# XFEL Injector concept and expected performance

ESFRI XFEL Workshop

Oct. 30, 2003

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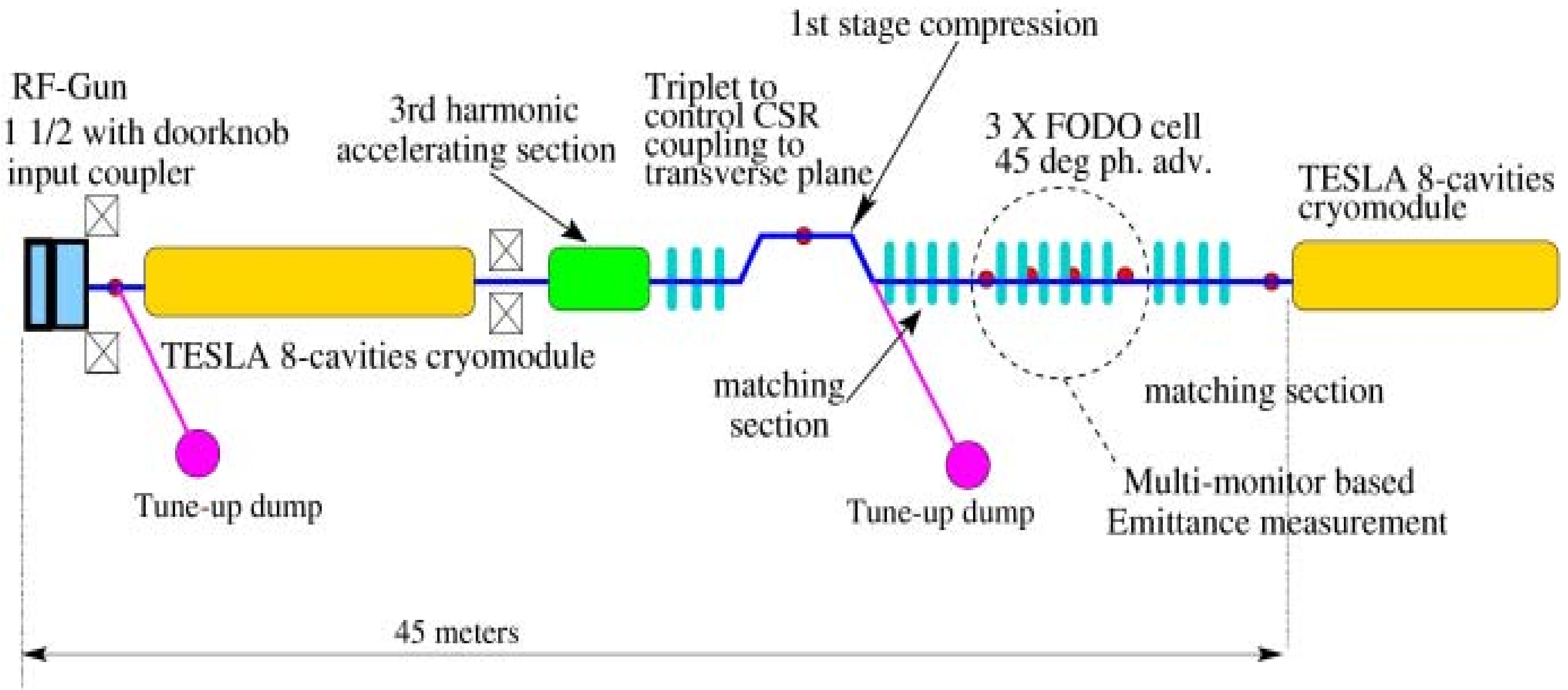
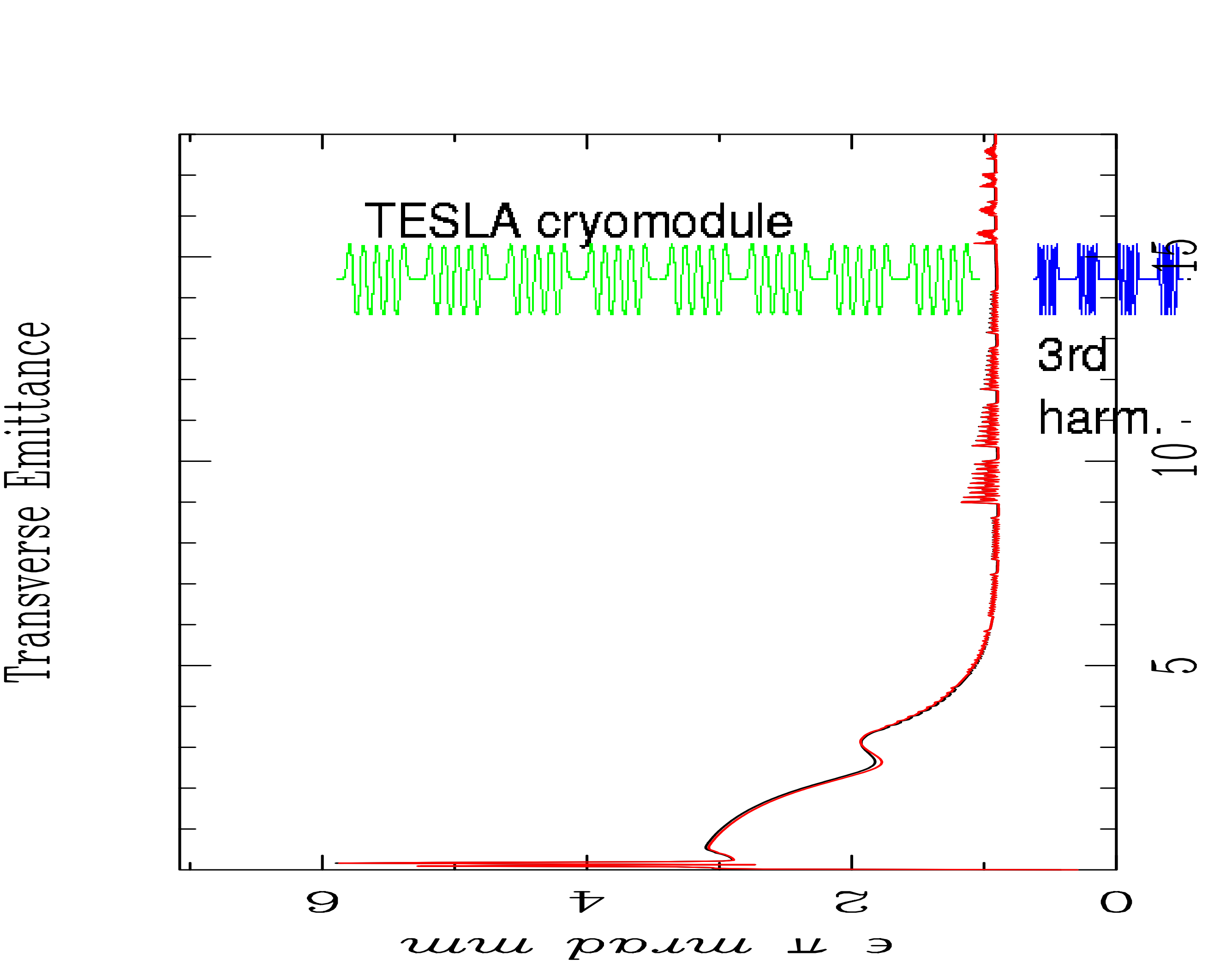
# Schematic overview of the TESLA XFEL Injector



# Development of the transverse Emittance




– **1nC charge**

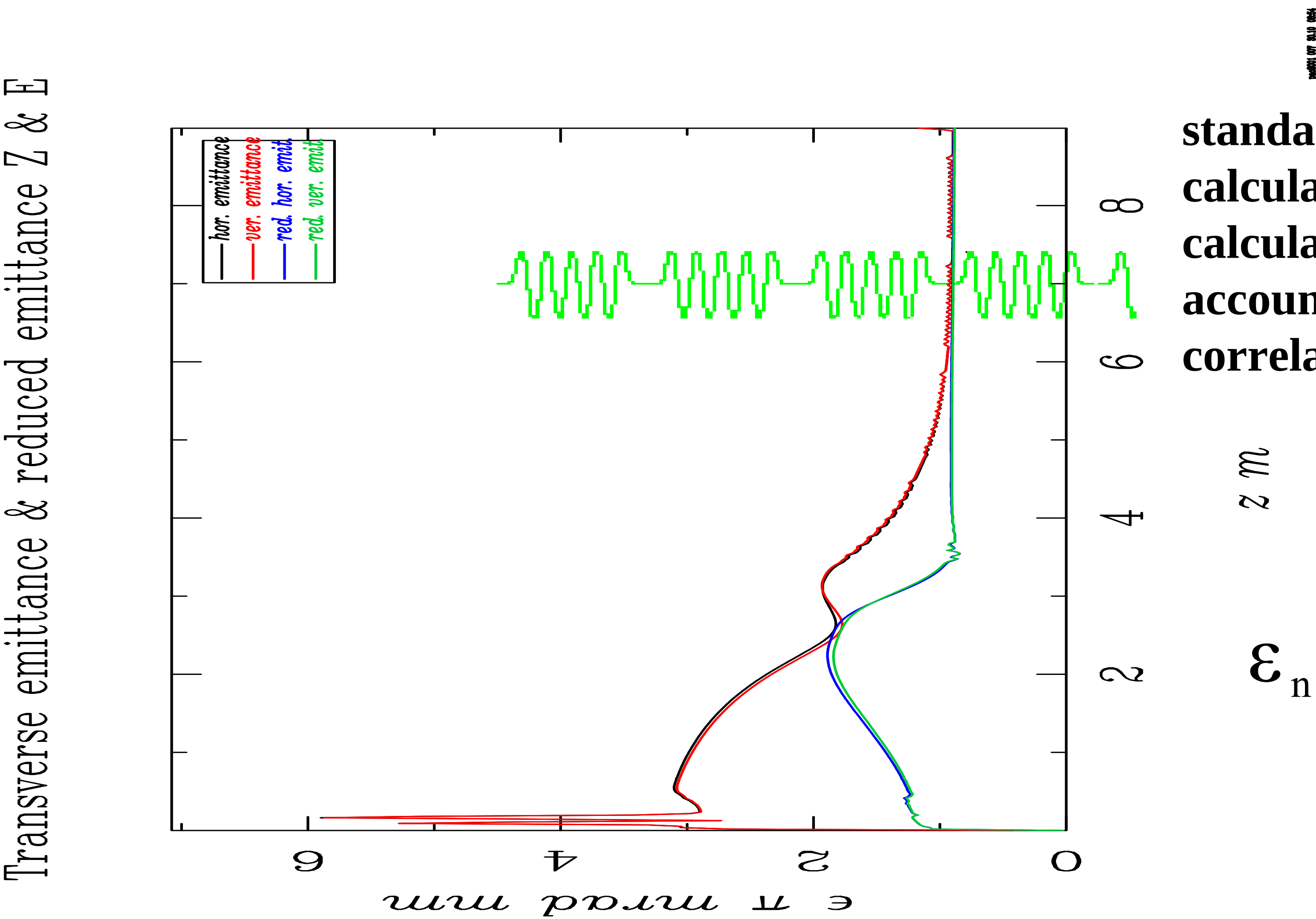
– **uniform transverse distribution**

– **longitudinal flat-top with 2 ps rise time**

– **incl. thermal emittance**

$$\varepsilon_n = 0.9\ \mu m$$

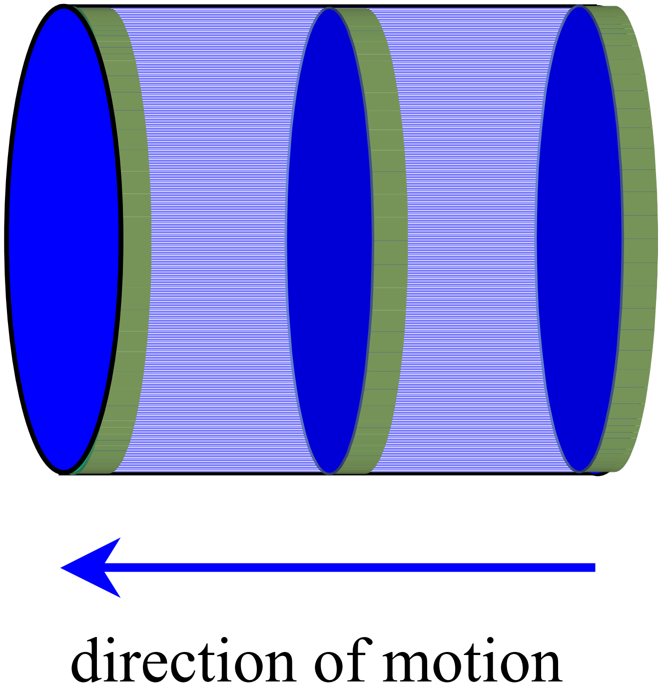
# Development of the transverse Emittance

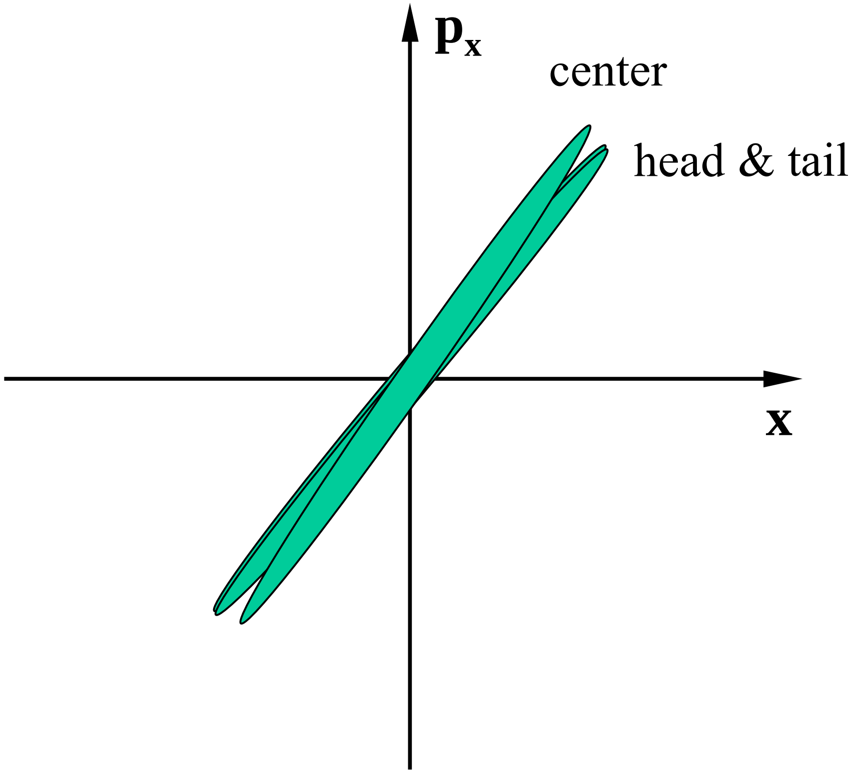



**standard emittance calculation and calculation taking into account x - $p_x$ - z correlations.**

$$\varepsilon_n = 0.9\ \mu m$$

# Correlated Emittance Contributions



# Slice Emittance Concept

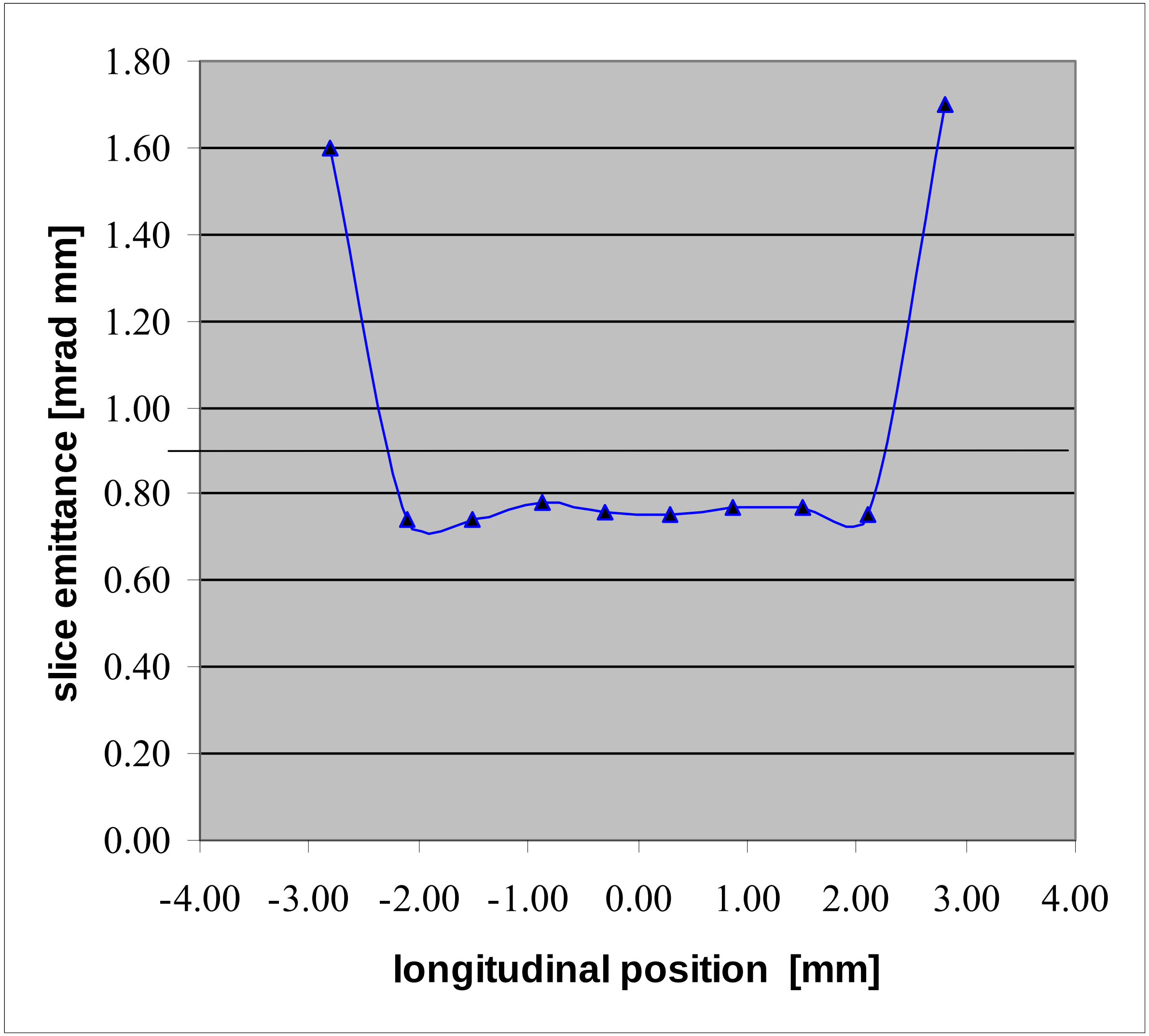
Electrons interact only over a short longitudinal distance - the cooperation length - with each other in the SASE process. For the performance of the FEL the transverse and longitudinal emittance within a longitudinal slice is relevant.

Correlated distortions in the phase space lead often to an increased projected emittance.

# Slice Emittance Concept

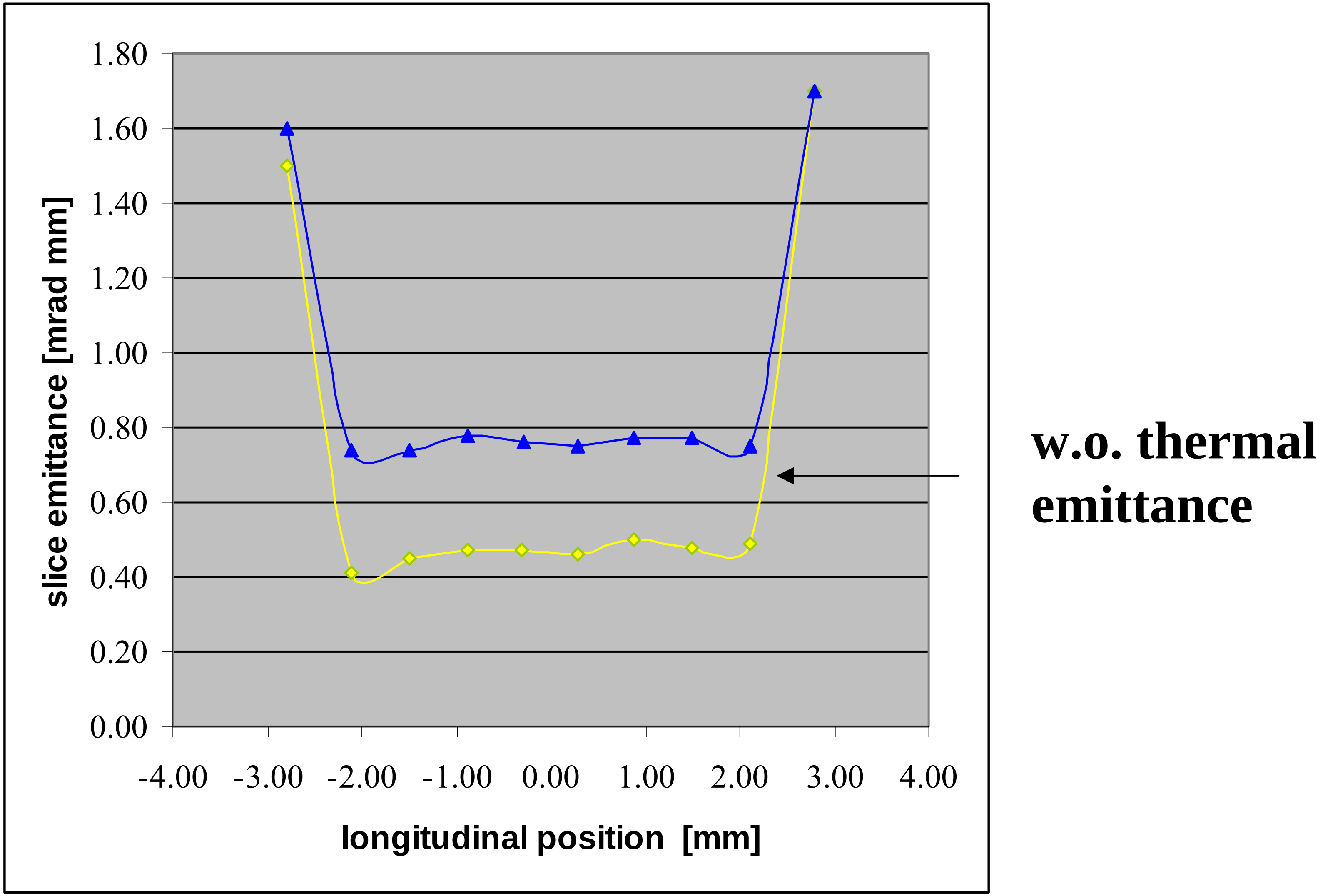
Therefore the emittance in short longitudinal slices has to be calculated and measured in addition to the projected emittance to understand the performance of an FEL.

# Slice Emittance at the Injector exit

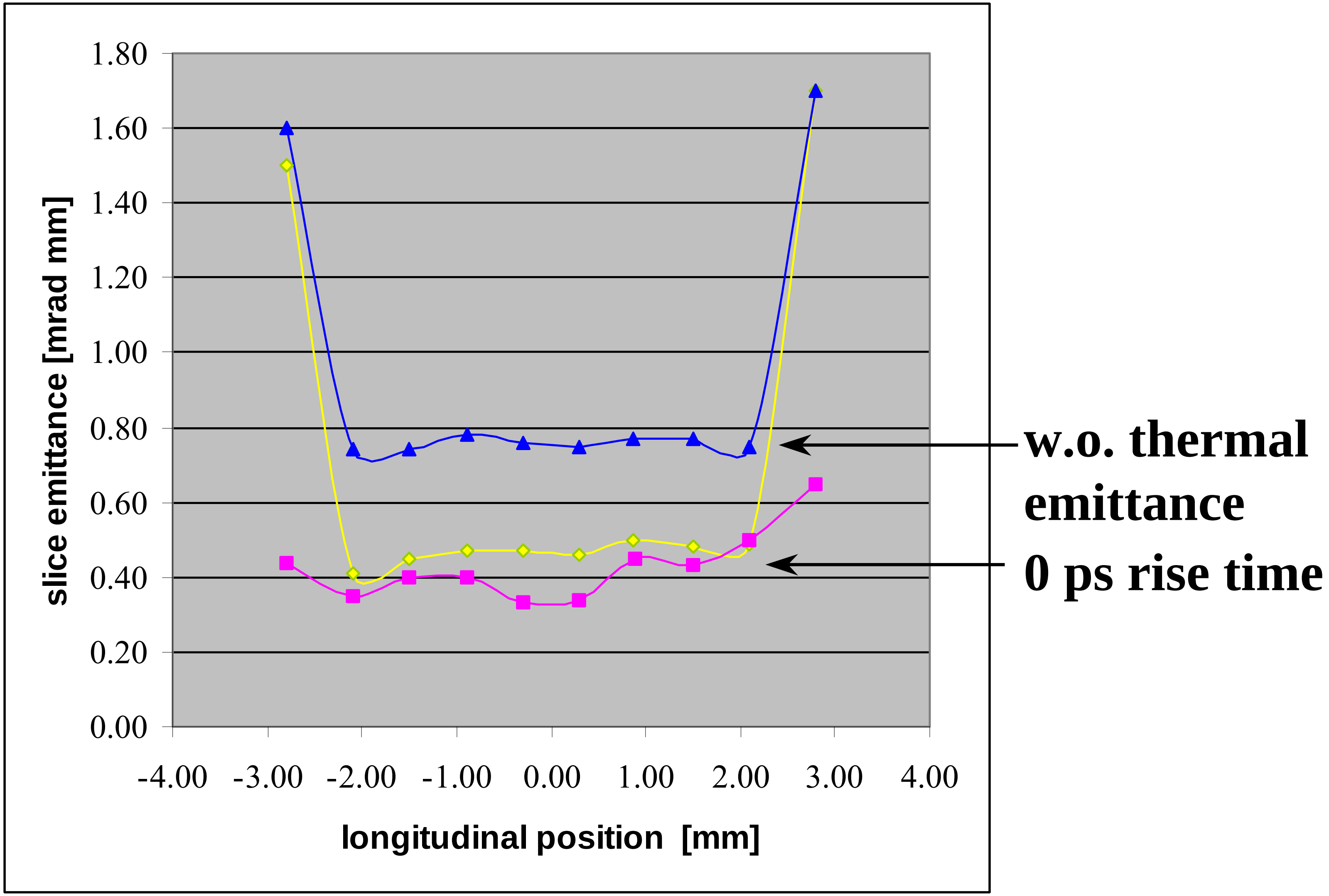



emittance in longitudinal slices of the bunch

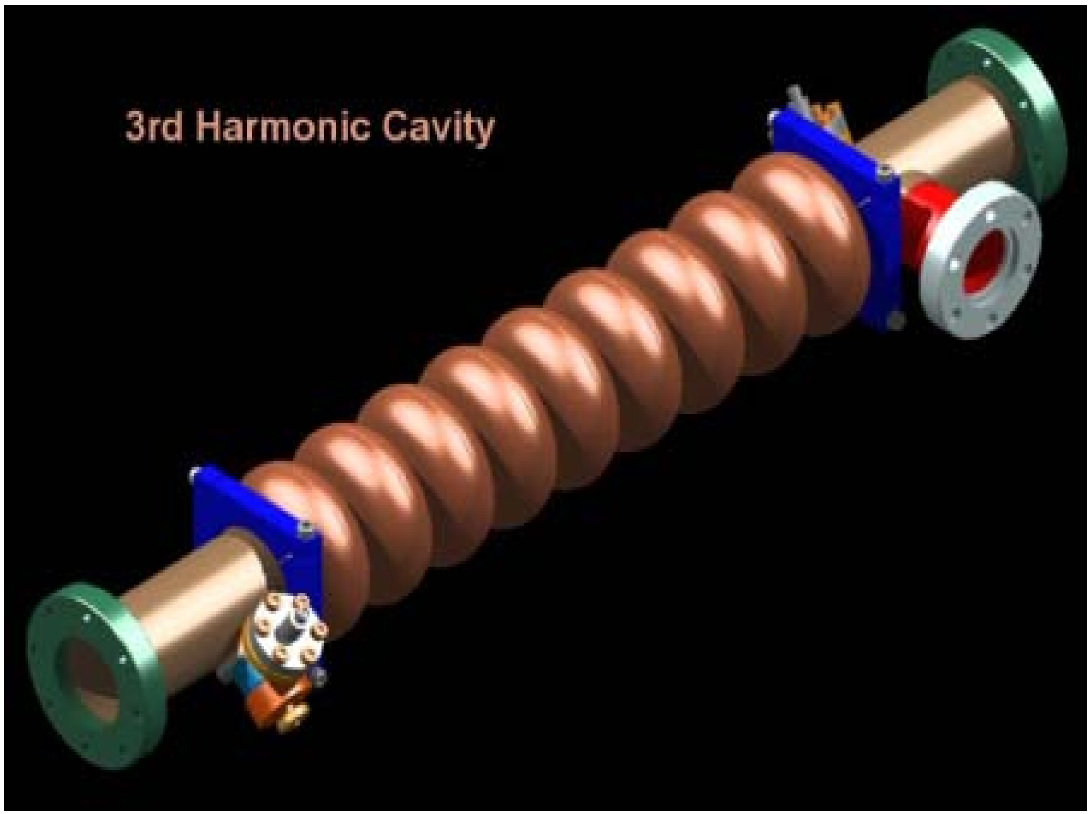
# Slice Emittance at the Injector exit



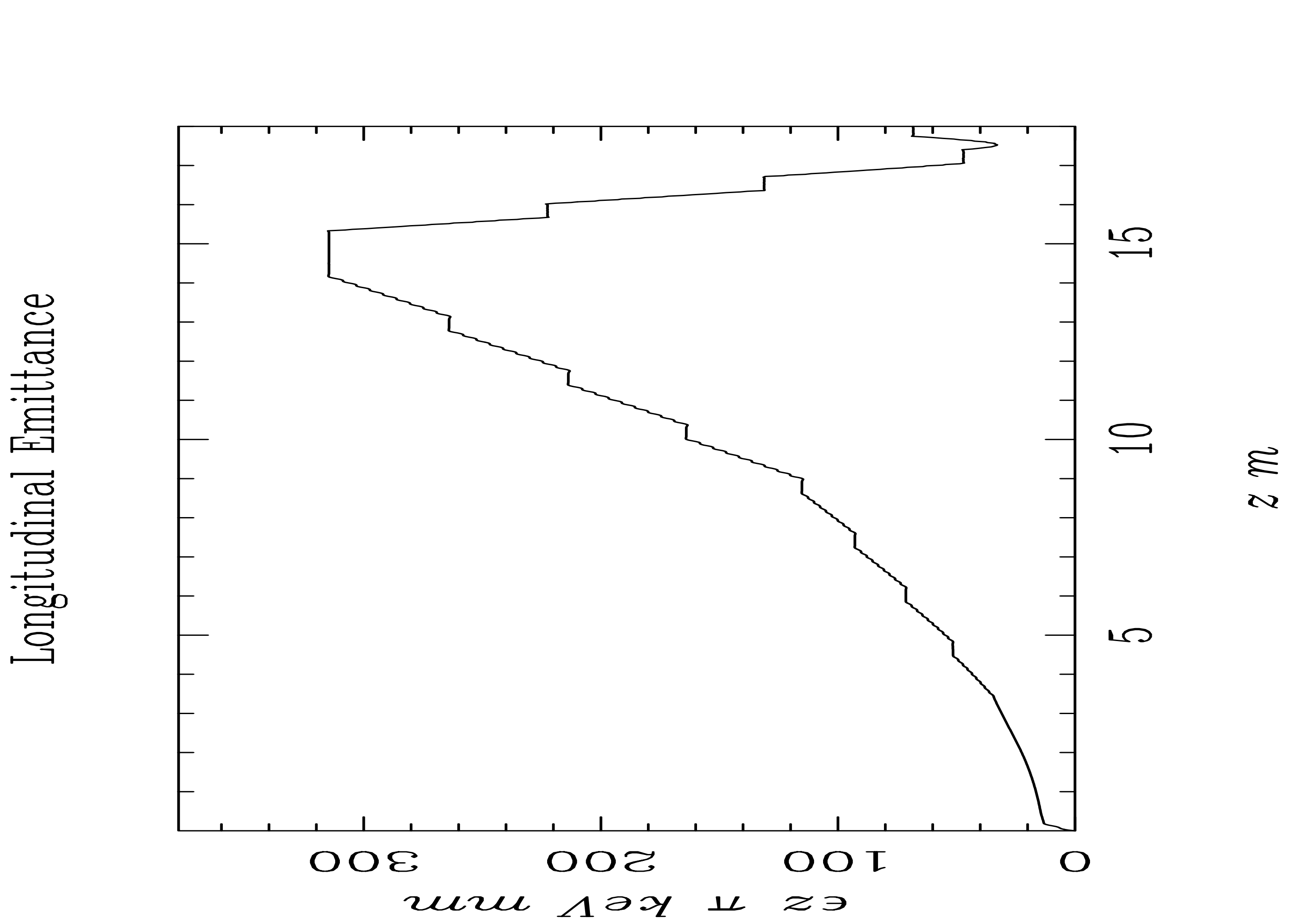
# Slice Emittance at the Injector exit



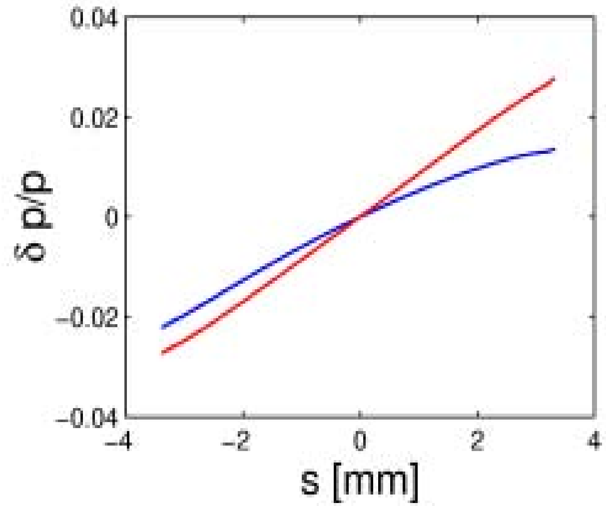
# The 3rd harmonic section

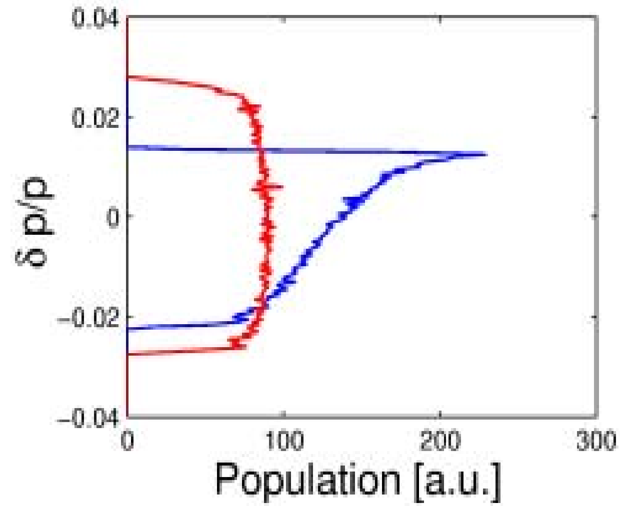



# Development of the longitudinal Emittance

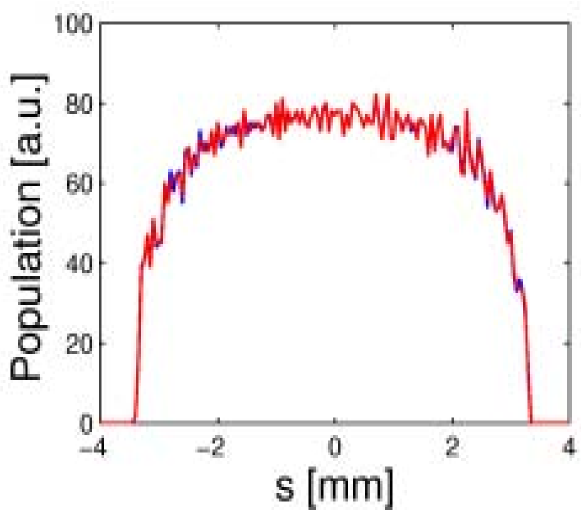


# The longitudinal phase space



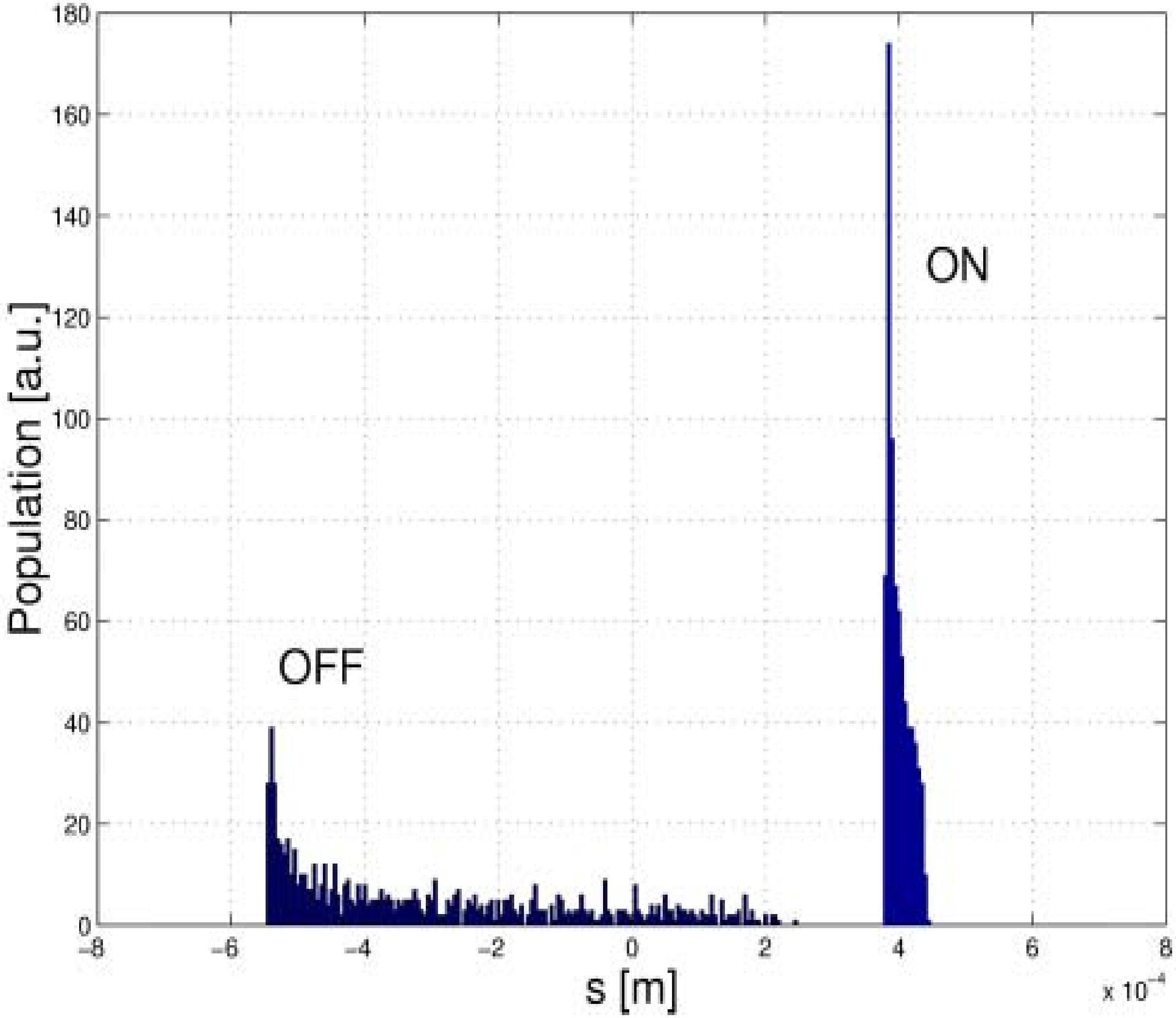

Longitudinal phase space in front of the bunch compressor with (red) and without (blue) the 3rd harmonic system. The remaining curvature of the phase space is matched to the second order compression factor of the bunch compressor.




**$E_{acc}$ = 20 MV**

**φ = 183.5 °**

# The longitudinal phase space




Longitudinal particle distribution behind bunch compressor with and without the 3rd harmonic system.

# Parameters of the injector

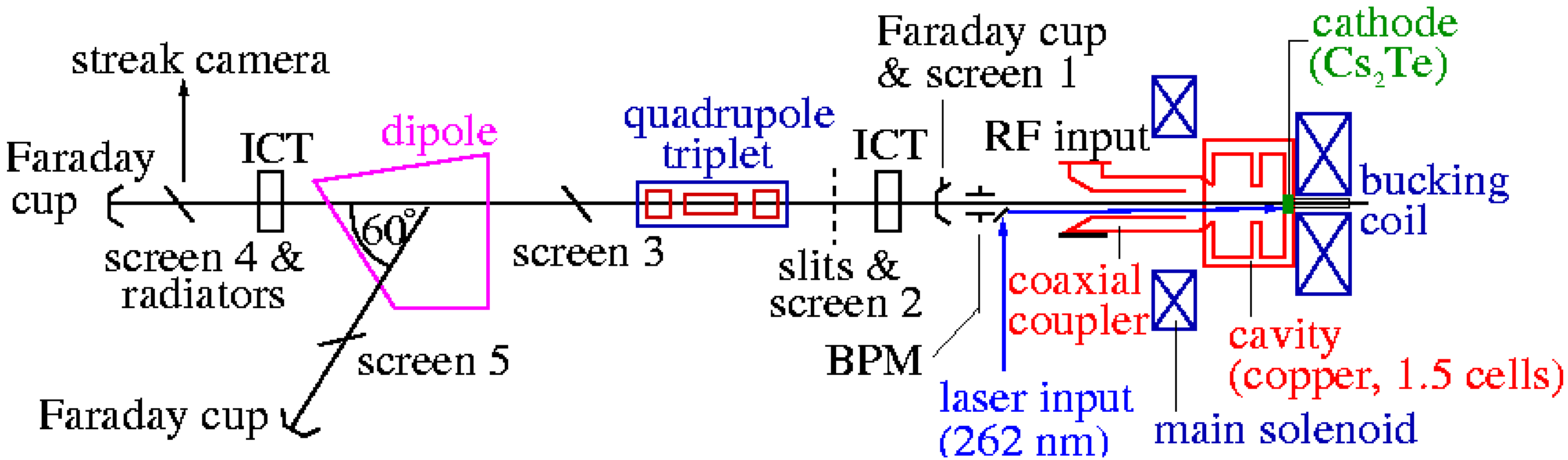
| | |
|---|---|
| charge | 1nC |
| $\varepsilon_{x,y}$ | 0.9 mrad mm |
| $\sigma_z$ | 270 µm (1 kA) |
| $\sigma_{E,\ uncorr}$ | 93 keV |

# Injector R&D in the TESLA Collaboration

- Cathode development at INFN Milano.
- Simulation code development at DESY and FNAL.
- 3$^{rd}$ harmonic cavities at FNAL.
- Experimental investigations at the A0 Photo injector at FNAL.
- Injector operation at TTF I and TTF II.
- Experimental investigations at the Photo injector Test stand in Zeuthen PITZ.

# The Photo Injector Test stand in Zeuthen PITZ

# The Photo Injector Test stand in Zeuthen PITZ

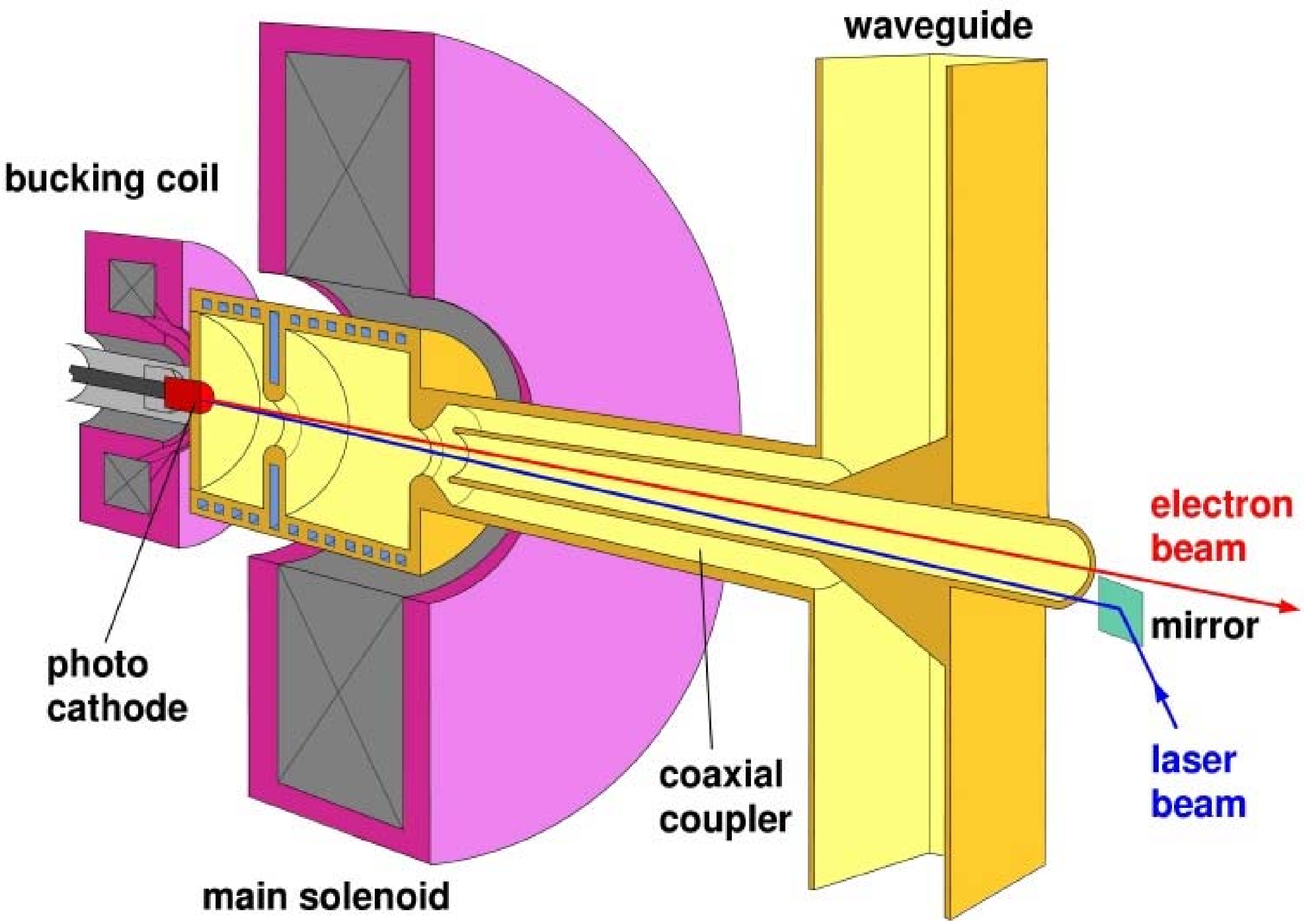



**Schematic layout of the PITZ Facility**

Goals of the Facility:

- Investigate beam dynamics in the gun area (without booster cavity).
- Reach design parameters for TTF II operation.

# RF Gun for the TESLA XFEL



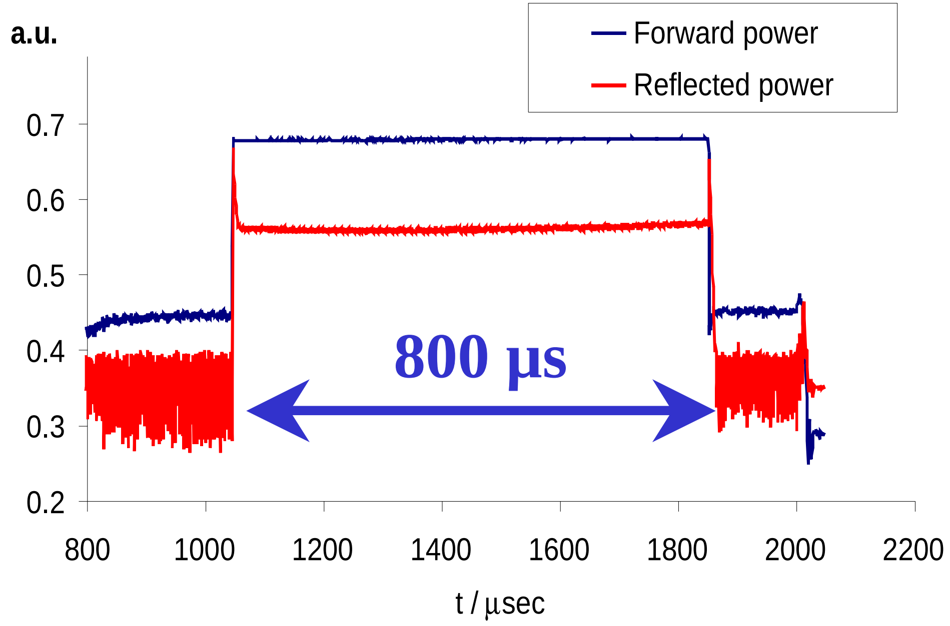
# PITZ Results: high duty cycle operation

**40 MV/m at the cathode** (~ 3 MW),

**10 Hz**, **800 µs**

**duty cylcle: 0.9 %,**

**average rf power: 27 kW**



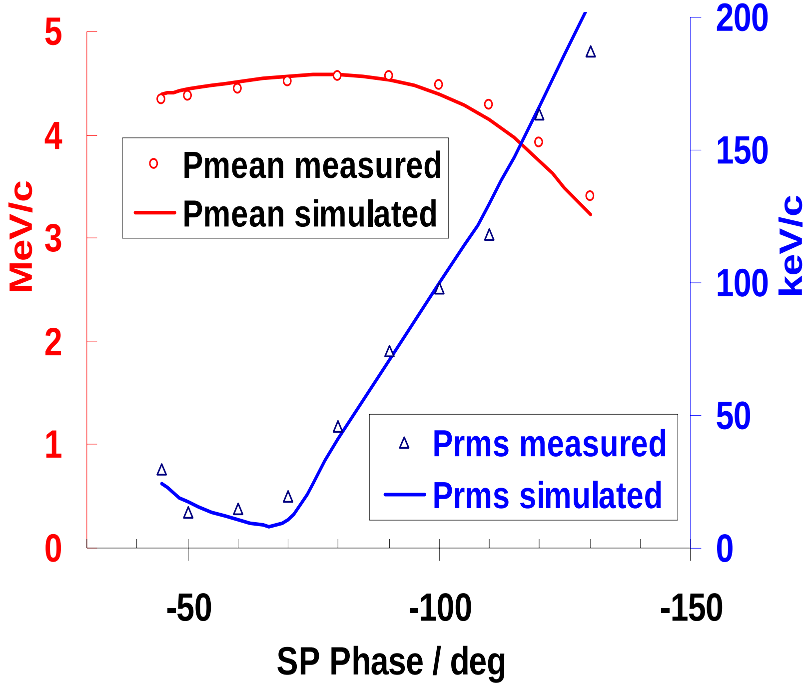

**no rf trips !!**

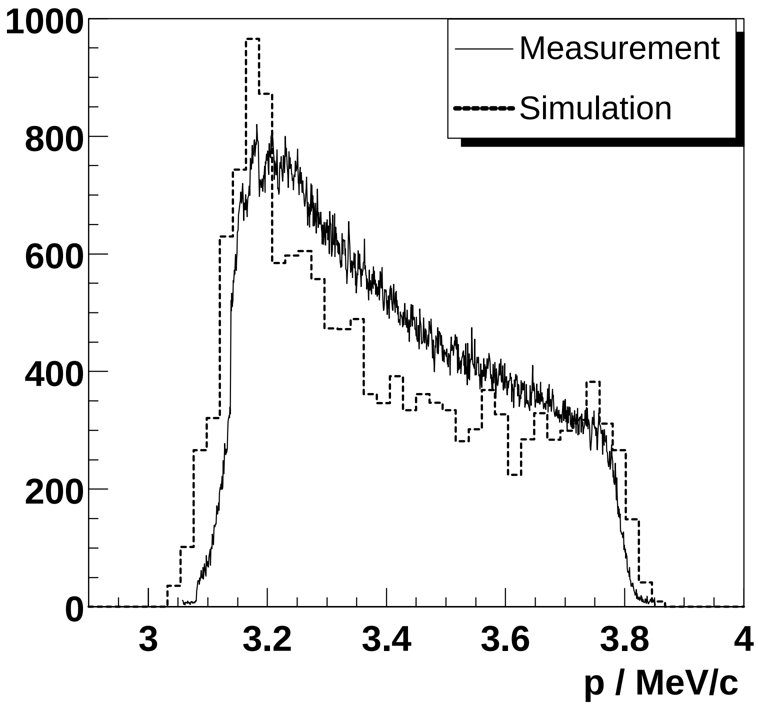
**(results limited by conditioning time)**

# PITZ Results: beam dynamics

Energy and Energy spread measurements

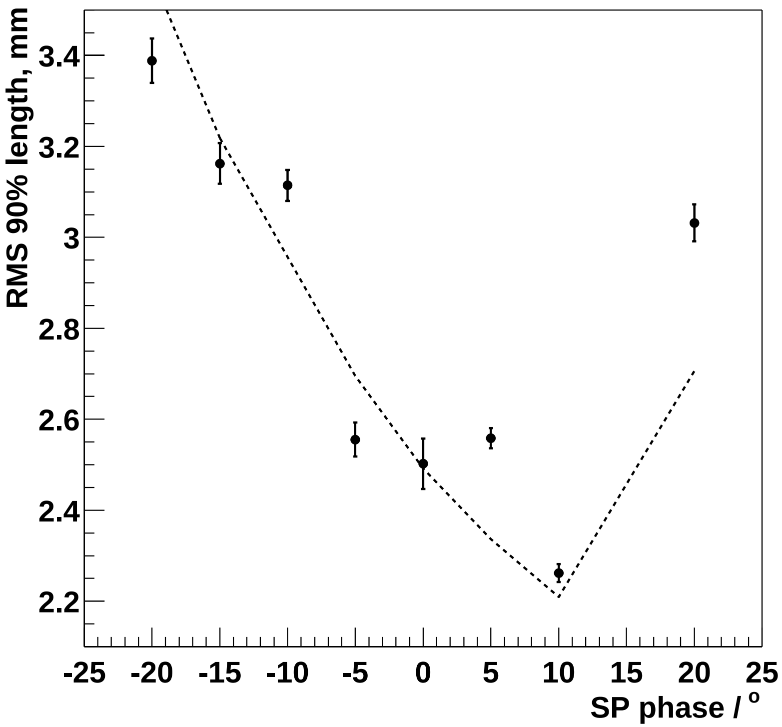
(0.5-1nC)

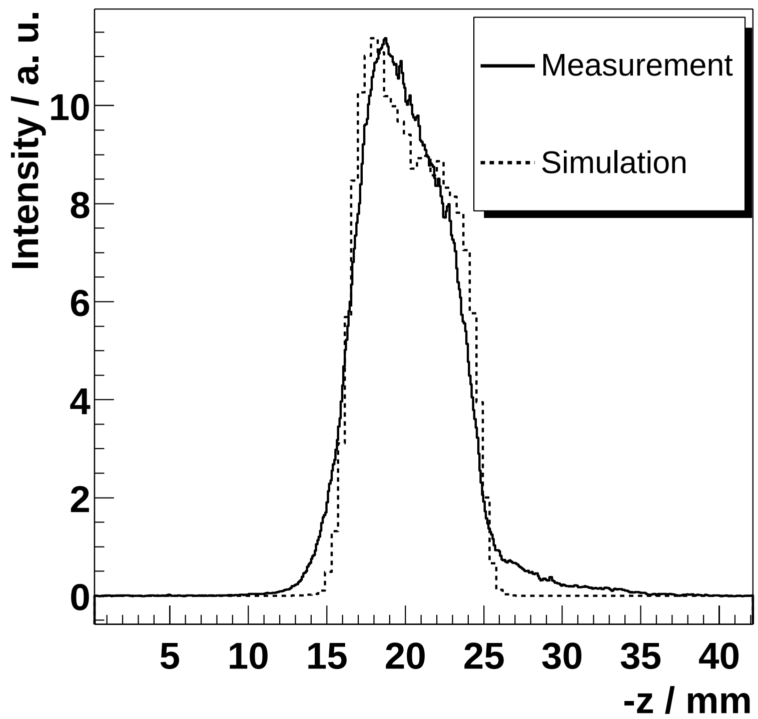


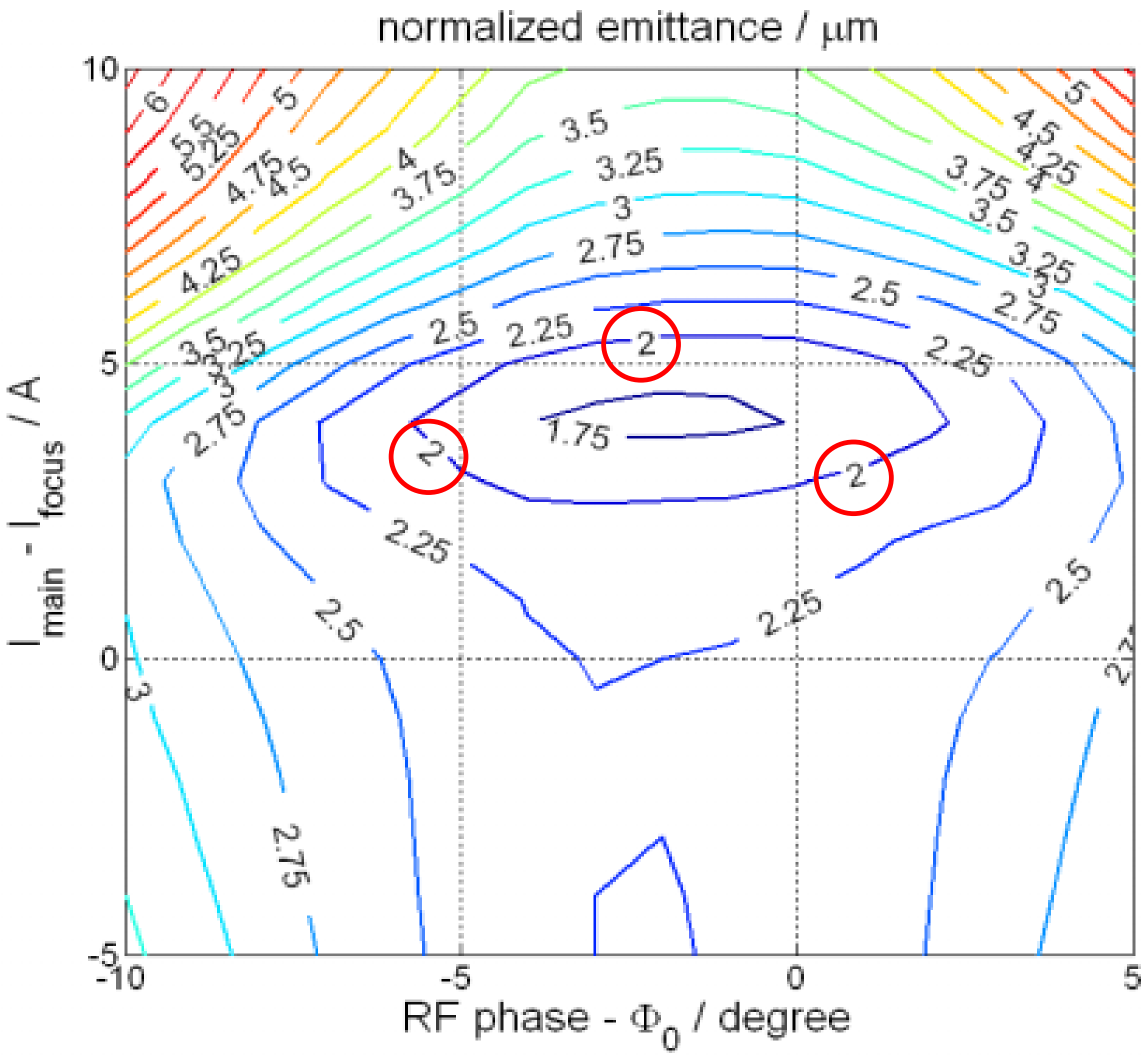
# PITZ Results: beam dynamics

Example of bunch length measurements



# Simulation Results on transverse Emittance

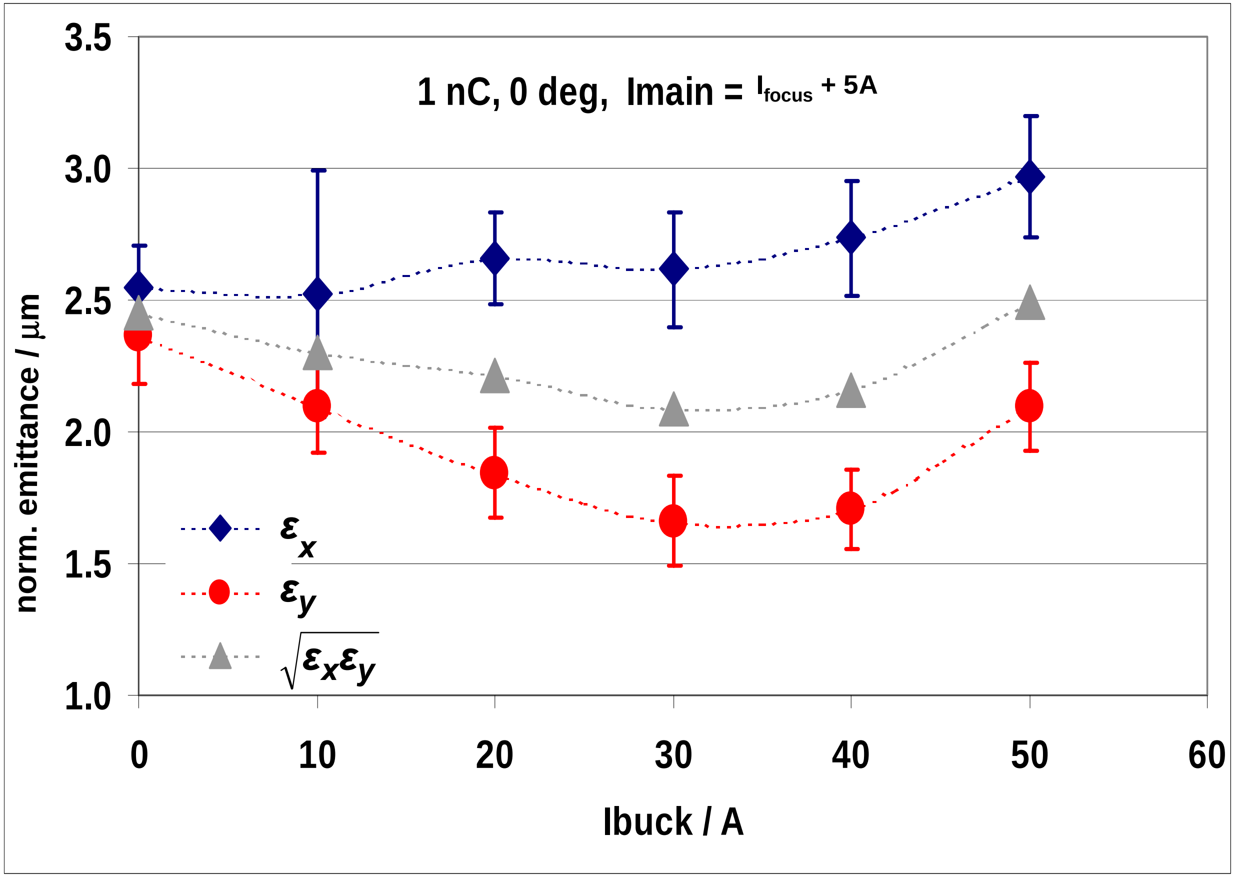



Expected lowest transverse emittance for the present parameters of gradient and laser at PITZ:

$\varepsilon_n \leq 2.0\ \mu m$

# PITZ Results: transverse emittance

Best measured transverse Emittance



# From TTF II to the XFEL

TTF II parameters have been achieved at PITZ.

In order to reach the XFEL parameters we have to:

- increase the gradient on the cathode from 40 MV/m to 60 MV/m – this is scheduled for the first half of next year.
- improve the transverse and longitudinal laser profile further – ongoing.
- install a booster cavity at PITZ for improved emittance compensation and measurements – upgrade to PITZ II.

# Schematic Layout of PITZ II