Fermi National Accelerator Laboratory

FERMILAB-Conf-91/112

Hyperon Radiative Decays, the α parameter of $\Sigma^+ \to p\gamma$ First Results from Fermilab E761

The E761 Collaboration

presented by

Maurice Foucher
Yale University
Fermi National Accelerator Laboratory
P.O. Box 500
Batavia, Illinois 60510

May 1991

* Presented at the *XXVIth Rencontres de Moriond, High Energy Hadronic Interactions,* March 17 - 23, 1991, Les Arcs, Savoie - France.

Operated by Universities Research Association Inc. under contract with the United States Department of Energy

HYPERON RADIATIVE DECAYS, THE α PARAMETER OF $\Sigma^+ \to p\gamma$ FIRST RESULTS FROM FERMILAB E761

Maurice Foucher
Yale University
Current Address: E761 MS219, Fermilab, Batavia IL 60510, U.S.A.

Abstract

A high statistics study of the hyperon radiative decay, $\Sigma^+ \to p\gamma$, has been performed in the Proton Center charged hyperon beam at Fermilab. A preliminary result for the α parameter for $\Sigma^+ \to p\gamma$ is presented. We find the α parameter to be -0.69 ± (0.11 statistical) ± (0.11 ± 0.11 systematic).

A high statistics study of one of the hyperon radiative decays, $\Sigma^+ \to p\gamma$, has been performed by the Fermilab E761 collaboration[1]. We report here a preliminary result for the α asymmetry parameter for $\Sigma^+ \to p\gamma$.

Hyperon radiative decays represent a class of baryon decays which require both weak and electromagnetic contributions. These decays test the interplay of electroweak and strong interactions as applied to the underlying quark structure of baryons. Hyperon radiative decays have been analyzed theoretically using single quark transitions, internal W exchange, penguin diagrams, long distance effects, and QCD sum rules.[2] Some of the diagrams that contribute to these decays are shown in Figure 1.

What is the α parameter in hyperon radiative decays? In the rest frame of a polarized Σ^+, the angular distribution of the decay proton with respect to the Σ^+ polarization direction is given by:

$$\frac{dN}{d\Omega} = \frac{A(\theta)\,N_O}{4\pi}\,[1 + \alpha P_\Sigma \cos\theta] \qquad (1)$$

where α is the asymmetry parameter we are measuring, $A(\theta)$ is the acceptance, P_Σ is the polarization of the Σ^+, N_O is the total number of events, Ω is the solid angle, and θ is the angle between the proton momentum and the Σ^+ polarization direction.

Hyperon radiative decay experiments are difficult to perform. The branching ratio[3] of $\Sigma^+ \to p\gamma$ is 1.25×10^{-3}. The branching ratio[3] for $\Sigma^+ \to p\pi^\circ$ is 0.5157. Therefore the primary background occurs at a rate ≈400 times the signal. This provides a challenge to the trigger and the analysis. The α parameter[3] for $\Sigma^+ \to p\gamma$ is $-0.83 \pm .12$ based on 3 experiments[4] with a total of 297 events. The α parameter[3] for $\Sigma^+ \to p\pi^\circ$ is $-0.980 \pm .016$. Since the background has a large asymmetry it is important that the experimenters understand and control this background.

A schematic view of the experiment is shown in Figure 2. It consists of 3 spectrometers, one for each of the particles in the decay, $\Sigma^+ \to p\gamma$, a hyperon , a baryon , and a photon spectrometer. The hyperon spectrometer measures the Σ^+ momentum to 0.7% (σ). It is made up of 3 stations of silicon strip detectors (SSD) and 1 magnet. The baryon spectrometer measures the proton momentum to 0.2%(σ). It is made up of 4 stations of proportional wire chambers (PWC) and 3 magnets. The angular resolution of both the hyperon and baryon spectrometers is $\approx 10\mu$rad(σ). The photon spectrometer measures the photon position and energy. We measure the photon position by converting the photon in two steel plates, each 2.54 cm thick. The high energy charged component of the produced shower follows closely the original photon direction. We use transition radiation detectors (TRD) to detect this high energy component. The threshold of the TRD is about 2.5 GeV. Wire chambers are used to supplement the TRD.

An 800 GeV/c proton beam impinges onto the Cu target at a finite targetting angle of ±4 mrad horizontal, producing a 375 GeV/c polarized hyperon beam. The polarization is along the direction given by the cross product of the incident proton momentum and the outgoing Σ^+ momentum. We can reverse the targetting angle and thus reverse the polarization direction. This gives us 2 sets of data, spin up and spin down and allows us to cancel biases in the apparatus by averaging over them. The center of mass angular distribution of the proton is given by (1). We take the ratio of the difference over the sum of the spin up and spin down data. This yields

$$\alpha P_\Sigma \cos\theta \quad \equiv \quad A\cos\theta \qquad (2)$$

where A is defined as the asymmetry. We average over $\cos\theta$ to determine A. From the measured asymmetries for both decay modes $\Sigma^+ \to p\pi^0$ and $\Sigma^+ \to p\gamma$ we find for α_γ

$$\alpha_\gamma = \frac{A_\gamma}{A_0}\ \alpha_0 \qquad (3)$$

where α_0 is -0.980 ± 0.016. We measure A_γ and A_0 from our data sample we collected in the 1990 Fermilab fixed target run. Shown in Figure 3 is the missing mass squared distribution from our full data sample assuming the decay $\Sigma^+ \to p + X$. After making reasonable track fitting and kinematic cuts, we find a value for A_0 = -0.1135 ± 0.0003 (statistical) ± 0.0120 (systematic). Our preliminary systematic error is taken from the scatter in the run to run measurements and probably can be decreased significantly.

From Figure 3 it is clear that the dominant background is $\Sigma^+ \rightarrow p\pi^0$. How do we separate $\Sigma^+ \rightarrow p\gamma$ from $\Sigma^+ \rightarrow p\pi^0$? Assuming the decay $\Sigma^+ \rightarrow p + X$ we project the missing neutral direction onto the photon spectrometer. We form a TRD χ^2 of the miss distance from the projected neutral track to the closest wire to the track. $\Sigma^+ \rightarrow p\gamma$ should have a low TRD χ^2. $\Sigma^+ \rightarrow p\pi^0$ should have a larger TRD χ^2 because of the finite opening angle of the photons from the π^0 decay. We also require that there be a large amount of local energy in the photon calorimeter around the projected neutral track. Shown in Figure 4 is the missing mass squared distribution for TRD $\chi^2 < 100$ and TRD $\chi^2 > 200$ normalized in the mass squared region 0.0072 to 0.0100 GeV^2/c^4. The mass squared distribution with TRD $\chi^2 > 200$ is a good model to our background. A clear peak is seen at the mass squared of the photon.

We construct 4 regions:

signal	$-0.0040 < m^2_x < 0.0040$ GeV^2/c^4	TRD $\chi^2 < 100$.
background	$-0.0040 < m^2_x < 0.0040$ GeV^2/c^4	TRD $\chi^2 > 200$.
normalization	$0.0072 < m^2_x < 0.0100$ GeV^2/c^4	TRD $\chi^2 < 100$.
normalization	$0.0072 < m^2_x < 0.0100$ GeV^2/c^4	TRD $\chi^2 > 200$.

We define the signal fraction, f, to be the number of $\Sigma^+ \rightarrow p\gamma$ events in the signal region over the total number of events in the signal region. We find f = 0.6767 ± .0024. The asymmetry in the signal region is made up of 2 terms, the asymmetry of $\Sigma^+ \rightarrow p\gamma$ times f and the asymmetry of the background times (1-f). If we invert this we get this expression for the asymmetry of $\Sigma^+ \rightarrow p\gamma$,

$$A_\gamma = \frac{A_s-(1-f)A_b}{f} \qquad (4)$$

where A_s is the asymmetry in the signal region and A_b is the asymmetry in the background region. We find $A_s = -0.087 \pm .008$ and $A_b = -0.103 \pm .007$. Thus we find $A_\gamma = -0.079 \pm .012$. Therefore we find for $\alpha_\gamma = -0.69 \pm$ (0.11 statistical) ± (0.11 ± 0.11 systematic.) This is based on 37816 ± 261 events. We have performed only preliminary systematics studies therefore we are quoting a range of 0.00 to 0.22 for the systematic error. We believe this is our best present estimate of the systematic error.

We find for the α parameter for $\Sigma^+ \rightarrow p\gamma$ a value of -0.69 ± (0.11 statistical) ± (0.11 ± 0.11 systematic.) This is a preliminary result. There are many improvements that we foresee. If we can reduce our systematic error to essentially zero and fully exploit the statistics of our sample the smallest statistical error we can expect is ±0.07.

This work was supported by the U. S. DOE under contract #DE-AC02-76CH03000.

REFERENCES

1. Members of the Fermilab E761 collaboration: R. Carrigan, P. S. Cooper, H. Gottschalk, J. Lach, A. Morelos (Graduate student from CINVESTAV-IPN) of Fermilab; Li Yunshan, Tang Fukun, Lang Pengfei, Li Chengze, Shi Huanzhang, Zhao Wenheng, Dai Lisheng, Zheng Shuchen, Zhong Yuanyuan, Yan Jie of Institute of High Energy Physics Beijing, PRC; N. F. Bondar, A. S. Denisov, V. L. Golovtsov, V. T. Grachev, A. V. Khanzadeev, V. M. Samsonov, N. K. Terentyev, I. I. Tkatch, L. N. Uvarov, A. A. Vorobyov of Leningrad Nuclear Physics Institute Leningrad, USSR;P. A. Goritchev, M. A. Kubantsev, V. N. Lebedenko of Institute of Theoretical and Experimental Physics Moscow, USSR; T. Dubbs, E. McCliment, C. Newsom of University of Iowa; I. F. Albuquerque, C. Escobar, P. Gouffon, J. Mahon of University of Sao Paulo, Brazil; M. Foucher of Yale University; A. M. F. Endler of Centro Brasileiro de Pesquisas Fisicas Rio de Janeiro, Brazil; M. C. Pommot Maia of Conselho Nacional De Pesquisa CNPq (on a leave of absence from UFRJ, Rio de Janeiro), Brazil; D. Chen of State University of New York; V. J. Smith of H. H. Wills Physics Laboratory University of Bristol, United Kingdom.
2. M. K. Gaillard, X. Q. Li, and S. Rudaz, Phys. Letters **158B**, 158(1985)
   I. I. Balitsky, V. M. Brawn, A. V. Kolesnichenko, Sov. J. Nucl. Phys. **44**, 1028(1986)
   D. Palle, Phys. Rev. D **36**, 2863(1987)
   Y. I. Kogan and M. A. Shifman, Sov. J. Nucl. Phys. **38**, 628(1983)
   F. J. Gilman and M. B. Wise, Phys. Rev. D **19** 976(1979)
   C. Goldman and C. O. Escobar, Phys. Rev. D **40** 106(1989)
   M. D. Scadron and M. Visinescu, Phys. Rev. D **28**, 1117(1983)
3. Particle Data Group: Phys. Letters B **239** II.22(1990)
4. M. Kobayashi et al, Phys. Rev. Letters **59**, 868(1987)
   A. Manz et al, Phys. Letters **96B**, 217(1980)
   L. K. Gershwin et al, Phys, Rev. **188**, 2077(1969)

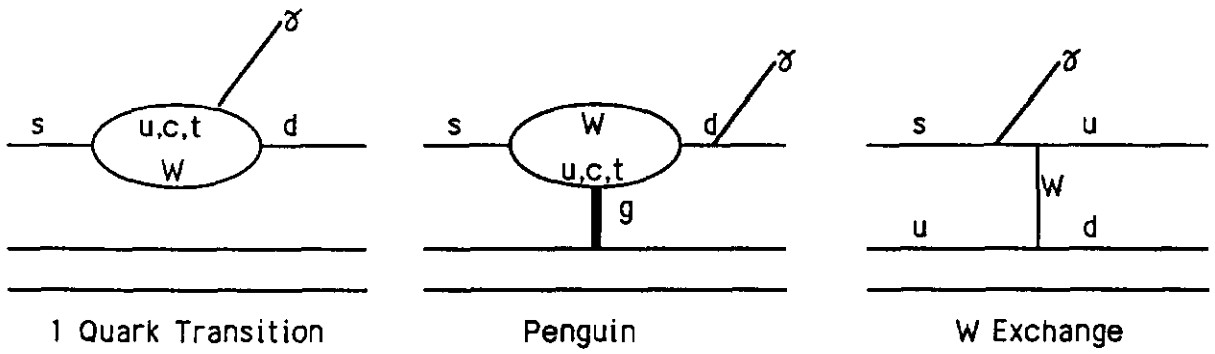

Figure 1: Diagrams contributing to hyperon radiative decays

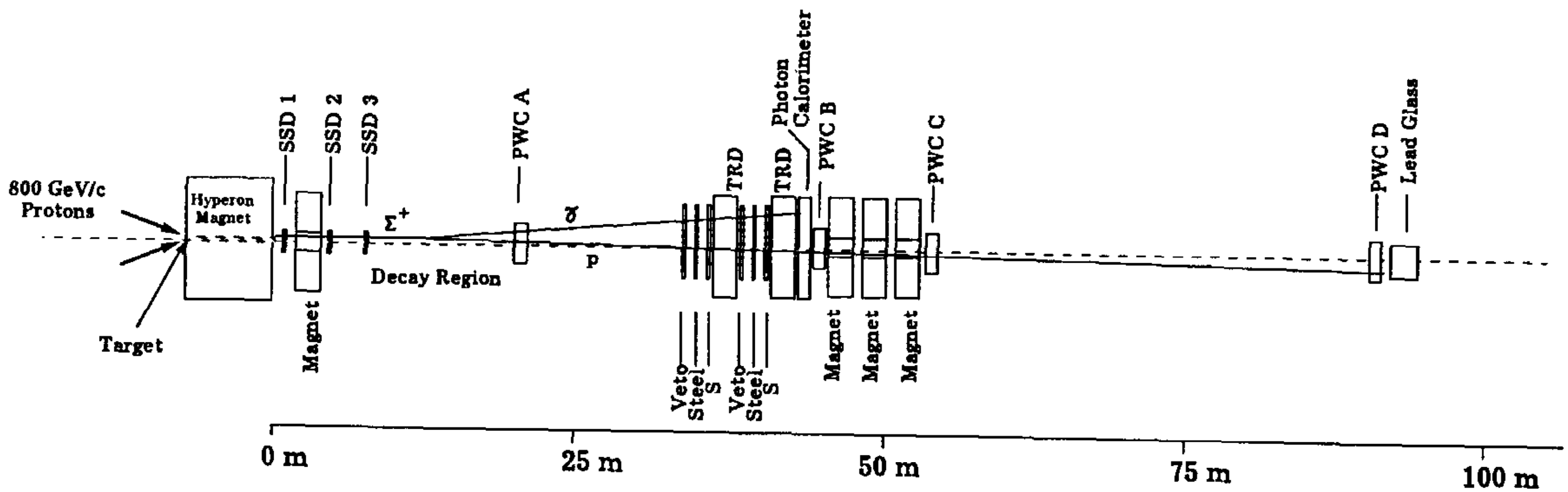

Figure 2: E761 experimental layout in Fermilab Proton Center Charged Hyperon Beam

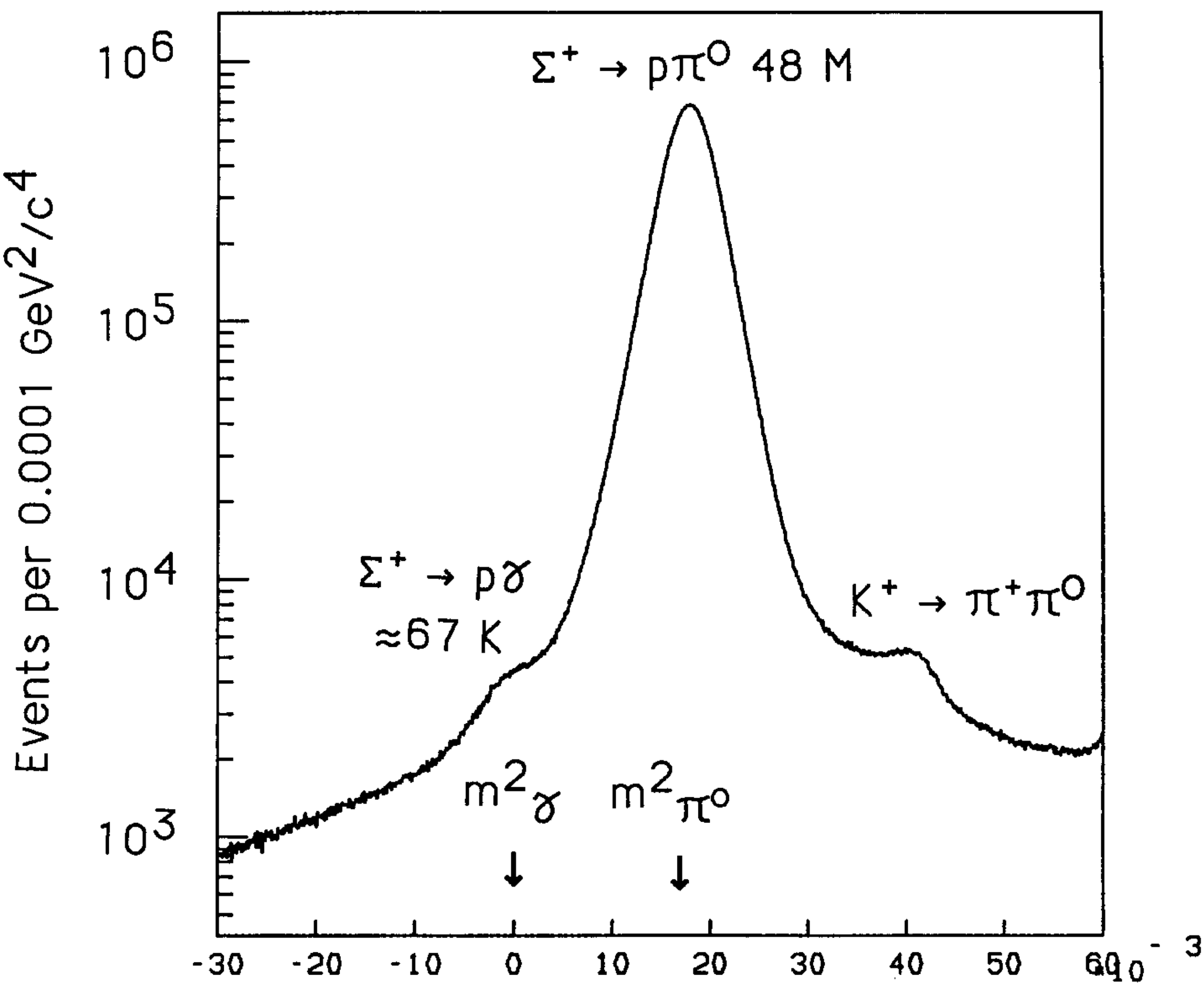

Figure 3: $m^2{}_X$ distribution, $\Sigma^+ \rightarrow p + X$ (GeV^2/c^4)

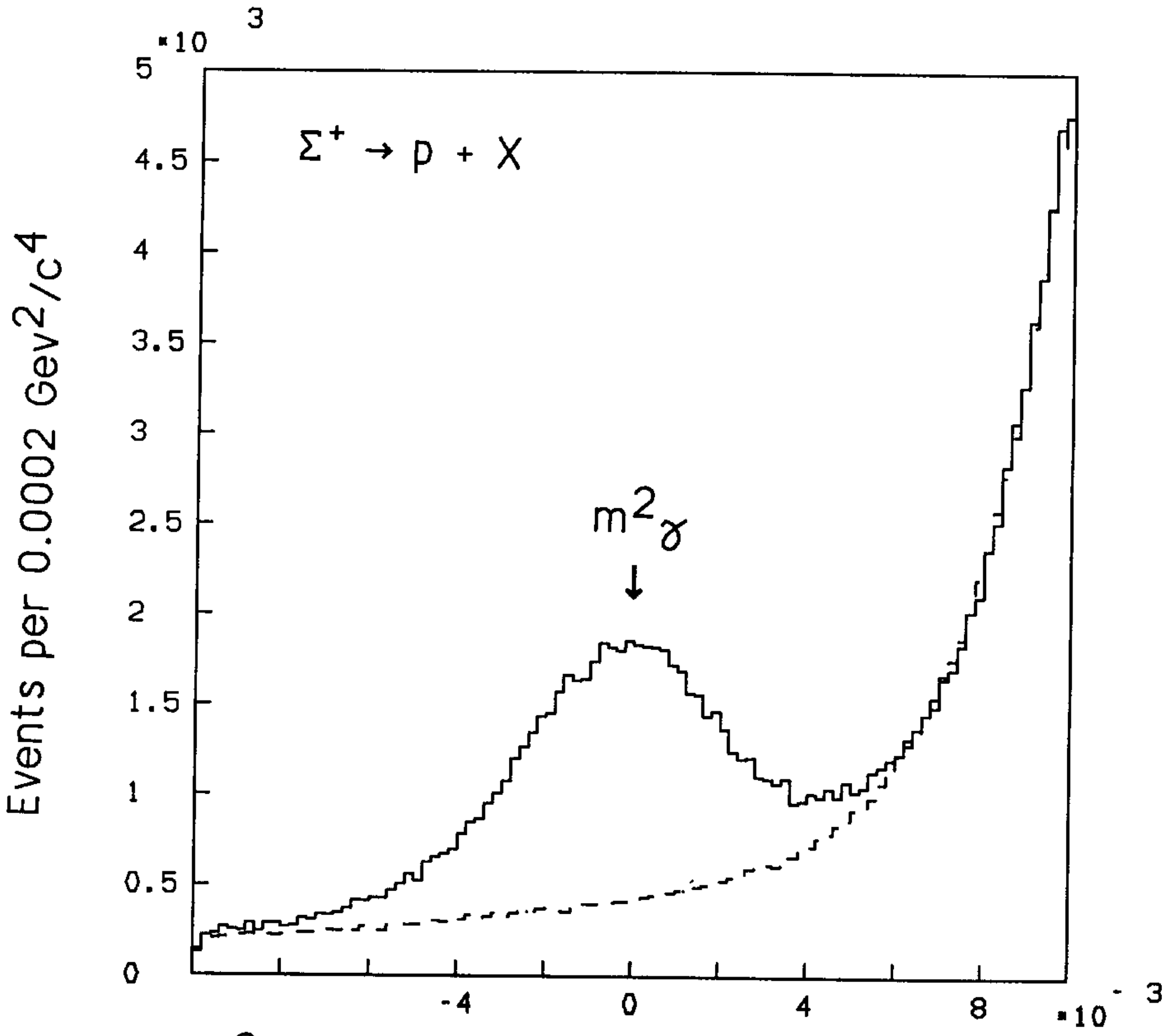

Figure 4: m^2_X (Gev^2/c^4) signal and background(dashed)