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WW CROSS SECTIONS AND W BRANCHING RATIOS

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On behalf the LEP collaborations

OUTLINE

- W Pair production at LEP
- W selections
- WW cross sections
- W Branching ratios
- Measurements of $|V_{cs}|$
- Conclusions

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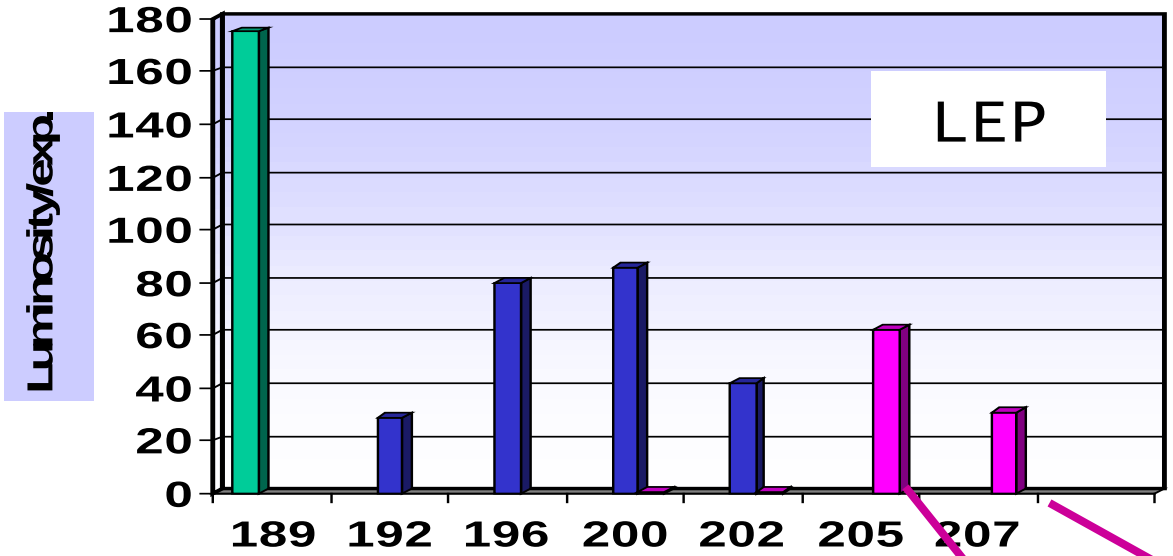
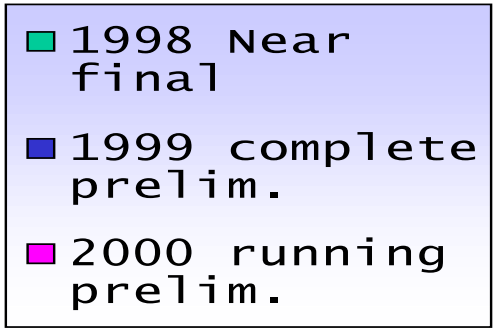
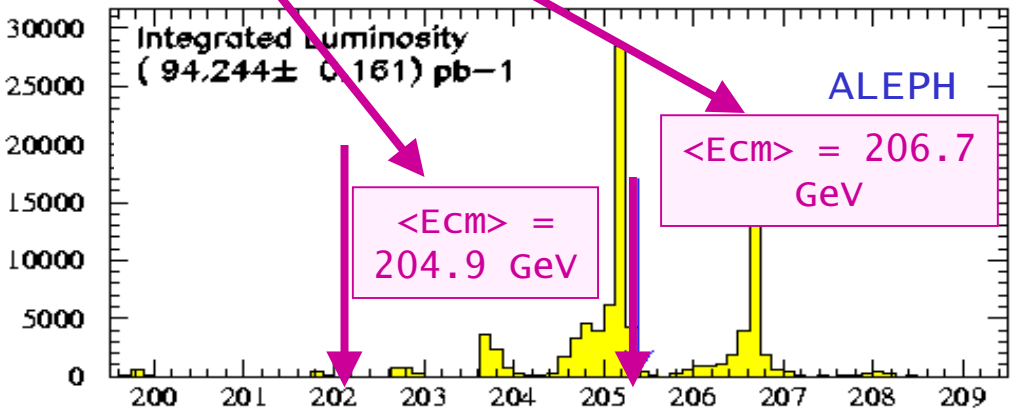
LEP DATA collected / experiment





∫ Luminosity/exp. 96-99 :
475 pb^{-1} => ≈ 6300 WW

∫ Luminosity/exp. 2000
: ≈ 90 pb^{-1} => ≈ 1500 WW



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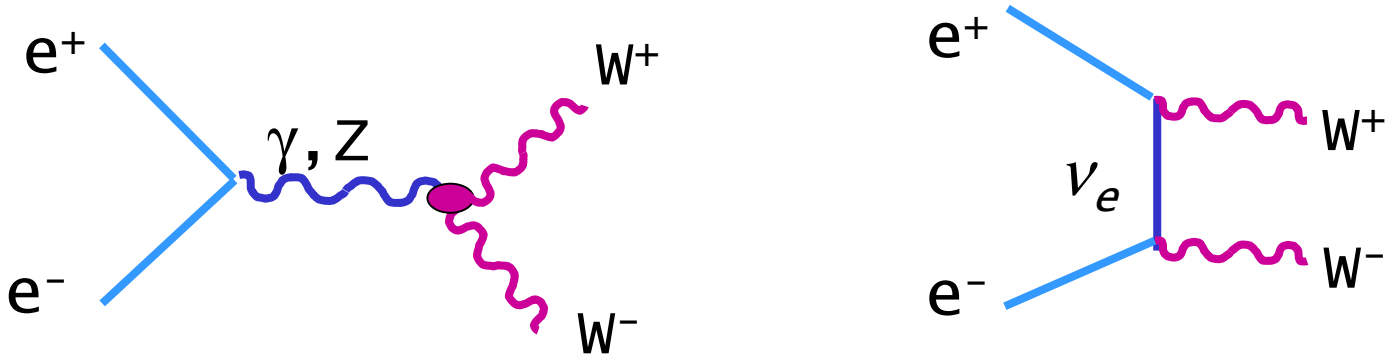
WW PRODUCTION AT LEP

- WW are pair created mainly through 3 diagrams at Born level (CC03):



- Measurements of CC03 cross sections, are corrected for 4-fermion diagram interference.

- WW belongs to the more general CC 4-fermion final states:

WW -> ffff
- → qqqq(46%)
- → qqlν(44%)
- → lνlν(11%)

with l= e,μ,τ

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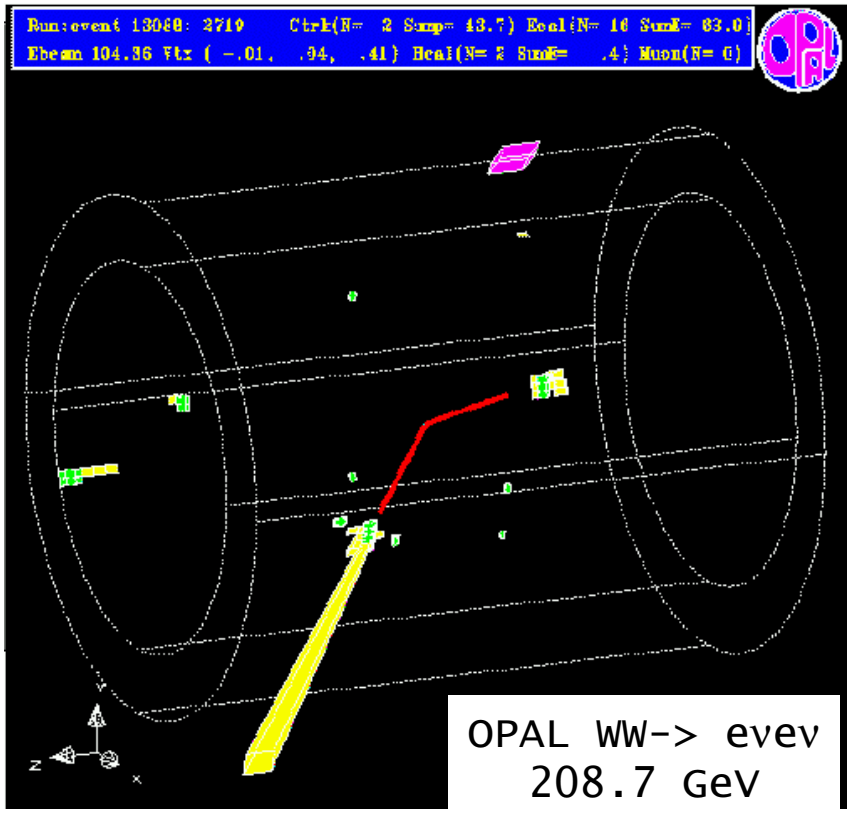
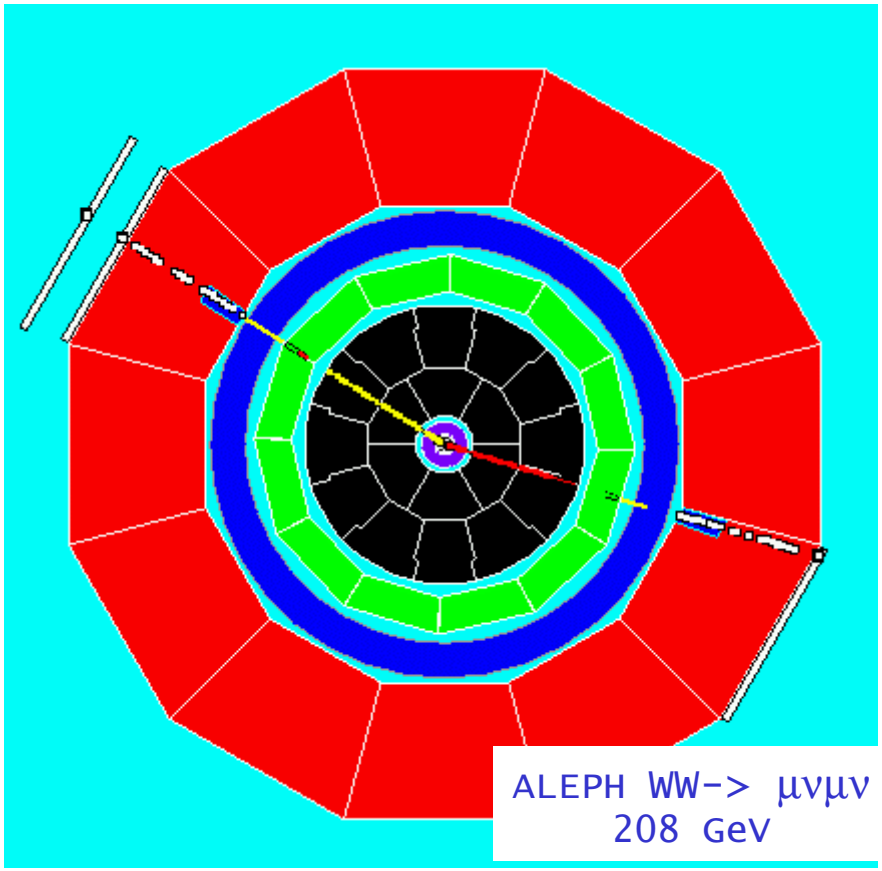
WW SELECTIONS

WW -> lνlν l=e,μ,τ
(11%)





- Characteristics
- 2 acoplanar leptons
- missing energy

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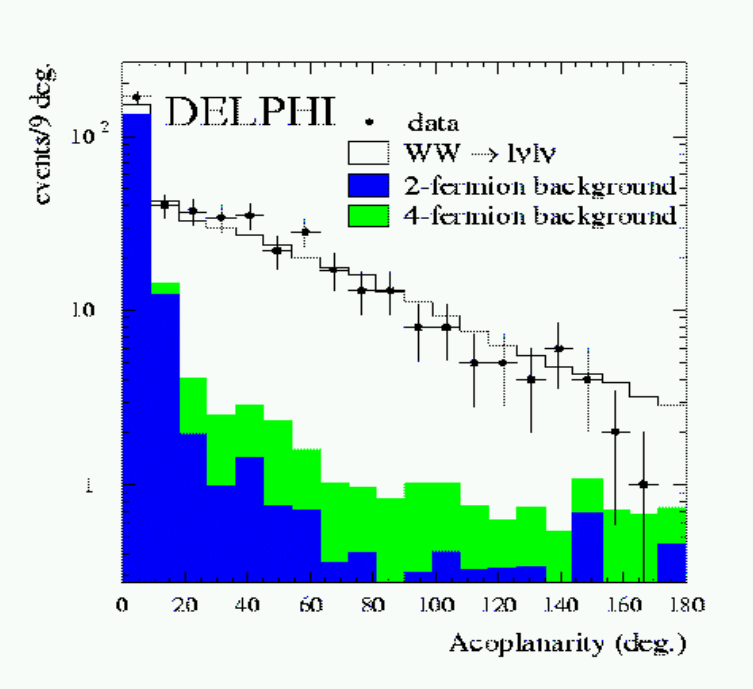
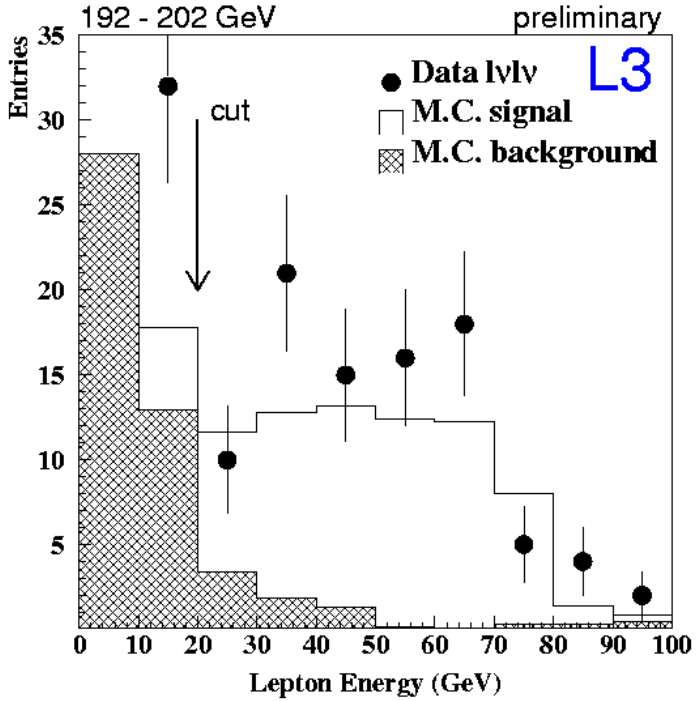
WW SELECTIONS

WW -> lνlν l=e,μ,τ

- Selections

Cut based analyses:
Acoplanarity,lepton momentum,missing energy





Typical efficiencies 60-80 %
background level 150 fb
WW cross section level 2 pb

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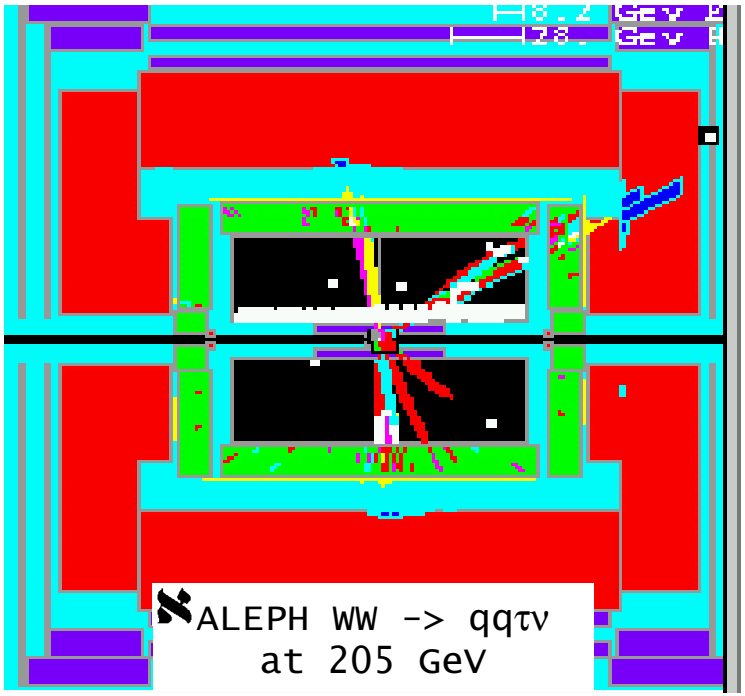
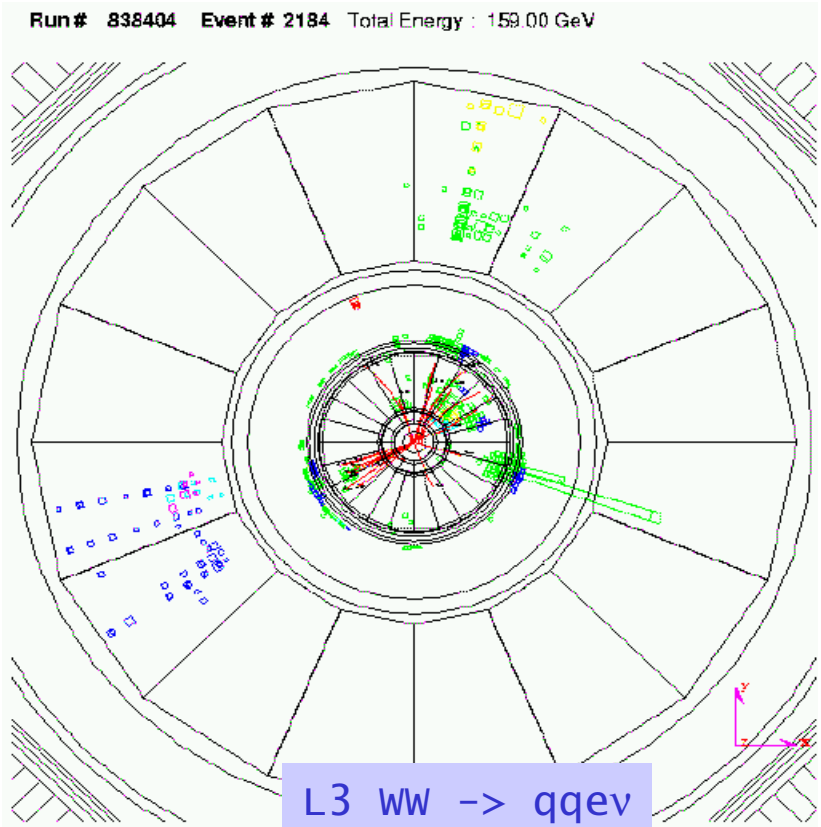
WW SELECTIONS

WW -> qqlν l=e,μ,τ (44%)

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



ALEPH WW -> qqτν
at 205 GeV



L3 WW -> qqeν
at 206 GeV

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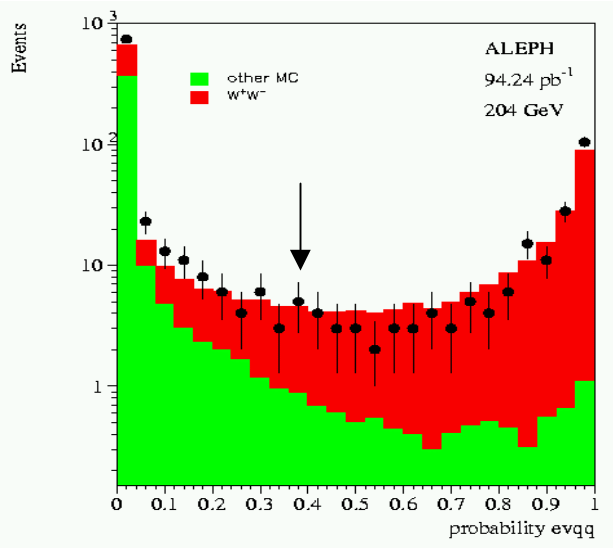
WW SELECTIONS

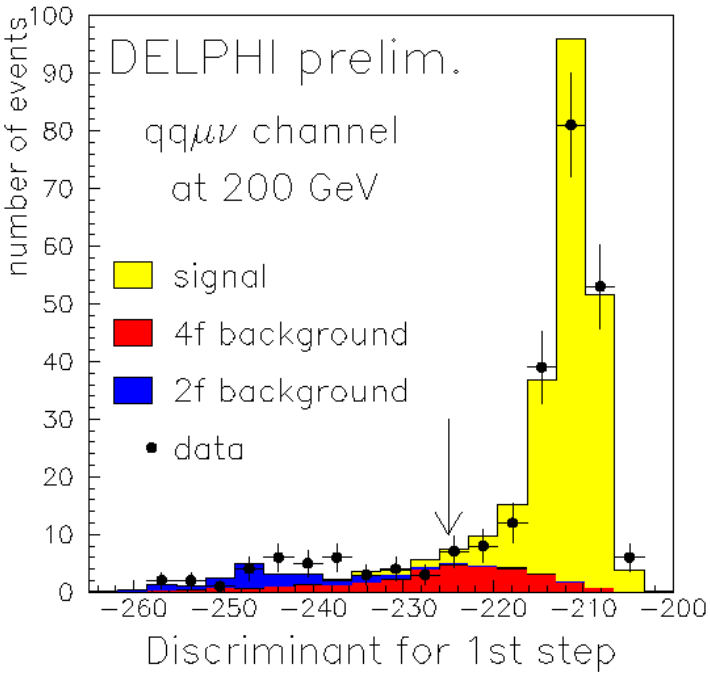
WW -> qqlν l=e,μ,τ

- Selections

Cut based analyses and/or probabilities/likelihood

- based on E_{lepton}, isolation criteria
- τ jet identification





Typical efficiencies e/μ 85 %
τ 60 %
background level e/μ 100 fb
τ 200 fb
WW cross sections level 3 pb
each channel

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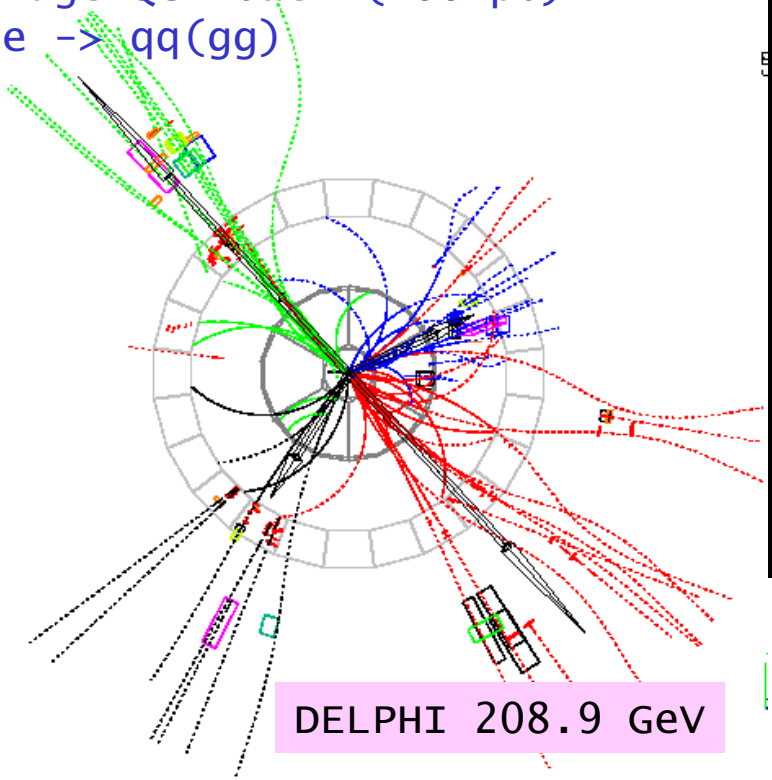
WW SELECTIONS

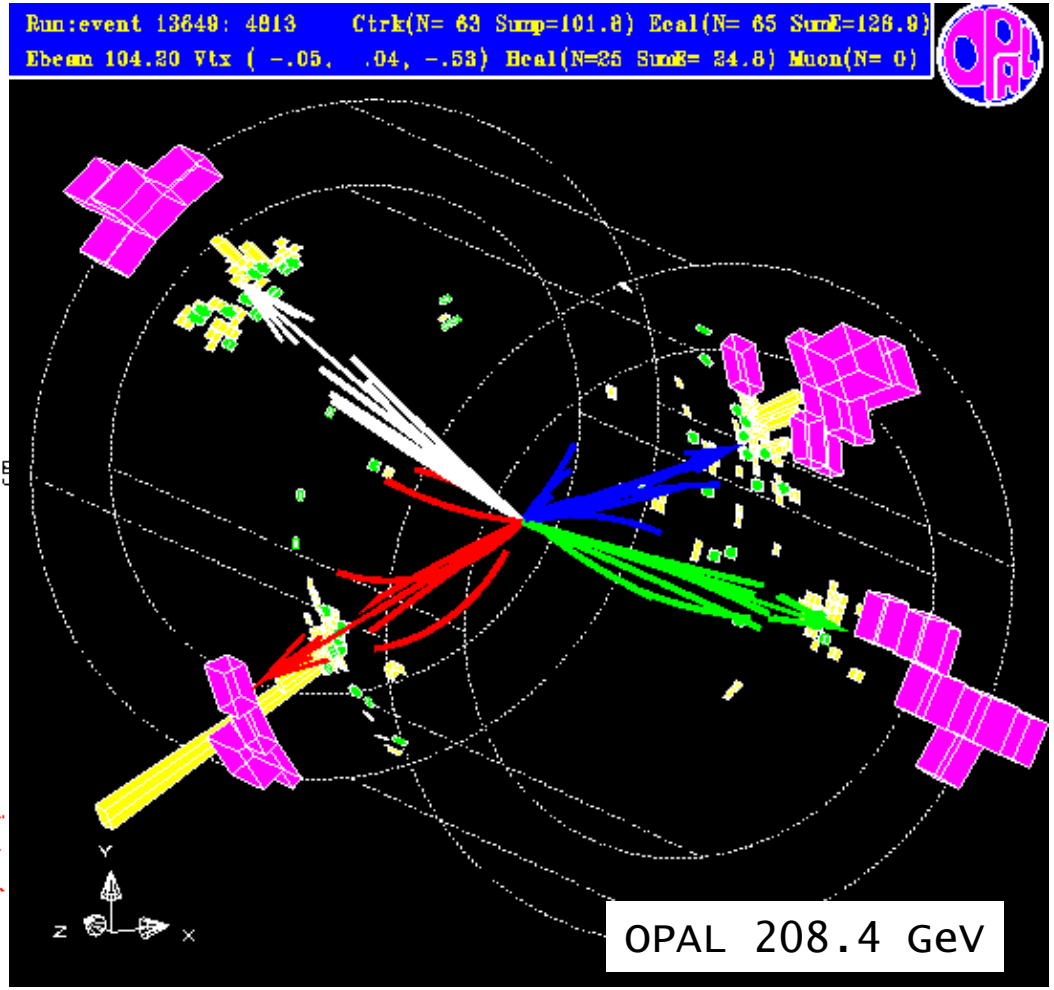
WW -> qqqq (46%)

- Characteristics
- 4 hadronic jets
- No missing energy
- Huge QCD back.(100 pb)

ee -> qq(gg)



DELPHI 208.9 GeV



OPAL 208.4 GeV

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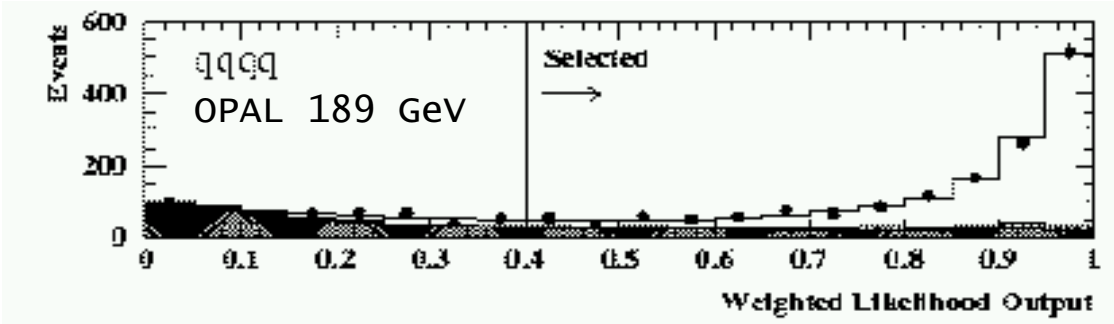
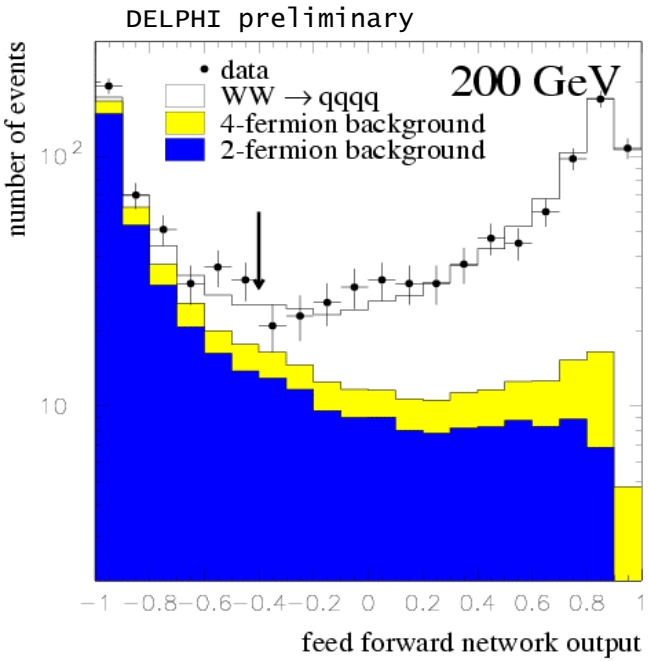
WW SELECTIONS

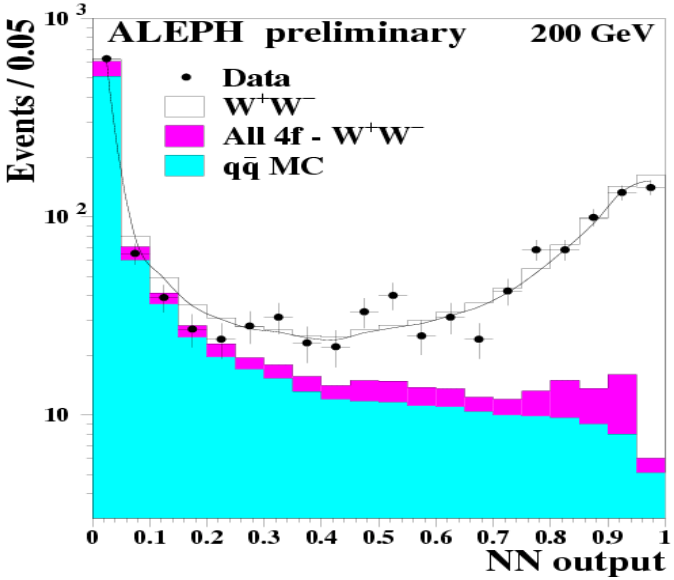
WW -> qqqq

- Selections

Neural Networks,
Likelihood analyses







Typical efficiencies 90 %
background level 2 pb
WW cross section level 8 pb

WW CROSS SECTIONS

I

Extraction of the cc03 cross sections/channel:

Maximum likelihood fit between the number of observed events and the number of expected events

$$L = \prod_i P(N_i^{obs}, N_i^{exp}) \quad \text{with} \quad N_i^{exp} = l * \sum_j \varepsilon_{ij}\sigma_j + N_i^{bkg}$$

Luminosity

Efficiency matrix

Background +cc03-4f corr

Extraction of the total cross section and branching ratio

$$\sigma_j = b_j * \sigma_{WW}$$

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

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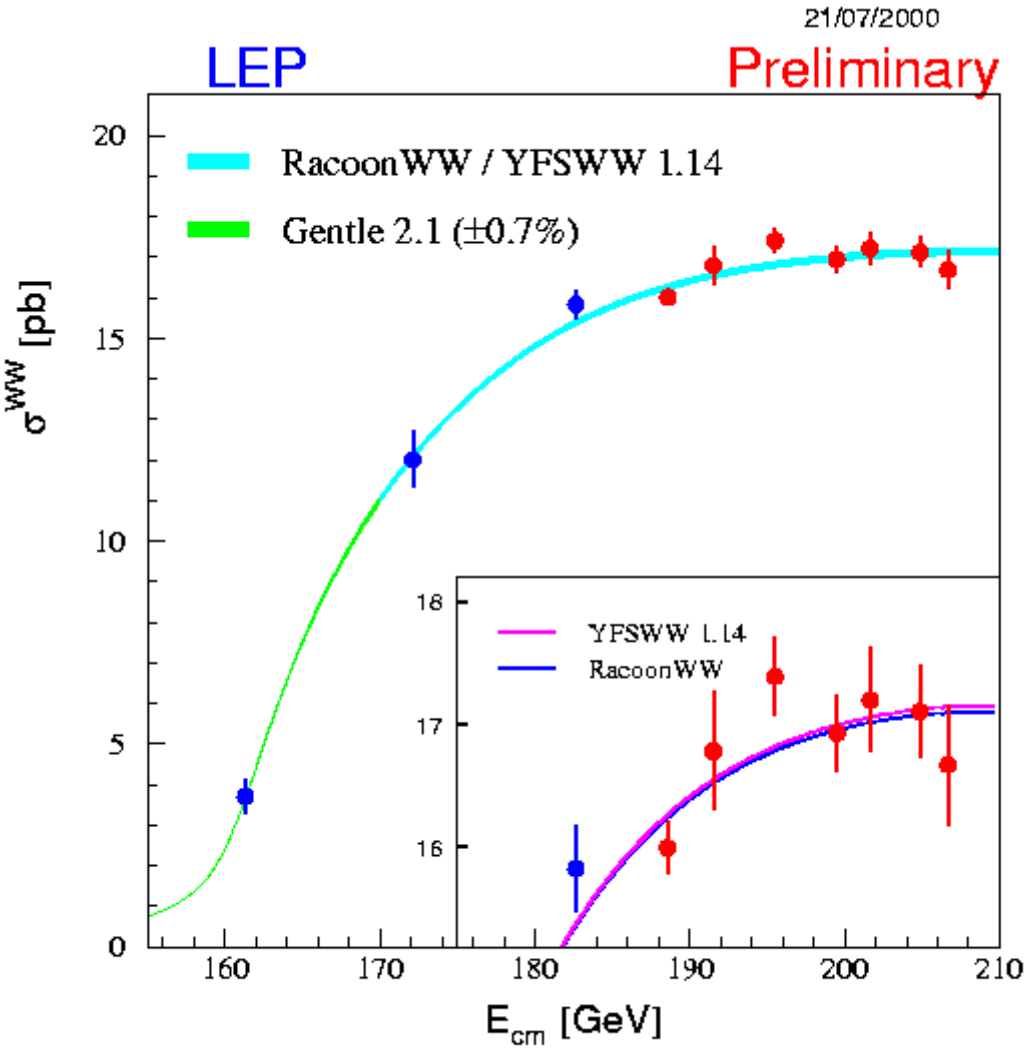
WW CROSS SECTIONS



Theoretical improvements:

- New models with DPA calculation (RacoonWW and YFSWW)
  Error =f(Ecm,Mw) 0.4%-0.7%
- New Gentle 2.1
  Error 2% -> 0.7%
  (only due to ISR)

Better agreement with experimental values

Ref: RacoonWW: hep-ph/0006307
YFSWW 1.14: UTHEP 00-0101
for details see hep-ph/0005309
and ref in

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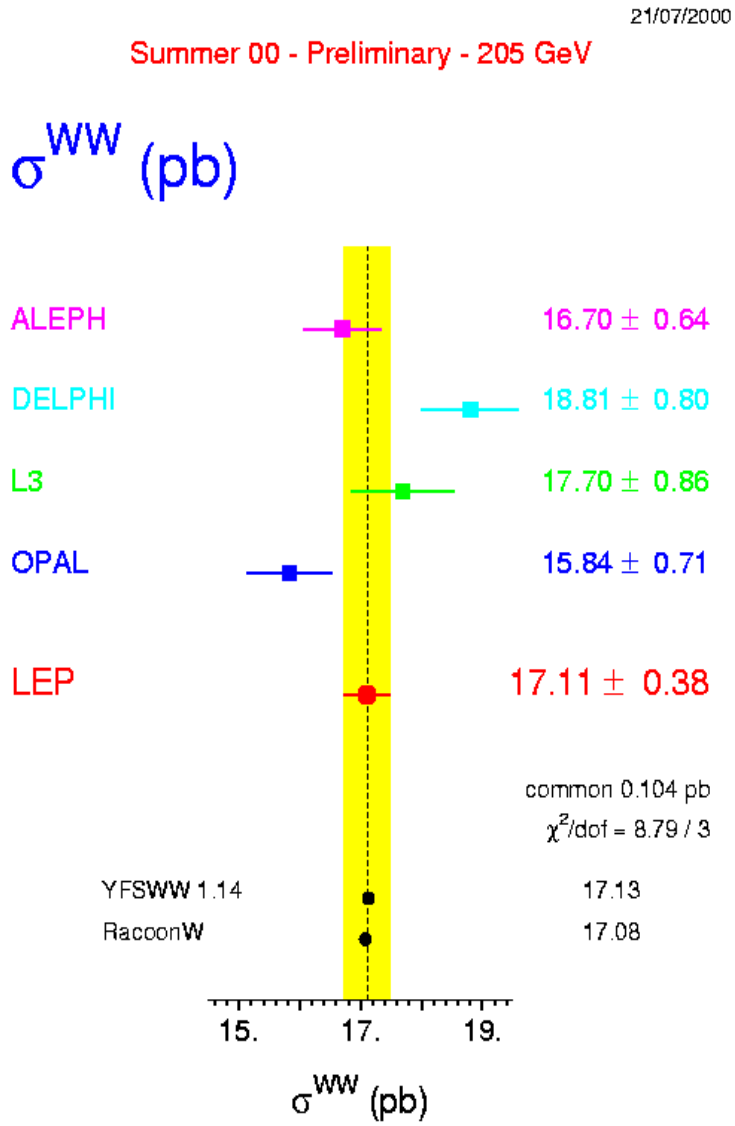
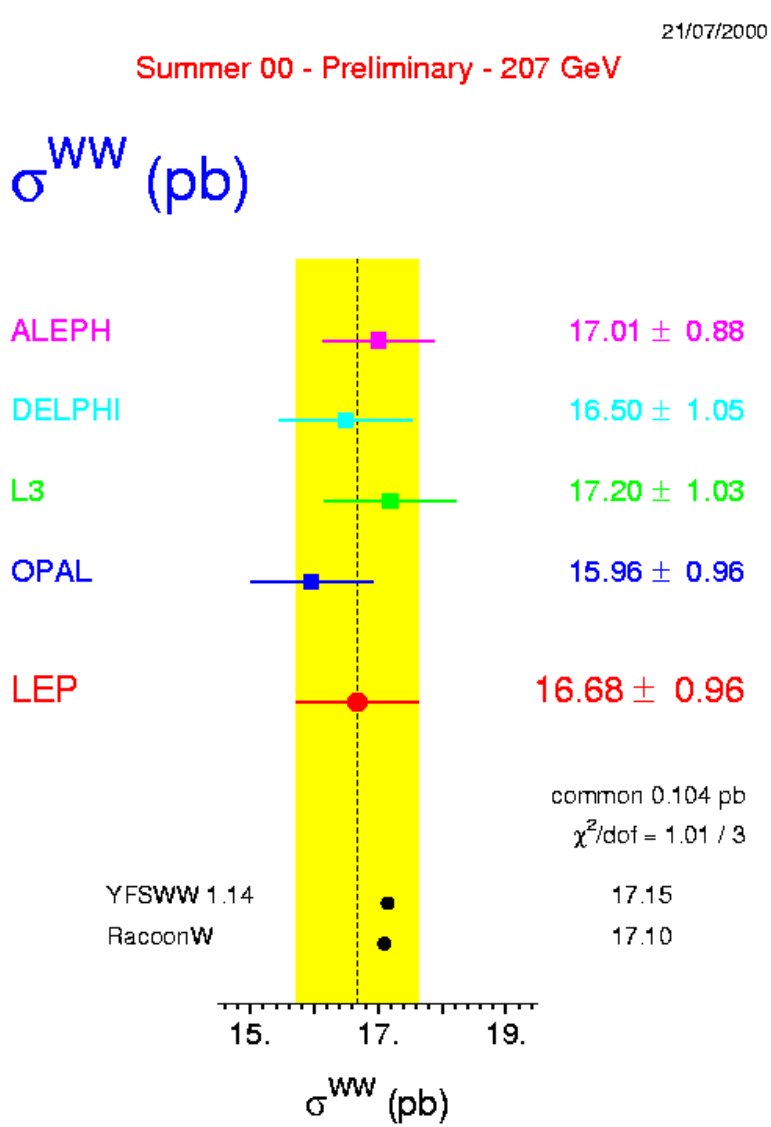
WW CROSS SECTIONS





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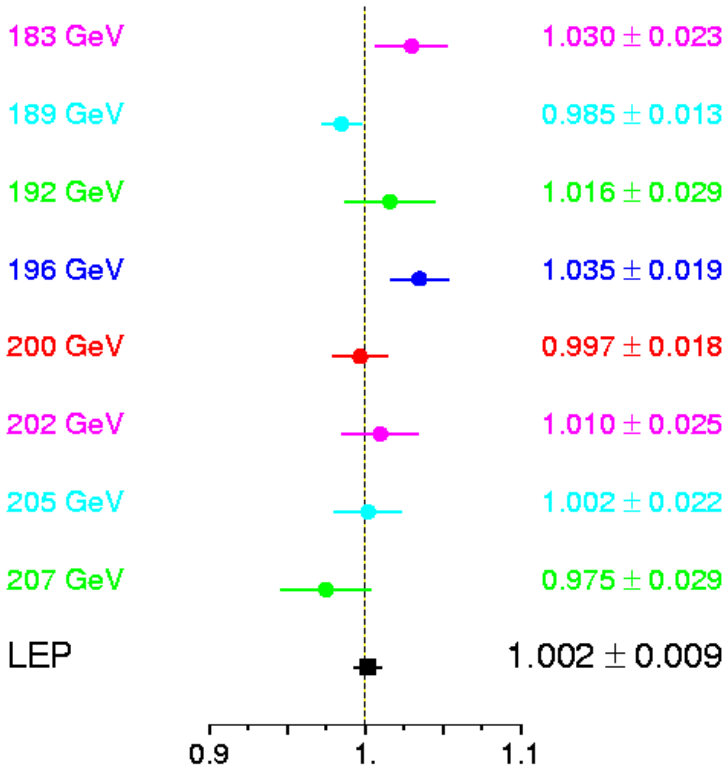
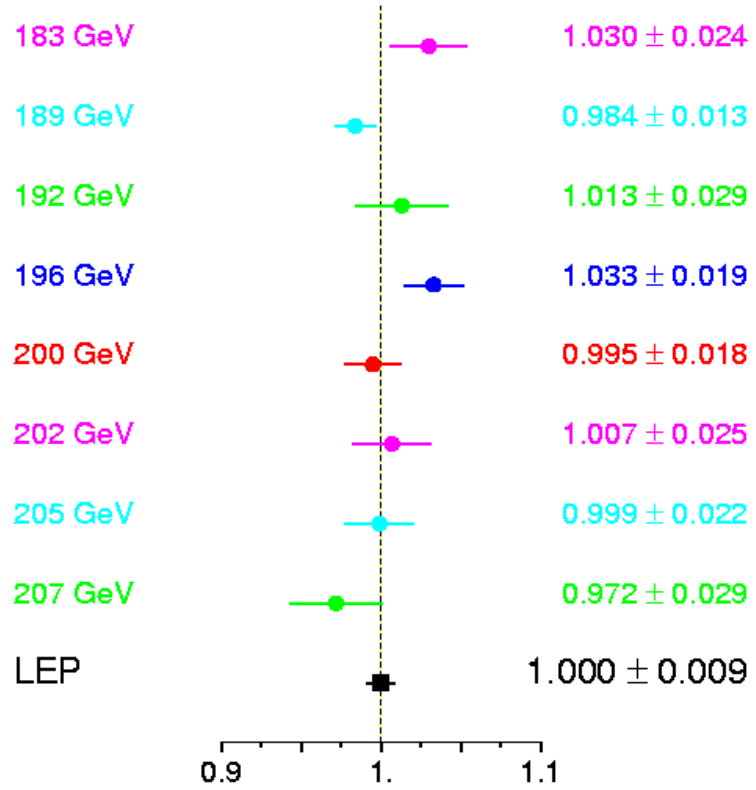
WW CROSS SECTIONS

Summer 00 - Preliminary - Measured σ^{WW} / RacoonW



Summer 00 - Preliminary - Measured σ^{WW} / YFSWW 1.14



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WW Branching Fractions

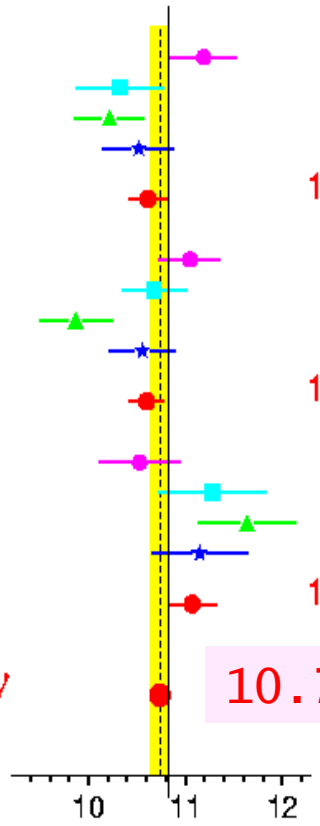
21/07/2000

Summer 00 - Preliminary - [161-207] GeV

W Leptonic Branching Ratios

ALEPH	11.19 ± 0.34
DELPHI	10.33 ± 0.45
L3	10.22 ± 0.36
OPAL	10.52 ± 0.37
LEP W→eν	10.62 ± 0.19
ALEPH	11.05 ± 0.32
DELPHI	10.68 ± 0.34
L3	9.87 ± 0.38
OPAL	10.56 ± 0.35
LEP W→μν	10.60 ± 0.18
ALEPH	10.53 ± 0.42
DELPHI	11.28 ± 0.56
L3	11.64 ± 0.51
OPAL	11.15 ± 0.50
LEP W→τν	11.07 ± 0.25
LEP W→lν	10.74 ± 0.10%

DELPHI [161-202] GeV
L3 [161-202] GeV



Br(W→lν) [%]

SM = 10.8 %

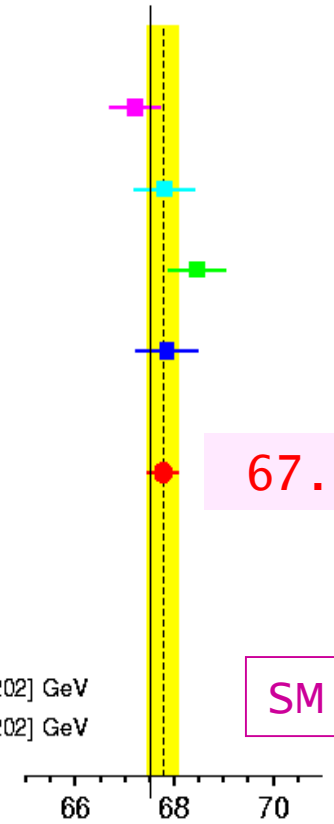
20/07/2000

Summer 00 - Preliminary - [161-207] GeV

Br(W→hadrons) [%]

ALEPH	67.22 ± 0.53
DELPHI	67.81 ± 0.61
L3	68.47 ± 0.59
OPAL	67.86 ± 0.62
LEP	67.78 ± 0.32%

DELPHI [161-202] GeV
L3 [161-202] GeV



Br(W→hadrons) [%]

SM = 67.5 %

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$|V_{cs}|$ MEASUREMENT

Indirect Measurement from Br(W -> qq)

$$\frac{Br(W \to q\bar{q})}{1-Br(W \to q\bar{q})} = \left(1+\frac{\alpha_s}{\pi}\right) \sum_{i=u,c;j=d,s,b} |V_{ij}|$$

Using
- The LEP Br(W -> qq)
- world average of V_{ij}
- $\alpha_s(M_W^2) = 0.121 \pm 0.002$

$$|V_{cs}| = 0.989 \pm 0.016$$

(Without assuming unitarity)

Direct measurement from charm content in W decays

$$R_c = \frac{\Gamma(W \to cX)}{\Gamma(W \to qq)} = \frac{|V_{cd}|^2 + |V_{cs}|^2 + |V_{cb}|^2}{\sum_{i=u,c;j=d,s,b} |V_{ij}|^2}$$

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SUMMARY on $|V_{cs}|$

Summer 00 - Preliminary - Vcs

from R_C

ALEPH [183] GeV 1.00 ± 0.13

DELPHI [172] GeV 0.87 ± 0.26

L3 [183] GeV 0.98 ± 0.23

New → OPAL[183-189] GeV 0.91 ± 0.13

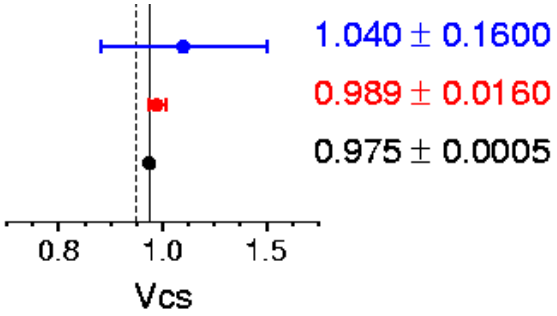
LEP DIRECT 0.95 ± 0.08

Other measurement

PDG D→Klν 1.040 ± 0.1600

New → LEP W→qq 0.989 ± 0.0160

Unitarity 0.975 ± 0.0005



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CONCLUSIONS

•LEP2 is working very successfully at very high Energies (up to 209 GeV)..and is still running

•WW Cross section measurements updated: 2 new points at 205 and 207 GeV added (overall of 10 energies points)

•Good agreement with the recent calculations of RacoonWW / YFSWW

•Branching ratios extraction from Combined LEP data: Ecm = 161 GeV to 207 GeV

Br(WW -> qq) = 67.78 ± 0.32 % (SM: 67.5 %)
Br(WW -> lν) = 10.74 ± 0.10 % (SM: 10.8 %)

•From WW production $|V_{cs}| = 0.989 \pm 0.016$