# Possible upgrade of RF bunch rotation

I.A.Koop, BINP, Novosibirsk

RF bunch rotation is an important ingredient of CR beam longitudinal profile transformation prior to the stochastic cooling. It starts immediately after injection and lasts roughly one quarter of the synchrotron oscillation. Most stringent requirements to the RF system parameters are addressed by the RIB-optics mode, which differs from the antiproton one by the large value of the slip factor: ηRIB = - 0.2 instead of ηpbar = - 0.014. Therefore it requires V1= 200 kV of RF-voltage at first harmonic instead of 100 kV for the case of antiprotons. The Figure1, Figure2 present results of numerical simulation of such a process, assuming the initial bunch length τ= ± 25 ns (± 0.176 rad) and maximum energy deviation δ= ± 1.1%.



Fig.1 Initial phase-space distribution with a bucket boundary and the RF wave superimposed.



Fig.2 Phase-space distribution after rotation by single first harmonic only. The maximal relative energy deviation reaches δ= ± 0.239% (δp/p= ± 0.35%).



Fig.3 Initial phase-space and superposition of first and second RF harmonics V1=200 kV, V2=50 kV.



Fig.4 Phase-space after 80 turns affected by the superposition V1=200 kV, V2=50 kV.



Fig.5 Final phase-space after additional 124 turns under superposition V1=200 kV and reversed phase of the second harmonic: V2= -50 kV. Maximal energy deviation reached δ= ± 0.121% (δp/p= ± 0.175%).

**Bunch rotation of the antiproton beam.**



Fig.6 Bunch rotation of the pbar beam with V1=100 kV first harmonic RF only. It takes 1220 turns. Maximal energy deviation reaches δ= ± 0.585% (δp/p= ± 0.62%).



Fig.7 Bunch rotation of the pbar beam with V1=180 kV first harmonic RF only. It takes 820 turns. Maximal energy deviation reaches δ= ± 0.558% (δp/p= ± 0.59%).

**Now let’s switch on the second harmonic at 1800 relative to first harmonic phase after beam is partly rotated by the first harmonic.**



Fig.8 Bunch rotation of the pbar beam with V1=100 kV first harmonic RF (during 800 turns), then was added the second harmonic V2=30 kV (acts during 440 turns). Maximal relative energy deviation reaches δ= ± 0.35% (δp/p= ± 0.37%).

These numerical simulations shows that the most effective way to improve the quality of the bunch rotation is the use of the second harmonic RF, which should be switched on in the opposite to first harmonic phase during the final part of the bunch rotation. Just doubling of the voltage of the first harmonic does not help very much – the effect counts less than 5% (see Fig.6 and Fig.7), whereas with the second harmonic assistance the reduction reaches 40%.