

A Road toward/along MLF Construction and Realization

- importance of domestic and international collaboration -



Lund Tram to ESS
(12月12日開通)

Masatoshi Arai

Technical Coordinator
European Spallation Source, ESS

Professor Emeritus
High Energy Accelerator Research Organization, KEK

2020 Dec. 23
On KENS 40th Anniversary Ceremony



Lund cathedral



J-PARC

Hadron Experiment Facility

30GeV Synchrotron (0.75MW)

Materials & Life Science Facility (MLF)



3GeV Synchrotron (25Hz, 1MW)

Neutrino Exp. Facility (294km to Super KAMIOKANDE)

Construction; 2001-2009

Transmutation Facility (Phase II)

Linac (400MeV)

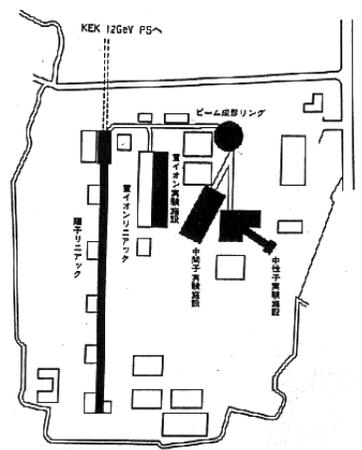


As of 2014

JRR-3M 800m to MLF

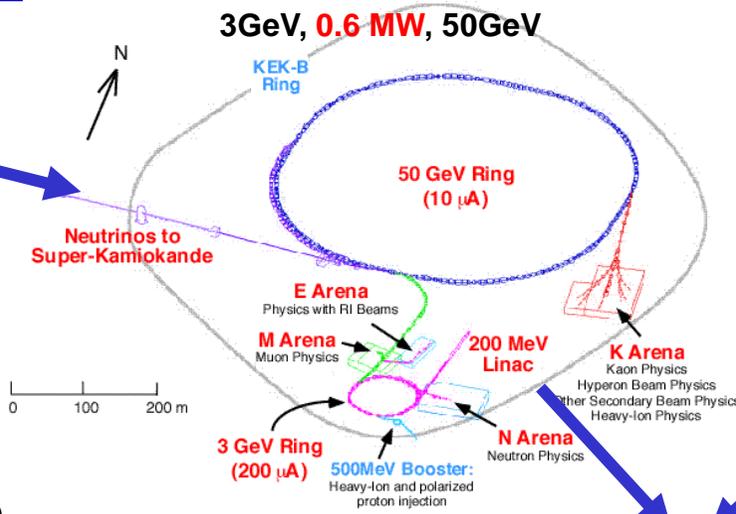
JHF/JHP(1985) ⇒ Joint Project (1998) ⇒ J-PARC(2000)

Japan Hadron Project (JHP)
Tokyo Univ., KEK 1985

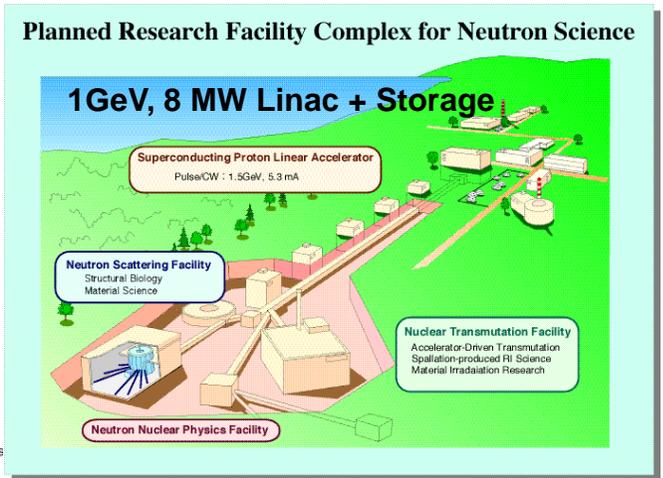


JHF, KEK 1995

Japan Hadron Facility (JHF) Project at KEK



JAERI Project 1990's



1GeV Linac+storage

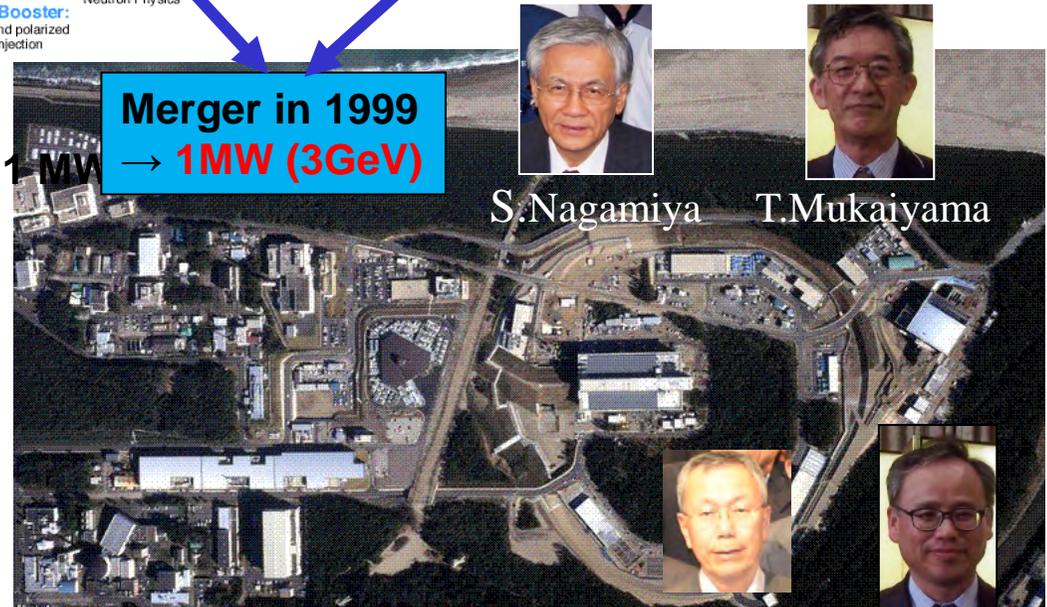


1999年3月 統合計画

覚書調印式

JAERI 松浦理事長 (当時) KEK 菅原機構長 (当時)

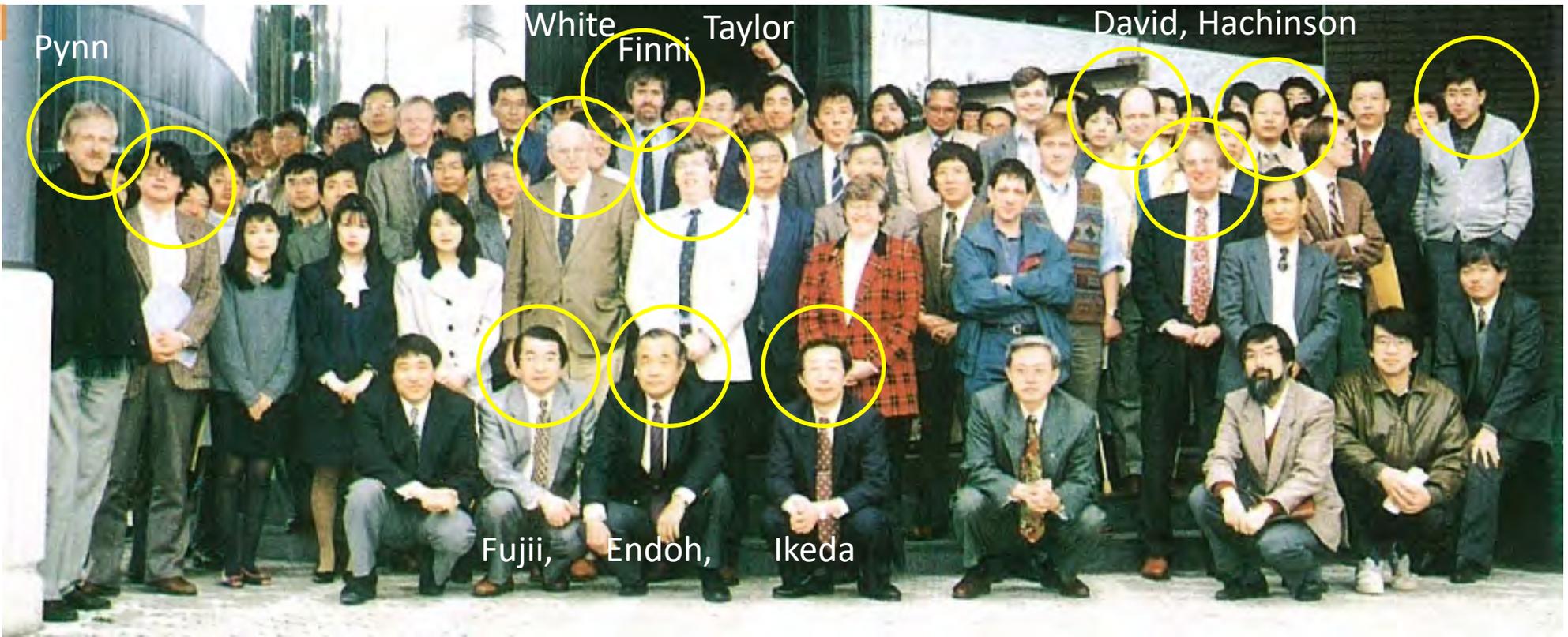
Merger in 1999
→ **1MW (3GeV)**



S. Nagamiya T. Mukaiyama

H. Yokomizo Y. Oyama

Construction: 2001-2009



International Workshop on Science in Neutron-arena of JHF at KEK in 1996

1999 03. Joint Project started

KENS had well experienced users → Key personnel for Instrument design works.

World reputation and collaboration → Especially help from ISIS.

2001 Apr. Approval of J-PARC budget

Joint Project



MA Acknowledge Colleagues worked with MA, the supporters to J-PARC and Int'l Collaborators.



It was also good timing that JSNS was established in 2000.
(Prof. Fujii)



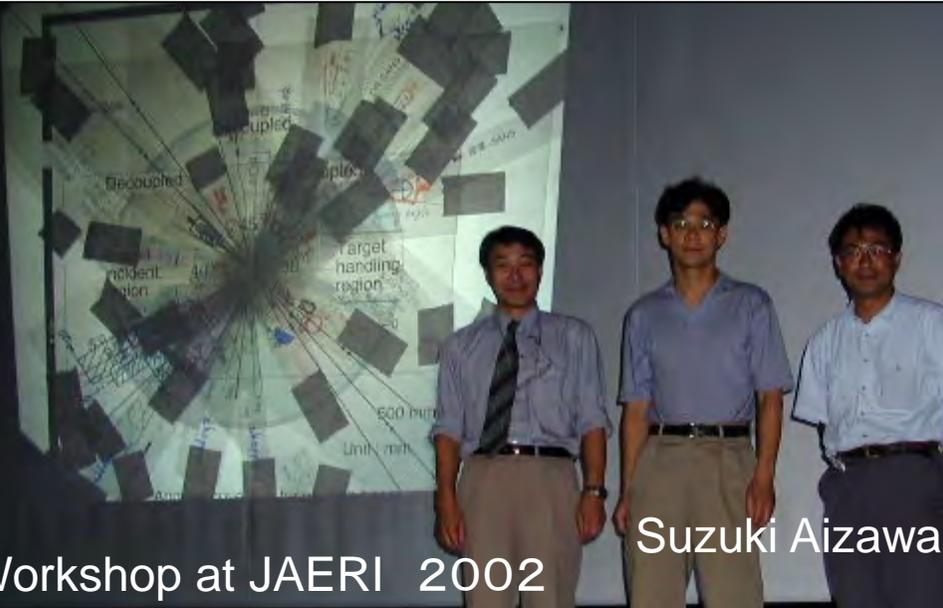
Neutron News 11, No.3 (2000)
Neutron Scattering Association
of Japan Elects Executive Officers

In 2000 May, 100 Volunteers to design instruments



Instrument Suit and Layout of Experimental Hall.

Each Correspondence attached instrument on OHP. 2002



Suzuki Aizawa

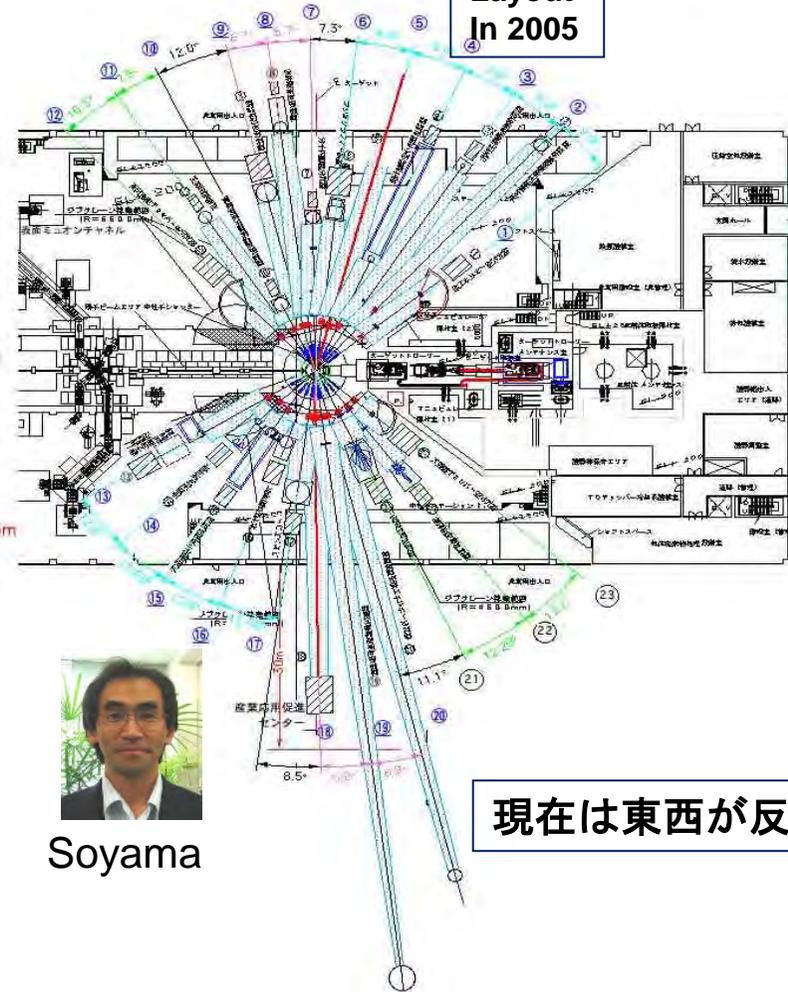
Workshop at JAERI 2002

資料 Ver.14(2002.6.6)

- 低エネルギー型分光器20m
- 高分解能生物構造解析装置50m
- 汎用生物構造解析装置40m
- 高分解能型小角散乱装置20m
- テスト(基礎物理)50m
- ラジオグラフィ装置25m
- 分子内励起分光器25m
- 汎用粉末回折装置40m
- 残留応力回折装置30m
- 構造物性用単結晶回折装置12m
- 生物用非弾性30m
- 高分解能チョッパー型分光器15m
- 二結晶型極小角散乱装置20m
- 垂直型反射率計12m
- 大強度型小角散乱装置12m
- 水平型反射率計12.5m
- スピンエコー20m
- テスト(残留応力・粉末)50m
- 超高分解能粉末回折装置100m
- 液体用全散乱装置20m
- 大強度チョッパー型分光器12m

物質・生命科学実験

Layout In 2005



Soyama

現在は東西が反転

Instrument Team; 100 voluntaries in 2001
Proposed 40 instruments

Determined all 3 H₂, 20K moderators
Decision of Port angle gaps -> 23 ports
CM(11BL, 12deg), DM(6BL, 9deg), PDM(6BL, 7deg)
Importance of Coupled moderator (a half port)



Determine Exp. Hall size, Height
Where to make expansion in future



Project 10 Instruments (KEK + JAERI) in 2005 (23 (+1) Inst)

[1]で提案された装置	関連研究分野	減速材	第1飛行距離 L1(m)	プロジェクト10台として選定	最終的に
高分解能粉末回折装置 (iMATERIA)	結晶学、物質材料分野	非結合ポイズン	30~40	○(茨城県が採用) 2006	茨城県
残留応力回折装置 (TAKUMI)	工学材料分野、物質材料分野、	非結合ポイズン(高分解能型)	30	○JAEA	JAEA
高分解能残留回折装置 (SPICA)	工学材料分野、物質材料分野、	非結合ポイズン(高分解能型)	50		NRDO
超高分解能粉末回折装置 (SHRPD)	結晶学、物質材料分野	非結合ポイズン(高分解能型)	70~100	○ KEK	KEK
単結晶構造解析装置(iBIX)	生命科学	結合型液体水素	10	○(茨城県が採用) 2006	茨城県
単結晶構造解析装置	生命科学	結合型液体水素	20		
単結晶構造回折計 (SENJU)	結晶学、固体物理	非結合型水素	10		共用法
全散乱装置(NOVA)	非晶質材料、液体	非結合型水素	14	○ KEK	KEK (NEDO)
液体全散乱装置 (-> PLANET)	非晶質材料、液体	非結合型水素	20		JAEA, 高圧装置(科研費)
高分解能型SANS装置	高分子、物質材料分野	結合型液体水素	20		
大強度SANS装置 (TAIKAN)	高分子、物質材料分野	結合型液体水素	9	○ JAEA	共用法
ポンゼ・ハート型SANS装置	高分子、物質材料分野	結合型液体水素	10~20		
垂直型反射率計 (SOFIA)	高分子、物質材料分野	結合型液体水素	10	○ KEK	KEK
水平型反射率計 (SHARAKU)	磁性材料分野	結合型液体水素	11.5		共用法
チョッパー型分光器 (HRC)	固体物理、物質材料分野	非結合型水素	15	○ KEK	KEK
大強度型チョッパー (4 SEASONS)	固体物理、物質材料分野	非結合型水素	15	科研費 2005	JAEA, KEK (科研費)
冷中性子チョッパー (AMATERAS)	固体物理、物質材料分野、高分子	結合型液体水素	30	○ JAEA	JAEA
高分解能結晶アナライザー分光器	生命科学、高分子	非結合型水素	85		
汎用高エネルギー分光器	化学、固体物理、	結合型液体水素	16.30.60		
スピンエコー (VIN ROSE)	高分子、固体物理	結合型液体水素	20		KEK
ラジオグラフィー (RADEN)	工学材料、農業	結合型液体水素	20-Oct		共用法
生物用非弾性(DNA)	生命科学、高分子	非結合型水素	30	○ JAEA	共用法
基礎物理実験装置 (BL05)	高エネルギー用		未定		KEK
基礎物理実験装置	VNC	結合型液体水素		ポンゼ・ハート型SANSと共用	



Beam Line / Instruments Status in 2008

The 1st neutron beam, May 2008

		FY2006			FY2007								FY2008														
		2007.1	2	3	4	5	6	7	8	9	10	11	12	2008.1	2	3	4	5	6	7	8	9	10	11	12	2009.1	
J-PARC accelerator (Linac, 3GeV RCS)					Linac acceleration Jan, 24, 2007								3GeV RCS acceleration Oct, 31, 2007														
1st Hall	BL01 4-SEASONS (Fermi chopper)	Grant (JAEA, KEK, Tohoku U)																									
	BL03 iBIX (Bio-Molecule Diff.)	Ibaraki Pref.																									
	BL04 Neutron Cross-section Measurement	Grant (Hokkaido Univ., etc)																									
	BL05 NOP (Neutron optics and physics)	Grant KEK																									
	BL08 SHRPD (High-Resolution Powder Diff.)	KEK																									
	BL12 HRC (High-E Resolution Fermi chopper)	KEK																									
2nd Hall	BL14 AMATERAS (low E chopper)	JAEA																									
	BL16 Neutron Reflectometer with Horizontal-Sample Geometry	KEK																									
	BL19 TAKUMI (stress analysis)	JAEA																									
	BL20 iMATERIA (Versa. Powder Diff.)	Ibaraki Pref.																									
	BL21 Versa. Total Scatt. Diff.	NEDO KEK																									



Extension building for BL08



Extension building for BL19

User programme

2004年10月17日 Target Station Outer-Liner設置開始

那珂湊港(2km)
から2時間かけて搬送



相沢、梶本、鈴木、松林、曾山、鳥飼、大友

利用系7人の侍

Experiment hall was built in very robust

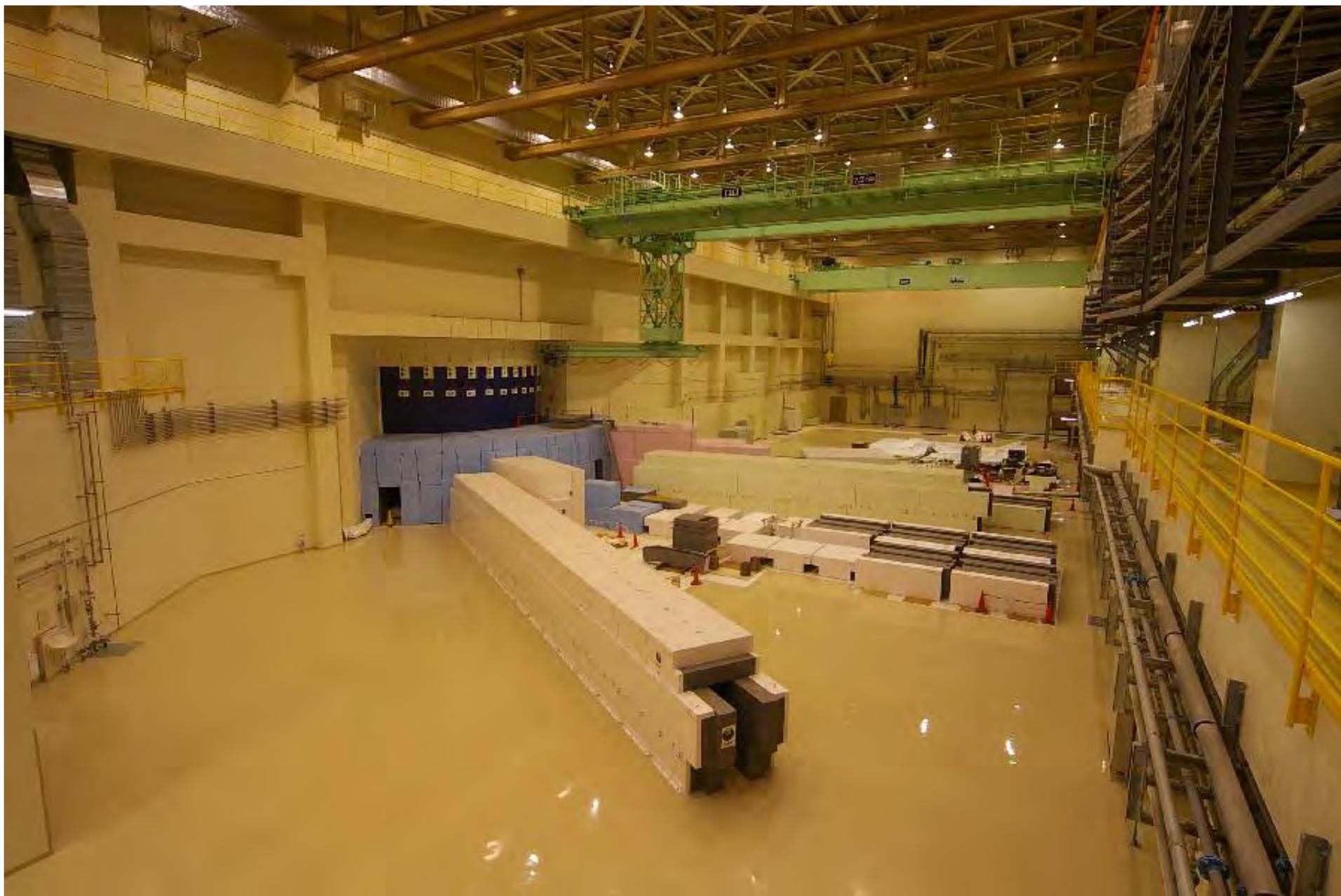


Target Center



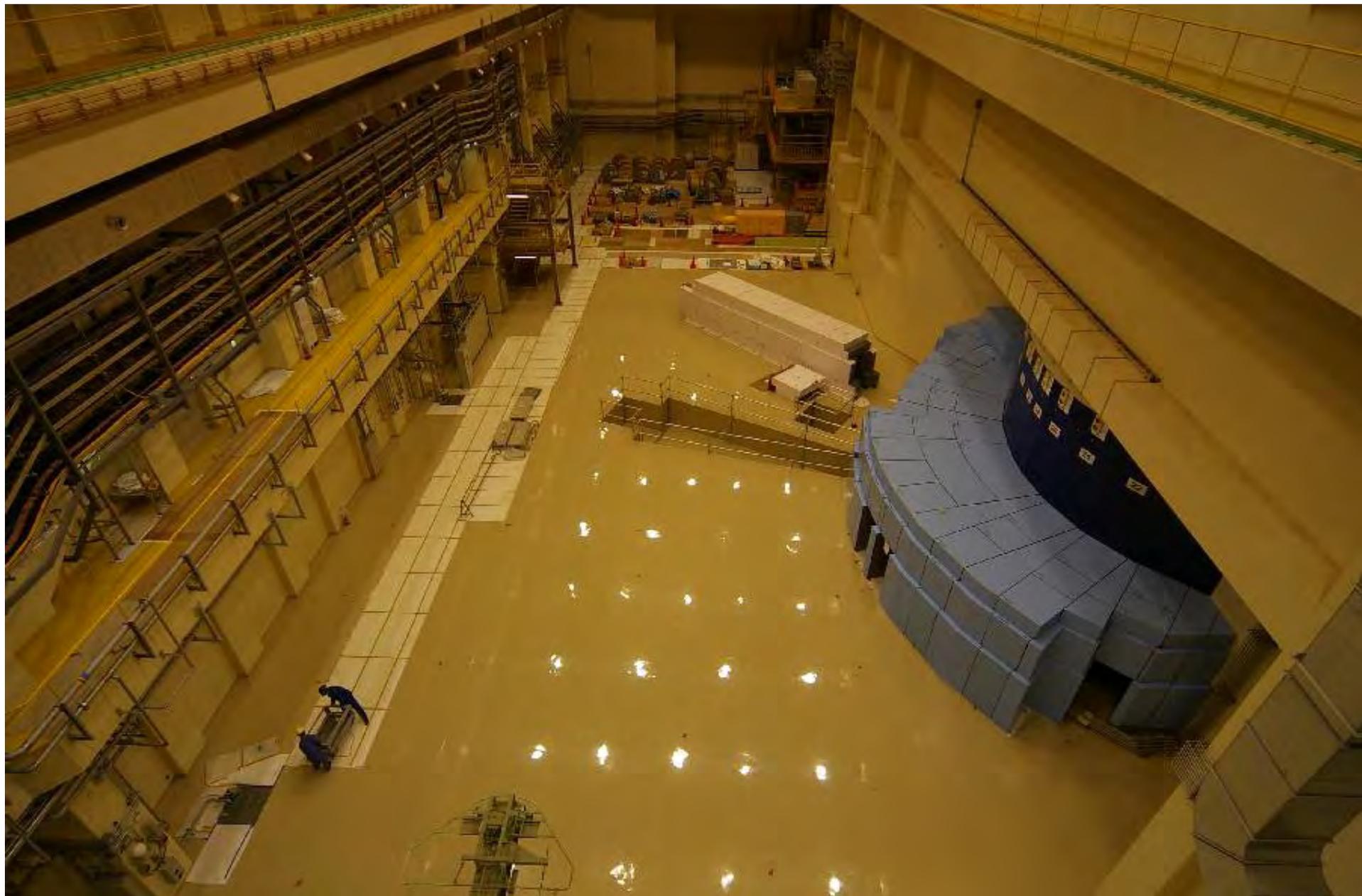


Hall # 1 in 2007





Hall No.2 in 2007



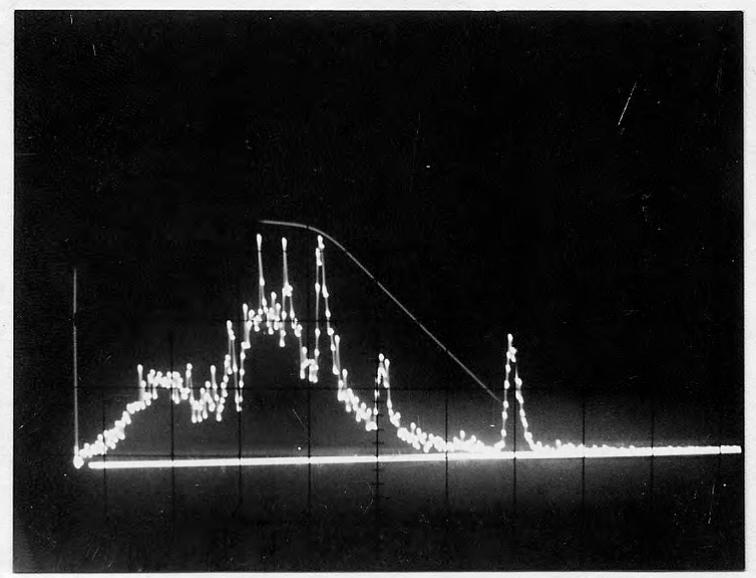
KENS the 1st Beam in 1980 June



N.Watanabe



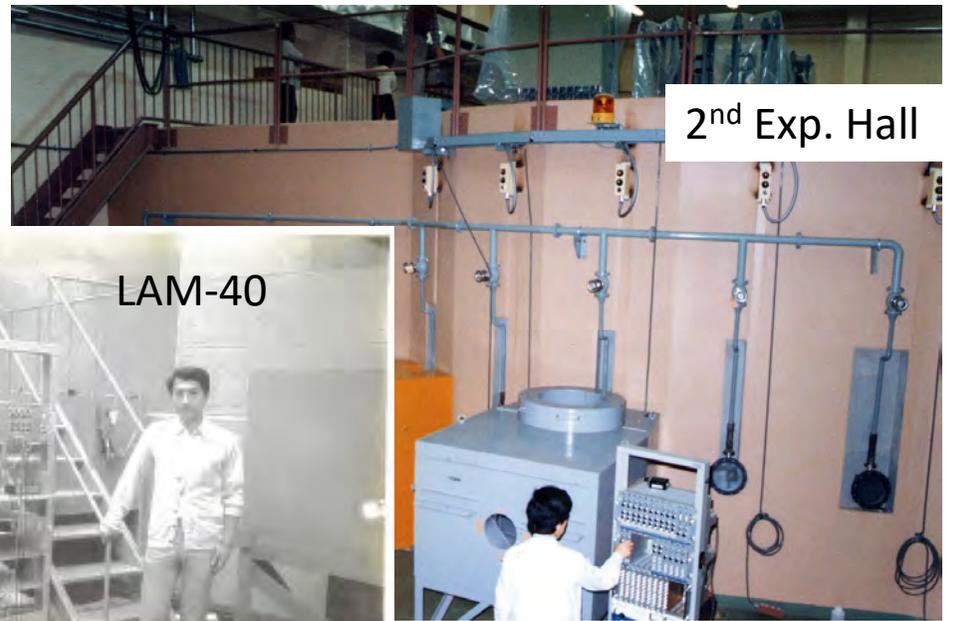
Prof. Fukuchi, Ishikawa, Sasaki



③ 多結晶 Fe の中性子回折



1st Exp. Hall

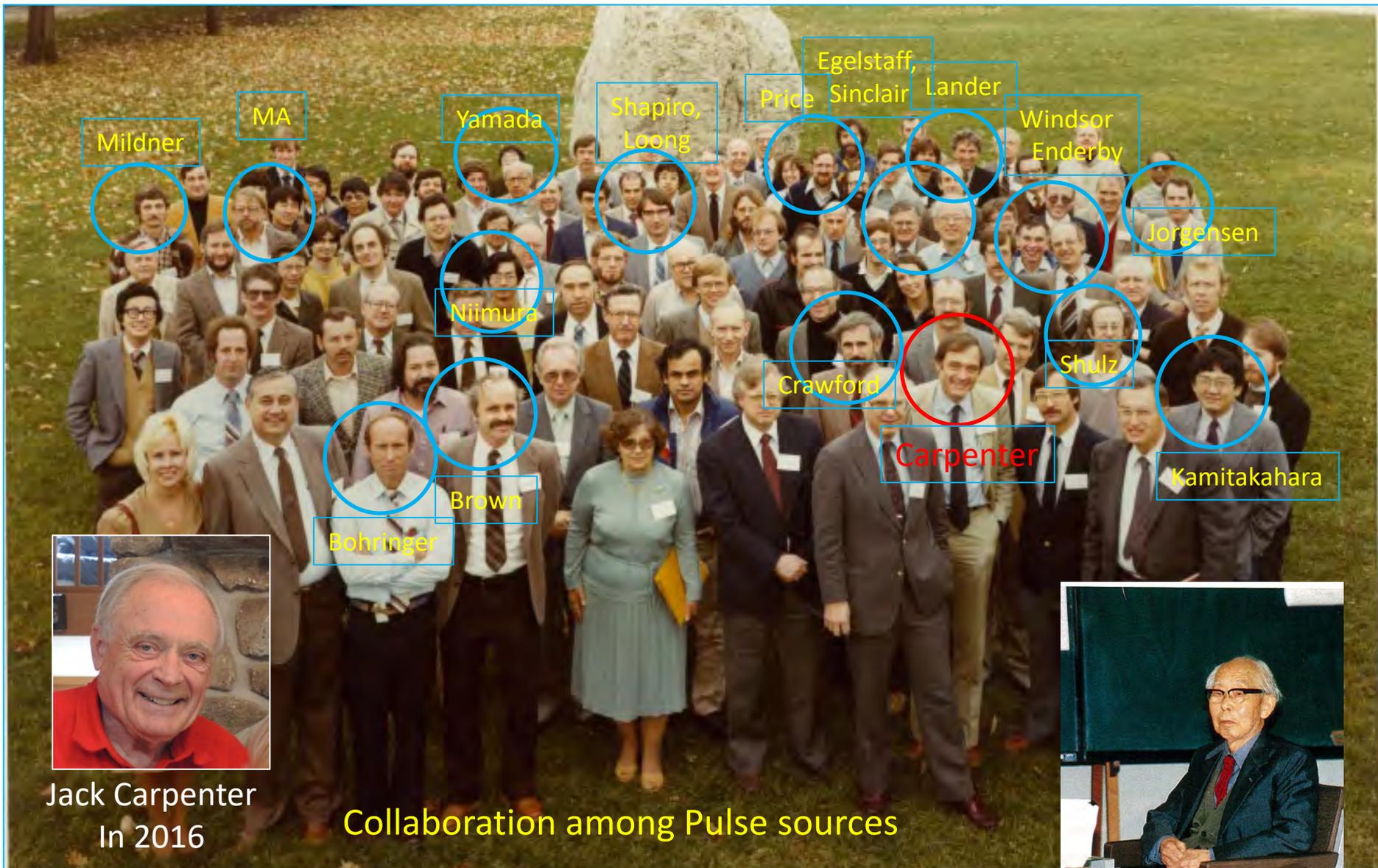


2nd Exp. Hall



LAM-40

Y.Kiyanagi



Jack Carpenter
In 2016

Collaboration among Pulse sources



Prof. Motoharu Kimura ¹⁸
(Frontier of Pulsed Neutron)



IPNS USERS MEETING
November 15 – 16, 1983
Argonne National Laboratory
Argonne, Illinois 60439

UK-Japan Collaboration since 1987 (ISIS-KENS)

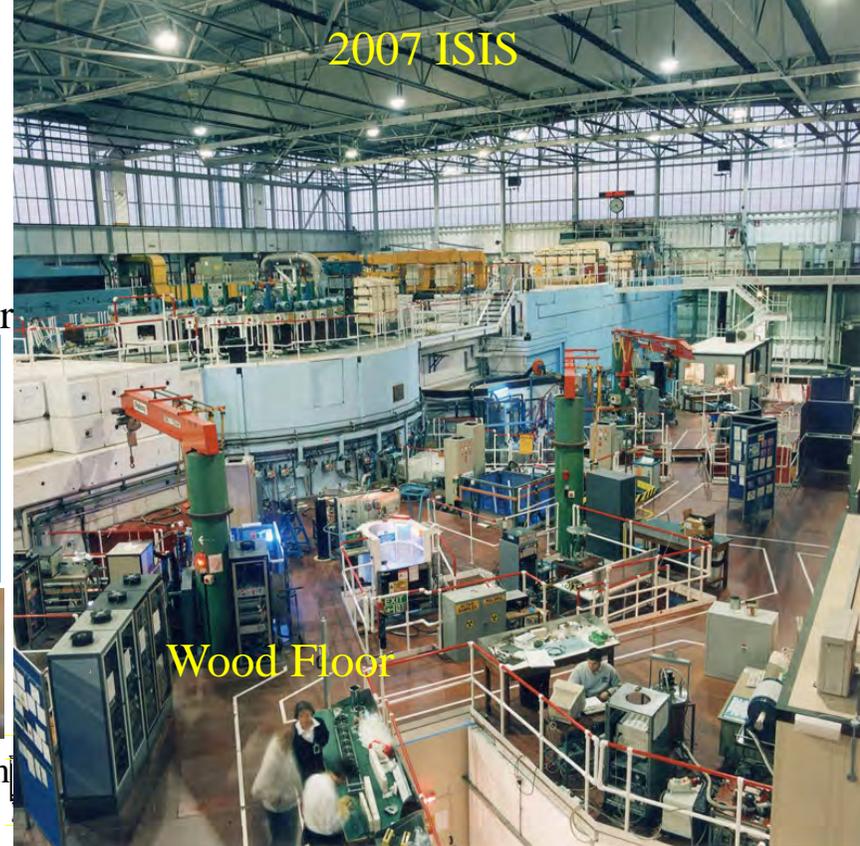


Y. Ishikawa A. Leadbetter

N. Watanabe U. Schteigenberger

Experiences on Construction of MARI and Science,
also Instrumentation, Software, Facility, Utility,
User Support, User Program, Organization, Network
→ Reflected to the MLF, J-PARC Design

2007 ISIS



Wood Floor



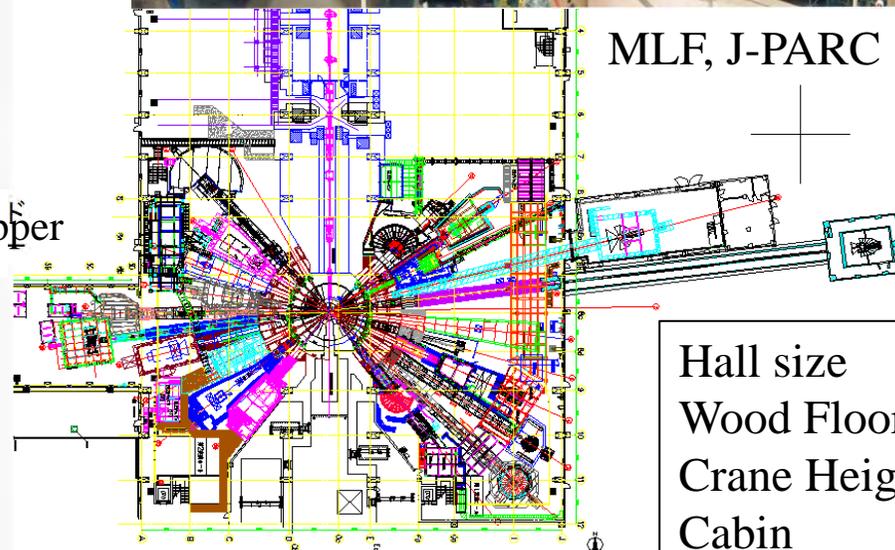
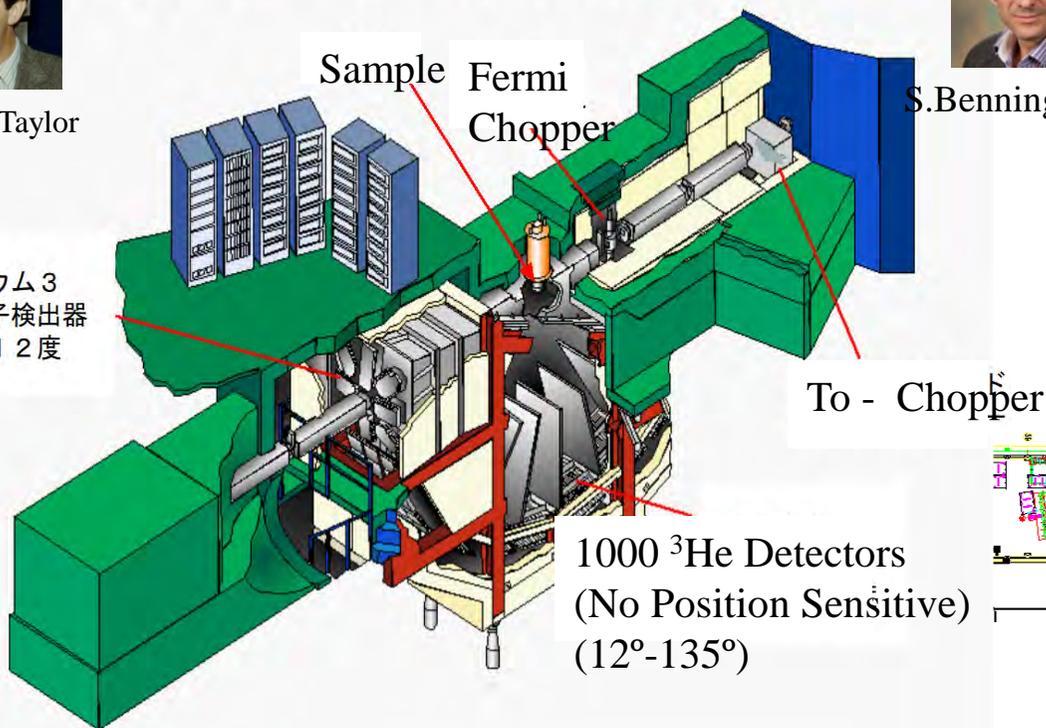
A.D. Taylor

MARI 分光器

KEKとラザフォード・アップルトン研究所との協力



S. Bennington



Hall size
Wood Floor
Crane Height
Cabin



Friendship and Collaborations with ISIS

-> support MLF design and construction

Many Japanese delegate visited ISIS during MLF's construction

UK-Japan Collaboration workshop at Izura, 2003
北茨城、五浦



2005年9月 日英協力研究会 日光
UK-Japan Collaboration Workshop at Nikko, 2005

Exciting time for Spallation Source Development

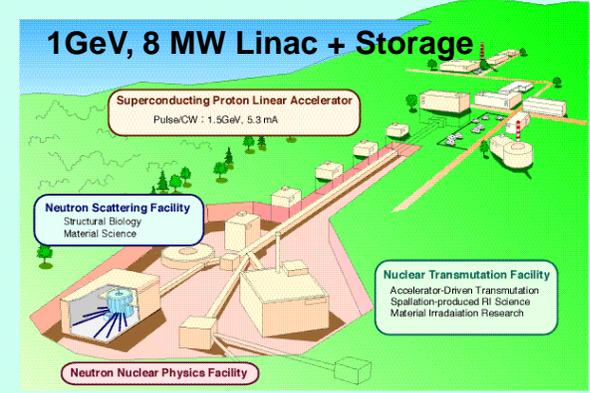
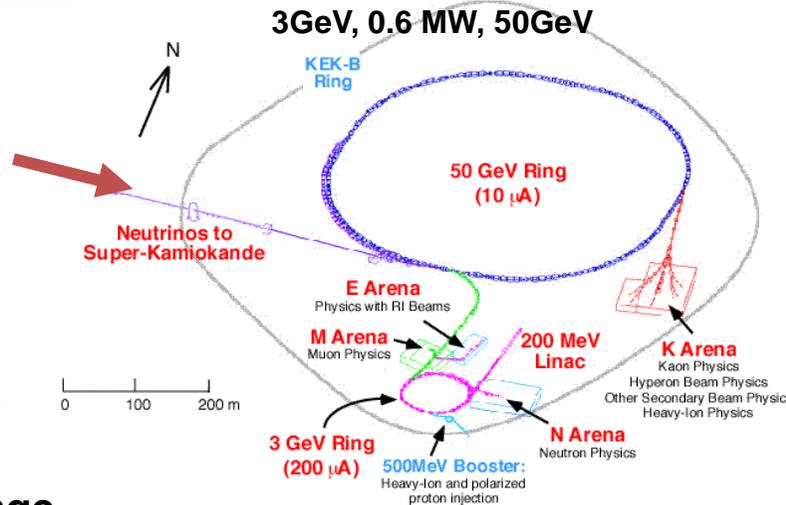
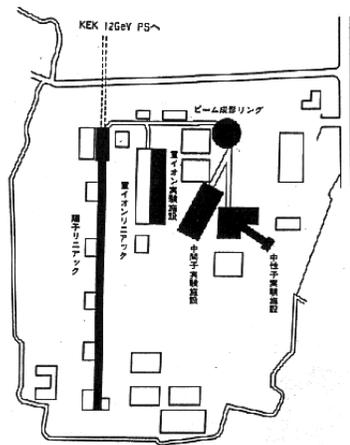
Japan Hadron Project (JHP)
Tokyo Univ., KEK 1985

JHF, KEK 1995

JAERI Project 1990's

Japan Hadron Facility (JHF) Project at KEK

Planned Research Facility Complex for Neutron Science



1GeV Linac+storage



Jülich planned ESS in 1990's

ESS started in 2014 at LUND

ANS (350MW, 1984-1994)-> SNS 2006 BOT



Hg- Target Test at BNL-AGS (1-24GeV) (ASTE)

The World Team (Jülich, BNL, ORNL, JAEA, KEK, Hokkaido)

1997 June

Hg-Target Prototype



World Team

Jülich for ESS

BNL

JAERI 1GeV

KEK 3GeV

Oak Ridge for SNS

AGS Tunnel, 100 μ Sv/h



Kiyanagi

Conrad

Jülich Team

Neef

Takada



Y. Ikeda
Leader

6 25 '97

Kasugai

J. Hastings

Nakashima

JAEA Team

Futakawa

Development of the Hg-Target system



Takada



Haga

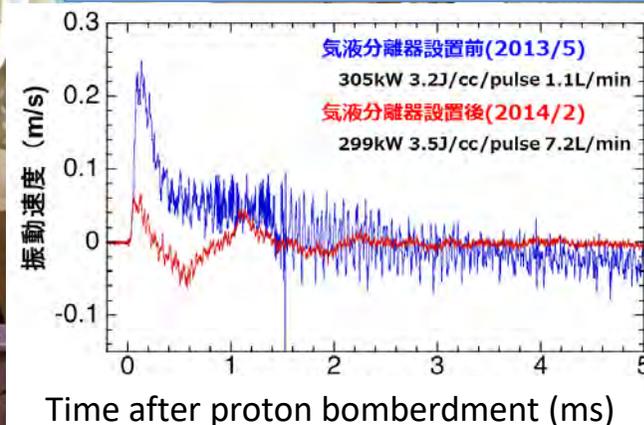


Futakawa



Pitting Damage on target

Vibration on the target container



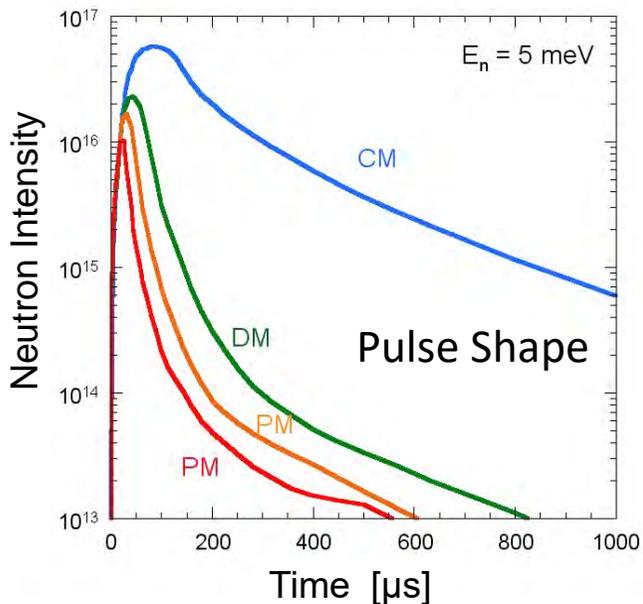
Expertise of JAERI could only realize the target system
Mitigation of Pitting on the Target container

- Injection of He bubbles to mitigate the pitting problem.

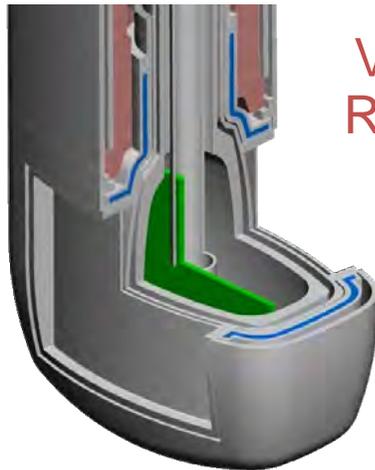
Now about to realize 1MW, 25Hz 3GeV



Three Hydrogen Moderators

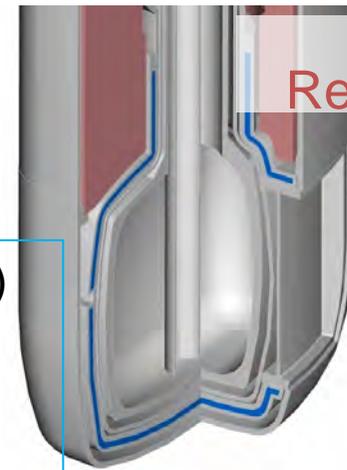


Decoupled Poisoned M



Very High Resolution

Decoupled M



Med Resolution

- * Ag-In-Cd (AIC) Decoupler @ 1 eV
- * Cd Poisoning



Teshi



Harada



Maekawa

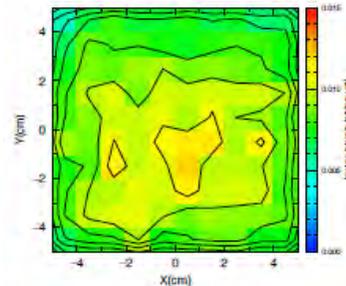
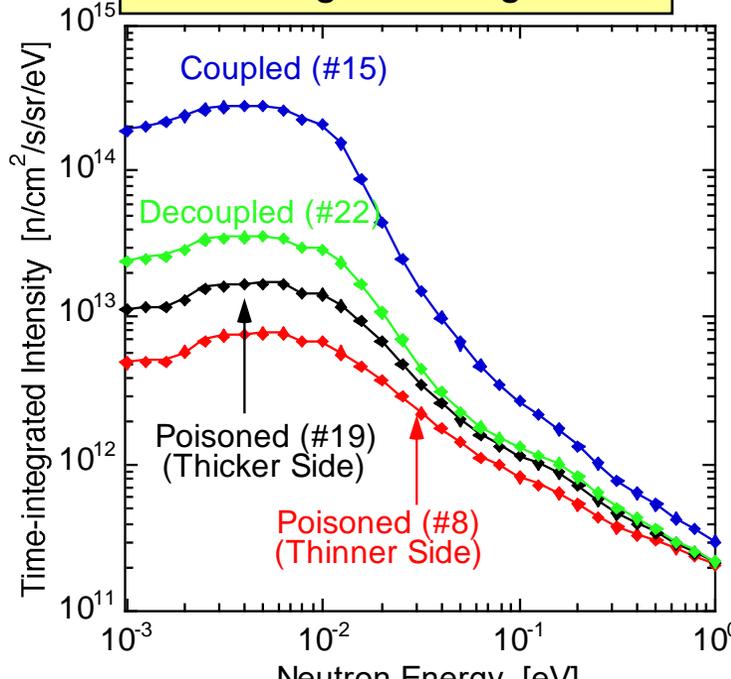


High Intensity

Coupled M

(Watanabe- Kiyonagi) 可

Time-integrated Brightness



BL19

Source Term for each Port

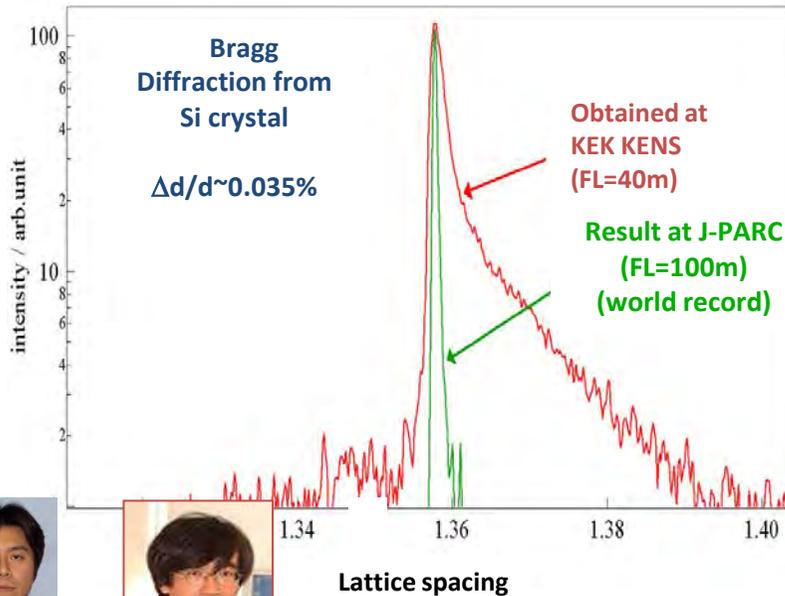
The first neutron production at MLF in 30 May, 2008 After 7-year construction.



We have confirmed the designed performances by the real beam

PHITS: precision ($\pm 20\%$)
 Energy in $10^9 \Rightarrow 10^{-3} \text{eV}$ order of 12
 Intensity $10^{17} \Rightarrow 10^8$ order of 9

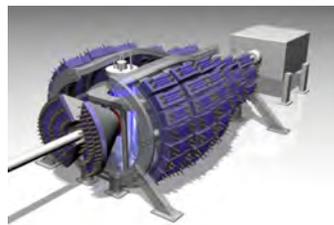
Resolution at BL08 (June, 2008)



S. Torii

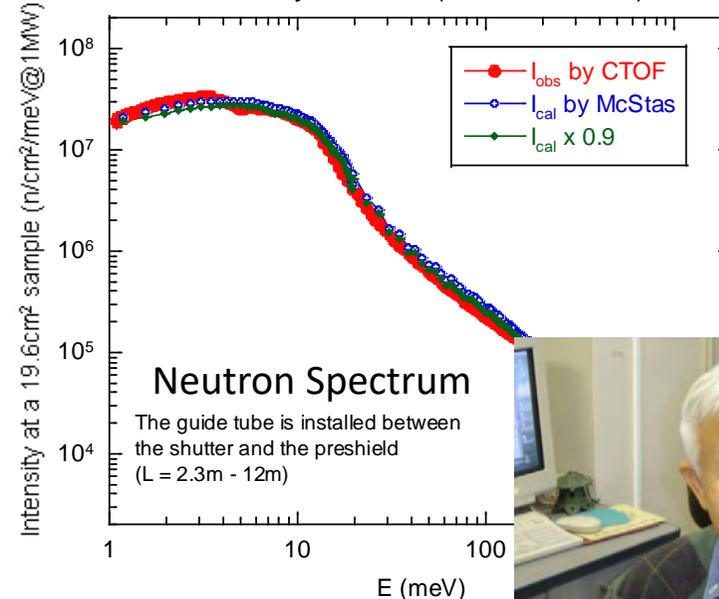


T. Kamiyama



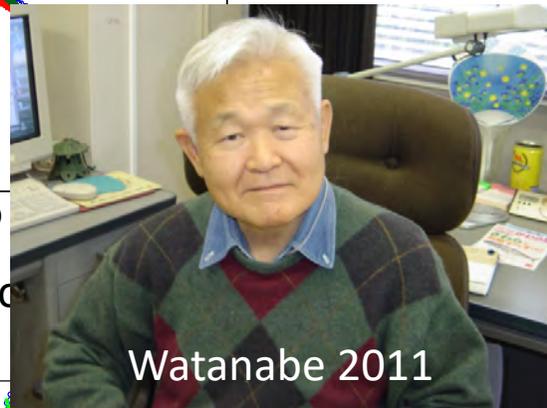
High resolution
 $\Delta d/d \sim 0.03\%$

Intensity at BL01 (Dec. 25, 2008)

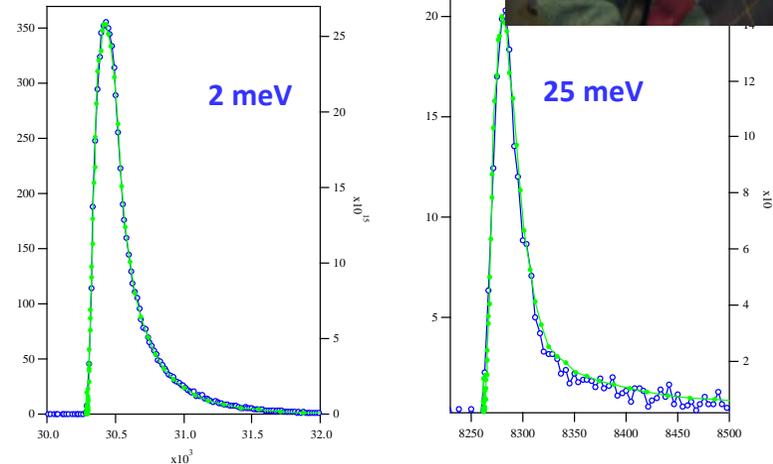


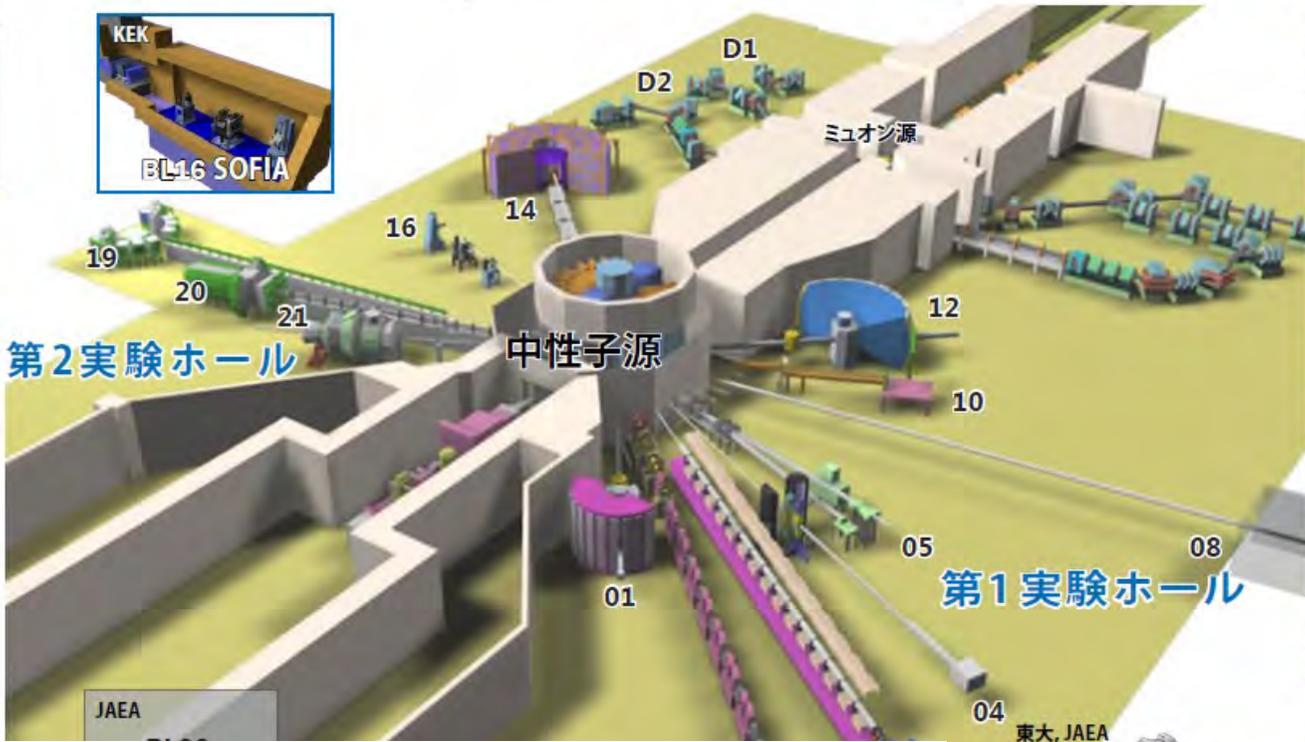
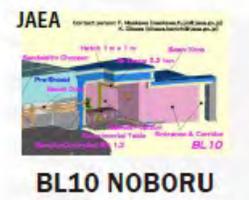
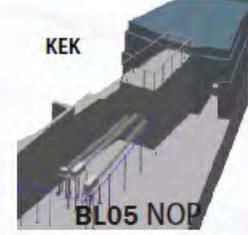
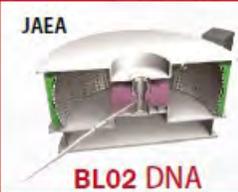
Y. Ikeda

Peak structure (calc/obs)
 ピーク構造 (計算/実測)



Watanabe 2011





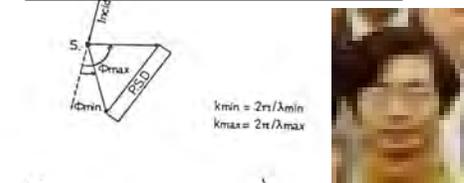
Development of Instrumentation Benchmark on performance, functionality, background etc.



Development on TOF-PSD Technology

KAKURI-ken 1978

The first TOF-PSD Diffractometer in the world.



N.Niimura

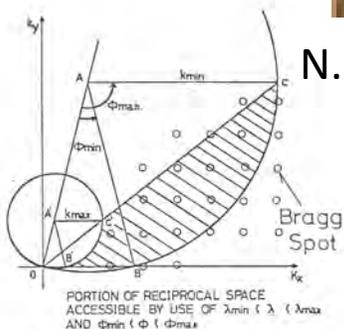
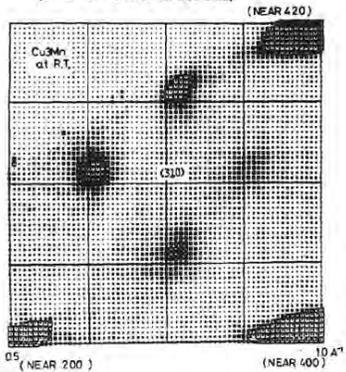


Fig. 1. The portion of reciprocal space accessible by use of the PSD.

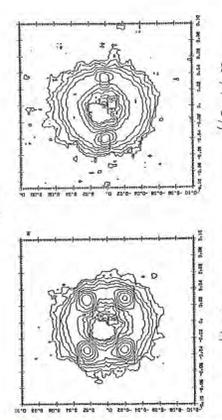
INTENSITY DISTRIBUTION IN RECIPROCAL SPACE (WITH PSD)



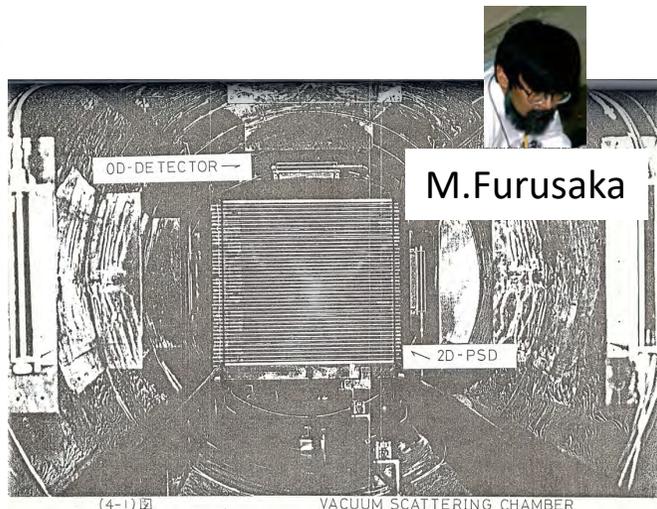
Cu_3Mn Diffuse Scattering (atomic, magnetic short range order)

1980 KENS

PSD - SAN



MnSi



M.Furusaka

1994 KENS

SIRIUS

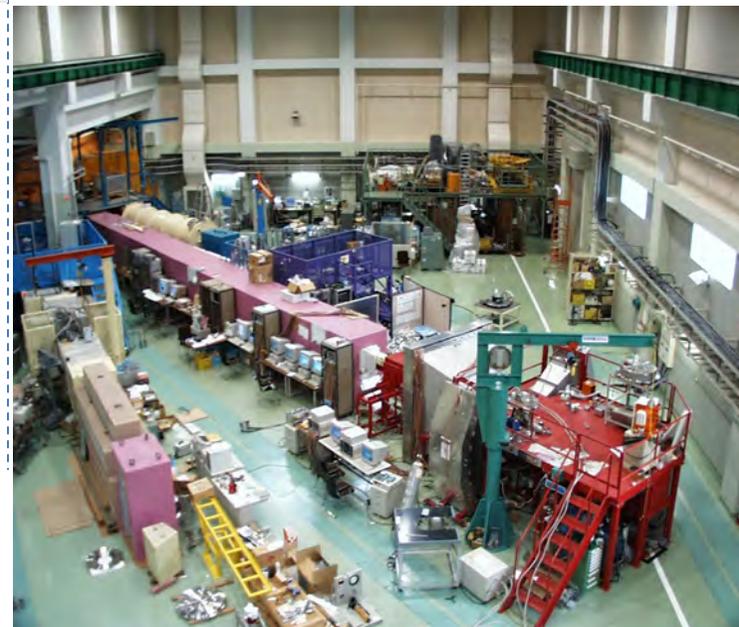
First Large PSD Installation



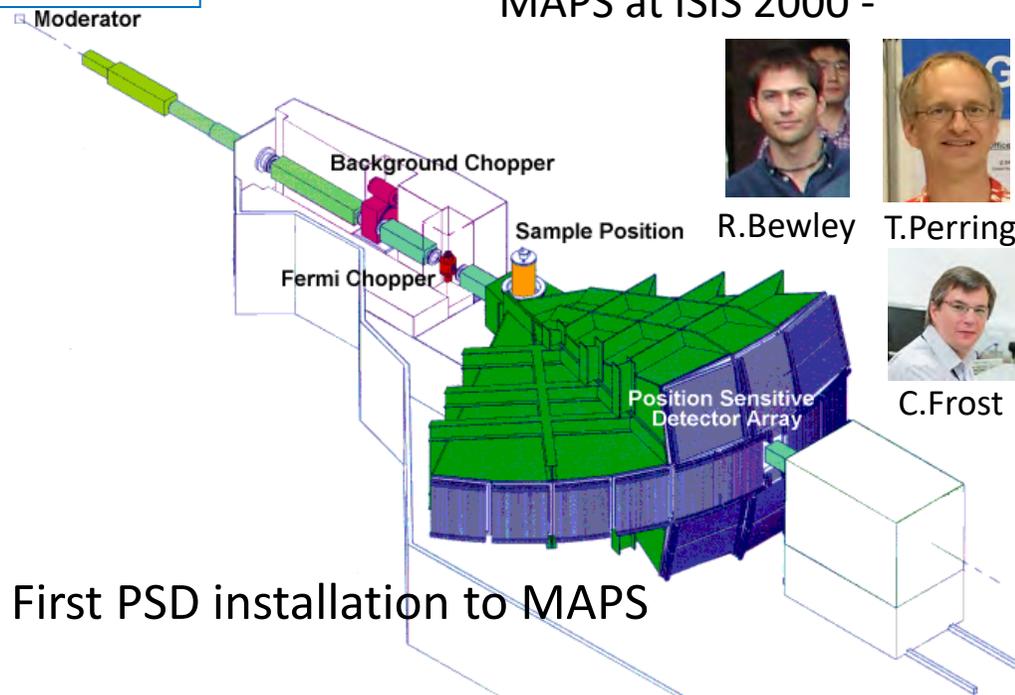
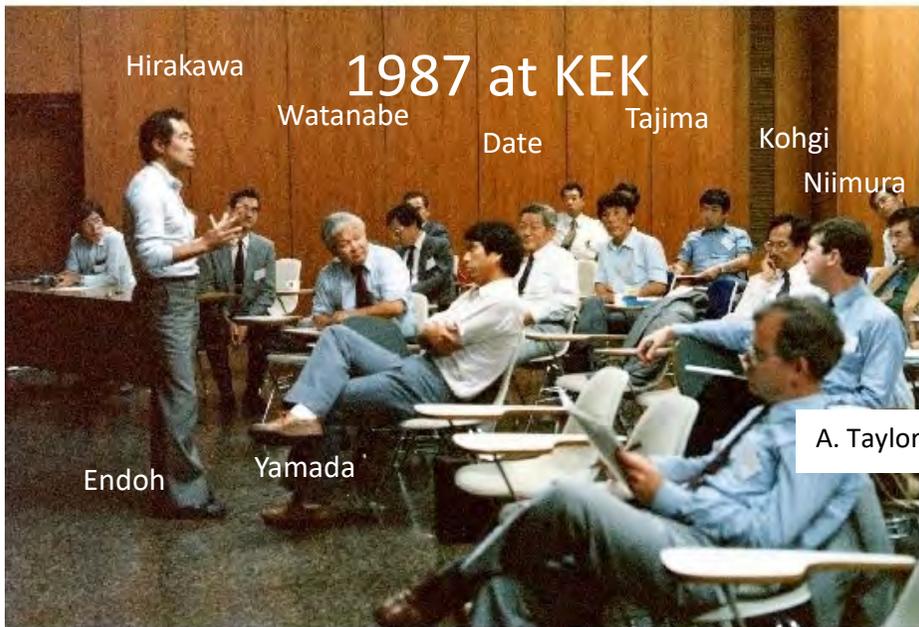
S.Satoh



T.Kamiyama



Single Crystal on MARI and MAPS

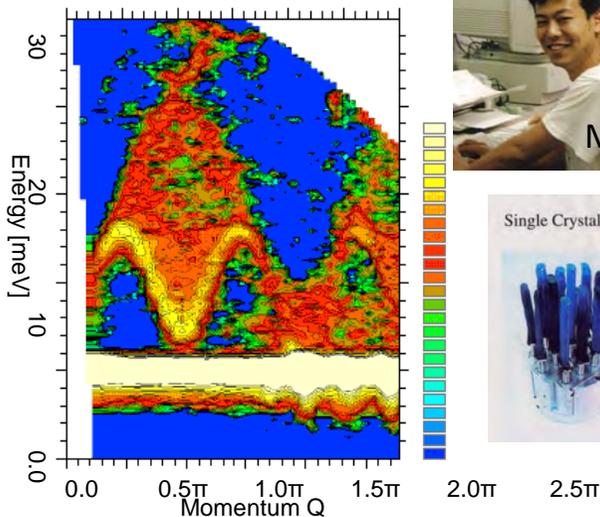


MAPS at ISIS 2000 -



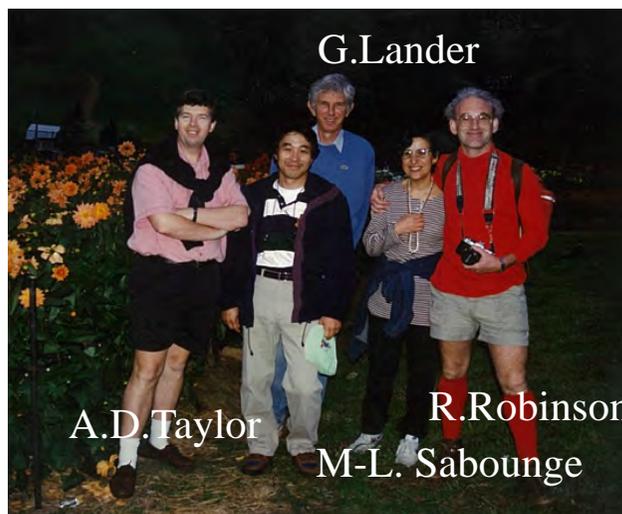
First PSD installation to MAPS

S(Q,E) of 1-D S=1/2 System of CuGeO₃



the 1-D Quantum Spin Excitation after 30 years of the Theoretical Prediction.

1994 Conceptual Design at Zao





R. Lechner

Collaboration on Inelastic Instrument

湯城さん 東芝

P. Sokol

R. Bewley

Discussed PSD (ISIS, SNS, MLF)

阿部さん

セーコー

F. Mezei

J.G. Park

Nathan
GE

I. Zaliznyak

Nakajima

Workshop on Inelastic Neutron Spectrometers 2004
In JAERI

2004 12 Kaneko

2004 Dec. 1st WINS

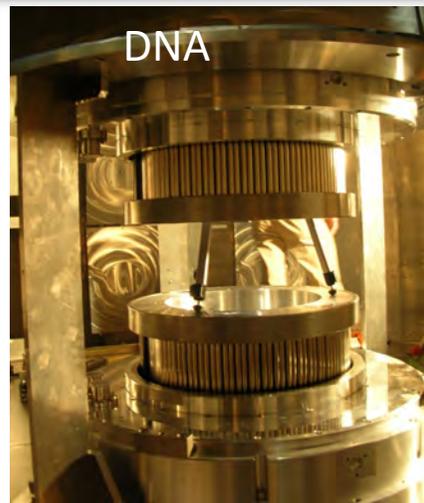
4SEASONS, AMATERAS, LET, MERLIN, CNCS, HYSPEC

All MLF instruments equipped with PSD

Test @JRR3



Shibata



Collaboration with
PSD-suppliers



N.Johnson GE

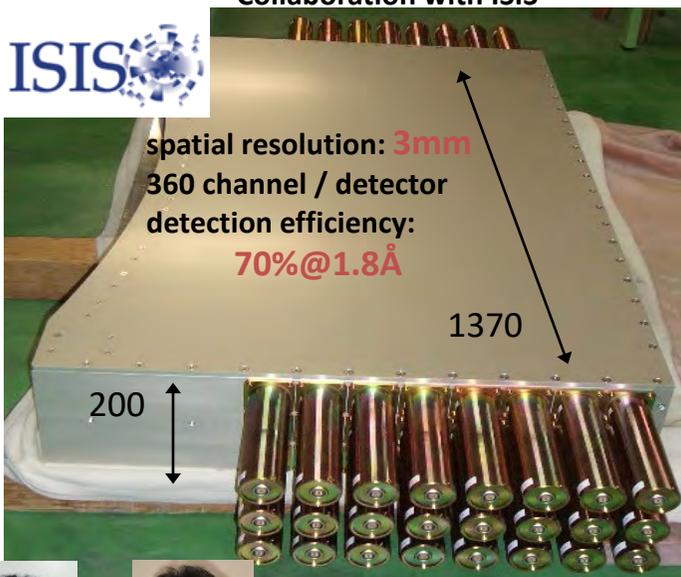


Yushiro TOSHIBA

Scintillation Detector Developments

1-d scintillation detector with large area

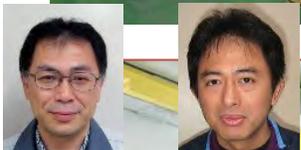
Collaboration with ISIS



spatial resolution: **3mm**
360 channel / detector
detection efficiency:
70%@1.8Å

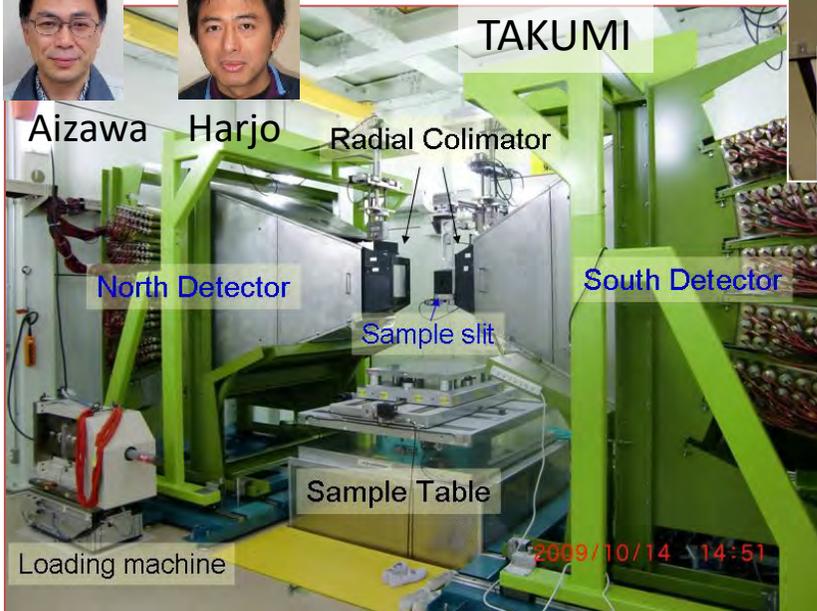
1370

200



Aizawa Harjo

TAKUMI



Radial Collimator

North Detector

South Detector

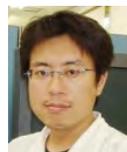
Sample slit

Sample Table

Loading machine

2009/10/14 14:51

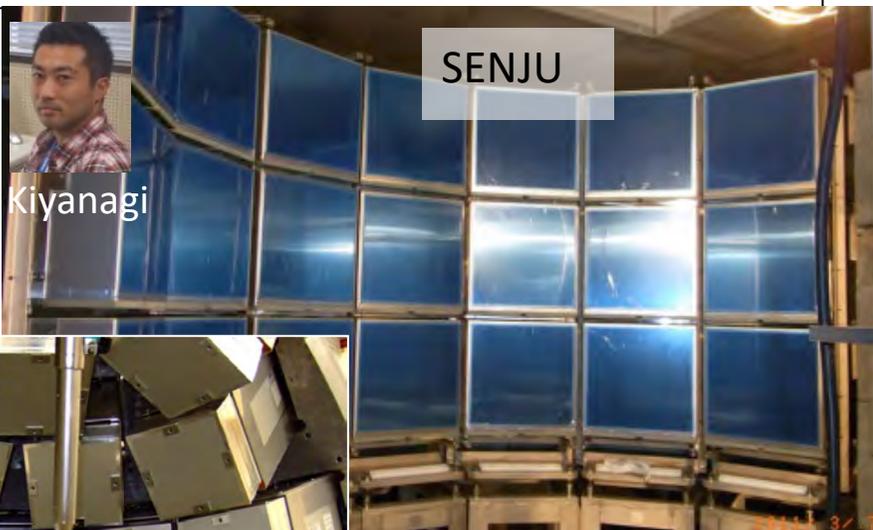
2-d scintillation detector with large area



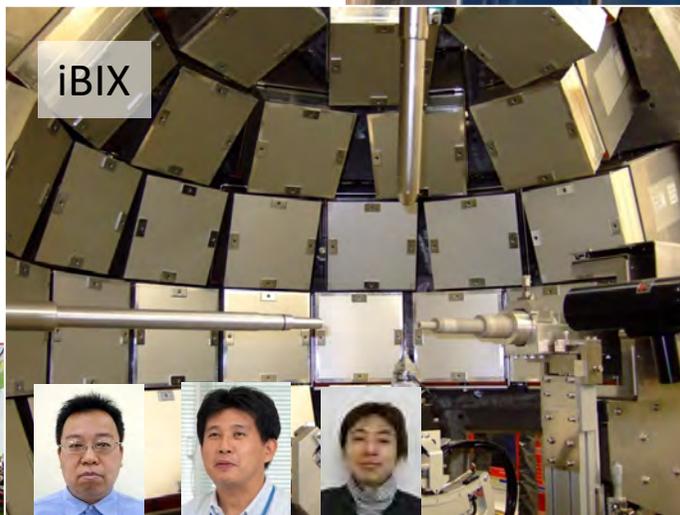
Ohara.



Kiyanagi



SENJU



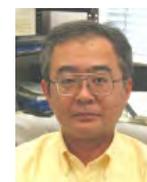
iBIX



Kusaka Tanaka Hosoya



Katagiri



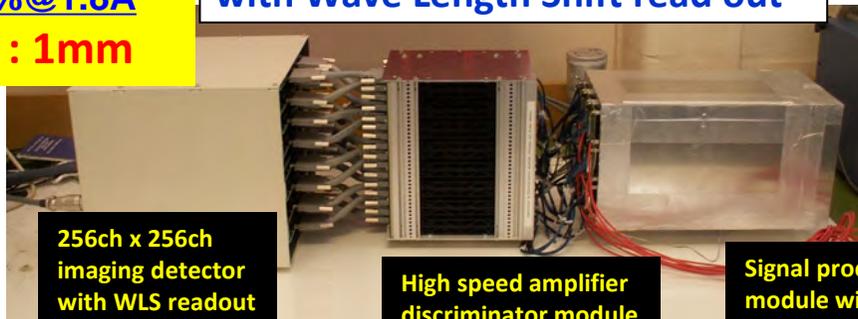
Sakasai



Nakamura

Det. efficiency:
70%@1.8Å
 $\Delta r : 1mm$

2-d scintillation detector
with Wave Length Shift read out



256ch x 256ch
imaging detector
with WLS readout

High speed amplifier
discriminator module

Signal processing
module with FPGA

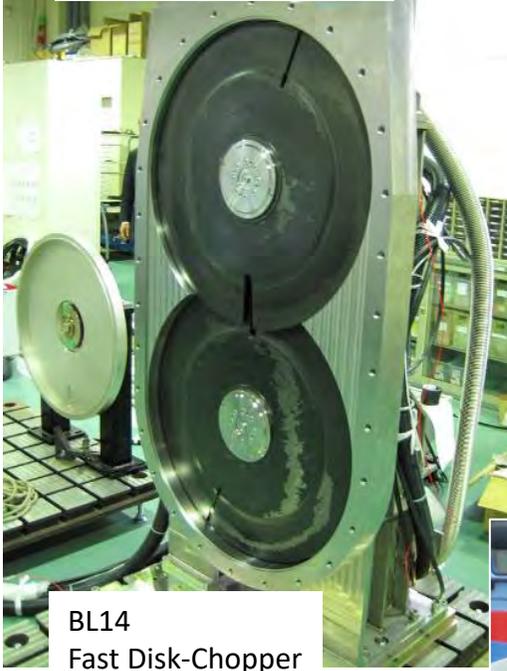


Chopper Developments、To, Disk. Fermi choppers



Itoh

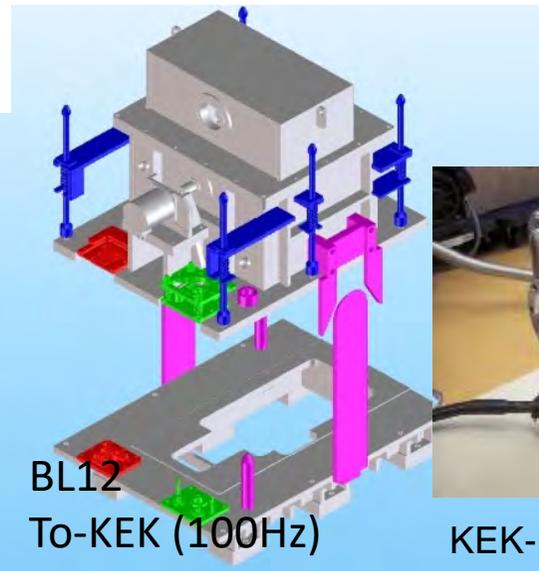
Pulse Shaping



BL14
Fast Disk-Chopper
Tandem Type



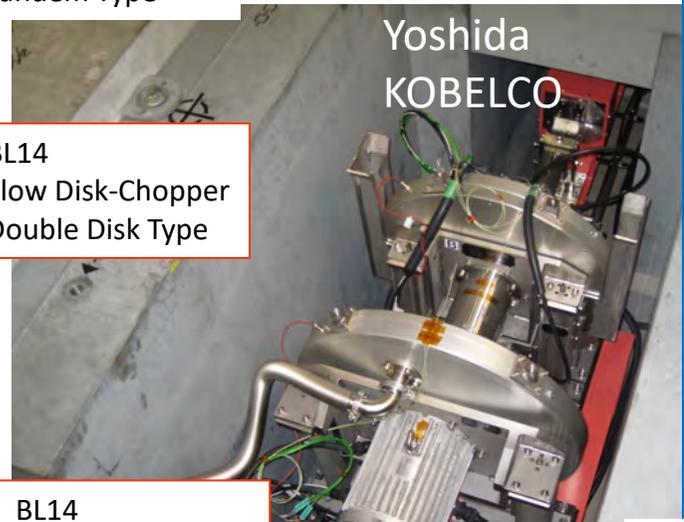
BL14
Slow Disk-Chopper
(Double Disk Type)



BL12
To-KEK (100Hz)



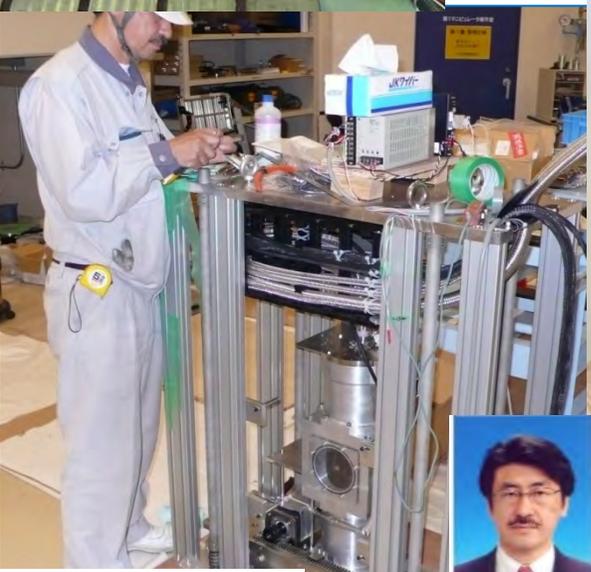
KEK-Fermi chopper



BL14
Slow Disk-Chopper
Double Disk Type

Yoshida
KOBELCO

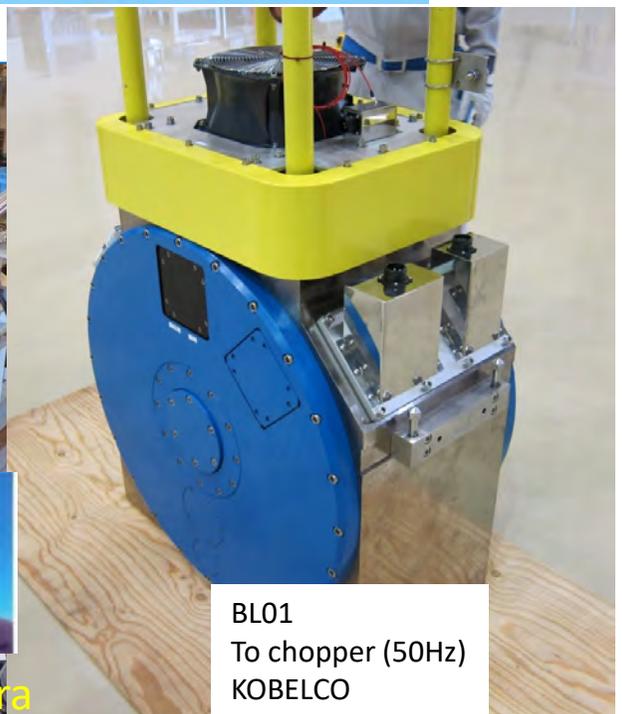
BL14
Fast Disk-Chopper
KOBELCO



BL01
Fermi chopper (SKF, SNS)

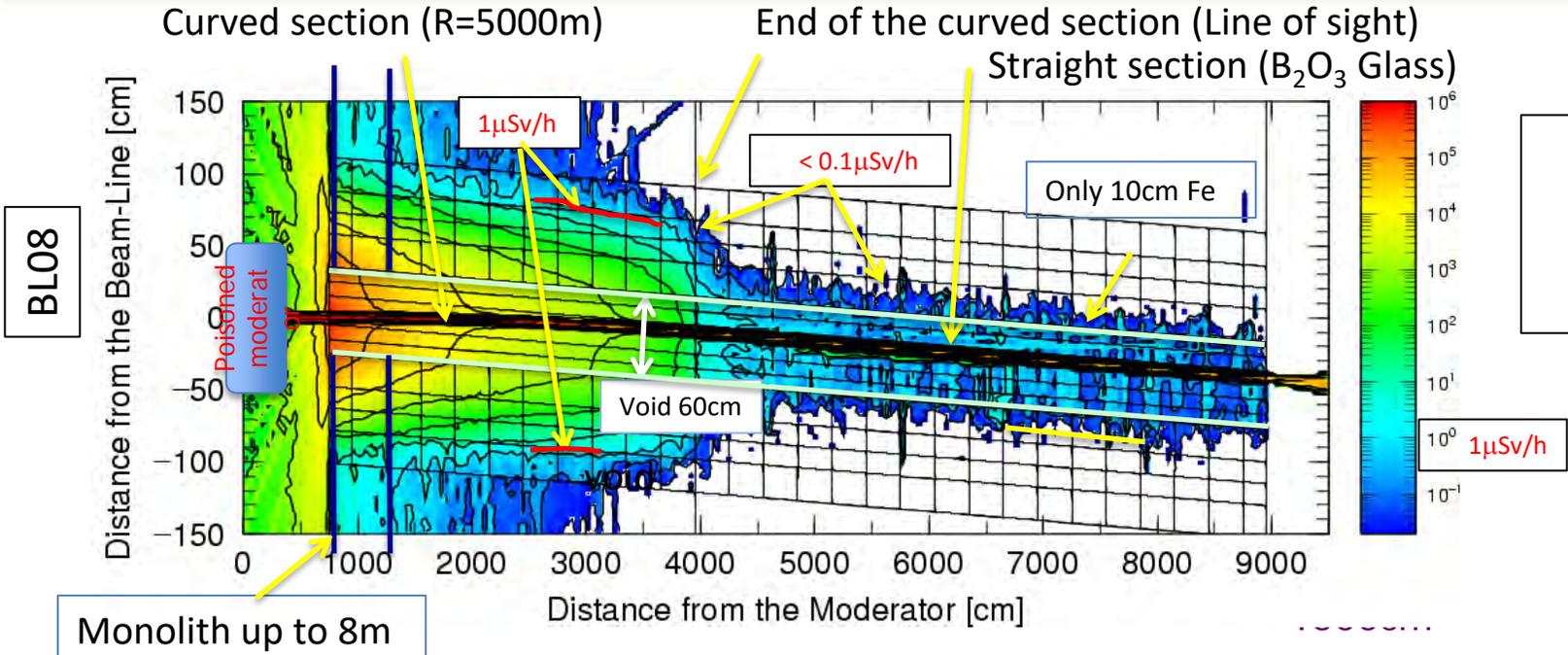


Kambara



BL01
To chopper (50Hz)
KOBELCO

PHITS's Innovative Shield Simulation (developed for long instrument); RIST

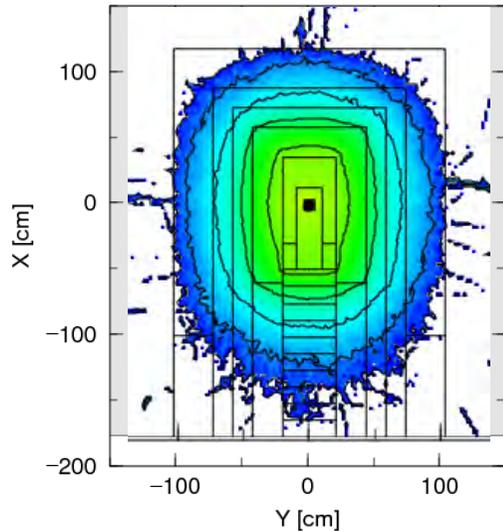


Shielding Design Optimization (Duct Source) Maekawa



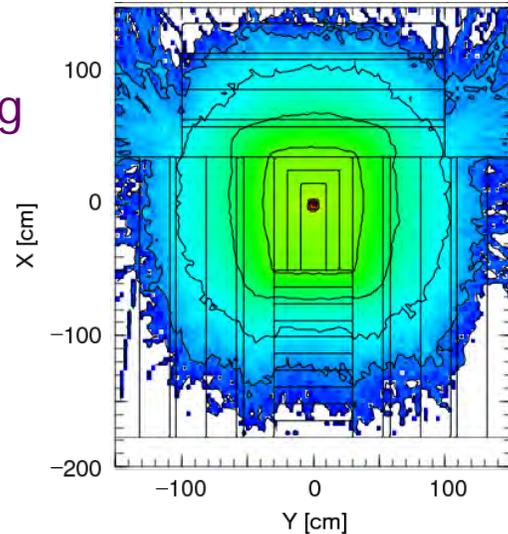
K.Niita

Monolith up to 8m



(Value Engineering Cost Down 1/3)

Fe 5 ton/m

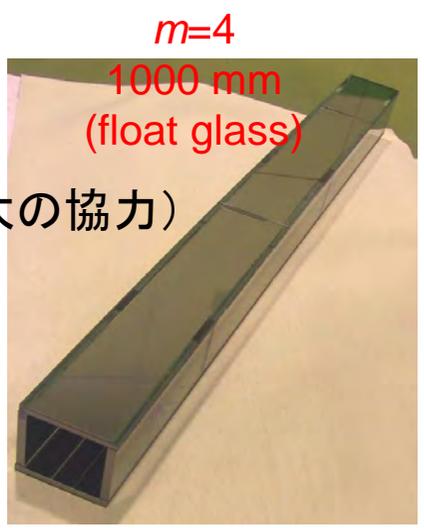
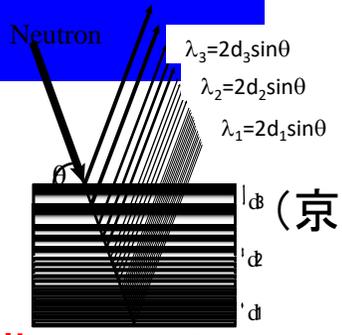


Fe 45 ton/m

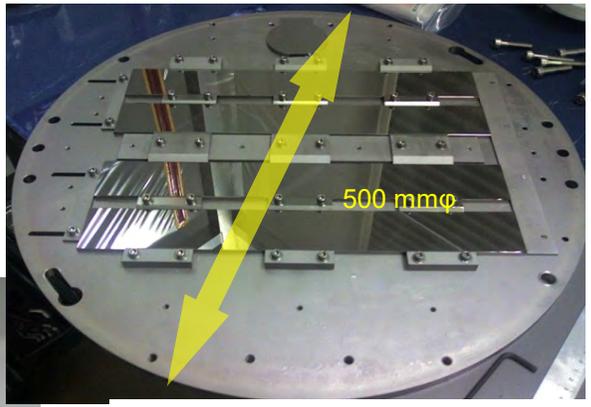
Fe
Concrete

Inhouse Tech on Supermirror

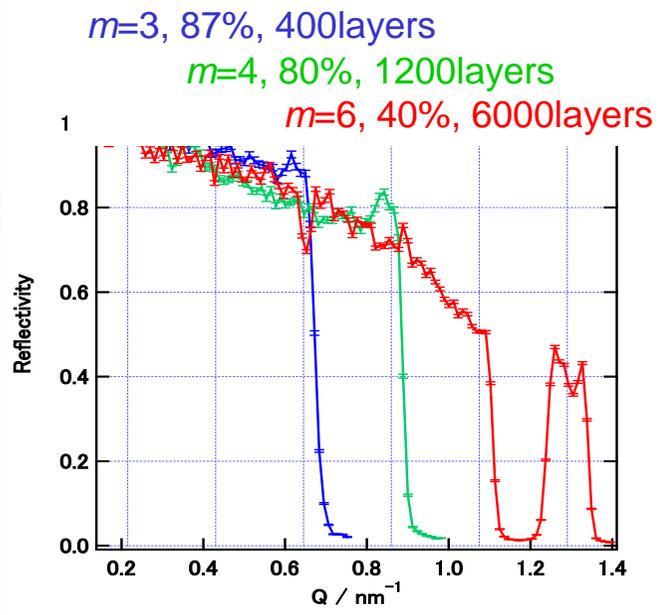
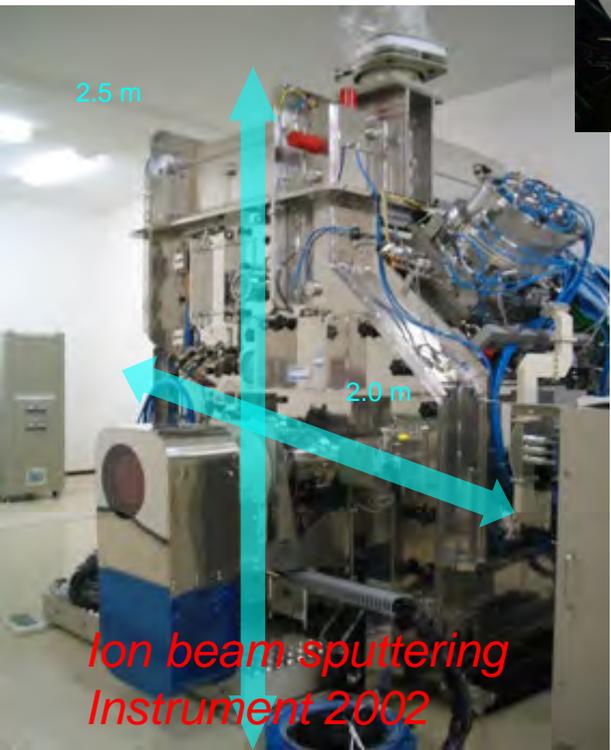
Inhouse Manufacturing $m > 4$
 Purchase from companies $m < 3$
 (No. of layers $\sim m^4$)
 Develop own tech on installation & alignment



Soyama Maruyama Yamazaki



Installation



Instruments in 2007

(All designed inhouse)



T. Kamiyama



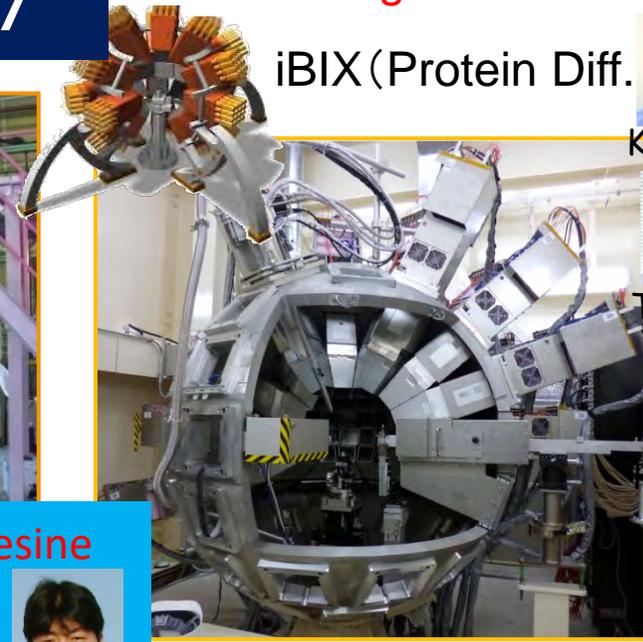
S-HRPD
(Powder Diff.)



Otomo Oshita



NOVA
(Liquid, Amor. Diff.)



iBIX (Protein Diff.)



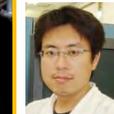
Kusaka



Tanaka



Hosoya



Ohara



S. Torii



iMATERIA (Powder Diff.)



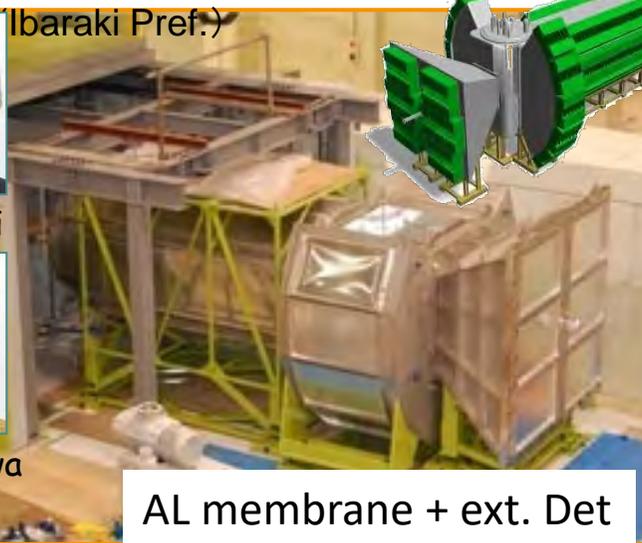
B₄C-resine



Suzuya Yokoo



T. Ishigaki



AL membrane + ext. Det

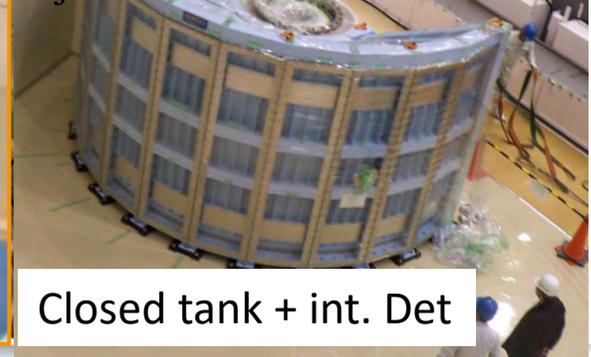


Kajimoto



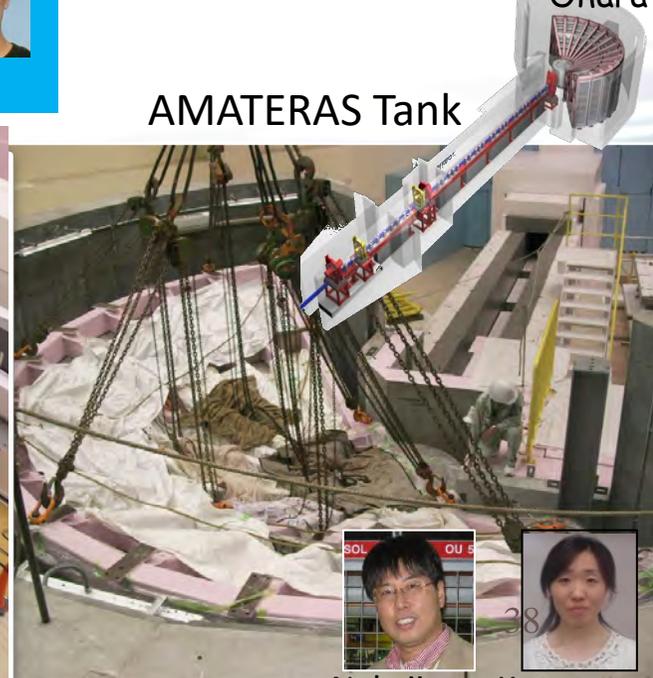
Nakamura

4 SEASONS



Closed tank + int. Det

AMATERAS Tank



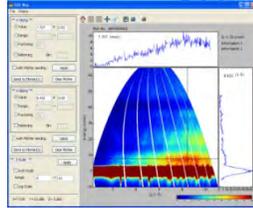
Nakajima



Kawamura

MLF Computing Environment

frame-work and **Event Recording**



Visualization
Common Interface

2D 3D >3D

Experimental control

Common Library

Device control

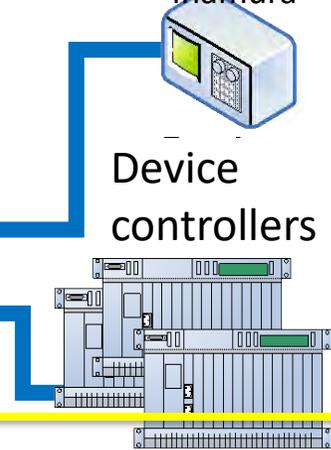
DAQ-Middleware

Software Framework

Python

Working Desktop

Integrated User Interface



DAQ FRONT END ELC

Storage

API Library

Raw data

NeXus File

XML File

Network Storage

Analysis "Manyo-Lib"

Common Library

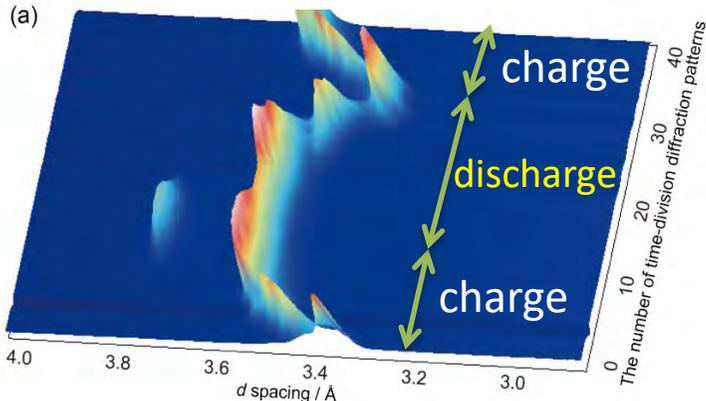
Instruments specific Lib.

Powder Diff. Single Xtal

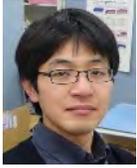
Chopper etc.

Res. Stress

Structural change of a Li battery electrode.



Event Recording Data Acquisition makes things very effective/flexible



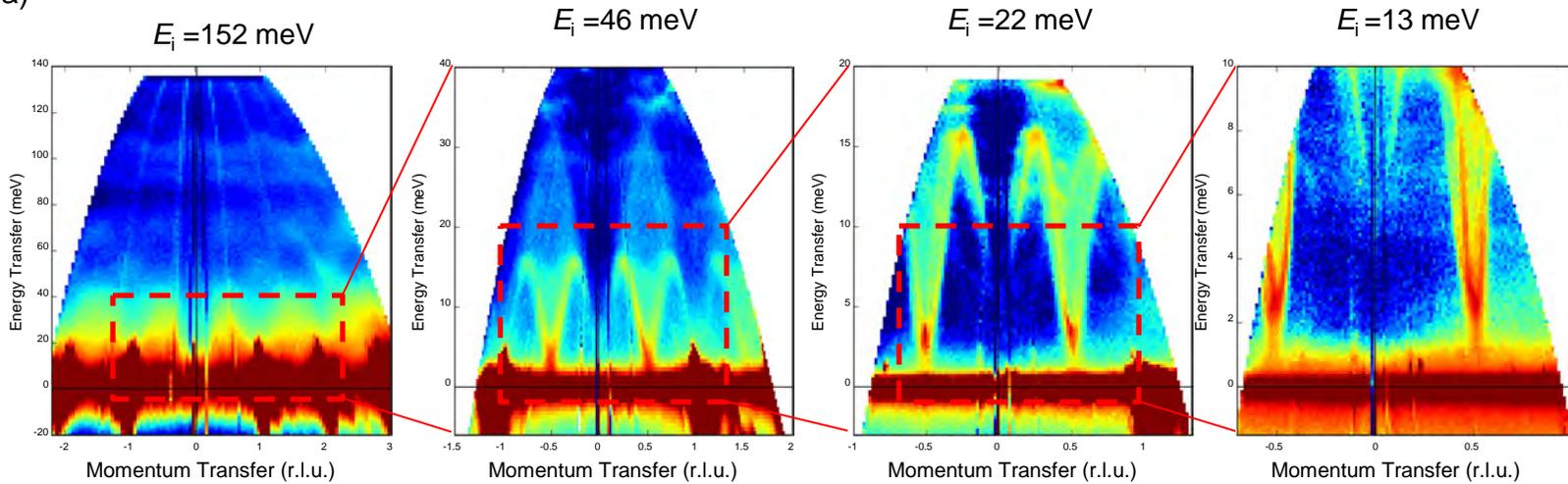
Use of Multi-E_i scan ズームイン・ズームアウト

Kajimoto Nakamura

1D-AF-CuGeO₃

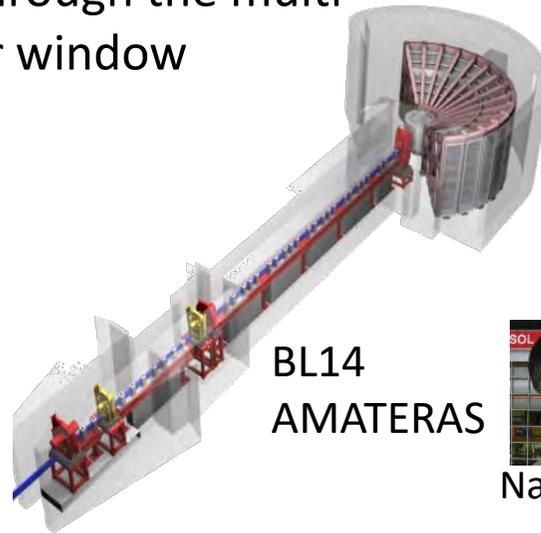
Spin-Peierls system

Whole Spin Excitation with details of Spin-gap



Use neutrons get through the multi-opening of chopper window

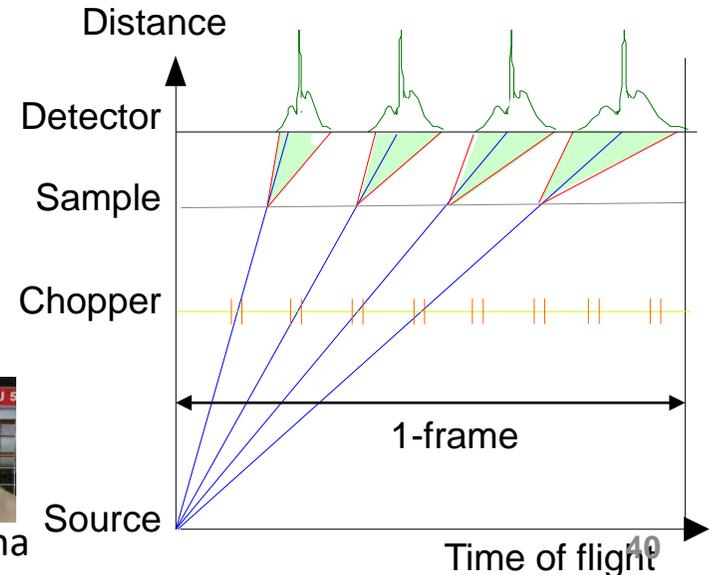
BL01
4SEASONS



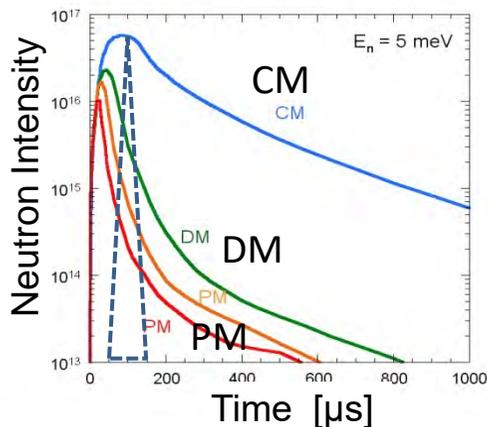
BL14
AMATERAS



Nakajima



Realization of both High Intensity and High Resolution



DNA Shibata Kawakita Takahashi
backscattering

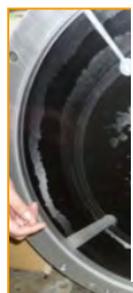
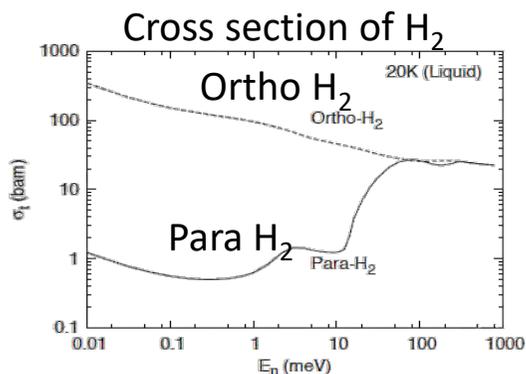
Nakajima Kawamura

AMATERAS

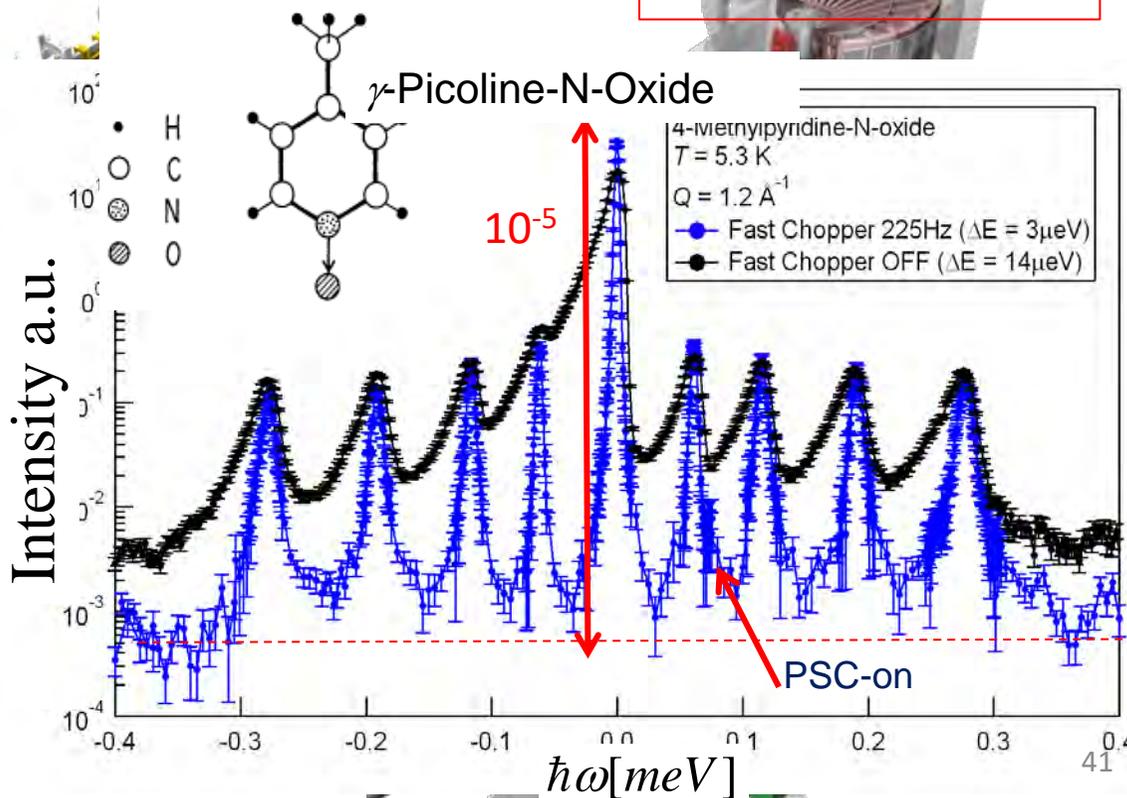
Flexibility in resolution/intensity with very low bgd



Very low background
order of 10^{-5}



Pulse
Chop



Para H_2 Coupled Moderator

Covers Very Wide Dynamical Range in one time with low Bgd (advantage of cold source with sharp epithermal n. with 25Hz Rep.)



Suzuki



Takata

BL15 TAIKAN

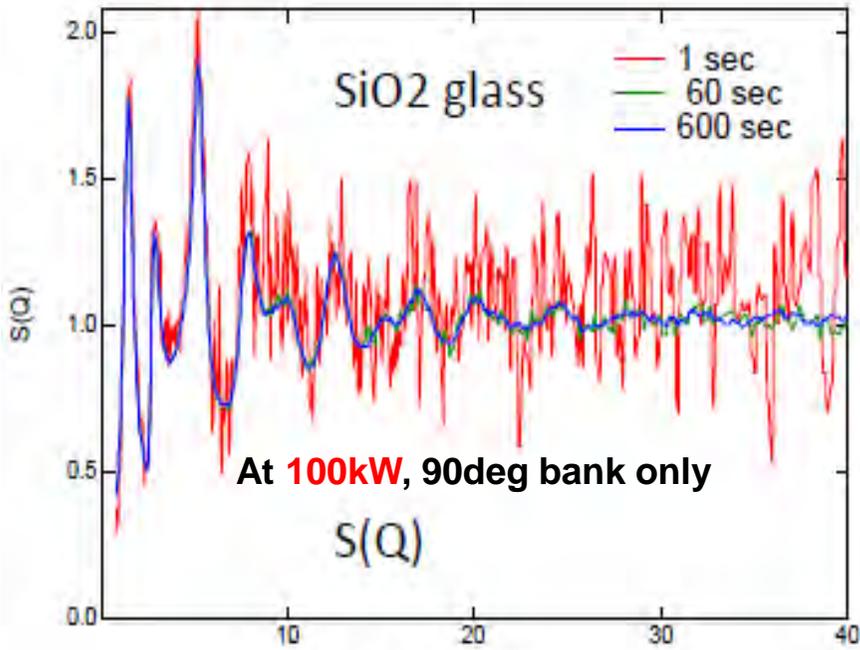
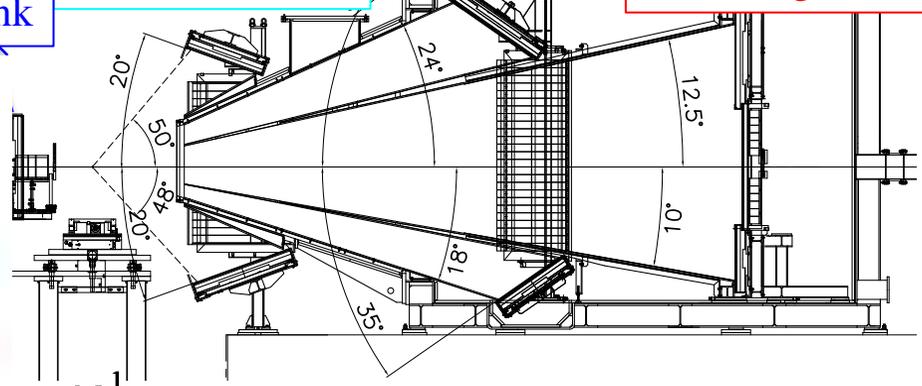


backward angle bank

high-angle bank

middle-angle bank

small-angle bank



Q-range

BL11 NOVA
(Liquid Amorphous)

B₄C-resine



Otomo



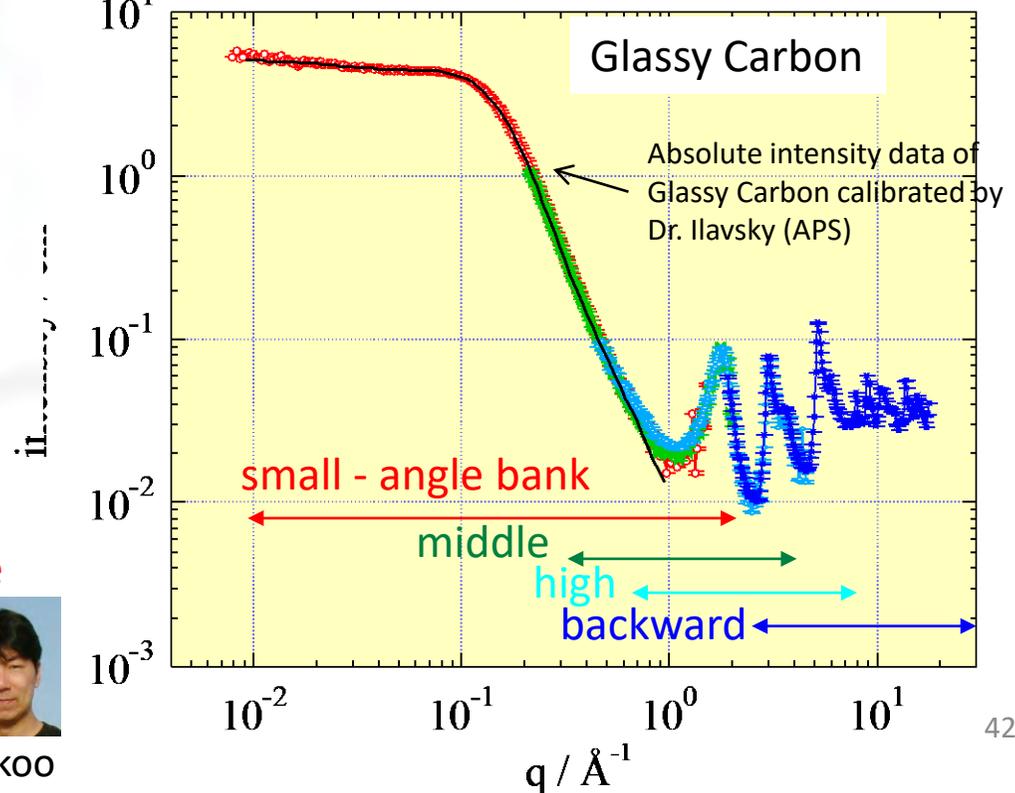
Ikeda



Suzuya



Yokoo



High-Pressure and extreme temperature

Simulate environment in the earth
Multi-anvil press. (Spring-8)

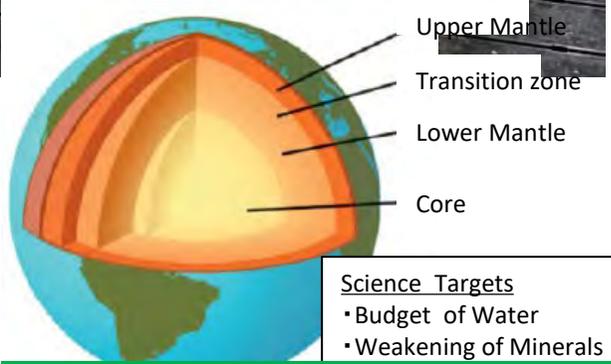


Hattori



Sano

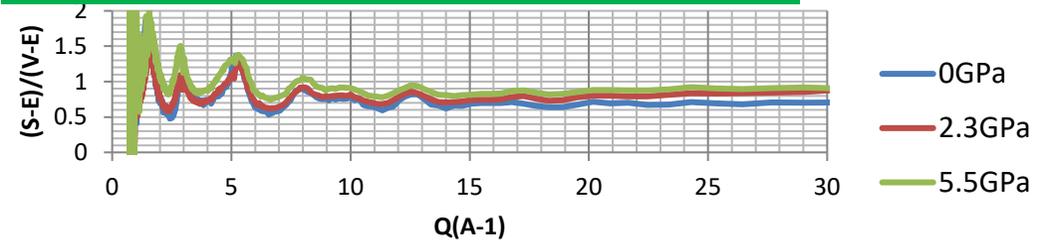
6-axis Multi-Anvil Press [ATSU-HIME] 20GPa, 2000C



- Science Targets
- Budget of Water
 - Weakening of Minerals

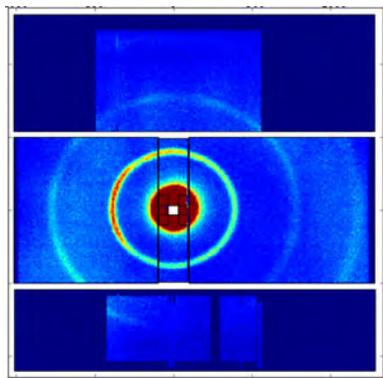
Low back ground and wide dynamical range

Liquids & Amorphous:
SiO₂ glass
P=0-5.5GPa

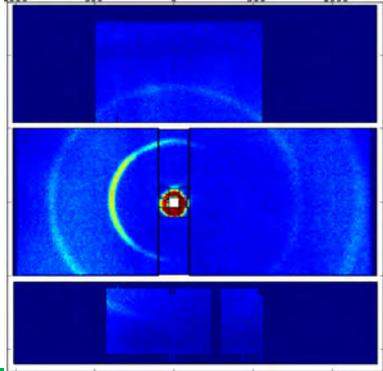


3He Polarization Filter (SEOP)

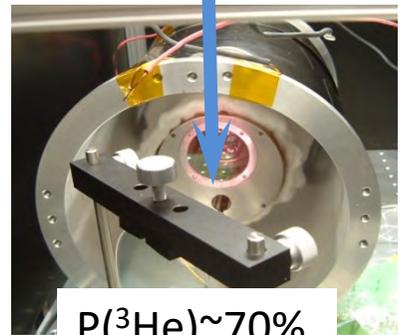
(a) Spin flipper On
(Non-spin flip condition)



(b) Spin flipper Off
(Spin flip condition)



³He cell in an oven



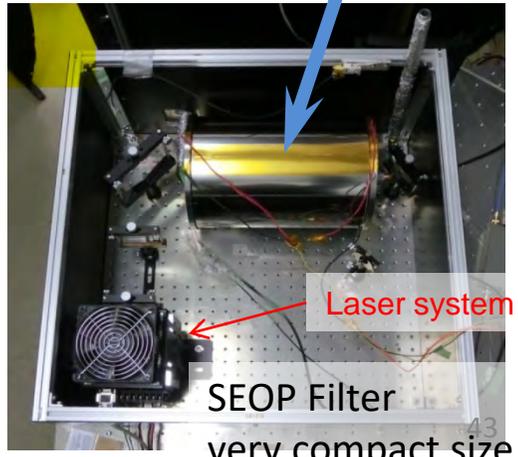
Oku



Kira



Ino



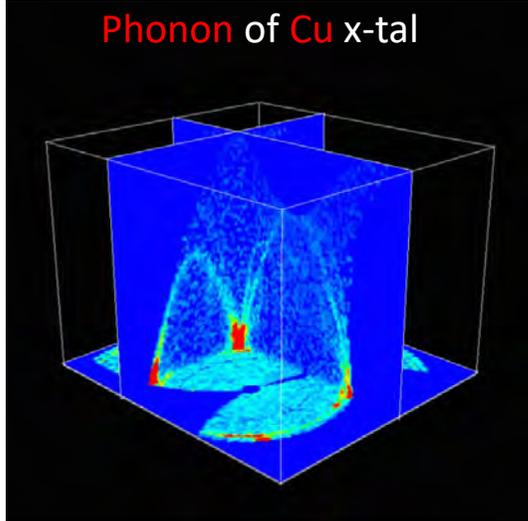
Laser system

SEOP Filter
very compact size

Imaging in the Reciprocal Space (4D-data)

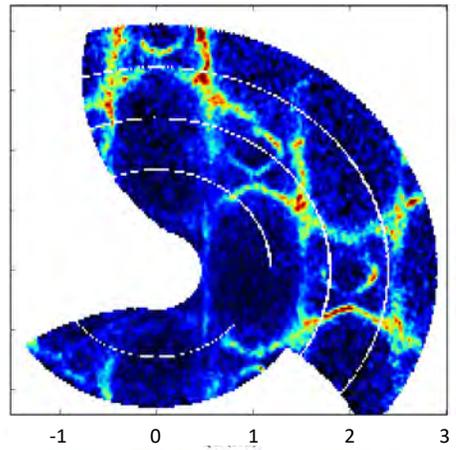


Kajimoto Nakamura Inamura

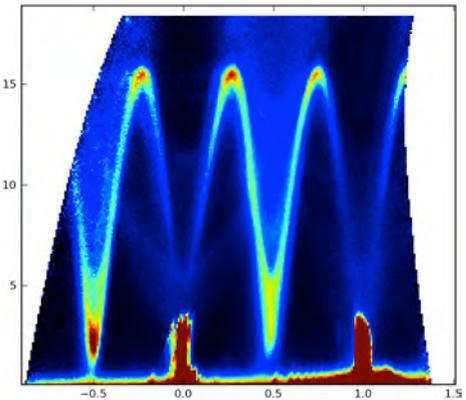


Phonon of Cu x-tal

Constant-E slice

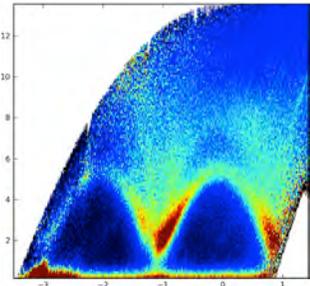


1D-Q Spin System CuGeO3



L (r.l.u.)

Chain direction

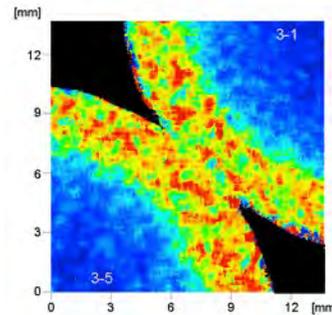


K (r.l.u.)

Perpendicular direction

Real Space Imaging

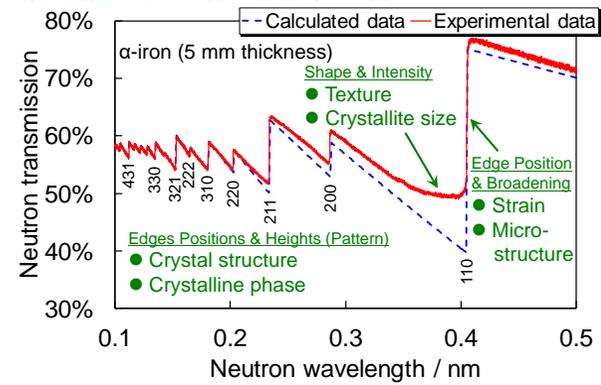
Bragg-edge imaging



Texture of Steel
On Heat Treatment
Sato (北大)
Kiyanagi



Shinohara



Segawa



Kai

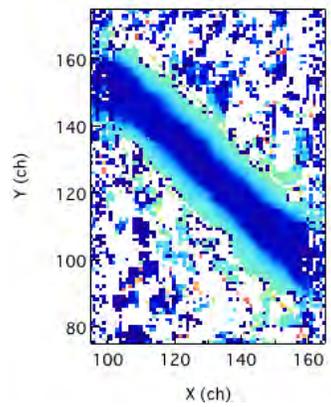


Hayashida



Oikawa

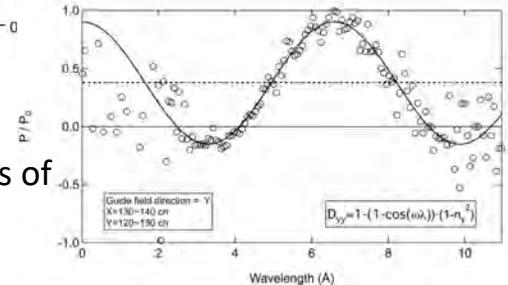
Polarized neutron imaging



Mag. Field in
a solenoid coils

Hiroi

Polarization Analysis of
transmitted beam



Guide field direction = Y
 $x=130-140$ cm
 $y=120-130$ cm

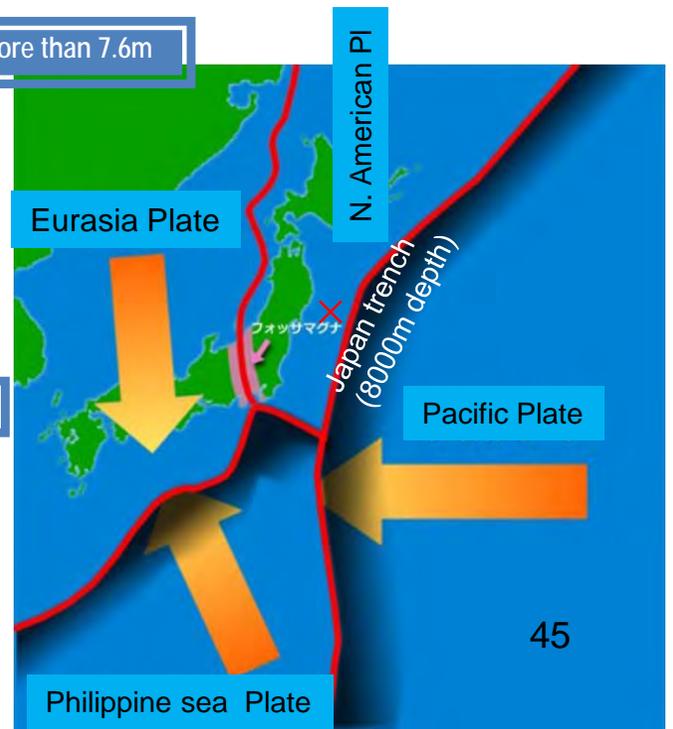
$D_{yy} = 1 - (1 - \cos(\omega)) \cdot (1 - n_y^2)$

East Japan Devastating Disasters on 11 (Fri). March, 2011

Earthquake (M9), Tsunami (once in one thousand years) & Reactor Accident (never experienced)

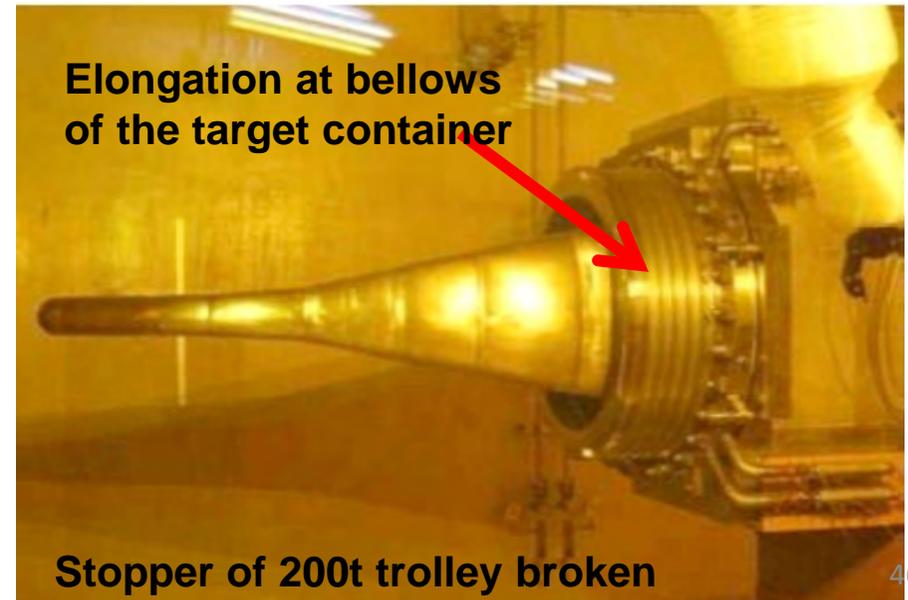


Death 15,561
Missing 5,313
(as of 15 July)



Damage at J-PARC

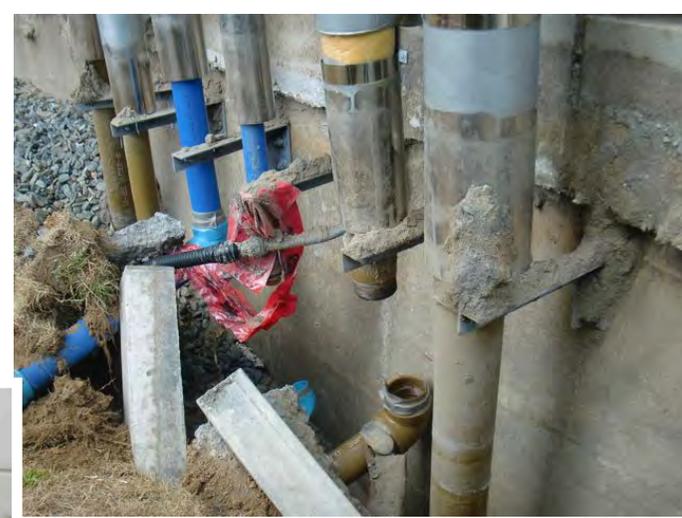
(Tsunami height was 4m)



Damage around MLF



Cutting utility pipes



Sagged and distorted road

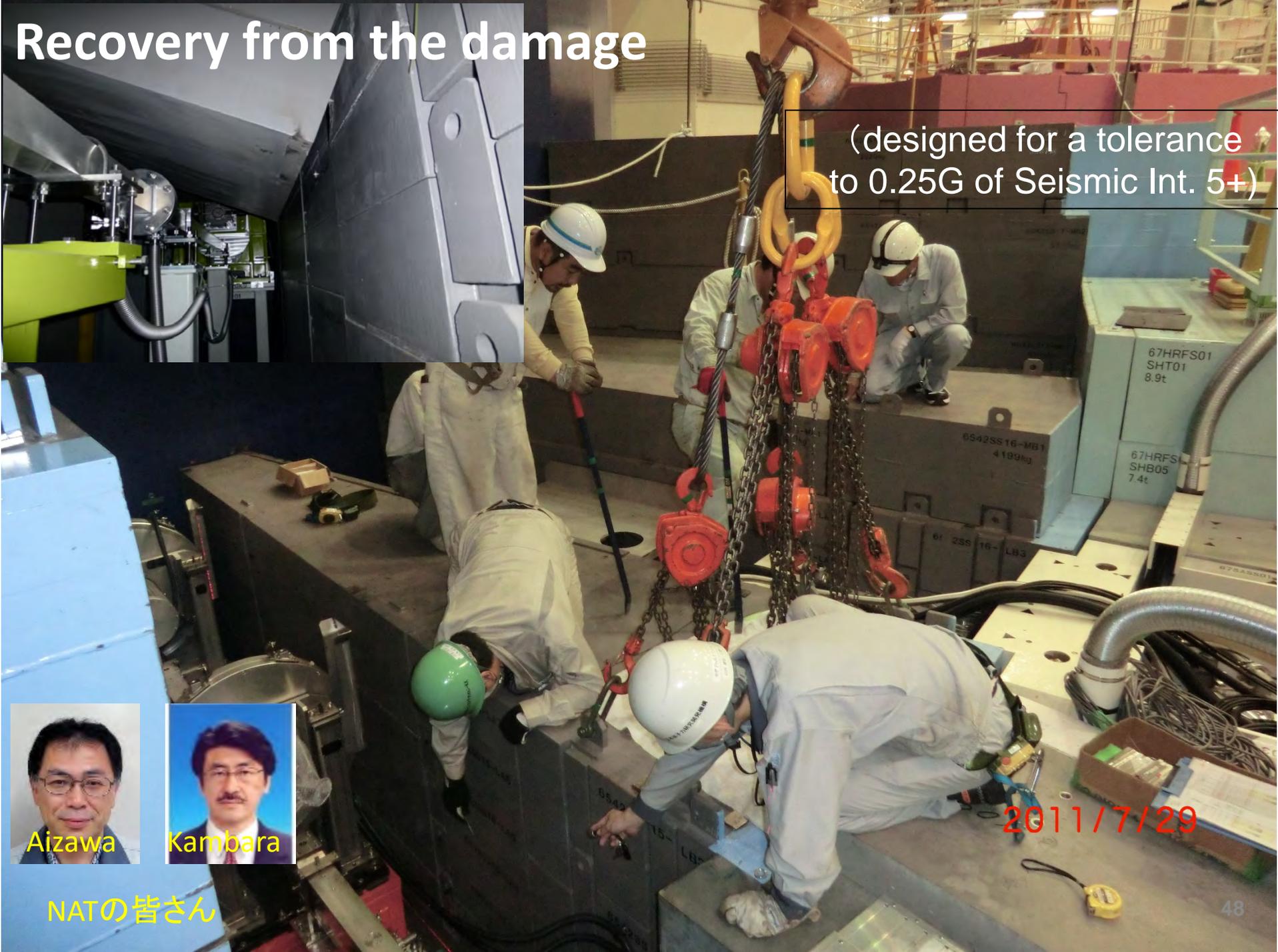


1.5m subsidence around MLF



Recovery from the damage

(designed for a tolerance to 0.25G of Seismic Int. 5+)



Aizawa



Kambara

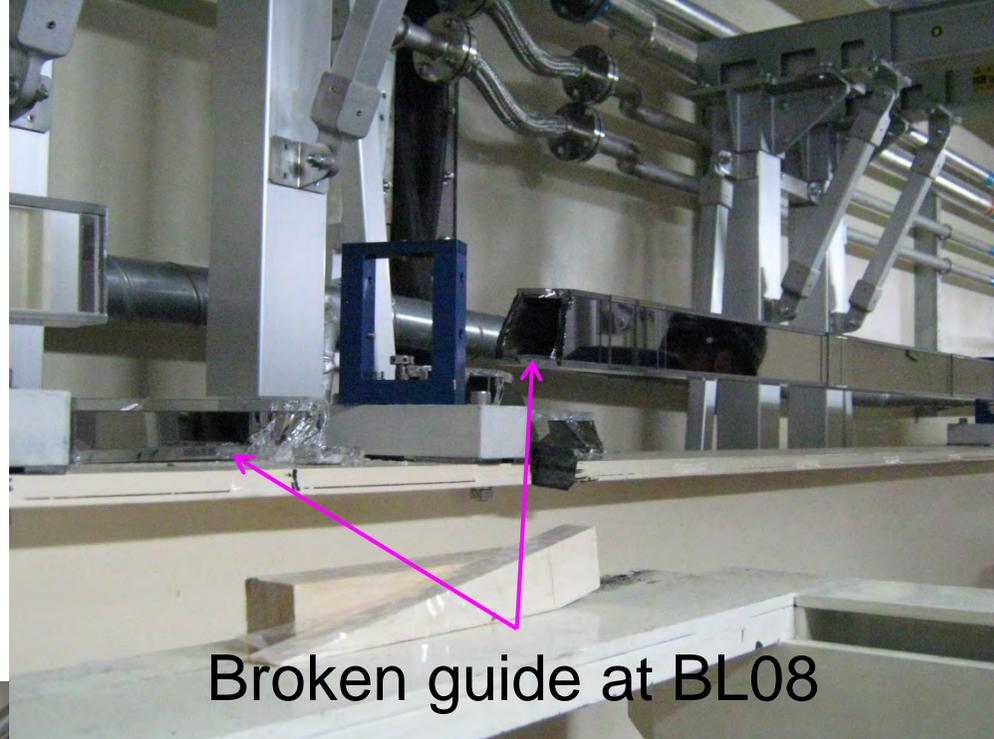
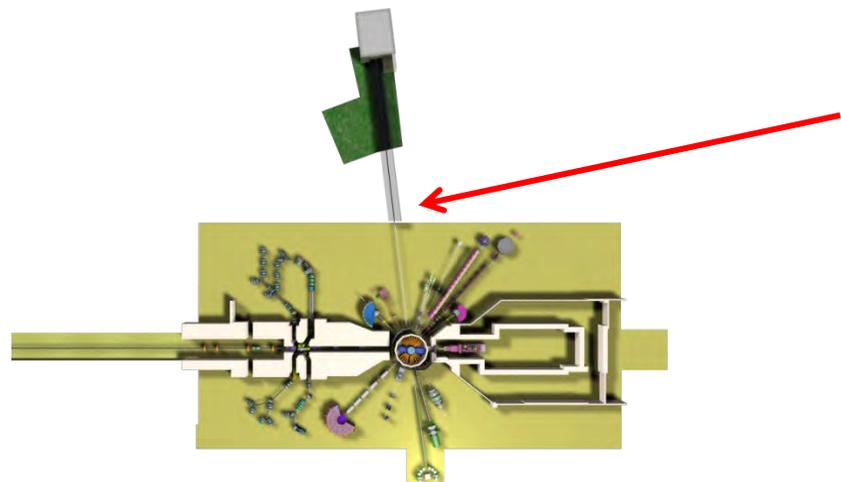
2011/7/29

NATの皆さん

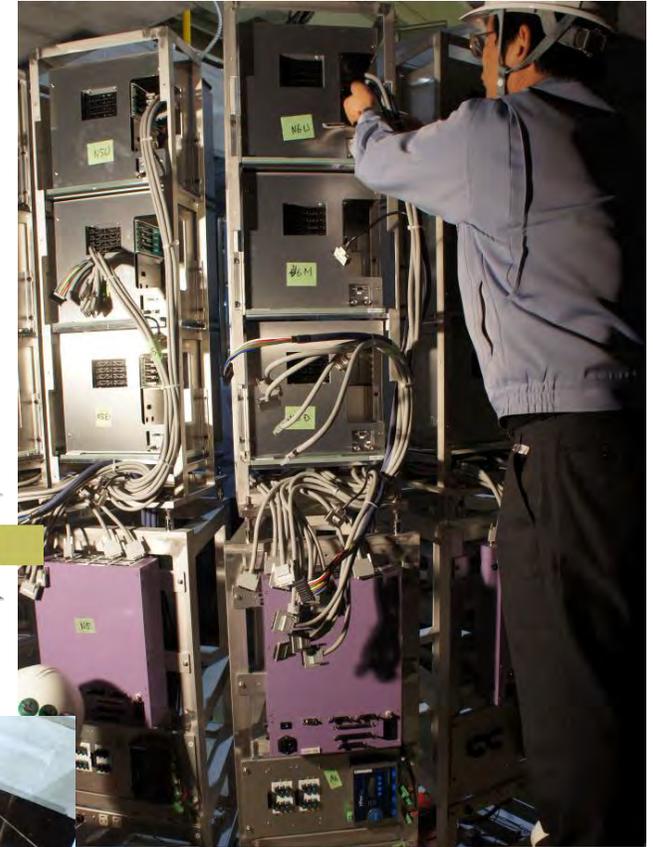
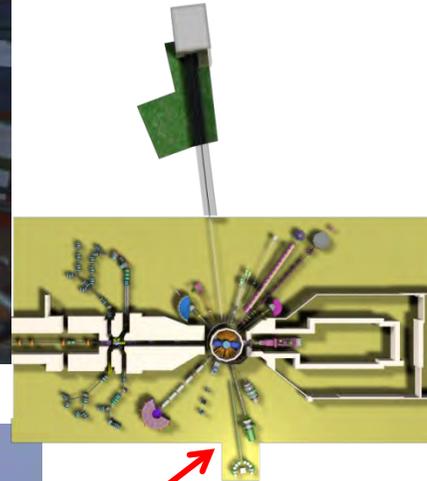


BL08

Damage at the building boundary



Severe damages in an instrument at a building boundary (BL18, 19, 20)



Just after installing detector Feb 2011

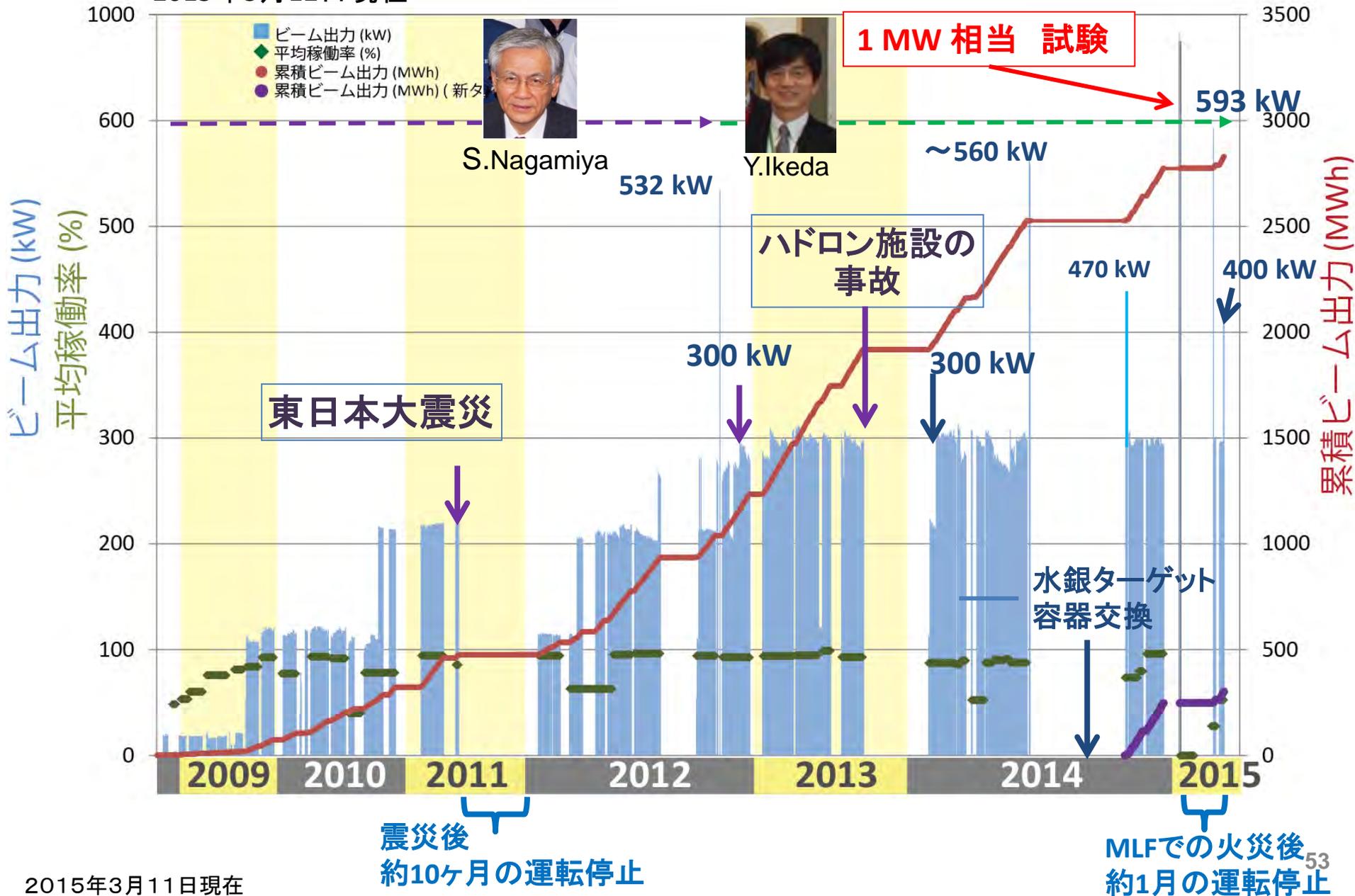




The Spirit of Resurrection (24 June, 2011)
and
KEK, JAEA, CROSS, Ibaraki U.

MLF中性子源のビーム運転履歴

2015年3月12日現在



2015年3月11日現在

MLFでの火災後
約1月の運転停止⁵³



Thanks
感謝します。

Followings are Backups

Development Continued

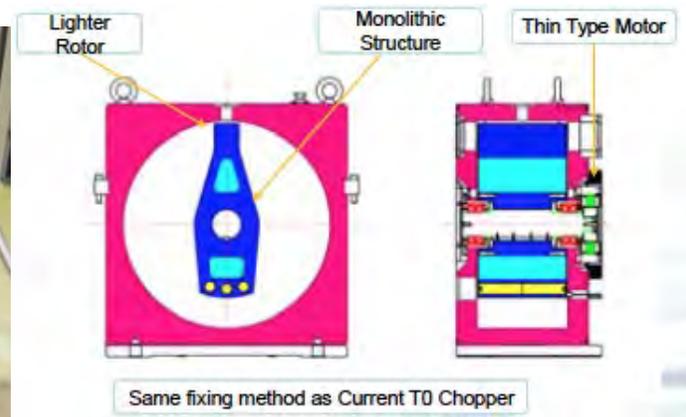
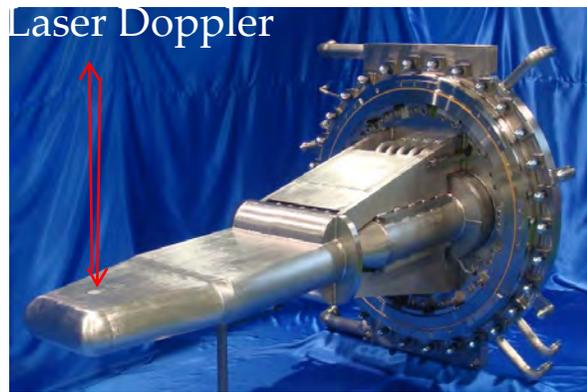
To Chopper (Kambara)

Polarization (Oku)

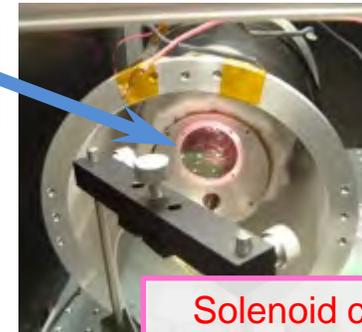
30T Pulse Magnet (Watanabe)

Deuteration Technique (ANSTO)

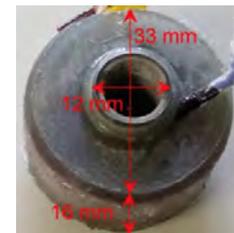
Target (Haga) > 500kW



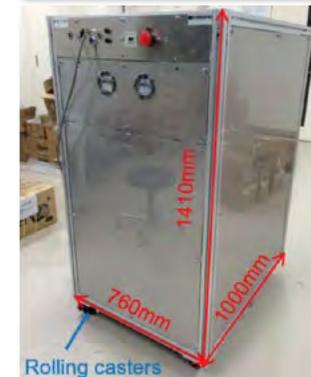
^3He cell is located inside an oven



Solenoid coil with double μ -metal shield



30T P. Mag



Suggestion on a further development

Improve Software Environment