DUAL TRANSVERSE AND LONGITUDINAL STREAK CAMERA IMAGING AT ELSA*

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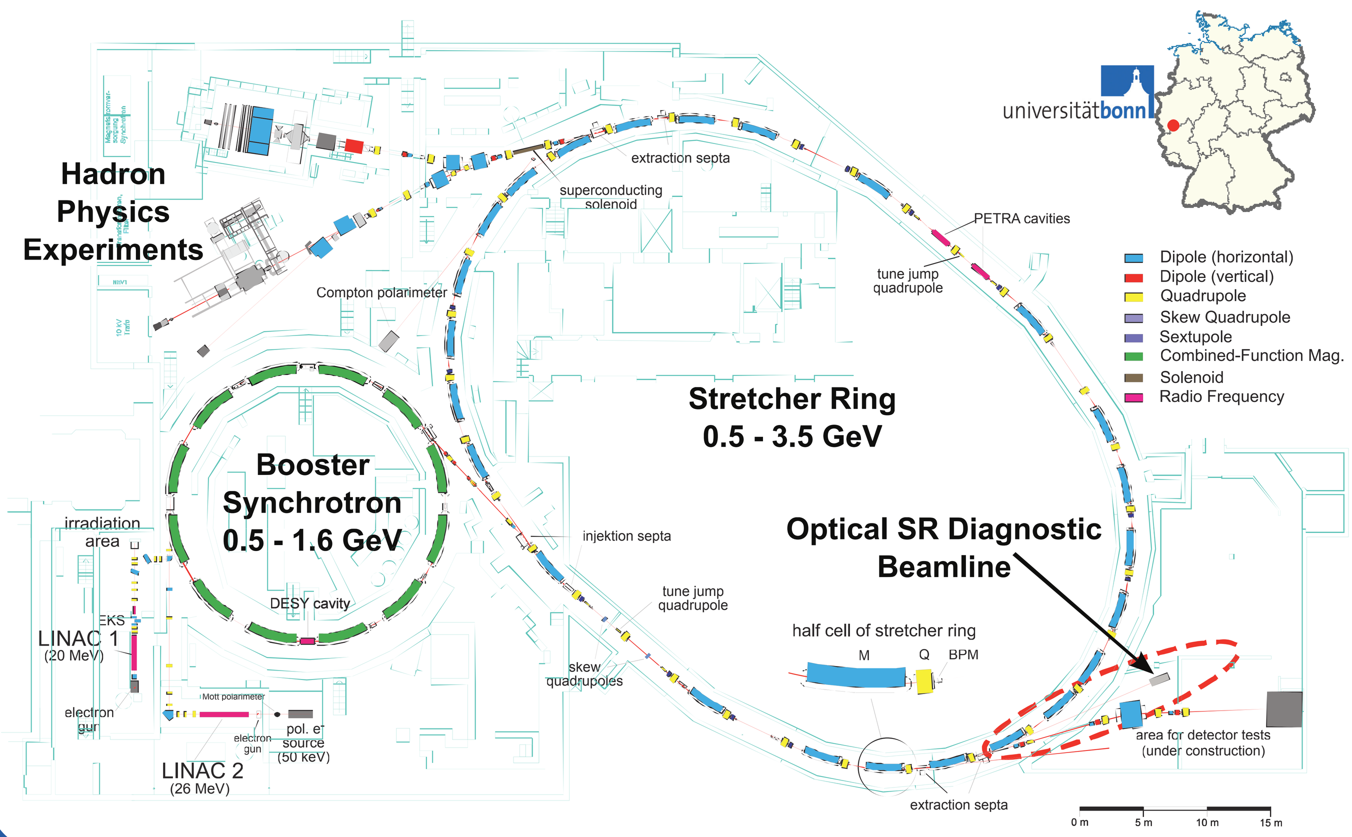
The pulse stretcher ring ELSA accelerates polarized and non-polarized electrons to energies between 0.5 and 3.5 GeV. The current funding period supports the upgrade for an increase of stored and extracted beam currents, beam quality and degree of polarization. In order to gain information of fast beam dynamics with temporal resolution, ELSA has recently been equipped with a diagnostic synchrotron radiation beamline housing a streak camera as main beam imaging device. As streak cameras convert three dimensional beam information into a two dimensional image with aspect on longitudinal resolution, the dimension of one transverse plane is always suppressed naturally, either by the streak action or by the narrow slit of the input optics. As for certain events capturing dynamics in all three dimensions is of interest, a method for dual transverse imaging is introduced and demonstrated. Measurements of interest regarding longitudinal beam dynamics are also presented.

The Electron Stretcher Facility ELSA



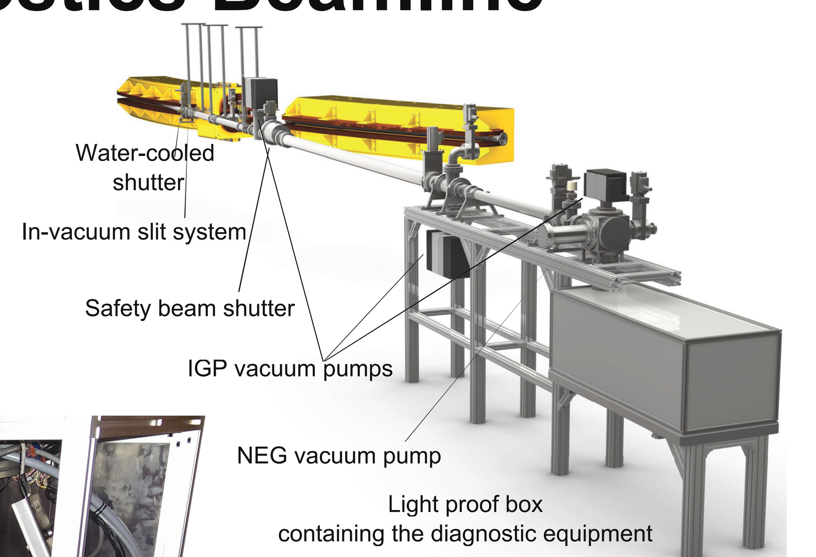
Located at the University of Bonn, ELSA provides spin polarized and unpolarized electron beams for photoproduction experiments and detector tests. Continuous extraction currents in the order of nanoamperes are deliverable by excitation of a hor. betatron resonance. Injection of up to 200 mA stored beam in less than a second is possible. In combination with a fast energy ramp ≤ 6 GeV/s the stretcher ring provides a duty cycle of up to 98%.

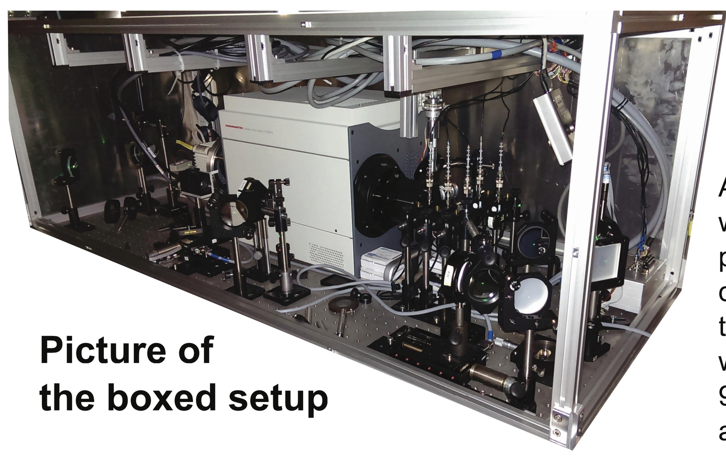
Pulse stretcher ring parameters:

Parameter	Value
Beam energy E	0.5–3.5 GeV
Revolution period T_{rev}	548 ns
Cavity RF frequency f_{RF}	499.67 MHz
Momentum compaction α_c	6.3 %
Bending radius R	10.88 m
Natural emittance ϵ_x (1.2 GeV)	105 nm rad
Bunch length σ_s (1.2 GeV)	34 ps
Synchrotron frequency f_s	88 kHz
Tune Q_x, Q_z	4.61, 4.43

Optical Diagnostics Beamline

The protection of the primary mirror from blackening reactions with residual gas molecules is of importance, as it accepts the full load of the emitted synchrotron radiation. Therefore a 12 m long beam pipe allows for sufficient differential vacuum pumping, but is also responsible for a large beam diameter at the vacuum window.

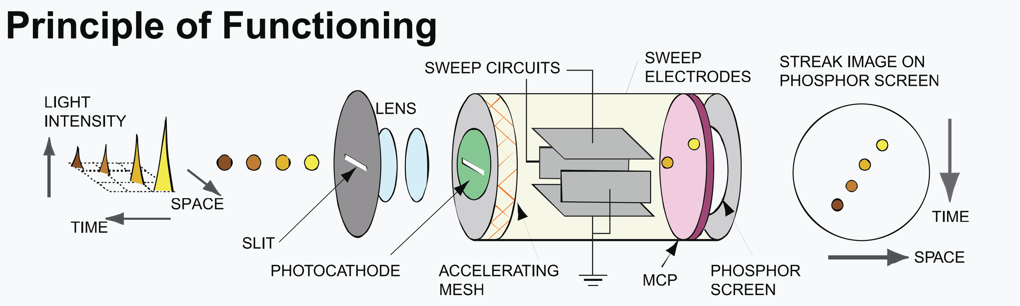




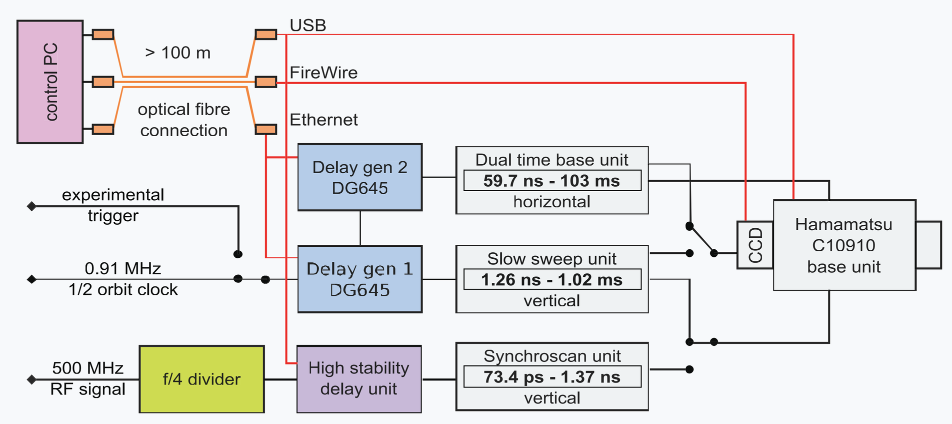
A primary focusing lens creates a real image with magnification M = 0.088, acting as source point for a relay line (Fig. ↓) whose lens pair defines the final image magnification. Inbetween the beam is split by a 50% beam splitter of which one branch is transversally rotated by 90°. Both beams rejoin with slight displacement and angular deviation at the camera.

Streak Camera & Timing

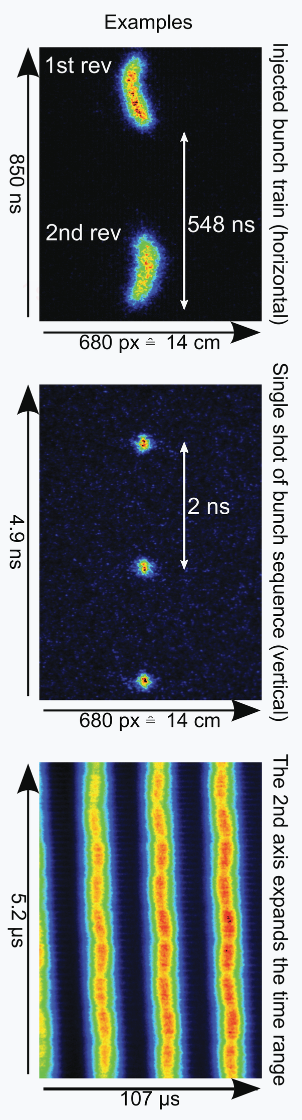
Principle of Functioning



As the visible part of the synchrotron radiation hits the 0.15 x 4.41 mm^2 large photocathode, electrons are emitted and accelerated in the streak tube. Electric fields sweep the beam transversely with adjustable sweeping velocity. A multi channel plate (MCP) multiplies the number of electrons which then illuminate a phosphorous screen. The image is digitized by a 12 bit CCD camera.



The sweeping units are triggered by the orbit clock, the RF master signal and/ or for common events by an experimental trigger. The latter allows beam manipulator (e.g. a kicker) and diagnostic tool to be fired synchronously. Delay units allow fine adjustment of the timing.



Dual Transverse Measurements

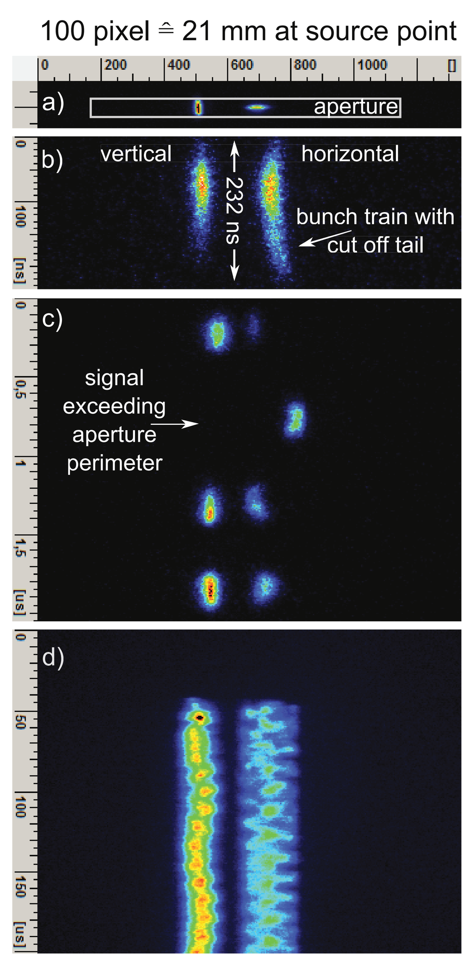
Beam Splitting Optical Table Setup and Limits

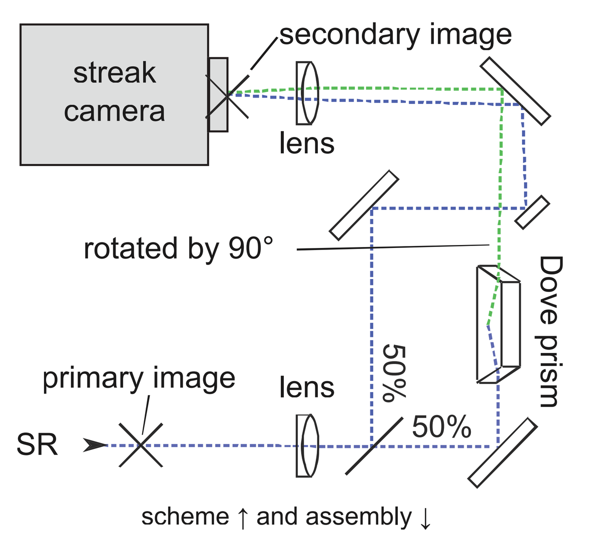
a) In focus mode the sweeping units are switched off. The CCD camera observes the stored beam of ELSA as upright and flat ellipse. The dimension of the photocathode is illustrated as aperture.

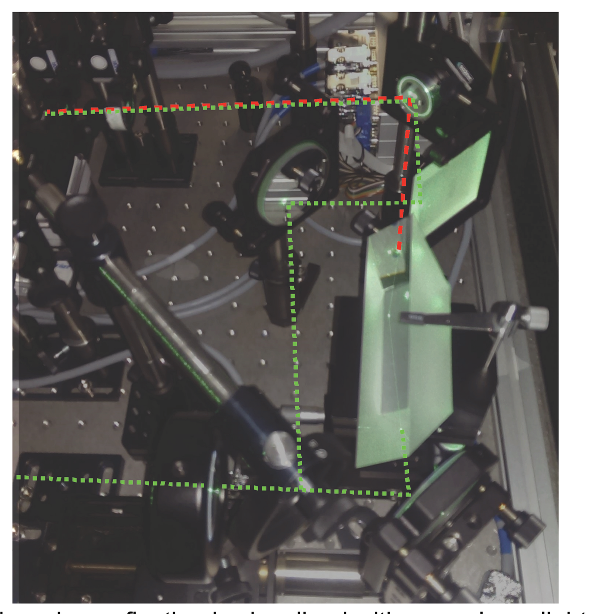
b) An image of the injected bunch train from the booster synchrotron is captured at its first revolution in ELSA. The horizontal deformation occurs occasionally and is most likely caused by a magnetic field ripple of the booster extraction kickers. The tail differs in signal strength and suggests that a collision with an aperture has caused partial beam loss.

c) Within 2 µs the injected bunch train revolves four times around ELSA and strongly oscillates horizontally due to the displacement at the injection septum. The observed phase of the oscillation behaves according to the betatron phase advance of approx. 80° at the SR source point and the tune Q_x = 4.61. As the horizontal amplitude is large in turn two, the bunch train is not displayed vertically because the projected image has exceeded the aperture's perimeter. The closer to the aperture, the lower the signal strength.

d) The natural horizontal damping constant at 1.2 GeV is 37 ms. As the maximum time window of the slow sweep unit is 1 ms, this image shows an overlap of slowly damped transverse oscillations.





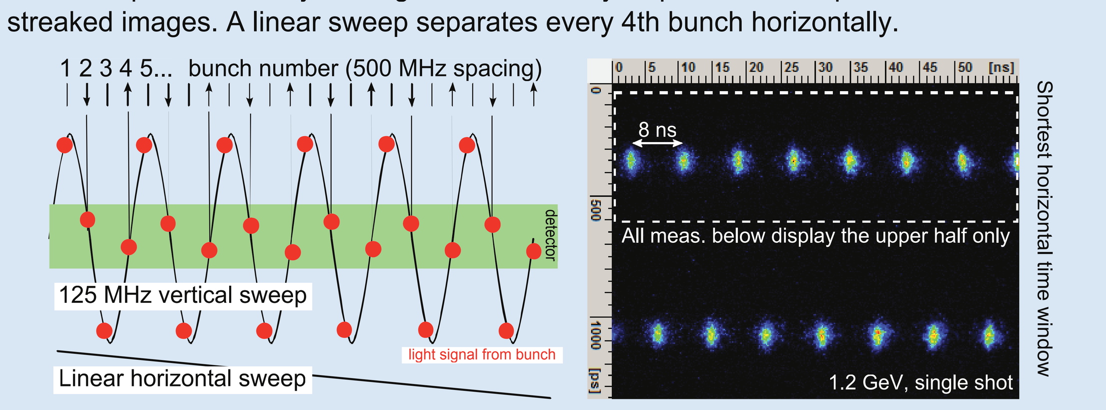


The prism reflection is visualized with green laser light

Synchroscan Measurements - Longitudinal Damping

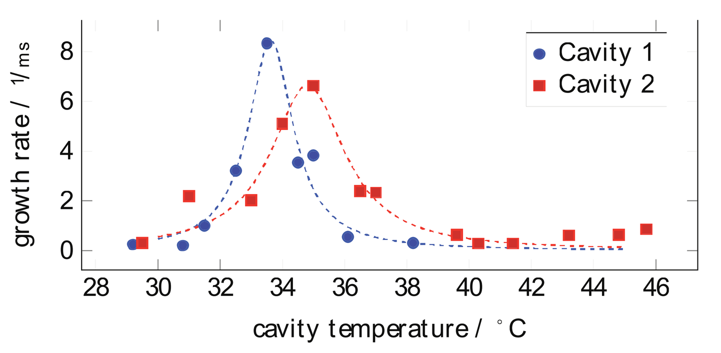
Principle of Synchroscan Operation

The vertical sinusoidal sweeping field is synchronized to the master RF, providing excellent phase stability. A slight vertical delay separates the up- and downwards streaked images. A linear sweep separates every 4th bunch horizontally.



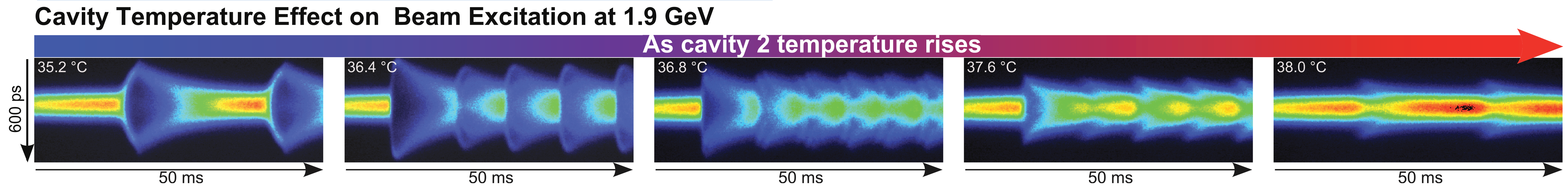
Temperature Influence on Damping Measurements

Grow-damp measurements were carried out by switching off the longitudinal bunch-by-bunch feedback for a few milliseconds. When a cavity HOM frequency overlaps with the beam's resonant frequency the synchrotron motion is excited to an observable amplitude. Changing the cavities' temperature results in a frequency shift of their HOMs.



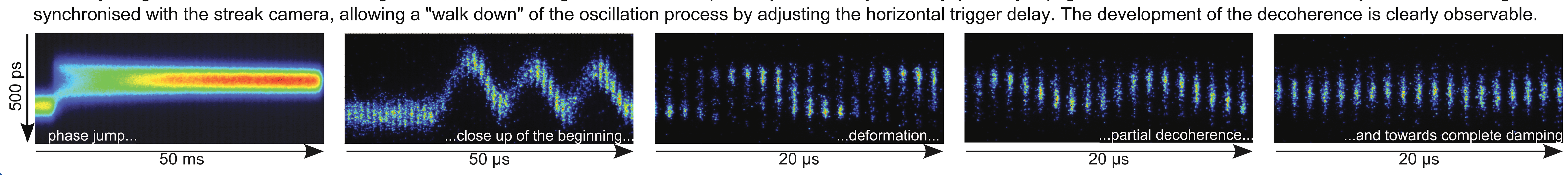
The figure shows the growth rates of the excited synchrotron oscillation depending on the cavities' temperatures measured with the bunch by bunch feedback system's diagnostics capability. Excitation at different temperatures is illustrated below.

Cavity Temperature Effect on Beam Excitation at 1.9 GeV

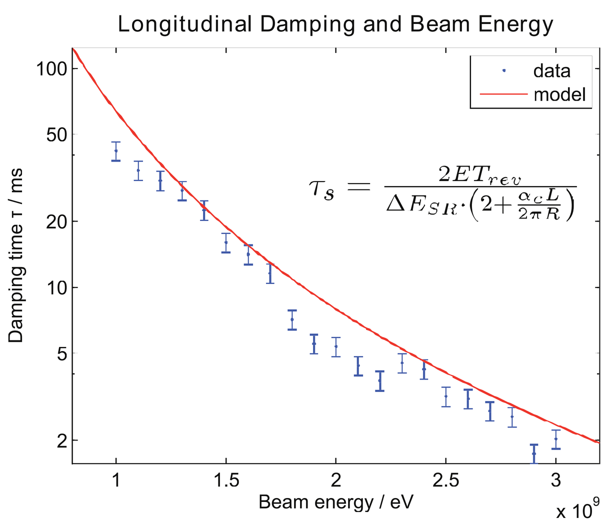


Decoherence Process of Single Bunch Oscillation

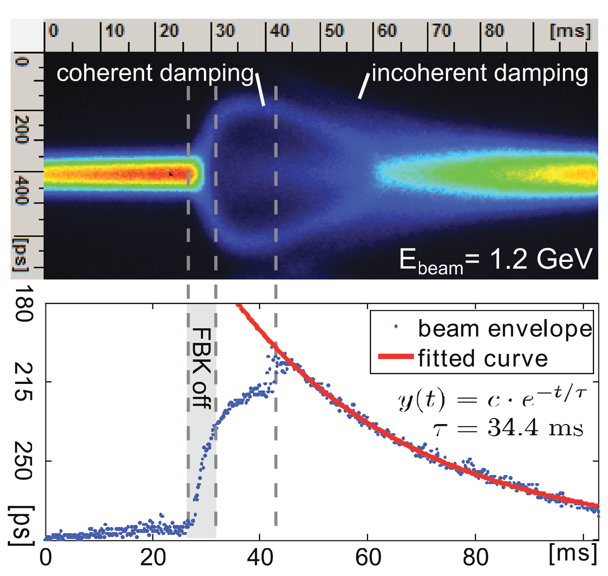
To study longitudinal oscillations including decoherence, a single bunch was repeatedly excited by a cavity phase jump generated with the low level RF system. The timing was synchronised with the streak camera, allowing a "walk down" of the oscillation process by adjusting the horizontal trigger delay. The development of the decoherence is clearly observable.



Damping Rates at Different Energies



Longitudinal damping was observed for a variety of ELSA beam energies. The plot shows the comparison of measured and calculated damping rates. The damping constant is determined by fitting an exponential function to the decaying envelope of the beam. The algorithm parses each column downwards and links the first pixel above noise level to the respective time grid.



An example for lower energies is shown on the bottom. As the feedback system is switched on again it shows little effect, due to the strong coherent excitation of HOMs. As decoherence increases, the FBK starts to catch the coherent oscillation. Natural incoherent damping remains.

Contact: