低温超高分解能角度分解光電子分光による超伝導体の研究

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内容

1．低温超高分解能角度分解光電子分光装置

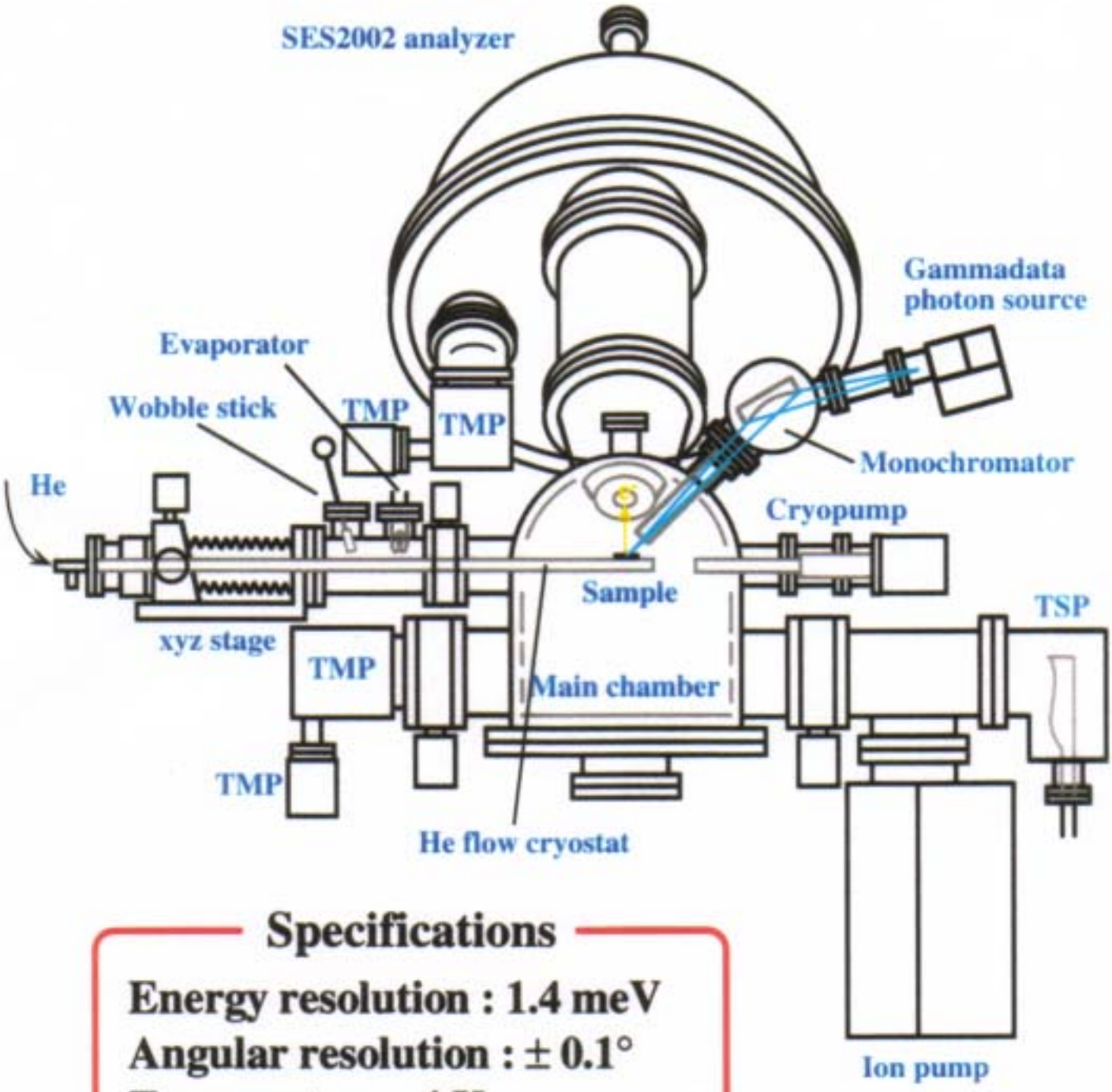
2．単体金属の超伝導ギャップの直接観測

3．$2H$-$NbSe_2$の角度分解光電子分光実験結果

- 超伝導ギャップのフェルミ面依存性
- 超伝導ギャップの異方性

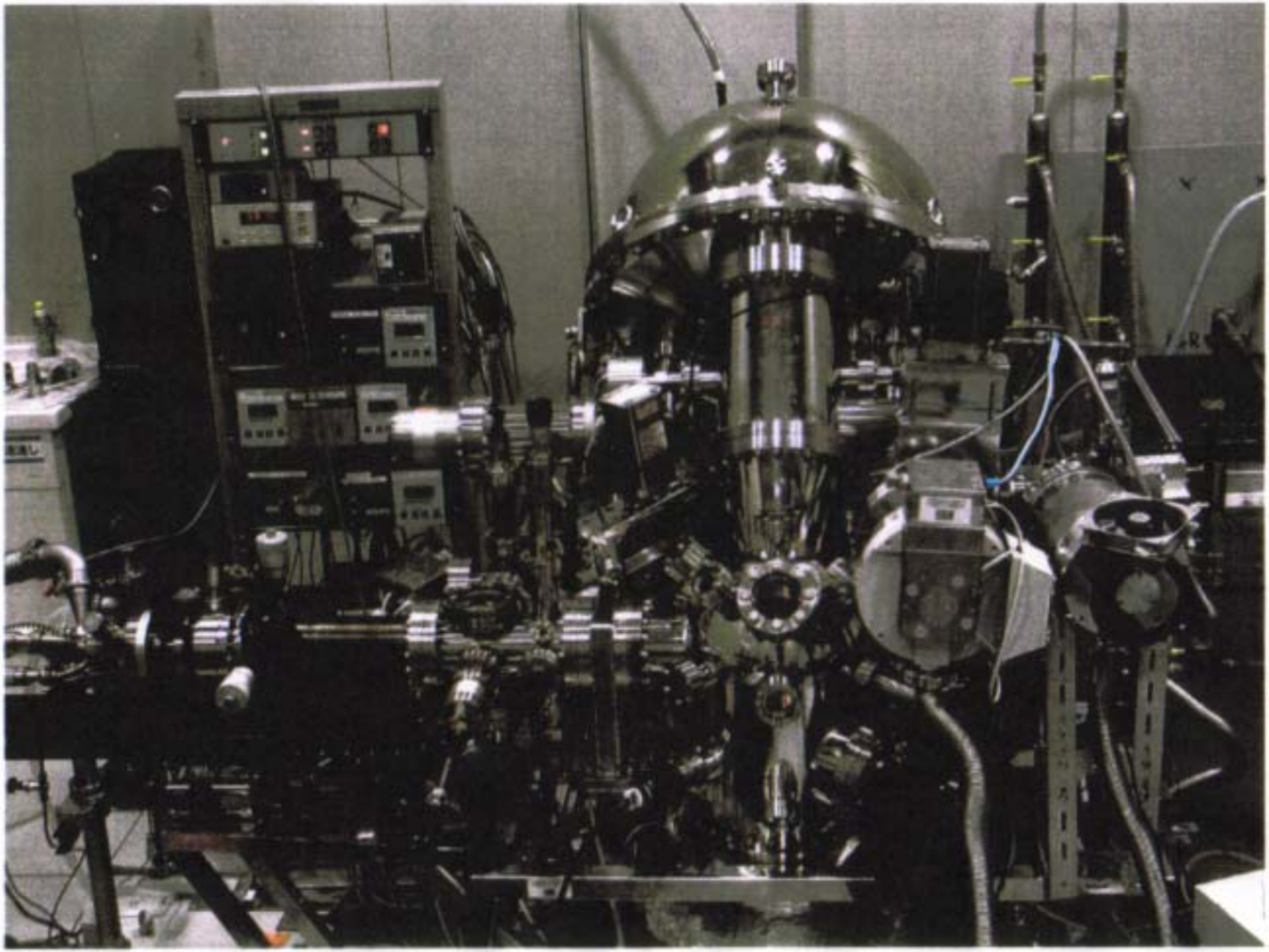
4．まとめ

Schematic Diagram of Ultrahigh-Resolution Photoemission Spectrometer

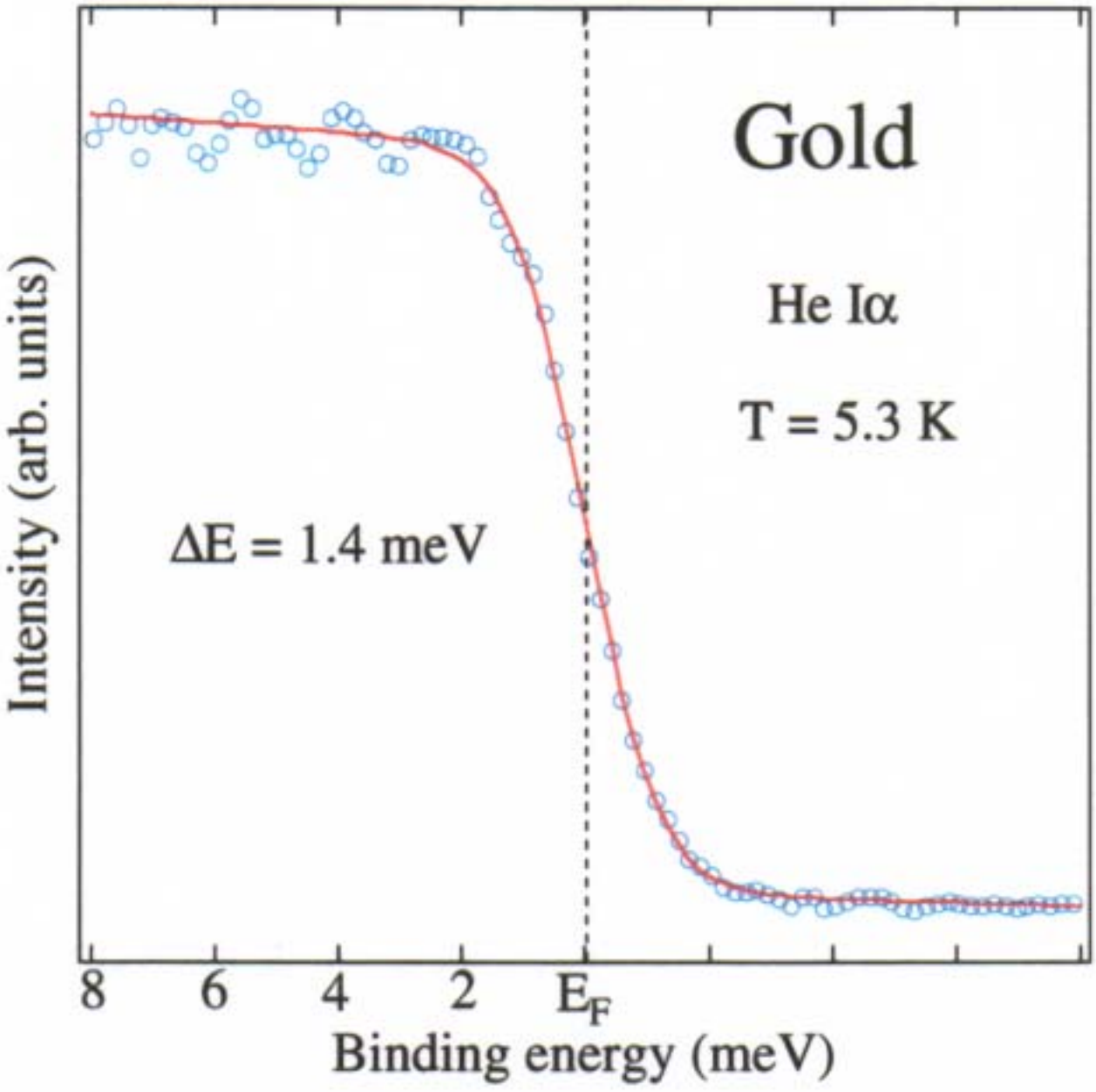


Specifications

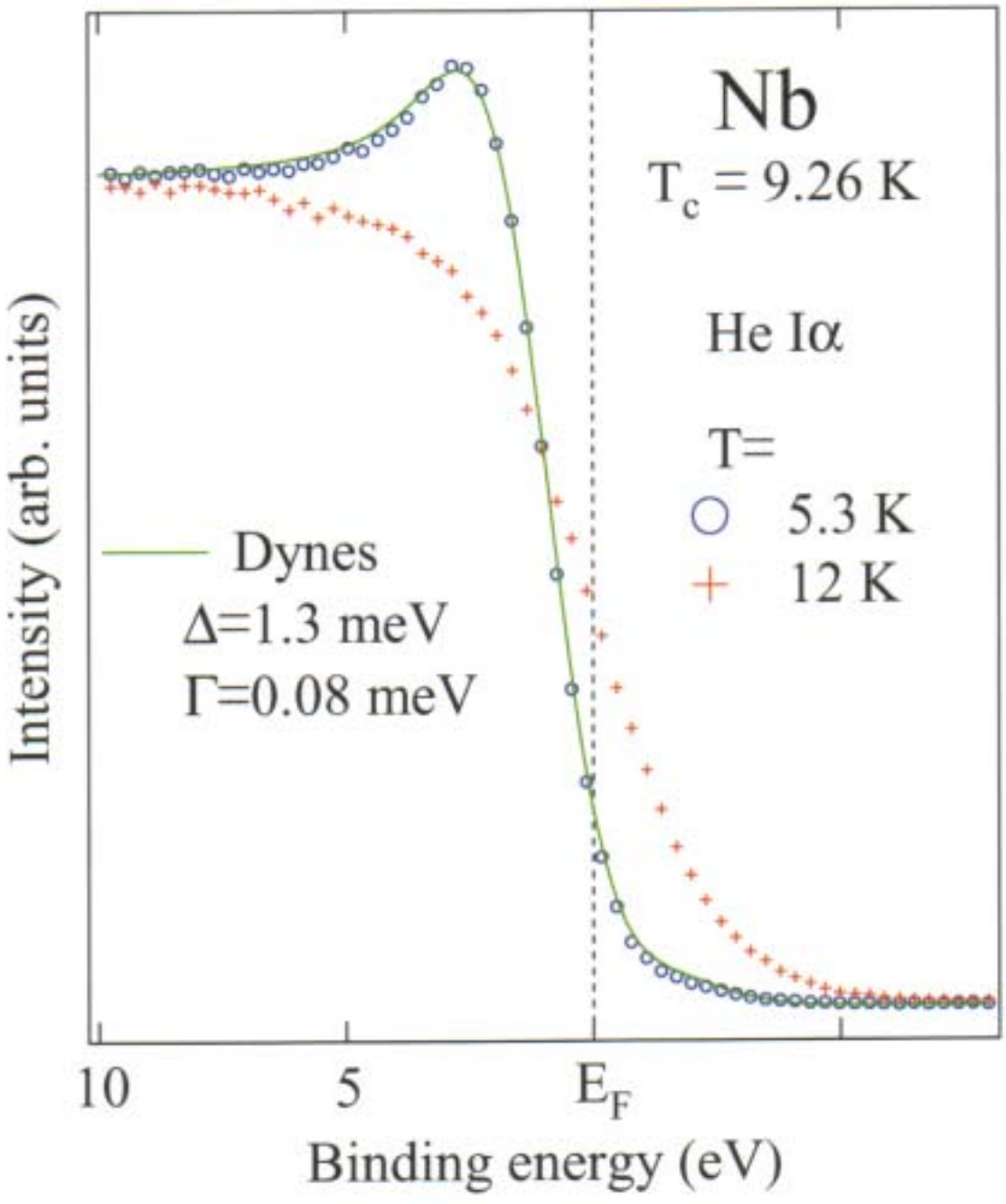
Energy resolution : 1.4 meV
Angular resolution : ± 0.1°
Temperature : 4 K
Base pressure : 4 x 10^{-11} Torr



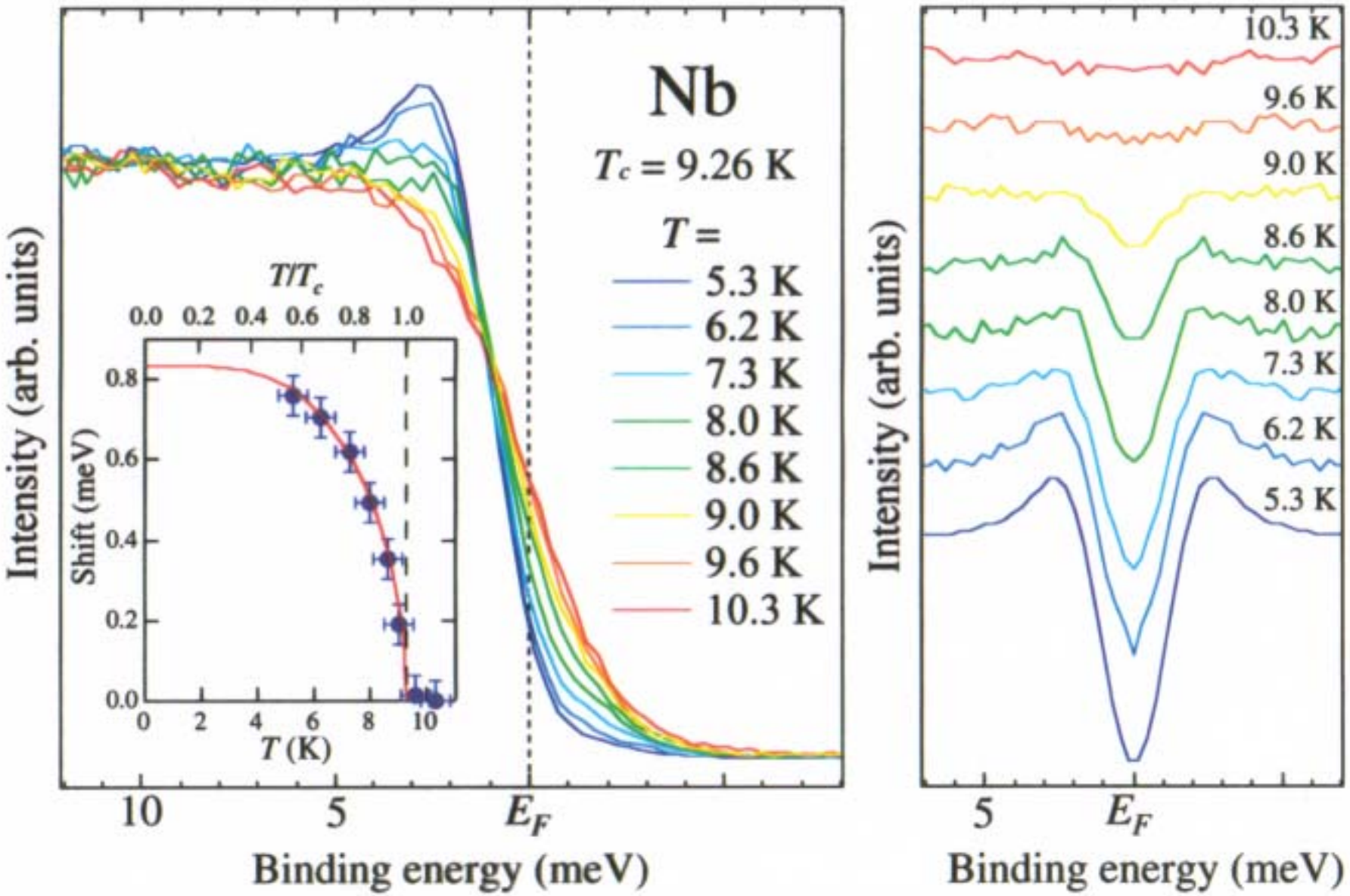
Ultrahigh-resolution photoemission spectrum near E_F of Gold at 5.3 K obtained with He Iα resonance line



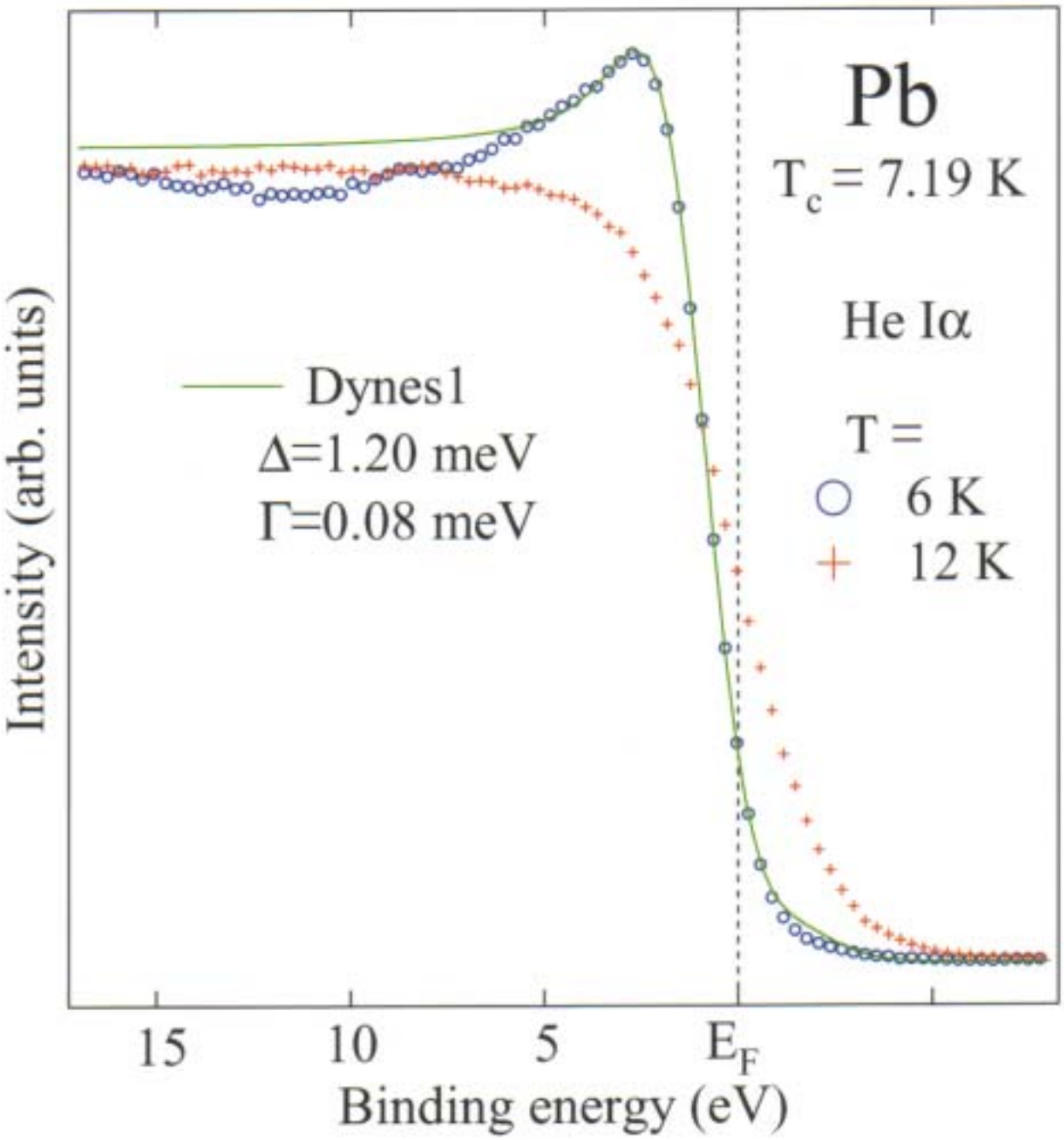
Ultrahigh-resolution spectra of Nb measured at 5.3K and 12.0K together with a result of numerical calculation using Dyne's function



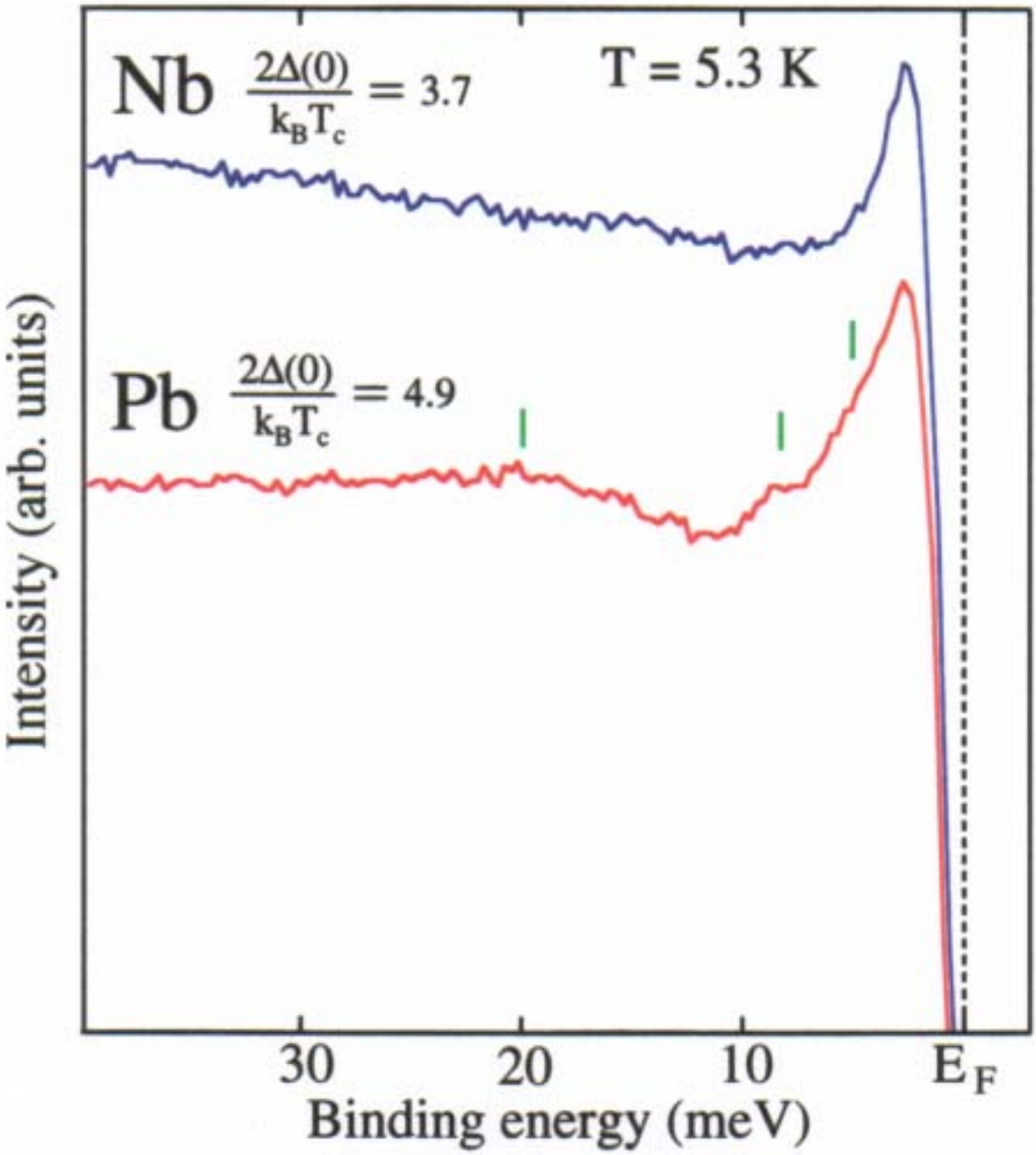
Temperature dependent photoemission spectra of Nb (left) and result of symmetrized analysis (right)



Ultrahigh-resolution spectra of Pb measured at 5.3K and 12.0K together with a result of numerical calculation using Dyne's function



Ultrahigh-resolution photoemission spectra near E_F of Nb (T_c=9.26 K) and Pb (T_c=7.19 K) measured at 5.3 K



2*H*-$NbSe_2$

Crystal structure (C27)

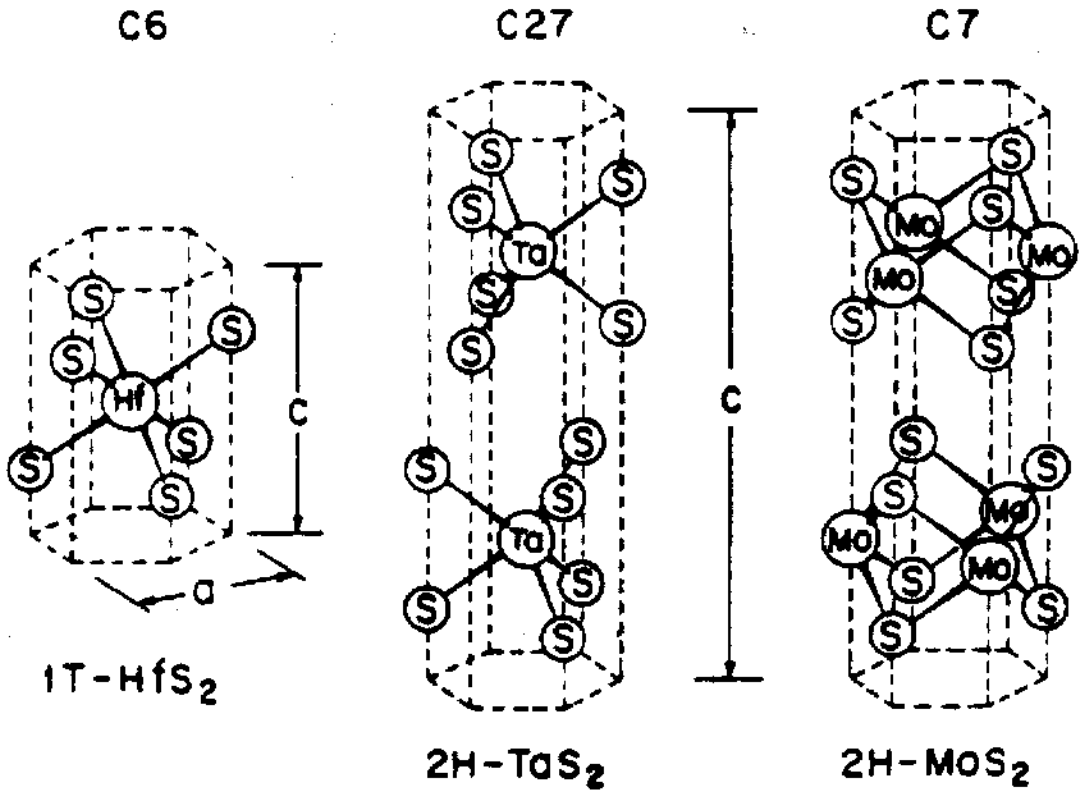


FIG. 1. Symmetric unit cells for the C6 (1T-HfS_2), C27 (2H-TaS_2), and C7 (2H-MoS_2) crystal structures.

L. F. Mattheiss, Phys. Rev. B **8**, 3719 (1973)

CDW transition

T_{CDW}~35K Incommensurate

Superconducting transition

T_C=7.2K

Band calculation of $2H$-$NbSe_2$

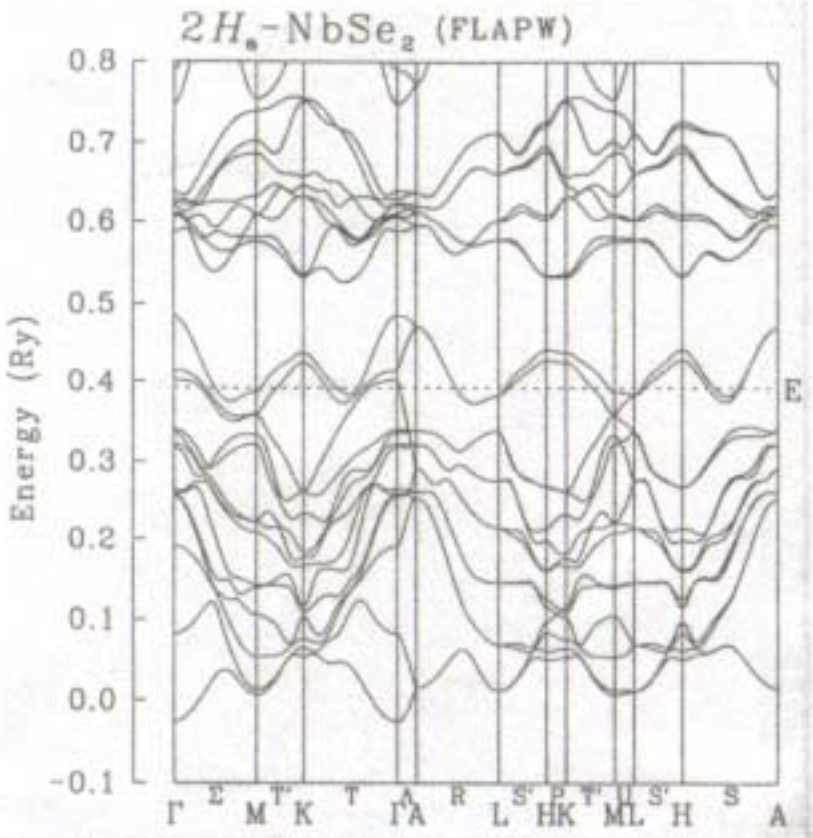


Figure 6. FLAPW band structure of 2H-$NbSe_2$. The dashed line indicates the Fermi level (0.3925 Ryd). Se 4s bands located between −0.6 Ryd and −0.5 Ryd are not shown. Note that the spin–orbit interactions lift the degeneracy at the K point and on the A–L–H plane except the A–R–L axes.

R. Corcoran *et al.*, J. Phys.: Condens. Matter 6 (1994)4479

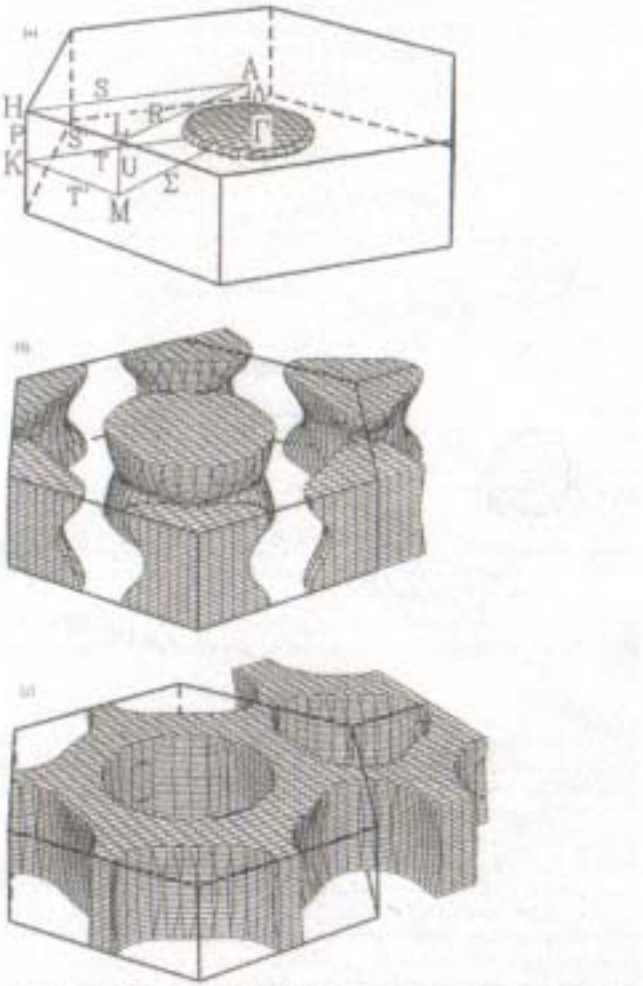


Figure 8. (a) The hole Fermi surface in 2H-$NbSe_2$ around the Γ point derived from the 16th band. (b) The hole Fermi surface derived from the 17th band. (c) The electron Fermi surface derived from the 18th band.

Data of STM

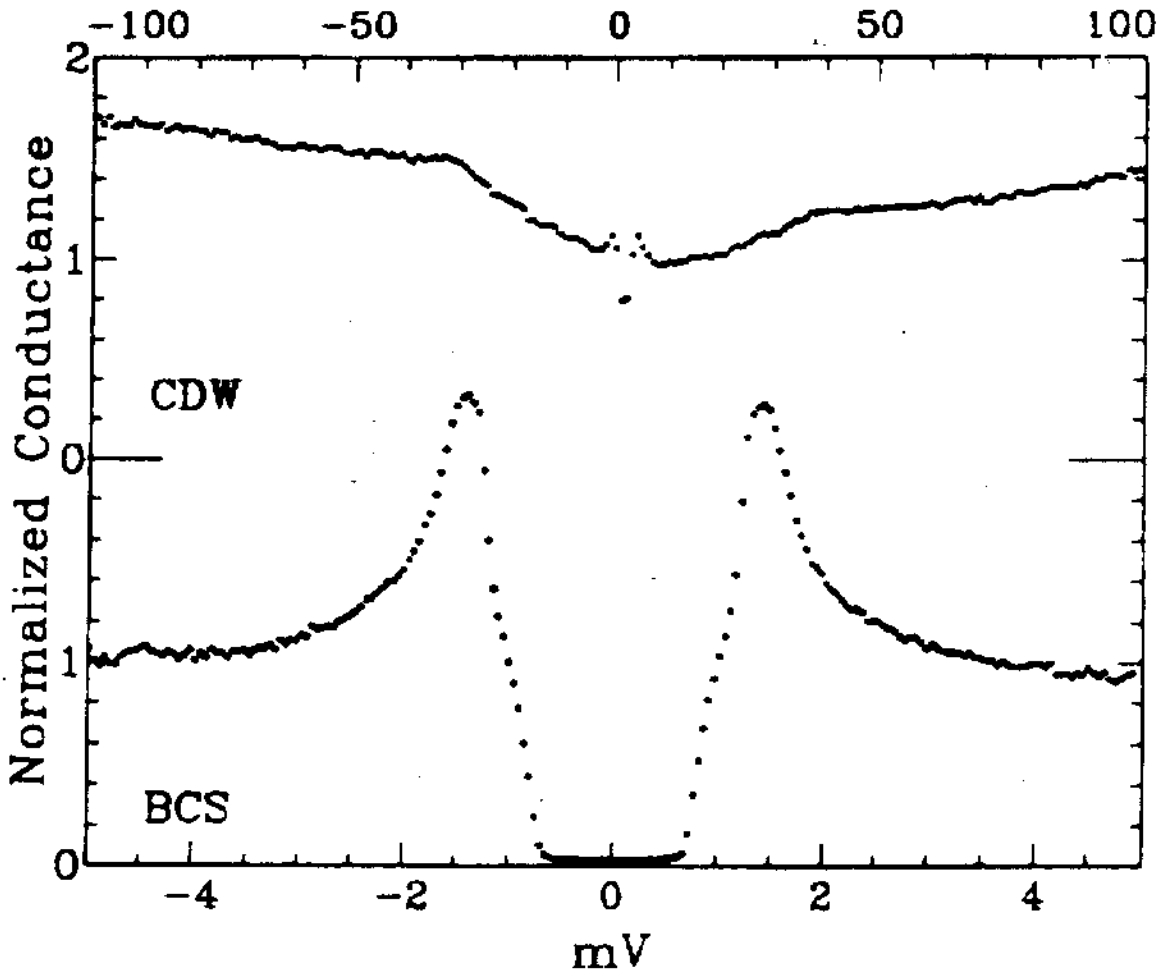
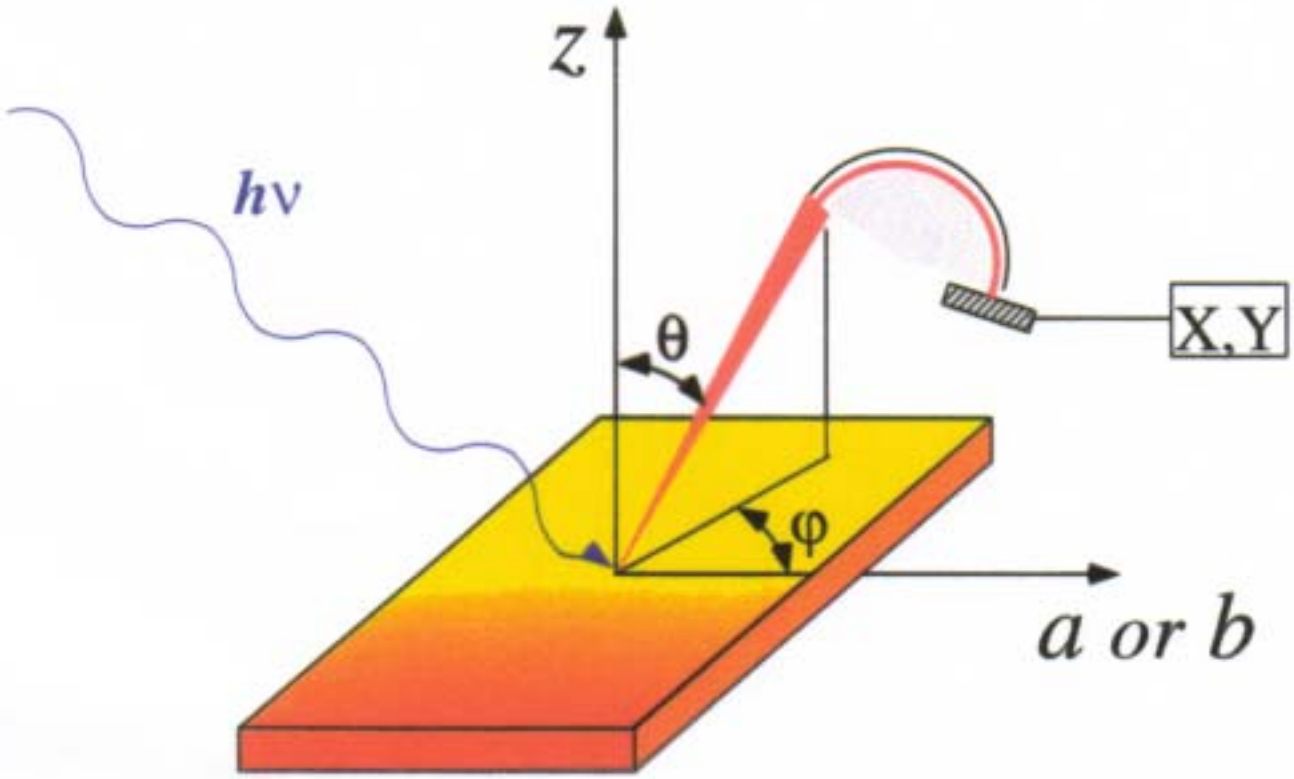


Fig. 1. Tunneling spectra given by dI/dV vs. V showing the CDW gap at 35 mV (upper curve at 4 K) and a more detailed view of the BCS gap (lower curve at 50 mK).

H. F. Hess, R. B. Robinson and J. V. Waszczak, Physica B **169**, 422-431 (1991)

Diagram for angle-resolved photoemission process



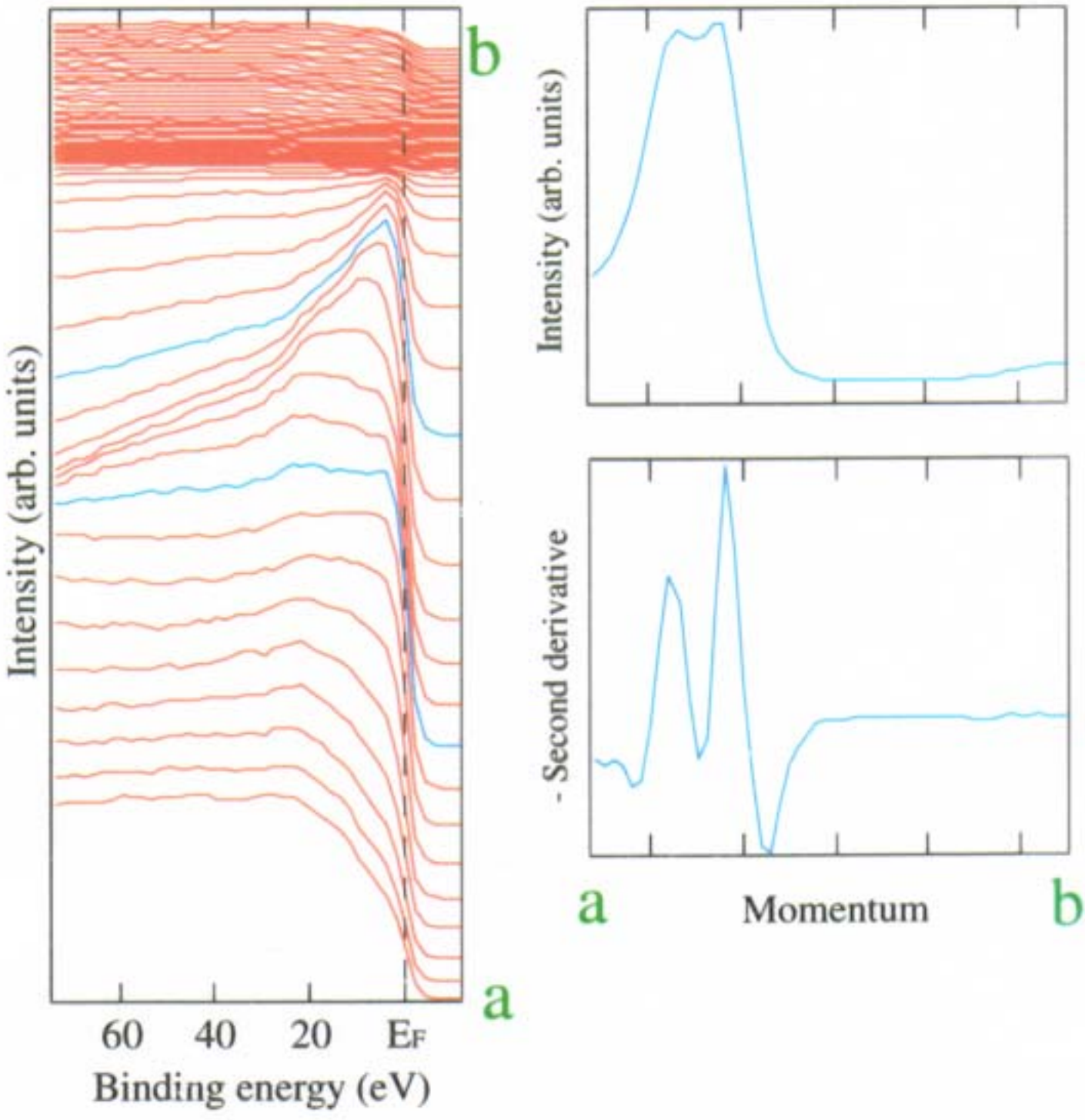
並進対称性より $\hbar K_{\perp} \neq \hbar k_{\perp}$, $\hbar K_{//} = \hbar k_{//}$

$$\hbar k_{//} = (2mE_k)^{1/2}\sin\theta$$

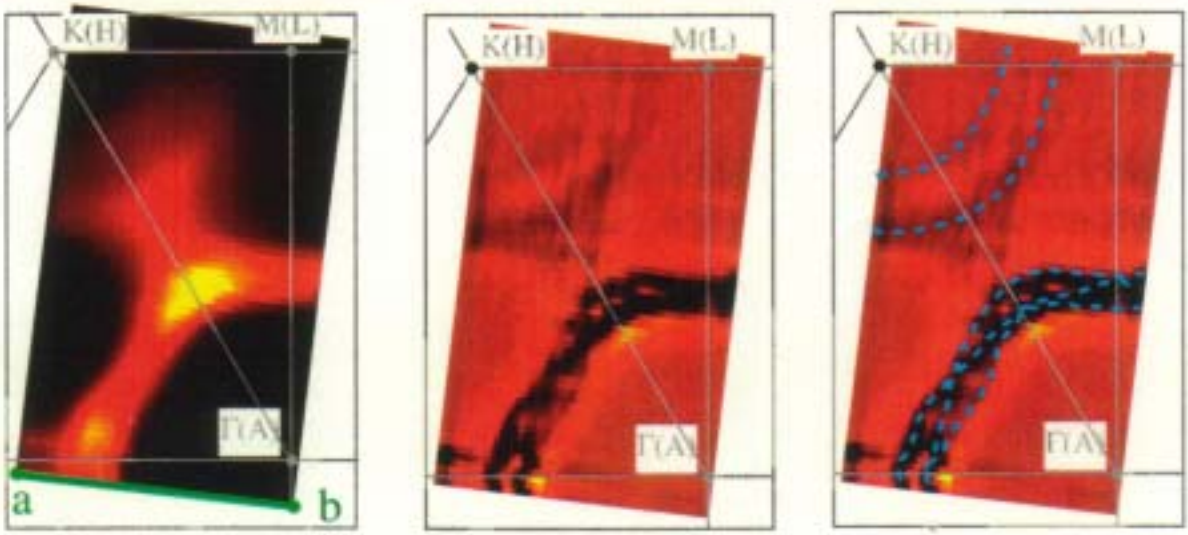
$$= [2m(E_i + \hbar\omega - \phi)]^{1/2}\sin\theta$$

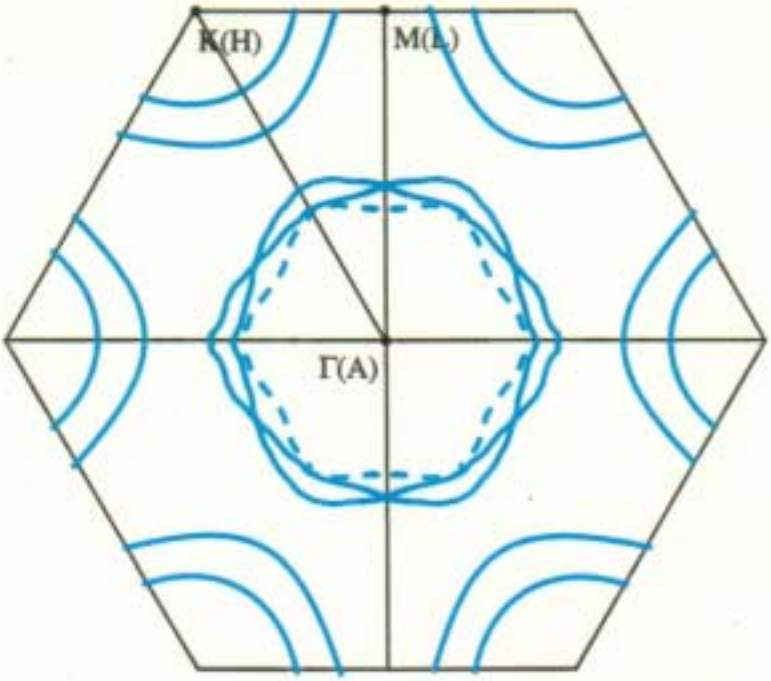
$$\hbar k_{\perp} = \{2m[(E_i + \hbar\omega - \phi)\cos^2\theta + V_0)]^{1/2}$$

フェルミ波数(k_F)決定の方法

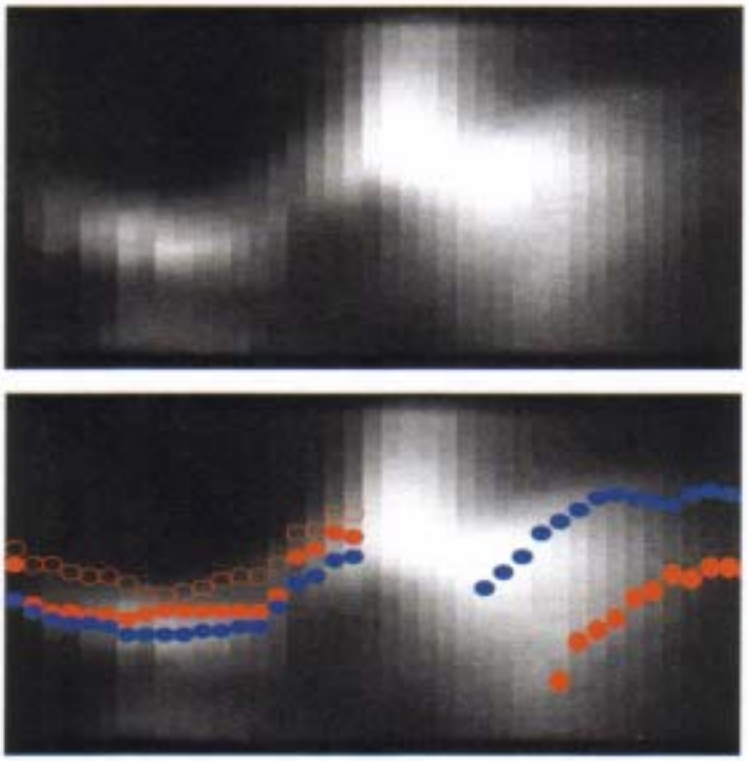


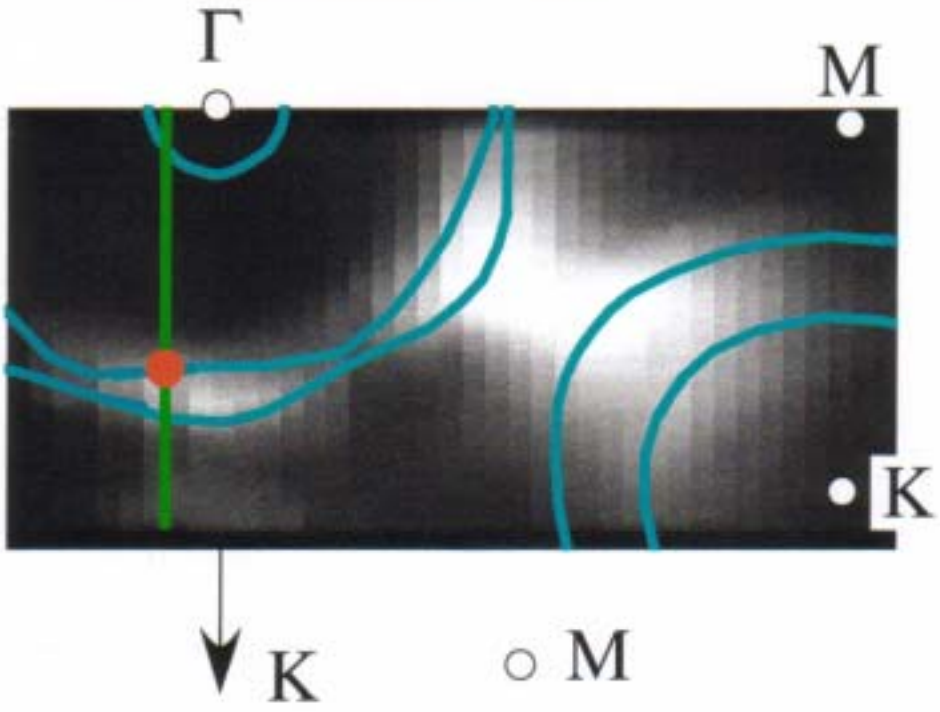
Fermi surface of 2H-$NbSe_2$ determined from present ARPES study



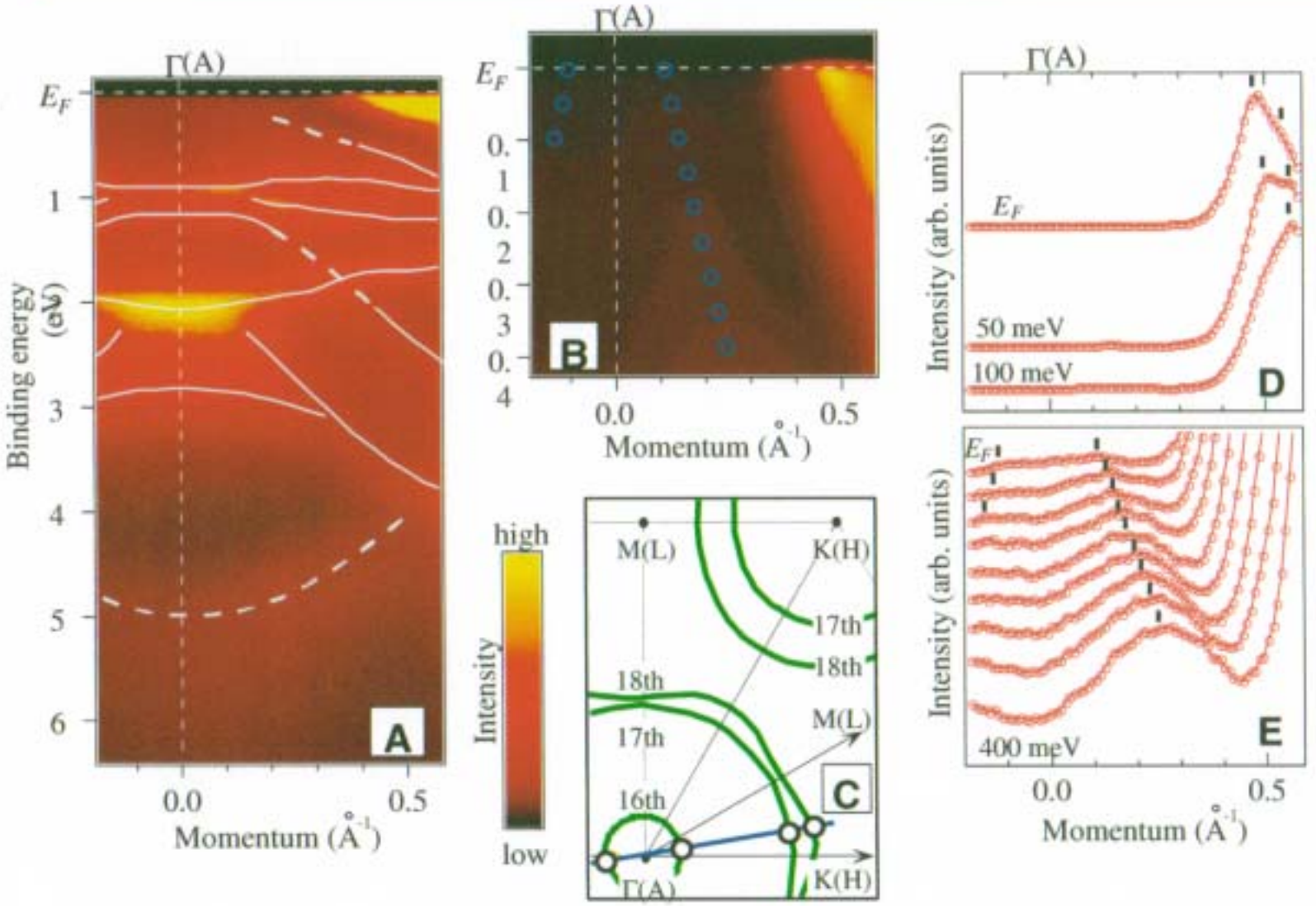


Fermi surface of $2H$-$NbSe_2$ determined by Ultrahigh resolution photoemission spectroscopy



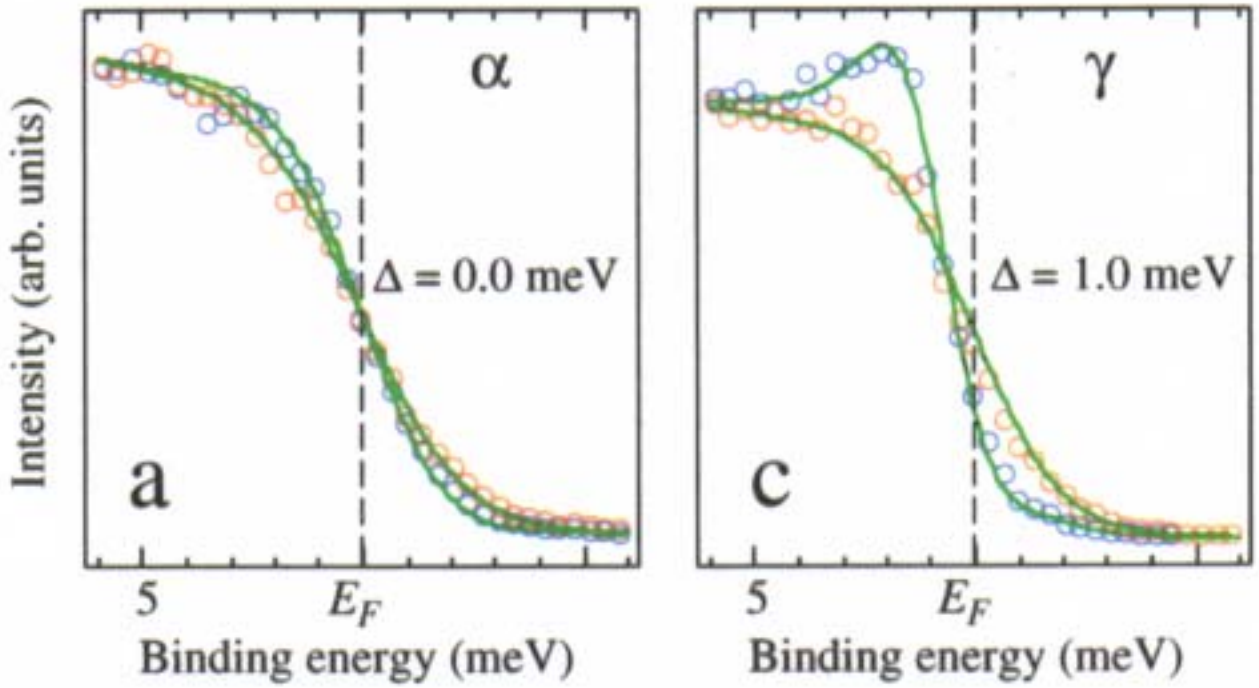


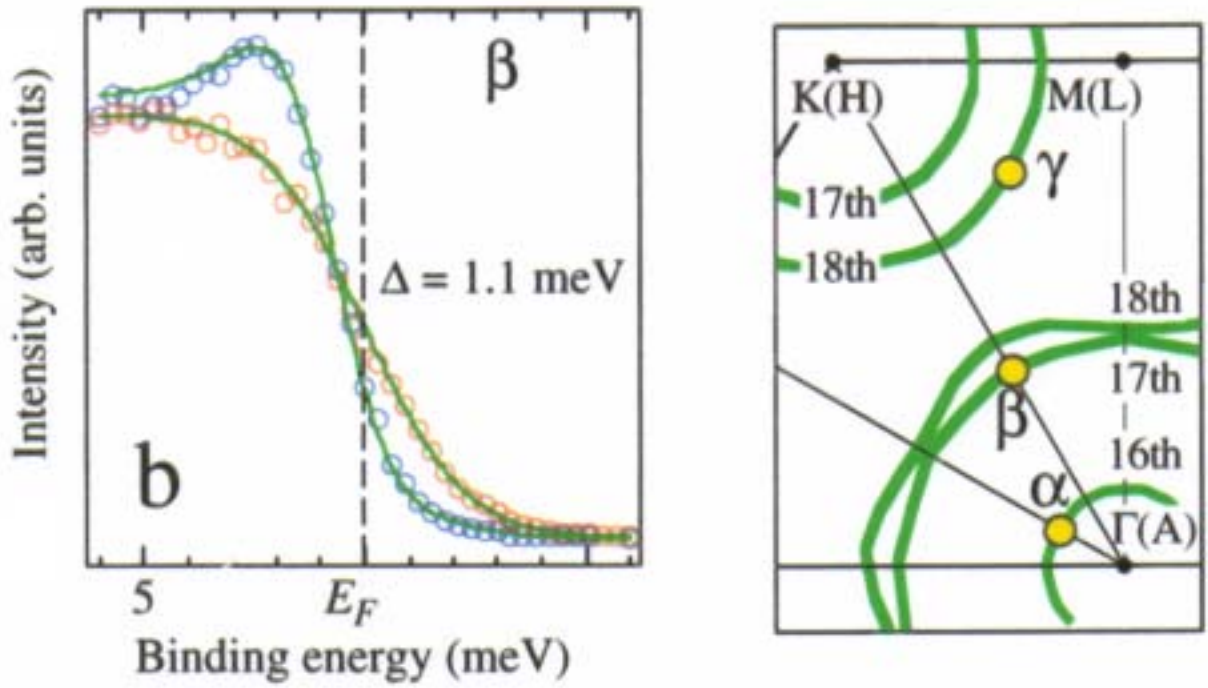
Ultrahigh-resolution ARPE spectra of $2H$-$NbSe_2$



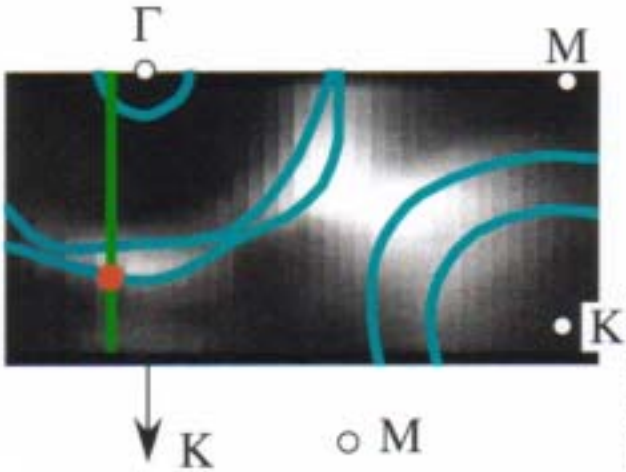
T. Yokoya, T. Kiss et al., Science 294 (2001) 2417.

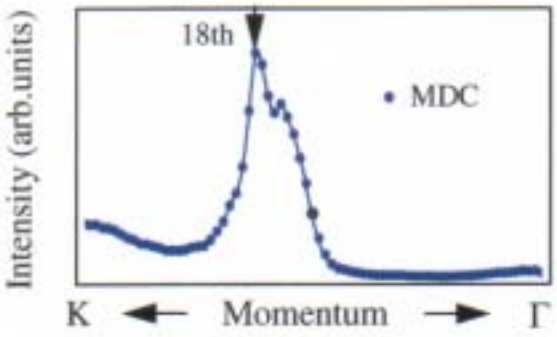
Ultrahigh-resolution ARPE spectra of 2H-$NbSe_2$ (T_c=7.2K) measured below and above T_c

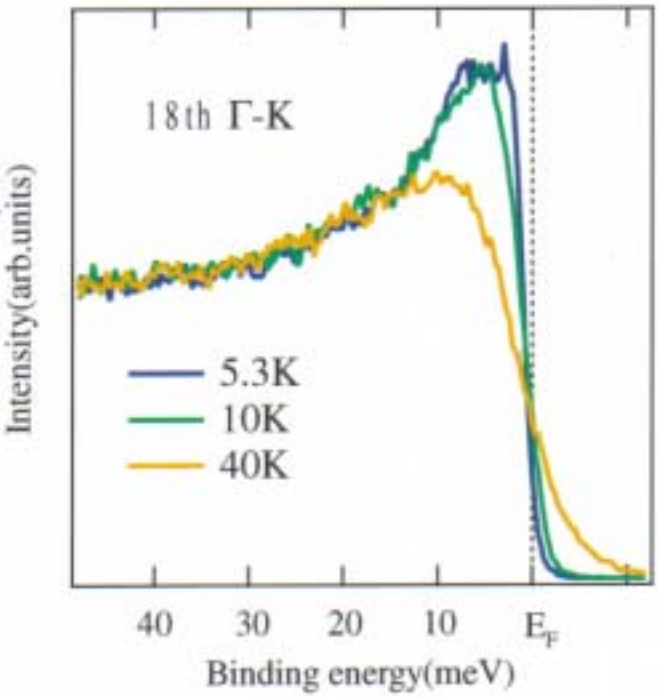


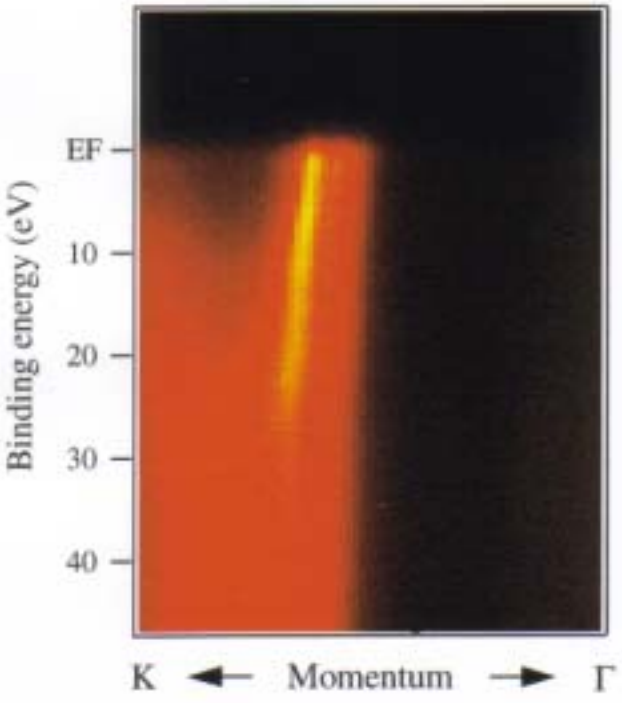


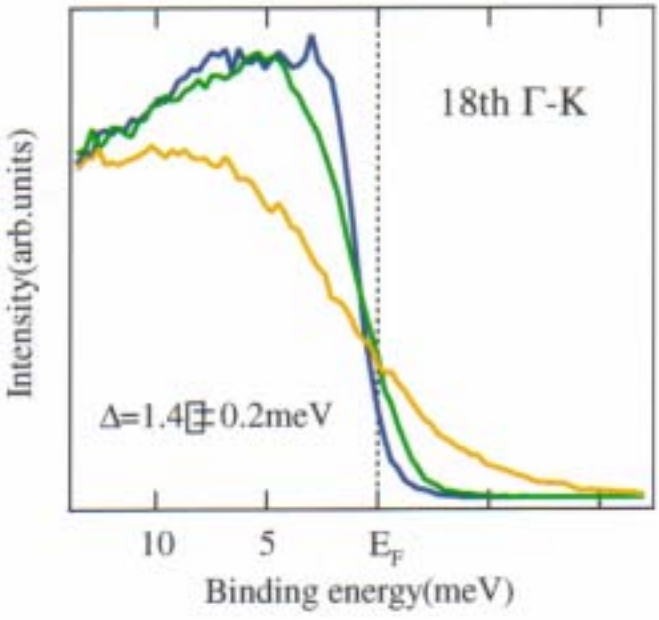
EDC, MDC, and intensity plot of ultrahigh-resolution ARPE spectra of 2H-$NbSe_2$



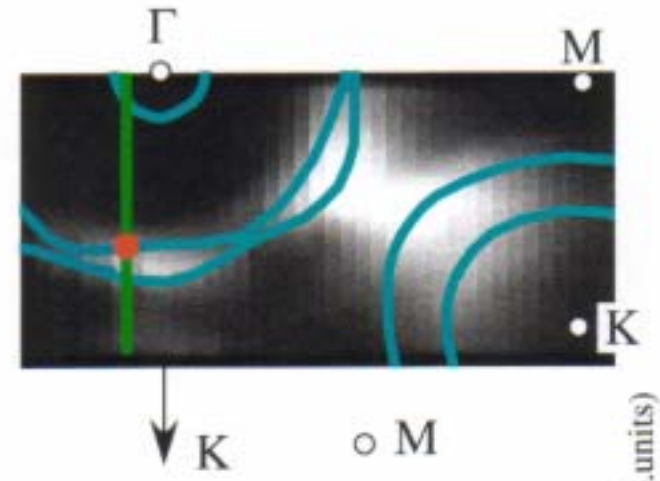


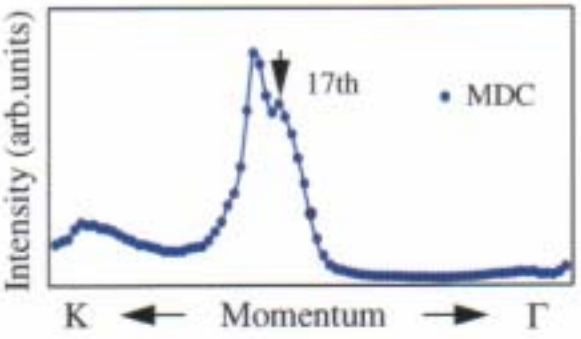


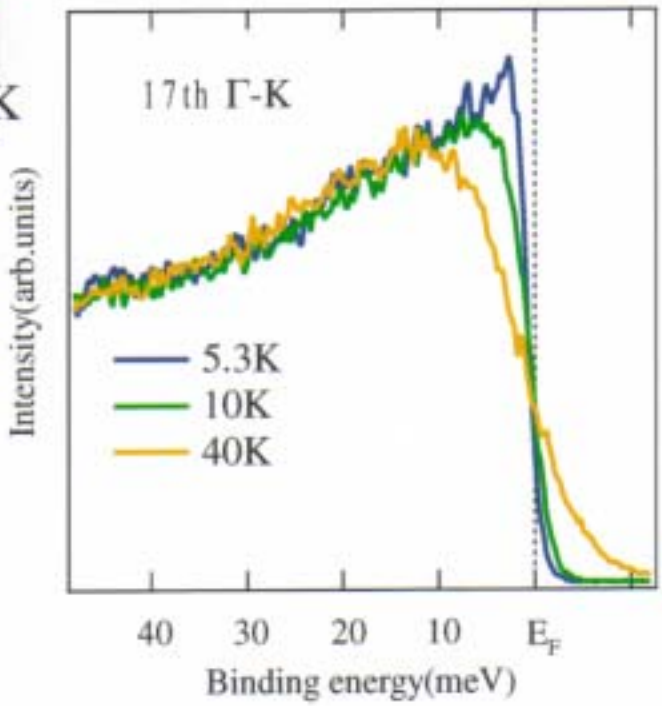


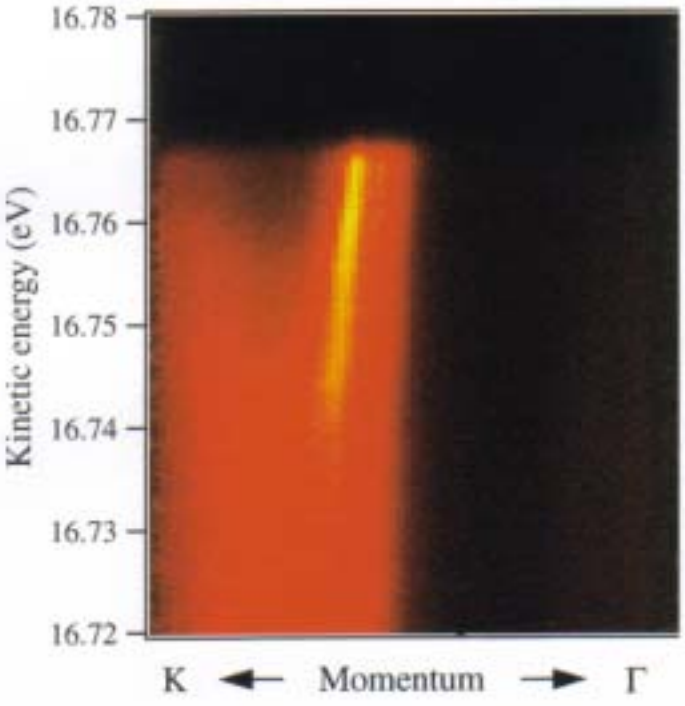


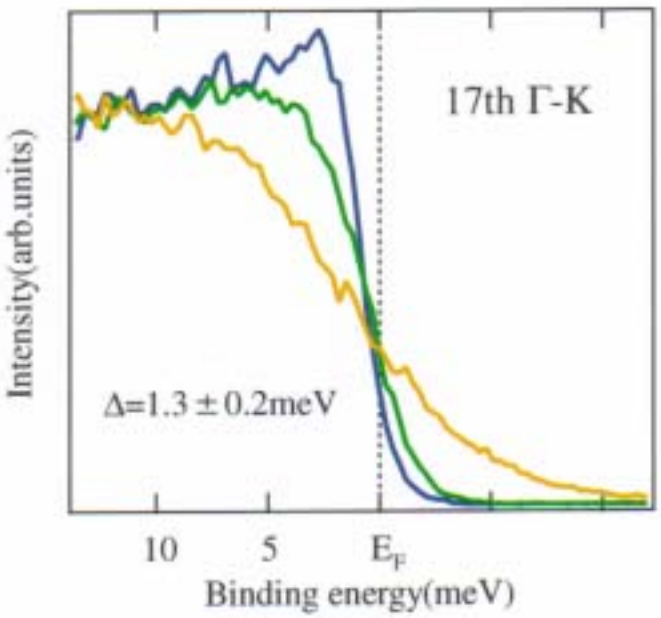
Ultrahigh resolution Angle-resolved photoemission spectra of $2H$-$NbSe_2$



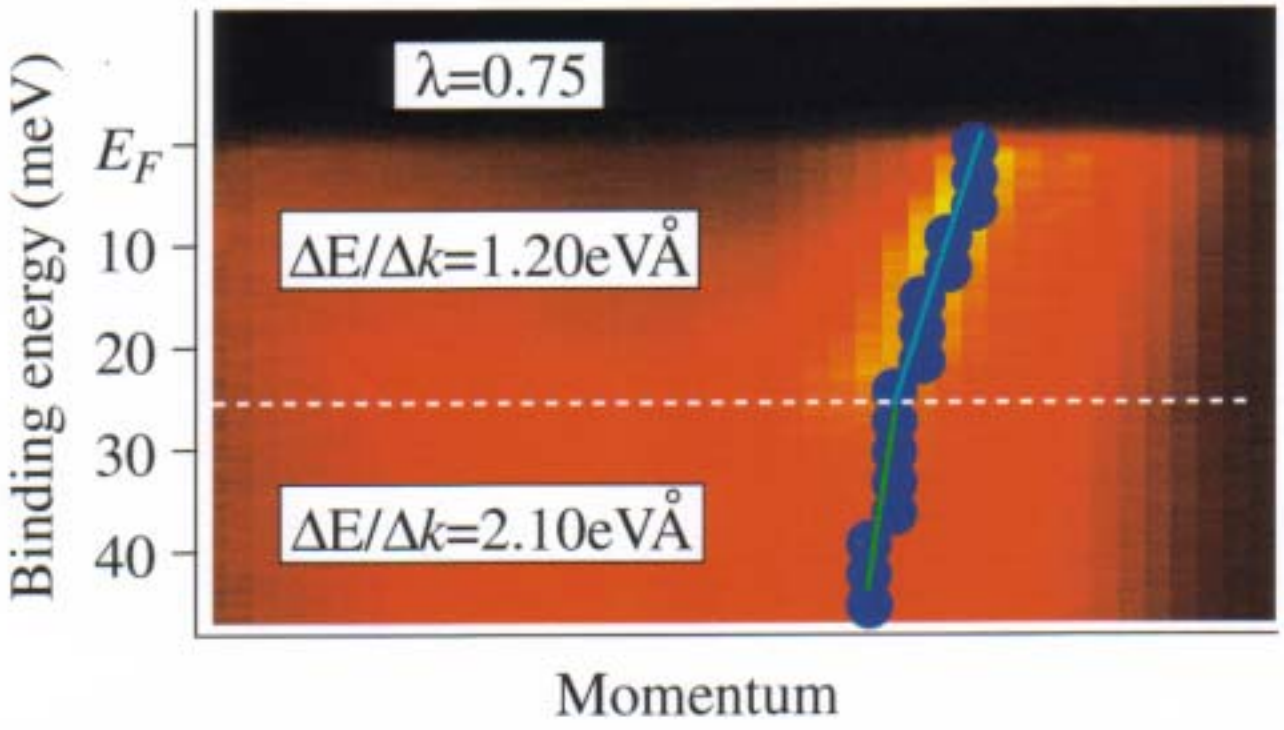


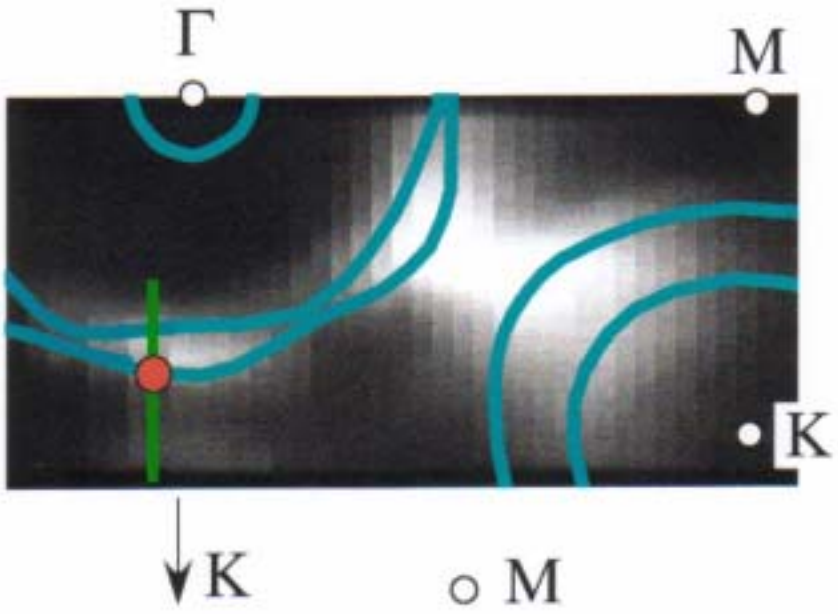






Fermi velocity of the band along ΓK of 2H-$NbSe_2$

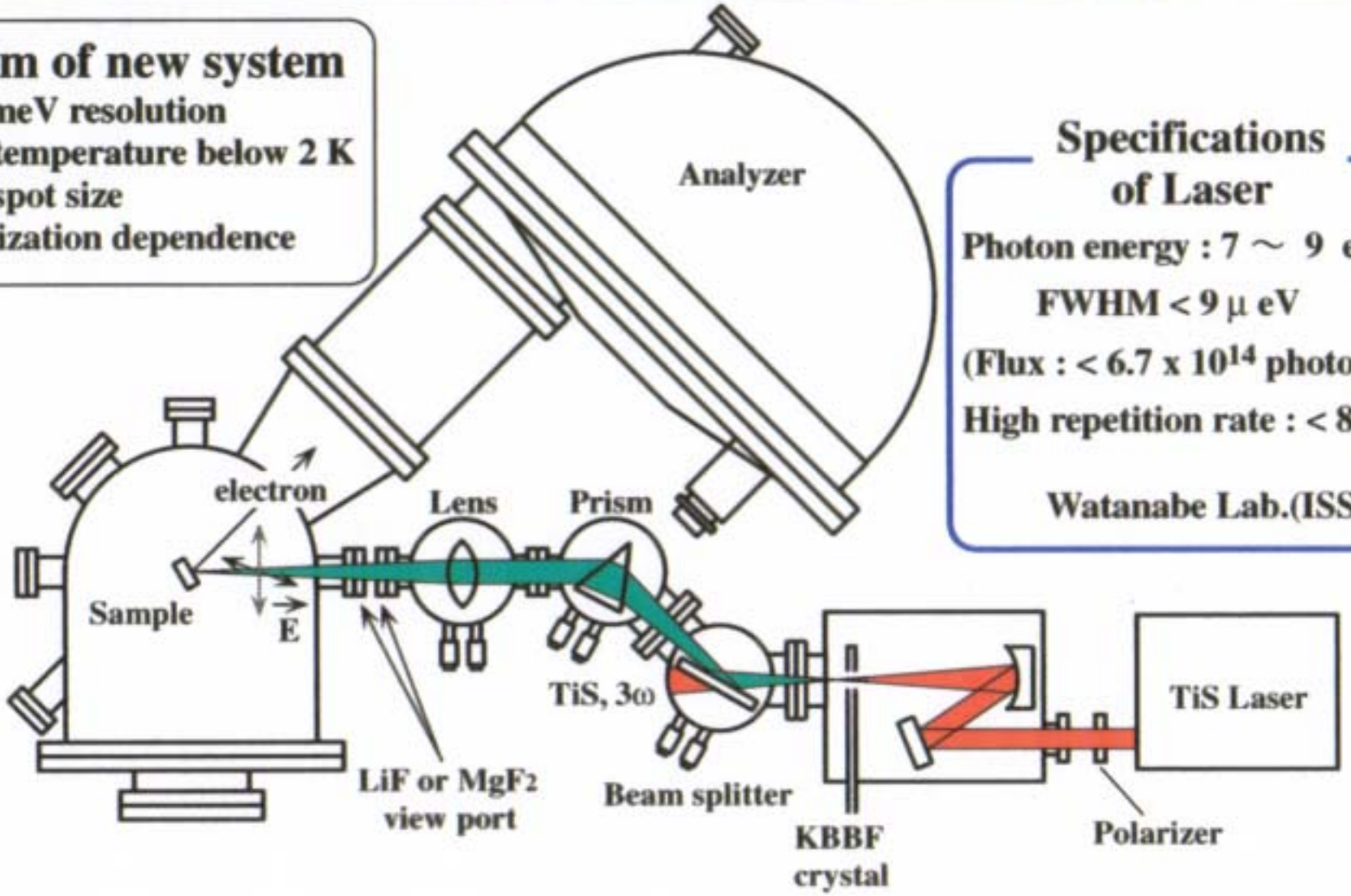




Schematic Diagram of Ultrahigh-Resolution Photoemission Spectrometer using Laser as Photon Source

The aim of new system

1. Sub-meV resolution
2. Low temperature below 2 K
3. 10-μ spot size
4. Polarization dependence



Specifications of Laser

Photon energy : 7 ~ 9 eV

FWHM < 9 μ eV

(Flux : < 6.7 x 10^{14} photons/sec)

High repetition rate : < 80 MHz

Watanabe Lab.(ISSP)

まとめ

- 超高分解能化・低温化

  微細電子構造の観測

  low-T_c superconductors

- 角度分解光電子分光

  multi-band fermi surface

  SC-gap sheet-dependence

  T. Yokoya, T. Kiss, A. Chainani, S. Shin, M. Nohara, H. Takagi,
  Science **294** (2001) 2417

  SC-gap anisotropy (momentum-dependence)

試料(2*H*-$NbSe_2$)提供

高木 英典　（東大新領域）

野原 実　（東大新領域）

花栗 哲郎　（東大新領域）