INVESTIGATIONS OF THE LONGITUDINAL PHASE SPACE AT PITZ *

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Abstract

In order to optimize photo injectors for Free Electron Lasers (FELs) the correlation between the longitudinal positions of the electrons in the bunch and their longitudinal momenta has to be analysed. Longitudinal phase space measurements at the upgraded PITZ facility [1] will be presented in this paper. Measurements of the complete longitudinal phase space and its projections downstream the copper gun are compared with simulations. Momentum measurements after a 9 cell booster cavity will be discussed.

INTRODUCTION

The main goal of PITZ is the test and optimization of L-Band RF photo injectors for Free-Electron Lasers (FELs). The demands on such a photo injector are a small emittance, short bunches and a charge of about 1 nC. The linac of a FEL incorporates a 1.5 cell RF gun capable of producing a high charge density, followed by an acceleration section and a magnetic bunch compressor. For an effective bunch compression detailed studies of the longitudinal phase space have to be performed. Besides the projections of the longitudinal phase space, i.e. temporal and momentum distribution of the electron bunch, the correlation between the longitudinal positions of the particles in the bunch and their momenta has to be understood. The momentum distribution is measured by deflecting the electron bunch using a spectrometer magnet into the dispersive arm. A subsequent Cherenkov radiator transforms the electron bunch into a light pulse with equal temporal and spatial distribution, which is imaged onto a streak camera by an optical transmission line to measure the longitudinal phase space [2]. Another Cherenkov radiator is used in the straight section in order to measure the longitudinal electron distribution.

MOMENTUM AFTER THE BOOSTER

A copper booster cavity was installed after the RF gun in order to study the emittance conservation principle. The

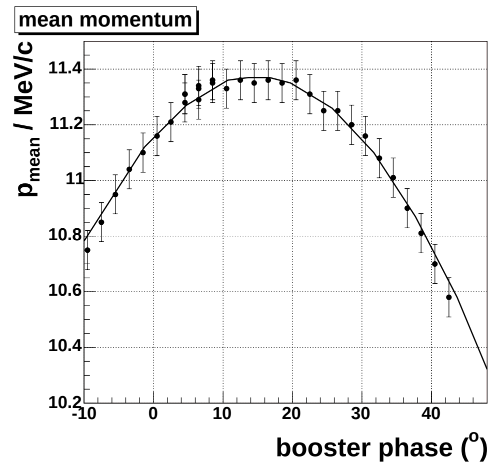

Figure 1: Mean momentum after the booster measured for different booster phases at a gun phase with maximum energy gain. The solid line presents the results from ASTRA simulations.

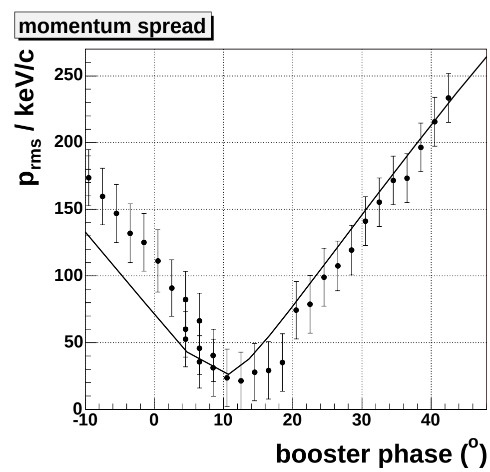

Figure 2: Momentum spread after the booster measured for different booster phases at a gun phase with maximum energy gain. The solid line presents the results from ASTRA simulations.

momentum distribution was measured for different phases of the booster for about 1 nC beam charge, a gun phase with maximum momentum gain, and flat-top transverse and longitudinal laser distribution. Mean momentum and momen-

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tum spread are shown in figures 1 and 2. Simulation and measurement of the mean momentum fit rather well and show a sinusoidal shape. There are still discrepancies between measured and simulated momentum spread which might be caused by inadequate focusing of the beam, some phase drift or an unbalanced rf field distribution. This has to be analysed in more detail. In order to get stable measurement conditions, the measurement was not performed with the highest possible gradient in the gun and the booster cavity. Figures 3 and 4 show the mean momentum and momentum spread for different gun and booster phases. The highest mean electron beam momentum measured at PITZ up to now was 13.7 MeV/c.

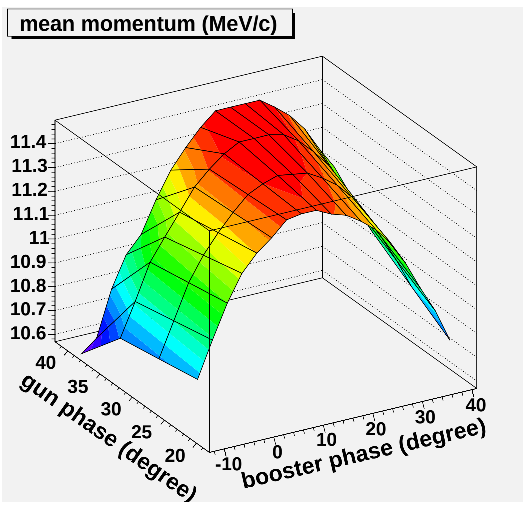


Figure 3: Mean momentum after the booster measured for different booster phases and gun phases.

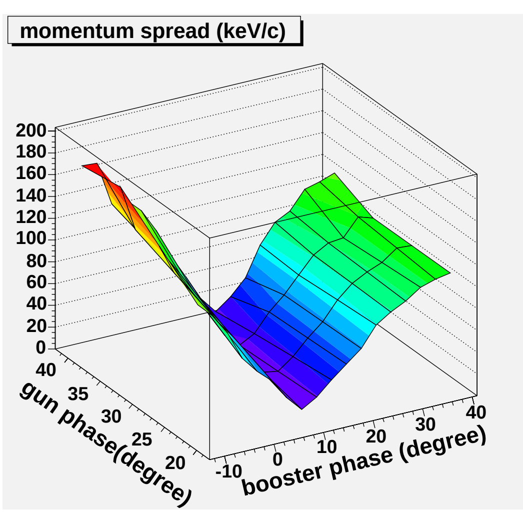


Figure 4: Momentum spread after the booster measured for different booster phases and gun phases.

RESOLUTION OF STREAK MEASUREMENTS

In 2005, the upgrade of the PITZ facility from PITZ 1 to PITZ 1.5 involved a movement of some diagnostic elements. The dipole magnet and its screen station as well as the screen station used for the bunch length measurement were moved upstream by about 2 m. This necessitated an extension of the optical transmission line [3] from the Cherenkov radiator to the streak camera. The new beamline contains an additional telescope consisting of two achromats with a focal length of 500 mm. Thus, the effect of dispersion in the optical transmission line is increased. The arrival time of Cherenkov photons with different wavelengths were measured by using optical transmission filters (10 nm bandwidth). Figure 5 shows measurements in the straight section for both versions of the optical transmission line, and in the dispersive arm for the actual version. To measure bunch lengths in the order of 20 ps, it is necessary to use an optical transmission filter with a narrow bandwidth. Usually 500 nm or 550 nm filters with 10 nm bandwidth were used. Figure 6 shows the expected resolution of the optical transmission line by using a 550 nm filter with a bandwidth of 10 nm FWHM (Melles Griot), calculated from the curve in figure 5 and the transmission curve of the filter provided by the producer. For the 550 nm filter the resolution is 1.15 ps in the straight section and 1.04 ps in the dispersive arm for the current optical transmission line. In addition, the resolution of the streak camera [4] and streak camera slit width determine the temporal resolution of the measurement. Since the intensity of the Cherenkov light is strongly reduced by the filter, a large slit width of about 0.1 mm has to be used. The influence of the slit width can be determined by measuring the signal without deflecting streak field. Investigations towards an optical transmission line using reflected optics are ongoing.

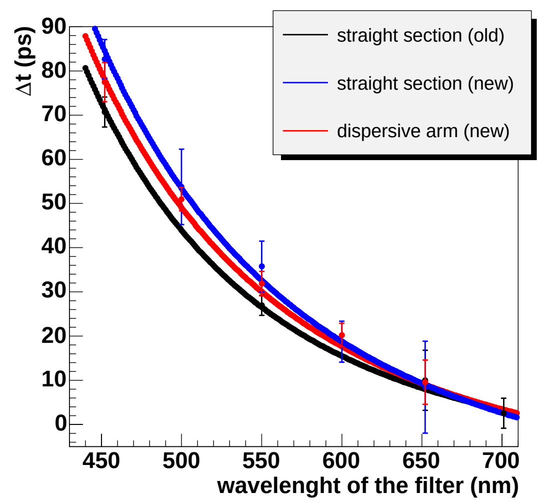


Figure 5: Arrival time of photons with different wavelength.

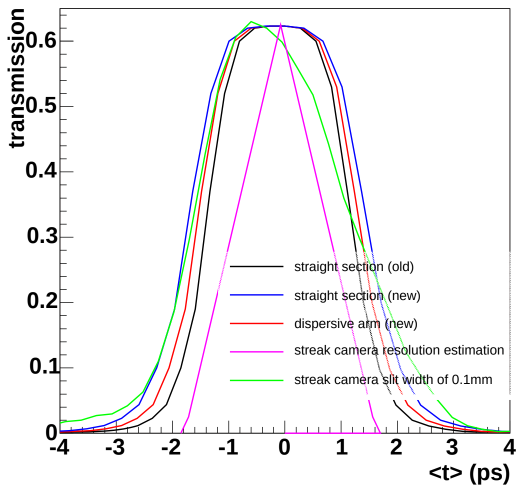
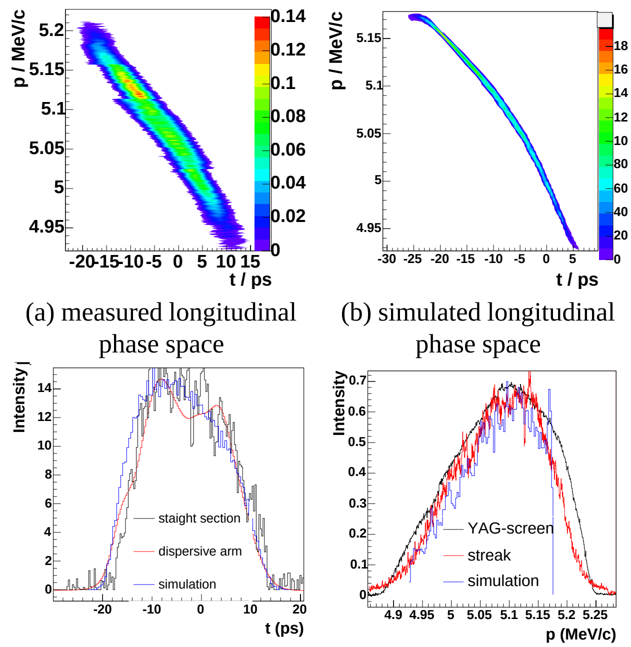


Figure 6: Effect of the dispersion on the resolution by using an optical transmission filter of 550nm with a bandwidth of 10nm (FWHM) compared with the resolution of the streak camera C5680 [4] and the influence of a 0.1 mm streak camera slit width to the resolution.



(a) measured longitudinal phase space (b) simulated longitudinal phase space

(c) longitudinal distribution (d) momentum distribution

Figure 7: Measured (a) and simulated (b) longitudinal phase space and their projections: longitudinal (c) and momentum (d) distribution for 1.1 nC bunch charge, phase with maximum energy gain + 10° and a longitudinal laser distribution with about 20 ps FWHM pulse length. In (c) and (d) the black curves are direct measurements, the red ones are the projections of the measured longitudinal phase space and the blue ones are ASTRA simulations.

LONGITUDINAL PHASE SPACE

Figure 7 shows the comparison between measured and simulated longitudinal phase space. Several corrections were applied to the measured distribution [5]. The measured longitudinal phase space was composed of 5 images taken with different dipole currents. Some transitions of the assembling are still visible. The electron bunch entering into the dipole spectrometer is changing its distribution. The elongation of the longitudinal spread because of the beam size and divergence of the bunch at the entrance of the dipole can be corrected by the deconvolution for known distributions. This corrections were performed, but some simplifications had to be assumed. In addition, the measured signal is too noisy, so that the deconvolution can produce some modulations. Due to this fact, small modulations are visible in the longitudinal distribution measured in the dispersive arm. The shape of the measured phase space reproduces the simulation results, but the resolution of the optics and the streak camera limits the temporal resolution. A plausible determination of the longitudinal emittance is impossible with this resolution.

CONCLUSION

The longitudinal phase space was measured at PITZ. For different phases an example was shown. The shape of the longitudinal phase space can be identified. In order to increase the resolution of the measurement, investigations towards an optical transmission line using reflected optics have started.

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