Heavy Flavour Results from the Tevatron

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• Winter 2012 results - A selection of recent results

• CDF Bs → μμ search (full dataset)
• DØ A_b^{sl} Anomalous Dimuon
• CDF Bs → J/ψΦ (full dataset)
• DØ Bs → J/ψf’_2(1525) (Hot off the press, full dataset)
• DØ New State decaying to Υ(1S) + γ
• DØ Λ_b Lifetime (Λ_b → J/ψΛ^0) (Hot off the press, full dataset)
• CDF CP Violation in Charm (full dataset)

• Other recent results not covered here
  • CDF: Br(Bs→D_S^{(*)}D_S^{(*)}), D Meson Fragmentation, CPV in D^0→K_sπππ, Υ(ns) Spin Alignment, B_c Lifetime
  • DØ: Bs → J/ψf_0(980)
CDF: $B_s \rightarrow \mu \mu$ (full dataset)

- SM prediction (A. Buras et al., arXiv:1012.2126):
  
  \[
  \begin{align*}
  \text{Br} (B_s \rightarrow \mu \mu) &= (3.2 \pm 0.2) \times 10^{-9} \\
  \text{Br} (B_d \rightarrow \mu \mu) &= (1.0 \pm 0.1) \times 10^{-10} 
  \end{align*}
  \]

- New Phenomena could lead to much higher BR.

- CDF 2011 result showed a 2.7σ deviation above the expected background.
  

- This result has been updated with the complete Tevatron dataset (30% increase in the dataset).

- CDF uses the same data selection with no improvements to test the result.

- In $B_d$ the extracted limit is $<4.6 \times 10^{-9}$ (consistent with background) expected limit $4.2 \times 10^{-9}$
CDF: $B_s \rightarrow \mu\mu$ (full dataset)

2-sided limit - reduced significance slightly to about $2.2\sigma$

$$0.8 \times 10^{-9} < BR(B_s \rightarrow \mu\mu) < 3.4 \times 10^{-8} @ 95\%$$

$$[BR = (1.3^{+0.9}_{-0.7}) \times 10^{-8}]$$
D0 - Dimuon Charge Asymmetry

\[ A_{sl}^b = (-0.787 \pm 0.172 \text{(stat)} \pm 0.093 \text{(syst)})\% \]

- Anomalous Dimuon - 3.9\(\sigma\) deviation from SM expectations

\[ a_{sl}^d = (-0.12 \pm 0.52)\%, \]
\[ a_{sl}^s = (-1.81 \pm 1.06)\%. \]

- Need to investigate in as many different ways as possible.

- Flavour-specific measurements, integrated mixing probability, further IP studies.
CDF: $B_s \rightarrow J/\psi \Phi$ (full dataset)

- Analysis of full data set: $\sim 11k$ events
- Joint fit to mass, production flavour, decay-time, decay-angles

Look at other $B$ ($\epsilon D^2 \sim 1.4\%$)

Look at $K$ in fragmentation with $B_s$ ($\epsilon D^2 \sim 3\%$)

Trace the time-evolution and fast $B_s$ oscillations

Disentangle CP-even/CP-odd final state
Include $J/\psi KK$ S-wave contribution
CDF: $B_s \rightarrow J/\psi \Phi$ (full dataset)

CDF Run II Preliminary $L = 9.6 \text{ fb}^{-1}$

$\phi_s = [-0.60, 0.12] \text{ @68\% CL}$

$\Delta \Gamma_s = 0.068 \pm 0.026 \pm 0.007 \text{ ps}^{-1}$

$\tau_s = 1.528 \pm 0.019 \pm 0.009 \text{ ps}$

CDF Note: 10778

Strong phases fitting range restricted based on $B^0 \rightarrow J/\psi K^*$

$\phi_s = -0.55 \pm 0.38$

$\Delta \Gamma_s = 0.163 \pm 0.065 \pm 0.064 \text{ ps}^{-1}$

$\tau_s = 1.443 \pm 0.038 \pm 0.035 \text{ ps}$
Comparison - All Experiments
DØ Bs → J/ψf’₂(1525) (full dataset)

- Preliminary result - to be submitted next week.
- Analysis Outline:
  - Determine identity of decay;
  - Extract Bs → J/ψf’₂(1525) yield from fitting Bs yield vs M(KK);
  - Measure the Spin.
- f’₂(1525) decays to KK, f₀(1500) large ΠΠ - observe only KK.
- Major Background is K*⁺(1430)

Data favour J=2, but also consistent with a coherent superposition of J=0 and J=2.
Incompatible with J=0 or J=1
• Combined fit - includes relativistic BW with $J=2$ plus a constant S-wave contribution

• Constant fraction = 0.33 ±0.09

\[ R_{f'/\phi} = 0.22 \pm 0.05\text{ (stat)} \pm 0.04\text{ (syst)} \]  

Compare with LHCb result (PRL, 108, 151801 (2012))

\[ R_{f'/\phi} = 0.264 \pm 0.027\text{ (stat)} \pm 0.024\text{ (syst)} \]
DØ: New State decaying to $\Upsilon(1S) + \gamma$

- Confirmation of ATLAS observation (arXiv:1112.5154)

$\Upsilon(1S) \rightarrow \mu \mu$

$\gamma \rightarrow e e$

$M(X) = 10.551 \pm 0.014\text{(stat)} \pm 0.016\text{(syst)} \text{GeV}/c^2$
DØ: New State decaying to $\Upsilon(1S) + \gamma$

$DØ \, M(X) = 10.551 \pm 0.014 \text{(stat)} \pm 0.016 \text{(syst)} \text{GeV/c}^2$

$ATLAS \, M(X) = 10.530 \pm 0.005 \text{(stat)} \pm 0.009 \text{(syst)} \text{GeV/c}^2$

- Interpretation - the new state has not been fully identified.
- Narrow Structure
- Branching ratios?
  Spin structure?
  Just one state?

\begin{align*}
\Upsilon(4S) & \quad X_b \approx 10.53 - 10.55 \text{ GeV} \\
\Upsilon(3S) & \quad \chi_b(2P) \\
\Upsilon(2S) & \quad \chi_b(1P) \\
\Upsilon(1S) & \quad 1-- \quad 0^{++} \quad 1^{++} \quad 2^{++}
\end{align*}

Kwong, Rosner  
$m(\chi_b(3P)) \approx 10.520 \text{ GeV}$

Törnqvist  
m$(B\bar{B}^*) \approx 10.545 \text{ GeV}$
**$\Lambda_b$ Lifetime ($\rightarrow J/\psi \Lambda^0$)**

- **CDF 2011 Result** 2\(\sigma\) above WA
- **Theoretical prediction (HQET):** PRD 70, 094031 (2004)
  \[
  \frac{\tau_{\Lambda_b}}{\tau_{B_d}} \bigg|_{\text{NLO}} = 0.88 \pm 0.05
  \]
- **Current best results**
  - CDF: \(1.020 \pm 0.030 \pm 0.008\)
  - DØ: \(0.811^{+0.096}_{-0.087} \pm 0.034\)
DØ $\Lambda_b$ Lifetime ($\rightarrow J/\psi \Lambda^0$) (full dataset)

- Submitted to PRD-RC on Wednesday (arXiv:1204.2340) Makes use of full dataset
- Use two similar processes: $\Lambda_b \rightarrow J/\psi \Lambda^0$ and $B_d \rightarrow J/\psi K_s$
  where $J/\psi \rightarrow \mu\mu$, $K_s \rightarrow \pi\pi$, $\Lambda^0 \rightarrow p\pi$
- Use selection criteria that does not bias the lifetime

(a) DØ, 10.4 fb$^{-1}$

$\Lambda_b \rightarrow J/\psi \Lambda^0$

755 ± 49

(b) DØ, 10.4 fb$^{-1}$

$B_d \rightarrow J/\psi K_s$

5671 ± 126
Extract lifetimes

\[ \tau(\Lambda_b^0) = 1.303 \pm 0.075 \text{ (stat.)} \pm 0.035 \text{ (syst.)} \text{ ps}, \]
\[ \tau(B^0) = 1.508 \pm 0.025 \text{ (stat.)} \pm 0.043 \text{ (syst.)} \text{ ps}, \]

in agreement with WA results

\[ \frac{\tau(\Lambda_b)}{\tau(B_d) \text{ NLO}} = 0.88 \pm 0.05 \]

\[ \frac{\tau(\Lambda_b)}{\tau(B_d)} = 0.864 \pm 0.52(\text{stat.}) \pm 0.033(\text{syst.}) \]

- Consistent with theoretical prediction
- 2.2\sigma discrepancy with CDF result
- Need additional measurement (LHC experiments?)
CDF - CP Violation in Charm

- Previous results
  - CDF 2011: use displaced track triggers to obtain huge data samples PRD85, 012009 (2012)
    \[ A_{CP} \left( D^0 \rightarrow K^+ K^- \right) = (-0.24 \pm 0.22 \pm 0.10) \% \]
    \[ A_{CP} \left( D^0 \rightarrow \pi^+ \pi^- \right) = (+0.22 \pm 0.24 \pm 0.11) \% \]
  - LHCb 2012: 3.5σ deviation from SM PRL 108, 111602 (2012)
    \[ \Delta A_{CP} = A_{CP}(D^0 \rightarrow K^+ K^-) - A_{CP}(D^0 \rightarrow \pi^+ \pi^-) \]
    maximally sensitive to NP.

  Experimentally convenient:
  instrumental asymmetries cancel.

  \[ \Delta A_{CP} = (-0.82 \pm 0.21 \pm 0.11) \% \]
CDF - $\Delta A_{\text{CP}}$ with the Full Dataset

- Optimised data selection for $\Delta A_{\text{CP}}$ doubling the signal
- loosened selection (removing IP requirement)
- Get $D^0$ flavour from $D^* \rightarrow D^0\pi$

the soft pion induces $O(1\%)$ asymmetries - use difference to cancel detector based effects and accentuate effect of NP.

$$\Delta A_{\text{CP}} = (A(K^+K^-) + \delta(\pi_s)) - (A(\pi^+\pi^-) + \delta(\pi_s))$$
CDF - $\Delta A_{CP}$ with the Full Dataset

- Consistent with the LHVb result (same sensitivity).
  \[ \Delta A_{CP} = (-0.82 \pm 0.21 \pm 0.11)\% \]

- When combining using HFAG method the result is $\sim 4\sigma$ from SM result of zero.
  \[ \Delta A_{CP}^{\text{dir}} = (-0.67 \pm 0.16)\% \]
  \[ A_{CP}^{\text{ind}} = (-0.02 \pm 0.22)\% \]

\[ \Delta A_{CP} = [-0.62 \pm 0.21(\text{stat}) \pm 0.10(\text{syst})] \% \]
Summary

• Tevatron still producing new, high impact results with the Full Run II dataset
  • CPV in Charm sector!
    CDF confirms LHCB's evidence of CPV in charm with same precision!
  • Rare B decays.
    extension to full sample confirms summer result.
  • Bs mixing
    Closer to SM expectations.
  • Confirmation of $B_s \rightarrow J/\psi f'_2(1525) - J=2$ confirmed
  • ASL needs independent confirmation!
  • Confirmation of $X_b$.
  • DØ $\Lambda_b$ Lifetime consistent with HQET
Summary

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- CPV in charm sector! CDF confirms LHCB's evidence of CPV in charm with same precision!

- Rare B decays. Extension to full sample confirms summer result.

- Bs mixing. Closer to SM expectations.

- Confirmation of Bs → J/ψf_2(1525).

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- Confirmation of Xb.

- DØ Λ_b Lifetime consistent with HQET.

- Many more results to come.