Measurement of the longitudinal phase space at the Photo Injector Test Facility at DESY Zeuthen, PITZ

D. Lipka, J. Bähr, I. Bohnet, K. Flöttmann, J. H. Han, M. Krasilnikov, V. Miltchev, A. Oppelt, F. Stephan

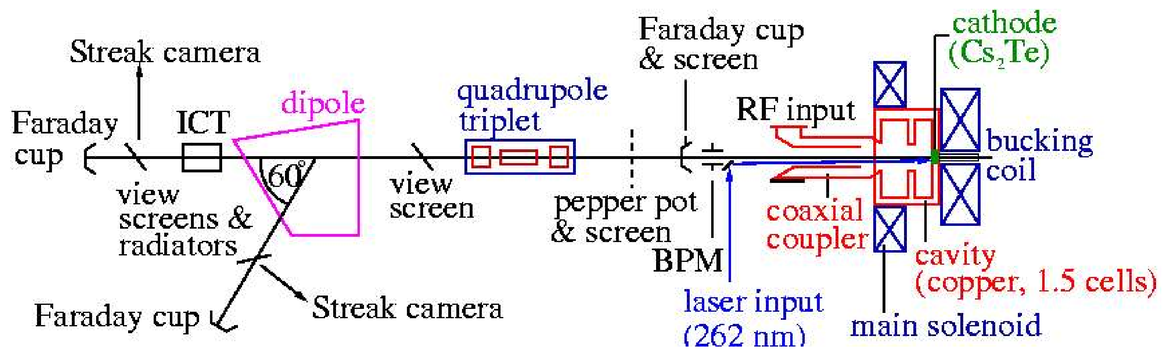
DESY, 22603 Hamburg and 15738 Zeuthen, Germany

Description and scientific goals of the project

A Photoinjector Test Facility for Free Electron Lasers (FEL) and the TESLA linear collider has started operation at DESY Zeuthen. The project is a common effort of a collaboration consisting of the following institutions: BESSY Berlin, DESY (Hamburg and Zeuthen), Max-Born-Institut Berlin, Technical University Darmstadt, INFN Milano, INRNE Sofia, YERPHI Yerevan, INR Troitsk.

Goals: optimize photoinjectors for FEL´s and linear colliders, compare detailed experimental results with simulations, condition and test optimized cavity resonators for the TESLA Test Facility, test new components (laser, cathodes, beam diagnostics), test new concepts for the production of flat beams and polarized electrons

Sketch of the gun and diagnostics section



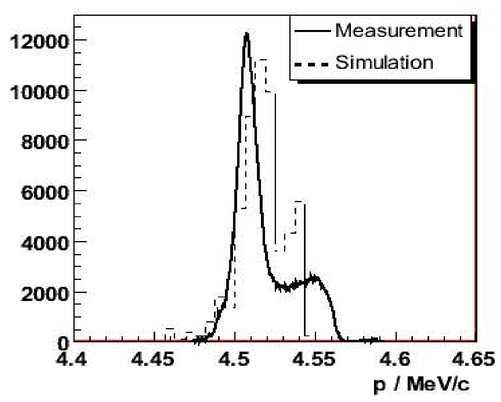
Measurement of the momentum distribution

Goal: Optimize momentum distribution of the electron bunch

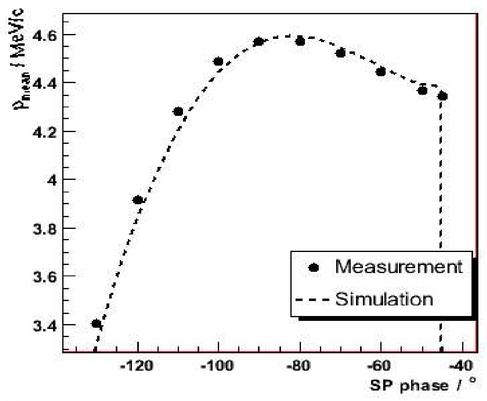
Setup: spectrometer dipole and YAG screen

Results:

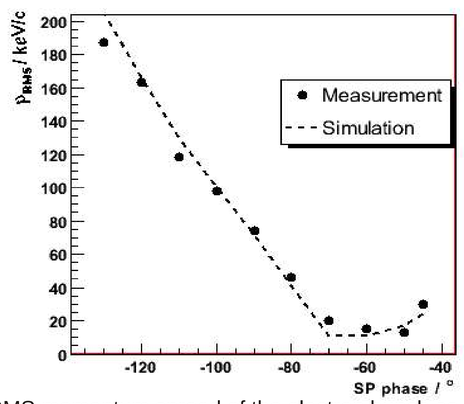
- Measured smallest RMS momentum spread of 15 keV/c for 1 nC
- Highest momentum achieved: 4.7 MeV/c, corresponds to a maximum gun gradient of 41.5 MV/m
- Maximum RF power in the gun: 3.15 MW



Momentum distribution with simulation at set point (SP) phase -70 degrees, gradient 40.5 MV/m, bunch charge 1.1 nC



Mean momentum of the electron bunch as a function of phase for a gradient of 40.5 MV/m. The errors of the measurements are of the order of 50 keV/c.

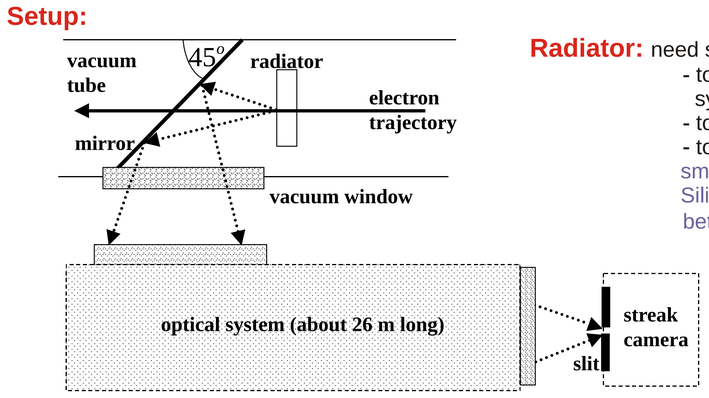


RMS momentum spread of the electron bunch as a function of phase for a gradient of 40.5 MV/m. At small RMS momentum spread the errors are of the order of 5 keV/c.

Measurement of the bunch length

Goal: Convert the electron beam into a photon beam using a Cherenkov radiator and measure the photon pulse length with a streak camera.

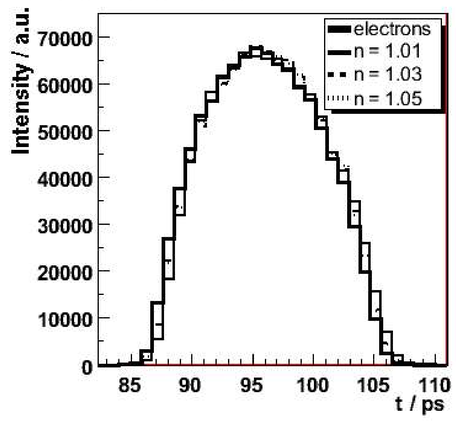
Setup:



Radiator: need small output angle
- to match with the following optical system of about 26 m length [1]
- to avoid total reflection in the radiator
- to reach good time resolution

small refractive index, solution Silica aerogel (SiO_2), refractive index between 1.01 and 1.05

Electron beam: A simulated electron beam is used as input for Geant 4 simulations. It results in Cherenkov photon bunch time distributions for the considered aerogels. The mean momentum is 4.5 MeV/c.

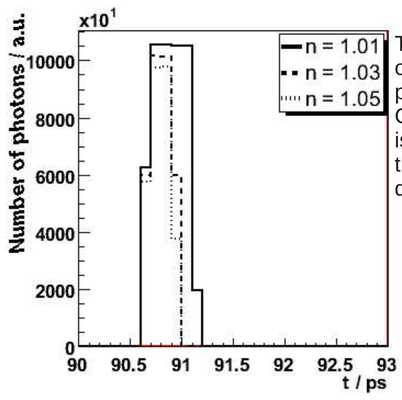


Time distributions of simulated electron bunch and Cherenkov photon bunches. The distributions fit very well.

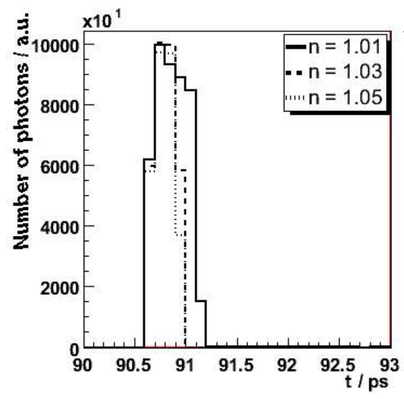
n	l / mm	σt / ps
1,01	20	0,51
1,03	2	0,12
1,05	1	0,11

Time resolution:
Calculated time resolutions of different aerogels. l refers to the thickness of aerogel which is chosen to obtain same number of photons.

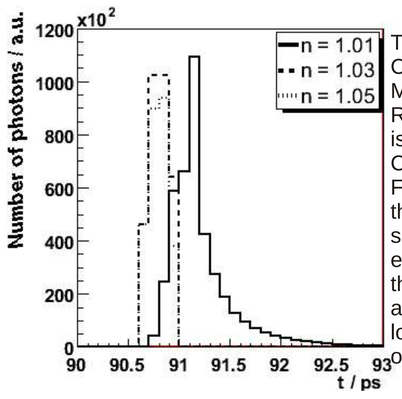
Point source: Geant 4 simulation of Cherenkov photons coming from Silica aerogel with a pointlike electron source. The thickness for the different refractive indices are optimized to get the same photon yield at a momentum of 4 MeV/c. The simulations are made for 4.5 MeV/c. An acceptance angle of the optical system of 20 degrees is applied.



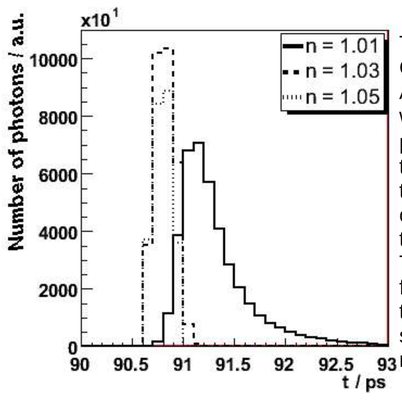
Time distributions of Cherenkov photons. Only the Cherenkov effect is applied at these distributions.



Time distributions of Cherenkov photons. Rayleigh scattering is added to the Cherenkov effect.



Time distributions of Cherenkov photons. Multiple and Rayleigh scattering is added to the Cherenkov effect. For thicker aerogels the multiple scattering of electrons is larger, therefore for the aerogel n = 1.01 a long photon tail is observed.

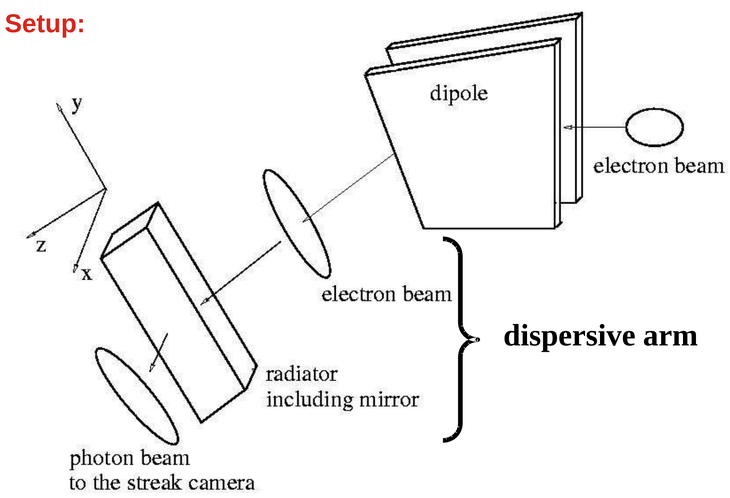


Time distributions of Cherenkov photons. An Aluminium window with thickness of 20 µm is placed in front of the aerogel to prevent the cathode from outgasing of aerogel in the vacuum chamber. The peak disappeares for n = 1.01 because the electrons are scattered before they reach the aerogel.

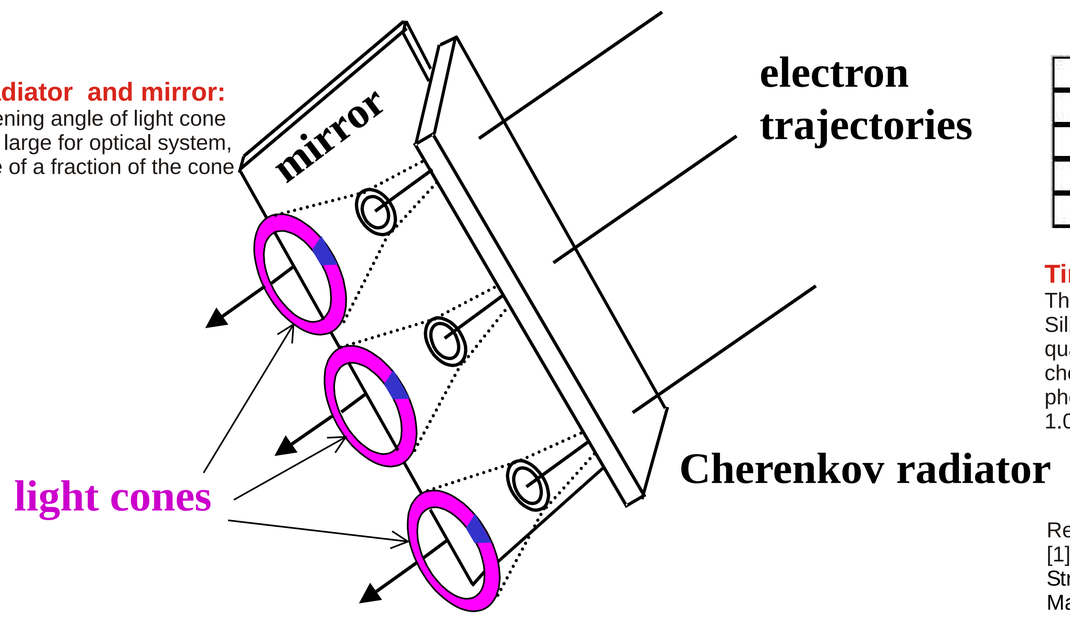
Measurement of the longitudinal phase space

Goal: Measure momentum spread, bunch length and their correlation simultaneously by using a dipole, Cherenkov radiator and streak camera

Setup:



Radiator and mirror:
opening angle of light cone too large for optical system, use of a fraction of the cone



n	l / mm	σt / ps
1,01	20	3,98
1,03	2	0,43
1,05	1	0,35
1,46	0.1	0,41

Time resolution:
The table shows the calculated time resolution for Silica aerogel with different refractive indices and quartz at a momentum of 4 MeV/c. The thickness l is chosen to provide the same amount of emitted photons. Silica aerogel with a refraction index of 1.05 and quartz will be used.

Reference:
[1] J. Bähr, et al., Optical transmission system for Streak camera measurement at PITZ, Dipac 2003, Mainz

http://desyntwww.desy.de/pitz/