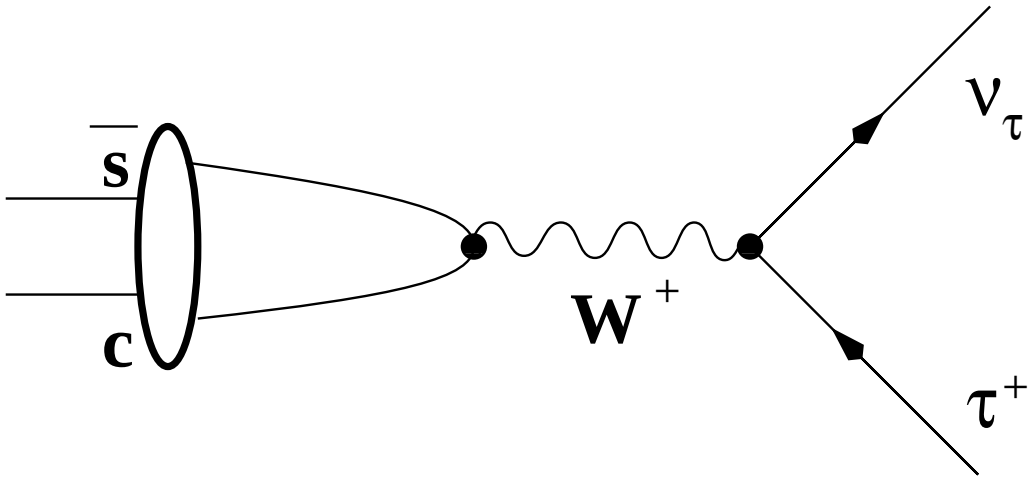
LEPTONIC DECAYS OF THE D_S MESON AT LEP

- ALEPH 2001-051
- DELPHI 97-105 CONF 87
- L3, Phys. Lett. B396 (1997) 327
- OPAL, CERN-EP-2001-19, accepted by Phys. Lett. B



'2nd generation pion decay'

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

- Decay constant f_{Ds} predicted by potential models, QCD sum rule models and lattice QCD calculations.
- Decay constant f_B important for extracting CKM matrix elements from B^0-$\bar{B}^0$ oscillations measurements, but currently only limits on B->lν_l.
- f_{Ds} measurements can test models used to predict f_B

Analysis Strategy:

D_s final state:
1 lepton, 3 neutrinos

$$e^+e^- \to Z \to c\bar{c} \to D_s^{\star -} X$$
$$\hookrightarrow \gamma\, D_s^-$$
$$\hookrightarrow \tau\bar{\nu}_\tau$$
$$\hookrightarrow \ell^-\bar{\nu}_\ell\nu_\tau \quad (\ell = e, \mu)$$

- Require large missing energy in signal hemisphere
- Require one identified **electron or muon** in the signal hemisphere
- Enrich sample in charm quark decays

DELPHI, L3, OPAL:

- Require photon from **D_s^*->$D_s\gamma$** decay
- Reconstruct signal peak in **$D_s\gamma$** invariant mass distribution

ALEPH:

- Use linear discriminants to obtain maximum discrimination between signal and background
- no photon required

How do we reconstruct the D_s four-momentum ?

All missing energy assumed to be due to neutrinos:

$$\vec{P}_{\mathrm{D_s}} = -\sum_{i \neq \mathrm{lepton}} \vec{p}_i$$

$$E_{\mathrm{D_s}} = \sqrt{s} - \sum_{i \neq \mathrm{lepton}} E_i$$

$$\sqrt{E_{\mathrm{D_s}}^2 - P_{\mathrm{D_s}}^2} = M_{\mathrm{D_s}}$$

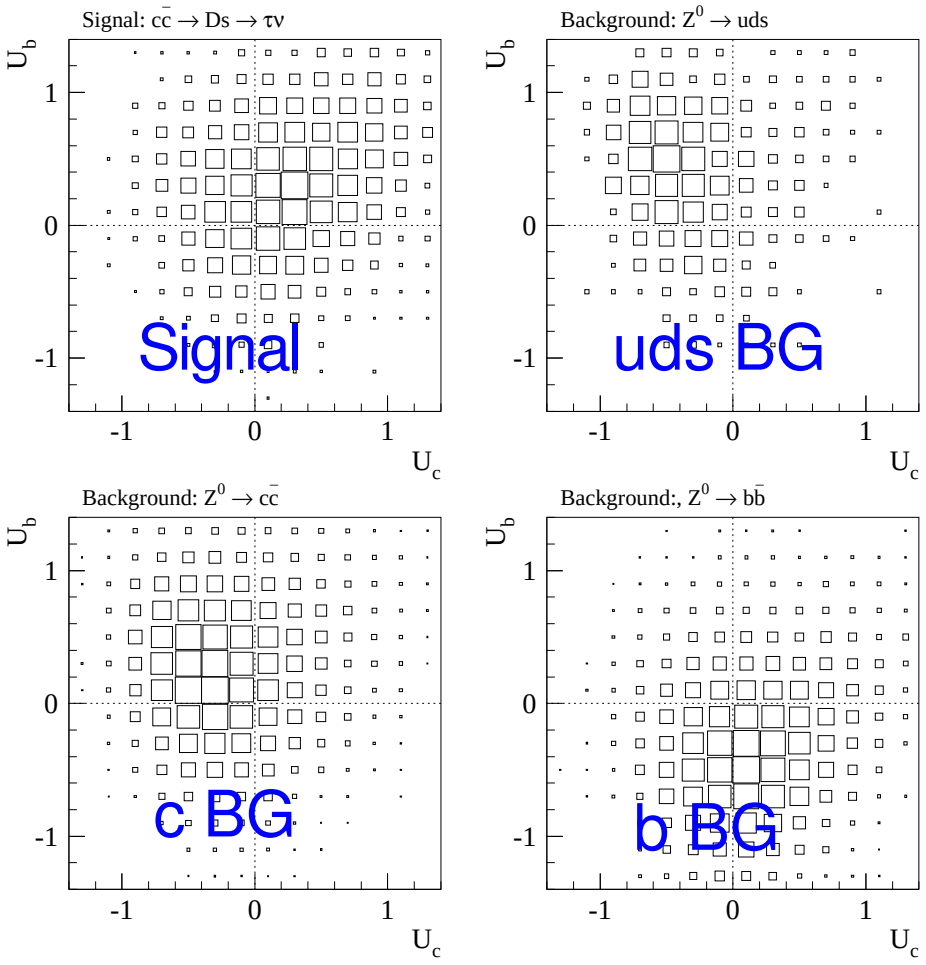
$$\chi^2 = \sum_{i \neq \mathrm{lepton}} \frac{(E_i^{\mathrm{fit}} - E_i^{\mathrm{meas}})^2}{\sigma^2_{E_i^{\mathrm{meas}}}}$$

Resolution on missing energy significantly improved (final resolution about 3-3.5 GeV)

All experiments require large E_{Ds} and/or large missing energy

ALEPH uses linear discriminants (e.g. muon channel):

Monte Carlo:



Two-dimensional unbinned maximum likelihood fit of signal and three background contributions

Important variables:

- -fitted p_{Ds}
- -angle between lepton and D_s direction in D_s rest frame
- -b tagging
- -P_T(lepton) wrt nearest jet

Signal :

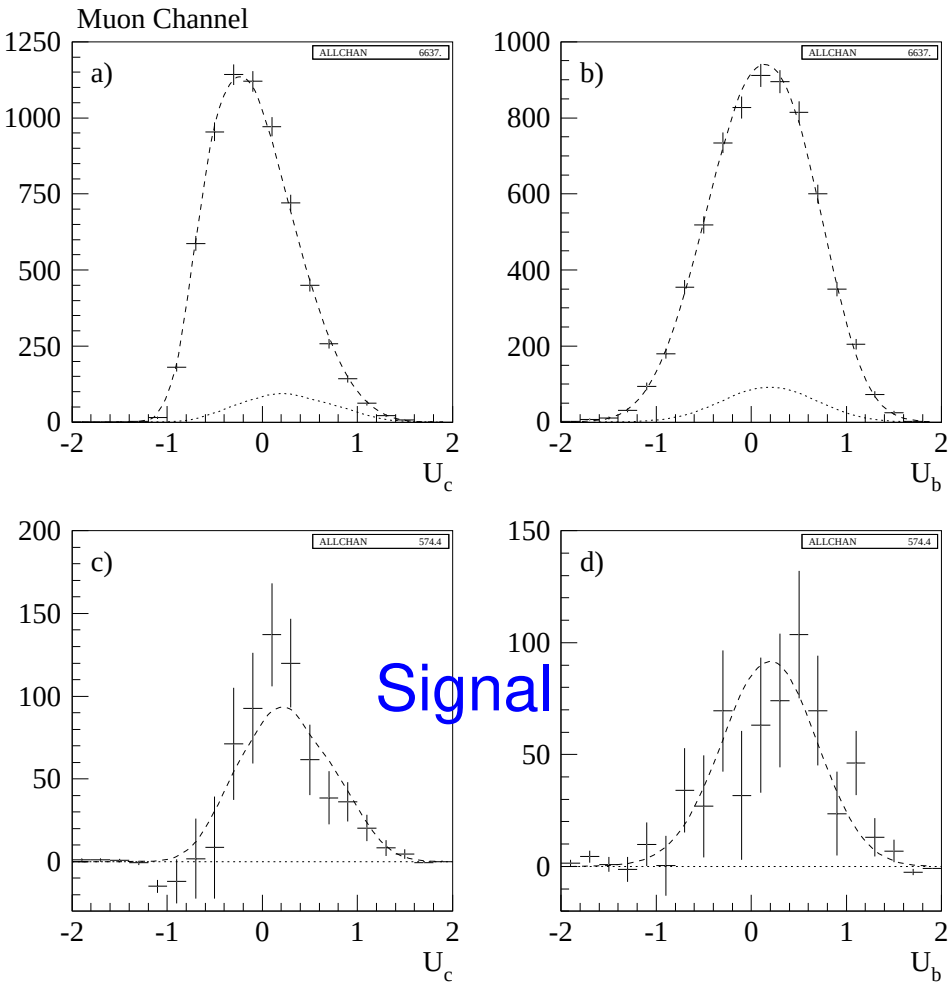
$D_s \to \tau\,\nu$ **$D^+ \to \tau\,\nu$**

$D_s \to \mu\,\nu$ **$D^+ \to \mu\,\nu$**

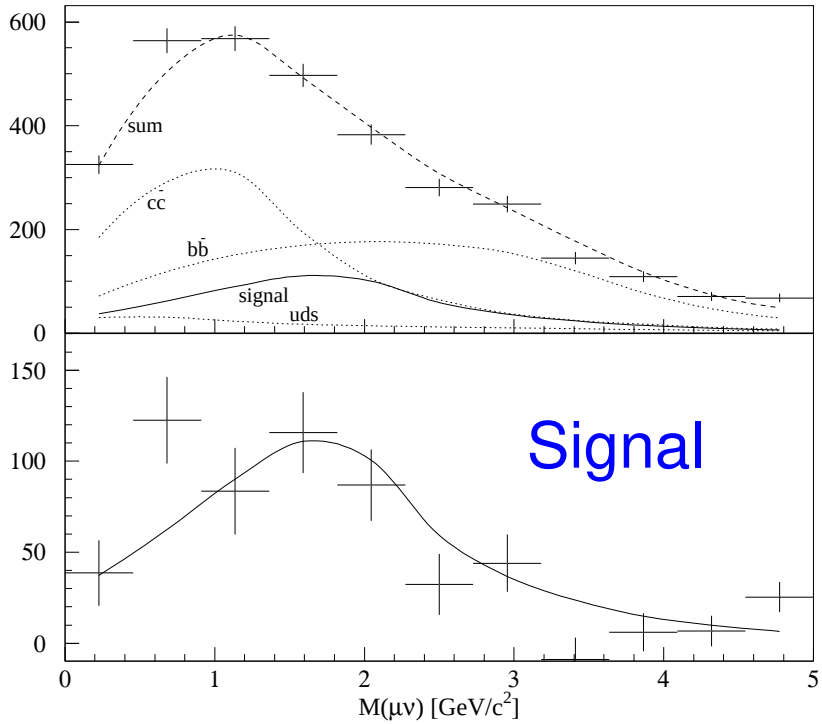
<8 %

Projections for data:

$D_s \to \tau \nu$



$D_s \to \mu \nu$



$M_{\mu\nu}$: mass from kinematic fit

4 ANNs with 6-12 input variables to enrich data sample in Ds->τν decays

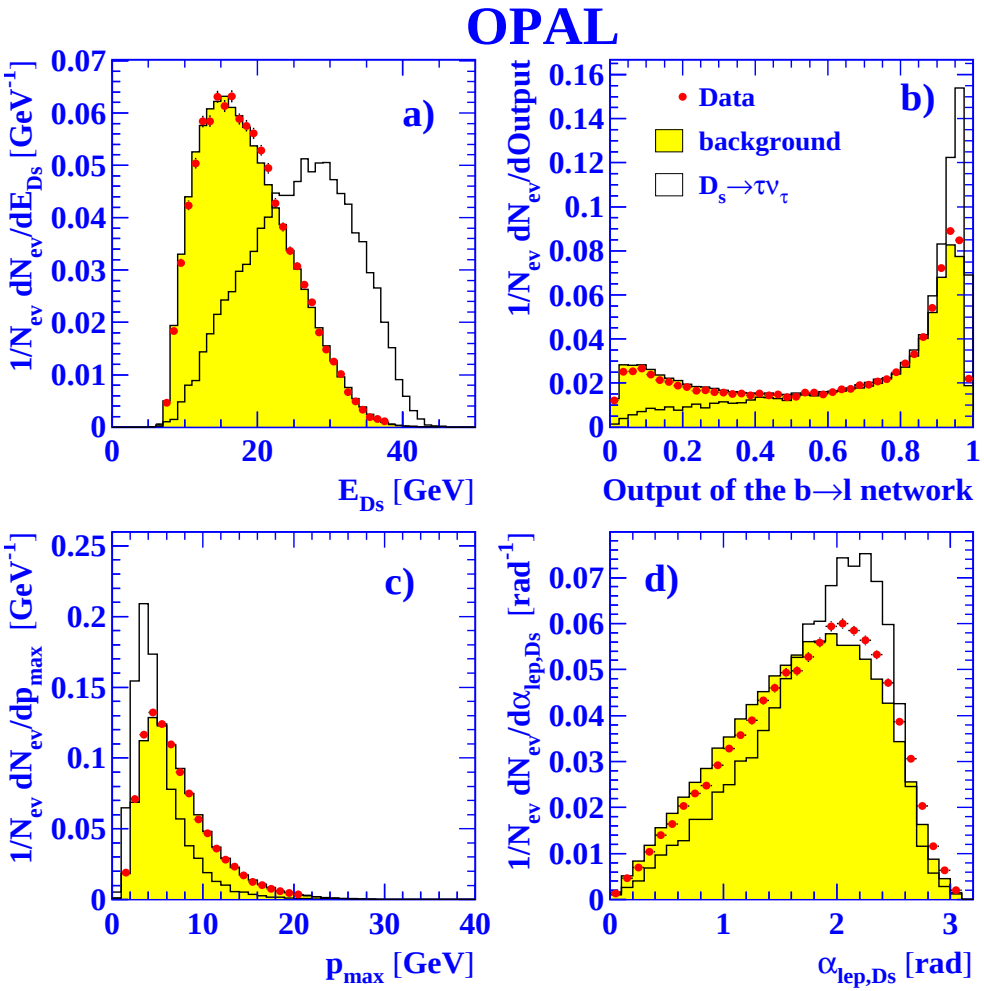
signal background

μ Z->$c\bar{c}$

e Z->$b\bar{b}$

fitted E_{Ds}

ANN inputs:



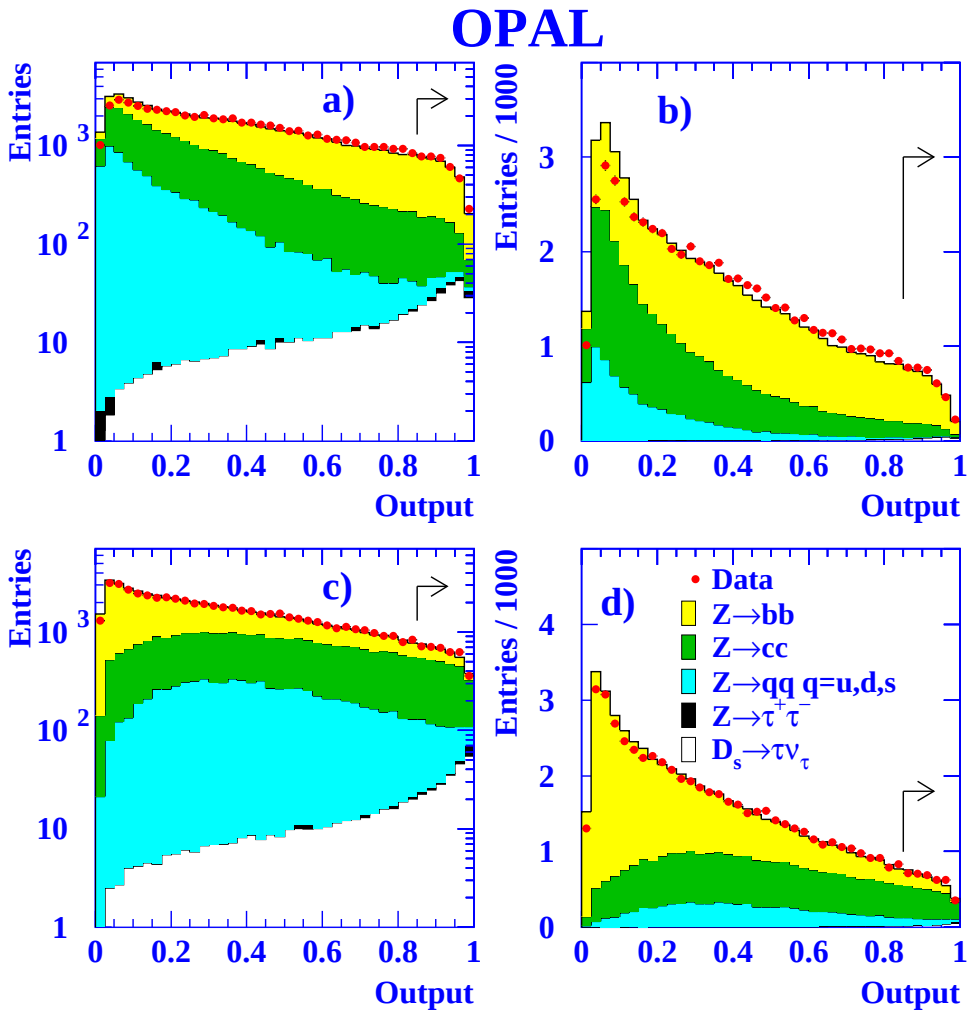
output of a b->lepton neural network

highest momentum of any particle with charge opposite to charge of the lepton

angle between the lepton in the Ds rest frame and the Ds

~1 % signal contribution

ANN outputs (muon channel):

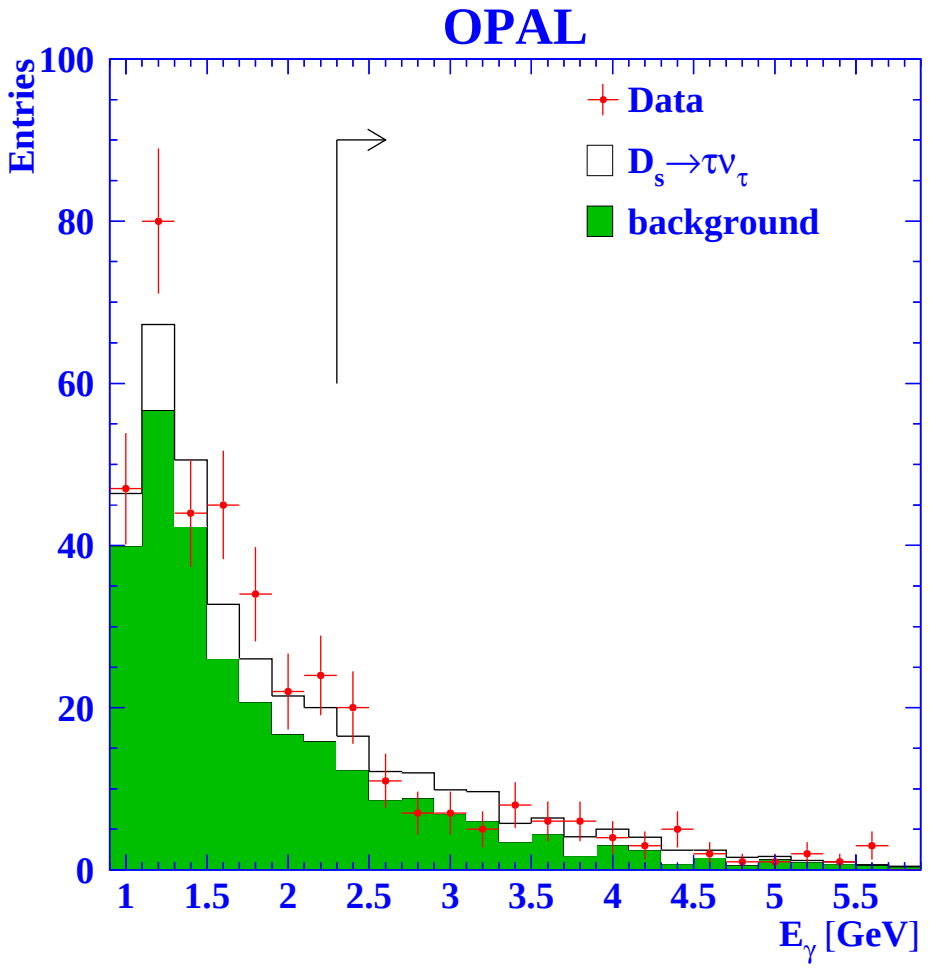


vs Z->$c\bar{c}$ background

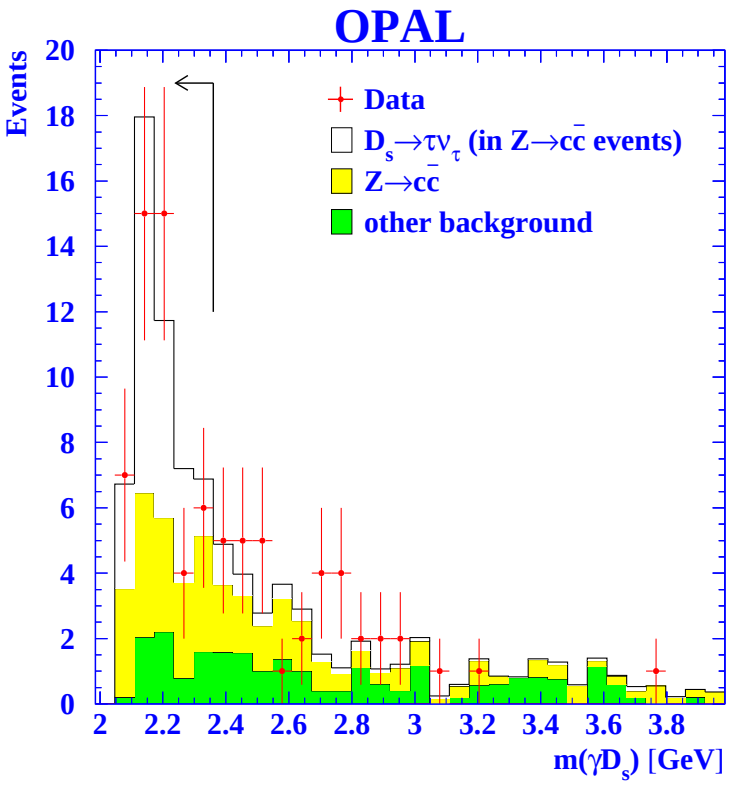
vs Z->$b\bar{b}$ background

plus further cuts on b likelihood, missing energy

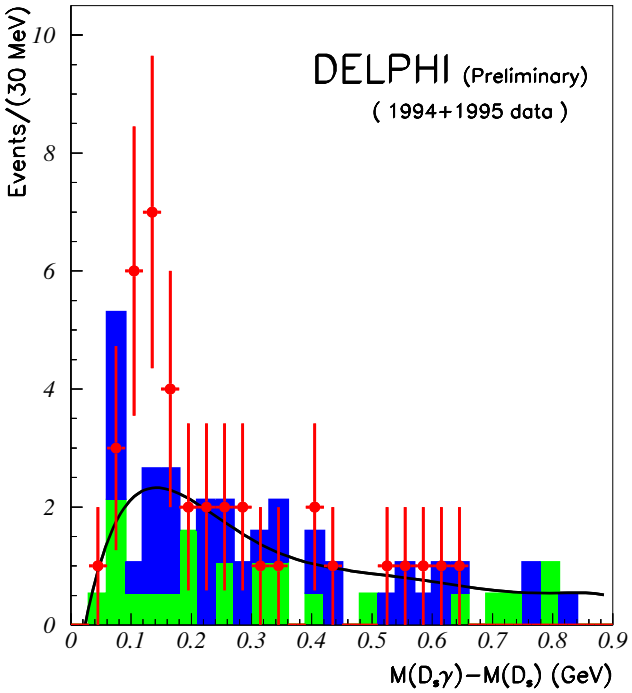
Reconstruct photon from D_s^*->D_s γ decay:



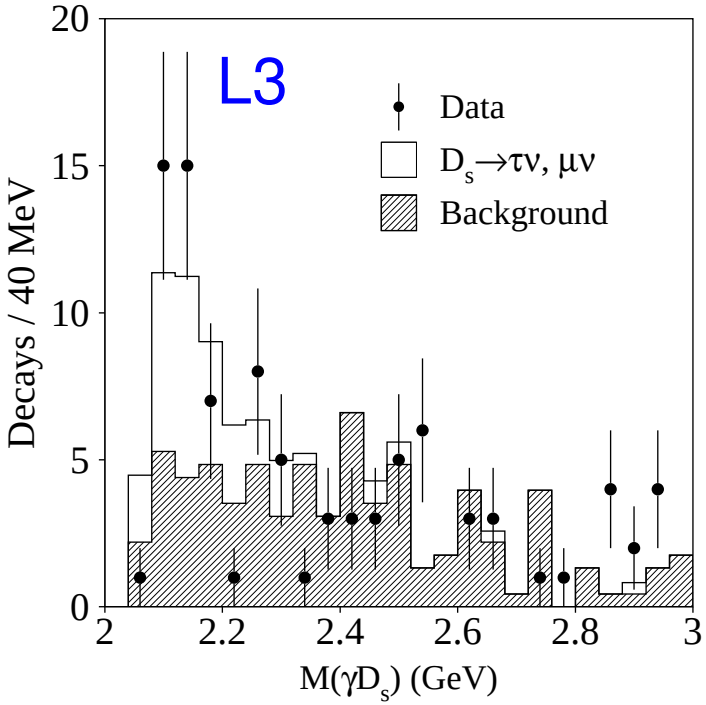
E_γ>2.3 GeV



E_γ>1.5 GeV



3<E_γ<5 GeV



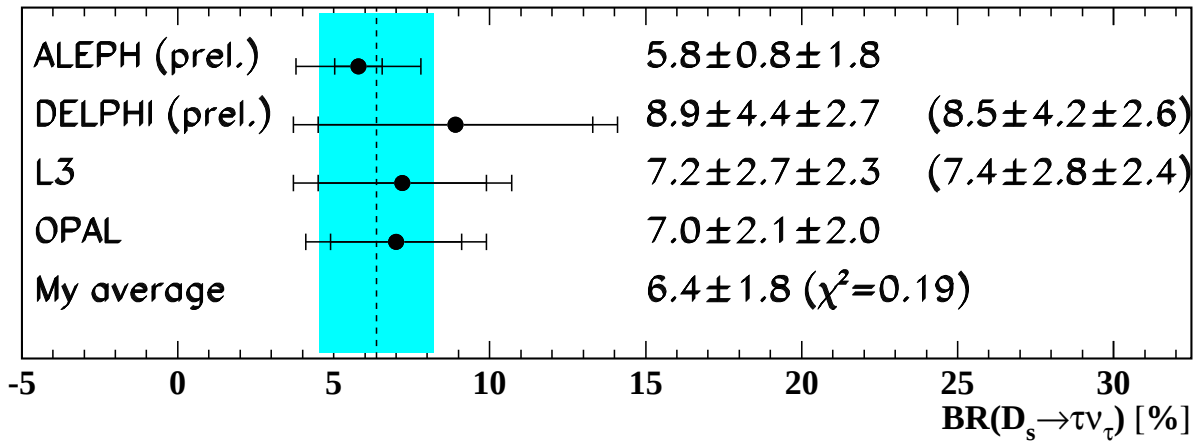
$$\mathrm{BR}(\mathrm{D_s^-} \to \tau^- \bar{\nu}_\tau) = \frac{N_{\mathrm{cand}}}{2N_{\mathrm{Z}} \cdot R_{\mathrm{c}} \cdot f(c \to \mathrm{D_s^-}) \cdot P_V(\mathrm{D_s^\star}, \mathrm{D_s}) \cdot \mathrm{BR}(\mathrm{D_s^{\star -}} \to \gamma \mathrm{D_s^-})} \times \frac{1}{\mathrm{BR}(\tau \to l \bar{\nu}_l \nu_\tau) \cdot \epsilon(\mathrm{D_s^-} \to \tau^- \bar{\nu}_\tau) + \frac{\mathrm{BR}(\mathrm{D_s^-} \to \mu^- \bar{\nu}_\mu)}{\mathrm{BR}(\mathrm{D_s^-} \to \tau^- \bar{\nu}_\tau)} \cdot \epsilon(\mathrm{D_s^-} \to \mu^- \bar{\nu}_\mu)}$$

- blue: measured using data or MC
- magenta: taken from PDG or LEP combination
- extrapolated from measurements of P_V(D*,D)=0.61 +- 0.03 (ADO):

$$P_V(\mathrm{D_s^\star}, \mathrm{D_s}) = \frac{N(\mathrm{D_s^\star})}{N(\mathrm{D_s^\star}) + N(\mathrm{D_s})} = 0.64 \pm 0.05$$

-D** effects neglected
-quark mass effects small

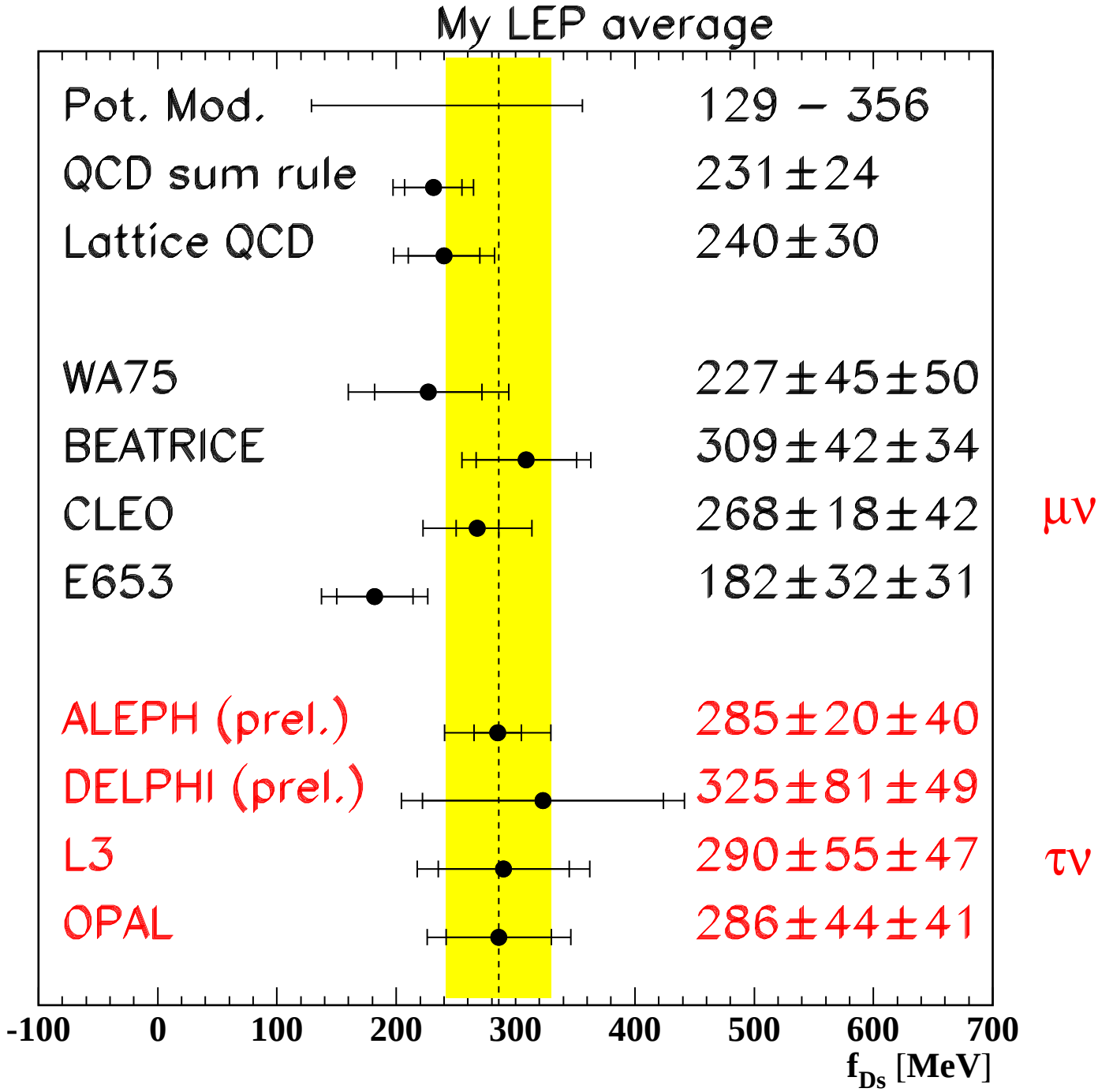
irreducible: $\dfrac{\mathrm{BR}(\mathrm{D_s^-} \to \mu^- \bar{\nu}_\mu)}{\mathrm{BR}(\mathrm{D_s^-} \to \tau^- \bar{\nu}_\tau)} = 0.103 \;\; (\mathrm{factor}\; m_\ell^2)$



DELPHI and L3 values were recalculated using newest PDG values and $P_V(D_s^*,D_s)=0.64$

Statistical and detector related uncertainties are assumed to be independent

Normalisation uncertainty (~22 %, mainly from $f(c\to D_s^-)=0.121 \pm 0.025$) dominates, it was assumed to be fully correlated


My LEP average
Pot. Mod.
129 – 356
QCD sum rule
231 ± 24
Lattice QCD
240 ± 30
WA75
227 ± 45 ± 50
BEATRICE
309 ± 42 ± 34
CLEO
268 ± 18 ± 42
μν
E653
182 ± 32 ± 31
ALEPH (prel.)
285 ± 20 ± 40
DELPHI (prel.)
325 ± 81 ± 49
L3
290 ± 55 ± 47
τν
OPAL
286 ± 44 ± 41
-100
0
100
200
300
400
500
600
700
f_{Ds} [MeV]

Summary

- Two final and two preliminary LEP measurements of leptonic D_s decays have been presented
- DELPHI, L3 and OPAL reconstruct signal in $D^*_s \to D_s \gamma$ decays
- ALEPH uses linear discriminants to separate signal and background
- The precision is limited by the correlated systematic uncertainties on charm meson production in c decays