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Top Physics Prospects in Run II and TeV33

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The top production rate in the future Tevatron run at $\sqrt{s} = 2$ TeV with the increased luminosity is summarized. The expected top yield seen by the upgraded detectors which have larger acceptance and better efficiency will give statistical and systematic improvements for various top decay properties and standard model values.

1 Tevatron Upgrade

In the Tevatron collider run, "RUN II", the Main Injector and $\bar{p}$-Recycler upgrades will allow the collection of 2 fb^{-1} of useful events.[1] This run maybe followed by "TeV33", in which an upgraded $\bar{p}$-source would extend the integrated luminosity to 30 fb^{-1} by the end of 2006[2]. The history and projections of luminosity growth are summarized in the following table:

Run	$\sqrt{s}$ (TeV)	typical Lum ($cm^{-2}sec^{-1}$)	best Lum ($cm^{-2}sec^{-1}$)	Integ. Lum (fb^{-1}/year)
1989	1.8	1.6×10^{30}	2.1×10^{30}	0.017
Ia	1.8	5.2×10^{30}	9.2×10^{30}	0.057
Ib	1.8	1.7×10^{31}	2.5×10^{31}	0.17
II	2.0	2.0×10^{32}	NA	2.0
TeV33	2.0	1.0×10^{33}	NA	10.0

The top physics program in Run II and TeV33 also benefits from the ~ 40 % higher top production rate at $\sqrt{s} = 2$ TeV.

2 Detector Upgrades

The upgraded CDF and D0 detectors for Run II have larger acceptance and better efficiency for top events[3,4,5]. Ingredients needed for Top measurements are leptons ($e\&\mu$), b-tagging, $\not{E}_{\mathrm{T}}$, and E_{jet} measurements. Key features of the CDF Run II Upgrade relevant to the detection of top production are:

	Run Ib	Run II
Plug Calorimeter		
Active material	gas	scintillator
$\delta E/E$(EM)	$(25/\sqrt{E} \oplus 2)\%$	$(17/\sqrt{E} \oplus 1)\%$
$\delta E/E$(Had)	$(108/\sqrt{E} \oplus 6)\%$	$(80/\sqrt{E} \oplus 5)\%$
Muon Detector		
Central η coverage	< 0.74	< 0.93
Forward η coverage	2.0-3.6	1.5-3.0
Central Outer Tracker		
Radiation length	1.7%	1.3%
# of stereo layers	24	48
$\delta p_{\rm T}/p_{\rm T}^2$ (trigger)	3.5%	~1.2%
$\delta p_{\rm T}/p_{\rm T}^2$ (offline)	0.11%	~0.11%
Silicon Vertex Detector		
η coverage	1.0	2.4
Radial coverage	3.0 - 7.8 cm	2.4 - 10.7 cm
# of layers	4 single side	5 double sided
Intermediate Fiber Tracker		
η coverage	-	2.0

These detector improvements will extend lepton identification, improve lepton $\overrightarrow{E}(\overrightarrow{P})$ measurements, extend b-tagging out to $|\eta| = 2$, improve systematics on E_{jet} and $\not{E}_{\rm T}$ measurements, and improved reconstructed mass resolutions. In addition, the following upgraded frontend and trigger electronics systems :

	Run Ib	Run II
Trigger (bandwidth)		
Level 1 accept	1 kHz	50 kHz
Level 2 accept	50 Hz	300 Hz
Level 3 accept	10 Hz	50 Hz
Readout electronics		
(bunch spacing)	3.5 μsec	132 $n$sec

will have minimal deadtime with a pipeline architecture ($>$ 90% livetime at peak luminosity with full acceptance for high $p_{\rm T}$ physics) and sharper $p_{\rm T}$ turn-on in the trigger system. The detector goal for TeV33 will be to maintain the same level of performances as in Run II.

3 Top Production Rate & Yield

From existing measurements with Run I data, the acceptance and yield for top events in the upgraded CDF detector can be extrapolated for Run II and TeV33 using the theoretical cross section as summarized below. More details can be found in references 6 and 3. With the detector improvements as described above, the acceptance for the primary leptons will increase by 36% for electrons and 25% for muons. The b-tagging efficiency is expected to be doubled to $\sim$ 80% per top event. The expected acceptance for top events was calculated by folding in branching ratio, distribution of decayed daughters, detector coverage, and detection efficiency at $\sqrt{s} = 2$ TeV. The estimated data samples for each experiment per run is:

total $t\bar{t}$ produced	Run I 0.8k		Run II 14k		TeV33 204k
channel	acc (%)	yield (#evt)	acc (%)	yield (#evt)	yield (#evt)
ee,$\mu\mu$,$e\mu$	0.78	7	1.1	155	2325
l+$\geq$3j	9.2	76	11.2	1520	22800
l+$\geq$3j, $\geq$1 b tag	3.7	31	7.2	980	14700
M_{top} sample $w/$ $\geq$1 b tag	3.0	25	5.8	790	11850
M_{top} sample $w/$ $\geq$2 b tags	0.52	5	1.8	245	3675
$\sigma_{t\bar{t}}$ measured	$7.5^{+1.9}_{-1.6} pb$		??		
$\sigma_{t\bar{t}}$ theory	4.8 pb		6.8 pb		

The larger data sets will give statistical and systematic improvements for the measurements of various top decay properties.

4 Prospects of Measurements

All statistical uncertainties will be scaled as $1/\sqrt{N_{\text{events}}}$. Some systematic errors which depend on other physics type events such as absolute energy scale (use Z+jet events) and gluon radiation (use Z+jet, W+jets, γ+jets, and $b\bar{b}$ events) will scale with luminosity ($\propto 1/\sqrt{L}$). Other systematic errors, such as b-tagging bias, jet energy correction, and background reduction will improve from detector upgrades. Many expected standard model values can be measured with precision, and this may give some hints to probe for physics beyond the standard model. Expectations for various measurements are :

- Top mass: Using various methods,[7] M_{top} can be determined better than about 4 (1) GeV/c^2 in Run II (TeV33) per experiment. Noted that the current uncertainty from CDF is about 9 GeV/c^2. With improvements in the W mass measurement[8,9] ($180 \rightarrow 40 \rightarrow 15 MeV/c^2$ for current $\rightarrow$ Run II $\rightarrow$ TeV33), a smaller range of uncertainty for a standard model Higgs boson mass can be achieved.

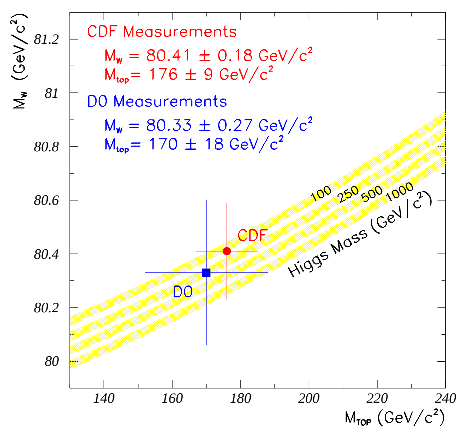

Figure 1: The current measured M_W vs M_{top} from CDF & D0

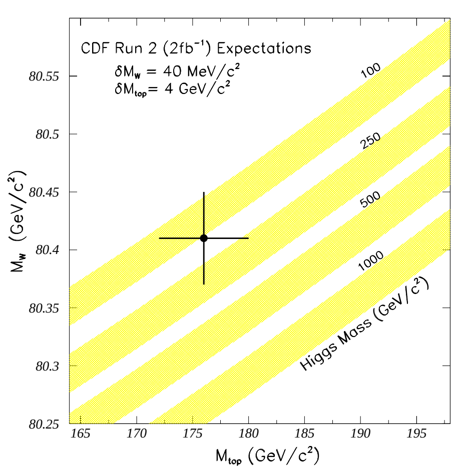

Figure 2: M_W vs M_{top} projected in Run II per experiment. With 30 fb^{-1}, the errors will be narrowed down to 1 GeV/c^2 for M_{top} and $15 MeV/c^2$ for M_W.

- Top production cross section as a test of the QCD Lagrangian at large Q^2 will be sensitive to non-Standard Model decays and probing for resonances which is predicted in some models of electroweak symmetry breaking. The $\delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}}$ is expected to be measured to 24%(now) $\rightarrow$ 5%(Run II) $\rightarrow$ 3% (TeV33) for each experiment.

- Branching ratios: couplings at decay vertex $R_1 = Br(t \rightarrow Wb)/Br(t \rightarrow Wq)$, $R_2 = Br(t\ \bar{t} \rightarrow ll + X)/Br(t\ \bar{t} \rightarrow l + X)$, and longitudinally polarized $WBr(t \rightarrow W_o b)$ can be measured and compared to the expected standard model values.

- Angular distributions: measurements of $cos(\theta_t^*)$ and η_t probe non-universal weak couplings and search for anomalous right-handed couplings, and can be done by fitting longitudinally polarized W to helicity angle measurements.

- Single top ($p\bar{p} \rightarrow tb + X$) is produced mostly via $s-$channel virtual W decay and some from $t-$channel. Using large samples of single top events and its cross section measurement, $,_{t\rightarrow Wb}$ can be determined and used to extract $|V_{tb}|$ with a high precision.

- Numerous precision measurements of top properties will extend the searches for rare decays and exotic physics such as $t \rightarrow Zc, \quad \gamma c, \quad WZb$, and W^+W^-c

Estimated precisions per experiment for various measurements are summarized in the following table. Combined errors from CDF and D0 will be factor of $\sim 1/\sqrt{2}$ smaller.

Measurement	Run I $110pb^{-1}$	Run II $2fb^{-1}$	TeV33 $30fb^{-1}$
δM_{top} (GeV/c^2)	9	4	< 1
$\delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}}$ (%)	24	5	3
$\delta R_1/R_1$ (%)	25	3	< 2
$\delta R_2/R_2$ (%)	50	10	4
$\delta Br(W_0 b)$ (%)	-	3	~ 0.5
$\delta ,_t$ (%)	-	13	5
$\|V_{tb}\|$	-	> 0.26	> 0.5

5 Conclusions

Large integrated luminosity data samples at the Tevatron will enable numerous precision top quark measurements and tests and will give additional interesting physics potentials. In summary, we have

- Tevatron, CDF and D0 upgrades are on track which will enable
- Excellent tests for the Standard Model for the next 10 years at Tevatron Collider. In addition,
- Extrapolations from measurements in a well understood environments will give a strong handle on searches for new physics. These measurements from the
- Tevatron will give good directions into the next century.

Acknowledgments

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