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2006 J. Phys.: Conf. Ser. 37 11

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Institute of Physics Publishing Journal of Physics: Conference Series **37** (2006) 11–15
doi:10.1088/1742-6596/37/1/003 IX Mexican Workshop on Particles and Fields

Search of the Exotic State U(3100) in SELEX

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Abstract. Using data from the SELEX Experiment (Fermilab E781)[1] we searched for a previously reported exotic state at $3.100\,\mathrm{GeV}/c^2$ decaying into $\Lambda^0\bar{p} + n\pi^{\pm}$, $(n = 1, 2, 3)$. No signal in any of the different charge modes is observed.

1. Introduction

Nearly 2 decades ago, two experiments, WA62 at CERN[2] and BIS-2 at Protvino[3], reported the observation of a state near $3100\,\mathrm{MeV}/c^2$, with a width compatible with experimental resolution ($\sim 20\,\mathrm{MeV}/c^2$). The resonance, named $U(3100)$, was observed in four different charge states (U^+, U^0, U^-, U^{--}), in the decay modes $U \to \Lambda + \bar{p} + n\pi^{\pm}$; also the corresponding anti-particles were observed.

The mode observed with the highest statistical significance, the $U^+ \to \Lambda\bar{p}\pi^+\pi^+$, has strangeness -1 and positive charge, an exotic combination of quantum numbers. Together with the number of different charge states and the small width, an interpretation as a isospin 3/2 2 quark–2-anti-quark Baryonium exotic resonance was suggested[4].

A quark is a SU(3) color anti-triplet. A diquark can be in a color triplet or sextet state. One diquark and one anti-diquark can only form a color singlet if both are in triplet or sextet states; mixed combinations are not possible. If both are in a triplet state, the resulting particle is called a True-Baryonium; a quark and an antiquark from a gluon-split can readily form two baryons together with the diquarks. The expected state should be broad. With the diquarks in sextet states (Mock-Baryonium), a single gluon exchange can not lead to the formation of a baryon - antibaryon pair, some higher order processes are necessary; this is a possible explanation for the small width of the observed states. For more details on this model please see[5, 6] and references therein.

In both experiments the antiproton in the decay was not unambiguously identified. The SELEX experiment has very good particle identification with the use of a Ring Imaging Cherenkov Detector (RICH)[7]. This, together with the available statistics, motivated us to search for these resonances in the SELEX data[8].

2. The SELEX Experiment

The SELEX experiment used the Fermilab charged hyperon beam at $600\,\mathrm{GeV}/c$ to produce charm particles in a set of thin foil targets of Cu or diamond. The negative beam composition was about 50% Σ^- and 50% π^-. The positive beam was 90 % protons. A beam Transition

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Table 1. Investigated decay modes and number of candidates after the first part of the analysis.

Investigated Decay Modes	SELEX Candidates
$U^+ \rightarrow \Lambda^0\,\bar{p}\,\pi^+\,\pi^+$	8,482,007
$U^0 \rightarrow \Lambda^0\,\bar{p}\,\pi^+$	5,692,231
$U^0 \rightarrow \Lambda^0\,\bar{p}\,\pi^+\,\pi^+\,\pi^-$	12,203,717
$U^- \rightarrow \Lambda^0\,\bar{p}\,\pi^+\,\pi^-$	20,482,269
$U^{--} \rightarrow \Lambda^0\,\bar{p}\,\pi^-$	5,827,162
$U^{--} \rightarrow \Lambda^0\,\bar{p}\,\pi^+\,\pi^-\,\pi^-$	12,698,985

Radiation Detector identified each beam particle as meson or baryon with zero overlap. The three-stage magnetic spectrometer is shown elsewhere[9]. The most important features are the high-precision, highly redundant, vertex detector that provides an average proper time resolution of 20 fs for charm decays, a 10-m long Ring-Imaging Cerenkov (RICH) detector that separates π from p up to 340 GeV/c[7], and a high-resolution tracking system that has momentum resolution of $\sigma_P/P < 1\%$ for a 150 GeV/c proton.

The experiment selected usually charm candidate events using an online secondary vertex algorithm. A scintillator trigger demanded an inelastic collision with at least four charged tracks in the interaction scintillators and at least two hits in the positive particle hodoscope after the second analyzing magnet. Event selection in the online filter required full track reconstruction for measured fast tracks ($P \gtrsim 15\,\mathrm{GeV}/c^2$). These tracks were extrapolated back into the vertex silicon planes and linked to silicon hits. The beam track was measured in upstream silicon detectors. A full three-dimensional vertex fit was then performed. An event was written to tape if any of the fast tracks in the event was *inconsistent* with having come from a single primary vertex. This filter passed 1/8 of all interaction triggers and had about 50% efficiency for otherwise accepted charm decays. The experiment recorded data from 15.2×10^9 inelastic interactions and wrote 1×10^9 events to tape using both positive and negative beams. The online filter was not suited directly for the search of short-lived resonances. Nevertheless, additional events were passed with an identified proton or kaon in the RICH detector. Also, most of the filtered events are inconsistent with coming from one vertex due to tracking errors related to the fast nature of the online filter.

3. Data Selection and Analysis

In the offline analysis only charged tracks with reconstructed momenta were used. Tracks which traversed the RICH ($P \gtrsim 22\,\mathrm{GeV}/c$) were identified as protons or kaons if those hypotheses were more likely than the pion hypothesis. All other tracks were assumed to be pions. Λ^0 candidates were formed when a proton and a π^- originated from a common vertex within an invariant mass window $1070\,\mathrm{MeV}/c^2 \leq M(\Lambda^0) \leq 1160\,\mathrm{MeV}/c^2$. RICH identified anti-protons and charged pions from the interaction vertex were combined with the Λ^0 candidates, and the invariant mass of the Λ^0 $\bar{p}$ $\pi^{\pm}$'s system was calculated. The number of combinations within the mass range $2.9 - 3.3\,\mathrm{GeV}/c^2$ is shown table I. No enhancement was observed over the full mass range in any of the decay modes.

Additional cuts applied to suppress possible backgrounds were a minimum momentum of the charged pions of $P > 8\,\mathrm{GeV}/c$ and the invariant mass of the Λ^0 candidate had to be within $\pm 10\,\mathrm{MeV}/c^2$ of the nominal mass[10]. We also required $P(\bar{p}) > 110\,\mathrm{GeV}/c$ to allow for a perfect

Figure 1. Distribution of invariant masses for different channels $\Lambda^0\bar{p}\pi^{\pm}$, with the final cuts described in the text applied.

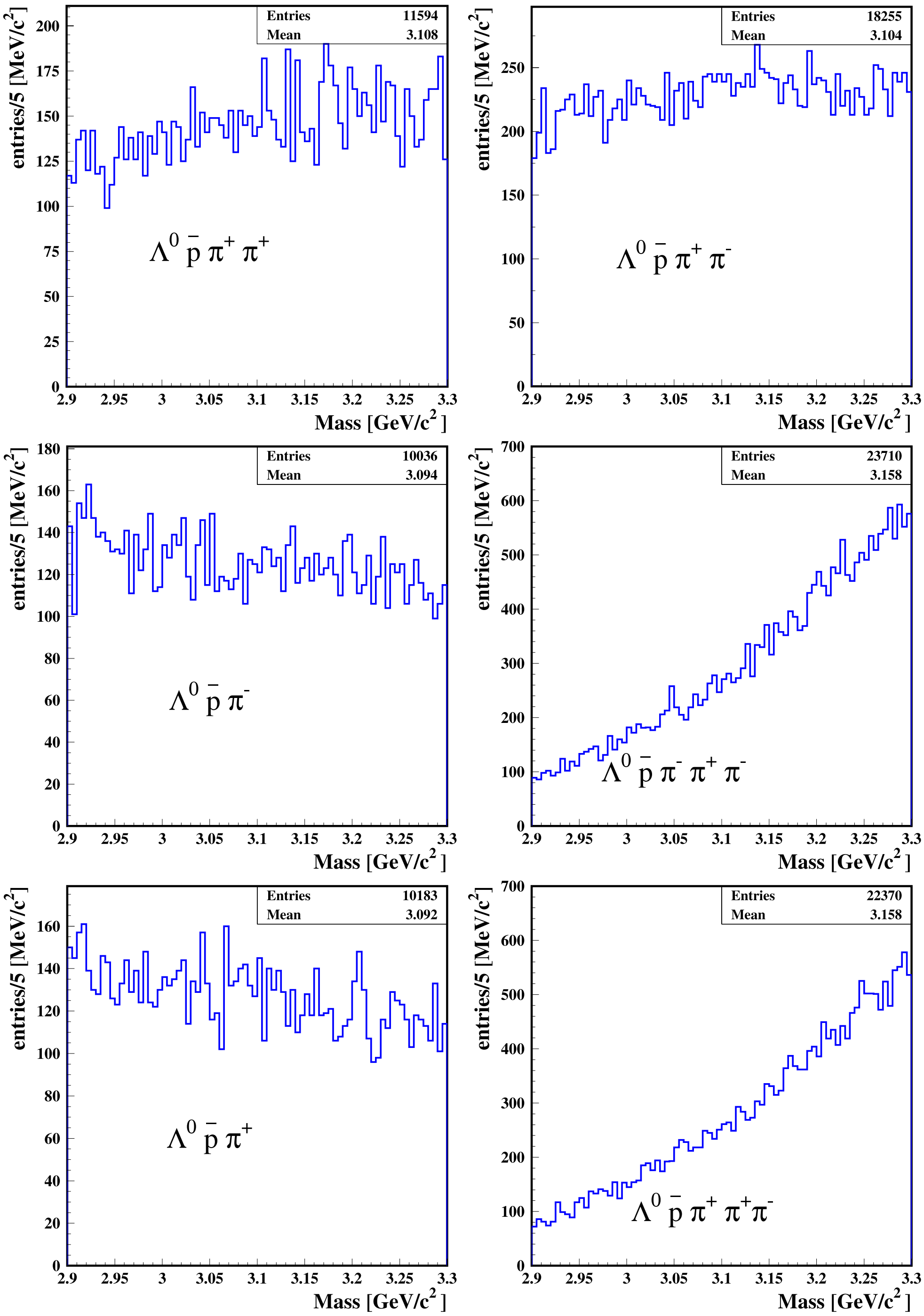

Table 2. Additional cuts for $U^+(3100) \rightarrow \Lambda^0\bar{p}\pi^+\pi^+$. Similar cuts were applied to the other modes.

Cut	Value
$P(\bar{p})$	$> 110\,\mathrm{GeV}/c$.
$P(\pi)$	$> 8\,\mathrm{GeV}/c$.
$P(U$ candidate$)$	$> 300\,\mathrm{GeV}/c$.
$M(\Lambda^0$ candidates$)$	$\pm 10\,\mathrm{MeV}/c^2$
$P(\Lambda^0)/P(U)$	< 0.3
$P(\pi(\mathrm{fast}))/P(U)$	> 0.1
$P(\pi(\mathrm{slow}))/P(U)$	> 0.035

identification of the antiproton with the RICH. A Monte Carlo Simulation indicated that the expected resolution for the $U(3100)$ should be around $15\,\mathrm{MeV}/c^2$. We also followed a previous search for these particles[11] and developed with a detailed Monte Carlo simulation a set of cuts in the ratios of the momenta of the different particles involved, assuming phase space decay of the $U(3100)$[8]. The cuts used are detailed for the decay $U^+(3100) \rightarrow \Lambda^0\bar{p}\pi^+\pi^+$ in table II. Similar cuts were used for the other modes.

With the above cuts, we obtain the distributions shown in fig. 1. No significant enhancements have been observed.

Acknowledgments

This work was supported by CONACyT and UASLP. A.B.C. thanks CONACyT for the stipendium during his master thesis.

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