HARMONIC BASED BEAM POSITION MEASUREMENTS ON DEBUNCHED BEAMS

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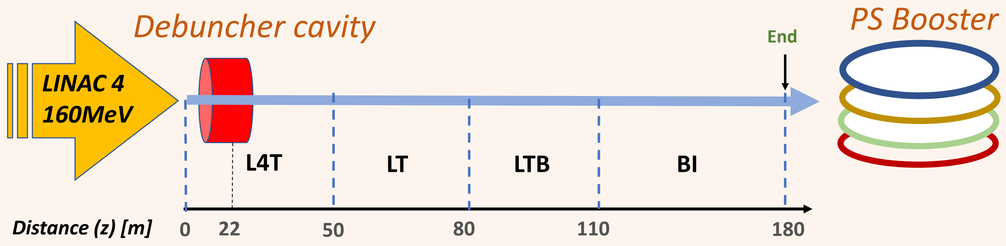
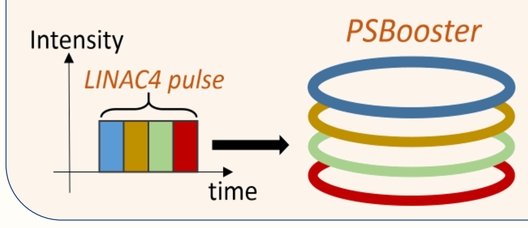
Abstract

Often the beam position is measured (e.g. in LINACs) with a BPM operating at one strong harmonic component present in the beam signal. This approach has limitations once the beam gets debunched and the harmonic components drops. Nevertheless, from a signal processing point of view the signal to noise ratio can be still acceptable with highly debunched beams, leading, in principle, to a reasonable, even if degraded, position measurement. A simplified beam transport model developed for the CERN BI transport-line between Linac 4 and the PS Booster demonstrates, that in some case, the harmonic component cannot be used anymore for position measurement despite the fact it is still significative in amplitude.

CERN LINAC4 to PSB transfer line overview



1. 160MeV H^- beam pulses bunched at 352MHz injected
2. (De)buncher cavity for energy spread tuning
3. BPM system operating at352MHz

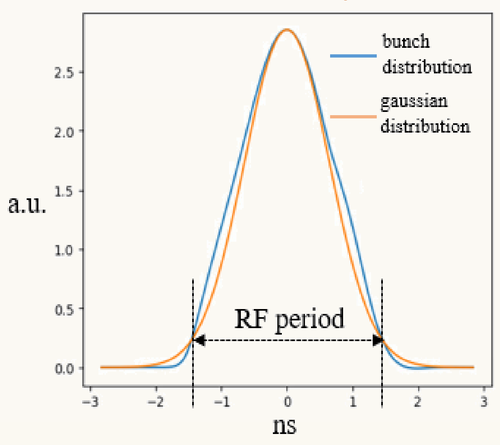


4. LINAC pulse sliced before injection in the booster
5. BPM measure average position of each slice
6. All the settings are unchanged along the pulse

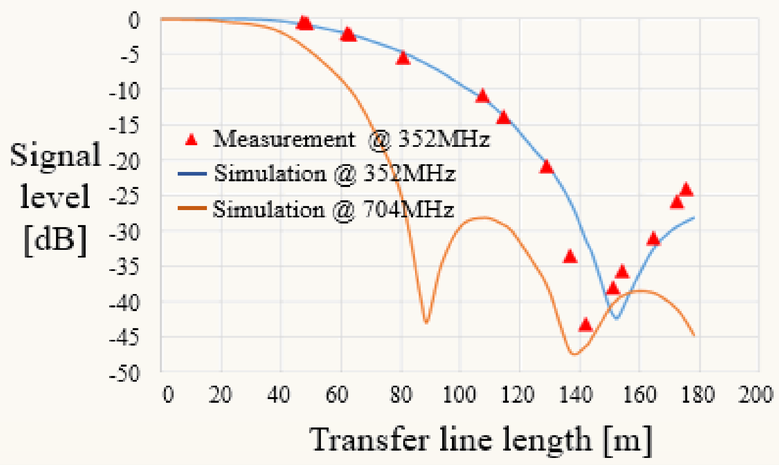
Harmonic components along the transfer line

1. Energy spread and space charge → bunch length increase along the transfer line
2. Bunch shape loses gaussian profile even if gaussian beam would be injected
3. Non gaussian shape of the transported beam cause notches at specific location in the transfer line
4. At the first harmonic (352MHz) used by the BPM system one notch is present at ~140m in the BI line with the high energy spread beam

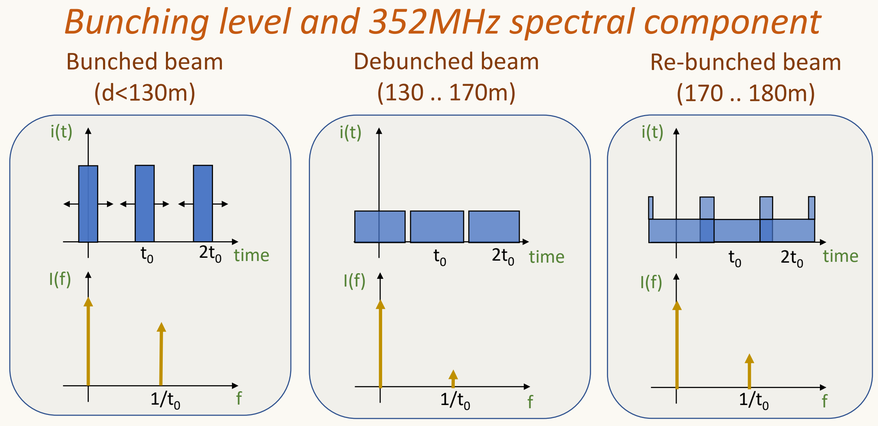
Bunch shape



Beam current components



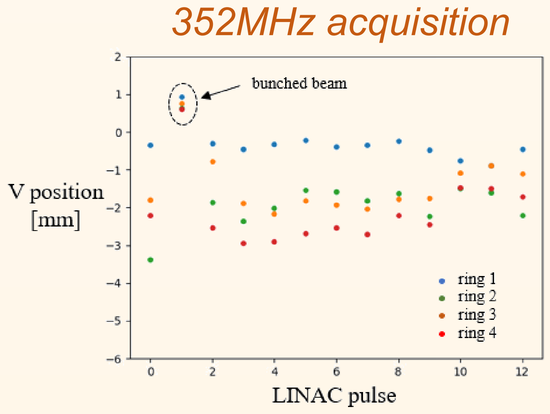
Bunching level and 352MHz spectral component



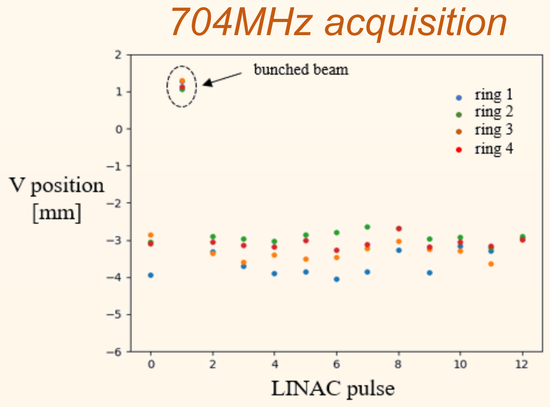
Position measurement fluctuation with high energy spread beam

With the high energy spread beam the position measured using harmonics of the bunching frequency in the region of the notch (~140m) fluctuate unrealistically: the position of the four slices of the same beam pulse should be very close each other

352MHz acquisition



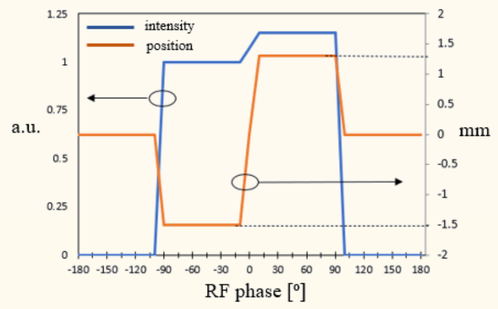
704MHz acquisition



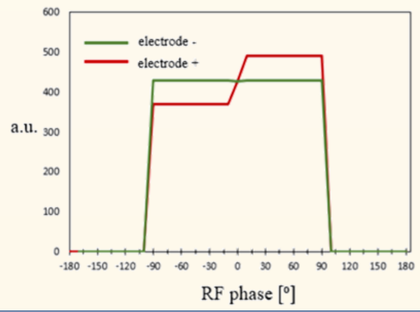
By contrast the low energy spread beam (pulse #1) is properly measured

An accuracy degradation mechanism

Bunch intensity and position



Linear pickup output signals



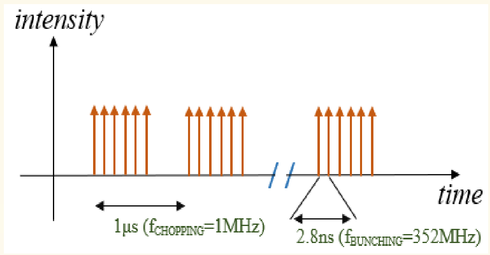
Here the intensity and position trace of a bunch having the weighted position, expected from the BPM system, equal to zero by construction.

The minus electrode output signal is a perfect square pulse that eventually loses any spectral component (but DC) when the bunch length approach 360^o.

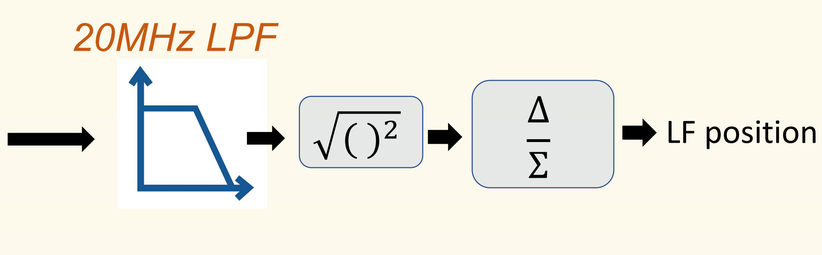
A positive offset position is measured in such condition using RF harmonics.

Exploiting the LINAC4 chopping pattern: Low Frequency (LF) processing

Structure of the LINAC 4 beam

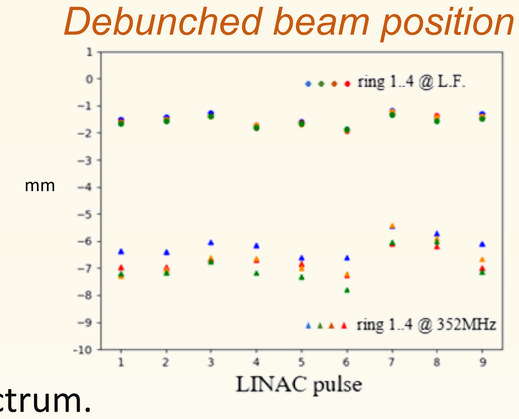


20MHz LPF

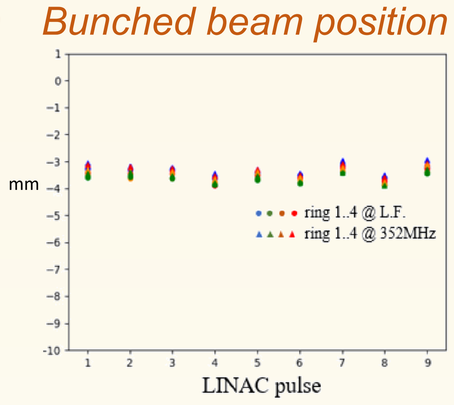


The LINAC4 beam is chopped at 1MHz rate to inject into PS Booster RF buckets.
Harmonics multiples of 1MHz are present in the pickup signals.
The beam position can be estimated using the low frequency part of the signal energy spectrum.

Debunched beam position



Bunched beam position



Final considerations

Position measurement using bunching harmonics is unstable with debuched beam in a region of the transfer line not because of a low S/N ratio

LF measurement looks stable with both bunched and debunched beam and in agreement with measurement at 352MHz for bunched beam

The position measured using bunching harmonics could be affected by variation of the bunch profile but this mechanism has not been proved