TABLE I. Isotopic composition of xenon extracted from 371 g of a 1.5×10^9 year old mineral containing 70 percent Bi_2Te_3. The total xenon content was 2.6×10^{-7} cc S.T.P.

Mass	Bi_2Te No. 4	Normal	Diff.	Difference normalized
124	<0.004	0.0005	<0.0035	<0.29 —
126	<0.005	0.0005	<0.0045	<0.38 —
128	<0.014	0.011	<0.003	<0.25 —
129	≡1.000	0.1525	0.8475	71.66 ±0.7
130	0.0652	0.0236	0.0416	3.52 ±0.17
131	0.4088	0.1235	0.2853	24.12 ±0.3
132	0.1566	≡0.1566	≡0.0000	≡0.00 —
134	0.0651	0.0611	0.0040	0.34 ±0.25
136	0.0562	0.0519	0.0043	0.36 ±0.16

xenon has been given in the last row of the table. These percentages were calculated by assuming that all of the Xe^{132} present was normal (atmospheric), and by subtracting corresponding amounts at the other mass positions. It is evident from the table that, aside from the somewhat questionable excess xenon at mass 134 and 136 (possibly due to uranium fission), the excess xenon is distributed among the isotopes Xe^{129}, Xe^{130}, and Xe^{131}.

The excess Xe^{129} and Xe^{131} is probably caused by (n,γ) reactions on Te^{128} and Te^{130}. To account for the neutron "flux" required to produce this much xenon in 1.5×10^9 years, it is necessary to assume that there was considerable uranium in the immediate neighborhood of the tellurium mineral. Dr. Grip informs us that unusually large amounts of the uranium mineral thucholite have been found in the stope from which the Bi_2Te_3 was taken. Thus we ascribe the excess Xe^{129} and Xe^{131} to the proximity of such a deposit.

An interesting discrepancy appears in the ratio of Xe^{129} to Xe^{131} found in the sample. The present measurements show this to be 3.0, whereas one would expect a ratio of 0.6 from Seren's values[2] for the tellurium cross sections. One possible explanation is that Xe^{129} was also produced by the decay of small amounts of $I^{129}(\sim3\times10^7$ yr.) present in the mineral. This nuclide, as yet undetected in nature, may have been formed originally in amounts comparable to that of I^{127}.

The excess Xe^{130} is attributed to double beta-decay of Te^{130}. There appears to be no other explanation for its formation. Assuming an age of 1.5×10^9 years for the Bi_2Te_3, the excess Xe^{130} present corresponds to double beta-decay of Te^{130} with a half-life of 1.4×10^{21} years. This result is to be compared with theoretical half-lives of 6×10^{14} years and 10^{24} years. the former computed from the Majorana theory of the neutrino, and the latter from the Dirac theory. Both calculations are for allowed transitions with 1.6 Mev of available energy.

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The Effect of the Compressibility of the Earth on Its Magnetic Field

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IN his recent review of geomagnetism associated with the earth's interior Elsasser[1] has noted that the equation for the magnetic induction **B** in a fluid moving with velocity **v** reduces to

$$D\mathbf{B}/Dt=\mathbf{B}\cdot\mathbf{grad}\mathbf{v}-\mathbf{B}\ \mathrm{div}\mathbf{v}, \tag{1}$$

provided displacement currents and decay may be neglected. He remarks that "we may safely drop the last term, considering the fluid as incompressible," so that (1) reduces to a form "analogous to the well-known Helmholtz equations for the conservation of vorticity . . . ," whence results analogous to the Helmholtz theorems follow.

While the neglect of volume changes is doubtless justified for motions at uniform depth, the great pressure gradients conjectured to exist in the earth's interior make it rather unlikely that Elsasser's approximation is justified if there be any considerable vertical motion. In some of the models suggested by Bullard[2] a part of the flow is nearly vertical. The neglect of compressibility effects is quite unnecessary, however, to obtain the conservation theorems. Equation (1) as it stands is a youthful discovery of Lagrange,[3] and Nanson[4] observed that by using Euler's continuity equation

$$\mathrm{div}\mathbf{v}=-D\log\rho/Dt, \tag{2}$$

where ρ is the density, one can reduce it to the form

$$D(\mathbf{B}/\rho)/Dt=(\mathbf{B}/\rho)\cdot\mathbf{grad}\mathbf{v}. \tag{3}$$

Hence the analogs of the Helmholtz theorems for the present instance may be stated in the following form: (a) the lines of induction are material lines, (b) the flux of induction,[5] $\int_S\mathbf{B}\cdot d\mathbf{S}$, is constant in time for a material surface S.

Among the finest proofs of these results are those of Kirchhoff,[6] who derived them directly from Cauchy's formula[7]

$$\mathbf{B}/\rho=\mathbf{B}_0/\rho_0\cdot\mathbf{GRAD}\ \mathbf{r}, \tag{4}$$

where $\mathbf{B}_0$ and ρ_0 are the values of **B** and ρ at some arbitrary initial instant $t=0$, and **GRAD r** is the gradient of the present position field **r** with respect to the initial position field **R**. It is easy to see that (4) is the general solution of (3).

In fact, however, Zorawski[8] showed directly that a condition of the form (a) is both necessary and sufficient for the validity of theorems of the Helmholtzian type for the field **B**, irrespective of its physical significance.

Equivalent to (b) is the conservation of the circulation of the magnetic vector potential around a material circuit.

For motions in the earth's interior the case when the flow is rotationally symmetric and the field **B** is perpendicular to the axial planes might be relevant for part of the motion. Equation (4) then reduces to a result analogous to the vorticity convection theorem of Svanberg:[9]

$$B/r\rho=\mathrm{const}. \tag{5}$$

for each particle, r being the distance from the axis of symmetry. In motions of this type the effect of density changes appears in a particularly lucid way, tending to counteract the increase in B incident upon approaching the axis of symmetry.

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5 This result was discovered by Cowling. See W. M. Elsasser, Phys. Rev. **72**, 821 (1947), see p. 827.
6 G. Kirchhoff, *Vorlesungen über mathematische Physik: Mechanik* (Leipzig, 1876); second edition (1877); third edition (1883). See Vorlesung 15, §3.
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The Production of π^+-Mesons by Protons on Protons in the Direction of the Beam*

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A SIMPLE method[1] has recently been developed for measuring the differential production cross sections of positive and negative π-mesons when various nuclei are struck by high energy charged particles from the 184-in. synchrocyclotron. In this

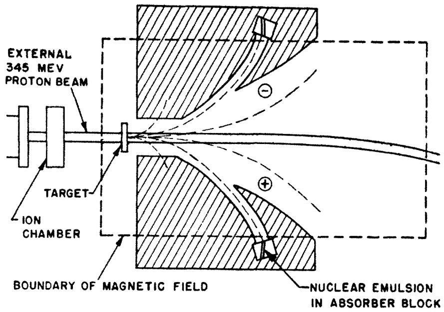

FIG. 1. Experimental arrangement for observing mesons produced in direction of proton beam.

method mesons and other particles leave a target and lodge in suitably arranged absorber blocks. Nuclear emulsions are embedded in these blocks to sample the population of stopped positive and negative π-mesons of all energies. The method is not very desirable for extreme forward angles, however, because the number of scattered beam particles relative to the number of mesons leaving the target rises very rapidly in the forward direction.

We have developed the following technique for making easy and reliable observations in the extreme forward directions. A magnetic field is produced in the region about the target (Fig. 1). The external beam from the cyclotron traverses this target after being integrated by a calibrated ionization chamber. Positive and negative π-mesons leaving the target in the forward direction circle out and away from the beam on opposite sides, as is indicated by the dotted trajectories in the diagram. Broad channels are cut symmetrically in massive Cu shielding blocks as shown in Fig. 1. Positive and negative mesons possessing appropriate momenta are able to traverse these channels and to lodge in the absorber blocks. Nuclear emulsions are embedded in these blocks, as in our previous method. Some protons and other heavy charged particles also are able to traverse the channel on the positive side, but those which do so must necessarily possess roughly the same momenta as do the mesons. Hence their ranges will be much smaller than the meson ranges, and a complete separation is obtained between the positive π-mesons and the "background" of heavy charged particles coming from the target. On the negative side no trouble is to be expected from electrons because they do not ionize sufficiently heavily to leave background tracks in the nuclear emulsions employed.

This technique for measuring meson production cross sections can easily be adapted for use over the entire meson energy and angular spectrum.

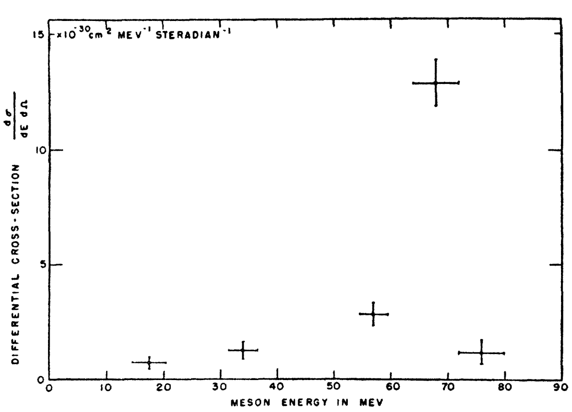

FIG. 2. Absolute differential cross section for production of π^+-mesons by 345-Mev protons on protons in the direction of proton beam.

In our first application of this method we have used the 345-Mev external proton beam from the cyclotron. Two different targets were used, of which one was pure carbon and the other was $(CH_2)_n$ (polyethylene). The angle of observation was $0°\pm5°$. By subtracting the carbon production cross section from that of the CH_2 molecule, we obtain the production from the two "free" protons. The preliminary results on the $p-p$ differential production cross section are presented in Fig. 2. These results are based on 231 π^+-mesons from the CH_2, and 176 π^+-mesons from the C. The errors indicated are statistical probable errors, and are valid for the relative values. The absolute scale is uncertain by ±15 percent.

The main features of this curve are the cut-off around 75 Mev and the high peak near this cut-off. From energy and momentum considerations no mesons should be formed with energies above 70 Mev if a free neutron and proton are the resulting heavy particles. However, at this meson energy, the heavy particles are ejected with the same momenta. G. F. Chew has suggested to us that the peak may be due to the attractive $n-p$ resonance interaction in the final states. If a deuteron is formed the cut-off would be around 74 Mev. We are now investigating, with improved energy resolution, the exact cut-off energy and possible fine structure in the peak.

We wish to thank Professor E. O. Lawrence for his interest and encouragement. We wish also to thank Mr. J. Vale and the cyclotron crew for making the bombardments.

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On the Positive and Negative Excess of the Penetrating Component of Cosmic Radiation at 3500 m above Sea Level

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WITH a device similar to that of Bernardini *et al.*[1] (Fig. 1), measurements on the "charge effect" of the hard component of cosmic radiation were made at the Laboratio della Testa Grigia, 3500 m above sea level, 45° 50′ north geographical latitude. We recorded the coincidences (AB) per minute between counters A and B, those (BC) between counters B and C, and the threefold coincidences (ABC) the cut-off energy of each lens is about 230 Mev for mesons. The crossed counters worked in anticoincidence. The axis of the telescope was inclined at 0° to the vertical, 60° east and 60° west of the vertical. The "charge effect" is the ratio

$$\delta=[2(N_{cc}-N_{dd})/(N_{cc}+N_{dd})]\times 100$$

where N_{cc} and N_{dd} refer, respectively, to the measurements taken with the magnetic lenses converging the positive or negative particles. Our present results, agreeing well with previous ones obtained at different altitudes, are summarized in Tables I and II. Lacking definite information on the meson spectrum at high altitudes, from Table I we can conclude only that the "positive

TABLE I. Charge effect in vertical direction.

Altitude above sea level (m)	δ_{AB}	δ_{BC}	δ_{ABC}
88	2.8 ± 1.3	2.5 ± 1.1	7.3 ± 1.3
3500	2.5 ± 0.7	7.2 ± 0.7	12.3 ± 0.4
5100	9.4 ± 1.4	11.4 ± 1.0	12.8 ± 3.0
7300	13.6 ± 1.2	5.0 ± 1.2	11.7 ± 3.5