Bunch length measurements at BC2 using coherent far-infrared radiation

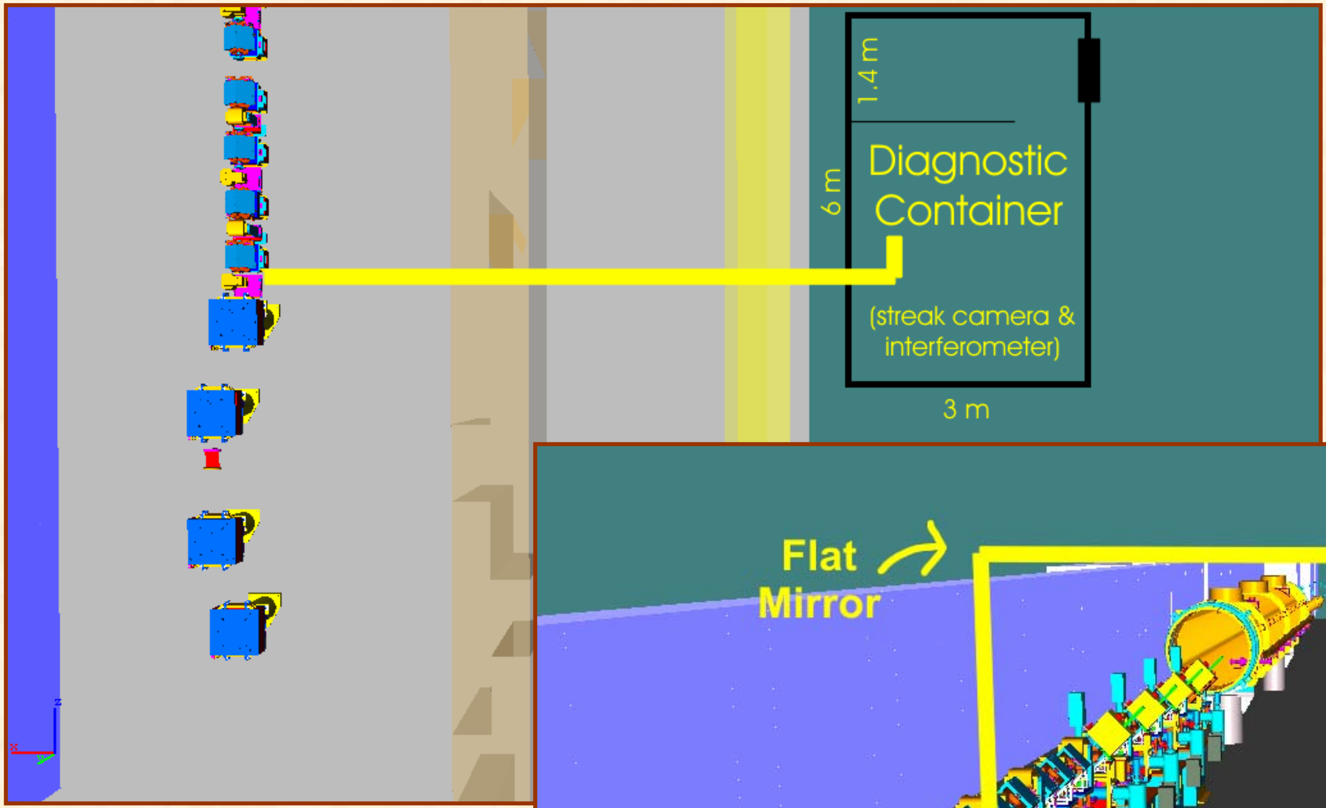
TESLA Collaboration Meeting

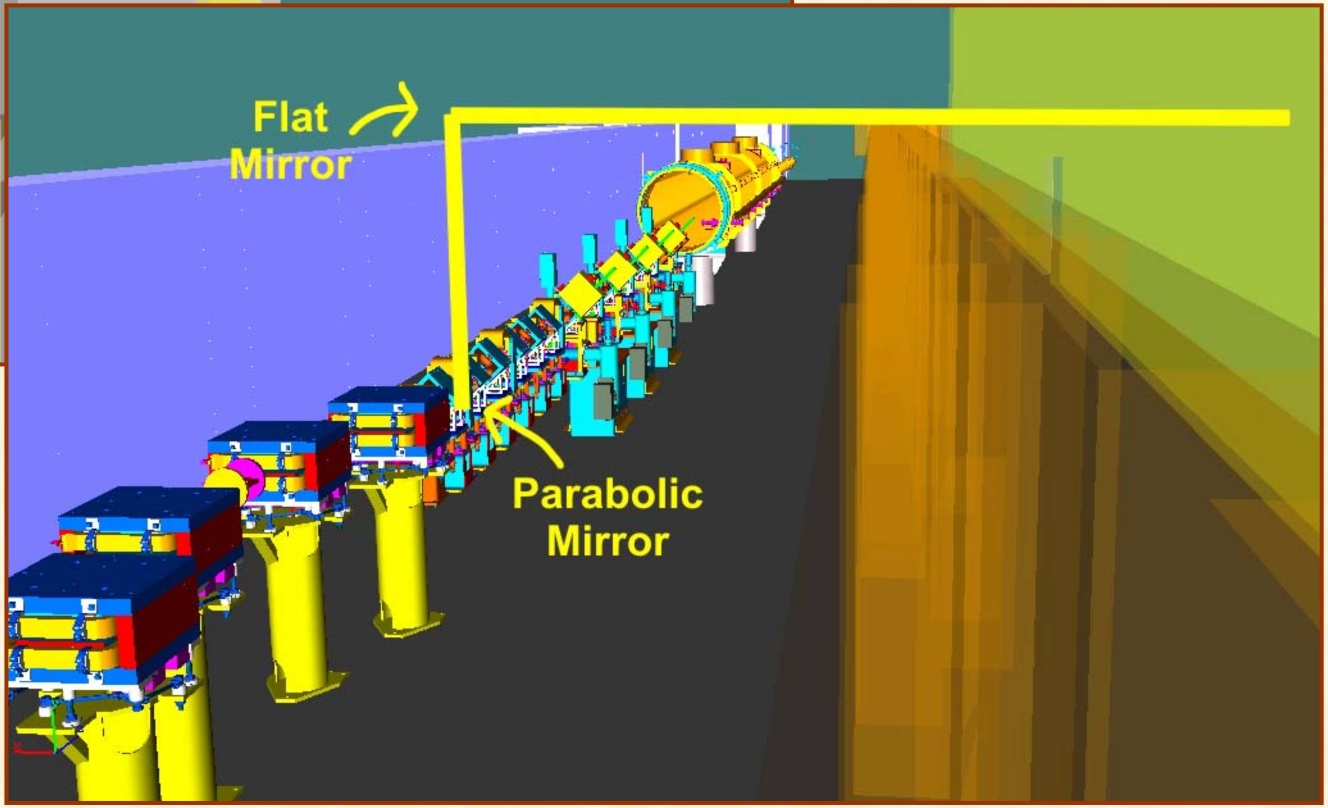
DESY Zeuthen 21-23/1/2004

Oliver Grimm

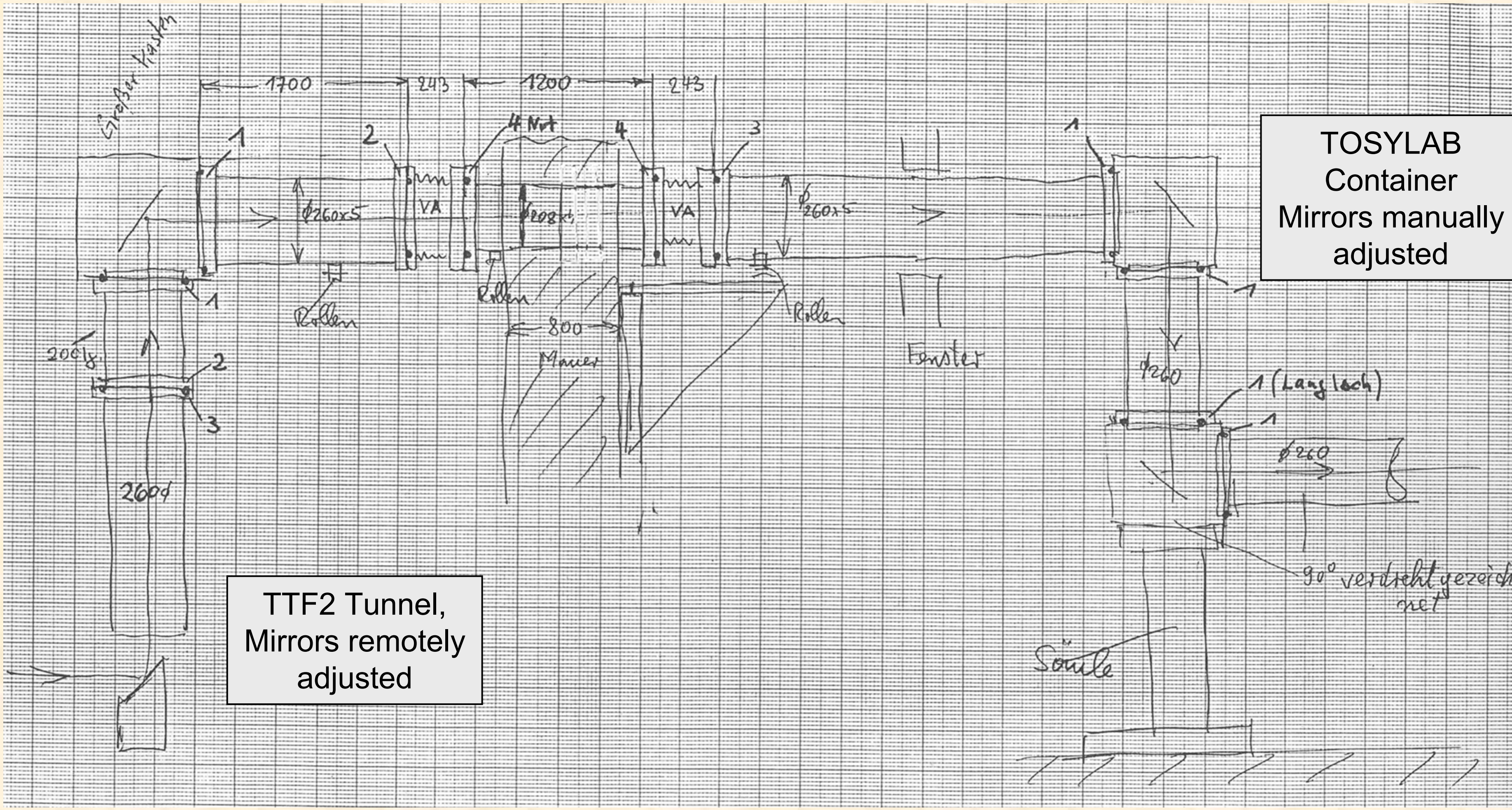
1. Status of beam line at BC2
2. Some illustrations of expected spectra

Layout of BC2 Infrared & Optical Beam Line





Design of Beam Line



Beam pipes Ø260×5, over radiation protection wall Ø208×4.
Projected sizes: Parabolic mirror Ø100, first flat mirror Ø177, remaining mirrors Ø108.

Features of Beam Line

- Prepared for Nitrogen flushing (probably from TOSYLAB to tunnel)
- Interferometer will also be included in Nitrogen shield
- *Partly* prepared for later evacuation to fore-vacuum

- Parabolic mirror mounted on rotation stage (remote controlled, to facilitate adjustment and to compensate offsets from nominal electron beam trajectory)
- Parabolic mirror focus can be moved by +5 cm/-2 cm (manually)

- Large flat mirror angle adjustable (remotely)
- Small flat mirror angles in container manually adjustable (can also be moved within their planes)

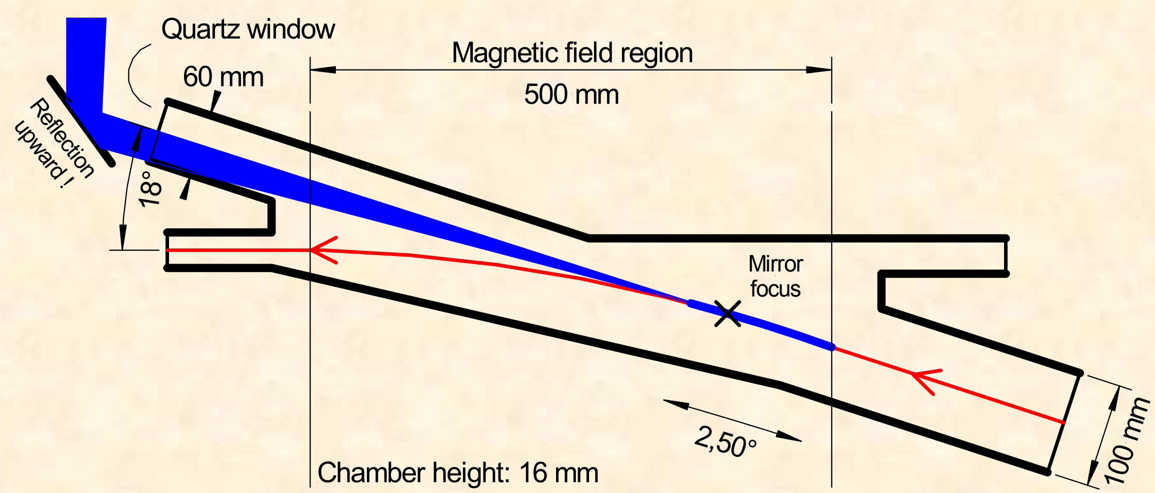
- Crystalline Quartz window (z-cut, clear aperture Ø 60 mm)

<u>Mirror parameters</u>

- Parabolic mirror: Ø 100 mm projected, Aluminium, 8 λ, better at centre
- Large flat mirror: Ø 250 mm, Aluminium, 1 λ
- Small flat mirrors: Ø 152.4 mm, Aluminium coating, λ/5

Adjustment of mirrors

- Parabolic mirror focal point initially set to 5 cm from beginning of bending arc (not critical to the millimetre level)
- Laser beam guided backwards vertically down on parabolic mirror. Verticality adjusted with mechanical marks.
- Expanded laser beam (Ø 50 mm) used to check focal point
- Height and orientation of rotation plane adjusted to nominal beam plane using several marks by survey department on the tunnel wall and by turning of the parabolic mirror
- Optimum angular position of parabolic mirror determined by maximizing signal in operation, flat mirror adjustment with optical synchrotron radiation

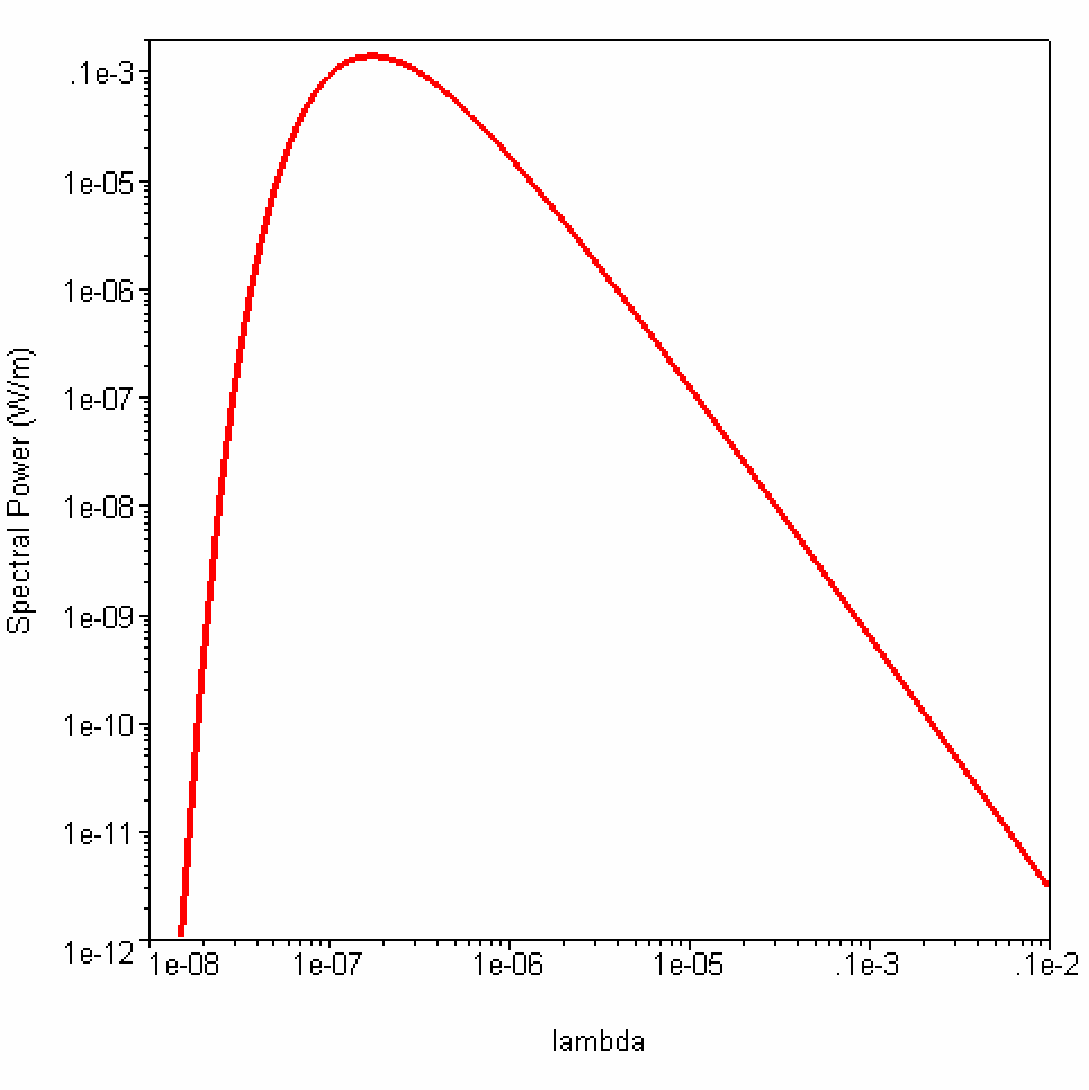


Status of beam line construction

- Double I-beam carrier system ready
- Aluminium beam pipes in hand (Ø260 black anodized, Ø208 grey anodized, will be painted black)
- Mirror chamber parts, flanges etc. currently machined or already in hand (will be black anodized or painted as far as practical)
- Carrier system including large mirror chamber planned to be installed first week of February (or later if closing of tunnel roof is delayed)
- Remaining components mid February
- Small flat mirrors in hand
- Delivery of parabolic and large flat mirror beginning of March (??) (company tries to deliver earlier)
- Construction by Otto Peters, Manufacturing supervised by Mathias Böttcher (ZM31)

Some components

Spectrum of incoherent synchrotron radiation at BC2



- R=1.6 m (130 MeV, 18°, 0.27 T)
- Single electron, circular motion

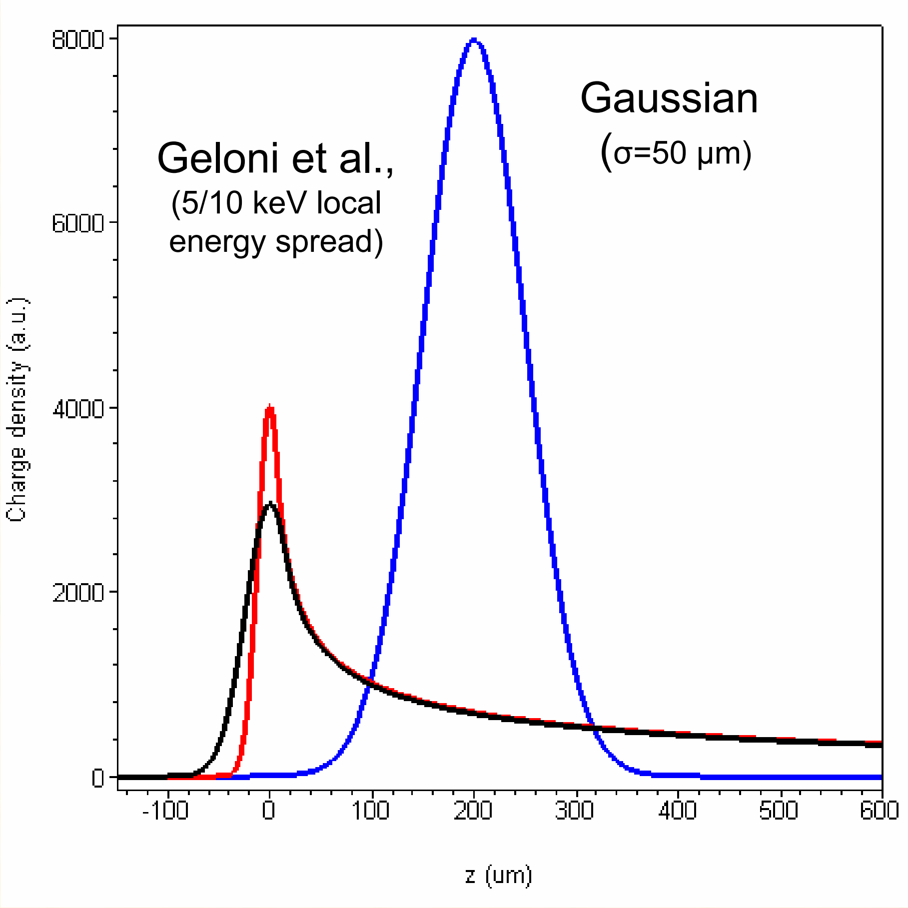
$$\left(\frac{\mathrm{d}P}{\mathrm{d}\lambda}\right)_0 = \frac{\sqrt{3}e^2 c}{4\pi\varepsilon_0}\frac{\gamma\lambda_c}{R\lambda^3}\int_{\lambda_c/\lambda}^{\infty} \mathrm{K}_{5/3}(x)\mathrm{d}x,$$

$$\lambda_c = \frac{4\pi R}{3\gamma^3}$$

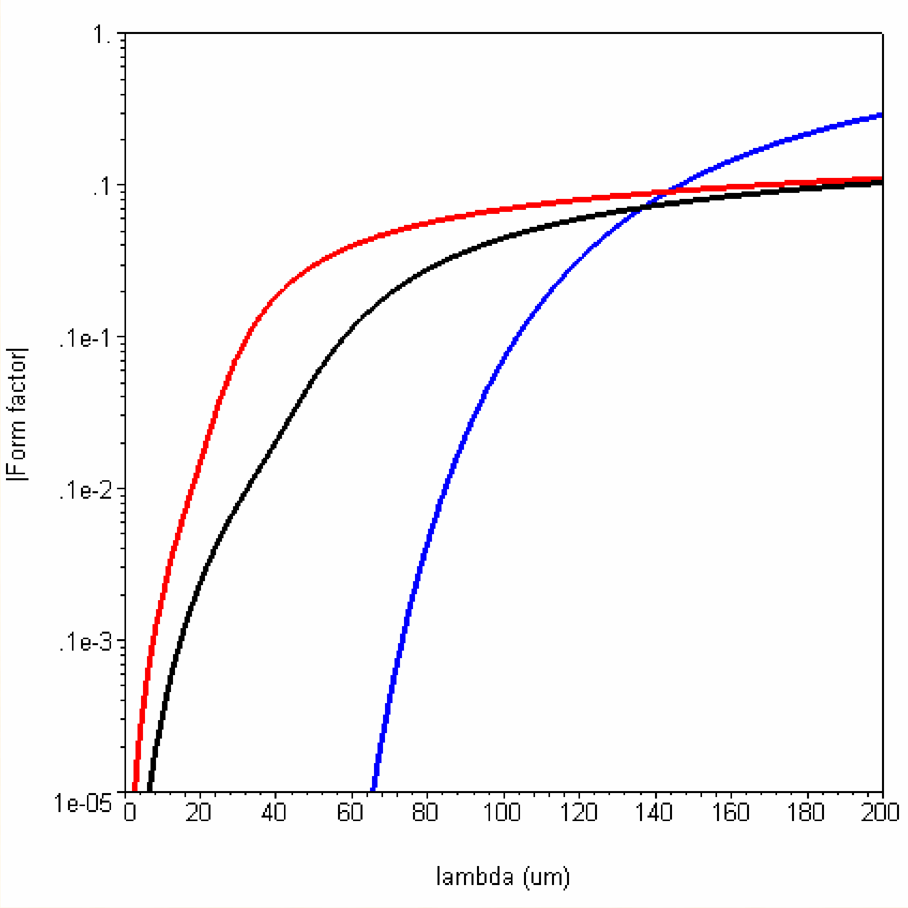
Bunch form factor (1-dimensional)

$$F(\lambda) = \int e^{2\pi i z/\lambda} N S(z)\,\mathrm{d}z, \qquad \lim_{\lambda\to\infty} |F(\lambda)| = 1, \quad \lim_{\lambda\to 0} |F(\lambda)| = 0$$

Longitudinal bunch shape S(z)

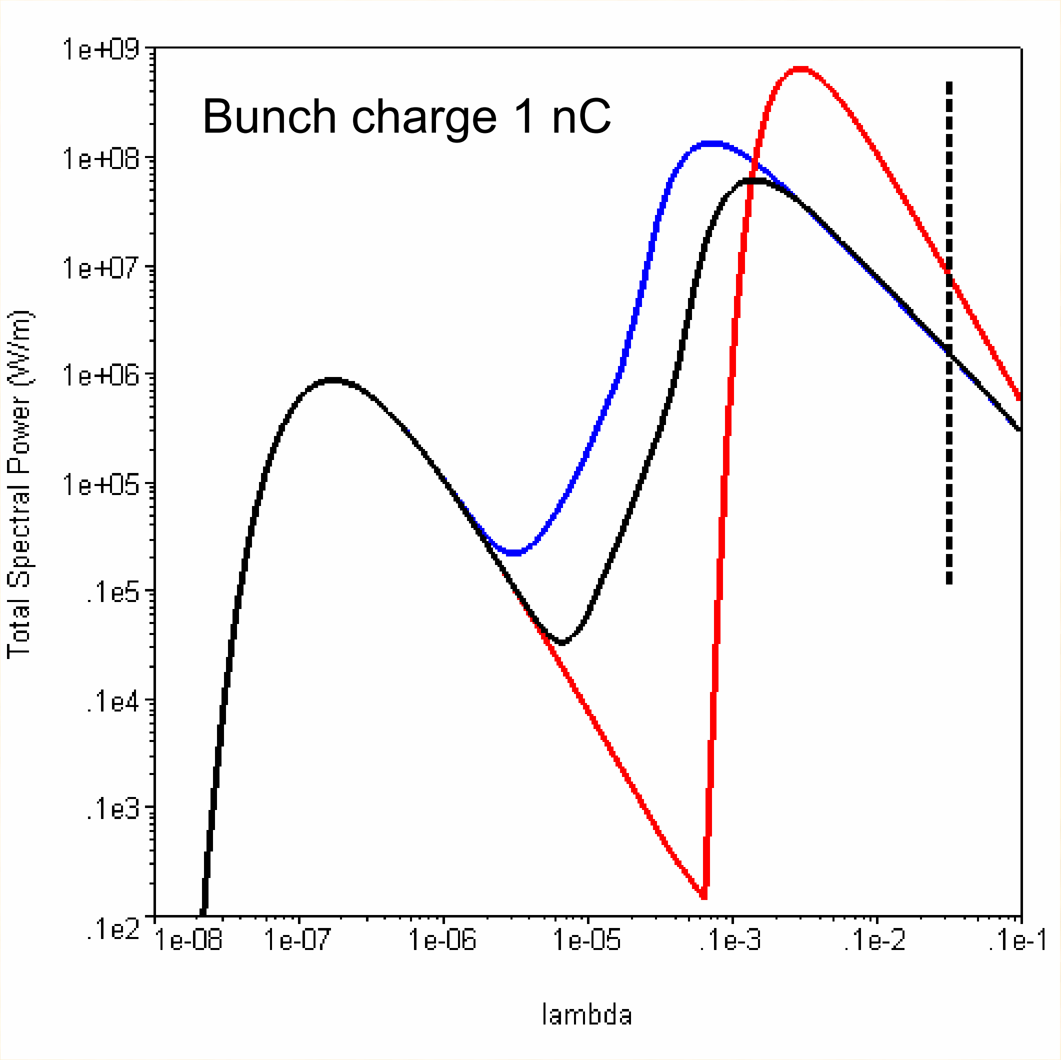


Absolute value of form factor



see: G. Geloni et al., DESY 03-031 (March 2003)

Resulting total synchrotron radiation spectrum

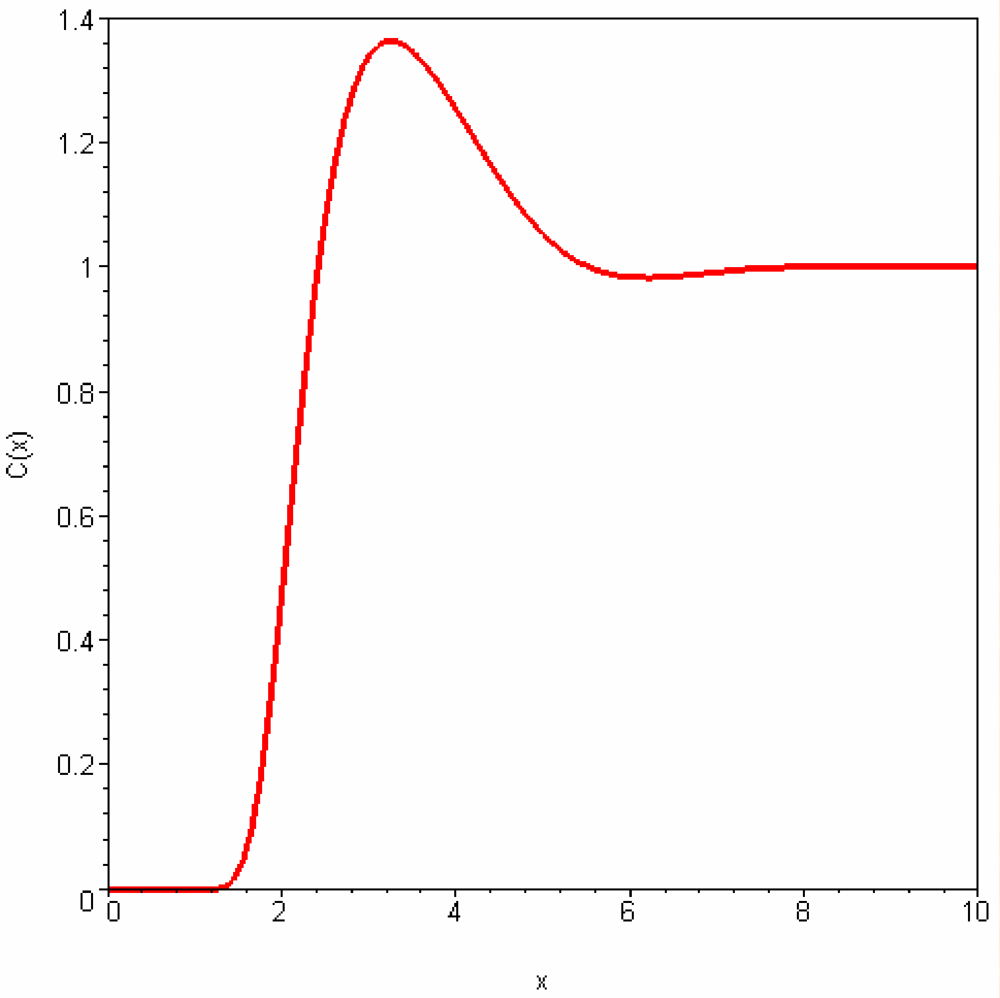


$$\left(\frac{\mathrm{d}P}{\mathrm{d}\lambda}\right)_{\text{total}} = \left(\frac{\mathrm{d}P}{\mathrm{d}\lambda}\right)_0 \cdot \left(N + N(N-1)\left|F(\lambda)\right|^2\right)$$

‚Typical' chamber cut-off for 16 mm vacuum chamber height (see, e.g., R.L. Warnock, SLAC-PUB-5375 (November 1990))

$$\lambda_{cut} = 2h\sqrt{\frac{h}{R}} \approx 3.2\,\mathrm{mm}$$

Chamber cut-off function

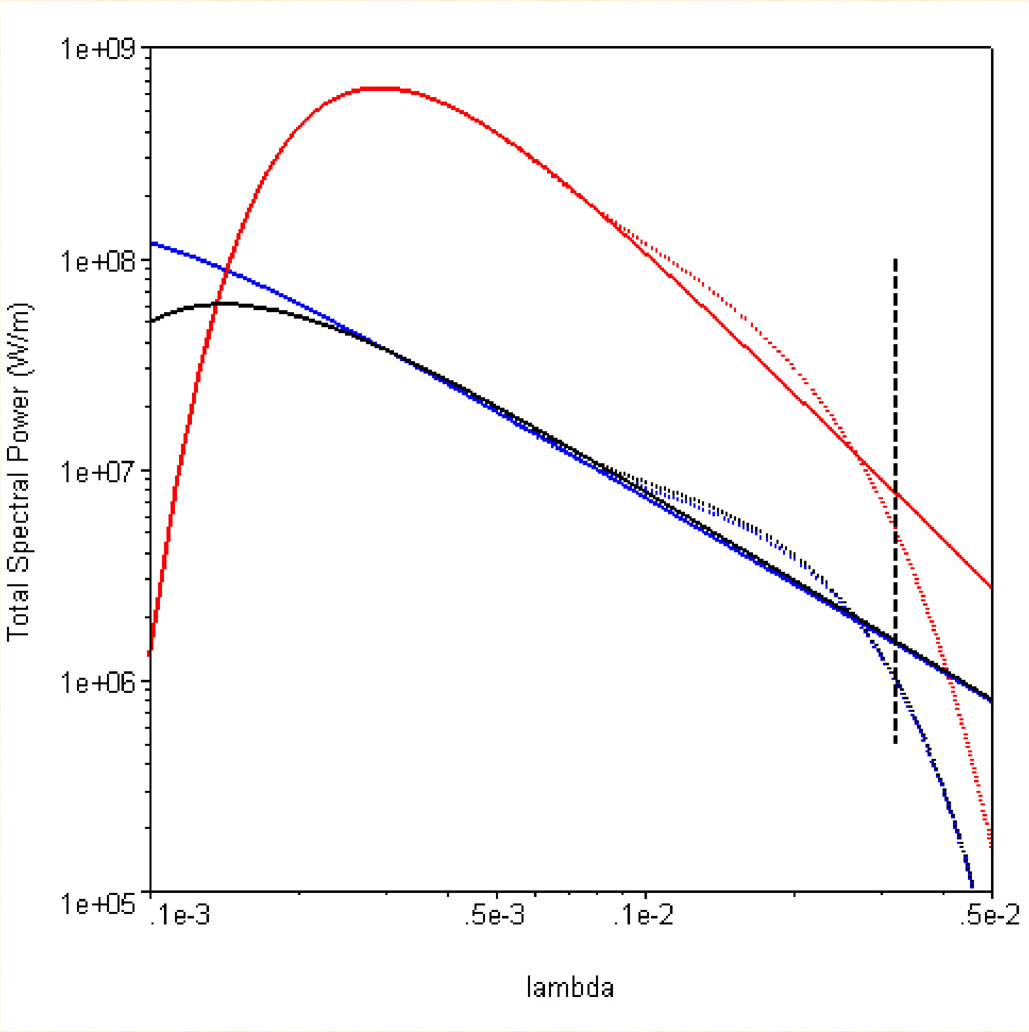


Calculated for circular, ultra-relativistic motion with bending radius R in a vacuum chamber of height h with infinite, perfectly conducting chamber walls.

$$x = h \cdot \sqrt[3]{\frac{(2\pi)^2}{\lambda^2 R}}$$

from: M. Dohlus, T. Limberg, Nucl.Instr.Meth. **A407**, 278(1998)

Total synchrotron radiation spectrum including chamber cut-off



- Existing Martin-Puplett Interferometer: (0.1–few(?)) mm
- Absolute power hard (impossible?) to measure, need to rely on *shape*
- Finite magnetic field (edge effects) not taken into account
- Beam transport line needs to be accounted for (GLAD?)

1. Need to access shorter wavelengths
2. Full, independent bunch shape reconstruction (Kramers-Kronig analysis) certainly difficult