COMMISSIONING AND TUNING OF THE NEW BUNCHER SYSTEM IN THE 870 KEV INJECTION BEAMLINE

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Abstract

During the shutdown period 2006 the buncher system in the 870 keV injection line of PSI Injector 2 has been modified. The new buncher configuration consists of a 50 MHz main buncher followed by a low amplitude 150 MHz debunching stage. The motivation for the alternation is outlined. Results of the commissioning and first high intensity beam tests are reported.

MOTIVATION

Since 2003 PSI's high power proton accelerator facility undergoes an upgrade project with the ambitious goal to enhance the beam intensity from 1.9 mA nowadays towards 3 mA [1,2]. Part of this upgrade programme is the modification of the bunching devices in the 870 keV beamline, performed during the shutdown period 2006. The new buncher configuration consists of a 50 MHz main buncher followed by a low amplitude 150 MHz debunching stage. This allows to enhance the beam intensity accelerated with Injector 2 to the desired level without increasing the proton current produced at the ion source.

SIMULATION OF THE BUNCHER CONFIGURATION

The optimal parameter settings have been searched for with a refined code based on the SPUNCH programme [3]. The simulation routines have been newly coded in the MATLAB language. The ability to calculate a double buncher configuration has been added as well as a variety of plot outputs. Despite its simplicity the one dimensional longitudinal space charge model was sufficient to describe the essential beam physical effects. In the charge

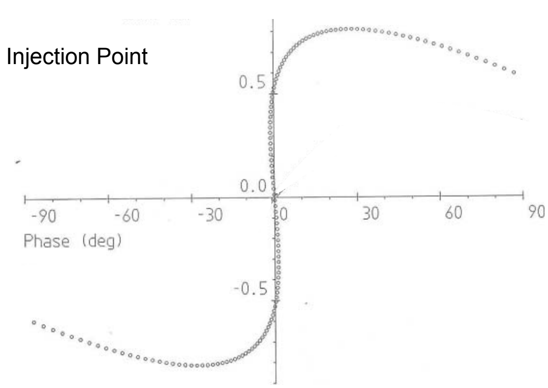

Figure 1: Bunching effect in a charge less model. The linear velocity distribution yields a concentration of the particles in phase but the energy spread from the buncher remains unchanged.

less buncher model all particles seeing the linear part of the buncher voltage get piled up at the buncher focus after some travelling distance (Fig. 1). In the extremely high charge density versus phase of a charge less buncher model the particles have a high energy spread because the energy variation from the buncher is persisting. In presence of strong space charge forces the leading

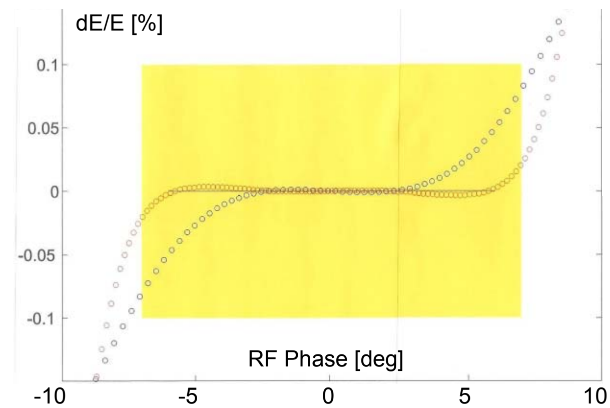

Figure 2: Almost monochromatic beam part at the buncher focus caused by the repelling space charge forces. The blue circles refer to the single harmonic buncher, the red ones show the effect of the long linear slope buncher system with 1st and 3rd harmonic.

particles get additional acceleration and the lagging parts deceleration as the beam approaches the buncher focus. This counteracts the energy variation from the buncher and the beam under space charge regime can become almost monochromatic at the focus (Fig. 2). Only such nearly monochromatic beams can successfully be accelerated in Injector 2. PSI's high intensity accelerator facility is thus depending on this "being helped" by the space charge effect since 1992 [4]. With appropriate

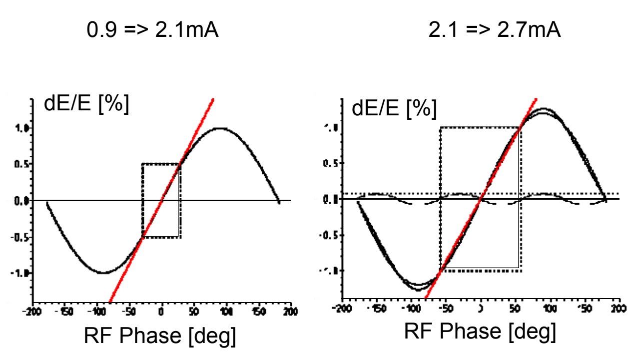

Figure 3: Widening of the linear part by applying a negative 3rd harmonic component to the buncher voltage.

parameter settings a longitudinal crossover of beam parts before the buncher focus can be avoided. The fraction of the initial DC beam that can be clustered around the buncher focus can therefore be greatly enhanced by extending the linear part of the buncher voltage as a function of time. To enhance the efficiency of a buncher system therefore means to produce an extended linear slope of the effective voltage. Best would be a saw tooth shaped RF-pattern, but already a simple addition of a debunching stage operating in 3rd harmonic mode at 13% of the main buncher amplitude yields a significant widening (Fig. 2, 3).

IMPLEMENTATION

Fig. 4 shows the implementation of the buncher constellation. The 50 MHz main buncher is followed by the 150 MHz debunching stage. The two bunchers are situated in the 870 kev injection beamline between the two bending magnets AWB and AWC and spaced by a

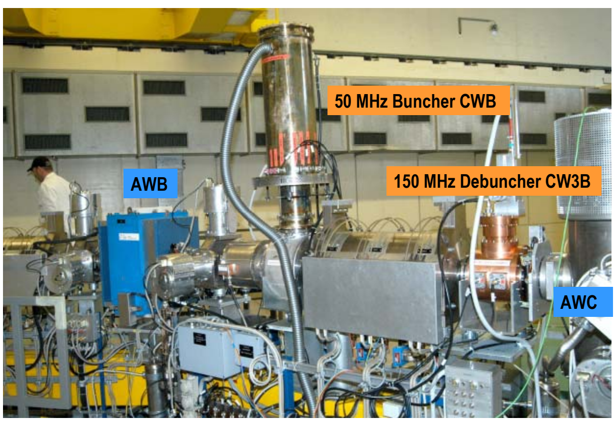

Figure 4: Location of the buncher configuration in the 870 keV injection line to PSI Injector 2.

quadrupole doublet. The travelling distance to the injection point (buncher focus) in Injector 2 counts to 4.2 m. The key parameters of the two bunchers are listed in table 1 below. Due to the low voltage needed for the 3rd harmonic debunching the second buncher can rely on simple ambient air cooling.

Table 1: Buncher Specifications

Buncher	**Main Stage**	**3rd harmonic Stage**
Ekp [MeV]	0.87	0.87
Fo [MHz]	50.6	151.8
Unom [kV]	8.5	1.2
Pnom [W]	125.	22.
Pavail [W]	300.	50.

COMMISSIONING

The layout of the centre region is sketched in Fig. 5. The bunched beam coming from the injection line crosses the two gaps of resonator 1 where the voltage of the acceleratimg RF-fields adds to the energy distribution in the beam. With the dispersion of sector magnet 2 the total energy as a function of time is converted into a radial pattern. E.g. the beam is waggling perpendicularly to its propagation like a dog's tail.

The decelerated beam phases hit the inner collimator KIP1. The movable phase selecting collimator KIP2 gets the accelerated particles except the phase range to be selected for further acceleration. With the part of the beam that is let to pass KIP2 the intensity is controlled.

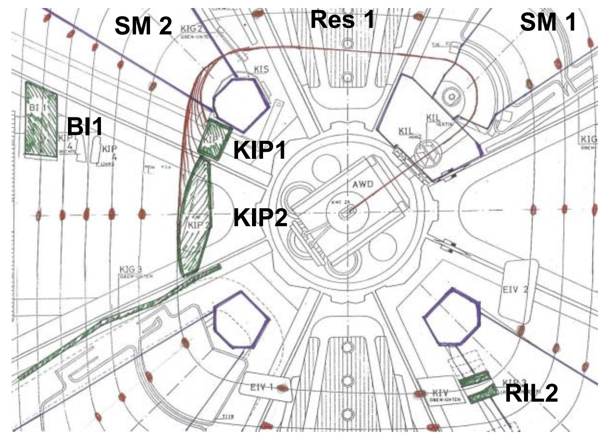

Figure 5: Centre Region of PSI Injector 2. The beam sheaf of the dispersion created in sector magnet 2 is collected by the collimators KIP1 and KIP2.

For commissioning a removable beam stopper BI1 is located at the 5th turn. On this stopper the amount of beam captured for acceleration can be measured without being forced to set up a proper extraction. In connection with the collimator KIP2 this element can be used as a sensitive probe to optimize the buncher parameters. If the buncher phase is adjusted correctly, the bunch is located symmetrically around the crest of the cosine shaped RF-voltage (Fig. 6). For the narrow phase range of the buncher focus the variation of the RF voltage can be neglected. The amount of beam passing KIP2 and found on BI1 therefore reflects the quality of the buncher focus

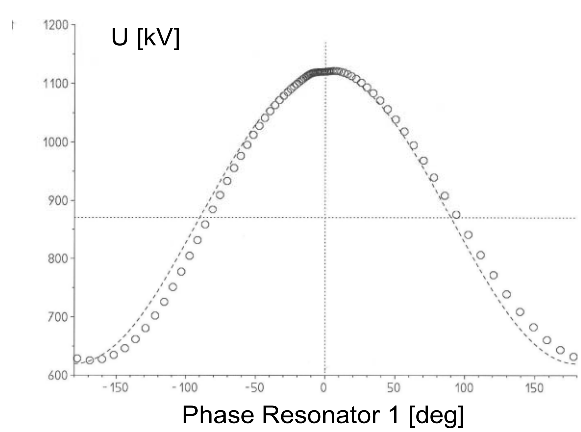

Figure 6: Energy distribution of the beam after having crossed resonator 1. The bunch is located symmetrically to the crest of the RF voltage

and its proper placing on the RF voltage crest A second collimator RIL2 is placed between KIP2 and BI1 for the purpose of cleaning beam tails. If now the KIP2 collimator is moved across the beam the steepness of the intensity recorded by BI1 with respect to the KIP2 position indicates the charge density across the beam. Since any deviation, either in buncher phase or in voltage decreases the local charge density it can be detected looking at the slant of this intensity graph.

Based on this layout, the commissioning of the new buncher configuration is performed in two steps. By means of scanning the beam intensity deposited on the beam dump BI1 as a function of the buncher phases and

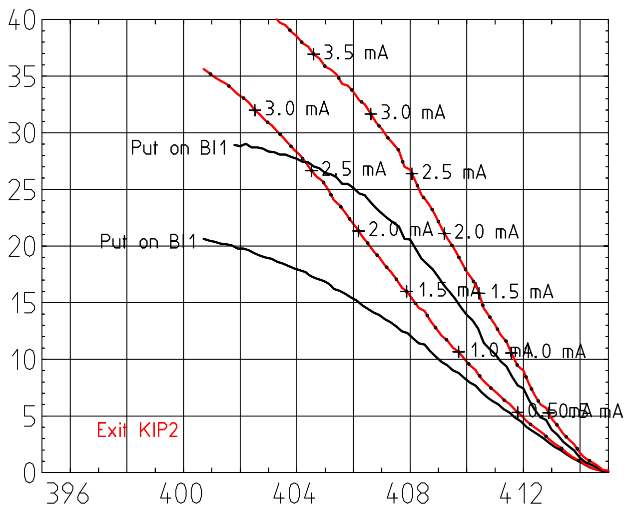

Figure 7: Fraction of DC proton current deposited on beam dump BI1 in % as a function of the KIP2 position in mm. For the beam going through the collimator set “Put on BI1” the gain is more marked with the double buncher.

amplitudes, a first estimate of the appropriate buncher setting can be found. In a second pass fine tuning of the buncher parameters is applied, maximizing the core density of the injected proton beam on the basis of the charge density evaluation explained in Fig. 7.

Following the successful optimisation of the buncher settings the subsequent acceleration across Injector 2 confirmed that a significant step forward in beam intensity had been achieved. After careful adjustment of the relevant cyclotron parameters a proton current of 2.7 mA could be extracted from the Injector 2. The beam at the extraction region is monitored by the single wire radial beam probe RIE1 (Fig. 8). The evaluation of the last seven turns in the cyclotron yields an average beam width “BRAV” of approximately 14 mm, corresponding to a beam emittance of 2.3 π-mmmrad. In the turn pattern the separation between successive turns is clearly visible. The lower beam density curve that displays the signal in logarithmic scale shows that in some of the valleys between turns the current density is more than two orders of magnitude below the peak value. Although the significant parameters of this beam lie clearly inside the window of acceptance for the Ringcyclotron, the successful acceleration to 590 MeV and its extraction with minor losses will require further upgrading effort. One important upgrading that has already started is the stepwise replacement of the old accelerating cavities by new ones made from copper and stainless steel. The lower

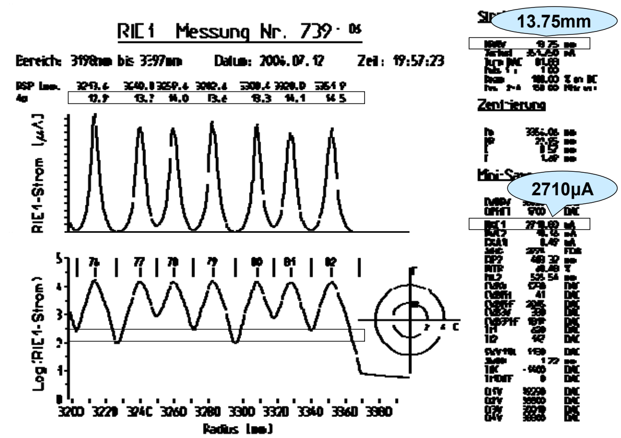

Figure 8: Display of the RIE1 current monitor probe. The blue highlighted data represent the key parameters for the subsequent acceptance by the Ringcyclotron.

electric losses of the new cavities will allow to operate them at a higher voltage using the same power amplifiers. Another upgrade is planned with the insertion of a rebuncher in the 72 MeV transfer line.

CONCLUSIONS

Being equipped with a double buncher system in its injection line, PSI Injector 2 is ready to deliver up to 2.7 mA of proton beam at an energy of 72 MeV.

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