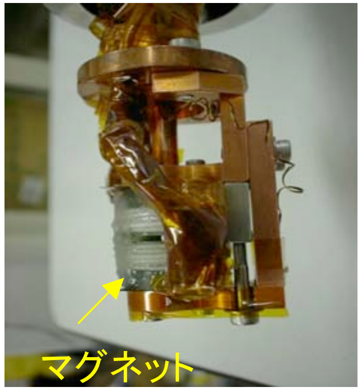
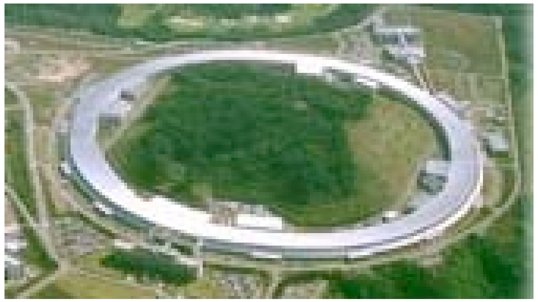
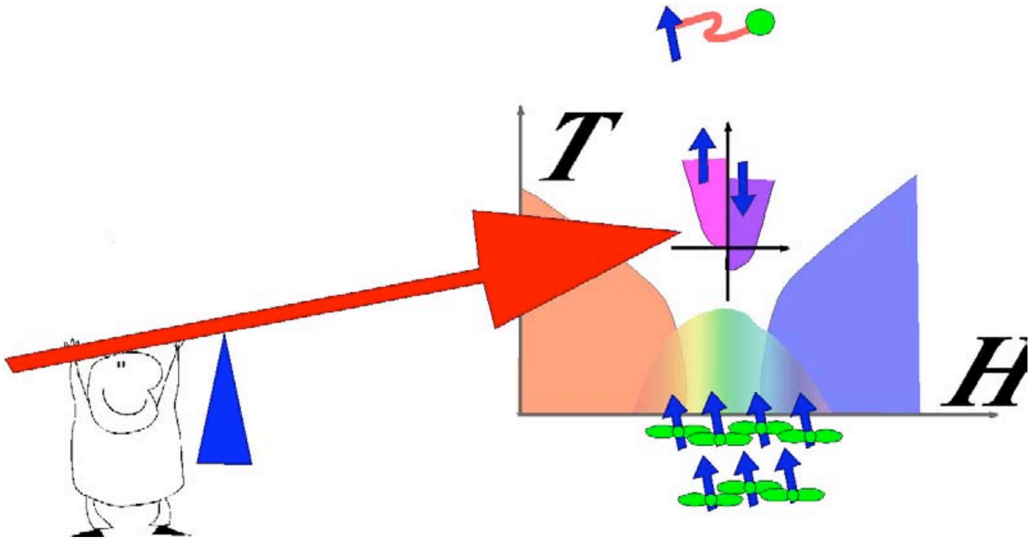
X-ray spectroscopy and diffraction experiments by using mini-coils:

applications to valence state transitions and frustrated magnets

H. Nojiri, IMR Tohoku Univ., Sendai Japan





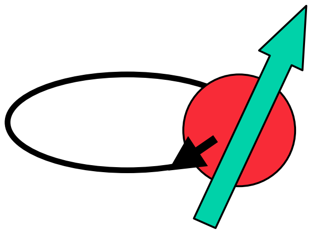


http:spin100.imr.tohoku.ac.jp

Contents

High Magnetic Field

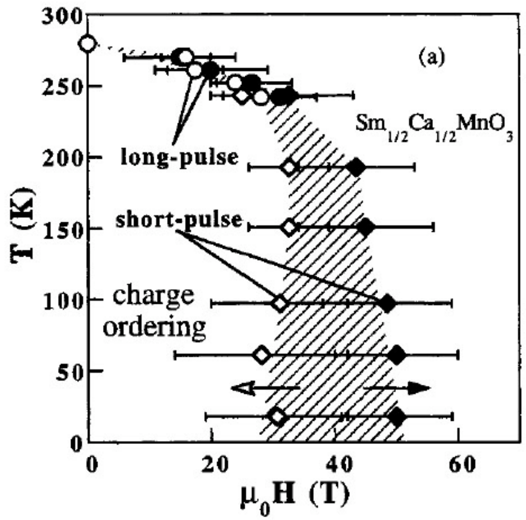
Couple to spin and orbital moment of electron, which control properties of condensed matters



	Strong	Precise	Non-Contact	Time control	soft
H	√	√	√	√	√
E		√	√	√	
P	√				
T					

Basis of the research of materials

Magnetism CMR →
Superconductivity High-Tc
Semiconductor Quantum Hall effect
Chemistry Molecular magnet
Biology Protein(NMR)



High Magnetic Field Generator

Easy installation

to the quantum beam facilities

High applicability

to various kinds of measurements

(several Beamlines, Spectrometers)

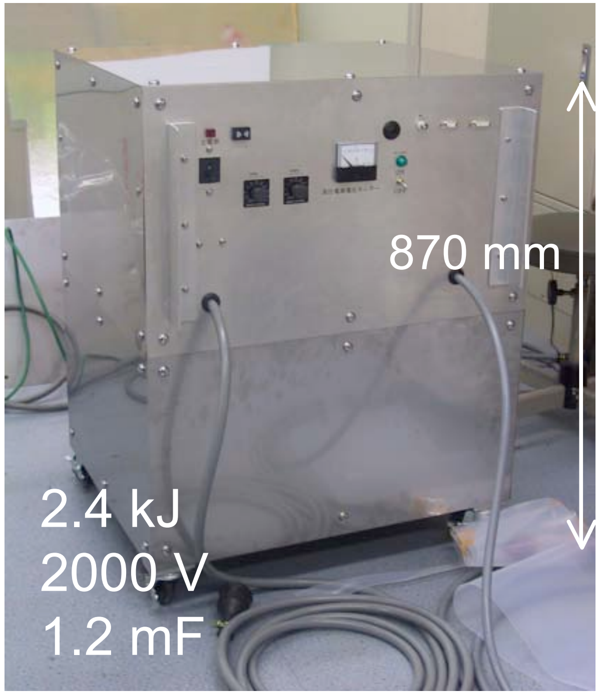
Increase opportunities

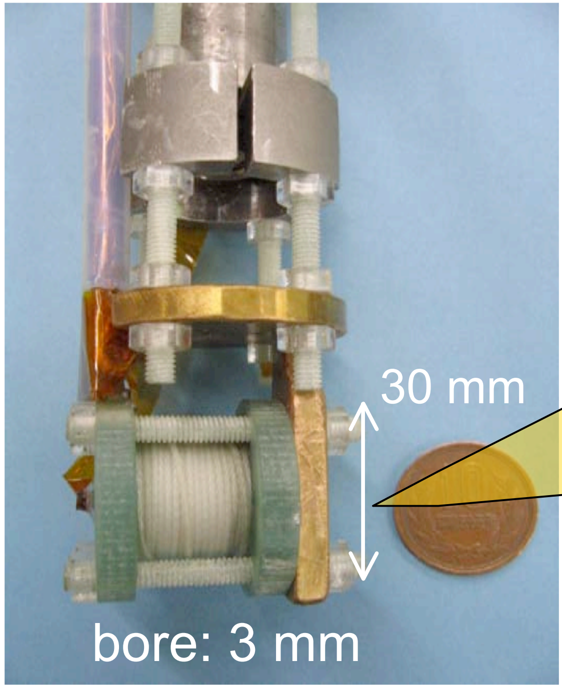
to discover interesting field-induced phenomena

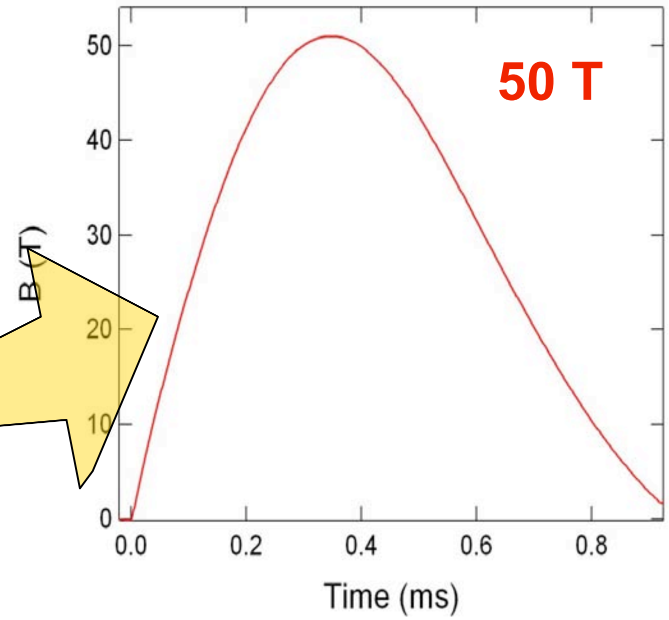
Development of

***Miniature Pulsed Magnet* technique**

Miniature Magnet and Portable Capacitor Bank







Small Energy

Small Space

High Magnetic Field

Mini coil+Portable Capacitor Bank

＜Magnet＞

ID 3 mm

Split

$\Delta 2\theta$ = 60 deg.

$\Delta\chi$ = 9 deg.

Maximum field 33 T

Pulse width 1 ms

Repetition 15 minutes

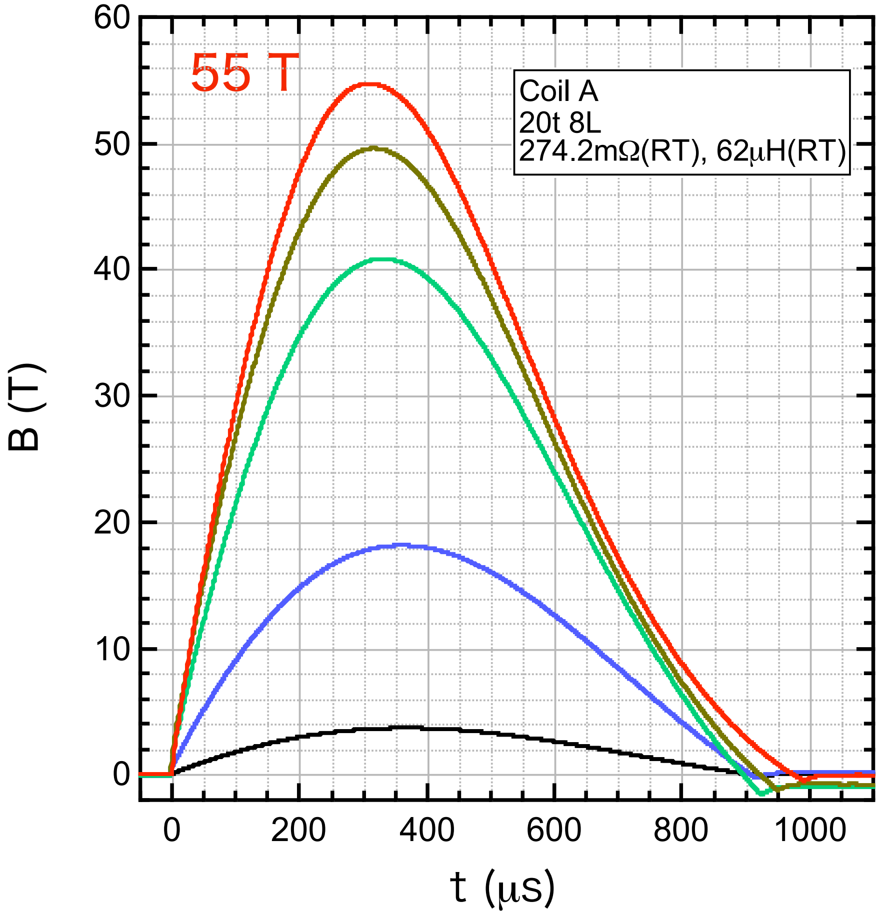
＜Bank＞

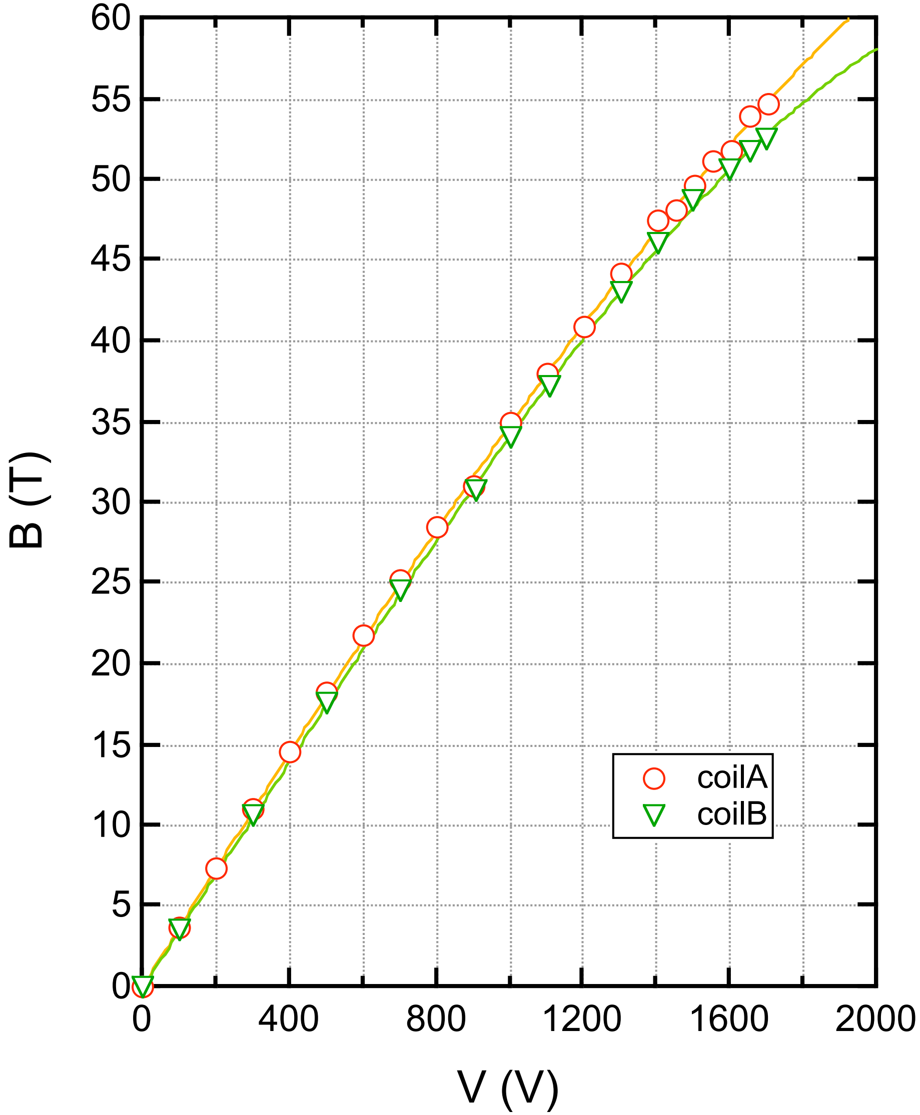
5.6 kJ （2000 V , 2800 μF）350 kG

2.4 kJ （2000 V , 1200 μF）100 kG

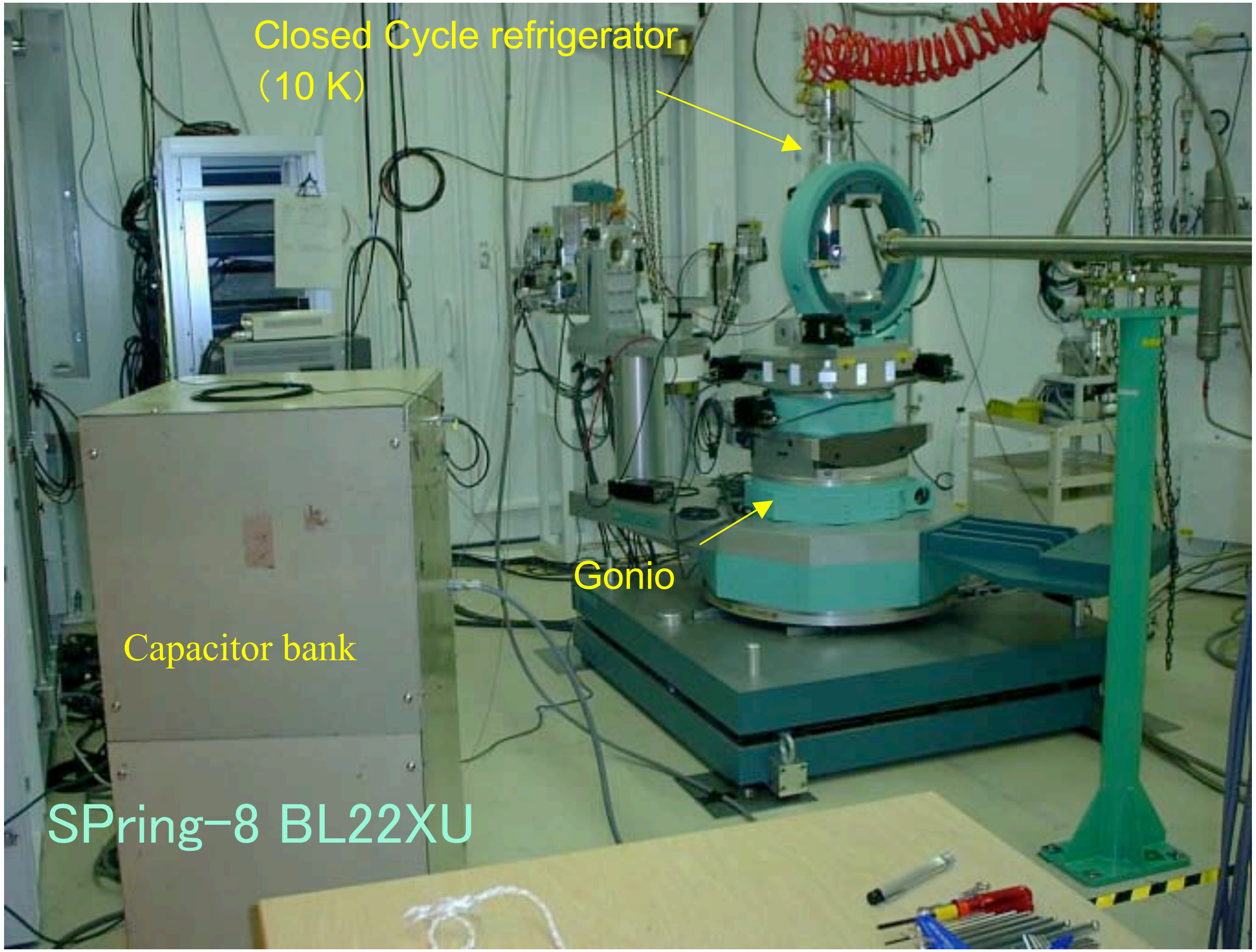
Solenoid Coil for XAS

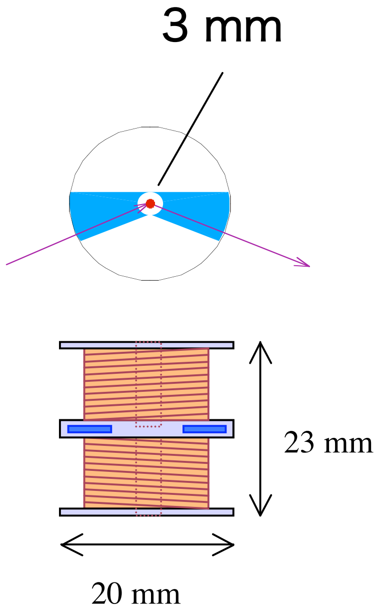
ID 3mm
AgCu wire 0.7mmOD
Limited by heating

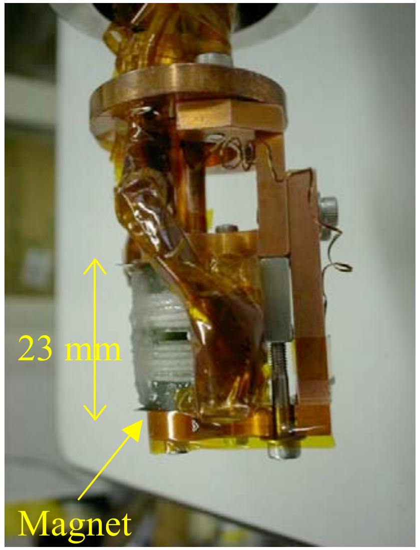




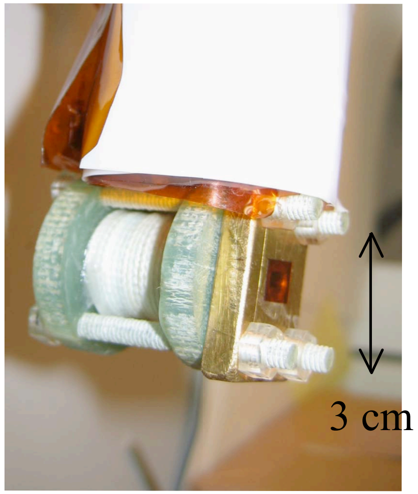
Out look of experimental port







High Magnetic Field XAS Experiments

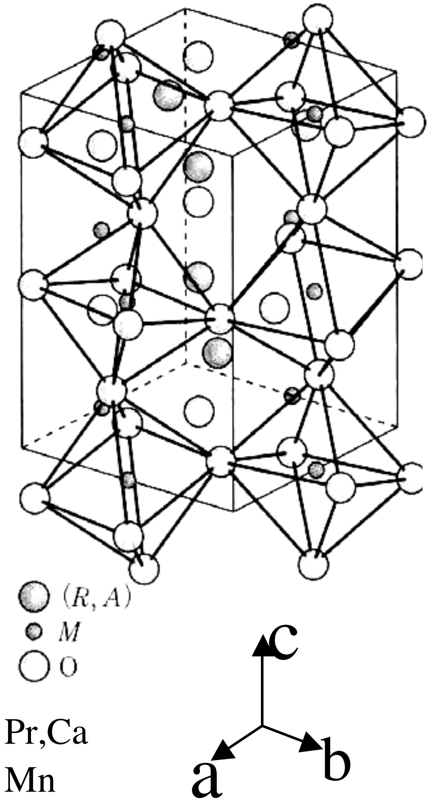


SPring-8 BL22XU

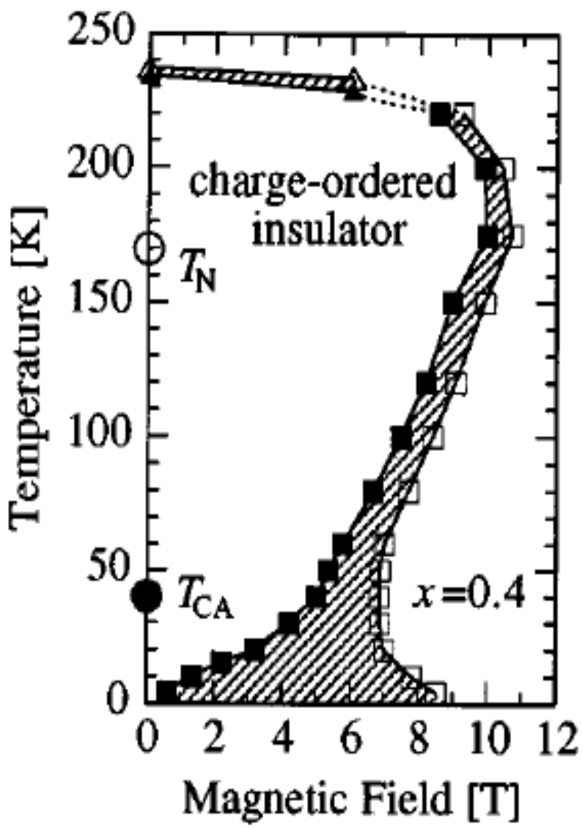
- ♦ Low Temperature T>2K
  He flow cryostat
  (Orange Cryo.)
- ♦ Transmission measurement
  Powdered sample is brushed onto Scotch tape
- ♦ Detection
  PIN photo diode
- ♦ Time domain measurements
  Recorded by Digital Storage Oscilloscope

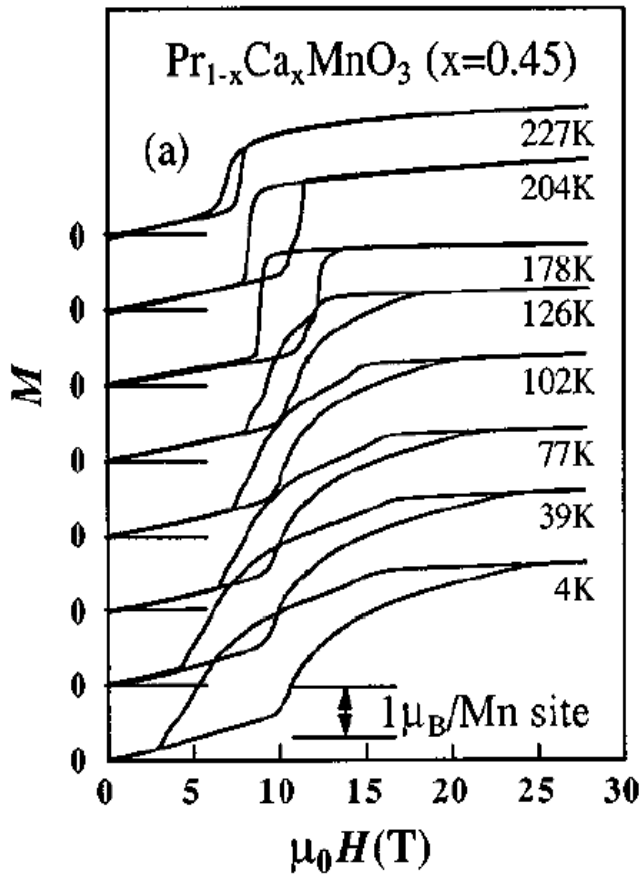
X-ray diffraction in $Pr_{1-x}Ca_xMnO_3$

Metal-insulator transition associated with structural phase transition



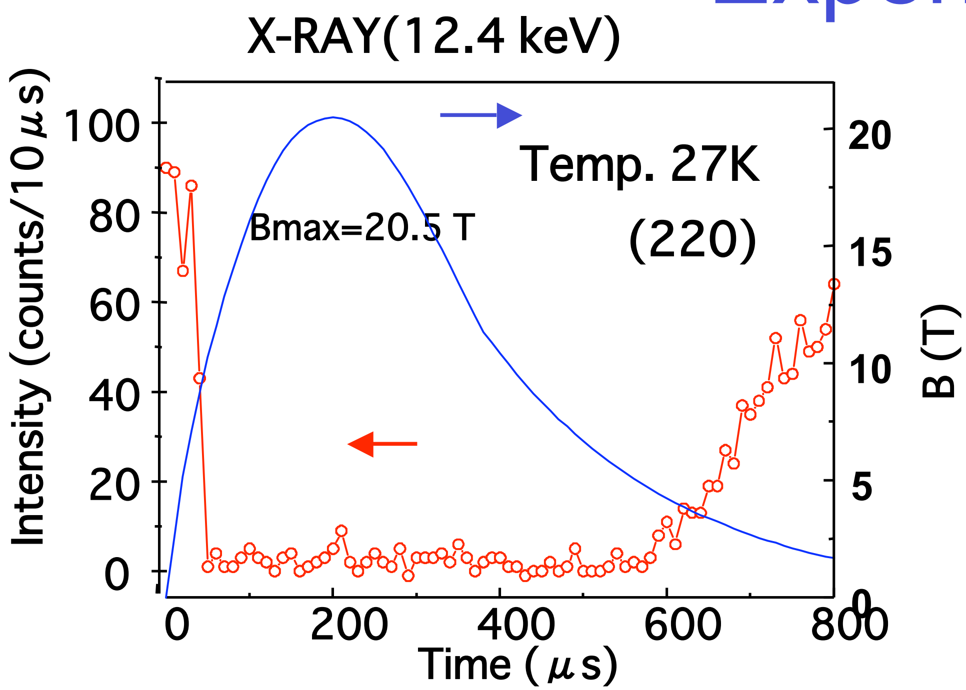
Pr,Ca
Mn
O

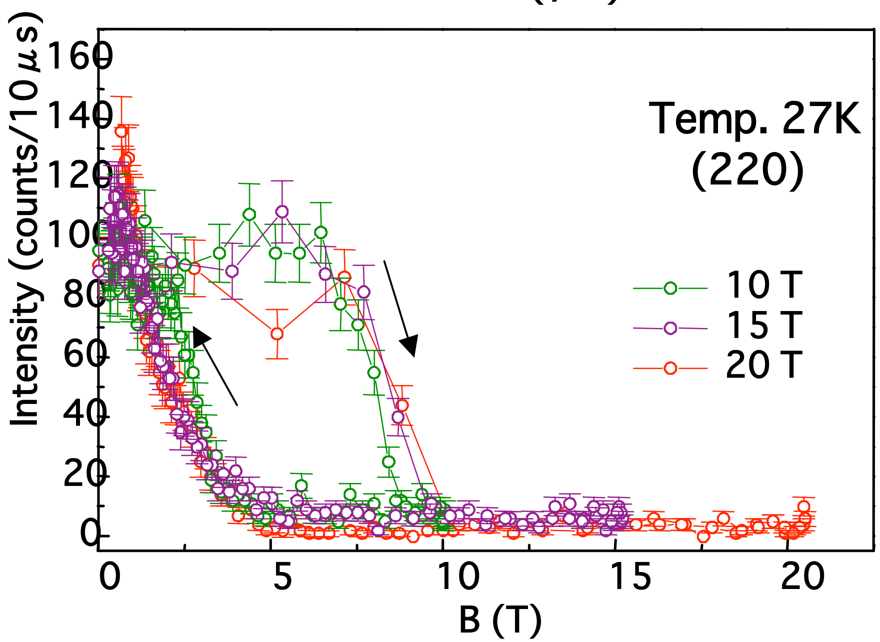


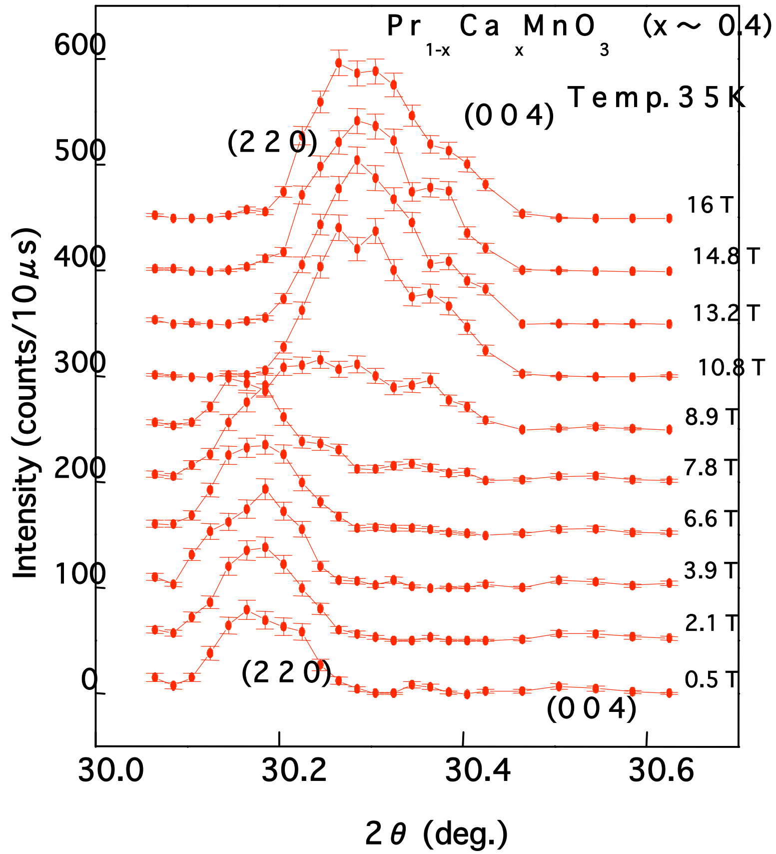


M. Tokunaga et al., Phys. Rev. B57 (1998) 5259

Experimental results







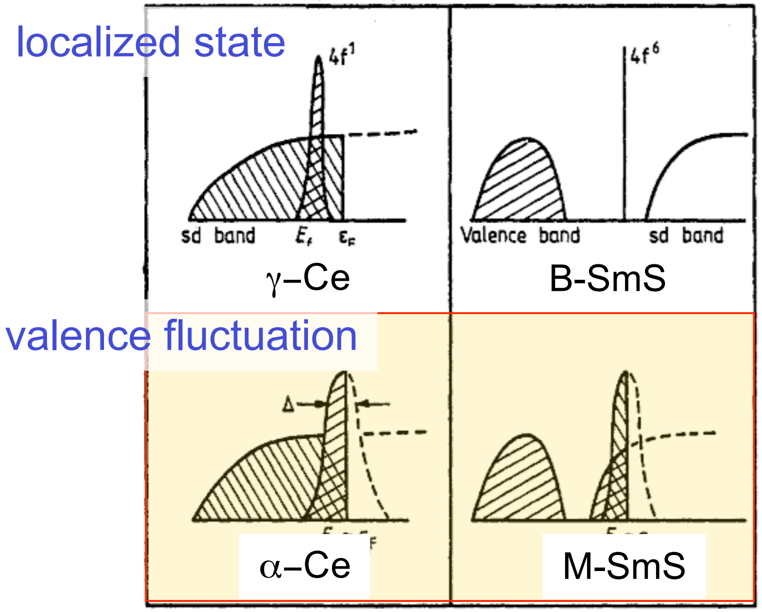
T. Arima G.

Valence Fluctuation

Found in some rare-earth intermetallic compounds

for example,

Ce	$YbAgCu_4$
SmS	$EuPd_2Si_2$
$YbInCu_4$	$EuNi_2(Si_{1-x}Ge_x)_2$



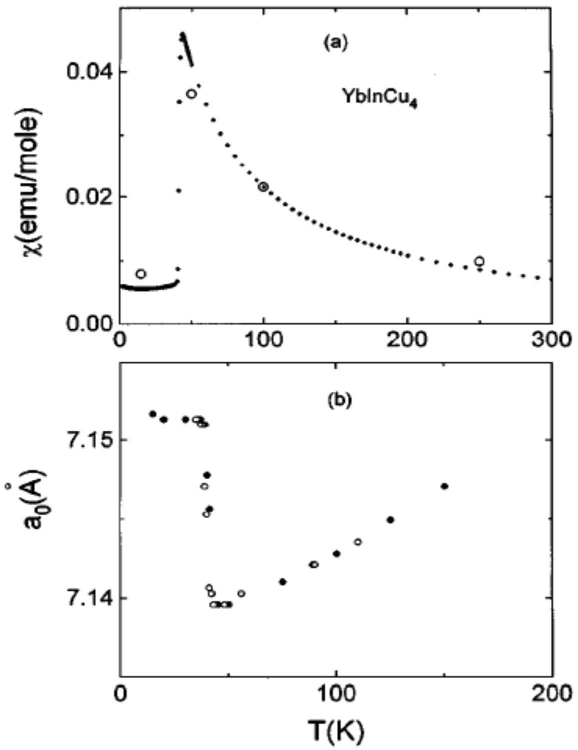
J. M. Lawrence et al., Rep. Prog. Phys. 44 (1981) 1.

Ce	3	5/2	$4f(5d,6s)^3$
	4	0	$(5d,6s)^4$
Sm	3	5/2	$4f^5(5d,6s)^3$
	2	0	$4f^6(5d,6s)^2$
Eu	2	7/2	$4f^7(5d,6s)^2$
	3	0	$4f^6(5d,6s)^3$
Tm	3	6	$4f^{12}(5d,6s)^3$
	2	7/2	$4f^{13}(5d,6s)^2$
Yb	2	0	$4f^{14}(5d,6s)^2$
	3	7/2	$4f^{13}(5d,6s)^3$

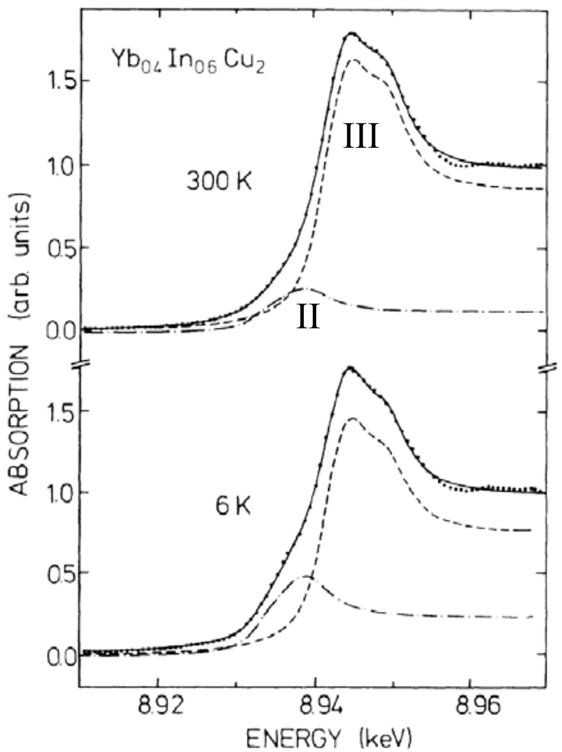
- strong c-f hybridization
- intermediate valence
- itinerant f-electron
- Fermi liquid state
- non-magnetic state
- sensitive to (***T***, ***P***, ***B***)

Field Induced Valence Transition

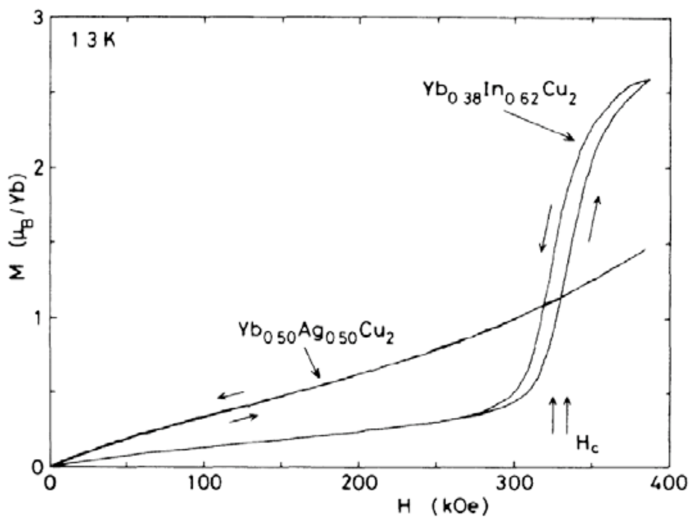
$YbInCu_4$ $Yb^{3+} \rightarrow Yb^{2.9+}$ $T_v = 42$ K



J.M. Lawrence et al.,
PRB55 (1997) 14467

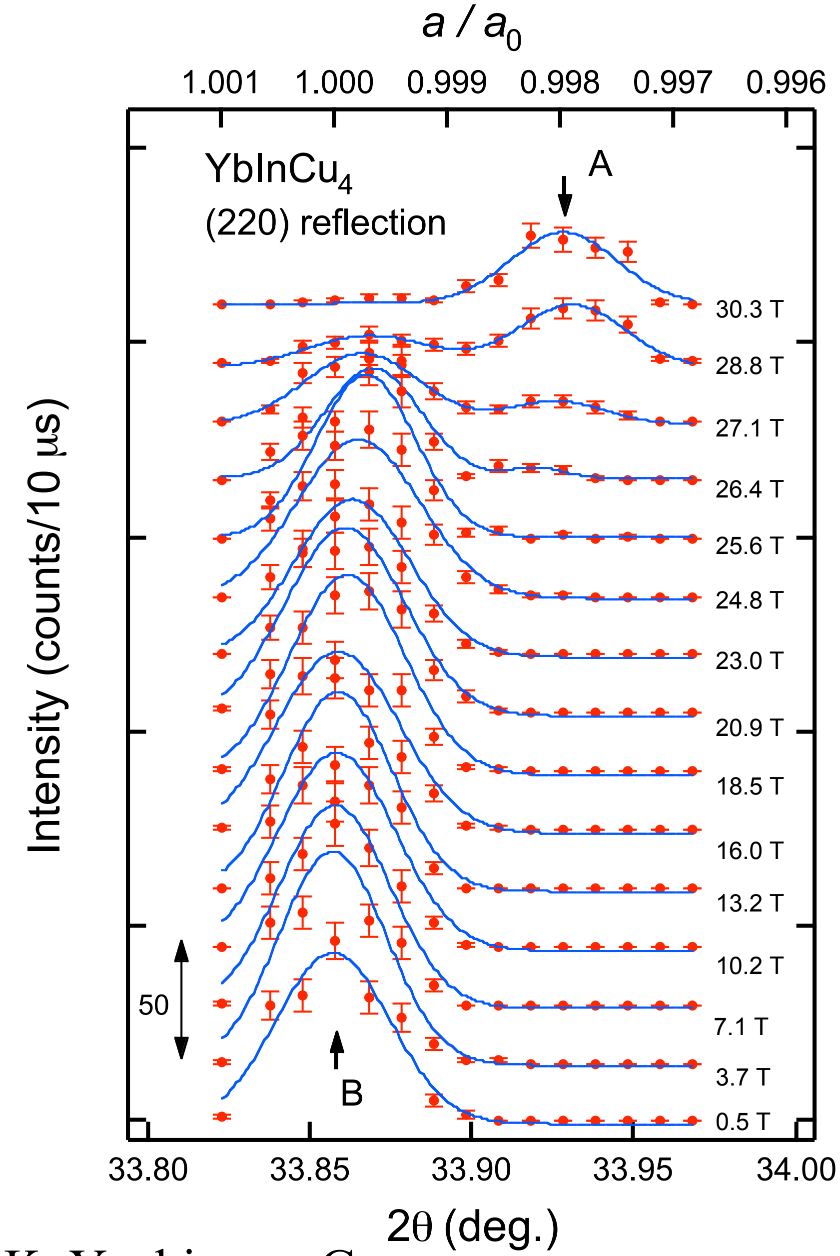


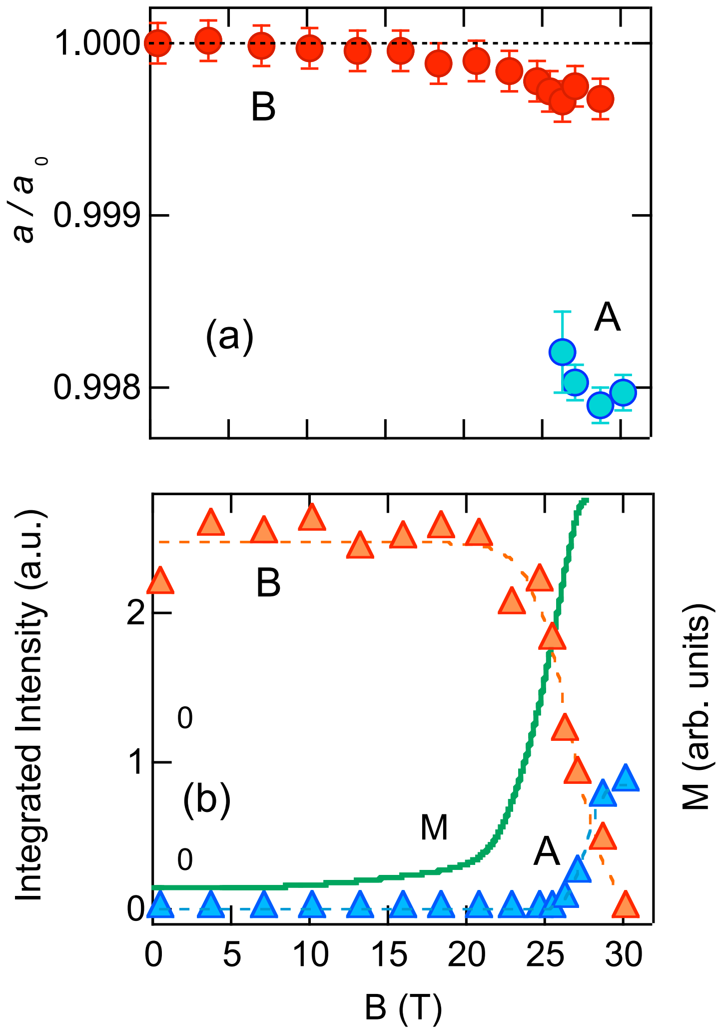
I. Felner et al.,
PRB35 (1987) 6956



K. Yoshimura et al.,
PRL60 (1988) 851

VALENCE STATE TRANSITION



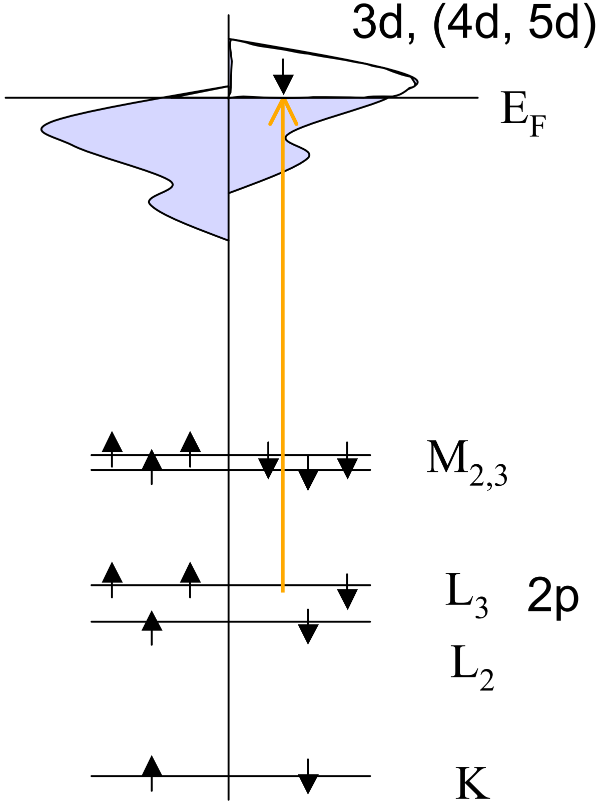


K. Yoshimura G.

JPSJ **75** (2006) 024710

Synchrotron X-ray Absorption Spectroscopy (XAS)

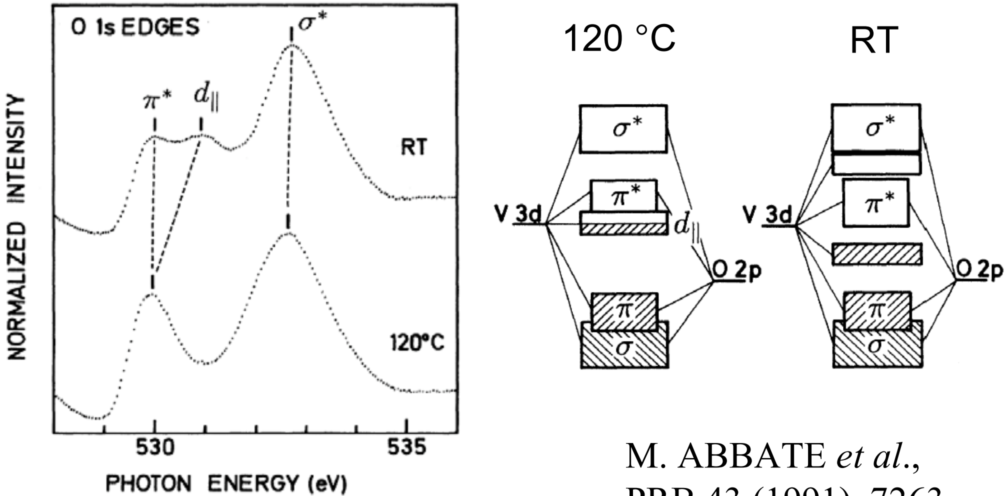
Electronic Structure



Inner shell transition
e.g, L_3 transition :
$2p_{3/2} \Rightarrow 3d$ (4d, 5d)

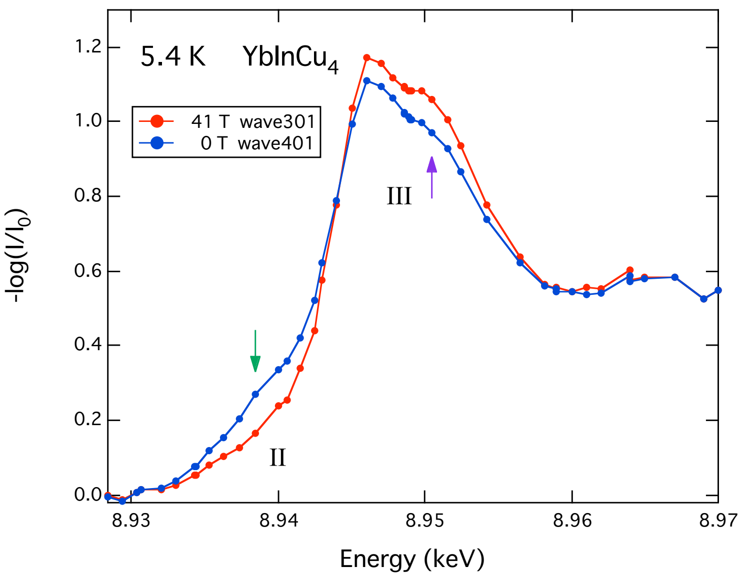
Element selective

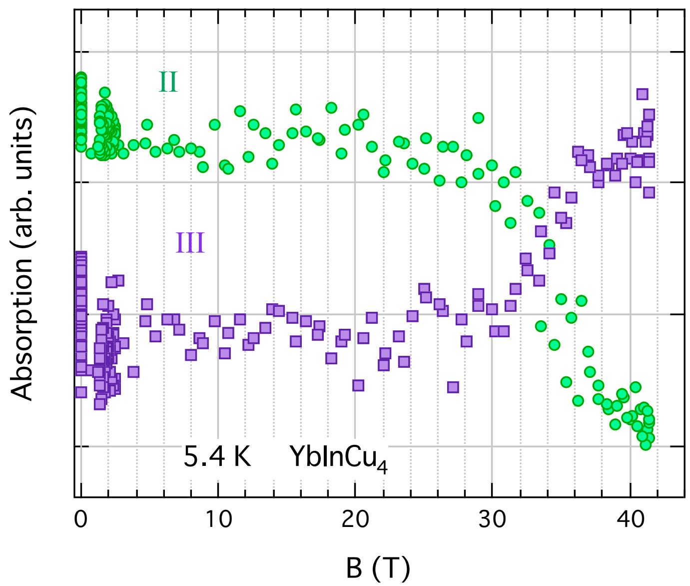
VO_2 M-I Transition

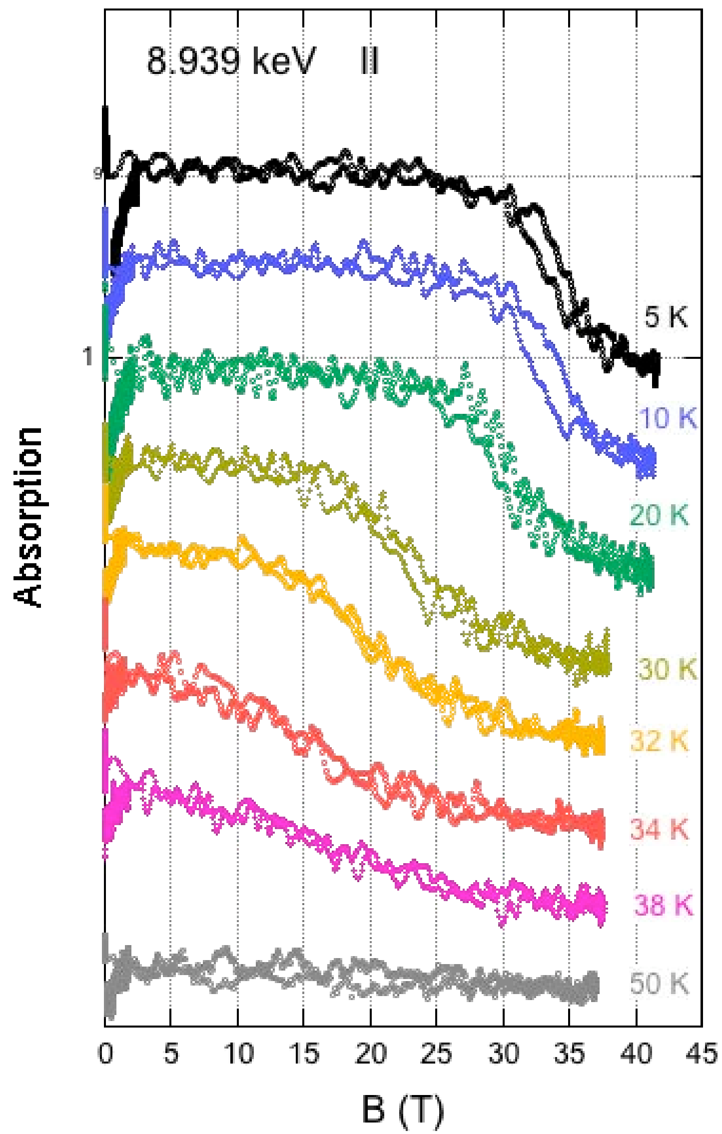


M. ABBATE *et al.*,
PRB 43 (1991) 7263

Direct determination of valence change



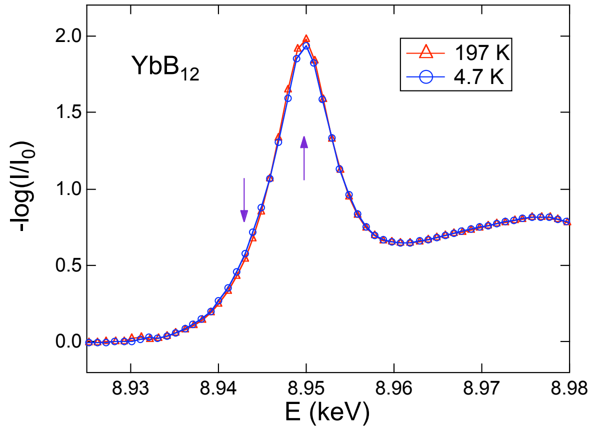


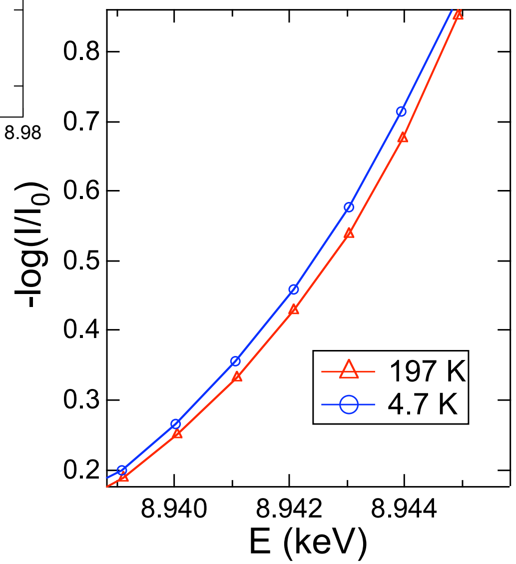


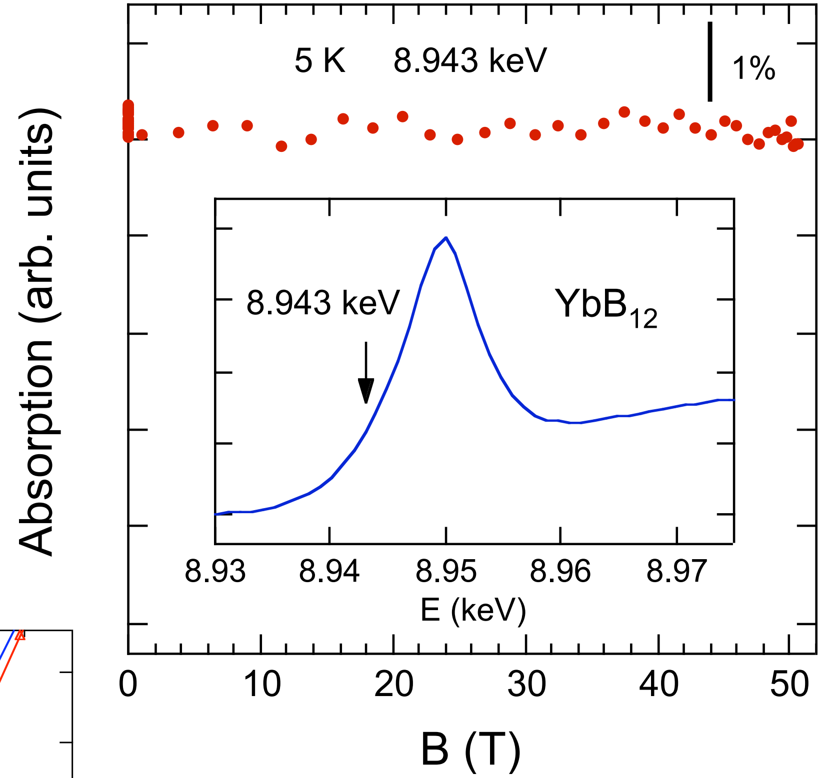
High magnetic field electronic state of YbB_{12}

Typical Kondo Semiconductor
Valence fluctuation : $Yb^{2.95+}$

Valence change at closing of the Kondo gap ?







No Change!

Future R&D

Detection- Time and Space resolved

Low noise

Multi-wave length

Field Longer duration

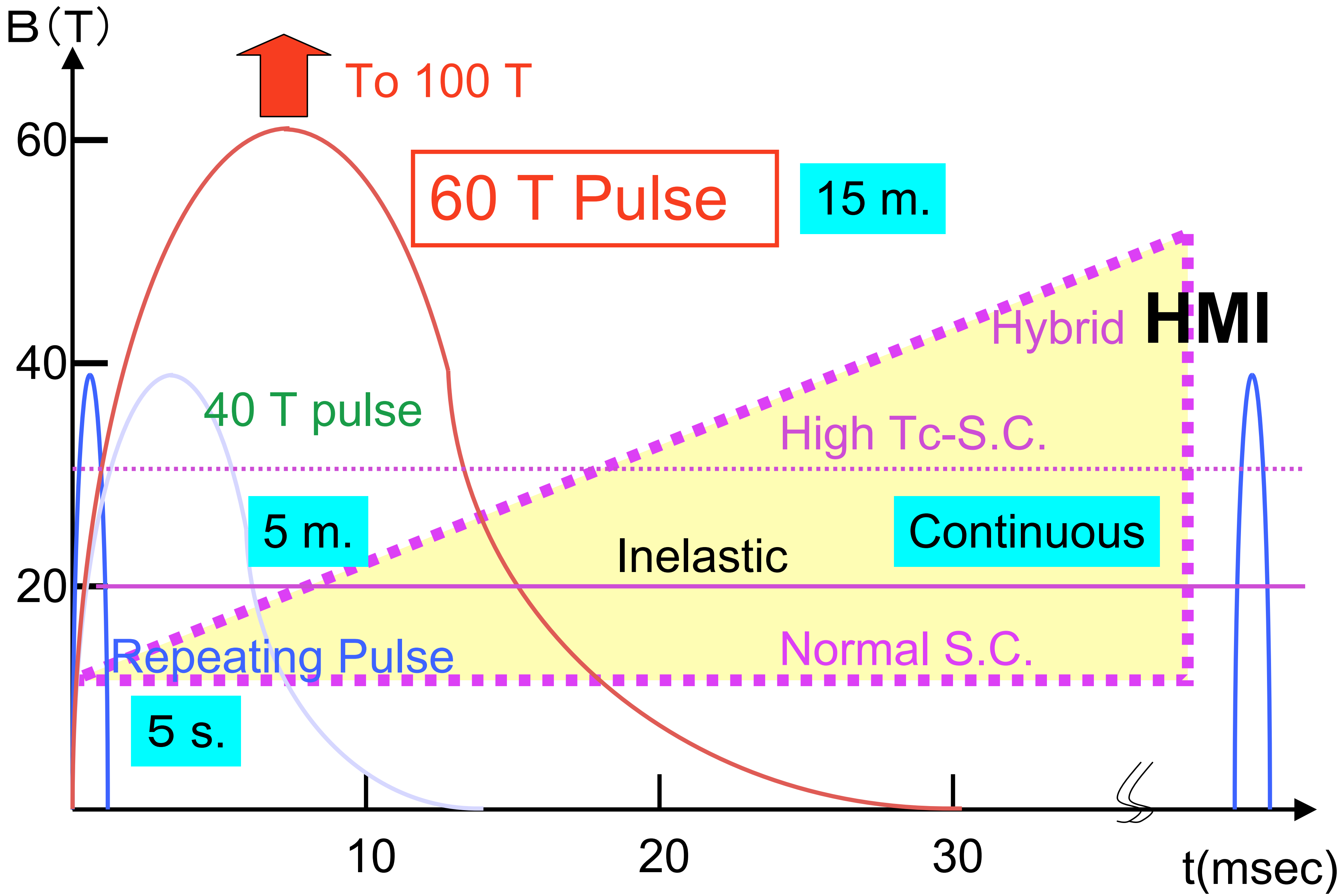
Fast cooling-nitrogen cooling

Repetitive

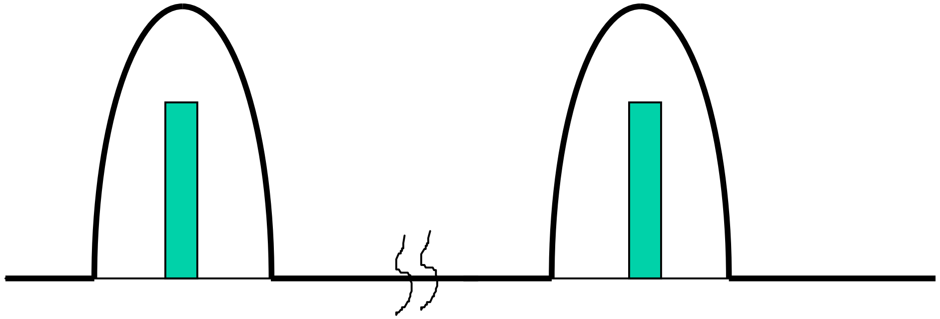
Short Pulse(Dynamics)

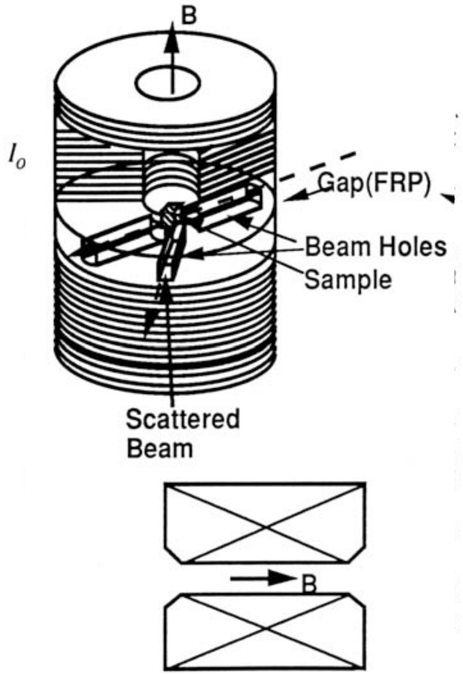
Method MCD, Resonant, Soft X-ray, Time-resolved

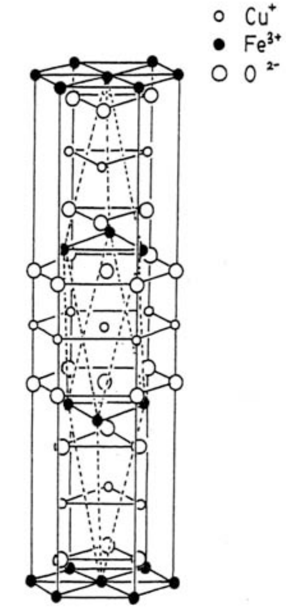
Various High field devices for Neutron



ND in repeating pulsed magnetic field







- Pulse Neutron
- KENS in Tsukuba
- 25 T experiment

$CuFeO_2$

Multi-ferroic for NC structure

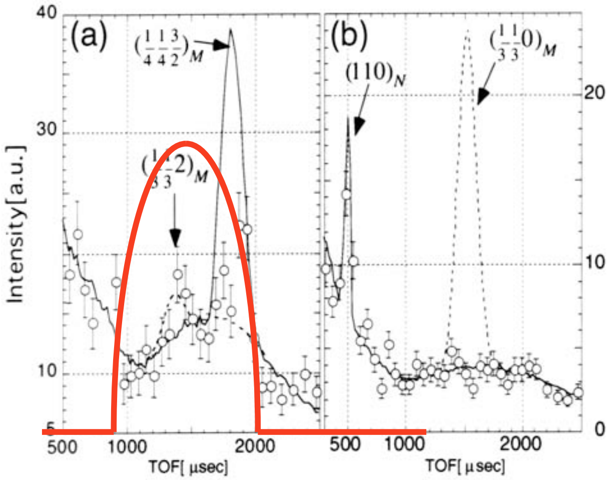
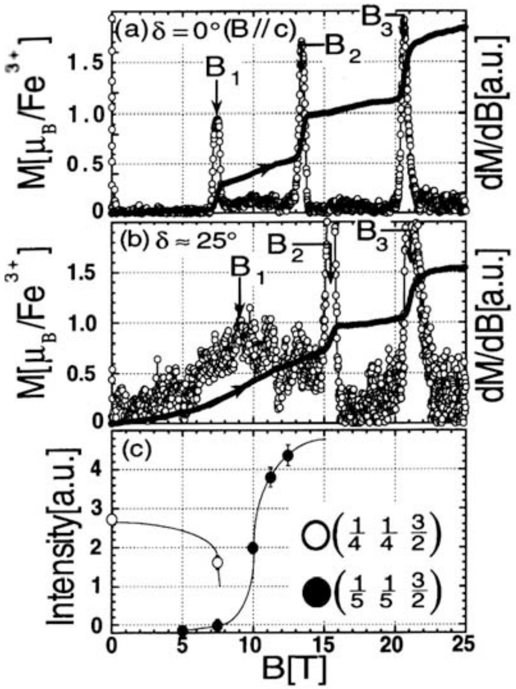


Fig.1 TOF spectrums: Solid lines and open circles represent the data taken under zero and finite magnetic field, respectively. Dashed lines denote the spectrums estimated from the magnetic structural models



Mini Coil for Neutron

The Highest Magnetic Field for ND

Repating :25T @ KEK

(Motokawa et al. 1989)

ND over 20T is still Difficult.

Reactor Facility

High Beam Flux

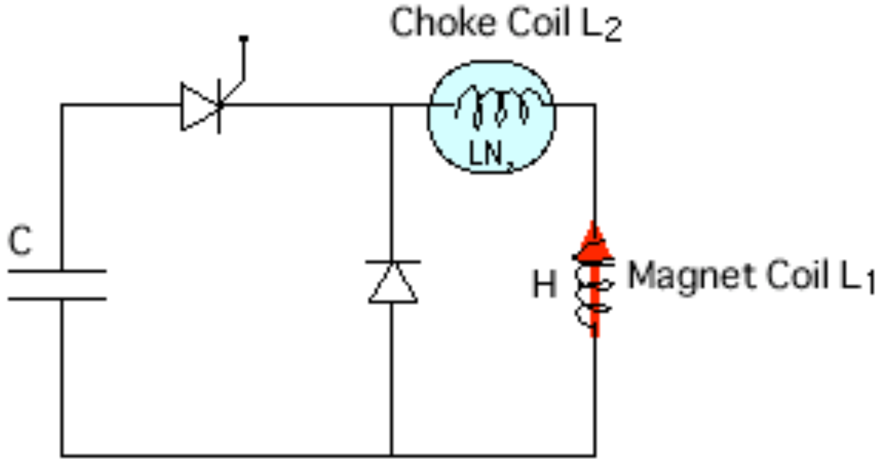
Beam Focusing is easier.

Development of Easier and more Diffusive Techniques

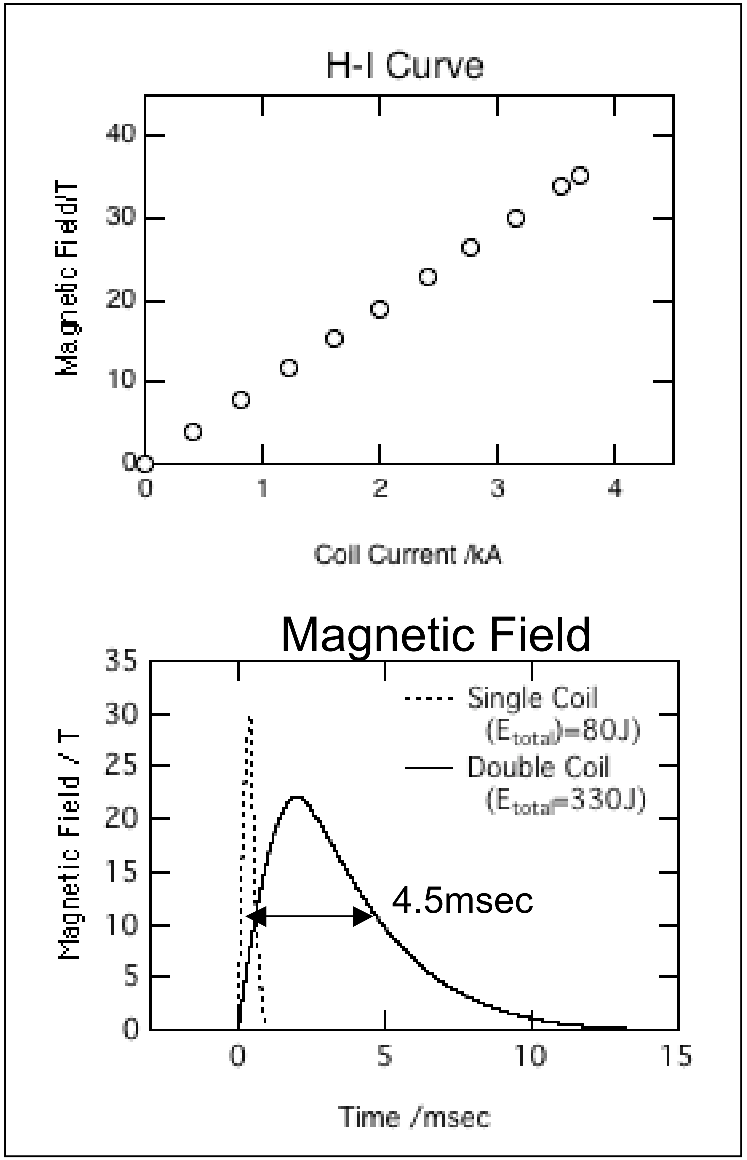
Target : H=40T
Goal: Observation of Magnetic Transitions by ~100 Shots Experiments

Development to J-PARC

Double Magnet System



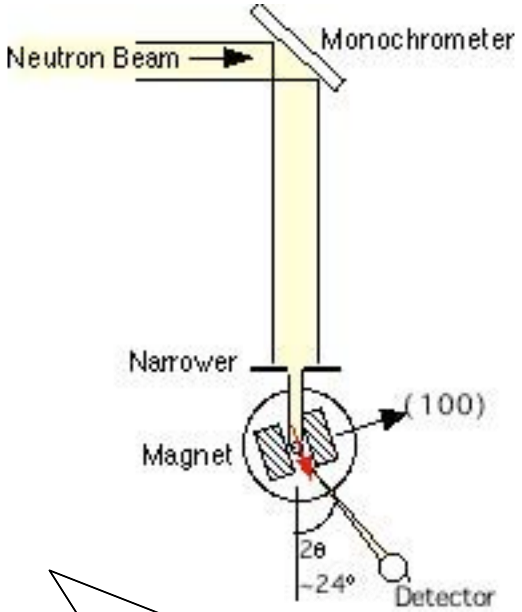
L_1~0.1mH, L_2~1mH
C=0.96mF (Short Pulse)
C=2.8 mF (Long Pulse)

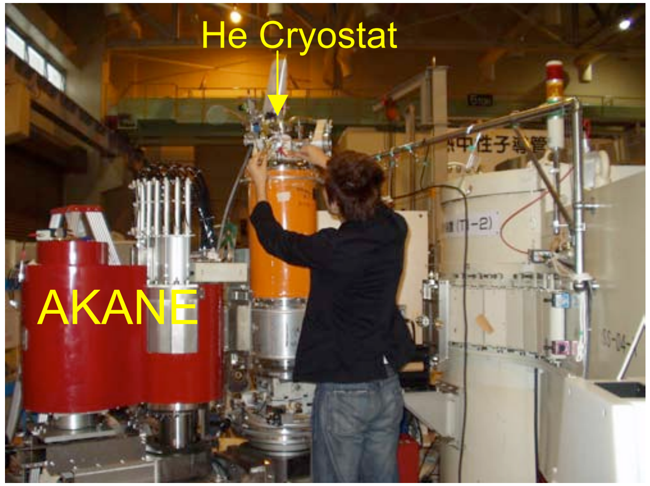


Longer Pulse
Low loss
Effective injection
Current limit
Design Freedom

Experimental

The Triple Axis Spectrometer, AKANE of Tohoku Univ.
@ JRR-3M, JAEA, Japan





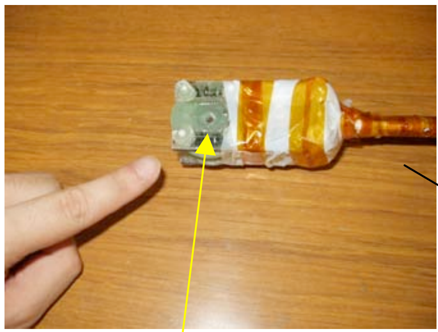
The coil & Sample were cooled in a liquid-He cryostat.

λ=2.0Å

Colimation: guide-Open-S-Blank-Blank

Scattering Plane: a*-c*

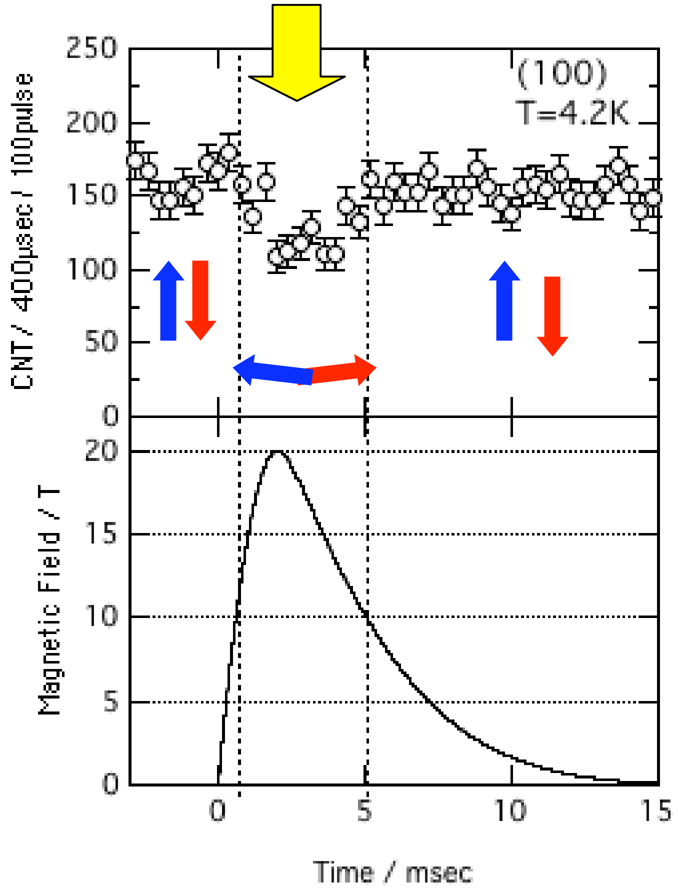
H//c



Sample Space
(ϕ5mm L10mm)

Observation of Spin-Flop at 10T

Integration of (100) magnetic reflection after 100shots



We succeeded in observing intensity change due to SF transition at 10T after 100 shots.

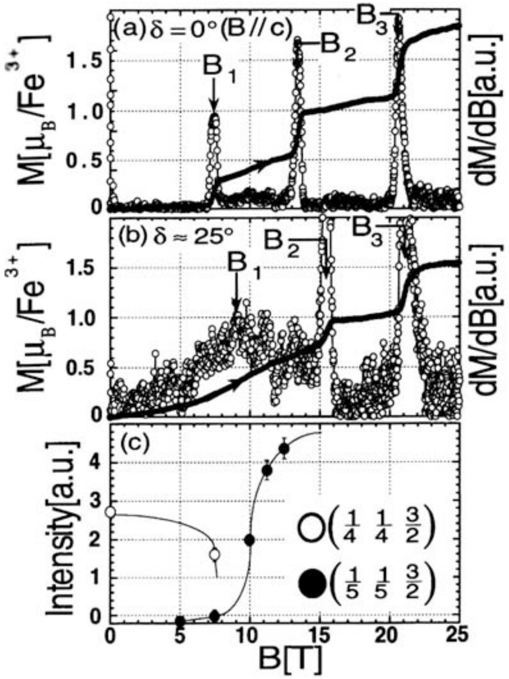
Pulse Interval: ~17min.

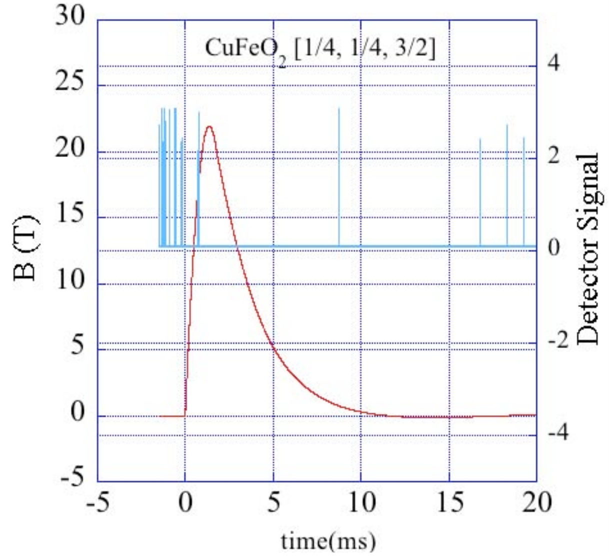
100 Pulse ~ 25hr.

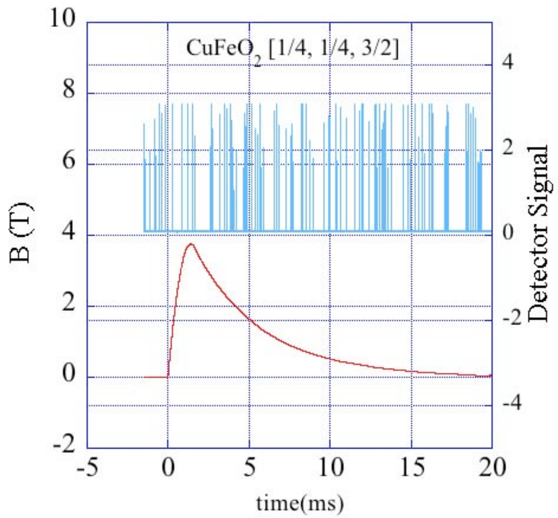
Test for 30 T

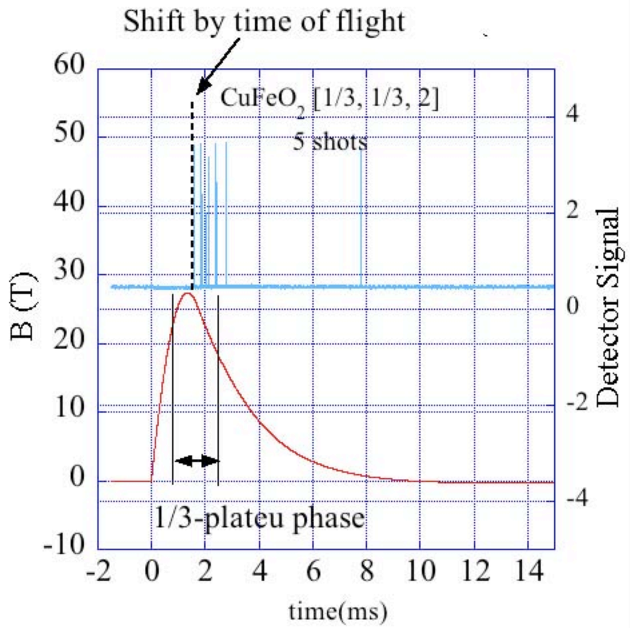
0.35cc

Single



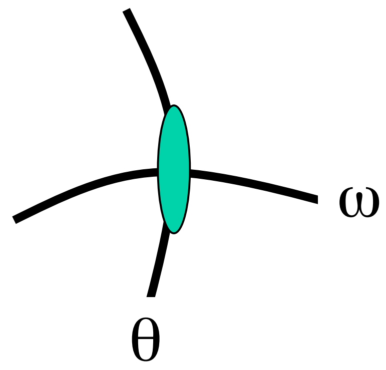






Problems to be solved

- ○ Long Duration of experiments: ~25hr
  ⇒ Higher Beam Flux
- ○ Resolution Control
- ○ Coil Optimization, low resistive
- ○ Cooling efficiency, Nitrogen coil



- ○ Peak Profiles cannot be observed at the present.
  ⇒ PSD system

Practical Experiments

Summary

Miniature magnets are useful for the quantum beam experiments.

Structural study (X-ray Diffraction)
Electronic States (X-ray Absorption)
Magnetic Structure (Neutron Diffraction)

→ apply to various kinds of interesting materials

Combination of Pulsed field and X-ray, neutron opens a new horizon in condensed matter