Power management, coherence and photon propagation for ESRF-EBS beamlines

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Across the globe, synchrotron facilities are embracing 4th generation storage rings based on multi-bend achromats. Since 2020, the ESRF operates the Extremely Brilliant Source (EBS). The EBS boasts impressive brilliance and coherence thanks also to the long undulators (~2 m) with short magnetic periods (less than 18 mm), in-vacuum cryogenic permanent magnets (CPMU) and reduced gaps. These features result in a significant amount of heat being deposited onto the components of the beamline, necessitating efficient cooling mechanisms. It is imperative to thoroughly assess and minimize the surface deformations induced by the absorbed heat and to study how these deformations impact the properties of the photon beam (size, flux, coherence fraction, etc.). In this context, this work introduces simulations and tools that have been developed and employed by the ESRF-Mechanical Engineering Group to tackle various challenges encountered in the EBS beamlines.

EBS and new Insertion devices at the ESRF

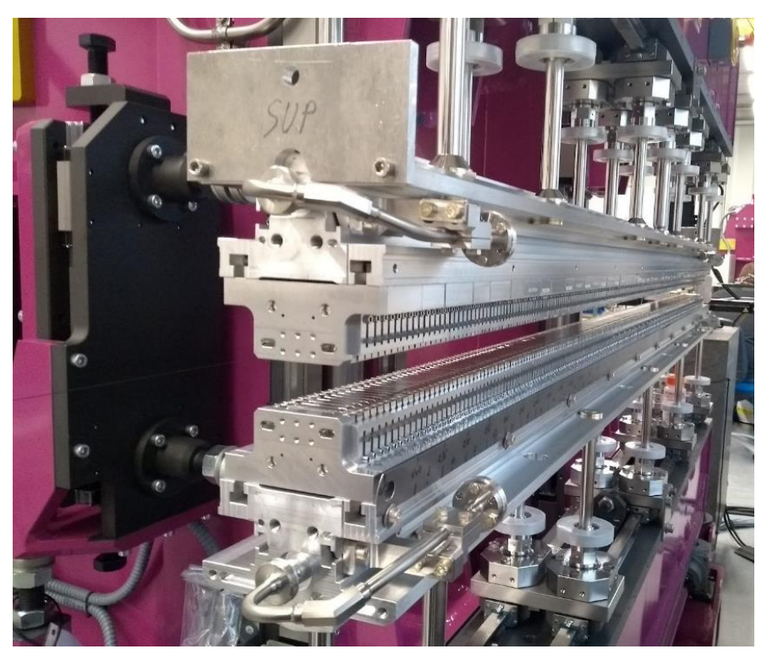
-EBS: H - emittance (pm rad):
4000 → 133

Higher photon flux and coherence

-CPMU: short period Insertion Devices (ID ≤ 18 mm)

-Small gap ID: mini-beta sections [1] (gaps ≤5 mm)

CPMU at the ID Laboratory

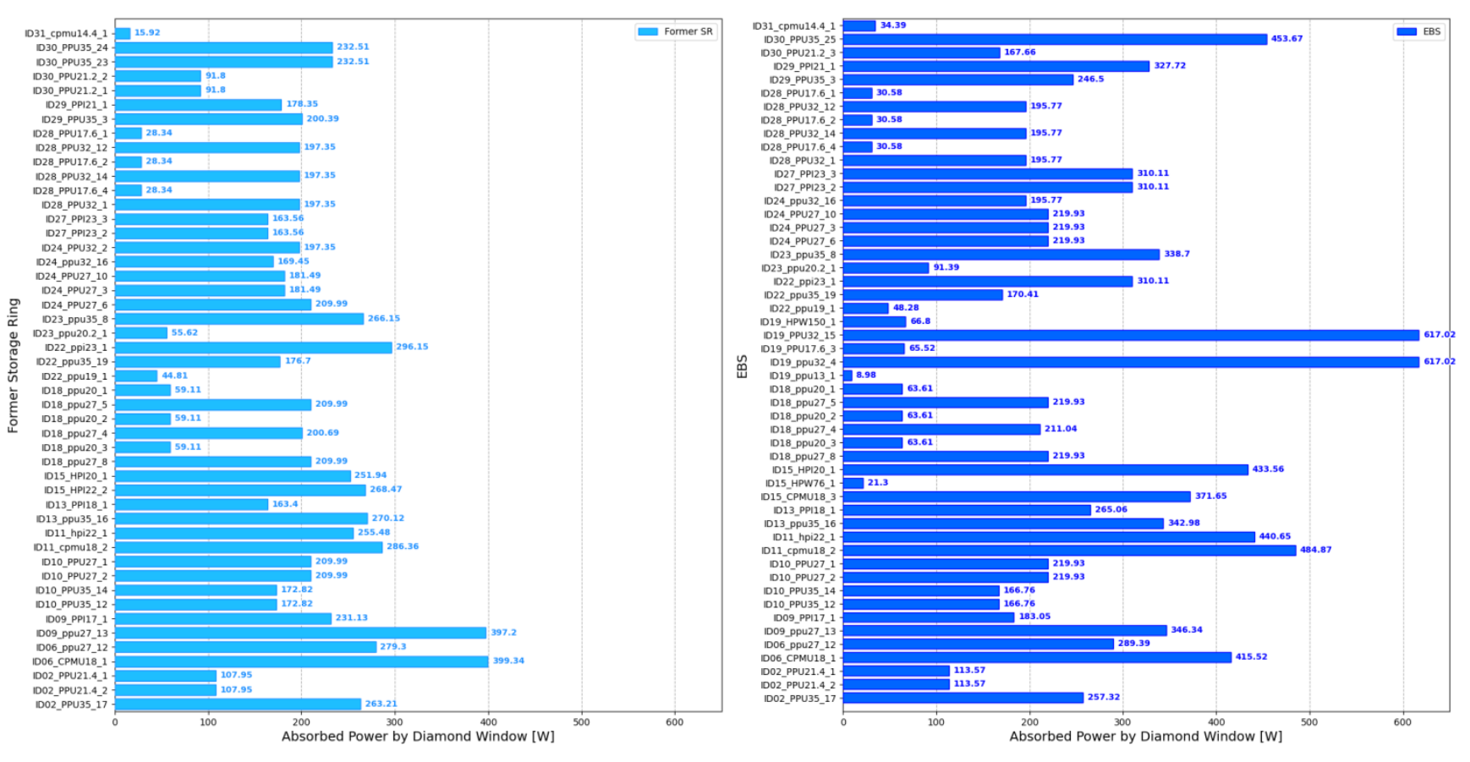


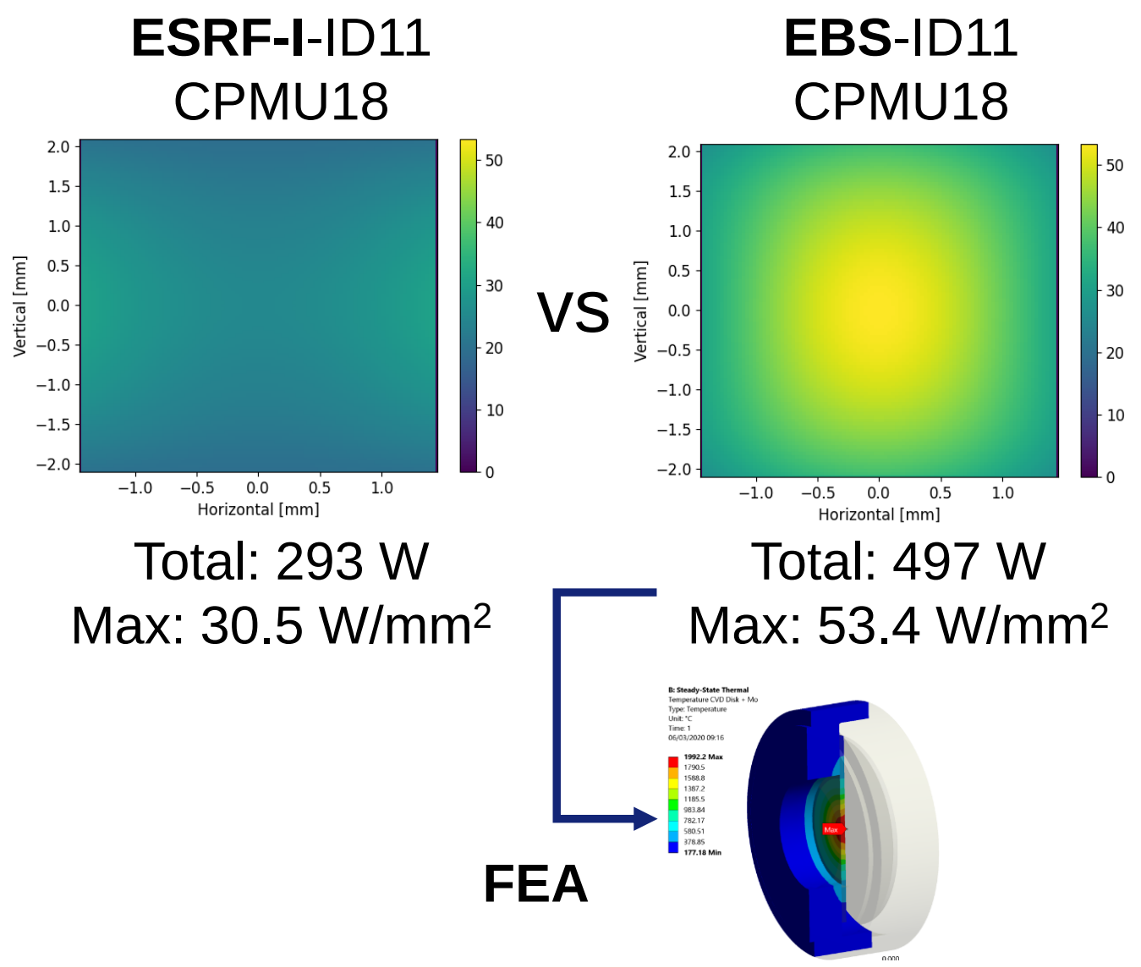
Credit photo: Juan Reyes/ESRF

Heat-load review

During the transition to EBS we performed a power calculation campaign to identify possible issues in the beamlines front end components.

ESRF-I vs EBS: absorbed power by FE diamond window





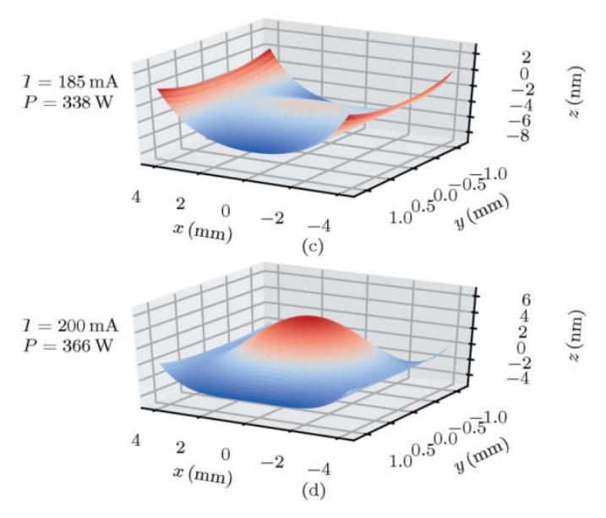
ESRF-I-ID11: Total: 293 W, Max: 30.5 W/mm^2

EBS-ID11: Total: 497 W, Max: 53.4 W/mm^2

Power management

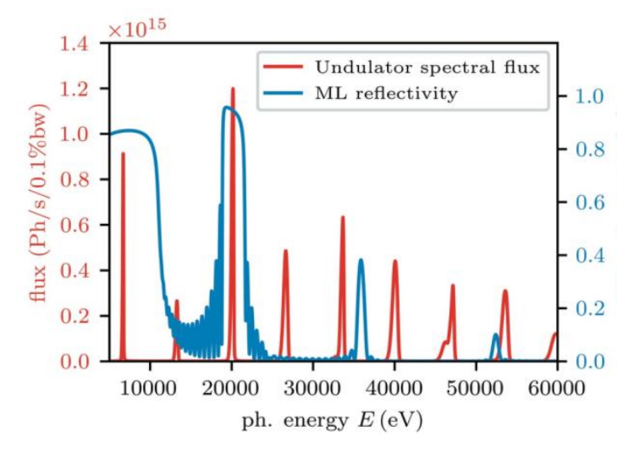
Optical elements from the beamline must be designed to handle the high heat load from new sources, e.g.: Slits, Mirrors and Crystals.

- High heat-load crystal monochromator [2].

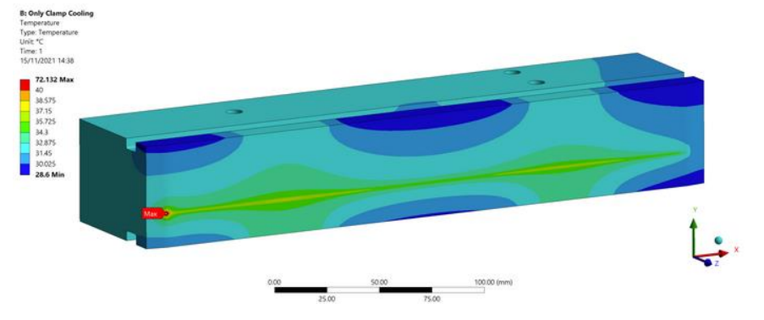


Negligible effects on vertical plane due thermal load over the crystal, will be implemented in the refurbish nuclear resonant ID14 beamline.

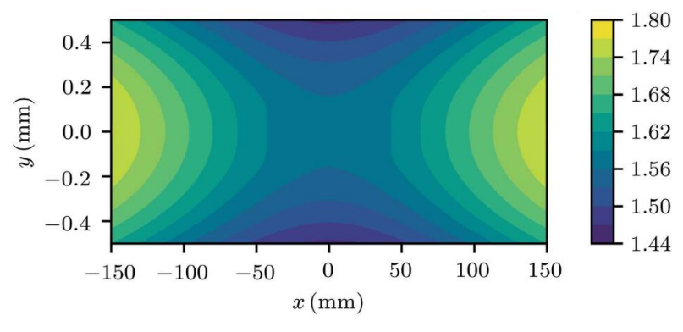
- Optimization of high heat-load multilayer monochromator for the new hard X-ray microscope at ID03 [3].



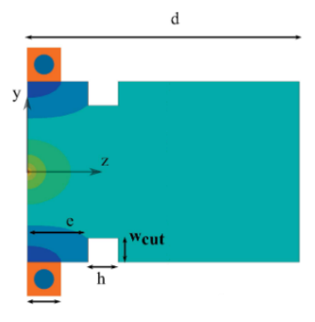
Finite element analysis



Multilayer absorbed power distribution



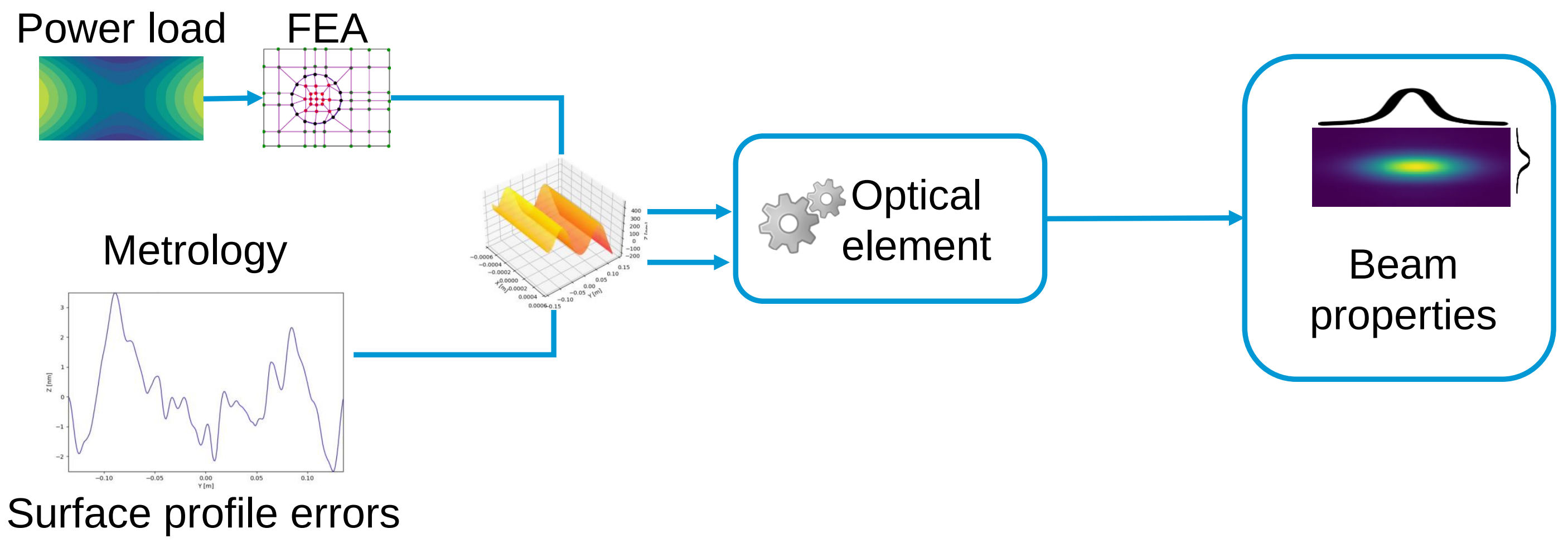
Design optimization



Photon propagation

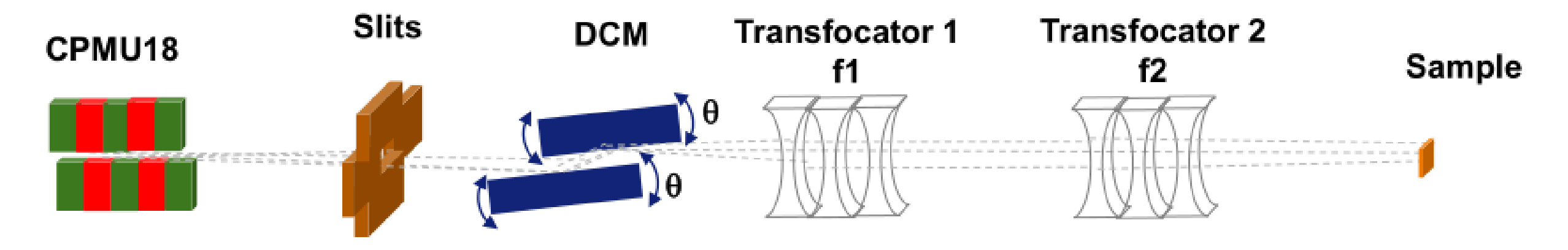
Using ray-tracing we have been modeling the beamlines under different circumstances, for example:

- Mirrors and crystal surface profile errors and deformations.

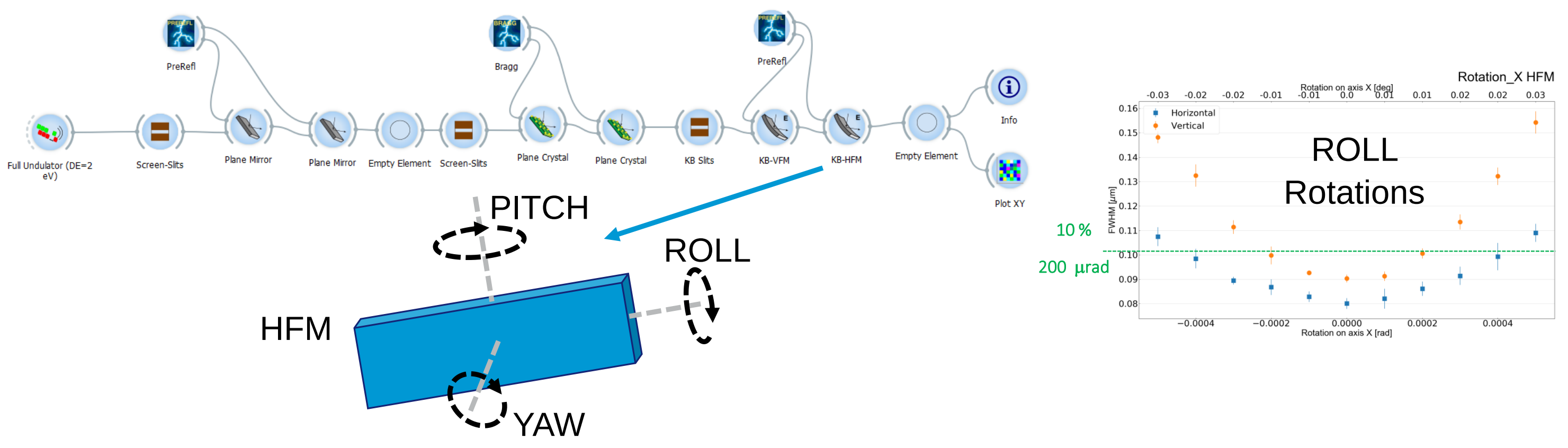


- Misalignment or vibrations issues.

Double Crystal Monochromator pitch angular vibrations impact on sample size

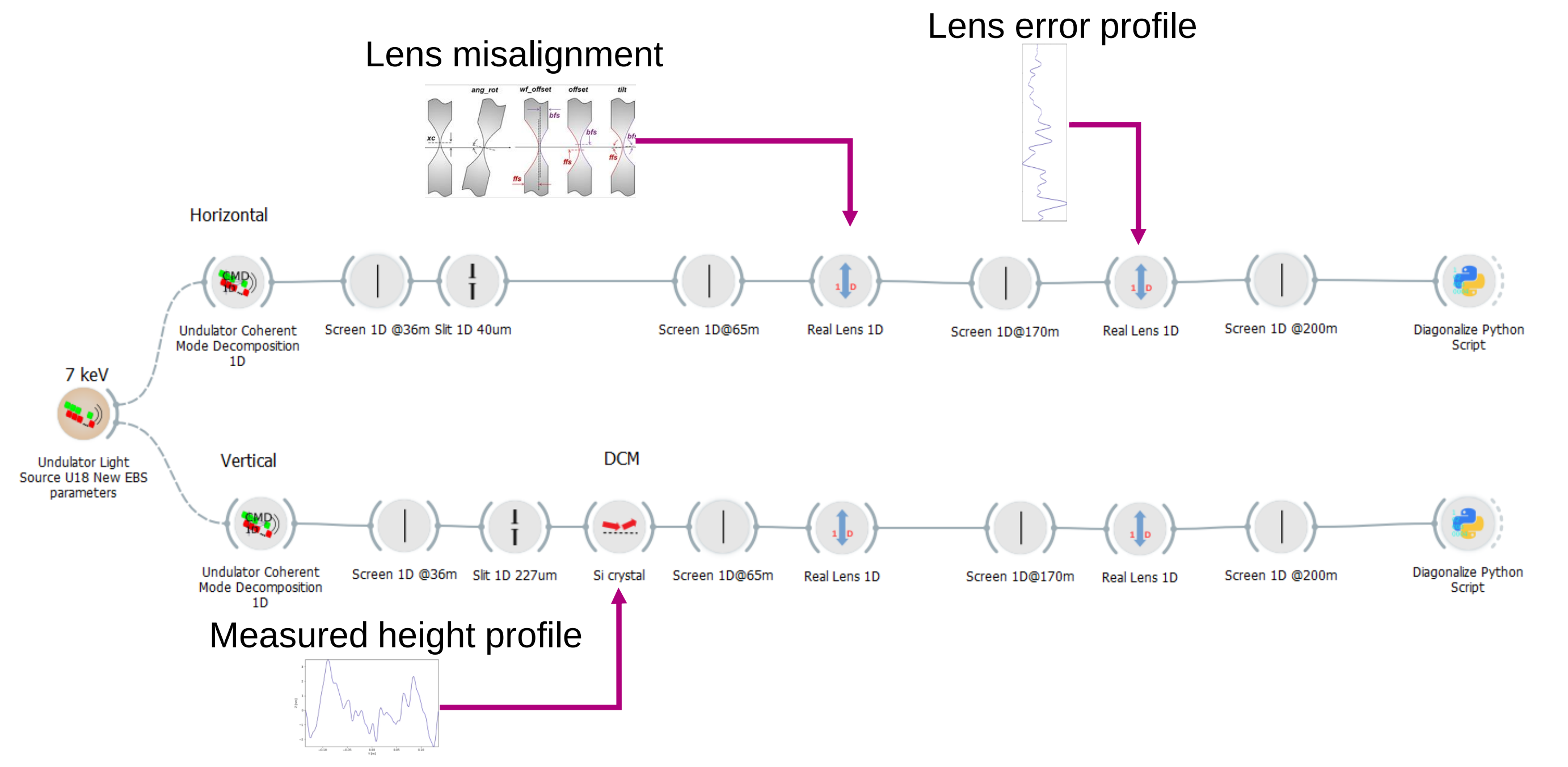


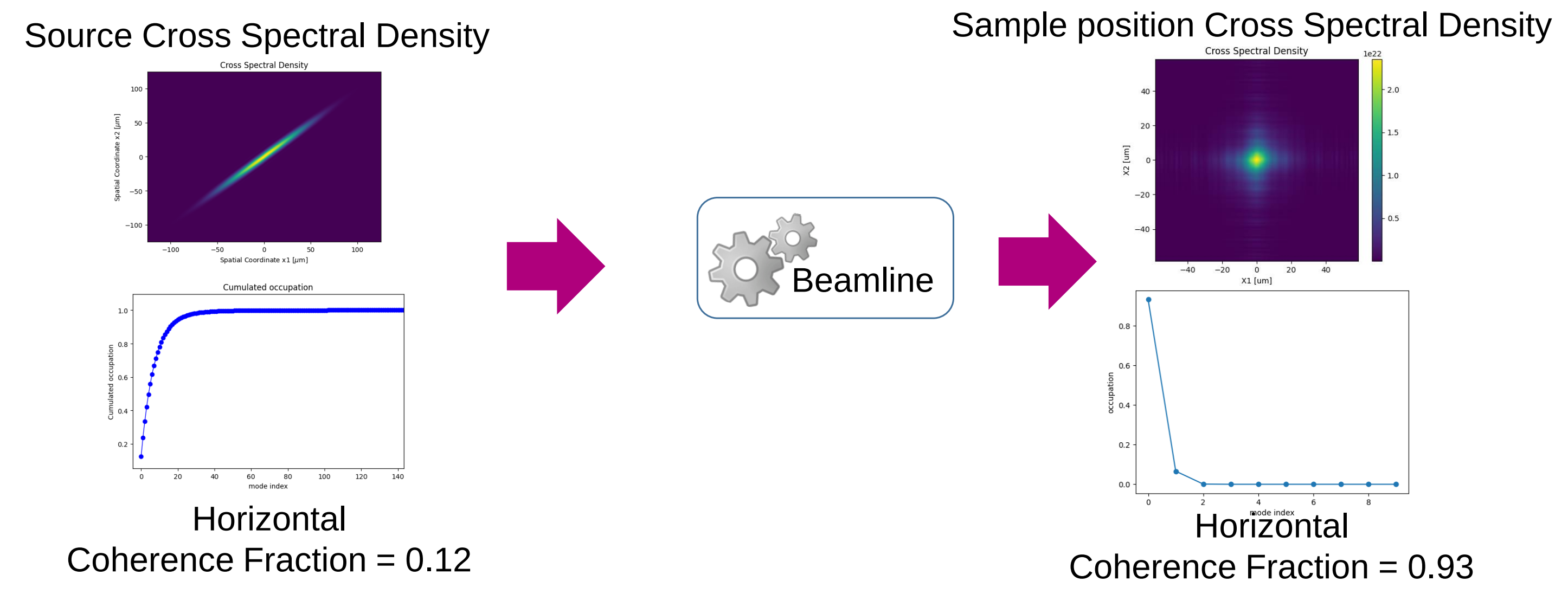
Angular misalignments KB mirrors



Coherence propagation

We developed different tools to simulate the coherence propagation trough the beamlines, e.g. WOFRY1D [4].





Source: Horizontal Coherence Fraction = 0.12

Sample position: Horizontal Coherence Fraction = 0.93

ESRF-EBS
Extremely Brilliant Source

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*All X-ray optics calculation were performed with OASYS tools.

[1] J-L. Revol et al., First year of operation of the ESRF-EBS Light Source, in Proc. IPAC’22.
[2] P. Brumund et al., J. Synchrotron Rad. (2021) **28** 91.
[3] P. Brumund et al., J. Synchrotron Rad. (2021) **28** 1423.
[4] M. Sanchez del Rio et al., J. Synchrotron Rad. (2022) **29** 1354

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