Direct measurements of the weak decay Constants $f_{Ds}(f_D)$, and D_S (D) branching fractions to $\mu\nu$, $\Phi\pi$, $eX(\mu\nu)$ at BES

(Initial Charm Program)

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Motivation for $f_{Ds}(f_D)$ measurement

- Large discrepancies in f_{Ds}, from 90 to 350 MeV, remain between various theoretical approaches:
  - ✓ Lattice QCD
  - ✓ Potential Model
  - ✓ Factorization Hypothesis
  - ✓ Relativistic QM
- f_B determination is of considerable importance, since it relates B_0-$\overline{B_0}$ mixing to CKM matrix elements
- The ratios $f_{Ds} : f_D : f_B$ are more reliably predicted
- f_B can be estimated from Lattice Gauge calculations if f_{Ds} is known

Precise value of the decay constant f_{Ds} (f_D) provides

- **unambiguous test of lattice QCD**
- **discrimination among models and reliable improvement of f_B estimates**

Proposal and Approval

- Experimental study of D_S physics and current status
  (Chao-His Chang, C.C. Zhang, Xue-Qian Li, Mar. 1990)
- Proposal of D_S physics study at BES/BEPC
  (Chao-His Chang, C.C. Zhang, Oct. 1990)
- D_S physics study at BES/BEPC
  (M. Fero and W. Toki, Jan. 1991)
- Common consensus on D_S run among the BES collaborators of both China and US had been reached.

- **The proposal of D_S run approved by BES in Sept. 1991**
- **D_S data taking at BES/BEPC started in Feb. 1992**

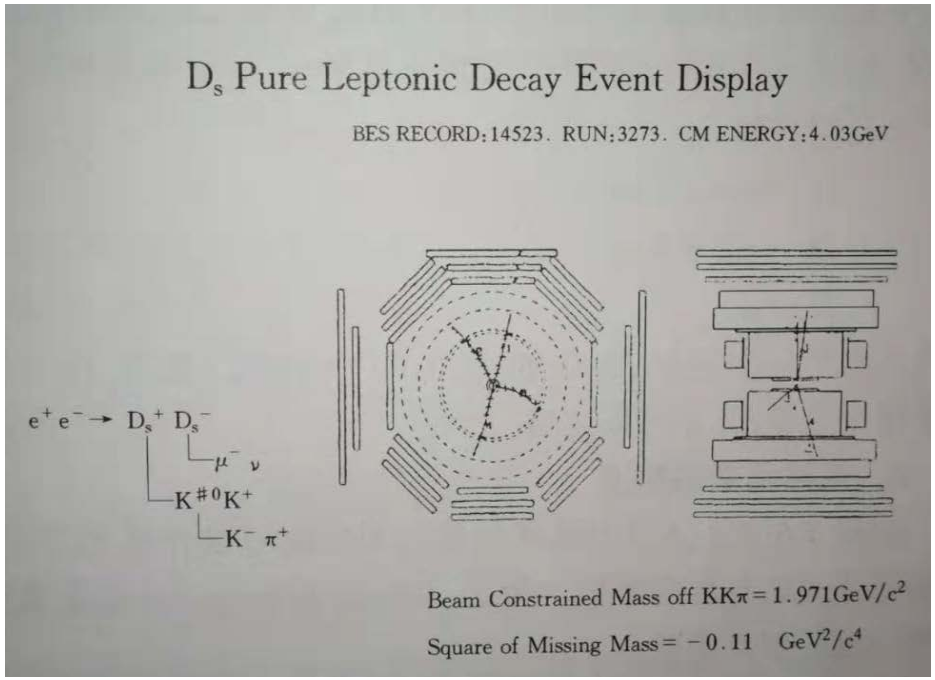
c.m. energy for *Ds* run

- Charm strange contributions to R in the couple-channel model
  - ✓ $\sigma(D_S \overline{D_S})$ = 750 pb, Ecm = 4.03 GeV
  - ✓ $\sigma(D_S^* \overline{D_S})$ = 900 pb, Ecm = 4.14 GeV, (MarkIII, 6.3 pb^{-1})
  - ✓ $\sigma(D_S^* \overline{D_S^*})$ = 1100 pb, Ecm = 4.25 GeV
- Ecm = **4.03** GeV is chosen for BES D_S runs
  - ✓ No production of both $D_S^* \overline{D}_S$ and $D_S^* \overline{D_S^*}$
  - ✓ Narrow *Ds* mass resolution with no contribution from D_S^*
  - ✓ Avoiding heavy background from low energy photons
  - ✓ 1-c fit requiring overall event four-momentum balance

◆ No D_S signal at Ecm=4.04 GeV seen by DASP at DESY (R scan data)

first D_s signal at BES in 1992

- D_S data taking started at BES/BEPC in Feb. 1992
- $D_S \rightarrow \phi\pi$ signal observed in Apr. 1992
- First event of $D_S \rightarrow \mu\,\nu$ decay observed in May 1992



◆ A decision to keep D_S physics run is made at BES annual meeting in the summer of 1992

D_S data and its quality Check

- Total integrated luminosity for D_S data is 22.3 pb^{-1}

Year	D_S data			Data taking for other topics and BEPC machine study
	L_{int} (pb^{-1})	Run time (day)	L_{int} (pb^{-1}) per month	
1992	3.22	65	1.5	Tau scan, 10^6 J/ψ events
1993	4.51	-	-	J/ψ scan, 10^6 ψ' events
1994	14.57	114	3.8	BEPC peak luminosity doubled

- Data quality check
  - ✓ Completed run-by-run for each of subdetectors
    momentum (MDC), time (TOF),
    energy (BSC), position (μ-CTR),
    and their resolutions
  - ✓ Number of events for $D^+ \rightarrow K^-\pi^+\pi^+$ decay after normalization
  - ✓ Done by groups of data prod. , calib. , and phys. anal.

Careful study of e/π/k/μ identification

- For **π/k** identification, systematic offsets in t_{TOF} and dE/dx, (calibrated with e^+e^-), are corrected.

By taking into account of
- ✓ type of hadrons π, k
- ✓ momentum
- ✓ polar angle

Using pure hadron sample of
- ✓ $J/\psi \to \omega\pi^+\pi^-$ for π
- ✓ $J/\psi \to \phi k^+k^-$ for k

- **e/μ** identification: using joint confidence level with t_{TOF} , $(dE/dx)_{MDC}$, and E_{BSC} information

- For e^+e^- events, efficiency of e identification after $D_S \to \tau\nu \to e3\nu$ selection criteria is > 80% over full momentum range
- Known π misidentified as e at a rate of ≈ 5%

- For cosmic μ, efficiency of μ identification is ≈ 85%
- Known π misidentified as μ is at a rate of ≈ 4%

Singly tagging of $D_S\overline{D_S}$ events

- Singly tagged D_S decay to $\phi\pi$, $\bar{K}^0K$, $\bar{K}^{*0}K$ with $\phi \to K^+K^-$, $\bar{K}^0 \to \pi^+\pi^-$ and $\bar{K}^{*0} \to K^-\pi^+$

✓ To suppress background from D^+ decays, requiring $\Delta E = |E_{beam} - E_{Ds}| < 50\ MeV$, where $E_{Ds} = \sum E_i$

✓ With 1-C fit requiring *Ds* candidate and recoil system to have equal mass, D_S mass resolution is 4 *MeV*

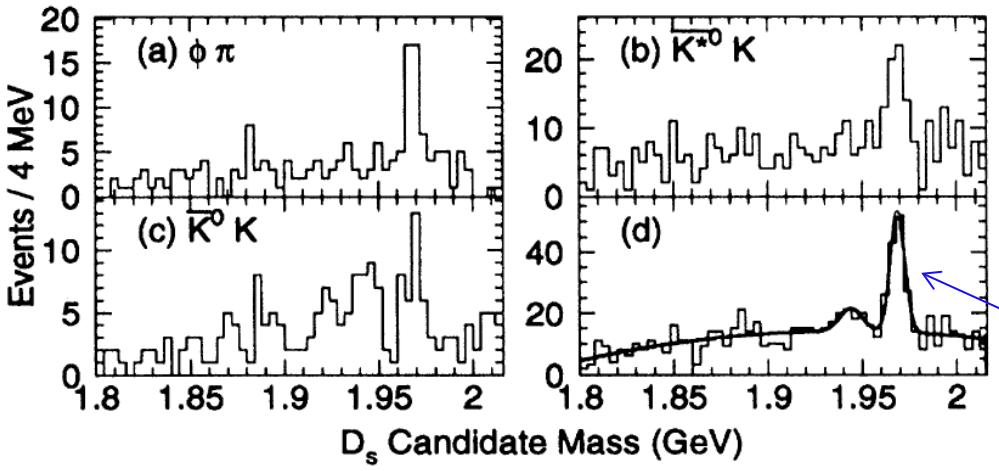


FIG. 1. The invariant mass distributions, calculated using 1-C fit momentum vectors, for (a) $\phi\pi$, (b) $\bar{K}^{*0}K$, and (c) $\bar{K}^0K$ D_s decay candidates; the combined distribution is shown in (d), where the curve corresponds to the fit described in the text.

- An unbinned maximum likelihood fit to the combined distribution of Fig. 1(d)
- A singly tagged D_S signal of 94.3 ± 12.5 events
- Mass $M_{DS} = 1968.7 \pm 0.6 \pm 0.5$ MeV

decay Constant $f_{Ds}(f_D)$ and
$D_S(D)$ branching fraction to $\mu\nu$

D_S leptonic decay candidates

➢ D_S leptonic decay are searched among recoil systems against singly tagged D_S candidates (incl. $\phi\pi$, $\bar{K}^0K$, $\bar{K}^{*0}K$ decays)

The recoil system is required

- ✓ **having a single, vertex-associated charged track**
- ✓ carrying charge opposite that of D_S tag
- ✓ with no isolated photon
- ✓ ID criteria of either e or μ is satisfied

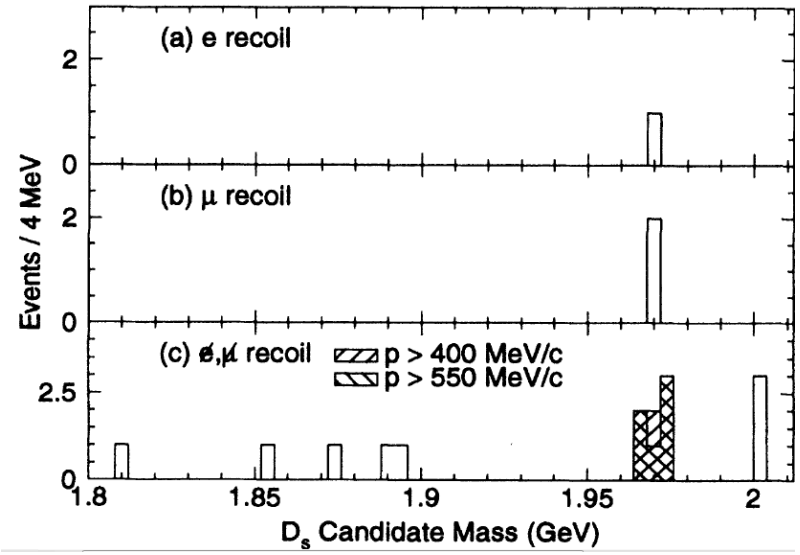


TABLE I. Three candidates for D_s leptonic decay.

Event	1	2	3
Tagging D_s decay	$\phi\pi^+$	$\bar{K}^{*0}K^+$	$\bar{K}^0K^+$
Subsystem mass (MeV)	1019.3	873.4	491.5
D_s mass (MeV)	1970.2	1970.9	1969.0
Recoil lepton	μ^-	μ^-	e^-
p_{lepton} (MeV/c)	751	1216	489
M^2_{miss} (GeV^2)	0.778	−0.115	1.627
D_s leptonic decay	$\tau\nu(\mu 3\nu)$	$\mu\nu$	$\tau\nu(e3\nu)$

Detection efficiencies and background

- The efficiencies for D_S tagging and leptonic decay

  - ✓ 51% for $D_S \to \mu\nu$,
  - ✓ 6.3% for $D_S \to \tau\nu$, $\tau \to \mu\nu\nu$
  - ✓ 8.2% for $D_S \to \tau\nu$, $\tau \to e\nu\nu$

  ← Including the τ branching fractions

  Rate of D_S decay to $e\nu$ is negligible

- Background mainly contributed from hadron misidentification

  - ✓ $D_S \to K^0_L K$, $K^0_L \to \pi e\nu$, $\pi\mu\nu$
  - ✓ $D_S \to \tau\nu$, $\tau \to \pi\nu$

  - ✓ estimated with events which
  - ✓ satisfy the lepton kinematic requirements but
  - ✓ have recoil system as neither e nor μ

  Background estimate

  - ✓ 0.35 events for $D_S \to \tau\nu$, $\tau \to e\nu\nu$
  - ✓ 0.20 events for $D_S \to \tau\nu$, $\tau \to \mu\nu\nu$
  - ✓ 0.04 events for $D_S \to \mu\nu$

  Negligible background for $D_S \to \mu\nu$

Maximizing likelihood function and result

- Joint likelihood function for D_S leptonic decay : $L = L_p L_\mu L_e L_g$

✓ L_p : Poisson for $D_S \to l\nu$ candidates
✓ L_g : Gaussian for singly tagged D_S candidate events

✓ $L_\mu(m^2_{miss})$, L_e (m^2_{miss}) are probability functions normalized with observed events of $D_S \to \mu\nu$, $\tau\nu$ and background

- Maximizing the likelihood function for the branching fractions to μν and τν independently

$$Br(D_S \to \mu\nu) = (2.0^{+4.4}_{-1.7})\%$$
$$Br(D_S \to \tau\nu) = (12^{+20}_{-10})\%$$

- Assuming μ-τ universality and the theoretical prediction of the ratio $Br(\tau\nu)/Br(\mu\nu) = 9.74$,

$$Br(D_S \to \mu\nu) = [1.5^{+1.3}_{-0.6}(\text{stat})^{+0.3}_{-0.2}(\text{syst})]\%$$
$$Br(D_S \to \tau\nu) = [15^{+13}_{-6}(\text{stat})^{+3}_{-2}(\text{syst})]\%$$

Weak decay constant f_{Ds}

- D_S leptonic decay width

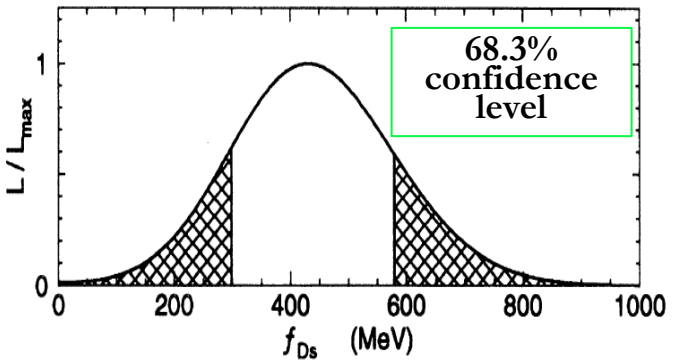
$$\Gamma(D_s \longrightarrow \ell\nu_\ell) = \frac{G_F^2|V_{cs}|^2}{8\pi} f_{D_s}^2 m_{D_s} m_\ell^2 \left(1 - \frac{m_\ell^2}{m_{D_s}^2}\right)^2 \qquad (1)$$

where Fermi constant G_F, c → s CKM matrix element V_{cs} = 0.975

$$B(D_s \longrightarrow \ell\nu_\ell) = \frac{\tau_{D_s}}{\hbar} \Gamma(D_s \longrightarrow \ell\nu_\ell) \qquad (2)$$

- Maximizing likelihood function with respect to f_{Ds} directly gives

$$f_{Ds} = [\,4.3^{+1.5}_{-1.3}(\text{stat})^{+0.4}_{-0.4}(\text{syst})\,]\times 10^2 \text{ MeV}$$



Results of Br and f_{Ds} are independent of
- ✓ **luminosity and $D_S\overline{D_S}$ cross section, and**
- ✓ **have no model-dependent assumption**

- **First direct measurement of Br and f_{Ds} though sizable uncertainties**
- **Central value of f_{Ds} is larger than, but consistent with, current theoretical predictions ranging from 90 to 350 MeV**

Weak decay constant f_D

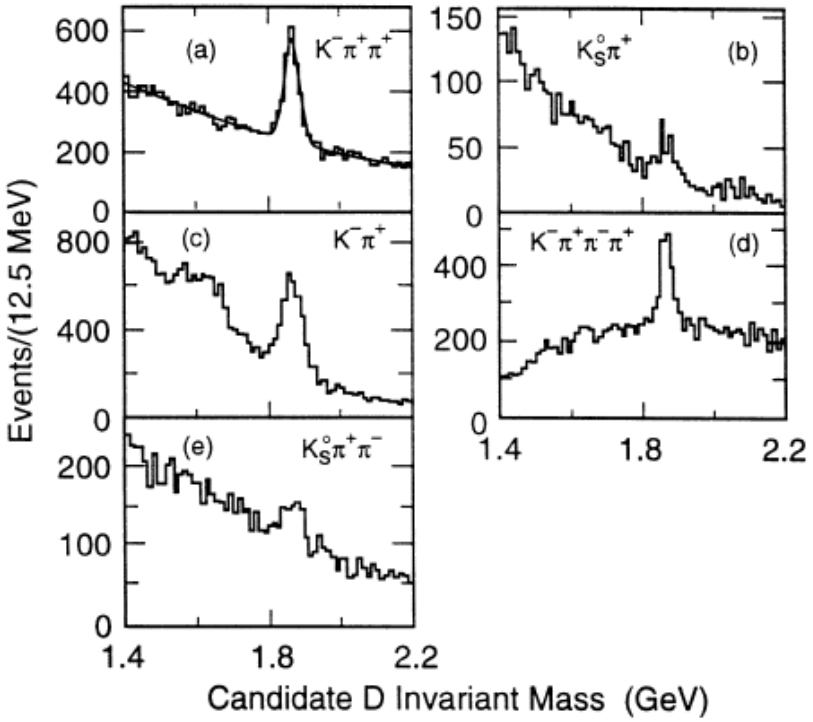
- Leptonic decay $D \rightarrow \mu\nu$, recoiling against a singly tagged D^0 or D^+ , is searched at E_{CM} = 4.03 GeV

  - ✓ Two charged decay modes

    $D^+ \rightarrow K^- \pi^+ \pi^+,\ Ks^0 \pi^+$

  - ✓ Three neutral decay modes

    $D^0 \rightarrow K^- \pi^+,\ K^- \pi^- \pi^+ \pi^+,\ Ks^0 \pi^+ \pi^-$



- The cross section at E_{CM}=4.03 GeV is found to be

$$\sigma(e^+e^- \rightarrow D^{*+} D^-) = 2.33 \pm 0.23\ nb$$

Pseudoscalar decay constant f_D

- After **μ** selection criteria for recoil system, main background resulted from
  - ✓ $D^{*+}D^{-}$ events in which one D decay via tagging mode, while the other via $K_L^0\pi$, $K_L^0\mu\nu$, or $\mu\nu\pi^0$
  - ✓ Study of contours show that signal and background regions are well-separated in missing mass squared M^2miss
  - ✓ Then, requiring $M^2miss < 0.7\ GeV^2$
- **A single event candidate was found in e+e- → $D^{*+}D^{-}$, where $D^{*+} \to \pi^+ D^0$, with $D^{+0} \to K^-\pi^+$, and recoiling $D^- \to \mu^-\nu$.**
- **Corresponding background is 0.03 events, which is estimated with MC and checked with Data.**
  - $Br(D \to \mu\nu) = 0.08^{+0.16}_{-0.05}(\text{stat})^{+0.05}_{-0.02}(\text{syst})\ \%$
  - $f_D = 300^{+180}_{-150}(\text{stat})^{+80}_{-40}(\text{syst})\ \text{MeV}$
  - First direct measurement of Br and f_D

D_S branching fraction to $\Phi\pi$

Direct measurement of $B(D_S \to \phi\pi)$

➢ Motivation

- ✓ Branching fractions of many D_S decays known relative to B($D_S \to \phi\pi$)
- ✓ Estimates of absolute branching fractions of D_S decays require theoretical input such as
  - a) Normalization based on total D_S production
  - b) Ratio $\Gamma(D_S^+ \to \phi e^+ \nu)/\Gamma(D^+ \to K^-\pi^+\pi^+)$
- ✓ Published results for B($D_S \to \phi\pi$) range from 3.1 to 5.1%

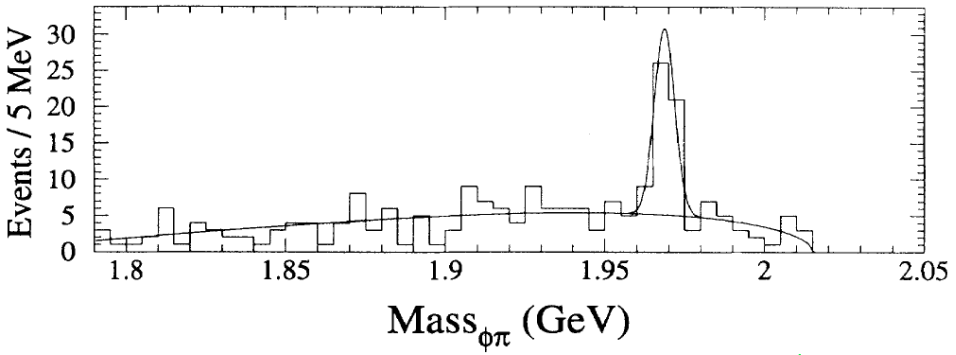
➢ **Singly** and **doubly** D_S tagged events

- ✓ Events, with only one (both) D_S decay(s) fully reconstructed, termed singly (doubly) D_S tagged
- ✓ Relative rate of detection of doubly and singly tagged events provides a direct measurement of absolute branching fraction
- ✓ Previous B($D_S \to \phi\pi$) values before BES are measurement of the relative branching fraction (thus indirect)

Singly tagged events of $D_S \to \phi\pi$

➢ Event selection

- ✓ Using $\phi \to K^+K^-$ decay mode only
- ✓ Each of three charged tracks required to originate from within
  - 1.2 cm of beam position in transverse plan
  - 15 cm of of center of interaction region along beam direction
  - Polar angle $|\cos\theta| < 0.8$
  - π/K identification
- ✓ πK^+K^- candidates subject to 1-C fit
  - Overall event 4-momentun conservation
  - Recoil system have same mass
  - Fit confidence level > 1%
- ✓ Selection of $\phi \to K^+K^-$
  - $|M_{K^+K^-} - M_\phi| < 18$ MeV
  - Helicity angle $|\cos\theta_K| > 0.25$



Unbinned maximum likelihood fit yields

D_S mass of M = 1968.7±0.6 MeV,

signal of $N_{\phi\pi}$ = 40.8±7.2 events

Then, cross section at E_{CM}=4.03 GeV

$$\sigma(D_S^+ D_S^-) = 320 \pm 56 \pm 81 pb$$

Doubly tagged events

- Decay modes $D_S \to \phi\pi$, $\bar{K}^0 K$, $\overline{K}^{*0} K$ incuded
- Expected number of doubly tagged events

$$\langle N \rangle = [\sigma_{D_s^+ D_s^-} B_{\phi\pi}] \, (\int \mathcal{L}\, dt) \, B_{\phi\pi} \sum b_i b_j \epsilon_{ij} + N_{bg}$$

- ✓ Branching ratios
  $b_i = B(D_S \to \text{mode i}) / B_{\phi\pi}$
- ✓ ε_{ij} is efficiency for mode (i, j)
- ✓ Background N_{bg}

- ✓ 1-C fit, requiring equal mass for *Ds* candidate system, confidence level > 0.1%
- ✓ K^+K^-, $K^-\pi^+$ and $\pi^+\pi^-$ submasses within 18, 50, 20 MeV of nominal ϕ,, $\overline{K}^{*0}$, K^0 masses
- ✓ Helicity angle from $\overline{K}^{*0}$ decay $|\cos\theta_{K^*}| > 0.4$

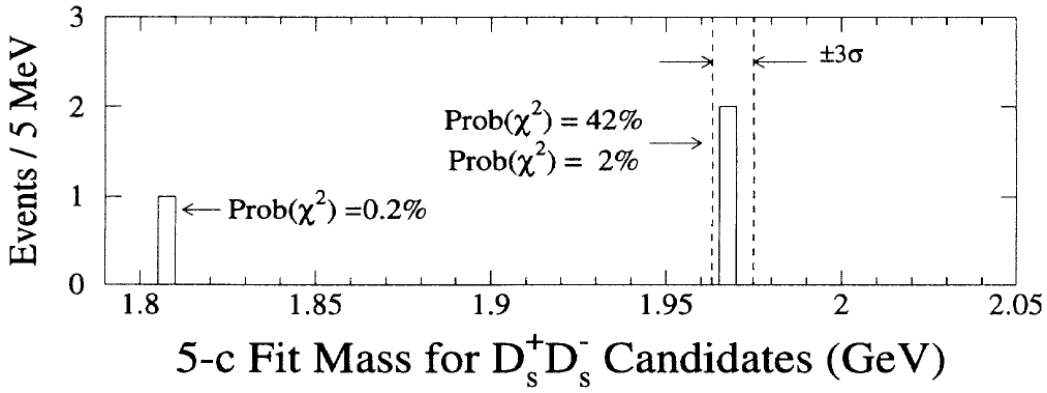


TABLE I. Doubly-tagged $D_s^+ D_s^-$ events.

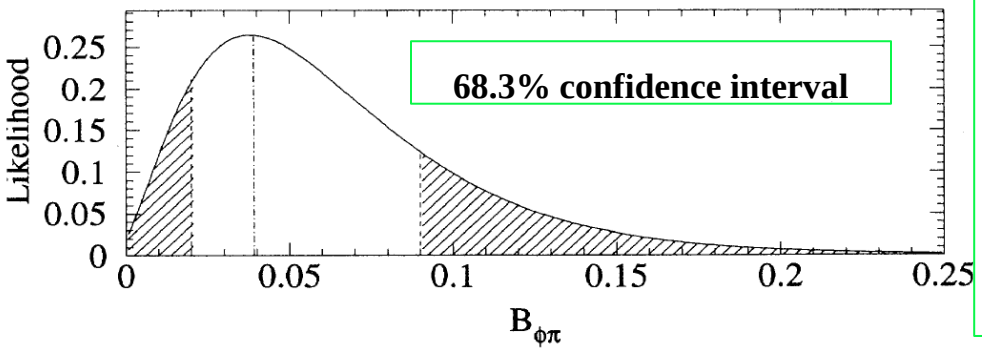
Event	Using 1C fit momentum vectors: D_s mass (MeV)	Using 1C fit momentum vectors: Resonant submass (MeV)	Using 5C fit momentum vectors: D_s mass (MeV)	Using 5C fit momentum vectors: Resonant submass (MeV)
$\phi\pi$ vs	1969	1014	1968	1012
$\bar{K}^{0*}K$	1963	847		853
$K^{0*}\bar{K}$ vs	1968	876	1967	875
$\bar{K}^{0*}K$	1962	915		918

2019/9/5

Maximizing likelihood function and result

- Two doubly tagged events in the D_S signal region, background level conservatively estimated as 0.2 ± 0.2 events
- Maximizing the likelihood function

$$L(B_{\phi\pi}, N_{\phi\pi}) = \frac{\langle N \rangle^{N_{\rm obs}} e^{-\langle N \rangle}}{N_{\rm obs}!} \frac{\exp[-\frac{1}{2}(\frac{N_{\phi\pi} - N_{\phi\pi,\rm obs}}{\sigma_{\phi\pi}})^2]}{\sqrt{2\pi} \cdot \sigma_{\phi\pi}}$$



- ✓ $L(B_{\phi\pi})$ value is marginalized by integrating over singly tagged events $N_{\phi\pi} = 40.8 \pm 7.2$
- ✓ Solution

$$B_{\phi\pi} = [\,3.9^{+5.1}_{-1.9}(\text{stat})^{+1.8}_{-1.1}(\text{syst})\,]\%$$

- **First direct measurement of D_S branching fraction to $\phi\pi$**
- **Consistent with world average of values resulting from indirect or model-dependent procedures, $B_{\phi\pi} = (3.5 \pm 0.4)$, in 1994**

D_S branching fraction to eX

D_S branching fraction to eX

➢ Motivation

- ✓ Test of Spectator model
  - a) Heavy Q → q + W, where light q plays as spectator as W boson decay
  - b) Inclusive e semileptonic decay

    $B(D^+ \to e^+ X) = (17.2 \pm 1.9)\%$, and

    $B(D^0 \to e^+ X) = (7.7 \pm 1.2)\%$

    Consistent with $\Gamma_{SL}(D^+) \approx \Gamma_{SL}(D^0)$
- ✓ $B(D_S \to e^+ X)$ upper limit 20%

  at 90% C.L. by MarkIII

➢ Singly D_S tagged events

- ✓ $D_S \to \phi\pi$, $\overline{K_S^0}K^+$, $\overline{K}^{*0}K^+$, $\overline{K_S^0}K^+\pi^+\pi^-$ decays included.
- ✓ Totally, $N_{Ds} = 171 \pm 21(\text{stat}) \pm 15(\text{syst})$

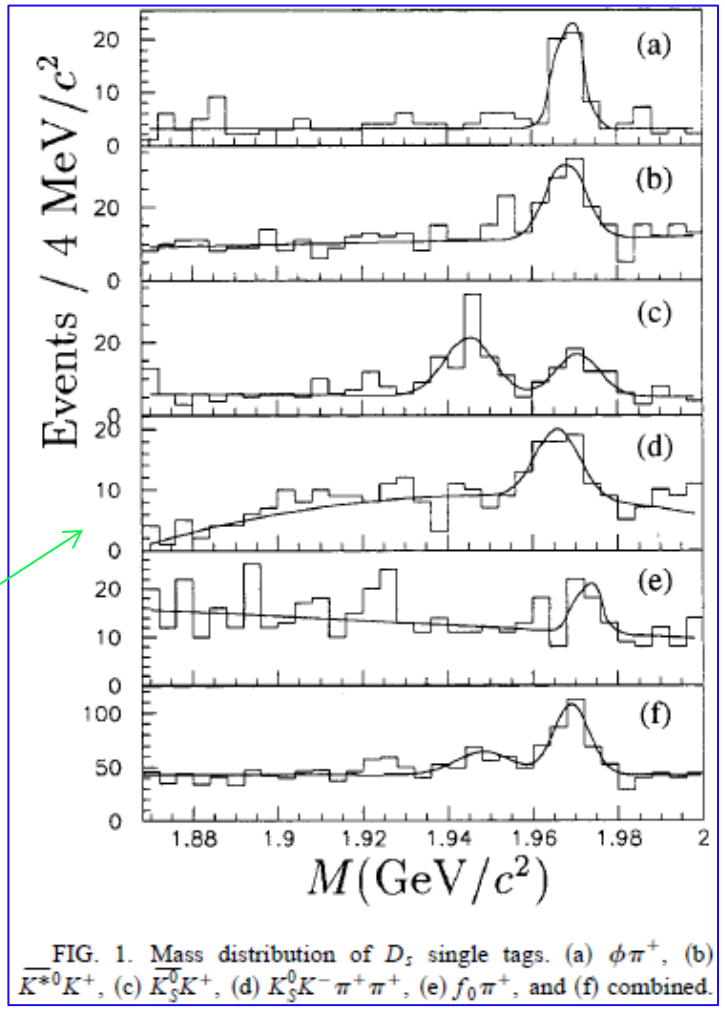


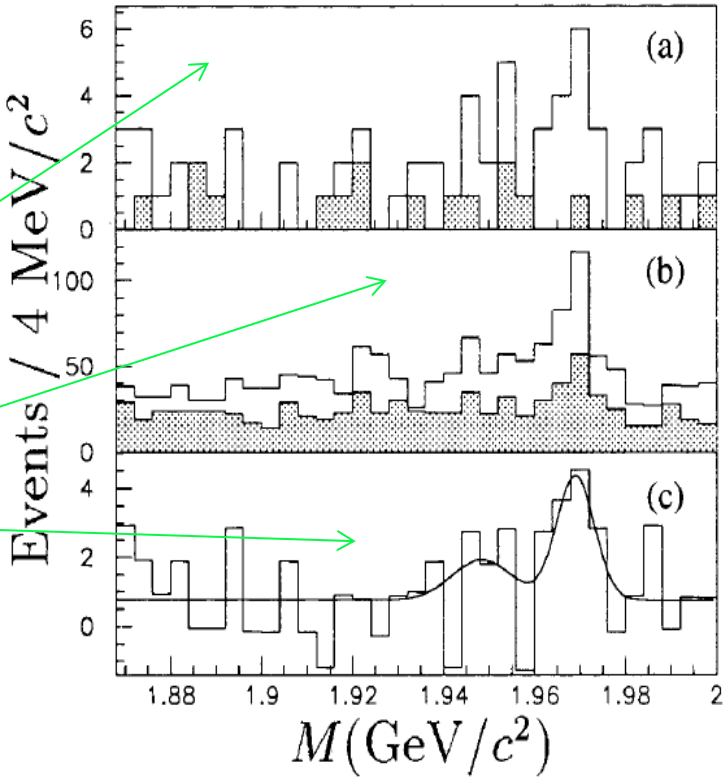
FIG. 1. Mass distribution of D_s single tags. (a) $\phi\pi^+$, (b) $\overline{K}^{*0}K^+$, (c) $\overline{K}_S^0K^+$, (d) $K_S^0K^-\pi^+\pi^+$, (e) $f_0\pi^+$, and (f) combined.

Careful study of e/π separation

- Joint confidence level for t_{TOF}, dE/dx and BSC requirement

  - ✓ > 1% for e hypothesis
  - ✓ < 5% for π,K

- For e^+e^- events, efficiency of e identification after $D_S \to eX$ selection is > 82%
- Known π misidentified as e at a rate of < 0.8%



- ✓ Single tag mass spectra for (a) electron, (b) hadron, and (c) net electron corrected with charge symmetric background, in recoil system
- ✓ Unshaded(shaded) curve denotes right(wrong) charge sign

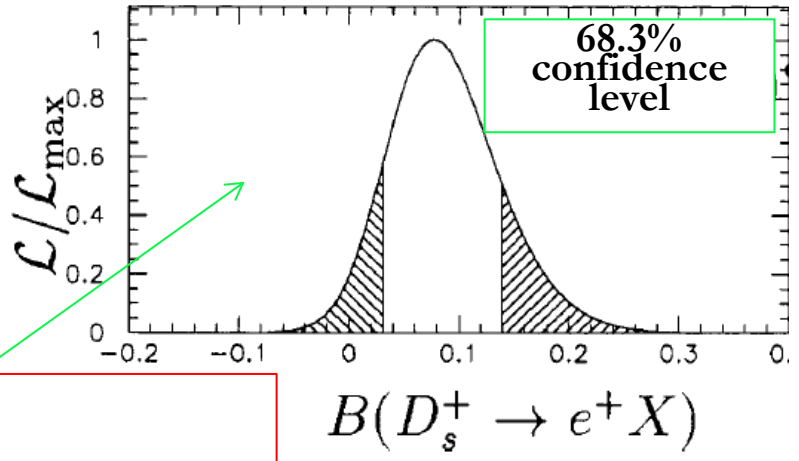
Maximizing likelihood function and result

- Unbinned likelihood fits to the four distributions of Figs. (a) and (b) on previous page
- The likelihood function defined as

$$\mathcal{L}(s,b_1,b_2)=e^{-s-b_1-b_2}\prod_{i=1}^{N}[sf_s(x_i)+b_1f_1(x_i)+b_2f_2(x_i)]$$

where x_i effective mass (loop over candidate events), s number of signal events, b_1 and b_2 number of background events, N total number of candidate events

- ✓ **Omit details on the calculation**
- ✓ **Maximizing likelihood function for the true number of electrons with respect to the number of hadrons.**



- Absolute inclusive semileptonic decay
  - $Br(D_S \to e^+X) = [7.7^{+5.7}_{-4.3}(\text{stat})^{+2.4}_{-2.1}(\text{syst})]\%$
  - $\Gamma_{SL}(D_S \to e^+X) = [1.65^{+1.23}_{-0.91}(\text{stat})^{+0.51}_{-0.45}(\text{syst})]\times 10^{11}\text{s}^{-1}$
  - **Consistent with Spector model : $\Gamma_{SL}(D^+) \approx \Gamma_{SL}(D^0) \approx \Gamma_{SL}(D_S)$**

Summary

Summary

- **First direct measurements of f_{Ds} and D_S branching fractions to $\mu\nu$, $\Phi\pi$**

✓ The f_{Ds} result is cited in the major Review of PDG in 1996.

$f_{D_s^+} = 232 \pm 45 \pm 20 \pm 48$ MeV [7]	**WA75 (1993)**
$f_{D_s^+} = 344 \pm 37 \pm 52 \pm 42$ MeV [8]	**CLEO (1994)**
$f_{D_s^+} = 430^{+150}_{-130} \pm 40$ MeV [9]	**BES (1995)**

✓ Branching fraction **B($D_S \to \Phi\pi$)** is shown in the list of PDG 1996.

$\Gamma(\phi\pi^+)/\Gamma_{total}$ **Γ_{13}/Γ**

For the first time, we have model-independent measurements of this branching fraction, and so we no longer use the earlier, model-dependent results. See the "Note on D Mesons" in the D^+ Listings for a discussion.

VALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
0.036 ±0.009 OUR FIT						
0.036 ±0.009 OUR AVERAGE						
0.0359±0.0077±0.0048			[19] ARTUSO	96	CLEO	e^+e^- at $\Upsilon(4S)$
$0.039\ ^{+0.051}_{-0.019}\ ^{+0.018}_{-0.011}$			[20] BAI	95C	BES	e^+e^- 4.03 GeV

Summary (cont.)

- First direct measurements of D_S branching fractions to $\mu\nu$, eX

✓ Branching fraction B($D_S \to \mu\nu$) is shown in the list of PDG 1996.

$\Gamma(\mu^+\nu_\mu)/\Gamma_{total}$ Γ_6/Γ

See the "Note on Pseudoscalar-Meson Decay Constants" in the Listings for the $\pi^\pm$.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$0.015^{+0.013}_{-0.006}{}^{+0.003}_{-0.002}$	3	[6] BAI	95	BES	$e^+e^- \to D_s^+ D_s^-$
$0.004^{+0.0018}_{-0.0014}{}^{+0.0020}_{-0.0019}$	8	[7] AOKI	93	WA75	π^- emulsion 350 GeV
<0.03	0	[8] AUBERT	83	SPEC	μ^+ Fe, 250 GeV

✓ Branching fraction B($D_S \to eX$) is shown in the list of PDG 1998.

$\Gamma(e^+ \text{anything})/\Gamma_{total}$ Γ_5/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$0.077^{+0.057}_{-0.043}{}^{+0.024}_{-0.021}$		BAI	97	BES	$e^+e^- \to D_s^+ D_s^-$

Summary (cont.)

- First direct measurements of D_S branching fractions to ΦX

✓ Branching fraction B($D_S \rightarrow \Phi X$) is shown in the list of PDG 1998.

$\Gamma(\phi \text{ anything})/\Gamma_{\text{total}}$ Γ_6/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
$0.178^{+0.151\ +0.006}_{-0.072\ -0.063}$	3	BAI 98	BES	$e^+e^- \rightarrow D_s^+ D_s^-$

Publication and Conference talk

Publication

- ✓ J. Z. Bai et al., Phys. Rev. Lette. **74**, 4599 (1995).
- ✓ J. Z. Bai et al., Phys. Rev. D **52**, 3781 (1995).
- ✓ J. Z. Bai et al., Phys. Rev. D **56**, 3779 (1997).
- ✓ J. Z. Bai et al., Phys. Rev. D **57**, 28 (1998).
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- ✓ C. C. Zhang, "Direct Measurement of the Pseudoscalar Decay Constant f_{Ds} from BES", in Proceedings of the XXVII International Conference on High Energy Physics", Glasgow Scotland UK, July 1994.
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Reward

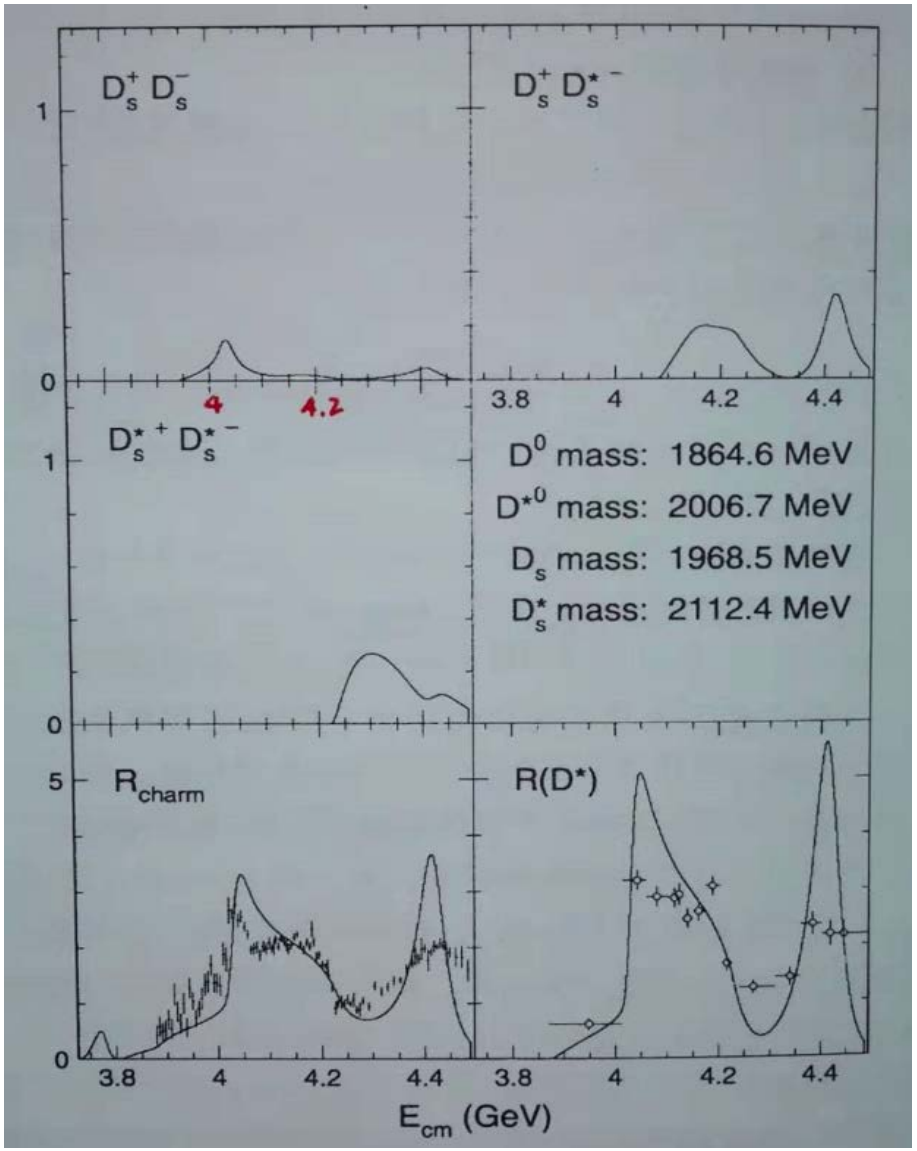
- **获奖名称：北京谱仪Ds物理的研究**

  - ✓ **获奖类别：** 中国科学院自然科学奖 (CAS Award for Natural Sciences)
  - ✓ **获奖等级：** 一等奖 (first class)
  - ✓ **授奖部门：** 中国科学院
  - ✓ **获奖时间：** 1997
  - ✓ **主要完成人：** 张长春、李卫国、毛慧顺、顾建辉、李小南、荣 刚

Thanks

Backup

Cross sections predicted by Couple-channel mode



2019/9/5