SEARCH FOR THE DECAY $J/\psi \to D/\overline{D}X_u$

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- **Physics Motivation**
- **BES Data Sample**
- **The Inclusive Analysis**
  $D^0 \to K^-\pi^+, K^-\pi^+\pi^+\pi^-$
- **The Exclusive Analysis**
  $J/\psi \to \overline{D}^0\rho^0$, $J/\psi \to D_S^+K^-$
- **Upper Limits on $Br(J/\psi \to D/\overline{D}X_u)$**
- **Summary**

BES Physics Workshop • IHEP • Beijing • December 15-16, 1999

- **Weak Decay of J/ψ**

Standard Model predicts the weak decays of J/ψ at a level about $10^{-7\sim-8}$.

Using $10^8 - 10^9$ J/ψ data to be taken with BES-III at BEPC-II, we can search for the decays such as:
$J/\psi \to D_S^{\pm}l^{\mp}\nu, D_S^{\pm}\pi^{\mp}, D_S^{\pm}\rho^{\mp}, D_S^{\pm}K^{\mp}, \ldots$

Study of those decays can help one understand the mechanism and the hadronization of the decays.

PHYSICS MOTIVATION

- **Flavor Changing Process $c \to u$**

In the Standard Model, the process is predicted to be unobservable comparing to J/ψ hadronic and radiative decays. So the process can serve as probe of new physics. (For more details please see paper "Flavor changing process in quarkonium decays" by A. Datta, P.J. O'Donnell, S. Pakvsa, and X. Zhang, published in PRD, 60, 14001, 1999.)

If the flavor changing process $c \to u$ is observed at rate $> R^{S.M.} \sim 10^{-8}$, there would be new physics beyond the Standard Model.

- $J/\psi \to D/\overline{D}X_u$

Theoretical calculation gives the branching fraction for $J/\psi \to D/\overline{D}X_u$ to be $\sim 10^{-5}$ and

$$Br(J/\psi \to D^0\pi^0) \sim \frac{1}{14} \times Br(J/\psi \to D/\overline{D}X_u).$$

BES DATA SAMPLE

- **Data taken at $\sqrt{s} = 3.097$ GeV**

$8 \times 10^6 J/\psi$ events were accumulated using BES detector at $\sqrt{s} = 3.097$ GeV at BEPC.

4 prongs DST (NDST) data is used to search for $J/\psi \to D/\overline{D}X$ Flavor Changing process from the underling $c \to u$ transition.

- **Data taken at $\sqrt{s} = 4.03$ GeV**

A data sample of 22.3 pb^{-1} was collected at a center-of-mass energy of $\sqrt{s} = 4.03$ GeV with the BES at the BPEC during the time period from 1992 to 1994.

This data sample is used to study the Charmed Meson decay properties.

The data sample is used here to check our analysis program for searching for the decays $D^0 \to K^-\pi^+$, $D^0 \to K^-\pi^+\pi^+\pi^-$, and $J/\psi \to D_S^+K^-$.

INCLUSIVE ANALYSIS

- Singly tagged D^0 and D^+

  Feed the data collected at $\sqrt{s} = 4.03$ GeV into the singly tagged D programs to search for D decay events through the three decay modes: $D^0 \to K^-\pi^+$, $D^0 \to K^-\pi^+\pi^+\pi^-$, and $D^+ \to K^-\pi^+\pi^+$.

  (see plots)

- Search for decay $J/\psi \to D/\overline{D}X_u$

  Feeding the data taken at $\sqrt{s} = 3.097$ GeV into the singly tagged D programs we search for the decays $D^0 \to K^-\pi^+$, $D^0 \to K^-\pi^+\pi^+\pi^-$, and $D^+ \to K^-\pi^+\pi^+$ events.

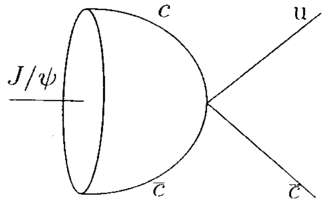
  (see plots)

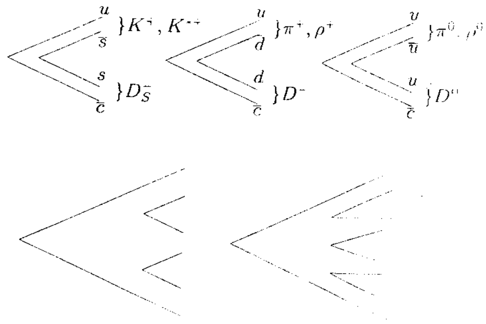
No event is observed for the inclusive D analysis from the J/ψ decays.

No signal for $J/\psi \to D/\overline{D}X_u$ is found.

EXCLUSIVE ANALYSIS

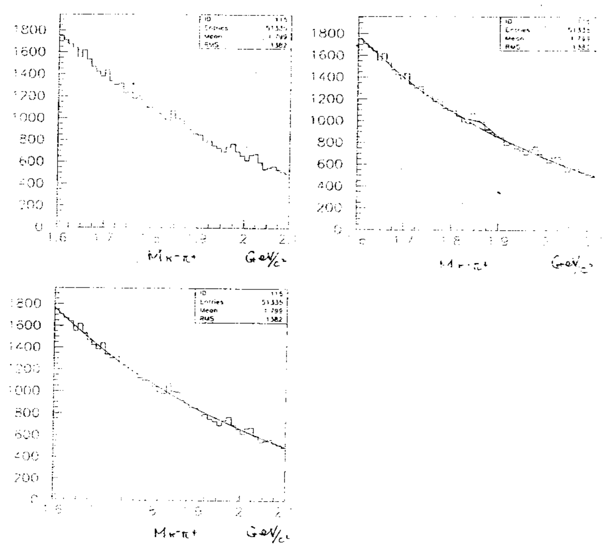
- A possible transition[1]





[1] Based on discussion with Professor X. M. Zhang

Inclusive Analysis   Data taken @ $\sqrt{s}$ = 3.097 GeV



- Search for decay $J/\psi \to \overline{D^0}\rho^0$
  - Invariant mass

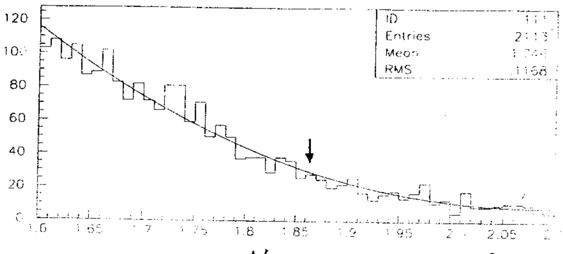
    (see plots)
  - Kinematic fit (4C fit) mass

    (see plots)

No signal for $J/\psi \to \overline{D^0}\rho^0$ is found.

Exclusive Analysis

Data taken @ $\sqrt{s} = 3.097$ GeV



$M_{K^-\pi^+}$ GeV/c^2

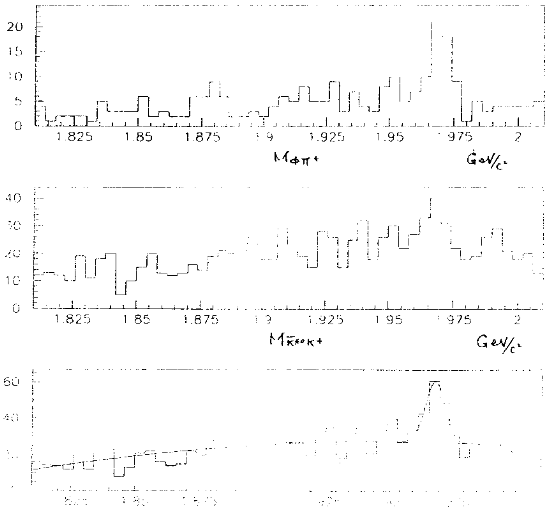
Search for $J/\psi \to D^0 \rho^0$

$\hookrightarrow K^-\pi^+$

No signal for $D^0 \to K^-\pi^+$ is observed.

12 Dec., 1999

$\sqrt{s} = 4.03$ GeV



$M_{\phi\pi^+}$ GeV/c^2

$M_{\overline{K}^{*0}K^+}$ GeV/c^2

$M_{\phi\pi^+,\ \overline{K}^{*0}K^+}$ GeV/c^2

(Fit Mass)

EXCLUSIVE ANALYSIS (cont)

- Test programs to tag $D_S^+ \to \phi\pi^+, \overline{K^{*0}}K^+$

  Feeding the data collected at $\sqrt{s} = 4.03$ GeV into the programs (1C fit) we observed clearly signal for $D_S^+ \to \phi\pi^+, \overline{K^{*0}}K^+$.

  (see plots)

- Search for decay $J/\psi \to D_S^+ K^-$

  Feeding the data collected at $\sqrt{s} = 3.097$ GeV into the programs (4C fit) we do not observe signal for $D_S^+ \to \phi\pi^+, \overline{K^{*0}}K^+$.

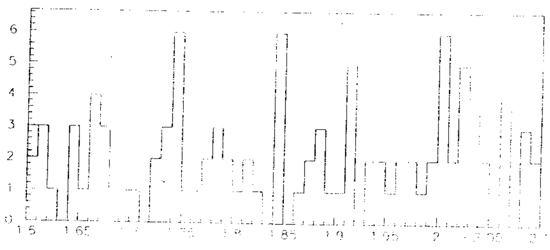
  (see plots)

No signal for $J/\psi \to D_S^+ K^-$ is found.

12 Dec., 1999

$\sqrt{s} = 3.097$ GeV

Data



$M_{K^\mp\pi^\pm}$ GeV/c^2

(Fit Mass)

4C K.F. to $e^+e^- \to K^-\pi^+\pi^+\pi^-$ @ $\sqrt{s} = 3.097$ GeV

No signal for $J/\psi \to D^0 \rho^0$ is observed
$\rho^0 \to \pi^+\pi^-$
$\hookrightarrow K^-\pi^+$

EXCLUSIVE ANALYSIS (cont)

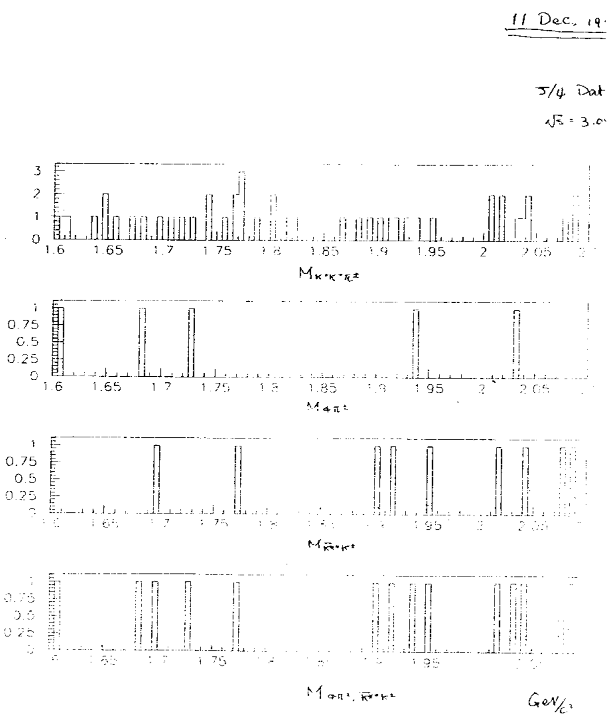
- **Test programs to tag $D_S^\pm \to \phi\pi^+, \overline{K^{*0}}K^+$**
  Feeding the data collected at $\sqrt{s} = 4.03$ GeV into the programs (1C fit) we observed clearly signal for $D_S^\pm \to \phi\pi^+, \overline{K^{*0}}K^+$.

  (see plots)

- **Search for decay $J/\psi \to D_S^\pm K^-$**
  Feeding the data collected at $\sqrt{s} = 3.097$ GeV into the programs (4C fit) we do not observe signal for $D_S^\pm \to \phi\pi^+, \overline{K^{*0}}K^+$.

  (see plots)

No signal for $J/\psi \to D_S^\pm K^-$ is found.



UPPER LIMITS ON $Br(J/\psi \to D/\overline{D}X)$

Based on 8×10^6 J/ψ events accumulated and the efficiencies estimated for the singly and exclusively analysis, the upper limits on the decay branching fractions for $J/\psi \to \overline{D}^0\rho^0$ and $J/\psi \to D_S^\pm K^-$ are set to be

$$Br(J/\psi \to \overline{D}^0\rho^0) < 1.25 \times 10^{-5} \text{ at } 90\% \text{ C.L.}$$

and

$$Br(J/\psi \to D_S^\pm K^-) < 2.8 \times 10^{-5} \text{ at } 90\% \text{ C.L.}$$

respectively.

The upper limits on the decay branching fraction for $J/\psi \to D/\overline{D}X_u$ is set to be

$$Br(J/\psi \to D/\overline{D}X) < 1.7 \times 10^{-4} \text{ at } 90\% \text{ C.L.}$$

These results are preliminary !

SUMMARY

- **With the $10^8 - 10^9$ J/ψ data to be taken using BES-III at BEPC-II, we can search for the Flavor Changing Process $c \to u$ to probe new physics.**
- **Those data sample make it possible to study of weak decays of J/ψ.**
- **Based on 8×10^6 J/ψ events we did a pre-study of searching for the decay J/$\psi \to D/\overline{D}X_u$. No signal for the decay is observed. The upper limit on the branching fraction is set to be**

$$Br(J/\psi \to D/\overline{D}X_u) < 1.7 \times 10^{-4} \text{ at } 90\% \text{ C.L.}$$

The result is preliminary !

- **In the next round BES-II experiment, 5×10^7 J/ψ will be accumulated. The upper limit on the branching fraction is expected to be reduced to $\sim 3 \times 10^{-5}$.**

Search for Some Exclusively Involved a ϕ Meson Semileptonic Decays of D^0 and D^+ Mesons

GANG RONG

BES Annual Meeting 2000

1. Introduction

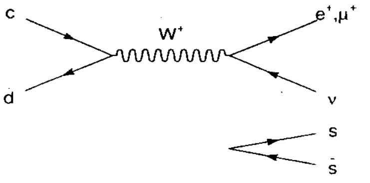
2. Method

3. Singly Tagged $D^{(0,+)}$ Sample

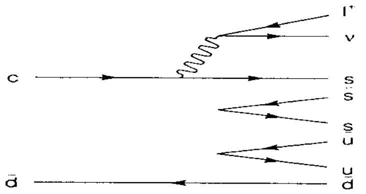
4. Result

5. Summary

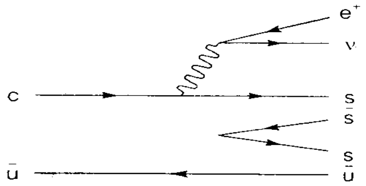
The talk was firstly given at BES Monthly Meeting, April 13 2000



(a)



(b)



(c)

INTRODUCTION

- In the frame of Standard Model, the D^+ and D^0 mesons can decay into $\phi l^+\nu$, $\phi K^-\pi^+l^+\nu$, ... and $\phi K^-l^+\nu$ ..., respectively.

- Search for some rare decay modes and measure their branching fraction are helpful in completing the weak decay picture of the Charmed mesons.

- At present, there is no experimental information about the decays $D^+ \to \phi K^-\pi^+l^+\nu$ and $D^0 \to \phi K^-l^+\nu$ available.

- Using the existing data taken at 4.03 GeV with BES at BEPC, we have searched for the decay modes and placed upper limits on the branching fractions for each of the modes.

METHOD

<u>Double Tag Method</u>

One side tagging the neutral or charged D mesons, and the other side to tag the specific decay final states, such as $D^+ \to \phi e^+\nu$, $D^+ \to \phi K^-\pi^+e^+\nu$, $D^0 \to \phi K^-e^+\nu$, and $D^0 \to \phi K^-\mu^+\nu$.

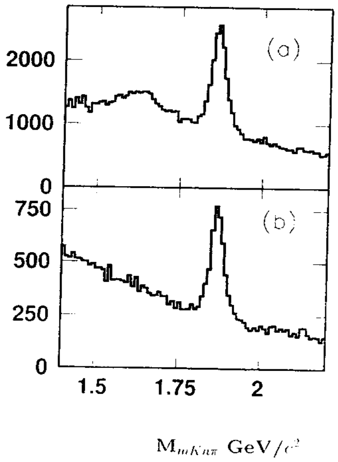
<u>Combinative D^0 and D^+ Double Tag Method</u>

Based on the Combinative D^0 and D^+ Double Tag Method, the number of D^0 and D^+ in the system recoiling against the tagged $\overline{D}$ can be determined.

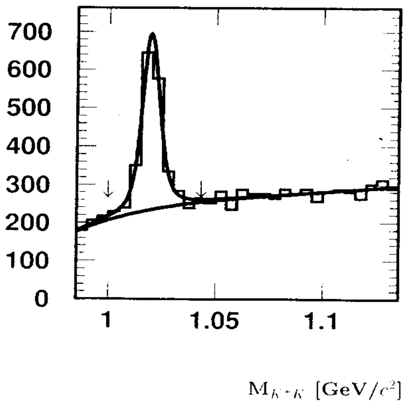
Using 5 hadronic decay modes ($D^0 \to K^-\pi^+, K^-\pi^+\pi^+\pi^-, \overline{K^0}\pi^+\pi^-$, $D^+ \to K^-\pi^+\pi^+, \overline{K^0}\pi^+$) to accumulate the neutral and charged D meons. (see figures)

• **Singly Tagged Side**

$$N_{D^{0,+}_{tag}} = 10100 \pm 162 \pm 59$$



• **Include ϕ signal**

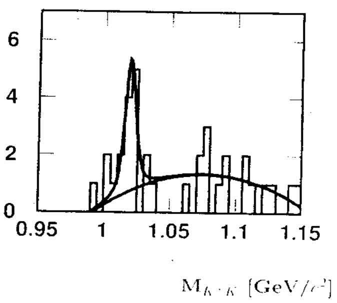


• **Recoil Side**

$$N^{\overline{D}^0}_{D^0_{tag}} = 7629 \pm 240$$

$$N^{D^-}_{D^+_{tag}} = 2471 \pm 209$$

Search for the candidates $D^+ \to \phi l^+\nu, \phi K^-\pi^+l^-\nu$ and $D^0 \to \phi K^-l^+\nu$ in the recoil.



No signal for the $D^+ \to \phi l^+\nu, \phi K^-\pi^+l^+\nu$ and $D^0 \to \phi K^-l^+\nu$ was found.

Monte Carlo efficiencies for detection of the decays

$$\epsilon_{D^+\to\phi e^+\nu} = 0.069$$

$$\epsilon_{D^+\to\phi K^-\pi^+e^+\nu} = 0.047$$

$$\epsilon_{D^0\to\phi K^-e^+\nu} = 0.057$$

$$\epsilon_{D^0\to\phi K^-\mu^+\nu} = 0.057$$

Result

Poisson Probability & Likelihood

$$P(n) = \frac{n^N}{N!}e^{-n},$$

where $n = B_i \times n_{D^{+(0)}} \times \epsilon_i$, B_i $(i = 1, 2, 3, 4)$ is branching fraction for the i_{th} mode, $n_{D^{+(0)}}$ (n_{D^+} or n_{D^0}) are the parameters for the $N_{D^{+(0)}}$ (N_{D^+} or N_{D^0}).

Likelihood function

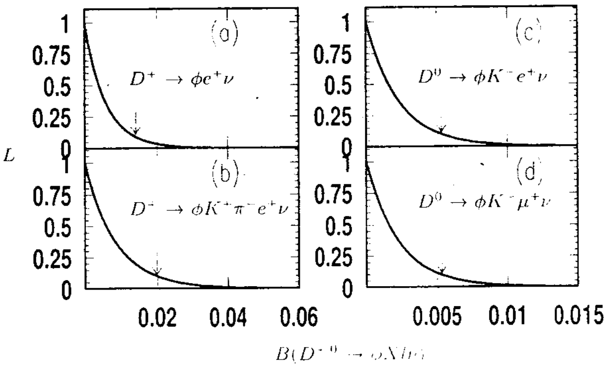
$$L(B, n_{D^{+(0)}}) = \frac{n^N}{N!}e^{-n} \times \frac{e^{-\frac{1}{2}\left(\frac{N_{D^{+(0)}} - n_{D^{+(0)}}}{\sigma_{N_{D^{+(0)}}}}\right)}}{\sqrt{2\pi}\sigma_{N_{D^{+(0)}}}}.$$

where $N_{D^+} \pm \sigma_{N_{D^+}} = 2471 \pm 209$, $N_{D^0} \pm \sigma_{N_{D^0}} = 7629 \pm 2$[illegible].

By integrating over the $n_{D^{+(0)}}$, we obtain

$$L(B) = \int L(B, n_{D^{+(0)}})dn_{D^{+(0)}}.$$

Decay Mode	No. of Events Observed	$\epsilon_{\phi X l \nu}$	Branching Fraction (%)	PDG98 (%)
$D^+ \to \phi e^+ \nu$	0	0.069	< 1.38	< 2.09
$D^+ \to \phi K^+ \pi^- e^+ \nu$	0	0.047	< 2.01	N/A
$D^0 \to \phi K^- e^+ \nu$	0	0.057	< 0.53	N/A
$D^0 \to \phi K^- \mu^+ \nu$	0	0.057	< 0.53	N/A



Summary

Using the existing data taken at 4.03 GeV with BES at BEPC, we have searched for the semileptonic decays $D^+ \to \phi e^+ \nu$, $D^+ \to \phi K^+ \pi^+ e^+ \nu$, $D^0 \to \phi K^- e^+ \nu$, and $D^0 \to \phi K^- \mu^+ \nu$. No event of the decays was found.

Upper limits on the branching fractions have been placed. Among them we first set three upper limits on the branching fractions for the decays $D^+ \to \phi K^+ \pi^- e^+ \nu$, $D^0 \to \phi K^- e^+ \nu$, and $D^0 \to \phi K^- \mu^+ \nu$.

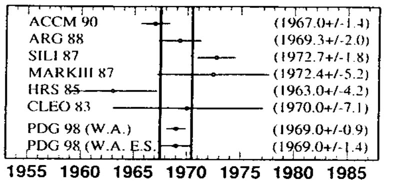
A Measurement of the Mass of D_S^+ Meson

GANG RONG

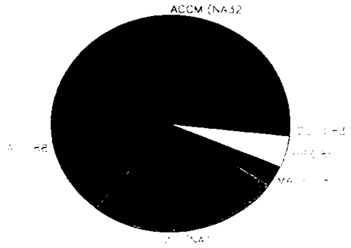
BES Annual Meeting 2000

1. Motivation
2. Method
3. Invariant Mass Spectra
4. Result
5. Conclusion

The talk was firstly given at BES Monthly Meeting, April 13, 20



Measured values of the mass of D_S^+ meson, used in the averaged value of PDG98



The weights of the measured values of the mass of D_S^+ meson, which contribute to the value of the mass averaged by PDG98

MOTIVATION

- A Foundamental Constant

  The mass of D_S^+ meson is a foundamental physical constant in particle physics. It is important to improve the precision of its measured value.

- Theoretical Prediction

  Potential models based on QCD can predict mass spectra of light and heavy mesons. .... Some other models predict hyperfine splittings ...

  By comparing the measured values of the masses of mesons, the models can be developed.

- Experimental Status

  The most precise measurement of the mass of D_S meson was performed in NA32 Experiment by ACCM Collaboration. They obtained

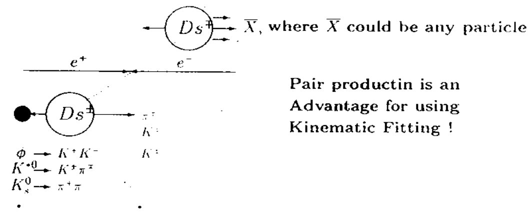
$$M_{D_S^+} = 1967.0 \pm 1.0 \pm 1.0 \text{ MeV}/c^2$$

Using the existing data taken at 4.03 GeV with BES at BEPC, we can *improve* the measurement of the mass of the D_S^+ meson.

METHOD

$D_S^+ D_S^-$ Pair Production

At $\sqrt{s} = 4.03$ GeV, the $D_S^+ D_S$ are produced in pair.



The kinematic signature of production and decay of $D_S^+ D_S^-$

Kinematic Fit (KF)

Taking the advantage of the pair production, we can use kinematic fit to some specific particle combinations to improve the ratio of signal to noise, and mass resolution. In the KF, one constraint of

$$M_X = M_{fit}$$

is required, where M_{fit} is the invariant mass of $nKm\pi$ ($n = 0, 1, or\ 2$ and $m = 1, 2, 3, or\ 4$), which is calculated based on the fittet 4-momentum vector.

Invariant Mass Spectra

Using 5 hadronic decay modes ($\phi\pi$, $K^{*0}K$, K_s^0K, $K_s^0K\pi\pi$, $f_0\pi$) to accumulate the D_S^+ sample. (figure (a), (b), (c), (d) and (e) for each of the modes, respectively.)

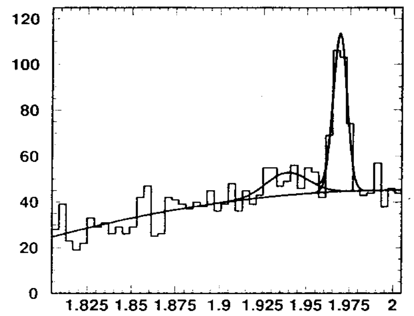
Invariant Mass of $nKm\pi$ [GeV/c^2]

A fit to the mass spectra with a Gaussian function for the D_S^+ signal and a quadratic function for combinatorial background and another Gaussian function for the $D^+ \rightarrow \overline{K}_S^0\pi^-$ and $D^+ \rightarrow K_S^0K^-\pi^+\pi^+$ background yields a total number of

$$183.6 \pm 24 \pm 6.5$$

singly tagged D_S^+ mesons. The first error is statistical, the second systematic evaluated by varying the parameterization of the background.

Result



Invariant Mass of $nKm\pi$ [GeV/c^2]

The fitted mass of D_S^+ meson is

$$\boxed{M_{D_S^+} = 1969.3 \pm 0.5 \pm 0.6 \text{ MeV}/c^2}$$

$$\boxed{M_{D_S^+} = 1969.3 \pm 0.8 \text{MeV}/c^2}$$

which consistents with the World Averaged Value of

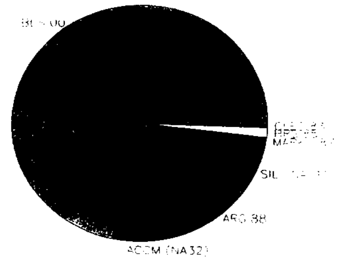
$$\boxed{M_{D_S^+} = 1969.0 \pm 0.9 \text{ MeV}/c^2 \quad \text{PDG98 Average}}$$

with a standard deviation of 4.3 ± 0.5 MeV/c^2. The first error in the value of the fitted mass of D_S^+ is statistical and the second systematic.

Source of systematic uncertainty in $M_{D_S^\pm}$

Several systematic sources considered at present are shown in the table.

Analysis Cuts and Others	Uncertainties in $M_{D_S^\pm}$	Note
Fit Probability	±0.06	
Fit Range	±0.10	
Bin Size	±0.09	
background shape	±0.08	
Mass Scale	±0.10	
Other ...?	N/A	To be studied
	(±0.5 ?)	concervative Estimation
Total	±0.20	
	(±0.54)	



The weights of the measured values of the mass of $D_S^\pm$ meson which contribute to the new weighted averaged value of the mass It includes the BES measured value of the mass of $D_S^\pm$ meson.

Mass Scale – Mass Calibration

Using the same kinematic fit method as used in tagging $D_S^\pm$ decays events, we select the $D^0 \to K^-\pi^+$ and $D^+ \to K^-\pi^+\pi^+$ decays, and measured their masses. We obtain the D^0 and the D^+ masses of

$$\boxed{M_{D^0} = 1864.7 \pm 0.9 \pm 0.3\ \mathrm{MeV}/c^2}$$

and

$$\boxed{M_{D^+} = 1869.2 \pm 1.1 \pm 0.3\ \mathrm{MeV}/c^2}$$

By comparing the PDG98 D^0 and D^+ masses

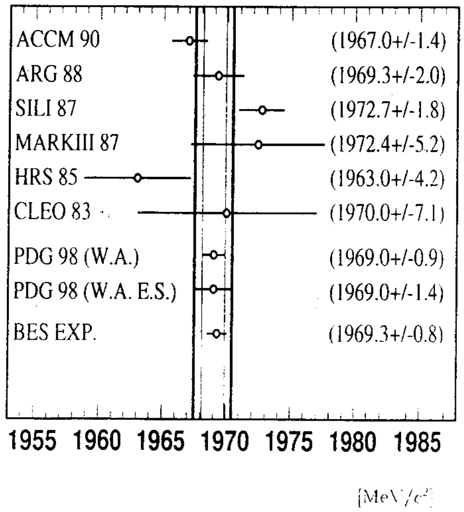
$$M_{D^0} = 1864.1 \pm 1.0\ \mathrm{MeV}/c^2 \quad \mathrm{PDG98}$$

and

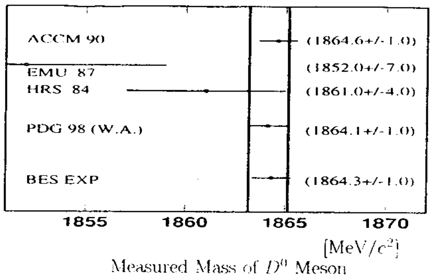
$$M_{D^+} = 1869.4 \pm 0.5\ \mathrm{MeV}/c^2 \quad \mathrm{PDG98}$$

we set an uncertainty of $0.6\ \mathrm{MeV}/c^2$ in the measured mass scale for the measurement of the mass of $D_S^\pm$ meson.

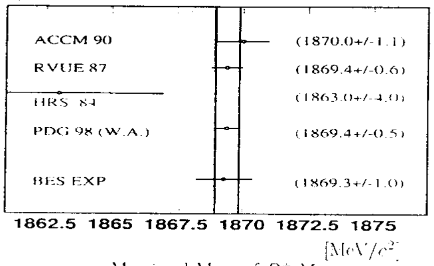
Comparison of the result with that from other EXP.



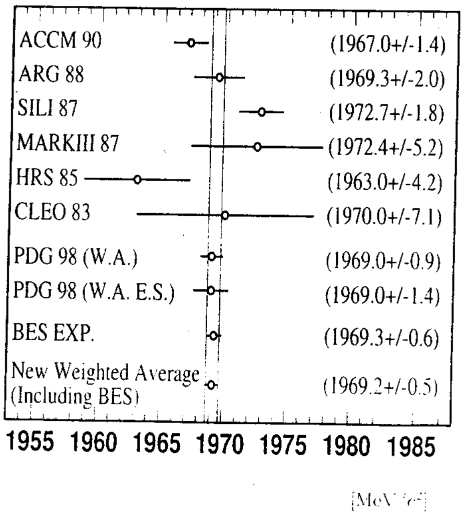
Measured Values of the Mass of $D_S^\pm$ Meson



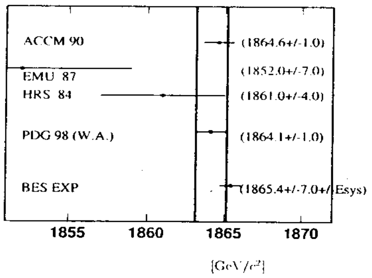
Measured Mass of D^0 Meson



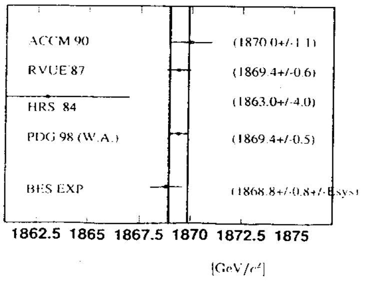
Measured Mass of D^+ Meson



Measured Values of the Mass of D_S^+ Meson



Kinematicly fitted Invariant Mass of $K^-\pi^+$.



Kinematicly fitted Invariant Mass of $K^-\pi^+\pi^+$

CONCLUSION

Using the existing data taken at 4.03 GeV with BES at BEPC, we made a measurement of the mass of the D_S^+ meson. Our measured value of

$$\boxed{\mathrm{M}_{D_S^+} = 1969.3 \pm 0.5 \pm 0.6\ \mathrm{MeV}/c^2}$$

$$\boxed{\mathrm{M}_{D_S^+} = 1969.3 \pm 0.8 \mathrm{MeV}/c^2}$$

is consistent with the World Averaged Value of

$$\boxed{\mathrm{M}_{D_S^+} = 1969.0 \pm 0.9\ \mathrm{MeV}/c^2 \quad \text{PDG98 Average}}$$

Our measured value of the mass of D_S^+ meson is a significant improvement of the mass measurements, and will reduce error in the world averaged value of the mass of D_S^+ meson.

Actually using the data, we can also make an improved measurement of the masses of the D^0 and the D^+ mesons. Some detail work on improved measurement of the masses of the D^0 and the D^- mesons is still in progress.