超伝導ウィグラーを使った最稀少同位元素 ^{180}Ta消滅断面積の測定

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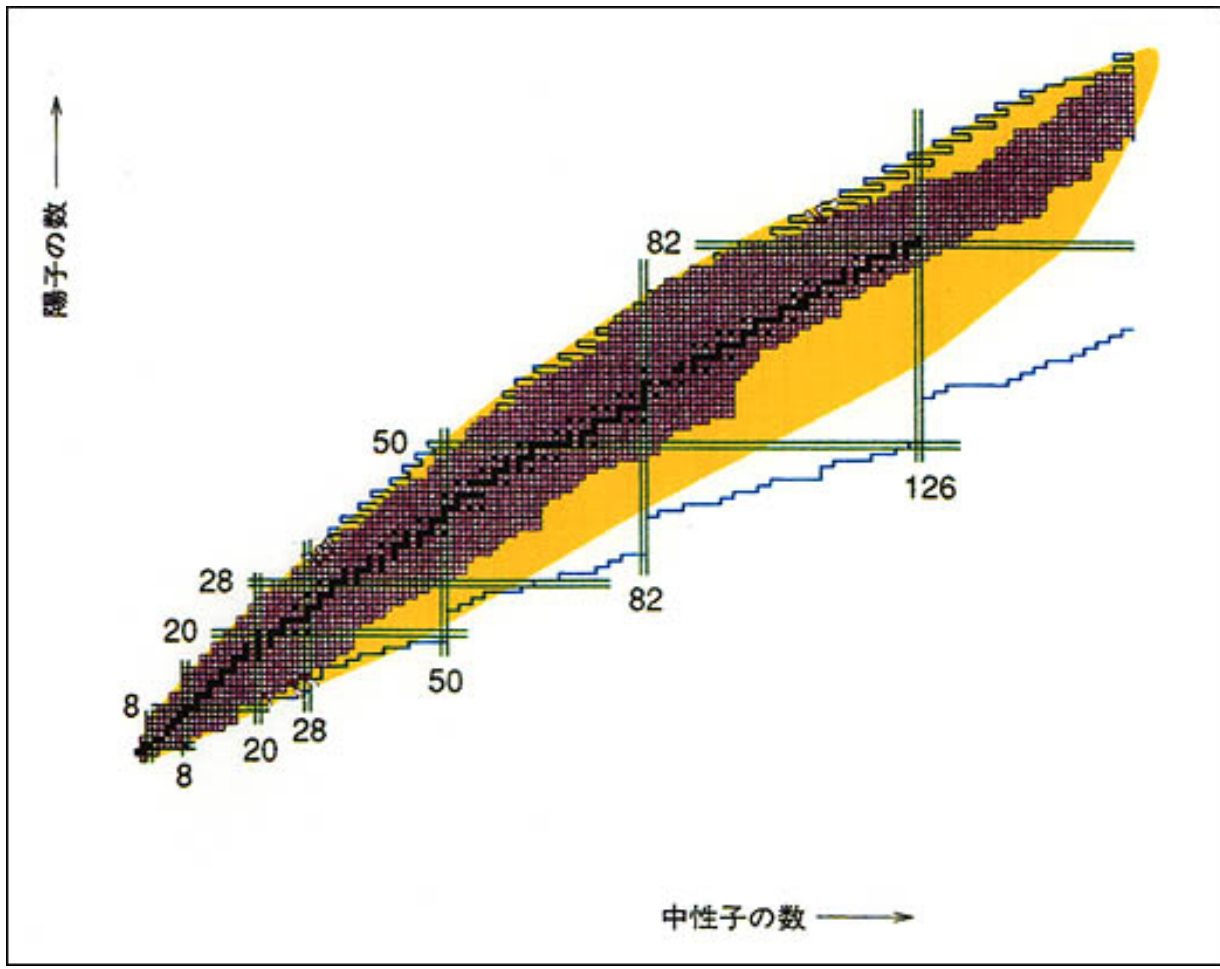
Nucleosynthesis

- Big-Bang
- Nuclear Fusion
- Slow Neutron Capture (s-process)
- Rapid Neutron Capture (r-process)
- Other Process



Nuclear Table

^{180}Ta(9^-) Nature's rarest isotope

odd-odd nucleus

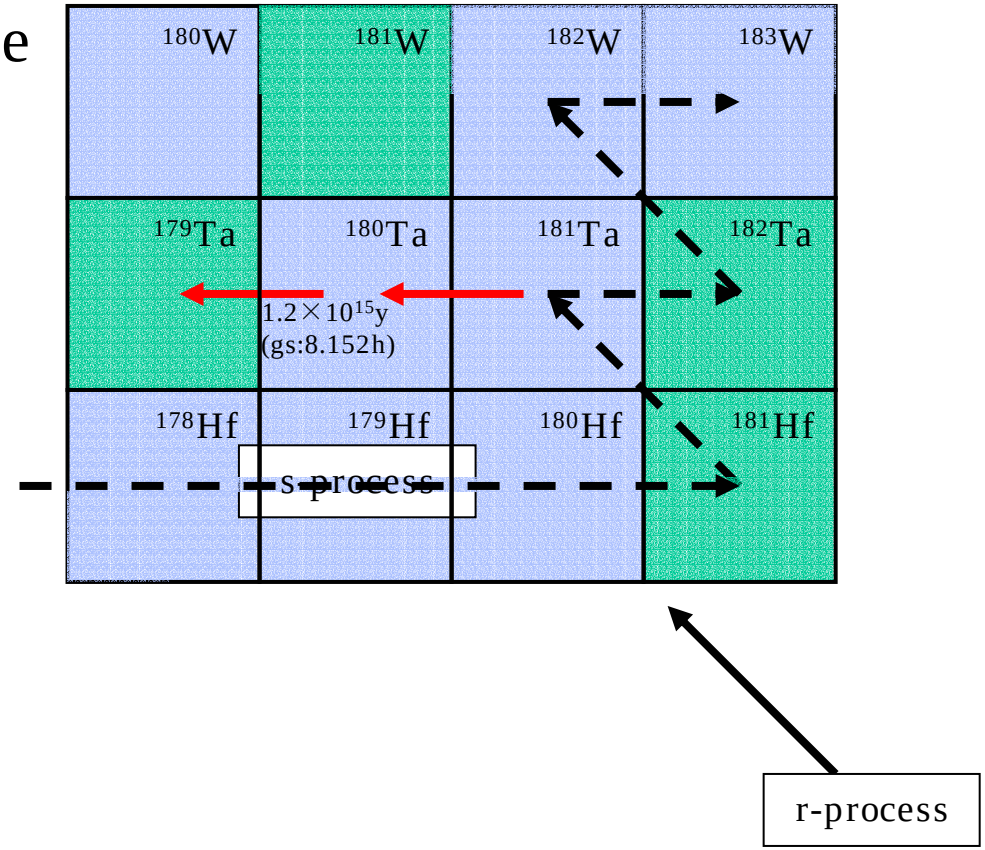
abundance 0.012%

halflife $>1.2\times10^{15}$y

Ex = 75keV

^{180}Ta(gs)

halflife 8.152h



p-process ^{181}Ta(γ ,n)^{180}Ta

Stable

Unstable

p-process nuclei

Type II Supernova Scenario

Pranzos(1989), Rayet(1987,1990),

Woosley & Haward(1987)

Explosive burning of O/Ne rich layers by shock wave heating

T_9=2-3, ρ =10^6[g/cm^3],

τ_{ex}<1[sec]

Reaction Rate

$$\lambda(T) = \int_0^\infty c n_\gamma(E,T)\sigma_\gamma(E)dE$$

$$n_\gamma(E,T) = \left(\frac{1}{\pi}\right)^2\left(\frac{1}{\hbar c}\right)^3 \frac{E^2}{\exp(E/kT)-1}$$

Plank Distribution for Thermal Photon Bath (T_9=2-3)

GDR Cross Section Peak : 13MeV

Astrophysical Energy Window

1-2MeV

0

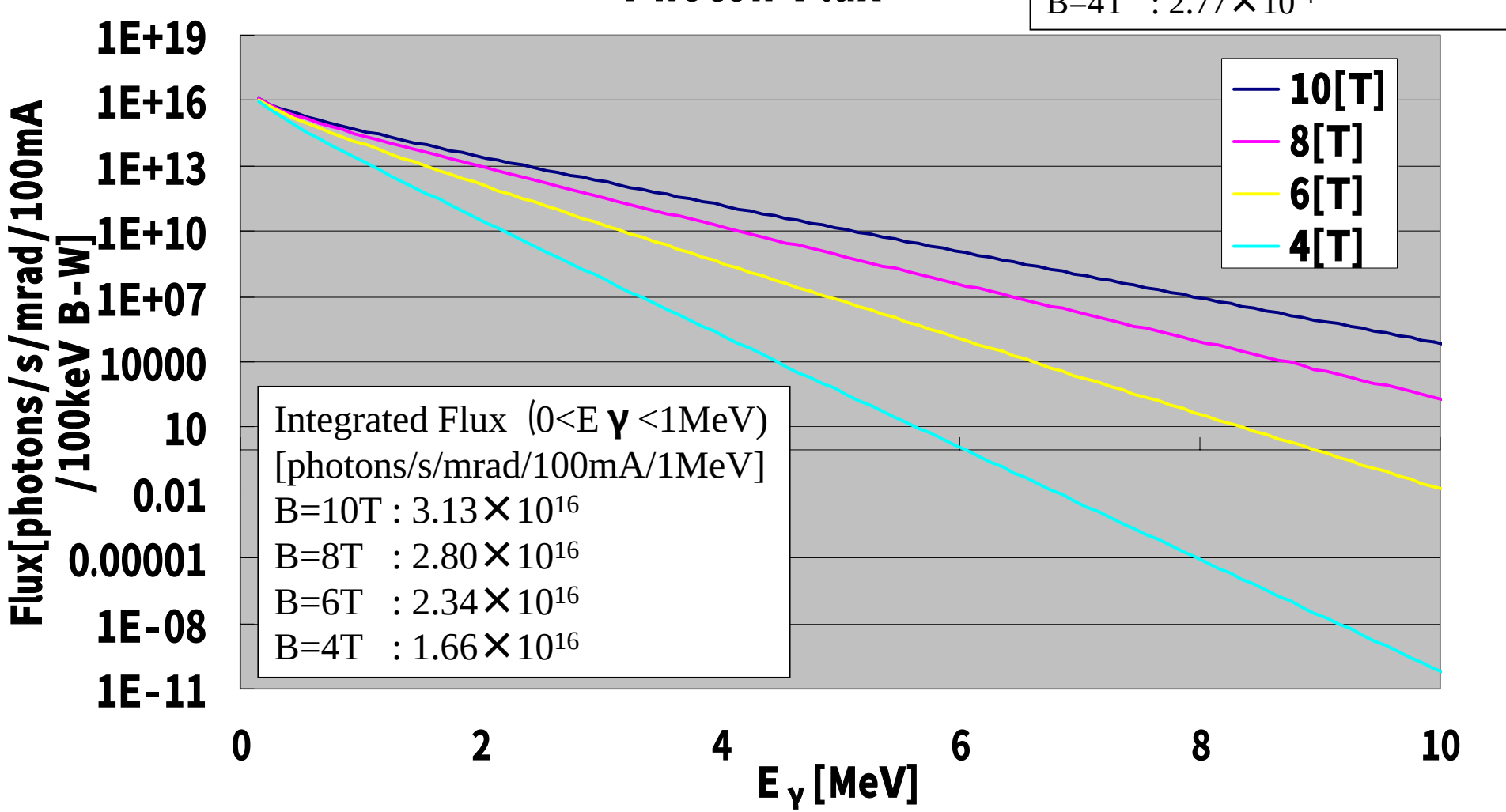
200-300keV

Neutron Threshold 7.576MeV

E_γ

超伝導ウィグラーからのγ線Flux

Integrated Flux
(7.5MeV<Eγ<8.5MeV)
[photons/s/mrad/100mA/1MeV]
B=10T : 1.11×10^{8}
B=8T : 1.26×10^{6}
B=6T : 7.12×10^{2}
B=4T : 2.77×10^{-4}



Target Material Tantalum

^{181}Ta

- Abundance : 99.988%
- Threshold : 7.578MeV
- Half Life : Stable

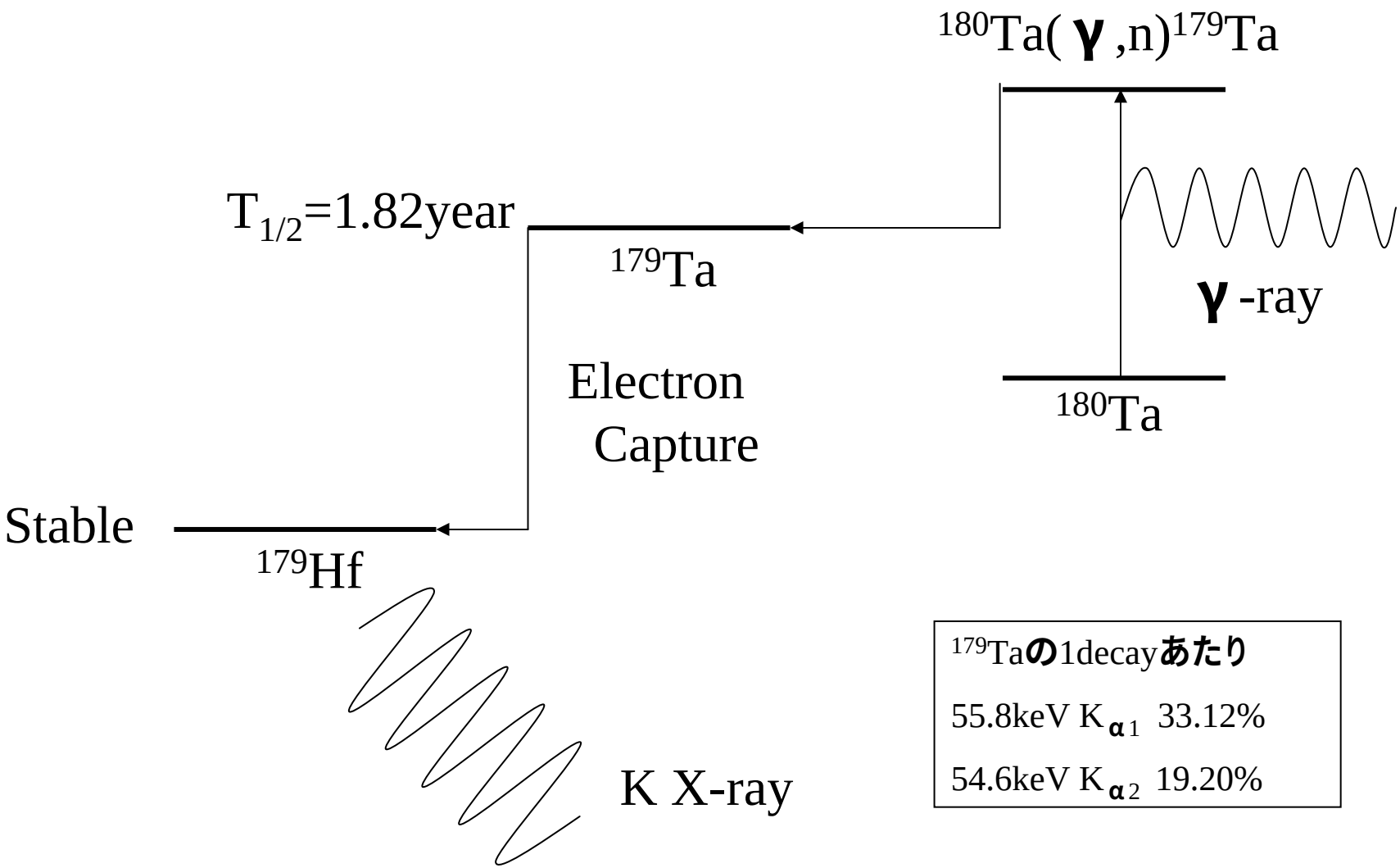
^{180}Ta

- Abundance : 0.012%
- Threshold : 6.645MeV
- Half Life :

  ground state : 8.152h

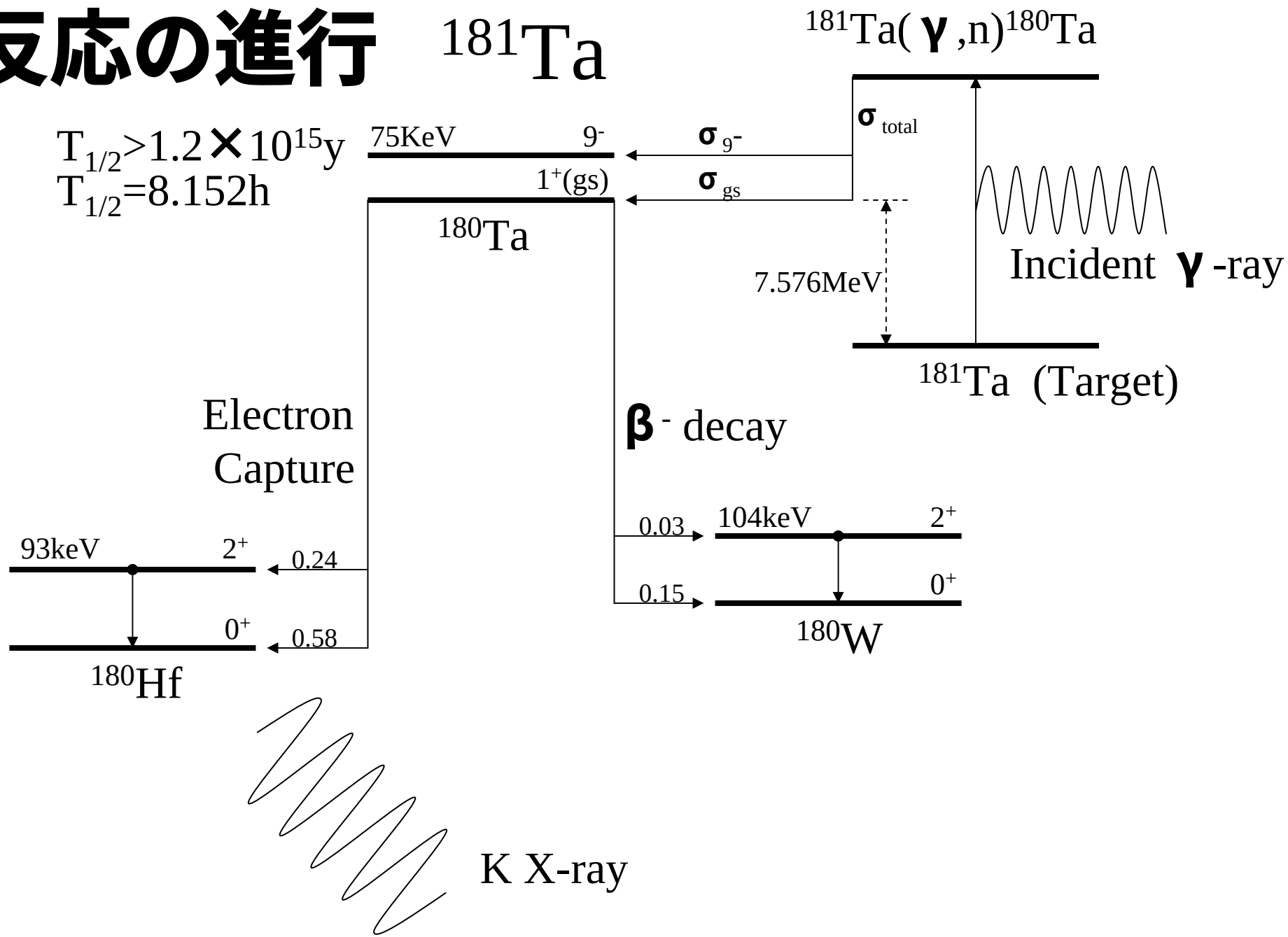
  9^-state :$>1.2\times10^{15}$y

反応の進行 ^{180}Ta



^{179}Taの1decayあたり	
55.8keV $K_{\alpha 1}$	33.12%
54.6keV $K_{\alpha 2}$	19.20%

反応の進行


181Ta
181Ta(γ,n)180Ta
σ total
T1/2>1.2×10^15y
T1/2=8.152h
75KeV
9-
σ 9-
1+(gs)
σ gs
180Ta
7.576MeV
Incident γ-ray
181Ta (Target)
Electron Capture
β- decay
0.03
104keV
2+
93keV
2+
0.24
0.15
0+
0+
0.58
180W
180Hf
K X-ray

$_{73}$Taターゲット(purity:99.985%)に含まれる不純物

- $_{1}$H <0.0005%
- $_{6}$C <0.001%
- $_{7}$N 0.001%
- $_{8}$O 0.004%
- $_{14}$Si 0.001%
- $_{22}$Ti <0.001%
- $_{26}$Fe <0.001%
- $_{28}$Ni <0.001%
- $_{41}$Nb 0.001%
- $_{74}$W <0.01%

^{181}Ta

- $^{181}Ta(\gamma,n)^{180}Ta^{gs} \rightarrow {}^{180}Hf(86\%)$
  $^{180}W(14\%)$
- Content : 99.973%
- Threshold : 7.577MeV
- Decay Mode : Electron Capture, β^- decay
- Half Life : 8.152hour
- X-ray : 55.790keV($K_{\alpha 1}$),54.611kev($K_{\alpha 2}$)

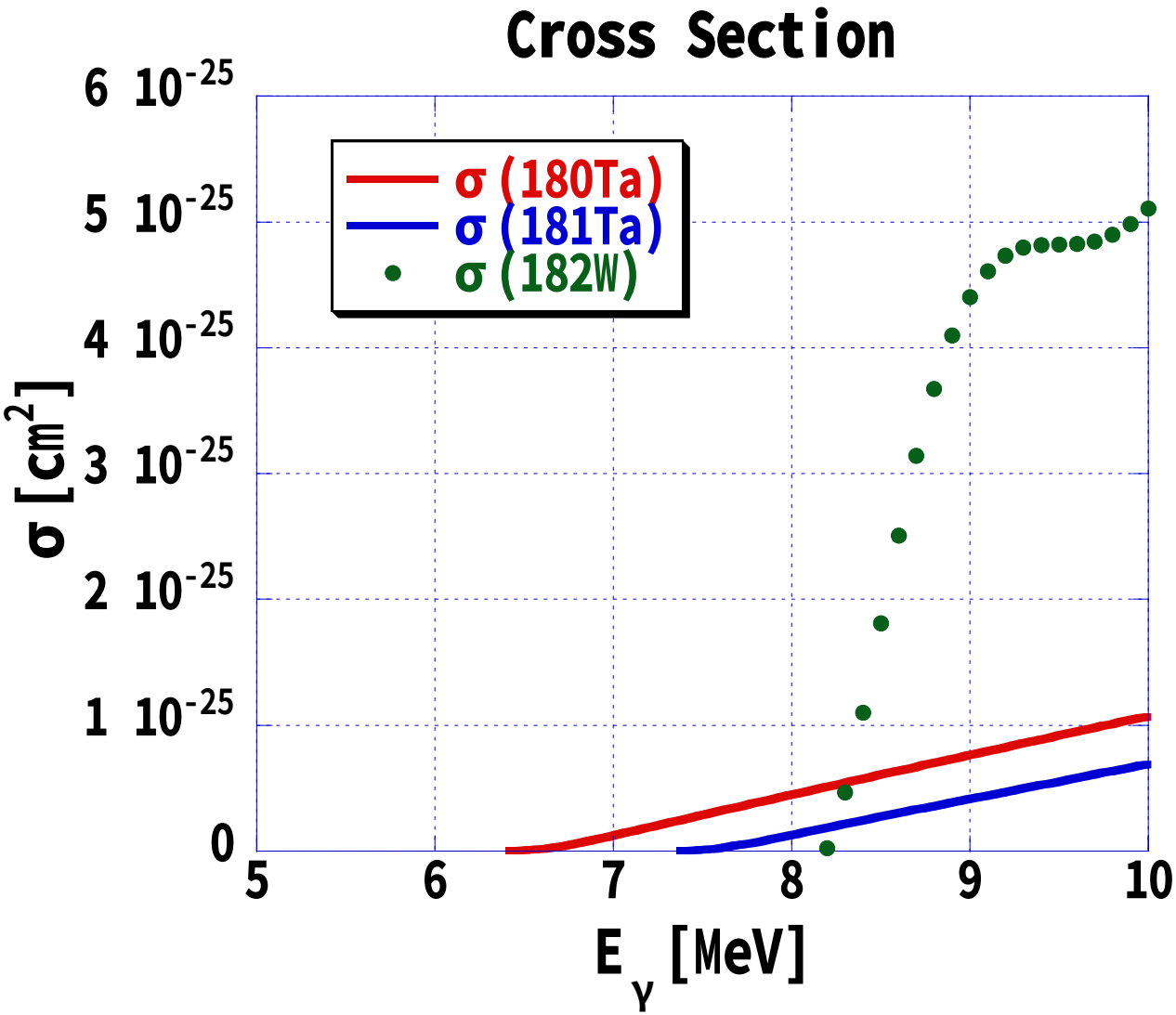
^{180}Ta

- $^{180}Ta(\gamma,n)^{179}Ta \rightarrow {}^{179}Hf$
- Content : 0.012%
- Threshold : 6.645MeV
- Decay Mode : Electron Capture
- Half Life : 1.82year
- X-ray : 55.790keV($K_{\alpha 1}$),54.611kev($K_{\alpha 2}$)

^{182}W

- $^{182}W(\gamma,n)^{181}W \rightarrow {}^{181}Ta$
- Content : 0.00265%
- Threshold : 8.064MeV
- Decay Mode : Electron Capture
- Half Life : 121.2day
- X-ray : 57.535keV($K_{\alpha 1}$),56.280kev($K_{\alpha 2}$)

$$\sigma = \sigma_0 \left(\frac{E_\gamma - S_n}{S_n} \right)^p$$



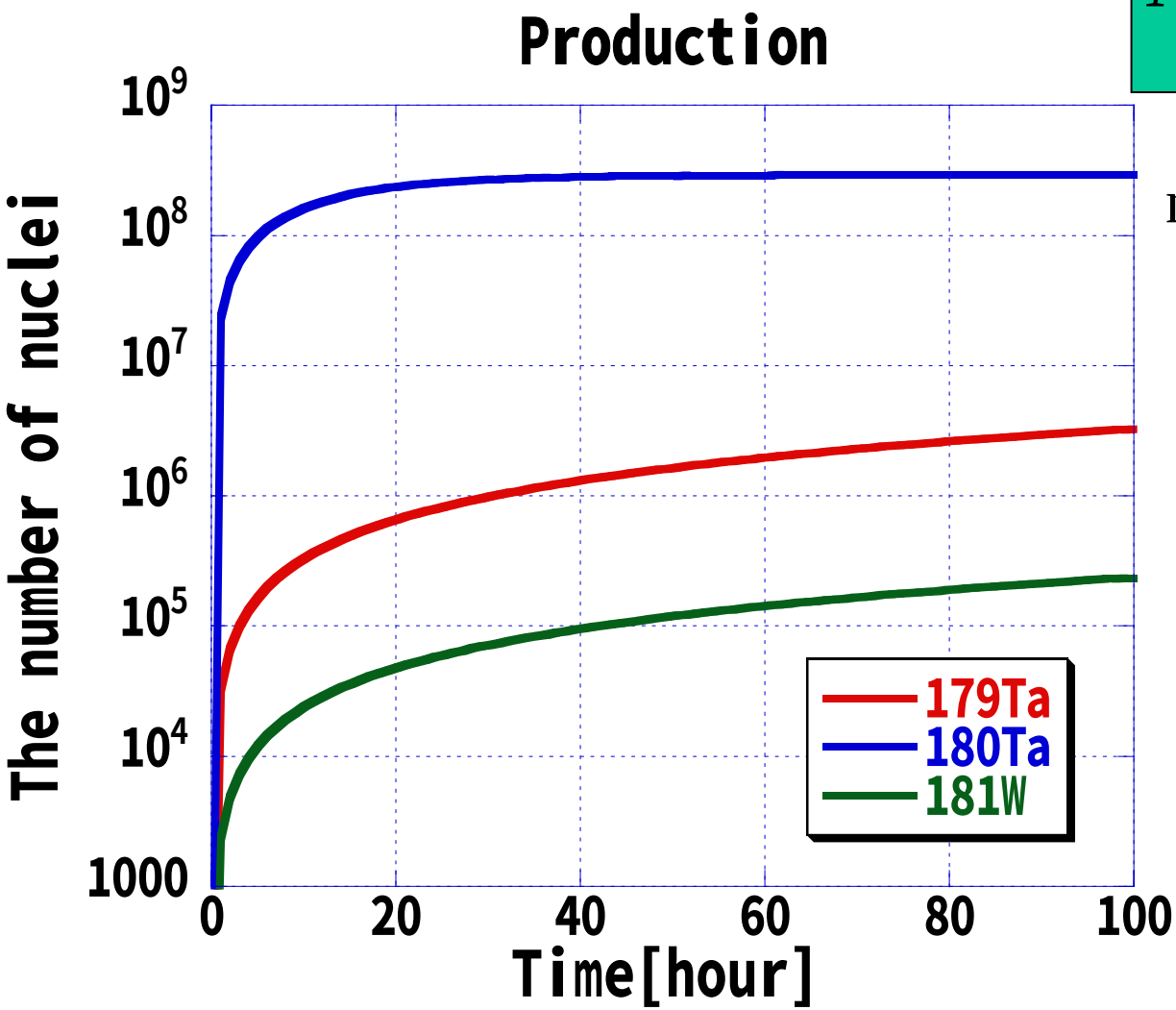
Threshold

^{181}Ta : 7.577MeV

^{180}Ta : 6.645MeV

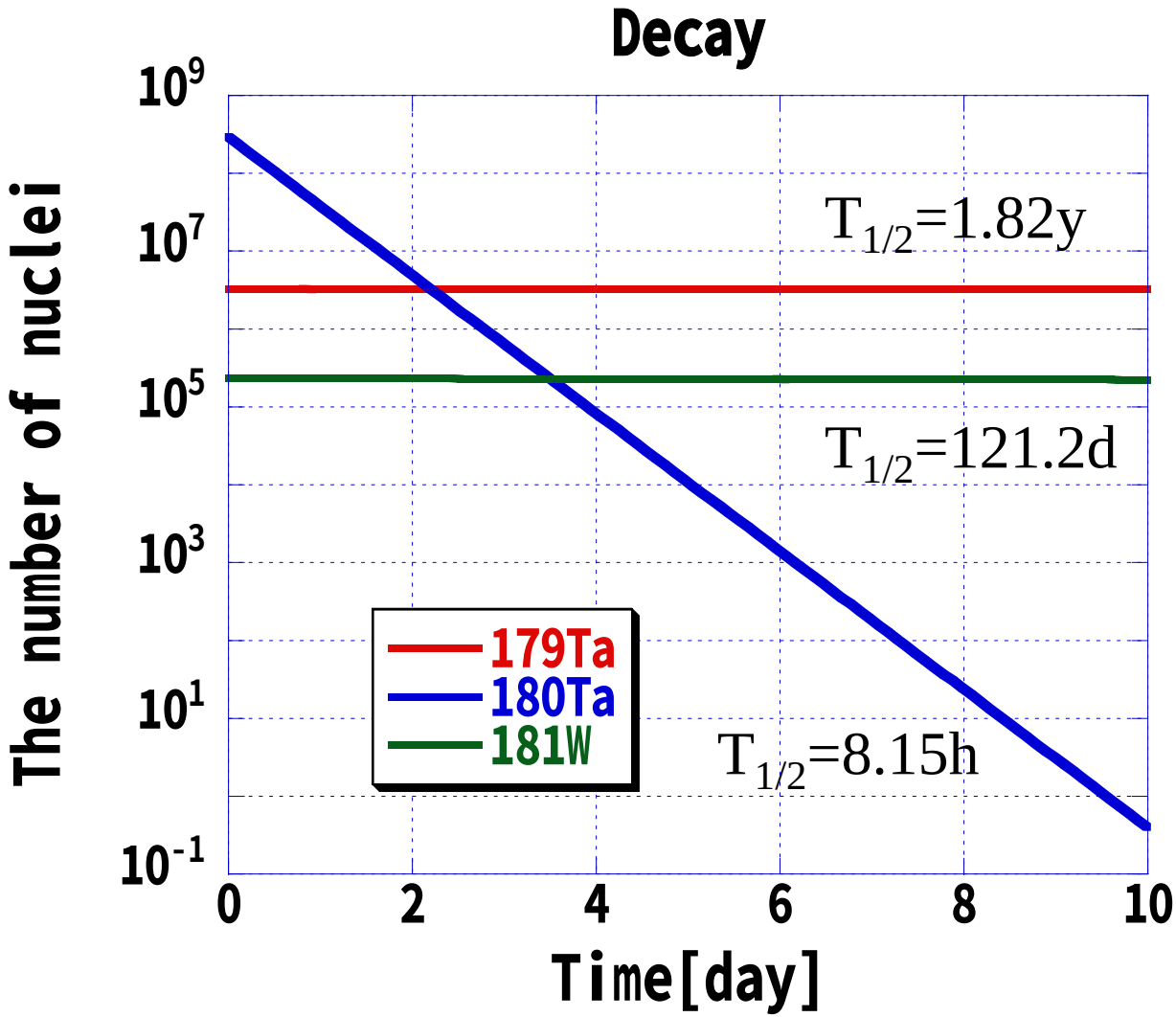
ターゲットの100時間照射

$$N = \frac{n\sigma I}{\lambda}\left(1 - \frac{1}{e^{\lambda t}}\right)$$

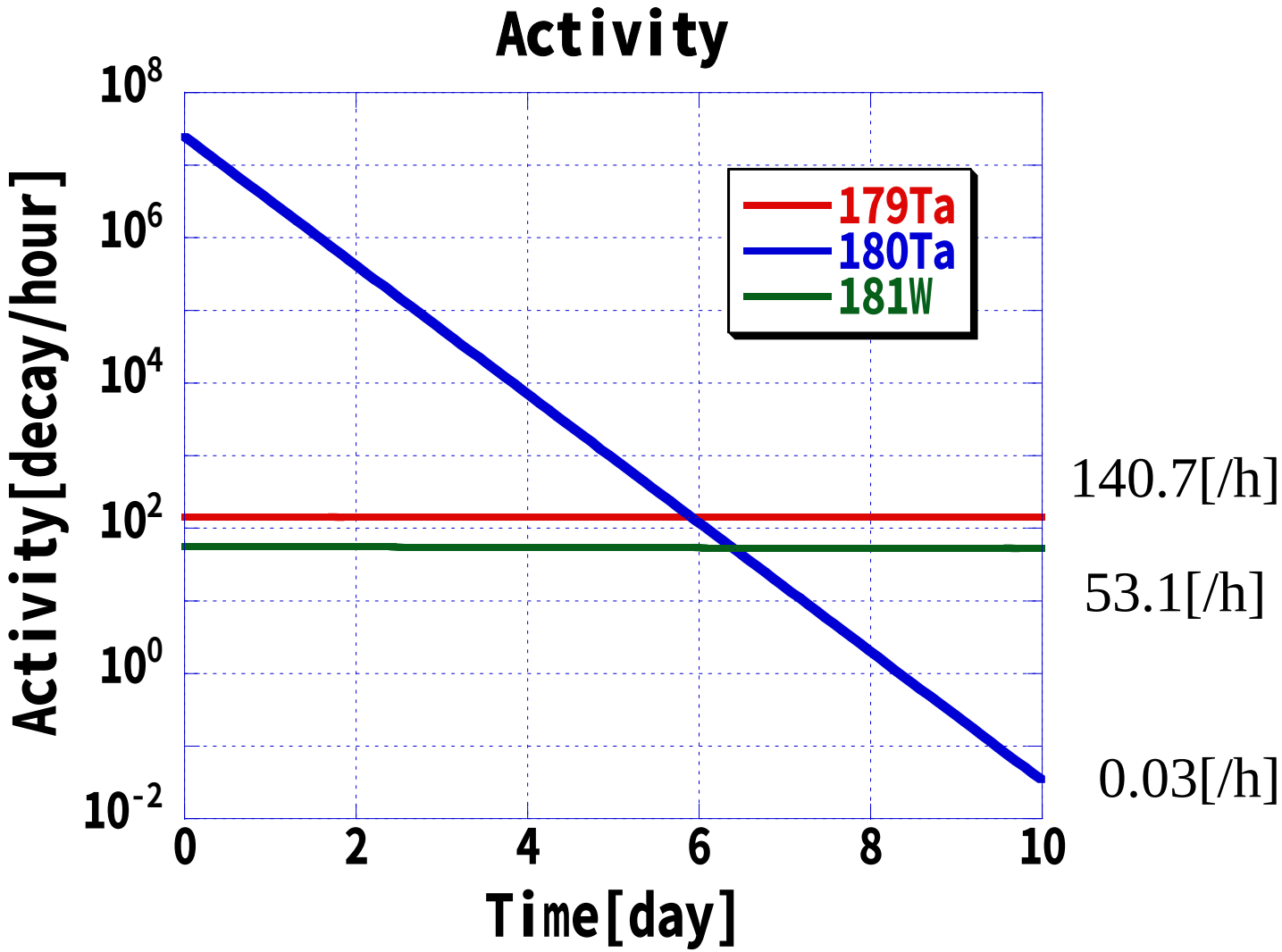


n_t : 5.54×10^{21}[/cm^2]

100時間照射後の娘核崩壊



100時間照射後の娘核放射能

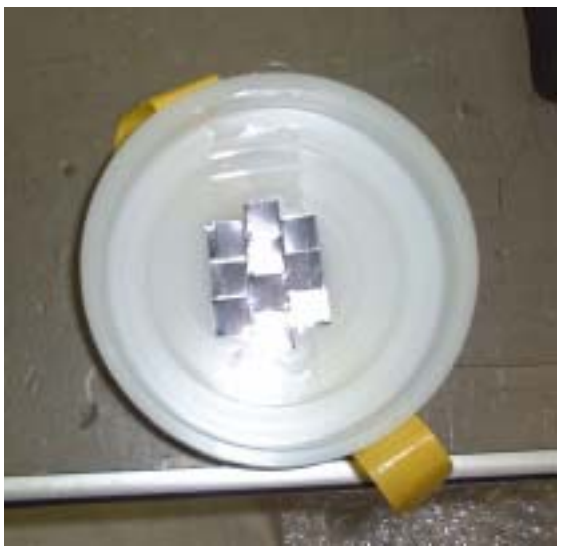


Ge Detector Set-up

$^{181}Ta(\gamma,n)^{180}Ta^{m}$

Cross Section Measurement

at AIST



Activated Ta Foils

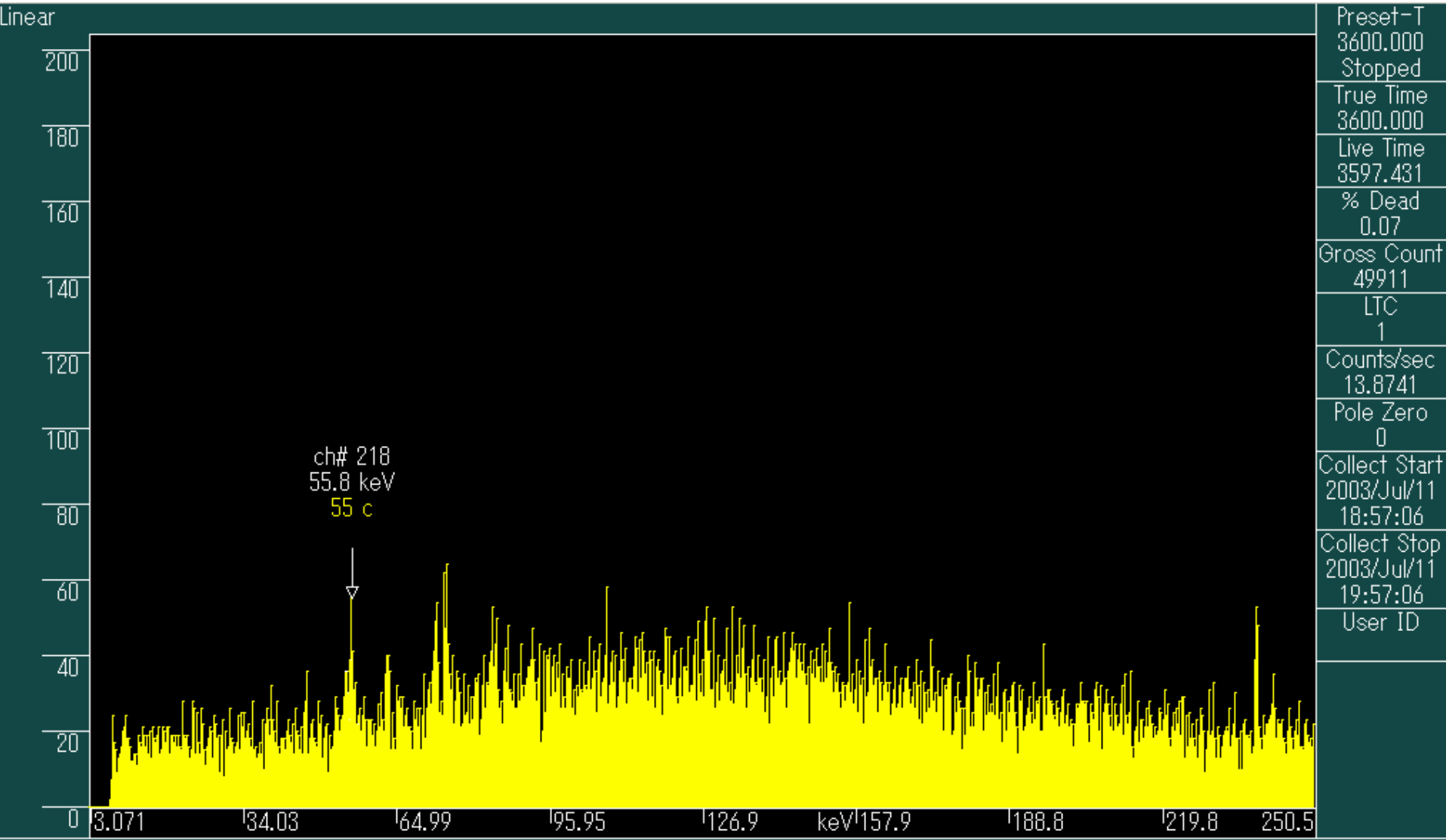
on Polyethylene Cap

KX-ray Measurement

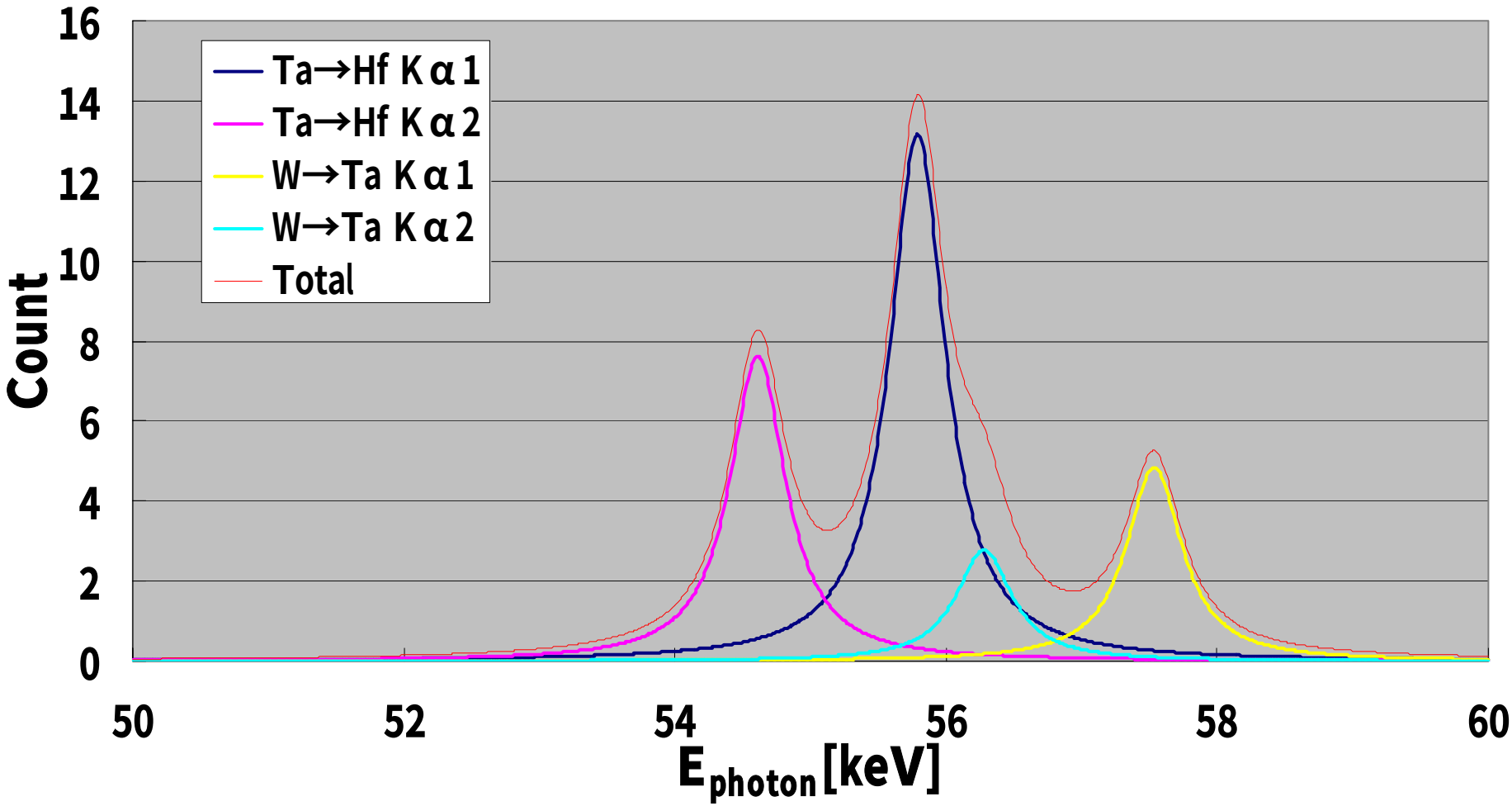
- Activity 140.7[decay/hour]
- X**線放射確率** $K_{\alpha 1}$ 33.12**%**
  $K_{\alpha 2}$ 19.20**%**
- Ge Detector Efficiency 34.4%✕2
- Self Absorption (0.1[mm]thick) 27%

Count Rate 36.9[counts/hour]

Photon Spectrum measured at AIST



予想されるスペクトル


X-ray Spectra
Ta→Hf Kα1
Ta→Hf Kα2
W→Ta Kα1
W→Ta Kα2
Total
Count
16
14
12
10
8
6
4
2
0
50
52
54
56
58
60
Ephoton[keV]