PB05

Fast Wire Scanner at the KEK-PS

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Abstract

The KEK 12GeV proton synchrotron is scheduled to serve an intense beam for a neutrino oscillation experiment. This experiment is foreseeing about two times higher proton intensity than the current one, and accelerator machine studies are going on to improve the current proton intensity. The most important machine study is the investigation of an emittance blow up mechanism during the injection/acceleration period. An observation of a fast transverse emittance blow up is one of the key issue in this machine study and a flying wire monitor is now developing at KEK-PS.

1. Introduction

A transverse beam profile provides so many information related to the blow up mechanism, such as orbit miss matching, strength of resonances, space charge effect etc. The beam profile varies turn by turn during the acceleration. The slow profile change is caused from, for instance, weak resonance and adiabatic damping etc. It can be detectable by employing a residual gas ion monitor[1], which collects the ions produced from the ionization of the residual gas by circulating proton. However, this type of monitor has ambiguity due to the space charge and the finite ion drift time to the electrode. A flying wire profile monitor is one of the candidate to check each other and to observe the fast profile change during the acceleration[2)-5)].

The KEK-PS flying wire monitor is designed to observe the vertical beam profile by rotating a thin Aluminum wire (25μmϕ) into the beam bunch by a speed of 20m/sec. Then the crossing time duration is about 3msec and make it possible to observe the fast profile variation during the injection/acceleration period. A single photo-multiplier mounted beside the rotator detects the secondary particles produced by the proton/wire interaction. Figure 1 shows a mechanical device.

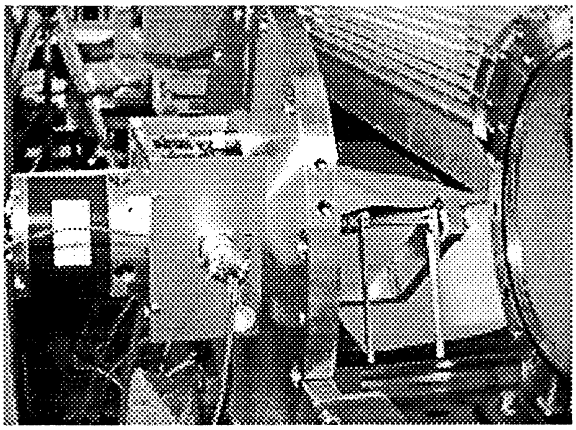

Fig.1 Mechanical device

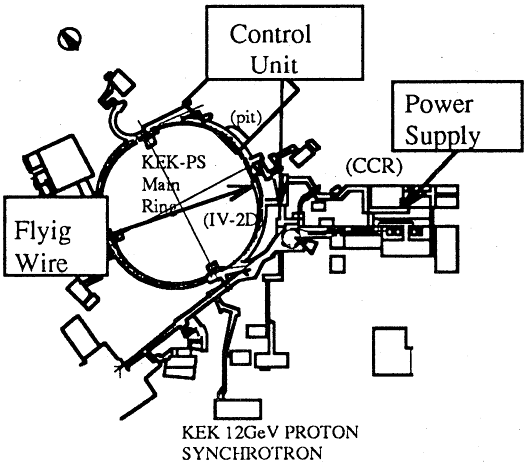

Fig.2 Instrument position

2. Flying wire mechanism

Flying Wire monitor is installed just behind a lattice defocus magnet as shown in Fig.2. It consists of the low inertia U-shape fork, the high precision potentiometer and the high power DC servo motor. The U-shape fork has a gap of 66mm with an aluminum wire of 25μm diameter stretched. The fork spacing and length are determined to cover whole beam size at the location where the wire is installed. The fork is placed aiming to observe the vertical beam profile and it crosses the circulating beam from up to down with the maximum velocity of 20m/sec using a DC servo motor. An angle of rotating fork is detected by the potentiometer which is connecting to DC servo motor by pulley. The fork velocity is automatically controlled by comparing the motor driving signal and the rotational angle signal.

Collision between the proton beam and the wire material produces secondary particles, number of which is proportional to the proton density in the beam bunch.

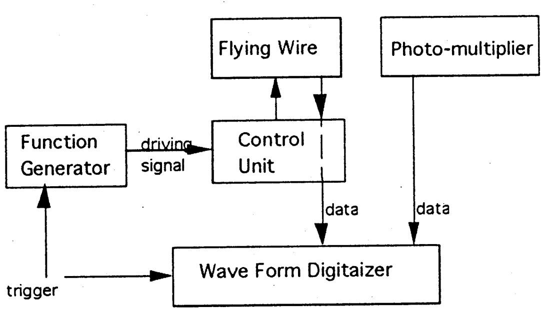

Fig.3 System block diagram

3. Data acquisition

Figure 3 shows a block diagram of the signal flow. The photo-multiplier signal and the potentiometer signal are digitized simultaneously by a Wave Form Digitizes(WFD). The photo-multiplier signals is a pulse train each of which has a length of about 100nsec and varied according to the acceleration RF frequency from 6.0MHz to 7.8MHz. Therefore the sampling rate should be at least 200Msample/sec to obtain 20samples for 100nsec. Total memory of 0.6Mbyte is necessary to cover all the times where the wire crosses the whole beam cross section. Since the harmonic number of the KEK-PS main ring is nine, a tagging signal is necessary in addition to two signals mentioned above in order to identify each bunch. The WFD stores three signals in 1Mbyte/channel memory, and transmits them to a high speed Work Station (WS) through a 16 bit parallel I/O which can transmit them by 4Mbyte/sec.

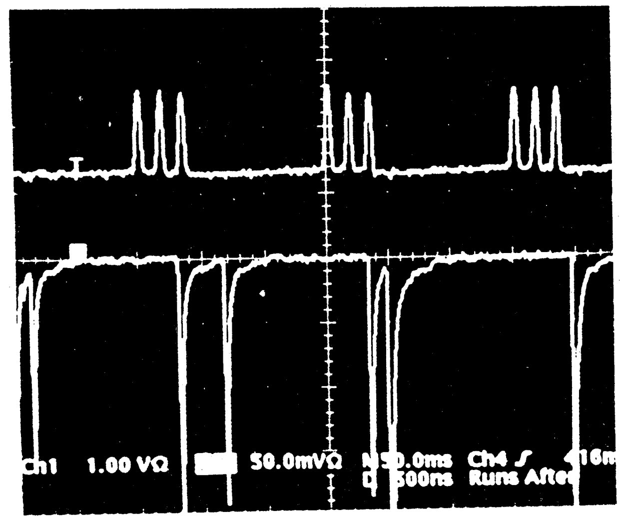

Fig.4 Tagging signal and photo-multiplier signal when three bunches were injected.

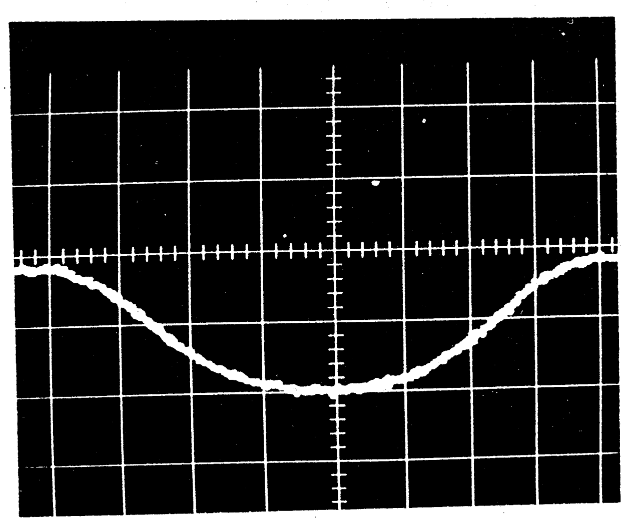

Fig.5 Potentiometer signal

The data from the WFD is analyzed by a high speed WS. Photo-multiplier signal express the integration of number of secondary particles.

The peak of photo-multiplier signal is proportional to the number of secondary particles produced when a bunch hits the wire. The analysis program of the WS looks for the peak value of the each bunch signal and plot it on the Y-axis as a function of the wire rotation angle on the X-axis. Since the bunch identification by the tagging signal is carried out, the beam profile of each bunch can be also deduced. The tagging signal and the photo-multiplier signal are shown in Fig.4, and potentiometer signal shown in Fig.5.

4. Heating of the wire and the emittance blow up

Beside the high energy secondary particle shower detected by the photo-multiplier, the beam/wire interaction also causes a multiple scattering of the circulating proton and the proton losses its energy at the same time. The temperature rise of the wire material, ΔT, is assumed to be caused by every loss of the proton without considerlation of the energy transfer to the secondary particle etc.

$$\Delta T = \frac{dE/dX\ d}{m\ Cv} \quad (1)$$

where dE/dX, m, d and Cv are the minimum ionization loss, mass, thickness and specific heat of the wire, respectively.

Temperature rise is estimated by using eq.(1) and that of all wire materials is much less than the melting point as shown in Table 1.

Table 1.

	d [μmφ]	ΔT [K]	melting point [K]
W	10	433.924	3660
Al	25	35.028	993
C	10	29.435	3773

The emittance blow up, $\Delta\varepsilon$, is described as

$$\Delta\varepsilon = \left(\frac{3}{2}\frac{\sqrt{\beta_y}}{\pi} d <\theta^2> n\right)^{2/3} \quad (2)$$

where β_y is the vertical beta function, d is thickness of the wire, θ is the rms value of multiple scattering angle and n is the number of revolution, respectively. θ is estimated[6] by

$$\theta = \frac{20[MeV/c]}{P\beta}\sqrt{\frac{d}{L_R}}\left[1+\frac{\log_{10}(\frac{d}{L_R})}{9}\right] \quad (3)$$

where P, β and Z_{inc} are the momentum (in MeV/c), Lorentz factor and a charge number of the incident particle, d and L_R are the thickness and the radiation length of scattering medium, respectively. Typical circulating beam emittance, ε, is 45mm-mrad. Dependence of the emittance blow up on the wire materials is estimated as shown in Table 2. It is obvious that W(tungsten) causes about 10% blow up, then we don't use it.

Table 2.

	d [μm]	Δε [mm-mrad] (500MeV)	Δε [mm-mrad] (12GeV)	Δε/ε [%]
W	10	4.2464	0.13117	9.437
Al	25	0.27922	0.0086182	0.620
C	10	0.25911	0.0079973	0.576

By the taking account of the temperature rise and the emittance blow up, we decided to use aluminum wire which is more easy to stretch on the fork than a carbon wire.

5. Conclusion

Design of the fast wire scanner at the KEK-PS main ring was described. This flying wire has just installed on early September. A feasibility study and the software development are now going on. The result of the study will be presented at the Symposium.

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