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

P. Puzo, J. Buon, J. Jeanjean, F. Le Diberder, and V. Lepeltier

Laboratoire de l'Accélérateur Linéaire
Université de Paris Sud
Bâtiment 200
F 91405 Orsay Cedex
France

Abstract

A gas-ionization beam size monitor has been developped for the Final Focus Test Beam (FFTB) at SLAC [1], to measure dimensions in the nanometer range. This detector is also sensitive to longitudinal beam distorsions. The first extensive runs of the FFTB[2] have been performed in April 1994. We report here the first results of the monitor.

1. DETECTOR

The detector consists (cf Figure 1) of a pulsed gas target located at the focal point and triggered at the passage of an electron bunch. Ions, produced in the spot area, are expelled by the space charge field of the bunch and detected by an array of 8 pairs of microchannel plates (MCP), surrounding the beam line.

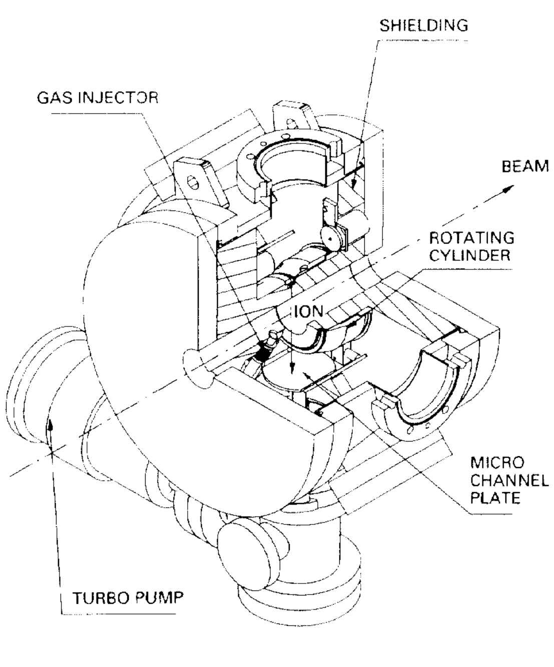

Figure 1. Schematics of the detector.

Each ion delivers on the MCP anode a charge of 0.5-1.0 pC. The signals are read at the ends of 80 resistive strip lines parallel to the beam axis, that allow to reconstruct the azimutal distribution of the ions, as well as the longitudinal position of their impact on the MCP. The signals of the 160 electronic channels are amplified and then digitized by an HAMU[3] at a 200 MHz frequency.

2. SPACE CHARGE FIELD

The ions are created at rest by the beam with a transverse distribution that roughly follows the transverse distribution of the electrons in the bunch.

For ultrarelativistic electrons ($\gamma \approx 10^5$), the electric field is transverse to their trajectory, so are the force and the motion of the ions. After the passage of the beam, the velocity of an ion is given by the integral of the space charge field it experienced. For the very focused FFTB beams (1 µm x 60 nm @10^{10} electrons per bunch), the maximum electric field reaches 2.5 V/Å

The space charge field increases with the distance to the center in the core, reaches a maximum at the edge and decreases outside. The maximum value of the electric field is inversely proportional to the largest dimension of the beam, with some correction due to the other dimension [4].

3. MEASUREMENTS

3.1. The aspect ratio $R = \sigma_x / \sigma_y$

In the case of light ions (He^+), their mass is low enough to make them oscillating in the potential well of the electron bunch during the passage of the beam. Depending on their creation position and time, they can perform up to 2 or 3 oscillations for the nominal FFTB beams.

In the case of a horizontally flat beam, the azimutal distribution of the emitted He^+ is peaked along the horizontal direction [4]. For a round beam, the azimutal distribution is isotropic. *The anisotropy of the azimutal distribution of He^+ ions gives the aspect ratio of the beam.* Figure 2 presents an experimental azimutal distribution of He^+ ions. There are two peaks in the horizontal direction, at lefthand and righthand (resp.). That even anisotropy is only significant and useful when the bunch has submicronic dimensions.

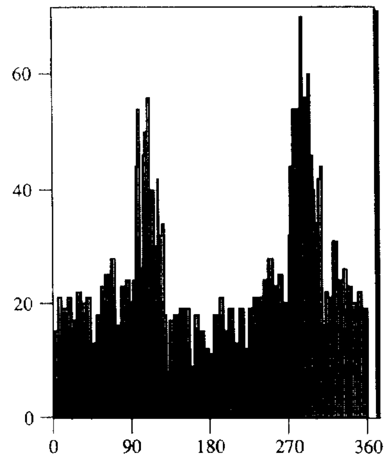

Figure 2. Azimutal distribution of He^+ ions (beam size≈1.3x.65 μm).

3.2 The horizontal dimension σ_x

To measure the horizontal dimension, one rather uses a heavy gas target : Argon ions are so heavy that they do not move significantly during the passage of the electron bunch. Their maximum velocity is then inversely proportional to the horizontal dimension of the beam. *The measurement of the minimum time of flight of Ar^+ ions gives the horizontal dimension of the beam.*

Ar^{2+} ions can also be produced by a two-step ionization of Argon atoms. Up to 15 % of Ar^{2+} have been observed in these first runs with a smaller time of flight (cf Figure 3). An electrostatic separation of Ar^+ and Ar^{2+} has been implemented in the monitor, but not yet used in these first runs.

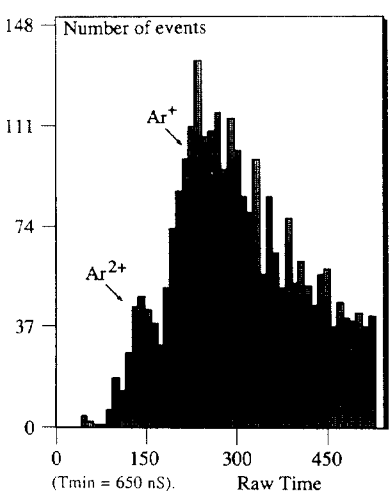

Figure 3. Time of flight spectrum obtained with Argon gas

Even if they are oscillating, we used for these first runs the He^+ ions, as the production of He^{2+} is negligeable. The minimum time of flight also depends on the horizontal dimension σ_x, but with a smaller sensitivity.

Figure 4 shows an experimental time of flight spectrum obtained with Helium gas. The minimum time of flight is given by the sharp edge. The few counts before the edge are attributed to H^+ ions, likely produced by the dissociation of residual water vapor.

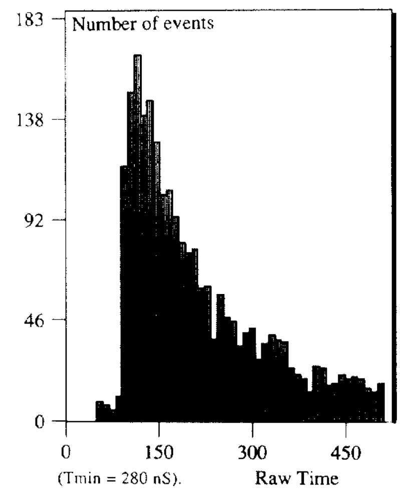

Figure 4. Time of flight spectrum obtained with Helium gas

The minimum time of flight is much more sensitive to an increase of the horizontal dimension than to an increase of the aspect ratio. Nevertheless, the precise measurement of σ_x needs to take into account σ_y.

3.3. Beam tails

When the beam is symmetric, the azimutal distribution can only have an even anisotropy. But the symmetry is broken in presence of a transverse tail. The ions are preferentially attracted in the direction of the tail, leading to a single peak. That odd anisotropy is maximum when the tail results from a transverse displacement of the bunch center in the back part of the bunch ("banana" effect). *A tail in the bunch creates an anisotropy in the direction of the tail.* The odd anisotropy can be separated from the even one's due to the flatness of the beam by a Fourier analysis. Figure 5 and 6 show the He^+ azimutal distribution obtained with upward and downward tails respectively.

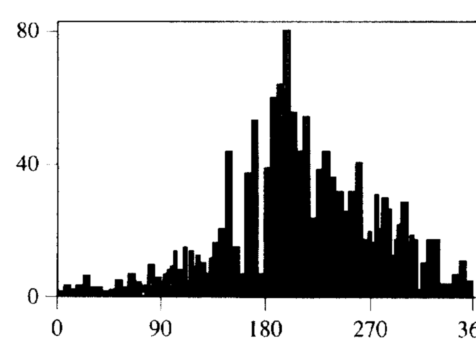

Figure 5. Azimutal distribution of He^+ ions with a downward tail.

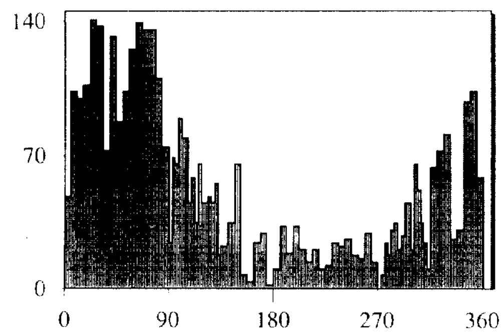

Figure 6. Same distribution with an upward tail.

The data of Figures 5 and 6 have been obtained with transverse beam dimensions of several microns and cannot show any even anisotropy.

Figure 7 shows a correlation plot between the amplitude of a bump creating a tail in the linac, that is vertical at the focal point, and the cosine Fourier coefficient of order 1 of the azimutal distribution. It appears that the sensitivity of the monitor to detect these tails is much larger than the one of the usual wire scanners .

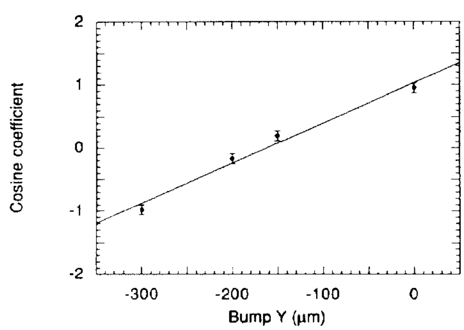

Figure 7. Cosine Fourier coefficient of order 1 of the azimutal distribution versus the amplitude of a linac bump creating a tail.

3.4. *Beam tilt*

The direction of the two peaks in the azimutal distribution also allows to determine the tilt of the beam in case of a flat beam. Figure 8 shows the correlation between the measured tilt and a coupling sextupole knob.

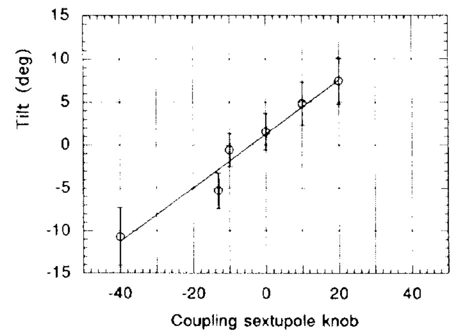

Figure 8. Correlation between a coupling sextupole knob and the measured tilt of the beam.

4. OPERATIONAL CONDITIONS

4.1. *Background*

The background has been reduced to a negligeable level. There was only a few charged particles giving a signal in coincidence with the beam. As the ions drift to reach the detector, they are separated in time from the background.

4.2. *Dynamical range*

Using He^+ for the time of flight measurement allows (cf Figure 9) to easily capture the waist of the beam up to dimensions of several tens of microns, even if the error inscreases due to the incertainty on the aspect ratio.

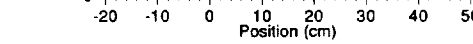

Figure 9. Correlation between the distance to the waist and the measured dimension.

CONCLUSION

In these first FFTB runs we were able to measure beam sizes in the range of 100 to 200 nm by 2 μm. We are now implementing the on line acquisition of the results.

5. REFERENCES

[1] FFTB Project Design Report, SLAC Report 376 (1991)
[2] D. Burke, these proceedings.
[3] D. Freytag et al. : *Waveform Sampler CAMAC Module*, IEEE, Vol. 33, No. 1 (February 1986).
[4] J. Buon et al. : *A beam Size Monitor for the Final Focus Test Beam*, Nucl. Instrum. Meth. A306 (1993) 93-111.