Coherent Diffraction Radiation experiment

Konstantin Lekomtsev, Grahame Blair, Gary Boorman, Pavel Karataev, Maximilian Micheler
John Adams Institute at Royal Holloway University of London

Roberto Corsini, Thibaut Lefevre
CERN

K.V.Lekomtsev@rhul.ac.uk

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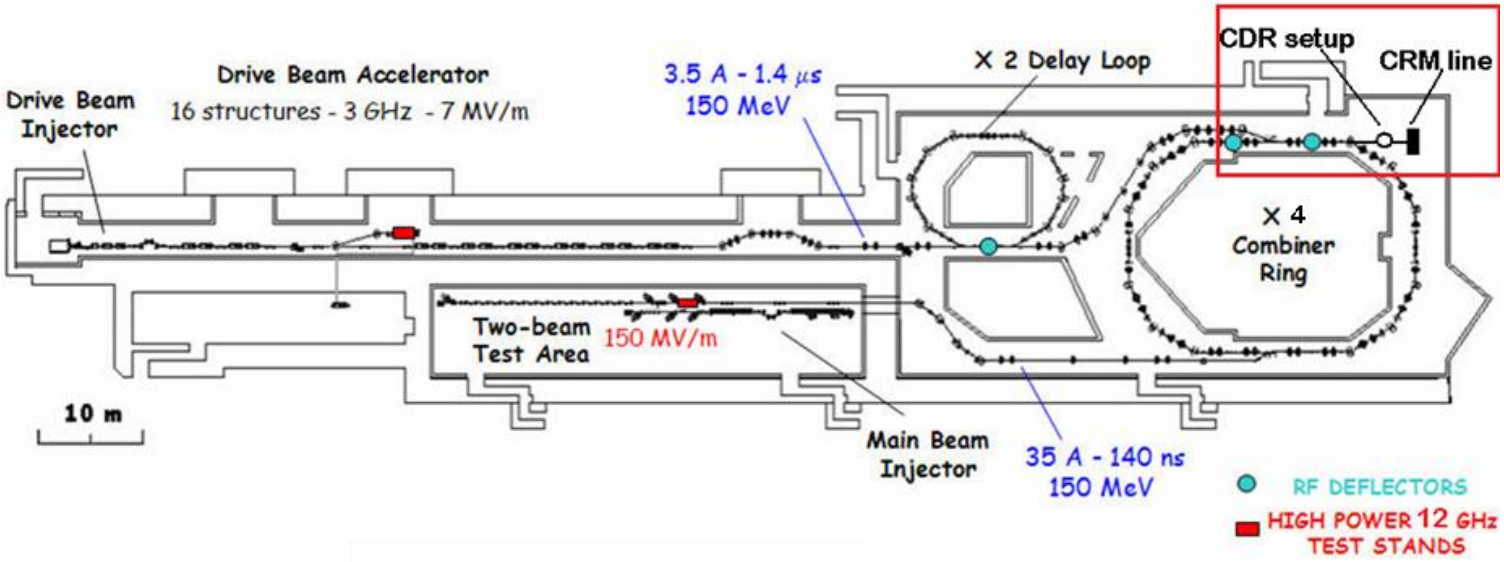
Introduction

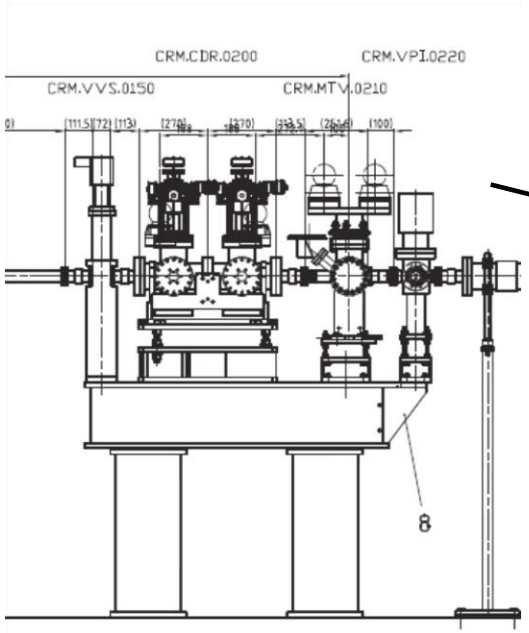
1) CDR setup at the CTF3.
2) Simulations for one target configuration.
3) Simulations for two target configuration.
4) Experimental setup and interferometric system.
5) Current status of the experiment.
6) Conclusions and outlook.

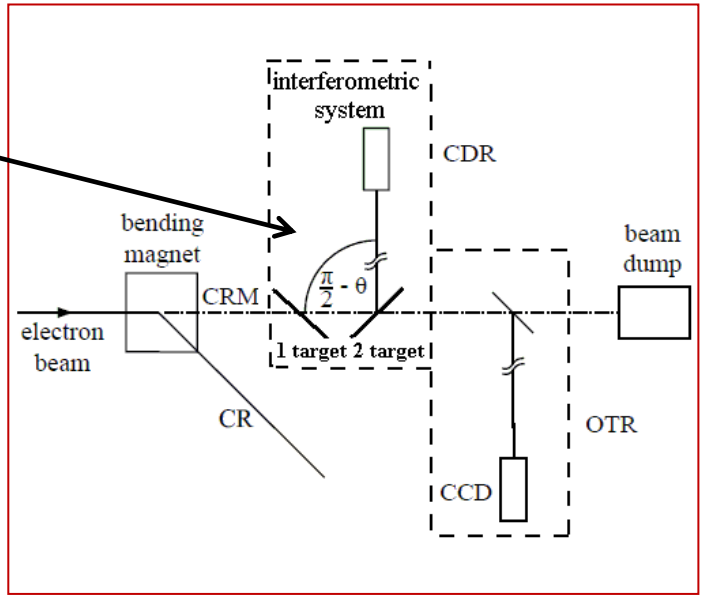
K.V.Lekomtsev@rhul.ac.uk

CLIC Test Facility 3 & CDR experiment



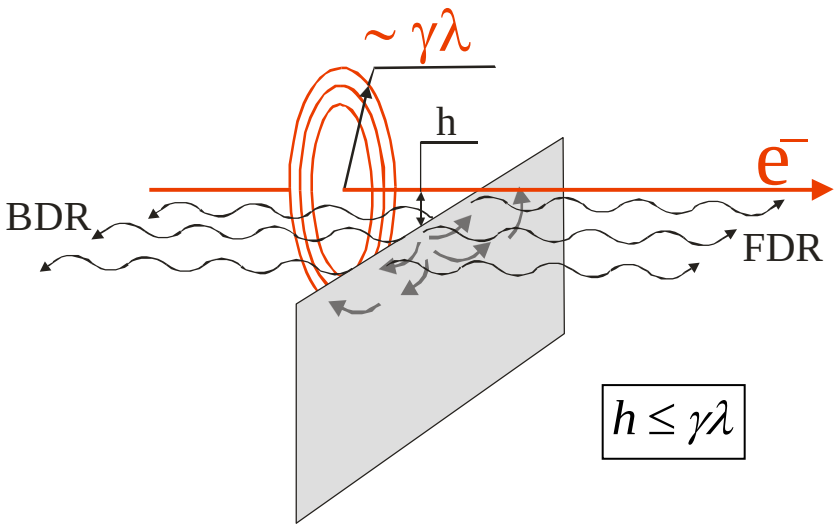
During the experiment running the electron beam had the train length of 100 to 300 ns, the bunch sequence frequency of 3GHz and the nominal current of 3.5 A.





K.V.Lekomtsev@rhul.ac.uk

Coherent Diffraction Radiation phenomenon



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

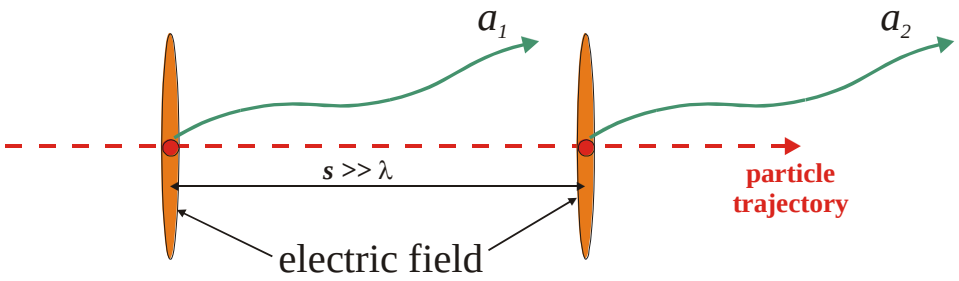
Impact parameter h – the shortest distance between a particle and a target.

λ – observation wavelength,

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

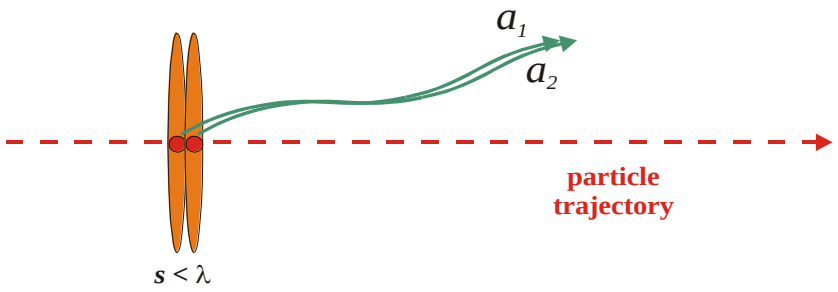
Incoherent radiation:

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



Coherent radiation:

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



K.V.Lekomtsev@rhul.ac.uk

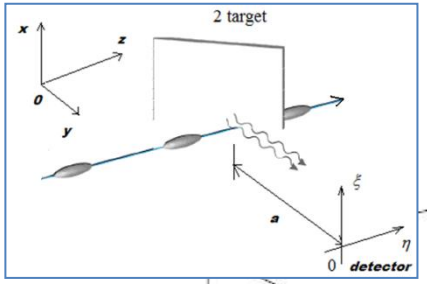
CDR from the single target

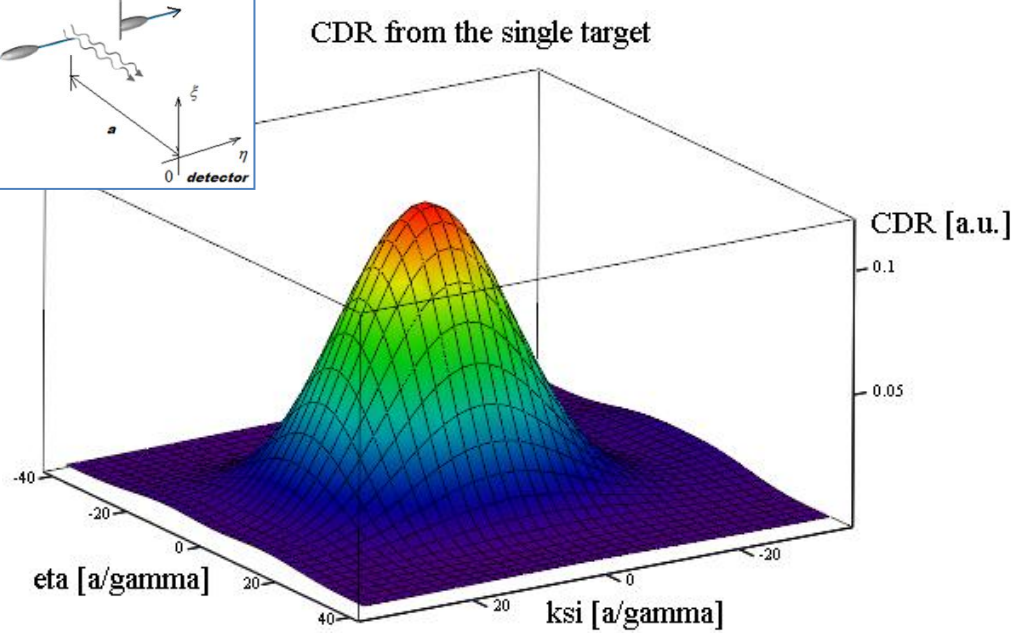
$$E_{x,y} = \frac{1}{4\pi^2}\frac{iek}{\pi\gamma}\frac{e^{ika}}{a}\iint\begin{pmatrix}\dfrac{x}{\sqrt{x^2+y^2}}\\ \dfrac{y}{\sqrt{x^2+y^2}}\end{pmatrix}K_1\left(\frac{k}{\gamma}\sqrt{x^2+y^2}\right)\exp\left[\frac{ik}{2a}\left((x-\xi)^2+(y-\eta)^2\right)\right]dx\,dy$$

x, y - the coordinates at the target surface. η, ξ - the coordinates at the observation plane.

a - the distance from the target to the observation plane. k - the wave number.

Target dimensions: $40mm \times 60mm$
Beam energy: $\gamma = 235$
Radiation wavelength: $\lambda = 5mm$
Impact parameter: $h = 10mm$

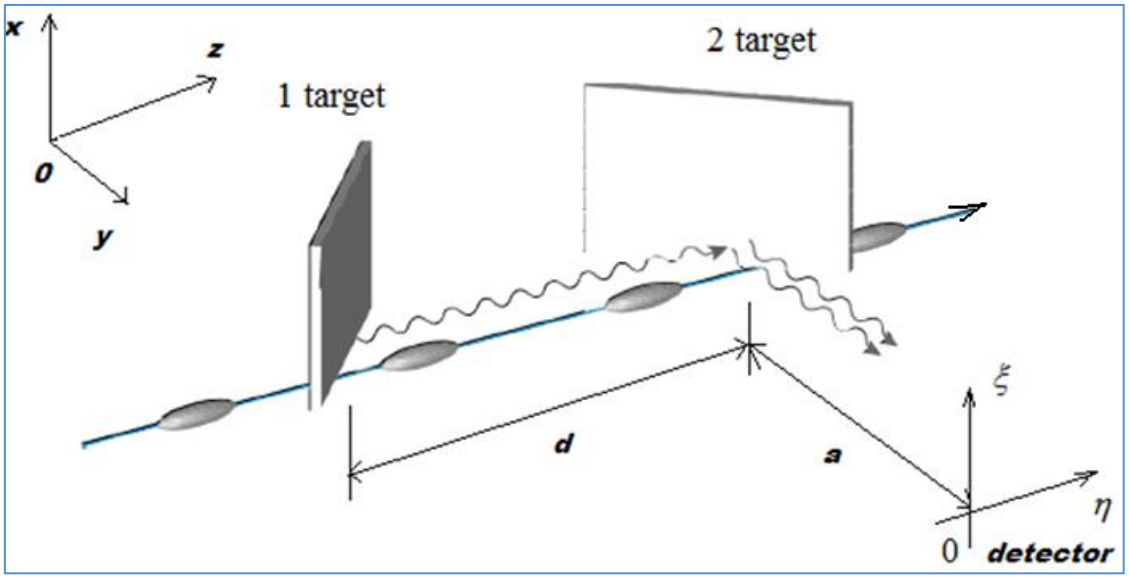


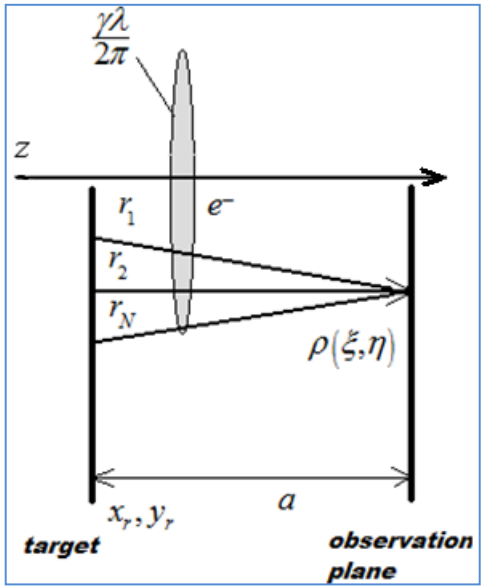


- The target is positioned in the vacuum in the infinite space.
- Ideal conductor approximation is utilized.
- Limited target dimensions.
- BDR is observed.

K.V.Lekomtsev@rhul.ac.uk

Two target configuration





- Backgrounds suppression by the first target.
- The first target is additional source of DR.
- Transverse kick compensation, by positioning the targets at 45 deg.
- Possibility of multiple reflection suppression, by installing an absorber in the upstream cross.

- Targets dimensions, distance between the targets and to the observation plane are fixed.
- Thin foil approximation is used.
- FDR and BDR are considered to be identical for given wavelength and a thin foil.
- The first stage of the process is electric field of FDR produced from the first target and diffracted at the second one.
- The second stage of the process is BDR from the second target.
- Targets are assumed to be positioned in the vacuum in the infinite space.
- Destructive interference is observed.

K.V.Lekomtsev@rhul.ac.uk

Two target configuration, theory

$$E_{x,y}^{DR} = \frac{1}{4\pi^2}\iint_{r1} E_{x,y}^{1}\left(x_{r1}, y_{r1}\right)\frac{e^{i\varphi}}{r}dy_{r1}dx_{r1} - \frac{1}{4\pi^2}\iint_{r2} E_{x,y}^{2}\left(x_{r2}, y_{r2}\right)\frac{e^{i\left(\varphi-\frac{kd}{\beta}\right)}}{r}dy_{r2}dx_{r2}\ *$$

$x_{r1}, y_{r1}(x_{r2}, y_{r2})$ - the coordinates of the arbitrary elementary source on the first (second) target surface.

$E_{x,y}^{1(2)}$ - amplitude of the arbitrary elementary source positioned on the first (second) target surface.

r - distance from the elementary source on the target to the observation point.

φ - phase advance of the photons emitted by each elementary source to the observation point.

$\beta = v/c$ -the speed of an electric charge in terms of the speed of light.

K.V.Lekomtsev@rhul.ac.uk

*M.L. Ter-Mikaelyan, High Energy Electromagnetic Processes in Condensed Media, Wiley-Interscience, New York , 1972

Radiation spatial distribution

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

E_x^{DR} - vertical polarization component of the DR from the target/targets.

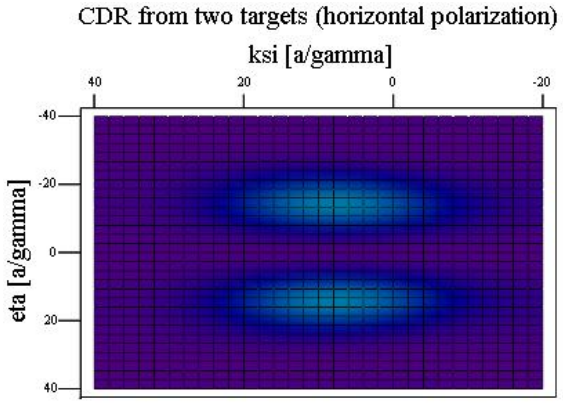
E_y^{DR} - horizontal polarization component of the DR.

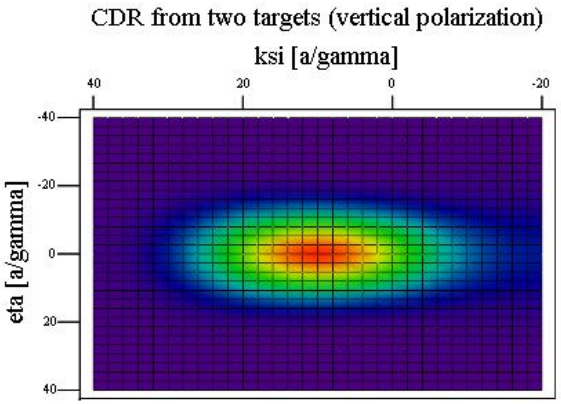
$k = \frac{2\pi}{\lambda}$ is the wave number where λ is the wavelength of the DR.

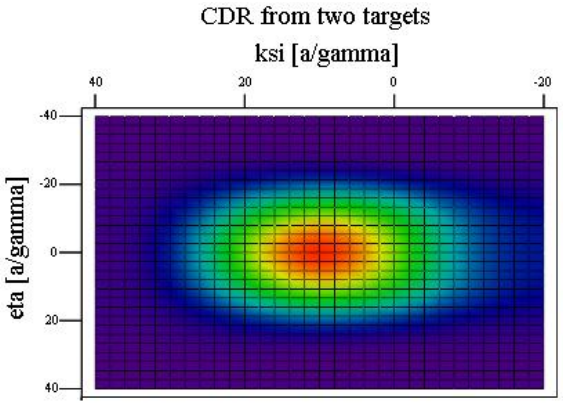
a - distance between the target and the observation point.

K.V.Lekomtsev@rhul.ac.uk

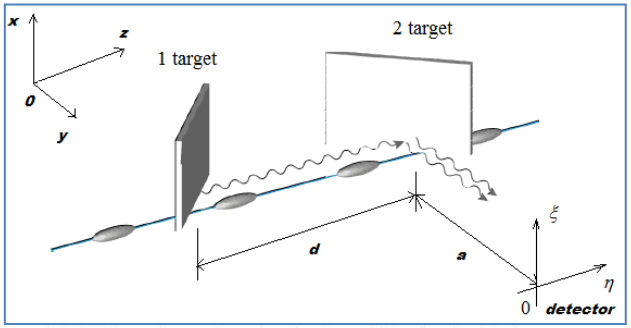
CDR distribution from the two target configuration



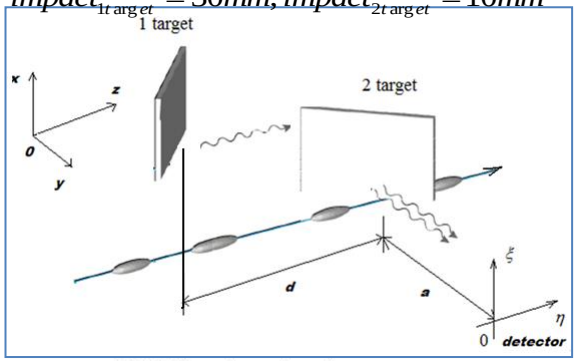


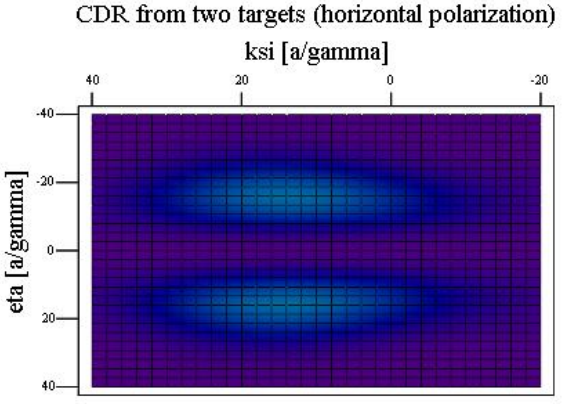


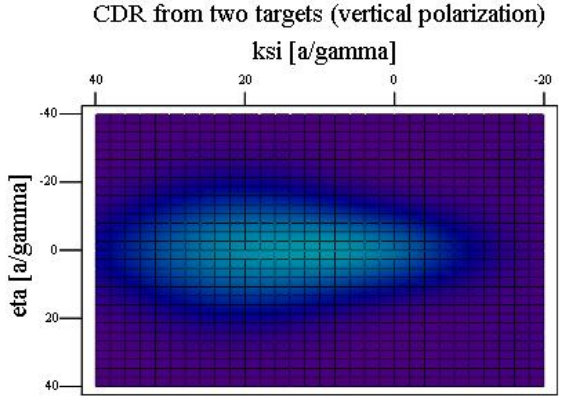
$impact_{1target} = 10mm; impact_{2target} = 10mm$

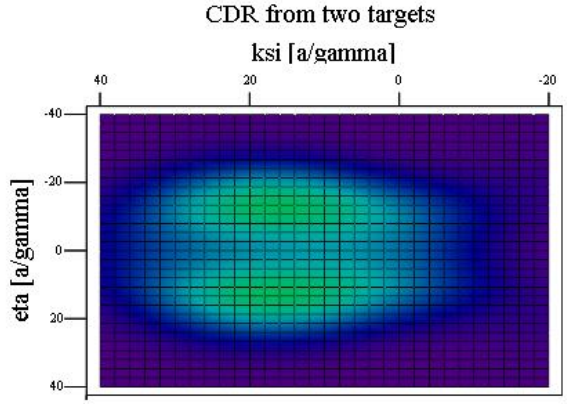


$impact_{1target} = 30mm; impact_{2target} = 10mm$



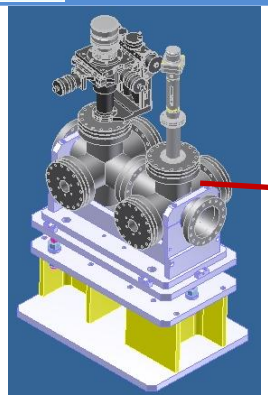


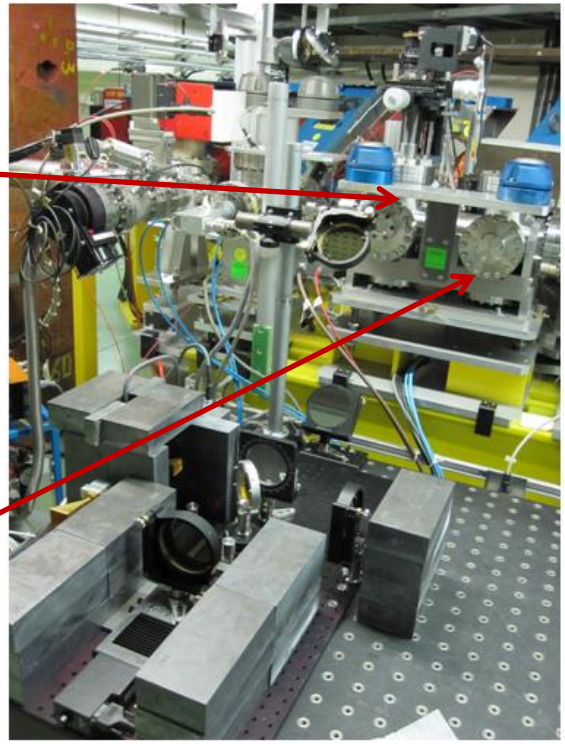


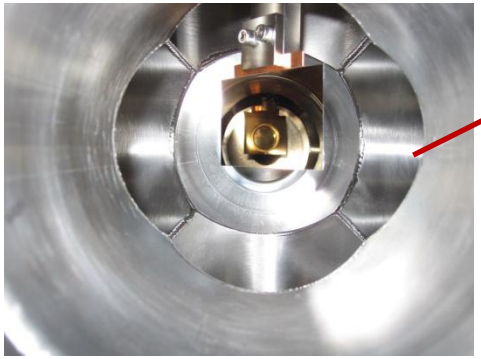


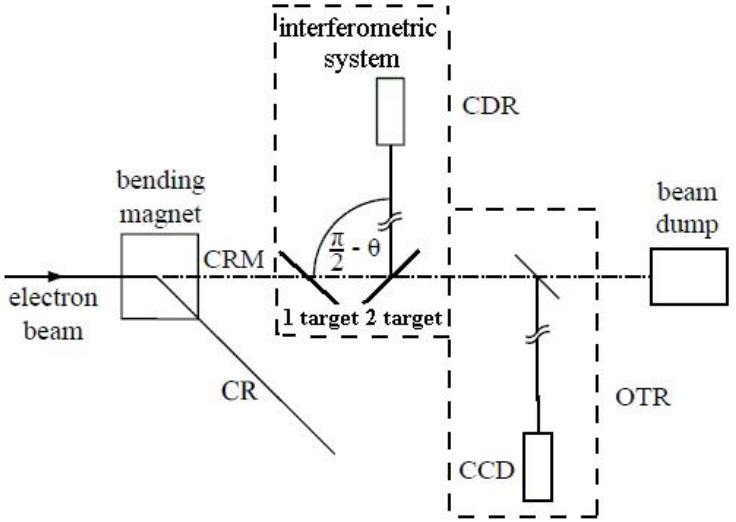
K.V.Lekomtsev@rhul.ac.uk

Experimental setup at CTF3









- Two UHV six-way crosses contain aluminium coated silicon targets (60mmx40mm) to one side of the beam.
- The targets are attached to the UHV manipulators, which provide precise control of rotational and vertical translation axes for the downstream target and vertical translation axis for the upstream target.
- The radiation originated from the targets is translated vertically by the periscope towards the interferometer.

K.V.Lekomtsev@rhul.ac.uk

Interferometric system

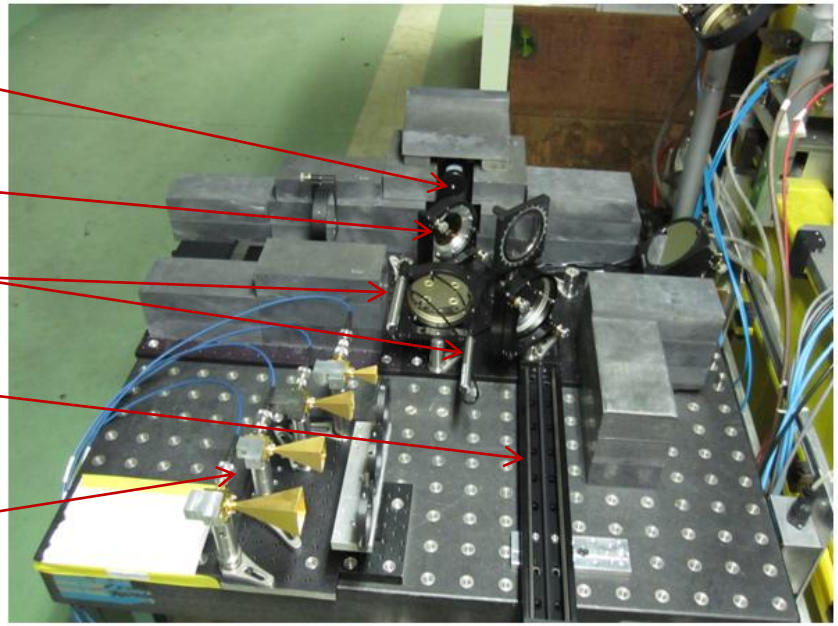
Pyroelectric detector.

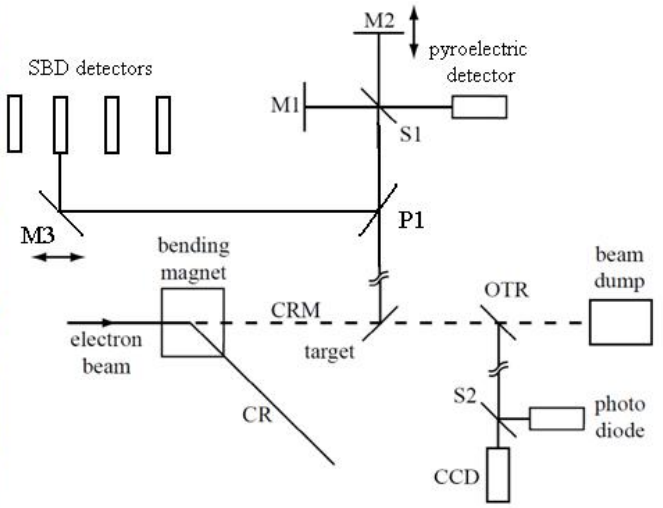
Silicon splitter.

Mirror actuators.

Additional linear stage.

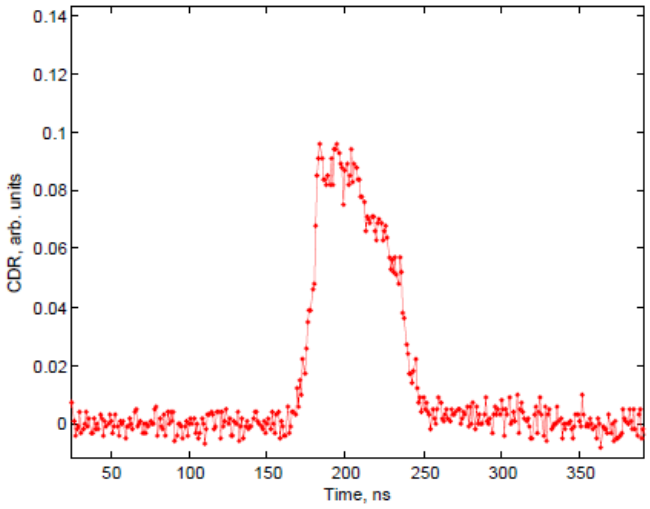
Schottky barrier diode detectors.

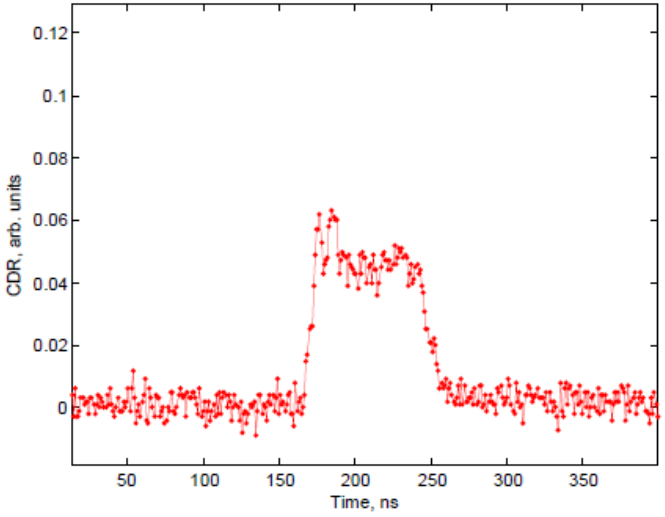




Sample signal from the pyroelectric detector .

Sample signal from the DXP12 (60 – 90 GHz)





K.V.Lekomtsev@rhul.ac.uk

Spectral measurements

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

$S_{coh}(\omega)$ -coherent radiation spectrum (derived from the interferometric measurements by applying Fourier transformation)

N - number of electrons in the bunch (derived from the current readout)

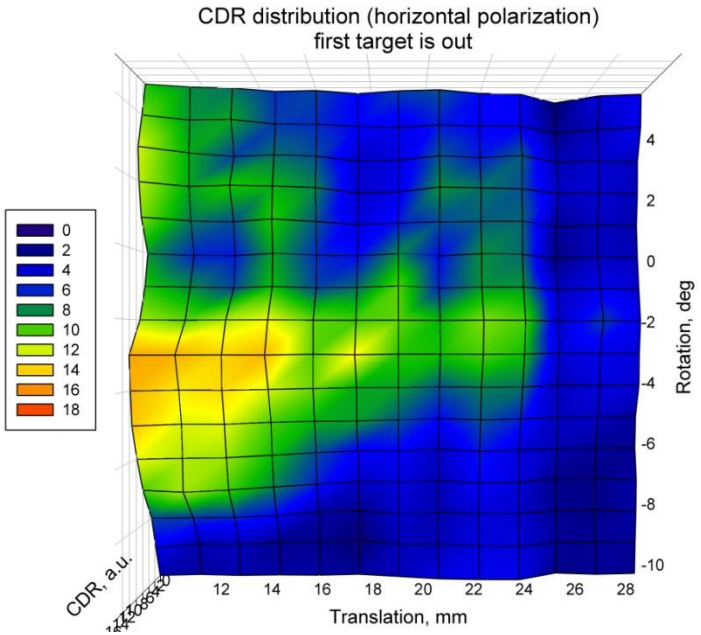
$S_e(\omega)$ - single electron spectrum (can be obtained by integrating the CDR distribution over the detector aperture)

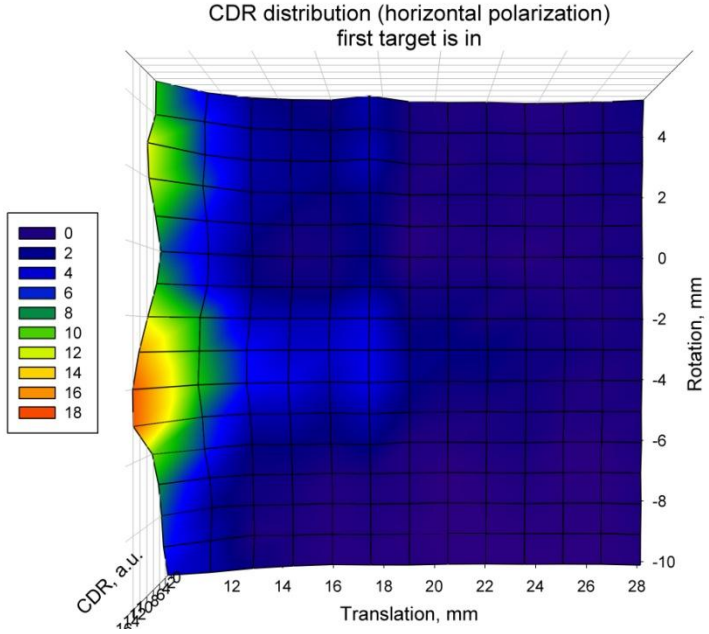
$F(\omega)$ -longitudinal bunch form factor (the ultimate goal of the measurements, form factor is used for minimal phase and bunch charge distribution reconstruction)

K.V.Lekomtsev@rhul.ac.uk

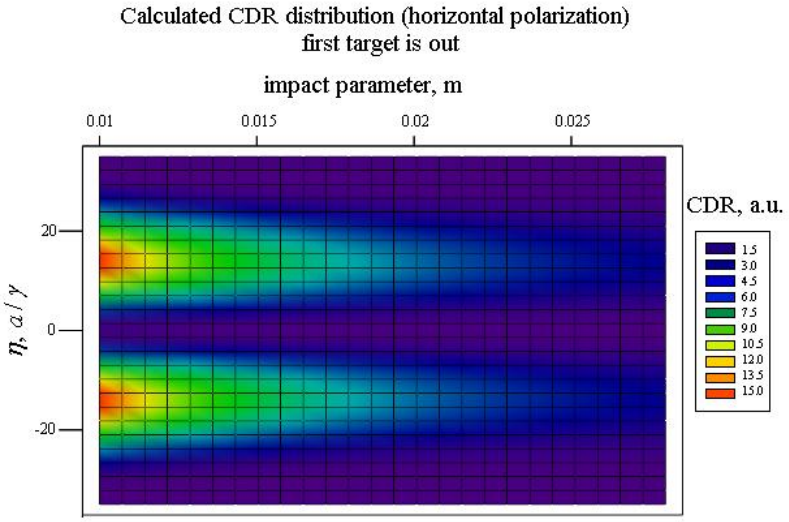
Experimental results & Simulations

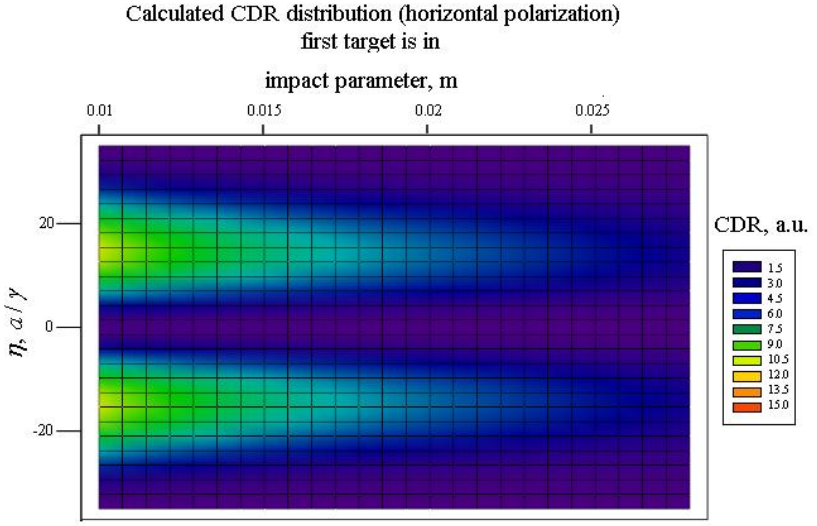
Experiment





Simulations





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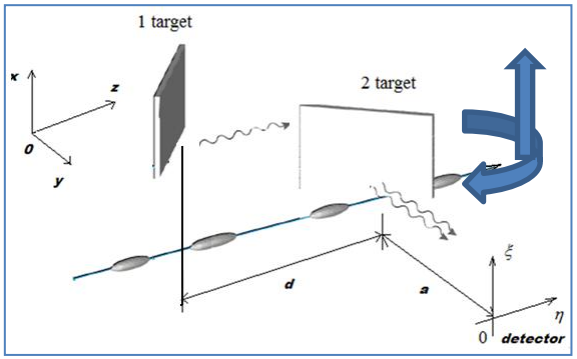
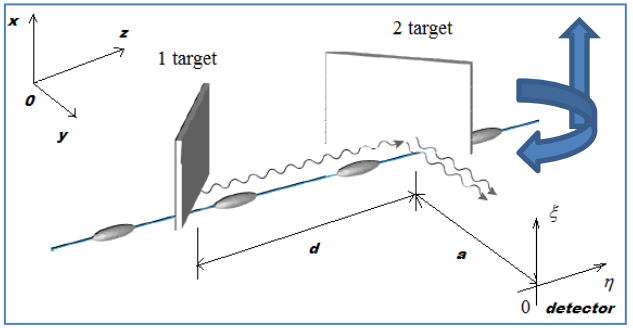
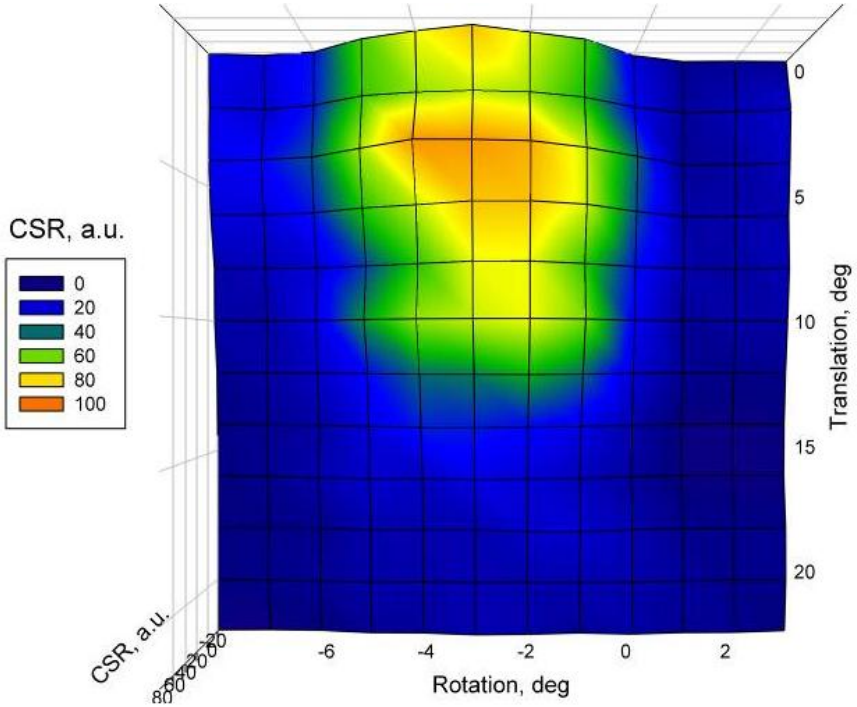
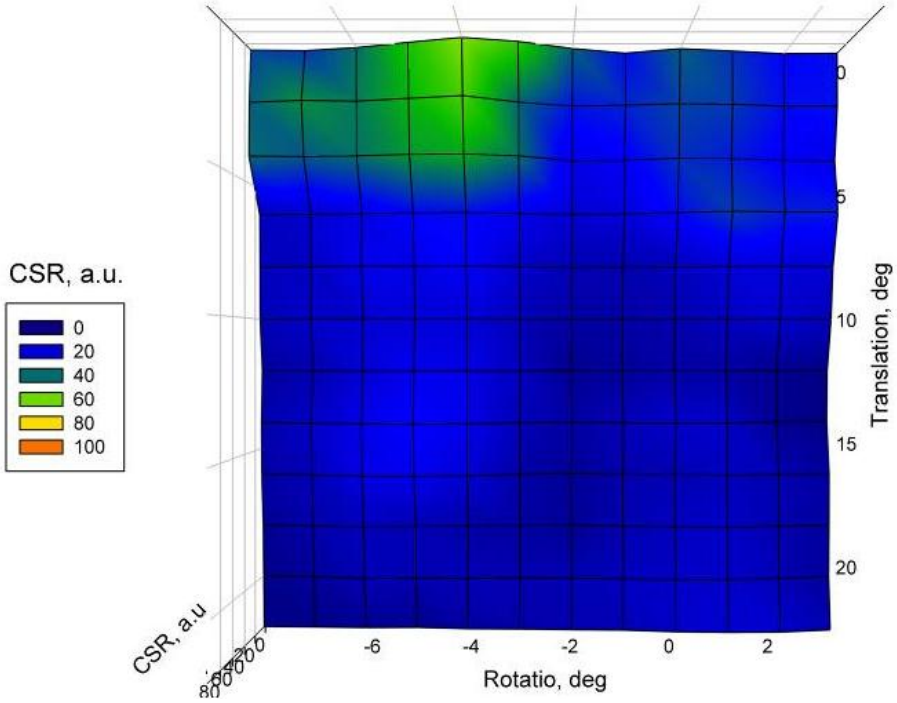
CSR scans



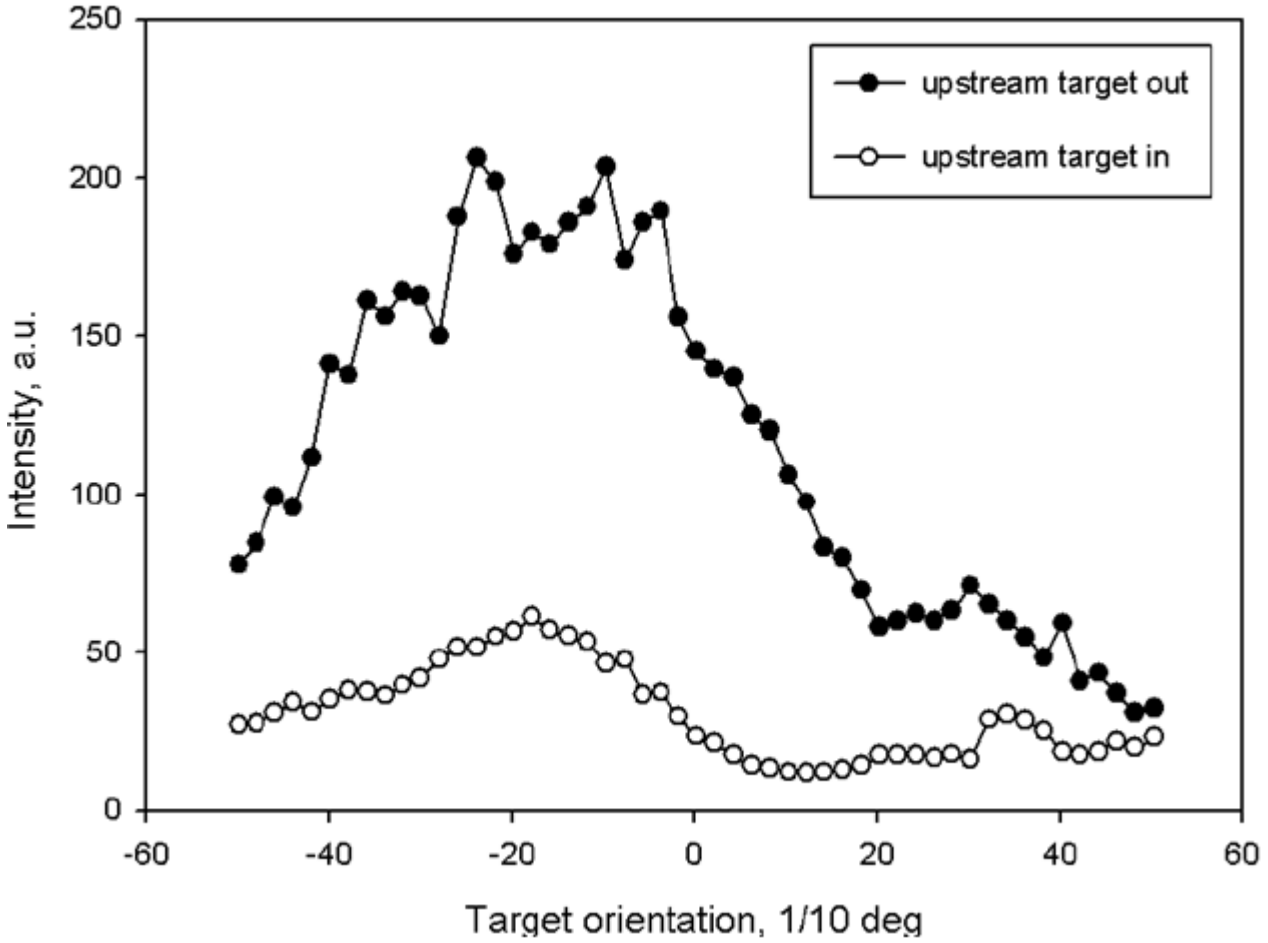


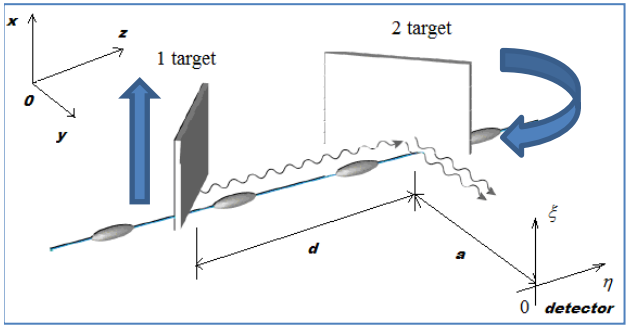




K.V.Lekomtsev@rhul.ac.uk

Rotation scans





Scans were taken for CSR for two main configurations of the setup:

1. The first target and the second target are in the centre of the beam pipe.
2. The first target is out of the beam pipe and the second target is in the centre.

K.V.Lekomtsev@rhul.ac.uk

Conclusions & Outlook

- Recent upgrade has been performed which included: installation of the second target with UHV manipulator, new pyroelectric detector, set of Schottky Barrier Diode detectors, new silicon beam splitter, mirror actuators and automatisation of the corresponding components.
- Background contribution studies have been performed.
- 2D scans of the CDR distribution have been done to prove that the newly installed target is effectively blocking the backgrounds originating from upstream of the setup. Measurements have been performed for different targets position in order to find the optimal two target configuration.
- Good agreement was revealed between measured and simulated CDR distributions, apart from inequality of the peak intensities and the distortions caused by the backgrounds.
- Interferometric measurements have not been finalized due to insufficient sensitivity of the pyroelectric detector.

- As a solution a new more sensitive pyroelectric detector will be installed in the near future.
- Shielding of the interferometric system will be improved as well.
- Interferometric measurements will be resumed as soon as necessary improvements are finalized.