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@Sanjyo Kaikan, University of Tokyo

Portable High Energy X-ray and Neutron Sources and Applications

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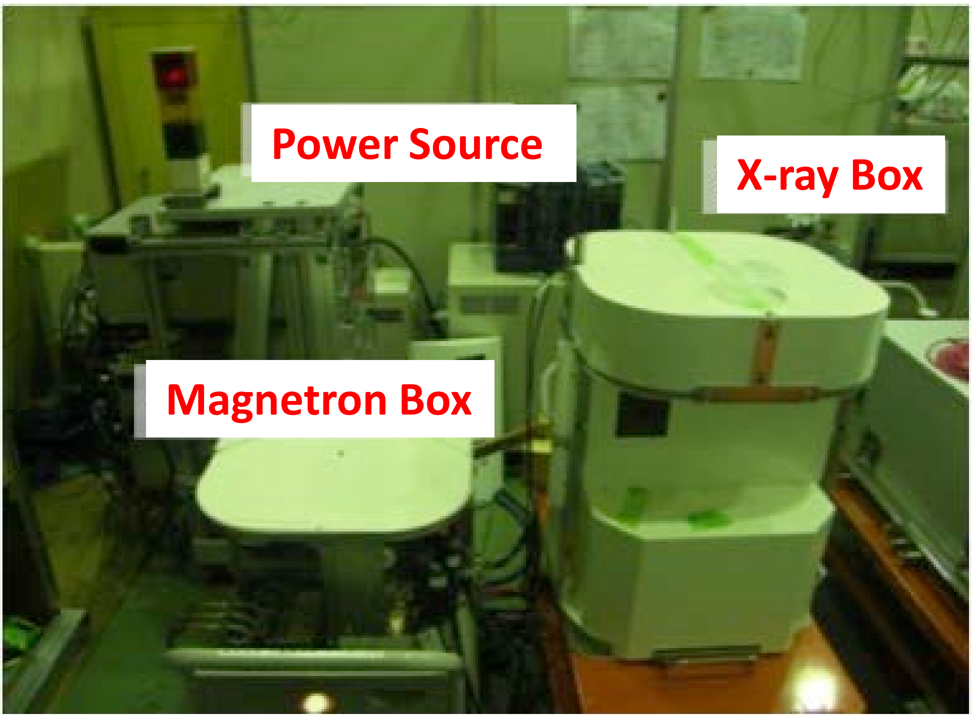
Upgraded 950 keV System by Side-coupling

The portable X-band 950keV linac system we have developed is consist of three boxes.



Parameters of Accelerator	
Operating frequency	9.3 [GHz]
RF source	Magnetron
RF Power	250kW
Width and number of repetitive of pulse	2[μs], 280[PPS]
Length of acceleration tube	25[cm]
Form of acceleration tube	Side coupled structure
Number of accelerating cell	Half1 + full8
Coupling between cells	3%
Filling time	0.18μs
Shunt impedance	110-130MΩ/m Regular part
Beam current	64mA or more
Focusing fashion	RF focusing
Intensity of X-ray	50[mGy/min] or more at 1[m]
Voltage of electron gun	20KV
Electron gun	Triode

On-site Inspection by 950 keV X-band linac X-ray sources

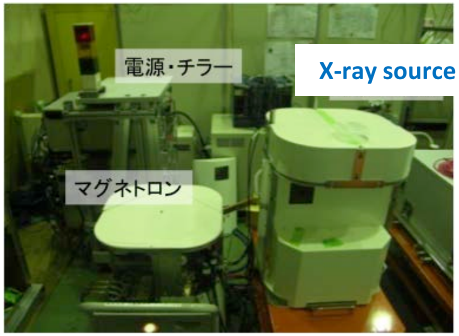
National Institute for Land and Infrastructure Management


Tent

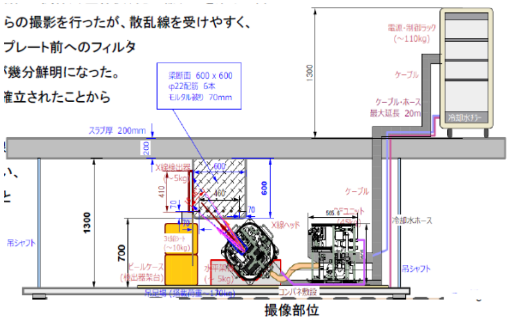

Generator and Linac and bridge

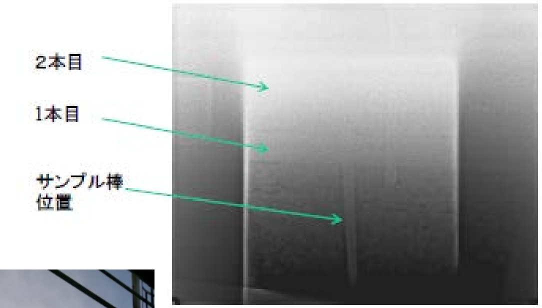

Linac on the frame

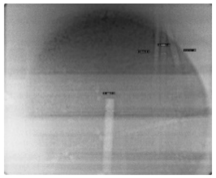

FPD on the frame

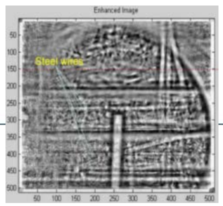


Reinforced Concrete Peer





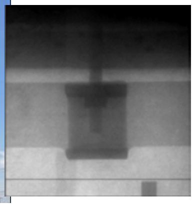


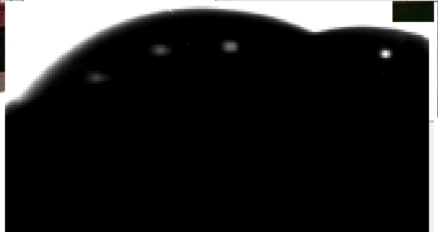



Bridge sample

Synchronized Quasi-Static Imaging of Rotor

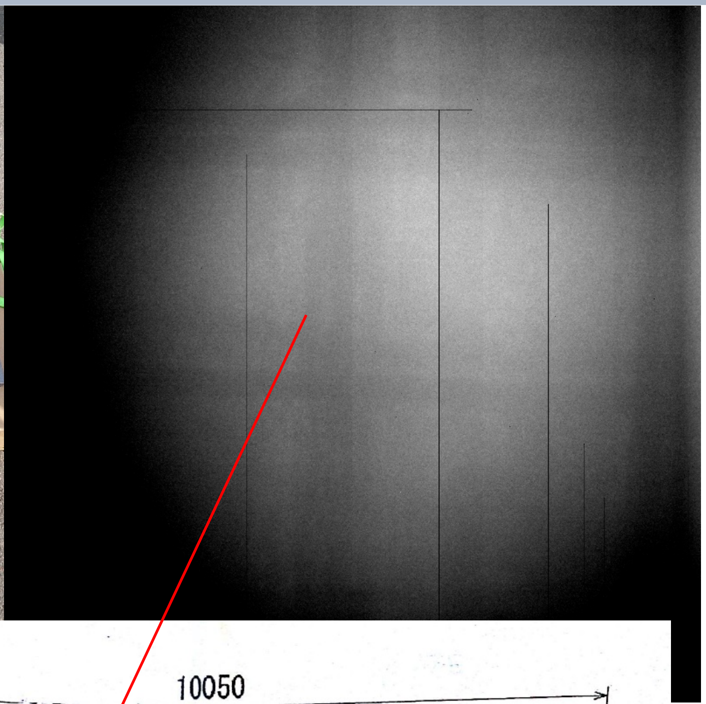
Chemical Reaction Chamber

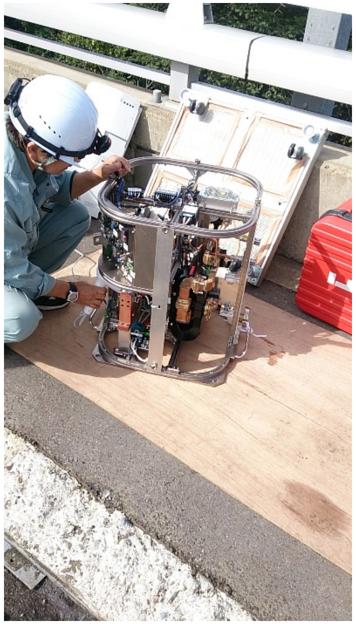


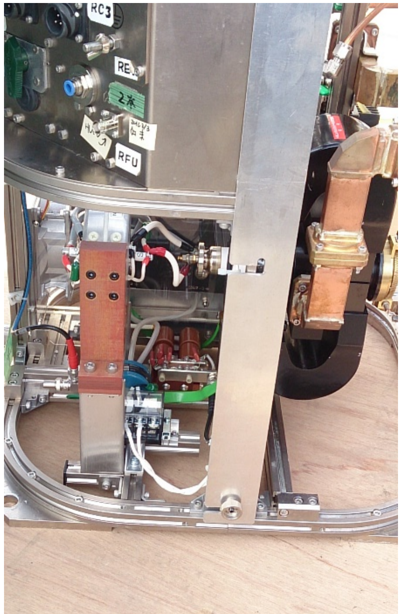


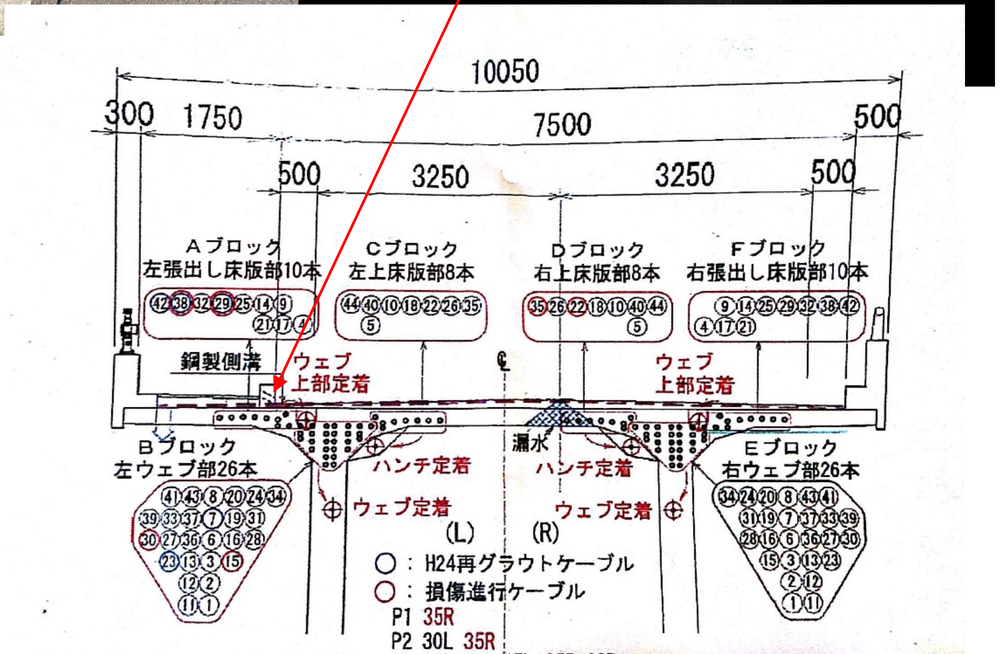
Dynamic Imaging of Inner Fluid

Third Bridge Inspection by 950 keV X-ray Source on Oct.6,7, 2016

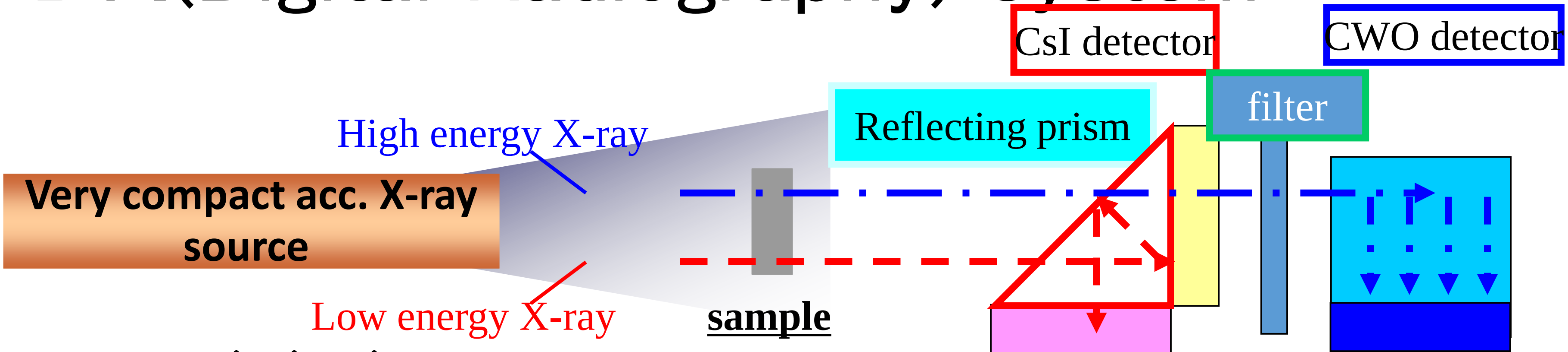








Quasi 2-colored X-ray DR(Digital Radiography) system



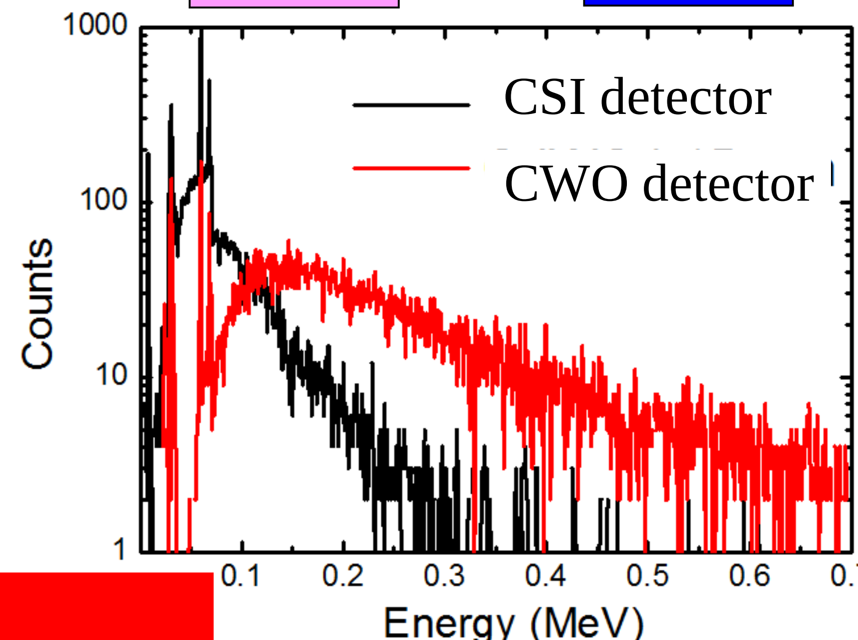
detector optimization

Low energy X-ray →

CsI detector
peak energy:74keV

High energy X-ray →

CWO detector
peak energy:251keV



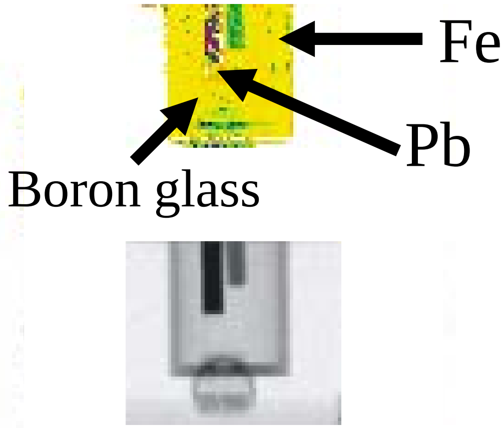
Sensitivity for X-ray energy

2 color X-ray simultaneous measurement

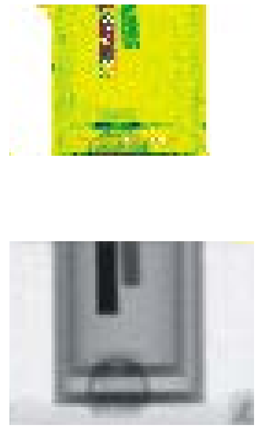
⇔improvement of detector：

Reflecting prism→parallel arrangement detector

Material concealed by Boron glass

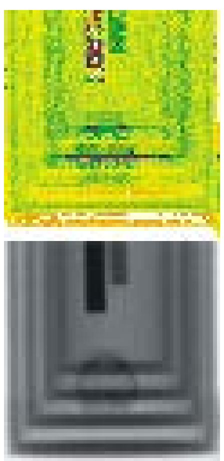


5 mm



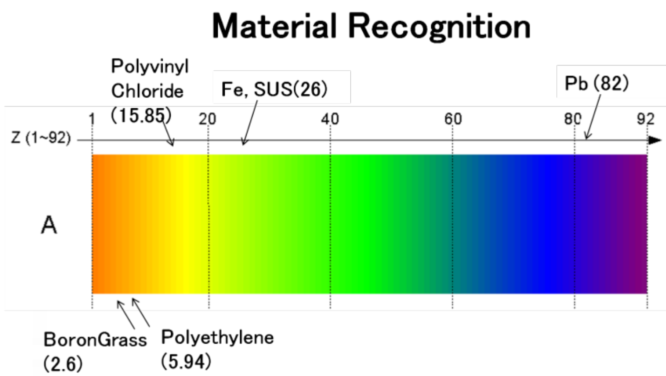
10 mm

15 mm



20 mm

25 mm



Picture analysis operation programming

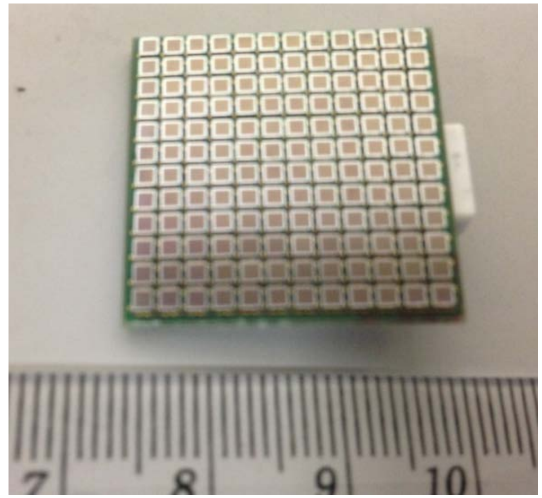
→Pb（nuclear material model）, Fe distinction

Pb（violet） Fe（light green） Distinction ： Possible

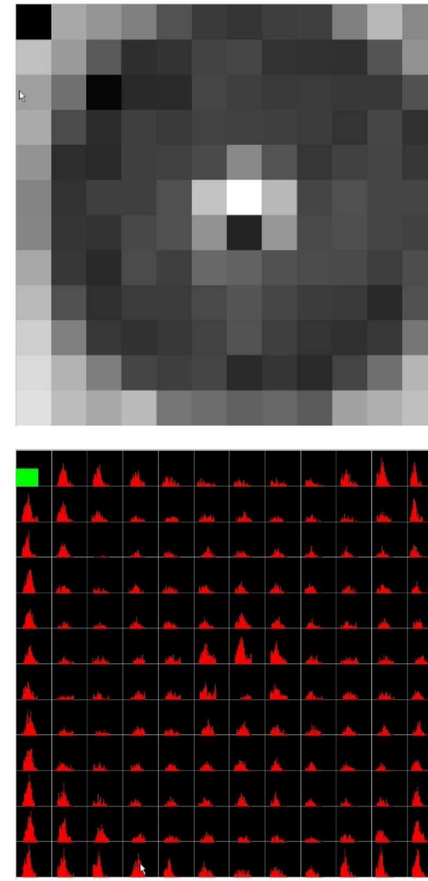
Combination of Tunable Multicolored X-ray Detectors by Ce:GAGG scintillation crystals and Silicon Photomultipliers

Prof.Hiroyui Takahashi, Univ. Tokyo

Scintillator	$Ce:Gd_3Al_2Ga_3O_{12}$ Ce:GAGG
Density(g/cm3)	6.63
Light Yield (Photons/MeV)	~56 000
Decay Time	92 ns [86%], 174 ns [14%]
Peak Emission	520 nm
Hygroscopic	No
Natural activity	No

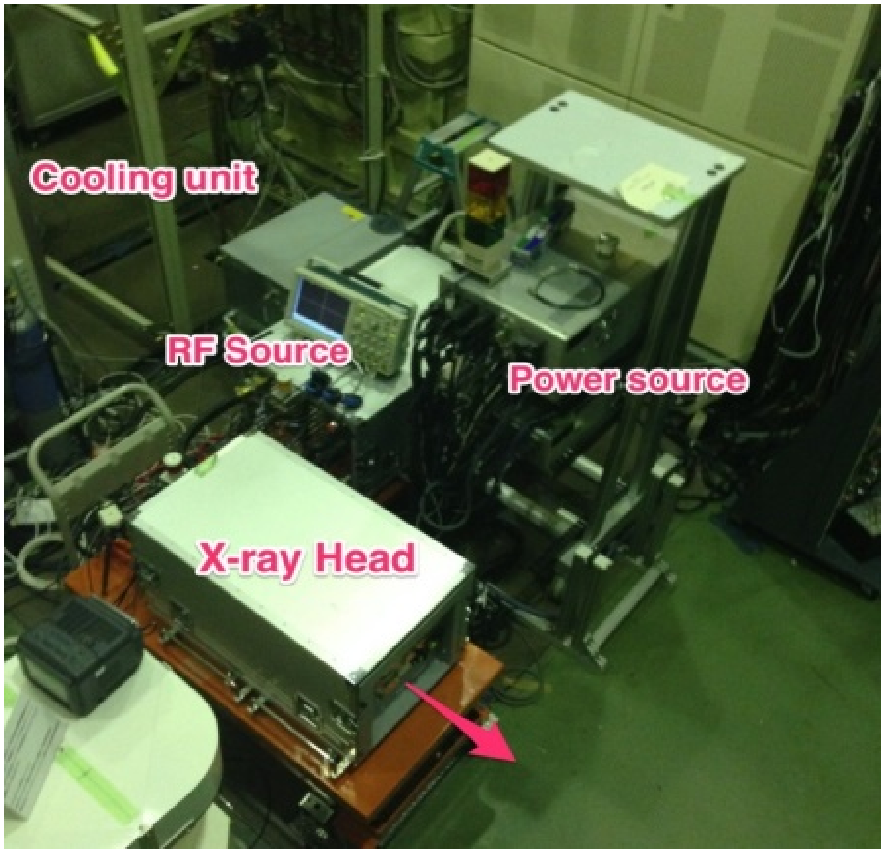


SiPM 1.6 x 1.6 mm^2 of 1.9 mm pitch based on PM1150 (KETEK)



Transmission image (50 yen coin) measurement using ^{241}Am source (60 keV) and energy spectrum

Portable 3.95MeV X-band linac X-ray source of University of Tokyo

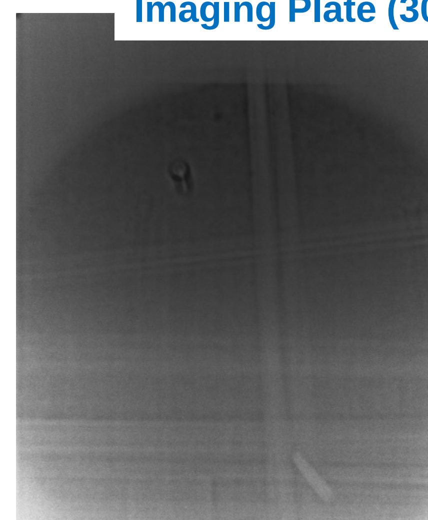


Main unit	Accelerating tube	RF Source	HVPS Control
Weight (kg)	80+62 (Collimator + Accelerating tube)	62	116
Parameters	Electron gun output current 300mA	Frequency 9.3GHz	
	Electron gun voltage 20kV	Pulse width 4µs	
	Beam current 100mA	Repetition rate 200pps	
		RF power output 1.5 MW	

First Legal On-site Inspection of 3.95 MeV X-band Linac X-ray Source at Public Works Research Institute in Japan on January 29, 2015

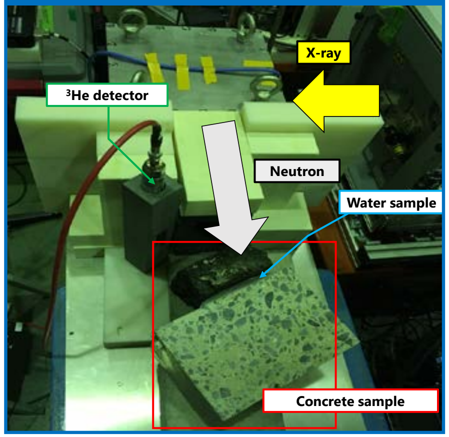
X-ray Flat Camera(1s)

Imaging Plate (30s)

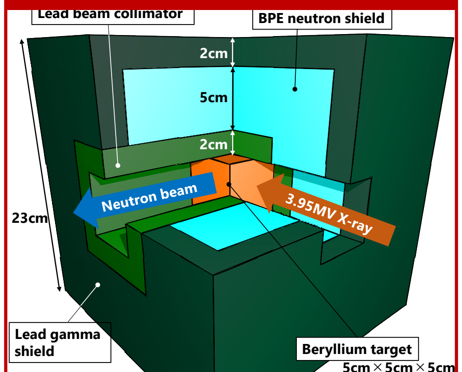


3.95MeV X-ray Source + Be Target for Water Detection in Bridge

Experiment using real degraded bridge sample

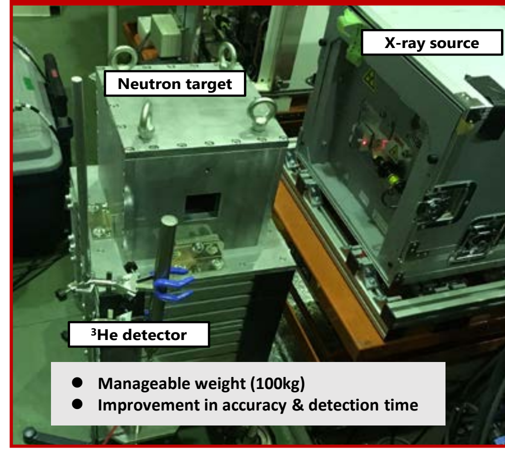


Modified neutron source design (August 2016)



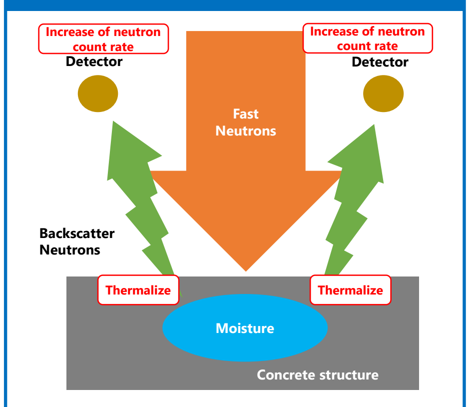
- Target weight 100 kg
- Total neutron yield ~10^6 n/s
- Neutron flux (@target surface) ~10^3 n/s/cm^2

Modified Be target + X-ray source

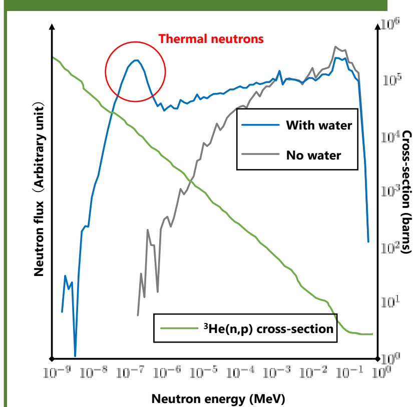


- Manageable weight (100kg)
- Improvement in accuracy & detection time

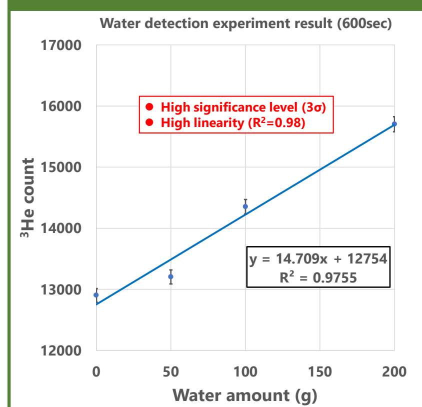
Moisture detection using neutron backscattering

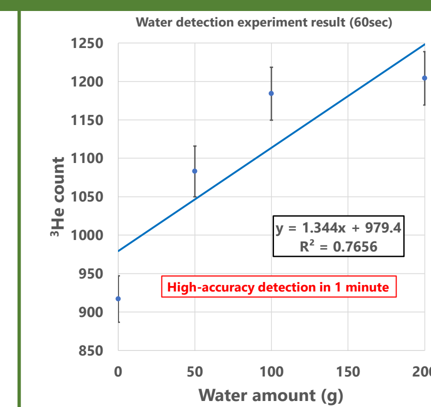


Comparison of backscatter neutron spectrum



Experimental results





We are optimizing the system to realize ~10^8n/s@4μs, ~10^7n/s@500ns.

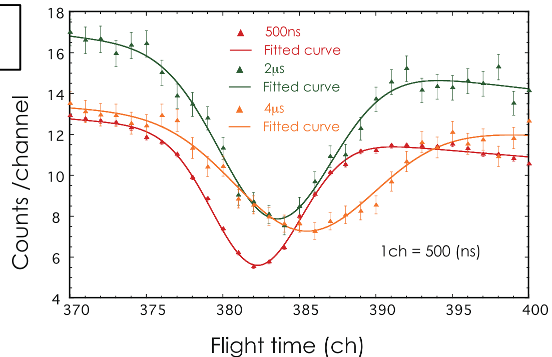
Short pulsed neutron source for ~5m TOF is required.

<u>Some disadvantages from DT neutron source</u>:

- This is a fixed system, we need a more compact and mobile neutron source
- Need shorter pulse (around 500 nanoseconds) for shorter Time of Flight line (~5m)

Uncertainties of measurements with different pulse widths
（JAEA, Kyoto University）

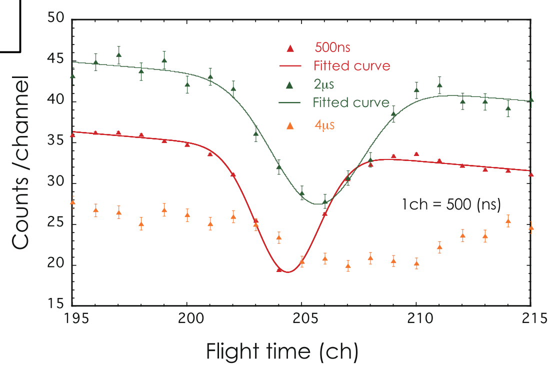
7.64 eV



e-beam paluse width	Peak channel	FWHM
500ns	382.2±0.1	4.1±0.1
2μs	383.4±0.1	5.1±0.2
4μs	385.4±0.2	6.5±0.4

Longer pulse width
=
Wider peak

27.0 eV



e-beam paluse width	Peak channel	FWHM
500ns	204.4±0.1	2.0±0.1
2μs	205.6±0.1	2.8±0.2
4μs	-	-

*Peak does not appear at 4 μs pulse

In that case, we need shorter neutron pulse for wider range of energy measurement

JAEA and Kyoto University