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Experimente

Laboratory Angular and Momentum Distributions of Protons, Kaons and Pions from Photoproduction on Hydrogen at Energies up to 5.8 GeV

German Bubble Chamber Collaboration

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Abstract

This paper contains information on the laboratory angular and momentum distributions of protons, π^+ and π^- Mesons and K_s^o - Mesons produced by a photon beam with an apprcximate bremsstrahlung spectrum on hydrogen. The data may be useful for designing secondary pion and kaon beams, for planning experiments and for background estimates at electron accelerators.

1. Experimental Details

The data of this report come from work done with the 84 cm hydrogen bubble chamber at DESY[1] to study photoproduction of hadrons on hydrogen at photon energies E_γ up to 5.8 GeV. The photon beam used for this experiment was obtained by bremsstrahlung from a momentum analysed electron beam in a thin (∿ 0.1 radiation lengths) target. The resulting photon beam was hardened by passing it through a beam hardener of 0.6 radiation lengths of Li H. Figure 1 shows the photon energy spectrum of the beam in the bubble chamber. This energy spectrum was determined by measuring electron-positron pairs in the bubble chamber and using the (known) cross sections for electron-positron pair production as a function of E_γ[2]. The maximum energy of the beam was 5.8 GeV for 2/3 of the data and 5.35 GeV for 1/3 of the data. All photoproduction events with three and more outgoing charged particles were measured on 800 000 pictures. Events with one charged outgoing track were measured in about 10 % of the film only and added to the corresponding distributions of the other events with the appropriate weights. The distributions in the figures are therefore a representative sample of all photoproduction reactions. More details on the experimental procedure are given in ref. [1].

A preliminary technical report has already been circulated[3]. The present report contains considerably improved statistics. Similar work has also been presented by the Cambridge Bubble Chamber Group[4]. Their results agree with those contained in this paper.

2. Use of the Figures

The figures contain information on:

1) The laboratory momentum distributions of protons, π^+ and π^- Mesons

for various intervals of the laboratory angle θ_L. (θ_L is the angle between the particle and the incident photon in the laboratory system).
2) The laboratory angular distributions of protons, π^+ and π^- Mesons for various intervals of the laboratory momentum p_L. The figures 2 - 4 give the number of particles per degree as a function of θ_L for various intervals of p_L. The figures 5 to 7 on the other hand give the number of particles per unit momentum interval as a function of p_L for various intervals of θ_L. Momenta are given in GeV, angles in degrees. For example, the number of protons with a lab. momentum between 0.2 and 0.5 GeV/c and with lab. angles between 39.5° and 40.5° is 450 according to fig. 2, and the number of protons with lab. angles between 20° and 30° and momentum between 0.95 and 1.05 GeV/c is 200 according to fig. 5.

The curves in the figures were obtained by smoothing the original histograms. The histograms themselves may be reconstructed from the dots in the figures.

3. Photon Flux

The flux of equivalent quanta through the bubble chamber was obtained from the experimental energy spectrum in fig. 1 and from counting the number of electron positron pairs on the pictures. The number of equivalent quanta is defined as

$$N_{eq} = \left(\int E_\gamma \frac{dN(E_\gamma)}{dE_\gamma} dE_\gamma\right)/E_{\gamma max}$$

$\frac{dN(E_\gamma)}{dE_\gamma}$ is the photon energy spectrum, $E_{\gamma max}$ is the maximum photon energy.

The numbers of particles given in the ordinates of the figures correspond then to a product of (total flux of equivalent quanta) × (target thickness) = 1.5×10^6 (equivalent quanta) × (radiation lengths). (The radiation length in hydrogen = 65 g/cm², the average path length of the beam in the scanning volume chozen in the chamber was 46 cm, the number of equivalent quanta in the chamber was 3.5×10^7).

4. Neutral K-Mesons

Figure 8 shows a scatter diagram of laboratory momentum vs. laboratory angle for K_s^o Mesons decaying into $\pi^+\pi^-$ inside the chamber. In order to convert these numbers into K^o flux values, corrections for the unobserved decay modes (mainly $\pi^o\pi^o$) and for decays outside the chamber must be made. This gives a correction factor of about 1.7. If one assumes that the numbers of K_s^o and of K_L^o mesons are equal, one must multiply the number of events in the plot by another factor of 2, resulting in an over all factor of 3.4, in order to deduce values for the flux of K^o and $\bar{K}^o$ mesons produced by the (flux × target thickness) = 1.5×10^6 (equivalent quanta × radiation lengths).

Acknowledgements

We are greatly indebted to the machine group of DESY for the excellent performance of the synchrotron, to the crews of the bubble chamber and the beam, in particular to Messrs. Cords, Eschricht, Kessler, Linser and to Dr. Degèle and the Hallendienst. We also thank Dr. D. Lublow, Dr. H.O. Wüster and the crew of the computing center of DESY for their efforts. We are also thankful to the other computing centers involved and the scanners of all laboratories. The work in the laboratories in Aachen, Bonn, Hamburg, Heidelberg and München was supported by the Bundesministerium für Wissenschaftliche Forschung.

References

1) German Bubble Chamber Collaboration (Aachen-Berlin-Bonn-Hamburg-Heidelberg-München), Proceedings of the International Symposium on Electron and Photon Interactions at High Energies, Hamburg, 1965, Vol. II, p. 36; Nuovo Cimento 41, 270 (1966); DESY report 1966, Contributions to the International Conference on High Energy Physics, Berkeley 1966.

2) We used the cross section according to J.A. Wheeler and W.E. Lamb, Phys. Rev. 55, 858 (1939) and 101, 1836 (1956). For the total cross section at 5 GeV we find 19.8mb. The Wheeler-Lamb cross sections seem to agree best with experimental measurements, see for example D.C. Gates, R.W. Kenney, and W.P. Swanson, Phys. Rev. 125, 1310 (1962). There seems to be some uncertainty as to other corrections to be applied, see for example J. Joseph and F. Rohrlich, Rev. Mod. Phys. 30, 354 (1958); K.S. Suh and H.A. Bethe, Phys. Rev. 115, 672 (1959); D. Bernstein and W. Panofsky, Phys. Rev. 102, 522 (1956); these corrections will be discussed in a later paper.

3) Unpublished Laboratory Report, 1965.

4) Cambridge Bubble Chamber Group
Contributions to the International Conference on High Energy Physics, Berkeley 1966, and Phys. Rev., to be published.

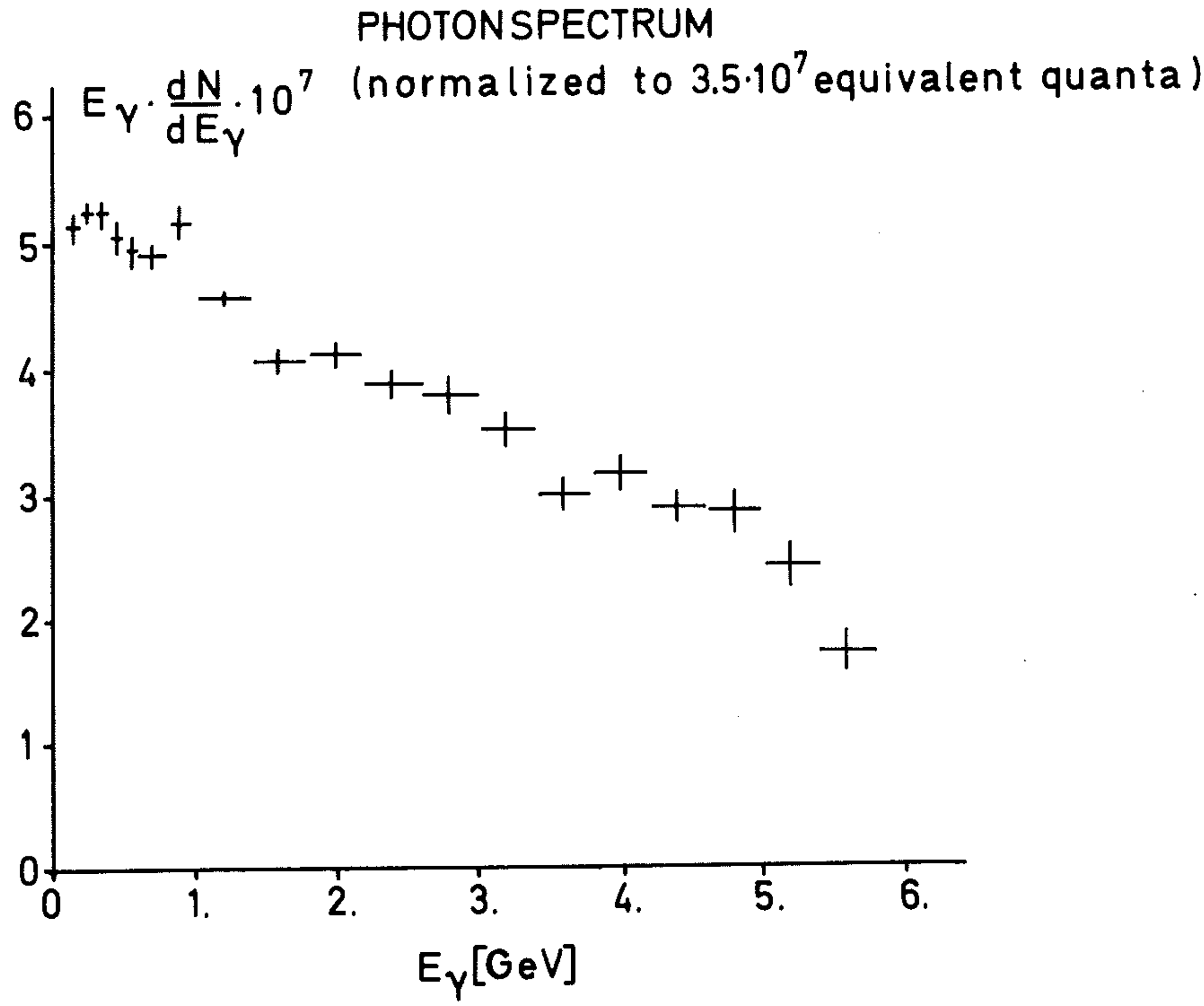

PHOTONSPECTRUM
Eγ · dN/dEγ · 10^7 (normalized to 3.5·10^7 equivalent quanta)
6
5
4
3
2
1
0
0
1.
2.
3.
4.
5.
6.
Eγ[GeV]

Fig.1

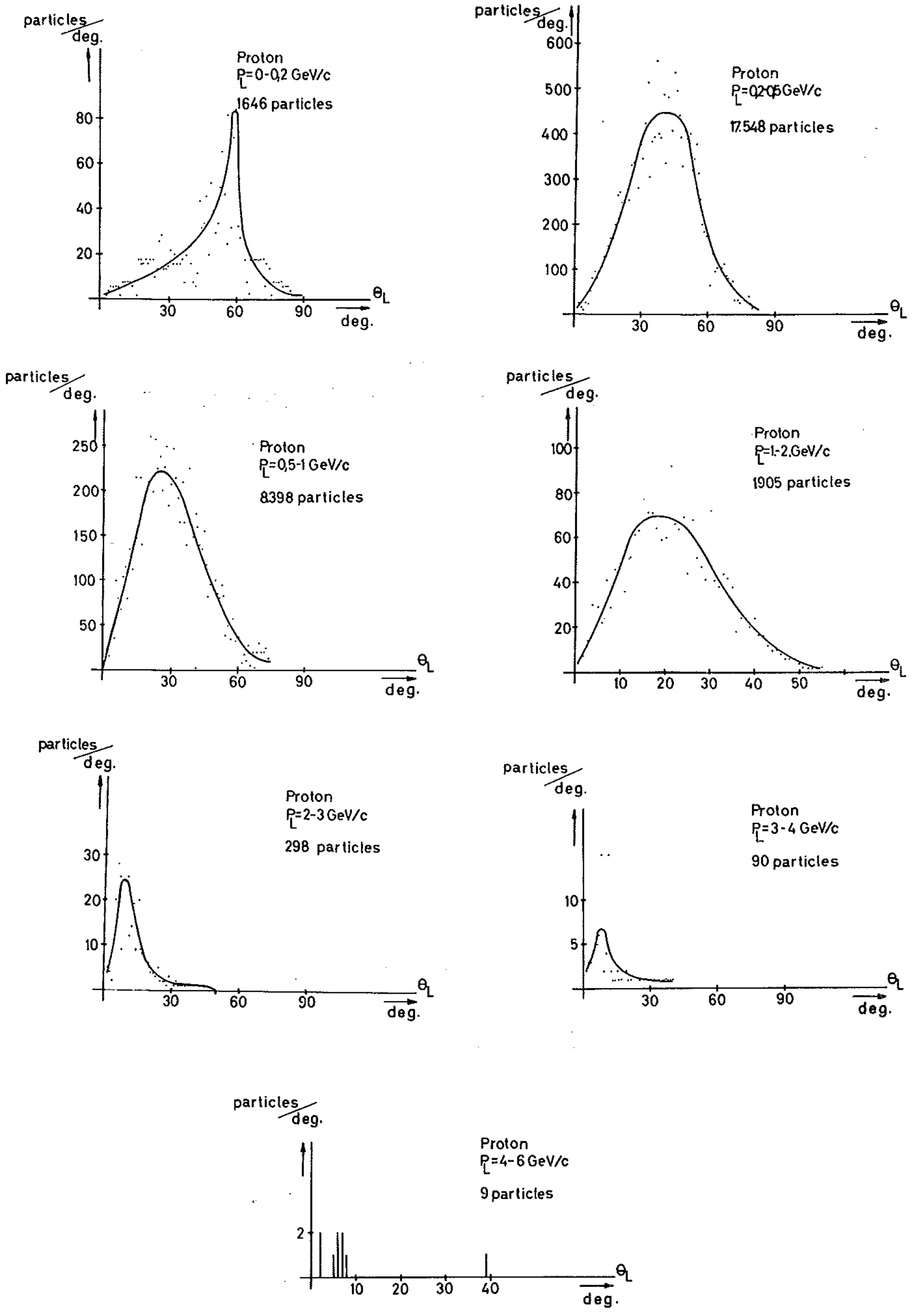

particles/deg.
Proton
P_L=0-0,2 GeV/c
1646 particles
θ_L
deg.
Proton
P_L=0,2-0,5 GeV/c
17.548 particles
Proton
P_L=0,5-1 GeV/c
8398 particles
Proton
P_L=1-2 GeV/c
1905 particles
Proton
P_L=2-3 GeV/c
298 particles
Proton
P_L=3-4 GeV/c
90 particles
Proton
P_L=4-6 GeV/c
9 particles

Fig. 2

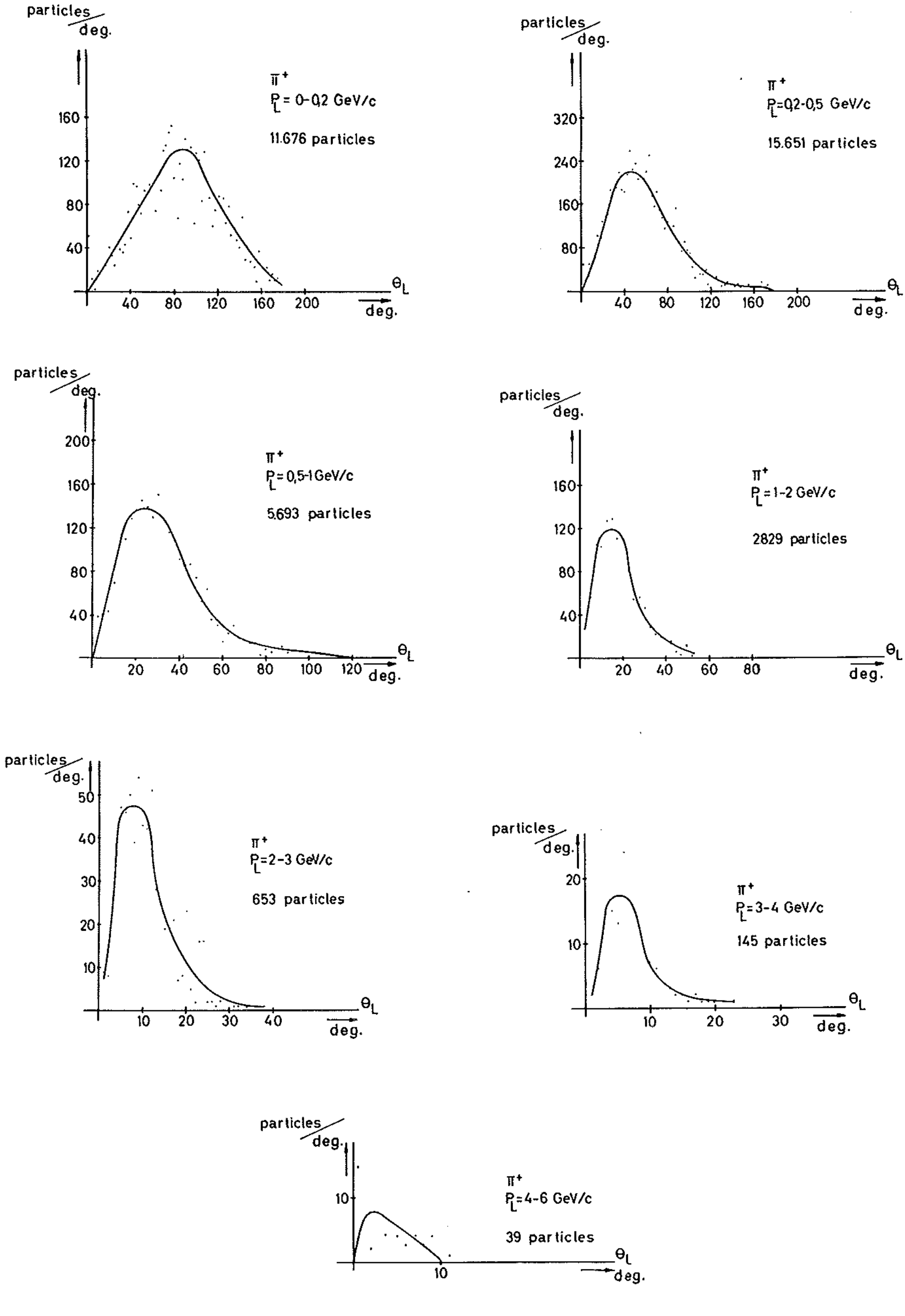
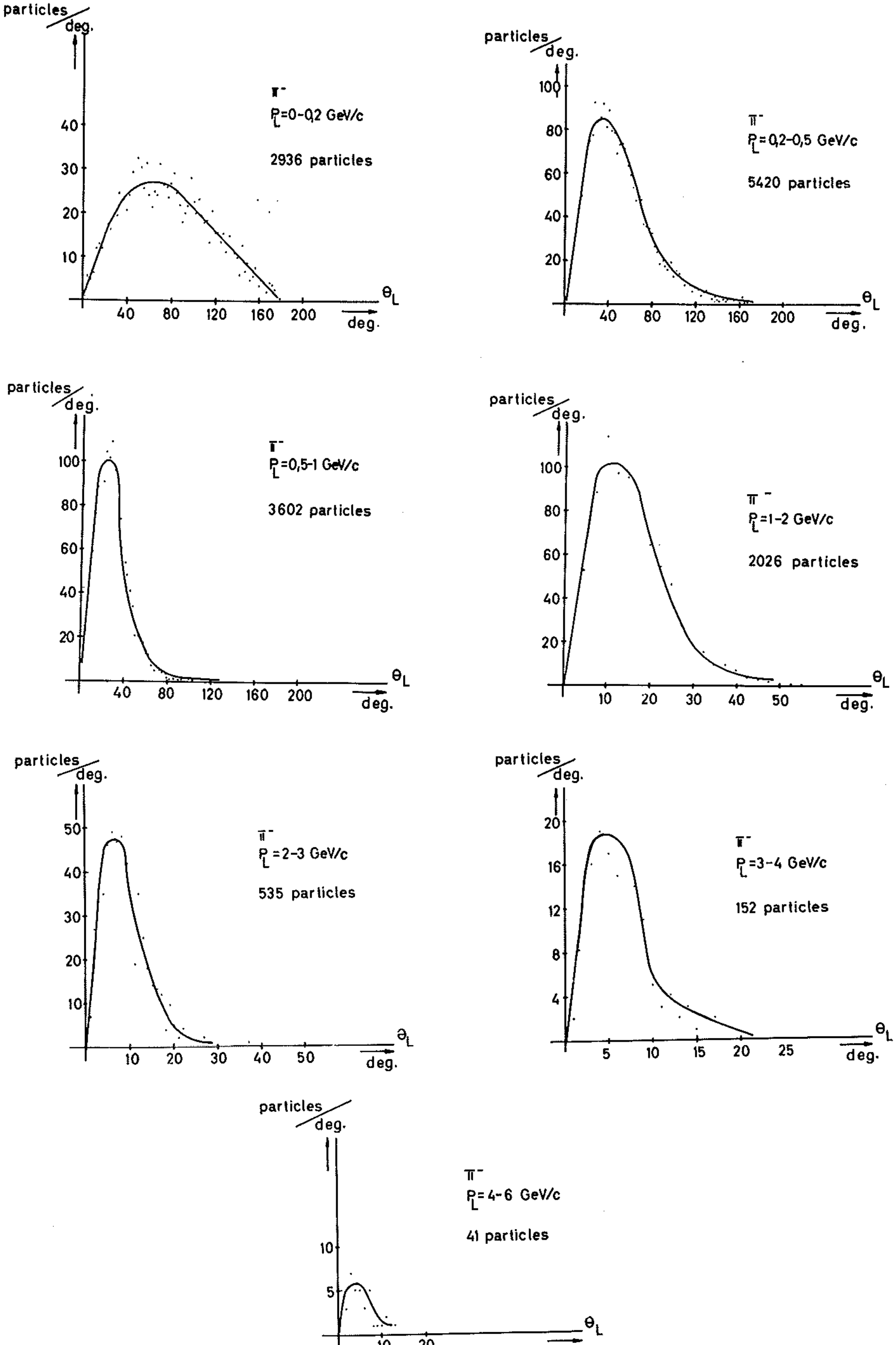
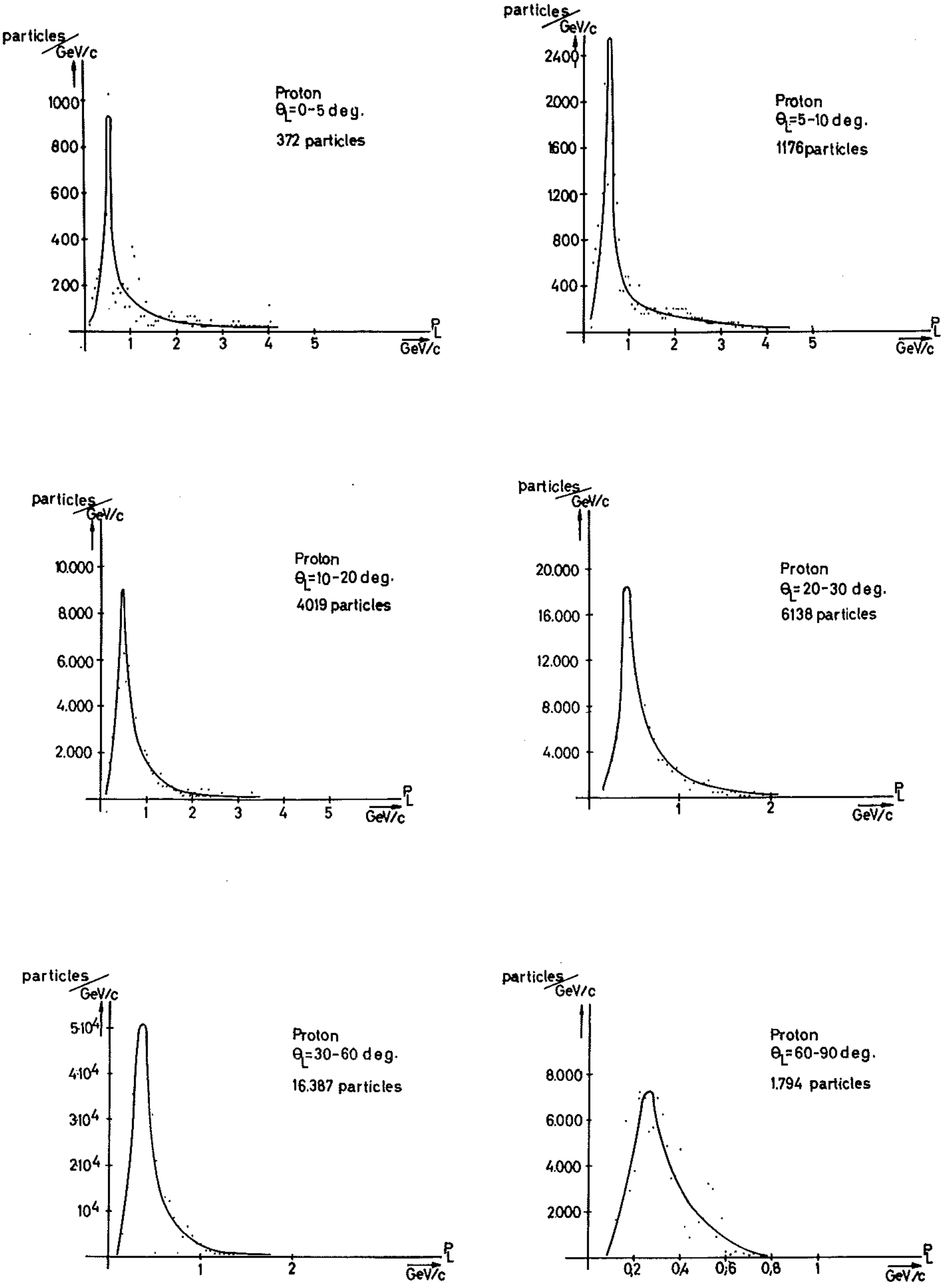

particles/deg.
π⁺
P_L = 0-0,2 GeV/c
11.676 particles
π⁺
P_L=0,2-0,5 GeV/c
15.651 particles
π⁺
P_L = 0,5-1 GeV/c
5.693 particles
π⁺
P_L = 1-2 GeV/c
2829 particles
π⁺
P_L=2-3 GeV/c
653 particles
π⁺
P_L=3-4 GeV/c
145 particles
π⁺
P_L=4-6 GeV/c
39 particles
θ_L
deg.

Fig. 3



particles/deg.
π⁻
P_L=0-0,2 GeV/c
2936 particles
θ_L
deg.
particles/deg.
π⁻
P_L=0,2-0,5 GeV/c
5420 particles
θ_L
deg.
particles/deg.
π⁻
P_L=0,5-1 GeV/c
3602 particles
θ_L
deg.
particles/deg.
π⁻
P_L=1-2 GeV/c
2026 particles
θ_L
deg.
particles/deg.
π⁻
P_L=2-3 GeV/c
535 particles
θ_L
deg.
particles/deg.
π⁻
P_L=3-4 GeV/c
152 particles
θ_L
deg.
particles/deg.
π⁻
P_L=4-6 GeV/c
41 particles
θ_L
deg.

Fig.4



particles/GeV/c
Proton
θ_L=0-5 deg.
372 particles
1000
800
600
400
200
1
2
3
4
5
P_L
GeV/c
particles/GeV/c
Proton
θ_L=5-10 deg.
1176particles
2400
2000
1600
1200
800
400
1
2
3
4
5
P_L
GeV/c
particles/GeV/c
Proton
θ_L=10-20 deg.
4019 particles
10.000
8.000
6.000
4.000
2.000
1
2
3
4
5
P_L
GeV/c
particles/GeV/c
Proton
θ_L= 20-30 deg.
6138 particles
20.000
16.000
12.000
8.000
4.000
1
2
P_L
GeV/c
particles/GeV/c
Proton
θ_L=30-60 deg.
16.387 particles
$5\cdot10^4$
$4\cdot10^4$
$3\cdot10^4$
$2\cdot10^4$
10^4
1
2
P_L
GeV/c
particles/GeV/c
Proton
θ_L=60-90 deg.
1.794 particles
8.000
6.000
4.000
2000
0,2
0,4
0,6
0,8
1
P_L
GeV/c

Fig. 5

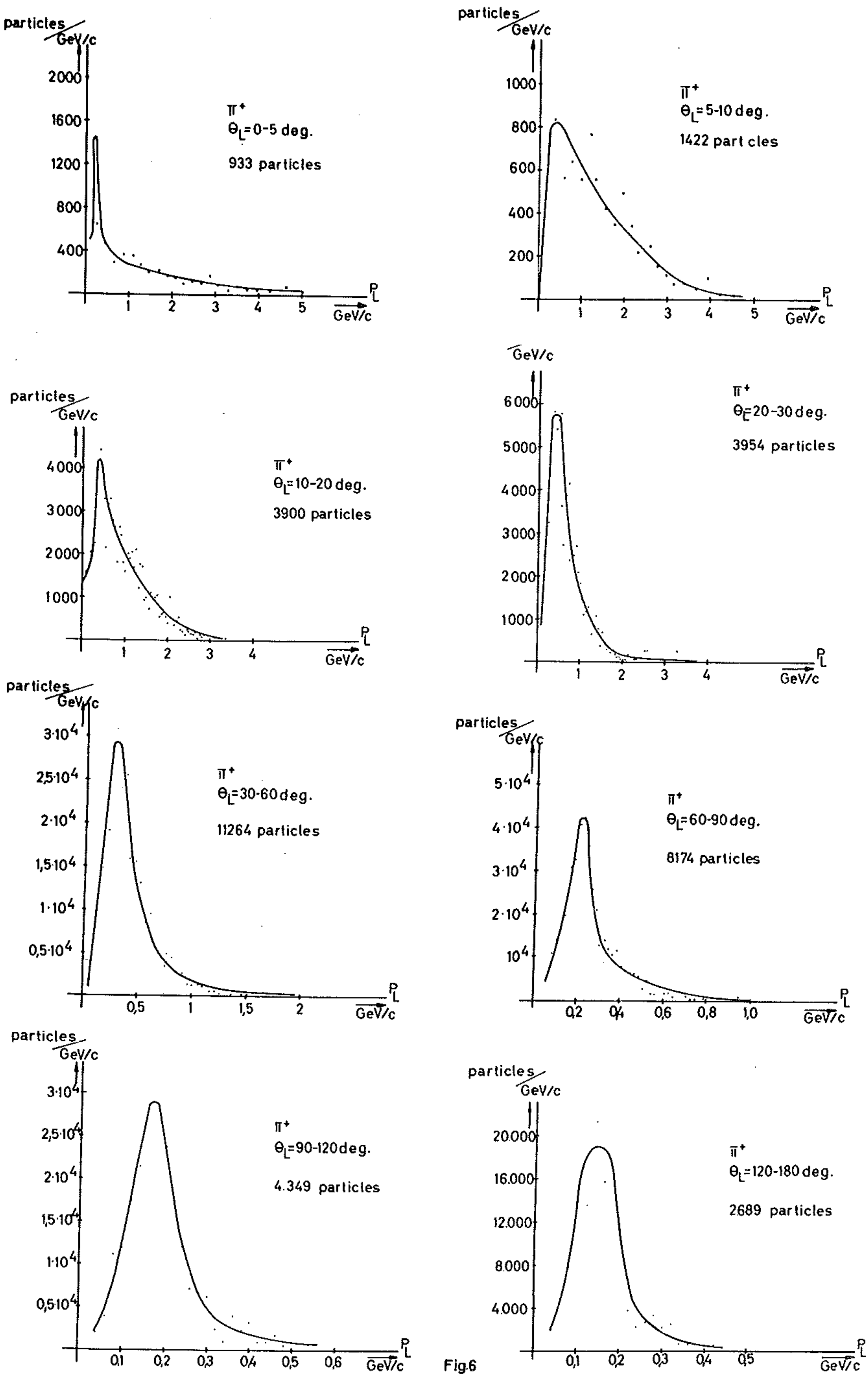
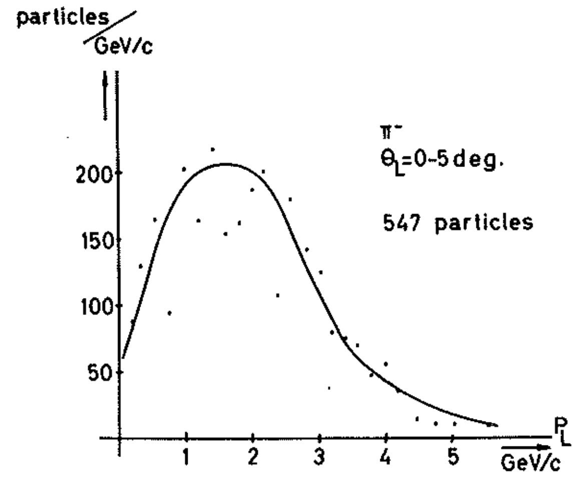
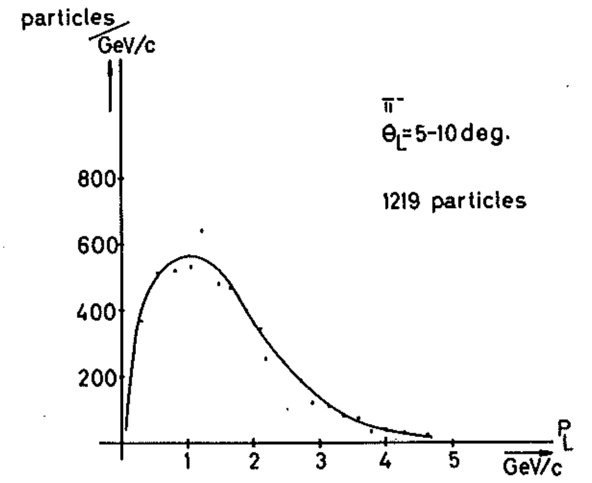
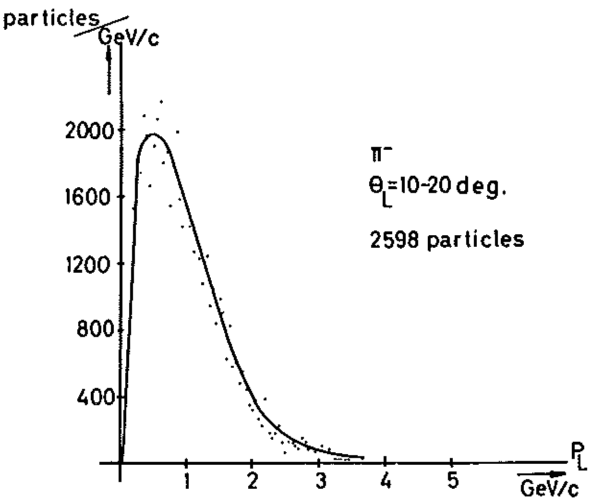
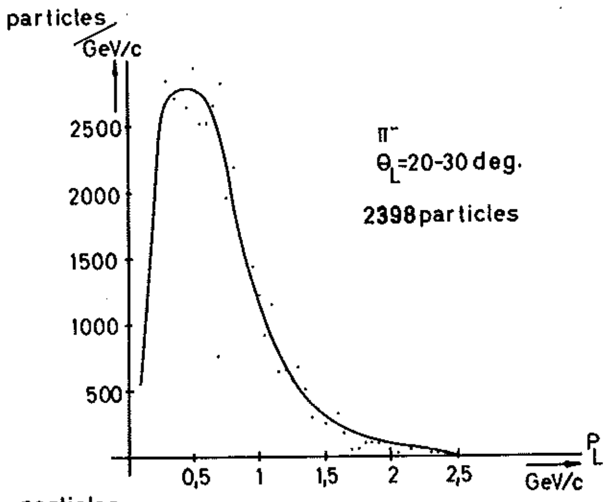

particles / GeV/c
π+
θL=0-5 deg.
933 particles
π+
θL=5-10 deg.
1422 part cles
π+
θL=10-20 deg.
3900 particles
π+
θL=20-30 deg.
3954 particles
π+
θL=30-60 deg.
11264 particles
π+
θL=60-90 deg.
8174 particles
π+
θL=90-120 deg.
4.349 particles
π+
θL=120-180 deg.
2689 particles
PL
GeV/c

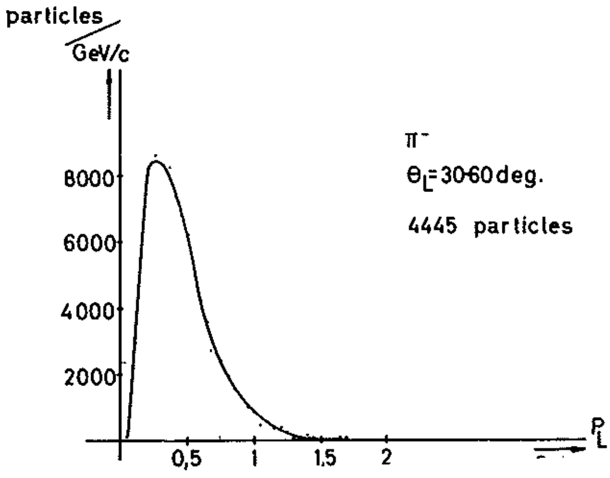
Fig.6

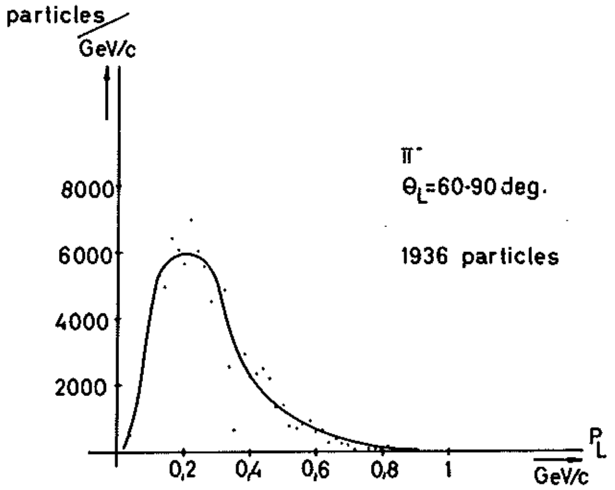

particles/GeV/c
π⁻
θL=0-5 deg.
547 particles
200
150
100
50
1
2
3
4
5
PL
GeV/c

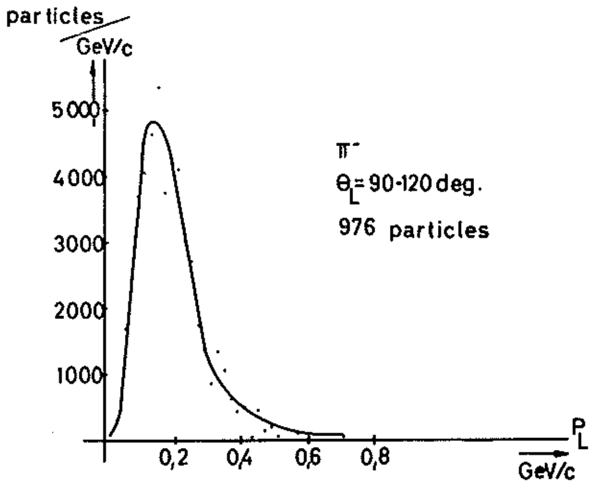

particles/GeV/c
π⁻
θL=5-10 deg.
1219 particles
800
600
400
200
1
2
3
4
5
PL
GeV/c

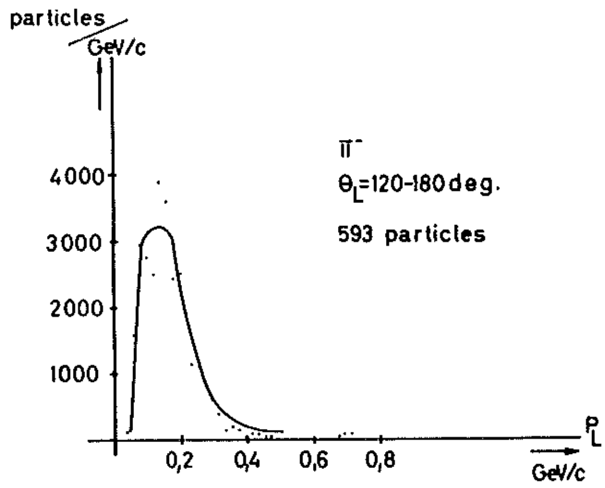

particles/GeV/c
π⁻
θL=10-20 deg.
2598 particles
2000
1600
1200
800
400
1
2
3
4
5
PL
GeV/c

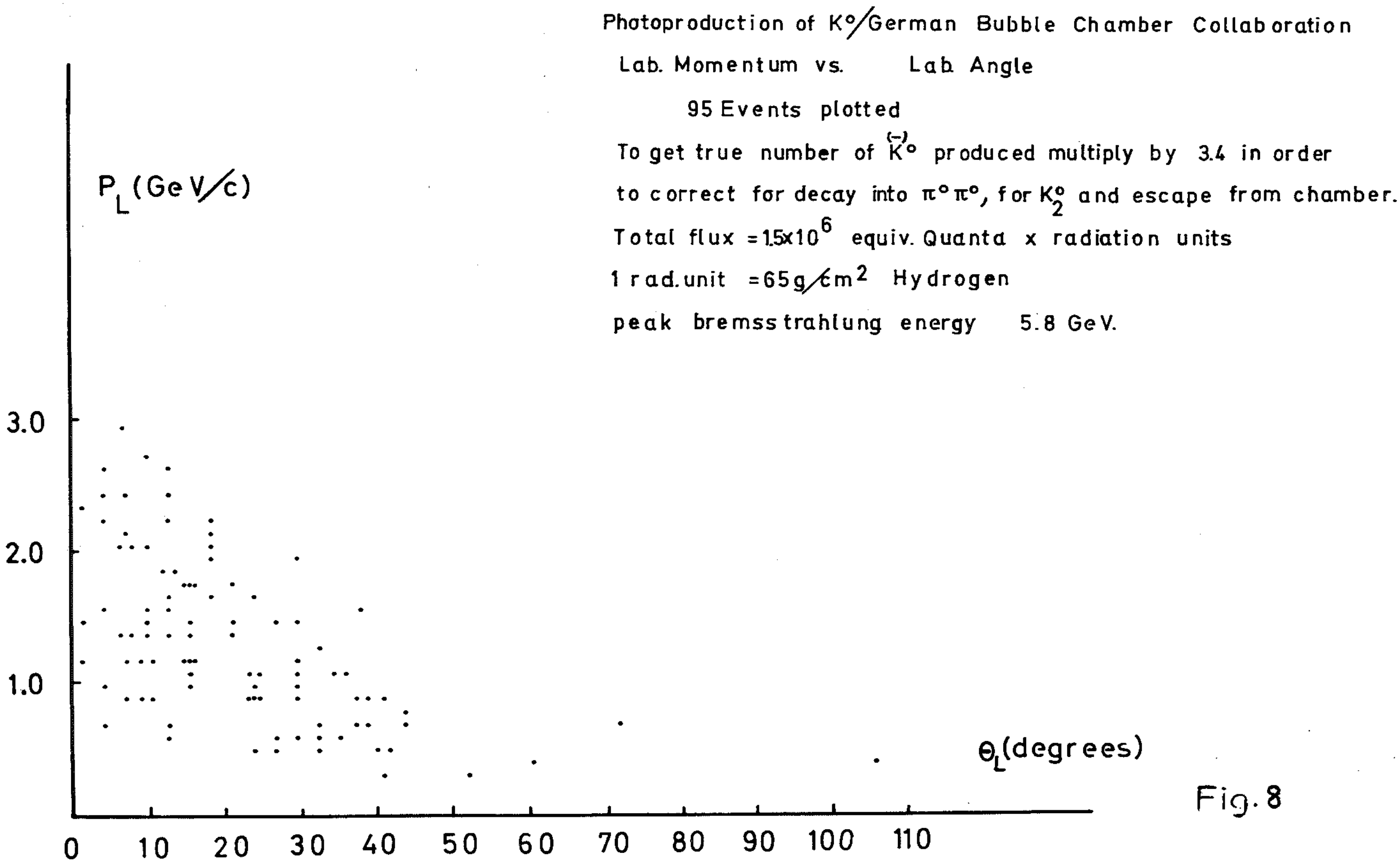

particles/GeV/c
π⁻
θL=20-30 deg.
2398 particles
2500
2000
1500
1000
500
0,5
1
1,5
2
2,5
PL
GeV/c


particles/GeV/c
π⁻
θL=30-60 deg.
4445 particles
8000
6000
4000
2000
0,5
1
1,5
2
PL


particles/GeV/c
π⁻
θL=60-90 deg.
1936 particles
8000
6000
4000
2000
0,2
0,4
0,6
0,8
1
PL
GeV/c


particles/GeV/c
π⁻
θL=90-120 deg.
976 particles
5000
4000
3000
2000
1000
0,2
0,4
0,6
0,8
PL
GeV/c


particles/GeV/c
π⁻
θL=120-180 deg.
593 particles
4000
3000
2000
1000
0,2
0,4
0,6
0,8
PL
GeV/c



Photoproduction of K°/German Bubble Chamber Collaboration
Lab. Momentum vs. Lab. Angle
95 Events plotted
To get true number of $\overset{(-)}{K}{}^{o}$ produced multiply by 3.4 in order to correct for decay into $\pi^{o}\pi^{o}$, for K_2^o and escape from chamber.
Total flux = 1.5×10^{6} equiv. Quanta x radiation units
1 rad. unit = 65 g/cm^2 Hydrogen
peak bremsstrahlung energy 5.8 GeV.
P_L (GeV/c)
3.0
2.0
1.0
Θ_L (degrees)
0
10
20
30
40
50
60
70
80
90
100
110

Fig. 8

Laboratory Angular and Momentum Distributions of Protons, Kaons and Pions from Photoproduction on Hydrogen at Energies up to 5.8 GeV

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