

Subject: Emittance Measurement Procedure

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Emittance Measurement Procedure

This note describes the procedure developed for measuring beam emittance and Twiss parameters in the NLCTA. It is intended as a guide for operators or physicists who might wish to make such measurements. The procedure involves the use of three different computer environments. It has been automated as much as possible for now. (As suitable quads and quad strengths become established for particular profile monitors, the Correlation Plots set up should be facilitated by scp macros.) While I shall briefly indicate what is being done at each step, I hope to avoid obscuring the procedure with too much detail.

To prepare to make an emittance measurement:

- Make sure the *Global Lab Image* software is up and the profile monitors display properly on the PC to the right of COW12. (Do not leave profile monitor screens inserted when not in use, as the surface coating is deteriorated by the beam.)
- From a DECTERM on the NCD terminal, go to the directory `user_disk_mcc:[mccscp.nantista]`. Open *MATLAB* and enter the command "*emitpanel*". This will bring up a user interface panel over two figure windows. Separate the windows so they can all be seen.
- On the scp, make sure the beam line is set to the current model. Go to MODEL(e^- NLCTA, BEAM CODE 7) → MODEL APPLICATIONS → MARKER POINTS, and enter the beam ENERGY in GeV. Back on the APPLICATION panel, go to MODEL MAGNET and do KMOD TO BDES and KMOD TO BCON. Finally, go to a QUADS panel, select ALL QUADS, and TRIM.

To set up the measurement:

- Choose a nearby quad upstream of the profile monitor to be used, focusing for an x measurement or defocusing for a y measurement, and enter it on a knob.
- Insert the profile monitor screen with *GLI* in the Live mode, and determine a range of the quad strength which causes the beamspot to pass through a focus in the desired coordinate. Make sure the beam stays on the screen over the range, and try to avoid the screen calibration holes and imperfections. Use a corrector, if necessary, to adjust the beam position on the screen or to center it in the quad so that it does not get steered by the quad. Adjust the profile monitor iris (and perhaps the gain on the *GLI* camera tool) so that the video is not saturated when the beam is tightly focused. The *GLI* profile tool can be used to check for saturation.

- Set up Correlation Plots (BEAM CODE 7) to scan the chosen quad through seven values over the determined range. Include a time delay of 1s between steps. Enter BACT as phys_variable 16 (first box, top row) and the TMIT of the nearest upstream BPM to the profile monitor as phys_variable 18 (second box, top row). Set up the YY-trigger by going to DISPLY PANEL → OPTION PANEL → RDGS SELECT TRIGER (sic.) and entering "TA02 114" and then hitting SCHED TRIGER. If the BPM entered is on micro TA01 (324-1111), enter another from micro TA02 (1130-2220), so that trigger 114 will fire.
- In *Global Lab Image*, load the script *spots* if it doesn't already appear under the *SCRIPTS* menu. Then run it by selecting it. A box will appear indicating that the frame grabber is armed for a trigger.

To make the measurement:

- Run Correlation Plots to acquire data. Triggers will be sent to the frame grabber, and *GLI* will save an image for each step.
- Go to DISPLY → AUXILIARY I/O panel on the scp, and save the Correlation Plots data to MATLAB ("MATLAB 20/20 OUTPUT") in the file "*ASSET:quadat.mat*".
- Remove the profile monitor screen. Display all units and verify that none is *selected*.
- Restore quad and any correctors used to original values. (Restore knobs.)
- On the NCD, run MATLAB routines with the user interface panel. The lower section of the panel is for emittance measurements¹.
 - a) Press *IMPORT*, and wait a few seconds for the image files to be transferred from the PC to the VAX. Progress is shown in the DECTERM window.
 - b) From the drop-down menu, select the profile monitor that was used to acquire the images.
 - c) Click the appropriate radio button, *x* or *y*, to indicate the coordinate of interest.
 - d) Press *FITS*. MATLAB will calculate the sigmas of the beam spots by fitting gaussians to their projections. This takes a couple of minutes, so be patient. The fits and sigma values will be displayed in the *figure 1* window (along with plots of integrated light over TMIT and centroid position).

[d') If, for some reason, the energy in the model has been changed since the data was taken (but not the model itself), one can enter the old value in the provided text window. Note, however, that if the wrong value was in the model when the data was taken, the lattice will not have been adjusted properly to produce the effect of the transfer matrices used in the following calculation.]

¹ The upper, older section is for analyzing individual beamspots, chosen from the drop-down menu or entered in the text field (sans ".tif"). Pressing *SHOWSPOT* results in the *x* and *y* projections being plotted in the *figure 1* window, along with gaussian fits and measured sigmas and centroids, and, if *Contour?* is pressed, a 2-D contour plot of the spot being drawn in the *figure 2* window. To make the contour plot look nice (and not take forever), the image is filtered or smoothed first. If the image file data is already smoothed (e.g. by *GLI*), one can speed things up by indicating so with the *Filtered?* button.

fitted parabola overlays the data, and the chi-square per degree of freedom for the fit is indicated. From this parabola and the transfer matrices, the beam emittance is calculated², as are the Twiss parameters alpha and beta, which are swum back through the lattice to a marker point for comparison to matched values. The second plot shows the transformed beam ellipse³ overlaid with a dashed circle of the measured emittance to accentuate any mismatch. The axes are in units of 10⁻⁵ meter-radians.

In addition to the two plots, several values are displayed in this window. In the lower left quadrant are the beam energy from the model or text entry (not a measurement), and the measured beta and alpha at the marker point ("_i" indicates "initial") with uncertainties. In the upper right quadrant are the normalized emittance ($\gamma\epsilon$), a mismatch parameter

$$B_{\text{mag}} = \frac{1}{2} \left[\frac{\beta^*}{\beta} + \frac{\beta}{\beta^*} + \left(\alpha \sqrt{\frac{\beta^*}{\beta}} - \alpha^* \sqrt{\frac{\beta}{\beta^*}} \right)^2 \right],$$

where the asterisks signify measured values and the un-asterisked variables are matched design values, and the product of the two. Uncertainties are given which do not include the effect of energy error.

The use of this MATLAB user interface panel is illustrated in Figures 1-4. Figure 5 shows an example of the results of pressing *FITS*, and Figure 6, the corresponding results of pressing *EMITTANCE*.

² See M.C. Ross, *et al.*, "Automated Emittance Measurements in the SLC," SLAC-PUB-4278, March 1987.

³ See, for example, M. Sands, "A Beta Mismatch Parameter," SLAC-AP-85, April 1991.

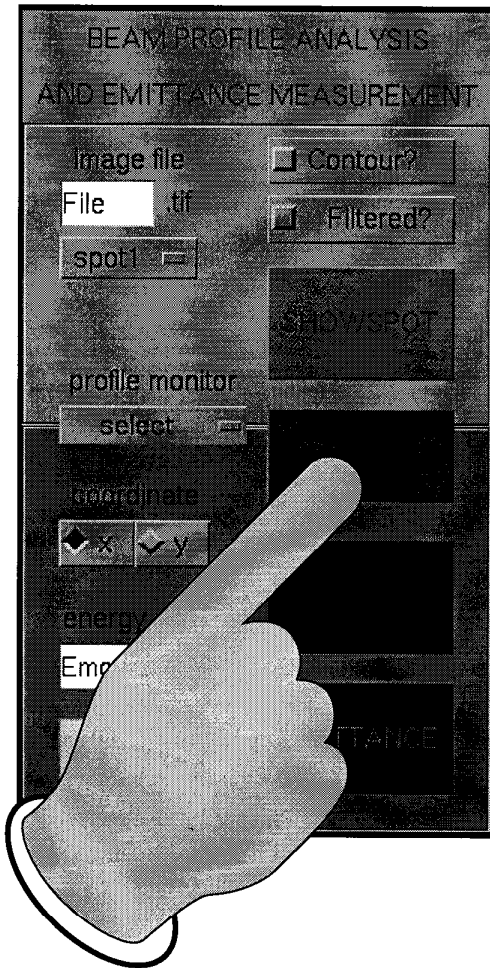


Figure 1. Press "IMPORT" to import beamspot image files from PC via FTP.

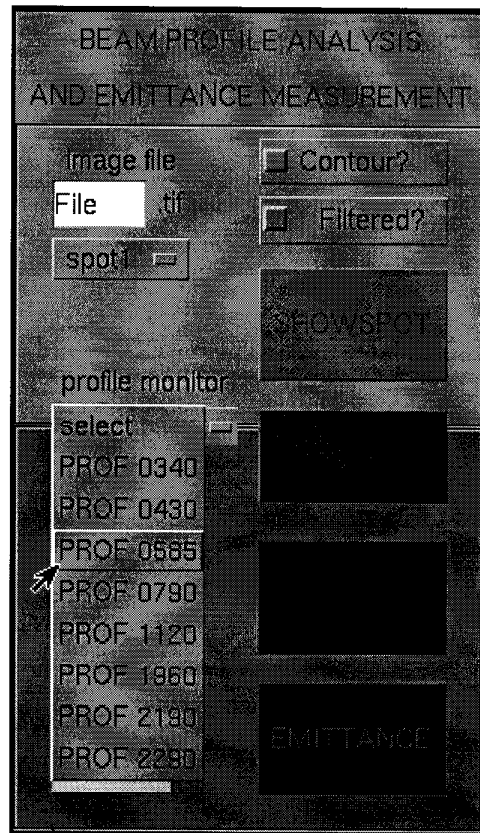


Figure 2. Indicate profile monitor used from drop-down menu.

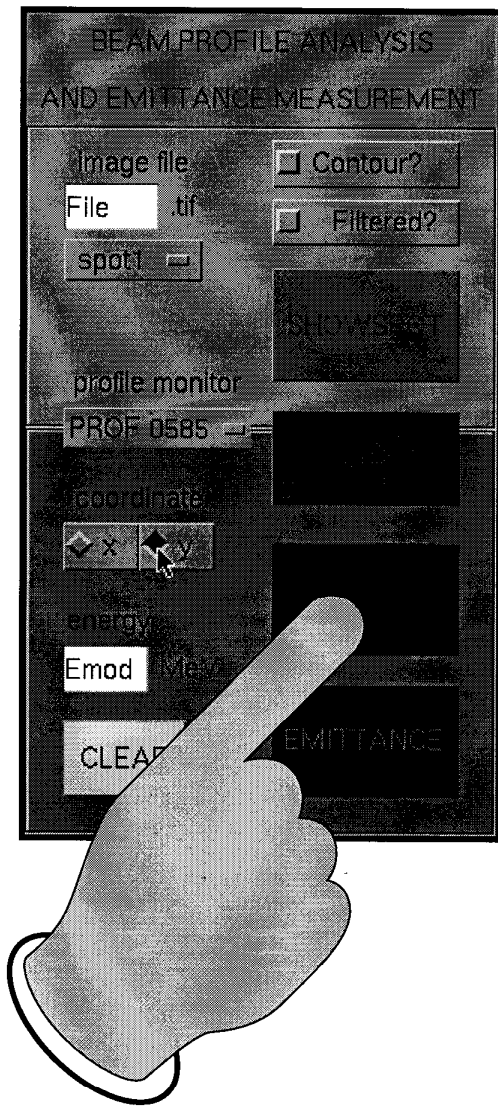


Figure 3. Select coordinate and press “FITS” to load files and fit gaussians to projections.

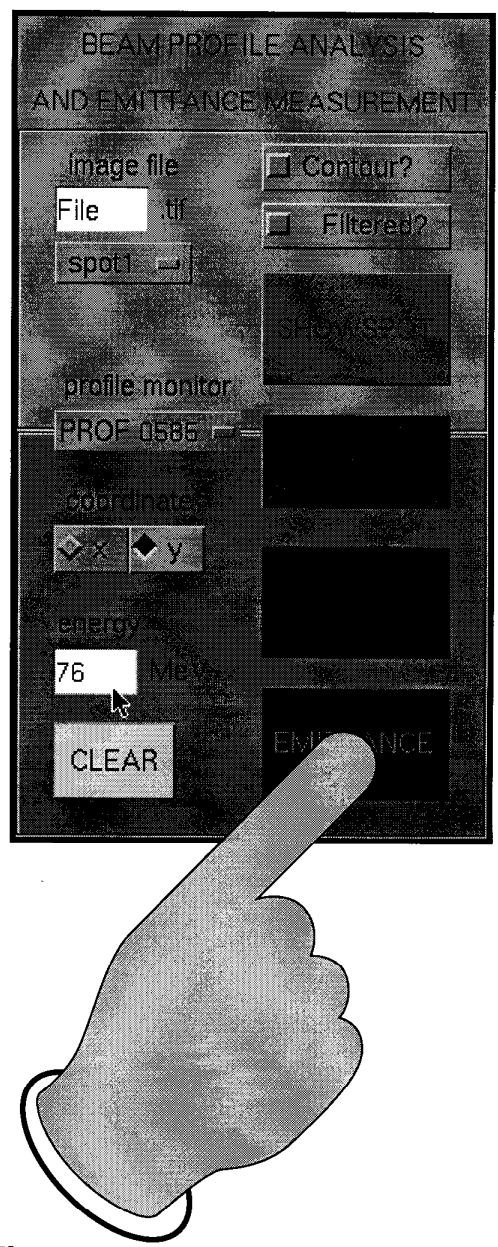


Figure 4. When fit results have been displayed press “EMITTANCE”. (Enter energy first only if different than Emod.)

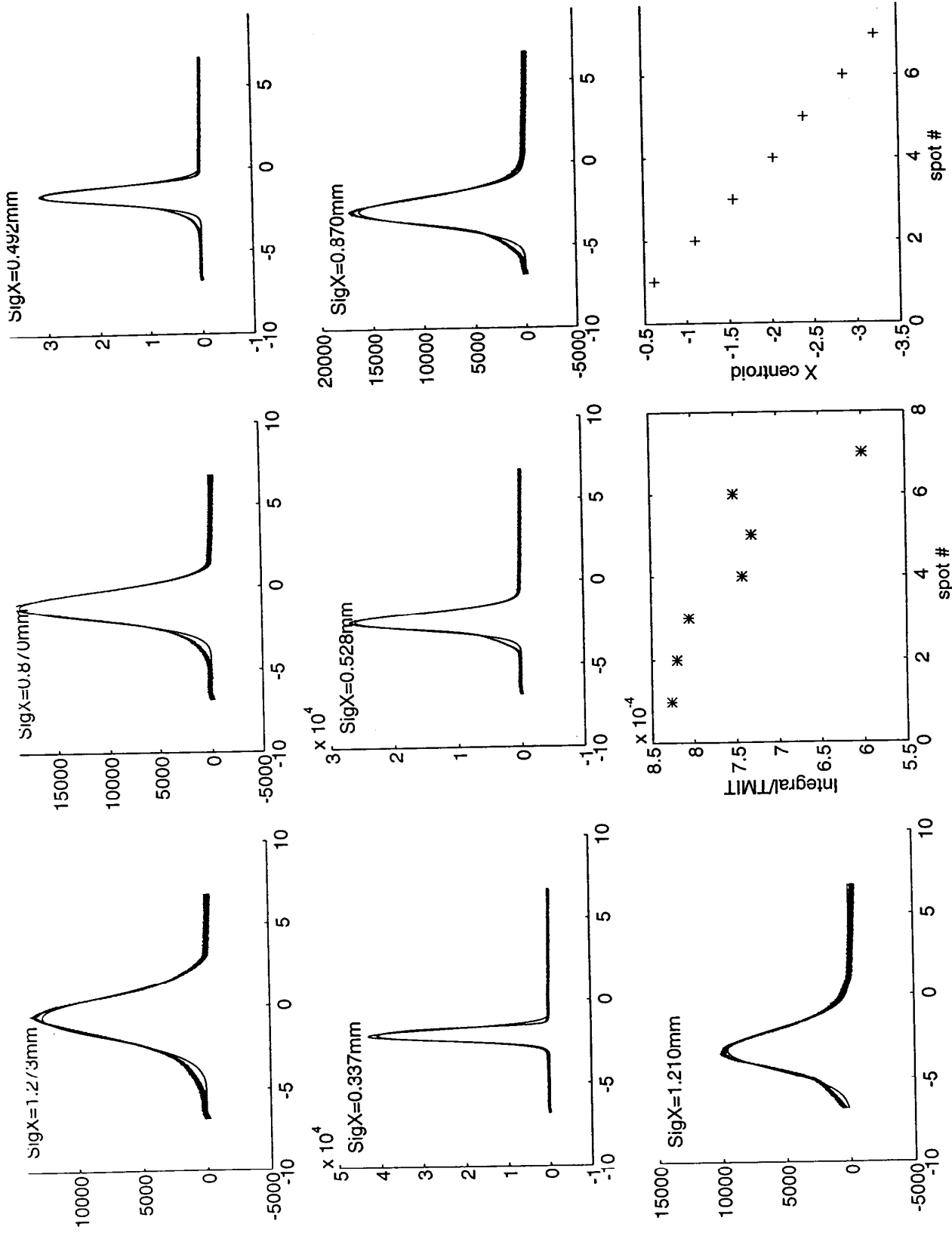
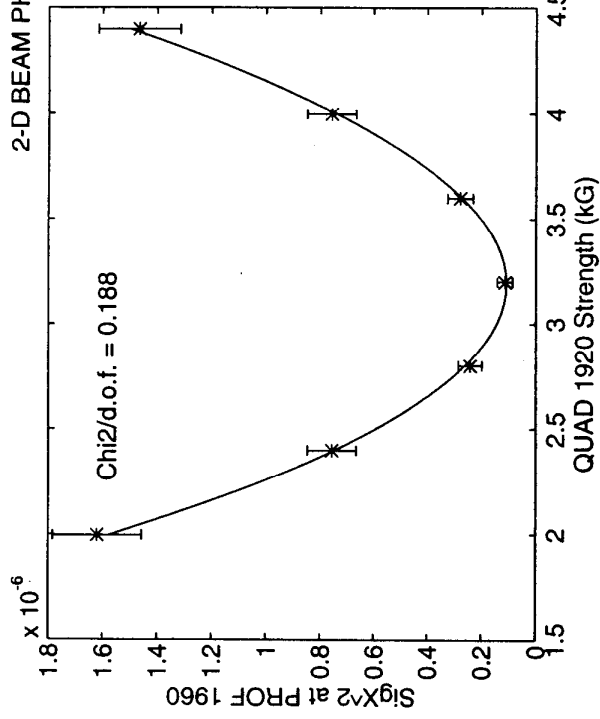


Figure 5. Beamspot projections and gaussian fits.

2-D BEAM PHASE SPACE ANALYSIS



$$\text{EnX} = 6.297 \times 10^{-5} \text{ m-r}$$

$$\pm 0.734 \times 10^{-5} \text{ m-r}$$

$$\text{BmagX} = 1.240$$

$$\pm 0.051$$

$$\text{BmagX} * \text{EnX} = 7.805 \times 10^{-5} \text{ m-r}$$

$$\pm 0.812 \times 10^{-5} \text{ m-r}$$

(E = 58.70 MeV)

$$\text{BetaX}_i = 0.876 \text{ m}$$

$$\pm 0.082 \text{ m}$$

$$\text{AlphaX}_i = 0.642$$

$$\pm 0.065$$

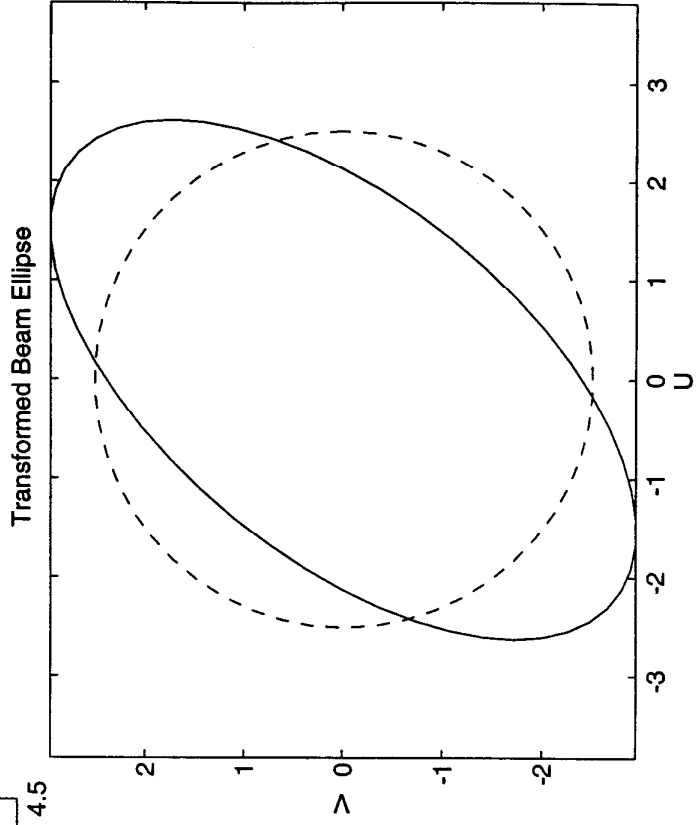


Figure 6. Emittance calculation results.