Recent B physics results from Tevatron

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Moriond QCD and High Energy Interactions

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Contents

Today's talk highlights 4 new measurements from CDF since Oct. 2010, based on 1.4 – 6 fb^{-1} data:

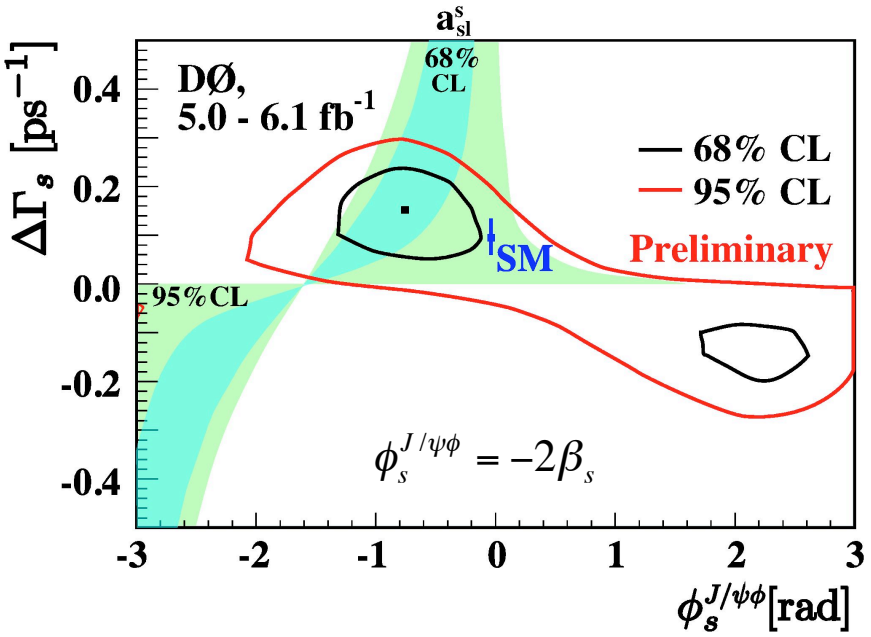
- **Search for New Physics in B_s sector:**
  - $\overline{\chi}$ **:Time integrated mixing probability of B mesons**
  - **$B_s \rightarrow J/\psi\ f_0(980)$ BR measurement**
- **Competitive results with B factories in B/charm sector:**
  - **BR and A_{CP} in doubly Cabibbo suppressed $B^{\pm} \rightarrow D^0\ h^{\pm}$ decays**
  - **Time integrated CP violation in $D^0 \rightarrow h^+\ h^-$ decays**
- **Summary**

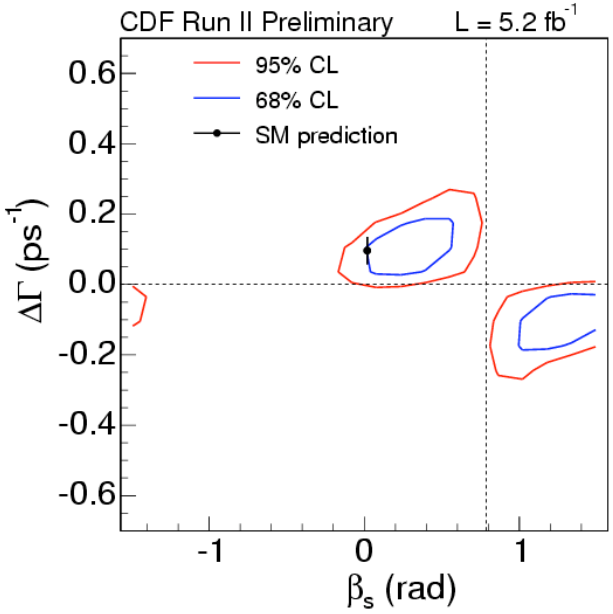
Search for NP in B_s decays

- B_s mixing phase is expected to be tiny in SM ($\beta_s^{SM} \approx 0.02$) and unconstrained by the 2006 measurement of the B_s mixing frequency.
  - Presence of NP can lead to large values of the phase, not experimentally excluded
- Access β_s^{SM} through:
  1) Time evolution of flavor tagged $B_s \rightarrow J/\psi\phi$ decays
  2) Inclusively, by measuring anomalous mixing rate difference between B_s and $\overline{B}_s$ (A^b_{SL})
- Both the methods are pursued at CDF and DØ. Initial results indicate departure from SM.
  - Call for more scrutiny through independent measurements.

1) CPV from mixing in $B_s \rightarrow J/\psi\phi$ decays

- Best way of probing CPV due to NP in B_s mixing
- BUT.. difficult angular analysis to disentangle CP even and odd components.
- DØ: 6.1 fb^{-1} data
  - Sees 1.1σ deviation from SM
- CDF: 5.2 fb^{-1} data
  - Sees 0.8σ deviation from SM





Need updated measurements to shed light on the situation.

A simpler way to access β_s

- In early searches for CP violation $B_s \rightarrow J/\psi\varphi$ decays a 1.5σ deviation from standard model was observed.
- It is suggested that the decay $B_s \rightarrow J/\psi f_0(980)$, $f_0(980) \rightarrow \pi^+\pi^-$ (pure CP odd state) can be used to measure CP violating phase $\beta_s^{J/\psi\varphi}$ without need for angular analysis.
- As a first step: CDF searched for this suppressed decay mode with 3.8 fb^{-1} data collected using a di-muon trigger. **CDF Public Note 10404**
- Use an NN to suppress background. Then perform a log-likelihood fit on signal and normalization mode simultaneously.

$B_s \to J/\psi\, f_0(980)$ BR result

NEW!

- Observed 571±37(stat)±25(sys) signal events with a 17.9σ significance and 2302±49 $B_s \to J/\psi\, \Phi$ events.
- Measured:

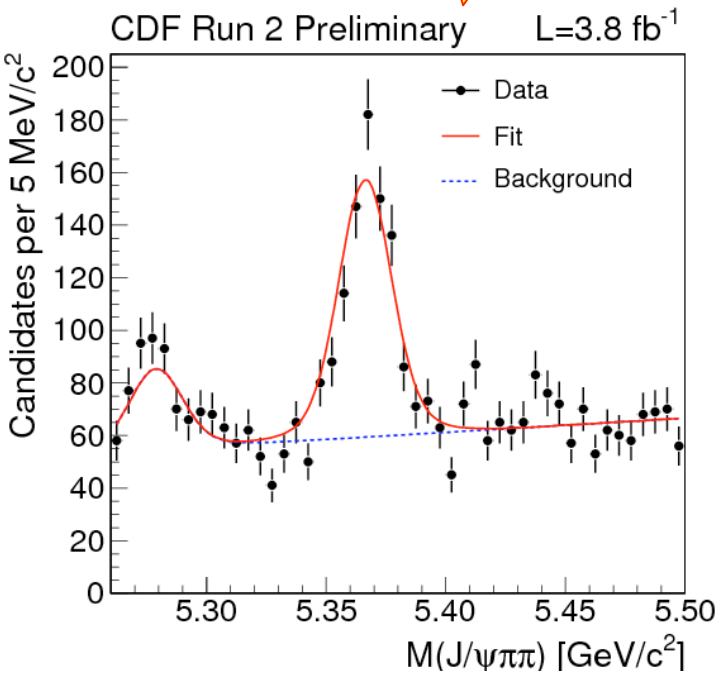
$$R_{f^0/\phi} = \frac{\mathrm{BF}(B_s \to J/\psi f_0(980)) \cdot BF(f_0(980) \to \pi^+\pi^-)}{\mathrm{BF}(B_s \to J/\psi\phi) \cdot BF(\phi \to K^+K^-)}$$
$$= 0.292 \pm 0.020(\mathrm{stat}) \pm 0.017(\mathrm{sys})$$

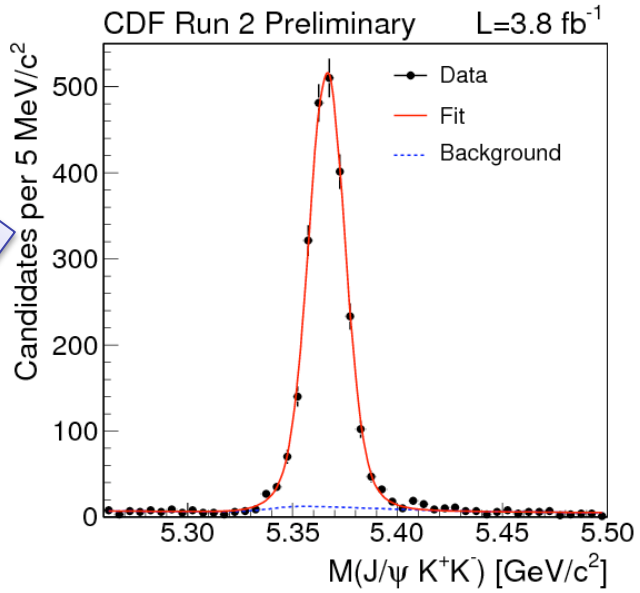
(Theory: 0.1 – 0.5)

- Derived:

$$\mathrm{BF}(B_s \to J/\psi f_0(980)) \cdot BF(f_0(980) \to \pi^+\pi^-)$$
$$= [1.85 \pm 0.13(\mathrm{stat}) \pm 0.11(\mathrm{sys}) \pm 0.57(\mathrm{pdg})] \cdot 10^{-4}$$

Most precise result!





2) Dimuon charge asymmetry recap

V. A. Abazov et al, Phys. Rev. Lett. 105, 081801 (2010)

$$A_{sl}^{b} = \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}}$$

- Where, $N_b^{++,--}$ are number of same sign dimuon events produced due to the b hadrons decaying semileptonically, one before and the other after mixing.
- Is close to zero if mixing rates $B \to \overline{B} = \overline{B} \to B$ (SM expectation is a few 10^{-4}).

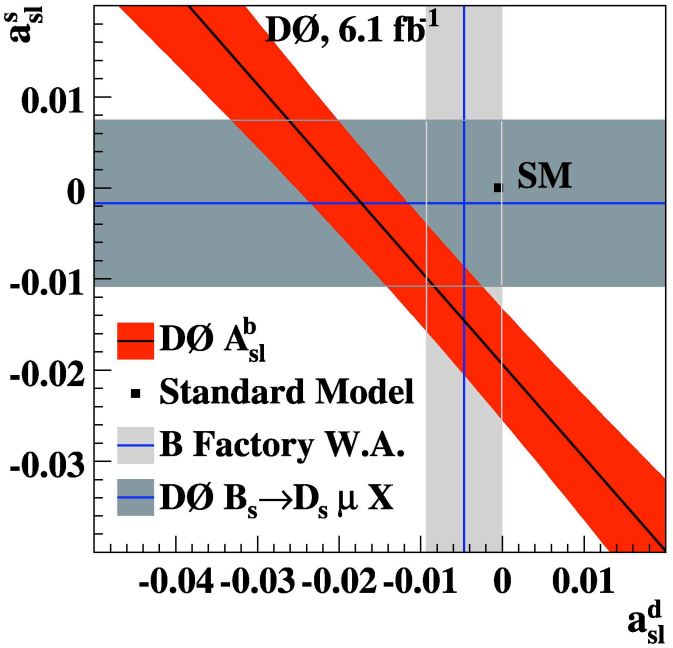
- DØ 6.1 fb^{-1} result:

$$A_{sl}^{b} = (-0.957 \pm 0.251(\text{stat}) \pm 0.146(\text{syst}))\%$$

- Differs from SM by ~3.2σ:

$$A_{sl}^{b}(\text{SM}) = (-0.023^{+0.005}_{-0.006})\%$$

- Indication of large β_s?



CDF on the way to measuring A^b_{sl}

- CDF is pursuing an alternate path for independent verification of the interesting DØ result.
- Use muon impact parameter (IP) information to fit for sample composition, separating same-sign dimuons $\mu^+\mu^+$ and $\mu^-\mu^-$ that originate from B decays (i.e. are long lived).
- IP fitter is a standard robust technique demonstrated in the correlated $B\bar{B}$ cross-section measurement: *PRD 77, 072004 (2008).*
- As a first step: measure time-integrated mixing probability $\bar{\chi}$
  - Comparison to LEP $\bar{\chi}$ validates the IP fitter.

Time integrated mixing prob. measurement

CDF Public Note 10335

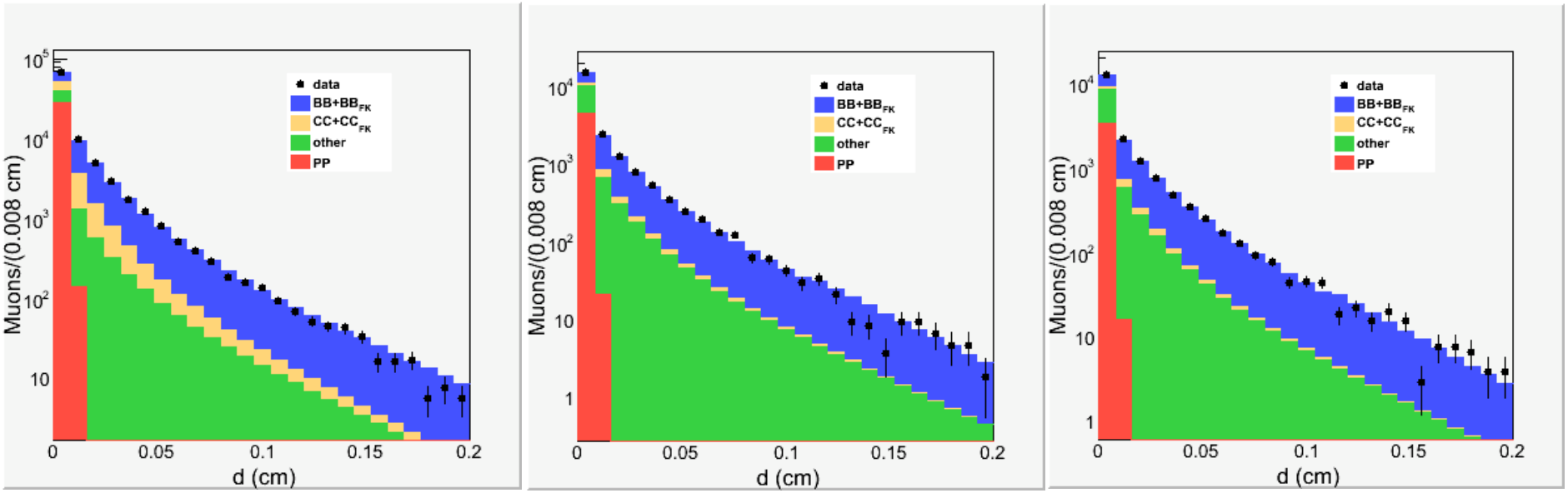
- Data sample: **1.45 fb^{-1}** from CDF di-muon trigger
- Ratio of like-sign (LS) to opposite-sign (OS) di-muons, **R**, measure the average time-integrated mixing probability ($\bar{\chi}$) of the mixture of semileptonic decays of B and B mesons.

$$\bar{\chi} = \frac{\Gamma(B^0_{d,s} \to \bar{B}^0_{d,s} \to \ell^+ X)}{\Gamma(B_{all} \to \ell^{\pm} X)} = f_d \cdot \chi_d + f_s \cdot \chi_s$$

Where, $f_{d,s}$ are production fractions
And $\chi_{d,s}$ are mixing probabilities for B^0 and B_s.

- Earlier Tevatron $\bar{\chi}$ measurement is 0.147±0.011 *Phys.Rev.D69:012002,2004* which differs from LEP measurement of 0.1259±0.0042 (a 1.8σ deviation).
- Fit the observed impact parameter distribution for muon pairs simultaneously to extract $\bar{\chi}$

IP fit projections



OS **LS ++** **LS --**

- Much tighter selection than previous measurement. Require muon tracks to originate before R=1.5 cm.
- Various components from b, c and prompt and other (BC + BP+ CP) sources add up to data well.

Time integrated mixing probability result

- Accounting for all sources a 2D fit of the dimuon impact parameters yields the LS to OS ratio,

$$R = 0.467 \pm 0.011$$

- The resulting mixing probability is,

$$\bar{\chi} = 0.126 \pm 0.008$$

- It includes systematic uncertainties of 0.005 due to R and 0.006 due to effective fraction of dimuons from sequential decays.

- Good agreement with LEP measurement of 0.1259±0.0042

  ➲ **IP fitter is ready for A^b_{sl} extraction.**

New measurements competitive with B-Facs:

1) BR and A_{CP} in DCS $B^{\pm} \rightarrow D^0 h^{\pm}$ decays
2) Time integrated CP violation in $D^0 \rightarrow h^+ h^-$ decays

BR and A_{CP} in DCS $B^{\pm}\to D^0 h^{\pm}$ decays

- BR and A_{CP} in $B^-\to D^0 K^-$ allow for a theoretically-clean way of measuring the CKM angle γ (known to 10-20^o level)

- Atwood-Dunietz-Soni method: Interference between
  - $B^- \to D^0 K^-$ (color allowed); $D^0_{DCS}\to K^+\pi^-$
  - $B^- \to \bar{D}^0 K^-$ (color suppressed); $\bar{D}^0_{CF}\to K^+\pi^-$

  can lead to large A_{CP}.

- Define DCS fractions and asymmetries:

$$R_{ADS}(K) = (BR(B^-\to[K^+\pi^-]_D K^-) + BR(B^+\to[K^-\pi^+]_D K^+))/(BR(B^-\to[K^-\pi^+]_D K^-) + BR(B^+\to[K^+\pi^-]_D K^+))$$
$$= r_D^2 + r_B^2 + r_D r_B \cos\gamma \cos(\delta_B+\delta_D)$$
$$A_{ADS}(K) = (BR(B^-\to[K^+\pi^-]_D K^-) - BR(B^+\to[K^-\pi^+]_D K^+))/(BR(B^-\to[K^+\pi^-]_D K^-) + BR(B^+\to[K^-\pi^+]_D K^+))$$
$$= 2\, r_B r_D \sin\gamma \sin(\delta_B+\delta_D)/R_{ADS}(K)$$

[Similar for $R_{ADS}(\pi)$ and $A_{ADS}(\pi)$]

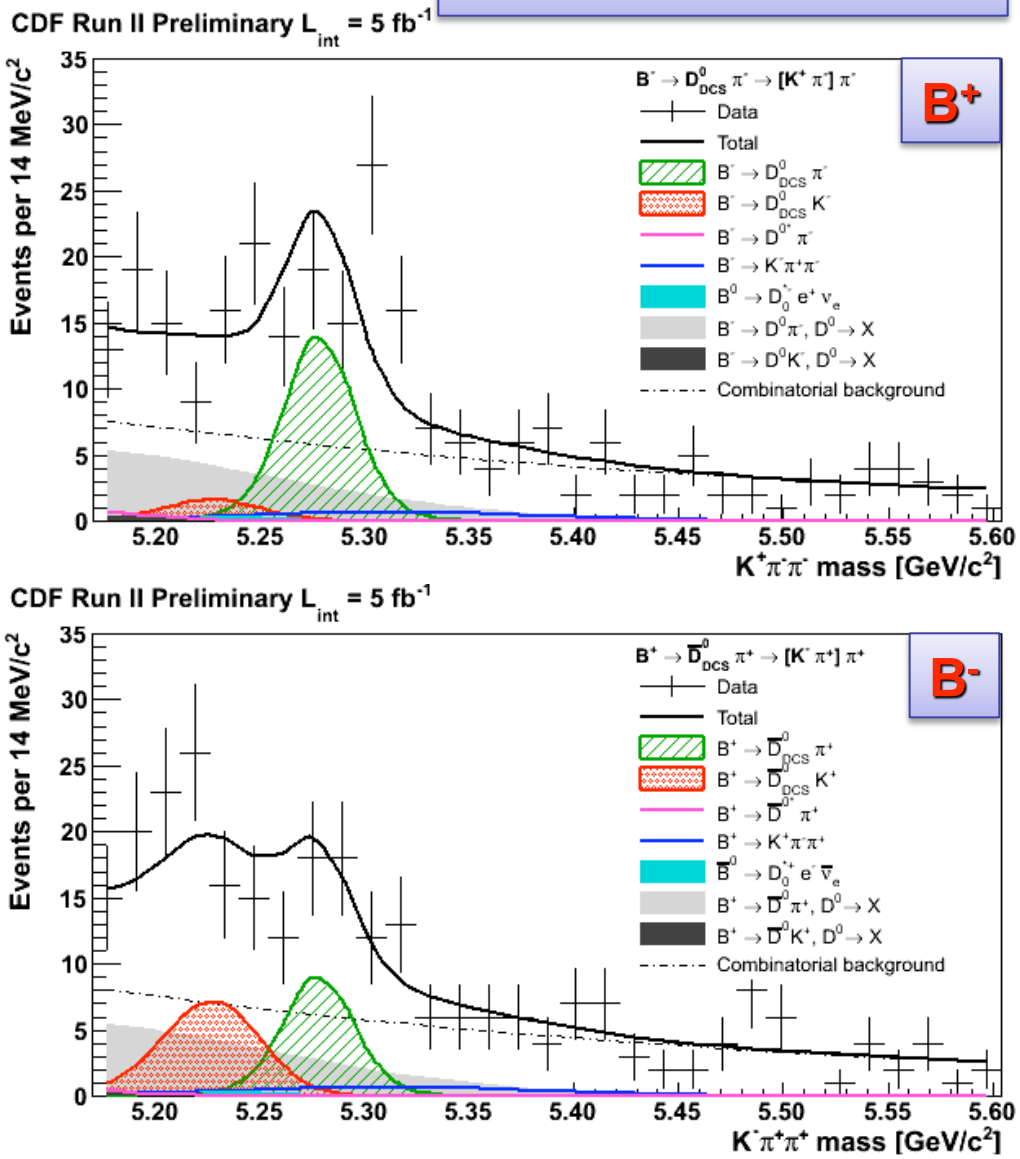
$r_B = |A(b\to u)/A(b\to c)|$ and
$\delta_B = \arg[A(b\to u)/A(b\to c)]$

r_D and δ_D: For D decays

BR and A_{CP} in DCS $B^{\pm} \rightarrow D^0 h^{\pm}$ decays

CDF Public Note 10309

- Data analyzed: **5 fb^{-1}**
- First measurement in a hadron collider experiment
- Perform an unbinned maximum likelihood fit, that combines mass and particle ID (dE/dx) information, to separate signal (π, K) from backg.
- Reconstructed DCS modes:
  - B → $D^0\pi$: **73 ± 16** events and
  - B → D^0K: **34 ± 14** events



ADS Method: Results

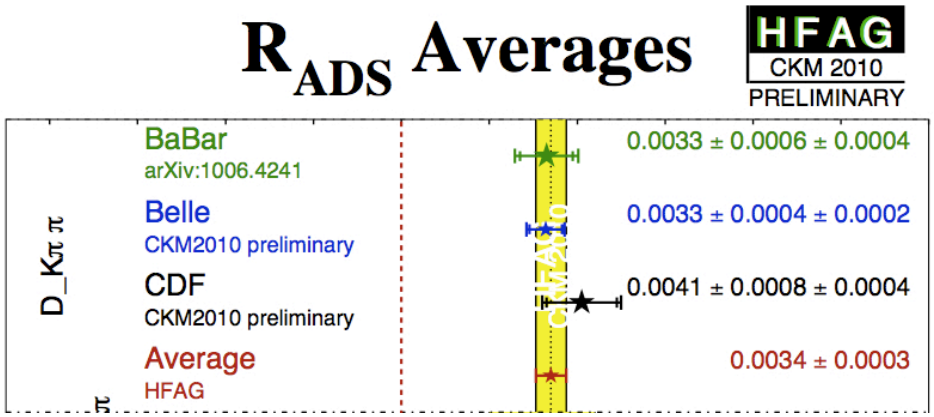
$$R_{ADS}(\pi) = (4.1 \pm 0.8\ (stat) \pm 0.4\ (syst)) \cdot 10^{-3}$$

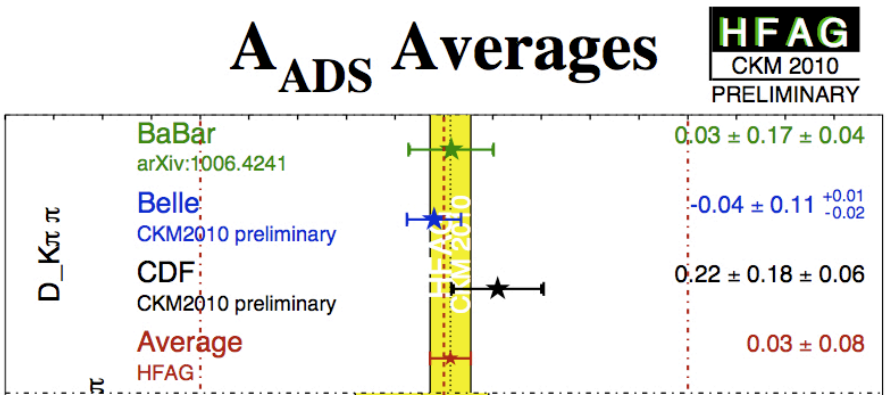
$$R_{ADS}(K) = (22.5 \pm 8.4\ (stat) \pm 7.9\ (syst)) \cdot 10^{-3}$$

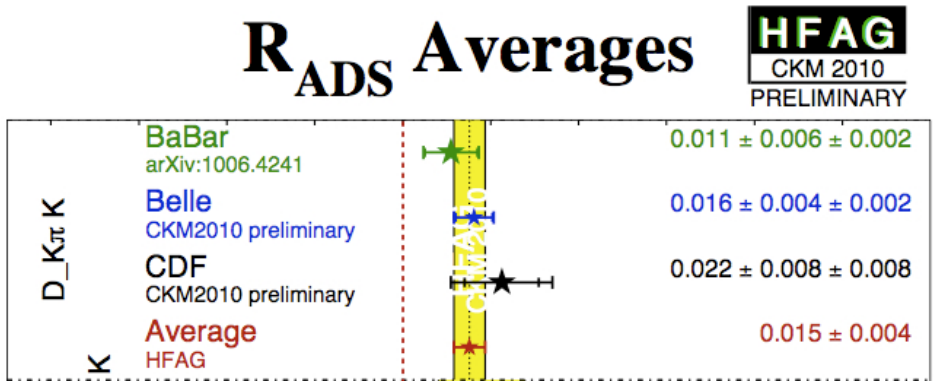
$$A_{ADS}(\pi) = 0.22 \pm 0.18\ (stat) \pm 0.06\ (syst)$$

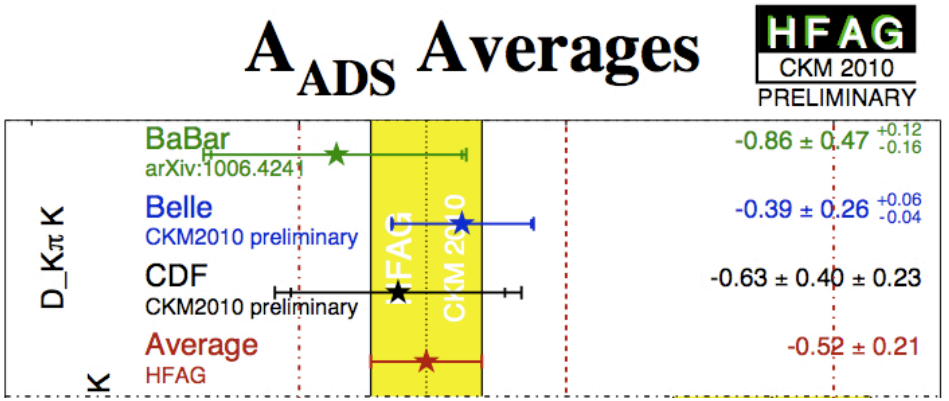
$$A_{ADS}(K) = -0.63 \pm 0.40\ (stat) \pm 0.23\ (syst)$$

First time in a hadron machine!









Time Integrated A_{CP} in $D^0 \to h^+ h^-$ Decays

- Negligible penguin contribution to the charm decays in SM
  - CPV larger than ~0.1% in charm would point to new physics
  - Unique probe of the up quark sector.
- Asymmetry: $$A_{CP} = \frac{\Gamma(D^0 \to h^+h^-) - \Gamma(\bar{D}^0 \to h^+h^-)}{\Gamma(D^0 \to h^+h^-) + \Gamma(\bar{D}^0 \to h^+h^-)}$$
- Time-Integrated Asymmetry:

$$A_{CP} = a_{CP}^{Direct} + \frac{\langle t \rangle}{\tau} a_{CP}^{Indirect}$$

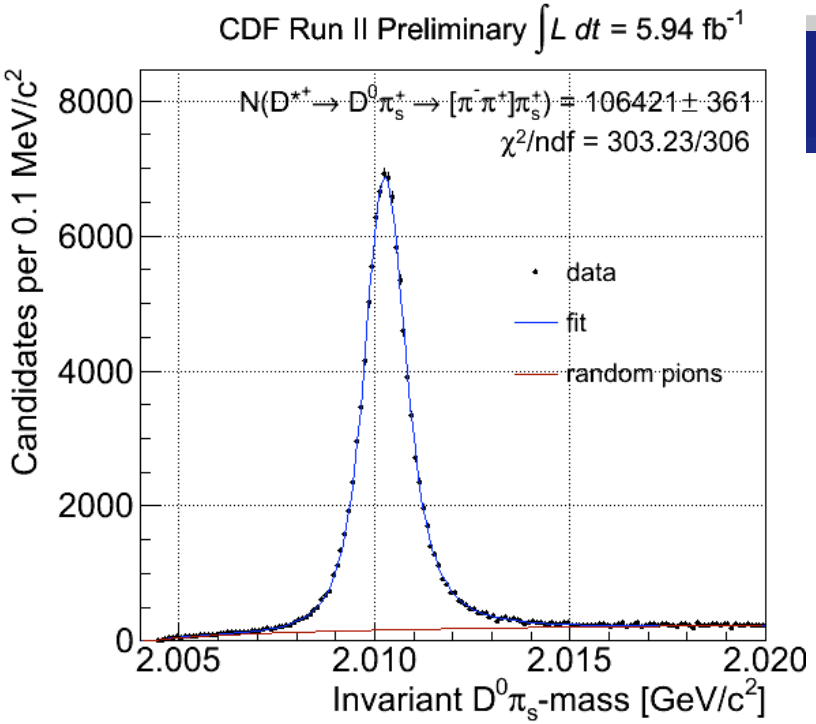
- Use self-tagged $D^{*\pm} \to D^0 \pi_s^{\pm} \to [h^+ h^-] \pi_s^{\pm}$ decays to select clean $D^0 \to h^+ h^-$ samples.

D* Tagged Analysis

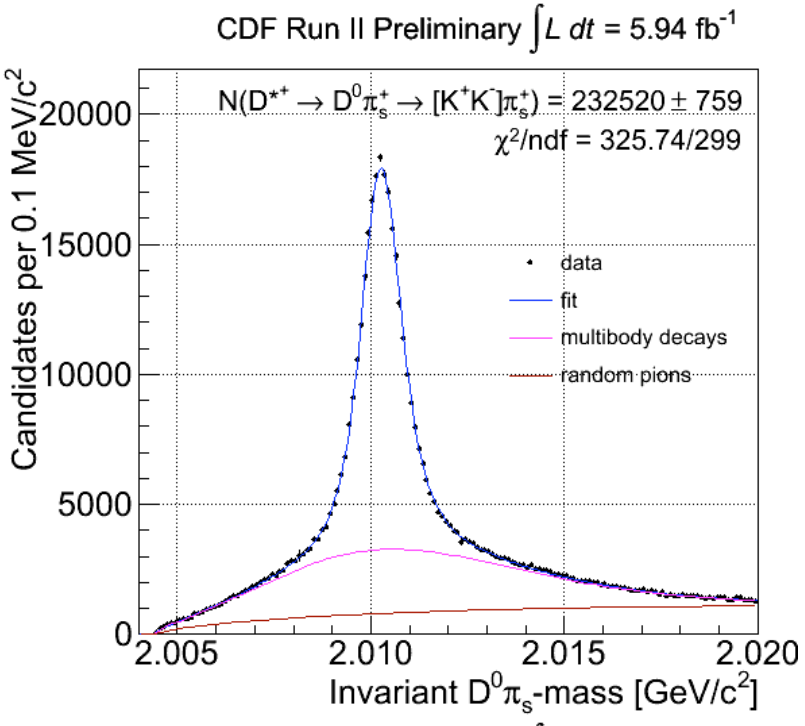
CDF Public Note 10296

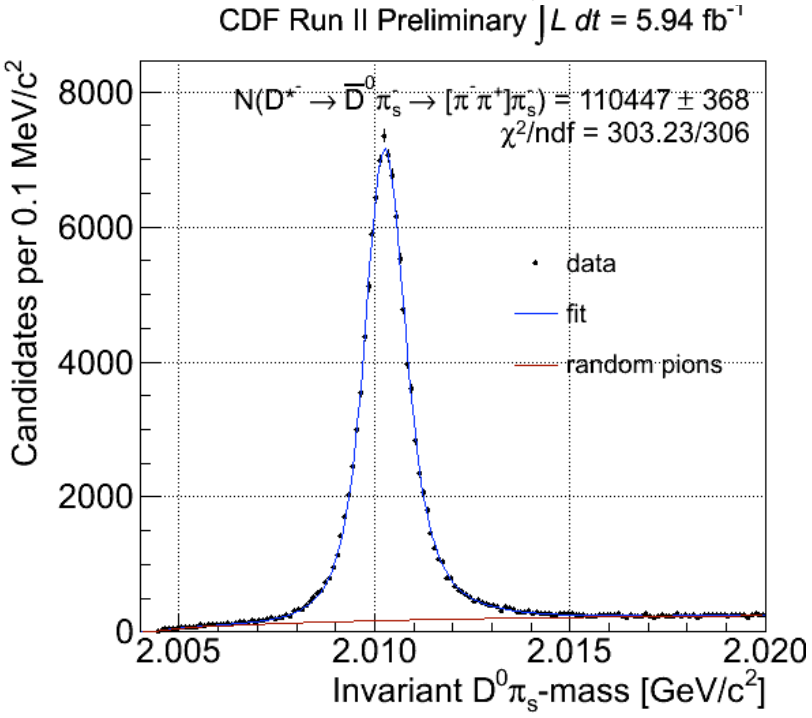
- Data sample: 5.94 fb^{-1}, with CDF two displaced track trigger.
- Measure asymmetry in $\pi^+\pi^-$ and K^+K^- samples and correct for instrumental asymmetry using $K\pi$ samples.
- Assume:
  - Soft pion efficiency independent of D^0 decay mode
  - No production charge asymmetry for D^0 or D^*
- The asymmetries are extracted by binned χ^2 fits to the charm and anti-charm invariant mass distributions for $\pi^+\pi^-$ and K^+K^- samples separately.

Fits

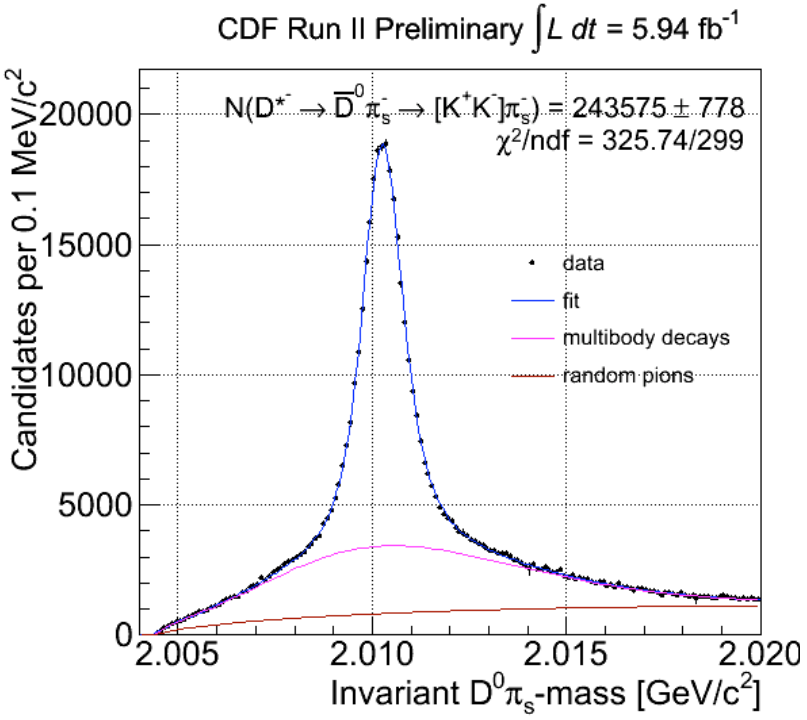

CDF Run II Preliminary $\int L\,dt$ = 5.94 fb^{-1}
$N(D^{*+} \to D^0\pi_s^+ \to [\pi^-\pi^+]\pi_s^+) = 106421 \pm 361$
χ^2/ndf = 303.23/306
data
fit
random pions
Candidates per 0.1 MeV/c^2
Invariant $D^0\pi_s$-mass [GeV/c^2]

D*+


CDF Run II Preliminary $\int L\,dt$ = 5.94 fb^{-1}
$N(D^{*+} \to D^0\pi_s^+ \to [K^+K^-]\pi_s^+) = 232520 \pm 759$
χ^2/ndf = 325.74/299
data
fit
multibody decays
random pions
Candidates per 0.1 MeV/c^2
Invariant $D^0\pi_s$-mass [GeV/c^2]


CDF Run II Preliminary $\int L\,dt$ = 5.94 fb^{-1}
$N(D^{*-} \to \bar{D}^0\pi_s^- \to [\pi^-\pi^+]\pi_s^-) = 110447 \pm 368$
χ^2/ndf = 303.23/306
data
fit
random pions
Candidates per 0.1 MeV/c^2
Invariant $D^0\pi_s$-mass [GeV/c^2]

D*-

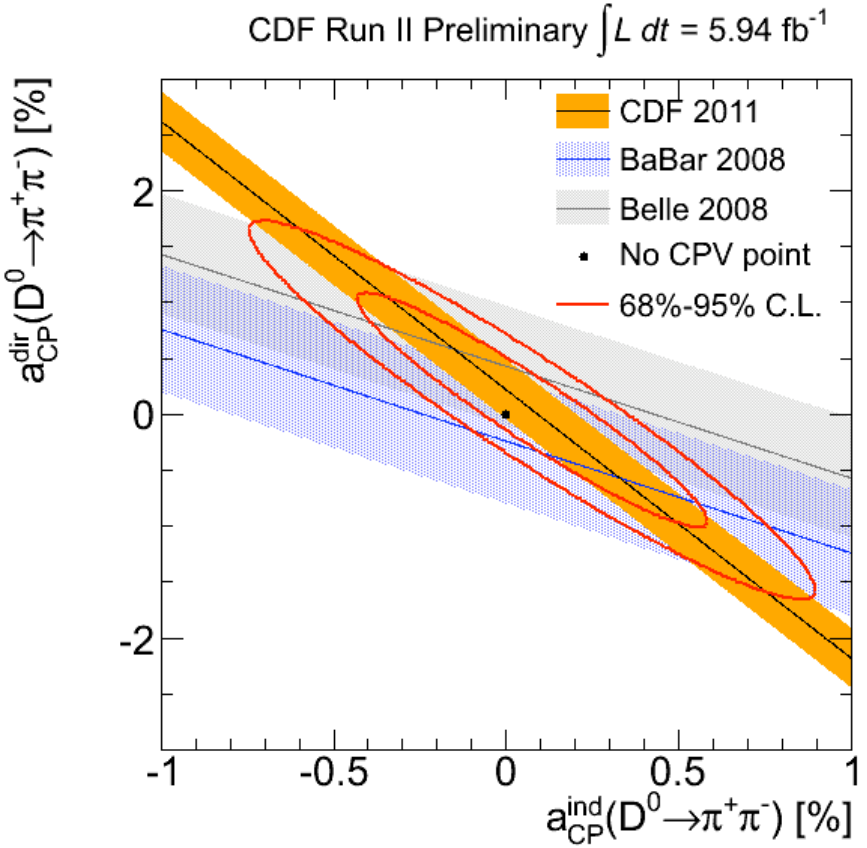

CDF Run II Preliminary $\int L\,dt$ = 5.94 fb^{-1}
$N(D^{*-} \to \bar{D}^0\pi_s^- \to [K^+K^-]\pi_s^-) = 243575 \pm 778$
χ^2/ndf = 325.74/299
data
fit
multibody decays
random pions
Candidates per 0.1 MeV/c^2
Invariant $D^0\pi_s$-mass [GeV/c^2]

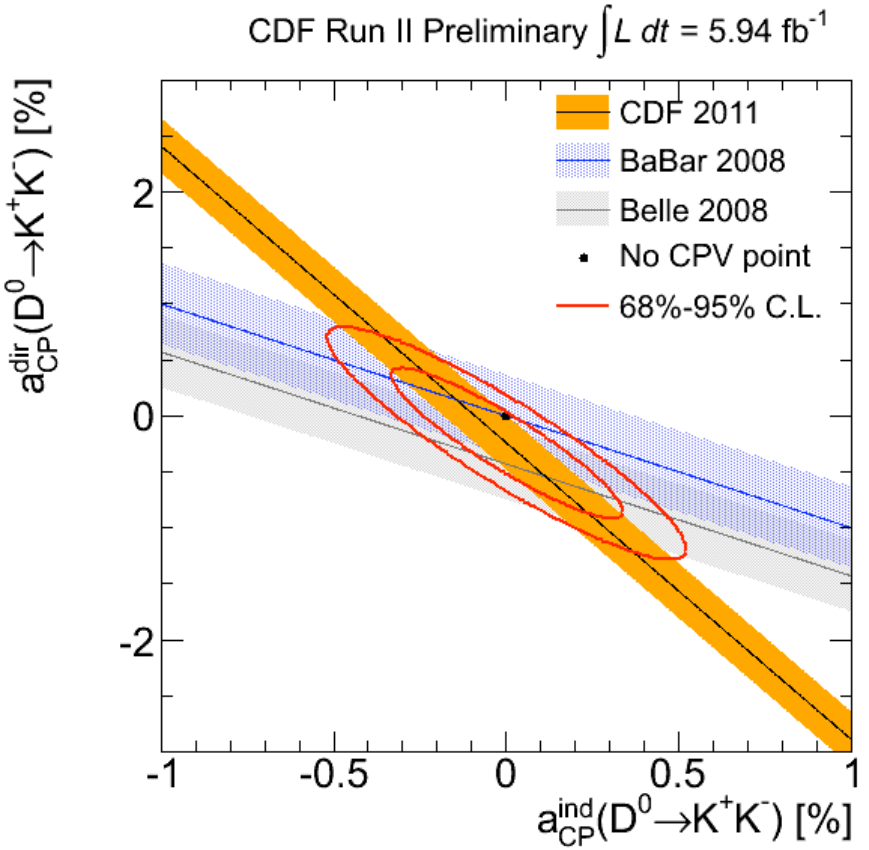
Results

World's Best!

- $A_{CP}(D^0 \to \pi^+\pi^-)$= +0.22±0.24 ±0.11 %
- $A_{CP}(D^0 \to K^+K^-)$= -0.24±0.22 ±0.10 %

[+0.43±0.52(stat.)±0.12(syst.)]% **Belle 2008** [-0.43±0.30(stat.)±0.11(syst.)]%

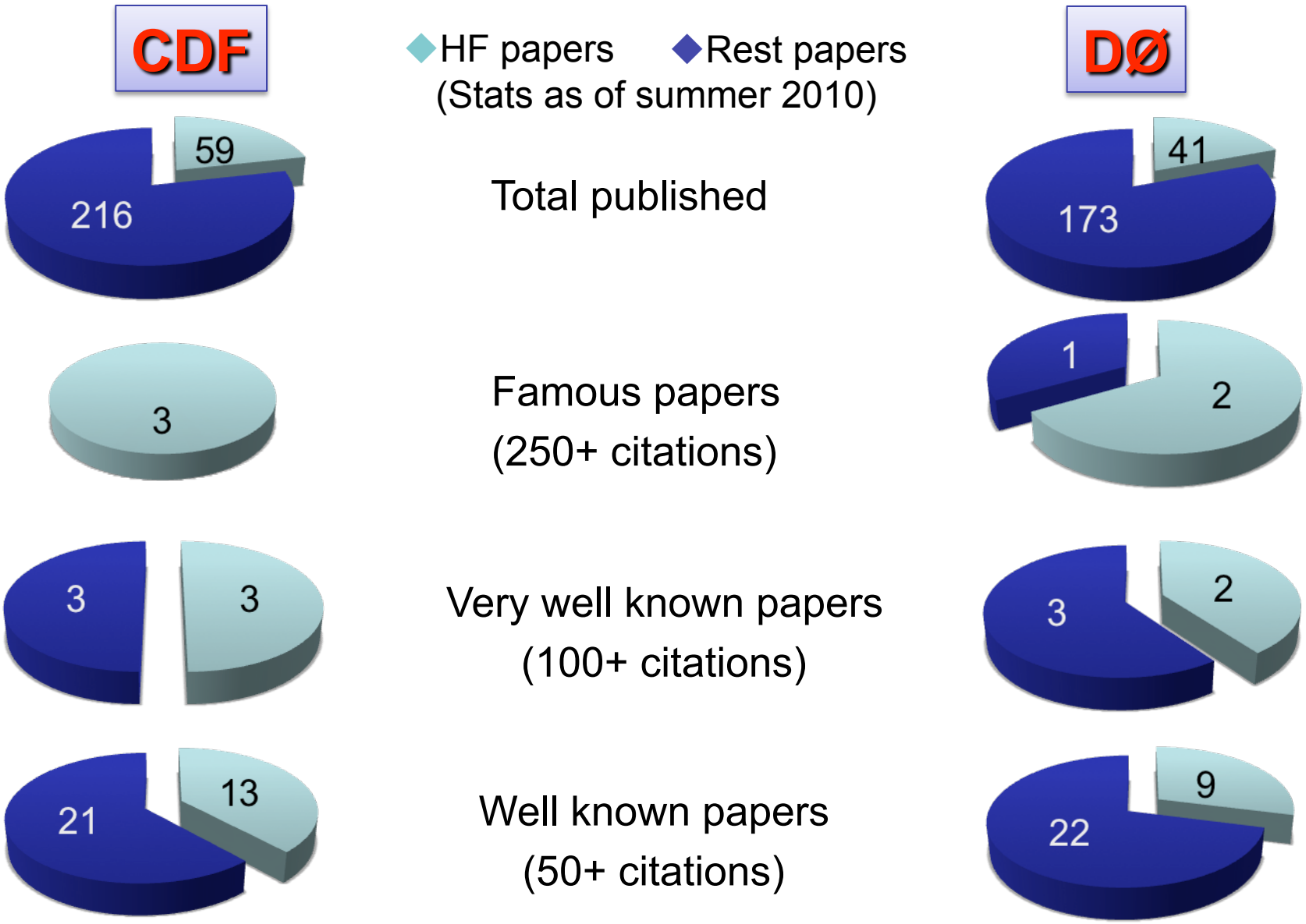




Conclusions

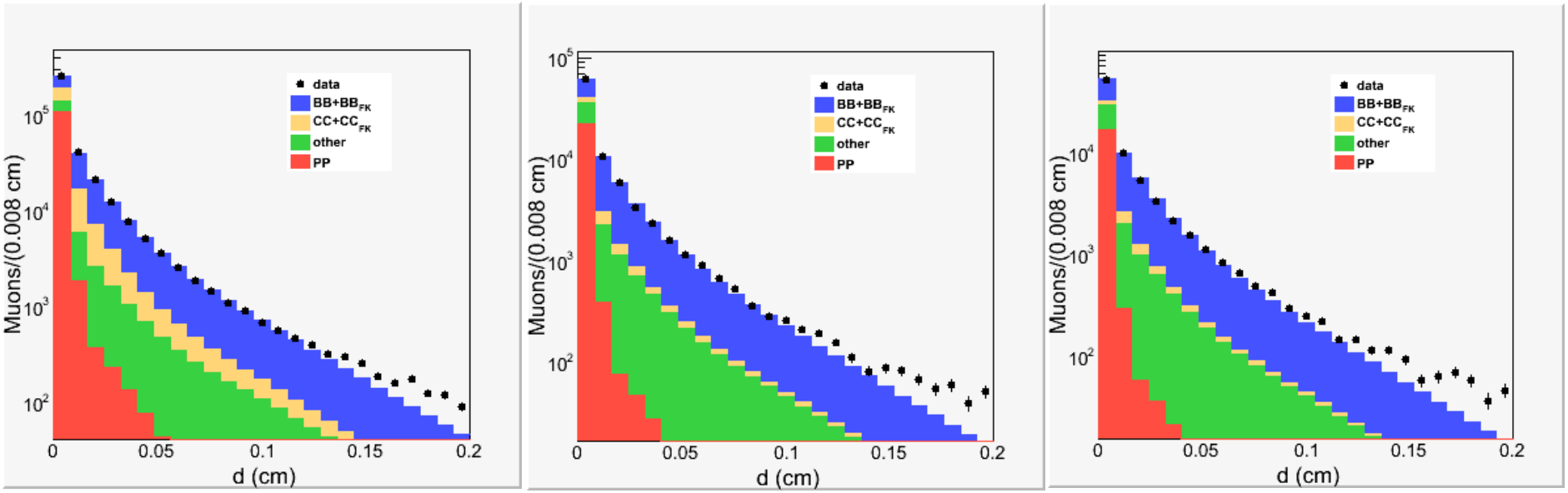
- Very rich heavy flavor program at the Tevatron. With over 9 fb^{-1} data to be accumulated per experiment by the end of Run II, more precision results are yet to come.
- The $B_s \rightarrow J/\psi\, f_0(980)$ decays and measurement of $\overline{\chi}$ open up alternate means to measuring β_s and A^b_{sl}. A thorough program is in place to systematically explore the NP-sensitive region of the B_s mixing phase.
- We have presented A_{CP} results in DCS $B^{\pm} \rightarrow D^0\, h^{\pm}$ decays for the first time in a hadron collider experiment and world's best measurement of A_{CP} in $D^0 \rightarrow h^+ h^-$ decays.
- For more results visit our results pages:
  - CDF: http://www-cdf.fnal.gov/physics/new/bottom/bottom.html
  - DØ: http://www-d0.fnal.gov/Run2Physics/WWW/results/b.htm

Impact of Heavy Flavor Program @ Tevatron



BACKUP SLIDES

Chi-bar: IP fit projections (with standard silicon requirements)



OS **LS ++** **LS --**

- When muons are selected with standard silicon requirement, the tail region of data is not fitted well.
- This is understood as the source of discrepancy between Run I and LEP results.

A_{CP} in $D^0 \to h^+ h^-$: Extraction method

- Asymmetry of signal sample:
  - $A(h^+h^-,\pi_s) = \mathbf{A_{CP}(h^+ h^-)} + \delta(\pi_s)$

$\delta(X)$: Detector induced asymmetry due to the particle/state X

- Asymmetry of D* tag in CKM favored mode:
  - $A(K^-\pi^+,\pi_s) = A_{CP}(K^-\pi^+) + \delta(K^-\pi^+) + \delta(\pi_s)$
- Using asymmetry from $D^0 \to K^-\pi^+$ (without a D* tag):
  - $A(K^-\pi^+) = A_{CP}(K^-\pi^+) + \delta(K^-\pi^+)$
- Derive:
  - $\mathbf{A_{CP}(h^+ h^-)} = A(h^+ h^-,\pi^*) - A(K^-\pi^+,\pi^*) + A(K^-\pi^+)$
- Measure the three asymmetries