



17TH ADVANCED BEAM DYNAMICS WORKSHOP ON

FUTURE LIGHT SOURCES

Characterization of Electron Density in 5-Dimensional Phase Space and Control of Phase Space Distribution through the Laser Distribution

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APRIL 6-9, 1999

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EMITTANCE CORRECTION:

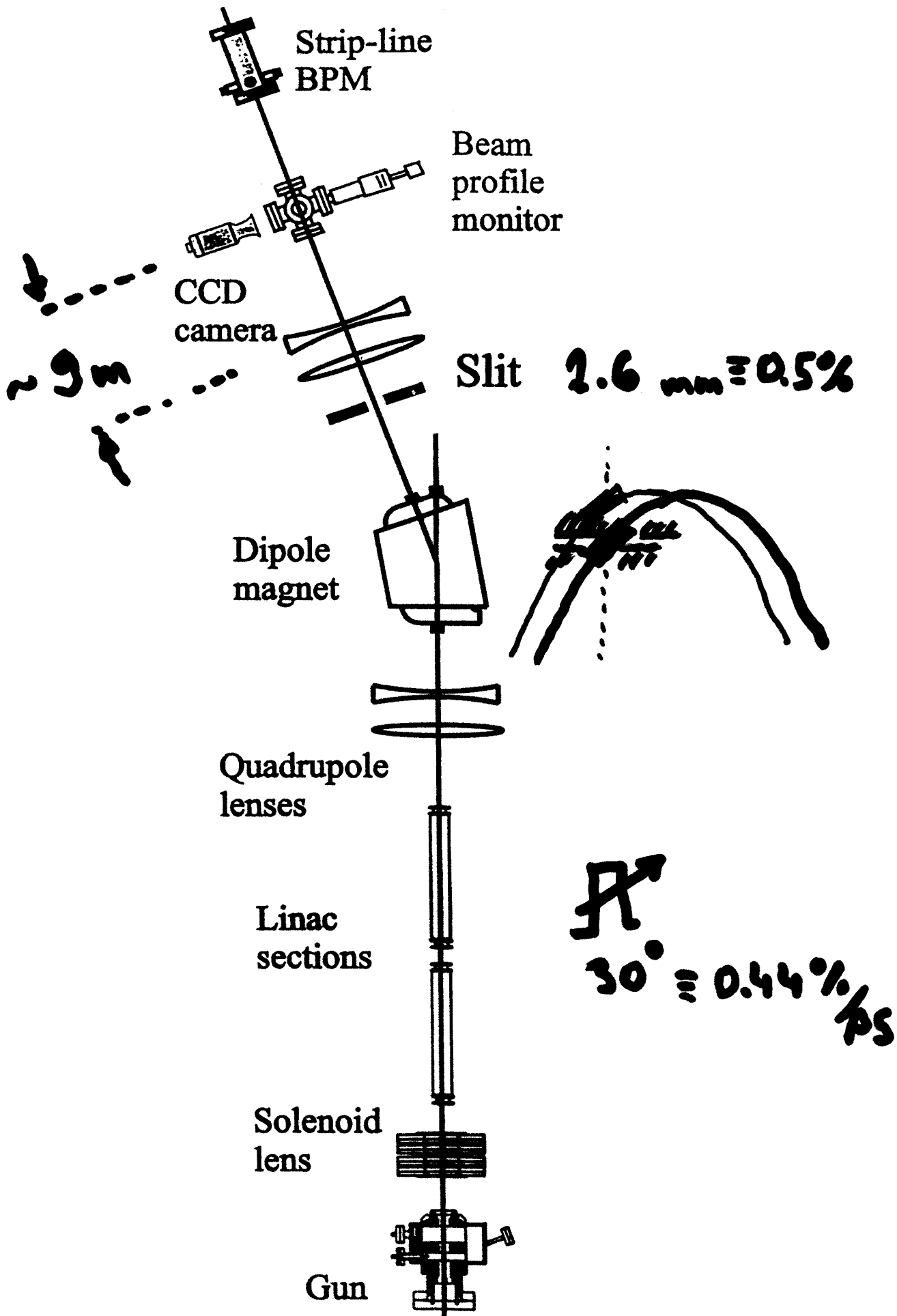
Improvement of the projected emittance in transverse phase-space by removing correlations with longitudinal parameters. (Carlesten, 1988.) One parameter (solenoid current.)

NON-LINEAR EMITTANCE CORRECTION:

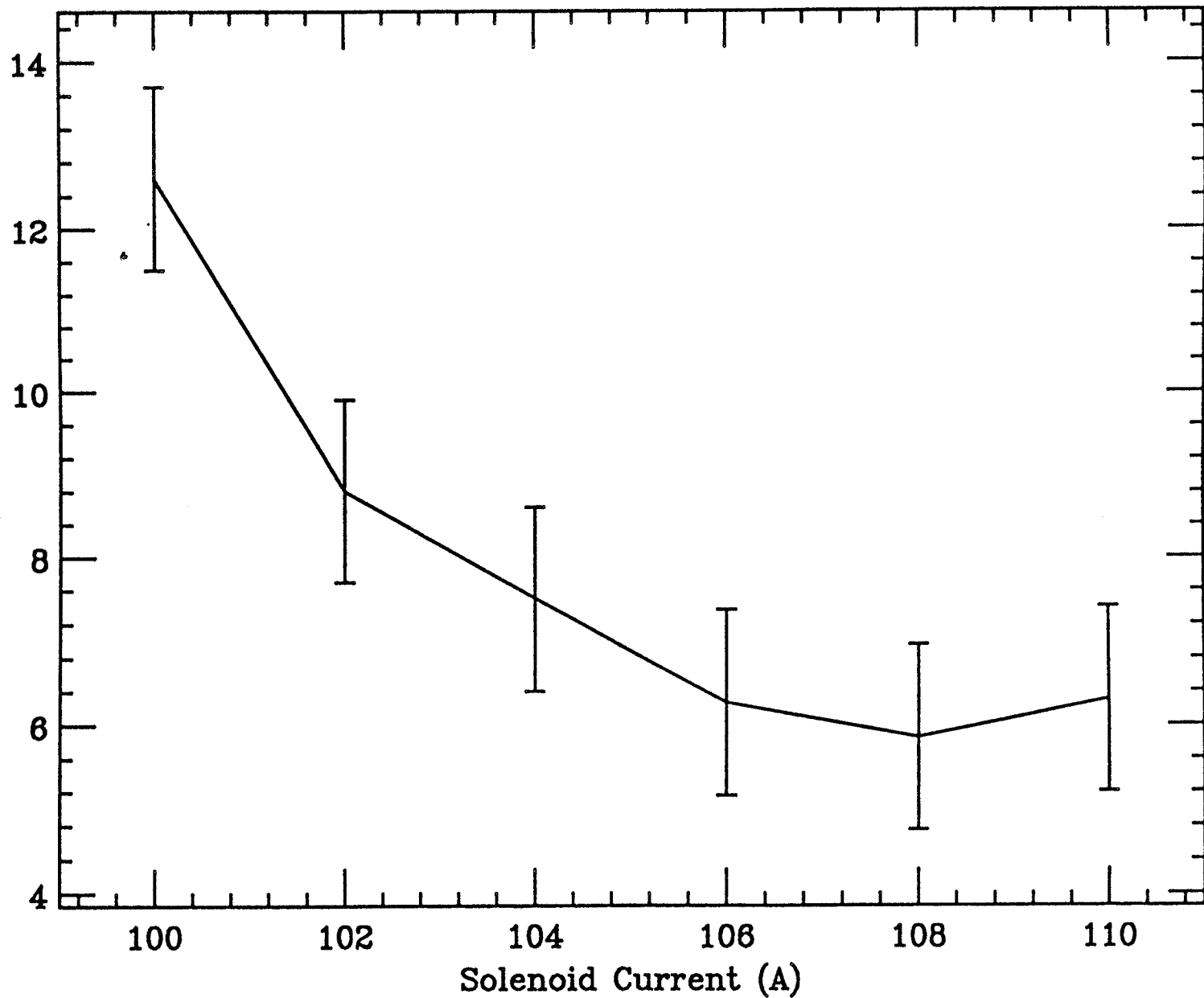
LONGITUDINAL –
MULTI PARAMETRIC CORRECTION.

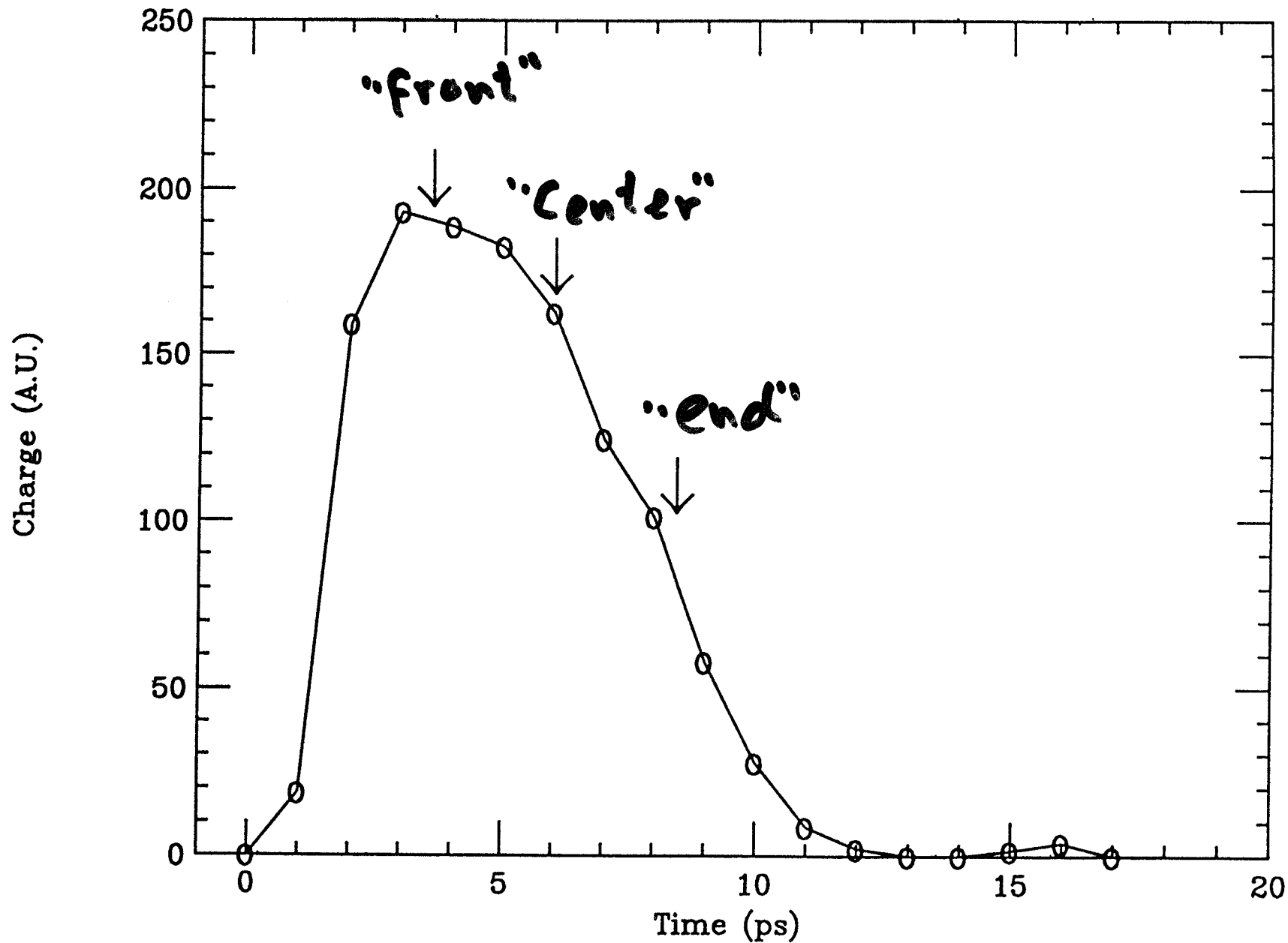
TRANSVERSE –
CONTROL OF RADIAL DISTRIBUTION
OF CHARGE.

HOW?
USE THE LASER DISTRIBUTION IN A
PHOTOINJECTOR.

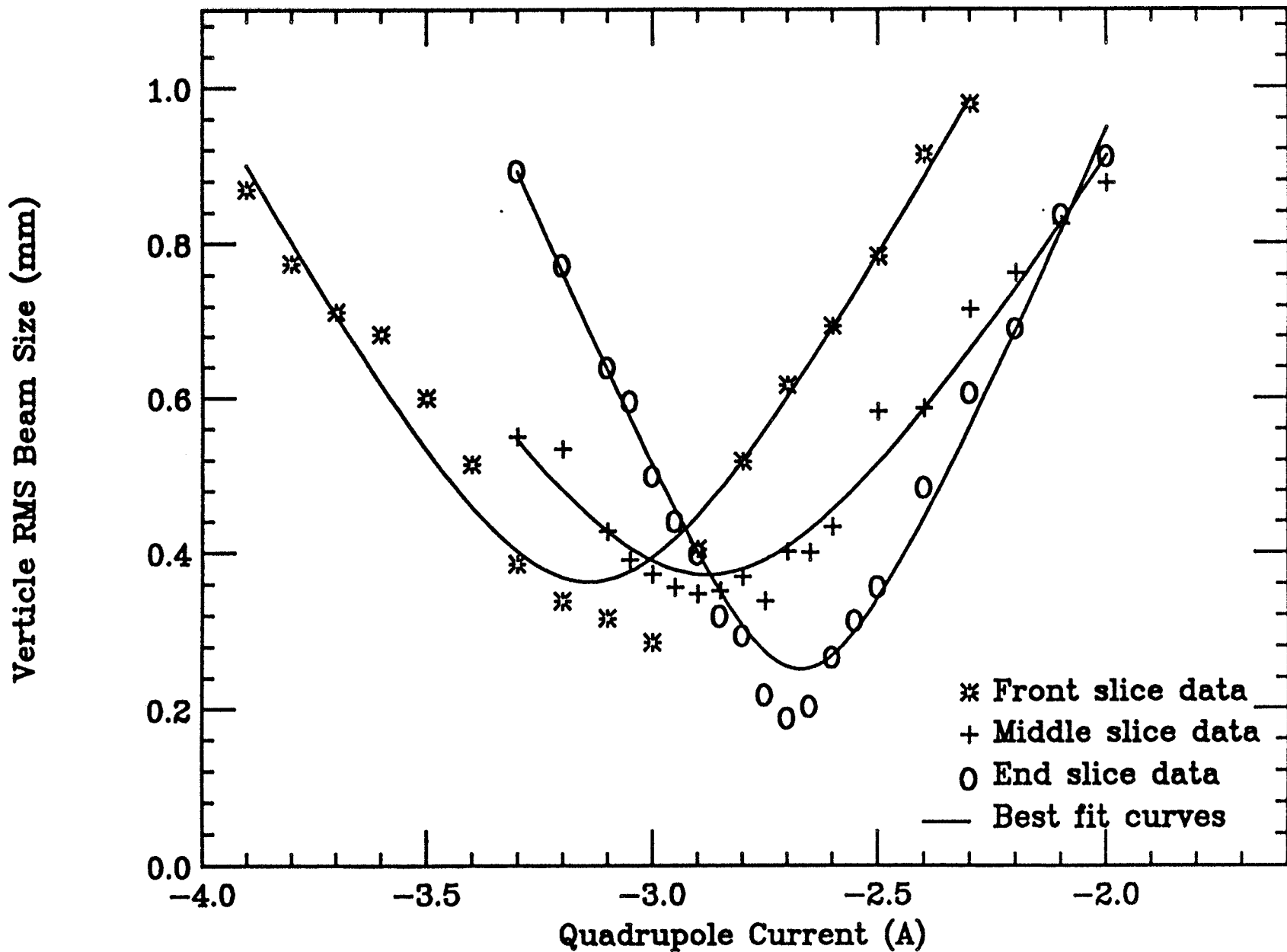


Vertical Total RMS Normalized Emittance (mm·mrad)

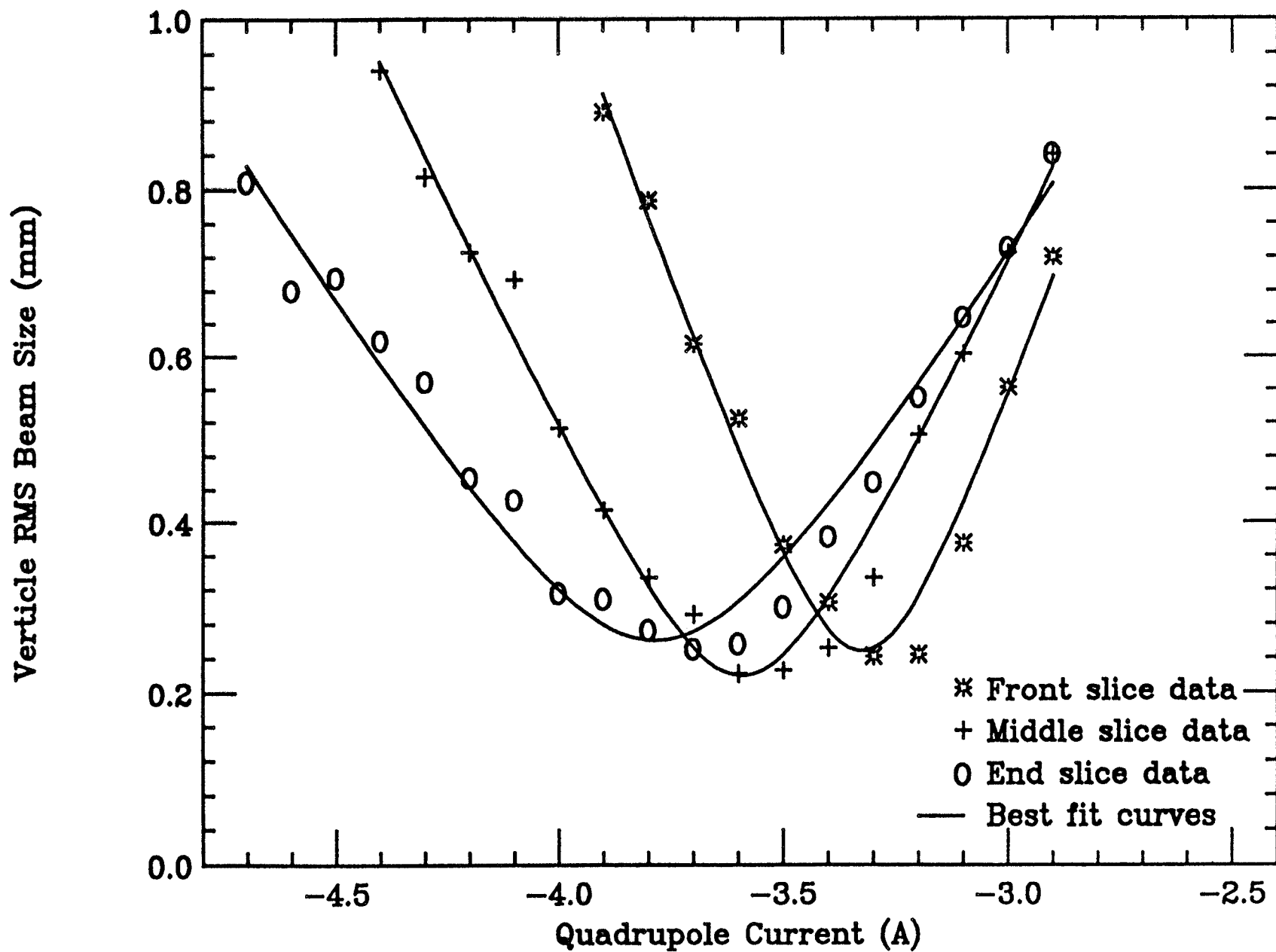




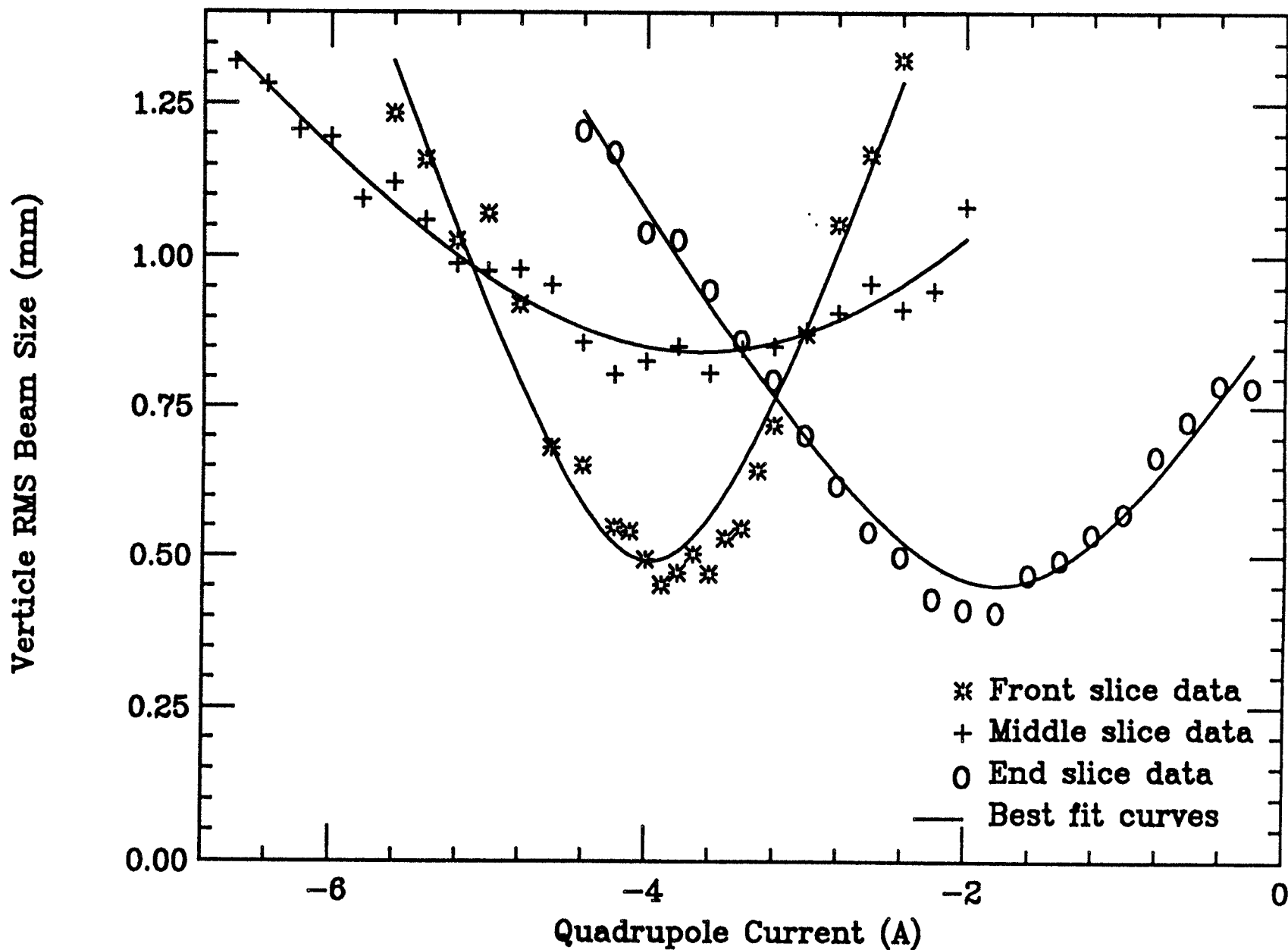
Solenoid 102 A



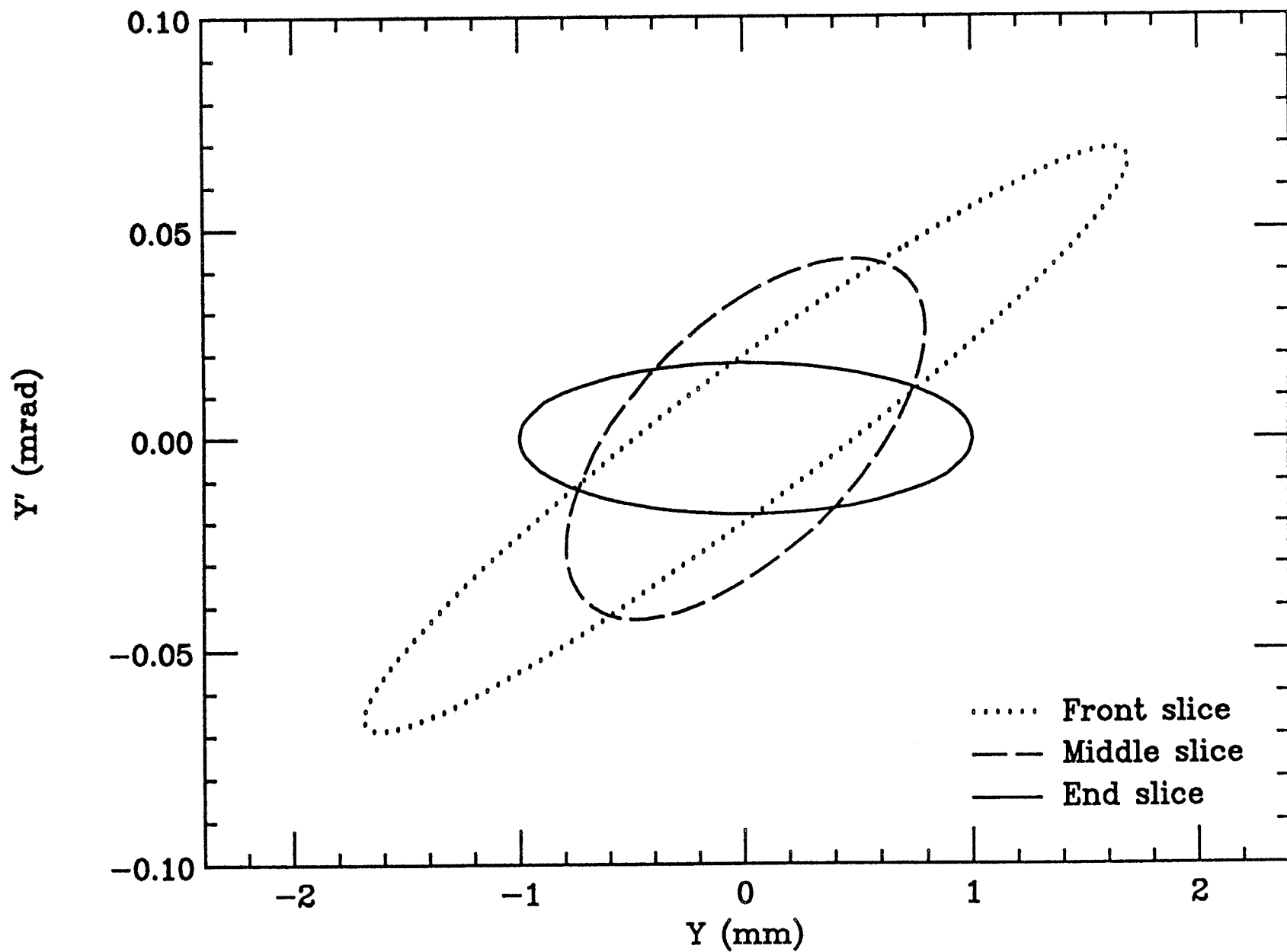
Solenoid 106 A



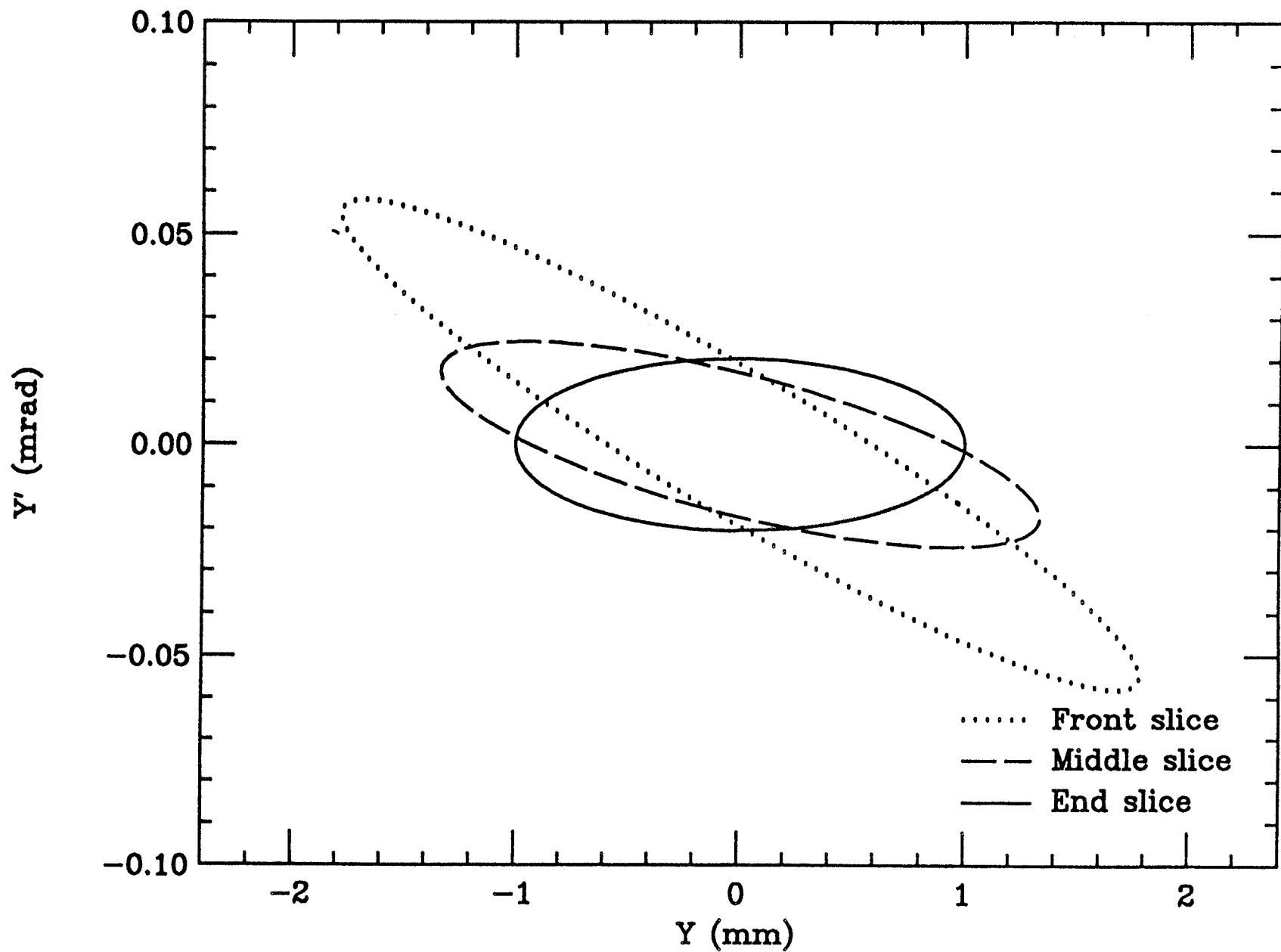
Solenoid 110 A



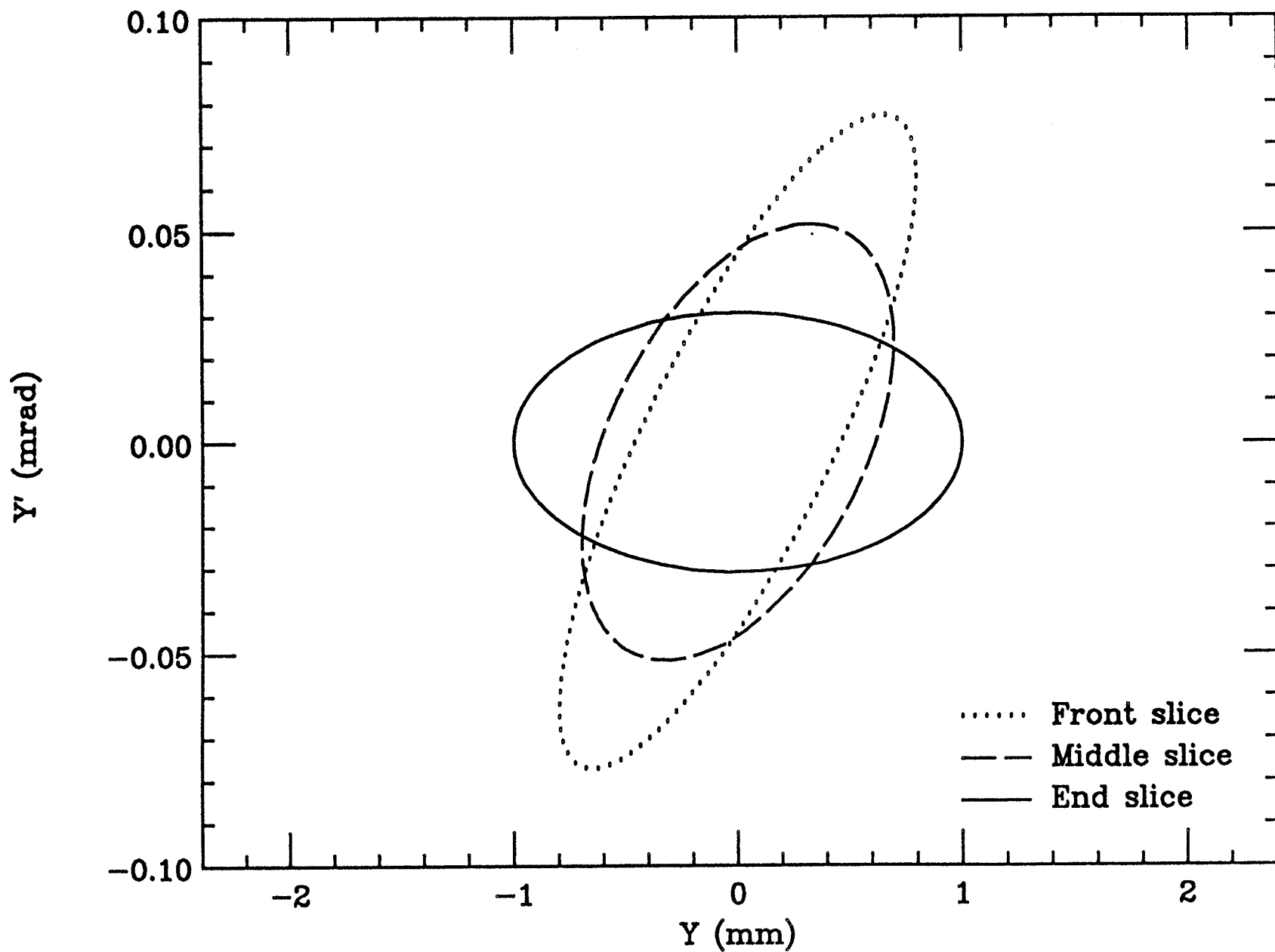
Solenoid 102A



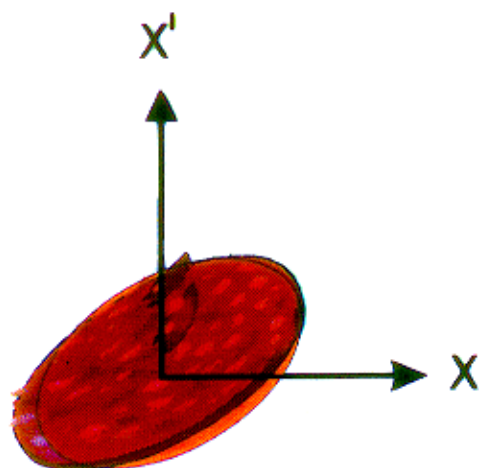
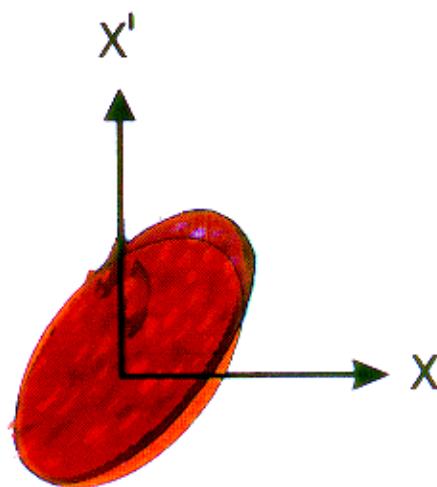
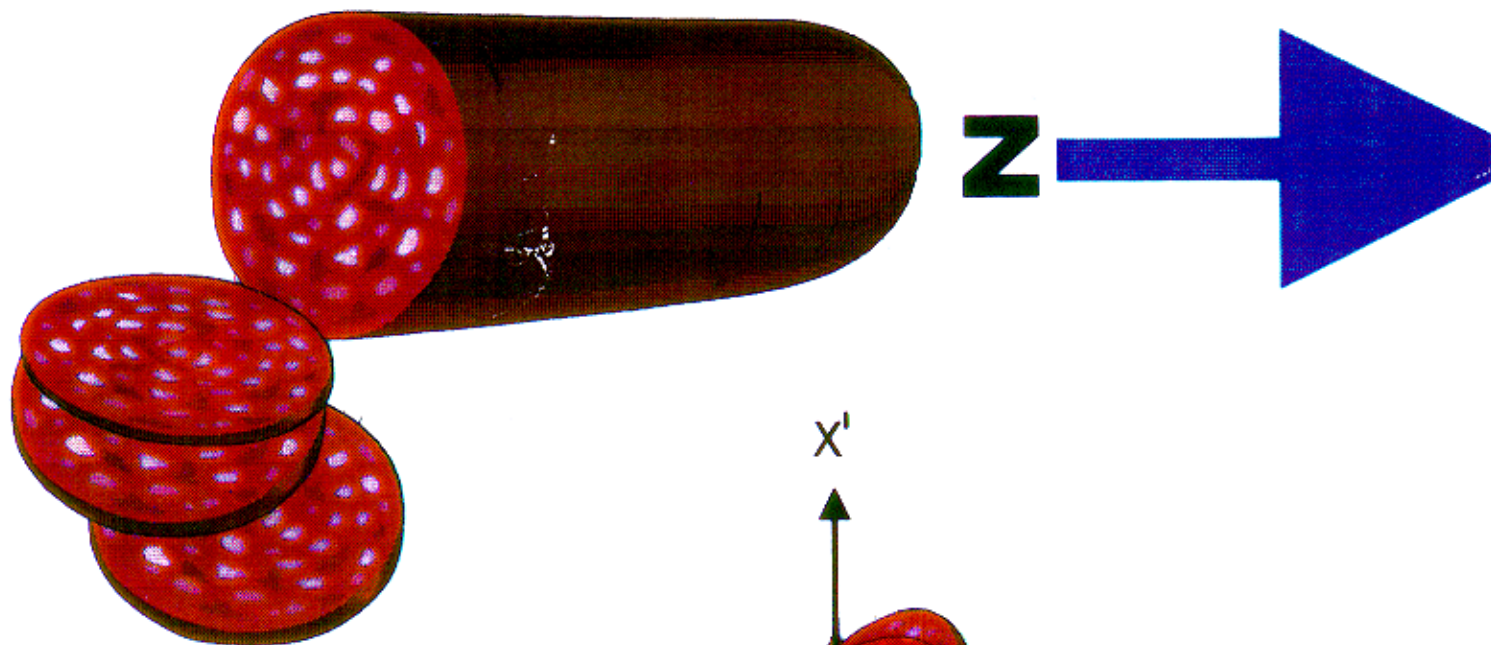
Solenoid 108 A



Solenoid 110A



Beam bunch



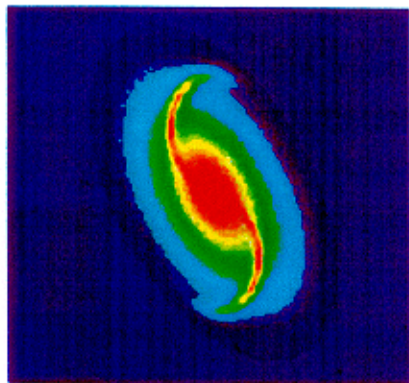
**Transverse
phase
space
of slices**

Tomographic recovery.

Tomography is the technique of reconstructing an object from its projections. In the Physics of beams one can use tomographic techniques to reconstruct a beam density distribution in phase space using its projections in real space. In other words, the images of a beam on a phosphorescent screen (taken, for example, by a CCD camera) can be used to derive the phase-space density-distribution. In order to do that, we must be able to rotate the distribution in phase space to generate independent projections on the screen. This is done by changing the beam transport matrix, using variable strength lenses.

Analysis of required number of projections:

Phantom image:



A special electron beam distribution with fine features (a "phantom") was chosen to simulate the recovery and compare it to the original phantom, as shown in Fig. 1. The fine structure details (tails) are on a size scale approximately 1/10 of the core.

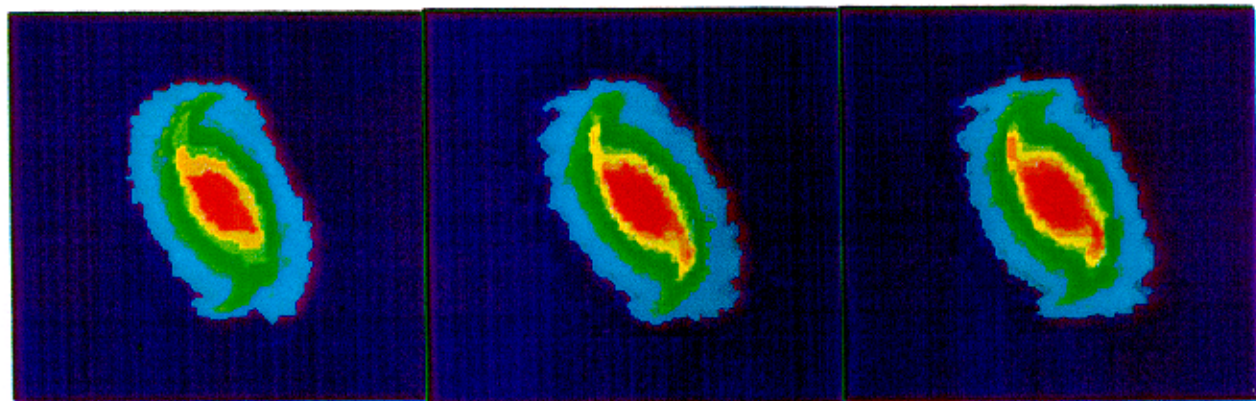
Required accuracy of the phase rotation angle and the transversal

- Left: 10% simulated RMS error in phases;
- center: 10% simulated RMS errors in transversal stretching;
- right: 10% phase and 10% stretching.

10 % angular

10% scale

10% angular + 10%
scale



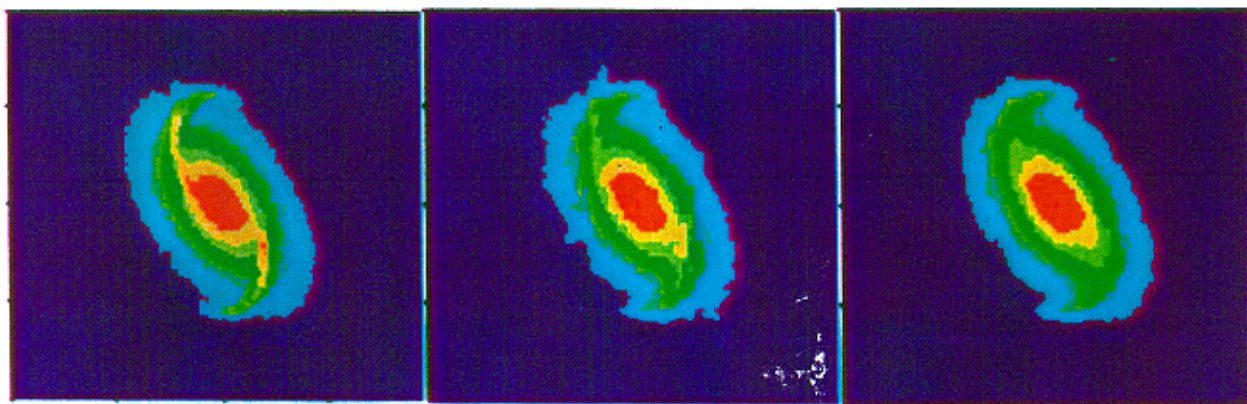
We conclude that the rotation phase error should be of the order of 10%.

Number of the measured projections.

32 x 32

16 x 16

16 x 32

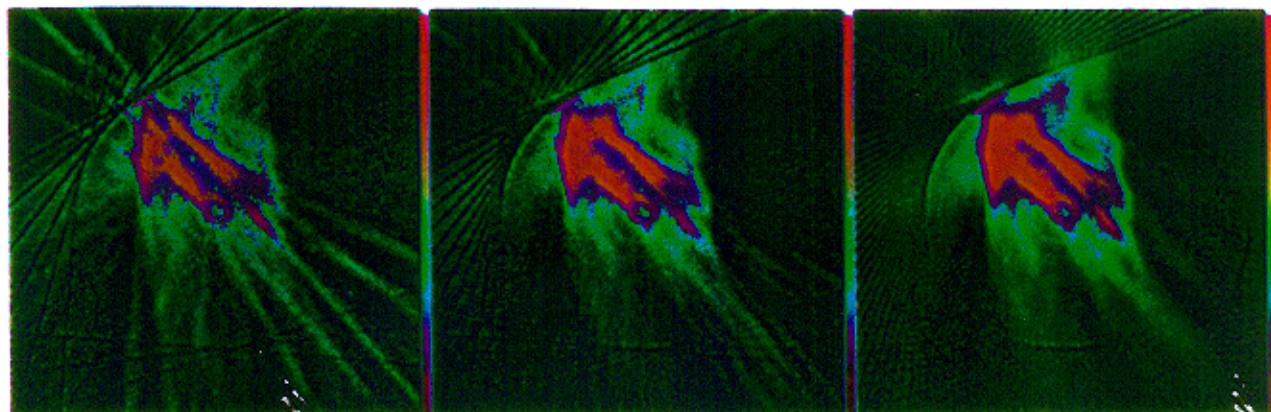


- The image on figures below presents recovery of a real beam from experimental data.
- The accelerator was set to conditions that produce a significant phase space distortion, to produce fine details in the distribution.

16 projections

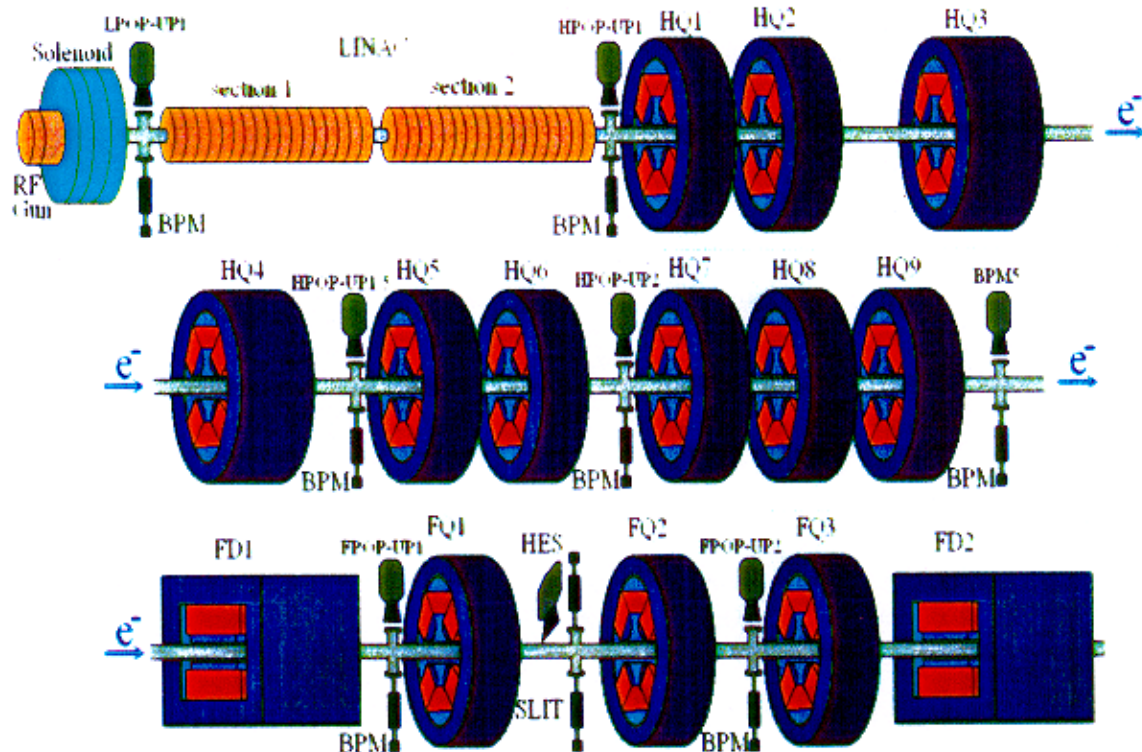
32 projections

64 projections

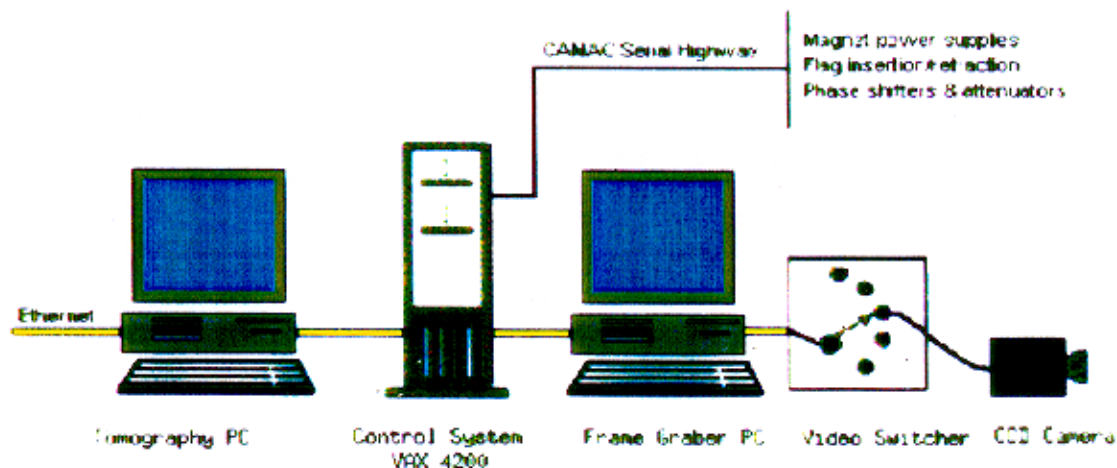


Experimental setup

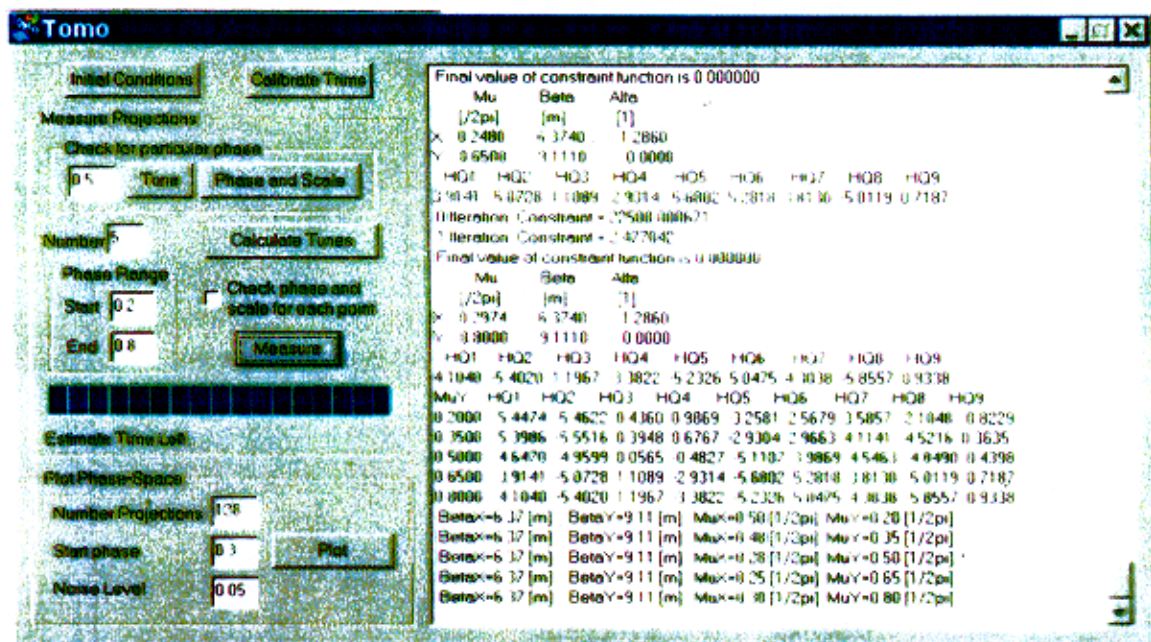
- 0.1 - 1.0 nC charge
- 0.5 - 5 mm mrad emittance
- 1 - 10 ps bunch length
- 5 MeV laser driven RF gun
- 50 MeV LINAC
- Emittance correction solenoid
- Phosphor screen monitors with CCD cameras
- Quadrupole magnets



Computer control of the experiment

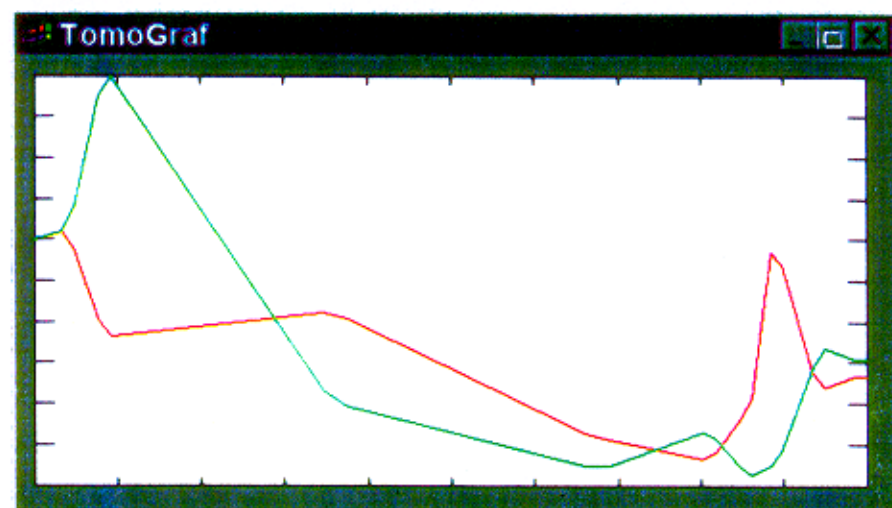
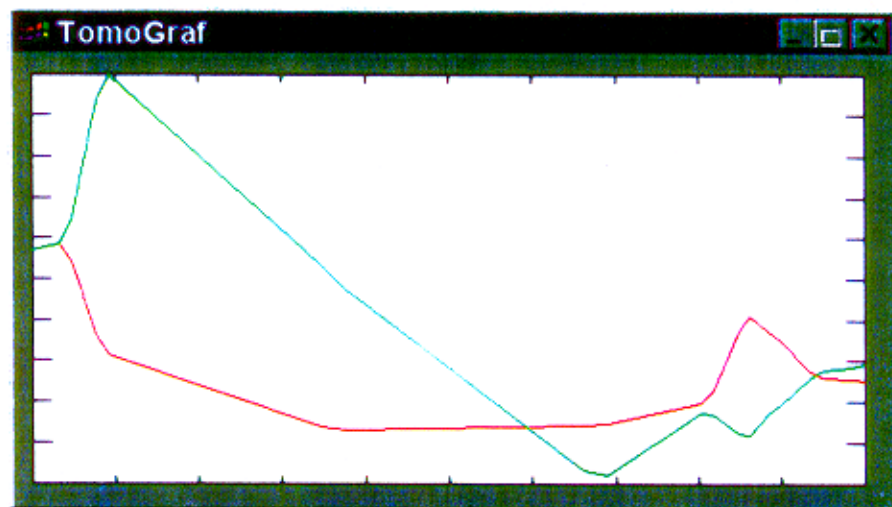
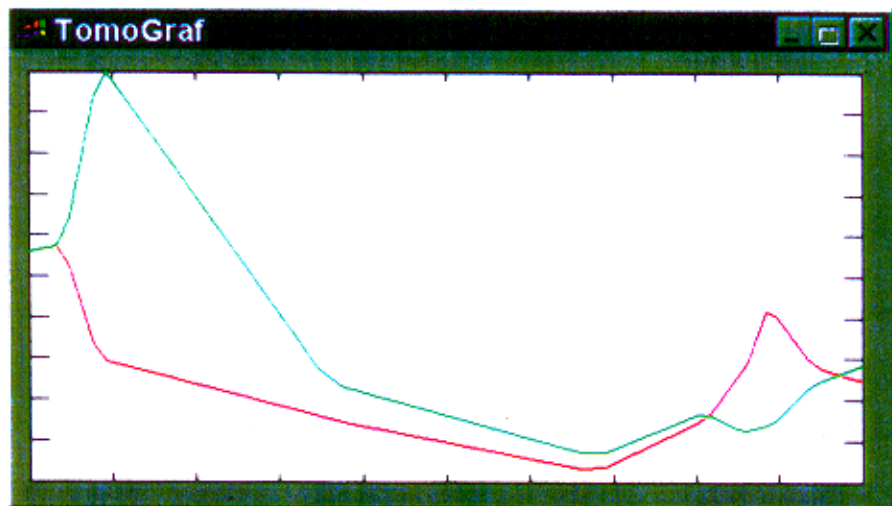


The interface of the program "TOMO"



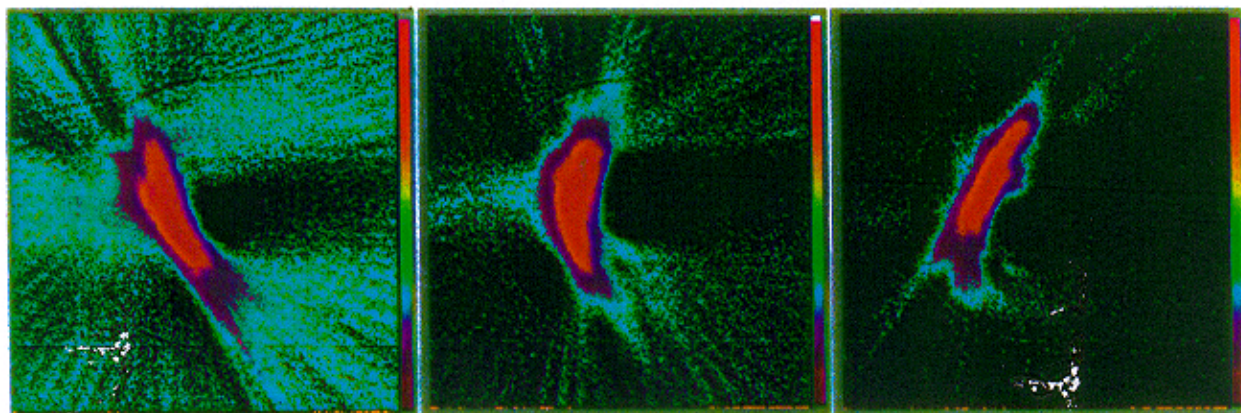
In this program we have an optional feature to get possibly a more precise determination of the phase and scale control by orbit distortion measurements, using calibrated trims pairs in the X and Y planes. That option was not tested and debugged yet.

Calculation of the tunes for different phase advances (0.3, 0.5 and 0.9 of 360 grad):

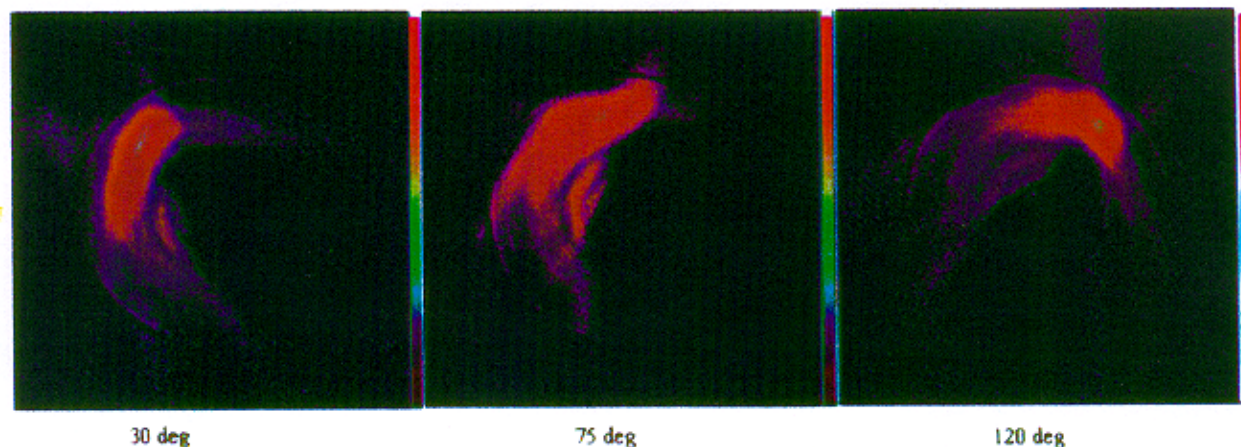


Phase space recovery results

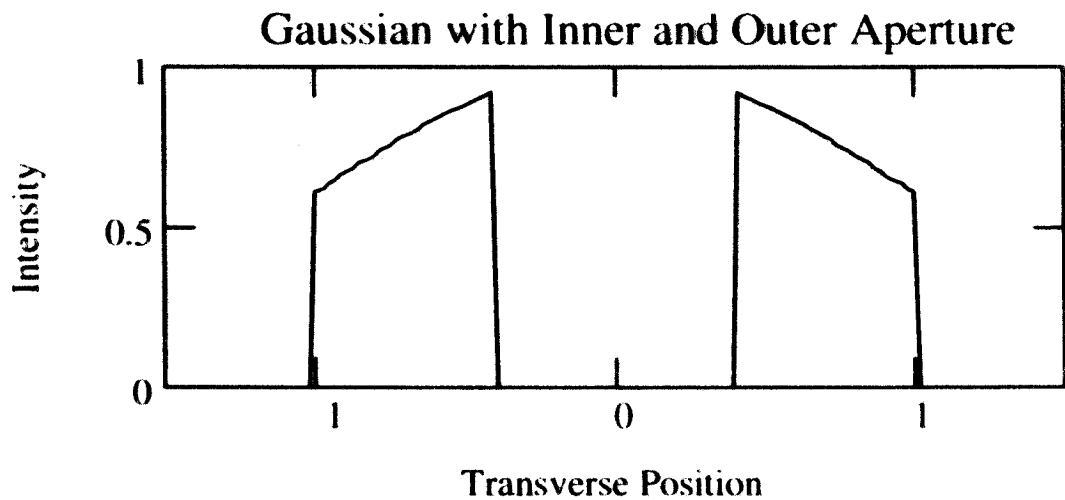
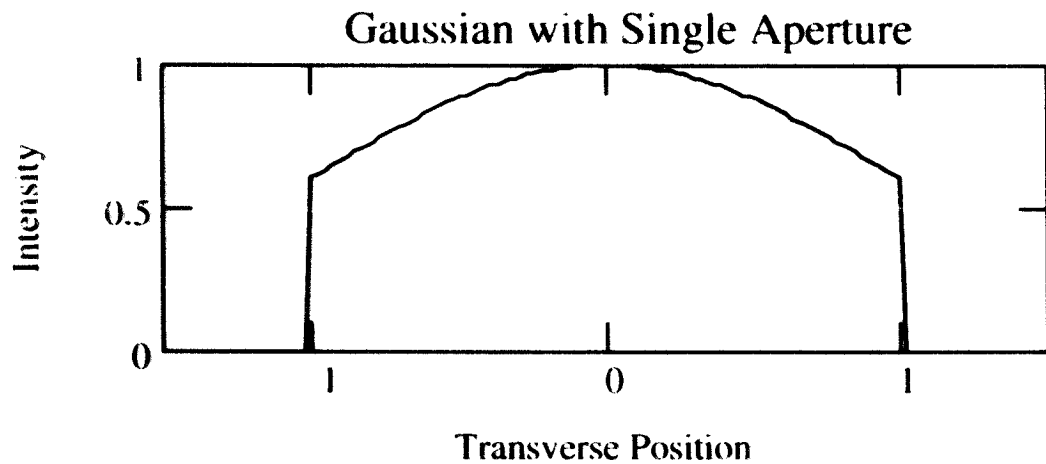
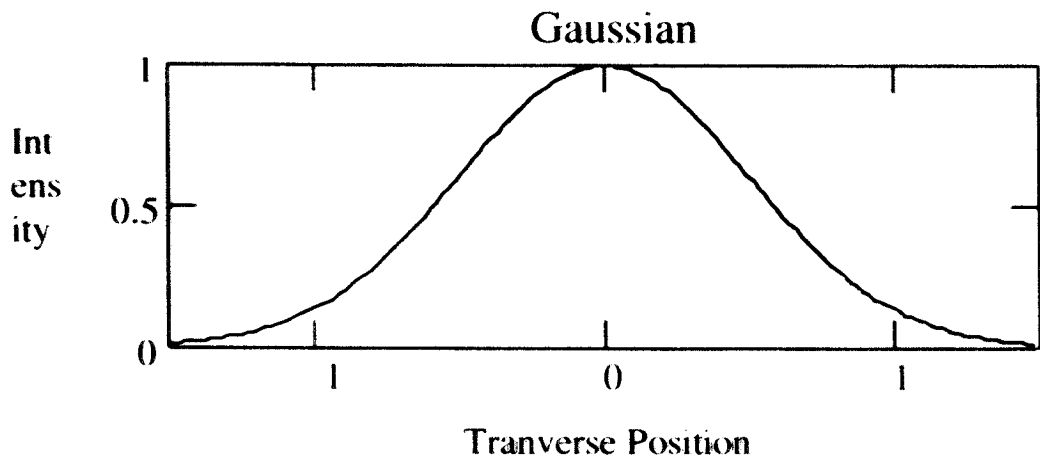
Different solenoid settings:



One of the ways to check accuracy of the recovery procedure is to use different parts of the measured data. On the pictures presented below recoveries using data from $[30 : 210]$, $[75 : 255]$ and $[120 : 300]$ degrees sets are comparing to each other.



Transverse shaping of laser profile.

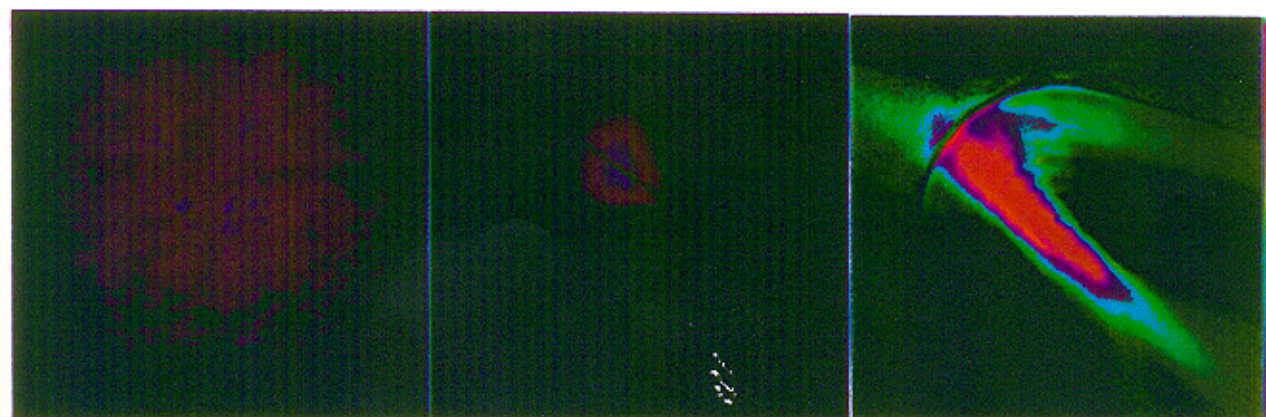
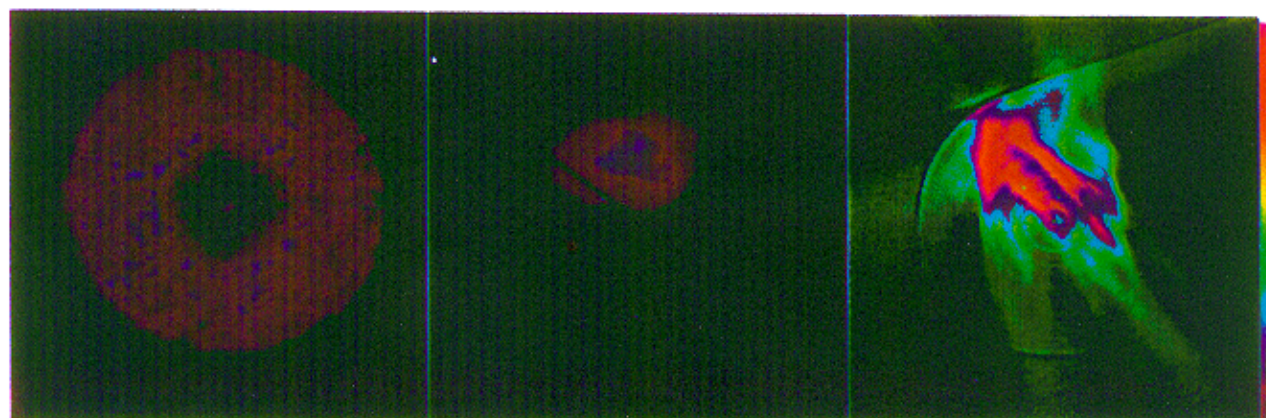
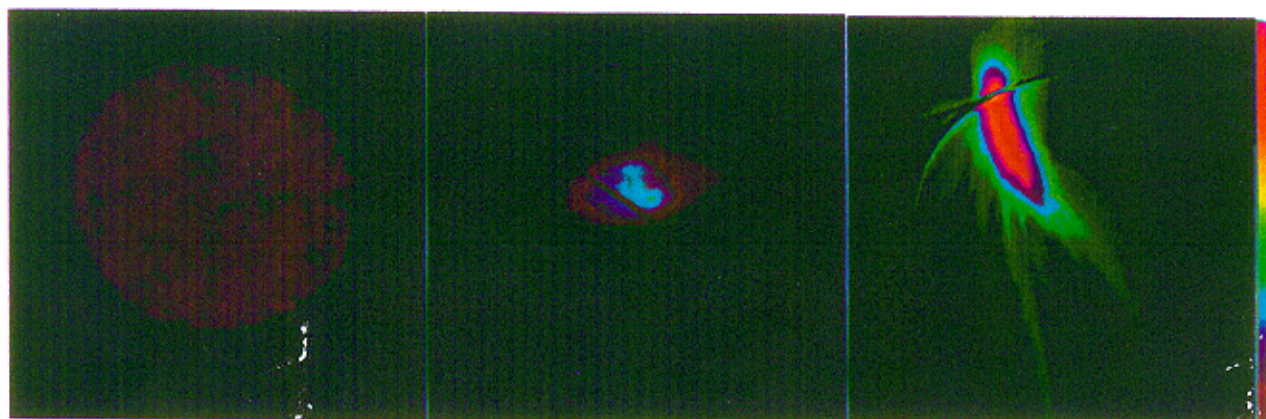


Different laser profiles:

Laser profile

Electron beam image

Recovered phase-space



Summary

- The combination of
 - Slice Emittance
 - and
 - TomographyAllows the measurement of density distribution in 5 dimensions of phase space.
- We are in a position to improve brightness by
Non Linear Corrections