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**
  - $A_{FB}$: $\sin^2 \theta_{eff}$ 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 bb are complementary to the final states from the LHC.

Observed significance is 3.0σ at a Higgs mass of 125 GeV.

Tevatron combination published
- PRD 88, 052014 (2013)
• 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 $W' \to tb$ and $Z' \to tt$ 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
  - DZero: PRD 89, 072006 (2014)
- 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
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

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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 $B^0$ ($a_{s l}^d$): PRD 86, 072009 (2012)
  • Semi-leptonic asymmetry in $B_s$ ($a_{s l}^s$): 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

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

- $A_{FB}$ from leptons provides a powerful way to measure $\sin^2 \theta_{\text{eff}}$

- **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 $\sin^2 \theta_{\text{eff}}$ measurement is in $ee$ final state
  - Public Note 6426

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**Graph:**

- $A_{FB}$ values for different final states:
  - $A_{FB}^0$ (CDF), $2.0 \text{ fb}^{-1}$
  - $A_{FB}^\mu$ (CDF), $9 \text{ fb}^{-1}$
  - $A_{FB}$ (DZero), $9.7 \text{ fb}^{-1}$ preliminary

- $\sin^2 \theta_{\text{eff}}$ values:
  - TeV and LEP-2: $80.385 \pm 0.015$
  - LEP-1 and SLD ($m_t$): $80.365 \pm 0.020$
  - NuTeV: $80.135 \pm 0.085$
  - CDF $ee$ 2 $\text{ fb}^{-1}$: $80.297 \pm 0.048$
  - CDF $\mu \mu$ 9 $\text{ fb}^{-1}$: $80.365 \pm 0.047$

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David Toback, Texas A&M University
Fermilab Users Meeting – Tevatron Physics

June 2014
**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**
  - $\sigma_{zz} = 1.04^{+0.32}_{-0.25}$ 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)
  - $M_W = (80387 \pm 16) \text{ MeV/c}^2$
  - 0.02% precision!

- Further reduction of uncertainties are difficult and time consuming
  - Full-data results from both CDF and DZero in progress
Top Pair-Production Cross Section

- Combined CDF/DZero results from \( \sim 8.8 \text{ fb}^{-1} \) published
  - PRD 89, 072001 (2014)
- Result is 7.60\( \pm 0.41 \) pb
- CDF version in lep+jets with the full dataset nearing release
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
• 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 6.3σ**
Forward-Backward Asymmetry in ttbar

- Hot topic for a number of years
- CDF Lep+Jets results show anomalies
  - In total reconstructed asymmetry
    - CDF: PRD 87, 092002 (2013)
    - Most pronounced as a function of mass
  - In $d\sigma/d\cos\theta$, 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

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- Expect ~30 papers in 2014
- Expect ~15 in 2015
- Expect ~25 papers in 2014
- Expect ~15 papers in 2015
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