Prospects for W Boson Physics at the Tevatron

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Outline

- Upgrades to CDF and DØ Detectors and Tevatron
- Significant W Boson Measurements
  - ▷ W Mass and Width
  - ▷ W Charge Asymmetry and QCD studies
  - ▷ Rare W Decays and New Heavy Gauge Bosons
  - ▷ Anomalous Vector Boson Couplings
- Summary

Upgrades

- Tevatron: Main Injector and Recycler Ring
- Commissioning run Fall 2000, Run 2 data-taking to commence March 2001
- Comparison with Run 1 (1992-95):

	Run 1	Run 2A	Run 2B
$\mathcal{L}$ ($\mathrm{cm}^{-2}\mathrm{s}^{-1}$)	5×10^{30}	10^{32}	5×10^{32}
$\int \mathcal{L}dt$ / experiment	120 pb^{-1}	2 fb^{-1}	15 fb^{-1}
bunch crossing	3.5 μs	396 ns	132 ns

- CDF Upgrades:
  - ▷ Open cell drift chamber, silicon tracker
  - ▷ Scintillating tile endplug calorimeter
  - ▷ Time-of-flight system
- DØ Upgrades:
  - ▷ Magnetic spectrometer
  - ▷ Silicon and scintillating fiber tracker
  - ▷ Central and forward preshowers
- CDF and DØ Upgrades:
  - ▷ Enhanced central and forward muon system
  - ▷ Front-end electronics, trigger and DAQ

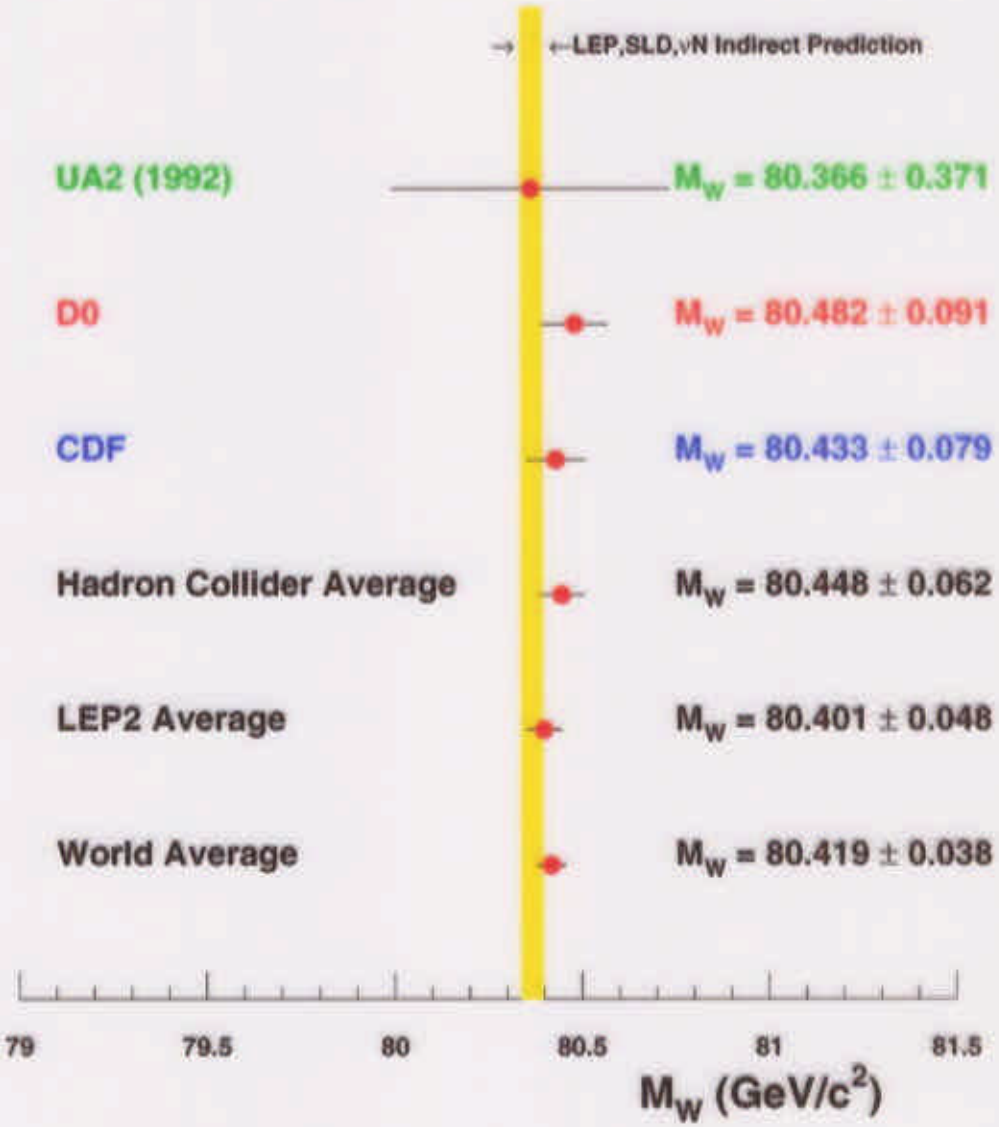
Impact of Run 2 on W Boson Physics

	Run 1	Run 2A	Run 2B
W (Z) statistics	$130k$ ($10k$)	$2M$ ($200k$)	$14M$ ($1.4M$)

Channel	Events	$\sigma_{2.0\ TeV}/\sigma_{1.8\ TeV}$	$A_{\lvert\eta\rvert<2.0}/A_{\lvert\eta\rvert<1.0}$
$W \to e\nu$	$1.4M$	1.12	2.0
$W \to \mu\nu$	$650k$	1.12	2.6
$W\gamma$	$1.5k$	1.13	1.5
$WW \to l\nu l\nu$	77	1.17	2.1
$WZ \to l\nu ll$	10	1.22	4.4

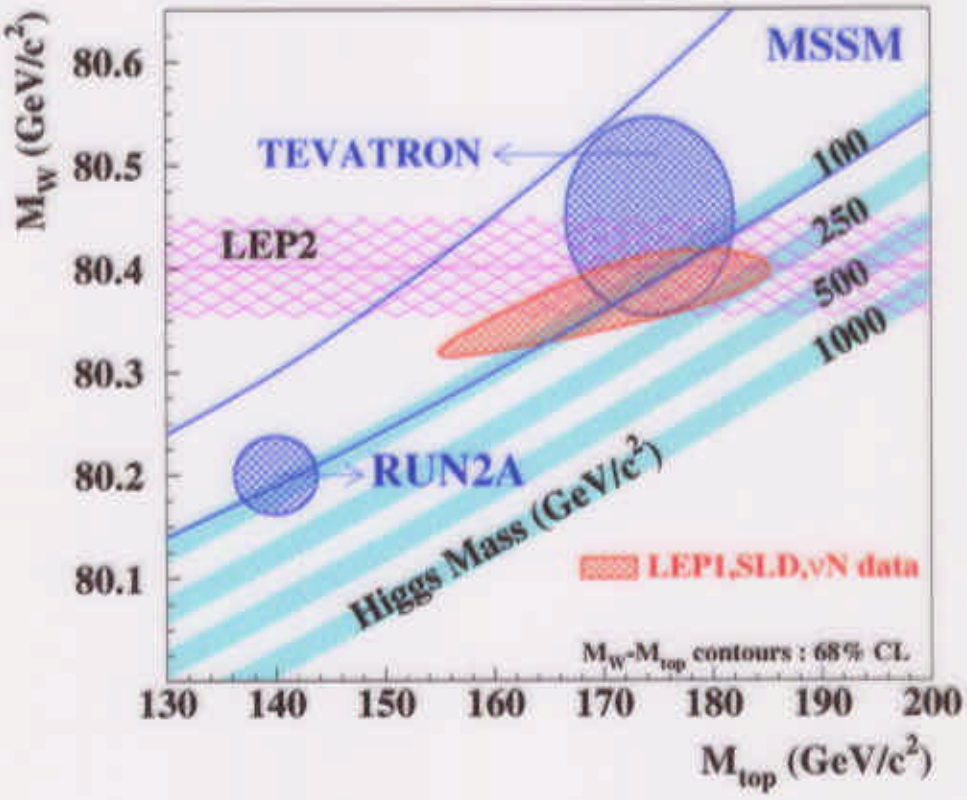
- Entering new era of "precision" W boson physics
- Electroweak physics
  - ▷ W mass, width
  - ▷ Anomalous gauge boson couplings
- QCD
  - ▷ W, Z p_T
  - ▷ W, Z + jets
  - ▷ PDF constraints
- Non-standard model physics
  - ▷ Rare decays
  - ▷ Heavy W', Z', compositeness, technicolor, extra dimensions

W mass



- Expected Tevatron Run 2A precision $\sim$ 25 MeV

W mass

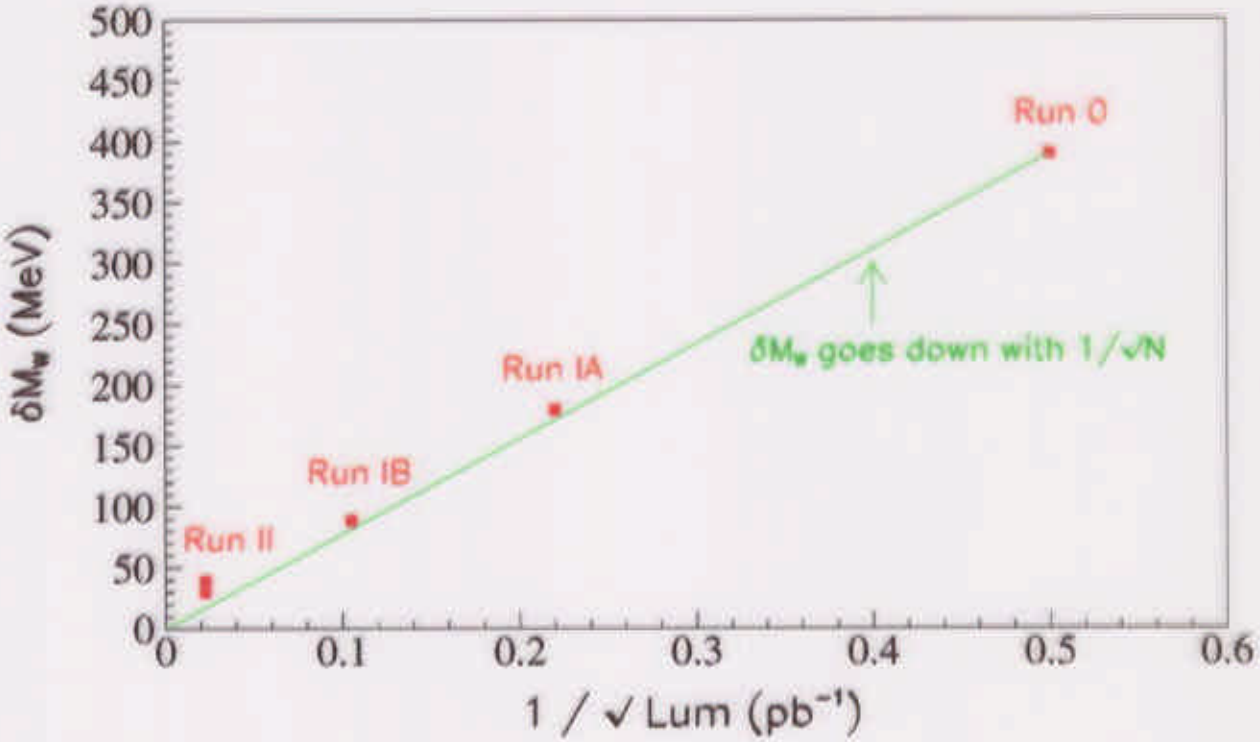


- Current contraint on SM Higgs from all electroweak measurements: $m_H = 77\ ^{+69}_{-39}$ GeV ($\Delta\log_{10}(m_H/\mathrm{GeV}) \sim 0.29$)
- $\Delta M_W = 25$ MeV $\Leftrightarrow$ $\Delta m_H/m_H = 40\%$ assuming all other inputs precisely known
- Other dominant uncertainties - Δm_{top}, $\alpha(M_Z)$
  - ▷ Run 2A: $\Delta m_{top} \sim 2.5$ GeV ($\Leftrightarrow \Delta M_W = 15$ MeV)
  - ▷ $\Delta\alpha(M_Z) \Leftrightarrow \Delta M_W = 15$ MeV due to hadronic contribution to evolution
- After Run 2A at the Tevatron: $\Delta m_H/m_H \sim 45\%$ ($\Delta\log_{10}(m_H/\mathrm{GeV}) \sim 0.13$)

W mass

Scaling of W mass uncertainties

- Detector systematics eg. leptonic and hadronic energy scales, resolutions, backgrounds measured from control samples (e.g. Z data) expected to scale with statistics
- "Theoretical" uncertainties - W production and decay model, radiative corrections, PDFs
  - ▷ new QED calculations
  - ▷ measurements of W production and decay model are statistics-limited



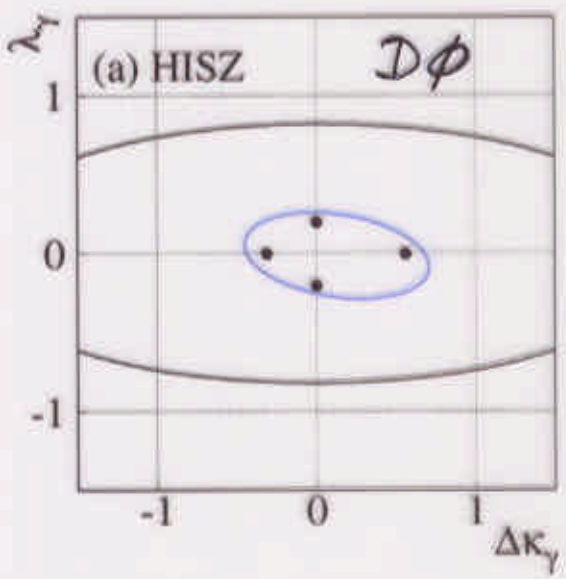
W Width

- Information on possible W decays to new particles, and input to W mass measurement
- Direct measurement from high transverse mass tail of $W \to l\nu$ decays - limited by statistics of data and control samples
  - ▷ Run 1 CDF measurement $\Gamma_W = 2.05 \pm 0.13$ GeV
  - ▷ expected from Run 2A data: $\Delta\Gamma_W \sim 25$ MeV
- Indirect measurement from ratio of $W \to l\nu$ and $Z \to ll$ cross sections
  - ▷ CDF: $\Gamma_W = 2.064 \pm 0.084$ GeV
  - ▷ DØ: $\Gamma_W = 2.152 \pm 0.066$ GeV
- Systematic uncertainties due to theoretical input - $\sigma(W)/\sigma(Z)$ and QED radiative corrections - amount to $\Delta\Gamma_W \sim 35$ MeV

Anomalous Couplings

- Trilinear and quadrilinear gauge boson couplings are fundamental predictions of standard model
- Anomalous couplings destroy cancellation between different diagrams - Tevatron sensitive to anomalous couplings through increase in cross section at high boson p_T
- Search for WW, $W\gamma$, WZ final states - combined DØ analysis yields

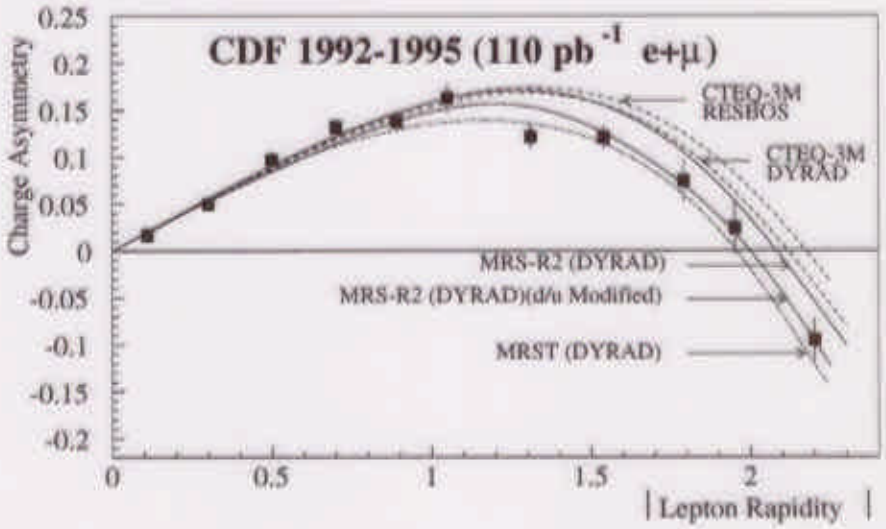
$$\lambda_\gamma = 0.00^{+0.10}_{-0.09}$$
$$\Delta\kappa_\gamma = -0.08^{+0.34}_{-0.34}$$



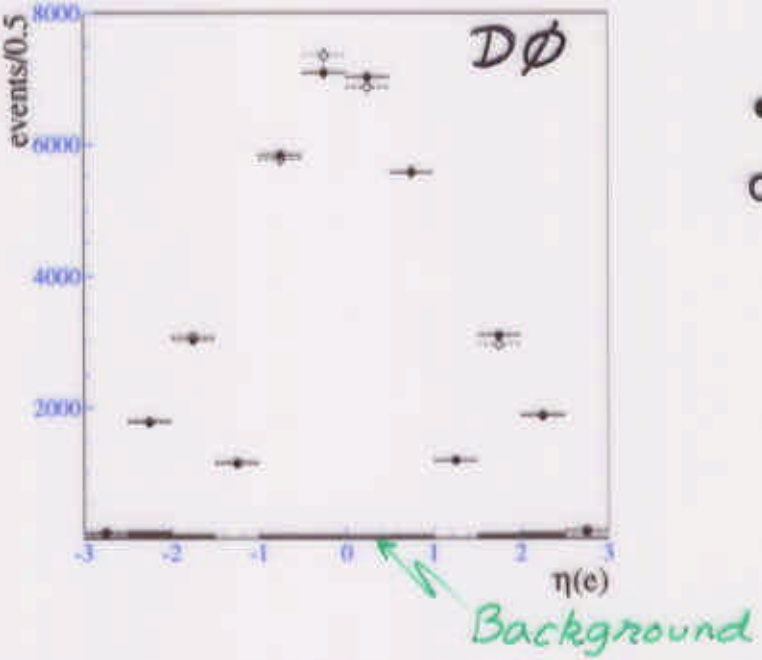
- Run 2 improvements - increased cross section due to higher energy, and larger acceptance due to extended rapidity coverage
- Increased anomalous coupling sensitivity by factor of 3 (5) in Run 2A (B)

Constraints on Parton Distribution Functions

- CDF measurement of forward-backward W charge asymmetry is a sensitive probe of d/u PDF ratio ($\delta M_W \sim 15$ MeV)



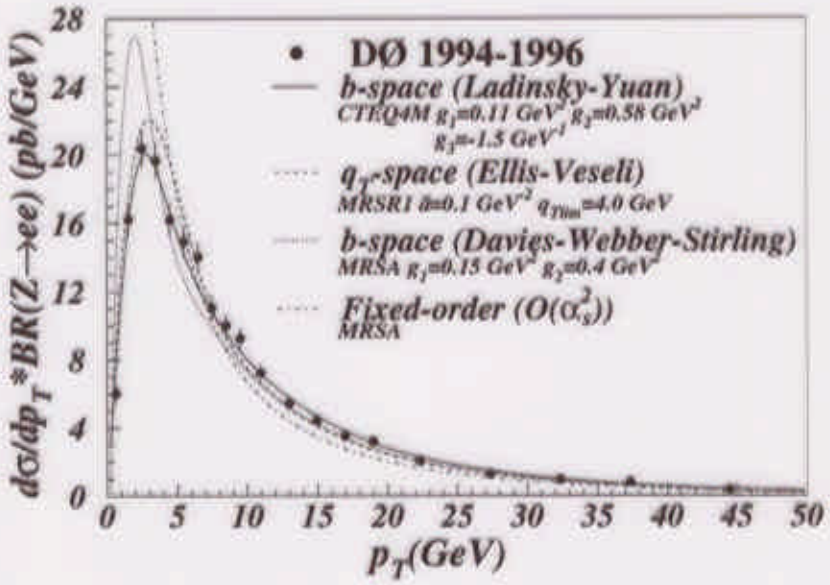
- DØ has checked electron rapidity distribution from W decay ($\delta M_W \sim 34$ MeV)



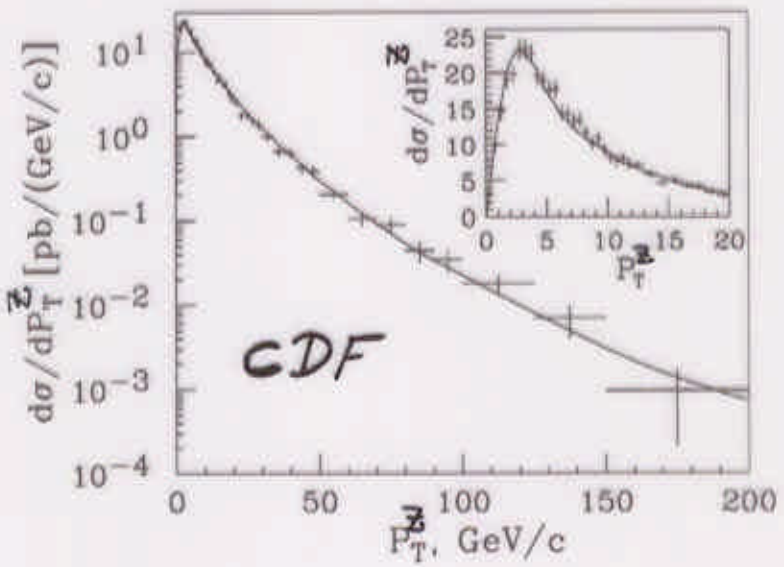
- DØ W mass measurement with central and forward electrons demonstrates reduced PDF sensitivity ($\delta M_W \sim 7$ MeV)

Boson transverse momentum

- Measurement at low p_T confirm QCD resummation calculations and measure non-perturbative form factor: important input to W mass measurement

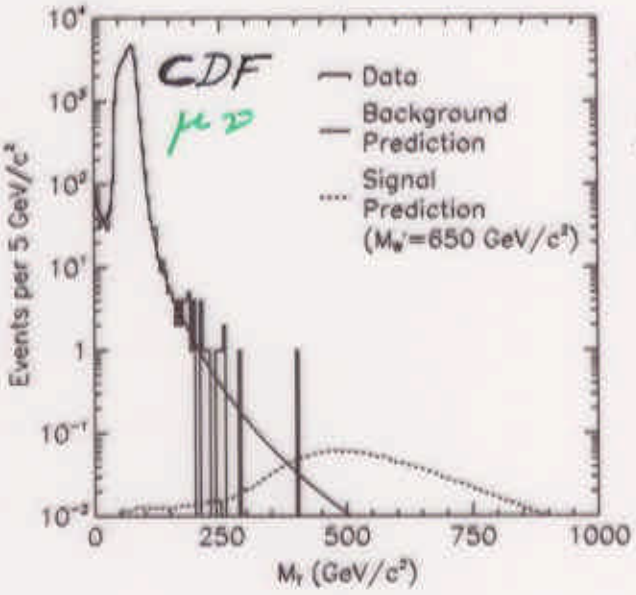


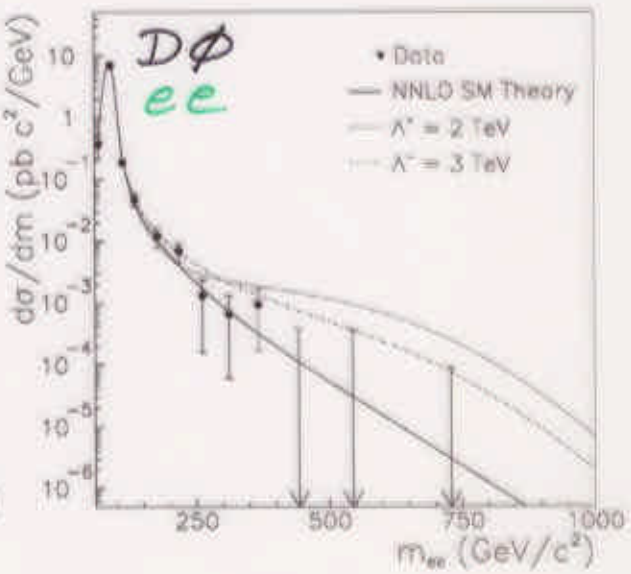
- High p_T region provides measurement of perturbative QCD and sensitivity to new particles decaying to W or Z



High Mass Searches

- Run 1 results (95% C.L. limits):
  - ▷ New heavy bosons: $M_{W'} > 720$ GeV (DØ); $M_{W'} > 660$ (652) GeV in CDF μ (e) channel; $M_{Z'} > 690$ GeV (CDF); $M_{Z'} > 670$ GeV (DØ preliminary)
  - ▷ Compositeness: $\Lambda > 3.1 - 6.3$ TeV (CDF); $\Lambda > 3.3 - 6.1$ TeV (DØ best qe limits)
  - ▷ Extra dimensions: $M_S > 1.0 - 1.3$ TeV for $2 \leq n \leq 7$ (DØ preliminary)
  - ▷ Technicolor: $M_{\rho_T, \omega_T} > 207$ GeV (DØ preliminary)





- Run 2A: W' sensitivity upto 990 GeV
- Double (triple) the M_S sensitivity reach in Run 2A (2B)

Summary

- Tevatron Run 2 begins September 2000 (comissioning), March 2001 (physics)
- 15 fb^{-1} at $\sqrt{s} = 2$ TeV by ~2005, 2 fb^{-1} by 2003
- DØ: new magnetic spectrometer
- CDF: improved coverage for high rapidity leptons
- Both: new tracking systems, vertex detectors, trigger and DAQ systems
- With first 2 fb^{-1}: $\Delta M_W \sim 25$ MeV, $\Delta m_{top} \sim 2.5$ GeV provide a significant constraint on the Higgs mass $\Delta m_H / m_H \sim 45\%$
- Accompanied by precision measurements of W width, W and Z production properties, gauge boson couplings and sensitive direct searches for new physics.