BNL-105217-2014-TECH

Booster Technical Note No. 173;BNL-105217-2014-IR

TESTS OF NEW EMIT APPLICATION TO THE HEBT LINE

A. Kponou

August 1990

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

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TESTS OF NEW EMIT APPLICATION TO THE HEBT LINE

BOOSTER TECHNICAL NOTE
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A. KPONOU and A. LUCCIO

AUGUST 14, 1990

ALTERNATING GRADIENT SYNCHROTRON DEPARTMENT
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

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APPLICATION TO THE HEBT LINE

A.Kponou, A.Luccio

In a recent meeting of A.Luccio, K.Reece and J.Skelly the importance of testing the algorithms and codes contained in the package NEW_EMIT[1] on some real examples was proposed, not only to check its correct operation, but also how good the code is for general use.

The HEBT line from the linac to the AGS provides a good case example, since there are available several sets of measured data of beam profiles at up to seven monitors (SEM's). The line has been already modelled with TRACE-3D and the emittance calculated with SEM_ANAL. We use those results for comparison.

The first step in applying NEW_EMIT was to calculate the transfer matrices between the SEMs and the entrance to the line where the beam emittance is calculated. This was accomplished with MAD. Previous MAD runs for the HEBT yielded twiss functions in good agreement with values calculated with other models. The transfer matrices are also in good agreement.

Profile measurements in HEBT are done at all SEMs, with quadrupoles at their standard or retuned values. We have six sets of data, as many as the SEMs, more than enough to perform a meaningful statistical analysis. (The profile of the very first SEM is not used in the analysis. That SEM is the first element in HEBT).

The next step was the FFT smoothing of data to get rid of the high frequency noise. For both planes, there were 140 points at each SEM. By trial-and-error we found that using only the first 40 frequencies gave a reasonable smooth fit to the raw data, without noticeable oscillations in the tails. Therefore, we decided to retain only the first 40 frequencies. The result of the smoothing, for monitors 1 through 6 are shown in the figures 1-6.

Next, the widths of the distribubution, for different percent emittance cuts were calculated. Here, we applied two algorithms and obtained comparable results.

Algorithm (i). See figure 7. Assume that the smoothed data are represented by a curve

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[1] A.Luccio. Booster Tech.Note # 172

$$f = f(z), \quad z = x, y$$

If we want to find the half width $w(p)$ for a percent emittance p, then a possible way is to numerically integrate f up to $(1-p)/2$ and then to $(1+p)/2$ of the integral of the complete curve

$$\int f(z)\,dz$$

finding the abscissae z_1 and z_2, respectively, and then

$$w(p) = \frac{1}{2}(z_2 - z_1)$$

z_1 and z_2 are found by linear interpolation.

If the beam profile is not symmetrical, however, the values of the function corresponding to z_1 and z_2 are not necessarily the same, and the cut of the curve at that "height" -whatever it may mean- may be slightly tilted. A solution is to integrate in a way that the sum of the two excluded areas - shaded in figure 8- is equal to $1-p$ times the complete integral. The latter leads to a somewhat more complicated algorithm, probably not worth the effort in practice.

Algorithm (ii). Figure 7. The center of a distribution and its rms half-widths are found by numerical integration -with a Simpson's 1/3 rule- as first and second order momenta

$$\bar{z} = \frac{\int z\, f(z)\,dz}{\int f(z)\,dz}; \quad \sigma^2 = \frac{\int (z-\bar{z})^2 f(z)\,dz}{\int f(z)\,dz} = \frac{\int z^2 f(z)\,dz}{\int f(z)\,dz} - \bar{z}^2$$

Then, instead of, say, 20%, 50%, etc. percent emittance profile cuts, we use the, say, 0.5σ, σ, 2σ cuts, and so on.

[Algorithm (iii)] Newton-Raphson fitting. This is discussed in Ref[1]. We did not apply it here, because in its standard form it tries to fit the distribution with a 3-parameter gaussian or raised cosine, i.e. with symmetrical curves. Algorithms (i) and (ii) above apply to any distribution, either symmetrical or not. SEM-ANAL uses a simplified least-squares 3-parameter gaussian fit.

Both algorithms (i) and (ii) give comparable results with TRACE-3D and SEM-ANAL as can be seen from Table I and figures 8 and 9. We have a penchant for Algorithm (ii), because it is rather compact and mathematically satisfactory.

Figures 8 and 9 show a comparison between values of the emittances, ε_x and ε_y at the beginning of the HEBT calculated with (i), (ii) and TRACE-3D, respectively. The error bars are for statistics on readings on SEM 1 to 4 (4 combinations of the 4 SEMs by 3).

Table I gives the values of the Twiss parameters β and α at the entrance of the line.

Table I

	NEW_EMIT (i) (70%)	NEW_EMIT (i) 20 to 80%	NEW_EMIT(ii) σ	TRACE_3D* σ	SEM_ANAL σ
β_x	2.150 ± 0.254	2.184 ± 0.153	2.415 ± 0.101	2.197 ± 0.126	2.653
α_x	0.627 ± 0.163	0.590 ± 0.105	0.874 ± 0.080	0.535 ± 0.065	0.749
β_y	3.660 ± 0.436	3.679 ± 0.388	4.220 ± 0.726	3.457 ± 0.372	3.056
α_y	-0.619 ± 0.135	-0.637 ±0.122	-0.631 ± 0.162	-0.640 ± 0.120	-0.558

A link between the PC that acquires the SEM profile data and the Apollo will be set up. This will enable us to analyze the HEBT emittance data using the NEW_EMIT package during the commissioning of LTB.

* The profile widths (sigmas) used in TRACE-3D were obtained from the fitted gaussians in the first part of SEM-ANAL.

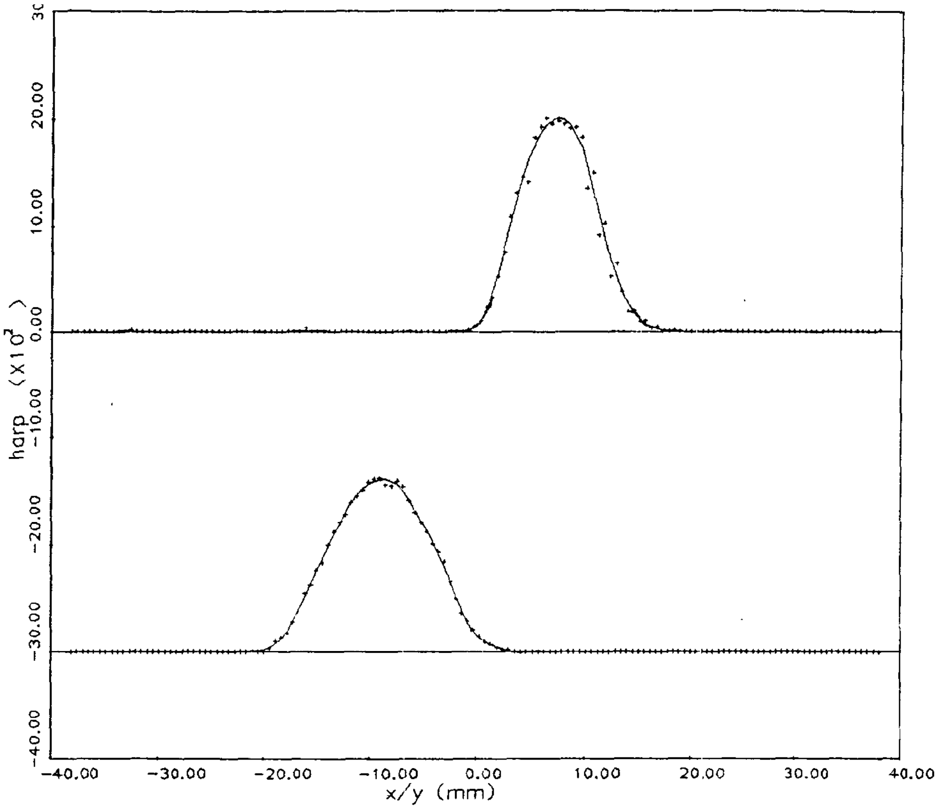

Fig. 1. SEM1 profile. Top: horizontal, bottom: vertical. Dots are measured values (140), solid line is the results of fft smoothing with 40 harmonics.

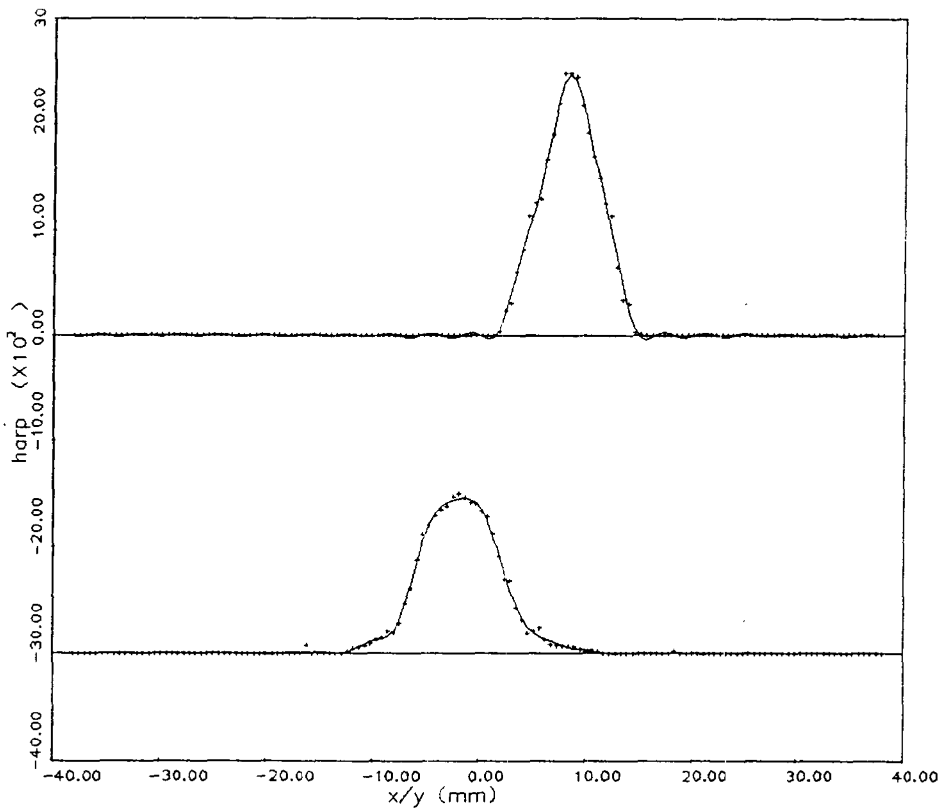

Fig. 2. SEM2 profile. As in Fig. 1

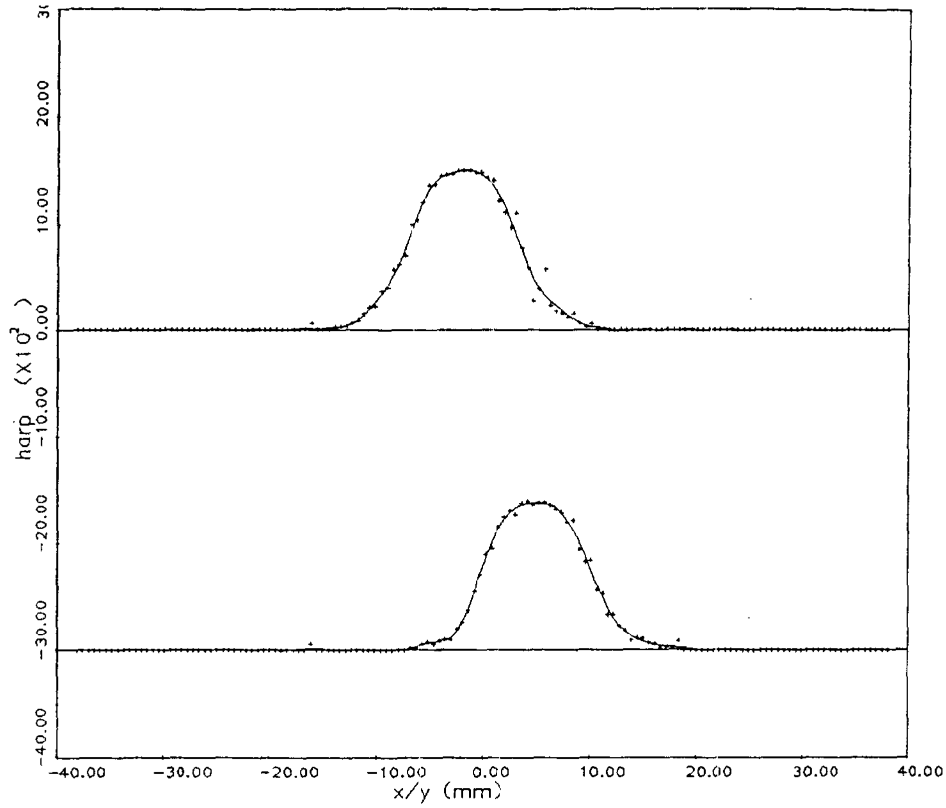

Fig. 3. SEM3 profile. As in Fig. 1

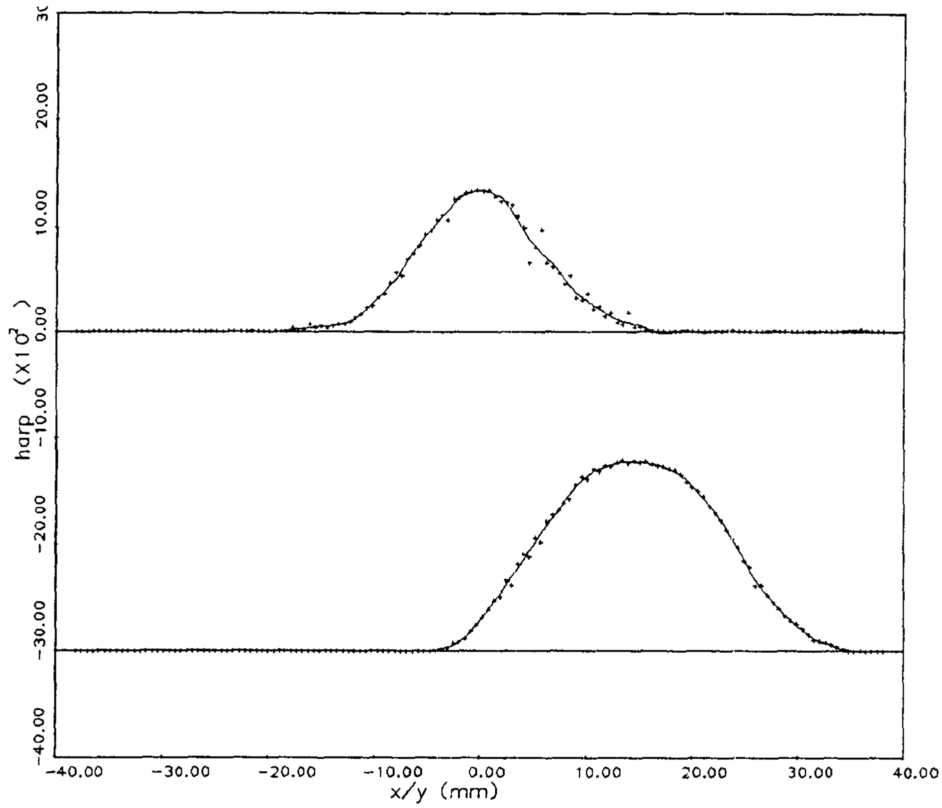

Fig. 4. SEM4 profile. As in Fig. 1

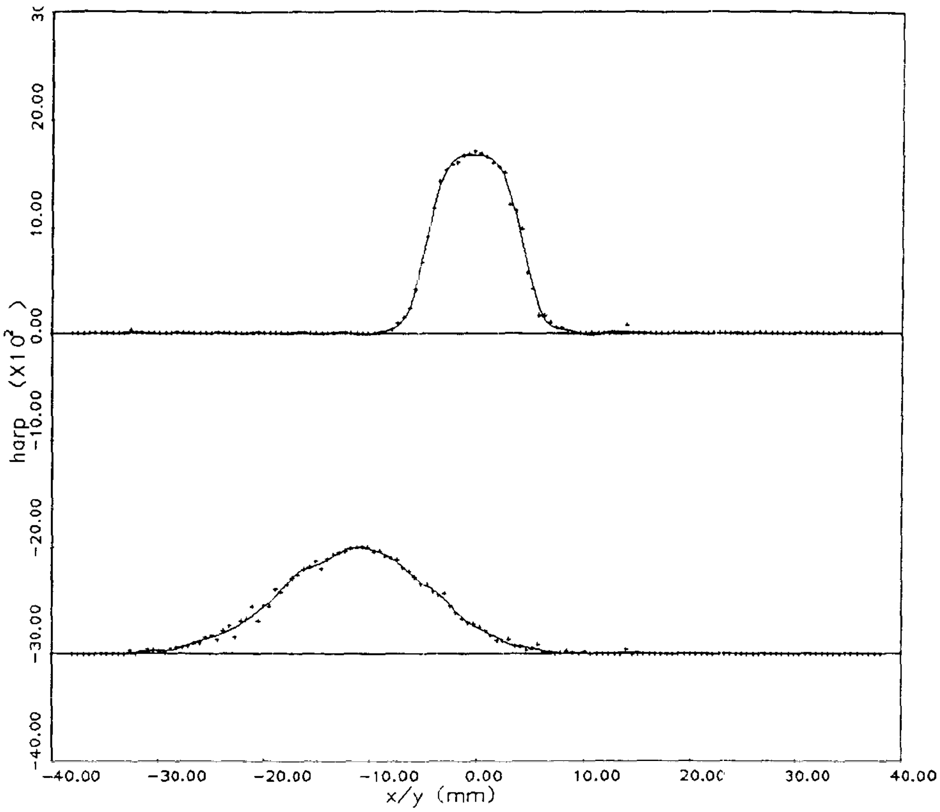

Fig. 5. SEM5 profile. As in Fig. 1.

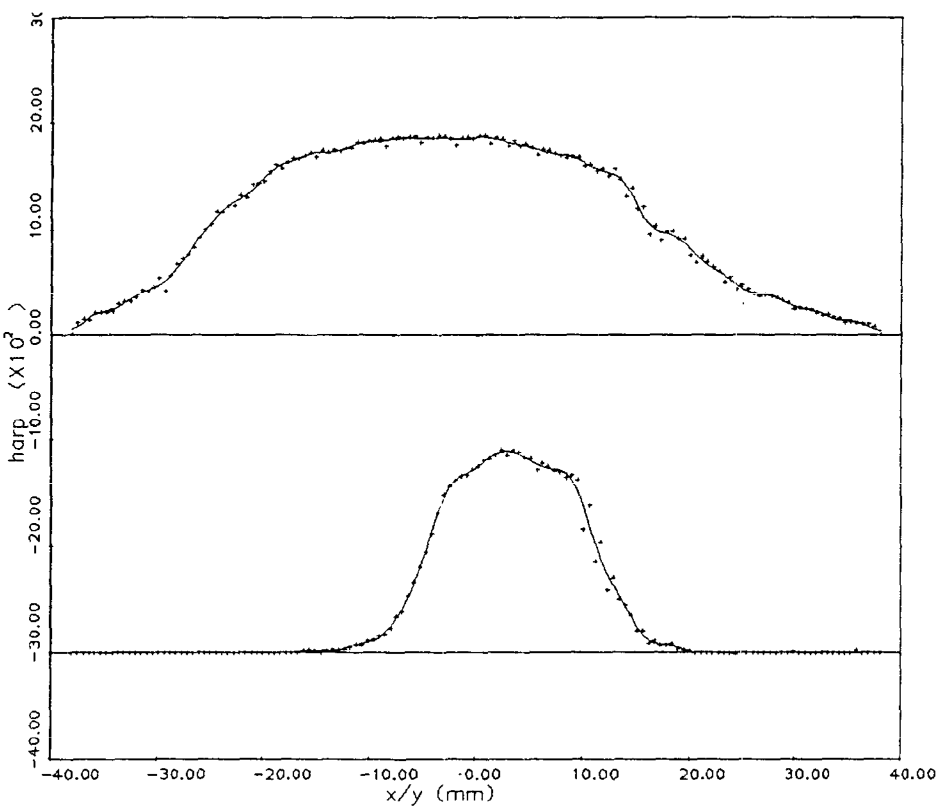

Fig. 6. SEM6 profile. As in Fig. 1.

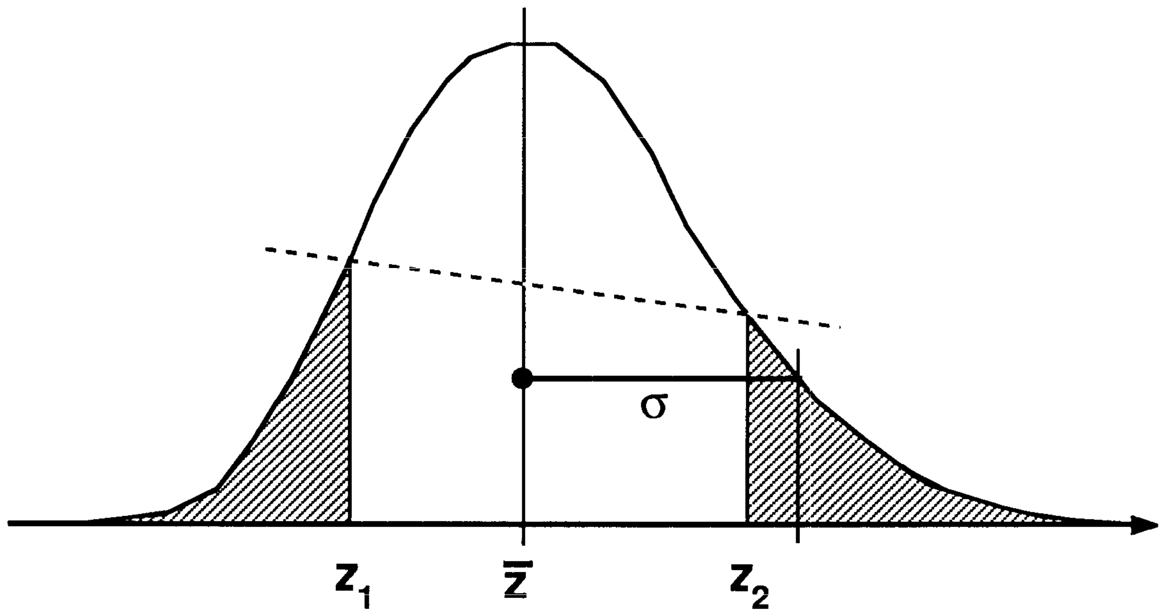

Fig. 7. Shows how the widths -and σ's- are calculated.

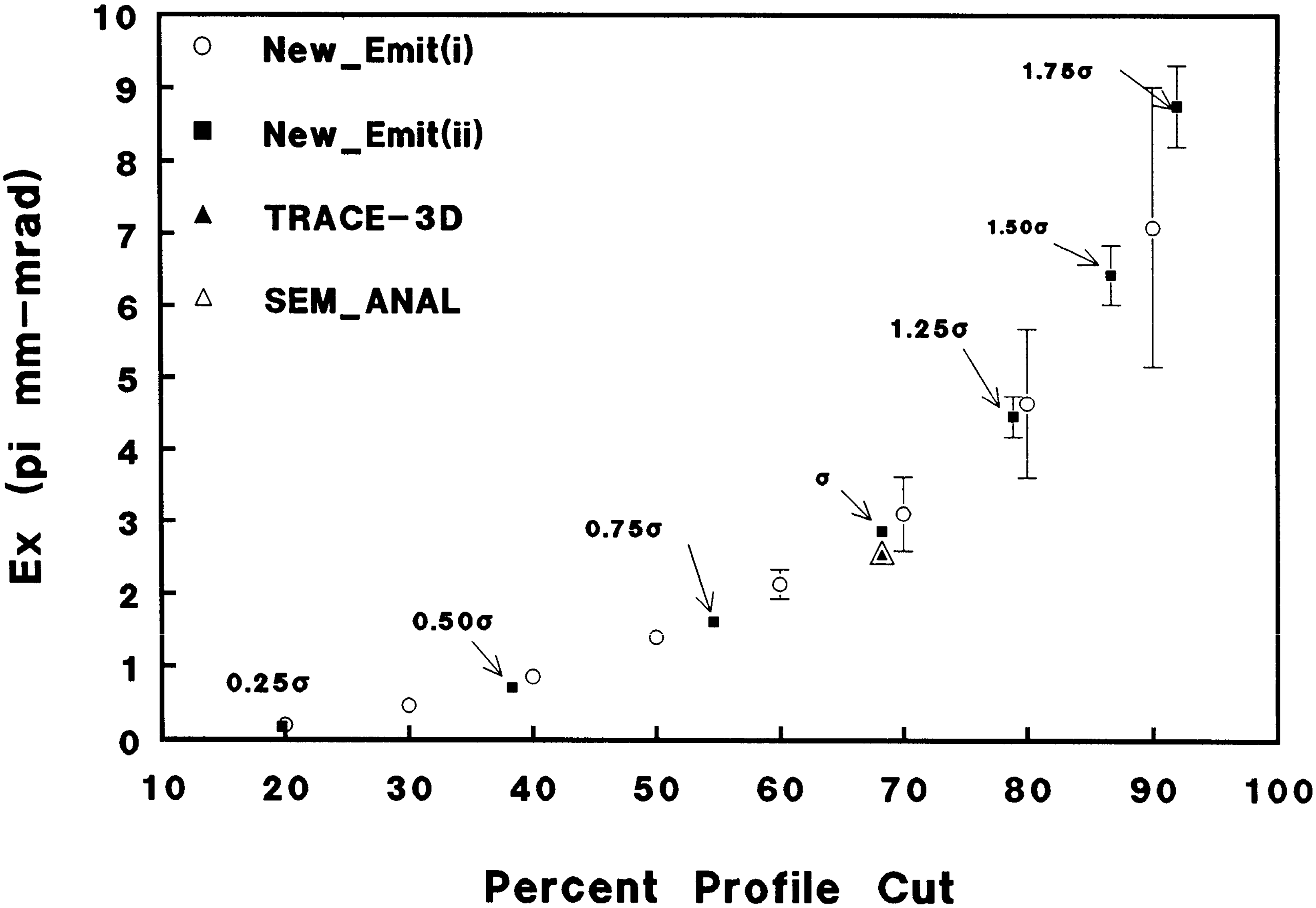

Fig.8. Horizontal emittance calculated with NEW_EMIT (i), NEW_EMIT (ii), and TRACE-3D. The error bars come from statistics over the four combinations of readings from SEM1 to SEM4.

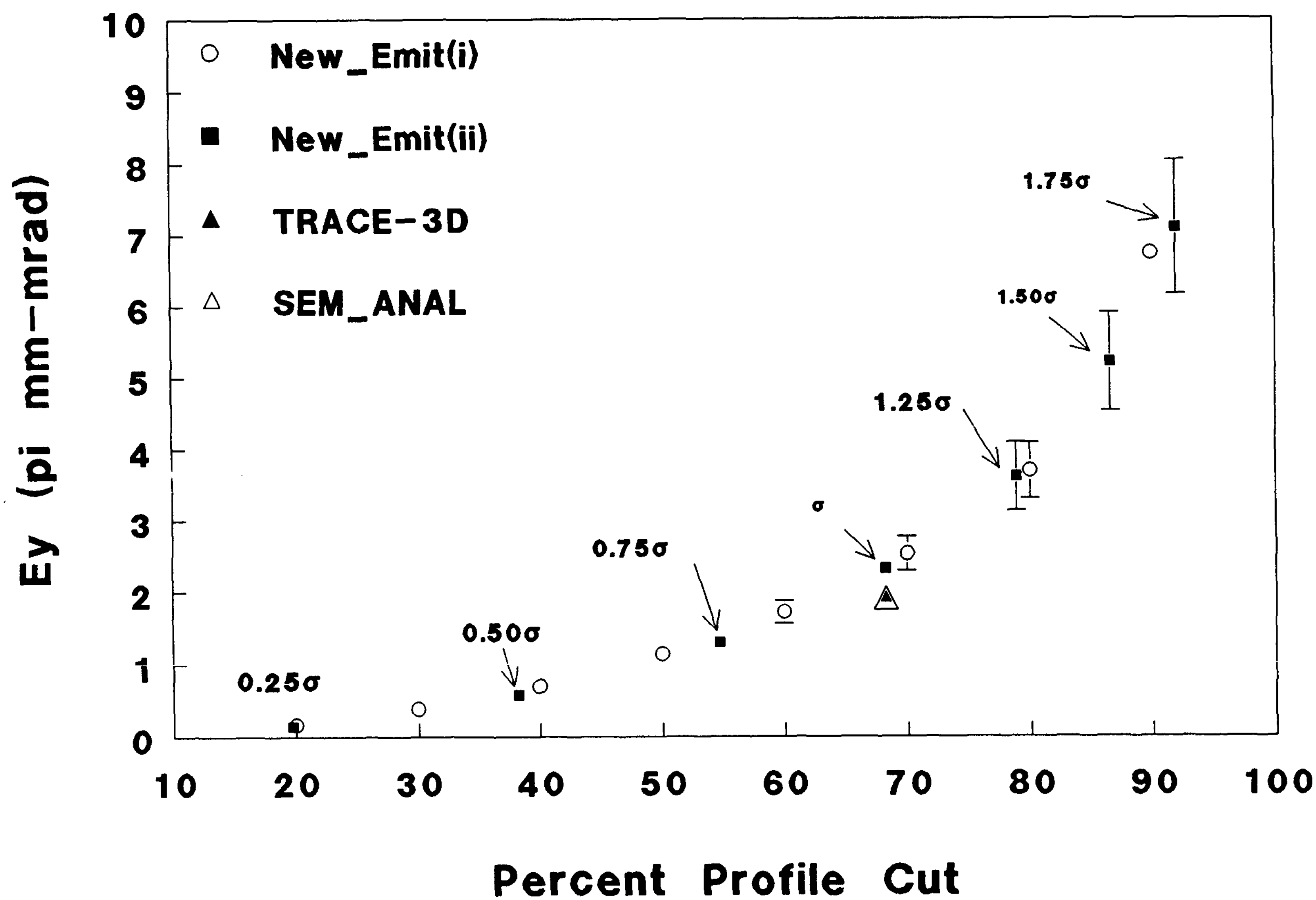

Fig.9. Vertical emittance calculated with NEW_EMIT (i), NEW_EMIT (ii), and TRACE-3D. The error bars come from statistics over the four combinations of readings from SEM1 to SEM4.