Results of the Orsay Spot Size Monitor for the Final Focus Test Beam

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Abstract

A new gas-ionization monitor has been developed and installed to measure transverse bunch sizes of the FFTB beam at SLAC smaller than 100 nanometers. It has also been successfully used to monitor the beam, and to detect and cancel 'banana' shapes of the bunch.

1 INTRODUCTION

A prototype focusing system for a future linear collider, the Final Focus Test Beam (FFTB), has been developed at SLAC and operated by a collaboration between DESY (Hamburg), FNAL (Batavia), KEK (Tsukuba), INP (Novosibirsk), LAL (Orsay), MPI (Munich) and SLAC (Stanford) (1). One of the challenge was to measure transverse beam sizes smaller than 100 nm. Two new beam size detectors have been built, a laser-Compton monitor by the KEK group (2), and a gas-ionization monitor by the Orsay LAL group.

2 PRINCIPLE

The principle has been already described in detail elsewhere (3). A low pressure He gas pulse is injected at the passage of the electron bunch near the waist. He^+ ions are created, and trapped in the high transverse electric field of the electron beam ($\sim$ 1V/Å). They oscillate during the bunch passage in the transverse plane. The horizontal amplitude of this oscillation being wider than the vertical one for a flat beam, the ions oscillate mainly horizontally, and after the bunch passage, drift with a constant velocity towards the two horizontal directions. The information on the transverse dimensions of the beam is contained in the two peaks of the azimuthal distribution, and in the minimum time of flight of He^+ ions.

3 EXPERIMENTAL SET-UP

A fast electromagnetic valve mounted on the pipe near the focal point and triggered at the beam passage (at 10 Hz) injects He gas at an adjustable pressure. The small amount of gas is taken out of the pipe by two turbomolecular pumps located on both sides of the monitor. After oscillation during the beam passage, He ions have to go through a narrow slit adjustable from 0 to 1.2 mm. So only ions coming from the focal region along a longitudinal length comparable with the β^*_y of the beam reach the ion detector. It consists of eight pairs of microchannel plates (MCP) surrounding the beam line at a distance of 65 mm (fig.1). The charges delivered by the MCP's are collected by a set of 80 strip lines parallel to the beam direction. The signals are then locally amplified, and transported through 35 m long cables to shapers. The 30 ns wide shaper signals are sampled at 200 MHz, stored in analog memories and digitized. A microcomputer controls and pilots the monitor. It reads the data and recognizes the ion signals, which are characterized by their time of flight, azimuth, and collected charge. It stores the data during a preselected time, typically a few ten bursts. Then it determines the minimum time of flight t_m of the ions, and the first Fourier coefficients A_1, A_2, ... of the azimuthal distribution, t_m depending mainly on the horizontal dimension, and A_2 on the vertical one. From these two parameters it calculates the two transverse spot sizes on-line.

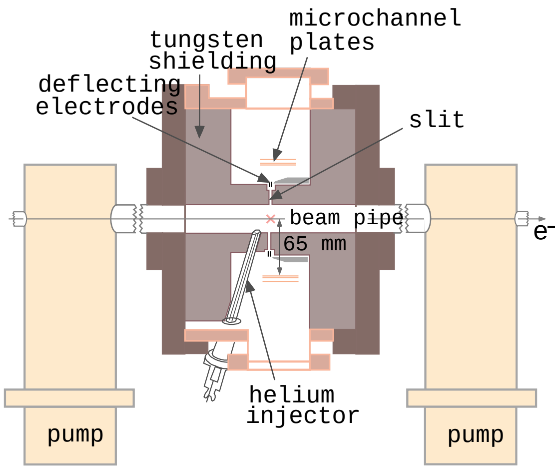

Figure 1: Longitudinal view of the monitor

4 RESULTS

The Orsay beam size monitor has been installed on the FFTB line in 1993, and measurements have been preformed in 1994 and 1995. Figure 2 shows the time of flight distribution of He^+ ions. The 1-2 ns resolution on the determination of the minimum t_m of this distribution is not affected by the 1 % contamination from H^+ ions appearing at lower time. Not shown on the figure 2 is the small background with time of flight less than 40 ns, due to fast electrons or X-rays. On figure 3 is shown the azimuthal distribution of the same ions, showing two peaks in the horizontal directions, after a significant correction for the pile up signals (40 % on the peaks). From the minimum t_m of the time distribution, and the second order Fourier coefficient A_2 of the azimuthal distribution, knowing the bunch length and population, an algorithm calculates the transverse beam dimensions σ_x and σ_y by comparison with Monte-Carlo simulations. The best result obtained, corresponding to figures 2 and 3 is $\sigma_x = 1.5 \pm .2$ μm and $\sigma_y = 73 \pm 10$ (stat)$\pm$ 10 (sys) nm, the systematic uncertainty is mainly due to MCP relative inefficiencies.

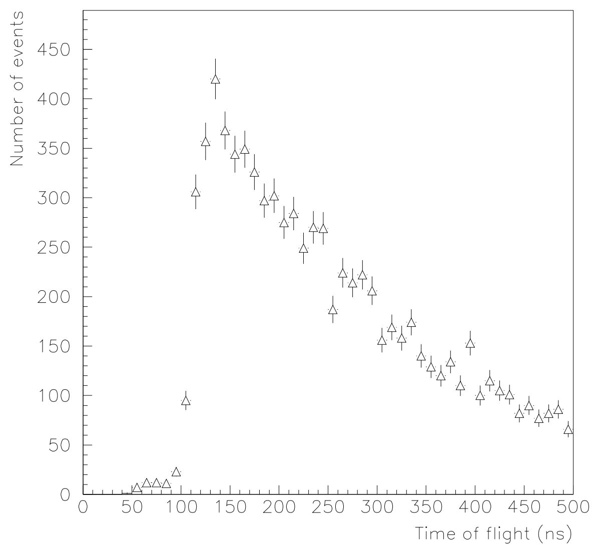

Figure 2: Time of flight spectrum of He^+ ions (statistics for 400 electron bursts)

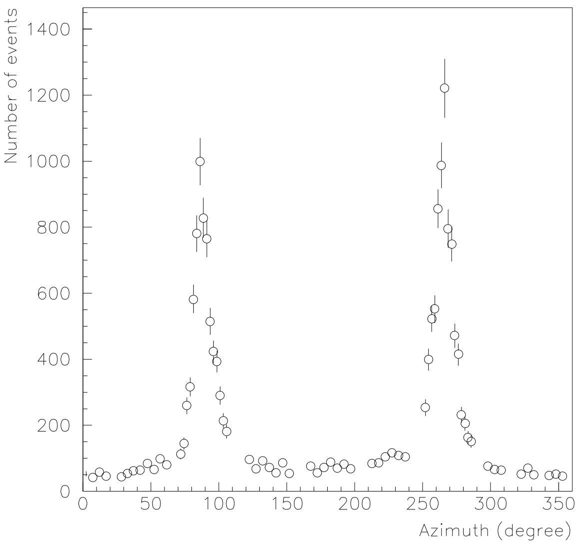

Figure 3: Azimuthal distribution of He^+ ions corrected for the pile up. The azimuth origin is the upward direction

The Orsay monitor has been also intensively used to optimize the beam: by minimization of the minimum time of flight one can minimize the horizontal spot dimension with a large dynamical range (from 100 μm to 1 μm) and by the maximization of the Fourier coefficient A_2 it is possible to minimize the vertical spot size, with a smaller dynamical range (from about 1000 to a few ten nm). An unexpected and very interesting result of the Orsay monitor is its sensitivity to any kind of asymmetry of the electron distribution in the bunch, for example to a transverse tail of the bunch longitudinal distribution named 'banana' shape: for such a distribution, ions created by the head of the bunch are attracted by the tail, in such a way that the azimuthal distribution exhibits a wide peak in the tail direction. Figure 4 shows experimental azimuthal distributions, due to tails generated by two horizontal bumps at 90 and 270 deg in the linac. The 'banana' tail can be estimated by the odd Fourier coefficient A_1 and the on-line determination of this parameter allows to reduce very quickly the tail amplitude.

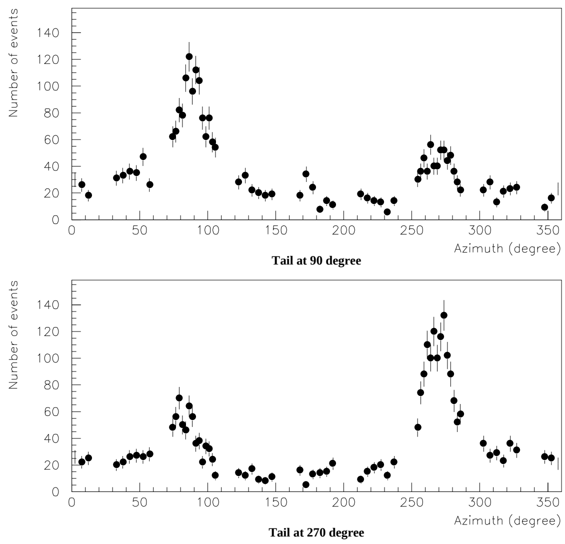

Figure 4: Azimuthal distribution of He^+ ions with a horizontal tail at 90° (top) and 270° (bottom)

5 CONCLUSION

The Orsay beam size monitor developed for the FFTB line at SLAC has been operated successfully. It is non destructive, insensitive to beam jitter and position, and can measure beam spot sizes as small as 50 nm. It is very efficient for tail cancellation, and very helpful for beam optimization.

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