iUCANS-I
Aug 15-18, 2010, Beijing

A plan for compact accelerator-based neutron source and detector systems at RIKEN

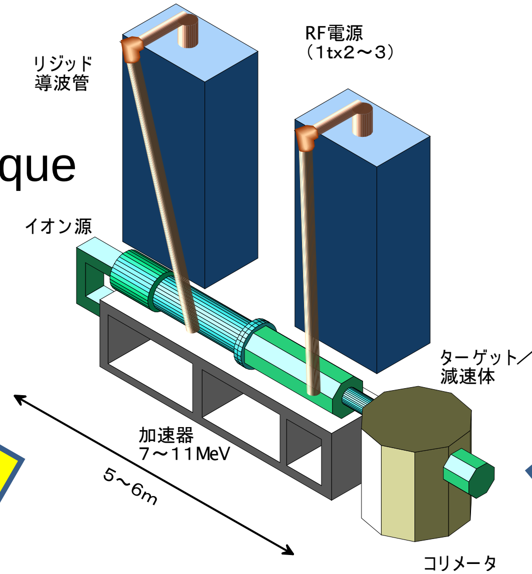
Katsuya Hirota
RIKEN Radiation lab.

RIKEN group
Hirota : Hardware
Yamagata : Software
Ju : Simulation (poster)
Morita : Neutron imaging experiment (poster)

RIKEN Project

Aug 15-18, 2010, Beijing

Neutron imaging technique



Applying to manufacturing technique

Quality control by small neutron sources at each factory

stationary

cheap price, easy to access, easy to handle

Applying to large scale structure materials

Measurement the bridge outdoors

transportable

Neutron source Plan (tentative plan)

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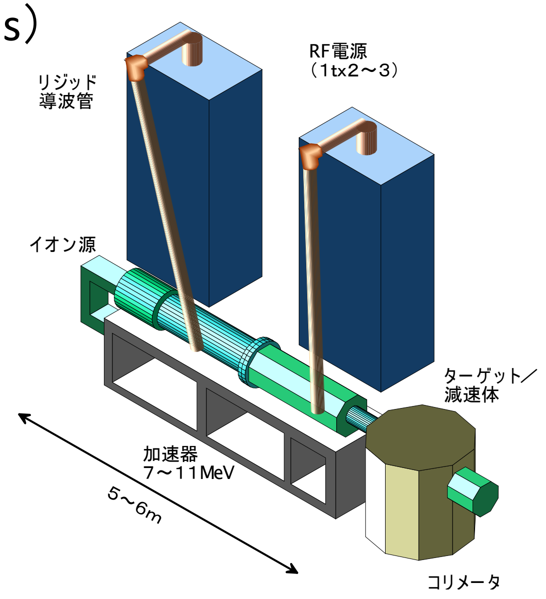
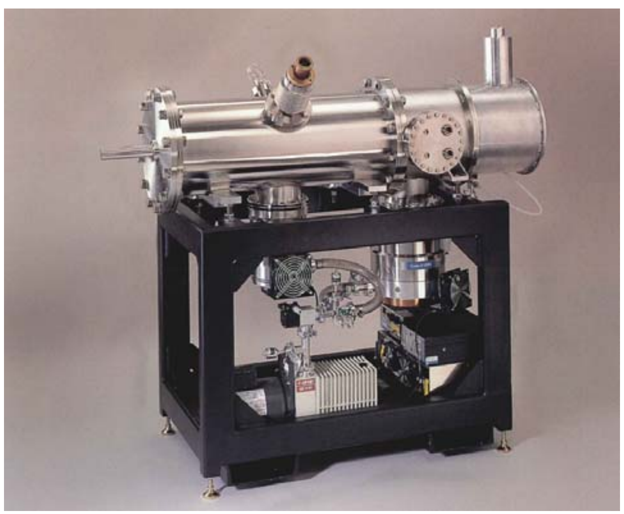
・Developing an as possible small neutron source system
The small machine is available to use for many factories.
・ We also want to develop the transportable neutron source.

accelerator
energy : proton 4-7 MeV
average current : 0.1 ～1mA
power : ～7 kW
neutron target : Be
neutron energy : thermal（fast neutron for structural materials）
pulse beam
neutron flux : 10^5 n/cm^2/s @sample position (L = 4m)
10^9 n/cm^2/s @ moderator surface



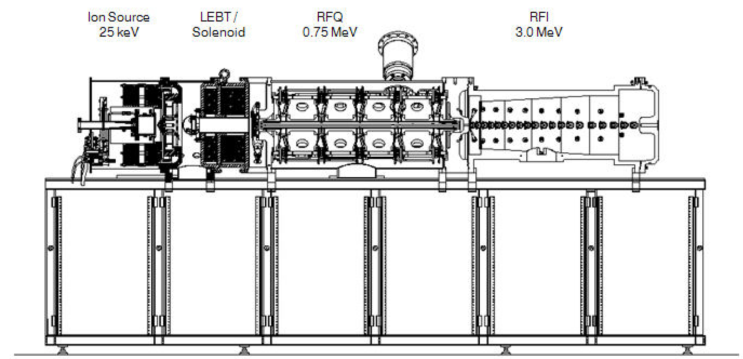
Commercial based accelerator

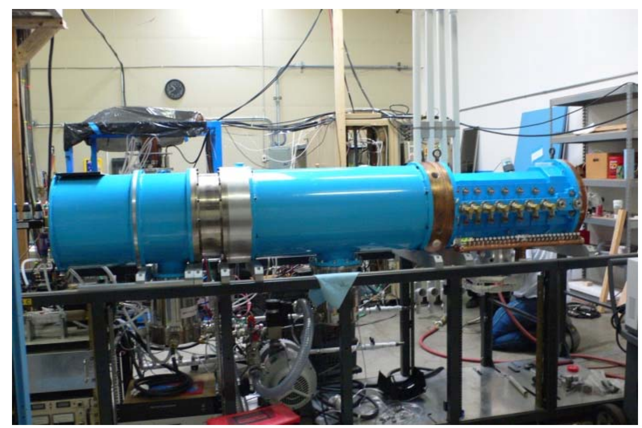
Model PL-7 Proton Linac



AccSys 2MeV p+/d+ Linac

Proton Linac 3-MeV





Linac Systems 2.5MeV

Target and Moderator system

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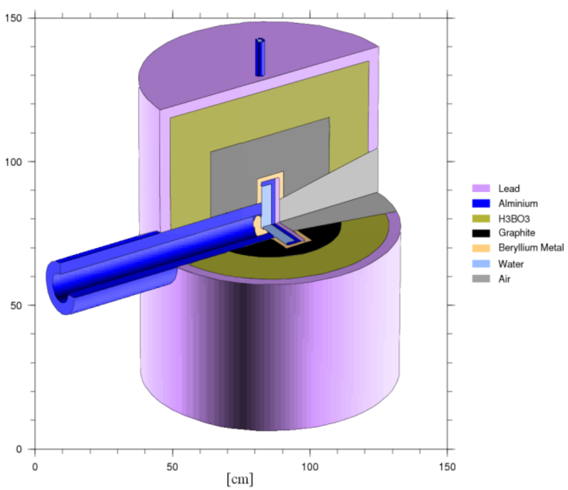
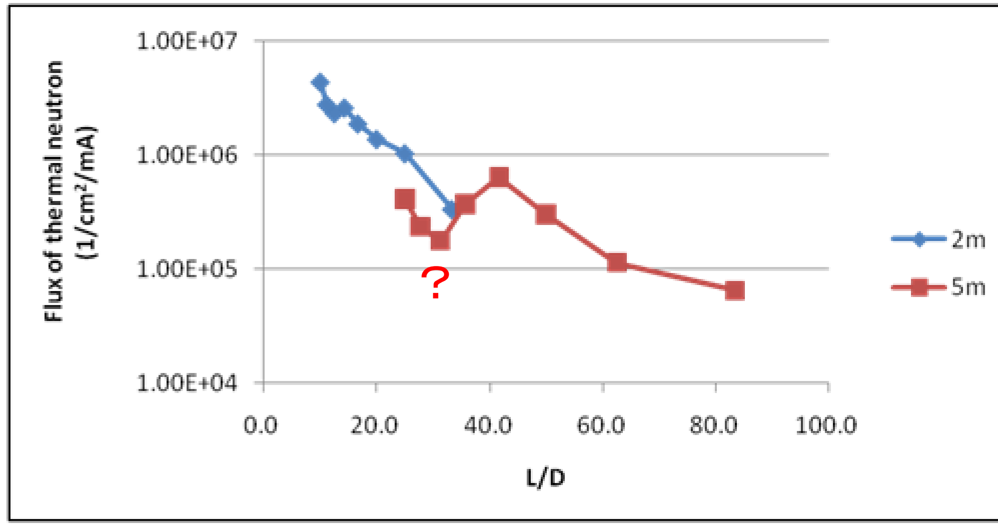
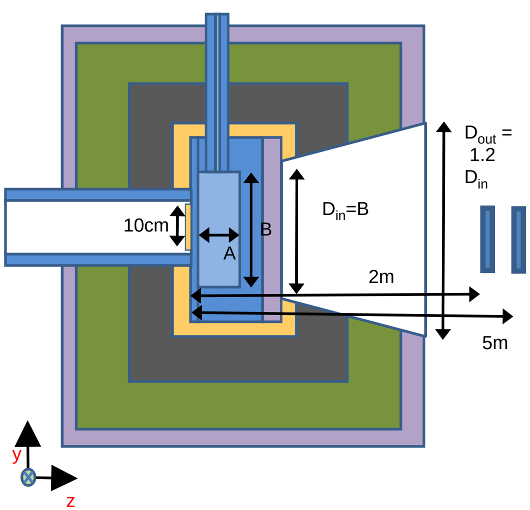
- We calculated the neutron flux by using simulation code "PHITS"
- The detail shows at Poster (J. Ju)







This calculation shows the flux $3x10^5$ n/cm^2/sec at L=5 m. (proton 5.4 MeV 1mA)

7MeV 1mA : $6x10^5$ 0.1mA: $6x10^4$

4MeV 1mA : $0.9x10^5$ 0.1mA: $0.9x10^4$

Fast neutron radiography

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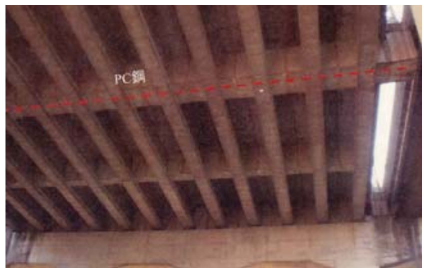

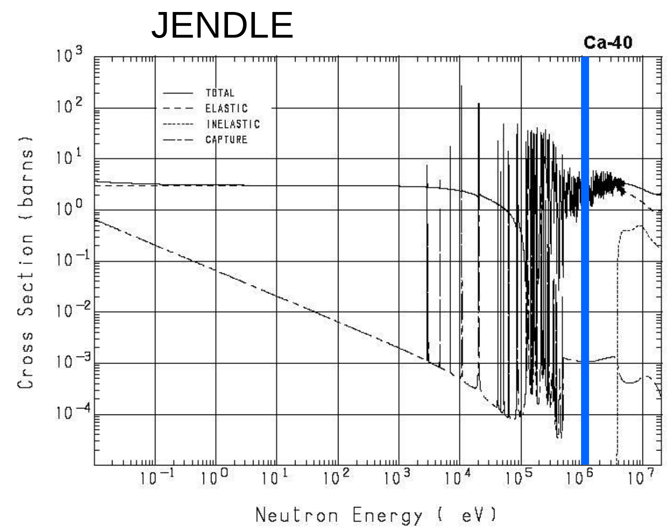

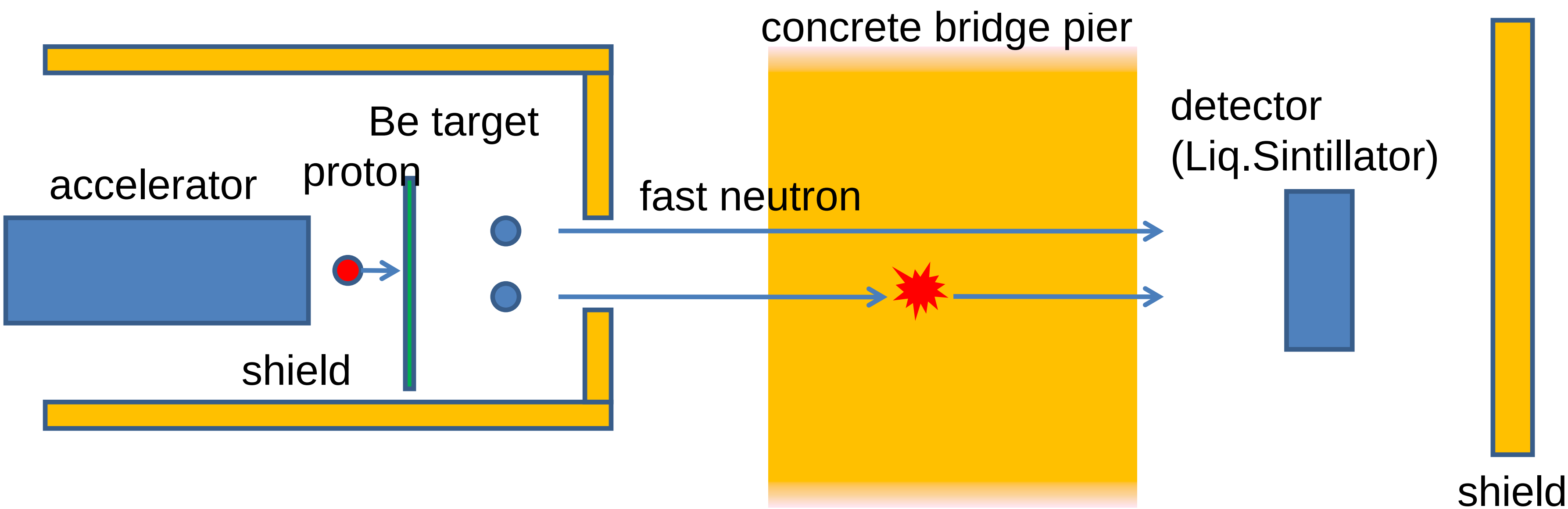

The simulation of the neutron flight

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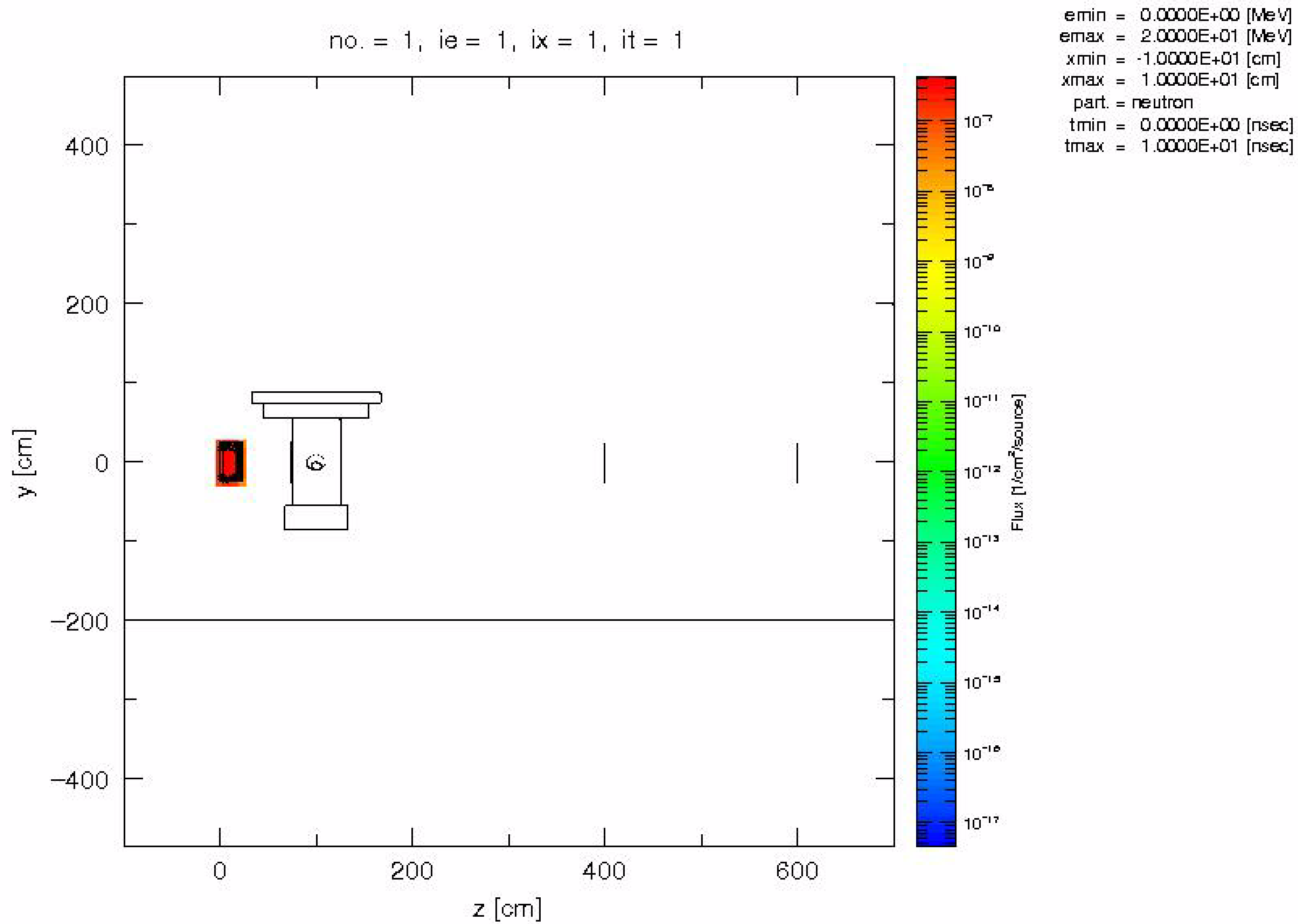

Fast Neutron Imaging (simulation)

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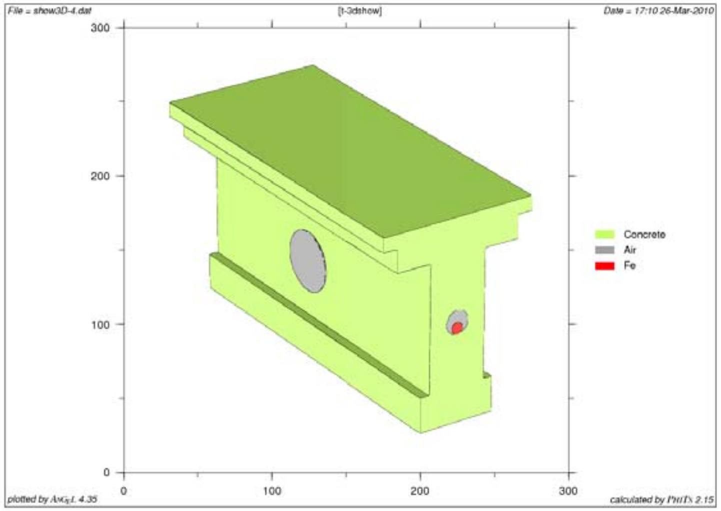
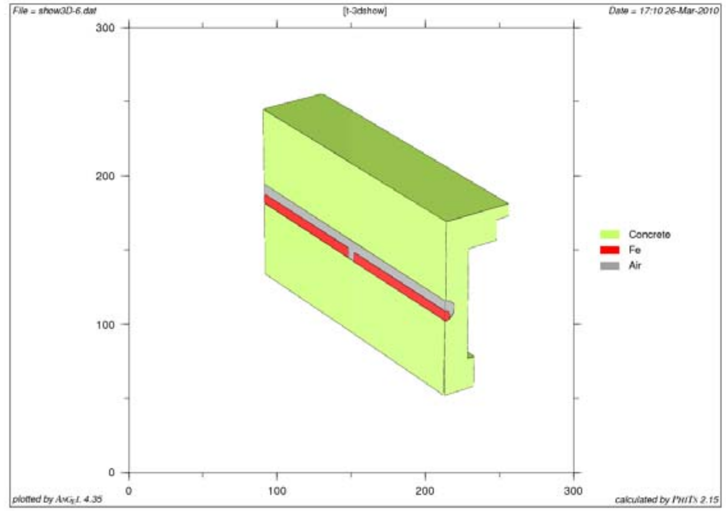
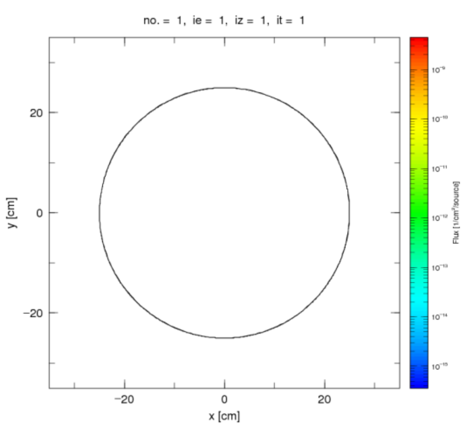
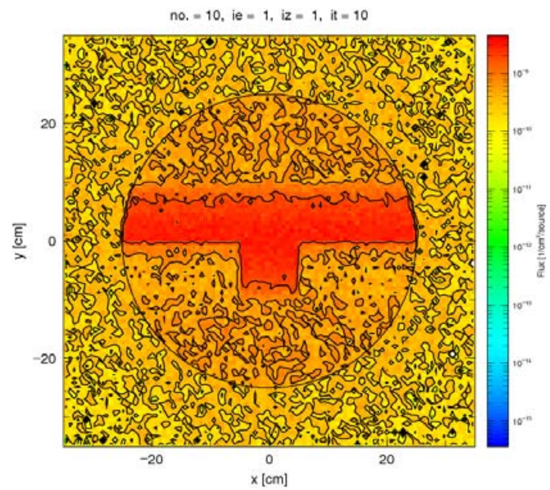




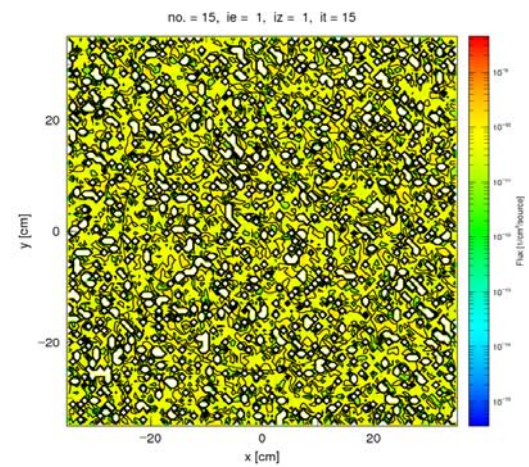
TOF image ⊿t= 10nsec



10ns



100ns



150ns

Model of the Transportable Neutron Source

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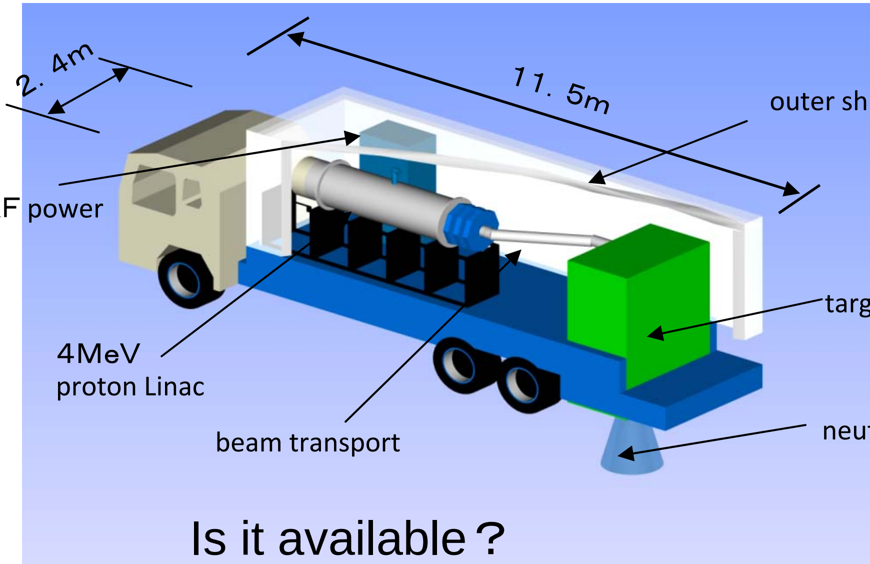
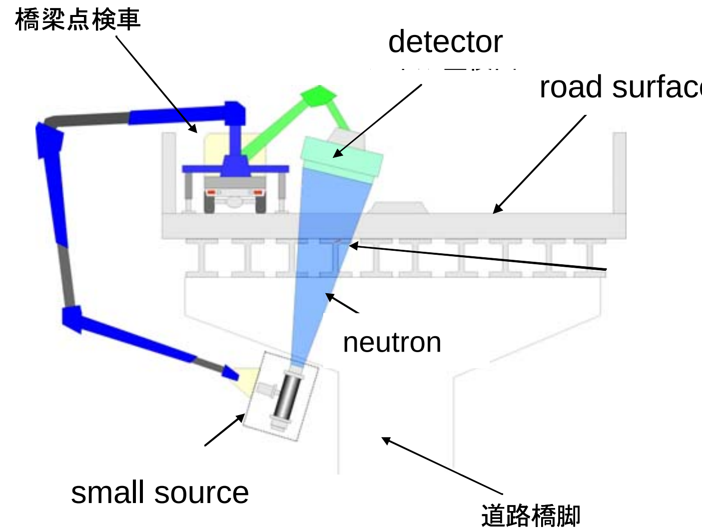




Is it available for PGAA?
It is too weak to use radiography.

AccSYS PL-7（7MeV, 150μA). This is a maker product machine.

Development

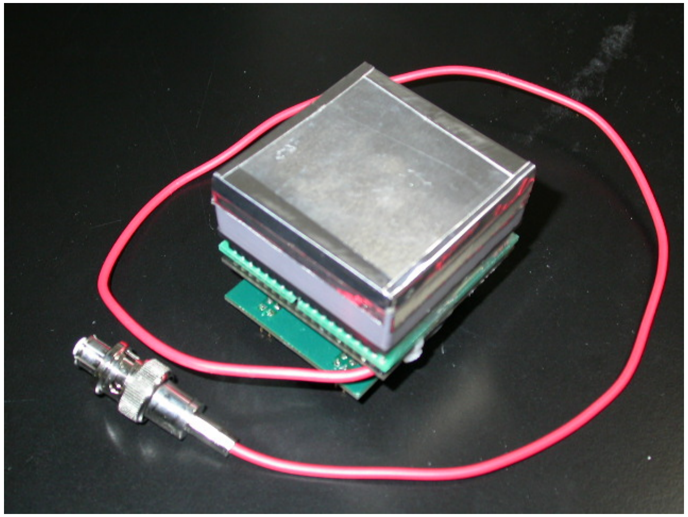
- design of Neutron Source
  - small accelerator low energy and high current , short pulse, stable RF amplifer（Klystrode/Triode）？
  - target（heat, blistering, Li/Be）, moderator
  - shield , Neutron Optics
  - Simulation（PHITS, GEANT4）
- Detector
  - Neutron I.I, Scintillator＋CCD, GEM, μPIC
  - fast neutron detector (liquid scintillator / μPIC？)
  - resolution (time / spatial)
- Image Processing/ 3-D reconstruction/ Modeling technique
  - noise reduction, super-resolution, clearness , CT reconstruction
- Simulation・Prediction technology
  - Using VCAD software, Collaborate with Civil engineering

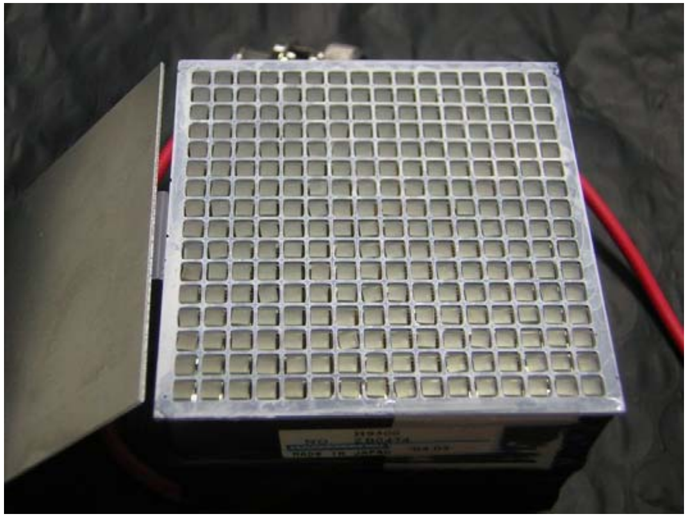
Time table

UCANS-I
Aug 15-18, 2010, Beijing

- October, 2009 ～
  - Preliminary Experiment
    at JRR-3, KUR, J-PARC, Linac (Hokkaido Univ.) , CYRIC(Tohoku Univ.)
  - Committee of accelerator based neutron source project
- January, 2010 ～
  - Budget demanding ← We are here.
- April , 2011 ～ Project Start
  - first neutron beam on March 2012 ?
  - thermal neutron radiography
  - Large Scale Structure Experiment（fast neutron radiography）、
    PGAA(Prompt Gamma Activation Analysis), Cl^- distribution in the concrete
  - phase contrast imaging
  - magnetic field measurement（polarization imaging）
  - strain, temperature measurement（pulse imaging）？
- 2016～
  - applying manufacturing in the factory
  - mobile system, outdoors
  - flux increasing

Detector and other devices

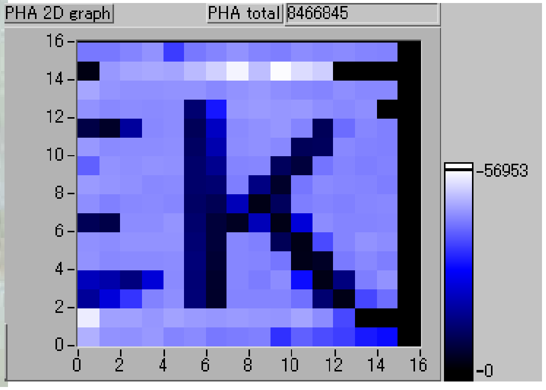




High counting rate detector
Li Pixel Detector
by Hokkaido University

Scintillator: ^{6}Li-glasss (GS20)
16 × 16 pixels (2.1 × 2.1 × 1 mmt /pixel)
Effective area 50 × 50 mm^{2}
spatial resolution 3 mm
efficiency 40% @thermal neutron
counting rate 2-3 Mcps/ detector

TOF : available



RPMT detector

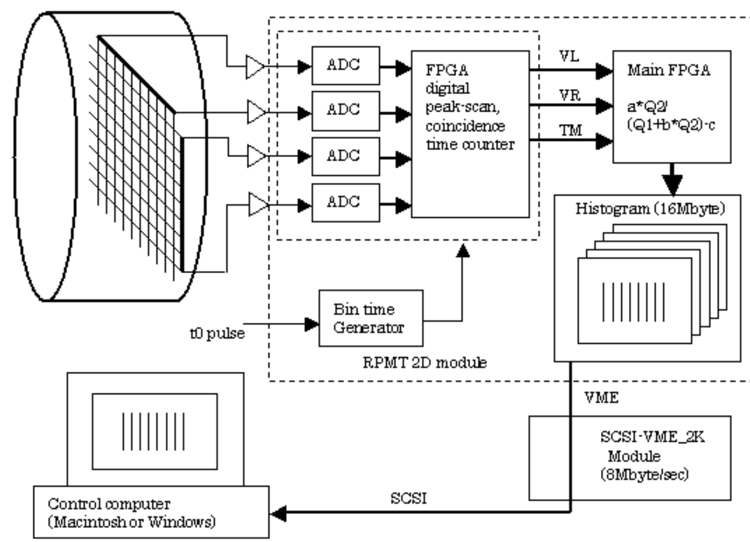
Hirota et.al., Phys. Chem. Chem. Phys. , 2005, 7, 1836

Scintillator: ZnS/^{6}LiF ^{6}Li-glasss
Effective area 35×35mm^{2}(ϕ3 PMT)
                60×60mm^{2}(ϕ5 PMT)
spatial resolution（FWHM）0.5～0.8mm
efficiency 20-30% @cold neutron
counting rate 20kcps@10% dead time

compact DAQ system USB2.0 transfer
→ 100BASE network (NEUNETsystem at J-PARC)

Easy to use and good performance

SANS(F-, mf-, vcn-), Spin Echo,
Reflectometer, Pulse Imaging, ･･･



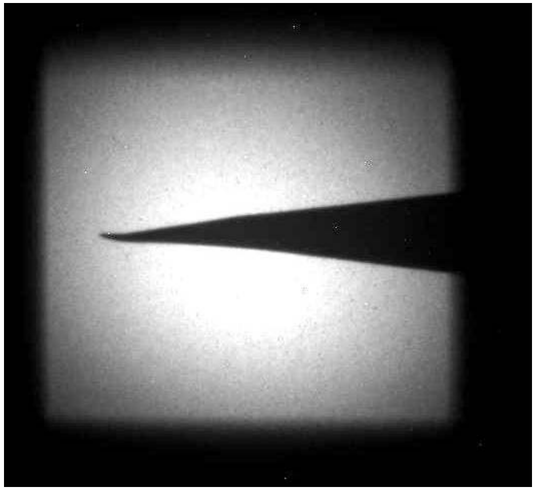
TOF : available

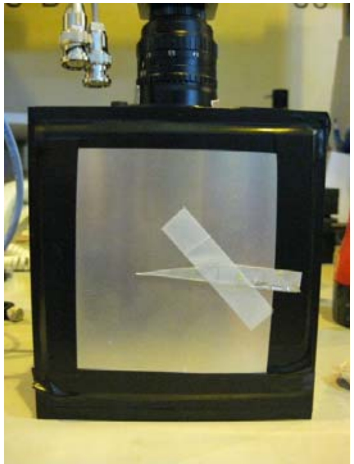
Compact CCD System

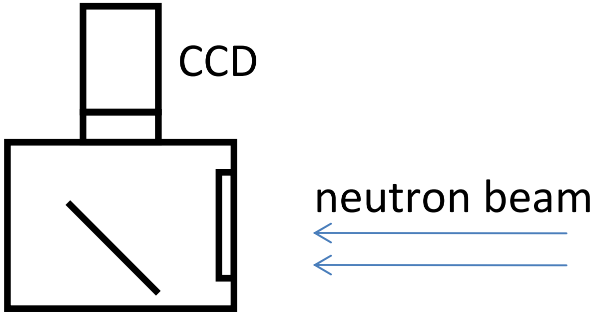
This system is made for contrast imaging measurement at JRR-3 cold beam line (ULS).
- compact and easy handle
- use at very low background

TOF : not-available

CCD: 1/2inch 656 x 484 pixsel
shutter: 1 μ sec - 3600 sec
data transfer: G bit ethernet
effective area: 53mm(H) x 40mm(V)
weight : 2kg (w/o shield)
spatial resolution : about 200 μ m







exposure time:20sec @ 4.4 Å, $3x10^5$ n/cm^2/s

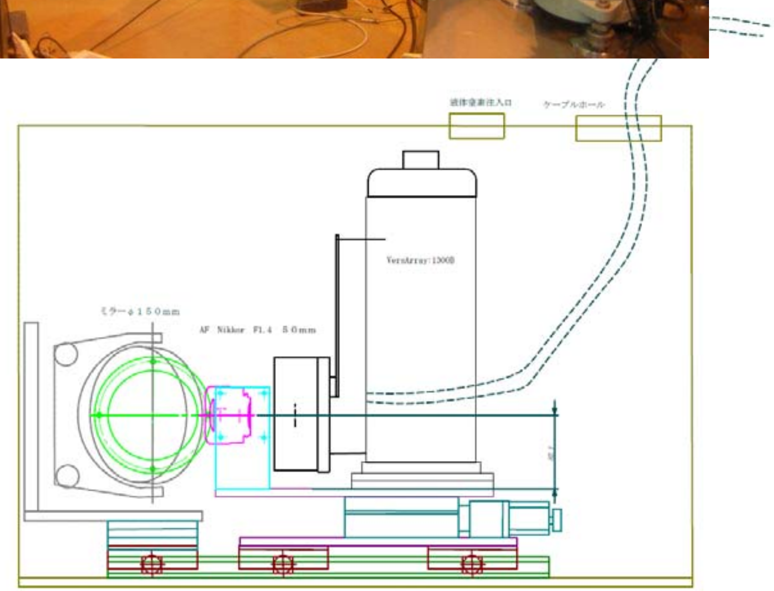
Standard CCD system

TOF : not-available

This system is using for neutron radiography at JRR-3 thermal beam line (guide hall).
- old system (made about 7 years ago)
- liquid N_2 Cooling CCD

CCD: 1340 x 1300 pixsels (VersArray/ Princeton)
data transfer: USB2.0
effective area: 50mm(H) x 50mm(V)
spatial resolution : about 200 μ m

available to change another CCD

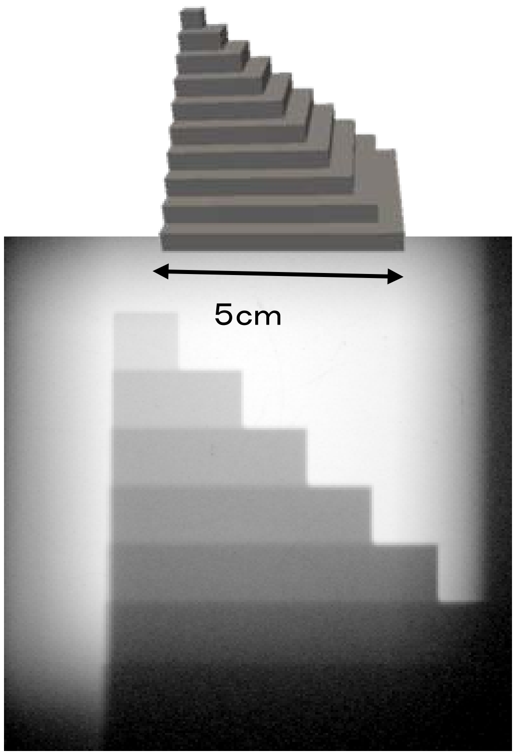


EMCCD:C9100-12
(Hamamatsu K.K.)
High sensitivity camera
512x 512 pixels

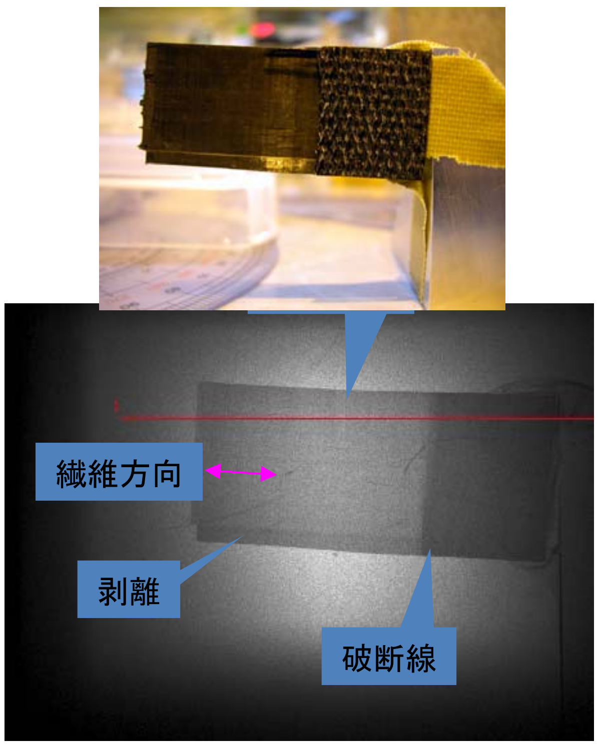
Thermal Neutron Radiography

(Morita's poster)

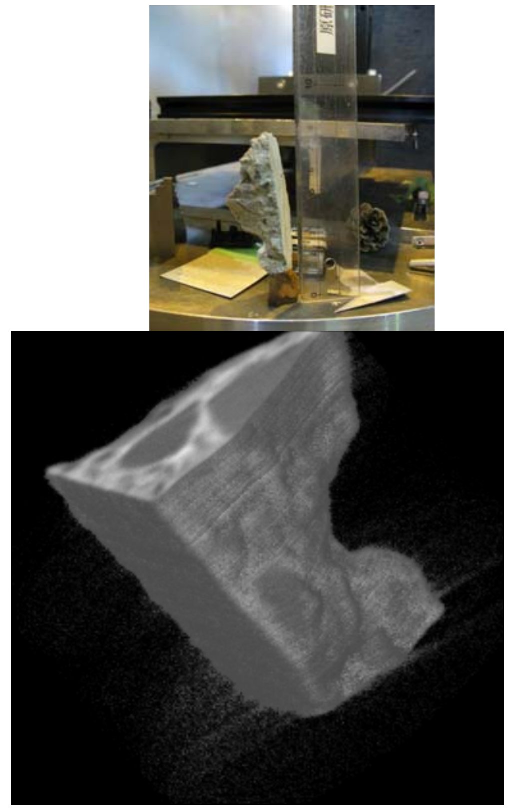
- We are measuring at JRR-3 MUSASI port, 8×10^5 n/cm^2/s
- This flux is about one order stronger than our small neutron source.
- The exposure time is tens sec for radiography and less than one hour for CT.



pyramid-shape ion alloy



Test piece of CFRP

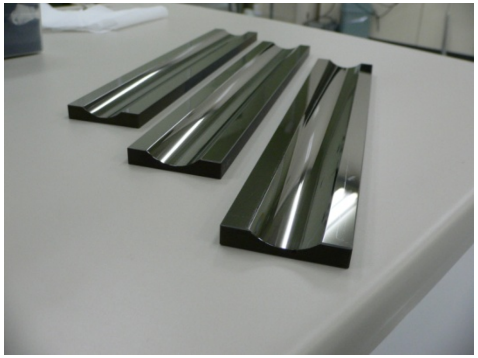


CT of concrete

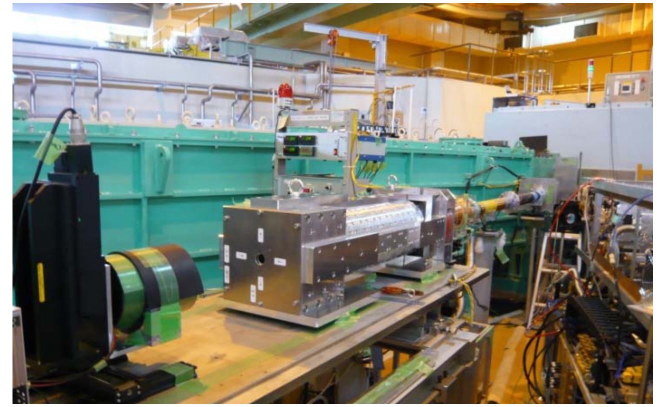
Neutron Optics devices

RIKEN, KEK, JAEA, Hokkaido Univ.

Curved mirror

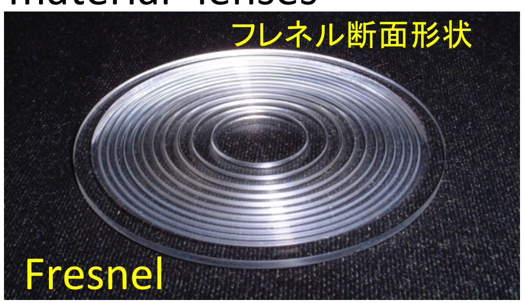


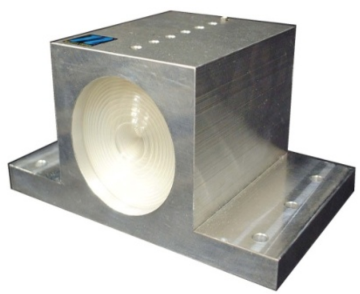
mf-SANS mirror

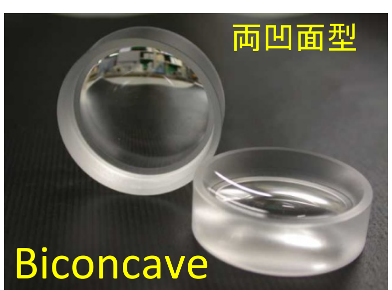


magnetic devices

material -lenses







Focusing-SANS

Summary

・RIKEN Group is planning to construct an accelerator-based neutron source.
The main purpose is thermal and fast neutron radiography.

accelerator

energy : proton 4-7 MeV
average current : 0.1 ～1mA, pulse beam
power : 1～10 kW
neutron target : Be / water moderator
neutron energy : thermal and fast neutron
neutron flux : about 10^5 n/cm^2/s @sample position

There are some neutron detector for thermal neutron, but poor for fast neutron.

Collaborators

RIKEN : A. Makinouchi, Y. Yamagata, H. Sunaga, H. Yokota, Y. Otake,
Y. Seki, S. Morita, T. Sera, J. Ju, S. Wan, S. Mihara, D. T.
KEK Dung
JAEA : H.M. Shimizu, S. Satoh , S. Mutoh, T. Ino, K. Mishima,
PWRI : T. Shinohara, T. Oku, J. Suzuki, N. Metoki
Hokkaido Univ. : Y. Kimura
Kyoto Univ. : Y. Kiyanagi, M. Furusaka, T. Kamiyama, F.Hiraga
Tokyo Univ. : Y. Iwashita
Hosei Univ. : H. Yoshizawa, A. Momose, W. Yashiro
: F. Kimura

And many graduate school students

Thank you for your attention !