Micron size laser wire station at the KEK Accelerator Test Facility extraction line

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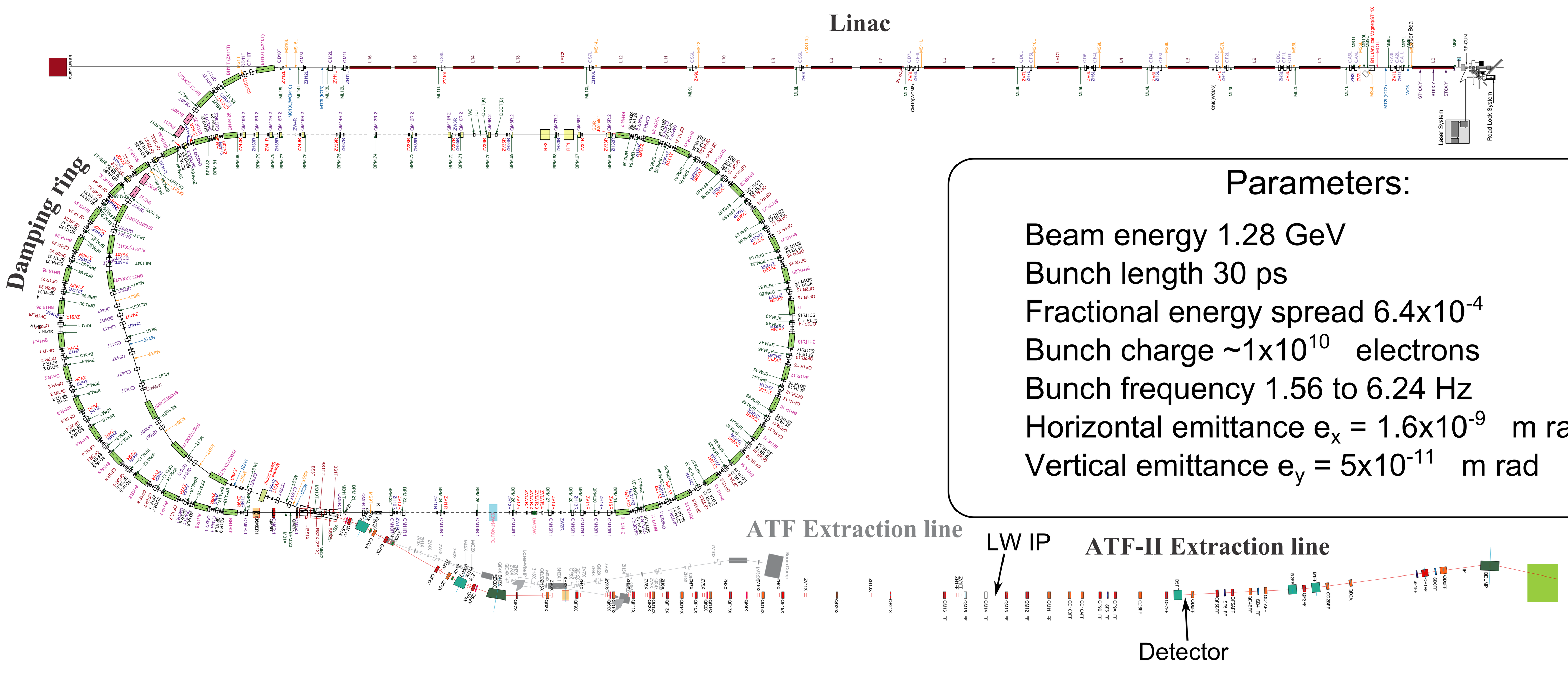


Parameters:

Beam energy 1.28 GeV
Bunch length 30 ps
Fractional energy spread 6.4×10^{-4}
Bunch charge $\sim1\times10^{10}$ electrons
Bunch frequency 1.56 to 6.24 Hz
Horizontal emittance $e_x = 1.6\times10^{-9}$ m rad
Vertical emittance $e_y = 5\times10^{-11}$ m rad

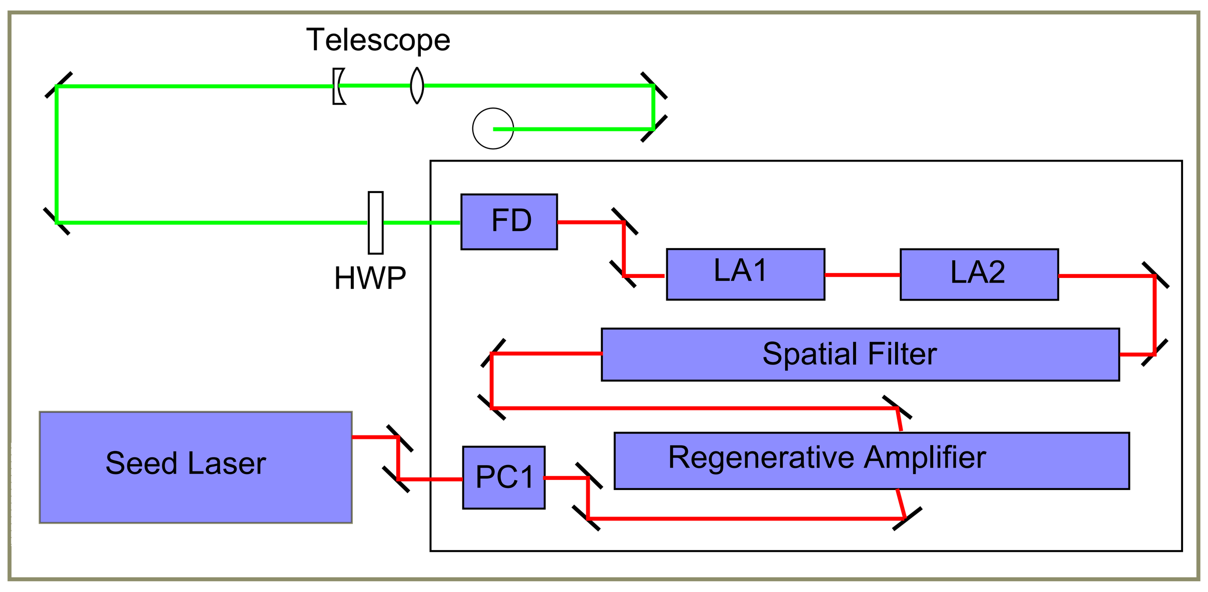
Abstract

Transverse electron beam diagnostics is crucial for stable and reliable operation of the future electron-positron linear colliders such as CLIC or Higgs Factory. A sub-micrometer resolution beam profile monitors are required to measure high-energy particle emittance. The-state-of-the-art in transverse beam diagnostics is based on the laser-wire technology, i.e. when a high power laser is focused in the interaction region down to a micrometer dimension and is scanned across the electron (positron) beam generating intense inverse Compton scattered photon beam. Another way is the beam profile monitor based on Optical Transition Radiation (OTR) The resolution of conventional OTR monitor is defined by a root-mean-square of the so-called Point Spread Function (PSF)-dimension - the source distribution generated by a single electron and projected by an optical system onto a screen.
In this report we present the results from laser wire and OTR system at the Accelerator Test Facility 2 during recent operation. The recent experimental results are presented.

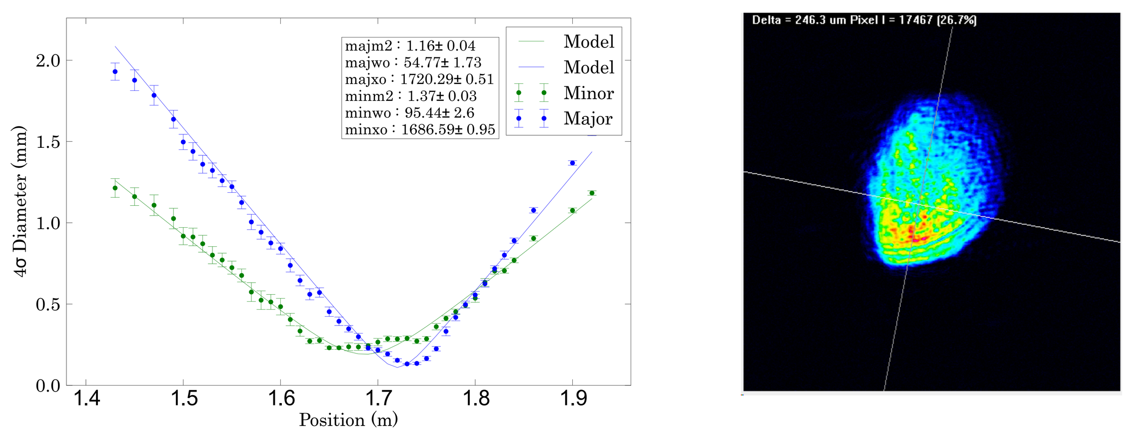
Laser Wire Beam Profile Monitor

Laser System

A seeded, Q-switched neodymium-doped yttrium aluminum garnet ($Nd{:}Y_3Al_5O_{12}$) laser with output energy ~ 150 mJ, wavelength of 532 nm and pulse length of 77 ps was used.



Schematic of the laser system used. PC1 is the first EOM that modulates the beam, LA1,2 are the linear amplifiers and FD is the frequency doubling crystal. The red line represents the path of the laser beam before FD and the green line represents the frequency doubled light afterwards. HWP is a half-wave plate.



Measured laser propagation in both axes (left) and typical intensity profile (right) of the ATF2 laser system

Interaction Point & Detector

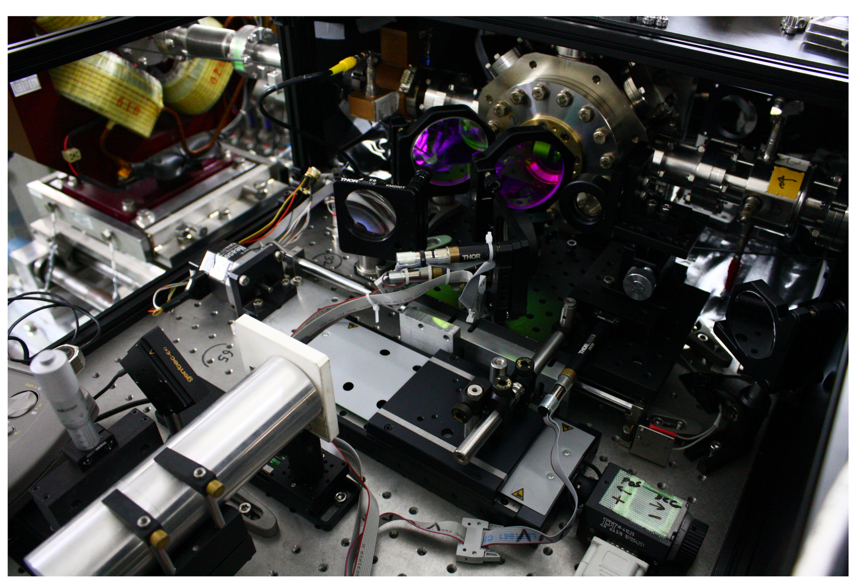
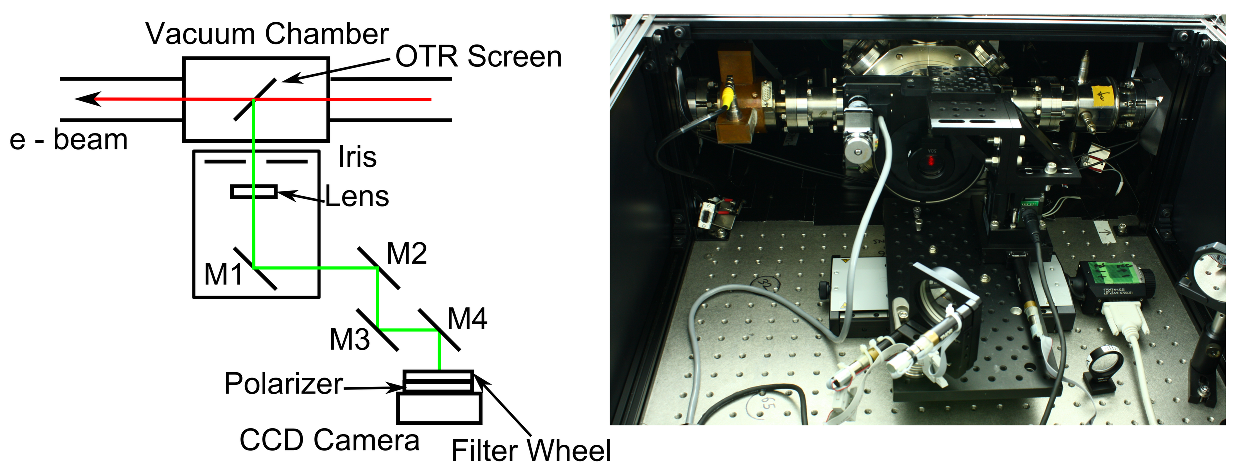


Photo of the Laser Wire setup from the post IP side

The detector consists of a 4 × 4 × 0.6 cm lead plate followed by an Aerogel scintillator of the same size, a light tight and guiding pipe and finally a shielded photomultiplier tube.

OTR Beam Profile Monitor

Experimental Setup

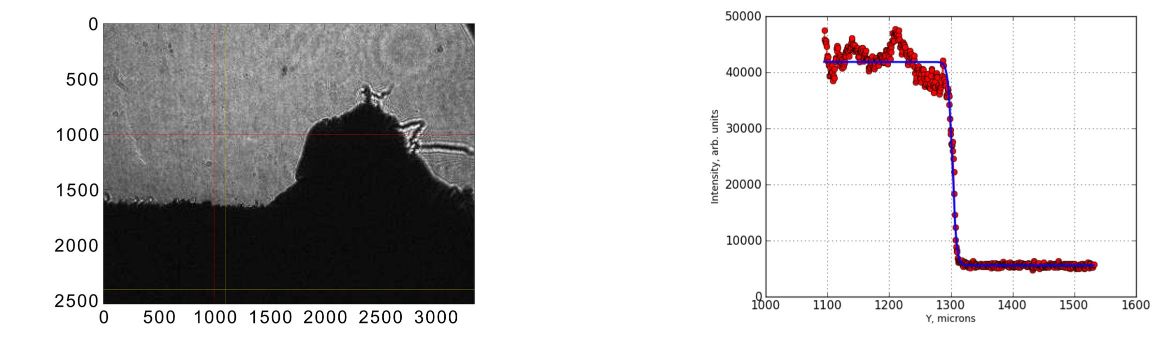


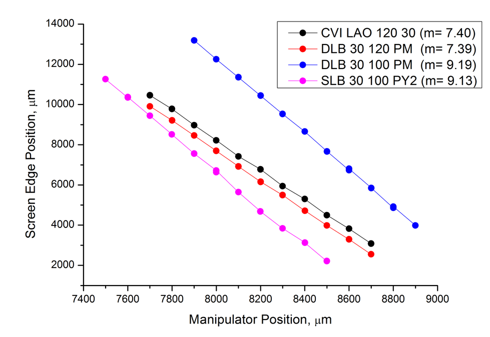
Schematic layout and photogrph of the OTR experimental setup

All measurements were performed with asingle-bunch 3.25 Hz repetition rate operation mode with 0.9 nC bunch charge.

The SBIG ST-8300 camera based on the large format interline Kodak KAF-8300 (monochrome) sensor with low dark current, low noise, and high resolution was used.

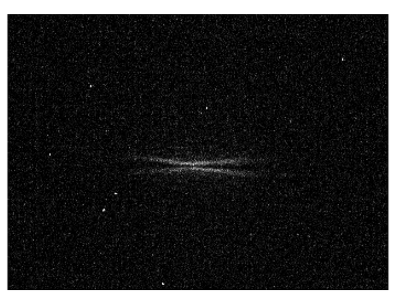
Calibration





CCD image of the target edge zoomed by the optical system (top left); vertical projection with fit (top right) is used to define the exact screen edge position; calibration curves for different lenses (bottom right) with linear fit. The magnification factor is derived from the fit.

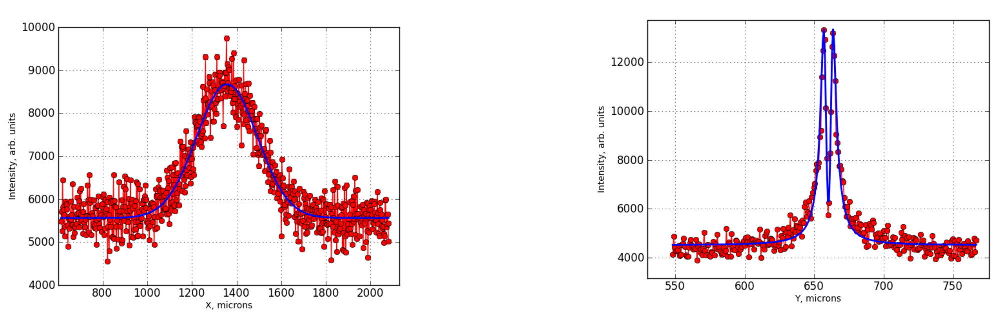
Analysis



CCD imae of the OTR spot

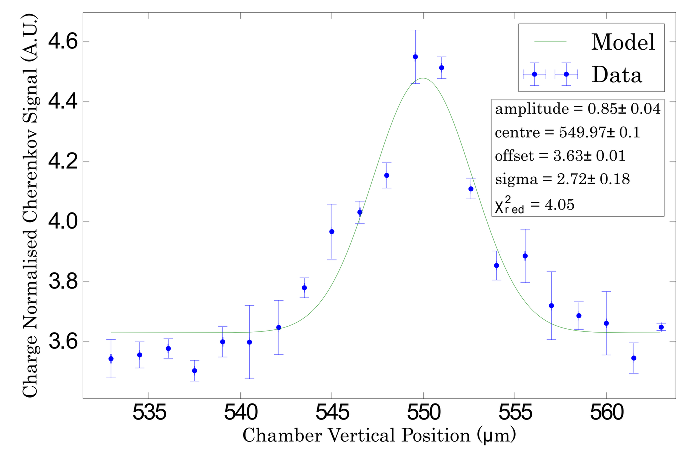
$$f(x) = a_0 + \frac{a_1\left(a_4 + (x-a_3)^2\right)}{1 + \left(a_2(x-a_3)\right)^4}$$

Here a_0,...,a_4 are free parameters of the fit function:
a_0 - vertical offset of the distribution with respect to zero
a1 - amplitude of the distribution
a2 -smoothing parameter dominantly defined by the beam size
a3 - horizontal offset of the distribution
a4 - distribution width

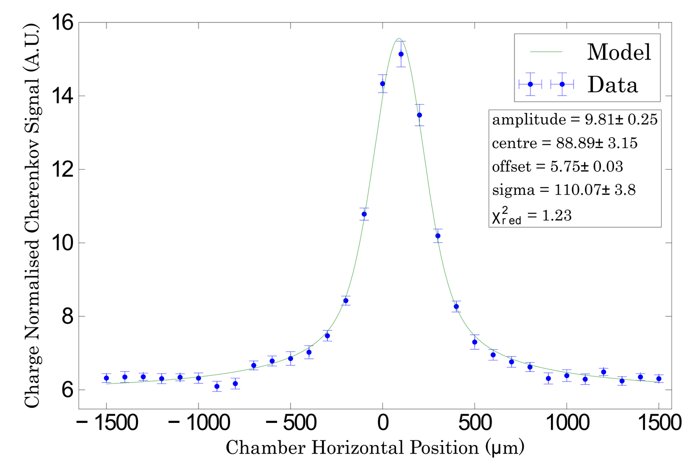


CCD imae projections: horizontal (left) and vertical (right)

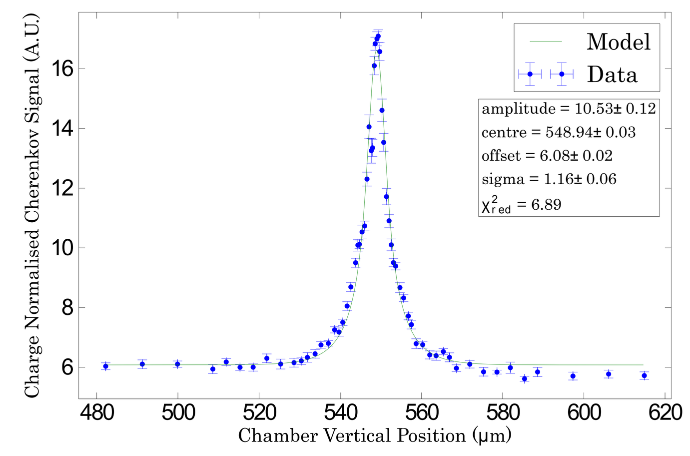
Recent Results



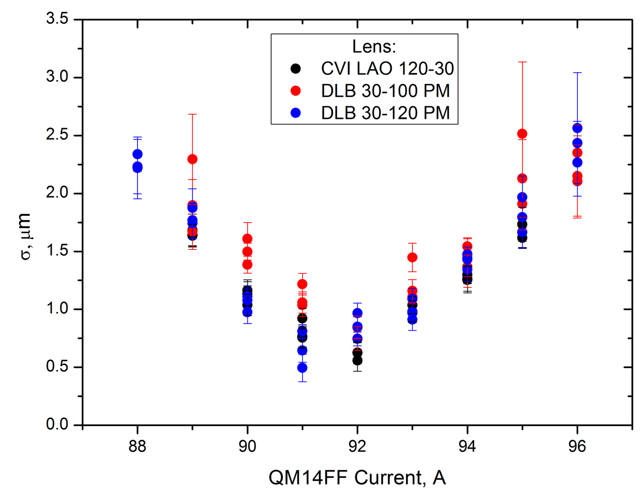
Initial vertical LW scan of the electron beam.



Horizontal LW scan of the electron beam.



Detailed nonlinear vertical LW scan of the electron beam.



Quadrupole OTR scan for 3 different lenses. Minimum measured size: 0.7541+-0.034 um (CVI lens, f=120mm); 0.7938+-0.0354 um (DLB lens f=120mm); 1.0094+-0476 um (DLB lens f=1)00mm

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