**7.76%**	**7.51%**

Selection

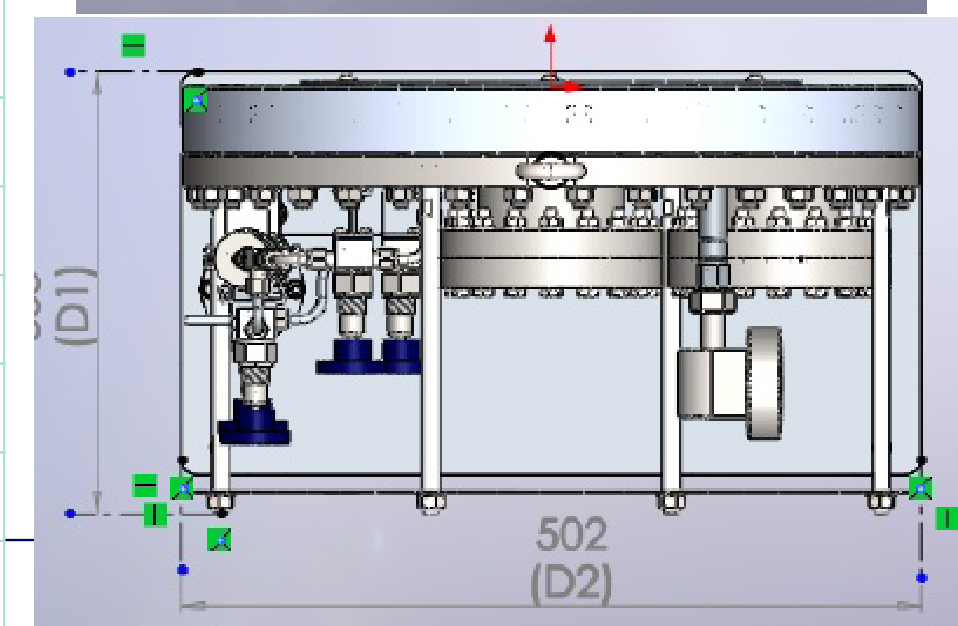
Test of the four sets of the wire detector

8.0atm MWPC detector

- Final designed for 200mm MWPC and produced to assemble
- Readout Chs : 142 CHs
- Diameter of detector: 500mm
- Sealed method: Metal seal
- Vacuum testing: 10^{-4}Pa
- Active area:202mm×202mm
- Gas leak: 1×10^{-10}atm.ml/s
- Interface
  - Discussion and confirmation with electronics
  - Discussion and confirmation with support device

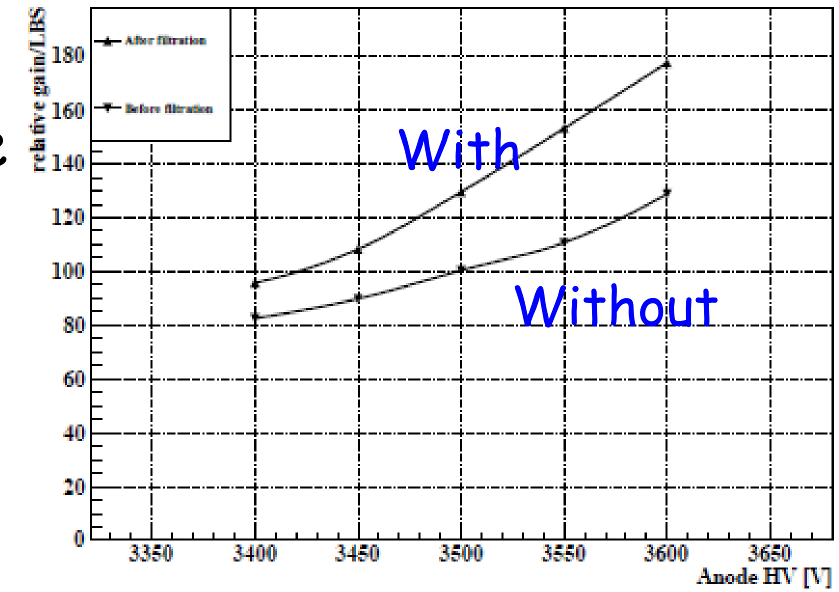


Items	Diameter(mm)	Height (mm)	Material
Front Cap	500	48	T7075 Al
End Cap	500	25	304 SS
Flange*2	152	20	304 SS+CE
SHV Flange	70	12.7	304 SS+CE
Gas purity	38	150	304 SS
Pump	70	26	304 SS



Gas purification device@Self-designed

- Self-designed gas purification device
- Achieved an effective gas purification cycle
- Integrated in the detector chamber
- 8.0atm 3He operation gas fully cycled in 30mins~50mins
- Items ready
  - 2 sets of the gas purification device
  - valves and connectors

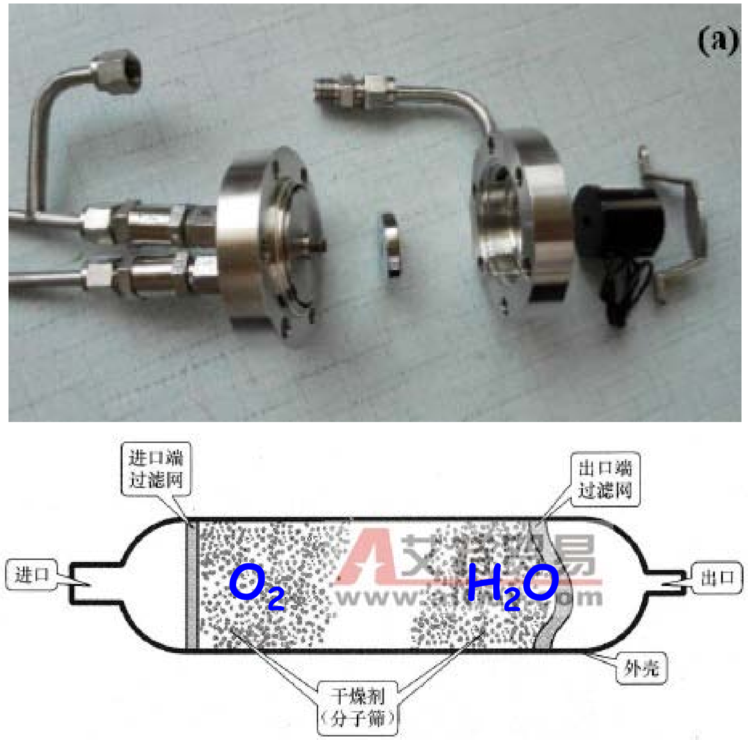


Detector test results

Previous design

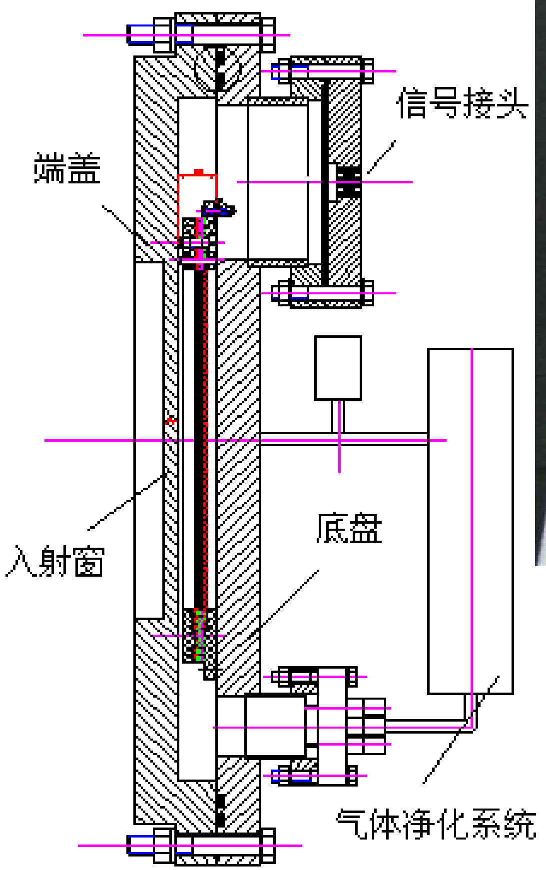
Update design v1

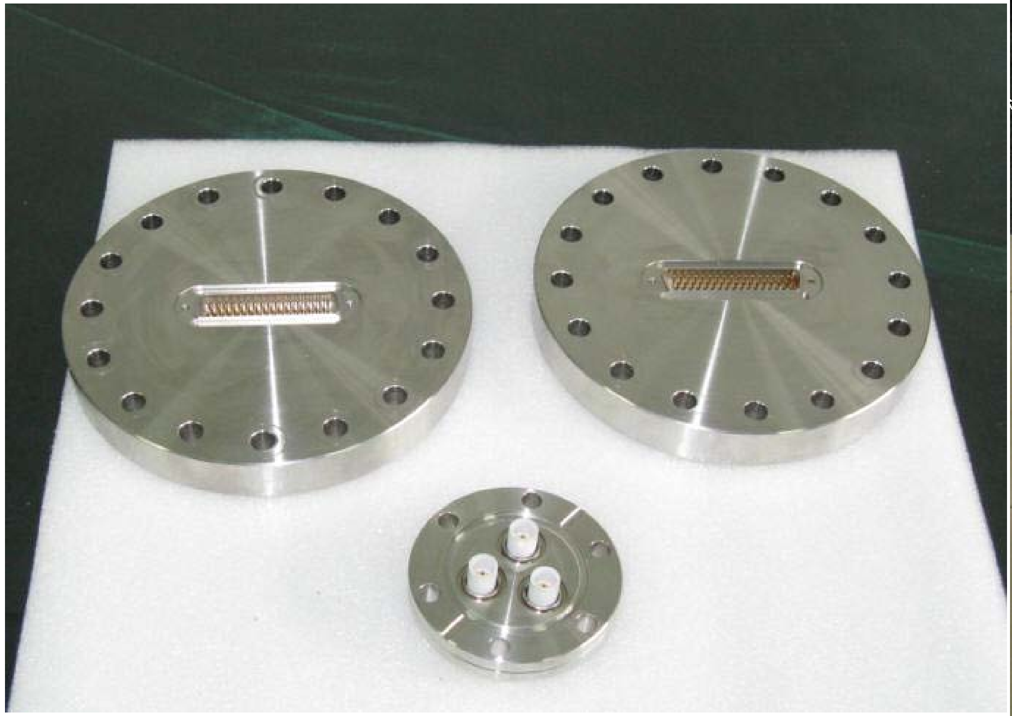
Update final design

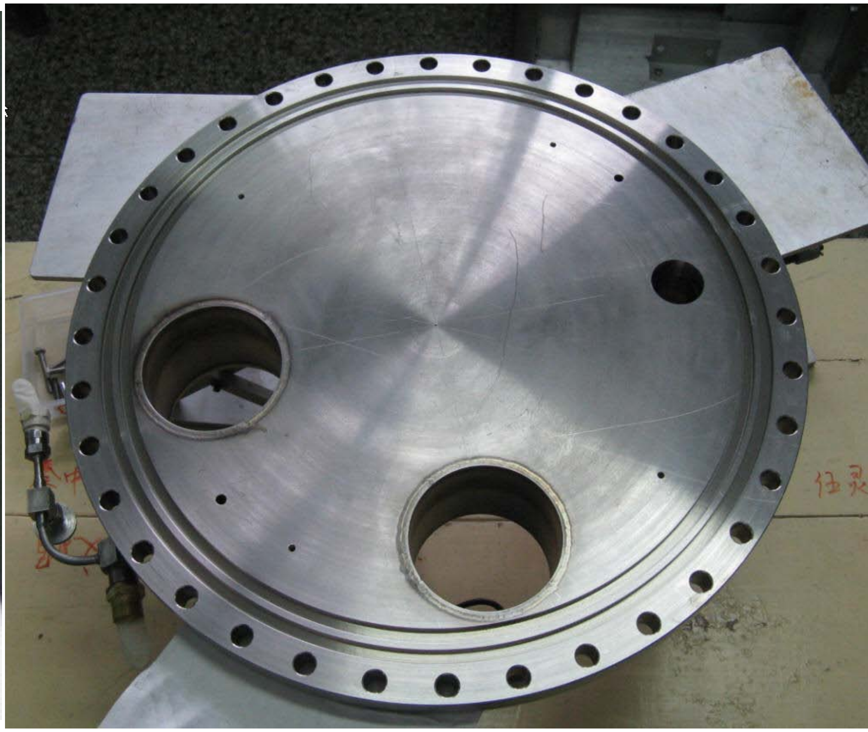


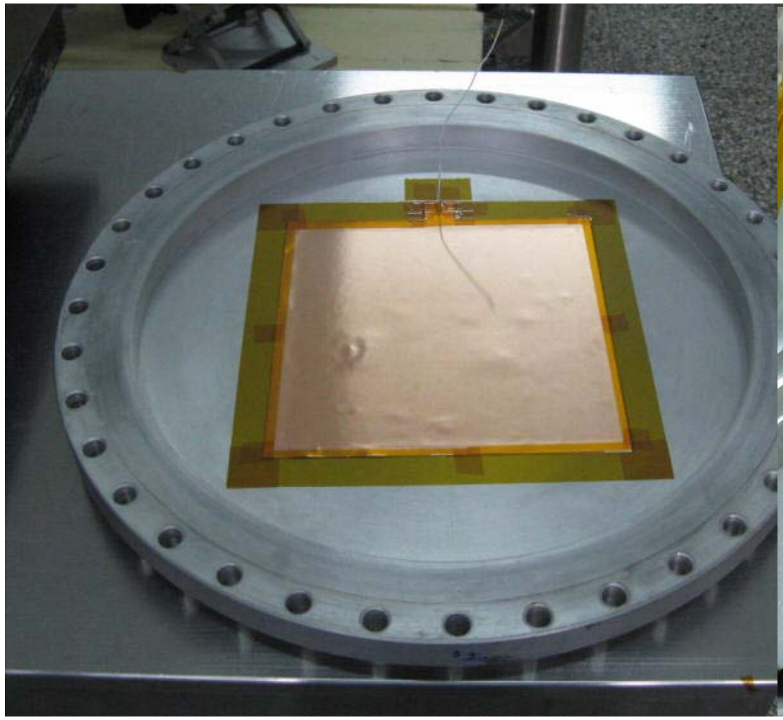
Principle of the device

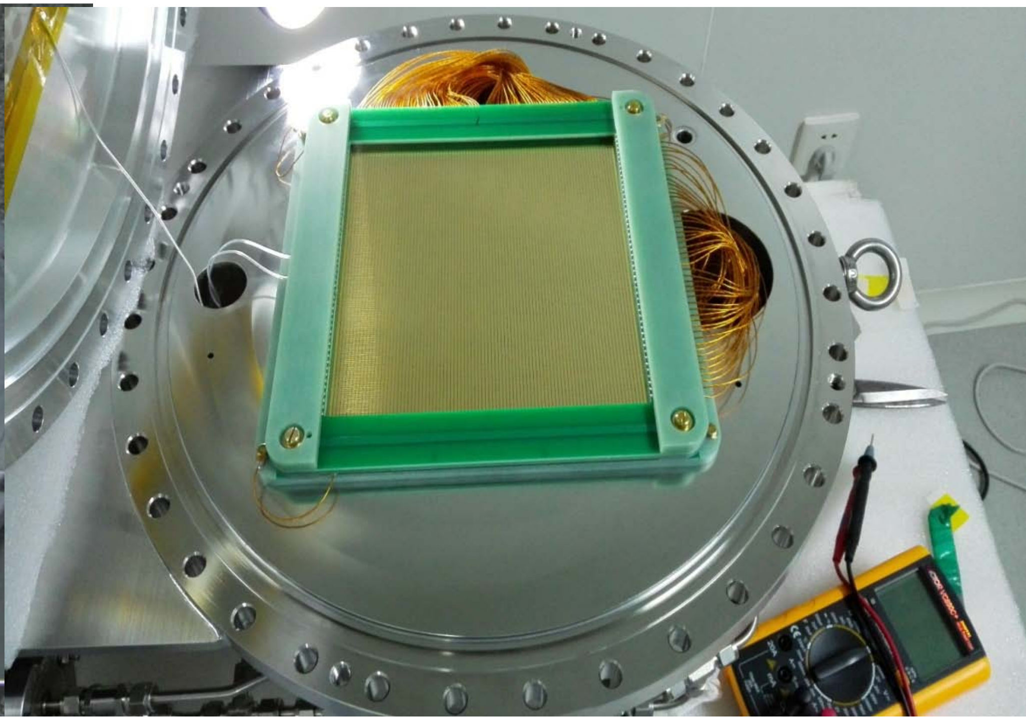
Photo of the detector





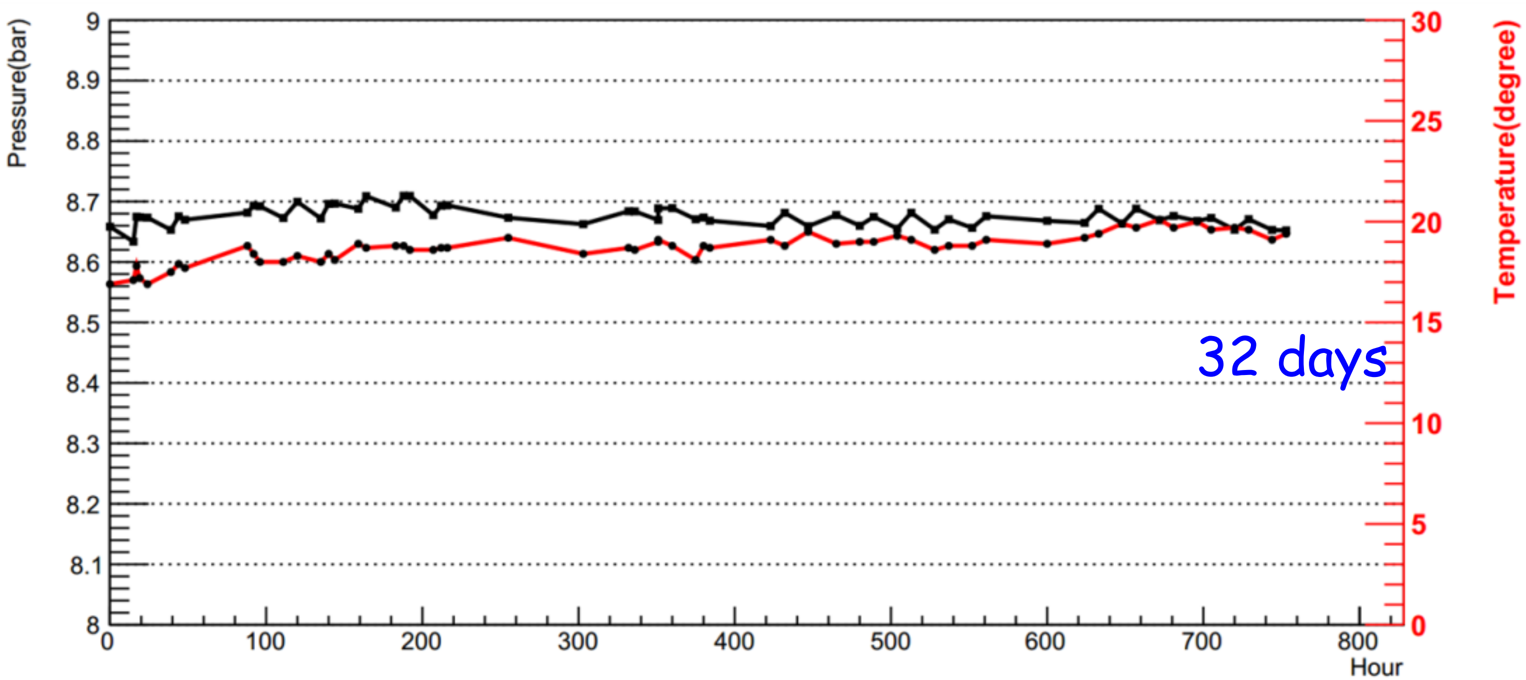






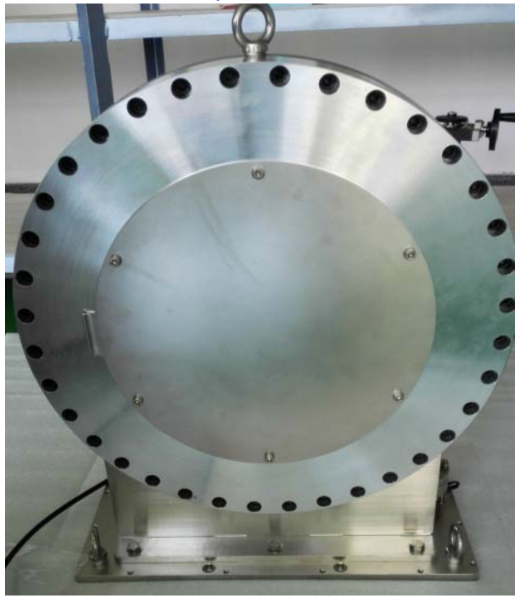
Stable of the gas pressure

- Assembled the detector
- Window of Al: 9.0mm+-0.1mm
- Gas leak: 10^{-7} mbar.l/s
- Pressure and temperature: >32 days
- High voltage training: Done
- Wire detectors: pre-heating at 100 degree



Pressure and temperature@^{4}He gas

Photo of the detector



Electronics and DAQ

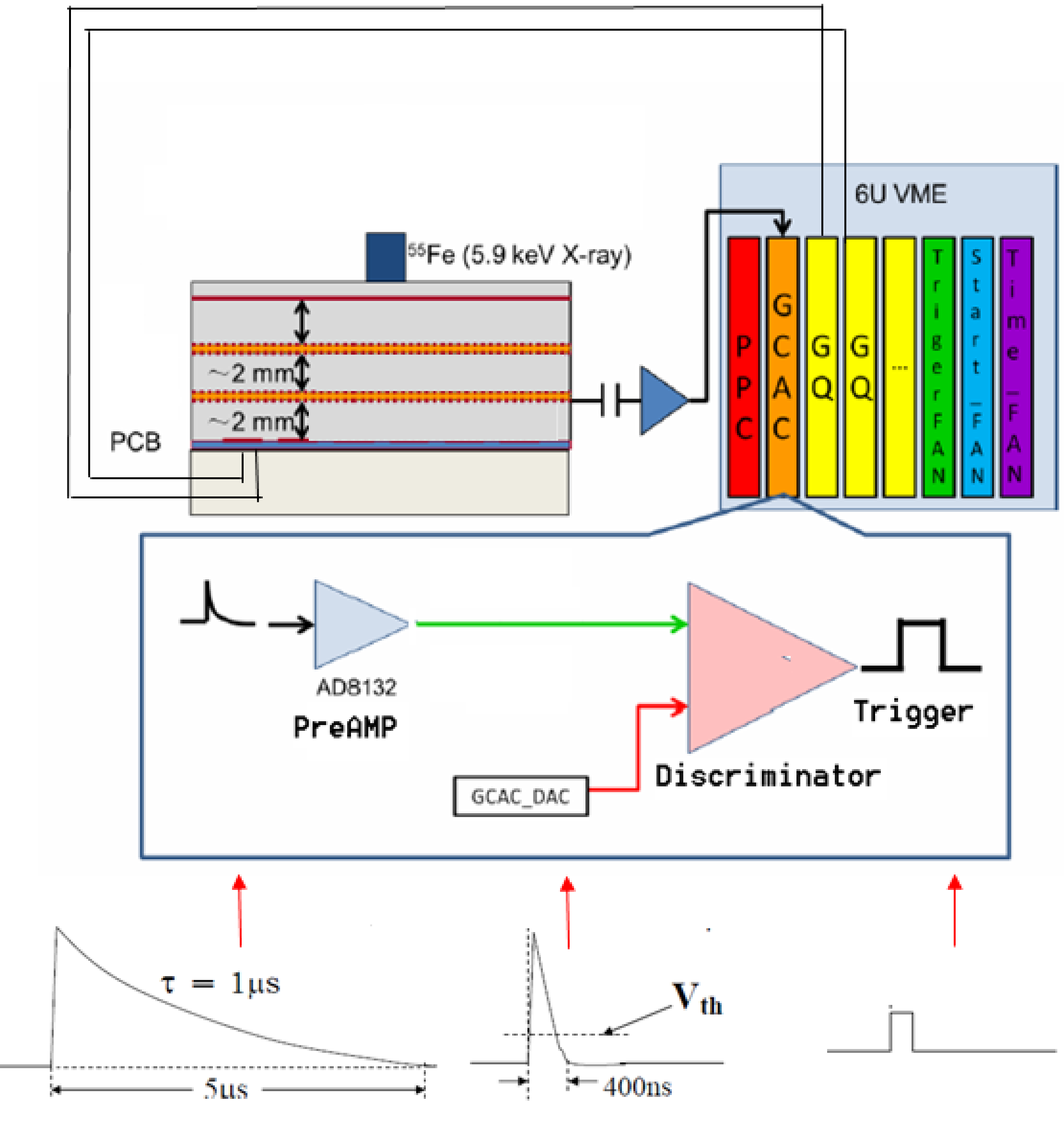


Diagram of the DAQ

- DAQ Trigger Pulse

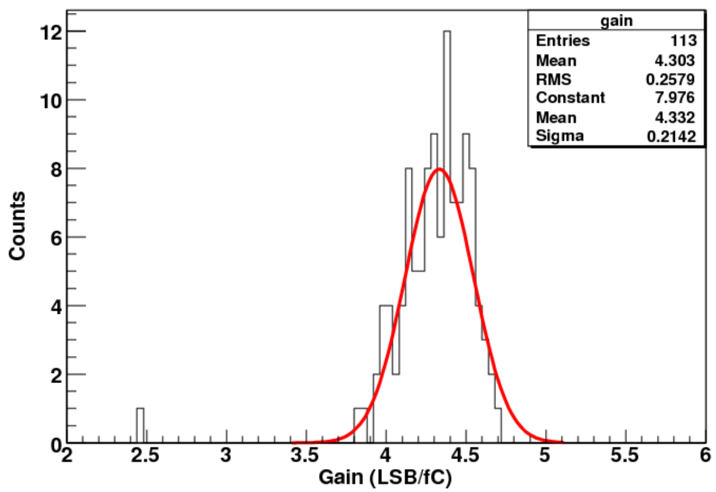
  Signal from the ne

  -> PreAMP + Discriminator

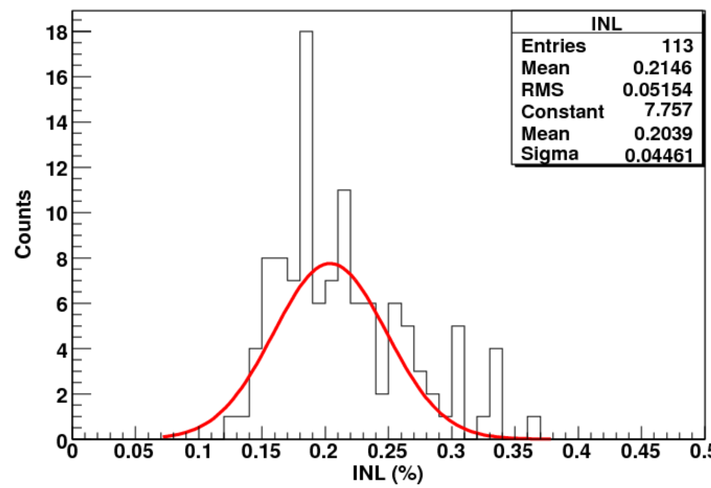
  -> input to GCAC Board and the output as DAQ gate
- GQ Modules
  - 16 Channels/Module
  - FPGA +Amplifier/Module
- All DAQ Boards mounted in 6U VME crate
- Data transfer with PowerPC, Network and Serial Server to PC
- DAQ software with LabView and C++ Program

Electronics

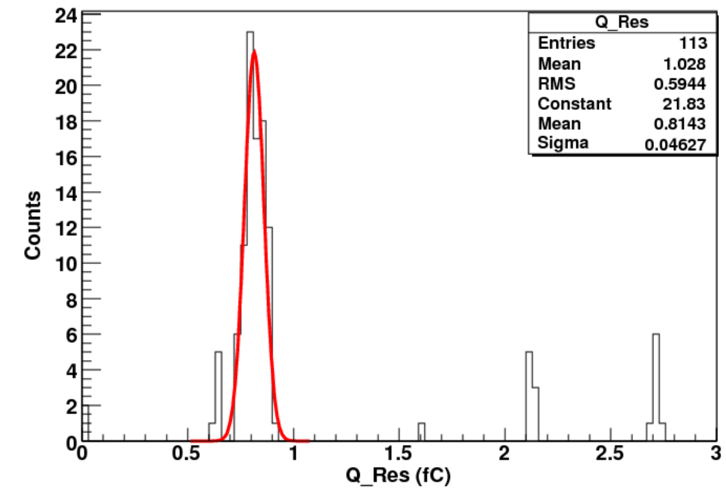
Status of the MWPC Detector for MR: Electronics



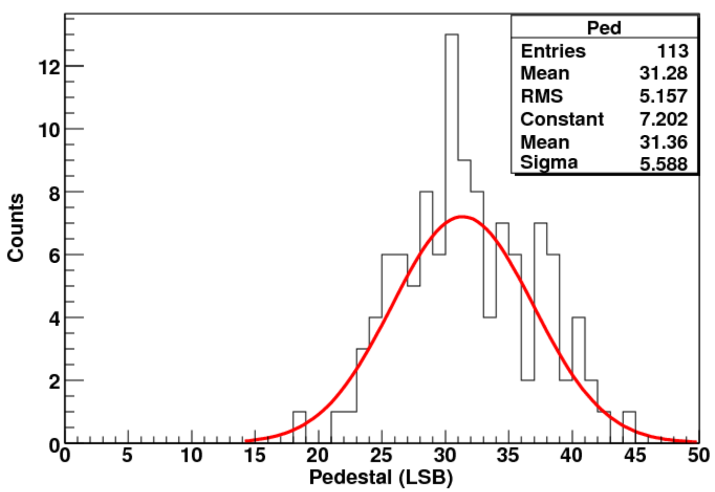
Charge Sensitivity



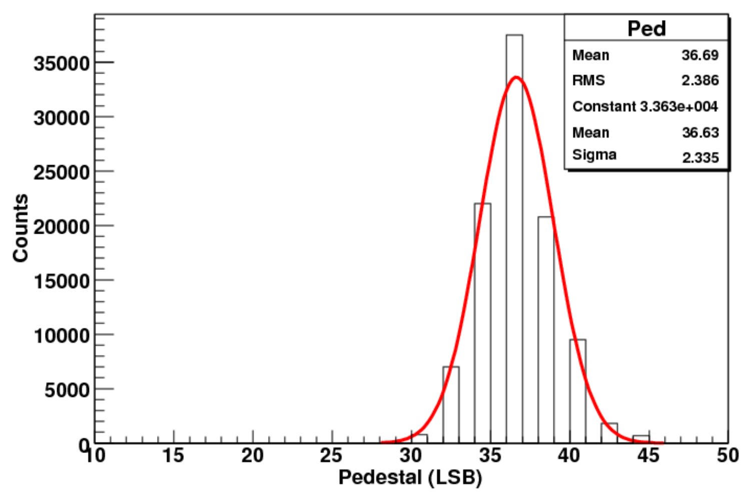
Integral nonlinearity



Charge Resolution



Average value of baseline distribution



Baseline distribution of One channel

Gain: 4.332 ± 0.2142 LSB/fC

(Anode: 2.46 LSB/fC)

INL: 0.204%±0.045%

(Anode:0.368%)

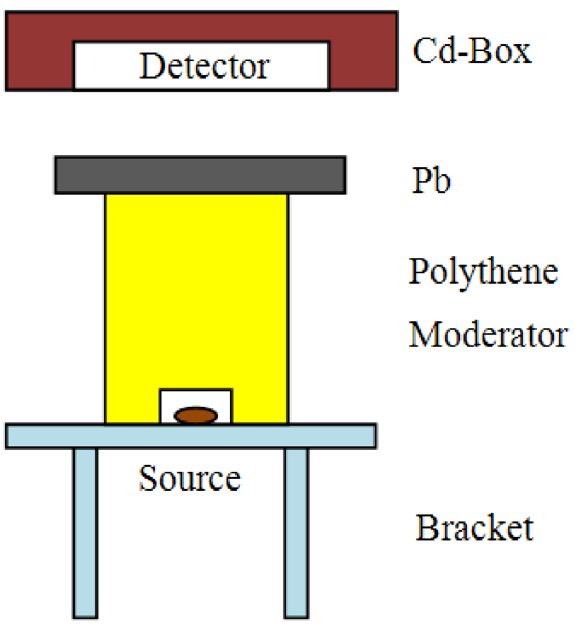
Charge Resolution:

0.814 fC ± 0.046 fC

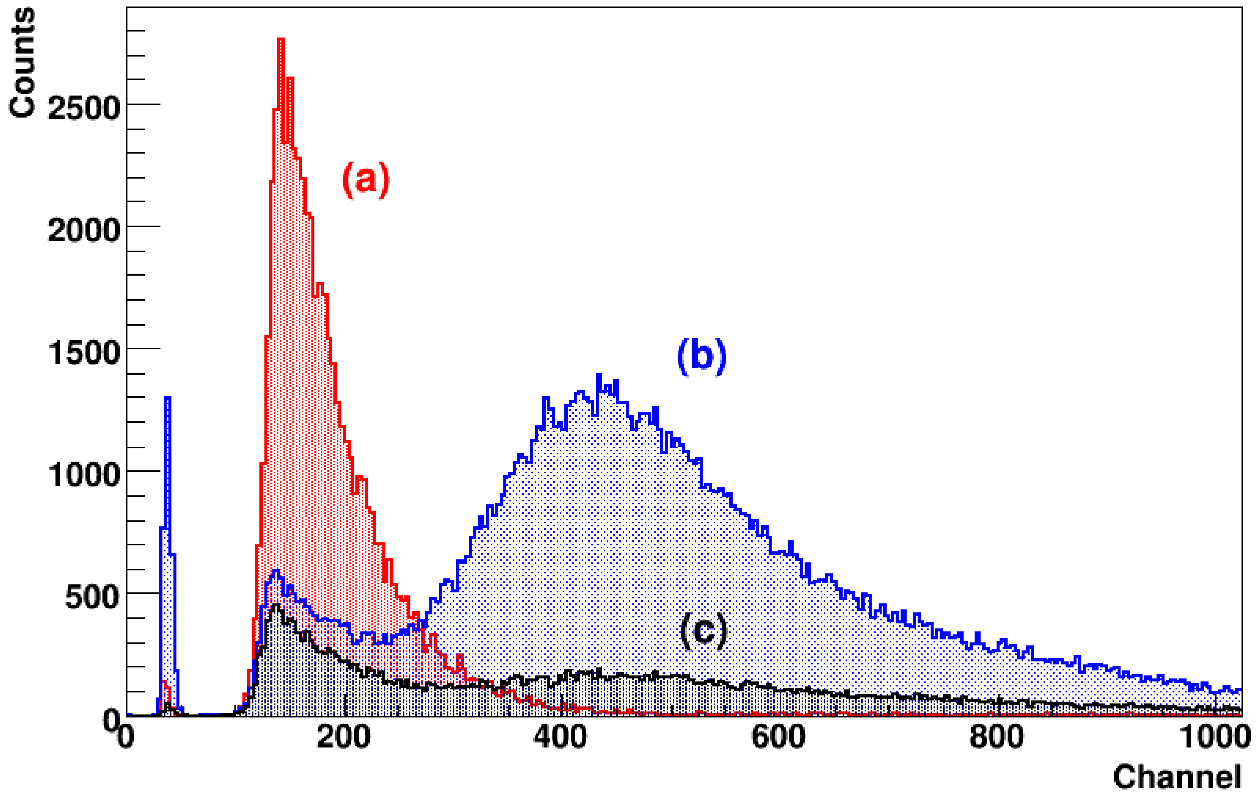
Baseline: 31.4±5.6 (LSB)

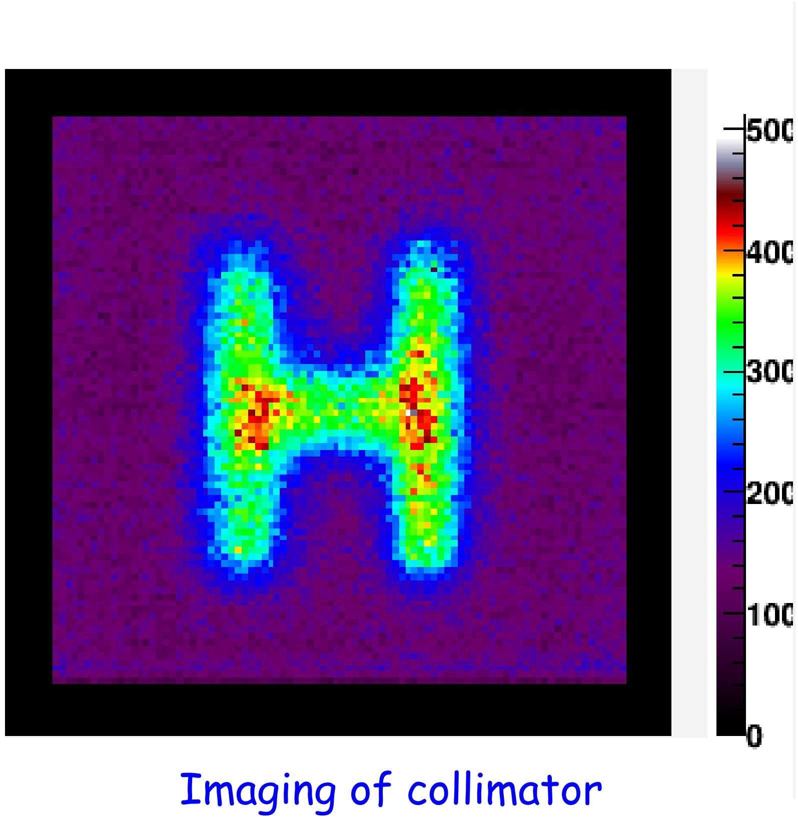
Neutron Source test

- Neutron Source: Am-Be
- The intensity: 5.18×10^5n/s (emitting in 4Pi radian);
- Average energy of the neutrons: 4.5MeV;
- The half life: 433 years.
- γ rays : 60keV, 4.438MeV, 3.216MeV, 558.6keV, 651.3keV

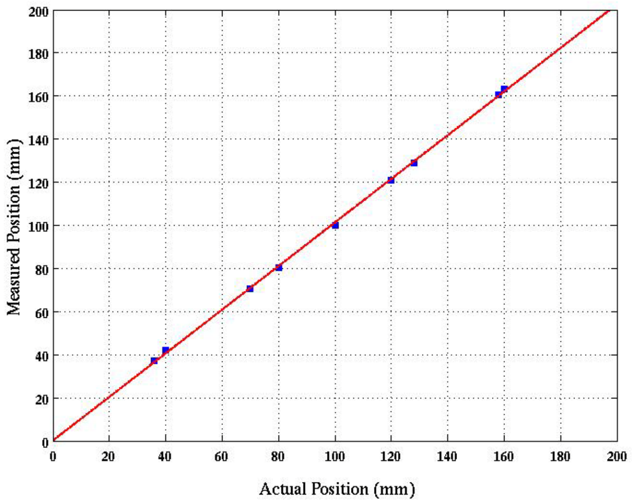


Neutron Source test





Imaging of collimator



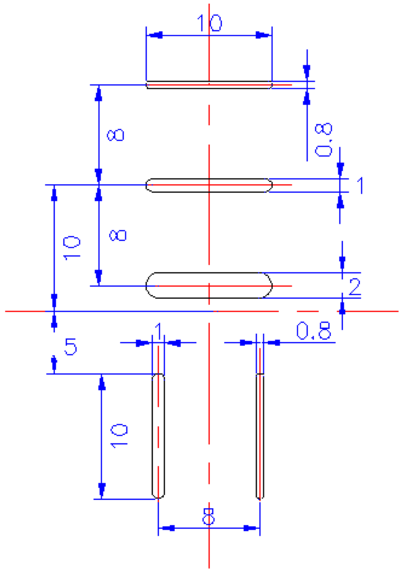
Linear of the position

(a) Tested with the ^{137}Cs gamma ray source;

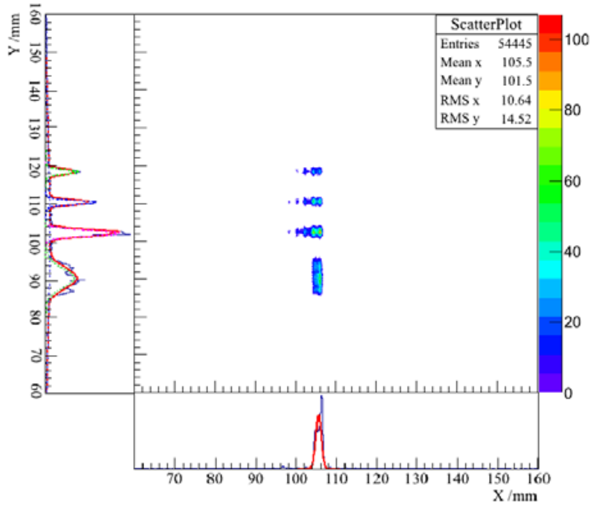
(b) Tested with an Am-Be source with a moderator before the window;

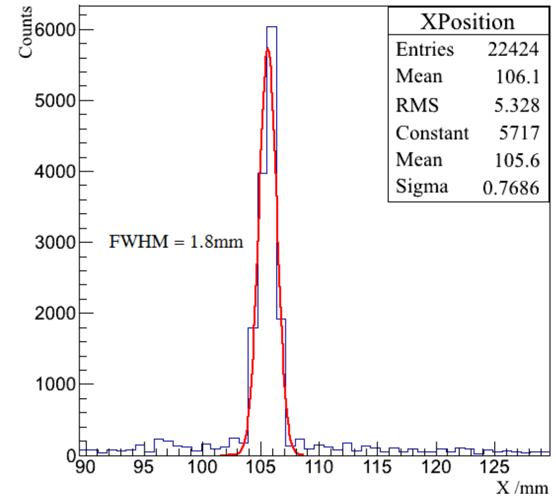
(c) The same with (b) but 4mm cadmium more covered the window to stop the thermal neutron.

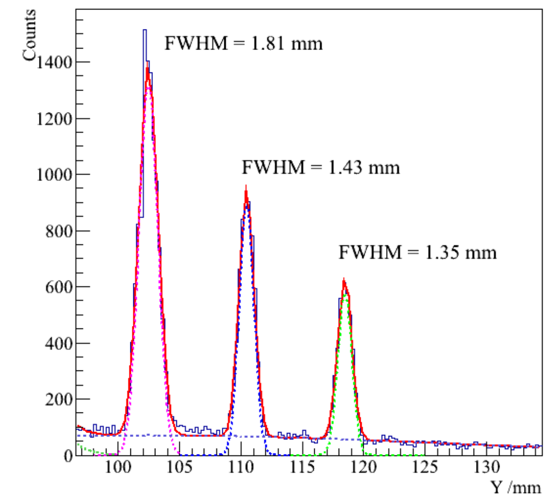
Neutron Beam test - preliminary

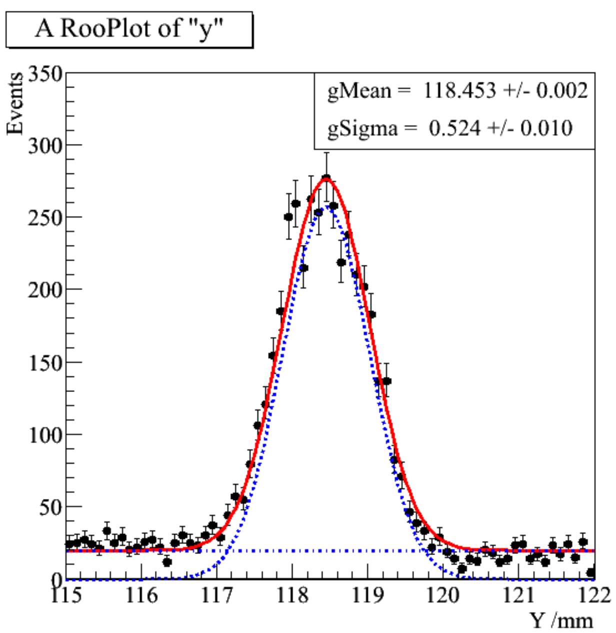


Cadmium slit









	Slit width @mm	Total resolution FWHM @mm	detector's position resolution FWHM @mm
1	0.8	1.35	1.23$\pm$0.02 mm
2	1.0	1.43	1.18$\pm$0.02 mm
3	2.0	1.81	1.22$\pm$0.02 mm

MWPC's position resolution was obtained:

X: 2.0mm(FWHM) Y: 1.2mm(FWHM)

Summary

- A two-dimensional MWPC(200mm*200mm) has already been constructed
  - Pressure stable in more than 32 days
  - Tested by 55Fe 5.9keV X-ray @Prototype
  - Energy resolution (FWHM) about 23%
  - The position resolution (FWHM) of about 378.8μm
  - Tested by Cf252 neutron source @MWPC
  - Energy map and an imaging of "H" were obtained
  - Tested by neutron beam @MWPC
  - Position resolution were obtained X: 2.0mm(FWHM) Y: 1.2mm(FWHM)

- Future prospective
  - 2D 8.0atm MWPC detector will been assembled in CSNS
  - More experiments will been continued at MR

Thank you very much !