CHARMED PARTICLES PRODUCTION *in* *p*A-INTERACTIONS *at* 70 GeV

Kokoulina Elena. On behalf of the SVD-2 Collaboration (IHEP-JINR-SINP MSU)

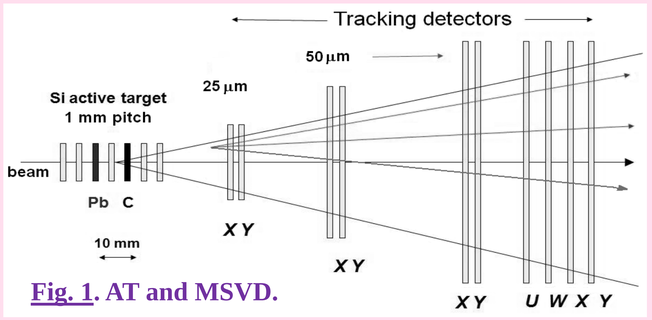


Fig. 1. AT and MSVD.

The SERP-E-184 experiment "Investigation of mechanisms of the production of charmed particles in *p*A- interactions at 70 GeV and their decays" at *U*-70 accelerator (IHEP, Protvino) was carried out at the SVD-2 (Spectrometer with Vertex Detector) setup. This setup was constructed to study the charmed particles production in *pp*- and pA-interactions by the SVD collaboration including IHEP (Protvino), JINR (Dubna), SINP MSU (Moscow, Russia).

The main elements of the setup are the high-precision micro-strip vertex detector (MSVD) with an active target (AT) and a magnetic spectrometer (MS) of the aperture equal to 1.8 x 1.2 m^2 and the field of 1.18 T within the region 3 m long. AT contains 5 Si detectors each 300 μm thickness and 1-mm pitch strips, the Pb-plate (220 μm thick) and C-plate (500 μm thick), placed as Si-Si-Pb-Si-C-Si-Si. All the inter-plane distances were set to 4 mm. The tracking part of MSVD consists of 10 Si-detectors: four XY pair and one XYUV quadruplet , U and V are the oblique planes.

The primary vertex space resolutions were calculated as 70 ÷ 120 μm for Z-coordinate and 8 ÷ 12 μm for X and Y coordinates. For the two-prong secondary vertices (K^0_s, Λ^0) these values were 250 μm and 15 μm respectively. The impact parameter (the distance between track and primary vertex) for 3 ÷ 5 GeV momentum tracks was measured with the precision of 12 μm. The angular acceptance of MSVD was ±250 mrad. The spectrometer features allow one to get the effective mass resolution of σ=4.4 MeV/c^2 for K^0_s and 1.6 MeV/c^2 for Λ^0_c masses.

SIMULATIONS AND DATA PROCESSING

The *p*A-interactions have been simulated by means of FRITIOF7.02 code. It treats hadronic events as independent collisions of an incident particle with nucleons of the target. The Fermi motion of nucleons, the deformation of nucleus and multiple re-scattering are taken into account. The nucleon distribution density in a nucleus is described in our case by the Woods–Saxon. The production of quark-antiquark pairs in mini-bias events was simulated within the dipole cascade model, with hadronisation processes described by the Lund scheme.

Monte Carlo (MC) events have been obtained with FRITIOF separately for interactions on carbon, silicon, and lead with charm production. Decays of unstable particles happened later within GEANT code. Certain decay modes were imposed for charmed particles ($D^0 \to K^-\pi^+$, $\check{D}^0 \to K^+\pi^-$, $D^+ \to K^-\pi^+\pi^+$, $D^- \to K^+\pi^-\pi^-$, $\Lambda_c^+ \to pK^-\pi^+$). GEANT3.21 package was used to simulate registration of *p*A-interactions.

SELECTION of EVENTS with CHARMED PARTICLES

I. Neutral mesons

We have analyzed the simulated events in order to search for neutral meson decays: $D^0 \to K^-\pi^+$, $\check{D}^0 \to K^+\pi^-$. Candidates for events with D^0 or $\check{D}^0$ particle and its decay into $K\pi$ system were selected using the selection criteria [Phys.Atom.Nucl. 73 (2010) 1539] including the conditions on the primary and V^0 vertexes, the effective mass and momenta (p, p_T) of the Kπ system, the Armenteros-Podolansky criterion and verification by a physicist, by means of the designed graphic package.

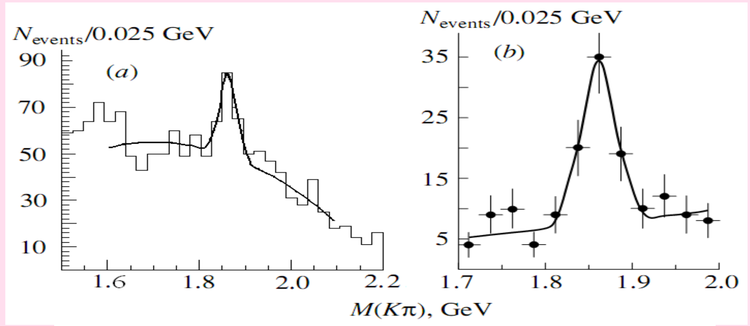


Fig. 2. Mass of $K\pi$ (a) before & (b) after visual inspection.

The effective mass spectra of the $K\pi$ system after applying the all criteria are presented in Fig. 2b by the sum of the straight line and the Gaussian function. It gives 1861 MeV/c^2 for D^0 ($\check{D}^0$) (PDG is 1865) mass with σ = 21 MeV/c^2 (χ^2/NDF =5.5/6) and the signal- to-noise ratio of (51±17)/(38±13). The detection efficiency of (D^0/$\check{D}^0$) particles with efficiency of visual inspection is equal to ε(D^0/$\check{D}^0$) = 0.036.

II. Charged charmed mesons

For charged charmed mesons the $K\pi\pi$-systems are analyzed: $D^+ \to K^-\pi^+\pi^+$, $D^- \to K^+\pi^-\pi^-$. $D^{+/-}$ mesons were found by analyzing the events with a three-prong secondary vertex. The selection procedure of events included [Phys.Atom.Nucl. 77 (2014) 716]: search for the third track to be associated with a two-prong secondary vertex taking into account charges and kinematics; momentum of the $K\pi\pi$ systems, p > 7 GeV/c; using of the Dalits plot for M($K\pi_1$) and M($K\pi_2$) variables, cutting of background by applying the condition $M(\pi^+\pi^-)_1 + M(\pi^+\pi^-)_2 < 1.2$ MeV/c^2; discard of hypotheses for ($K^-K^+\pi^+$) system (possible D_S) with the $M(K^-K^+\pi^+) > 1.93$ MeV/c^2, suppression of the background events by the decay length value.

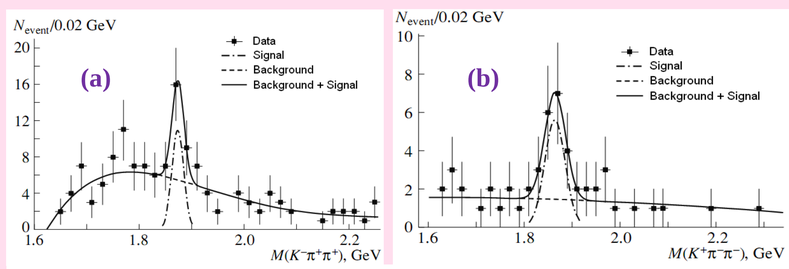


Fig. 3: Effective masses of (a) $M(K^-\pi^+\pi^+)$ and (b) $M(K^+\pi^-\pi^-)$ after using of all selection criteria. Fit: the sum of the Gaussian function and the sixth (a) and second (b) order polynomials.

The effective mass spectra of the $K^-K^+\pi^+$ and $K^+\pi^-\pi^-$ are presented in Fig. 3. After parameterizing the spectrum as sum of the Gaussian function and polynomial we get 15.5 ± 5.6 (15.0 ± 4.7) signal events from D^+ (D^-) meson decay over the background of 16.6 ± 6.0 (8.7 ± 2.7) events. Also, the $M(D^+)$ = 1874 ± 5 MeV/c^2 (PDG is 1869.6), $\varepsilon(D^+)$ = 0.014 (efficiency); $M(D^-)$= 1864 ± 8 MeV/c^2, $\varepsilon(D^-)$ = 0.008.

III. Λ_c^+ baryon

The charmed Λ_c^+ baryon was analyzed with the three-prong decay $\Lambda_c^+ \to pK^-\pi^+$. After application of all selection criteria [Phys.Atom.Nucl. 79 (2016) 144] its effective mass spectrum is shown in Fig. 4, with the signal-to-noise ratio: (21.6 ± 6.0)/(16.4 ± 4) and mass $M(\Lambda_c^+)$ = 2287 ± 4 MeV/c^2, $\varepsilon(\Lambda_c^+)$ = 0.011 (PDG is 2286.5).

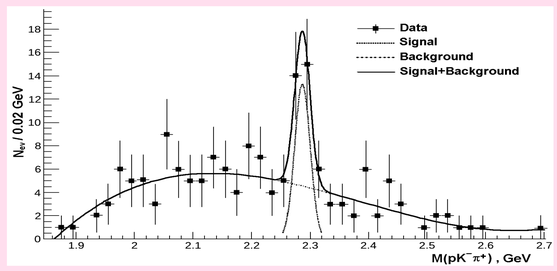
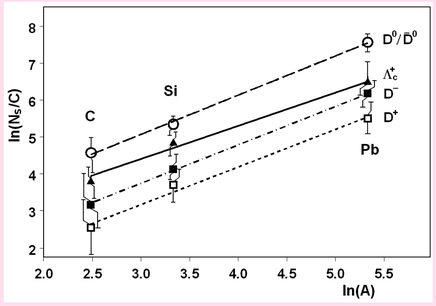


Fig. 4. $M(pK^-\pi^+)$ after all selection criteria. Fit: the sum of the Gaussian function and the third order polynomial.

CROSS SECTIONS for CHARMED PARTICLES PRODUCTION and THEIR A-DEPENDENCE

We calculate inclusive cross sections for charmed particle i using the relation: $N_s(i) = (N_0\ \sigma(i)\ A^\alpha)/(\sigma_{pp}\ A^{0.7})(B(i)\ \varepsilon(i))/K_{tr}$ or $\ln(N_s(i)/C(i)) = \alpha\times\ln(A) + \ln\ \sigma(i)$, i = D^0, $\check{D}^0$, $D^\pm$, Λ_c^+. Fig. 5 shows A-dependence of the charmed particle production in *p*A-interactions in AT (C, Si and Pb) closing to 1 for all charmed particles [Phys.Atom.Nucl. 79 (2016) 144].



α(D^+) = 1.02 ± 0.26,
α(D^-) = 1.08 ± 0.12,
α(Λ_c^+) = 0.9 ± 0.2,
α(D^0/$\check{D}^0$) =
= 1.123 ± 0.024.

Fig. 5. The A-dependence of cross sections for the charmed particles production in *p*A-interactions.

For the largest number of the reconstructed mesons (D^0/$\check{D}^0$) the dependences of α-parameter on x_F, p_T^2 and p_{lab} is shown in Fig. 6.

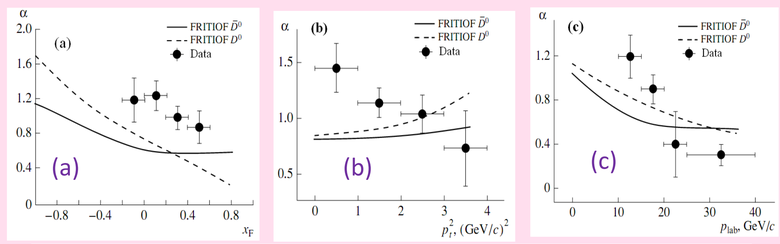


Fig. 6. The α-parameter as a function of (a) x_F, (b) p_T^2, (c) p_{lab} for (D^0/$\check{D}^0$) particles. The lines describe MC events (FRITIOF).

TOTAL CROSS SECTION and RAITIOS of CHARMED PARTICLES YIELDS

The total cross section of the charmed particles production in *pp* at 70 GeV/c is, $\sigma_{tot}(c\check{c})$=½ (σ_{D+} + σ_{D0} + σ_{D^-} + $\sigma_{\check{D}0}$ + $\sigma_{\Lambda c+}$ + σ_{Ds} + $\sigma_{\check{D}s}$) has been estimated (Fig. 7):

$\sigma_{tot}(c\check{c})$ = 7.1 ± 2.3(stat) ± 1.4(syst) μb/nucleon.

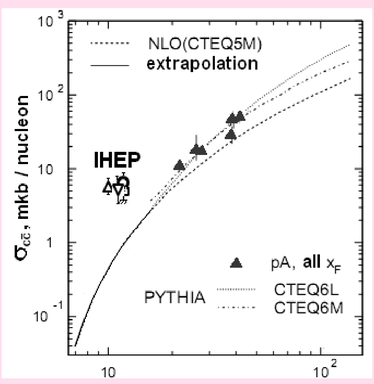


Fig. 7. σ_{tot} (cč) in *p*A-interactions. Extrapolation is the solid line. Experiments: ○ – SVD-2, □ – SCAT bubble chamber, ∇ – beam-dump, Δ –BIS-2 spectrometer. Other lines are taken from various models.

The charmed particles yields measured in our experiment are given in Fig. 8 along with the data from other experiments and theoretical predictions.

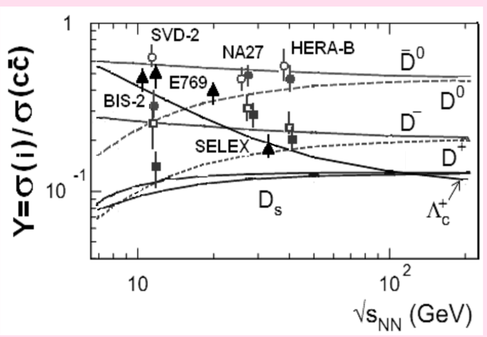


Fig. 8. Relative yields of charmed particles. ●– D^0,○ – $\check{D}^0$, ■ – D^+, □ – D^-, ▲– Λ_c^+ are the experimental points, the theoretical curves with designation of a particle are taken from Z.Phys. C 37(1988) 243

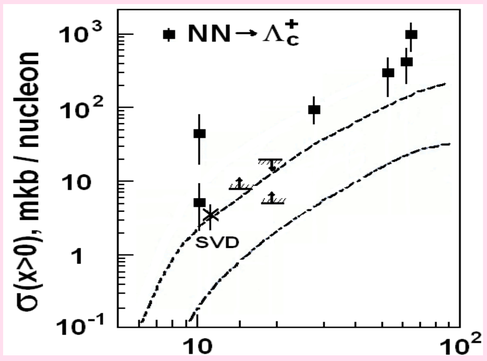


Fig. 9. σ (Λ_c^+) at x_F > 0; ■ - world data, X - the result of our experiment. Lines - the model predictions based on QCD.

RESULTS:

*** σ(cč) = 7.1 ± 2.3(stat) ± 1.4(syst) μb/nucl at c.m. energy √s = 11.8 GeV is high above the QCD model predictions (Fig. 7);**

*** the contributions of σ(i), i = $D^{0,\pm}$, Λ_c^+ into σ(cč) vary at the lower collision energies (Fig. 8);**

*** σ(Λ_c^+) at √s > 30 GeV contradicts σ(cč) for the open charm production (Fig. 9), σ(Λ_c^+) is extraordinarily large in this area.**

38th INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS
AUGUST 3 - 10, 2016
CHICAGO
ICHEP2016CHICAGO