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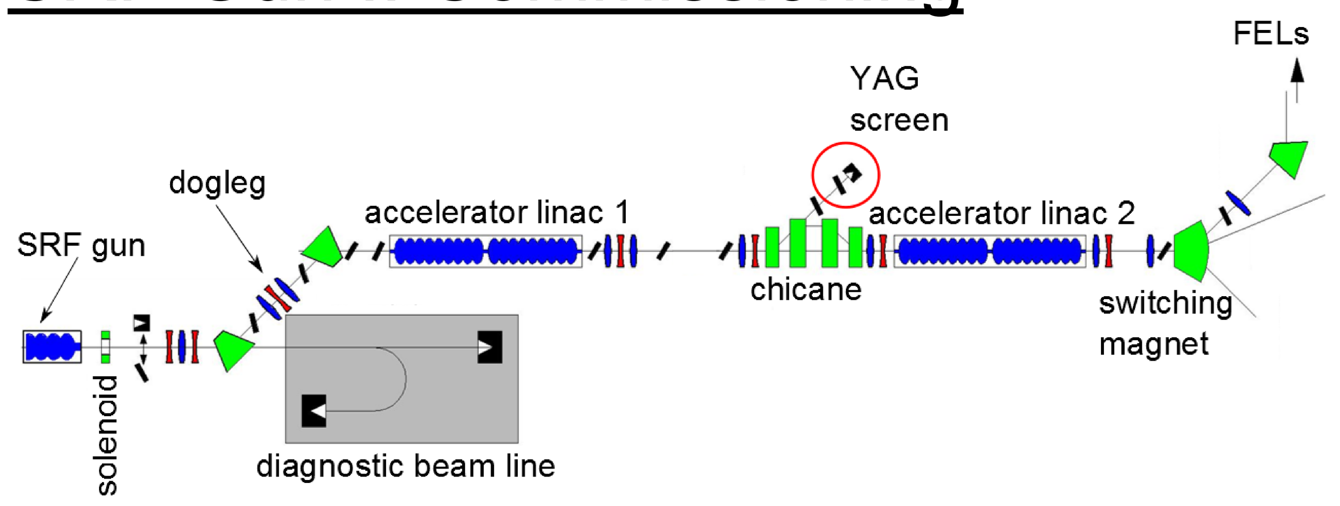
SRF GUN CHARACTERIZATION - PHASE SPACE AND DARK CURRENT MEASUREMENTS AT ELBE

Motivation

RF photoelectron sources with superconducting cavities provide the potential to generate high quality, high brightness electron beams for future accelerator applications. Helmholtz-Zentrum Dresden-Rossendorf provides a test stand for SRF gun technology. The SRF Gun can also be used as an electron source for the two-stage super-conducting linear accelerator ELBE.
Future applications, such as driving X-Ray FEL facilities, require a good understanding of the longitudinal phase space distribution of the photoelectron source. Furthermore, in order to provide a stable, high quality electron beam sources of dark current as well as un-wanted beam transport from the SRF gun to the linear accelerator must be investigated.

SRF Gun II Commissioning



SRF Gun		
Laser wavelength	λ	266 nm
Laser rep. rate	f_{Laser}	100 kHz
Laser pulse length	σ_{Laser}	6 ps
DC bias cathode	V_{bias}	-5 kV
Field	E_{acc}	7 MV/m
Beam energy	E_{kin}	3.6 MeV

ELBE		
Gradient C1	E_{acc}(C1)	9.7 MV/m
Gradient C2	E_{acc}(C2)	5.3 MV/m
Beam energy	E_{kin}	19 MeV

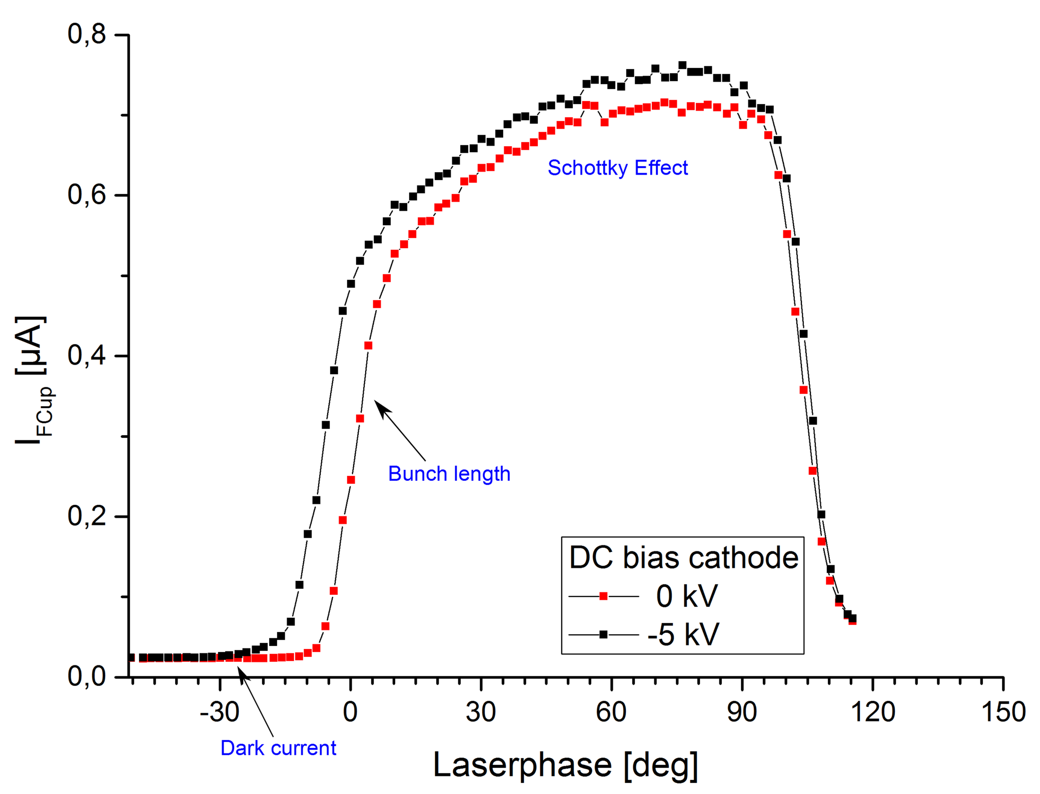
Longitudinal phase space of the SRF Gun II

Diagnostic beamline with 180° dipole

Measurement for two different laser phases 49.4° and 56.6°

→ Beam **Energy**: E_{kin} = 3.59 Mev

→ **Energy Spread**: σ_E (49.4°) = 23.04 ± 0.96 keV
σ_E (56.6°) = 13.44 ± 0.96 keV



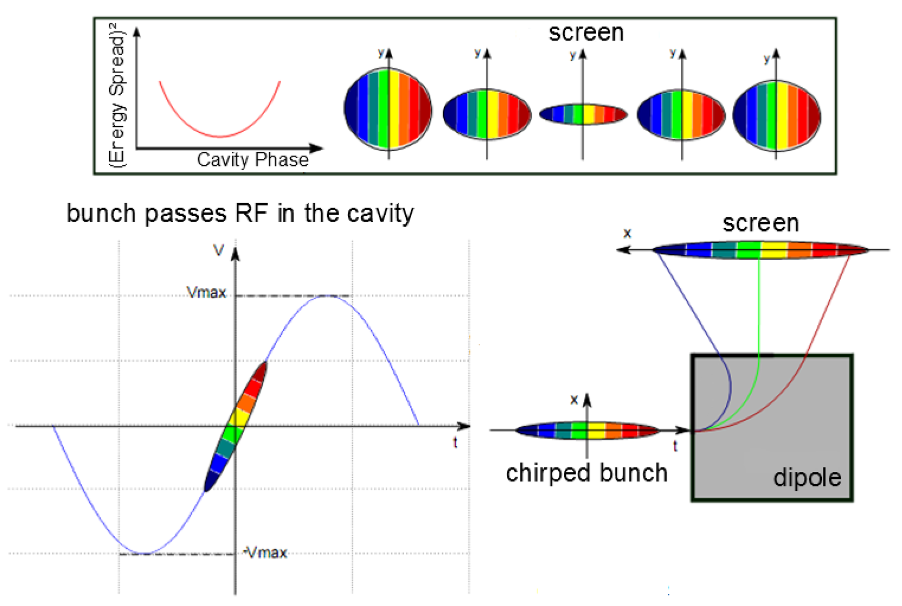
Schottky Scan

Measurement for two different DC bias voltages 0 kV and - 5 kV at photocathode

→ Dark current offset: 20 nA
→ Whole bunch accelerated at 10°
→ Further increase of the beam current due to Schottky effect
→ Extract emission time from the slope:
- Assume a Gaussian longitudinal bunch distribution
- Fit the slope with a Gauss error function $F(x) = \frac{1}{2}(1 + \mathrm{erf}(\frac{x-\mu}{\sqrt{2\sigma^2}}))$

Emission time σ_t = 10.7 ± 2.6 ps
↔ Laser pulse length 6 ps
Overestimated due to rising Schottky effect, beam dynamics, fit quality and accuracy of the displayed laser phase (± 0.5°)

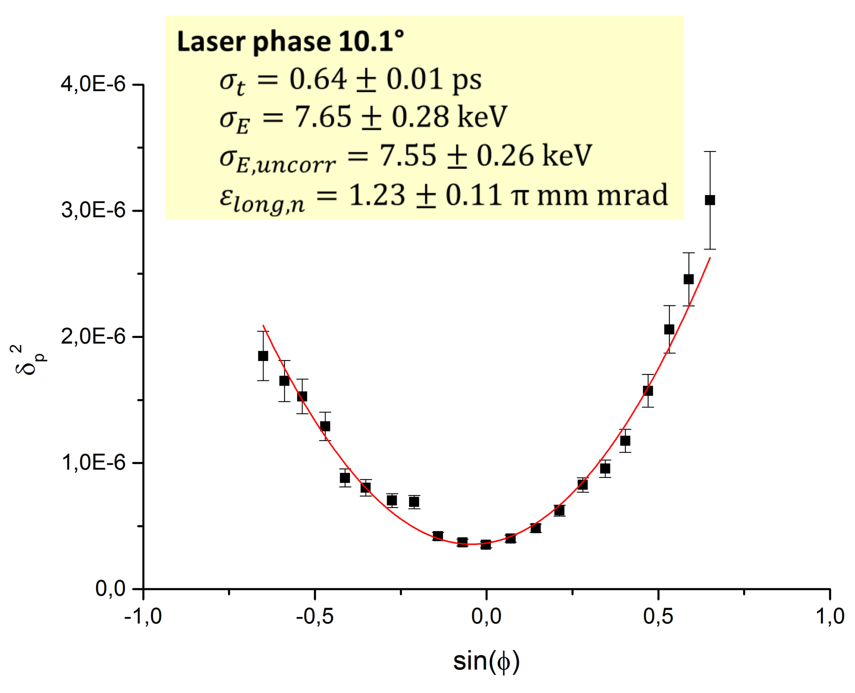
Longitudinal Phase Space

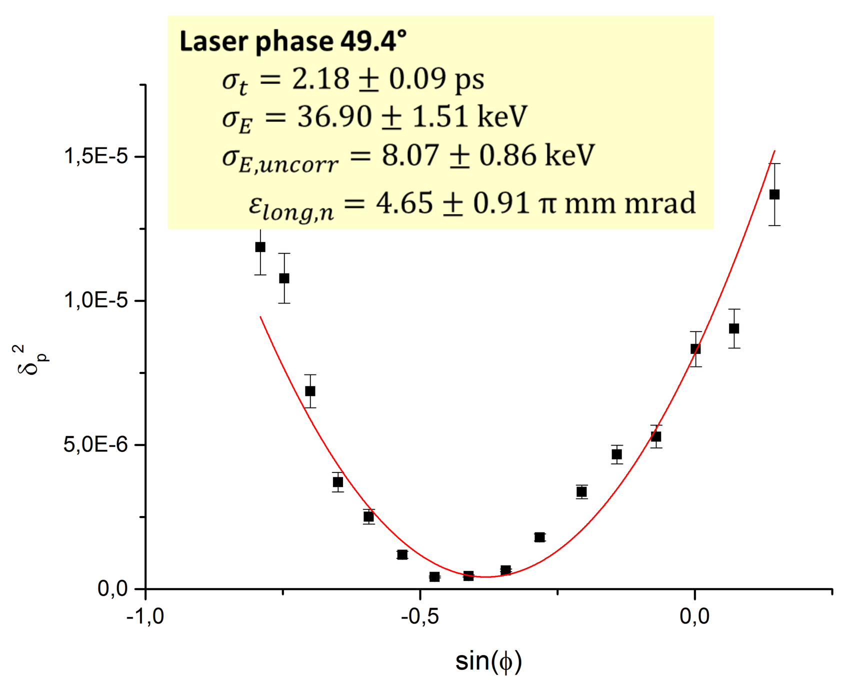


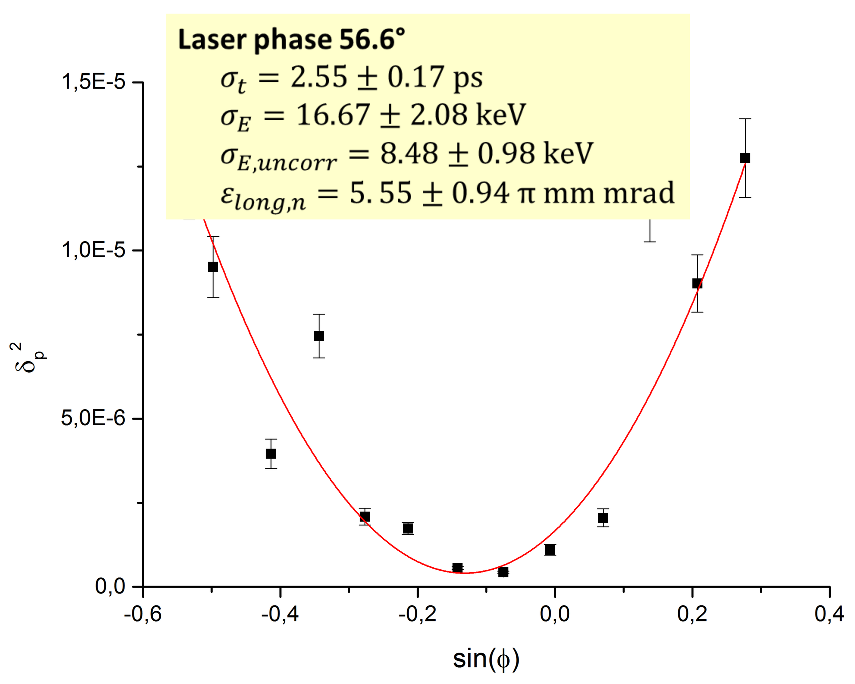
Phase scan technique

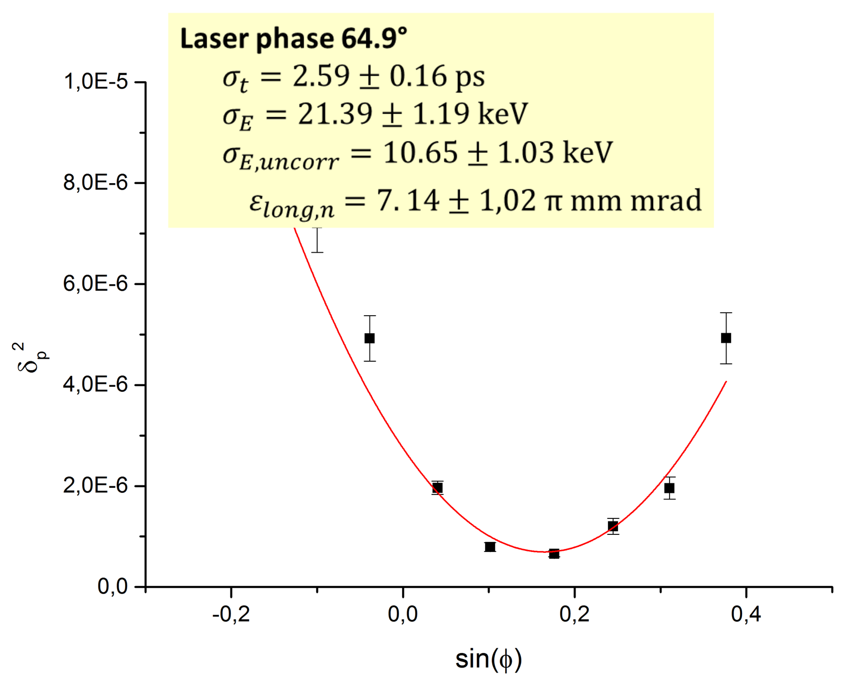
- Bunch of finite length receives energy chirp in RF cavity module
- Passing a dipole the energy spectrum is projected in the transverse plane
- Measuring the rms energy spread for different RF phases of linac cavity
- Fitting the measured rms energy spread for several linac phases with parabola function

Longitudinal Parameters at cavity entrance

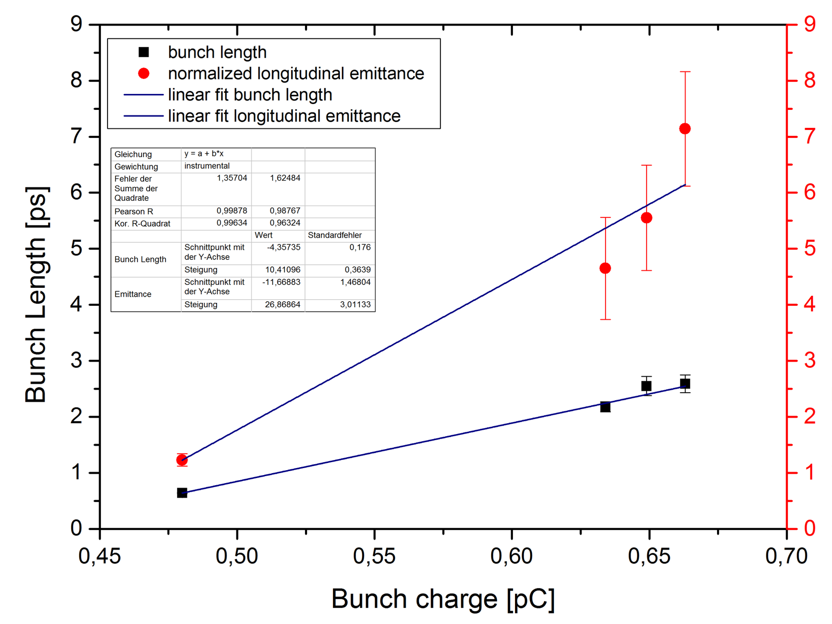




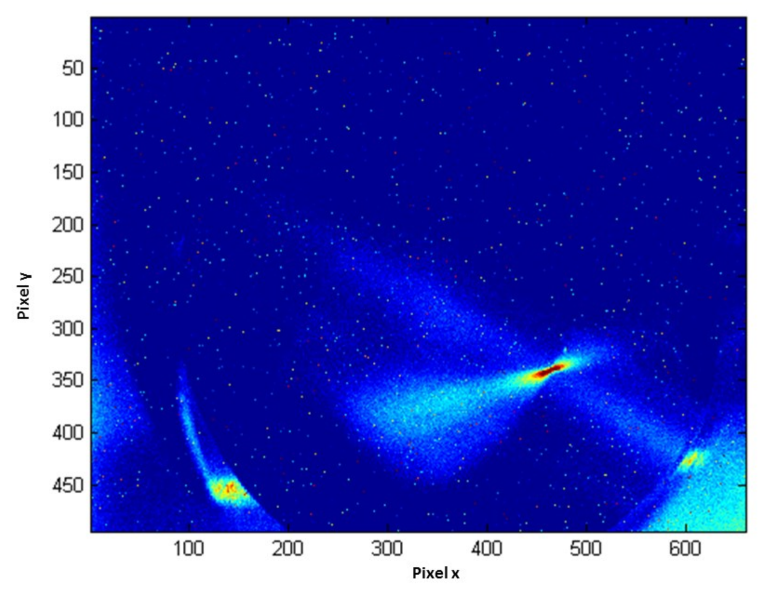




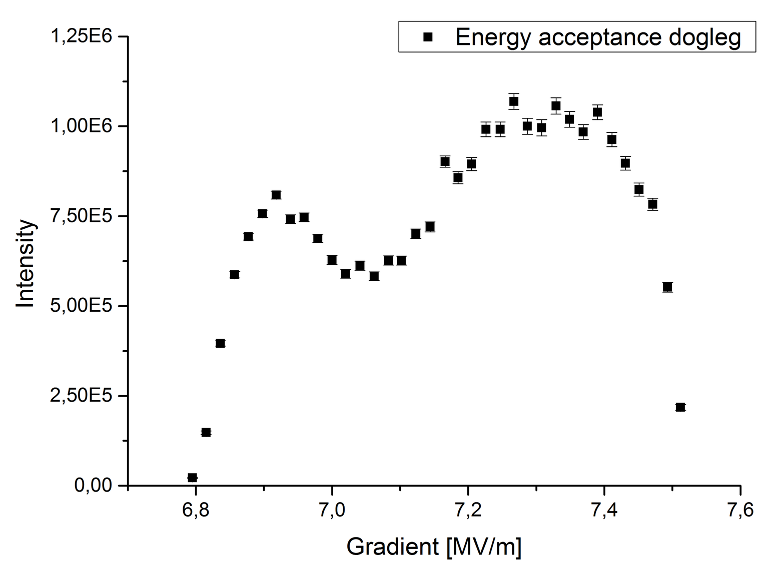
- **Correlated energy spread** represents the two energy spread minima from SRF gun at low laser phase and 57°
- **Vertex shift** at both minima is zero
- **Vertex shift correlation** with the gun laser phase
- **Uncorrelated energy spread** nearly constant at 8 keV dominated by thermal and RF contributions
- **Bunch length** shorter than laser pulse length of 6 ps due to RF compression
- **Bunch length** and **long. emittance** grow linearly with laser phase and therefore with bunch charge



Dark Current and Energy Acceptance of the Dogleg



- Dark current: 18±2 nA (Faraday-Cup)
- One significant dark current peak at 2.3 MeV
→ Field emission at the cavity walls



- Unwanted beam transport to ELBE determined by energy acceptance of the dogleg
- Measurement: Variation of gun gradient between 6.8 MV/m and 7.5 MV/m (i.e. energy [3.2 MeV, 3.6 MeV])

Dark current peak at 2.3 MeV does not match the energy acceptance of the dogleg

J. Teichert et al., "Commissioning of an Improved Superconducting RF Photoinjector at ELBE", THP061, Proceedings of FEL'14, Basel, Switzerland (2014)_J. Teichert et al., "Evaluation of Critical R&D Issues of SRF Guns", EuCARD SRF Review 2011_T. Kamps et al., Rev. Sci. Instrum., 79 (2008) p. 093301_J. Rudolph, "Bunch Length Measurements and Status of the Slice Diagnostics System for ELBE/SCRF Gun", EuCARD SRF Review 2010_D.H.. Dowell et al., Nucl. Instr. and Meth. A 507 (2003) 331_S. Kashiwagi et al., "Photo-electron beam longitudinal phase space tomography studies at the ATF", Proceedings of LINAC'00, Monterey, California (2000)