# COMMISSIONING OF CeC PoP ACCELERATOR*

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## *Abstract*

Coherent electron cooling is new cooling technique to be tested at BNL. Presently we are in the commissioning stage of the accelerator system. In this paper we present status of various systems and achieved beam parameters as well as operational experience. Near term future plans are also discussed.

## INTRODUCTION

The coherent electron cooling experiment is expected to demonstrate cooling of a single hadron bunch circulating in the relativistic heavy ion collider (RHIC) [1]. The system layout is shown in Fig. 2. A superconducting RF gun operating at 113 MHz frequency generates the electron beam. 500-MHz normal conducting cavities provide energy chirp for ballistic compression of the beam. 704 MHz superconducting cavity will accelerate beam to the final energy. The electron beam merges with the hadron beam and after cooling process is steered to a dump. The FEL-like structure enhances the electron-hadron interaction. The electron beam parameters are shown in the Table 1.

Table 1: Parameters of the Electron Beam

| Parameter | Value |
|---|---|
| Energy | 22 MeV |
| Bunch charge | 1-5 nC |
| Normalized emittance | < 5 mm mrad |
| Energy spread | $< 10^{-3}$ |

## TEST OF THE EQUIPMENT IN THE COMMON SECTION

One of the first tasks was to measure the effect of the CeC PoP equipment installed in the common section on the hadron beams circulating in RHIC. The motivation was verify ability to commission systems in the background mode without substantial disturbance to RHIC operations.

Eight quadrupoles placed in the common section were energized to the extremes and tunes and orbit were monitored. The results of the experiment are shown in the Fig. 1. The tune change at injection energy from an individual quadrupole was 0.005. This requires that currents in the quadrupoles were changed simultaneously and then influence of focusing and defocusing quadrupoles will compensate each other.

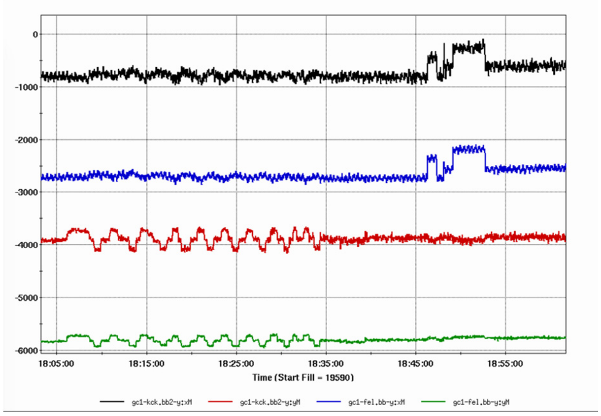

Figure 1: Effect of the CeC quadrupoles and dipoles on RHIC beam. The measurements were performed at injection energy where two hadron beams are separated vertically and beam motion is more prominent.

We also checked the influence of the dipoles used for merging electron and hadron beams (the rigidity of which differs substantially). We have installed two compensating dipole that should limit the orbit disturbance to the interaction region. The measurements confirmed the utilized approach but we also observed change of the tunes due to the fringe fields. The change value was found tolerable for operations.

## GUN COMMISSIONING

The CeC PoP gun has quarter-wave structure and operates at 113 MHz. It has manual tuners for coarse set of the resonant frequency, while fine-tuning is performed by a fundamental power coupler (FPC).

Gun commissioning started with conditioning of the FPC for multipacting [2]. Then we performed helium condition of the cavity suppress dark current an increase cavity voltage. At the end we were able operate at 1.25 MW in CW mode and 1.7 MV in the pulsed mode.

Gun conditioning was done with molybdenum puck identical to the cathode but without photoemissive coating. Upon completion of the conditioning we inserted photocathode and scanned cavity phase [3].

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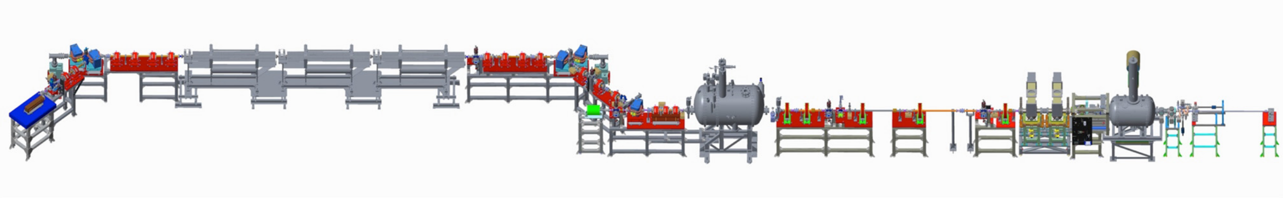

Figure 2: Rendering of the electron accelerator and beamline. The gun is on the right and has cathode launch mechanism attached. Further from right to left are two 500 MHz copper cavities, low energy beamline, 704 MHz accelerator cavity, dogleg structure for beam merge, FEL system, and high power beam dump.

Due to the high gradient and relatively low frequency we are able extract electron from almost 180 degrees span as shown in Fig. 3. One of the first beam profiles is shown in Fig. 4.

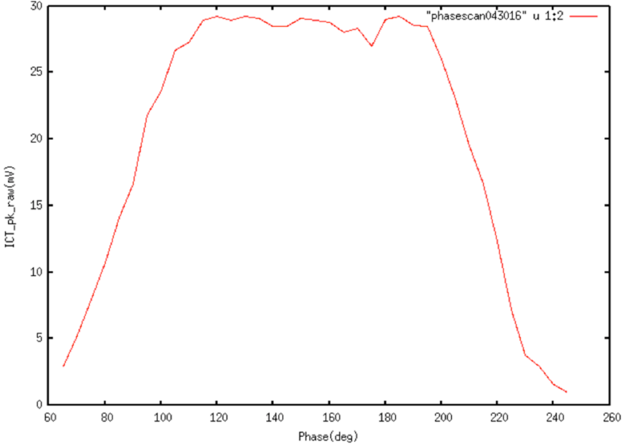

Figure 3: Integrating current transformer (ICT) signal at various cavity phases.

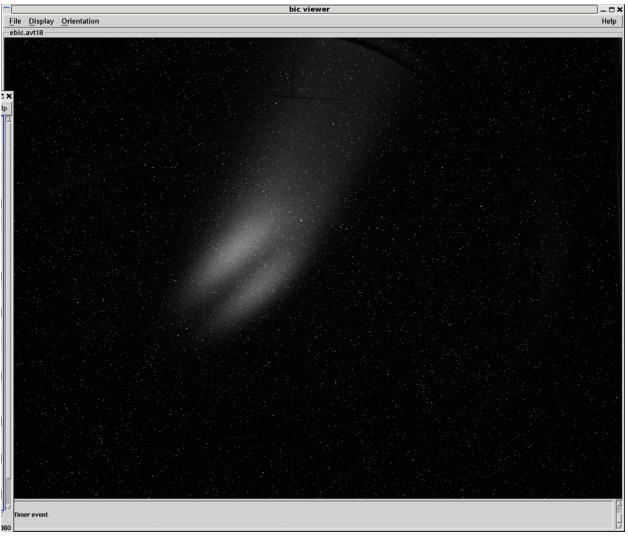

Figure 4: First image of the beam.

## BEAM INSTRUMENTATION TESTS

After receiving the first electron beam we started its propagation further in the beamline and testing beam instrumentation. The first element was ICT, which signal initially was observed on the oscilloscope. We connected its output to the ADC with Zynq processor by Xilinx. Low signal levels and high noises were overcome with isolation transformer and amplifier. Since June 6th we were continuously logging data. Later we found that stray electrons are charging the internal surface of the ceramic brake in the ICT causing beam deflection and shape change. Presently we are acquiring new ICT with shield to prevent such an effect.

We observed beam on the second profile monitor and were able to measure beam emittance with a set of the horizontal and vertical slits installed before it.

Beam position was monitored using Libera Single Pass processors by Instrumentation Tecjnologies. The raw signal from the ADC is shown in Fig. 5. The electron BPMs have RF front end filter tuned to 500 MHz.

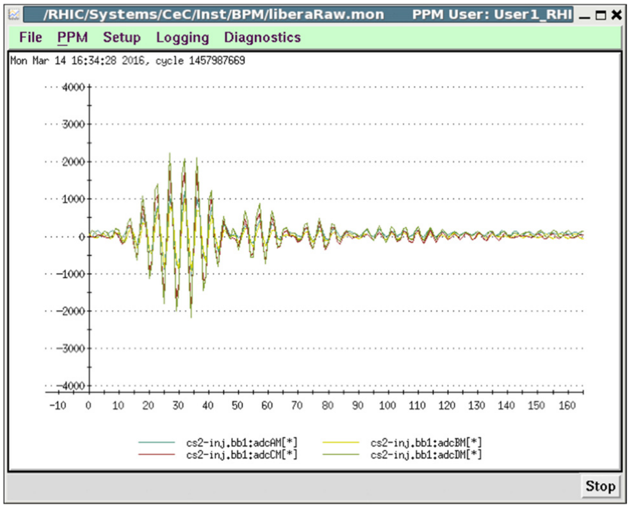

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Figure 5: Electron BPM digitizer input.

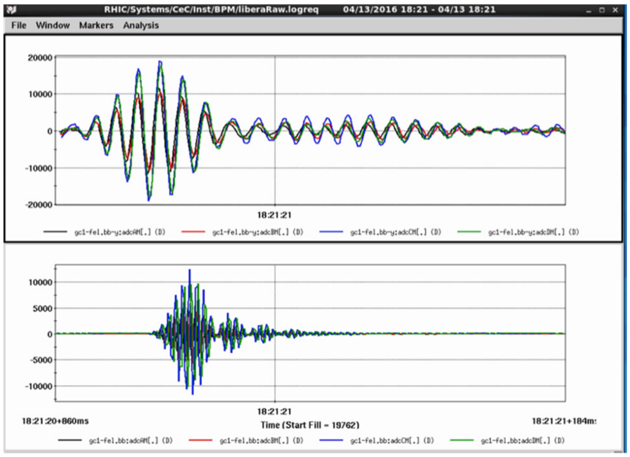

Figure 6: Raw ADC signal excited by the hadron beam. Upper trace is 9 MHz unit, and lower is for the 500 MHz unit.

The hadron BPMs are equipped with 9 MHz filter. The signals from the pick-up electrodes in the common section are passing through diplexers: low frequency branch is used for the hadron monitoring and high frequency for the electron beam position measurement. The raw ADC signals excited by the hadron beams for both systems are shown in Fig. 6.

The beam energy was measured using the profile monitor in the dogleg section after beam was bent by the dipole.

## BEAM ACCELERATION

In order to propagate beam to the common section and to the high power dump we need to accelerate beam with 704 MHz cavity. To have low energy spread bunch should be compressed. The 500 MHz cavities provide energy chirp and beam is compressed by ballistic bunching. Initial phasing of the bunching cavities with the electron beam was performed in the following manner. We found cavity phase and voltage which provides for the minimal energy spread while observing beam on the profile monitor in the dogleg section (see Fig. 7). Knowledge of the ratio between gun frequency and bunching cavities allows verification the cavities voltage. The found phase corresponds to 180 degrees phase (deceleration). Now need only to change phase by 90 degrees. Proper direction of the shift was checked with BPM signal amplitude – the shorter bunch has higher frequency content while longer (debunched) beam does not.

After establishing compression we turned on previously conditioned 704 MHz accelerator cavity and properly phased it by maximizing beam energy and minimizing the energy spread. Then beam delivered to the high power dump.

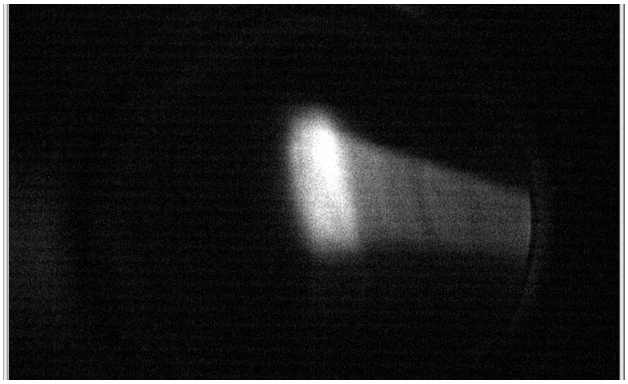

Figure 7: Image of the 1.1 MeV beam from the gun with energy spread compensated by 500 MHz cavities.

We were not able to accelerate beam to the desired energy of 22 MeV due to the strong heat load on the cryogenic system accompanied by substantial radiation levels. Most likely the cavity was contaminated during installation. Another problem was with the cavity tuners. The fast piezoelectric was damaged and stepper motor driven broke during operation. We will fix the cavity prior start of RHIC operation in Run 17.

It should be noted that we were able to measure electron position even with circulating hadron beam which induces its signal on the 500 MHz BPMs by placing the electron bunch into the 1 microsecond abort gap (see Fig. 8). The trace of the raw ADC signal is shown in Fig. 9.

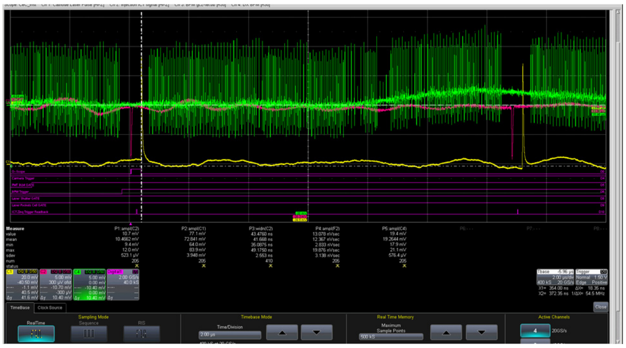

Figure 8: Electron beam signal (magenta) inside the abort gap of the circulating hadrons (green).

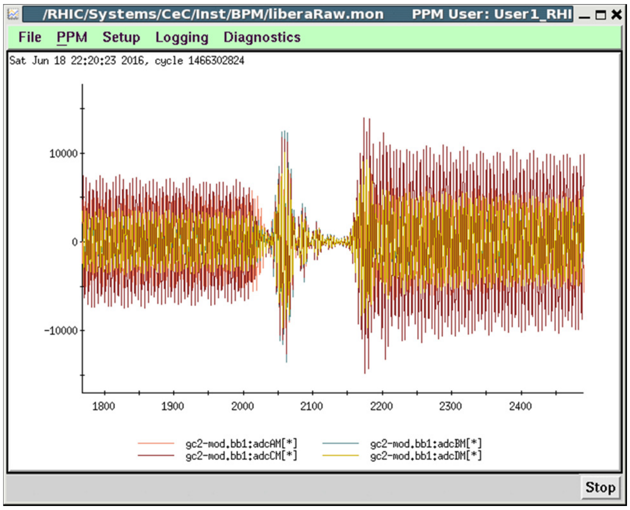

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Figure 9: Raw ADC signal induced by the hadrons as well as electron bunch (in the middle).

## CONCLUSION

We started commissioning of CeC PoP equipment. Most systems (instrumentation, SRF gun, 500 MHz cavities, magnets) operated without substantial problems. We will resume conditioning of the accelerator in 2017.

## REFERENCES

[1] V.N. Litvinenko *et al.*, “Proof-of-principle Experiment for FEL-based Coherent Electron Cooling”, in *Proc. PAC’11*, paper THOBN3.

[2] I. Pinayev *et al.*, “First Results Of the SRF Gun Test for CeC PoP Experiment”, in *Proc. of FEL 2015*, paper TUD03.

[3] I. Pinayev *et al.*, “Performance of CeC PoP Gun During Commissioning”, presented at NAPAC'16, Chicago, IL, USA, paper WEPOB59, this conference.