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## L = 2, 4 MIXING RATIOS IN $Am^{243}$ α-DECAY AND MAGNETIC PERTURBATION EFFECTS

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September 1963

# L = 2, 4 MIXING RATIOS IN $Am^{243}$ α-DECAY AND MAGNETIC PERTURBATION EFFECTS

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Our investigations are concerned primarily with the attenuation coefficient, $G_2$ , of free atoms or ions determined by integral α- γ directional correlations from $Am^{243}$ under an applied magnetic field. The technique[1,2] involves preparation of a very thin source of $Am^{243}$ on a thin backing plate and detecting those α particles which pass through the plate. The recoil nuclei associated with the detected alpha particles are ejected from the backing plate into vacuum. After traveling some fraction of a millimeter in the vacuum system most of the $Np^{239}$ recoils emit a 75 keV gamma ray. The pertinent part of the $Am^{243}$ alpha decay scheme is shown in Figure 1. The principal correlation with which we are concerned is that between the most intense alpha group, $\alpha_{75}$ , and the intense 75 keV E1 gamma ray. This alpha group is composed principally of a mixture of L = 0 and L = 2 alpha waves. The alpha groups, $\alpha_{118}$ and $\alpha_{174}$ , are composed principally of L = 2 with small amounts of L = 4. By a simple approximation given by Bohr, Fröman and Mottelson[3] (BFM) for transitions of these types it is easy to calculate the L = 2 contribution in the main group from the intensities of either $\alpha_{118}$ or $\alpha_{174}$ . The ratio of L = 2 to L = 0 in $\alpha_{75}$ is then $\delta^2 = 0.22$ (BFM)[1,2] as determined from $\alpha_{118}$. Comparison of $\alpha_{118}$ and $\alpha_{174}$ , and of similar groups in many the nuclei show a deviation in the approximation of ~ 30%. A discrepancy of this type also might extend to the main group, $\alpha_{75}$. Chasman and Rasmussen[4] (CR) have analyzed this discrepancy in $U^{233}$ as a function of the interaction of the nuclear quadrupole moment with the alpha wave. They have concluded for $U^{233}$ that the L = 2 contribution in the main group should be increased by ~ 40%. The resulting theoretical anisotropies[5] are

are 45.6% (BFM) and 50.5% (CR). This uncertainty will be reflected in all of our values of $G_2$ and will be in addition to the listed standard deviations.

In the early work[1,2] it was found that the correlation $\alpha_{75} - \gamma_{75}$ with recoils going into vacuum was highly attenuated with a $G_2$ of 0.11 (BFM) where $W(\theta) = 1 + A_2 G_2 P_2 \cos\theta$. This attenuation was ascribed[1,2] to the hyperfine interaction. With the sample reversed, such that the recoils travelled into the Ag backing plate rather than into vacuum, $G_2$ had a value of 0.5 (BFM).

In the present experiment[5] with a sample about an order of magnitude thicker than in the early work, $G_2$, for recoils going into vacuum, was found to be 0.17 ± 0.02 (CR) or 0.19 ± 0.02 (BFM). Our values are consistent with the hard core value of $G_2$, 0.20. The vacuum anisotropy was studied as a function of an external magnetic field applied parallel to the path of the alpha particles. The magnet was designed by Professor Siebgahn and is shown in Fig. 2. It can operate continuously at a field of 11000 gauss. The field is constant to 10% over the surface of the sample. The observed anisotropies as a function of the applied magnetic field are shown in Fig. 3. It is seen that nearly all of the correlation is restored with 11000 gauss. Figure 4 shows the variation of $1 - G_2$ as a function of the applied magnetic field (CR). The indicated exponential dependence of $1 - G_2$ on H is very likely fortuitous because of the relatively large standard deviations.

The anisotropy was also measured with the alpha particles going directly into vacuum and the recoils going into the Ag backing plate. No increase in anisotropy was observed with an applied magnetic field. With and without an 11000 gauss magnetic field the respective values (CR) were 0.52 ± 0.05 and 0.59 ± 0.02.

A Ag cover foil was placed about 0.005 cm away from the sample so that the recoils would strike the cover foil after spending $\sim 1.5 \times 10^{-10}$ sec in vacuum. With no applied magnetic field, the anistropy was still highly attenuated ($G_2 \lesssim 0.2$). Under an applied magnetic field of 11000 gauss $G_2$ was restored to a

value of 0.62 (CR) or 7.70 (HFM). The significance of this experiment is that the vacuum perturbation of the correlation takes place is appreciably less than $1.5 \times 10^{-10}$ seconds.

The correlation between $\alpha_{118}$ and $\alpha_{75}$ was measured with the recoils in an $\mu$g environment. This was an attempt to determine the L = 2 and L = 4 admixtures in $\alpha_{118}$. Figure 5 shows the gamma ray spectrum in coincidence with $\alpha_{118}$. The energies and relative intensities of the observed gamma rays were 75 keV (~ 91%), 88 keV (~ 3%), and 118 keV (~ 6%). The observed anisotropy, after finite-size corrections, is 0.075 ± 0.023. Figure 6 shows the theoretical values of the anisotropy as a function of various mixtures of L = 2 and L = 4 waves. The experimental value of the anisotropy was corrected by assuming $G_2 = 0.59$ (CR), the same value as found for $\alpha_{75}$. The value of $\delta$ (L = 4/L = 2) is then - 0.17 ± 0.10, exclusive of the error in $G_2$. For $U^{233}$ favored alpha decay Chasman and Rasmussen deduced the L = 2 and L = 4 waves had the same sign. In earlier analyses of alpha decay transition probabilities of even-even nuclei, Rasmussen[6] had deduced that the L = 4 wave would change sign in the vicinity of Cm (one atomic number higher than Am). Our negative value of $\delta$ may mean that the L = 4 wave has changed sign for $Am^{243}$ favored alpha decay. With the standard deviations in our measurements, however, there is a 5% possibility that $\delta$ has a positive sign, exclusive of any error in $G_2$. Finally the value of $G_2$ may be in error. If a substantial perturbation of the $\alpha_{75} - \gamma_{75}$ correlation occurs in $< 10^{-10}$ seconds due to a quadrupole interaction, then the perturbation will be smaller for the $\alpha_{118} - \gamma_{75}$ correlation since the quadrupole moment of the 118 keV rotational state should be much smaller than that of the 75 keV state. The probability that $\delta$ can be positive might then be as high as ~ 15%. Therefore our value for negative value of $\delta$ is suggestive but not conclusive.

## FOOTNOTES AND REFERENCES

*Work performed under the auspices of the U.S. Atomic Energy Commission.

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## FIGURE CAPTIONS

Figure 1. Partial alpha decay scheme of $Am^{241}$.

Figure 2. $\alpha$-$\gamma$ angular correlation magnet and detector arrangement.

Figure 3. $Am^{243}$ $(\alpha_{75} + \alpha_{118})$ - $\gamma_{75}$ angular correlation as a function of an applied magnetic field. The recoiling nuclei are in a vacuum enviroment.

Figure 4. The attenuation factor, $G_2$, for the $Am^{243}$ $(\alpha_{75} + \alpha_{118})$ - $\gamma_{75}$ correlation in a vacuum enviroment as a function of an applied magnetic field. The theoretical anisotropy was calculated with the correction of Chasman and Rasmussen. The dashed line, which is the best representation of the data from 1-12 kgauss can be expressed by the equation $1-G_2 = 0.7 \times 10^{-0.06H}$.

Figure 5. Gamma ray spectrum in coincidence with $Am^{243}$ $\alpha_{118}$.

Figure 6. $Am^{243}$ $\alpha_{118}$ - $\gamma_{75}$ angular correlation anisotropy.

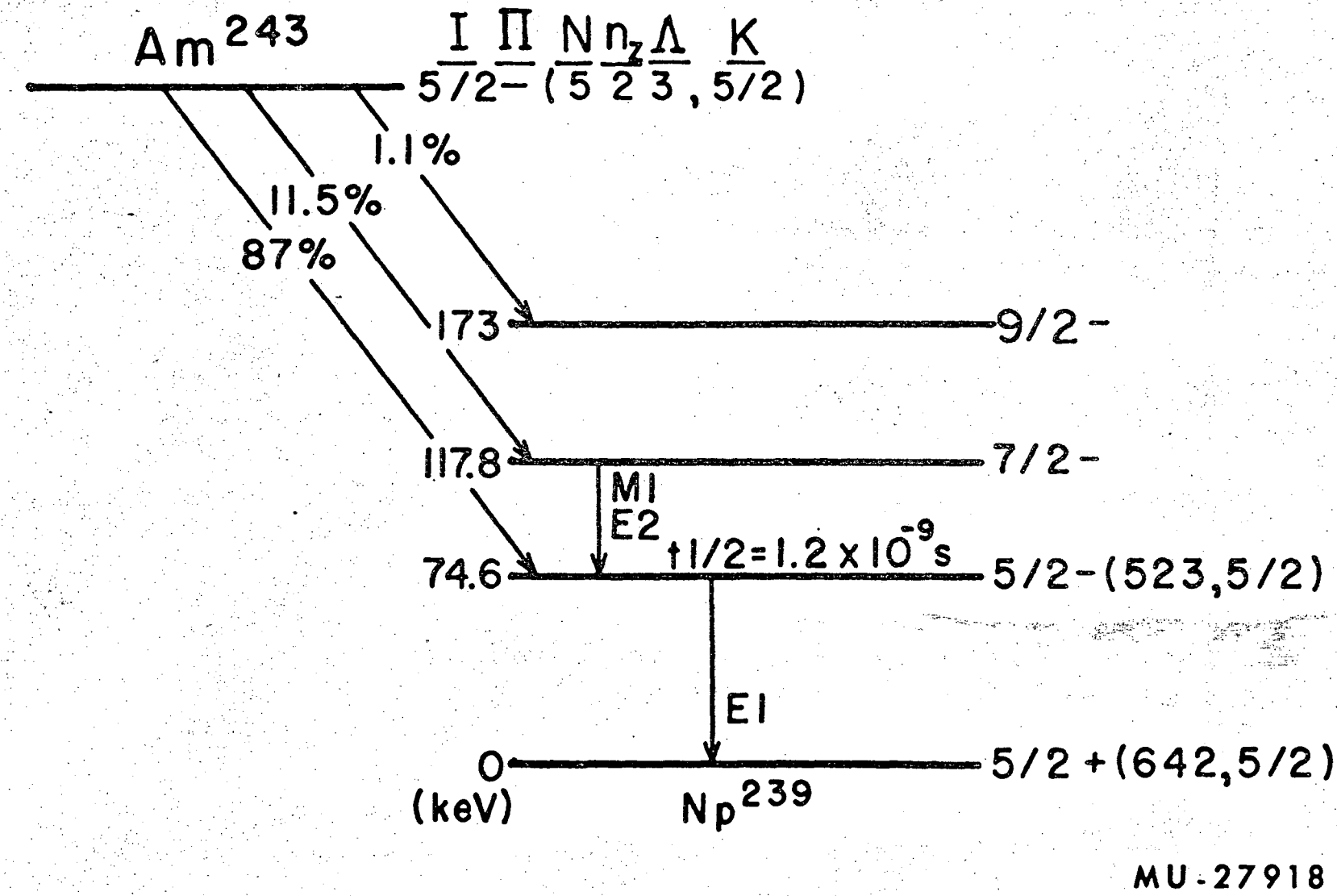
Am243
I Π N nz Λ K
5/2− (5 2 3, 5/2)
1.1%
11.5%
87%
173
9/2−
117.8
7/2−
M1
E2
t1/2=1.2 x 10-9 s
74.6
5/2−(523,5/2)
E1
0
(keV)
Np239
5/2+(642,5/2)
MU-27918

Fig. 1.

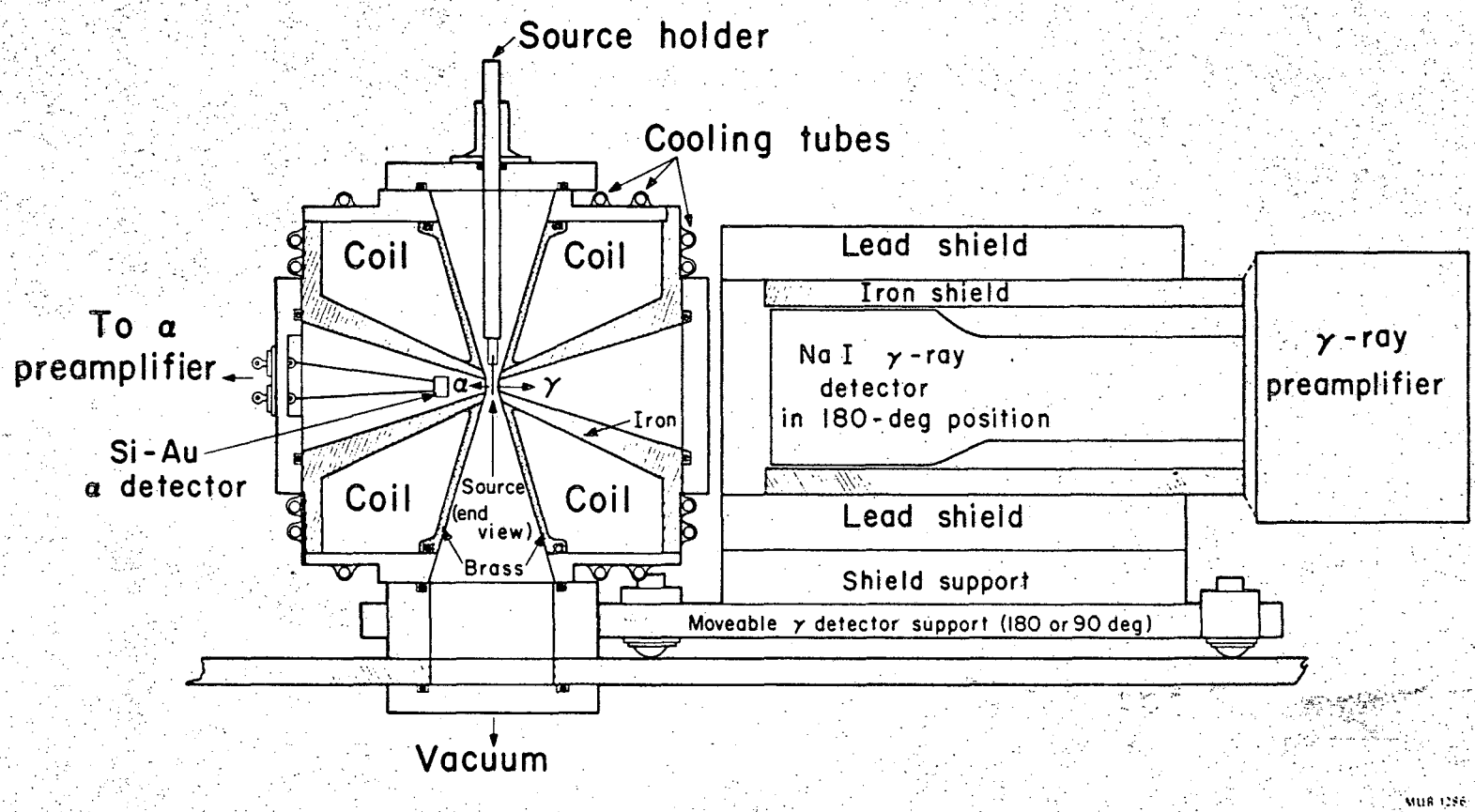
Source holder
Cooling tubes
Coil
Coil
Coil
Coil
To α preamplifier
Si-Au α detector
α
γ
Iron
Source (end view)
Brass
Vacuum
Lead shield
Iron shield
Na I γ-ray detector in 180-deg position
Lead shield
Shield support
Moveable γ detector support (180 or 90 deg)
γ-ray preamplifier
MUB 1256

Fig. 2.

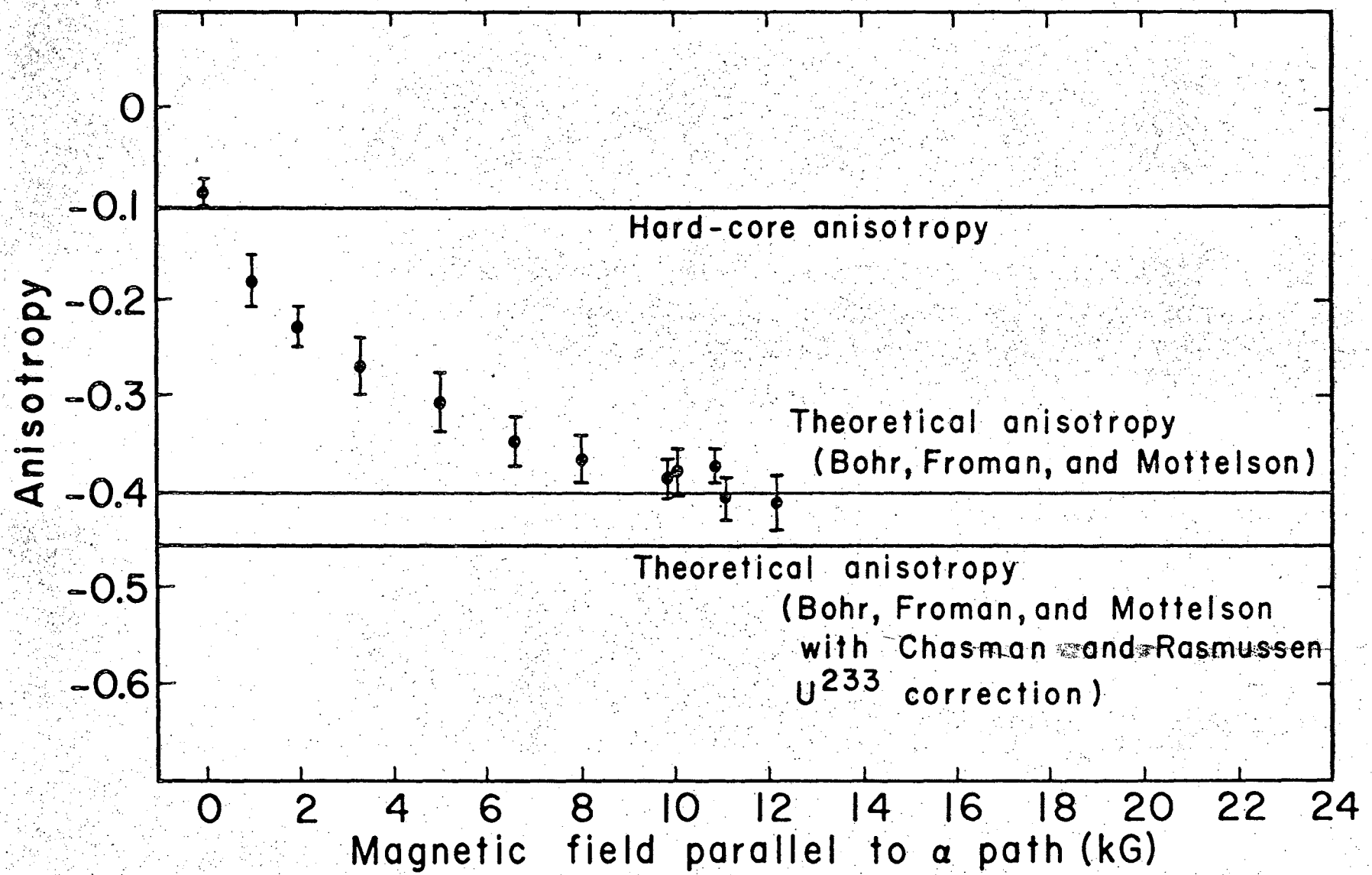


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Fig. 3.

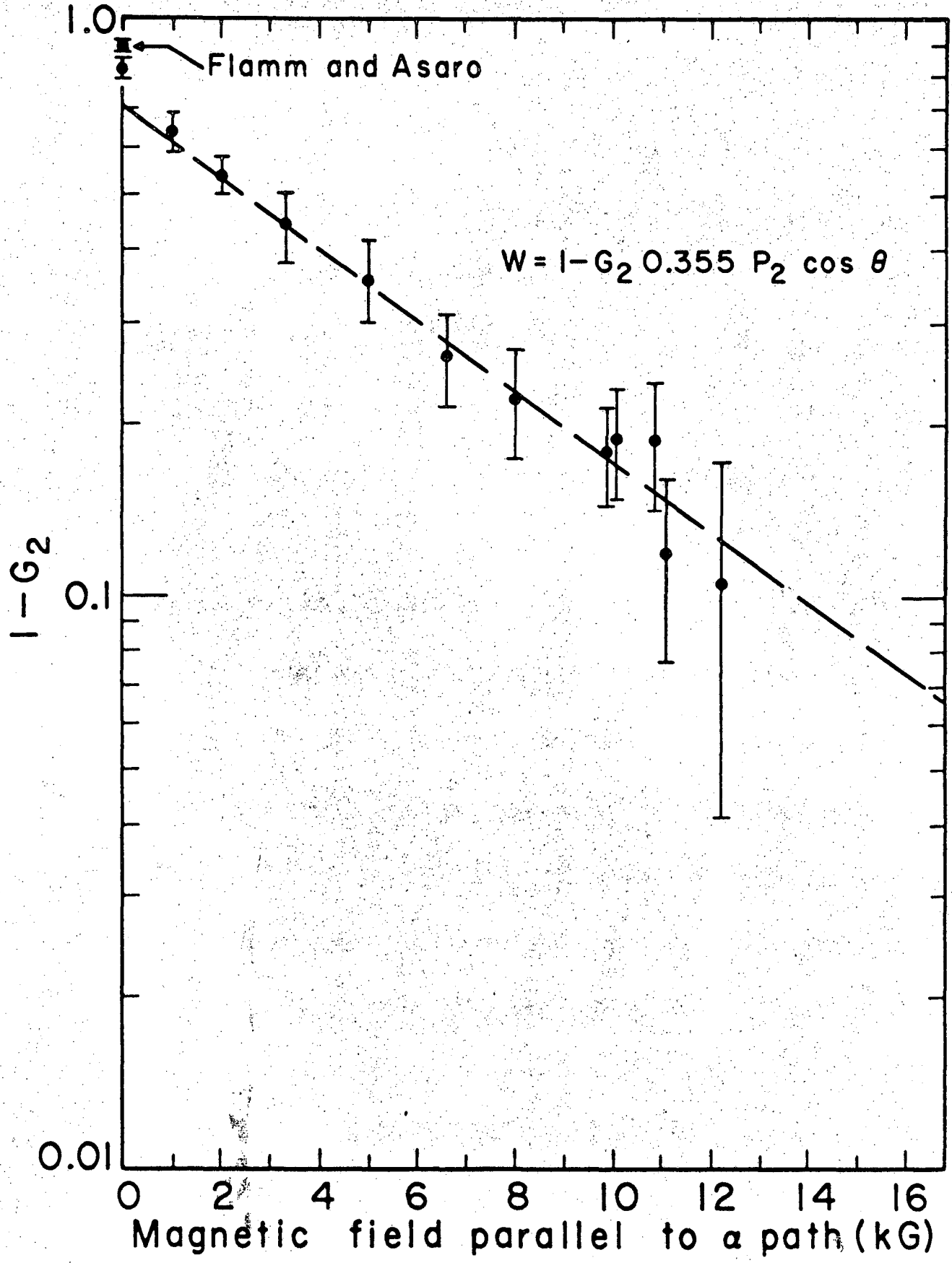


Fig. 4.

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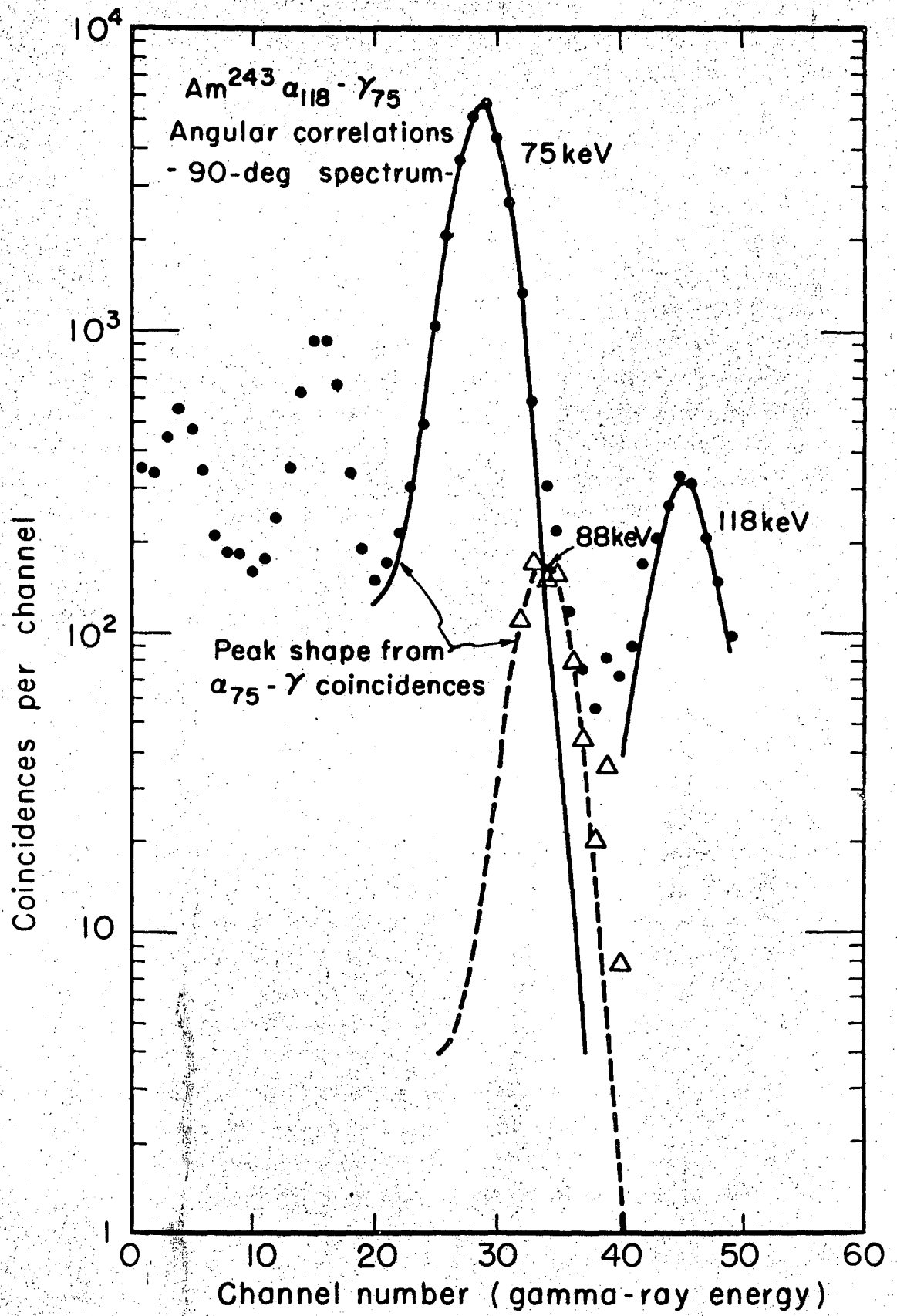


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Fig. 5.

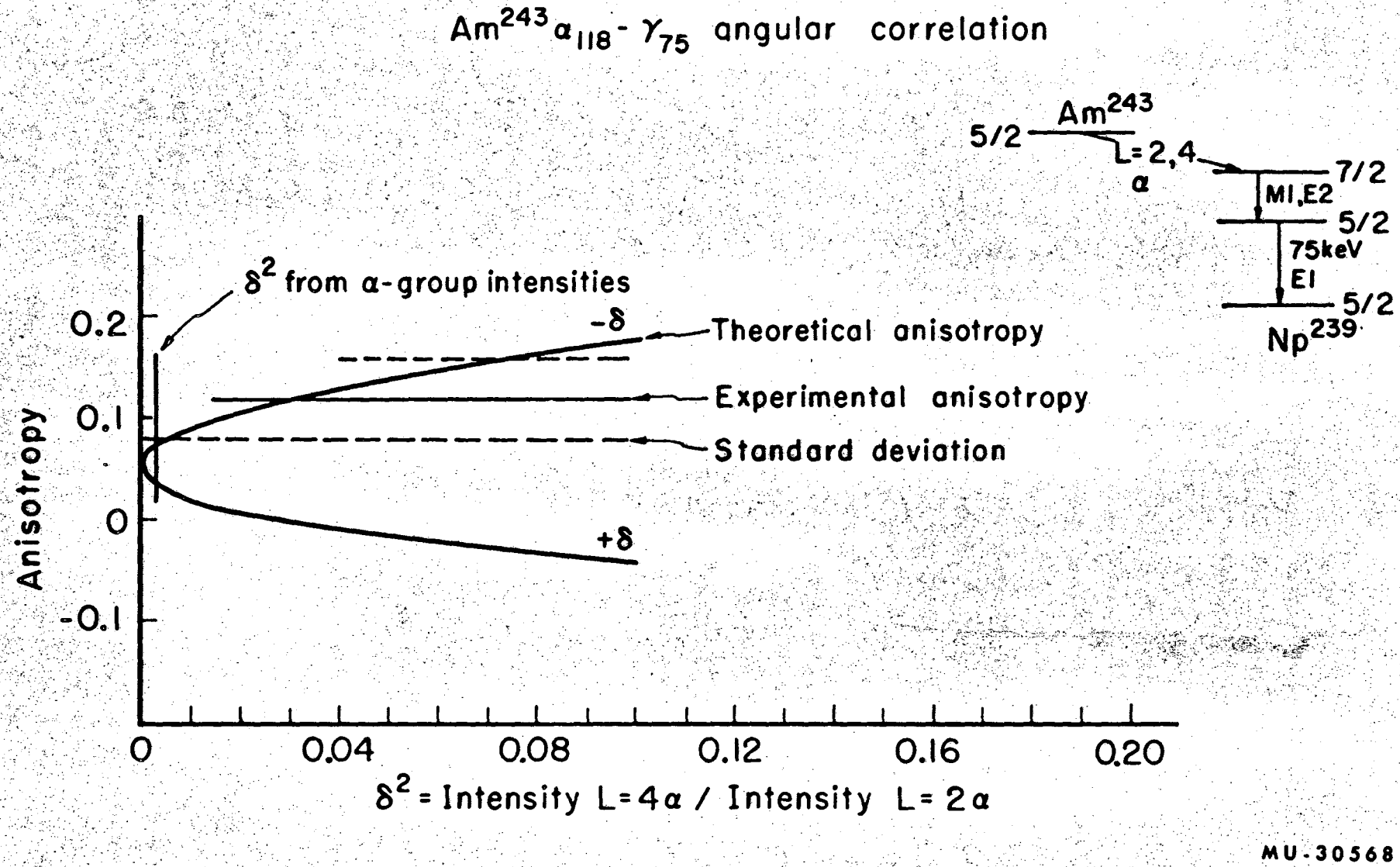
Am243 α118 - γ75 angular correlation
Am243
5/2
L=2,4
α
7/2
M1,E2
5/2
75keV
E1
5/2
Np239
δ2 from α-group intensities
-δ
Theoretical anisotropy
Experimental anisotropy
Standard deviation
+δ
Anisotropy
0.2
0.1
0
-0.1
0
0.04
0.08
0.12
0.16
0.20
δ2 = Intensity L=4α / Intensity L=2α
MU-30568

Fig. 6.

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