

Tevatron Electroweak Working Group: Status and Plans

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for the TeVEWWG

- Mission
- Strengths of TeVEWWG
- Accomplishments
- Run 2 Plans
- Summary



Mission

Coordination, combination and interpretation of electroweak physics results from the Tevatron, for precision Standard Model tests and predictions of new physics.



Need for TeVEWWG

- Electroweak measurements are pieces of a jigsaw puzzle – make full impact when assembled in the framework of the standard model – what is the big picture?
- Tevatron is now the only accelerator at the energy frontier taking data
- Extensive electroweak physics program at Run 2 (building on very successful Run 1)
- TeVEWWG created to work close to where the pieces are produced, to help solve the puzzle



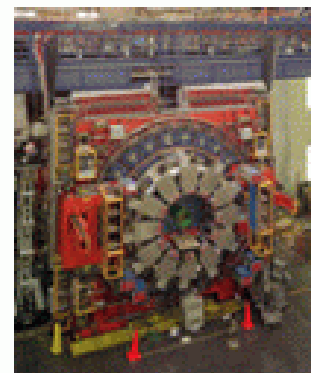
Tevatron Electroweak Working Group established September 2003

Details of results and subgroups can be found at <http://tevewwg.fnal.gov>

First combined analysis group at Fermilab to publish in refereed journal.

New working group boosts electroweak physics

Some 20 physicists from both the DZero and CDF collaborations formed the [Tevatron Electroweak Working Group](#), aiming to increase the accessibility of electroweak physics at Fermilab. "We want to standardize the analysis inputs, combine all our results, and interpret them so that the rest of the physics community can use our results easily," says founding member Ashutosh Kotwal of Duke University and CDF. The group will address the properties of the W and Z bosons and the top quark, and their implications for the Higgs boson.



CDF Detector



DZero Detector

Electroweak Physics Topics at the Tevatron

- Production cross sections – W , Z , $t\bar{t}$, single top
- Ratios $R = \sigma(W \rightarrow l\nu)/\sigma(Z \rightarrow ll)$, indirect extraction of W width
- Tests of universality in W decays
- Luminosity measurement with W , Z counting
- Direct mass and width measurements of W and top
- Diboson production
- W/Z asymmetry, $d\sigma/d(\cos\theta^*)$, $A_{\text{FB}}(M_{ll})$, $d\sigma/dM_{ll}$
- Tests of theory, parton distribution functions

Group Organization and Membership

- Umbrella group TeVEWWG (mailing list tev-ewwg.fnal.gov) open to all (49 current subscribers including 6 theorists)
- Subgroups for internal CDF & D0 discussions, open to all CDF and D0 collaborators
 - W and Z properties (26 subscribers)
 - Top quark properties (14 subscribers)
 - Higgs physics

Current Members

William Ashmanskas, Patrizia Azzi, Ulrich Baur, Emanuela Barberis, John Beacom, Craig Buttar, William Carithers, Brendan Casey, Marcel Demarteau, Luc Demortier, Thomas Diehl, Tommaso Dorigo, Sarah Eno, Robin Erbacher, Harald Fox, Henry Frisch, Michele Gallinaro, Gervasio Gomez, Paul Grannis, Martin Grunewald, Leslie Groer, Nickolas Hadley, Raymond Hall, Eva Halkiadakis, Beate Heinemann, Ulrich Heintz, Gavin Hesketh, Eric James, Aurelio Juste, Gordon Kane, Young-Kee Kim, Boaz Klima, Jaco Konigsberg, Ashutosh Kotwal, Mark Kruse, Yaroslav Kulik, Mark Lancaster, Ronald Madaras, Giulia Manca, Victoria Martin, Sean Mattingly, Klaus Moenig, Hugh Montgomery, Pasha Murat, Jason Nielsen, Larry Nodulman, Emily Nurse, Neeti Parashar, Charles Plager, Arnulf Quadt, Michael Ramsey-Musolf, Peter Renton, Heidi Schellman, Michael Schmitt, Alan Sill, Georg Steinbrueck, Mark Strovink, Paul Telford, Evelyn Thomson, David Toback, Marco Verzocchi, John Wahl, Darien Wood, Terry Wyatt, Qichun Xu, Taka Yasuda, Bing Zhou, Junjie Zhu

Strengths of TeVEWWG

- Collaborators from CDF, D0, past collaborators from LEP experiments and LEPEWWG, and theorists
- Best suited to analyse results from Tevatron experiments, understand systematic uncertainties and correlations
- Carry information back to experimental analyses of data, leading to improved results
- Share theoretical input, facilitating future comparisons and combinations
- Provide collective experience and memory for future generations of analyses at the Tevatron
 - Code, documentation and minutes of meetings
- Perform standard model fits
- Set priorities for future analyses at the Tevatron

Accomplishments

- Combination of CDF and D0 Run 1 results on W boson mass and width
 - [Hep-ex/0311039](#), accepted for publication in PRD
- Combination of CDF and D0 Run 1 results on top quark mass
 - [Hep-ex/0404010](#)
- Combination of CDF and D0 preliminary Run 2 results on $R = \sigma(W \rightarrow l\nu) / \sigma(Z \rightarrow ll)$
- Run 2 Workshop on theoretical inputs to the W mass measurement

Run 1 W mass & width combinations

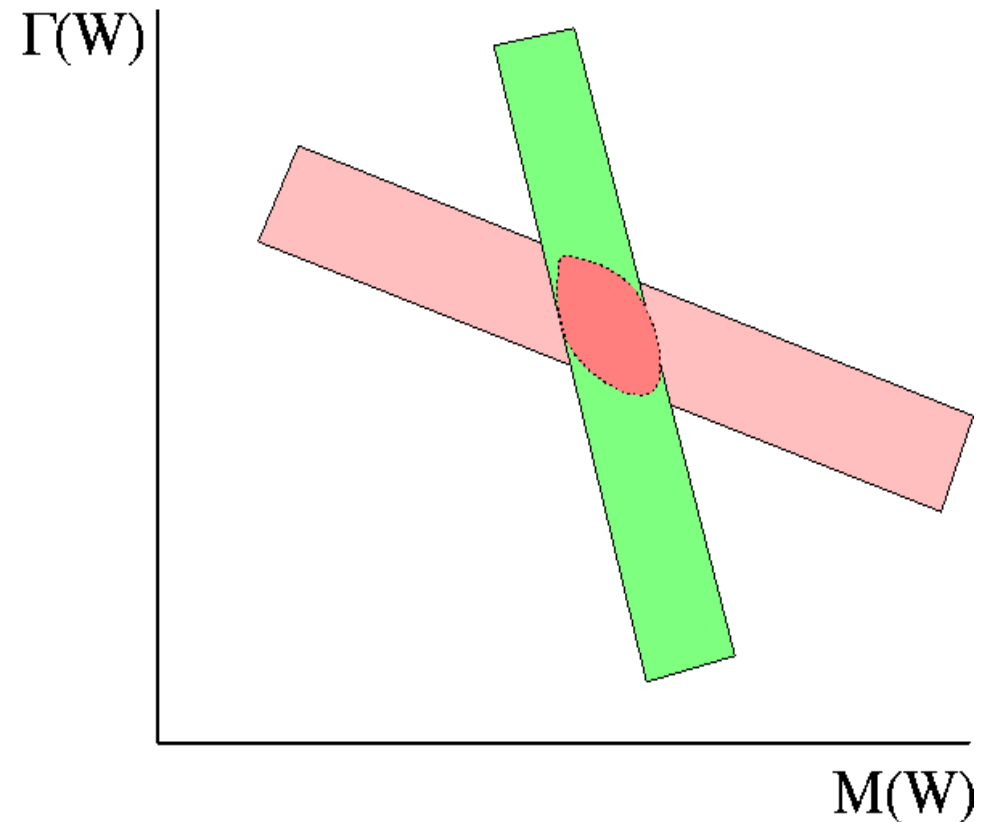
- Tevatron (CDF and D0) Averages:
 - $M_W = 80.456 \pm 0.059 \text{ GeV}$ (19 MeV correlation)
 - $\Gamma_W = 2.115 \pm 0.105 \text{ GeV}$ (26 MeV correlation)
 - Correlated uncertainties due to QED radiative corrections, parton distribution functions, and W mass/width inputs
 - Important to understand and reduce correlations for Run 2

Joint $M_W - \Gamma_W$ combination

- No external W mass or width information used:
 - $M_W = 80.452 \pm 0.060 \text{ GeV}$
 - $\Gamma_W = 2.105 \pm 0.106 \text{ GeV}$
 - Correlation coefficient = -0.17
- Eliminates a source of limiting systematic for Run 2

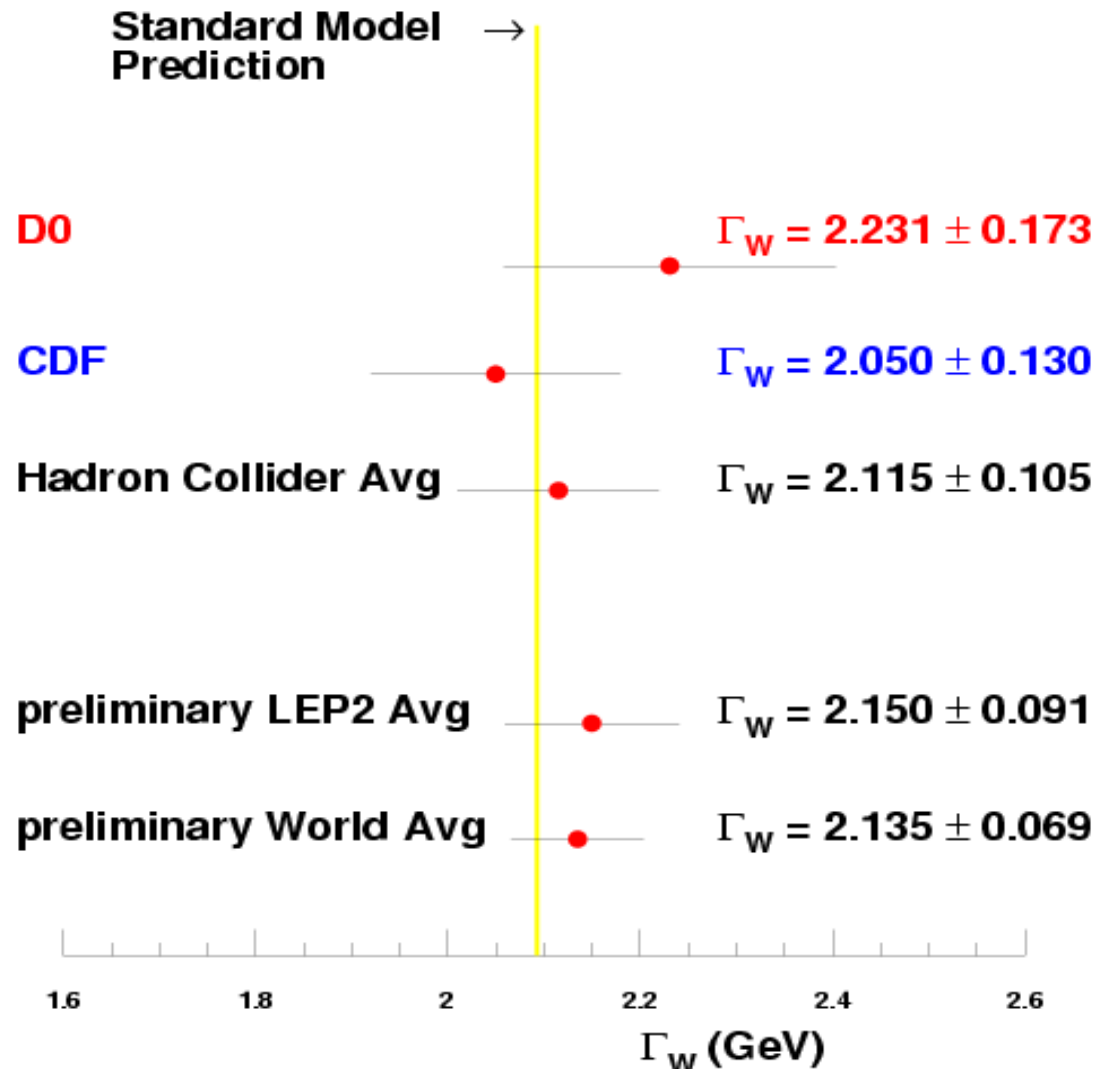
Joint M_W - Γ_W combination

- Correlation between fitted M_W and Γ_W due to
 - Jacobian lineshape
 - Energy scale and resolution
- Correlated effects cancel, leading to
 - Reduced reliance on external input
 - no loss of precision
- Most useful method of presentation for standard model fits: preferred Run 2 technique



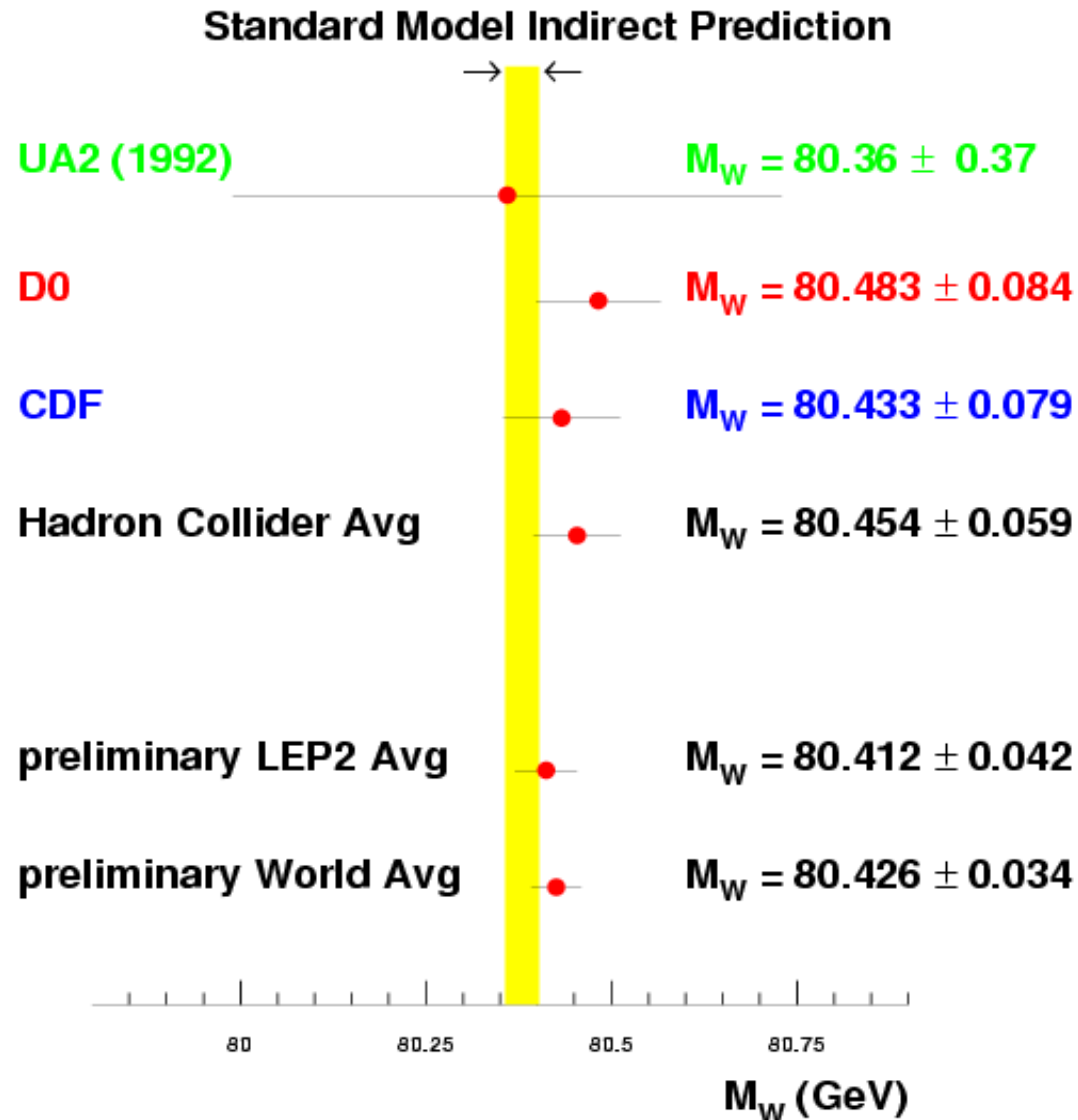
Run 1 Results

- Γ_W is consistent with the standard model



Run 1 Results

- M_W favors low Higgs mass

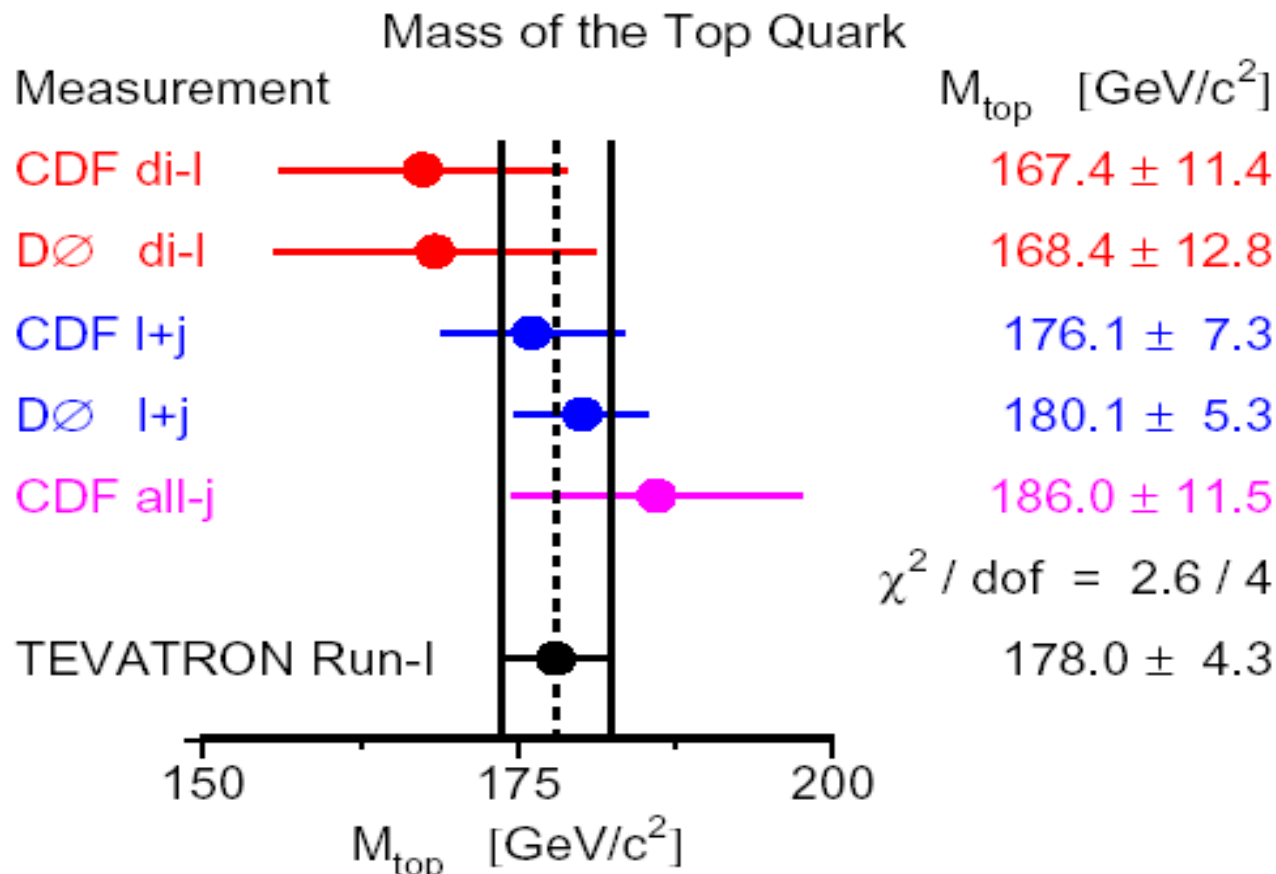


BR($W \rightarrow l\nu$) and $\Gamma(W \rightarrow l\nu)$ (Run 1)

- $R^{\text{Tevatron}} = 10.59 \pm 0.20$ (uncorr) ± 0.11 (corr)
 - Correlated uncertainty dominated by QED radiative corrections
- $\text{BR}(W \rightarrow l\nu) = R \times \sigma^W / \sigma^Z \times \text{BR}(Z \rightarrow ll) = (10.61 \pm 0.28) \%$
receives approximately equal uncertainty contributions from R and σ^W / σ^Z (scheme-dependence of $\sin^2\theta_W$)
- $\Gamma(W \rightarrow l\nu) = \text{BR}(W \rightarrow l\nu) \times \Gamma^{\text{direct}}(W) = 224 \pm 13 \text{ MeV}$
can be compared with precise standard model calculation
 $\Gamma^{\text{SM}}(W \rightarrow l\nu) = 227.1 \pm 0.6 \text{ MeV}$
 - $\Gamma^{\text{direct}}(W)$ uncertainty (5%) dominates over $\text{BR}(W \rightarrow l\nu)$ uncertainty (2.4%)
- TeVEWWG: consult with theorists to reduce uncertainty associated with theory inputs

Top Mass (Run 1)

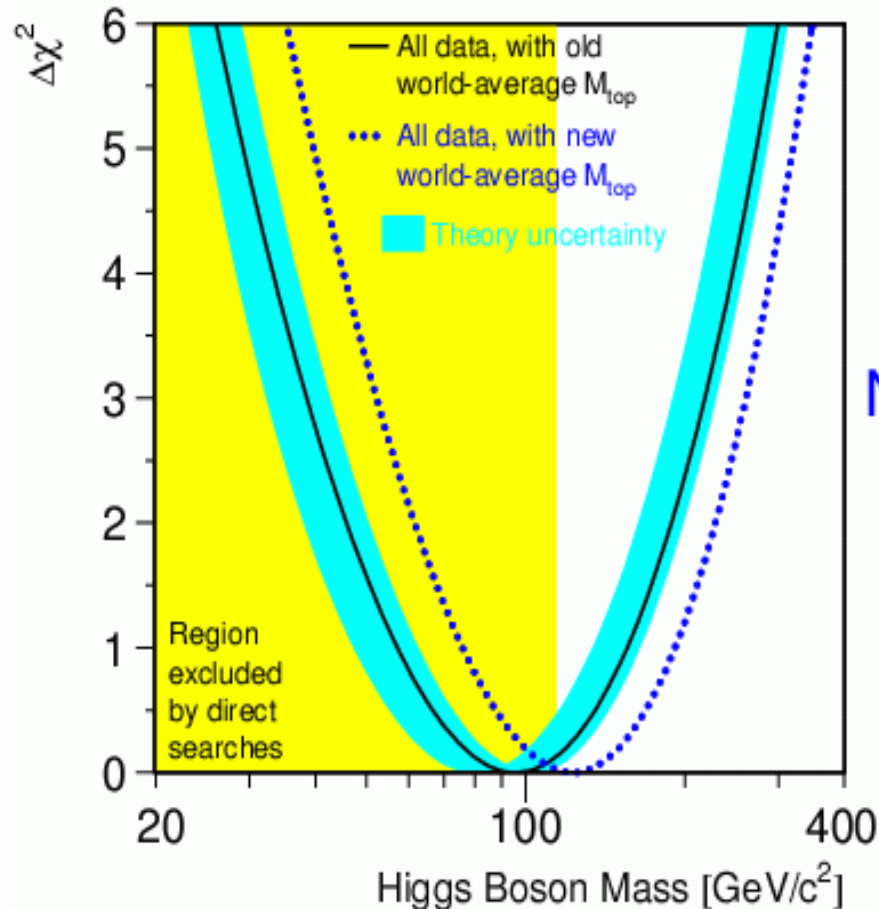
- New D0 Run 1 analysis (submitted to NATURE)
 - $m_{\text{top}} = 180.1 \pm 3.6 \text{ (stat)} \pm 3.9 \text{ (syst)}$
 - Considerable improvement in uncertainties from previous l +jets D0 measurement: $m_{\text{top}} = 173.3 \pm 5.6 \text{ (stat)} \pm 5.5 \text{ (syst)}$



Consequence for Standard Model Higgs

Precision electroweak data:

Constrain M_H in the MSM



Old:

$$M_{\text{top}} = 174.3 \pm 5.1 \text{ GeV}$$

$$\log M_H = 1.98^{+0.21}_{-0.22}$$

$$M_H = 96^{+60}_{-38} \text{ GeV}$$

$$\text{or } < 219 \text{ GeV (95\% CL)}$$

New:

$$M_{\text{top}} = 178.0 \pm 4.3 \text{ GeV}$$

$$\log M_H = 2.07^{+0.20}_{-0.21}$$

$$M_H = 117^{+67}_{-45} \text{ GeV}$$

$$\text{or } < 251 \text{ GeV (95\% CL)}$$

(Procedure as in hep-ex/0312023!)

(From M. Grunewald)

MWG

Run 2 Outlook on M_W and m_{top}

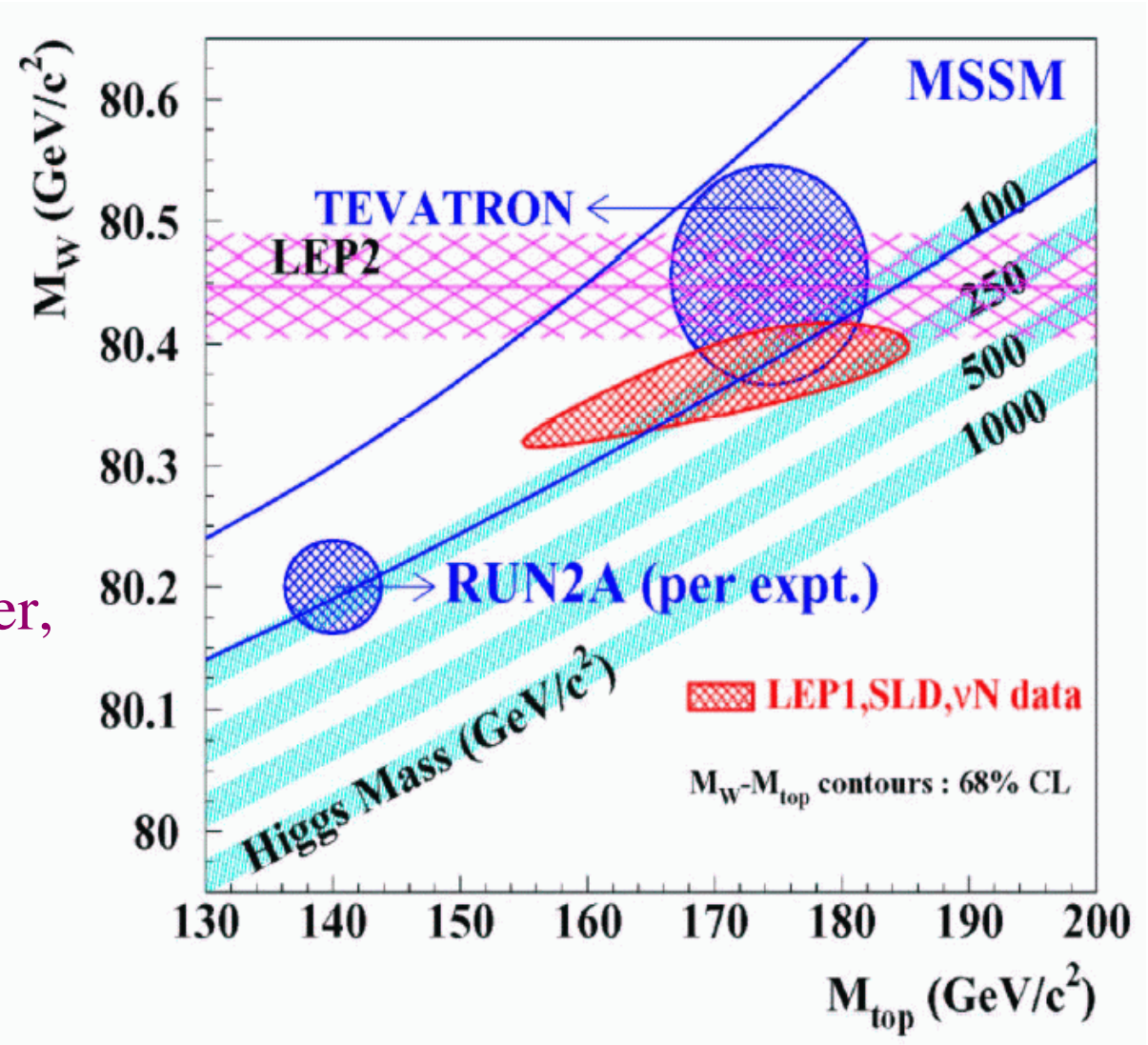
Run 2a (2 fb^{-1}) expectation shown:

$$\delta M_W \sim 40 \text{ MeV}$$

$$\delta m_{\text{top}} \sim 2.5 \text{ GeV}$$

per Tevatron experiment

To achieve this, and do better, combined analysis of Run 1 results provides very useful post-mortem feedback.



Run 2 Combinations

TeVWWG

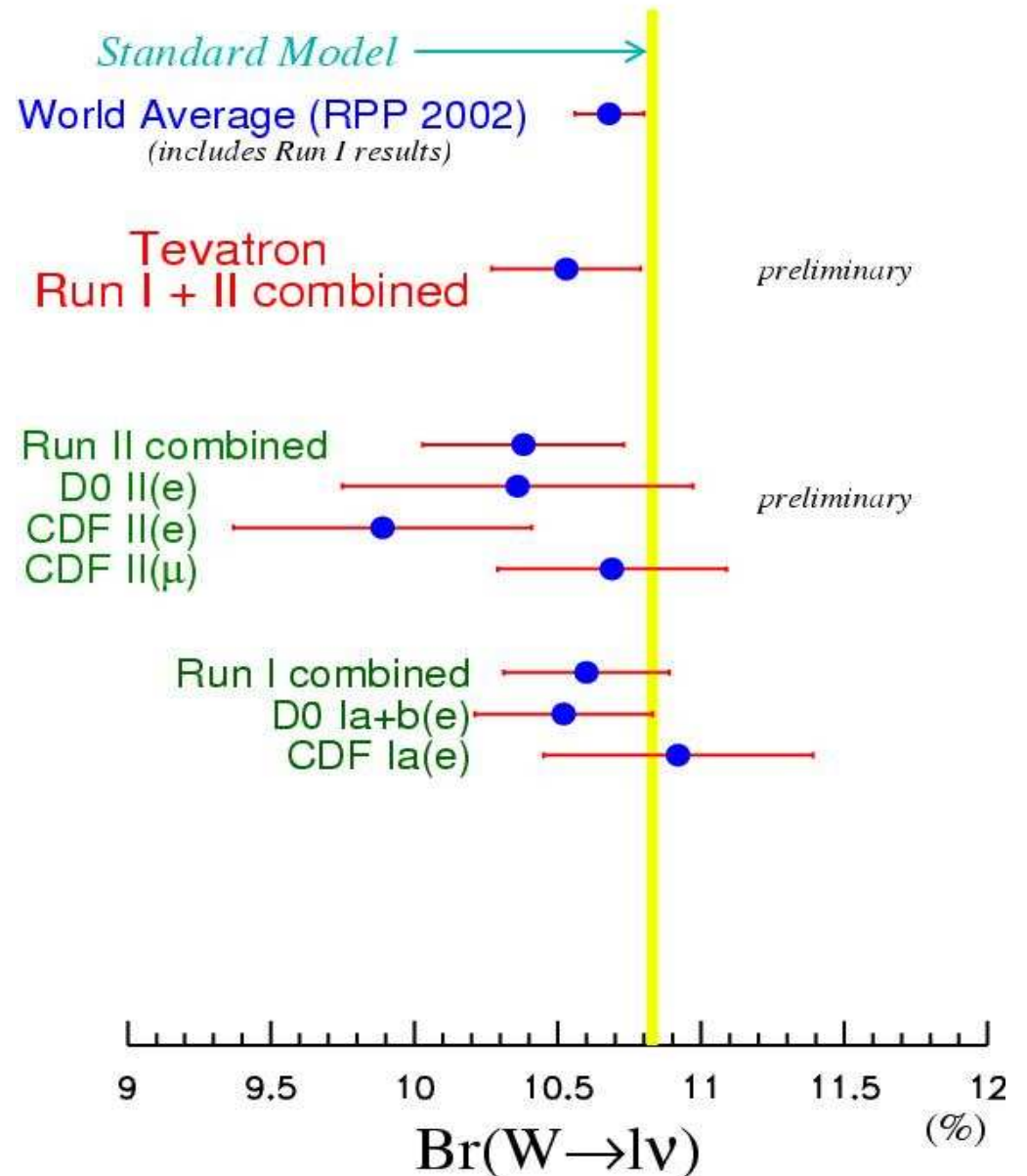
- Combination of preliminary Run 2 results on R from CDF (e, μ) and D0 (e):

– $BR(W \rightarrow l\nu) = (10.38 \pm 0.35) \% \text{ (Run 2)}$

$= (10.53 \pm 0.26) \% \text{ (Run 1 + Run 2)}$

- Reduction in uncertainty expected as

- Analyses finalised
- Theory error reduced
- More data analysed



W Mass Theory Workshop (2003)

- Improve theory inputs to the Run 2 W mass measurement:
 - Electroweak radiative corrections
 - Parton distribution functions
 - Boson p_T and rapidity distributions
- Theorists participating: Csaba Balazs, Ulrich Baur, Q.-H. Cao, Pavel Nadolsky, Doreen Wackeroth, C.-P. Yuan
- Discussions of
 - RESBOS (QCD) program
 - WGRAD/ZGRAD (QED) programs
 - multi-photon effects
 - CTEQ error PDF ensemble

W Mass Theory Developments

- Incorporate FSR photon radiation from WGRAD into RESBOS
=> combined QCD & QED generator “RESBOS-A” by Q.-H. Cao and C.-P. Yuan - Done !
- Incorporate 2-photon physics in WGRAD/ZGRAD – U. Baur and D. Wackeroth
- P. Nadolsky – potential for difference in non-perturbative contribution to $p_T(W)$ and $p_T(Z)$ due to charm-induced W production: Done !
 - effect is small, probably negligible: S. Berge, P. Nadolsky and F. Olness (LoopFest III @ Santa Barbara Workshop, paper in preparation)
- Interaction with PDF fitters (CTEQ via J. Huston *et al*) regarding true confidence interval represented by error PDF ensemble

Plans

- Update combination of R with new results this summer
- Include new Run 2 results on top mass from CDF
- Run 1 $t\bar{t}$, cross section combination in progress, include Run 2 measurements when available
- Extend to diboson measurements and differential cross section measurements
- Coordinate with lower energy electroweak measurements
 - Atomic, electron, muon, neutrino measurements
 - Weak decays, rare processes
 - Recent workshop “*Zero to Z⁰: Precision Electroweak Physics*” at Fermilab (May 2004), sponsored by Sub-Z Working Group and TeVEWWG (funded by FNAL and URA)

Plans

- Continue workshop series to improve understanding of theory-related systematics
- Proposed workshops for this summer:
 - W mass theory workshop (followup from 2003)
 - Top mass theory workshop (QCD ISR/FSR radiation)
 - Sign up on tevewwg.fnal.gov to receive notification
 - Useful for new students to come up to speed quickly
- Annual summary writeup of new results, combinations and impact on standard model fits

Summary

- Tevatron Electroweak Working Group created, to
 - Combine and interpret results
 - Provide real-time feedback to ongoing analyses
 - Increase interaction better experimenters and theorists on common issues
- Good track record in the first year:
 - Two documents produced
 - Two workshops organized
- Anticipate continued growth in TeVEWWG's output and effectiveness
- New members welcome !