Measurements of M_W and Γ_W at OPAL

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Representing the OPAL Collaboration

Outline:

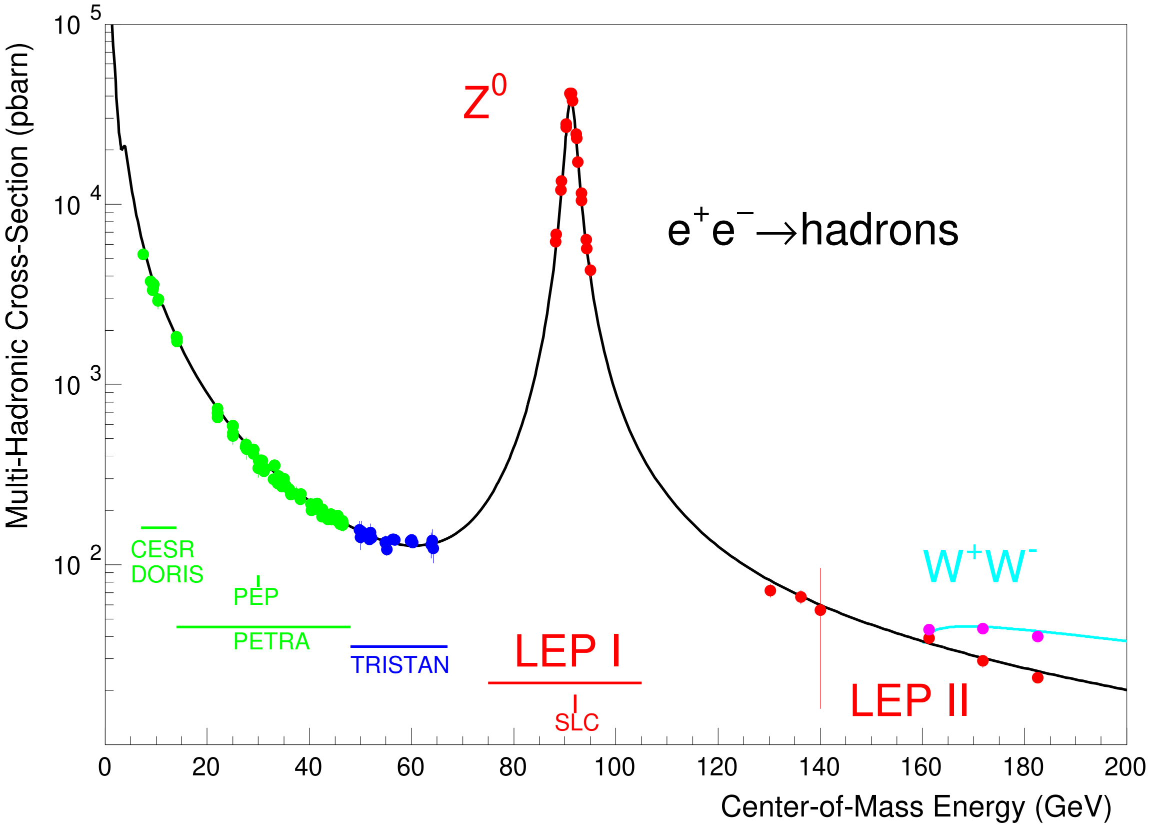
- Introduction
- Event Selections
  - $\mathrm{W^+W^-} \to \mathrm{q\overline{q}}\ell\overline{\nu}_\ell$
  - $\mathrm{W^+W^-} \to \mathrm{q\overline{q}q\overline{q}}$
- The Mass $\oplus$ Width Fit
- Systematic Errors
  - Color Reconnection and Bose-Einstein Effects
- LEP Combined Results

The Bottom Line(s):

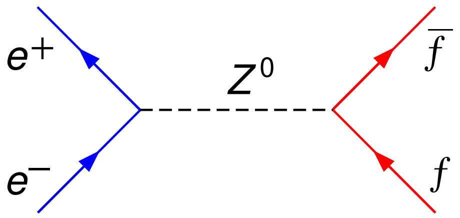
OPAL $\delta M_W(\mathrm{stat} \oplus \mathrm{syst}) \sim 130\ \mathrm{MeV}$	**1997 Running**
LEP $\delta M_W(\mathrm{stat} \oplus \mathrm{syst}) \sim 60\ \mathrm{MeV}$	**1997** $+\frac{1}{2}$ **1998 Running**

★ **LEP will double its data set** ★

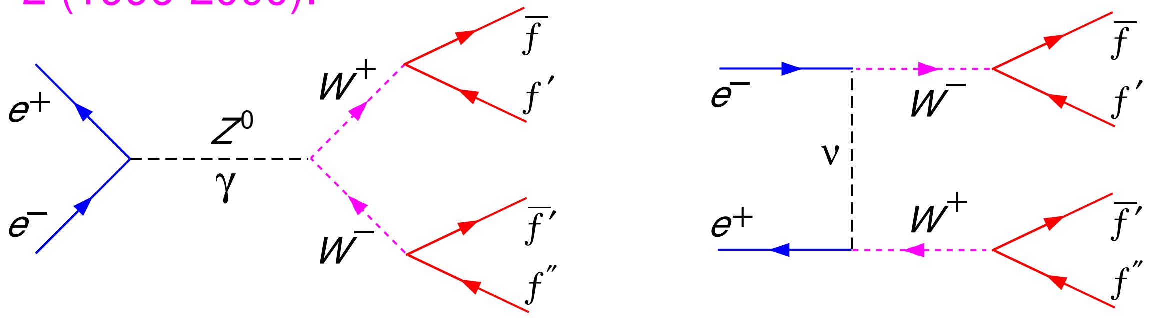
Physics Landscape at LEP



LEP I (1989-1995):



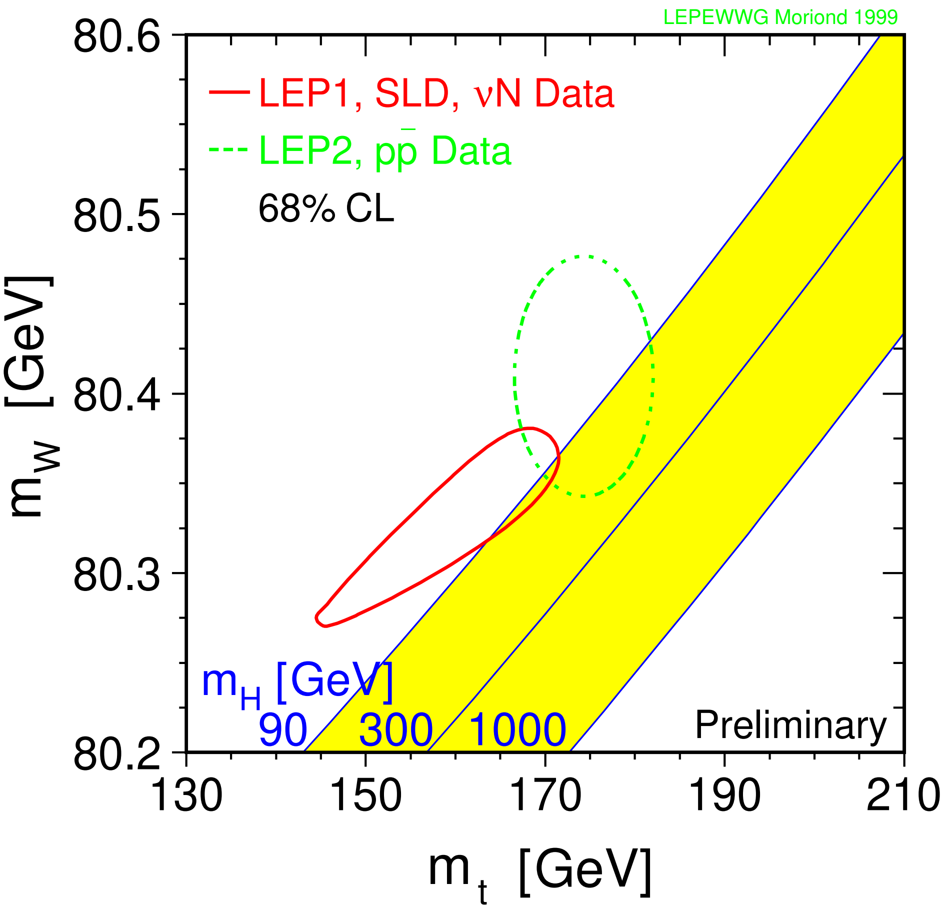
LEP 2 (1996-2000):



W^+W^- Production dominated by CC03 Diagrams

Motivation

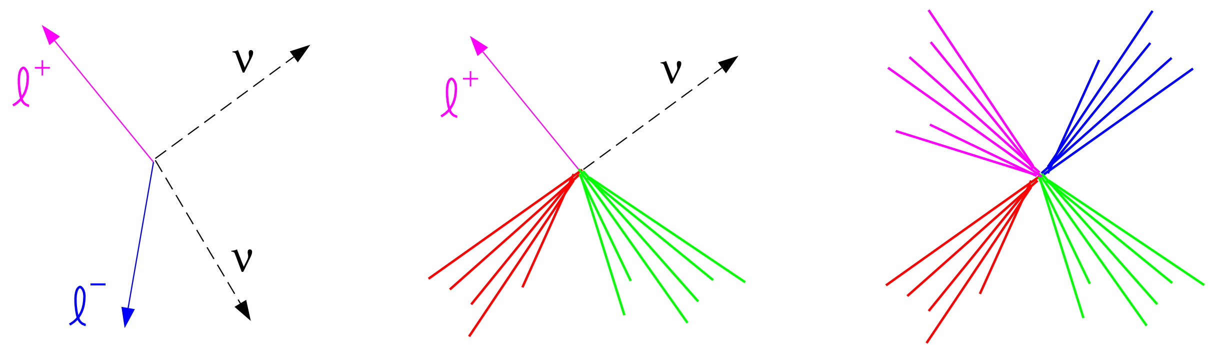
Test Higher-Order Standard Model Predictions



- With 190 pb^{-1} this year: $\Delta M_W \sim 45\ \mathrm{MeV}$

Results Dominated by Direct Reconstruction Method:

$\mathrm{W^+W^-} \to \ell^+\nu_\ell\ell'^-\overline{\nu}_{\ell'}$	$\mathrm{W^+W^-} \to \mathrm{q\overline{q}}\ell\overline{\nu}_\ell$	$\mathrm{W^+W^-} \to \mathrm{q\overline{q}q\overline{q}}$
10.5%	43.9%	45.6%



lepton momenta   jet-jet mass   jet-jet: 3 combinations

Kinematic fits (Conservation of E, $\vec{p}$) used for reconstruction

Event Sample

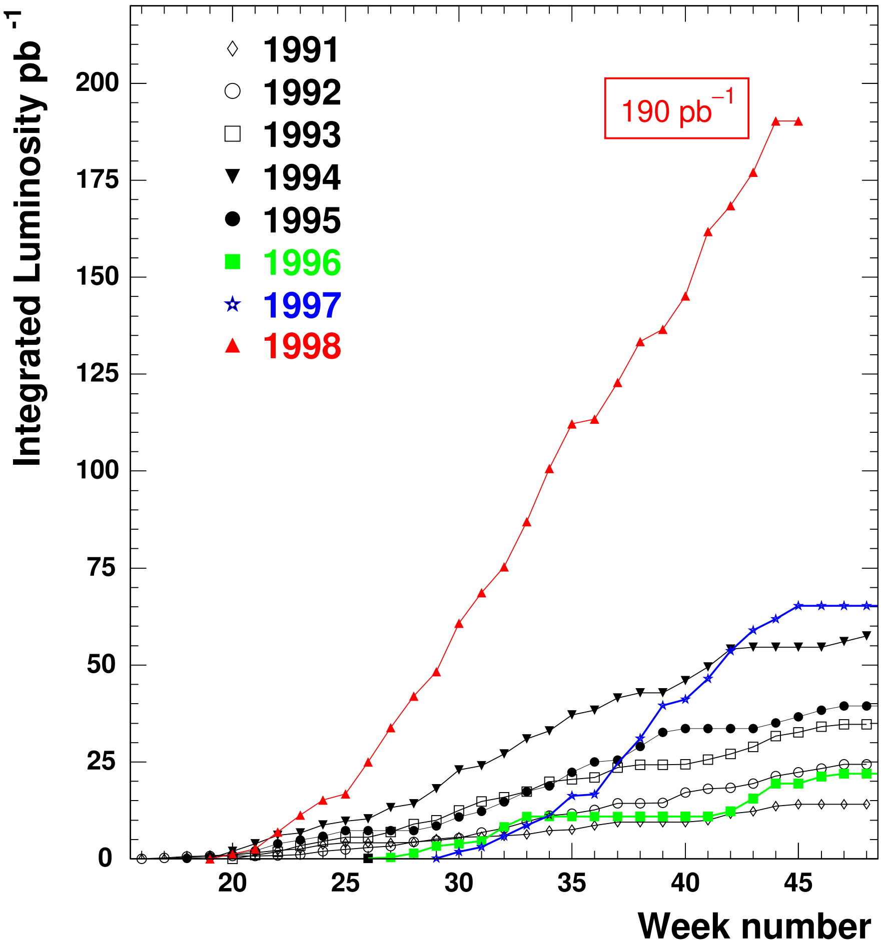
OPAL Data Sample:

1996: 10 pb^{-1} at 161 GeV 12 pb^{-1} at 172 GeV

1997: 57 pb^{-1} at 183 GeV

1998: 187 pb^{-1} at 189 GeV (still working)

OPAL Integrated Luminosity



- Cross section for $e^+e^- \rightarrow W^+W^-$ at 183 GeV is $\sim$ 16 pb

  $\Rightarrow$ $\sim$ 900 Events/Experiment before event selection

Event Selection: $WW \rightarrow q q \ell \nu$

Preselection cuts 90% of Z^0/γ background, keeps 90% of $WW \rightarrow q q \ell \nu$

Separate Multivariate Likelihoods for each channel:

Based on lepton momentum, isolation, missing momentum, event kinematics

channel	efficiency(%)	Candidates	Expected
$\mathrm{W^+W^-} \rightarrow \mathrm{q\bar{q}e\bar{\nu}_e}$	84.0	140	129.8$\pm$3.6
$\mathrm{W^+W^-} \rightarrow \mathrm{q\bar{q}}\mu\bar{\nu}_\mu$	86.2	120	123.2$\pm$2.8
$\mathrm{W^+W^-} \rightarrow \mathrm{q\bar{q}}\tau\bar{\nu}_\tau$	64.6	101	118.2$\pm$3.3
Total	84.7$\pm$1.3	361	371.2$\pm$8.2

- Dominant backgrounds from $Z^0/\gamma \rightarrow q\bar{q}$, $q\bar{q}q\bar{q}$, and $q\bar{q}\ell\bar{\ell}$

Inputs for Mass Measurement:

- For $\mathrm{W^+W^-} \rightarrow \mathrm{q\bar{q}e\bar{\nu}_e}$ and $\mathrm{W^+W^-} \rightarrow \mathrm{q\bar{q}}\mu\bar{\nu}_\mu$

  2C Kinematic Fit applied to each event

- For $\mathrm{W^+W^-} \rightarrow \mathrm{q\bar{q}}\tau\bar{\nu}_\tau$

  $M_{\mathrm{jet-jet}}$ scaled to E_{beam} is used

Only use events with:

- $\mathcal{P}(\chi^2) > 0.001$,
- $m_{\mathrm{rec}} > 65$ GeV, and
- $\sigma(m_{\mathrm{rec}}) > 0.5$ GeV

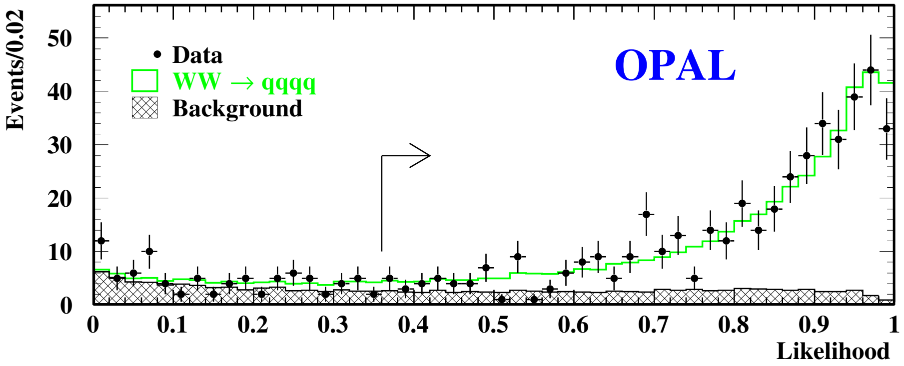
- 300 $WW \rightarrow q q \ell \nu$ Events for Mass Measurement

Event Selection $WW \rightarrow q\bar{q}q\bar{q}$

Preselection removes 97.7% of Z/γ background, keeps 88.8% of $WW \rightarrow q\bar{q}q\bar{q}$

Likelihood-Based Selection:

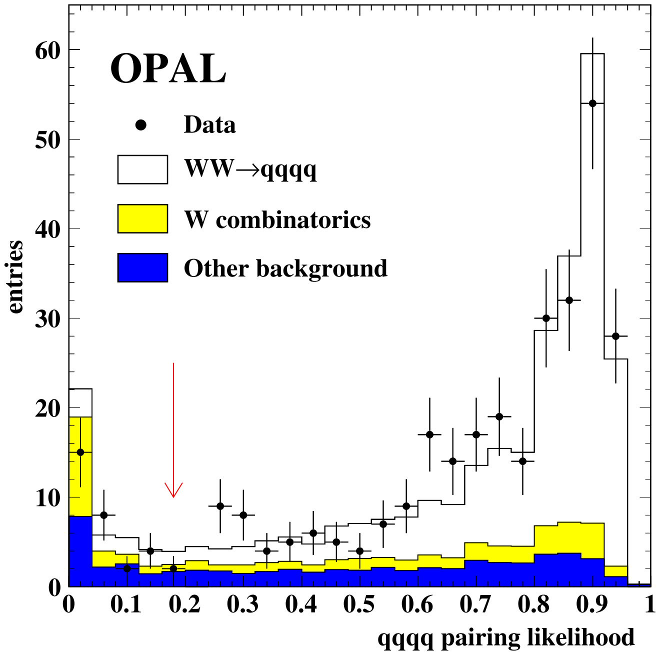
Inputs: y_{45}, W_{420}, $|\cos\theta_{N-R}|$,S



- Efficiency of 85% with 78% Purity
- Dominant Backgrounds from $Z^0/\gamma \rightarrow q\bar{q}$ and $Z^0/\gamma \rightarrow q\bar{q}q\bar{q}$
- 438 events selected

Jet Pairing Likelihood:

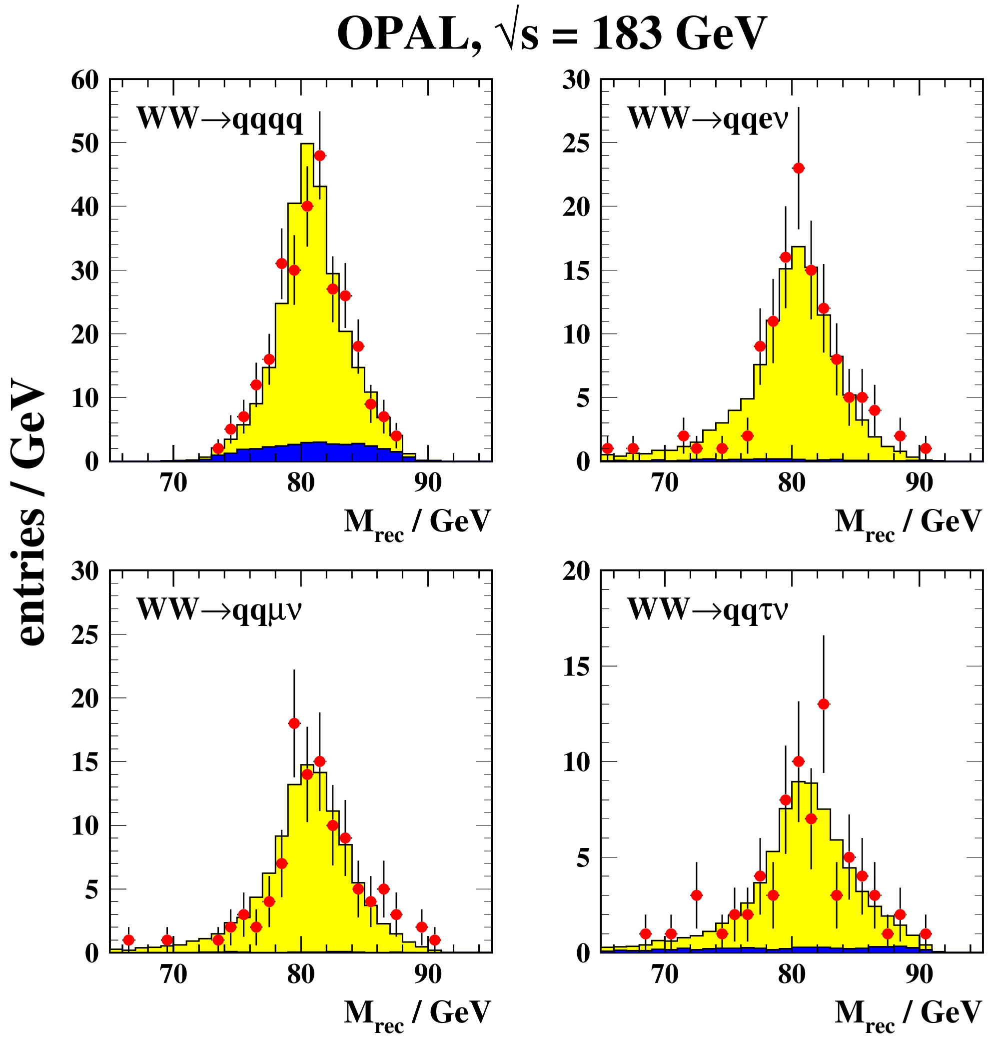
Inputs: $|M_1 - M_2|$(4C), $\theta_{12} + \theta_{34}$, M_W(5C)



- 69% of W events survive/60% background cut
- 87% have correct jet pairing
- 282 events for mass measurement → 5C Mass

Mass and Width Determination

Reconstructed Mass Distributions



Reweighting Method Used to fit for M_W, Γ_W

- MC events at different masses, widths, are combined
  - continuous set of mass and width “templates”
- Binned-Likelihood fit of data to extract M_W, Γ_W
  - separate fit for each final state
  - $qq\ell\nu$ events fit in bins of kinematic fit error
- Fits with Breit-Wigner and with “Convolution” Method consistent

Results and Errors

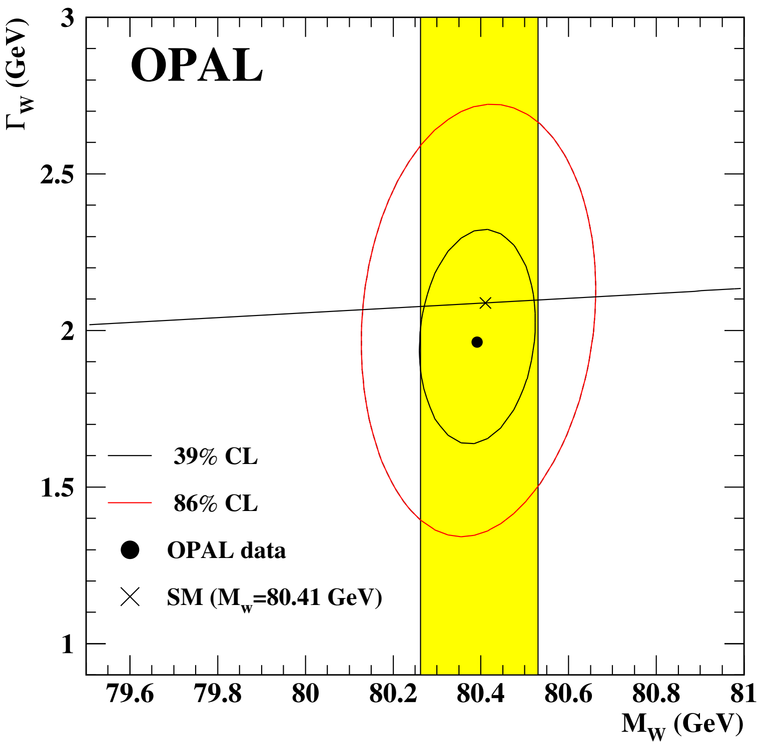
Channel	Measured M_{W}	Expected error
$\mathrm{W^+W^-} \to \mathrm{q\overline{q}e\overline{\nu}_e}$	80.23 ± 0.24	0.31
$\mathrm{W^+W^-} \to \mathrm{q\overline{q}}\mu\overline{\nu}_\mu$	80.42 ± 0.27	0.30
$\mathrm{W^+W^-} \to \mathrm{q\overline{q}}\tau\overline{\nu}_\tau$	80.40 ± 0.40	0.45
$\mathrm{W^+W^-} \to \mathrm{q\overline{q}}\ell\overline{\nu}_\ell$	80.33 ± 0.17	0.19
$\mathrm{W^+W^-} \to \mathrm{q\overline{q}q\overline{q}}$	80.53 ± 0.23	0.20

1997 Results:

$$M_W(183) = 80.39 \pm 0.13(\mathrm{stat}) \pm 0.05(\mathrm{syst})\ \mathrm{GeV}$$

OPAL Combined:

$$M_W(161-183) = 80.38 \pm 0.12(\mathrm{stat}) \pm 0.05(\mathrm{syst})\ \mathrm{GeV}$$



OPAL Combined:

$$\Gamma_W(161-183) = 1.84 \pm 0.32(\mathrm{stat}) \pm 0.20(\mathrm{syst})\ \mathrm{GeV}$$

Systematic Errors

Systematic errors (MeV)	M_W $q\bar{q}q\bar{q}$	$q\bar{q}\ell\bar{\nu}_\ell$	comb.	Γ_W	ΔM_W
Beam Energy	22	22	22	5	0
Initial State Radiation	10	10	10	15	10
Hadronization	21	21	16	52	15
Four-fermion	30	28	21	52	40
Detector Effects	38	31	26	90	46
Fit Procedure	15	15	15	45	20
Background	25	10	10	79	25
MC statistics	15	15	11	40	21
Sub-total	67	58	49	154	74
Bose-Einstein Correlations	32	0	11	55	—
Colour Reconnection	49	0	16	109	—
Total systematic error	89	58	53	196	74

- 4-Fermion Effects: compare CC03, complete set of interfering diagrams
- Detector Effects: Energy Scale and Jet Angle Errors
- Final State Interactions are dominant systematic for $q\bar{q}q\bar{q}$
  - – W Decay Length (0.1 fm) $\ll$ Hadronisation Scale ($\sim$1 fm)
  - $\Rightarrow$ **Non-Independent Fragmentation** could cause **Mass Shifts**
  - ★ Not included in Standard Monte Carlos

In principle,

$\Delta M_W \equiv \left(M_W^{q\bar{q}q\bar{q}} - M_W^{q\bar{q}\ell\bar{\nu}_\ell} \right)$ can provide a *measure* of bias

OPAL Combined:

$$\Delta M_W (161 - 183) = 0.08 \pm 0.26 \pm 0.07 \text{ GeV}$$

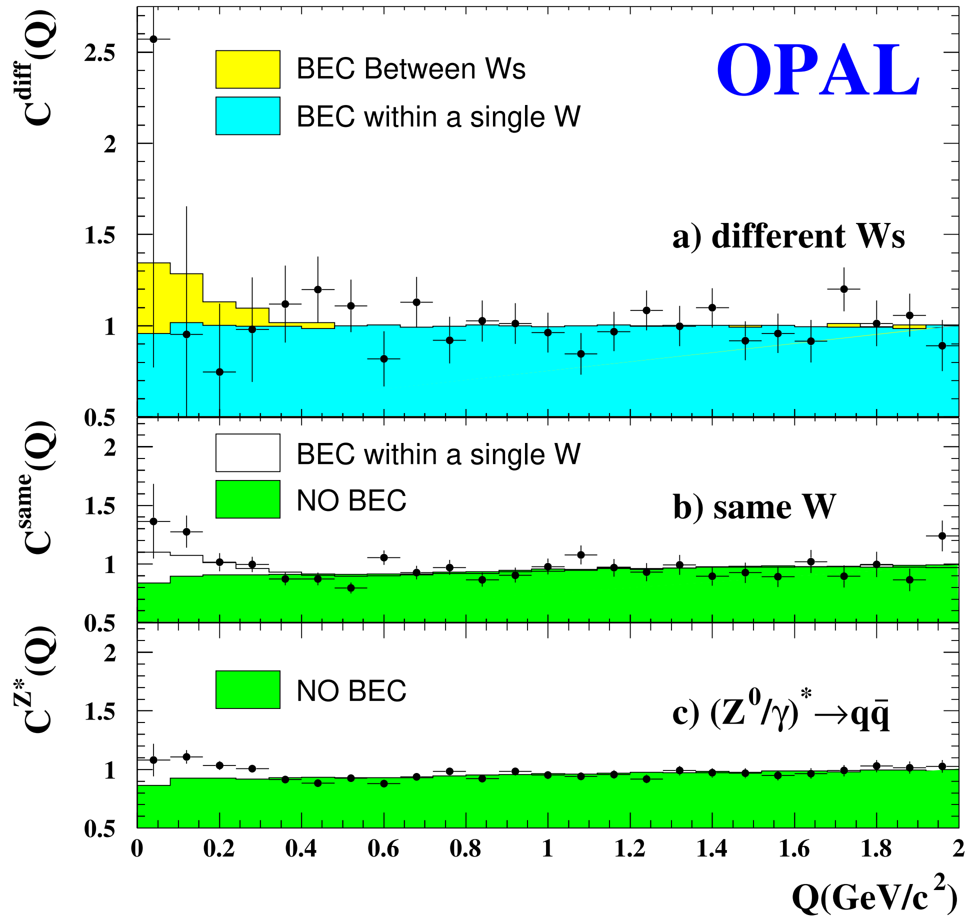
Comments on Final State Interactions

- Colour Reconnection Error estimated by comparing Models:

Model	Mass Shift
SK I	$+11 \pm 25$
SK II	-23 ± 25
SK II′	-22 ± 25
AR 2	$+49 \pm 14$
AR 3	$+145 \pm 21$*

*Theoretically and Experimentally Disfavoured

- Bose-Eistein Correlation Effects measured with Data



  - Statistically consistent with **No Effect**
  - Systematic error from statistics of MC comparison

LEP Combined M_W