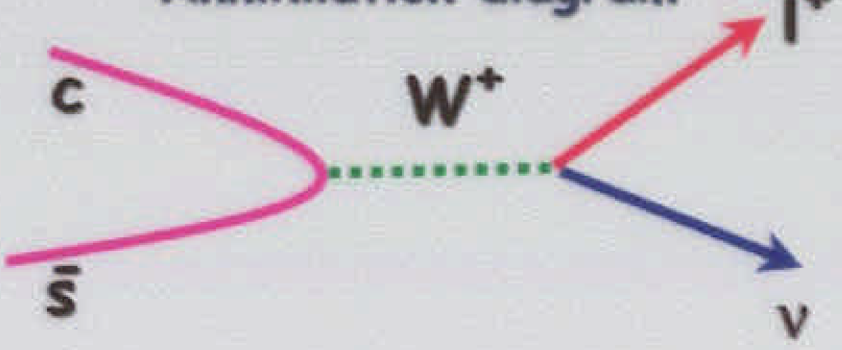
Leptonic decays of the D_s meson at LEP

- What do we measure?
- Why ?
- How ?
- Results
  - ALEPH New (ABS 172)
  - DELPHI ('97,Jerusalem)
  - L3 ('96, published)
- Summary

What do we measure

Cabibbo allowed
Annihilation diagram



Easiest experimentally accessible heavy meson decay
Extract decay constant f_{D_s}

Standard Model predicts:

$$BR(D_s \to l\nu) = \frac{G_F^2}{8\pi} \tau_{D_s} f_{D_s}^2 |V_{cs}|^2 m_{D_s} m_l^2 \left(1 - \frac{m_l^2}{m_{D_s}^2}\right)^2$$

For f_{D_s} = 260 MeV ➡

- $BR(D_s \to \tau\nu) = 5.2\%$
- $BR(D_s \to \mu\nu) = 0.54\%$
- $BR(D_s \to e\nu) = 1.3 \times 10^{-7}$

Why ?

f_{D_s} is calculated in a number of theoretical frameworks

- potential models f_{D_s} = 129 to 356 MeV
- QCD sum rules f_{D_s} = 231 ± 24 MeV
- Lattice QCD f_{D_s} = 240 +30 -25 MeV

↓

Check validity of calculations

In particular ....
lattice QCD predicts f_B to constrain ρ and η in the CKM matrix

No experimental values of f_B available

The measured value of f_D is very important to test lattice QCD

How do we measure
(ALEPH)

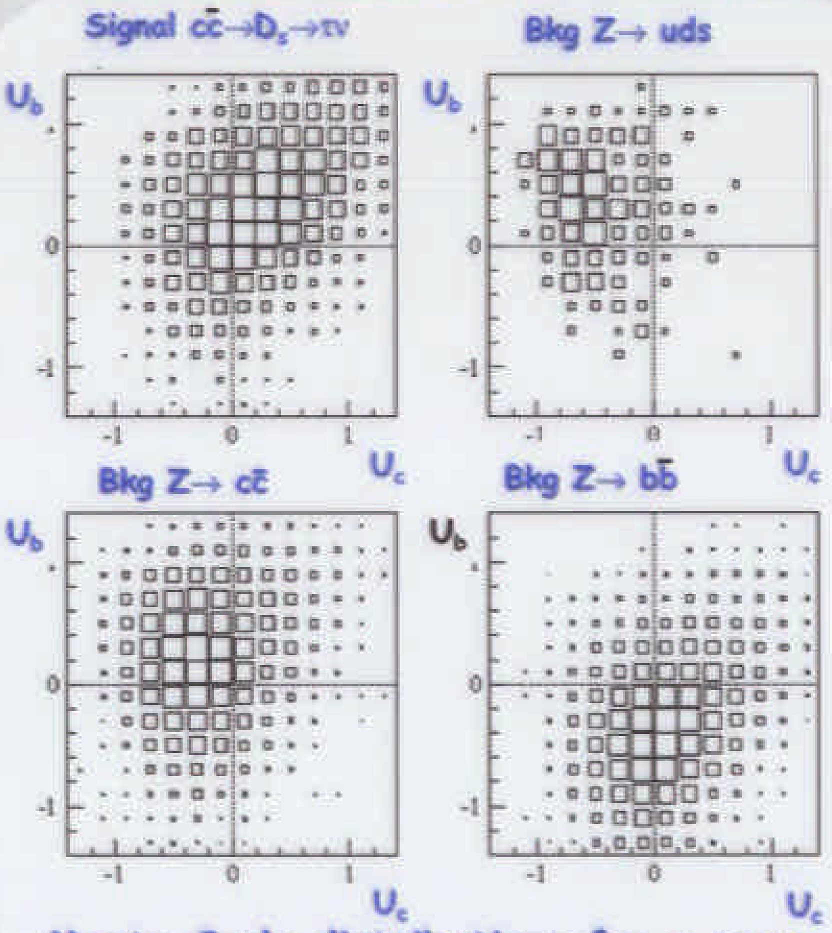
4M Z hadronic decays from '91 to '95
Look for $Z \to c\bar{c} \to D_s X$ with:

$D_s \to \tau\nu$
$\hookrightarrow e\nu\bar{\nu}$ or $\mu\nu\bar{\nu}$

$D_s \to \mu\nu$

- search for hemispheres with large momentum e or μ and missing energy
- In $c\bar{c}$ events all charged tracks, but the lepton, come from I.P.
- Small, irreducible bkg form $D+ \to l\nu$ treated like signal taking into account $f_{Ds}/f_{D+} = 1.11{+0.06}{-0.05}$

Signal - Background separation



Monte Carlo distributions for $\tau \to e\nu\nu$

Get the maximum separation between signal and bkg by using Linear Discriminant Variables technique:

- Find the best linear combination between a number of variables (mainly fitted $\vec{P}_{Ds}$, angle between $\vec{P}_l$ and $\vec{P}_{hemi}$, btag neural net, $\vec{P}_t$ of lepton w.r.t. jet)

and build

- U_b to separate signal from $b\bar{b}$ bkg
- U_c to separate signal from $c\bar{c}$ bkg

Signal - Background separation

For $D_s \rightarrow \tau\nu$

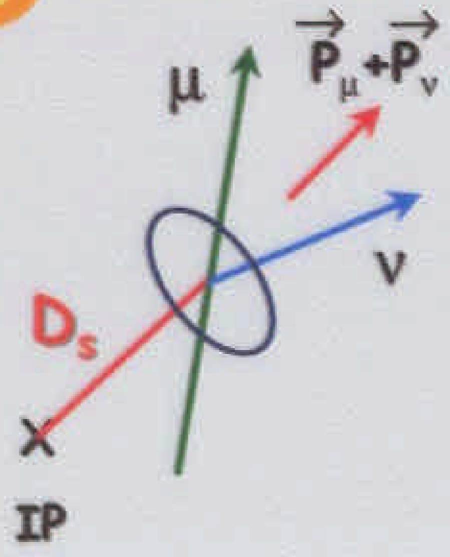
Perform 'one constraint' kinematics fit to get E_{Ds}

- **Remove lepton**
- **Impose $M_{miss} = M_{Ds}$**

For $D_s \rightarrow \mu\nu$

Perform '2 constraint' kinematics fit

- Impose $M_{miss} = 0$
- Missing P // plan defined by I.P and P_μ



2D Fit for $D_s \to \tau\nu$

Build the total fit function by parametrizing the 2D distributions for all the components:

- signal in $c\bar{c}$ and $b\bar{b}$ (contributions from both D_s and D^+ in e and μ chan)
- $b\bar{b}$, $c\bar{c}$ and uds bkg
- Relative normalization given by
  - the charm hadron production rate
  - theoretical $\tau\nu/\mu\nu$ ratio
  - lattice QCD f_{Ds}/f_{D+} = 1.11+0.06−0.05
- Unbinned likelihood 2D fit ➡ number of events for each component

	e	μ
Data	3956	6637
Signal	306 ± 62	575 ± 84
uds bkg	111 ± 56	455 ± 139
cc bkg	2310 ± 101	3750 ± 182
bb bkg	1228 ± 56	1857 ± 74

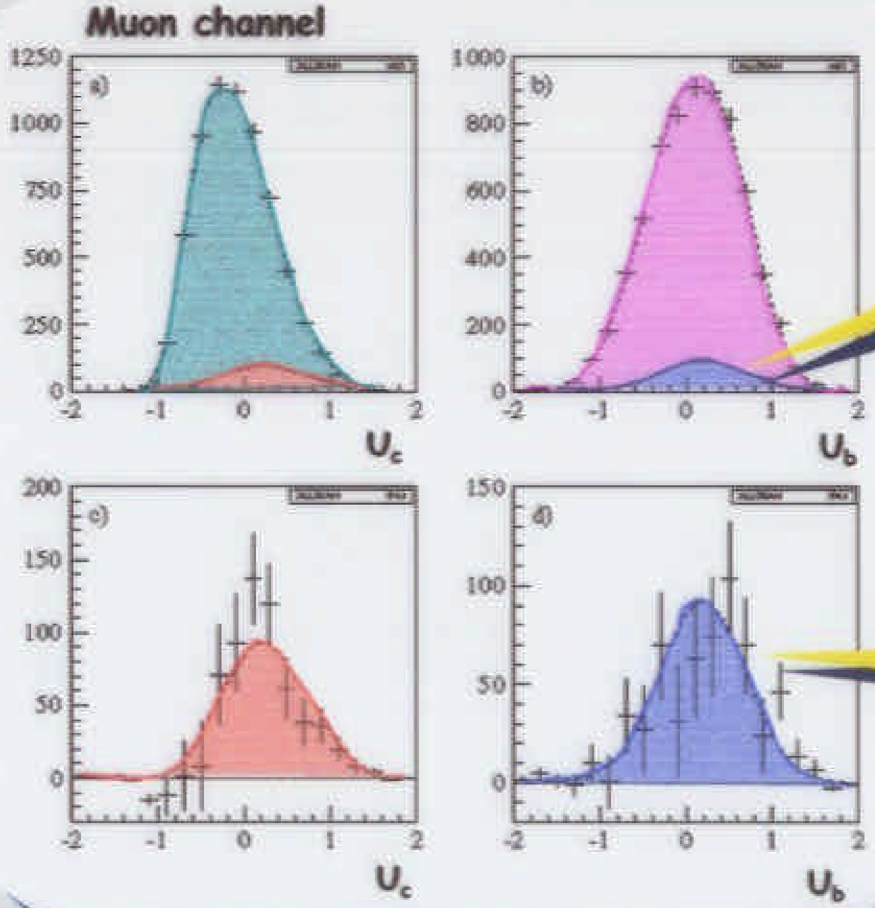
$BR(D_s \to \tau\nu)(e) = (5.86 \pm 1.18)\%$ stat

with C.L.=83%

$BR(D_s \to \tau\nu)(\mu) = (5.78 \pm 0.85)\%$ stat

with C.L.=81%

2D Fit for $D_s \to \tau\nu$

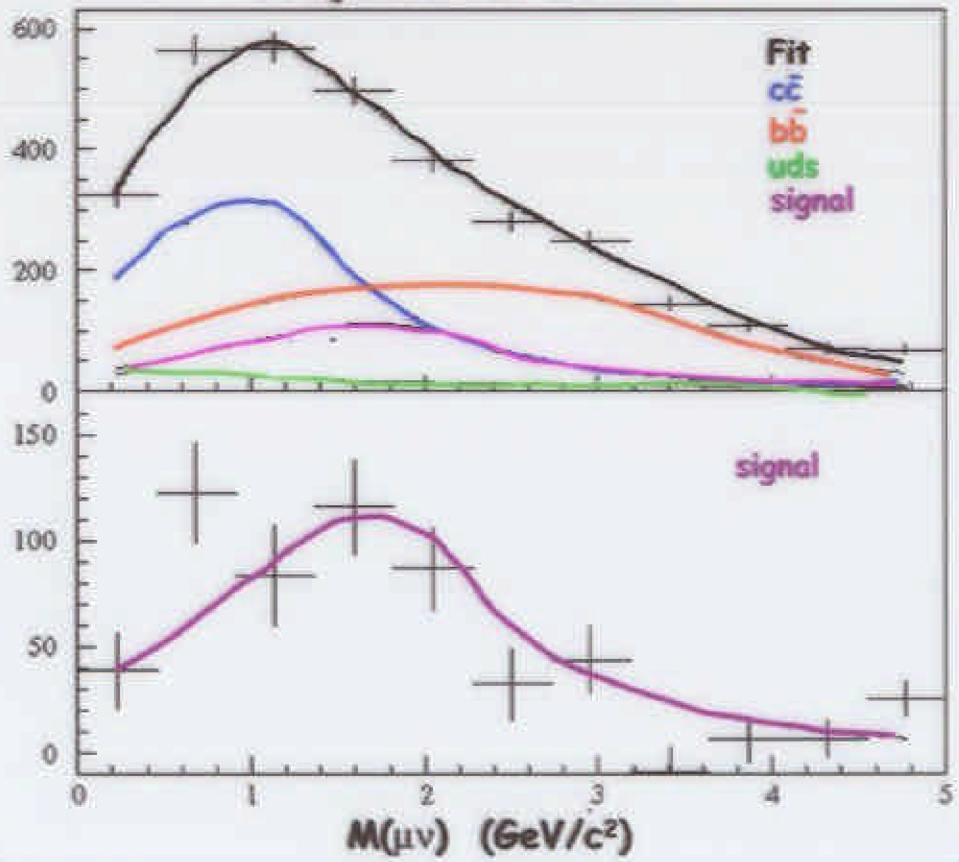


Projecting the fit in each variable Contribution from fitted signal

Same distributions after subtracting the fitted bkg

Multidimensional Fit for $D_s \to \mu\nu$

Projection of 3D fit



3D binned fit in the space $(U_c, U_b, M_{\mu\nu})$

↓

Extract the total number of signal events

Signal	553 ± 93
uds bkg	166 ± 47
cc bkg	1251 ± 71
bb bkg	1291 ± 62

$BR(D_s \to \mu\nu) = (0.68 \pm 0.11)\%$ stat

C.L.=69%

Main Systematics

Source	$D_s \to \tau\nu(e)$ %	$D_s \to \tau\nu(\mu)$ %	$D_s \to \mu\nu$ %
Charm hadron prod	25.4	21.4	19.6
c fragmentation	16.7	14.8	12.1
Detector resolution	13.6	12.7	4.0
Total	35.7	30.3	26.0

Main uncertainty:
21% on $f(c \to D_s)$

Aleph Summary

$BR(D_s \to \tau\nu) = (5.86 \pm 1.18 \pm 2.09)\%$ ⟹ $f_{Ds} = (275 \pm 28 \pm 49)$ MeV (e)

$(5.78 \pm 0.85 \pm 1.76)\%$ ⟹ $(273 \pm 20 \pm 42)$ MeV (μ)

Combined: $BR(D_s \to \tau\nu) = (5.79 \pm 0.76 \pm 1.78)\%$, $f_{Ds} = (273 \pm 18 \pm 42)$ MeV

$BR(D_s \to \mu\nu) = (0.68 \pm 0.11 \pm 0.18)\%$ ⟹ $f_{Ds} = (291 \pm 25 \pm 38)$ MeV

Combined $f_{Ds} = (285 \pm 20 \pm 40)$ MeV

DELPHI, L3

- Different strategy: look for $D_s^* \rightarrow D_s\gamma$, $D_s \rightarrow \tau\nu$ requiring a combination of photon, lepton and missing energy in the same hemisphere and cut on $M(D_s\gamma)-M(D_s)$
- No separation between electron and muon channel
- bb bkg rejection with lifetime based method
- Number of signal events given by the total candidates in a given mass window - bkg expected from MC for the same number of Z hadronic decays.

$BR(D_s \rightarrow \tau\nu) =$

- Delphi-data '94-'95: $(8.5 \pm 4.2 \pm 2.6)\%$
- L3 -data '94: $(7.4 \pm 2.8 \pm 1.6 \pm 1.8)\%$

Conclusions

Aleph new analysis gives:

- consistent $D_s \to \tau\nu$ signals in $e\nu\nu$ and $\mu\nu\nu$
- the combined BR($D_s \to \tau\nu$) is the world's most accurate
- first observation at LEP of $D_s \to \mu\nu$ leads to a
- consistent value of f_{Ds}

Lattice QCD $\to f_{Ds} = 240 + 30 - 25$ MeV

	f_{Ds} (MeV)
ALEPH	285±20±40
DELPHI	330±95
L3	309±58±50
CLEO	280±17±42
BEATRICE	323±44±36
E653	194±35±24

ALEPH 2000-062
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Plenary session: PL-03
17 July 2000

Leptonic decays of the D_s meson

The ALEPH Collaboration

Abstract

The purely leptonic decays $D_s \to \tau\nu$ and $D_s \to \mu\nu$ are studied in a sample of four million hadronic Z decays collected with the ALEPH detector at the LEP e^+e^- collider. The branching fractions are extracted from a combination of two analyses, one optimized to select $D_s \to \tau\nu$ decays with $\tau \to e\nu\bar{\nu}$ or $\mu\nu\bar{\nu}$, and the other optimized for $D_s \to \mu\nu$ decays. The results are used to evaluate the D_s decay constant, within the Standard Model: $f_{D_s} = [285 \pm 20(\text{stat}) \pm 40(\text{syst})]$ MeV.

Contributed paper to ICHEP2000
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