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π^0 PHOTOPRODUCTION FROM HYDROGEN AT 6 - 18 GeV*

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ABSTRACT

We have measured π^0 photoproduction between $t = -0.1$ and $-0.4\ (\mathrm{GeV}/c)^2$ at incident photon energies of 4, 6, 9, 12, and 18 GeV, using a high-pressure, low-temperature gaseous hydrogen target and a collimated bremsstrahlung beam from the 20 GeV Stanford Linear Accelerator. The process was identified by observing the recoil proton in the SLAC 1.6 GeV/c spectrometer. Including previously reported results from a liquid target, our measurements now cover the region from $t = -0.1$ to $-1.4\ (\mathrm{GeV}/c)^2$ at energies from 6 to 15 GeV.

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We have extended our previous measurements[1] of π^0 photoproduction to include four-momentum transfers down to $t = -0.1$ $(\mathrm{GeV/c})^2$. This was particularly interesting since at small values of $|t|$ the process is expected to be dominated by Reggeized ω exchange in the t-channel, even in models that rely heavily on cuts or absorption to explain the behavior of the cross section at larger $|t|$.

A collimated bremsstrahlung photon beam from the SLAC accelerator was passed through a gaseous hydrogen target and stopped downstream in a secondary-emission quantameter (SEQ), our primary beam monitor. This SEQ was frequently calibrated against a silver calorimeter, using a Cerenkov monitor as the intermediate standard. The yield of protons recoiling from the target was measured as a function of laboratory angle for various recoil momenta and incident beam energies, using the SLAC 1.6 GeV/c spectrometer. This is a 90° bend (254 cm radius), second-order corrected, weak-focusing magnet in which momentum and production angle of the incident charged particles are focused in a single plane normal to the central flight path.

A gas target was used because the lower limit on momentum transfers we could observe was set by multiple scattering and range of the low momentum recoil protons. To avoid too great a reduction in counting rate, the target cell was cooled to about 34°K and filled to a pressure of approximately 150 psi, giving a hydrogen density of $0.01\ \mathrm{gm/cm^3}$. The cell wall facing the spectrometer had a 0.025 cm thick mylar window, and the scattering chamber was connected directly to the spectrometer vacuum. Thus the amount of material between the center of the target and the spectrometer was reduced to about 0.002 of a radiation length.

Protons were identified by pulse height in a series of backing counters, and the proton trigger was then put in coincidence with a "missing-mass hodoscope" of eight counters in the spectrometer focal plane, each 25 cm × 1.9 cm × 0.6 cm thick. The first two backing counters, before the hodoscope, were only 0.08 cm thick, while the others were 1.25 cm thick. The hodoscope elements were rotated about the central flight path to align with (p, θ) lines of constant missing-mass according to the equation

$$MM^2 = 2E_0(p\cos\theta - T) - 2M_pT$$

where p, θ, T are the proton momentum, production angle, and kinetic energy, and E_0 is the beam energy.

With a bremsstrahlung beam and fixed spectrometer field, the proton rate across the hodoscope will show a step at the threshold for production of a single neutral particle such as π^o. An example is shown in Fig. 1. The dashed lines show a least-squares fit assuming smooth backgrounds from "ghost protons" and multipion production. The π^o step heights so obtained were converted to cross sections taking into account the spectrometer acceptance, beam monitor calibrations, and various corrections. The total correction was typically between 10 and 20%, and the overall normalization uncertainty is about 5%. Since the experimental resolution was not sufficient to separate π^o photoproduction from proton Compton scattering, it was necessary to make a further correction using our recent measurements of the Compton effect.[2] For consistency, our previous measurements with a liquid target (out to $t = -1.38$ GeV^2) were included in the analysis. Details are available in Ref. 3.

At each value of t, the differential cross section versus photon energy on a log-log scale may be fitted to a straight line with a good chi-square. An example is shown in Fig. 2 for $t = -0.3$ (GeV/c)^2. The effective Regge α has been obtained by setting the slope of the straight line equal to $2\alpha-2$. To provide angular distributions at standard energies, and as an average over the numerous individual points, values of $d\sigma/dt$ were taken from these straight-line fits at fixed values of $E_0 = 6$, 9, 12, and 15 GeV. The results are listed in Table I and plotted in Fig. 3. The distributions show a "dip" around $t = -0.5\ (\mathrm{GeV}/c)^2$, not changing much with energy. Differences from our earlier publications are mainly due to the Compton correction, for which only estimates were previously available. The behavior of the dip is quite sensitive to this correction, but it should be noted that our Compton measurements contain essentially the same systematic errors as the π^0 results.

The effective trajectory $\alpha(t)$ is plotted in Fig. 4. A least-squares fit to a straight-line gives $\alpha(t) = 0.18 + 0.26\ t$, although from pure ω-exchange we would expect $\alpha(t) = 0.45 + 0.9\ t$. The measured values of α seem to indicate that the cross section falls off somewhat slower than s^{-2} for small t-values, in qualitative agreement with most theories.[4] It remains to be seen, however, if these models can give a quantitative fit to all the results now available on π^0 photoproduction.

We are indebted to J. Grant, E. Cheatham and J. Schroeder who gave us invaluable support in the preparation of the experiment. We are grateful to J. Cochran for his help in the design of the high-pressure gas target. We wish to acknowledge the help we received from the operation and support crew at the Stanford Linear Accelerator Center, especially A. Golde.

TABLE I

$\gamma + p \rightarrow \pi^0 + p \qquad \frac{d\sigma}{dt}\ ,\ \mu b/(GeV/c)^2$

$\lvert t \rvert, (GeV/c)^2$	E_o = 6 GeV	E_o = 9 GeV	E_o = 12 GeV	E_o = 15 GeV
.1	1.13 ± .11	.59 ± .07	.37 ± .05	
.15	.86 ± .06	.47 ± .05	.30 ± .04	.22 ± .03
.2	.67 ± .05	.33 ± .04	.20 ± .03	.137 ± .020
.3	.34 ± .04	.138 ± .020	.073 ± .013	.045 ± .009
.4	.130 ± .014	.058 ± .008	.033 ± .006	.021 ± .005
.5	.078 ± .010	.039 ± .006	.024 ± .004	.016 ± .003
.6	.095 ± .012	.045 ± .008	.027 ± .006	.018 ± .004
.7	.122 ± .010	.054 ± .005	.030 ± .003	.019 ± .003
.8		.066 ± .013	.038 ± .003	.024 ± .003
.9	.140 ± .007	.063 ± .004	.036 ± .003	.0231 ± .0025
1.1	.129 ± .005	.051 ± .003	.027 ± .002	.0160 ± .0013
1.38	.0849 ± .0045	.0321 ± .0024	.0161 ± .0013	.0094 ± .0009

REFERENCES

1. R. L. Anderson et al., Phys. Rev. D1, 27 (1970).
2. R. L. Anderson et al., to be published.
3. J. Johnson, Ph.D. Thesis, Stanford University (1970), also Report No. SLAC-124.
4. K. Lübelsmeyer in Proceedings of the 4th International Symposium on Electron and Photon Interactions at High Energies, Liverpool (1969).

FIGURE CAPTIONS

1. The observed proton yield, in counts per hodoscope element per 10^{12} equivalent quanta, is plotted versus $(\text{missing-mass})^2$ in the vicinity of the π^0 threshold. The photon end-point energy is 6 GeV and $t = -0.15$ $(\text{GeV/c})^2$.
2. For $t = -0.3$ $(\text{GeV/c})^2$, $d\sigma/dt$ in $\mu b/(\text{GeV/c})^2$ is plotted versus photon end-point energy in GeV; both scales are logarithmic. The solid line is a fit of the form $d\sigma/dt \sim E_0^{2\alpha-2} \sim \left(s-M_p^2\right)^{2\alpha-2}$; the value of α is listed.
3. $d\sigma/dt$ in $\mu b/(\text{GeV/c})^2$ is plotted versus t for incident photon energies of 6, 9, 12, and 15 GeV. The dashed lines are only to guide the eye.
4. Values of the effective α are plotted versus t. The solid line is a least-squares fit giving $\alpha = 0.18 + 0.26\ t$. The dashed line indicates the $\alpha(t)$ as predicted by pure ω-exchange.

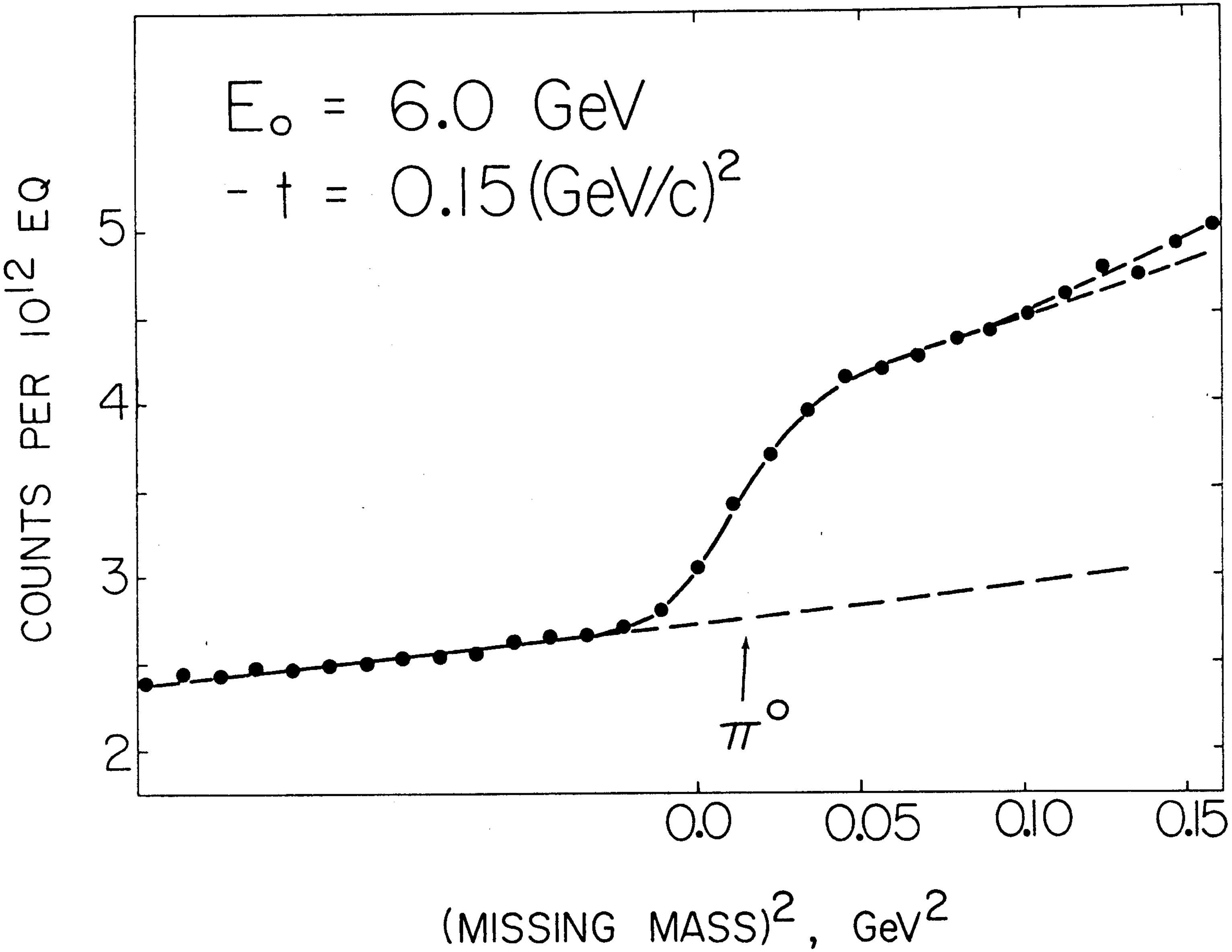

Fig. 1

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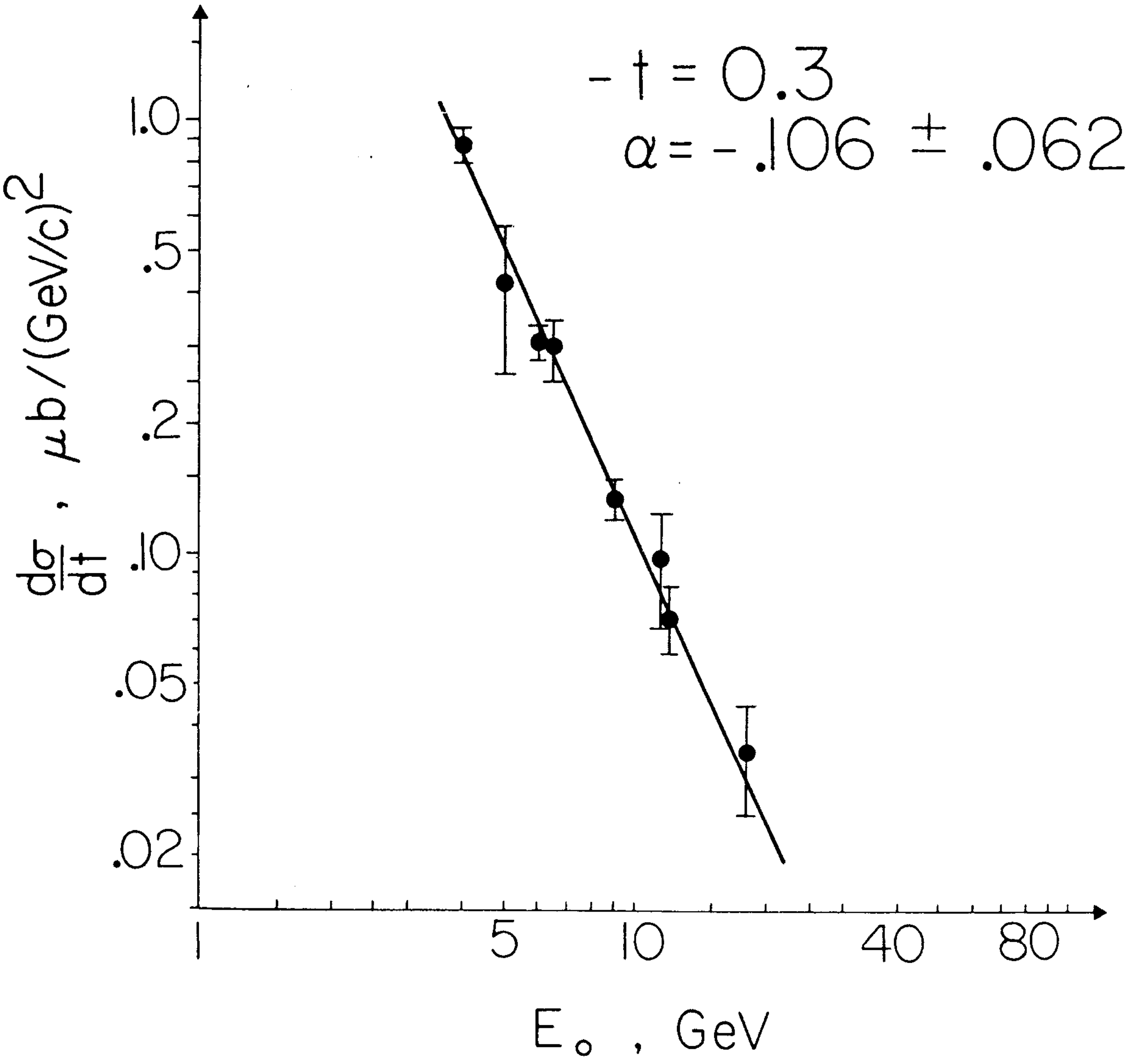

Fig. 2

[illegible] file

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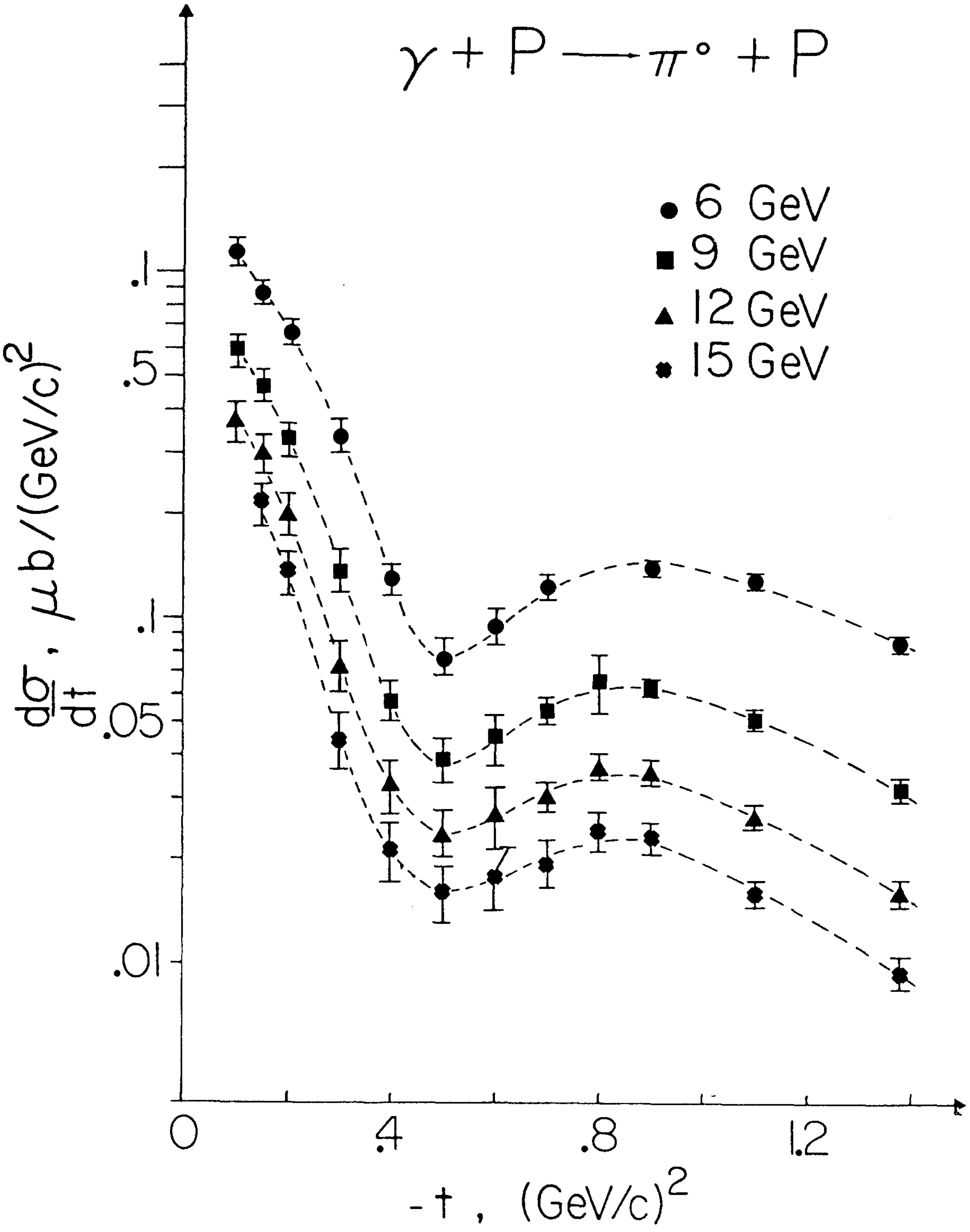

Fig. 3

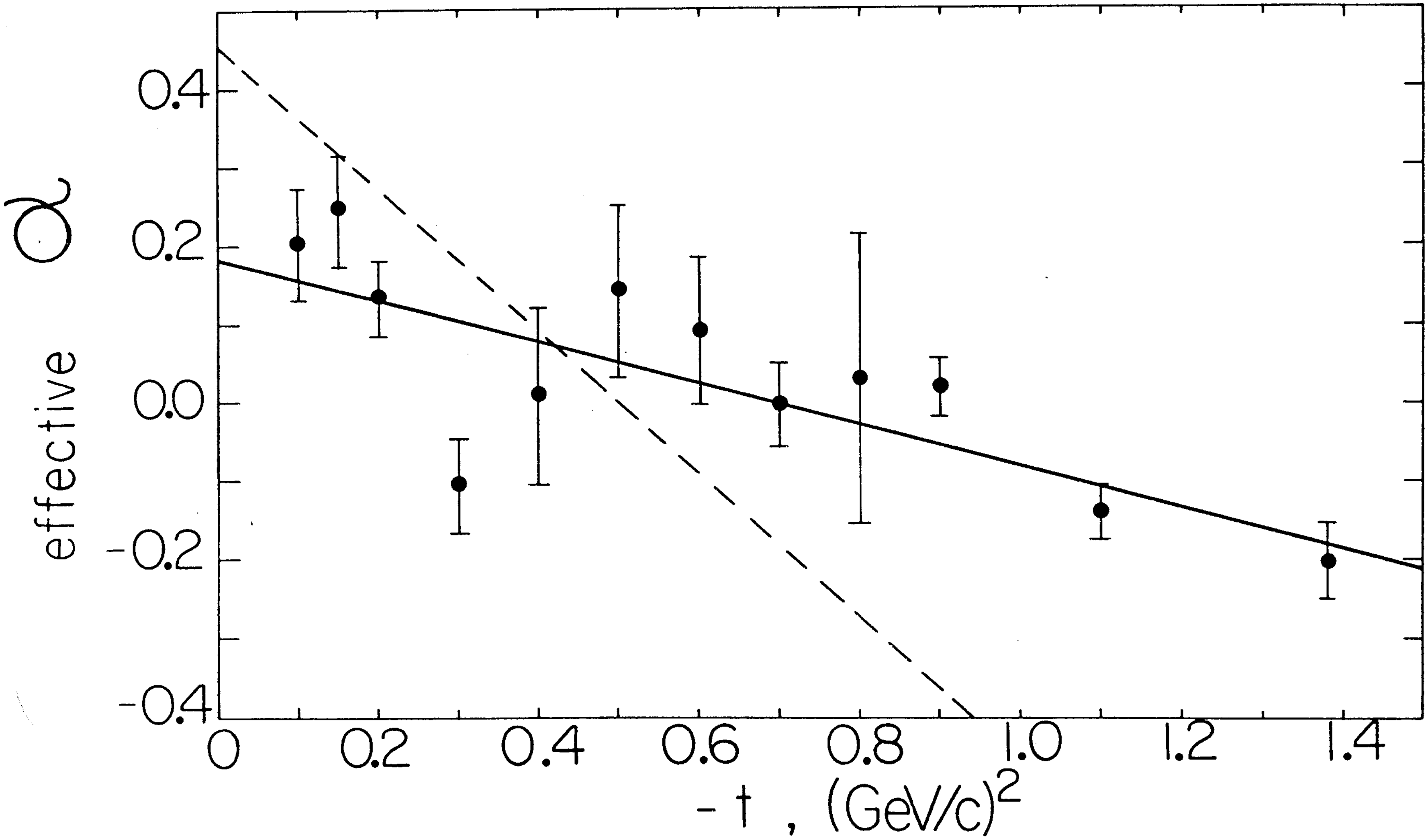

Fig. 4