Focus: Charm Spectroscopy and Lifetimes

Sergio P. Ratti†

Nuclear Physics Department of the University and Istituto Nazionale di Fisica Nucleare,
Sezione di Pavia, via A. Bassi, 6 - I27100 Pavia (PV) (Italy)
E-mail: `ratti@pv.infn.it`

1. Introduction

In this contribution we report on some preliminary results from a selection of analyses in progress within the FOCUS collaboration, mostly concerning charmed baryons and heavy quark spectroscopy. The experiment has collected over 7 billion triggers of charm photoproduction candidates in the Wide Band Laboratory of Fermilab. The apparatus is an improved E687 spectrometer[1]. We shall concentrate on the D^* spectroscopy, on some aspects of charm baryon spectroscopy and on remeasurements of some charm particle lifetimes.

2. Meson spectroscopy

In charm meson spectroscopy the D and D^* ground states are well established but only the J^P of the $D_s^*(2112)$[2] has been determined. On about 55%

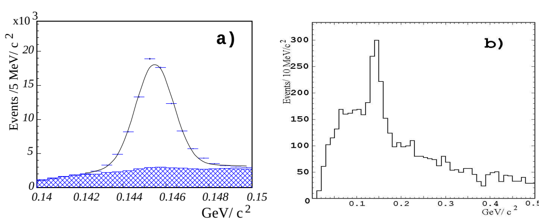

Figure 1. a- Mass difference $[M(D^o\pi) - M(D^o)]$ (55% stat.); b- Evidence for $D_s^{*+} \rightarrow D_s^+\gamma$ (20% stat.).

of the Focus data we observe a healthy signal of more than 60,000 events $D^*(2010)^+ \rightarrow D^o\pi^+$ (see fig. 1a), which will prove important to start a systematic investigation of higher D excited states. In fig. 1b, our preliminary evidence for the radiative decay $D_s^{*+} \rightarrow D_s^+\gamma$ is also reported. Although the $D^{*+} - D^o$ mass difference is very well measured, the measurement of the $D^{*o} - D^o$ mass difference requires γ detection. Using $\approx 24\%$ of the data we measured preliminarily $m_{D^{*o}} - m_{D^o} = 142.12 \pm .07$ MeV, and $m_{D^{*+}} - m_{D^+} = 140.64 \pm .10$ MeV. The ΔM values are compatible with the PDG data [2], while the errors are already half of the PDG values. The measurement of the D^{*+}, D^{*o} isospin splitting (provided by CLEO based on a sample of 1,200 events) will be significantly improved using the expected 25,000 events from FOCUS. Taking advantage of the low multiplicity of the photoproduction process, the clean primary vertex identification and the large amount of clean D^* formation (as shown in fig. 1a), our collaboration is investigating[3] the $L = 1$ excited mesons predicted by HQS which decouples the heavy quark spin S_Q from the light quark q degrees of freedom, so that S_Q and $j_q = s_q + L$ become the conserved quantum

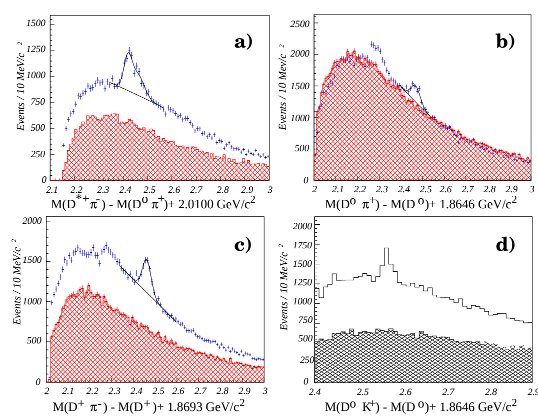

Figure 2. Preliminary D^{**} signals, FOCUS partial data sets (Shaded histograms: wrong sign spectra): a) $D_1^0(2420) \rightarrow D^{*+}\pi^-$ and $D_2^{*0}(2460) \rightarrow D^{*+}\pi^-$; b) $D_2^{*+}(2460) \rightarrow D^0\pi^+$; c) $D_2^{*0}(2460) \rightarrow D^+\pi^-$; d) $D_{sJ}^+(2573) \rightarrow D^0K^+$ ($m > 2.4$ GeV to cut reflections).

† Co-authors: J.Link, M.Reyes, P.M.Yager (**UC DAVIS**); J.Anjos, I.Bediaga, C.Gobel, J.Magnin, I.M.Pepe, A.C.Reis, A.Sánchez-Hernández, F.R.A.Simão (**CPBF, Rio de Janeiro**); S.Carrillo, E.Casimiro, H.Mendez, M.Sheaff, C.Uribe, F.Vasquez (**CINVESTAV, México City**); L.Cinquini, J.P.Cumalat, J.E.Ramirez, B.O'Reilly, E.W.Vaandering (**CU Boulder**); J.N.Butler, H.W.K.Cheung, I.Gaines, P.H.Garbincius, L.A.Garren, S.A.Gourlay, P.H.Kasper, A.E.Kreymer, R.Kuschke (**Fermilab**); S.Bianco, F.L.Fabbri, S.Sarwar, A.Zallo (**INFN Frascati**); C.Cawlfield, E.Gottschalk, K.S.Park, A.Rahimi, J.Wiss (**UI Champaign**); R.Gardner (**IU Bloomington**); Y.S.Chung, J.S.Kang, B.R.Ko, J.W.Kwak, K.B.Lee, S.S.Myung, H.Park (**Korea University, Seoul**); G.Alimonti, M.Boschini, B.Caccianiga, A.Calandrino, P.D'Angelo, M.DiCorato, P.Dini, M.Giammarchi, P.Inzani, F.Leveraro, S.Malvezzi, D.Menasce, M.Mezzadri, L.Milazzo, L.Moroni, D.Pedrini, F.Prelz, A.Sala, S.Sala (**INFN and Milano**); T.F.Davenport III (**UNC Asheville**); V.Arena, G.Boca, G.Bonomi, G.Gianini, G.Liguori, M.Merlo, D.Pantea, C. Riccardi, L.Viola, P.Vitulo (**INFN and Pavia**); A.M.Lopez, L.Mendez, A.Mirles, E.Montiel, D.Olaya, C.Rivera, W.Johns, Y.Zhang (**Mayaguez, Puerto Rico**); N.Copty, M.V.Purohit, J.R.Wilson (**USC Columbia**); K.Cho, T.Handler (**UT Knoxville**); D.Engh, M.Hosack, M.Nehring, M.Sales, P.D.Sheldon, M.Webster (**Vanderbilt**); K.Stenson (**Wisconsin, Madison**); Y.Kwon (**Yonsei University, Korea**) .

numbers. The four states are: D_o^*, $D_1(j_q = \frac{1}{2})$, $D_1(j_q = \frac{3}{2})$ and D_2^*. Parity and angular momentum conservations force the $(j_q = \frac{1}{2})$ states to decay to the ground states via S-wave (broad width), while $(j_q = \frac{3}{2})$ states would decay via D-wave (narrow width).

In fig. 2a-c our preliminary results on about 55% of the data are shown. Fig. 2a shows the mass difference $\Delta M[D^{**o}) - D^{*+}]$, added to the central value $m = 2.01$ GeV from fig. 1a; the two states $D_1^0(2420)$ and $D_2^{*0}(2460)$ in fig. 2a can be resolved using angular distributions. Fig.s 2b and 2c show evidence for the $D_2^{o,+}(2460)$ decaying directly into a $D\pi$ state: i.e. the $D_2^{*o}(2460)$ and the $D_2^{*+}(2460)$ respectively. Fig. 2d instead, shows preliminary evidence (on all data) for the state $D_{S2}^+(2573) \rightarrow D^o K^+$.

3. Baryon spectroscopy

FOCUS is able to provide large samples of charmed baryons. (see fig. 3). From the total sample of more than 20,000 $\Lambda_c^+ \rightarrow pK^-\pi^+$, our collaboration can easily select a sample of over 3,000 events with a s/n ratio of ≈ 8.4 (fig. 3a). The relatively rare decay

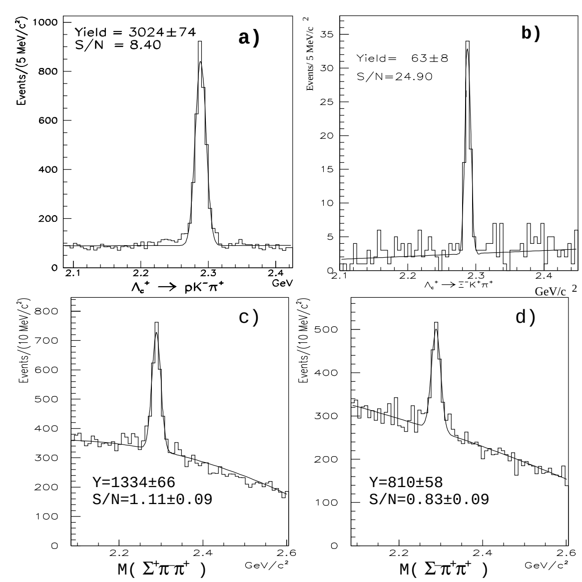

Figure 3. Λ_c^+ decays: a- low background plot for the "golden decay mode" $\Lambda_c^+ \rightarrow pK^-\pi^+$ (80% of data): b- $\Lambda_c^+ \rightarrow \Xi^- K^+\pi^+$ (75% of data); c- $\Lambda_c^+ \rightarrow \Sigma^+\pi^-\pi^+$; d- $\Lambda_c^+ \rightarrow \Sigma^- 2\pi^+$ (about all data).

$\Lambda_c^+ \rightarrow \Xi^- K^+\pi^+$, thanks to the strong signature provided by the Ξ^- hyperon, can be selected with an excellent s/n ratio of ≈ 25 (fig. 3b). Among the many investigated modes we show the signals obtained for the channels: $\Lambda_c^+ \rightarrow \Sigma^+\pi^-\pi^+$ (fig. 3c) and $\Lambda_c^+ \rightarrow \Sigma^- 2\pi^+$ (fig. 3d) which improve significantly the statistics provided by E687 (103 $\Sigma^- 2\pi^+$ events)[4]. The charm baryon spectroscopy is largely incomplete. No doubly charmed baryons have been observed yet. Only the spin assignment of the Λ_c^+ is known. An open issue here is the Σ_c mass splitting. Selecting a good sample of about 17,000 Λ_c^+ baryons, FOCUS provides preliminary values for the mass differences between the Σ_c charged states. There are theoretical expectations of a significant positive mass difference between Σ_c^o and Σ_c^+[5]. The data are shown in fig. 4. Fig. 4a displays the Λ_c^+ sample used to build the histograms to locate Λ_c^{*+}'s (fig. 4b); the Σ_c^o (fig. 4c) and the Σ_c^{++} (fig. 4d). The preliminary mass differences are: $\Delta M(\Sigma_c^o - \Lambda_c^+) = [167.17 \pm .26(stat.) \pm .27(syst.)]$ MeV; $\Delta M(\Sigma_c^{++} - \Lambda_c^+) = [167.45 \pm .17(stat.) \pm .36(syst.)]$ MeV; $\Delta M(\Sigma_c^{++} - \Sigma_c^o) = [0.28.17 \pm .31(stat.) \pm .15(syst.)]$ MeV. This observation supports the isospin degeneracy of the Σ_c triplet. Fig.s 4b,c,d show also evidence for the Σ_c^*. The search for Σ_c^+ is more difficult due to the presence of π^o's. This study is still underway.

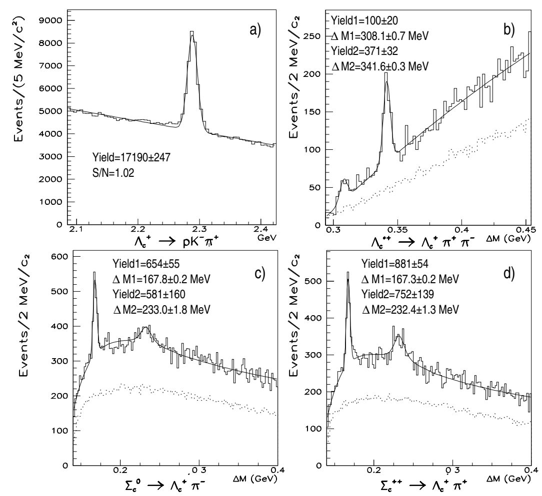

Figure 4. Λ_c^* and Σ_c states (80% of data): a) $\Lambda_c^+ \rightarrow pK^-\pi^+$, b) M($\Lambda_c^+\pi^-$)-M($\Lambda_c^+$), c) M($\Lambda_c^+\pi^+$)-M($\Lambda_c^+$), d) M($\Lambda_c^+\pi^+\pi^-$)- M($\Lambda_c^+$) [dotted histograms are Λ_c^+ sidebands regions]. Σ_c^* signals are also shown.

FOCUS has also searched for charm-strange baryons on partial samples of the full data set. CLEO measured the mass of the Ξ_c^+ with 147 events. Our collaboration is collecting a much larger statistics. Some signals are shown in fig. 5. On about 75% of data, a preliminary measurement of the Ξ_c^+ mass, with a sample of 203 events (fig. 5a), gives a value $m = 2467 \pm 1$ MeV which is compatible with the PDG value[2] while the error is already about half of it[6]. Compared to E687, the Ξ_c^o

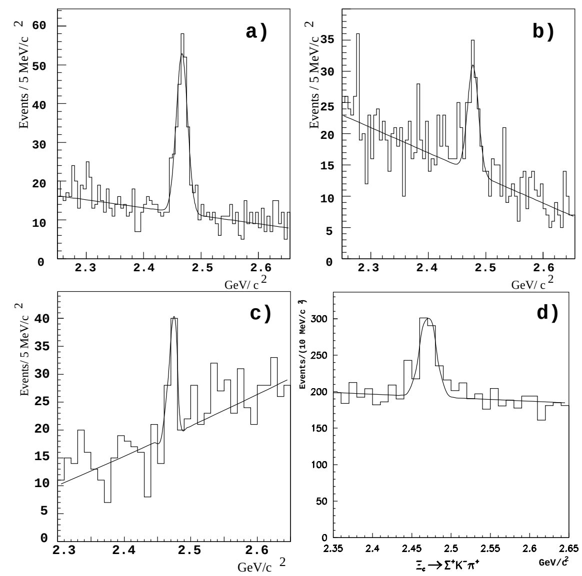

Figure 5. Evidence for some Ξ_c decays: a- "golden mode" decay $\Xi^+ \to \Xi^- 2\pi^+$; b- "golden mode" $\Xi^o \to \Xi^- \pi^+$ (75% of data); c- $\Xi^+ \to \Lambda^o K^- 2\pi^+$ (30% of data); d- $\Xi^+ \to \Sigma^+ K^- \pi^+$ (about all data).

particle is somewhat more difficult to detect due to its shorter lifetime and to the lower beam energy. On a sample of 80 events (fig. 5b) the preliminary Ξ_c^o mass is $m = 2478 \pm 2$ MeV, which is consistent with the PDG value. Additional preliminary signals are shown for $\Xi_c^+ \to \Lambda^o K^- 2\pi^+$ (fig. 5c) and for $\Xi_c^+ \to \Sigma^+ K^- \pi^+$ (fig. 5d). Our collaboration has

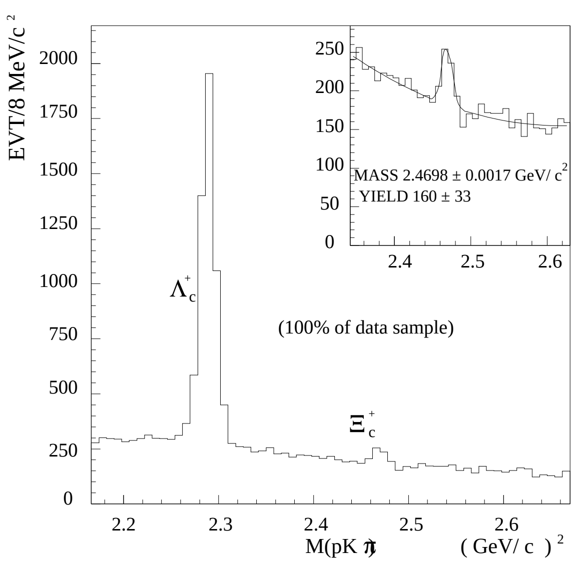

Figure 6. Cabibbo suppressed decay $\Xi_c \to pk^-\pi^+$: M($pK^-\pi^+$) distribution. Inserted plot: enlargement for $M(pK^-\pi^+) > 2.3 GeV/c^2$.

confirming evidence for the Cabibbo suppressed decay $\Xi_c^+ \to pK^-\pi^+$. The result is shown in fig. 6. We will be able to measure soon the branching ratio relative to the $\Xi^- 2\pi^+$ "golden mode", as well as the production probability of the charm-strange baryon relative to the Λ_c^+ baryon.

4. Charm lifetimes

E687 has measured the lifetime of all charmed particles, both mesons and baryons[7]. While $\tau(D^+)$ and $\tau(D^o)$ are difficult to improve as their statistical errors are about 1%, $\tau(D_s^+)$ is still affected by a 5% error. It is of interest to measure $r = \frac{\tau(D_s^+)}{\tau(D^o)}$ which accounts for the contributions from either annihilation diagrams (D^+ decay) or exchange diagrams (D^o decay). From PDG, the world average for r is $r = 1.193 \pm .027$. In the baryon sector, only $\tau(\Lambda_c^+)$ has an error of $\approx 5\%$, while the lifetimes of the remaining baryons are only estimates with errors of order $20\% - 30\%$. FOCUS presents preliminary measurement of the lifetimes $\tau(D_s^+)$ and $\tau(\Lambda_c^+)$. The new preliminary lifetime

Table 1. Preliminary FOCUS lifetimes (10^{-13}s).

Exp.	part.	τ	$\epsilon(stat.)$	$\epsilon(syst.)$
E687	D^o	4.13	0.04	0.03
E687	D_s^+	4.74	0.20	0.07
FOCUS	D_s^+	5.06	0.08	==
PDG	D_s^+	4.67	0.17	==
E687	Λ_c^+	2.15	0.16	0.08
FOCUS	Λ_c^+	2.045	0.034	==
PDG	Λ_c^+	2.06	0.12	==

measurements are compared to the values measured by E687, as well as to the world averages, in Table 4. The samples used are $\approx 8,600$ (50% of data) for $\tau(D_s^+)$ and $\approx 8,500$ for $\tau(\Lambda_c^+)$; $\tau(D_s^+)$ is lower that the PDG value. Using $\tau(D^o)$ from PDG, the new preliminary ratio $r = \frac{\tau(D_s^+)}{\tau(D^o)}$ becomes r=$1.22 \pm .02$, definitely incompatible with 1.

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