Beam Measurement Simulations

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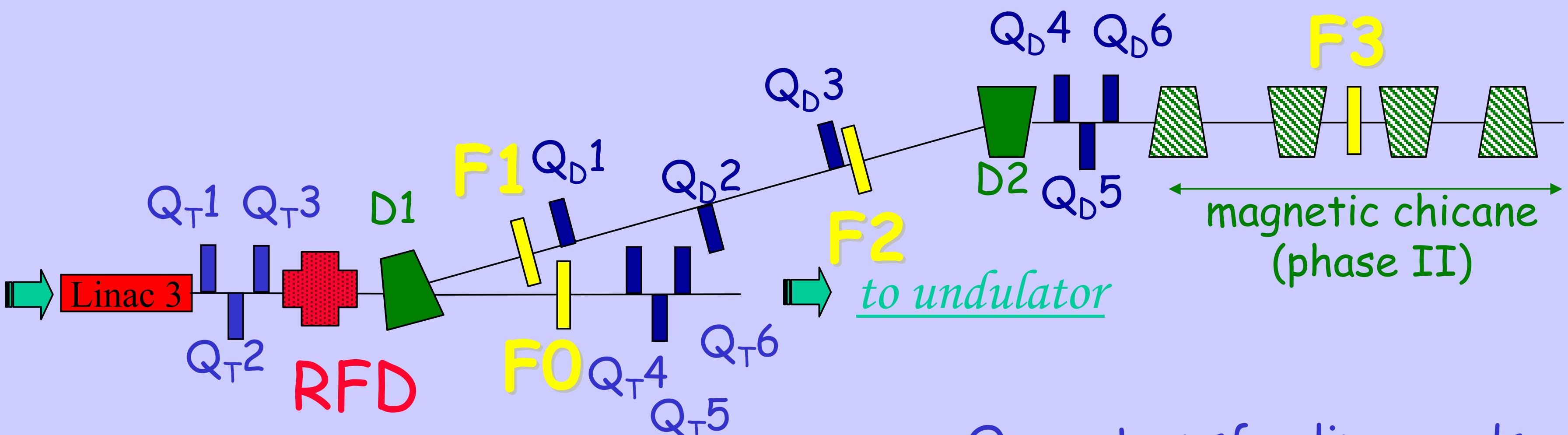
Outline

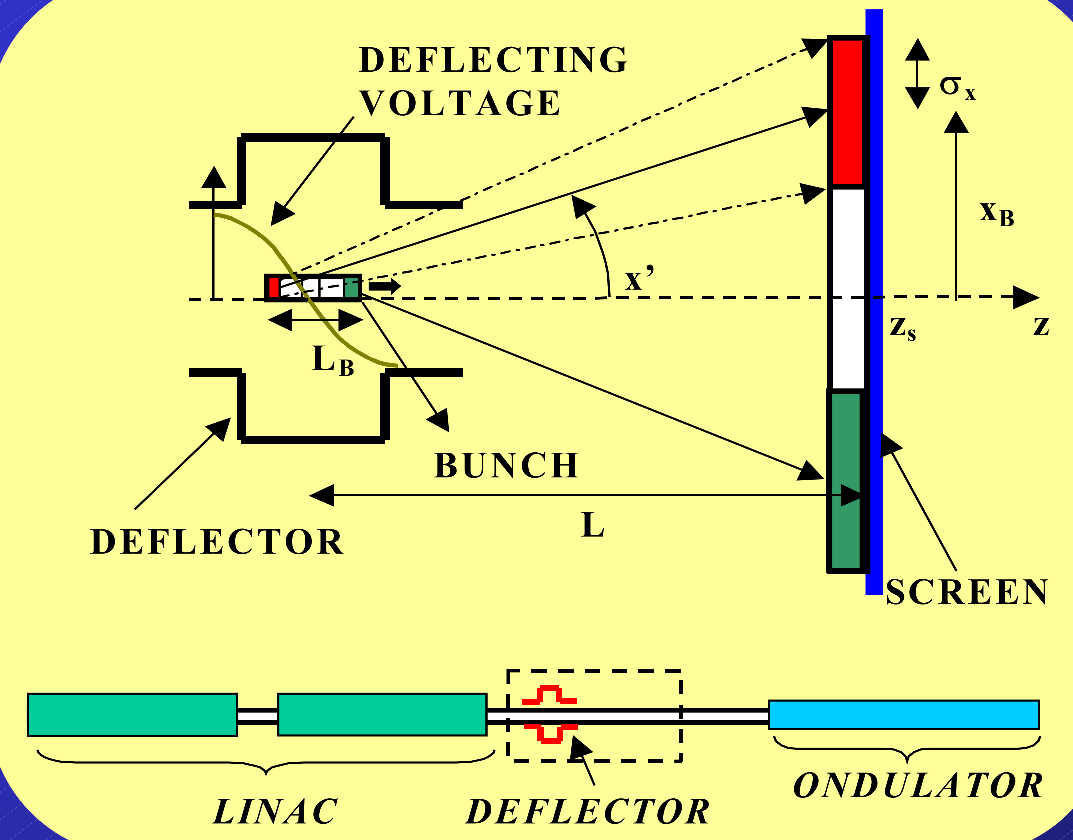
- Bunch length measurement
- Longitudinal phase space reconstruction
- Slice emittance measurement

SPARC measurement layout for high energy beam characterization



Q_T = transfer line quads
Q_D = dogleg quads
RFD = RF deflector
D = dogleg dipoles
F = flags

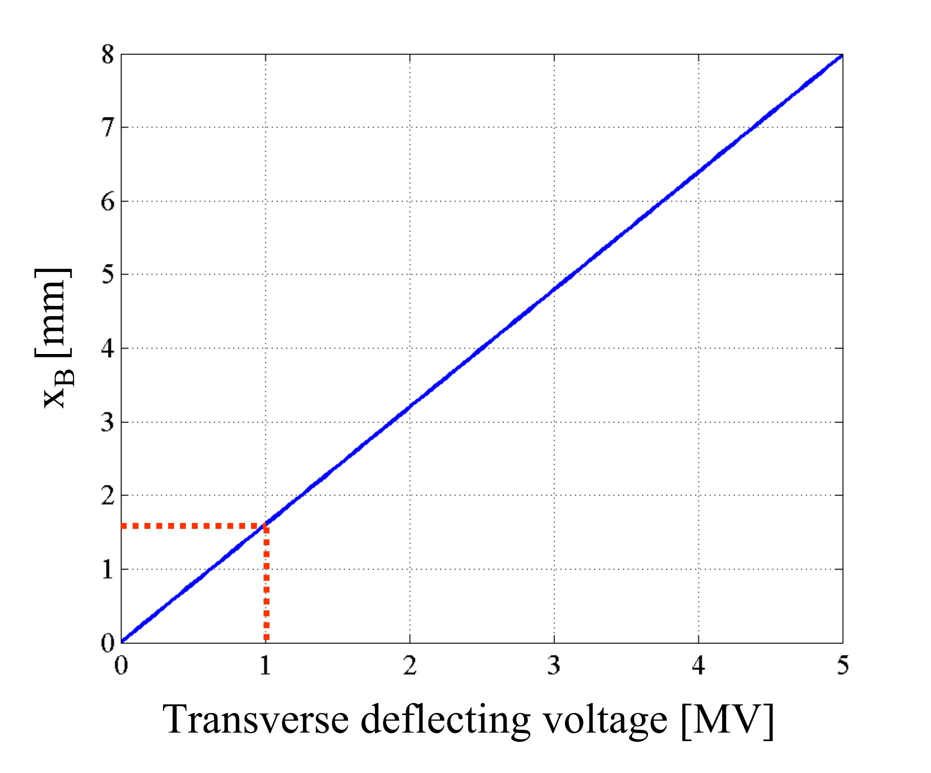
Bunch length measurement schematic setup with the RF deflector



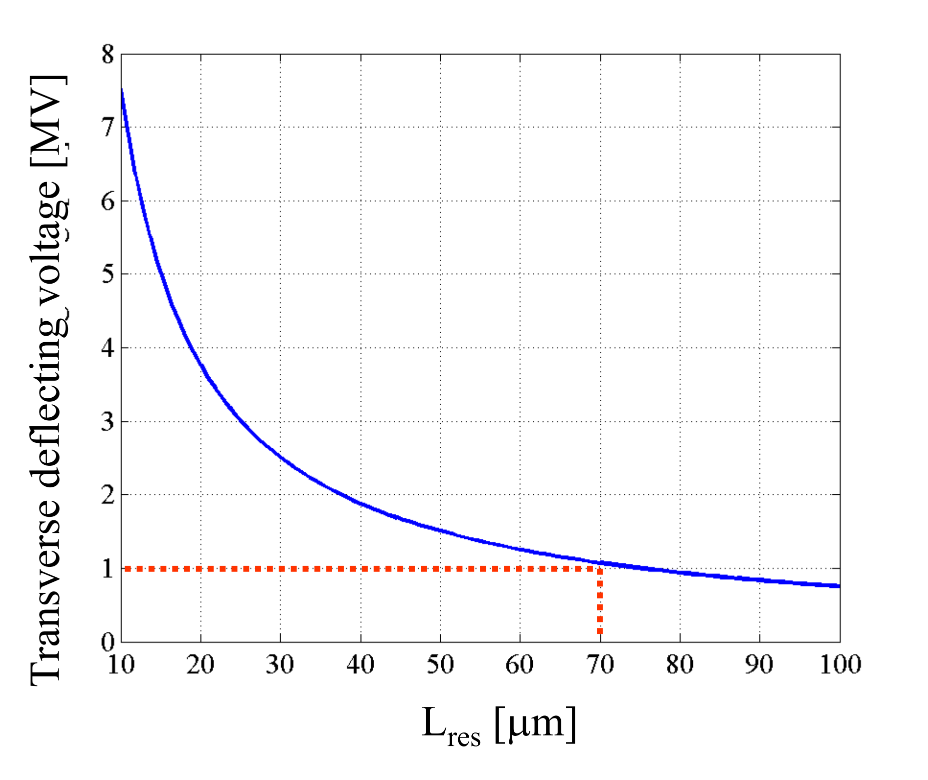
$$x_B = \frac{\pi\, f_{RF} L L_B V_\perp}{cE/e}$$

$$V_\perp = \frac{\sigma_x cE/e}{\pi f_{RF} L L_{res}}$$

RF deflector parameters



Total transverse dimensions of the bunch as a function of the deflecting voltage $V_{\perp}$.

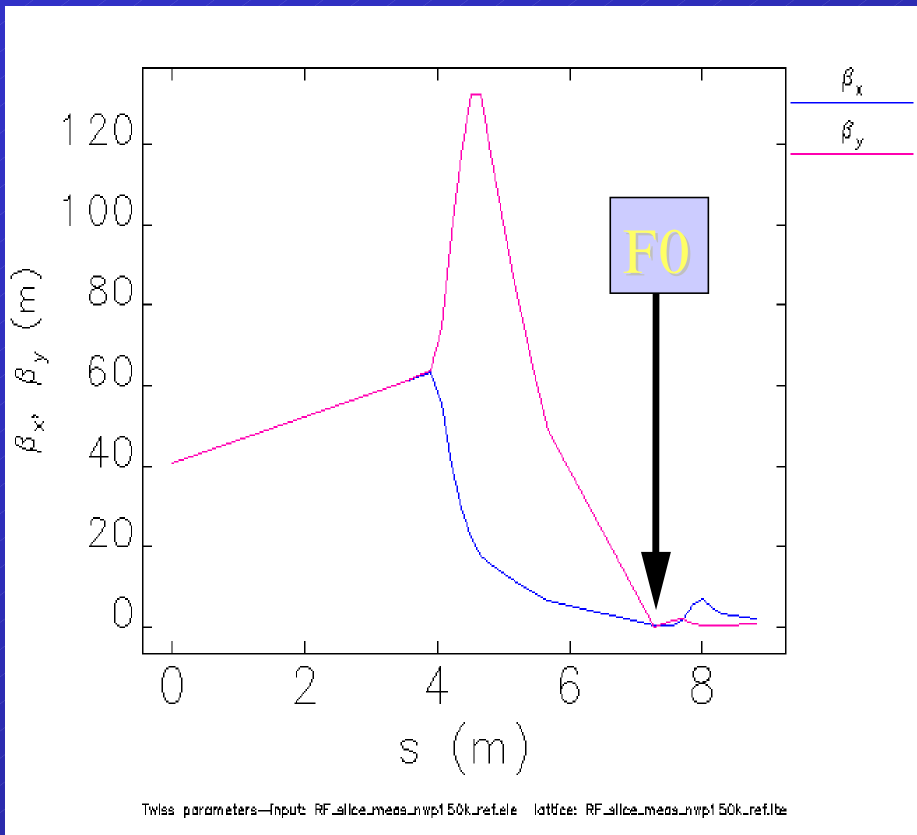


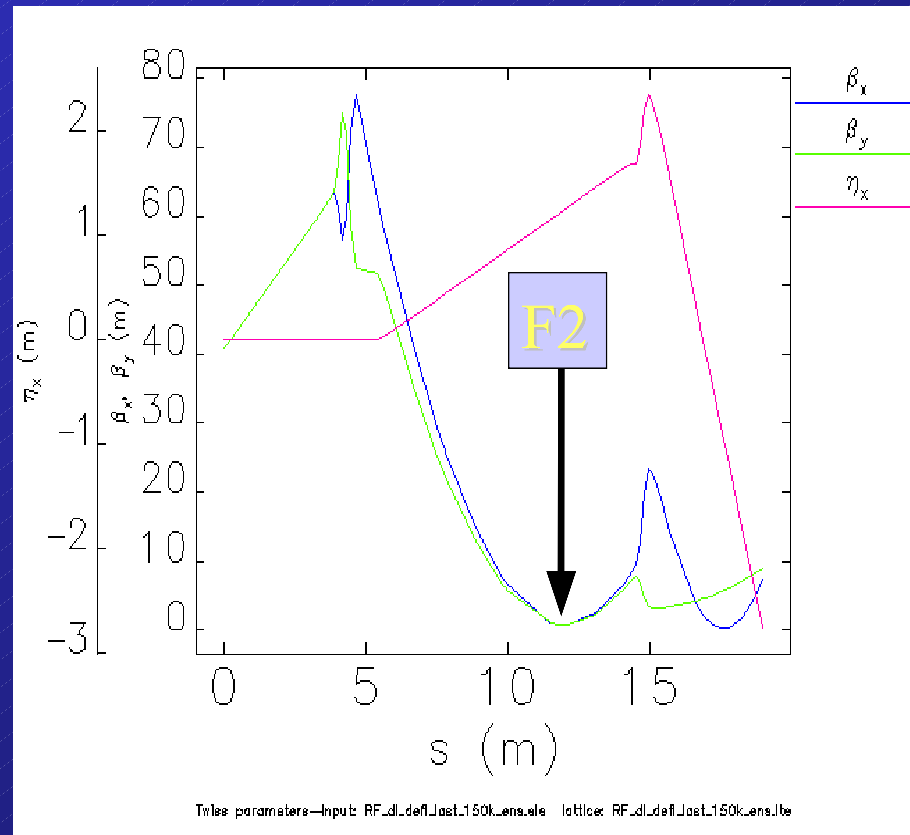
Deflecting voltage $V_{\perp}$ as a function of L_{RES}

Measurement layout

FLAG 0:
β_x= .38 m, β_y= 0.05 m

FLAG 2
β_x= 0.72 m, β_y= 0.84 m , η_x= 1.27 m

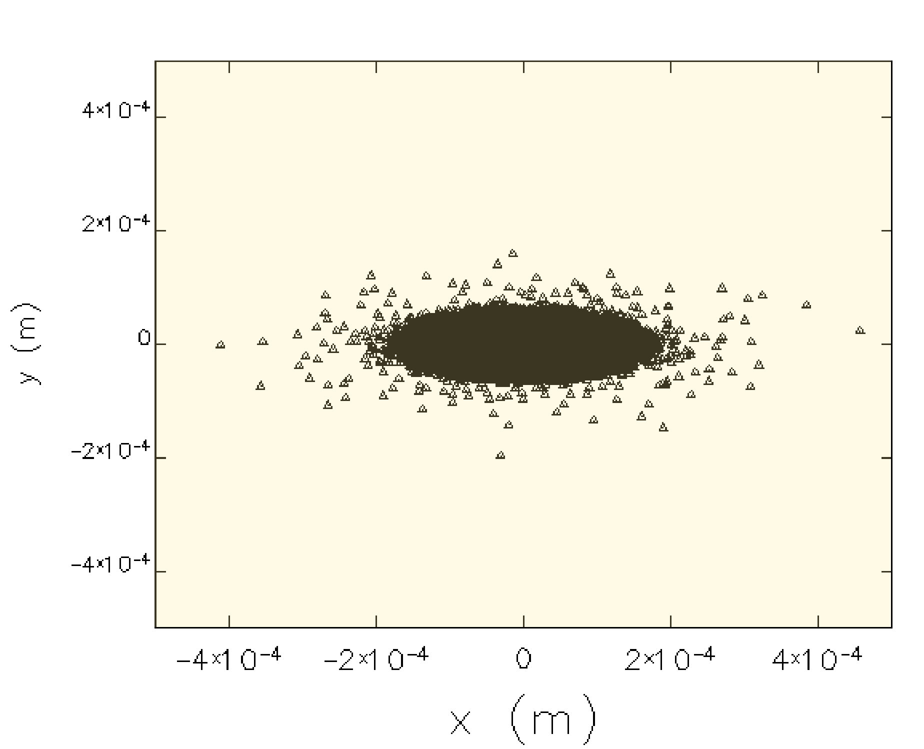


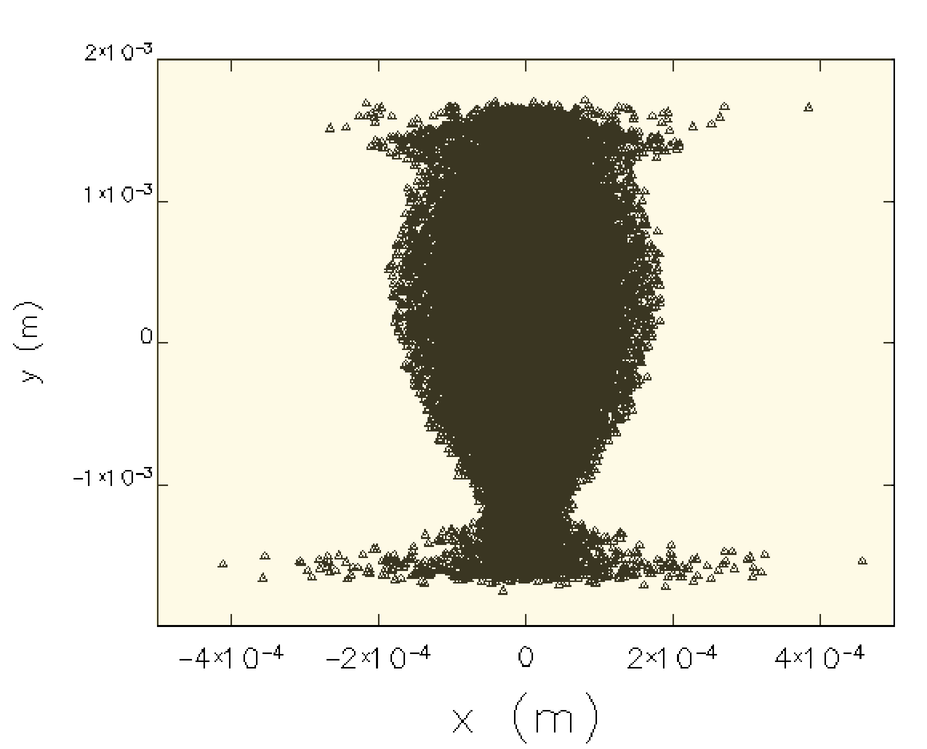


a) bunch length measurement

b) longitudinal phase space

Bunch transverse distribution* at the screen location F0



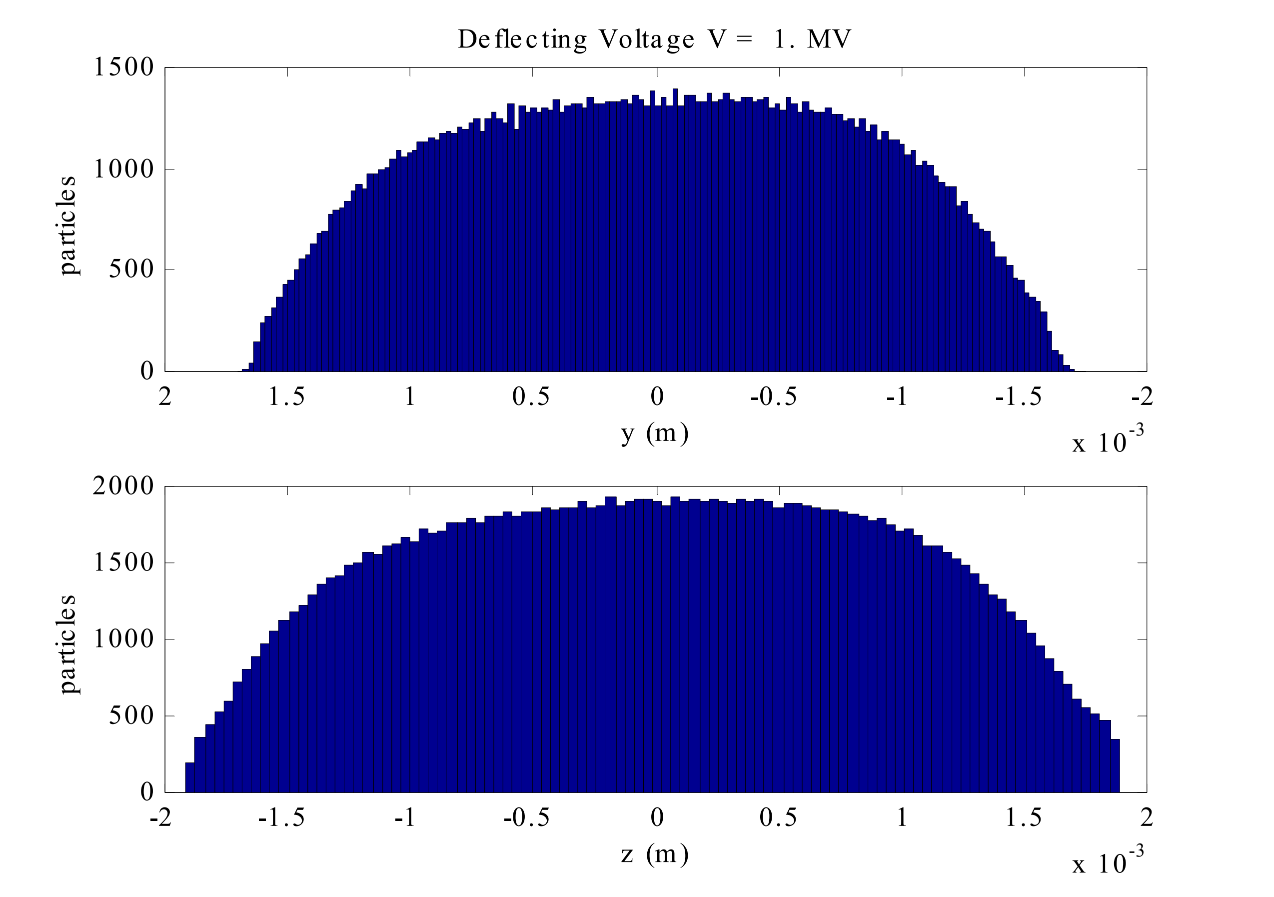


RFD OFF

RFD ON (V_O = 1 MV)

*Elegant tracking output, N_{part}=150k

Tracking results

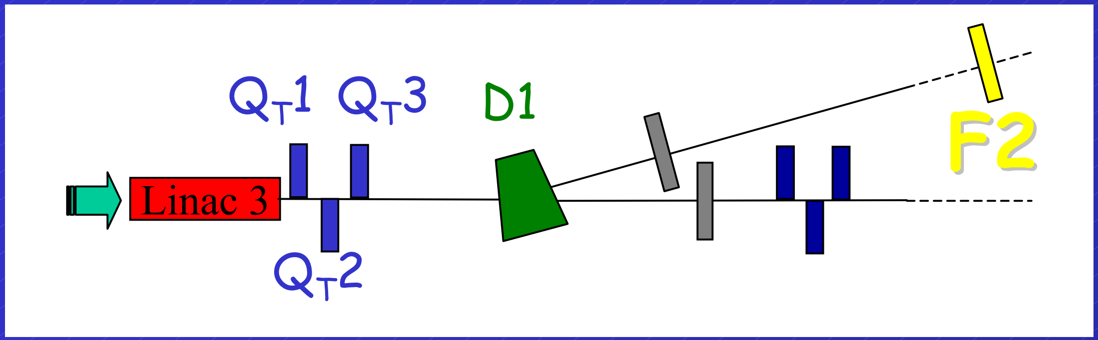


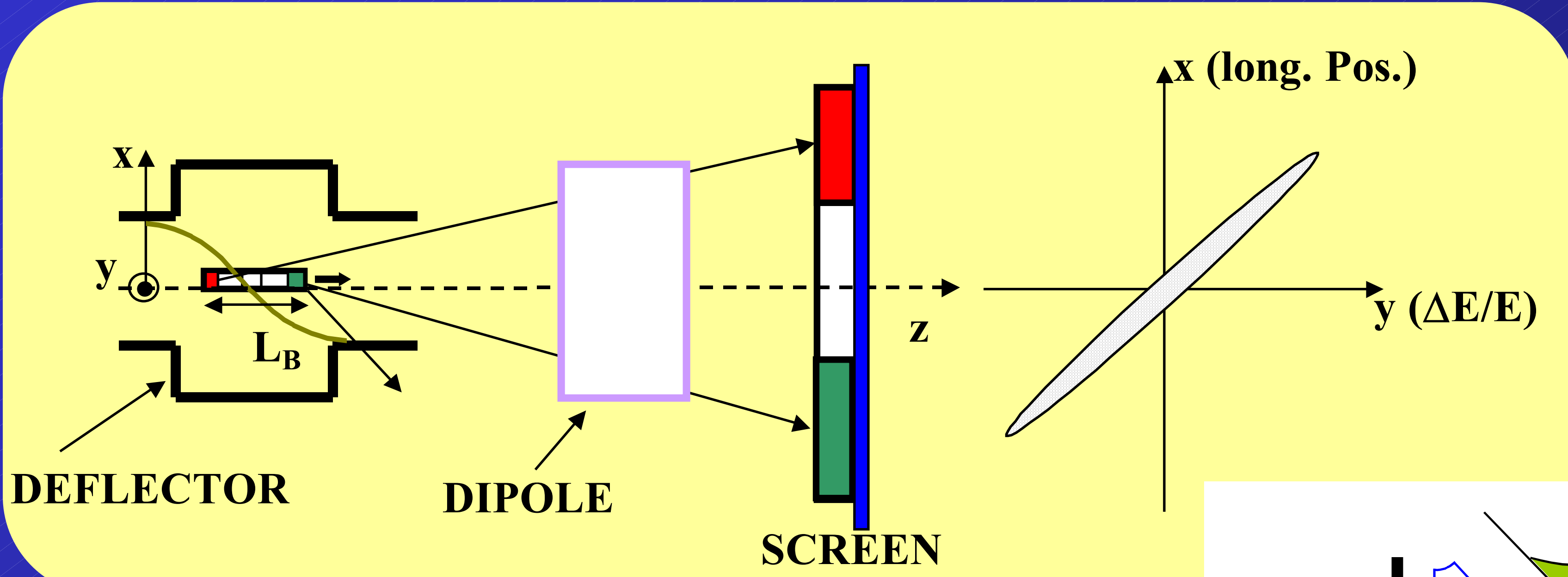
$$\sigma_z = \sigma_y \frac{cE/e}{\pi f_{RF} L L_B V_\perp} = 0.934\,mm$$

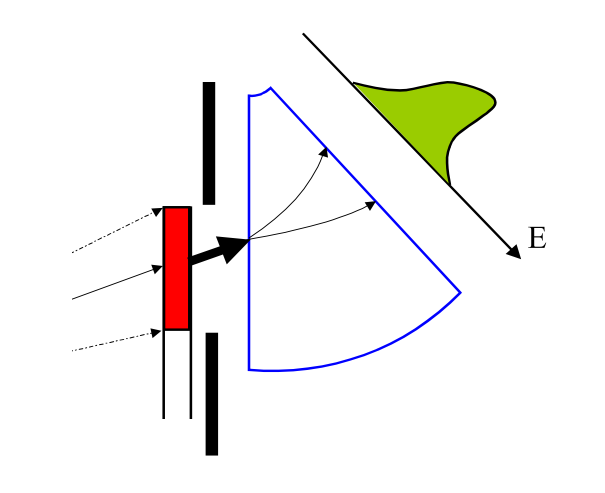
from tracking data :

$$\sigma_z = 0.934\,mm$$

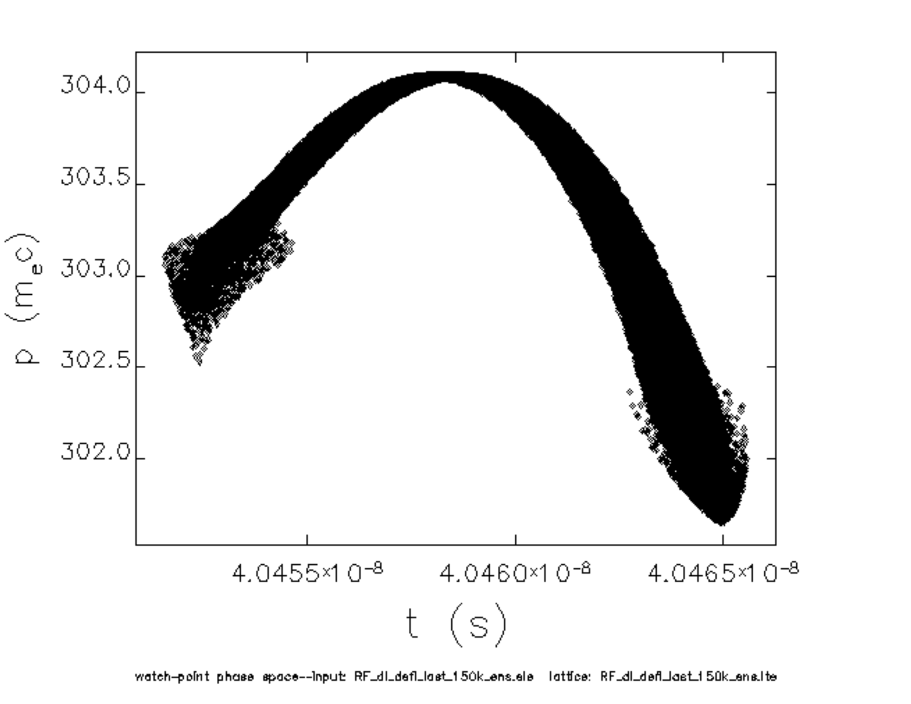
Longitudinal phase space reconstruction

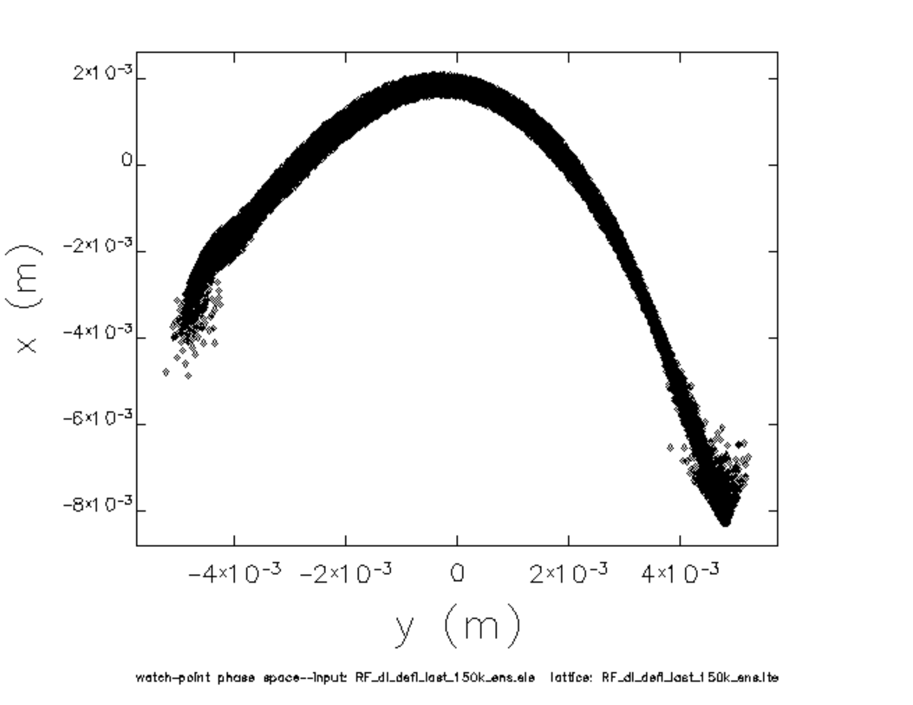






Tracking results

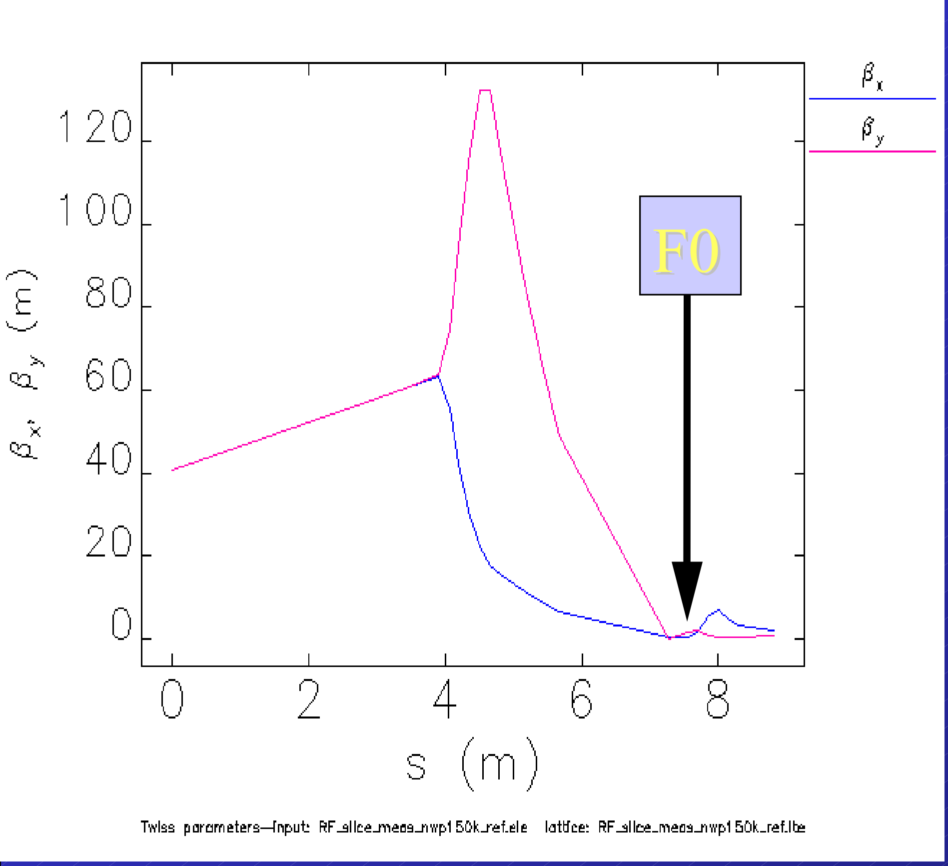




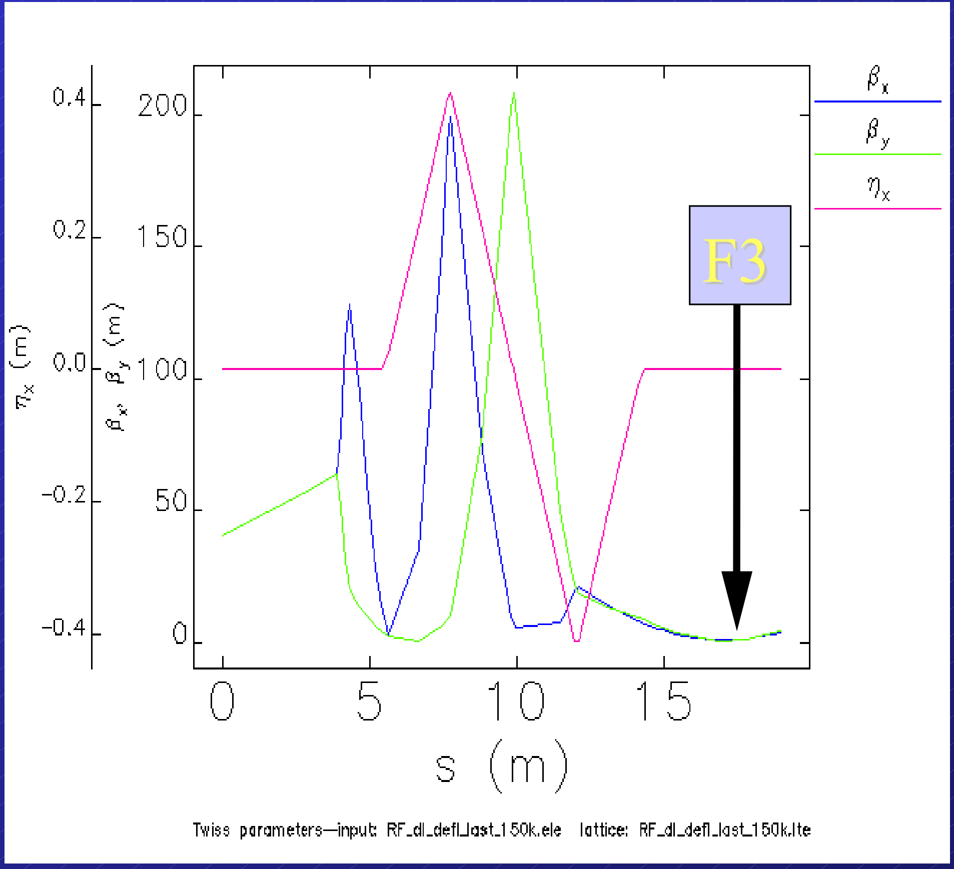
bunch energy distribution vs time at F2

bunch transverse distribution at F2

Slice emittance measurement



SPARC **Transfer Lines** optic functions for the horizontal quad scan at F0. The origin of the longitudinal coordinate corresponds to the exit of the second Linac section.



SPARC **Dogleg** optic functions for the horizontal quad scan at F3. The origin of the longitudinal coordinate corresponds to the exit of the second Linac section.

- The transverse phase space characterization is obtained measuring the beam slice emittance in both the transverse planes.
- The slice emittance is the transverse emittance of a short time interval (slice) of the microbunch. It can be measured using a beam with a linear energy-time correlation, or chirp; the chirp is combined with the quadrupole scan technique to determine the emittance of the slices along the bunch.
- This type of energy-time correlation can be provided by the RF deflector or using a dispersive system.
- Using the RF deflector the horizontal slice emittance ε_x can be measured either on the transfer lines or on the dogleg, at the flags F0 and F3
- The beam emittance can be calculated by the following equation:

$$\sigma_{11}\sigma_{22} - \sigma_{12}^2 = \varepsilon^2$$

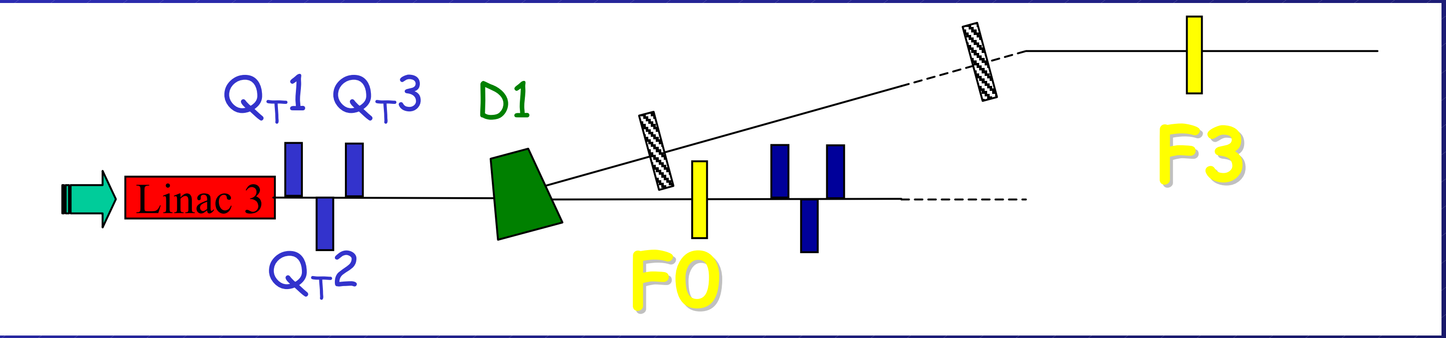
that comes from the equation of an n-dimensional ellipse written in the form :

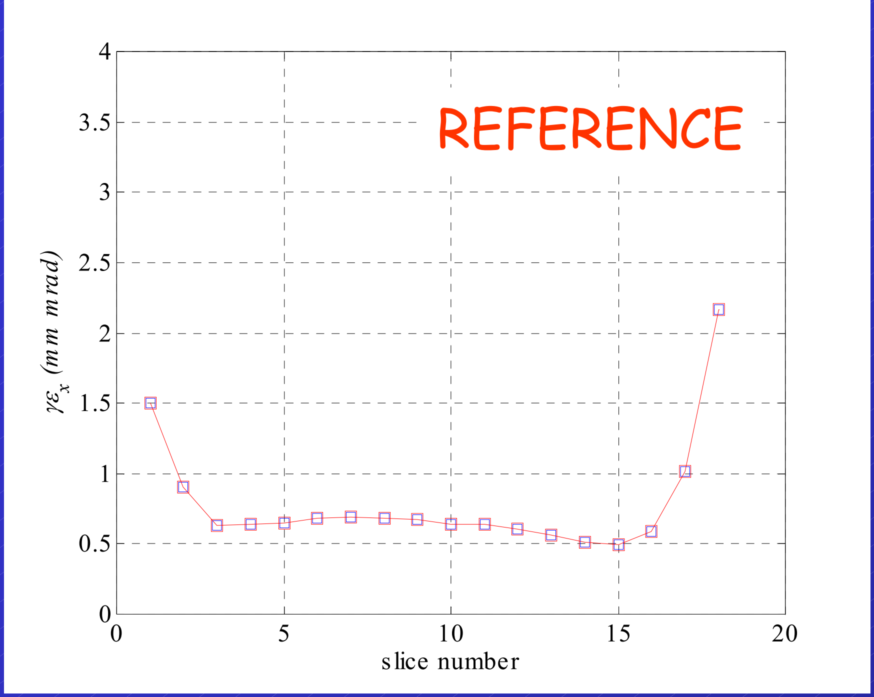
$$\mathbf{u}^T \boldsymbol{\sigma}^{-1} \mathbf{u} = 1$$

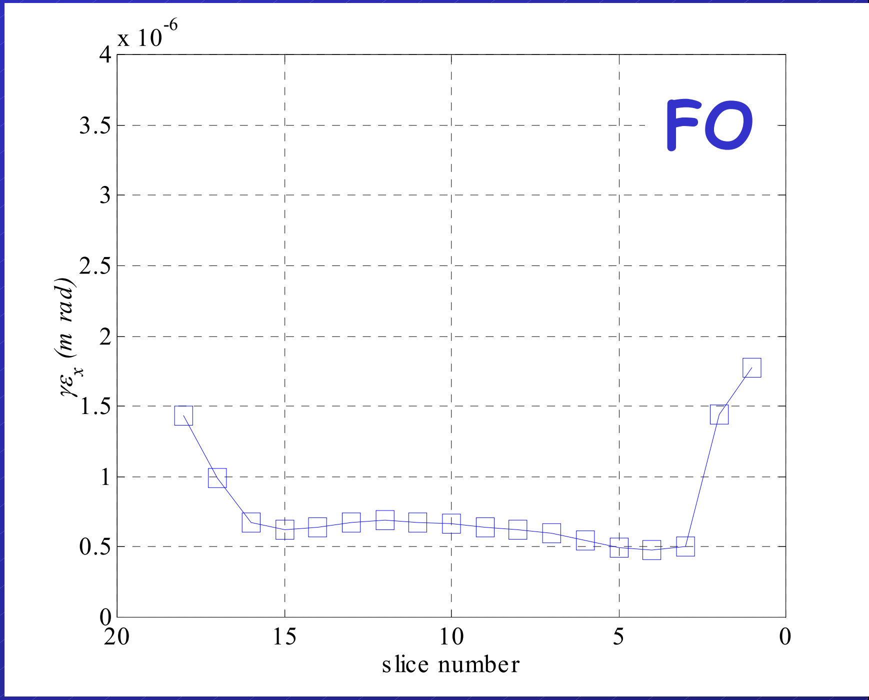
The first two quads after the linac sections, Q_T1 and Q_T2 , are used in this case for the quadrupole scan: the beam horizontal size at the the screen (F0,F3) is varied keeping constant the vertical one. The measurement results are fitted following the equation:

$$\sigma_{11}^{screen} = R_{11}^2 \sigma_{11}^{s_o} + 2R_{12}R_{11}\sigma_{12}^{s_o} + R_{12}^2 \sigma_{22}^{s_o}$$

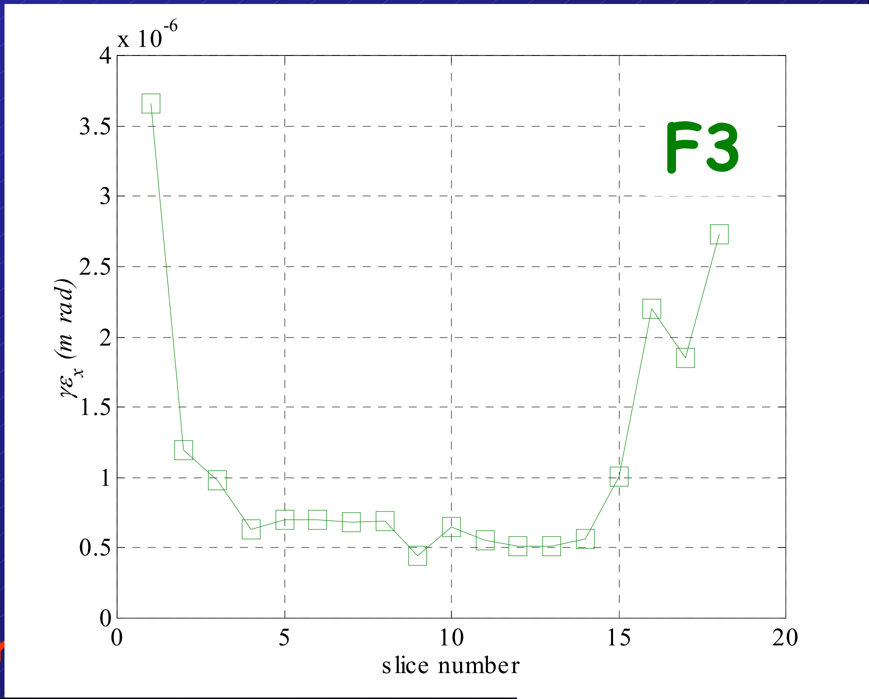
where σ_{11} is the horizontal beam rms size measured at the screen, and R_{11} and R_{12} are the first two elements of the beam transport matrix, from the first scanning quadrupole to the screen considered.



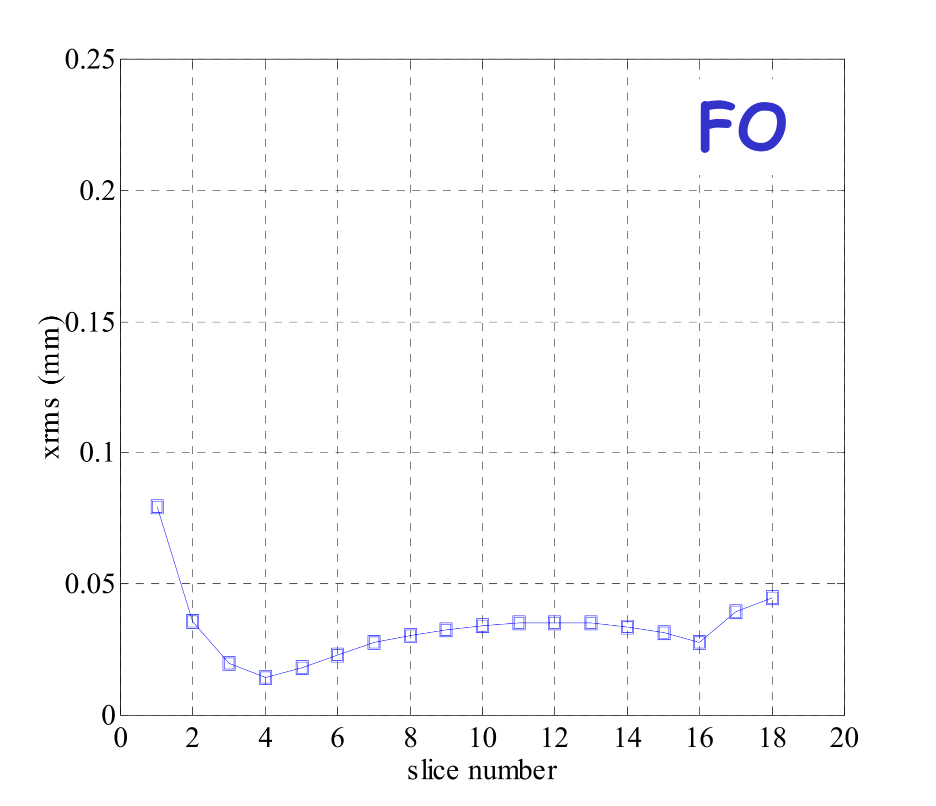


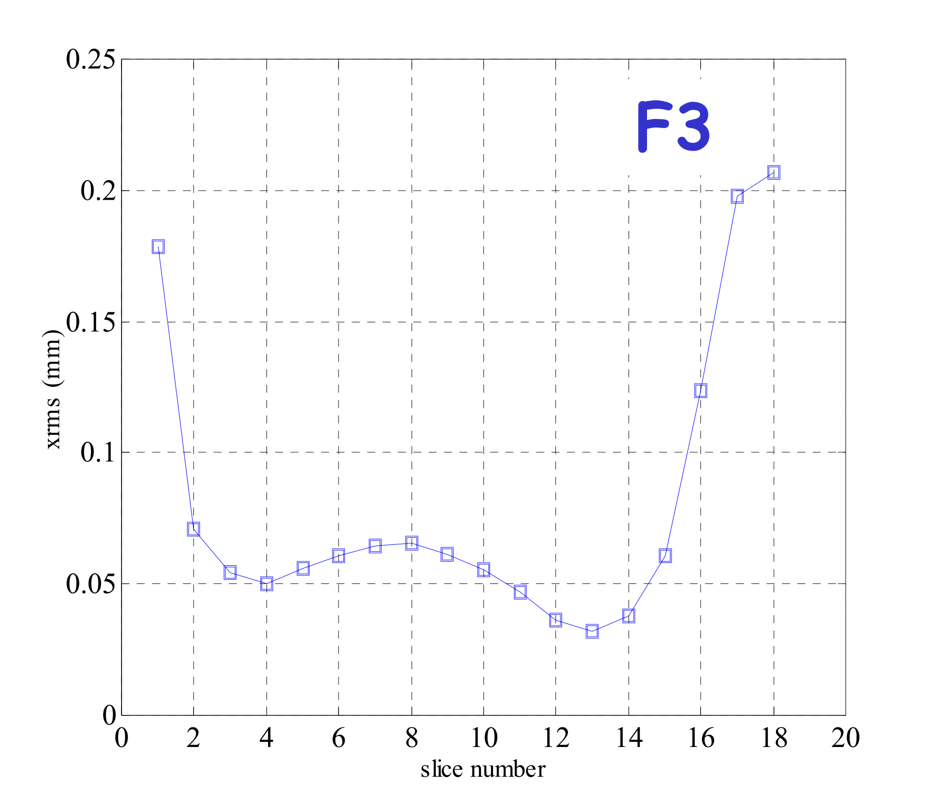


The beam horizontal slice emittance is reported for the two simulated measurements at F0 (above) and F3 (below), respectively; above the result of the temporal analysis of the raw data is reported for the two cases, below the reconstructed horizontal slice emittance.



The main difference between the results obtained scanning at F0 or F3 is the minimum value of the horizontal rms beam size. This aspect provides a tool to investigate a wide range of beam emittance values without loosing the measurement accuracy.





Conclusions

- We showed that the RF deflector is a powerful and versatile tool for advanced beam diagnostic of slice correlated beams.
- It is also critical tool for beam manipulation in the context of newly conceived SASE-FEL operating modes.