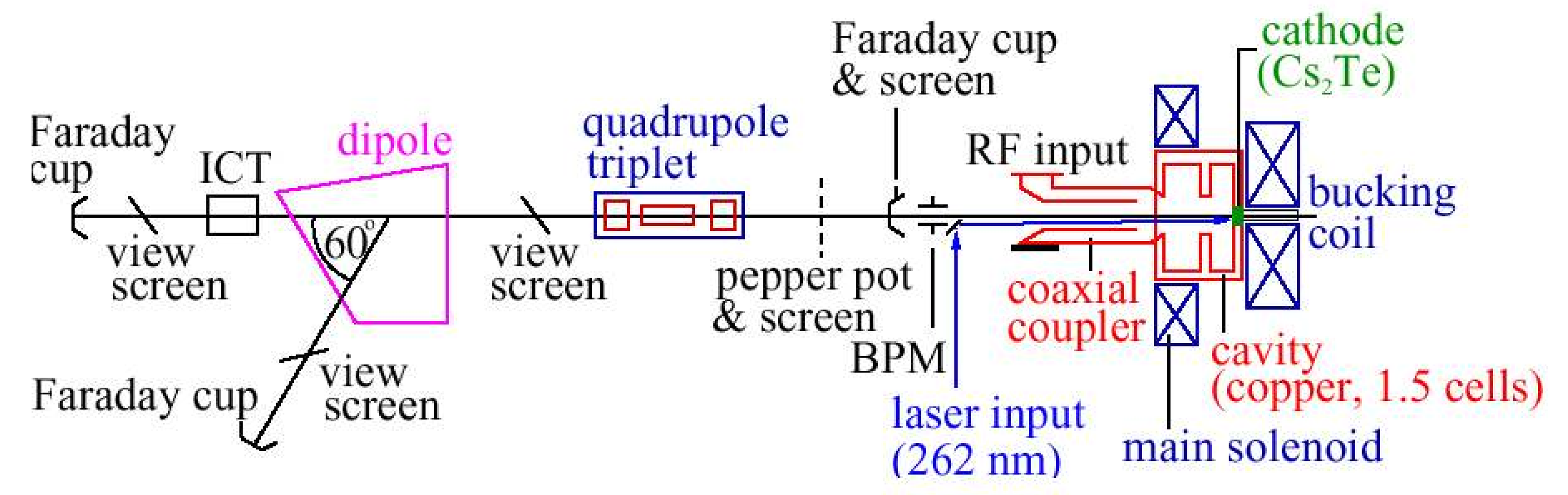
Transverse emittance measurements at the Photo Injector Test Facility at DESY Zeuthen, PITZ

V. Miltchev*, K. Abrahamyan[$], J. Bähr*, I. Bohnet*, K. Flöttmann[#],
M. Krassilnikov*, D.Lipka*, A. Oppelt*, F. Stephan*, Iv. Tsakov[&]
* DESY Zeuthen, Zeuthen, Germany
# DESY Hamburg, Hamburg, Germany
& INRNE Sofia, Bulgaria
$ YERPHI Yerevan, Armenia

Schematic of PITZ



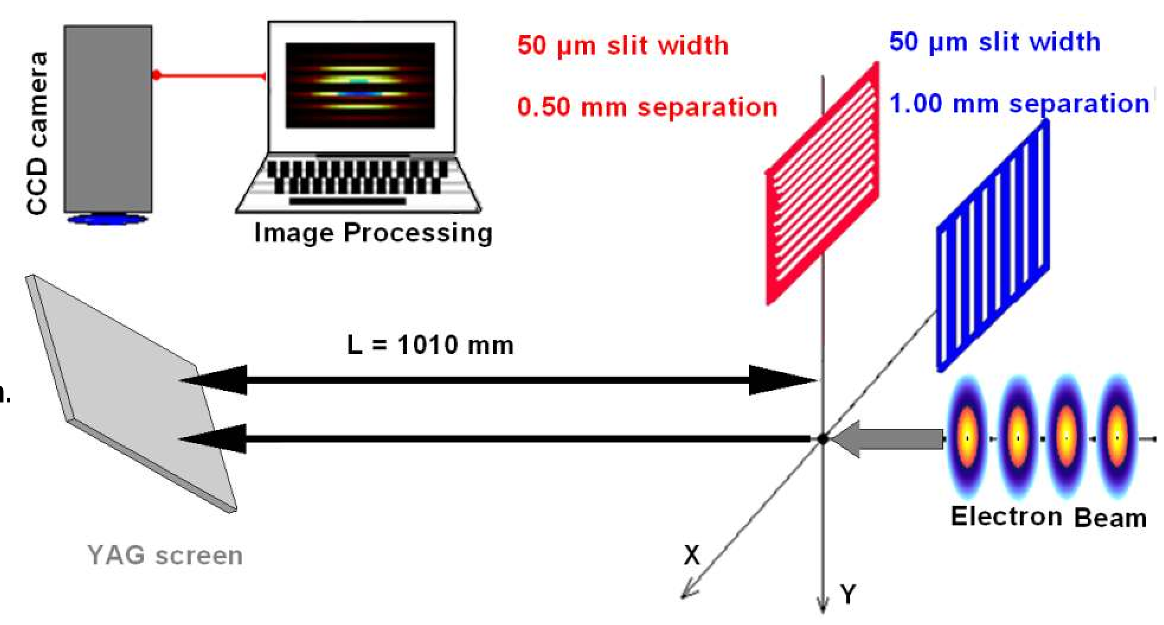
Overview of the emittance measurement system at PITZ

For measuring the transverse emittance the slit/pepper pot technique is employed. The RMS size of the electron beam is measured directly at the position of the slit masks. The uncorrelated divergence is evaluated after analysis of the beamlet profiles observed on a YAG screen downstream.

$\sqrt{\langle x^2 \rangle}$ - the measured RMS beam size .

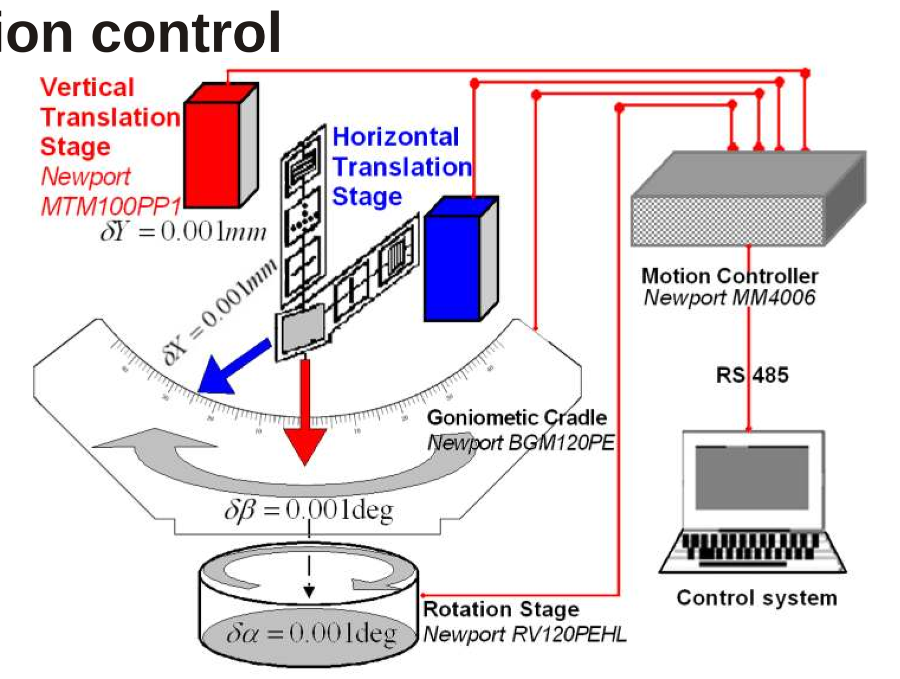
$\sqrt{\langle \sigma'^2 \rangle}$ - the uncorrelated divergence

$$\varepsilon_{n_{rms}} = \beta\gamma \sqrt{\langle x^2 \rangle} \sqrt{\langle \sigma'^2 \rangle}$$



Motion and motion control

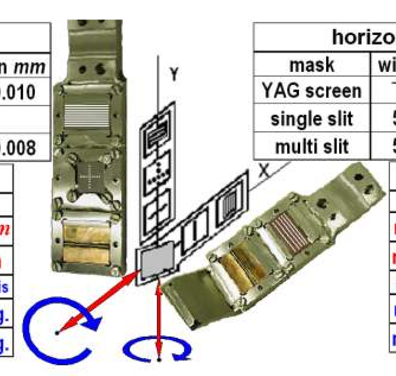
The motion controller put into operation at PITZ is of type Newport MM4006. An operation from remote is possible due to an RS485 interface. The controller handles all four axes of motion. The rectilinear motions along vertical and horizontal axes are performed by translation stages . The rotation of the entire emittance measurement system around the central vertical axis is performed by a rotation stage.The rotation around the horizontal axis is performed by a goniometic cradle.



Masks and actuators

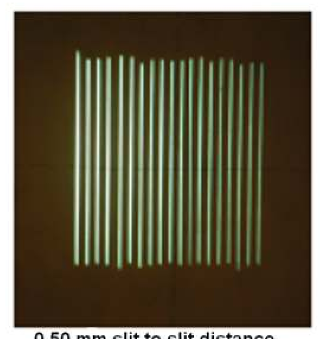
vertical actuator		
mask	width µm	separation mm
pep. pot	50 ± 4	0.800 ±0.010
single slit	50 ± 4	—
multi slit	50 ± 8	0.500 ±0.008

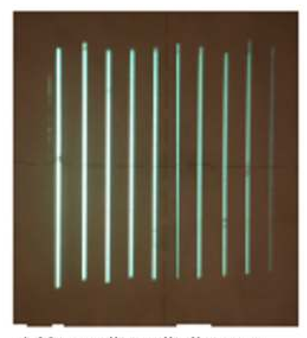
vertical motion	
translation	
min. step size	1.0 µm
motion range	91.0 mm
rotation around horizontal axis	
min. step size	0.001 deg.
motion range	2.997 deg.



horizontal actuator		
mask	width µm	separation mm
YAG screen	—	—
single slit	50 ± 4	—
multi slit	50 ± 4	1.000 ±0.00 4

horizontal motion	
translation	
min. step size	1.0 µm
motion range	91.0 mm
rotation around vertical axis	
min. step size	0.001 deg.
motion range	4.011 deg.

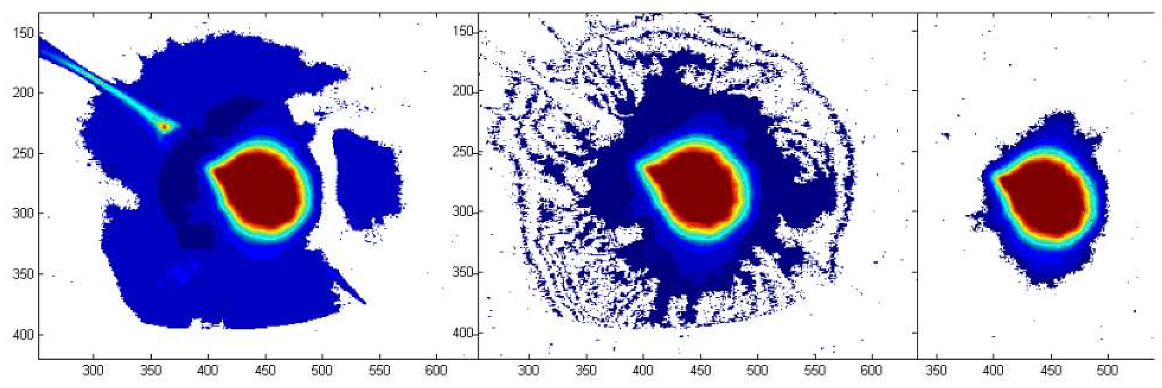

0.50 mm slit to slit distance


1.00 mm slit to slit distance

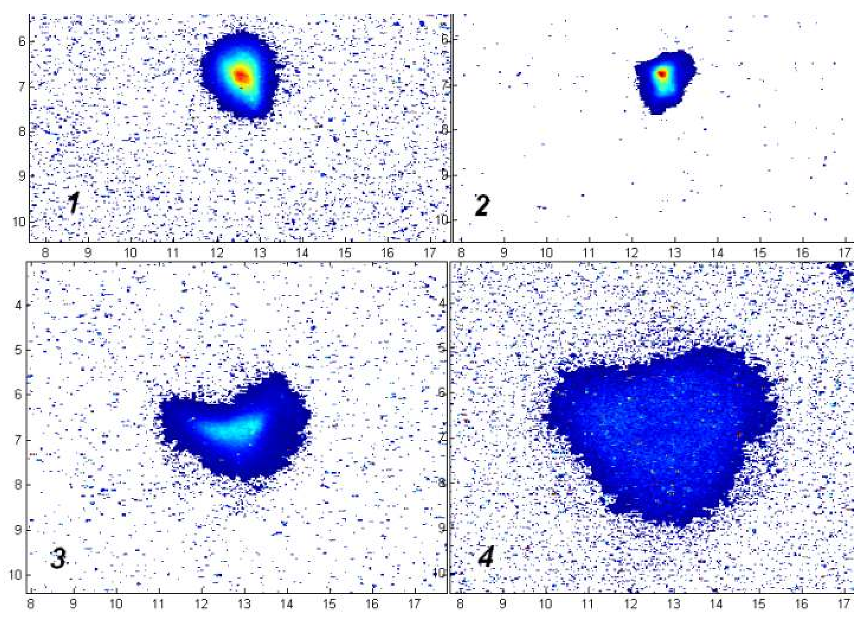
The following requirements are taken into account for the fabrication of the slit masks:
-The beamlets produced by a slit mask must be emittance dominated
-The contribution of the initial beamlet size to the beamlet size at the observation screen should be as small as possible
-The distance between the slits is a compromise between obtaining a good representation of the phase space and avoiding overlapping of the beamlets
-The thickness of the mask is a compromise between the need to scatter electrons in an uniform background and the desire to avoid the 'edge scattering'. Finally 1mm thick tungsten was chosen

Measurements of beam size and transverse emittance

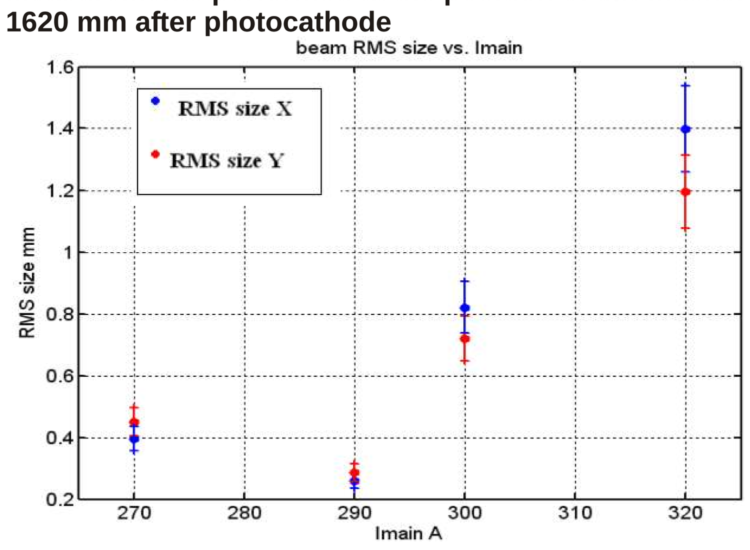
- Beam size measurements



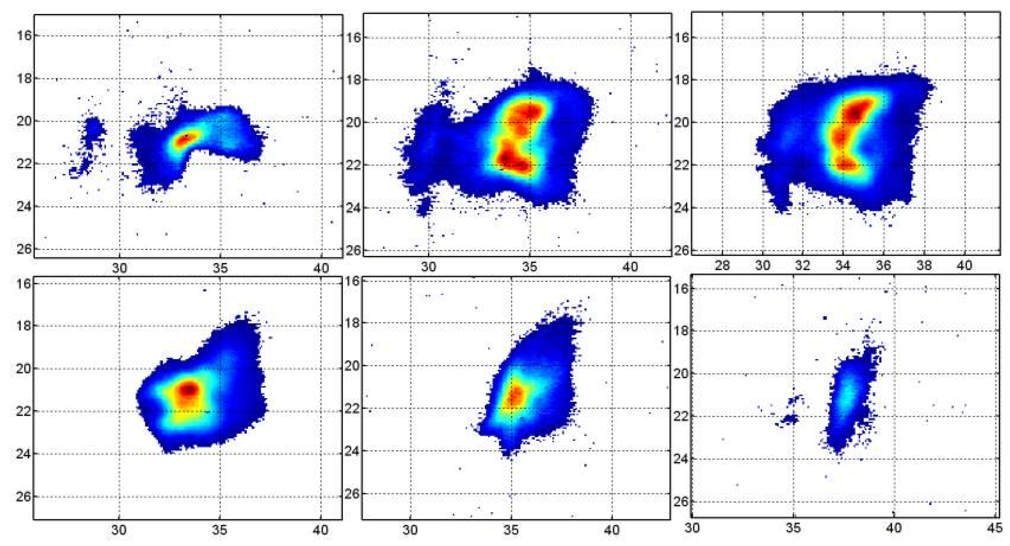
1)Without background subtraction
2)With an average background subtracted
size Xrms = 1.80 mm
size Yrms = 1.80 mm
3)With an envelope background subtracted
size Xrms = 1.50 mm size Yrms = 1.50 mm.
Finally: Sx = Sy =1.65+/- 0.15 mm

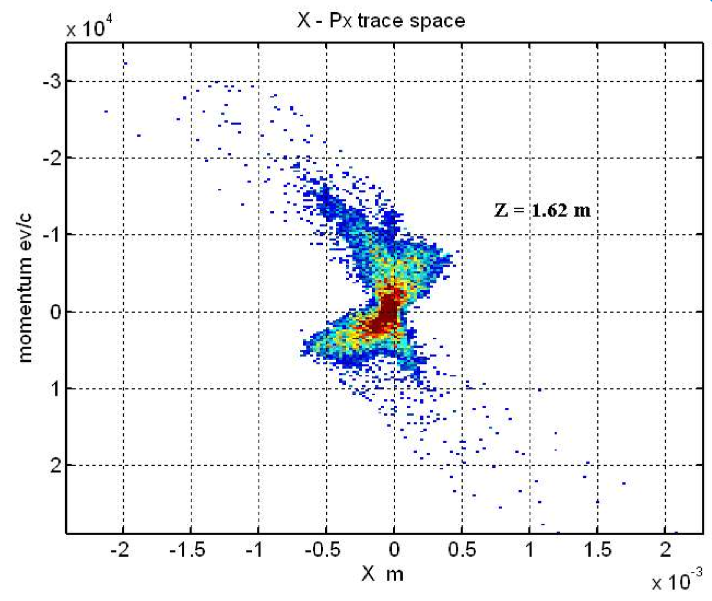


Change of the beam size with the change of solenoid current:
1)*Imain*=270 A; 2) *Imain*=290 A; 3)*Imain*=300 A; 4) *Imain*=320 A
Measurements performed at the position of slit-masks:
1620 mm after photocathode



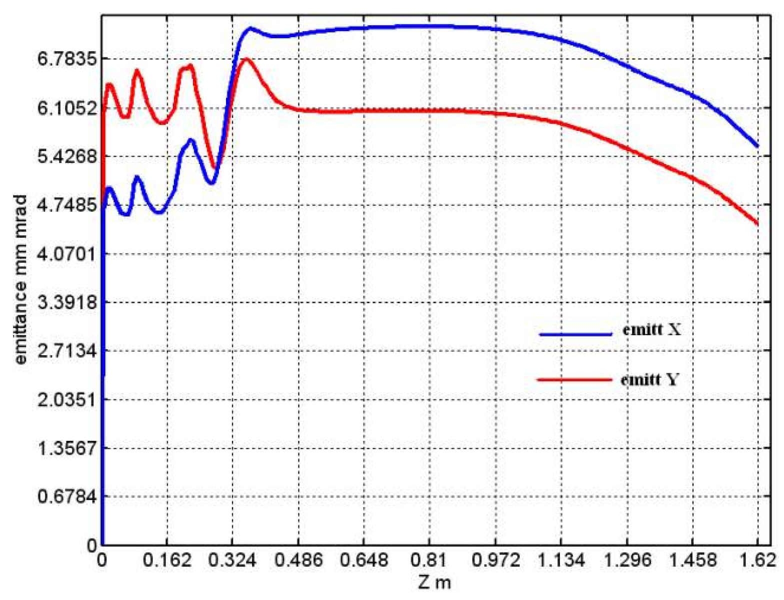
- Measurements using single - slit

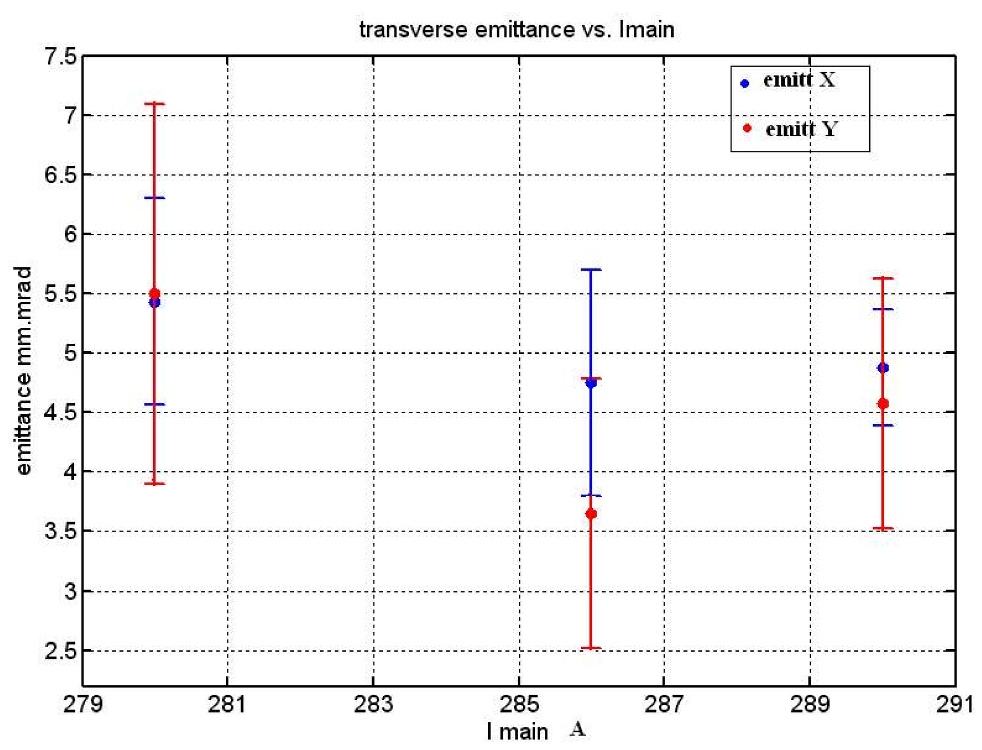




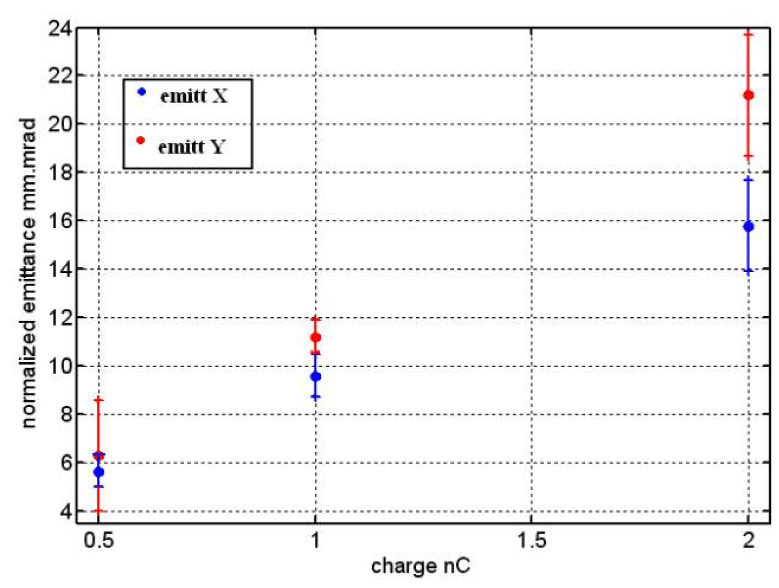
ASTRA simulation of the X-P*x* phase space and emittance at the same conditions

Scanning with a single slit through the horizontal cross section of the beam. The scanning step is 0.300 mm. The bunch charge: 0.66 nC. The mean momentum was measured to be 4.57 Mev/c. The current in the main solenoid: *Imain*=290 A. The X-RMS size of the beam at the position of slit (1.62 m after photocathode) was measured directly as 0.38 +/- 0.01 mm. The measured normalized X-RMS emittance is equal to 5.3 +/- 0.7 mm.mrad. Analog an Y-RMS emittance of 4.7 +/- 0.5 mm.mrad is obtained





Transverse emittance as a function of the current of the main solenoid. The measurement were done at the following conditions:
Gun gradient = 40.0 MV/m
Bunch charge = 0.66 nC
Mean momentum = 4.58 MeV/c

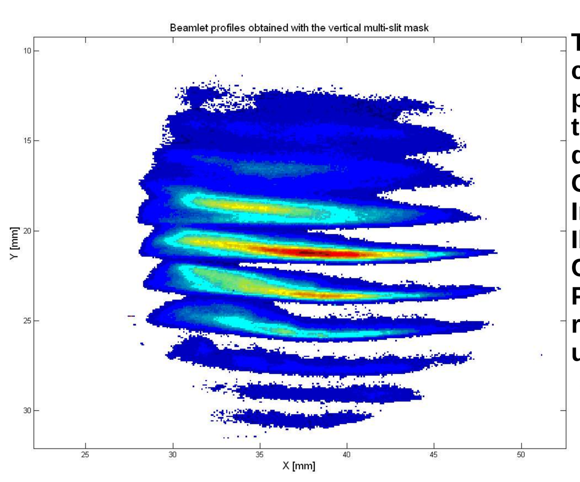


Measurement of the transverse emittance as a function of the bunch charge. For this measrement the single slit masks were used.
At each charge the focusing current was adjusted so that the electron beam has a waist at the position of the slits. Respectively the values of the focussing current are as follows: 1) *Imain* (0.5 nC) = 292 A
2) *Imain* (1.0 nC) = 290 A 3) *Imain* (2.0 nC) = 289 A

CONCLUSIONS AND OUTLOOK

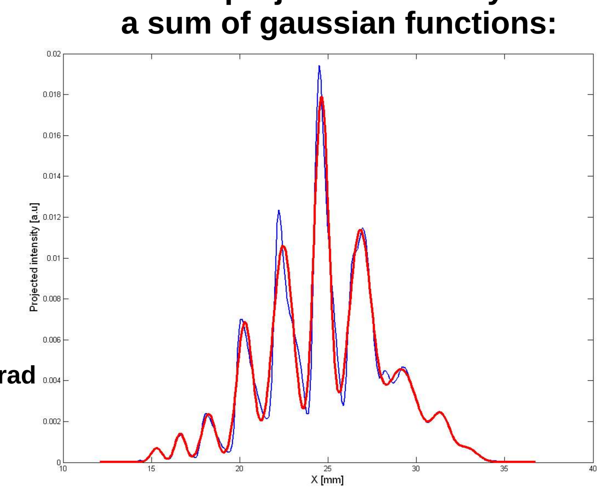
The emittance measurement system at PITZ is fully commissioned. Measurements of the transverse beam emittance were done in a wide range of machine parameters. The transverse emittance numbers presented are not the optimum values that are possible with the RF gun at PITZ. The main reason for this is that the current laser system produces very short pulses of 7 ps FWHM, which lead to strong space charge forces at the cathode. The short laser pulse profile is done in preparation of installing a flat top longitudinal laser profile in 2 months. Also the current longitudinal position of the main solenoid is optimised for the future flat top laser shape. All this means that better experimental results are expected in near future

- Multi-slit masks measurements



The emittance measurement corresponding to the beamlet profiles in the left was done at the following conditions:
date: 28.04.2003
Gun gradient = 40.5 Mv/m
Imain [A] = 300 A
Ibuck [A] = 0 A
Charge =0.49 nC
Pmean = 4.56 MeV/c
rms size at slits = 1.05 mm
uncorrel. divergence Y = 0.60 mrad
$\varepsilon_{y rms} = 5.75 \pm 0.6$ mm mrad

Fit the projected intensity to a sum of gaussian functions:



- Transverse phase space reconstruction