Title

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Authors

Dahl, O.L.
Johnson, R.A.
Kenney, R.W.
et al.

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O. L. Dahl, R. A. Johnson, R. W. Kenney, M. Pripstein, A. V. Barnes, D. J. Mellema, A. V. Tollestrup and R. L. Walker

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DISCLAIMER

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O. L. Dahl, R. A. Johnson, R. W. Kenney, M. Pripstein
Lawrence Berkeley Laboratory, University of California

and

A. V. Barnes, D. J. Mellema, A. V. Tollestrup, R. L. Walker
Department of Physics, California Institute of Technology, Pasadena

ABSTRACT

Preliminary $d\sigma/dt$ distributions are presented for the reaction $\pi^- p \to \eta n$ ($0 < -t < 1.2$ $(\mathrm{GeV}/c)^2$). Incident pion momenta were 20.7, 40.6, 66 and 101 GeV/c, obtained at the NAL Meson Laboratory. The effective Regge A_2 trajectory for these data is discussed. Evidence from neutral final states is presented for the production of ω^o and η' mesons as well as for an enhancement in the f^o, A_2 mass range.

AEC Contract No. W-7405-eng-48 (LBL) and AT(11-1)-68 (CIT)

I. Introduction

An experiment is in progress at NAL to measure neutral final state reactions of π^- mesons on protons. We report here some preliminary results obtained in the interval between 20 GeV/c and 100 GeV/c for the reaction

$$\pi^- p \rightarrow \eta n \quad (\eta \rightarrow \gamma\gamma) \tag{1}$$

as well as some evidence for production of other neutral final states, for example, $\eta' n$ and $\omega^o n$. In an accompanying paper [1] we give results for the reaction $\pi^- p \rightarrow \pi^o n$.

The $\pi^- p$ reaction leading to the ηn final state is considered to be one of the simplest examples of the Regge mechanism because this reaction is dominated by the exchange of a single Regge trajectory, namely the A_2. However, polarization measurements [2] suggest that the interaction is more complicated than the simple exchange of a single trajectory. In order to investigate the Regge character of reaction (1) it is important to obtain measurements at high energy over as large an energy and momentum transfer range as possible. We have therefore measured the differential cross section for the reaction (1) throughout the momentum transfer range from $-t=0$ to $-t \simeq 1.2\ (\text{GeV/c})^2$ at momenta from 20 to 100 GeV/c and have determined the effective A_2 trajectory using these data in conjunction with published data from 2.9 to 18.2 GeV/c. [3].

II. Experimental Description

The data for reaction (1) were taken simultaneously with the data for the reaction $\pi^- p \rightarrow \pi^o n$. The apparatus and experimental arrangement were identical for studying both reactions, and the reader is referred to the accompanying paper [1] for details.

The trigger condition assured that the final state was completely neutral. The trigger was, of necessity, precisely that trigger used in the charge exchange experiment since the data for both reactions were collected simultaneously. The cut structure used in the selection of the ηn final state differed from that used in the charge exchange reaction only in restricting the mass cut to the η mass peak. For completeness the entire cut structure will be listed here for the ηn reaction.

1. The CLEAN requirement. There must be no pulse in any photon veto counter, thereby eliminating events with photons outside the solid angle of the detector.
2. Cerenkov tag. A pulse in the threshold Cerenkov counter is required, thereby eliminating kaons and antiprotons from the beam flux.
3. Energy in the π^0 detector. The measured energy was required to be within the full energy peak corresponding to the incident π^- beam energy.
4. Number of photons. It was required that two individual showers be resolved by the detector for the ηn reaction.
5. Cos θ cut. In the decay $\eta \to \gamma\gamma$, the emission angle θ of the photons in the η rest frame with respect to the η line-of-flight can be calculated from the data. Those events with $|\cos \theta| > 0.7$ are eliminated because one photon has very small laboratory energy near $\cos \theta=1$. This arbitrary cut is well outside the region where the detection efficiency falls below 100%.
6. Mass cut. For reaction (1), the value of the mass M measured by the detector is required to be within the η mass peak.

In calculating cross sections it is necessary to correct for the loss of genuine reaction (1) events which are eliminated from our data sample by various cuts, and to correct for the inclusion of background events in the data sample. These corrections are listed in Table I. Most of the corrections were measured directly from the data or from several special runs interspersed with the data collection. Several of these corrections are for well-defined physical processes for which a reliable calculation can also be made; wherever possible the empirically determined corrections were verified by calculation.

The fraction of recoil neutrons detected by the veto house was empirically measured by examining the pulse height distribution of $\pi^- p \to \pi^0 n$ events as a function of the azimuthal angle of the π^0, and thus, of the recoil neutron. A similar analysis was carried out for the charged veto counters on a sample of data collected for this purpose. The efficiencies of the veto house counters as a function of energy for both photons and neutrons were also measured using a tagged photon beam at the Stanford Mark III accelerator and a tagged neutron beam at the LBL 184" cyclotron.

As an additional check on our overall normalization, we measured the $\pi^- p$ total cross section at 40 GeV/c using the same beam logic and liquid hydrogen target. Our result of $\sigma = (24 \pm 2)$ mb is in good agreement with the 50 GeV/c result of 24.1 mb reported by Baker et al. [7]

III. Results

In Fig. 1(a) we plot the square of the mass (M^2) for events at 101 GeV/c satisfying all cuts listed in Secton II except for the mass cut. There is a prominent peak around $M^2 \approx 0.3\ (\mathrm{GeV}/c^2)^2$ associated with the $\eta \to \gamma\gamma$ decay mode. The level of background on each side of the peak is minimal, permitting clean separation of η events. In addition there is a large peak at low mass due to π^0 production and a small enhancement at $M^2 \approx 0.9\ (\mathrm{GeV}/c^2)^2$ which may be associated with η' (958) production, decaying into two γ's.

Figures 1(b) and 1(c) give the M^2 spectra at 101 GeV/c for $N_\gamma=3$ and $N_\gamma \geq 4$, respectively, where N_γ is the number of individual photons resolved by the detector. The events in these histograms have been subjected to cuts 1, 2 and 3 from Sec. II. In Fig. 1(b) there is a peak around $M^2 \simeq 0.6$ $(GeV/c^2)^2$ due to ω production where the ω decays into $\pi^0\gamma$. (A small enhancement in Fig. 1(a) around $M^2 \simeq 0.6$ $(GeV/c^2)^2$ is due to $\omega \to \pi^0\gamma$ events in which the detector distinguishes only two of the three photon showers.) There is evidence in Fig. 1(c) of an enhancement in the region $1.3 < M^2 < 1.9$ $(GeV/c^2)^2$ due to f^0 and/or A_2^0 production. Furthermore, there are peaks in Fig. 1(c) in the η and η' mass regions, mainly associated with the $3\pi^0$ decay mode of the η and the $\pi\pi\eta$ decay mode of the η', respectively. (For purposes of analyzing reaction (1) we have not used η events in the $N_\gamma \geq 4$ category, but have restricted ourselves to the $\eta \to \gamma\gamma$ mode as seen in Fig. 1(a).)

The preliminary differential cross sections $d\sigma/dt$ for reaction (1) at 20.7, 40.6, 66, and 101 GeV/c are given in Fig. 2. At 20.7 GeV/c the region of good acceptance for η's was confined to a limited range of momentum transfer, and thus we present data for this energy only between $-t=0$ and 0.5 $(GeV/c)^2$. For the three higher energies the data is presented over the range $0 < -t < 1.2$ $(GeV/c)^2$. The total number of events at each energy for reaction (1) is listed in Table II. There is a forward peak at each energy which flattens out at small t and which has a smooth exponential falloff in the region $0.2 < -t < 1.0$ $(GeV/c)^2$. In Table II we list values for

$$\sigma\left(\pi^- p \to \eta n \atop {\hookrightarrow \gamma\gamma}\right) = \int_{-1.5}^{0} \frac{d\sigma}{dt}\, dt$$

at each energy. These values are also plotted in Fig. 3 as a function of p_{lab} along with integrated cross sections for reaction (1) from other experiments [3, 4, 5, 6]. The data points of the present experiment tend to be systematically lower than those of ref. [4]. The solid curve in Fig. 3 shows the result of a fit to the functional form

$$\sigma\left(\pi^- p \to \eta n \atop \hookrightarrow \gamma\gamma\right) = A\, p_{lab}^{-N} \qquad (2)$$

based on the data of this experiment and of ref. [3] over the range of p_{lab} from 2.9 to 100 GeV/c. The fitted parameters were determined to be $A = (297 \pm 27)$ μb and $N = 1.47 \pm 0.03$. Bolotov et al.[4] report values of $A = (230 \pm 30)$ μb and $N = 1.35 \pm 0.04$ using their data as well as that of Ref. [3].

A study has been made of the effective Regge A_2 trajectory by fitting data from reaction (1) to the form

$$\frac{d\sigma}{dt} = \frac{B}{sq^2}\, s^{2\alpha} \qquad (3)$$

where α and B are parameters to be determined as a function of t, and q is the CM momentum. An overall fit (Fit 1) from 3 to 100 GeV/c has been carried out at several t values, using the data of Ref. [3] and of the present experiment. The results of this fit are summarized in Table III, and plots of $d\sigma/dt$ versus p_{lab} are given in Fig. 4 for several representative values of t. The curves in Fig. 4 show the best fit to (3) at each of these t values. Fitted values for α are displayed in Fig. 5(a). For purposes of comparison, we also show in Fig. 5(a) the values of α obtained by fitting the data of Refs. [3] and [4] from 6 to 50 GeV/c (Fit 2), as reported in Ref. [4]. We have not attempted a fit including both our data and the data of Ref. [4] because of the inconsistency between their results and our preliminary results. The two sets of α's are in good agreement except at $-t = 0.05\ (\mathrm{GeV}/c)^2$ where α from Fit 1 is larger than α from Fit 2 by about 0.1.

We have also fit separately the data of Ref. [3] from 3-18 GeV/c (Fit 3) and the data of the present experiment from 20-100 GeV/c (Fit 4). (In Fit 4 we have determined values of α only for $-t < 0.5$ GeV/c, since the 20.7 GeV/c data is restricted to this t region. Without the 20.7 GeV/c data, the s-interval of the remaining data is too small to obtain a meaningful fit.) The results of Fits 3 and 4 are listed in Table III and are plotted in Fig. 5(b). The points from Fits 3 and 4 are compatible within errors for all t values, indicating that the effective Regge pole parameterization (3) is not incompatible with reaction (1) data from 3 to 100 GeV/c.

V. Acknowledgments

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Table I

Cross Section Corrections for $\pi^- p \rightarrow \eta n$, $\eta \rightarrow \gamma\gamma$

	20.7 GeV/c	40.6 GeV/c	66 GeV/c	101 GeV/c
Length of LH_2 target	40.1 cm	40.1 cm	40.1 cm	60.4 cm
Spurious charged veto				
δ-rays from π^-	-5%	-5%	-5%	-7%
Conversion of γ-rays	-5%	-5%	-5%	-6%
Recoil neutron veto*	-2%	-2%	-2%	-2%
Accidentals	-5%	-2%	-4%	-6%
Spurious shower veto				
Recoil neutron veto*	-5%	-5%	-5%	-5%
Accidentals	-1%	-1%	-1%	-3%
η detection efficiency				
Geometrical acceptance*	-20%	-1%	-1%	-1%
$N_\gamma = 2$ cut	-0.5%	-0.5%	-0.5%	-0.5%
Cosine θ cut	-30%	-30%	-30%	-30%
Background				
Target empty	+3%	+5%	+4%	+3%
N^* contamination	+3%	+3%	+3%	+3%

*Averaged over t

Table II

Preliminary Results for $\pi^- p \rightarrow \eta n$, $\eta \rightarrow \gamma\gamma$

	Number of Events	$\sigma\left(\pi^- p \rightarrow \eta n,\ \eta \rightarrow \gamma\gamma\right)$
20.7 GeV/c	530	(4.0 ± 0.3) μb
40.6	3925	(1.29 ± 0.08)
66	1277	(0.61 ± 0.04)
101	2775	(0.35 ± 0.03)

Table III

Effective Regge Trajectory Values
for $\pi^- p \rightarrow \eta n$

Range of p_{lab}	Fit 1 3-100 GeV/c	Fit 3 3-18 GeV/c	Fit 4 20-100 GeV/c
Data Used	Ref. 3 and Present Expt. (Prelim. results)	Ref. 3	Present Expt. (Preliminary results)
Values of α:			
$-t = 0.05\ (GeV/c)^2$	0.37 ± 0.02	0.38 ± 0.05	0.32 ± 0.04
0.15	0.33 ± 0.02	0.30 ± 0.05	0.30 ± 0.04
0.25	0.27 ± 0.02	0.24 ± 0.05	0.18 ± 0.05
0.40	0.14 ± 0.02	0.17 ± 0.05	0.08 ± 0.06
0.60	0.00 ± 0.02	0.13 ± 0.07	---
0.85	-0.09 ± 0.04	---	---

Figure Captions

Fig. 1 Spectra of M^2 at 101 GeV/c.

(a): Distribution of events satisfying cuts 1-5.

(b) and (c): Distribution of events with $N_\gamma=3$ and $N_\gamma \geq 4$, respectively, where N_γ is the number of photon showers resolved by the detector. Events in these plots satisfy cuts 1-3.

Fig. 2 (a-d): Distributions of $d\sigma/dt$ for reaction (1) at 20.7, 40.6, 66, and 101 GeV/c, respectively. The errors shown are statistical only.

Fig. 3 A plot of the integrated cross section for reaction (1) as a function of p_{lab}. The solid curve is a fit to the data of Ref. [3] and the present experiment.

Fig. 4 Plots of $d\sigma/dt$ versus p_{lab} for reaction (1) at several values of t. The solid curves are the results of fitting the data of Ref. [3] and of the present experiment to expression (3).

Fig. 5 Effective trajectory values for reaction (1) displayed as a function of t.

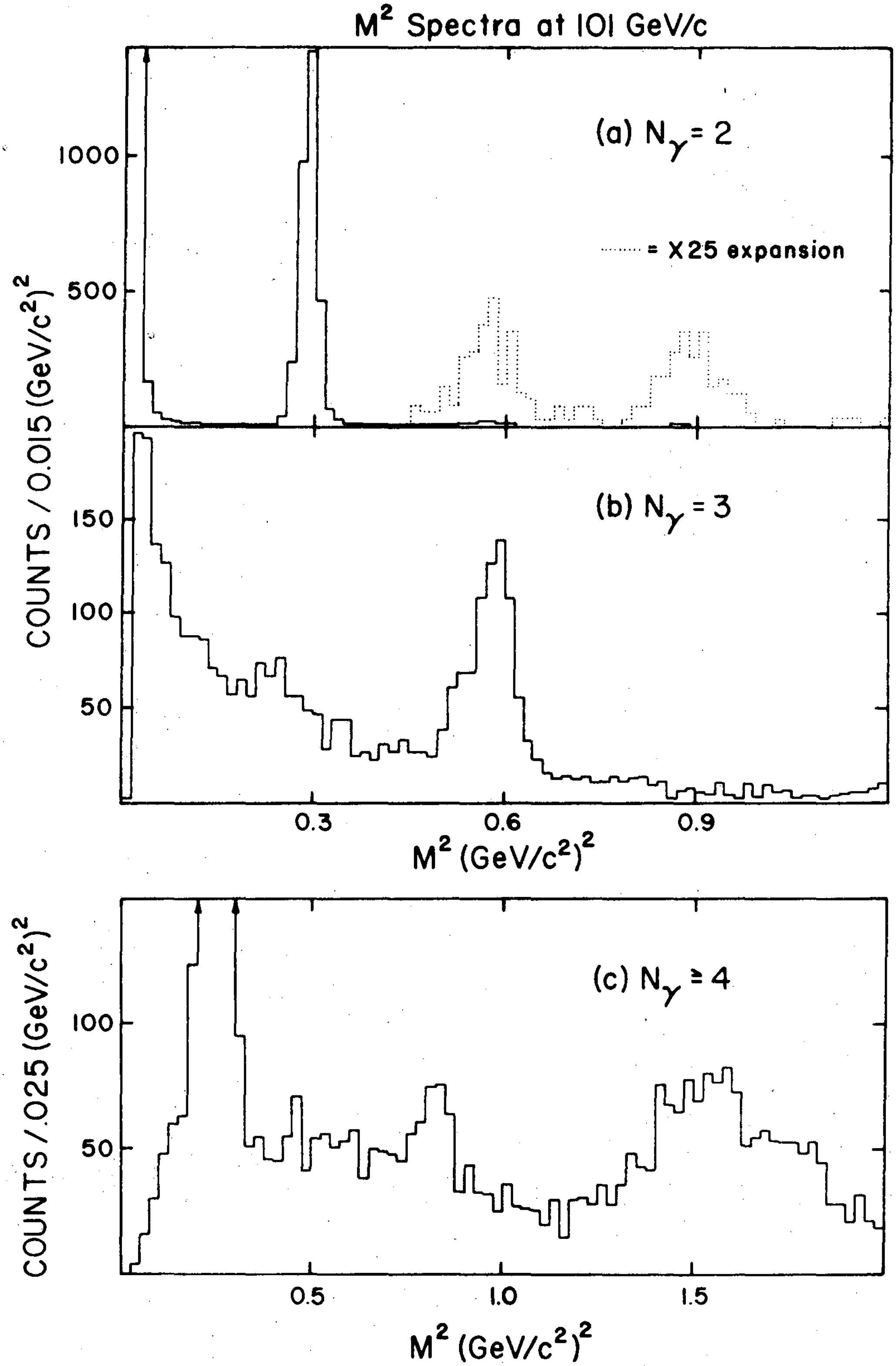

M² Spectra at 101 GeV/c
(a) Nγ = 2
= X25 expansion
(b) Nγ = 3
COUNTS / 0.015 (GeV/c²)²
1000
500
150
100
50
0.3
0.6
0.9
M² (GeV/c²)²
(c) Nγ ≥ 4
COUNTS / .025 (GeV/c²)²
100
50
0.5
1.0
1.5
M² (GeV/c²)²

Figure 1

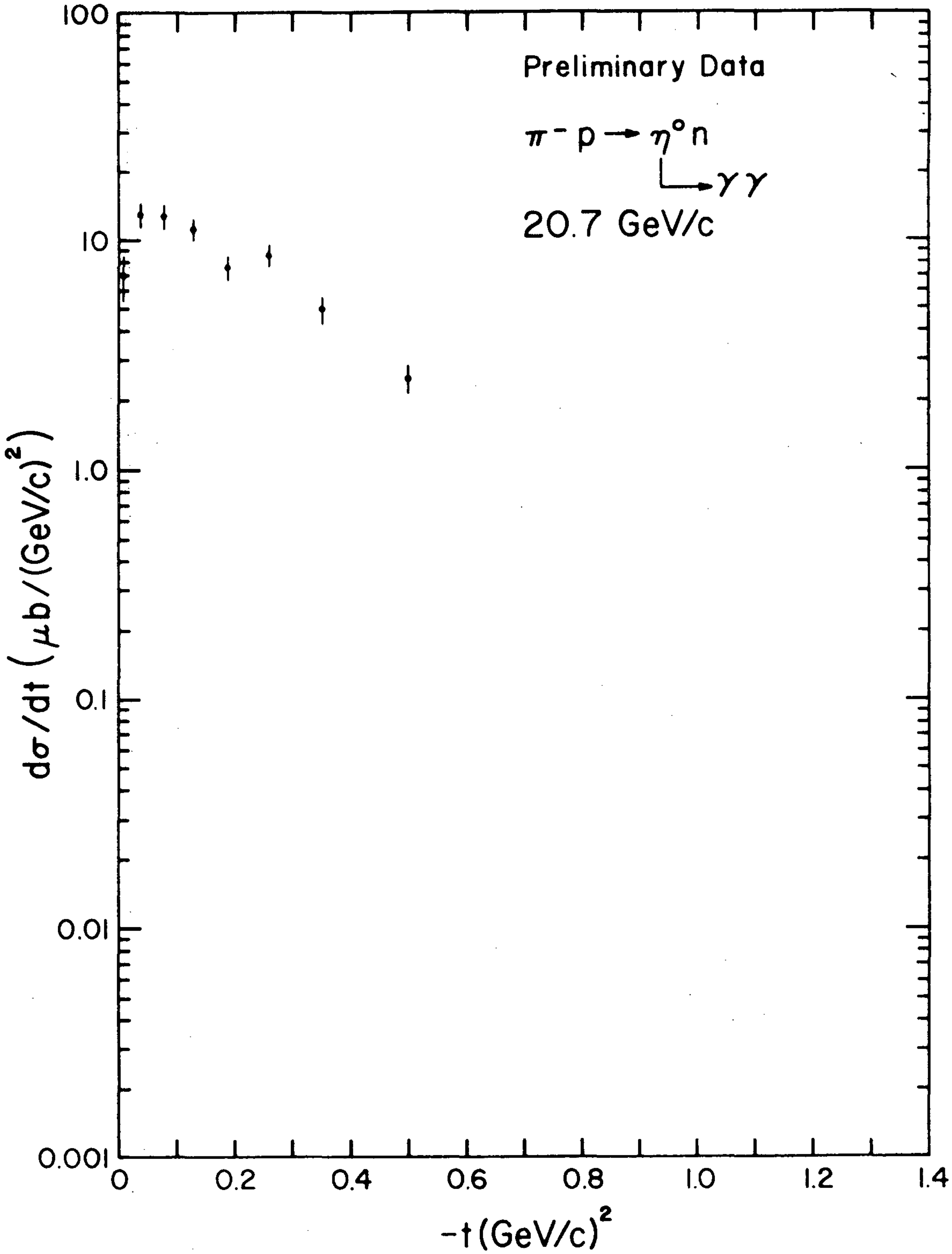

Preliminary Data
$\pi^- p \rightarrow \eta^\circ n$
$\hookrightarrow \gamma\gamma$
20.7 GeV/c
100
10
1.0
0.1
0.01
0.001
$d\sigma/dt\ (\mu b/(GeV/c)^2)$
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
$-t\ (GeV/c)^2$

Figure 2(a)

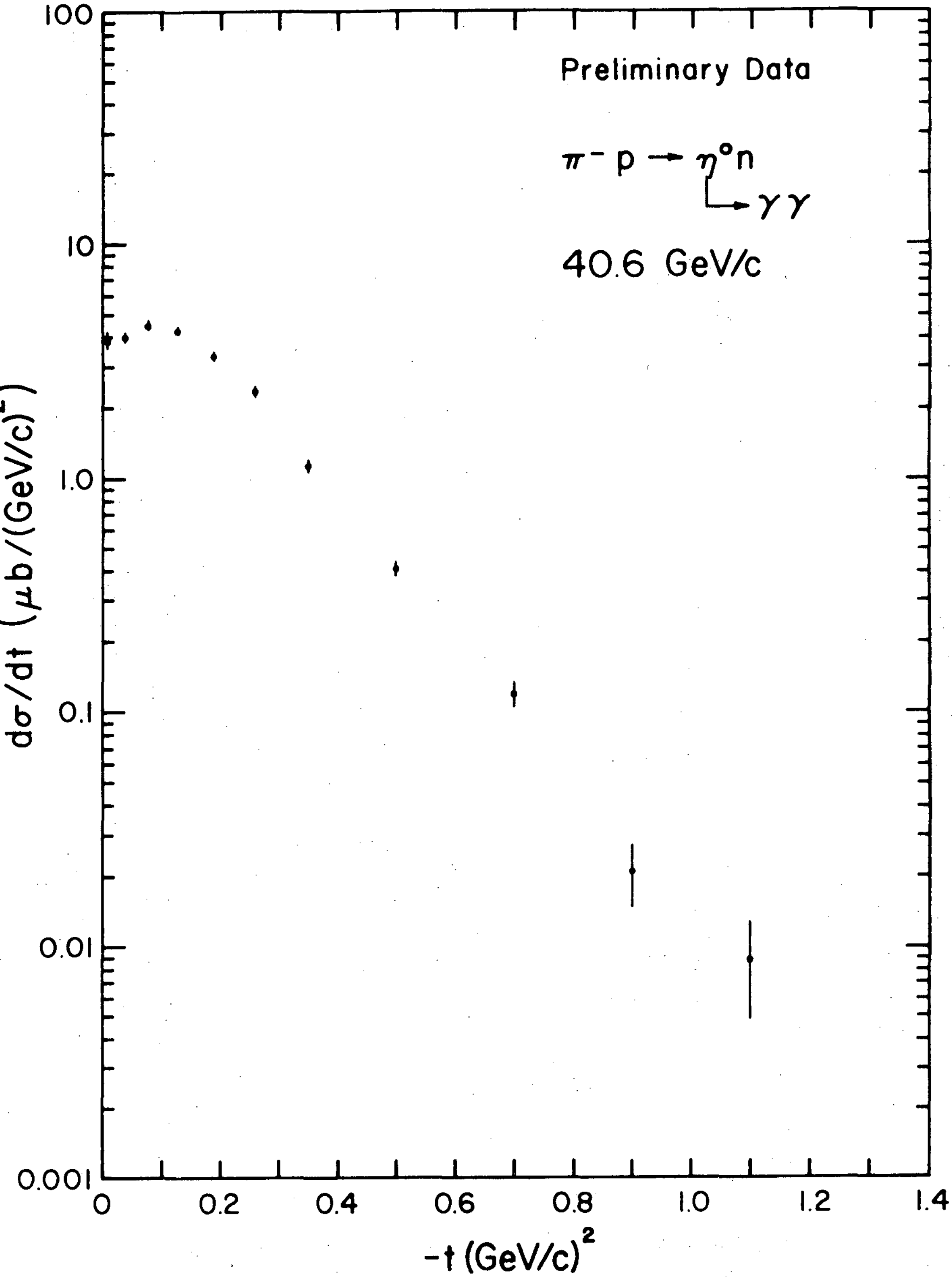

Preliminary Data
$\pi^- p \rightarrow \eta^\circ n$
$\rightarrow \gamma\gamma$
40.6 GeV/c
100
10
1.0
0.1
0.01
0.001
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
$d\sigma/dt \; (\mu b/(GeV/c)^2)$
$-t\;(GeV/c)^2$

Figure 2(b)

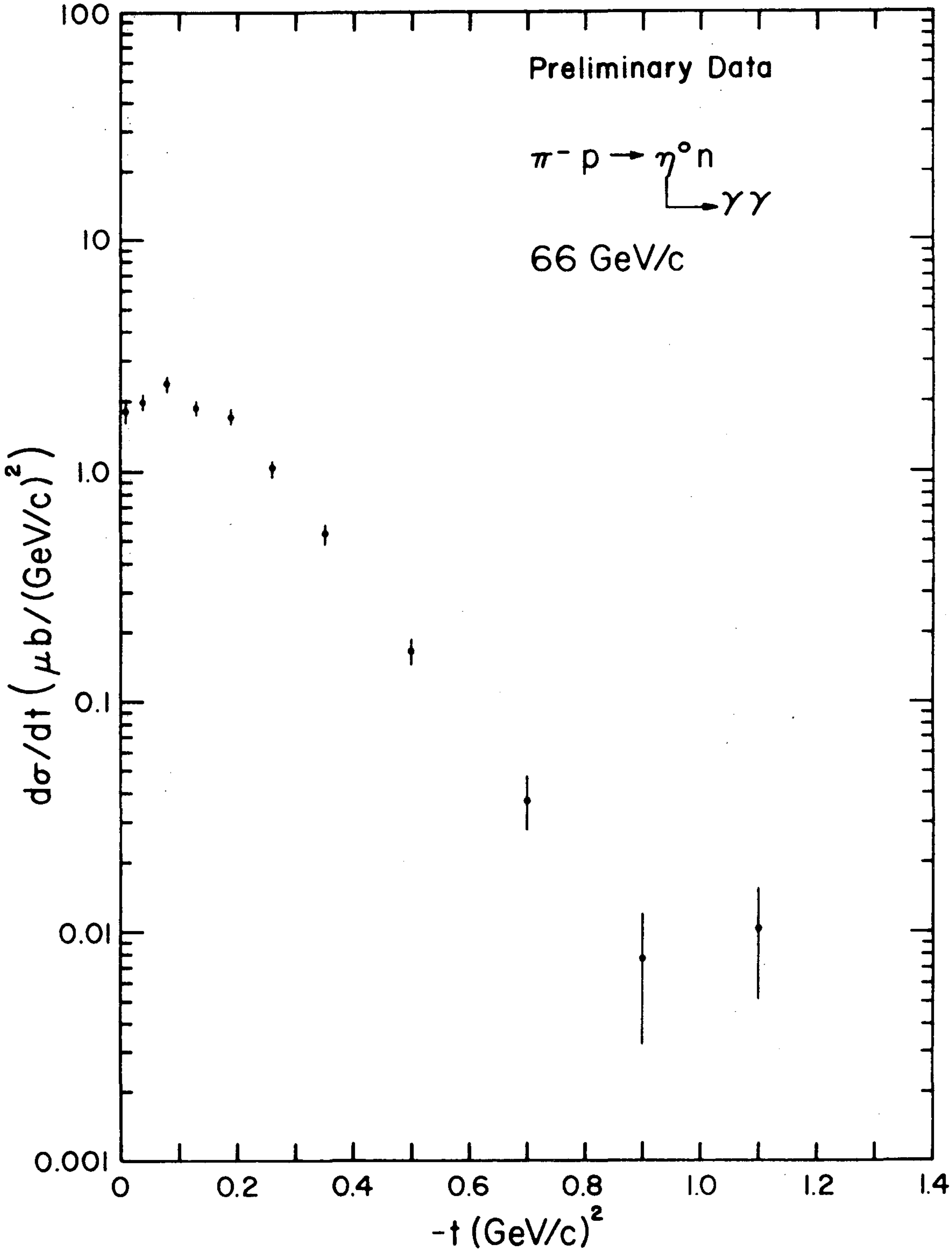

Preliminary Data
π⁻ p → η° n
→ γγ
66 GeV/c
dσ/dt (μb/(GeV/c)²)
100
10
1.0
0.1
0.01
0.001
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
-t (GeV/c)²

Figure 2(c)

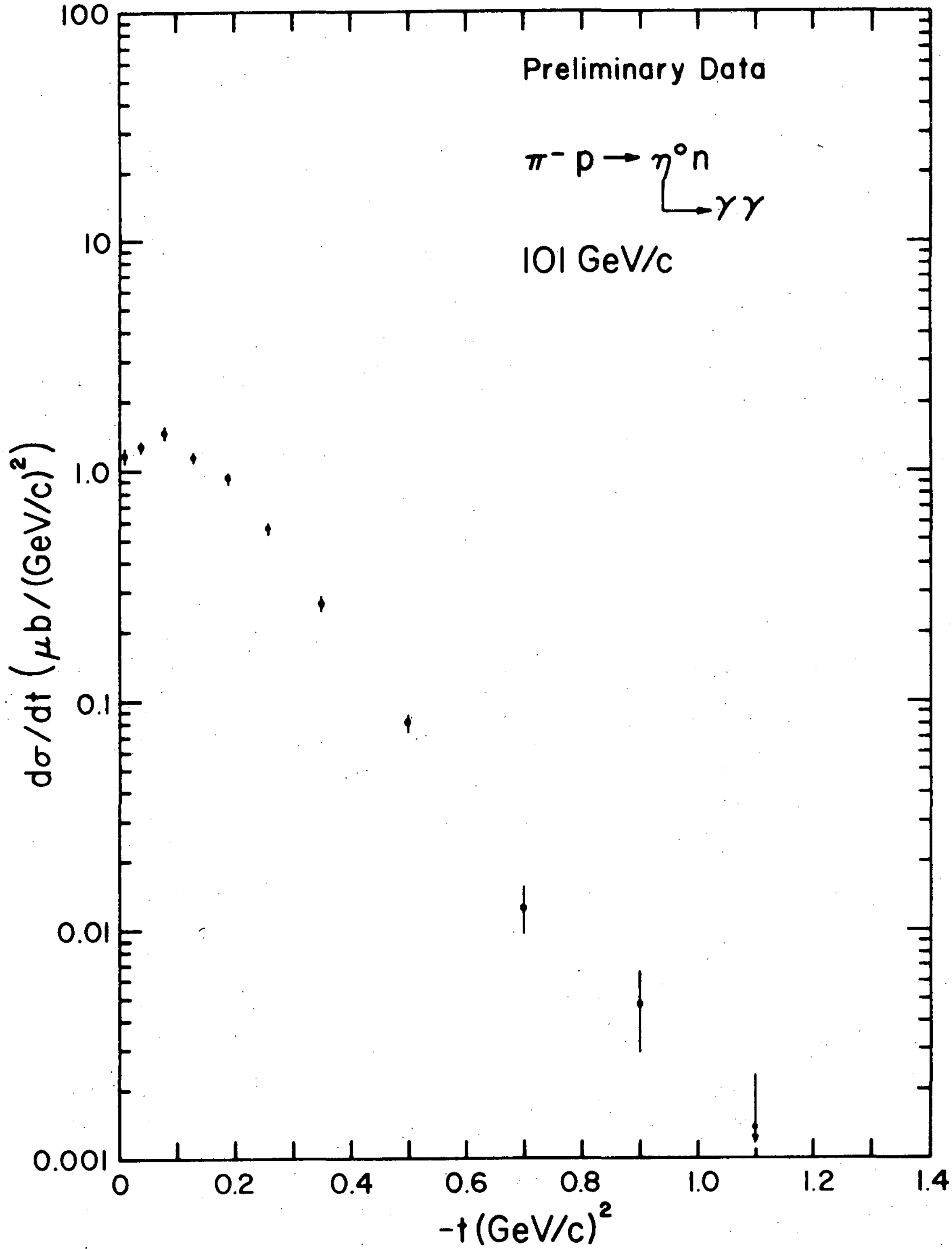
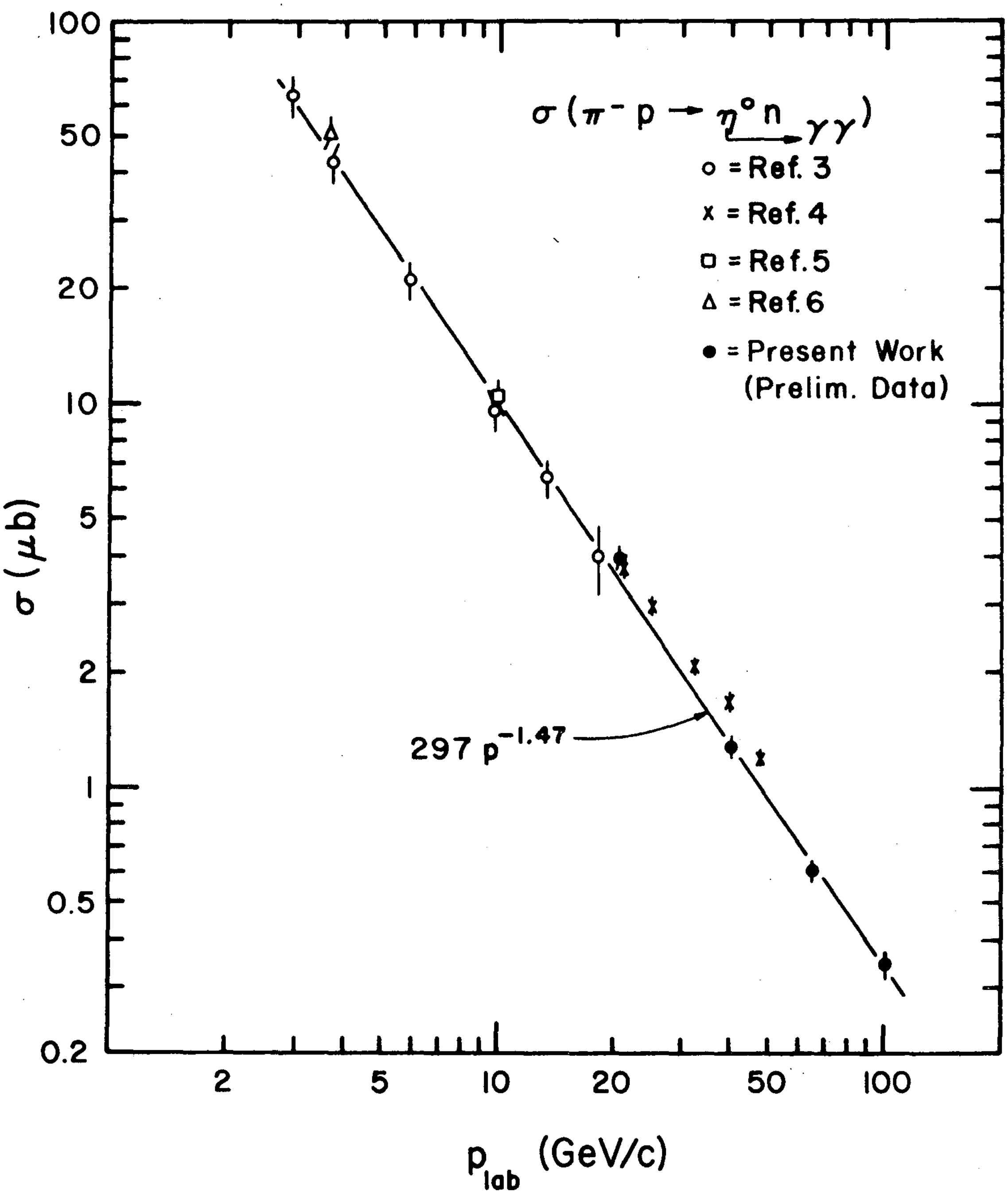
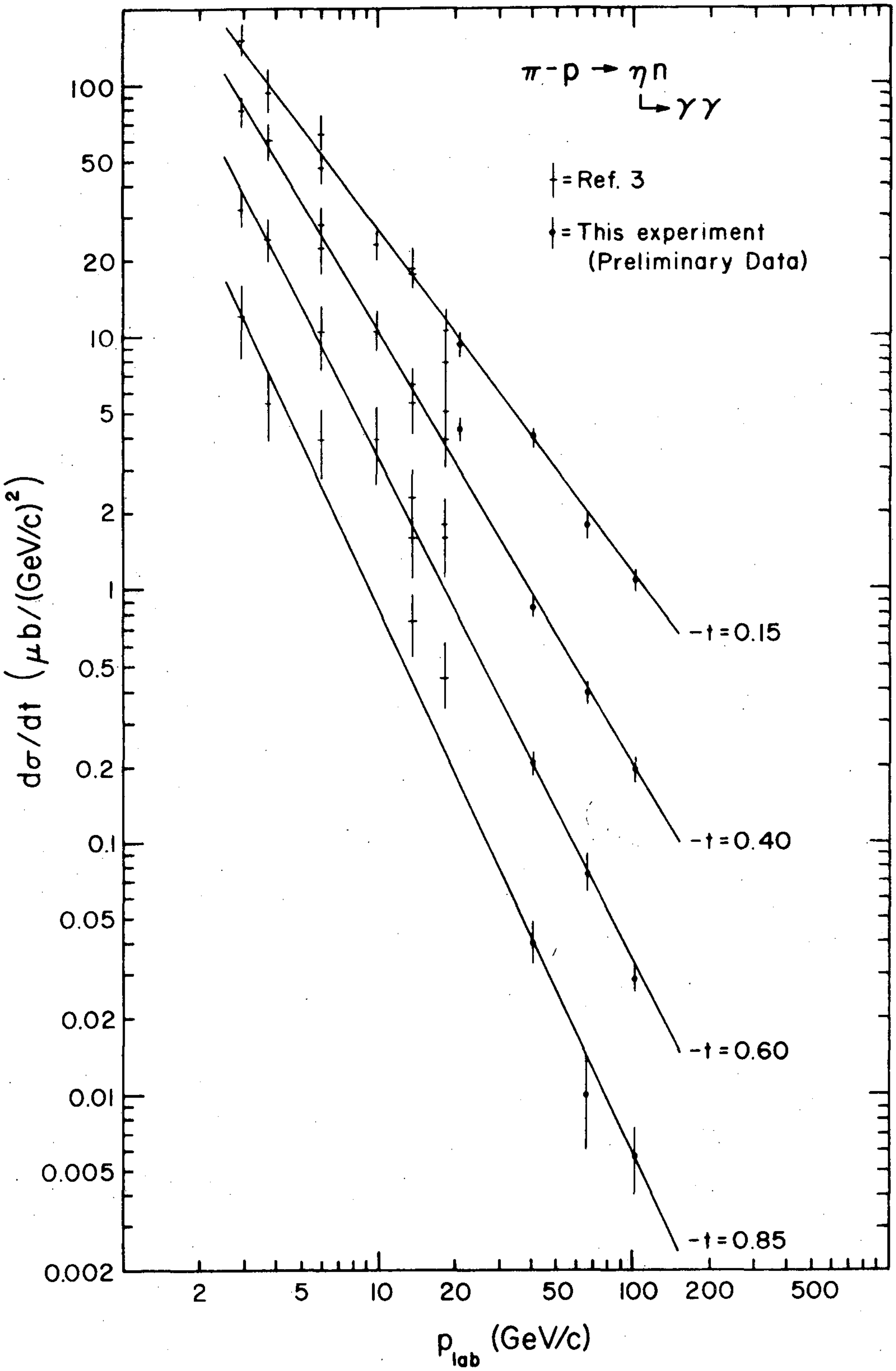

Preliminary Data
π⁻ p → η° n
→ γγ
101 GeV/c
dσ/dt (μb/(GeV/c)²)
100
10
1.0
0.1
0.01
0.001
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
-t (GeV/c)²

Figure 2(d)



σ (π⁻ p → η° n → γγ)
○ = Ref. 3
x = Ref. 4
□ = Ref. 5
Δ = Ref. 6
● = Present Work (Prelim. Data)
297 p^-1.47
σ (μb)
100
50
20
10
5
2
1
0.5
0.2
2
5
10
20
50
100
p_lab (GeV/c)

Figure 3



π- p → η n
↳ γ γ
= Ref. 3
= This experiment
(Preliminary Data)
-t = 0.15
-t = 0.40
-t = 0.60
-t = 0.85
dσ/dt (μb/(GeV/c)²)
100
50
20
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
0.005
0.002
2
5
10
20
50
100
200
500
p_lab (GeV/c)

Figure 4

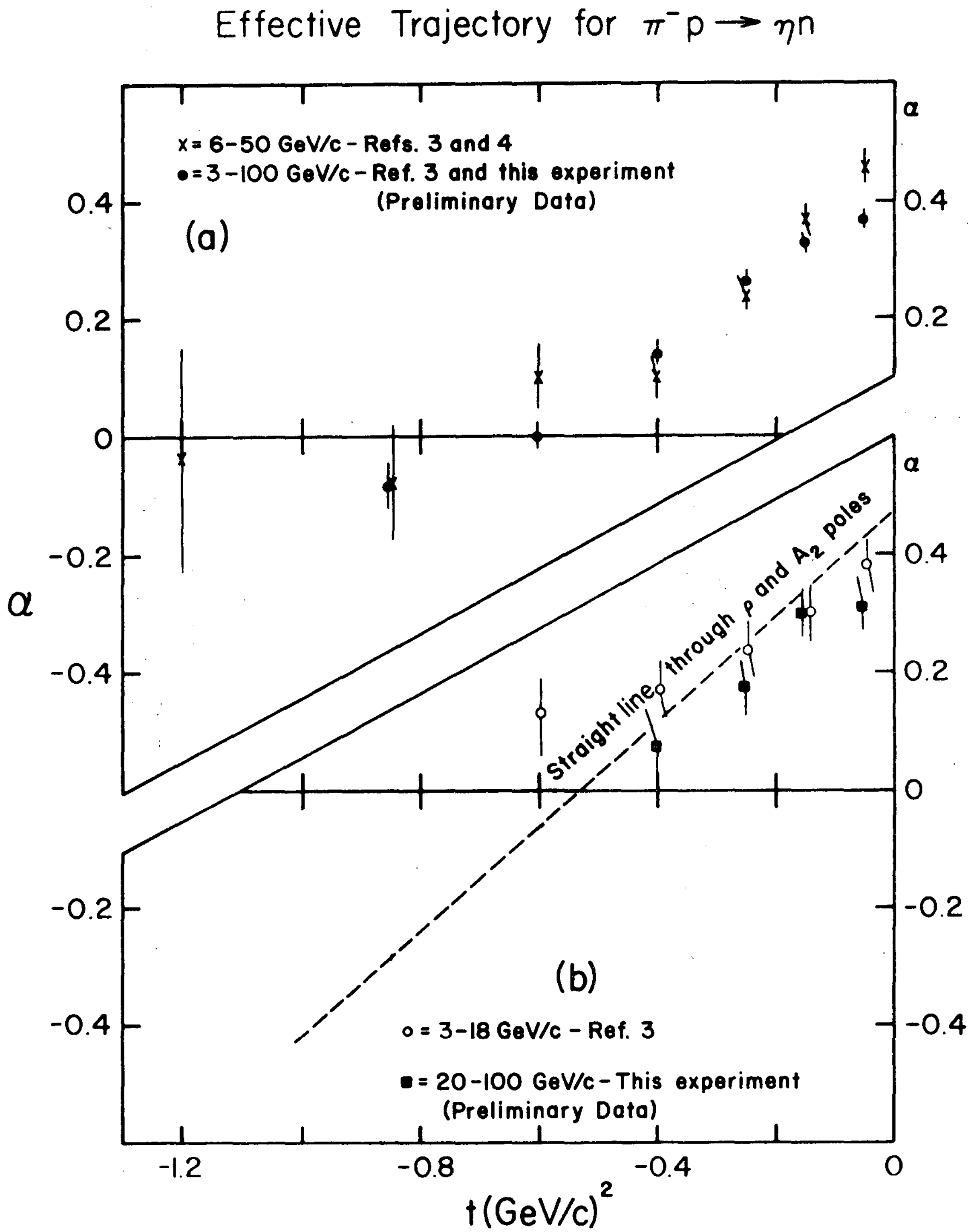

Effective Trajectory for $\pi^- p \rightarrow \eta n$
x = 6-50 GeV/c - Refs. 3 and 4
● = 3-100 GeV/c - Ref. 3 and this experiment
(Preliminary Data)
(a)
α
0.4
0.2
0
-0.2
-0.4
Straight line through ρ and A_2 poles
(b)
○ = 3-18 GeV/c - Ref. 3
■ = 20-100 GeV/c - This experiment
(Preliminary Data)
-1.2
-0.8
-0.4
0
$t\,(\mathrm{GeV}/c)^2$

Figure 5

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720