Charm Counting in *b* and *c* Events at LEP

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Abstracts:
5-422 (ALEPH) ~~5-15 (OPAL)~~
5-96 (DELPHI) 5-97 (DELPHI)

Outline

- new results of R_c from charm counting
- new result of R_c from D^* exclusive/inclusive reconstruction
- new results on n_c from charm counting
- overview on results on n_c
- D^* fragmentation

→ $R_c = \Gamma(Z \to c\bar{c}) / \Gamma(Z \to \text{had})$
$n_c \sim c$ multiplicity per b decay

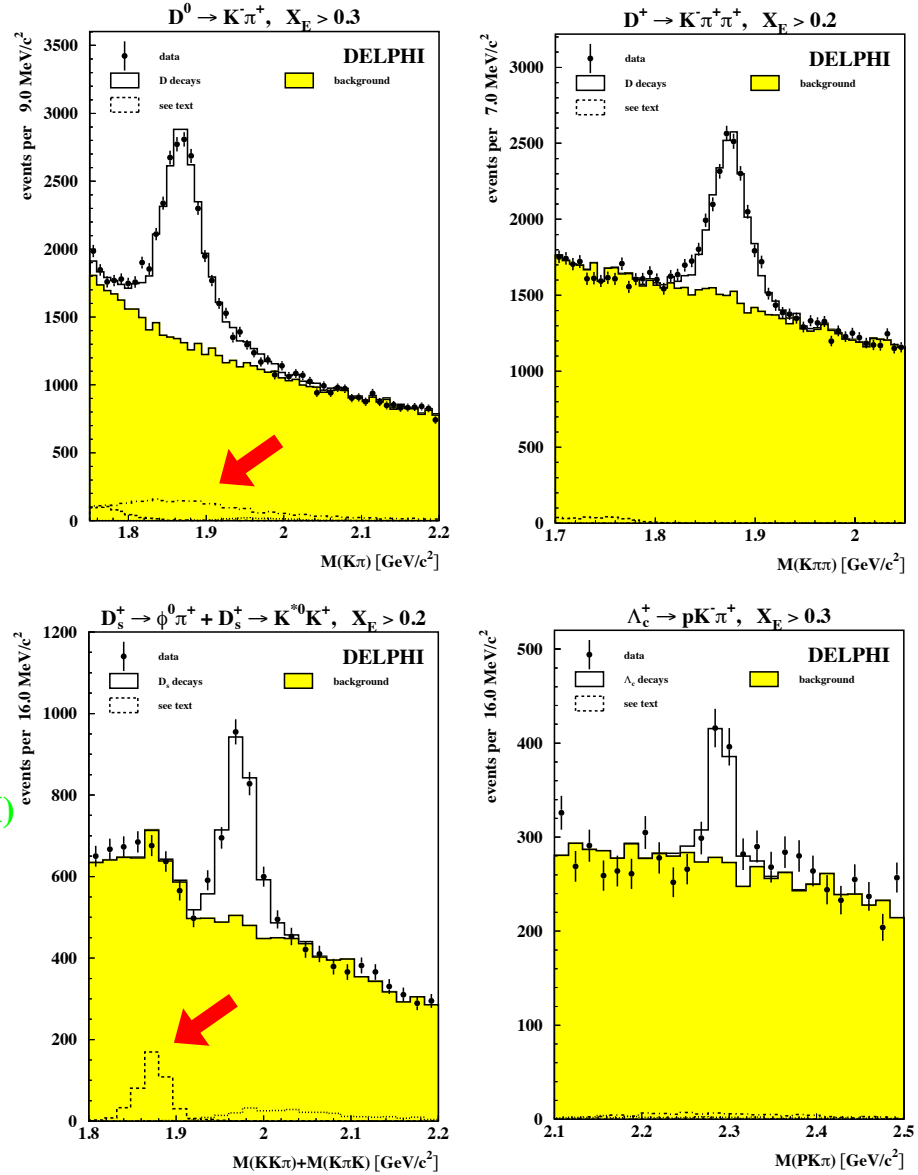
→ Common input:
results are corrected using
PDG98 + LEPHF values

Mode	branching fraction
$D^0 \to K^-\pi^+$	0.0385 ± 0.0009
$D^+ \to K^-\pi^+\pi^+$	0.090 ± 0.006
$D_s^+ \to \phi(1020)\pi^+$	0.036 ± 0.009
$\frac{BR(D_s^+ \to \bar{K}^* K^+)}{BR(D_s^+ \to \phi\pi^+)}$	0.95 ± 0.10
$\Lambda_c^+ \to pK^-\pi^+$	0.050 ± 0.013 *

*error increased by factor 2 since PDG96

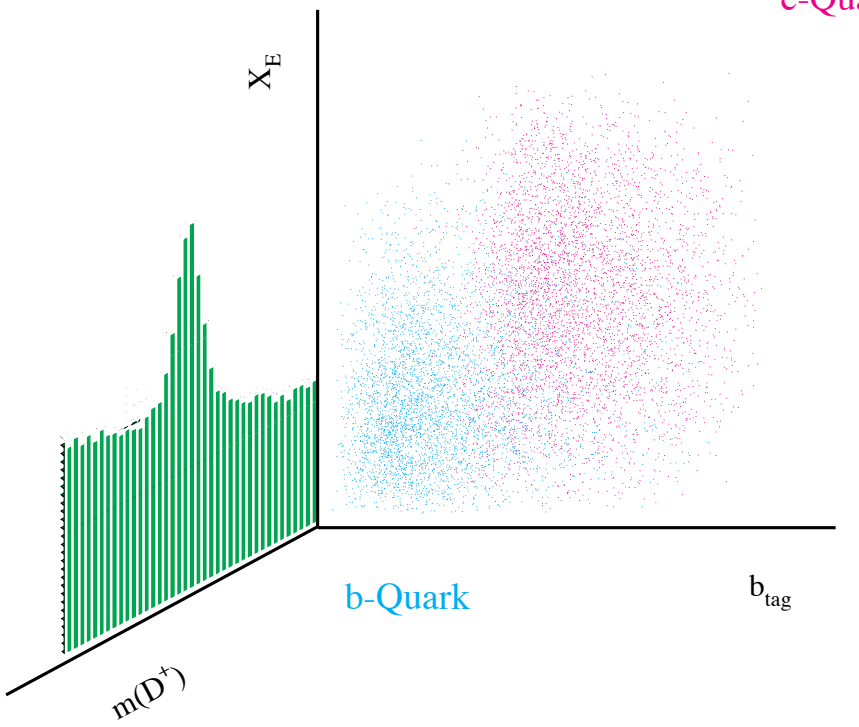
Weak decaying ground states

- sum over all ground states :
  - c events → R_c
  - b events → n_c
- exclusive reconstruction
  - ~ invariant mass
  - ~ kinematic cuts
  - ~ vertex reconstruction
  - ~ particle id. dE/dx + RICH (DELPHI)
- subtract background and reflections
- final updates :
  - ALEPH ~ c events
  - DELPHI ~ b and c events



(ALEPH uses $D_S \to \phi\pi$)

b / *c* separation



- use energy spectra and lifetime
  - ~ $c \rightarrow D$: high $X_E(D)$ / low ΔL
  - ~ $b \rightarrow D$: low $X_E(D)$ / high ΔL
- subtract $g \rightarrow cc$ (talk Stefan Schmitt)
- use impact parameter b tagging
  - DELPHI ~ substract D (especially D+ bias)
  - ALEPH ~ opposite hemisphere
- DELPHI : 3 dim. fit to *mass* / $X_E(D)$ / *b tag* for all channels
  - ~ extract $c \rightarrow D$ and $b \rightarrow D$ at same time, correlations -35%
- ALEPH : $X_E(D) > 0.5$ and high purity b tag veto
  - ~ 79 % pure *c* event sample

Results on *c* events

- measured R_c*P($c \to D$)*BR($D \to X$)
- divide by BR($D \to X$) (PDG)
- correct Λ_c rate for Ω_c and Ξ_c ~15±5%
  (assume strange baryon ratios)
- new result :

$R_c = 0.1738 \pm 0.0047(stat) \pm 0.0113(syst)$ ALEPH

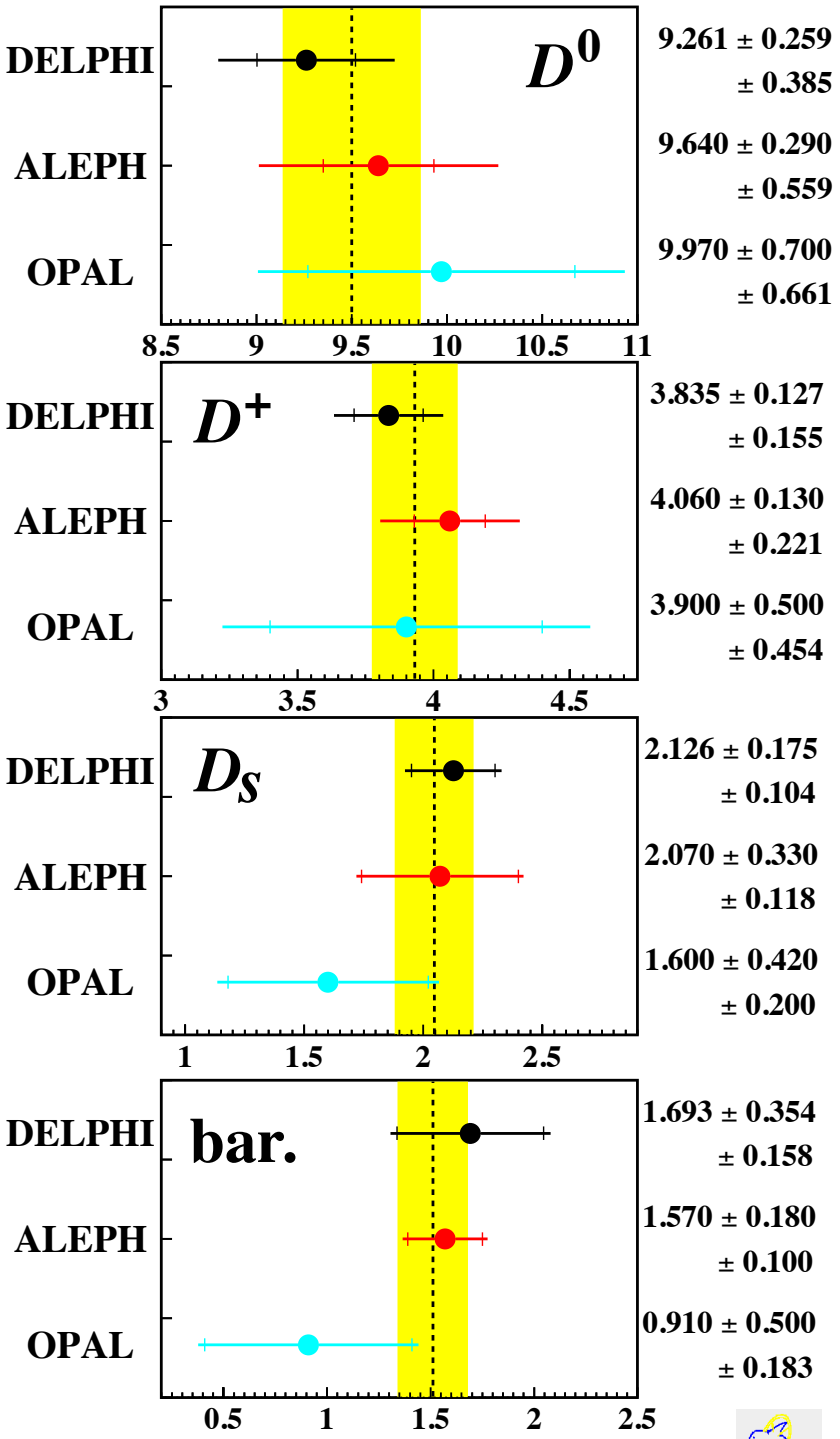
$R_c = 0.1692 \pm 0.0047(stat) \pm 0.0097(syst)$ DELPHI

old OPAL (→1993) :

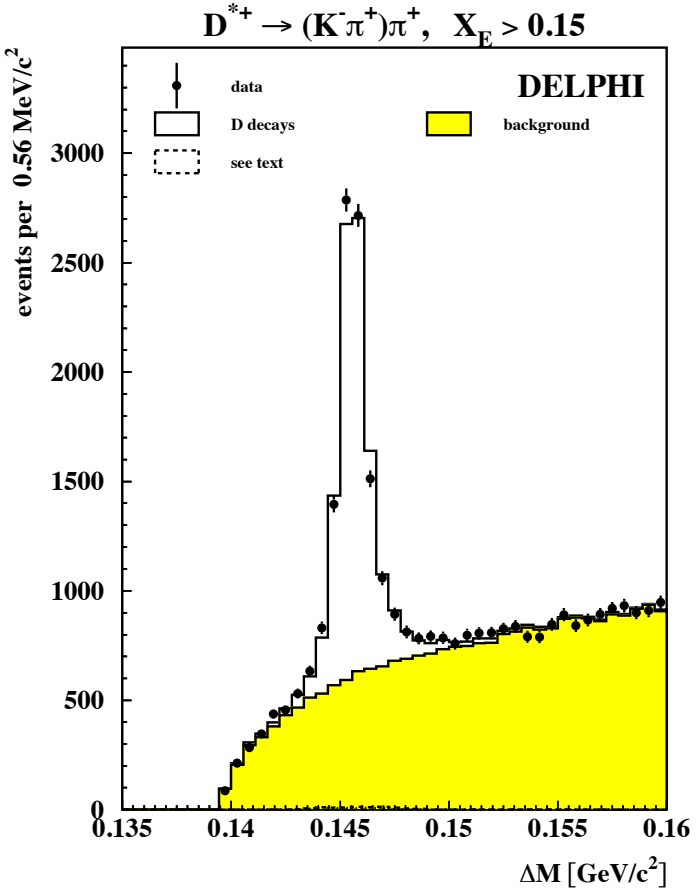
$R_c = 0.1670 \pm 0.0110(stat) \pm 0.0130(syst)$

- biggest common systematic ~ BR
  (not included in plots)

R_c*P($c \to X$) [%] →

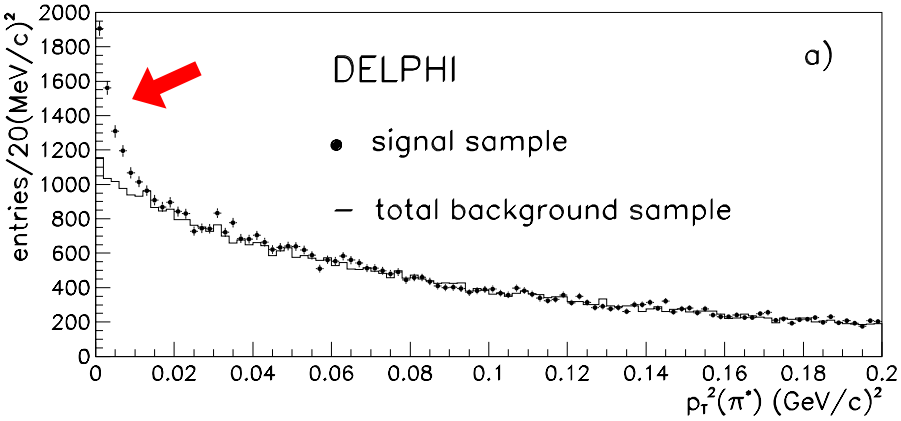


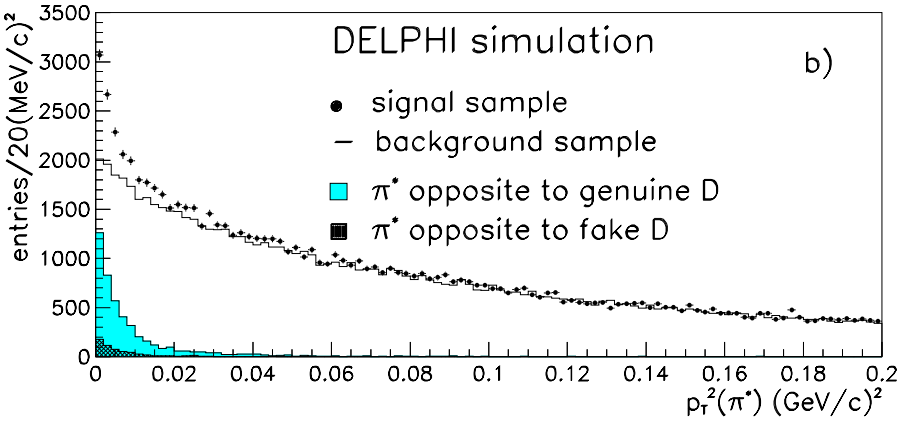
DELPHI double tagging analysis



- final update of exclusive vs inclusive analysis
- use $D^* \to (K\pi)\pi$ channel
  - ~ mass difference trick
  - ~ $\Delta m = m(D^*) - m(D)$
- b / c separation like for counting
- $R_q P(q \to D^*) BR(D^* \to D\pi) BR(D \to K\pi)$
  - ~ c events : 0.01089±0.00027(stat)±0.00039(syst)
  - ~ b events : 0.01315±0.00035(stat)±0.00053(syst)
  - correlation -0.34 %
- divide by PDG $BR(D \to K\pi)$
- measure $P(c \to D^*) BR(D^* \to D\pi)$ from p_t^2 of slow pion

- use 7 exclusive *D* channels
- apply *b* tagging veto
- total of 21898±216 *D* mesons
  c purity ~ 81 %
- opposite hemisphere
  ~ tag $D^* \rightarrow D\pi$ using low
  p_t^2 of π to jet axis
  ~ 2371±137±27 events
- correct for *b* background,
  b mixing and hem. correlations

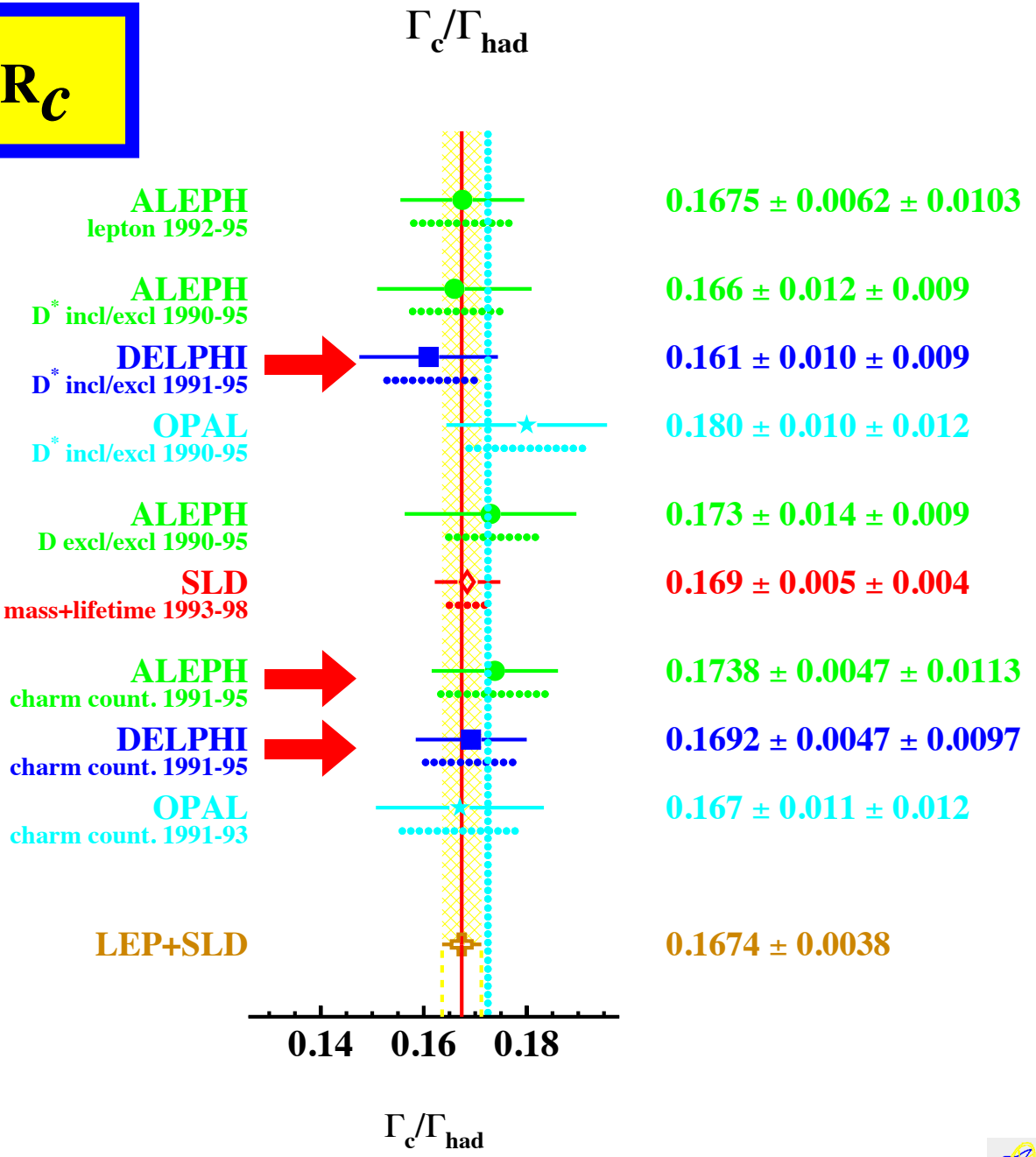




- result : $P(c \rightarrow D^*)BR(D^* \rightarrow D\pi) = 0.174 \pm 0.010(stat) \pm 0.004(syst)$
  and $R_c = 0.1610 \pm 0.0104(stat) \pm 0.0088(syst)$

LEP and SLD results on R_c

- fractions (sum = 1) :
  - $f(D^+) = 0.240 \pm 0.016$
  - $f(D_S^+) = 0.118 \pm 0.025$
  - $f(\text{bar}) = 0.084 \pm 0.022$
  - (input for Rb)
- $P(c \to D^*)BR(D^* \to D\pi) = 0.1652 \pm 0.0053$



Charm counting in *b* decays

- measured $R_b^* P(b \to D)^* BR(D \to X)$
- divide by R_b(LEP) $BR(D \to X)$ (PDG)
- add 2x measured charmonia ~4.0±1.3%
  (assume η_c:J/ψ :χ_c:ψ'_c= .57:1: .27: .31 Kühn et al.)
- correct for Ξ_c ~ 4.0±1.6%
  (use CLEO BR and correct for B_s and Λ_b)
- updated DELPHI result :

$n_c = 1.166 \pm 0.031 \pm 0.059 \pm 0.054$(BR)

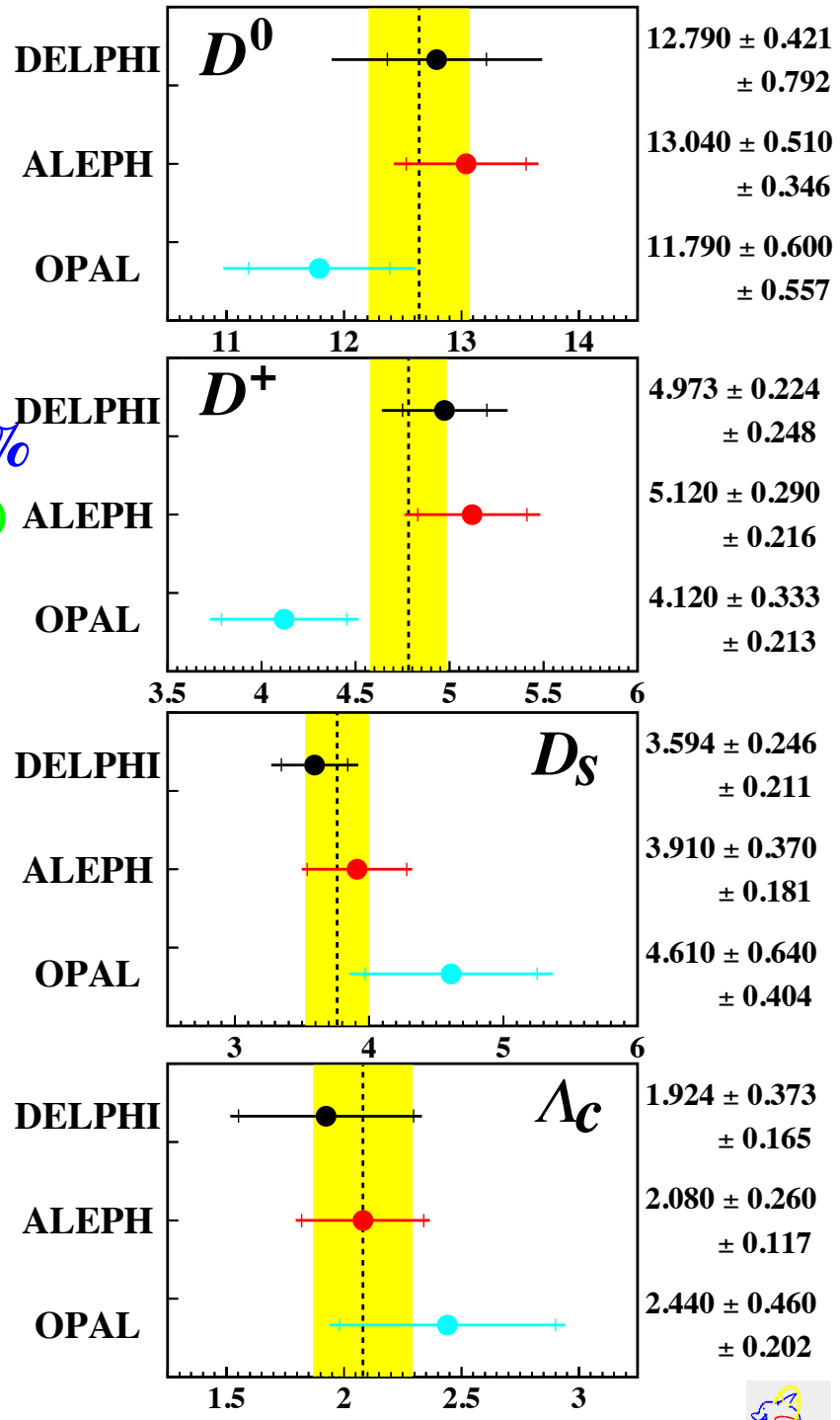
old ALEPH yields : $n_c = 1.190 \pm 0.034 \pm 0.065$

old OPAL yields : $n_c = 1.137 \pm 0.048 \pm 0.084$

- correlated average :

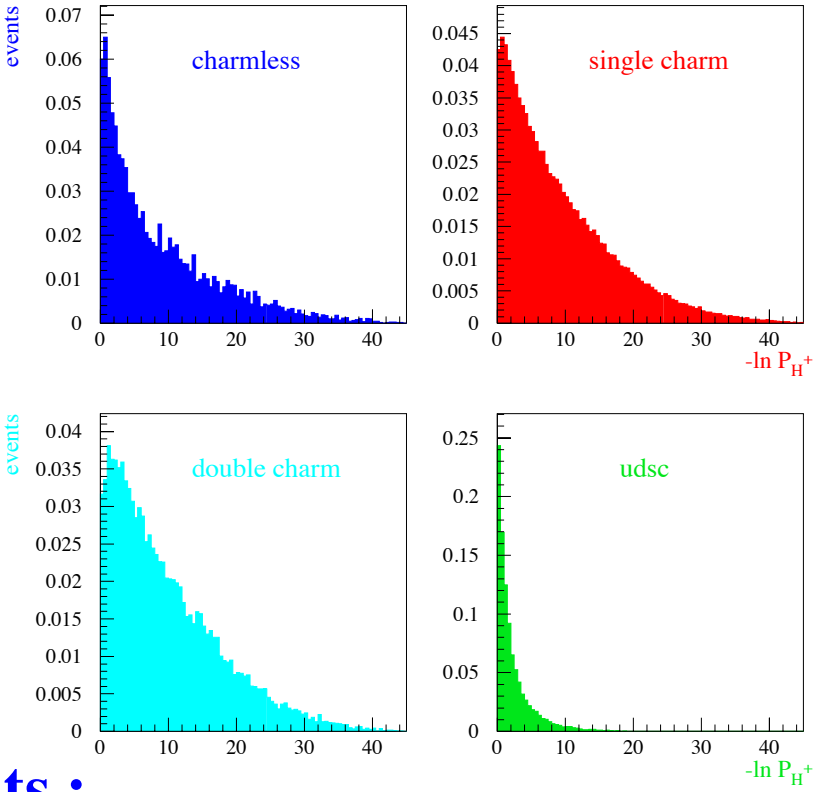
$n_c = 1.151 \pm 0.022 \pm 0.022 \pm 0.051$(BR)

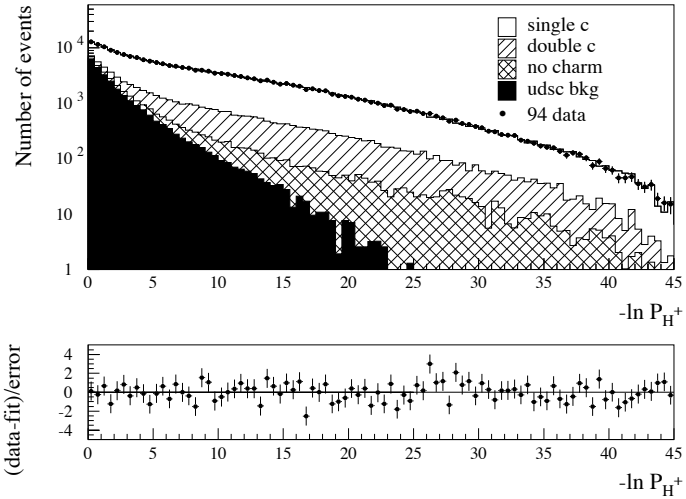
(BR not included in plots) $R_b^* P(b \to X)$ [%] →



Inclusive n_c measurement

- based in impact parameter b tag
- tag one hemisphere ~ 84% purity
- other hemisphere, fit spectra of :
  - ~ no open *c* (*b* → *uud, sg, …,* hidden charm)
  - ~ double open *c* (*b* → *uud*)
- norm = 1 ~ single *c* (*b* → *cud, ucs, clν*)
- subtract light quark background





- results :

  n(no open *c*) = 0.033±0.021

  n(2 open *c*) = 0.139±0.042

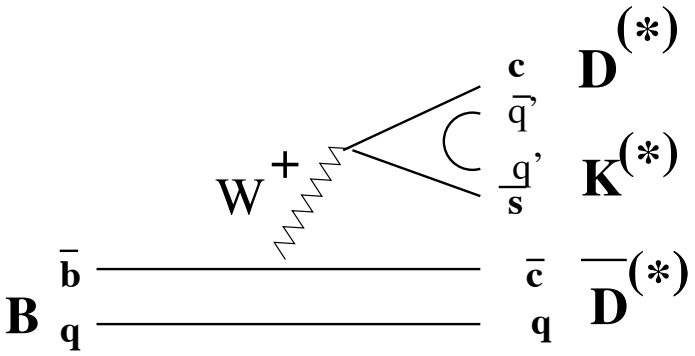
  this yields n(no *c*)<0.035 95%CL

  n_c = 1.147±0.041±0.008

- correlated LEP average :

  n_c = 1.149±0.036

Exclusive double charm



➡ CLEO uses *D lepton* correlations

➡ result :

$\Gamma(B \to DX)/\Gamma(B \to \bar{D}X)=0.100\pm0.031$

or $B \to$ upper vertex $D = 7.9\pm2.2$ %

➡ add contributions from D_s, cc, bar :

$BR(B \to ccs) = 21.9\pm3.7$ %

➡ ALEPH measures exclusive double $D_{(s)}$ decays :

$BR(b \to D_{(s)}D_{(s)}) = 20.9\pm3.0\pm2.4\pm3.7$ %

➡ add contribution from cc : $BR(b \to ccs) = 22.6\pm5.4$ %

➡ average : $BR(b \to ccs) = 22.1\pm3.1$ %

➡ assume SM charmless $b < \sim0.02$ (Dunietz et al.) yields :

$n_c = 1.201\pm0.037$

➡ <u>check:</u> deduce $BR(b \to \bar{c} \to l) \sim 1.62\pm0.57$ % DELPHI : 1.68±0.46 %

(HEP'99 # 5_522)

n_c vs Br($B \to l$)

➡ **Y4S averages :**

$n_c = 1.10 \pm 0.05$ (CLEO)

Br($B \to l$) = 10.45±0.21% (PDG)

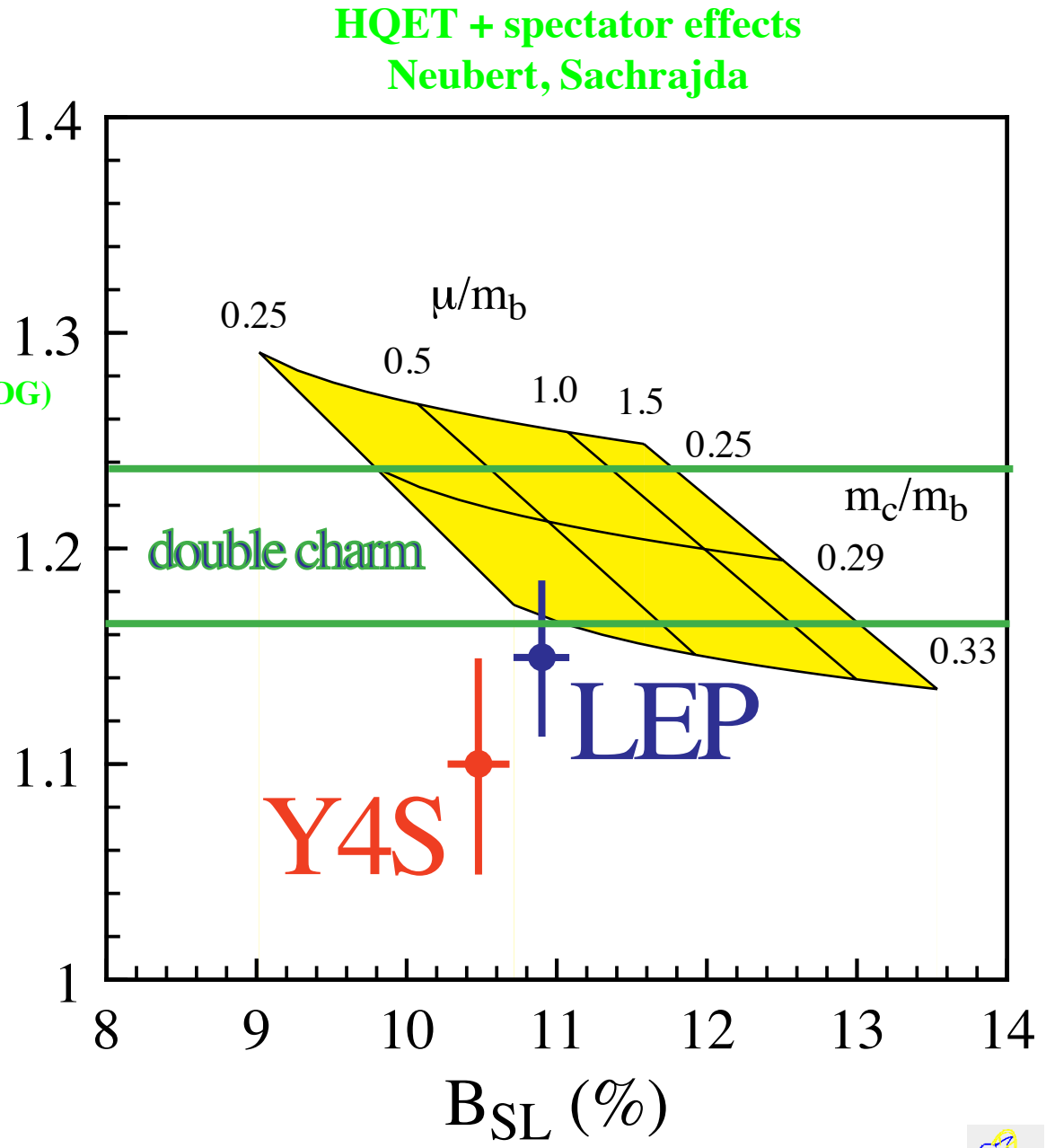
➡ **LEP measures Br($b \to l$), use:**

$$Br(B \to l) \cong \tau_B / \tau_b \, Br(b \to l)$$

(see next talk by Pauline Gagnon)

➡ **LEP average :**

$n_c = 1.149 \pm 0.036$



ALEPH results on D* production

- analyse D^* energy spectra
- → extract $g \rightarrow c\bar{c}$ (talk Stefan Schmitt)
- → b tag veto to substract b spectra
- → fit Peterson et al. function to c events :

$$\langle X_E(D^*) \rangle = 0.4878 \pm 0.0046 \pm 0.0061$$

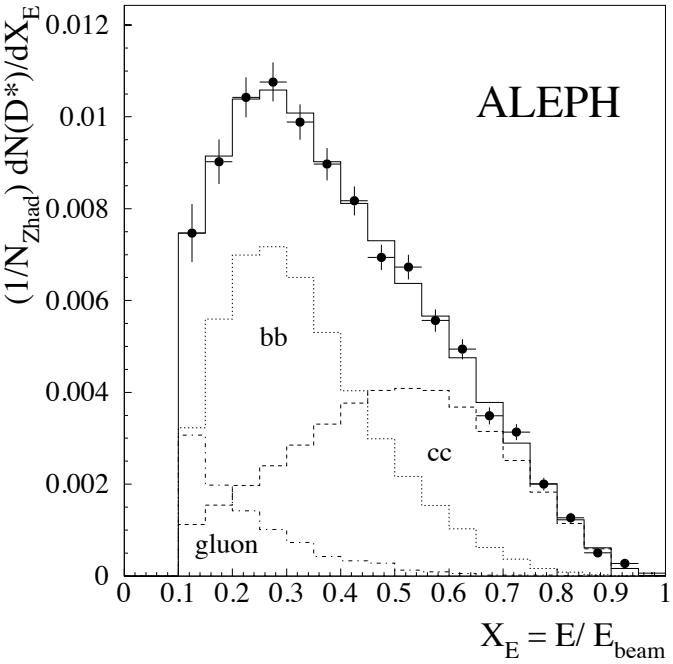
- → divide rate by R_c and BR to extract

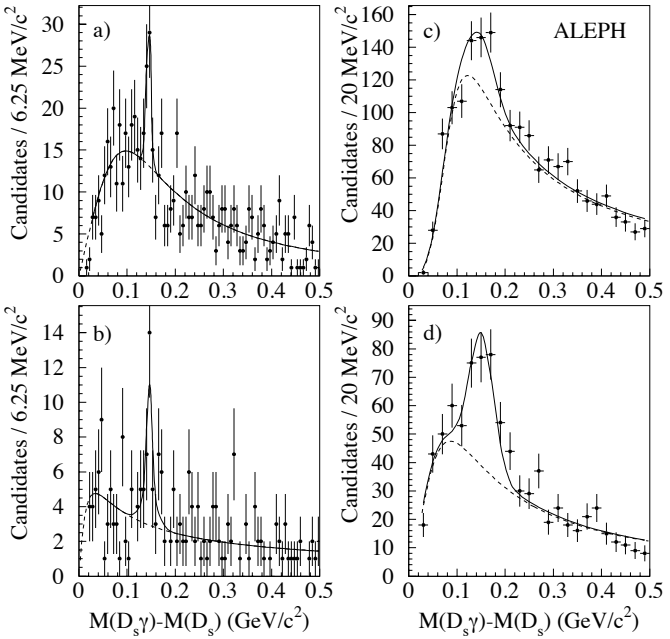
$$P(c \rightarrow D^*) = 0.2333 \pm 0.0102 \pm 0.0158$$

- analysis of $D_S^* \rightarrow D_S \gamma$
- → γ conversions + calorimeter
- → b and c enriched samples :

$$P(c \rightarrow D_S^*) = 0.069 \pm 0.018 \pm 0.019$$

$$P(b \rightarrow D_S^*) = 0.113 \pm 0.035 \pm 0.028$$





The effective V/(V+P) ratio in *c* events

- difference between D^+ and D^0 rates due to D* decays
- check consistency of results: $\frac{P_{c\to D^0} - P_{c\to D^+}}{2P_{c\to D^{*+}} BR_*} = 1$

  DELPHI ~ 0.963±0.051±0.074 ALEPH ~ 1.02±0.12
- extract effective V/V+P :

  $P_{c\to D^{*+}} BR_* = Y\, f_d(c)$

  $P_{c\to D^0} = (1+Y)\, f_d(c)$ $\quad Y = BR_* \cdot \frac{V}{V+P}$

  $P_{c\to D^+} = (1-Y)\, f_d(c)$

  ALEPH ~ 0.595±0.045

  DELPHI ~ 0.620±0.014±0.029
- ALEPH result on D_s^* production yields : 0.60±0.19
- old OPAL value using D^{*+} and D^{*0} results : 0.57±0.05
- expectation :

  naive spin counting ~ 3 / 4

  string fragmentation (D**) / thermodynamical approach ~ 0.66

  Yi-Jin Pei F. Becattini

Summary

- final updates R_c from charm counting and D^* reconstruction :

  $R_c = 0.1738 \pm 0.0047(\text{stat}) \pm 0.0113(\text{syst})$ ALEPH

  $R_c = 0.1692 \pm 0.0047(\text{stat}) \pm 0.0097(\text{syst})$ DELPHI

  $R_c = 0.1610 \pm 0.0104(\text{stat}) \pm 0.0088(\text{syst})$ DELPHI

- results on n_c from counting and inclusive tagging

  $n_c = 1.151 \pm 0.022 \pm 0.022 \pm 0.051(\text{BR})$ ALEPH / DELPHI / OPAL

  $n_c = 1.147 \pm 0.041 \pm 0.008$ DELPHI

  open $B \rightarrow DDX$ yields $n_c = 1.201 \pm 0.037$ CLEO / ALEPH

- LEP + SLD averages :

  $R_c = 0.1674 \pm 0.0038$ SM : 0.172

  $n_c = 1.149 \pm 0.036$ expect : 1.20 ± 0.06 (Neubert, Sachrajda)