CDF b (+ SOME c) RESULTS

J. Rosner – Beauty 2014, Edinburgh – July 17, 2014

CDF member since February 2011

Special thanks to Jonathan Lewis, Patrick Lukens

Topics:

Baryon masses, lifetimes: PR D **89**, 072014 (2014), 9.6 fb^{-1}

CP violation in charmless baryon decays: 1403.5586, 9.3 fb^{-1}

$B_c \to J/\psi\mu\nu$ vs. $B^+ \to J/\psi K^+$: CDF Note 11083, 8.7 fb^{-1}

$A_{FB}(b\bar{b})$ at high $b\bar{b}$ mass: CDF Note 11092, ≤ 9.5 fb^{-1}

L-excited B mesons, new $B\pi$ resonance: 1309.5961, 9.6 fb^{-1}

Full Run II (2001-2011) samples, based on 12 fb^{-1} delivered

Some differences in recorded samples depending on triggers

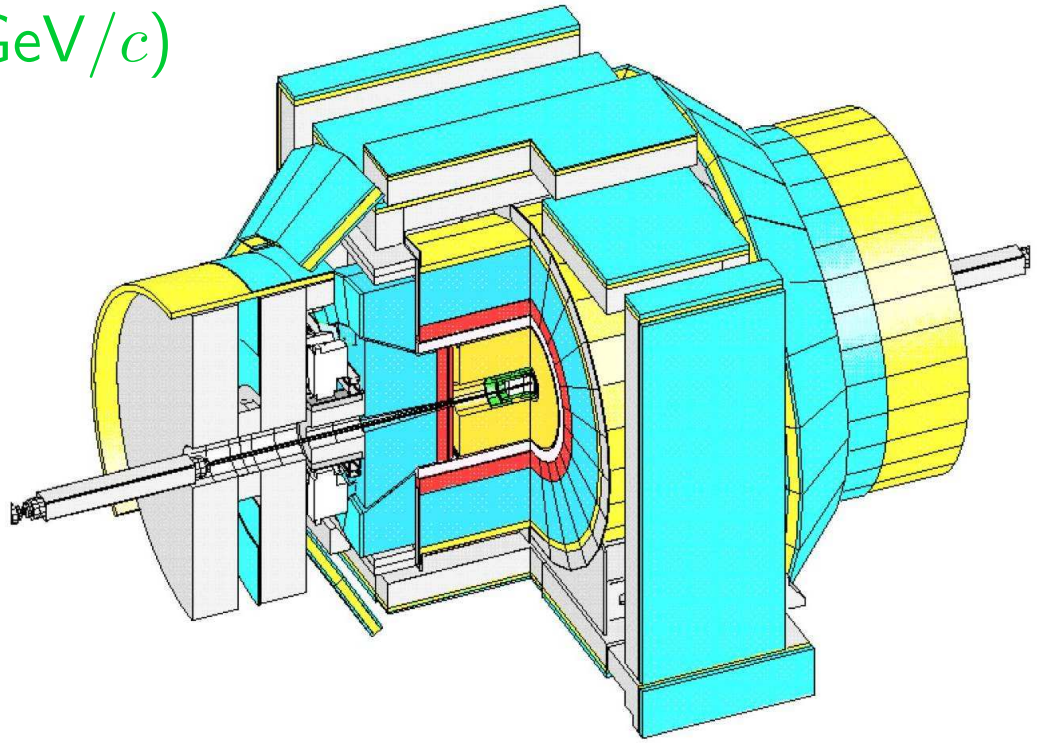
TRIGGERS IN CDF II

Triggers:

$\mu^+\mu^-$ trigger ($p_T(\mu) > 1.5$ GeV/c)
selects J/ψ

Unbiased with respect to

decay time for b-hadrons



Displaced track trigger
selects B decays

Biased for long decay time

Dimuon trigger: match central tracker, μ chamber tracks

Drift chamber tracks $\Rightarrow$ "roads" to silicon vertex detector; demand flight from beam > 200 μm

Performance of the Run II silicon vertex detector: 1301.3180

BARYONS WITH ONE b

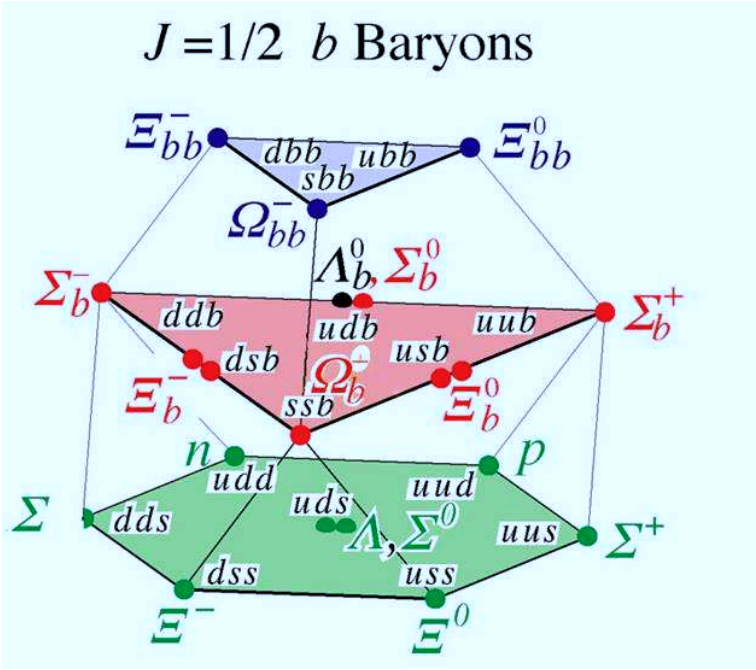
$\Lambda_b = bud$

$\Sigma_b^{+,0,-} = b(uu, ud, dd)$

$\Xi_b^{0,-} = bs(u, d)$

$\Omega_b^- = bss$

Also $\Xi_c^{+,0} = cs(u, d)$



CDF: results on nearly all baryons with one b quark

Previously: CDF discovery of four $\Sigma_b^{(*)\pm}$ states ($J_{\text{light}} = 1$)

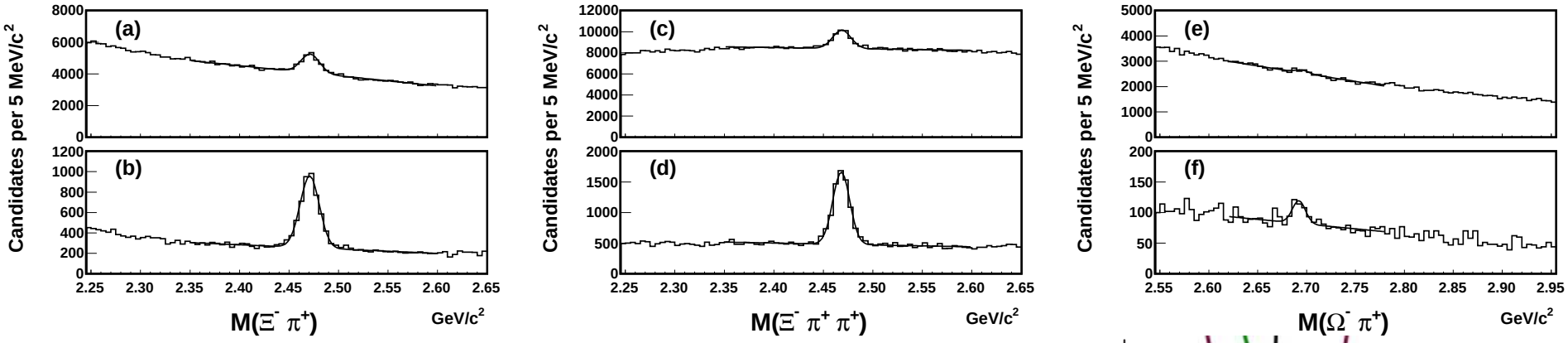
	$M(\Sigma_b^{(*)+})$ (MeV/c^2)	$M(\Sigma_b^{(*)-})$ (MeV/c^2)	ΔM (MeV/c^2)
$\Sigma_b(J = 1/2)$	$5811.3^{+0.9}_{-0.8} \pm 1.7$	$5815.5^{+0.6}_{-0.5} \pm 1.7$	$-4.2^{+1.1}_{-1.0} \pm 0.1$
$\Sigma_b^*(J = 3/2)$	$5832.1 \pm 0.7^{+1.7}_{-1.8}$	$5835.1 \pm 0.6^{+1.7}_{-1.8}$	$-3.0^{+1.0}_{-0.9} \pm 0.1$

BARYON TRACK RECONSTRUCTION

Updated results on $\Xi_c^{(0,+)}, \Lambda_b, \Xi_b^{(-,0)}, \Omega_b$ masses, lifetimes

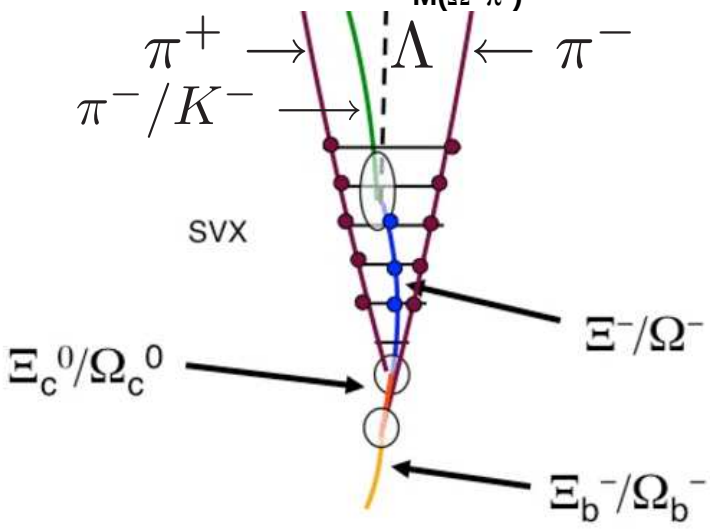
Top plots: all charmed hyperon candidates; bottom plots: subset with negative hyperon tracked in the silicon detector and impact parameter with respect to the beam line less than 100 μm

$\Xi_c^0 \to \Xi^-\pi^+$ $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ $\Omega_c \to \Omega^-\pi^+$



Improvement due to silicon:

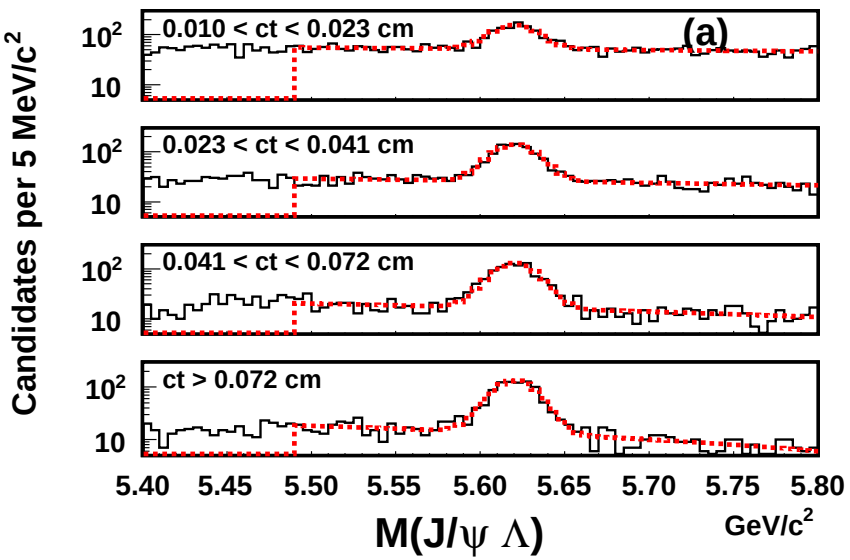
	No silicon	With silicon
Ξ_c^0 purity	0.15 ± 0.01	0.63 ± 0.01
Ξ_c^+ purity	0.11 ± 0.01	0.61 ± 0.01
Ω_c purity	0.03 ± 0.01	0.22 ± 0.05

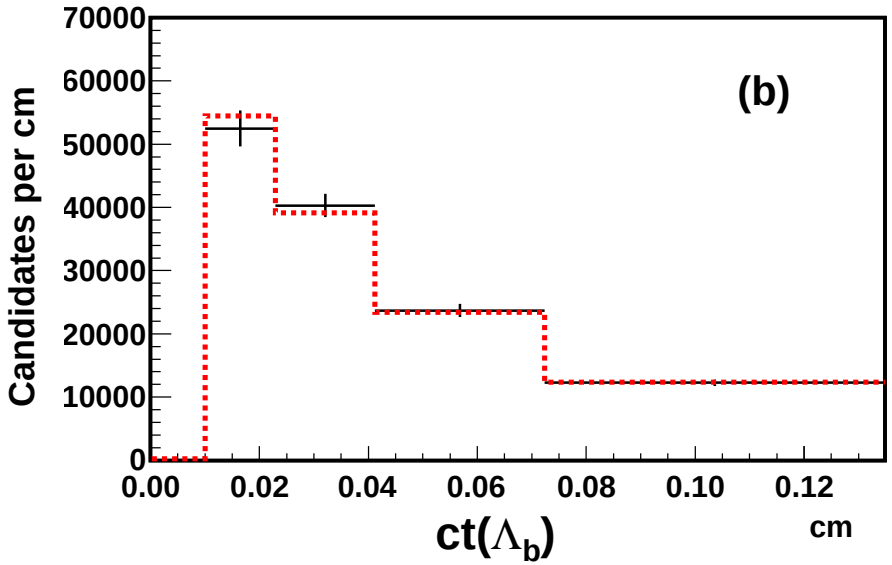


Λ_b LIFETIME

Long-standing problem: Theory favored $\tau(\Lambda_b)/\tau(B^0)$ close to 1 while many experiments favored ~ 0.8

More data, better vertex detection $\Rightarrow$ lifetime $\sim$ theoretical predictions





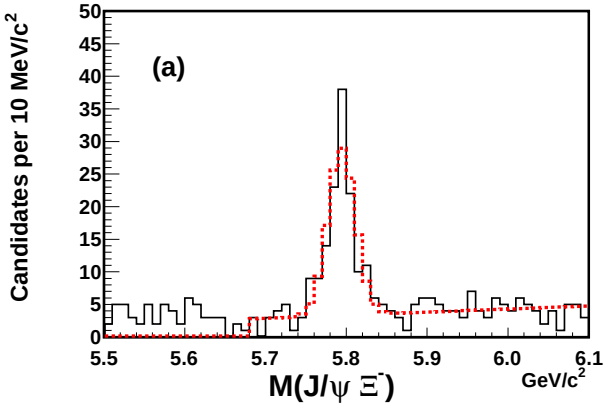
Mass distributions plotted in four proper time bins

Reference plots: $B^+ \to J/\psi K^+$; $B^0 \to (J/\psi K^{*0}, J/\psi K^0_S)$

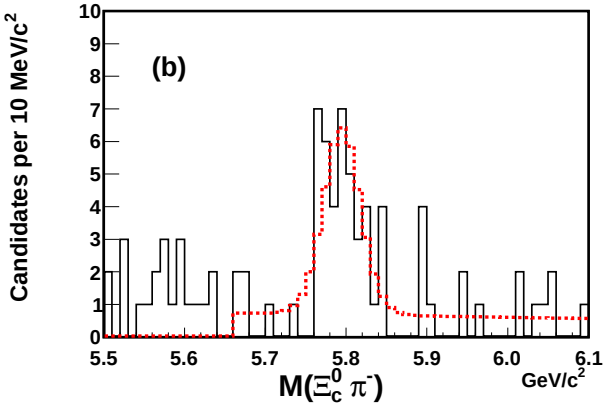
Meson lifetimes within 1% or better of world averages

b-FLAVORED HYPERONS

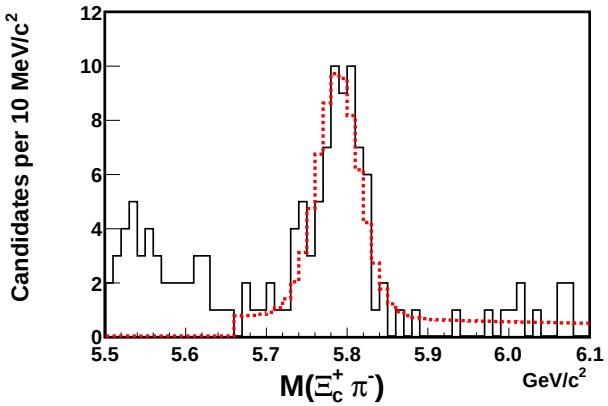
$\Xi_b^- \to J/\psi \Xi^-$



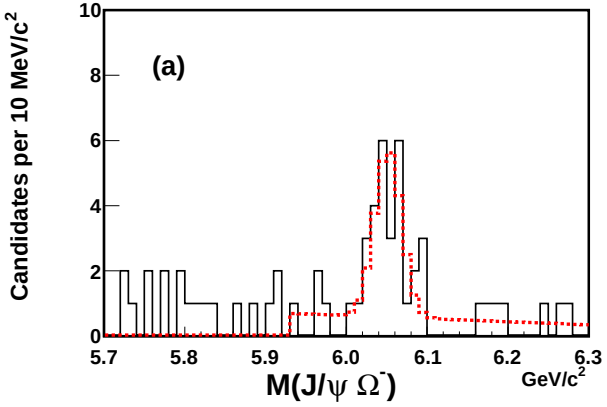
$\Xi_b^- \to \Xi_c^0 \pi^-$



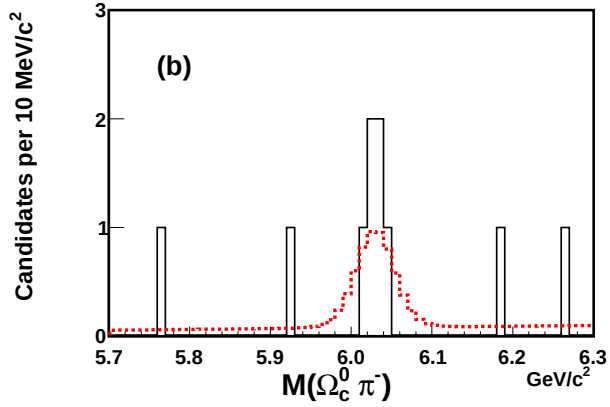
$\Xi_b^0 \to \Xi_c^+ \pi^-$



$\Omega_b^- \to J/\psi \Omega^-$



$\Omega_b^- \to \Omega_c^0 \pi^-$



Decay modes:

$\Xi_c^0 \to \Xi^- \pi^+$

$\Xi_c^+ \to \Xi^- \pi^+ \pi^+$

$\Omega_c^0 \to \Omega \pi^-$

$\Xi^- \to \Lambda \pi^-$

$\Omega^- \to \Lambda K^-$

$\Lambda \to p \pi^-$

Solid black curves: data; dotted red curves: fits

Lifetime measurements for $\Xi_b^- \to J/\psi \Xi^-$, $\Omega_b^- \to J/\psi \Omega^-$

c, b-BARYON RESULTS

Masses: [Predictions: M. Karliner *et al.*, Ann. Phys. **324**, 2 (2009)]

Baryon	Mass (MeV/c^2)	PDG 2012	Karliner+ pred.
Ξ_c^0	$2470.85 \pm 0.24 \pm 0.55$	$2470.88^{+0.34}_{-0.88}$	Input
Ξ_c^+	$2468.00 \pm 0.18 \pm 0.51$	$2467.8^{+0.4}_{-0.6}$	Input
Λ_b	$5620.15 \pm 0.31 \pm 0.47$	5619.4 ± 0.7	Input (vs. Λ_c)
Ξ_b^-	$5793.4 \pm 1.8 \pm 0.7$	5791.1 ± 2.2	5795 ± 5
Ξ_b^0	$5788.7 \pm 4.3 \pm 1.4$	5788 ± 5	(Chg. avg.)
Ω_b^-	$6047.5 \pm 3.8 \pm 0.6$	$(D0 \neq CDF)$	6052.1 ± 5.6
$M(\Xi_c^0) - M(\Xi_c^+)$	$2.85 \pm 0.30 \pm 0.04$	$3.1^{+0.4}_{-0.5}$	–
$M(\Xi_b^-) - M(\Xi_b^0)$	$4.7 \pm 4.7 \pm 0.7$	3 ± 6	6.24 ± 0.21

Lifetimes: [PDG: $\tau(B^0) = 1.519 \pm 0.007$ ps]

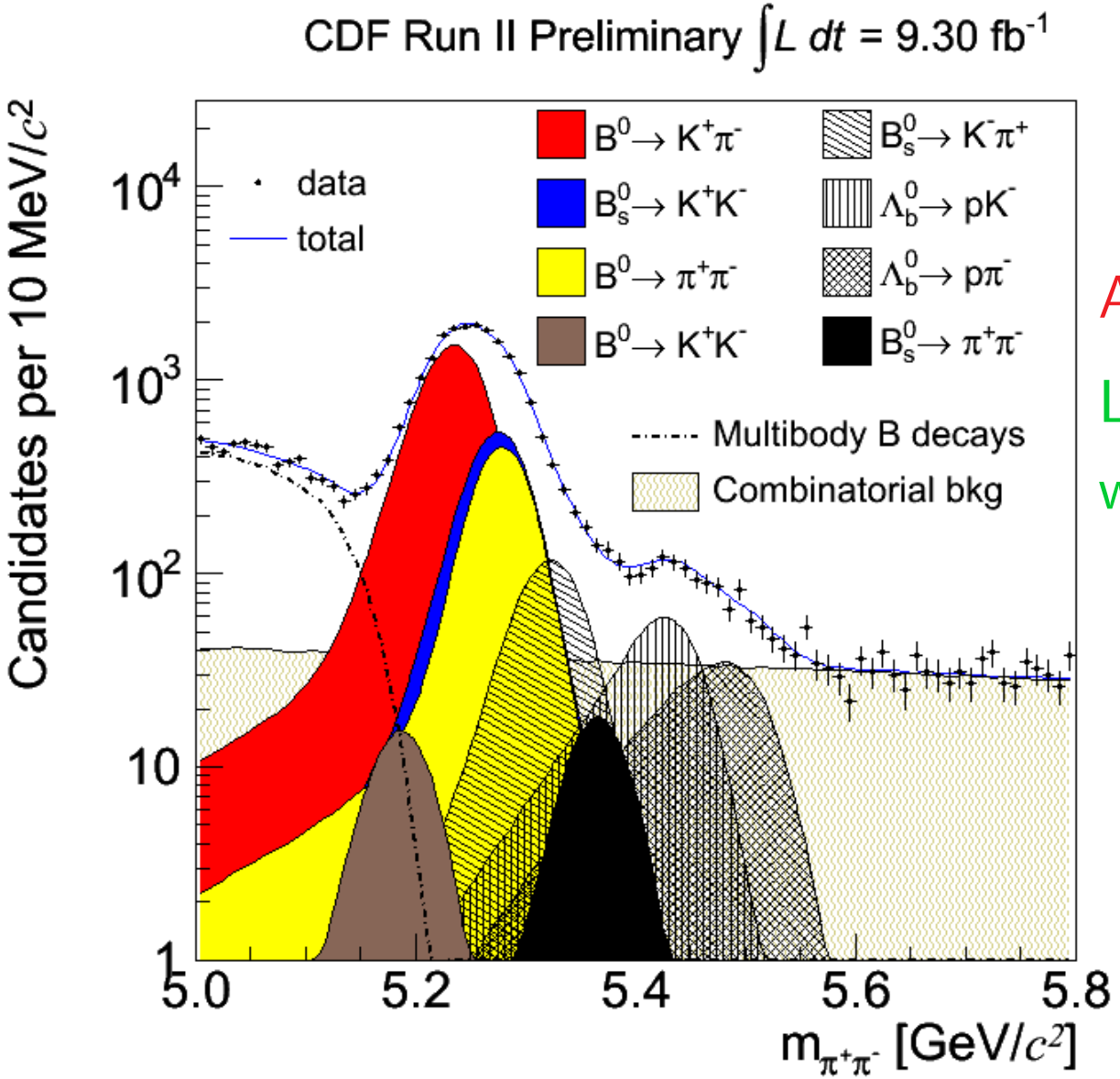
Baryon	CDF (ps)	LHCb (ps)
Λ_b	$1.565 \pm 0.035 \pm 0.020$	$1.468 \pm 0.009 \pm 0.008$
Ξ_b^-	$1.36 \pm 0.15 \pm 0.02$	$1.53^{+0.10}_{-0.09} \pm 0.03$
Ω_b^-	$1.66^{+0.53}_{-0.40} \pm 0.02$	$1.54^{+0.26}_{-0.31} \pm 0.05$

$\tau(\Lambda_b)/\tau(B^0)$:
1.021±0.024±0.013
(CDF)
0.974±0.006±0.004
(LHCb)

PL B **379**, 267 (1996): $\tau(\Lambda_b)/\tau(B^0) \simeq 1$ to 1%

CHARMLESS BARYON DECAYS

$\Lambda_b \to h^+h^-$ a composite of contributions:



All tracks treated as pions

Leads to displaced peaks

when tracks are not pions

BRANCHING RATIOS AND CP VIOLATION

$\mathcal{B}(\Lambda_b \to p\pi^-)/\mathcal{B}(\Lambda_b \to pK^-)$

Source	Reference	Value
CDF	PRL **103**, 031801 (2009)	$0.66 \pm 0.14 \pm 0.08$
LHCb	JHEP 10 (2012) 037	$0.86 \pm 0.08 \pm 0.05$
pQCD	PR D **80**, 034011 (2009)	$2.6^{+2.0}_{-0.5}$

pQCD may do poorly on penguin (main contributor to $\Lambda_b \to pK^-$)

PR D **89**, 037501: $\Lambda_b \to \pi^{\pm}\Sigma^{\mp}, K\Xi$ might also be penguin-dominated

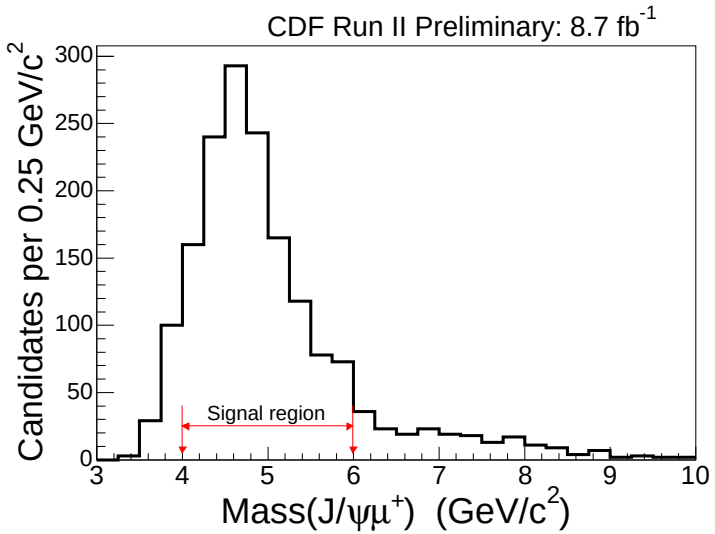
CP-asymmetry results:

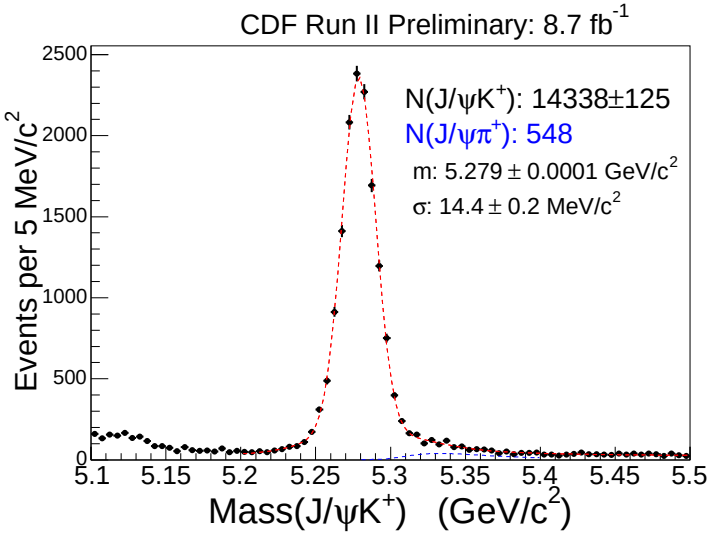
Decay	$\mathcal{N}_{b\to f}$	$\mathcal{N}_{\bar{b}\to \bar{f}}$	$\mathcal{A}(b \to f)(\%)$	
$B^0 \to K^+\pi^-$	5313 ± 109	6348 ± 117	$-8.3 \pm 1.3 \pm 0.4$	} Ratio: U-spin
$B_s^0 \to K^-\pi^+$	560 ± 51	354 ± 46	$+22 \pm 7 \pm 2$	
$\Lambda_b^0 \to p\pi^-$	242 ± 24	206 ± 23	$+6 \pm 7 \pm 3$	} Diff. $16 \pm 12\%$
$\Lambda_b^0 \to pK^-$	271 ± 30	324 ± 31	$-10 \pm 8 \pm 4$	

pQCD predicts $\mathcal{A}(p\pi^-) - \mathcal{A}(pK^-) = -26\%$

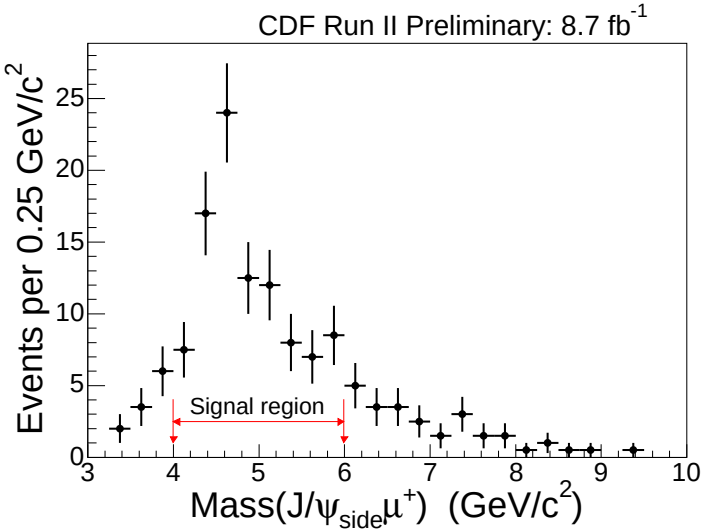
B_c PRODUCTION

Compare $B_c \to J/\psi\mu\nu$, $B^+ \to J/\psi K^+$





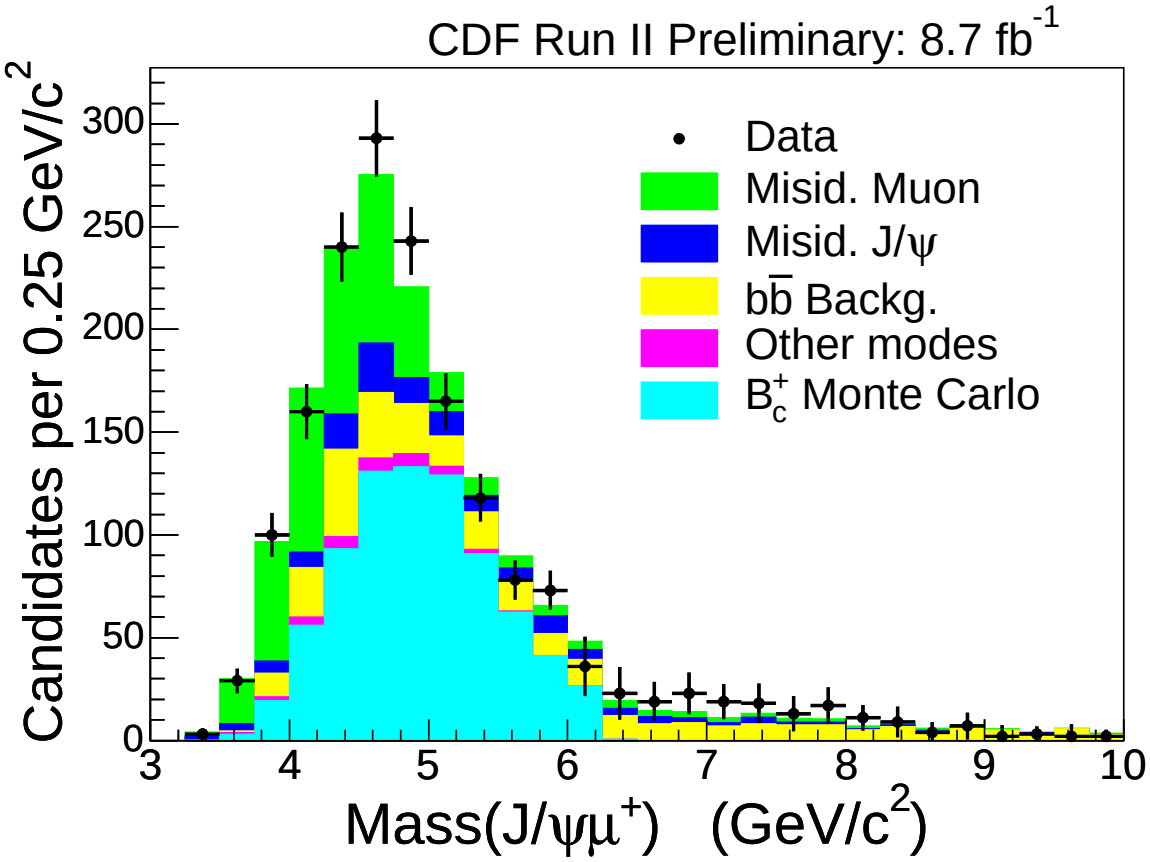
Misidentified J/ψ + third muon: use J/ψ sidebands:



Other backgrounds:

- Misidentified muon
- $b\bar{b}$ background
- Other modes (with $\psi(2S), \tau, \ldots$)

INVARIANT MASS DISTRIBUTION



"B_c Monte Carlo" is *signal*
with Monte Carlo *shape*

LHCb uses this mode to find

$\tau(B_c) = 509 \pm 8 \pm 12$ fs

[EPJ C **74**, 2839 (2014)]

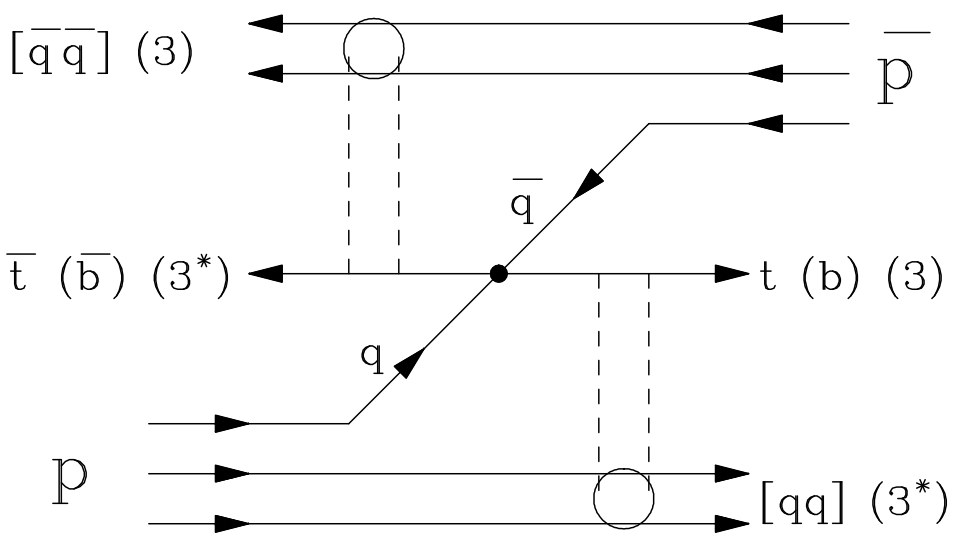
Quantity	Value
$N(B_c^+ \to J/\psi\mu^+\nu)$	$739.5 \pm 39.6^{+19.8}_{-23.9}$
$N(B^+ \to J/\psi K^+)$	14338 ± 125 (stat. only)
$\epsilon_{\rm rel}$	$4.093 \pm 0.038^{+0.401}_{-0.359}$
$\frac{\sigma(B_c^+)*\mathcal{B}(B_c^+\to J/\psi\mu^+\nu)}{\sigma(B^+)*\mathcal{B}(B^+\to J/\psi K^+)}$	$0.211 \pm 0.012^{+0.021}_{-0.020}$

$P_T(B) > 6$ GeV/c, $|y| < 0.6$

FORWARD-BACKWARD $b\bar{b}$ ASYMMETRY

Larger-than-expected A_{FB} in top production raises the question of whether $A_{FB}(b\bar{b})$ is observable at the Tevatron

Tevatron $p\bar{p}$ collider addresses this question uniquely



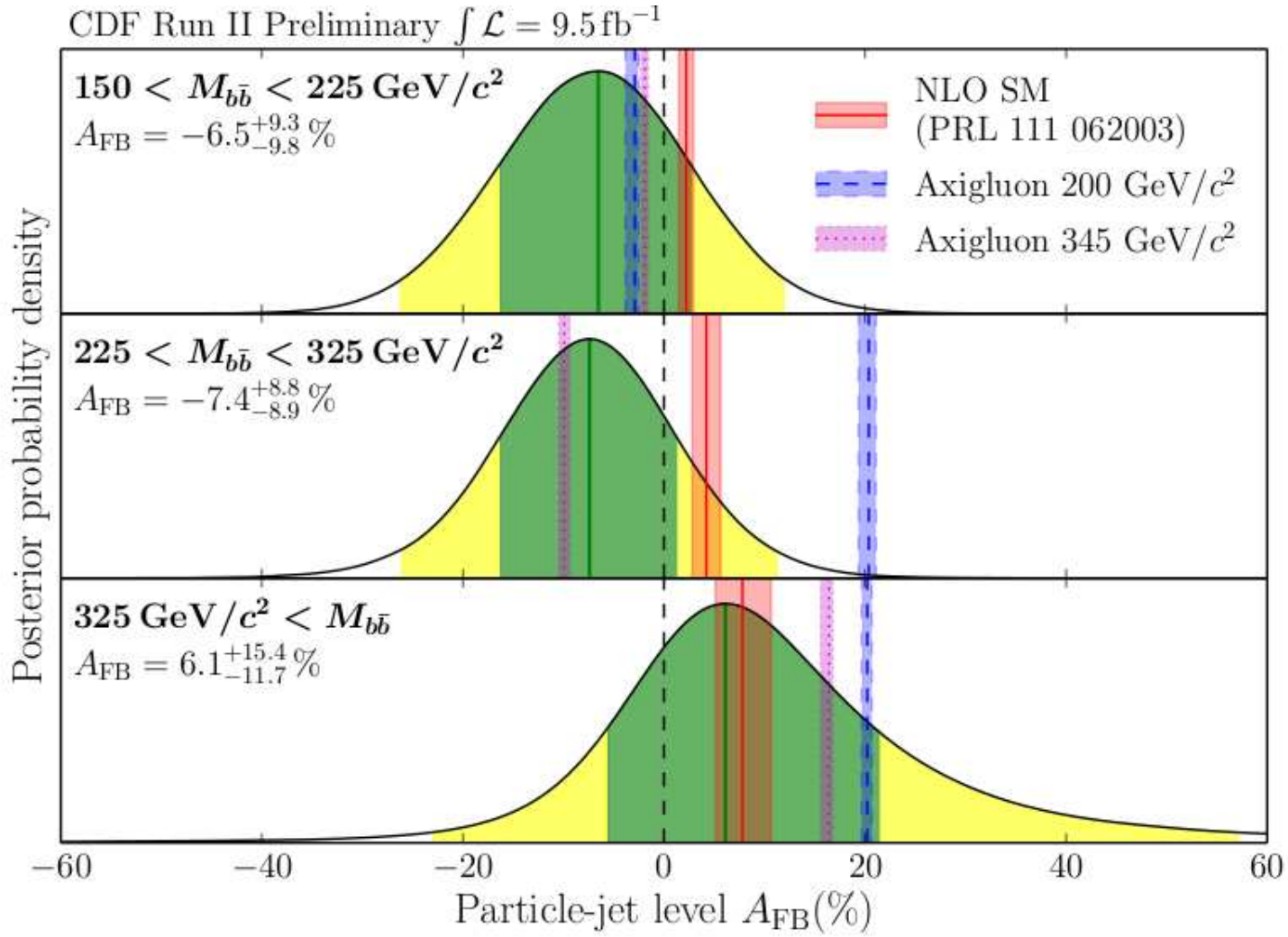
Proposed "string-drag" mechanism [PR D **86**, 014011 (2012)] gives much too small an effect for top

"Axigluon" of mass 200 GeV/c^2 one proposal among many [e.g., PR D **81**, 114004 (2010)]

Asymmetry in $q\bar{q} \longrightarrow b\bar{b}$ best probed at high $M(b\bar{b})$

Various theoretical expectations in SM (CDF Note 11092): e.g., Grinstein + Murphy, PRL **111**, 062003 (2013)

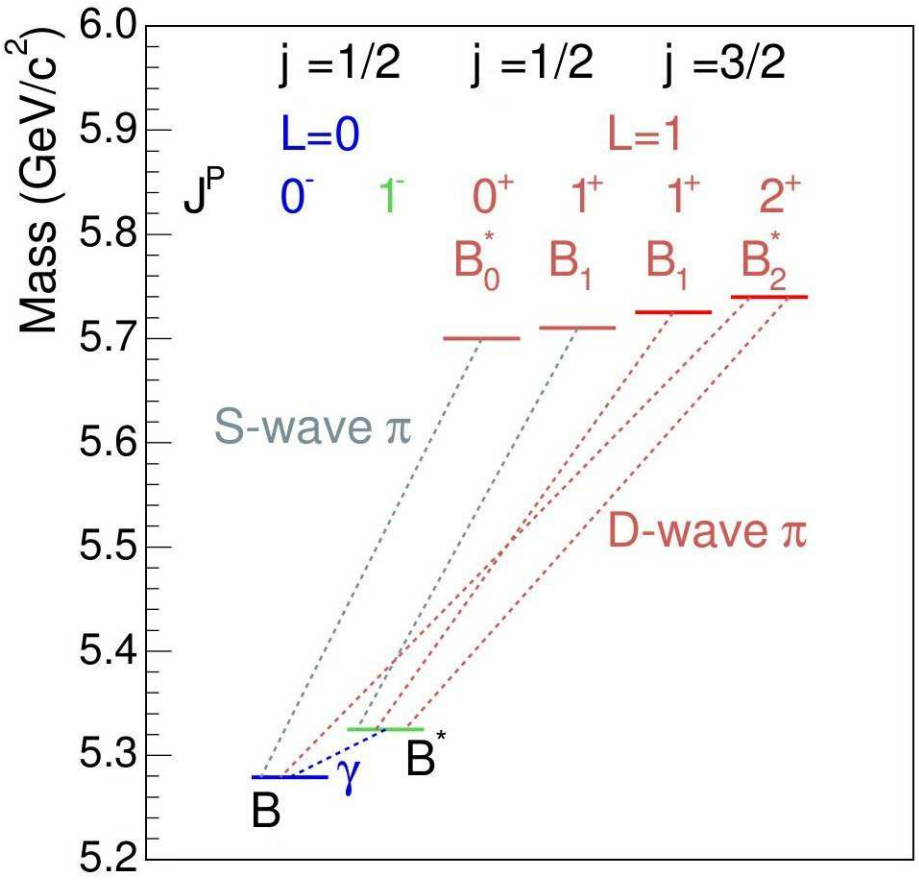
ASYMMETRY PROBABILITY DISTRIBUTIONS



Consistent with Standard Model and with a 345 GeV/c^2 axigluon but not with a 200 GeV/c^2 axigluon

LHCb: Charge asymmetry $A_C^{b\bar{b}}$ [asymmetry in $\Delta y(b\bar{b})$] also $\simeq 0$

L-EXCITED, NEW Bs



Results (details next):

State	Mass (MeV/c^2)
B_1^0	$5726.6 \pm 0.9^{+1.1}_{-1.2} \pm 0.4$
B_2^{*0}	$5736.7 \pm 1.2^{+0.8}_{-0.9} \pm 0.2$
B_1^+	$5727 \pm 3^{+1}_{-3} \pm 2$
B_2^{*+}	$5736.9 \pm 1.2^{+0.3}_{-0.9} \pm 0.2$
B_{s1}^0	$5828.3 \pm 0.1 \pm 0.2 \pm 0.4$
B_{s2}^{*0}	$5839.7 \pm 0.1 \pm 0.1 \pm 0.2$
$B(5970)^0$	$5978 \pm 5 \pm 12$
$B(5970)^+$	$5961 \pm 5 \pm 12$

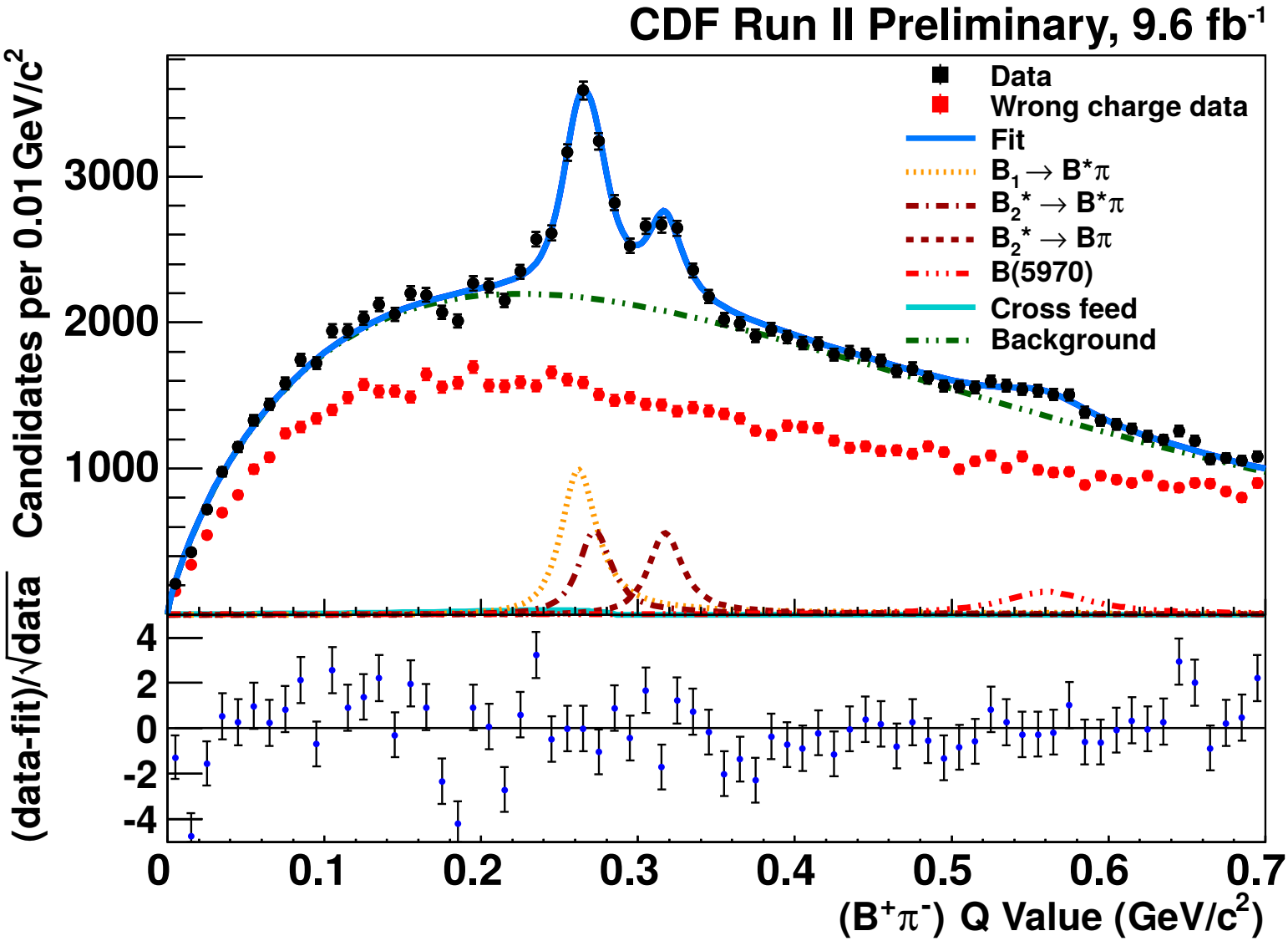
$B(5970)$: New state $\rightarrow B\pi$

Preds.: $B_1 \sim 5700$–5800 MeV/c^2; B_2^* 5–20 MeV/c^2 higher

$B_{s1} \sim 5800$-5900 MeV/c^2; B_{s2}^* 10–20 MeV/c^2 higher

Most recent unquenched lattice [UKQCD, PR D69, 094505 (2004)]: $M(B_{s1,2*}) = (5889 \pm 52, 5901 \pm 52)$ MeV/c^2 (large errors!)

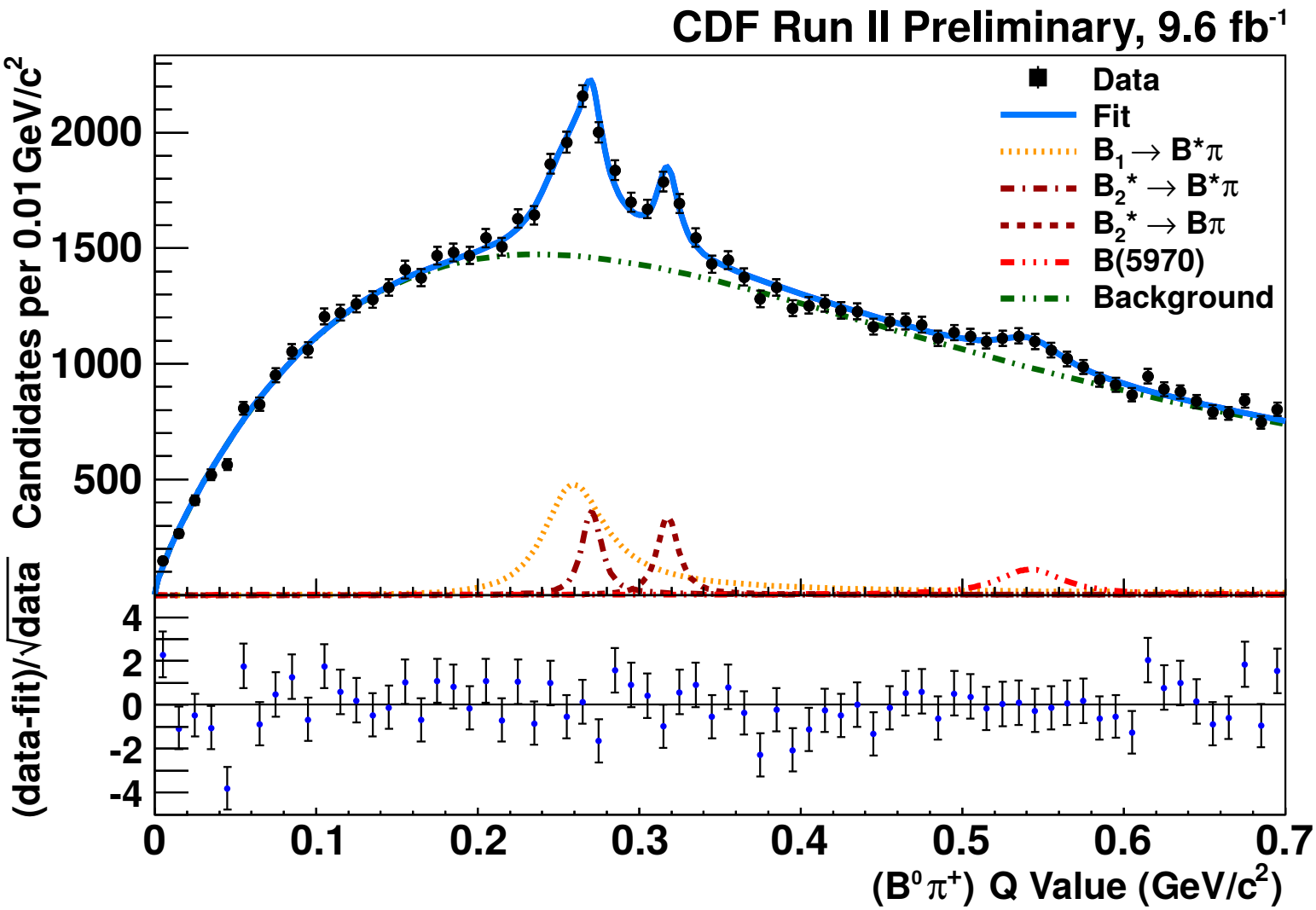
NEUTRAL $B\pi$ SPECTRUM



Contributions to fit listed in order of increasing Q-value

$\Gamma(B_1, B_2^*, B(5970)) = (23 \pm 3 \pm 4, 22^{+3+4}_{-2-5}, 70^{+30}_{-20} \pm 30)$ MeV/c^2

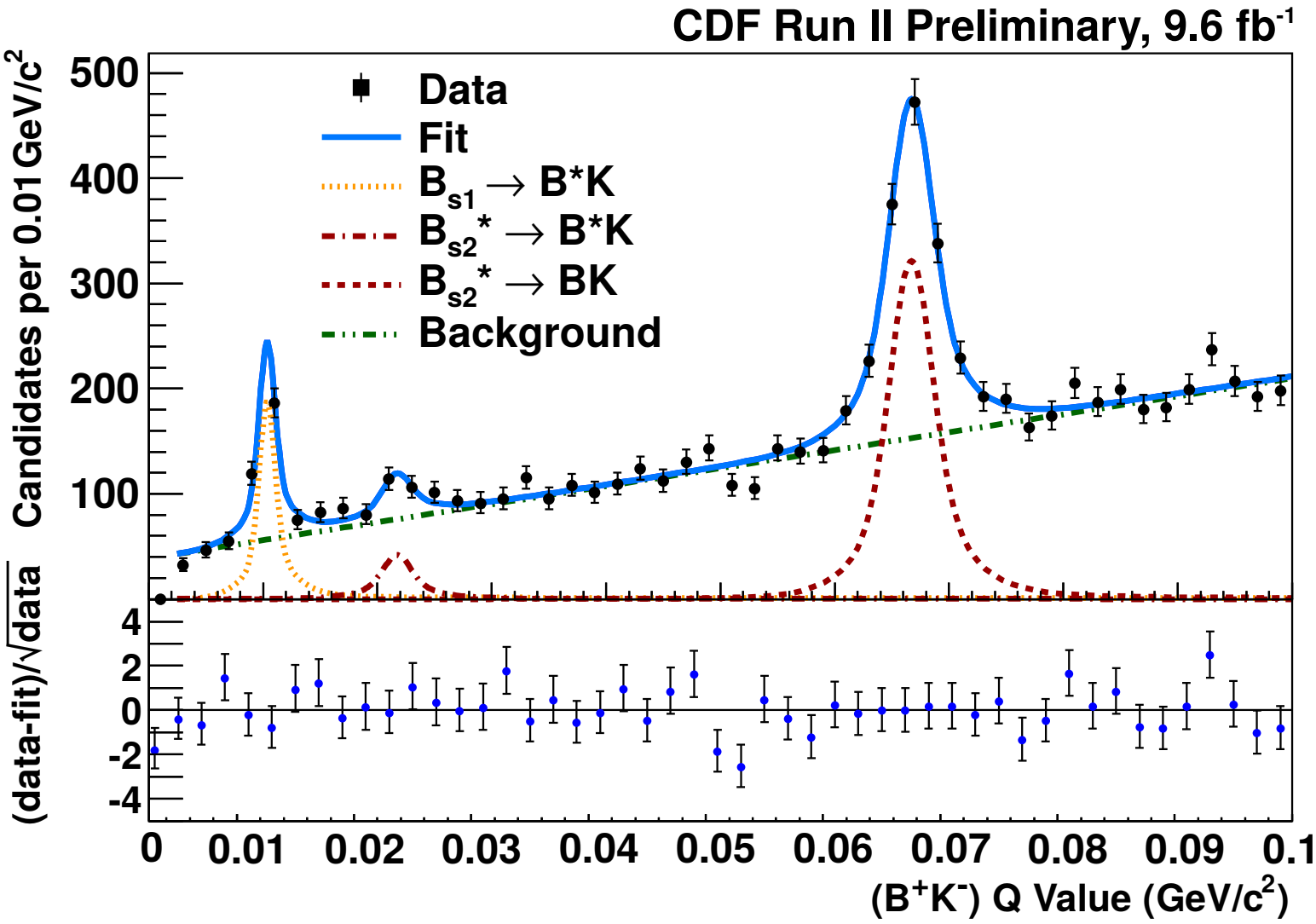
CHARGED $B\pi$ SPECTRUM



$\Gamma(B_1, B_2^*, B(5970)) = (49^{+12+2}_{-10-13}, 11^{+4+3}_{-3-4}, 60^{+30}_{-20} \pm 40)$ MeV/c^2

$B(5970)$ could be radial excitation of B decaying to $B^*\pi$ (photon from B^* missed), or radial excitation of B^* decaying to $B\pi$

B^+K^- SPECTRUM



$$\Gamma(B_{s1}, B^*_{s2}) = (0.5 \pm 0.3 \pm 0.3, 1.4 \pm 0.4 \pm 0.4)\ \text{MeV}/c^2$$

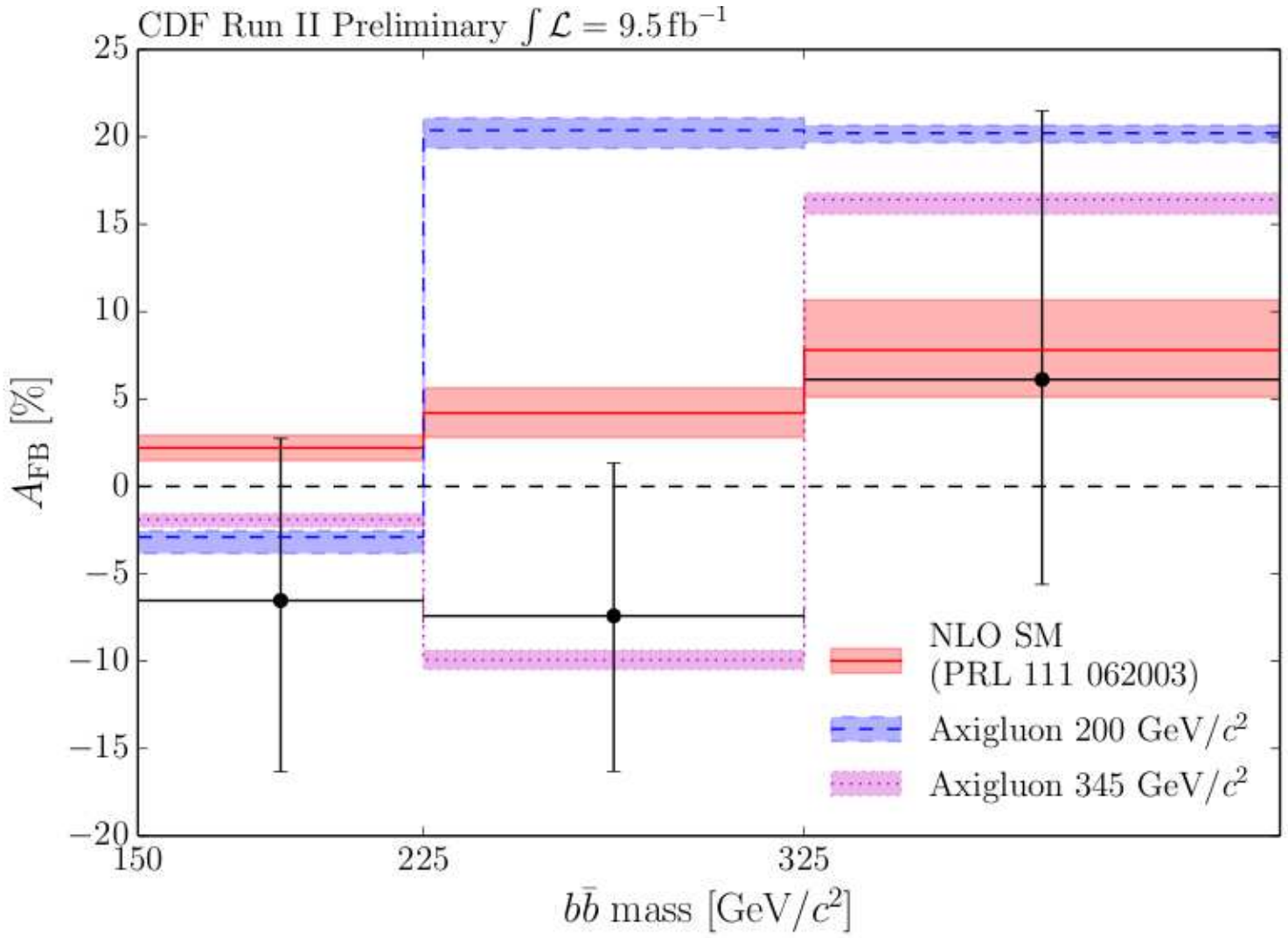
CONCLUSIONS

CDF: unique capabilities for studying b physics:

- b baryon masses, lifetimes agree with SM predictions
- Charmless b baryon decays show no CP violation (yet!)
- B_c production $\sigma \times \mathcal{B}(J/\psi\mu\nu)$ measured
- Measurement of $A_{FB}(b\bar{b})$ rules out 200 GeV axigluon
- L-excited B mesons and new state $\rightarrow B\pi$

These capabilities exceeded expectations! My thanks to CDF colleagues for the chance to present these results

A_{FB} VERSUS $b\bar{b}$ MASS



In the three bins $A_{FB} = (-6.5^{+9.3}_{-9.8}, -7.4^{+8.8}_{-9.9}, 6.1^{+15.4}_{-11.7})\%$