Improving W Boson Mass Templates for Run 2 at CDF

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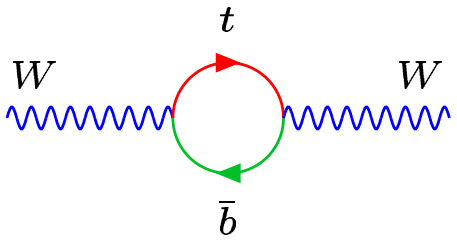
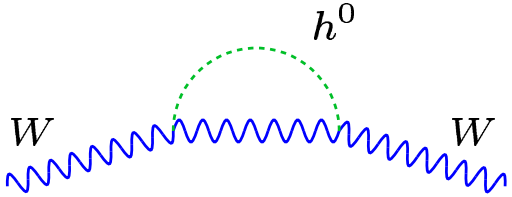
Outline

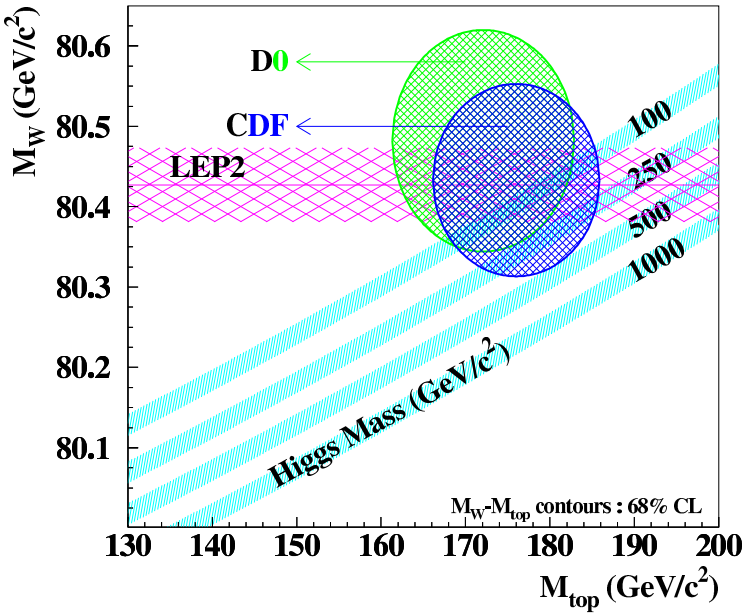
- Introduction
- W Events at the Tevatron
- Measuring M_W
- Improving W Mass Templates
- Conclusion

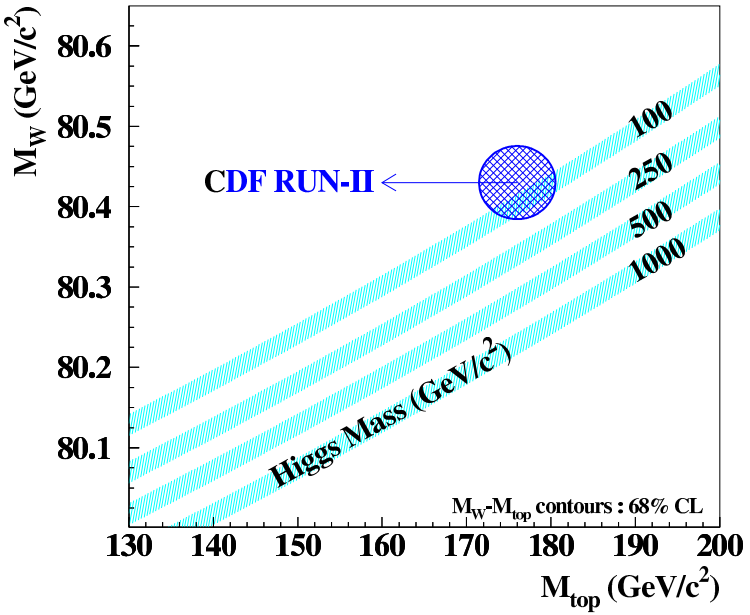
Introduction

- Measuring M_W constitutes a test of the Standard Model
- Measuring M_W and M_{top} constrain M_{Higgs}





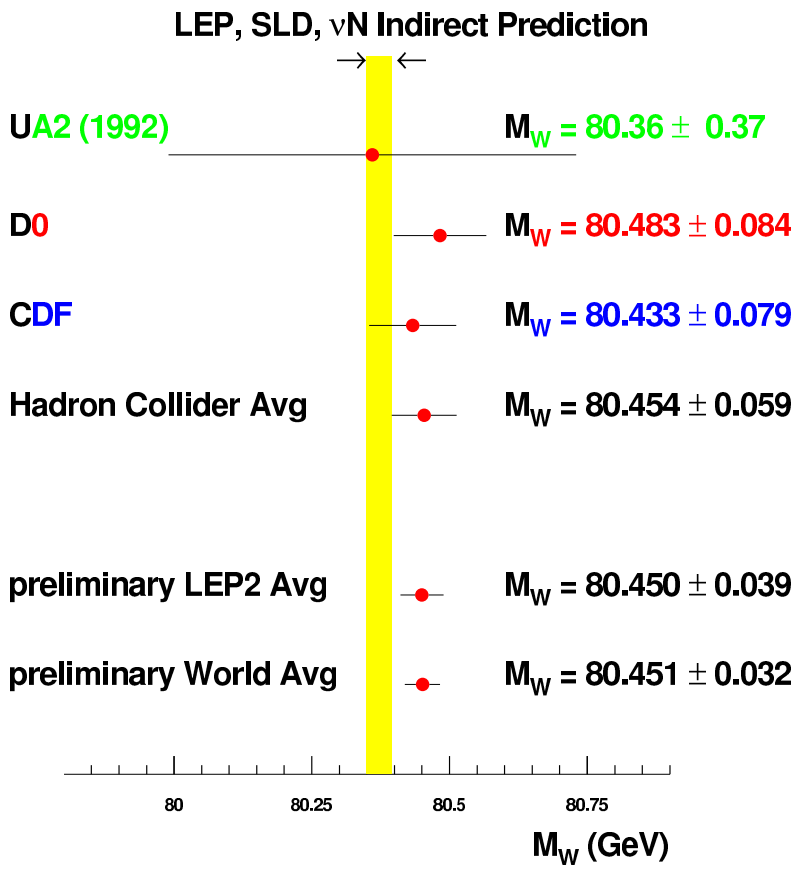




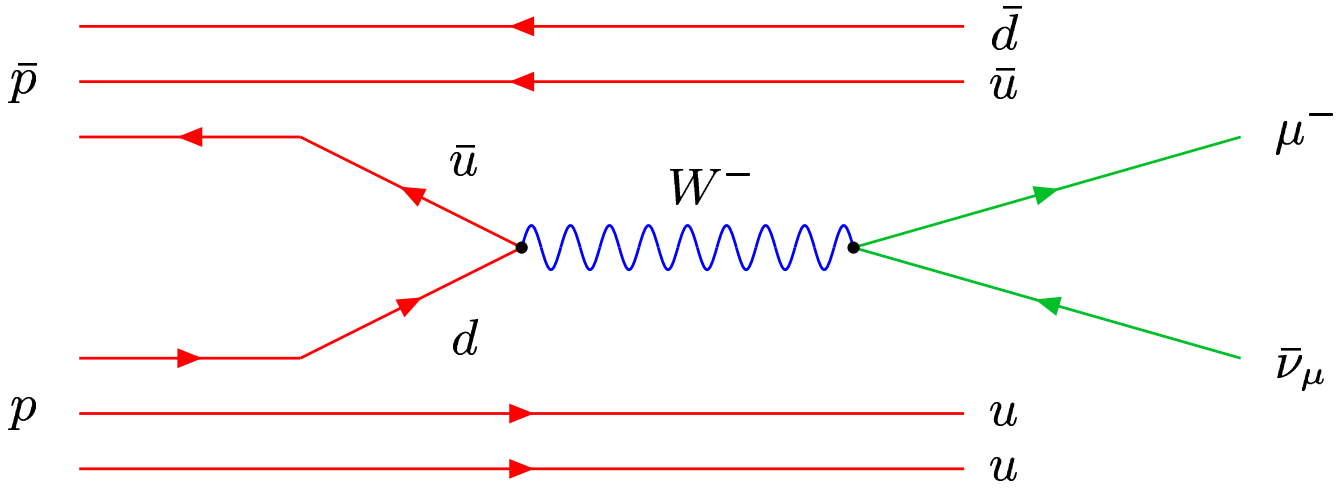
Introduction

- Best precision measurements to date: CDF and LEP2
- Currently pushing experimental limits to obtain more precise measurements

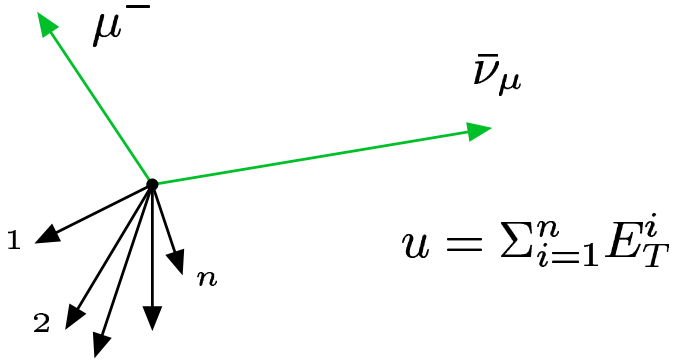
With Run 2a measurement CDF will have M_W with a precision of $40 - 60$ MeV



W Events at the Tevatron



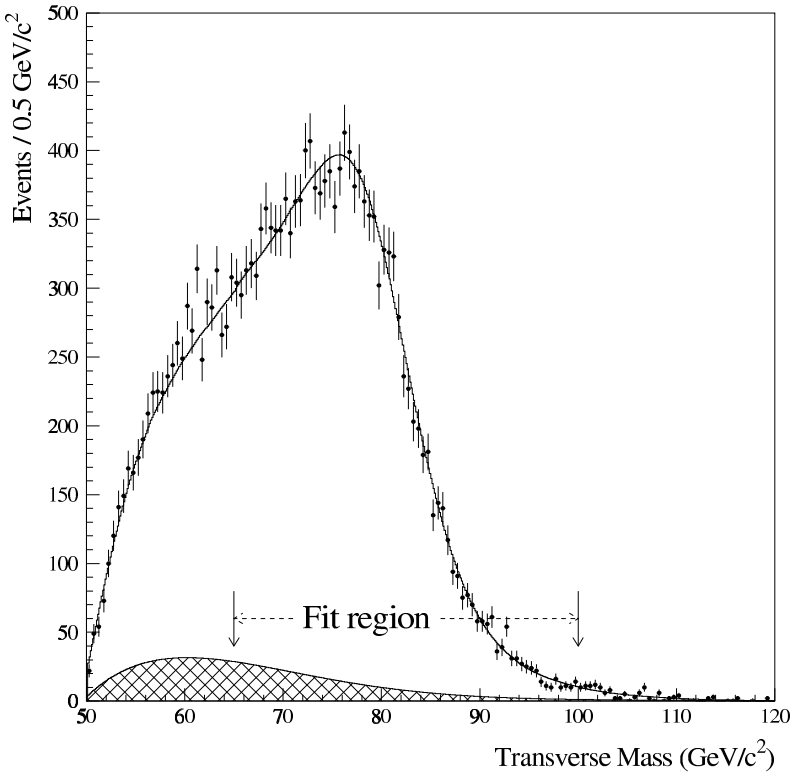
- W bosons are produced via $q\bar{q}' \to W$
- Event signature is a high p_T charged lepton and large $\not{E}_T$



Measuring M_W

- Most common method: fit to transverse mass spectrum of the W

- Compare data to Monte Carlo simulations for various W masses
- Perform binned maximum likelihood fit to extract mass



- Other methods: fit to transverse momentum spectrum of charged lepton or neutrino

Measuring M_W (Uncertainties)

	Uncertainty (MeV) for $W \to \mu\nu$		
Source of Uncertainty	Run 1a ($20\,\text{pb}^{-1}$)	Run 1b ($80\,\text{pb}^{-1}$)	Run 2a ($500\,\text{pb}^{-1}$)
Statistical	205	100	40
Lepton Energy/Momentum Scale	50	85	30
Lepton Energy/Momentum Resolution	60	20	10
Recoil Modeling	60	35	12
Backgrounds	25	25	15
Trigger, Event Selection	25	15	13
W Production Model†	75	30	30
Total Systematic	130	103	55
Total Uncertainty	243	144	68

† Includes p_T^W, PDFs, higher order QCD corrections and QED radiative corrections

Generating W Mass Templates

- Mass templates are constructed from:

  (i) event generation

  (ii) detector simulation

- Event generators contain little or no QCD corrections and QED corrections are plugged in at the end

Need to improve W event generation for Run 2a M_W measurement

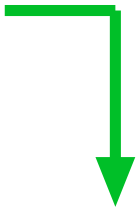
- Recently, several programs have become available that deal well with either QCD or QED effects
- Best ones are: **WGRAD** for QED and **RESBOS** for QCD

Merging **RESBOS** and **WGRAD**

Idea: numerically merge output of programs in a way that preserves the QCD and QED corrections from each

- In particular want to preserve changes in angular distribution of W decay leptons induced by initial state gluon radiation

1. Match kinematics of the W bosons from each
2. Match a quantity that contains QCD effects
3. Boost **WGRAD** W with **RESBOS** p_T^W



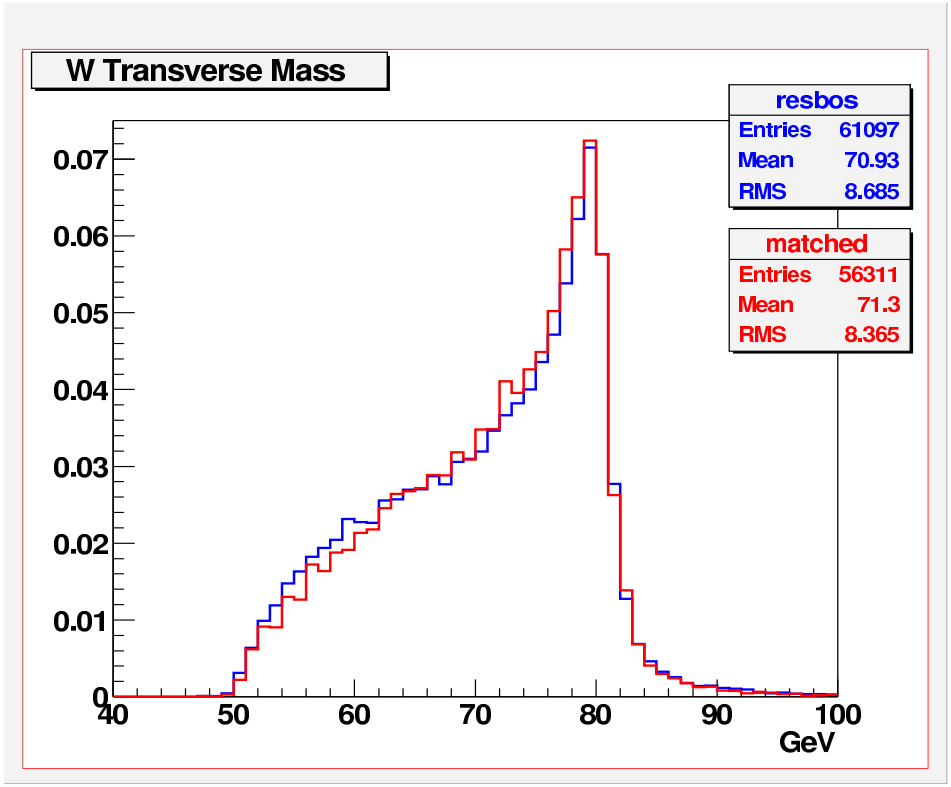
- M_W and y_W are invariant under boosts
- θ^l_{CS} distribution contains the QCD physics we want

Quantity	**WGRAD**	**RESBOS**
M_W	$l\,\nu\,\gamma$	$l\,\nu$
y_W	$l\,\nu\,\gamma$	$l\,\nu$
θ^l_{CS}	l	l

Merging **RESBOS** and **WGRAD**

- Generated ~ 100K unweighted **RESBOS** events
- Matched with a "lookup table" of 100K unweighted **WGRAD** events
- For each **RESBOS** event found closest **WGRAD** event in $(M_W, y_W, \theta^l_{CS})$ space by minimizing $d = \sqrt{\frac{\delta^2 M}{\sigma^2_M} + \frac{\delta^2 \theta}{\sigma^2_\theta} + \frac{\delta^2 y}{\sigma^2_y}}$
- Boosted **WGRAD** event with **RESBOS** p_T^W

Transverse Mass (generator level)

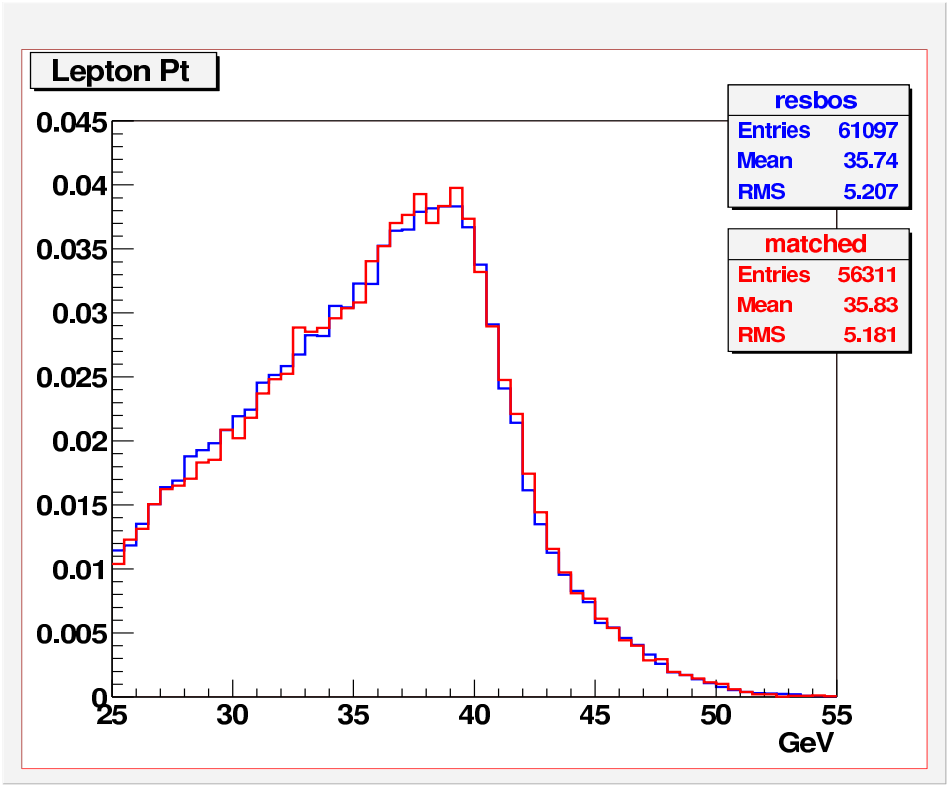


- Expect a small shift in the peak position ($\sim$ tens of MeV) due to QED corrections
- Expect a similar magnitude shift due to **RESBOS** effects, also will see some broadening of the peak

Both have cuts:

$$p_T^l,\, p_T^\nu > 25,\, u < 20$$

Charged Lepton Transverse Momentum (generator level)



- Expect similar effects to those for M_T^W distribution

Both have cuts:

$$p_T^l,\, p_T^\nu > 25,\, u < 20$$

Conclusion

- M_W is a fundamental parameter of the Standard Model and a more precise measurement can help constrain M_{Higgs}
- For Run 2a mass measurement need improved W generation
- Numerical merger of **RESBOS** and **WGRAD** is first attempt to patch together a solution
- Need to determine if this method is adequate: if not may need full NLO + QED calculation

Potential to drive down overall systematic uncertainty on Run 2a W mass measurement by ~ 10 MeV

Collins-Soper Frame

- CS frame is a W rest frame where the $p\bar{p}$ pair lies in the xz plane and the z axis is chosen to bisect the angle between the p and $\bar{p}$
- In the CS frame the p and $\bar{p}$ appear to make an angle with z axis due to transverse boost of the W