Bottom-Quark Forward-Central Asymmetry at LHCb

Christopher W. Murphy

Pisa, Scuola Normale Superiore

Implications of LHCb measurements and future prospects – 13/10/2016

Outline

This talk:

(1) Introduction

(2) Theoretical Predictions

(3) Current Experimental Results

Next talk by Rhorry Gauld:

(4) Future Prospects

Bibliography

- B. Grinstein, and C.M., "Bottom-Quark Forward-Backward Asymmetry in the Standard Model and Beyond," *Phys.Rev.Lett.* **111** (2013) 062003, [arXiv:1302.6995].
- C.M., "Bottom-Quark Forward-Backward and Charge Asymmetries at Hadron Colliders," *Phys.Rev.* **D92** (2015) 054003, [arXiv:1504.02493].
- R. Gauld, U. Haisch, B.D. Pecjak, and E. Re, "Beauty-quark and charm-quark pair production asymmetries at LHCb," *Phys.Rev.* **D92** (2015) 034007, [arXiv:1505.02429].

Introduction

- Million dollar question:
  - What lies Beyond the Standard Model (BSM)?
- Measuring asymmetries (forward-backward, CP, forward-central, production, forward-backward of decay products, . . .) helps to answer this question.

$$A(x) \equiv \frac{N(x > 0) - N(x < 0)}{N(x > 0) + N(x < 0)}$$

- precision predictions / small SM values $\rightarrow$ excellent probe of BSM

Introduction

- Million dollar question:
  - What lies Beyond the Standard Model (BSM)?
- Measuring asymmetries (forward-backward, CP, forward-central, production, forward-backward of decay products, . . .) helps to answer this question.

$$A(x) \equiv \frac{N(x>0) - N(x<0)}{N(x>0) + N(x<0)}$$

- precision predictions / small SM values $\rightarrow$ excellent probe of BSM

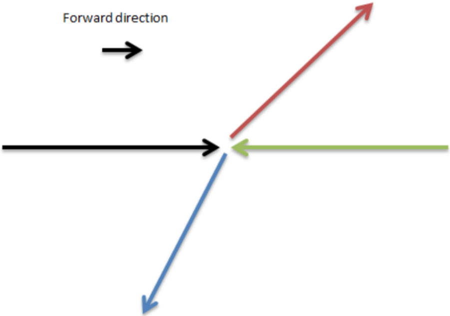
Forward-Backward Asymmetries

Collider w/ asymmetric initial state (e^+e^-, $p\bar{p}$):

$$A_{FB} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

Example:

- $e^- e^+ \to Q\bar{Q}$
- $\Delta y = y_Q - y_{\bar{Q}}$



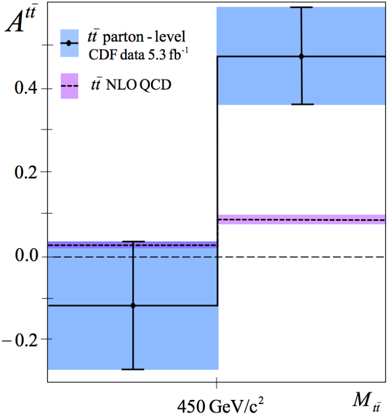
Forward-Backward Asymmetries

LEP 1 – $A_{FB}^{(0,b)}$ (Z-pole) – 2.3σ

Quantity	Value	Standard Model	Pull
M_Z [GeV]	91.1876 ± 0.0021	91.1880 ± 0.0020	-0.2
Γ_Z [GeV]	2.4952 ± 0.0023	2.4955 ± 0.0009	-0.1
$\Gamma(\text{had})$ [GeV]	1.7444 ± 0.0020	1.7420 ± 0.0008	—
$\Gamma(\text{inv})$ [MeV]	499.0 ± 1.5	501.66 ± 0.05	—
$\Gamma(\ell^+\ell^-)$ [MeV]	83.984 ± 0.086	83.995 ± 0.010	—
σ_{had}[nb]	41.541 ± 0.037	41.479 ± 0.008	1.7
R_e	20.804 ± 0.050	20.740 ± 0.010	1.3
R_μ	20.785 ± 0.033	20.740 ± 0.010	1.4
R_τ	20.764 ± 0.045	20.785 ± 0.010	-0.5
R_b	0.21629 ± 0.00066	0.21576 ± 0.00003	0.8
R_c	0.1721 ± 0.0030	0.17226 ± 0.00003	-0.1
$A_{FB}^{(0,e)}$	0.0145 ± 0.0025	0.01616 ± 0.00008	-0.7
$A_{FB}^{(0,\mu)}$	0.0169 ± 0.0013		0.6
$A_{FB}^{(0,\tau)}$	0.0188 ± 0.0017		1.6
$A_{FB}^{(0,b)}$	0.0992 ± 0.0016	0.1029 ± 0.0003	-2.3
$A_{FB}^{(0,c)}$	0.0707 ± 0.0035	0.0735 ± 0.0002	-0.8
$A_{FB}^{(0,s)}$	0.0976 ± 0.0114	0.1030 ± 0.0003	-0.5
$\bar{s}_\ell^2$	0.2324 ± 0.0012	0.23155 ± 0.00005	0.7

PDG

CDF – $A_{FB}^{t\bar{t}}$ ($M_{t\bar{t}} > 450$ GeV) – 3.4σ



CDF arXiv:1101.0034

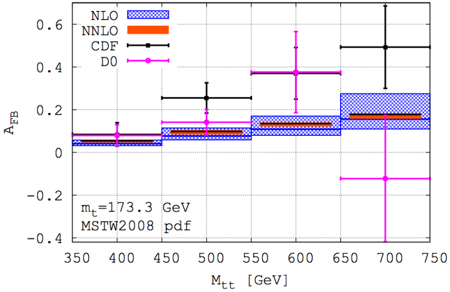
Forward-Backward Asymmetries

LEP 1 – $A_{FB}^{(0,b)}$ (Z-pole) – 2.3σ

Quantity	Value	Standard Model	Pull
M_Z [GeV]	91.1876 ± 0.0021	91.1880 ± 0.0020	-0.2
Γ_Z [GeV]	2.4952 ± 0.0023	2.4955 ± 0.0009	-0.1
$\Gamma(\text{had})$ [GeV]	1.7444 ± 0.0020	1.7420 ± 0.0008	—
$\Gamma(\text{inv})$ [MeV]	499.0 ± 1.5	501.66 ± 0.05	—
$\Gamma(\ell^+\ell^-)$ [MeV]	83.984 ± 0.086	83.995 ± 0.010	—
σ_{had}[nb]	41.541 ± 0.037	41.479 ± 0.008	1.7
R_e	20.804 ± 0.050	20.740 ± 0.010	1.3
R_μ	20.785 ± 0.033	20.740 ± 0.010	1.4
R_τ	20.764 ± 0.045	20.785 ± 0.010	-0.5
R_b	0.21629 ± 0.00066	0.21576 ± 0.00003	0.8
R_c	0.1721 ± 0.0030	0.17226 ± 0.00003	-0.1
$A_{FB}^{(0,e)}$	0.0145 ± 0.0025	0.01616 ± 0.00008	-0.7
$A_{FB}^{(0,\mu)}$	0.0169 ± 0.0013		0.6
$A_{FB}^{(0,\tau)}$	0.0188 ± 0.0017		1.6
$A_{FB}^{(0,b)}$	0.0992 ± 0.0016	0.1029 ± 0.0003	-2.3
$A_{FB}^{(0,c)}$	0.0707 ± 0.0035	0.0735 ± 0.0002	-0.8
$A_{FB}^{(0,s)}$	0.0976 ± 0.0114	0.1030 ± 0.0003	-0.5
$\bar{s}_\ell^2$	0.2324 ± 0.0012	0.23155 ± 0.00005	0.7

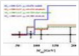
PDG

- No significant excess w.r.t. SM
- Agreement not perfect



Czakon, Fielder, Mitov arXiv:1411.3007

What is the Source of A_{FB}?



Quark asymmetries hint at physics beyond the Standard Model ▸ phys.org

84

3 years ago by davidreiss666

21 comments share

All 21 Comments

sorted by: best (suggested)

[–] **hikaruzero** 1 7 points 3 years ago*

Why should there be any asymmetry at all, even in the Standard Model? Anybody who's up on their science care to elaborate?

Edit: I realize I worded the above question pretty vaguely, so for anyone else who wants to take a stab, please see a revised question below:

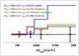
What is the *source* of the forwards-backwards asymmetry that is predicted by the Standard Model? For example, is this due to neutral particle oscillation in briefly-existing B+B-bar systems, or due to the CP-violating phase in the CKM matrix, etc.?

2nd Edit: I was given the answer by one of the paper's authors! Check it out!

permalink embed

What is the Source of A_{FB}?

84



Quark asymmetries hint at physics beyond the Standard Model ▸ phys.org

3 years ago by davidreiss666

21 comments share

All 21 Comments

sorted by: best (suggested)

[–] hikaruzero 1 7 points 3 years ago*

Why should there be any asymmetry at all, even in th ...
elaborate?

Edit: I realize I worded the above question pretty vag ... a
revised question below:

What is the *source* of the forwards-backwards asymm ...
this due to neutral particle oscillation in briefly-existin ... KM
matrix, etc.?

2nd Edit: I was given the answer by one of the paper

HANDWAVING IS UNDERSTANDING

Home From Radiation Parity Violation

QUALITATIVE EXPLANATION OF FORWARD BACKWARD ASYMMETRY

After phys.org published a report on my work with Chris Murphy on Forward-Backward asymmetry in b-bbar production at the Tevatron, I was alerted to a report and discussion of it in reddit.

I wanted to clarify some questions in reddit about why the Standard Model has forward-backward asymmetries. The inquisitive contributor was adamant: not what is it but why is it. I welcome the challenge. After all, Feynman said something along the lines that if you cannot explain it to a non-specialist, you simply don't understand it.

I found that the space provided by reddit is too limiting, so I decided to write my own page about it and posted the link. There are a couple of

[–] bgrinstein 2 points 3 years ago

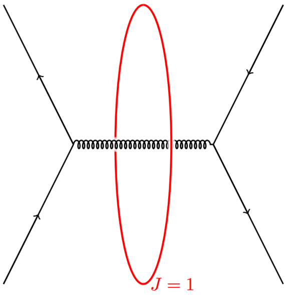
I can explain :"why" there is a FB asymmetry. (I should, I am one of the authors of the paper being reported here). But it takes more than a couple of lines. So I prepared a web page for this. Visit:

http://leewick.ucsd.edu/~ben/FBasymmetry/Blank.html

permalink embed parent

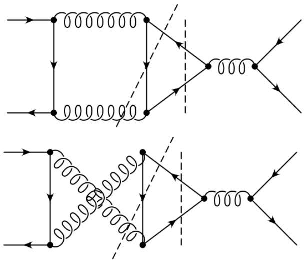
What is the Source of A_{FB}?

(1) Kinematics – need odd powers of $\cos\theta$ in $d\sigma$



- Spin-0: $P_0(\cos\theta)$
- Spin-1: $P_{0,1,2}(\cos\theta)$
- t-channel: $P_{\text{all}}(\cos\theta)$

Fig. from CDF Conf. Note 10974



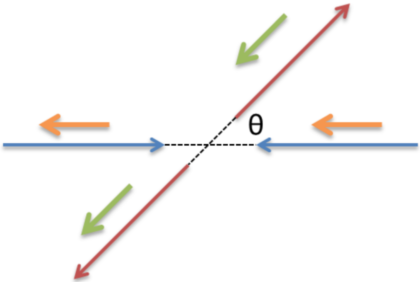
- Interference between 1- and 2-photon/gluon exchange
- $d\sigma$ odd in $\cos\theta$ by $\mathcal{C}$-conjugation invariance

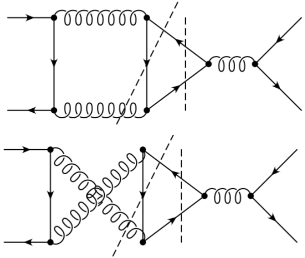
Fig. from Kühn, Rodrigo hep-ph/9807420

What is the Source of A_{FB}?

(2) (non-)symmetries (gauge, discrete) of theory

$$\frac{d\sigma}{d\Omega}(q_L\bar{q}_R \to V_\mu \to Q_L\bar{Q}_R) \sim g_{Lq}^2 g_{LQ}^2 (1+\cos\theta)^2$$





$U(1)$, $SU(N \geq 3) \to A_{FC}$ at NLO

Fig. from Kühn, Rodrigo hep-ph/9807420

Parity violation $\to$ tree level A_{FC}

Heavy Quark A_{FB} at Hadron Colliders

Contributions to asymmetry:

- LEP – directly sensitive to asymmetry from matrix elements
- Tevatron – matrix elements *and* PDFs must be asymmetric

Extracting a heavy quark asymmetry:

- $t\bar{t}$: decay products preserve info about $A_{FB}^{t\bar{t}}$
- $b\bar{b}$, $c\bar{c}$: hadronize before decaying
  - Hadron based: $p\bar{p} \to B^{\pm}X$ w/ $q_{FB} = -Q_B \,\mathrm{sign}(\eta_B)$

$$A_{FB}(B^{\pm}) = \frac{N(q_{FB} > 0) - N(q_{FB} < 0)}{N(q_{FB} > 0) + N(q_{FB} < 0)}$$

  - Jet based: $p\bar{p} \to b\bar{b}X$ w/ $\Delta y = y_b - y_{\bar{b}}$

$$A_{FB}^{b\bar{b}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

What about at LHCb?

- LHC: symmetric initial state
  - $A_{FB} = 0$ by construction
  - underlying matrix elements still asymmetric
  - exploit asymmetry between PDFs of q and $\bar{q}$
- Hadron based: $pp \to B^{\pm}X$ – production asymmetry

$$A_P(B^{\pm}) = \frac{N(B^-) - N(B^+)}{N(B^-) + N(B^+)}$$

- Jet based: $pp \to b\bar{b}X$ – forward-central asymmetry

$$A_{FC}^{b\bar{b}} = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$$

now with $\Delta|y| = |y_b| - |y_{\bar{b}}|$

A_{FC} in the Standard Model

$$A_{FC} \sim \frac{\alpha^2 \tilde{N}_0 + \alpha_s^3 N_1 + \alpha_s^2 \alpha \tilde{N}_1 + \alpha_S^4 N_2 + \cdots}{\alpha^2 \tilde{D}_0 + \alpha_s^2 D_0 + \alpha_s^3 D_1 + \alpha_s^2 \alpha \tilde{D}_1 + \cdots}$$

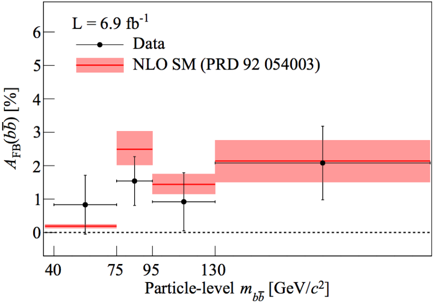
- NLO QCD dominant contribution to $A_{FB}^{t\bar{t}}$ at hadron colliders ($\sim \alpha_s N_1 / D_0 + \cdots$)
- Grinstein, CM 1302.6995 showed previously neglected tree level Z exchange dominates $A_{FB,FC}^{b\bar{b}}$ for $M_{b\bar{b}} \sim M_Z$
- Z can decay to $b\bar{b}$, $c\bar{c}$ (but not $t\bar{t}$) $\rightarrow$ resonant enhancement ($Z - \gamma$ interference not enhanced)
- Gauld et al. 1505.02429: Z contribution to $\tilde{N}_1$ (not enhanced), $O(\alpha^2 \alpha_s)$ corrections, qg initiated asymmetry ($\sim 10\%$ of N_1, unlike $t\bar{t}$ case)

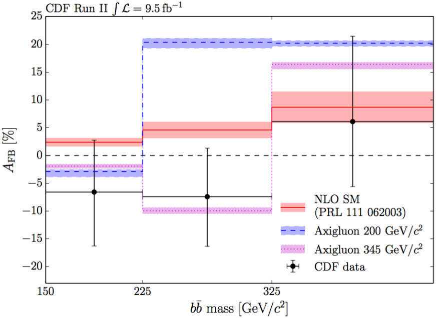
A_{FC} in the Standard Model

$$A_{FC} \sim \frac{\alpha^2 \tilde{N}_0 + \alpha_s^3 N_1 + \alpha_s^2 \alpha \tilde{N}_1 + \alpha_S^4 N_2 + \cdots}{\alpha^2 \tilde{D}_0 + \alpha_s^2 D_0 + \alpha_s^3 D_1 + \alpha_s^2 \alpha \tilde{D}_1 + \cdots}$$

- NLO QCD dominant contribution to $A_{FB}^{t\bar{t}}$ at hadron colliders ($\sim \alpha_s N_1/D_0 + \cdots$)
- Grinstein, CM 1302.6995 showed previously neglected tree level Z exchange dominates $A_{FB,FC}^{b\bar{b}}$ for $M_{b\bar{b}} \sim M_Z$
- Z can decay to $b\bar{b}$, $c\bar{c}$ (but not $t\bar{t}$) $\rightarrow$ resonant enhancement ($Z - \gamma$ interference not enhanced)
- Gauld et al. 1505.02429: Z contribution to $\tilde{N}_1$ (not enhanced), $O(\alpha^2 \alpha_s)$ corrections, qg initiated asymmetry ($\sim 10\%$ of N_1, unlike $t\bar{t}$ case)

CDF $A_{FB}^{b\bar{b}}$ Results



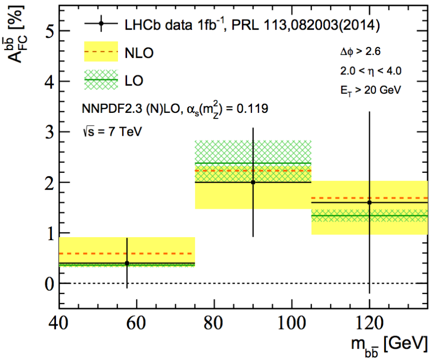


Low Mass Analysis 1601.06526

High Mass Analysis 1504.06888

SM predictions from CM 1504.02493

LHCb 7 TeV $A_{FC}^{b\bar{b}}$ Results



NLO	$A_{FC}^{b\bar{b}}$ [%]	QCD	QCD-EW	EW
$m_{b\bar{b}} \in [40, 75]$ GeV	$0.59^{+0.32}_{-0.26}$	100.6%	−4.9%	4.3%
$m_{b\bar{b}} \in [75, 105]$ GeV	$2.23^{+0.09}_{-0.75}$	33.5%	−1.4%	67.9%
$m_{b\bar{b}} > 105$ GeV	$1.69^{+0.34}_{-0.72}$	86.6%	−7.1%	20.5%
LO				
$m_{b\bar{b}} \in [40, 75]$ GeV	$0.36^{+0.04}_{-0.03}$	105.0%	−5.1%	0.2%
$m_{b\bar{b}} \in [75, 105]$ GeV	$2.38^{+0.45}_{-0.37}$	30.9%	−1.2%	70.3%
$m_{b\bar{b}} > 105$ GeV	$1.34^{+0.12}_{-0.12}$	96.8%	−8.3%	11.5%

Shape of SM prediction drastically different w/o EW terms

Fig. & SM predictions from Gauld, Haisch, Pecjak, Re 1505.02429; LHCb results from 1406.4789

LHCb $A_{FC}^{b\bar{b}}$ Results & Future Prospects

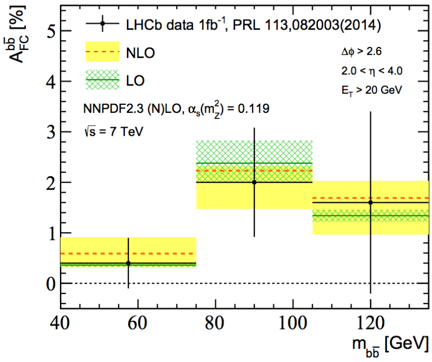
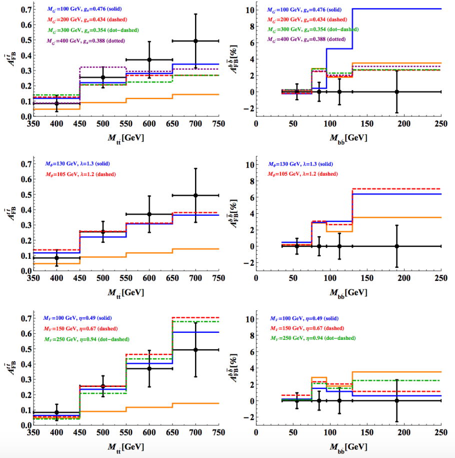


Fig. & SM predictions from Gauld et al. 1505.02429; LHCb results from 1406.4789

SM Future Prospects

- $A_{FC}^{b\bar{b}}$ becomes systematically limited around ~ 10 fb^{-1}
- Central value smaller at 13/14 TeV than 7/8 TeV (even smaller for 100 TeV)
- $A_{FC}^{b\bar{b}}(Z\text{-pole})$ currently non-zero at 1.8σ
  - 3.0σ w/ 10 fb^{-1} & same central value
  - 1.7σ w/ 10 fb^{-1} & 13 TeV SM central value

LHCb $A_{FC}^{b\bar{b}}$ Results & Future Prospects



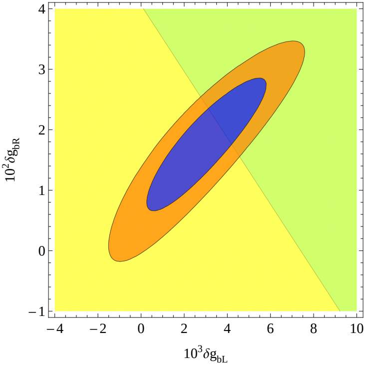
BSM Future Prospects

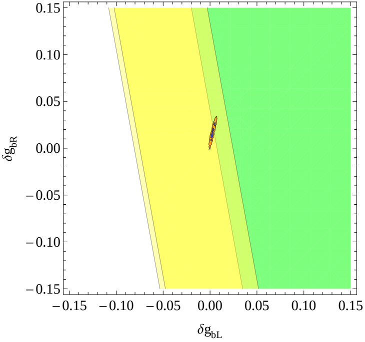
- Lighter mass BSM ($M \lesssim 250$ GeV) already constrained by Tevatron + LHC7
- More data useful for constraining heavier BSM scenarios
- Distinguish flavor structure of competing BSM models

Grinstein, CM 1302.6995; CM 1504.02493

Modified $Zb\bar{b}$ Couplings

- Current hadron collider results not competitive w/ LEP
- See next talk by Rhorry for future prospects





CM 1504.02493

Production Asymmetries at LHCb

Production asymmetry can mimic CP violation

$$A(t) \approx A_{CP} + A_D + A_P \frac{\cos(\Delta m t)}{\cosh(\Delta\Gamma t/2)}$$

$$A_{CP} = \frac{\Gamma(\bar{B}^0 \to \bar{f}) - \Gamma(B^0 \to f)}{\Gamma(\bar{B}^0 \to \bar{f}) + \Gamma(B^0 \to f)}, \quad A_D = \frac{\epsilon_{\bar{f}} - \epsilon_f}{\epsilon_{\bar{f}} + \epsilon_f}, \quad A_P = \frac{N(\bar{B}^0) - N(B^0)}{N(\bar{B}^0) + N(B^0)}$$

- $A_P(D_s^\pm) = (-0.33 \pm 0.22 \pm 0.10)\%$ 1205.0897
- $A_P(D^\pm) = (-0.96 \pm 0.26 \pm 0.18)\%$ 1210.4112
- $A_P(B^0) = (-0.35 \pm 0.76 \pm 0.28)\%$ 1408.0275
- $A_P(B_s^0) = (1.09 \pm 2.61 \pm 0.66)\%$ 1408.0275

Production Asymmetries at LHCb

Production asymmetry can mimic CP violation

$$A(t) \approx A_{CP} + A_D + A_P \frac{\cos(\Delta m t)}{\cosh(\Delta\Gamma t/2)}$$

$$A_{CP} = \frac{\Gamma(\bar{B}^0 \to \bar{f}) - \Gamma(B^0 \to f)}{\Gamma(\bar{B}^0 \to \bar{f}) + \Gamma(B^0 \to f)}, \quad A_D = \frac{\epsilon_{\bar{f}} - \epsilon_f}{\epsilon_{\bar{f}} + \epsilon_f}, \quad A_P = \frac{N(\bar{B}^0) - N(B^0)}{N(\bar{B}^0) + N(B^0)}$$

LHCb-CONF-2012-031

- Reports $\sigma(pp \to \Lambda_b^0 X)$ and $\sigma(pp \to \bar{\Lambda}_b^0 X)$
- $A_P(\Lambda_b^0) = (-0.23 \pm 0.13)\%$ w/ 36.4 pb^{-1}
- $A_P(\Lambda_b^0) = (-0.23 \pm 0.06)\%$ (naïvely) w/ full Run-1 dataset, non-zero at 3.4σ

Summary

- Measuring a more significant non-zero asymmetry at 13/14 TeV (w.r.t. 7 TeV) naïvely requires improved systematics or undiscovered BSM
- More data useful for constraining BSM scenarios w/ $M \gtrsim 250$ GeV (provided there is some motivation for such models)
- Update $A_P(\Lambda_b^0)$ measurement with at least full Run-1 dataset (currently stat. limited)
- Charm-Quark Asymmetry?

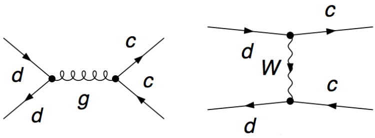
Backup Slides

Charm-Quark Asymmetry

Z-pole asymmetry about half as big as $b\bar{b}$ case:

$$\frac{\tilde{N}_{0,c\bar{c}}}{\tilde{N}_{0,b\bar{b}}} \sim \frac{3-8s_W^2}{3-4s_W^2} \approx 0.55$$

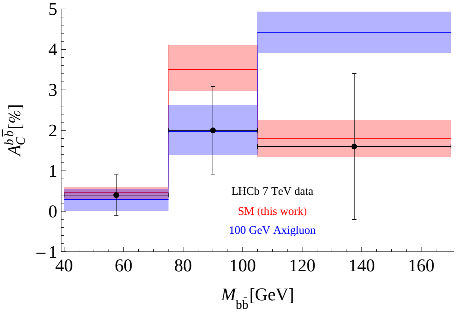
t-channel W exchange – less CKM suppression than $b\bar{b}$, $t\bar{t}$:



$$\frac{d\sigma_A^{\alpha_s\alpha}}{d\cos\theta} = -\frac{\alpha_s\alpha\,|V_{cd}|^2}{s_W^2}\frac{\pi C_F}{N_C}\frac{\beta\cos\theta}{8\hat{s}} f(\cos^2\theta,\, m_c^2,\, M_W^2,\, \hat{s})$$

$\sim -6\%$ of NLO QCD contribution to $A_{FC}^{c\bar{c}}$ at large $M_{c\bar{c}}$ CM 1504.02493

LHCb $A_{FC}^{b\bar{b}}$ Results & Future Prospects



CM 1504.02493

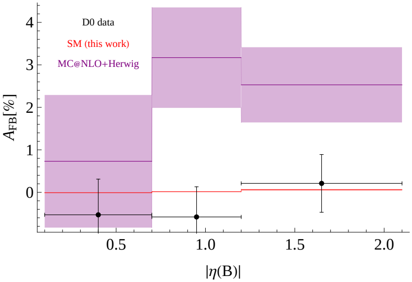
BSM Future Prospects

- Lighter mass BSM ($M \lesssim 250$ GeV) already constrained by Tevatron + LHC7
- More data useful for constraining heavier mass scenarios
- Distinguish flavor structure of competing BSM scenarios

Hadron Asymmetry Measurements

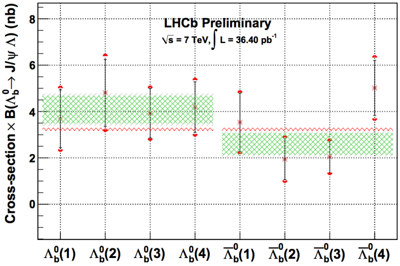
- Perturbative calculation not always relevant
- MC generators not always accurate (worse for $A_{FB}(\Lambda_b^0)$)

$A_{FB}(B^{\pm})$



D0 1411.3021; CM 1504.02493

$A_P(\Lambda_b^0)$



MC seems fine here

LHCb-CONF-2012-031

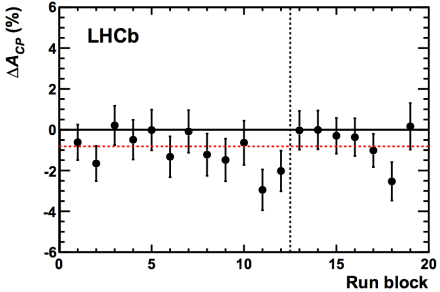
Production and CP Asymmetries at LHCb

Production asymmetry can mimic CP violation

$$A(t) \approx A_{CP} + A_D + A_P \frac{\cos(\Delta m t)}{\cosh(\Delta\Gamma t/2)}$$

$$A_{CP} = \frac{\Gamma(\bar{B}^0 \to \bar{f}) - \Gamma(B^0 \to f)}{\Gamma(\bar{B}^0 \to \bar{f}) + \Gamma(B^0 \to f)}, \quad A_D = \frac{\epsilon_{\bar{f}} - \epsilon_f}{\epsilon_{\bar{f}} + \epsilon_f}, \quad A_P = \frac{N(\bar{B}^0) - N(B^0)}{N(\bar{B}^0) + N(B^0)}$$

Measure instead $\Delta A_{CP} = A_{CP}(K^-K^+) - A_{CP}(\pi^-\pi^+)$; A_D, A_P cancel



1112.0938 See also talks by Petridis, de Boer, Davis, . . .

Forward-Backward Asymmetry of Decay Products

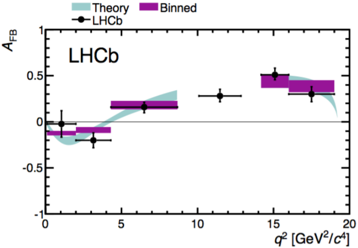
$$\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\,\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\hat{\phi}} = \frac{9}{16\pi}\Big[F_{\mathrm{L}}\cos^2\theta_K + \frac{3}{4}(1-F_{\mathrm{L}})(1-\cos^2\theta_K) - F_{\mathrm{L}}\cos^2\theta_K(2\cos^2\theta_\ell - 1) + \frac{1}{4}(1-F_{\mathrm{L}})(1-\cos^2\theta_K)(2\cos^2\theta_\ell-1) + S_3(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\cos 2\hat{\phi} + \frac{4}{3}A_{\mathrm{FB}}(1-\cos^2\theta_K)\cos\theta_\ell + A_9(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\sin 2\hat{\phi}\Big].$$

$$R_K = \frac{\Gamma(B^+ \to K^+\mu^+\mu^-)}{\Gamma(B^+ \to K^+ e^+ e^-)}$$

$$R_K = 0.745^{+0.090}_{-0.074} \pm 0.035$$

$$M^2_{\ell^+\ell^-} \in [1,\ 6]\ \mathrm{GeV}^2$$

2.6σ deviation from SM



1304.6325 (left)
1406.6482 (right)

See also talks by Martin Camalich, Petridis, Mahmoudi, . . .

Lepton A_{FB} in $B^0 \to K^{*0}\ell^+\ell^-$ at LHCb

- Take ratio of $A_{FB}(\mu^+\mu^-)$ vs. $A_{FB}(e^+e^-)$
- Distinguish between competing explanations of R_K

Observable	Ratio of muon vs. electron mode			
	$C_9^{\rm NP} = -1.07$	-1.10	-0.53	-1.06
	$C_9' = 0$	0.45	0	0
	$C_{10}^{\rm NP} = 0$	0	0.53	0.16
$10^7 \frac{d\rm BR}{dq^2}(\bar{B}^0 \to \bar{K}^{*0}\ell^+\ell^-)_{[1,6]}$	0.83	0.77	0.77	0.79
$10^7 \frac{d\rm BR}{dq^2}(\bar{B}^0 \to \bar{K}^{*0}\ell^+\ell^-)_{[15,19]}$	0.78	0.72	0.75	0.74
$F_L(\bar{B}^0 \to \bar{K}^{*0}\ell^+\ell^-)_{[1,6]}$	0.93	0.90	0.98	0.93
$F_L(\bar{B}^0 \to \bar{K}^{*0}\ell^+\ell^-)_{[15,19]}$	1.00	0.97	1.00	1.00
$A_{\rm FB}(\bar{B}^0 \to \bar{K}^{*0}\ell^+\ell^-)_{[4,6]}$	**0.33**	**0.33**	0.74	**0.35**
$A_{\rm FB}(\bar{B}^0 \to \bar{K}^{*0}\ell^+\ell^-)_{[15,19]}$	0.90	0.96	0.99	0.92

Altmannshofer, Straub 1411.3161

See also talks by Martin Camalich, Petridis, Mahmoudi, . . .