

Coherent Diffraction Radiation (CDR) for short bunch length diagnostics

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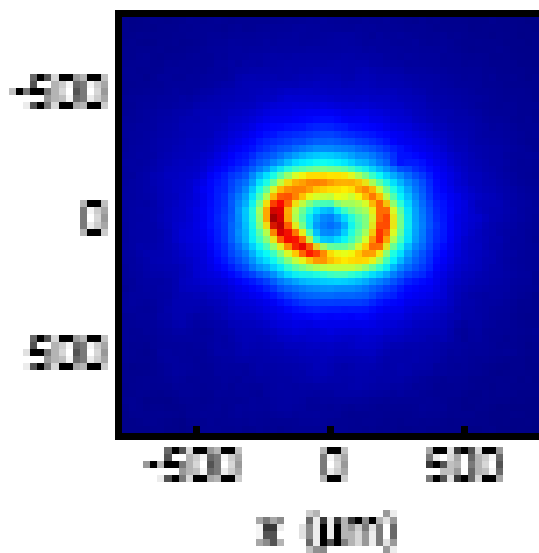
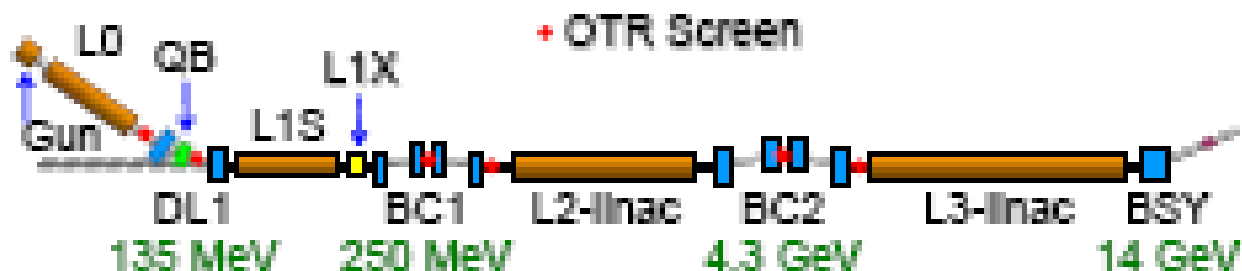


Bunch length for various accelerators

ILC	500fs
CLIC	130fs
XFEL	80fs
LCLS	75fs



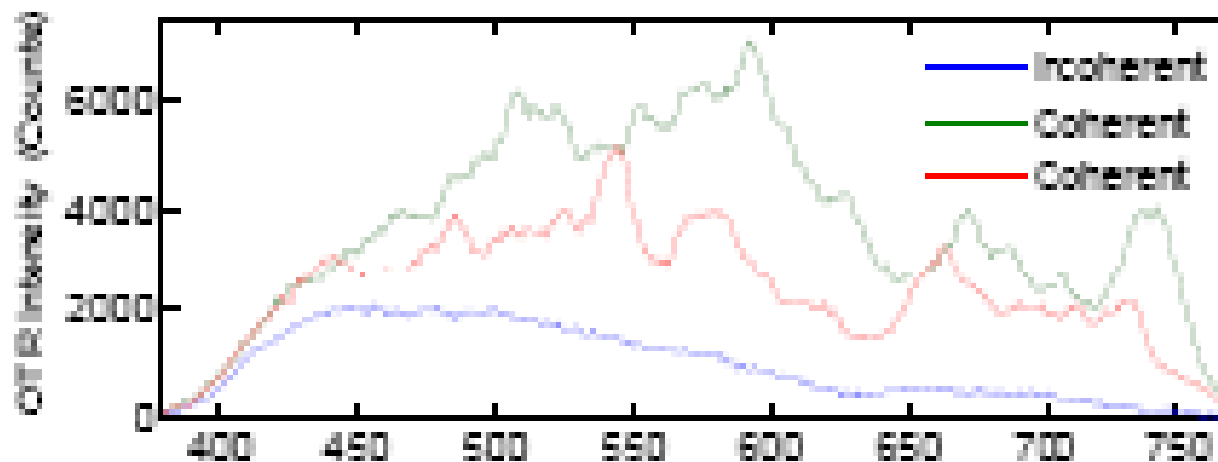
Coherent Optical Transition Radiation Observation at LCLS



H. Loos, et al., SLAC-pub-13395

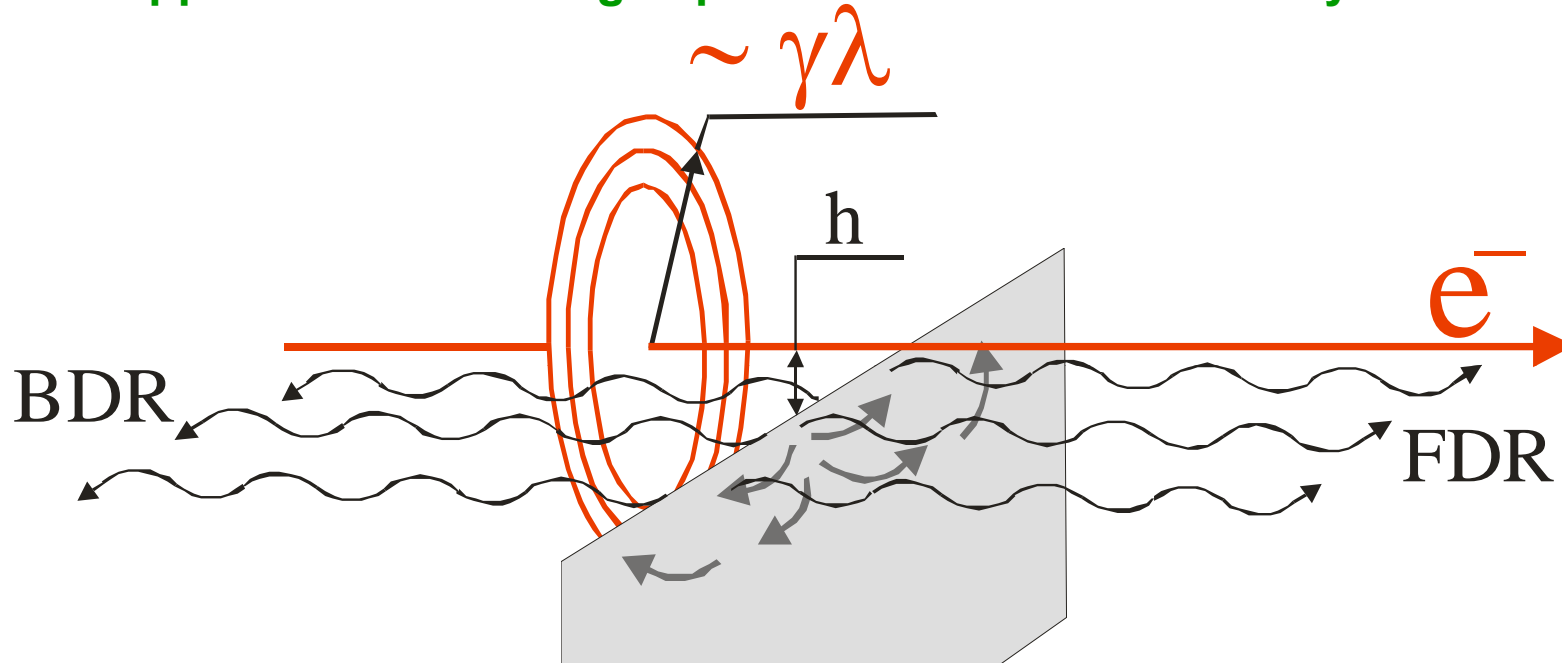


COTR spectra



- The form of the coherent spectrum fluctuates from shot to shot
- Existence of spikes in the spectrum suggests that there are a few microbunches in the longitudinal particle distribution
- The coherent part of the OTR intensity could be much higher than the incoherent one

It appears when a charged particle moves in the vicinity of a medium



**For our setup at CTF3, $h \approx 15 \text{ mm} \ll \gamma\lambda = 1175 \text{ mm}$
for $\gamma = 235$ and $\lambda = 5 \text{ mm}$.**

Impact parameter, h , – the shortest distance between the target and the particle trajectory

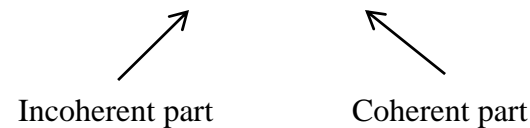
$$h \leq \gamma\lambda$$

λ - observation wavelength
 $\gamma = E/mc^2$ – Lorentz - factor

- **Non-invasive method**
- **Instantaneous emission**
- **Single shot measurement option**
- **Large emission angles ($0 \sim 180^\circ$)**
- **Single electron spectrum is predictable**
- **Relatively inexpensive and easy in use**
- **No theoretical resolution limit**
- **Gives information about the longitudinal profile**

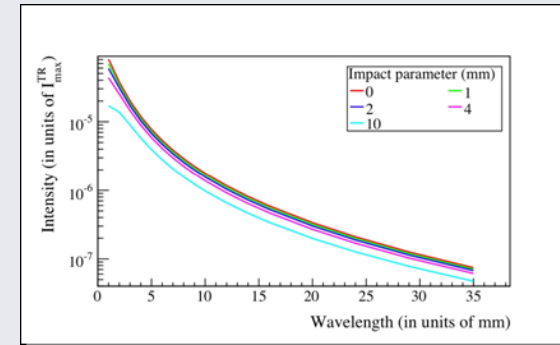
- Coherent radiation:

$$S(\omega) = [N_e + N_e(N_e - 1)F(\omega)] S_e(\omega)$$

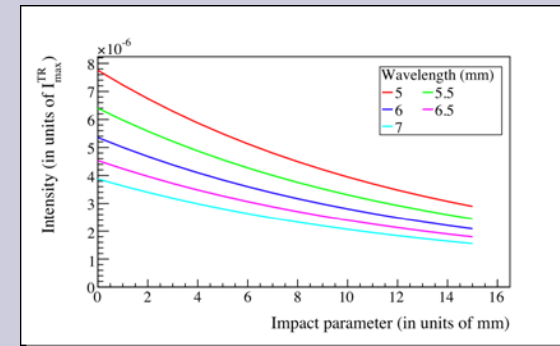


- $S(\omega)$ is **the signal**, known from the experiment
 - this can be obtained by using an interferometer
- $S_e(\omega)$ is **the single electron radiation**, which should be predictable from theory
- N_e is the **number of electrons**, known from the experiment
- $F(\omega)$ is the **longitudinal bunch form factor**, which is the **measurement purpose**.
 - the bunch form factor is just the Fourier transform of the spatial charge distribution in space
 - the **longitudinal bunch profile** can therefore be reconstructed using Kramers-Kronig relation

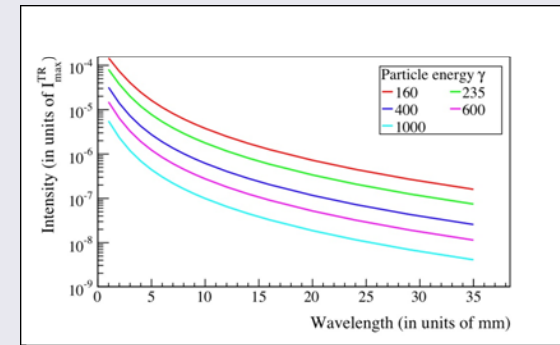
- Diffraction radiation spectra with [REDACTED]
 - needed in the de-convolution of the spectral information (see previous slide)
 - $S(\omega) = N_e^2 F(\omega) S_e(\omega)$



- Intensity dependence on impact parameter ($\gamma=235$):
 - at a considerable distance from the beam the signal level is still high
 - **non-invasive measurements**

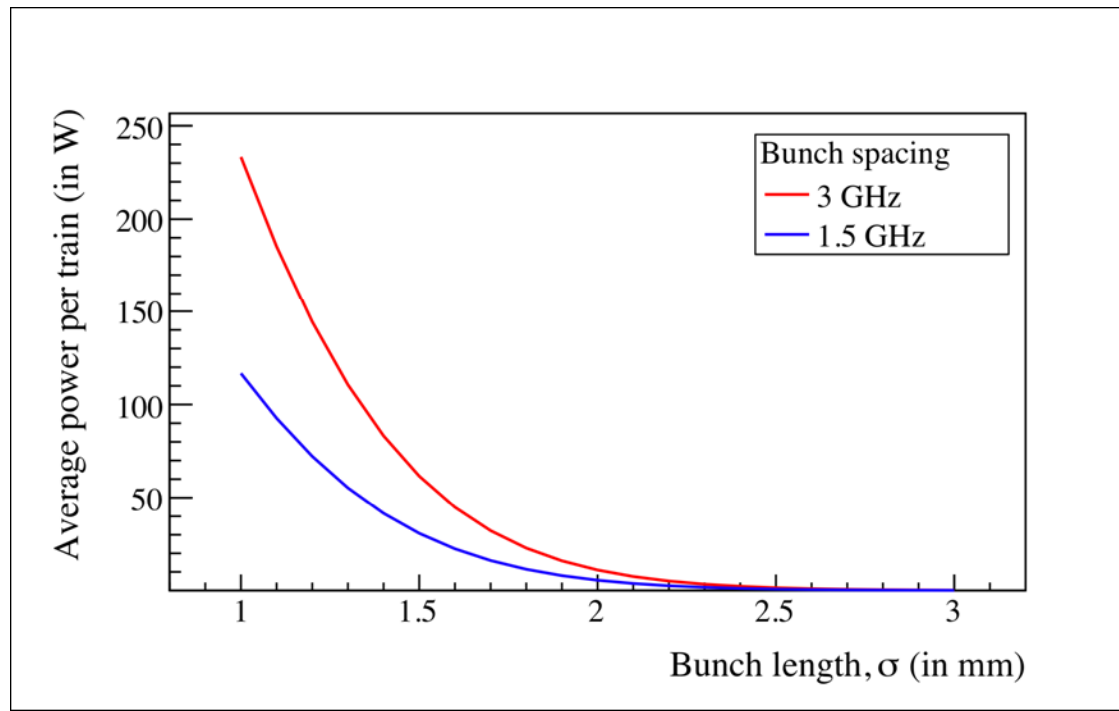


- Diffraction radiation spectra for different beam energies
 - zero-impact parameter
 - for higher energies the intensity increases



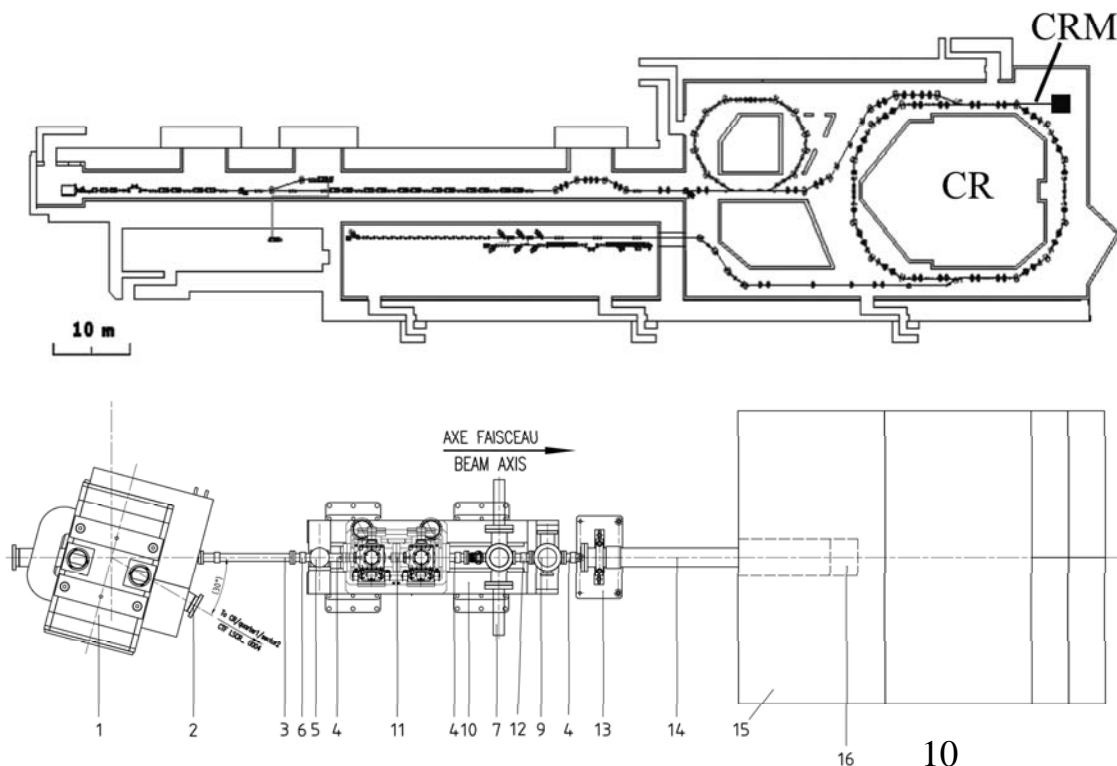
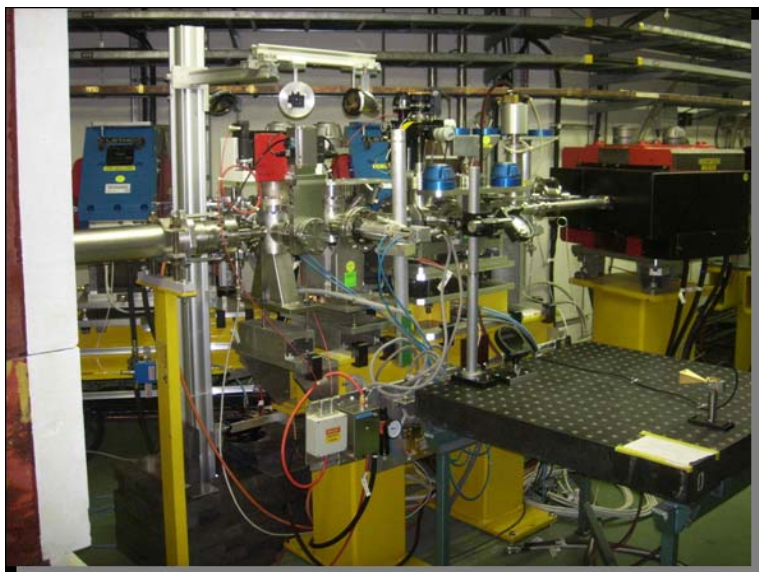
Average power emitted per train by DR for DXP19 and impact parameter ($h=10$ mm):

- For a 2mm Gaussian beam the energy emitted into the detector is 3.6×10^{-9} J/bunch
- The average power per train is 5.5W and 11.0W for 1.5GHz and 3GHz operation
- For 2.5×10^{10} electrons per bunch the energy contribution per electron is 0.9eV



CDR setup:

- Installed the vacuum hardware in the CRM line at CTF3
- The technical drawing of the CRM line (bottom right) shows the CDR setup (11) just in front of the OTR screen (7)



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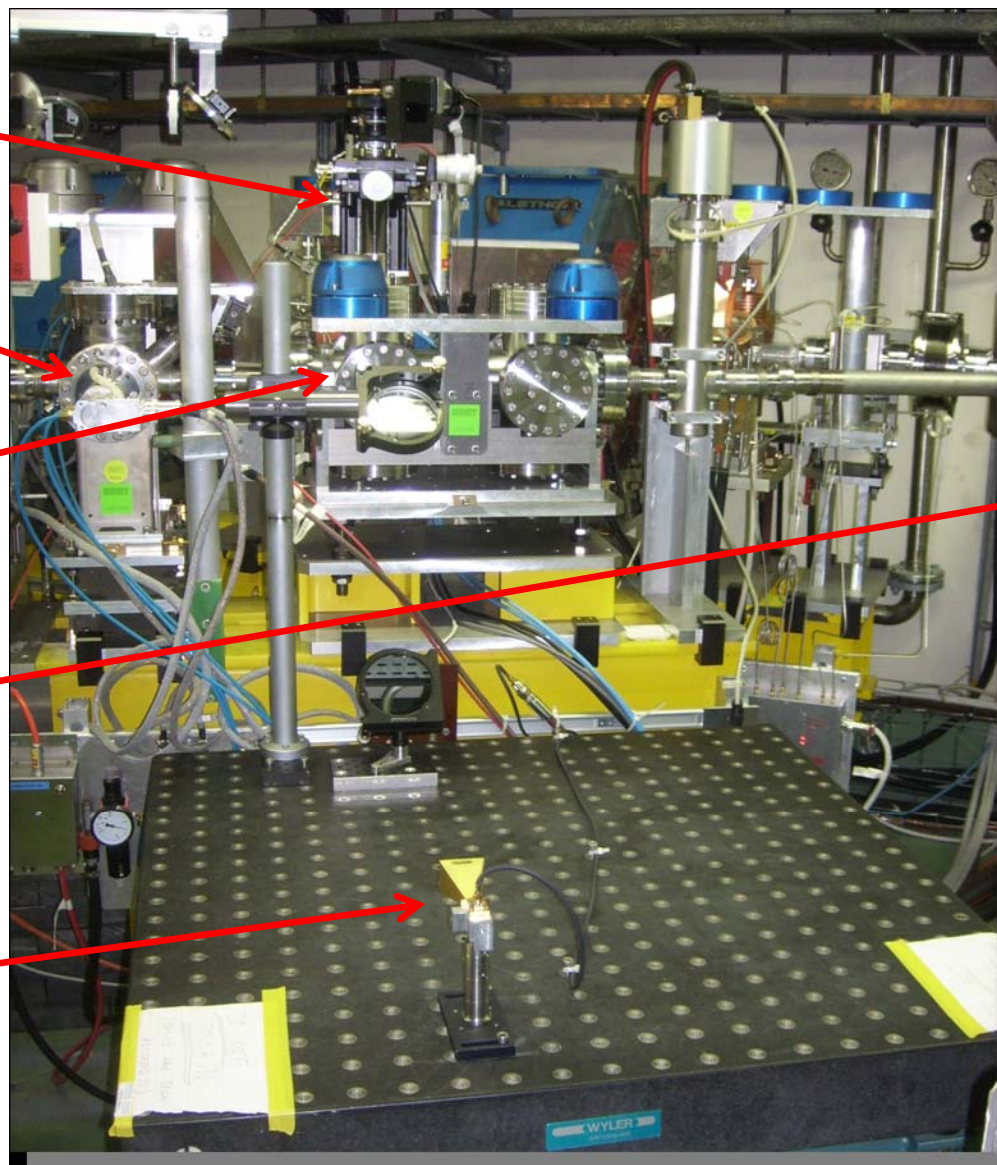
Vacuum manipulator
for target rotation and
translation

OTR screen for target
reference position

CDR target within six-
way cross

BPM (not shown in
picture) for beam position
and charge readings

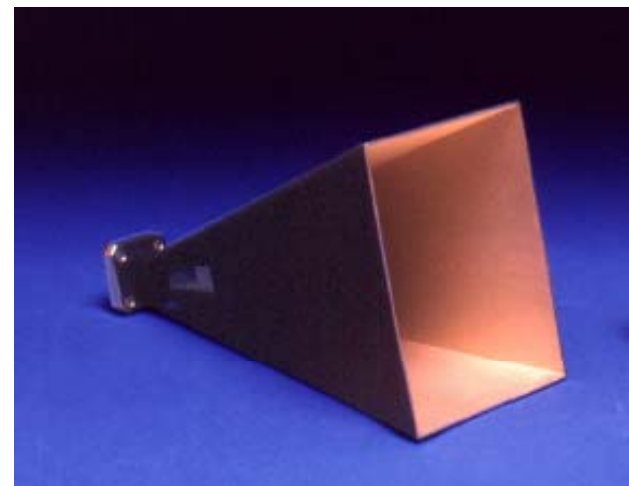
Schottky barrier diode
detector connected to
DAQ



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As a detector we used an Ultra-fast Schottky Barrier Diode with the following parameters

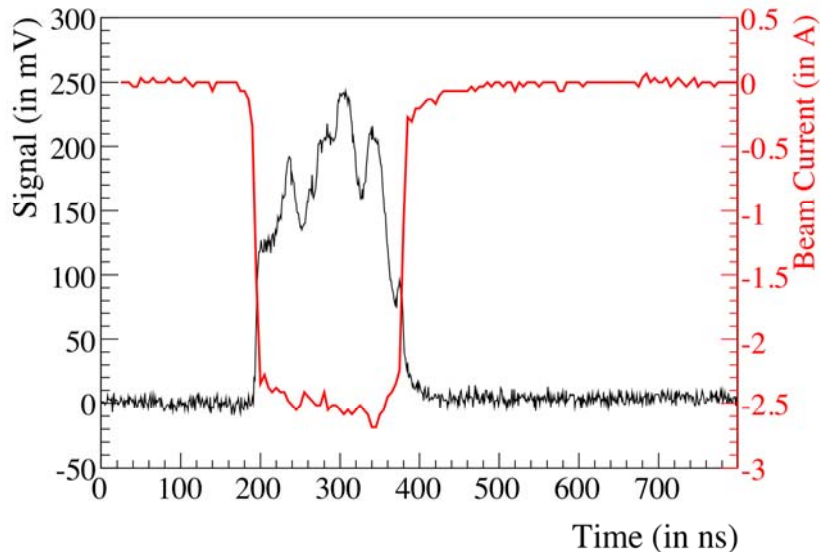
Frequency range	90 – 140 GHz
Wavelength range	2.14 – 3.33 mm
Sensitivity range (freq. dep.)	1530 - 400 – mV/mW
Horn Antenna Gain (freq. dep.)	22.42 – 23.69
Time response (FWHM)	~250ps



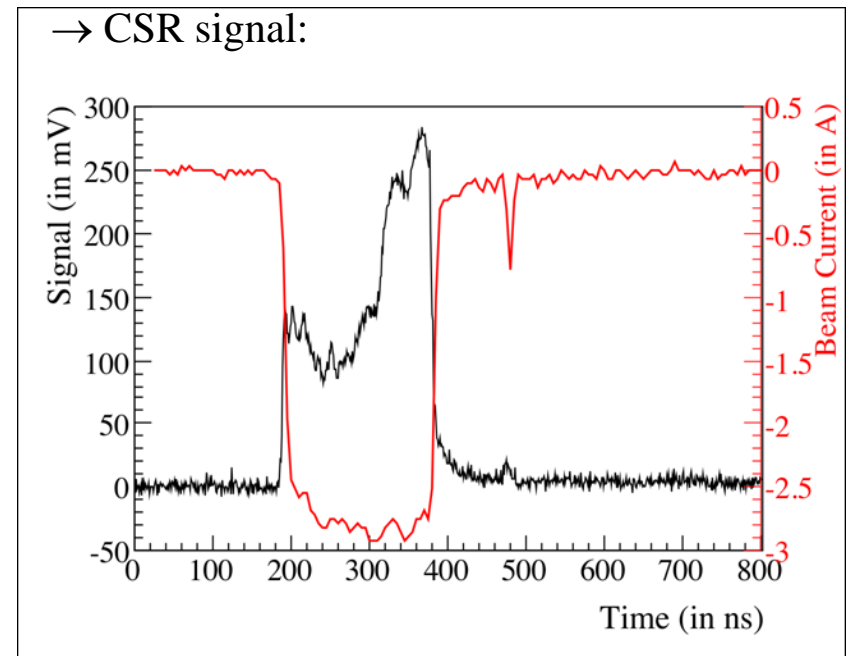
Signals observed at CTF3 in 2008:

- Signal of CDR and CSR including the BPM current reading
- Variation of the SBD signal for CSR and CDR suggests a bunch length variation along the train

→ CDR signal:



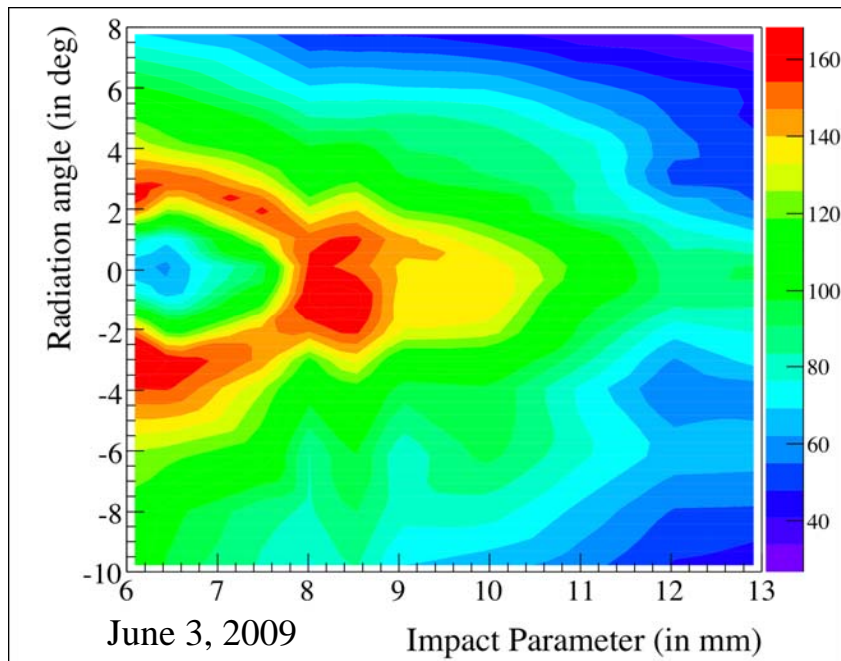
→ CSR signal:



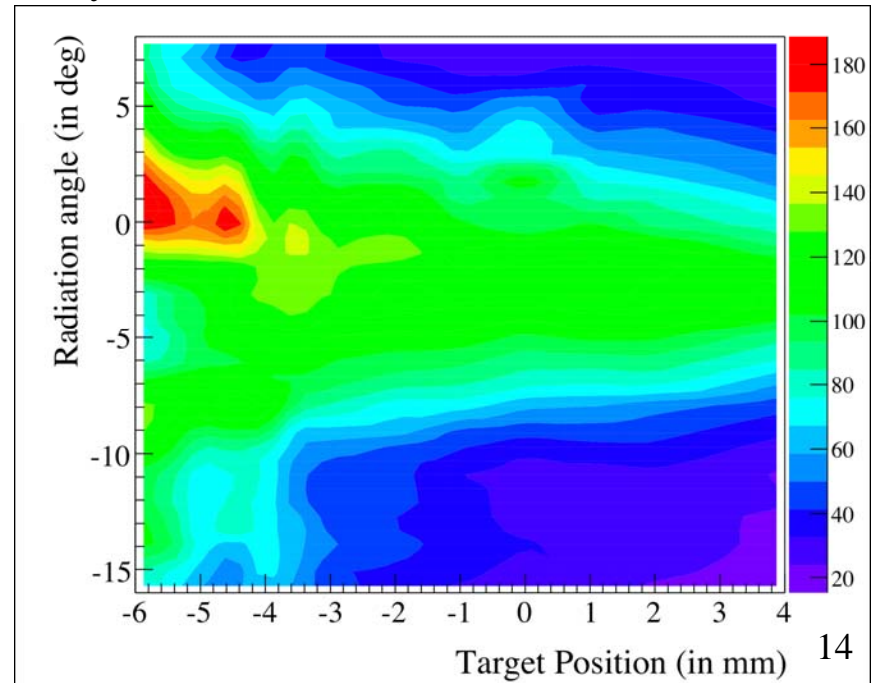
CDR and CSR signal dependences (horizontal polarization):

- Checked the signal level depending on the target position and orientation
- Good agreement with expectation but some distortion (CDR, CSR) and offset (CSR)
 - Distortion can be explained by background caused upstream (wake-fields, CSR, etc.)
 - Offset can be explained by the offset beam in the bending magnet

Diffraction radiation:

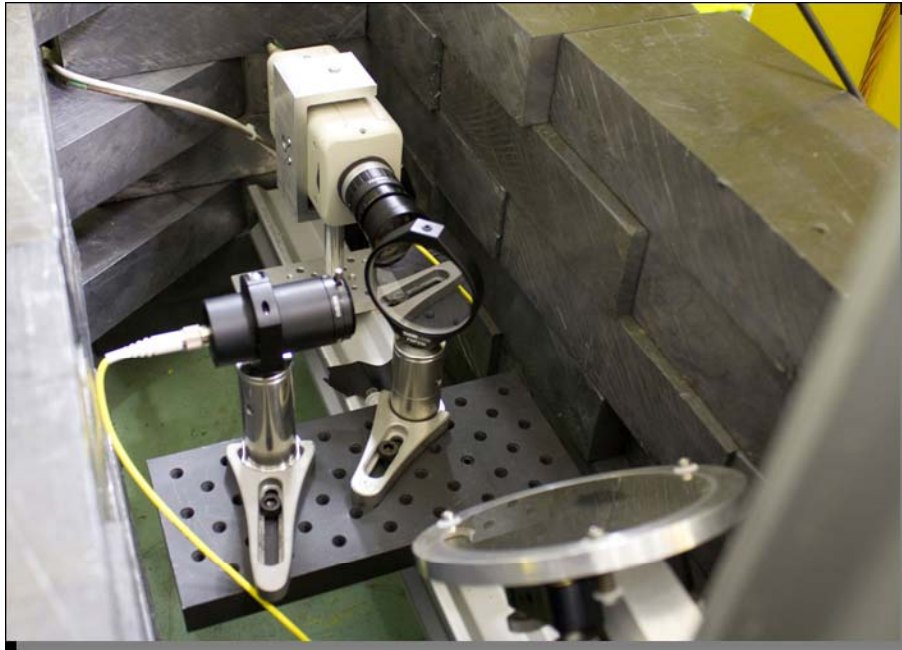


Synchrotron radiation:

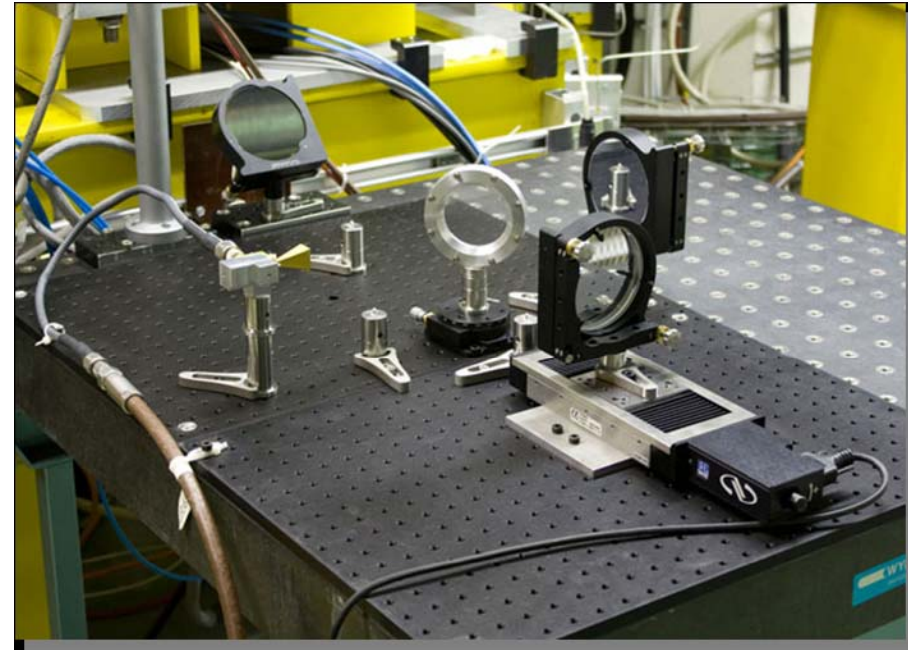


2009 Upgrades:

- Installed the interferometer (right hand picture)
- Photo diode (incl. beam splitter) in the OTR optical line installed (left hand picture) for fast charge measurements
 - OTR light is linearly proportional to the bunch charge



June 3, 2009



15



Status of experiment at CERN:

- Installed the update of the system in the CRM line
 - Interferometer
 - Photodiode in OTR optical line
- Currently experiencing some problems
 - Did not have sufficient beam time to find interference with CDR (dedicated beam time)
 - Cabling between the photo diode and the DAQ
- Still debugging the system and understanding the new setup

Plans:

- Continue debugging and understanding the system
- Interferometric measurements
- Reconstruction of the longitudinal bunch shape using Kramers-Kronig method (on going)
- Calculate interferometer splitter efficiencies (on going)



Insert a second target to cut the background off

