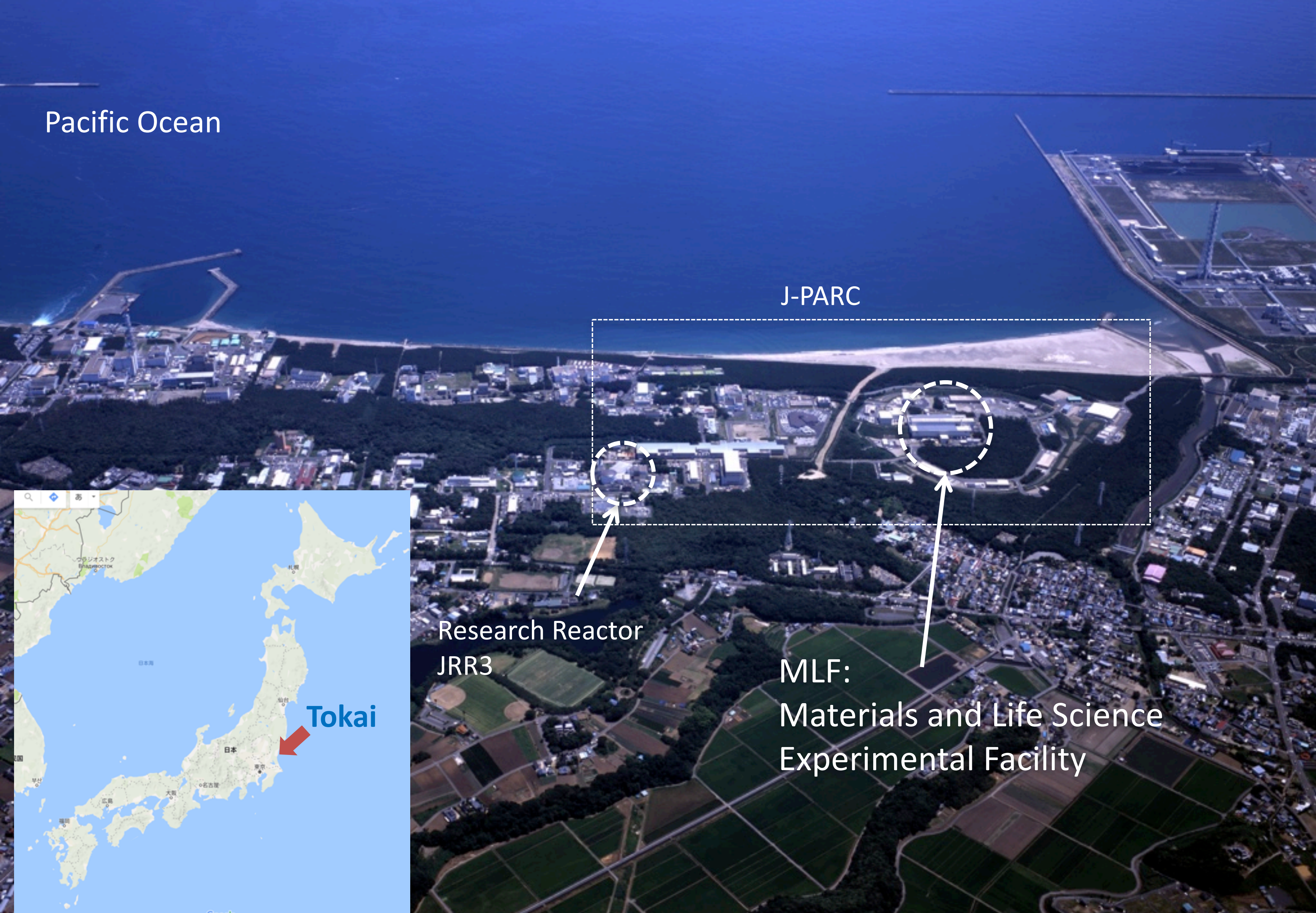
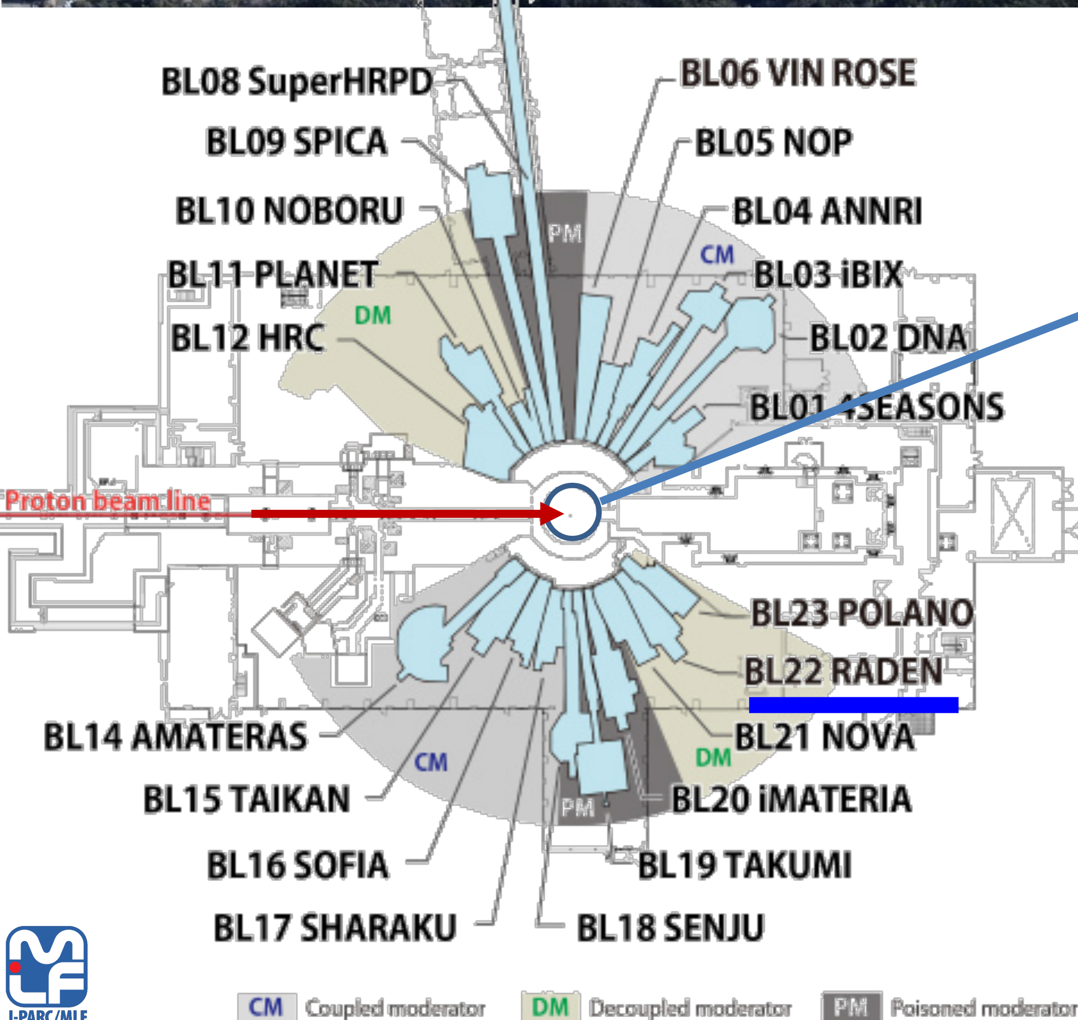
Current Status of The Energy-Resolved Neutron Imaging System RADEN at J-PARC MLF

J-PARC Center, Japan Atomic Energy Agency
Takenao Shinohara

J-PARC -Japan Proton Accelerator Research Complex-



Materials and Life Science Experimental Facility



23 Neutron Beam Ports

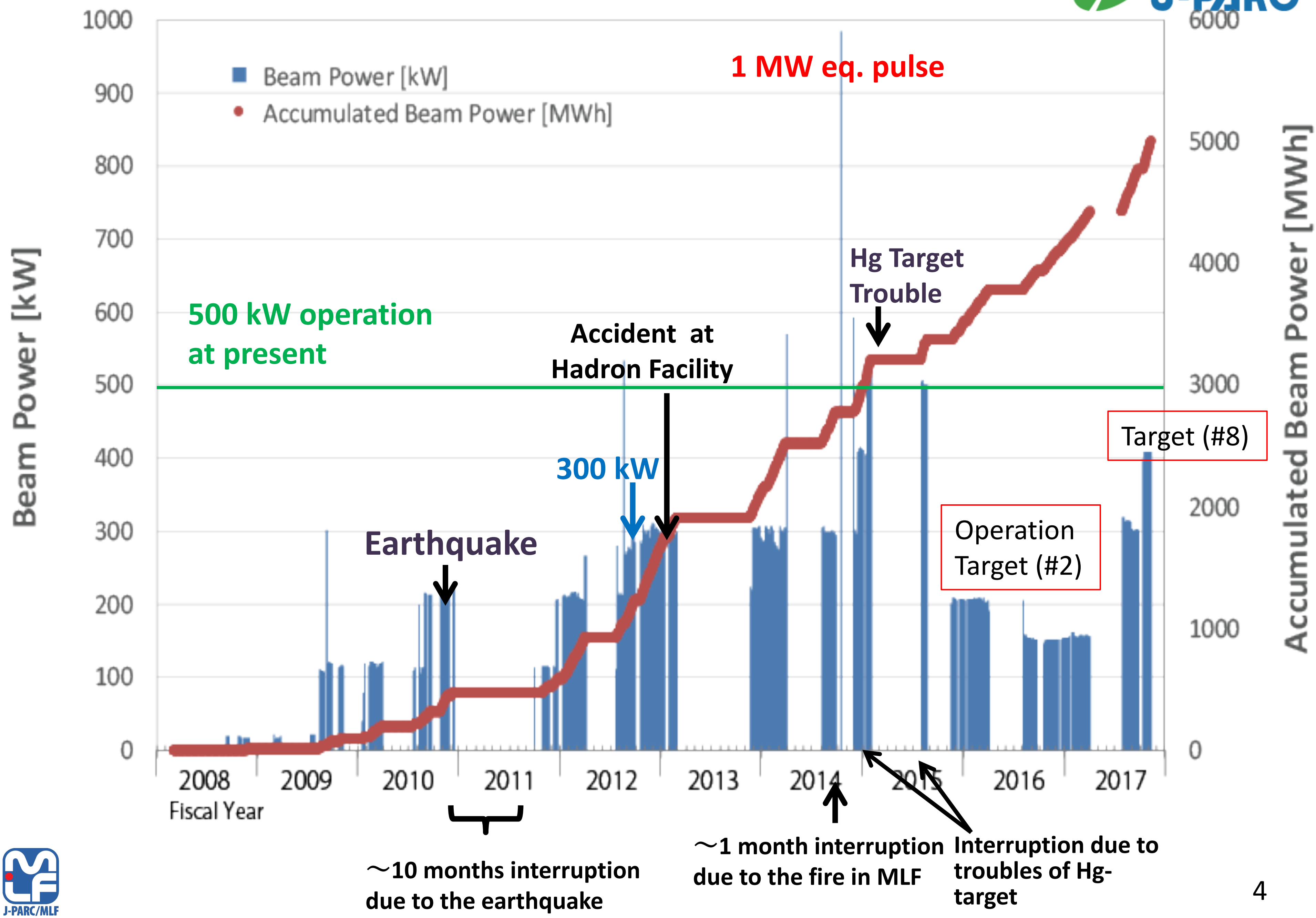
Operation :20

Commissioning: 1

4 Muon Beam Ports

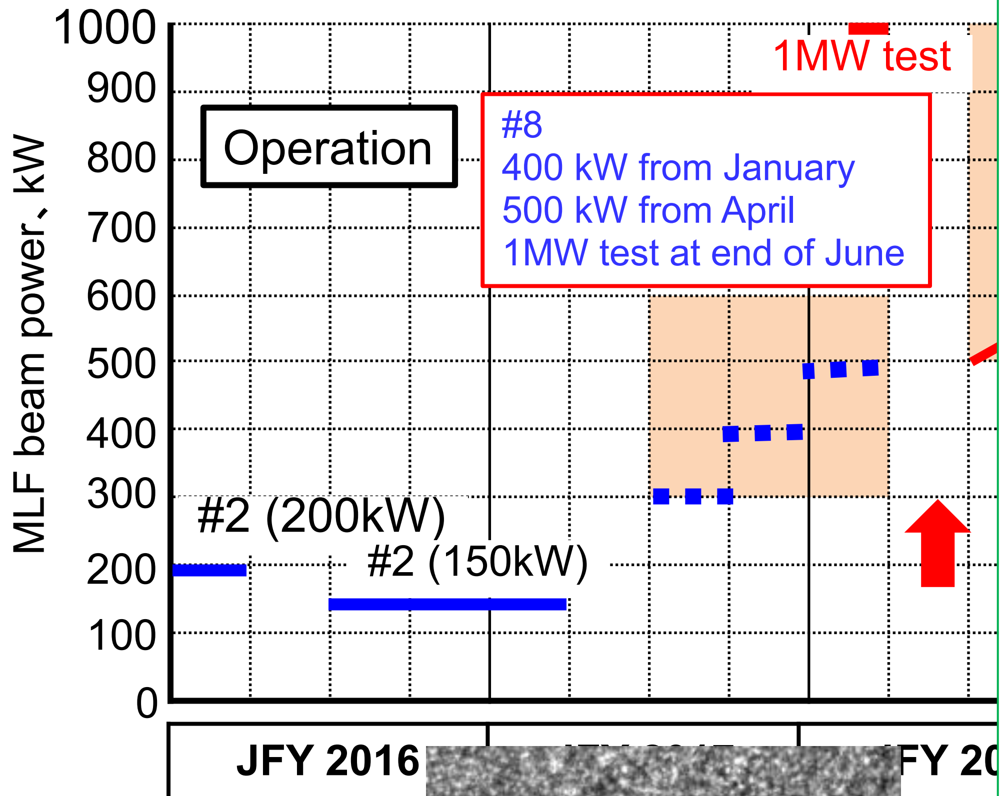
J-PARC/MLF

J-PARC Beam Power History

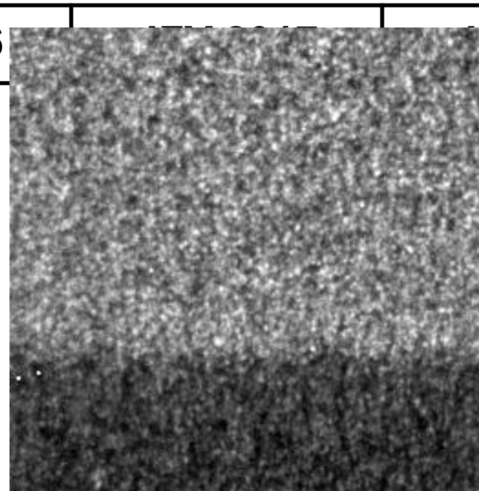


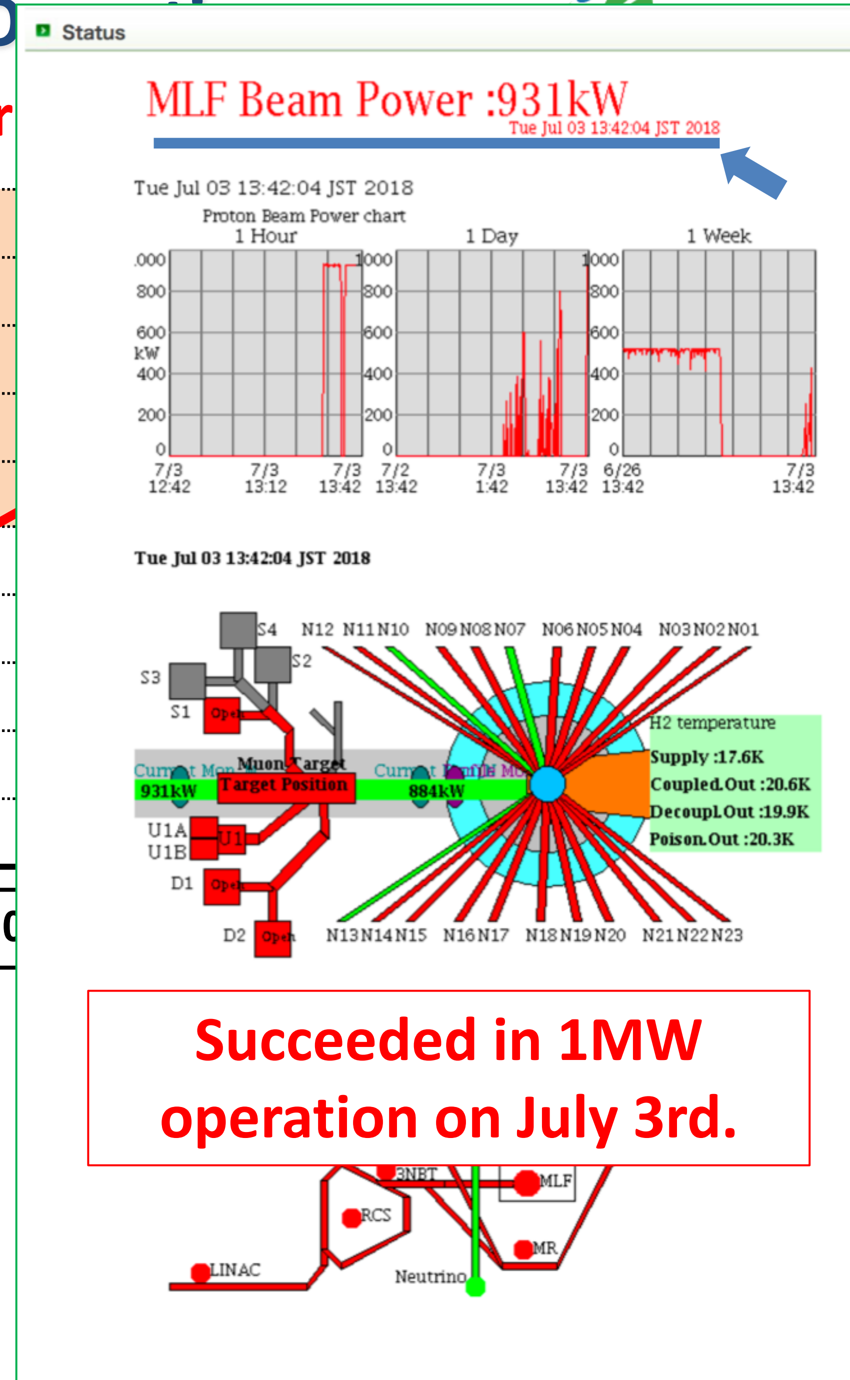
Scenario for 1MW Beam Power O

We are expecting full-power



Waterdrops
Δt = 5msec
Rep. = 25Hz
By Kai & Matsumoto

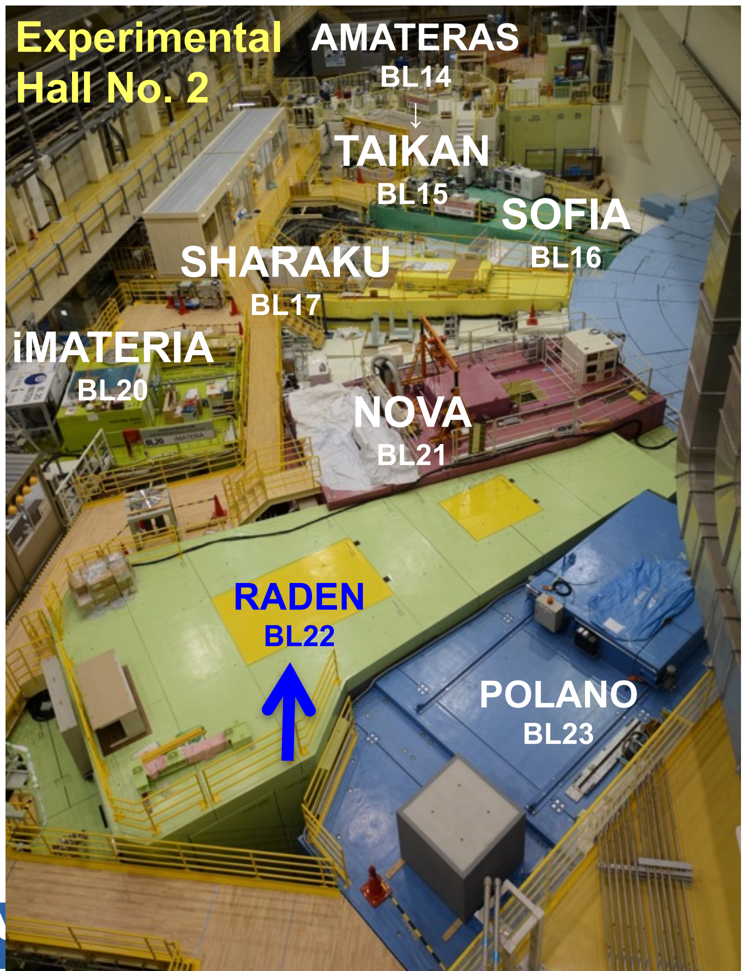




Succeeded in 1MW operation on July 3rd.

Energy-Resolved Neutron Imaging System "RADEN" at J-PARC/MLF

"RADEN" (螺鈿)
Mother-of-pearl work



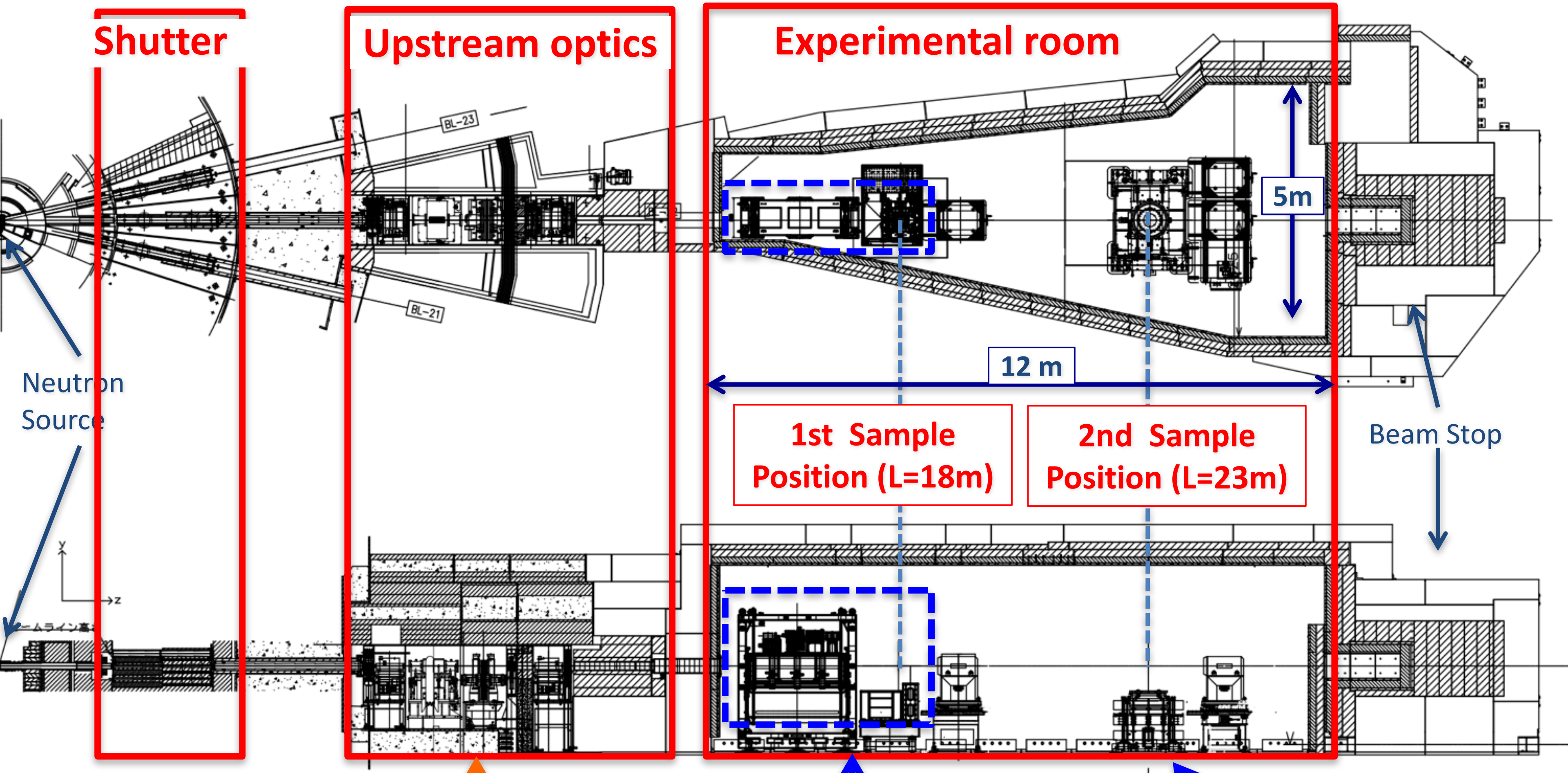
The first instrument dedicated to pulsed neutron imaging in the world

- ✓ Pioneering facility for Energy-resolved neutron imaging fully using pulsed neutrons
  - Bragg edge imaging
  - Resonance absorption imaging
  - Polarization analysis
  - Phase imaging
- ✓ Leading neutron radiography & tomography facility in Japan
  - Fine spatial resolution (> 50 μm)
  - Large field of view (300 x 300 mm^2)
  - Flexible sample positioning
- ✓ New neutron imaging technique development

RADEN -Energy-Resolved Neutron Imaging System-

J-PARC

Top View



Side View

Optical devices: Choppers, Collimators, Flters, Slit…

Polarization analysis and phase imaging equipment

Large sample stage

J-PARC/MLF

Performance of RADEN

Wavelength range

λ < 8.8 Å @L=18m , < 6.9 Å @L=23m

Wavelength resolution

$\Delta\lambda/\lambda$ = 0.26% @L=18m , 0.20% @L=23m

Time averaged neutron flux (< 0.5 eV)

2.6×10^7 n/sec/cm^2@L=18m, L/D=180

1.6×10^7 n/sec/cm^2@L=23m, L/D=230

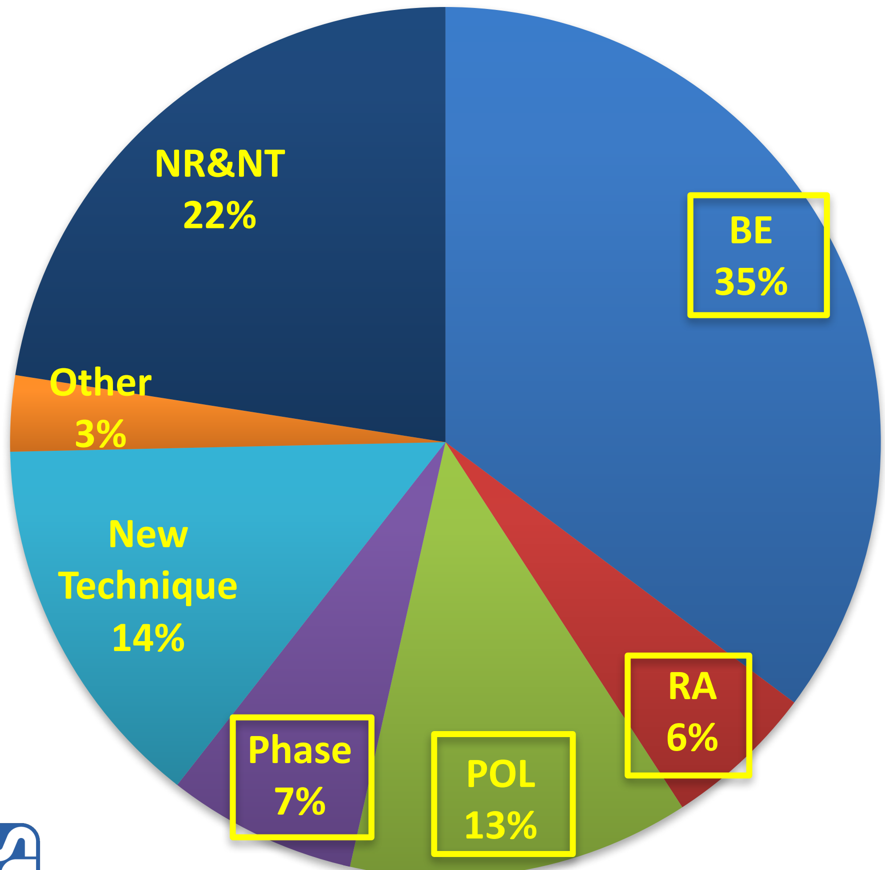
Beam Size and L/D

	Collimator	100x100	50.1mmϕ at 3.1m	26.4mmϕ at 4.3m	15mmϕ at 8m	5mmϕ at 8m	2mmϕ at 8m
L=23 m	L/D (calc.)	230	400	720	1000	3000	7500
	L/D **(measured)**	**251**	**446**	**715**	**990**	**3005**	-
	Beam Size (calc.)	100	250	300	144	173	181
	Beam Size **(measured)**	**103(H) 104(V)**	**263(H) 265(V)**	**300(H) 301(V)**	**209(H) 162(V)**	**230(H) 197(V)**	**210(H) 197(V)**

Status of RADEN

- ✓ 176 days operation for 2018A and 2018B periods.
- ✓ 26 general user programs and 3 Long-term proposals have been approved.
- ✓ Call for proposal of 2019A period will start in the middle of October.

Proposals classified by technique
(from 2015 to 2018A)



- More than 60% of the proposals are using energy-resolved techniques.
- Bragg edge imaging is the largest population.

Variety of subjects

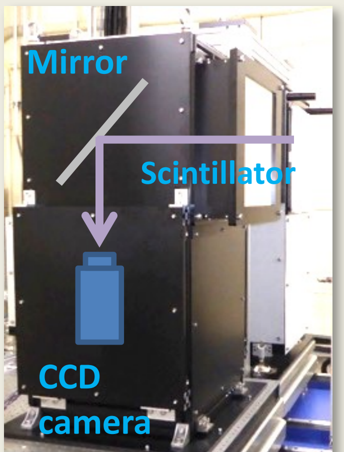
Engineering
Industrial application
In situ experiment
Cultural heritage
Agriculture
Physics etc…

Improvement of Neutron Imaging Detectors

Detectors available at RADEN

Presentation by J.D. Parker tomorrow

Camera type

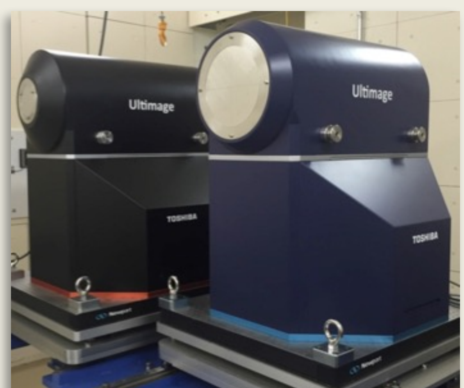


Single-mirror CCD camera

- Andor iKon-L, EMCCD
- Δx >50μm
- No TOF
- Automated system for CT

Neutron Color I.I.

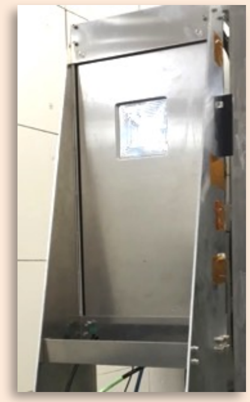
- High-resolution (Δx=100 μm)
- High-speed (10k, 30k, 100k fps)

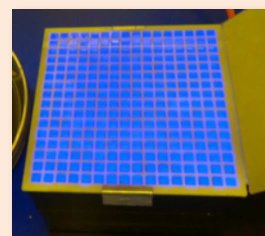


Counting type

nGEM

- Micro-pattern
- ^{10}B (10% eff.)
- FOV: 10 × 10 cm^2
- **Δx=1mm**, Δt=15ns, < 0.5 Mcps



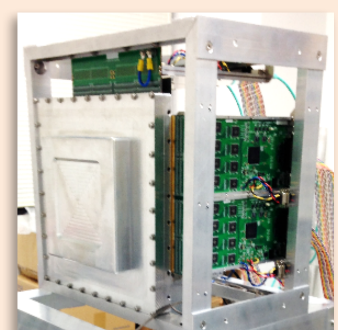


LiTA12

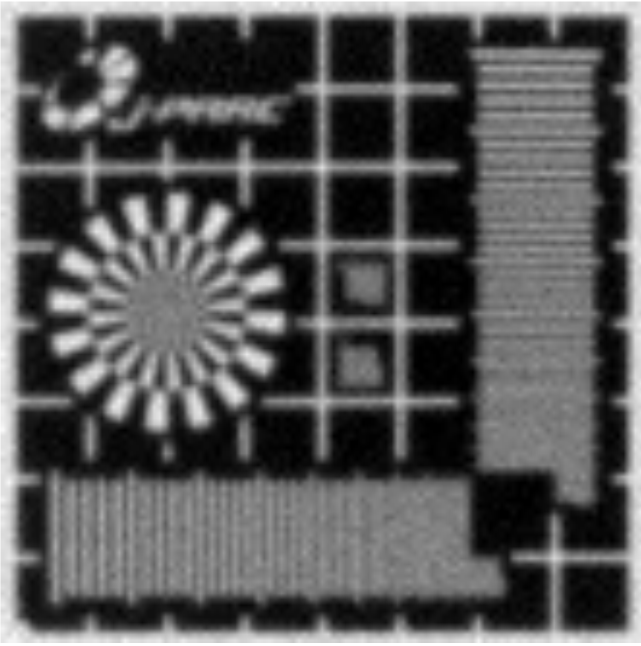
- Li-glass scint. (23% eff.)
- FOV: 5 × 5 cm^2
- **Δx=3mm**, Δt=40ns,6 Mcps

μNID

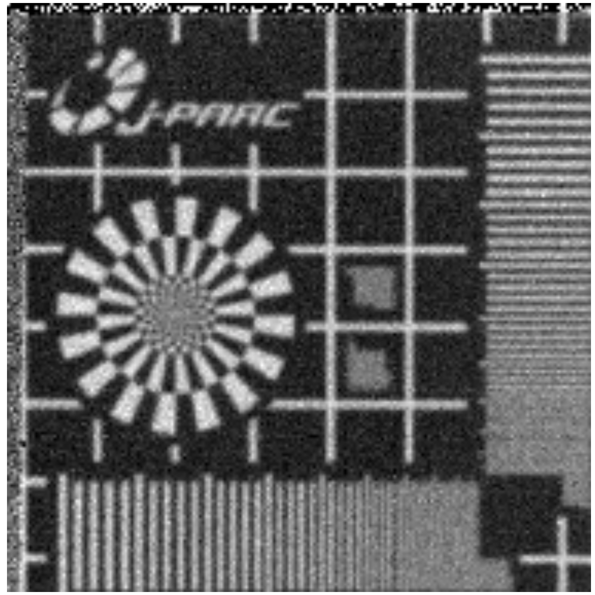
- Micro-pattern
- ^{3}He (26% eff.)
- FOV: 10 × 10 cm^2
- **Δx=0.1mm**, Δt=0.25μs, 1 Mcps



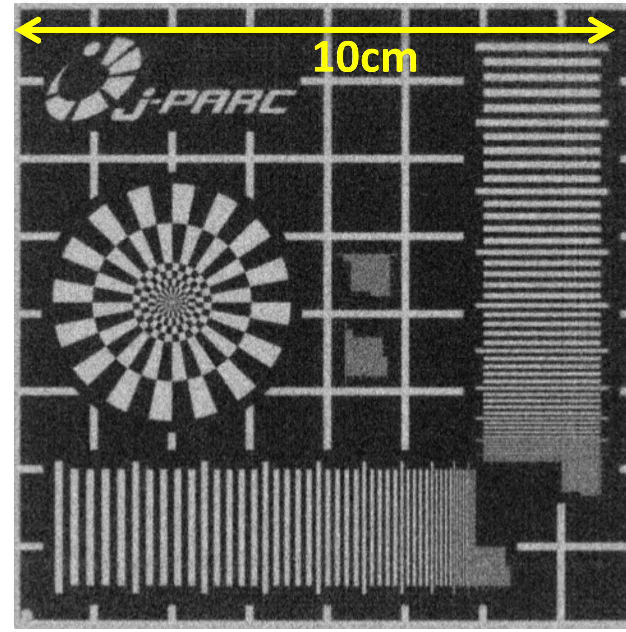
Spatial Resolution of Counting Detectors



nGEM
Spatial resolution: 1 mm
Count Rate: < 0.2 Mcps
Efficiency: 10%



B-µNID (1.6atm)
Spatial resolution: 0.45 mm
Count Rate: > 22 Mcps
Efficiency: 3 ~ 5%



µNID
Spatial resolution: 0.1 mm
Count Rate: 1 Mcps
Efficiency: 26%

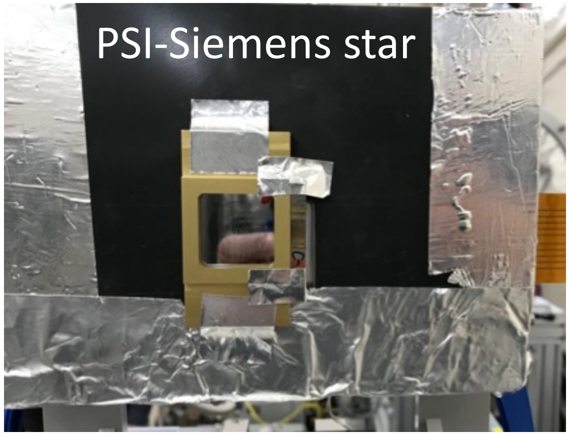
µNID : **Now available for user programs.**

B-µNID : **Development of ^{10}B layer for higher efficiency is needed.**
Smaller pitch read-out board is under testing. **400µm -> 200µm**

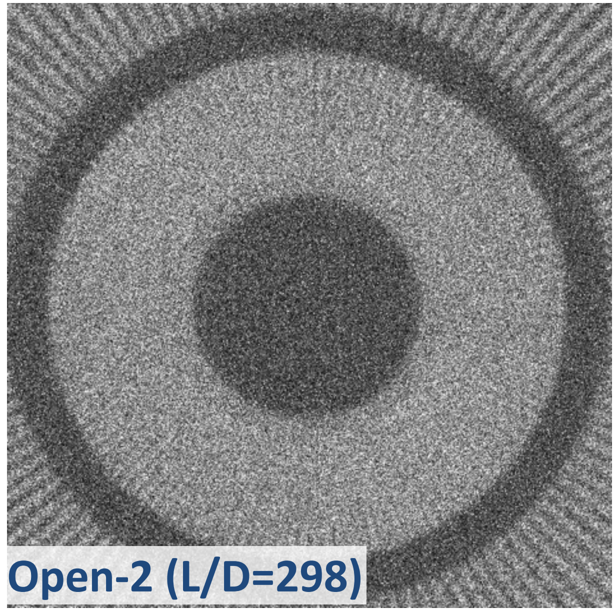
LiTA12 : **Under development. Centroiding and super resolution methods worked to make better spatial resolution.**

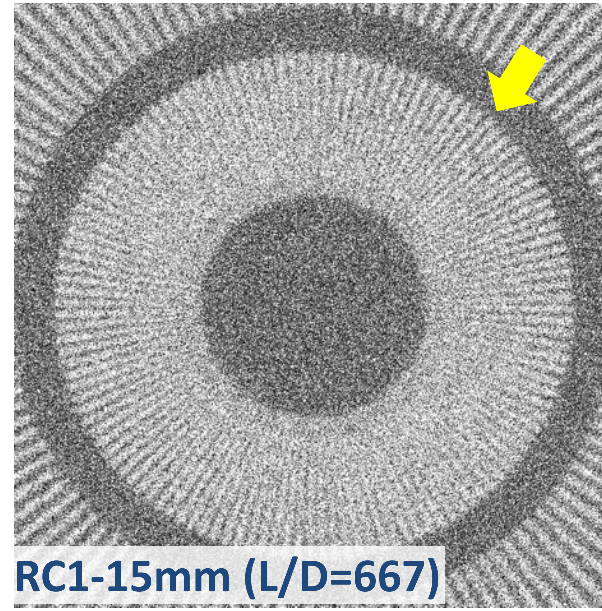
High Spatial Resolution Trial

Fine spatial resolution ~ 15 µm (Thanks to Dr. A. Tremsin)

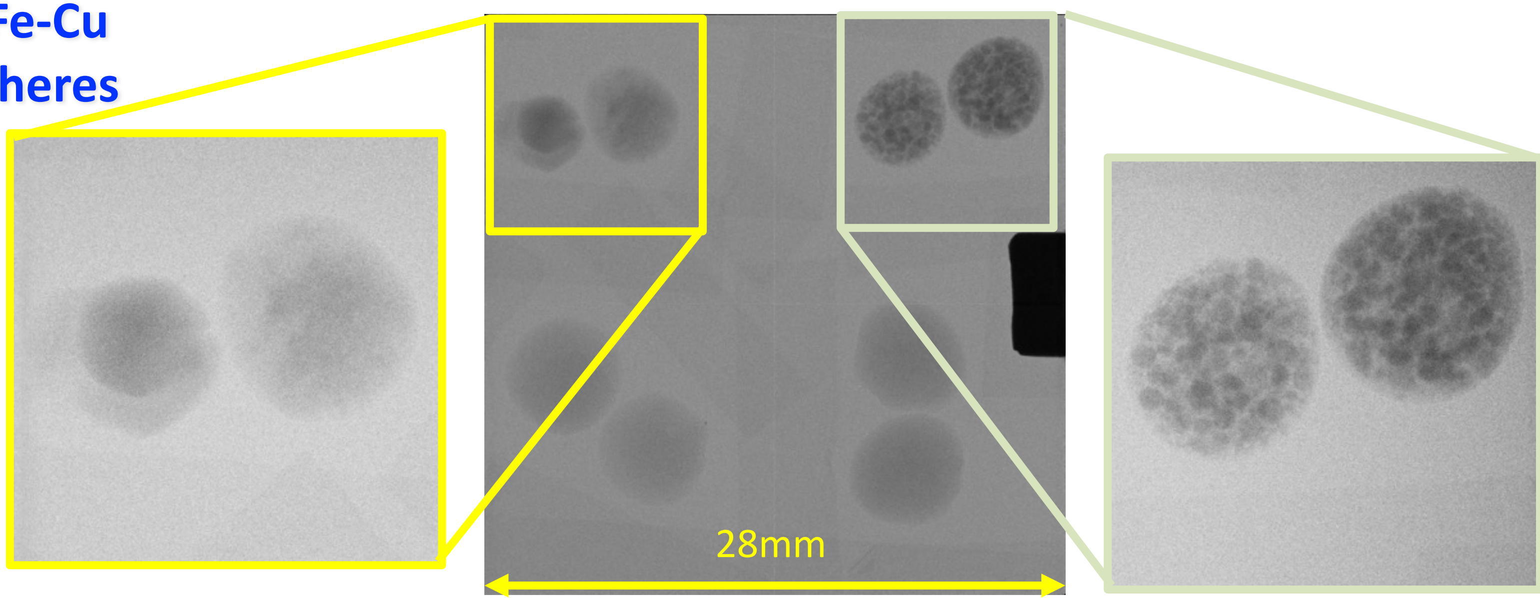


MCP detector

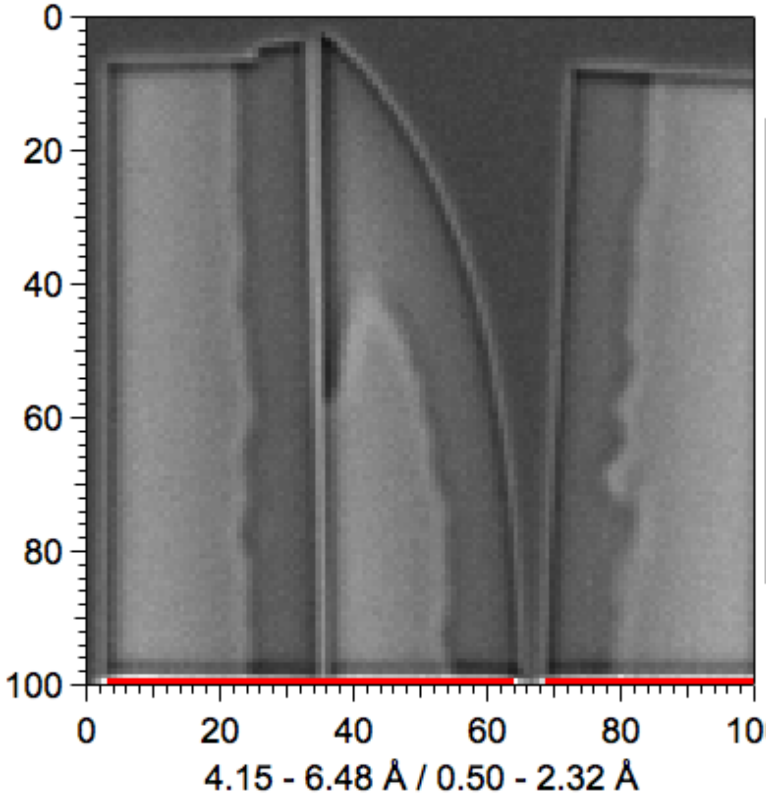


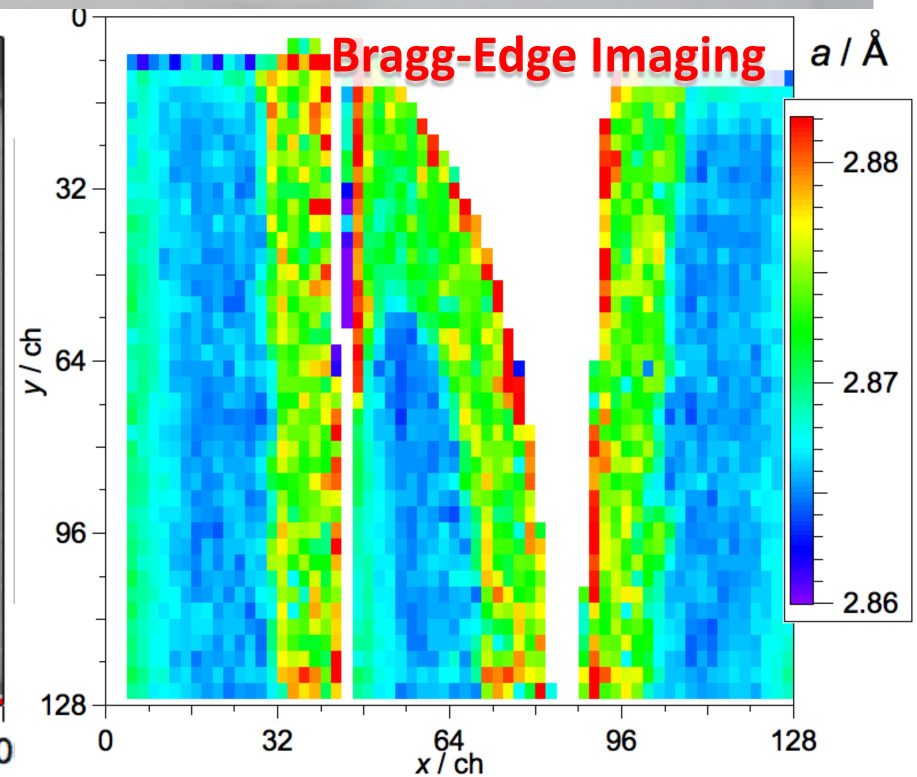


Co-Cu, Fe-Cu alloy spheres



Application of ER-NI   Japanese Swords





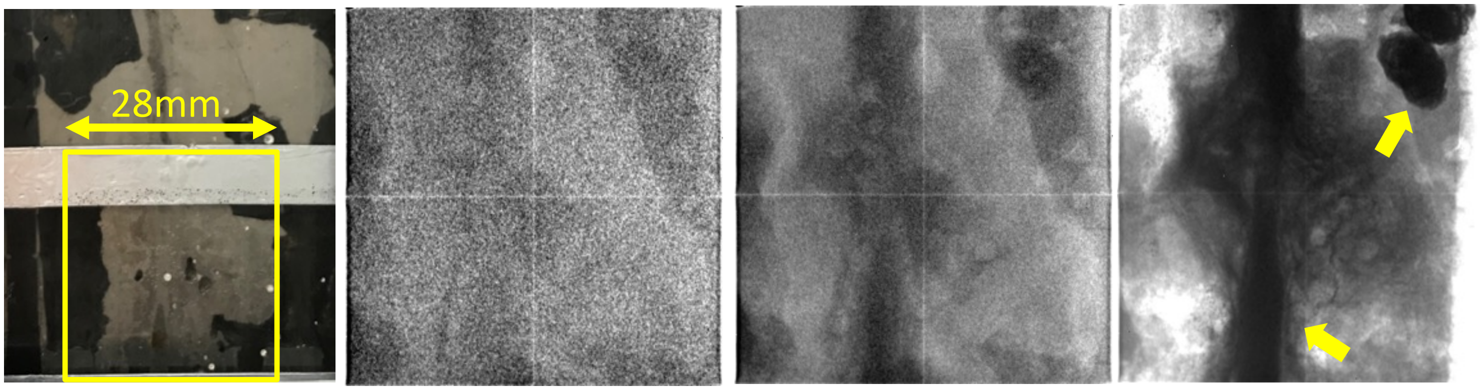
Presentation by Prof. Kiyanagi tomorrow
and posters by Oikawa, Ohmae, Matsumoto , Sato

Application of ER-NI

Melted Fuels

To clarify Boron concentration in melted fuels

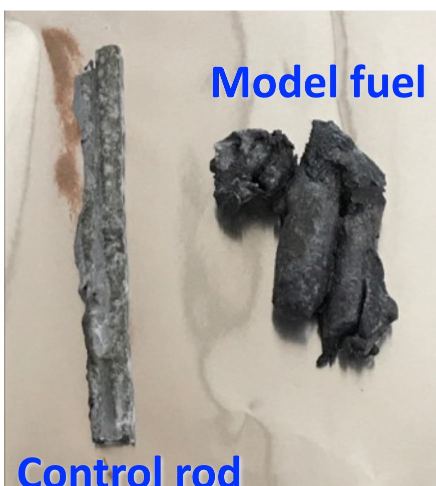
Energy dependent radiography



Detector : MCP | 10keV-500eV | 500eV-10eV | 1eV-1meV

Epi-thermal neutron tomography

For strong absorption material study



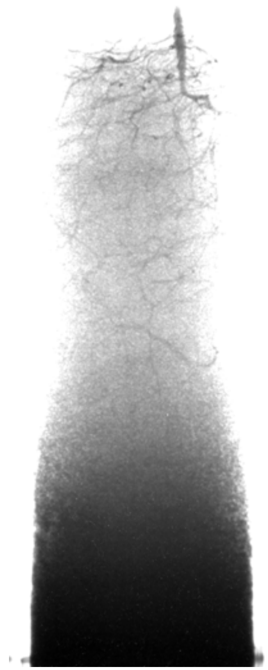
A model body for the Core Material Melting and Relocation (CMMR) study

Y. Abe and I. Sato of JAEA

Tomography at RADEN

Poster by Y. Matsumoto

Roots of Soybean



Testing FBP and SART reconstruction code with GPU

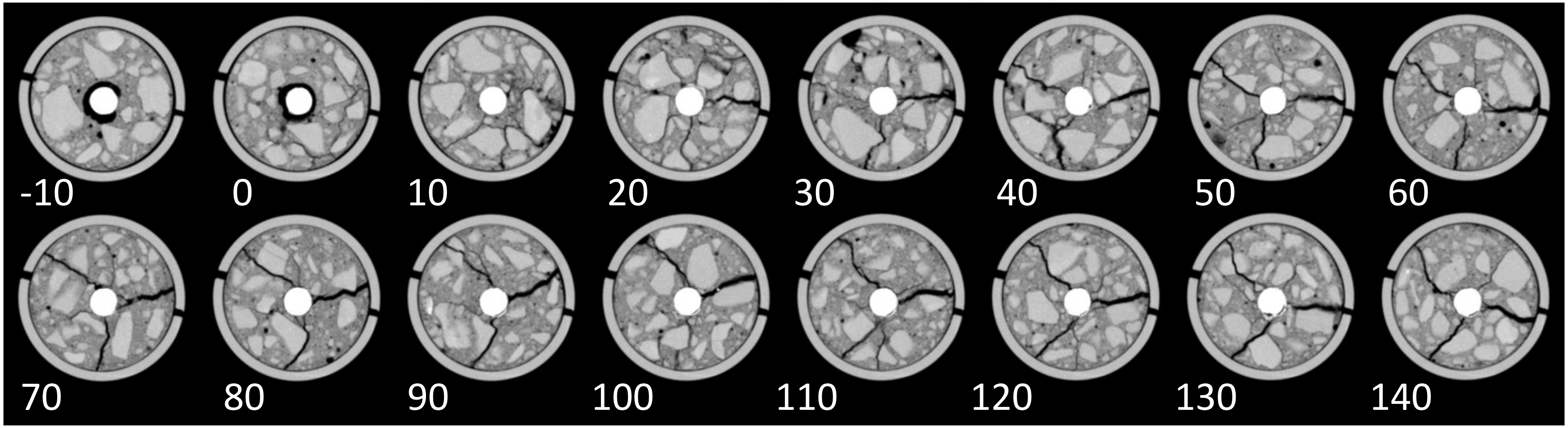
Energy-range effect on the quantification of CT value

Tomography at RADEN

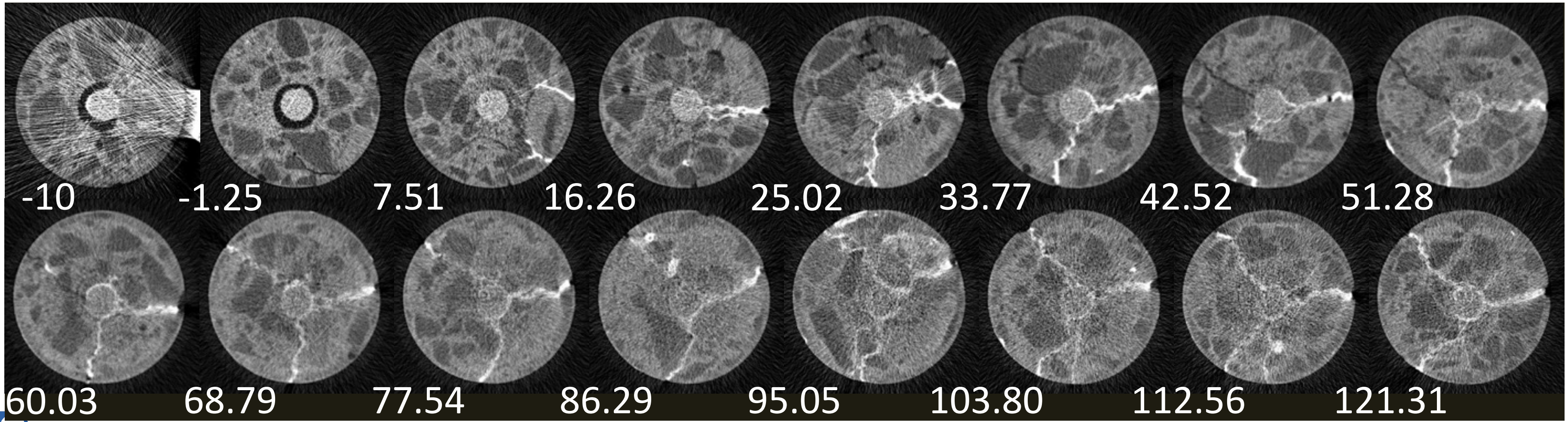
Comparison of X-ray CT and Neutron CT

M. Kanematsu et al.
Tokyo Univ. of Sci.

Cracks in a concrete specimen before repair (X Ray-CT)

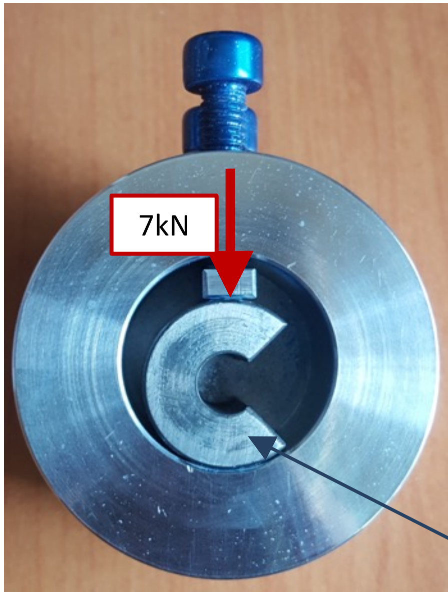


Cracks in a concrete specimen after repair by Epoxy resins (Neutron CT)

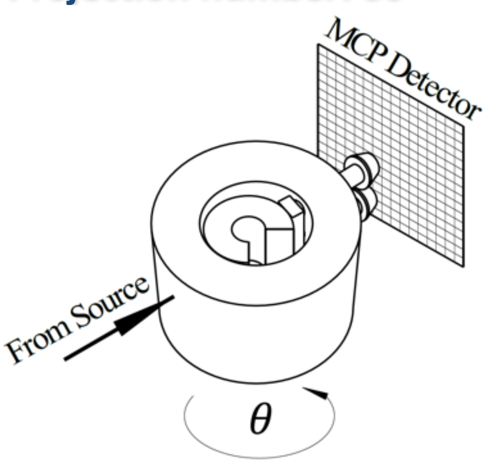


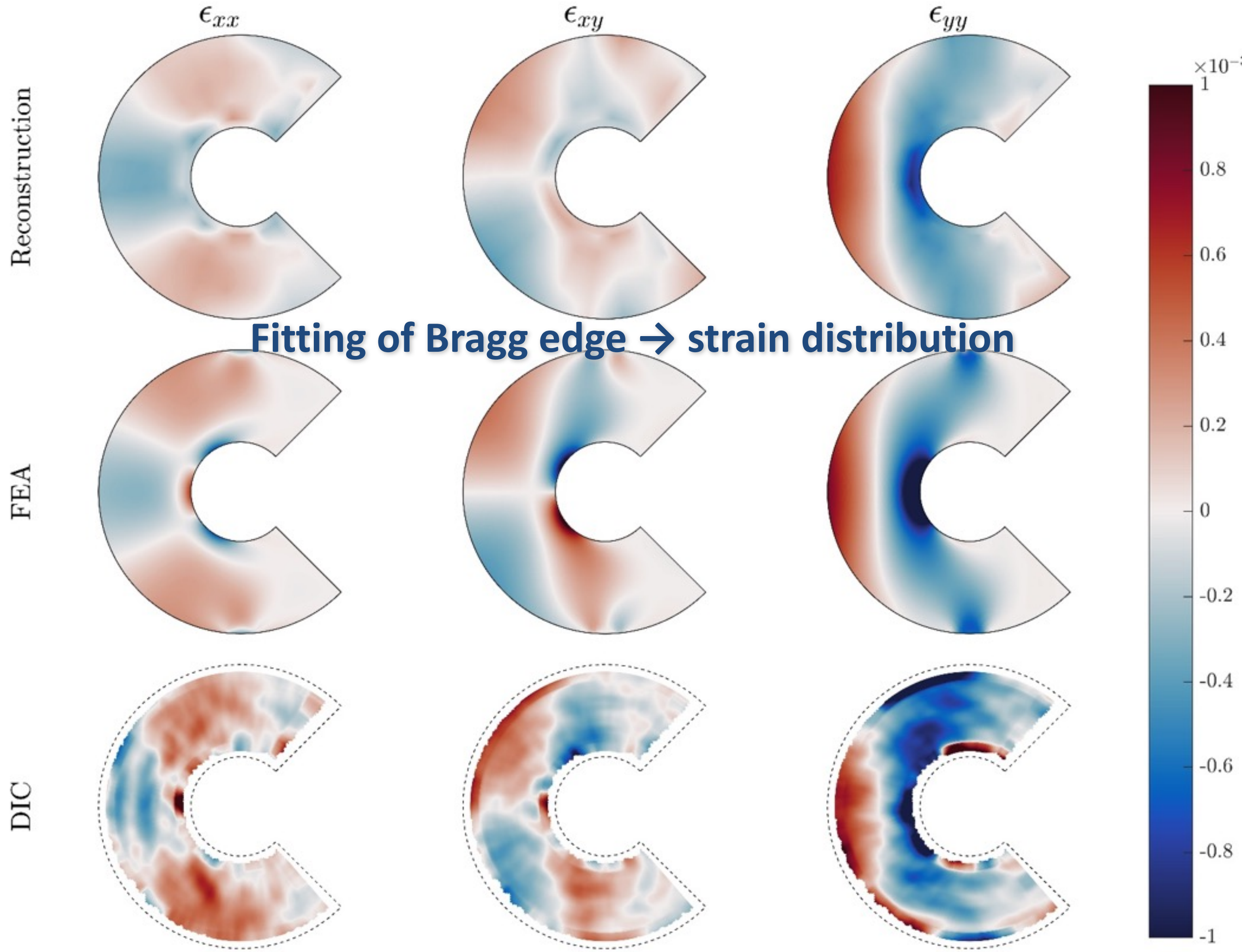
Bragg-edge Tomography

Presentation by A. Gregg on Thursday



Sample: C-shaped Steel (EN26) + Al jig
Detector: MCP detector (A. Tremsin)
Projection number: 86





Fitting of Bragg edge → strain distribution

Chris Wensrich et al. @ Univ. Newcastle

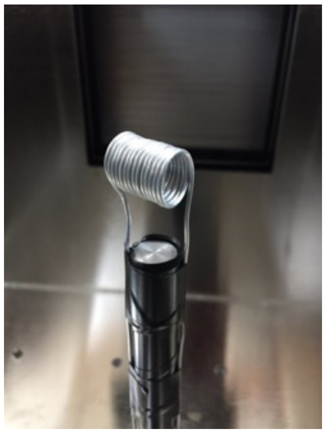
"Bragg-edge elastic strain tomography for in situ systems from energy-resolved neutron transmission imaging "J. N. Hendriks, et al. Phys. Rev. Mater., 1, 053802 (2017)

3D Polarimetric Tomography

Reconstruction of 3D distribution of both field strength and direction

Søren Schmidt et al. @ DTU

"Three Dimensional Polarimetric Neutron Tomography of Magnetic Fields"
M. Sales et al. Sci. Rep. 8, 2214 (2018)



Al wire coil (D= 9 mm, n=15)
Applied current: I=0.6A

Rotation 0 ~ 360 deg. (6 deg. x 60 projections)
6 min. exposure per projection @200kW
18 configuration (9 matrix elements for each spin polarity)

Summary

- RADEN is in the stage of user operation.
  Accepting about 30 user proposals every year.
  J-PARC will start full-power operation in a few years.
- Upgrading work is going on.
  Development of detector, improvement of devices and software, preparing new sample environments.
- Continuing technical development and application of ER-NI.
  Japanese sword study project, Melted fuel study, CT
- User proposals are producing interesting results.
  Not only by pulsed neutron imaging but also by conventional technique.
  Proposals of "in situ experiment" are increasing.

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Instrument Member

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Advisor and Collaborator

Japanese Swords

Y. Kiyanagi, K. Watanabe, K. Ohmae (Nagoya Univ.)

T. Ohba, S. Morito, P.H. Anh (Shimane Univ.)

M. Ito (Wako Museum)

H. Stefanus (J-PARC)

H. Sato, M. Ohnuma (Hokkaido Univ.)

Melted Fuels

Y. Abe, I. Sato (JAEA)

3DPNT

Morten Sales, Søren Schmidt, Luise Theil Kuhn (DTU)

Markus Strobl (PSI)

Anton Tremsin (UC Berkeley)

Thank you for your attention.