W Mass Measurement at LEP2

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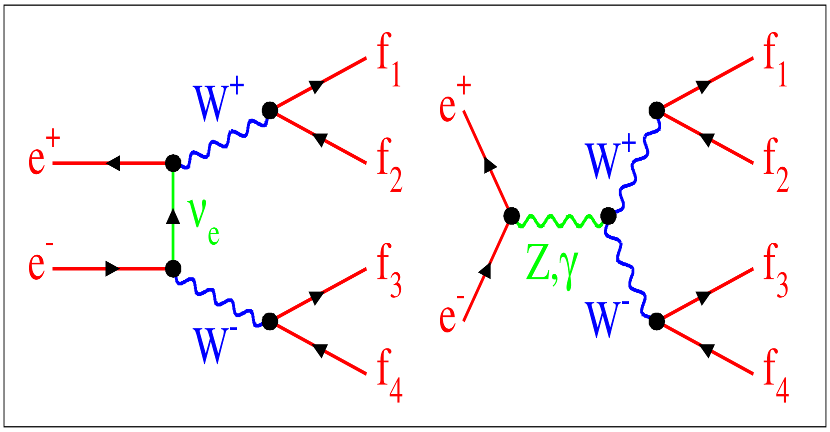
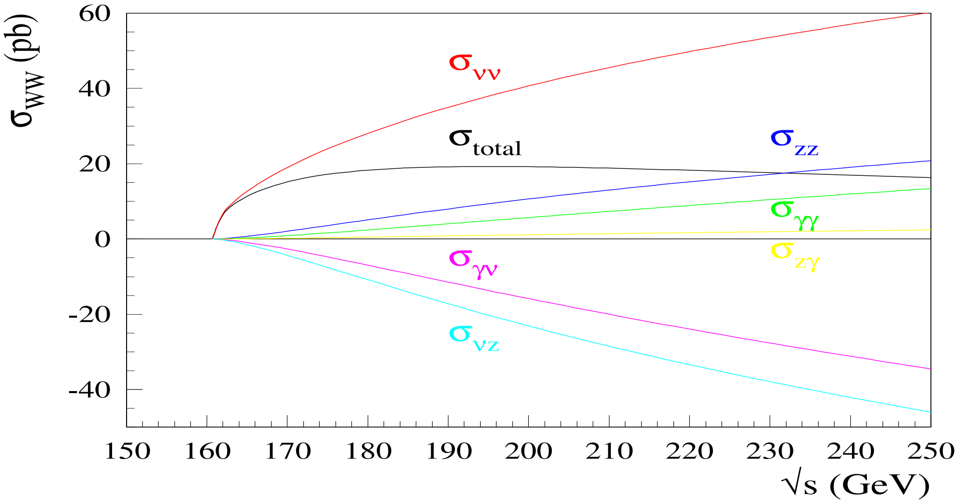
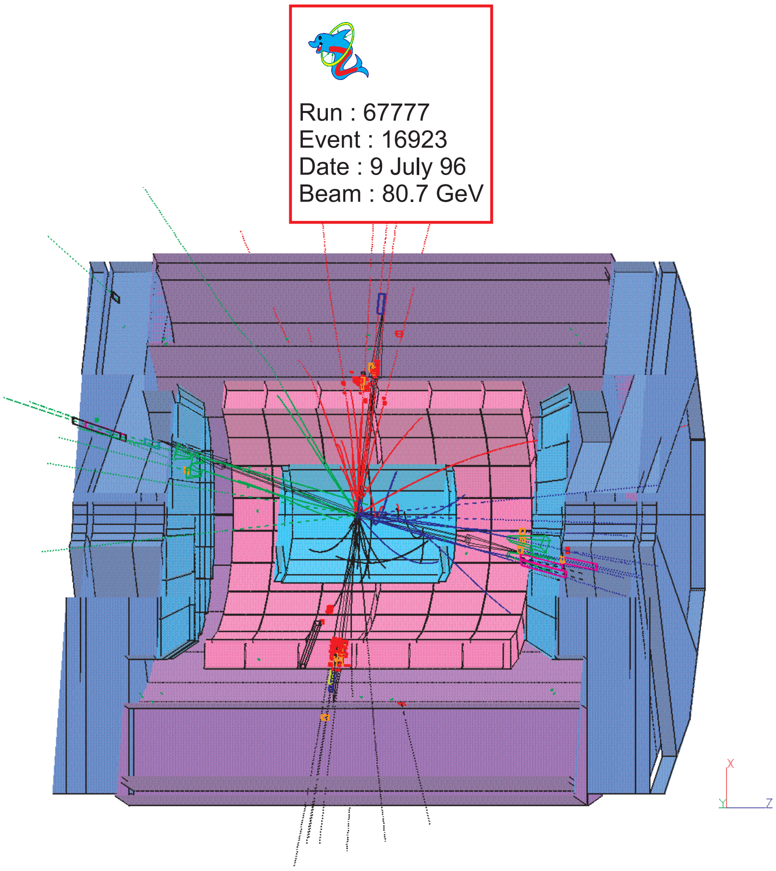


- W mass from Direct Reconstruction → Systematics
- W Width from Direct Reconstruction
- Conclusion and Prospects



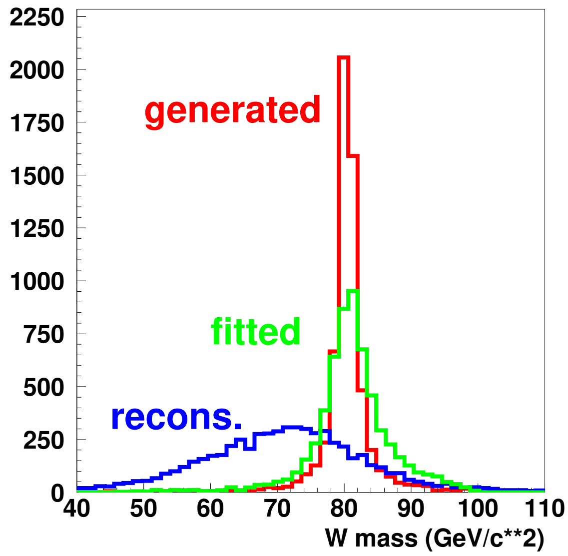
First WW Event



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

Analysis Technique

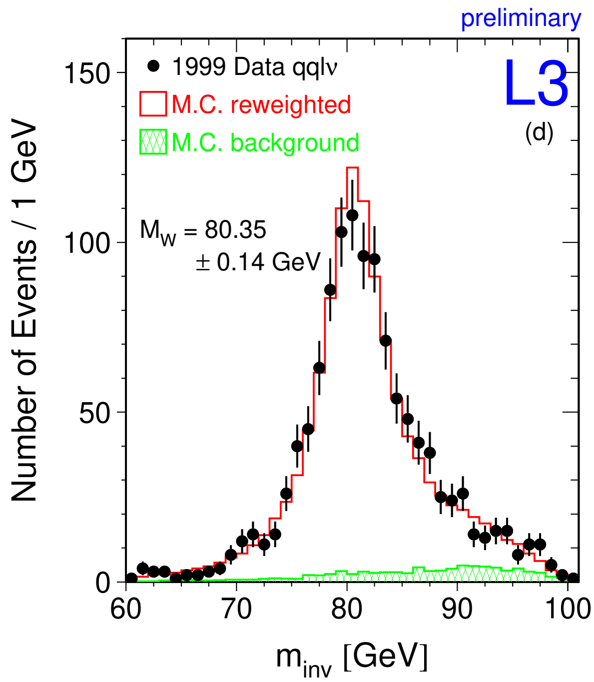
- Select Events $l\overline{\nu}_l q\bar{q}'$(BR=44%), $q\bar{q}'\bar{q}q'$(BR=46%)
- Reconstruct lepton and jets (also gluon jets)
- Impose Kinematic Constraints → improve resolution

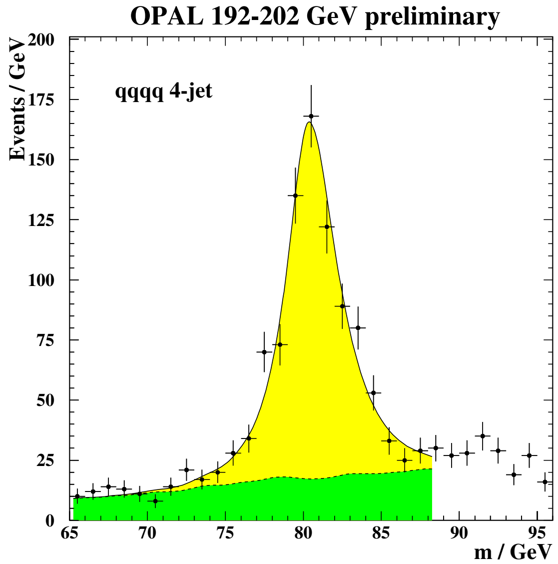


- **E,p conservation**
- **M1,M2 or M1=M2**

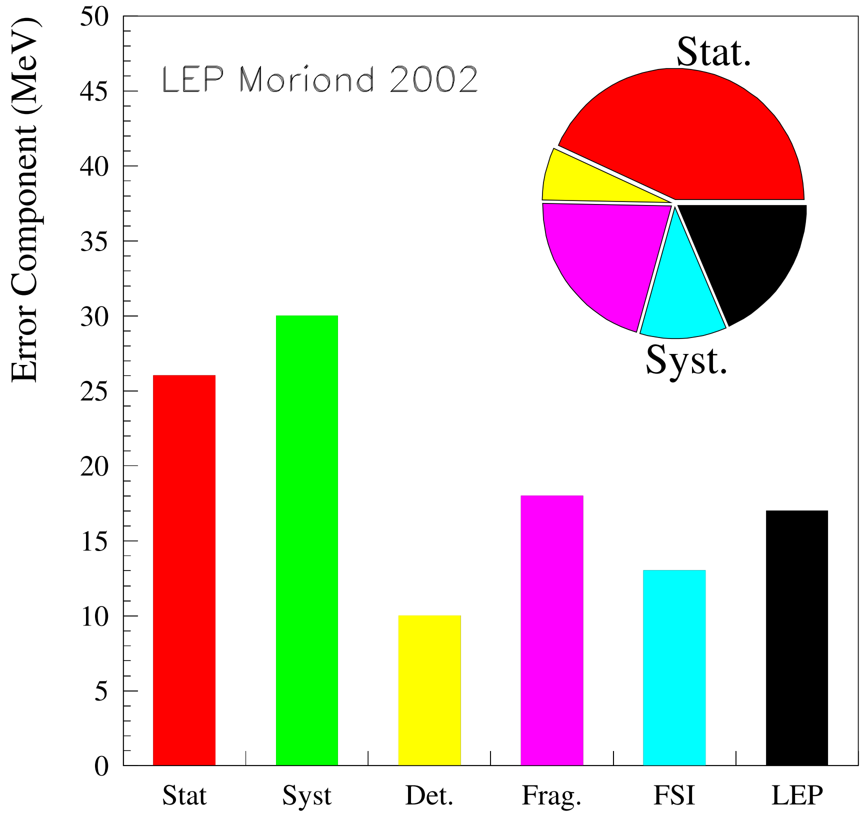
- $q\bar{q}'\bar{q}q'$ **events select/weight jet pairings**

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**



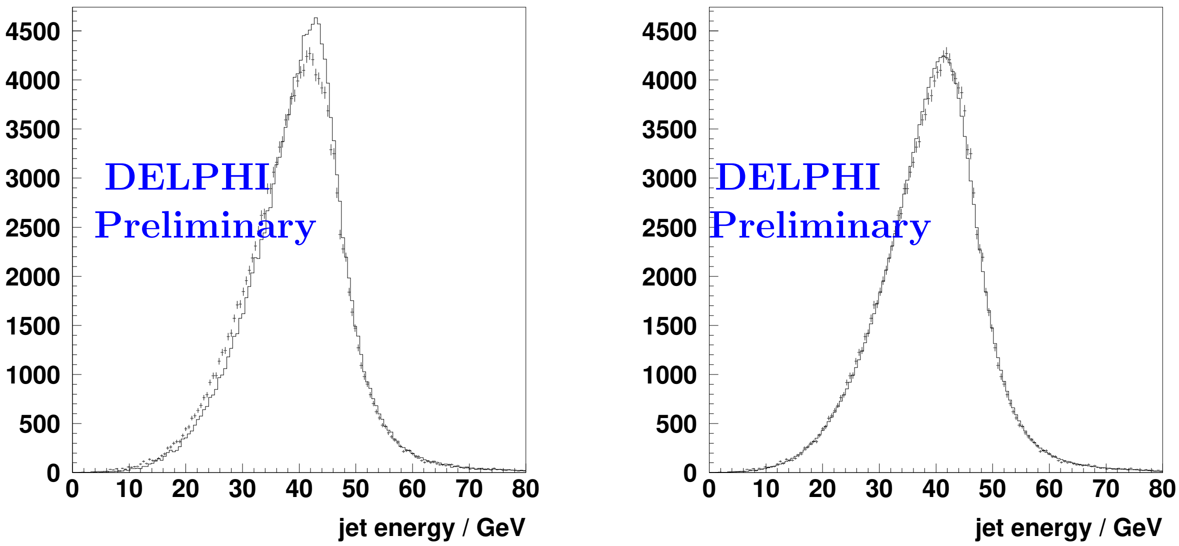
Systematics on MW

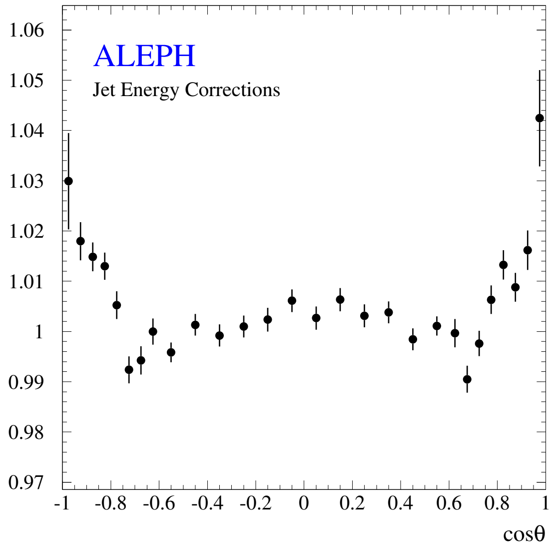
- Systematics dominated measurement
- Inter-experiment collaboration
  - LEP WW workshops
- Detector Effects
- Fragmentation
- FSI
- EBeam
- $\mathcal{O}(\alpha)$

Detector Effects

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

RAW $\rightarrow$ CORRECTED





Study using $\rightarrow$

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

more work $\rightarrow$ lower error ?

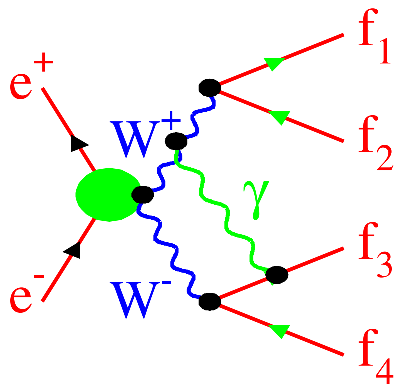
Energy non-linearities

- 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 ←→ reconstruction**

$\mathcal{O}$ 10 MeV ?

LEP Beam Energy Determination

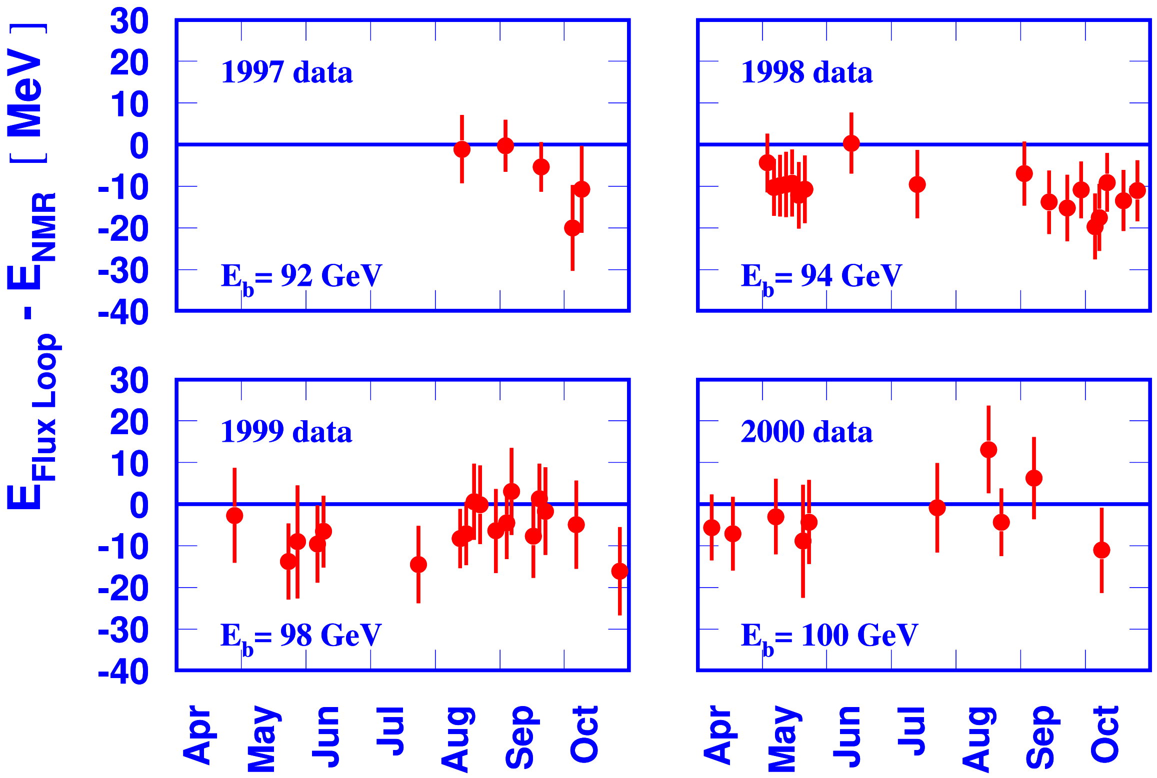
$\frac{\Delta M_W}{M_W} = \frac{\Delta E_{\text{BEAM}}}{E_{\text{BEAM}}}$ **Correlated between all Expts.**

- **Spin precession frequency of polarised e^+e^- beams** $(\Delta E_{\text{BEAM}} = 200 keV)$

  Polarisation < 60 GeV → Calibrate other methods

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

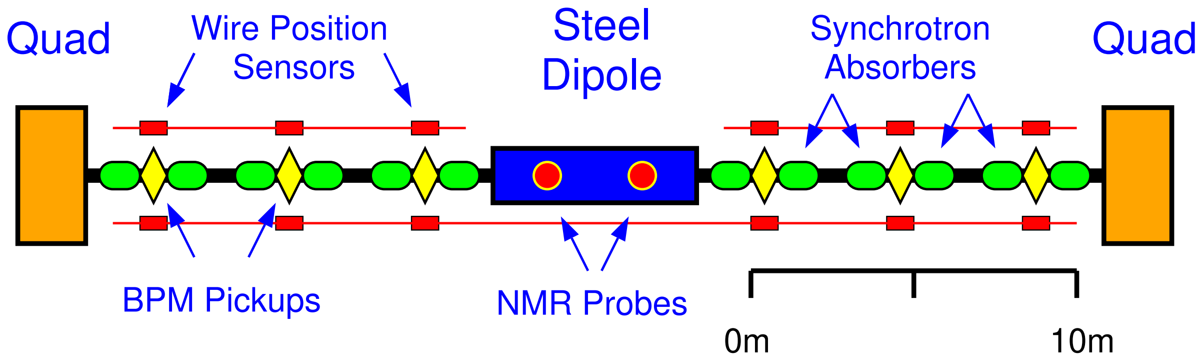
  Compare :
  - **local field probes in dipoles (NMR)**
  - **integrated field (flux loop)**



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** $\approx \mu\mathrm{m}$
- **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**

$\rightarrow$ **talk of Guy Wilkinson**

Fragmentation

Important $\mathrm{q\bar{q}'\bar{q}q'}$ **and** $\mathrm{l\overline{\nu}_l q\bar{q}'}$
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`

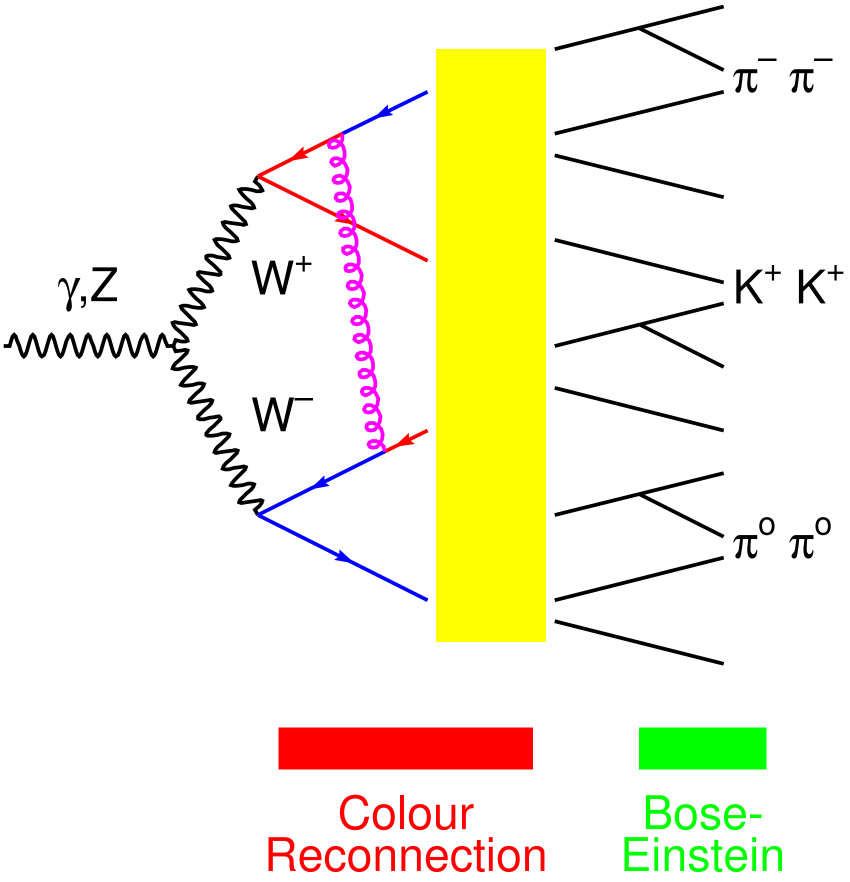
$\mathrm{M_W}$ `JETSET`−`HERWIG` **189** GeV

Channel	OPAL
$\mathrm{q\bar{q}'\bar{q}q'}$	-18 ± 11 MeV
$\mathrm{l\overline{\nu}_l q\bar{q}'}$	-6 ± 10 MeV

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

Final State Interactions

- W^+W^-decay vertices separation $\approx$ 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-peturbative QCD region

Colour Reconnection

- **Current measurements**
  M_W most sensitive observable ? !!
  $\rightarrow$ 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** $\mathrm{W^+W^-}$ **....**
- 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**

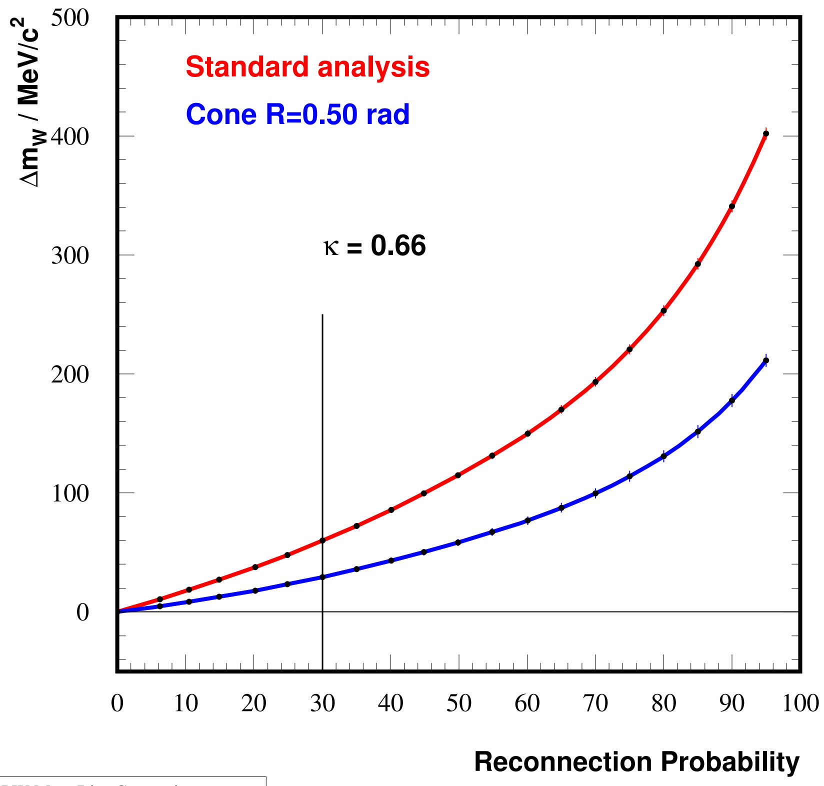
- sacrifice statistical sensitivity

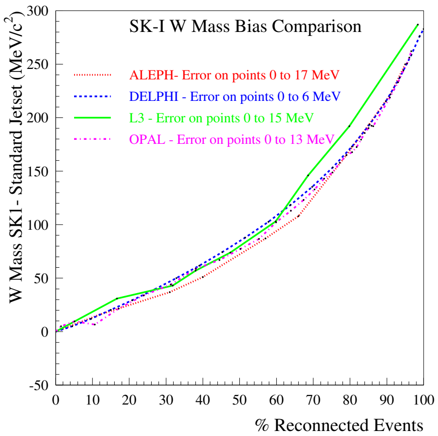
- **BUT model dependent**

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

→ talk of Jorgen D'Hondt

DELPHI preliminary SK1 curves

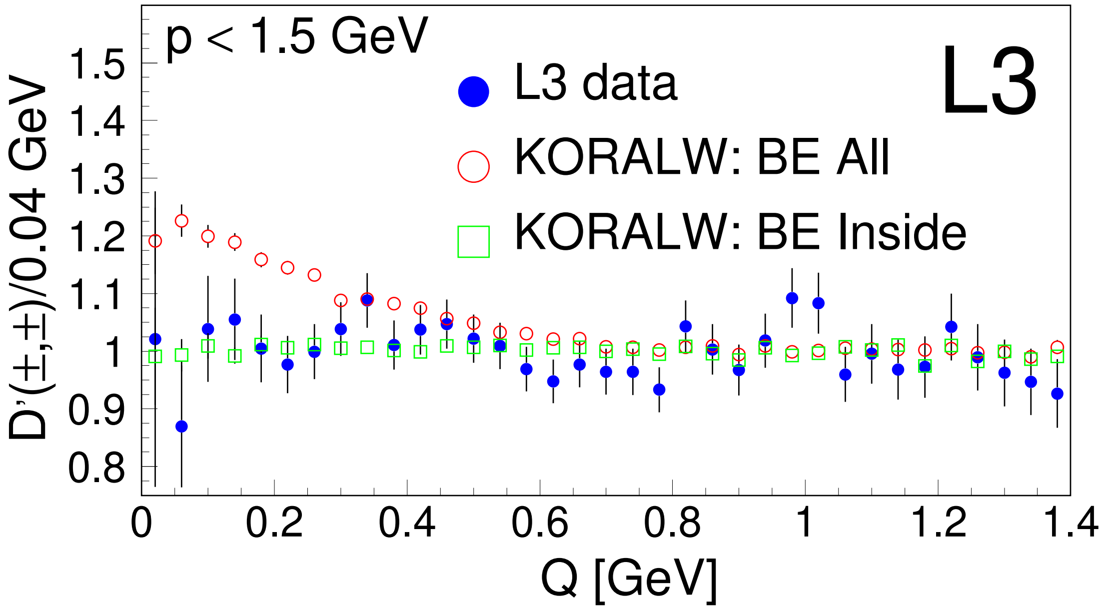




Demonstrated fully correlated between experiments

Bose-Einstein Correlations

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



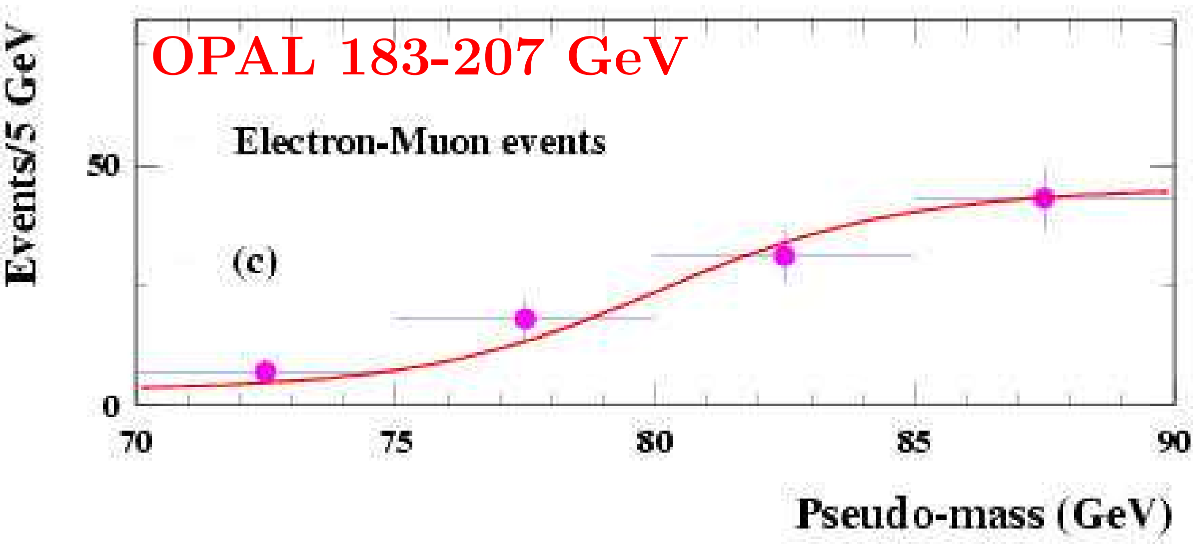
- JETSET LUBOEI model used
  - Re-tuning / checking of JETSET parameters
  - Range of schemes to restore E,p conservation
  - Correlation strength λ

LUBOEI mass shift 189GeV

Expt	Scheme	M_W shift
OPAL	BE_3	47 ± 27 MeV
ALEPH	BE_3	29 ± 21 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 : $\mathbf{p = 0, \sqrt{s} = 2 * EBeam, M1 = M2}$ **: 1 quantity**

arbitrary constraint: neutrinos in charged lepton plane

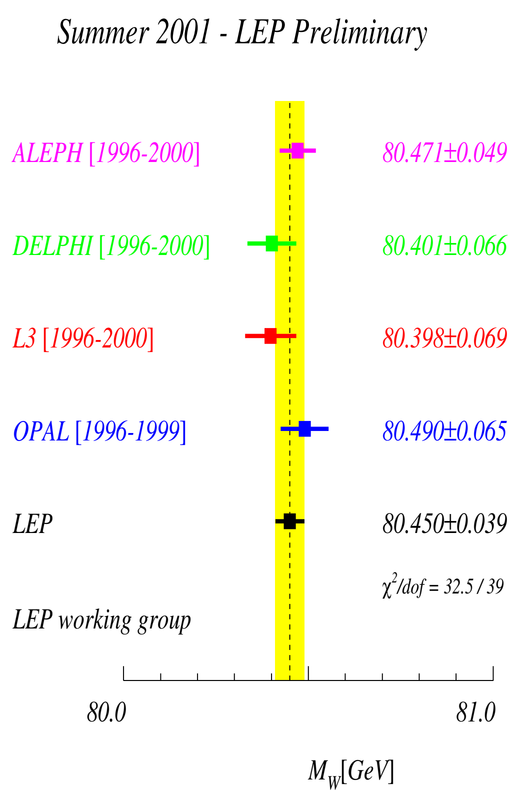
$\rightarrow$ **pseudo-mass**

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



Preliminary LEP2

±26 (stat.) ±21 (syst.)

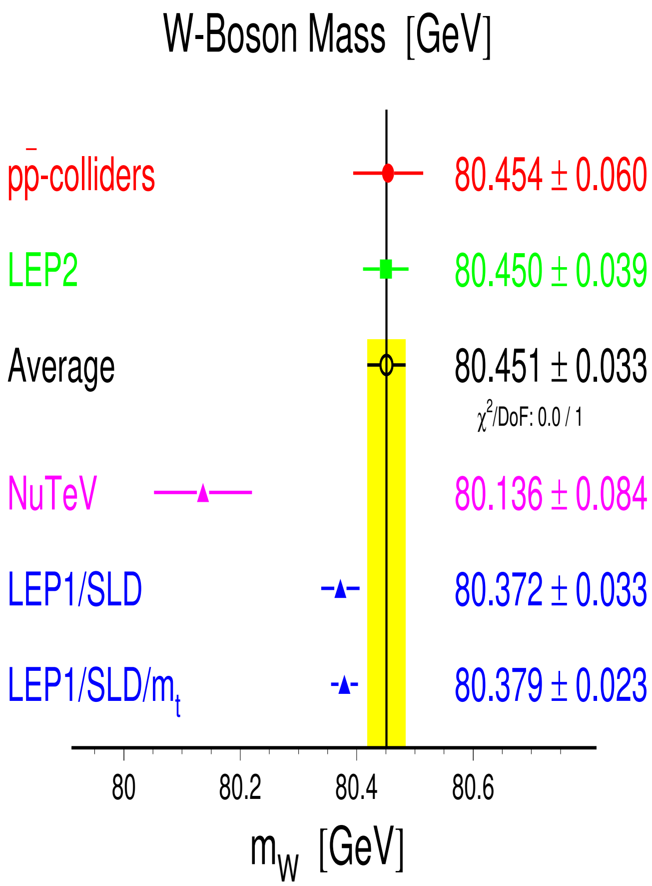
±13 (FSI) ±17 (LEP)

Mass difference

Fragmentation, no FSI

$M_W(q\bar{q}'\bar{q}q' - l\bar{\nu}_l q\bar{q}')$

$= +9 \pm 44$ MeV



World Average

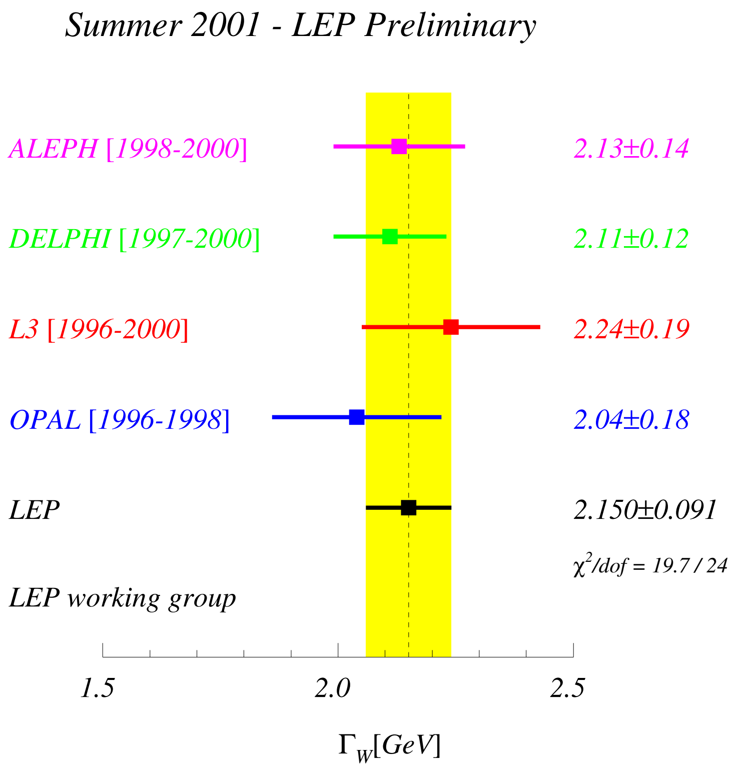
Winter '02

LEP2 includes

Threshold

W Width Results

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

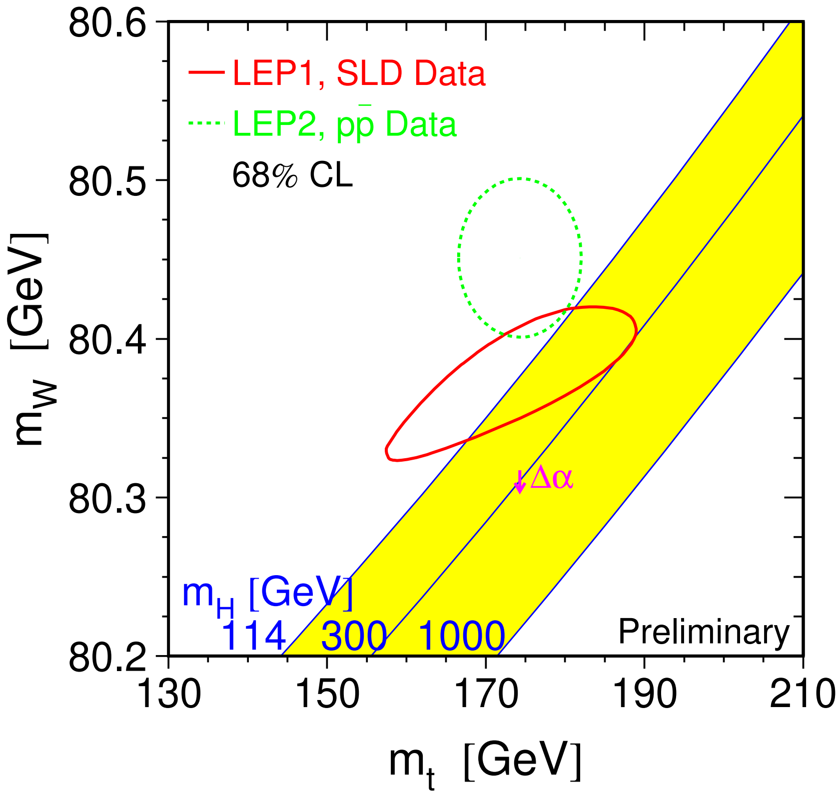


CDF direct width determination :

$\Gamma_{\mathrm{W}} = 2.055 \pm 0.125$ GeV

Conclusion

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



Final LEP2 Δ M_W **Statistical** $\approx$ **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
(Δ M_W $\approx$ **30 MeV**)