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PRODUCTION OF π^{+}-MESONS BY X-RAYS AS A FUNCTION OF ATOMIC NUMBER

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The electronic method of meson detection developed by Steinberger and Bishop[1] has been used to study the relative cross sections of various elements for production of π^+-mesons by x-rays.

This study has been made at an angle of 90 ± 8 degrees to the x-ray beam, at approximately 317 Mev synchrotron energy, and at meson energies of 42 ± 7 Mev and 76 ± 6 Mev. The targets used were of identical shape and approximately 1.5 grams/cm^2 for both x-ray beam and mesons. With two exceptions the targets were of approximately equivalent meson range. The tin and lead targets were of about 1/10 the range and corrections of about 10 percent were required for this. The other corrections required for meson range, attenuation of the x-ray beam, impurities,[2] and decay of mesons in flight were of the order of 2 percent or less in most cases. No correction has been made for nuclear scattering or nuclear absorption of the mesons in the absorbers. The hydrogen cross section was obtained by a polyethylene, carbon subtraction.

The values of the relative cross sections per proton in the nucleus are tabulated below in arbitrary units.

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(1) J. L. Steinberger and A. S. Bishop, Phys. Rev. 78, 493 (1950)

(2) Analysis of purity done by Conway and Moore.

Element	42 Mev	Standard Deviation (percent)	76 Mev	Standard Deviation (percent)
H	6.6	17	8.07	11
Li	3.32	10	2.80	11
Be	2.82	11	2.13	10
B	3.02	11	2.28	15
C	2.60	6	1.93	5
Al	2.50	11	1.68	9
Cu	1.92	19	1.17	15
Sn	1.66	25	0.51	55
Pb	0.51	91	0.80	65

Additional non-statistical errors may be as large as 10 percent for hydrogen, tin, and lead and 5 percent for the others.

Steinberger, Panofsky, and Steller have made similar measurements as yet unpublished[3] on the yields of 75 Mev neutral mesons, using the method described in their recent paper.[4] Relative cross sections were obtained for hydrogen, lithium, beryllium, carbon, aluminum, copper, and lead. When these are tabulated in terms of the cross section per nucleon, $\frac{\sigma_{\pi^0}}{A}$, and arbitrarily normalized to the $\frac{\sigma_{\pi^+}}{Z}$ data at beryllium, all except hydrogen agree within the statistical error. Their hydrogen value is approximately the same as the lithium cross section per nucleon.

It is apparent from the above that at least two factors contribute to the decrease of $\frac{\sigma}{Z}$ with atomic number, one dependent on and the other independent of the meson charge. Drs. Chew and Lewis[5] have suggested that for π^+-mesons $\frac{\sigma}{Z}$ may be higher for hydrogen than for other elements since the exclusion principle limits the phase space available for the residual neutron. For other elements lower neutron states are occupied. Such an effect would be less with neutral mesons since the residual nucleon does not have a changed sign.

The further decrease of $\frac{\sigma_{\pi^+}}{Z}$ and $\frac{\sigma_{\pi^0}}{A}$ with atomic number is not incompatible with the possibility that only the nucleons on the surface of the nucleus take part in the production of mesons. The decrease cannot readily be explained by screening of the internal nucleons from the x-rays and hence possibly may be caused by an interaction of the outgoing π-mesons with the nucleons.

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(3) Steinberger, Panofsky, and Steller have been very kind in allowing me to quote their as yet unpublished work.

(4) J. Steinberger, W. K. H. Panofsky, and J. Steller, Phys. Rev. 78, 802, (1950)

(5) G. Chew, Private communication.

If it is assumed that such an interaction is the entire cause of the effect, a calculation can be made of the mean free path of mesons in nuclear matter. Although the calculated decrease is relatively insensitive to the mean free path assumed, the data are incompatible with a mean free path greater than approximately five times the proton radius.

It is a pleasure to acknowledge the assistance of Dr. J. Steinberger in all parts of this experiment. I wish also to express my gratitude to Professor E. McMillan and W. K. H. Panofsky for their interest and advice. My sincere thanks also go to Mr. Walter Gibbins and the entire synchrotron crew. This work was sponsored by the Atomic Energy Commission.

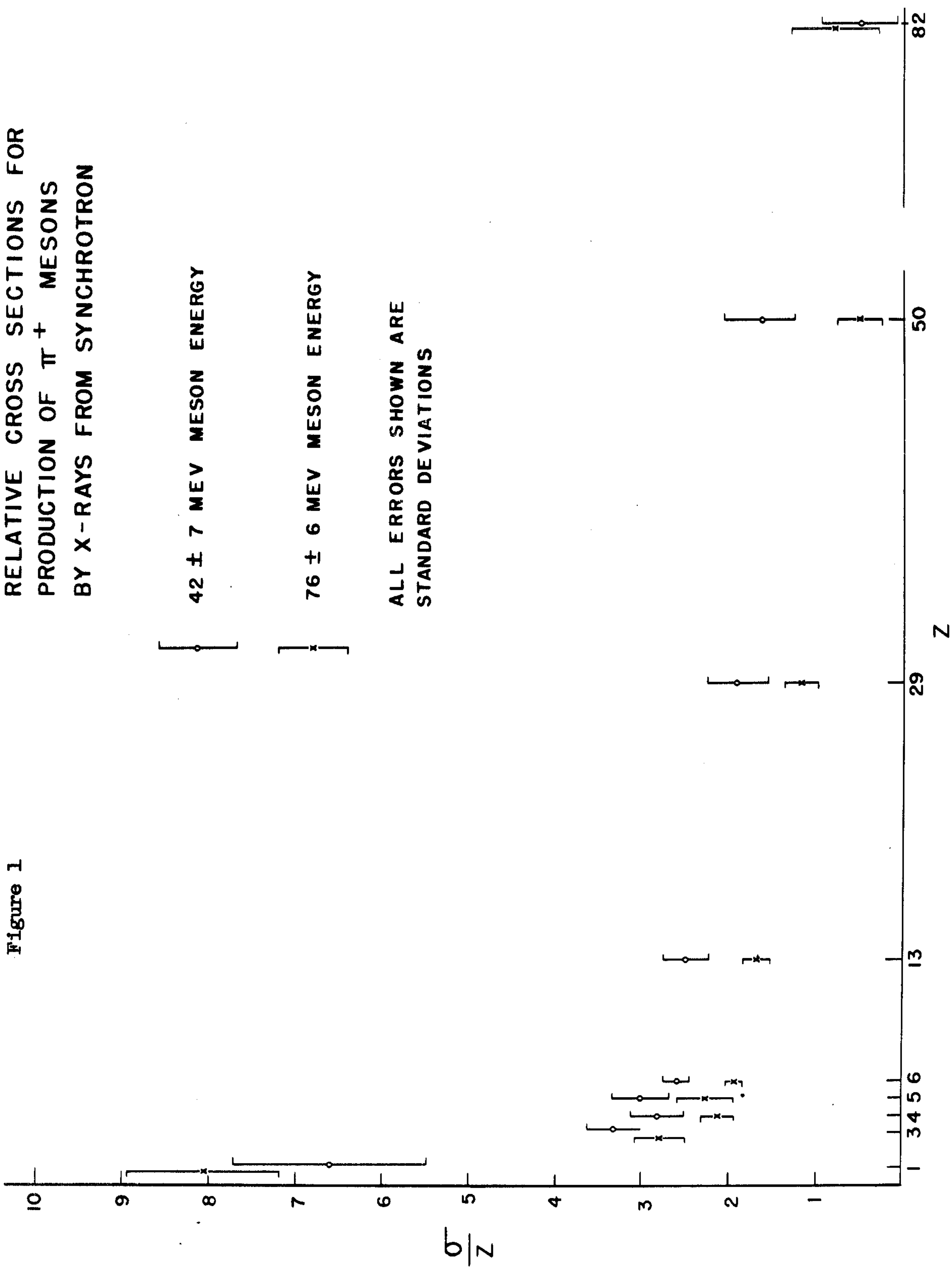

Figure 1

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