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W Mass Measurements using Semileptonic and fully Leptonic Events at LEPII

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1. Event selection.
2. Mass extraction.
3. Systematic uncertainties.
4. M_W from fully leptonic events.
5. Impact of M_W on electroweak results.

$\mathrm{M_W}$ **from** $\mathrm{W^+W^-} \to q\bar{q}l\nu$

- 43.8 % of all W pairs decay semileptonically.
- Clear event signature with low background.
- All particles except the high-energetic lepton originated from the same W.
  - No jet pairing uncertainty
  - No FSI between the two W's.

Event selection:

- Two jets and one lepton.
- For e and μ: loose lepton identification and isolation cuts.
- For τ: isolated low multiplicity jet.
- High purity and high efficiency.

Some non $\mathrm{W^+W^-}$ background in $q\bar{q}\tau\nu$ channel

Cross contamination from e, μ in $q\bar{q}\tau\nu$ has the same mass information.

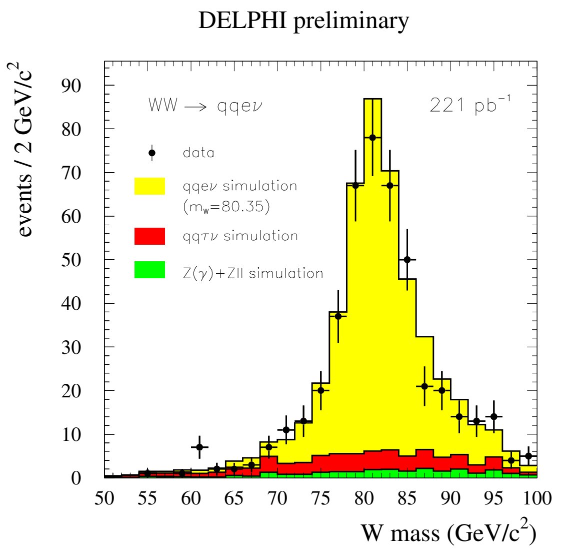
Kinematic Fit

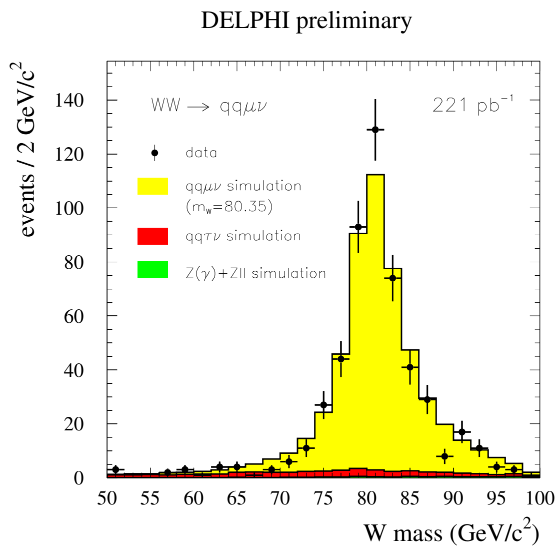
5 possible constraints:

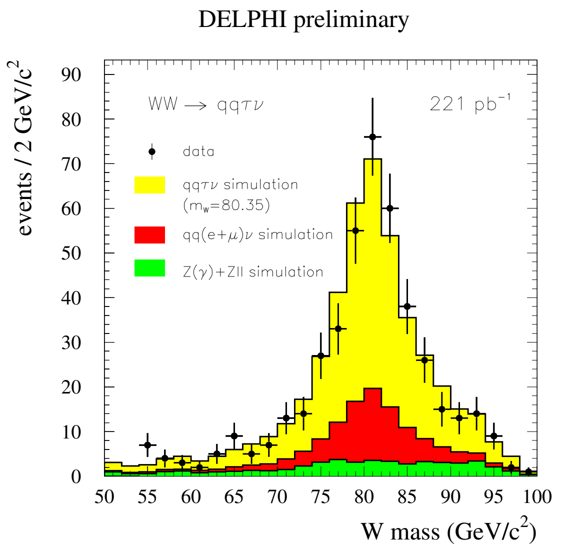
(E,$\vec{p}$ conservation, $E_{q\bar{q}} = E_{l\nu} = E_{beam}$.)

- For e, μ: 3 unknowns ($\vec{p_\nu}$)
  $\Rightarrow$ 2C and 1C fits possible.

- For $\mathrm{M_W} \rightarrow q\bar{q}\tau\nu$: Only the direction of the τ can be determined (one extra unknown).
  $\Rightarrow$ Mass from the hadronic system with a 1C fit $E_{q\bar{q}} = E_{beam}$.







Mass Extraction

One knows mass and error from the 2C (M_W^{2C}, σ_{2C}) and 1C (M_W^{1C}, σ_{1C}) kinematic fit.
Reweighting Monte Carlo to arbitrary values of M_W and Γ_W .
Extraction of M_W where data and MC best agree.
(For M_W measurement Γ_W fixed by the standard model prediction.)

- 3-dim. distribution in M_W^{2C}, σ_{2C} and M_W^{1C} for e and μ and 2-dim. in M_W^{2C}, σ_{2C} for τ (ALEPH).
- 1-dim. distribution in M_W^{2C} (L3) with data divided in 4 bins of σ_{2C}. (OPAL)

1-dim. convolution fit: For each event M_W^{2C}, σ_{2C} can be used to calculate a Likelihood as a function of M_W.
(DELPHI, OPAL)

Systematic uncertainty

The mass extraction relies on the comparison of the data with Monte Carlo expectation.
$\Rightarrow$ Systematic uncertainties due to uncertainties in the Monte Carlo simulation.

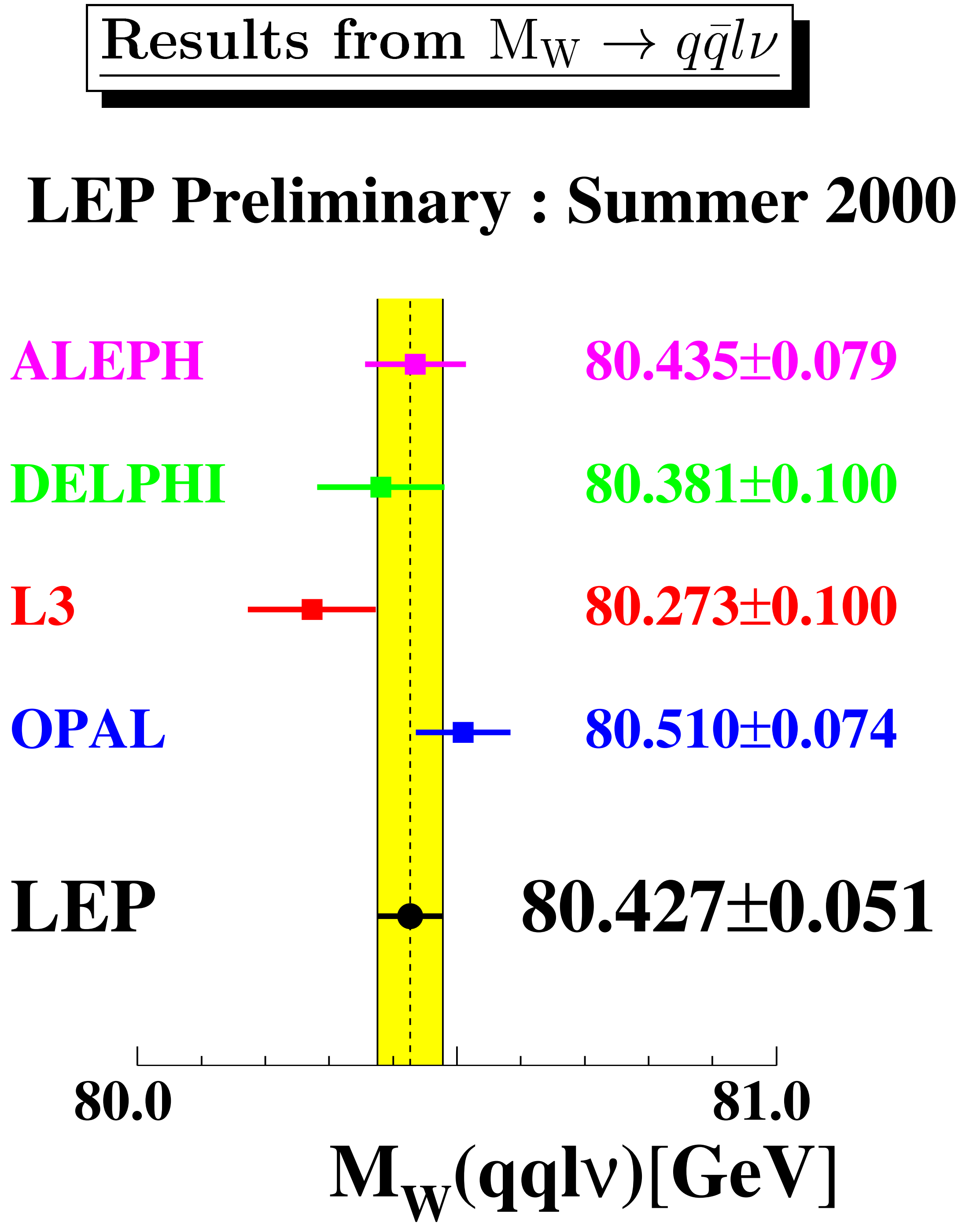
- Detector simulation: Each year also data at Z^0 resonance are taken. This is used to measure the energy scale and the energy and angular resolution for jets and leptons.
- Hadronisation: Comparison of different Monte Carlo generators (PYTHIA, HERWIG, ARIADNE) and different Monte Carlo tunes.
  Cross-checked by:
  - Analyzing Z^0 calibration data emulating a W in W^+W^- after a suitable Lorentz boost (DELPHI).
  - Propagating the difference between data and Monte Carlo in fragmentation related observables as weights through the mass analysis and thus estimating the effect of the difference in M_W (ALEPH)

Systematic uncertainties cont.

- Beam Energy: Detailed studies of the LEP energy working group.
- Initial and final state radiation: The difference between the ISR treatment in KoralW and Excalibur or between different orders in KoralW are used to estimate the ISR uncertainties.
  The full $\mathcal{O}(\alpha)$ effects are not included yet. (Calculations using double-pole approximations indicate possible mass shifts of about 10 MeV, but full simulations are not available yet.)

Typical errors

Source	Error
Detector Systematic	11 MeV
Hadronisation	26 MeV
LEP Beam Energy	17 MeV
ISR/FSR	8 MeV
Other	5 MeV
Total Systematic	35 MeV
Statistical	38 MeV
Total	51 MeV

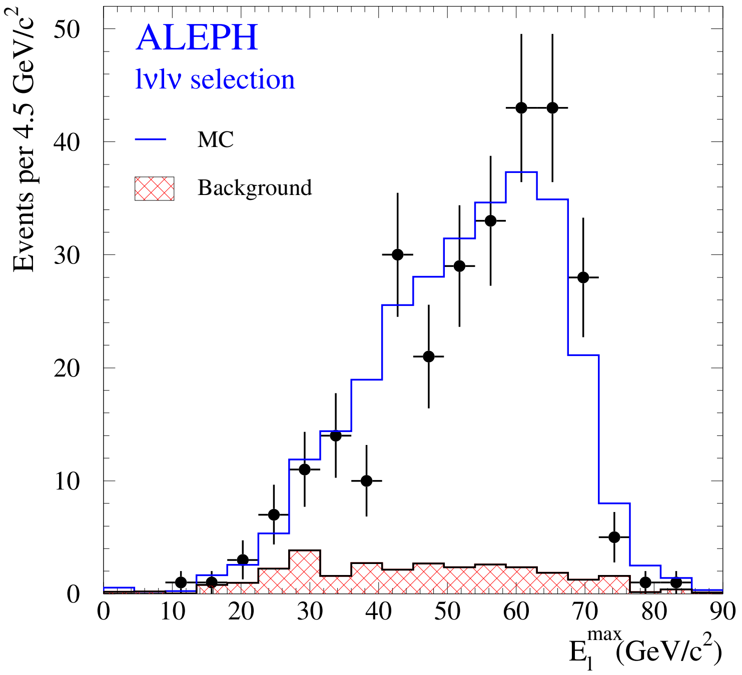

Results from $M_W \to q\bar{q}l\nu$
LEP Preliminary : Summer 2000
ALEPH
80.435±0.079
DELPHI
80.381±0.100
L3
80.273±0.100
OPAL
80.510±0.074
LEP
80.427±0.051
80.0
81.0
$M_W(qql\nu)$[GeV]

M_W from fully leptonic decays

- 10.6 % of all W pairs decay fully leptonically.
- Clear event selection. (Two leptons and missing energy.)
- 2 missing $\nu \Rightarrow$ reconstruction of W's not possible.
- But: On can use distributions sensitive to M_W to extract the mass of the W.

The lepton energy spectrum is:

$$E_\ell = \frac{\sqrt{s}}{4} + \cos\theta^*_\ell \sqrt{\frac{s}{16} - \frac{M_W^2}{4}}$$



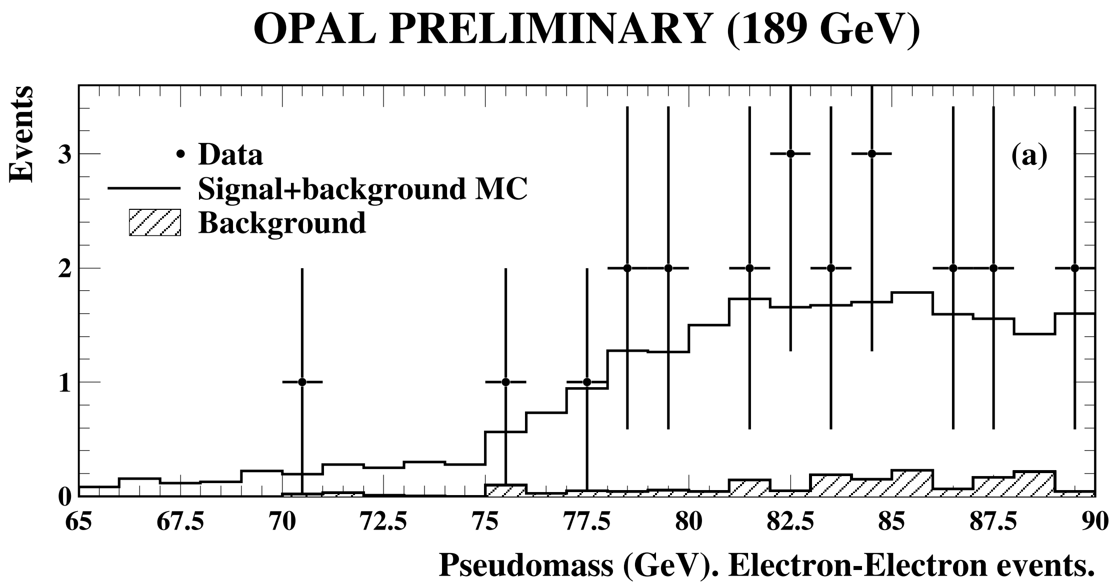
M_W from fully leptonic decays

One has 6 unknowns (from the 2 ν's) but only 5 external constraints.

One can use as 6th constraint the assumption that the neutrinos are in the same plane as the leptons.

If the assumption is nearly true, one reconstructs the right mass, otherwise one gets a larger mass.

$\Rightarrow$ Distribution (called pseudo-mass) with an edge which depends on M_W.



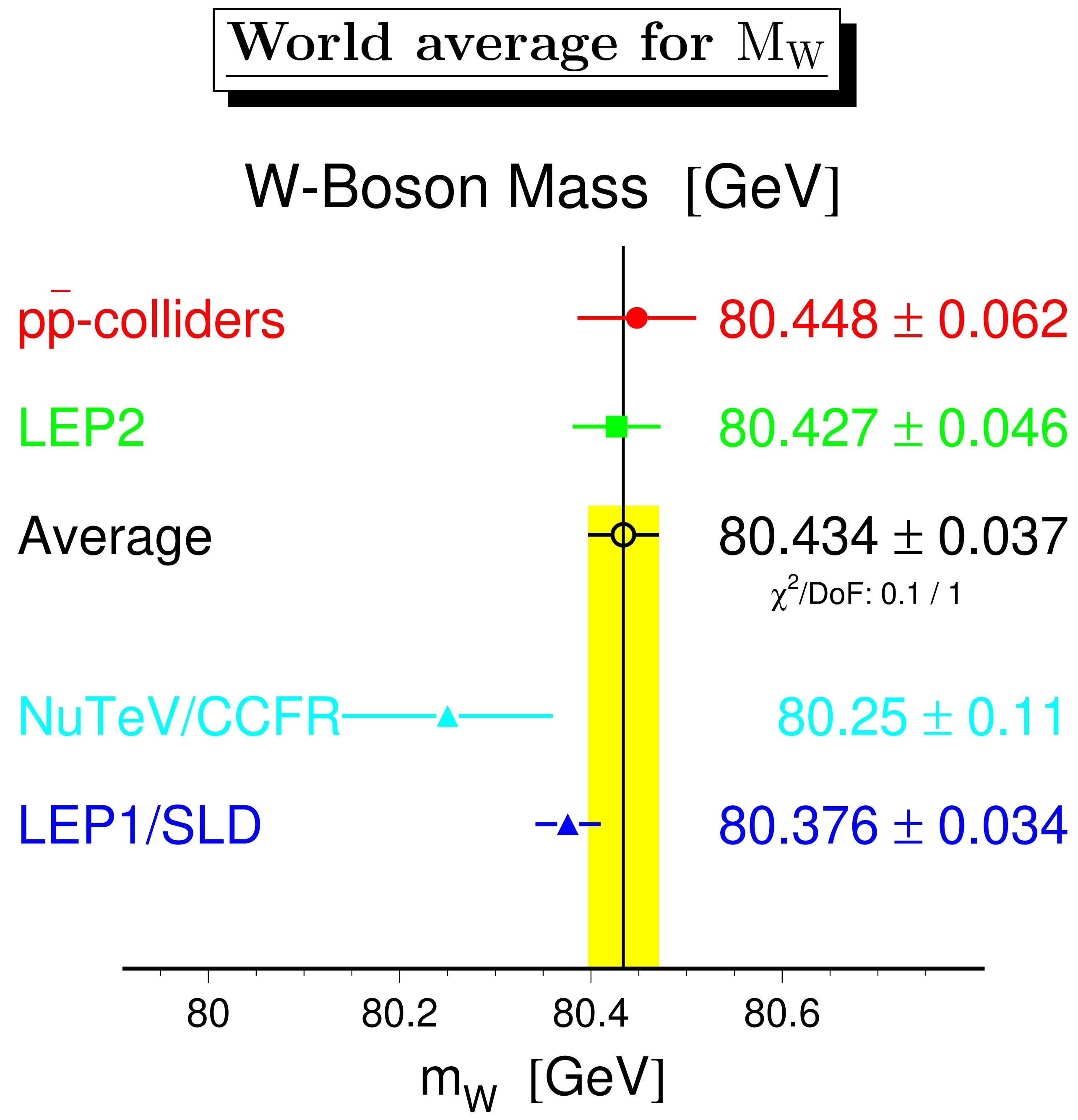
ALEPH (lepton energy 189 GeV data)

$$M_W^{l\nu l\nu} = 81.81 \pm 0.67(\text{stat.}) \pm 0.20(\text{syst.})\ \text{GeV}$$

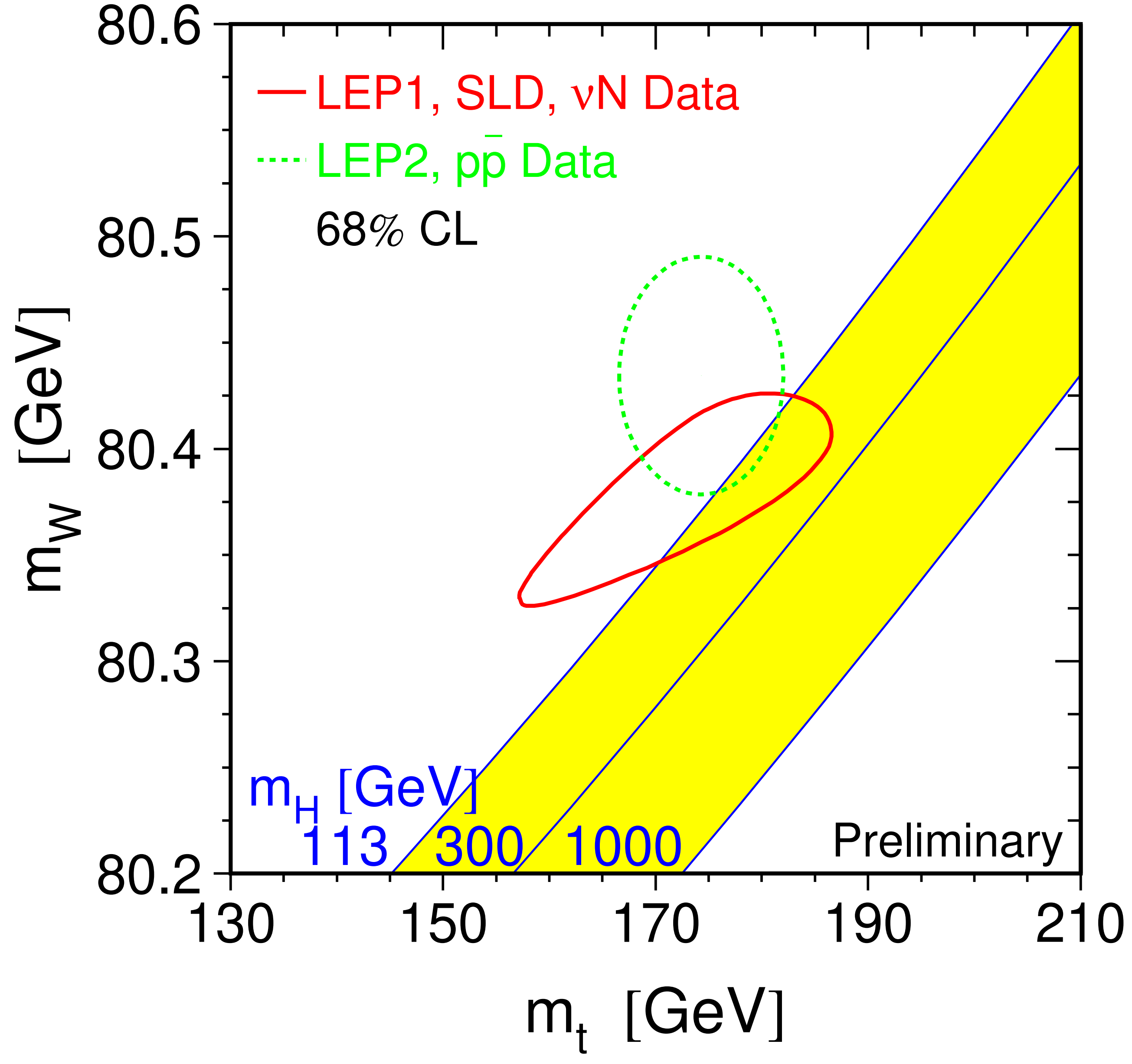
OPAL (lepton energy and pseudo-mass 183-202 GeV)

$$M_W^{l\nu l\nu} = 80.27\ {}^{+0.51}_{-1.62}(\text{stat.})\ \pm 0.14(\text{syst.})\ \text{GeV}$$

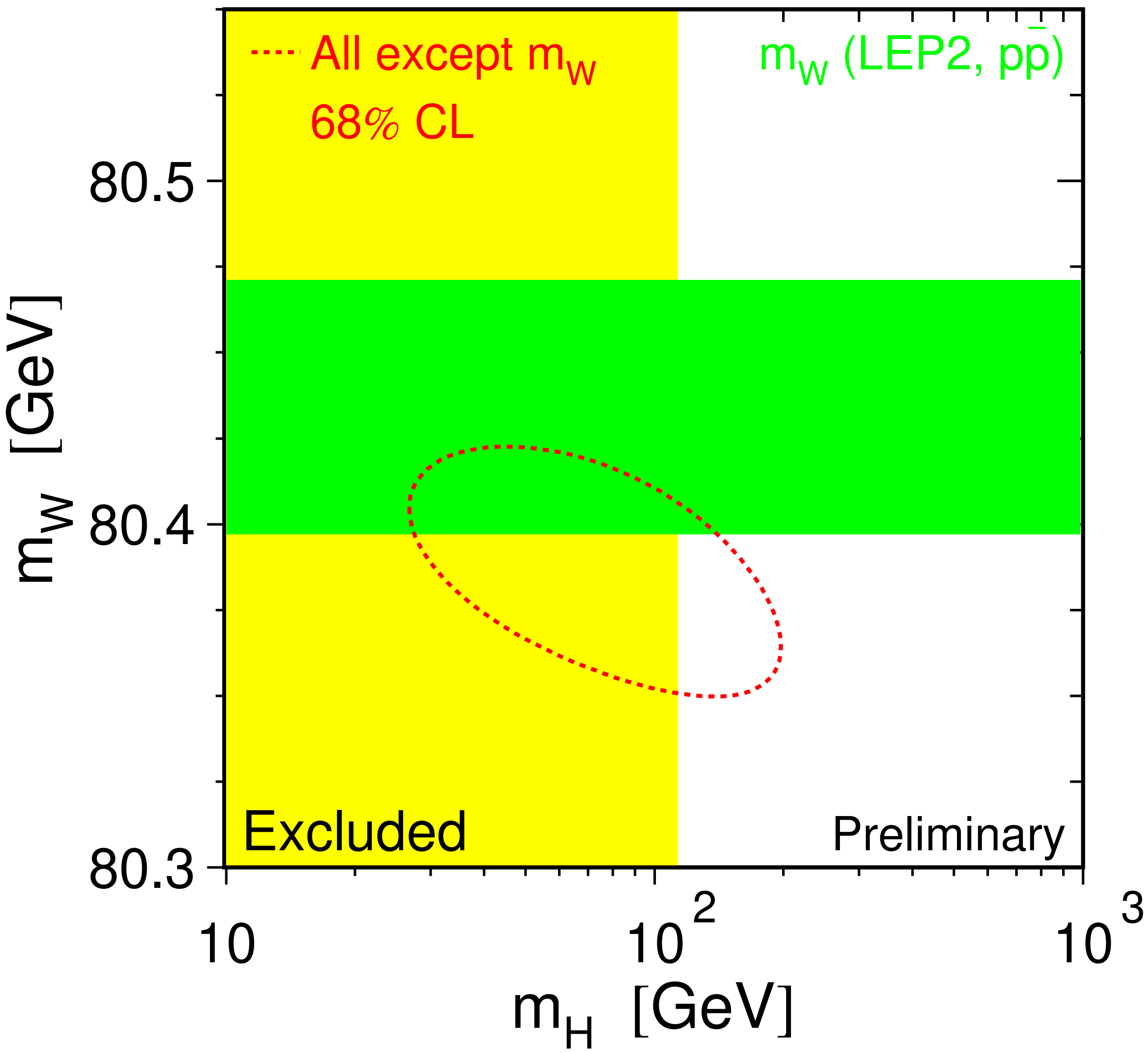
(Parabolic error at $M_W = 80.5$ GeV: ~ 0.5 GeV)


World average for M_W
W-Boson Mass [GeV]
$p\bar{p}$-colliders
80.448 ± 0.062
LEP2
80.427 ± 0.046
Average
80.434 ± 0.037
χ^2/DoF: 0.1 / 1
NuTeV/CCFR
80.25 ± 0.11
LEP1/SLD
80.376 ± 0.034
80
80.2
80.4
80.6
m_W [GeV]

M_W **and electroweak data**



Influence of M_W on Higgs mass prediction



Conclusions

- The direct measurements of M_W have reached the same precision as the indirect prediction from electroweak fits.
- The measurement starts to be dominated by systematic uncertainties.
- We still expect an improvement of the LEP2 M_W measurement with this year's data and with refined analysis.