EuPRAXIA Doctoral Network

Ultra-short Bunch Length Measurements with fs Resolution (WP3)

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University of Liverpool

The Cockcroft Institute

UK Research and Innovation

Core Areas of R&D Activity

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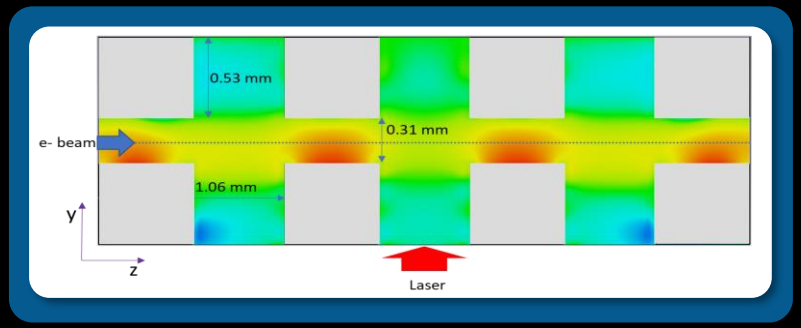

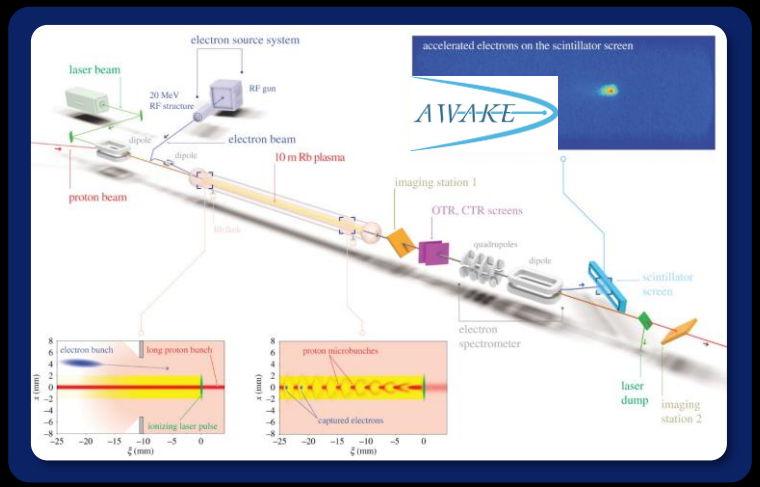

Structure-based

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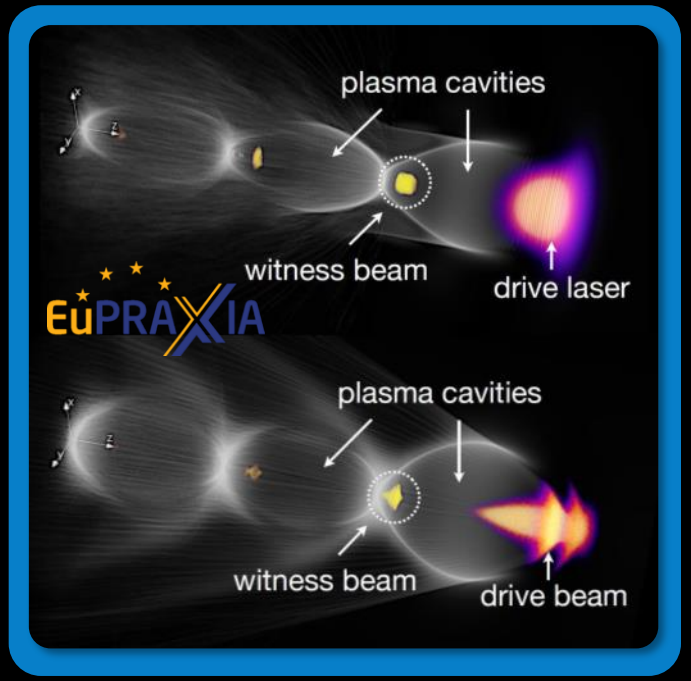

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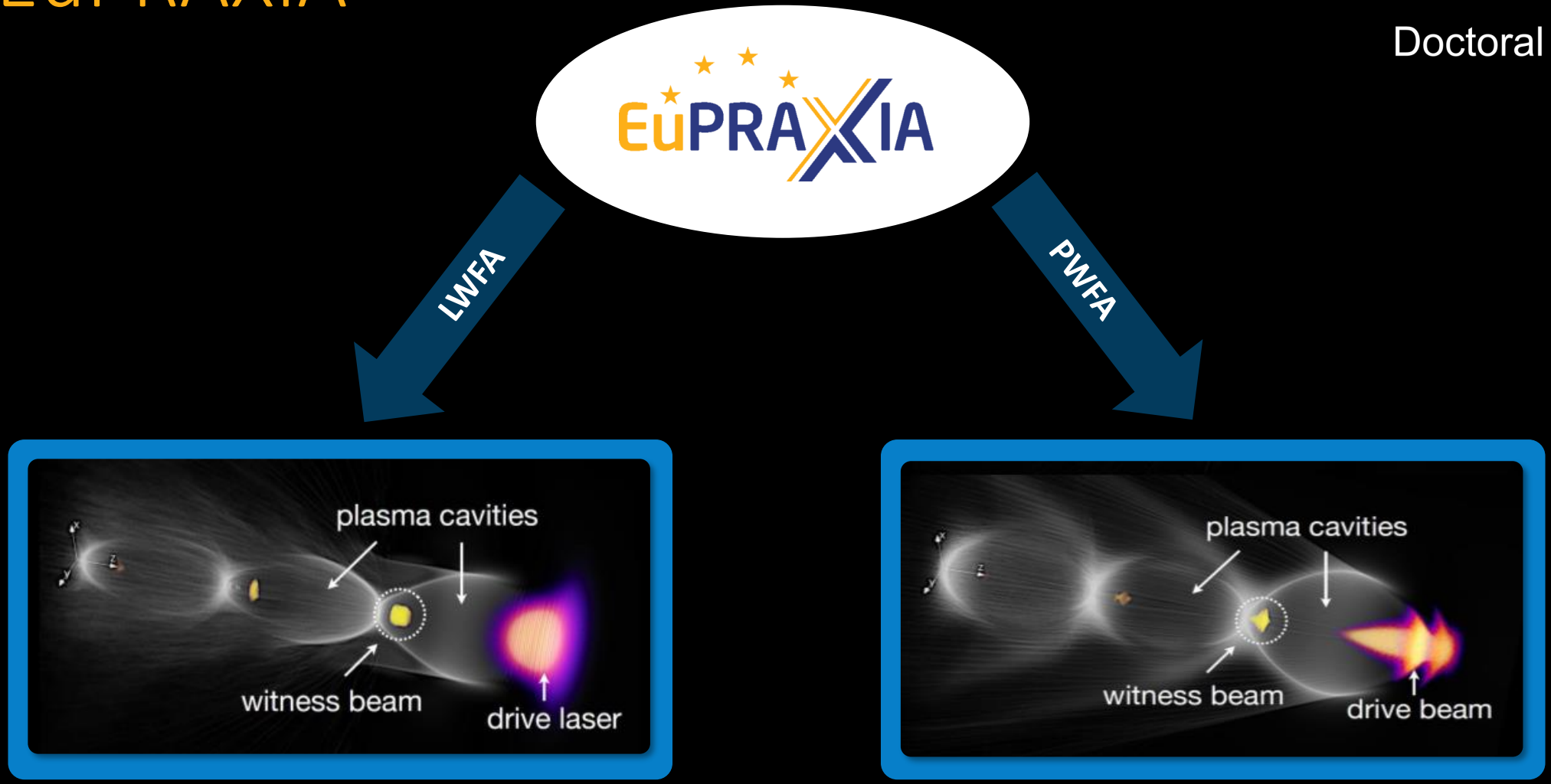

Broadband imaging of CxR bunch length monitor

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- Types of CxR under investigation
  - CTR – Coherent Transition Radiation
  - CSR – Coherent Synchrotron Radiation
- Experimental work at MAX IV
- Machine learning
- Simulation work

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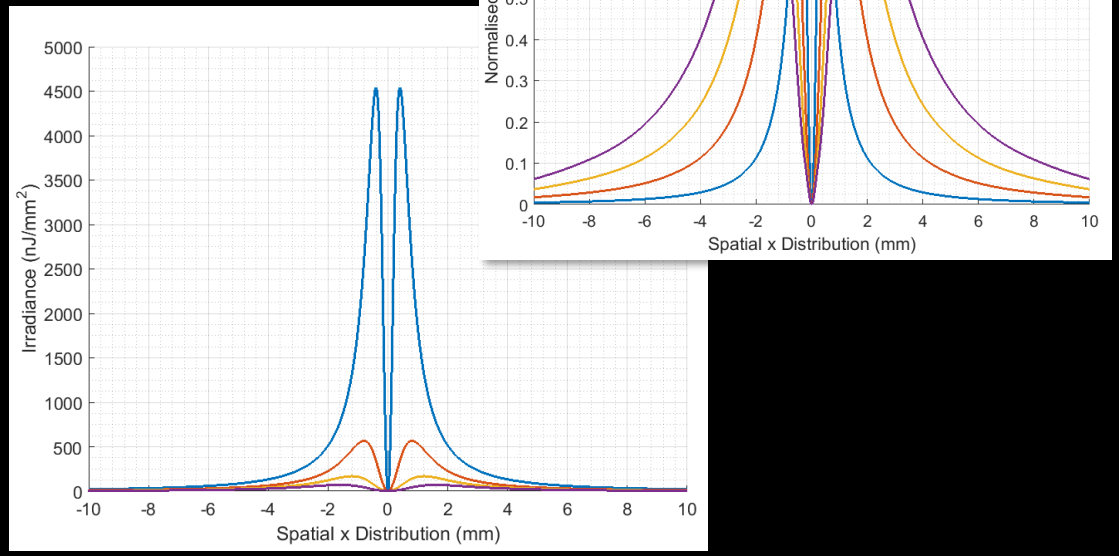
MAX IV

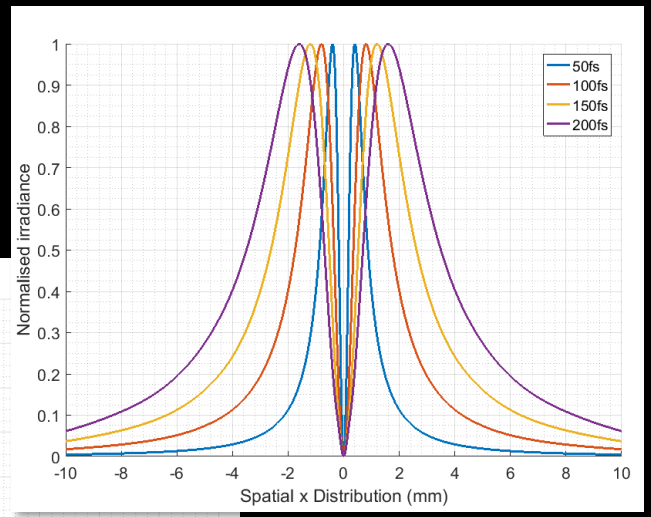
UKRI Science and Technology Facilities Council

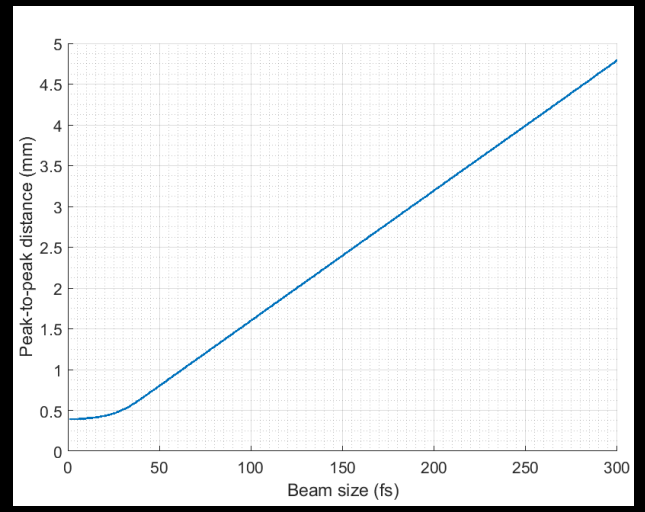
Broadband imaging of CxR bunch length monitor

$$\frac{dI^i_{bunch}}{dr} \approx N_e^2 \int_{\Delta\omega} \frac{d^2 I^i_e}{d\omega dr} |F_z(\rho(z),\omega)|^2 d\omega$$

- Bunch Image
- No. of e⁻
- Bandwidth
- Single e⁻ Spectral Image
- Bunch Form Factor







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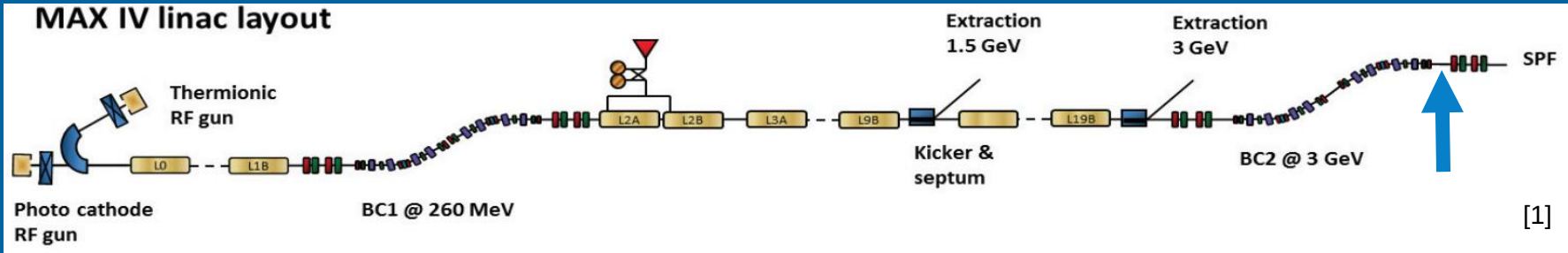
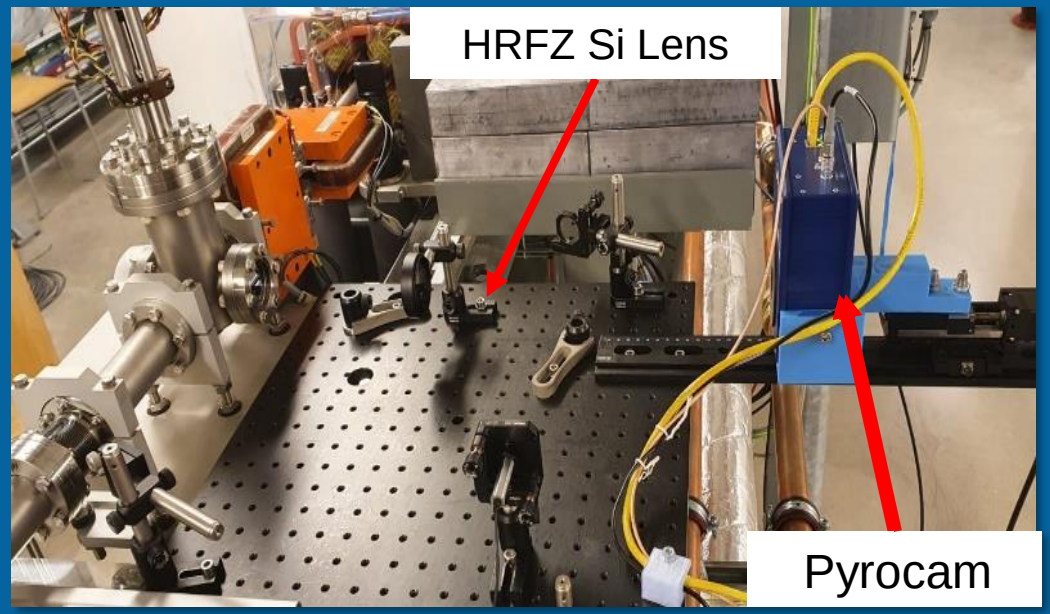
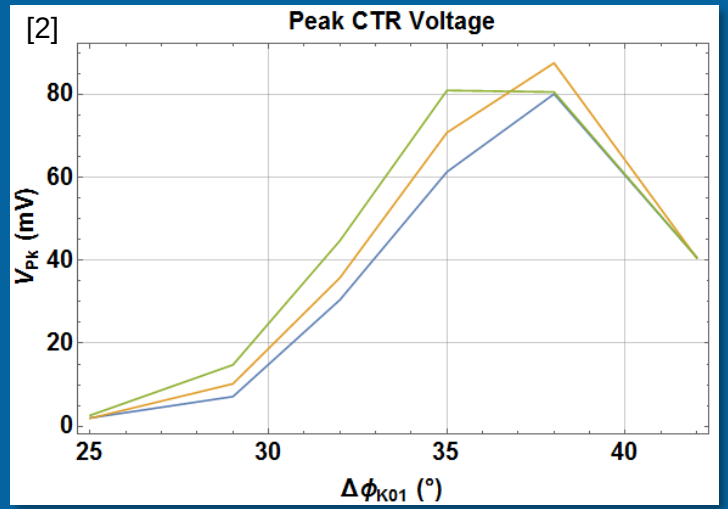
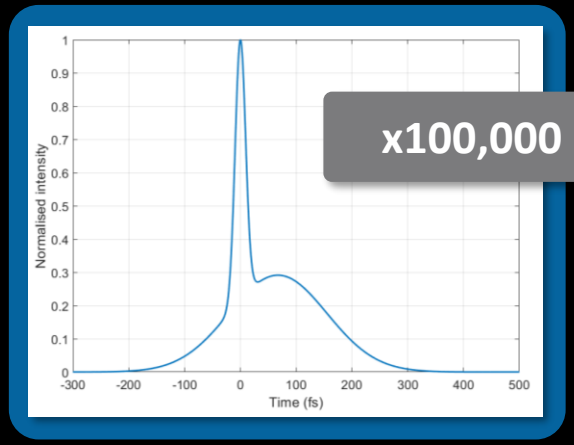
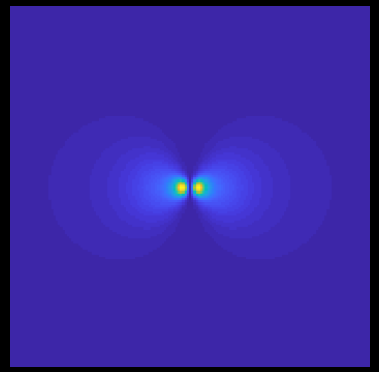






Broadband imaging of CxR bunch length monitor





- Machine Learning simulations
- Generated 100,000 double Gaussians with varying amplitudes, offsets, and widths
- Simulated CTR image for each
- Verified physics by fixing certain parameters and checking model outputs, ensuring phase couldn't be predicted

Broadband imaging of CxR bunch length monitor

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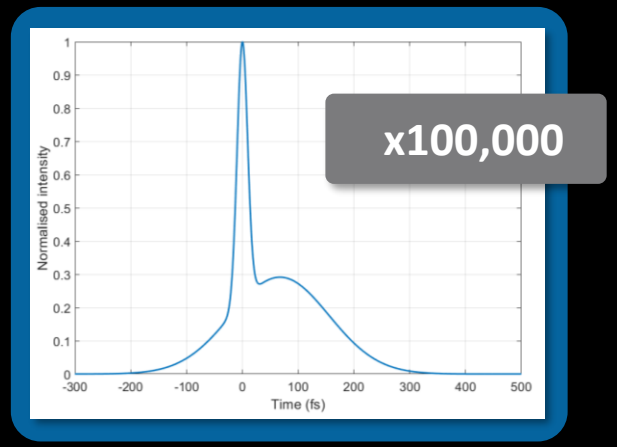
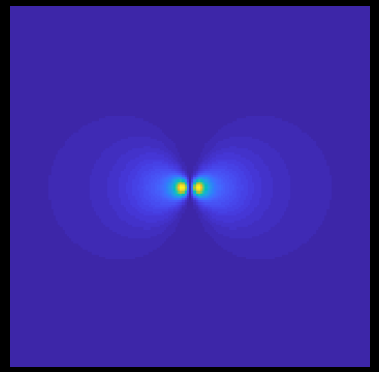
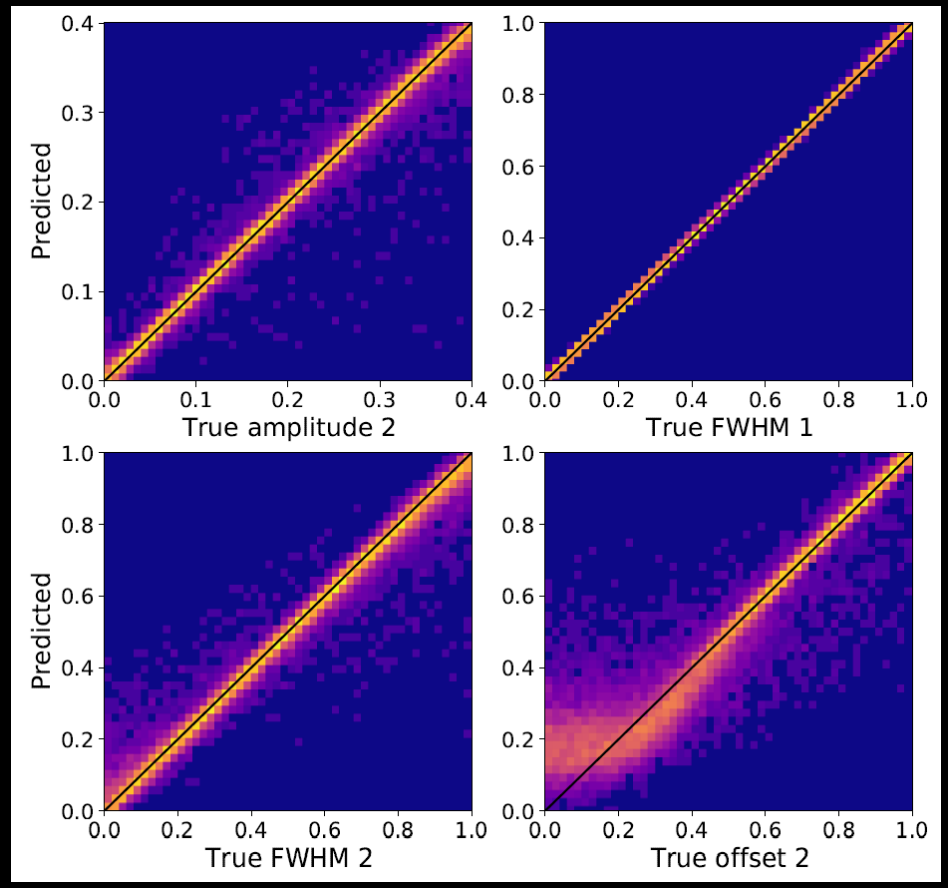




6.7% RMSE

6.2% RMSE



1.0% RMSE

17.2% RMSE

MAX IV
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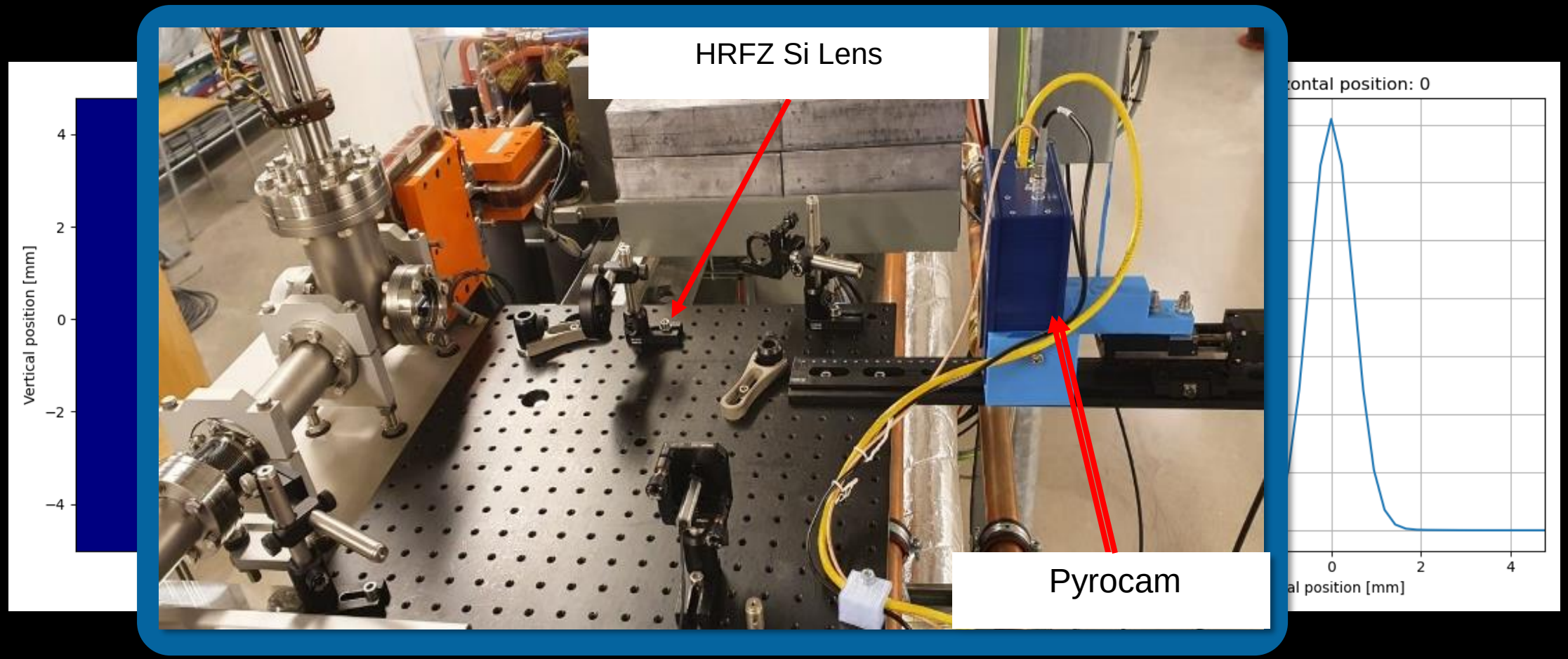
C. Swain, QUASAR Group

Broadband imaging of CxR bunch length monitor



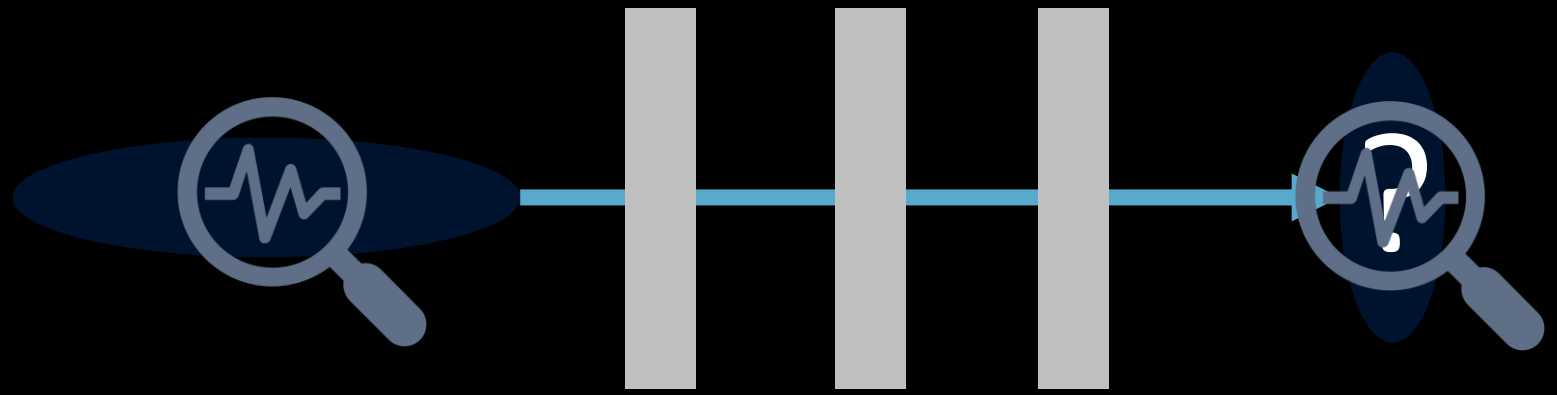
EuPRAXIA-DN Project

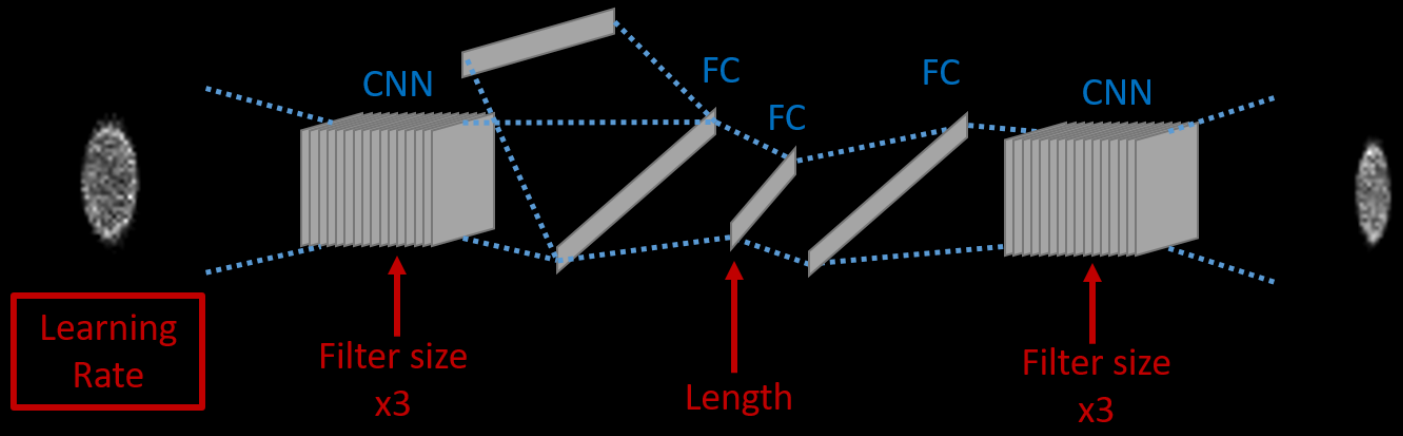
- CxR bunch length monitor
  - CTR imaging set up currently in place in MAX IV and operational as a compression monitor
  - ML analysis of simulated CTR images model capable of predicting bunch profiles at high level of accuracy (no phase), and will be tested on experimental data in the near future
  - SR simulations of CSR version of monitor are underway

This is the existing PhD project of Catherine Swain. This will be the basis for the project in EuPRAXIA-DN.

Target: high resolution plus integration with wider diagnostics!

Virtual Diagnostics





Potential applications:
1. User facilities
2. Medical accelerators
3. High power machines

Project Overview

Fellow	Host institution	PhD enrolment	Start date	Duration [months]	Deliverables
DC4	ULIV	ULIV	9	36	D10, D11
Project Title and WP(s) to which it is related: Ultra-short Bunch Length Measurements with fs Resolution (WP3)					
Objectives: Investigate non-invasive single-shot method of measuring detailed longitudinal profile information with DBEAM. Study optimum accelerator integration (M5, m27) so the monitor can operate online and non-invasively. Integrate machine learning techniques and combine with existing diagnostics to develop “virtual diagnostics” for EuPRAXIA.					
Expected Results: Monitor prototype with demonstrated fs resolution (D10, PDE, m33), virtual diagnostics concept demonstrated and published (D11, PDE m45).					
Secondment(s): $DBEAM_{12}$ (monitor development and optimization, various), $INFN_4$ (test with beam, m30).					

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