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PENTAQUARK RESULTS FROM CDF

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Abstract

We have carried out three searches of pentaquarks at CDF. First, we will present the search for a neutral pentaquark Θ_c which decays into D* and proton. This search has been performed using 240 pb^{-1} data samples of a displaced-two-track trigger. Second, we will present the search for a charged pentaquark Θ^+which decays into K_s^0 and proton. This search has been performed using data samples of a minimum bias trigger and a jet trigger. Third, we will present the search for a doubly-charged pentaquark which decays into Ξ and π. This search has been performed using 220 pb^{-1} data samples of a displaced two-track trigger and a jet trigger

I. Introduction

One of the recent research excitements is the evidence of Θ^+ particle which is postulated as one type of the pentaquarks. As shown in figure 1, ten experiments [1-9] around the world have reported evidences since the end of 2002. These findings have revived the search for pentaquark states. Many theoretical papers have been published in order to explain the observed Θ^+ mass and the peculiar narrow width.

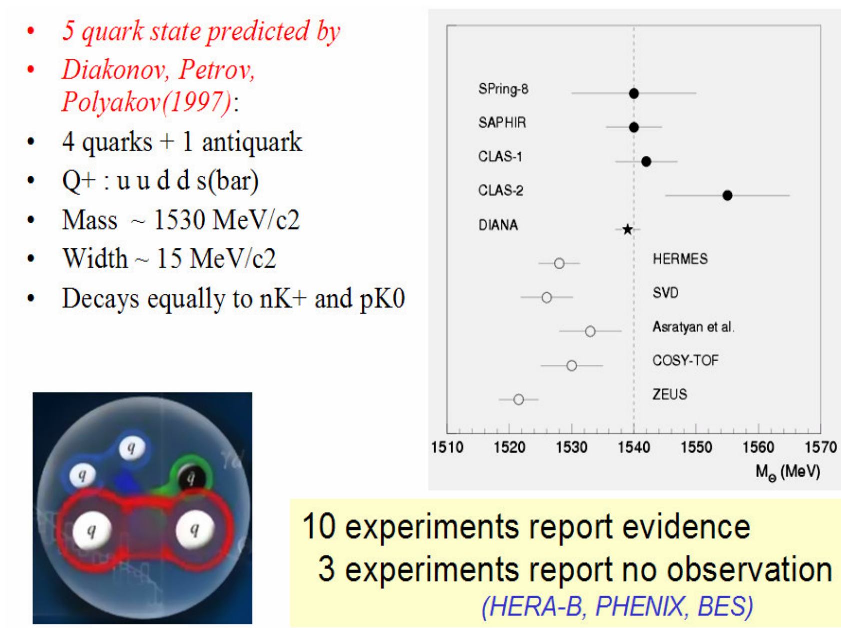


Figure 1: The Θ^+ mass measurements. The solid circles are for nK^+ and the open circles are for pKs results.

The NA49 experiment[10] claimed to have found the other pentaquark state Ξ (1860). In addition, H1[11] also claimed to have found the evidence of pentaquark Θ_c early this year. We at CDF collaboration group were motivated by these news to search for pentaquarks in our data samples. We started at 3 pentaquark search modes. We will report the CDF detector, search strategies, three searches for $\Theta_c \rightarrow D^*p$, $\Theta^+ \rightarrow pKs$, and $\Xi(1860) \rightarrow \Xi\,\pi$, summary and conclusion in the following sections.

II. CDF Detector

By thoughtful design, quality construction, and careful operation, CDFII detector as shown schematically in figure 2 has very good tracking components to record and reconstruct charged tracks from particle decays with high momentum resolution. Furthermore, we are able to reconstruct the displaced vertex with high position precision in identifying heavy flavor decay. In addition, we also have particle identification capability using the Time-Of-Flight (TOF) and dE/dx techniques.

We used the data collected from the tracking and particle identification components of the CDF detector to do these three pentaquark search analyses. All the charged tracks are reconstructed with the drift chambers and silicon detector located in the center part of the whole detector. Precise vertex reconstruction was achieved by adding the information obtained from the silicon vertex detector. The particle identifications were carried out using both TOF information from the TOF counters which are located outside the tracking volume and dE/dx information from the drift chambers.

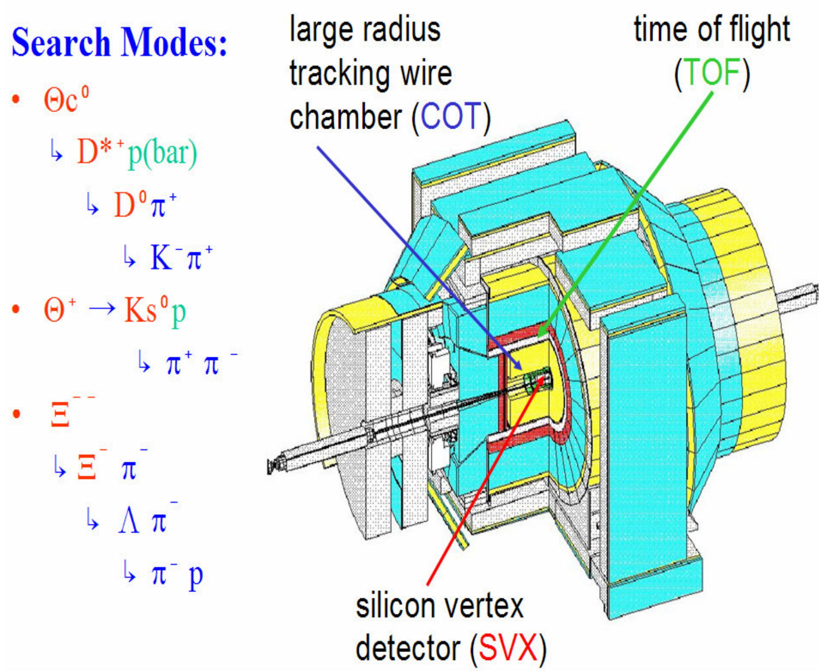


Figure 2: CDFII detector. The relationships between particle reconstruction of three pentaquark search modes and the detector components are indicated by red, blue, and green colors and arrows.

III. General Search Strategy

There are several unknown factors in searching for pentaquark at $p\overline{p}$ collider of $\sqrt{s}=1.96$ TeV. First, we do not know the pentaquark production cross sections at this energy, therefore, we do not know which type of pentaquark is the best to look for. Second, we do not know the specific production mechanism at $p\overline{p}$ collider, therefore, we do not know which data set is the best to look for. Third, we don't know the specific distinguished decay properties, therefore, we do not know which kinematic region is the best to look for. Additional difficulty is the large combinatorial background in high track multiplicity environment of $p\overline{p}$ collider. We do not know in prior whether we have the sensitivity to search for pentaquarks.

Despite of these uncertainties, we came out a working search strategy: First, we start with the claimed pentaquark candidates, i.e. Θ_c , Θ^+, and Ξ (1860). Second, we selected possible datasets for each search. Third, we assumed the production ratio of pentaquark to that of known resonance is independent of c.m. energy, therefore, we don't need to use cuts which are pentaquark specific. As for the sensitivity issue, we selected known resonances with similar decay products and event multiplicity as the search reference signals.

IV. Search for Θ_c

We search for Θ_c in the D*p decay mode. This is a hadronic decay and the Silicon Vertex Trigger (SVT) has the capability to trigger on 2 displaced tracks in an event using the silicon information. Therefore, this data set is ideal for the D*p search. The reference mode chosen is the D_1 and D_2* resonances in the D* π mass spectrum by replacing the third track with the pion mass.

In total, we reconstructed 3M D^0 with half width of 8 MeV and 0.5 M of D* with half width of 1.2 MeV. Both the D_1 and D_2* peaks are clearly seen in the D*π mass spectrum with a yield of 14,700. This indicates that we should be able to find Θ_c if its production yield is at the same order.

The D*p mass resolution at 3.1 GeV was found to be 2.5 MeV using zero width Monte Carlo data. With this excellent mass resolution, we should be able to resolve the Θ_c peak claimed by H1. The proton P_T range was found to be from 1 to 8 GeV assuming Θ_c has the same P_T spectrum as that of J/Psi. By studying the proton and pion separations in particle identification pull distributions, we decided to apply TOF cuts for proton track $P_T < 2.75$ GeV and dE/dx cuts for proton track $P_T > 2.75$ GeV.

Proton P_T was required to be larger than 500 MeV. The χ^2 of D* p vertex was required to be smaller than 30. The mass difference M(D*)-

$M(D^0)$ was required to be between 142.5 and 148.5 MeV. The left plot of figure 3 shows the D*p mass spectrum with the TOF cuts on the proton track and the left plot of figure 4 shows the D*p mass spectrum with the dE/dx cuts on the proton track. In this search, we did not find any resonance structure around 3.1 GeV. These mass spectra were used to set yield upper limits assuming the 0 and 12 MeV widths. The right plots of figure 3 and figure 4 show the yield upper limits as function of mass.

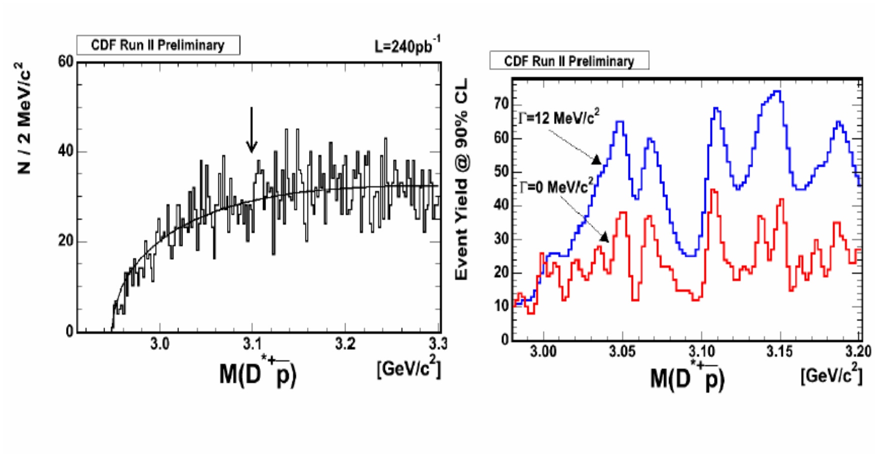


Figure 3: D*p mass spectrum with TOF cuts is shown in the left plot and the 90% CL event yield upper limit as function of mass is shown in the right plot. The blue line is for width of 12 MeV/c^2 and the red line is for zero width.

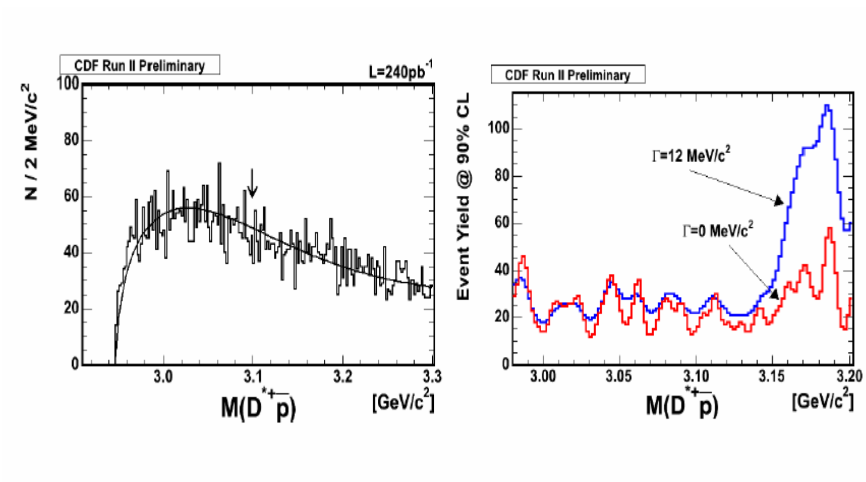


Figure 4: D*p mass spectrum with dE/dx cuts is shown in the left plot and the 90% CL event yield upper limit as function of mass is shown in the right plot. The blue line is for width of 12 MeV/c^2 and the red line is for zero width.

V. Search for Θ^+

We search for Θ^+ in the pK_s decay mode where K_s decay into $\pi^+\pi^-$. Both minimum bias sample and jet 20 data sample in which the jet Et is required to be larger than 20 GeV were used to search for Θ^+ .

In total, we reconstructed 667,000 Ks in the minimum bias data set. Proton from Λ decay was removed. $\varphi \to K^+K^-$, $\Lambda(1520) \to pK^-$, $K^{*+} \to K_s \pi^+$ were clearly seen as reference channels. The pK_s mass resolution at 1.54 GeV was found to be 2.5 MeV using zero width Monte Carlo data. With this mass resolution, we should be able to resolve the Θ^+ peak seen by other experiments [1-9]. Since most of the proton P_T range was found to be less than 3GeV, we used TOF for proton identification.

The left plot of figure 5 shows the pK_s mass spectrum of the minimum bias data with the TOF cuts on the proton track and the right plot is for the jet20 data. In this search, we did not find any resonance structure around 1.54 GeV.

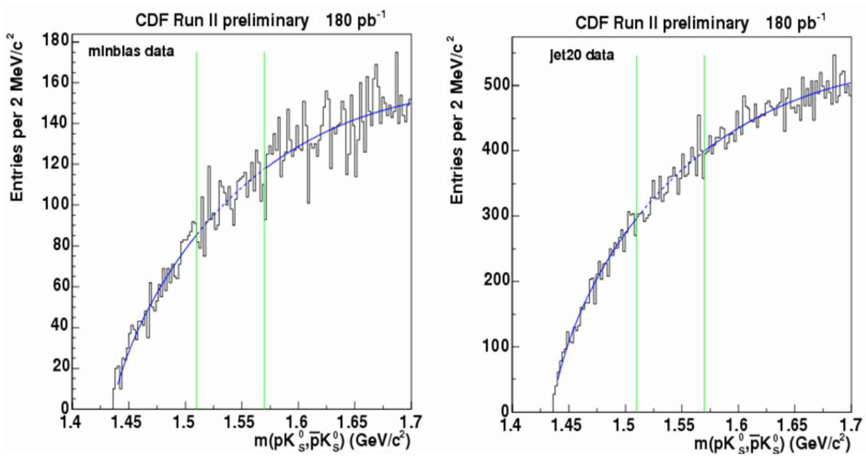
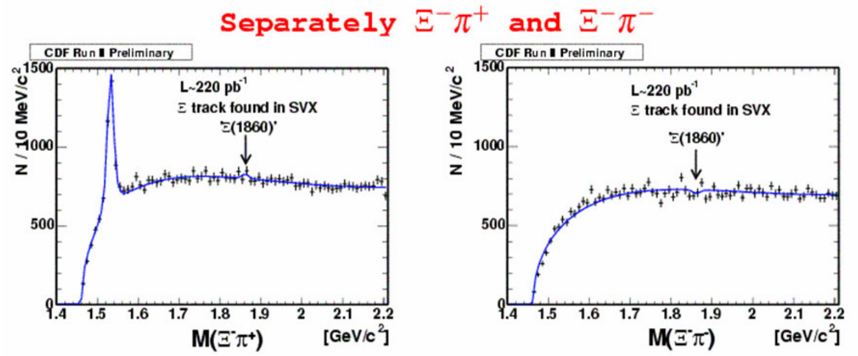


Figure 5: pK_s mass spectrum. The left plot is for the minimum bias data and the right plot is for the jet 20 data.

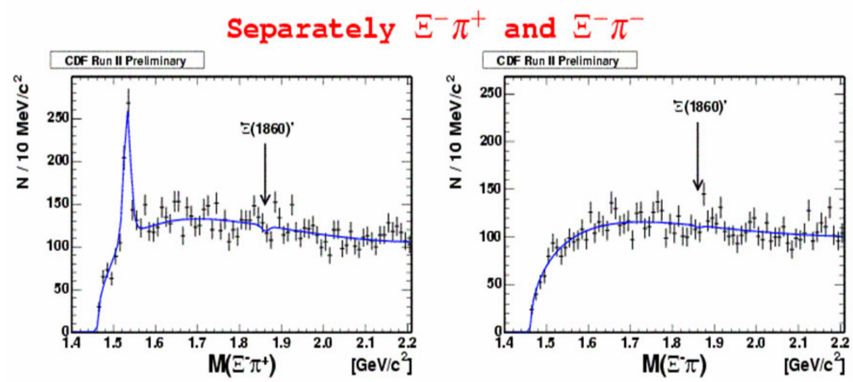
VI. Search for Ξ(1860)

We search for Ξ(1860) in both the $\Xi^- \pi^+$ and $\Xi^- \pi^-$ decay modes where Ξ^- decays into $\Lambda \pi^-$. Both displaced track and jet 20 data samples were used to search for Ξ(1860). The Ξ^- peaks were clearly seen in both data sets. In total, we reconstructed 36,000 Ξ^- in the displaced track dataset. In figure 6 and 7, the Ξ(1530) was clearly seen in the $\Xi^- \pi^+$ mass spectra in both data sets and served as a reference channel. The $\Xi \pi$ mass resolution was found to be 5.8 MeV using zero width Monte Carlo data. With this mass resolution, we should be able to resolve the Ξ(1860) peak seen by the NA49 experiment[10]. Figure 6 shows the $\Xi \pi$ mass spectra of the minimum bias data and the figure 7 is for the jet20 data. In this search, we did not find any resonance structure around 1.860 GeV in either $\Xi^- \pi^+$ or $\Xi^- \pi^-$ spectra.



Channel	# of events	UL 90 % CL	UL 95 % CL
$\Xi^-\pi^+$	57±51	126	144
$\Xi^-\pi^-$	-54±47	51	63

Figure 6: the $\Xi\,\pi$ mass spectra of the displaced track sample. The left plot shows the $\Xi^-\,\pi^+$ mass spectrum and the right plot shows the $\Xi^-\,\pi^-$ mass spectrum.



Channel	# of events	UL 90 % CL	UL 95 % CL
$\Xi^-\pi^+$	-14±19	25	30
$\Xi^-\pi^-$	-4±18	28	33

Figure 7: the $\Xi\,\pi$ mass spectra of the jet 20 sample. The left plot shows the $\Xi^-\,\pi^+$ mass spectrum and the right plot shows the $\Xi^-\,\pi^-$ mass spectrum.

VII. Summary and Conclusion

We have searched for Θ_c , Θ^+, Ξ (1860) pentaquark states. With no application of knowledge for pentaquark production mechanisms and decay properties in all analyses, no evidences of these states have been found at CDF. We are vigorously searching for another pentaquark states.

VIII. Acknowledgements

I would like to acknowledge the workshop organizers and Professor Takashi Nakano for their hospitality and for their invitation to this vivid and successful workshop. I also would like to thank the efforts and information provided by the CDF pentaquark task force members. I also would like to thank Dr. J. Antos for bringing this interesting topic to my attention.

IX. References

[1] LEPS Collaboration, T.Nakano *et al.,* Phys. Rev. Lett. 91 (2003) 012002.
[2] SAPHIR Collaboration, J.Barth *et al.,* Phys. Lett. B 572 (2003) 127.
[3] CLAS Collaboration, V. Kubarovsky *et al.,* Phys. Rev. Lett. 91 (2003) 252001.
[4] DIANA Collaboration, V.V. Barmin *et al.,* Phys. Atom. Nucl. 66 (2003) 1715.
[5] HERMES Collaboration, A. Airapetian *et al.,* Phys. Lett. B 585 (2004) 213.
[6] SVD Collaboration, A. Alee *et al.,* Preprint hep-ex/0401024,2004.
[7] A.E. Asratyan, A.G. Dolgolenko, and M.A. Kubantsev, hep-ex/0309042.
[8] COSY-TOF Collaboration, M. Abdel-Bary *et al.,* Preprint hep-ex/0403011, 2004.
[9] Zeus Collaboration, S. Chekanov *et al.,* DESY-04-056, hep-ex/0403051.
[10] NA49 Collaboration, C. Alt *et al.,* Phys. Rev. Lett. 92 (2004) 042003.
[11] H1 Collaboration, A. Akta *et al.,* Preprint hep-ex/0403017, 2004.