does not contribute any uncertainty. Note that whereas the two β^2 differ by a factor of about *four* near $N\sim 66$, this factor is more nearly *three* near $N\sim 44$, and perhaps only about *two* at $N\sim 26$. We have plotted our results in terms of β^2, a description which actually presupposes sizeable equilibrium deformations; however, a number of symptoms have been noted recently[16] attesting to the inadequacy of the "strong coupling" description in this region (e.g., departure from simple rotational level spacings and spin sequences). It is worth noting that the favored factor F (see foregoing) ranges from 10 to 60 for these nuclei; we encountered similar factors in odd-A nuclei.[3,17]

Bohr and Mottelson, in a recent study of rotational moments of inertia,[18] have offered an explanation of the $\beta_E-\beta_B$ discrepancy in the rare earths (which is evidently due to β_E) in terms of residual internucleon interactions. They also derive the following rough criterion to be satisfied by the energy of the first-excited state in order that one may expect a conventional rotational spectrum:

$$E_{2^+}<9.22\times 10^5/A^{5/3}\text{ kev.}$$

It is interesting to note that, in addition to the nuclei shown in Fig. 1, a number of our cases in Fig. 2 satisfy this condition.

A detailed report on the data of Fig. 2 is in preparation.

* The contents of this note were presented at the Ann Arbor Conference on Nuclear Structure, June 27–July 1, 1955 (unpublished).

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Mass Measurements of Particles and Existence of 1450 m_e Mesons

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(Received July 5, 1955)

Recent measurements we have made on fast particles from stars in G5 nuclear emulsions, 600μ thick, exposed to cosmic rays in balloon flights[1] give no indication of the existence of a group of mesons with mass about 1450 m_e, such as has been tentatively put forward by Fowler and Perkins.[2] Their work suggested a group intermediate in mass between conventional K mesons ($\simeq$965 m_e) and protons, with intensity about 8% that of protons. Some work by Husain and Pickup[3] gave similar indications, although the statistical accuracy was such that this group could have been a statistical fluctuation on the edge of the proton distribution.

Ionization (blob counting) and scattering measurements were made on tracks in three emulsions, each track being measured only in one emulsion. Blob density, b, was plotted against the scattering parameter, $p\beta$, thus giving curves corresponding to the different mass values, the individual standard errors of measurement being mostly 6–10% for scattering and $\gtrsim$1% for blob counting. Masses were then determined relative to the best proton line, and the combined results for 119 tracks in three emulsions are shown in the mass histogram in Fig. 1. The dashed curves superimposed on the histogram are normal distributions for a standard error of 9%. Scattering measurements were corrected for noise, and any distortion corrections were negligible. Some of the earlier results of Husain and Pickup[3] are included in the mass histogram, although most of the particles of "intermediate mass" are now excluded because they do not satisfy the minimum statistics.

It will be seen that the present results are adequately explained on the basis that the particles emitted in the stars are pions, K mesons ($\simeq$965 m_e), protons, deuterons, and tritons. One particle is also very probably a hyperon with mass 2470±210 m_e. The presence of a group with mass $\simeq$1450 m_e should, with our statistics, have given a small continuous distribution between the K mesons and protons, but there is no indication of this here, and we would conclude that 1450 m_e mesons, if they exist at all, are less frequent than conventional K mesons.

If the 1450 m_e group were real, the mesons must be unstable and, according to the path length observed by Fowler and Perkins,[2] they would have a lifetime long enough to come to rest before decaying (rather than decay in flight). The τ meson mass (965 m_e) and mode of decay into three pions are well known, and an examination of the collected mass data from emulsion work[4] on K mesons decaying at rest into single charged par-

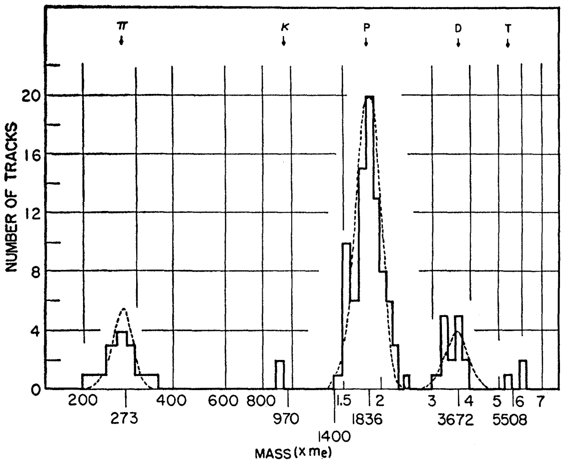

FIG. 1. Experimental mass spectrum of medium energy particles from stars: dashed curve is normal distribution with s.e. = 9%.

ticles indicates that at least 90% of the mesons have measured masses between 800 and 1200 m_e, consistent within the errors with a real mass about 965 m_e, and there seems to be no evidence for mass $\simeq$1450 m_e.

One example of a Λ^0 meson with energy several hundred Mev, decaying in flight, but not apparently connected with a star, was also found during the course of this work.

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Rotational Levels in the Beta Decay of Protactinium Isotopes

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ACCORDING to the Bohr-Mottelson unified model,[1] aspects of collective nuclear motion and of individual particle motion are coupled. In regions well removed from closed shells the coupling strength is very great and gives rise to the rotational excited states. For even-even nuclides the energies of these levels are proportional to 1.00:3.33:7.00. The levels are in the 2+, 4+, and 6+ states, respectively, and are de-excited by a cascade of $E2$ transitions. A number of these transitions has been already reported.[1]

In an investigation of the beta decay of protactinium isotopes[2] indications were found of rotational levels in the even-even daughter nuclides (U or Th). In Table I is listed a part of the results of beta-spectrometric measurements of Pa^{228}, Pa^{230}, Pa^{232}, and Pa^{234} (UZ) done in a 30-cm double-focusing magnetic beta-ray spectrometer.[3] More detailed information of these investigations will be published in *Physica* and in *Arkiv för Fysik*.

Column 2 shows the energy values of the gamma transitions which were supposed to be $E2$ radiations. According to Gellman *et al.*[4] and to Rose[5] low-energy $E2$ radiations are mainly converted in the $L_{\rm II}$ and the $L_{\rm III}$ subshells, the conversion probability in the $L_{\rm I}$ subshell being very slight. The theoretical $L_{\rm III}/L_{\rm II}$ conversion ratios[5] for $Z=85$ and $Z=55$ are represented in Fig. 1 by the drawn and the dashed lines, respectively. The dots indicate experimental data of $E2$ transitions in nuclides with $Z \geqslant 80$, while the triangles represent the data in nuclides with Z between 50 and 80. The $L_{\rm III}/L_{\rm II}$ conversion ratios we observed in the decay of the protactinium isotopes are represented by crosses. In most cases, our experimental data agree with the theoretical expectations for $E2$ transitions.

Assuming that these gamma rays de-excite the rotational levels above the ground levels of the daughter nuclides, the energy ratios of these levels are as given in column 4. These values agree with the predictions of the Bohr-Mottelson model. In column 5 the $\hbar^2/2J$ values were calculated from the lowest gamma-ray energies. The figures show a decrease of $\hbar^2/2J$ with increasing mass number, due to a larger deformation of the nuclides.

The Bohr-Mottelson model not only predicts the occurrence of rotational levels on the ground state, but also on higher excited states. In the odd-A nuclides, the presence of the latter has been discussed by Asaro and Perlman.[6] A first indication of it in the even-A nuclides was reported by Slätis *et al.*[7] In Pu^{238}, they found two close-lying levels at about 1.03 Mev above the ground state which were assumed to form a rotational band system. The energy difference between these levels agrees fairly well with the energy of the first rotational level above the ground state (44.1 kev).

In Th^{228} two excited levels were found at 1.070 and 1.125 Mev; a similar configuration was supposed to be

TABLE I. Results.

Daughter nuclide	E_γ (kev)	$L_{\rm I}$	$L_{\rm II}$	$L_{\rm III}$	$E(2+):E(4+):E(6+)$	$\hbar^2/2J$
$_{90}Th^{228}$	57.48	—	1	1.00	1:3.24	9.6
	128.64	—	1	0.75		
$_{90}Th^{230}$	52.8	—	1	0.85		
	(121.3)				1:3.30	8.8
$_{92}U^{232}$	47.2	—	1	0.90		
	109.1	—	1	0.45	1:3.31:6.80	7.9
	(175.3)	—	1			
$_{92}U^{234}$	43.0	—	1	0.85		
	99.2	—	1	0.75	1:3.31:6.87	7.2
	152.6	—	1	0.50		