Injection studies for the EIC with dual RF system

D. Kayran, S. Seletskiy, A. Fedotov, V. Schoefer, K. Mernick, M. Blaskiewicz, V. Ptitsyn, A. Blednykh

APEX meeting on Jan 26, 2024

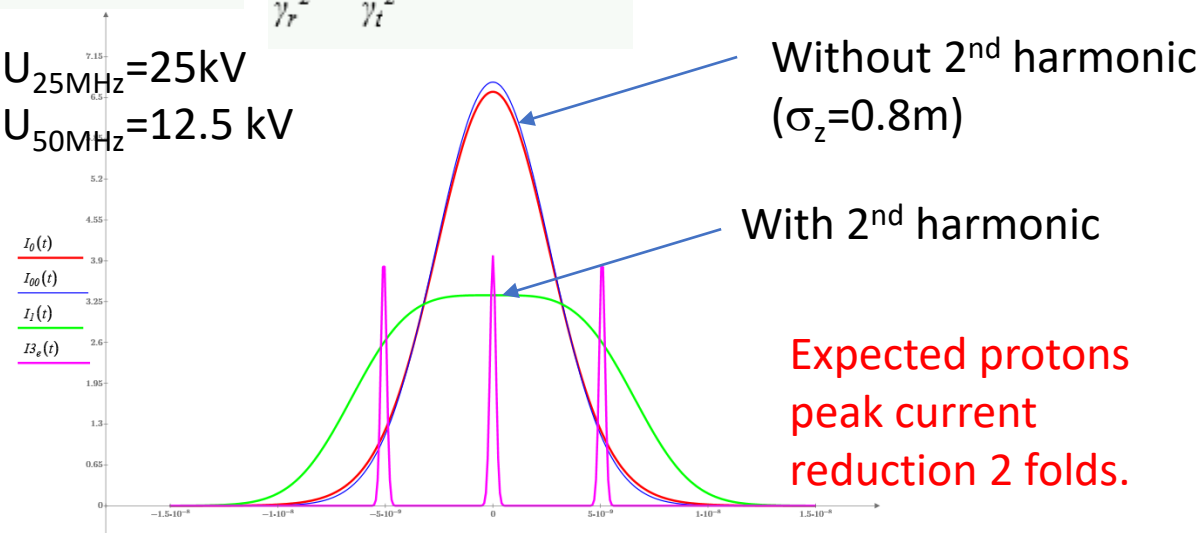
Goal:

In the EIC, high-intensity protons will be injected in modified 28MHz (24.6 MHz) RF system just above transition energy. To allow strong cooling of vertical emittance and maintain good proton beam lifetime, requires reducing peak current of proton bunches. Such peak current reduction can be achieved by using higher frequency RF used in counter phase, which flattens longitudinal profile of proton bunch. However, above transition energy and especially very close to transition energy, this can lead to various beam instabilities. The goal of this experiment is to explore parameters of high intensity bunch at injection with dual RF system and study beam stability.

$\gamma_t := 22.344 \quad \gamma_r := 24$

$\frac{1}{\gamma_r^2} - \frac{1}{\gamma_t^2} = -2.669 \cdot 10^{-4}$

U_{25MHz}=25kV
U_{50MHz}=12.5 kV



Proton bunch and electron bunches longitudinal profiles during cooling at the injection energy

Rms Energy spread=6e-4
Assuming longitudinal emittance from AGS 95%=0.8 eV.sec

The closest to EIC configuration: main RF 28MHz and 2nd harmonic 56 SRF cavity for flattening profile.

We understand that the 56 SRF system is very complicated system and it's very unlikely it can be used for APEX this year

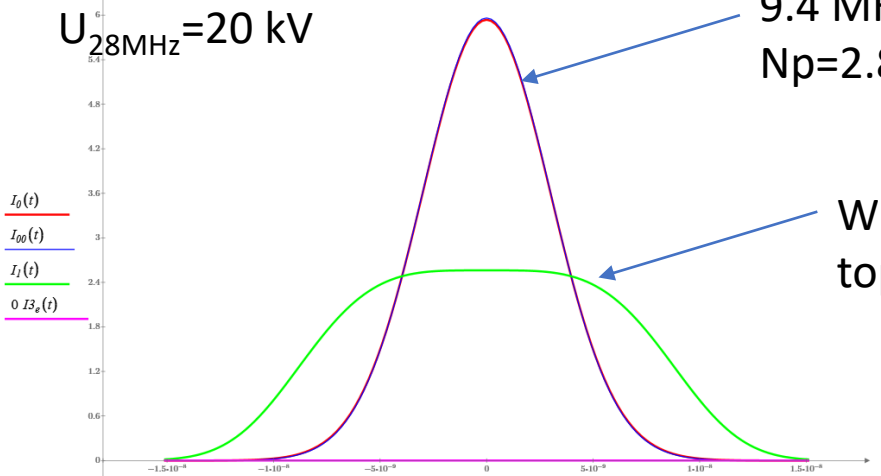
We propose to use 9 MHz system with 28MHz as a 3rd harmonic (similar configuration as it was used during Low Energy Run in 2021)

Plans for APEX

1. Inject high intensity proton bunches in 9MHz RF. Measure longitudinal and transverse emittances.
2. Inject high intensity proton bunches in dual RF with 28MHz RF in counterphase.
   - Measure peak current reduction.
   - Record longitudinal profiles (WCM)
3. Repeat for intensities 1e11, 2e11, 3e11.
   - If beam becomes unstable longitudinally or transversely, find regime and setting to make beam stable. Study effect of the additional Landau damping cavity.
   - Record proper settings.

4. Conduct these studies in both rings (different impedances)

$U_{9.4MHz}$=60kV
U_{28MHz}=20 kV



9.4 MHz only (Gaussian σ_z=0.9m, Np=2.8E11, I_{peak} =6 A)

With 3rd harmonic (Flat top, I_{peak}=2.5A)

Example: Expected longitudinal bunch profiles

S. KRINSKY and J. M. WANG. LONGITUDINAL INSTABILITIES OF BUNCHED BEAMS SUBJECT TO A NON-HARMONIC RF POTENTIAL

$$\frac{eI_{peak}}{2\pi E_0 \alpha (\sigma_\varepsilon/E_0)^2}\left|\frac{Z(n_0\omega_0)}{n_0}\right| \leq 1.$$

Using parameters for regular bucket and assuming Z/n=3 Ohm

$$Ipeak_{th} := \frac{2 \cdot \pi \cdot E0 \cdot \mathrm{abs}(\alpha_p) \cdot \sigma_p^2}{\beta_r^2 \cdot Zn} = 5.213$$ A

Time and other resources

Instrumentation: WCM, IPM, RF setup

Time:

1) Protons with 9MHz RF for different intensities (1h)
2) Protons with dual RF system: 9 and 28Mhz RF (4 hrs)

a. – find proper RF setup to reduce peak current 1 hr
b. – measurements for different intensities and longitudinal emittances: 1 hr
c. - collect data in both rings in parallel to save time

Total time: ~~5~~ 6-8 hours

Personnel: The MCR support. RF support. Both Yellow and Blue Rings