Overview

• The CDF and DZero collaborations are still doing exciting physics and publishing at a strong rate

• Focusing on legacy results that are competitive and complementary to the LHC

• In a phrase, our motto is “get the papers out!”
CDF and DZero: ~30 paper each in 2013
Excellent results in all physics groups
Tevatron Legacy: Over 1,000 papers published and 1,000 PhD’s granted
Rich Program

Selected Results

- **Higgs**
  - Final Higgs Combination
  - Higgs Couplings
- **Exotics/New Phenomena**
  - Search for Heavy Vector Bosons
- **QCD**
  - Exclusive production
  - Double parton Interactions
  - W/Z + Jets
  - Vector Boson +HF
- **Heavy Flavor**
  - CP Violation B⁺⁻ decays
  - Excited B-mesons
  - \(b\)-Baryon properties
  - Di-muon charge asymmetry
- **EWK**
  - \(A_{FB}: \sin^2\theta_{\text{eff}}\) and \(M_W\)
  - WW and ZZ Results
  - W Mass
- **Top**
  - Top Pair-Production Cross section
  - Top Mass
  - Single Top s+t
  - Single Top in s-only
  - \(A_{FB}\) in tt
  - \(A_{FB}\) in bb
The Higgs groups at both CDF and DZero have completed their search work. Powerful results in $b\bar{b}$ are complementary to the final states from the LHC. Observed significance is $3.0\sigma$ at a Higgs mass of 125 GeV. Tevatron combination published – PRD 88, 052014 (2013).
Higgs Couplings

• The world-wide emphasis has shifted to property measurements

• Combination of CDF and DZero results on Higgs Spin-parity is in progress
  – DZero results are public (Conf Notes 6387 and 6404)
  – CDF results are nearing completion

• All results are currently consistent with the SM
• While the Tevatron isn’t competitive for the high mass searches any more, there are still a number of places where it has advantages
  – PPbar vs. PP
  – Low number of interactions per crossing
• New limits on $W' \rightarrow tb$ and $Z' \rightarrow tt$ are the world’s best at intermediate masses
  – PRL 110, 121802 (2013)
  – CDF Public note 11079
• A few more results to come in the next year
  – Delayed photons
  – Monopoles
  – Others
QCD: Exclusive Production

- Measurements of Exclusive Production are important in their own right as well as for input in our Monte Carlos (Pythia, Herwig++ etc.)
- Central Exclusive Hadron Pair Production
  - CDF Public Note 10841
- Many other exclusive results
  - High mass di-jet production
  - Exclusive di-jet production,
  - exclusive di-photon
  - exclusive $\chi_c$ production
- Measurements at multiple Tevatron energies
  - 300, 900 and 1960 GeV
  - CDF Pub Note 10841 and 10874
Double Parton Interactions

• Ability to separate single and double parton interactions

• Measurements in both $\gamma + 3$ jets and $\gamma + b/c + 2$ jets events

• In agreement with the SM
W/Z+Jets

Z+jets & W+jets Cross Section Measurements

CDF: Public Note 10216
DZero: PRD 88, 092001 (2013)

QCD@NLO works reasonably well and is very useful for model builders.
• Using the low pileup environment to pushing down to low rate and/or soft production
• V+Charm jet
• V+D*
  – New method allows for lower $P_T$ Charm
  – CDF Public Note 11087
• W/Z+Upsilon
  – No observation, new limits
  – CDF Public Note 11099

<table>
<thead>
<tr>
<th>$\Upsilon + W$</th>
<th>$\Upsilon + Z$</th>
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<tbody>
<tr>
<td>expected limit (pb)</td>
<td>5.5</td>
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<tr>
<td>observed limit (pb)</td>
<td>5.5</td>
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</table>
CP violation in $B^\pm$ decays

- Analyzed decay multiple modes of $B^\pm$ for CP violation
  - $B^\pm \rightarrow J/\psi K^\pm \rightarrow \mu^+\mu^- K^\pm$
  - $B^\pm \rightarrow J/\psi \pi^\pm \rightarrow \mu^+\mu^- \pi^\pm$
- World’s most precise measurement
  - $A^{J/\psi K} = (0.59 \pm 0.36)\%$
  - $A^{J/\psi \pi} = (-4.2 \pm 4.8)\%$
- Consistent with SM expectations
  - DZero: PRL 110, 241801 (2013)
Excited B-mesons

- First evidence of resonances (4.4σ) consistent with two states of orbitally excited (L=1) B⁺-mesons
  - In both B⁰π⁺ and a B⁺π samples
- Measured masses and widths of all states, as well as the relative production rates
  - CDF: arXiv:1309.5961

<table>
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<tr>
<th>Quantity</th>
<th>Value (MeV/c²)</th>
<th>Stat. uncert. (MeV/c²)</th>
<th>Syst. uncert. (MeV/c²)</th>
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<td>12</td>
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<td>Q(B(5970)+)</td>
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<tr>
<td>m(B(5970)⁰)</td>
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<td>12</td>
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<tr>
<td>m(B(5970)+)</td>
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<td>3</td>
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<tr>
<td>Γ(B(5970)⁰)</td>
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<td>31</td>
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<tr>
<td>Γ(B(5970)+)</td>
<td>60</td>
<td>20</td>
<td>40</td>
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</table>

Masses are calculated assuming the state decays to Bπ.
$b$-Baryon Properties

- Best measurements of the masses and lifetimes of $\Xi_c$ and $b$-baryons

- First observations of $\Omega_b \to \Omega_c \, 0 \pi^-$ and $\Xi_b^0 \to \Xi_c^+ \pi^-$
  - CDF: PRD 89 072014 (2014)
  - Not yet seen at LHC
Like-sign di-muon charge asymmetry

- Current result deviates from the SM prediction by $3.0\sigma$
  - DZero: PRD 89, 012002 (2014)
- Result is consistent with independent DZero measurements
  - Semi-leptonic asymmetry in $B^0$ ($a^d_{sl}$): PRD 86, 072009 (2012)
  - Semi-leptonic asymmetry in $B_s$ ($a^s_{sl}$): PRL 110, 011801 (2013)
- This effect is one of a few remaining puzzles from the Tevatron program which might indicate physics beyond standard model
Precision EWK: $A_{FB}$ from leptons

$\sin^2 \theta_{eff}$ and W-mass

- $A_{FB}$ from leptons provides a powerful way to measure $\sin^2 \theta_{eff}$
- CDF:
  - Interpret the results as an indirect W mass measurement → quite competitive
  - New $\mu\mu$ measurement in PRD 89, 072005 (2014)
  - Result for $ee$ in progress
- DZero:
  - Single most precise $\sin^2 \theta_{eff}$ measurement is in $ee$ final state
  - Public Note 6426

David Toback, Texas A&M University
Fermilab Users Meeting – Tevatron P
WW and ZZ Results

- **WW cross section**
  - New full data set results as a function of $N_{\text{jet}}$ and $\text{Jet } E_T$
    - CDF Public note 11098
    - Dzero: PRD 88, 112005 (2012)

- **ZZ Cross Section**
  - $\sigma_{zz} = 1.04^{+0.32}_{-0.25} \text{ pb}$
  - CDF: PRD 89, 112001 (2014)
  - DZero: PRD 88, 0230080 (2013)

- All in agreement with the SM
W Mass Measurement

- Tevatron Combination
  - PRD 88, 052018 (2013)
    - CDF: PRD 89, 072003 (2014)
    - DZero: PRD 89, 012005 (2014)
  - $M_W = (80387 \pm 16)$ MeV/c$^2$
  - 0.02% precision!

- Further reduction of uncertainties are difficult and time consuming
  - Full-data results from both CDF and DZero in progress
• Combined CDF/DZero results from ~8.8 fb\(^{-1}\) published
  – PRD 89, 072001 (2014)

• Result is 7.60±0.41 pb

• CDF version in lep+jets with the full dataset nearing release

### Tevatron Run II

<table>
<thead>
<tr>
<th>Process</th>
<th>Value (pb)</th>
<th>Luminosity (fb(^{-1}))</th>
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<tbody>
<tr>
<td>CDF dilepton</td>
<td>7.09 ± 0.83</td>
<td>8.8 fb(^{-1})</td>
</tr>
<tr>
<td>CDF ANN lepton+jets</td>
<td>7.82 ± 0.56</td>
<td>4.6 fb(^{-1})</td>
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<tr>
<td>CDF SVX lepton+jets</td>
<td>7.32 ± 0.71</td>
<td>4.6 fb(^{-1})</td>
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<tr>
<td>CDF all-jets</td>
<td>7.21 ± 1.28</td>
<td>2.9 fb(^{-1})</td>
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<tr>
<td>CDF combined</td>
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<td></td>
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<tr>
<td>DØ dilepton</td>
<td>7.36 ± 0.85</td>
<td>5.4 fb(^{-1})</td>
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<tr>
<td>DØ lepton+jets</td>
<td>7.90 ± 0.74</td>
<td>5.3 fb(^{-1})</td>
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<tr>
<td>DØ combined</td>
<td>7.56 ± 0.59</td>
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</table>

\[ p\bar{p} \rightarrow t\bar{t} \text{ cross section (pb) at } \sqrt{s}=1.96 \text{ TeV} \]

\[ m_t = 172.5 \text{ GeV} \]
Top Mass

- CDF Combination now complete in all channels
  - Public Note 11080
- Tevatron Combination
  - arXiv:1305.3939
- Strong impact on World combination
  - arXiv:1403.4427
- New DZero results in lepton+jets
  - Very small uncertainties:
    \[ M_{\text{top}} = 174.98 \pm 0.76 \]
  - arXiv:1405.1756
Single Top $s+t$

- CDF Results in Met+Jets and Lep+Jets
  - Public Notes 10793 and 10926
  - Combined results coming soon

- DZero Result

- Tevatron Combination is well underway, results expected soon
Observation of Single Top in the S-Channel

- Single top production in the S-only Channel has now been observed
  - Combination complete
  - PRL 112, 231802 (2014)
- Observed significance $6.3\sigma$
Hot topic for a number of years

CDF Lep+Jets results shows anomalies
  - In total reconstructed asymmetry
    - CDF: PRD 87, 092002 (2013)
    - Most pronounced as a function of mass
  - In $d\sigma/d\cos\theta_t$ in $l+$jets
    - CDF: PRD 88, 072003 (2013)
  - In lepton asymmetry
    - CDF: PRL 111, 182002 (2013)

Full suite of CDF and DZero results since then
  - Leptonic: $l+$jets & dileptons
  - Full Reconstruction: Lep+Jets only

Recent results from CDF and DZero are more consistent with SM
  - DZero Reconstructed: arXiv:1403.1294

Not sure what the final conclusion is: working to finish results, reconcile them all and combine
$A_{FB}$ in High Mass $bb$

- The $A_{FB}$ in $tt$ suggests that looking in the lower mass $bb$ state is useful at large $bb$ invariant masses
- New results consistent with SM
  - CDF Public note 11092
- DZero and CDF low mass results in the works
# Future Publication Plans

## CDF
- Expect ~30 papers in 2014
- Expect ~15 in 2015

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## DZero:
- Expect ~25 papers in 2014
- Expect ~15 papers in 2015

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Conclusions

• The CDF and DZero collaborations are still doing exciting physics and publishing at a strong rate
• The Tevatron has now published over 1,000 papers and graduated over 1,000 PhD students
• The last year(s) have had many successes by focusing on legacy results that are competitive and complementary to the LHC
  – Single Top, W Mass, Top Mass, $A_{FB}$ in $tt$, Higgs(bb)
• Modest support from the laboratory and funding agencies around the world is well leveraged and will assure many more important results to come based on the Tevatron data
• In the next year or so we expect many exciting results including the final Tevatron word on the Higgs Spin-parity in $VHiggs(bb)$ Top mass, $A_{FB}$ in $tt$ and $bb$, W charge asymmetry and a W Mass measurement in the 10-15 MeV range