

**Comments by VU-Nikhef in Amsterdam on LHCb-PAPER-2011-029:  
First evidence of direct CP violation in charmless two-body decays of  $B_s^0$   
mesons.**

Dear authors of this important paper,

We discussed the draft with Nikhef and VU Amsterdam group members on Friday 27. First of all we would like to congratulate you with finishing the analysis and thank you for providing such a high quality draft. It must have been difficult to reduce its length to that of a Letter; the information density is still rather high.

We start with a few general comments. See in the attached .tex or .pdf file for the more detailed comments on the text.

- In reports of this analysis at conferences, we have always separated the mass distributions for  $B$  and  $\bar{B}$ , which so clearly shows the asymmetry even without a fit. This is potentially a textbook plot and we feel that we really owe it to the community to reproduce it in the paper.

We understand that it is hard to fit this in the paper, but since you do it in Fig. 2 (which is much less important), it should be possible. You could for example save space by plotting the label and title on the left vertical axis only once when drawing  $B$  and  $\bar{B}$  next to each other. The size of the legend in the plot could easily be adjusted, such that its font size matches the text size when the figure is reduced to the column width.

- In between lines 346 and 383 you make an effort to explain how the experimental asymmetries are extracted from the  $D$  sample. However, we feel that people reading this will still not understand it. It would really help to explain in more detail what are the "various contributions" (line 351), how many unknowns there are and what are the constraints. Since you are limited by space, we propose to remove the discussion of the fitted curves (line 364 till 376), which is not important to get the result.

- You explain how the radiative tails for the two-body decay has been taken into account. However, we have seen in other analyses that the mass resolution is not properly described by a single Gaussian leading to tails on both sides. This potentially affects the extraction of the  $B_s$  asymmetry. How do you deal with this?

- It is quite customary in CPV measurements to report the asymmetry in the background as well. If the background is symmetric it gives more confidence to our claim of CPV. If it is not symmetric, you'd want to explain why. Do we have anything to hide here?

- You have tried to save space by using as few formulas in display format as possible. Unfortunately, the definition of  $A_{CP}$  is rather hard to find now. In addition you rely a lot on a function ' $\Phi$ ' for the asymmetries, the definition of which escaped some of us entirely. In the attached pdf (and tex) file, we make a proposal to fix this.

- In the conclusion you claim a significance of  $6\sigma$ , but you don't specify how the significance is evaluated. We guess that you assumed that all errors are Gaussian. How confident are you about this? If you assume Gaussian errors, then we propose to specify that when quoting the significance.

Below follow comments on the text.

- Abstract.
  - Integrated luminosity  $0.32 \rightarrow 0.37$ , or justify this number. We rely on <https://twiki.cern.ch/twiki/bin/viewauth/LHCbPhysics/>

LuminosityMeasurements#Approximation\_for\_Stripping13b\_a

- Remove 'unambiguous' as it suggests that previous results were ambiguous. Move ", with a significance exceeding  $6\sigma$ ," between 'observation' and "of CP violation".

- Lines 164-166:  
It's correct that  $B_s$  is the last neutral meson. But as you look (also) for direct CP, all charged mesons could also yield CPV:  $\pi^+$  (unlikely),  $K^+$ ,  $D^+$ ,  $D_s$ ,  $B^+$ ,  $B_c$ .  
Why are they ignored?
- Line 176:  
Replace 'upon' with 'on'.
- Line 178:  
Replace "with the LHCb detector" with "with data collected with the LHCb detector".
- Line 184:  
Add " $pp$  collision" before 'data'.
- Lines 176-197:  
The ordering in this section is unconventional and shows several jumps between detector and physics issues. We propose to move the sentence starting in line 191 ("The direct ... Tevatron [13-15]") directly after 'throughout' in line 179. Then, start a new paragraph with "LHCb is a forward spectrometer ..."
- Line 191, 192:  
- Replace "decay rates" by "decay widths".  
- The choice of  $\Phi$  for asymmetry is counterintuitive.  $\mathcal{A}$  might be a better choice throughout the Letter.  
- As this is the most important equation including the first use and the definition of  $\Phi$  which is used at several places in this Letter, it deserves an Equation. Now it is buried in the dense text.  
- ( $f = K^+\pi^-$ ) could be mistaken as  $\bar{f}$  in stead of  $f$  belonging to  $B_s^0$ .  
- The following may be a solution for the above mentioned problems:

$$A_{CP}(B_{(s)}^0 \rightarrow K\pi) = \mathcal{A}[\Gamma(\bar{B}_{(s)}^0 \rightarrow f), \Gamma(B_{(s)}^0 \rightarrow \bar{f})], \quad (1)$$

where  $f = K^-\pi^+$  for  $B^0$  decay,  $f = \pi^-K^+$  for  $B_s^0$  decay and  $\mathcal{A}[\Gamma_1, \Gamma_2] = (\Gamma_1 - \Gamma_2)/(\Gamma_1 + \Gamma_2)$ .

- Lines 213-224:  
To save space and not confuse the reader with extra numbers, you could remove the values for the HLT cuts. They are anyway superseded by the offline cuts in table I.
- Line 218 and other places :  
Could  $IP$  be replaced by  $d_{IP}$  as is done for  $d_{CA}$ ? It is unusual to have a variable consisting out of two characters. To avoid confusion with  $I \times P$  the variable  $IP$  should then be written as IP like in IQ.
- Table I:  
- We discussed if  $h_1, h_2$  in stead of  $h, h'$  would be better recognized as a distinction between two types of hadrons,  $\pi$  and  $K$ . Maybe  $h, h'$  can be omitted at all as the signs  $+$  and  $-$  in their context make this distinction. In that case it is also not needed to add superscript  $h$  to Track  $p_T$  and  $IP$ .

- Does the order of the variables have a relevant meaning? If not, it would be best to start with the  $B$  properties.

- Line 226;  
Add "sets of" between 'Two' and "offline selection criteria".
- Line 235, 458  
Tab. → Table.
- Line 238:
  - Is it relevant here to separate between statistic and systematic? If so, indicate the two uncertainties.
  - To save space we might consider to skip the equation and state only once that "a tighter selection is needed because the probability for a  $b$  quark to decay as  $B_s^0 \rightarrow K\pi$  is about 14 times smaller than to decay as  $B^0 \rightarrow K\pi$  [16]."
- Line 244-245:  
Replace "using the particle identification ... detectors." with "using particle identification provided by the two Ring-Imaging Cherenkov (RICH) detectors".
- Line 245-252:  
With "great importance" and "key role" this section becomes a bit prosaic. We propose to remove "The calibration of PID observables ... great importance for this analysis" and replace the rest with something like: "To estimate the background from other two-body  $B$  decays with a misidentified pion or kaon, the relative efficiencies of the RICH PID selections must be determined".
- Line 258, 259:  
Replace "In neither case is use made of PID information in selecting ..." with "In neither case PID information is used to select ..."
- Lines 268-269:  
Missing hyphen in "meas-urement of ...."
- Line 272:  
Add " $K\pi$  invariant" before "mass spectra".
- Line 278:  
*Argus* should be roman style in the text, like in the reference.
- Line 304:  
We are afraid that only few readers will understand why the minus sign is in brackets.
- Line 312:  
The limits for the integrals in the equation between line 311 and 312 are missing. Without limits, kappa is not a number.
- Lines 316-319:
  - "... by using signal decay time distributions extracted from data" is too vague. Maybe "... by comparing experimental and theoretical distributions on control channels of charm meson decays" describes the procedure as well or better.
  - Does it make sense to consider only statistical errors here?

- Fig.1 :
  - We have argued above that the figure should be split between  $B$  and  $\bar{B}$ . Even in case you keep it, some work must be done to make this publication quality, in particular the fonts: no need to use bold, use same font-size for x and y axis, choose font not much larger than in text ('a', 'LHCb'), etc.
  - Do you understand why the fit in Fig.1a looks poor between 5.4 and 5.5 GeV/c<sup>2</sup>?
- Line 339, 340:
 

Remove "(and some trigger conditions)" and add "and for changing trigger conditions in the course of the run" at the end of the sentence.
- Lines 346-383:
  - This section contains too much detail on production asymmetry and on fit function shapes and might be shortened. Important are the extracted instrumental asymmetries.
  - Some parts may need more clarification. For example, by giving "the various contributions" mentioned in line 351.
- Fig.2:
  - Some characters are smaller than used in the text.
  - Replace "Mass spectra ..." by "Distributions for the invariant mass or invariant mass difference of ...".
- Line 406:
 

Remove 'conservatively' or motivate it with a reference. Maybe the sentence reads better with: "The effect of a  $B_s^0$  production asymmetry as large as  $A_P(B^0)$ , which we do not expect, is negligible for the  $B_s^0$  correction factor due to the small value of  $\kappa_s$ ." or even shorter "The  $B_s^0$  production asymmetry is expected to be smaller than the  $B_d^0$  production asymmetry [citation]. Due to the small value of  $\kappa_s$  its effect is negligible."
- Lines 419-441:
 

The repeated use of 'we' should be avoided in 419: we perform, 427: We also investigate, 431: We investigate, 435: We determine, 437: we repeat, 439: we repeat, and 441: we estimate.