Title
ANGULAR CORRELATIONS IN THE BETA-DELAYED TWO-PROTON DECAY OF 22Al

Author
Jahn, R.

Publication Date
1984-12-01

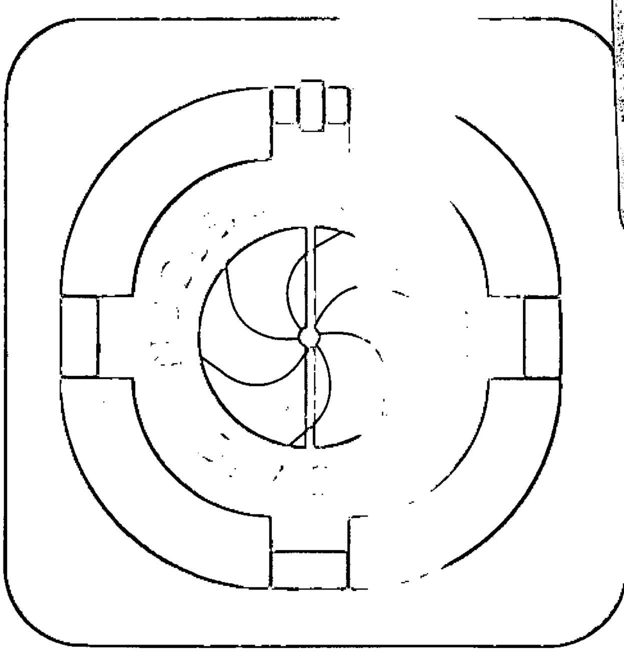
Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Submitted to Physical Review Letters

ANGULAR CORRELATIONS IN THE BETA-DELAYED TWO-PROTON DECAY OF ^{22}Al

R. Jahn, R.L. McGrath, D.M. Moltz, J.E. Reiff,
X.J. Xu, J. Aysto, and J. Cerny

December 1984



Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

DISCLAIMER

Angular Correlations in the Beta-Delayed Two-Proton Decay of ^{22}Al.*

R. Jahn

Institut fur Strahlen- und Kernphysik, University of Bonn
53 Bonn 1, Federal Republic of Germany

R. L. McGrath

Department of Physics
SUNY, Stony Brook, N.Y. 11794

D. M. Moltz, J. E. Reiff, X. J. Xu[a)], J. Aysto[b)]
and Joseph Cerny

Department of Chemistry and
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

*This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U. S. Department of Energy under Contract DE-AC03-76SF00098.

Angular Correlations in the Beta-Delayed Two-Proton Decay of ^{22}Al.*

R. Jahn

Institut fur Strahlen- und Kernphysik, University of Bonn
53 Bonn 1, Federal Republic of Germany

R. L. McGrath

Department of Physics
SUNY, Stony Brook, N.Y. 11794

D. M. Moltz, J. E. Reiff, X. J. Xu[a], J. Aysto[b]
and Joseph Cerny

Department of Chemistry and
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

December 1984

Abstract

Position-sensitive detectors have been used to measure the angular correlation of the two protons de-exciting the 4^+, T = 2 isobaric analog state in ^{22}Mg fed in the β^+ decay of ^{22}Al. The observed isotropy indicates a predominantly sequential decay mechanism. However, a 15% admixture of correlated di-proton (^{2}He) emission cannot be excluded.

Radioactivity: ^{22}Al from ^{24}Mg(^{3}He,p4n) at $E_{^3He}$ = 110 MeV;
measured angular correlation for beta-delayed two protons.

Light neutron-deficient nuclei are frequently found through their beta-delayed proton emission. The latest[1,2] such discoveries, ^{22}Al and ^{26}P, are nuclides which belong to the odd-odd, $T_z = -2$ series. These two nuclides can be distinguished from other delayed proton emitters because recent experiments have shown ^{22}Al and ^{26}P to be the first observed examples of beta-delayed two-proton emission.[3,4] In principle, the two protons can result from several decay mechanisms, which include decay involving a final state interaction between the two protons (^{2}He emission), uncoupled simultaneous emission, or sequential emission.[5]

The actual decay mechanism involved in two-proton emission can be deduced from energy and angular correlation measurements between the protons as described in detail in our summary paper[6] on ^{22}Al and ^{26}P. In the case of ^{2}He emission, a strong angular correlation at small angles between the emitted protons is expected. A most probable angle of $\sim 30^{o}$ can be deduced from the distribution of the ^{2}He breakup energy observed in reaction studies.[7,8] On the other hand, a nearly isotropic angular correlation is expected in the non-coupled simultaneous and sequential emission of two protons. Nearly identical two-proton sum peaks are expected in small and large angle experiments, with a measurable kinematic shift to higher energies at large angles, except for ^{2}He emission which will not be observed at large angles. Individual proton spectra vary such that: (a) ^{2}He emission will produce a continuum at small angles, (b) simultaneous uncoupled emission will produce a continuum-like spectrum at both small and large angles, and (c) sequential emission will yield discrete energy first and second proton groups with the latter exhibiting the small to large angle kinematic shift. The energy correlation measurements described in our prior work performed at both small (~ 40^{o}) and large (~ 120^{o}) relative proton angles showed that the dominant mechanism for beta-delayed two-proton emission in each isotope was sequential decay.

The decay scheme of ^{22}Al based on the information obtained in prior experiments[6] is shown in Fig. 1. It features a fast, superallowed beta branch to the 4^{+}, T = 2 isobaric analog state in ^{22}Mg. Subsequently, this state is de-excited by the isospin forbidden emission of a single proton to ^{21}Na or by isospin forbidden two-proton emission to the ground or first excited state of ^{20}Ne. These last channels are dominated by the sequential emission of the two protons proceeding via intermediate states in ^{21}Na. However, a small component of the two-proton decay proceeding by another mechanism, such as ^{2}He emission, remained a possibility for ^{22}Al decay. For this reason more detailed angular correlation measurements were necessary.

In this paper we wish to report the results of an experiment in which the proton-proton angular correlation over a wide angular range was measured using position-sensitive detectors. Due to the wide angular range covered, two separate detector setups were used. Because of the limited production rate of ^{22}Al, both setups had to be optimized with respect to detection efficiency and angular resolving power. The large angle setup of the telescopes is shown in Fig. 2. Each telescope consisted of 27μm surface barrier ΔE detectors and 300μm surface barrier position-sensitive E detectors (PSD). They each subtended a solid angle of 3.3% of 4π. Position (X) and subsequent angular information were obtained by software determination of EX/E. This setup measured angles ranging from 70^{o} to 164^{o}. The small angle setup was similar to that in a previous experiment.[6] In this case, in order to place reasonable limits upon the angular acceptance, collimators were used to restrict the subtended solid angle of each telescope to 1% of 4π, thereby covering angles from 10^{o} to 46^{o}.

^{22}Al was produced by bombarding 1 mg/cm^2 natural magnesium targets with 110 MeV $^3He^{+2}$ beams of 3-7 μA intensities from the Lawrence Berkeley Laboratory 88-inch cyclotron. Recoiling product nuclei were transported with a helium-jet and collected on a catcher wheel to form thin sources for particle spectroscopy with the solid state telescopes described above. Data were collected in the large angle setup for an integrated beam current of 2.1 Coulombs and in the narrow angle setup for 1.7 Coulombs. A summed two-proton coincidence spectrum shown in Fig. 3 was obtained with the large angle setup by using data in the angular range of 70^{o}-128^{o} corrected for kinematic shifts. The peaks labeled "x" and "g" in this figure correspond to decay energies to the first excited and ground states of ^{20}Ne. At angles above 128^{o} the two-proton coincidence events were contaminated by a neutron induced background. This background was caused by protons knocked out of the PSD in one telescope which then traversed the ΔE detector of this telescope, stopping in the E detector of the opposing telescope.

With the position information obtained from the PSD's in the large angle setup, the coincident two proton events corresponding to the energy of the transition to the first excited (2+) state in ^{20}Ne were converted to eight 11.75^{o} angular bins. Poorer statistics in the ground state peak of Fig. 3 prevented a similar analysis for this group. The angular efficiency curve for the large angle setup has a triangular shape[8] from the minimum angle of 70^{o} to the maximum angle of 164^{o} with the peak at 120^{o}. This efficiency curve was used for the large angle data to generate the normalized angular correlation shown in Fig. 4. The small angle data were consolidated into a single point at $\sim 28^{o}$ in Fig. 4.

The essentially isotropic angular correlation shown in Fig. 4 combined with our prior experimental results on energy correlations at small and large angles confirm that the two proton decay of the 4^{+}, T = 2 isobaric analog state in ^{22}Mg to the first excited state in ^{20}Ne is predominantly a sequential process. The observed minor enhancement at small relative angles between the two decay protons cannot be interpreted as positive evidence for correlated diproton emission (^{2}He) because of the large errors arising from the poor statistics of this low yield reaction. However, a 15% admixture of this process cannot be excluded. The dotted line in Fig. 4 has been calculated assuming the breakup properties of ^{2}He observed in the reaction studies.[7,8]

The present data indicate that further studies with substantially improved statistics would be of interest in confirming details of this decay.

We wish to thank B. Rathbun and C. Maples for aiding in the data analysis on the new distributed processor MIDAS and F. Sottile for aid in the data taking.

References

*This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098.

a) Permanent address: The Institute of Modern Physics, Lanzhou, China.
b) Permanent address: Dept. of Physics, Univ. of Jyvaskyla, Finland.

1. M. D. Cable, J. Honkanen, R. F. Parry, H. M. Thierens, J. M. Wouters, Z. Y. Zhou, and J. Cerny, Phys. Rev. C26, 1778 (1982).
2. M. D. Cable, J. Honkanen, R. F. Parry, S. H. Zhou, Z. Y. Zhou, and J. Cerny, Phys. Lett. 123B, 25 (1983).
3. M. D. Cable, J. Honkanen, R. F. Parry, S. H. Zhou, Z. Y. Zhou, and J. Cerny, Phys. Rev. Lett. 50, 404 (1983).
4 J. Honkanen, M. D. Cable, R. F. Parry, S. H. Zhou, Z. Y. Zhou, and J. Cerny, Phys. Lett. 133B, 146 (1983).
5. V. I. Gol'danskii, Pis'ma Zh. Eksp. Teor. Fiz. 32, 572 (1980); JETP Lett. 32, 554 (1980).
6. M. D. Cable, J. Honkanen, E. C. Schloemer, M. Ahmed, J. E. Reiff, Z. Y. Zhou, and J. Cerny, Phys. Rev. C30, 1276 (1984).
7. R. Jahn, D. P. Stahel, G. J. Wozniak, R. J. de Meijer, and J. Cerny, Phys. Rev. C18, 9 (1978).
8. D. P. Stahel, R. Jahn, G. J. Wozniak, and J. Cerny, Phys. Rev. C20, 1680 (1979).

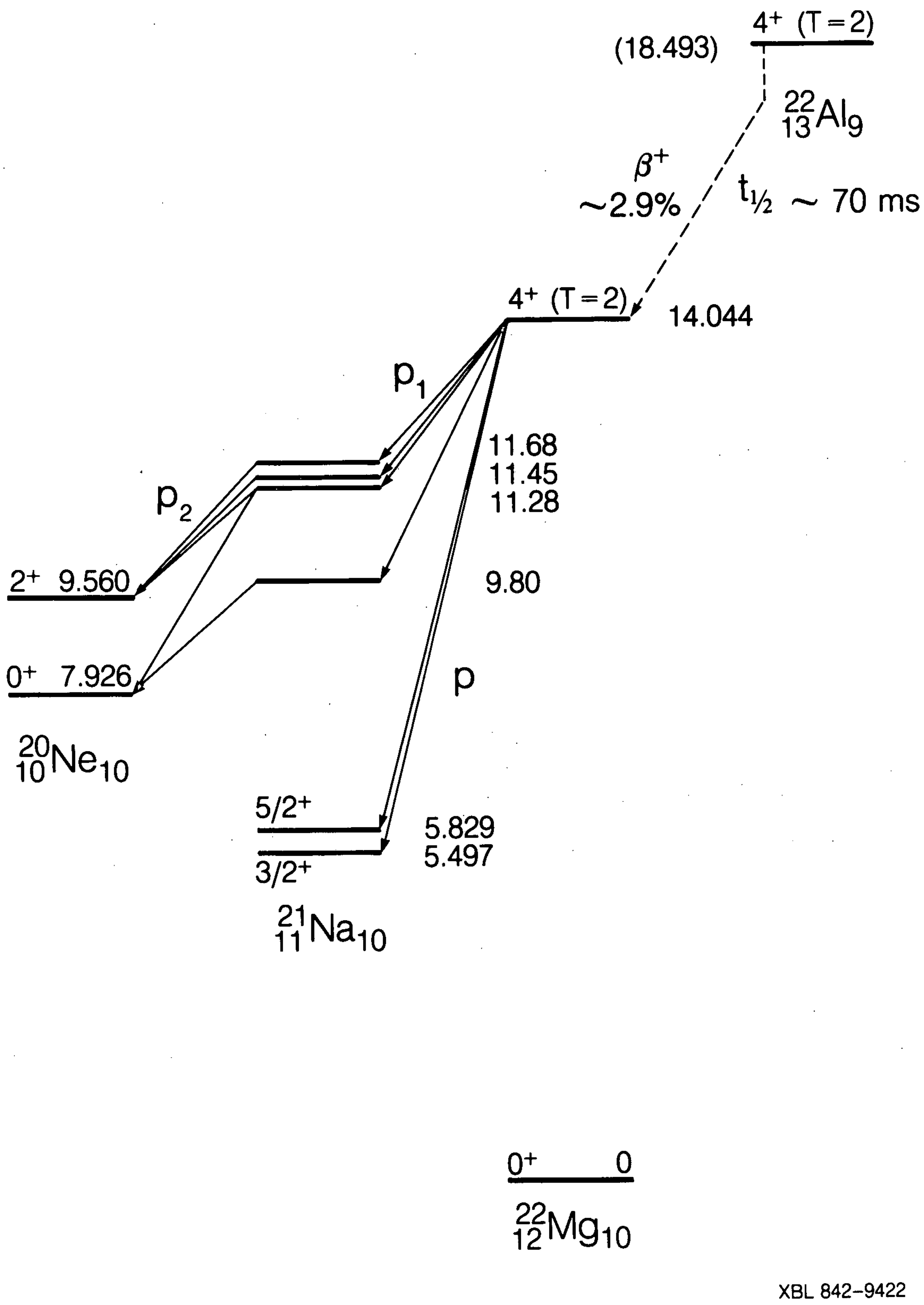
Figure Captions

Fig. 1. Proposed partial decay scheme for ^{22}Al.

Fig. 2. Schematic diagram of the large angle detector system used to measure the relative angles of the two protons in the beta-delayed two-proton decay of ^{22}Al. The sensitive direction of the position sensitive detectors (PSD) lies in the dimension shown.

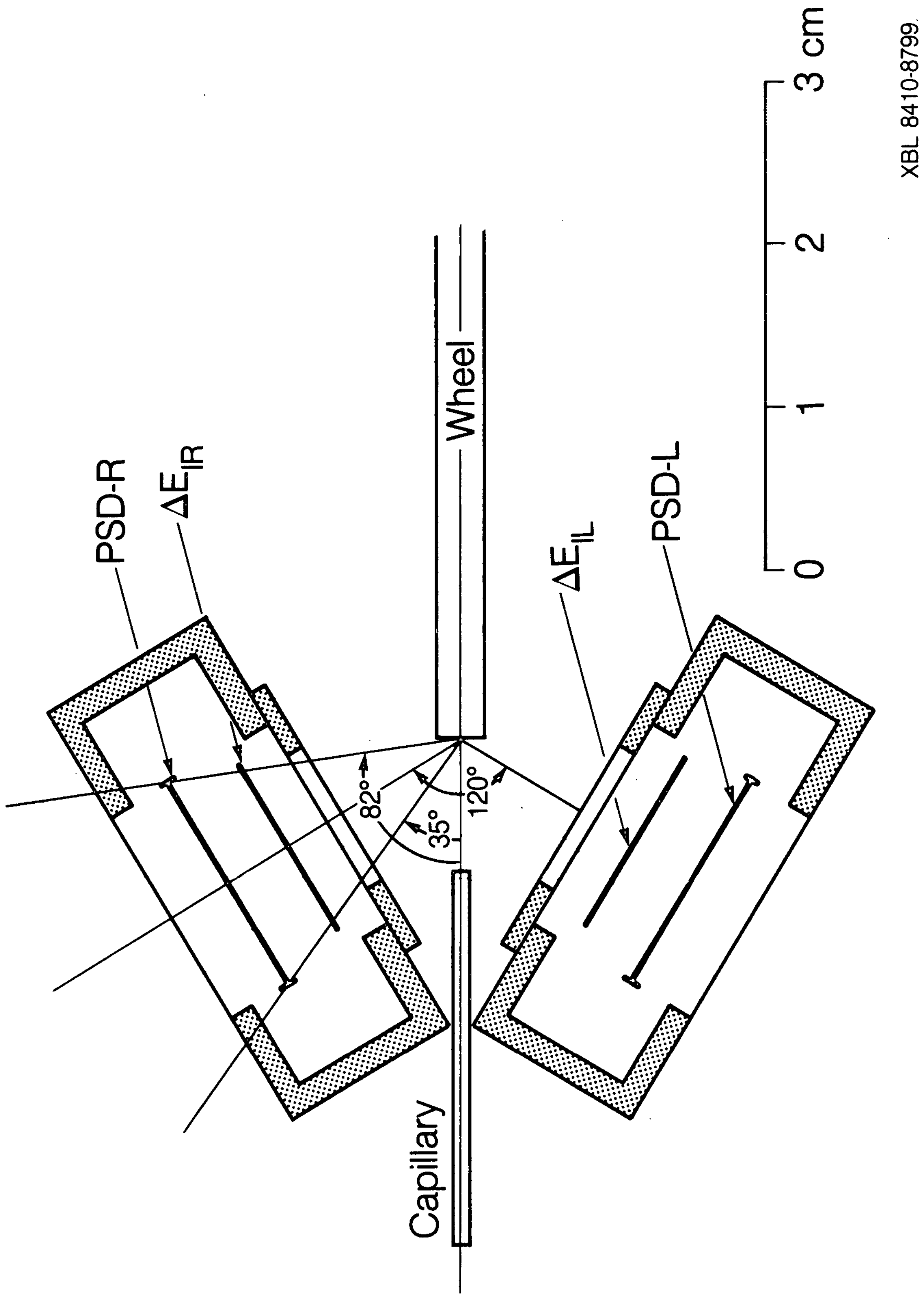
Fig. 3. Proton-proton summed energy spectrum obtained with the large angle detector system. This spectrum has been formed from events in the angular range 70^{o}-128^{o}. See text.

Fig. 4. Normalized angular correlation for the two protons from the beta-delayed two-proton emission of ^{22}Al. The dotted line corresponds to a 15% admixture of ^{2}He emission to an otherwise isotropic distribution. See text.



4+ (T=2)
(18.493)
22 13 Al 9
β+
~2.9%
t½ ~ 70 ms
4+ (T=2)
14.044
p1
11.68
11.45
11.28
p2
2+ 9.560
9.80
0+ 7.926
20 10 Ne 10
p
5/2+
5.829
5.497
3/2+
21 11 Na 10
0+
0
22 12 Mg 10
XBL 842-9422

Fig. 1.



PSD-R
ΔE_IR
Wheel
ΔE_IL
PSD-L
82°
35°
120°
Capillary
0
1
2
3 cm
XBL 8410-8799

Fig. 2.

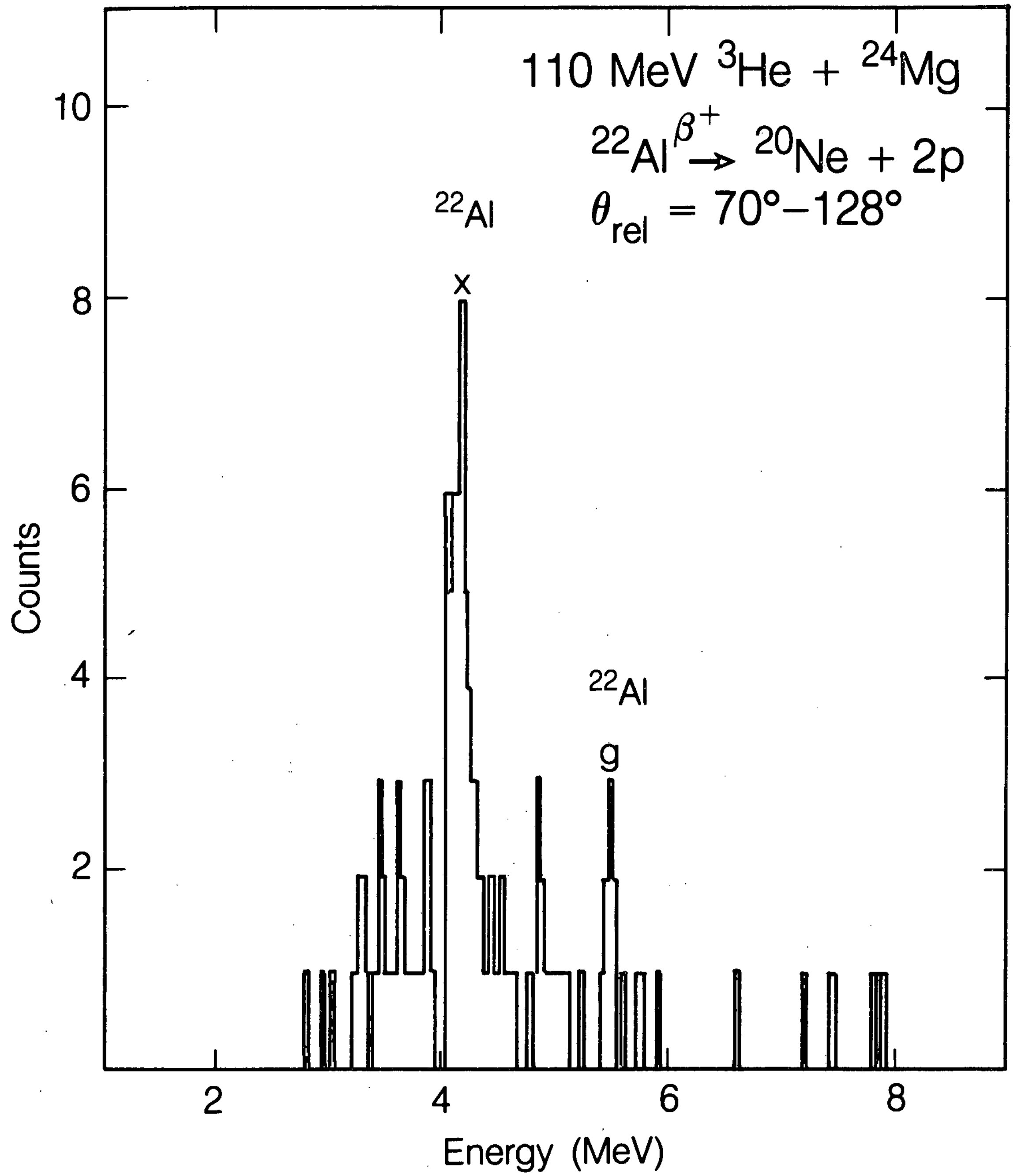
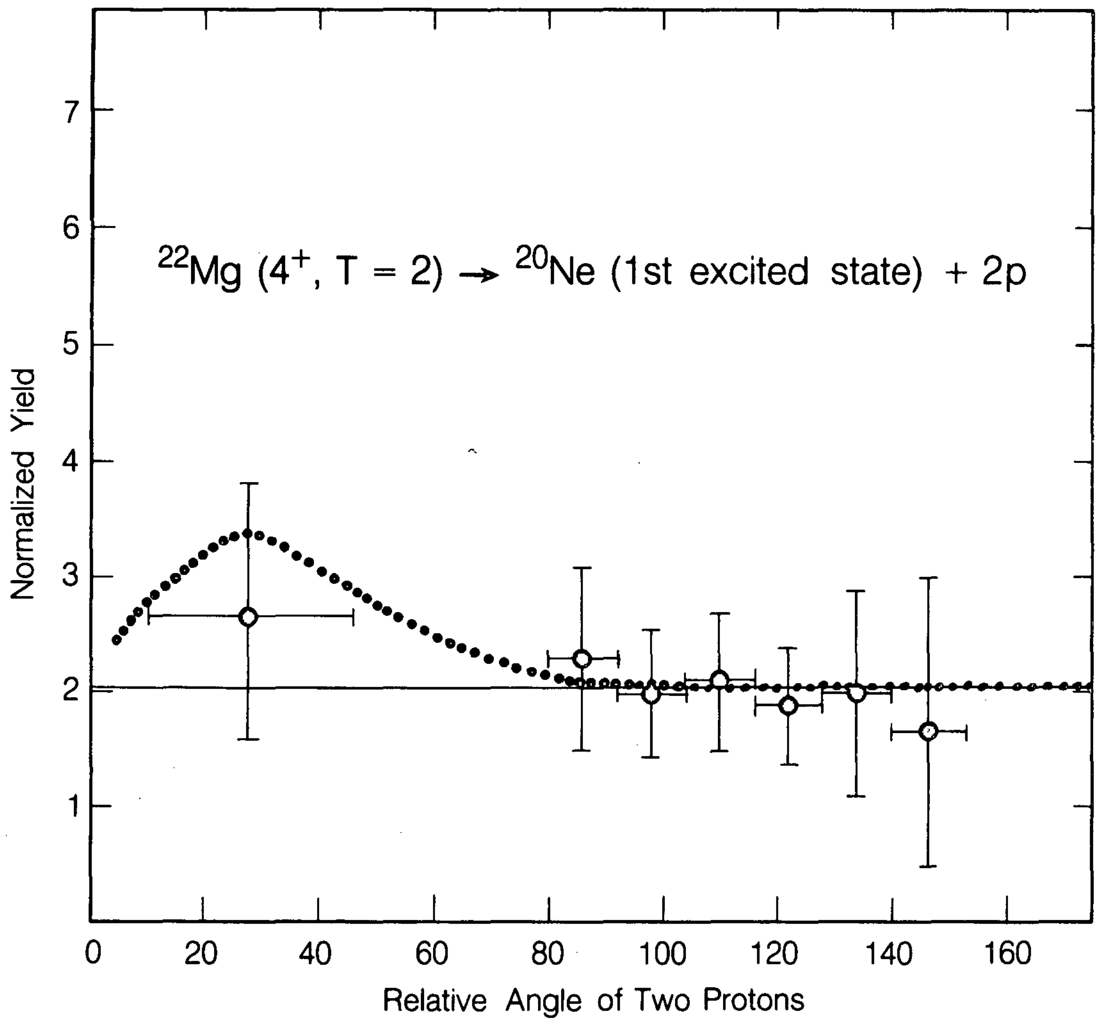


Fig. 3. XBL 8410-8800



XBL 8410-8798

Fig. 4.

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720