ChDR Bunch Length Monitor Tests at CLEAR

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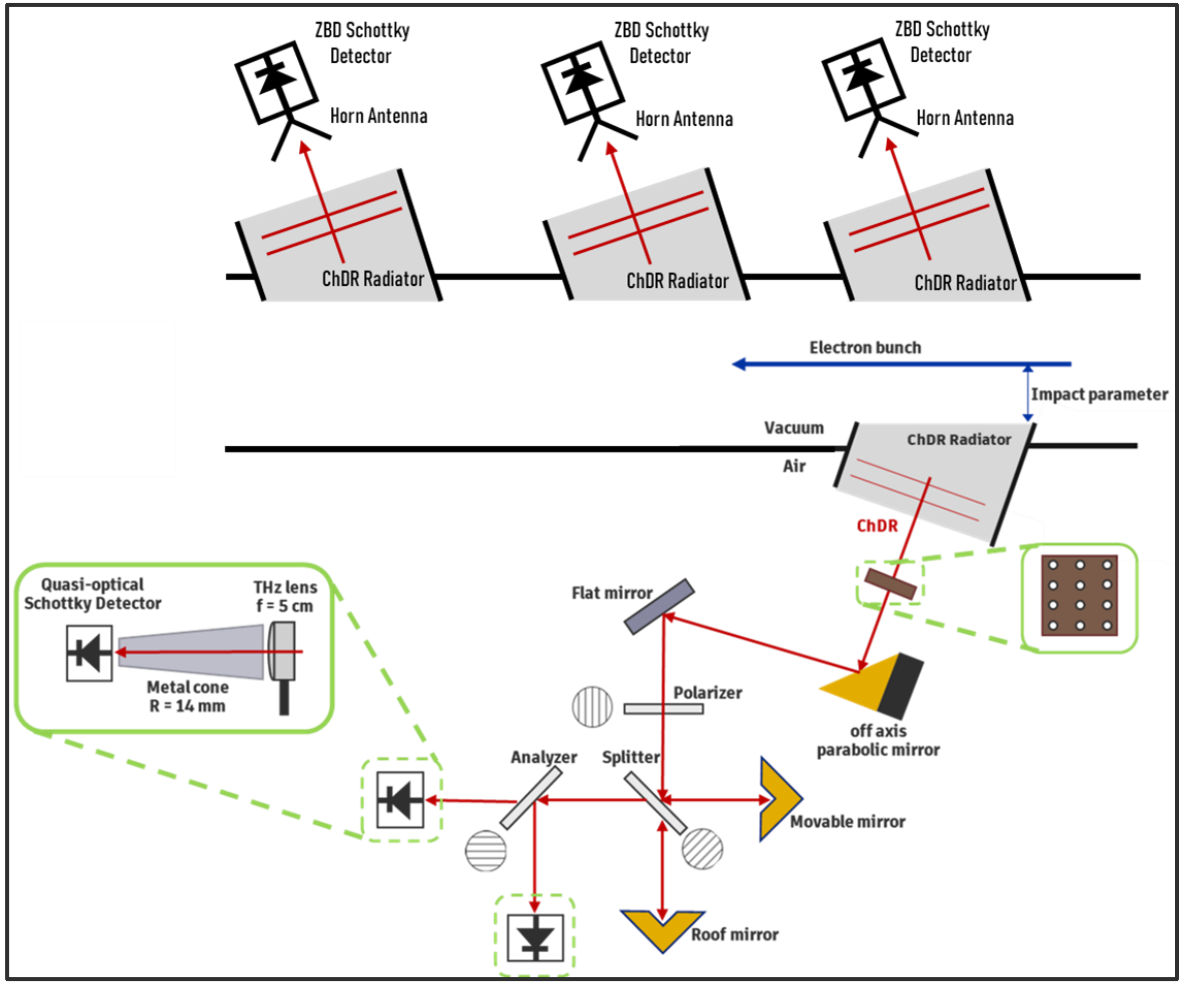
Outline

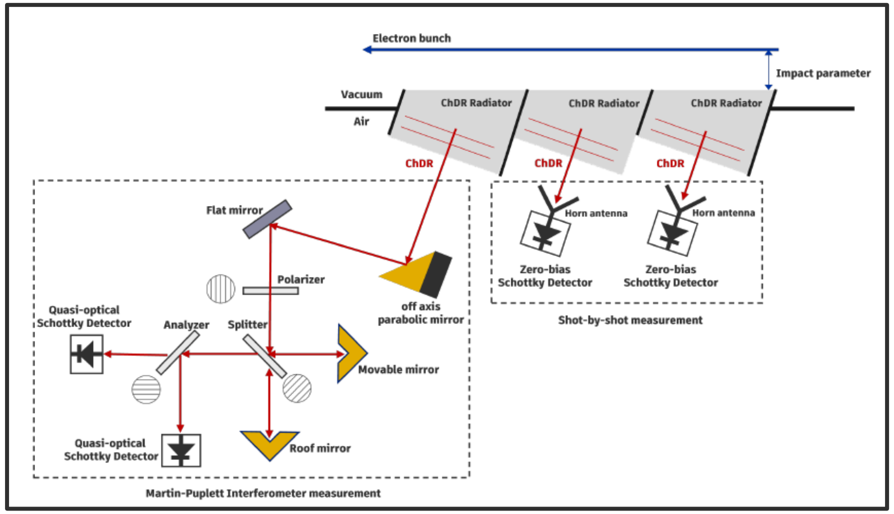
- Recap of the experimental setup
- Installation plan
- Goals of the experiment
- CST simulations
- Conclusions

Recap of the experimental setup

Experimental Setup



Previous Experimental Setup



- RMS Bunch Length Measurements: 3 Zero-bias Schottky diodes with the following frequency ranges.
  - 50-75 GHz
  - 90-140 GHz
  - 400-600 GHz
- Bunch Profile Measurements: A Martin-Puplett Interferometer with QODs with a frequency range of 0.1 - 1 THz

Installation Plan

- CLEAR beam will run between March and end of June. The vacuum chamber will be installed in February along with breadboards and supports.

- Make adjustments to the alumina radiator configuration in the vacuum chamber with the help of Ben Moser.

- New Equipment:
    - 50-75 GHz and 90-140 GHz diodes with attenuators (Arriving mid March).
    - THz lens for 400-600 GHz to improve S/N ratio.

- Beamtime requested for 2 weeks. Approximately 1 week end of May and 1 week end of June.

- Parasitic measurements before dedicated beamtime.

Goals of the Experiment

- The experiment will be focussed more on the RMS bunch length measurements from the ZBDs. However, some MPI profile measurements may be taken along side these.

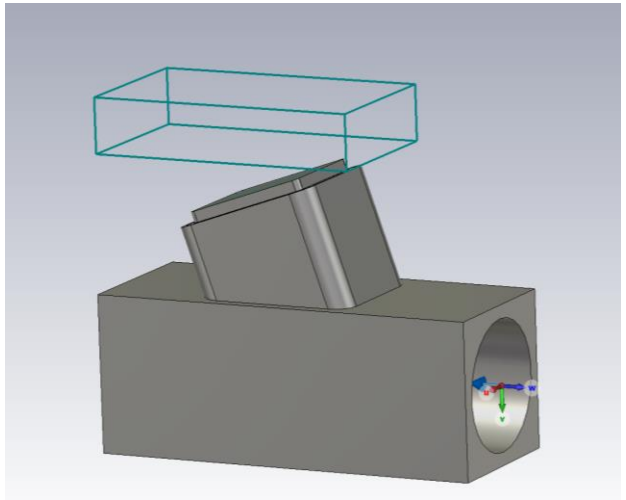
- Parasitic Measurements:
  - Observe Signal from all detectors
  - Check S/N ratio
  - Perform alignments
  - Test attenuation/amplification scheme

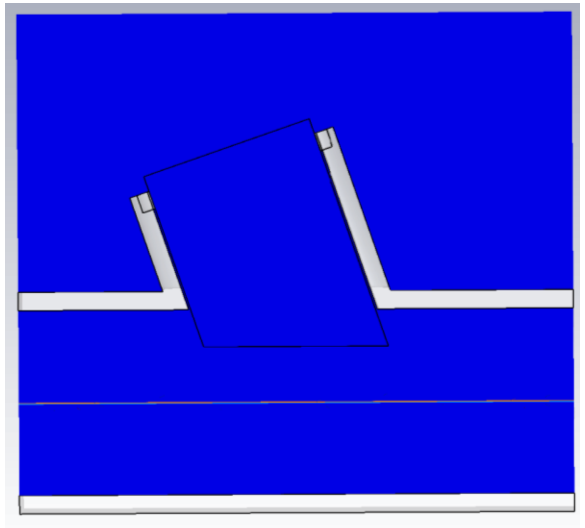
- 2 weeks dedicated beamtime:
  - Charge scan
  - Bunch length scan
  - Impact parameter scan
  - Angular jitter scan

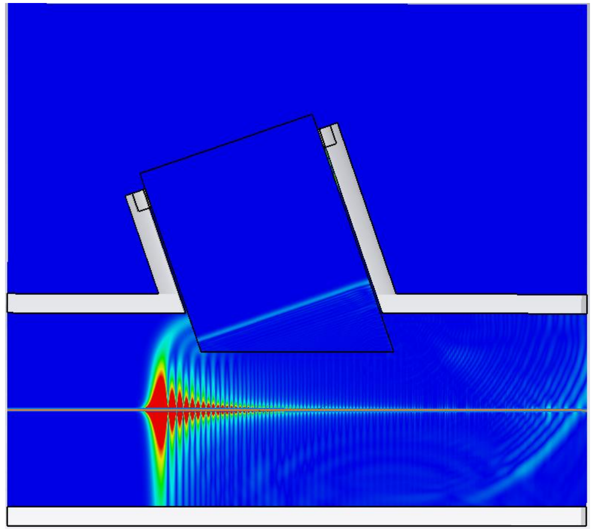
CST simulations

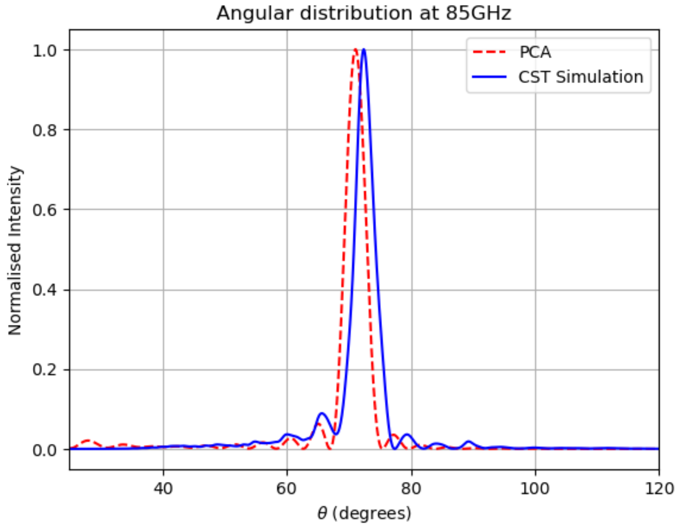
Model based off dimensions of the vacuum chamber and radiator we use.

The simulations show a 2ps electron bunch with a 100 pC charge and beam energy 150 MeV









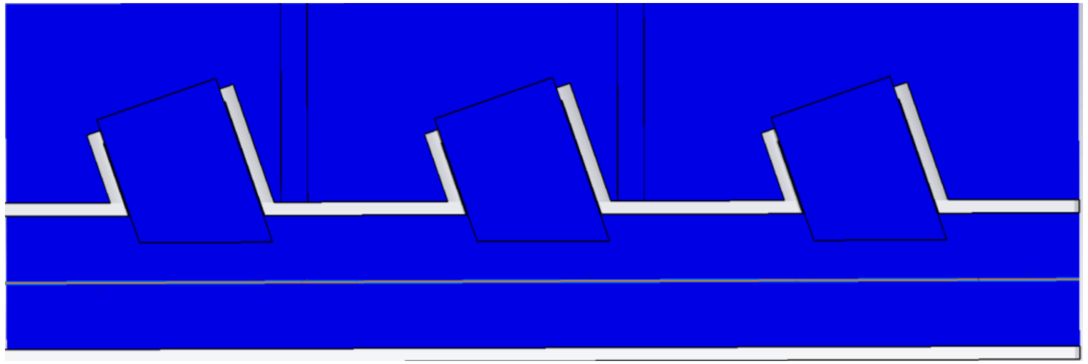
The angular distribution shows a similar distribution with a slight shift

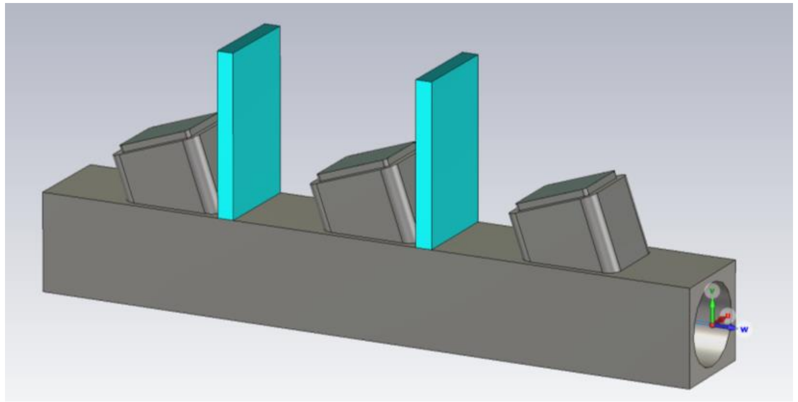
The snapshot on the left shows the field curving after transversing along the radiator

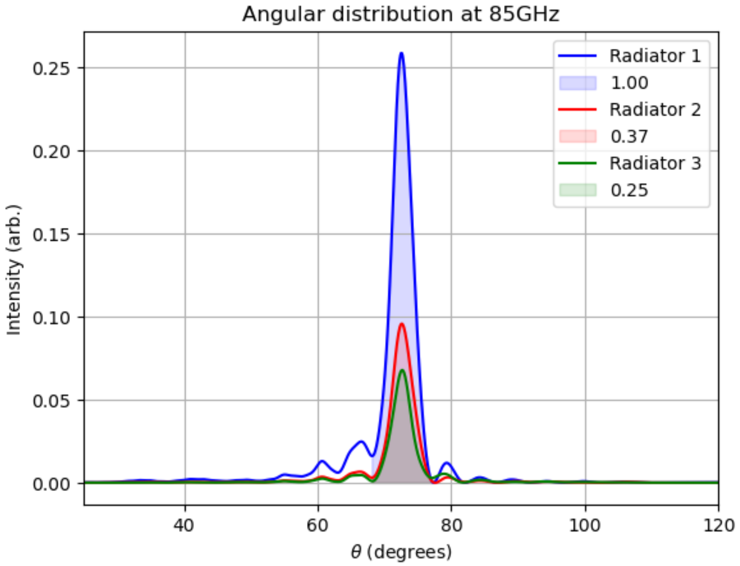
CST simulations

The gap between the radiators are based on the vacuum chamber we have (76.914 mm).

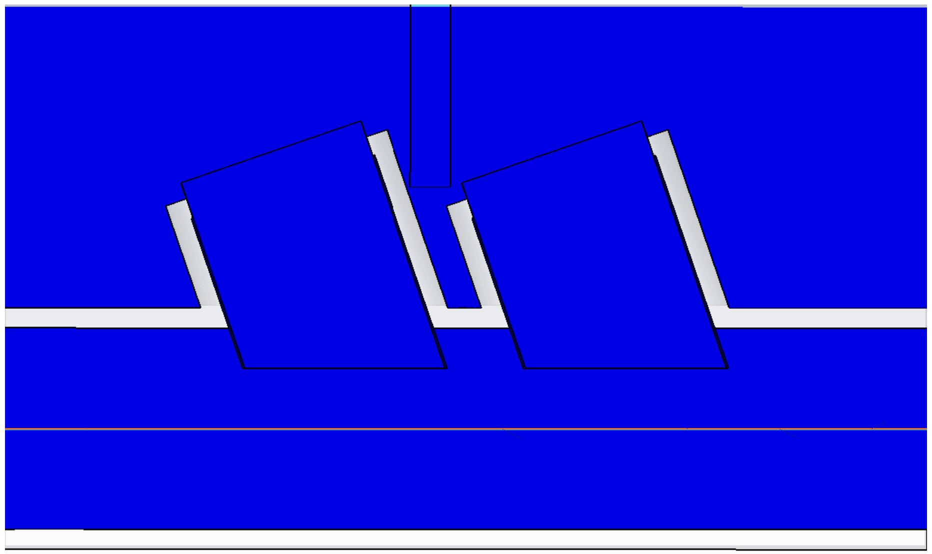
In blue is some shielding to prevent radiation from being detected from other radiators



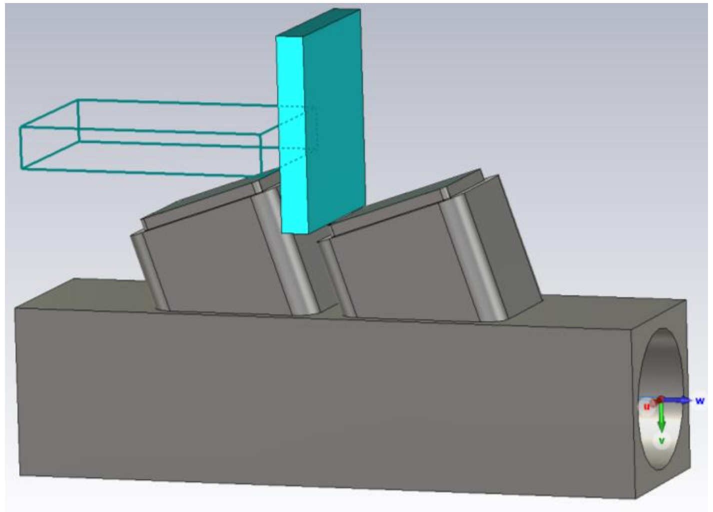


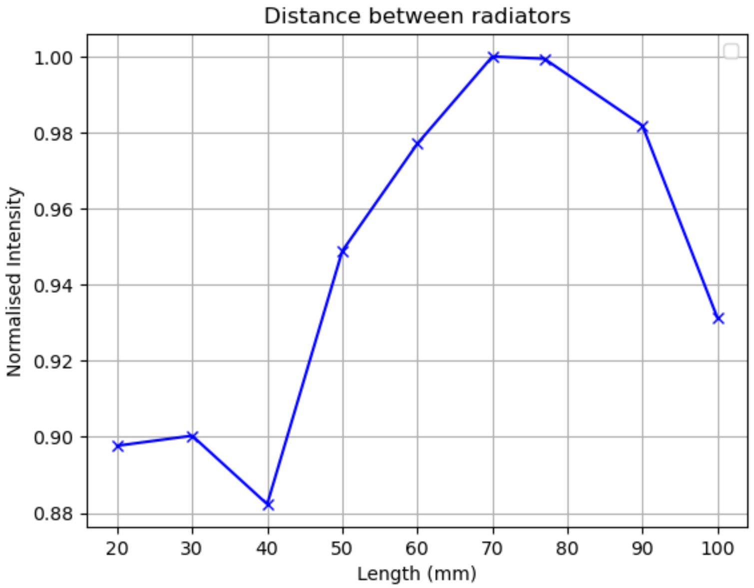


CST simulations



This study is to measure the ChDR intensity when changing the distance between the radiators





We should expect to see the intensity increase when increasing the gap between radiators.

Summary

- The vacuum chamber, breadboards and supports will be installed in February.
- I have requested beamtime for 2 weeks: 1 week in May & 1 week in June.
- In addition to dedicated beamtime, we will collect parasitic measurements.
- I performed CST simulations to calculate:
  - the angular distribution and compare to PCA calculations.
  - the difference in intensity between each radiators based on our existing vacuum chamber.
  - the difference in intensity when changing the gap between radiators.
  - I will repeat the simulation studies involving shields and use faces at the exit of the radiators.

Congratulations to Can Davut for having his paper accepted to PRR for publication based on his ChDR bunch length monitor studies!

Design and experimental verifcation of a bunch length monitor based on coherent Cherenkov diffraction radiation

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(Dated: January 16, 2025)

This paper presents the design and experimental commissioning of a novel, non-invasive electron bunch length monitor based on the detection of coherent Cherenkov diffraction radiation (ChDR). The measurement technique effectively eliminates the influence of bunch-by-bunch charge fluctuations, as each detector measures the signal from the same bunch while mitigating the impact of bunch position jitter on the measurements, providing a potential real-time diagnostic tool with significant operational advantages. The sensitivity of the measurements to both bunch length and longitudinal bunch profile was experimentally demonstrated, with results validated against invasive RF deflector measurements at the CLEAR electron test facility at CERN. The ChDR bunch length monitor can be applied to accelerators operating with ultra-short bunches.

Thank you for Listening!

Numerical Bunch Length Calculation

- The bunch length can be calculated using the following for a Gaussian ($\alpha = 0$) and Skew-Gaussian bunch:

$$\sigma_t = \sqrt{\frac{1}{|\omega_2^2 - \omega_1^2|}\left|\ln\left(\frac{I_1(\omega_1)I_{e2}(\omega_2)|F_{sk2}(\omega_2)|^2}{I_2(\omega_2)I_{e1}(\omega_1)|F_{sk1}(\omega_1)|^2}\right)\right|}$$

Where: $F_{sk}(\omega) = (1 - \mathrm{erf}\left(\frac{\alpha\sigma_t\omega}{\sqrt{1+2\alpha^2}}\right))$