The 24th meeting of the International Collaboration on Advanced Neutron Sources

The future and the present of neutron detectors for instruments at China Spallation Neutron Source

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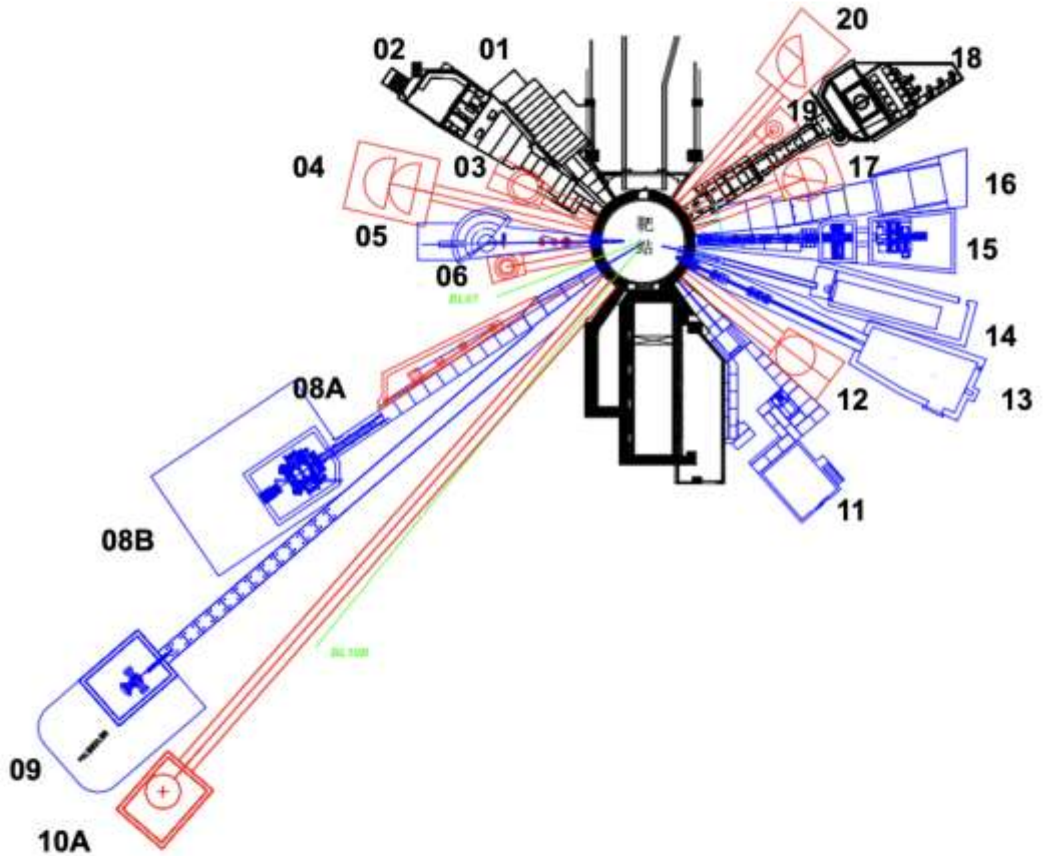
Contents

Report Outline

Introduction to the detector and electronics team

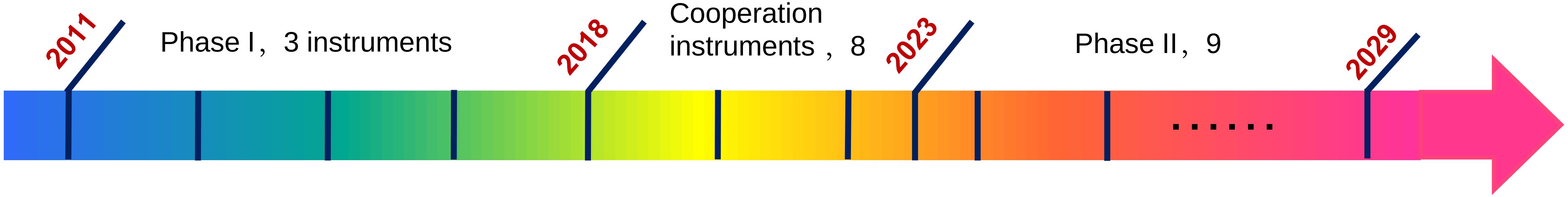
- **Team Mission:**
  - **Focusing on the requirements of the CSNS neutron Instruments**
  - **Developing advanced neutron detection system**



- **Team composition:**
  - **Professors: 4, Senior Researchers: 11**
  - **Total Number of Members: 40+**
  - **Expertise: Detection Physics , Electronics, Data Acquisition, Mechanics, and Engineering Processes**
  - **Average Age: ~35 years old**

Roadmap

- **Provide a complete solution for neutron instruments at CSNS (detector "family")**



Detector

- **Neutron Scattering experiments**
  - Diffraction, Inelastic; Large area coverage ($>1m^2$, Res ~cm) → ^{3}He tube array detector; Scintillation detector
  - SANS, Reflection; High spatial resolution ($<1m^2$, Res ~ mm) → GEM neutron detector; Beam monitor
- **Neutron imaging experiments**
  - Large FOV or High spatial resolution (20cm*20cm, Res ~ μm) → Scintillator coupled with CCD camera
  - Timing resolution for energy resolution (Timing Res ~1μs, Res ~10 μm) → nMCP detector; Scintillator coupled with TPX4Camera

Contents

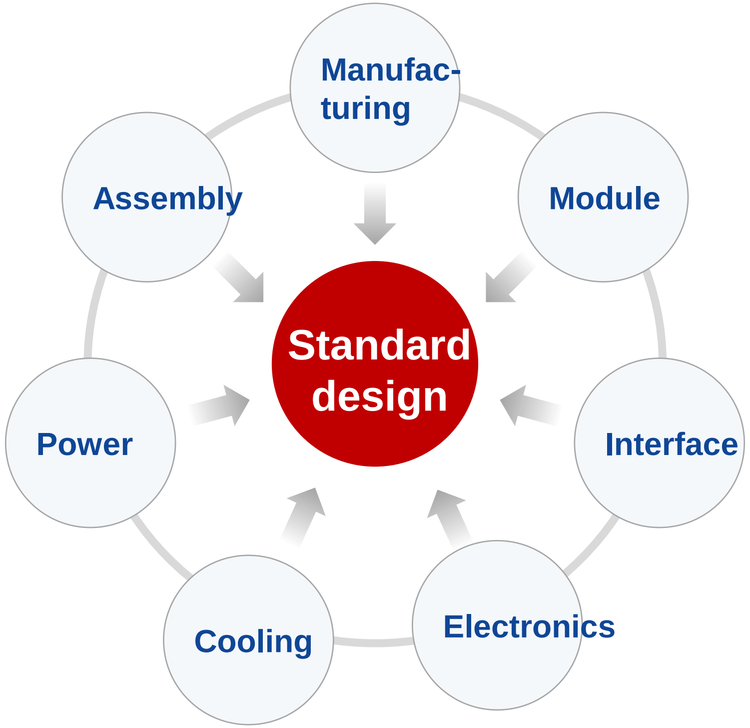
Report Outline

Large-Area ^{3}He Tube Array Detector - Standardization

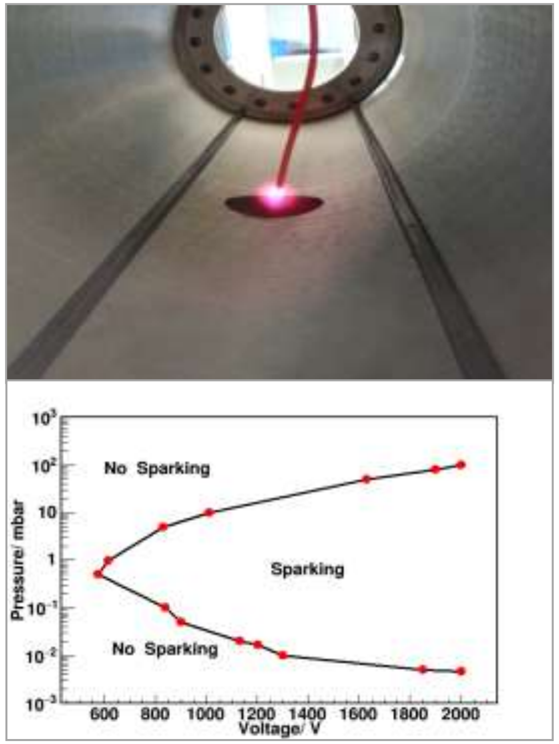
A continuously optimized and Standardized Engineering Design

- Three technical solutions for atmosphere, high vacuum and low vacuum
- Solve vacuum discharge, electronics cooling, space limitation, system noise and channel consistency.

Standardized Engineering Design



HV Discharge in vacuum



Continuously upgrade solutions

- Module design with 8 or 16 tubes
- Key component from multiple supply, avoiding single source dependency.
- FEE close to detector to reduce noise
- Optical fiber connections between devices to prevent electromagnetic interference.
- Improve stability and real-time monitoring

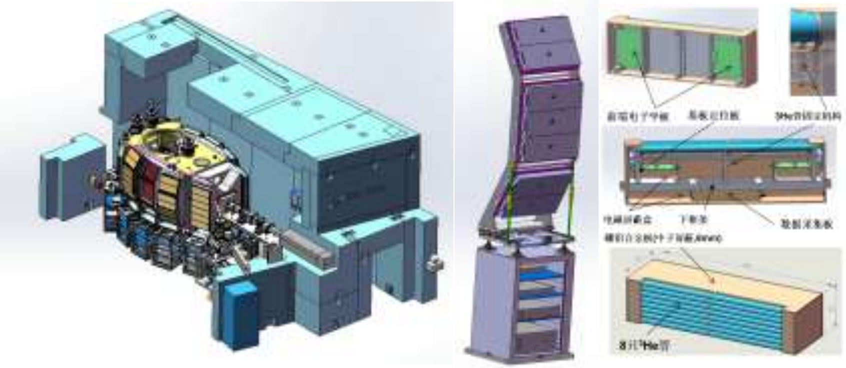
Large-Area ^{3}He Tube Array Detector - Atmosphere

Multi-Physics Instrument (MPI) detector system

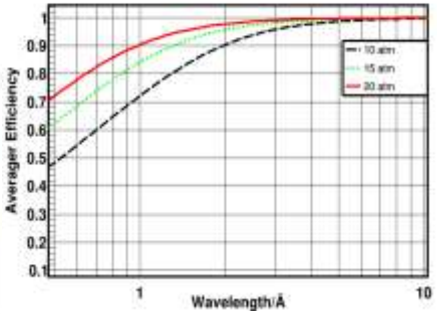
RDTM 2021, 5: 200-206. Nuclear Science and Techniques, 2022, accepted

- Large-area coverage: 6.6m^2 (544 1-inch diameter ^{3}He tube)
- Start operation in July 2021 and run stably for 2 years

Detector system design

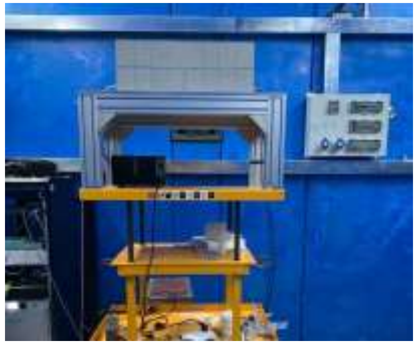


M.C. simulation

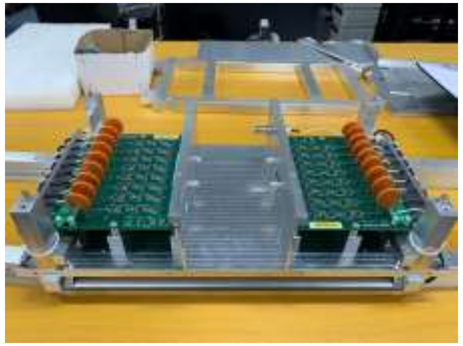


Technical review

Beam test



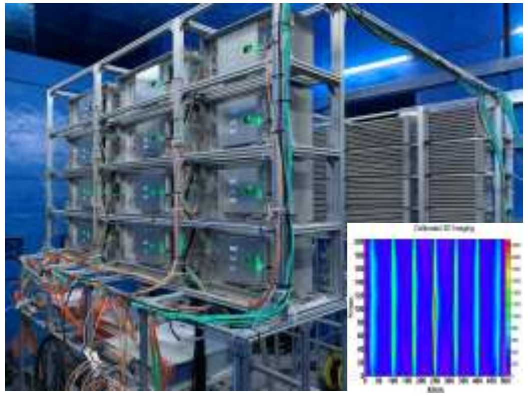
Key technology



Mass production

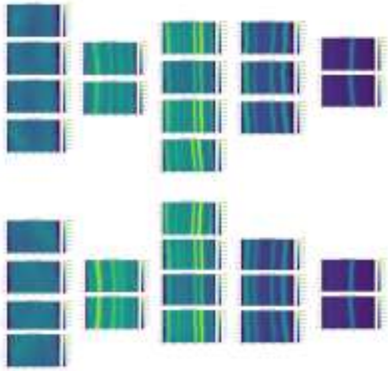
Assembly & testing

System calibration



On-site installation

Sample experiment

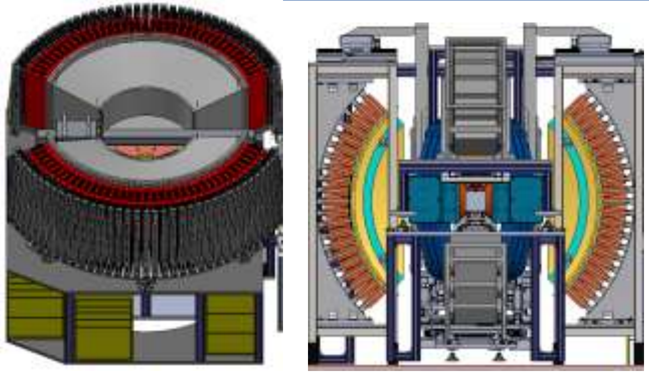


Large-Area ^{3}He Tube Array Detector - High Density

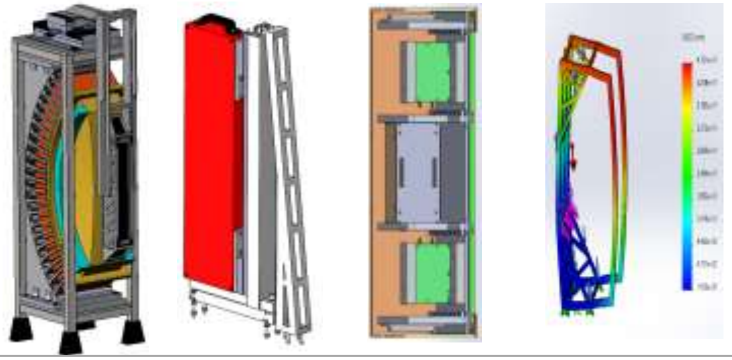
High Pressure Neutron Diffractometer (HPND) & High Resolution Diffractometer(HRD)

HPND: 928 8mm/half-inch ^{3}He tube, one module with 16 tubes, finished in next 6 months.

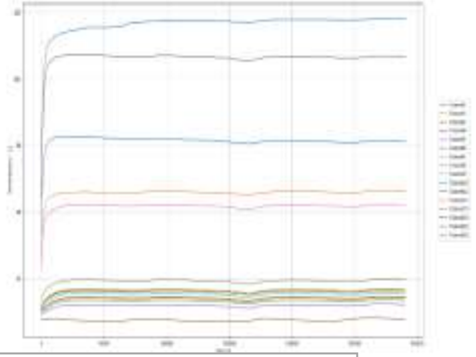
Engineering Design of HPND



Detector Module Design

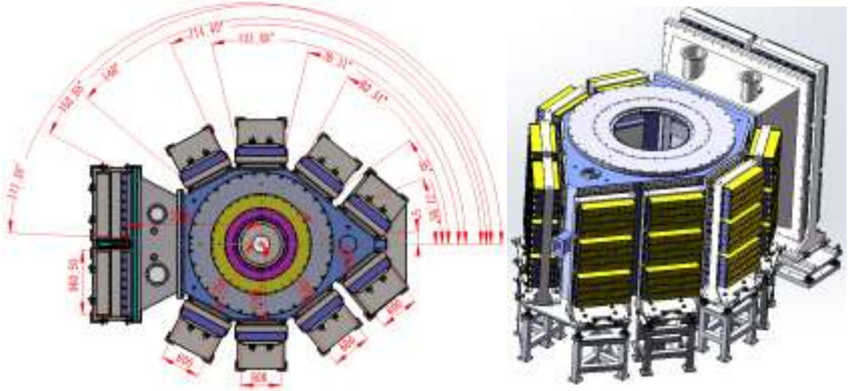


Prototype Development & Testing

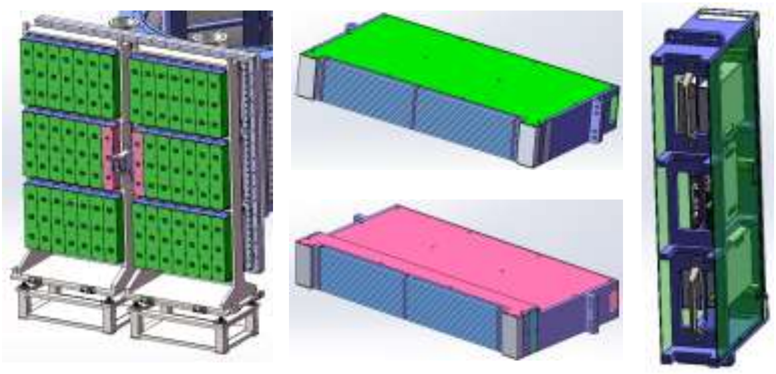


HRD: 1376 8mm/half-inch ^{3}He tube, one module with 16 tubes, finished in next 6 months.

Engineering Design of HRD



Detector Module Design



Prototype Development & Testing

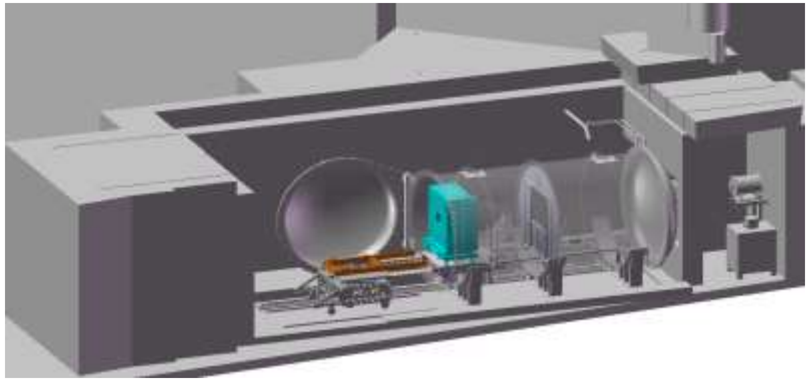
Large-Area ^{3}He Tube Array Detector - Low Vacuum

Nuclear Science and Techniques, 2022, 33: 89

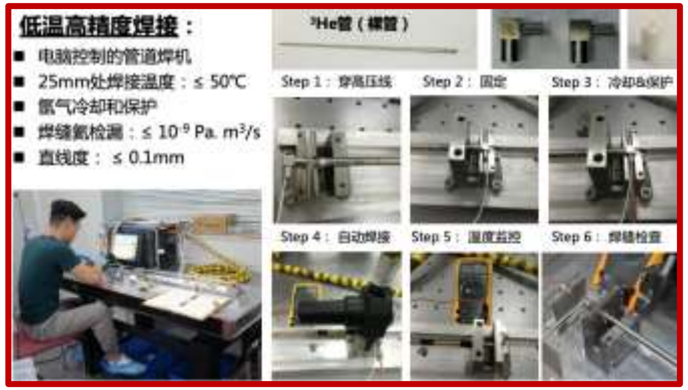
Small-Angle Neutron Scattering (SANS) detector system

- 120 8mm diameter ^{3}He tubes, small space, low vacuum environment (10Pa), movable base.
- All-metal connections and low-temperature welding. Operating stably for 5 years.

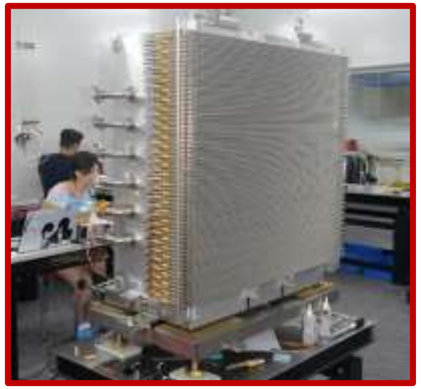
Detector system design



Low temperature and high precision welding on ^{3}He tube



All metal pipeline connection



Readout Electronics

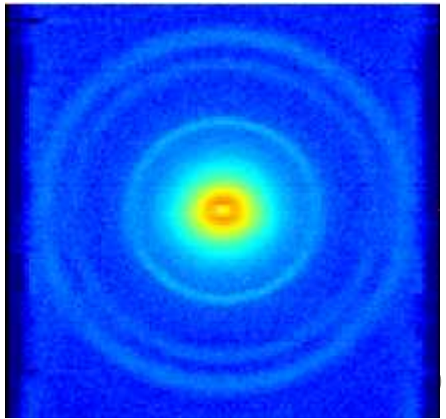
Beam test

Assembly and testing

On-site installation

Nature News @2017.11.1

Sample experiment

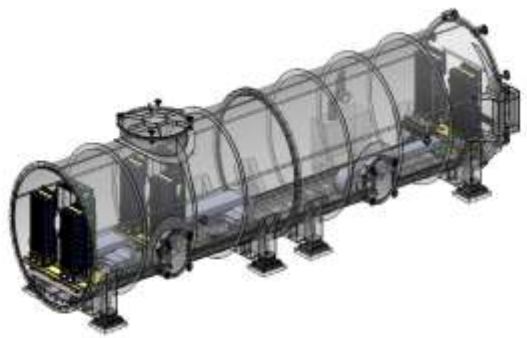


Large-Area ^{3}He Tube Array Detector - Low Vacuum

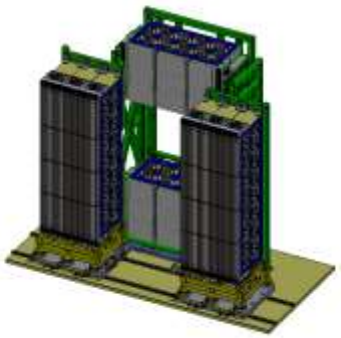
Very Small Angle Neutron Scattering (VSANS) detector system

- 512 8mm diameter ^{3}He tubes, low vacuum environment (10Pa), movable base.
- One module with 16 tubes. On-site commissioning is underway.

Detector system design



Module design



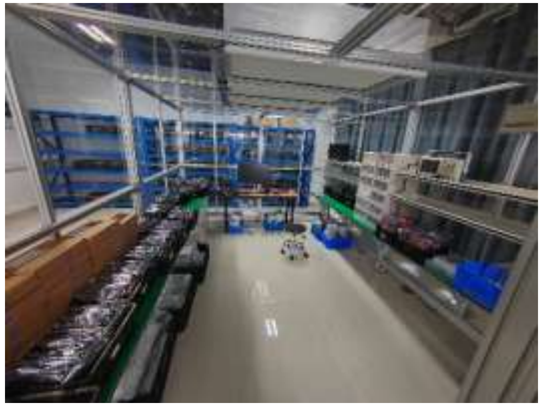
Technical review

Prototype development

key technology

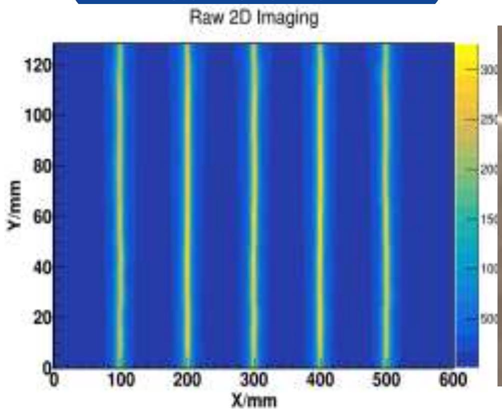
Batch manufacturing

Assembly and testing



Beam test

Calibration



On-site installation

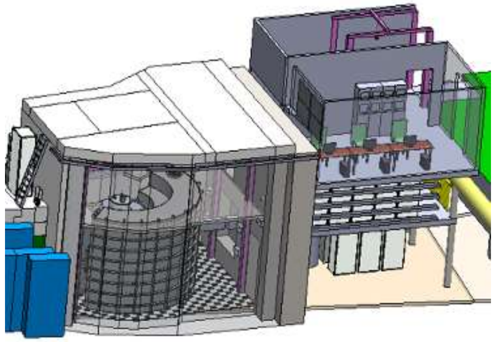
Large-Area ^{3}He Tube Array Detector - High Vacuum

SNS CHINESE ACADEMY OF SCIENCES

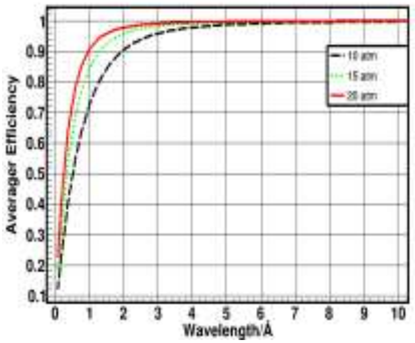
High energy Direct geometry inelastic neutron scattering instrument

- 264 1-inch, 3 meters long ^{3}He tube, high vacuum environment (10^{-4}Pa).
- The detector installation has been completed and systematic commissioning is underway.

Detector system design



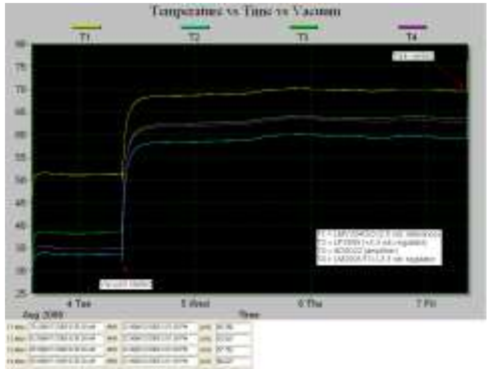
M.C. simulation



Technical review

Prototype development

key technology research

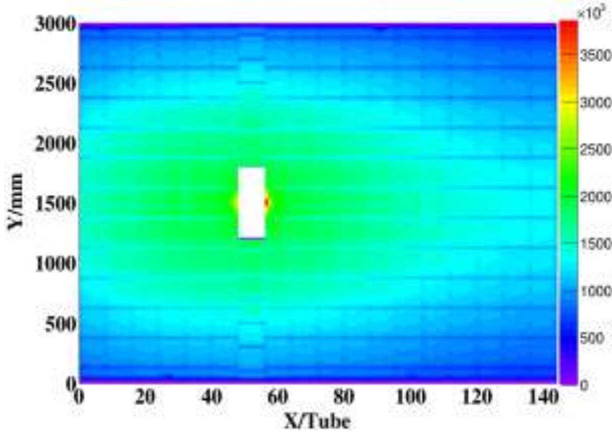


Mass production

Assembly and testing

On-site installation and commissioning

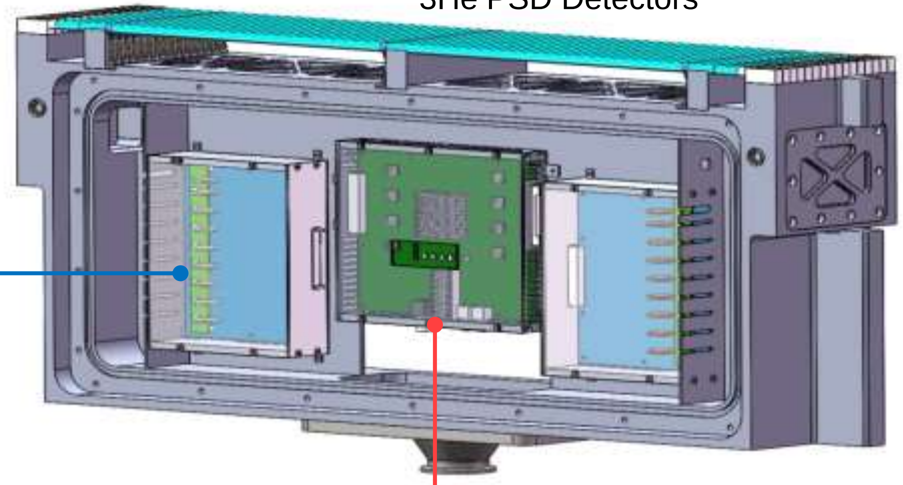
Position Calibration

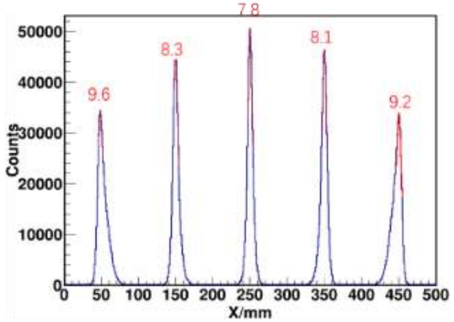


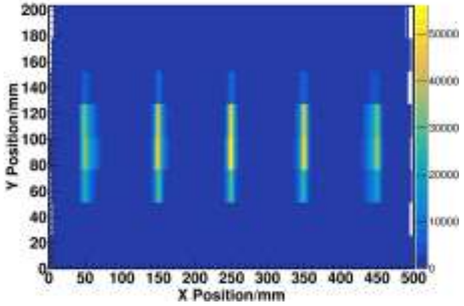
Large-Area ^{3}He Tube Array Detector Readout Electronics

Based on customized high-density pre-amplifier ASIC, with induvial DAC for threshold tuning

3He PSD Detectors







Pre-Amplifier Board x 2
- 8 channels
- CSA + CRRC + Single-ended to differential
- Shaping time: ~ 2 us
- High-Voltage distribution
- Power consumption: ~ 4 Watt

Digitization Board
- 16 input channels
- FPGA: Virtex5-LX85T
- Waveform sampling of 65 Msps @ 14bit
- Peak finding and hit-position calculation by charge division method
- Optical SiTCP for DAQ
- Power consumption: ~ 5 Watt
- T0/ID receiver for timing and tagging

Specs	Requirement	Results
Dynamic Range	100 - 800 fC	100 - 830 fC
Charge Resolution	< 15 fC	< 5 fC
INL	< 1%	< 0.5%
Counting Rate (Channel, peak)	> 100KHz	> 100KHz
Timing Resolution	< 1us	< 20 ns
Position Resolution	< 10 mm with 1m tube	< 8 mm

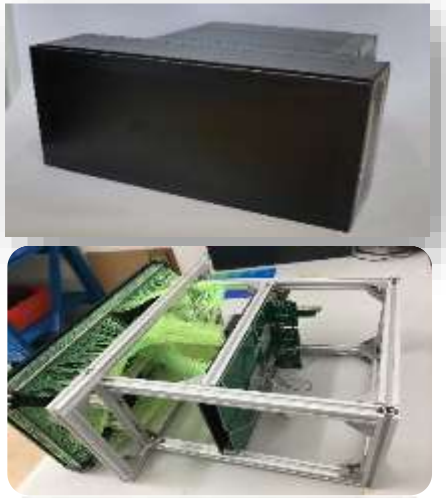
Large-Area Scintillator Detector

Module design: front-end digital for fast readout, highly integration and easy assembly

2010~2018

First-generation

- **0-> 1 Breakthrough**
- **laboratory-level to engineering-level products**



- **Engineering application: GPPD spectrometer 6m^2 space coverage**

2018~2023

Second -generation

- **Performance further improved**
- **implementation of batch production**

- **High integration, low power consumption**
- **Engineering application: EMD, ERNI and other spectrometers 8m^2 area coverage**

2023~2029

Third -generation

- **More compact**

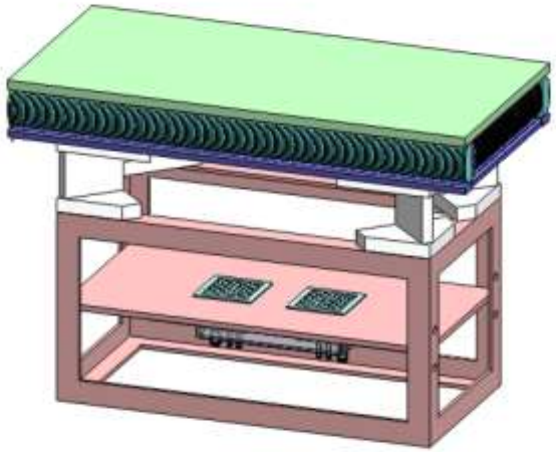
- **High spatial resolution: <1mm**
- **Can work in vacuum environment**
- **Domestic Key Components**
- **Engineering application: CSNS II**

Large-Area Scintillator Detector – 1st generation

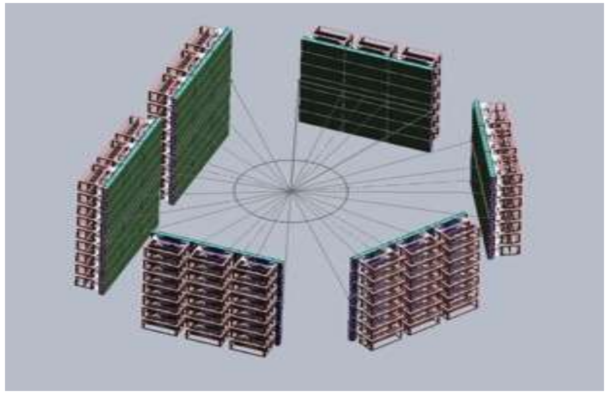
Flat Panel Scintillation Neutron Detector for GPPD

- Detection area 6m^2, $^6LiF/ZnS(Ag)$+WLSF+MA-PMT
- Start operation from August 2018 and run stably for 5 years.

Detector module design

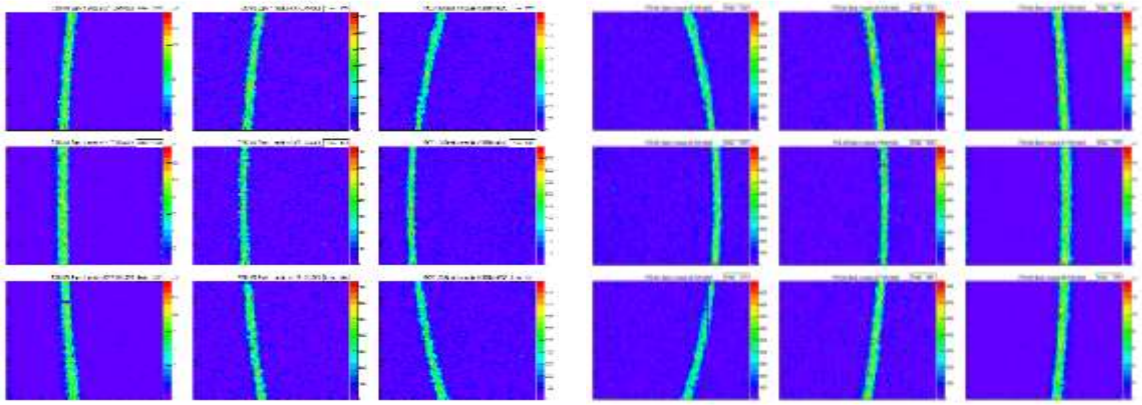


Detector array design

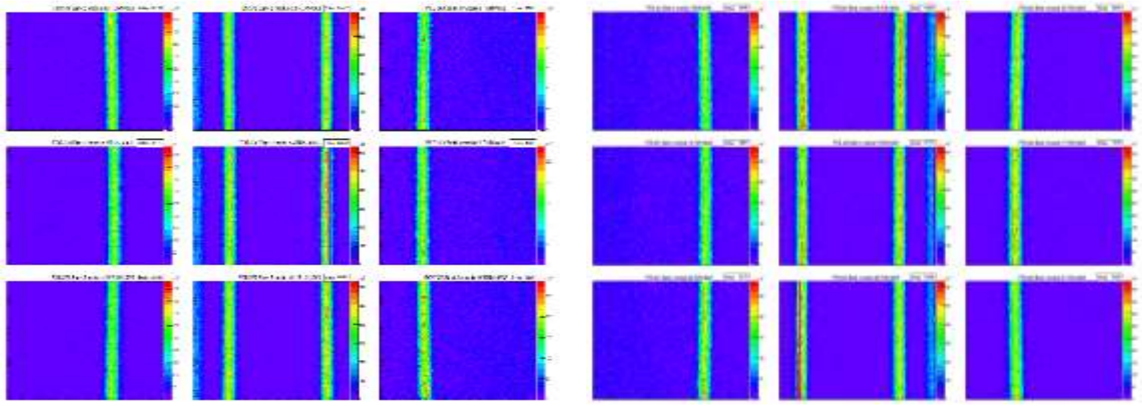


Sample experiments

Bank1 and Bank2



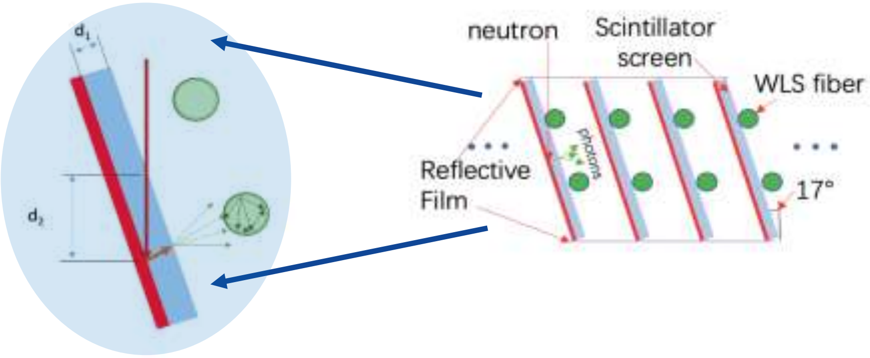
Bank3 and Bank4



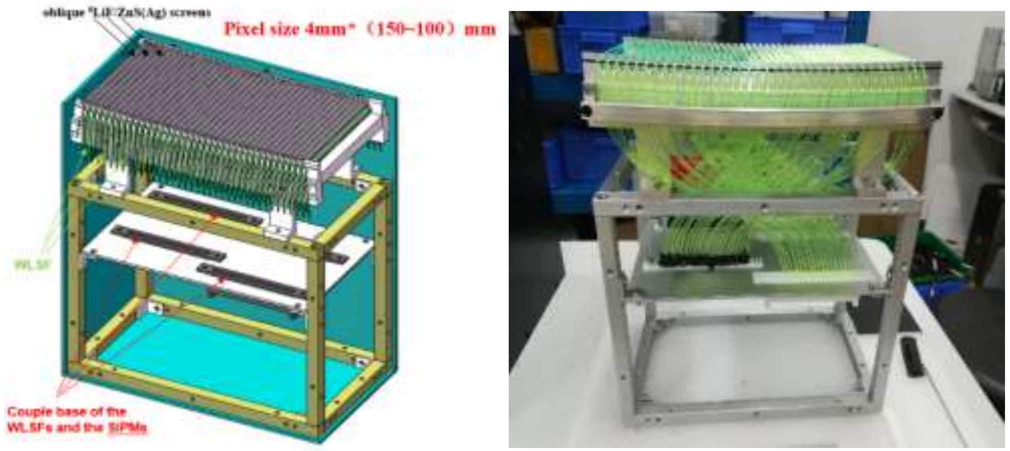
Large-Area Scintillator Detector – 2nd generation

Oblique Incidence Scintillation Detector Based on SiPM

- 80 detector modules, including electronics, SoC, power supply, temperature monitoring, temperature compensation modules.
- Commissioning is under way



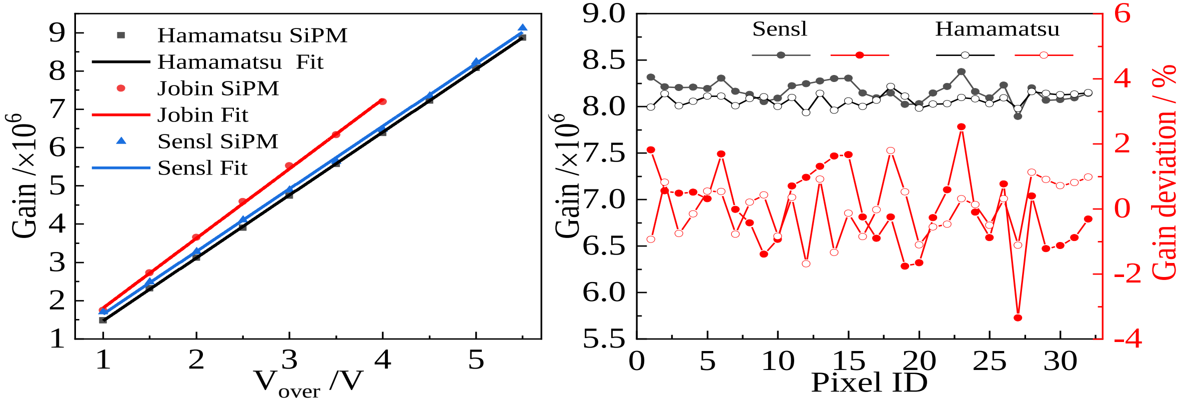
$$n + {}^{6}\mathrm{Li} \rightarrow \alpha(2.05\mathrm{MeV}) + {}^{3}\mathrm{H}(2.72MeV)$$



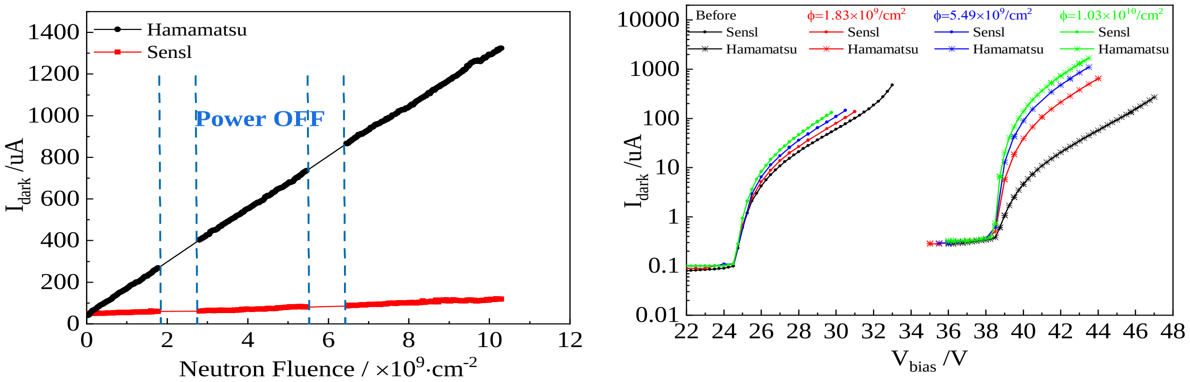
Detector module design

Solve problems of SIPM for large -scale engineering application

SiPM gain and gain uniformity comparison test



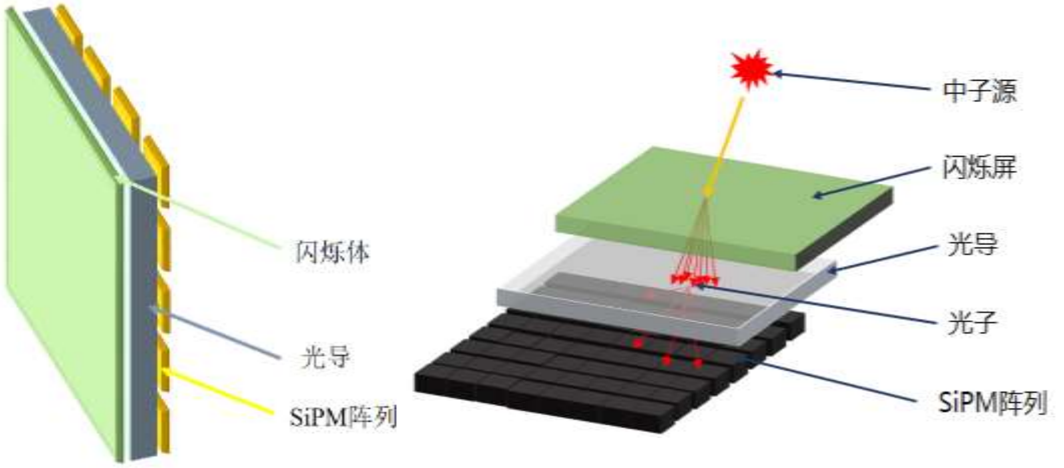
Thermal noise and I/V curve change before and after thermal neutron radiation

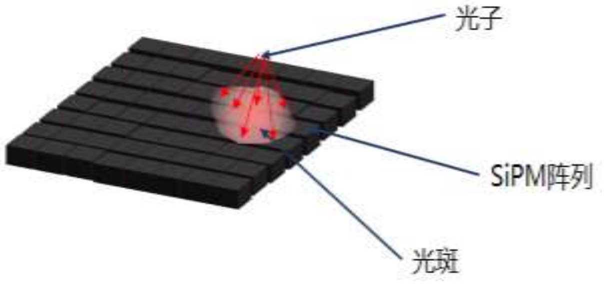


Large-Area Scintillator Detector – 3rd generation

High-Resolution Scintillation Detector

- Aiming at the urgent needs of high -performance neutron detector for CSNS II

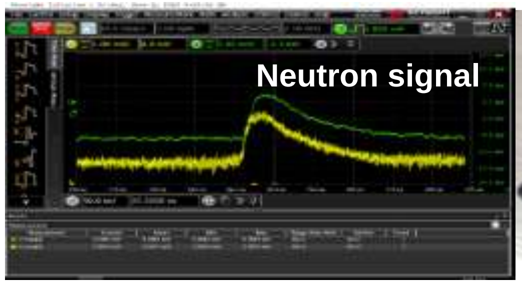




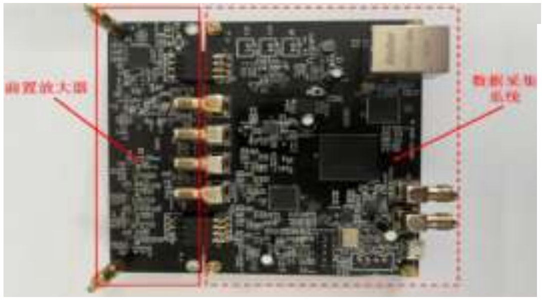
$$x = \frac{x_1 \times w_1 + x_2 \times w_2 + \cdots x_n \times w_n}{w_1 + w_2 + \cdots w_n}$$

$$y = \frac{y_1 \times w_1 + y_2 \times w_2 + \cdots y_n \times w_n}{w_1 + w_2 + \cdots w_n}$$

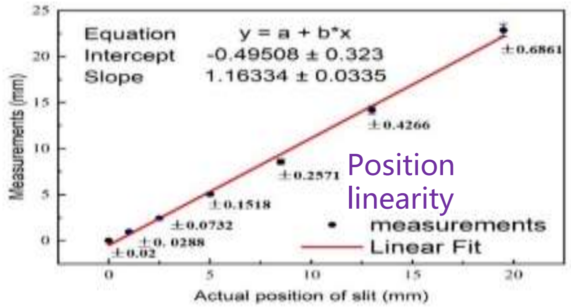
Detector module design

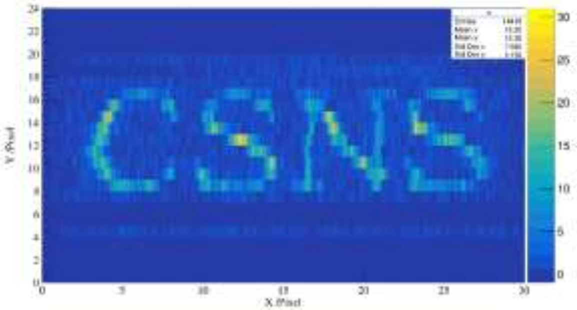


Prototype (10cm*10cm)

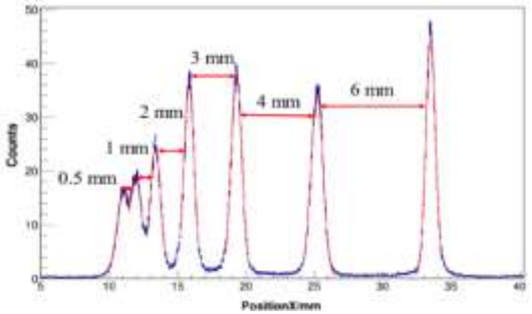


•Electronic readout system



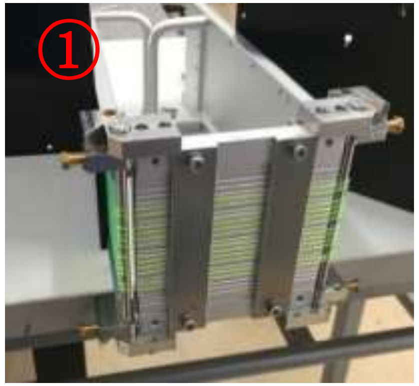


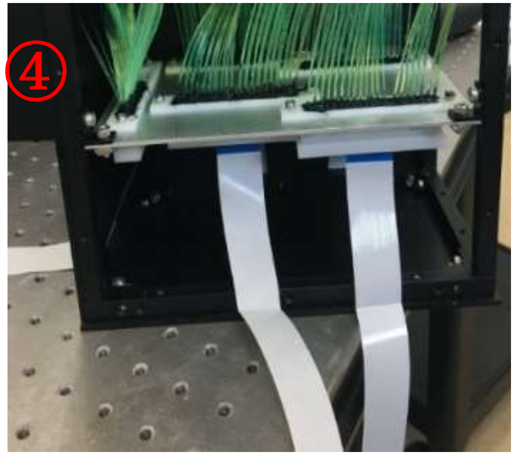
2D imaging

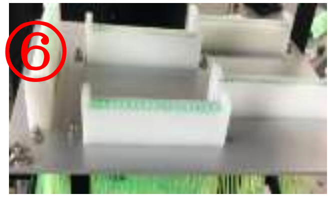


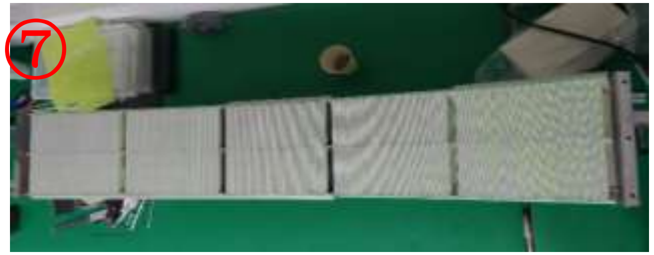
0.5mm position resolution

Mass production based on assembly line to reduce the impact of human factors in the process, improve the uniformity of the detector and control the quality







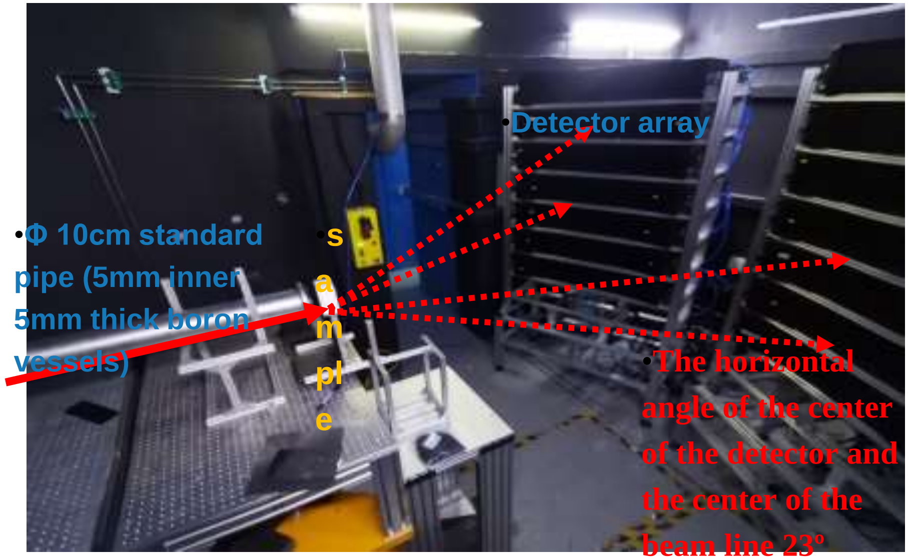


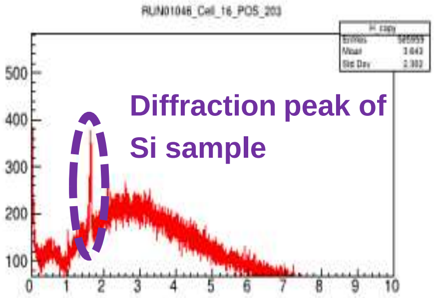
Large-Area Scintillator Detector

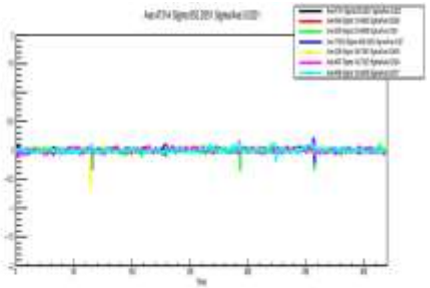
Applicated to Engineering Material Diffractometer (EMD) (100 units)

Batch calibration and optimization of the detector with neutron beam

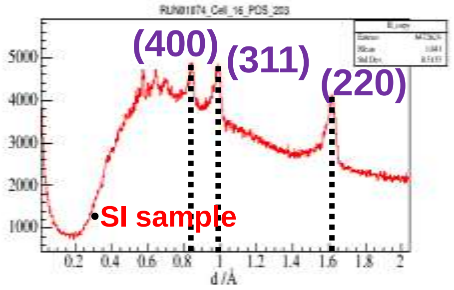
Beam Test

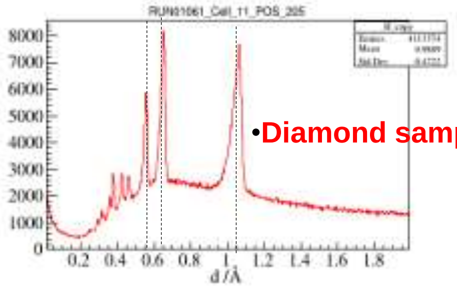






Uniformity of detection efficiency is better than 95%





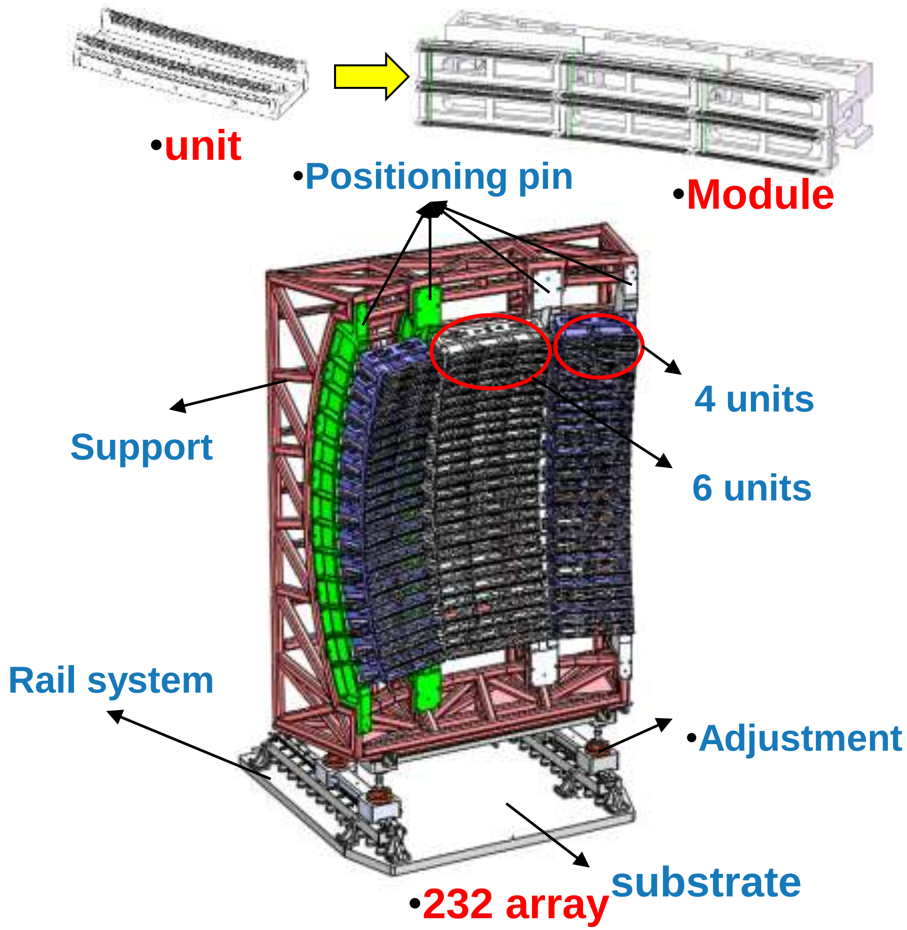
Characteristic diffraction peak of standard sample

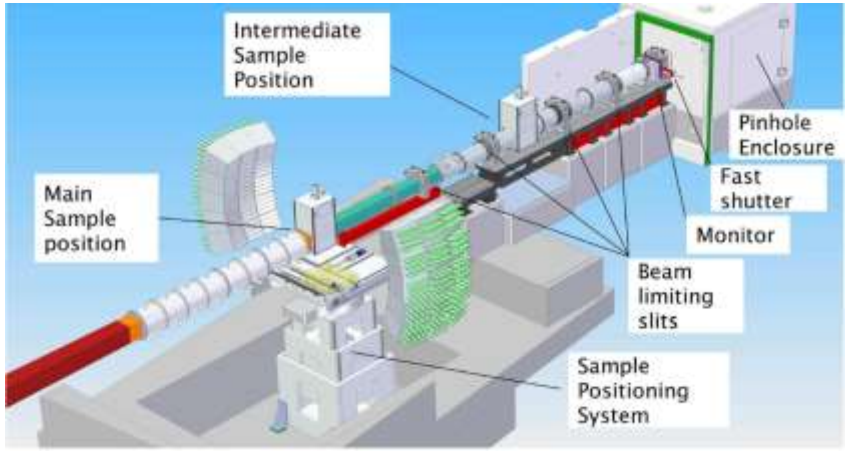
On-site installation and commissioning

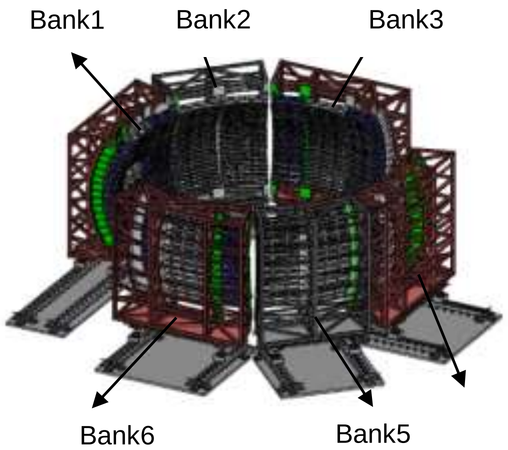
Large-Area Scintillator Detector

Applicated to Energy-Resolved Neutron Imaging instrument (ERNI) (400 units)

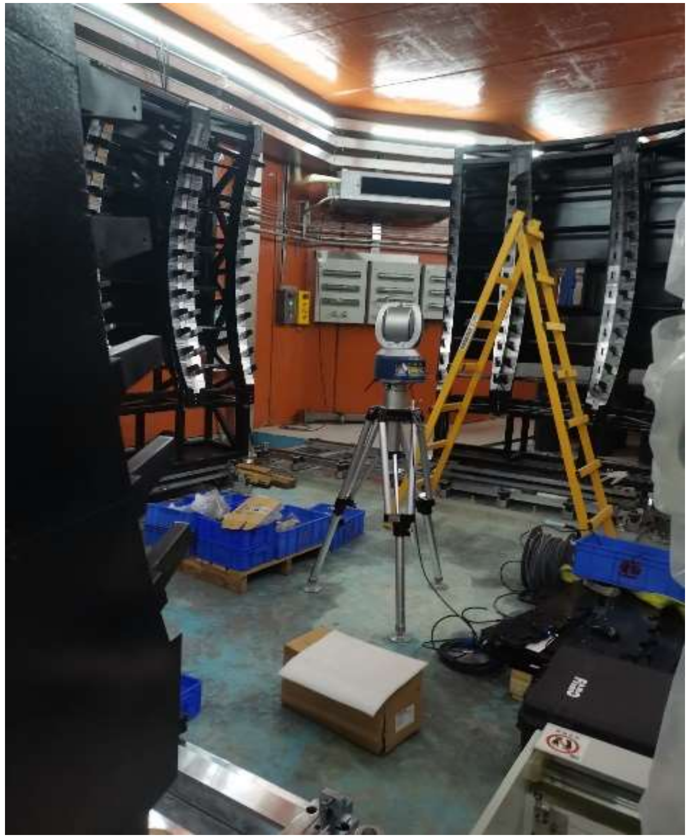
- **Detection area: ~ 3m^2, 25,000 channels of electronics, solved the problem of power consumption and heat dissipation, on-site installation and commissioning is underway.**







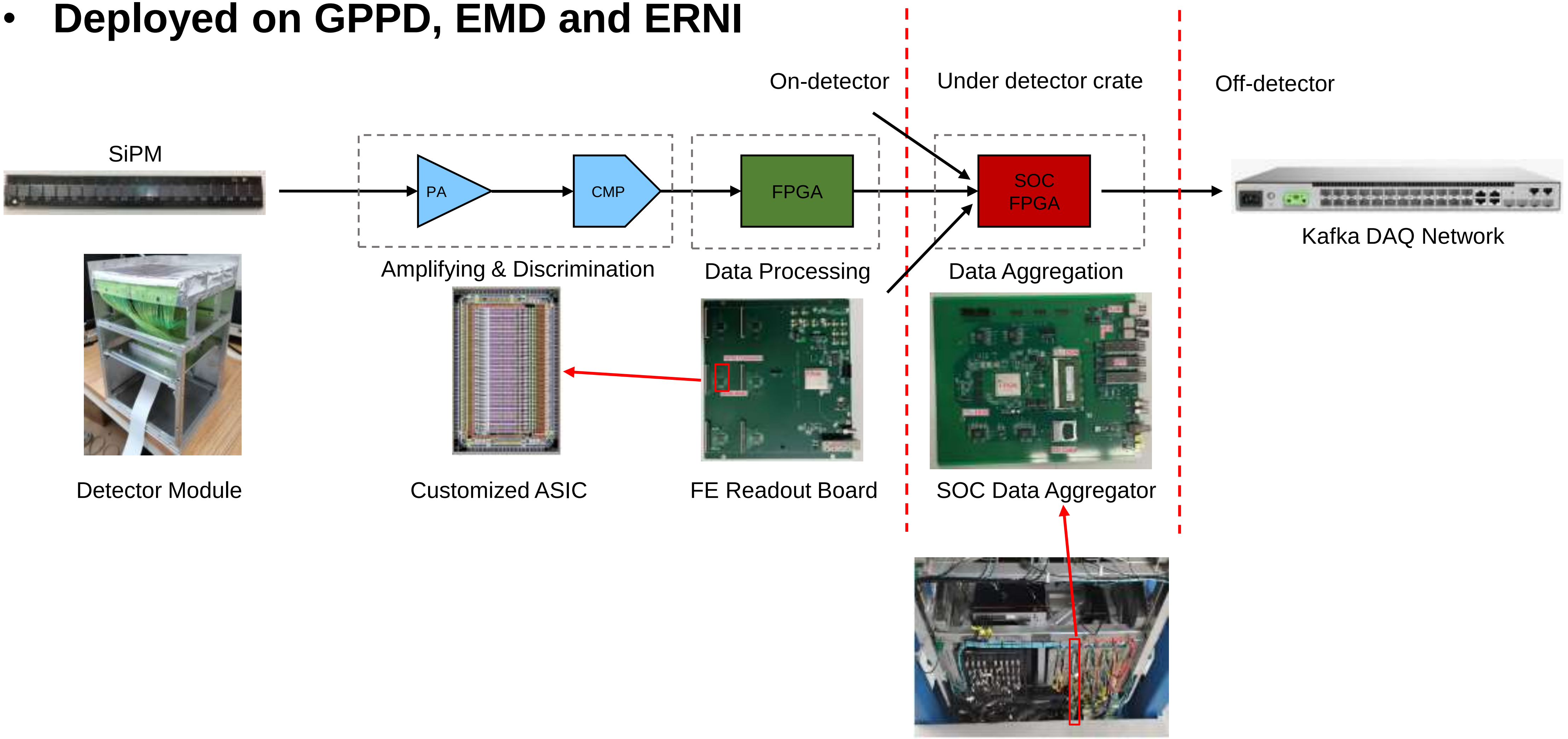
Detector engineering design



on-site installation and commissioning

Large-Area Scintillator Detector Readout Electronics

- **Based on customized high-density pre-amplifier ASIC, with induvial DAC for threshold tuning**
  - **Deployed on GPPD, EMD and ERNI**

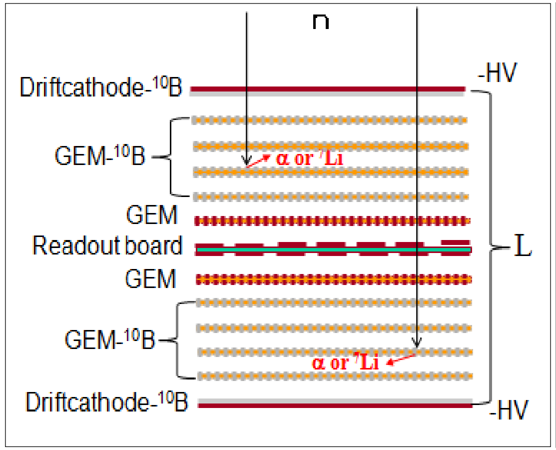


Ceramic GEM Neutron Detector

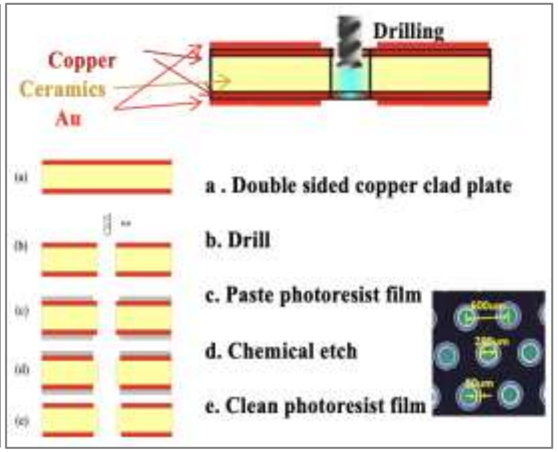
In 2013 the ceramic GEM was invented to reduce hydrogen containing materials with low neutron scattering, high radiation resistance and high temperature resistance

Aiming at engineering applications，ceramic GEM based detector design and key technology development

Detector design



Ceramic GEM development



CPC, 40(7):076002,2016

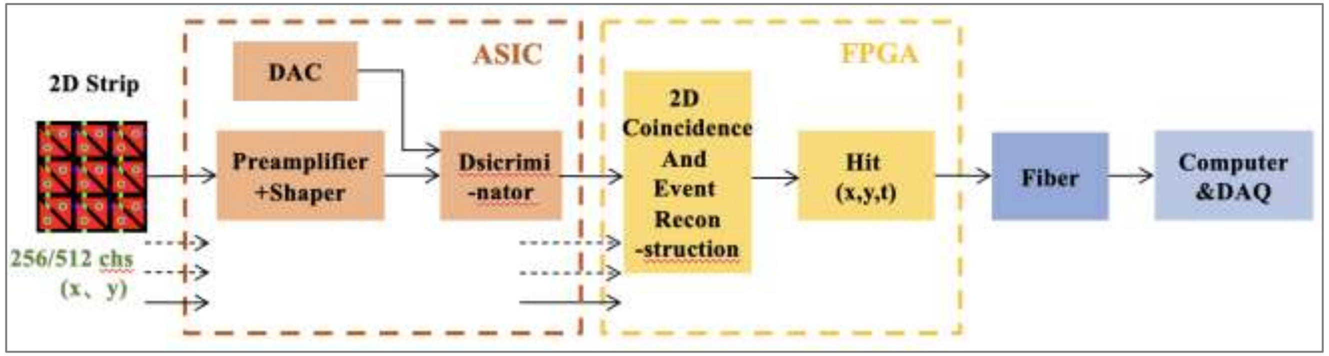
Large-area boron coating by magnetron sputtering

Rev. Sci. Instrum. 94, 093901，2023

R&D of multi-channel ASIC chip

Parameter	Specification
Input charge	±10fC ~ ±400fC
Counting rate	**1MHz/ ch**
Channels	32*2
Output	2.5V TTL
Threshold	DAC adjustable

Fast digital readout electronics



Ceramic GEM - Beam Monitor

High flux 2D position sensitive neutron beam monitor

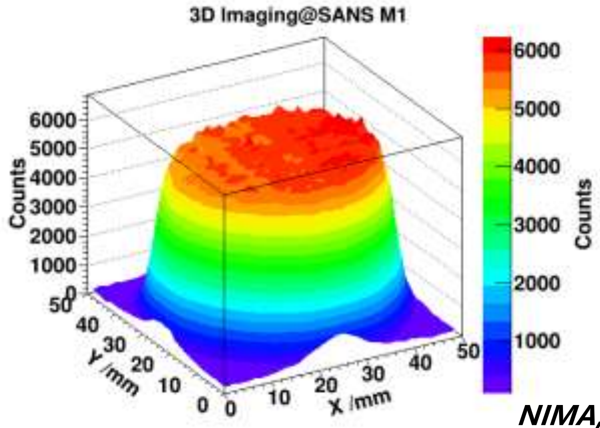
6 monitors were installed in CSNS I, operating stably for 5 years. 21 monitors totally used for instruments

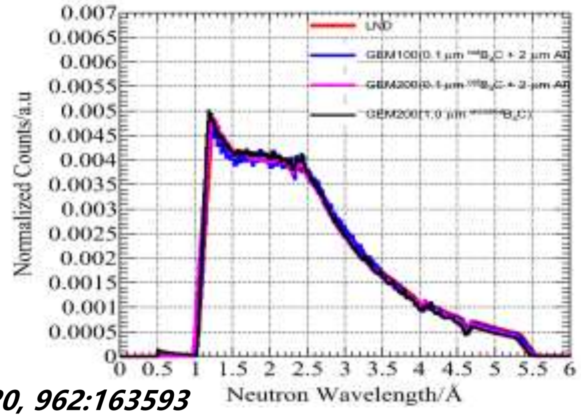
Monitor design parameters

Indicators	Specifications
Conversion layer	B_4C、C_2H_4，U
Effective area	50mm*50mm, 100mm*100mm, 200mm*200mm
Detection Efficiency @1.8Å	10^{-4}~10^{-2}
Counting rate	1 MHz
Neutron flux	10^{10} n/s

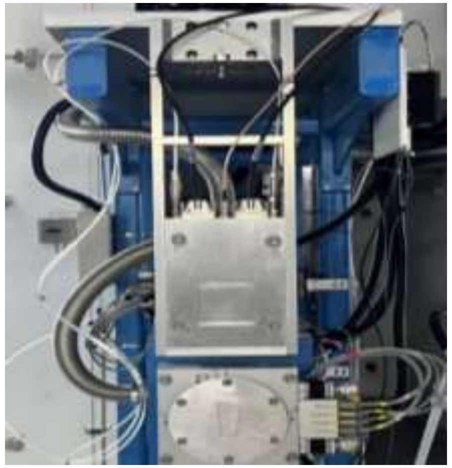
30 monitors have been mass-produced

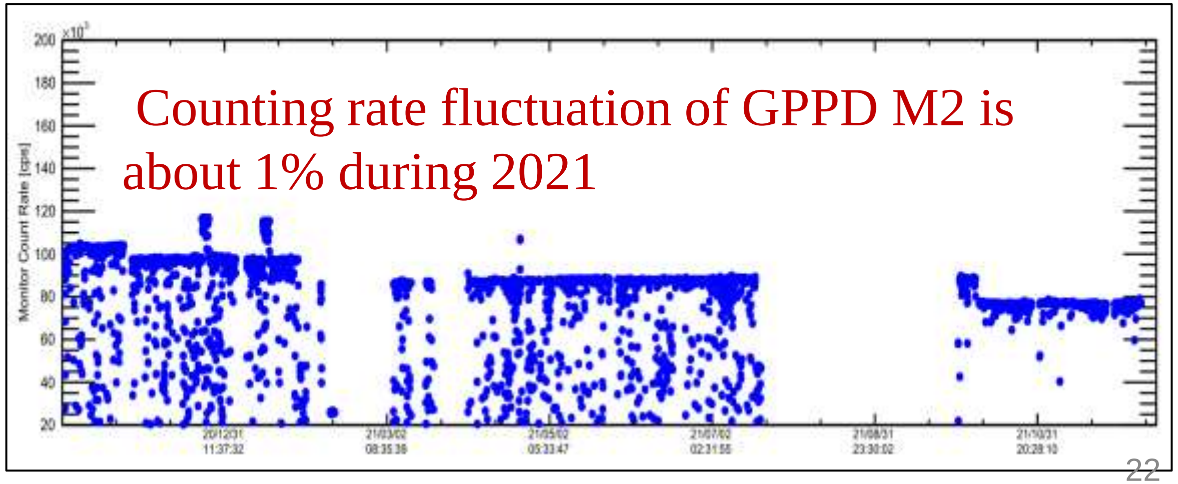
Monitor Operation Test Results





NIMA, 2020, 962:163593



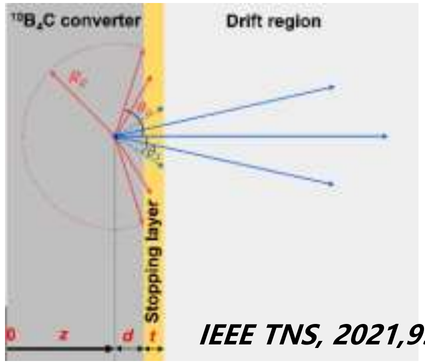


Ceramic GEM - Imaging Detector

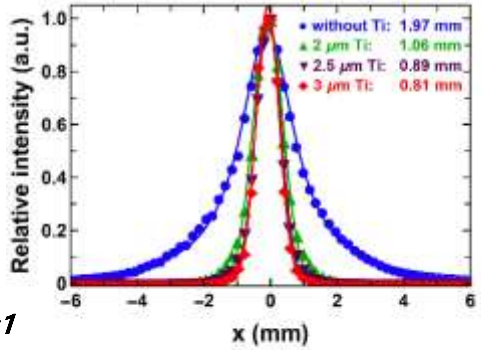
Large FOV GEM neutron detector for ERNI

Al/Ti film is used as a stop layer. Spatial resolution is improved to 0.8mm, and it has been installed to ERNI for commissioning.

M.C. simulation

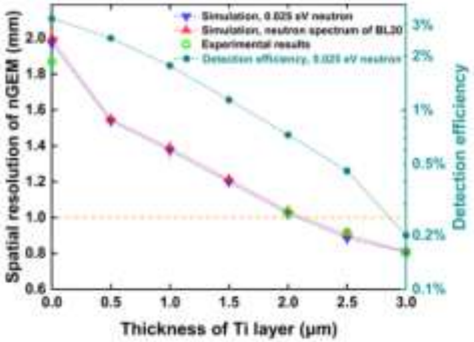


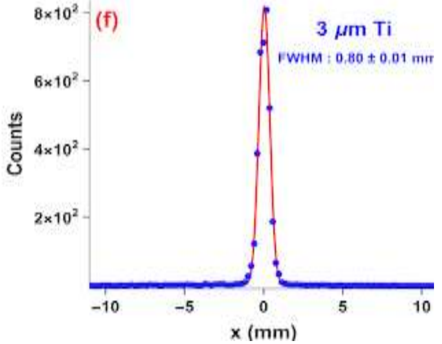
IEEE TNS, 2021,99:1



Prototype development

Test results of neutron beam test



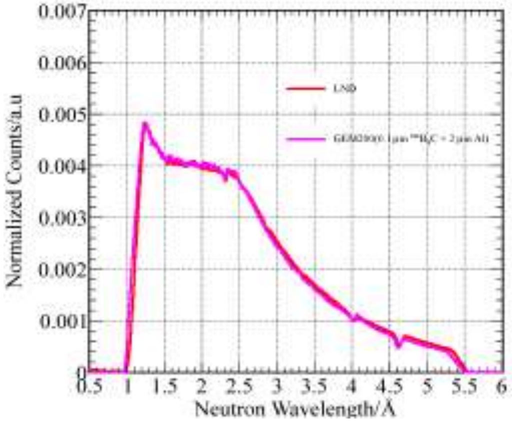


Detector design

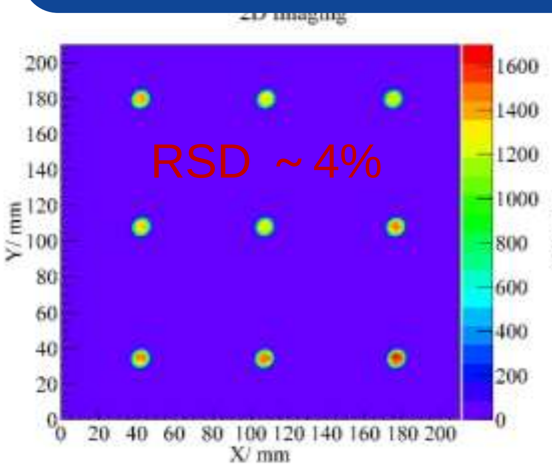
Indicators	Specifications
Conversion layer	0.1μm $^{nat}B4C$+2μm Al
Effective area	200mm*200mm
Pixel size	0.8mm
Detection Efficiency@1.8Å	10^{-4}
Counting rate	1 MHz
Neutron flux	10^{10} n/s

Detector photo

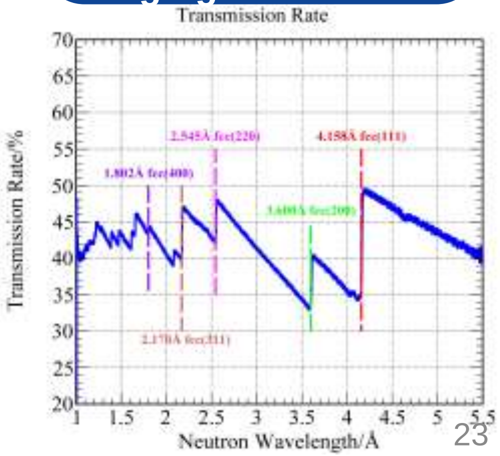
Neutron wavelength



Detecting surface uniformity



Bragg-Edge Neutron Imaging



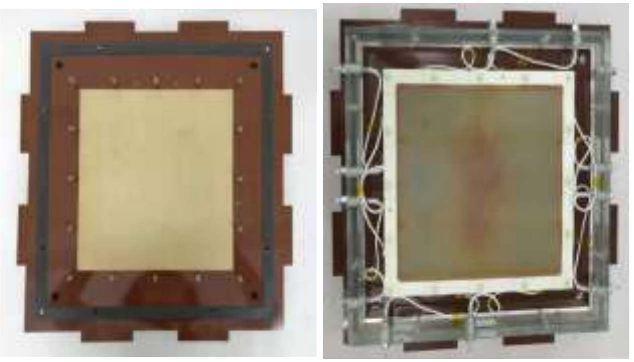
Ceramic GEM - High Resolution Detector

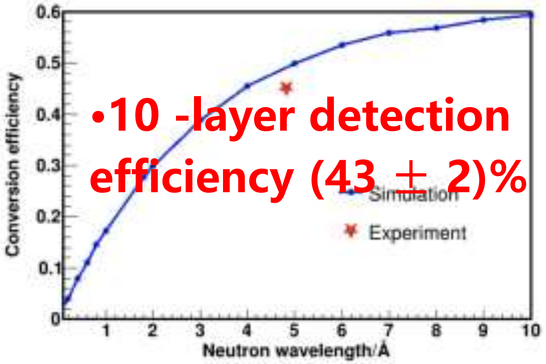
High Resolution Detector for VSANS

Multi-layer BGEM structure is used to improve the detection efficiency, and it has been installed at VSANS for commissioning

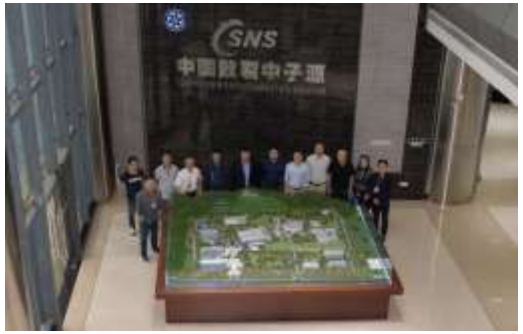
Detector design

Detector prototype development



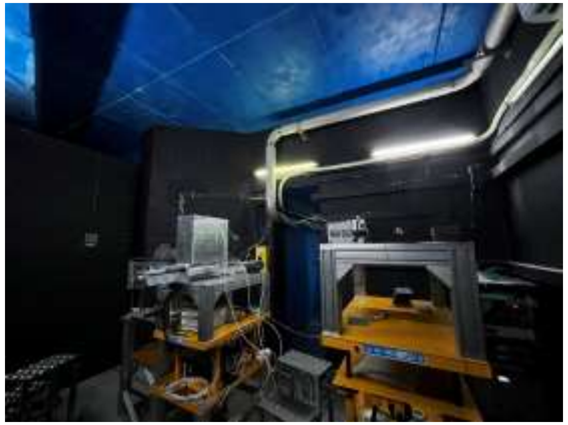


Project Acceptance by CAS@2019

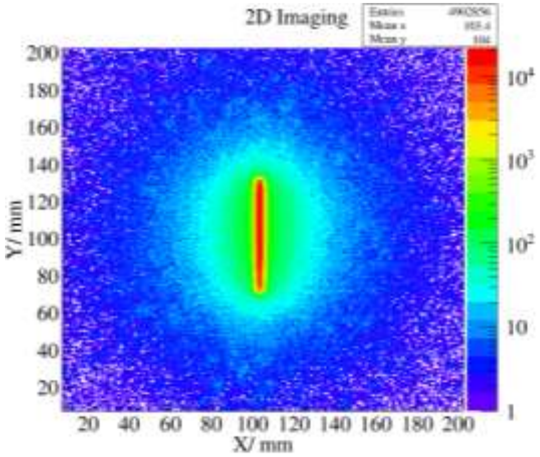


Detector photo

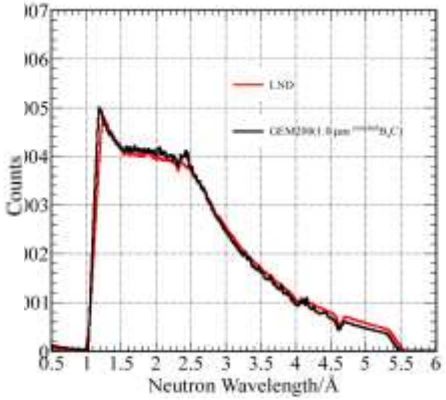
Neutron beam test



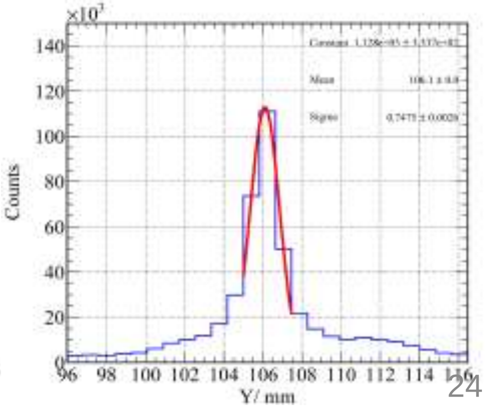
2D beam profile



Neutron wavelength



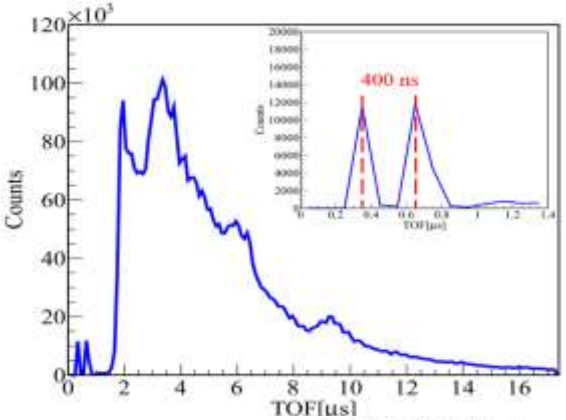
Spatial resolution

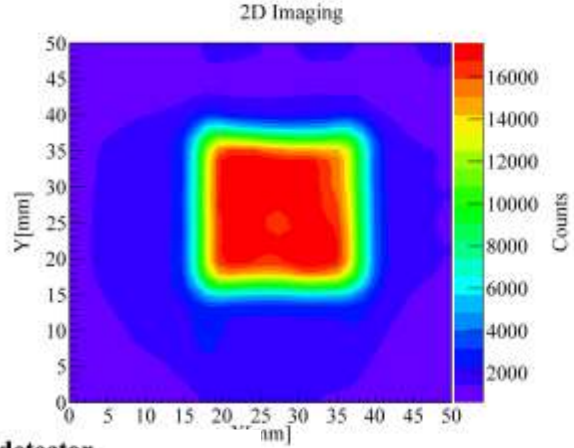


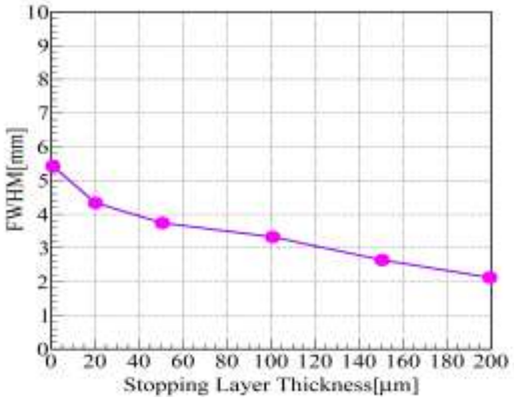
Ceramic GEM - Fast Neutron Detector

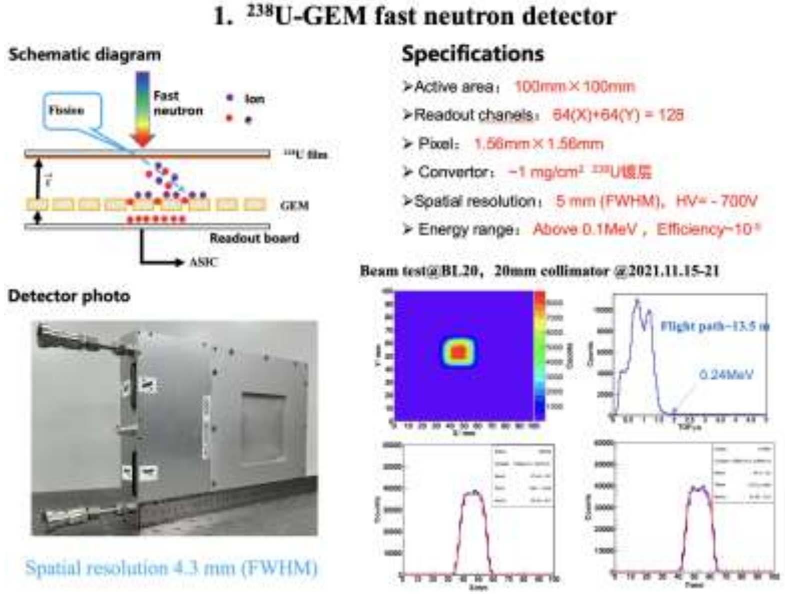
Atmospheric Neutron Irradiation Spectrometer 2D position sensitive detector

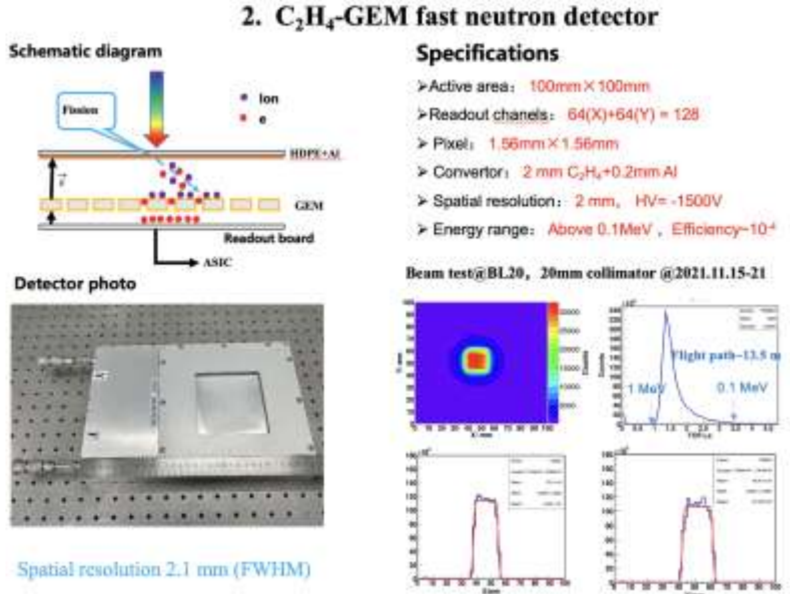
Use aluminum as stop layer and spatial resolution of fast neutron improved from 5mm to 2.1mm, has been installed at ANIS for commissioning











Ceramic GEM – Frontier Exploration

Sealed GEM neutron detector.

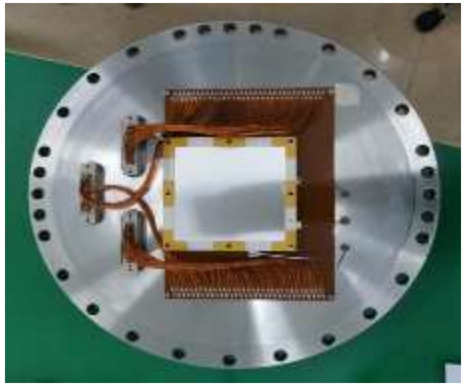
NIMA, 2021,995:165129

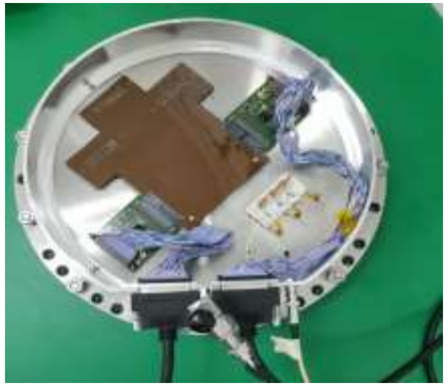
- Developed high-temperature resistant (100°C) ceramic GEM to meet baking outgassing.
- Enhancing detector stability, suitable for vacuum environments, future direction.

Detector design

Indicators	Specifications
Conversion layer	1μm B4C
Effective area	100mm*100mm
Pixel size	1.56mm
Detection Efficiency@1.8Å	~3%
Counting rate	1 MHz

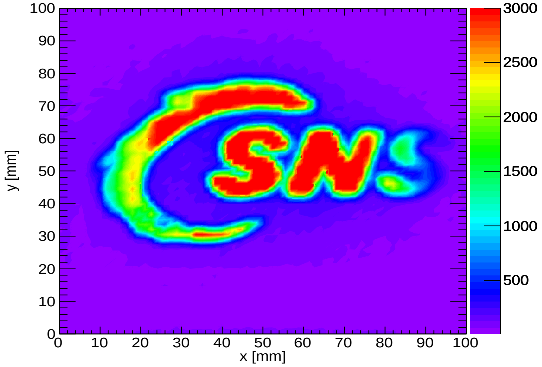
Detector assembly



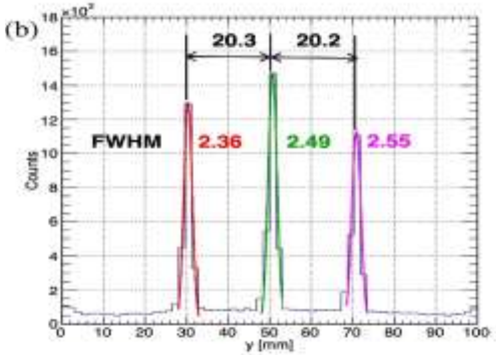


Detector baking outgassing system

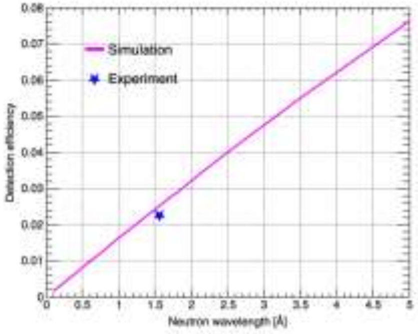
2D imaging



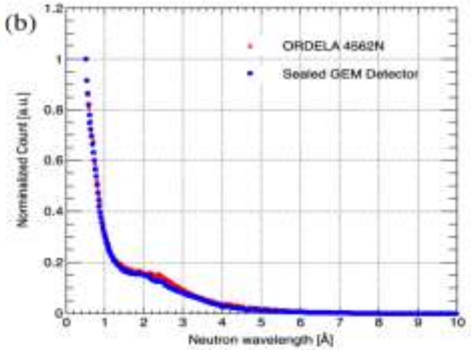
Spatial distortion



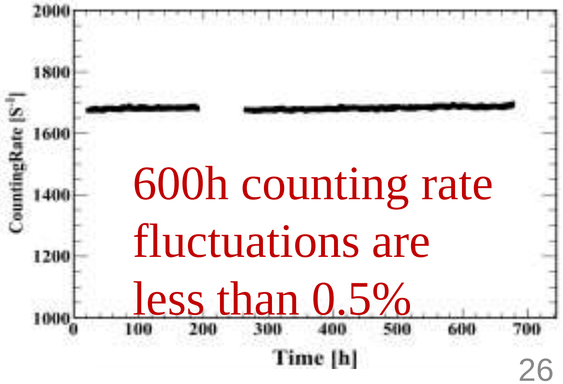
Detection efficiency



Neutron wavelength



Long-term stability



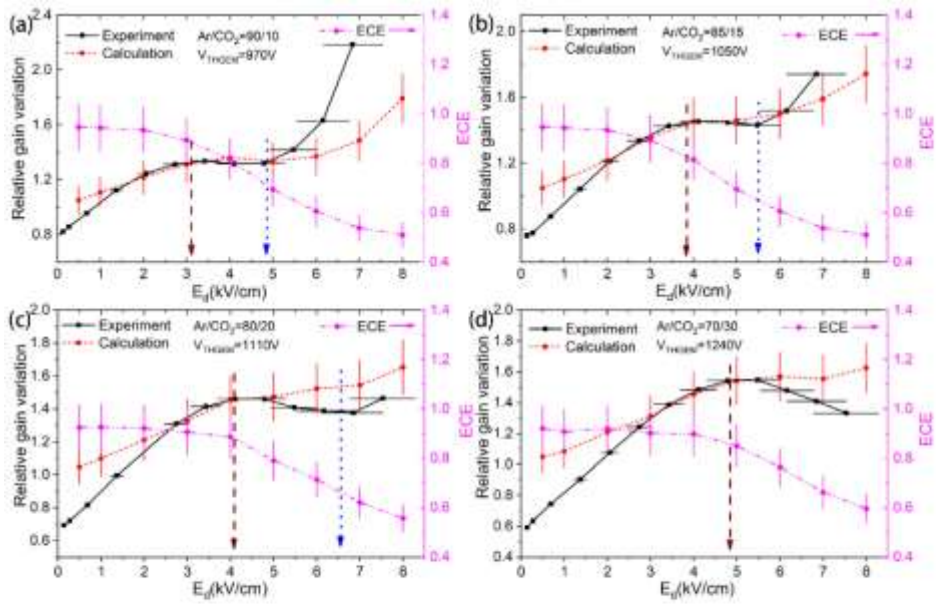
Ceramic GEM - International collaboration

Provided multiple batches of ceramic GEM detectors to several institutions abroad

Milano Uni. & INFN in Italy conducts research on the ceramic GEM and applications (NIMA, 2021, 988: 164907)

Ceramic GEM detector installed at ISIS VESUVIO instrument in UK (Jinst, 2021, 16: P06003)

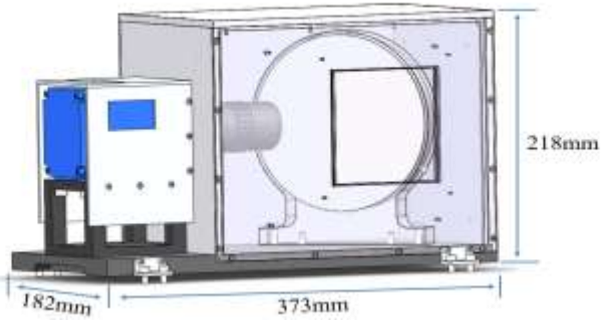
R&D of high-efficiency detector with GSI, German (NIMA, 2020, 953: 163051)

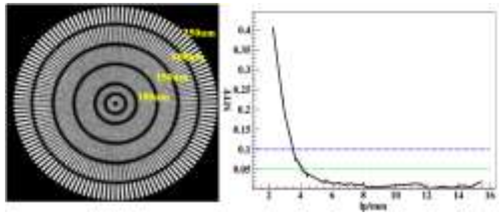


Neutron Imaging Detector

Aiming at the neutron imaging demands of CSNS and international frontiers, developing a variety of **high spatial resolution** and **high timing resolution** imaging detectors

Compact imaging detector

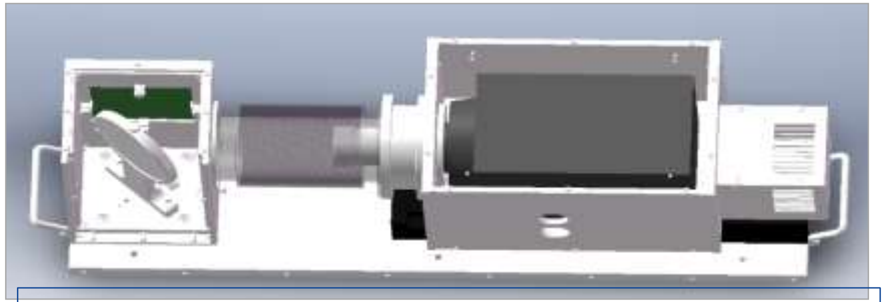




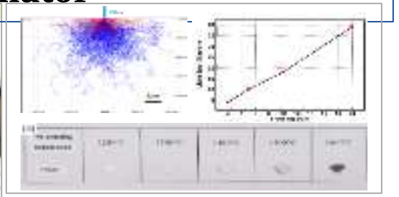
Latest beam test results: 122 μm@4.1LP/mm

NET, 2021, 53(6):1942-1946

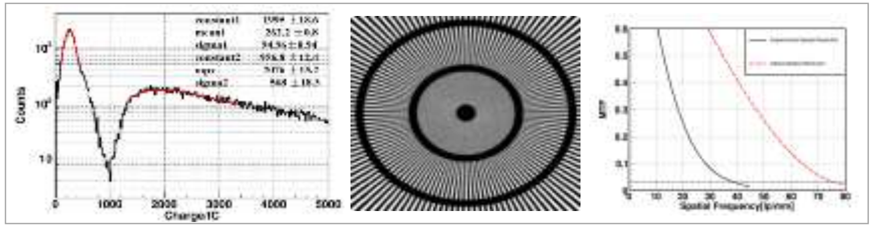
High-resolution imaging detector



Micrometer ultra-high resolution neutron imaging detector with ultra-thin GOS: Tb transparent ceramic scintillator



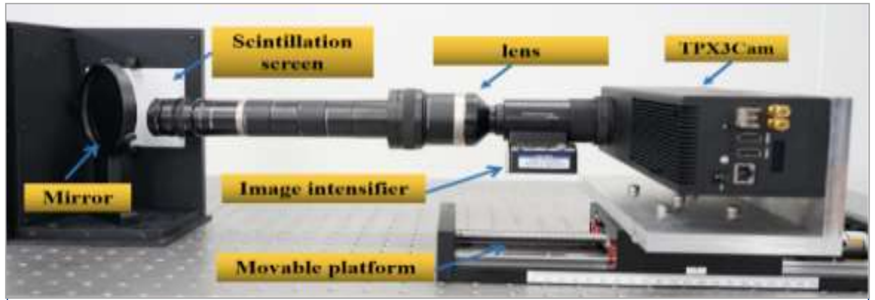
GOS Scintillator Simulation



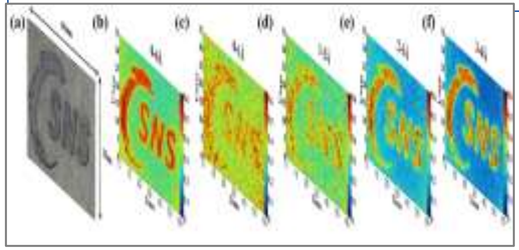
Latest beam test results: 13 μm@38LP/mm

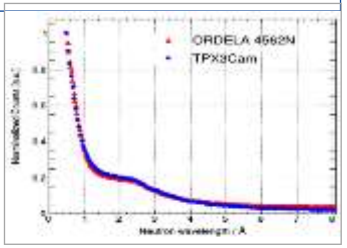
Optical Materials, 2020, 105: 10990 (cooperated with the Lijiang team of the Shanghai Institute of Ceramics)

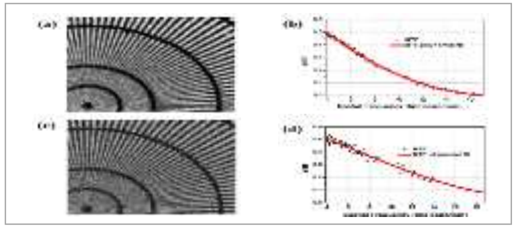
Energy resolution neutron imaging detector

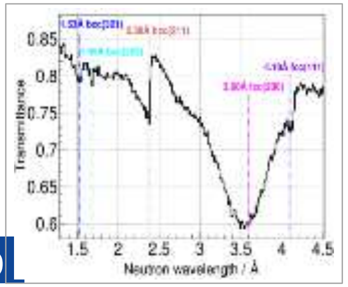


Energy resolution neutron imaging detectors can achieve high time resolution and high spatial resolution at the same time.









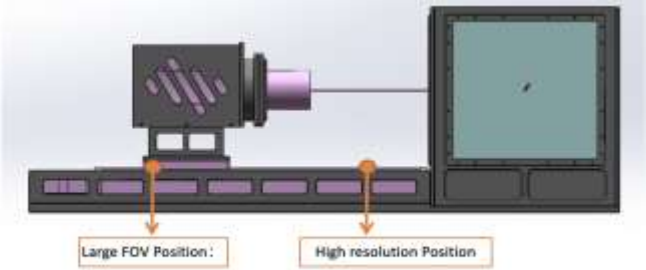
Latest beam test results: 20 μm (25 LP/mm)

NIMA, 2021, 1003: 165322

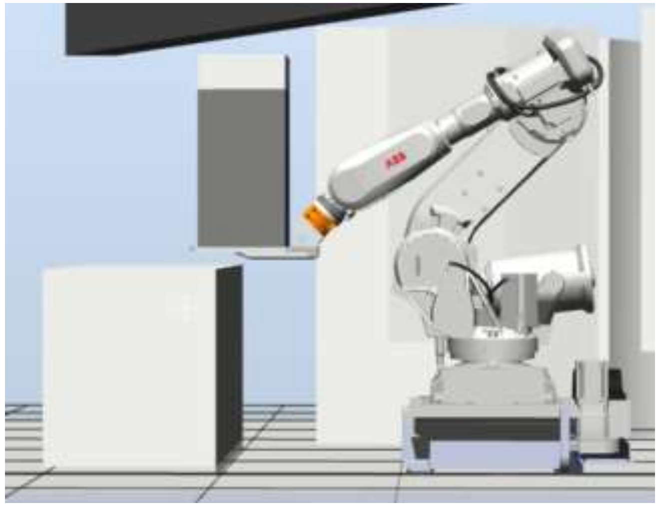
Neutron Imaging Detector - Large FOV

ERNI—Large FOV Imaging detector, the commissioning underway at ERNI.

Detector engineering design



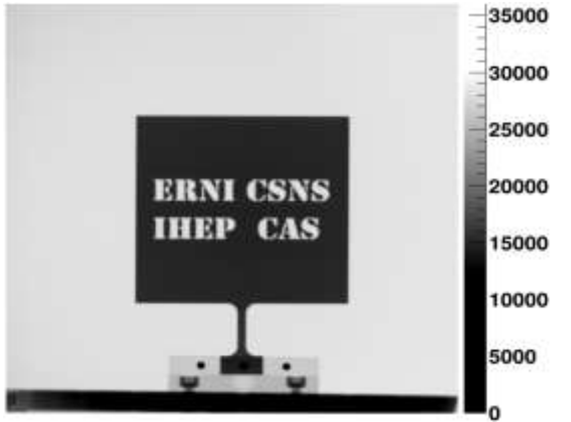
Lens	Magnification	FOV	Distance	Spatial resolution
Nikon AFSVRMICR O60_2.8	0.15	200mmX200mm	484mm	200μm
	0.3	100mmX100mm	242mm	100μm
Nikon AFSVRMICR O105_2.8	0.3	100mmX100mm	500mm	100μm
	0.5	60mmX60mm	423mm	60μm
	1	30mmX30mm	343mm	30μm

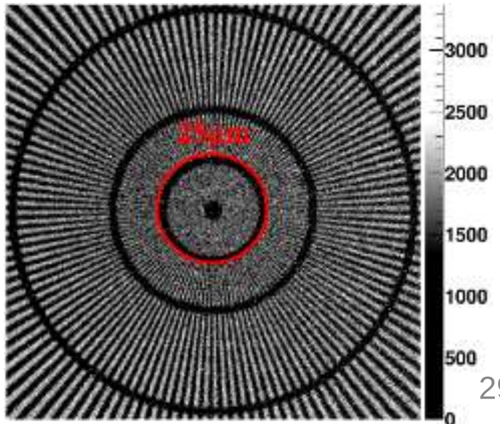


Large FOV Imaging detector

Neutron beam test

The maximum FOV is 220mm*210mm, and the best spatial resolution is 25 μm measured at ENRI





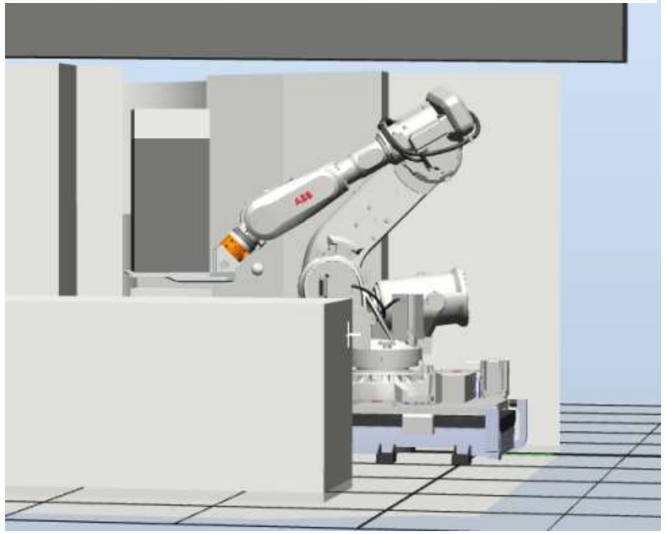
Neutron Imaging Detector-Energy Resolution (TOF)

SNS
CHINESE ACADEMY OF SCIENCES

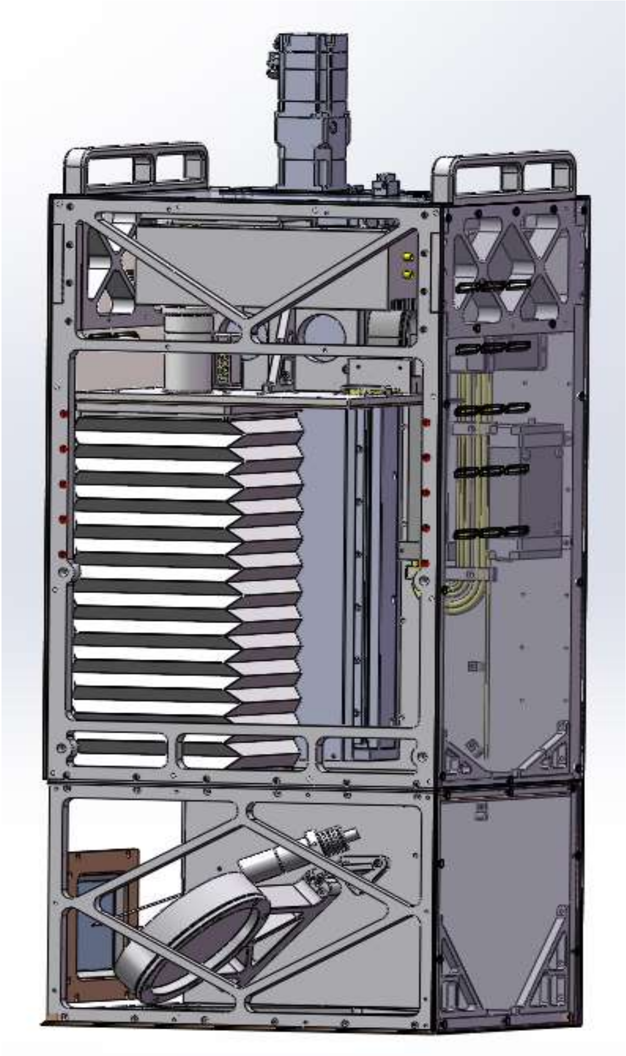
Energy resolved imaging detector, currently undergoing commissioning at ERNI.

Detector engineering design

Lens	Magnification	FOV	Distance	Spatial resolution
Nikon AFSVRMIC RO60_2.8	0.12	100mmX100mm	622mm	458μm
	0.14	90mmX90mm	507mm	393μm
	0.3	42mmX42mm	302mm	183μm
Nikon AFSVRMIC RO105_2.8	0.3	42mmX42mm	519mm	183μm
	0.5	25mmX25mm	399mm	110μm
	1	12.7mmX12.7mm	299mm	55μm

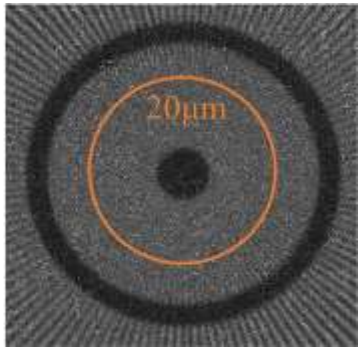


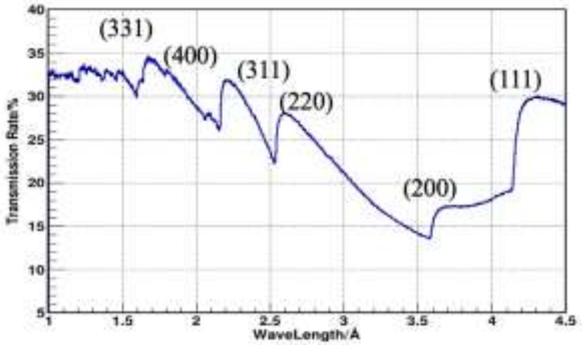
Energy resolved neutron imaging detector



Installation and commissioning at the ERNI

Preliminary test results of ENRI





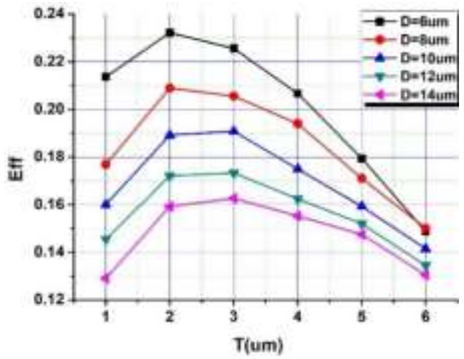
Neutron Imaging Detector-Energy Resolution (TOF)

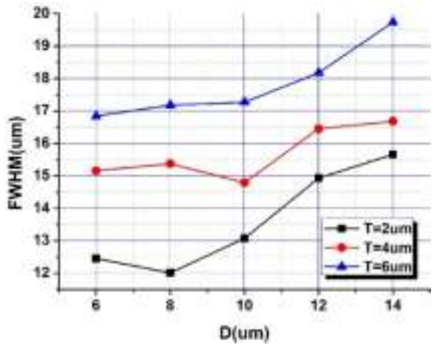
Development of neutron sensitive Micro Channel Plate (nMCP)

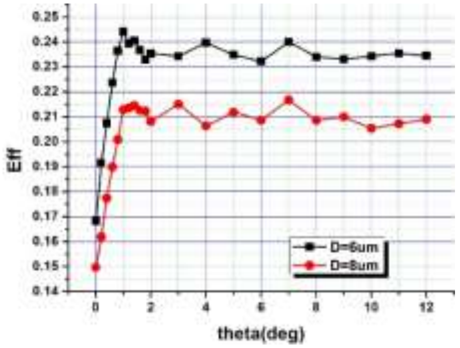
- Challenges: Low γ sensitivity and high boron-doped concentration in nMCP, reducing high Z materials.
- Achieved 20 mole% boron-doped nMCP, successfully applied in GPPD

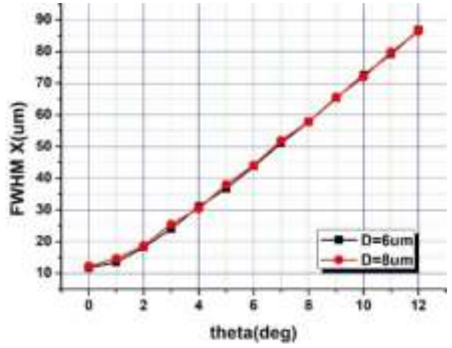
NIMA , 2022, 167828

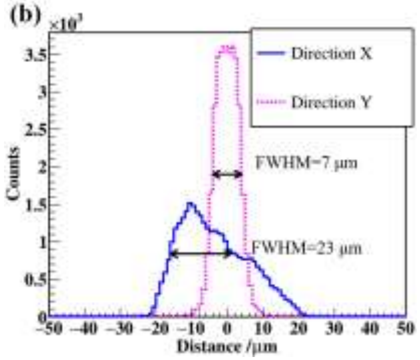
Design and optimization of nMCP based on Geant4 simulation



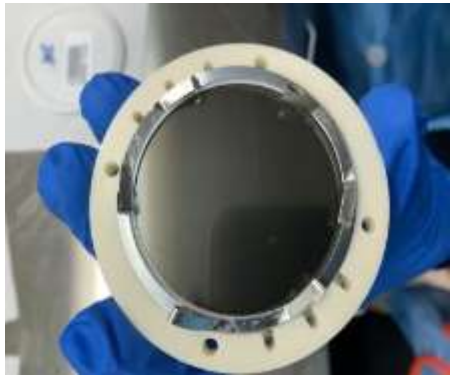


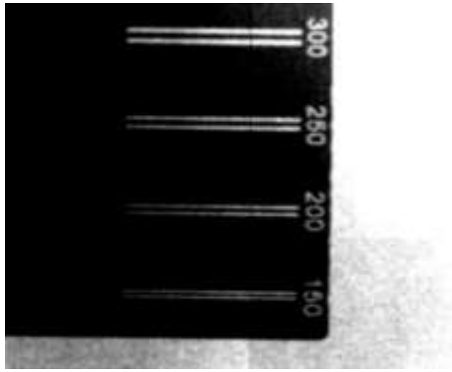


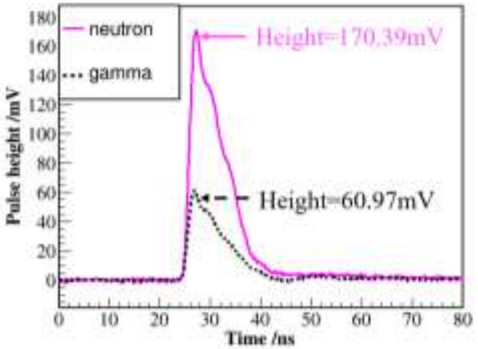


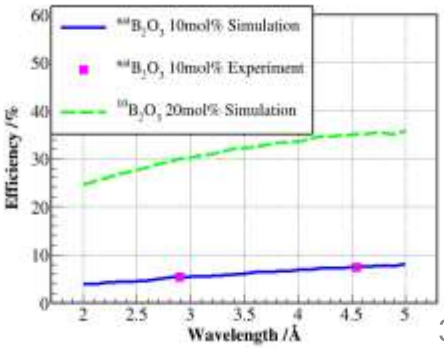


B-nMCP photo | **GPPD application** | **Spatial resolution** | **n/γ discrimination** | **Detection efficiency**



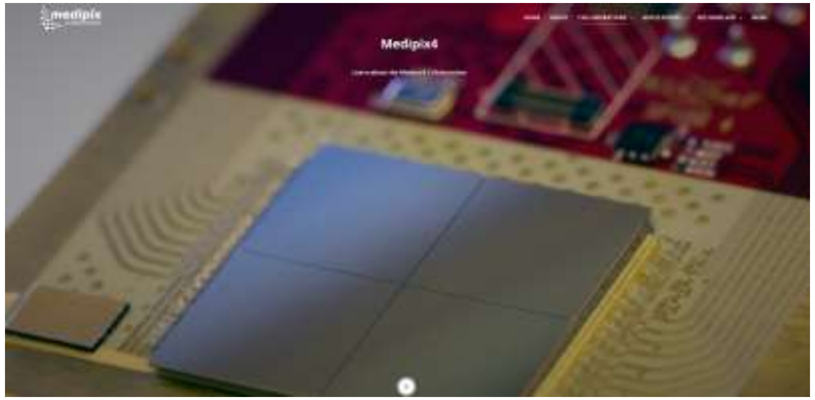






High Speed Readout Electronics for Neutron Imaging

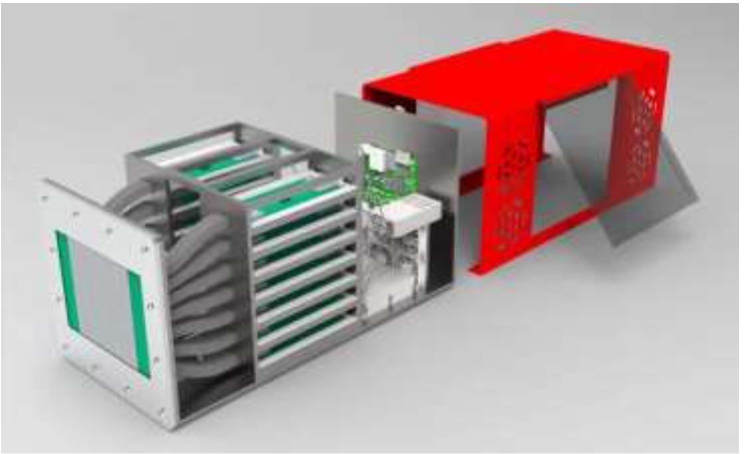
Joined the Medipix4 international collaboration group



- Medipix International Collaboration Group
  - Led by CERN, established for over 20 years, CSNS officially joined in 2022.
  - Dedicated to the R&D and promotion of pixel detector chips.
  - Latest pixel detector chip - Timepix4
  - Pixel Size/Time Resolution: 55um/200 ps
  - Maximum Count Rate: 3.5M hit/mm^2/s
  - Utilizes TSV (Through Silicon Via) technology to minimize dead zone.

Conducting key technology research for high-performance energy-resolved neutron imaging detector based on Timepix4 detector modules.

Long term goal: Large area high speed neutron camera



- High-efficiency, high-resolution scintillation screens.
- Large FOV
- High time resolution: < 1ns
- High spatial resolution: < 50 um (CoM algorithm)

Readout based on single-chip module

Single chip module

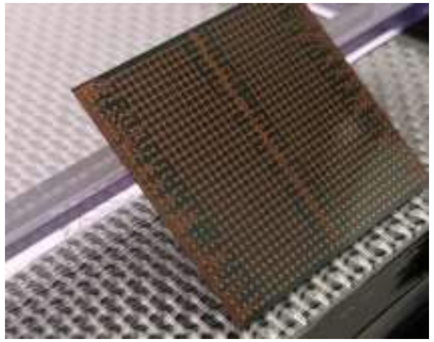
ZU + Readout Platform

High-speed readout and data compression research based on the latest SOC platform

Neutron Imaging High Speed Camera Development

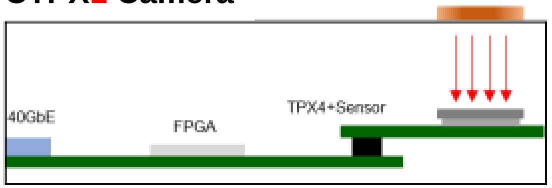
			Timepix3 (2013)	Timepix4 (2019/20)	
Technology			IBM 130 nm – 8 metal	TSMC 65 nm – 10 metal	
Pixel size			55 x 55 µm	55 x 55 µm	
Pixel arrangement			3-side buttable 256 x 256	4-side buttable (TSV) 512 x 448	3.5 x
Sensitive area			1.98 cm²	6.94 cm²	
Readout modes	Data driven (tracking)	Mode	ToT and TOA		
		Event packet	48-bit	64-bit	
		Max rate	< 43 Mhits/cm²/s	357.6 Mhits/cm²/s	8 x
		Pix rate equiv.	1.3 kHz/pix average	10.8 kHz/pix average	
	Frame Based (imaging)	Mode	Count: 10 bit + iToT	Count: 8 or 16 bit CRW	
		Frame	Zero suppressed (with pix addr)	Full frame (no pix addr)	
		Max count rate	82 Ghits/cm²/s	~ 800 Ghits/cm²/s	10 x
		Max frame rate	N/A (worst case: 0.8ms readout)	80 kHz CRW	
TOT energy resolution			< 2 keV	< 1 keV	2 x
Time resolution			1.56 ns	~ 200 ps	8 x
Readout bandwidth			≤ 5.12 Gbps (8 x 640 Mbps)	≤163.8 Gbps (16 x 10.2 Gbps)	32 x
Target minimum threshold			< 500 e⁻	< 500 e⁻	

Timepix4

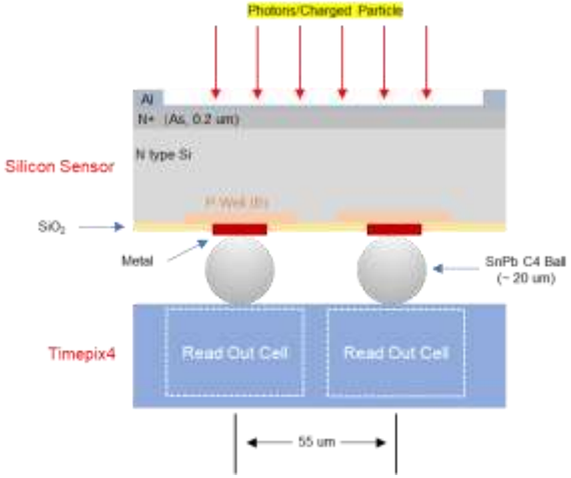


Timepix4 with TSV

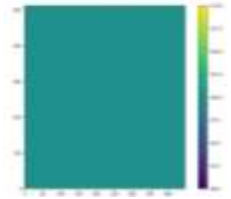
CTPX1 Camera



CTPX4 Camera



Timepix4 + Optical Silicon Sensor



Zynq Ultrascal+ Timepix4 Readout Demonstrator

- Scintillation screen Optical Silicon Pixel Sensor + Timepix4 based neutron imaging being developed at CSNS
- Two prototypes: CTPX1, CTPX4
- Key Specifications
  - Sensor: Si
  - *Pixel Array: 512 x 448 (CTPX1), 1792 x 512 (CTPX4)*
  - *Pixel Size: 55 um x 55 um*
  - *Maximum rate: 89 kfps (frame mode), 3.56 x 10^6/mm²/s*
  - *Real time buffering: 32 GB/Timepix4*
  - *Readout interface: 40GbE*
- Timeline for commissioning
  - *CTPX1: 2024Q1*
  - *CTPX4: 2024H2*

Contents

Report Outline

Future development for neutron instruments

- **Addressing Engineering Issues of Neutron Instruments:**
  - **Enter "Vacuum"**

    Solve challenges like vacuum discharge, electronics cooling, space limitation, system noise, and channel consistency
  - **Moving towards High Bandwidth + Large Scale:**

    High count rate, high dynamic range, distributed independent modules

- **Enhancing Performance of Neutron Instruments:**
  - **Moving towards "Real-Time"**

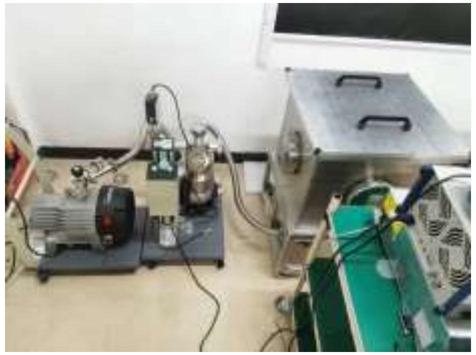
    Distributed information flow, data-driven, front-end physics analysis in real-time
  - **Moving towards High Resolution (Spatial, Temporal):**

    Wavelength resolution, spatial resolution.

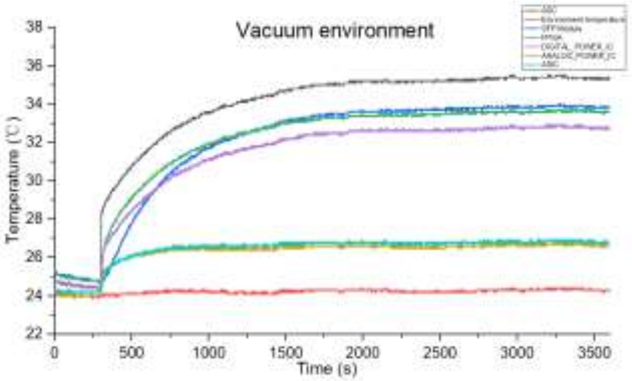
– Enter "Vacuum " @^{3}He PSD Tube Array Detector

Key Specifications

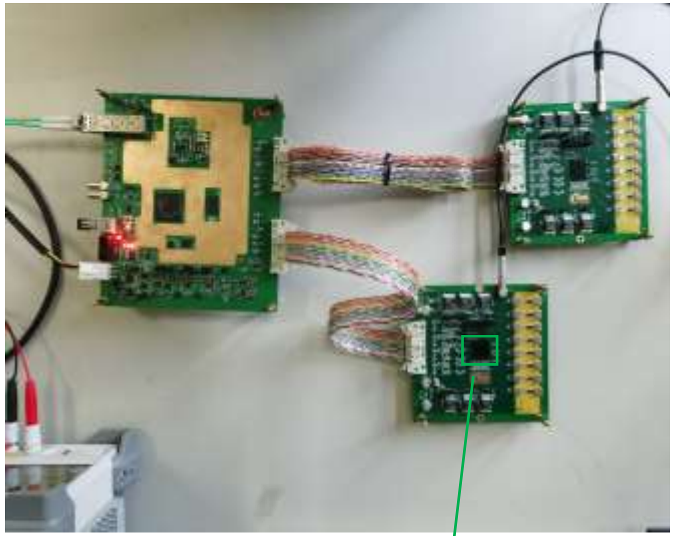
- Readout Method: Waveform sampling
- Ultra low power FPGA + ADC
- Customized ASIC (GF 180nm process)
- Modular design: 8 tube / set
- Remote firmware update
- Low power (< 3W/8 tube readout) for vacuum operation without climate chamber

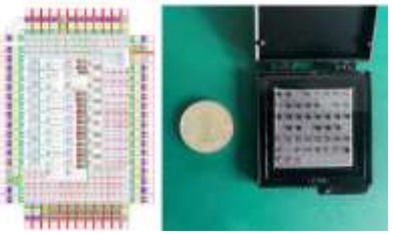


Vacuum Test Setup



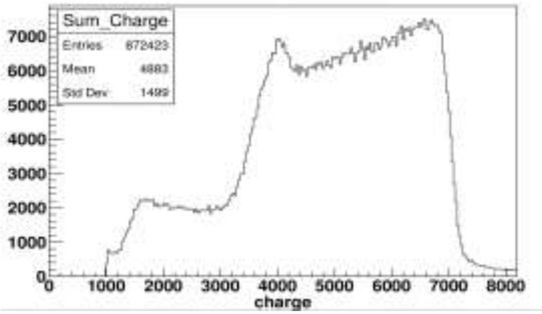
- Hottest component (ADC) stabilized @ ~ 35 °C in vacuum
- Use TOF gating further reduce dynamic power consumption



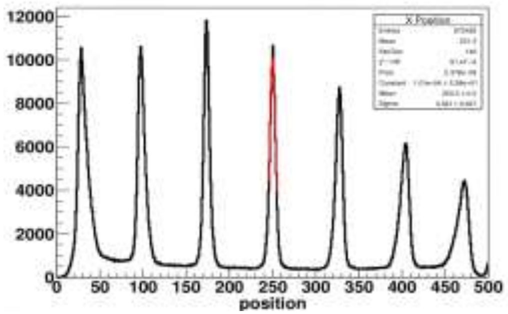


HEROC1 ASIC

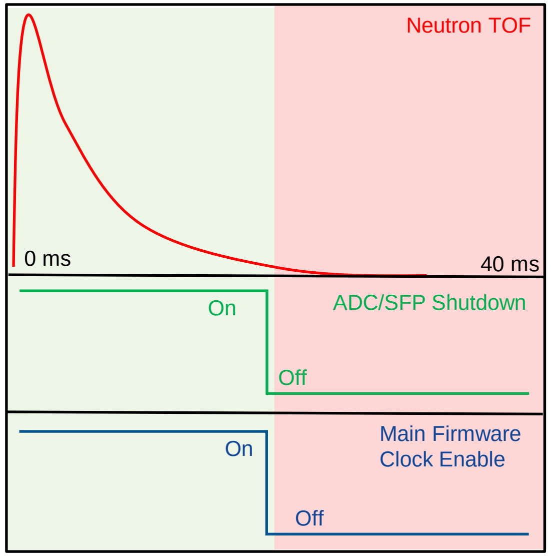
	Voltage	Current	Power (W)
Front-end Board	3.5V/-3.5V	0.075A/0.015A	0.315
Digital Board	3.5V/-3.5V	0.668A/0.001A	2.342
Subtotal			2.972



Sum charge spectrum in testbeam



< 8 mm position resolution achieved



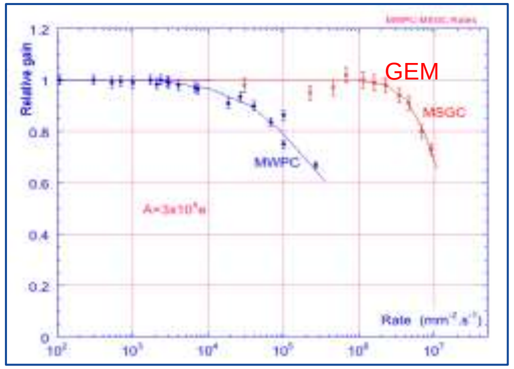
High count rate

Develop high count rate, high efficiency GEM detector to meet the requirements of liquid instrument

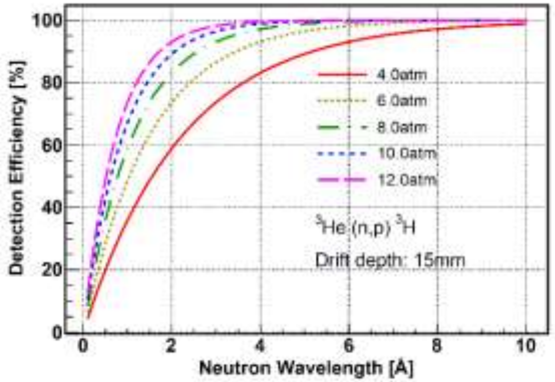
- **Bottleneck: traditional detector based on wire chamber can't meet the high flux measurement**
- **^{3}He + GEM may potentially achieve high efficiency and enhance high count rate by two orders of magnitude**

Parameter	^{3}He MWPC	^{3}He GEM needed
Effective Area	200mm × 200mm	600mm × 1000mm
Spatial resolution	≤ 2mm (FWHM)	≤ 2mm (FWHM)
Detect efficiency	≥ 80% @ 1.8Å	≥ 80% @ 1.8Å
Counting rate	≤ 100kHz	≥ 1MHz
n/γ discrimination	10^{-6}	10^{-6}

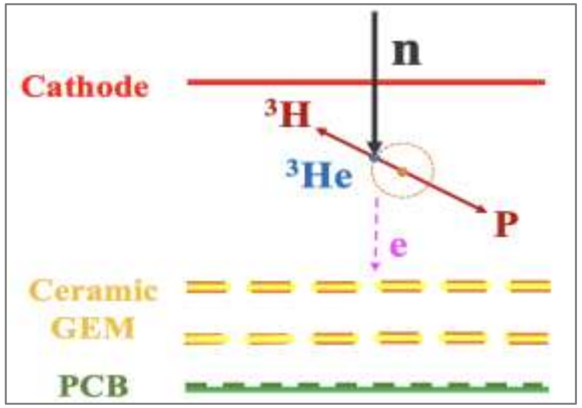
GEM counting rate 10 MHz



^{3}He gas advantage

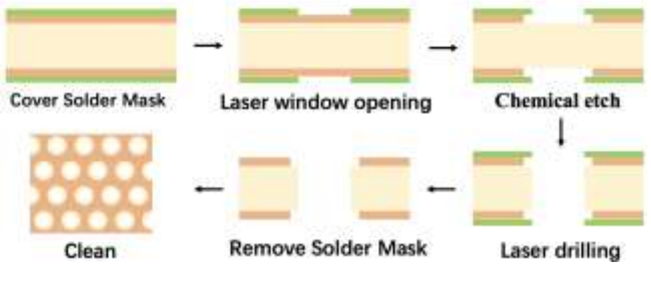


GEM neutron detector with ^{3}He

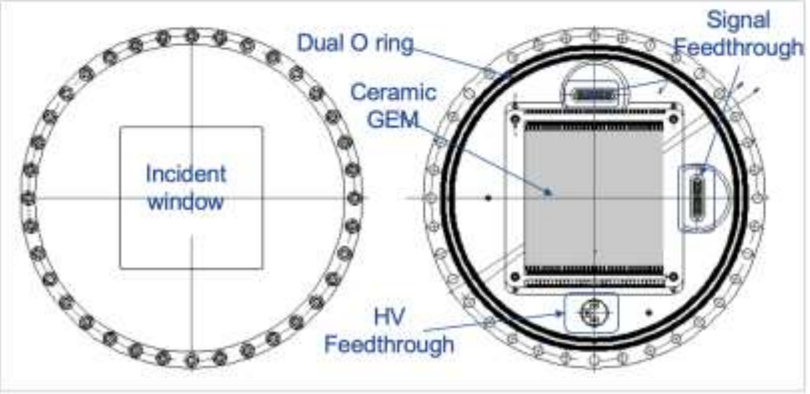


Laser drilling for ceramic GEM

- Laser preparation new technologies and methods
- Research ion feedback physics for new design



Detector high-pressure chamber design

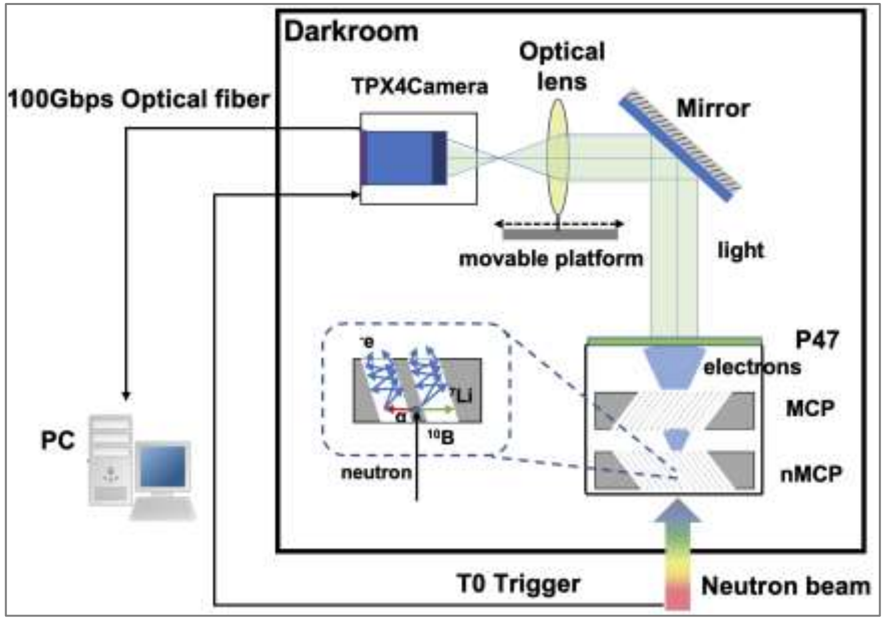


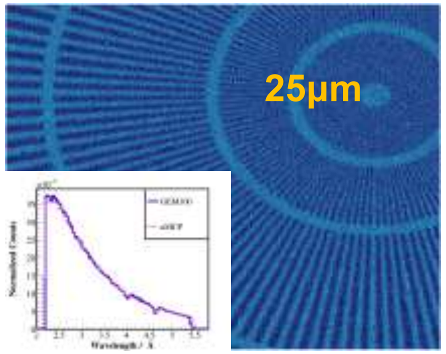
High resolution

Microsecond-level time resolution, and micron level spatial resolution

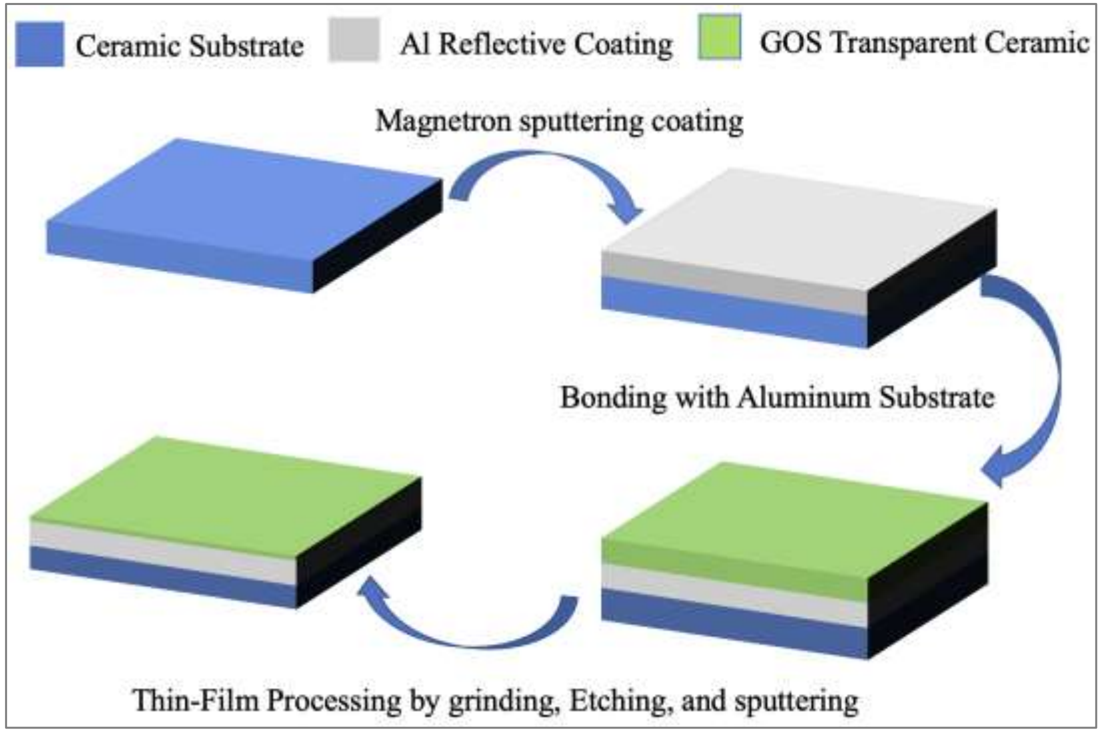
- Researching neutron image intensifiers, integrating neutron conversion and intensifier into a single vacuum device to improve integration.
- Developing ultra-thin transparent ceramic scintillators and TimePix4 cameras (already authorized by CERN).

Neutron image intensifier

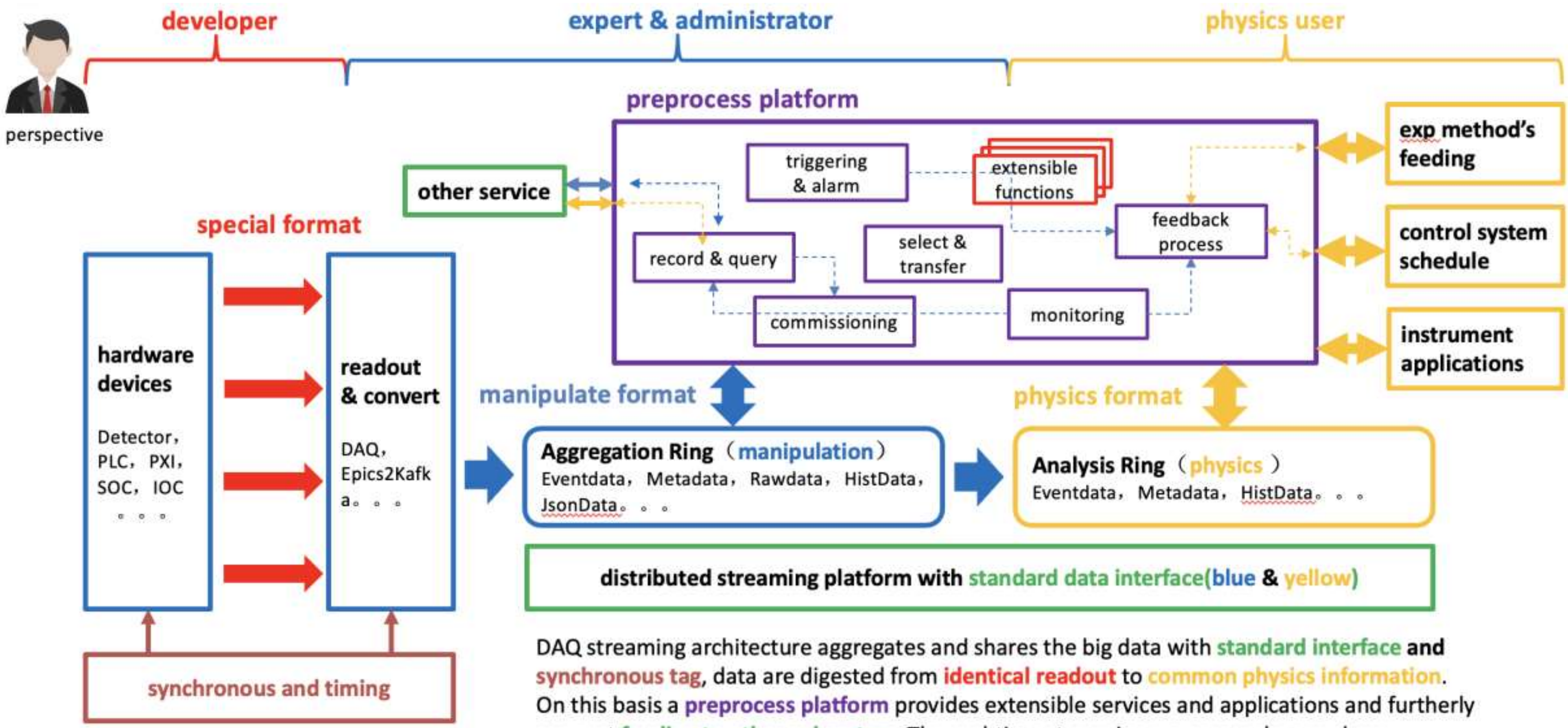




Ultra-thin transparent ceramic scintillator



“Real-Time” - Data-driven system (DSNI)



DAQ streaming architecture aggregates and shares the big data with standard interface and synchronous tag, data are digested from identical readout to common physics information. On this basis a preprocess platform provides extensible services and applications and furtherly connect feeding to other subsystem. The real-time streaming process and open-share manipulation characteristic benefit various future advanced experiment methods.

Summary

- Focus the requirements of neutron instruments, establish a neutron detector "family", promote engineering construction and exploration of new technologies.

- In the future, will focus on the demands of major scientific projects:
  - Solve engineering challenge, conducting engineering technical R&D (vacuum, magnetic field, electromagnetic interference, background suppression).
  - Exploring new technologies to enhance the performance of instruments

Thanks

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中华人民共和国科学技术部
Ministry of Science and Technology of the People's Republic of China

国家自然科学基金委员会
1986
NATIONAL NATURAL SCIENCE FOUNDATION OF CHINA

核探测与核电子学国家重点实验室
State Key Laboratory of Particle Detection and Electronics

中物院中子物理学重点实验室
Key Laboratory of Neutron Physics,CAEP

中国科学院青年创新促进会
Youth Innovation Promotion Association CAS

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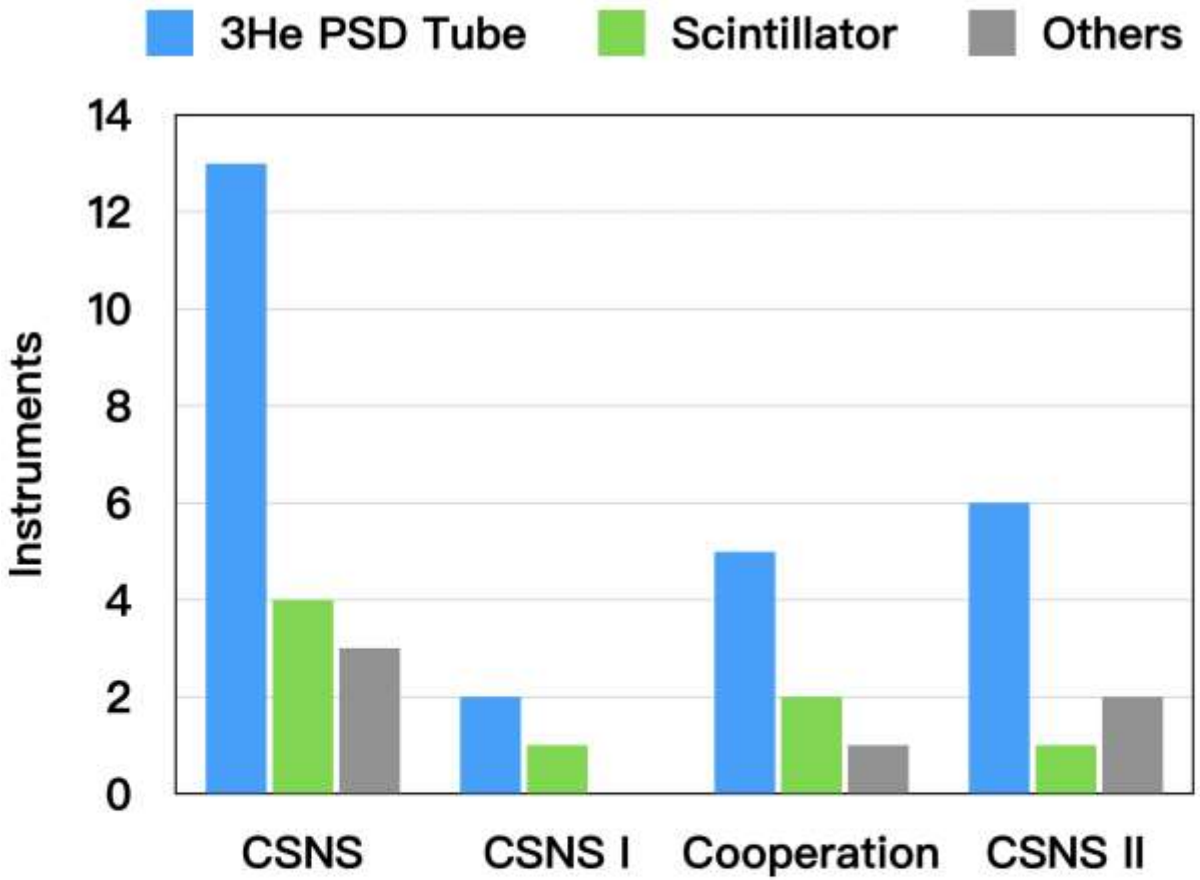
National Institute of Metrology,China

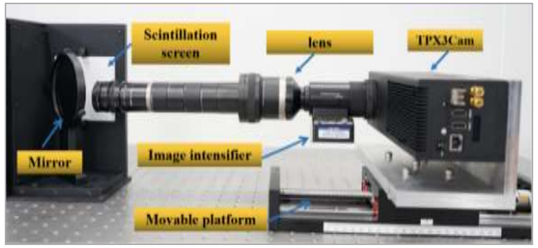
中国科学院 SIAT CHINESE ACADEMY OF SCIENCES 深圳先进技术研究院

KING BROTHER 金百泽科技


The end of the beginning
Still a long way to go
Thanks for your attention!

Detector requirements for instruments at CSNS

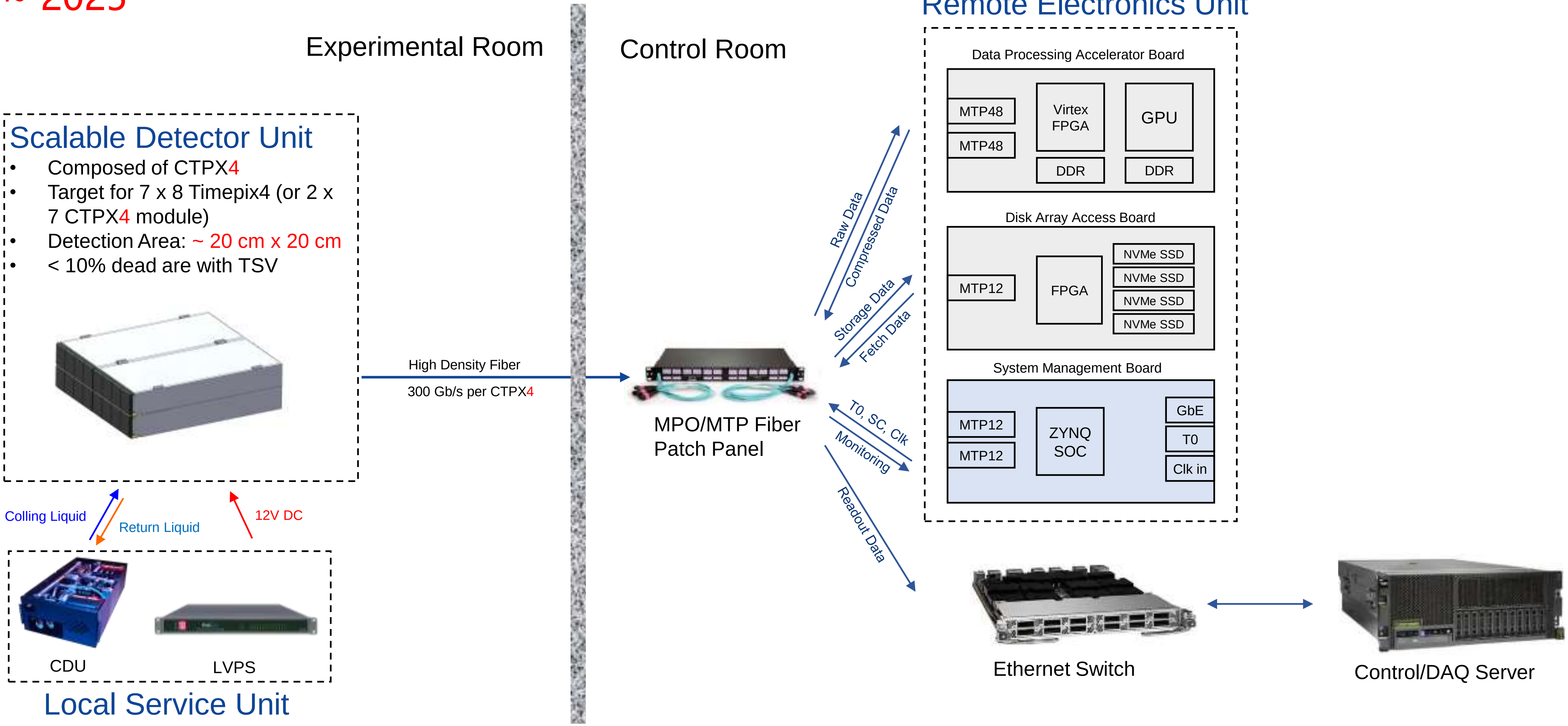




- The **present engineering approach** is based on the technology developed over the past 5-10 years.
- The **ongoing research** aims to provide the solution for the neutron instruments in the future.

Neutron Imaging High Speed Camera Development

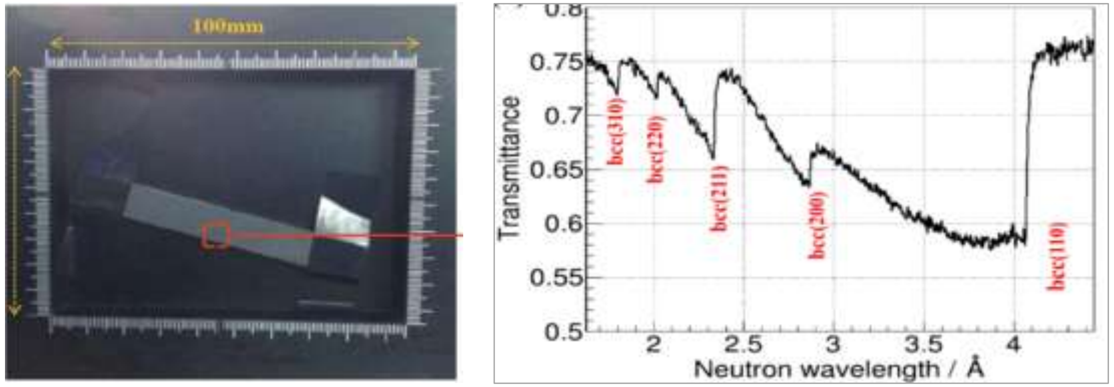
~ 2025



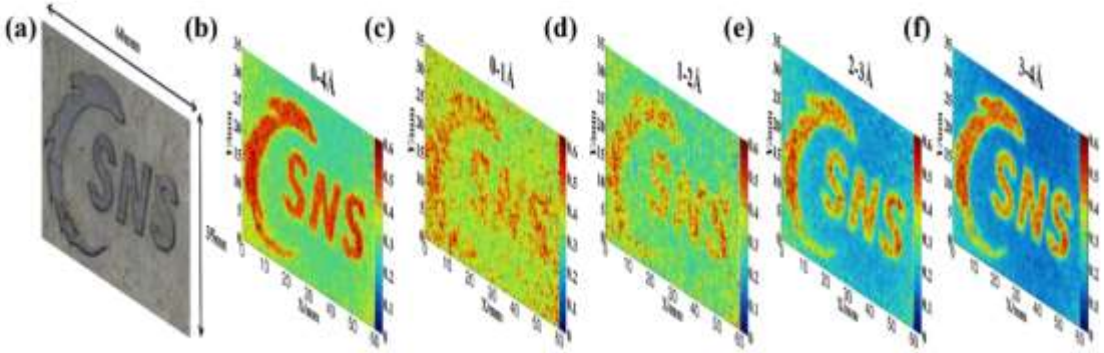
Neutron Imaging Detector-Applications

Successfully carried out several applications in multi fields at CSNS

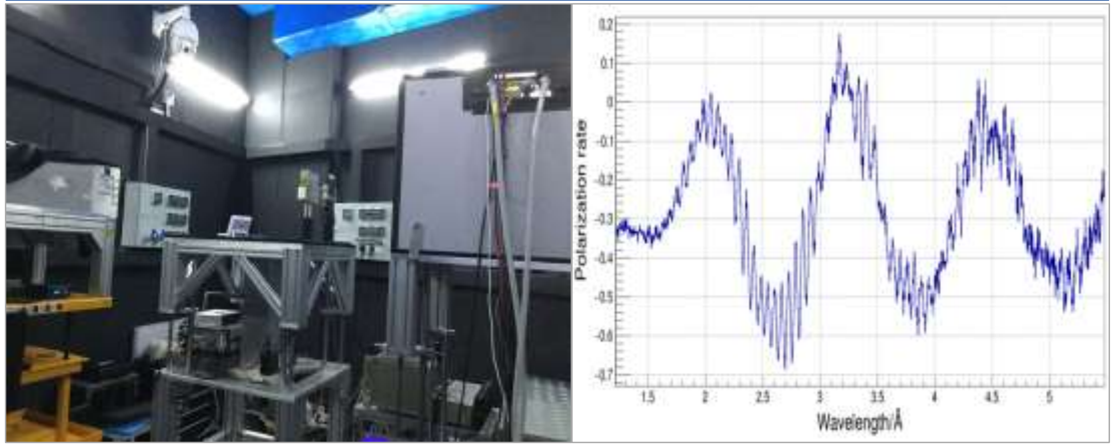
Bragg Edge Neutron Imaging Experiment (Chen Jie)



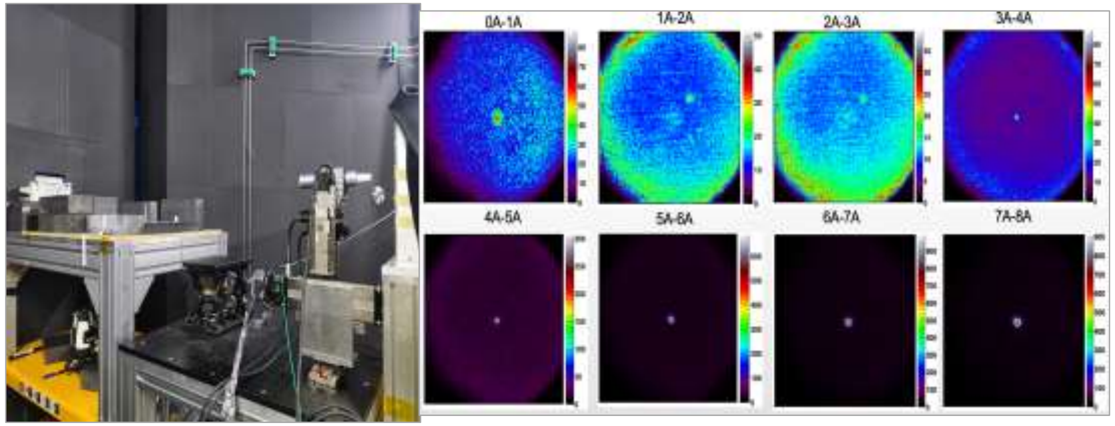
Energy Selective Neutron Imaging



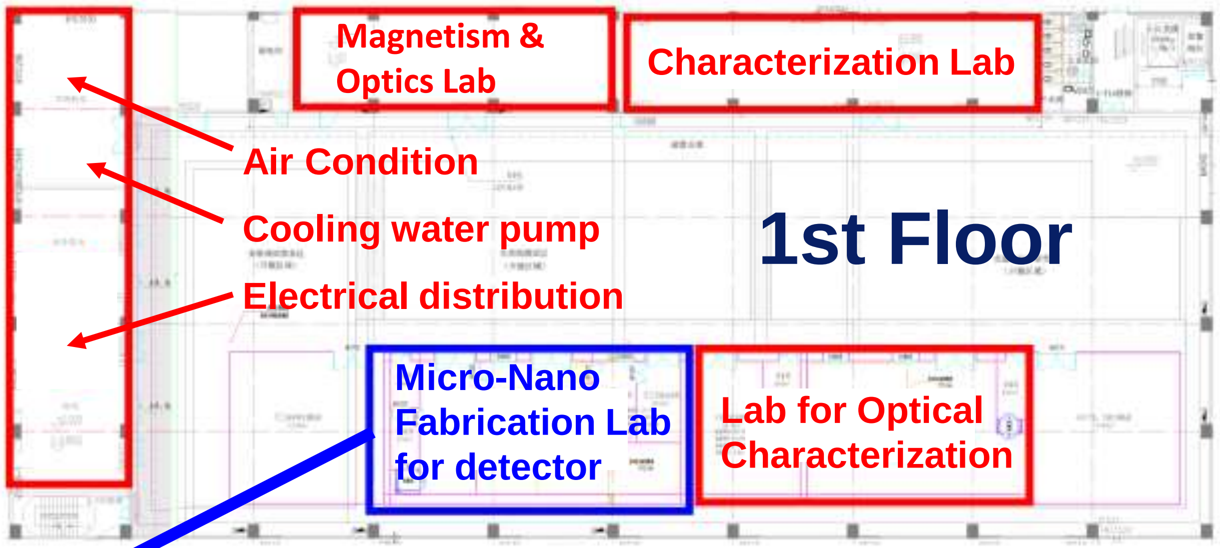
Polarized Neutron Imaging (Wang Tianhao)

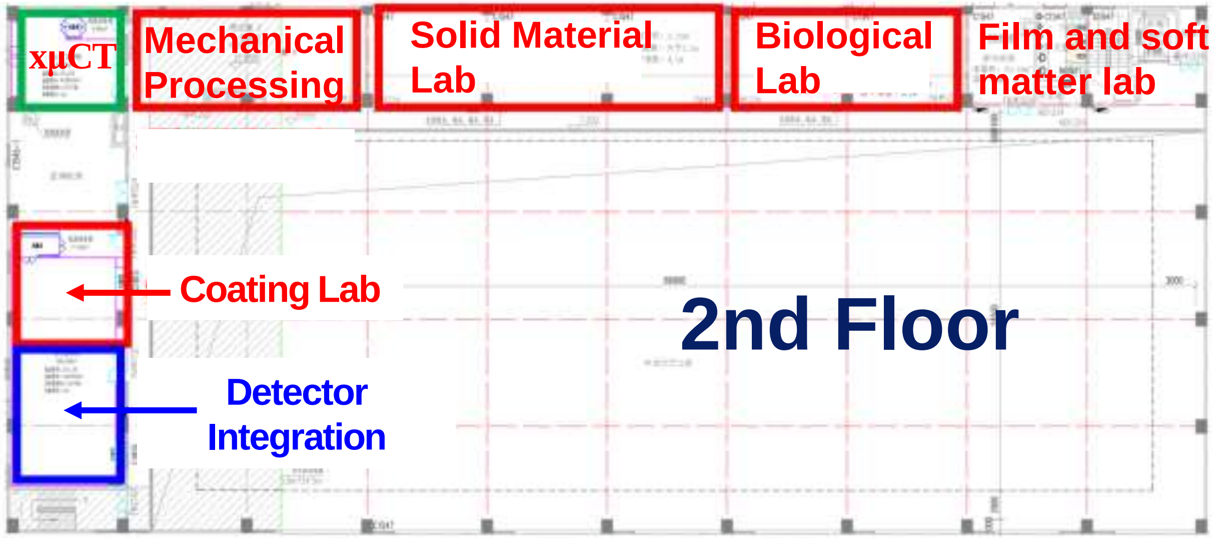


Polycapillary (Yi Tiancheng)



Southern Advanced Photon Source (SAPS) Testing Platform





Nanofabrication Lab for Detector Development

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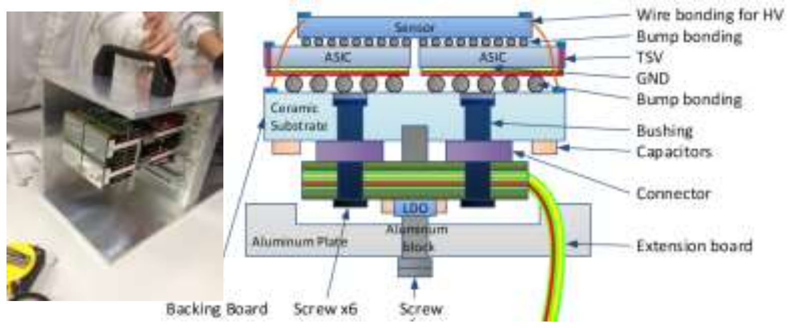
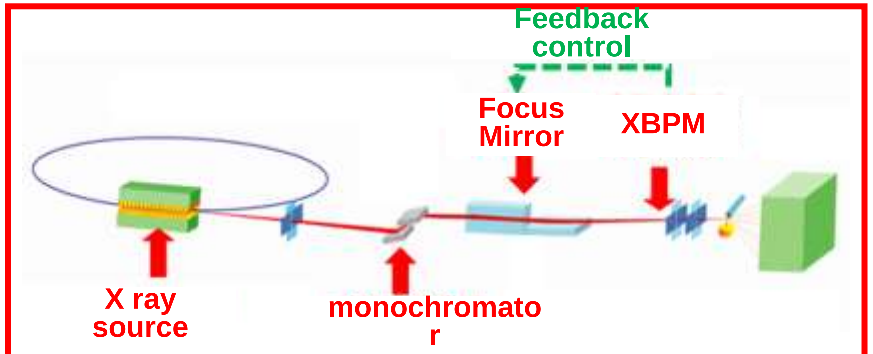
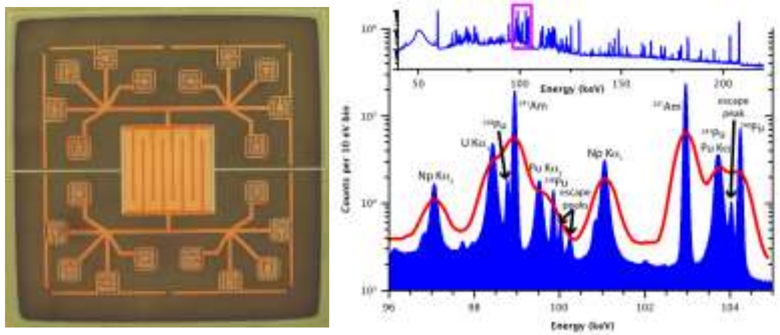
☐ Research feilds:



Multi-threshold photon counting pixel array detector



Beam position stabilization system based on diamond detectors



Ultra-high energy resolution detector based on TES

☐ Supporting Conditions:

Laser Direct Writing Lithography Machine

Magnetron Sputtering Coating machine

Reactive Ion Etching Machine

Wire bonding

Probe Station & Semiconductor Analyzer

Microscope

Micro-Nano Fabrication:
- Minimum critical dimension: 300nm
- Overlay alignment accuracy: 500nm
- Maximum substrate size: 6 inch

Packaging Integration:
- Maximum wire length: 8mm
- Bonding accuracy: 3μm
- Bonding Wire Range: 56mm*90mm

Testing and Calibration:
- I-V、C-V Curve, Voltage range: -210V~210V
- High-Bandwidth Oscilloscope, Bandwidth: 36GHz