Brief, incomplete, Historical comments on Triton Beams

R. F. Casten

(Apology: many of the slides are just cell phone shots from papers in bound volumes with all the distortions and curvatures that that entails)

Irony or Ironies: Just yesterday, I got an email from Los Alamos that they are now formally decommissioning the tandem there that provided so many triton beams.

Triton beams

Early triton beams: Aldermaston (UK) – ca. 1966; Los Alamos – ca. 1969-70s

- (t,p) reaction
  - Transfers 2 neutrons, can access neutron rich nuclei
  - Very positive Q value, hence spectra are very clean with few if any contaminants (up to some final nucleus excitation energy)
  - Transfers 2 neutrons in a relative S state so can probe pairing effects
  - Unique angular distributions (forward peak) for L=0 transfer so excellent for identifying 0^+ states [a la the famous set of (p,t) reactions at TUM]
  - Directly gives S_{2n} values, hence sensitivity to structural changes (early example: Mo; best known: Nd, Sm, Gd)

Triton beams

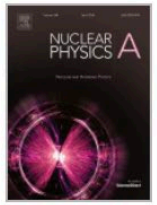
- Other reactions
  - Single nucleon transfer, such as (t,α) and (t,d): Bring in more angular momentum than their (d,t) and (d,p) counterparts.
  - (t,^{3}He) [vs (^{3}He, t)] – charge exchange, beta decay, isospin transfer, analogue states. More useful spectroscopically than (n,p) because of charged projectile focusing.
  - Polarized tritons, and on and on

Pioneering Aldermaston research, mid-1960s

ELSEVIER

Nuclear Physics A

Volume 103, Issue 1, 23 October 1967, Pages 33-70



The (t, p) reaction with the even isotopes of Ca

J.H. Bjerregaard, Ole Hansen, O. Nathan, R. Chapman, S. Hinds ††, R. Middleton †††

ELSEVIER

Nuclear Physics

Volume 86, Issue 1, October 1966, Pages 145-166

The (t, p) reaction with the even isotopes of Sm

J.H. Bjerregaard, Ole Hansen, O. Nathan, S. Hinds

https://doi.org/10.1016/0029-5582(66)90297-5

Abstract

The (t, p) reactions on the even isotopes of Sm have been investigated at a bombarding energy of 12 MeV with the purpose of exploring the transition from spherical to deformed nuclei. The reaction protons were detected in the Aldermaston multi-angle spectrograph, the overall energy resolution being about 20 keV FWHM. Levels in $^{146, 150, 152, 154, 156}$Sm were established below 2–3 MeV excitation energy. A

Aldermaston, mid-1960s, inspiring theory

High-Resolution Study of the $\mathrm{Fe}^{54}(t,p)\mathrm{Fe}^{56}$ Reaction

Bernard L. Cohen and Roy Middleton
Phys. Rev. **146**, 748 – Published 17 June 1966

Article | References | Citing Articles (45) | PDF | Export Citation

ABSTRACT

The $\mathrm{Fe}^{54}(t,p)\mathrm{Fe}^{56}$ reaction was studied with 12-MeV incident tritons using the Aldermaston tandem Van de Graaff and multigap spectrograph. The angular distributions of the protons are characterized by sharp structure. For eight cases where the spin and parity of the final state are known, the position of the first maximum agrees very well with predictions of the plane-wave Born approximation. These

Isospin Structure of Pairing Collective Motion

B. F. Bayman, D. R. Bes, and R. A. Broglia
Phys. Rev. Lett. **23**, 1299 – Published 1 December 1969

Article | References | Citing Articles (39) | PDF | Export Citation

ABSTRACT

The isospin degree of freedom of the pairing force is studied in the framework of the rotational ($\Delta \neq 0$) and vibrational ($\Delta = 0$) models. The magnitude Δ is the BCS gap parameter. The predictions of the two models concerning two-nucleon transfer reactions and energy levels are compared and contrasted. Some of the available experimental material around Ni^{56} is discussed in this framework. Further experiments are suggested which would help decide between the coupling schemes.

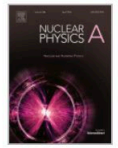
Received 25 August 1969

Aldermaston, mid-1960s

ELSEVIER

Nuclear Physics A

Volume 119, Issue 2, 28 October 1968, Pages 305-324



A study of ^{52}Cr, ^{54}Cr and ^{56}Cr by the (t, p) reaction

R. Chapman †, S. Hinds ††, A.E. MacGregor

Show more

+ Add to Mendeley Share Cite

https://doi.org/10.1016/0375-9474(68)90302-3 Get rights and content

Abstract

The (t, p) reactions leading to ^{52,54,56}Cr have been investigated at a bombarding energy of 12 MeV, using the Aldermaston multi-angle magnetic spectrograph. Levels in the final nuclei were measured for excitation energies below 5–6 MeV.

2006 !

Nuclear structure of ^{102}Mo

M. A. Rahman and M. S. Chowdhury

Phys. Rev. C **73**, 054311 – Published 19 May 2006

Don't forget about your old data!

Article | References | Citing Articles (11) | PDF | HTML | Export Citation

ABSTRACT

Nuclear structure of the ^{102}Mo nucleus has been studied using the ^{100}Mo$(t,p)^{102}$Mo reaction with the triton beam energy of 12 MeV obtained from the tandem Van de Graaff accelerator and a multichannel magnetic spectrograph. Proton spectra are obtained at 12 different angles from 5° to 87.5°, at an interval of 7.5° and are detected in nuclear emulsion plates. Thirty-five levels in the energy range from 0.000 to 3.248 MeV have been observed. The results yield a number of new levels with spin assignments. Absolute differential cross sections for the levels have been measured. The experimental angular distributions are compared with the theoretical distorted-wave Born approximation calculations to determine L and J^{π} values. The present results are compared with the previous results.

2006 paper: using Aldermaston closed before 1974

Los Alamos, late 1960s into the 1970s

Decommissioning starts today

^{104}Ru(t,p)^{106}Ru, 1970

Volume 32B, number 1 PHYSICS LETTERS 25 May 1970

^{106}Ru, A TRANSITIONAL NUCLEUS*

R. F. CASTEN, E. R. FLYNN, O. HANSEN and T. MULLIGAN
Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico 87544, USA

R. K. SHELINE
Florida State University, Tallahassee, Florida 32306, USA

and

P. KIENLE
Technische Hochschule, Physik Department München, Bayern, F.C., Germany

Received 28 April 1970

The low-lying energy levels of ^{106}Ru have been investigated with the ^{104}Ru(t, p)^{106}Ru reaction at 15 MeV bombarding energy. Spins and parities were obtained from the measured angular distributions. The energy levels are discussed in terms of the phonon and rotational models and ^{106}Ru is found to be of transitional character between these limits.

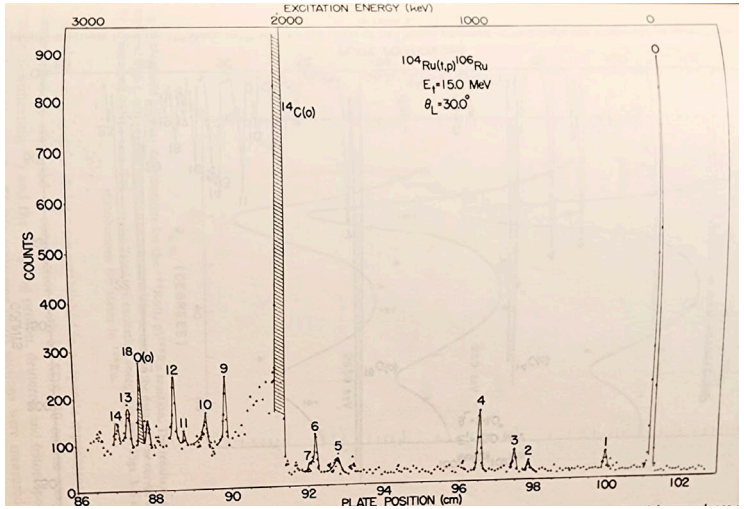
I.E.1:2.G *Nuclear Physics* A184 (1972) 357—376; © *North-Holland Publishing Co., Amsterdam*

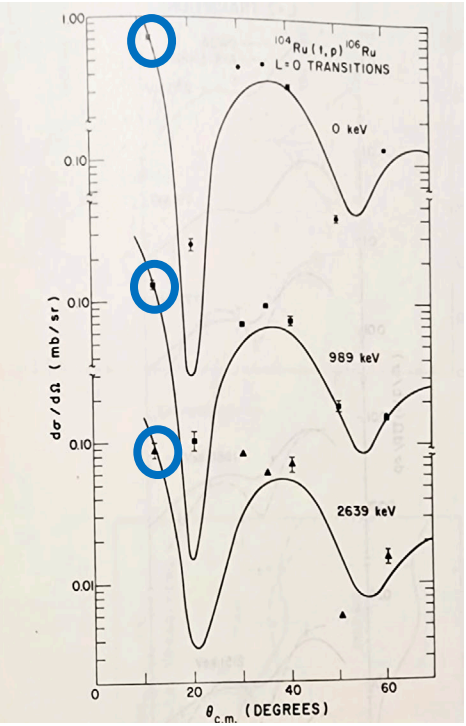
A STUDY OF THE NEUTRON-RICH ISOTOPES NEAR $A = 100$ BY MEANS OF THE (t, p) REACTION

R. F. CASTEN †, E. R. FLYNN, OLE HANSEN and T. J. MULLIGAN ††
Los Alamos Scientific Laboratory, University of California
Los Alamos, New Mexico 87544 †††

Received 18 November 1971
(Revised 11 January 1972)

Abstract: The (t, p) reaction has been used to study the nuclides ^{102}Mo, ^{106}Ru and ^{112}Pd, all of which





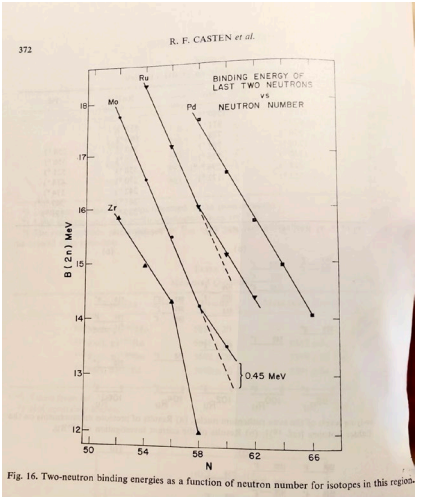


Fig. 16. Two-neutron binding energies as a function of neutron number for isotopes in this region.

Neutron rich
Clean spectra
L = 0 Ang. Dists: 0^+ States
S_{2n} Values and structure

printed from:
PHYSICAL REVIEW C VOLUME 6, NUMBER 5 NOVEMBER 1

(t, p) and (p, t) Reactions on Even Ce Isotopes*

T. J. Mulligan†
Department of Physics, Florida State University, Tallahassee, Florida 32036, and Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico 87544

and

E. R. Flynn, Ole Hansen, and R. F. Casten
Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico 87544

and

R. K. Sheline
Department of Physics, Florida State University, Tallahassee, Florida 32306

(Received 9 August 1971)

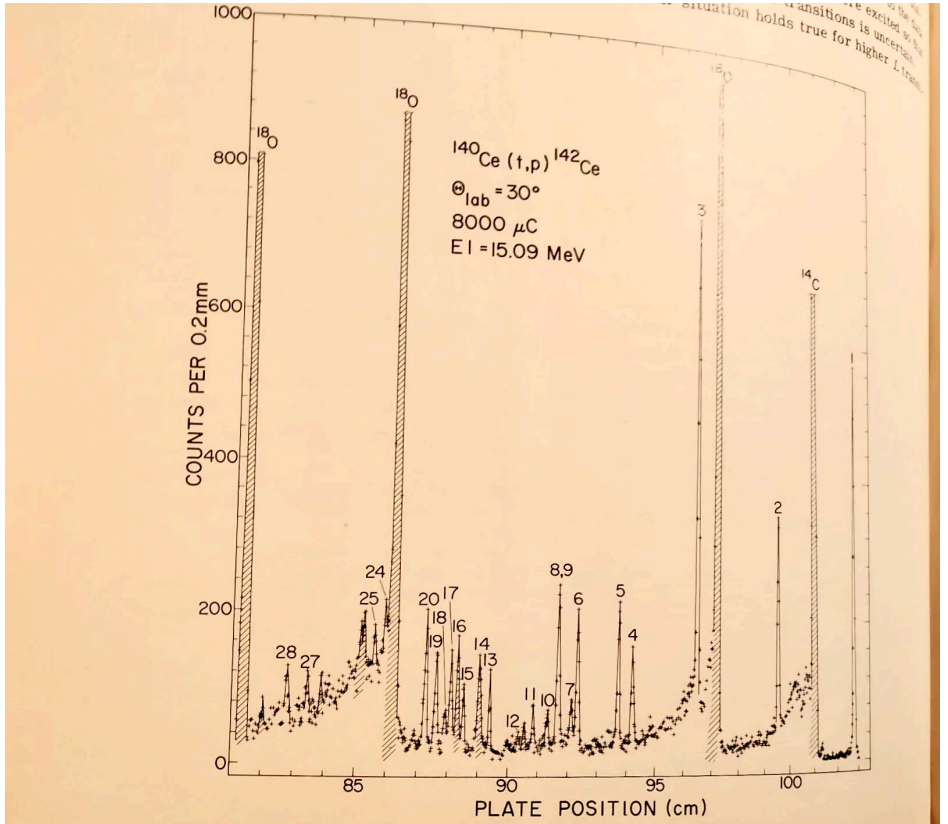


FIG. 2. Sample spectrum from the $^{140}Ce(t, p)$ reaction. The numbers above the peaks refer to the proton group numbers of Table IV. The major impurity peaks are cross-hatched while those due to C and O are labeled by the residual nuclei.

From Be to the Actinides

Volume 40B, number 2 PHYSICS LETTERS 26 June 1972

LEVELS OF ^{11}Be FROM A STUDY OF THE ^{9}Be(t, p)^{11}Be REACTION

F. AJZENBERG-SELOVE
*University of Pennsylvania *, Philadelphia, Pennsylvania* 19104, *USA*

and

R. F. CASTEN **, O. HANSEN and T. J. MULLIGAN ***
Los Alamos Scientific Laboratory, University of California ‡,
Los Alamos, New Mexico 87544, *USA*

Received 17 May 1972

The reaction ^{9}Be(t, p)^{11}Be has been studied with 20 MeV tritons and an Elbek-type spectrograph. Four previously unreported proton groups were observed corresponding to E_x = 5.25, 6.51, 6.72 and 8.84 MeV in ^{11}Be, and two broader groups.

Volume 40B, number 3 PHYSICS LETTERS 10 July 1972

SEARCH FOR (t, p) TRANSITIONS TO EXCITED 0$^+$ STATES IN THE ACTINIDE REGION *

R.F. CASTEN, E.R. FLYNN, J.D. GARRETT, O. HANSEN and T.J. MULLIGAN
Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico 87544, USA

D.R. BESS **
Comisión de Energía Atómica, Buenos Aires, Argentina and Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico 87544, USA

R.A. BROGLIA ***
Institute for Theoretical Physics, State University of New York at Stony Brook, Stony Brook, N.Y. 11790, USA

and

B. NILSSON ‡
Department of Physics, State University of New York at Stony Brook, Stony Brook, N.Y. 11790, USA

Received 26 May 1972

The (t,p) reactions from ^{230,232}Th and ^{234,236,238}U were studied at 15-20 MeV bombarding energy. The known excited 0$^+$ states in ^{232}Th, ^{236,238}U were not observed nor was any excited 0$^+$ strength located in ^{234}Th or ^{234}U. The previously reported strong L = 0 (p,t) transitions in this region as well as the weak L = 0 (t,p) strengths reported here constitute a strong indication of the existence of quadrupole pairing correlations in deformed superfluid nuclei.

Contrast of xtions for (p,t) and (t,p) to first excited 0$^+$ state → concept of quadrupole pairing

Pennsylvania, McMaster, and Daresbury, into the 1980s

PHYSICAL REVIEW C VOLUME 19, NUMBER 1 JANUARY 1979

Mechanism of $^{14}N(t,p)$ to the ground state quadruplet in ^{16}N

H. T. Fortune, O. M. Bilaniuk,* G. Stephans, and R. Middleton
Physics Department, University of Pennsylvania, Philadelphia, Pennsylvania 19104
(Received 3 April 1978)

Complete angular distributions (8°–168°) have been measured for the $^{14}N(t,p)^{16}N$ reaction, at a bombarding energy of 15 MeV, leading to the lowest four levels of ^{16}N. Results have been analyzed using

The experiment made use of a 15-MeV t beam from the University of Pennsylvania FN tandem

Proceedings of the Brookhaven National Laboratory Workshop on ISOL Systems, Oct. 31-Nov. 1, 1977

BNL-23361

Studies of ^{12}Be and Other Off-Stability Nuclei*

David E. Alburger

Brookhaven National Laboratory, Upton, New York 11973

Abstract

In collaboration with the Tandem Van de Graaff staff at the University of Pennsylvania the reaction $^{10}Be(t,p)^{12}Be$ at E_t = 12 MeV has been used to study the properties of ^{12}Be. The first excited state of ^{12}Be has been found to lie

(t, d) reaction on ^{124}Te, ^{126}Te, ^{128}Te, and ^{130}Te nuclei

M. A. M. Shahabuddin, J. A. Kuehner, and A. A. Pilt
Phys. Rev. C **23**, 64 – Published 1 January 1981

ABSTRACT

Differential cross section angular distributions have been measured for levels below 2.5 MeV in each residual nucleus in the $^{124,126,128,130}\mathrm{Te}(t,d)^{125,127,129,131}\mathrm{Te}$ reactions at $E_t = 16$ MeV. The reaction

Generation of radioactive ion species at daresbury laboratory

T.R. Charlesworth, R. Ryder, M.P. Holbourn, D.J. Leeman

https://doi.org/10.1016/0168-9002(86)90758-8

Abstract

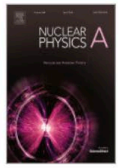
The generation of tritium and carbon-14 ion species is described. Tritium ions were produced from a commercial ion source which operated for a total period of 600 h, generating an average beam of 500 nA. Carbon-14 ions were produced from a

LASL - (t, ^{4}He), 1981

ELSEVIER

Nuclear Physics A

Volume 366, Issue 2, 17 August 1981, Pages 202-220



The ^{159}Tb(t, α)^{158}Gd reaction with 17 MeV polarized tritons

D.G. Burke, E. Hammaren *, C.L. Swift, J.A. Cizewski **, E.R. Flynn, J.W. Sunier, G. Løvhøiden

Show more

+ Add to Mendeley Share Cite

https://doi.org/10.1016/0375-9474(81)90284-0 Get rights and content

Abstract

The ^{159}Tb(t, α)^{158}Gd reaction has been studied using 17 MeV polarized tritons from the Los Alamos Scientific Laboratory Tandem Van de Graaff accelerator. The α -spectra were

MSU - (t, ^{3}He), 2005

The (t,^{3}He) and (^{3}He,t) reactions as probes of Gamow-Teller strength.

R.G.T. Zegers,[1,2,3] H. Akimune,[4] Sam M. Austin,[1,3] D. Bazin,[1] A.M. van den Berg,[5] G.P.A. Berg,[6,7] B.A. Brown,[1,2,3] J. Brown,[8] A.L. Cole,[1,3] I. Daito,[9] Y. Fujita,[10] M. Fujiwara,[11,12] S. Galès,[13] M.N. Harakeh,[5] H. Hashimoto,[12] R. Hayami,[14] G.W. Hitt,[1,2] M.E. Howard,[3,15] M. Itoh,[16] J. Jänecke,[17] T. Kawabata,[18] K. Kawase,[12] M. Kinoshita,[19] T. Nakamura,[20] K. Nakanishi,[12] S. Nakayama,[14] S. Okamura,[12] W.A. Richter,[21] D.A. Roberts,[17] B.M. Sherrill,[1,2,3] Y. Shimbara,[1,3] M. Steiner,[1] M. Uchida,[22] H. Ueno,[23] T. Yamagata,[19] and M. Yosoi[12]

[1]*National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, MI 48824-1321, USA*
[2]*Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA*
[3]*Joint Institute for Nuclear Astrophysics, Michigan State University, East Lansing, MI 48824, USA*
[4]*Department of Physics, Konan University, Kobe, Hyogo, 658-8501, Japan*
[5]*Kernfysisch Versneller Instituut, University of Groningen, Zernikelaan 25, 9747 AA Groningen, The Netherlands*
[6]*Department of Physics, University of Notre Dame, IN 46556-5670, USA*
[7]*Joint Institute for Nuclear Astrophysics, University of Notre Dame, IN 46556-5670, USA*
[8]*Department of Physics, Wabash College, Crawfordsville, IN 47933, USA*
[9]*Advanced Photon Research Center, Japan Atomic Research Institute, Kizu, Kyoto 619-0215, Japan*
[10]*Department of Physics, Osaka University, Toyonaka, Osaka 560-0043, Japan*
[11]*Kansai Photon Science Institute, Japan Atomic Energy Agency, Kizu, Kyoto 619-0215, Japan*
[12]*Research Center for Nuclear Physics, Osaka University, Ibaraki, Osaka 567-0047, Japan*
[13]*Institut de Physique Nucléaire, IN2P3-CNRS, Orsay, France*
[14]*Department of Physics, University of Tokushima, Tokushima 770-8502, Japan*
[15]*Department of Physics, The Ohio State University, Columbus, OH 43210, USA*
[16]*Cyclotron and Radioisotope Center, Tohoku University, Sendai, Miyagi 980-8578, Japan*
[17]*Department of Physics, University of Michigan, Ann Arbor, MI 48109-1040, USA*
[18]*Center for Nuclear Study, University of Tokyo, RIKEN Campus, Wako, Saitama 351-0198, Japan*
[19]*Department of Physics, Konan University, 8-9-1 Okamoto Higashinda, Kobe, Hyogo, 658-8501, Japan*
[20]*Tokyo Institute of Technology, Megro, Tokyo 152-8550, Japan*
[21]*Department of Physics, University of Western Cape, Bellville 7530, South Africa*
[22]*Tokyo Institute of Technology, 2-12-1 O-Okayama, Tokyo 152-8550, Japan*
[23]*Applied Nuclear Physics Laboratory, RIKEN, Wako, Saitama 351-0198, Japan*

(Dated: December 21, 2005)

Charge-exchange reactions are an important tool for determining weak-interaction rates. They provide stringent tests for nuclear structure models necessary for modeling astrophysical environments such as neutron stars and core-collapse supernovae. In this paper we demonstrate via a study of ^{26}Mg(t,^{3}He) that the (t,^{3}He) reaction at 115 MeV/nucleon is an accurate probe for extracting Gamow-Teller strengths. This study is complemented by ^{26}Mg(^{3}He,t) data taken at 140 MeV/nucleon which allows for a comparison of T=2 analog states excited via the mirror reactions. The combination of (^{3}He,t) and (t,^{3}He) is a powerful alternative for the (p,n) and (n,p) reactions, since both $\Delta T_z = -1$ and $\Delta T_z = +1$ directions can be studied with high-resolution spectrometers.

Conclusion

Modern triton beams have been long awaited

The FSU achievement is a wonderful opportunity.

YAAAAAY !!!! GO FOR IT !!!!