WEPP043

TIME-OF-FLIGHT TECHNIQUE FOR MATCHING ENERGIES IN ELECTRON COOLER

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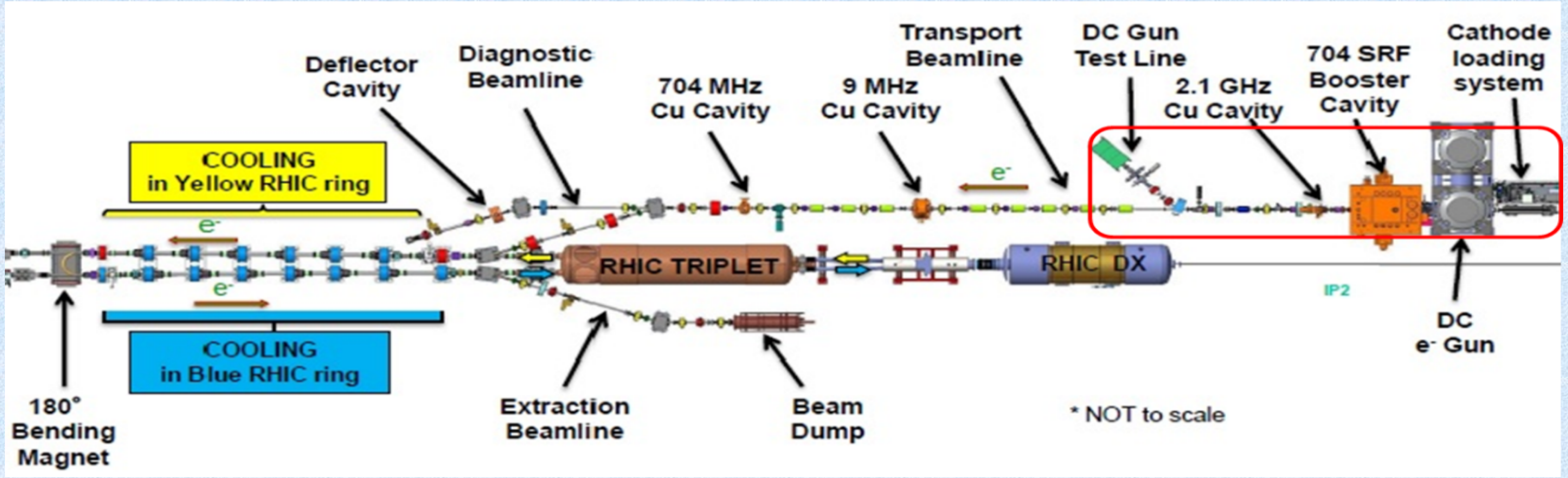


Layout of the LEReC electron accelerator. The electron beam is generated by DC photogun and accelerated by 704 MHz booster cavity. 9 MHz cavity provides compensation for the beam loading, while 2.1 GHz and 704 MHz copper cavities provide for small energy spread. The electron beam interacts first with hadrons circulating in the yellow RHIC ring and after 180-degree turn with hadrons circulating in the blue ring.

For the successful cooler operation, the energy match between hadrons and the electrons should be better than 10^{-3}. Such accuracy is hard to achieve with low-energy beams (relativistic factor γ=4-6). For this purpose, for redundancy three techniques have been developed. The 180-degree magnet and recombination monitor are described elsewhere. This paper is focused on the approach based on measurement of the phase difference of two signals excited by the beams on two beam position monitors (BPMs) with RF processing.

There are systematic errors in the phase difference measurements: the unequal delays in the cables and phase shifts in the RF front ends (filters, diplexers, amplifiers). They are out of the control, therefore we did not try to measure absolute energy but only aiming to match the relativistic factors. The proposed approach was to measure the phase difference between two signals excited the hadron beam by circulating in the RHIC and by adjusting the electron beam energy reproduce the measured phase difference.

Sensitivity of phase to the relativistic factor can be found from the formula below. As one can see strongly diminishes with growth of the beam energy.

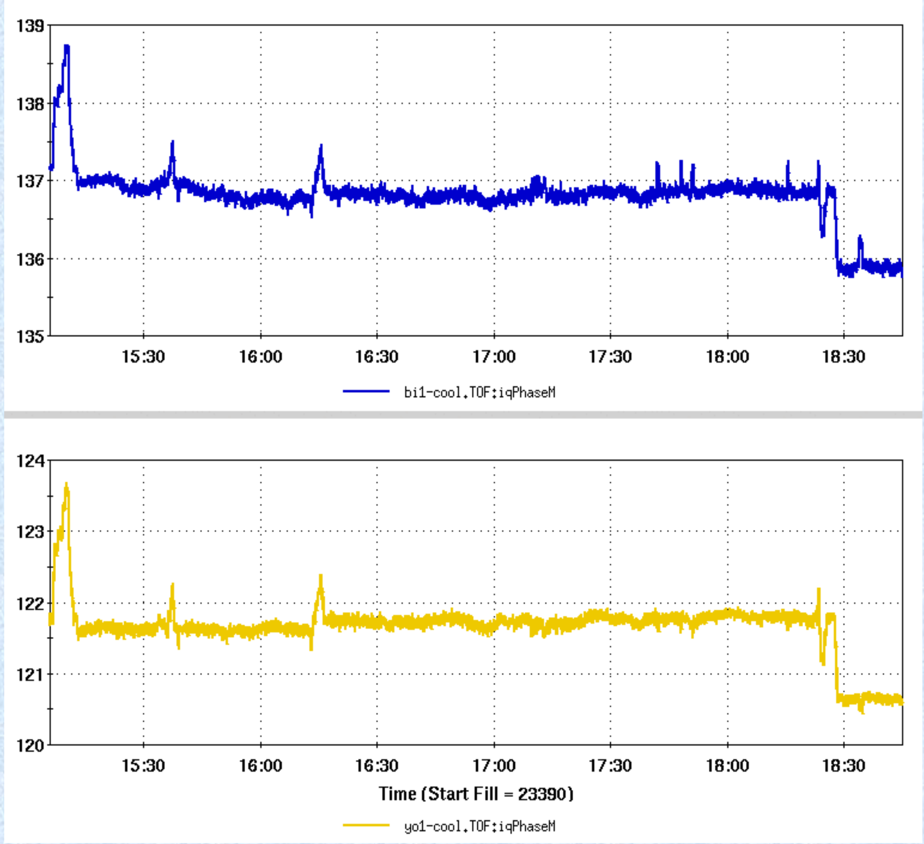
$$\Delta\phi = \frac{2\pi F_{proc} L_{drift}}{c\sqrt{1-1/\gamma^2}} \frac{1}{\gamma^2} \frac{\Delta\gamma}{\gamma}$$

For the strong signal the signal-to-noise ratio is defined by the jitter of the ADC clock and becomes independent of the processing frequency:

$$S/_N = \phi/_{2\pi\sigma_{clock}F_{proc}} = \frac{1}{\sigma_{clock}} \frac{L_{drift}}{c\sqrt{1-1/\gamma^2}}$$

There are five implemented time-of-flight (ToF) subsystems. The first one is in the DC gun test line and utilises two BPMs separated by 2.273 meters. The signal is processed at 713.4 MHz frequency to avoid interference with the RF field from the booster cavity.

Each cooling section has two subsystems one at high frequency (704.0 MHz) to monitor energy stability of the electron beam and one at low frequency (9.4 MHz) to perform matching of the relativistic factors. In the yellow ring distance between pick-up electrodes is 17.857 meters and in the blue ring it is 18.958 meters.

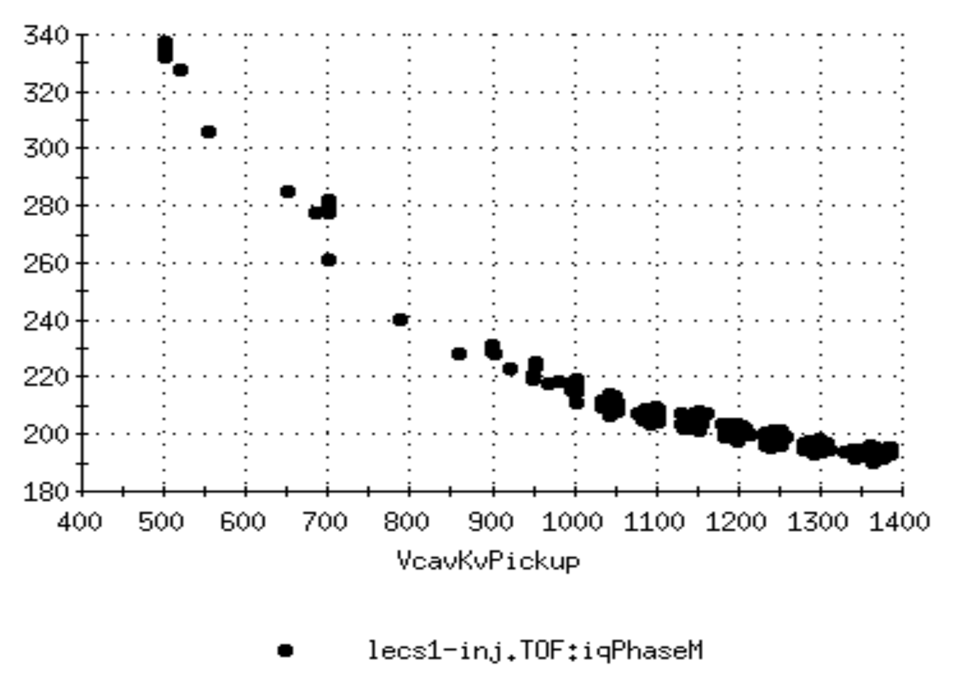


Time dependence of the phase difference in the high frequency ToF subsystems in the blue and yellow cooling sections with 13.8 mA of electron beam current.

Electron beam kinetic energy measured with the help of 180-degres bending magnet during the same time period.

CONCLUSIONS

The time-of-flight system for matching of the relativistic factors of the electron beam and hadron beams circulating in RHIC showed close but still not sufficient accuracy. We did not try out to bring the system to the specification because goal of matching was achieved by other means.

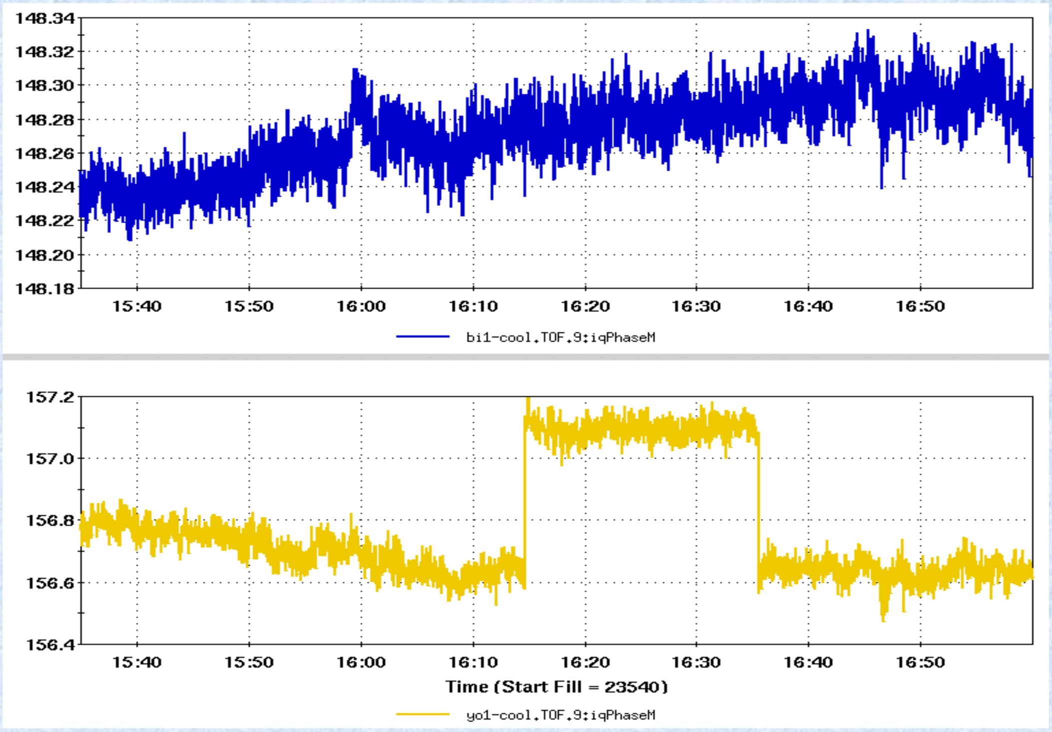


Dependence of the phase difference (in degrees) between two BPM signals vs booster cavity voltage in kV. Electron energy from the gun is 375 keV.

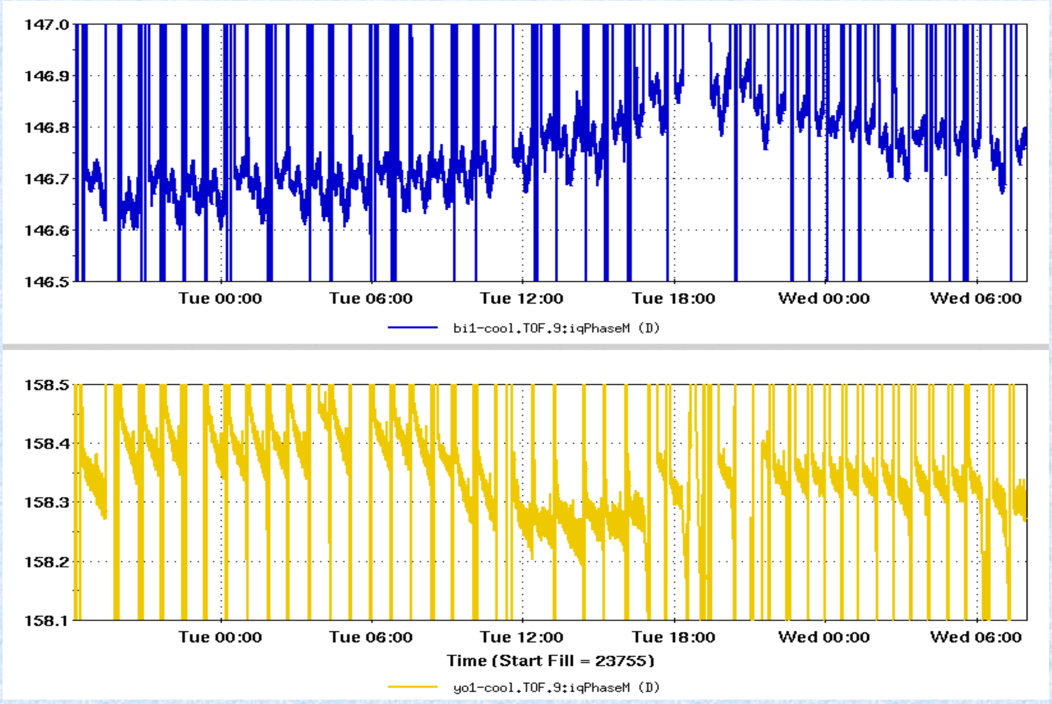
In general, the data behave in accordance with equation:

$$\phi = 2\pi \frac{L_{drift}}{c\sqrt{1-1/\gamma^2}} F_{proc}$$

However, the attempt to fit them with three parameters (gun voltage, initial phase shift, and scaling factor for the booster voltage) gave unreasonable values. There are two main reasons of it: a) due to the substantially non-relativistic beam from the gun the energy gain in the booster cavity is not proportional to the cavity voltage, b) for the same reason cavity phase needs to be adjusted for each voltage.



The phases obtained with low frequency systems excited with the electron beam. To obtain the desired accuracy the matching of the relativistic factors the phase difference should be determined with 0.004°. While the r.m.s. noise can be easily suppressed by averaging the drifts are substantial and are the limiting factor for this system. We also observed steps in the phase readings similar to one shown. Their origin is unknown.



Time dependence of the phase difference in the low frequency ToF subsystems in the blue and yellow cooling sections with hadrons circulating in both rings. The time span is over two days with multiple fills.