低電離タングステンイオンの電子捕獲断面積測定
Cross Sections for Electron Capture Collision of W Ions

京都大学 工学研究科 原子核工学専攻
今井 誠，入来 仁隆

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Status for charge transfer collision cross section of ions

H, He	◎
Li, Be, ・・・, Ne	○
Na, ・・・, Ar	△
以降	Fe, Cu, U等ごく一部

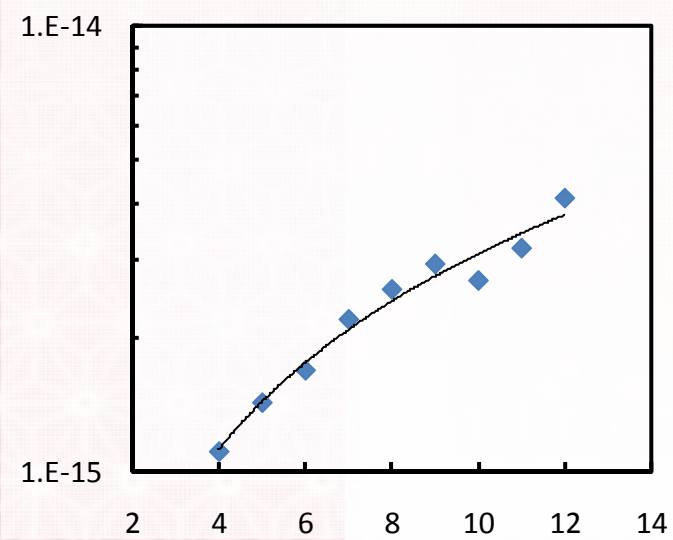
Status for charge transfer collision cross sections for W

- Measured cross section for single electron capture by Meyer *et al*. at 8.5, 11 MeV (46, 60 keV/u) in PRA19, 515 (1979).

W^{q+} + H, H_2, Ar (q = 6−15)

$$\sigma_{H_2} = 1.6\times10^{-16} q^{1.3} \left(\mathrm{cm}^2\right)$$

$$\sigma_{Ar} = 2.4\times10^{-16} q^{1.1} \left(\mathrm{cm}^2\right)$$



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- Production (measurements) of electron capture cross sections
  for some fusion-related processes in Kyoto University

  W^{+}, W^{2+} + He, Ne, Ar, Kr, H_2, N_2, CH_4, C_2H_6

- Theoretical study of single ionization of W ion by Ar
  by V. P. Shevelko (P. N. Lebedev Physical Institute, Russia)

  W^{+} + Ar

- Theoretical study of electron capture of W ion
  by R. J. Buenker (Bergische Universität Wuppertal, Germany)

  W^{+} + H, He, H_2

Production of Absolute Cross Sections for Fusion Related Electron Capture Processes

Energy = (0.5) 5 - 32 keV

Till 1994

$C^{1,2,3+}$ + H_2, CO_2, CH_4, C_2H_6, C_3H_8

1995 – 1997

$Cr^{1,2+}$ + He, Ne, Ar, Kr, H_2, CO, CO_2, CH_4, C_2H_6, C_3H_8

$Be^{1,2+}$ + He, Ne, Ar, Kr, H_2, CO, CO_2, CH_4, C_2H_6, C_3H_8

Be will be used as the First Wall Material in the ITER!

1998 – 2000

$Ni^{1,2+}$ + He, Ne, Ar, Kr, H_2, CO, CO_2, N_2, CH_4, C_2H_6, C_3H_8

2001 – 2004

Fe^{+} + He, Ne, Ar, Kr, H_2, CO, CO_2, N_2, CH_4, C_2H_6, C_3H_8

$Be^{1,2+}$ + He, Ne, Ar, Kr, H_2, CO, CO_2

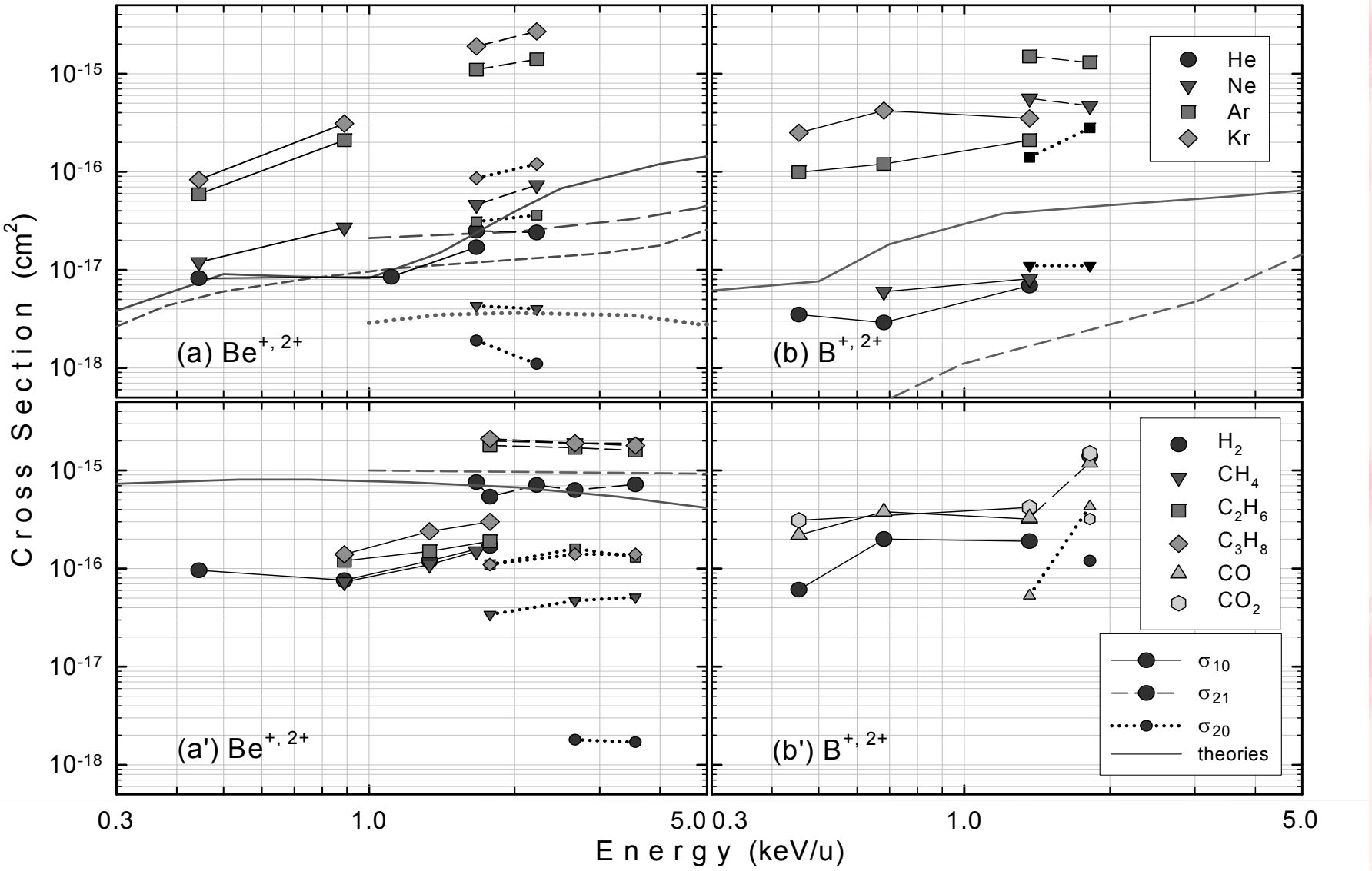
$B^{1,2+}$ + He, Ne, Ar, Kr, H_2, CO, CO_2

2005 – present

W^{+}, W^{2+} + He, Ne, Ar, Kr, H_2, N_2, CH_4, C_2H_6

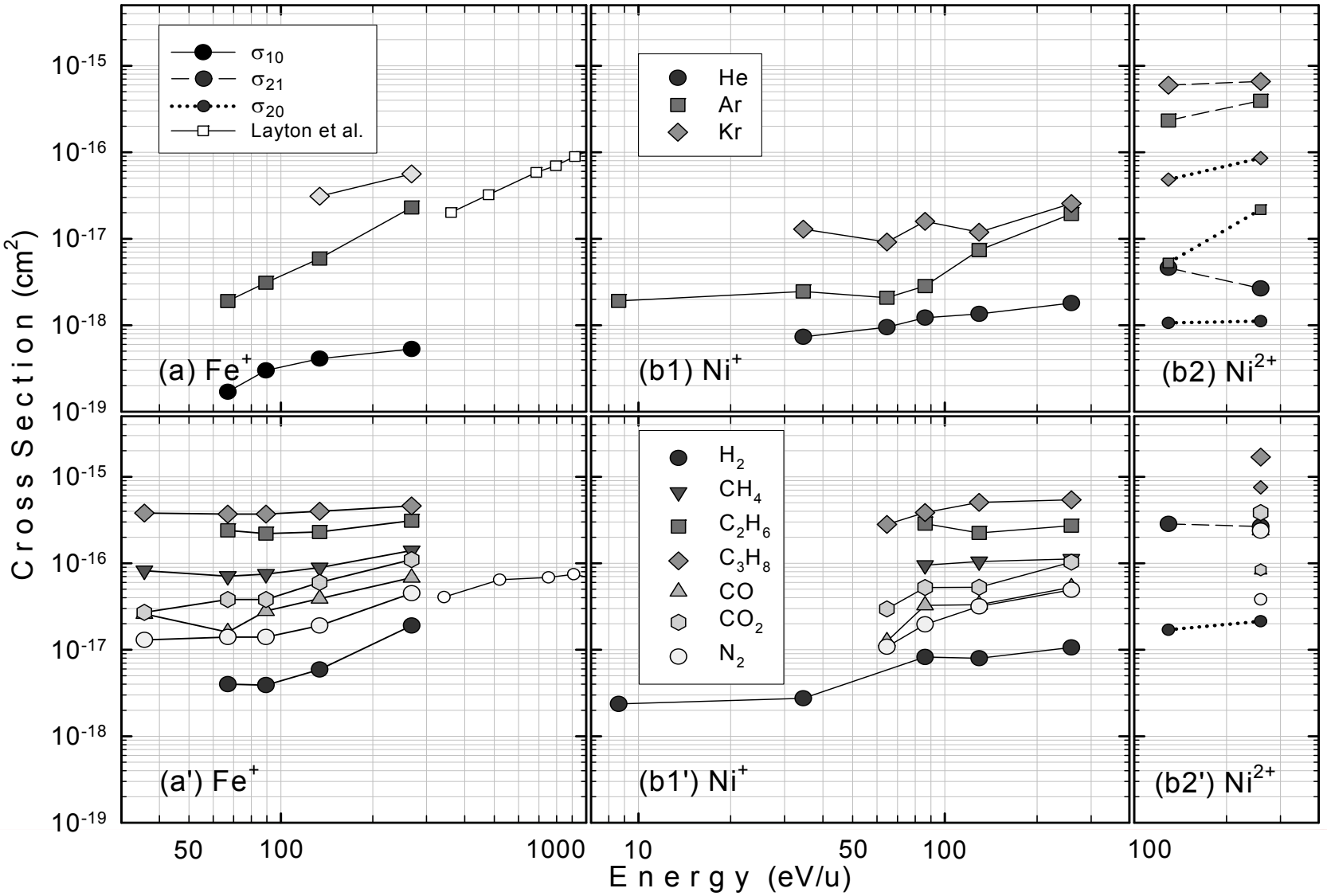
W will be used for DIVERTOR Buffle and Dome in the ITER!

IAEA Coordinated Research Project (CRP) on “Atomic Data for Heavy Element Impurities” (2005 – 2009) requires data for elements with atomic mass ≥ 13; (Ar, Kr, Xe), Si, Cl, **Cr**, **Fe**, **Ni**, Cu, Mo and **W**!



Single and double electron capture cross sections σ_{10}, σ_{21} and σ_{20} for Be and B ions.

J. Plasma Fusion Res. SERIES Vol.7, pp.323-326.



Single and double electron capture cross sections σ_{10}, σ_{21} and σ_{20} for Fe and Ni ions.

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The Experimental Apparatus

Pump Beam
0.9 MeV (20 keV/u) CO_2^+

Neutral Particle Rejector

Base Pressure
$< 4 \times 10^{-5}$ Pa

Accelerating Electrodes
Einzel Lens

Deflector

Collision Cell

Base Pressure
$< 3 \times 10^{-6}$ Pa

Signal 1

B

E

Accel. HV
< 16 KV

W Wire

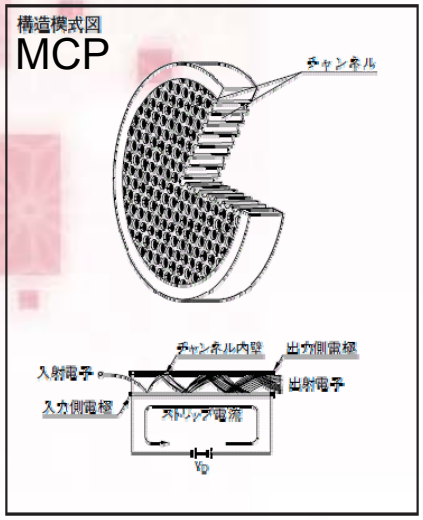
Wien Filter

Ion Source Chamber

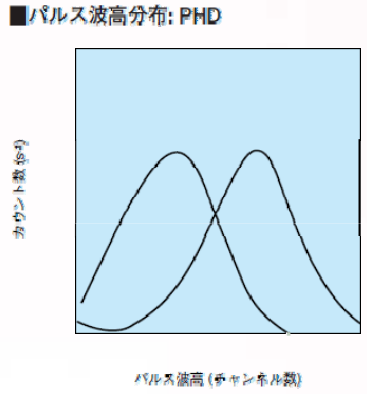
MCP
Biased Resistive Anode

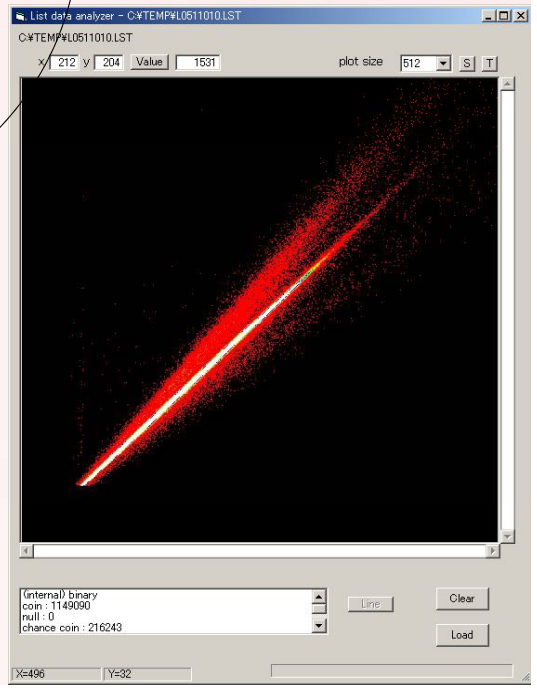
Signal 2

Collision Chamber



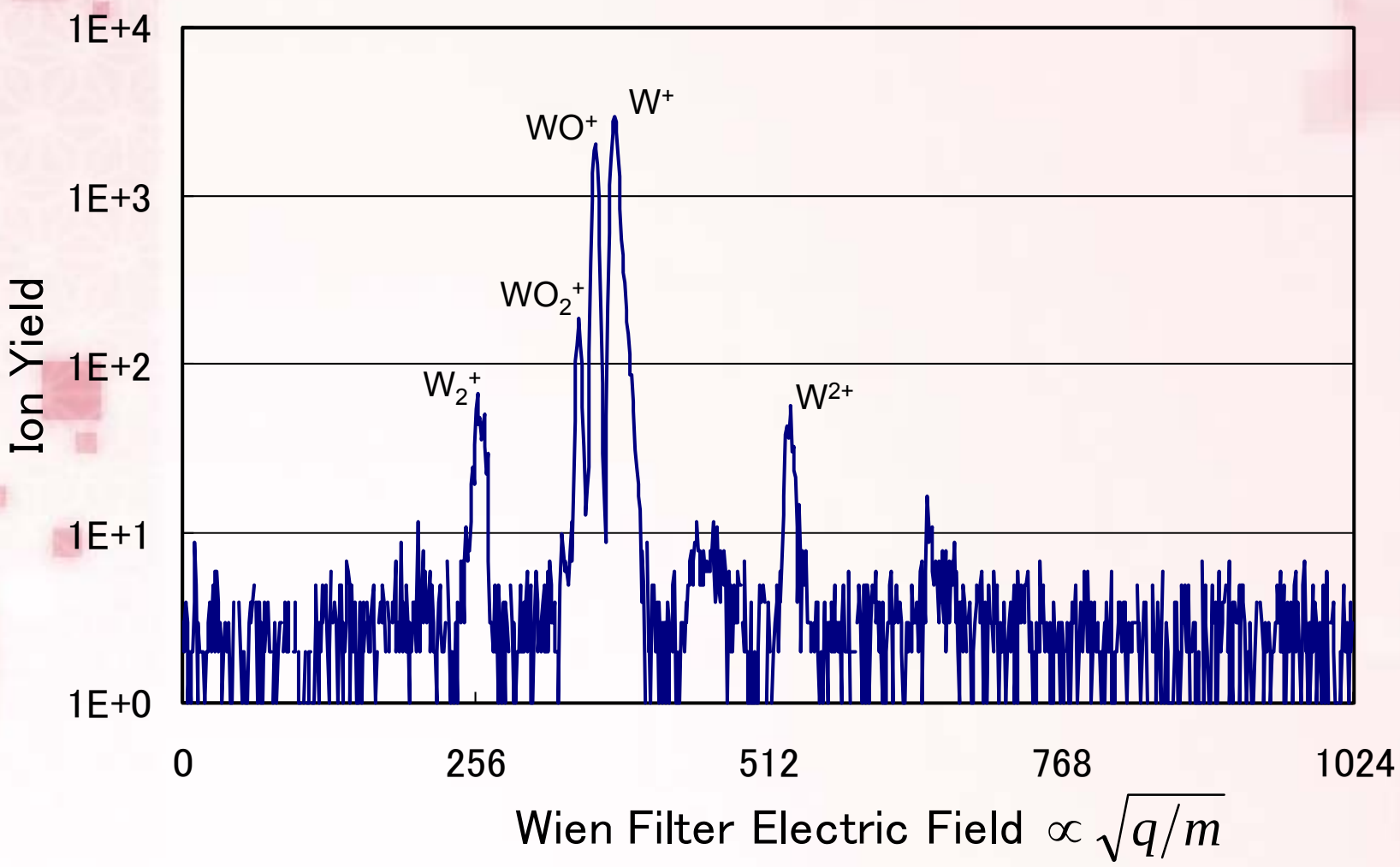
チャンネル径　12μm
開口率　60%





Projectile W Ion Selection

7.5 keV W^+ Extraction



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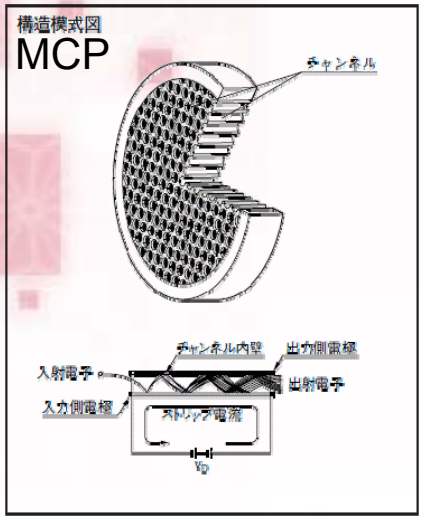

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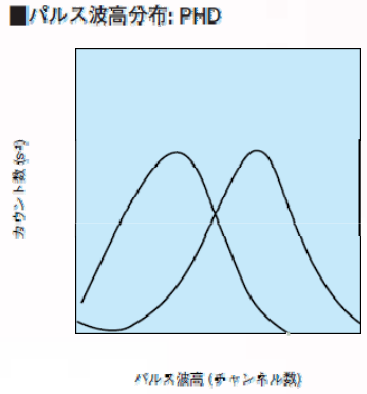
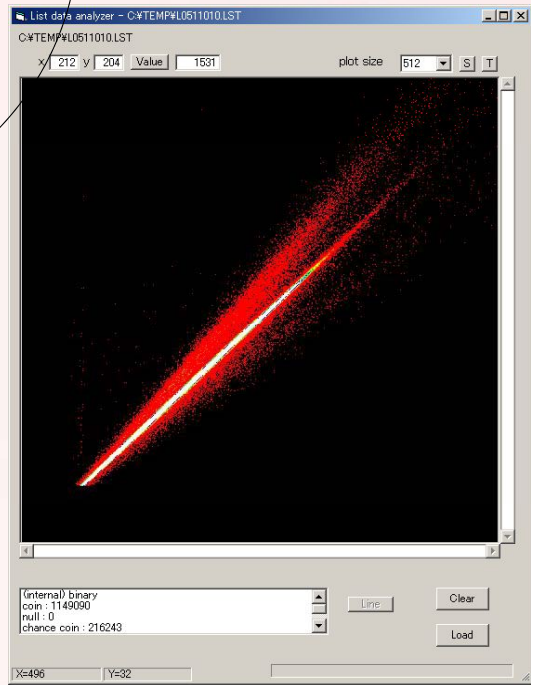




How to Derive Cross Sections

Rate equation for W^{i+} intensity $\dfrac{dF_i(\pi)}{d\pi} = \sum_{j\neq i}\left[F_j(\pi)\sigma_{ji} - F_i(\pi)\sigma_{ij}\right],$

$$\sum_i F_i(\pi) = 1,$$

where

$F_i(\pi)$: Relative Intensity of W^{i+} ion

π: Target Thickness (= Density × Length in /cm^2)

σ_{ji}: Charge Transfer Cross Section (cm^2) $W^{j+} \rightarrow W^{i+}$

Under the Single Collision Condition, this simultaneous equation reduces to $\dfrac{I_0}{I_2+I_1+I_0} = \sigma_{10}\pi$, $\dfrac{I_2}{I_2+I_1+I_0} = \sigma_{12}\pi$,

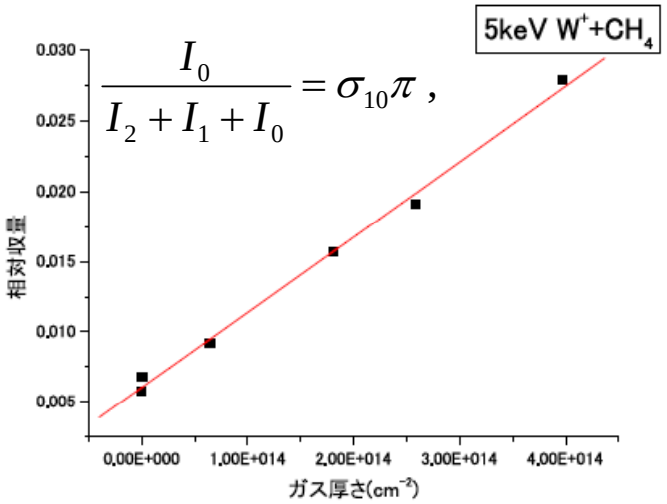
where

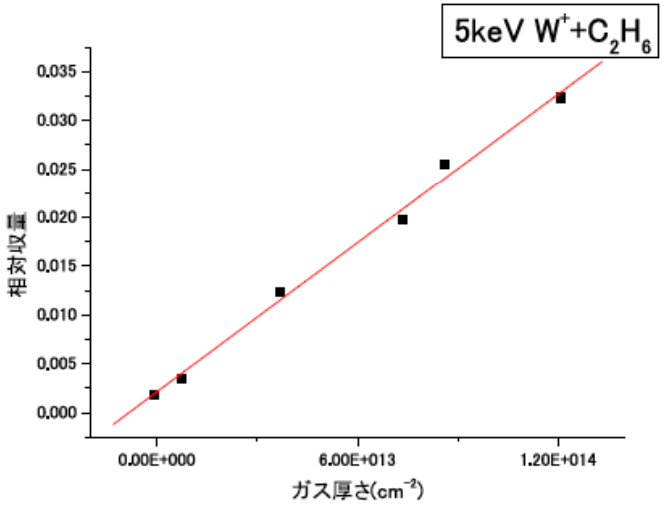
I_2, I_1, I_0: Intensity of W^{2+}, W^{+} and W^{0}, respectively.

Data Processing

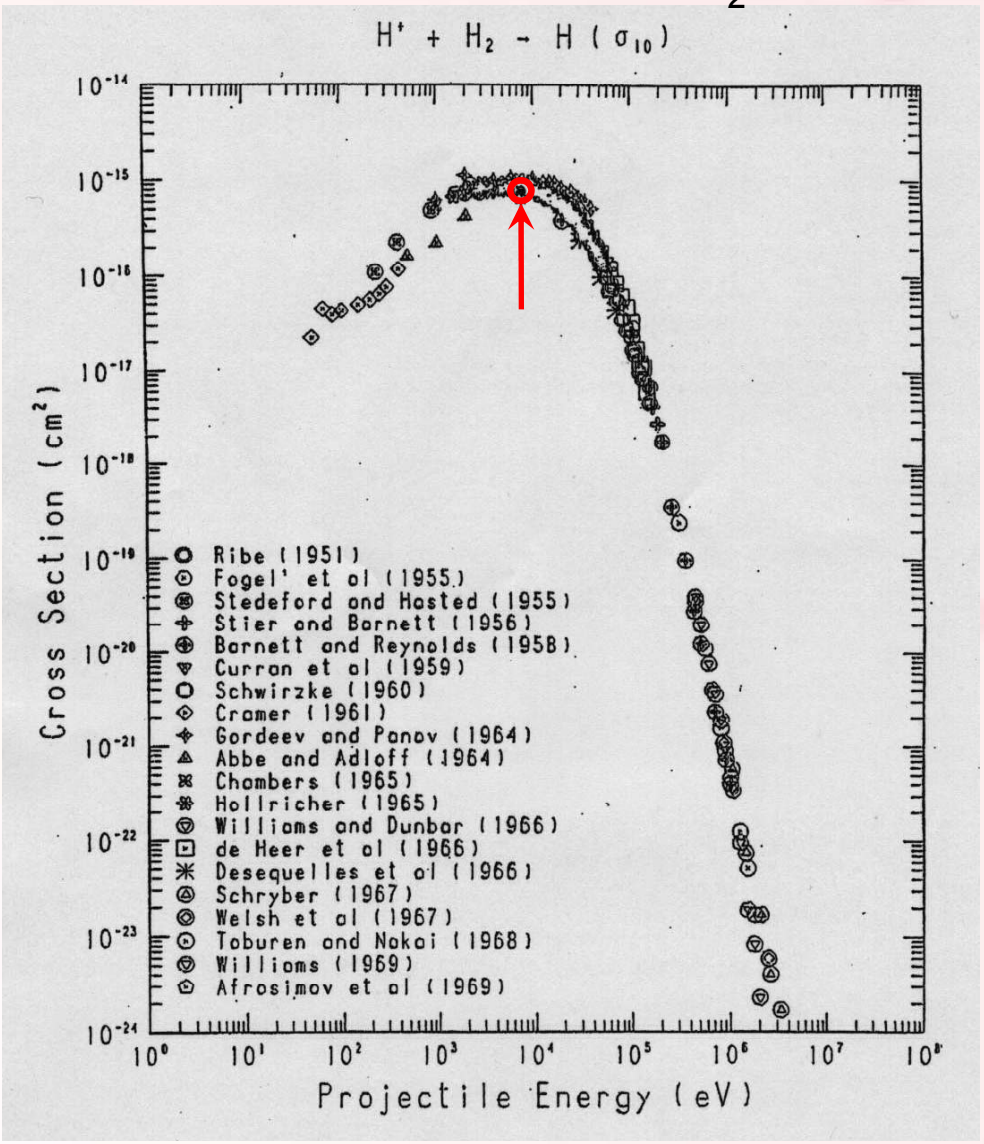
Growth Curve for 5 keV W^+

$$\frac{I_0}{I_2 + I_1 + I_0} = \sigma_{10}\pi ,$$

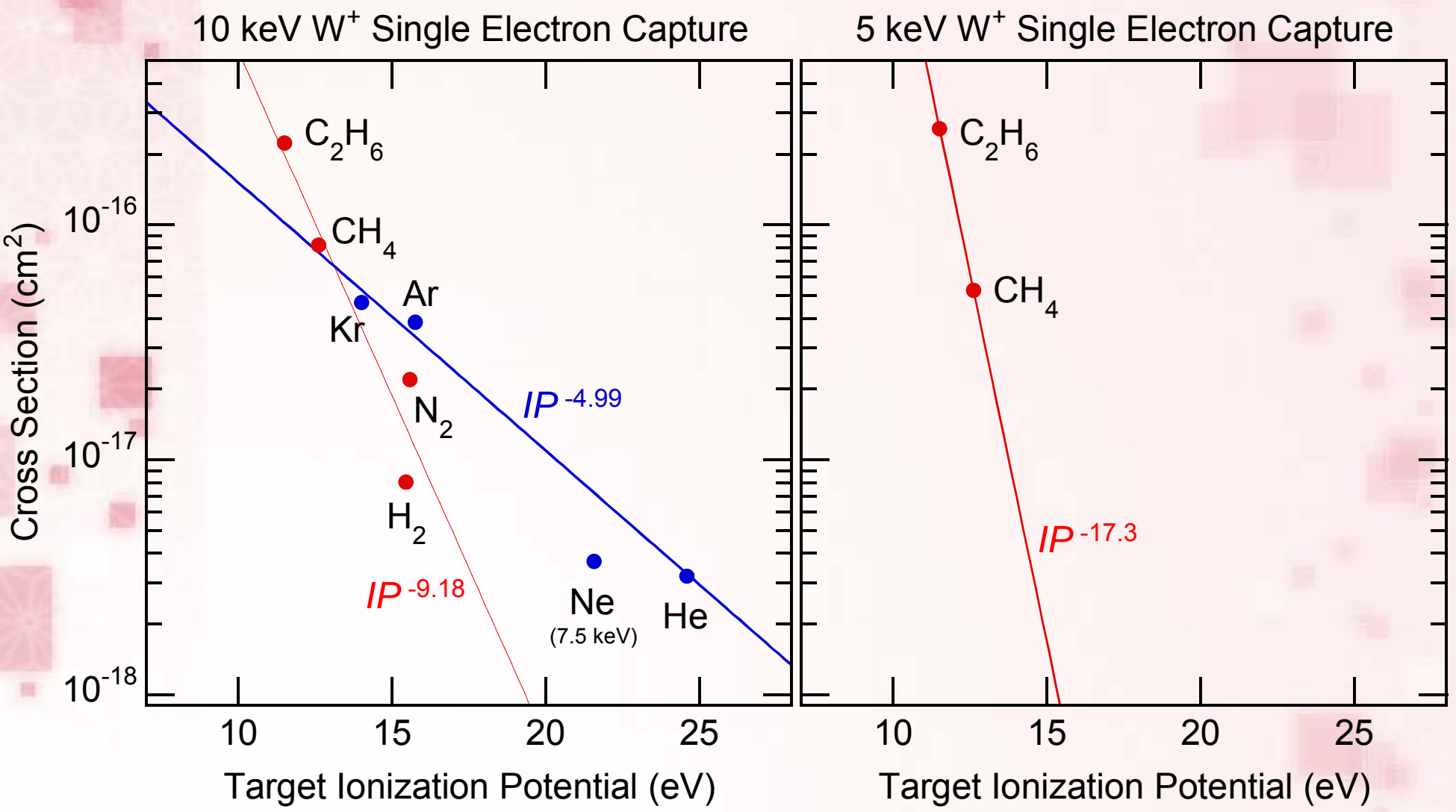




Bench mark for 7.5 keV $H^+ + H_2$ collision



Single Electron Capture Cross Sections for W^+ Ions on Gas Targets at 10 and 5 keV (54 and 27 eV/u)



Single Electron Capture Cross Sections for W^{2+} Ions on Gas Targets at 15 keV (82 eV/u)