

Lawrence Berkeley National Laboratory

Recent Work

Title

THE APPLICATION OF POSITION-SENSITIVE PHOSWICH DETECTORS FOR LOW-MASS
FRAGMENT DETECTION IN AN ARRAY-ENVIRONMENT

Permalink

<https://escholarship.org/uc/item/5xt6t6mc>

Authors

Chan, Y.
Chavez, E.
Dacal, A.

Publication Date

1988-09-01



Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

Presented at the ACS Meeting, Denver, CO,
April 5-10, 1987

The Application of Position-sensitive Phoswich Detectors for Low-mass Fragment Detection in an Array Environment

Y. Chan, E. Chavez, A. Dacal, S. Gazes,
B.A. Harmon, E. Plagnol, J. Pouliot,
M.E. Ortiz, and R.G. Stokstad

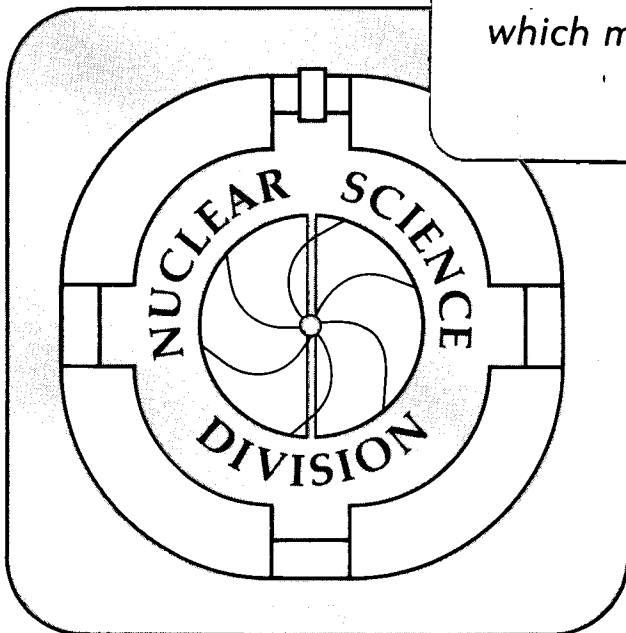
September 1988

LAWRENCE
BERKELEY LABORATORY

NOV 13 1988

TWO-WEEK LOAN COPY

*This is a Library Circulating Copy
which may be borrowed for two weeks.*



LBL-24529 c.2

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

The Application of Position-sensitive Phoswich Detectors for
Low-mass Fragment Detection in an Array Environment

Y. Chan, E. Chavez, A. Dacal, S. Gazes, B.A. Harmon,
E. Plagnol, J. Pouliot, M.E. Ortiz and R.G. Stokstad

Nuclear Science Division
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, California 94720

September 1988

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

The application of position-sensitive phoswich detectors for low-mass fragment detection in an array environment[‡]

*Y. Chan, E. Chavez, A. Dacal, S. Gazes, B.A. Harmon,
E. Plagnol, J. Pouliot, M.E. Ortiz and R.G. Stokstad*

Nuclear Science Division, Lawrence Berkeley Laboratory, Berkeley, Ca.94720

ABSTRACT

Large solid angle position-sensitive phoswich detectors have been constructed to replace smaller units in an array for detecting medium mass fragments ($Z \leq 15$) in nuclear experiments. The position information was obtained from a time analysis method.

1. Introduction

The average particle multiplicity emerging from heavy-ion collisions increases rapidly with bombarding energy in the domain of 30-200 MeV/nucleon. Consequently highly segmented and sophisticated detector-arrays are required to register all these particles. Such multi-detector arrays,¹ while having excellent geometrical efficiency and minimal phase-space biasing, are in general also very costly to build, simply due to the large number of detectors and electronics modules involved.

For most fixed target experiments, the majority of the energetic reaction products are kinematically focussed in the forward direction in the laboratory. One could therefore conceivably reduce the modular granularity of an array (thus the total cost) at large angles without losing much physics information, provided the solid angle coverage is identical, and the position information (the momentum vector) of the detected particles is preserved to the same degree of accuracy as with other segmented detectors. We report in this article the implementation of such detectors in a general purpose phoswich detector array² constructed for heavy-ion experiments in the energy domain of 20-60 MeV/nucleon. Each of these new position-sensitive elements replaces up to 10 non-position sensitive detectors of the array. The savings in electronics cost alone is almost six-fold. The performance of these detectors will be discussed, and a comparison with an individual standard detector module will be made.

[‡] Invited talk presented by Y. Chan at "Symposium for Nuclear Instrumentation", ACS Meeting, Apr. 1987, Denver, Colorado.

2. Position-sensitive phoswich detector

There are at least three major advantages in using position-sensitive phoswich detectors:

- (i) the large available geometrical coverage (for the present example, a single module covers $5^\circ \times 60^\circ$)
- (ii) the low electronics overhead cost as compared with a segmented configuration, and
- (iii) the possibility of obtaining *continuous* position information, which in some cases is very desirable as, for instance, in the study of sequential-breakup processes.

They are most useful in modular detector-array applications to cover the *medium* angular region, where particle multiplicity is reasonably low (since these detectors can not handle multiple-hits) and the energy cut-off is still tolerable.

Fig.1 shows a schematic drawing of the detector. It is composed of four major parts: the scintillator section, the photo-tube assembly, the LED light pulser, and a mechanical fixture. The dimension of the plastic scintillator section is 30cm \times 2.5cm \times 2.5cm (composed of a fast component made up of 0.5-1.0mm thick NE102A sheet and a slow, 2.5cm thick, NE115 counterpart. For some later versions, the slow part is 10cm thick and is tapered towards the front surface). To avoid the possibility of having a non-scintillating dead-layer at the central portion of the detector, the fast- and slow-scintillators are coupled together by optical cement only at the ends. The end portions of the detector are tapered on the side opposite to the photo-tubes. The tapered surfaces are coated with a highly reflective aluminum layer to improve light collection efficiency. The scintillator section is wrapped with 0.3mil aluminized mylar sheets.

Two 3/4" diameter photo-tubes (Hamamatsu R1450) are optically glued to the ends of the detector. The module is mechanically strengthened and supported by a 1/2" diameter aluminum rod and a rectangular-shaped mounting fixture that houses part of the μ -metal shield and the tube-base. A LED unit is positioned at the rear geometrical center of the detector.

3. Position response

It is well known that the light output of a scintillator slab is position dependent³ particularly when viewed from the narrow edges of the detector. Fig.2(a) shows the actual position response of this detector to monoenergetic 32.5MeV/nucleon ^{16}O particles impinging at different positions on the detector front surface. By fitting the experimental points to an exponential function of the form (Fig.2(b)),

$$I(x, Z, E) \sim F(Z, E) e^{-x/\mu}$$

where

x = position of the particle along the surface from the center

E = energy of the particle

Z = charge of the particle

the effective attenuation length μ was found to be ~ 2.6 cm, which is significantly smaller than the intrinsic attenuation length of the plastic scintillators. The additional attenuation probably comes from surface losses⁴, absorption at the various optical coupling joints, and is, generally speaking, geometry dependent.

While the position-dependent characteristic of the light output is a drawback for most applications, it is perfectly suitable for our goal. By using the amplitude difference method, a very satisfactory position resolution of ≤ 3 mm for 20 MeV/nucleon α -particles has been achieved by Schmidt *et al.*⁵. These authors use total light output (the long-gate signals) of the detector to deduce the average particle position. While this method works well with shallow depth phoswich detectors (the detector used in Ref. 6 is only 0.5cm thick), it poses severe problems when applied to much thicker detectors. This is best illustrated by Fig.3. With increasing particle energy and range, the long-gate signal samples a larger and larger region of the active scintillation-producing region, eventually losing the initial position definition. A better approach would be to use the short-gate signals instead, where it is known that the light output is dominated by the thin (fast) component, which has a much better definition for the initial impact position. It should be noted however that the short-gate signals are usually quite small for fast light particles and are susceptible to noise problems. An alternative method, which is described in the present article, is to obtain the position by using the intrinsic amplitude dependence of the leading edge discrimination technique. While undesirable in most applications, this method provides adequate information on the amplitude difference of the top and bottom signals based on the leading edge of the pulse, which is essentially dominated by the thin ΔE component.

The time difference approach we have used is very simple and straight forward. The two photo-tube signals, after a $\times 10$ amplification, are fed to two fast discriminators (PHILLIPS 708), which start and stop a Tennelec 2043 Time Analyser. The TAC range was set at 20ns. To study the actual position response, a slotted mask was positioned in front of the detector and was irradiated by a focussed beam of 32.5 MeV/nucleon ^{16}O particles at 0° . Fig.4 shows a sample experimental TAC spectrum thus obtained. In practice, the usable dynamical range for position is about 80%. Particles reaching the end portions of the detector usually cause saturation problems in the phototube as well as readout electronics. The position resolution averaged across the detector surface is about 0.7cm.

4. Particle identification

To examine the particle identification capability of the detector, we have used the same masked detector to detect reaction products emerging from the $^{16}\text{O}+^{12}\text{C}$ reaction at 32.5 MeV/nucleon. The long dimension of the slice detector is perpendicular to the scattering chamber plane, and the in-plane angle was $\sim 6^\circ$. Fig.5(a) and (b) show plots of the short-gate versus long-gate signal of the top and bottom photo-tubes. It can be seen that no discernable particle identification patterns are present. This is not surprising as one knows that the position dependence of the signal amplitude is very significant. As has been shown in Ref. 5, this dependence can be eliminated to first order by simply taking the square root of the product of the individual top and bottom short-(long-)gate signals. i.e.,

$$I_{\text{SHORT(LONG)}} \equiv \sqrt{I_{S(L)}^{\text{TOP}} \times I_{S(L)}^{\text{BOT}}}$$

The same data replotted against these two new parameters is shown in Fig.5(c). It is clear that particles with different charges (Z) are well separated, even though p,d,t resolution is still lacking. The overall information obtained by such a detector can be condensed and displayed as a triad in a 3-dimensional plot of the independent I_{SHORT} , I_{LONG} , and TAC_{POS} parameters (Fig.6). Without further correction, one can see that the position response is almost independent of Z for $Z \geq 3$, but has significant variations for $Z=1$ and 2 particles. This dependence is corrected for in practice through data analysis software.

5. Comparison with a single position-independent detector

It is of great interest to see how the performance of such a large solid angle detector compares with other smaller single units employed in the same array. For comparison, Fig.7 shows a typical particle identification (PID) pattern obtained by a position-independent single phoswich detector from the same $^{16}\text{O}+^{12}\text{C}$ reaction. It can be seen that while the Z -separation in these two types of detectors is of similar quality, the p,d,t resolution for the latter detector is far superior.

The lack of p,d,t resolution in the slice detector could be due to several factors. A major one undoubtedly is that particles impinging at different angles to the detector surface will encounter ΔE elements of different geometrical thicknesses (Fig.2). This effect in principle could be totally corrected for by software procedures from the known position information.

For illustration, Fig.8(a) and (b) compare the $Z=1, 2$ region of the slice PID-spectra with and without position gating. By setting a position-gate of $\sim 2\text{cm}$ at the center of the slice detector, one can see that the different isotopes of hydrogen are resolved (Fig.8(b)), even though the counting statistics is much lower.

6. Energy calibration

Conventionally, the major application of phoswich detectors is to detect only the very light hydrogen or helium isotopes. An important aspect of the present project is to try to extend the dynamical range of plastic phoswiches to much heavier fragments ($Z \leq 15$). As is well known, the light output from a scintillator is both charge and mass dependent. A fairly detailed energy calibration procedure with 10-20 MeV/nucleon α , ^{12}C , ^{14}N , and ^{16}O particles has been performed for the present detector. The energy response for different particle types is summarized in Fig. 9. One can see that for the same particle type, the energy response is quite linear within the whole range. But the offsets are different, and in particular the slope of the α particle curve displays noticeable differences when compared with the ^{12}C , ^{14}N , ^{16}O results. One should therefore use extreme caution in calibrating these detectors prior physics applications.

7. Summary

A large solid angle and position-sensitive plastic phoswich detector, based on rectangular geometry, has been constructed and shown to perform satisfactorily in our experiments. The detector could resolve fragment charge up to $Z \sim 15$. The position information was derived from a time analysis of the pulses arriving at the two photo-tubes.

We plan to improve the performance of the detector by altering the geometry from a rectangular shape to a tapered semi-circular concentric configuration. This has the advantage that all particles will impinge *normally* on the detector surface, and hence will traverse identical ΔE thicknesses. This alone should improve the Z-resolution even when the position correction is not done perfectly. The geometrical solid angle will also be enhanced.

References

1. A. Baden, H.H. Gutbrod, H. Lohner, M.R. Maier, A.M. Poskanzer, T. Renner, H. Riedesel, H.G., Ritter, H. Spieler, A. Warwick, F. Weik, and H. Wieman, Nucl. Inst. and Meth., **203**, 189 (1982).
2. J. Pouliot *et al.*, to be published in Nucl. Inst. and Meth.
3. X. Yao, Nucl. Inst. and Meth., **228**, 101 (1984)
4. M. Bantel, R.G. Stokstad, Y.D. Chan, and S. Wald, Nucl. Inst. and Meth., **A226**, 394(1984).
5. H.R. Schmidt, M. Bantel, Y. Chan, S.B. Gazes, S. Wald, and R.G. Stokstad, Nucl. Inst. and Meth., **A242**, 111(1985).

Figure Captions

Fig. 1 Schematic drawing of the position sensitive-phoswich detector.

Fig.2 (a) Position and energy response to monoenergetic ^{16}O beam particles and (b) light output versus position for both the top and bottom phototubes.

Fig.3 Geometrical consideration in obtaining position information from phoswich detectors.

Fig.4 TAC spectrum for deducing the position resolution of the detector.

Fig.5 Raw short-gate versus long-gate plots for (a) the top and (b) the bottom photo-tubes. The same data is plotted in (c) after position corrections described in the text. Up to $Z=10$ could be clearly separated.

Fig.6 A 3-dimensional correlation plot for the relevant parameters obtained from the detector.

Fig.7 A short- versus long-gate plot for a standard single module of the array.

Fig.8 Comparison of position gated (b) and ungated (a) PID spectra of the slice detector for $Z=1$ particles. The p,d,t groups are resolved in (b).

Fig.9 Light output response of the detector to different particles in the energy domain of 20-30 MeV/nucleon.

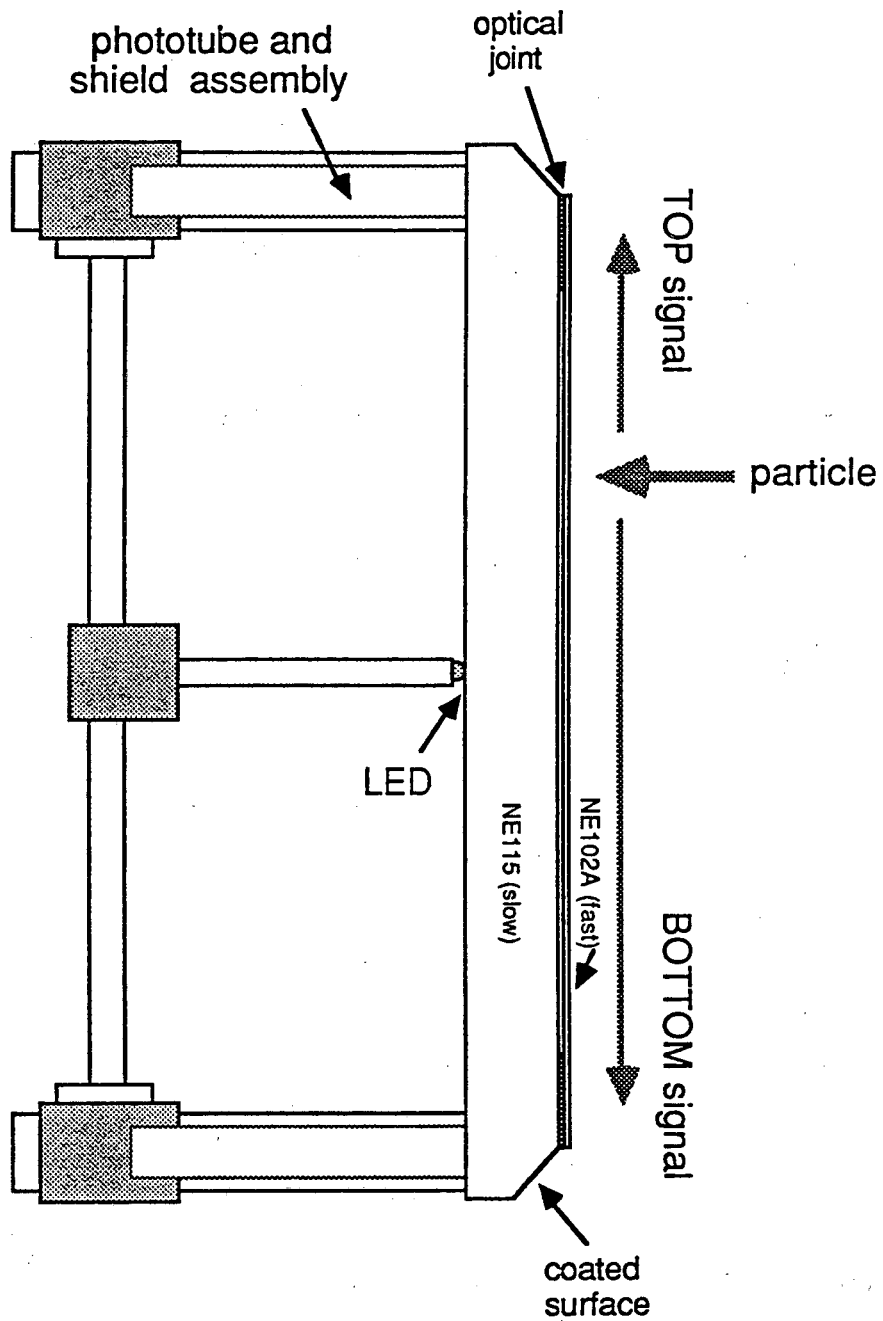


Fig.1 Schematic drawing of the position-sensitive detector.

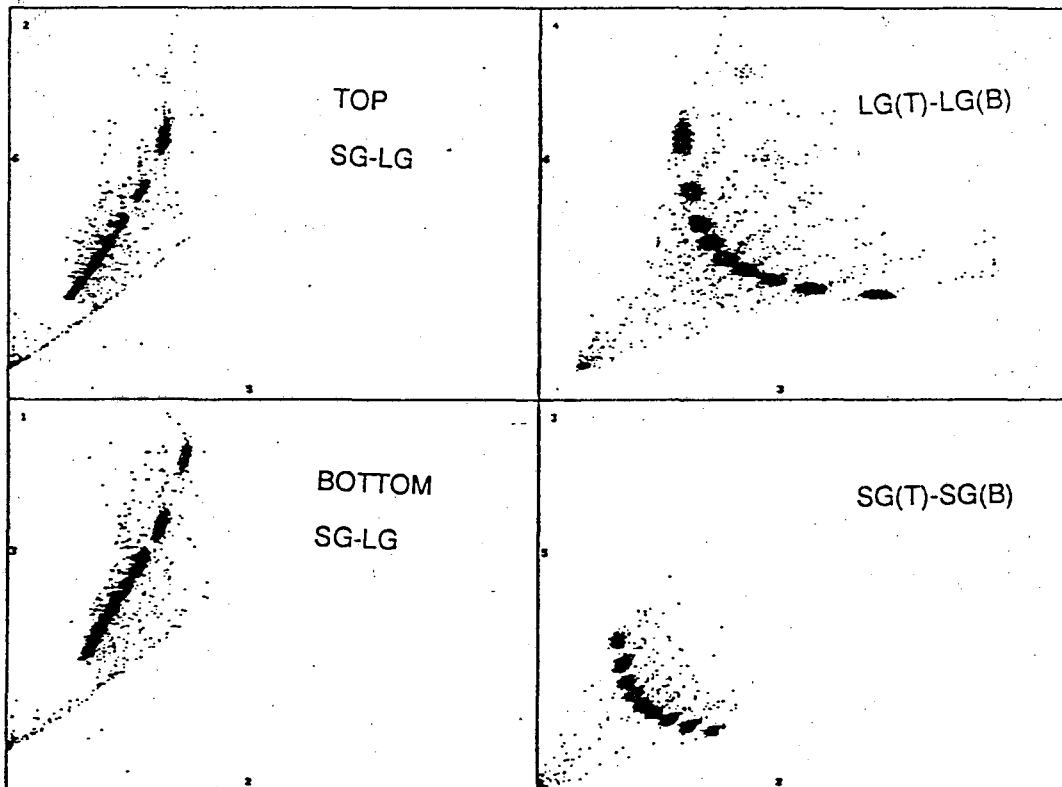
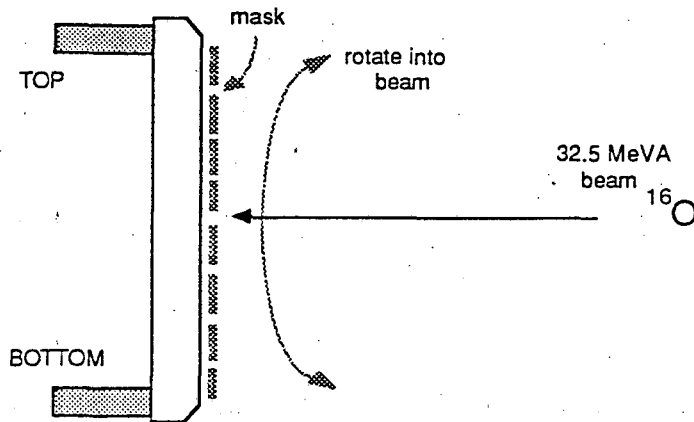


Fig.2(a) Position and energy response to monoenergetic heavy-ion beams

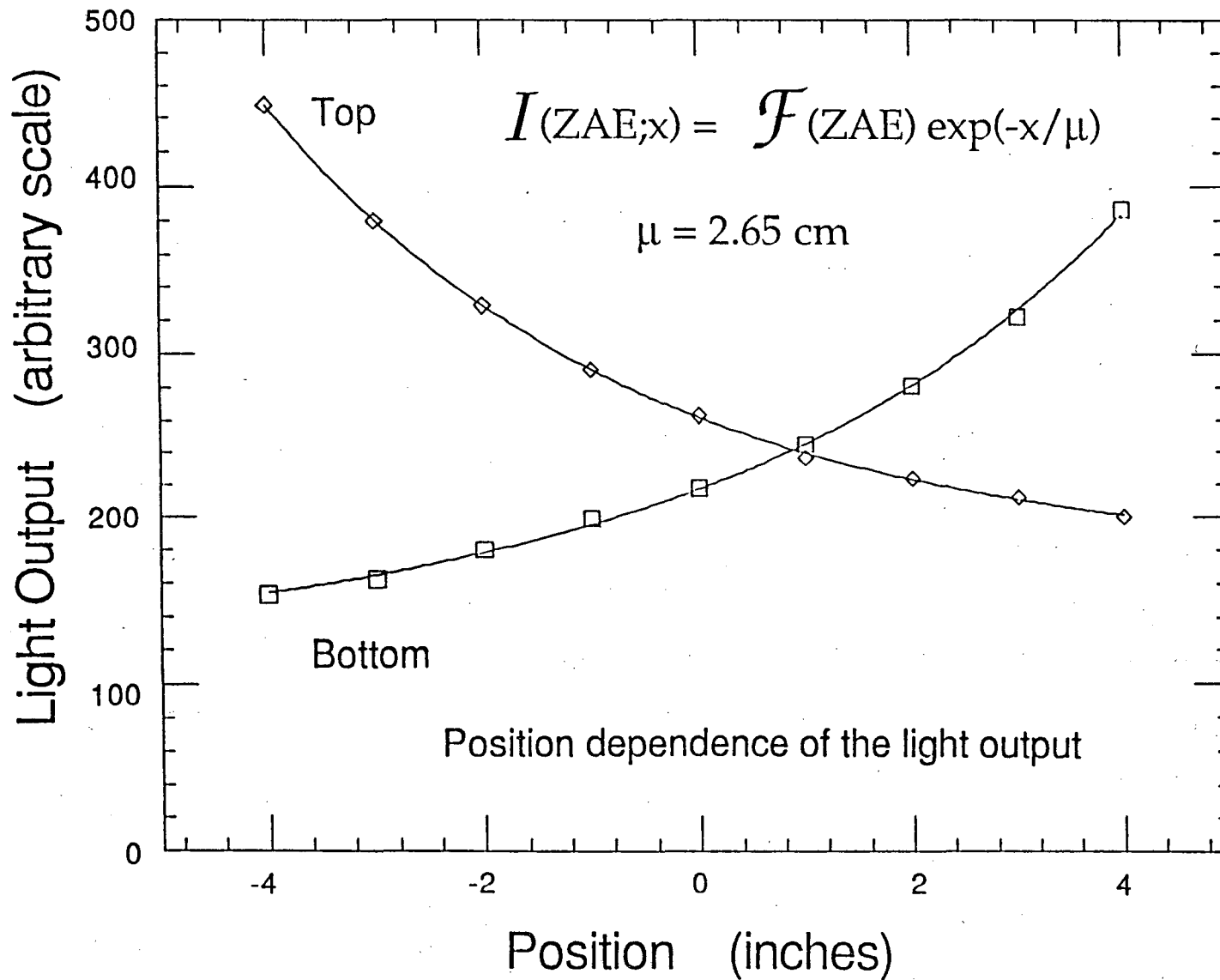


Fig. 2(b) Light output versus position for both the Top and Bottom phototubes.

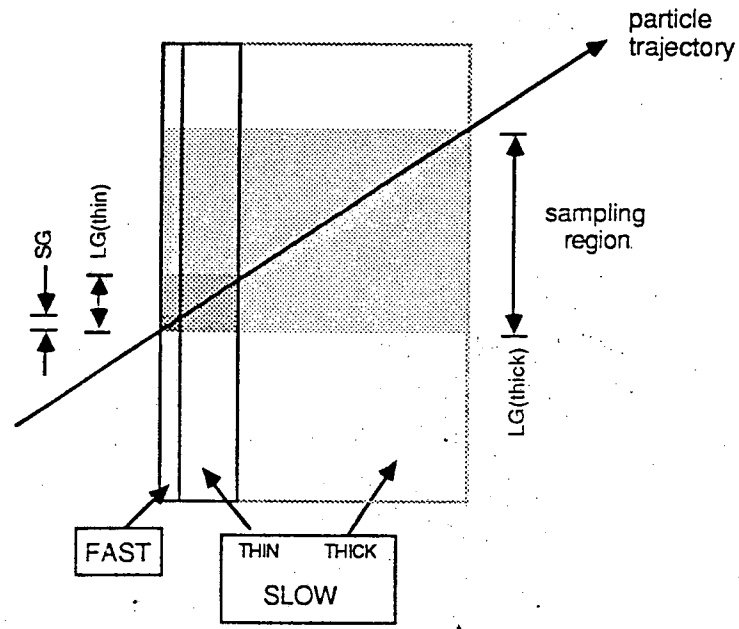


Fig.3 Geometrical consideration in obtaining position information from phoswich detectors.

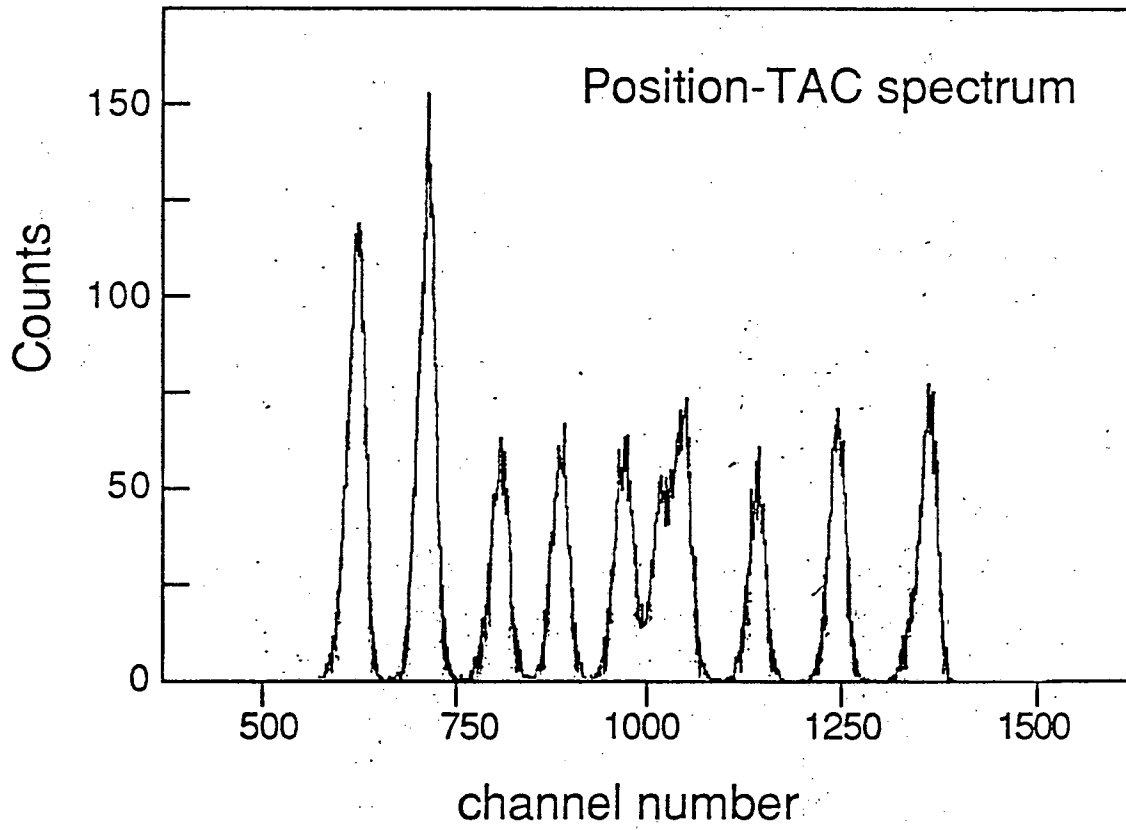
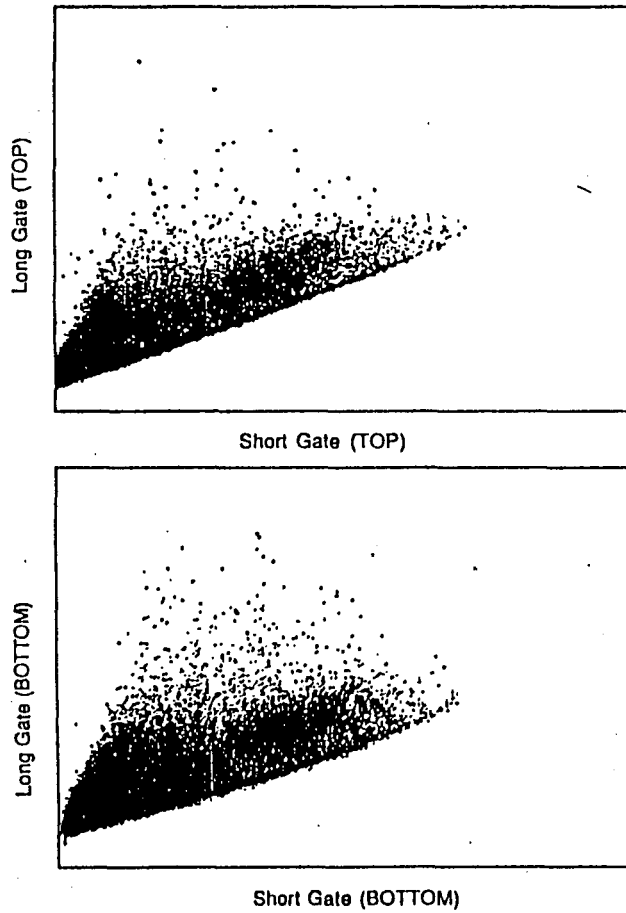


Fig.4 TAC spectrum showing the positron resolution of the detector.

RAW SIGNALS FROM A SLICE DETECTOR



First order position-corrected ΔE and E

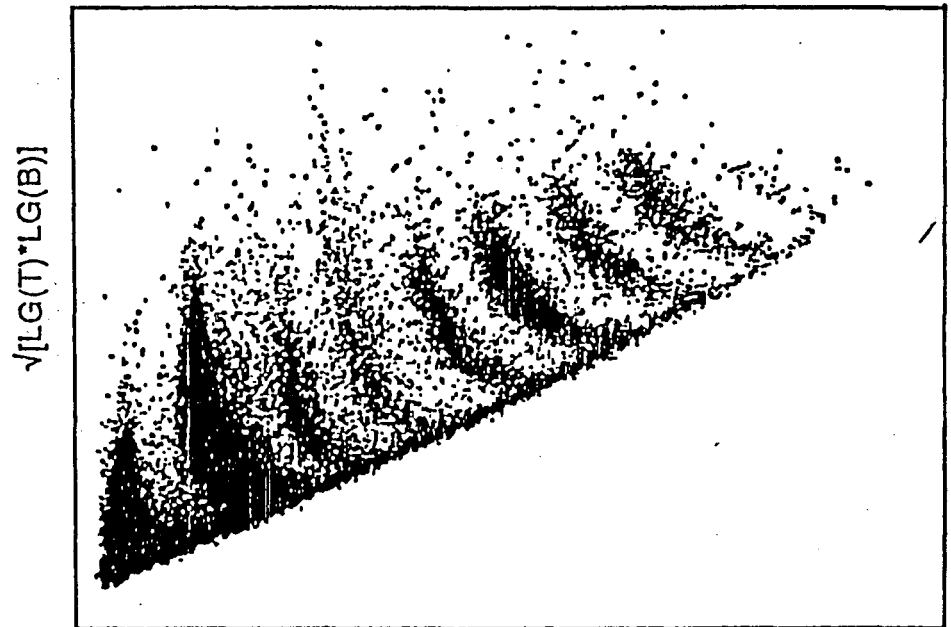


Fig.5 Raw short-gate versus long-gate plots for (a) the top and (b) the bottom photo-tubes. The same data is plotted in (c) after position corrections described in the text. Up to $Z=10$ could be clearly separated.

ΔE , $E(\text{tot})$ and Time-difference (position)
response for reaction products

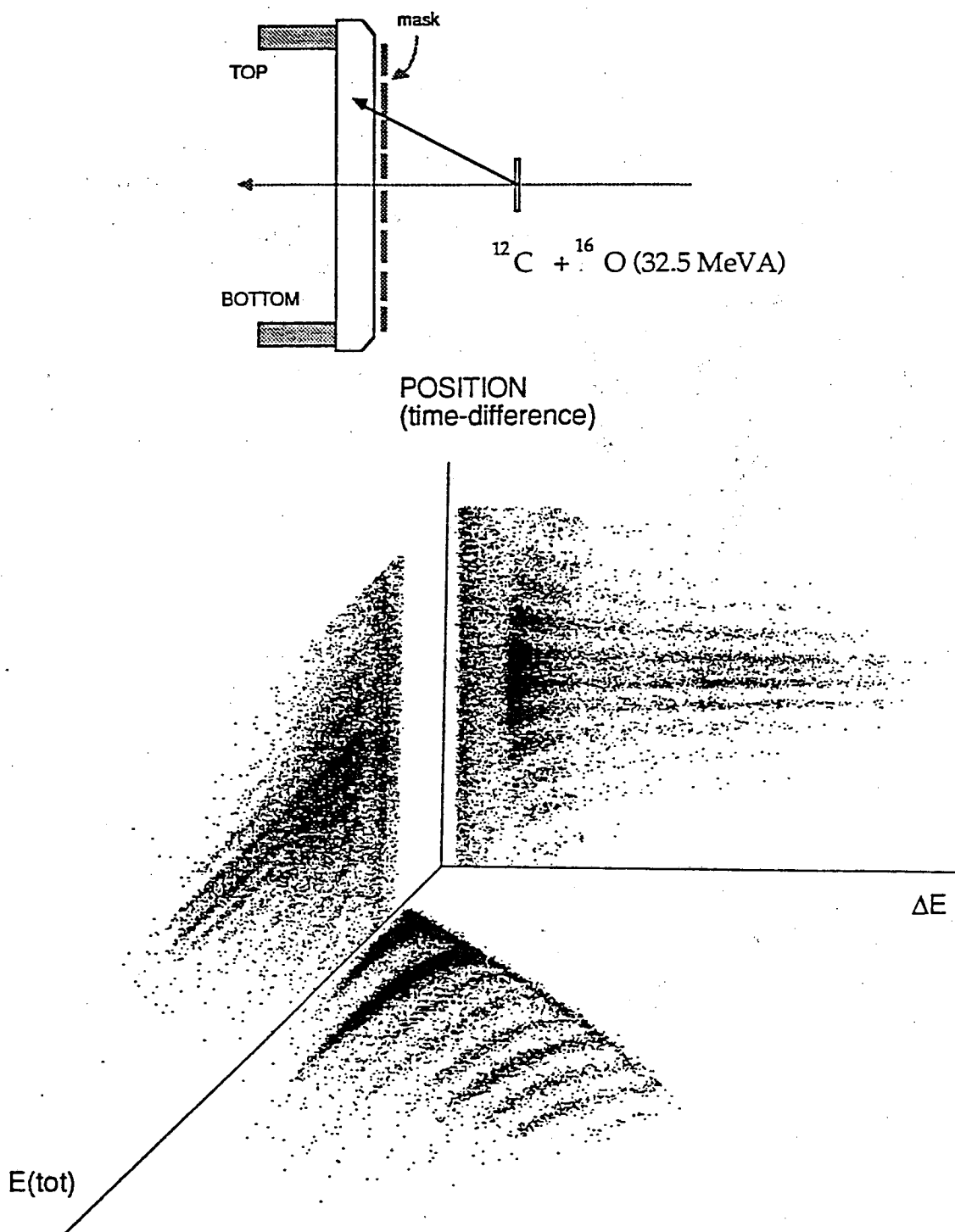


Fig.6 A 3-dimensional correlation plot for the relevant parameters obtained from the detector.

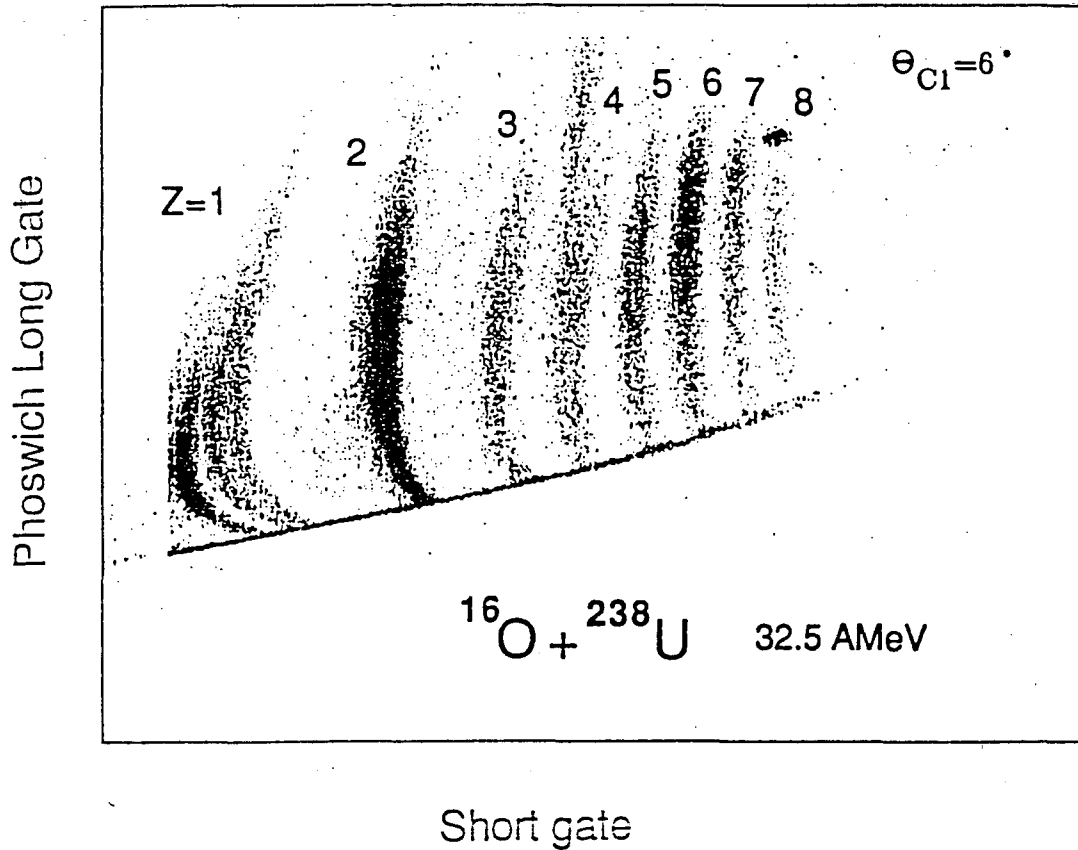


Fig.7 A sample short-gate versus long-gate plot for a non-position-sensitive phoswich detector in a detector array (Ref.2).

First order position-corrected ΔE and E

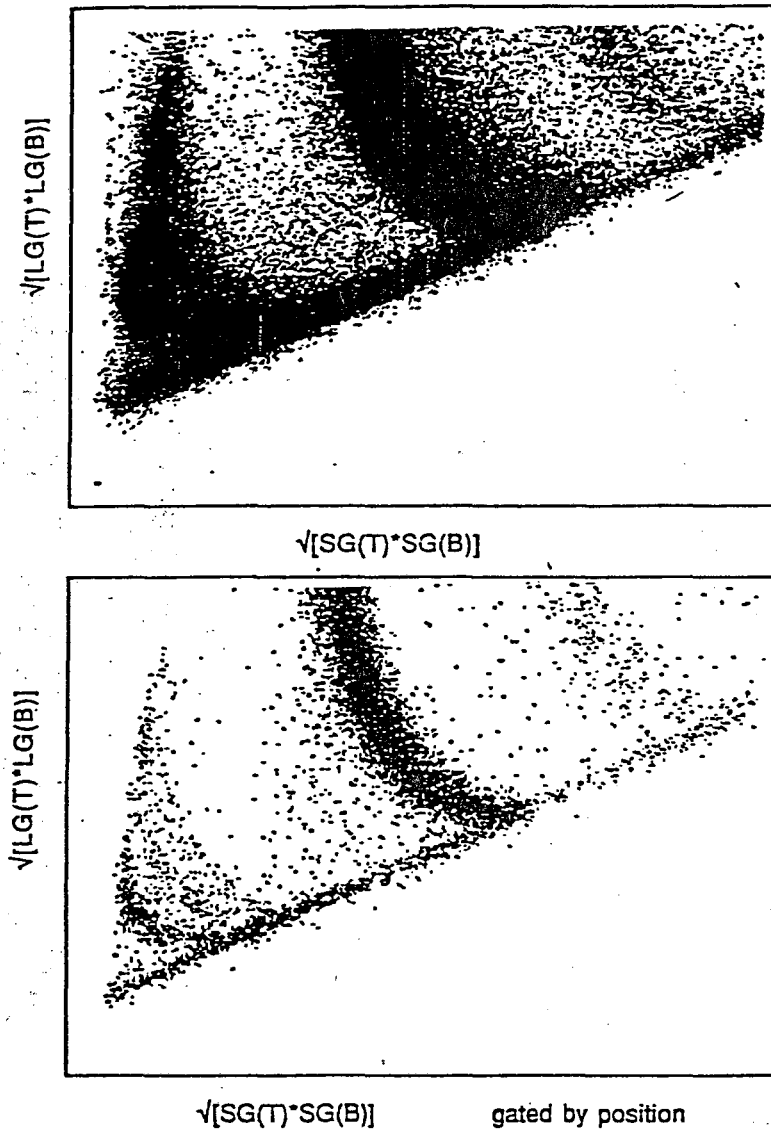


Fig.8 Comparison of ungated (a) and position-gated (b) PID spectra of the slice detector for Z=1 particles. Note the p,d,t resolution in (b) as compared with Fig.7.

Particle Energy versus Light Output

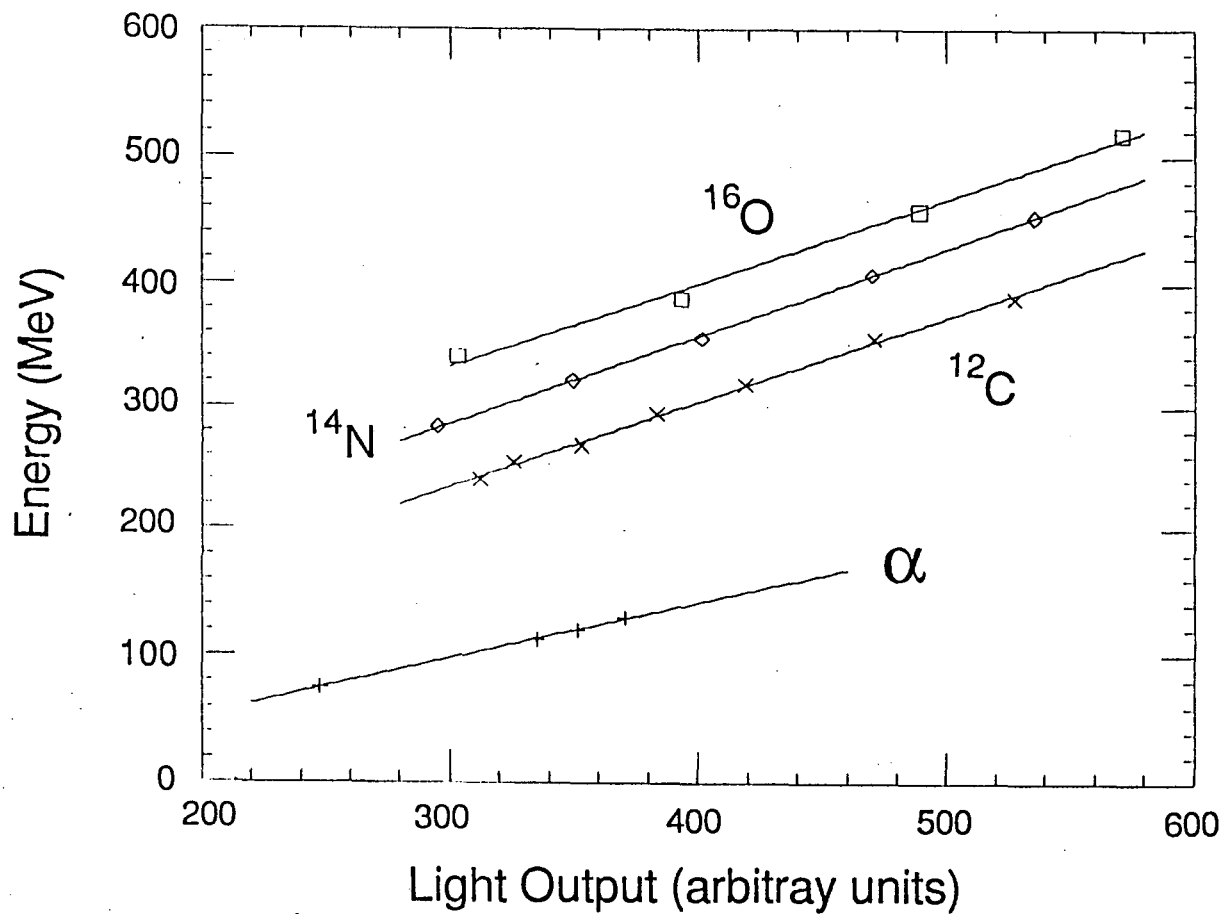


Fig.9 Light output response of the detector to different particles in the energy domain of 20-30 MeV/nucleon.

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