BEAM DYNAMIC STUDIES OF THE 72 MEV BEAMLINE WITH A SUPER BUNCHER

A. Adelmann, S. Adam,
R. Dölling, M. Pedrozzi,
J.-Y. Raguin, P.-A. Schmelzbach, PSI Villigen, Switzerland

Abstract

A significant increase of the beam intensity of the PSI 590 MeV proton accelerator facility above 2 mA requires a higher accelerating voltage in the main RF cavities. A corresponding increase of the voltage in the flattop cavity would result in a complete rebuild of this device. As an alternative, a scheme with a strong buncher in the 72 MeV beam transfer line is being studied [3]. The goal is to restore the narrow phase width (2 deg/RF FWHM at 50 MHz) of the beam bunches observed at extraction from Injector 2 at injection into the Ring Cyclotron. If we can find and inject a stable particle distribution, as done in the Injector 2, the flattop cavity might eventually be decommissioned. First results of multi-particle tracking in full 6 dimensional phase space with space charge are presented.

INTRODUCTION

Used as a driver for the Swiss spallation neutron source (SINQ), the PSI cyclotron facility consists of the 72-MeV injector cyclotron (Injector 2) and the 590-MeV main Ring Cyclotron. Injector 2, with two double-gap 50-MHz RF cavities and two smaller 150-MHz cavities, can accelerate and extract a 2.2 mA proton beam. The beam bunches are injected into the Ring Cyclotron through a 58 m long transport line (96 mm diameter). The main cyclotron, which is equipped with four 50-MHz cavities and one 150-MHz flattop cavity, routinely extracts 1.8 mA and stable operation at 2 mA has been demonstrated last year. Upgrading the 2 mA beam current to 3 mA brings new challenges [1]: higher accelerating voltages and power amplifiers capable of handling large RF power swings are required to mitigate the beam loading and space charge effects. Moreover, the cavities of the main cyclotron are already operating close to their thermal limits. A rebuncher installed in the transfer line would considerably relax the RF requirements of the main cyclotron cavities leading, at best, to the decommissioning of the 150-MHz flat-top cavity.

INITIAL CONDITIONS

The spacial initial conditions (bunch length and bunch width) are obtained from measurements at the exit of the Injector 2 cyclotron at 72 MeV and with different intensities as shown in Figure 1. A $\Delta E/E$ of 2×10^{-3} (FWHM) is assumed and the normalized transverse rms moments are $P_x/P_0 = 0.0037$ and $P_y/P_0 = 0.0028$. We obtained the unnormalized rms emittance $\epsilon_x = 6.04645e^{-5}$ and $\epsilon_x = 1.74661e^{-6}$ (m rad) by fitting profile monitor data

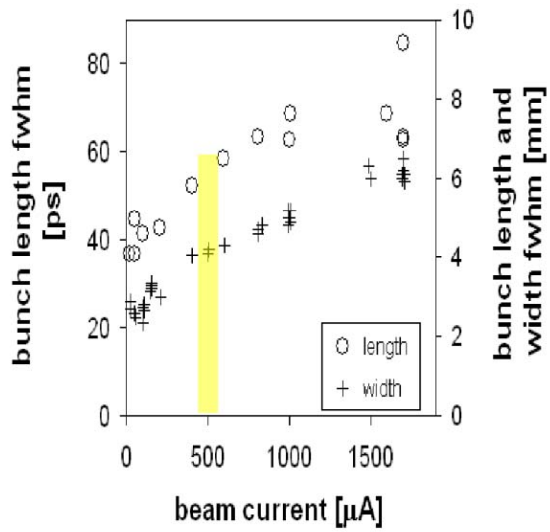

Figure 1: Spacial initial condition at entrance of the IW-2 line

as shown in Figure 2. Throughout all simulations reported here, 500 μA are used, due to lack of experimental data at higher intensities.

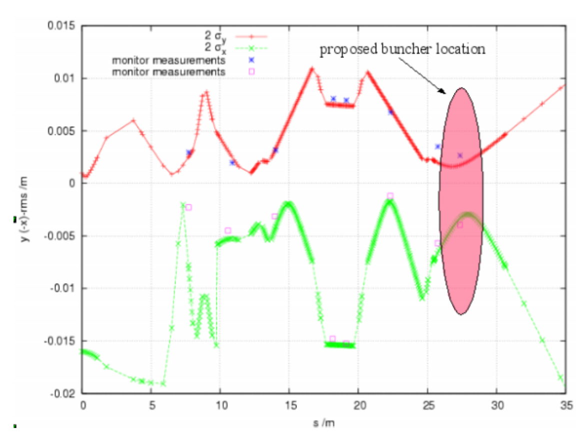

Figure 2: Transverse dynamics in the first part of the IW-2 line, comparing measurements and mad9p [2] calculations. The red ellipse indicates the proposed buncher location, around the double waist of the optics.

TRANSVERSE DYNAMICS

As shown in Figure 2 we obtain very good agreement between simulation and beam profile measurement in the first part of the IW-2 beam transport line on the 2σ level. All simulations where done self-consistently with Mad9p [2], using 10^7 particles and 64^3 grid points for the FFT based field solver. Our goal is to install the buncher in the double waist, as indicated in Figure 2. Finding the optimal position is a nontrivial optimization task with the following main objectives: minimize transverse halo at buncher position, minimize buncher voltage and obtain good longitudinal phase space quality.

In Figures 3 and 4 we show a 4σ cut to estimate the transverse halo at the worst case position as indicated in Figure 2.

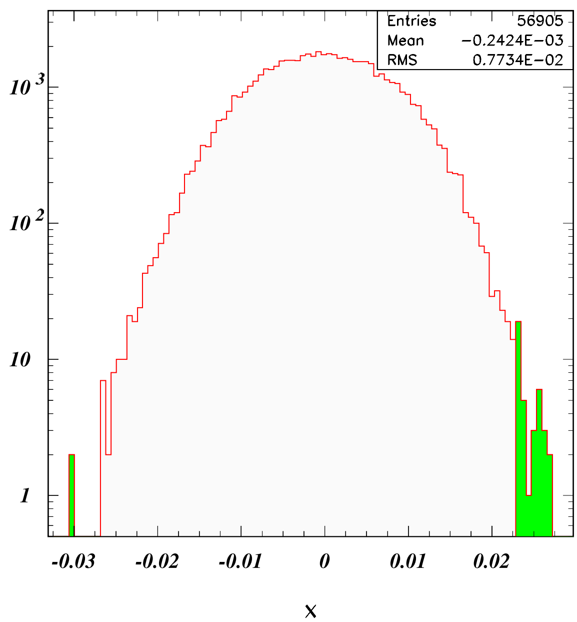

Figure 3: Histogram of the beam size at worst case buncher position in x direction

LONGITUDINAL DYNAMICS

Tow slit bunchers where studied [3]: 150 MHz with gap length $\beta\lambda/2$ and 500 MHz with gap length $\beta\lambda$. For the simulation we used a thin lens approximation for the buncher cavity with $E_z = E * \sin(\omega t + \phi)$ and obtained a buncher voltage $V_b = 218$ kV for the 500 MHz case and $V_b = 714$ kV for the 150 MHz case respectively. In these two cases we obtain at the entrance of the Ring Cyclotron the same phase with as at the exit of Injector 2 as shown in Figure 1.

The longitudinal phase space however is different in both cases and shown in Figures 5 and 6. In the 500 MHz case at the present buncher location we start seeing the nonlinear field. Figures 7 and 8 showing histograms of the phase space where we can see this effect in more detail.

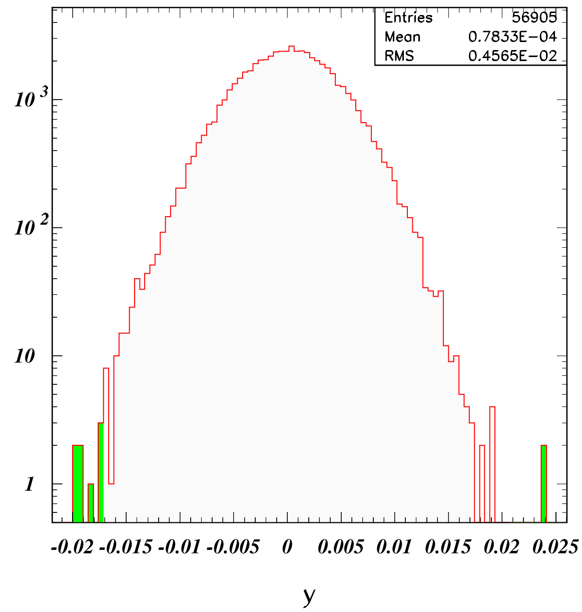

Figure 4: Histogram of the beam size at worst case buncher position in y direction

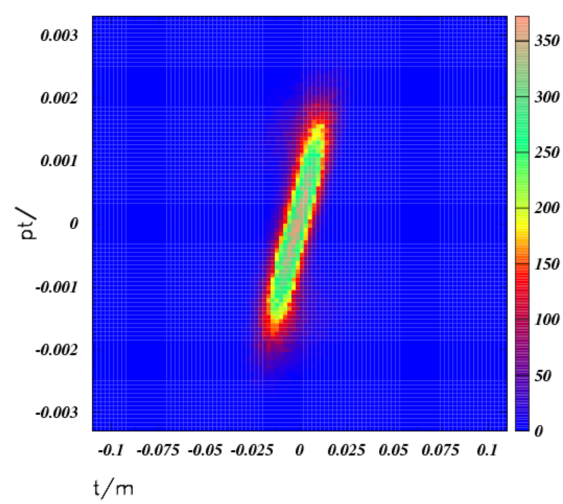

Figure 5: Longitudinal phase space with 500 MHz buncher

CONCLUSIONS

We are able to estimate the required buncher voltage to achieve at the entrance of the Ring Cyclotron the same phase width as is present at the exit of Injector 2. We include space charge [2] and the real lattice of the IW-2 beam line.

Halo estimation of the transverse beam dimension suggests that a bore radius of 4 to 5 centimeters for the buncher can be used.

However the longitudinal phase space with a 500 MHz super buncher has tails which are probable too large. At the moment we are not in the position to make a final statement because the detailed optics studies, including comparison

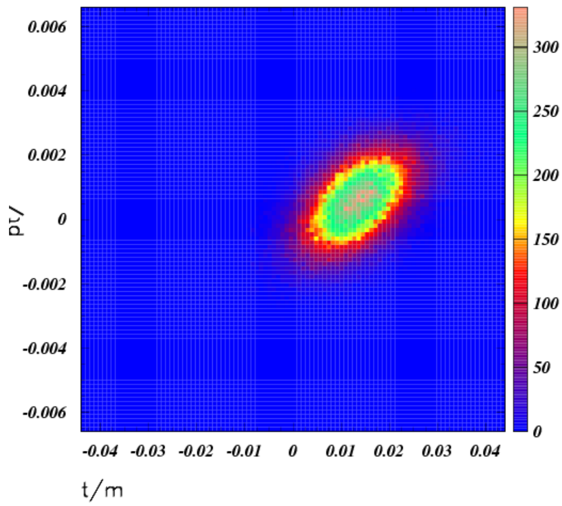

Figure 6: Longitudinal phase space with 150 MHz buncher

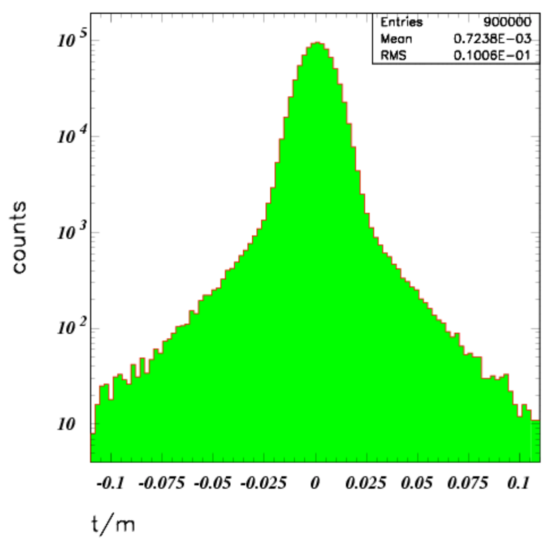

Figure 7: Histogram of bunch length with 500 MHz buncher at exit of the IW-2 line

with experimental data, are only done half way as shown in Figure 2. Specially important for the longitudinal dynamics are the several dipoles downstream from the buncher which have not been properly taken into account at this point.

The next steps include:

- finish transverse dynamics with currents up to 3 mA and compare simulation with experimental data.
- emittance measurement in the IW-2 line.
- detailed beam dynamics studies using an eigensolver for computing electromagnetic fields in the buncher cavity [4].
- rematch longitudinally including the real lattice

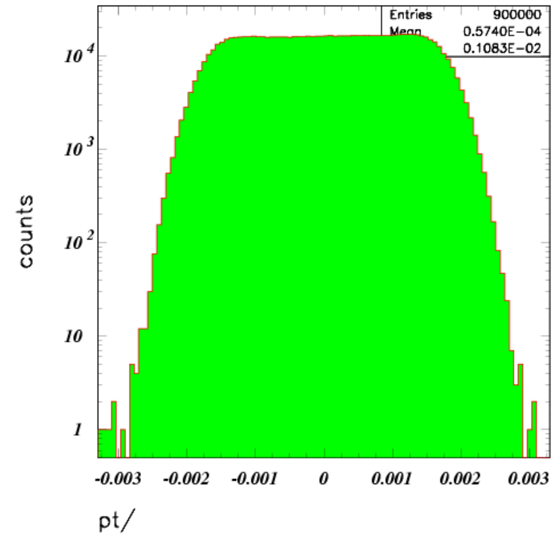

Figure 8: Histogram of $\Delta p/p_0$ with 500 MHz buncher at exit of the IW-2 line

- study the Ring Cyclotron dynamics with the new initial condition

ACKNOWLEDGMENT

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