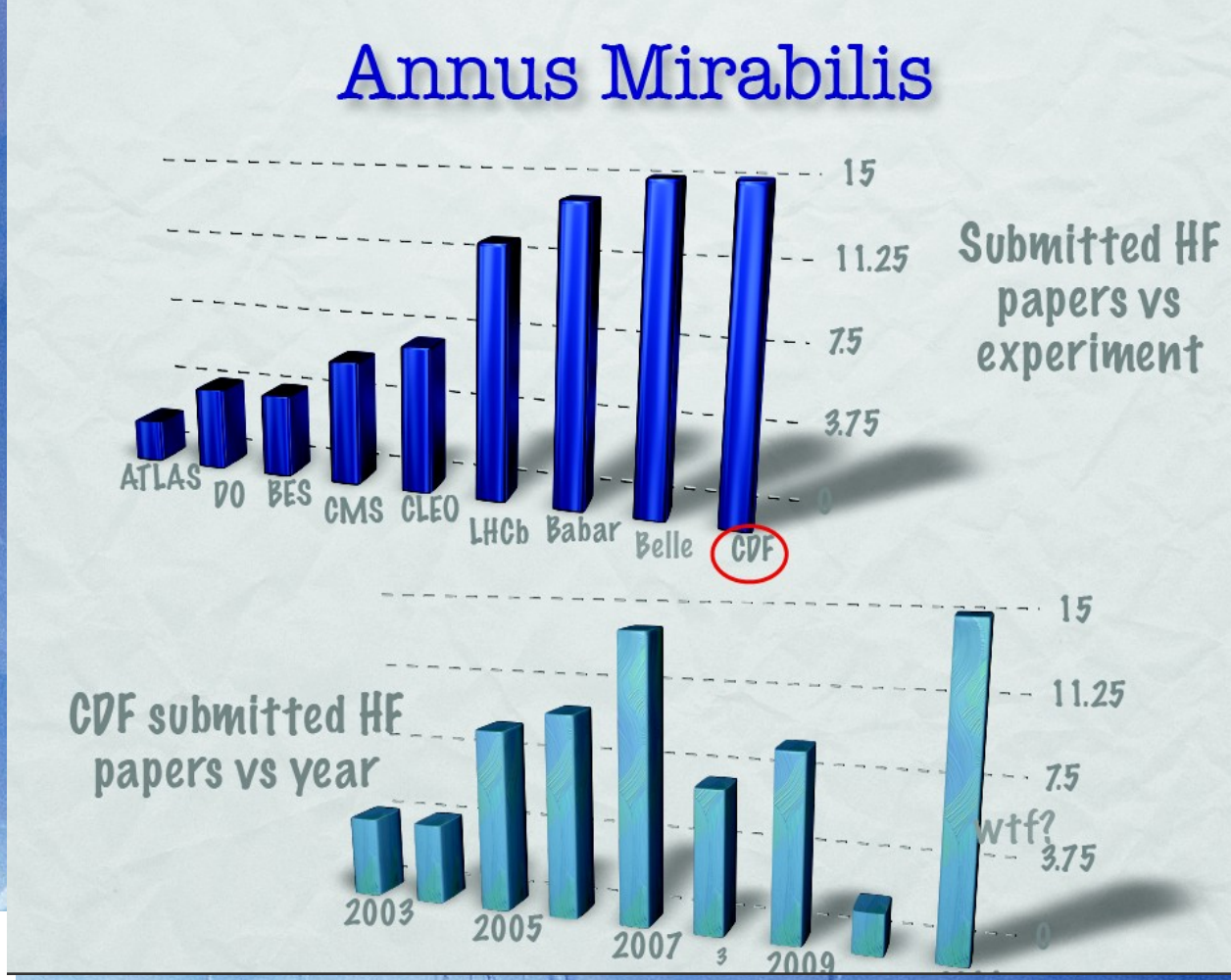
B_s (and other important) results from

Karlsruhe Institute of Technology

Martin Heck, for the CDF Collaboration

Tevatron ended running this October

Peak luminosity increased almost until the very end.
Integrated Lumi ~10 fb^{-1}



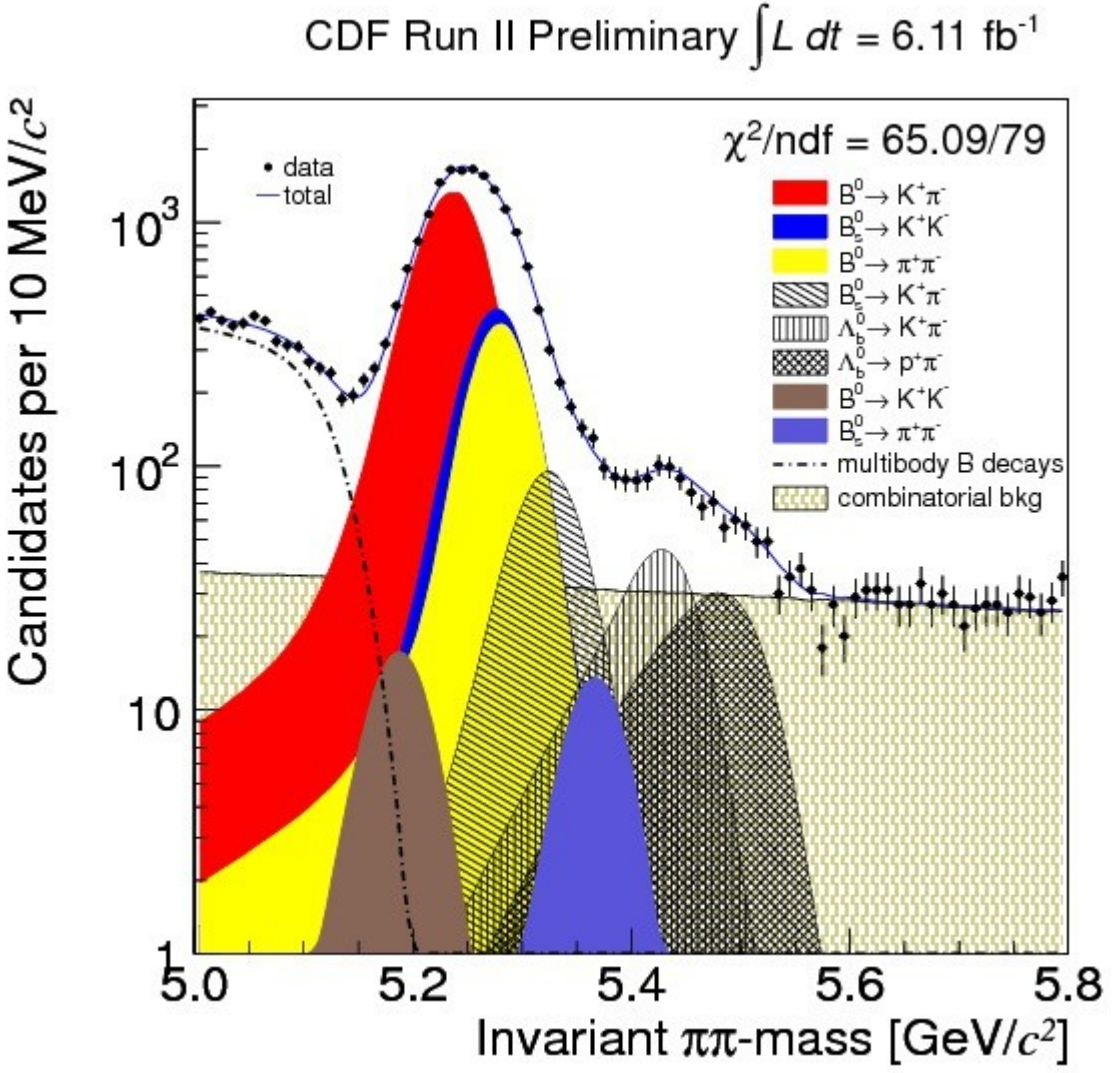
Not quite in rest, but more productive than ever, due to long experience with and good understanding of our detector and data!

Outline

- $B_s \rightarrow \pi\pi$ – Gauge for Penguin Annihilation
- $B_s \rightarrow \Phi\Phi$ – Polarization & Search for CP Violation
- $B_s \rightarrow D_s^{(*)} D_s^{(*)}$ - Estimations of $\Delta\Gamma_s$
- $B_s \rightarrow J/\psi\ f0(980)$ – First direct measurement of $B_{s,H}$ lifetime
- $B_s \rightarrow \mu\mu$ – Excellent Sensitivity to New Physics

- Non-B_s topics
  - $B \rightarrow K\mu\mu$
  - CPV in the charm sector

$B_s \rightarrow \pi\pi$ – Gauge for Penguin Annihilation



Size of penguin annihilation is difficult to calculate theoretically.
Various tests of CKM dynamics are compromised by this.

Experimental input can help.

$B_s \rightarrow \pi\pi$ (first evidence)

$B \rightarrow KK$ (two sided 90% limit)

$$N(B_s \rightarrow \pi^+\pi^-) = 94 \pm 28(stat) \pm 11(sys)$$

$$N(B^0 \rightarrow K^+K^-) = 120 \pm 49(stat) \pm 42(sys)$$

BR($\mathbf{B_s \rightarrow \pi\pi}$) = (0.57 ± 0.15 (stat) ± 0.10 (sys)) x 10^{-6}

Systematic uncertainty is dominated by f_s/f_d due to B^0 channel normalization.

$0.05 < BR(\mathbf{B^0 \rightarrow KK}) \times 10^6 < 0.46$ @90% confidence level

arXiv:1111.0485

$B_s \rightarrow \Phi\Phi$ – Polarization & Search for CP Violation

Decay is **P → V V**
→ **1** longitudinal and **2** transverse polarizations possible

Due to the V-A nature of weak interaction and helicity conservation in QCD one expects

fraction longitudinal polarized decays (f_L) **>>** fraction transversal polarized decays (f_T)

B factories confirmed this for tree level B decays, but in $B \rightarrow \varphi K^*$ decays, $f_L \sim f_T$.

$B_s \rightarrow \varphi\varphi$ is $b \rightarrow s$ penguin transition as well.

$f_L = 0.348 \pm 0.041\ (stat) \pm 0.021\ (sys)$

$f_T = 0.652 \pm 0.041\ (stat) \pm 0.021\ (sys)$ **arXiv:1107.4999**

We see the same behaviour.

Search for **CP violation** is done via measuring asymmetries in the triple products.

One finds one triple product, that is proportional to
$u = \cos(\varphi)\sin(\varphi)$,
and one proportional to
$v = \sin(\varphi)$ for $\cos(\theta_1)\cos(\theta_2) > 0$
$\sin(-\varphi)$ for $\cos(\theta_1)\cos(\theta_2) < 0$

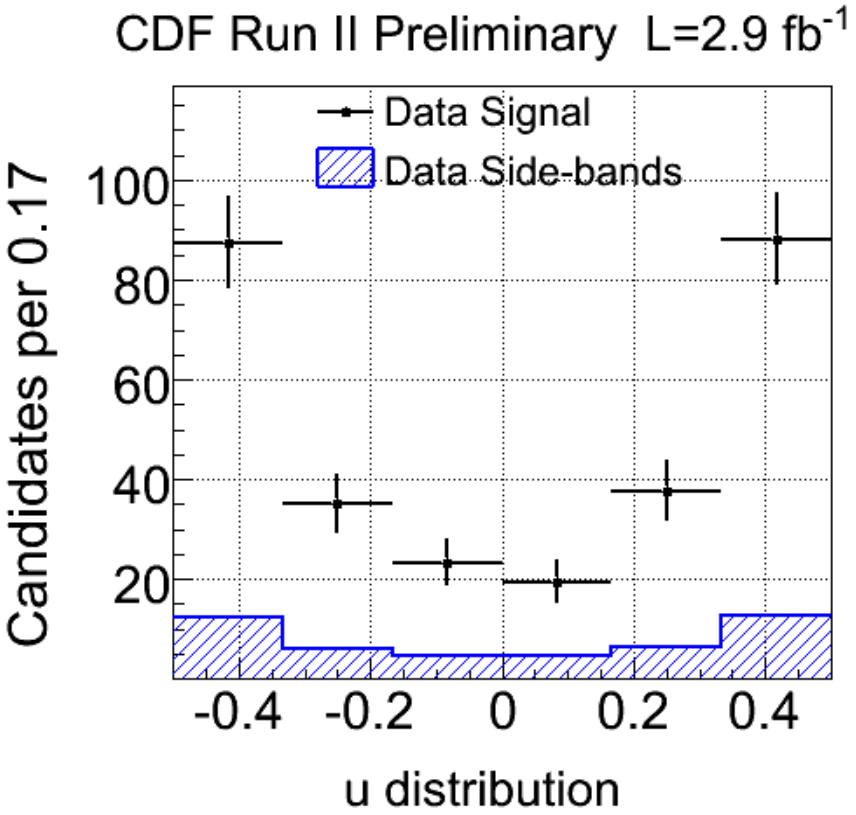
We find:

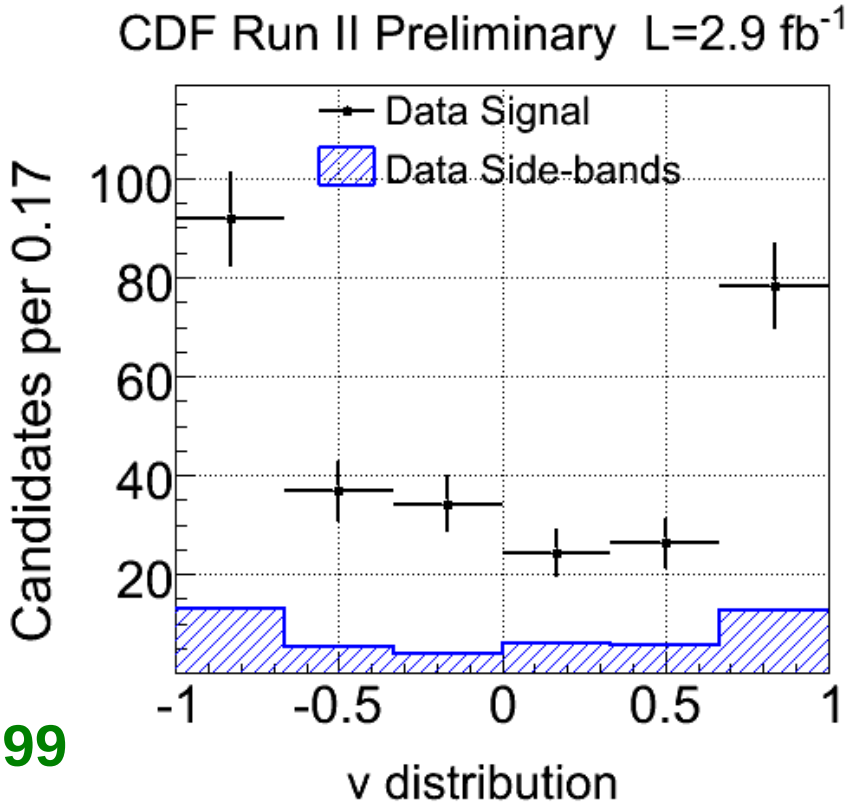
A_u = -0.007 ± 0.064 (stat) ±0.018 (syst)

A_v = -0.120 ± 0.064 (stat) ±0.016 (syst)

consistent with no CPV

The asymmetry is defined as $$A_{TP} = \frac{\Gamma(TP>0) - \Gamma(TP<0)}{\Gamma(TP>0) + \Gamma(TP<0)}$$





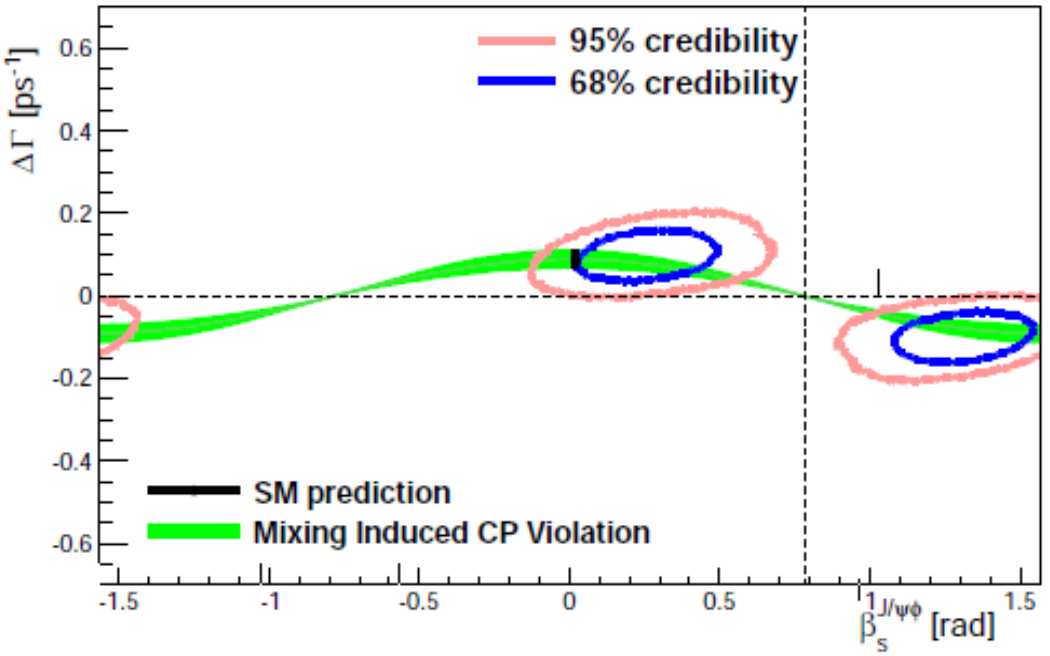
arXiv:1107.4999

Estimations of $\Delta\Gamma_s$

B_s and $\overline{B}_s$ mix to two new states B_{sH} and B_{sL}, which are CP Eigenstates in the absence of CP Violation.
In contrast to the B-system, the B_s system has a sizable **ΔΓ**.

There are two principal ways to access the lifetime difference.

- Directly measuring the **decay length distribution** of B_s decays. (see next topic, and this is as well the anchor for the $B_s \rightarrow J/\Psi\,\Phi$ analysis)



Update coming soon!

- Measuring the **partial decay widths of Bs to CP Eigenstates**.

There are theoretical motivations to believe, that $\mathbf{B_s \rightarrow D_s^{(*)} D_s^{(*)}}$ covers most of this partial decay widths. → Measurement soon to come!

However, this might need completion from three-body final CP Eigenstates.

If the lifetime difference measured by the two methods differs, the assumption of absence of CP Violation is wrong, but in the SM this should be very small.

$B_s \rightarrow J/\psi\, f_0(980)$ – First direct measurement of $B_{s,H}$ lifetime

$J/\psi\, f_0(980)$ is a purely CP odd final state.

In the absence of CP Violation, only the CP odd B_s Eigenstate can decay this way.

Therefore we can directly measure its lifetime.

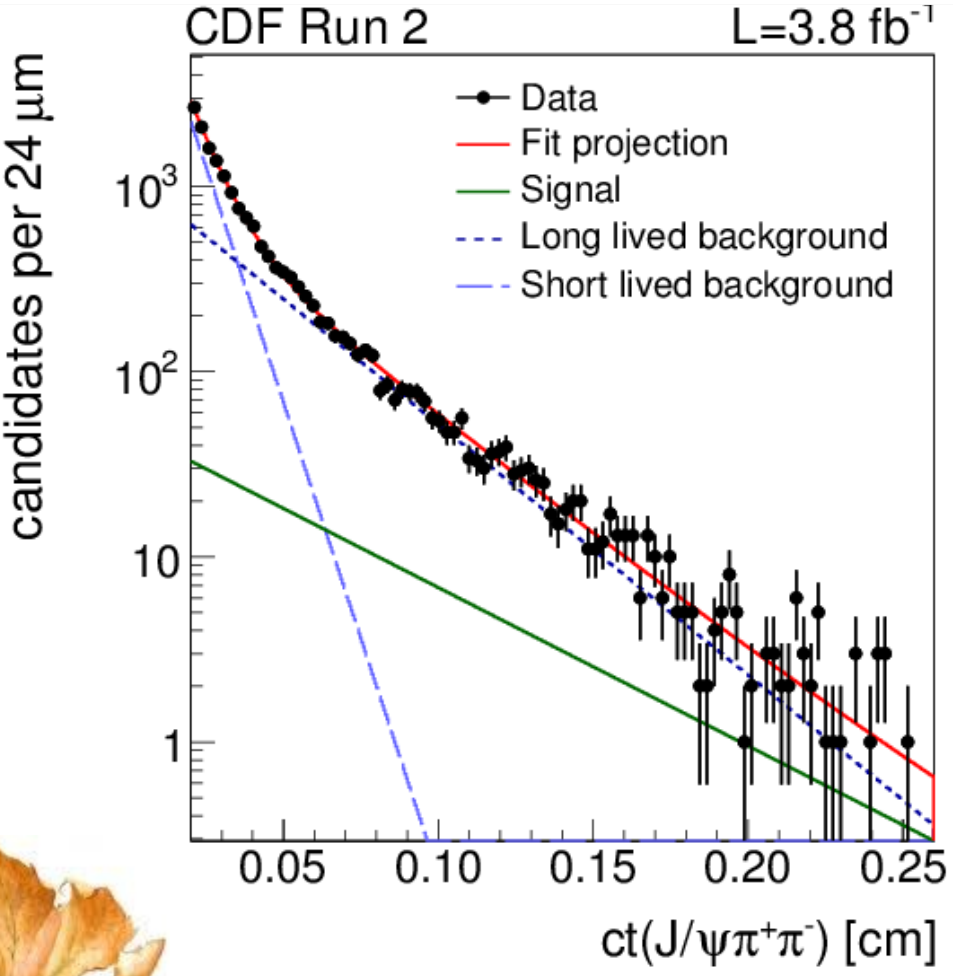
We measure

$\tau\,(B_s \rightarrow J/\psi\, f_0(980)) =$

$1.70^{+0.12}_{-0.11}$ (stat) ± 0.03 (sys) ps

Statistically dominated.

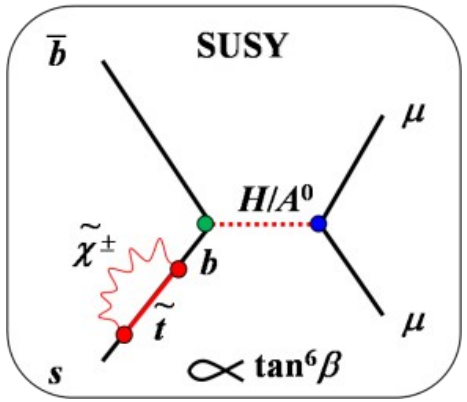
Phys. Rev. D 84 052012 (2011)

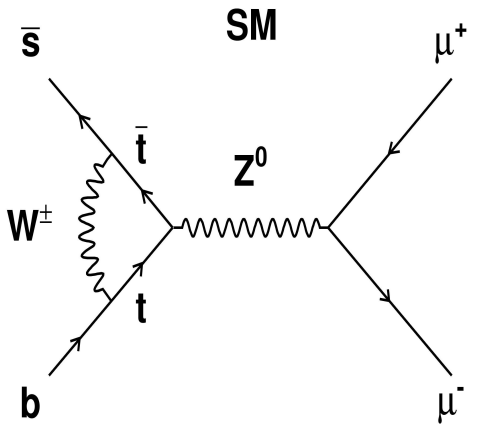


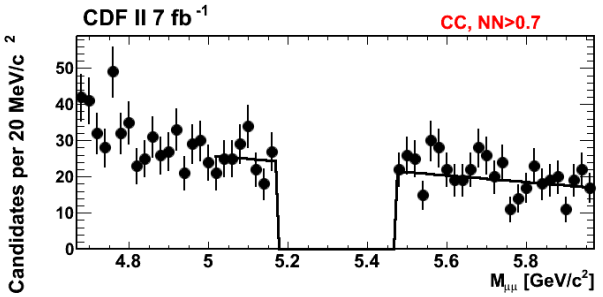
$B_s \rightarrow \mu\mu$ – Excellent Sensitivity to New Physics

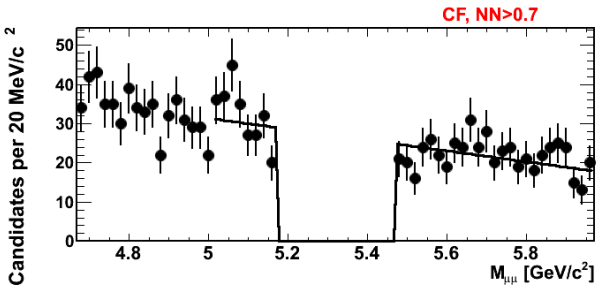
Strongly suppressed in the SM due to FCNC and Helicity suppression.

Observation with our sensitivity would mean New Physics.









General Analysis Procedure:

- Find two muons
- Enrich Signal
- Look for bump
- Normalize to $B \rightarrow J/\psi K$

Background Estimation:

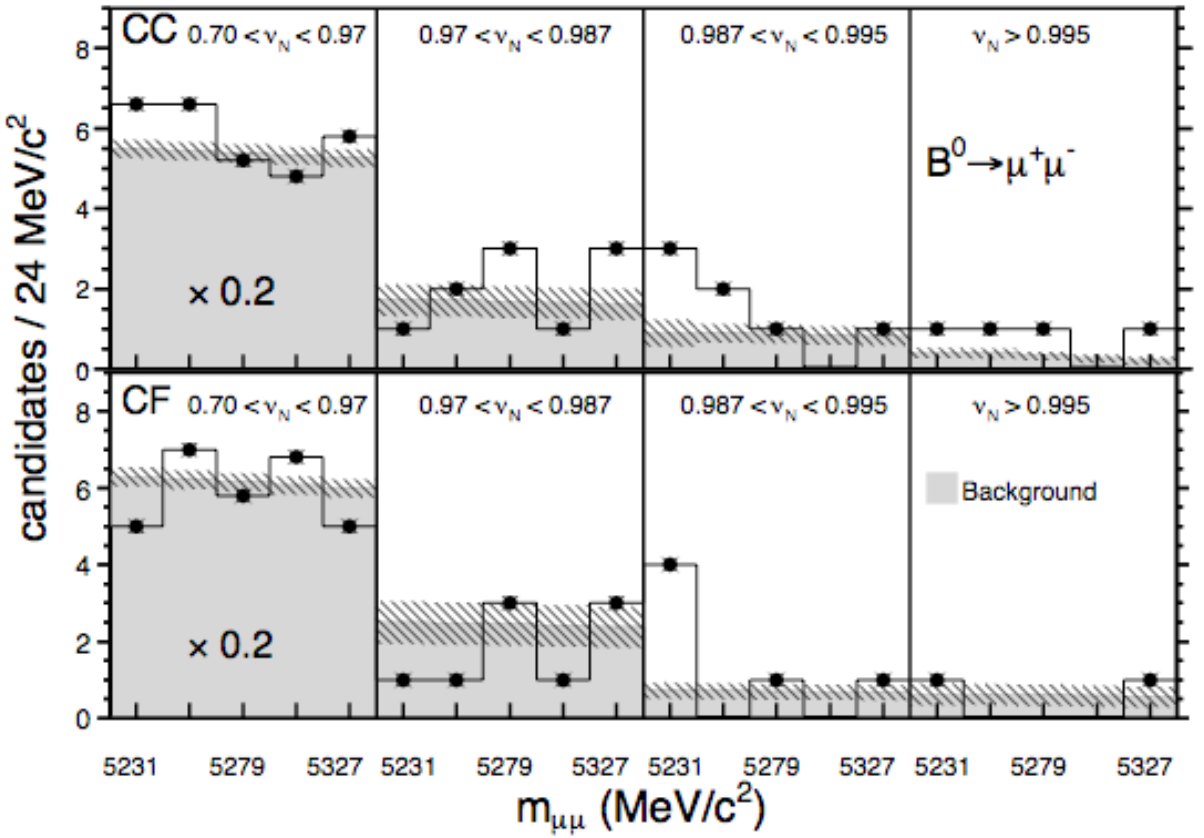
- Combinatorial Background from Sidebands in B_s Mass
- Only Peaking background is $B \rightarrow hh$, with misidentification of h
- Estimated from MC and D* tagged D decays (for estimating misidentification)

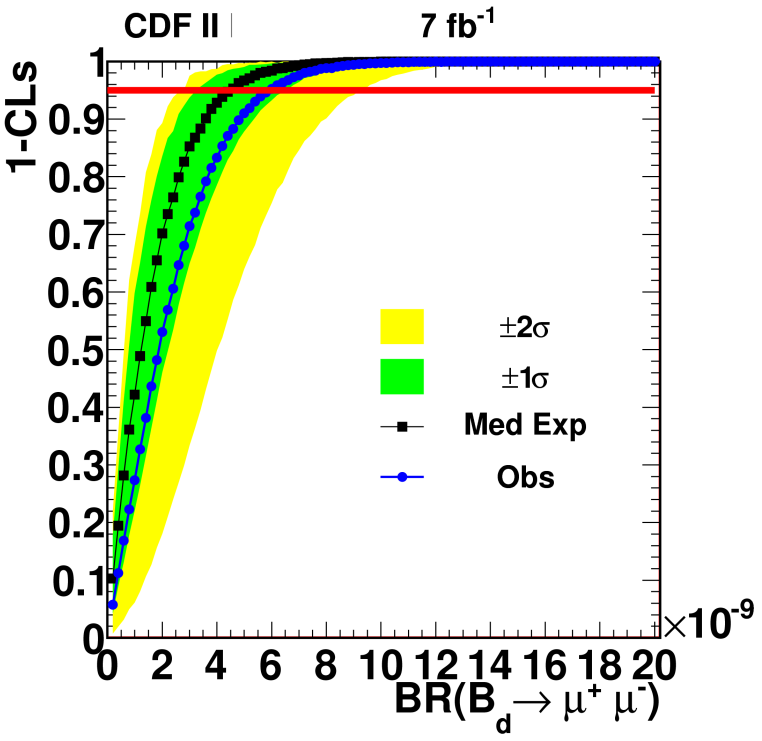
Key improvements over last CDF Analysis:

- ~50% more data (analysis of full data set is on the way)
- ~20% increase of acceptance, by taking muons, that point more in forward or backward direction
- New dE/dx calibration for better μ ID
- Improved fake rates for peaking background estimation
- New NN with 2x better background rejection

95% CL Limit:
BR($B_d \rightarrow \mu\mu$) < 6 x 10^{-9}

p-vlaue (background only) = 23.3%



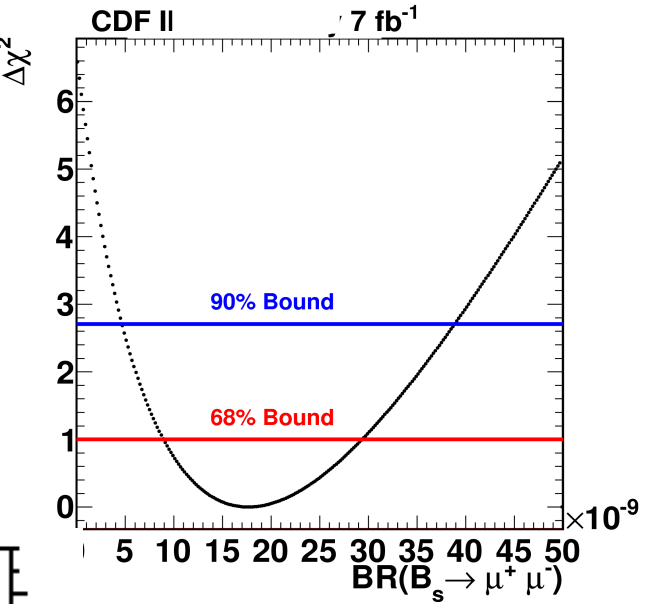


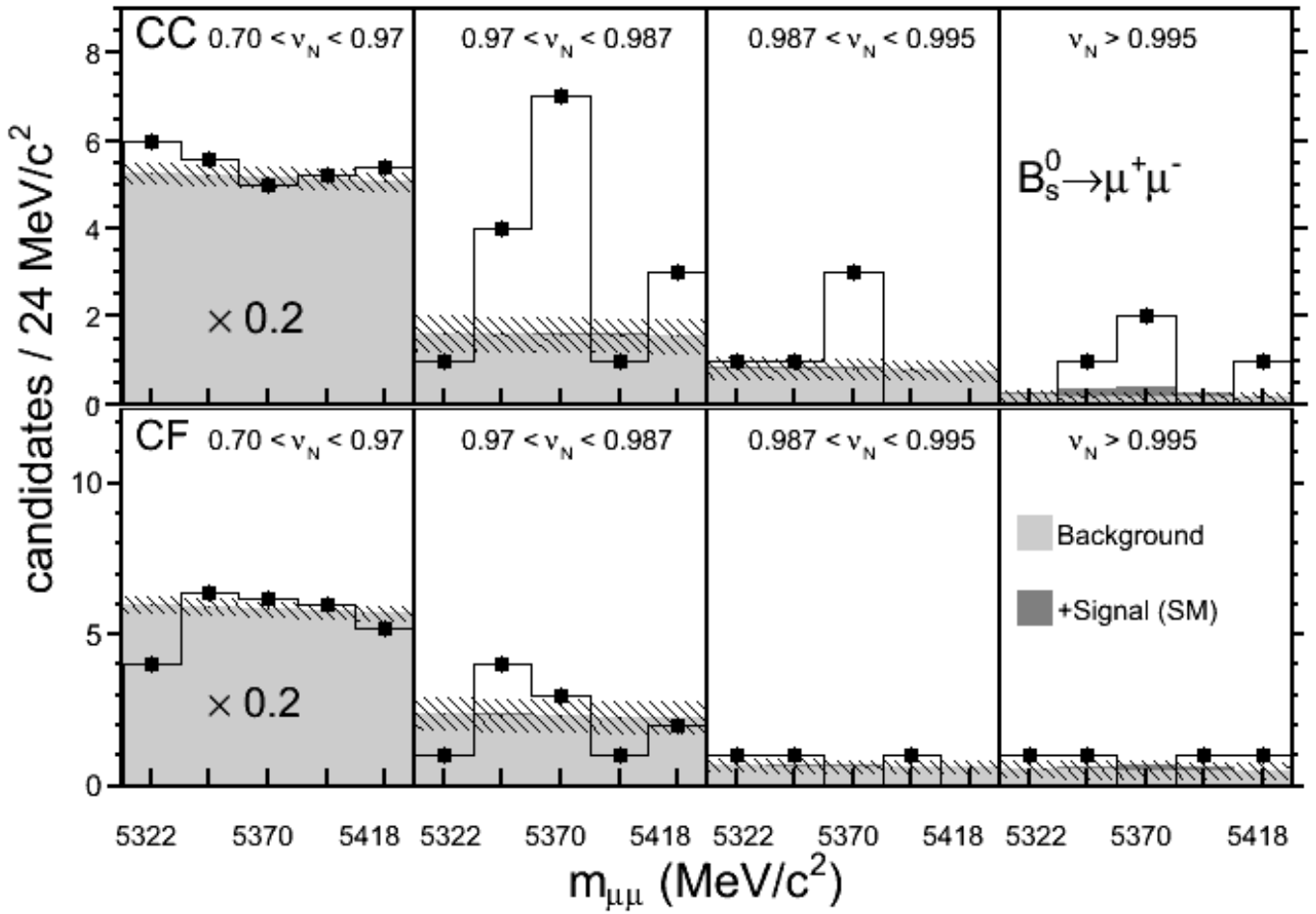
Data and background expectation agree very well.

- 90% CL region: $4.6 \times 10^{-9} < BR(B^0_s \rightarrow \mu^+\mu^-) < 3.9 \times 10^{-8}$

Using Loglikelihood Technique

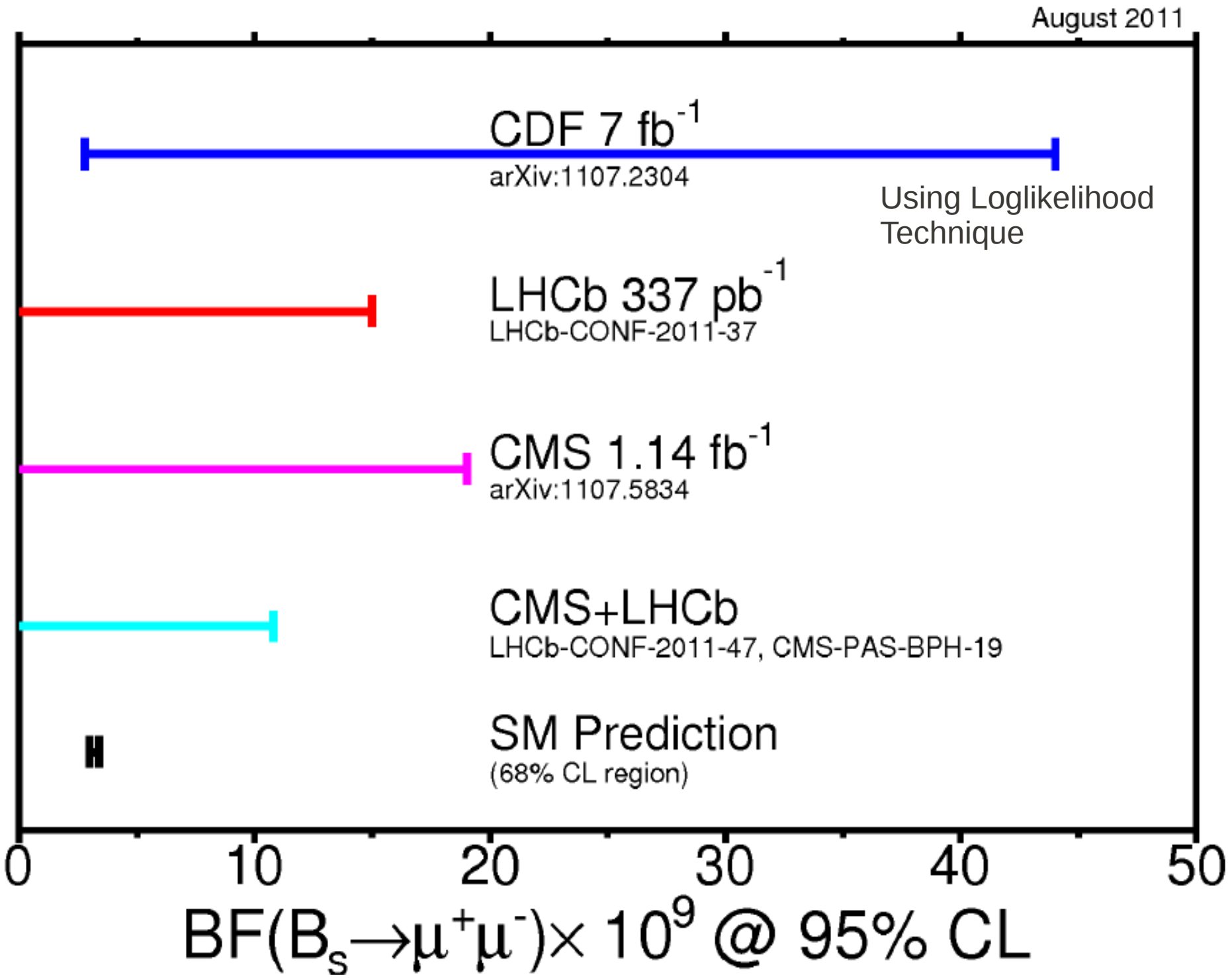
- Central value:
  - $BR(B^0_s \rightarrow \mu^+\mu^-) = 1.8\ ^{+1.1}_{-0.9} \times 10^{-8}$
- p-value for background-only hypothesis: 0.27%
- p-value for background+SM hypothesis: 1.9%





First two sided limit for $B_s \rightarrow \mu\mu$

Phys. Rev. Lett. 107, 191801 (2011)

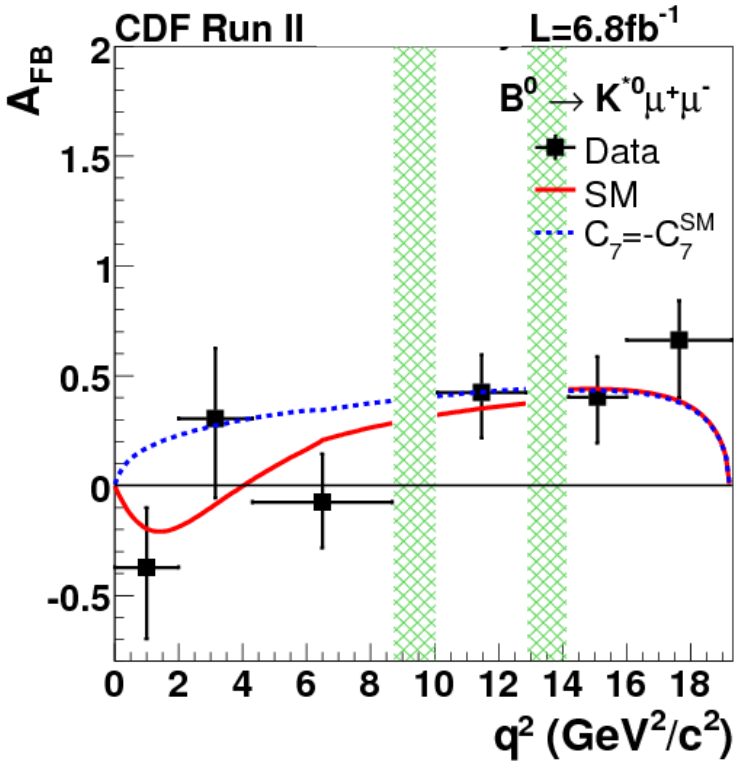

August 2011
CDF 7 fb-1
arXiv:1107.2304
Using Loglikelihood Technique
LHCb 337 pb-1
LHCb-CONF-2011-37
CMS 1.14 fb-1
arXiv:1107.5834
CMS+LHCb
LHCb-CONF-2011-47, CMS-PAS-BPH-19
SM Prediction
(68% CL region)
0
10
20
30
40
50
BF(Bs→μ+μ-)× 10^9 @ 95% CL

Non-B_s topics

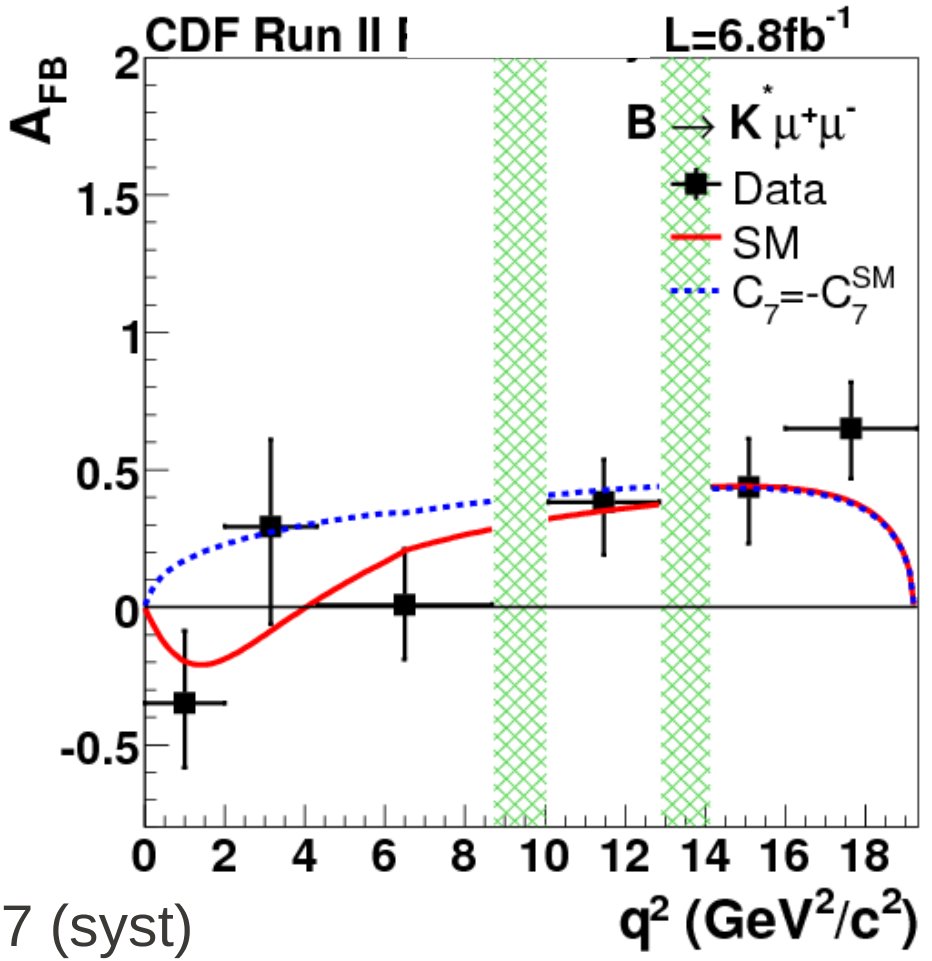
Forward/Backward assymmetry in B → K μ μ was for some time hot topic due to hints for non-SM like behaviour from B factories.
Phys. Rev. Lett. 107, 201802 (2011) covers as well the similar Λ_b decay.

CDF doesn't see hints for any deviation.

Neutral only



Charged and Neutral



AFB($1 < q^2 < 6$) = $0.29^{+0.20}_{-0.23}$ (stat) ± 0.07 (syst)

CP Violation in Charm

Using 215K D*-tagged $D^0 \to \pi^-\pi^+$ decays, 476K D*-tagged $D^0 \to K^-K^+$ decays, 5M D*-tagged $D^0 \to K^-\pi^+$ decays and 29M $D^0 \to K^-\pi^+$ decays where no D* tag was required, we obtain:

$A_{CP}(D^0 \to \pi^-\pi^+) = [\ 0.22 \pm 0.24\ (stat) \pm 0.11\ (sys)\ ]\%$

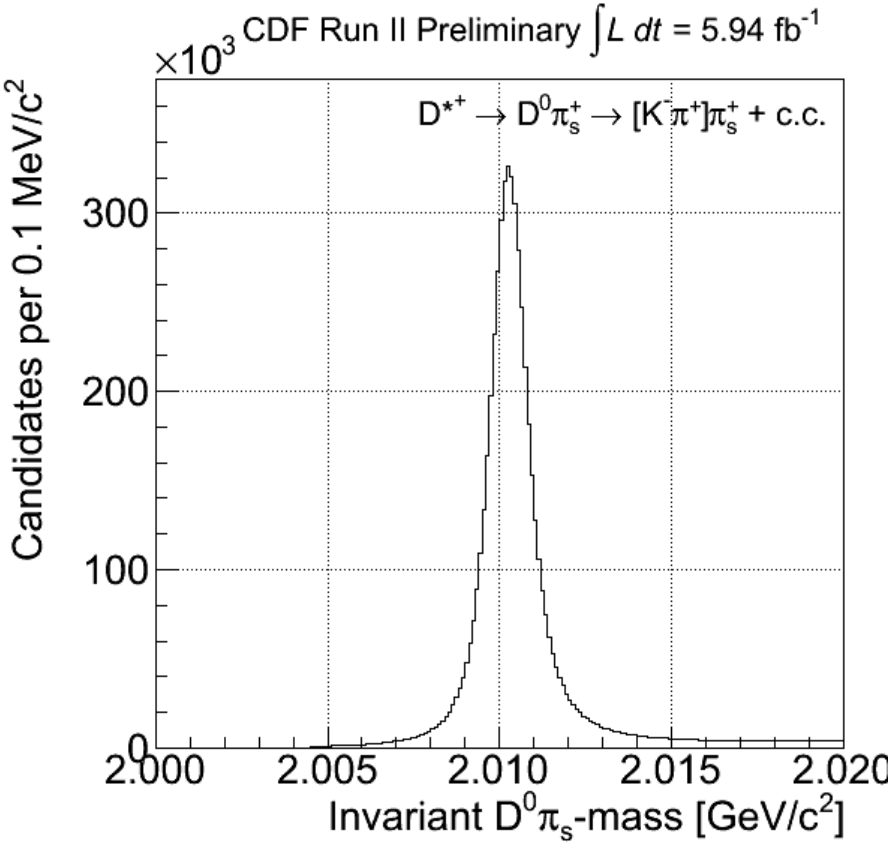
$A_{CP}(D^0 \to K^-K^+) = [\ -0.24 \pm 0.22\ (stat) \pm 0.10\ (sys)\ ]\%$

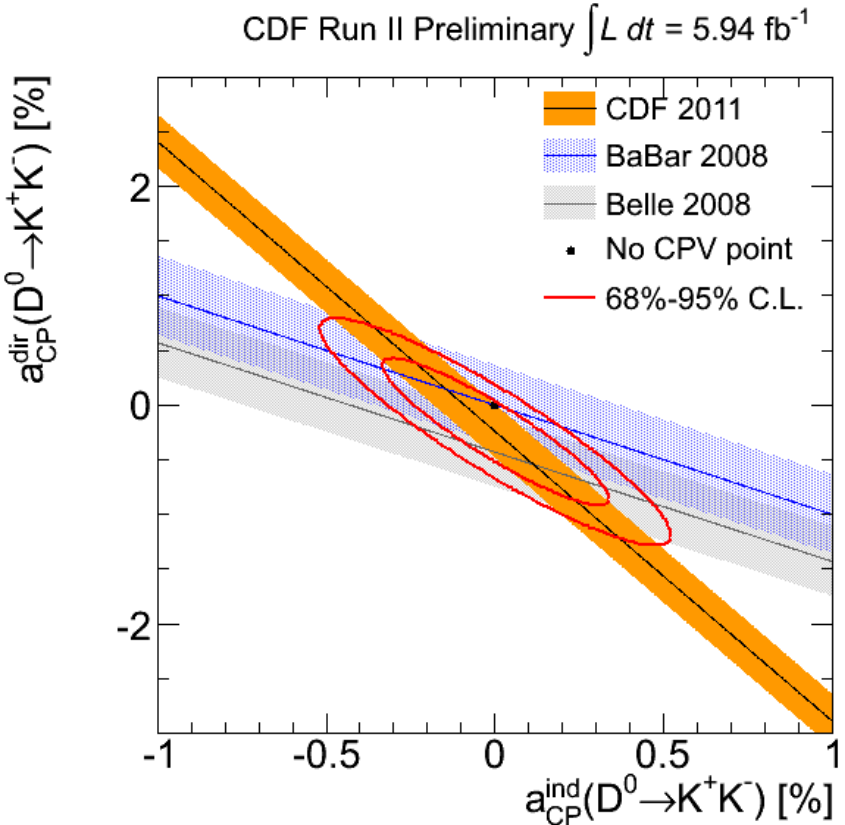
Assuming no direct CP violation and no large weak phases in the decay amplitude, we get for the indirect CPV averaging the results:

$A_{CP}^{ind}(D^0) = [-0.01 \pm 0.06\ (stat) \pm 0.04\ (sys)\ ]\%$

$A_{CP}(KK) - A_{CP}(\pi\pi) = [-0.46 \pm 0.31 \pm 0.12]\%$

arXiv:1111.5023





Summary

- CDF has pioneered B_s physics in the last 10 years and added much in the last 12 months, including:
  - even more detailed studies of the mixing phenomenology
  - charmless penguin annihilation
  - first hint for decay into two muons

- But CDF has competitive or world best results in the B and D sector as well, e.g.
  - $b \rightarrow s \mu\mu$
  - CP Violation in D^0 mixing

Visit www-cdf.fnal.gov/physics/new/bottom/bottom.html to learn more about the various physics topics, we are working on.