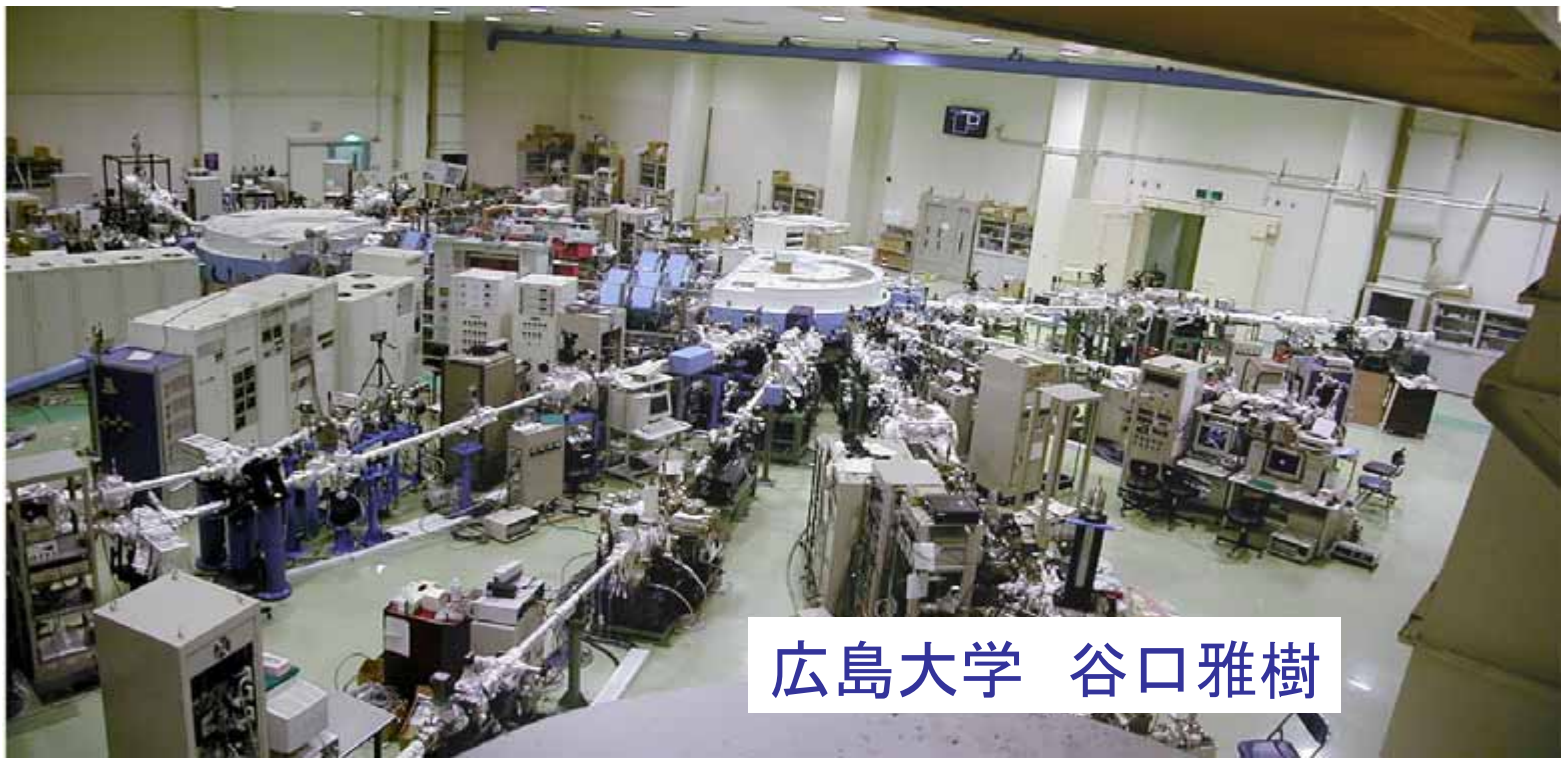
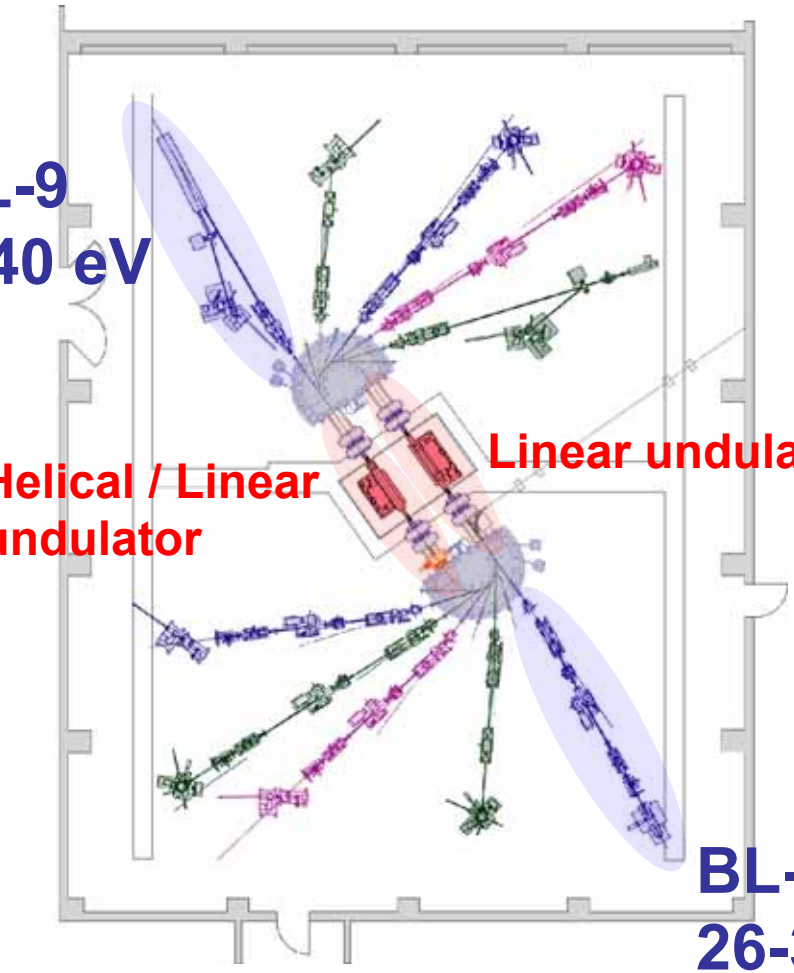
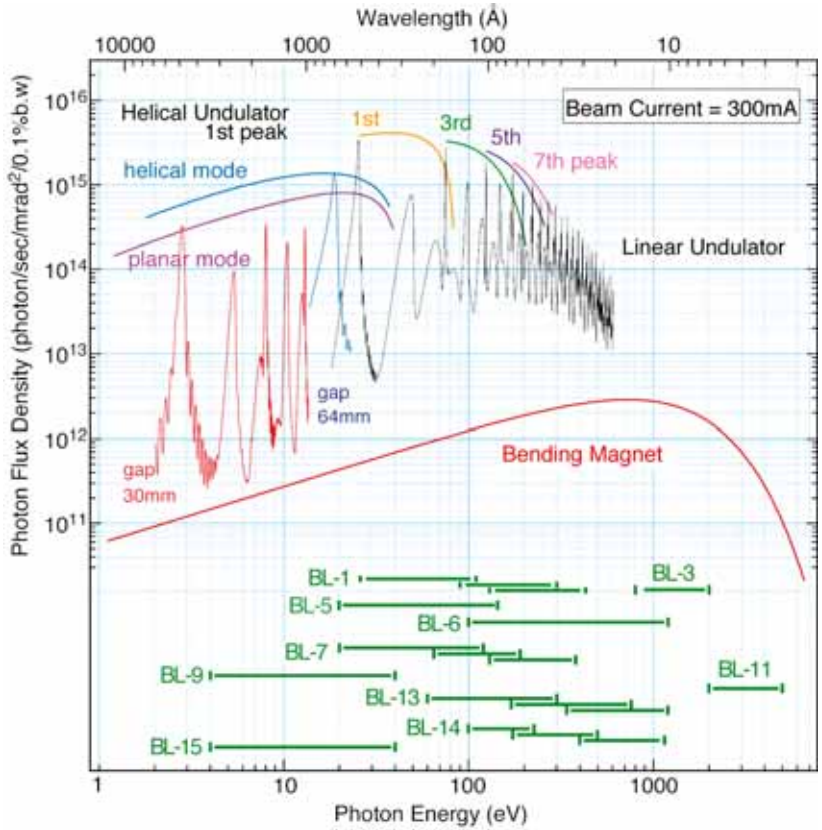
極低エネルギーで見るバルク電子状態



Layout of light source and beamlines

Hiroshima Synchrotron Radiation Center
Hiroshima University





700 MeV

Max. current: I_b = 350 mA

Advantage of Low-Energy SR Photoemission Spectroscopy

$h\nu < 15$ eV

Bulk Sensitivity

Escape depth ~ 50 Å (kinetic energy ~4 eV)

- Information intrinsic to bulk

High energy and momentum resolutions

ΔE_{tot} : 600-700 μeV $\Delta k : 4 \times 10^{-3}$ Å^{-1}

- Fine structures near the Fermi level

Tunability of excitation photons

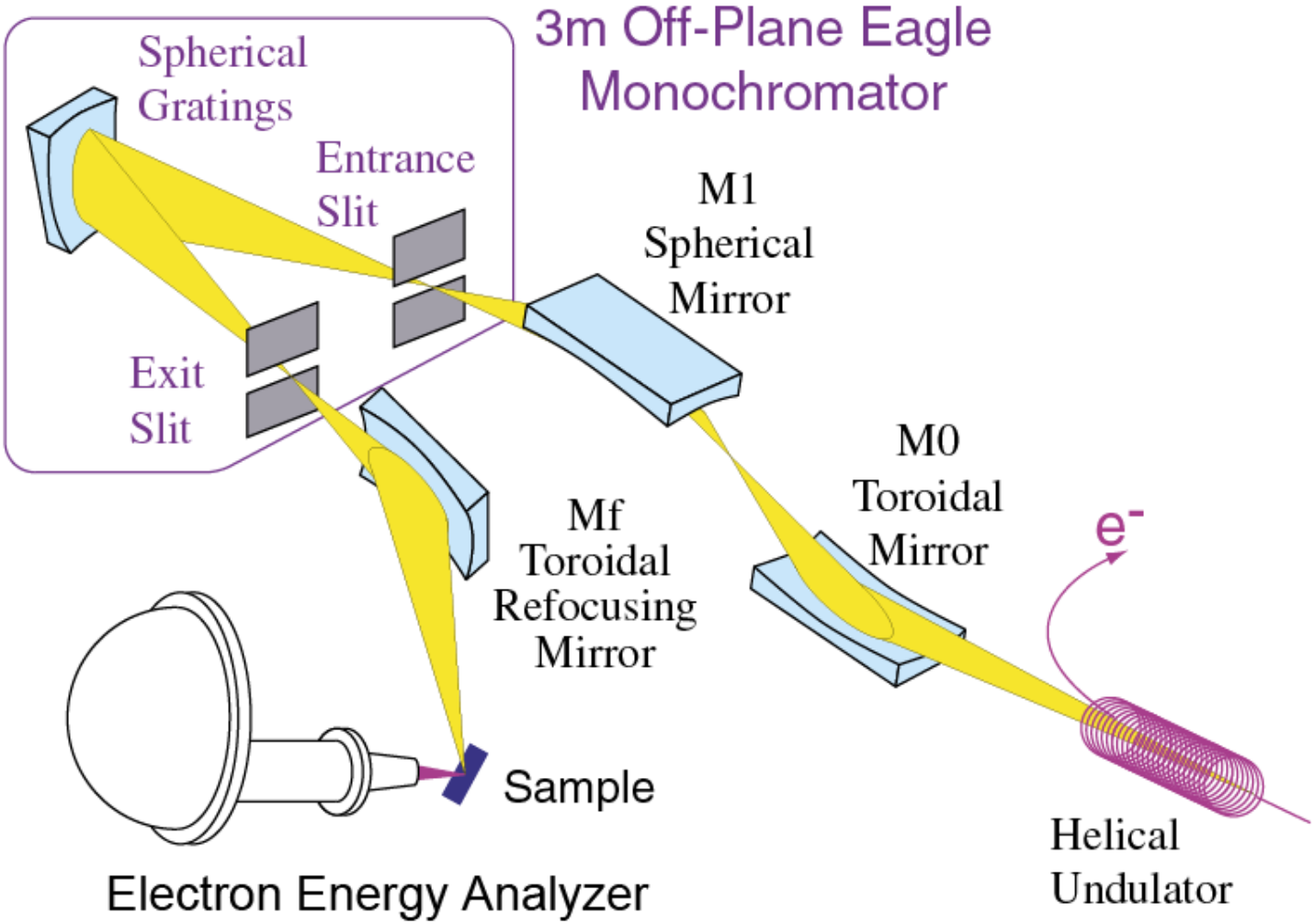
ΔE_{ph} : 230 μeV @ 7 eV

- Selective observation of specific electronic states using matrix-element effect

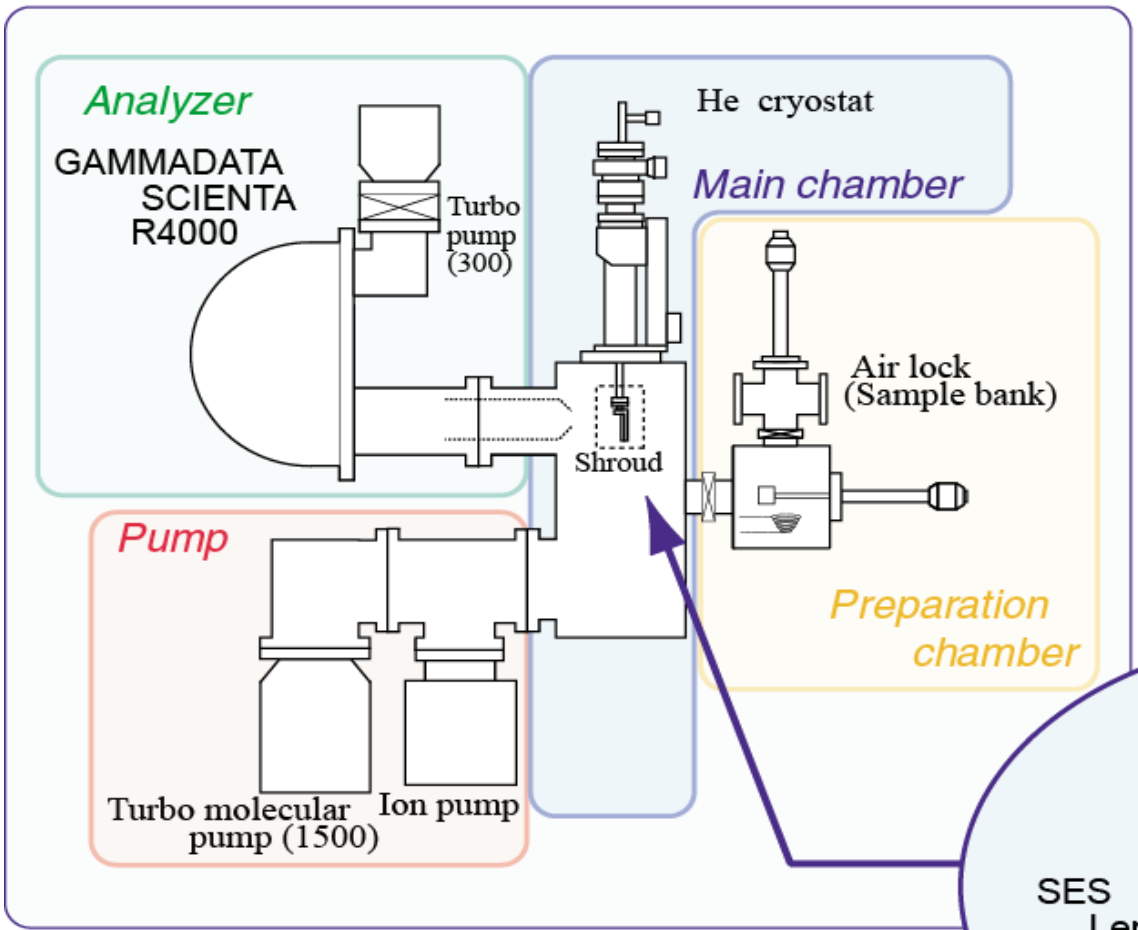
HiSOR BL-9

Energy Range
3.5 ~ 35 eV

hν=7eV
ΔE=0.23meV

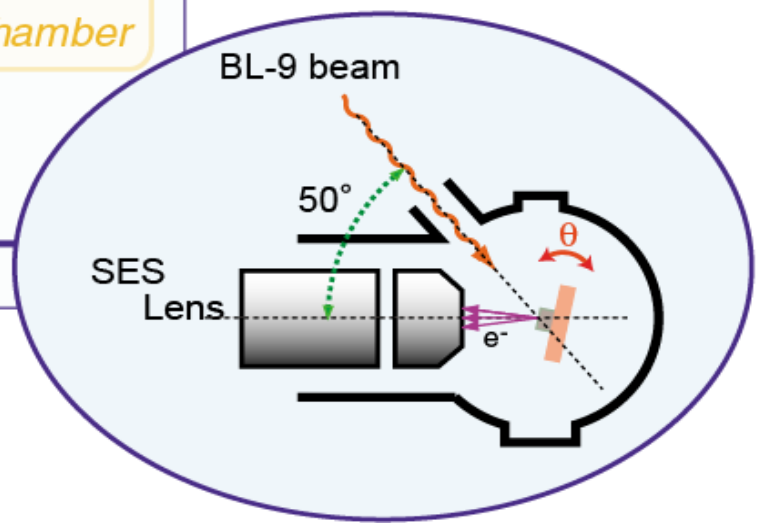


End Station



Main cham.
7×10^{-11} Torr
5axes manipulator
He refrigerator
(4.8～400K)
LEED

Preparation cham.
4×10^{-10} Torr
heating up to 1000 °C
Ar^+ sputtering



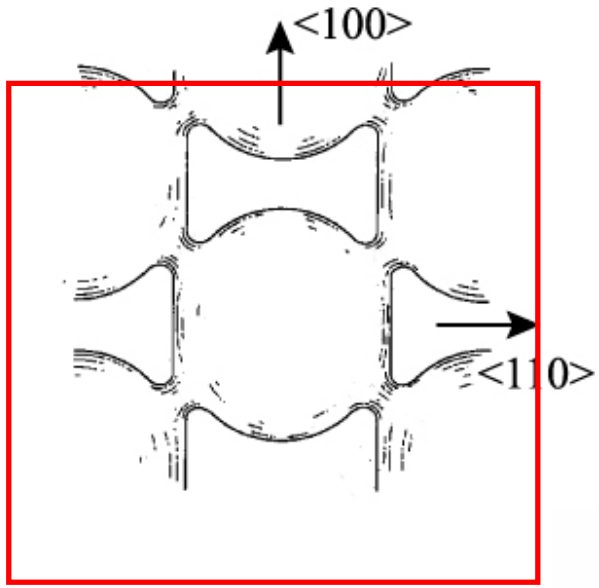
Configuration : Top View

Fermi surface of Cu

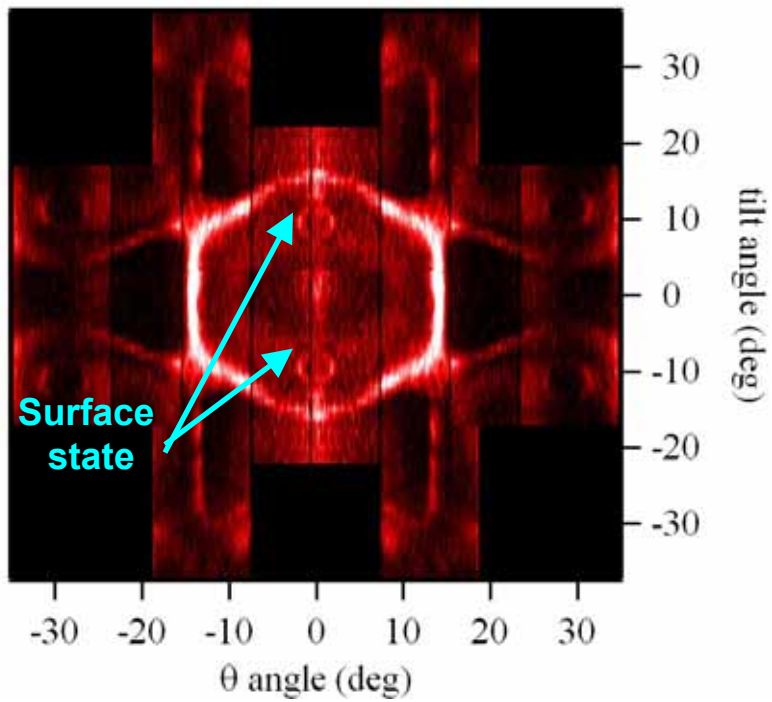
θ

ϕ

5-axes manipulator
4.8 – 400 K



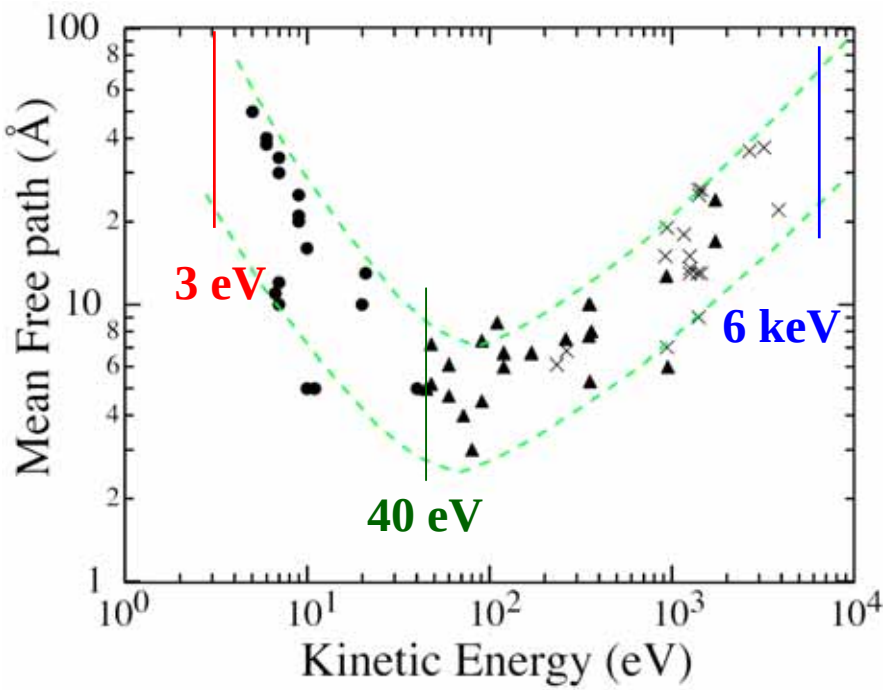
Calculation



hv=102 eV, DE=40 meV, T=140 K, 120 spectra

BL-1

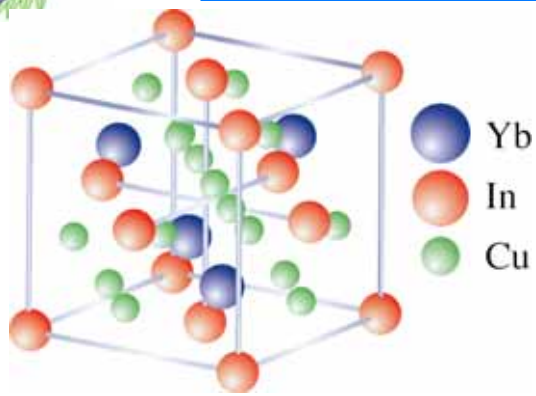
Escape Depth



Observation of electronic structures intrinsic to the bulk.

Low-energy PES **Hard x-ray PES**

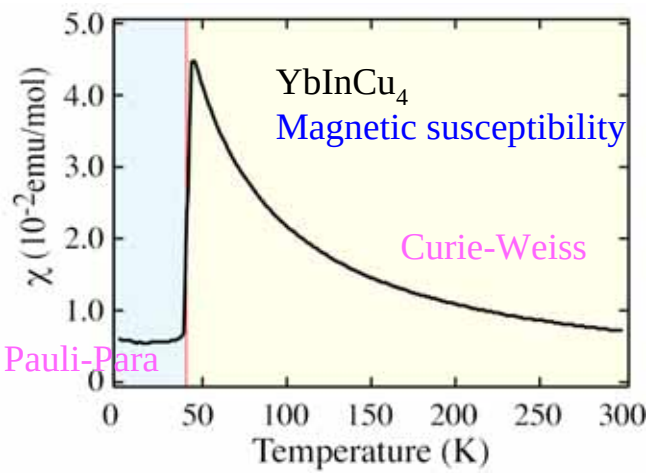
Valence transition in $YbInCu_4$



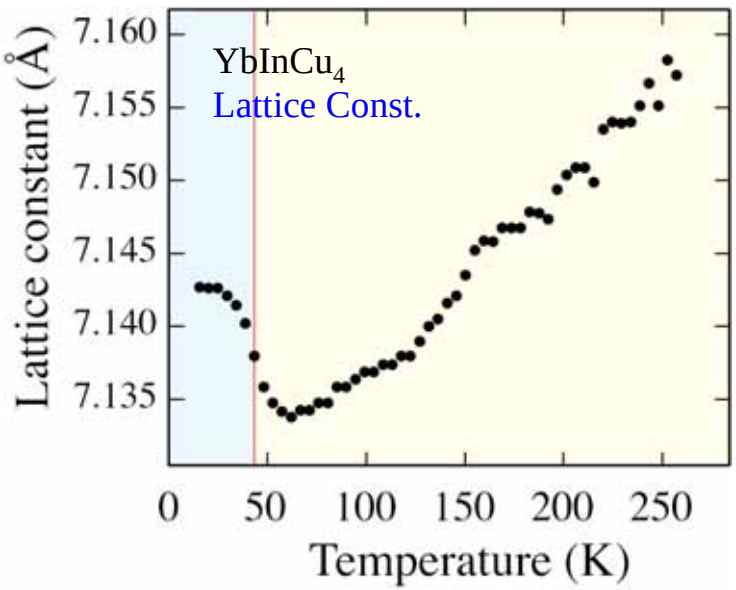
C15b-type

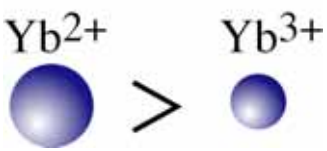
No change at T_V

T_K~400 K T_K~25 K



z~2.9 z~3

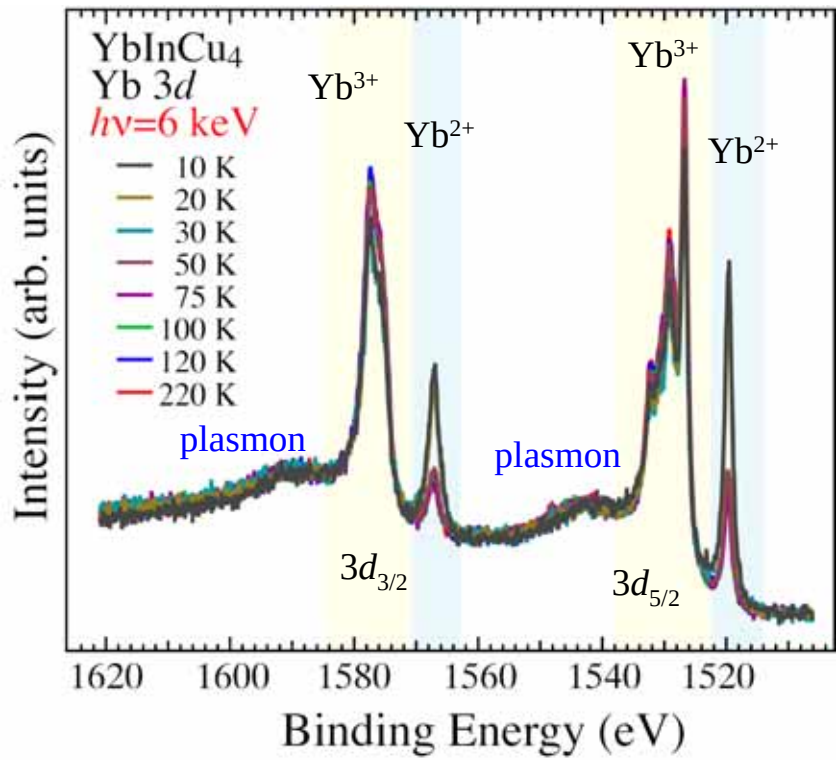




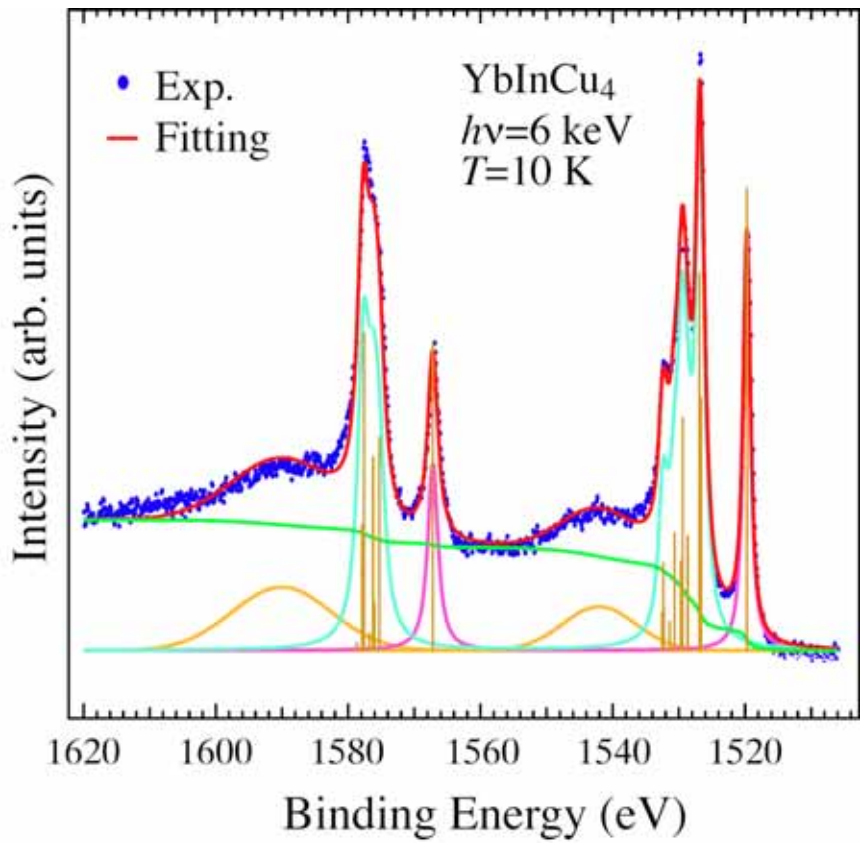
Valence transition at T_V=42 K

Valence Determination by Yb 3d PES Spectra

Yb 3*d* HX-PES

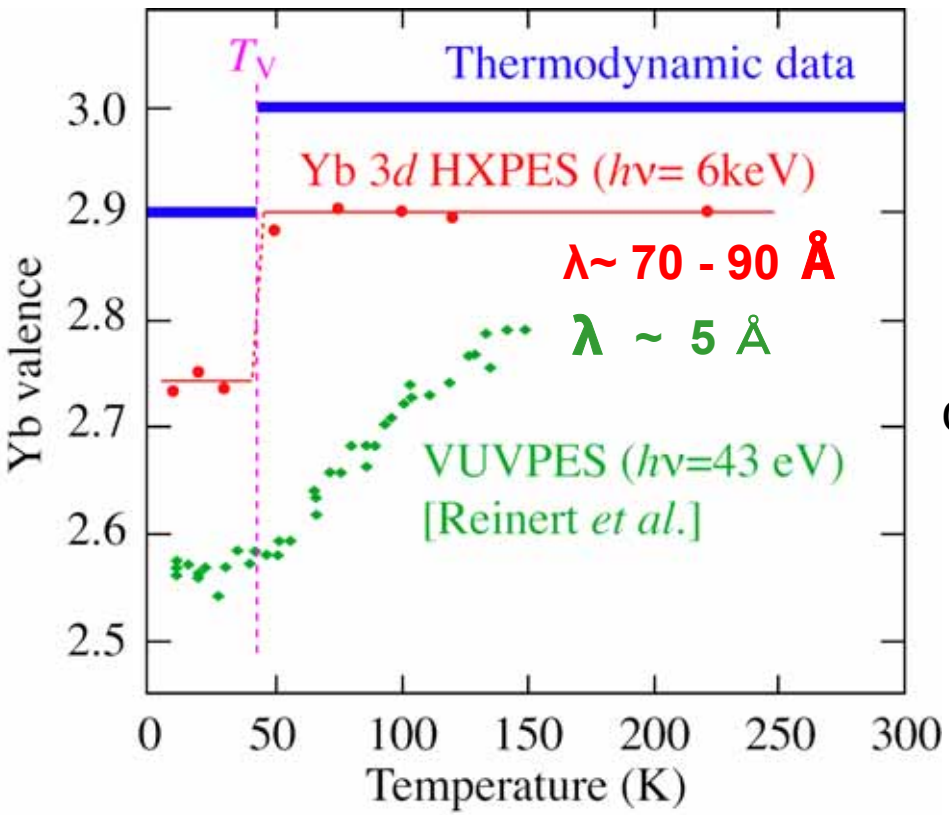


Fitting Analysis of Yb 3*d* HX-PES



Sharp change is observed at ~T_V

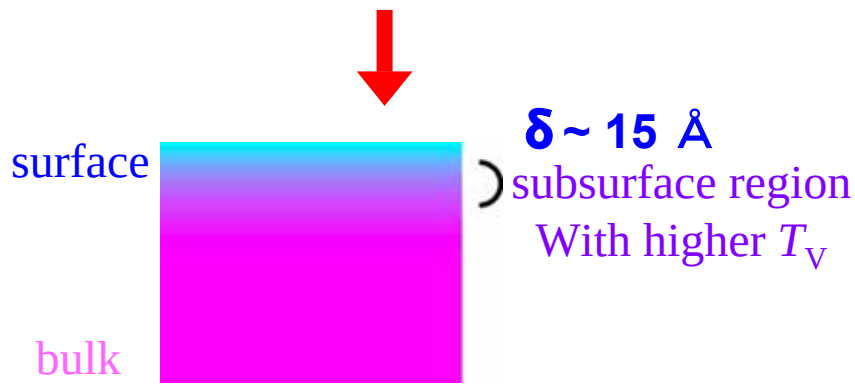
Temperature dependence of Yb valence



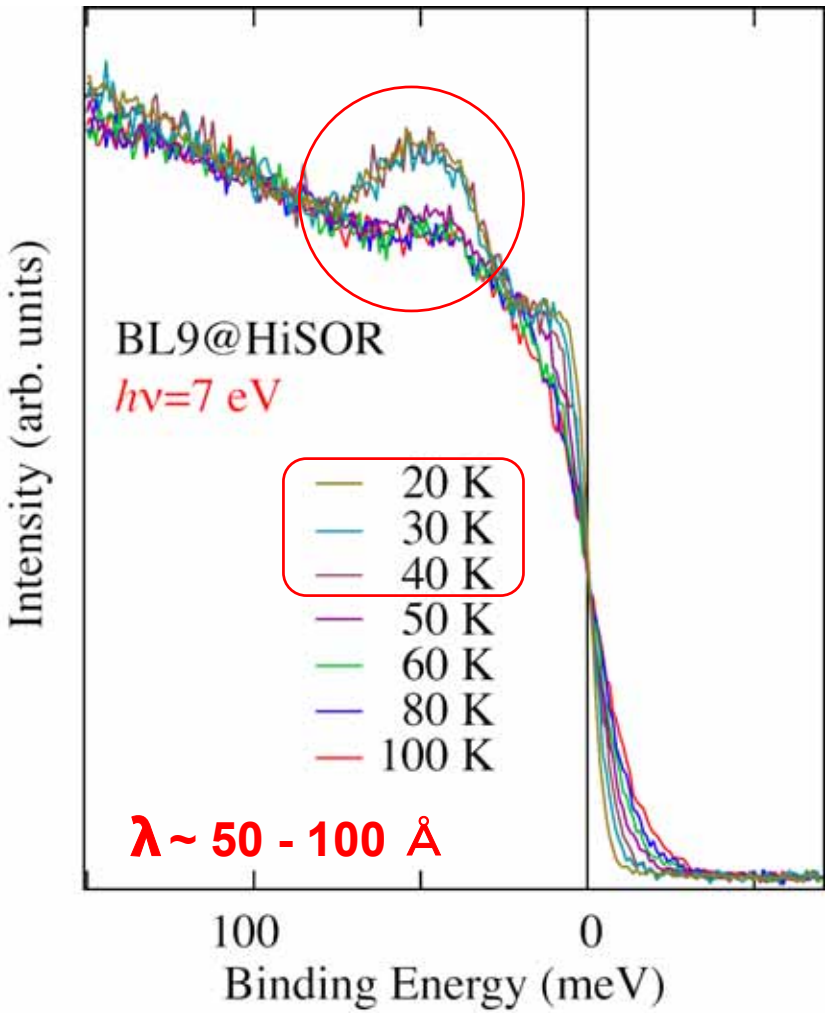
With increasing probing depth
change at T_V : sharper
Yb valence : close to 3+

Yb 3*d* HX-PES is suitable
for the Yb valence determination

Gradual decrease of Yb valence in HT phase



Observation of *c-f* hybridization by LE-PES



Low-Temperature (LE) phase
new structure @ 47 meV

↓

***c-f* hybridization increases at LT phase**
(In 5*p* – Yb 4*f*)

47 meV ⟹ **correspond to $k_B T_K$**
T_K ~ 400 K

↓

Kondo resonance peak

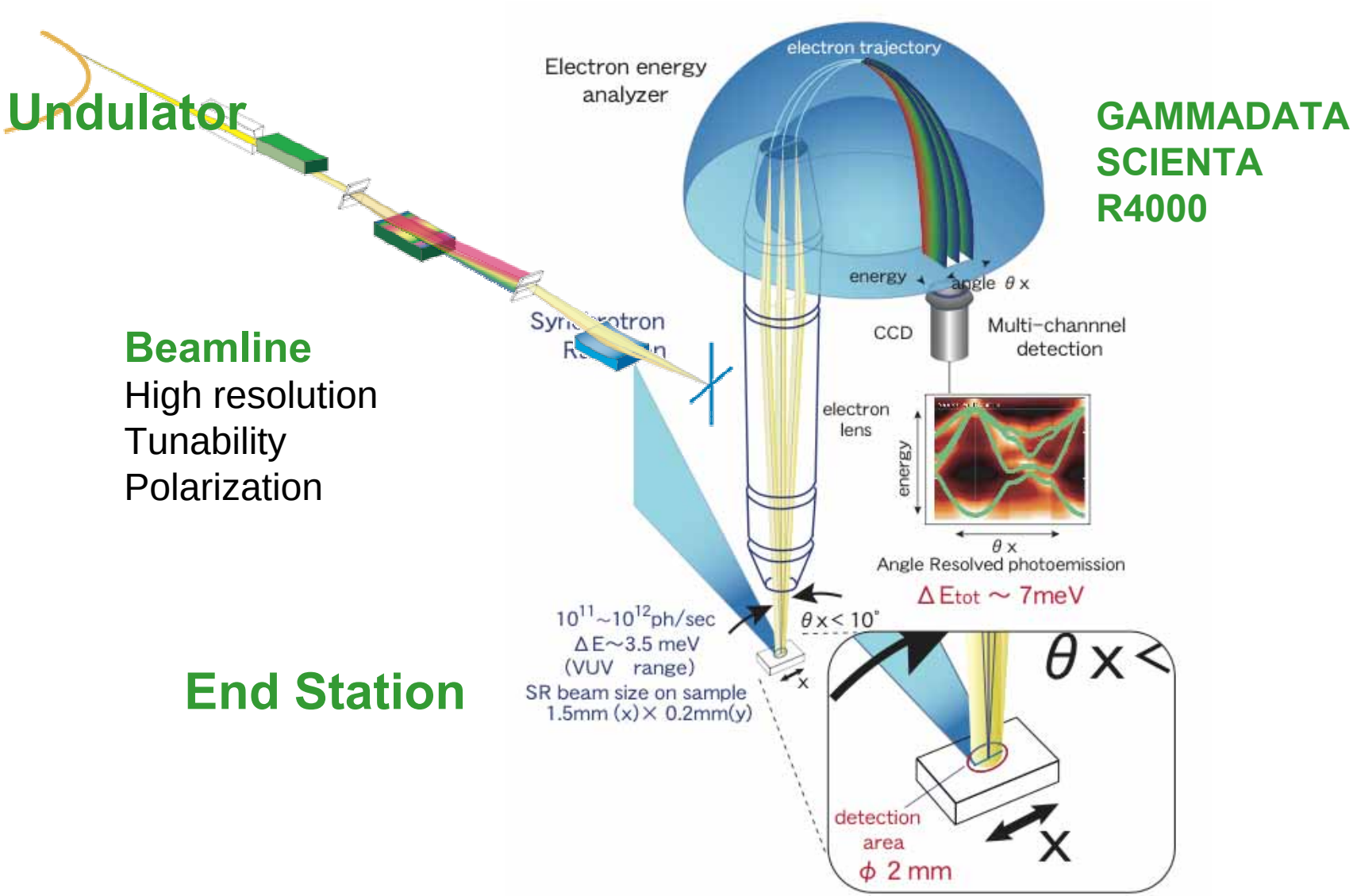
$Y_xYb_{1-x}InCu_4$: x ↑ , T_K ↓

High energy resolution

Undulator

Beamline
High resolution
Tunability
Polarization

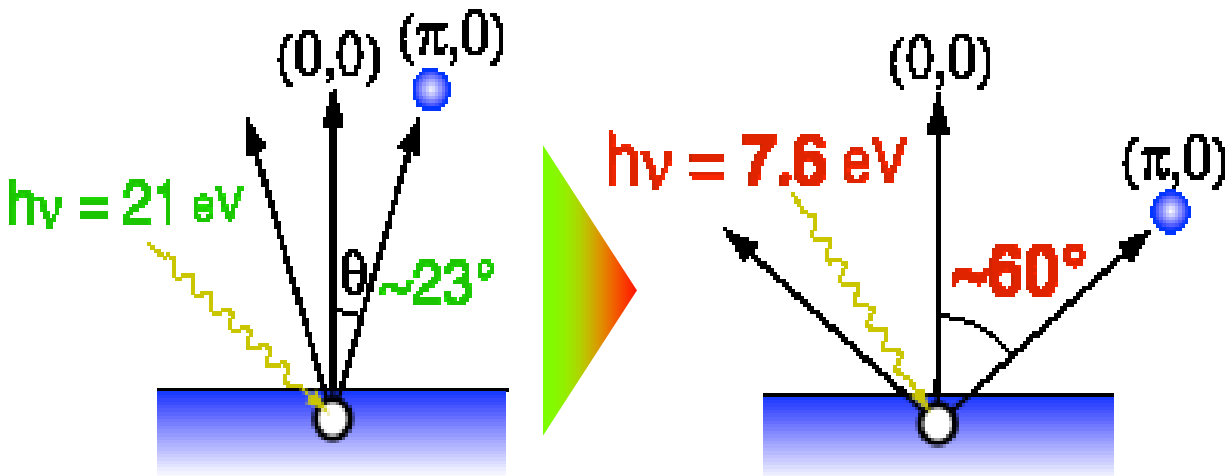
End Station



GAMMADATA SCIENTA R4000

Increase of momentum resolution in ARPES using low-energy excitation photons

<Wide Emission Angle>

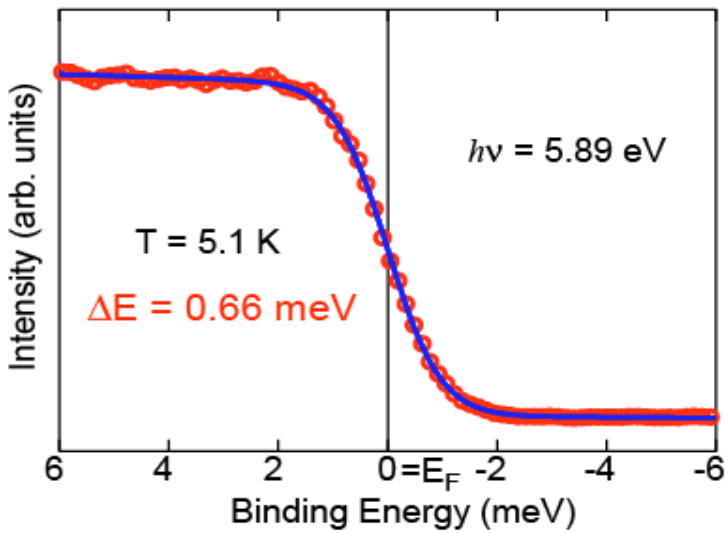


$$\sin\theta = \frac{\hbar \mathbf{k}_{\parallel}}{\sqrt{2m_e(h\nu - \Phi)}}$$

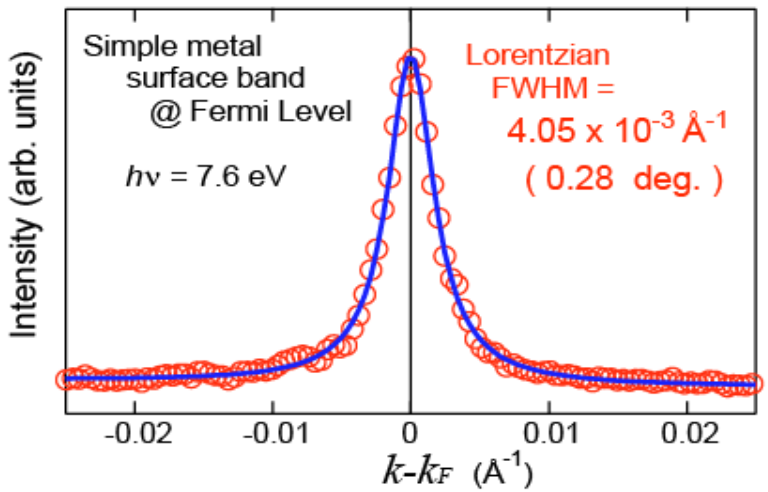
▷ **High momentum-resolution**

Total Energy and Momentum Resolutions

Total Energy Resolution



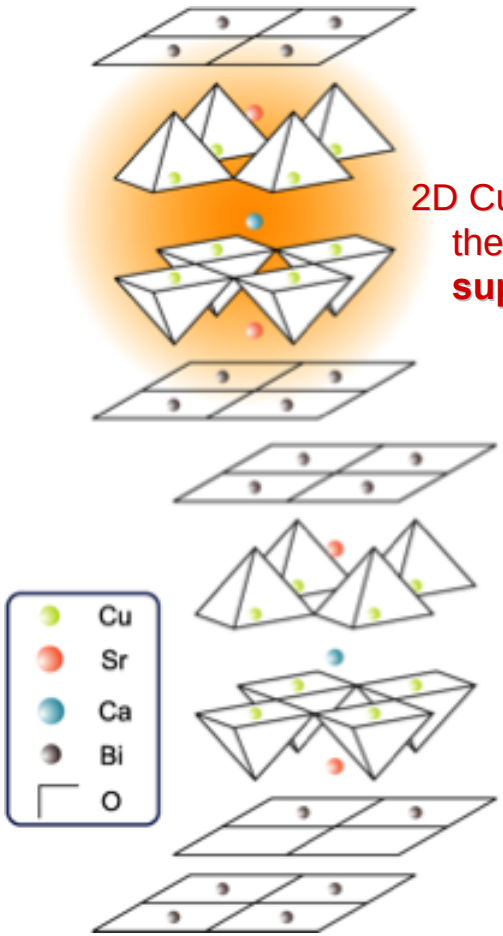
Momentum Resolution



ΔE_{tot} : 600-700 μ eV

$\Delta k : 4 \times 10^{-3}$ Å^{-1}

$Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi2212)

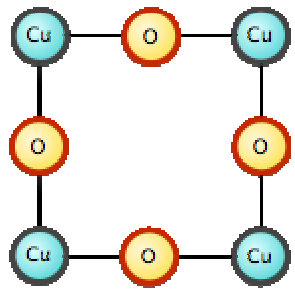


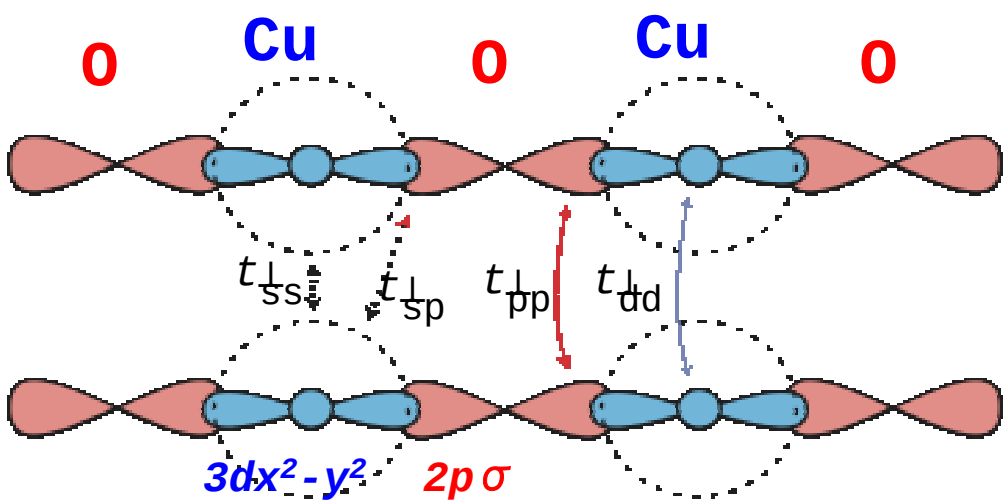
Crystal structure

2D CuO_2 plane:
the stage of
superconductivity

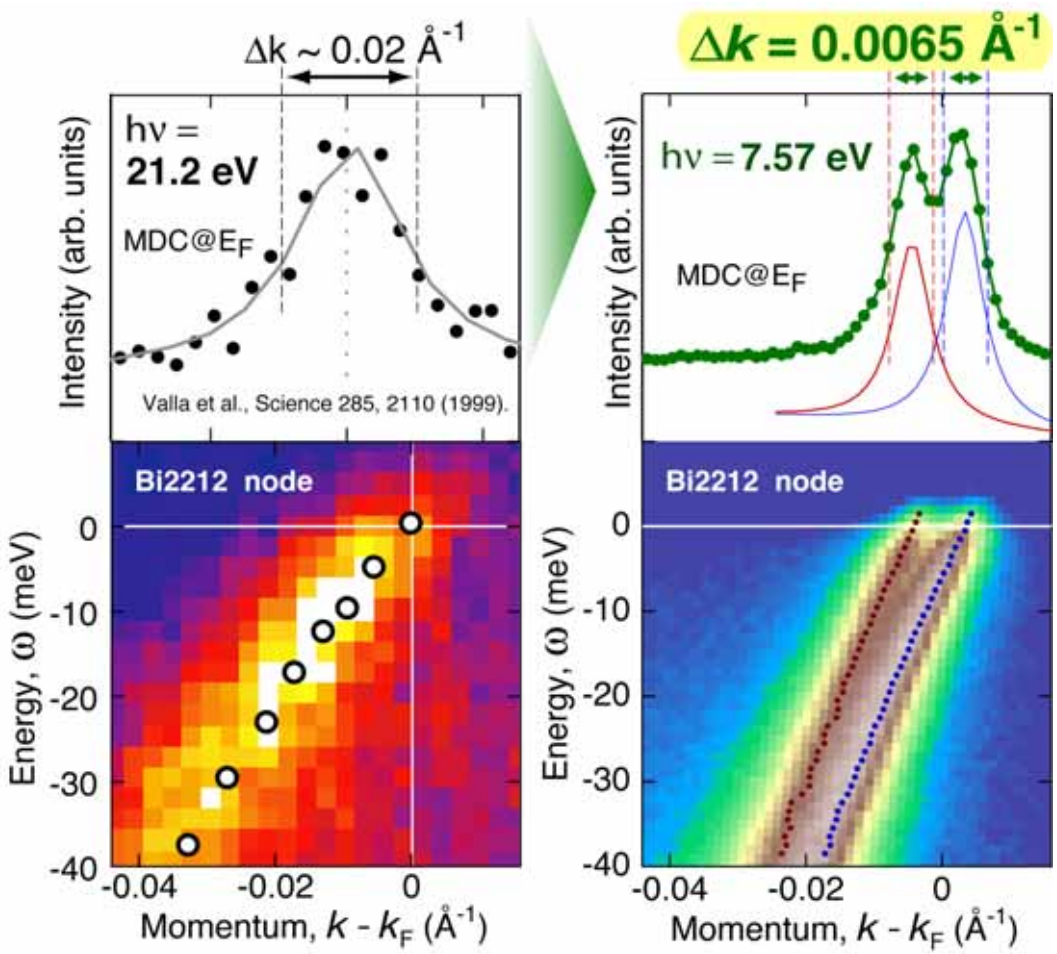
High-Tc superconducter
T_c = 92K

CuO_2 plane



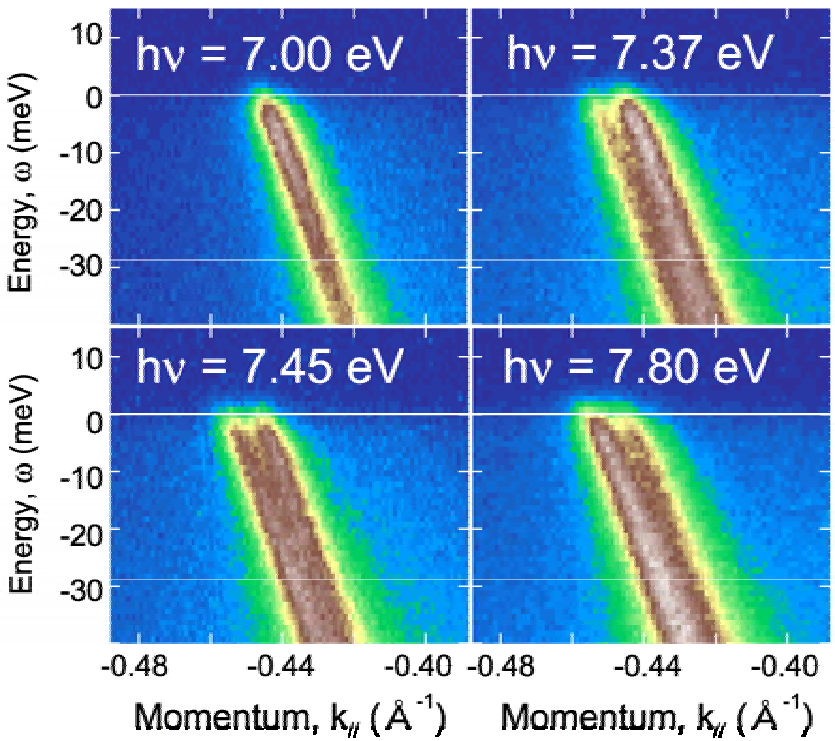


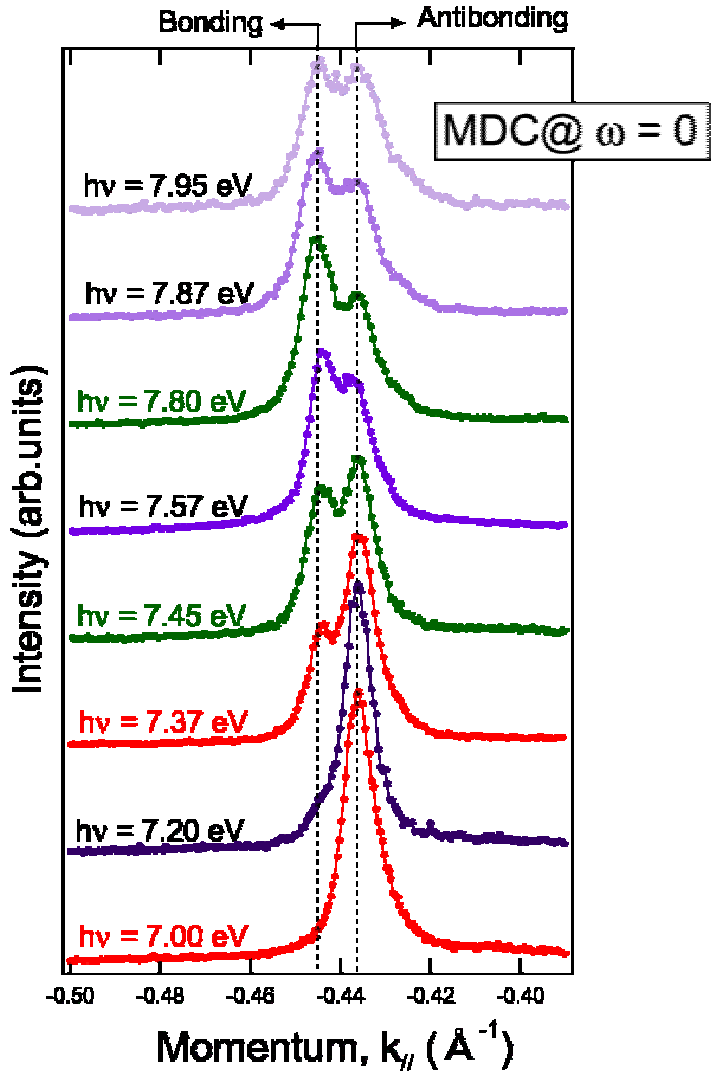
Observation of Bilayer Splitting



Advantage of High Energy- and Momentum-Resolutions !

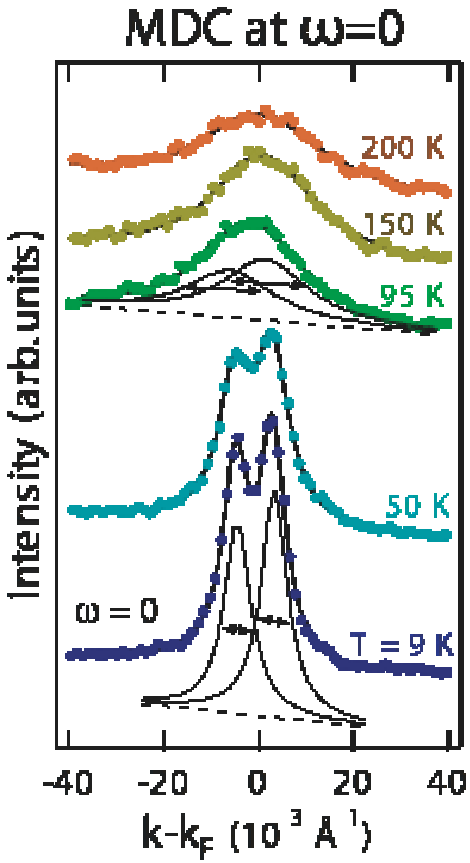
Photon energy dependence
-matrix element effect-



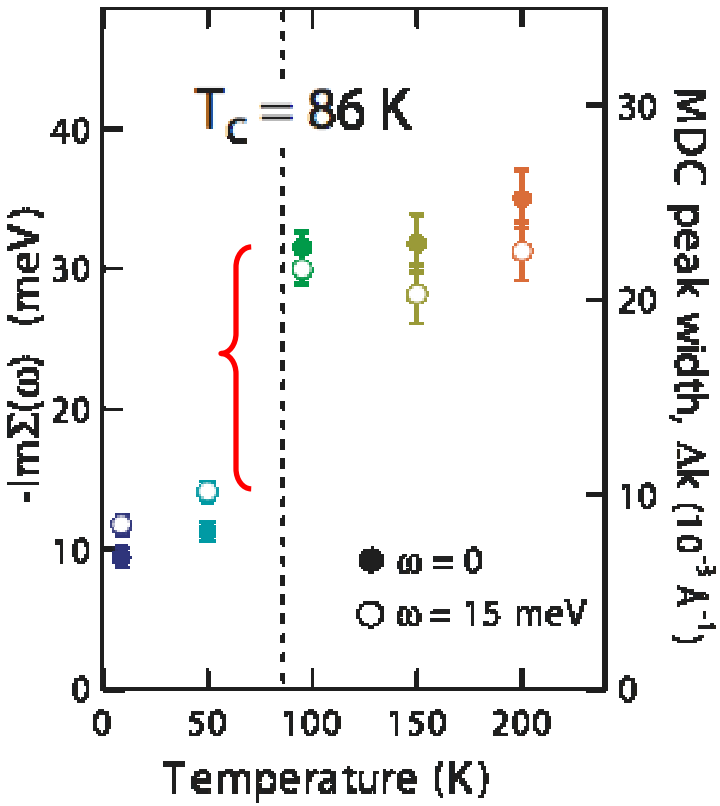


Advantage of SR Tunability !

Temperature dependence



Nodal scattering rate



Scattering-rate suppression below Tc

Advantage of Low-Energy SR Photoemission Spectroscopy

$h\nu < 15$ eV

Bulk Sensitivity

Escape depth ~ 50 Å (kinetic energy ~4 eV)

- Information intrinsic to bulk

High energy and momentum resolutions

ΔE_{tot} : 600-700 μeV $\Delta k : 4 \times 10^{-3}$ Å^{-1}

- Fine structures near the Fermi level

Tunability of excitation photons

ΔE_{ph} : 230 μeV @ 7 eV

- Selective observation of specific electronic states using matrix-element effect

Future Perspectives

☆Fine adjustment of electron energy analyzer

☆Extreme low temperature using ^{3}He refrigerator

☆Introduction of additional tools such as PEEM, STM

☆Fabrication and characterization of nano-structures

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Experiences on Beamline
Dedicated for
High Energy- and Momentum-Resolution ARPES

Hardware

Optimun integration of performances on light source, beamline and end station

Light source ⇔ High flux from insertion device

Beamline ⇔ Normal incidence monochromator and Light from helical undulator to reduce heat load on optics

End station ⇔ System fixed to the beamline, Development of relevant apparatus such as He refrigerator, 5-axex manipulator, sample preparation units etc..

Software

☆ **Concentration of scientists for construction and development of researches**

☆ **Collaboration with excellent scientists over the world**

☆ **Flexible beam time like laboratory**