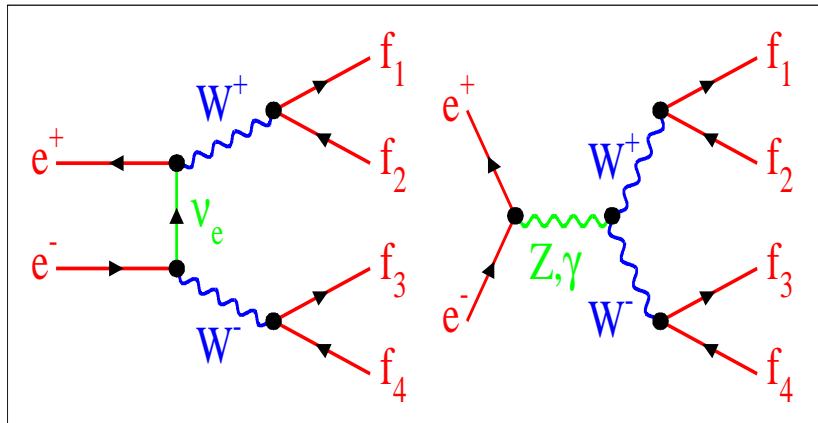




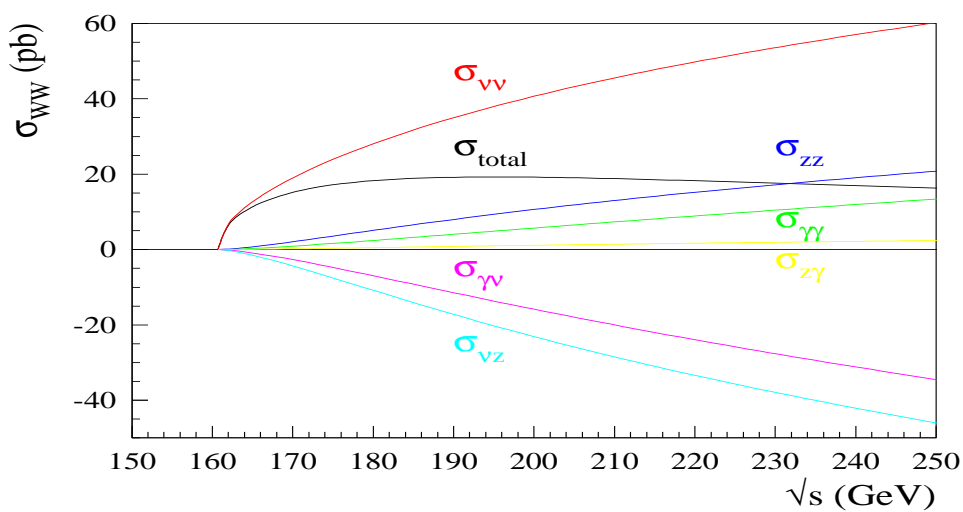
W Mass Measurement at LEP2

Chris Parkes

Glasgow / DELPHI

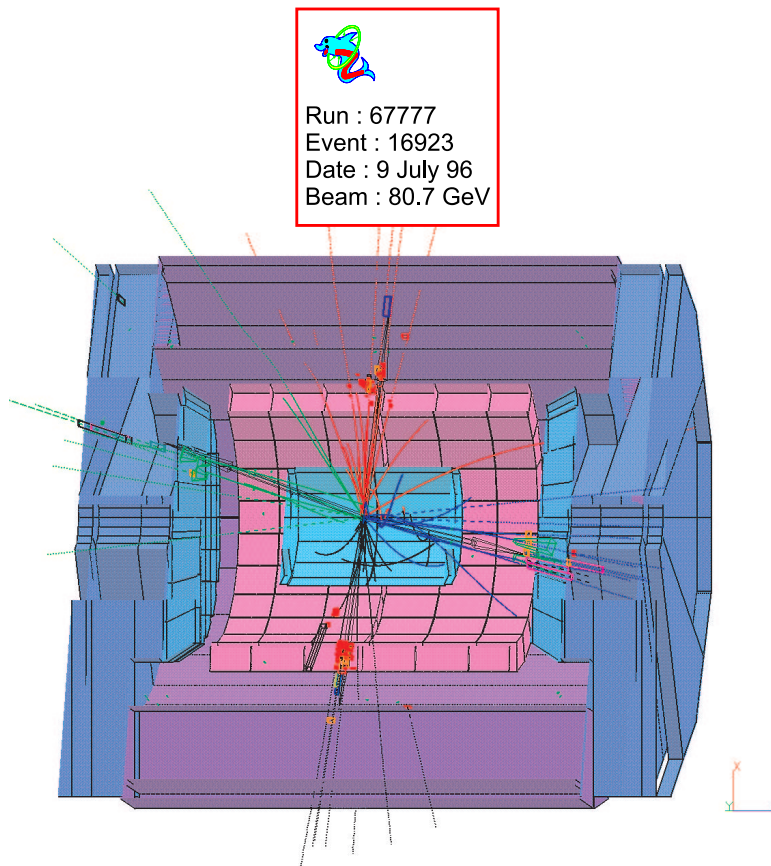


- W mass from Direct Reconstruction → Systematics
- W Width from Direct Reconstruction
- Conclusion and Prospects



W Mass at LEP2

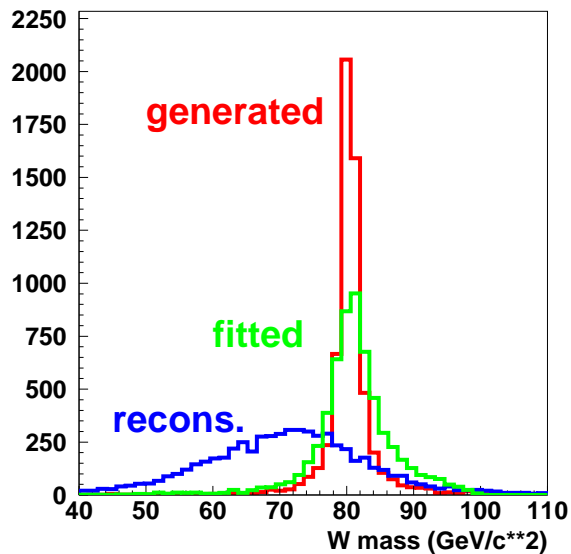
First WW Event



- 35,000 selected WW's at LEP
- Luminosity $\approx 700 \text{ pb}^{-1}$ per Experiment
- Energies 161 - 209 GeV

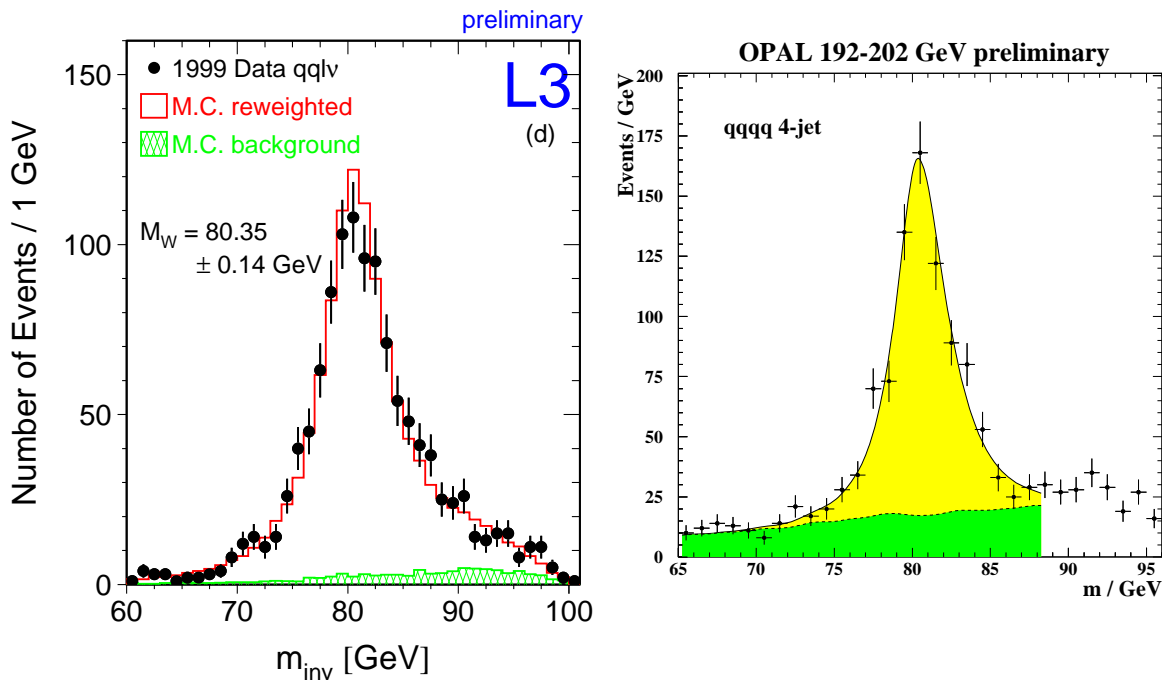
Analysis Technique

- Select Events $l\bar{\nu}_l q\bar{q}'$ (BR=44%), $q\bar{q}'\bar{q}q'$ (BR=46%)
- Reconstruct **lepton** and **jets** (also gluon jets)
- Impose **Kinematic Constraints** → improve resolution



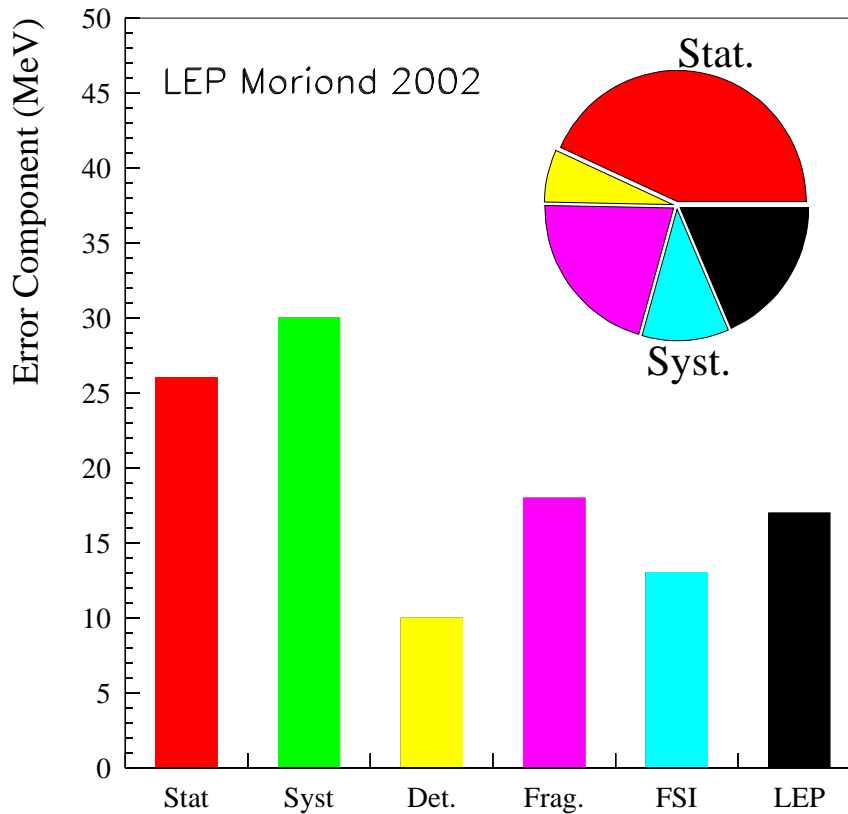
- E,p conservation
- M1,M2 or M1=M2
- $q\bar{q}'\bar{q}q'$ events select/weight **jet pairings**

W Mass at LEP2



- Perform maximum likelihood M_W fit to data
 - Reweight simulation
 - Compare (smeared) Breit-Wigner calibrate with simulation event by event resolution

W Mass at LEP2



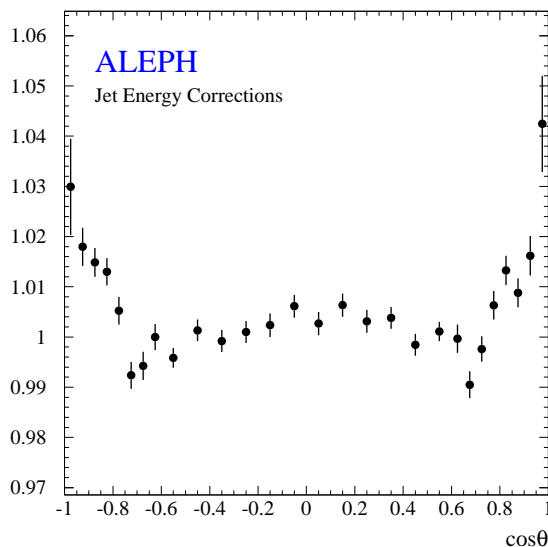
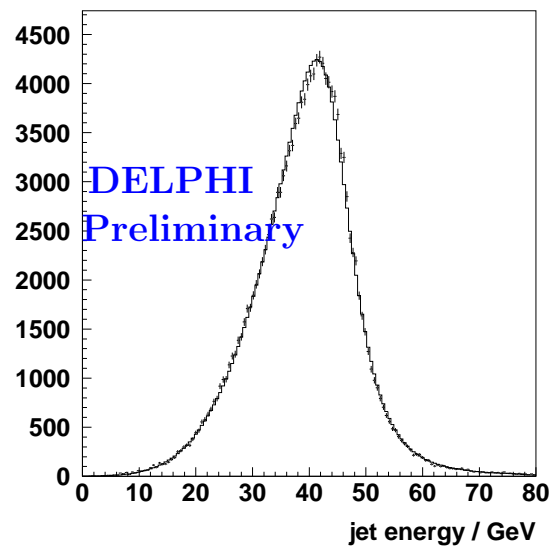
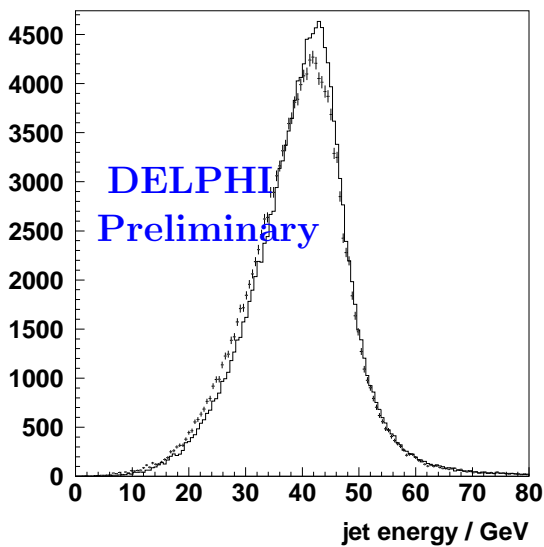
Systematics on MW

- Systematics dominated measurement
- Inter-experiment collaboration
 - LEP WW workshops
- Detector Effects
- FSI
- $\mathcal{O}(\alpha)$
- Fragmentation
- EBeam

Detector Effects

- Jet Energies/Resolutions
- Lepton Energies/Resolutions
- Detector Calibration/Alignment/Distortions

RAW → CORRECTED



Study using →

- $Z \rightarrow q\bar{q}, e^+e^-, \mu^+\mu^-, \tau^+\tau^-$

more work → lower error ?

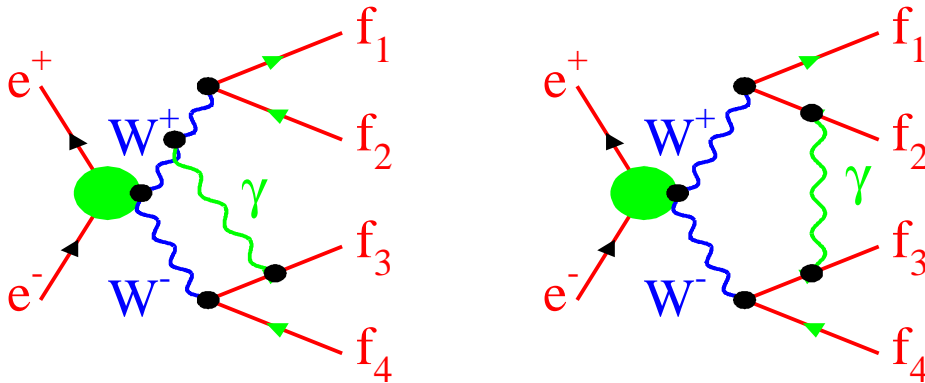
Energy non-linearities

- 3 jet Z peak events
- 2 jet high energy

Uncorrelated between Experiments

$\mathcal{O}(\alpha)$

Standard generators (KORALW/WPHACT)
neglect e.g.



- LEP Data and simulation reprocessing →
- Event Reweighting with YFSWW
($CC03_{DPA}$)

$$w_{DPA} = \frac{|4f_{DPA}|^2}{|4f|^2} = 1 - \frac{|CC03|^2}{|4f|^2} \left(1 - \frac{|CC03_{DPA}|^2}{|CC03|^2} \right)$$

Assessing systematic

- compare YFSWW, Racoon WW
- non-factorisable , ISR, electroweak non-leading
- theoretical \leftrightarrow reconstruction

\mathcal{O} 10 MeV ?

LEP Beam Energy Determination

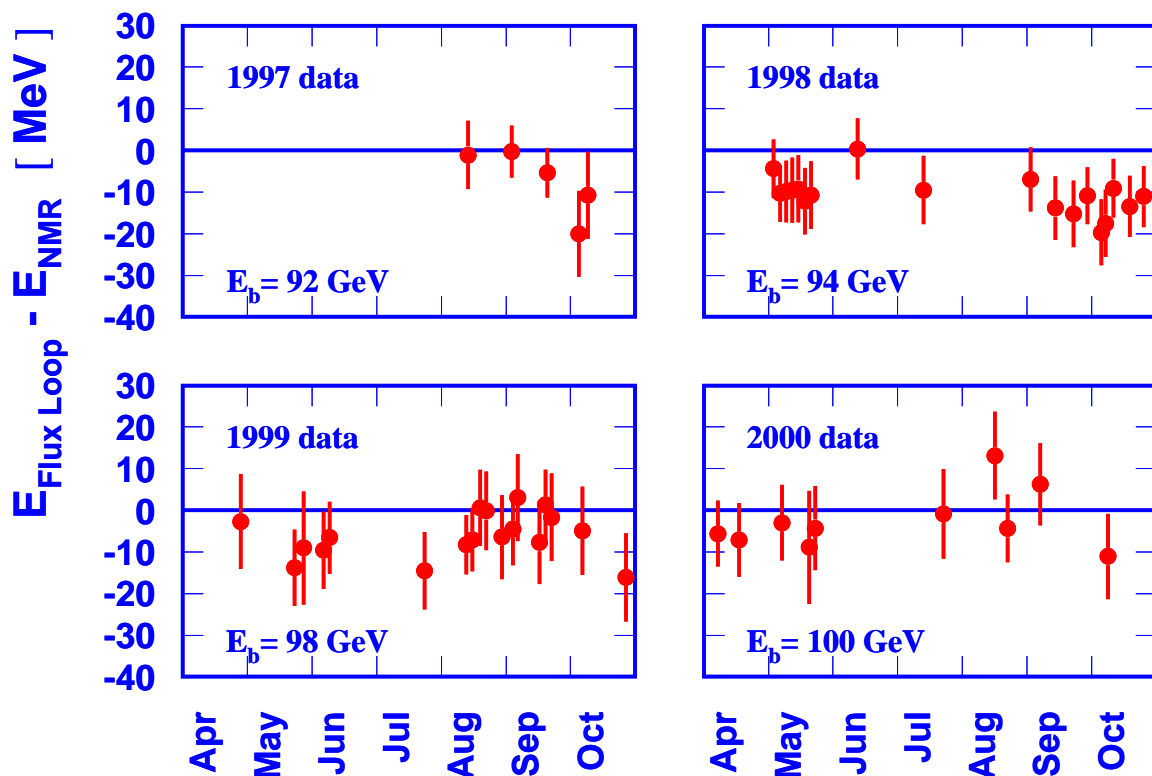
$$\frac{\Delta M_W}{M_W} = \frac{\Delta E_{\text{BEAM}}}{E_{\text{BEAM}}}$$

Correlated between all Expts.

- Spin precession frequency of polarised e^+e^- beams $(\Delta E_{\text{BEAM}} = 200\text{keV})$
Polarisation < 60 GeV \rightarrow Calibrate other methods

- Measurements of magnetic field of LEP bending magnets $(\Delta E_{\text{BEAM}} = 21\text{MeV})$

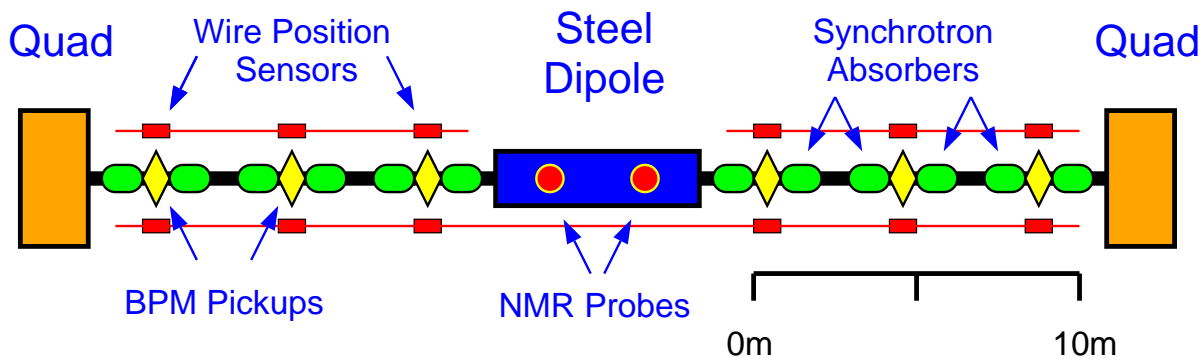
Compare :
 • local field probes in dipoles (NMR)
 • integrated field (flux loop)



E Beam Cross-Checks

(1) Longitudinal oscillations of beam around ideal orbit (Synchrotron tune) with RF voltage

(2) Spectrometer



Beam Position Monitors measure bend angle

- resolution $\approx \mu\text{m}$
- in magnetic field known to 0.001%

(3) Measure from data in $f\bar{f}\gamma$ events

- measure 'mass'
 - compare with known Z mass from LEP1
- talk of Guy Wilkinson

Fragmentation

Important $q\bar{q}'\bar{q}q'$ and $l\nu_l q\bar{q}'$

Assumed **correlated** between channels and between experiments

- Comparing Simulation
- $Z \rightarrow q\bar{q}$

JETSET Tuning

Use other experiments values

Varying parameters within errors

Compare JETSET, HERWIG, ARIADNE

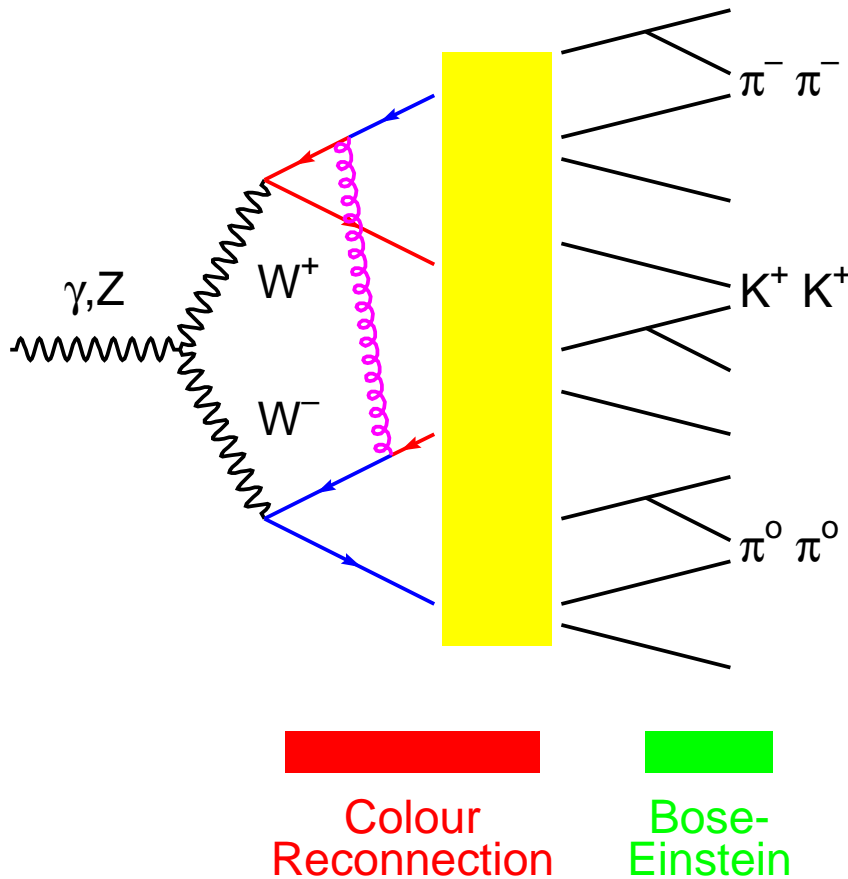
M_W JETSET–HERWIG 189 GeV

Channel	OPAL
$q\bar{q}'\bar{q}q'$	-18 ± 11 MeV
$l\nu_l q\bar{q}'$	-6 ± 10 MeV

Results currently statistically limited
($\Delta M_W < 10$ MeV requires 10^6 Events)

Final State Interactions

- W^+W^- decay vertices separation ≈ 0.1 fm
- Typical hadronisation scale 1 fm
- weight of $q\bar{q}'\bar{q}q'$ in combination 0.27



- **BEC** : between final state hadrons - identical bosons (pions/kaons) close in phase space
- **CR** : cross-talk between coloured objects in non-perturbative QCD region

Colour Reconnection

- Current measurements

M_W most sensitive observable ? !!

→ talk of Mark Dierckxsens

- Use largest shift from models compatible with data

Models :

- VNI

- Not tuned to data

- 10% reduction in multiplicity

- ARIADNE - II, III

- III Theoretically unlikely

- $q\bar{q} + g$ study strongly disfavours (OPAL)
but not for W^+W^-

- HERWIG

- compatible with SK-I (ALEPH)

- JETSET - SK-I, SK-II, SK-II' and GH

- SK-I largest shift

Reduce Sensitivity to CR ?

- **Cut-out inter-jet region**

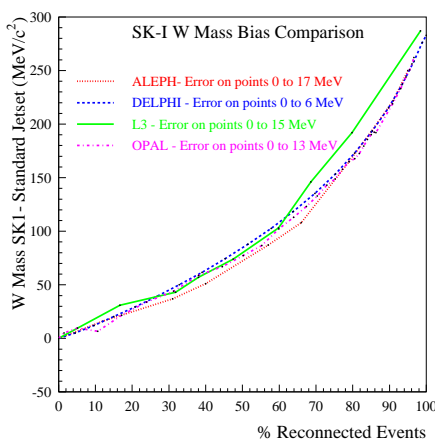
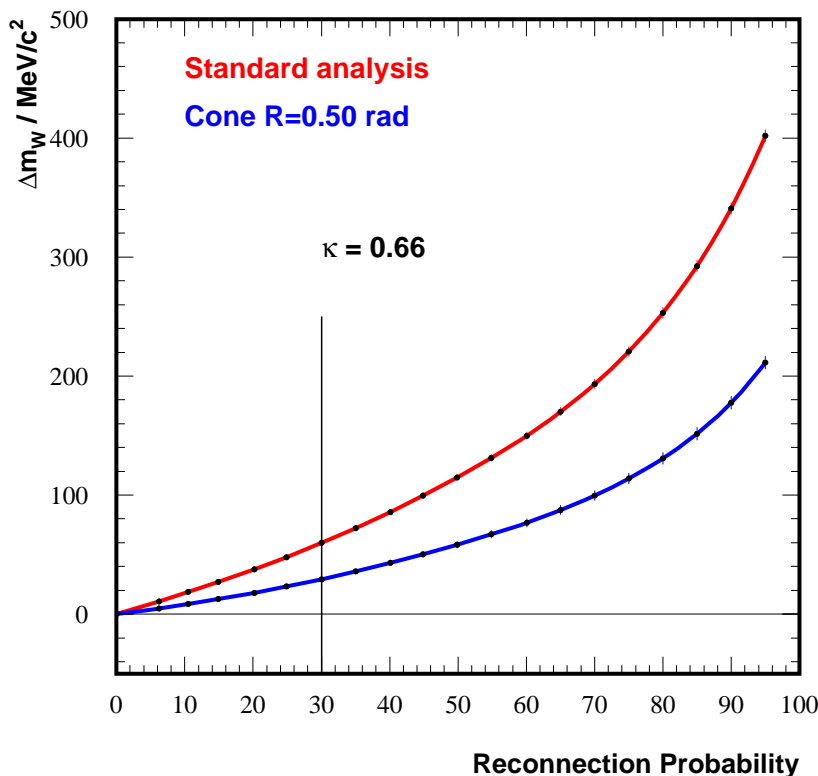
- sacrifice statistical sensitivity

- **BUT model dependent**

SK1 shift 50% decrease for 15% increase in statistical error

→ talk of Jorgen D'Hondt

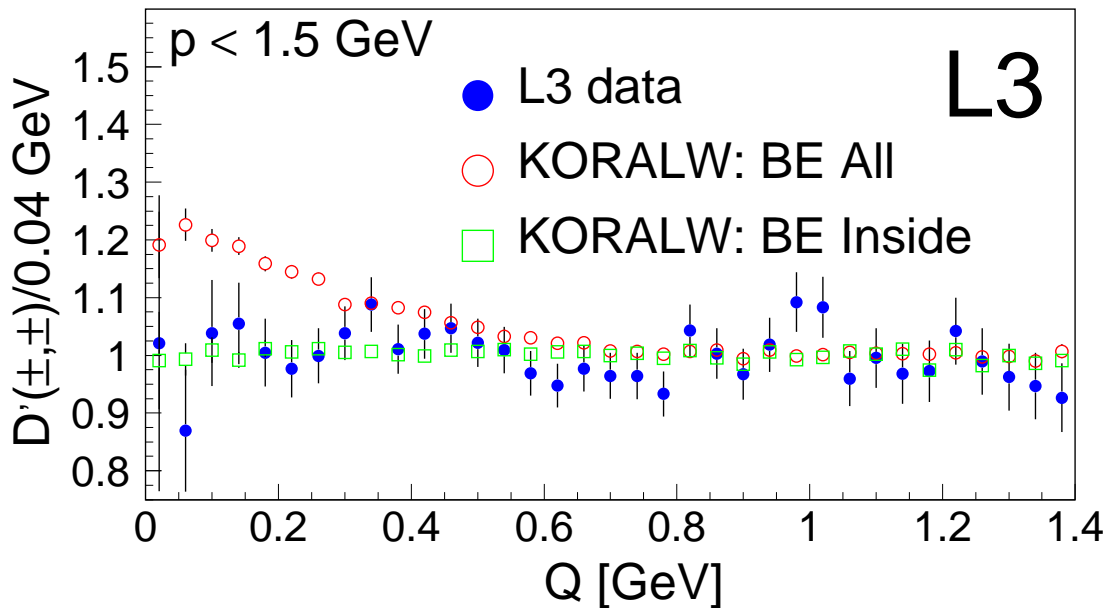
DELPHI preliminary SK1 curves



Demonstrated fully correlated between experiments

Bose-Einstein Correlations

- In Zs, In Ws
- Between W^+W^- ?



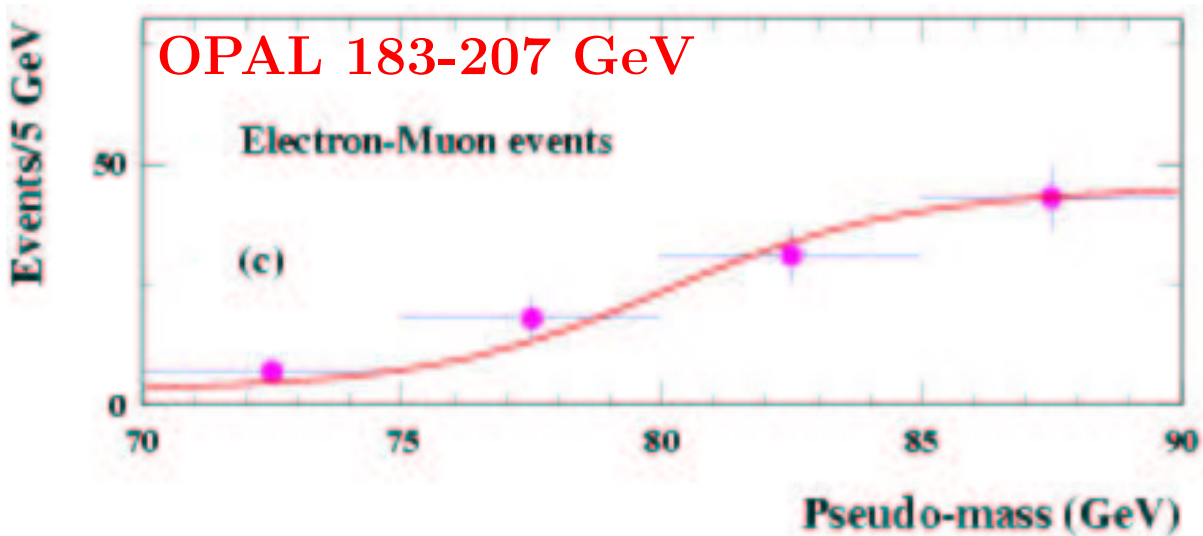
- JETSET LUBOEI model used
 - Re-tuning / checking of JETSET parameters
 - Range of schemes to restore E,p conservation
 - Correlation strength λ

LUBOEI mass shift 189 GeV

Expt	Scheme	M_W shift
OPAL	BE_3	$47 \pm 27 \text{ MeV}$
ALEPH	BE_3	$29 \pm 21 \text{ MeV}$

- Many models smaller/null shifts

Fully-leptonic W Mass determination



- Lepton energy sensitive to W Mass

- pseudo-mass

complete reconstruction : $4 \times p$: 12 quantities

measured : charged lepton p : 6 quantities

constraints : $p = 0, \sqrt{s} = 2 * E_{\text{Beam}}, M_1 = M_2$: 1 quantity

arbitrary constraint: neutrinos in charged lepton plane

→ pseudo-mass

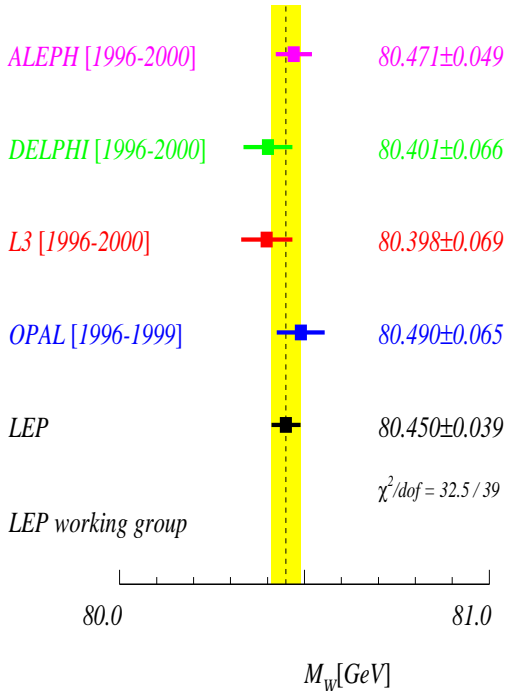
OPAL $M_W = 80.41 \pm 0.41 \pm 0.13$ GeV
(1997-2000)

- lepton energies, missing energy

ALEPH $M_W = 81.81 \pm 0.67 \pm 0.20$ GeV
(1997-1998)

W Mass at LEP2

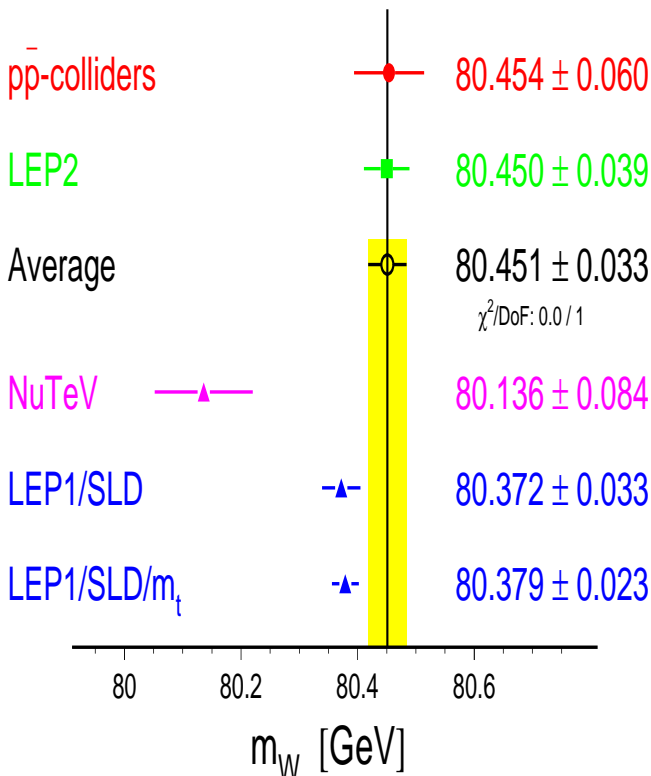
Summer 2001 - LEP Preliminary



Preliminary LEP2
 ± 26 (stat.) ± 21 (syst.)
 ± 13 (FSI) ± 17 (LEP)

Mass difference
 Fragmentation, no FSI
 $M_W(q\bar{q}'\bar{q}q' - l\bar{\nu}_l q\bar{q}')$
 $= +9 \pm 44$ MeV

W-Boson Mass [GeV]



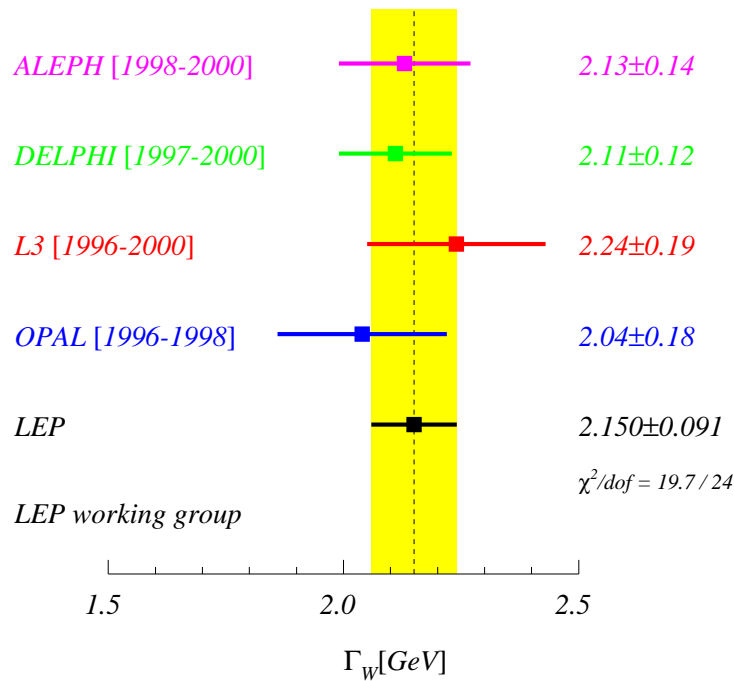
World Average
 Winter '02

LEP2 includes
 Threshold

W Width Results

- Same techniques as for mass measurement
- Systematics \rightarrow Fragmentation, FSI
- Correlation with mass is small

Summer 2001 - LEP Preliminary

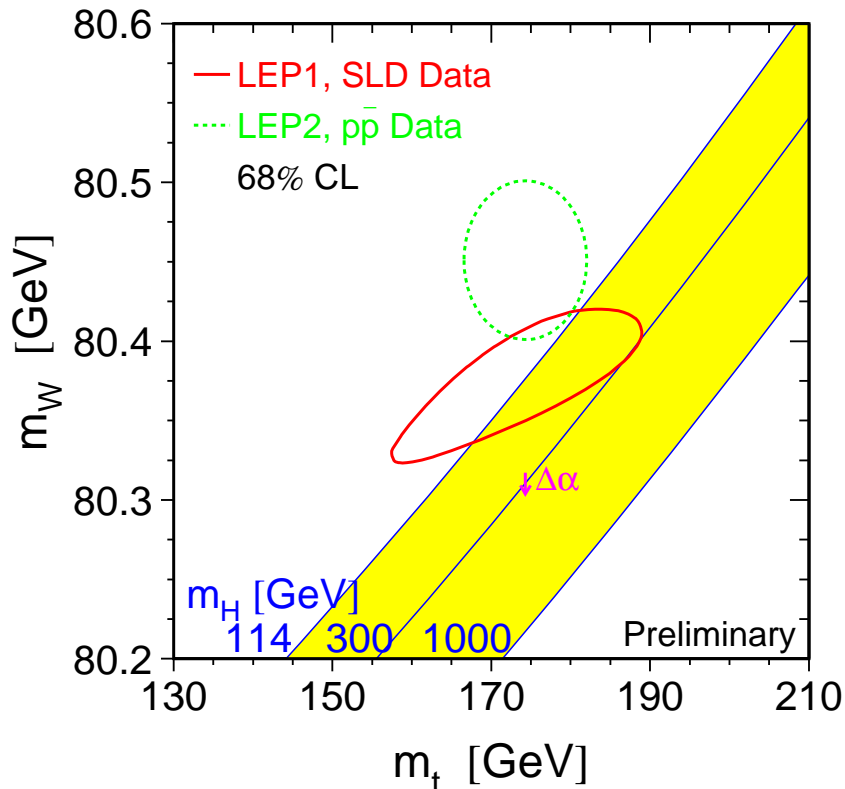


CDF direct width determination :

$$\Gamma_W = 2.055 \pm 0.125 \text{ GeV}$$

Conclusion

- **World average** $M_W = 80,451 \pm 33$ MeV
- **Standard Model Higgs is light**



Final LEP2 ΔM_W Statistical ≈ 22 MeV

Can we match it with Systematics ?

Limitations \rightarrow

$q\bar{q}'\bar{q}q'$ - FSI

($q\bar{q}'\bar{q}q'$ Error 47 MeV, Combination Error 13 MeV)

Fragmentation, LEP Beam Energy

Final LEP2 Moriond next year ?

Look forward to Tevatron run II

($\Delta M_W \approx 30$ MeV)