ENERGY DEPENDENCE OF π^-, K^- AND $\bar{p}$ TOTAL CROSS SECTIONS OF PROTONS IN THE MOMENTUM RANGE UP TO 65 *GeV/c*

L. M. Vasiljev, Yu. P. Gorin, S. P. Denisov, Yu. P. Dmitrevski, S. V. Donskov, Yu. M. Melnik, A. I. Petrukhin, Yu. D. Prokoshkin, V. S. Seleznev, D. A. Stoyanova and R. S. Shuvalov

Preliminary data are presented on the new π^-p, K^-p and $\bar{p}p$ total cross section measurements in the momentum range up to 65 *GeV/c*. The experiment has been performed at the 70 *GeV* accelerator of IHEP. The standard transmission technique was employed [1]. The beam transport system used at the momenta $p = 20 \div 65$ *GeV/c* is shown in fig. 1 and has been described earlier [1]. In comparison with the previous experiment [1], a liquid hydrogen target and a new high resolution differential Čerenkov counter were used. Also the electronics was improved to allow the cross-section measurement at higher intensity.

The liquid hydrogen target used in this experiment was a cylinder, 3 *m* long and 11.5 *cm* in diameter, providing approximately 21 g/cm^2 of hydrogen. The end windows of the target were constructed from copper 2×0.2 *mm* thick and mylar 2×0.3 *mm* thick. The hydrogen density was defined with an accuracy of $\sim 0.1\%$ by a saturated vapour pressure measurement. An identical evacuated dummy target was used for the empty target background subtraction.

For the particle identification at $20 \div 65$ *GeV/c* the 5 *m* differential and 7 *m* threshold Čerenkov counters were used. The differential counter [2] had a velocity resolution better than 10^{-5}, an efficiency higher than 80% and a background smaller than 0.1% for all particles. The counter was filled with nitrogen or helium.

The electronics allowed measurements of the total cross sections at an intensity of $\sim 10^5$ particles per pulse. In comparison with the previous experiment [I], it included additional units that vetoed the count if the beam flux exceeded $\sim 3 \cdot 10^5$ particles/cycle. The pulse height from counter S_3, positioned

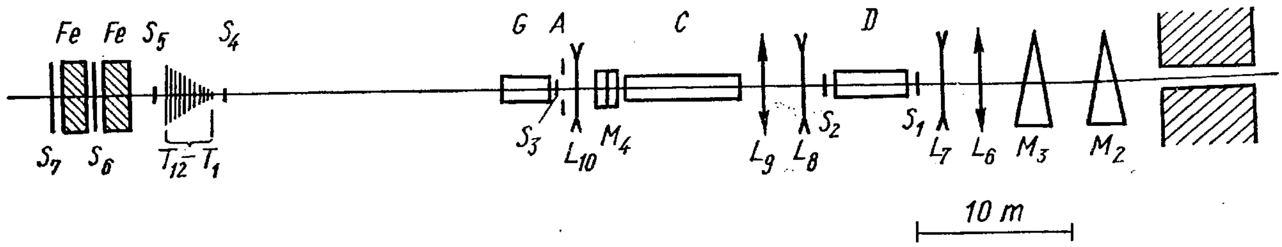


Fig. 1. The beam and equipment layout for the momentum range $p = 20 \div 65$ *GeV/c*. The head of the beam [1] is not shown. M_2, M_3 — horizontal bending magnets, M_4 — vertical bending magnet, $L_6 \div L_{10}$ — quadrupole lenses, S_1 — S_3 — scintillation counters defining the beam geometrically, A — anticoincidence scintillation counter, D — differential Čerenkov counter, C — threshold Čerenkov counter, T_1 — T_{12} — transmission scintillation counters, S_4 — S_5 — scintillation counter for the efficiency measurement, S_6, S_7 — scintillation counters for muon detection, Fe — steel absorber.

in front of the hydrogen target, was analyzed to forbid the detection of events when two or more particles struck the target within the resolution time.

The total cross-section measurements in the momentum range $p = 30 \div 65$ *GeV/c* have been carried out at the energy of accelerated protons $E_0 = 70$ *GeV/c*. The $20 \div 30$ *GeV/c* secondary particles were produced by 43 *GeV* protons. Typically, the beam fluxes were equal to $\sim 5 \cdot 10^4$ particles/cycle, when $\pi^- p$ cross-sections were measured and $\sim 10^5$ particles/cycle in the case of $K^- p$ and $\bar{p}p$ total cross sections measurement. The beam spill duration was approximately 0.6 *sec*.

During the whole run the efficiencies of the transmission counters T_i, which were higher than 99.8%, and background due to delay coincidence ($\sim 0.5\%$) were being controlled continuously.

A number of control experiments have been performed. To check the identity of the evacuated hydrogen and dummy targets, their comparison has been made with the 35 and 40 *GeV/c* π^- beams. The corresponding corrections for measured total cross-sections appeared to be equal to 0.15%. At 40 *GeV/c* the beam intensity was raised and lowered by a factor of three compared with the normal value. This showed that, within the statistical errors, such a decrease in beam intensity had no effect on the measured cross sections while the increase in beam intensity up to $3 \cdot 10^5$ particles/pulse lowered the total cross sections by a value of $\sim 0.5\%$. During other control experiments, it was shown that the increase of the beam spot at the focal plane, where the transmission counters were placed, as well as the increase of the distance between the transmission counters and target, resulted in the small changes in the obtained results. All these corrections were taken into account when determining the total cross sections.

Besides the measurements in the momentum range 20—65 *GeV/c*, the total cross sections at 6.65, 10 and 13.3 *GeV/c* have been obtained, using the low energy secondary particle beam [3] (fig. 2). A 3 *m* high pressure gas target was used in this experiment [1,4]. π^-, K^- and antiprotons have been separated by the differential and threshold Čerenkov counters [3].

At $p = 6.65$ *GeV/c* the measurement has been carried out by the same method as in the previous experiment [1]. A new element of the equipment at $p = 10$ and 13.3 *GeV/c* was a bending magnet M_5 placed between the target and transmission counters T_i (fig. 2). This magnet allowed the removal of the low energy particles produced in the target. For comparison of both methods the total cross-sections were measured at 13.3 *GeV/c* with the magnet M_5 on and off (in the latter case the transmission counters were positioned along the undeflected beam line). The results obtained by these two methods were in agreement within the experimental accuracy (0.5%).

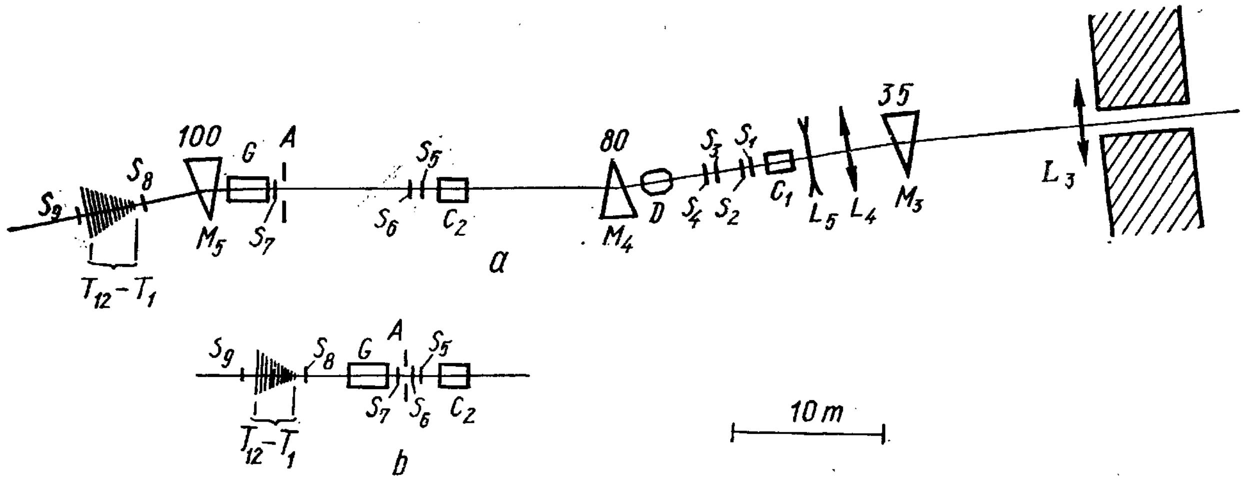


Fig. 2. The beam and equipment layout at *a*) $p = 10$ and 13.3 *GeV/c* and *b*) $p = 6.65$ *GeV/c*. The head of the beam is not shown. L_3 — L_5 — quadrupole lenses, M_3 — M_5 — bending magnets (the numbers near the magnets indicate the deflection angles in mrad), S_1 — S_7, A — scintillation counters, C_1, C_2 — threshold Čerenkov counters, D — differential Čerenkov counters, S_8 S_9 — small scintillation counters for the efficiency measurement, T_1 — T_{12} — transmission counters, G — gas target.

The experimental procedure consisted of the definition of partial cross-sections $\sigma(t_i)$, measured by the transmission counters T_i [1]:

$$\sigma(t_i) = \frac{1}{n} \ln \frac{N_{ie}/M_e}{N_{if}/M_f},$$

where the subscripts e and f refer to the measurements with the dummy and hydrogen targets respectively; n is a number of hydrogen nuclei per cm^2 in the target; M is the number of particles striking the target; N_i is the number of particles registered by the counter T_i; t_i is the maximum of the square of the four-momentum transfer of particles detected by T_i. To define the total cross-sections σ_{tot} in the momentum range of $20 \div 65$ *GeV/c*, the partial cross-sections were extrapolated to the value $t_i = 0$. The extrapolation was carried out using the relation

$$\sigma(t_i) = \sigma_{tot} \exp(at_i + bt^2_i).$$

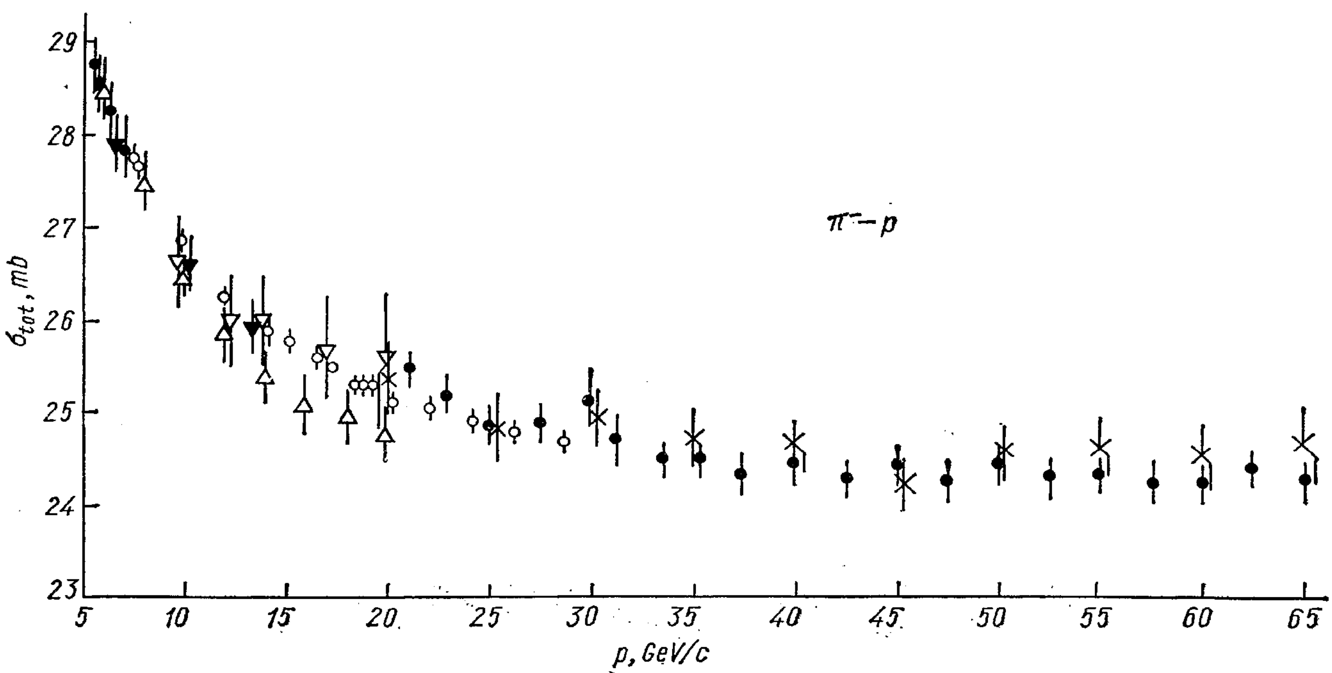
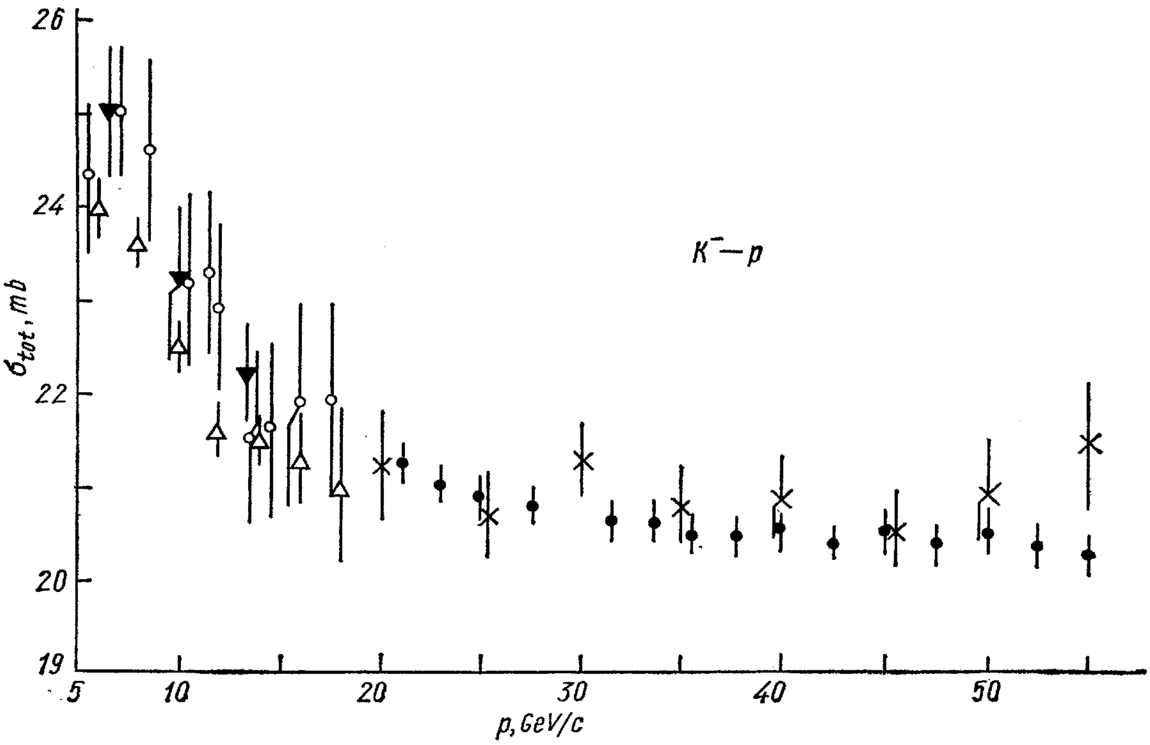
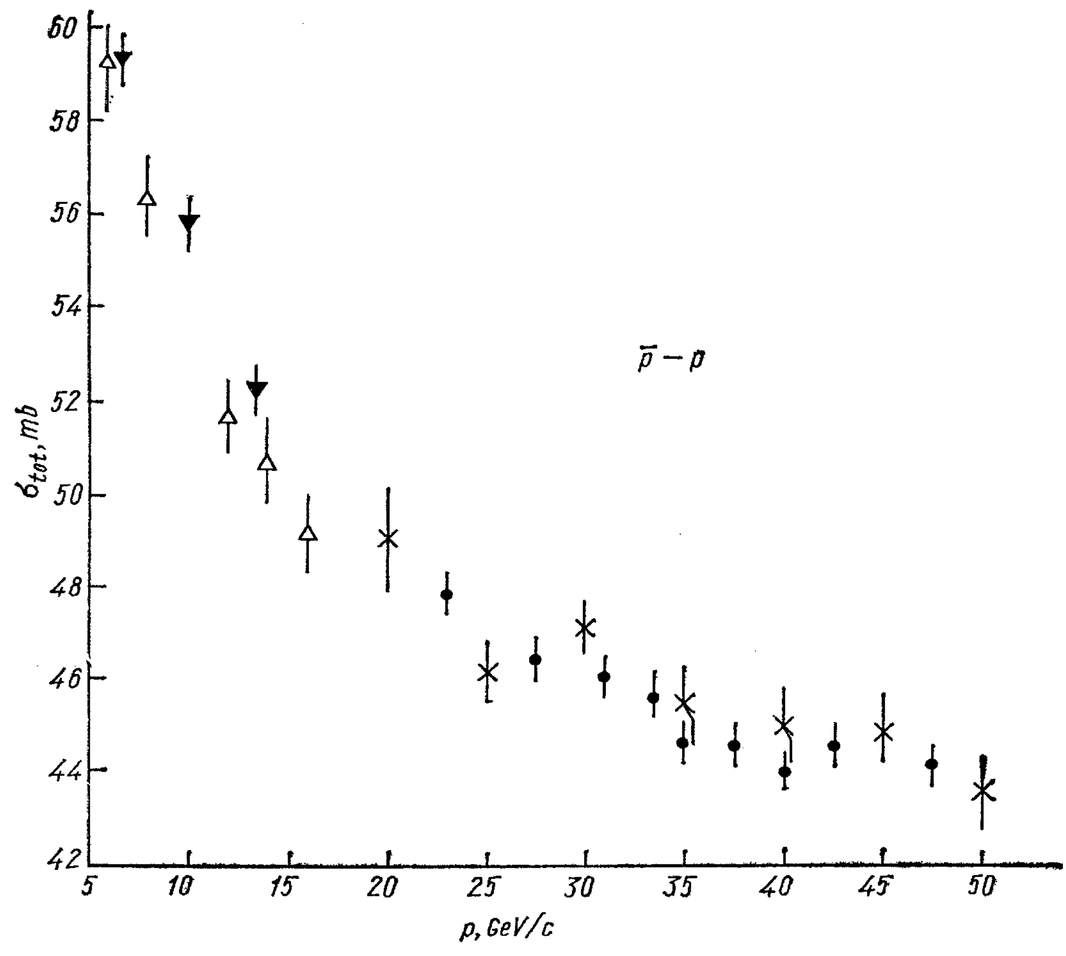


Fig. 3. $\pi^- p$ total cross-sections. The errors shown include both statistic and systematic errors. ●: this experiment (hydrogen target); ▼ this experiment (gas target).



26
24
22
20
19
σ_{tot}, mb
$K^- - p$
5
10
20
30
40
50
p, GeV/c

Fig. 4.



60
58
56
54
52
50
48
46
44
42
σ_{tot}, mb
$\bar{p} - p$
5
10
15
20
25
30
35
40
45
50
p, GeV/c

Fig. 5.

The partial cross-sections, measured in the t-range 0.015—0.059 $(GeV/c)^2$, were used in the extrapolation. In contrast with the previous experiment [1] the parameter b was defined for each point and was not averaged over the whole energy range. The extrapolation procedure at 6.65, 10 and 13.3 GeV/c was the same as described earlier [1].

The pion cross-sections were corrected for muon contamination in the beam. The μ-contamination was measured by the threshold Čerenkov counter and the scintillation counters S_6 and S_7, placed behind the steel absorber (fig. 1). Control measurements when the counters S_6, S_7 were put in coincidence or anticoincidence with the transmission counters proved the reliability of the procedures used for the muon flux evaluations. The measured muon corrections increased from $(1.0 \pm 0.3)\%$ at $p = 65$ GeV/c to $(5.9 \pm 0.5)\%$ at $p = 6.65$ GeV/c.

Figs. 3—5 present the results of this experiment together with previous measurements. The errors shown include both statistical $(0.3 + 0.5)\%$ and systematic errors. The systematic (scale) error was due mainly to

1) the uncertainty in the number of hydrogen nuclei per cm^2 ($\sim 0.2\%$),
2) the uncertainty of the extrapolation procedure ($\sim 0.4\%$),
3) randoms and other effects, connected with the high intensity ($\sim 0.3\%$),
4) the final size of the beam spot at the focal plane ($\sim 0.5\%$),
5) μ — contamination in the pion beam ($\sim 0.3\%$). The total error of the cross-section measured in the momentum range $p = 20 \div 65$ GeV/c is $\sim 1\%$.

As it can be seen from figs. 3—5 the agreement of our lower energy data with earlier results [5—9] is good. In the momentum range $20 + 65$ GeV/c the new data agree within the experimental errors with the previous measurements [1].

The π^-p total cross-sections decrease with increasing momentum up to $p \approx 35$ GeV/c. Beyond 35 GeV/c the pion total cross-sections have become constant within the error of 0.2 mb. If one approximates the energy dependence of the $\sigma_{tot}(\pi^-p)$ at $p \geqslant 35$ GeV/c by a straight line, the slope of this line appears to be equal to (-0.005 ± 0.004) $mb/(GeV/c)$.

The similar conclusion can also be reached for the new K^-p total cross-sections measured with a higher accuracy than earlier [1] (fig. 4). At the momenta $p \geqslant 35$ GeV/c the slope of the energy dependence of the $\sigma_{tot}(K^-p)$ appears to be close to zero: (-0.005 ± 0.006) $mb/(GeV/c)$.

As a whole the data obtained confirm the results of previous experiment [1]. Beyond 35 GeV/c the π^-p and K^-p total cross-sections have become constant and considerably different from the Regge-pole predictions, based on the low energy data [10, 11]. The $\bar{p}p$ total cross-sections are in agreement with the calculations [10, 11].

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