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MASS NUMBER DEPENDENCE OF PROTON SPECTRA WITH LARGE TRANSVERS MOMENTUM IN PROTON-NUCLEUS COLLISIONS

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А-зависимость инклюзивных спектров протонов с большими поперечными импульсами в протон-ядерных столкновениях

В рамках теории многократного рассеяния анализируются экспериментальные данные о сечениях реакций $p+A \to p+X$ при больших значениях поперечного импульса ($P_T > 1$ ГэВ/с).

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

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Дубна 1976

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Mass Number Dependence of Proton Spectra with Large Transvers Momentum in Proton-Nucleus Collisions

The experimental data of the cross sections of $p+A \to p+$ anything reactions at large transverse momentum ($P_T > 1$ GeV/c) are analysed in the framework of the multiple collision theory.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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The experimental study of charged particle yields with large transverse momenta ($P_T \sim 1 \div 6$ GeV/c) in the reactions

$$p + A \to c + \text{anything} \qquad (1)$$

(A- stands for a target nucleus, $c = \pi^{\pm}, K^{\pm}, p^{\pm}, d^{\pm}$) has revealed a flattening out of the P_T - dependence of the cross sections of these reactions with incrising the mass number of a target nucleus /1/.

Though it is natural to treat this result as the existence of effects of multiple particle collisions in a nucleus, the authors of ref. /2,3/ have given some arguments against such an interpretation. Their conclusions are essentially bassed on the assumption of the power (and not the exponential) decrease of cross sections of the reactions $a + N \to c$ + anything with increasing P_T . Such a behaviour for $P_T \to \infty$ is predicted by the parton model for spectra of any particles produced in hadron-hadron collisions. However, the transition rate to the asyptotic (power) regime can be, and in fact, is not eqal for the spectra of different particles /4/. While the spectra of nonliding particles ($c \neq a$) quite early (even at $P_T \sim 1 \div 2$GeV/c) turn essentially into power functions, for the spectra of leading particles ($c = a$) the exponential law dominates up to the momenta $P_T \sim 6$ GeV/c.

Since in the multiple scattering approach ideology /5-7/ the large momentum transfers are fulfilled mainly by small portions in a series of subsequent collisions, and just the collisions of a"leading" type are the most important. Then it is clear that the estimates of multiple collisions in the experiment of Cronin et al./1/ ($P_T^{max} \approx 6$ GeV/c) based on the assumption of power P_T-dependence for any spectral functions may turn out to be wrong.

Further by the p + A→ p + anything reactions we show that the results of the experiment/1/ allow the interpretation in the spirit of the theory of multiple collisions of particles in nuclei. To begin with we take the expression from ref./8/ relating the structure functions $\mathcal{F}_A(P_T,x)$ and $f(P_T,x)$ of the reactions p + A→ p + anything and p + N→ p + anything ;

$$E\frac{d\sigma^A}{d^3p} \equiv \mathcal{F}_A(P_T,x) = (2\pi)^{-3}\int d^2B\, d^2\beta\, d\alpha\; x^{i\alpha} J_0(P_T\beta)$$

$$\exp(-\sigma_{in}T(B))\left[\exp\{\omega(\alpha,\beta)T(B)\} - 1\right], \qquad (2)$$

where

$$\omega(\alpha,\beta) = \int d^2p_T\, dx\, f(P_T,x)\, x^{-i\alpha-1} J_0(P_T\beta)$$

$$T(B) = \int_{-\infty}^{+\infty} \rho(B,z)\, dz,$$

$\rho(B,z)$ is the density of nuclear matter, B is the impact parameter, σ_{in} is the total inelastic cross section of pN interections (σ_{in} = 32 mb).

In expression (2) we fail into account the terms correspon-ding to multiple elastic rescatterings as their consideration does not effect essentially the results we present below.

Suppose the simple parametrisation for the invariant cross section $f(P_T,x)$:

$$E\frac{d\sigma}{d^3p} \equiv f(P_T,x) = \frac{\sigma_{in}}{2\pi} B_p^2\, \ell\, x^\ell \exp(-B_p P_T)\,, \qquad (3)$$

where ℓ =(1-k)/k , and k is the pN inelasticity coefficient. Then for the p + A→ p + anything cross section we derive the

following expansion into a series over the multistep collisions:

$$\mathcal{F}_A(P_T,x) = f(P_T,x)\, e^{B_pP_T}\sum_{n=1}^{A} \frac{N_n^{eff}(A,\sigma_{in})}{\Gamma(n)\Gamma(\frac{3}{2}n)}\left(\frac{B_pP_T}{2}\right)^{\frac{3}{2}n-1}\left[\ell\, \ln(1/x)\right]^{n-1} \mathcal{K}_{\frac{3}{2}n-1}(B_pP_T), \qquad (4)$$

where
$$N_n^{eff}(A,\sigma) = \frac{1}{\sigma n!}\int \left(\sigma T(B)\right)^n \exp\left(-\sigma T(B)\right) d^2B \qquad (5)$$

and $\mathcal{K}_j(z)$ are the Macdonald functions.

Calculation results are compared with experimental data in Figs. 1-3.

Figure 1 shows the p + W→ p + anything invariant cross section versus transverse momentum P_T at the incident particle energy E_0= 300 GeV and the detection angle ϑ_L = 77 mrad in the laboratory frame.

Figure 2 plots the ratio

$$R_W(E_0/300) = E\frac{d\sigma^W}{d^3p}(E_0) \Big/ E\frac{d\sigma^W}{d^3p}(300) \qquad (6)$$

versus P_T for the incident energies E_0= 200 and 400 GeV.

The transverse momentum dependence of the effective power

$$n_{A/Be}(P_T) = \ln\left\{\mathcal{F}_A(P_T)/\mathcal{F}_{Be}(P_T)\right\} / \ln(A/A_{Be}) \qquad (7)$$

for Ti and W nuclei are given in Fig. 3 .

The calculations were carried out with the Saxon-Woods nuclear density

$$\rho(r) = \rho_0\left[1 + \exp(\frac{r-R}{c})\right]^{-1} \qquad (8)$$

where R = 1.12 $A^{1/3}$fm , c = 0.545 fm and the slope parameter B_p = 4.6 $(GeV/c)^{-1}$ /9/.

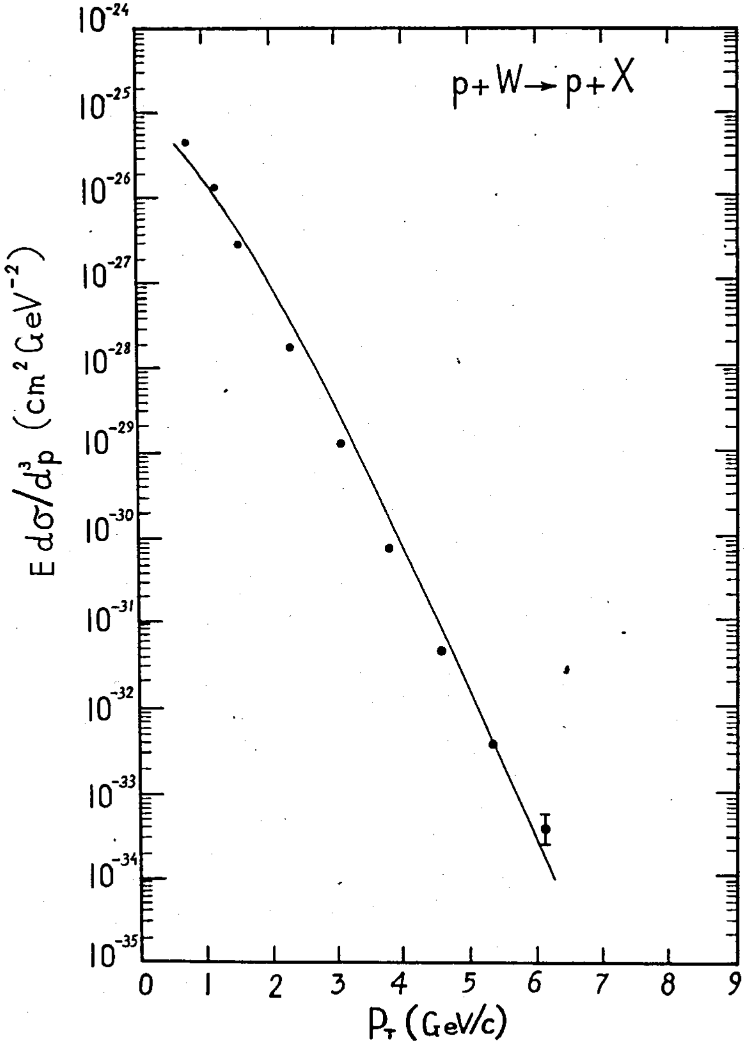

Fig. 1 Invariant cross section of the p + W → p + anything reaction versus P_T at incident energy E_0 = 300 GeV and the laboratory frame detection angle ϑ_L = 77 mrad.

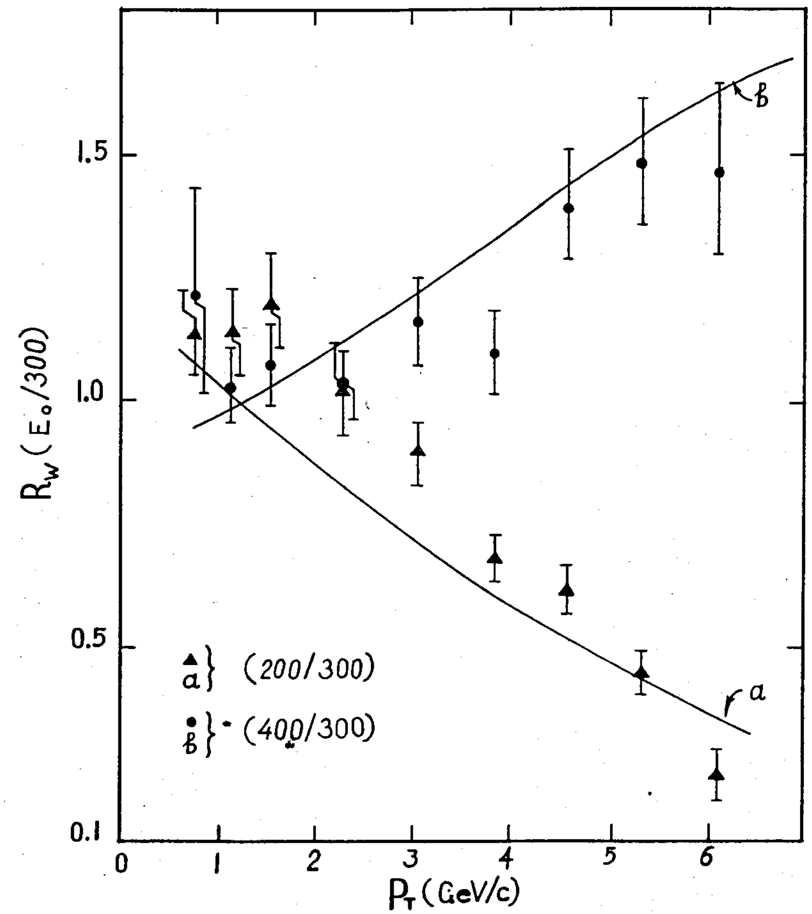

Fig. 2 The ratios R_W(200/300) (the curve "a") and R_W(400/300) (the curve "b") as a function of P_T .

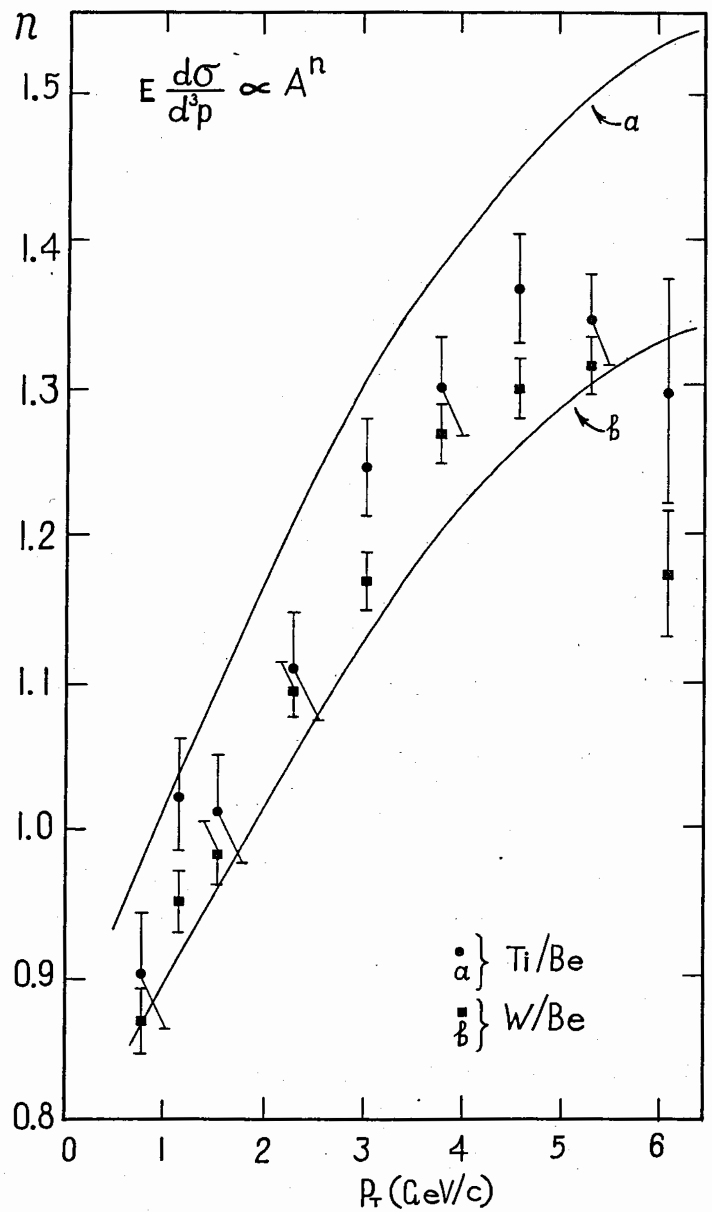

Fig. 3 Effective powers $n_{Ti/Be}$ (the curve "a") and $n_{W/Be}$ (the curve "b") as a function of P_T.

It should be noted that at $P_T \sim 6$ GeV/c in the reactions on the heavy nucleus (W) the main contribution comes from the five-, six-, and seven-fold inelastic collisions of protons with the nucleons incide the nucleus.

It is clear that even the use of very simplified parametrization (3) provides a fairly good qualitative agreement with the experiment /1/ on p + A ⟶ p + anything.

A more thorough study of the inclusive reactions on nuclear targets within the multiple scattering theory will be given elsewhere.

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