Hard X-ray Photoemission Spectroscopy Combined with Magnetic Circular Dichroism (MCD-HXPES)

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  MCD-HXPES → *Spin-resolved HXPES*

Introduction

◈ ***HX-PES Combined with MCD (MCD-HXPES)***

How to obtain magnetic information from PES spectra?

Spin-resolved PES → Direct way, but efficiency is very low.

Non spin-flip mean free path of high kinetic energy electron is unknown.

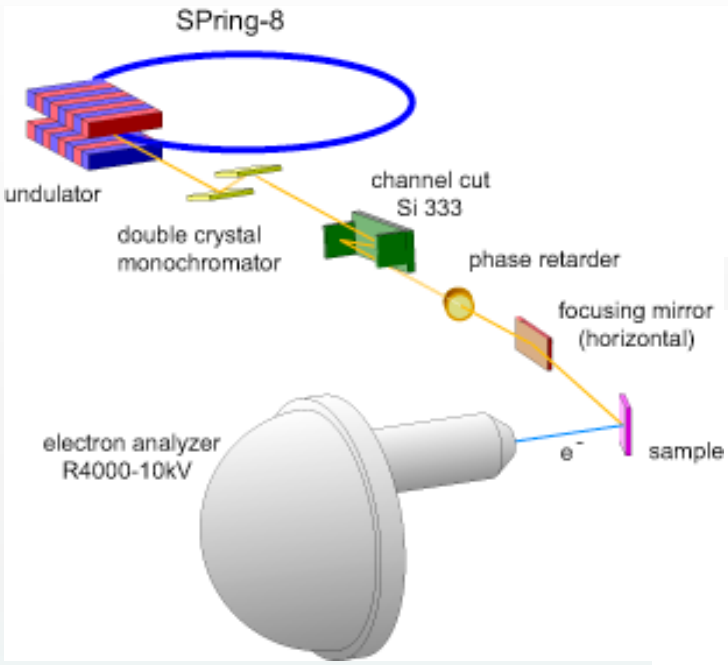
PES combined with MCD → Complementary experiment such as spin-resolved PES

MCD is determined by photo-excitation probability.

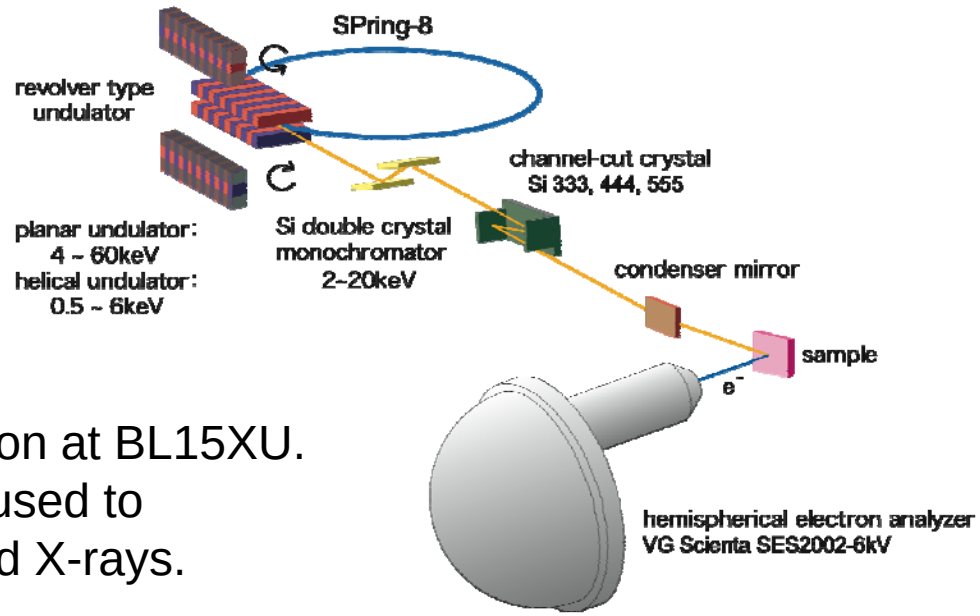
We expect that MCD-HXPES is conventional technique to obtain electronic structures and magnetic information of various materials without UHV condition, surface cleaning, and magnetization reversal in UHV.

MCD-PES using hard X-rays is very simple way in comparison with that using soft X-rays and ultra violet light.

Experiment



Experimental configuration at BL39XU.
A diamond phase retarder was used to obtain circularly polarized X-rays.
$h\nu$ = 7.94 keV, P_C ~ 0.95.



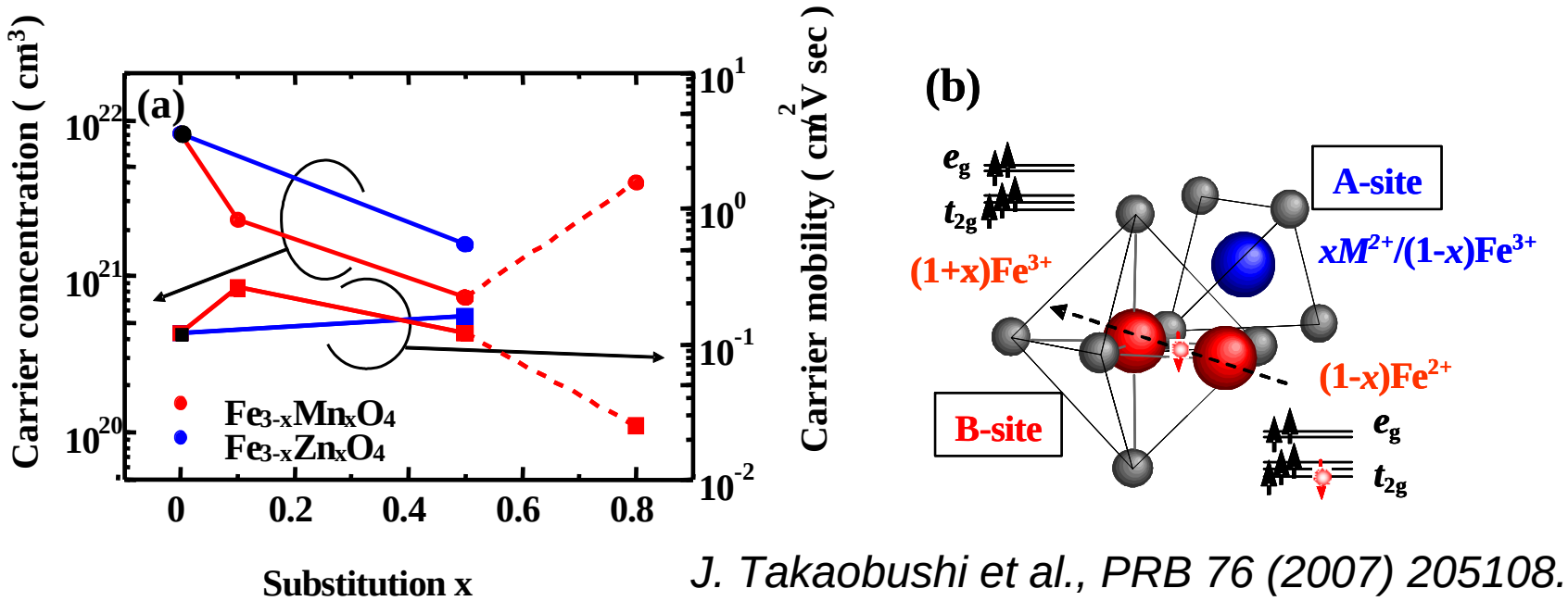
Experimental configuration at BL15XU.
A helical undulator was used to obtain circularly polarized X-rays.
$h\nu$ = 5.95 keV, P_C ~ 0.6.

For typical HXPES set-up, see e.g., Y. Takata et al., Nucl. Inst. Methods A ***547*** *(2005) 50.*

$Fe_{3-x}M_xO_4$ (M=Mn, Zn)

- We used a Fe_3O_4 thin film as a sample for MCD-HXPES experiments.

$Fe_{3-x}M_xO_4$ (M = Mn, Zn) : $T_C > RT$ and carrier control by M substitution ratio.

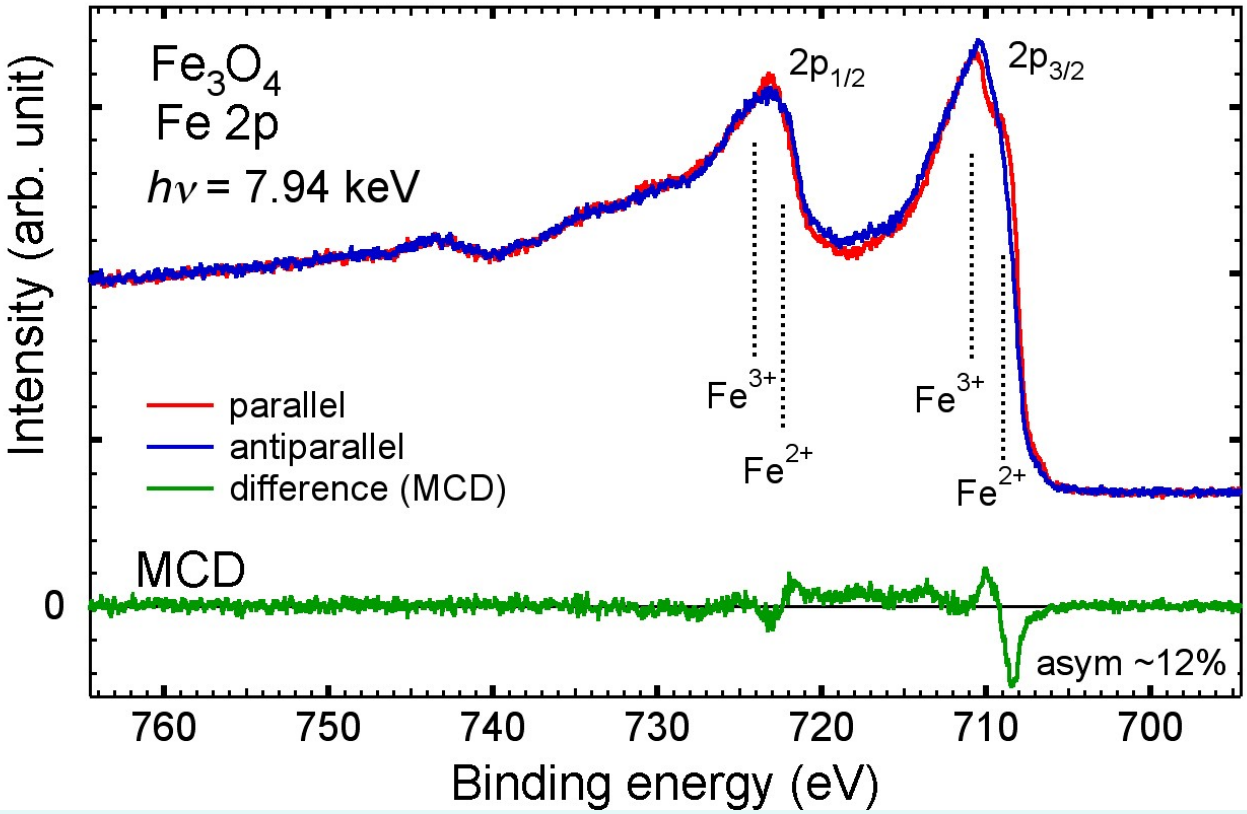


J. Takaobushi et al., PRB 76 (2007) 205108.

(a) Carrier concentration and mobility of $Fe_{3-x}M_xO_4$ (M = Mn, Zn) thin films on MgO(001).
(b) Schematic local structure of $Fe_{3-x}M_xO_4$ (M = Mn, Zn).

Highlight data *Fe 2p MCD-HXPES of Fe_3O_4 thin film*

10 nm thick film



- Helicity was changed by a diamond phase retarder.
- without surface cleaning.
- Magnetized in the air.

Measured at BL39XU

P_C ~ 0.95

M_R/M_S ~ 0.39

~ 40% asymmetry

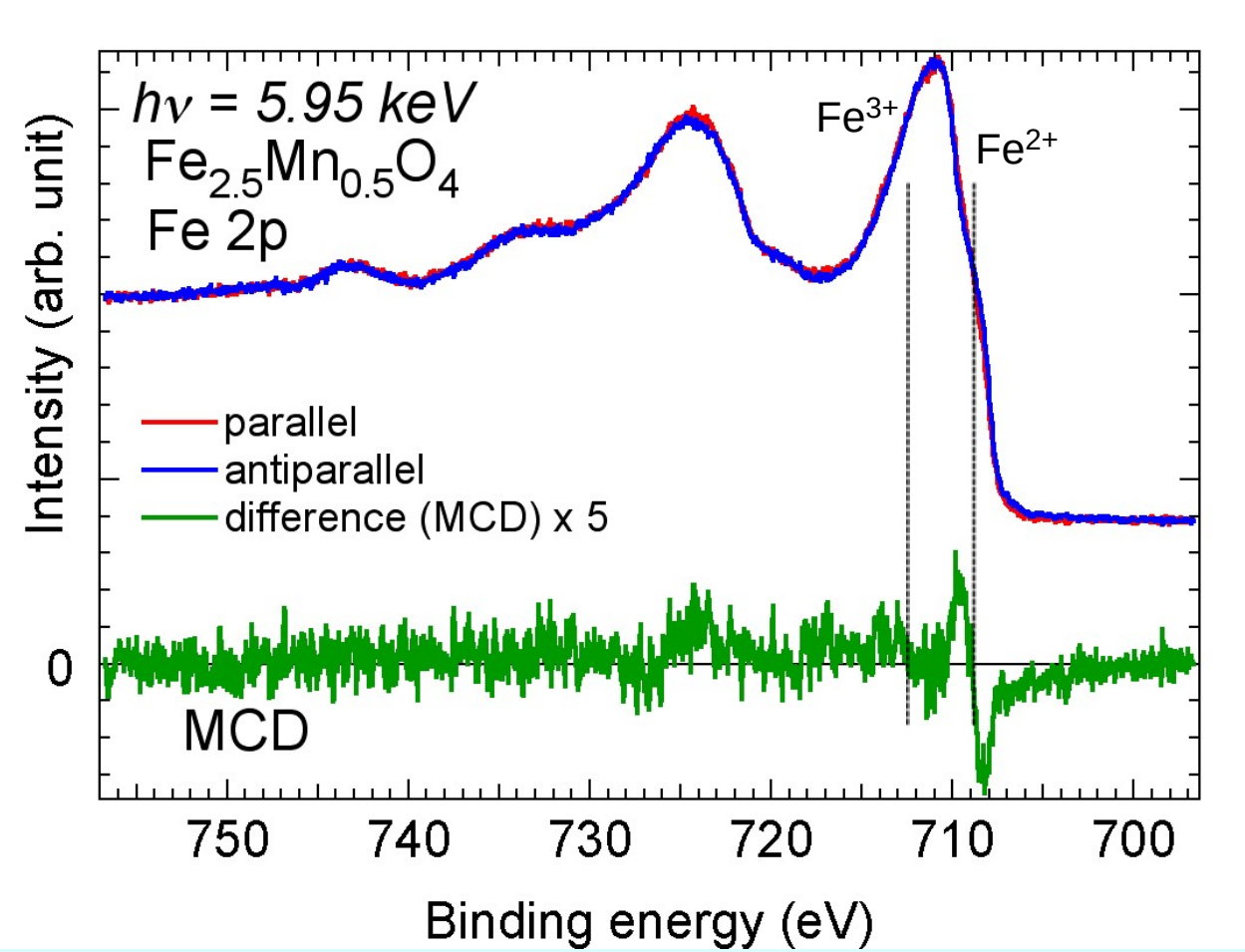
*S. Ueda et al., Appl. Phys. Express **1** (2008) 077003.*

$[Fe^{3+}(\downarrow:5\mu_B)]_A[Fe^{3+}(\uparrow:5\mu_B)Fe^{2+}(\uparrow:4\mu_B)]_BO_4$

We have succeeded in measuring MCD-HX-PES without surface cleaning.

Fe 2p MCD-HXPES of $Fe_{2.5}Mn_{0.5}O_4$ thin film

100 nm thick film



Measured at BL15XU

Helical undulator was used.

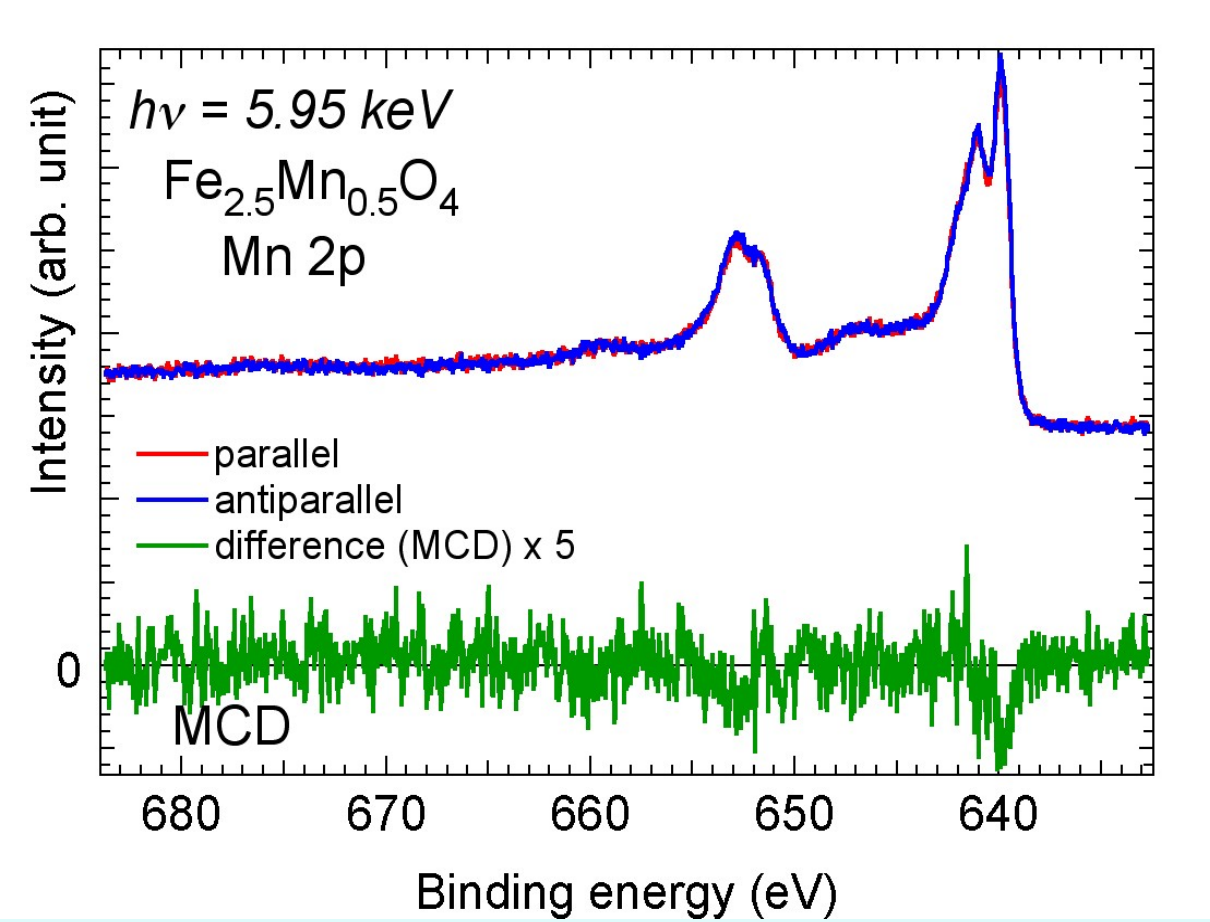
$P_C \sim 0.6$

without surface cleaning.

Magnetized in the air.

$M_R/M_S \sim 0.45$

Mn 2p MCD-HXPES of $Fe_{2.5}Mn_{0.5}O_4$ thin film



Measured at BL15XU

Helical undulator was used.

P_C ~ 0.6

without surface cleaning.

Magnetized in the air.

M_R/M_S ~ 0.45

Magnetic moments of Fe and Mn are parallel.

Summary and future plan

- We have succeeded in measuring MCD-HXPES in the simple practical way. (No UHV, no surface cleaning)
- MCD-HXPES can be an effective tool for measuring both electronic and magnetic states.

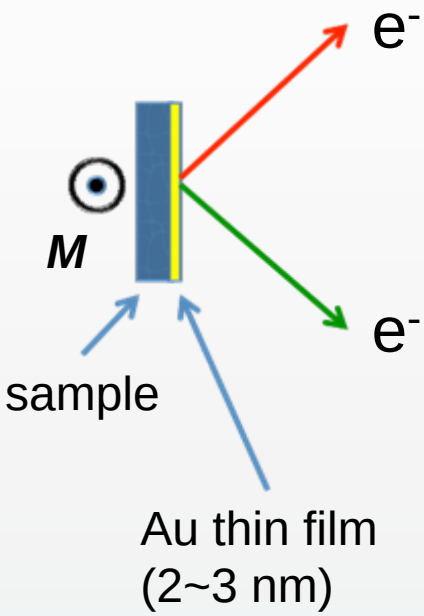
For spin-resolved HXPES,

Forward scattering geometry can be one of the methods to conduct the spin detection.

A planned spin-resolved HXPES does not require a spin detector.

What I would like to say is ….

A planned spin-resolved HXPES



Mott scattering in the capping layer helps to detect the spin polarization.

Simple way!

Problem: effective Sherman function ?
non spin-flip mean free path?

or insulator (BGO)

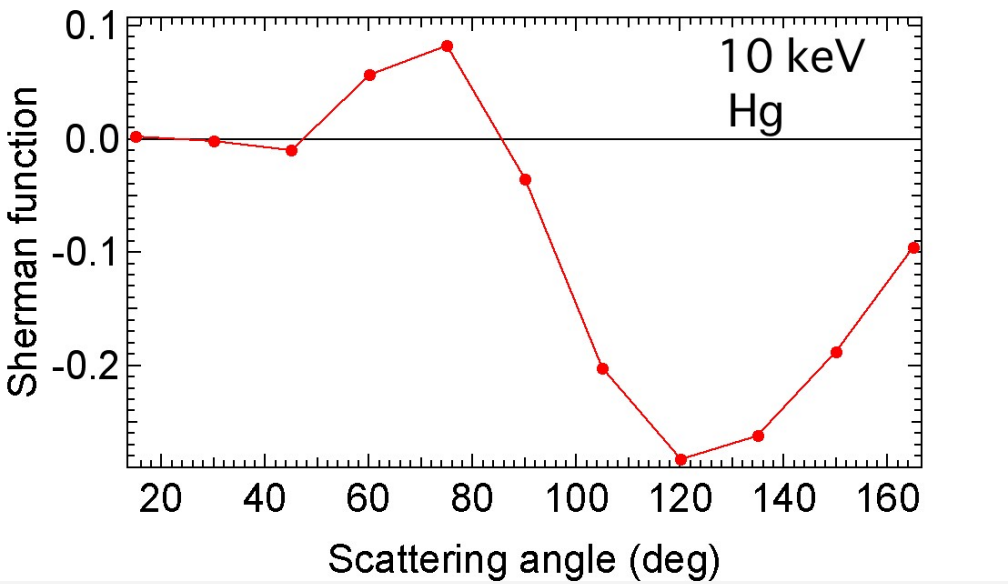
Insulating layer acts as a widow for valence bands near E_F.
*G. H. Fecher et al., APL **92** (2008) 193513.*

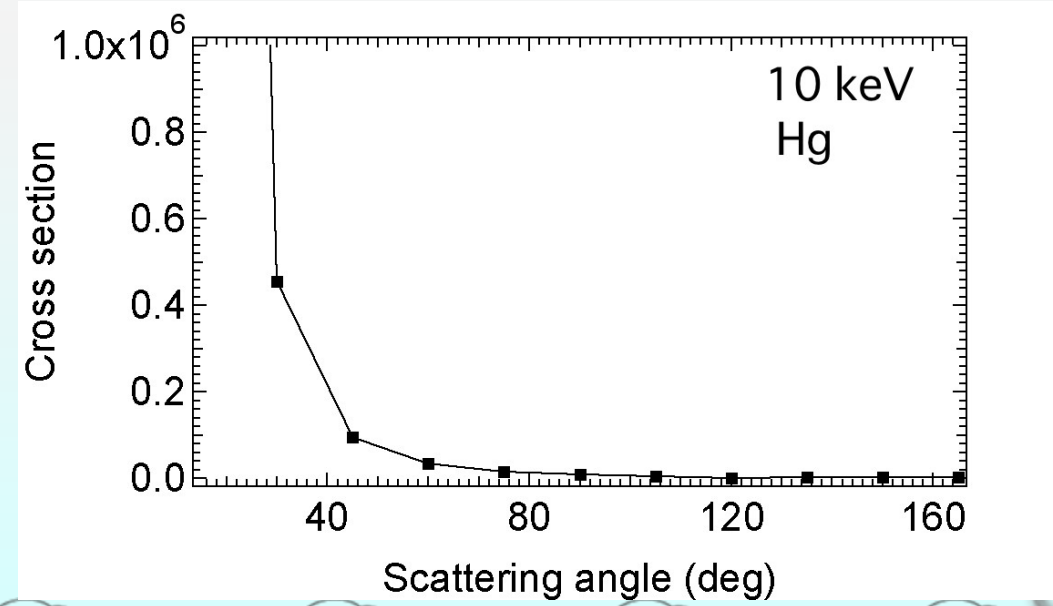
Combination with photoelectron diffraction will enhance the efficiency.

On Sherman function, N. Sherman, Phys. Rev. 103 (1956) 1601.

END

Thank you for your attention!


10 keV
Hg
Sherman function
0.1
0.0
-0.1
-0.2
20
40
60
80
100
120
140
160
Scattering angle (deg)


10 keV
Hg
Cross section
1.0x10^6
0.8
0.6
0.4
0.2
0.0
40
80
120
160
Scattering angle (deg)