CDR for bunch length monitoring applications

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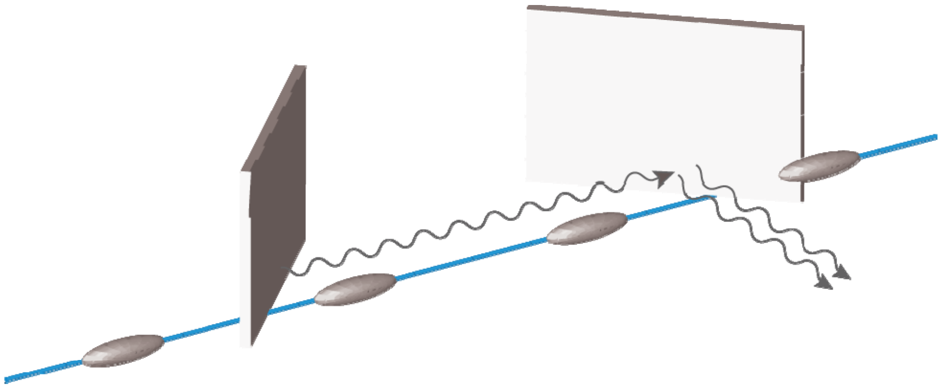
CDR Phenomenon

- Diffraction radiation appears when a charged particle moves in the vicinity of a medium
- Impact parameter, h, is the shortest distance between the target and the particle trajectory
- The criterion for diffraction radiation to be emitted is

$$h \leq \gamma\lambda$$

where γ is the Lorentz factor and λ is the observation wavelength



- For our setup at CTF3, $h \approx 15$ mm $\leq \gamma\lambda = 1175$ for $\gamma = 235$ and $\lambda = 5$mm.

Coherent radiation:

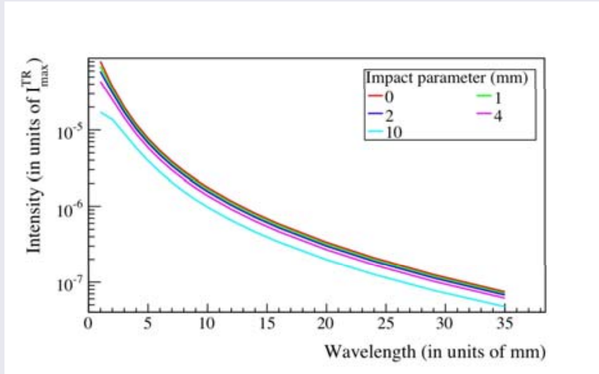
$$S(\omega) = [N_e + N_e (N_e - 1) F(\omega)]\, S_e(\omega)$$

Incoherent part (N_e)   Coherent part ($N_e (N_e - 1) F(\omega)$)

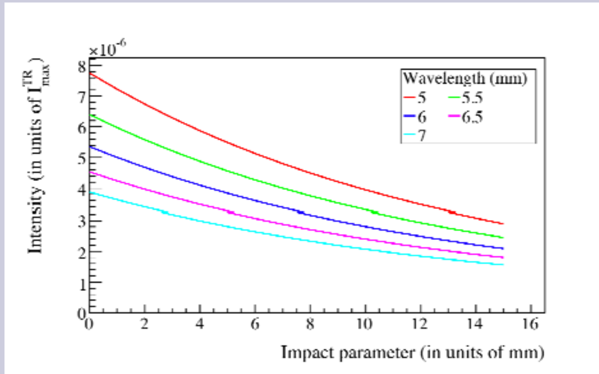
- $S(\omega)$ is the signal, known from the experiment
  - this can be obtained by using an interferometer
- $S_e(\omega)$ is the single electron radiation, which should be predictable form theory
- N_e is the number of electrons, known from the experiment
  - can be measured using the charge reading of a beam position monitor
- $F(\omega)$ 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

Simulation studies

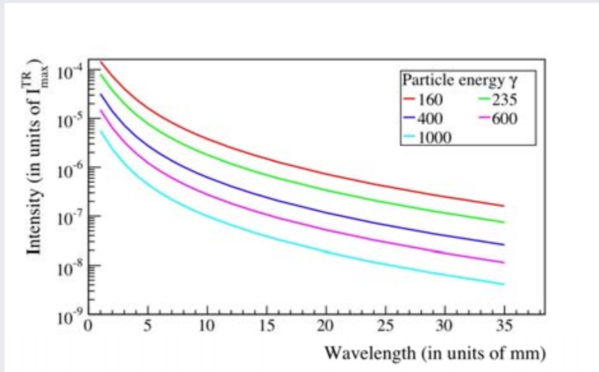
- Diffraction radiation spectra with $I_{max}^{TR} = \frac{\alpha\gamma^2}{4\pi^2}$
  - needed in the de-convolution of the spectral information (see previous slide)
  - $S(\boldsymbol{\omega}) = N_e^2\, F(\boldsymbol{\omega})\, S_e(\boldsymbol{\omega})$



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



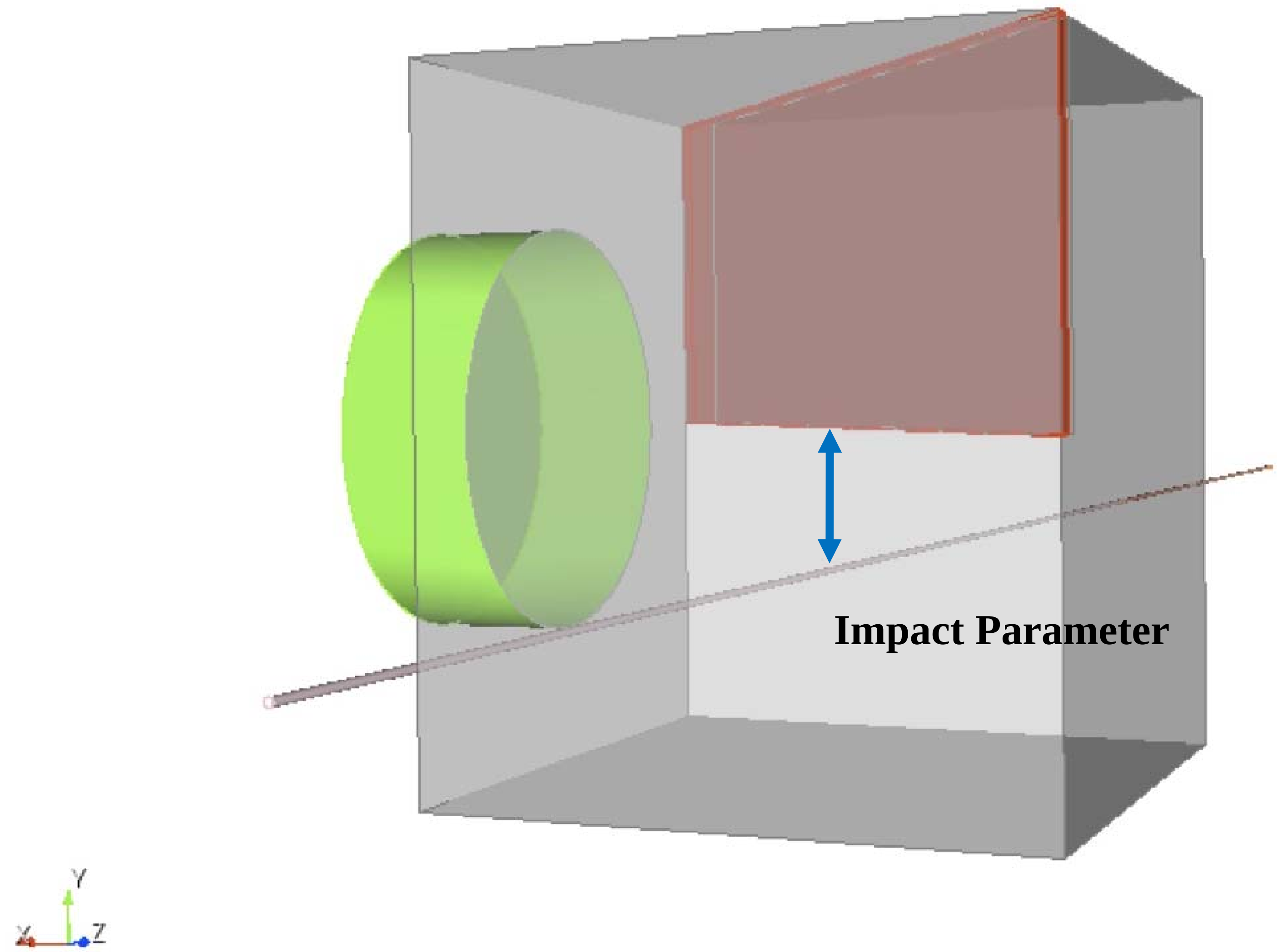
- Diffraction radiation spectra for different beam energies
  - zero-impact parameter
  - for higher energies the intensity increases



Simulations: ACE3P codes

	Module Name	Description
Frequency Domain	Omega3P	Eigen-solver for resonant modes
	S3P	S-Parameters
Time Domain	T3P	Excitation of fields by relativistic bunch
	Pic3P	PIC code for space-charge dominated devices
	Track3P	Particle tracking for multipacting & dark current
Multi-physics	TEM3P	EM, thermal, mechanical

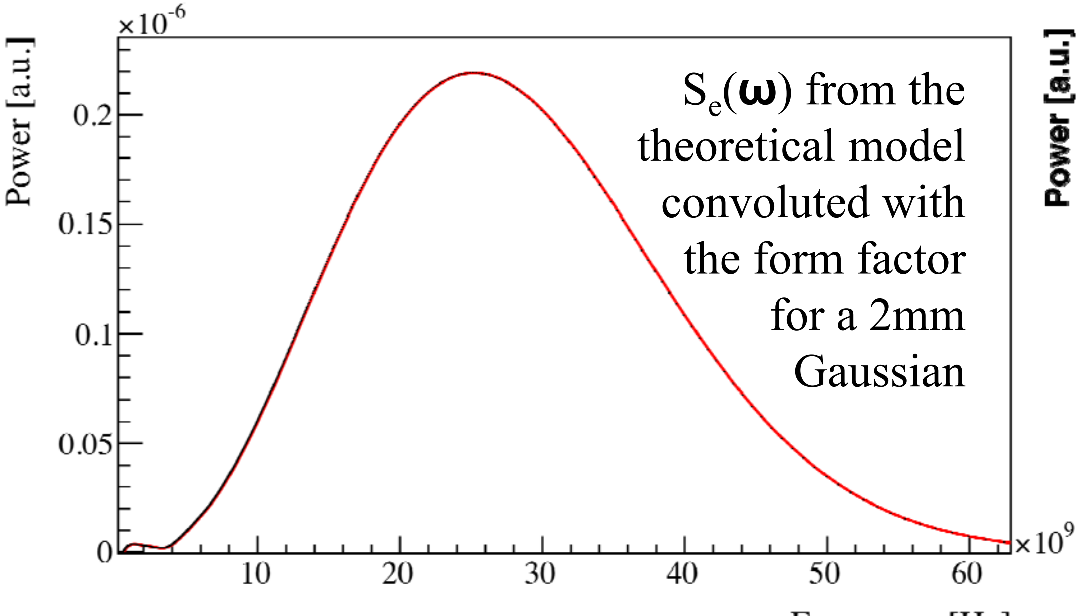
Simulations: Model

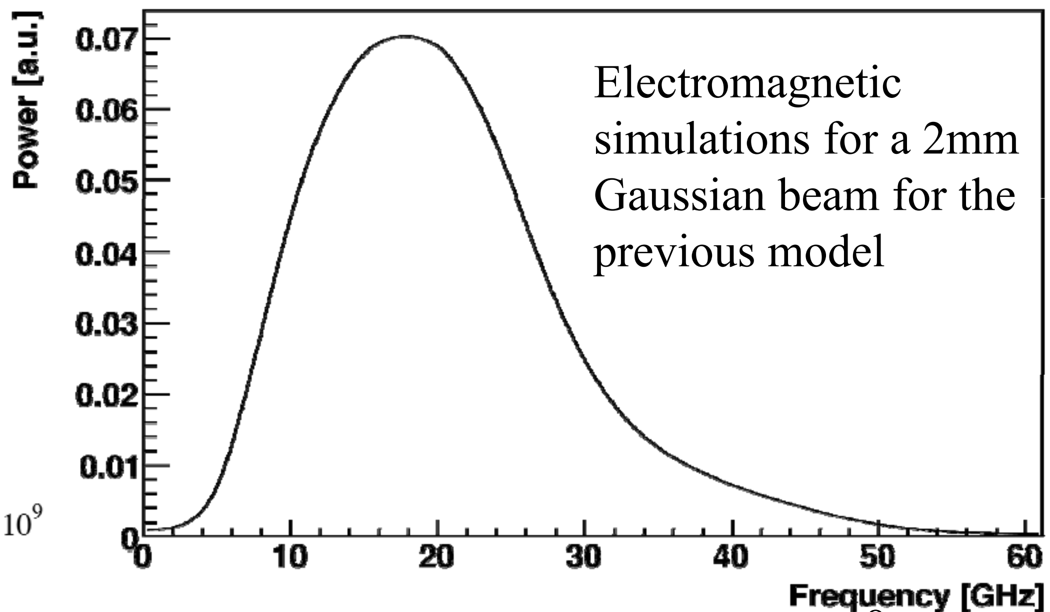


Simulations: Preliminary

Spectra from theoretical model and electromagnetic simulations:

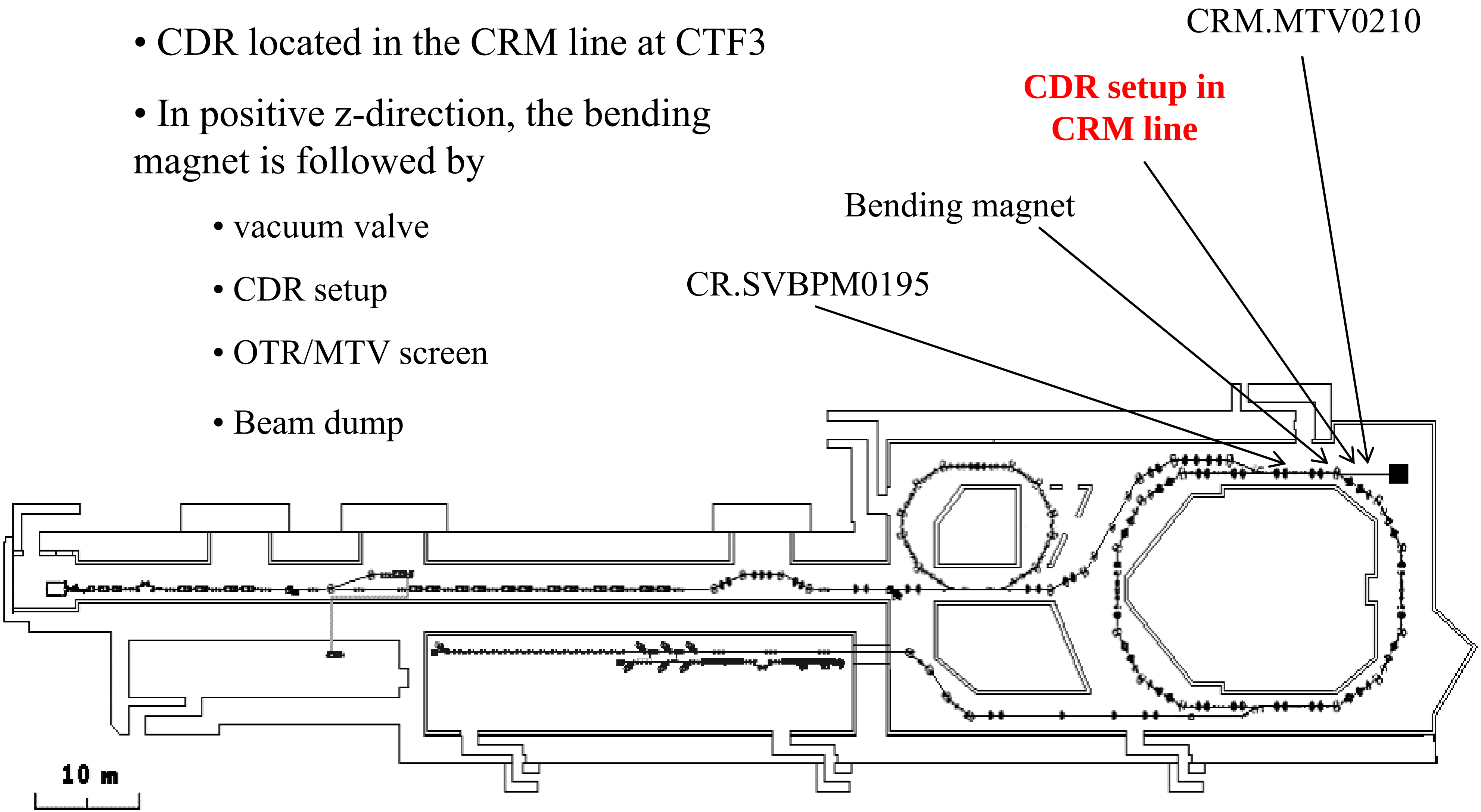
- Suppression of the power:
  - towards lower frequencies due to finite target dimensions
  - towards higher frequencies due to the form factor cut-off
- Discrepancies of the peak position for the two cases and slightly different shape
- Further simulation studies are ongoing and very promising





Location of CDR:

- CDR located in the CRM line at CTF3
- In positive z-direction, the bending magnet is followed by
  - vacuum valve
  - CDR setup
  - OTR/MTV screen
  - Beam dump



CDR setup

Vacuum manipulator for target rotation and translation

CRM.MTV0210 for target reference position

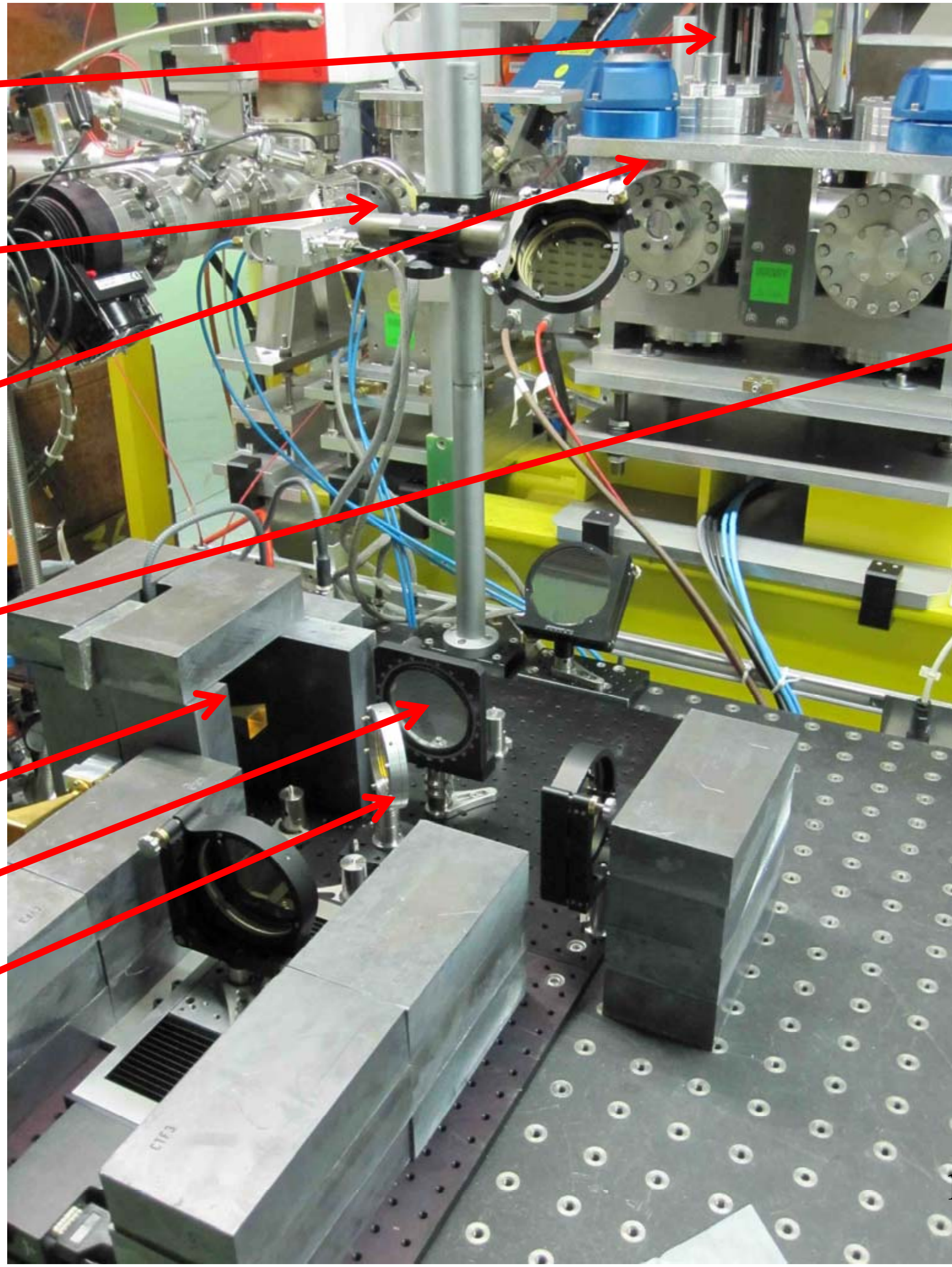
CDR target within six-way cross

CR.SVBPM0195 (not shown in picture) for beam position and charge readings

SBD detector

Polarisrer

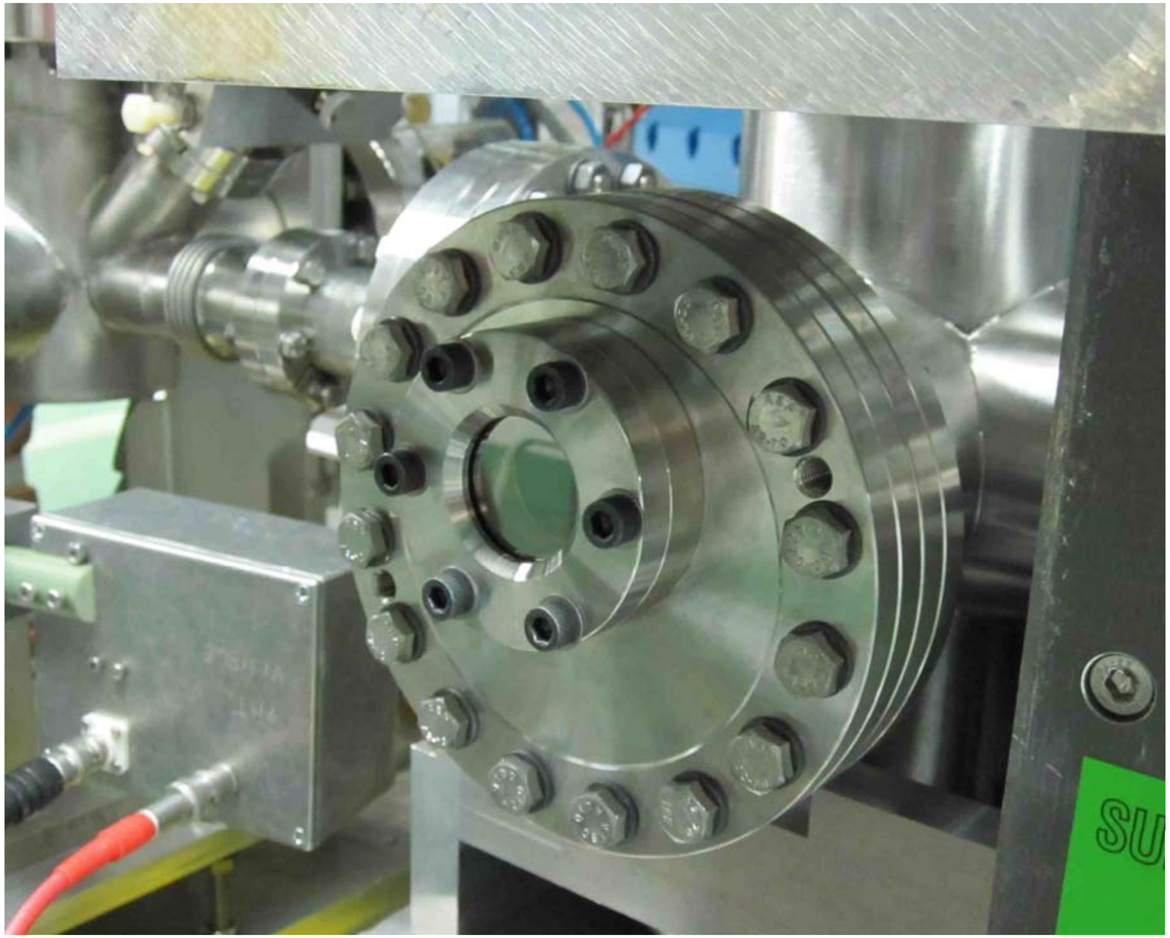
Beam splitter



Off-centre flange

Installation of an off-centre adapter flange (15mm):

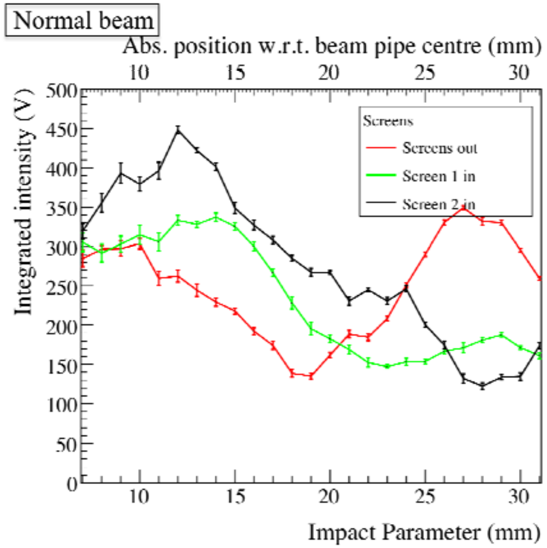
- Originally had a central viewport installed
- Small vacuum intervention in October 2009 to install the off-centre flange and diamond vacuum window
- Flange was installed because unwanted backgrounds were detected from the machine
- Able to cut out this background with such a flange
- Flat transmission spectrum for diamond viewport

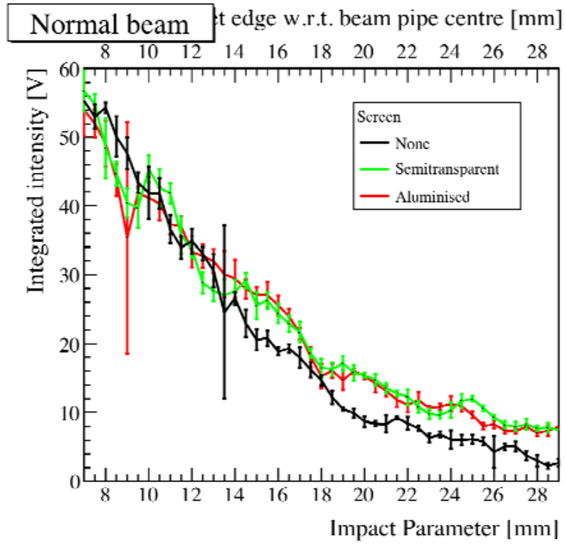


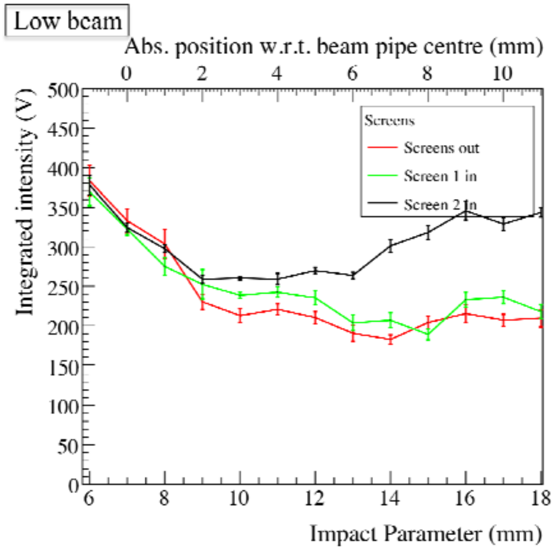
Off-centre flange

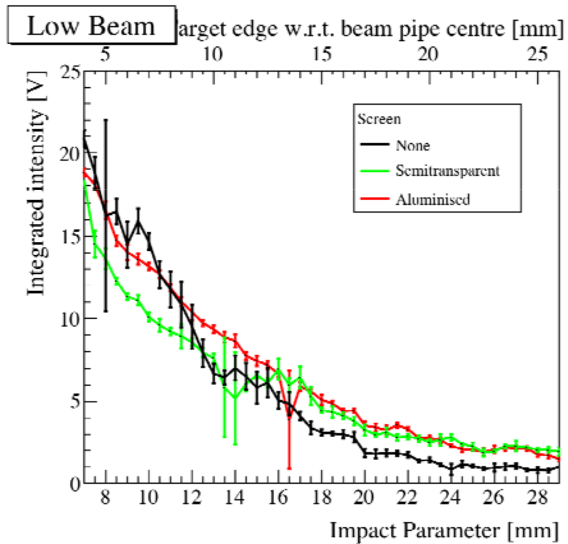
Installation of off-centre flange was a success:

- Comparison of the signals from a translation scan before and after the installation



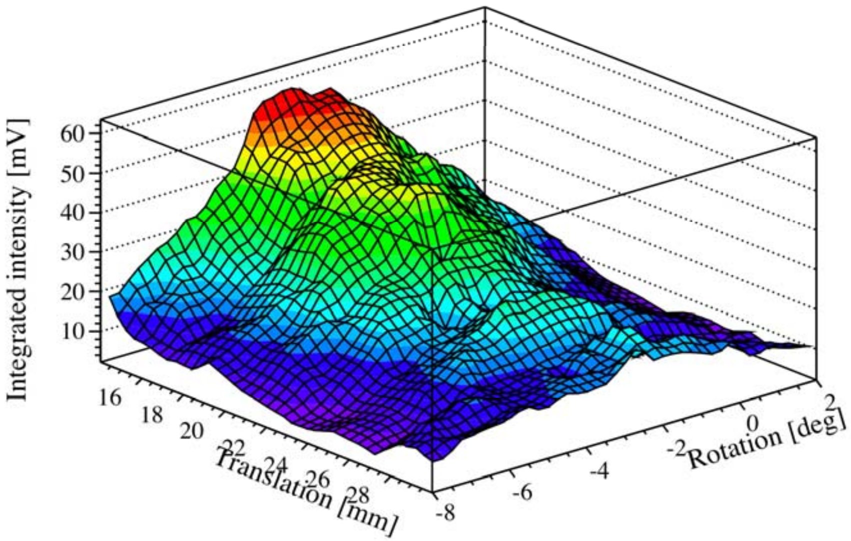


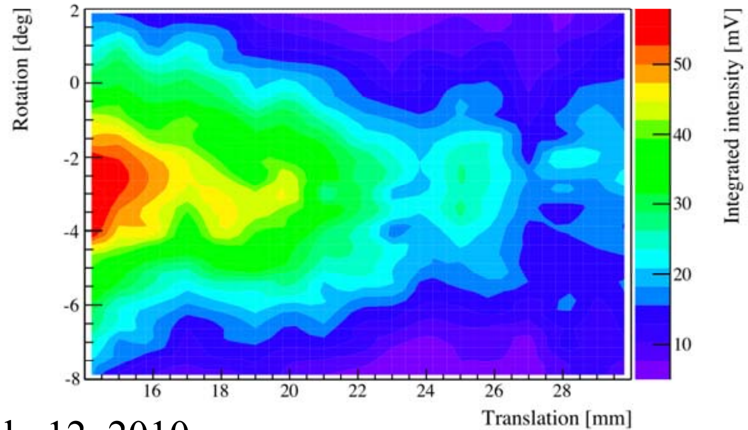




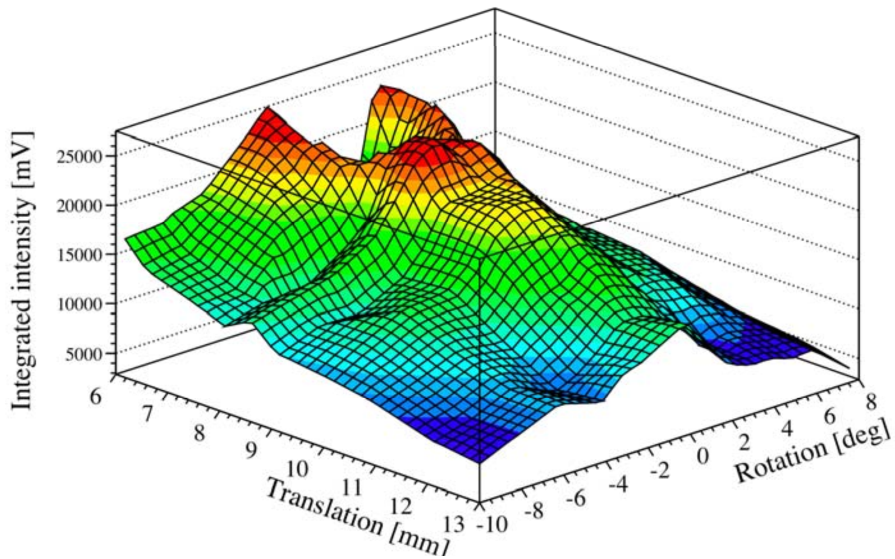
CDR Distribution scans

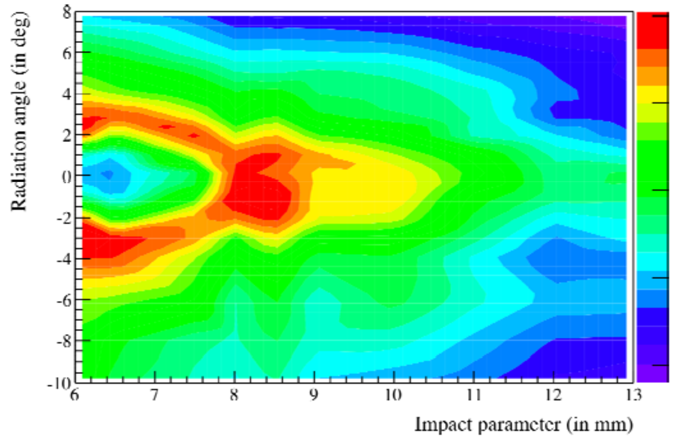
- Vertical polarisation





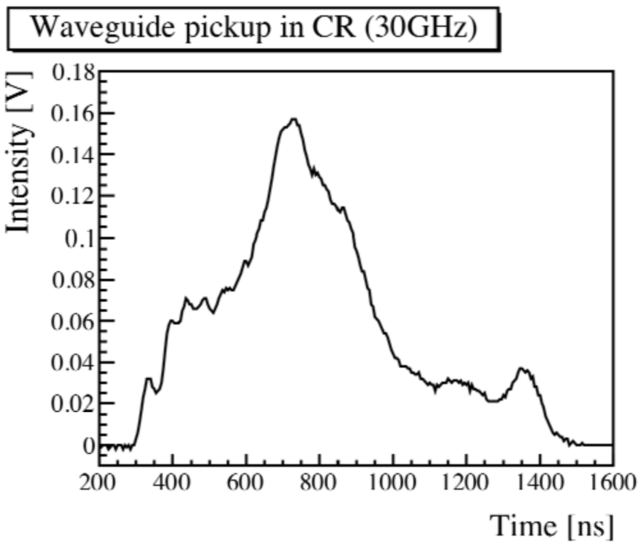
- Horizontal polarisation (no off-centre flange)

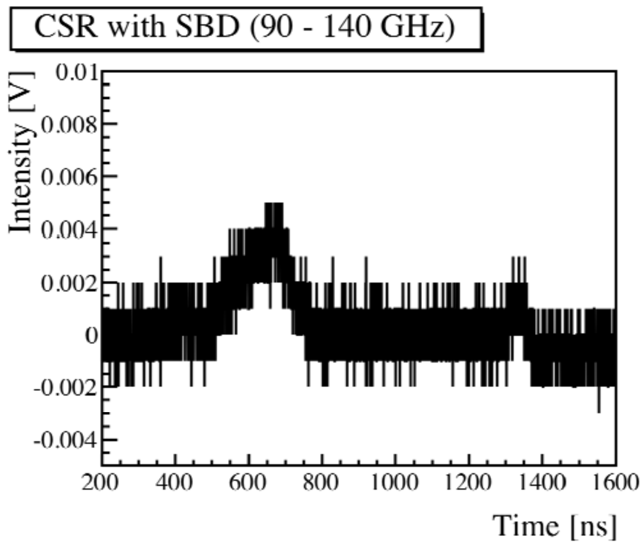




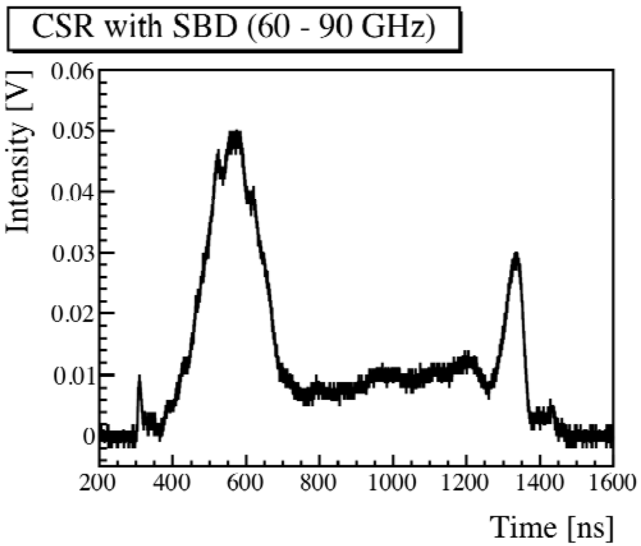
Longitudinal measurements:

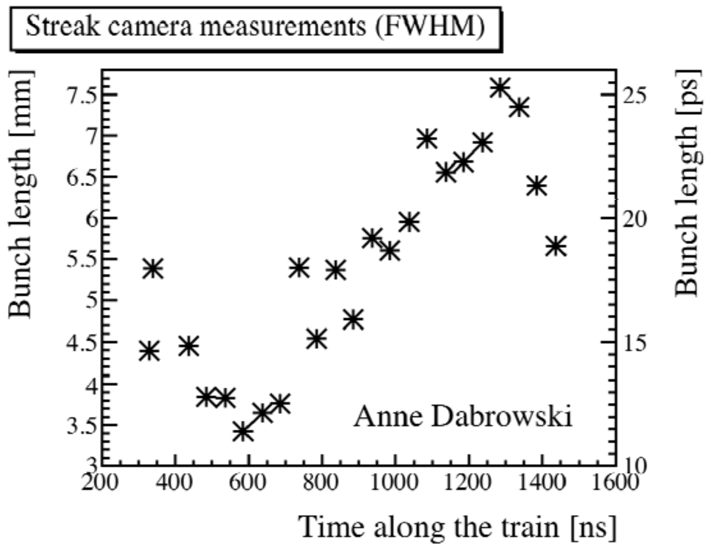
- Comparison of BPR (30 GHz), CSR with SBD detectors, and Streak camera





Digitization steps set to high (but can be changed)

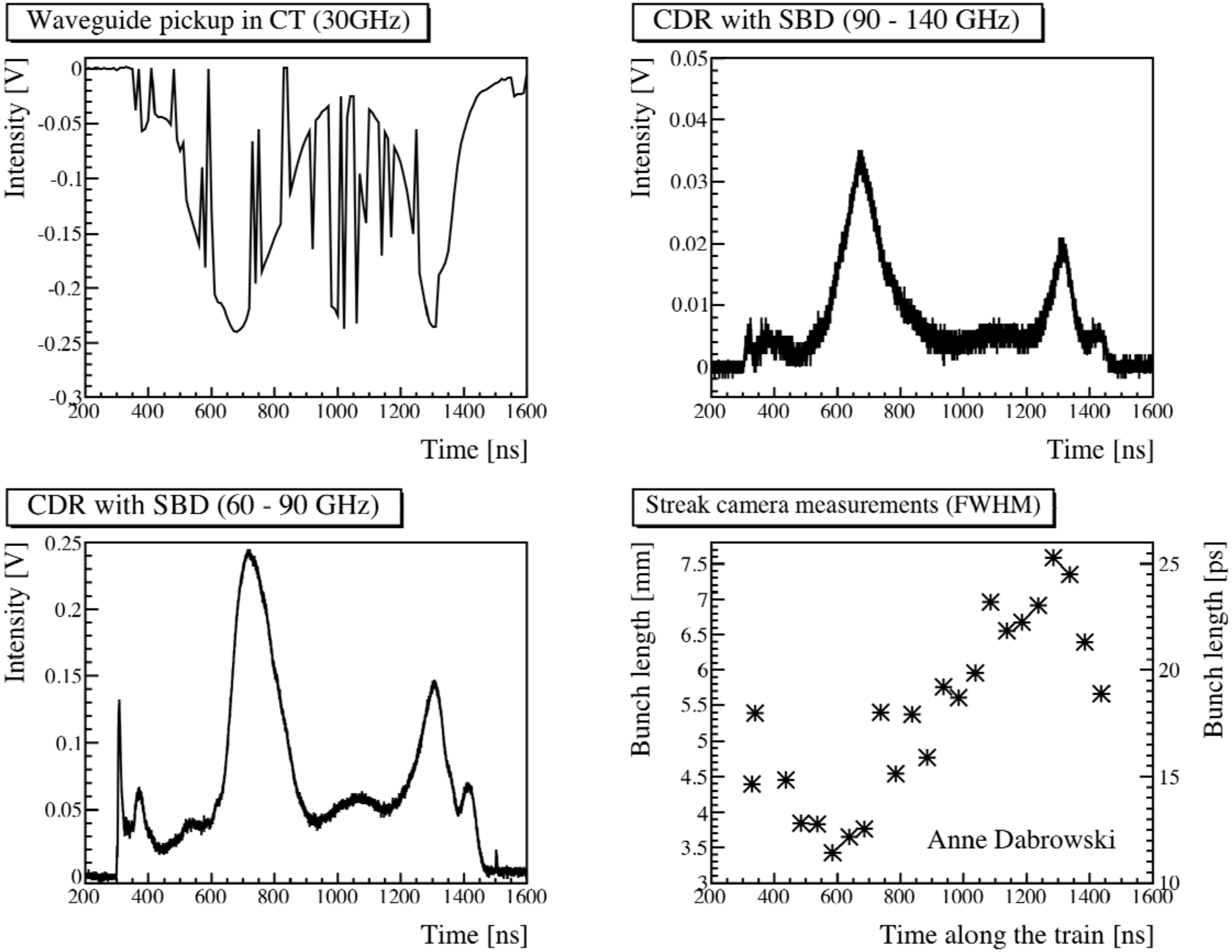




Longitudinal measurements

Longitudinal measurements:

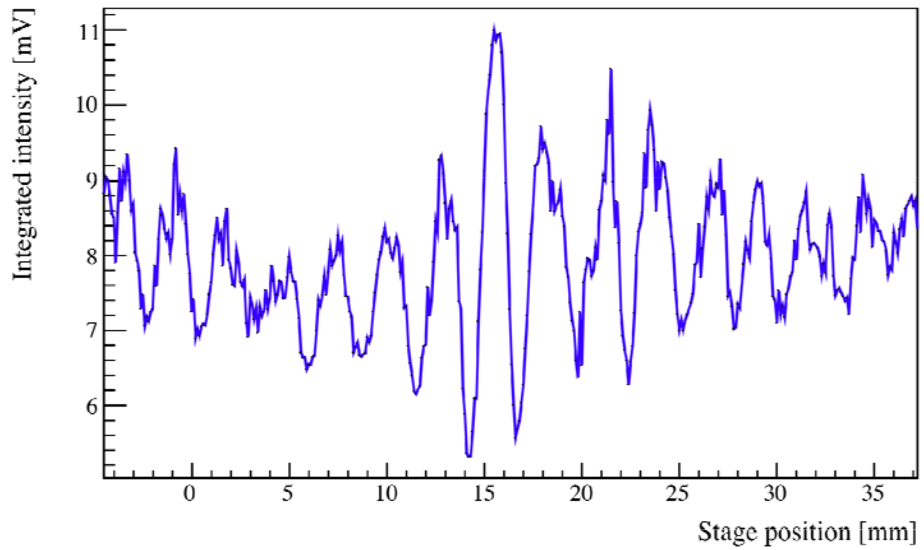
- Comparison of BPR (30 GHz) and CDR with SBD detectors

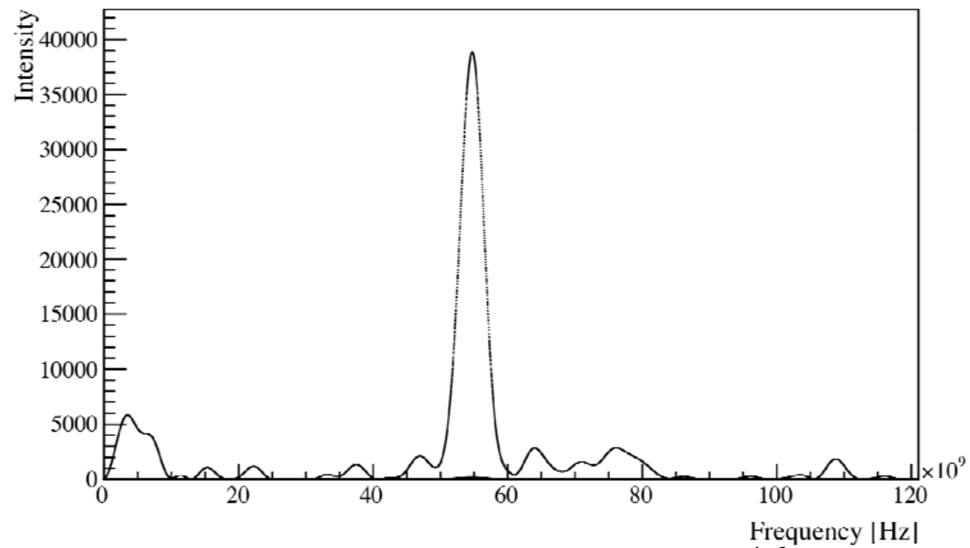


Interferometric measurements:

- A better understanding of the system has been achieved
- Interferograms look very promising, but there is some distortion
- Recovering a good spectrum is not trivial with a fairly narrow band detector
- Interferometric measurements have been influenced by:
  - splitter efficiency is not sufficient
  - hard to obtain good interferograms with narrow band detectors

CDR scan (16.11.09)





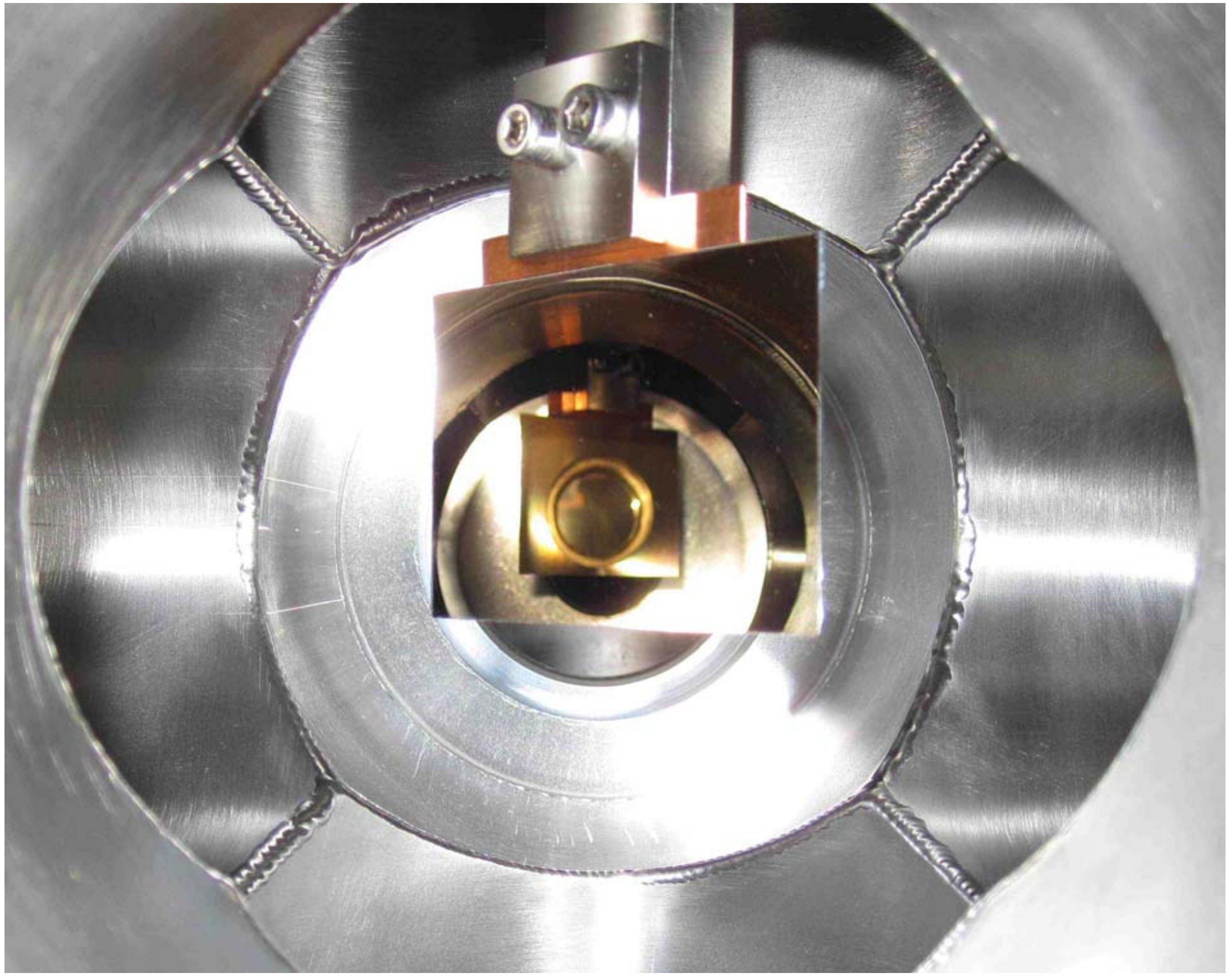
Interferometric measurements:

- A similar system to measure CSR has been installed at DIAMOND, UK
  - Millimeter Wave Technology (MMT) group at RAL confirmed a low splitter efficiency of Mylar and Kapton films in multi-mm wavelength range
  - MMT suggested to use an undoped Silicon wafer instead
  - Silicon wafer has been ordered
  - Slightly more difficult alignment as Silicon is opaque for laser, but …
- Young researcher's grant (CRF) from the University of London
  - Mirror actuators for interferometer
    - ☞ to perform a beam based alignment of the interferometer
  - Translation stage for multiple detectors
- We will try a broadband pyroelectric detector to measure the interferograms

2nd CDR target

Installation of the 2nd target:

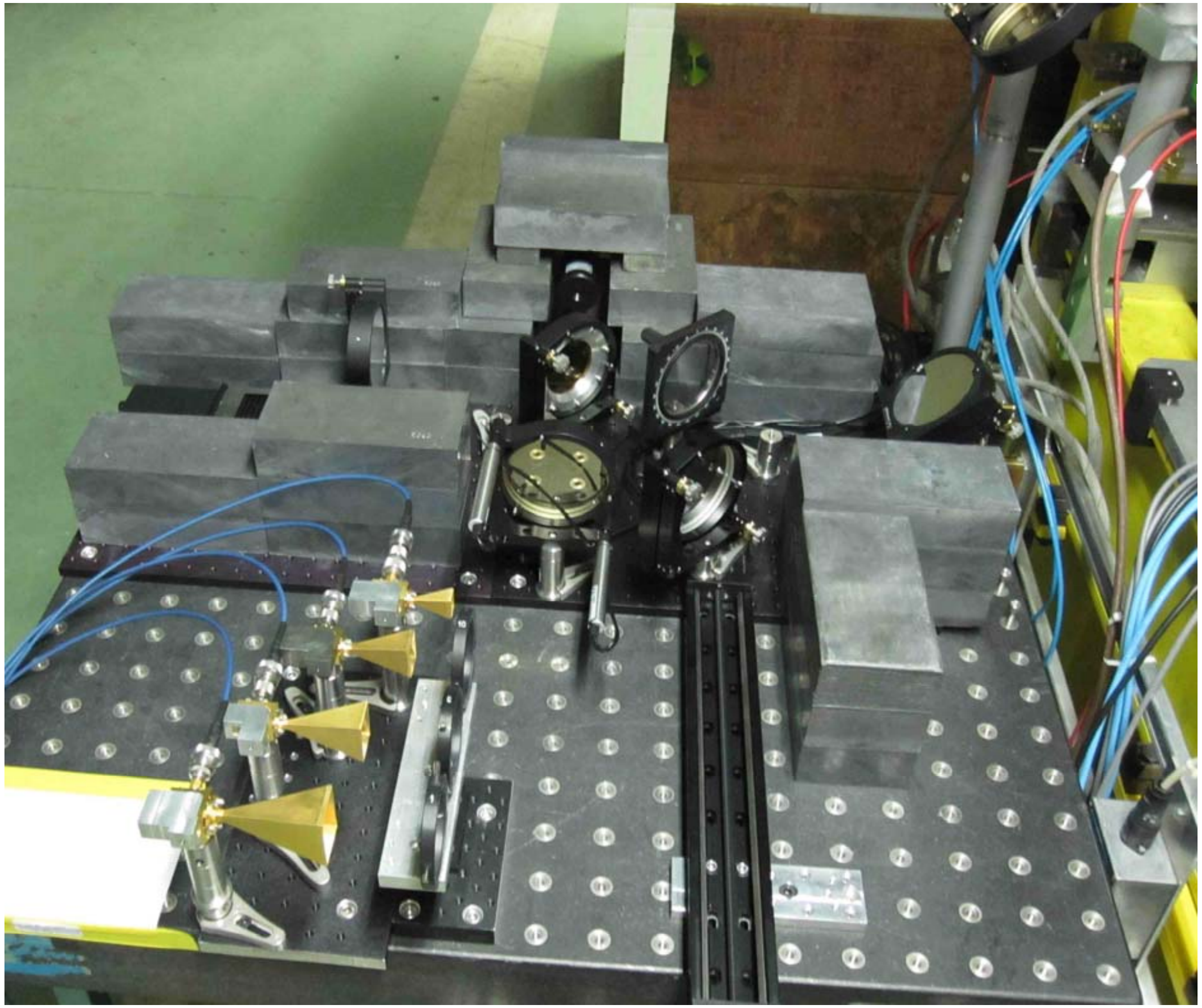
- Small vacuum intervention in the CRM line in February 2010
- Installed the 2nd target
- Used the occasion to install an additional vacuum window as well
- Studies commencing as soon as CTF3 is back up



Modified optics

Modified optics system for 2010:

- Use of polariser to split the radiation
- Pyroelectric detector for interferometric measurements
- Linear stage and array of SBDs to measure CDR directly within a certain frequency band
- Use of silicon splitter as soon as possible



Problems

Difficulties encountered whilst performing the experiment:

- Single electron spectrum prediction is questionable!

  - Electromagnetic simulations were started and some initial, very promising results have been obtained;

- A broadband detector is required!

  - ultrafast, room-temperature, and highly sensitive one

- Or a single shot spectrometer system is needed!

  - a grating spectrometer is considered.

- Limited access to the experimental area!

  - delays R&D process

Royal Holloway University of London

Solutions

A new program is being discussed with Millimetre Wave Technology Group based at RAL:

- Joint interest in development of an ultrafast broadband room-temperature and highly sensitive Schottky Barrier Diode detector

A microwave lab is being built at RHUL:

- Spectrometer tuning and alignment;
- Transmission measurements of various components;
- Detector Calibration;
- Novel THz radiation detector development with nano-physics and MMT groups;
- Involve UG students in the research

Future Plans

Experiment:

- Continue experimental work at CTF3;
- Measure spectrum with broadband pyroelectric detector to verify our approach for longitudinal bunch profile reconstruction using Kramers-Kronig relation;
- Demonstrate efficiency of the dual target system to avoid coherent backgrounds;
- Develop a fast broad band SBD detector with MMT group;
- Perform measurements with a few SBD detectors with different bands plus correlation studies with RF pickup and streak camera;
- In long term develop a single-shot grating based spectrometer system.

Simulation studies:

- develop a model to predict DR from our dual target to normalise our spectra;
- advanced simulation of a possible vacuum chamber prototype for the generation of diffraction radiation in CLIC