Branching Ratios for $D_S^+ \to K^\pm$ X

Zhang Chun

Jun.19,1998

- Intruduction
- Experiment and Method
- Single tag
- $K^\pm$ in recoiling side
- Branching ratio Br($D_S^+ \to K^\pm$ X) and comparing with Mark3 in measured result
- Summary

1. Introduction

- Physical interest

The process of $W^\pm$ emission is calculated theoretically by attributing all unsolvable facts to two factorized parameters, a_1,a_2, for simplification. Thus what value should be bestowed on a_1 and a_2 is an important problem in that kind of calculation. Up till now, this problem is in disputation and a resonable way to resovle it is extracting them from the measurement of the process, concerning $W^\pm$ emission but without other processes involved. $D_S^+ \to K^\pm$ X inclusive Decay is just such a process.

$D_S^+ \to K^\pm$ X are all Cabibbo favored processes, but $D^+ \to K^-$ X is Cabibbo favored process and $D^+ \to K^+$ X is Cabibbo suppressed process. So comparing them will help us understand the mechanism of decay concerning those processes.

- Present result listed in PDG

Now, in PDG, only Mark3 gave a measured result of this ratio. But their error is very large($\sim$ 100 %) due to a limited D_S tagged sample (only 68 D_S tags).

- What result is expected in our measurment

Because of the relatively larger D_S data sample in BES, we can obtain a more accurate result ($\sim$ 50 %)in our measurement.

2. Experiment and method

Our experimental facility is BES (BEijing Spectrumeter), which is a large detector running on BEPC (Beijing Electron Positron Collider). The analysis data sample is 22.3 pb^{-1} data accamulated at $\sqrt{s} = 4.03GeV$ from 1992 to 1994.

At 4.03 GeV, if a D_S meson is generated, it must be accompanied by a $\overline{D_S}$ meson. So we can employ double tag method in analysis at this energy point. That is to say, we tag a D_S meson in one side (single tag side) through some special D_S decay channel, then look for a K or π meson on the recoiling side.

3. Single tag

We choose such four Decay channels as $D_S \to \phi\pi$, $K^{*0}K$, K_s^0K and $K_s^0K\pi\pi$to tag one of the $D_S^+D_S^-$ mesons. In first two modes we select $K^+K^-\pi$ as final state charged tracks, but for the third mode $\pi\pi K$ and for the fourth $K_s^0K\pi\pi$ are selected, respectively

3.1. Primary event selection

3.1.1. Charged track preselection

- Single track fit value MFIT=2 or -9 or -19
- Impact parameter $| r_{xy} |< 1.2$cm but pions from K_s^0 decay are not confined by this cut
- Polar angle of track $| cos(\theta) |< 0.8$

3.1.2. Particle identification

- Prob($K(\pi)) > 0.01$ applied to K , π both
- LR($K) > 0.5$ applied to K only

3.2 Beam energy constrain

We required that the total energy of the three particles, which are selected for reconstructing D_S meson, satisfy below criterion

$$| E_{KK\pi(K\pi\pi)} - 2.015GeV |< 0.05 \text{ GeV}$$

Where 2.015 GeV means the norminal beam energy.

3.3 Kinematic fit

To reconstruct D_S meson , we use 1-c kinematic fitting in our analysis. Each event satisfying above criteria is required to pass a kinematic fit, which considers the event as a ee$\to X\overline{X}$ event. A X or $\overline{X}$ decay to $KK\pi$ or $\pi\pi K$, whereas the other has missed but it's mass is required to be equal to the mass of the charged track combination in the fitted side.

3.4 Analysis of each single tag channel

3.4.1. $D_S \to \phi\pi$

The analsis cuts of this channel list below

- $| cos(\theta_{K^+}) | > 0.25$ θ_{K^+} is the helicity angle
- $| M_{K^+K^-} - 1.02 | < 0.02$ GeV/c^2 $M_{K^+K^-}$ is the invariant mass of KK
- $P(\chi^2_{1C}) > 0.15$ $P(\chi^2_{1C})$ is $1C-$fit confidence level

Then with a binned maximum-likelihood fit, we can fit the histogram of $KK\pi$ invariant mass distribution and get the number of D_S single tag event in this decay mode. The histogram is shown in Figure 1.

$$N_(D_S \to \phi\pi) = 38 \pm 8$$

3.4.2. $D_S \to K^{*0}$**K**

The analsis cuts of this channel list below

- $| cos(\theta_{K^+}) | > 0.45$ θ_{K^+} is the helicity angle
- $| M_{K\pi} - 0.896 | < 0.07$ GeV/c^2 $M_{K\pi}$ is the invariant mass of Kπ
- $P(\chi^2_{1C}) > 0.15$ $P(\chi^2_{1C})$ is $1C$-fit confidence level

The number of D_S single tag event in this channel is

$$N(D_S \to K^{*0}K) = 40 \pm 9$$

Figure 2 show the invariant mass distribusion of $KK\pi$ combination in this mode.

3.4.3. $D_S \to K^0_S K$

All analysis cuts applied in this mode list below

- $| M_{\pi\pi} - 0.497 | < 0.03$ GeV/c^2 $M_{\pi\pi}$ is the invariant mass of $\pi\pi$
- $| L_{xy} | > 0.9$ cm L_{xy} is the decay lenth of K^0_S in xy plan
- $| \Delta Z | < 3.5$ cm ΔZ is the difference of two pions' at z axial
- $| cos(\theta_\pi) | > 0.6$ θ_π is the acolinial angle of $\pi\pi$
- prob(K^0_S) > 0.05 prob(K^0_S) is K^0_S fit confidence level

The number of D_S single tag event of this decay mode is

$$N(D_S \to K^0_S K) = 20 \pm 8$$

Figure 3 show the invariant mass distribusion of $\pi\pi K$ combination in this mode.

3.4.4. $D_S \to K^0_S K\pi\pi$

All analysis cuts applied in this mode list below

- $\mid M_{\pi\pi} - 0.497 \mid < 0.03$ GeV/c^2 $M_{\pi\pi}$ is the invariant mass of $\pi\pi$
- $\mid L_{xy} \mid > 0.9$ cm L_{xy} is the decay lenth of K_S^0 in xy plan
- $\mid \Delta Z \mid < 3.5$ cm ΔZ is the diffe two pions' at z axial
- $\mid cos(\theta_\pi) \mid > 0.6$ θ_π is the acolinial angle of $\pi\pi$
- prob(K_S^0) > 0.05 prob(K_S^0) is K_S^0 fit confidence level

The number of D_S single tag event of this decay mode is

$$N(D_S \to K_S^0 K) = 21 \pm 7$$

Result is shown in Figure 4.

As shown in Figure 5, we combine the three decay modes and obtain the total number of single tags, which is

$$N_{tag} = 109.6 \pm 13.57$$

4. Candidates of kaons and pions in recoiling side

4.1. Identify Kaon and Pion

In recoiling side, a charged track is considered as a kaon or pion only if it satisfy following cuts

- It is distinguised from the charged tracks in tag side.
- It is not a electron
- It's prob($K(\pi)$) > 0.01
- It's LR($K(\pi)$) > 0.5

As showing in Figure 6-9, we get the distribution of the invariant mass of the particle combination in single side, then fit it by using BW fit program to obtain the number of $K(\pi)$ in recoiling side

$$N_{K^+} = 19 \pm 4$$
$$N_{K^-} = 7 \pm 3$$
$$N_{\pi^+} = 53 \pm 11$$
$$N_{\pi^-} = 18 \pm 6$$

4.2. Kaon, Pion misidentification

Because of the efficency of particle identification and the misidentification the number of $K\pi$ Particles observed in recoiling side should be

$$N_K^{exp} = N_K^r \times M_{KK} + N_\pi^r \times M_{\pi K}$$
$$N_\pi^{exp} = N_K^r \times M_{K\pi} + N_\pi^r \times M_{\pi\pi}$$

Where the $M_{K\pi}$ is the element of the particle identification efficency and misidentification rate matrix, which can be obtained by using pure pion and kaon Monte Carol data sample to test our particle identification program. Then we can get the matrix in the momenta range [0.1 GeV, 1.3 GeV]

$$\begin{pmatrix} 0.769 & 0.122 \\ 0.186 & 0.824 \end{pmatrix}$$

the inverse matrix is

$$\begin{pmatrix} 1.3487 & -0.1997 \\ -0.3044 & 1.2587 \end{pmatrix}$$

Though this matrix, we can unfold the real number of kaons and pions in recoiling side,

$$N_K^r = N_K^{exp} \times 1.3487 - N_\pi^{exp} \times 0.1997$$
$$N_\pi^r = -N_K^{exp} \times 0.3044 + N_\pi^{exp} \times 1.2587$$

The transmit error is

$$\frac{\delta N_K^r}{N_K^r} = \sqrt{(1.212 \times \frac{\delta N_K^{exp}}{N_K^{exp}})^2 + (-0.139 \times \frac{\delta N_\pi^{exp}}{N_\pi^{exp}})^2} \tag{1}$$

where N_K^r , N_K^{exp} are real, observed number of kaon respectively. and M_{KK} is the element of that matrix. Then we get

$$N_{K+}^r = 15 \pm 4$$
$$N_{K-}^r = 6 \pm 4$$

5. Decay branching ratio of $D_S^+ \to K^\pm$ X

5.1 Estimating tatol efficiency

In order to obtain the efficiency of our analysis, we generate three different type MC data, which are all D_S decay channels in single tag side but, on the other side, are $\eta K, \eta' K, \eta K \pi^0$ respectively, each including Kaon in final state, then let each type of MC data to pass our analysis program. In each certain decay mode, we can get an analysis efficiency. Then, the final efficiency is the weight average according to their decay ratio in MC program. the result lists in table1

5.2. Result

This ratio is presented by

$$Br(D_S \to KX) = \frac{N_K^r}{N_{tag} \times \varepsilon} \tag{2}$$

The error transmition is

Table 1: Efficiency of differrent decay channels generated by MC

dacay mode	*single tag*	*recoiling* side	*ratio*	ε *in each* mode	*average* ε
ηK	276.855	146.205	0.15	0.5353	0.5780
$\eta' K$	293.959	174.722	0.35	0.5944	
$\eta K \pi^0$	297.564	156.389	0.30	0.5802	

$$\frac{\delta Br}{Br} = \sqrt{(\frac{\delta N^r_K}{N^r_K})^2 + (\frac{\delta N_{tag}}{N_{tag}})^2} \tag{3}$$

where ε is tatol efficiency of analysis.

Then we get

$$Br(D_S^+ \to K^+ X) = 25.8 \pm 7.8\%$$

$$Br(D_S^+ \to K^- X) = 10.3 \pm 6.8\%$$

The error listed above is only statiscal error. Here we conservely estimate the sysmatic error about 30% which is likely larger than the real value. The result combining statiscal error and estimated sysmatic error is listed in table 2. Study of the systematic uncertainties in the measured branching ratios is still in progress and this is a preliminary result.

5.3 Comparation

Table 2: Comparation of result between BES and Mark3

Group	*Br($D_S^+ \to$ K^+ X) (%)*	*Relative error (%)*	*Br($D_S^+ \to$ K^- X) (%)*	*Relative error (%)*
Our result	25.8	42	10.3	76
Mark3	20	+90 -70	13	+107.64 -92.31

6. Summary

Here we use 22.3 pb^{-1} data sample accamulated in BES to obtain 110 ± 14 singly tagged sample through three selected decay channels of D_S meason. By the singly tagged sample, we measured the braching ratios of $D_S^+ \to K^\pm X$ and accomplished a better result than $Br(D_S^+ \to K^\pm X)$ listed in PDG96.

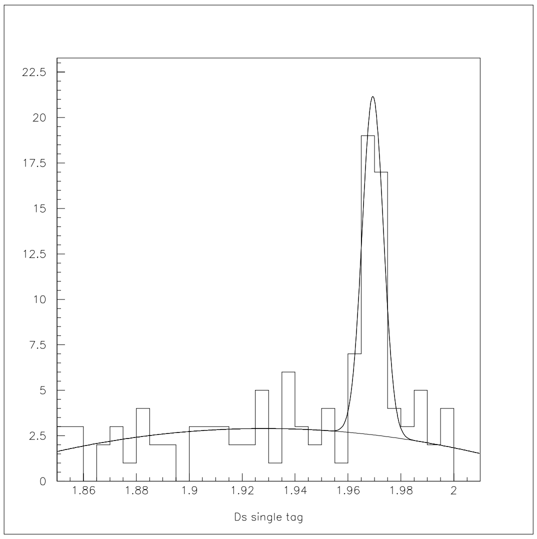

Figure 1: Invariant mass distribution of $\phi\pi$ in single tag side

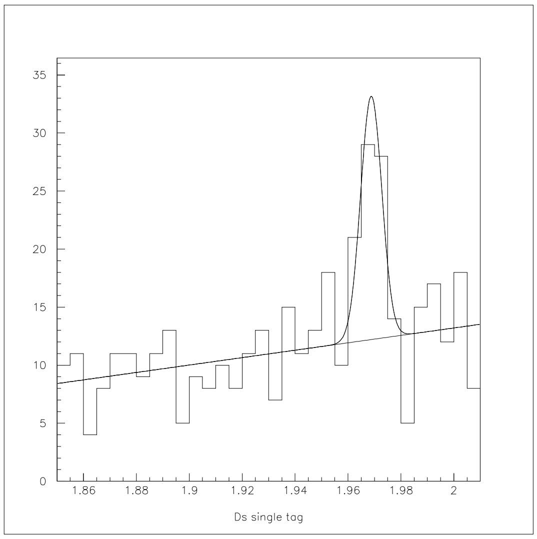

Figure 2: Invariant mass distribution of $K^{*0}K$ in single tag side

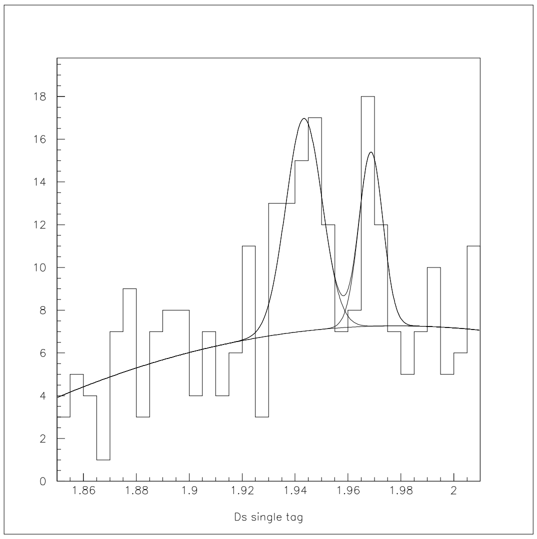

Figure 3: Invariant mass distribution of K_S^0K in single tag side

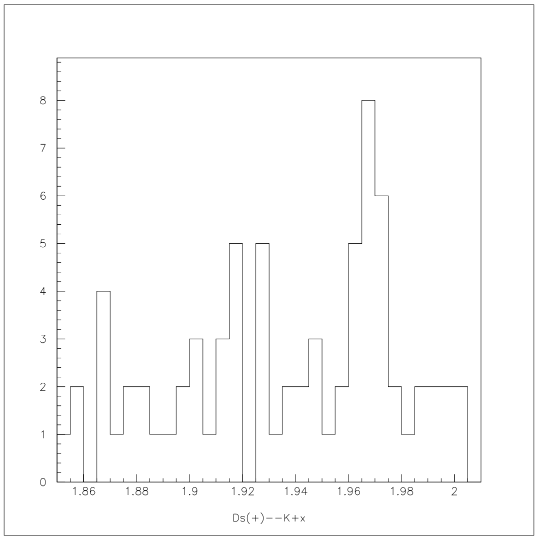

Figure 4: Invariant mass distribution of $K_S^0\pi\pi K$ in single tag side

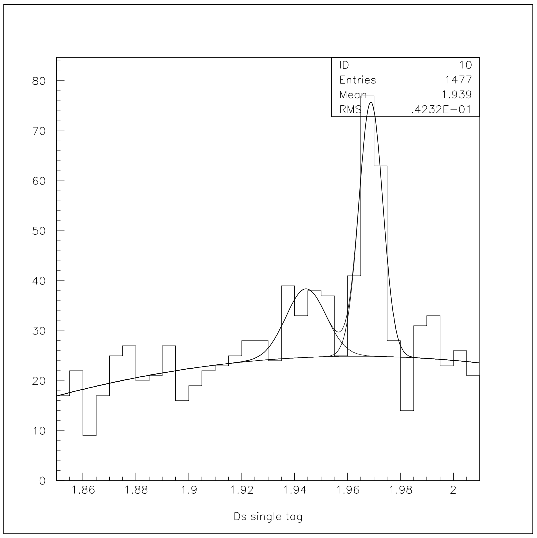

Figure 5: Invariant mass distribution of total single tag sample

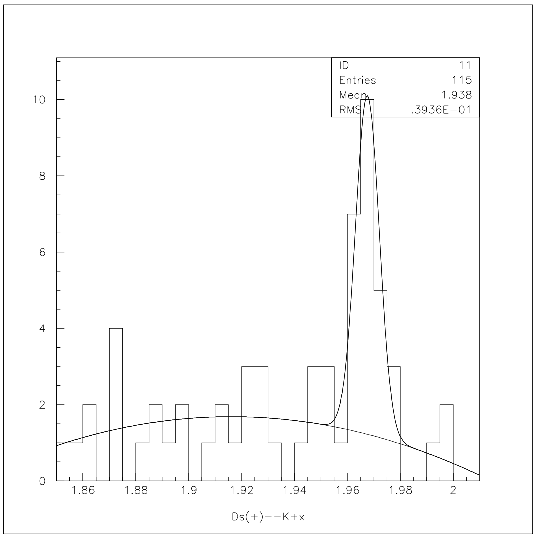

Figure 6: Invariant mass distribution of particle combination in single tag side when a K^+ is found in recoiling side

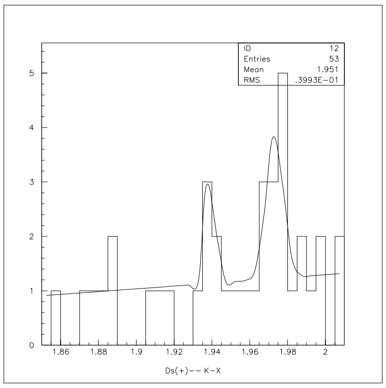

Figure 7: Invariant mass distribution of particle combination in single side when a K^- is found in recoiling side

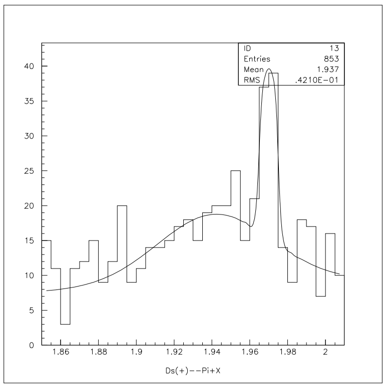

Figure 8: Invariant mass distribution of particle combination in single tag side when a π^+ is found in recoiling side

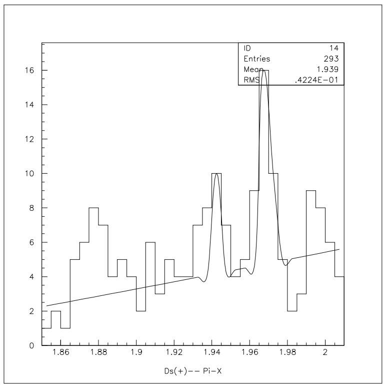

Figure 9: Invariant mass distribution of particle combination in single tag side when a π^- is found in recoiling side