Longitudinal dynamic in NICA Barrier Bucket RF System at transition energy including impedances in BLonD

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INTRODUCTION

At an experiment on acceleration of a polarized proton beam up to an energy at 13 GeV, the possibility of crossing the transition energy at 5.7 GeV by a jump is considered. The scheme of crossing by a rapid change of transition energy, assumes the longitudinal movement of the beam near the zero value of the slip-factor. The jump itself is carried out in the absence of an RF field.
The paper investigates the impedance influence on longitudinal dynamics during the procedure of transition energy crossing with a jump. A distinctive feature is the use of Barrier Bucket RF, as a result a specific distribution of the beam in the phase space, different from the classical one, formed by harmonic RF.

γ-TRANSITION JUMP

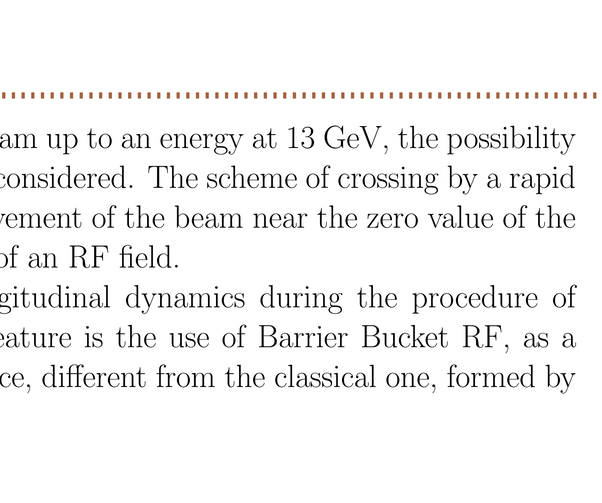
Equations of longitudinal motion describe a particle evolution in phase space. And at transition is necessary to consider high orders $\eta = \eta_0 + \eta_1\delta$, differs for each particle.

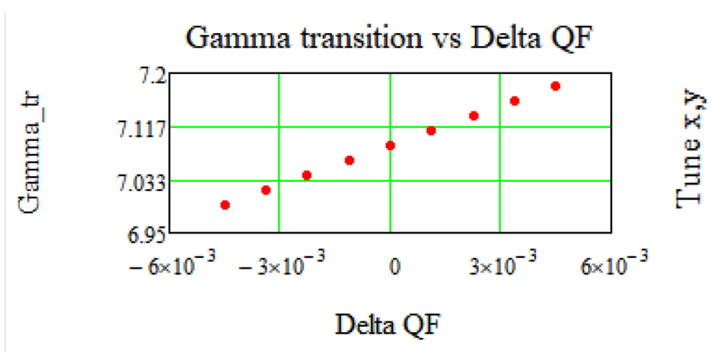
$$\frac{d\tau}{dt} = \eta(\delta) \cdot \frac{h \cdot \Delta E}{\beta^2 \cdot E_0}$$
$$\frac{d(\Delta E)}{dt} = \frac{V(\tau)}{T_0} \qquad (1)$$

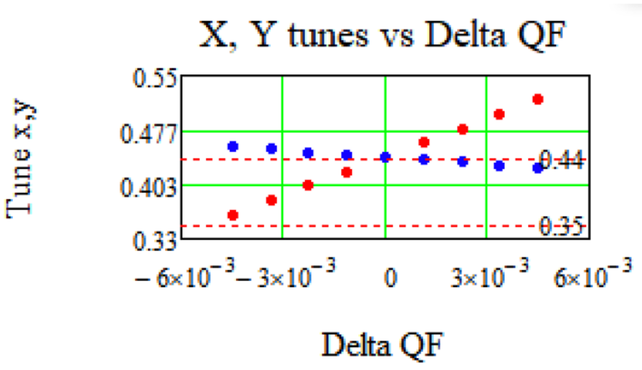
Longitudinal dynamics states based on γ_{tr} change:

1) acceleration from E_{inj} with stationary value;
2) smooth increase parallel with γ-particle to peak, slip-factor η_0 gets the minimal possible value;
3) jump over stationary value of transition, as soon as η_0 flipping over 0 value for all particles;
4) smooth recovery to stationary γ_{tr};
5) acceleration till the experiment energy;

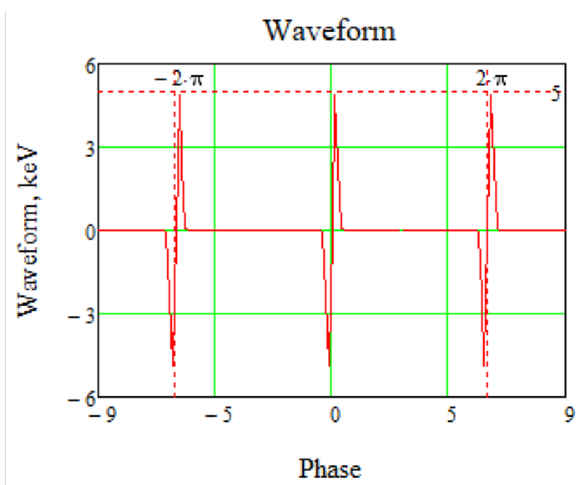
States 2-3-4 defines the γ_{tr}-jump procedure. To maintain, the magneto-optics changed by quadrupole gradients variation. This lead to dependance of γ_{tr} and tunes $\nu_{x,y}$. Stability region defines by dynamic aperture.

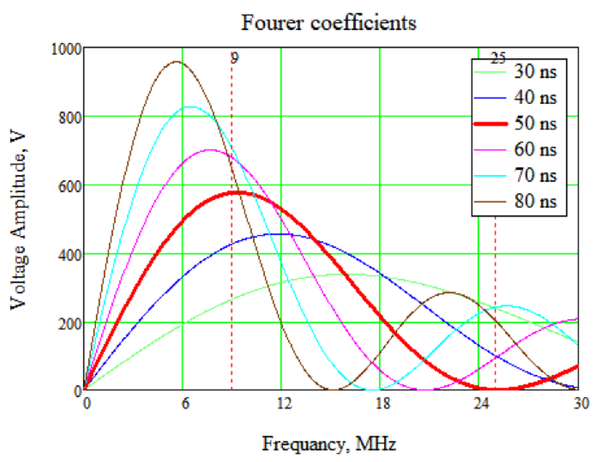






Barrier Bucket





Square Barrier Bucket RF signal fourier expansion.

$$b_n = \mathrm{sign}(\eta)\frac{2}{n\pi}\left[1 - \cos\left(\frac{n}{h_r}\pi\right)\right] \qquad (2)$$

Sigma-modulation make final signal smooth.

$$\sigma_{m,n} = \mathrm{sinc}^m \frac{n\pi}{2(N+1)} \qquad (3)$$

Voltage amplitude for each term.

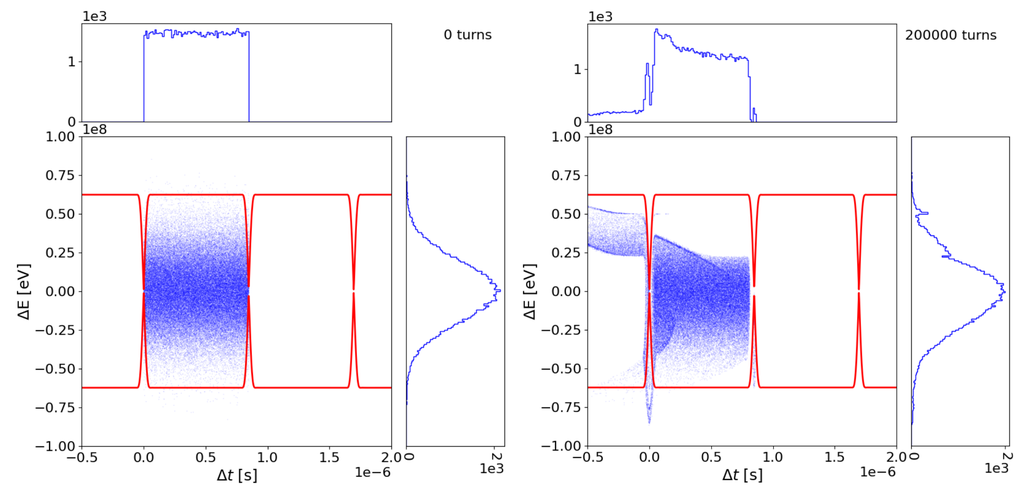
$$V_n = V^{\mathrm{peak}} b_n \sigma_{m,n}. \qquad (4)$$

Energy gain due to RFs kick. [1, 2]

$$\Delta E_i' = \Delta E_i + \sum_{i=1}^{n_{\mathrm{rf}}-1} V_j \sin\left(\omega_j \Delta t_i + \phi_j\right) \qquad (5)$$

TRACKING

Before jump



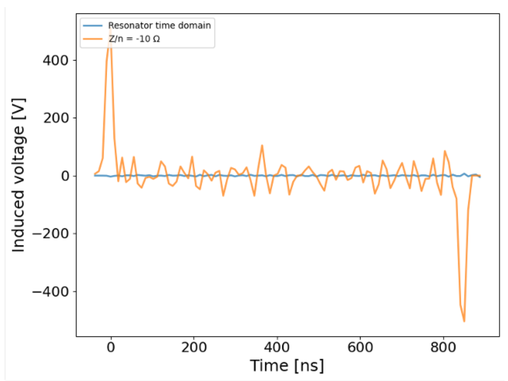
Acceleration before jump itself lasts for about 2×10^5 turns with RF focusing. And change polarity after jump. [3]

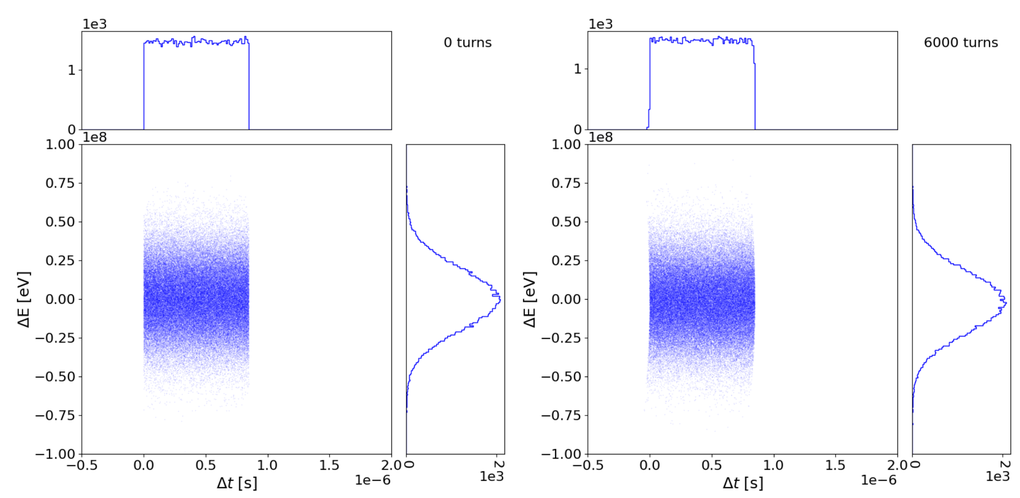
During jump

In considered case, space charge impedance plays a dominant role.

$$\frac{Z_{SC}}{n} = -\frac{Z_0\left[1 + \log\left(\frac{b}{a}\right)\right]}{2\beta\gamma^2} \qquad (6)$$

Due to special longitudinal distribution in Barrier Bucket, additional voltage produced by SC influence only on particles at the edge [4]. And don't make any distortion during jump without RF.





RF is swiched off during jump (6×10^3 turns) not to make any distortion, because particles move with different η, moreover, with various signs.

CONCLUSION

During the jump procedure the beam hold in separatrix. It helps to overcome the zero-value of slip-factor and don't lose beam. Jump procedure seems an available option cross transition energy.

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