W mass measurements using fully hadronic events at LEPII

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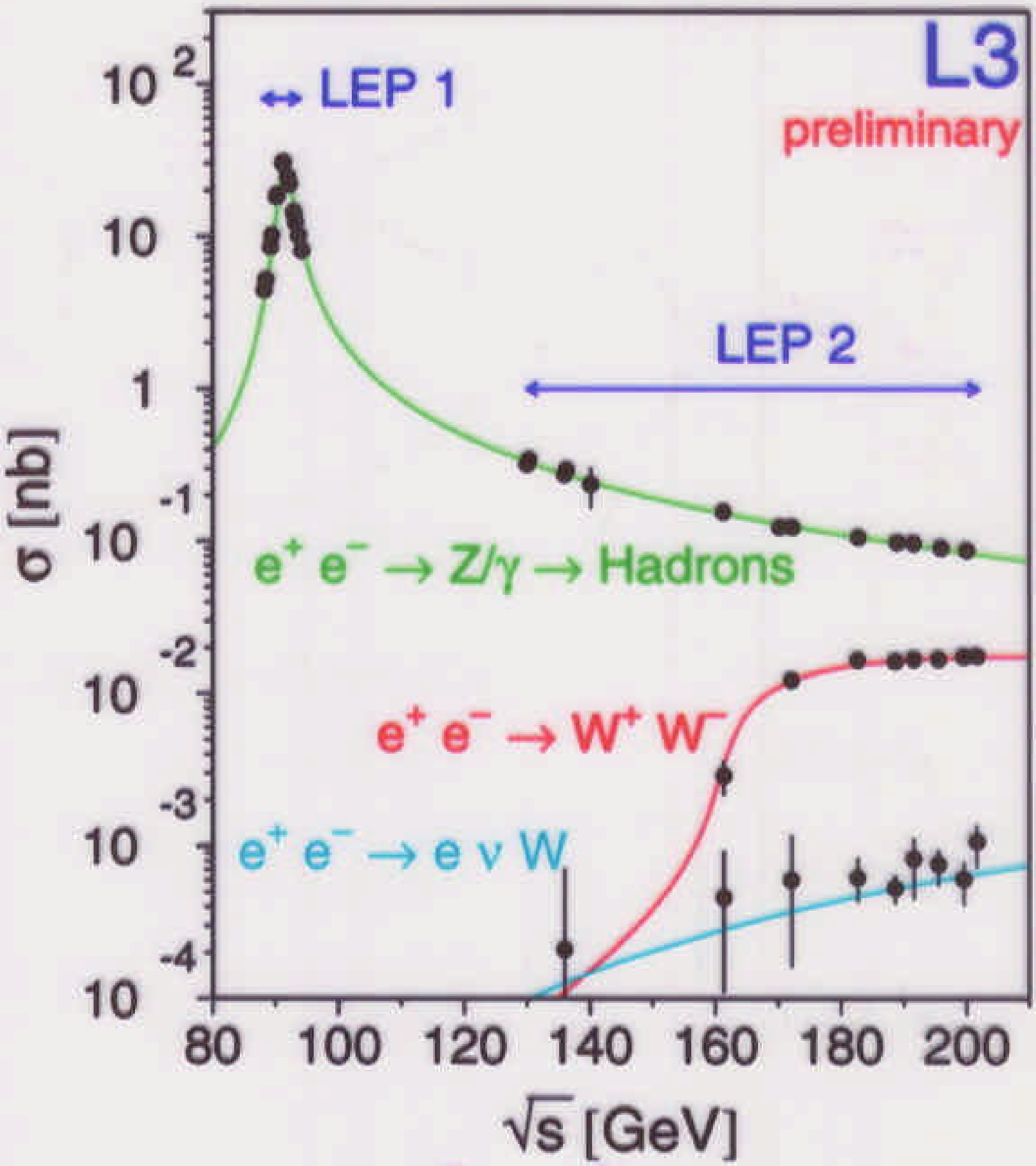
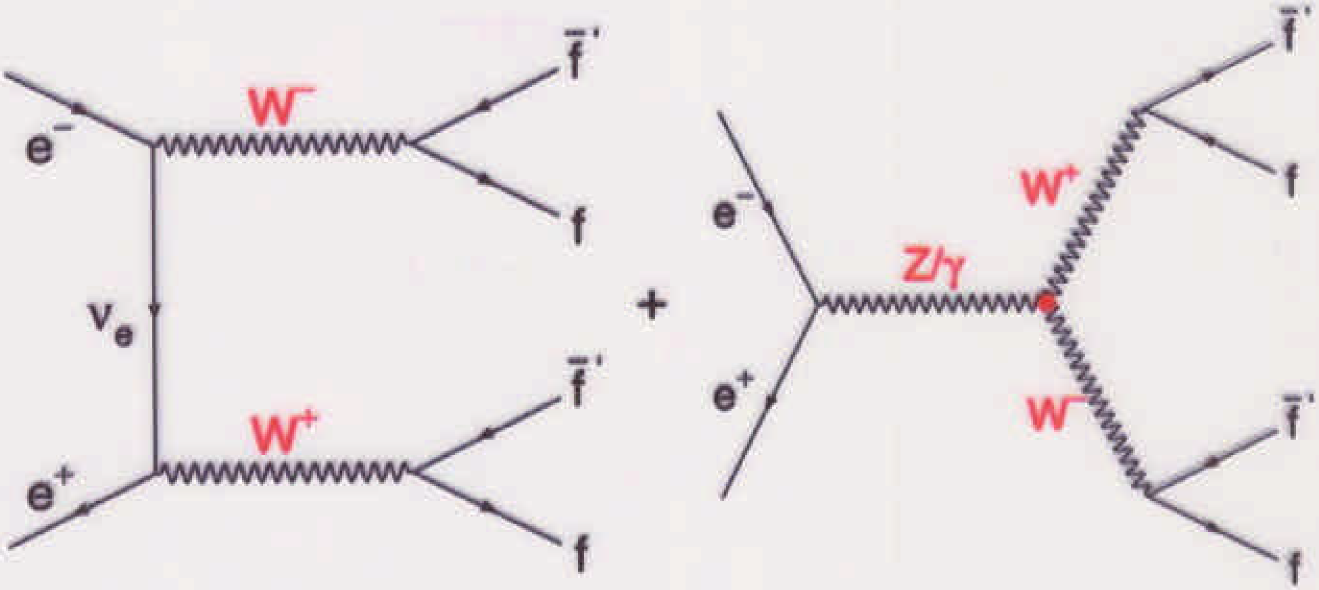
W boson production at LEP



- LEP: 460 – 500 pb^{-1} per experiment above the W-pair threshold up to 202 GeV
- more than 7000 W-pairs per experiment
- M_W & Γ_W:
  - all experiments: preliminary results from 192 - 202 GeV
  - improved LEP combination

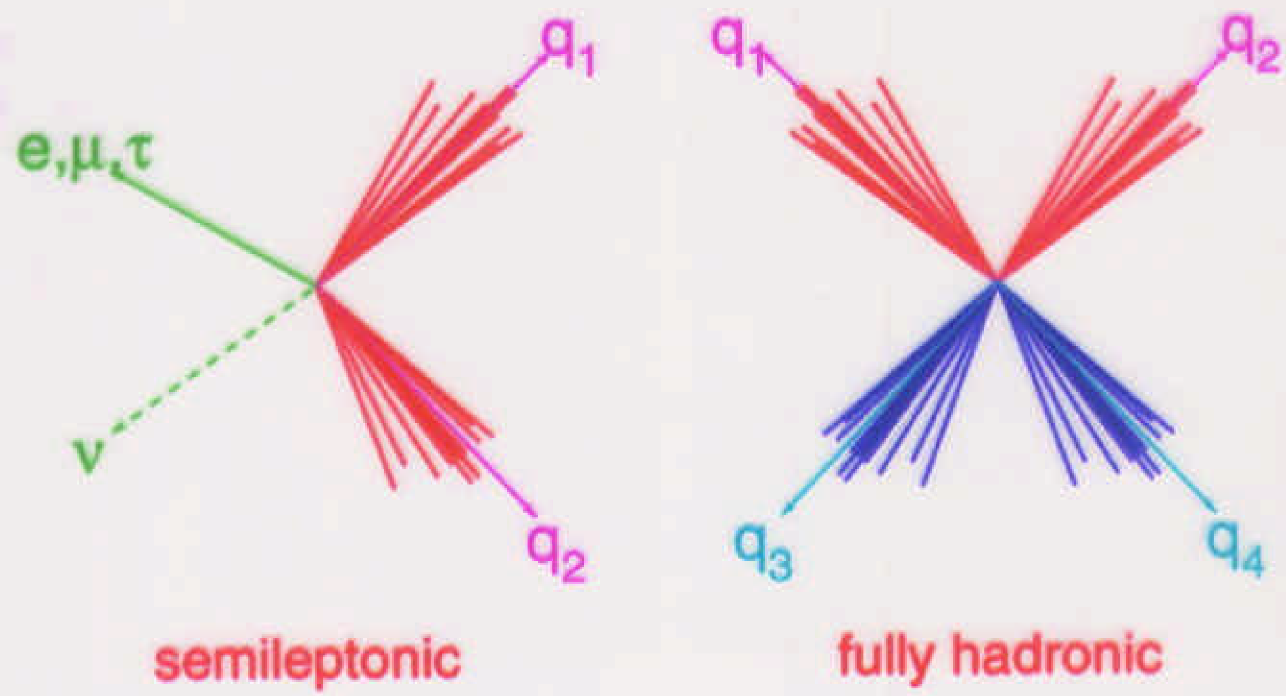
W boson production at LEP

- W^+W^- production at Born level (CC03):

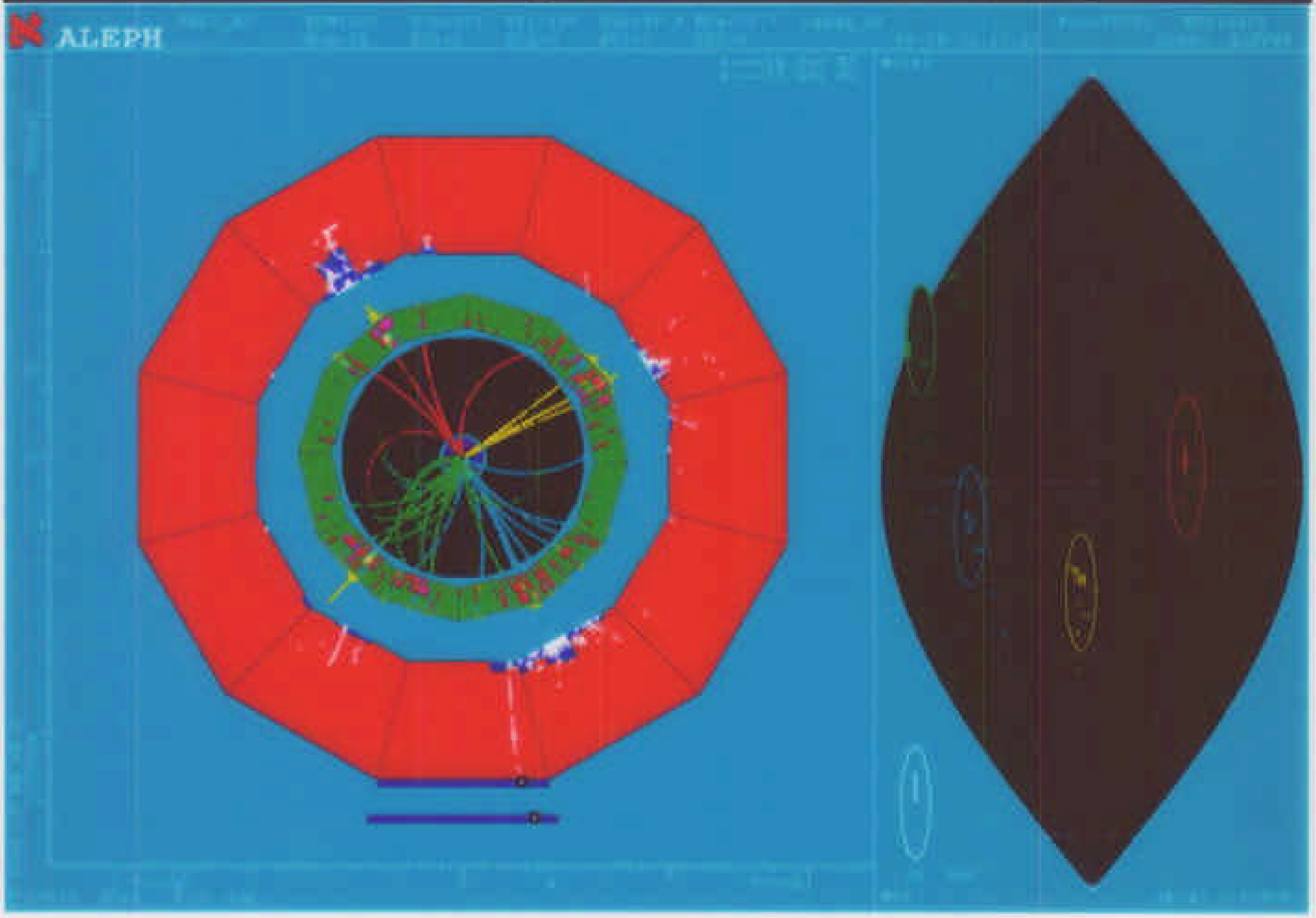


- W^+W^- decay channels:

$WW \rightarrow qqqq$		45.6 %
$WW \rightarrow qq\ell\nu$	$qqe\nu$, $qq\mu\nu$, $qq\tau\nu$	43.8 %
$WW \rightarrow \ell\nu\ell\nu$		10.6 %

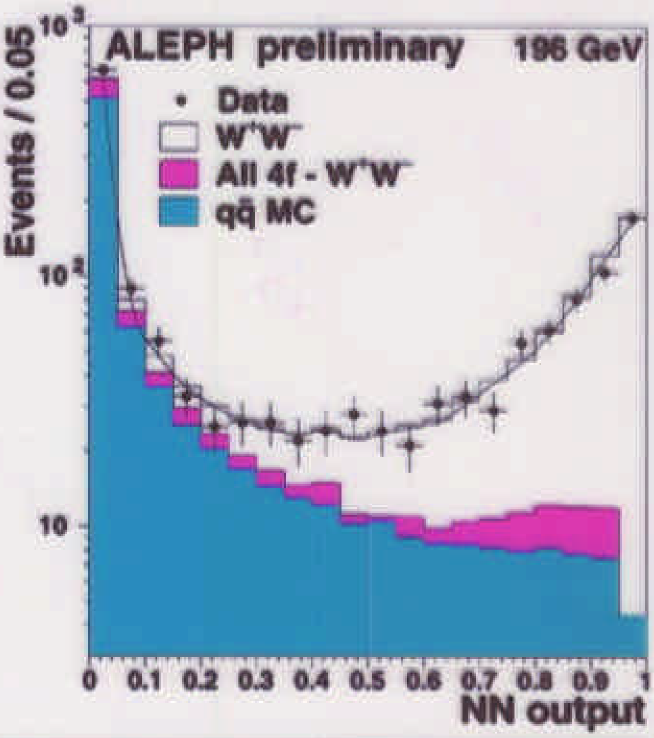


Selection of fully hadronic W^+W^- decays



- $W^+W^- \rightarrow qqqq$:
  - ▷ high multiplicity hadronic events and no missing energy
  - ▷ multivariate analysis to separate signal from background

• qqqq	efficiency	purity
ALEPH	89%	85%
DELPHI	85%	75%
L3	83%	84%
OPAL	85%	78%

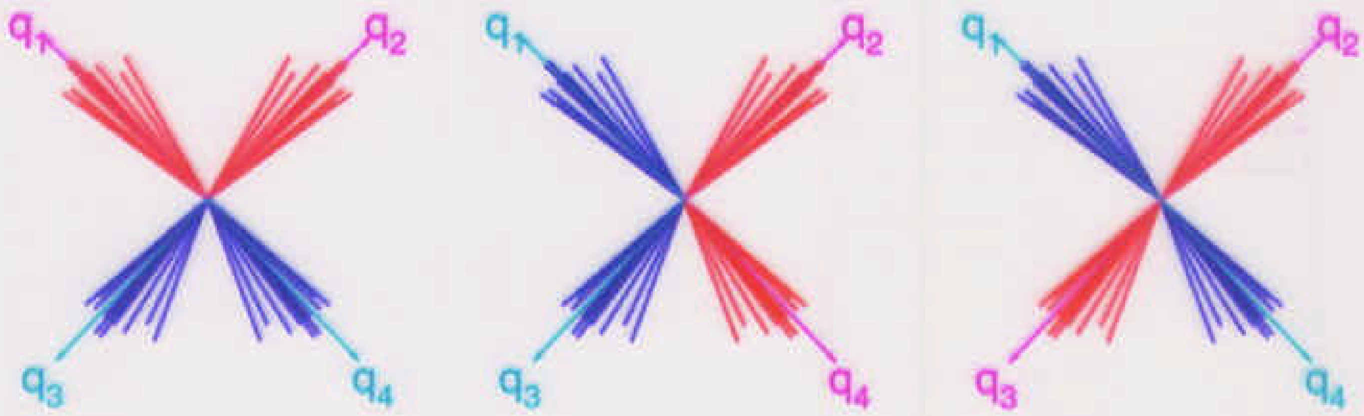


Mass reconstruction

- force event into 4 jets using cluster algorithm
- advantage of $W^+W^- \rightarrow qqqq$: all decay products are observed
- improve raw invariant mass imposing kinematic constraints:
  - E and $\vec{p}$ conservation → 4C
  - equal masses for W bosons → 1C

⇒ kinematic fit mainly improves energy resolution

- 5C kinematic fit and average mass $\langle M \rangle$: L, O
- 4C kinematic fit and two masses (M_1, M_2): A
- 4C kinematic fit and complete likelihood for each event: D



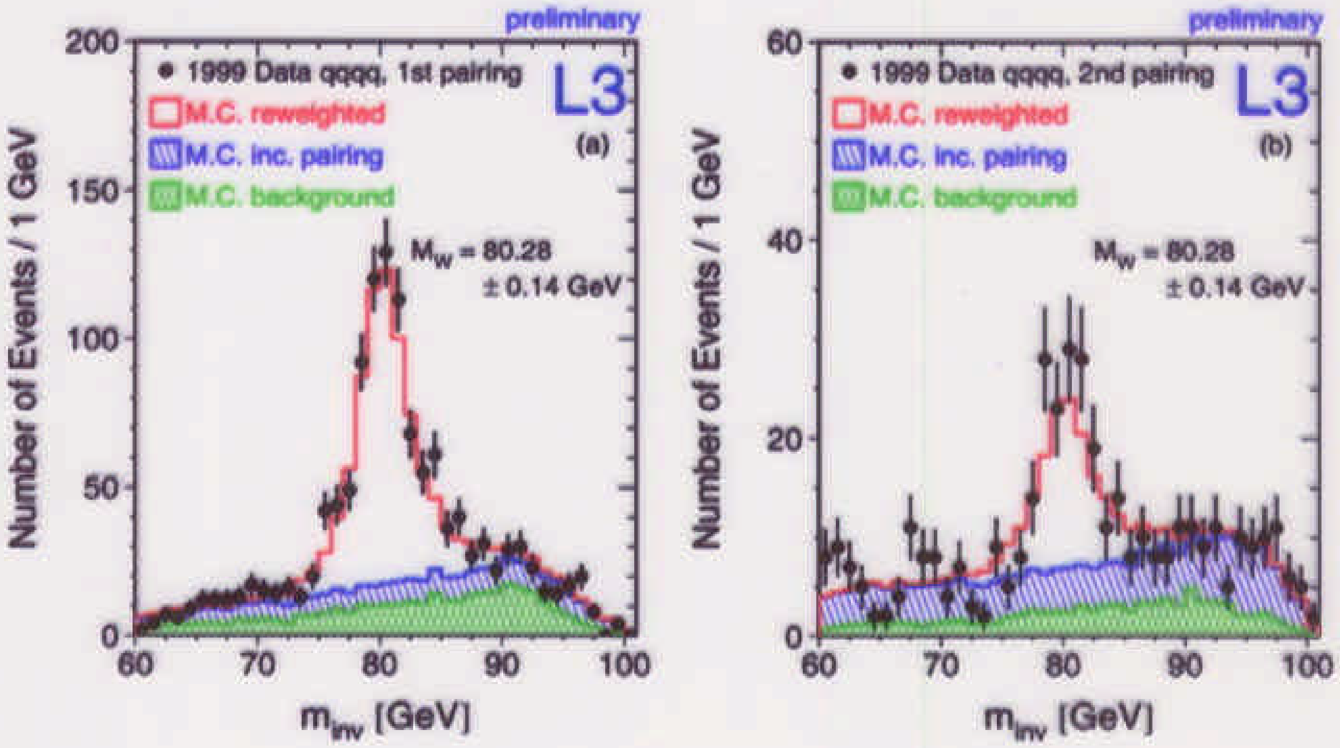
- $W^+W^- \rightarrow qqqq$: 3 pairings of jets possible
- combinatorial background due to incorrect pairing

Mass reconstruction: Pairing

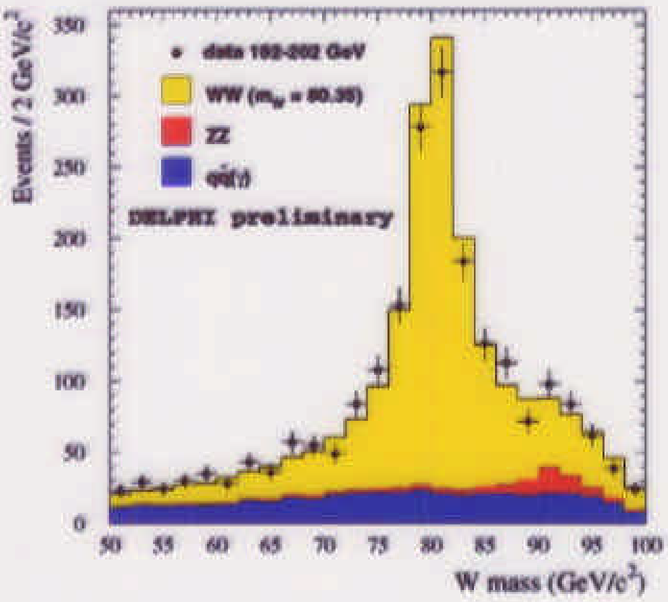
⇒ different approaches to improve correct pairing

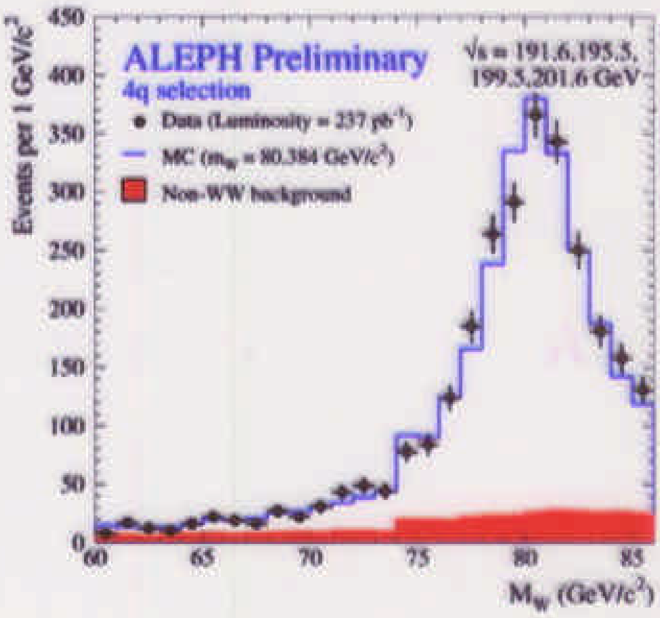
- best permutation applying pairing algorithm: A
  - ▷ matrix elements: $|\mathcal{M}_1|^2 > |\mathcal{M}_2|^2 > |\mathcal{M}_3|^2$
  - ▷ 1st or 2nd pairing satisfying cuts on mass window and sum of di-jet angles
- best pairing(s) from 5C kinematic fit: L, O
  - ▷ fit probabilities: $P_1 > P_2 > P_3$
  - ▷ 1st and 2nd pairing satisfying cuts on probabilities P_1 and P_2
- all pairings: D

⇒ correct combinations $\sim$ 90%



Mass reconstruction: Pairing



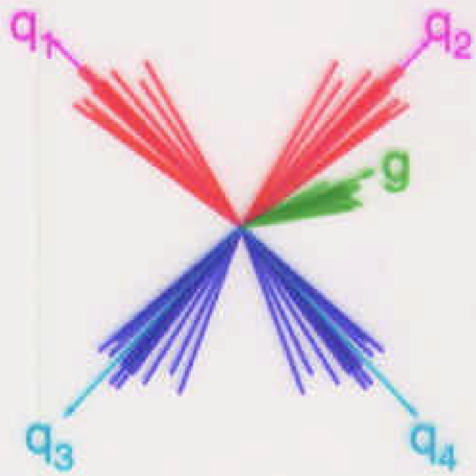


- more jets due to gluon radiation . . .

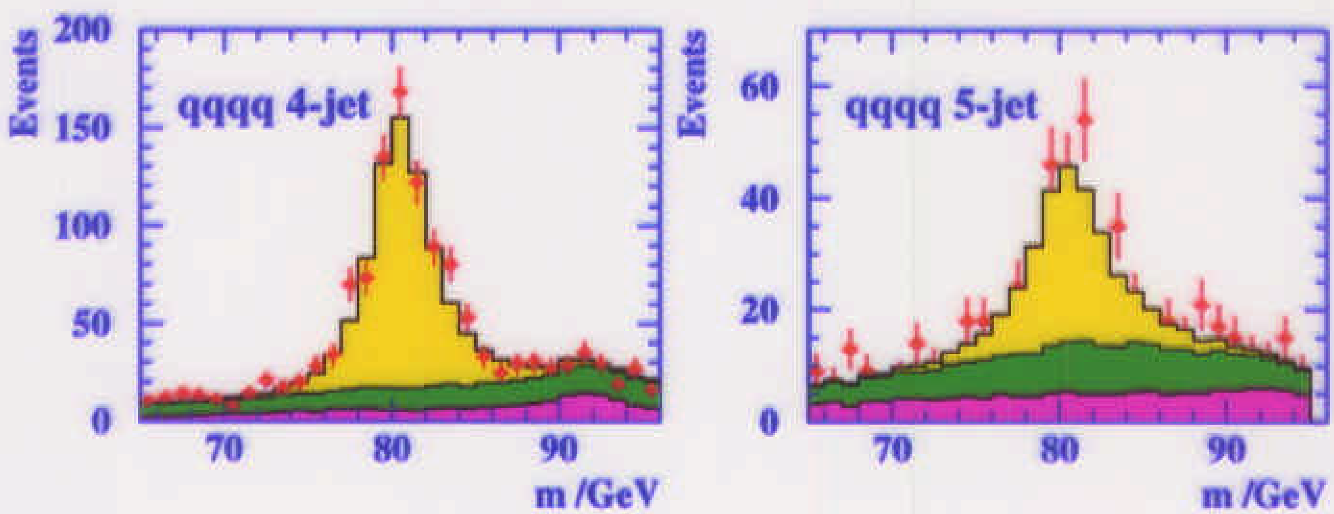
▷ 5 jets ⇒ 10 combinations

O: pairing likelihood to select preferred permutation

D: all permutations are taken into account



OPAL (Prelim.) 192-202 GeV



- measurement of W boson mass M_W:

▷ MC reweighting: $\omega_i = |\mathcal{M}_i(M_W^{fit})|^2 / |\mathcal{M}_i(M_W^{gen})|^2$

→ 1-dimensional fit to 5C mass $\langle M \rangle$ L,O

→ 2-dimensional fit to rescaled 4C A
masses $M'_{12} = M_{12} \cdot E_{beam} / (E_1 + E_2)$

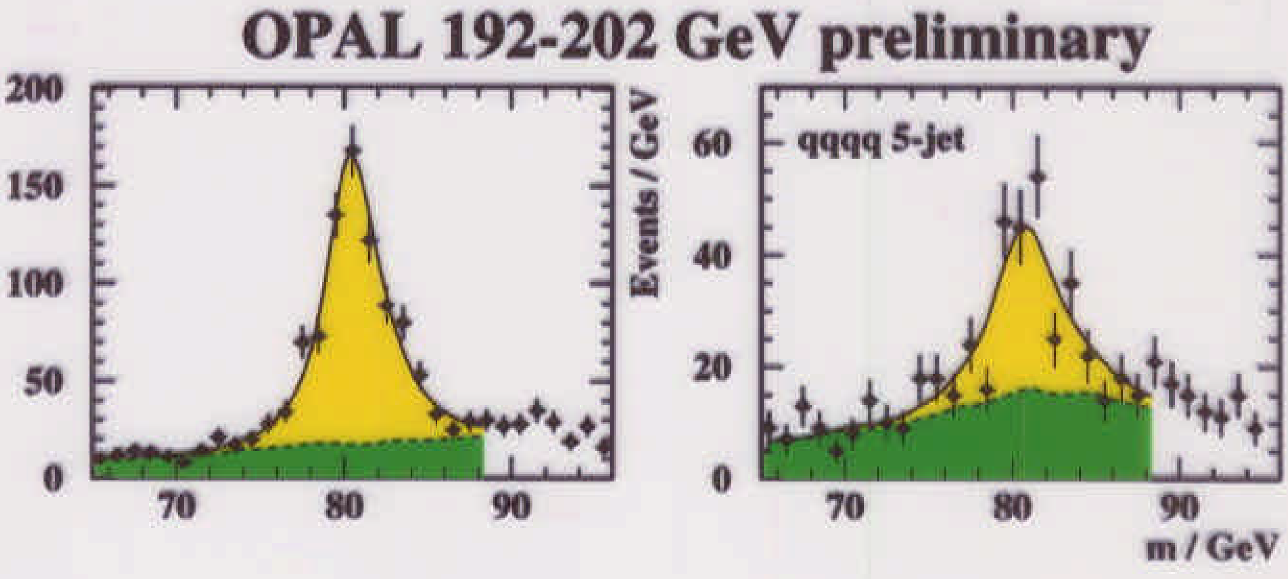
▷ fit $BW(\Gamma_+, M_W) \times BW(\Gamma_-, M_W)$ to 5C mass O

→ asymmetric mass peak due to ISR

→ calibration with many MC samples

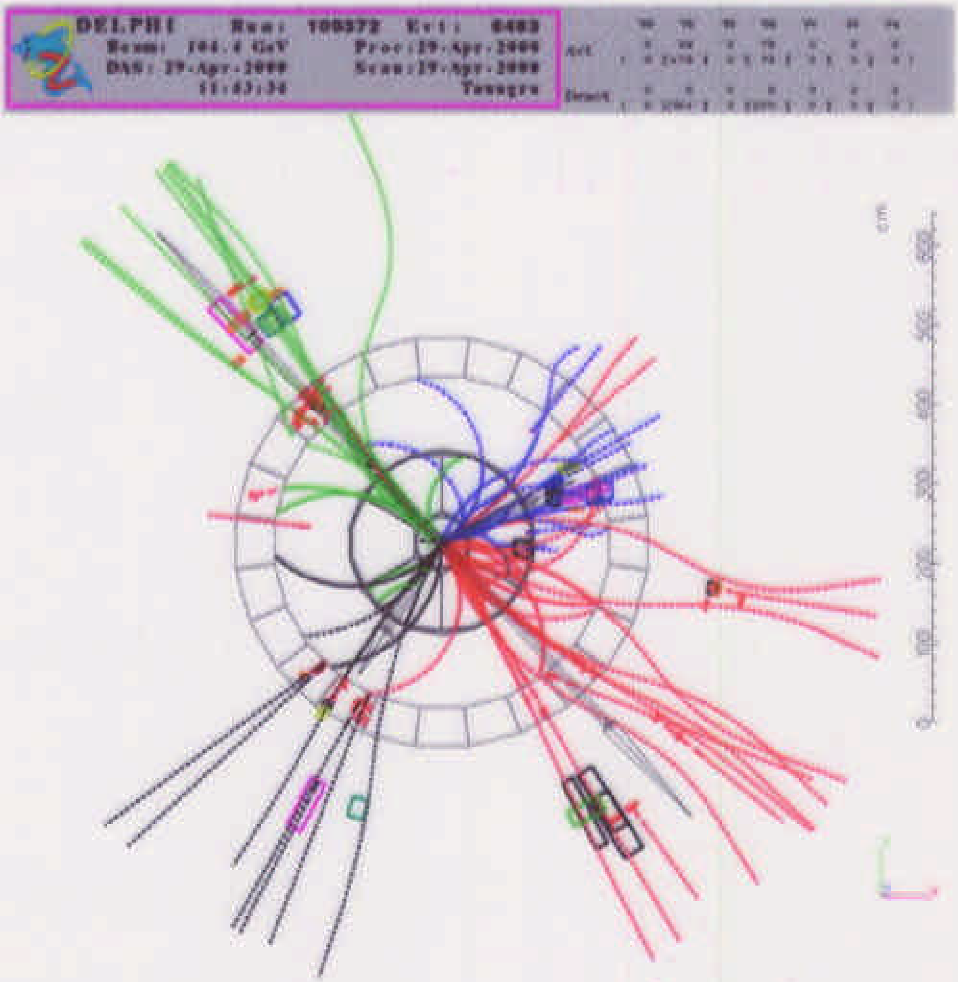
→ fitted mass corrected for shifts due to
selection, reconstruction and fitting

▷ convolution of 2-dimensional Breit-Wigner D,O
with resolution function

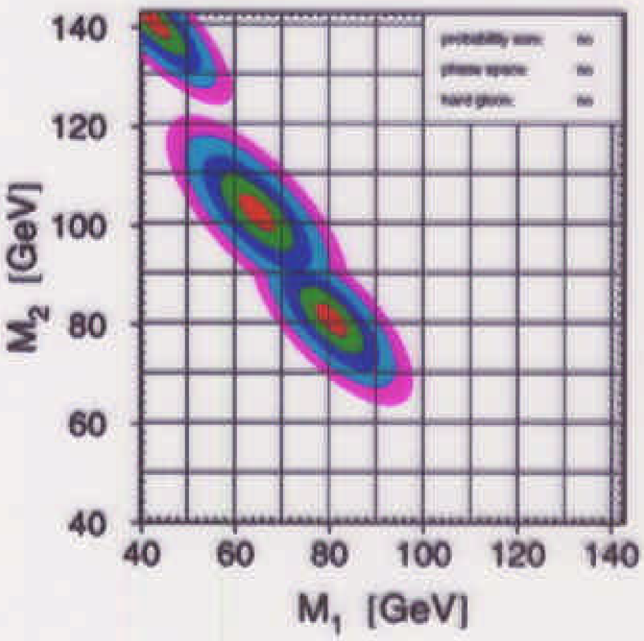


Mass reconstruction: Methods

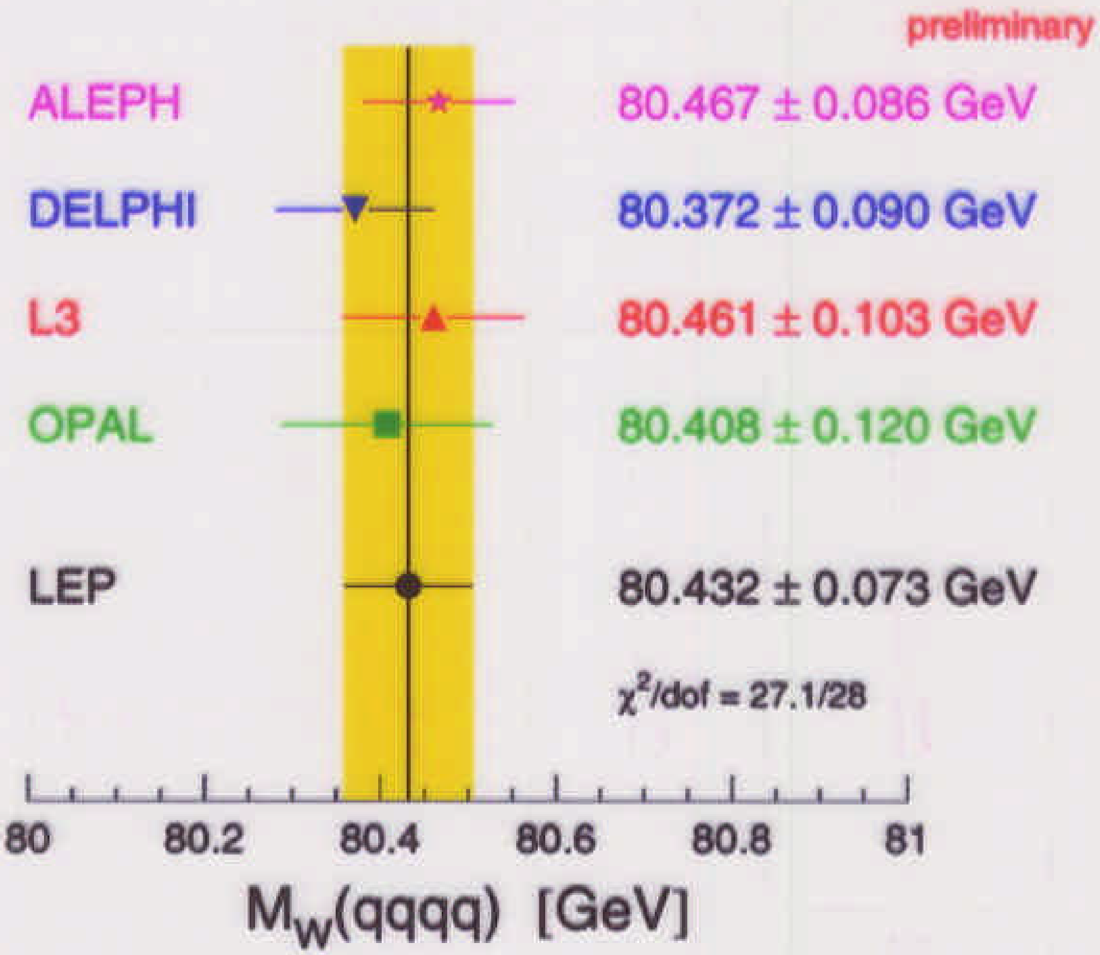
- DELPHI: $W^+W^- \rightarrow qqqq$ candidate at $\sqrt{s} = 208.8$ GeV



- 4C fit for each pairing $\rightarrow$ 2 masses
  - ▷ 2-dim. probability density for each pairing
  - ▷ PDF convoluted with $BW(M_1, M_2, M_W)$
  - ▷ event likelihood $\mathcal{L}(M_W)$



Mass of the W boson: fully hadronic decay



- different systematic errors due to Bose-Einstein correlations and Colour Reconnection
  - ▷ different sensitivities or reflection of different models? → test with MC samples with/without CR
  - ▷ equal sensitivities! → common uncertainty used in LEP combination for CR and BEC
- LEP: simultaneous fit to all individual results from the experiments for each channel and year
  - ▷ split in years/energies: correlated systematic errors treated correctly: → LEP beam energy
    → possible $\sqrt{s}$-dependence

Systematic uncertainties

- breakdown of typical systematic uncertainties for M_W from hadronic and all channels

Source	ΔM_W[MeV] qqqq	ΔM_W[MeV] qqqq and $qq\ell\nu$ combined
ISR/FSR	10	8
Hadronization	23	24
Detector systematics	7	10
LEP beam energy	17	17
Colour Reconnection	50	13
Bose-Einstein Correlations	25	7
Other	5	4
Total Systematic	64	36
Statistical	34	30

- Some errors are correlated between final states . . .
  - ▷ LEP beam energy, QED radiation effects (ISR/FSR)
  - ▷ Hadronization: compare string (JETSET) with cluster models (HERWIG)
  - ⇒ large contribution to combined systematic error
- Some errors are for qqqq only . . .
  - ▷ estimate $\Delta M_W(FSI) = 56$ MeV due to BEC and CR
  - ⇒ reduced contribution to combined M_W:

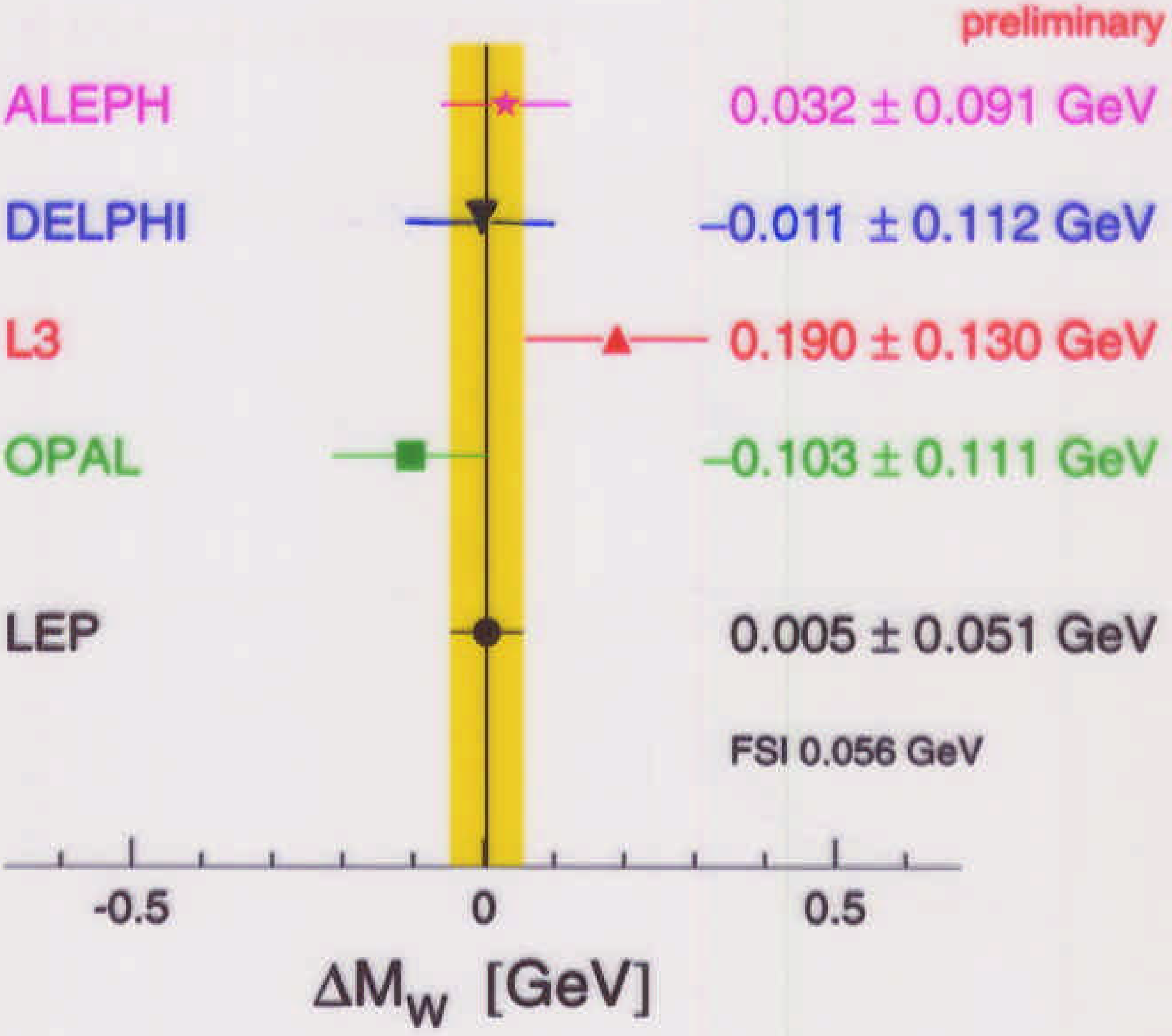
$$qq\ell\nu = 73\% \leftrightarrow qqqq = 27\%$$

Final state interactions: ΔM_W

- experimental test of possible FSI is difference

$$\Delta M_W = M_W(qqqq) - M_W(qq\ell\nu)$$

- ▷ systematic error due to BEC and CR set to zero
- ▷ LEP: correlations between two channels and experiments are taken into account



→ no indication of mass shift due to FSI

NB: considering fragmentation effects as uncorrelated between experiments ▷ increases only uncertainty

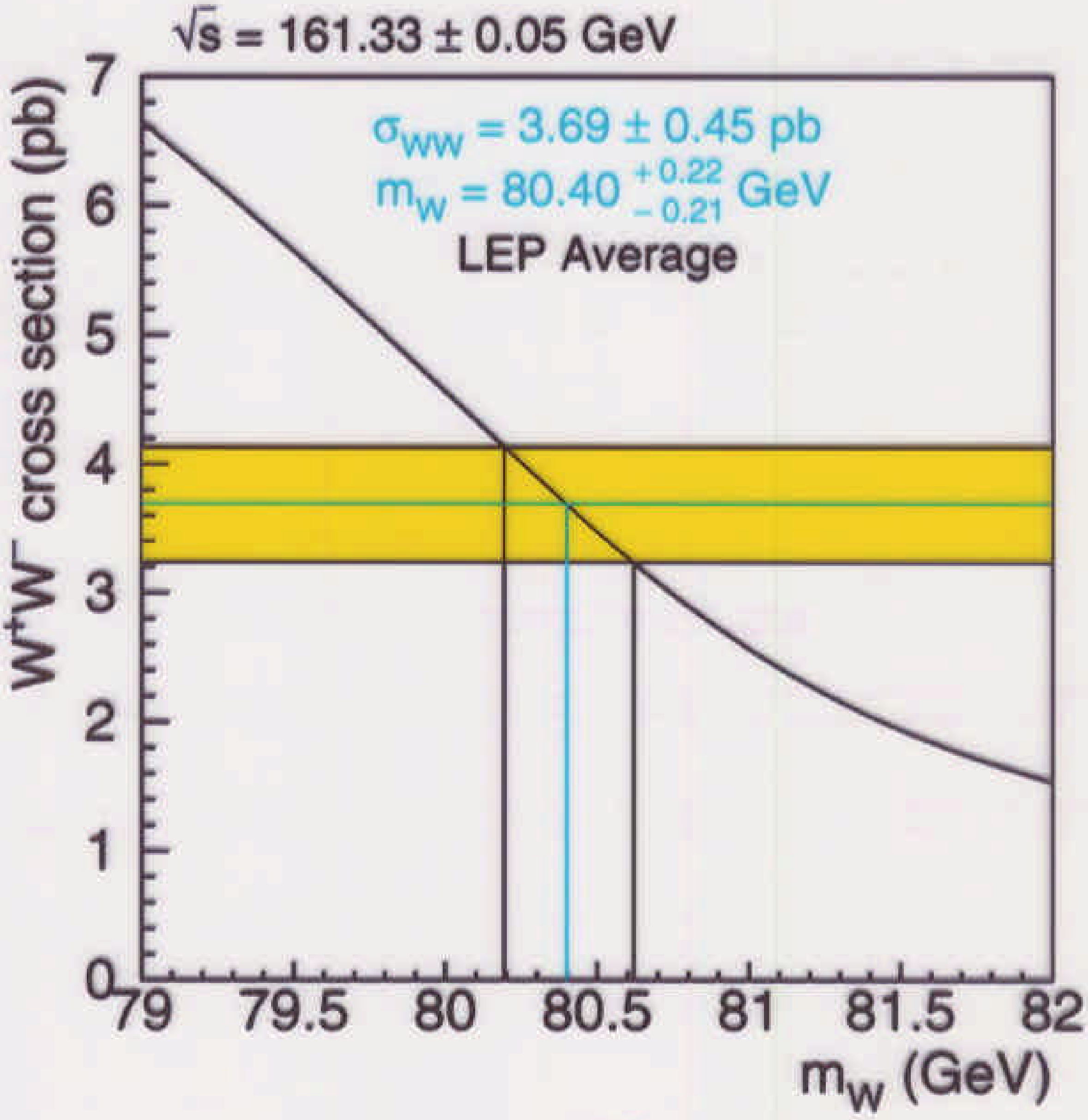
Mass of the W boson: Combined result

- combination of M_W from direct reconstruction from all energies 172 – 202 GeV

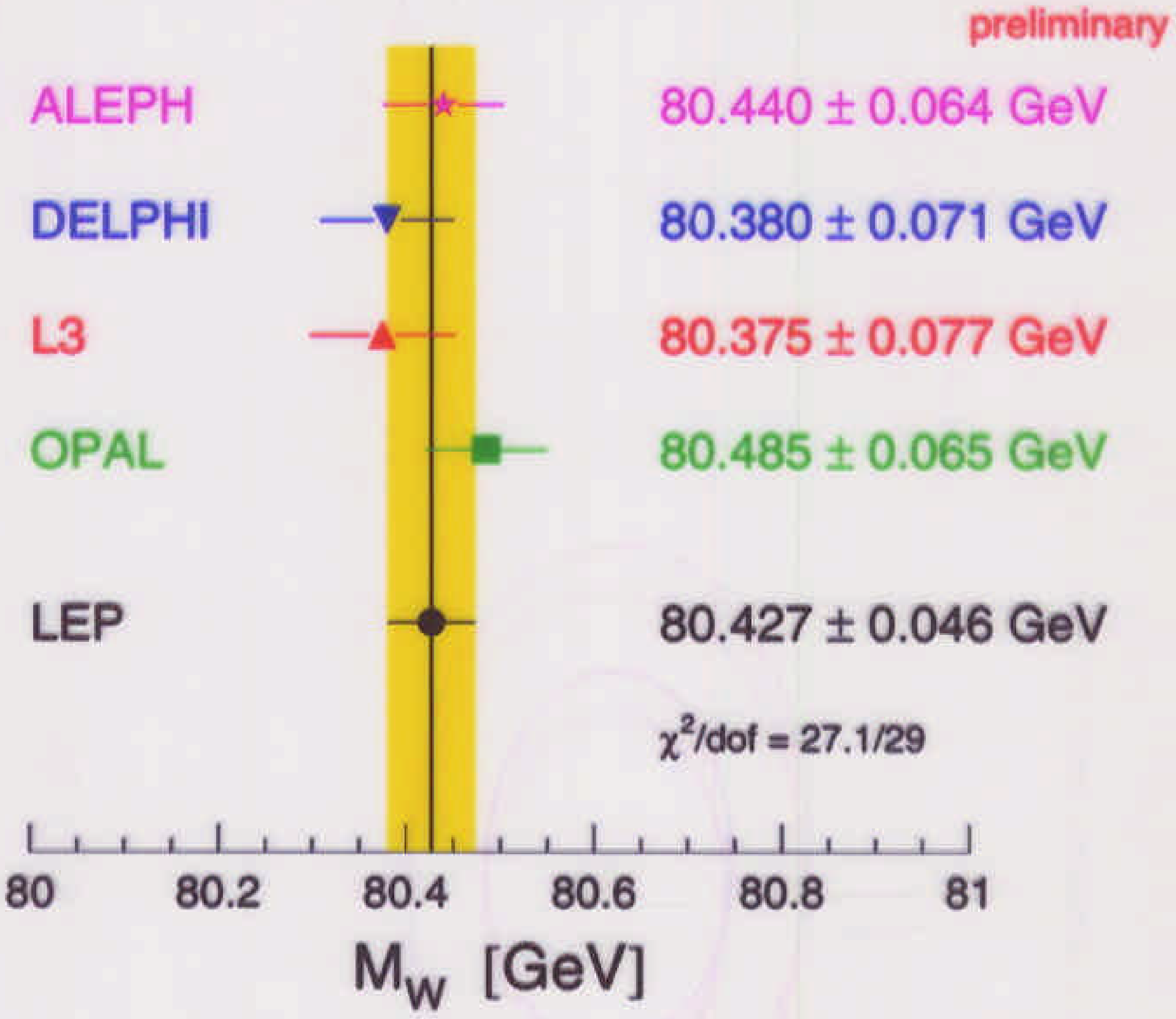
⊕ semileptonic M_W
⊕ M_W from fully leptonic
} talk by R. Ströhmer

- correlations between channels and experiments are included

⊕ threshold measurement at 161 GeV



Mass of the W boson: Combined result



... if there were no systematic effects ...

→ statistical precision on combined M_W: 25 MeV

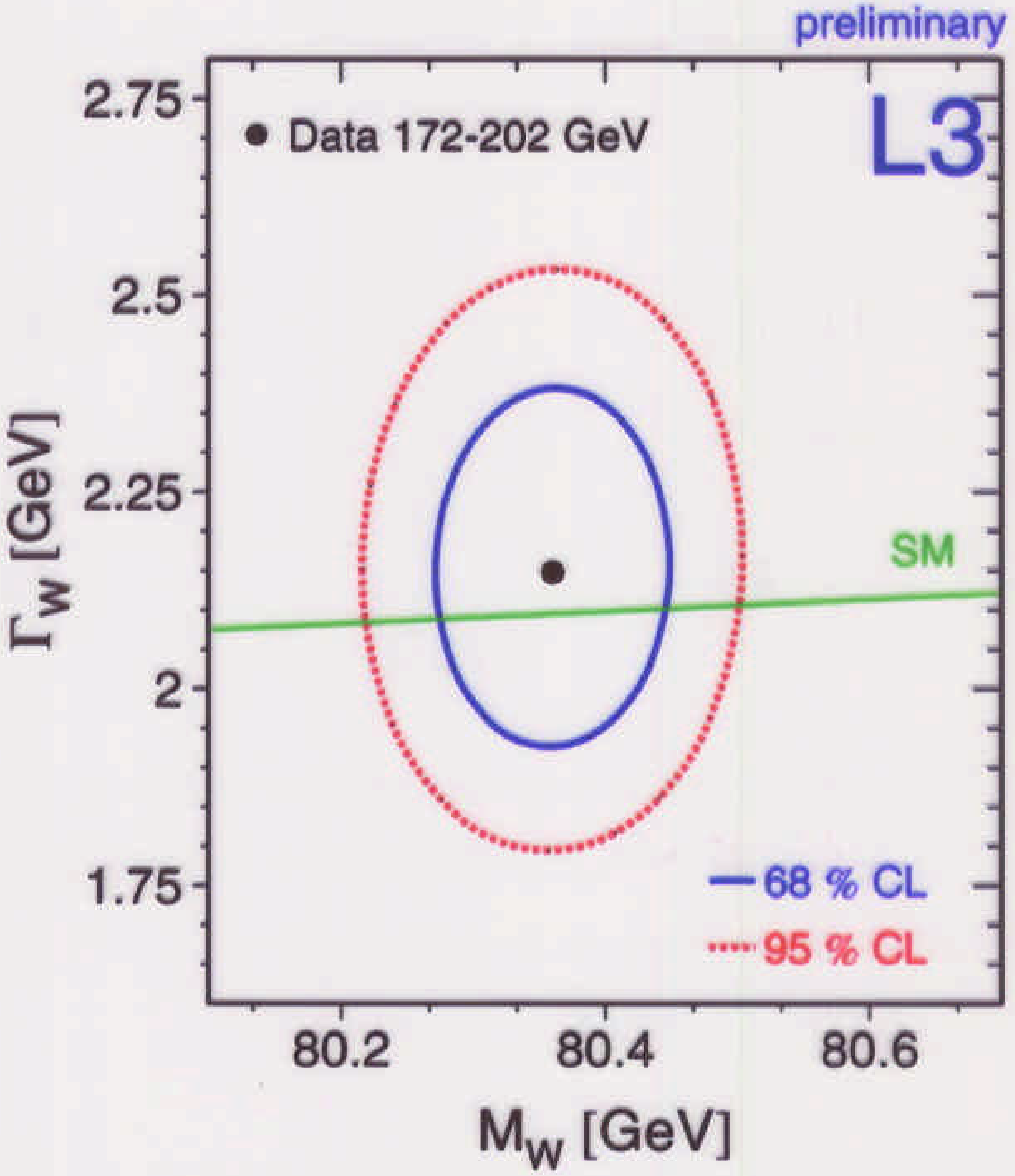
... actual statistical error contribution: 30 MeV

→ reflects reduced weight of hadronic channel

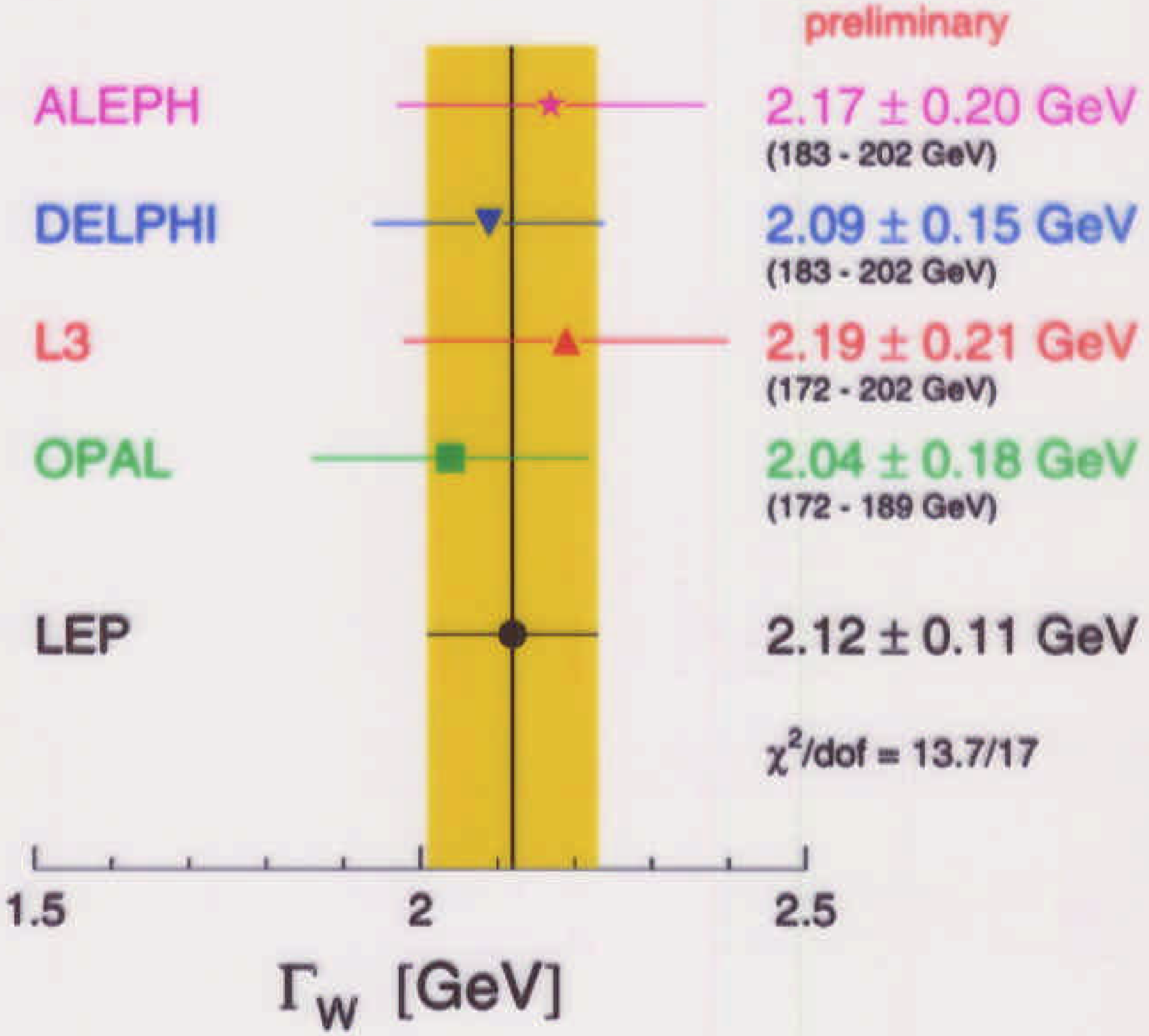
Width of the W boson

- mass fits: width Γ_W fixed to SM prediction

▷ method of direct reconstruction used to determine width Γ_W of the W boson: → fit to both M_W and Γ_W



Width of the W boson



- large differences between systematic uncertainties quoted by the experiments: 90 – 160 MeV
- LEP: ▷ similar combination procedure as for M_W
  ▷ correlated systematic uncertainties are taken into account
- CDF: ▷ direct determination of W boson width

$$\Gamma_W = 2.05 \pm 0.13 \text{ GeV}$$

Conclusions

- LEP: precise measurement of W mass and width

$$M_W = 80.432 \pm 0.073 \text{ GeV for qqqq}$$

$$M_W = 80.427 \pm 0.046 \text{ GeV}$$

$$\Gamma_W = 2.12 \pm 0.11 \text{ GeV}$$

... current uncertainty is dominated by systematics:

$$\Delta M_W(\text{stat.}) = 30 \text{ MeV}$$

$$\Delta M_W(\text{syst.}) = 36 \text{ MeV}$$

▷ largest contribution from Hadronization uncertainties

▷ better understanding of Bose-Einstein Correlations and Colour Reconnection and their impact on M_W and Γ_W needed

- 2000: experiments already collected 110 pb^{-1} each

▷ 200 pb^{-1} per experiment can be expected

▷ statistical error $\times$ 0.85

▷ final error $\Delta M_W = 30 - 40$ MeV