W Mass Measurements from the Tevatron

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Why Measure the W Mass?

Test of the **Standard Model**.

As an indirect constraint on the **Higgs mass**.

If LHC discovers Higgs, can compare indirect and direct mass measurements for indications of beyond the **Standard Model physics**.

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(Using WA $m_W$ excluding the two new Tevatron $W$ mass results)
The CDF and DØ

CDF

Silicon Tracker

MWPC Chamber

Calorimeters

Muon Chambers

DØ

Muon Scintillators

Muon Chambers

Calorimeter

Toroid

Shielding

η = 0

η = 1

η = 2

η = 3

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Why Measure the W Mass at the Tevatron?

High Statistics:

Combining bespoke detector simulation and extensive study can produce competitive systematics despite ‘messy’ hadronic collisions.
How to Measure the W Mass?

Two Channels:

\[ W \rightarrow e\nu_e \quad W \rightarrow \mu\nu_\mu \]

Template Fitting Procedure:

\[ M_T = \sqrt{2 p_T E_T^{\text{miss}} (1 - \cos \Delta \phi)} \]

“Transverse mass of the W boson”
What do we require for $m_T$ fits?

A typical W event:

Measure muon momentum in the tracker

Measure electron energy in the calorimeter

Measure recoil in calorimeter to calculate missing energy
Event Generation

Basic Generator: RESBOS
NLO QCD Corrections: RESBOS + parameters tuned to Z data

NLO QED Corrections: PHOTOS + comparison to HORACE or WGRAD/ZGRAD
CDF Momentum Scale Calibration

Precisely align COT using cosmic ray data

Set overall momentum scale by fits to J/ψ, Υ and Z data

Have sufficient J/ψs to break into <1/p_T> bins for a material scale fit
Testing the Momentum Calibration

Measure $Z \rightarrow \mu\mu$ mass using just $J/\psi$ and $\Upsilon$ contributions:

$$M_Z = 91180 \pm 16$$

(WA is 91187 \pm 0.002, this is consistent!)

Then incorporate $Z \rightarrow \mu\mu$ mass fit as a final contribution

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CDF Energy Scale Calibration I

Use both:

\[ \frac{E}{p} = \frac{\text{Electron Energy Measured in Calorimeter}}{\text{Electron Momentum Measured in Tracker}} \]

Momentum measurement uses precise momentum scale calibrations described previously.

Fit the peak

\[ \chi^2/\text{dof} = 18/22 \]
CDF Energy Scale Calibration II

And:

Use E/p calibration make a $M_Z$ measurement.

Result:

$m_Z = 91230 \pm 33$ MeV

(WA is $91187 \pm 0.002$, this agrees with WA)

Then combine both methods to obtain a final energy scale

Calorimeter Z mass
DØ Energy Scale Calibration

\[ E_{\text{Measured}} = \alpha (E_{\text{True}} - <E_{\text{True}}>) + \beta + <E_{\text{True}} > \]
Material Scale Determination

In Tracker:

- Measure $E$ in calorimeter
- Measure $p$ in tracker
- Use radiative tail of $E/p$ fit to determine material scale

Pair Production

Bremsstrahlung in Silicon tracker

Gamma

e-
Recoil Simulation

Define recoil as all the energy in the transverse plane not associated with the lepton.

Modelling using parameterisation tuned on min bias and Z data.
# Uncertainties

<table>
<thead>
<tr>
<th>Uncertainty Source</th>
<th>Total CDF Uncertainty (MeV)</th>
<th>DØ Uncertainty (MeV)</th>
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<tbody>
<tr>
<td>Energy (and Momentum) Scale Calibration and Resolution</td>
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<td>Recoil Model</td>
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<tr>
<td><strong>Total</strong></td>
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<td><strong>26</strong></td>
</tr>
</tbody>
</table>

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Results

Add in $p_T^l$ (and $p_T^\nu$ too at CDF) for additional statistical precision

CDF:

$$M_W = 80387 \pm 19 \text{ MeV}$$

arXiv:1203.0275

DØ:

$$M_W = 80367 \pm 26 \text{ MeV}$$

arXiv:1203.0293

Combining with previous measurement (on 1/fb) by DØ:

$$M_W = 80375 \pm 23 \text{ MeV}$$
New World Average

With the two new Tevatron results!

All results are re-weighted to the same W width value

New Indirect Higgs Constraint (95% CL):

\[ m_H < 152 \text{ GeV} \]
Conclusions?

Our conclusions is…

Before:

(Using WA $m_W$ excluding the two new Tevatron W mass results)
Conclusions

The blue circle is smaller but its center has moved down!

After:

(Using WA $m_W$ including the two new Tevatron W mass results)