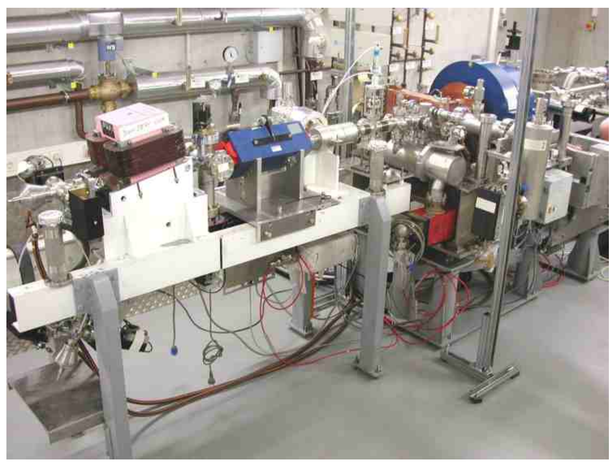
Measurement of the longitudinal phase space at the Photo Injector Test Facility at DESY Zeuthen, PITZ

D. Lipka, J. Bähr, K. Flöttmann, D. Richter*, F. Stephan

DESY, 22603 Hamburg and 15738 Zeuthen, Germany; *BESSY, 12489 Berlin, Germany

Description and scientific goals of the project

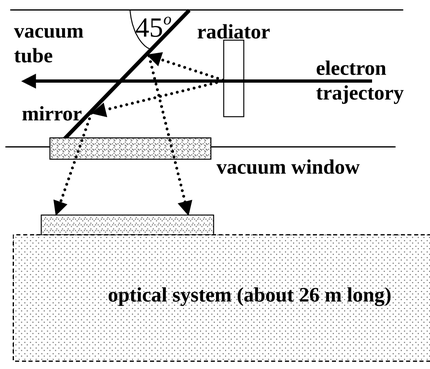


A Photoinjector Test Facility for Free Electron Lasers (FEL) and the TESLA linear collider has started operation at DESY Zeuthen. The project is a common effort of a collaboration consisting of the following institutions: BESSY Berlin, DESY (Hamburg and Zeuthen), Max-Born-Institut Berlin, Technical University Darmstadt
It is funded partially by the HGF-Vernetzungsfonds.

Measurement of 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:**



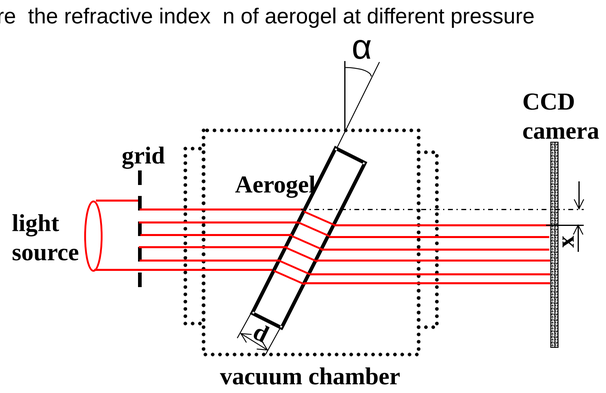
- **Radiator:** need small output angle
  - to match with the following optical system of about 26 m length
  - to avoid total reflection in the radiator
  - to reach good time resolution

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

Measurement of the refractive index of aerogel in vacuum

Goal: Measure the refractive index n of aerogel at different pressure

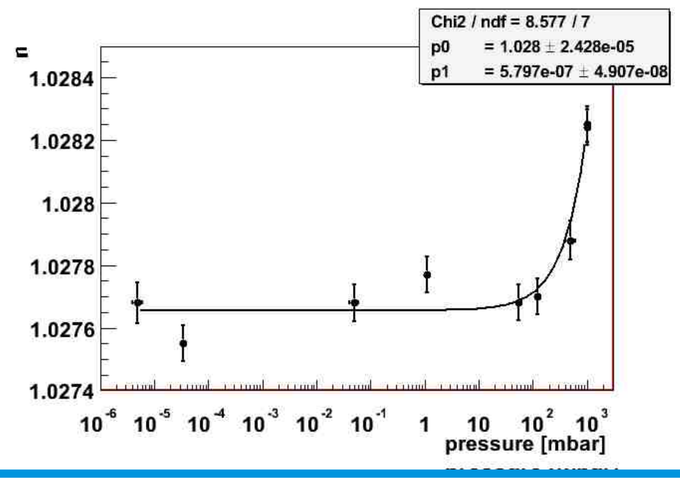
- **Setup:**



$$x = d\,\frac{\sin(\alpha-\beta)}{\cos\beta}$$

$$\sin\beta = \frac{\sin\alpha}{n}$$

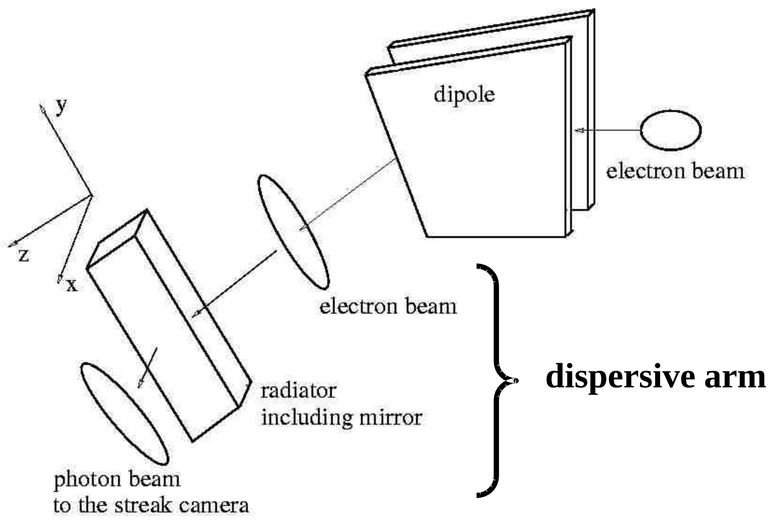
- **Result at different pressure:** the refractive index of aerogel, with the same properties as that used in the ring imaging Cherenkov detector at the HERMES experiment in DESY Hamburg, is constant up till the pressure of 1 mbar, above it increases linearly



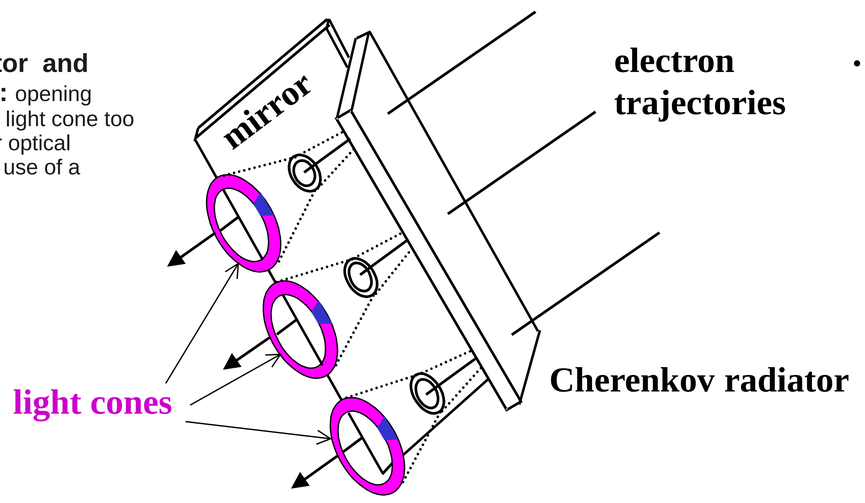
Longitudinal phase space

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

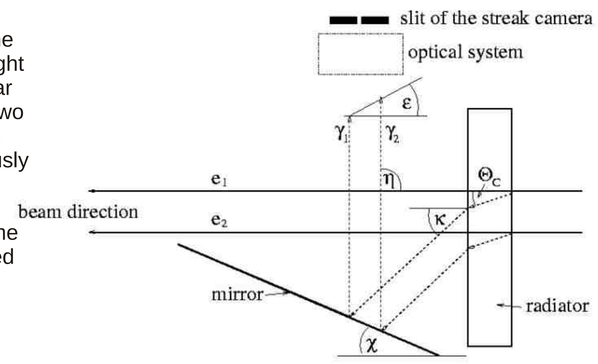
- **Setup:**



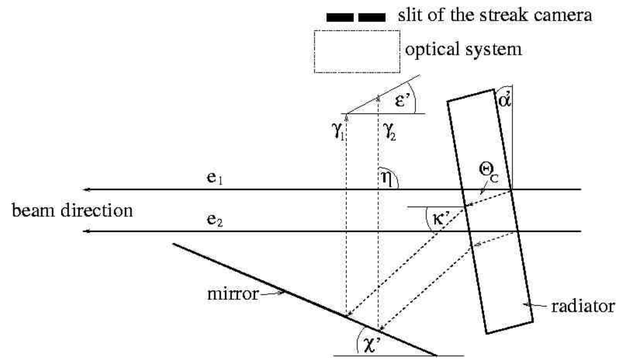
- **Radiator and mirror:** opening angle of light cone too large for optical system, use of a fraction



- **Radiator aerogel:** mirror is tilted so that one part of the Cherenkov light is reflected perpendicular to the beam direction. Two electrons which crosses the radiator simultaneously produce photons with a time difference at the vacuum window, the time difference is represented with the angle ε



- **Radiator quartz:** quartz will be used too because of its vacuum stability. To avoid total reflection quartz has to be tilted, it results in a larger time difference than for aerogel.



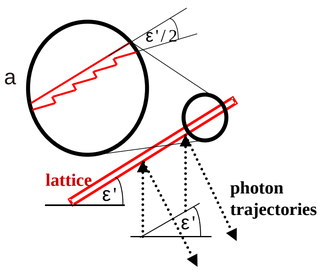
$$\kappa' = \arcsin\left(n\,\sin(\Theta_C - \alpha')\right) + \alpha'$$

$$\chi' = \frac{1}{2}\left(90^o - \kappa'\right)$$

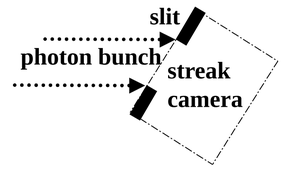
$$\tan\varepsilon' = \frac{\sin\alpha' + \sin(\kappa' - \alpha')}{\cos(\kappa' - \alpha')}$$

- **Decrease time difference:** 3 options:

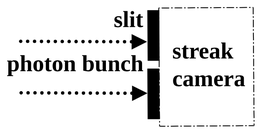
Option a: using of a special shaped reflecting lattice



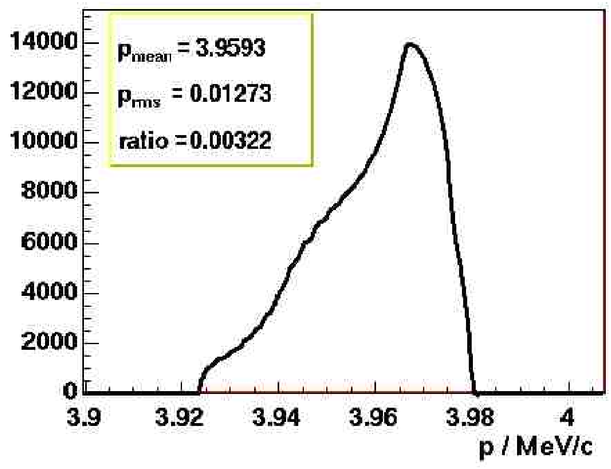
Option b: turn the streak camera that the photons hit the internal cathode simultaneously



Option c: transverse cut of the photon beam size with the slit of the streak camera



- **Measurement of momentum:**
  - Momentum distribution measured with YAG screen
  - charge of the electron bunch 30 pC
  - phase between RF and laser pulse for high electron momentum optimized
  - the measured rms momentum spread of about 13 keV/c represents the resolution limit of the spectrometer due to an optical mismatch which will disappear at higher charges



- **Radiator parameters:**
  the table shows the described angles and calculated time resolutions for both considered radiators at a momentum of 4 MeV/c
  - thickness d is chosen to provide the same amount of emitted photons
  - length of one step of the lattice is 50 µm
  - slit width is 100 µm

					Time resolution / ps				
Name	**n**	**d / mm**	**χ' / °**	**ε' / °**	**difference light – electron**	**angle distribution of electron bunch**	**multiple scattering**	**lattice**	**cut with slit**
aerogel	**1.01**	**20.0**	**43.24**	**3.49**	**0.25**	**0.26**	**3.98**	**0.01**	**0.02**
	1.03	**2.0**	**38.91**	**12.19**	**0.30**	**0.30**	**0.43**	**0.04**	**0.07**
	1.05	**1.0**	**36.46**	**17.07**	**0.29**	**0.29**	**0.35**	**0.05**	**0.10**
quartz	**1.46**	**0.1**	**10.16**	**64.04**	**0.37**	**0.37**	**0.41**	**0.15**	**0.69**

Best time resolution obtained with aerogel n = 1.05. Fused quartz will be used too.

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