BFCTI.400344 to HCA442 delay calibration for CNGS neutrino TOF

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September 26, 2011

Abstract

This document explains the calibrations made to measure the delay between the beam passing through BCTFI.400344 and the waveform acquisition made in cfc-hca4-saos12.

1 Introduction

Figure 1 gives a detailed view of the calibration chain from the beam passing through the BCT until the GPS system, as implemented during the 2010 run. In this schema there are two GPS receivers. One, the XLi, is able to generate an stable clock locked to GPS with a constant offset of 100ns and incertitude of 20ns rms. This GPS provides with a 10MHz and a PPS (Pulse Per Second) reference to the SPS timing system. The second GPS receiver is a Septentrio PolarRX2e timing GPS receiver clocked by a cesium clock (CS4000). The PolarRX2e accepts the GPS signal and the high stability CS4000 10MHz signal to generate a timebase whose offset respect to GPS UTC can be known a posteriori with an uncertainty of 3ns rms.

A general purpose timing receiver (CTRI) driven by the SPS timing, time tags the PPS coming from the PolarRX2e with an accuracy of 1ns. This time tag is stored the long term measurement database for the generation of a precise paper clock. A second CTRI in HCA442, time tags the kicker pulse that sends the SPS beam towards TT40. We can write that the

The kicker pulse is also used to start an acquisition of the BCTFI.400344 waveform for 20us at 1GS/s, which is as well stored in the long term database. The delay between the BCT and the scope aquisition has been estimated with two different methods. One uses the CS4000 PPS injected into the BCT calibration input and the other correlates the pick-ups and BCT waveforms in HCA442.

2 BCT calibration with Pick-ups

An absolute delay calibration of BCTFI.400344 is difficult to implement due to its relative complexity. In general the delay will depend on the beam position and the coil characteristics. Lab measurement show discrepancies of the order of 10ns, depending on the measurement setup. On the other hand, as suggested by the BI group, beam pick-ups are easy to model as the voltage induced on them is mainly capacitive. Cable delays between HCA442 and the pick-ups can be easily calculated using reflectivity at the 1ns level. The position between the accelerator elements is known at the cm level. Nevertheless, the alignment of the bunches between the pick-ups and the BCT is not obvious for the CNGS beam. With the data taken for calibration there

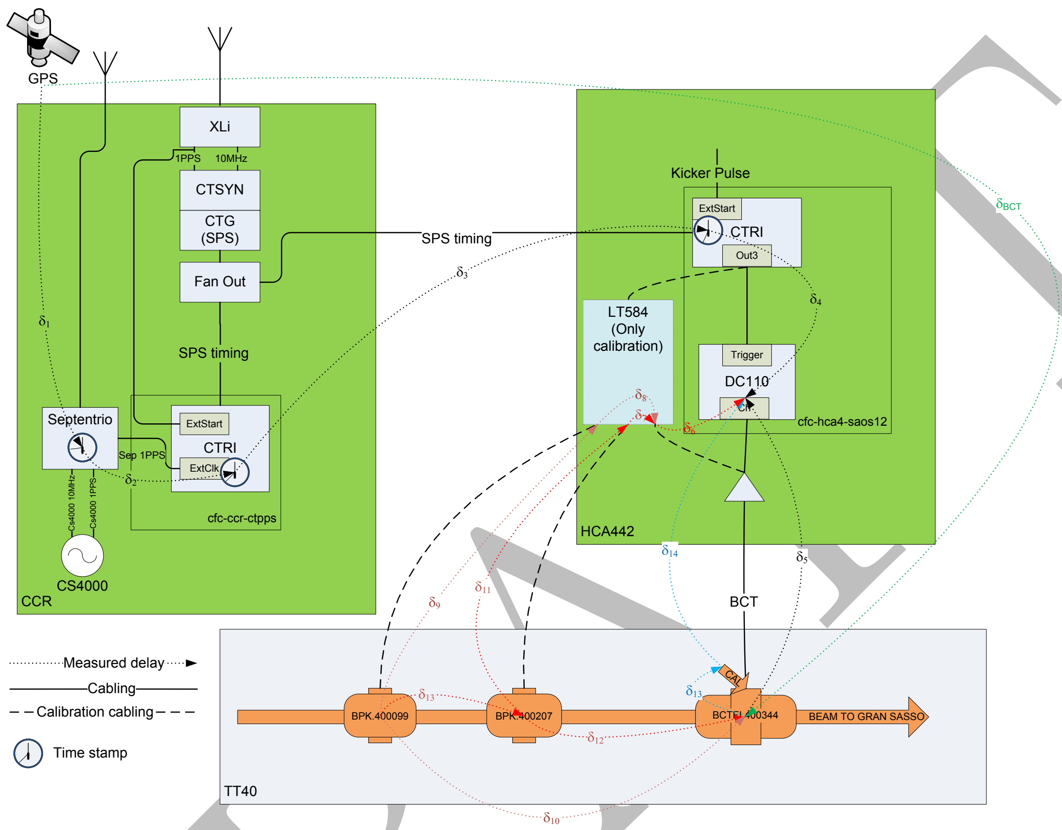

Figure 1: CERN layout and BCT calibration chain.

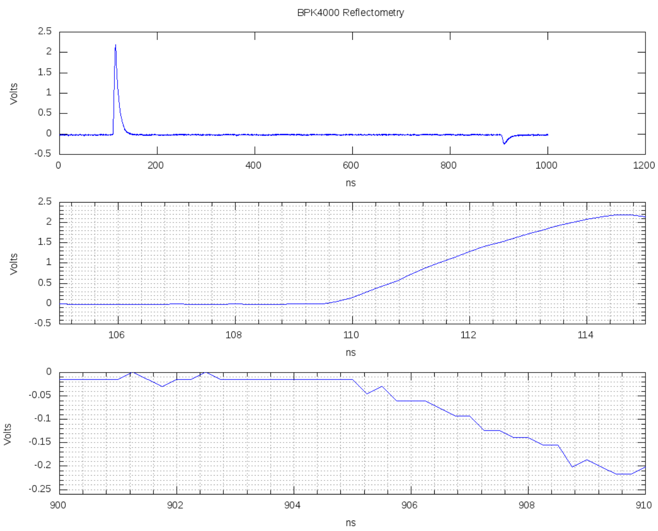

Figure 2: BPK.400277 reflectometry

is a possible error of +/-10ns (2 bunches). It is much easier to do this calibration with LHC bunches, which are separated by 50ns during the present run, giving enough time to distinguish them. The delay between the beam and the BCTFI.400344 acquisition has been performed by measuring the time of flight between the BCT and pick-ups BPK.400099 and BPK.4000207.

2.1 Pick-ups cable delays

The pick-ups cable delays have been calibrated using reflectometry. A fast pulse has been sent from HCA442 toward the pick-ups in the absence of beam.

From the Figures 2 to 4 we deduce that the cable delays for BPK.400207 to HCA442 are:

$$\delta_{11} = (906ns - 110ns)/2 = 398ns$$

and for BPK.400099 to HCA442

$$\delta_9 = (707ns - 111ns)/2 = 298ns$$

The time of flight between BPK400099, BPK400207 and BCTFI.400344 has been stimated in the presence of beam. The scope setup is as described in Figure 1. The calculations have been made with data from four different extractions. The precise time of flight between BPK.400099 and BPK.400207 as measured in HCA442 with the scope has been measured by superimposing both traces until the bunch oscillations match optimally.

$$\delta_8 - \delta_7 = 186ns$$

The time of flight between both position monitors can be calculated as:

$$\delta_{13} = (\delta_8 - \delta_7) - (\delta_{11} - \delta_9)$$

Resulting in:

$$\delta_{13} = 186ns - (398ns - 298ns) = 86ns- > 26m$$

as expected from the layout database.

This result is useful to validate the calibration system. The calculation of the transmission delay between BCTFI.400344 and the acquisition scope can now be deduced from the time of flight between one of the pick-ups and the BCT. Figure 5 shows the data taken without delay

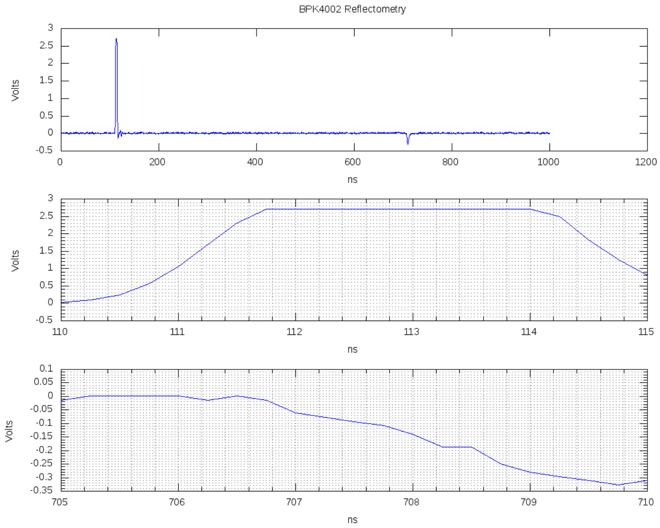

Figure 3: BPK.400099 reflectometry

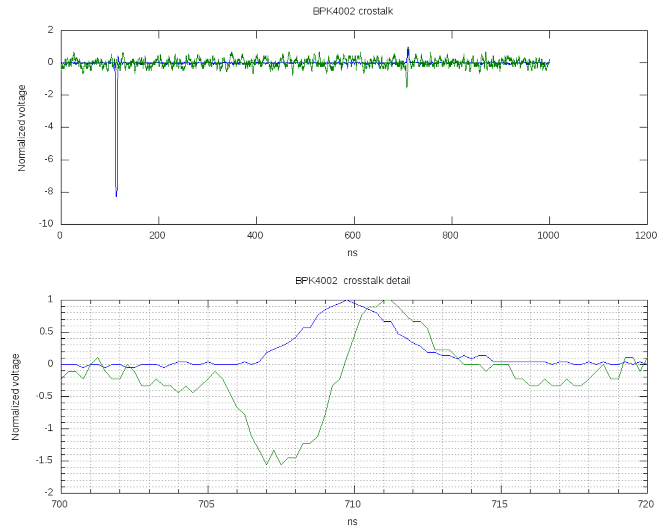

Figure 4: BPK.400099 crosstalk

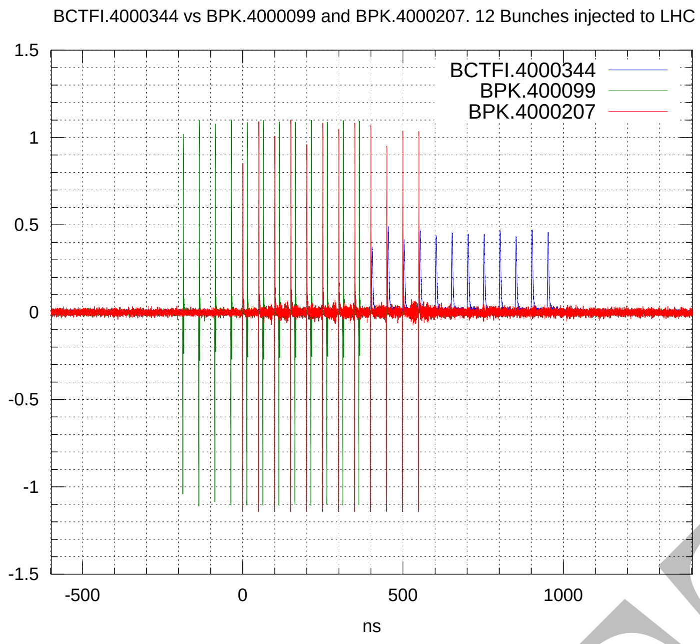

Figure 5: 12 LHC injection bunches.

correction. Figure 6 show the start and tail detail for the BCT and pick-up signals corrected with a 403ns for BPK.400207 and 589ns for BPK.400099.

$$\delta_8 = 589ns$$
$$\delta_7 = 403ns$$

the proton time of flight between BCTFI.400344 and BPK.400099 is:

$$\delta_{10} = 92m/c = 306.8ns$$

The propagation time from BCTFI.400344 to the acquisition scope is

$$\delta_5 = \delta_8 + \delta_9 - \delta_{10}$$

Which gives:

$$\delta_5 = 589ns + 298ns - 306.8ns = 580ns$$

This value coherent with the calibrations made with the CS4000 which gave a result of 589ns of propagation delay between the calibration coil to the acquisition scope (δ_{14}) in 2008.

3 CNGS beam overlap

The CNGS beam is much slower and denser than the LHC beam. Calculating the correct delay for this traces is difficult and prone to error, nevertheless it is worth verifying that the result of overlapping the pickup signals with the BCT at the beginning of the CNGS beam and at the tail is correct. Fig 8 and 7 show a detailed view of the beginning and end of the beam for four different CNGS beams

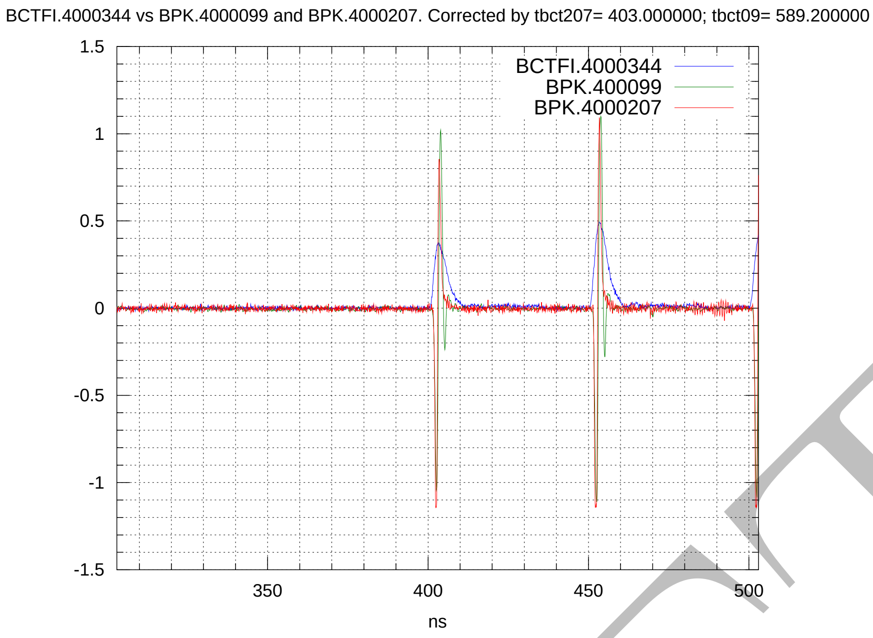

Figure 6: First LHC injection bunches with delay correction.

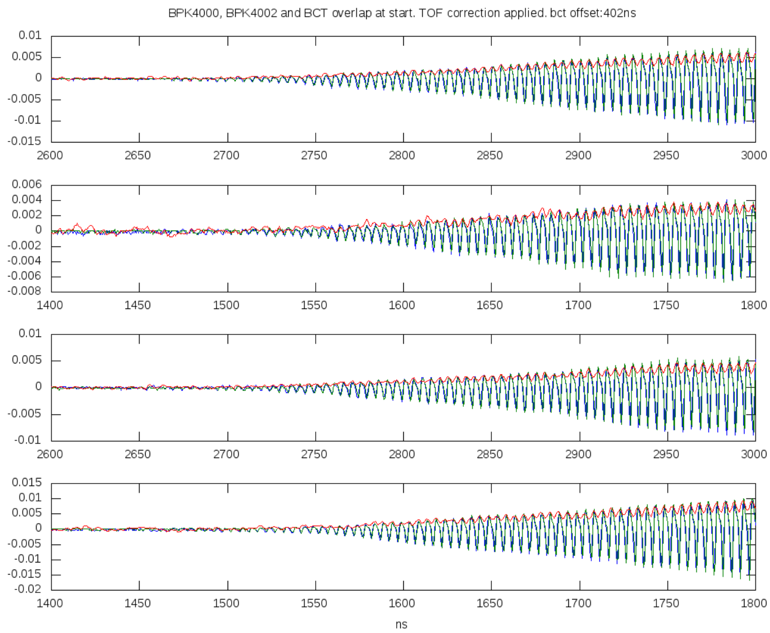

Figure 7

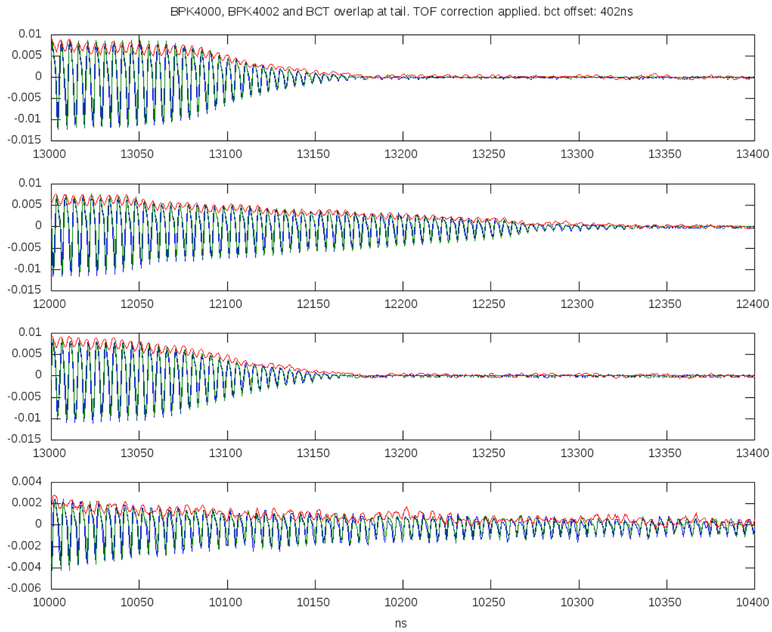

Figure 8

4 Acknowledgments

I would like to acknowledge the help of Javier Serrano, Hermann Schmickler, Rhodri Jones, Thierry Bogey, David Belhorad, Jean-Jacques Savioz, Benjamin Ninet, Giulia Brunetti and Dario Autiero in this measurement.