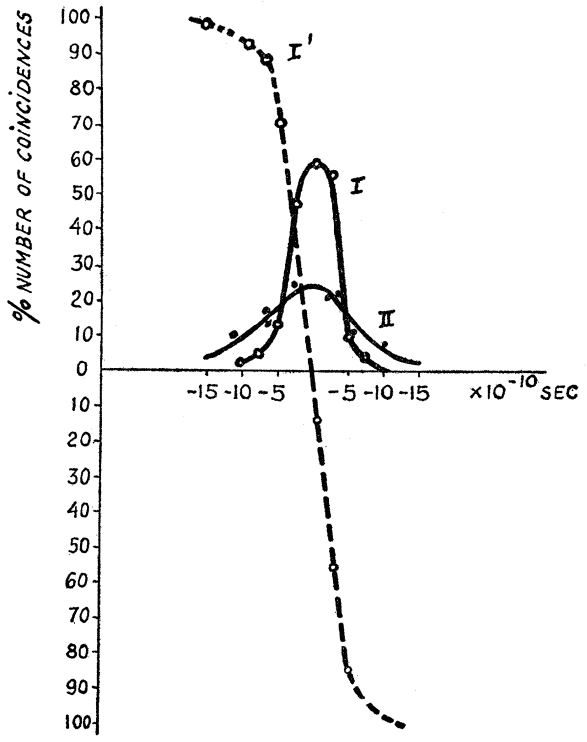

FIG. 2. Delayed coincidence curves obtained with Čerenkov counters. Curves I and I′ obtained with radiator type *B*. Curve II obtained with radiator type *A*.

To obtain short resolving times in spite of the prolongation of the pulses in the multipliers, amplifiers, and long cables, the differential coincidence circuit was used.[3] This gives positive outputs if the pulse from P_1 is earlier than that from P_2 (counting rate $D_+(T)$, T being the delay cable in one channel) and negative outputs if P_1 is later than P_2 [counting rate $D_-(T)$]. A separate diode bridge coincidence circuit[4] (resolving time 5×10^{-9} second) was used to count the total number of coincidence [counting rate $C(T)$], and to gate (10^{-6} second) the D_+ and D_- scalars. Plotting $R=(C_{\max}-D_+-D_-)/C_{\max}$ *versus* T, we obtain the normalized coincidence curves I and II in Fig. 2. It has been shown[5] that the area of such delay curves gives the resolving time (2τ) of the equipment independently of random time delays between the pulses from the two counters. The width of the delay curves ($2\tau'$=area divided by maximum value of R) measures a mean ($\bar{t}$) of the random time lags (t) which occur in the equipment including the counters. $\bar{t}$ for the separate channels is defined as follows:

$$\bar{t}=[(\tau'^2-\tau^2)/2]^{\frac{1}{2}}. \quad (1)$$

For Gaussian curves, which the data approximates, $\bar{t}$ and the root mean square time deviation, $\sigma_{\rm rms}$, have the connection

$$\sigma_{\rm rms}=(2/\pi)^{\frac{1}{2}}\bar{t}. \quad (2)$$

Curve I was taken with radiator type *B*. It gives $\tau=2.5\times10^{-10}$ second, $\tau'=4.4\times10^{-10}$ second, $\bar{t}=2.5\times10^{-10}$ second, and $\sigma_{\rm rms}=2.0\times10^{-10}$ second. Plotting, instead, $S=(D_+-D_-)/C_{\max}$ *versus* T we obtain the dotted curve I′, whose slope is 15 percent per 10^{-10} second. Curve II was taken with radiator type A. It gives $\tau=1.9\times10^{-10}$ second, $\tau'=7.5\times10^{-10}$ second, $\bar{t}=5.1\times10^{-10}$ second and $\sigma_{\rm rms}=4.0\times10^{-10}$ second.

The random time fluctuations ($\sigma_{\rm rms}$) for Čerenkov counters are shorter in spite of the smaller number of photoelectrons than those presently found for scintillation counters. Since the fluctuations in the circuitry are smaller than 10^{-10} second (checked by branched pulses from one tube), the fluctuations observed here must occur mainly in the first stages of the photomultiplier tubes. This view can be further supported by the difference between curves I and II. The light collection time for curve II is certainly negligible, yet $\bar{t}$ is about 2 times larger than for curve I. This is to be expected from the threefold reduction in the number of photoelectrons produced at the photocathodes. At the present time it is possible to measure time intervals to within an error of 10^{-11} second with these techniques,[6] provided one can limit statistical counting errors to one percent.

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The Absolute Determination of Resonant Energies for Radiative Capture of Protons by Beryllium in the Energy Range Below 520 kev

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THE electrostatic analyzer described previously[1] has been used to determine absolutely the proton energy for which resonances occur in the reaction $Be^9(p,\gamma)B^{10}$ in the energy range below 520 kev.

Thick target yield curves indicated that the yield below 200 kev was extremely small. The resonance postulated by Tangen[2] at about 150 kev therefore appears to be unlikely. The thick target curves could not be explained on the assumption of a single broad resonance at about 330 kev, since the yield continued to increase steeply up to 500 kev.

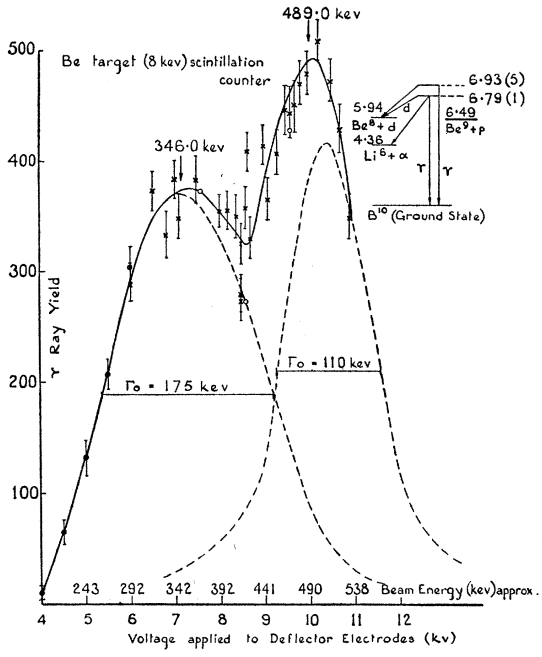

FIG. 1. Thin target (8-kev) yield curve for beryllium observed with a scintillation counter.

Tangen's tentative theory that the increased yield at higher energies was due to the increase in nonresonant radiation is not compatible with more recent work of Fowler, Lauritsen, and Lauritsen,[3] who found a $Be^9(p,\gamma)B^{10}$ resonance at 998 kev. This could be fitted closely to the Breit-Wigner formula even at the "tails," showing that nonresonant radiation at these energies was small. It follows that it must be even smaller in the energy range 400–500 kev.

In order to investigate this problem further, yield curves for thin targets of thickness in energy units between five and ten kev have been obtained. A typical curve is shown in Fig. 1. The efficiency of γ-detection has been increased by using a scintillation counter, and the targets were heated to 200°C and cold trapped. This has been found to be effective in eliminating carbon contamination.[1] The thin target yield curves were reproducible and had maxima at 341.8±2.0 kev and 485.0±3 kev. The rather large uncertainty was due to the great width of the resonances and consequent difficulty in determining precisely the points of maximum yield on the experimental curves.

The yield curve is thought to be due to two broad resonances incompletely resolved. Symmetrical curves obeying the Breit-Wigner formula and having maxima at 336.0±2 kev and 492.0±3 kev could be fitted closely to the experimental curve. The half-widths were 175±5 kev and 110±5 kev, respectively.

This corresponds to excited levels in the B^{10} nucleus at 6.79(1) Mev and 6.93(5) Mev, respectively. The figures in brackets lose their significance as absolute values because of the uncertainty in the Q value for the reaction (6.49 Mev).

Yield curves for this reaction have also been observed previously by Curran, Dee, and Petryilka.[4] They observed a highly asymmetric peak at about 350 kev and another at about 480 kev which they attributed to carbon contamination of the target. Tangen's value for the experimental peak was 330±10 kev. This was reduced to 310±10 kev by his corrections for the 150-kev resonance and the assumed increase in nonresonant radiation.

Thomas, Rubin, Fowler, and Lauritsen have investigated the $Be^9(p,d)Be^8$ and $Be^9(p,\alpha)Li^6$ yield curves. They observed resonant peaks at about 330 kev and 470 kev for the former reaction, and at 330 kev only for the latter. If it is assumed that the higher energy peak can be identified with the one observed in the present work, this would indicate that while the B^{10} level at 6.79(1) Mev is unstable both to α-particle and deuteron emission, α-particle emission is forbidden from the 6.93(5)-Mev level.

Walker[6] has observed γ-rays of energy 6.71 Mev from this reaction. The energy resolution of his spectrometer[7] was too low to separate γ-rays from the two levels suggested by the present work. Other investigations on the energy levels of this B^{10} nucleus have been reviewed by Hornyak *et al.*[8]

The author wishes to thank A. J. Salmon for his assistance in the design and operation of the scintillation counter.

He is also indebted to Dr. T. E. Allibone for permission to publish this letter.

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Saturation Effect of Plastic Scintillators*

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IT is known that for high energy losses the light output from a scintillating fluor is not proportional to the energy loss of the irradiating particle passing through it in the cases of organic crystals[1–7] and liquids,[8] and to a smaller extent, in the case of inorganic crystals.[9] Recently we made some measurements of this saturation effect in plastic scintillators and in phenylcyclohexane solution and in a NaI crystal making use of the negative pion beam and the outside proton beam of the Chicago cyclotron. The plastic samples were wrapped with 0.076-mm thick aluminum foil except for the end attached to a 5819 photomultiplier. Two scintillators were placed parallel to each other and perpendicular to the direction of the beam used. The output pulse of one phototube triggered the sweep of a synchroscope whose vertical plates were connected to the output of the second tube. The output pulse of the second tube was (a) observed visually and (b) recorded photographically with a specially designed camera. The two sets (a) and (b) of observations agreed within experimental errors. Absorbers of copper plates were placed between the scintillators to obtain particles of various energies. Calibration readings with Compton electrons of minimum ionization from the 1.3-Mev γ-rays of a Co^{60} source were intermittently made during the run. Figure 1 shows the variation of the light output from the scintillators *vs* energy loss. The phenylcyclohexane solution (containing 0.3 percent p-terphenyl and 0.001 percent diphenylhexatriene) was 3.4 cm in diameter and 3.4 cm in length. The NaI (Tl activated) crystal was 1.25-in. high, 2.25-in. wide and 0.5 in. in thickness. All the plastic samples were 1-in. square and 5-mm thick. The path length of the mesons and protons through the plastics was 0.5 mm. The specifications of the various plastics and the results obtained with the Co^{60} source and with the 5.3-Mev α-particles from a Po source are given in Table I.

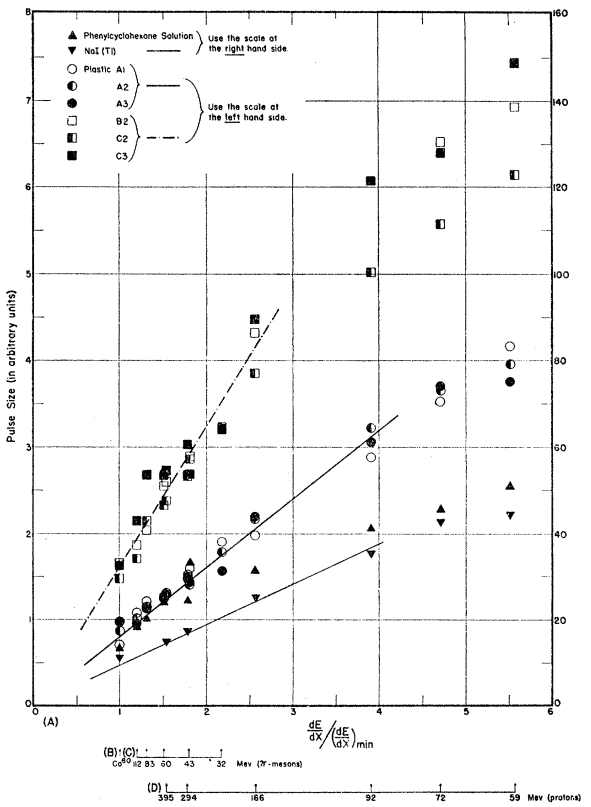

FIG. 1. Variation of light output from the scintillators with energy loss. The ordinate gives the pulse size (in arbitrary units) which is proportional to the light output. The abscissa gives the energy loss in the scintillators. The scale in row (A) represents the energy loss in units of the loss at minimum ionization. (B) refers to measurements with a Co^{60} source. Row (C) gives the energies of the pions in Mev corresponding to the energy losses represented in (A) and the scale in row (D) shows the proton energies corresponding to (A).