“Workshop on Atomic Effects in Nuclear Excitation and Decay”
June 15-19, 2009, ECT, Trento, Italy*

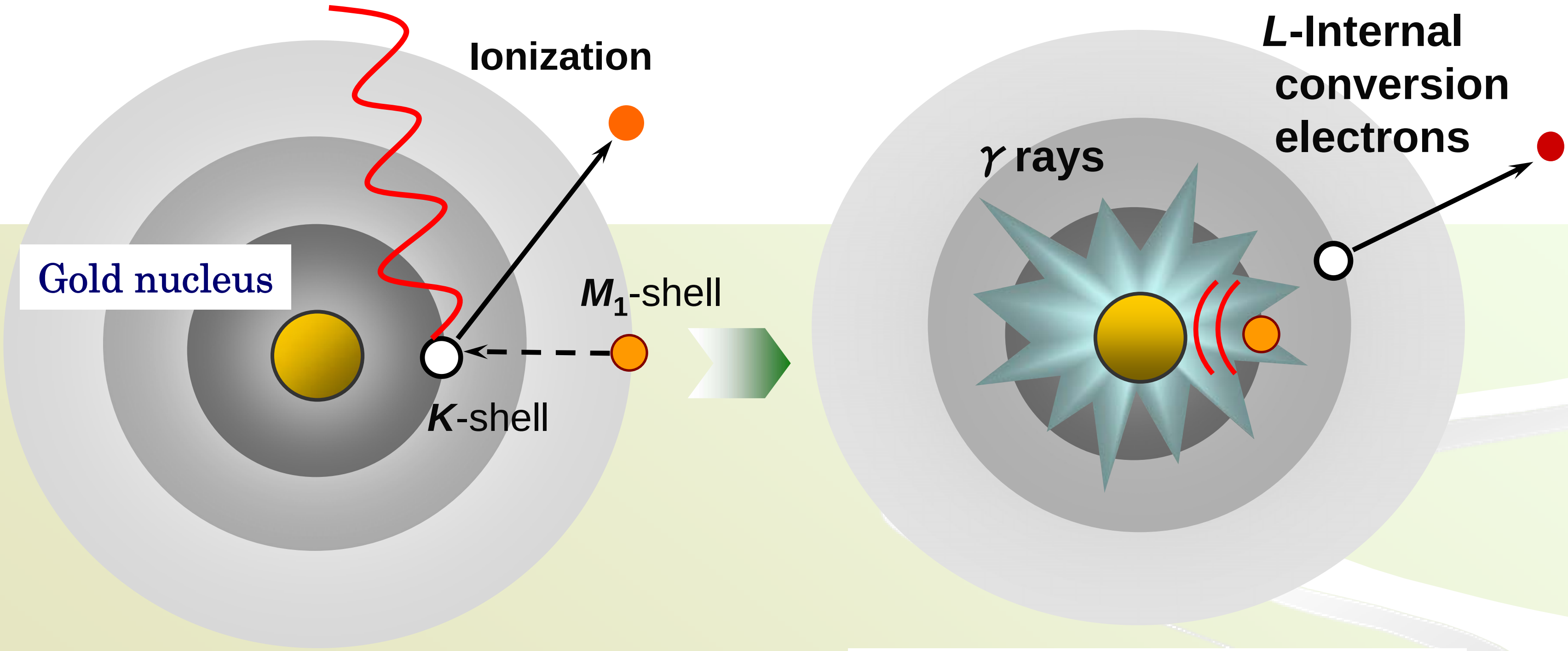
Observation of Nuclear Excitation by Electron Transition using Synchrotron X-rays

Shunji Kishimoto

Photon Factory,
Institute of Materials Structure Science
High Energy Accelerator Research Organization (KEK),
Japan

1. Nuclear Excitation by Electron Transition (NEET)

Ex. ^{197}Au, Phys. Rev. Lett. 85, 1831(2000)

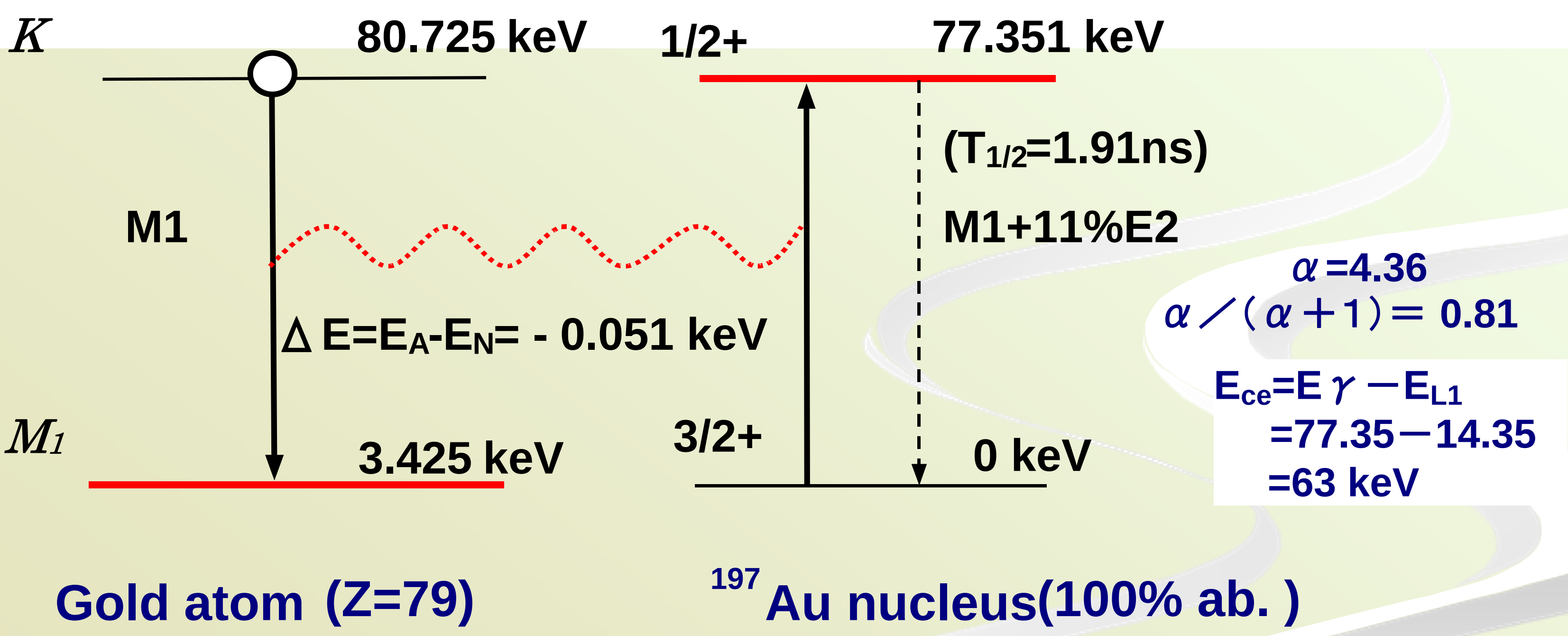


***K*-holes are produced by photoionization, and filled by an atomic transition from an outer orbit (Ex. M_1).**

The nucleus is then excited and followed by emitting radiation with a lifetime of the excited level.

NEET is observable if the energies of Atomic transition and of Nuclear transition are close and the transition type is common to both.

Ex. Au-197



NEET Probability :

P_{NEET} = (Nuclear Excitation) / (Core-electron hole Production)

M. Morita, Prog. Theor. Phys. 49, 1574 (1973) .

Nucleus Nat. ab.	E_{ion} (keV)	E_M(keV)	E_N (keV)	$T_{1/2}$(ns)	Δ E(keV) E_A-E_N	P_{NEET} (cal.) (exp.)
^{197}Au(Z=79) 100%	80.725 (K)	3.425(M_1)	77.351	1.91	-0.051	[A] 3.8×10^{-8} [B] $(5.0\pm0.6)\times10^{-8}$
^{193}Ir(Z=77) 62.7%	76.111 (K)	3.174(M_1)	73.044	6.09	-0.107	[C] 2.0×10^{-9} [D] $(2.8\pm0.4)\times10^{-9}$

[A] M.R.Harston, Nucl. Phys. A690(2001) 447.
[B] S.Kishimoto et. al., Phys. Rev. Lett. 85(2000) 1831.
Phys.Rev.C74(2006),031301(R).
[C] E.V.Tkalya, Phys. Rev. A75 (2005) 022509.
[D] S.Kishimoto et. al., Nucl. Phys. A748(2005) 3.

2. How can we observe NEET ? - Synchrotron X-ray experiments

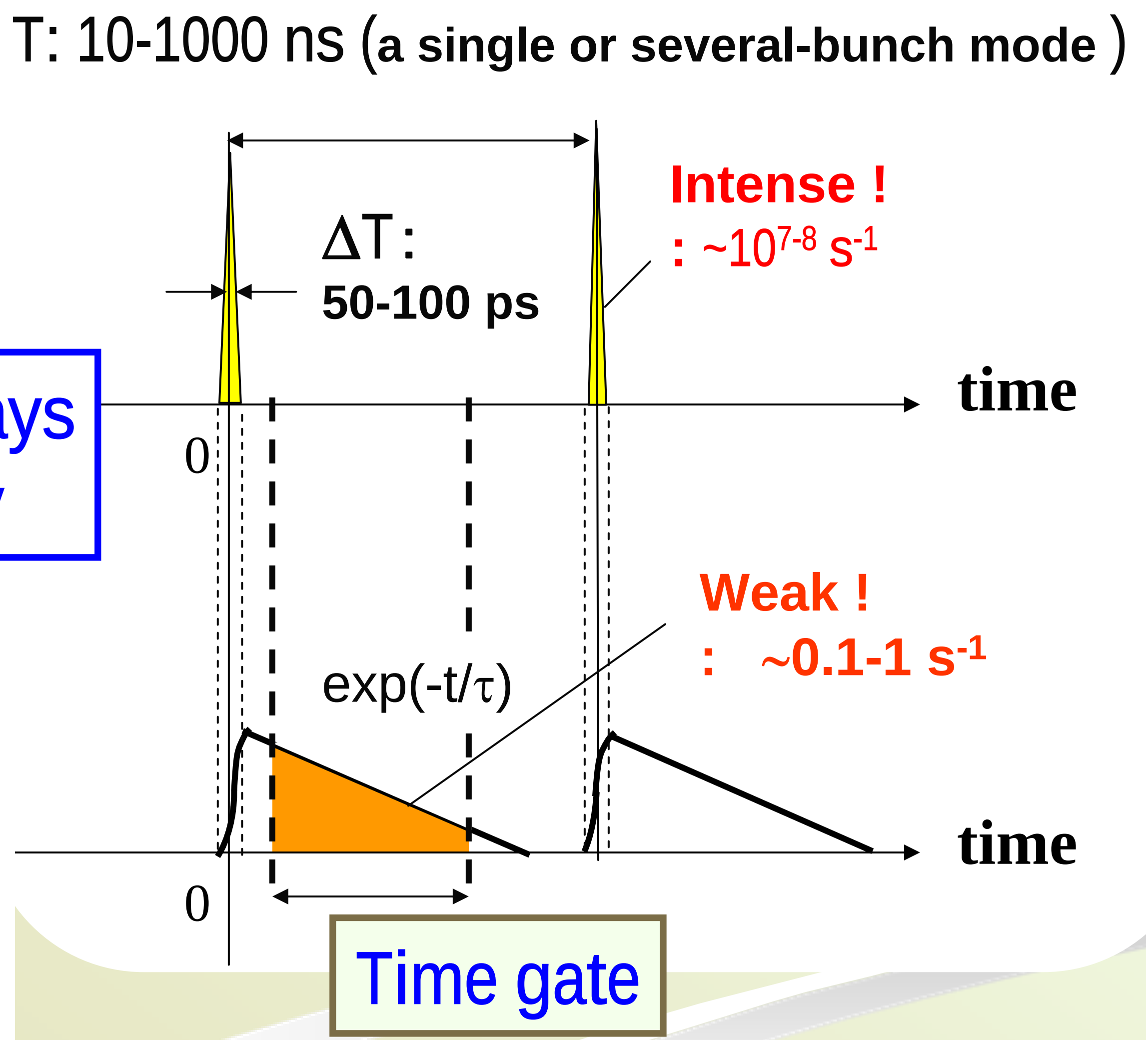
NEET: Rare events !

Prompt radiation by electronic scattering is more intense.

Pulsed synchrotron X-rays and Time Spectroscopy

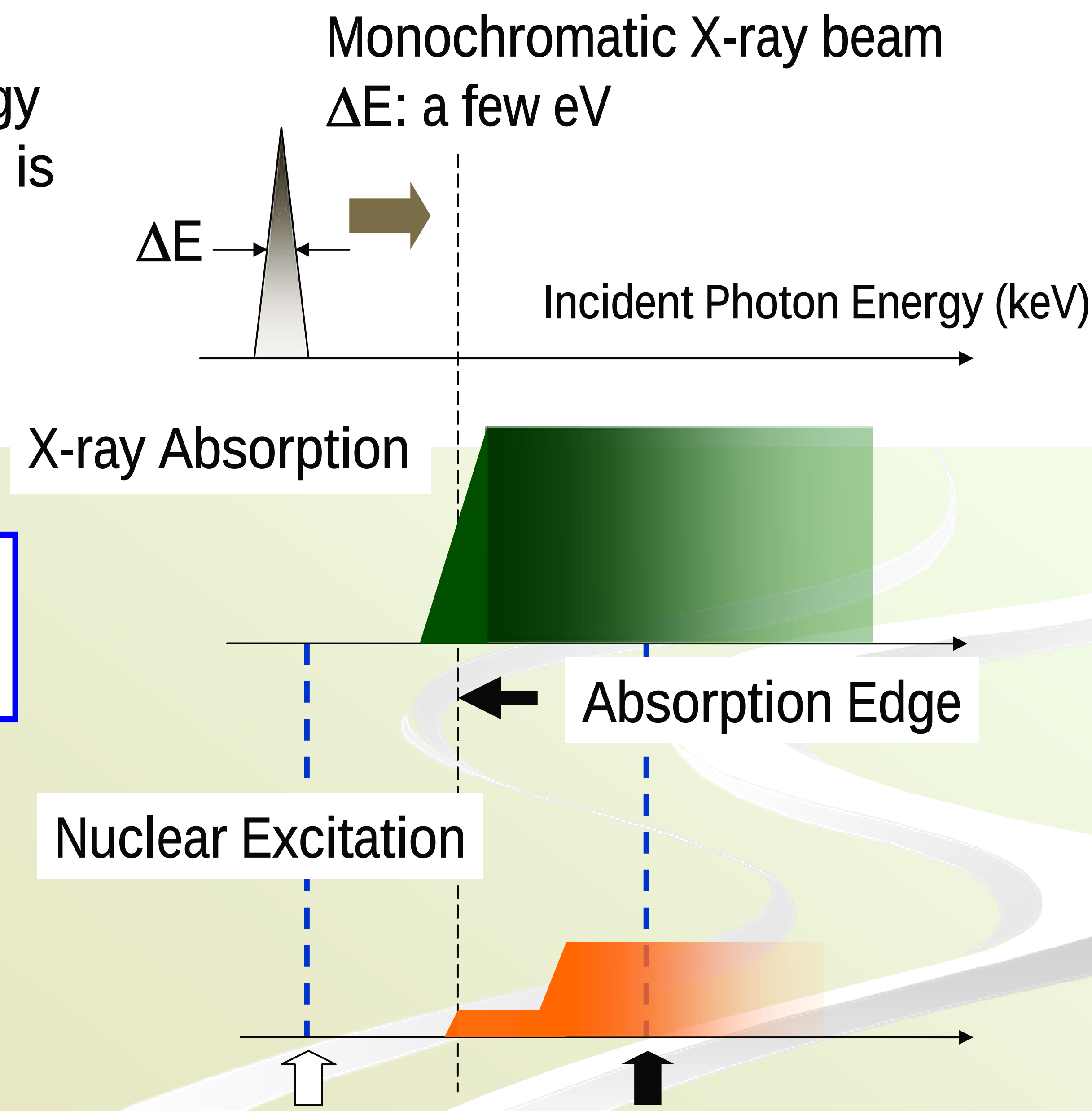
⬇

Nuclear-decay Events : can be separated from the prompt electronic scattering.



NEET can be confirmed by choosing the incident photon energy where decaying radiation is detected.

Synchrotron X-ray is tunable in energy:



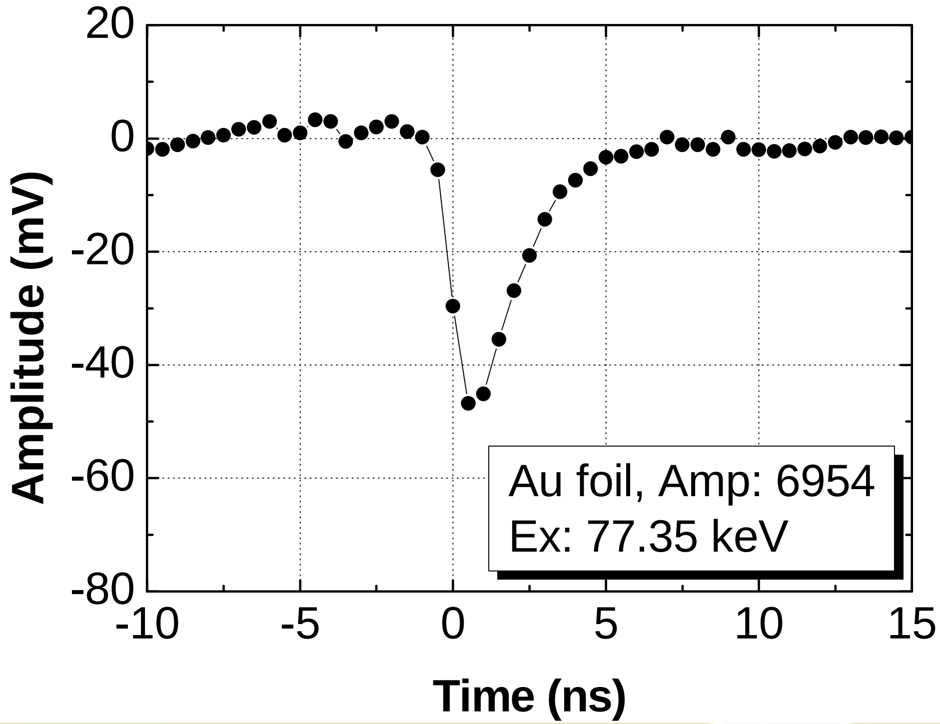
Detection of delayed electrons under the intense prompt radiation by Silicon Avalanche Diode

Si-AD : Hamamatsu S5344LC

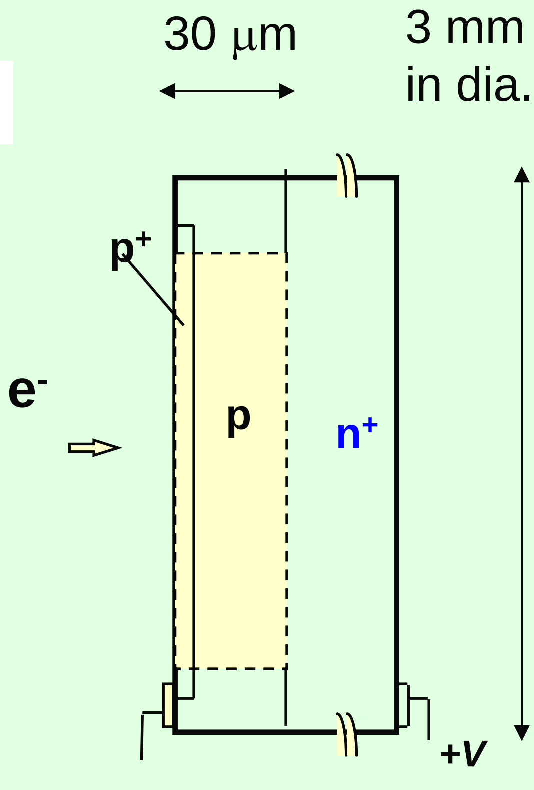
30 μm thick (*L_1* conv. E=63keV, λe ~24μm)

➡ **a thin SiO_2 layer : 15-20nm (cf. std. 130nm)**

Low efficiency for high energy X rays (< 0.1%)



Fast response: suitable for time gating



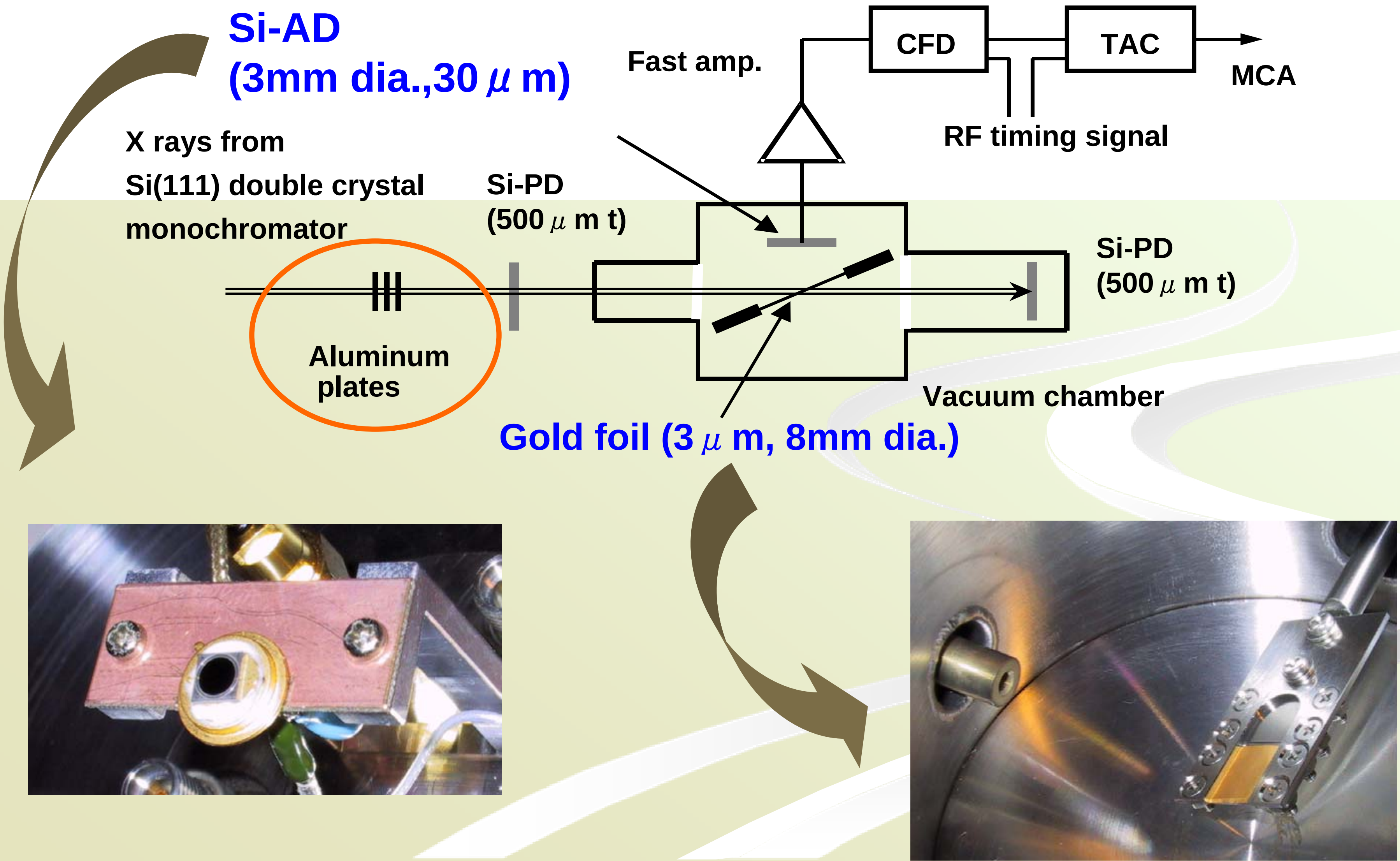
S5344(LC)

(3mm dia.)

Epitaxial Type

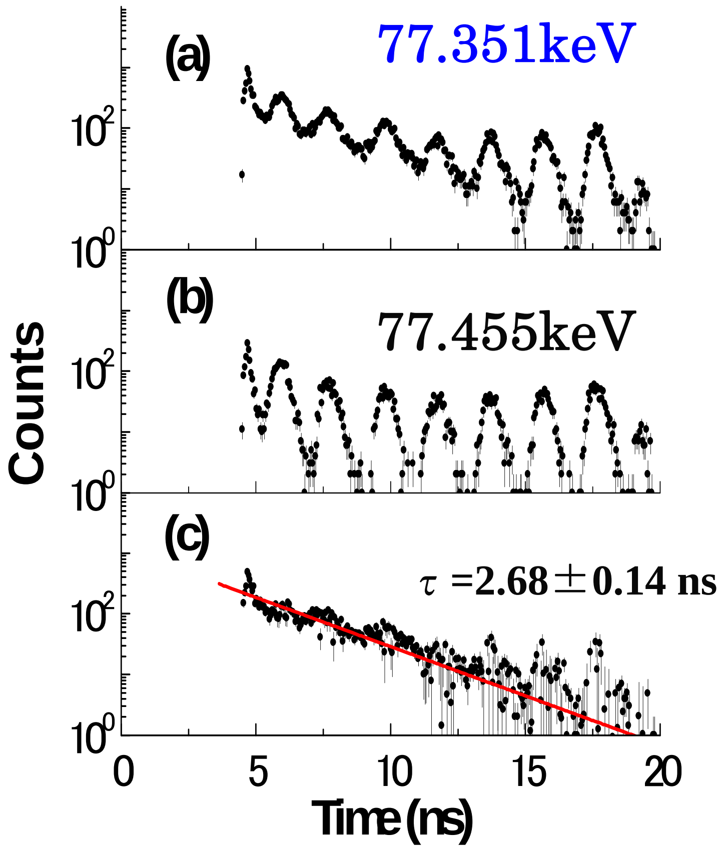
3. Experiments results on Au-197 and on Ir-193

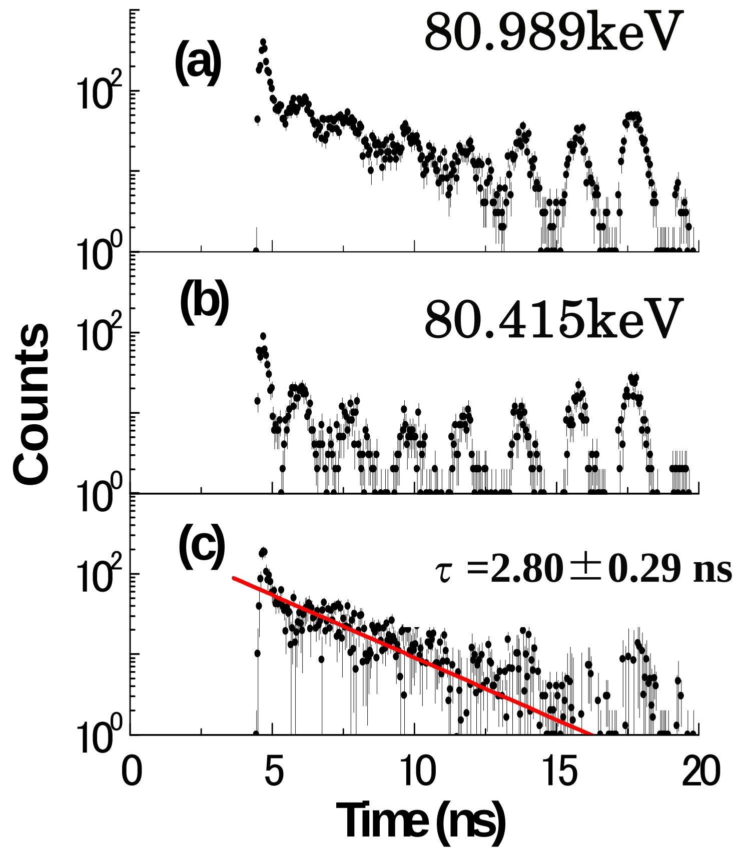
NEET experiment on Au-197 **at SPring-8 BL09XU in 1999 -**



Results in Au-197 Exp.

Time spectra of Nuclear Resonance (left) & NEET（right）

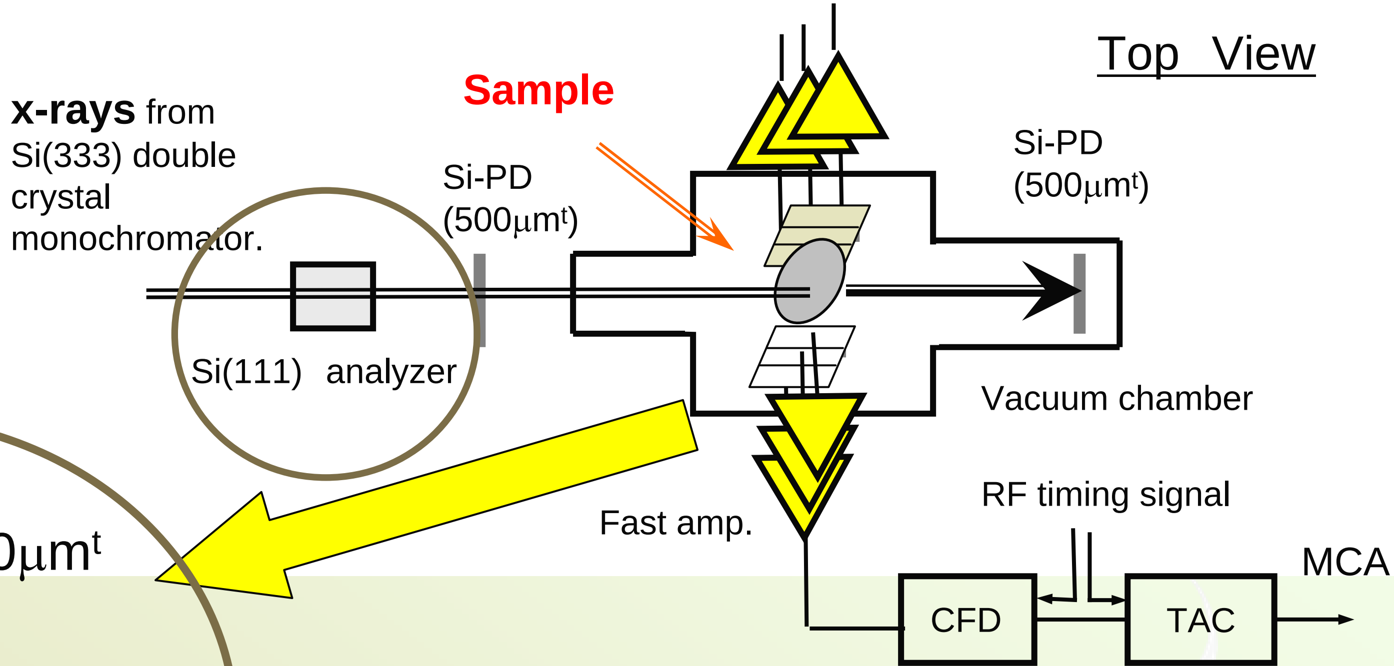




$T_{1/2}$=1.91ns→ τ = 2.76 ns

P_{NEET}= (5.0±0.6) ×10^{-8}

Improvements on the experimental set-up

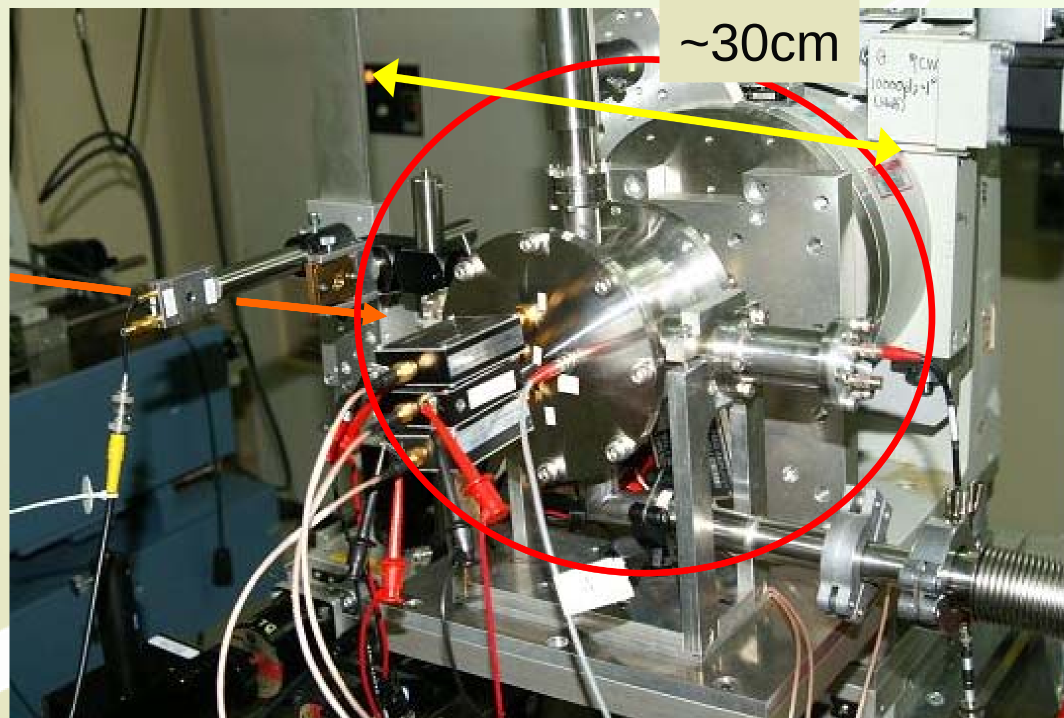


1×6 mm^2, 3 ch, $30\mu m^t$

18 mm^2

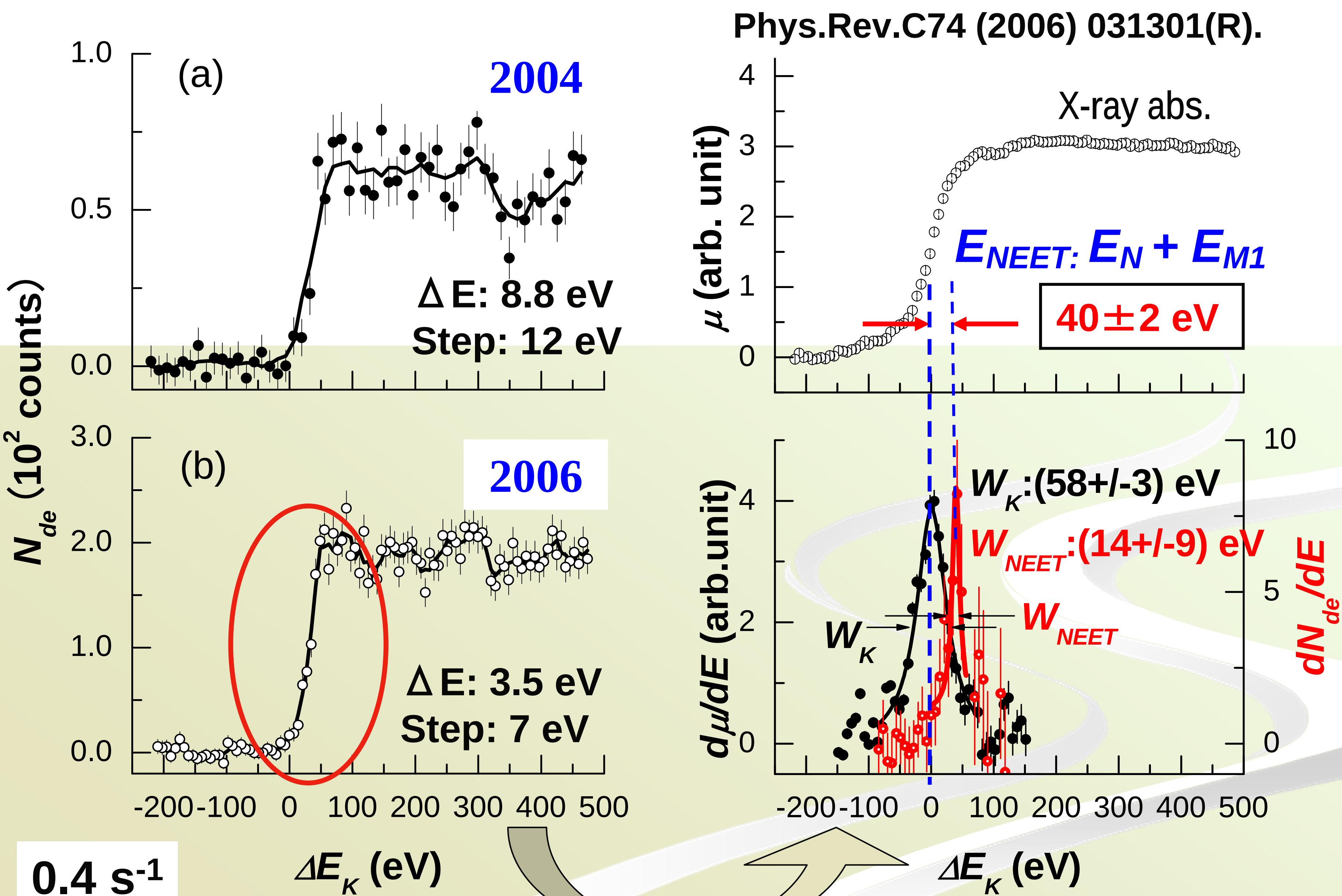
Φ3mm, 30μmt

7 mm^2



Nuclear events around the *K*-absorption edge

Phys.Rev.C74 (2006) 031301(R).



0.4 s^{-1}

$\Delta E_K = 0$: *K* edge

5. Next challenges

	E_{ion} (keV)	E_M(keV)	E_N (keV)	$T_{1/2}$(ns)	ΔE(keV)	P_{NEET} (cal)
^{189}Os(Z=76) 16.1%	73.856 (K)	3.049(M_1)	69.537	1.62	1.270	[E] 1.2×10^{-10}
^{187}Os(Z=76) 1.6%	12.971(L_1)	3.049(M_1)	*9.776 (9.746)	2.38	0.146	[F] 1×10^{-8} ?

[E] E.A. Tkalya, Phys. Rev. A 75 (2007) 022509.

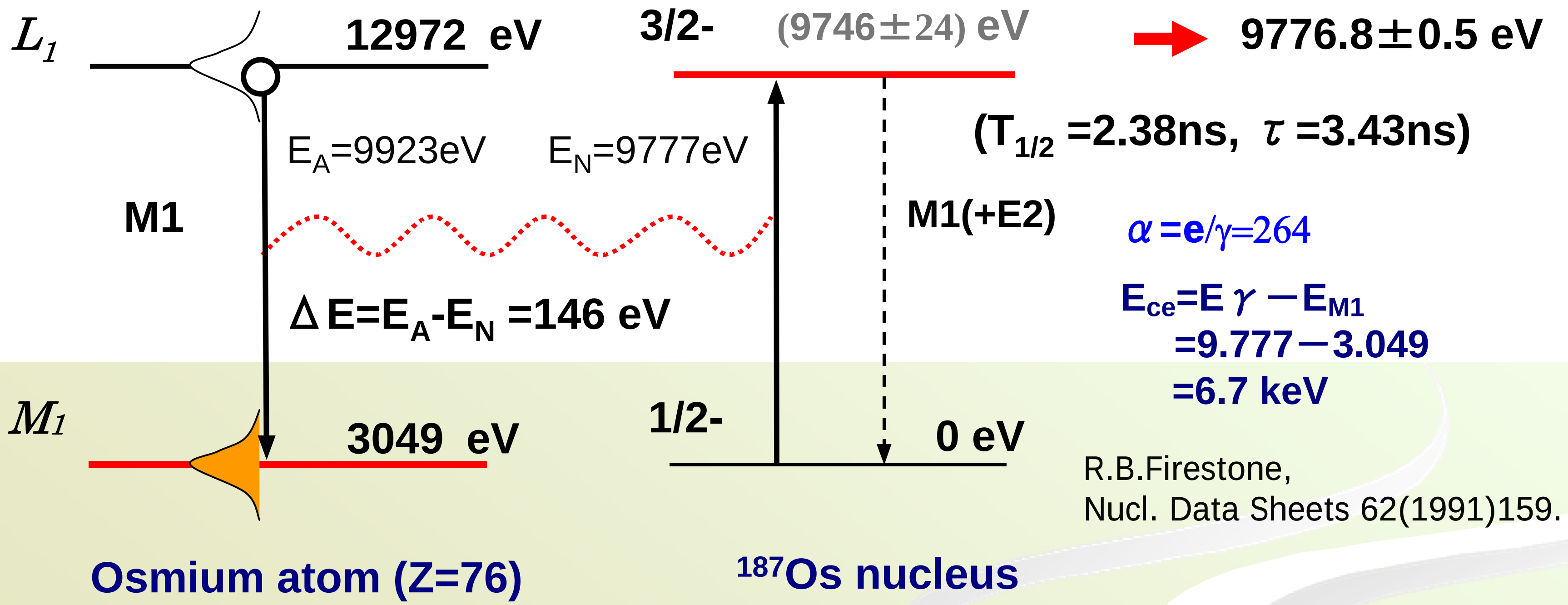
[F] E. A. Tkalya, private communications.

A. ^{189}Os ➡ ***ΔE* =1.27 keV**

P_{NEET}: very low ! < 1/10 of ^{193}Ir case

We need a larger efficiency in the detector system !

B. ^{187}Os

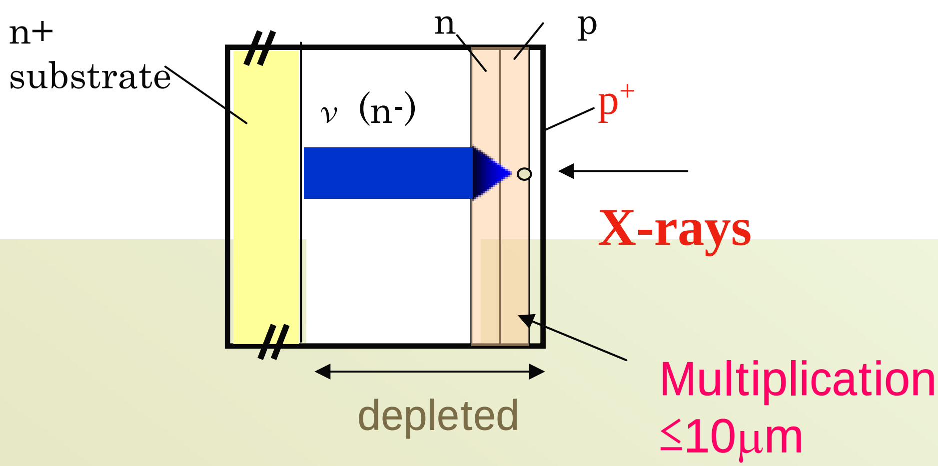


1×10^{-8} ? : P_{NEET} may not be so small, relatively.

Problems are there in low energy of excitation X-rays (12.8 keV) and the *M*-internal conversion electrons (6.7 keV).

The detector has to be not sensitive for the elastic scattering X-rays, with keeping the efficiency for the int. conv. electrons.

Reverse Type of Si-AD – “radiation sensitive” only near the surface region



HM S8664 series

C_p~20pF (3mm dia.)

A thin (< 5-μm) junction
to reduce the efficiency for elastic X-rays
in detecting the low-energy electrons.

For Os-187 exp.,
7-keV Electron: λe~0.6 μm

In a 5-μm layer,
12-keV X-rays: ε ~2%
Cf. 30-μm dep. ε~12%

6. Conclusions

1. NEET can be observed by the experiments using synchrotron X-rays and the Si-AD electron detector.

2. The NEET measurements on ^{197}Au and on ^{193}Ir are in progress of studying the fine structure in nuclear events from discussing existence of NEET.

3. Observing NEET on ^{189}Os and on ^{187}Os will be the next challenges with improving the efficiency and the device structure of the Si-AD detector.