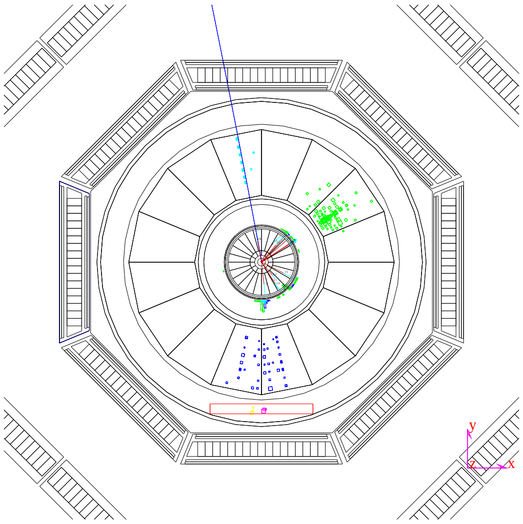
W Boson Properties

at LEP



EPS-HEP99

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Outline

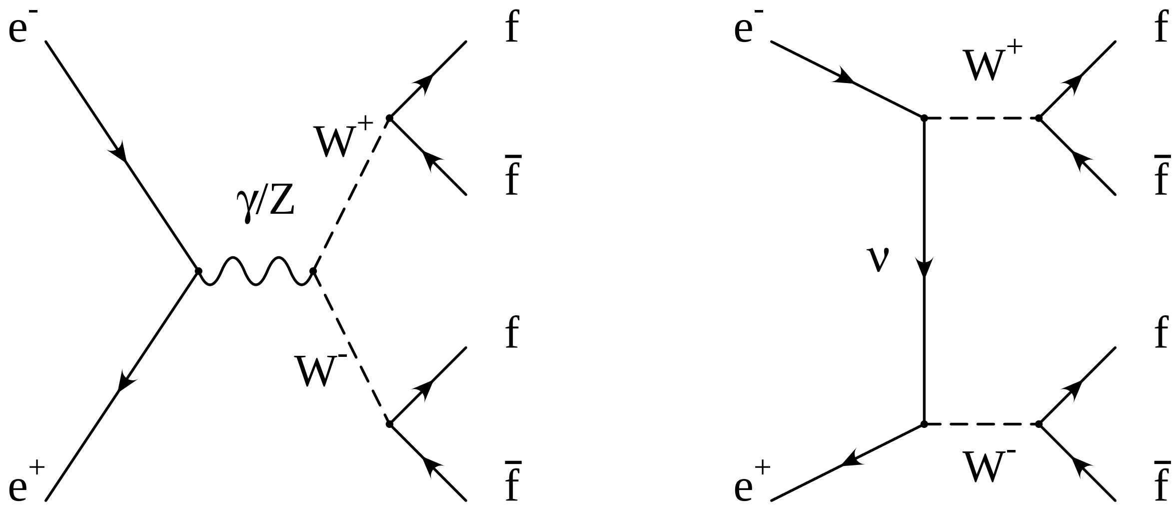
- Introduction
- Selection strategies
- Cross sections at $\sqrt{s} = 189$ GeV
- Branching ratios ($\sqrt{s} = 161-189$ GeV)
- $|V_{cs}|$
- A glance at $\sqrt{s} = 192$ & 196 GeV
- Summary and Conclusions

- Since 1996 LEP was operating above WW production threshold
- Four experiments located at LEP ring:
  Aleph , Delphi , L3 & Opal
- Amount of data collected per experiment (here L3):

Year	$\sqrt{s}$ (GeV)	$\mathcal{L}$ (pb^{-1})	σ_{WW}^{SM} (pb)	Events
1996	161	11	3.8	22
1996	172	10	12.4	110
1997	183	55	15.7	830
1998	189	175	16.6	2800
1999	192	> 29	16.8	> 450
1999	196	> 45	17.1	> 730
total				> 4860

- At these energies, W pairs are created mainly through 3 tree level diagrams, known as CC03:

$$ee \rightarrow WW \rightarrow ffff$$



- More generally, WW events belong to the family of 4-fermion final state processes, with a more complicated structure (CC56, NC56)

- We classify WW events in 3 groups:

$$\begin{array}{lr} WW \rightarrow qqqq & 45.6\% \\ WW \rightarrow qql\nu & 3 \times 14.6\% \\ WW \rightarrow l\nu l\nu & 10.6\% \end{array}$$

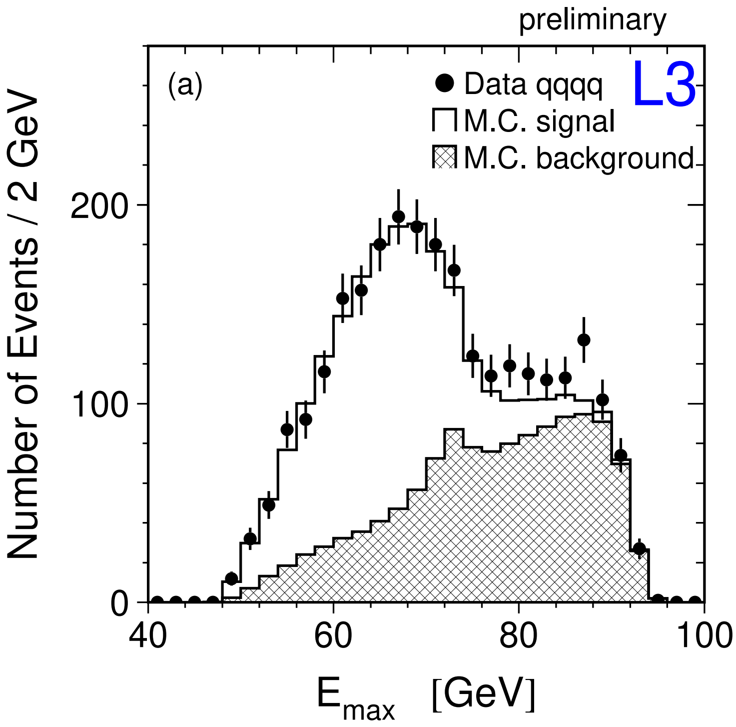
with $l = e, \mu, \tau$

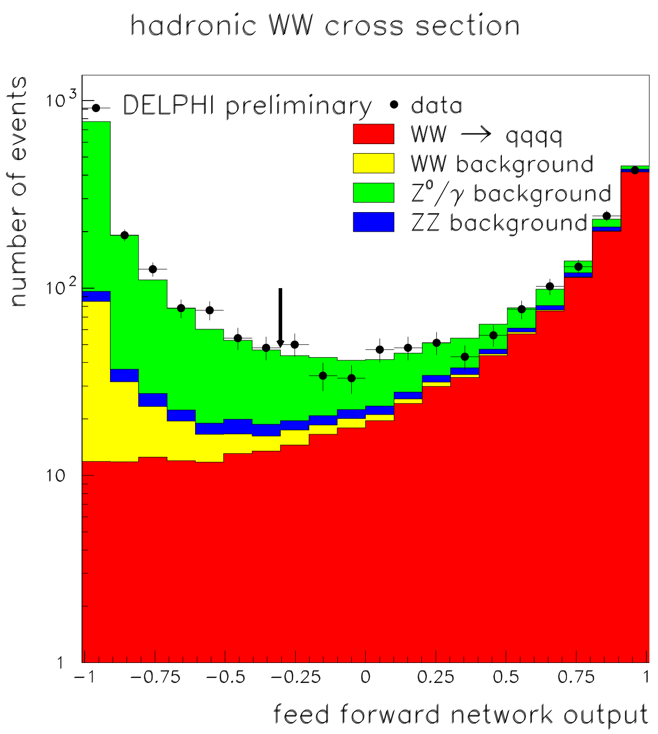
$ee \rightarrow WW \rightarrow q\bar{q}q\bar{q}$

characteristics:

- 4 hadronic jets
- no missing energy
- large QCD background

standard cut based analysis inefficient





different approaches:

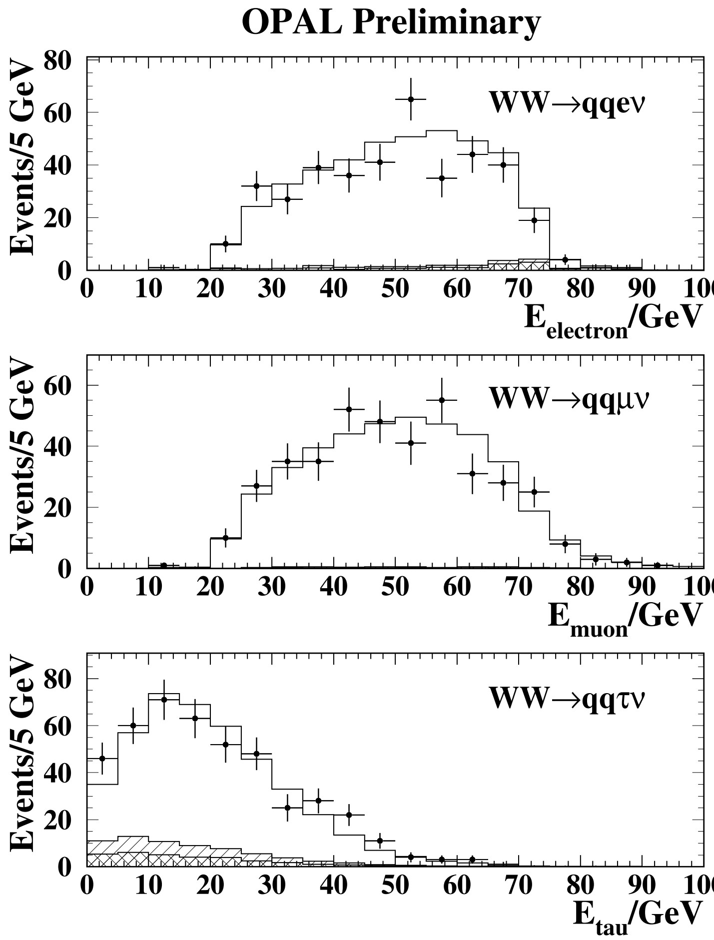
- neural networks
- likelihood method

- multivariable analysis
- best discriminating variables

At 189 GeV

typical efficiency:	$\sim$ 90%
typical accepted bkg:	$\sim$ 1.7 pb
SM signal cross section:	7.59 pb

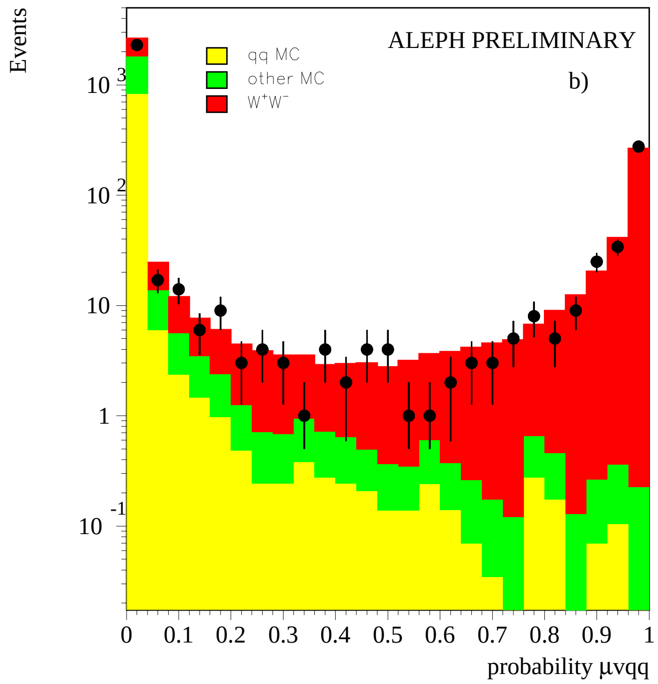
$ee \rightarrow WW \rightarrow q\bar{q}l\nu,\ l = e, \mu$



characteristics:

- 2 hadronic jets
- isolated energetic lepton
- missing energy

interference from CC20 diagrams in $qqe\nu$ channel



cut based analysis using:

- lepton energy and angular distributions
- lepton isolation

probability selection

likelihood selection

At 189 GeV

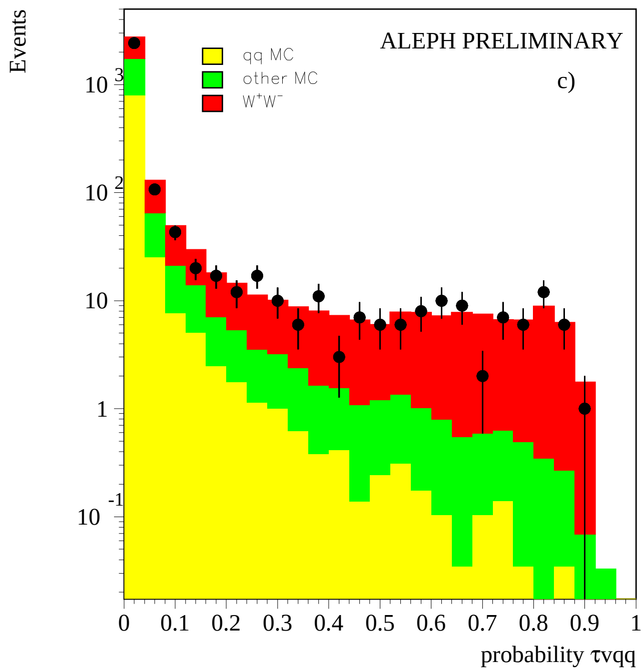
typical efficiency:	$\sim 85\%$
typical accepted bkg:	~ 100 fb
SM signal cross section:	2.43 pb

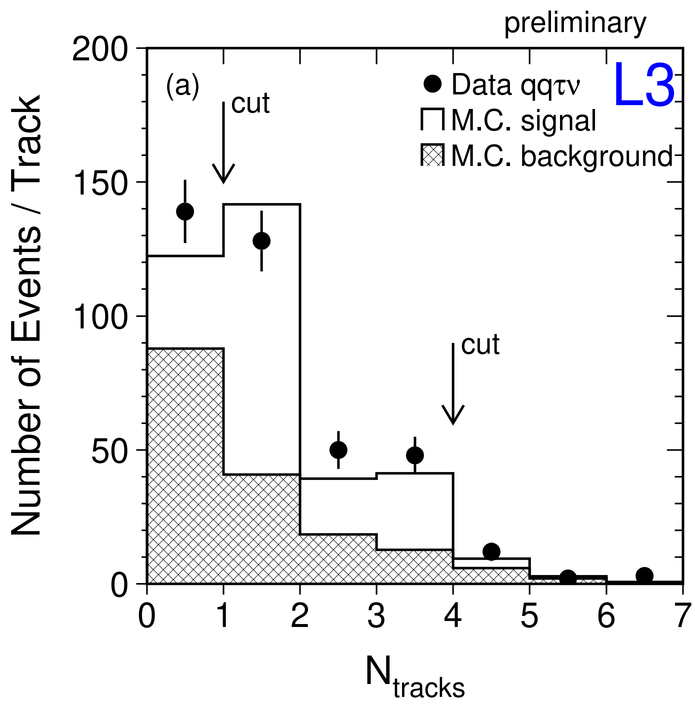
$ee \to WW \to q\bar{q}\tau\nu$

characteristics:

- 2 hadronic jets
- isolated lepton or low multiplicity jet
- missing energy

τ jet identification important





cut based analysis using:

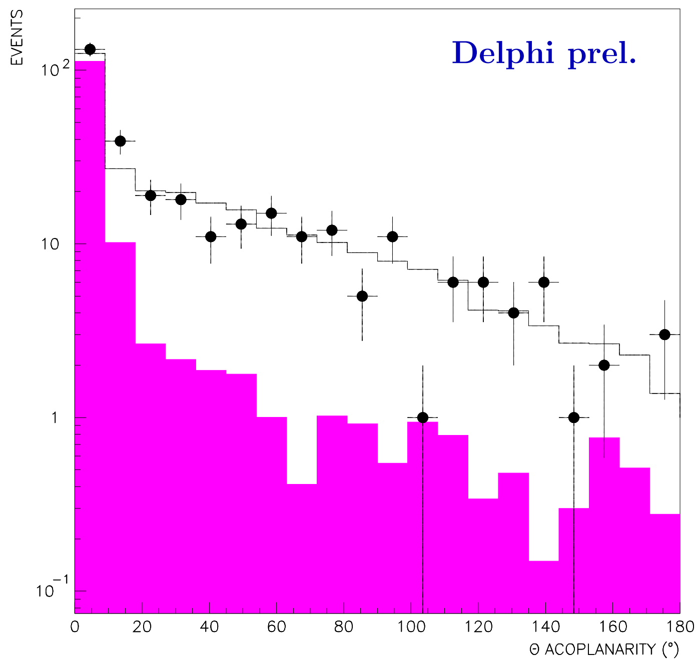
- lepton energy and angular distributions
- veto from $qqe\nu$ and $qq\mu\nu$ selection

likelihood based selection

topological selection

At 189 GeV

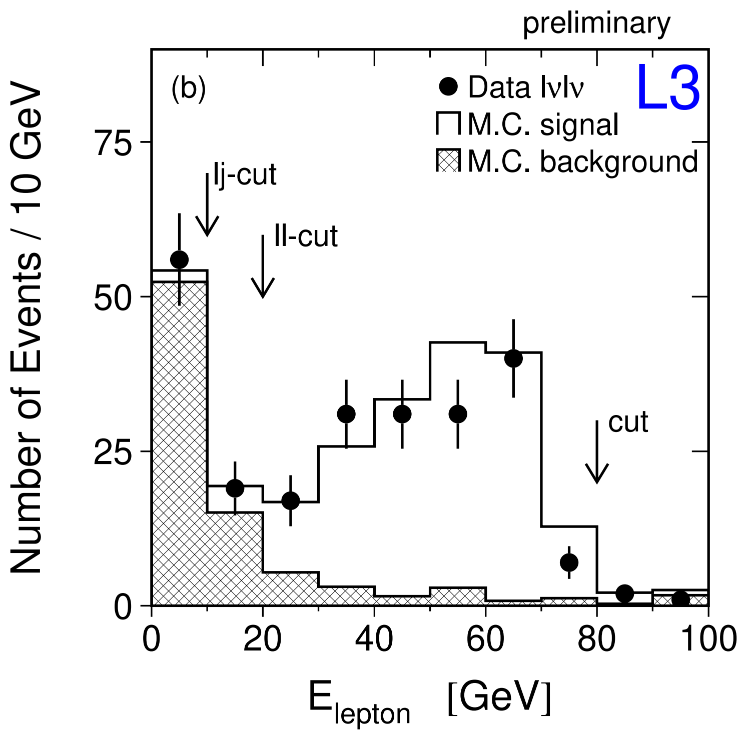
typical efficiency:	$\sim 60\%$
typical accepted bkg:	~ 250 fb
SM signal cross section:	2.43 pb



characteristics:

- 2 acoplanar, energetic leptons
- missing energy

High contribution from CC56+NC56 diagrams, fermion pairs



cut based analysis:

- acoplanarity
- lepton energy spectrum

At 189 GeV

typical efficiency:	$\sim 60\%$
typical accepted bkg:	~ 150 fb
SM signal cross section:	1.76 pb

Cross sections of all decay channels σ_j are determined simultaneously in one maximum likelihood fit:

$$L = \prod_i \mathcal{P}(N_i, \mu_i)$$

with

- the Poisson probability function $\mathcal{P}$,
- the observed number of events N_i, and
- the expected nr. of events μ_i:

$$\mu_i = \left(\sum_j \epsilon_{ij} \sigma_j + \sigma_i^{bkg} \right) \mathcal{L}$$

where

- ϵ is the efficiency matrix
- σ_j the cross section of process j to be determined
- σ_i^{bkg} the accepted non-WW background, and
- $\mathcal{L}$ the integrated luminosity

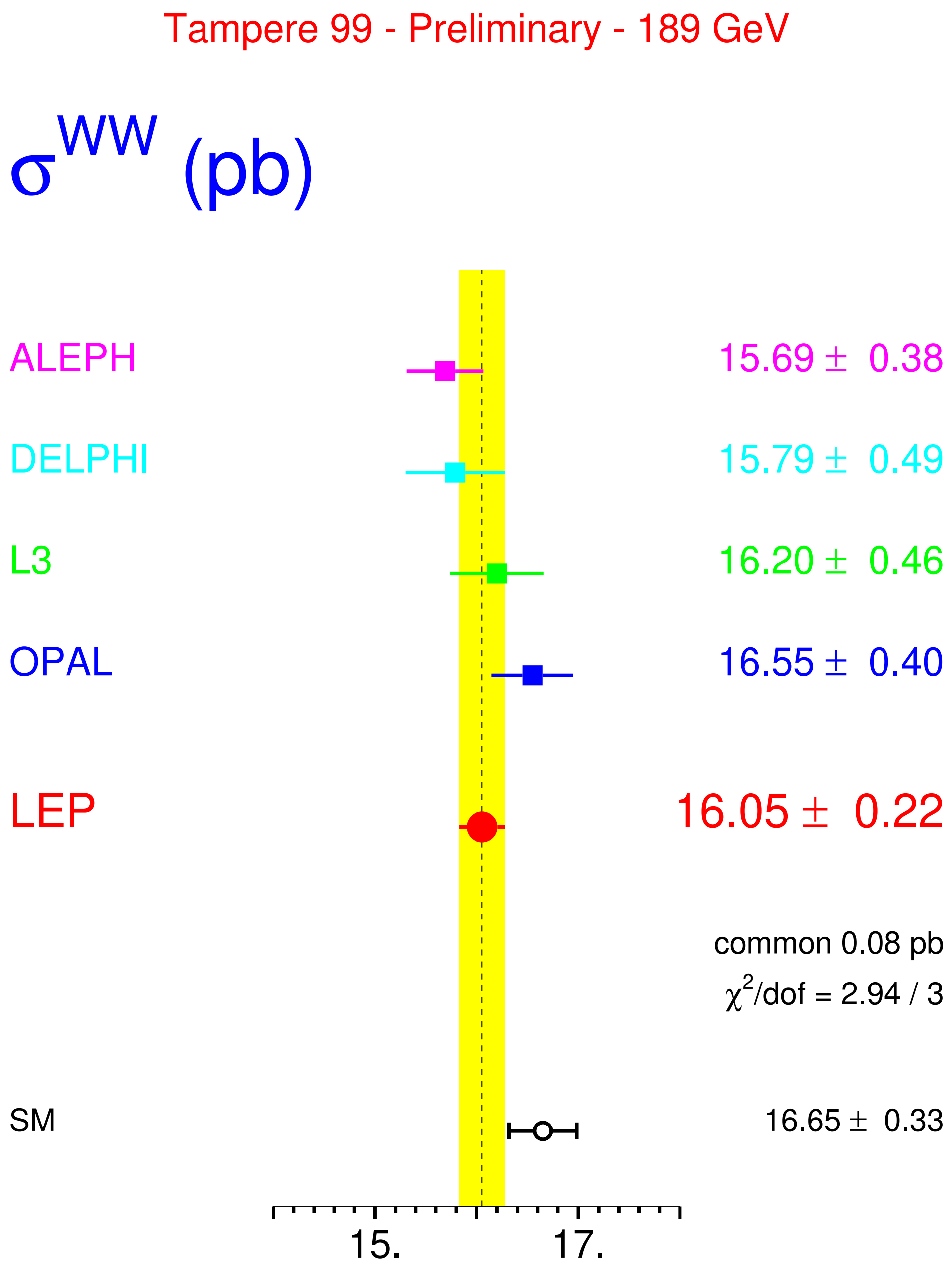
To account for non-CC03 contributions, the σ_j are scaled by a factor

$$f_j = \frac{\sigma_j^{CC03}}{\left[\sigma_j^{4f}\right]_{phase\ space}}$$

(corrections of 0-10%, mainly in $qqe\nu$ and $l\nu l\nu$)

To obtain full CC03 cross section and branching ratios, σ_j are replaced by $r_j\sigma_{WW}$, with

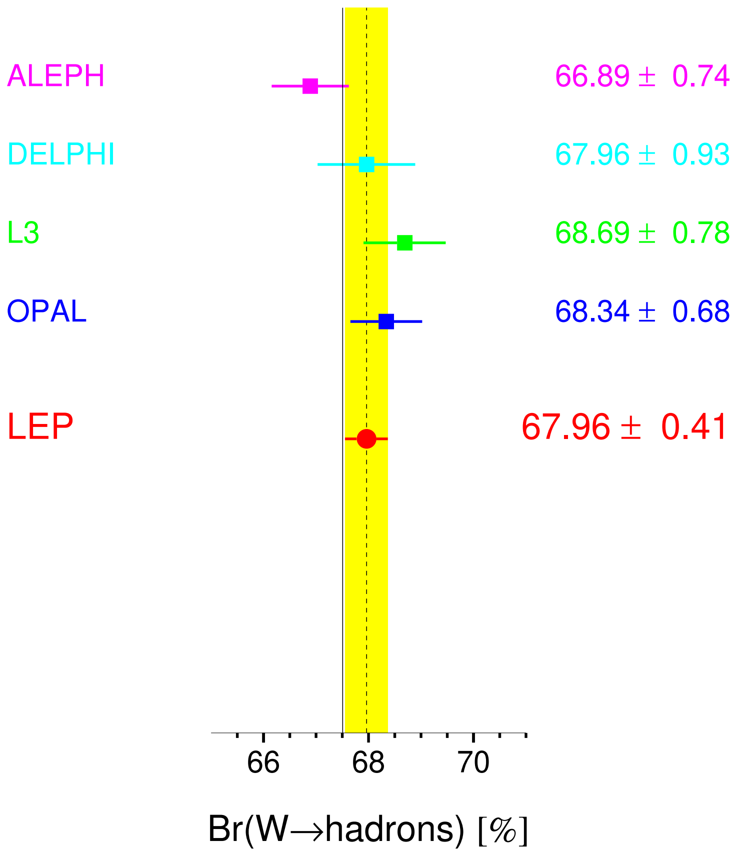
$$r_j = \begin{cases} Br(W \to q\bar{q})^2 & , j = q\bar{q}q\bar{q} \\ 2Br(W \to q\bar{q}) \times Br(W \to l\nu) & , j = q\bar{q}l\nu \\ Br(W \to l\nu)^2 & , j = l\nu l\nu \\ 2Br(W \to l\nu) \times Br(W \to l'\nu') & , j = l\nu l'\nu' \end{cases}$$



Measured Branching ratios

Tampere 99 - Preliminary - [161-189] GeV

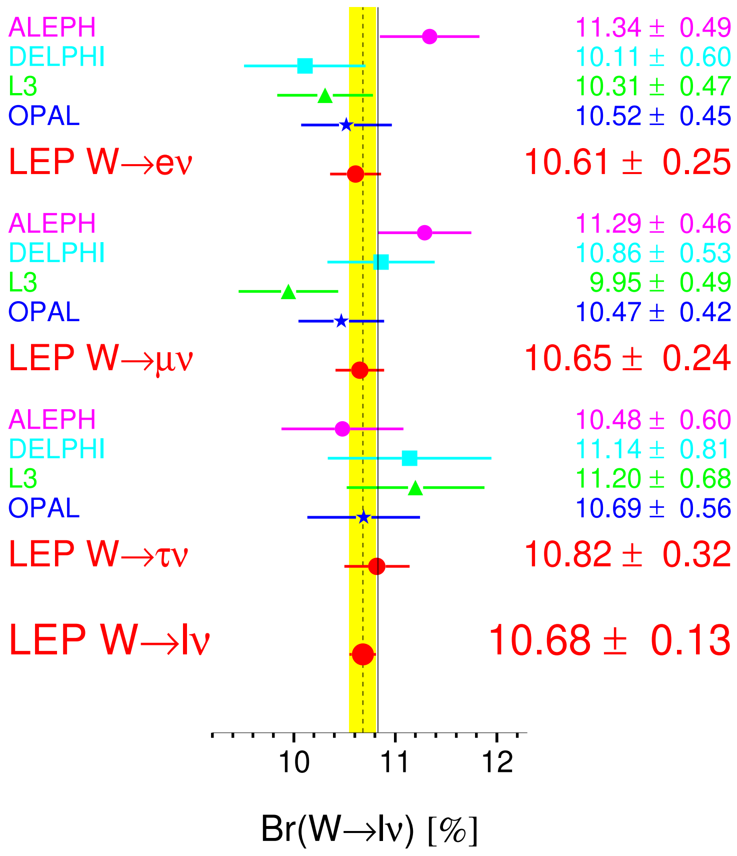
Br(W→hadrons) [%]



SM: 67.5%

Tampere 99 - Preliminary - [161-189] GeV

W Leptonic Branching Ratios



SM: 10.8%

Within Standard Model,

$$\frac{1}{Br(W \to l\nu)} = 3\left\{1 + \left(1 + \frac{\alpha_s(M_W^2)}{\pi}\right)\sum \left|V_{ij}^{CKM}\right|^2\right\}$$

$\Rightarrow$ we can extract $|V_{cs}|$ using

- combined LEP measurement of branching ratios
- world average of other $V_{qq'}$, and
- $\alpha_s(M_W^2) = 0.121 \pm 0.002$:

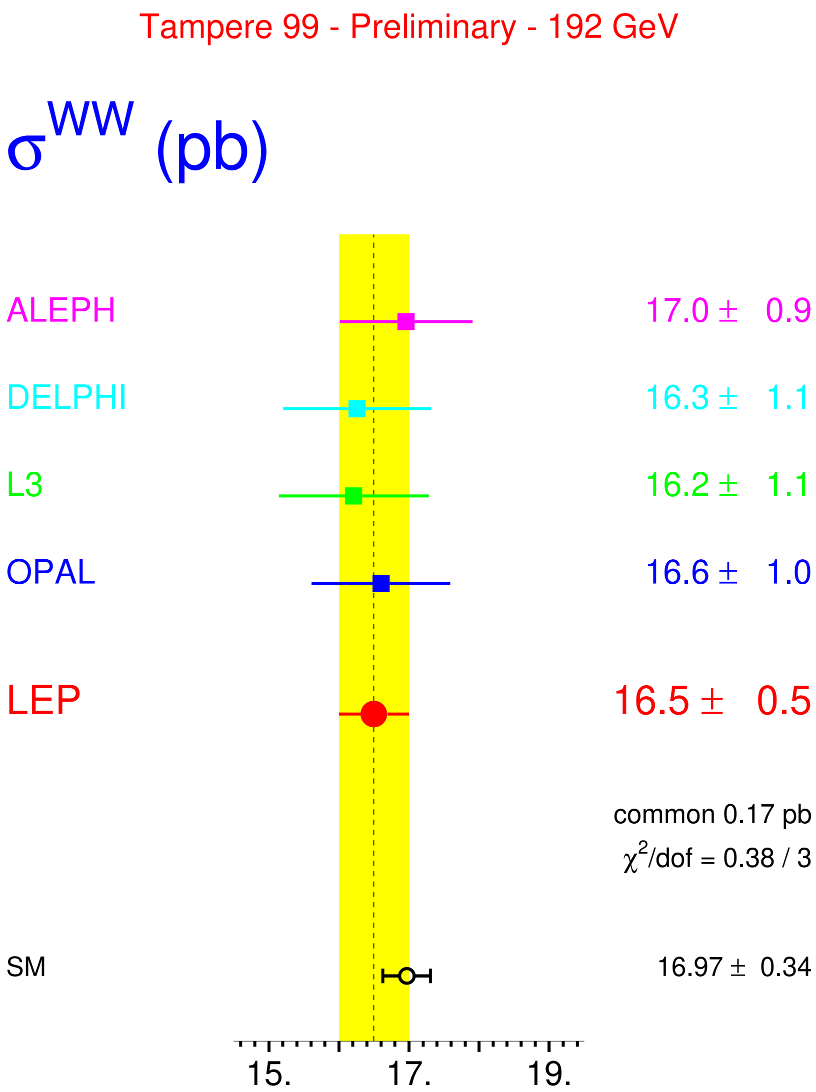
$$|V_{cs}| = 0.997 \pm 0.020$$

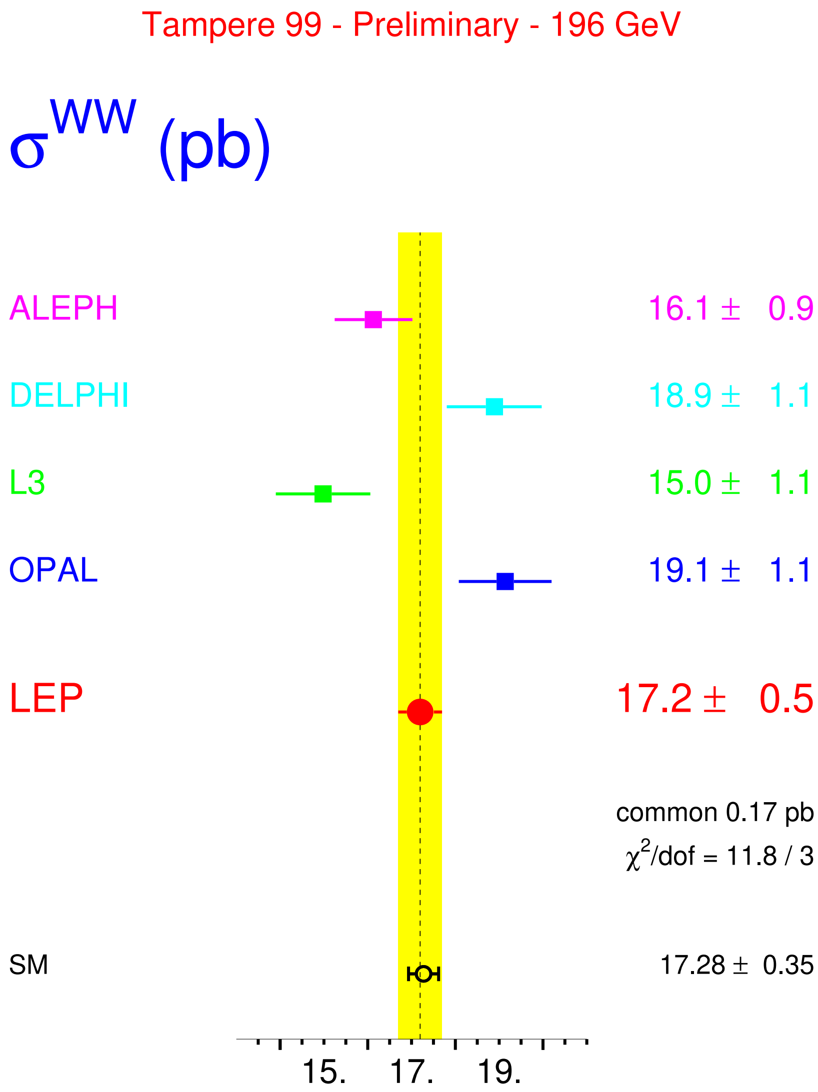
without assuming unitarity of V^{CKM}.

Direct measurement using charm tag:

Aleph: $|V_{cs}| = 1.00 \pm 0.11(stat.) \pm 0.07(syst.)$
Opal: $|V_{cs}| = 0.91 \pm 0.07(stat.) \pm 0.11(syst.)$

Preliminary results at $\sqrt{s}$ = 192 & 196 GeV





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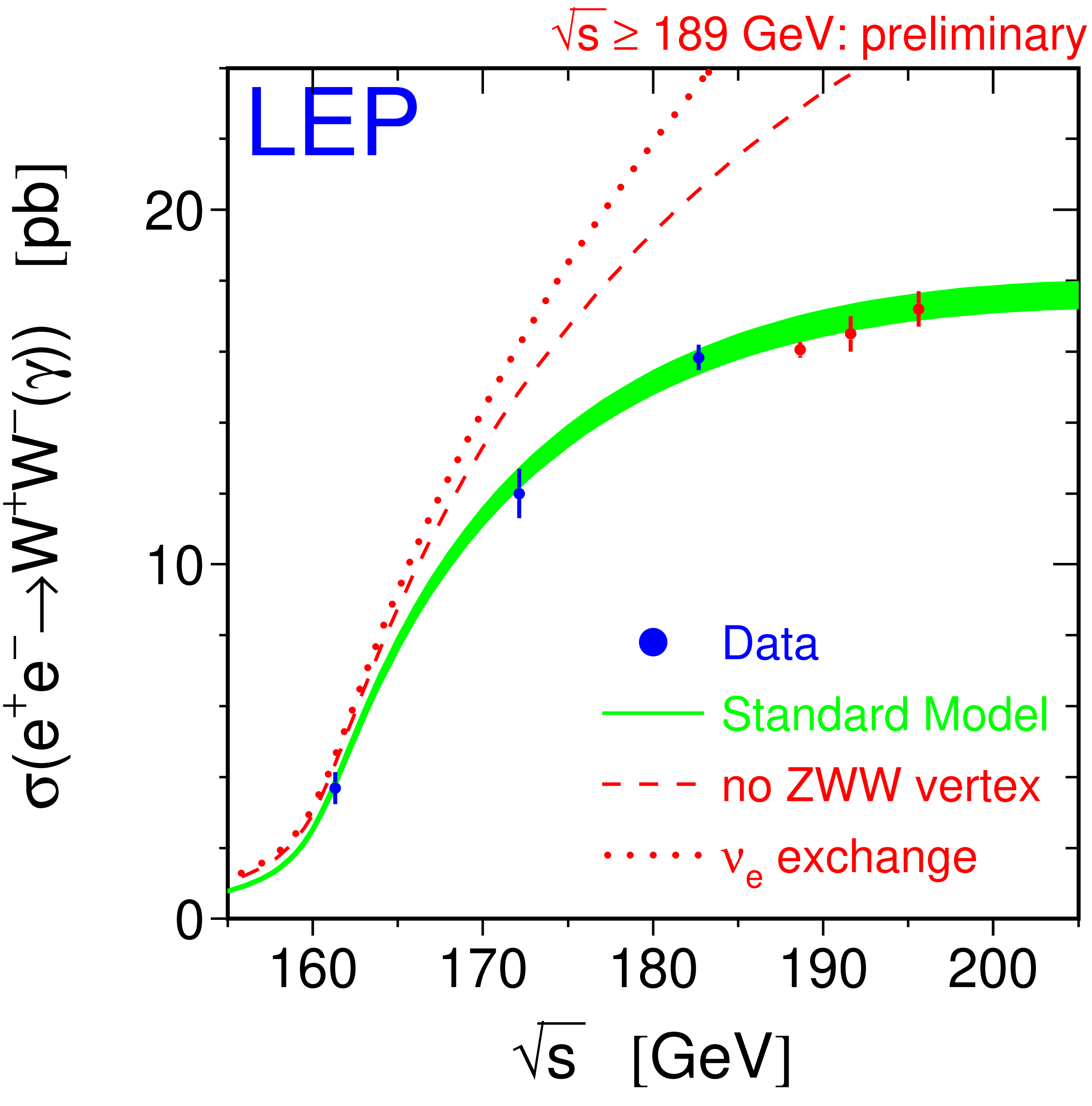
EPS-HEP99, Tampere, July 1999


√s ≥ 189 GeV: preliminary
LEP
σ(e+e−→W+W−(γ)) [pb]
0
10
20
160
170
180
190
200
√s [GeV]
Data
Standard Model
no ZWW vertex
νe exchange

Summary

- Very successful LEP II operation

- $\mathcal{O}(4500)$ WW events collected by each experiment so far

- Cross section measurement in good agreement between experiments and with SM prediction:

  $\sigma_{WW}^{CC03}(189\mathrm{GeV}) = 16.05 \pm 0.22$ pb (SM: 16.65 ± 0.33pb)

- Combined measurement of branching ratios from $\sqrt{s} = 161 - 189$ GeV LEP data is in good agreement with SM:

  $\mathrm{Br}(WW \rightarrow qq) = 67.96 \pm 0.41\%$ (SM: 67.5%)

  $\mathrm{Br}(WW \rightarrow l\nu) = 10.68 \pm 0.13\%$ (SM: 10.8%)

- $|V_{cs}| = 0.997 \pm 0.020$

- We are looking forward to continued LEP running at up to $\sqrt{s} = 200$ GeV