BEAM DIAGNOSTICS AT THE ALBA LINAC

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Abstract

The commissioning of the ALBA Linac (Autumn 2008) required a careful measurement of the beam parameters. This paper describes the diagnostics devices installed at the ALBA Linac and our experience with them.

INTRODUCTION

The ALBA Linac was supplied by Thales Communications and installed in Spring 2008 at the CELLS site. The installation of the first part of the transfer line Linac to Booster (LTB) and the Diagnostics Line (Lidia) was done simultaneously under the CELLS responsability. The Linac beam commissioning was performed in Autumn 2008. More details about the Linac installation and commissioning are found at Refs. [1, 2].

The Linac is designed to work in two operational modes: Single and Multi Bunch Mode (SBM and MBM, respectively). In SBM, the Linac delivers up to 8 pulses with a bunch spacing that can range between 6 and 50 ns, and a maximum charge of 2 nC total. In MBM, it provides a train between 112 and 1024 ns length with a maximum charge of 4 nC and a fixed bunch spacing of 2 ns. The Linac specifications are listed in Table 1.

Table 1: Linac Parameters. The acronym “ptp” refers to “pulse-to-pulse” variation (rms).

Parameter	SBM	MBM
# of bchs	1 ... 8	56 ... 512
pulse length, ns	≤ 1	112 - 1024
bch spacing, ns	6 - 50	2
charge, nC	≥ 1.5	≥ 3
Bunch purity	$\leq$1%	...
pos. stability* ptp	$\leq$0.2 mm	$\leq$0.2 mm
energy, MeV	$\geq$100	$\geq$100
energy spread	$\leq$0.5%	$\leq$0.5%
energy var. ptp	$\leq$0.25%	$\leq$0.25%
norm. emit, μrad	$\leq 30\pi$	$\leq 30\pi$

Figure 1 shows a sketch of the Linac, LTB and Lidia with the diagnostics systems. Thales responsibility ends after the diagnostics elements installed downstream the second accelerating structure. All components installed after that are CELLS responsability and their goal is to check whether the Linac fulfills the required specifications.

This paper shows the diagnostics components installed at the LTB and Lidia to check the main beam parameters, that is: beam charge, position, and size. Description of the emittance, energy and energy spread measurements is shown in Refs. [2, 3]. Figure 2 shows a picture with the diagnostics devices in the Linac and LTB, which will be seen throughout the text.

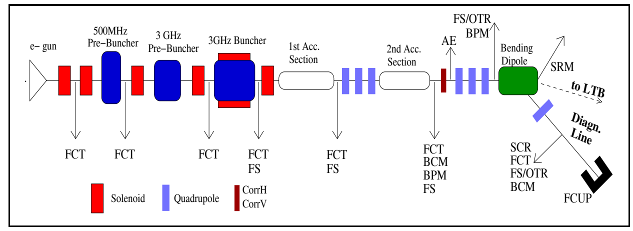

Figure 1: Sketch of Linac and LTB, with the diagnostics location.

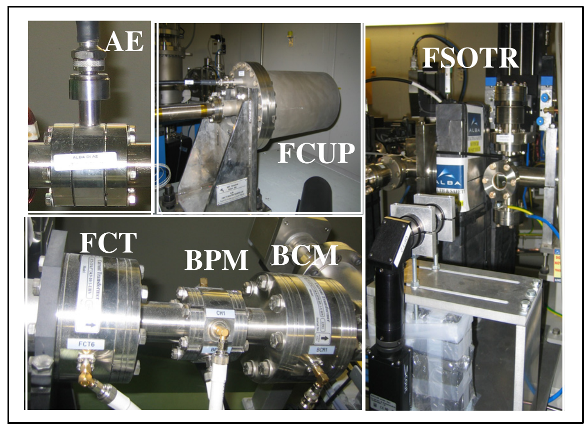

Figure 2: Diagnostics components at the Linac and LTB.

BEAM CHARGE MEASUREMENTS

Beam charge measurements are done using the commercially available Fast Current Transformer (FCT) and Beam Charge Monitors (BCM) [4], and with in-house designs manufactured by Cinel: Annular Electrode (AE) and Faraday Cup (FCUP).

Fast Current Transformers

Fast Current Transformers (FCT) are installed after each active element in the Linac and LTB (see Fig. 1). In total, we have 8 FCTs to monitor the transfer efficiency along the line, and they all have been very useful throughout the Linac commissioning.

Our model is the FCT-CF4”1/2-34.9-40-10:1, with a frequency range 5 kHz - 1.4 GHz. This limited frequency range implies that: 1) precise beam charge measurements

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should not be performed with this device, but use the BCM instead; and 2) the influence of the 3 GHz bunching system cannot be precisely distinguished. For this, we will better use the AE – see next.

Beam Charge Monitors

The Beam Charge Monitors (BCM) measure the charge of very fast pulses with high accuracy (resolution at the pC level) by means of a capacitively shorted transformer coupled to a fast readout transformer in a common magnetic circuit [4].

The BCM is composed by an Integrating Current Transformer (ICT) installed at the vacuum chamber and the integrating electronics card. The ICT model is ICT-CF4”1/2-34.9-40-05:1, the electronics card model is BCM-IHR-E. Both components are “off-the shelf” units calibrated together to allow charge measurements with pC precision.

Their commissioning required due care with the timing signal, and filter out the klystron noise. The latter was a cumbersome task. Figure 3 shows the noise in the ICT with no beam in the Linac but with the klystron “on”. This signal is produced by ground loops from/to klystrons, and as a result, the charge inferred by the BCM has an rms noise 150 pC. These ground loops were finnally suppressed wrapping the signal cable around a ferrite coil. Only then the rms noise could be decreased then to 4 pC – see Fig. 4.

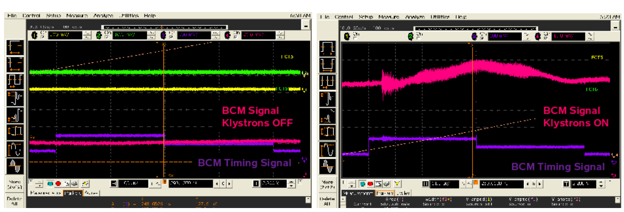

Figure 3: BCM signal with klystrons off (left) and on (right). The pink trace shows the raw ICT signal (before integration by the BCM-IHR-E). Integration by the BCM card the klystron noise produces the 150 pC rms noise shown in Fig. 4.

Annular Electrode

The advantage of the AE with respect to the Current Transformers is its sensitivity and larger bandwidth, which allows to distinguish low beam charges. However, they must be calibrated using the BCM. The AE signal is connected to a 4 GHz scope to see the 3 GHz Linac component in case of phase mismatch. In any case, the scope uses a 10 dB attenuator because the AE signals can be larger than 10 V.

The large AE signals are used to perform bunch purity measurements. Unfortunately, they are limited by ripples and cable reflections to a 2.5%.

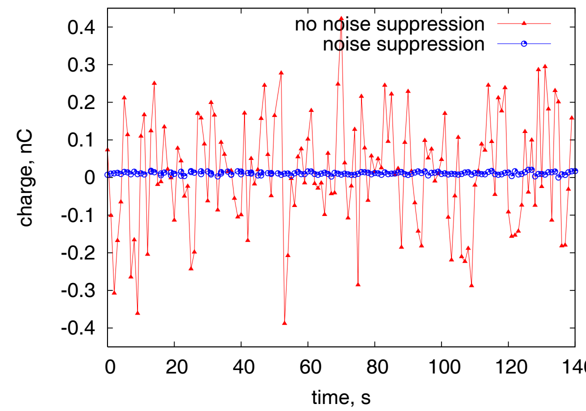

Figure 4: BCM measurements with no beam in the Linac and with klystrons “on”, with and without noise suppresion. The rms variation without noise suppression is $\pm$150 pC, with noise suppression is only $\pm$4 pC.

Faraday Cup

The FCUP is the last component at the Diagnostics Line and it is mainly designed as beam stopper. Therefore, it is optimized for charge collection efficiency rather than bandwidth.

The charge measured from this device is calibrated according to the measures of the BCM. The peak-to-peak voltages measured with both AE and FCUP are about a factor 5 larger than the ones measured by the FCTs (see Fig. 5). As the AE, the FCUP signal was attenuated by 10 dB to protect the scope.

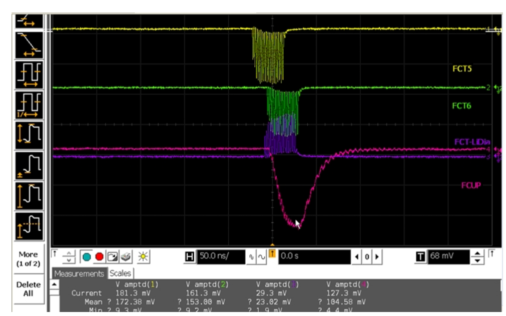

Figure 5: FCUP measurements compared with FCT signals. The FCT-Lidia signal is inverted because the coil is installed backwards.

BEAM TRANSVERSE PROFILES AND POSITION

The Linac specifications required a beam position stability “within a 10% of beam size”. Transverse size and position are measured with the Fluorescent Screen and Optical Transition Radiation monitors (FSOTR). Beam position is measured as well with the Beam Position Monitors (BPM).

Fluorescent Screen and OTR

The transverse beam spatial distribution is measured using the "FSOTR". This setup allows to introduce into the beam's path two kind of screens, which emit light upon collision with the electron beam. The first screen is a YAG:Ce screen that emits light by scintillation, the second is an Al-foil that emits transition radiation. The light is finally brought to the CCD camera using an optical system. More details about this monitor can be found at Ref. [5].

The optical calibration was set individually for each FSOTR monitor using reference marks at the screens. Typically, this was 1 pixel = 20μm. However, the absolute position inside the vacuum chamber could not be precisely calibrated. An example image of the beam out of the Linac with the downstream quadrupoles "off" is shown in Fig. 6.

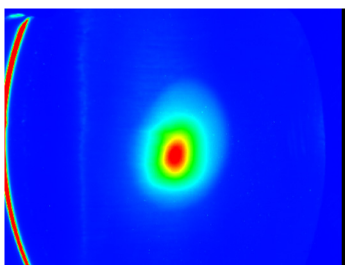

Figure 6: Image of the beam out of the Linac. The picture size is ~20x16 mm.

Figure 7 shows two histograms of the vertical beam centroid's position (left) and the corresponing vertical beam size (right) inferred using the FSOTR. The absolute vertical position is not properly calibrated and an arbitrarly offset has been substracted.

We can see that the rms displacements in the vertical direction are ± 0.04 mm (rms). For an average beam size of $\sigma_y = 1.94 \pm 0.02$ mm (see Fig. 7, right), we conclude that the vertical stability is 2%, much lower than the specified 10%. A similar analysis in the horizontal plane results in a position stability below 1%.

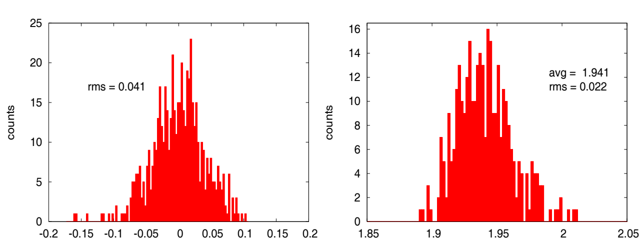

Figure 7: Variation of beam centroid (left) and size (right) inferred using the FSOTR after 700 samples.

Beam Position Monitors

Beam transverse position using the FSOTR are found with good precision, but its drawback is that it is a destructive method. It is therefore convenient to measure the beam position using the 4-buttons BPM.

Most difficulties regarding the BPMs commissioning were related to the proper electronics timing. Once this was achieved, horizontal and transverse position were obtained with an rms noise of $\pm$ 70μm – see Fig. 8. However, this noise can increase by about a factor 3 in case of for low charge beams (around 0.25 nC).

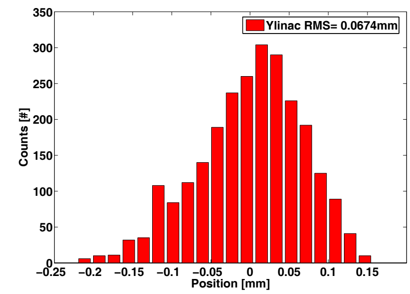

Figure 8: Beam position variation measured with the BPM after 2500 samples with a MBM of 4 nC.

SUMMARY

The experience with the diagnostics components at the ALBA Linac and LTB are presented. All in all, our experience with these devices and their commissioning is good and they allow a proper beam Linac commissioning. Only the bunch purity could not be measured with the proper precision. We would like to highlight that:

1) The charge measurements using the BCM is set to $\pm$ 4 pC after noise suppression.

2) Relative position pulse-to-pulse are better obtained with the FSOTR ($\pm$ 40 μm) than with the BPM ($\pm$ 70 μm).

3) Due care shall be taken with the FCUP and AE because their large signals compared with the FCT signals can damage the scope.

ACKNOWLEDGMENTS

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