Searches for New Physics In Charm and Bottom Decays at the Tevatron

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On behalf of the CDF and D0 collaborations

Rencontres de Moriond QCD and High Energy Interactions
La Thuile, Aosta valley, Italy

Flavor physics at the Tevatron

- Shut down on Sep 30, 2011 after 10 years of 2TeV $p\bar{p}$ collisions
- CDF and D0 have about 10 fb^{-1} of data on tape each
- Designed for high$-p_T$ physics but:
  - ✓ High-rate of all species of heavy flavors actually higher than “B factories” (CDF + D0)
  - ✓ Excellent mass resolution (CDF)
  - ✓ Precision vertex reconstruction capabilities (CDF + D0)
  - ✓ Powerful trigger on displaced vertices (CDF)
  - ✓ Charge-symmetric detector (D0)

Bs Mixing And CPV

Charm

Rare Decay

Spectroscopy

Charmless B(s) decays

Lifetimes

The projection of the unbinned LH fit onto the binned Q- distribution of Λ_b^{*0} candidates.

Current HF activity

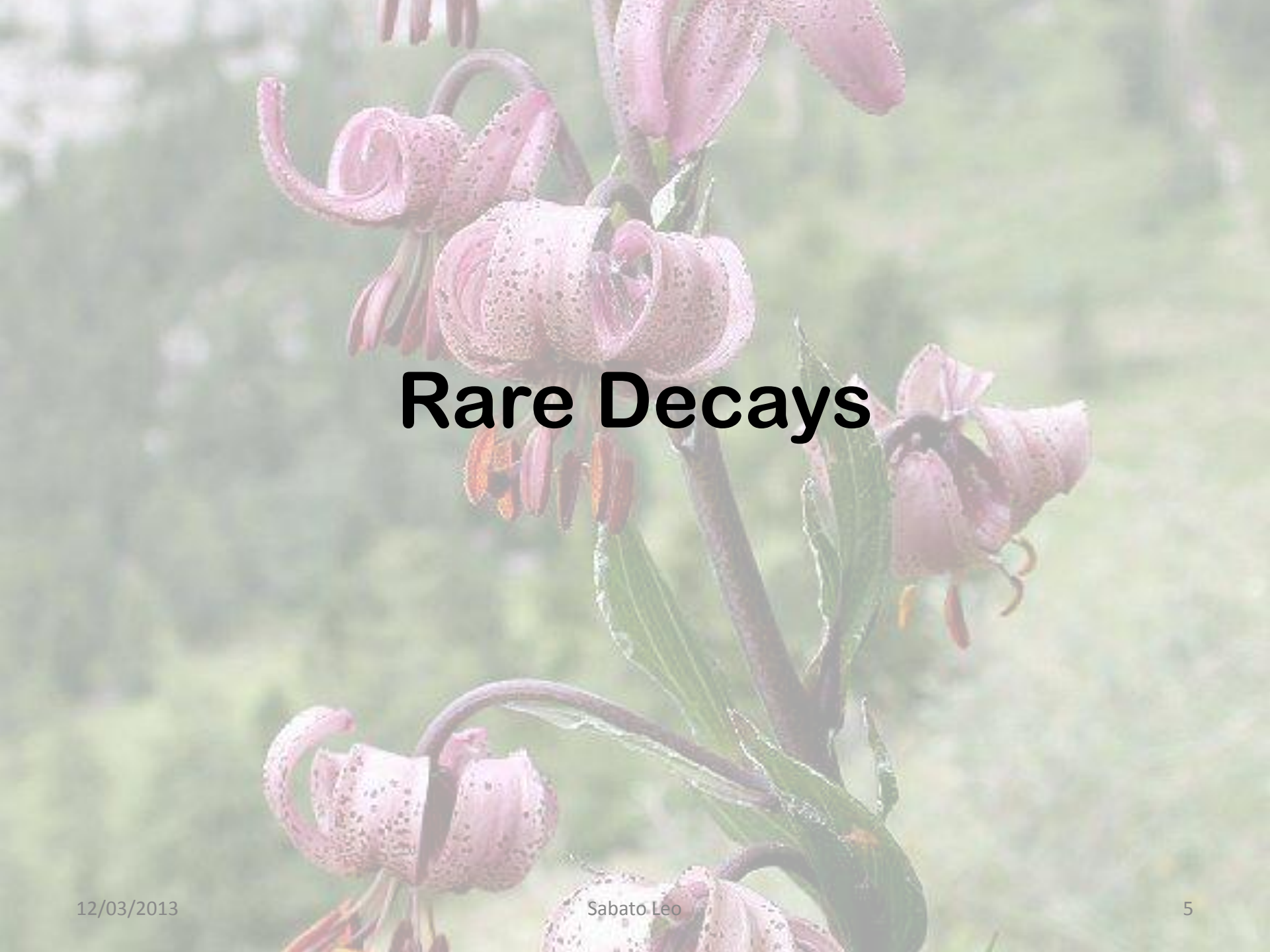
- Producing final results using the full 10/fb sample
  - ✓ CP violation in charmless B decays (CDF)
  - ✓ Br and asymmetries in rare decays (CDF/D0)
  - ✓ CP violation in Bd and Bs semi-leptonic decays (D0)

  This Talk
  - ✓ Spectroscopy (CDF)
  - ✓ Production and Quarkonium
- Detailed papers on flagship analyses

CPV in $D^0 \to hh$
PRL 109, 111801 (2012)
http://prd.aps.org/abstract/PRD/v85/i1/e012009
ΔA_{CP} = (-0.62 ± 0.21 ± 0.10)%

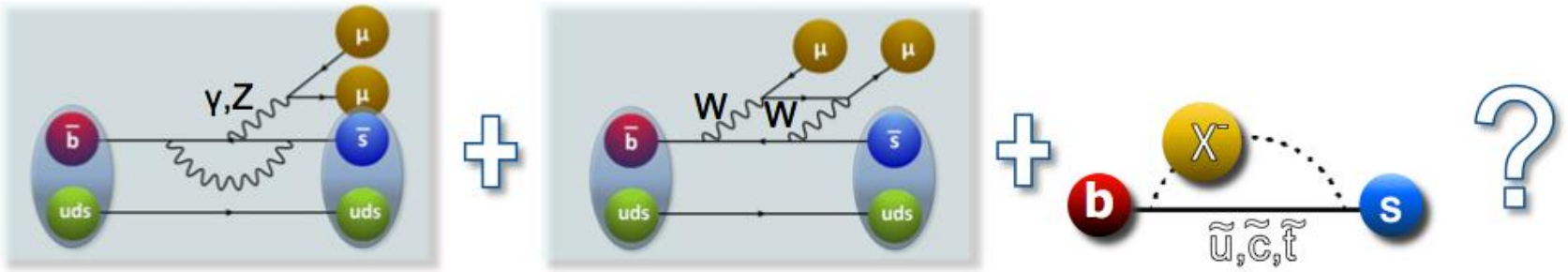
$B_s \to \mu\mu$
PRD Accepted arXiv: 1301.7048
BR(Bs) < $3.1 \cdot 10^{-8}$
PRD Accepted ,arXiv:1301.4507
BR(Bs) < $1.5 \cdot 10^{-8}$

B_s mixing phase
PRL 109, 171802 (2012)
$\beta_s \in$ [-0.06,0.30]rad @ 68% CL
PRL 108, 101803 (2012)
$\phi_s = 0.15 \pm 0.18\,(stat)\ 0.06\,(syst)\ rad$



Rare Decays

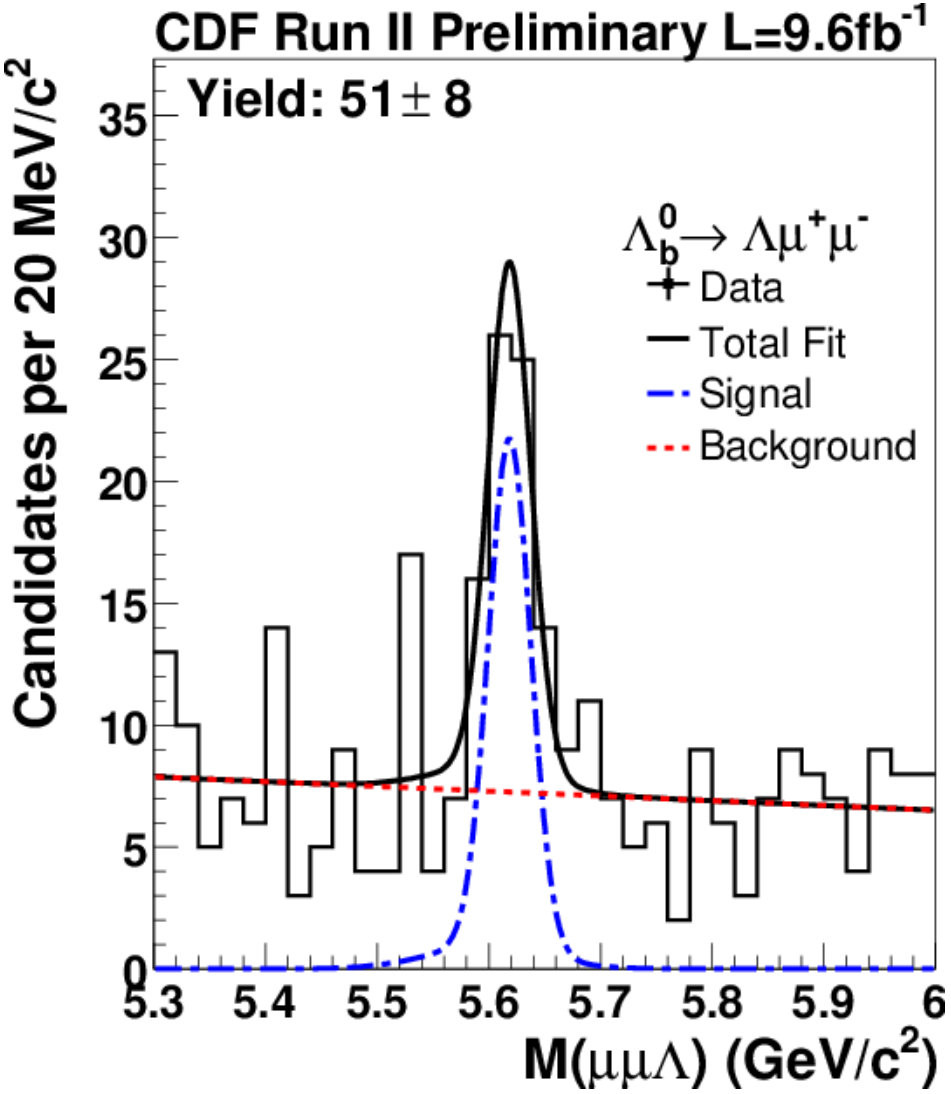
b→s $\mu^+\mu^-$ decays



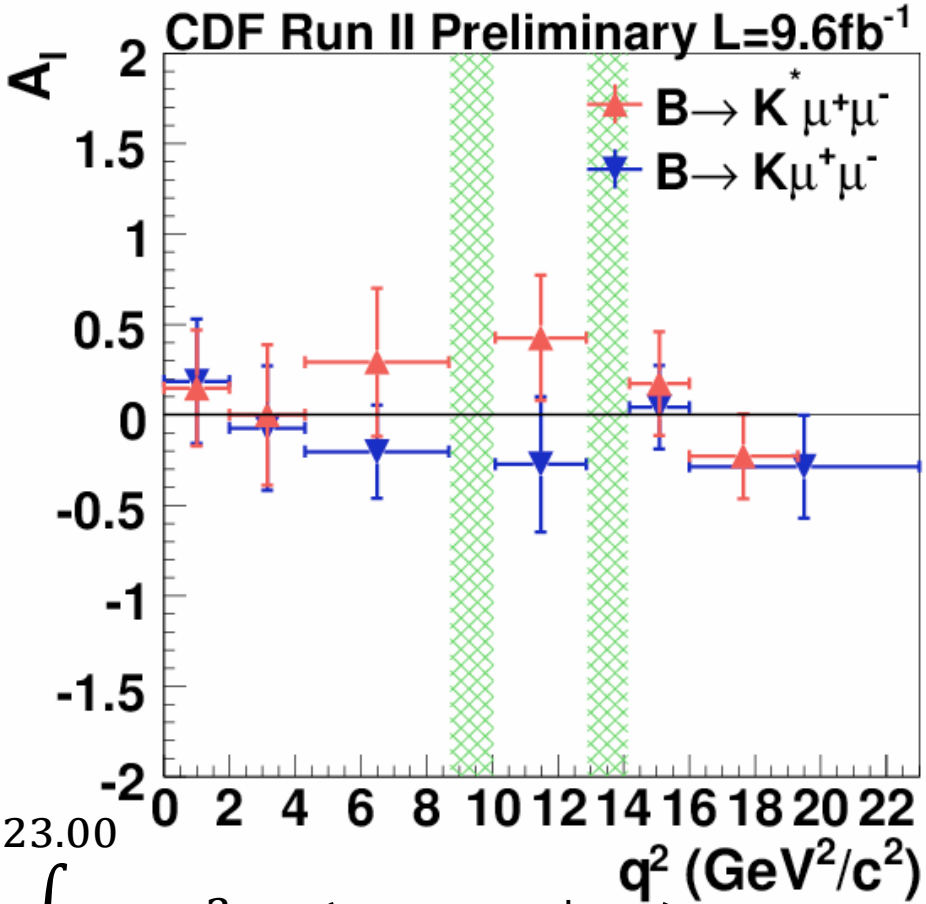
- Another flavor-changing-neutral-current golden probe
- 3-body decay provides many observables sensitive to NP
  - ✓ Total/differential BR, isospin asymmetry, forward-backward asymmetry….
- Rich CDF program:
  - ✓ asymmetries more precise than B factories and 1st observation of Λ_b^0 and B_s $b \to s \mu^+ \mu^-$ decays.

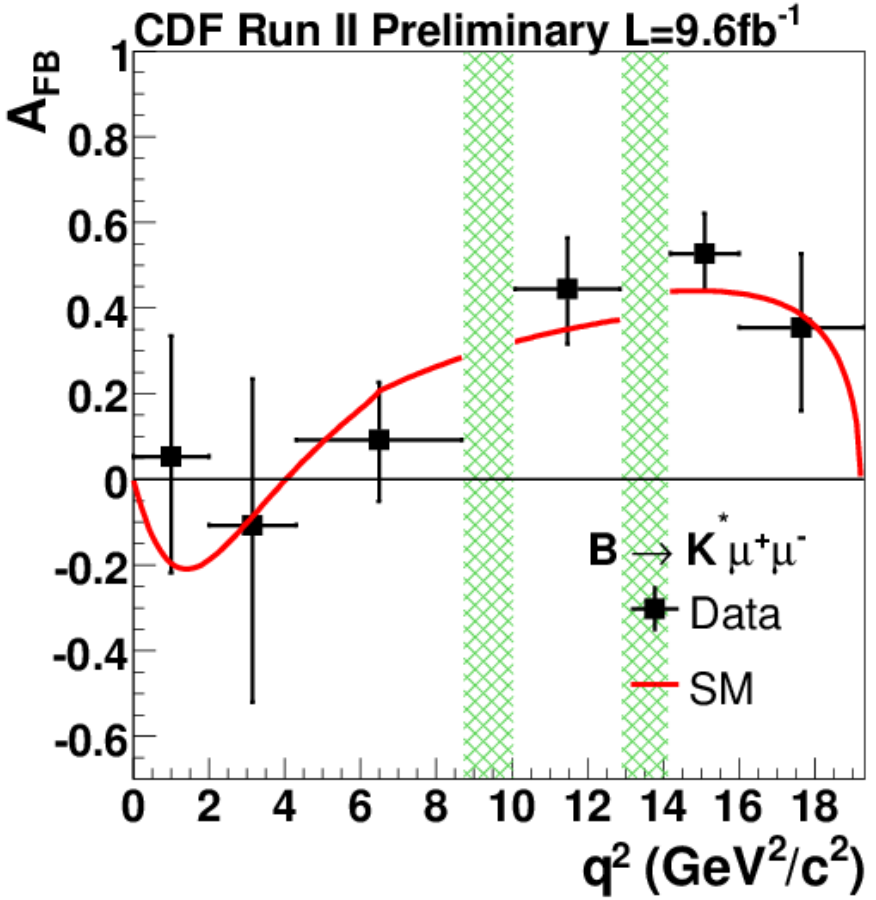
b→s $\mu^+\mu^-$ decays

- $B^+ \to K^+\mu^+\mu^-$,
  $B^0 \to K^{*0}(892)\mu^+\mu^-$,
  $B^0 \to K_S^0\mu^+\mu^-$,
  $B^+ \to K^{*+}(892)\mu^+\mu^-$,
  $B_s^0 \to \varphi\mu^+\mu^-$,
  $\Lambda_b^0 \to \Lambda\mu^+\mu^-$
- Di-muon trigger
- NN maximizes BR and A_{FB} significance
- Fit Mass for signal yields



Isospin and FB asymmetry



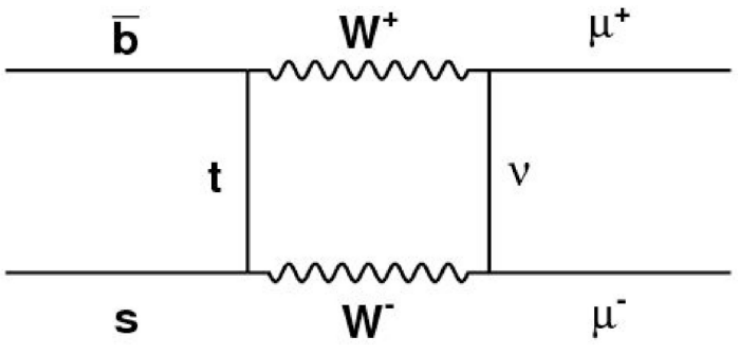


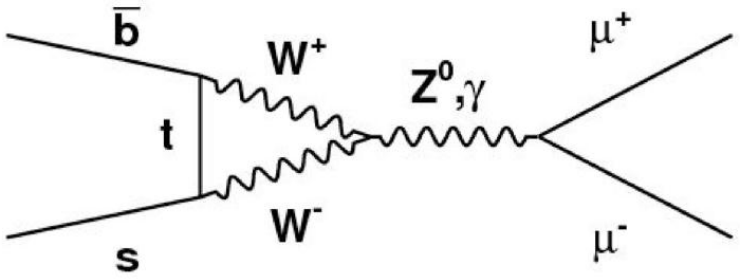
$$\int_{16.00}^{23.00} dq^2\, A_I(B \to K\mu^+\mu^-)$$

$$= -0.29 \pm 0.28(stat) \pm 0.06(syst)$$

Consistent with SM

BR of $B_s \to \mu^+\mu^-$



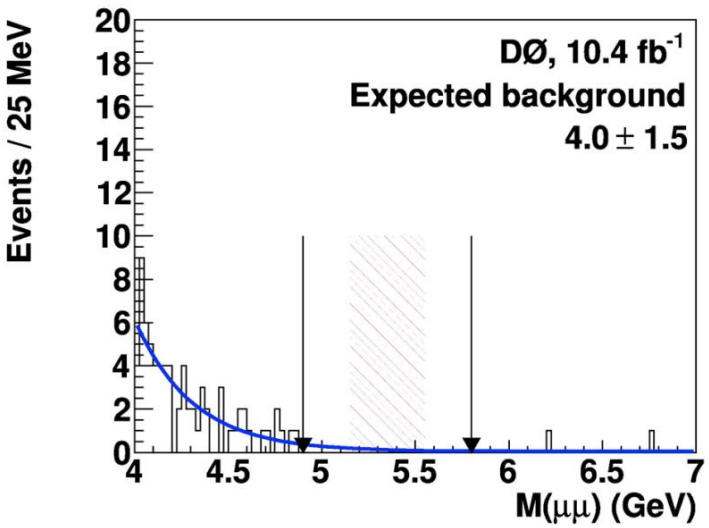


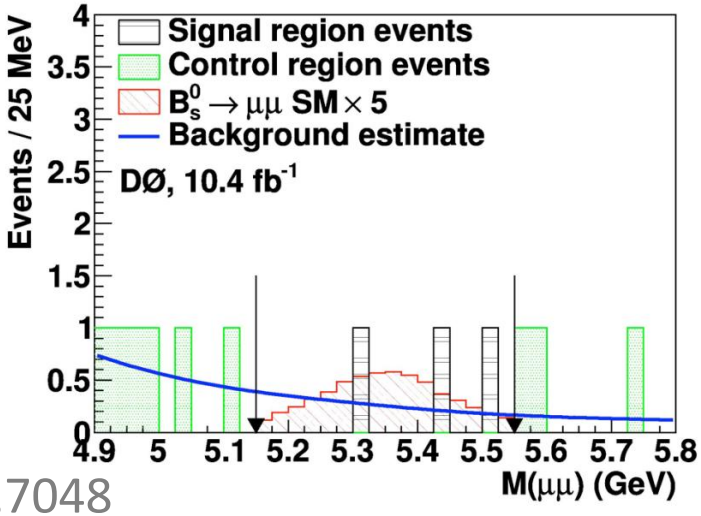
- Flavor-changing-neutral current, helicity-suppressed, and well predicted rate, $BR(B_s^0 \to \mu^+\mu^-) \sim 3 \cdot 10^{-9}$:
  - ✓ sensitive to a broad class of NP models
- Tevatron flagship:
  - ✓ upper limits improved by three orders of magnitude over the last 15 years.
  - ✓ Plethora of NP models excluded or tightly constrained

BR of $B_s \to \mu^+\mu^-$

- Normalization mode $B^{\pm} \to J/\psi K^{\pm}$
- BDT
  - ✓ Use data sidebands as background
- Blinded analysis
- Expected
  - ✓ SM Signal: 1.23 ± 0.13
  - ✓ Background: 4.0 ± 1.5
  - ✓ Limit: BR($B_s \to \mu^+\mu^-$) = $23 \cdot 10^{-9}$
- Observed 3 events:

$$\mathrm{BR}(B_s^0 \to \mu^+\mu^-) < 15 \times 10^{-9}$$

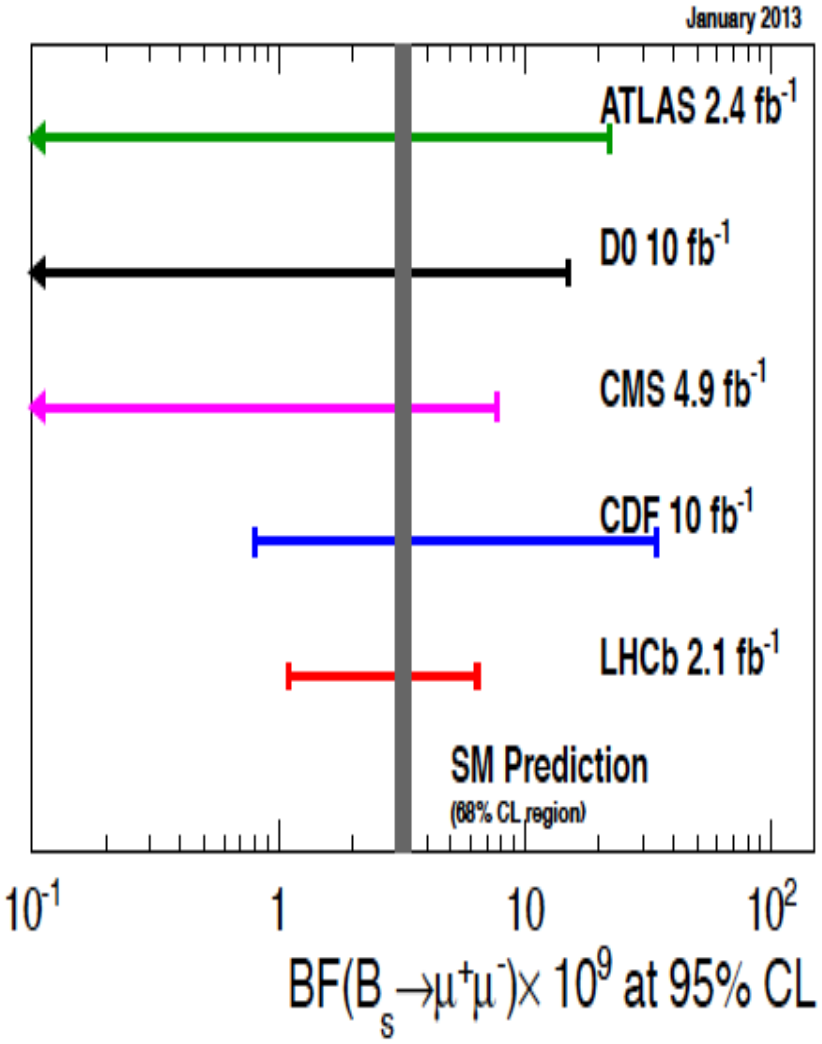


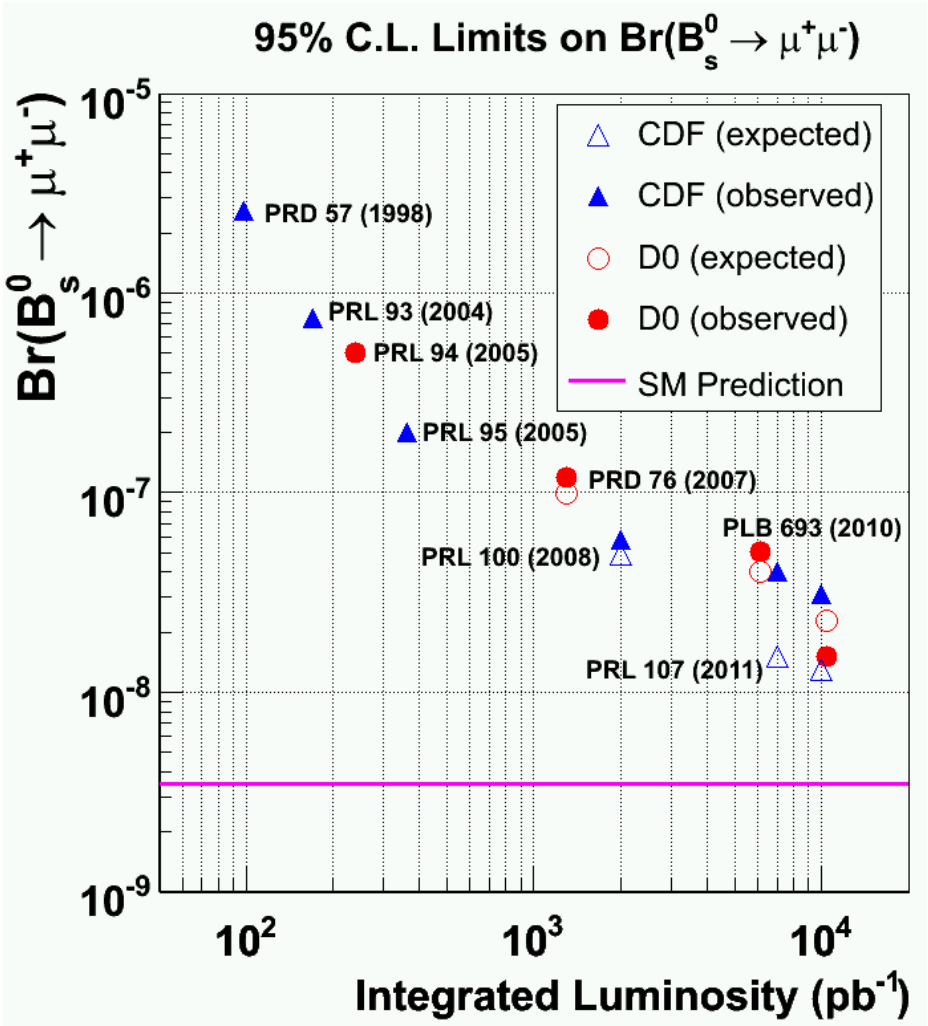


PRD Accepted,arxiv:1301.4507

CDF result:BR <$3.1 \cdot 10^{-8}$, PRD Accepted arXiv:1301.7048

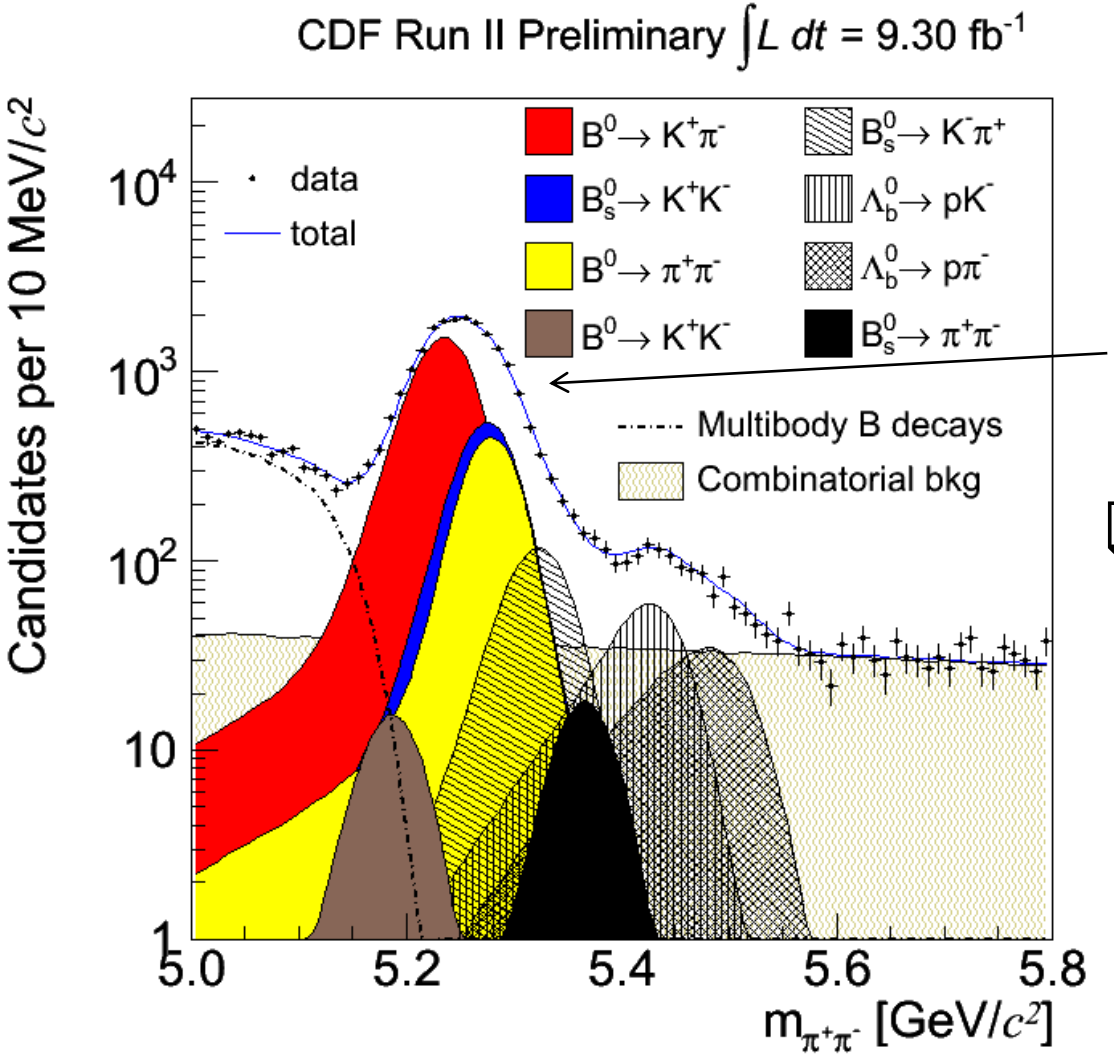
The Big Picture





CP Violation

CPV in charmless B



Several decays reconstructed in single narrow peak

- Fit events and correct for detector induced charged asymmetries using $D^0 \to K^+\pi^-$

$$\frac{\mathcal{B}(b \to f) - \mathcal{B}(\bar{b} \to \bar{f})}{\mathcal{B}(b \to f) + \mathcal{B}(\bar{b} \to \bar{f})} = \frac{N_{b\to f} - c_f N_{\bar{b}\to\bar{f}}}{N_{b\to f} + c_f N_{\bar{b}\to\bar{f}}}$$

Results

Fit

Mode	$\mathcal{N}_{b\to f}$	$\mathcal{N}_{\bar{b}\to \bar{f}}$
$B^0 \to K^+\pi^-$	6348 ± 117	5313 ± 109
$B_s^0 \to K^-\pi^+$	354 ± 46	560 ± 51
$\Lambda_b^0 \to p\pi^-$	242 ± 24	206 ± 23
$\Lambda_b^0 \to pK^-$	271 ± 30	324 ± 31

$$A_{CP}(B^0 \to K^+\pi^-) = (-8.3 \pm 1.3 \pm 0.3)\%$$

$$A_{CP}(B_s^0 \to K^-\pi^+) = (22 \pm 7 \pm 2)\%$$

$$A_{CP}(\Lambda_b^0 \to p\pi^-) = (7 \pm 7 \pm 3)\%$$

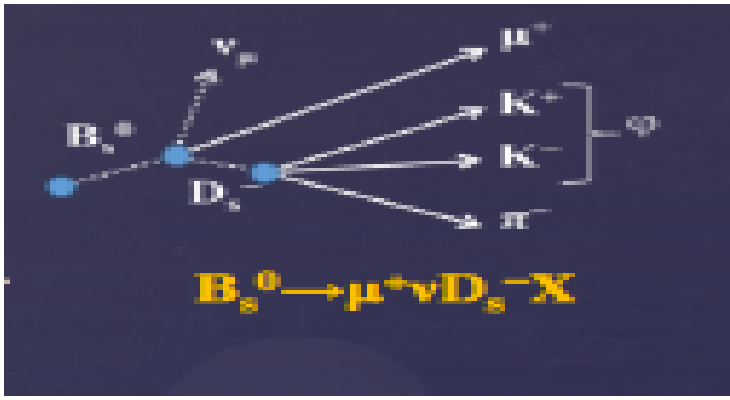
$$A_{CP}(\Lambda_b^0 \to pK^-) = (-9 \pm 8 \pm 4)\%$$

Consistent with zero. However the limited experimental precision does not allow a conclusive discrimination between SM prediction (~8%)

Measurement of b-baryon asymmetries still unique to CDF

CPV in B_s mixing

$$a_{\mathrm{sl}}^{s} = \frac{\Gamma(\bar{B}_s^0 \to B_s^0 \to \ell^+ \nu X) - \Gamma(B_s^0 \to \bar{B}_s^0 \to \ell^- \bar{\nu} \bar{X})}{\Gamma(\bar{B}_s^0 \to B_s^0 \to \ell^+ \nu X) + \Gamma(B_s^0 \to \bar{B}_s^0 \to \ell^- \bar{\nu} \bar{X})},$$



- SM predicts tiny value
  - ✓ $a_{\mathrm{sl}}^{s} = (-0.0019 \pm 0.0003)\%$

NP Sensitive

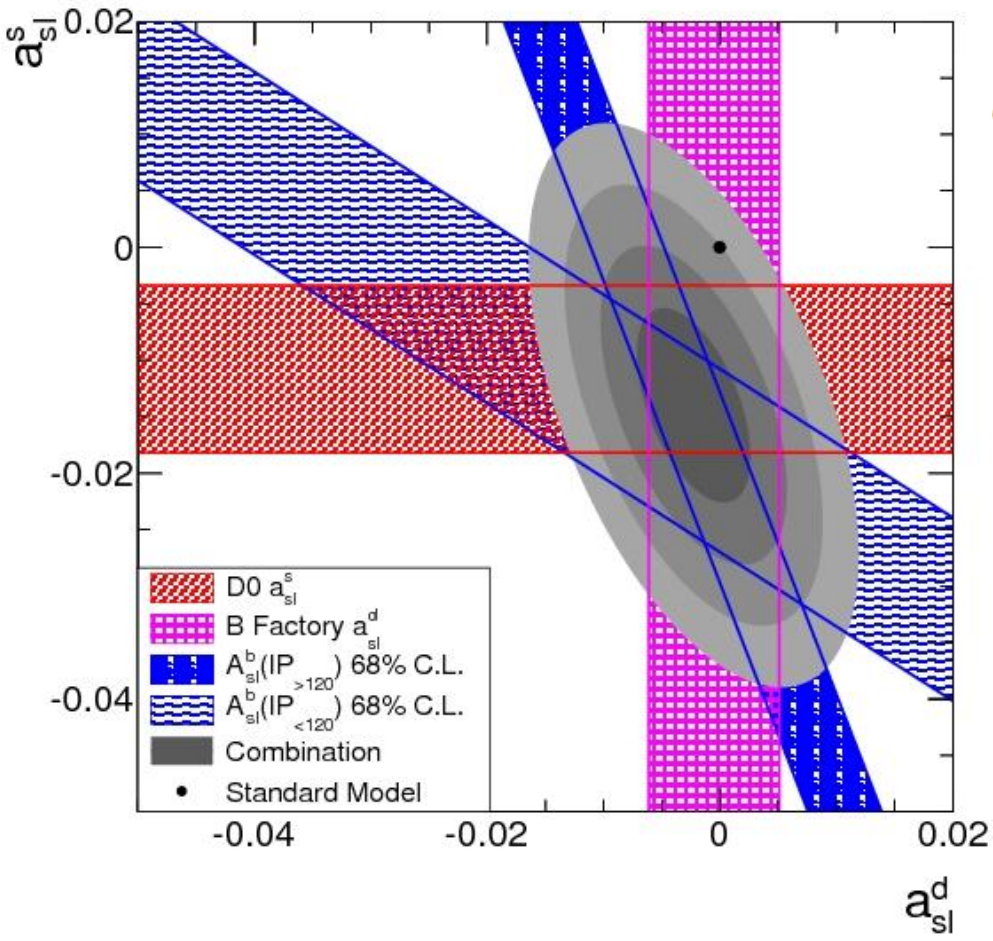
$$a_{sl}^{s} = \frac{A - A_{BG}}{F_{B_s^0}^{OSC}}$$

Detector-related asymmetries (Positive Kaons higher detection efficiency)

Raw asimmetry extracted by counting μD_s signal yields

Fraction of reconstructed μD_s decays from oscillated B_S^0 mesons

Semileptonic decays Results



$$a^s_{\rm sl} = [-1.12 \pm 0.74\,({\rm stat}) \pm 0.17\,({\rm syst})]\,\%,$$

Phys. Rev. Lett. 110, 011801 (2013)

$$a^d_{\rm sl} = [0.68 \pm 0.45\ ({\rm stat.}) \pm 0.14\ ({\rm syst.})]\%.$$

Phys. Rev. D 86, 072009 (2012)

- New results consistent with standard model, also consistent with previous results
- overall combination still ~ 3σ away from SM

Hadron collisions HF pioneers.

- *The heritage I:*
  - ✓ Bs mixing phenomenology and ~1000x improvement in $B_s \to \mu\mu$ limits ruled out plethora of BSM physics models.
  - ✓ New resonant states, new decays, and precise CPV asymmetries provided useful inputs to understanding of the weak decays and the strong interaction.
- *The heritage II:*
  - ✓ many original experimental and analysis techniques developed, pioneered, and established as industry standard.
- About 150 HF papers in 10 years. And counting….

Conclusions

- Getting analyses finalized in full dataset and documenting analysis techniques in detail
- All nicely consistent with the SM
- Keep searching while focusing on measurements that are unique to Tevatron or systematics-limited.