

# J-PARC/MLFにおける 2次元ガス検出器及び シンチレータ検出器の開発

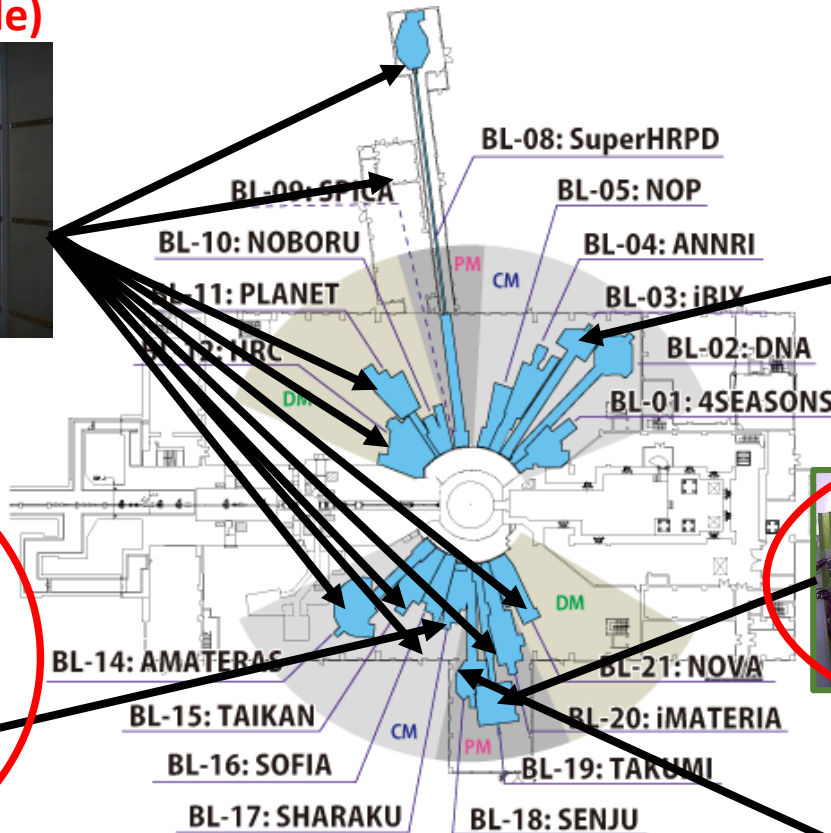
J-PARCセンター 物質生命科学ディビジョン  
坂佐井 馨

# MLFビームラインにおける検出器の現状

## He-3 detectors (commercially available)



BL01, BL02, BL08, BL09, BL11, BL12  
BL14, BL15, BL16, BL17, BL20, BL21



## Scintillator detectors



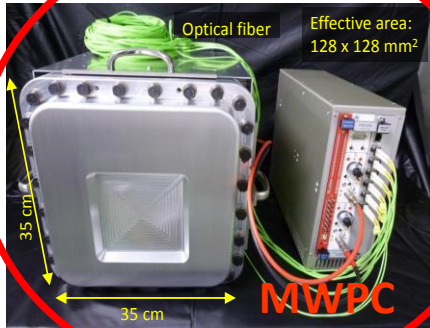
BL03



BL19



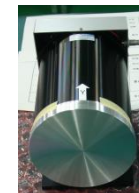
BL18



BL17

Multi-wire proportional counter

BL16, BL17  
RPMT



# Outline

- シンチレーション検出器の開発
  - 1次元シンチレーション検出器
  - 2次元シンチレーション検出器
- 2次元ガス検出器の開発
  - マルチワイヤ型検出器

# MLFにおけるシンチレーション検出器

**BL19(Takumi)** Residual stress diffractometer  
(2007 – 2009)

**Linear scintillation detector**



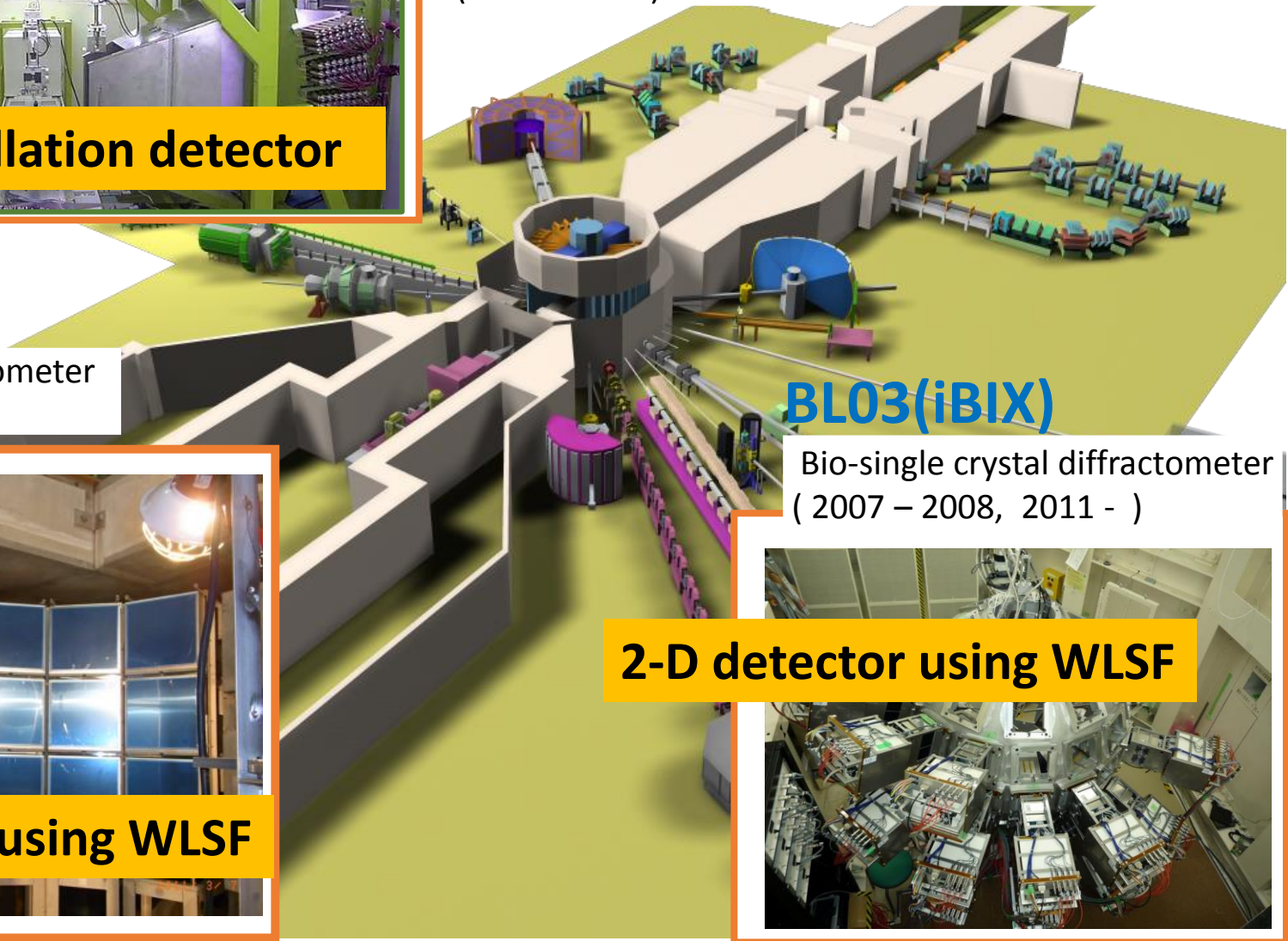
**BL18(Senju)**  
Single crystal diffractometer  
(2010 - 2013)



**2-D detector using WLSF**

**BL03(iBIX)**  
Bio-single crystal diffractometer  
(2007 – 2008, 2011 - )

**2-D detector using WLSF**



# Outline

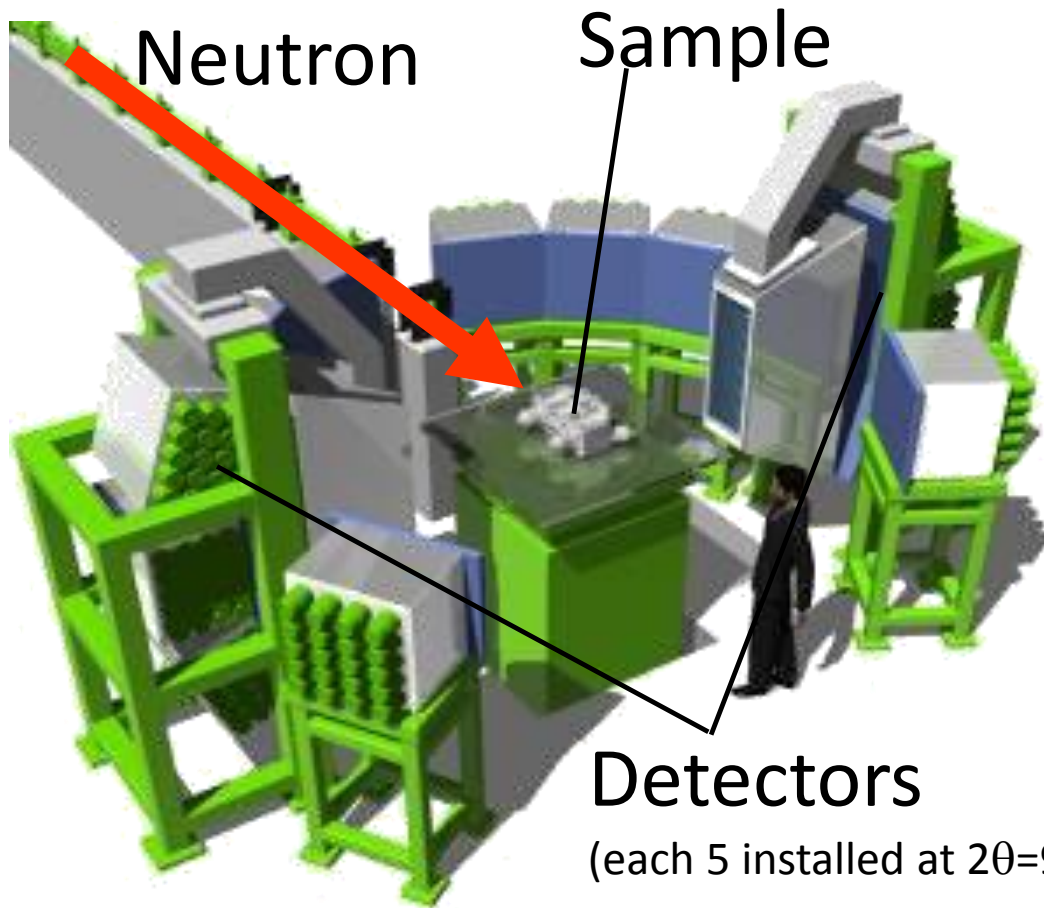
- シンチレーション検出器の開発
  - 1次元シンチレーション検出器
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2次元ガス検出器の開発

- マルチワイヤ型検出器

# BL19における1次元シンチレーション検出器

*Developed under collaboration with ISIS, RAL*



Number of detectors: 10

## Specifications of Detectors

The detector should have

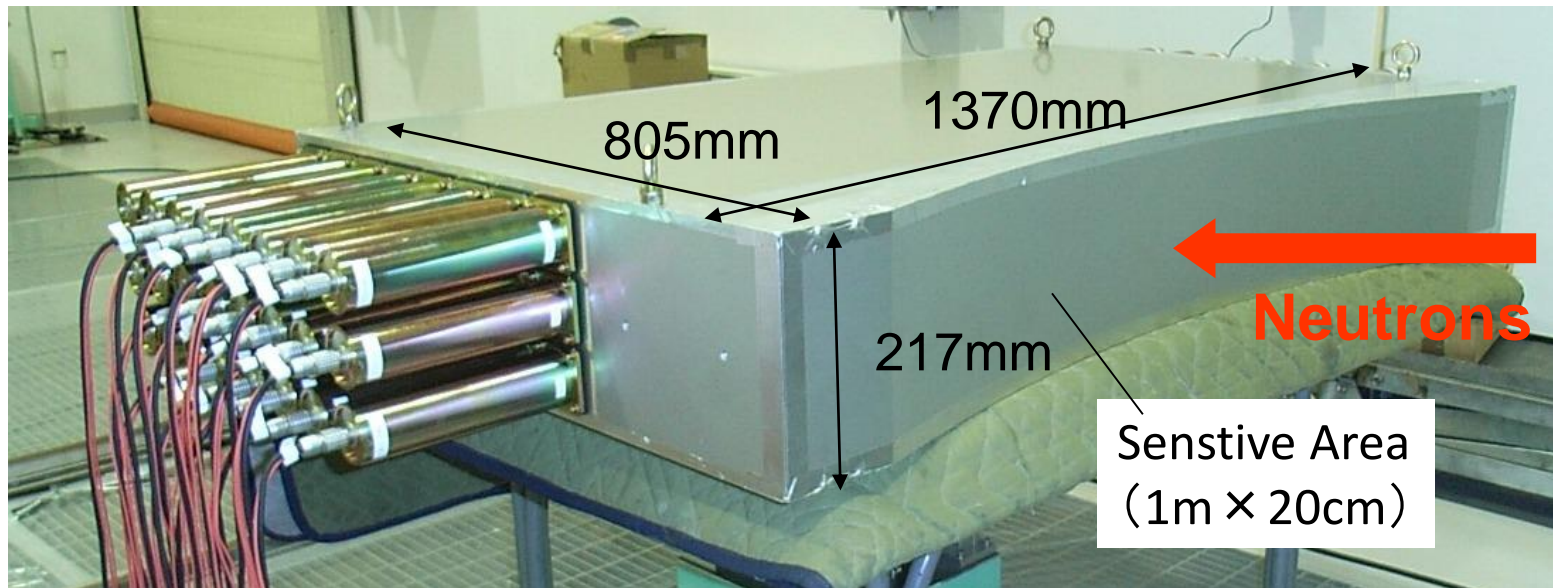
- Sensitive area: 1000 mm x 200 mm
- Position resolution: 3mm
- 360 pixels / detector
- Detection efficiency: >50%@1Å
- Gamma sensitivity: <math>10^{-6}</math>@1.3MeV

**Detectors**

(each 5 installed at  $2\theta=90$  degree position)

# BL19における1次元シンチレーション検出器

## Scintillation Detector using ZnS/LiF



Detector size without PMT :  $805 \times 1370 \times 217$ mm  
Detector size with PMT:  $805 \times \sim 2000 \times 217$ mm

weight :  $\sim 120$ kg (without PMT)  
weight :  $\sim 180$ kg (with PMT)

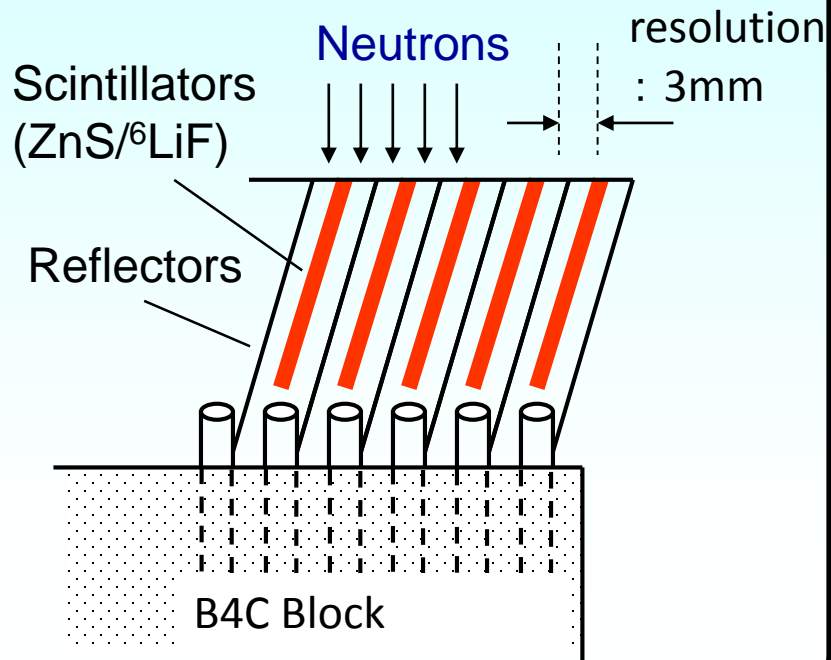
Sensitive area :  $1\text{m} \times 20\text{cm}$   
Radius curvature :  $R=2\text{m}$

Number of PMT : 48/detector  
Number of Pixels : 360  
Resolution : 3mm

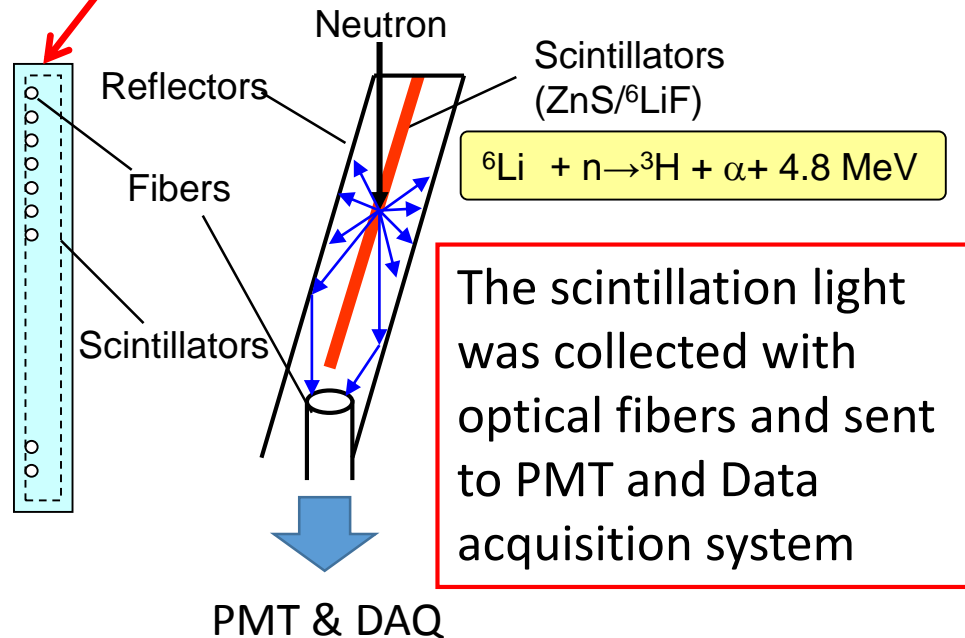
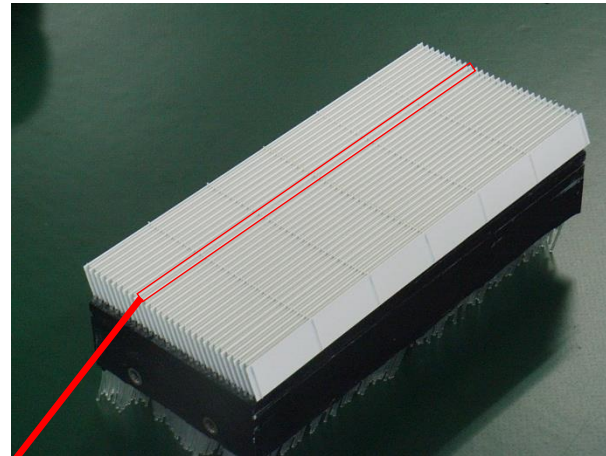
# BL19検出器のヘッドの構造

## Venetian Head

- Detection of scintillation light from both sides of scintillator
- Increase of detection efficiency using scintillators tilted to neutron direction (Effective thickness increased)



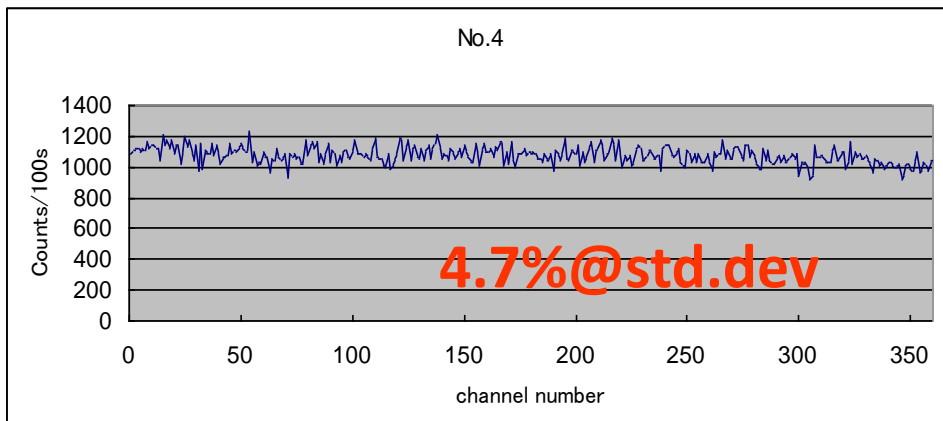
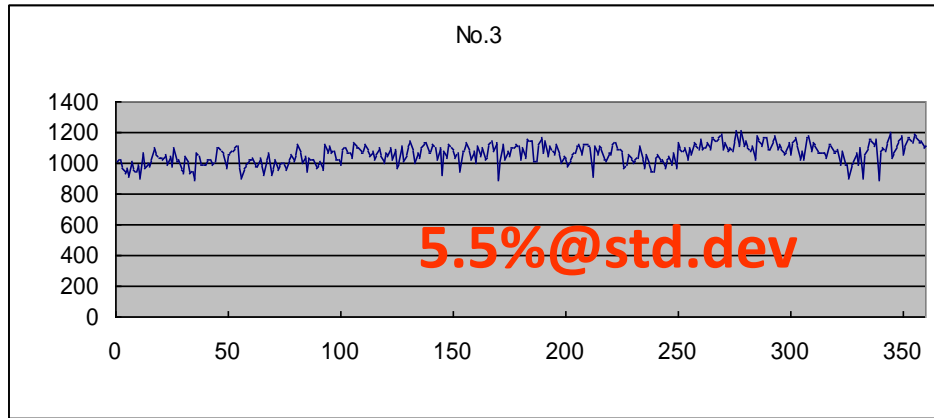
## Scintillator & grids



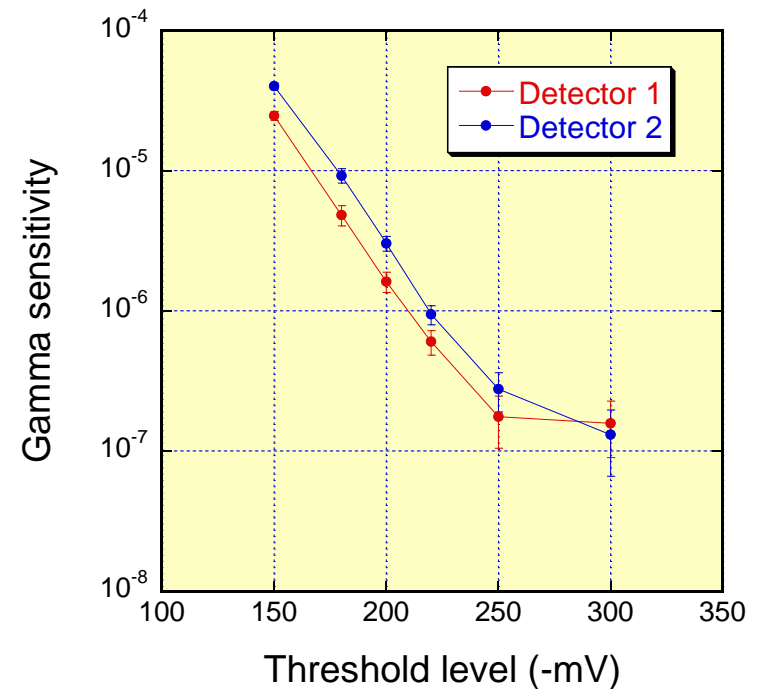


# BL19検出器の性能

## Uniformity measured with PE rod



## Gamma sensitivity



**Gamma sensitivity  $< 10^{-6}$   
with a  $^{60}\text{Co}$  source  
(at disc. level of 250mV)**

# BL19TAKUMI検出器

- 3mm position resolution
- Detection efficiency:  $>50\%$ @1Å
- Gamma sensitivity:  $<10^{-6}$ @1.3MeV
- $3 \times 196\text{mm}$  detector element
- 360ch/detector
- Total 10 detector
- Total 3600 elements
- $2.0\text{m}^2$  active area
- $75^\circ < 2\theta < 105^\circ$



**Total 10 detectors were installed and have been in service for several years**

# Outline

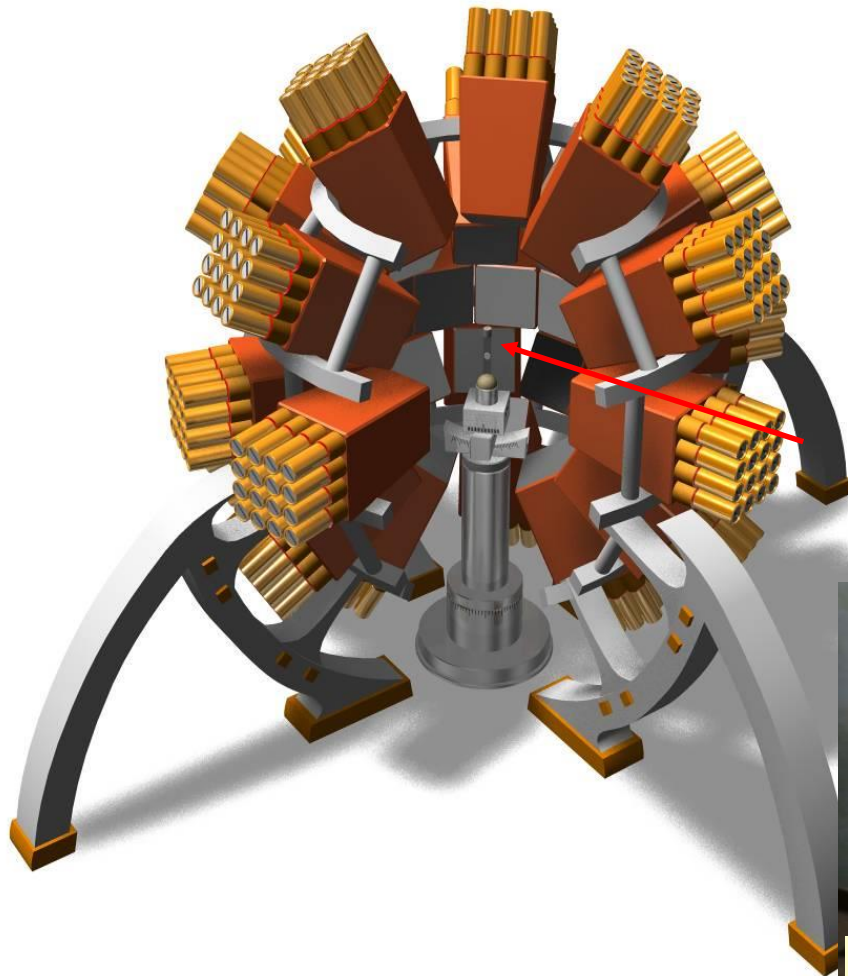
- シンチレーション検出器の開発
  - 1次元シンチレーション検出器
  - 2次元シンチレーション検出器

2次元ガス検出器の開発

- マルチワイヤ型検出器

# BL03における2次元シンチレーション検出器

- *iBIX* : Single crystal diffractometer for bio-molecular crystallography
- A first **WLS-fiber-based scintillator detector** developed at the J-PARC.



## Specifications required to detector

Detection efficiency : > 50% (1.8Å)

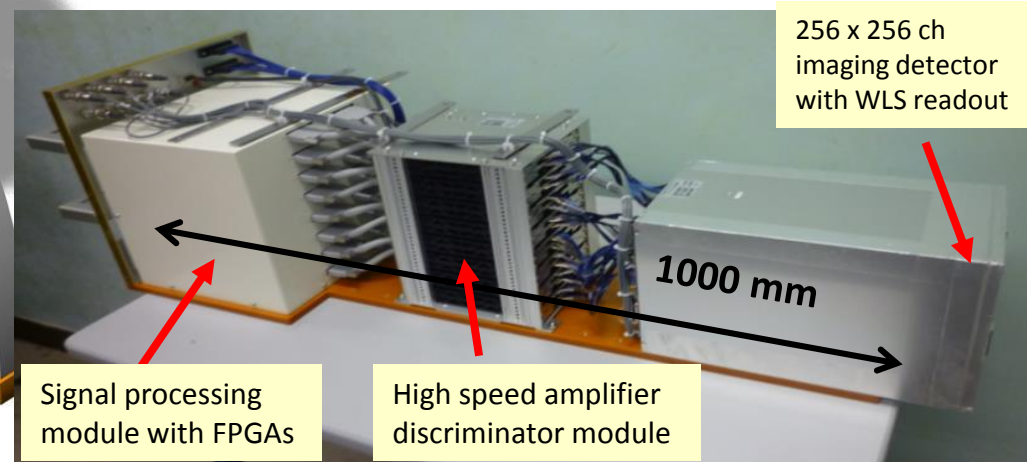
Spatial resolution : < 1 mm

Gamma sensitivity : <  $10^{-6}$

Packing density : ~ 70%

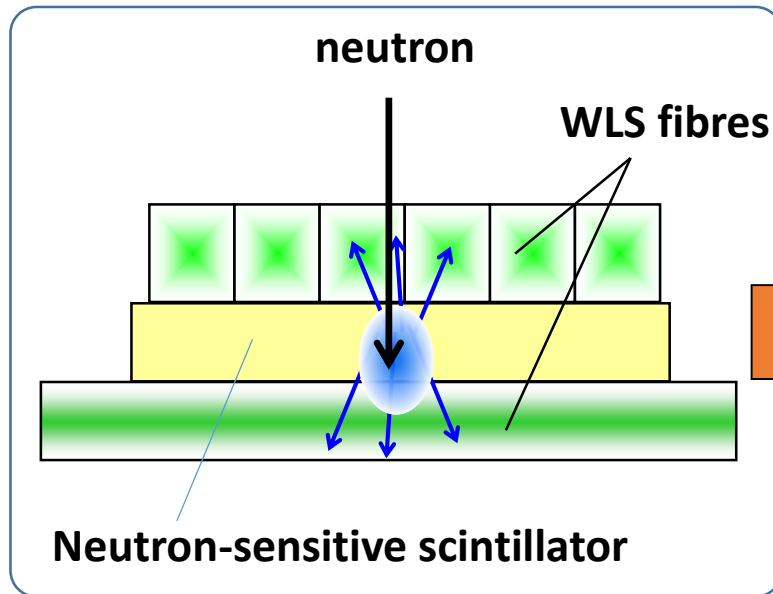
Compact

Neutron  
Prototype detector (in 2008)



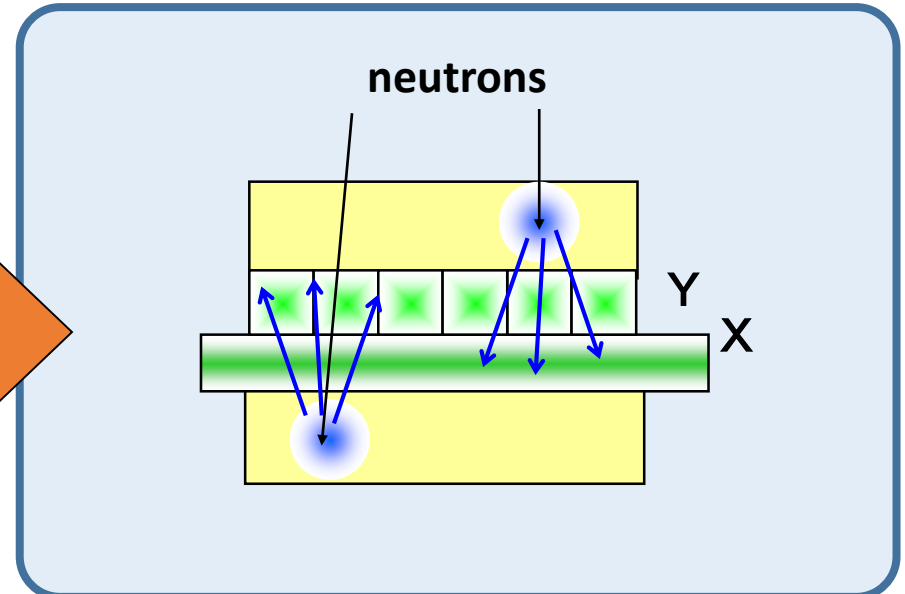
# iBIX検出器のヘッド構造

Conventional structure



Single Scintillator screen

**iBIX structure**



Double scintillator screens

(1) Developed a  $\text{ZnS}/^{10}\text{B}_2\text{O}_3$  scintillator and double the number of screens

→ High **detection efficiency**

(2) Packed ½-mm diameter WLS fiber ribbons → High **spatial resolution**

# iBIX検出器の位置分解能

Edge Spread function:

$$f(x) = A \operatorname{erf} \frac{x - \mu}{\sigma \sqrt{2}} + B$$

Fitting parameters

$$A = 0.5 \rightarrow 0.4483$$

$$B = 0.1 \rightarrow 0.09343$$

$$\mu = 50 \rightarrow 50.41$$

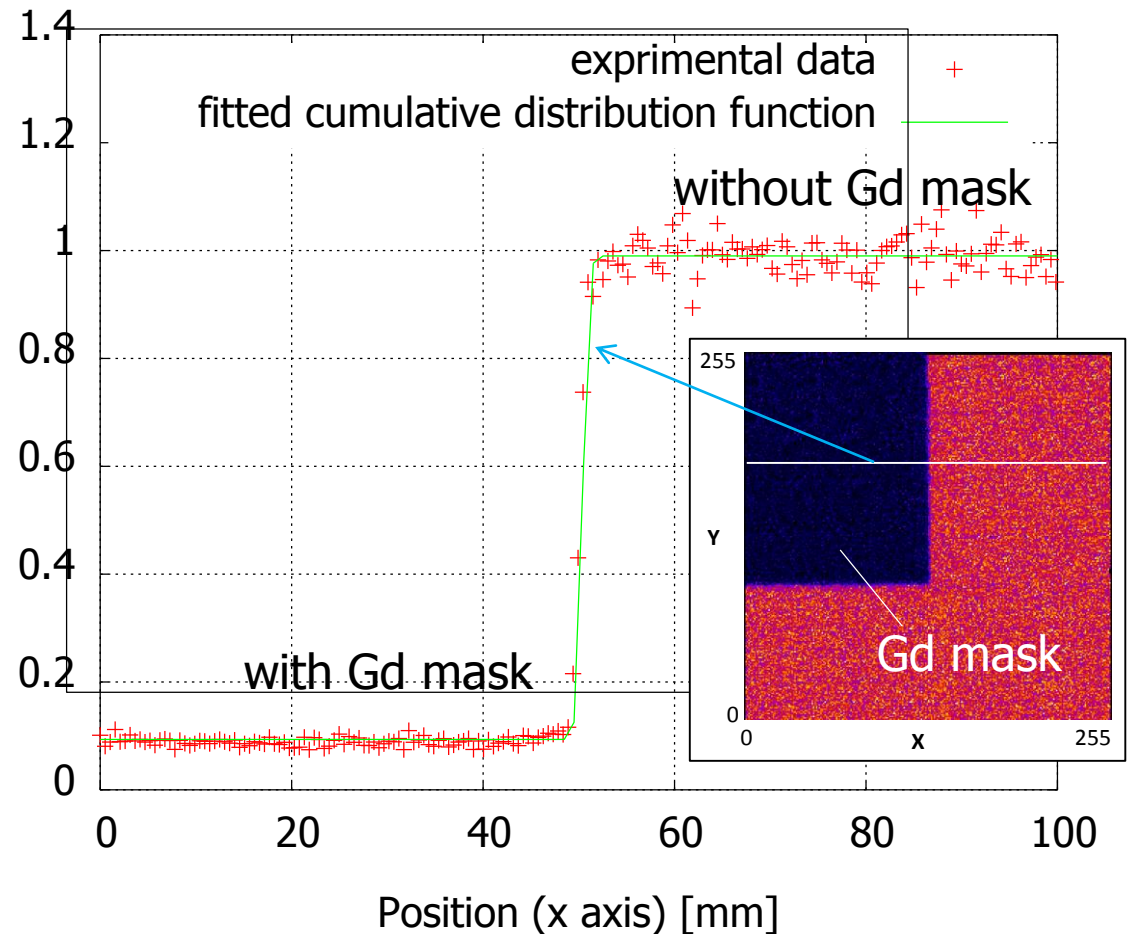
$$\sigma = 0.5 \rightarrow 0.5082$$

Spatial resolution (FWHM)

$$= \operatorname{SQRT}(2 \log 2) \sigma$$

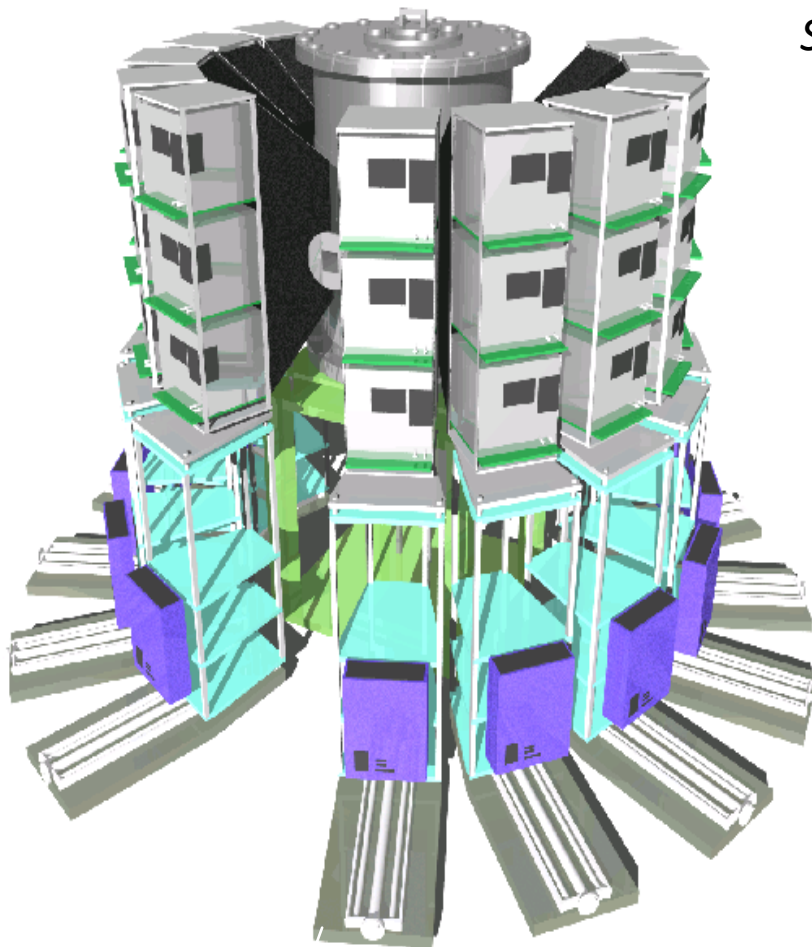
$$\sim 2.3548 \sigma$$

$$= \mathbf{1.19} \text{ [mm]}, \text{ including beam divergence}$$



# BL18(Senju)の2次元シンチレータ検出器

- \* *SENJU* : A time-of-flight Laue single crystal diffractometer
- \* A large area position-sensitive scintillator detector  
using **WLS fiber technology**



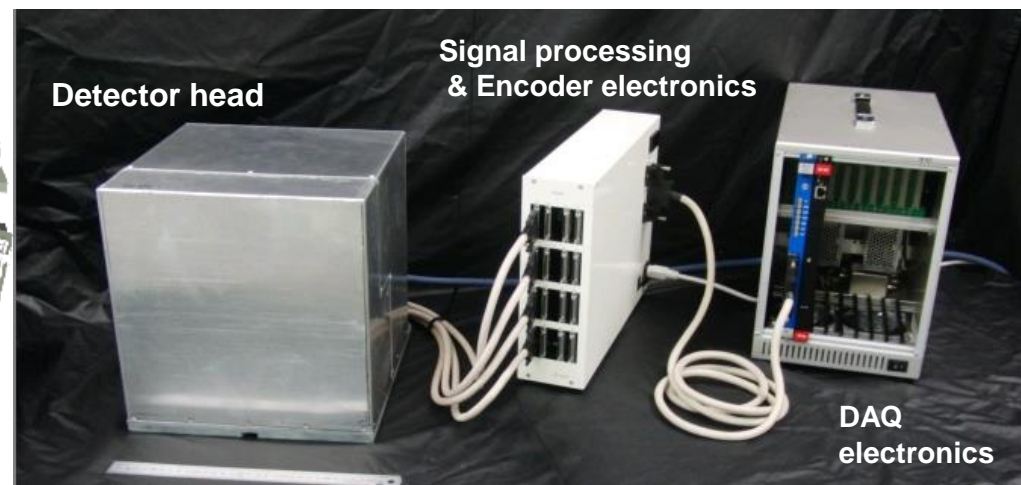
*Specifications  
required to detector*

Spatial resolution :  $\sim 4$  mm

Detection area :  $\sim 30 \times 30$  cm<sup>2</sup>

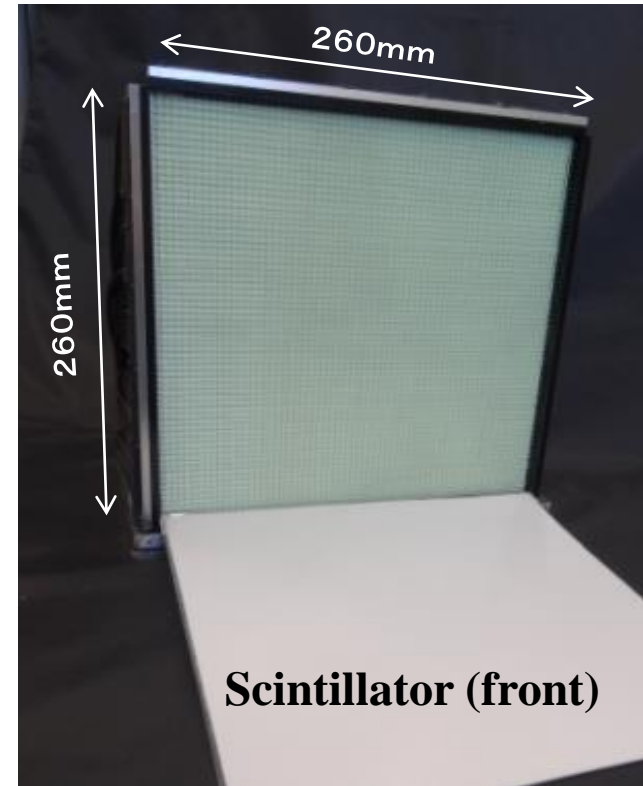
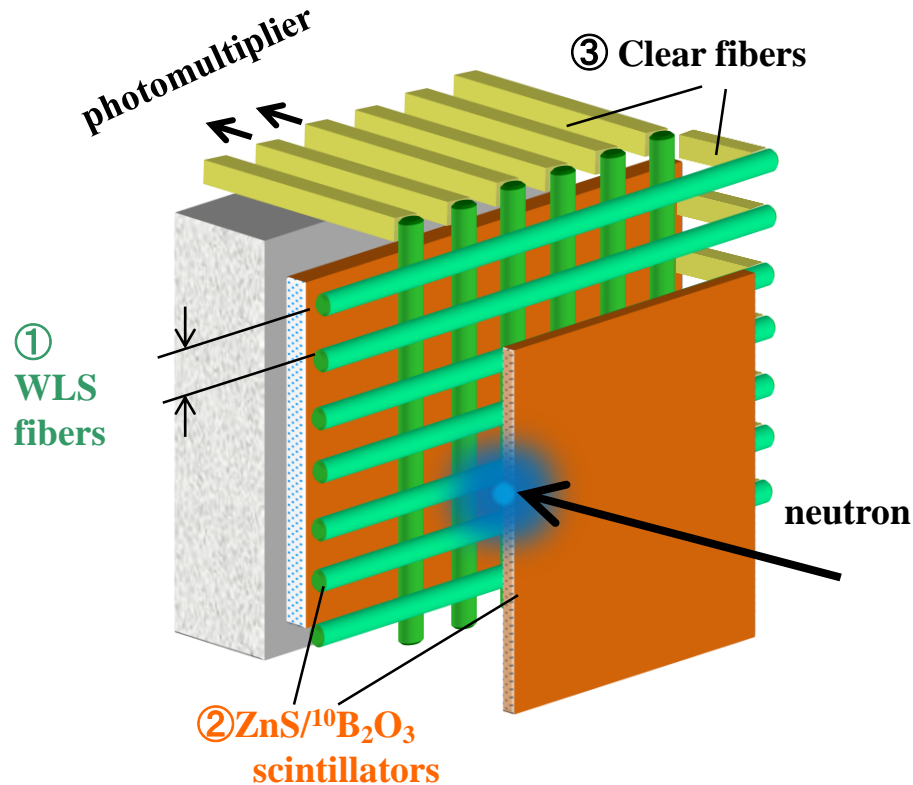
Detection efficiency :  $> 40\%$  @  $1.8\text{\AA}$

Gamma-ray sensitivity :  $< 10^{-6}$



# BL18検出器のヘッド構造

In the design, to increase a detector coverage at an affordable cost the WLS fibers are placed at a regular pitch of 4 mm.

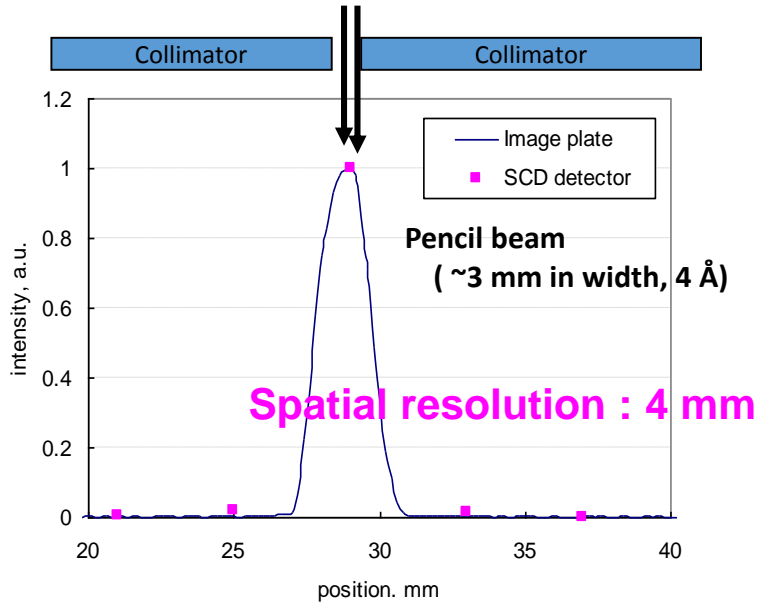


## Key Designs

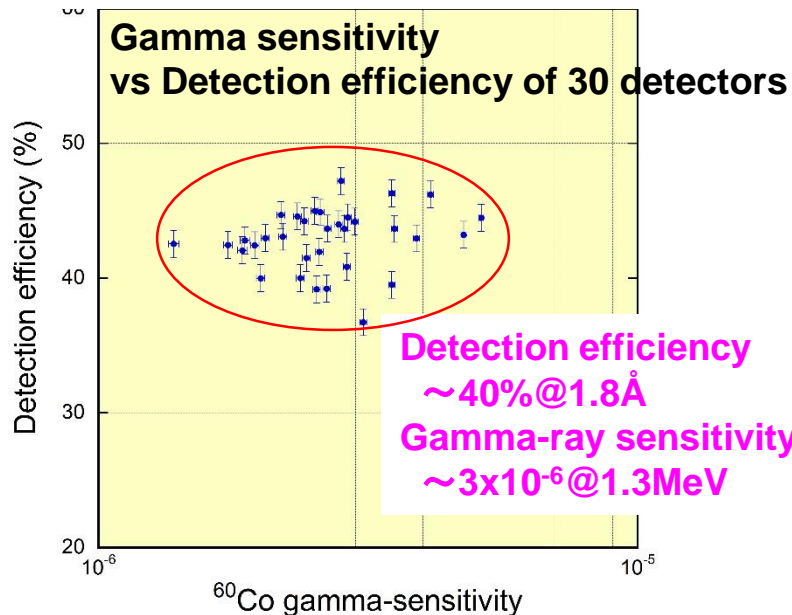
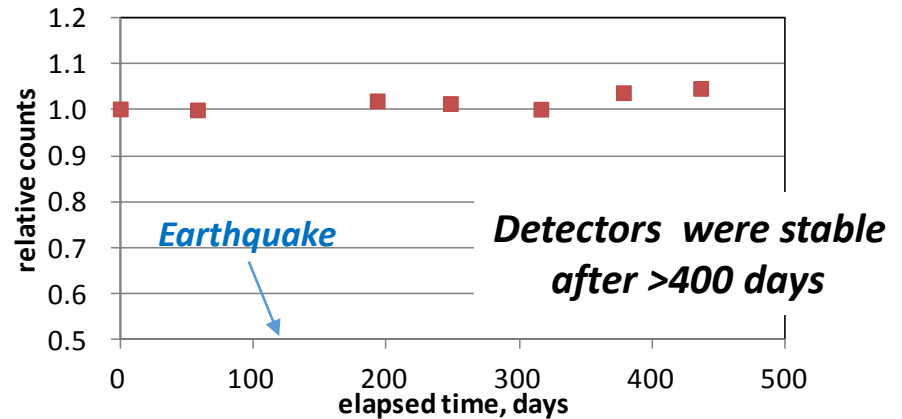
- (1) **WLS fiber placed at a 4-mm pitch** → Large area
- (2) **Two scintillator screens** → Detection efficiency
- (3) **Bend clear fiber backward** → Minimize dead area



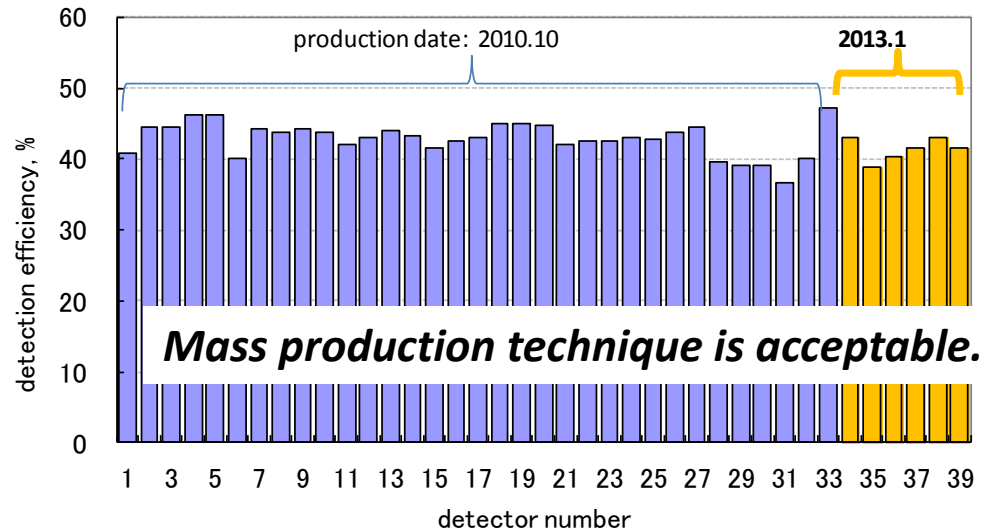
# BL18検出器の性能



## Count stability over time

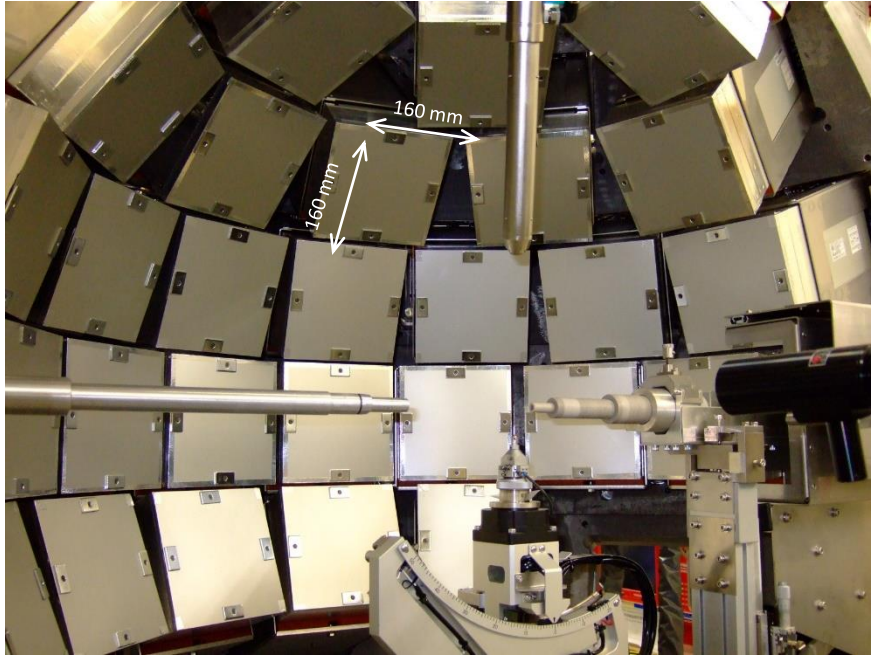


## Detector efficiency of 37+2 detectors



# 波長シフトファイバを用いたシンチレーション検出器

## BL03(iBIX)



### High spatial resolution detector

pixel size : 0.5 x 0.5 mm

detective area : 133 x 133 mm<sup>2</sup>

detector efficiency: ~50% for 1.8 Å

gamma sensitivity: ~1 x 10<sup>-6</sup>

**Total 30 detectors were installed  
and in service now**

## BL18(SENJU)



### Large area detector

pixel size : 4 x 4 mm

detective area : 256 x 256 mm<sup>2</sup>

detector efficiency: ~40% for 1.8 Å

gamma sensitivity: ~3 x 10<sup>-6</sup>

**Total 37 detectors were installed  
and in service now**

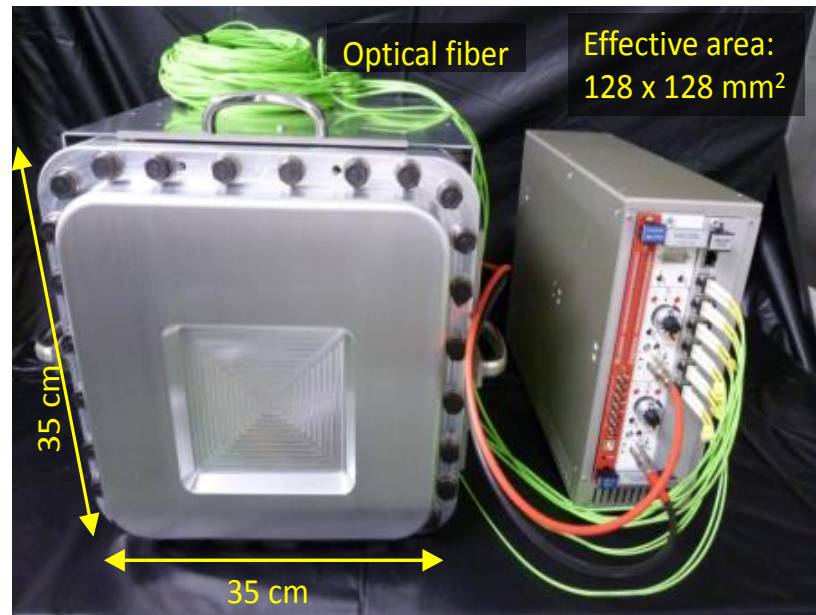
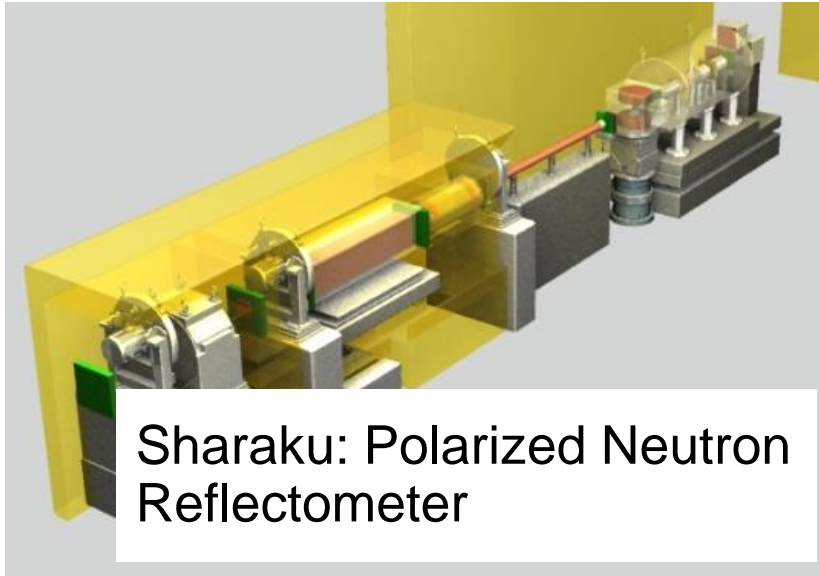
# Outline

シンチレーション検出器の開発

- 1次元シンチレーション検出器
- 2次元シンチレーション検出器

- 2次元ガス検出器の開発
  - マルチワイヤ型検出器

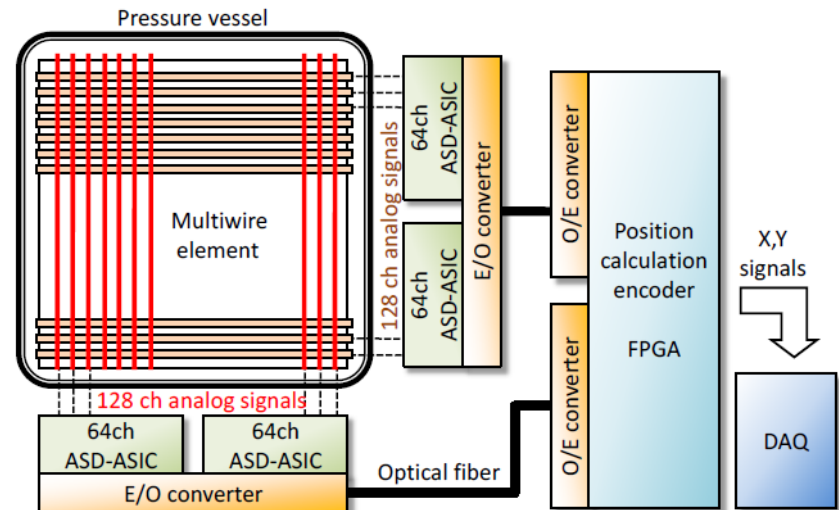
# BL17におけるマルチワイヤ型検出器



## MWPC system

Installed in MLF/BL17

- Pressure vessel withstanding up to 8 atm
- Multi-wire type detector element
  - Wire pitch: 1 mm
  - Sensitive area: 128 x 128 mm<sup>2</sup>
- ASD-ASIC for multi-channel signal processing
- Individual line readout
- Optical signal transmission

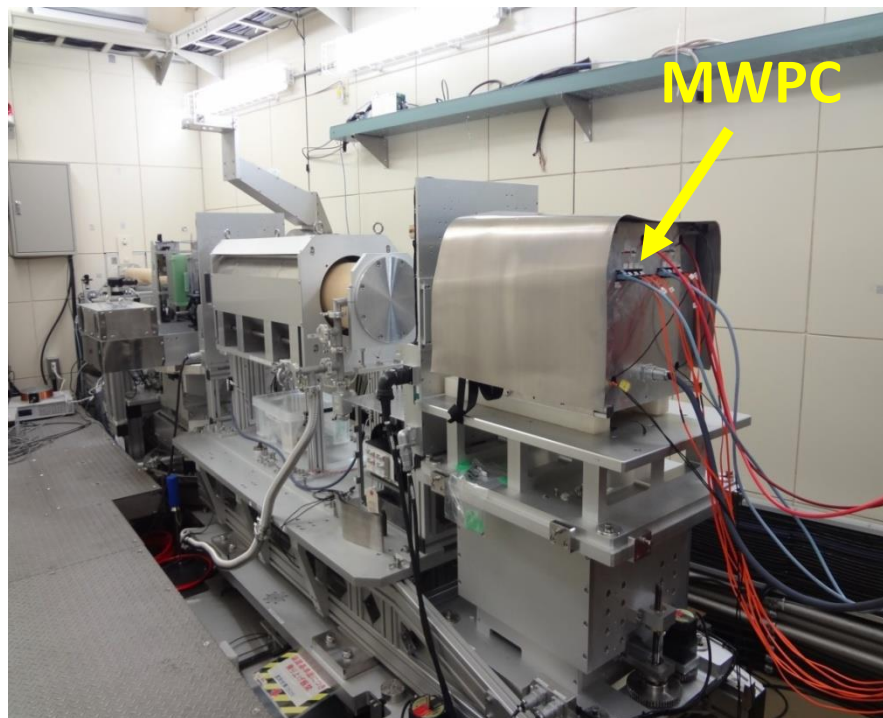
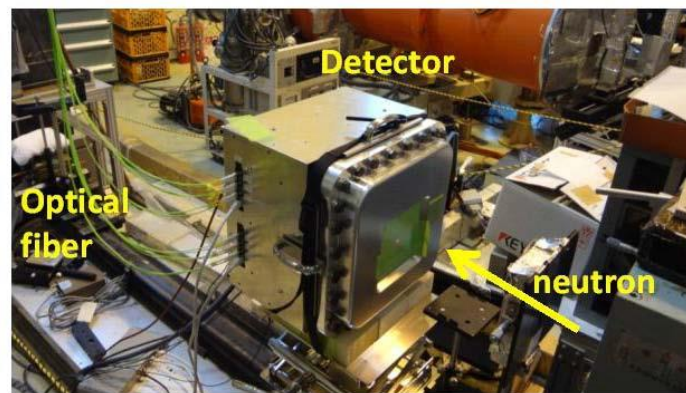


# 開発したMWPCの性能評価

Irradiation experiments were performed

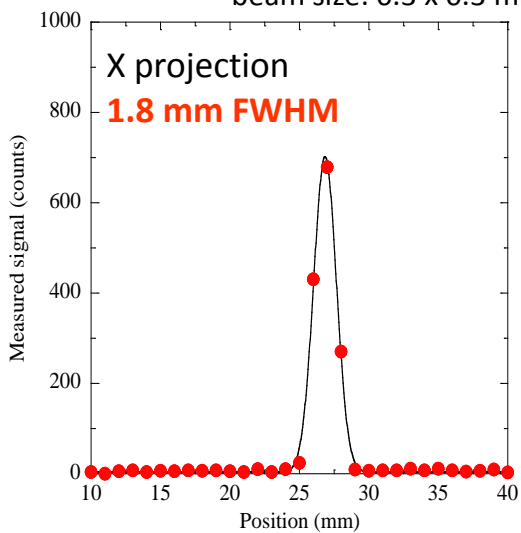
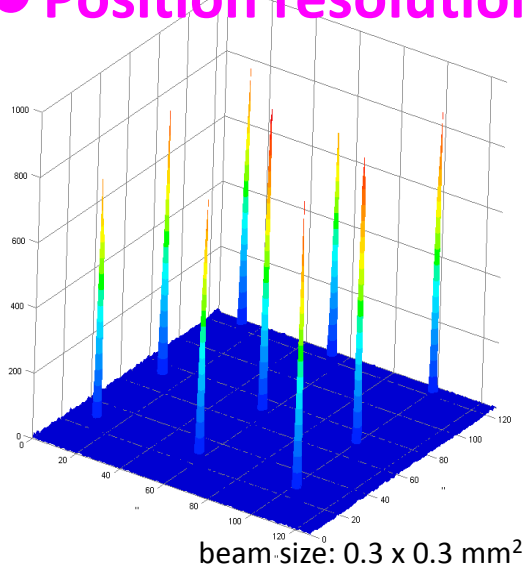
- using Cf-252
- at KUR/CN3
- at J-PARC/MLF BL17

Performance test at KUR

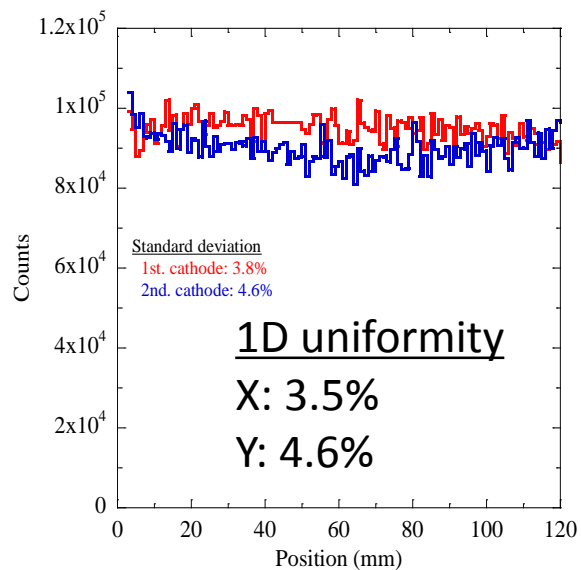
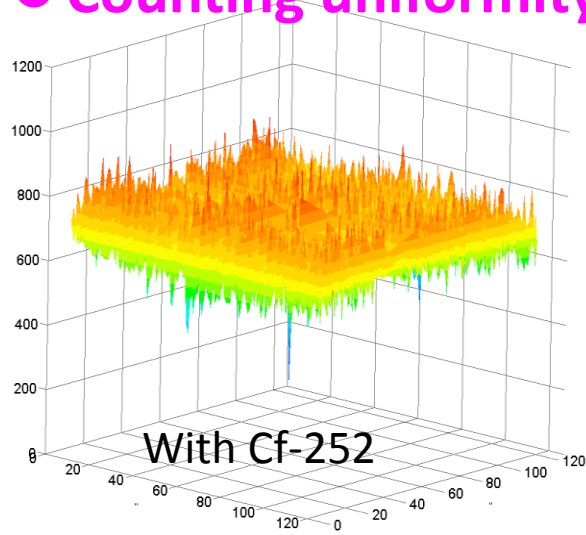


# Performances of MWPC

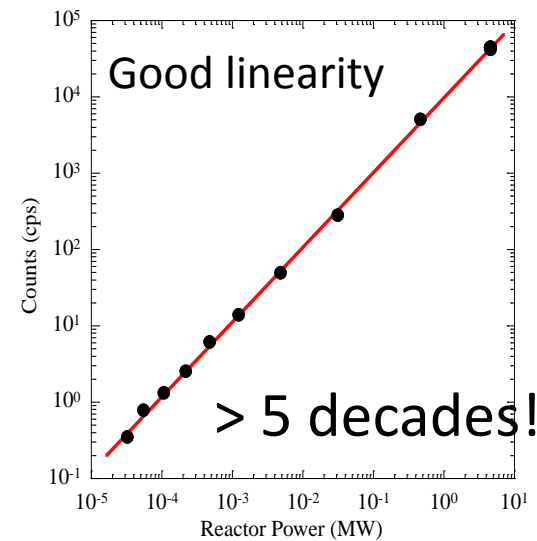
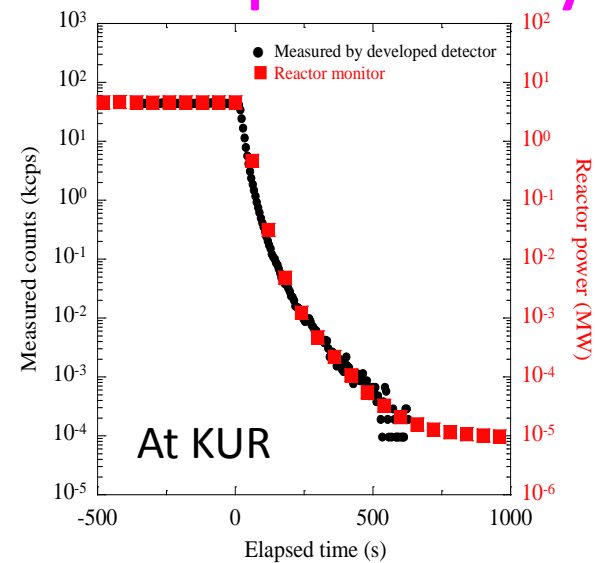
## ● Position resolution



## ● Counting uniformity



## ● Output Linearity



## まとめ

- 中性子検出器は中性子散乱実験等において、非常に重要な役割を果たしており、このため、我々はJ-PARC/MLFにおいて、様々な中性子検出器を開発してきた。

### シンチレーション検出器に関しては、

- BL19に対しては、大型の1次元検出器を開発した。BL03及びBL18に対しては波長シフトファイバを用いた2次元検出器を開発した。これらの検出器は共用開始後順調に稼働している。

### ガス検出器に関しては、

- BL17において、マルチワイヤ型検出器(MWPC)を開発した。位置分解能や一様性等のMWPCの性能をKUR等で確認した。