EXPERIMENTAL STUDY OF THE TRANSVERSE BEAM SIZE USED A FAST WIRE SCANNER IN THE U70 AT IHEP

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Abstract

Results of experimental study of the transverse beams size in the U70 synchrotron based on a fast wire scanner are given. Measurements of the transverse beam size were carried out at three special points of the U70 synchrotron magnetic cycle: on the injection flat top (1.3 GeV proton, 0.455 GeV/u carbon); in the region of the transition energy (7.959 GeV proton); on the main flat top (49 GeV proton). Results of the fast wire scanner approbation for determination of transverse injection errors and evaluating transverse feedback efficiency are presented.

INTRODUCTION

The goal of this work is to study the transverse dimensions of light-ion beams (protons and carbon) in various operating modes of the accelerator. The implementation of such studies contributes to an increase in the efficiency of the accelerator and to the improvement of the quality of the output beam. The possibility of such work is due to the commissioning of vertical and horizontal fast wire scanner. The horizontal scanner is located in vacuum chamber with a length of 600 mm in a 104 rectilinear gap. The vertical scanner is located in a 550 mm long vacuum chamber in a 94 rectilinear space. Betta functions for these sections are equal to β_R = 26.8 m, β_Z = 27.6 m. Scanners are developed on the basis of servomotor and servo controller and are described in [1]. The speed of intersection of the beam with a carbon filament in them was V = 16 m / sec. Stages of development of measurement systems for the profile of a circulating beam in IHEP are also presented in [2].

REGISTERING EQUIPMENT

Two secondary scintillation detectors with plastic scintillators with a high gain and with a time resolution of ~ 8-10 ns (SSDI-8 based on the SNFT3 photomultiplier and detectors based on the photomultiplier tube PMT-30) have been installed near the vacuum chamber to detect secondary radiation arising from the crossing of the circulating beam with a carbon filament. The use of such detectors allowed recording beam profiles along a coaxial cable up to 400 m long directly on an oscilloscope or ADC for a load of 50 Ohms and to observe each bunch as well as the entire beam profile. Taking into account the need to perform measurements both at the injection energy and with the carbon beam, we chose a carbon filament with a diameter of ~ 200 μm. The installed filament consists of a bundle of stranded 5 μm filaments. The created equipment allows detecting profiles of the proton beam in the energy range (1.3 ÷ 70 GeV) and intensities (10^{10}÷10^{13}), as well as beam of carbon nuclei in the energy range (0.455 ÷ 35 GeV/ nucleon) and intensity (10^9÷10^{10}) $^{12}C^{+6}$.

STUDY RESULTS

Measurements on the Injection Flat Top Magnetic Field 355 G

Measurements of the transverse dimensions of the beam on the injection plateau make it possible to estimate and correct such important parameters of the accelerator complex as: the dimensions of the output beam from U1.5; bug input errors from U1.5; stability of the magnetic field plateau; work of orbit corrections; position of the working point on the plane (Q_R, Q_Z); work of corrections of quadratic and cubic nonlinearities; analog narrow-band and digital broadband transverse feedback systems works, etc. The results of measuring the vertical and horizontal dimensions of the proton beam at an intensity I=5·10^{12} protons are shown in Fig. 1.

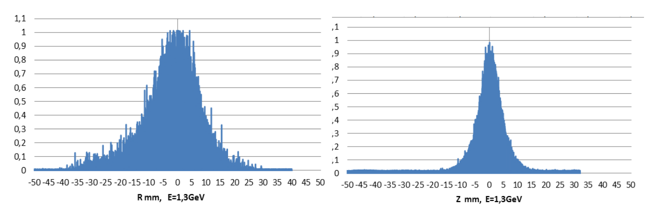

Figure 1: Transverse profiles of the proton beam (left – horizontal, right – vertical), 1.3 GeV and 5·10^{12} ppp.

The results of measuring the vertical and horizontal dimensions of the carbon beam (455 MeV/u) at an intensity I=3·10^9 $^{12}C^{+6}$ are shown in Fig. 2.

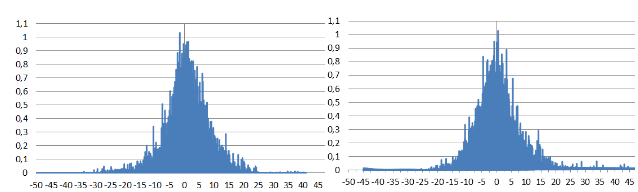

Figure 2: Transverse profiles of the carbon beam (left – horizontal, right – vertical), 455 MeV/u injection flat top magnetic field 355 G.

Measurements at the Transition Energy

The transition energy of a particular point in the acceleration of particles in a synchrotron is described in detail in [3]. The acceleration through transition can be accompanied by an increase in the transverse dimensions of the beam. The main factors influencing the beam size: an increase momentum dispersion associated with longi-

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tudinal mismatch; transverse instabilities associated with the space charge and the effect of resonances associated with the change in the position of the working point in the plane (Q_R, Q_Z). Measurement of the transverse dimension of the beam along the R direction near the transition energy is shown in Fig. 3.

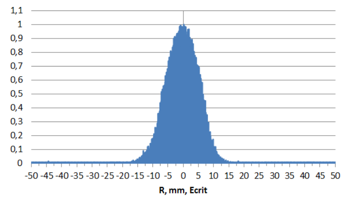

Figure 3: Transverse profiles of the proton beam, 7.69 GeV.

Measurements on the Flattop Magnetic Field 8590 G

The main types of extraction in the U70: slow resonant extraction (stochastic, classical); single turn fast ejection of arbitrary number of bunches (from 1 to 29); . slow extraction of protons by means of bent monocrystal; extraction of secondary particles generated on internal target. Controlling the transverse dimensions of the beam on the main plateau of the U70 magnetic field makes it possible to increase the efficiency of all types of extraction. The results of measuring the vertical and horizontal dimensions of the proton beam at an intensity $I=5{\cdot}10^{12}$ protons are shown in Fig. 4.

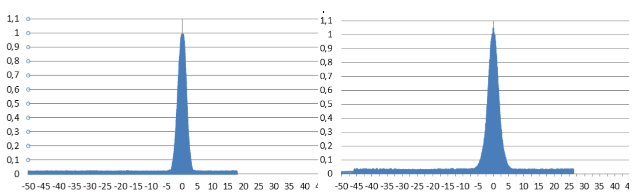

Figure 4: Transverse profiles of the proton beam, 50 GeV.

The effect of a Single Crossing of the Scanner Filament on the Beam Dimensions

Measurements of horizontal beam sizes were made to assess the impact of a single crossing of the scanner filament on a carbon beam (455 MeV/u). The beam profiles are shown in Fig. 5.

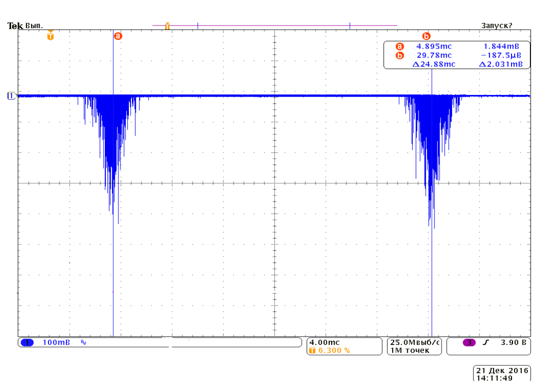

Figure 5: Transverse profiles of the carbon beam, 455 MeV/u.

From the Fig 5. it is possible to define that relative changes of the beam size ΔR/R ≤ 5%. For a proton beam at energy E =1.3 GeV ΔR/R ≤ 2.5%.

Fast Wire Scanner Approbation for Determination Of Transverse Injection Errors and Evaluating Transverse Feedback Efficiency

In addition, studies were made of the effect of analog narrow-band and digital broadband transverse feedback systems on the radial size of the proton beam. For this purpose, the error of introducing a beam from the U1.5 was artificially created by changing the current in one of the dipole magnets of the beam transfer channel. The results are shown in Fig. 6.

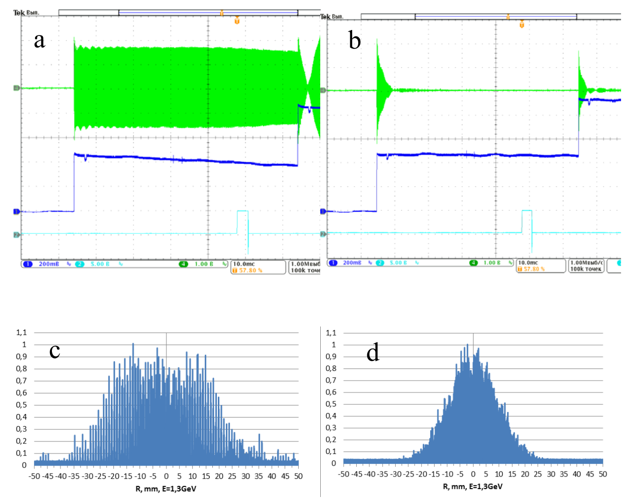

Figure 6: a) c) transverse feedback systems **off** b) d) transverse feedback systems **on**. At figures a) b) Traces from top to bottom: transverse beam offset signals, beam intensity, measurement trigger. At figures c) d) Horizontal profiles of the proton beam.

Longitudinal Resolution of the Scanner

Longitudinal resolution of the scanner are shown in Fig. 7. Period of circulation is 4.94 μs.

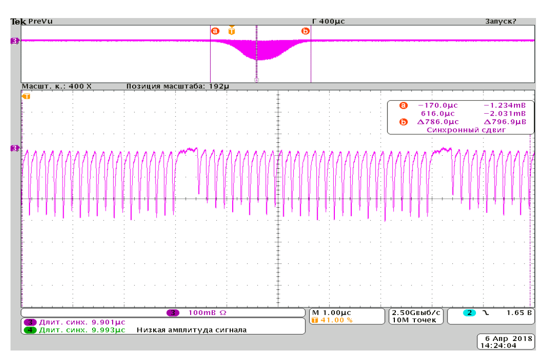

Figure 7: Longitudinal resolution of the scanner.

CONCLUSION

The scanner that was commissioned is applicable for measuring beam dimensions in a wide range of proton energies (1.3 ÷ 50 GeV) and carbon (0.455÷25 GeV/u).

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