# NON-DESTRUCTIVE EMITTANCE MEASUREMENT FOR THE KEK 20 MeV LINE

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## Abstract

The transverse emittance of the linac beam is measured non-destructively by the use of five profile monitors[1] which are the secondary emission type with the multi-wire. This measurement usually takes such assumptions that the emittance shape of the beam is elliptical and the intrinsic beam profile is the Gaussian distribution. Therefore, if the real beam is different from these assumptions, the error of the measurement becomes very large. In order to make this error small, we take only the former assumption, but don't use the latter one. Owing to this improvement, we can calculate the beam emittance which is very similar to the real one, even if the beam profiles are far from the Gaussian distributions.

## Fundamentals for the percent beam in the measurement

In order to measure the beam emittance non-destructively, the five profile monitors are installed in the 20 MeV beam transport line between the linac and the booster synchrotron. The square of the beam half width $W_k$, which is measured at the k-th profile monitor, is expressed as follows;

$$W_k^2 = (a_{11}^k)^2\ \varepsilon\ \beta_0 - 2a_{11}^k a_{12}^k\ \varepsilon\alpha_0 + (a_{12}^k)^2 \varepsilon\gamma_0 \qquad (1)$$

$$\beta\gamma - \alpha^2 = 1,$$

where $\varepsilon$ is the beam emittance, $\beta_0$, $\alpha_0$ and $\gamma_0$ are the twis parameters at the first profile monitor and $a_{1j}$ (j = 1, 2) is the element of the transfer matrix from the profile monitor to the k-th one. And the beam center $Y_k$ at the k-th profile monitor is expressed by the terms of the center $Y_k^0$ and its first derivative $Y_k^{0\prime}$ at the first profile monitor as follows;

$$y_c^k = a_{11}^k y_c^0 + a_{12}^k y_c^{0\prime} \qquad (k = 0,\ 1,\ ---,\ 4) \qquad (2)$$

The beam widths $W_k$ and the centers $Y_c^k$ are measured from the outputs of five profile monitors. Putting these values into the equations (1) and (2), the emittance parameters $\varepsilon_k$, $\alpha_k$, $\beta_k$, $\gamma_k$, $Y_k$ and $Y_k'$ are calculated by the least squar method.

As shown in the Fig. 1-b, the profile $g_{90}(x)$, in which 90 % of the beam is contained within the corresponding ellipse, can be calculated as follows;

$$g_{90}(x) = g_{100}(x) - (G_{100}/10\ S_{100})\ h(x)$$

where $g_{100} = \int_{x_{min}}^{x_{max}} g_{100}(x)\,dx$, which is corresponding to the 100% beam profile area,

$S_{100} = \int_{x_{min}}^{x_{max}} h(x)\,dx$, which is corresponding to the elliptical area of the 100% beam emittance,

h(x) in this equation means the height which is shown with the slant line in the Fig. 1-b. By using the equation (3), the profiles of the 90 % beam at every five profile monitors can be obtained. The half widths and the centers of the 90 % beam are easily calculated from the obtained profiles. Putting these values into equations (1) and (2), $\varepsilon$, $\alpha$, $\beta$, $\gamma$, $Y_k$ and $Y_k'$ at the 90 %

beam are calulated. Using the same technique, the characteristics of 90 %, 80 %, ..... and 10 % beam emittance are obtained successively.

The measurement and the calculation of the beam profile are performed with the minicomputer (MELCOM-70).

## Results

The emittance figure calculated by this method is shown in Fig. 2. As compared this figure with the emittance figure which is measured by the use of the single slit multi-collectors type emittance monitor[2], the emittance shapes agree well each other. The difference of the emittance size has been studied at present. Finally, the characteristics of the percent emittances are shown in the Table.

## References


1) H. Ishimaru et al., Recent Progress of the Beam Profile Measurements for KEK 12 GeV proton Synchrotron, Proceeding of the 2'nd Symposium on Accelerator Science and Technology, (1978) 125.
2) KEK Annual Report 1975, (1975) 11.


TABLE CHARACTERISTIC OF % EMITTANCE

| | 100% | 90% | 80% | 70% | 60% | 50% | 40% | 30% | 20% | 10% |
|---|---|---|---|---|---|---|---|---|---|---|
| EMIT | 79.79 | 65.09 | 57.61 | 42.61 | 37.60 | 28.63 | 26.71 | 25.58 | 25.40 | 23.99 |
| ALPH | -1.14 | -1.11 | -0.96 | -0.76 | -0.47 | -0.90 | -1.09 | -0.73 | -0.73 | -0.42 |
| BETA | 3.23 | 2.74 | 2.67 | 1.99 | 1.92 | 2.52 | 2.96 | 2.66 | 2.67 | 2.50 |
| GAMM | 0.71 | 0.81 | 0.72 | 0.79 | 0.67 | 0.72 | 0.73 | 0.58 | 0.58 | 0.47 |

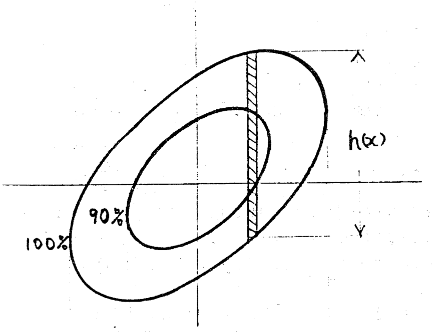


Fig.1-a %Emittance Figure

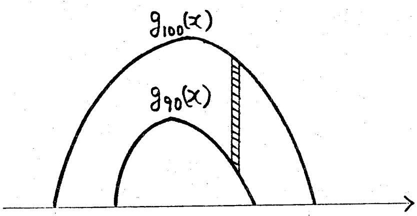


Fig.1-b Beam Profile

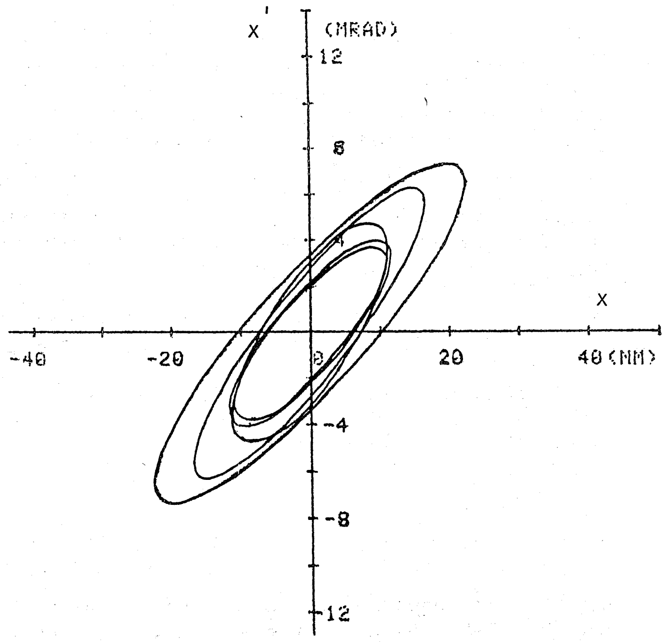


Fig.2 %Emittance Figure