

Status of THGEM based neutron detector in CSNS

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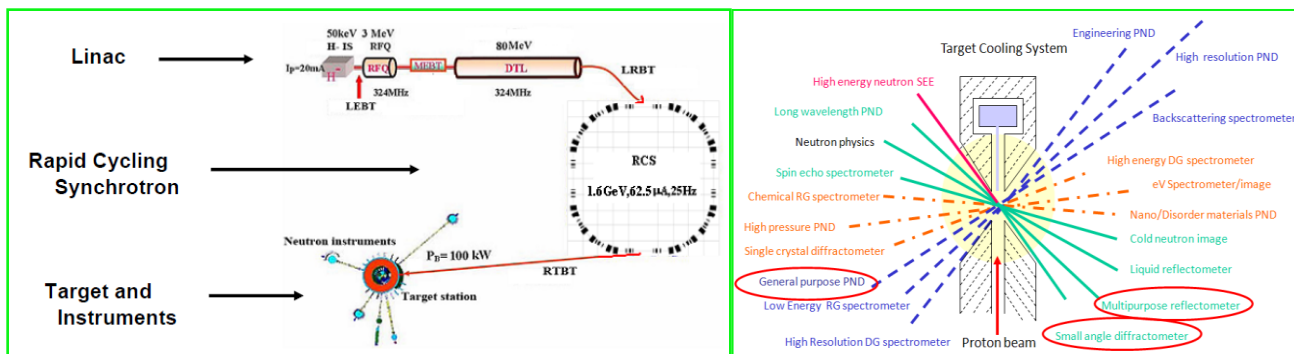
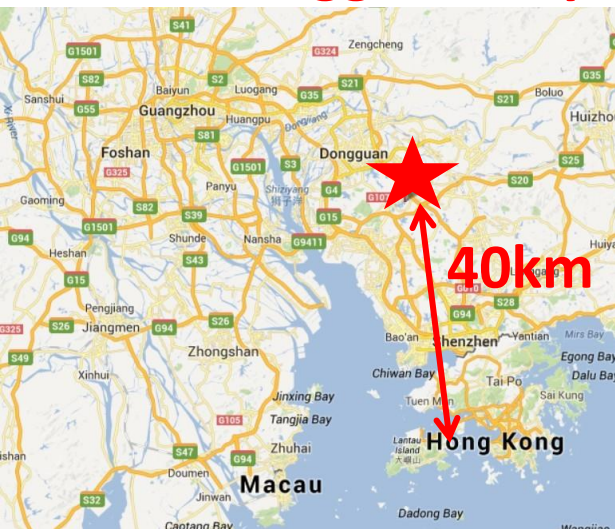


Outline

- China Spallation Neutron Source(CSNS)
- Motivation
- Detector configuration
- Performance of THGEM in Ar/CO₂ mixture
- Boron coating technology
- Prototype detector, the latest experiment results
- Summary

China Spallation Neutron Source(CSNS)

CSNS, Dongguan City



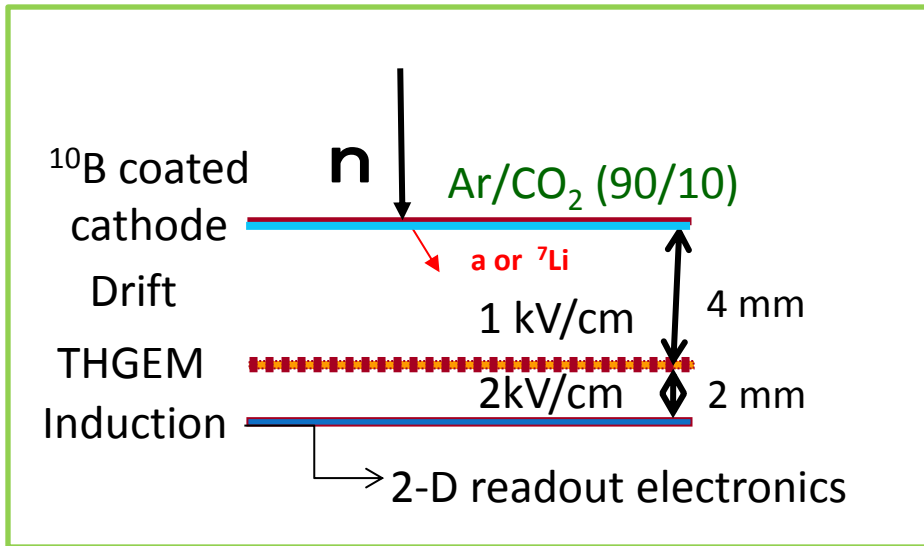
- Site: South of China and 40 km north of Hong Kong
- Budget: ~ 0.5 billion US dollars
- Specification: 1.6GeV proton@ tungsten target, 25Hz, $2.0 \times 10^{16} \text{ n/cm}^2 \cdot \text{s}$, 500kW
- Instruments: 20 in total, 3 in phase I (GPPD, SANS, MRS)
- Milestone: Groundbreaking in Oct. 2011, and the first neutron beam in Apr. 2018

Motivation

- Challenges for traditional neutron detection technologies:
 - Counting Rate Limit ~ 100 kHz
 - Global ^3He Crisis ---old News Now
- Alternatives under development:
 - ^{10}B solid, BF_3 , $^6\text{LiF/ZnS(Ag)}$ -scintillant
- A good candidate: ^{10}B coating and THGEM based
 - High counting rate ($>1\text{MHz}$), adequate gain (10^2 - 10^3), sub-millimeter spatial resolution
 - High n/ γ separation ability compared to ^3He
 - Industrial production , large-area and robust
 - Flexible detector shape and readout patterns

Detector configuration(1)

- Neutron Beam Diagnosis Detector



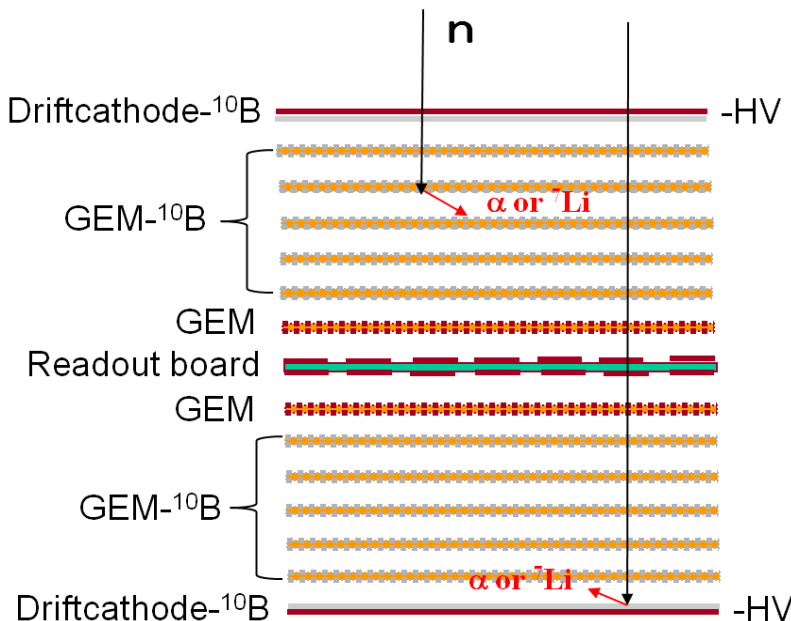
Parameter	Specification
Active Area	50mm*50mm
Neutron Flux	$<10^9 \text{n/cm}^2 \cdot \text{s}$
Spatial Resolution	$<3 \text{mm}$
Timing Resolution	$<1 \mu\text{s}$
Efficiency@1.8Å	$\sim 1\%$
Max Counting Rate	$>1 \text{MHz}$
Working mode	Real-time

- Application:

- Diagnosing neutron beam: profile, wavelength, intensity ...
- Beam Monitor ,for high flux direct measurement on line

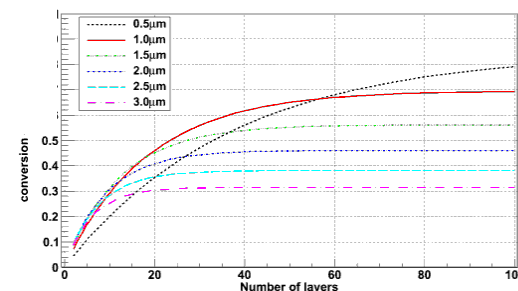
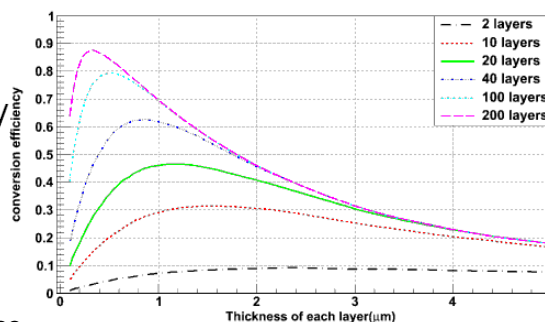
Detector configuration(2)

- Neutron Detector for Multi-function Reflection Spectrometer



Parameter	Specification
Active Area	200mm*200mm
Spatial Resolution	<3mm
Timing Resolution	<1μs
Efficiency@1.8Å	>40%
Max Counting Rate	>1MHz

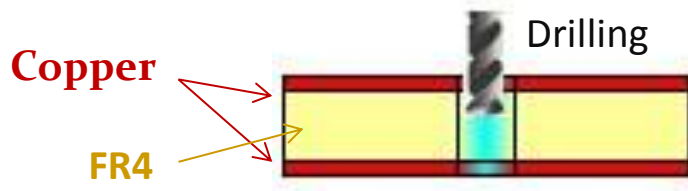
- No. of coatings: ~20
- Thickness of each ¹⁰B coating: ~1μm
- Fraction of copper covered on THGEM: > 86%



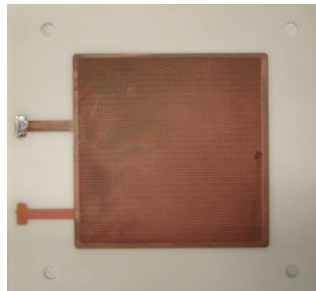
THGEM in China

- Manufactured by PCB factory in China using **standard PCB techniques**
- Thickness: 0.2-2.0mm, Insulator: FR4, ...
- Two kind of surface treatment:

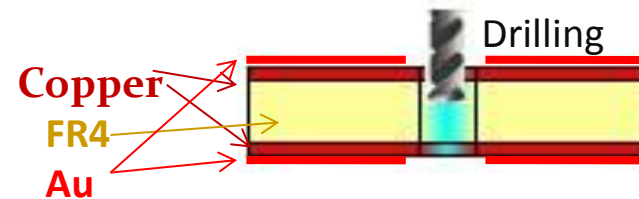
1. Cu-THGEM



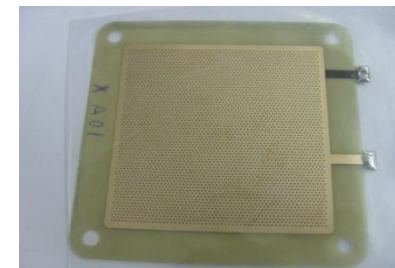
Prof. Y.H. Zheng@UCAS (see Poster)



2. Au-coated THGEM

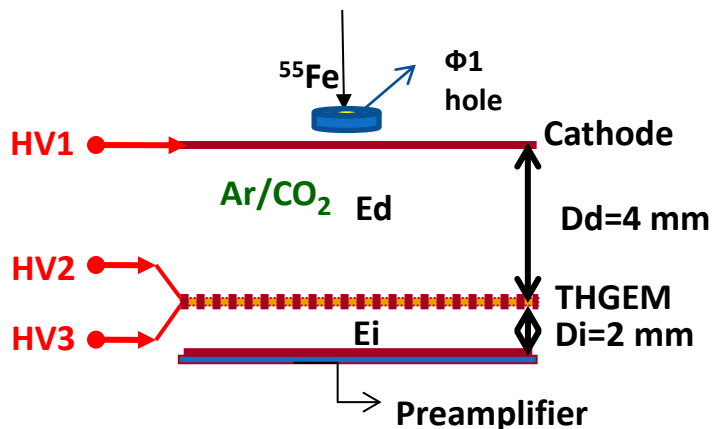


Dr. Y.G. Xie@IHEP(see Poster)



Performance of Cu-THGEM in Ar/CO₂ mixture using ⁵⁵Fe X ray

Arrangement:

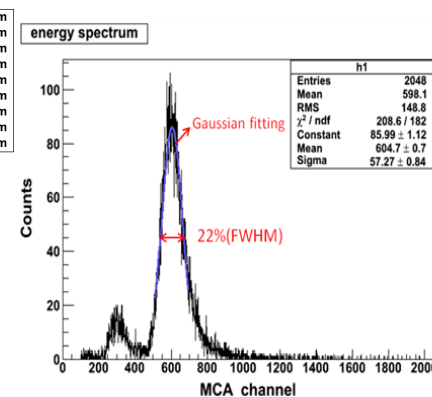
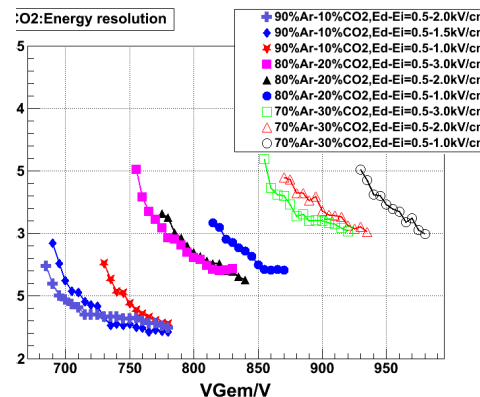
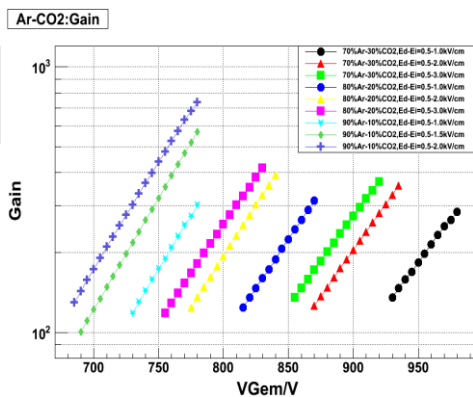
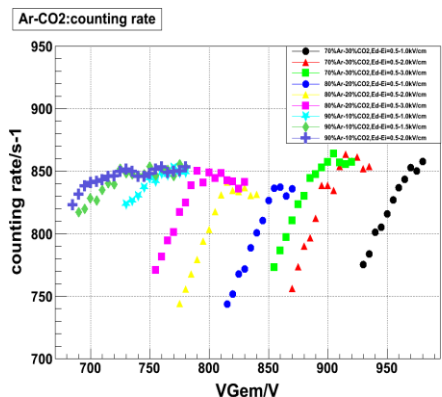


- Cu-THGEM(provided by Prof. Y.H.Zheng@UCAS) thickness 0.2 mm, hole 0.2mm, pitch 0.5mm
- Ar/CO₂ mixture: 90/10, 80/20, 70/30
- Results:
 - Mixture(90/10): higher gain at lower HV, longer plateau and better energy resolution
 - Working points: Ed 0.5kV/cm, Ei 2kV/cm, V_{THGEM} 720V-770V, Gain 100~1000

Counting rate plateau

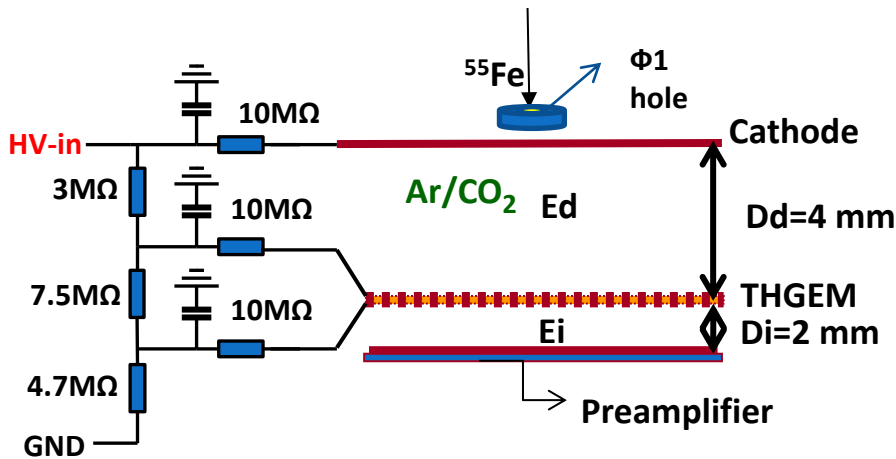
Gain

Energy resolution



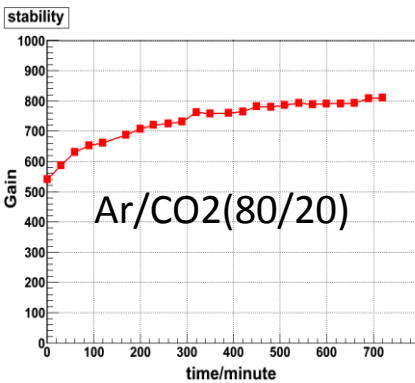
Performance of Au-THGEM in Ar/CO₂ mixture using ⁵⁵Fe X ray

Arrangement:

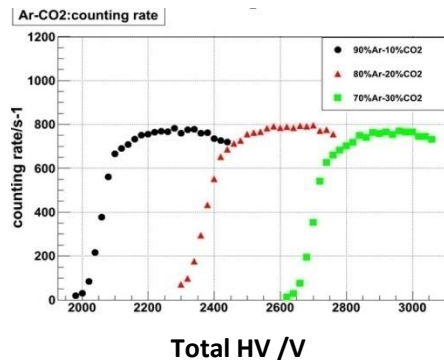


- Au-THGEM(provided by Y.G. Xie@IHEP) thickness 0.3 mm, hole 0.25mm, pitch 0.6mm
- Ar/CO₂ mixture: 90/10, 80/20, 70/30
- Results:
 - Mixture(90/10): higher gain at lower HV, longer plateau and better resolution
 - Working points: V_{total} 2100V-2400V, Gain 300~3000

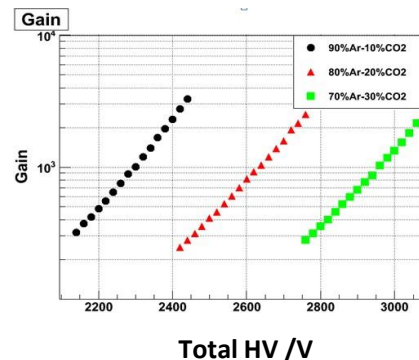
Stability@2600V



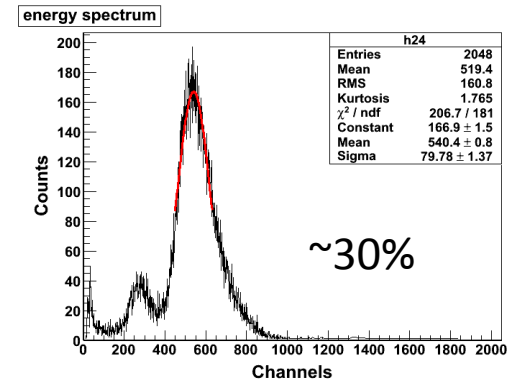
Counting rate plateau



Gain



Energy resolution



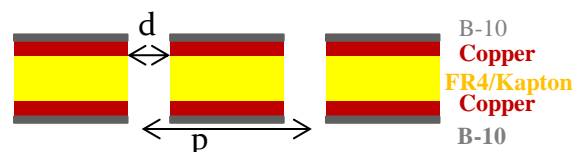
Boron coating technology(Pro. X.G. Diao, BUAA)

- Two kind of electrodes coated:

1st step: coating on the copper cathode



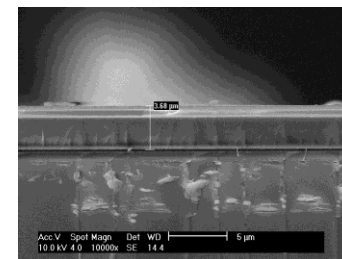
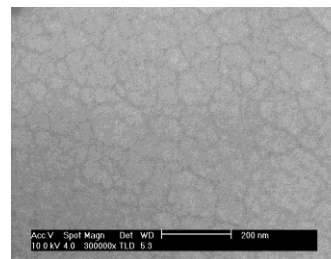
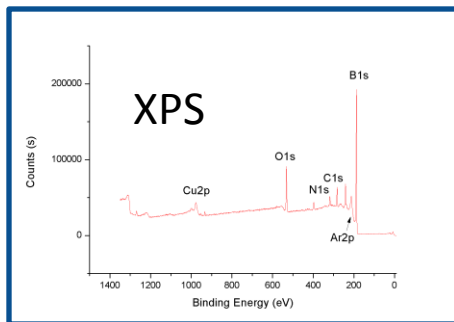
2nd step: coating on THGEM



- Requirements: 1.coating firmly 2. purity>99% 3. thickness variation <2%
- Magnetron Sputtering (Boron: insulator, melting point 2076°C,)



Magnetron Sputtering System



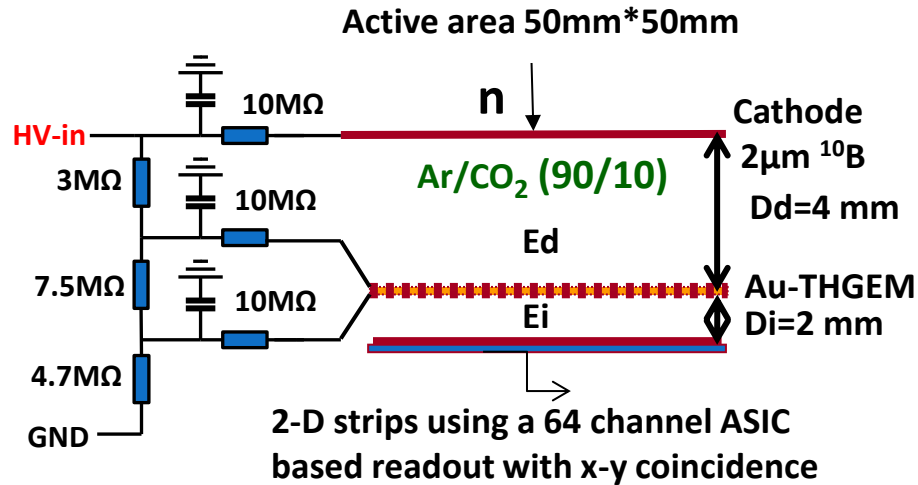
SEM

Status:

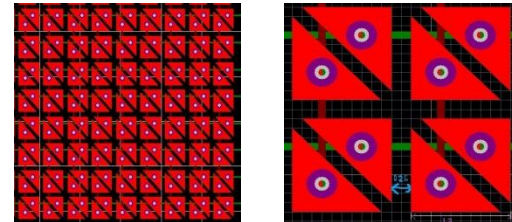
- 1st step achieved
- Next try to coat on THGEM

Prototype detector

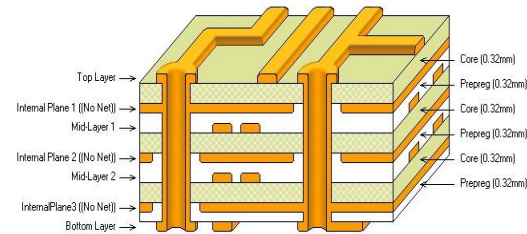
Schematic:



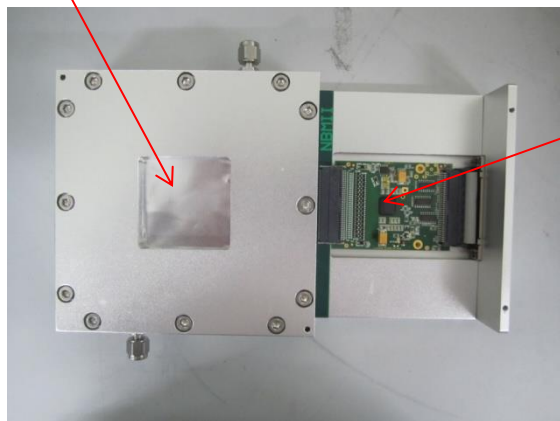
Readout board:



64 channels:
32 ch(x)+ 32ch(y)
Strip period:
1.56mm

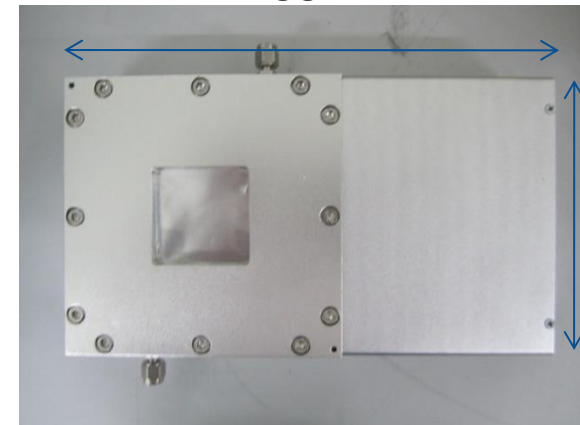


Incident window(50mm*50mm)



Front-end electronics(CDT):
64 channel CIPix-ASIC based
readout board

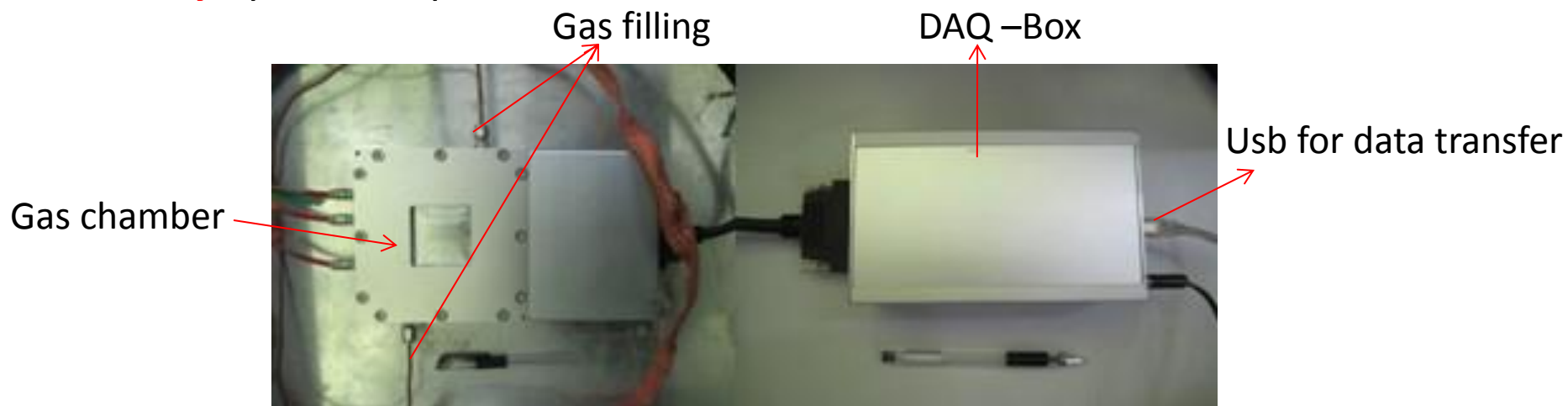
253mm



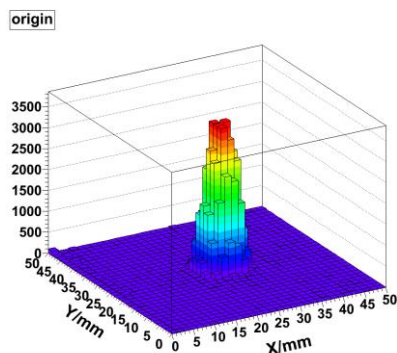
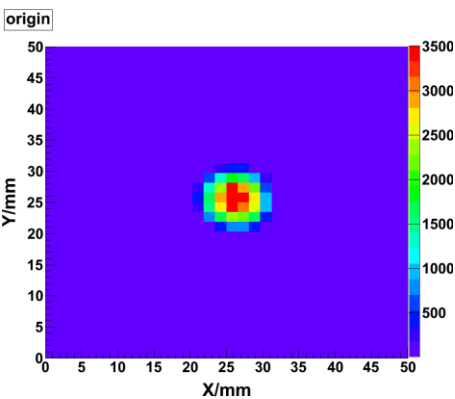
244mm

Prototype detector

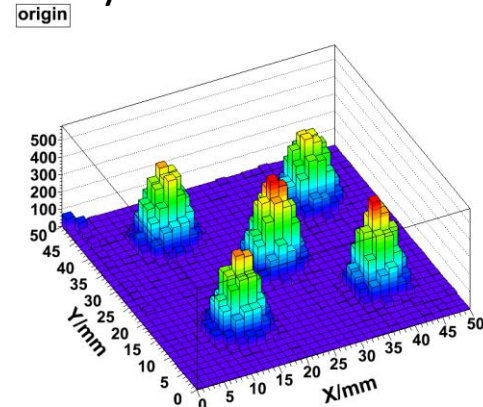
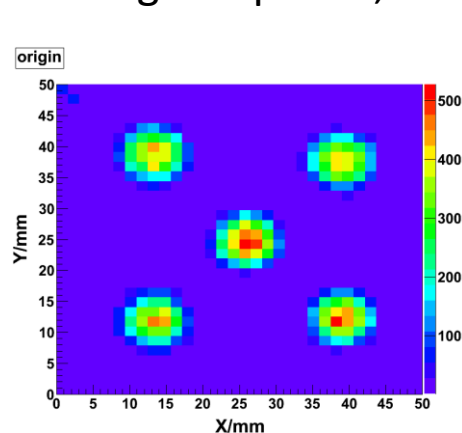
Uniformity by ^{55}Fe X ray source



Collimator $\Phi 2$



Scanning five points, uniformity better than 95%

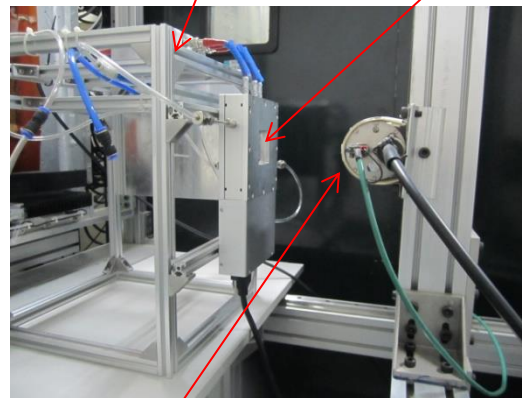


Prototype detector

Counting rate by X ray tube

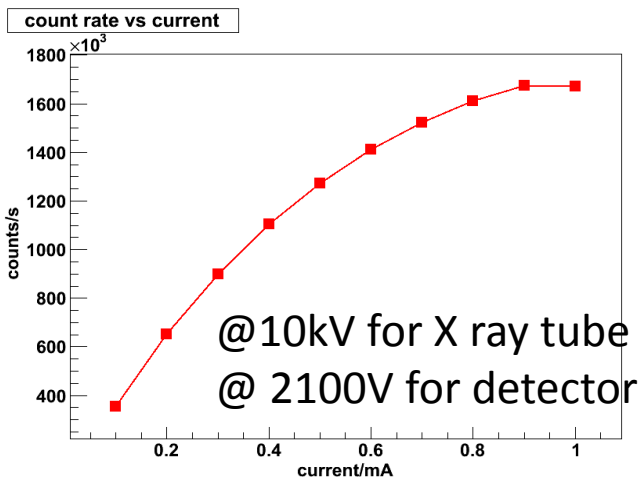
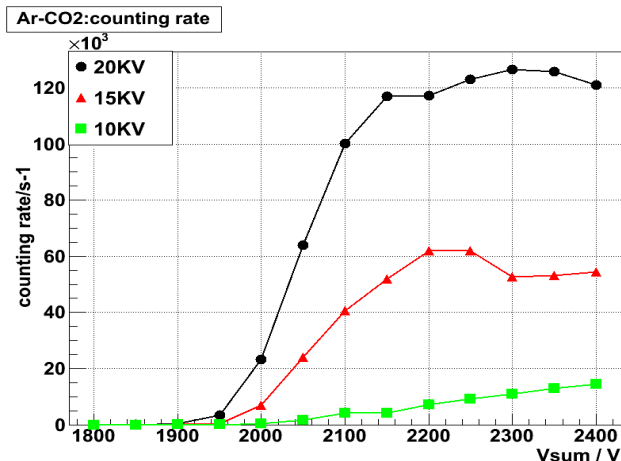
Oxford X ray tube :
Target: copper
Energy: 8 keV
HV: 10-50 kV
Current: 0.1-1mA

HV distribution Detector



X ray tube

Counting rate Vs total HV



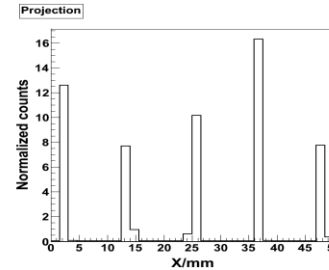
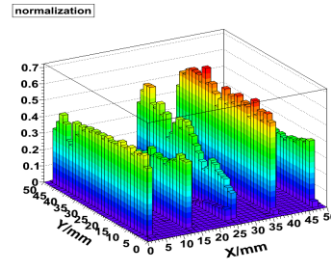
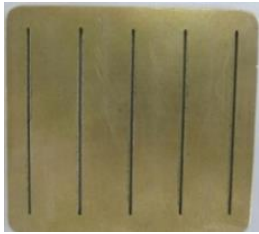
Results:

- Good linearity (<1MHz)
- Signal pile-up(>1MHz)
- DAQ stop at ~2MHz

Prototype detector

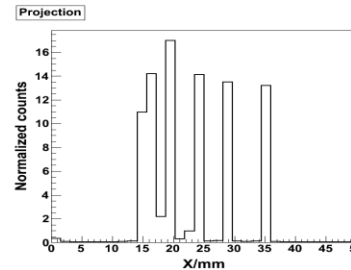
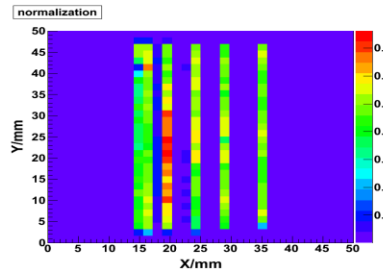
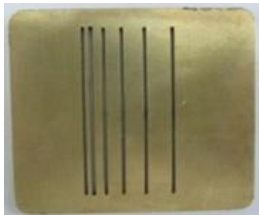
Spatial resolution

Method 1: 2mm thick copper mask, slit 0.7mm, pitch 10mm



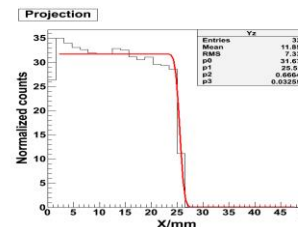
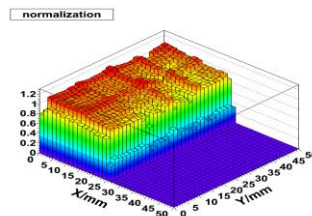
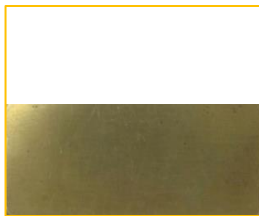
Resolution: 1 pixel 1.56mm

Method 2: 2mm thick copper mask, slit 0.7mm, pitch 1,2,3,4,5mm



2mm separation capacity

Method 3: 2mm thick copper mask for half area

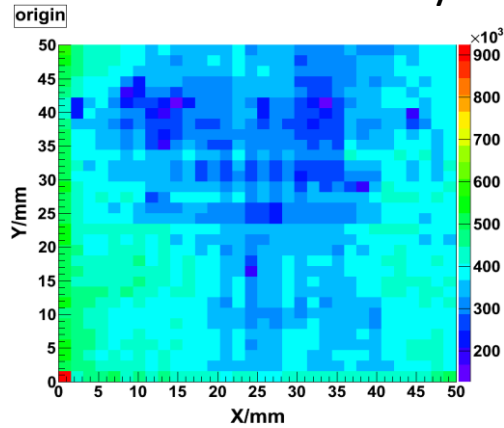


Gaussian cumulative function fitting
Resolution:
1.57mm(FWHM)

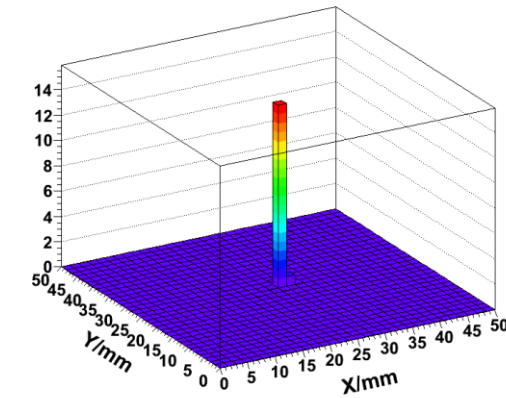
Prototype detector

2- D Imaging

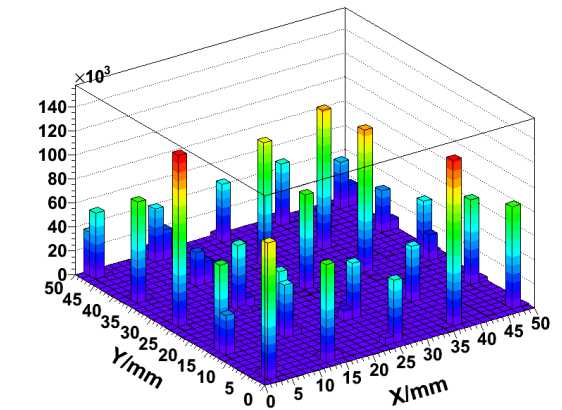
Profile of incident X ray tube



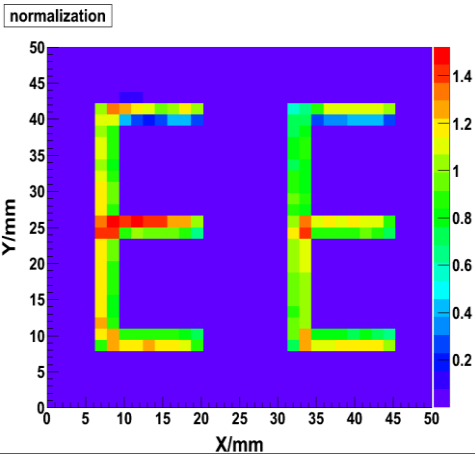
normalization $\Phi 0.5\text{mm hole}$



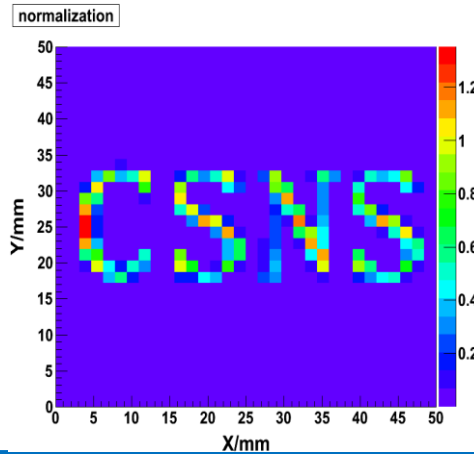
origin $\Phi 0.5\text{mm hole grid}$



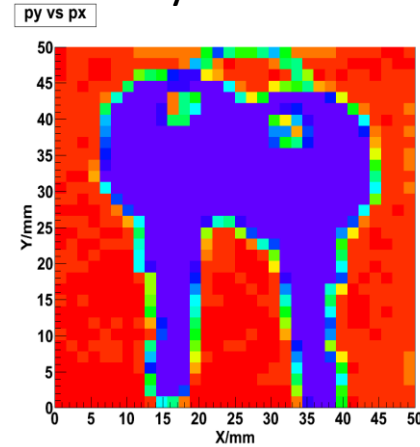
Mask with double E



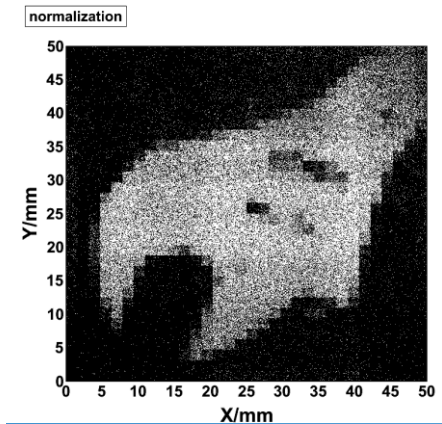
CSNS



Keys



Spanner



Prototype detector

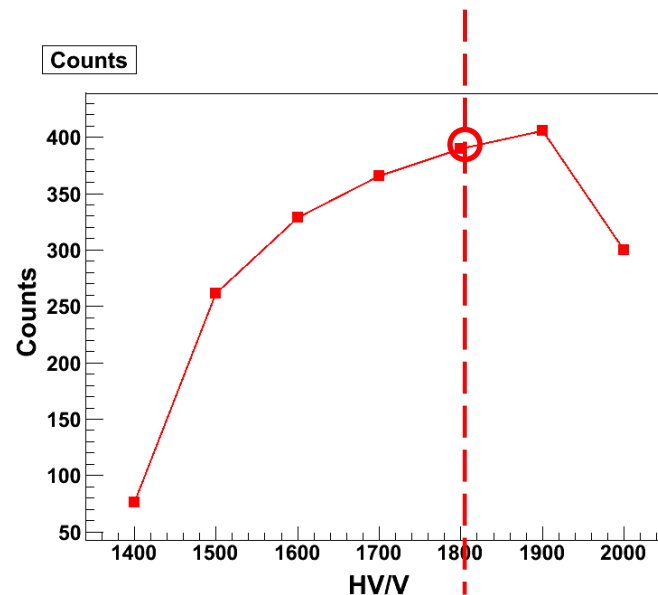
Test with neutron source ^{252}CF



Counting rate Vs total HV

Specifications:

- CF-252 Activity: 20MBq
- Diameter of neutron pipe: $\Phi 100$
- Incident thermal neutron flux : $\sim 1\text{n/cm}^2.\text{s}$

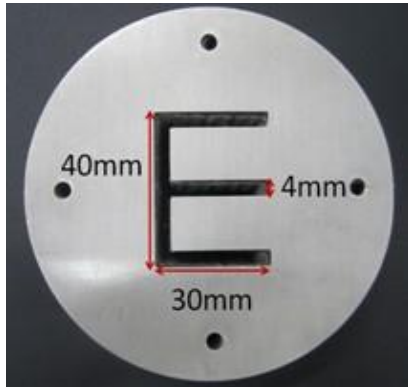


Total HV:
1800V for measurement

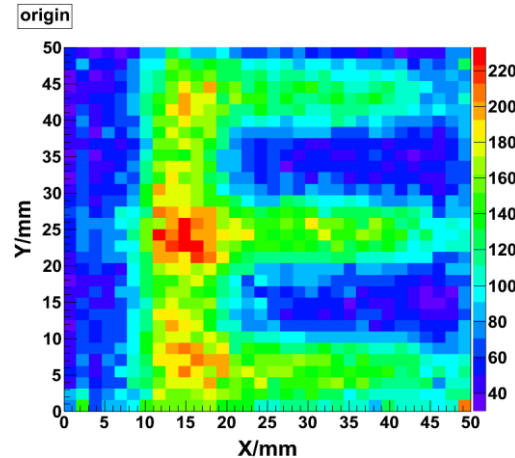
Prototype detector

2-D imaging

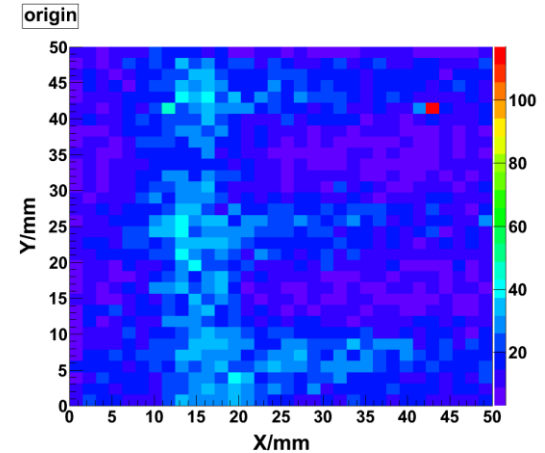
1mm thick Cd mask



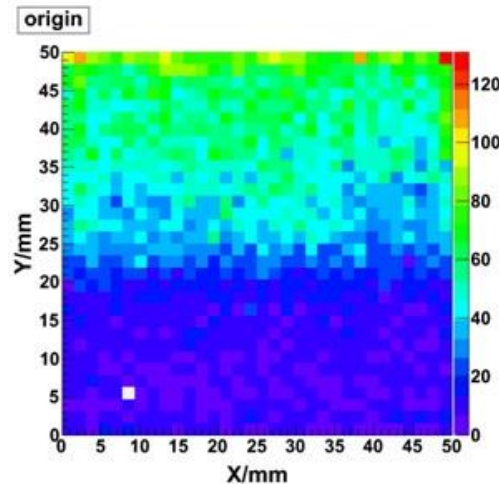
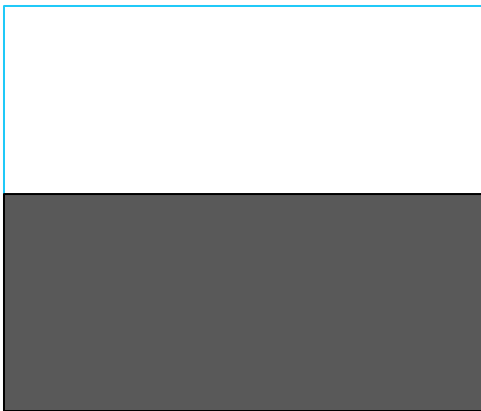
Without a moderator



With a 80mm long C₂H₄ moderator



1mm thick Cd mask for half area

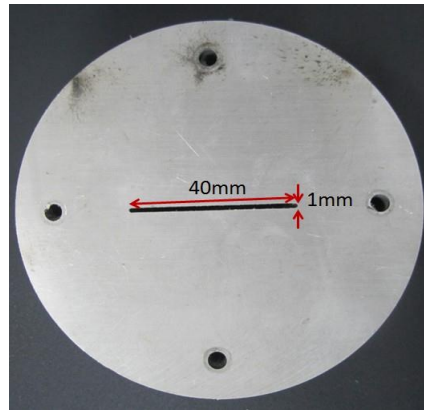


Results:

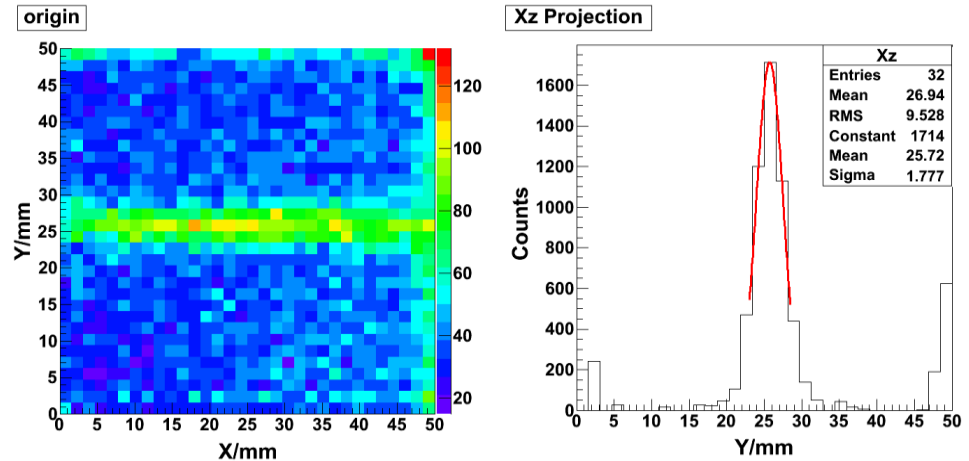
- More counts without a moderator
- Higher image contrast with a moderator

Prototype detector

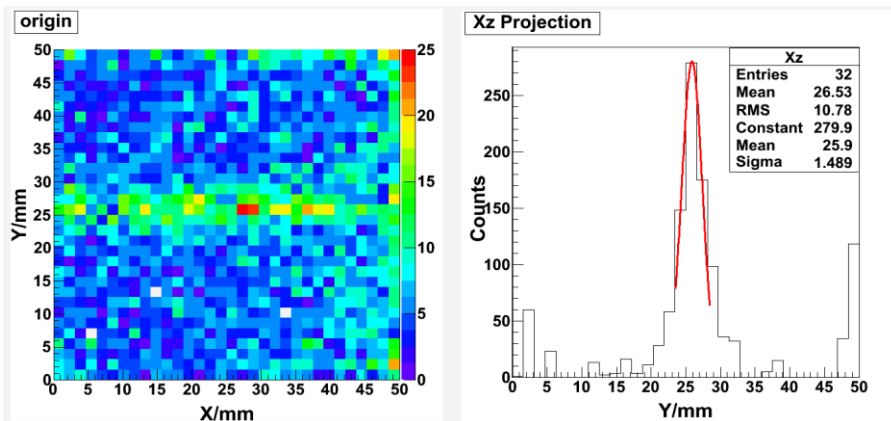
Spatial resolution



Without a moderator



With a 80mm long C_2H_4 moderator



- Spatial resolution
 - with moderator, 4.2mm(FWHM)
 - Without moderator, 3.5mm(FWHM)
- Due to the source much weak , the result is not ideal. We are searching a neutron beam line for further test.

Summary and Outlook

- A prototype with THGEM-based neutron detector has been developed, and it works very well.
- Counting rate for total area: >1MHz
- Spatial resolution
 - 1.56mm(FWHM)@8keV X ray
 - 3.5mm(FWHM)@²⁵²CF neutron source (will be expected better in beam test)
- Boron coating technology
 - Successfully coat on copper cathode with Magnetron Sputtering
 - Next to coat on the THGEM foil
- Need customized, robust thinner GEM for neutron detection

Thank you

