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# 天然元素から中性子照射により生ずる短寿命核種のγ線スペクトル

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# 天然元素から中性子照射により生ずる短寿命核種の γ 線スペクトル

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## 要　旨

天然に存在する元素に中性子を照射することによって生ずる放射性核種のうち，半減期が1秒ないし 5.5 分のもの26種について γ 線スペクトルを集録した．観測に用いた γ 線検出器は厚さ 2 inch の井戸型 NaI(Tl) 結晶である．各スペクトログラムに，照射試料の量，中性子束密度，照射時間，冷却時間，計数時間，スペクトログラムのたて軸（計数値軸）目盛の絶対値等を付記することによって，定量放射化分析にすぐ役立つようにした．

# Gamma-ray Spectra of Short Half-life Nuclides

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Radio Chemistry Laboratry

(Received Jul. 25, 1961)

## Summary

This report is a collection of gamma-ray spectrograms for 26 different nuclides which were produced from natural elements by neutron irradiation, with half-lives from to 1 second and 5.5 minutes.

These spectra were measured using a well-type, NaI (Tl) crystal (1¾ inch dia. ×2 inch thick).

The weight of samples, the neutron flux, the period of irradiation, the cooling and counting times, etc., are indicated on each spectrogram, an example of which is shown below.

2.5 sec $^{167m}$Er ……(half-life, nuclide)
4/27/60 ……(date of measurement)
Material : 778μg-Er with $NO_3^-$…… (sample, weight)
Neutron Flux : ~$5\times10^{10}$n/cm$^2$/sec
Time : 5 - 5 - 3 - 2 - 3 sec ……(irradiation-cooling-counting-cooling-counting)
Absorber……None
Source……In Well
Count Scale : 50 counts/div. ……(ordinate)
Energy Range : 0~0.3 MeV ……(abscissa)

These data are useful for the application of gamma-ray spectrometry to neutron activation analysis.

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** On the leave of absence from Kogyo-Gijutsu-In

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## ま え が き

中性子放射化分析において，γ 線スペクトロメトリーが有用であることはよく知られている．SALMON[1] は，中性子照射によって生ずる放射性核種のうち，半減期が 5.1 分以上のもの 117 種の線スペクトルを集録した．それ以前に HEATH[2] は，よく用いられる 95 種の RI の γ 線スペクトルを集めており，その中には半減期 5 分以下の核種が 3 種($^{27}$Al, $^{37}$S, $^{52}$V) 含まれている．他方，半減期が数十秒程度であるような放射性核種を利用する迅速放射化分析法[3~6]が報告されており，そのような短寿命核種を利用するさいにも長寿命核種利用の場合と同様に γ 線スペクトルのカタログが役立つと思われる．しかし短寿命核種に対するカタログはまだ作られていないので筆者らは中性子照射によって生ずる短寿命核種の γ 線スペクトルを集めることを計画した．

## 測 定 装 置

放射化分析においては，分析感度を高める目的で井戸型シンチレータがしばしば用いられるので，筆者らは井戸型のシンチレータを用いた．その寸法は，直径 1¾ inch，厚さ2 inch であって，直径 ¾ inch，深さ 1½ inch の井戸が掘ってある．このシンチレータを Du Mont 6292 光電増倍管にマウントし，それを RCL 社製の 256 channel波高分析器に接続した．この装置の分解能は $^{137}$Cs の 0.662 MeV γ 線に対して約 12% であった．

波高分析器のブラウン管モニタ上にγ線スペクトルを映像させ，それを写真にとった．

**γ 線スペクトルの配列および使用記号**

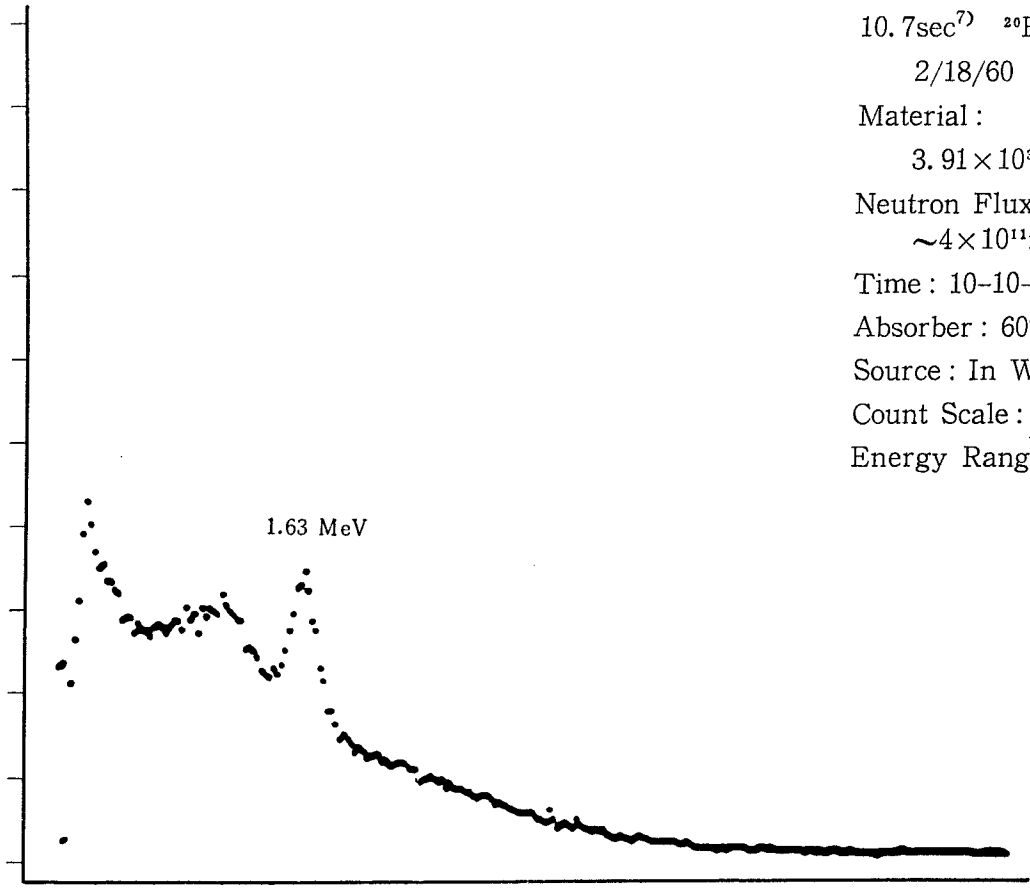
便宜上，γ 線スペクトルは標的核種の原子番号順に配列した．付記した半減期の値は，できるだけ新しい値をとった．

原料の項に共存イオンを記載したものは，ロ紙にしみこませた水溶液を意味する．

用いた吸収材の材質はアルミニウムである．

“Source Dist : 1cm” とあるのは，照射した試料がシンチレータの井戸の上方に置かれ，シンチレータ上端から試料までの距離が，約 1 cm であることを意味する．

本資料の作成にあたり，助言をいただいた矢島聖使博士，ならびにご協力いただいた茂木照十三氏および小野田儀弘氏に厚く感謝の意を表する．




10.7sec[7] $^{20}F$

2/18/60

Material :

$3.91\times10^{3}\mu$g-F in $PbF_2$

Neutron Flux :

$\sim4\times10^{11}$n/cm²/sec

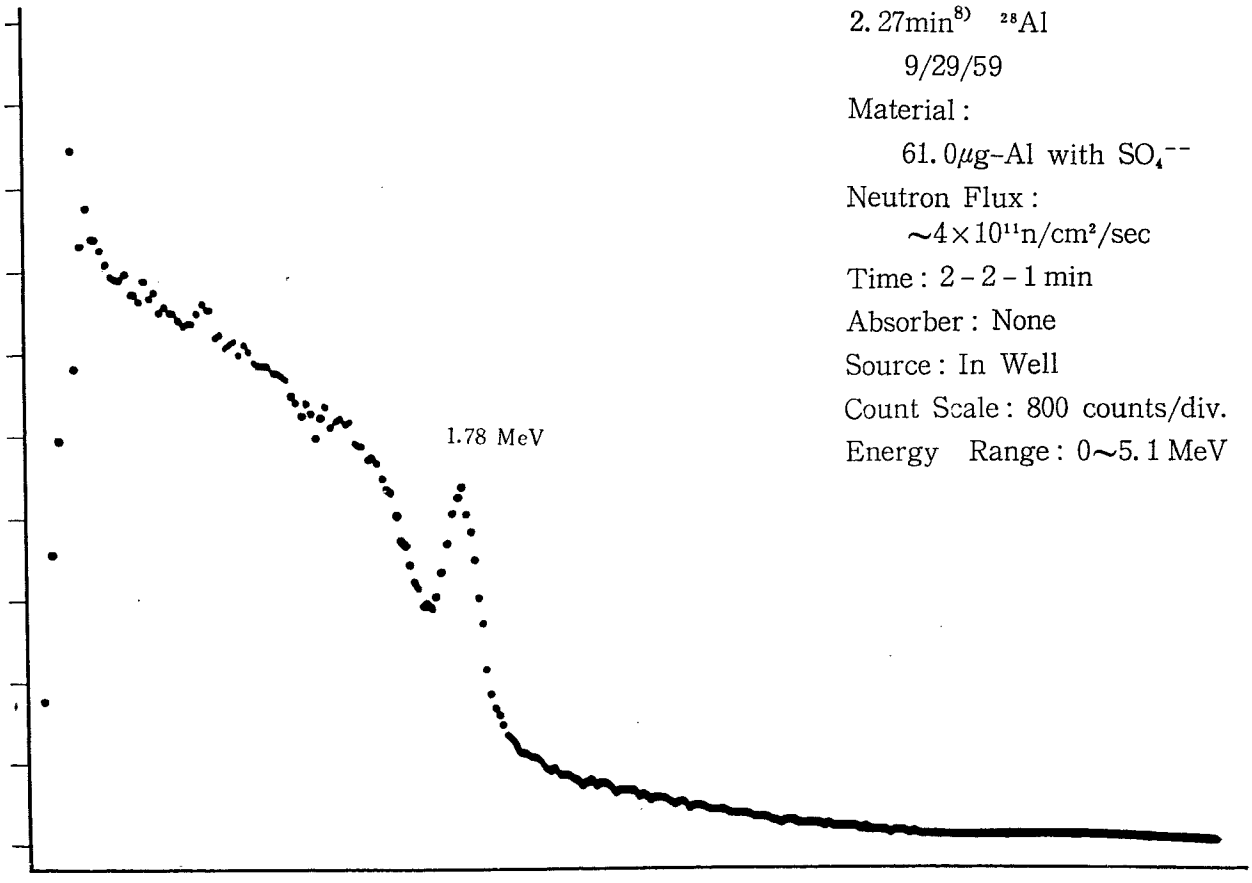
Time : 10-10-10 sec

Absorber : 607mg/cm²

Source : In Well

Count Scale : 400 counts/div.

Energy Range : 0~6 MeV




2.27min[8] $^{28}Al$

9/29/59

Material :

61.0$\mu$g-Al with $SO_4^{--}$

Neutron Flux :

$\sim4\times10^{11}$n/cm²/sec

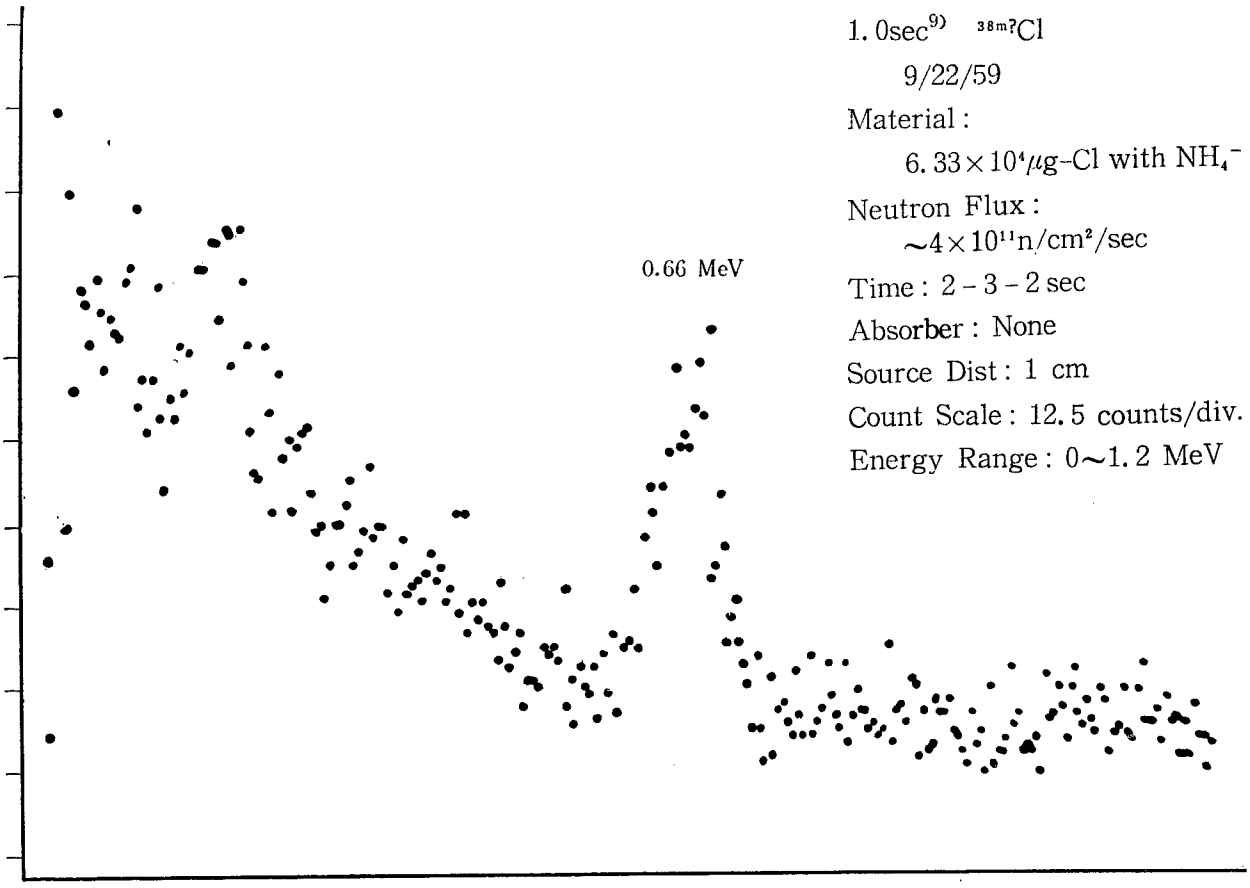
Time : 2 - 2 - 1 min

Absorber : None

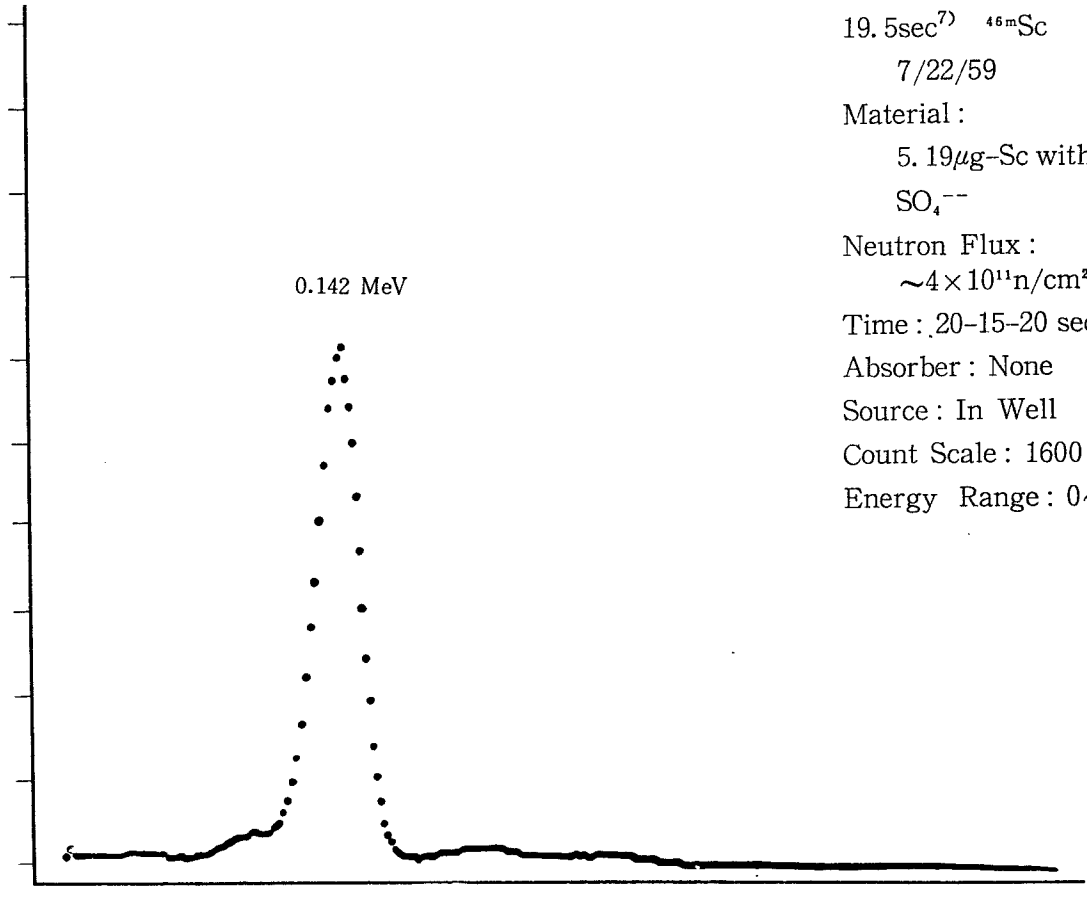
Source : In Well

Count Scale : 800 counts/div.

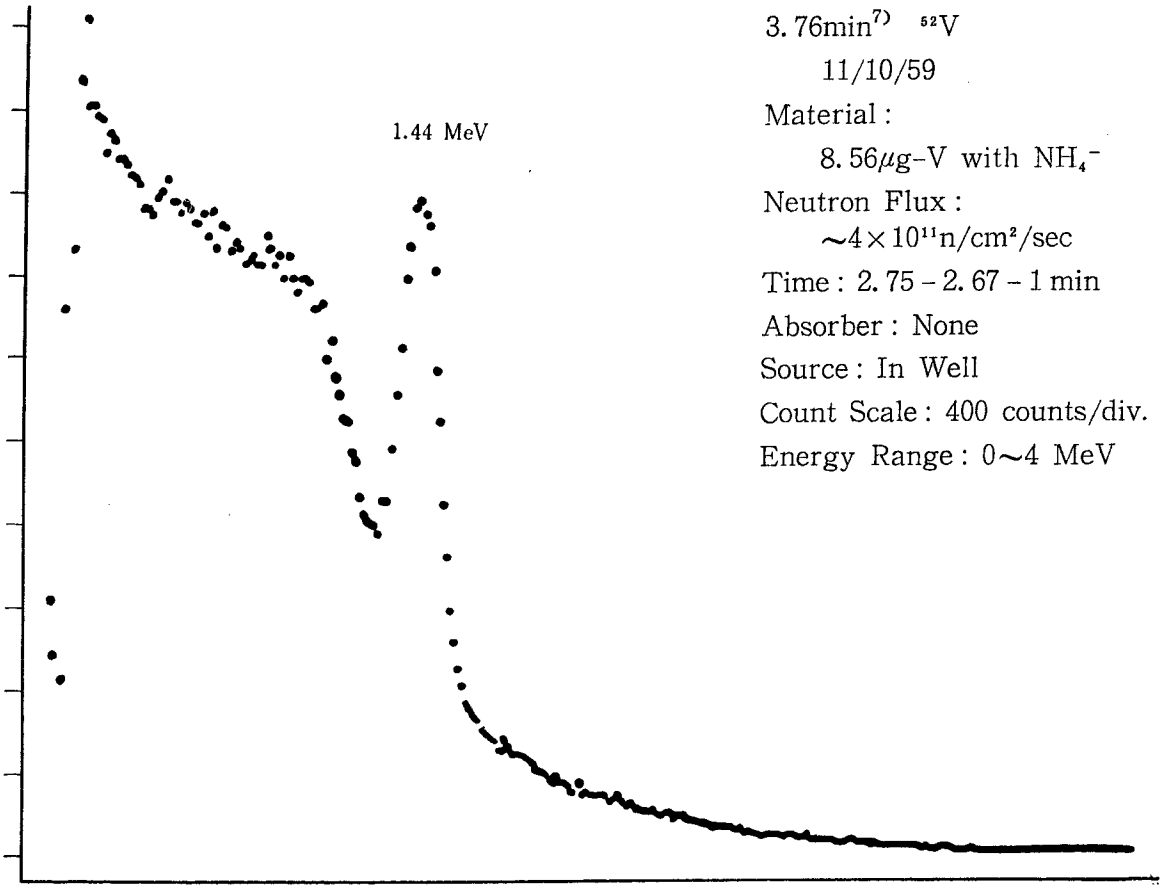
Energy Range : 0~5.1 MeV



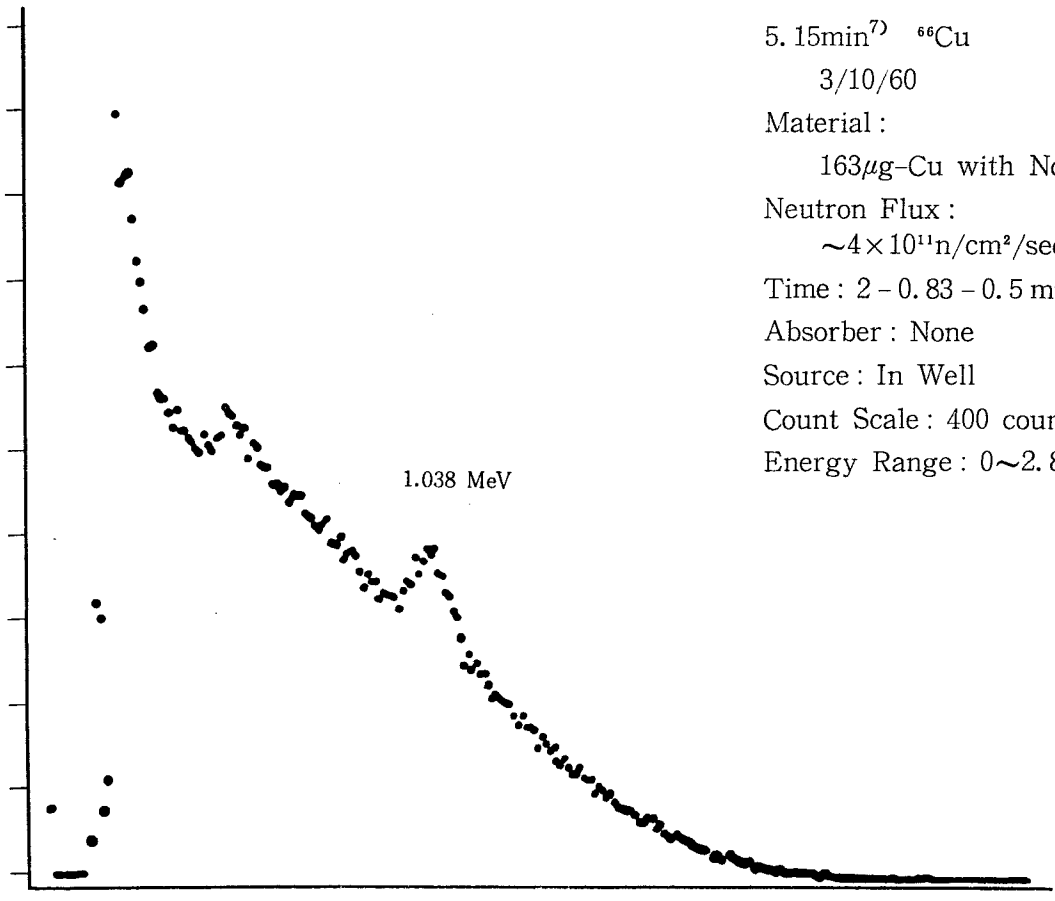

1.0sec[9] $^{38m}$?Cl
9/22/59
Material :
$6.33\times10^{4}\mu$g-Cl with $NH_4^-$
Neutron Flux :
$\sim4\times10^{11}$n/cm$^2$/sec
Time : 2 - 3 - 2 sec
Absorber : None
Source Dist : 1 cm
Count Scale : 12.5 counts/div.
Energy Range : 0~1.2 MeV



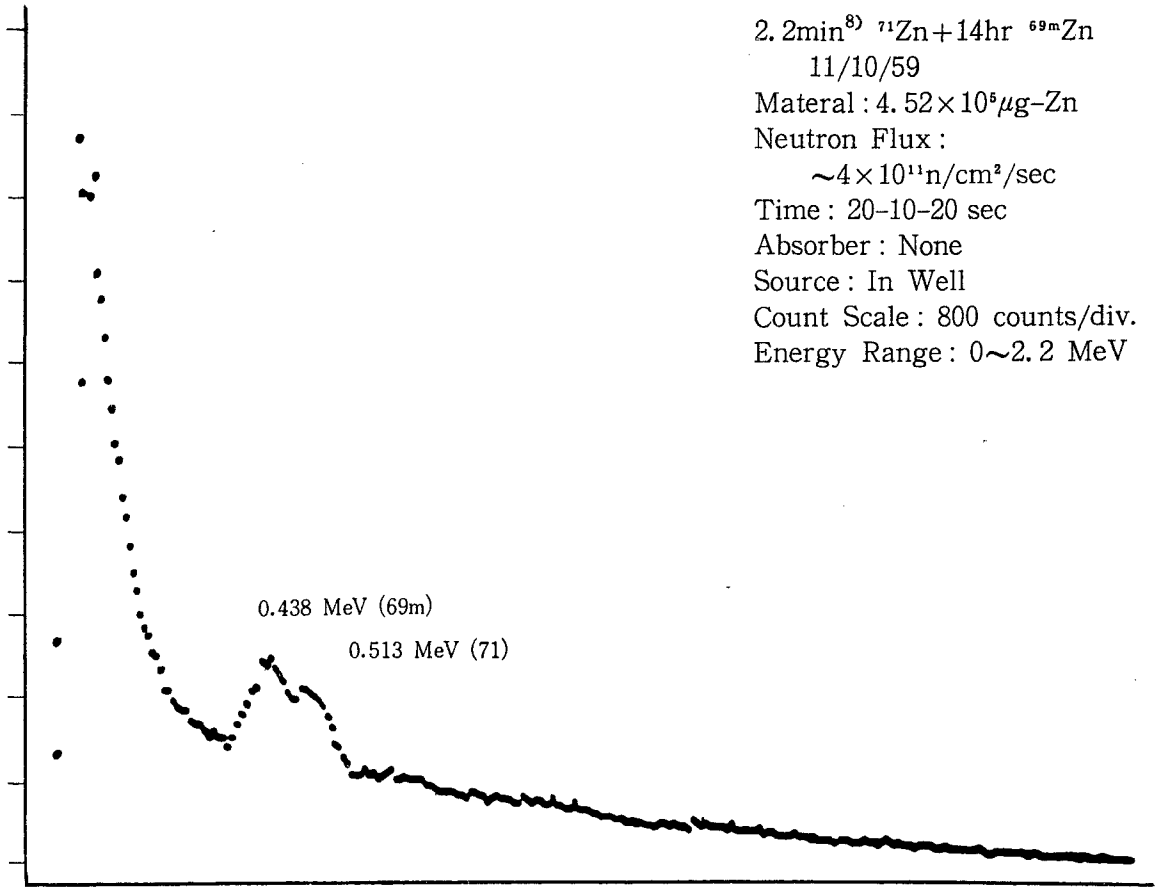

19.5sec[7] $^{46m}$Sc
7/22/59
Material :
$5.19\mu$g-Sc with $Cl^-$ &
$SO_4^{--}$
Neutron Flux :
$\sim4\times10^{11}$n/cm$^2$/sec
Time : 20-15-20 sec
Absorber : None
Source : In Well
Count Scale : 1600 counts/div.
Energy Range : 0~0.5 MeV



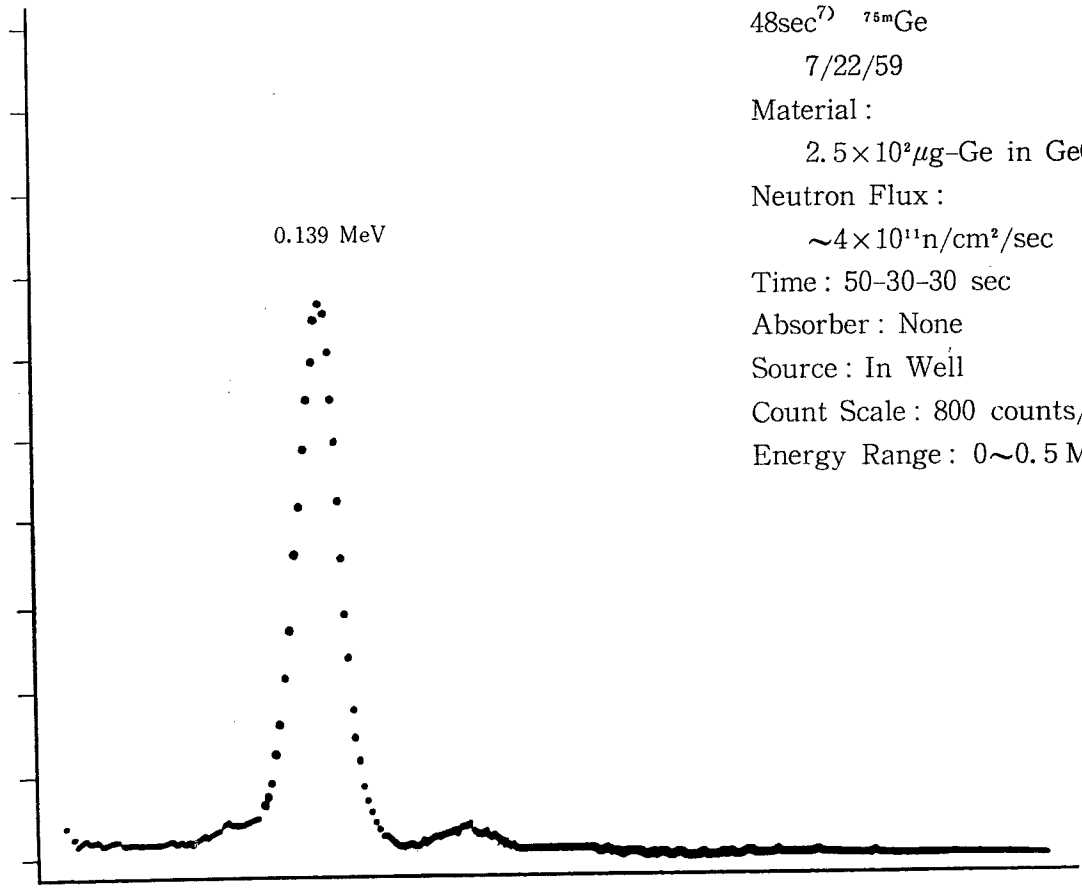

3.76min[7] $^{52}V$
11/10/59
Material :
8.56$\mu$g-V with $NH_4^-$
Neutron Flux :
$\sim 4 \times 10^{11}$n/cm$^2$/sec
Time : 2.75 - 2.67 - 1 min
Absorber : None
Source : In Well
Count Scale : 400 counts/div.
Energy Range : 0~4 MeV



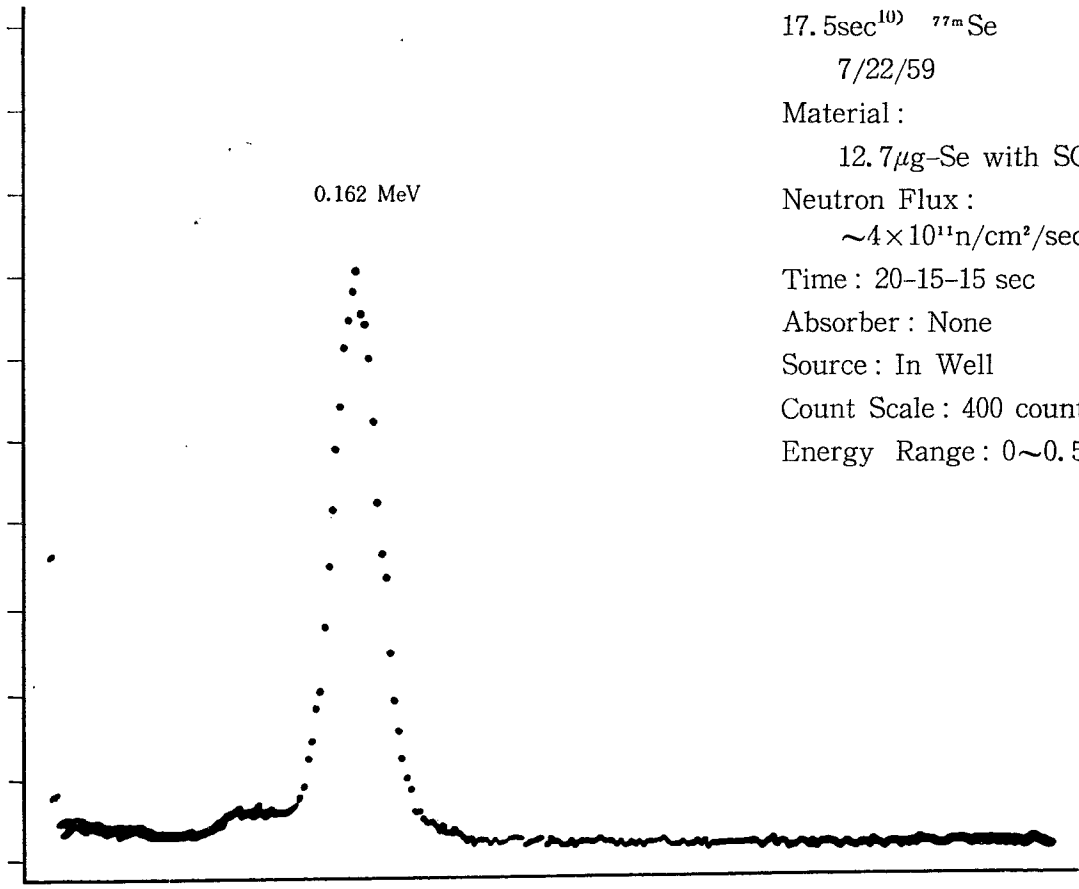

5.15min[7] $^{66}Cu$
3/10/60
Material :
163$\mu$g-Cu with $No_3^-$
Neutron Flux :
$\sim 4 \times 10^{11}$n/cm$^2$/sec
Time : 2 - 0.83 - 0.5 min
Absorber : None
Source : In Well
Count Scale : 400 counts/div.
Energy Range : 0~2.8 MeV



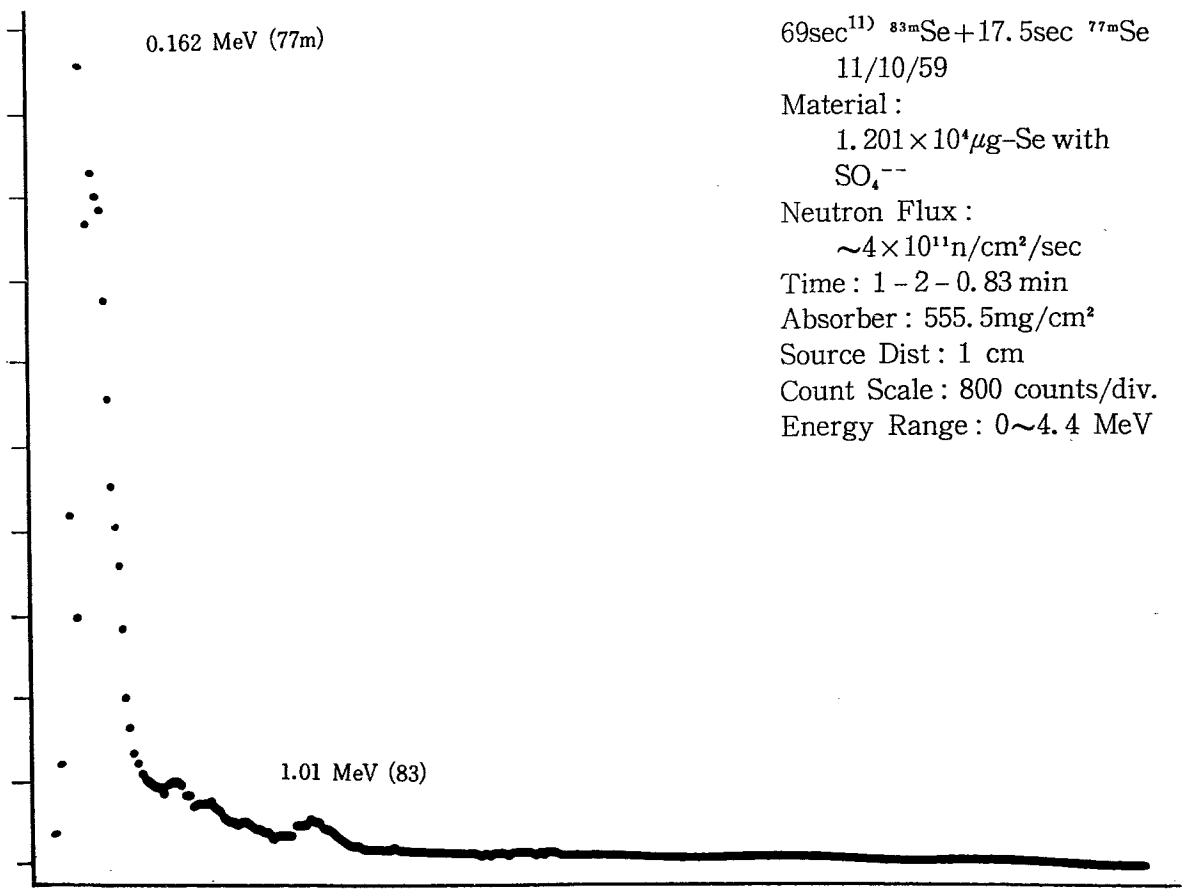

2.2min[8] $^{71}Zn$+14hr $^{69m}Zn$
11/10/59
Materal : $4.52\times10^{5}\mu g$-Zn
Neutron Flux :
$\sim4\times10^{11}n/cm^{2}/sec$
Time : 20-10-20 sec
Absorber : None
Source : In Well
Count Scale : 800 counts/div.
Energy Range : 0~2.2 MeV



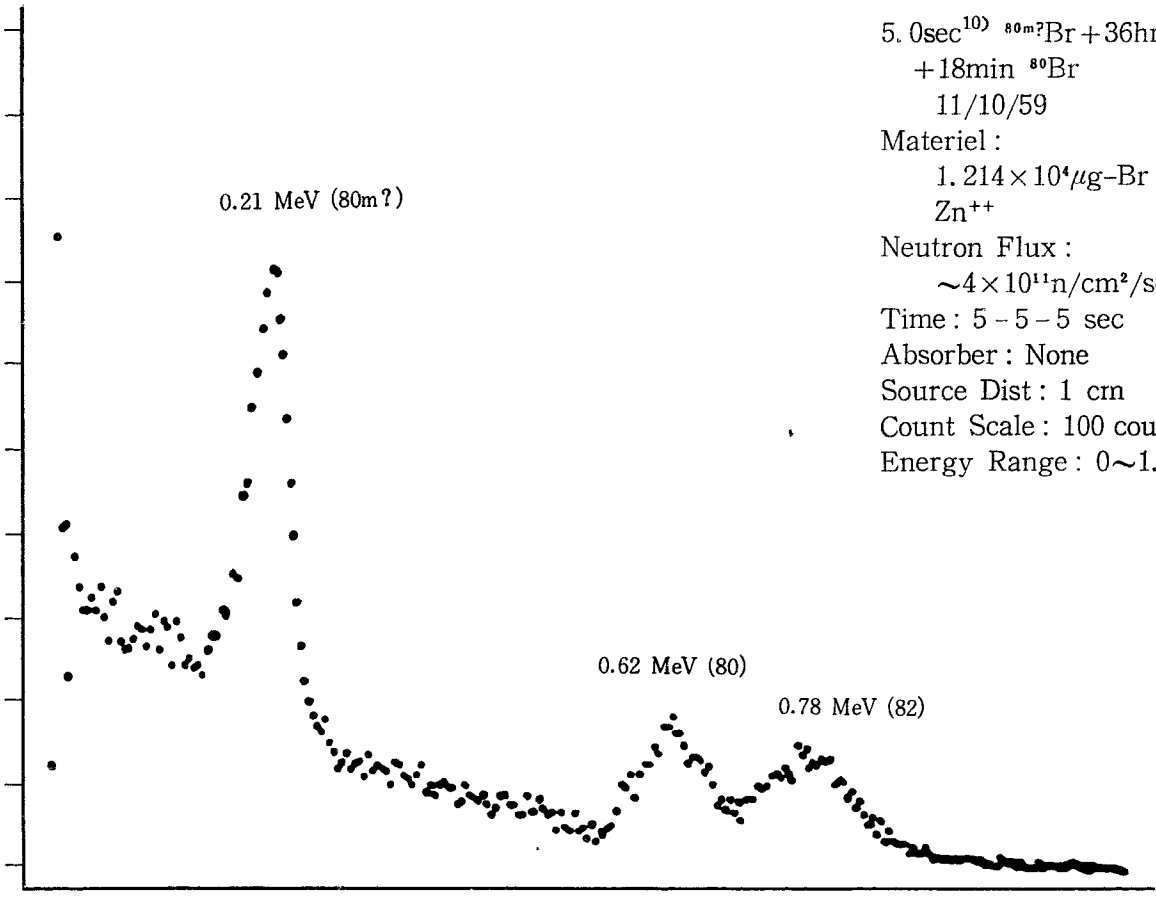

48sec[7] $^{75m}Ge$
7/22/59
Material :
$2.5\times10^{2}\mu g$-Ge in $GeO_2$
Neutron Flux :
$\sim4\times10^{11}n/cm^{2}/sec$
Time : 50-30-30 sec
Absorber : None
Source : In Well
Count Scale : 800 counts/div.
Energy Range : 0~0.5 MeV



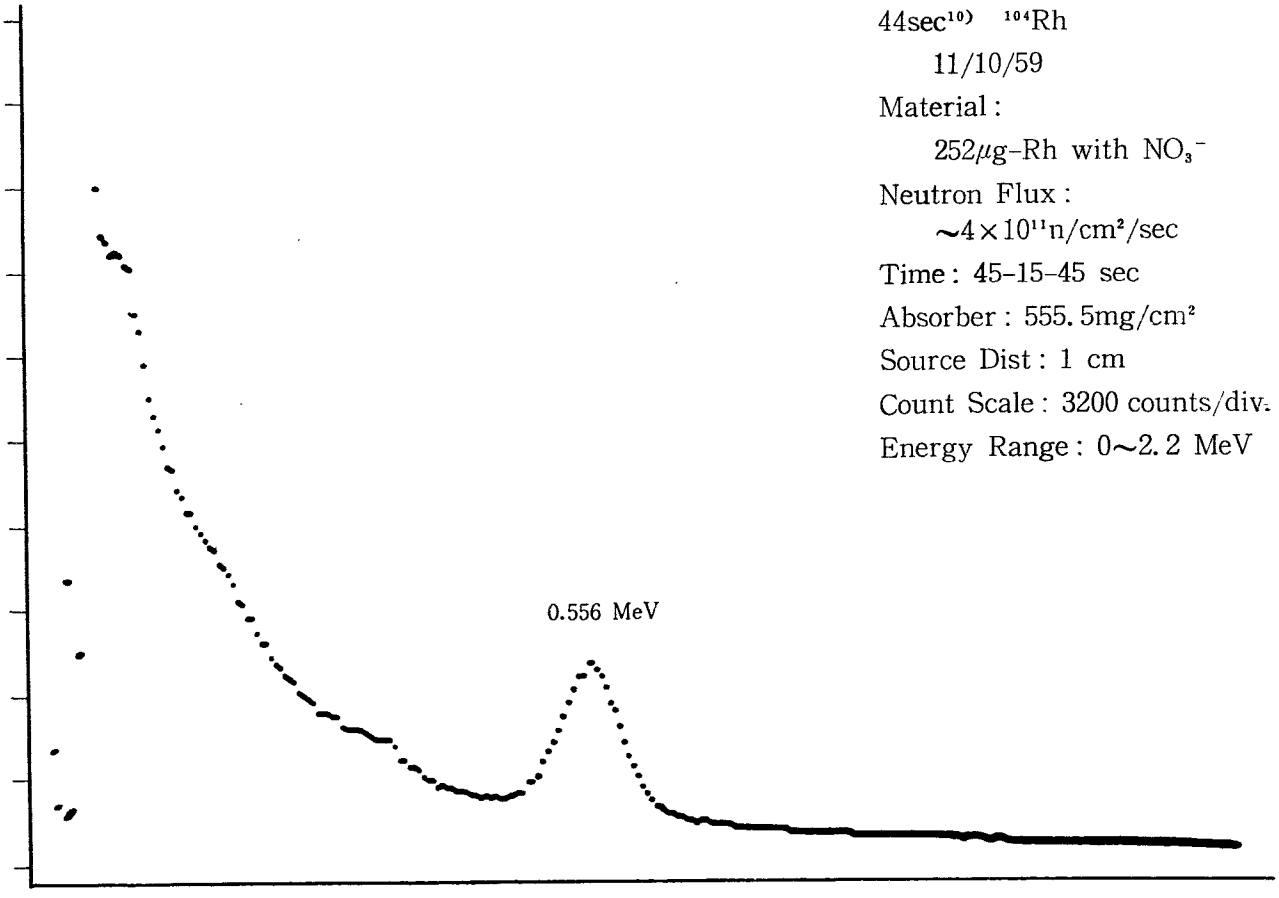

17.5sec[10] $^{77m}Se$
7/22/59
Material :
12.7$\mu$g-Se with $SO_4^{--}$
Neutron Flux :
$\sim 4\times10^{11}$n/cm$^2$/sec
Time : 20-15-15 sec
Absorber : None
Source : In Well
Count Scale : 400 counts/div.
Energy Range : 0$\sim$0.5MeV



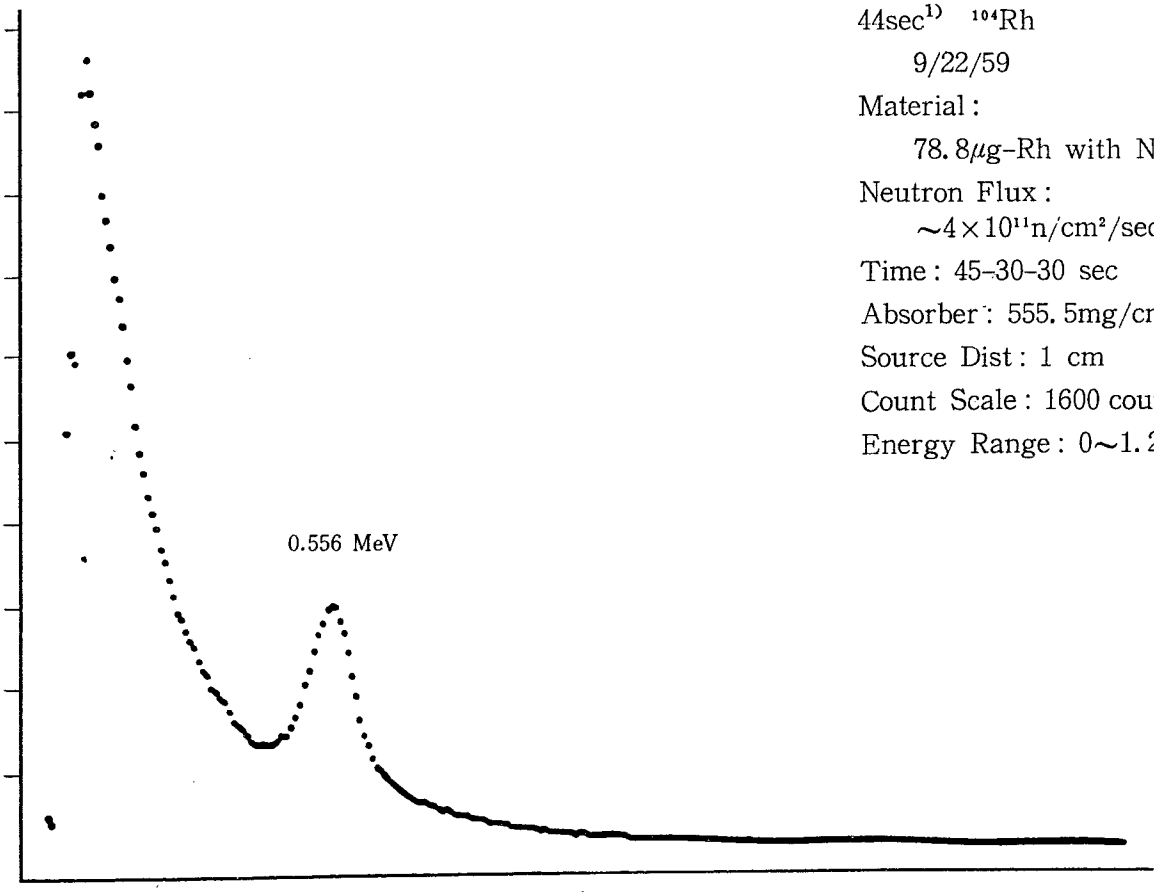

69sec[11] $^{83m}Se+17.5sec$ $^{77m}Se$
11/10/59
Material :
$1.201\times10^4\mu$g-Se with $SO_4^{--}$
Neutron Flux :
$\sim 4\times10^{11}$n/cm$^2$/sec
Time : 1 - 2 - 0.83 min
Absorber : 555.5mg/cm$^2$
Source Dist : 1 cm
Count Scale : 800 counts/div.
Energy Range : 0$\sim$4.4 MeV



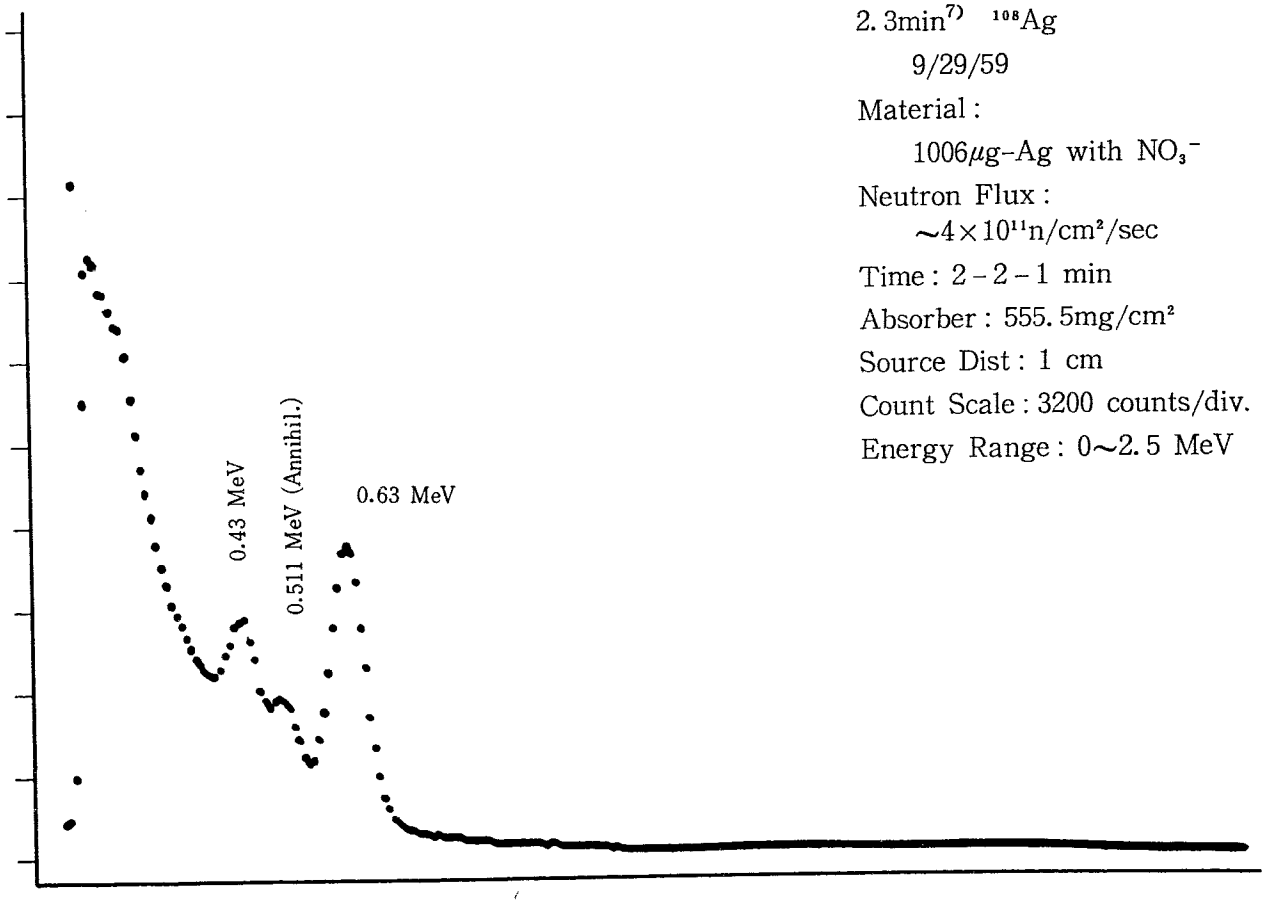

5.0sec[10] $^{80m?}Br$ +36hr $^{82}Br$
+18min $^{80}Br$
11/10/59
Materiel :
$1.214\times10^{4}\mu g$-Br with $Zn^{++}$
Neutron Flux :
$\sim4\times10^{11}n/cm^{2}/sec$
Time : 5 - 5 - 5 sec
Absorber : None
Source Dist : 1 cm
Count Scale : 100 counts/div.
Energy Range : 0~1.1 MeV



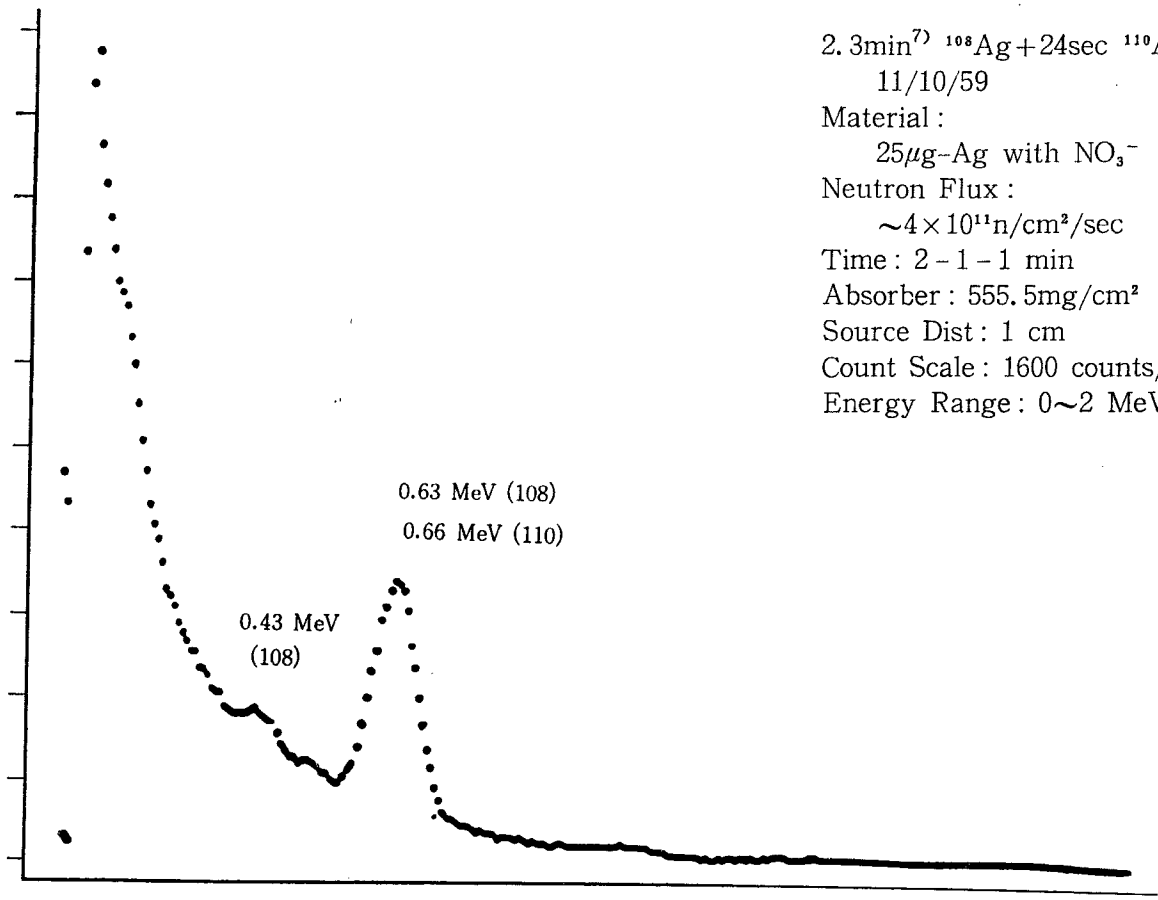

44sec[10] $^{104}Rh$
11/10/59
Material :
$252\mu g$-Rh with $NO_3^-$
Neutron Flux :
$\sim4\times10^{11}n/cm^{2}/sec$
Time : 45-15-45 sec
Absorber : 555.5mg/cm$^2$
Source Dist : 1 cm
Count Scale : 3200 counts/div.
Energy Range : 0~2.2 MeV



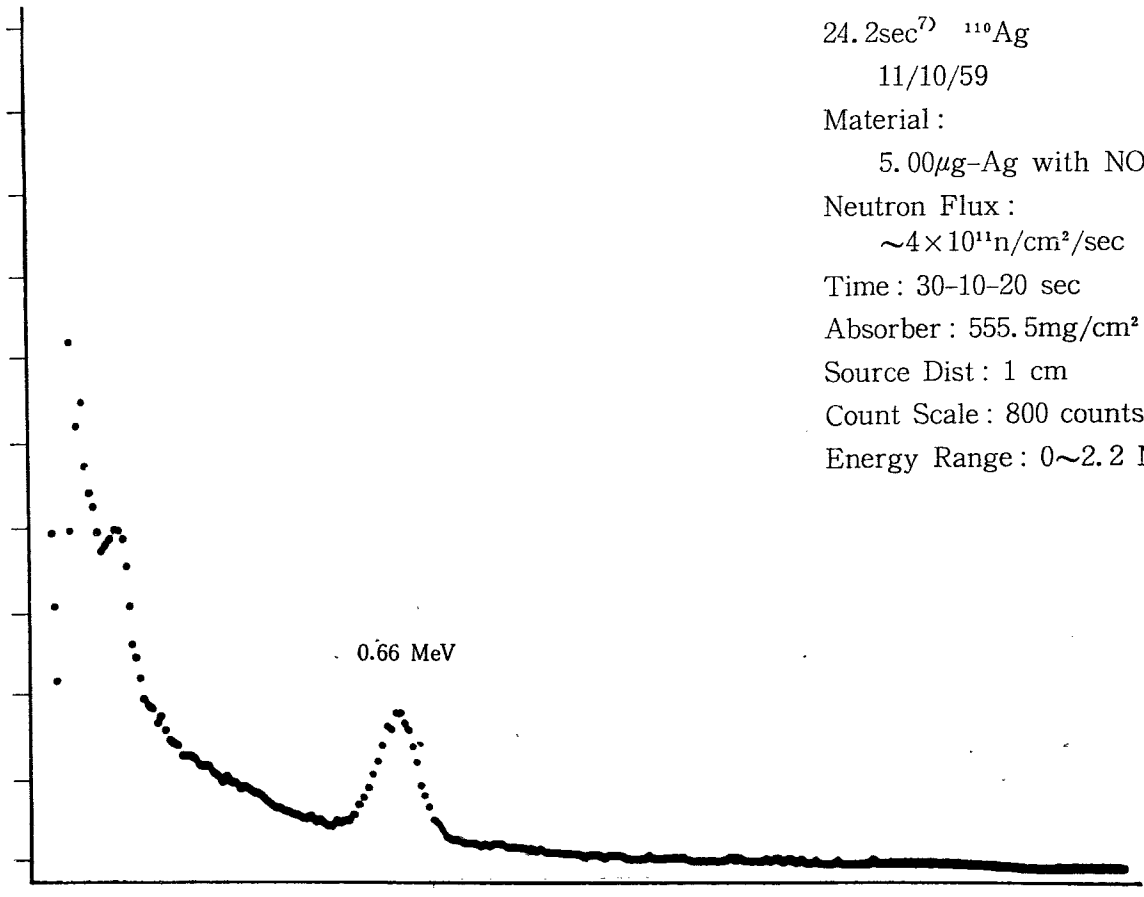

44sec[1] $^{104}Rh$
9/22/59
Material :
78.8$\mu$g-Rh with $NO_3^-$
Neutron Flux :
$\sim 4 \times 10^{11}$n/cm$^2$/sec
Time : 45-30-30 sec
Absorber : 555.5mg/cm$^2$
Source Dist : 1 cm
Count Scale : 1600 counts/div.
Energy Range : 0~1.2 MeV



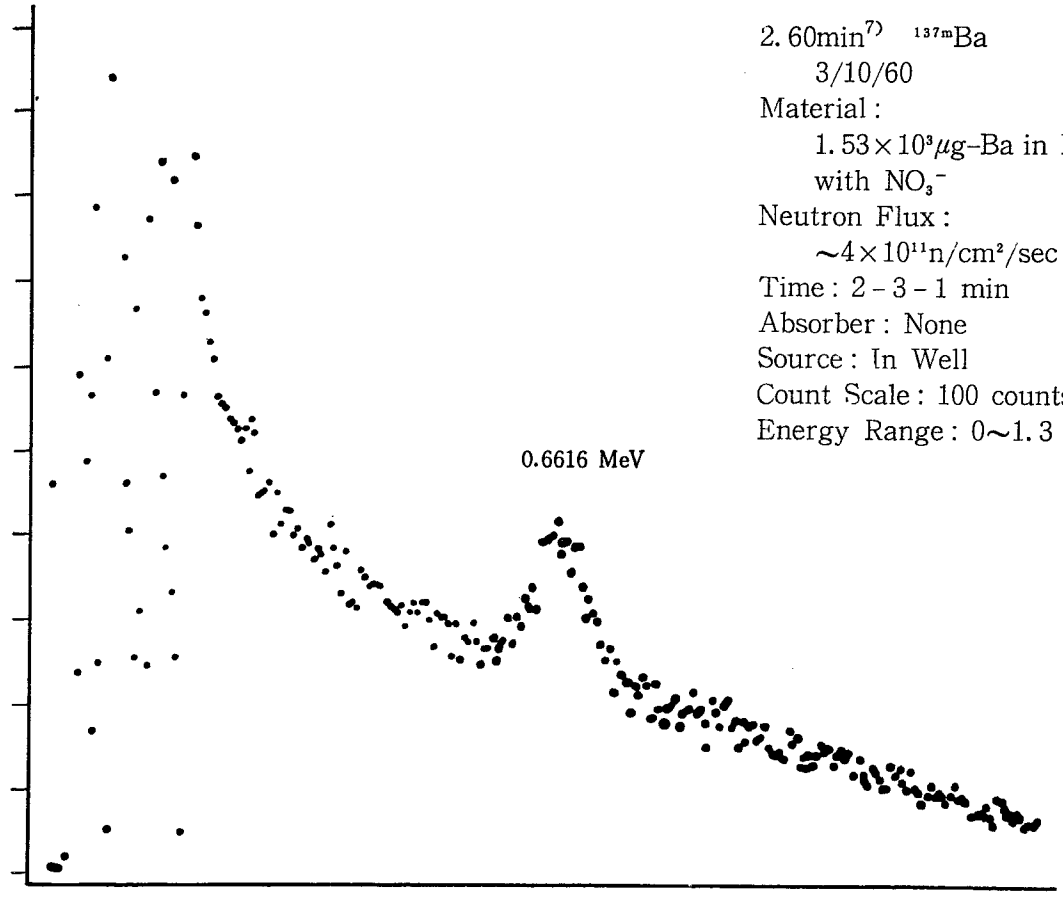

2.3min[7] $^{108}Ag$
9/29/59
Material :
1006$\mu$g-Ag with $NO_3^-$
Neutron Flux :
$\sim 4 \times 10^{11}$n/cm$^2$/sec
Time : 2-2-1 min
Absorber : 555.5mg/cm$^2$
Source Dist : 1 cm
Count Scale : 3200 counts/div.
Energy Range : 0~2.5 MeV



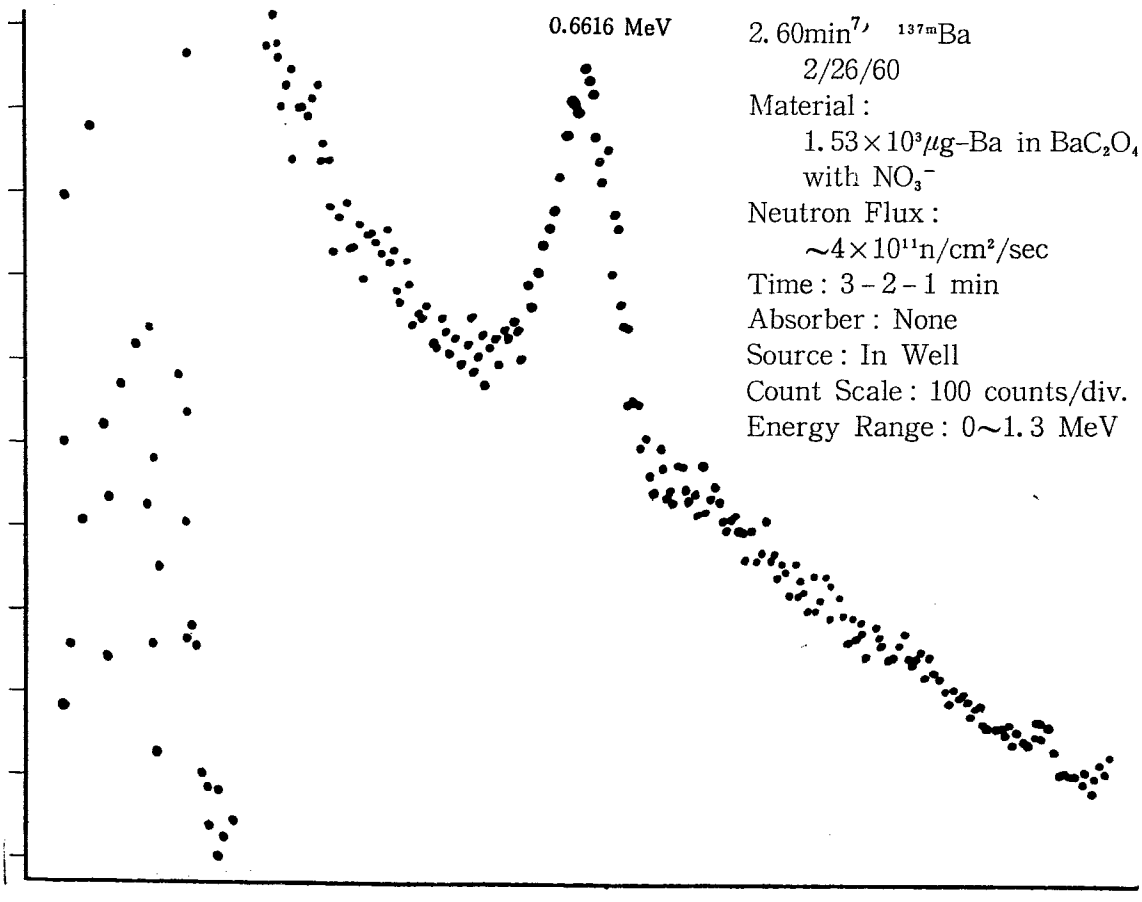

2.3min[7] $^{108}Ag+24sec$ $^{110}Ag$
11/10/59
Material :
25$\mu$g-Ag with $NO_3^-$
Neutron Flux :
$\sim 4\times 10^{11}$n/cm$^2$/sec
Time : 2-1-1 min
Absorber : 555.5mg/cm$^2$
Source Dist : 1 cm
Count Scale : 1600 counts/div.
Energy Range : 0~2 MeV



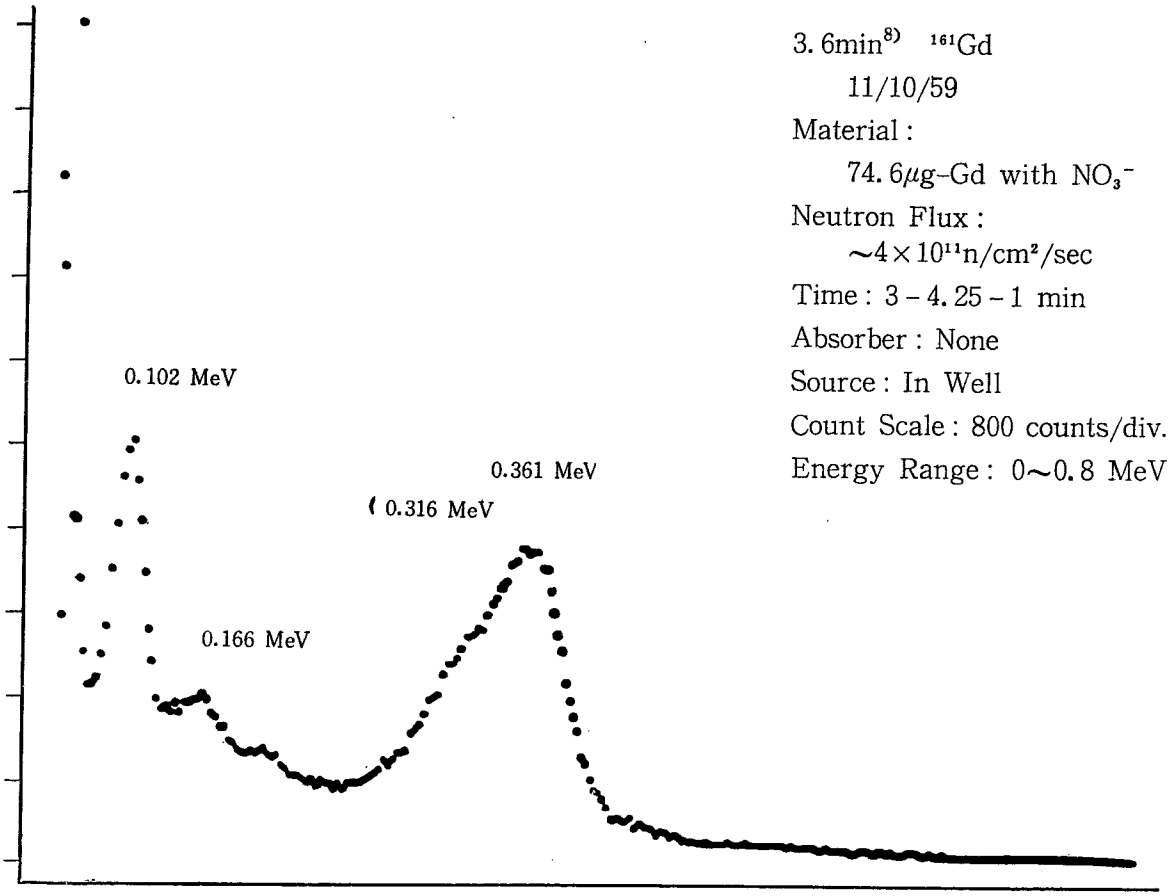

24.2sec[7] $^{110}Ag$
11/10/59
Material :
5.00$\mu$g-Ag with $NO_3^-$
Neutron Flux :
$\sim 4\times 10^{11}$n/cm$^2$/sec
Time : 30-10-20 sec
Absorber : 555.5mg/cm$^2$
Source Dist : 1 cm
Count Scale : 800 counts/div.
Energy Range : 0~2.2 MeV



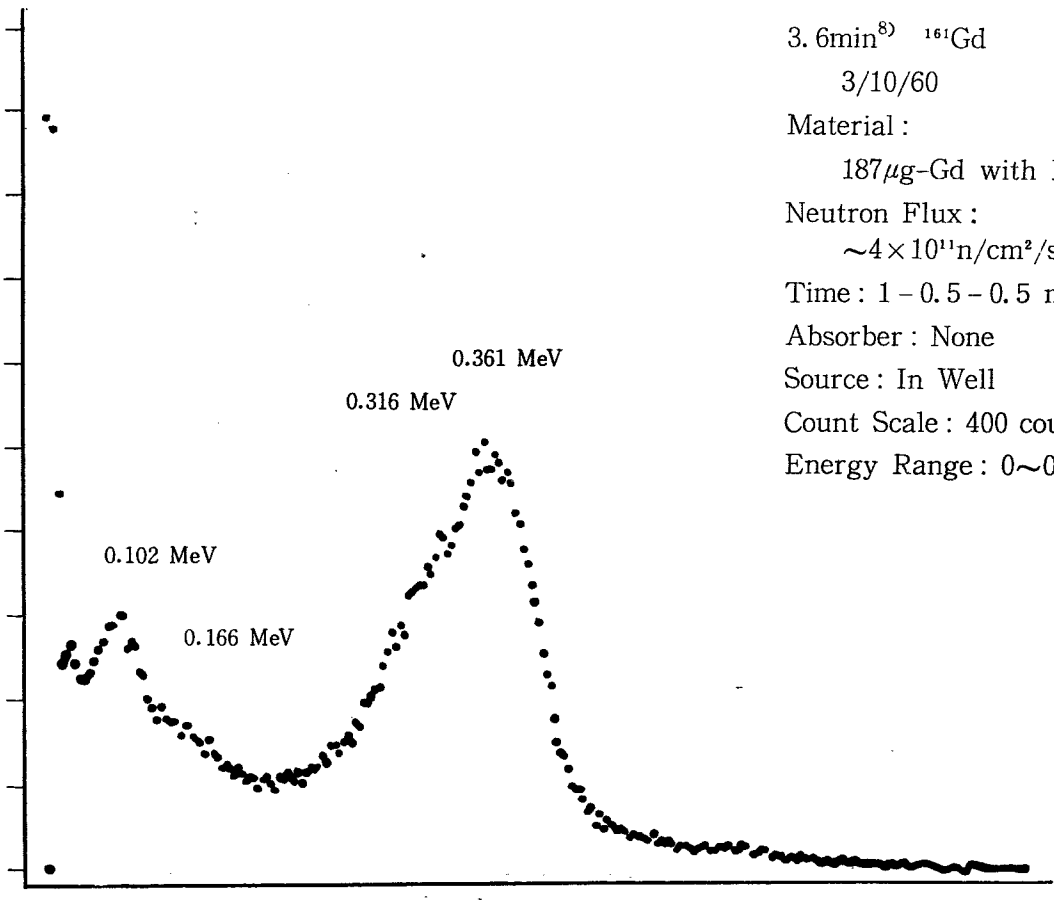

2.60min[7] $^{137m}$Ba
3/10/60
Material :
$1.53\times10^{3}\mu$g-Ba in $BaC_2O_4$
with $NO_3^-$
Neutron Flux :
$\sim4\times10^{11}$n/cm$^2$/sec
Time : 2 - 3 - 1 min
Absorber : None
Source : In Well
Count Scale : 100 counts/div.
Energy Range : 0~1.3 MeV



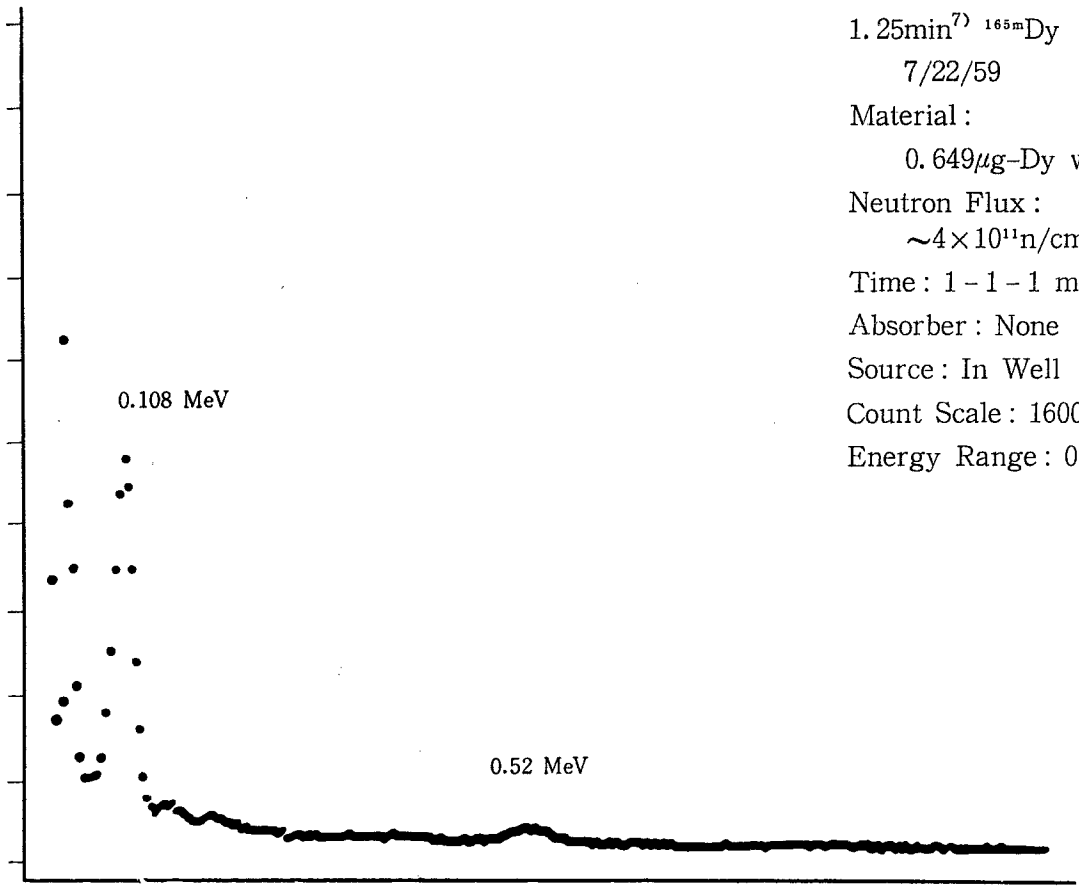

2.60min[7] $^{137m}$Ba
2/26/60
Material :
$1.53\times10^{3}\mu$g-Ba in $BaC_2O_4$
with $NO_3^-$
Neutron Flux :
$\sim4\times10^{11}$n/cm$^2$/sec
Time : 3 - 2 - 1 min
Absorber : None
Source : In Well
Count Scale : 100 counts/div.
Energy Range : 0~1.3 MeV



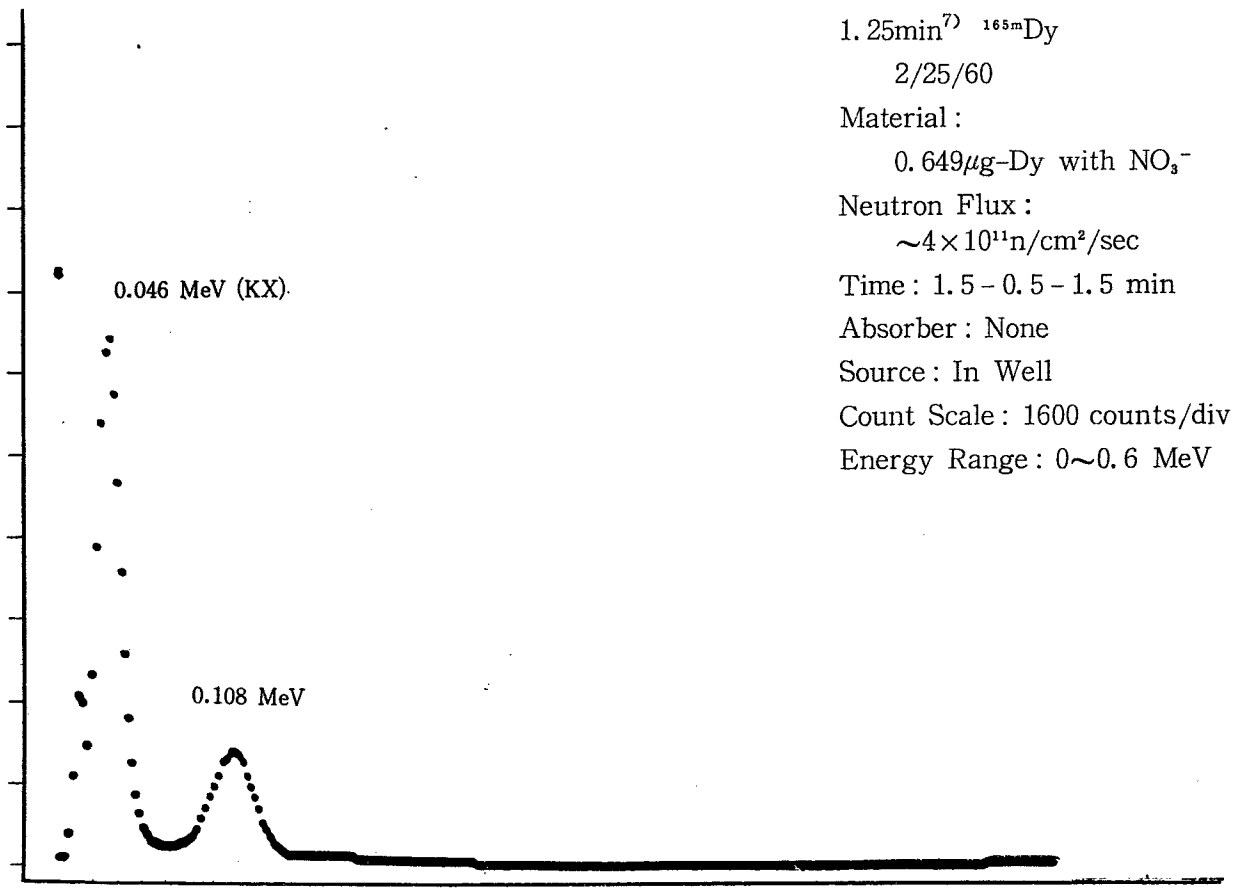

3.6min[8] $^{161}$Gd
11/10/59
Material :
74.6$\mu$g-Gd with $NO_3^-$
Neutron Flux :
$\sim 4\times10^{11}$n/cm$^2$/sec
Time : 3 - 4.25 - 1 min
Absorber : None
Source : In Well
Count Scale : 800 counts/div.
Energy Range : 0$\sim$0.8 MeV



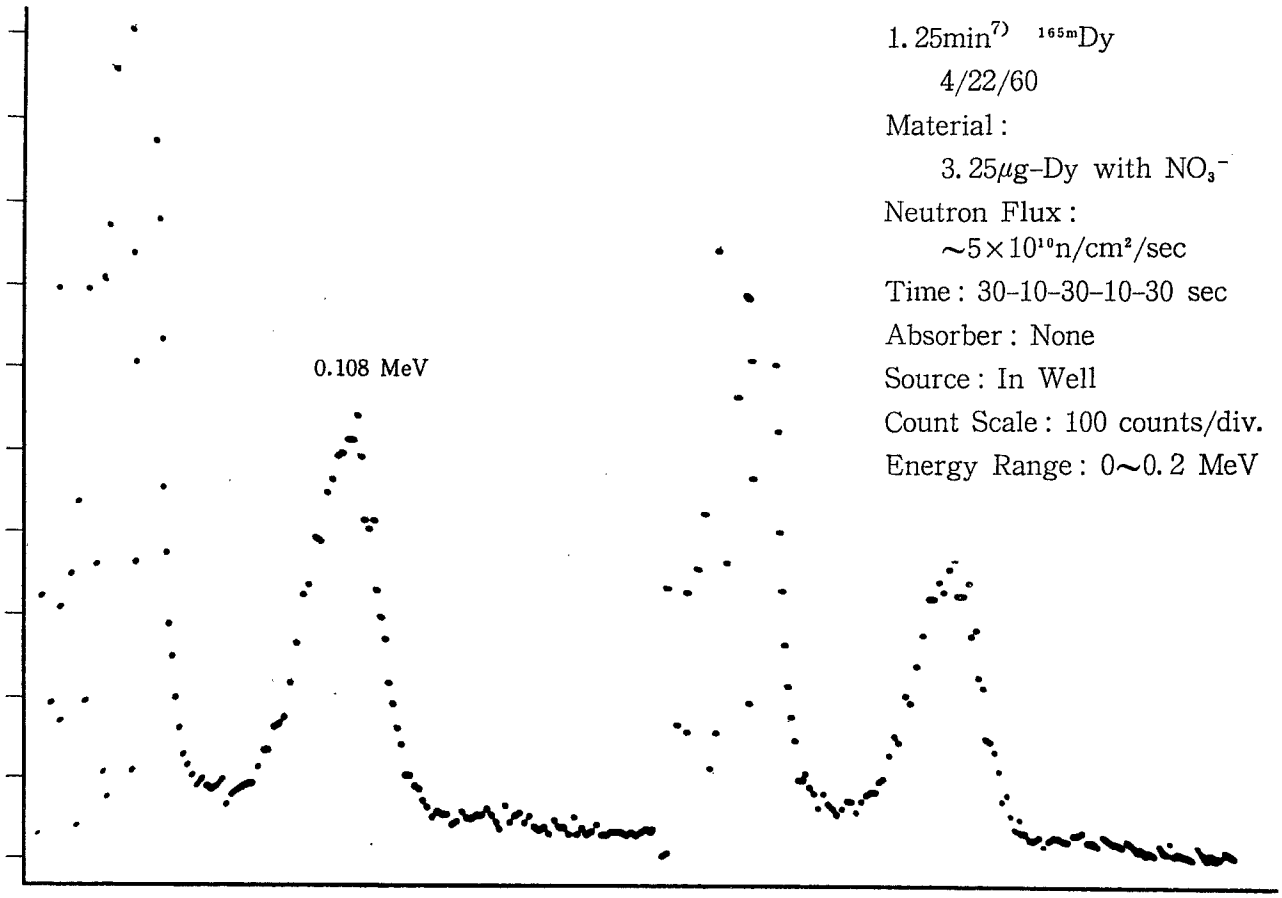

3.6min[8] $^{161}$Gd
3/10/60
Material :
187$\mu$g-Gd with $NO_3^-$
Neutron Flux :
$\sim 4\times10^{11}$n/cm$^2$/sec
Time : 1 - 0.5 - 0.5 min
Absorber : None
Source : In Well
Count Scale : 400 counts/div.
Energy Range : 0$\sim$0.7 MeV



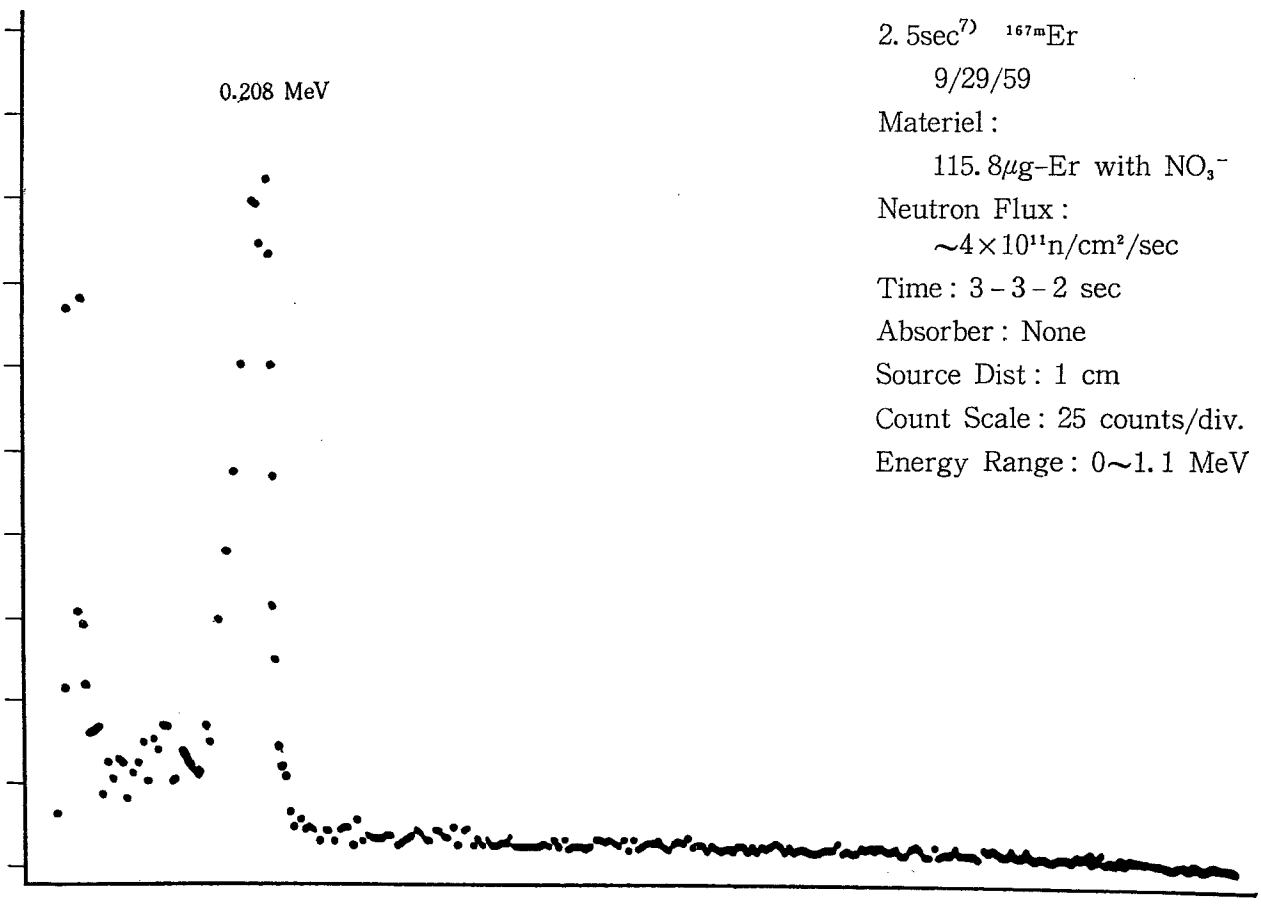

1.25min[7] $^{165m}$Dy
7/22/59
Material :
0.649$\mu$g-Dy with $NO_3^-$
Neutron Flux :
$\sim 4\times10^{11}$n/cm$^2$/sec
Time : 1 - 1 - 1 min
Absorber : None
Source : In Well
Count Scale : 1600 counts/div.
Energy Range : 0$\sim$1.1 MeV



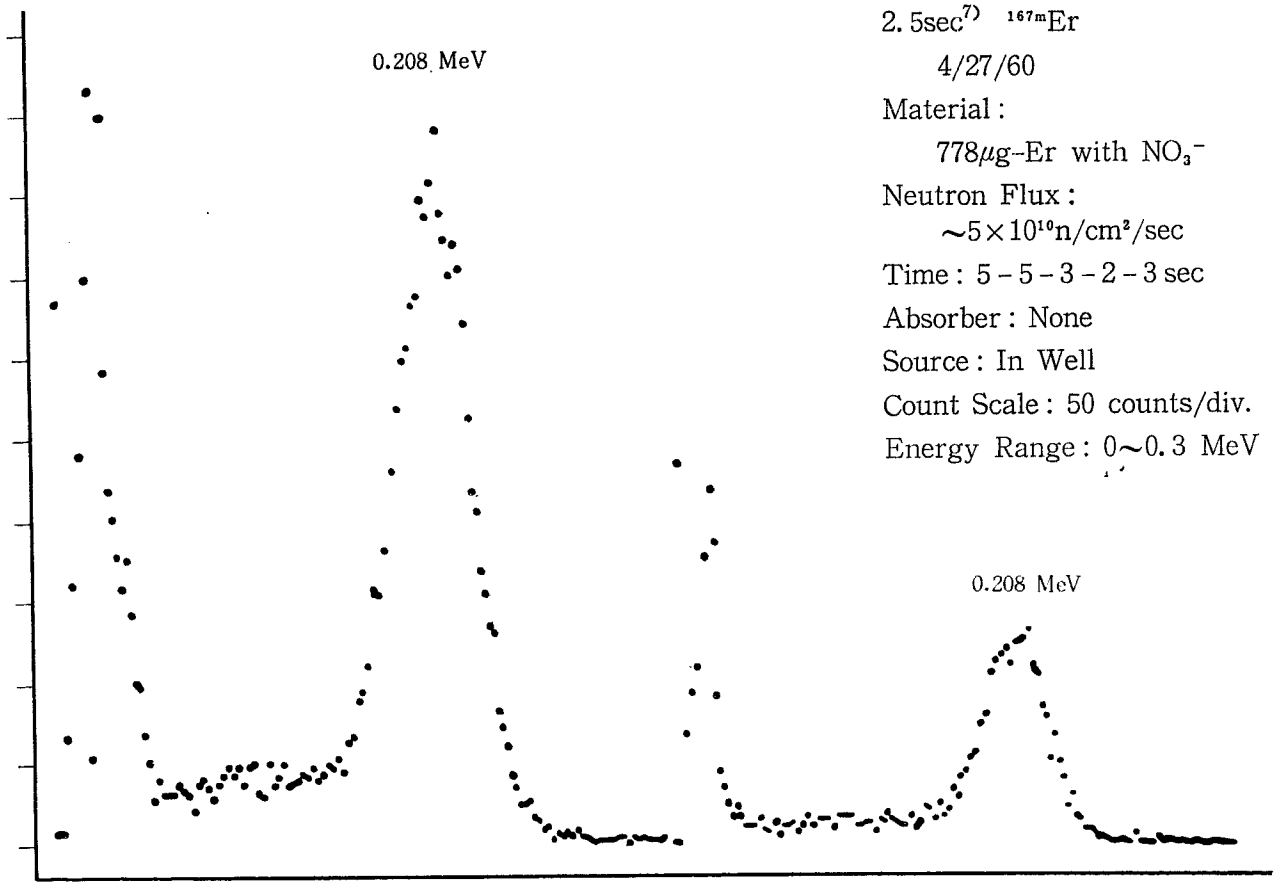

1.25min[7] $^{165m}$Dy
2/25/60
Material :
0.649$\mu$g-Dy with $NO_3^-$
Neutron Flux :
$\sim 4\times10^{11}$n/cm$^2$/sec
Time : 1.5 - 0.5 - 1.5 min
Absorber : None
Source : In Well
Count Scale : 1600 counts/div
Energy Range : 0$\sim$0.6 MeV



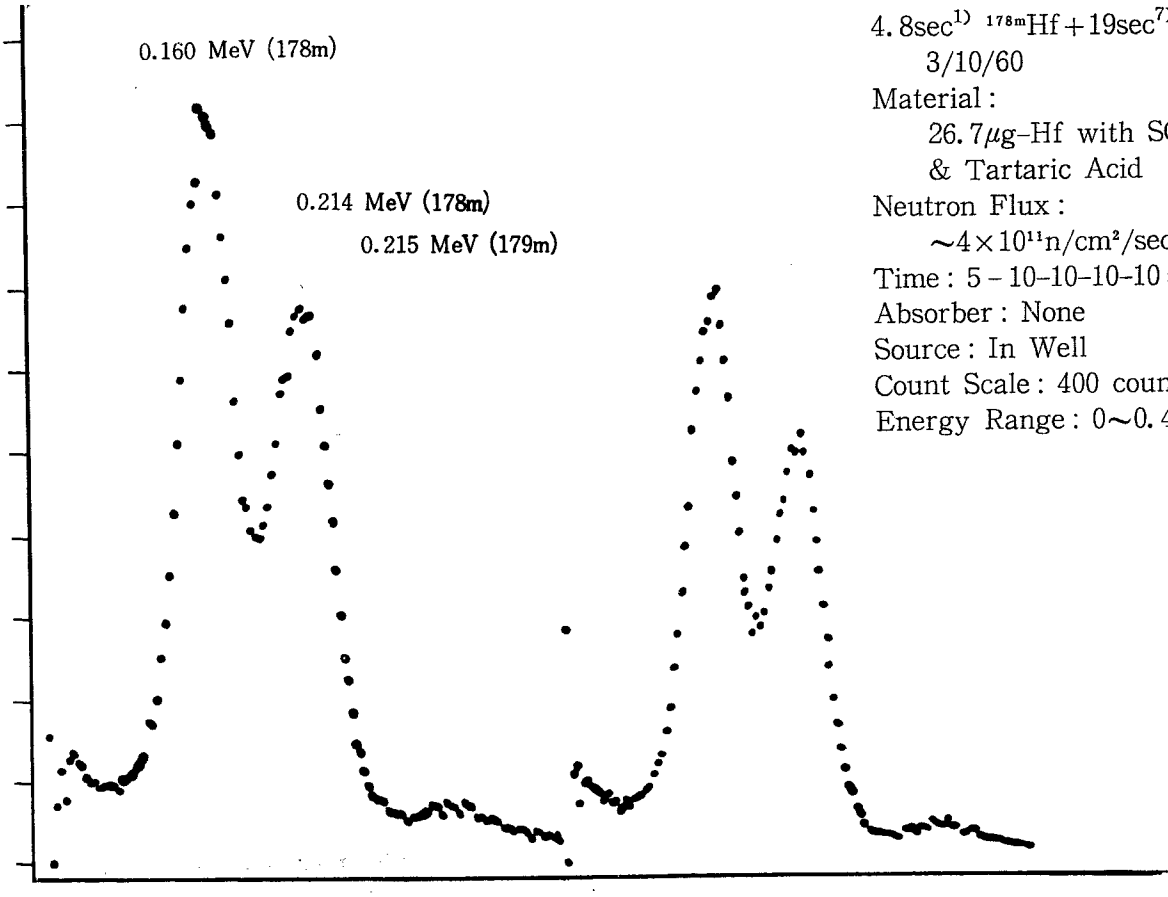

1.25min[7] $^{165m}Dy$
4/22/60
Material :
3.25$\mu$g-Dy with $NO_3^-$
Neutron Flux :
$\sim 5\times10^{10}$n/cm$^2$/sec
Time : 30-10-30-10-30 sec
Absorber : None
Source : In Well
Count Scale : 100 counts/div.
Energy Range : 0~0.2 MeV



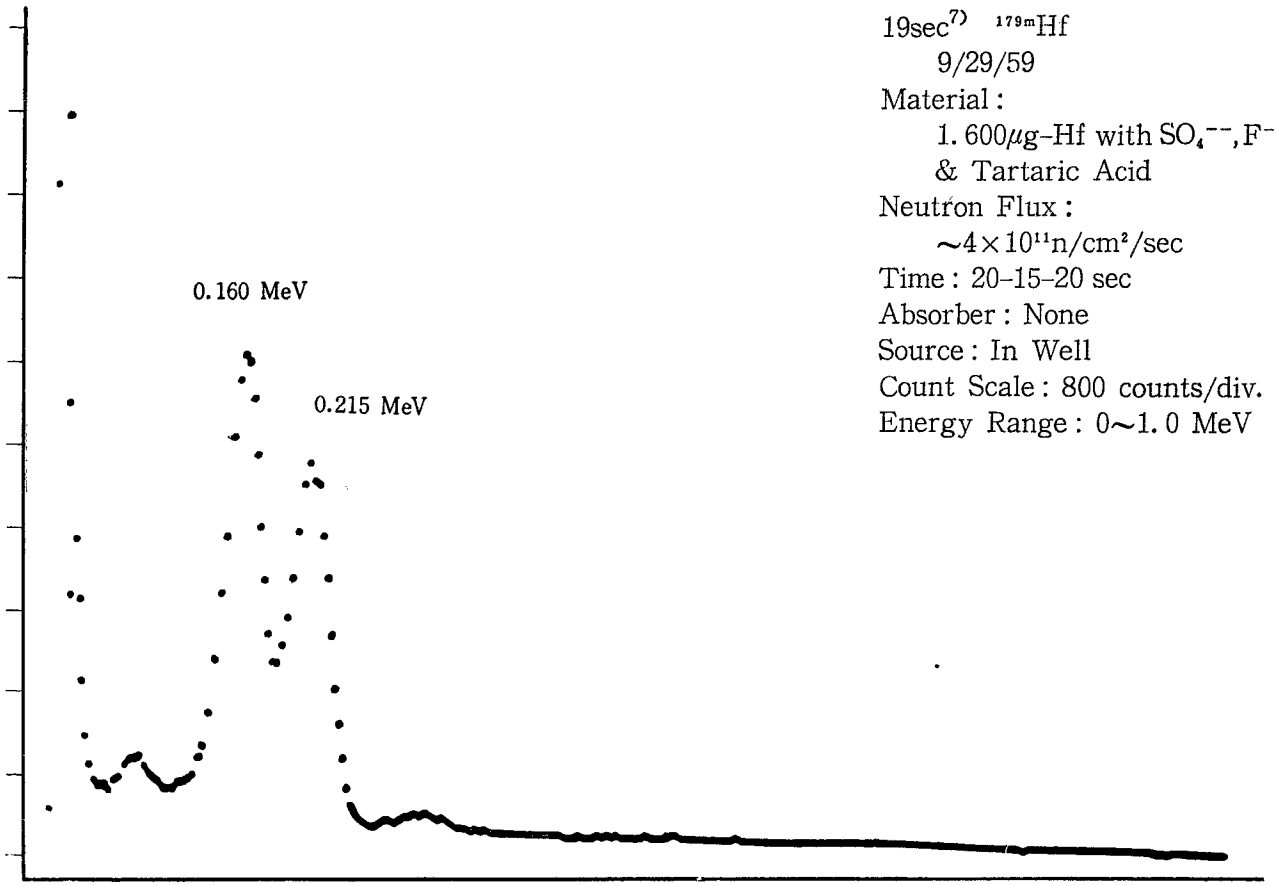

2.5sec[7] $^{167m}Er$
9/29/59
Materiel :
115.8$\mu$g-Er with $NO_3^-$
Neutron Flux :
$\sim 4\times10^{11}$n/cm$^2$/sec
Time : 3-3-2 sec
Absorber : None
Source Dist : 1 cm
Count Scale : 25 counts/div.
Energy Range : 0~1.1 MeV



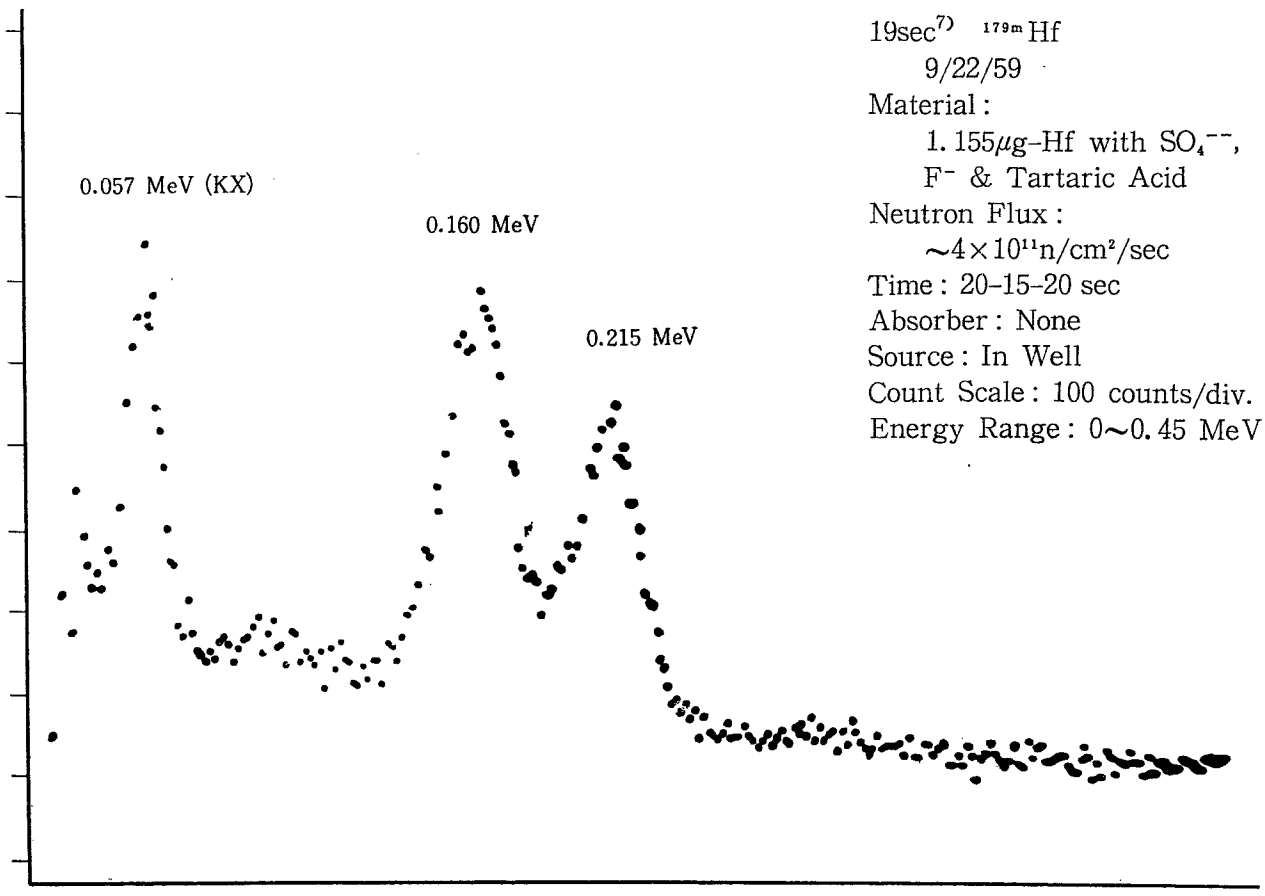

2.5sec[7] $^{167m}Er$
4/27/60
Material :
778$\mu$g-Er with $NO_3^-$
Neutron Flux :
$\sim 5\times10^{10}$n/cm$^2$/sec
Time : 5 - 5 - 3 - 2 - 3 sec
Absorber : None
Source : In Well
Count Scale : 50 counts/div.
Energy Range : 0$\sim$0.3 MeV



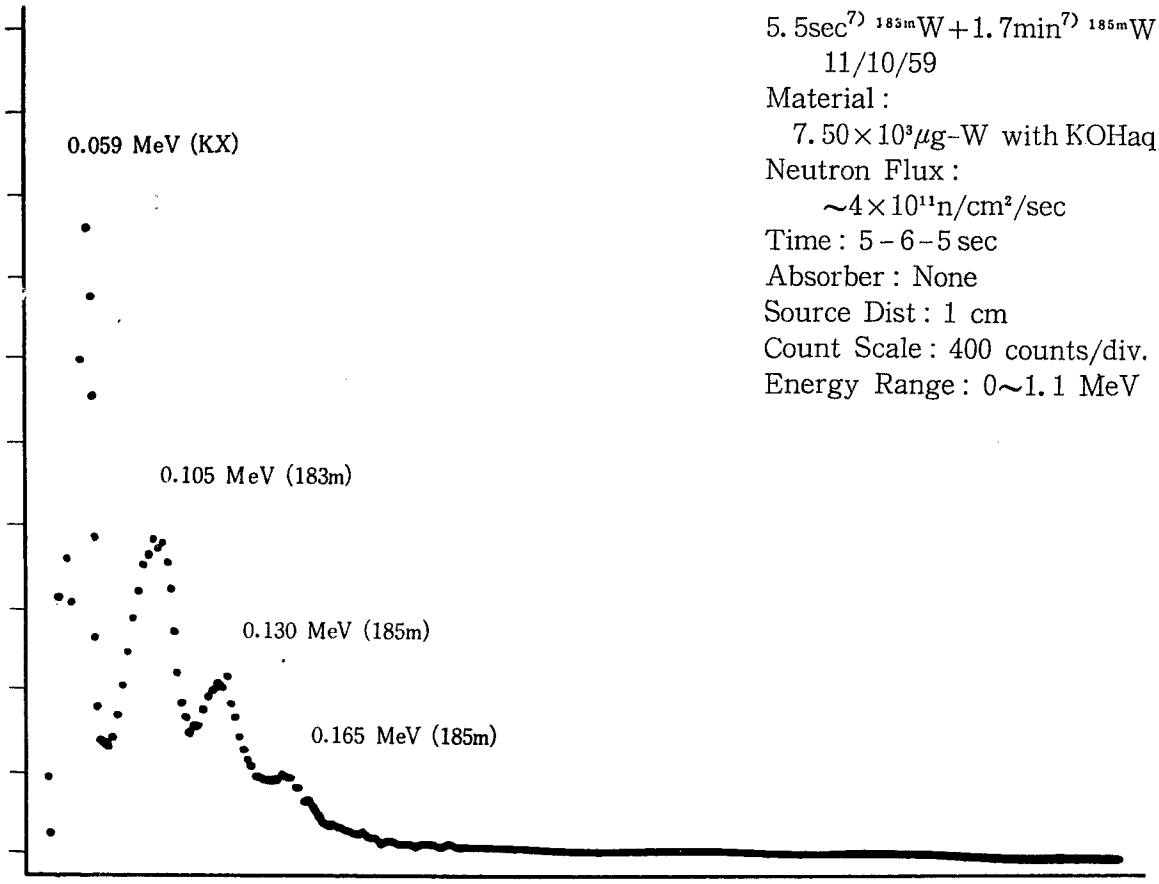

4.8sec[1] $^{178m}Hf$ + 19sec[7] $^{179m}Hf$
3/10/60
Material :
26.7$\mu$g-Hf with $SO_4^{--}$, $F^-$
& Tartaric Acid
Neutron Flux :
$\sim 4\times10^{11}$n/cm$^2$/sec
Time : 5 - 10-10-10-10 sec
Absorber : None
Source : In Well
Count Scale : 400 counts/div.
Energy Range : 0$\sim$0.4 MeV



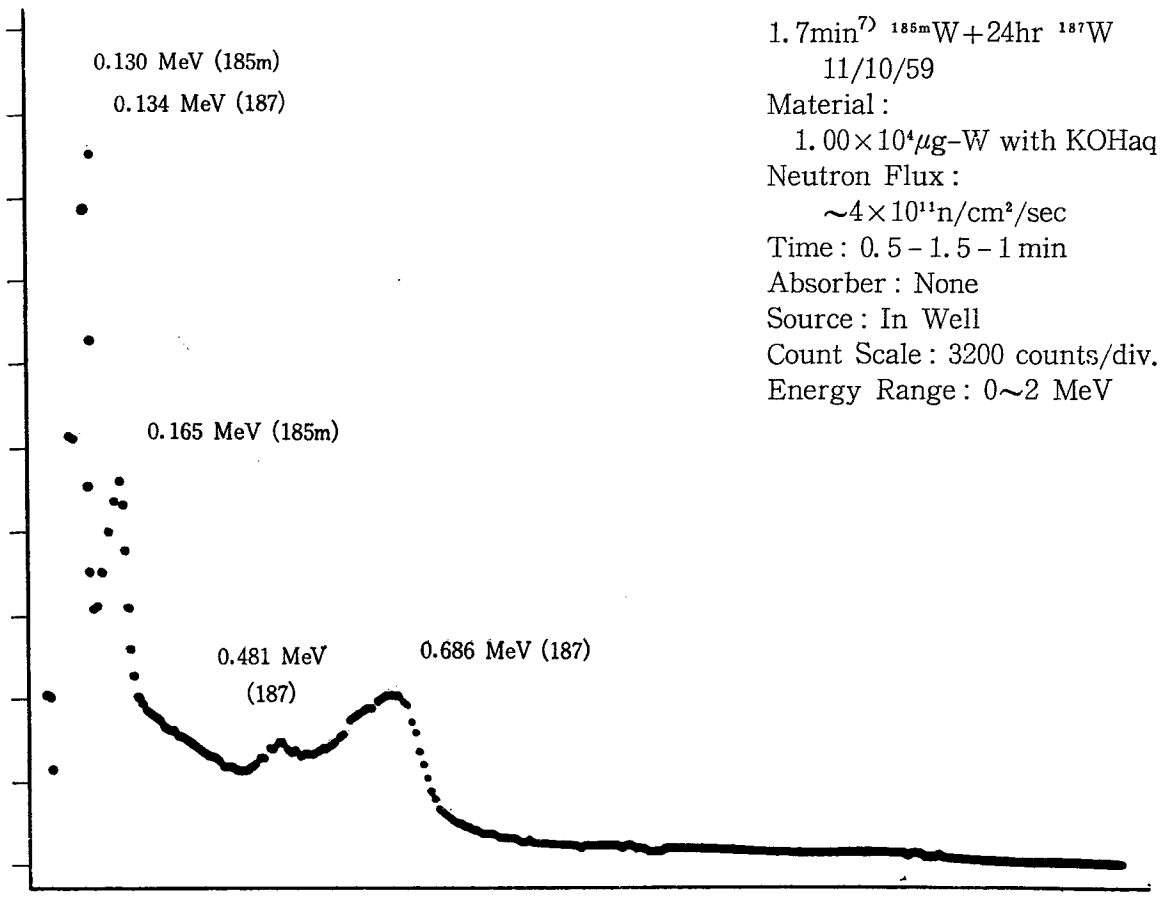

19sec[7] $^{179m}$Hf
9/29/59
Material :
1.600$\mu$g-Hf with $SO_4^{--}$, $F^-$ & Tartaric Acid
Neutron Flux :
$\sim 4\times10^{11}$n/cm$^2$/sec
Time : 20-15-20 sec
Absorber : None
Source : In Well
Count Scale : 800 counts/div.
Energy Range : 0~1.0 MeV



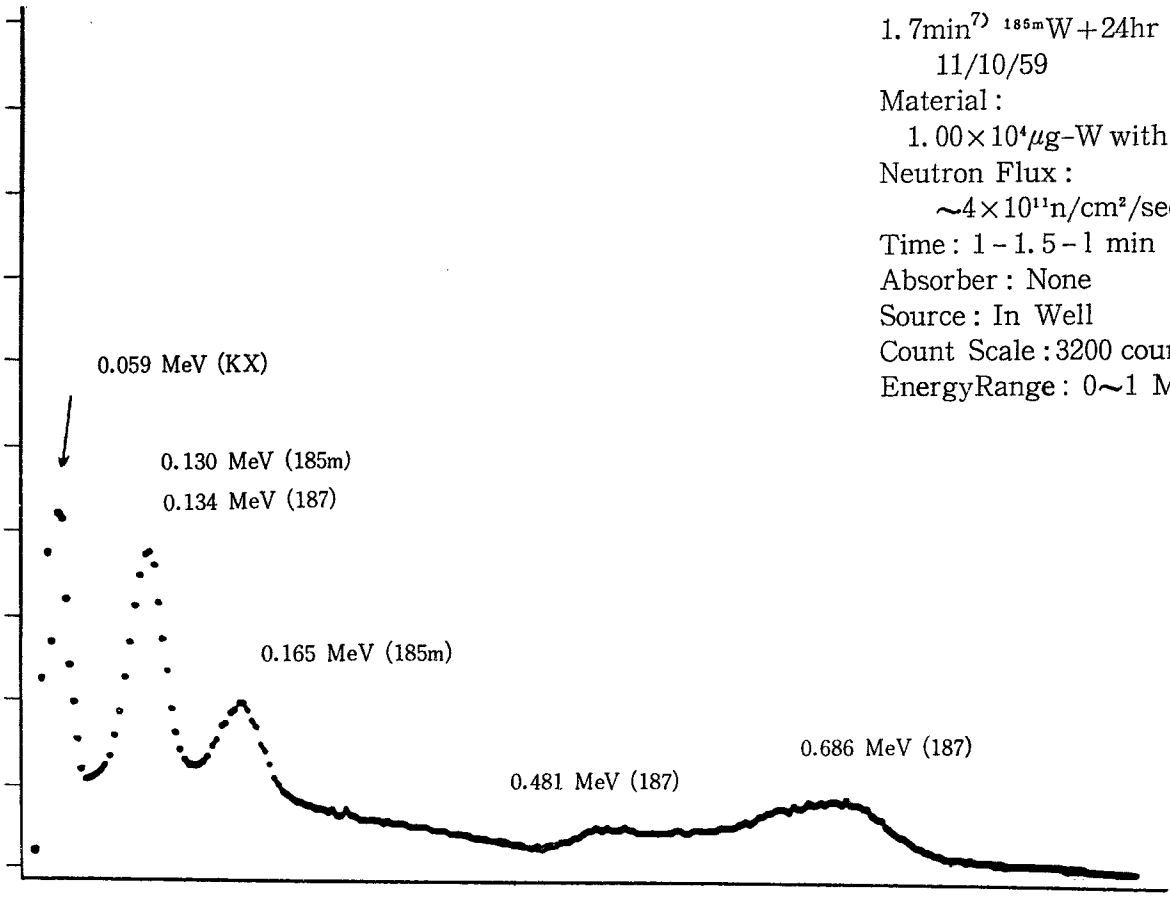

19sec[7] $^{179m}$Hf
9/22/59
Material :
1.155$\mu$g-Hf with $SO_4^{--}$, $F^-$ & Tartaric Acid
Neutron Flux :
$\sim 4\times10^{11}$n/cm$^2$/sec
Time : 20-15-20 sec
Absorber : None
Source : In Well
Count Scale : 100 counts/div.
Energy Range : 0~0.45 MeV



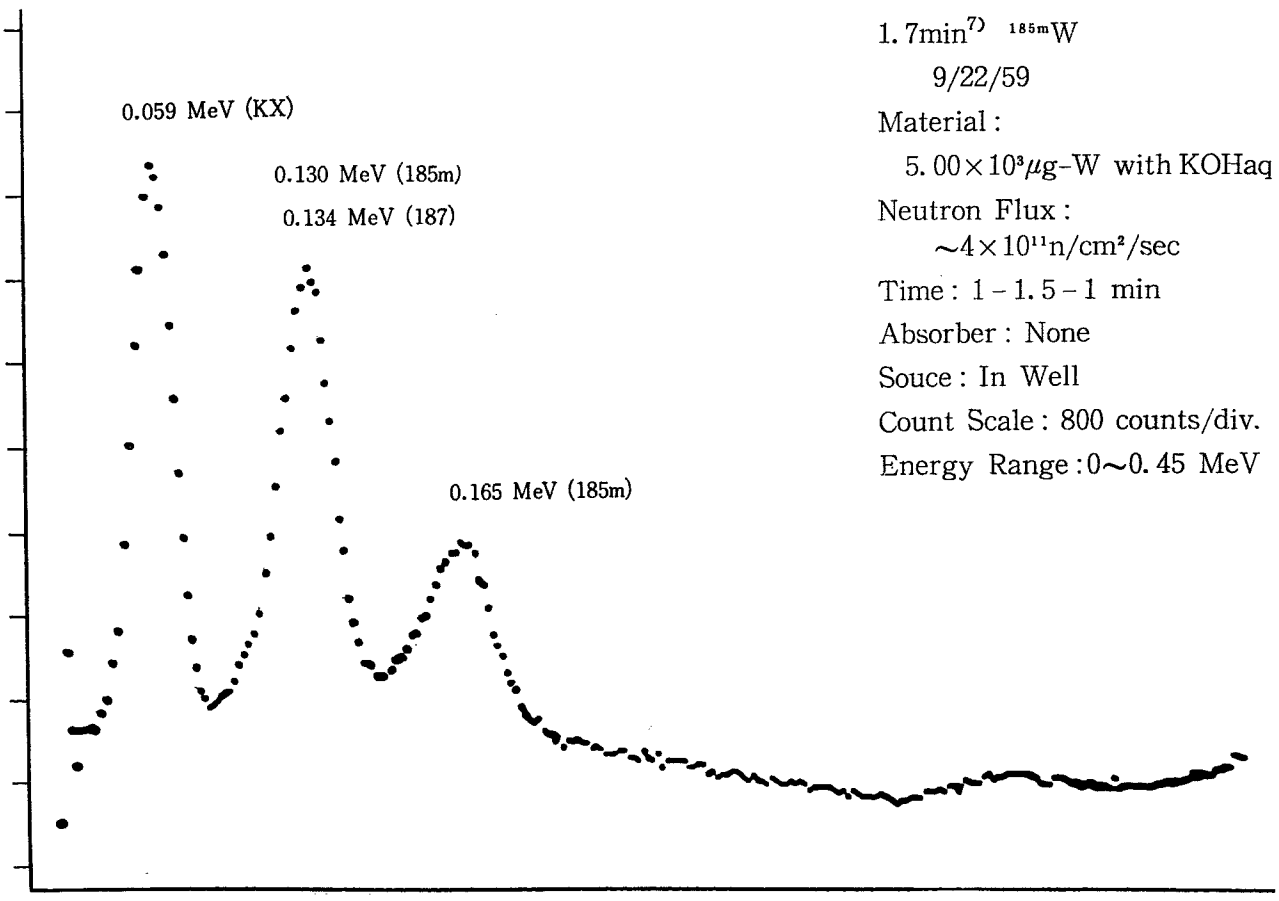

5.5sec[7] $^{183m}W$+1.7min[7] $^{185m}W$
11/10/59
Material :
$7.50\times10^{3}\mu$g-W with KOHaq
Neutron Flux :
$\sim4\times10^{11}$n/cm$^2$/sec
Time : 5-6-5 sec
Absorber : None
Source Dist : 1 cm
Count Scale : 400 counts/div.
Energy Range : 0~1.1 MeV



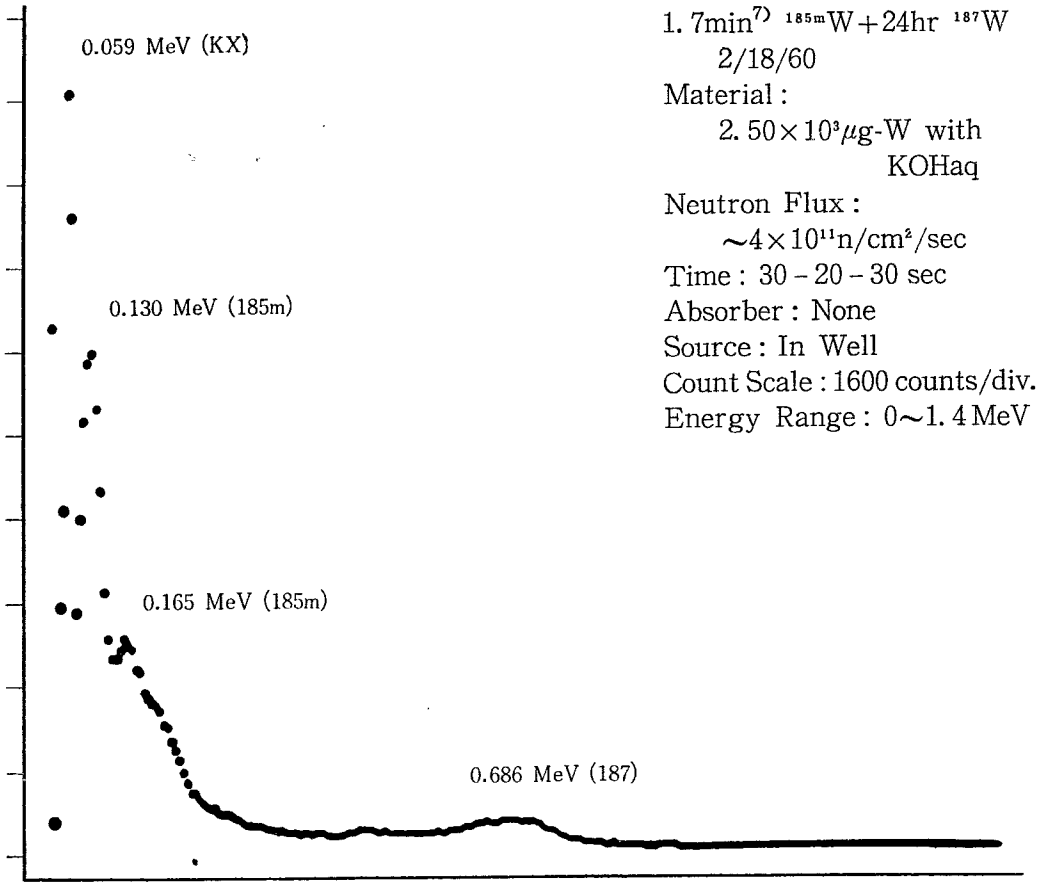

1.7min[7] $^{185m}W$+24hr $^{187}W$
11/10/59
Material :
$1.00\times10^{4}\mu$g-W with KOHaq
Neutron Flux :
$\sim4\times10^{11}$n/cm$^2$/sec
Time : 0.5-1.5-1 min
Absorber : None
Source : In Well
Count Scale : 3200 counts/div.
Energy Range : 0~2 MeV



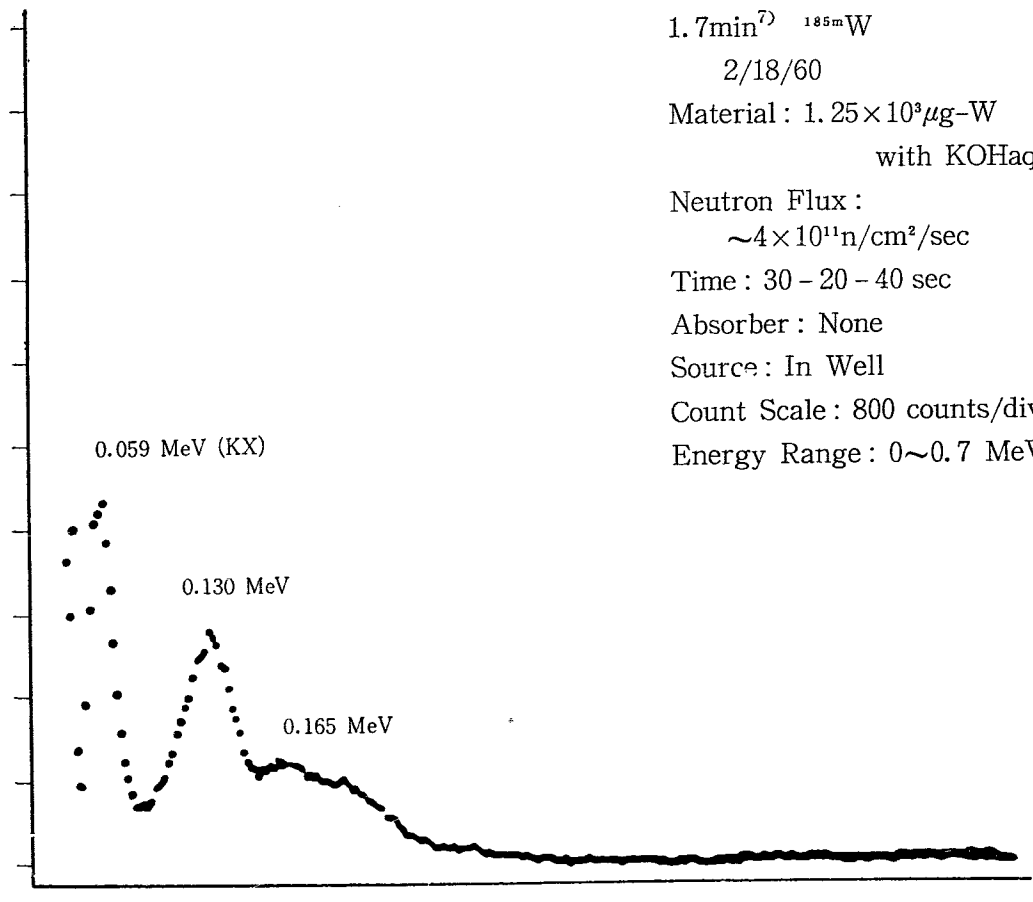

1.7min[7) $^{185m}W$+24hr $^{187}W$
11/10/59
Material :
$1.00\times10^{4}\mu$g-W with KOHaq
Neutron Flux :
$\sim4\times10^{11}$n/cm$^2$/sec
Time : 1 - 1.5 - 1 min
Absorber : None
Source : In Well
Count Scale : 3200 counts/div.
EnergyRange : 0~1 MeV.



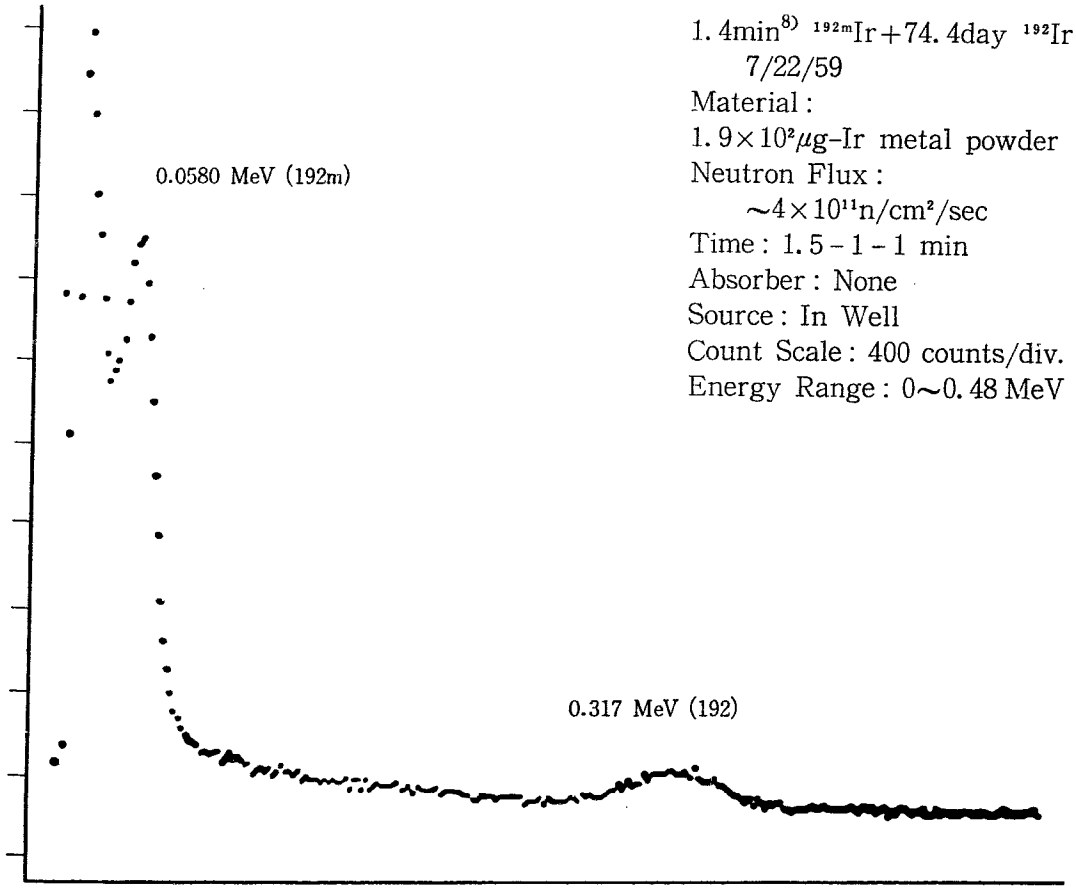

1.7min[7) $^{185m}W$
9/22/59
Material :
$5.00\times10^{3}\mu$g-W with KOHaq
Neutron Flux :
$\sim4\times10^{11}$n/cm$^2$/sec
Time : 1 - 1.5 - 1 min
Absorber : None
Souce : In Well
Count Scale : 800 counts/div.
Energy Range : 0~0.45 MeV



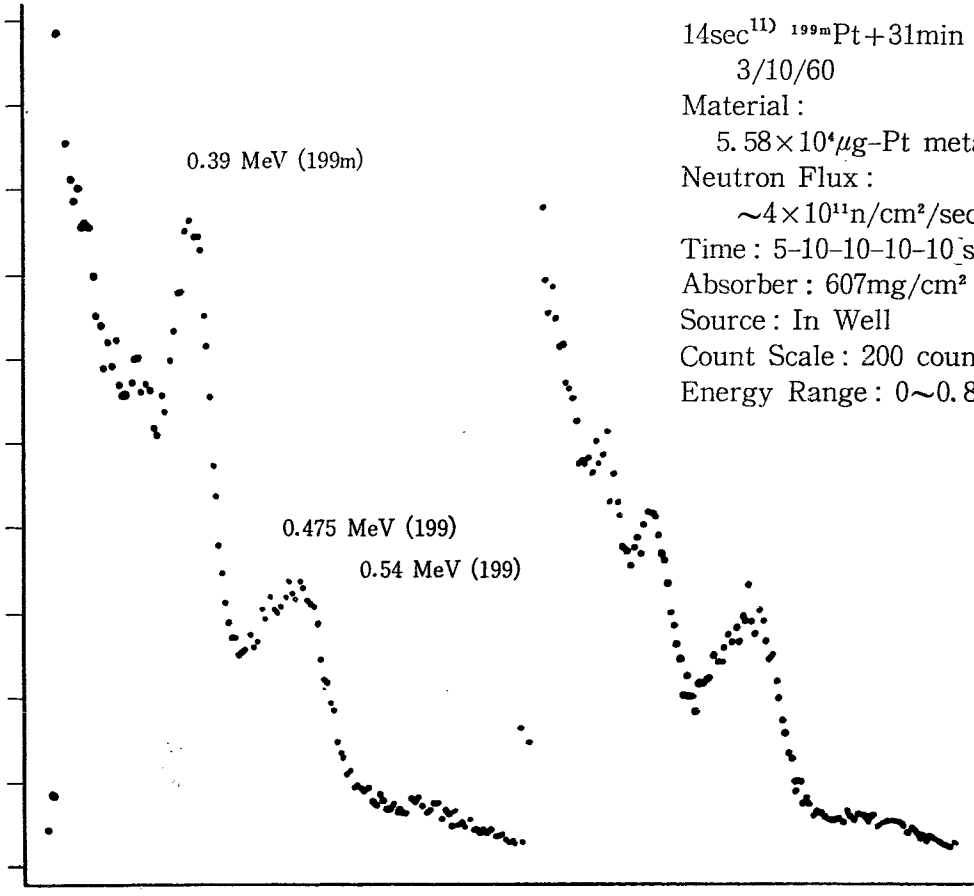

1. 7min[7] $^{185m}W$+24hr $^{187}W$
2/18/60
Material :
2. 50×10³μg-W with KOHaq
Neutron Flux :
~4×10¹¹n/cm²/sec
Time : 30 - 20 - 30 sec
Absorber : None
Source : In Well
Count Scale : 1600 counts/div.
Energy Range : 0~1. 4 MeV



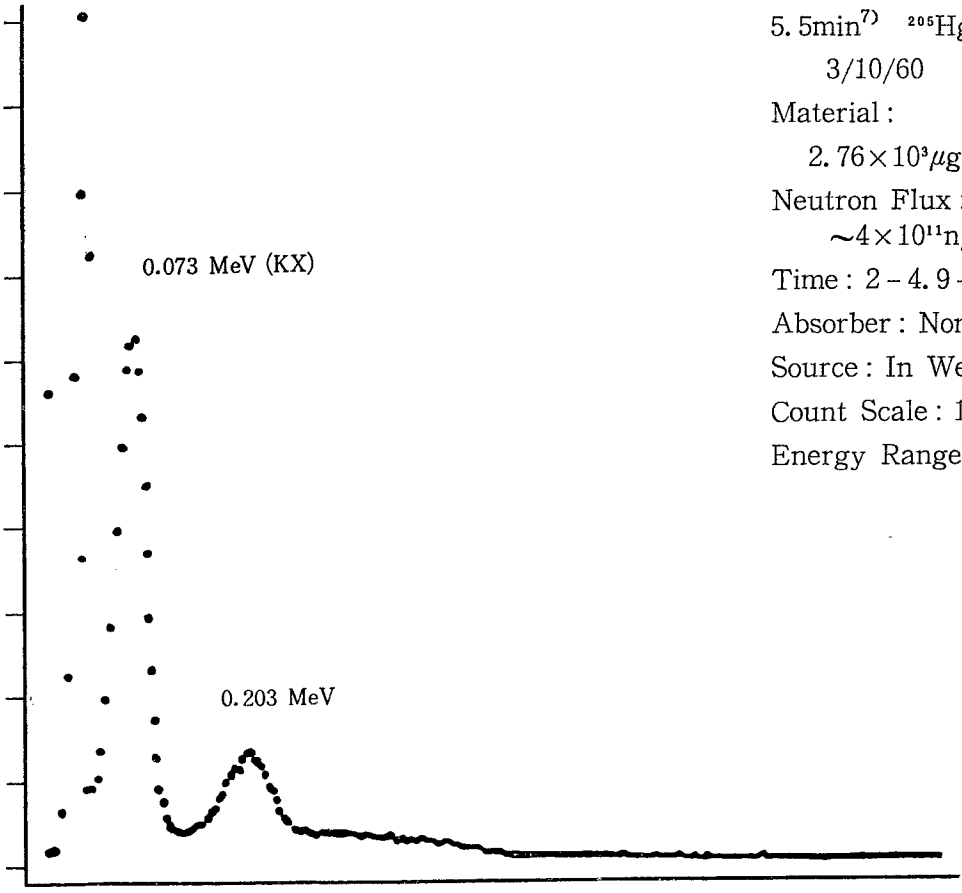

1. 7min[7] $^{185m}W$
2/18/60
Material : 1. 25×10³μg-W with KOHaq
Neutron Flux :
~4×10¹¹n/cm²/sec
Time : 30 - 20 - 40 sec
Absorber : None
Source : In Well
Count Scale : 800 counts/div.
Energy Range : 0~0. 7 MeV



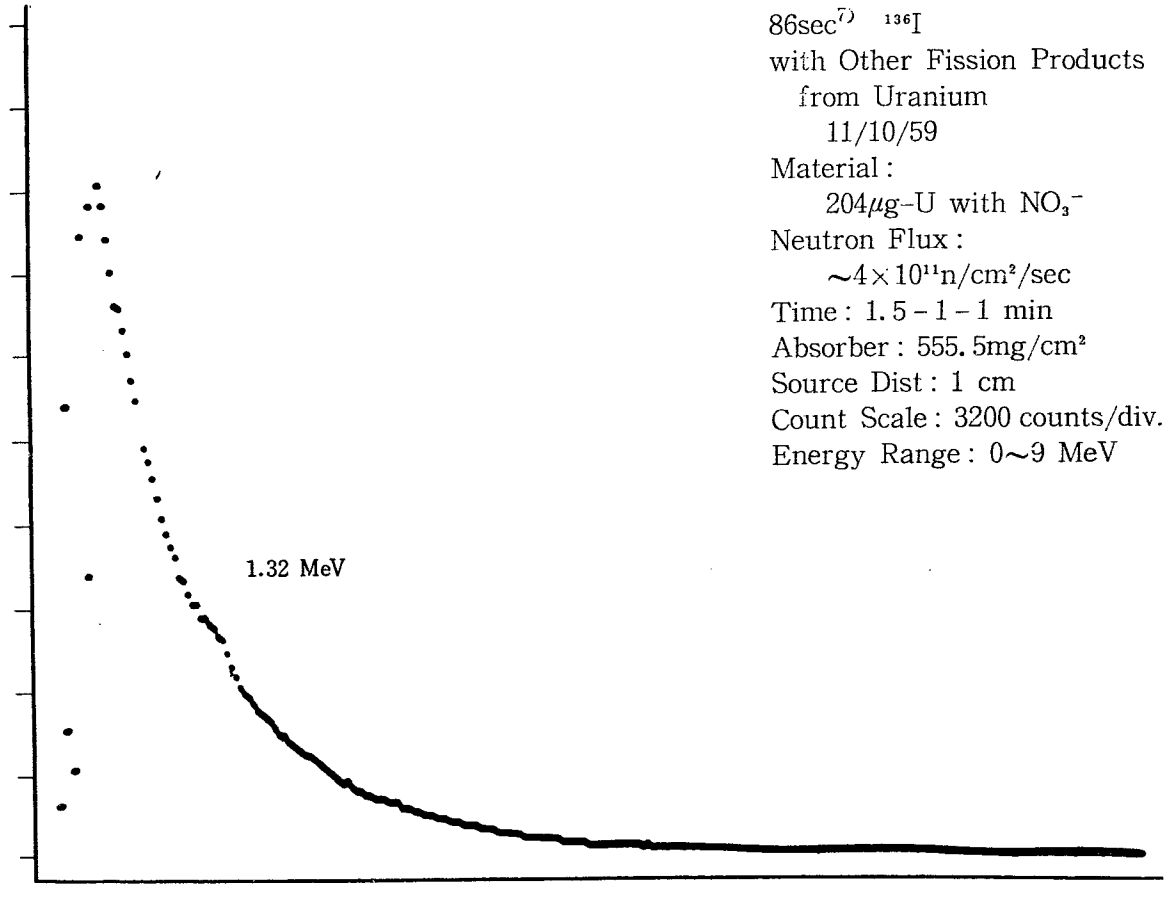

1.4min[8] $^{192m}Ir+74.4day$ $^{192}Ir$
7/22/59
Material :
$1.9\times10^{2}\mu g$-Ir metal powder
Neutron Flux :
$\sim4\times10^{11}n/cm^{2}/sec$
Time : 1.5 - 1 - 1 min
Absorber : None
Source : In Well
Count Scale : 400 counts/div.
Energy Range : 0~0.48 MeV



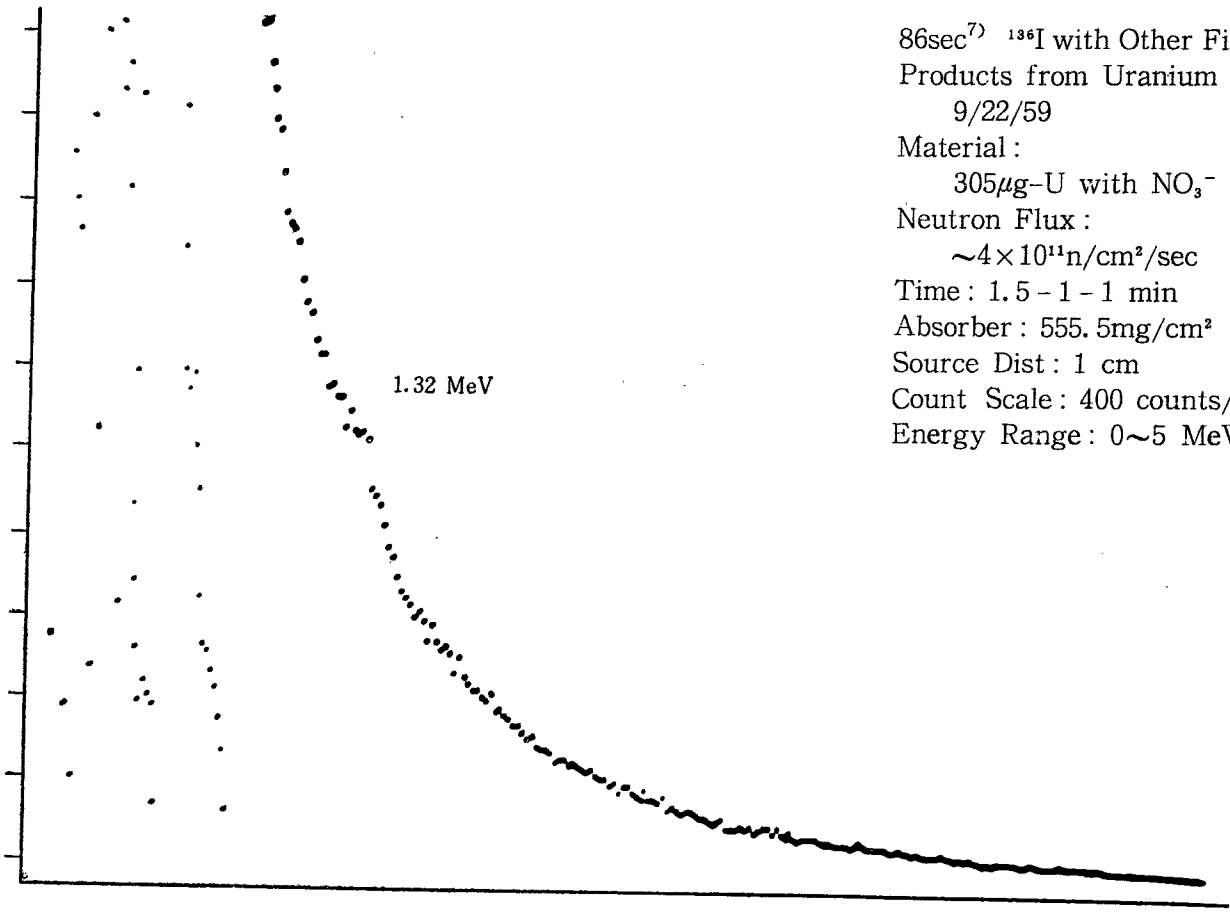

14sec[11] $^{199m}Pt+31min$ $^{199}Pt$
3/10/60
Material :
$5.58\times10^{4}\mu g$-Pt metal plate
Neutron Flux :
$\sim4\times10^{11}n/cm^{2}/sec$
Time : 5-10-10-10-10 sec
Absorber : $607mg/cm^{2}$
Source : In Well
Count Scale : 200 counts/div.
Energy Range : 0~0.8 MeV



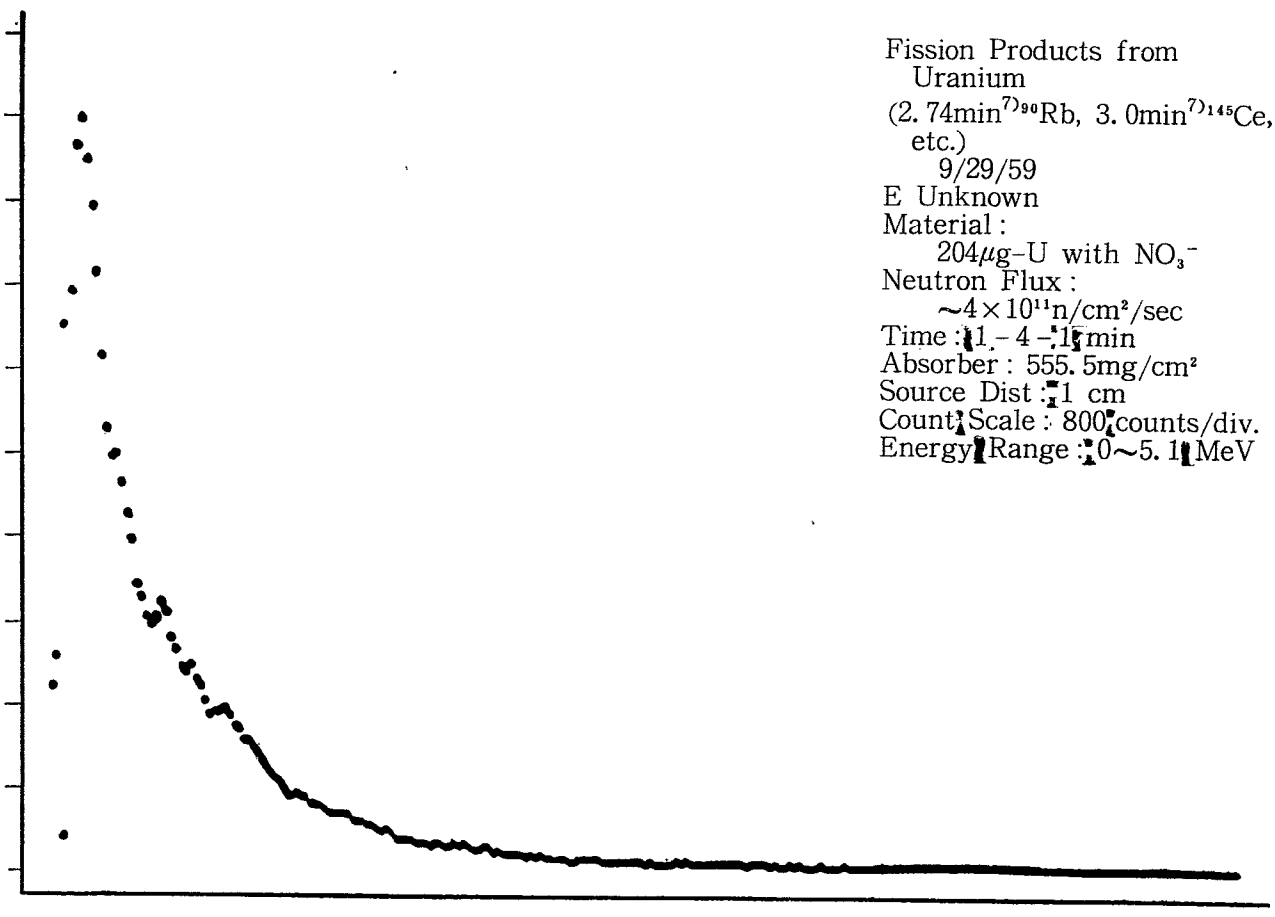

5.5min[7] $^{205}Hg$
3/10/60
Material :
$2.76 \times 10^3 \mu g$-Hg with $NO_3^-$
Neutron Flux :
$\sim 4 \times 10^{11} n/cm^2/sec$
Time : 2 - 4.9 - 1 min
Absorber : None
Source : In Well
Count Scale : 1600 counts/div.
Energy Range : 0~0.7 MeV




86sec[7] $^{136}I$
with Other Fission Products
from Uranium
11/10/59
Material :
$204 \mu g$-U with $NO_3^-$
Neutron Flux :
$\sim 4 \times 10^{11} n/cm^2/sec$
Time : 1.5 - 1 - 1 min
Absorber : $555.5 mg/cm^2$
Source Dist : 1 cm
Count Scale : 3200 counts/div.
Energy Range : 0~9 MeV




86sec[7] $^{136}I$ with Other Fission Products from Uranium
9/22/59
Material :
305$\mu$g-U with $NO_3^-$
Neutron Flux :
$\sim 4 \times 10^{11}$n/cm$^2$/sec
Time : 1.5 - 1 - 1 min
Absorber : 555.5mg/cm$^2$
Source Dist : 1 cm
Count Scale : 400 counts/div.
Energy Range : 0~5 MeV



Fission Products from Uranium
(2.74min[7] $^{90}Rb$, 3.0min[7] $^{145}Ce$, etc.)
9/29/59
E Unknown
Material :
204$\mu$g-U with $NO_3^-$
Neutron Flux :
$\sim 4 \times 10^{11}$n/cm$^2$/sec
Time : 1 - 4 - 1 min
Absorber : 555.5mg/cm$^2$
Source Dist : 1 cm
Count Scale : 800 counts/div.
Energy Range : 0~5.1 MeV

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