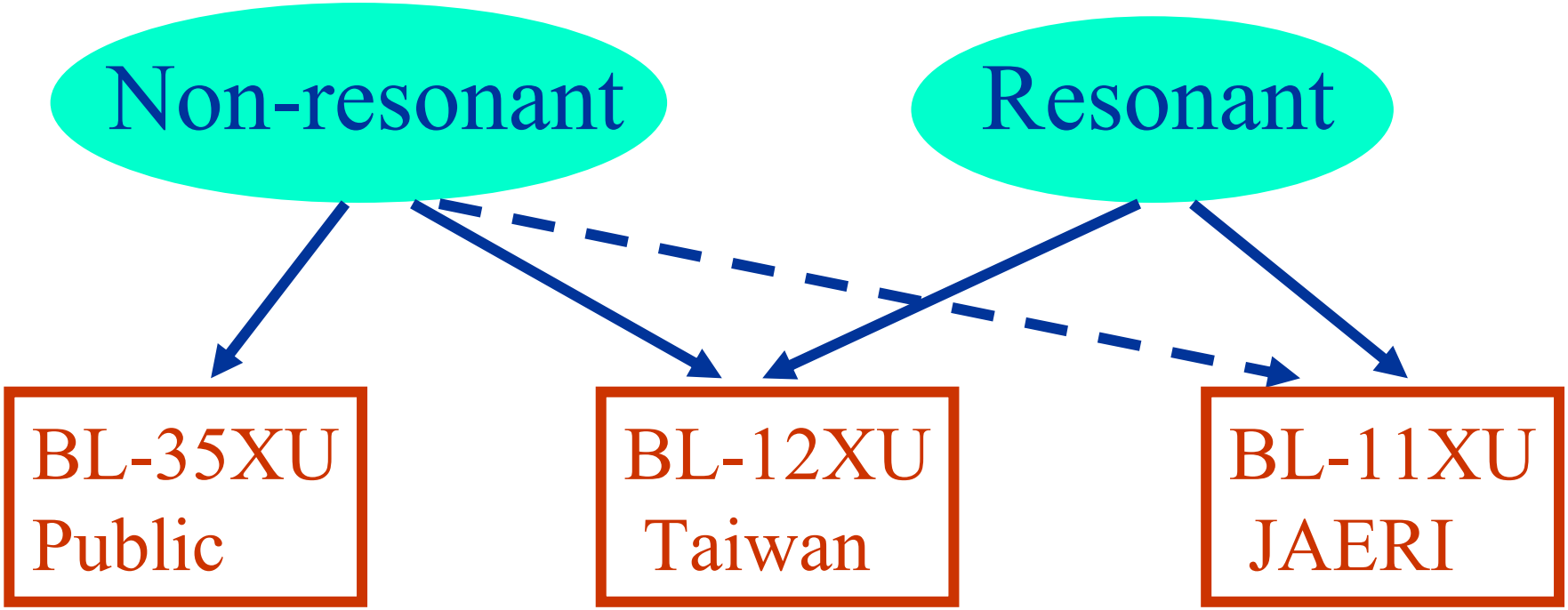
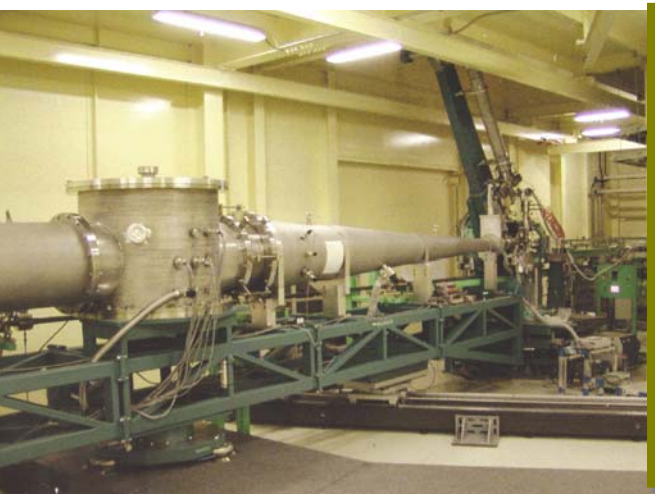
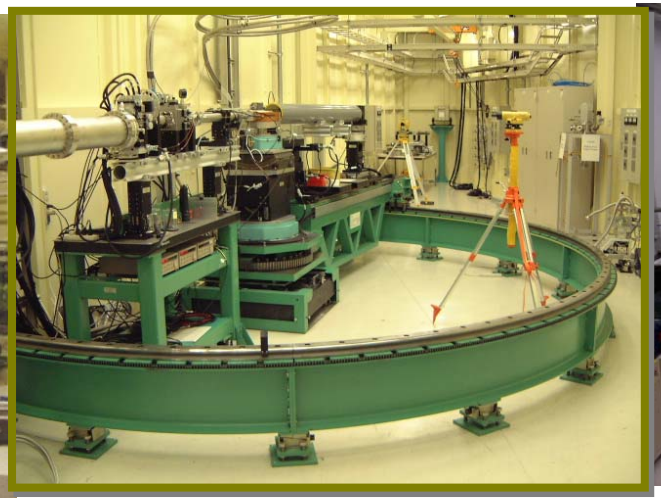
Activities of Resonant and Non-resonant Inelastic X-ray Scattering at SPring-8

Jun'ichiro Mizuki

JAERI & JASRI


Non-resonant
Resonant
BL-35XU
Public
BL-12XU
Taiwan
BL-11XU
JAERI



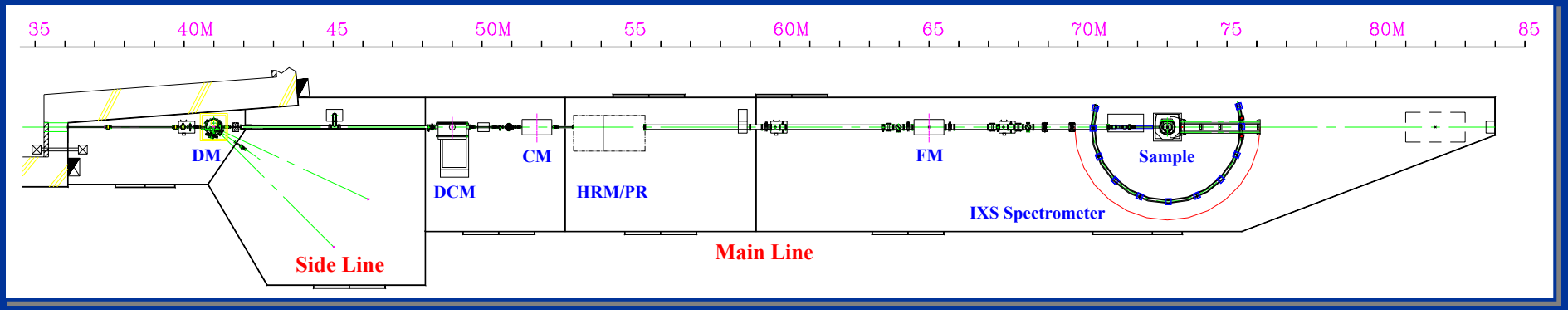


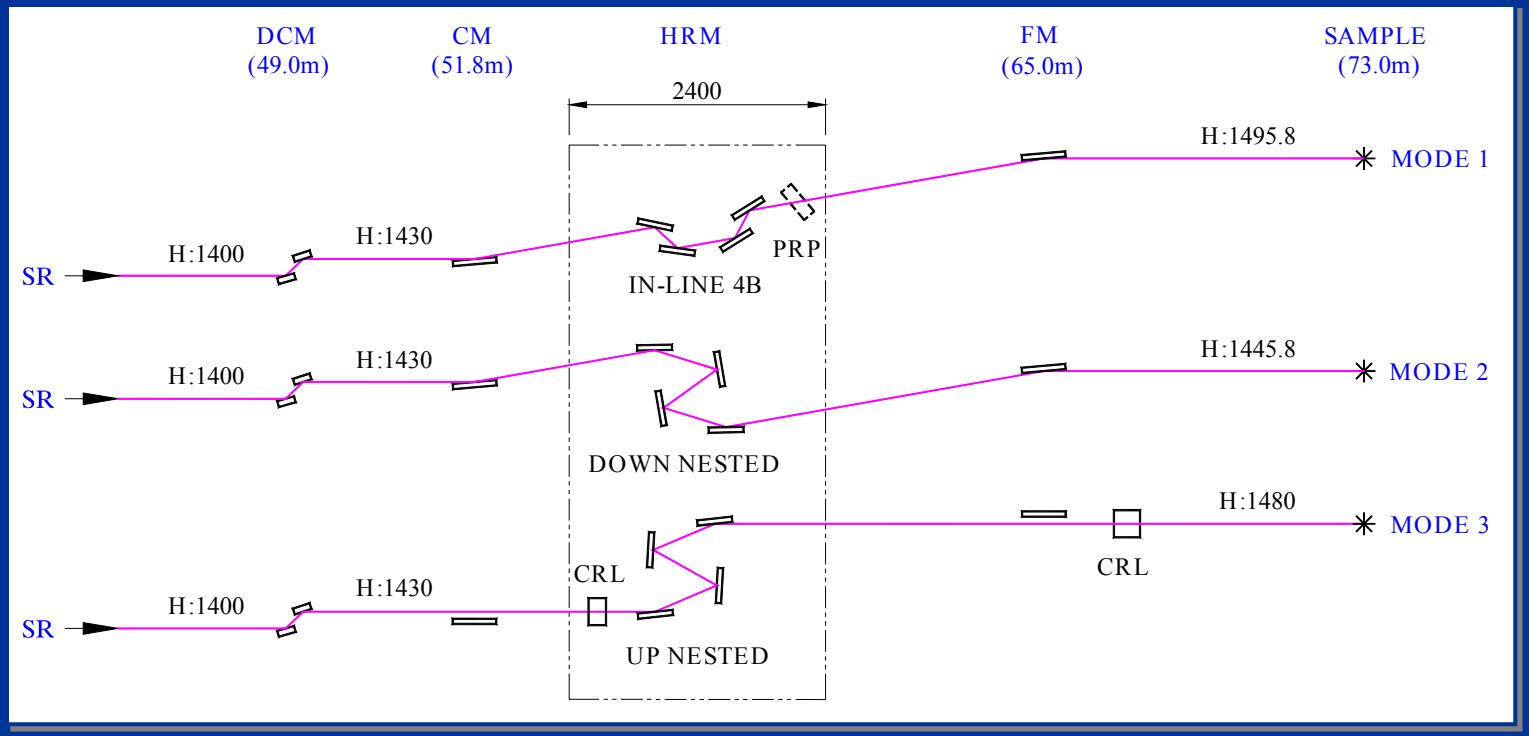
- **BL12XU: Inelastic X-ray Scattering Beamline**

Goals and Challenges

- **Realize 10-100 meV total energy resolution for both resonant and non-resonant inelastic scattering experiments**

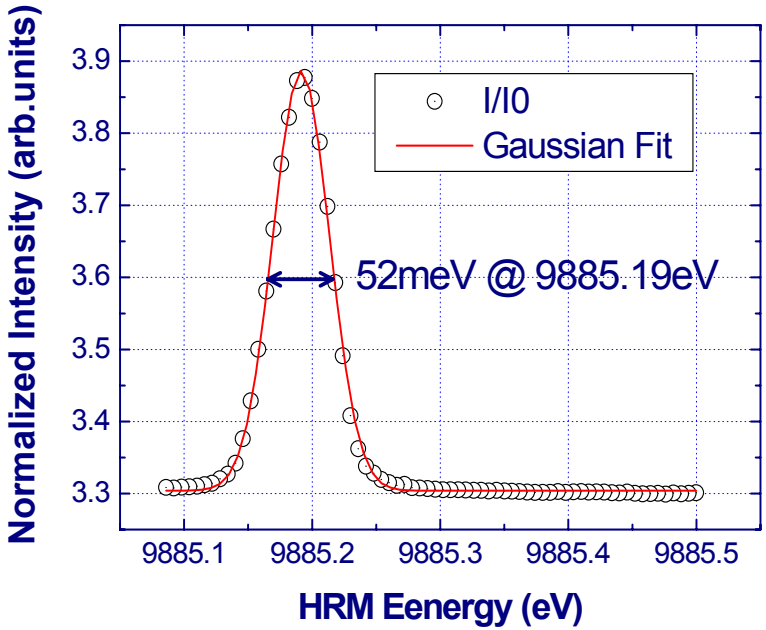
- **Team Members:**
  - **Dr. Yong CAI:** Beamline Scientist, Project Manager
  - **Dr. Paul CHOW:** Beamline Scientist, NRIXS
  - **Dr. Hirofumi ISHII:** Postdoctoral Fellow, RIXS
  - **Mr. Cheng-Chi CHEN:** Beamline Mechanical Engineer
  - **Dr. Chi-Chang KAO:** Project Advisor (Associate Chair, NSLS)
  - **Prof. Chien-Te CHEN:** Project Leader (Director, NSRRC)

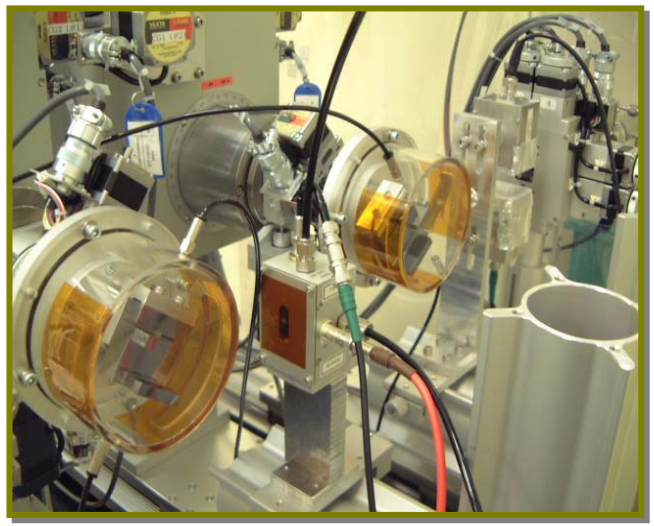


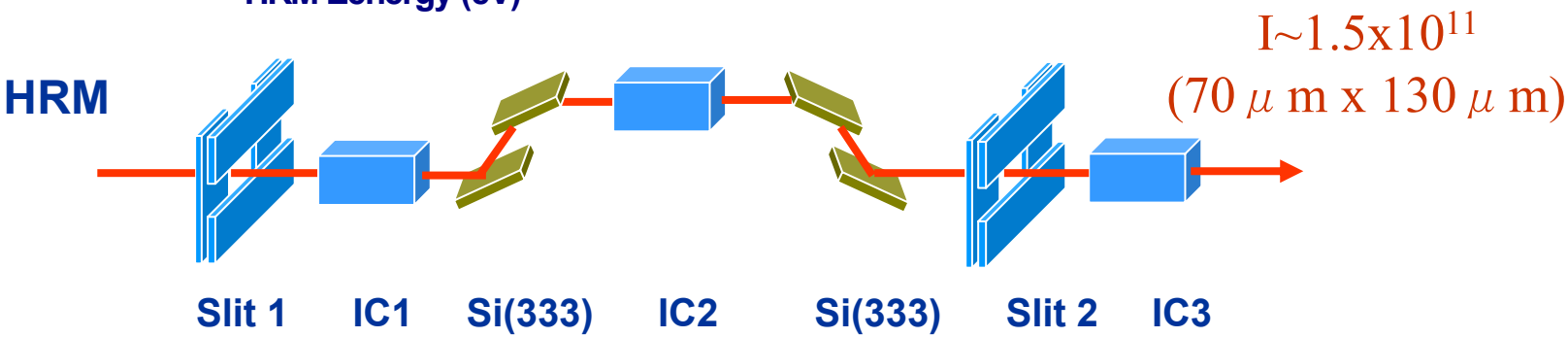


Operation Modes

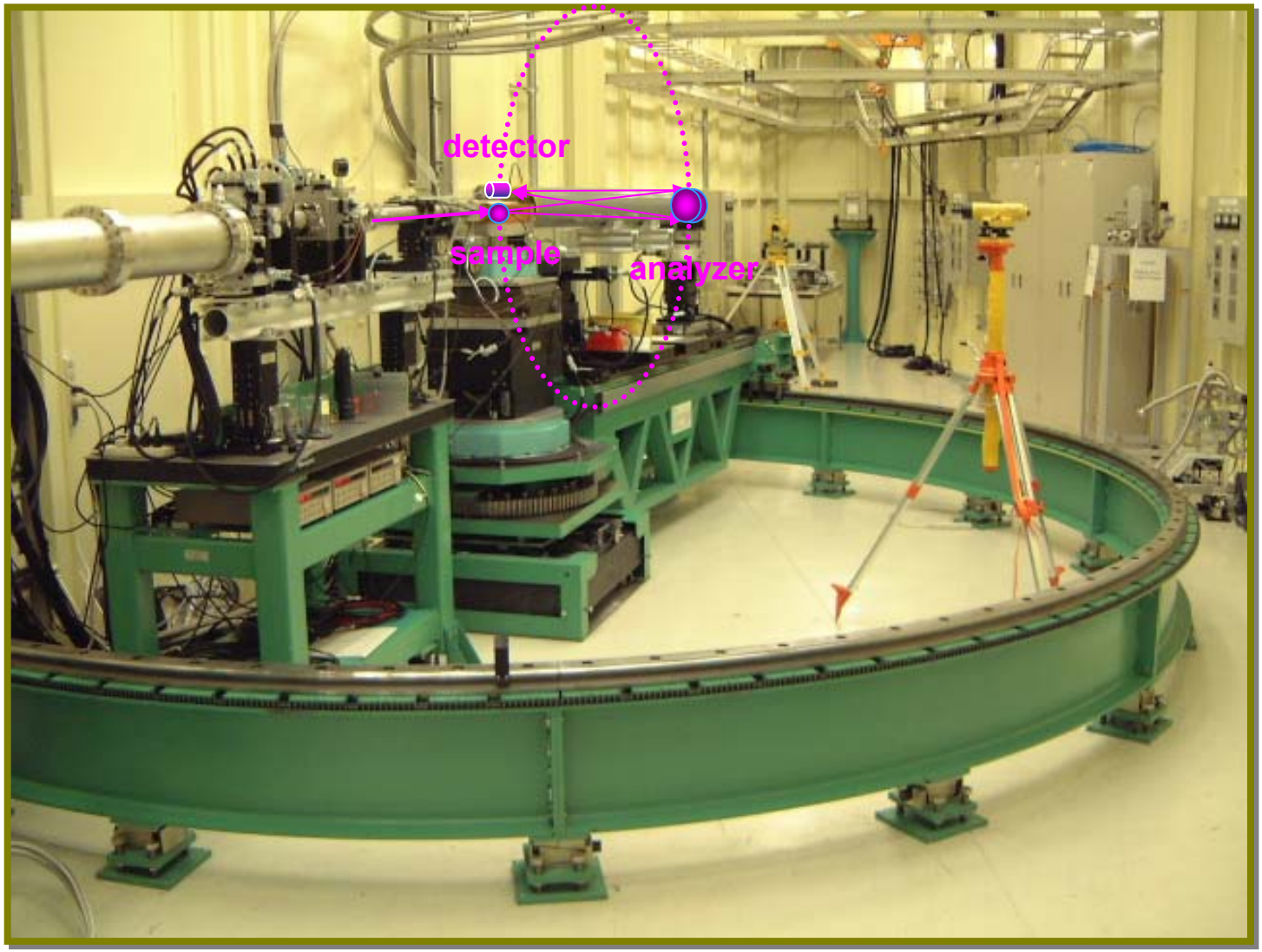
100meV Beamline Optics Set-up



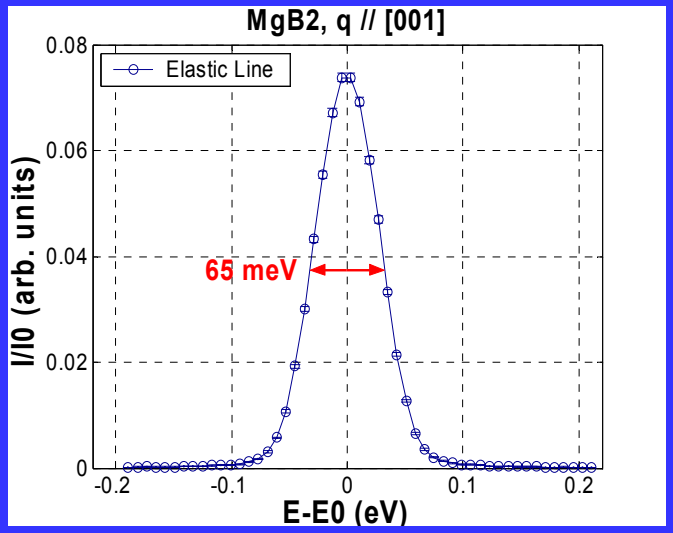


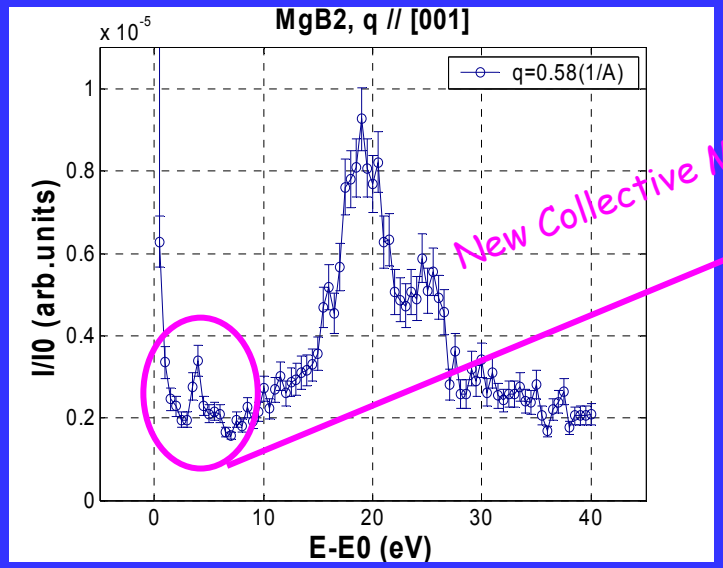


Non-resonant IXS set-up

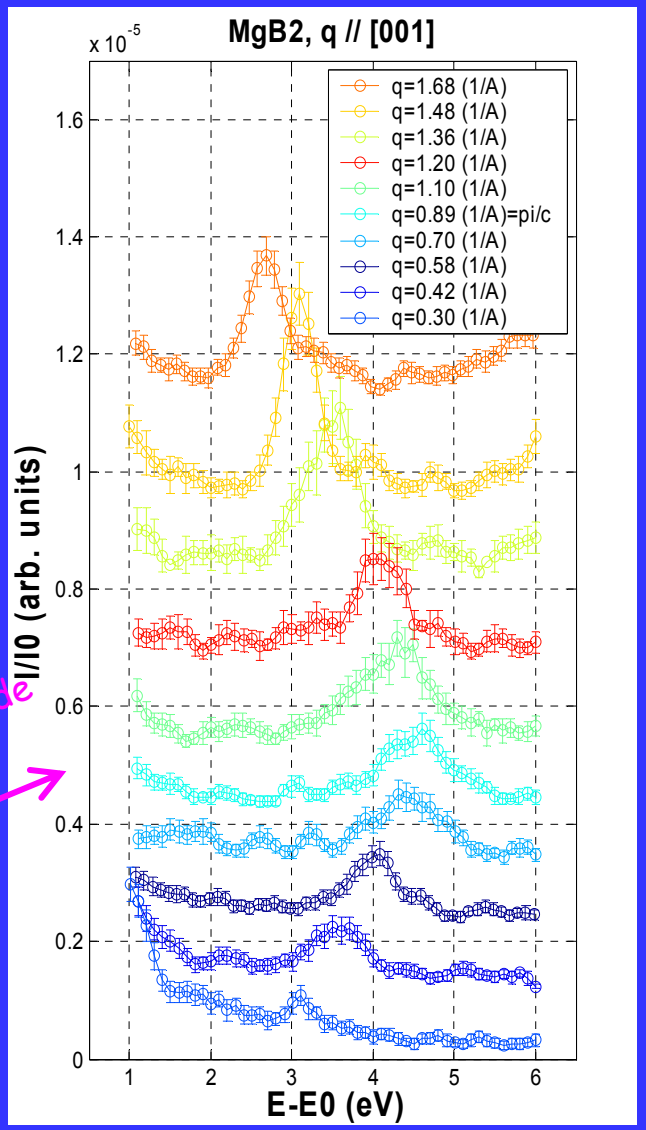


MgB_2 Experimental Results



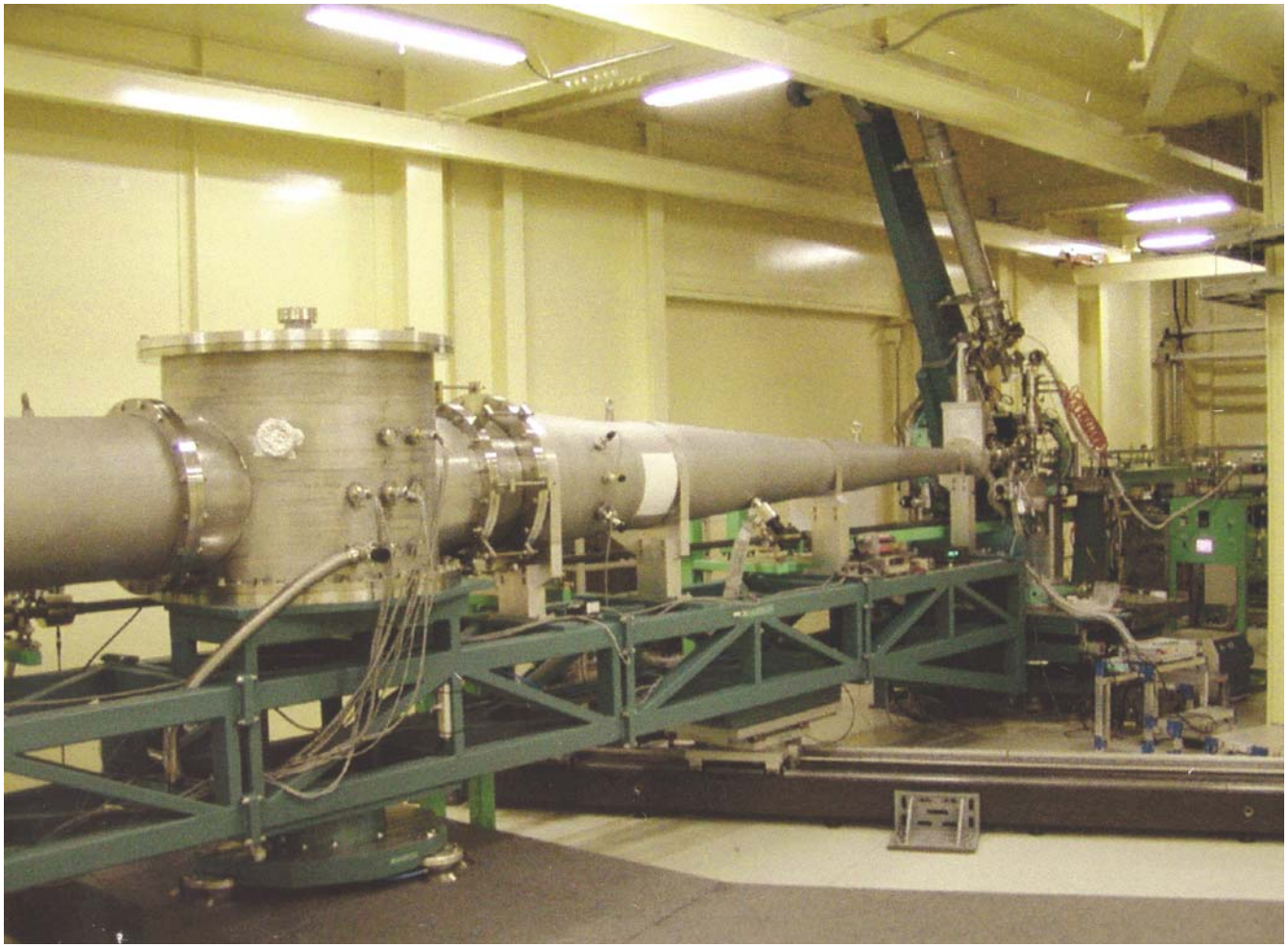


New Collective Mode



BL-35XU

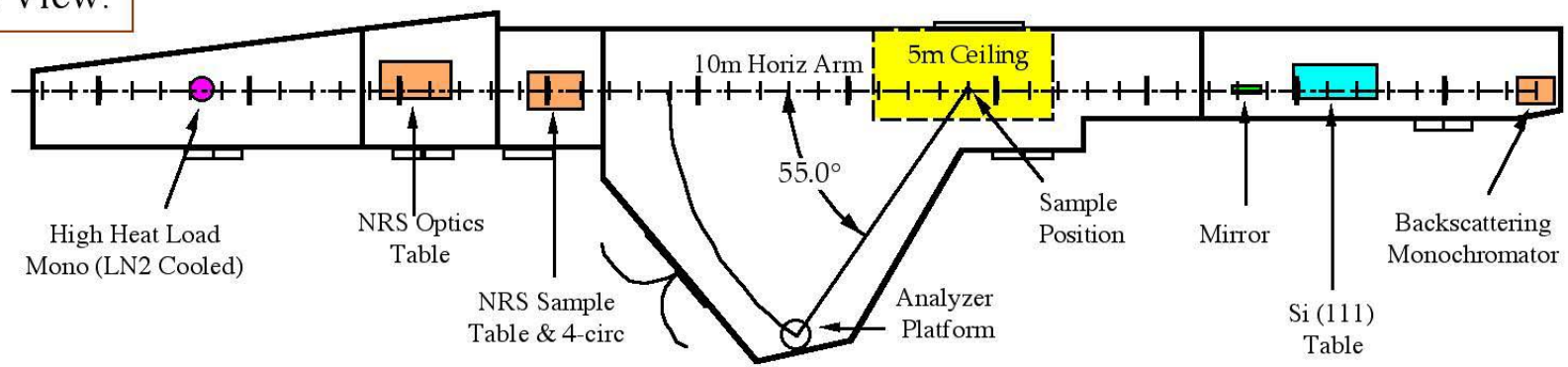
Design : A. Baron, T. Ishikawa, K. Takeshita, T. Goto, T. Matsushita, Y. Tanaka
Commiss.: A. Baron, Y. Tanaka, D. Ishikawa, D. Miwa, S. Tsutsui, T. Ishikawa
Staff : A. Baron, T. Tsutsui



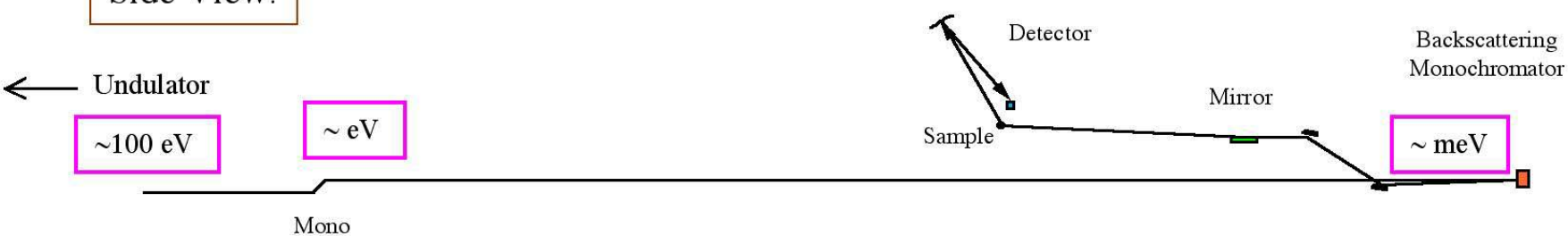
High Resolution Inelastic X-Ray Scattering Beamline SPring-8 (BL35XU)

A.Q.R. Baron, *et al,* J. Phys & Chem Solids **61,** (2000) 461.

Top View:



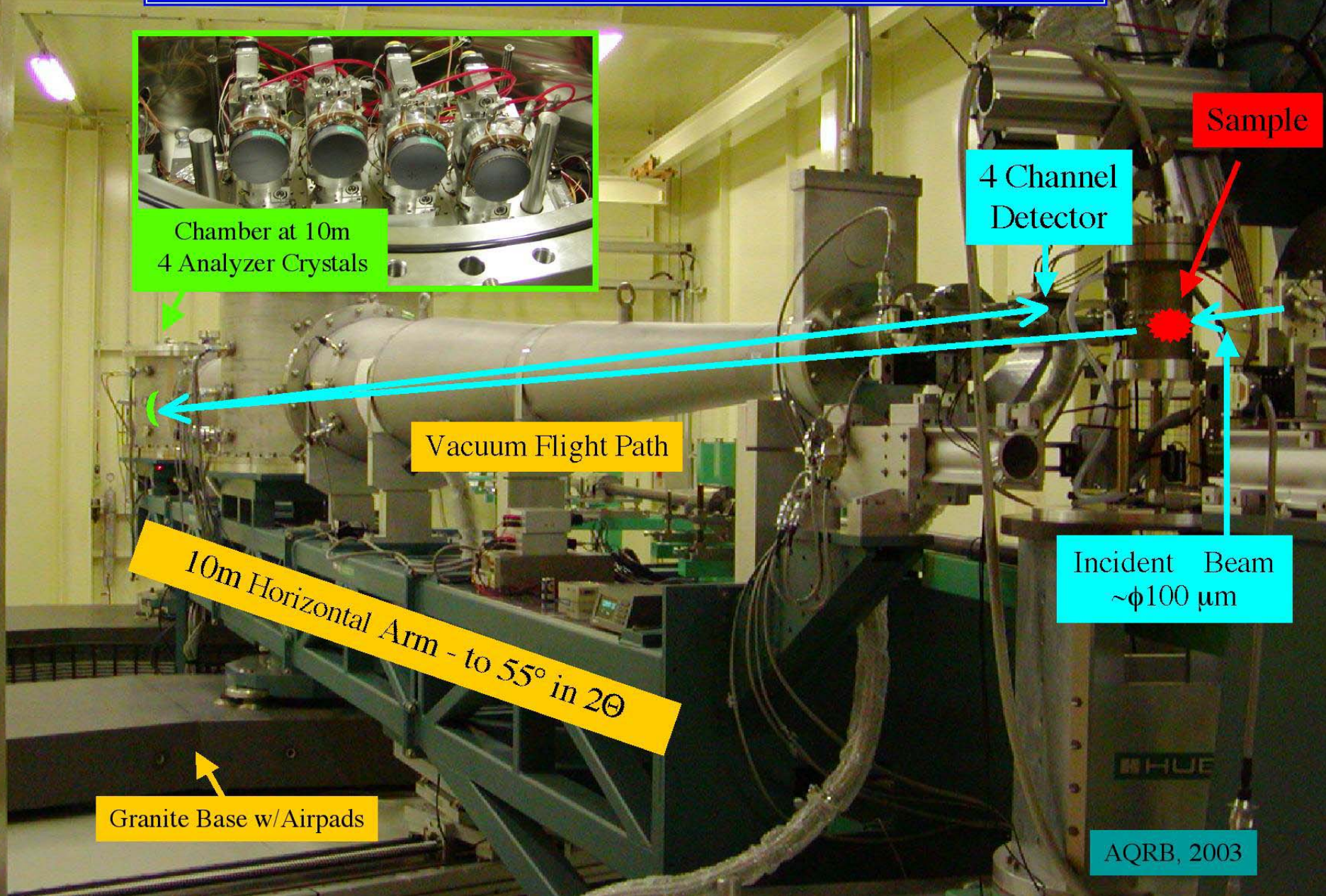
Side View:



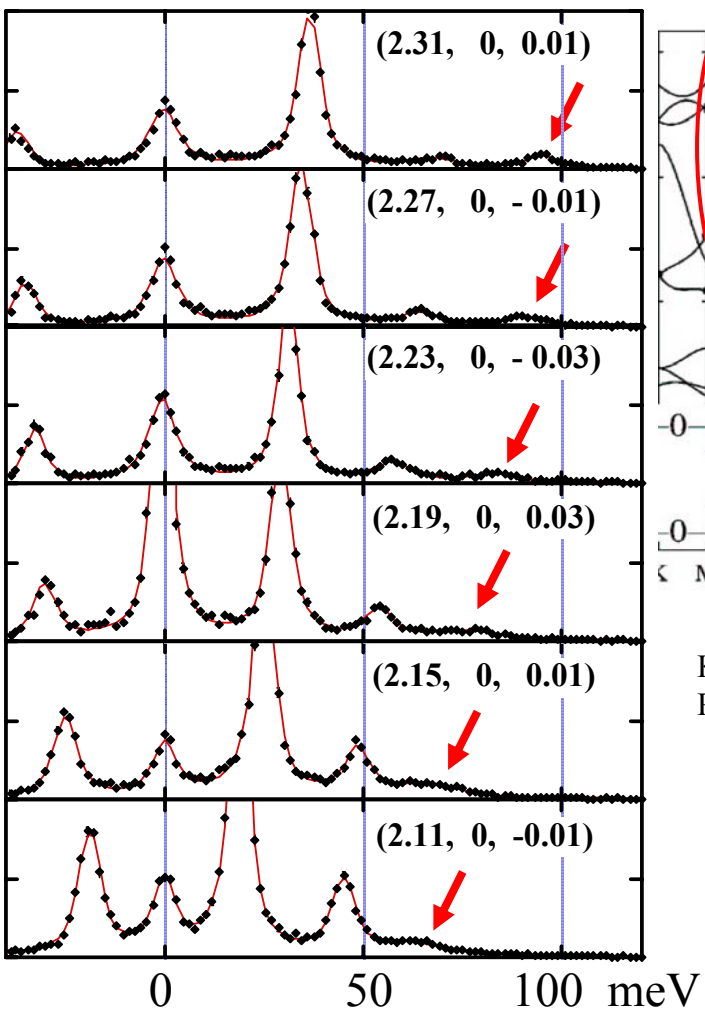
X-Ray Energy (keV)	Resolution (meV)	Flux Onto Sample (100 mA)	Spot Size (VxH, FWHM)
21.747	1.6	5 GHz / 0.8 meV	60 x 80 μm^2
15.816	6.0	30 GHz / 4.1 meV	120 x 90 μm^2

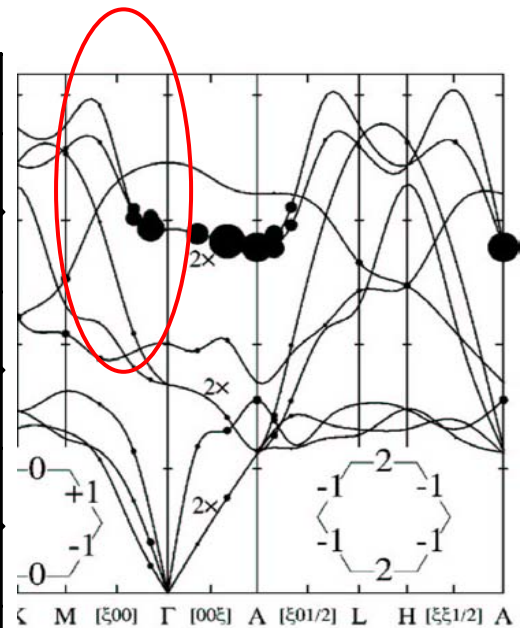
AQRB, May 2003

SPring-8 IXS Spectrometer (BL35XU)

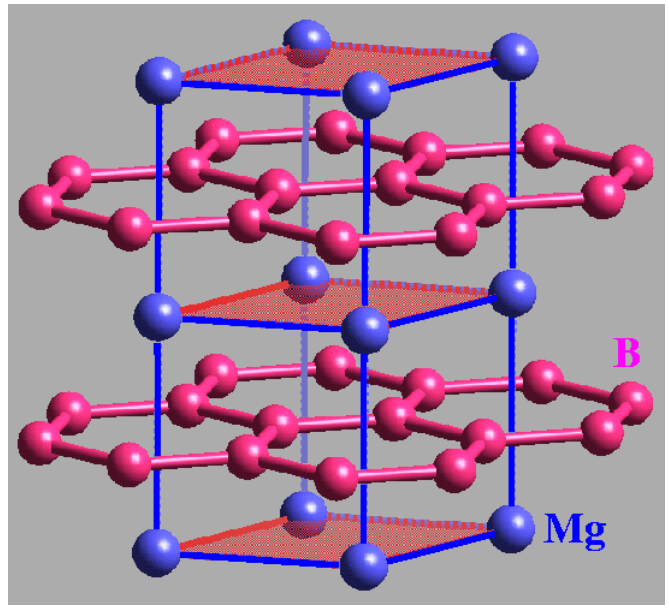


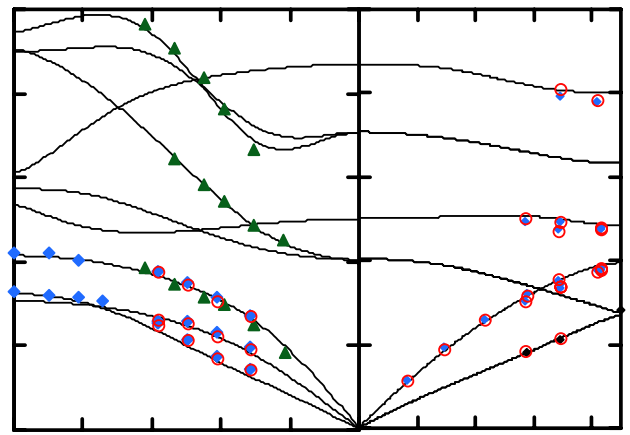
Phonon on MgB_2





Kong, et al.,
PRB. **64,** (201) 020501(R).

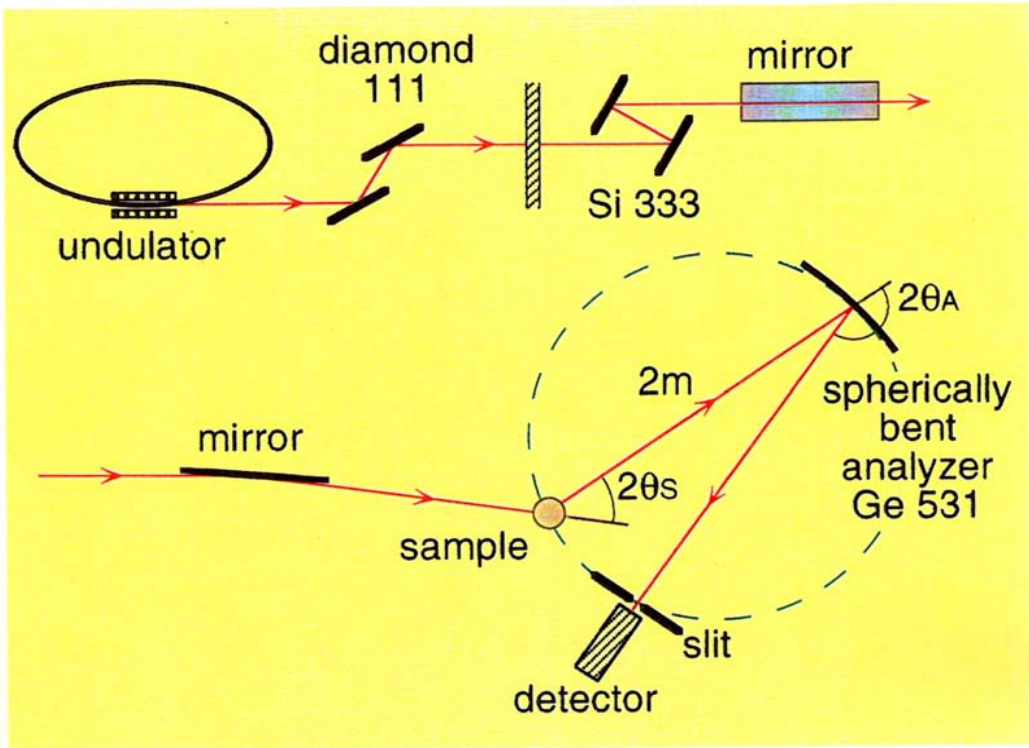


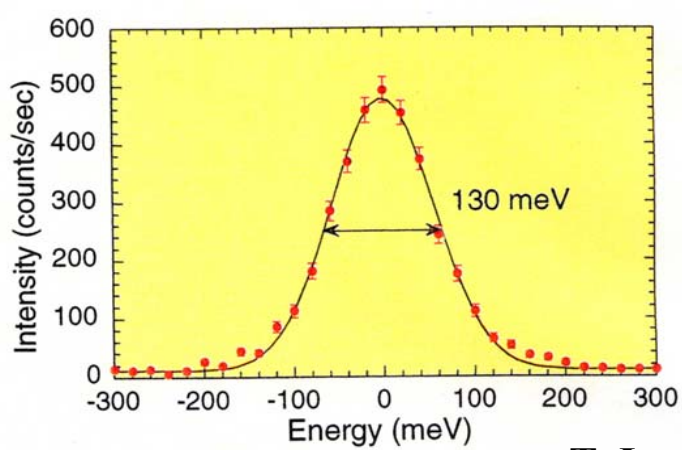


A.Q. R. Baron, H. Uchiyama, Y. Tanaka, S. Tsutsui, D. Ishikawa, S Lee, S. Tajima, T. Ishikawa

Set-up of Inelastic Scattering Spectrometer at BL-11XU

(JAERI)

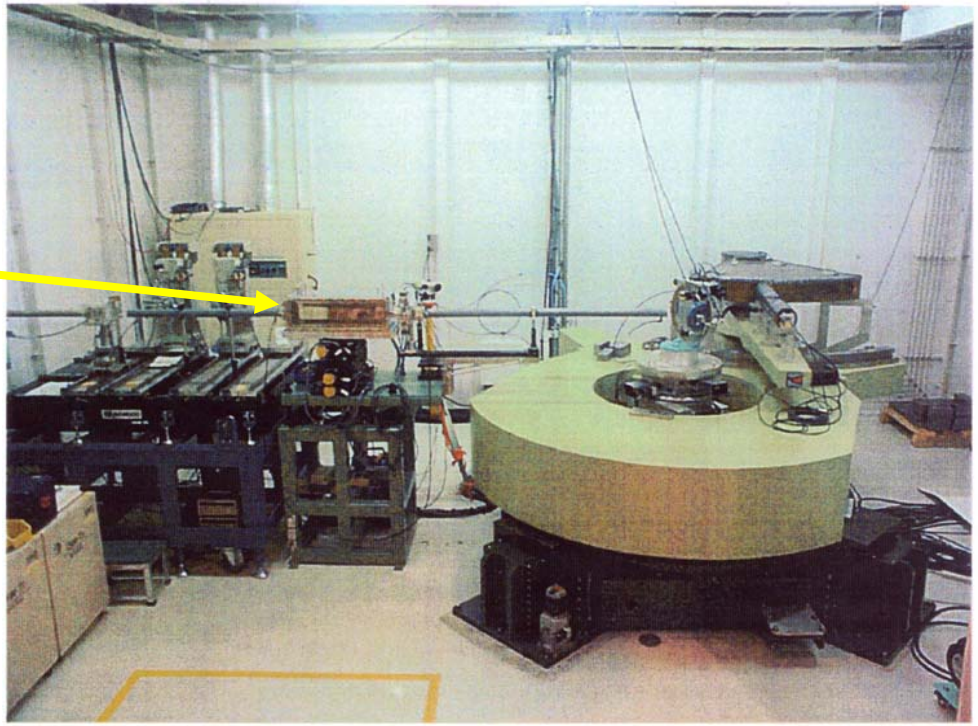




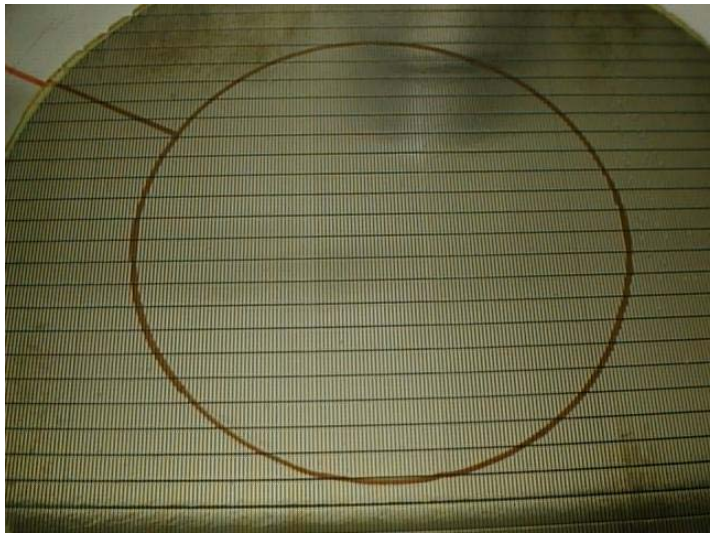
Observed energy
Resolution
at 6.5 keV

T. Inami et al., Nucl. Instr. Meth. A 467-468 ('01) 1081

Picture of the spectrometer at BL-11 XU, SPring-8



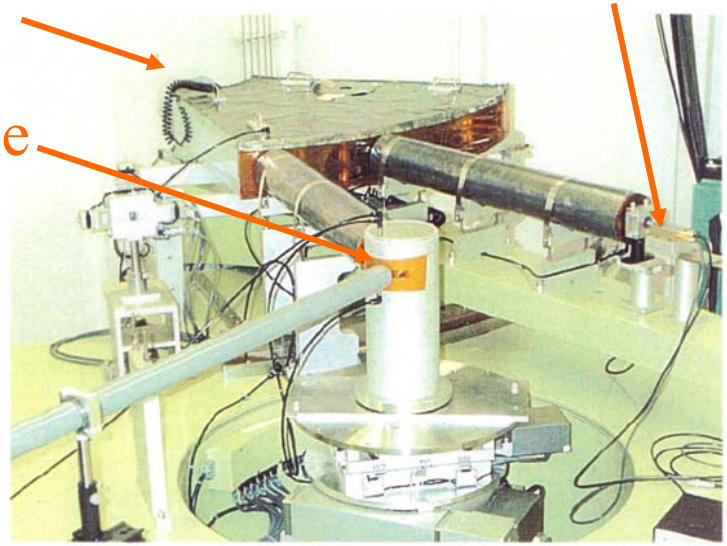
Focusing mirror



analyzer

detector

sample



Superconducting Magnet up to 8 T

Strongly correlated electron systems

colossal magnetoresistance

high Tc superconductor

$La_{1-X}Sr_XMnO_4$

↓

resonant inelastic scattering

at BL-11XU

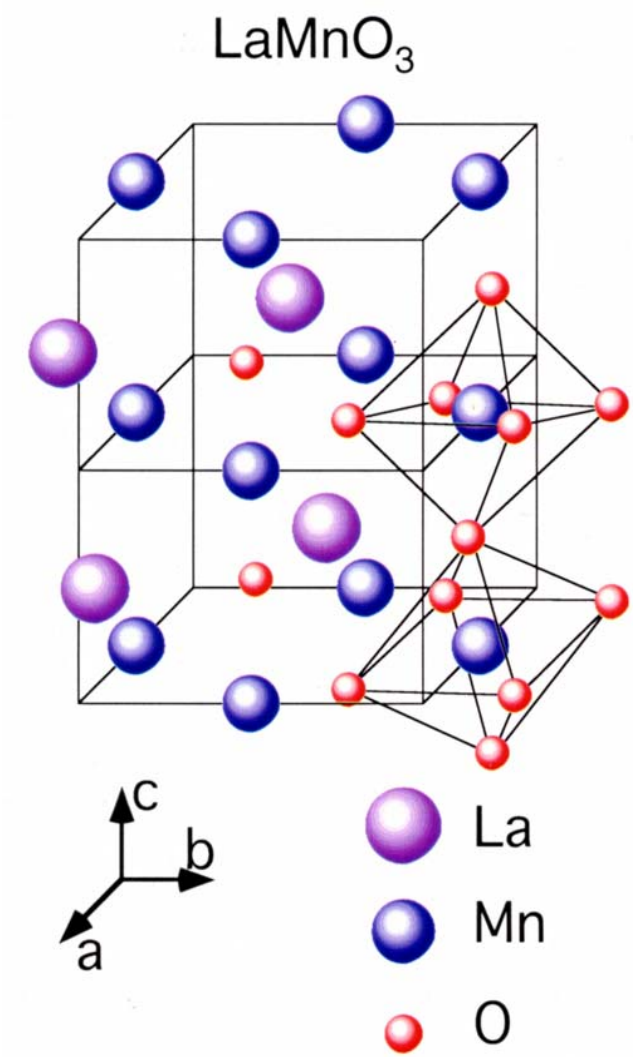
$La_{2-X}Sr_XCuO_4$

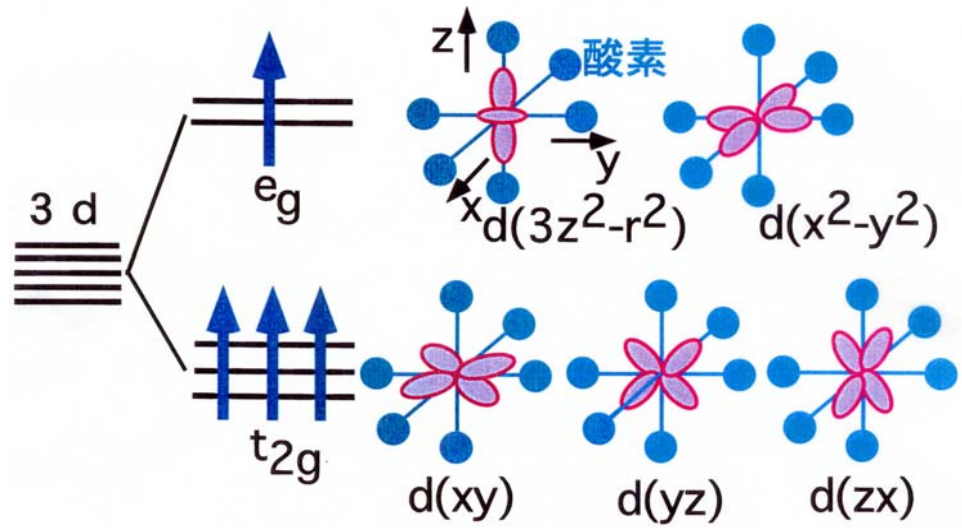
↓

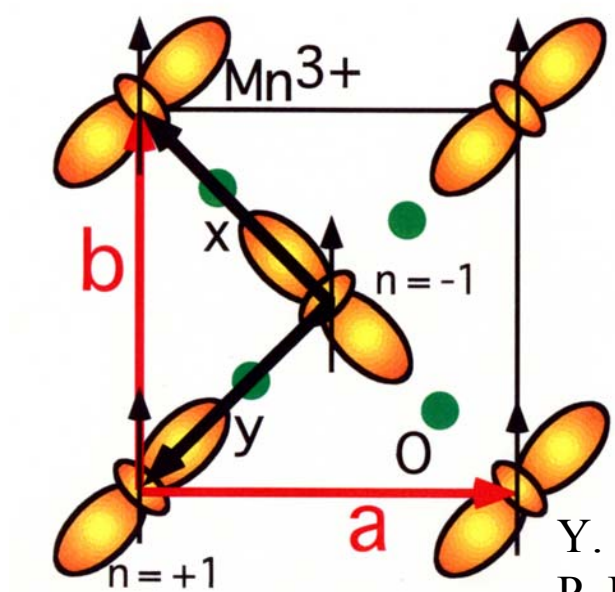
non-resonant inelastic scattering

at BL-35XU

Orbital excitation on Manganite

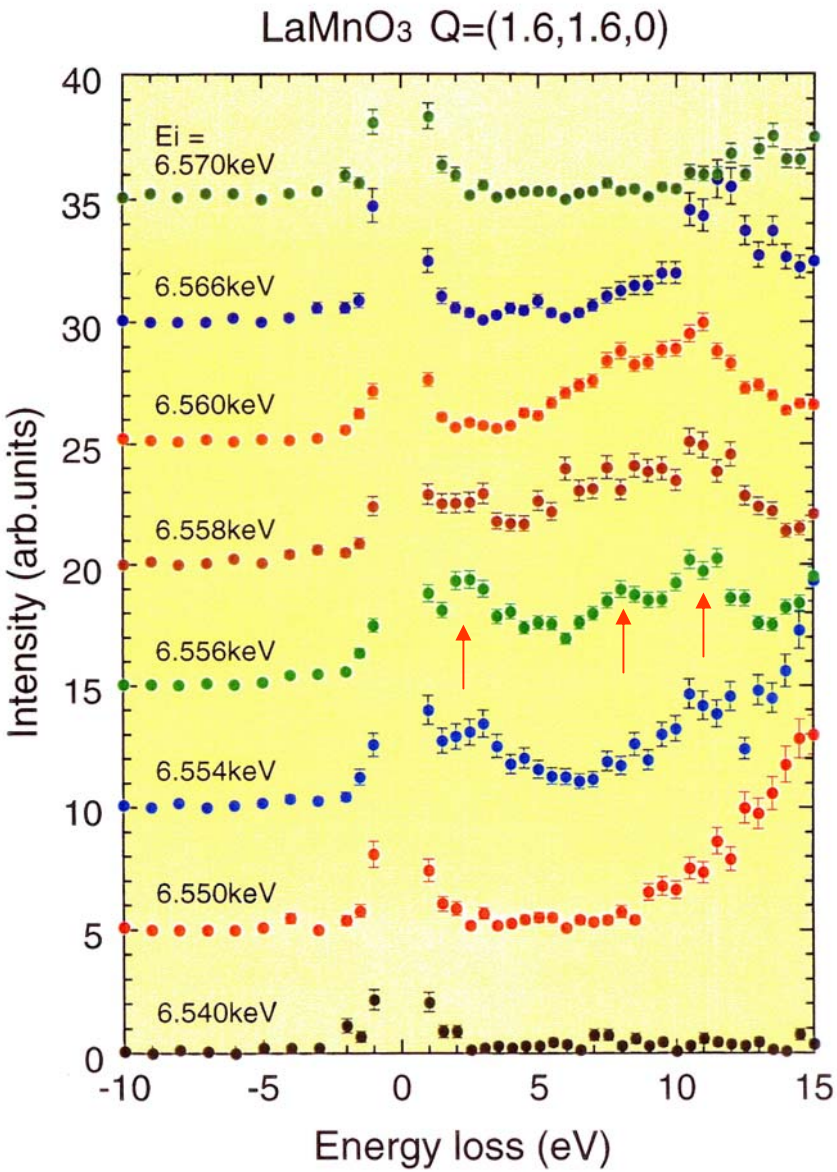


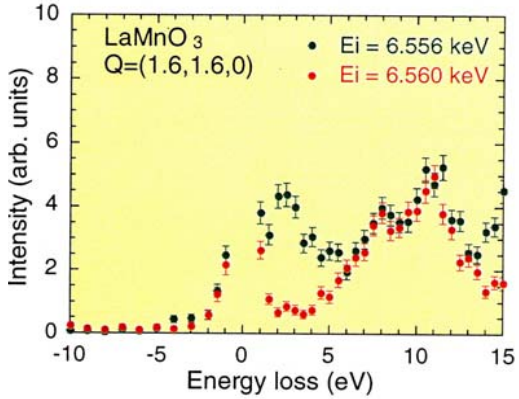


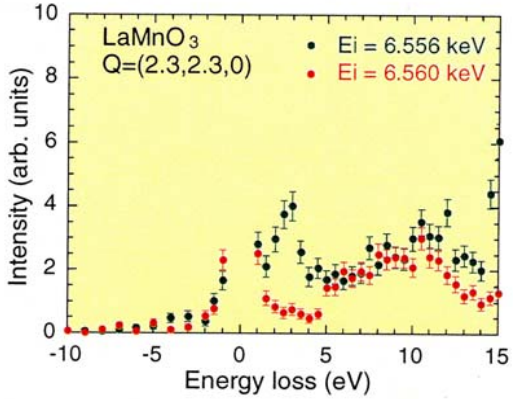


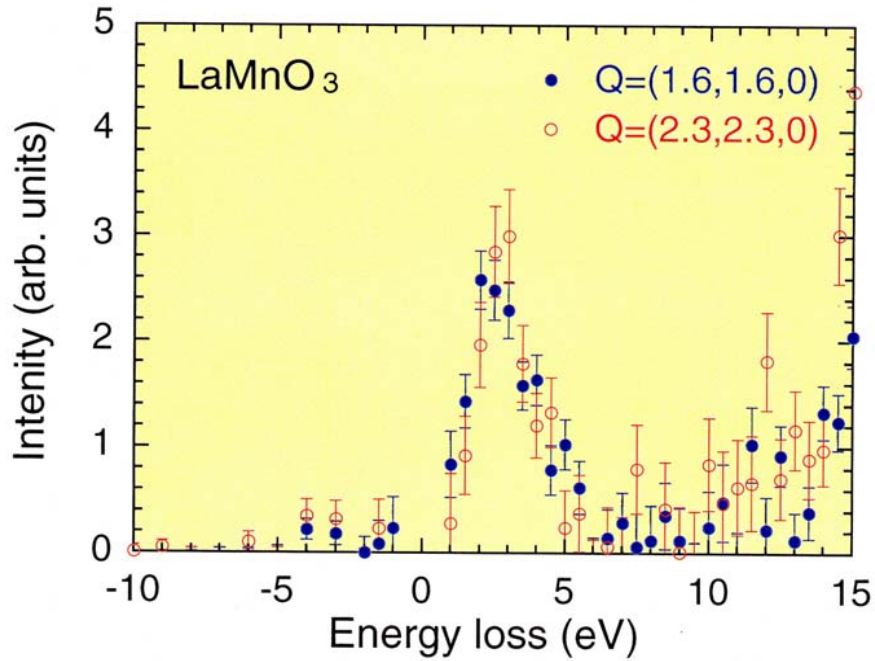
Y. Murakami et al.,
P. R. L. 81 ('98) 582

Incident Energy dependence



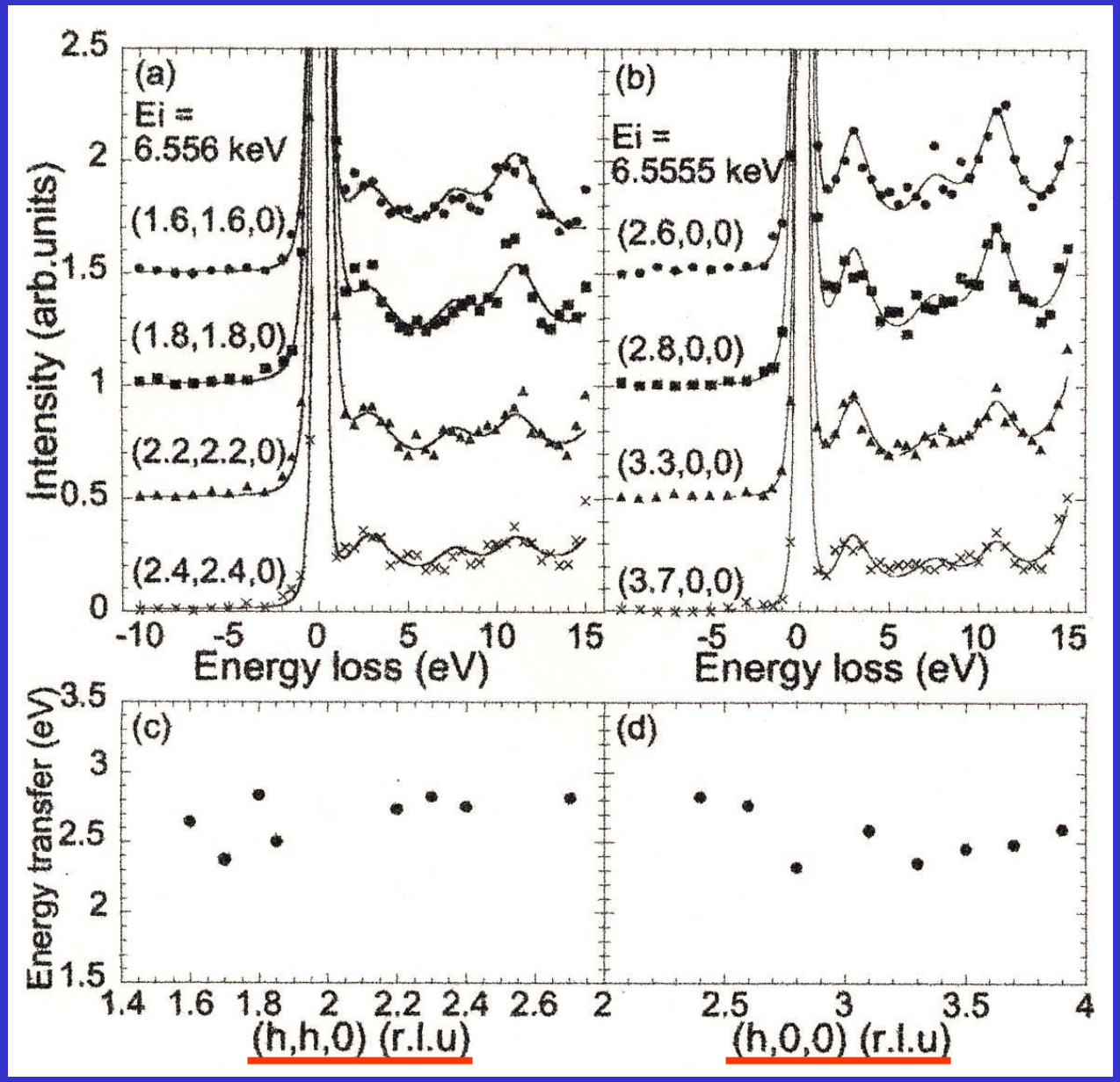






Q-dependence of the E's

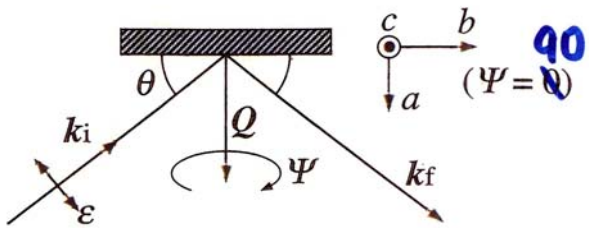
[1 1 0] direction

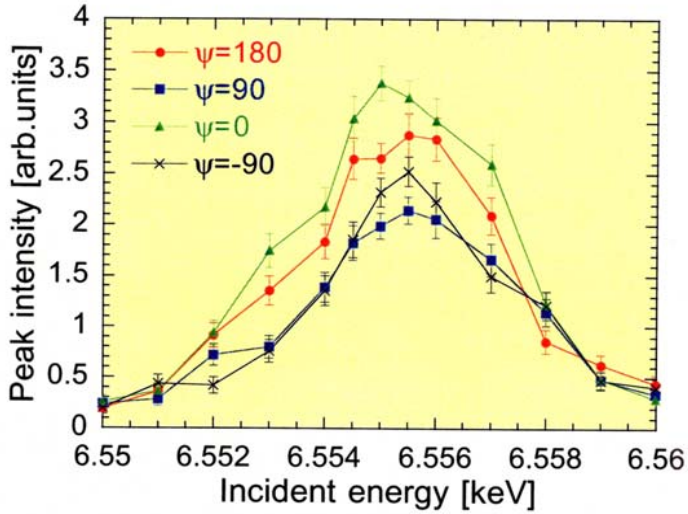


[1 0 0] direction

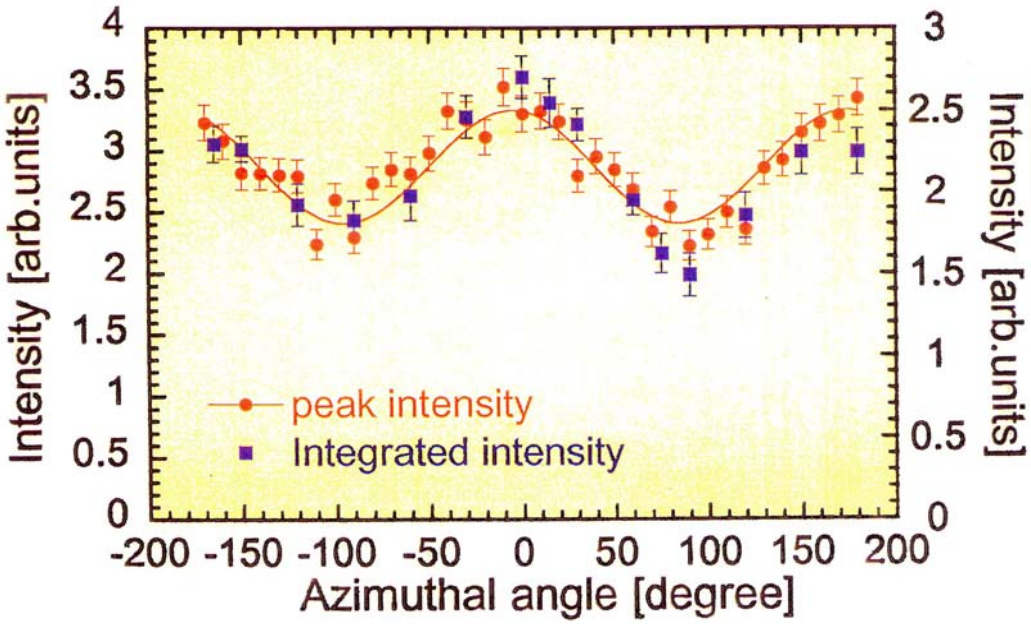
Azimuthal angle dep.

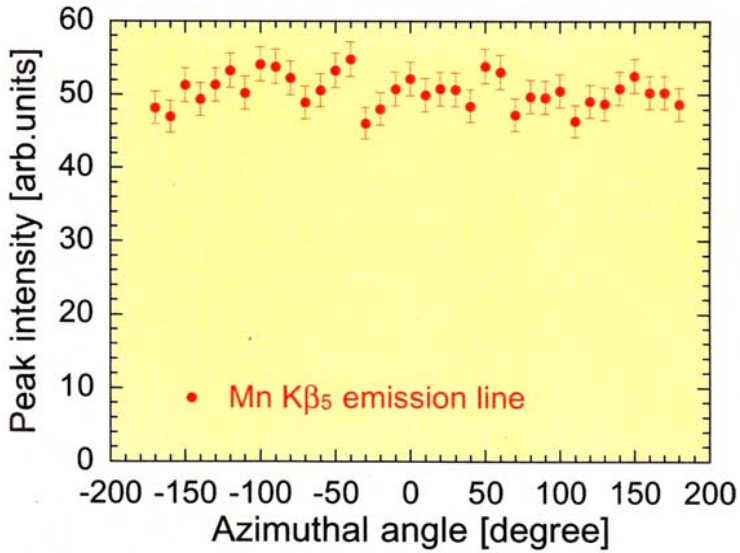
sample rotation about the scattering vector





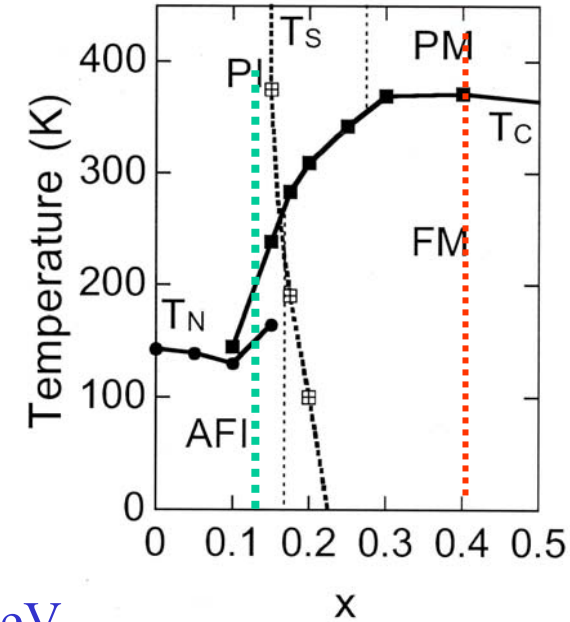
No azimuthal angle dependence of resonant energy !!



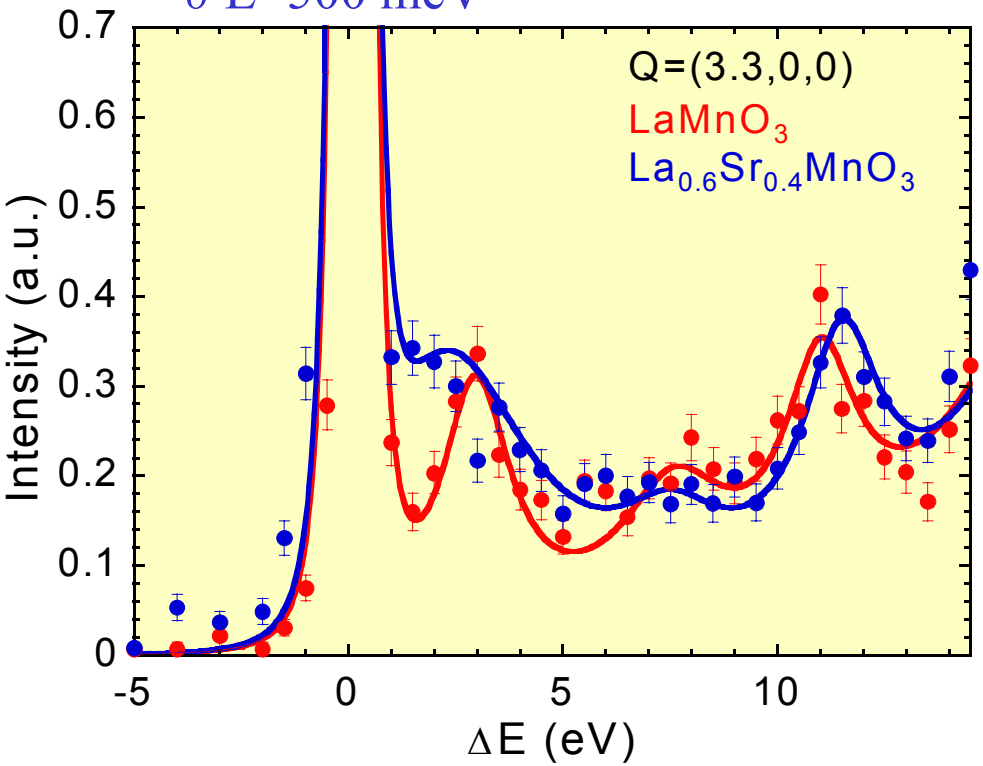


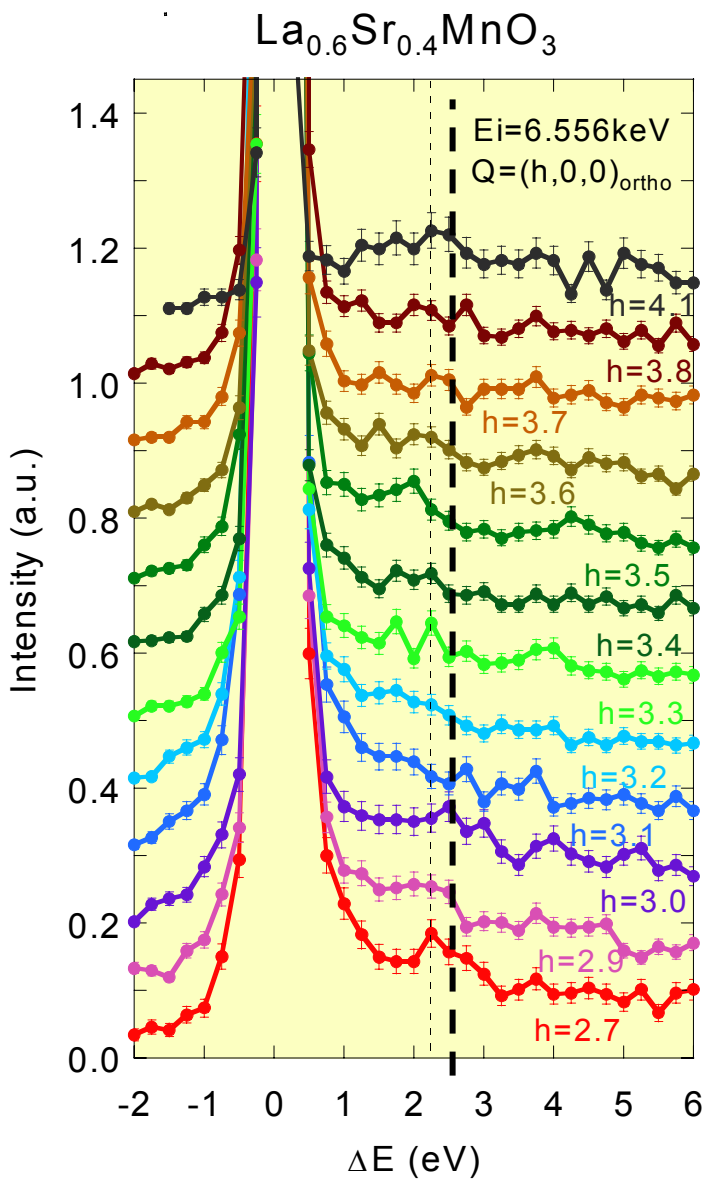
Doping effect

X=0.4



δ E=500 meV





δ E=230meV

Collaborators

T. Inami (JAERI)
K. Ishii (JAERI)
T. Fukuda (JAERI)
J. MIZUKI (JAERI)
K. Ohwada(JAERI)
K. Kuzushita(JAERI)
S. Ishihara (Univ. Tokyo)
H. Kondo (Tohoku Univ.)
S. Maekawa (Tohoku Univ.)
Y. Murakami (Tohoku Univ.)
Y. Endoh (Tohoku Univ.)
K. Hirota (Tohoku Univ.)
H. Nakao (KEK PF)

Theory

Phonons in High Tc superconductors

$La_{2-X}Sr_XCuO_4$

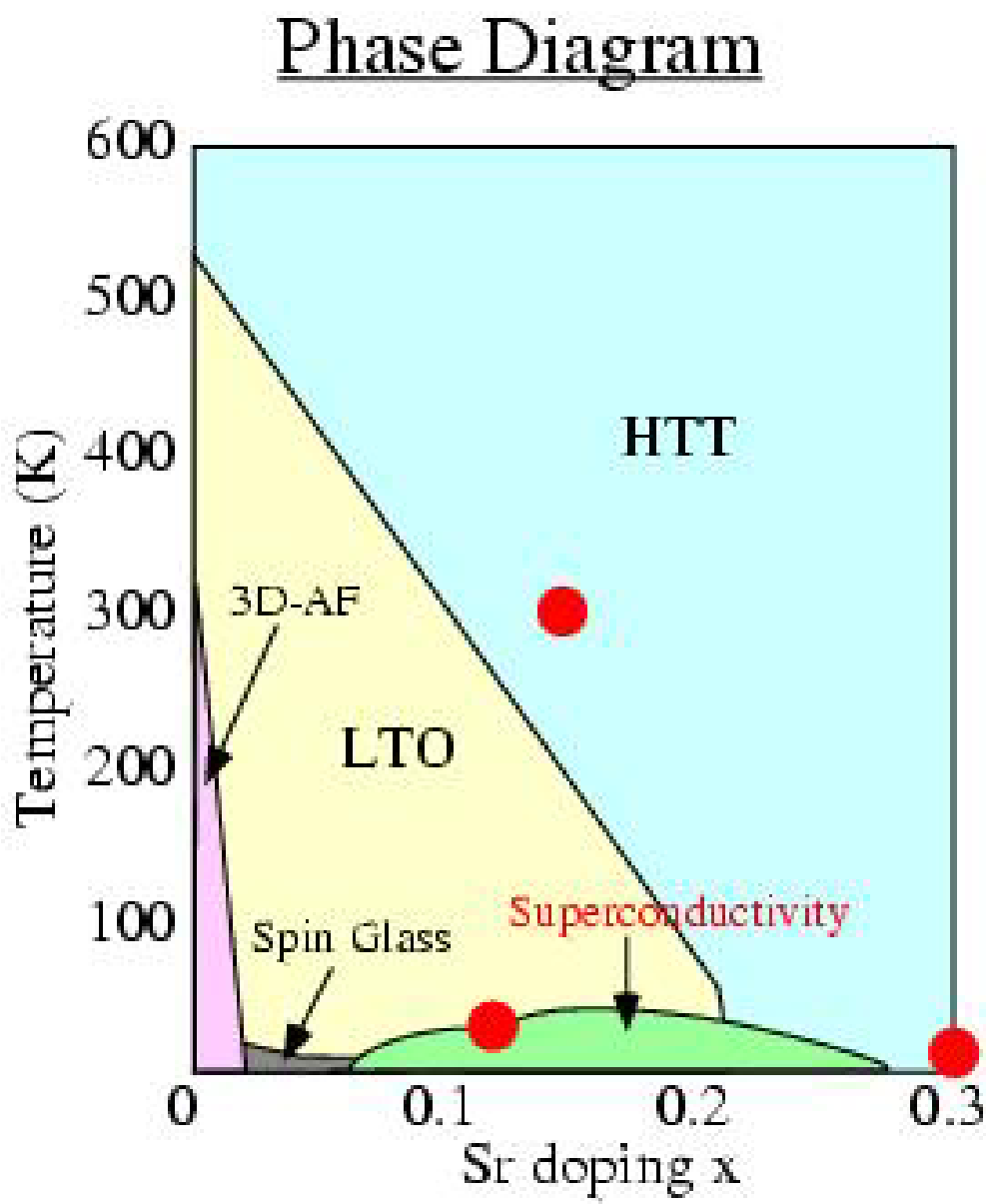
Collaborators

J. Mizuki
T. Fukuda } JAERI

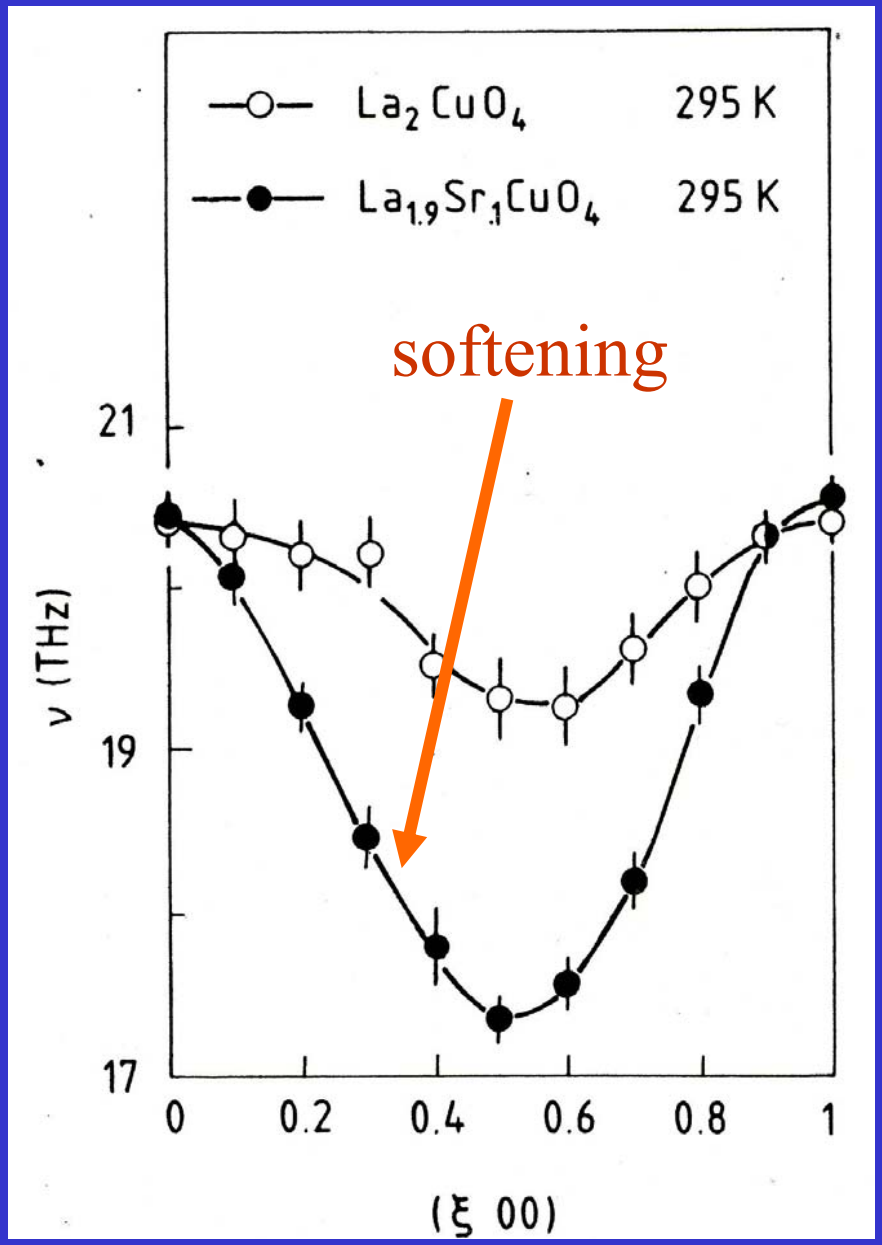
K. Ikeuchi
K. Yamada } Kyoto. U

A. Baron
T. Tsutsui } JASRI

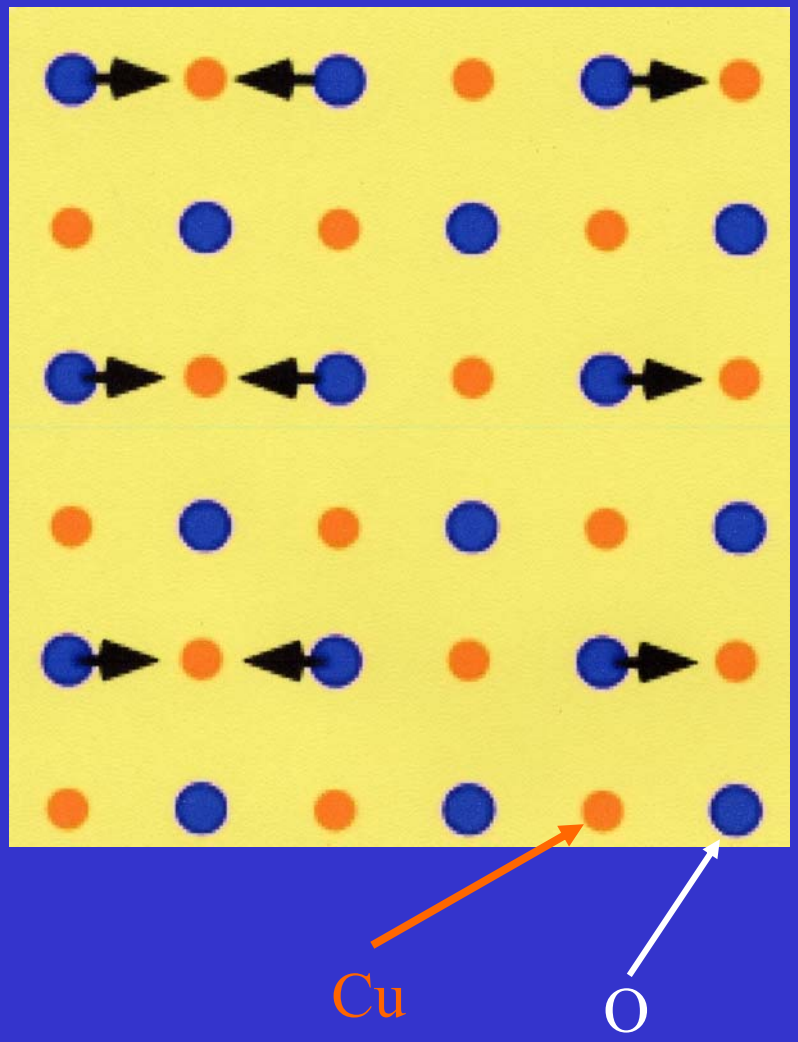
Y. Tanaka — RIKEN



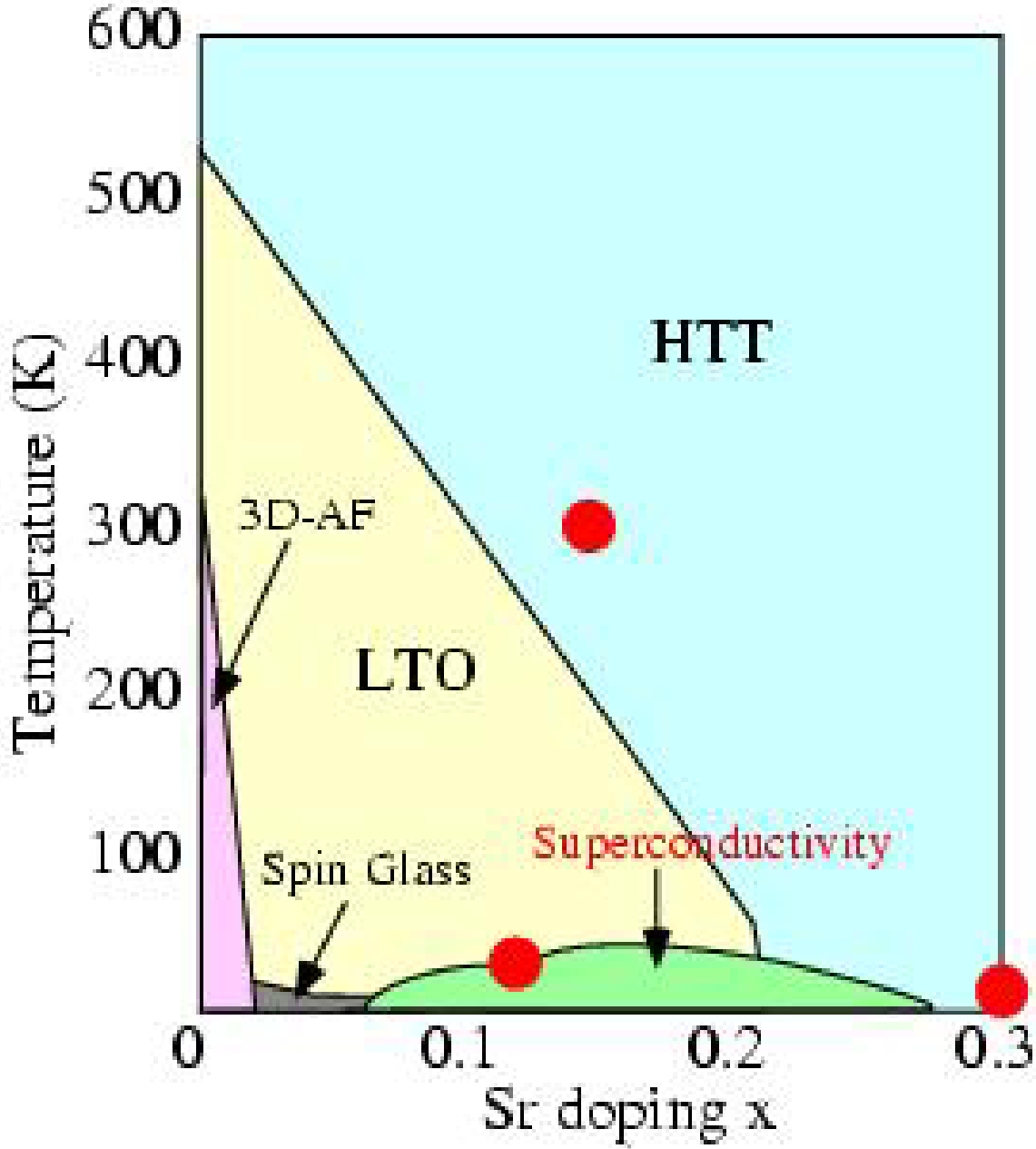
Inelastic Neutron Scattering works for Phonon on LSCO

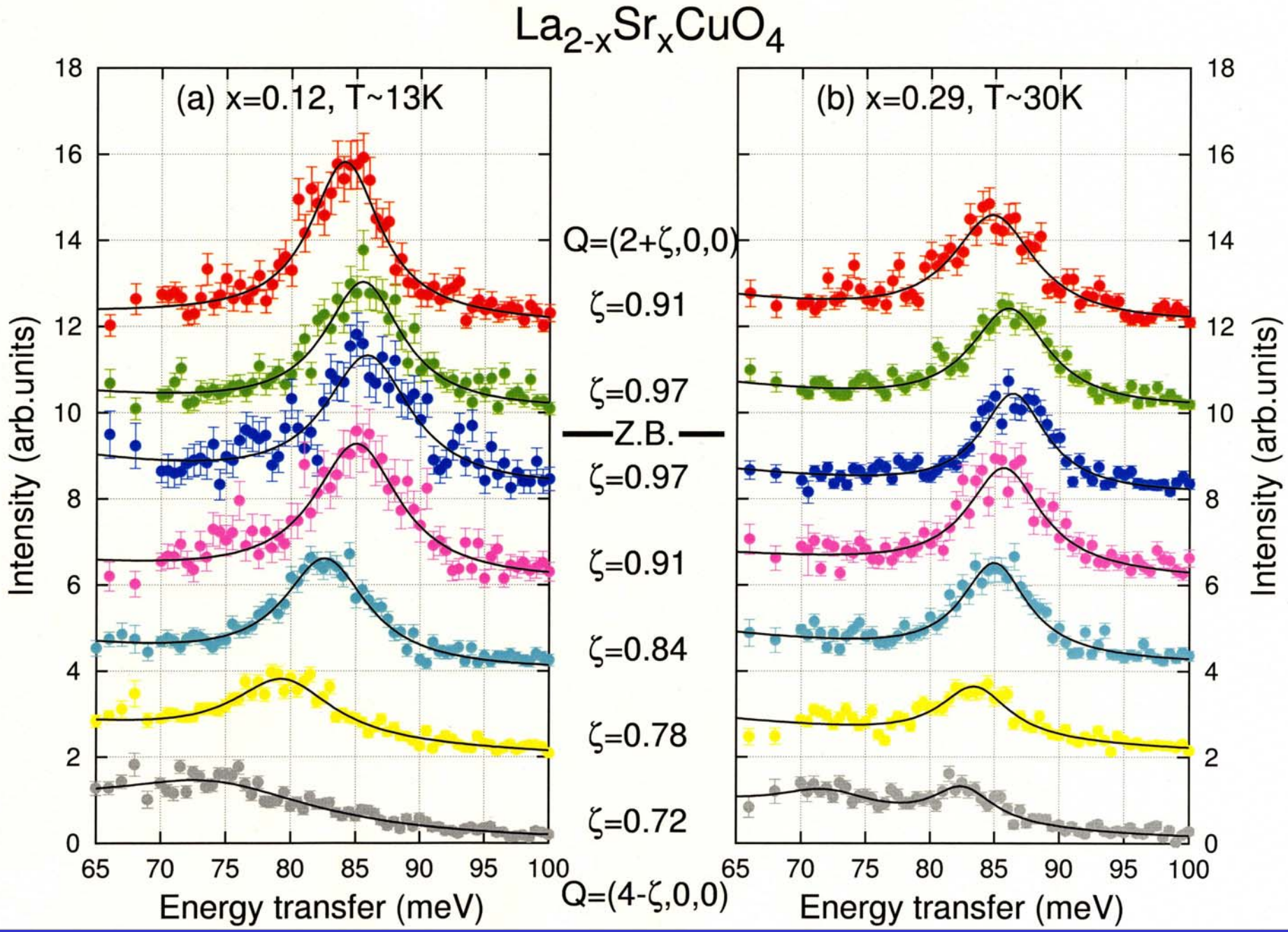


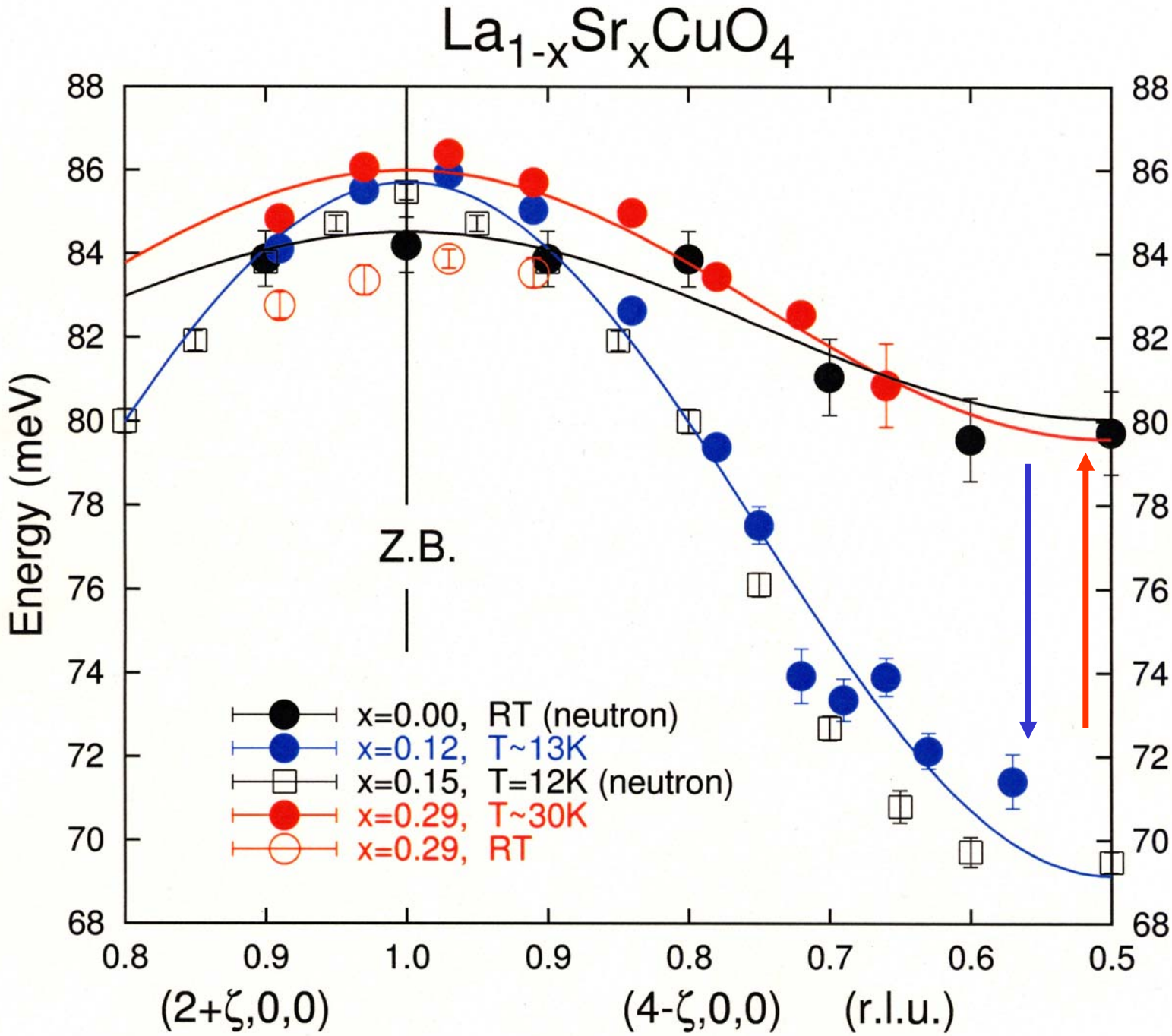
Pintschovius et al., Physica B 174 ('91) 323



Phase Diagram




La2-xSrxCuO4
(a) x=0.12, T~13K
(b) x=0.29, T~30K
Q=(2+ζ,0,0)
ζ=0.91
ζ=0.97
Z.B.
ζ=0.97
ζ=0.91
ζ=0.84
ζ=0.78
ζ=0.72
Q=(4-ζ,0,0)
Intensity (arb.units)
Energy transfer (meV)
0
2
4
6
8
10
12
14
16
18
65
70
75
80
85
90
95
100


La1-xSrxCuO4
Energy (meV)
88
86
84
82
80
78
76
74
72
70
68
Z.B.
x=0.00, RT (neutron)
x=0.12, T~13K
x=0.15, T=12K (neutron)
x=0.29, T~30K
x=0.29, RT
0.8
0.9
1.0
0.9
0.8
0.7
0.6
0.5
(2+ζ,0,0)
(4-ζ,0,0)
(r.l.u.)

In summary

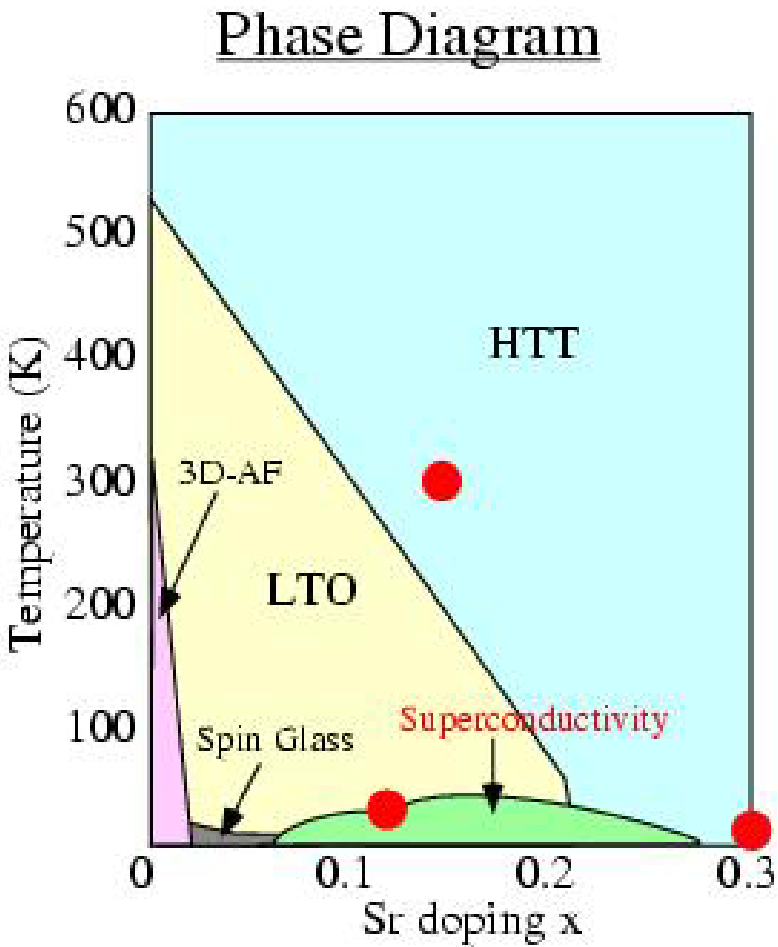
Softening of the LO-bond stretching mode is strongly related to the superconducting propertties !!

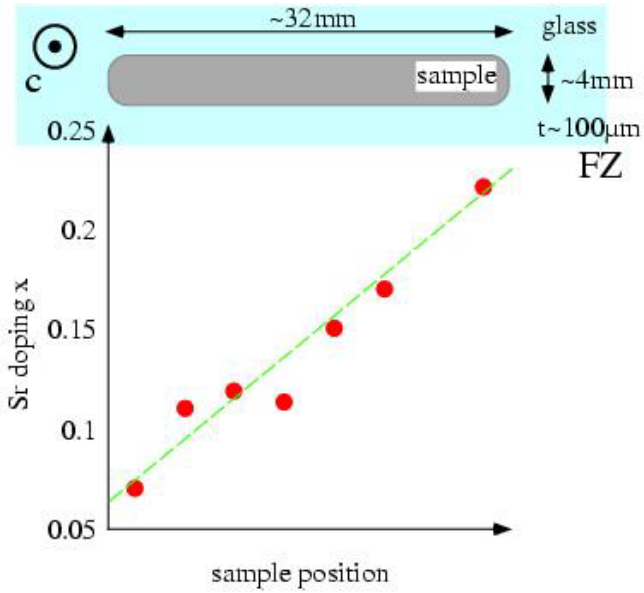
↓

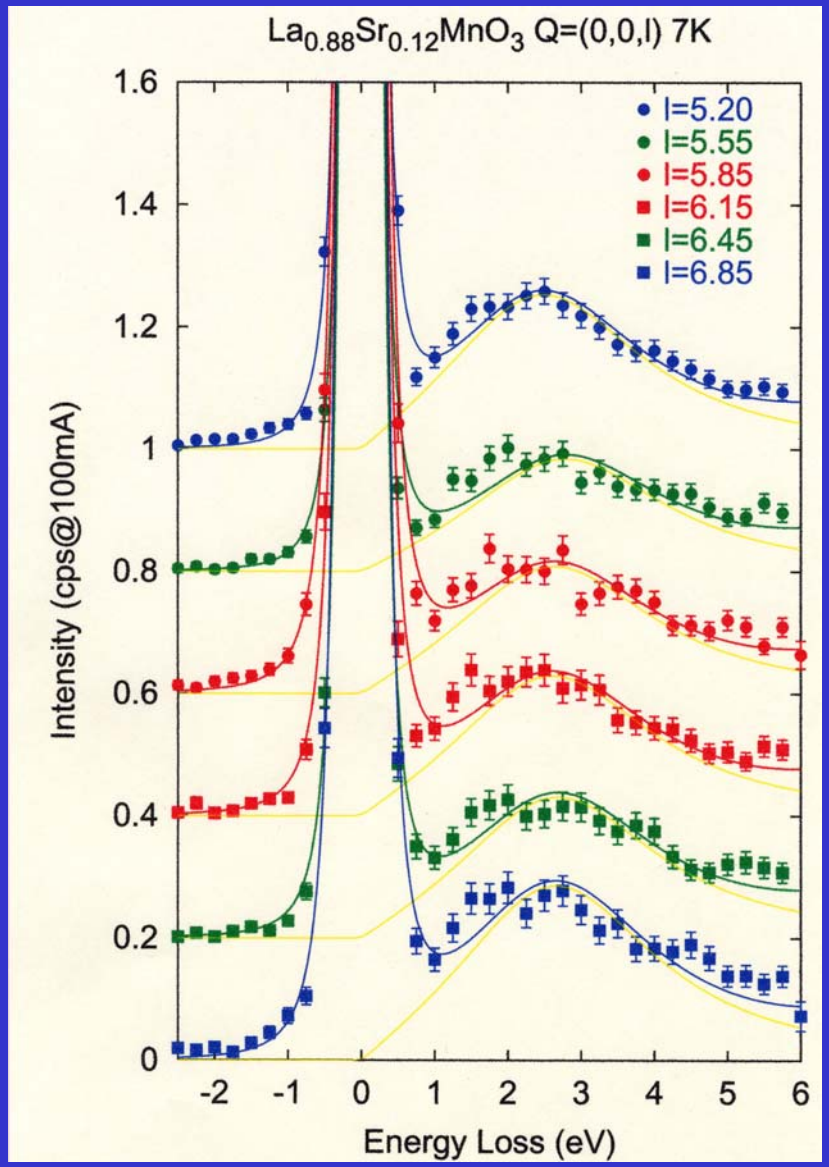
Electron-Phonon coupling mechanism !?

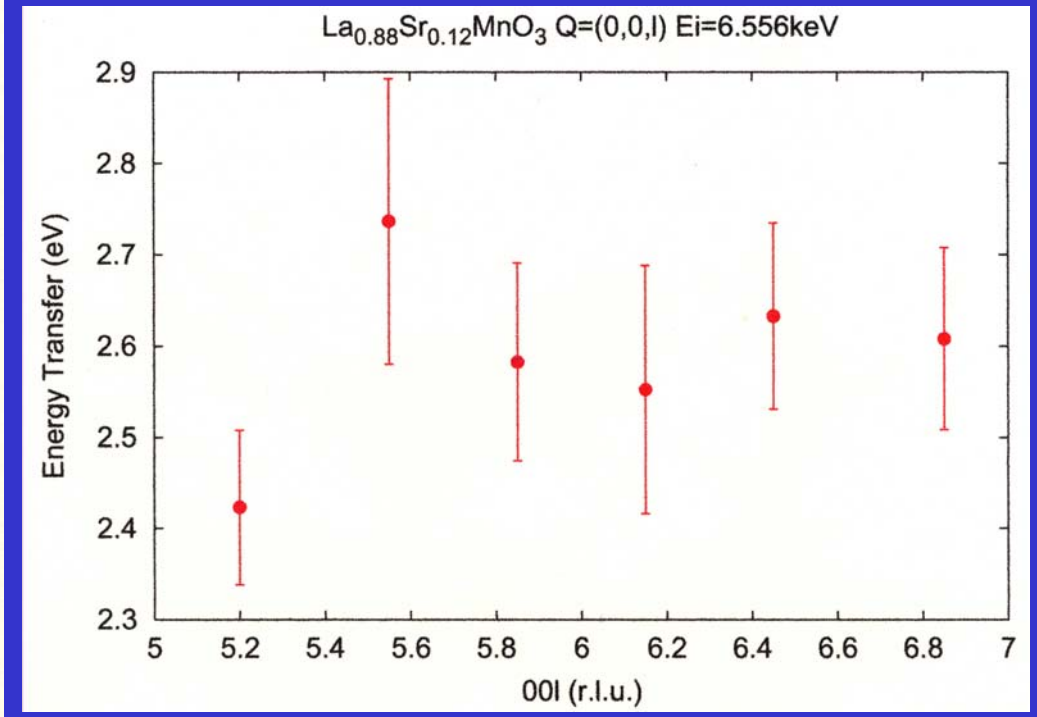
Phonons in High Tc superconductors

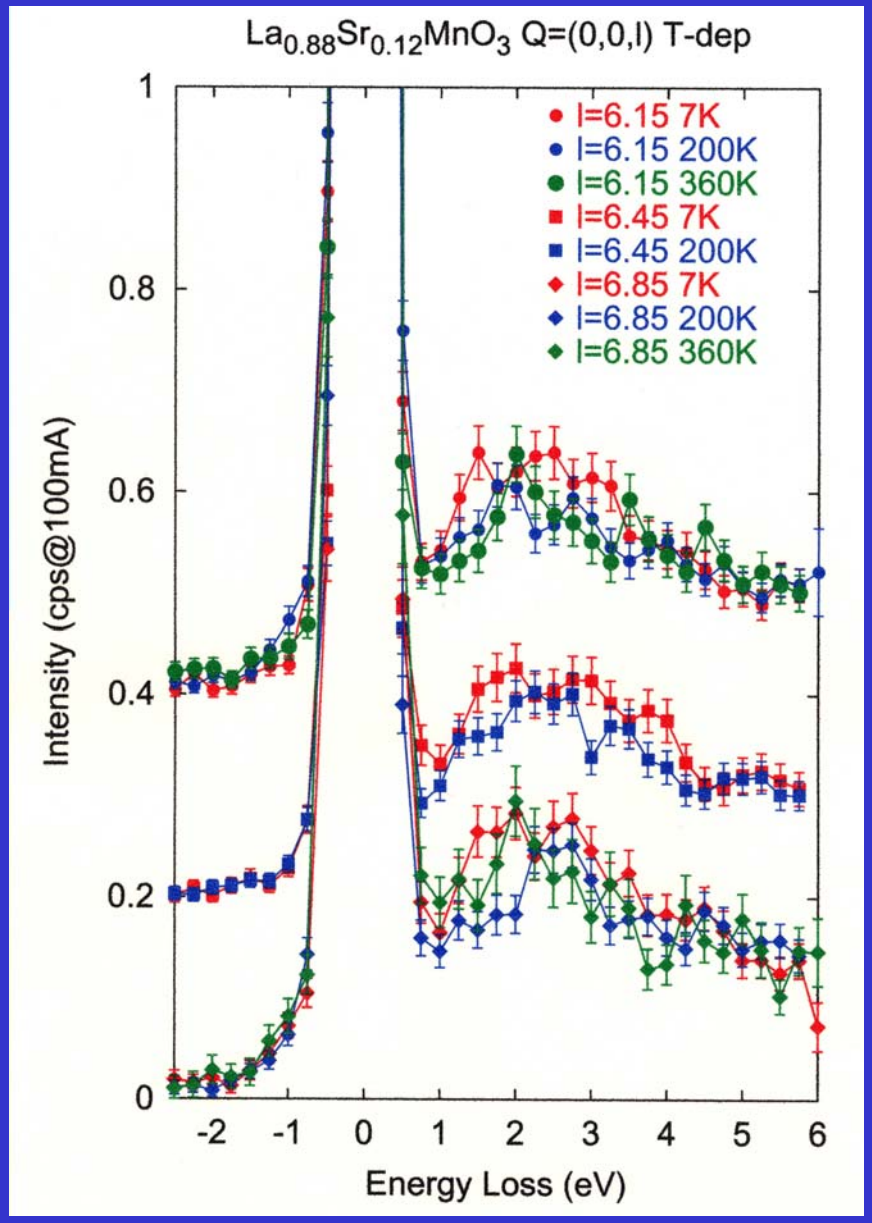
Sample : $La_{2-X}Sr_XCuO_4$ by Yamada Gr. of Kyoto Univ.

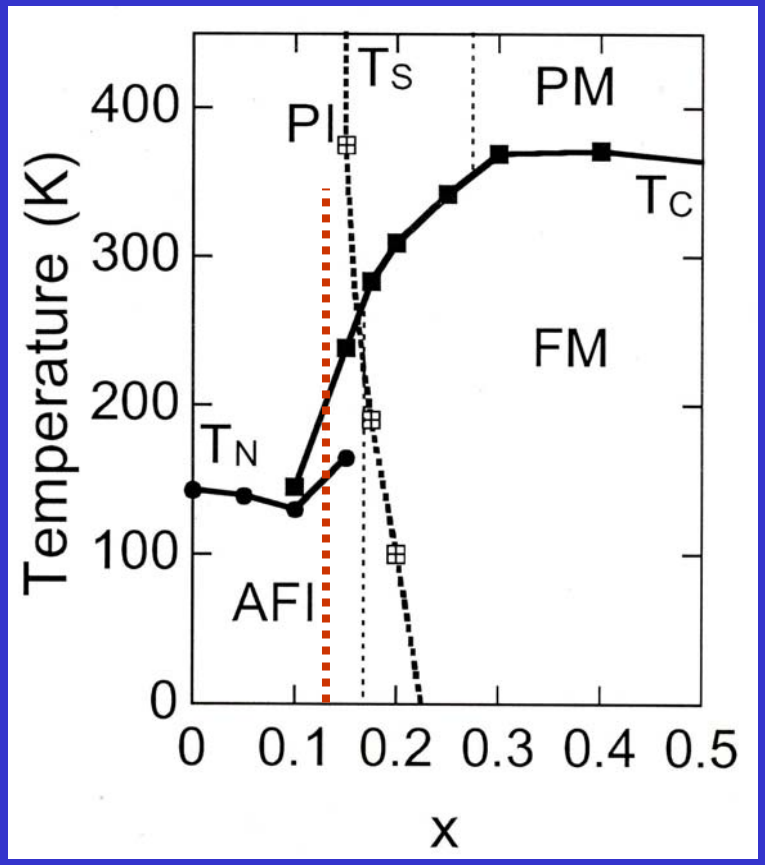




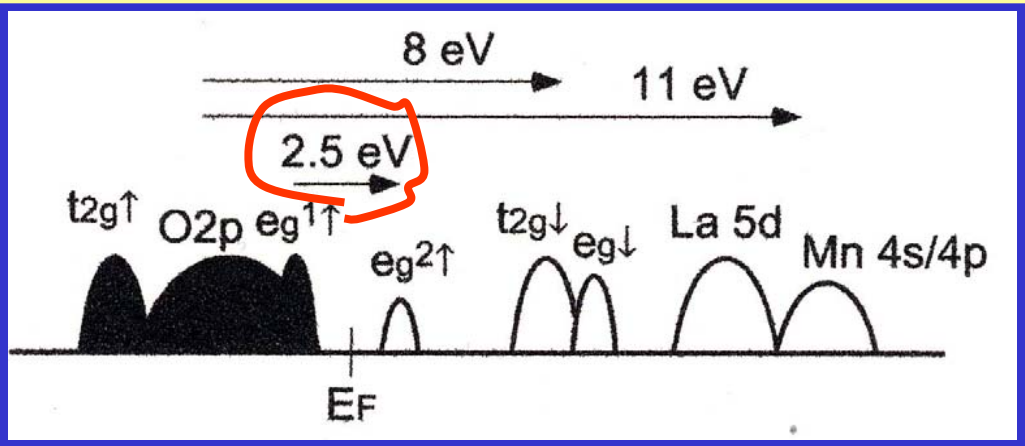

La0.88Sr0.12MnO3 Q=(0,0,l) 7K
l=5.20
l=5.55
l=5.85
l=6.15
l=6.45
l=6.85
Intensity (cps@100mA)
Energy Loss (eV)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-2
-1
0
1
2
3
4
5
6

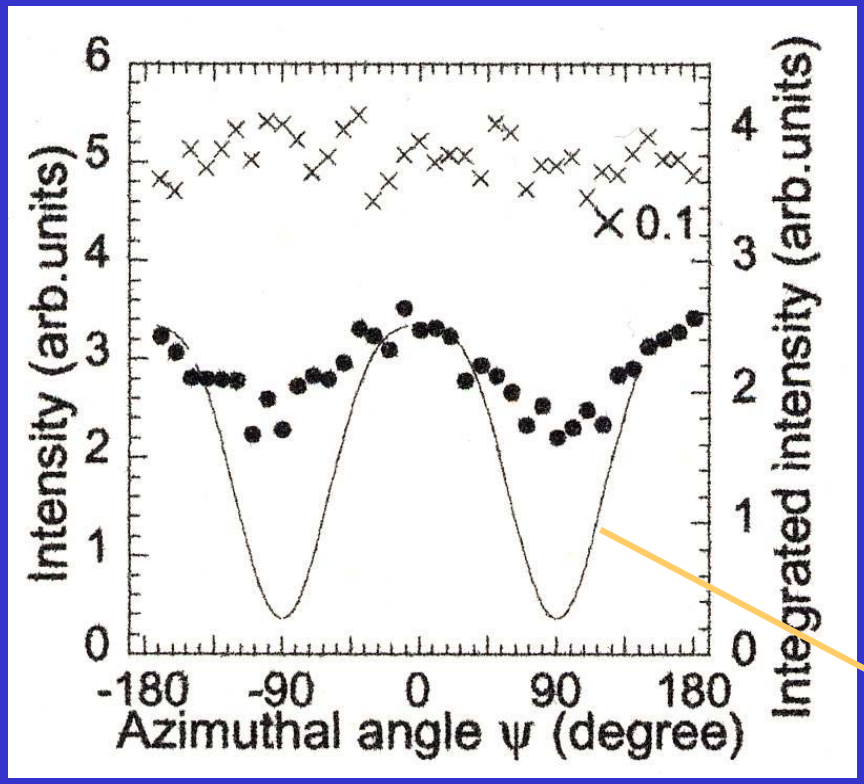

La0.88Sr0.12MnO3 Q=(0,0,l) Ei=6.556keV
Energy Transfer (eV)
00l (r.l.u.)
2.9
2.8
2.7
2.6
2.5
2.4
2.3
5
5.2
5.4
5.6
5.8
6
6.2
6.4
6.6
6.8
7

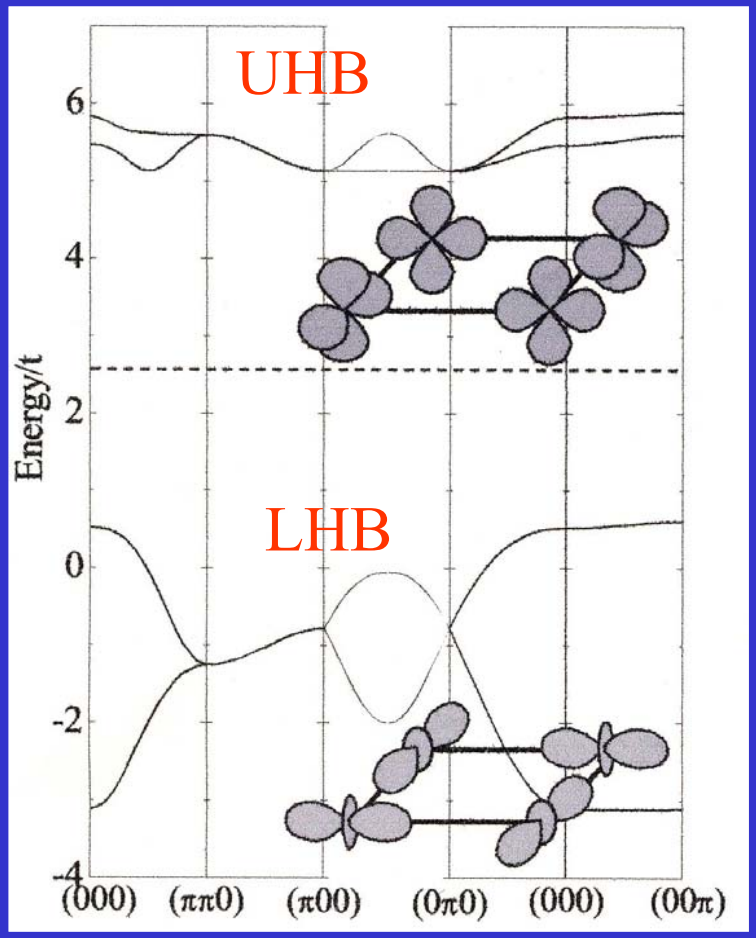

La0.88Sr0.12MnO3 Q=(0,0,l) T-dep
l=6.15 7K
l=6.15 200K
l=6.15 360K
l=6.45 7K
l=6.45 200K
l=6.85 7K
l=6.85 200K
l=6.85 360K
Intensity (cps@100mA)
Energy Loss (eV)
0
0.2
0.4
0.6
0.8
1
-2
-1
0
1
2
3
4
5
6


Temperature (K)
x
TS
PM
PI
TC
FM
TN
AFI
0
100
200
300
400
0
0.1
0.2
0.3
0.4
0.5

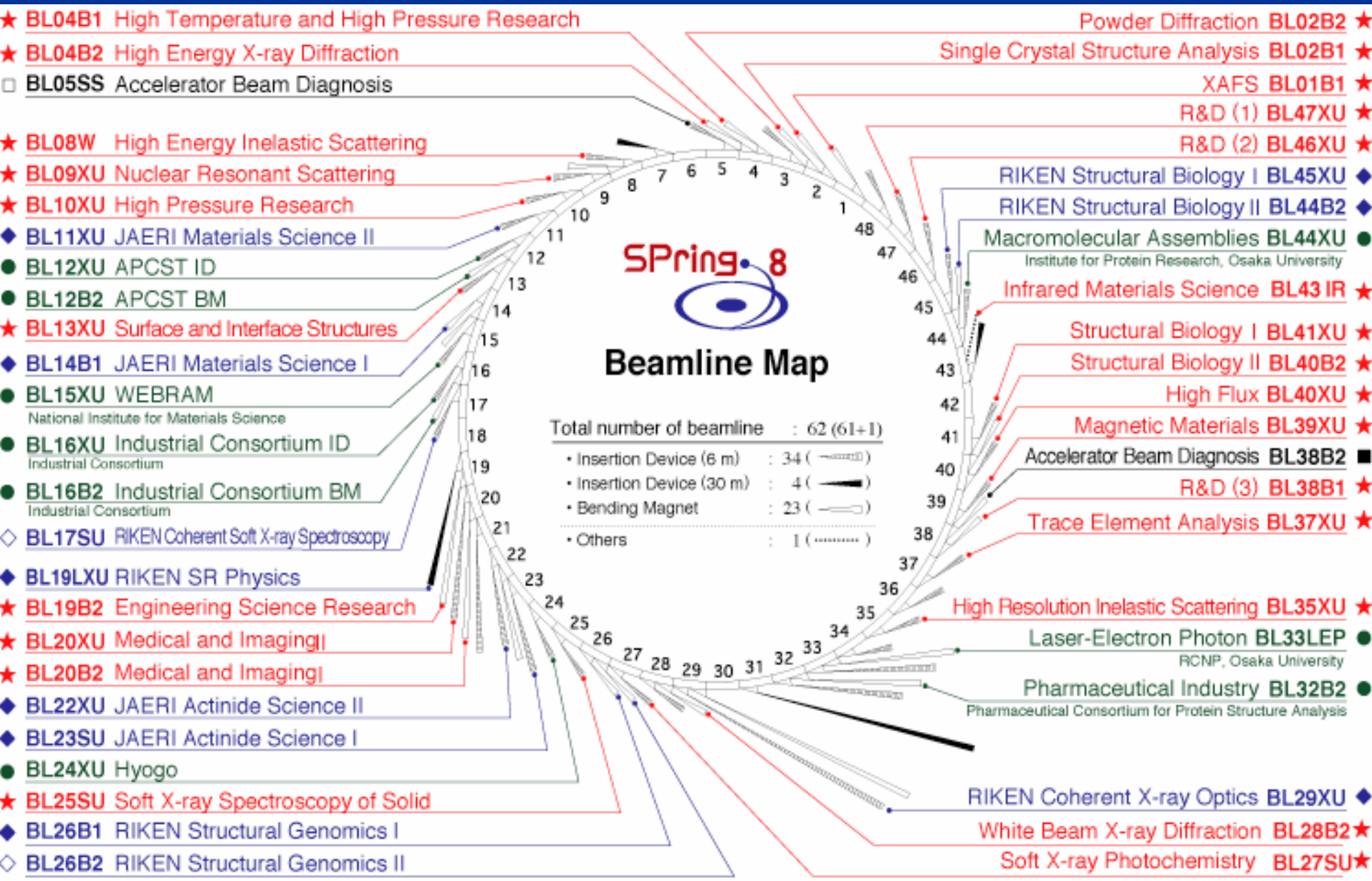
Theoretical work by Ishihara, Kondo and Maekawa







calculation


SPring-8
Beamline Map
Total number of beamline : 62 (61+1)
• Insertion Device (6 m) : 34
• Insertion Device (30 m) : 4
• Bending Magnet : 23
• Others : 1
BL04B1 High Temperature and High Pressure Research
BL04B2 High Energy X-ray Diffraction
BL05SS Accelerator Beam Diagnosis
BL08W High Energy Inelastic Scattering
BL09XU Nuclear Resonant Scattering
BL10XU High Pressure Research
BL11XU JAERI Materials Science II
BL12XU APCST ID
BL12B2 APCST BM
BL13XU Surface and Interface Structures
BL14B1 JAERI Materials Science I
BL15XU WEBRAM
National Institute for Materials Science
BL16XU Industrial Consortium ID
Industrial Consortium
BL16B2 Industrial Consortium BM
Industrial Consortium
BL17SU RIKEN Coherent Soft X-ray Spectroscopy
BL19LXU RIKEN SR Physics
BL19B2 Engineering Science Research
BL20XU Medical and Imaging II
BL20B2 Medical and Imaging I
BL22XU JAERI Actinide Science II
BL23SU JAERI Actinide Science I
BL24XU Hyogo
BL25SU Soft X-ray Spectroscopy of Solid
BL26B1 RIKEN Structural Genomics I
BL26B2 RIKEN Structural Genomics II
Powder Diffraction BL02B2
Single Crystal Structure Analysis BL02B1
XAFS BL01B1
R&D (1) BL47XU
R&D (2) BL46XU
RIKEN Structural Biology I BL45XU
RIKEN Structural Biology II BL44B2
Macromolecular Assemblies BL44XU
Institute for Protein Research, Osaka University
Infrared Materials Science BL43 IR
Structural Biology I BL41XU
Structural Biology II BL40B2
High Flux BL40XU
Magnetic Materials BL39XU
Accelerator Beam Diagnosis BL38B2
R&D (3) BL38B1
Trace Element Analysis BL37XU
High Resolution Inelastic Scattering BL35XU
Laser-Electron Photon BL33LEP
RCNP, Osaka University
Pharmaceutical Industry BL32B2
Pharmaceutical Consortium for Protein Structure Analysis
RIKEN Coherent X-ray Optics BL29XU
White Beam X-ray Diffraction BL28B2
Soft X-ray Photochemistry BL27SU