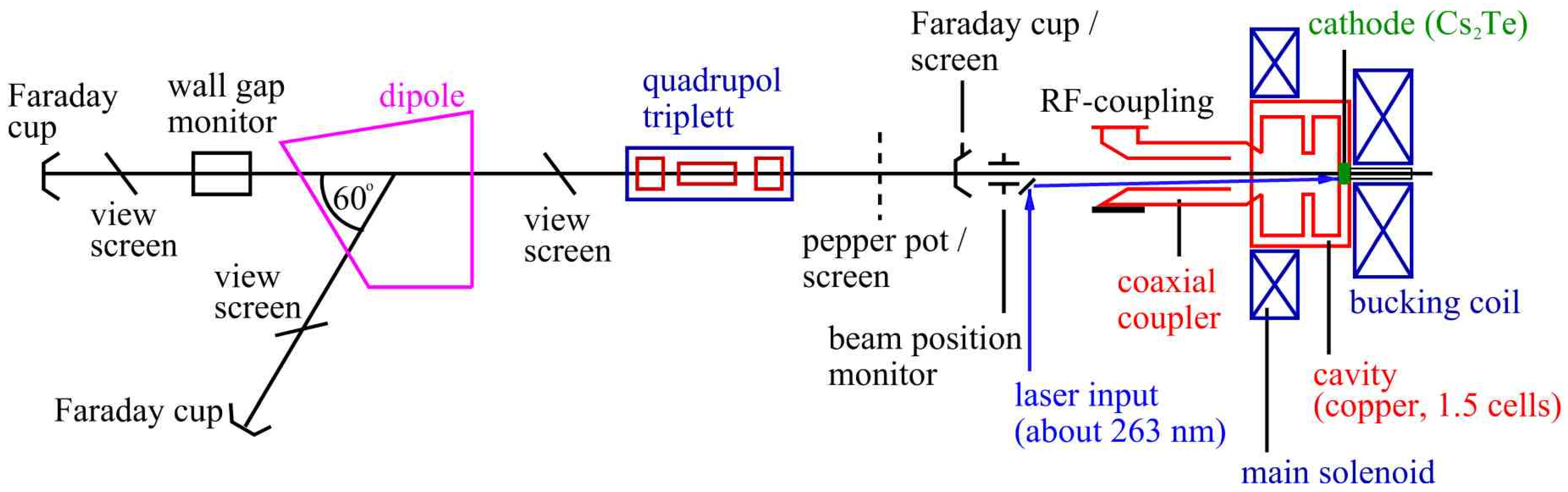
Measurement of the longitudinal phase space for the Photo Injector Test Facility at DESY Zeuthen, PITZ

D. Lipka, J. Bähr, I. Bohnet, K. Flöttmann, D. Richter*, F. Stephan, Q. Zhao
DESY, 22603 Hamburg and 15738 Zeuthen, Germany; *BESSY, 12489 Berlin, Germany

A photo injector test facility for free electron lasers (FEL) and the TESLA linear collider is under construction at DESY Zeuthen and will be commissioned in autumn 2001. The project is a common effort of a collaboration originated by the following institutions: BESSY Berlin, DESY (Hamburg and Zeuthen), Max-Born-Institut Berlin, Technical University Darmstadt.
It is funded partially by the HGF-Vernetzungsfonds.



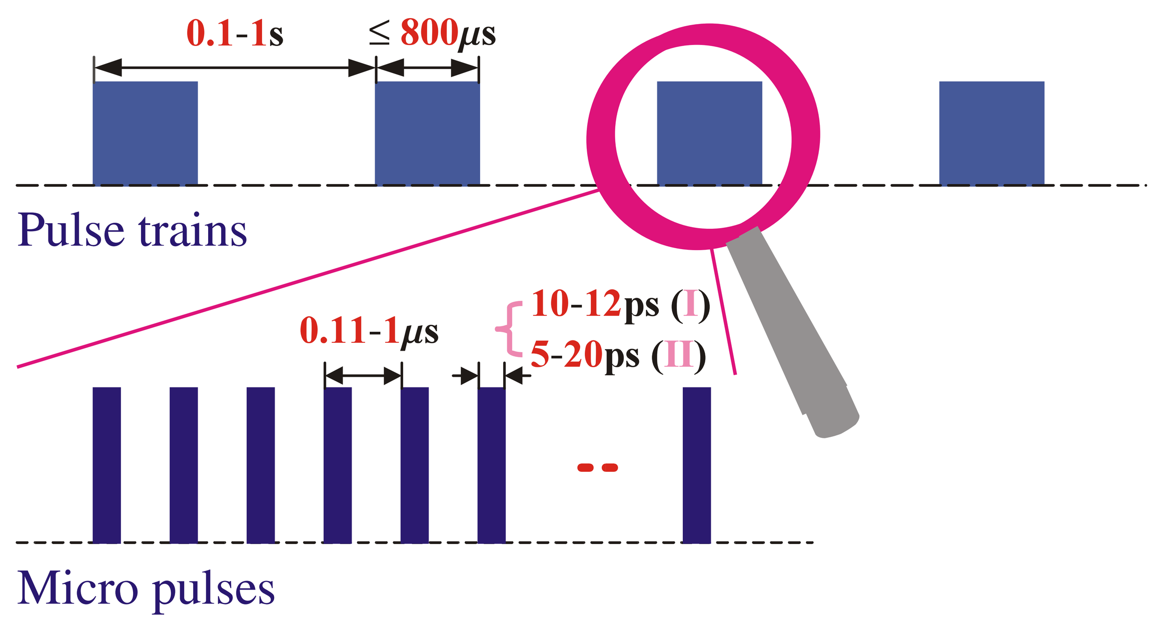
Main components of PITZ

- Photocathode: Cs_2Te
- Cavity: 1.5 cell geometry
- Laser: 263 nm
- RF-system: Klystron 5 MW...10 MW, 1.3 GHz
- Control system based on DOOCS (Distributed Object-Oriented Control System)
- Diagnostics section

Parameters of PITZ

- Charge per bunch: 1 nC
- Laser beam diameter on cathode: 1...10 mm diameter
- Electron beam energy: ~5 MeV (without booster), ~30 MeV (with booster)

Schematic time structures of the laser beam



I) Phase 1: gaussian shape s~6 ps

II) Phase 2: rectangular shape with rise and fall time < 1ps

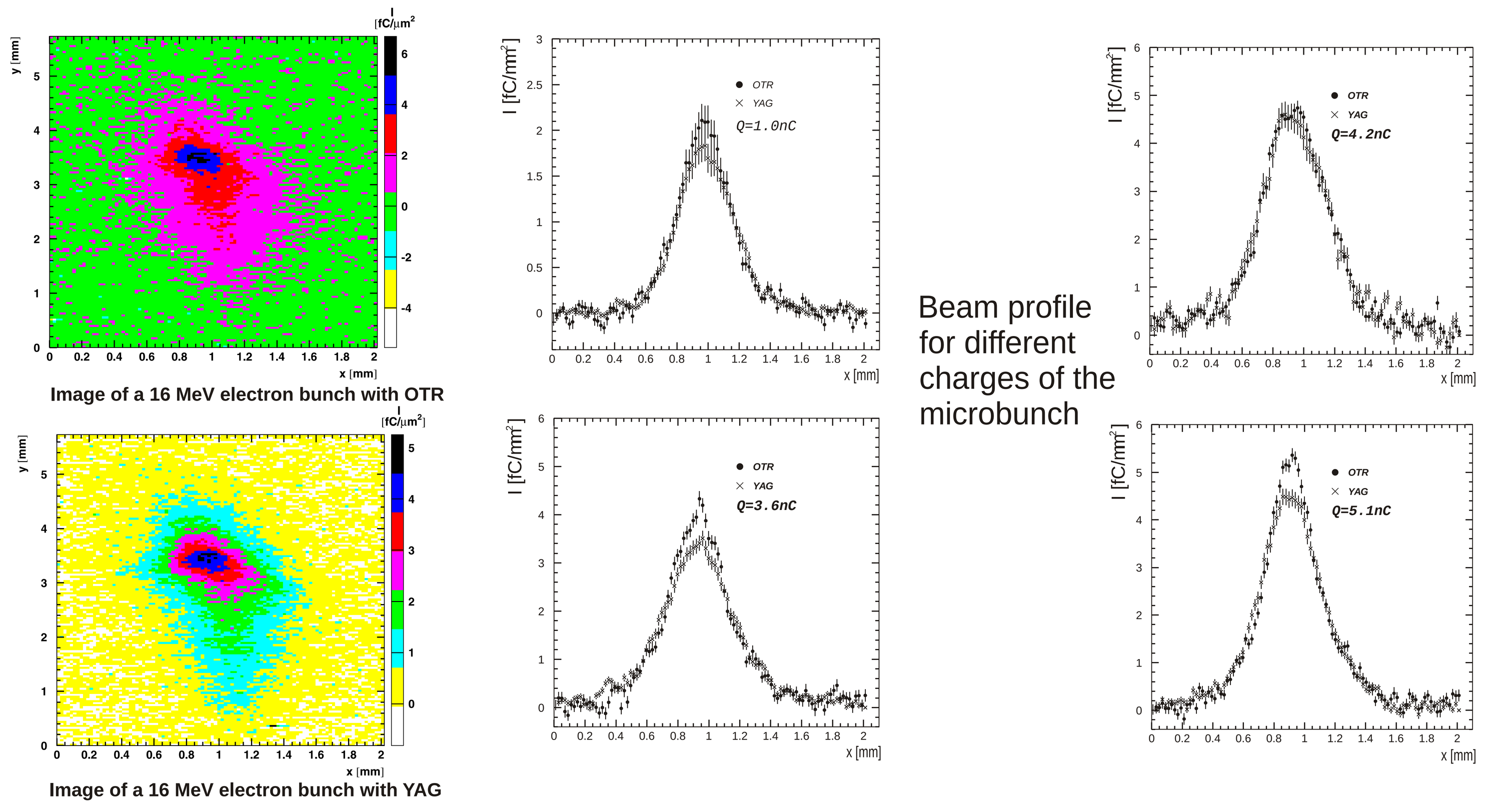
Diagnostics for longitudinal phase space and their properties

Measurement of momentum spread

Goal: measure the momentum spread Dp/p
Setup: dipole, YAG-screen, CCD-camera

- **Use of OTR-screen, saturation of YAG-screen**

At electron energies in the range of 5 MeV an OTR-screen does not deliver sufficient light intensity for single shot measurements. On the other hand, YAG-screens at high electron densities will reach saturation. For intensities below 4 fC/mm^2 no saturation is observed at TTF in comparison to OTR for 16 MeV electrons. The expected maximum intensity in the dispersive arm of our setup will be of the order of 1 fC/mm^2. The peak intensity of the YAG is lower than for the OTR image while the width of the distribution is broader.



- **Error of the momentum spread measurement**

Even neglegting not measured divergence and spotsize the uncertainty will be below 3% of the measured momentum spread

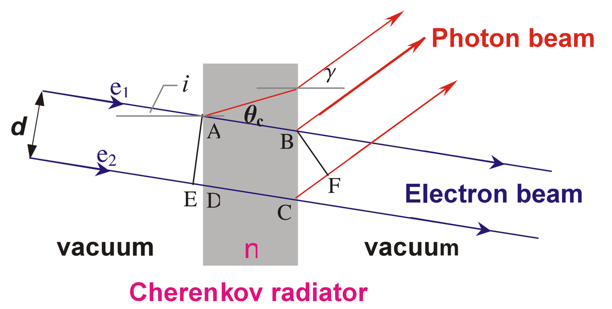
- **Momentum resolution**

Dependent of the transverse emittance at the entrance of the dipole the resolution will be below 0.5% of the electron energy

Measurement of bunch length

Goal: Convert the electron beam into a photon beam using Cherenkov radiators and measure the photon pulse length with a streak camera. The Cherenkov radiators (quartz, silica aerogel) are optimized to create a relativ small time spread.

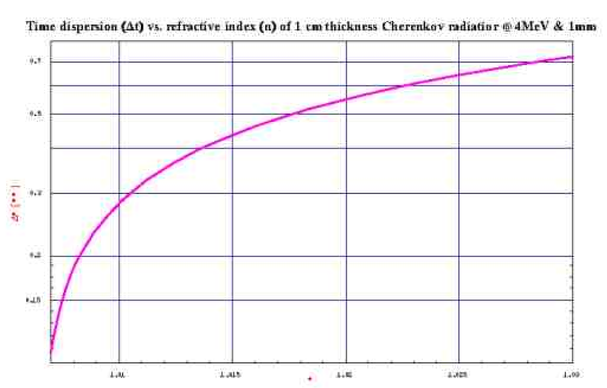
- **Time dispersion**



Schematic of the light production by two electrons in a bunch passing through a Cherenkov radiator (n).
=> Time dispersion ~ n, d

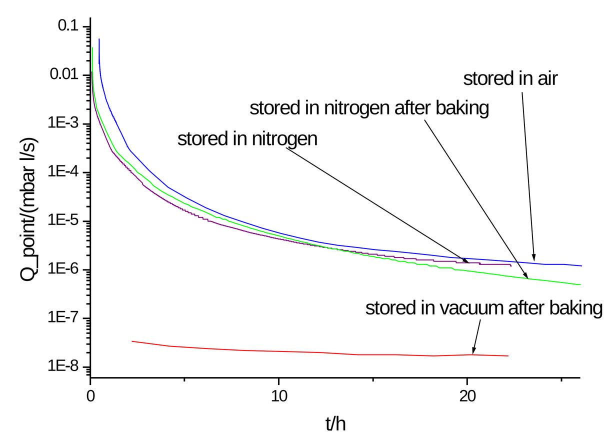
Time dispersion

$$\Delta t = \frac{d \cdot n \cdot \sin\theta_c}{c} = \frac{d}{c} \cdot \sqrt{n^2 - \frac{1}{\beta^2}}$$

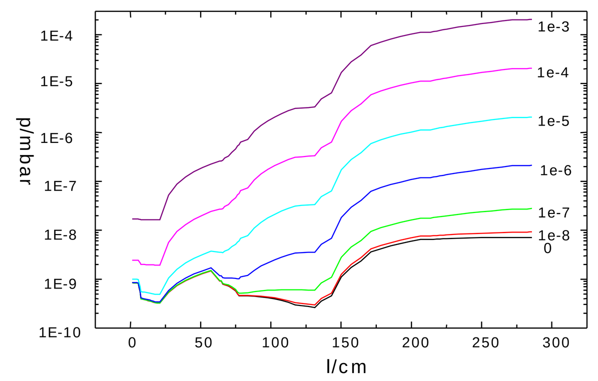


Time dispersion from Cherenkov radiator as a function of refractive index (electron energy: 4MeV, diameter of beam: 1mm).
=> To achieve high time resolution, one should choose a Cherenkov radiator with very low refractive index. => aerogel

- **Vacuum properties of Aerogel**

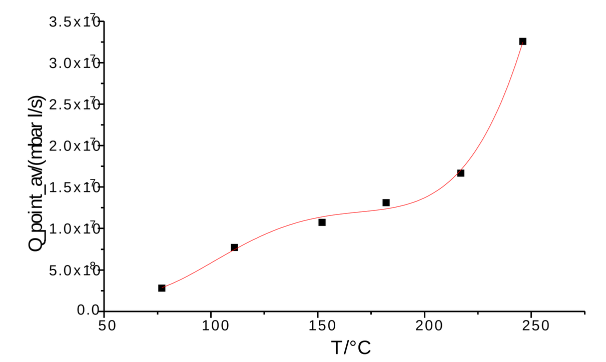


- **Influence of the gas load coming from the aerogel on the pressure distribution**

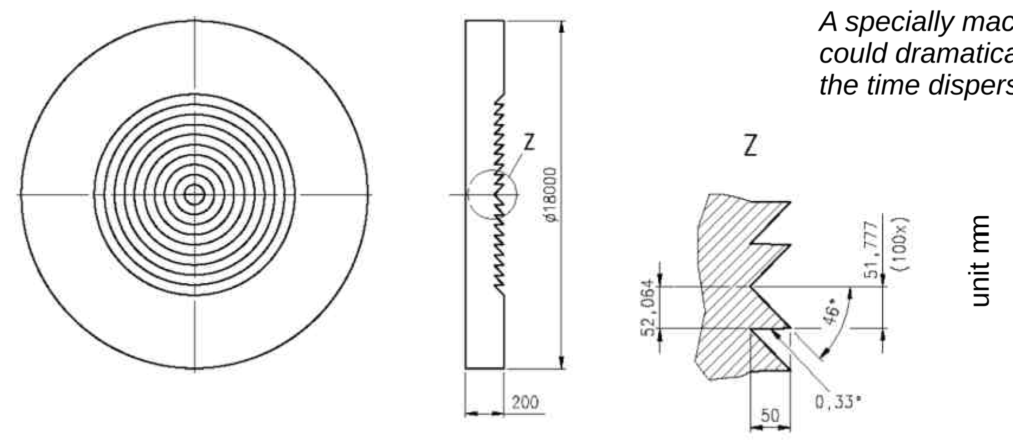


Assumption: pumping speed of the titanium sublimation pumps: 500 l/s
The tube to connect the pump with the electron beam tube was taken into consideration.

- **Av. gas load in a period of about 1 hour after a certain aerogel temperature is reached**

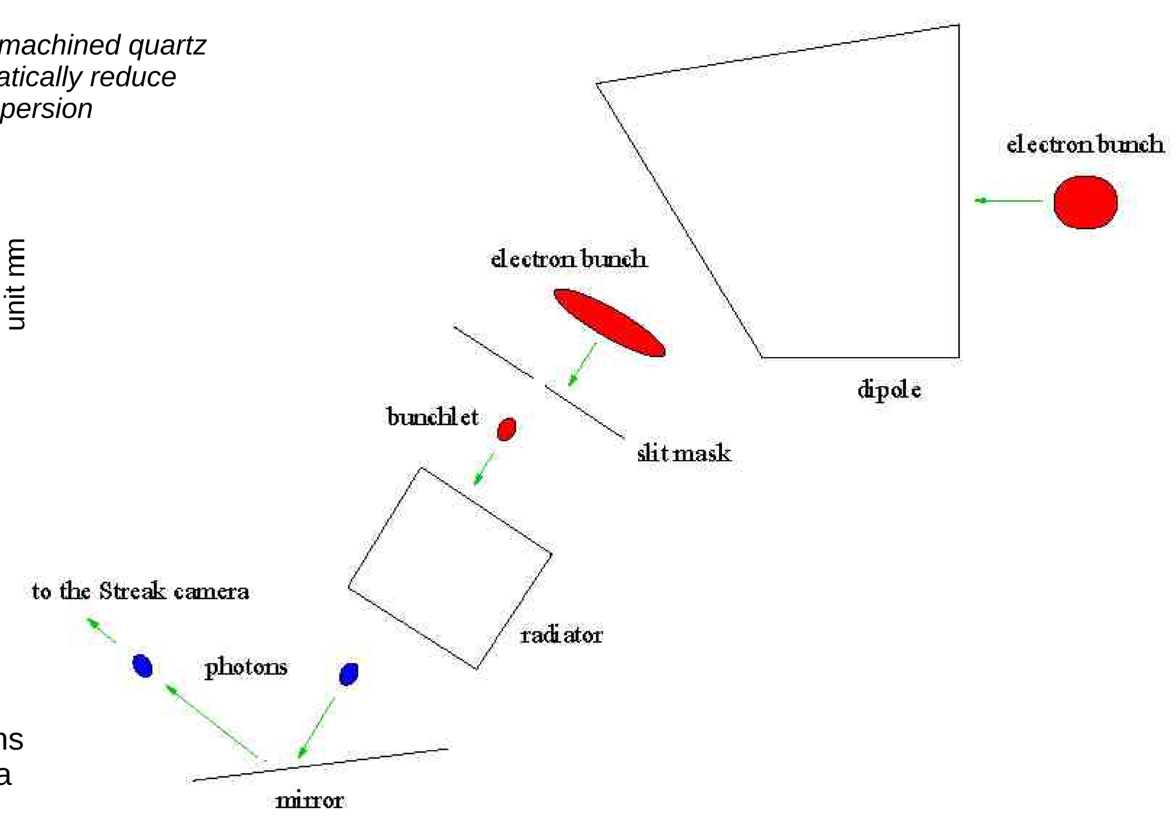


- **Fused silica**



A specially machined quartz could dramatically reduce the time dispersion

Measurement of longitudinal phase space



Goal: measure the longitudinal phase space (Dp/p, s_z)
Setup: dipole, slit, radiator and streak camera
Function:

- separation of momentum using dipole and slit
- transmit the electron bunch by a radiator in photons
- measure length of photon bunch by Streak camera
- measure complete longitudinal phase space by repeating the first three steps with different slit positions