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In studies of hadroic interaction at high energies, we use

There are mainly two methods used to determine total cross sections. In one

of which the removal from the beam of particles that interacted with the target,

measured under "good geometry" conditions using positioned

behind the target of passing counters /1-4. Every i-th missing count -

The detector registers particles escaping from the target within a defined range.

with this scattering angle counter in , and allows you to measure the corresponding

partial section corresponding to this angle sigma(t\_1) /4/ (here ti = -P^2 theta\_i^2 0. -max--max-

small value of the square of the transmitted 4-pulse; P-momentum of the particle).

The total cross section sigma\_tot is found by extrapolating the obtained partial cross sections to the zero angle. This method was used at the IHEP accelerator

studies of the energy dependence of the total cross sections of the inter-

actions of pions, kaons, protons, antiprotons and antideuteron proton-

/4-v/ mi in the pulse region up to 85 GeV/c.

Another method for determining total cross sections is to measure angular distribution of particles after the target using hodoscopes /9/.

The use of a hodoscopic installation allows you to achieve high angles

scattering than in the case of transmitting counters\* This reduces

There is a possible error associated with the partial extrapolation procedure.

ny sections,

This paper describes measurements of total cross sections in the region

three P-^bbGeV/c pulses performed at the 70-GeV IHEP accelerator at

using a hodoscopic installation. The installation was connected in line with

Computer Minsk-22, At the same time, the total cross sections were measured using

/7/

skipping counters,

This made it possible to carry out direct

experimental comparison of two methods for determining total cross sections

and along with checking the accuracy of the extrapolation procedure for partial sections,

we can find out the influence of systematic errors inherent in each

of these methods, on the measurement results.

The experimental scheme is shown in Fig. 1. Beam of particles, registered

measured by scintillation counters S - S, A and hodoscope H-,

1 3 passed through a liquid hydrogen or liquid oxide target G?/7

Particles of a given type were separated in the beam by differential and threshold

vym Cherenkov counters D, C

Coordinates of particles emitted

from the target U, were measured using a hodoscope H„" At the end of the installation

there were 1.5-meter steel absorbers and scintillation

counters S and S, which were used to measure the admixture of muo-

/4.7/ \*\* M

new

A special feature of the described experiment was the use

/12/

beam alignment with a high degree of parallelism • Angular divergence

particles in the beam, measured using hodoscopes N. and N, amounted to

less than 0.3 mrad (Fig. 2). This made it possible to measure particle scattering angles

on the target using only two hodoscopes, which greatly simplified

logical structure of electronics and increased the speed of event registration.

The i'L hodoscope consisted of two Planes (x and Y), each of which

The mixture contained 23 cells measuring 5 mm. Scintillator beam thickness

was equal to 5 mm. Hodoscope H„ contained 63 cells of the same size in

each of the planes. Distance between hodoscope H\_ and target G changed proportionally to the momentum of the particles in the beam P. Thanks to this

interval of t values. , covered by the hodoscopic installation, remained

being the same for all values ​​of the momentum (0.15 (GeV/s)^2). Minimum

installation resolution, determined by the geometry of the hodoscopes and angular beam divergence was delta t\_i « 4 • 10^-4 (GeV/s)^2 at t\_i = 0,

With growth | t. | magnitude the value of delta t\_i increased ( delta ti = 0.05 time sqrt (t\_i)) to 0.01 (GeV/s)^2.

The electronics of the hodoscope installation were made using integral

nal schemes. Temporal selection was carried out by gating pulses

PMT, This made it possible to eliminate the dead time of electronic circuits and semi-

The efficiency of particle registration with the hodoscope H„ is more than 89.98%\* Go"

doskop N- selected such events when one particle fell on the target G"

If two OR more particles hit any of the H\_ planes, then they

the coordinates were not transferred to the computer. In section measurements we used

a special high-speed solver that allowed recording

I will give the ZVM coordinates only of such particles that, after interacting,

The beams in the target deviated by an angle greater than the specified one (|t\_i| > 8 \* 10^-4(GeV/s)^2)

The use of this block made it possible to increase the speed of event registration

5-8 times and bring it to 30 thousand per accelerator cycle

The measurements of the total cross sections consisted of a series of experiments in which

Hydrogen, deuterium, and “empty” multipliers were periodically placed in the beam.

/4.7/ sheni. During the experiment, the position was continuously monitored

and parallelism of the beam, the level of random coincidences, was carried out

general control of the installation.

The values ​​of the total cross sections sigma\_tot were determined by extrapolation measured dependences sigma( t\_i ) to tj s 0 , Extrapolation was carried out according to the formula

Sigma(t\_i) = sigma\_tot e^at\_i + bt\_i^2. (1)

When extrapolating, small corrections to the Coulomb distribution were taken into account.

seeding and Coulomb-nuclear interference /7 8/. Partial sections, due to

measured by the skip counter method, are well described by the

Eq. (1) in area |t\_i | > 0.01(GeV/s)^2 . With smaller |t\_i| becomes

significant contribution of Coulomb scattering, leading to rapid growth

partial sections with decreasing |t\_i|.

The partial cross sections measured in this work (sms, e.g.

Fig. 3), are also well described by formula (1), Moreover, thanks to the

high resolution of the hodoscopic installation, deviation of values ​​sigma(t\_i )from dependence (1) becomes noticeable only at |t\_i| <= 0.005 (GeV/c)^2. Same minimum £11 | was obtained by calculation with

using the Monte Carlo method.

To check the accuracy of the extrapolation procedure (1), we carried out

comparison of total cross sections obtained by extrapolation of measured partial of cross sections sigma(t\_i) for different values ​​of the lower boundary of the interval extrapolation |t\_i|\_min, The upper limit of the extrapolation interval was chosen equal to 0.07 (GeV/s)^2, as in previous works /4-8/. In table 1, the results of measurements of the differences between the total cross sections are presented, corresponding to extrapolations with two values ​​of |t\_i|\_min are equal to

mi 0.01 (GeV/s)^2 and 0.015 (GeV/s)^2. We used data on cross sections of mutual actions of protons and pi--mesons with protons and deuterons, statistical The accuracy of which was better than 0.1%. Within the specified in the error table, the cross-section differences do not depend on the pulse P in interval P at 10 + 65 GeV/s. From the data in table. 1 it follows that the inaccuracy the cross-section extrapolation procedure does not exceed 0.2%, and it was correct/6-8/.

Extrapolation of partial cross sections to t\_i = 0 was carried out according to formula (1) both with free parameters a and b, and with b = 0.

In the latter case, the approximating curves are in poorer agreement with experiment dependences sigma(t\_i), and the values ​​of the total cross sections have are lower than with free b (Table 2). This difference in cross sections increases by a factor of 1.5 when moving from |t\_i|\_min = 0.01 (GeV/s)^2 and |t\_i|\_min = 0.015 (GeV/s)^2, Within the limits of measurement errors (Table 2), it does not depend on P,

The values ​​of the total cross sections for pp and pd interactions found

extrapolation of partial sections (1) measured in the interval 0.008 +

0.01 < |t\_i| < 0.07 (GeV/c)^2 are given in Table 3. Statistical accuracy

The accuracy of cross-section measurements was (0.3 \* 0.4)%. Systematic error uncertainty included the uncertainty of the target density ( = 0.1%), uncertainty accuracy of the extrapolation procedure (“0.2%) and other errors /6,7/, components in total ~0.3%. Impact adjustment substances in the path of the beam, was determined experimentally for pi-mesons with momentum P = 40 GeV/s. It turned out to be equal to (0.1 +- 0.1)%.

To find out how the angular divergence of particles in a beam affects

on the measured sections, measurements were carried out in which parallel

The beam efficiency (Fig. 1) was deteriorated by changing the currents in the quadrupole on the lenses of the magneto-optical channel. Difference in total cross sections sigma\_tot (pi- p)” obtained by increasing the minimum resolution delta\_t\_i (see above) from 4\* 10^-4 (GeV/s)^2 to 2 \* 10^-3 (GeV/s)^2, amounted to (0.08+ 0.12)%, and with an increase to 5 • 10^-3 (GeV/s)^2 - (-0.16 +- 0.25)%. Improvement of angular higher resolution of the hodoscopic installation due to increasing the distance between the hodoscope H\_ and the target also did not lead to a noticeable change

sections (<0.2%). HThe same correction, determined by calculation, has

was less than 0.1%.

A number of other amendments related to manufacturing inaccuracies and

installation of hodoscopes, was calculated by the Monte Carlo method taking into account real geometry of the experiment (Table 4). The last one listed in table 4 corrections were also determined experimentally on the beam

pi--mesons with momentum P = 50 GeV/c, It turned out to be equal to (0 +- 0.05)%.

Table 3 allows you to compare the results of measurements of total cross sections hodoscopic method with sections obtained simultaneously with those

same targets using the skip counter method. Average difference measured

total cross sections sigma\_tot (pp) in the interval P = (20 4-65) GeV/c is

(0.2 + 0.3)%, and sigma\_tot(pd)- (0.3 + 0.2)%

tistic scatter). Thus, a direct experimental comparison

two methods for determining total cross sections shows that they are consistent within the limits of statistical errors.

Measurements of total cross sections were also carried out for pi-, K-me-

zones and antiprotons. However, in this case, only one year was used

scopic installation, comparison of two methods for determining total sections was not carried out, and the main purpose of the measurements was to study the accuracy of the extrapolation procedure for partial sections. Obtained values sections are presented in table. 5\* Statistical errors in these measurements were greater than in experiments with protons. They were determined mainly fluctuations in the particle count rate associated with temporary instabilities beam characteristics, and amounted to (0.5 - 0.8)%

The average difference between those given in table. 5 sections and size

by us, previously determined by the method of skipping counters, is:

for pi-p and pi+p-sections - (0.7 +- 0.5)%, pi+-d „ (0.1 +- 0.3)%, K-p - (0.3 +- 0.4)%, K~d - (-0.2 + 0.4)%, pbarp - (0.4 + 0.7)% and pbard - (-1.5 + 0.8)%. Be-values ​​of the total cross sections for pi-p and pp-interactions obtained by hodoscopy /9/ chemical method

poking around.

A comparison of two methods for determining total cross sections shows that

they are free from noticeable systematic errors and both can be

used for accurate (0.5% and better) measurements of total cross sections, Godosko-

The peak method allows to achieve smaller systematic errors

thanks to more accurate extrapolation of partial sections, At the same time

the skip counter method has a number of advantages in research

energy dependence of total cross sections. Results of this work

confirm previous conclusions/4-7/ .

Table 3

Total proton interaction cross sections with protons and deuterons (in mbarn) (the table shows statistical errors)

Real job Skip Counter Method

Sigma\_tot (pp) at 65 GeV/c measured at 60 GeV/c

Table 4

Corrections to full sections due to manufacturing inaccuracies

and hodoscope installations (in%)

* Inaccurate manufacturing and installation hodoscope elements (0.1 mm)
* Final cell size of hodoscopes (5 mm)
* Rotation of H\_2 relative to H\_1 in plane bones X, Y (5 mrad)
* Shift of H\_2 relative to H\_1 in the plane bones X, Y (1 mm)