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SECOND SCHOOL ON THE USE OF SYNCHROTRON RADIATION IN SCIENCE AND TECHNOLOGY: *"JOHN FUGGLE MEMORIAL"*

25 October - 19 November 1993

Miramare - Trieste, Italy

I.A. Interaction : Absorption (Photoelectric)

A. Fontaine
L.U.R.E.
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I. A. INTERACTION : ABSORPTION (PHOTOELECTRIC)

a/ $h\nu \sim 1\,keV \overset{25\,keV}{\underset{100\,eV}{\uparrow}}$ ORDER OF MAGNITUDE OF BINDIND ENERGIES OF THE CORE ELECTRONS.

Zn	9659	1022	1045	1196
Cu	K	L_{III}	L_{II}	L_I
$h\nu$	8979.8 eV	932 eV	952 eV	1097
$\bar{e}$	1s	$2p^{3/2}$	$2p^{1/2}$	2s
	↑↓	↑↓↑↓	↑↓	↑↓
Ni	8333	853	870	1009

b/ Absorption is a microscopic effect

Atom
$r \simeq 10^{-10}\,m$ $\qquad c = 3\,10^{8}\,ms^{-1}$

and FAST PHENOMENON / Broad

$\delta t_{INT} \gg \delta t_{CROSS.}$ but still small $\left\{ \begin{array}{l} \downarrow \Delta\nu \text{ and} \\ \text{length of} \\ \text{the wave packet} \\ (\sim 10^{4}\lambda) \end{array} \right.$

$1\,eV \sim (10^{-15}\,s)$

c/ Absorption is a time-dependent phenomenum

d/ FINAL STATE (XAS) : SYSTEM LEFT WITH A CORE HOLE

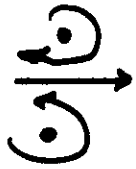
OUR AIM IS TO FIND GROUND STATE PROP.

e/ ABSORPTION is an INELASTIC PROCESS.

f/ Intense source of photons (x)

SYNCHROTRON RADIATION

- "white source"
- intense & collimated — brilliance/brightness
- polarized source



Right

Left

- pulsed source

g/ $h\nu > 100\,eV$ (boundary is Z-dependent)

<u>refractive index</u> is CLOSE TO 1

- At the opposite of visible light core electrons don't feel a local field. (Brewster = 45°)
- ⇒ SEMI CLASSICAL APPROX. (or STRONG "ELECTROM. FIELD")

Quantic effects remain small quantities compared to those given by classic physics

- IN OTHER WORDS X-RAY SEES A GAS of BOUND ELECTRONS, ONLY ONE (CORE $\bar{e}$) BEING POSSIBLY EXCITED.

$$n = 1 - \underbrace{\delta}_{10^{-5}} - i\underbrace{\beta}_{10^{-5}} \qquad \beta = \frac{\lambda\mu}{4\pi}$$

Aluminium

$n = (1-\delta) - i\beta$

$n'(\omega)$

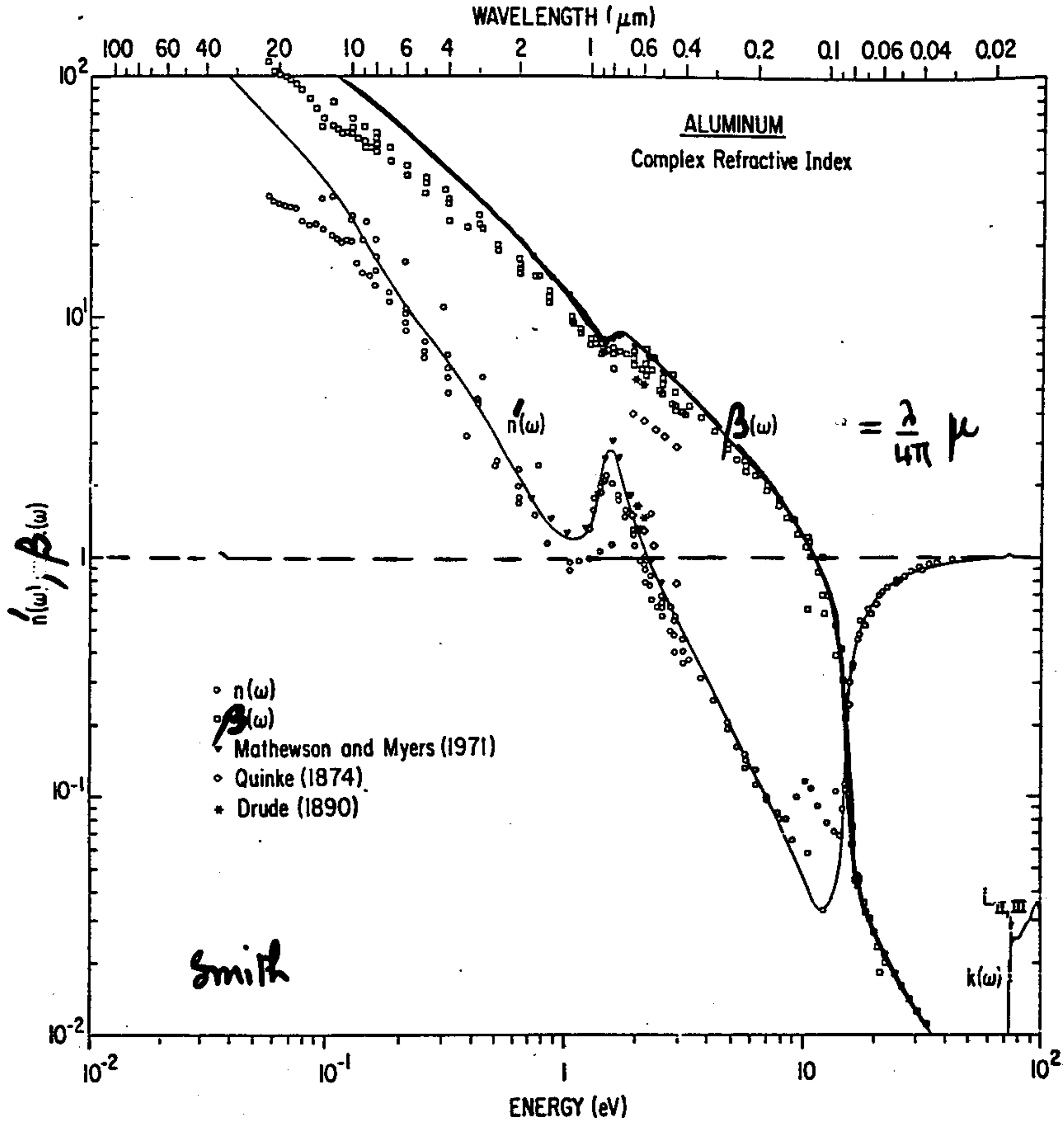


Fig. 4. The Complex Refractive Index [$n(\omega) + ik(\omega)$] of Metallic Aluminum. The solid curve is taken from Shiles et al.'s analysis of uhv reflectance data (Ref. 7). A portion of the uhv ellipsometric data of Matthewson and Myers (Ref. 87) is given for comparison. Quincke's (Ref. 28) and Drude's (Ref. 29) results for polished bulk samples are shown for historical interest; considering the materials and techniques available, these early measurements are remarkedly good, especially for $n(\omega)$. The remainder of the data points are given to show the range of values of $n(\omega)$ and $k(\omega)$ reported in the literature. Most refer to evaporated films prepared in conventional or high vacuum and measured using polarimetric, interferometric, etc., methods. The sources of these data are Refs. 9, 10, 22, 23, 24, 46, 50, 52, 62, 63, 70, 72, 83, and 108-116. Note that the $n(\omega)$ curve and the $k(\omega)$ curve cross each other at roughly 15 eV, the conduction electron plasmon energy. This corresponds to the condition $\epsilon_1(\omega_p) = n^2(\omega_p) - k^2(\omega_p) = 0$. The onset of the L absorption appears in the lower right corner. The corresponding dispersion is visible as a little "pimple" on the index curve near 72 eV.

3

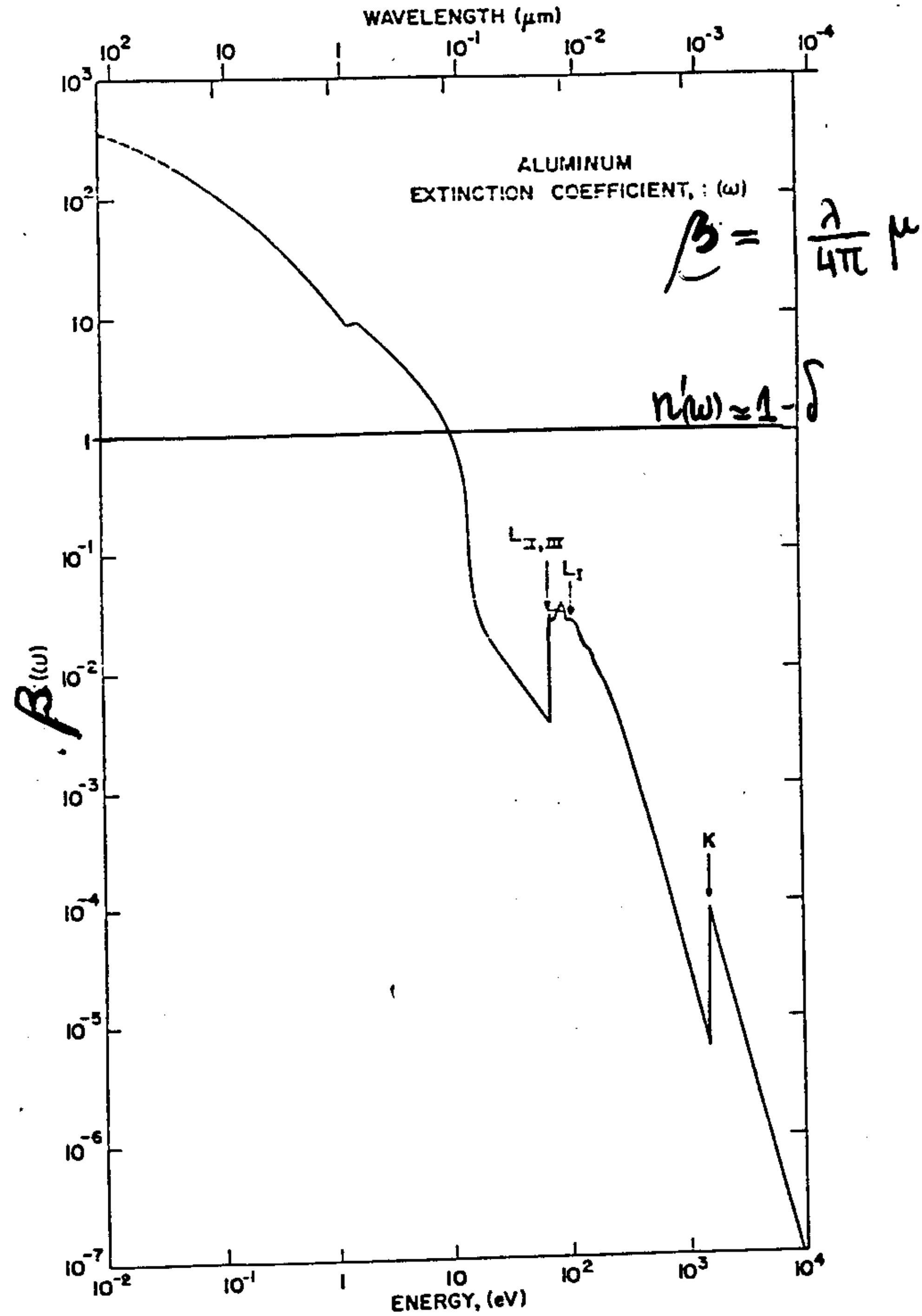


Fig. 1. The Extinction Coefficient (i.e., the imaginary part of the refractive index) for Metallic Aluminum at Room Temperature. After Shiles et al. (Ref. 7).

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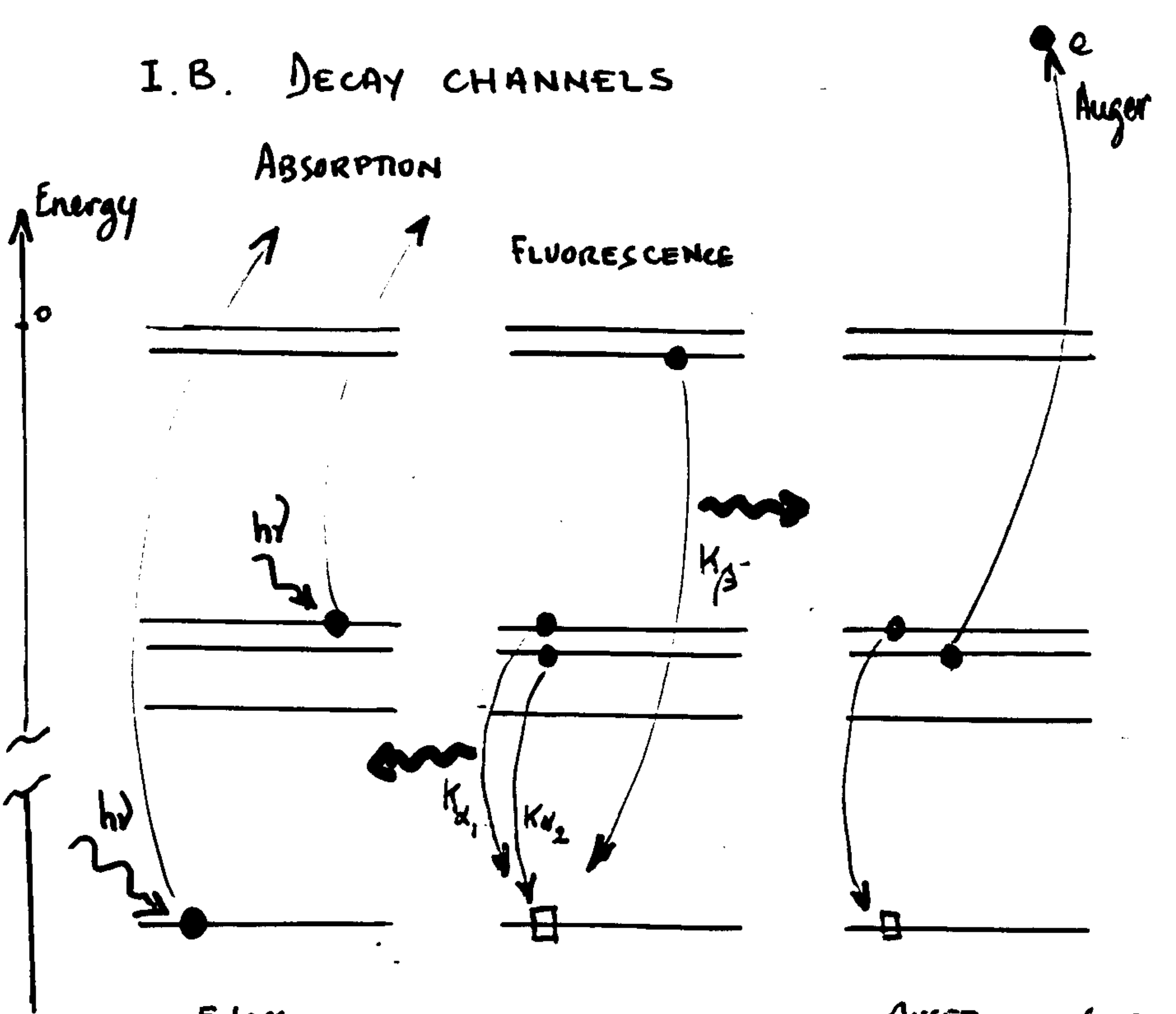
I.B. DECAY CHANNELS



Edges

K

L_I . BARKLA

L_{II}

L_{III}

M

fluorescence

MOSELEY

(Phil Mag. 1913, 26)

R.E. Identification

AUGER COSTER-

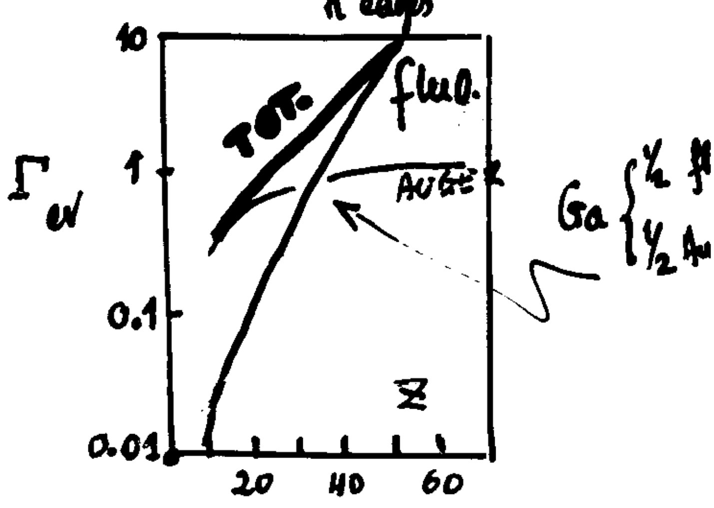
K L L

□ ē ē

K V V

□ ē ē

$$\Gamma\ (\text{width eV}) \sim \frac{1}{\text{lifetime}}$$



X. RAY ABSORPTION SPECT.

&

Resolution
- EXPERIMENTAL RESOLUTION $\delta E = E \cot g \theta \delta \theta$.
- CORE HOLE WIDTH.

DECAY CHANNELS

~ LIFE TIME of the EXCITED STATE

$$\Delta E \sim \frac{\hbar}{\tau}$$

- $\Delta E \simeq 1.5 eV$ @ Cu K edge
- $\Delta E \sim 4,5 eV$ @ RE L_{III}, L_{II} edges
- Is it possible to collect CORE-HOLE WIDTH - ~~FREE~~ data?

DRASTICALLY REDUCED.

YES?

K. Hamalainen, J. Hastings, D. Siddons

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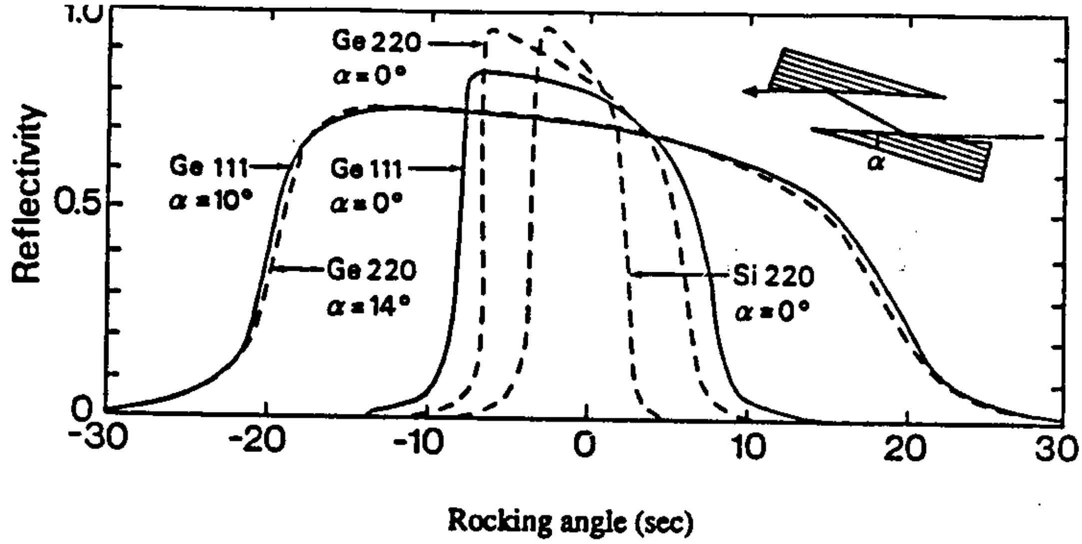
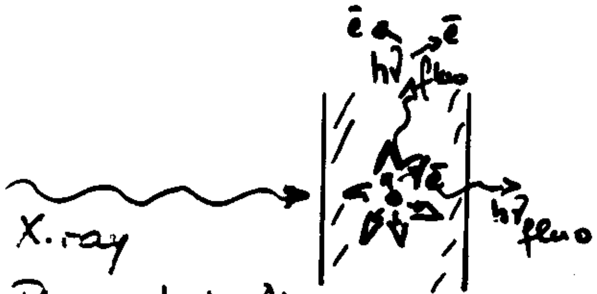


Fig. 6. Calculated double-reflection curves of grooved monochromators for symmetric and asymmetric reflections of silicon and germanium and for X-rays of 1.54 Å wavelength (After Kohra et al., 1978).

I. E. b/ INTERACTION WITHIN THE SENSING ELEMENT OF THE DETECTOR

AIM: PHOTON + MATTER $\begin{cases} \text{SOLID} & \text{Ge, Si} \\ \text{Gas} & \text{Xe, Kr, Ar} \end{cases} \Rightarrow$ BUNCH of ELECTRONS



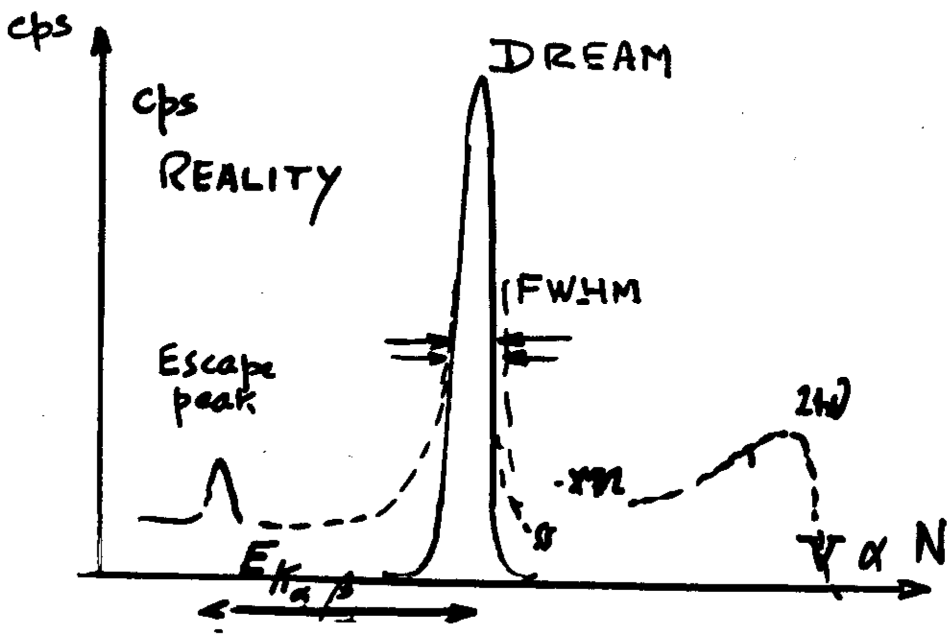
A Photoelect. Abs

1st step $\quad h\nu + Z \longrightarrow Z^{+} + \bar{e}_{\nu}$

decay
fluo
Auger

Second. electrons

secondary. electrons



$\propto N_{\bar{e}} = \dfrac{h\nu}{2.9\,eV}$ (Ge)

Si (3.7eV)

I.F. SUMMARY

WE 'D LEARNT

#1 X-RAY PHOTOELECTRIC ABSORPTION is THE DOMINANT PROCESS. ($h\nu \to \bar{e}$)

#2 CROSS-SECTIONS HAVE *ELEMENT-SPECIFIC THRESHOLDS*

Each core electron has a binding energy different from one element to another from $1s_K$ level to $2s, 2p_L, \ldots$ Bakle.

#3 DECAY CHANNELS CONTROL THE LIFE TIME of the EXCITED CORE LEVEL

i.e. THE WIDTH of the DISTRIBUTION of the KINETIC ENERGY of the PHOTOELECTRON

fortunately the COSTER-KRONIG CHANNELS DO NOT PLAY ANY ROLE (too weak) INTO CORE LEVEL ABSORPT. SPECT.

#4 REFRACTIVE INDEX ~ 1 but <1

- GOOD NEWS LOW ENERGY BAND PASS FILTER
- BAD NEWS NO "CONVENTIONNAL" LENS. TRICKY TO ACHIEVE (FRESNEL ZONES)

#5 DETECTION EASY FOR THE HIGH ENERGY SIDE > 5 keV

DIFFICULT OR "IMPOSSIBLE" (300–500 eV)

related to the PHOTOELECTRIC CROSS SECTION

not to COMPTON CROSS SECTION

$\Rightarrow$ ENERGY RESOLUTION.