Investigation of Coherent Diffraction Radiation from a dual target system at CTF3

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Introduction

1. Coherent Diffraction Radiation (CDR) phenomenon.

2. CLIC Test Facility 3 (CTF3) and the CDR experiment.

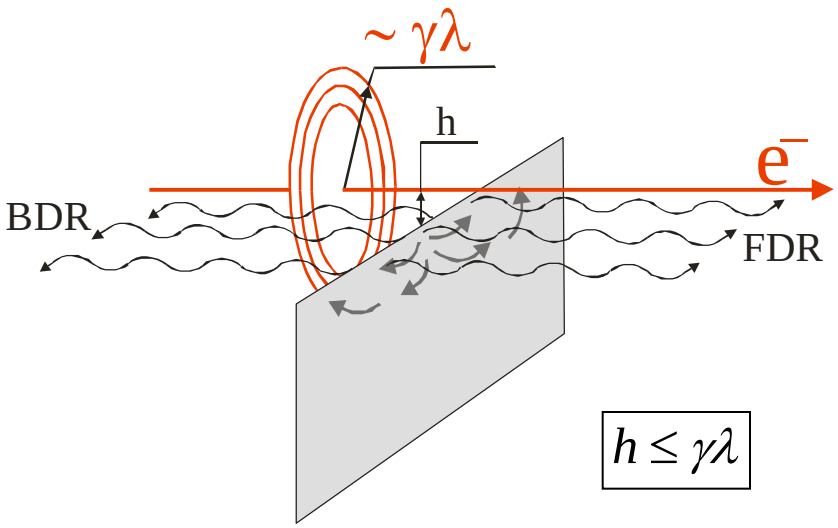
3. Theoretical investigation of the CDR from a dual target system at CTF3.

4. Experimental results and comparison with the theory.

4.1 CDR spatial distribution: theory and experiment.
4.2 Coherent Synchrotron Radiation contribution studies.
4.3 Interferometric measurements.
4.4 Bunch length and shape instabilities at CTF3.

5. Conclusions and outlook.

Coherent Diffraction Radiation phenomenon



$h \le \gamma\lambda$

Diffraction radiation appears when a charged particle moves in the vicinity of a medium.

Impact parameter h – the shortest distance between a particle and a target.

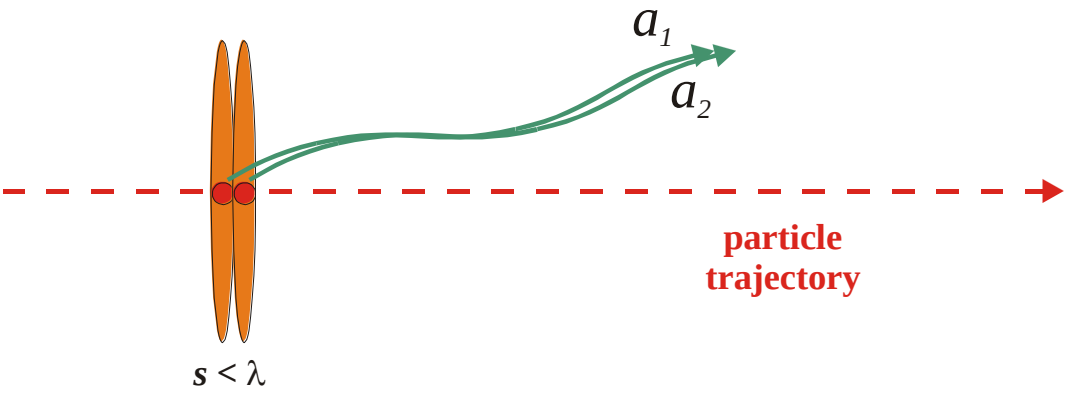
λ – observation wavelength,

$\gamma = \frac{E}{mc^2}$ – Lorentz factor.

The first experimental investigation:
Y. Shibata et al., Physical Review E 52, 6787 (1995).

Coherency of radiation:

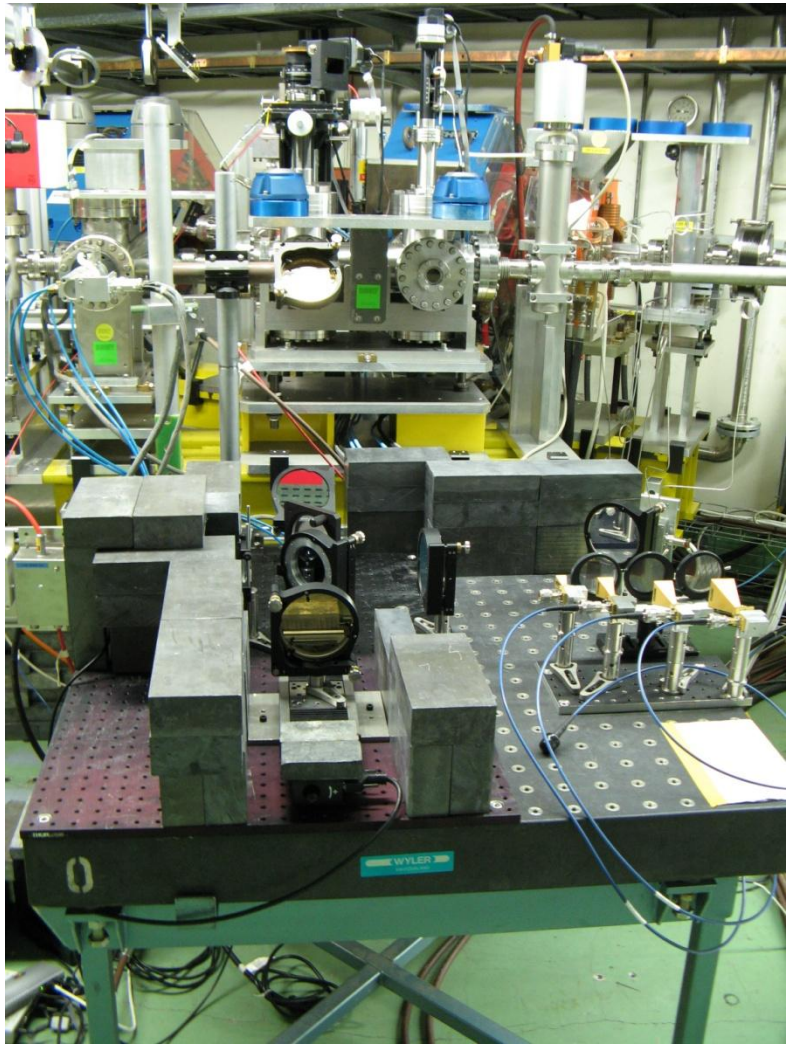
$$I = |a_1 + a_2|^2 = |2a|^2 = 4|a|^2 \rightarrow N^2 |a|^2$$

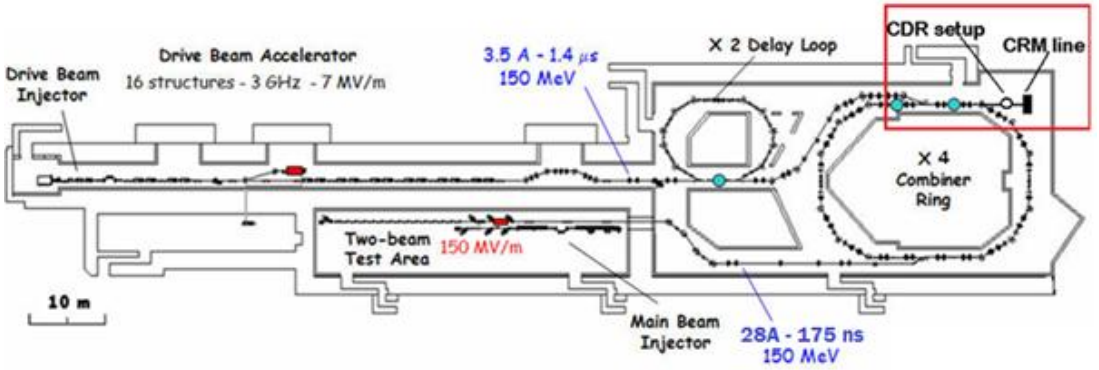


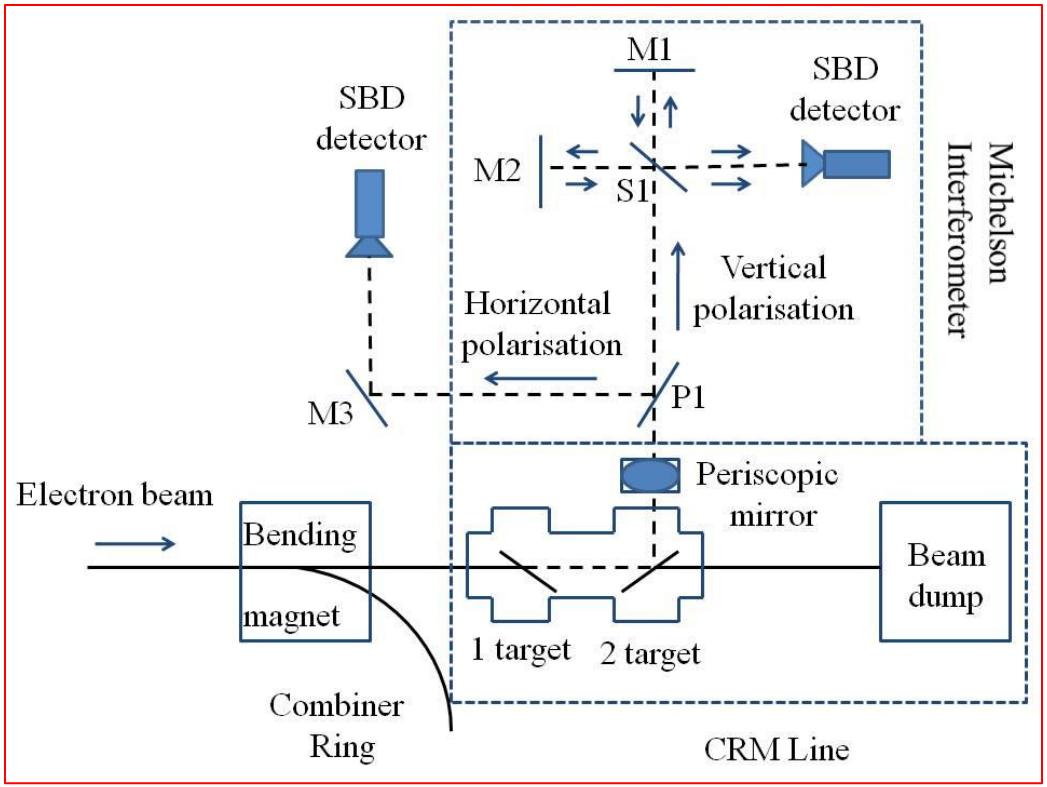
Application for beam diagnostics:

- Non-invasive tool for longitudinal beam diagnostics.
- No theoretical resolution limit on the minimum bunch length that can be measured.
- Low cost and complexity of the experimental setups.

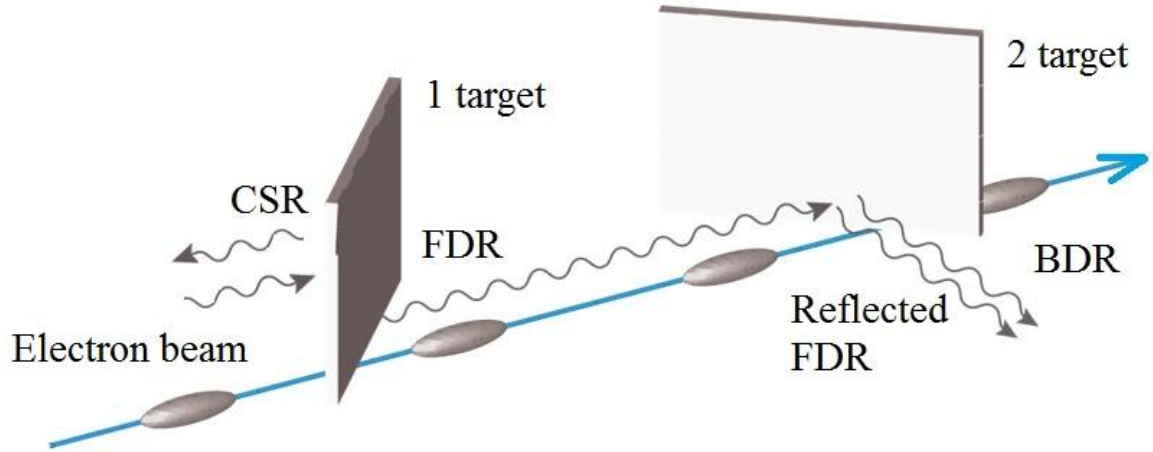
CLIC Test Facility 3 and CDR experiment







Dual target configuration



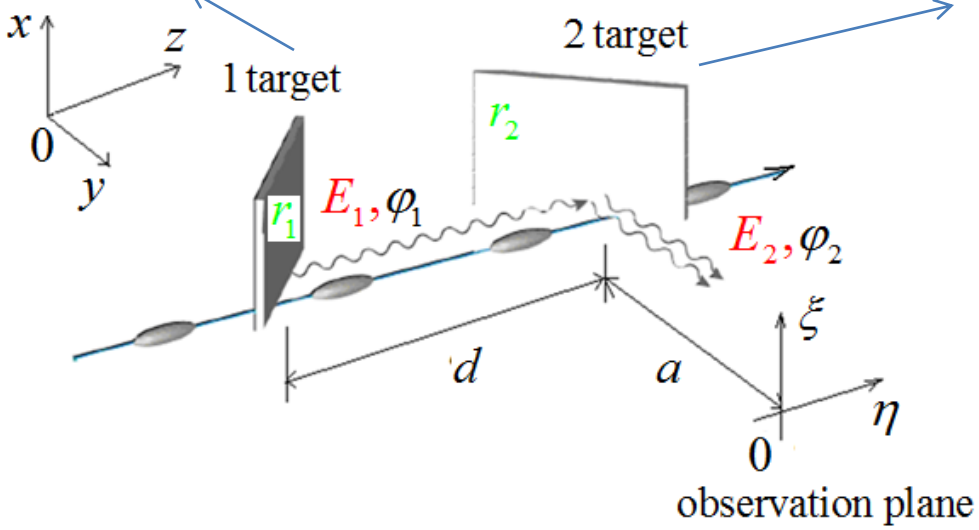
- CSR background suppression by the first target.
- Low cost and complexity of the configuration.
- Transverse kick compensation by positioning the targets at 45 deg.

Beam energy (γ)	235	
Bunch charge	2.3	nC
Bunch spacing frequency	1.5 or 3	GHz
Target dimensions (projected)	40x40	mm
Observation wavelength	5	mm
First target impact parameter (upper pos.)	30	mm
First target impact parameter (lower pos.)	10	mm
Second target impact parameter	10	mm
Distance between the targets	0.25	m
Distance from the second target to the observ. plane	2	m

Theoretical studies for the two target system.

Two polarisation components of the CDR from the two targets:

$$E_{\xi,\eta} = \frac{ik}{8\pi^3}\iint\limits_{r_1,r_2} E_1(r_1)\frac{\exp[i(\varphi_1+\varphi_2)]}{ad}dr_1dr_2 + \frac{1}{4\pi^2}\int\limits_{r_2} E_2(r_2)\frac{\exp[i\varphi_2 + ikd/\beta]}{a}dr_2.$$



The DR distribution at the observation plane can be calculated using the following formula:

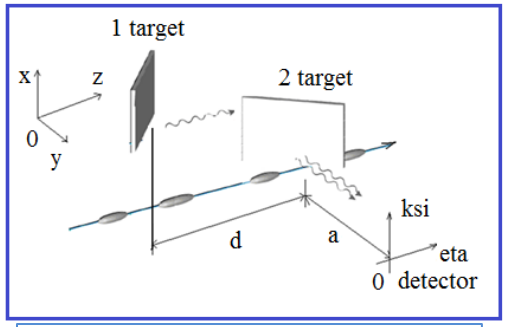
$$\frac{d^2W^{DR}}{d\omega d\Omega} = 4\pi^2k^2a^2\left[\left|E_\xi^{DR}\right|^2 + \left|E_\eta^{DR}\right|^2\right]$$

*K. Lekomtsev, G. Blair, G. Boorman, R. Corsini, P. Karataev, T. Lefevre and M. Micheler, Coherent Diffraction Radiation experiment at CTF3 – simulation studies, IL NUOVO CIMENTO Vol. 34C, N.4, 2010.

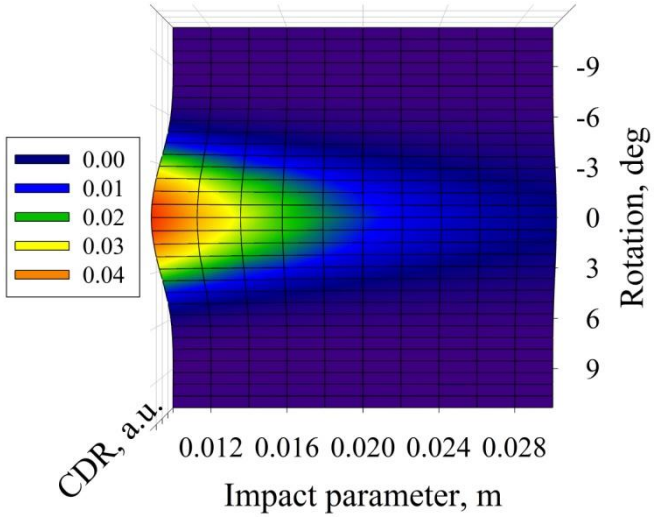
Vertical polarisation of the CDR distribution: theory and experiment

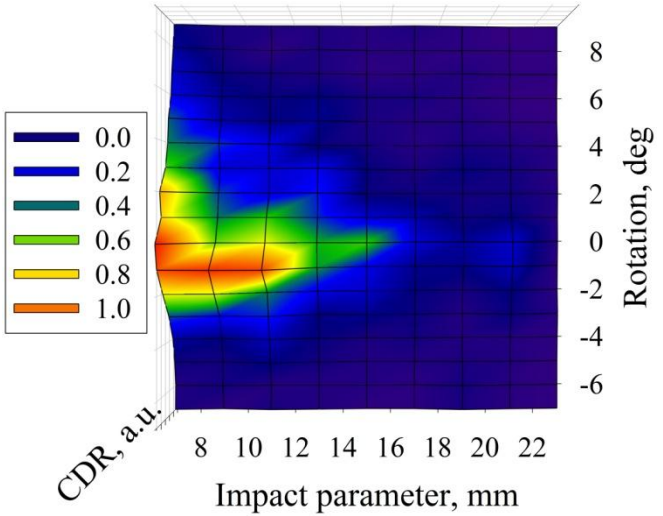
Theory

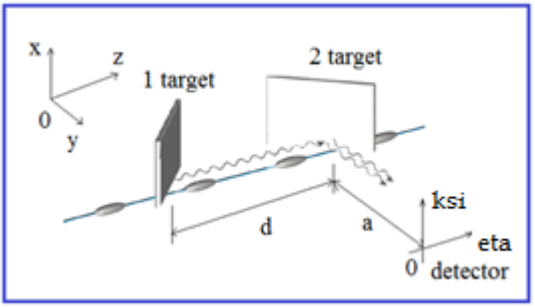
Experiment
Detector sensitivity: 50-75 GHz



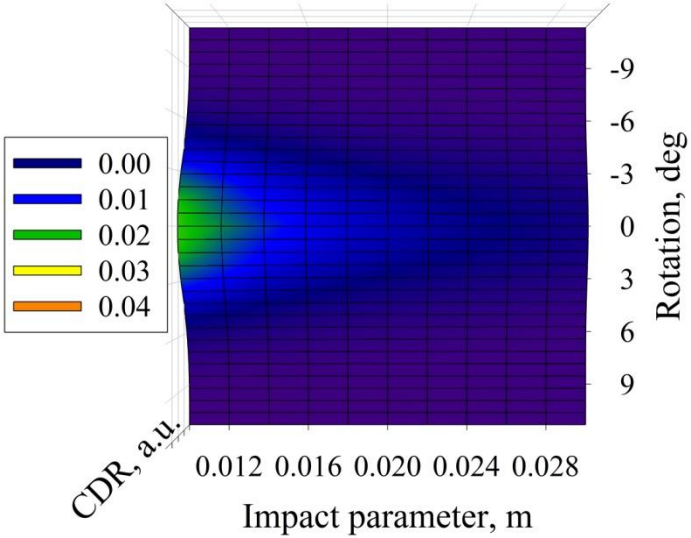
h1=30mm; h2=10mm

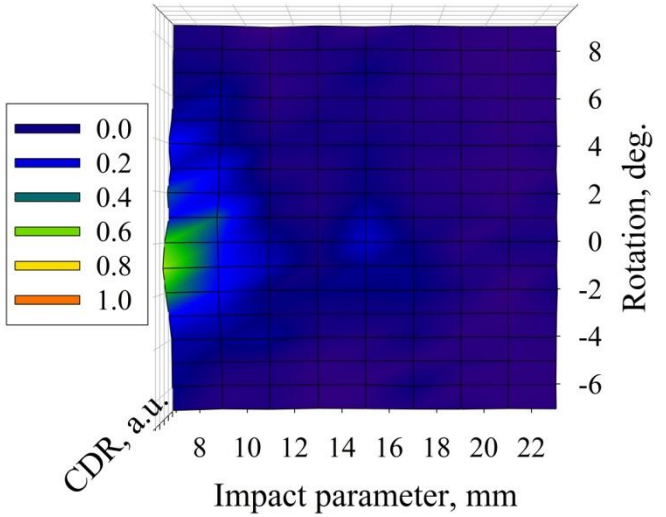






h1=h2=10mm

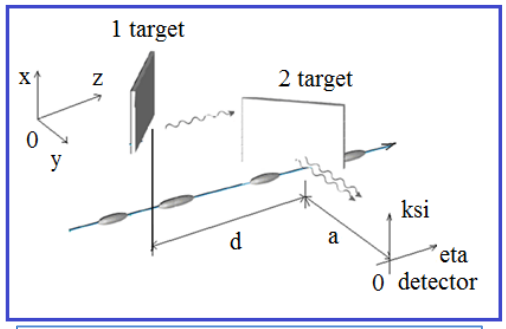




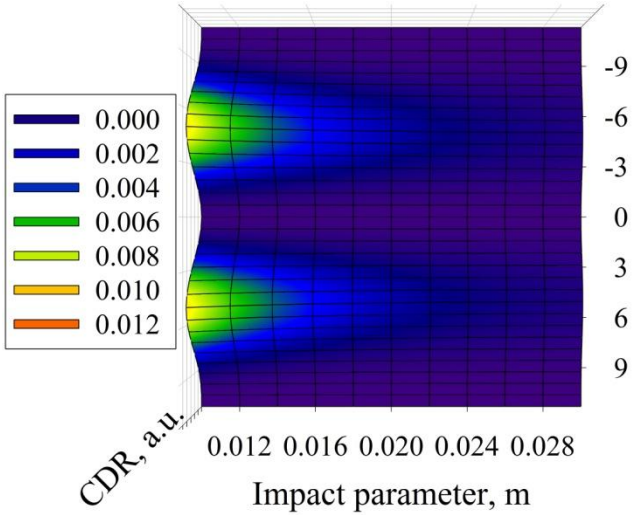
Horizontal polarisation of the CDR distribution: theory and experiment

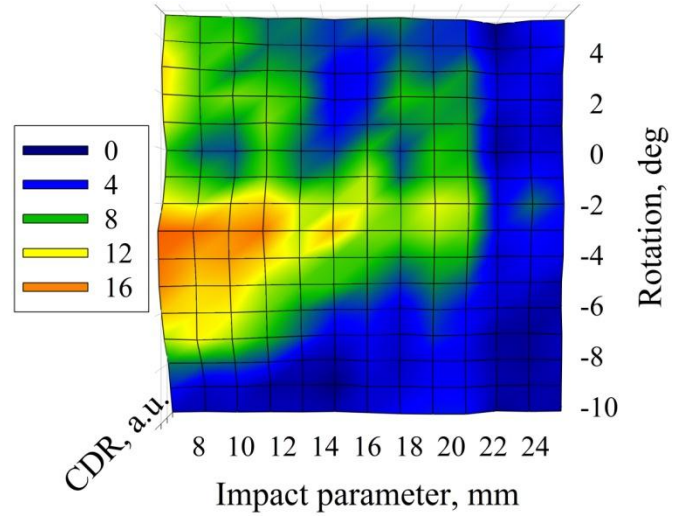
Theory

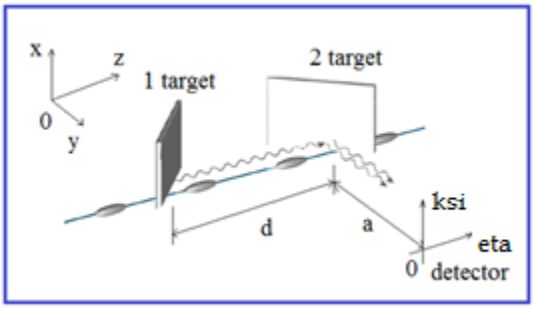
Experiment
Detector sensitivity: 50-75 GHz



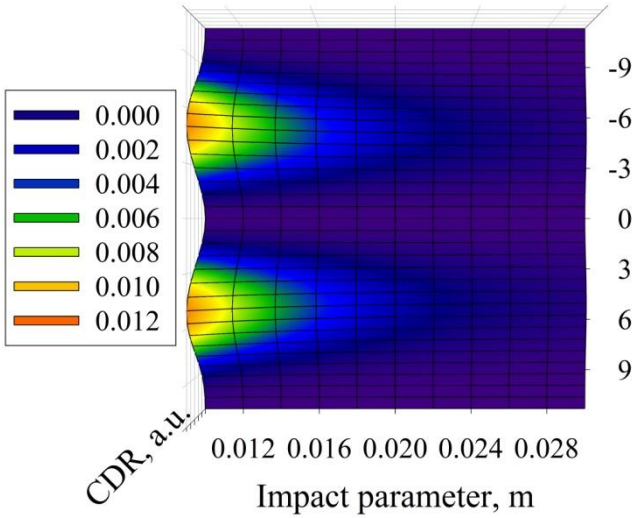
h1=30mm; h2=10mm

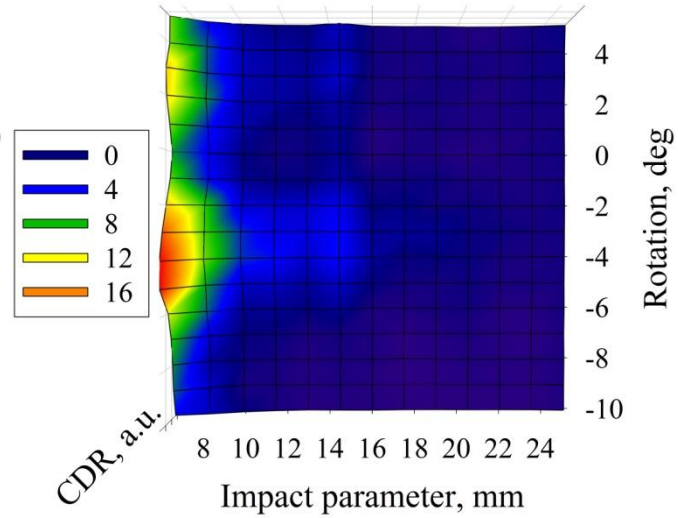






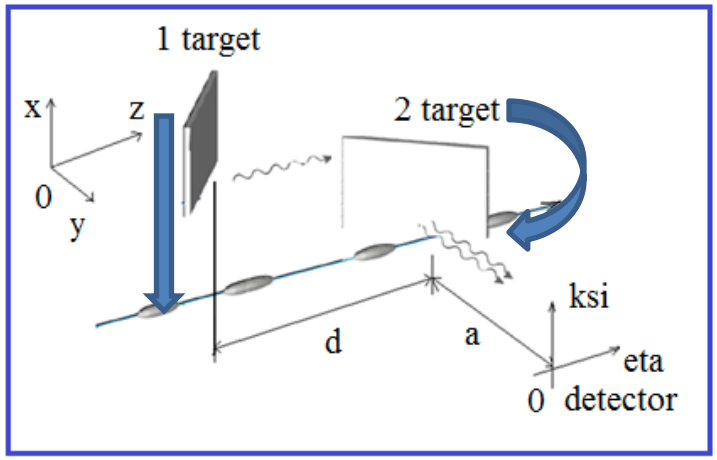
h1=h2=10mm

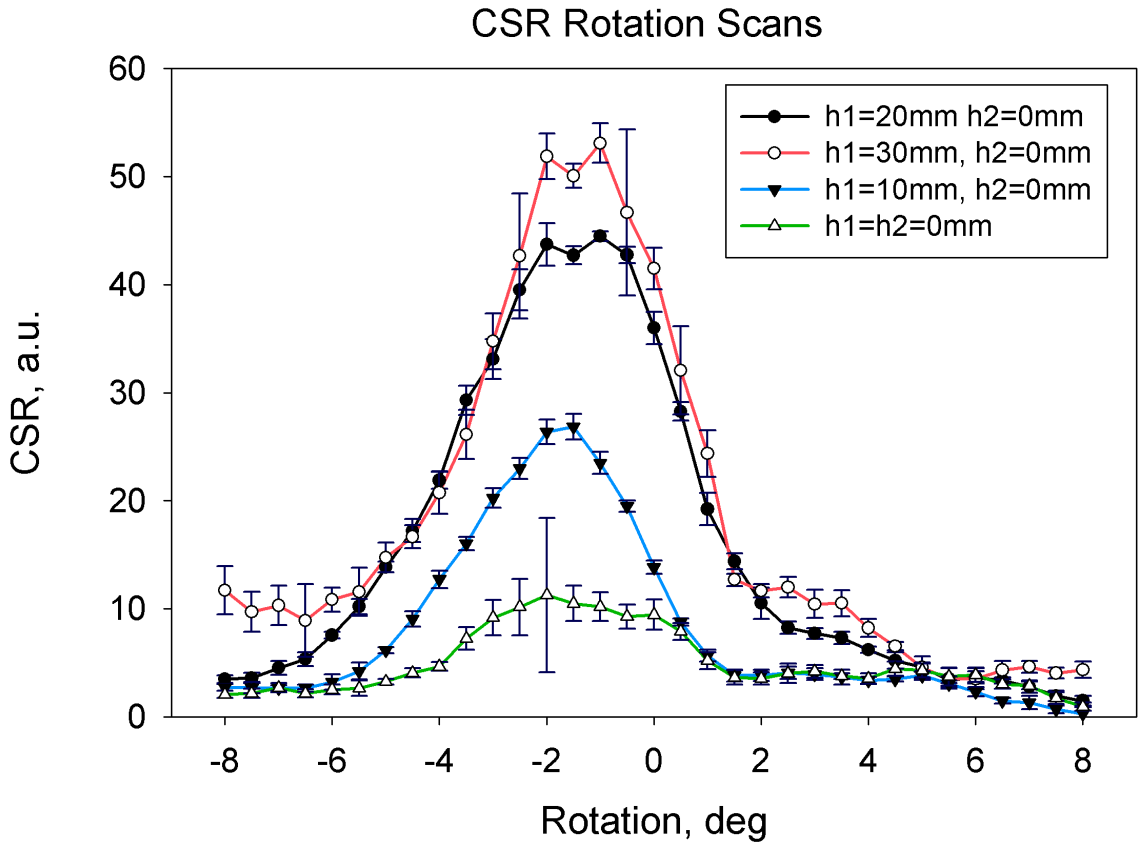




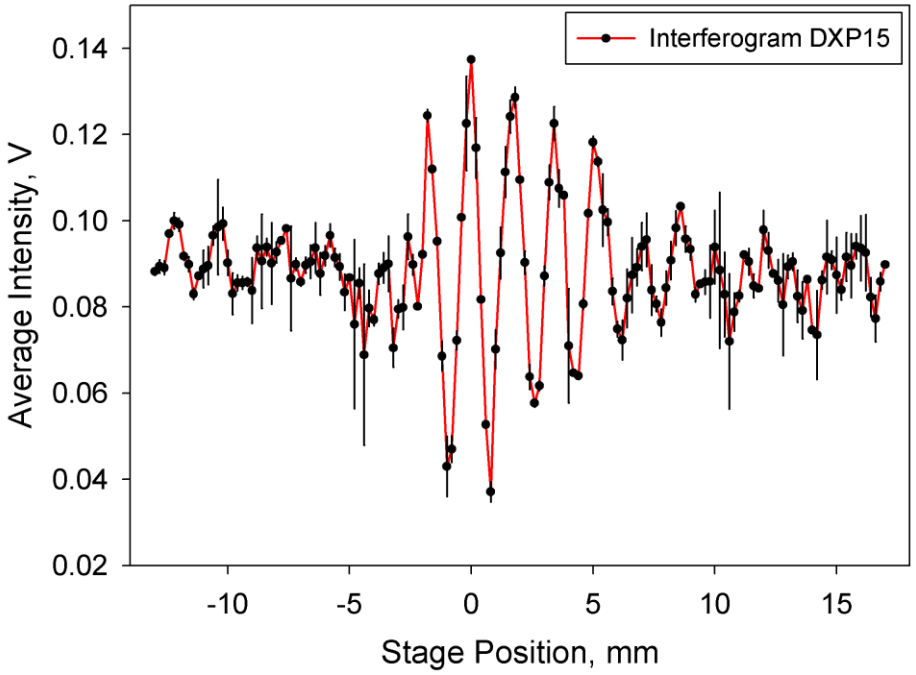
CSR background contribution studies

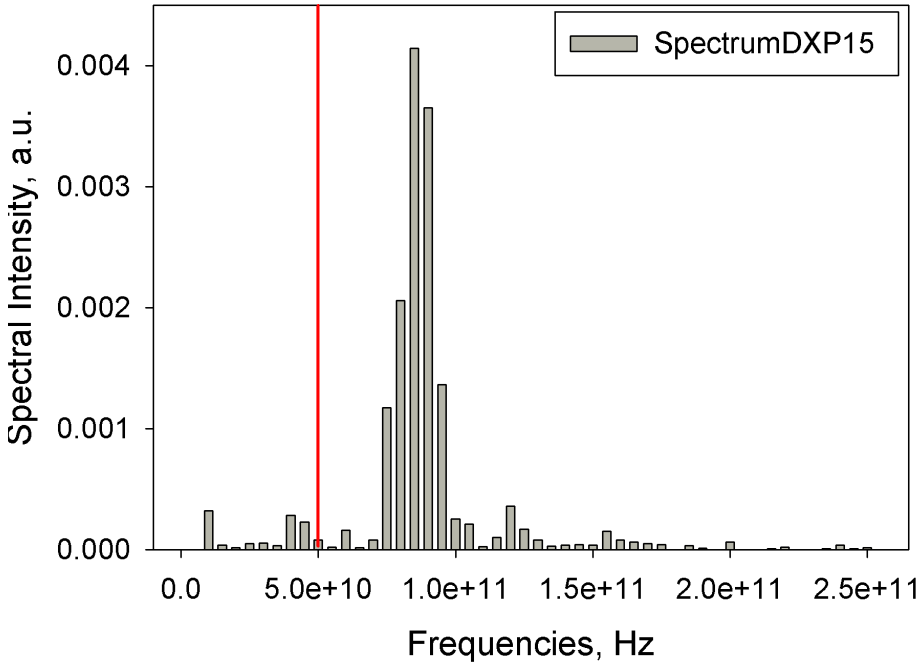
Reflection of the CSR from the 2nd target is investigated. The rotation scans of the horizontal polarisation component of the CSR are presented. The scans are taken for the 4 fixed positions of the first (upstream) target, while the second target is rotated and positioned in the centre of the downstream six-way cross.

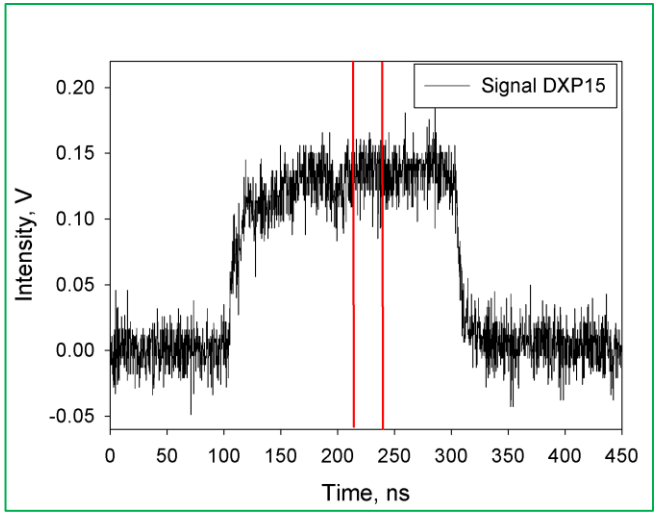




Interferometric measurements







$$S_{coh}(\omega) = N^2 S_e(\omega) F(\omega)$$

Coherent spectrum

Number of electrons in the bunch

Single electron spectrum

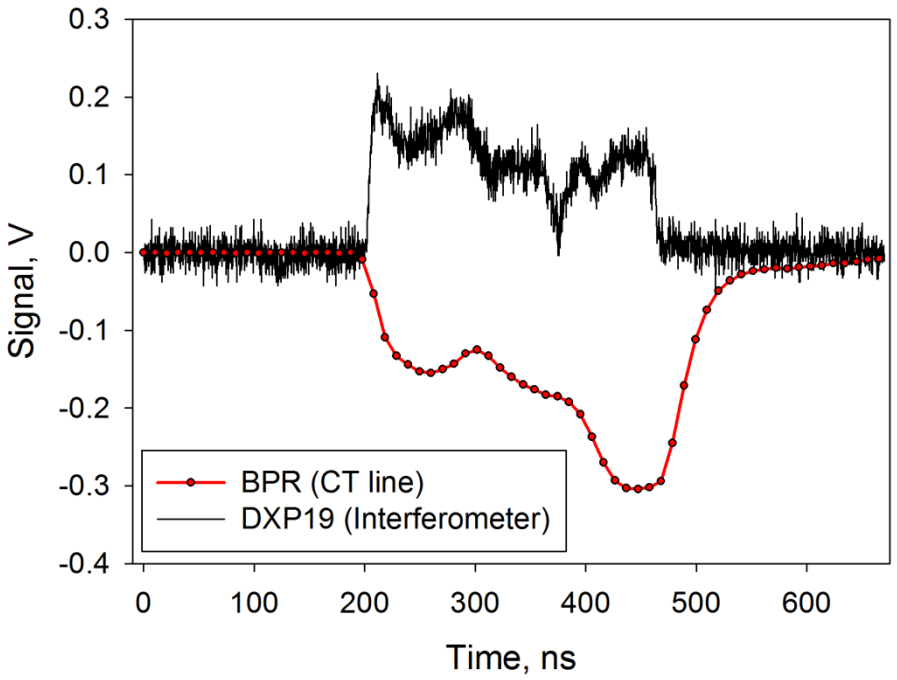
Form factor

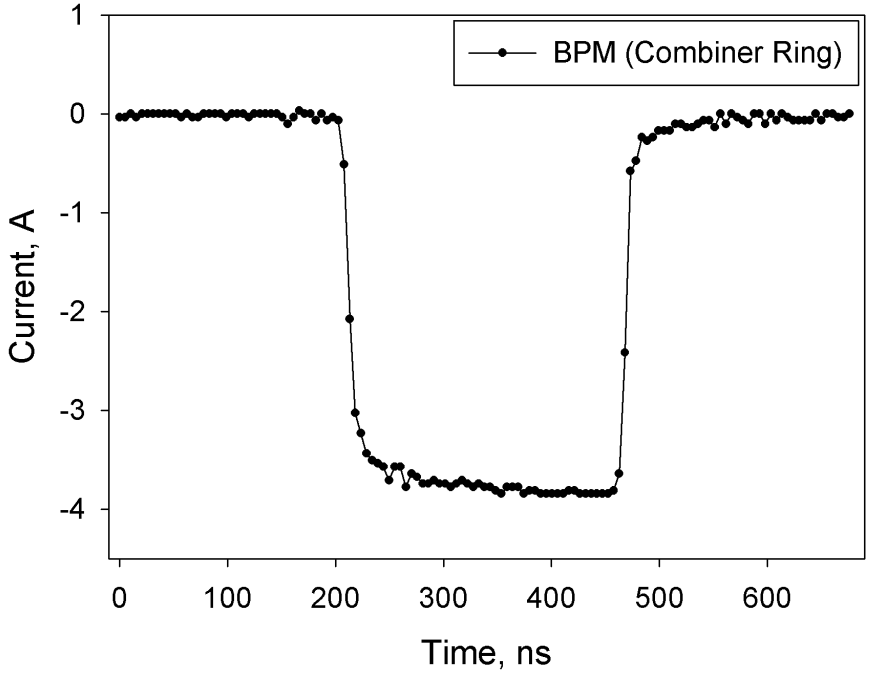
Bunch length/shape stability

Red curve: the signal from the waveguide pickup positioned upstream of the experimental setup, the power is detected by the SBD detector sensitive in 26.5 – 40 GHz.

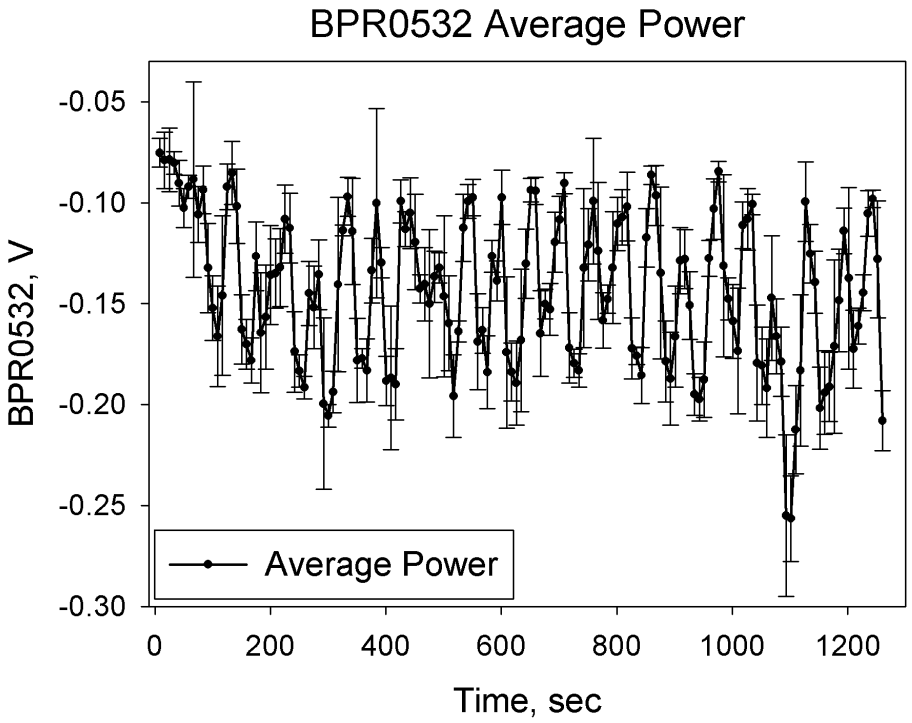
Black curve: the signal from DXP19 detector in the interferometer, sensitive in 40 – 60 GHz.

The signal from the last BPM before the experimental setup in the CRM line.



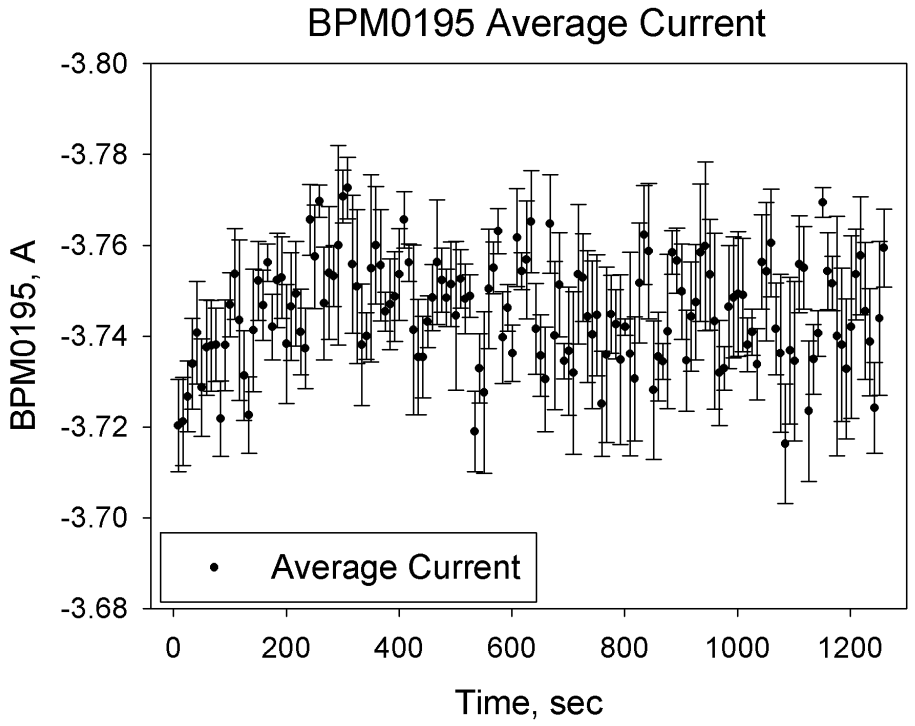


Bunch length/shape stability



Average power scan over 21 minutes. Represents peculiar behaviour of the machine at the measurement time and significant bunch shape variation along the pulse. The average power with approximately factor 2 variation.

Average current scan over 21 minutes. The current stability is approximately 2% with respect to the average value of the current.



Conclusions

- The theoretical model, based on the Classical Diffraction Radiation Theory, was developed.
- The CDR spatial distribution measurements were performed and compared with the theory.
- Bunch length and shape instabilities at CTF3 were investigated.
- The interferometric measurements were performed using the SBD detectors.

Problematic issues

- The bunch length/shape instabilities along the pulse.
- A long term machine drift.
- An idealised theory along with the coherent backgrounds, generated by the beam, complicate the results interpretation.

Outlook

- Usage of low frequency detectors to suppress the influence of a bunch shape variation;
- Shot by shot measurements, grating spectrometer.