Recent results from Selex

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on behalf for the SELEX Collaboration†

Abstract

The SELEX experiment (E781) is a 3-stage magnetic spectrometer for a high statistics study of hadroproduction of charm baryons out to large $x_F$ using 650 GeV $\Sigma^-$, $\pi^-$ and $p$ beams. The main features of the spectrometer are: a high precision silicon vertex system; powerful particle identification provided by TRD and RICH; forward $\Lambda_c$ decay spectrometer; and 3-stage lead glass photon detector. Preliminary results on asymmetry for $\Lambda_c$ produced by $\Sigma^-$, $\pi^-$ and $p$ beams at $x_F > 0.2$ and precise measurements of the $\Lambda_c$, $D^0$, and preliminary $D_s$ lifetimes are presented.

1. Introduction

Charm physics explores QCD phenomenology in both perturbative and nonperturbative regimes. Production dynamics studies test leading order (LO) and next to leading order (NLO) perturbative QCD. The present fixed target experiments on charm hadroproduction are in qualitative agreement with perturbative QCD calculations, but quantitative deviations from QCD are observed. More experimental data, using different incident hadrons ($\pi$, $p$ and $\Sigma^-$), may help to illuminate hadron-scale physics: color-drag, fragmentation, and intrinsic $k_t$ effects. Charm lifetime measurements test models based on $1/M_Q$ QCD expansions. Precise measurement of the lifetimes of charm meson and baryon weak decays are also important to understand perturbative QCD in term of non-spectator W-annihilation as well Pauli interference. For example, non-leptonic decay rate differences be-

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tween W-exchange in $D^0$ and $D^+_s$ may produce a lifetime difference of order $10^{-20}$% [1].

2. The Selex spectrometer

The SELEX experiment at Fermilab is a 3-stage magnetic spectrometer. The 600 GeV/$c$ Hyperon beam of negative polarity contains equal fraction of $\Sigma$ and $\pi$. The positive beam is composed of 92% of protons and the rest $\pi$’s. Beam particles are identified by a Transition Radiation detector (BTRD). The spectrometer was designed to study charm production in the forward hemisphere with good mass and decay vertex resolution for charm momentum in a range of 100-500 GeV/$c$. The vertex region is composed of 5 targets (2 Cu and 3 C). The total target thickness is 5% of $\lambda_{int}$ for protons and the targets are separated by 1.5 cm. Downstream of the targets there are 20 silicon planes with a strip pitch of 20-25 $\mu$m disposed in X,Y,U and V views. The M1 and M2 magnets effect a momentum cutoff of 2.5 GeV/$c$ and 15 GeV/$c$ respectively. A RICH detector, filled with Neon at room temperature and pressure, provides a single track ring radius resolution of 1.4% and $2\sigma$ $K/\pi$ separation up to about 165 GeV/$c$. A computational filter uses tracks identified by the RICH and linked to the vertex silicon by the PWCs to make a full reconstruction of the secondary vertex. Events consistent with only a primary vertex are rejected. A layout of the spectrometer can be found elsewhere [2].

3. Data set and charm selection

The charm trigger is very loose. It requires a valid beam track, two of opposite charge tracks to the beam with momentum $> 15$ GeV/$c$, two high momentum tracks linked to the Silicon vertex detector, and unconnected to all other tracks from the primary vertex. We triggered on about 1/3 of all the inelastic interactions. About 1/8 of them are written on the tape for a final sample of about $0.9 \cdot 10^9$ events. In the analysis secondary vertices were reconstructed if the $\chi^2$ of all tracks was inconsistent with single primary vertex. The RICH detector labelled all particles above 25 GeV/$c$.

All data reported here resulted from a first pass through the data.

3.1. Charm performance

The requirements to study charm physics and to reduce the background are:
- good decay vertex resolution, mass resolution and particle identification.

$\Lambda_c$ Asymmetry

Figure 1. $\Lambda_c^+$ asymmetry versus $x_P$ for different beams.

$D^0$ and $\Lambda_c^+$ Lifetimes

Figure 2. The acceptance corrected reduced proper lifetime distribution for the background subtracted signal (points) and the mass sideband (shaded) region for a) $D^0$ and b) $\Lambda_c$ lifetime. The dashed line is the lifetime fit. The solid line is the acceptance as function of reduced proper time.
beams. The hadroproduction asymmetry is defined as: 
\[ A = \frac{\langle \sigma_c - \sigma_f \rangle}{\sigma_c + \sigma_f} \]. There is a clear evidence that more leading \( \Lambda_c^+ \) are produced at high \( x_F \) in \( \Sigma^- \), \( p \) beams. In the \( \pi^- \) beam no asymmetry is found. No charge bias in the asymmetry due to the trigger hodoscope requirement has been observed in studies of these data. To lowest order QCD, charm and anticharm quarks are produced symmetrically in hadroproduction. Next to Leading Order (NLO) introduces small (1%) asymmetries in quark momenta due to interference between contributing amplitudes. The observed asymmetry can be explained by a recombination of charm quark antiquarks with the beam valence quarks or by different processes like in the intrinsic charm and in the quark-gluon string model [3].

In the SELEX experiment the \((\Sigma^- \text{ and } \pi^-)\) have a valence quark (d) in common with \( \Lambda_c^+ \) and \( D^- \) but not the \( D^0 \). Only the \( \Sigma^- \) has a valence quark in common with the \( D_c^- \). The proton beam has two valence quarks in common with \( \Lambda_c^+ \) (u and d quarks) and one quark with \( D^+ \) (d quark). The pattern of large and small cross sections and asymmetries in SELEX matches well with expectations from leading particle behavior.

The SELEX results show in more detail trends observed in earlier data. E769 has observed a \( \Lambda_c \) asymmetry integrated over \( x_F > 0 \) for a 250 GeV/c proton beam and in the same experiment has measured a D meson asymmetry for a 250 GeV/c pion beam [4]. The WA89 experiment has studied charm production in a 340 GeV/c \( \Sigma^- \) beam. Considerable production asymmetry between \( D^- \), \( D^+ \) and \( \Lambda_c^+ \), \( \overline{\Lambda_c^-} \) was observed [5].

5. Measurements of the \( \Lambda_c^+ \), \( D^0 \) and \( D_s \) lifetimes

The charm decay modes used to measure the lifetime were \( \Lambda_c^+ \rightarrow pK^-\pi^+ \), \( D^0 \rightarrow K^-\pi^+ \) and \( K^-\pi^+\pi^-\pi^+ \); and \( D_s \rightarrow K^+(892)K \) and \( \phi\pi \). The charm event selection criteria yield 1458±53, 10090±131 and 918±53 events after background subtraction for \( \Lambda_c^+ \), \( D^0 \) and \( D_s \) respectively. Candidate events have masses within 2.5\( \sigma_M \) (mass resolution 8 MeV/c^2) of their nominal charm mass value. For the \( D_s \) sample the resonance mass window for the \( K^+(892) \) (\( \phi \)) was 892±70 MeV/c^2 (1020±10 MeV/c^2). The yields for the \( K^+(892)K \) and \( \phi\pi \) channels are 395±30 and 368±18 signal events respectively.

\( \pi/K \) misidentification causes a reflection of \( D^* \) and \( D^+ \) under the \( D_s \) peak. The combination of the RICH Kaon identification and the \( \phi \) kinematics greatly reduces particle ID confusion in

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**Figure 3.** Corrected reduced proper time distributions for events under the \( D_s \) peak (dots) and results from the maximum likelihood fit (squares). The hatched region shows the fitted background. The dashed line shows the signal lifetime distribution.
the φπ channel. For both samples we limit the maximum kaon momentum to 160 GeV/c to reduce misidentification. We have studied the remaining contamination by taking all Ds candidates and computing the D± invariant mass obtained by replacing the K± mass by the pion mass to evaluate a D± candidate as a D±. We label any KKπ event having a pseudo-D0 mass in an interval of 20 MeV/c² at the central value of 1867 MeV/c² as a misidentified D± meson. Some of these are real Ds events; others really are misidentified D±. We remove them all, to eliminate an artificial lengthening of the Ds lifetime. After sideband background subtraction we find about 30 % of the signal in the KKπ and K*(892)K channels is removed by the D± reflection subtraction. For the φπ channel it is 5%. The statistical significance for the signal, S/√S+B, is 9.2 ± 0.3 and 14.3 ± 0.5 for K*(892)K and φπ respectively, (S (B) is the number of signal (background) events in the signal mass region.). Because the bin-smearing effects are small, we used a binned maximum likelihood fitting technique to determine the lifetimes. The fit was applied to a reduced proper time distribution, t* = M(1−tmin)/p with tmin = Nσ with N=8; M and p are the reconstructed mass and momentum values for each event. The acceptance as a function of t* is evaluated using the set of observed events. Each event is re-analyzed 1000 times with randomly chosen L values, holding event topology and momenta fixed. This technique preserves all the production and acceptance properties and correlation of the data without doing a simulation. A rethrown event is accepted if it passes the same cuts as those applied to the data [3]. For t* distributions in the signal and mass sideband regions as shown in Figs. 2 and 3 we make a simultaneous fit to both signal and sideband distributions. For Λc+ and D0 the sideband t* distribution is represented with a background function of two exponentials times acceptance. For the Ds the sideband t* distribution itself is normalized to the number of background events under the signal. The lifetimes from SELEX are: Λc+: 198.1±7.0±5.6 fs; D0: 407.9±6.0±4.3 fs; and Ds: 477.2±33.0 fs (K*(892)K), and 474.0±21.0 fs (φπ). Because systematic errors due to reflection subtraction are not a problem, we combine the Ds resonant modes to give τDs = 475.6 ± 17.5 fs. The uncertainties are statistical only, evaluated where -ln L increases by 0.5.

6. SUMMARY

The SELEX experiment explores charm hadroproduction in the large xF region using different beams. The SELEX experiment finds clear Λc+ asymmetry production at large xF in Σ and p beams. We report a preliminary lifetime measurement of τ(Λc) = 198.1±7.0±5.5 fs, τ(D0) = 407.0±6.0±4.3 fs. The preliminary Ds lifetime, using two independent resonant decay channels, K(892)±K and φπ, is 475.6 ± 17.5 ± 4.4 fs. Using our measured τDs we find a ratio, τDs/τD0, 3.3σ from unity.

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