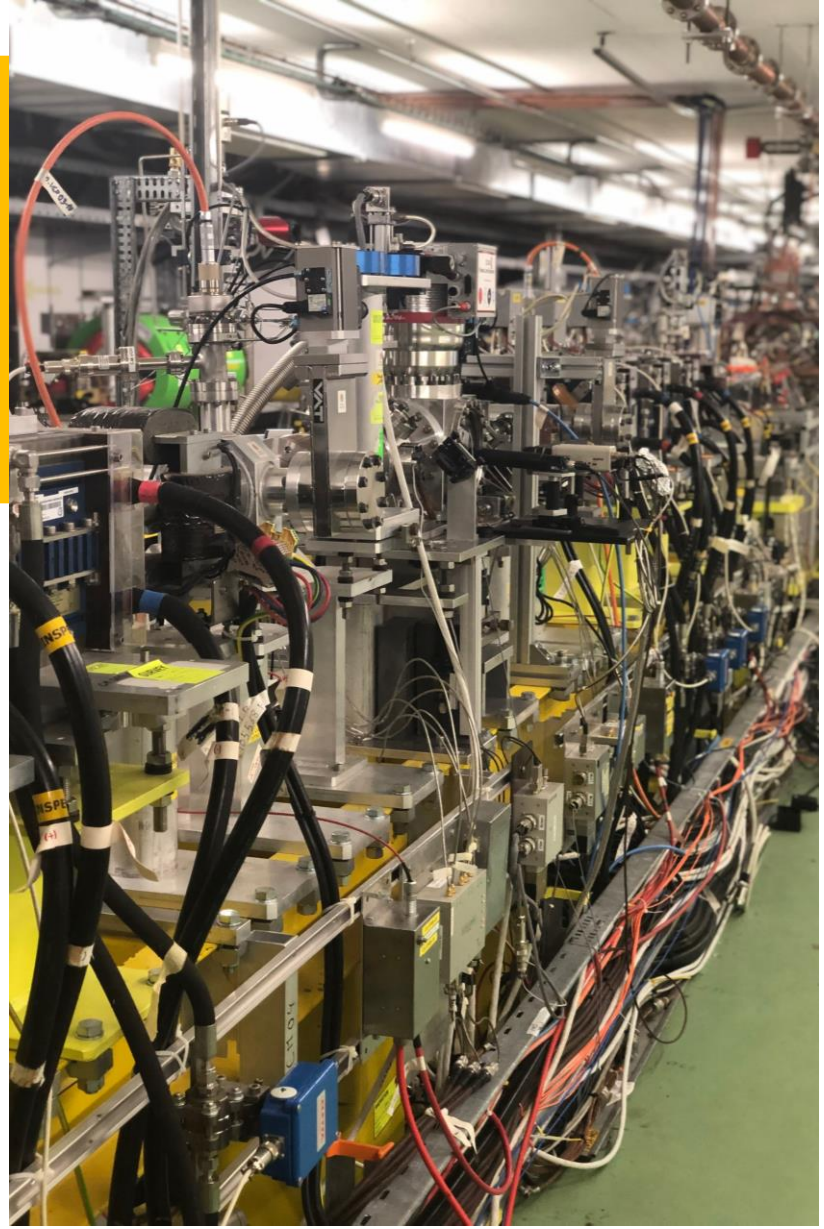
Machine Learning Applications for Beam Diagnostics and Automated Tuning at CLEAR



33rd Linear Accelerator Conference (LINAC 2026)

clear

CERN

Antonio Gilardi

17/08/2026

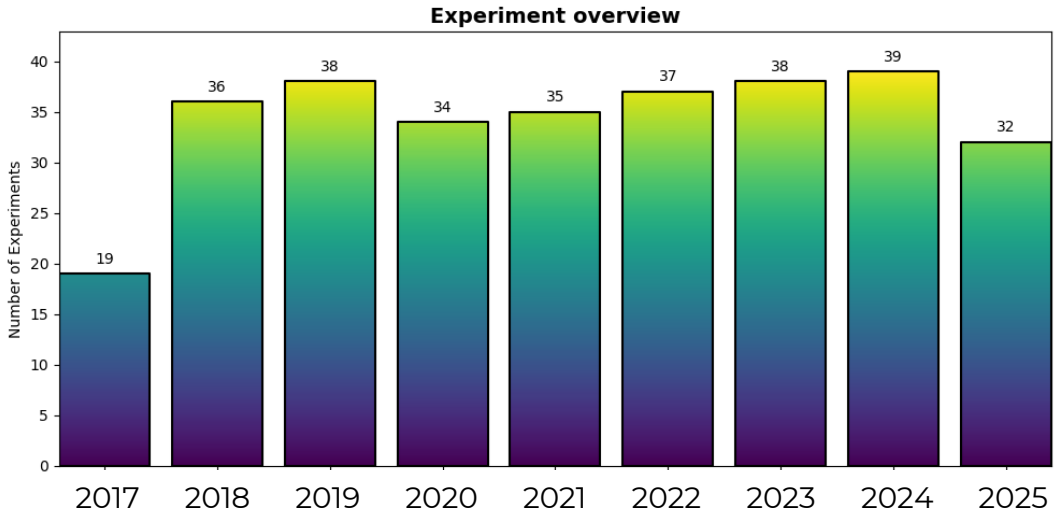
DAEJEON LINAC 2026

MOPO010

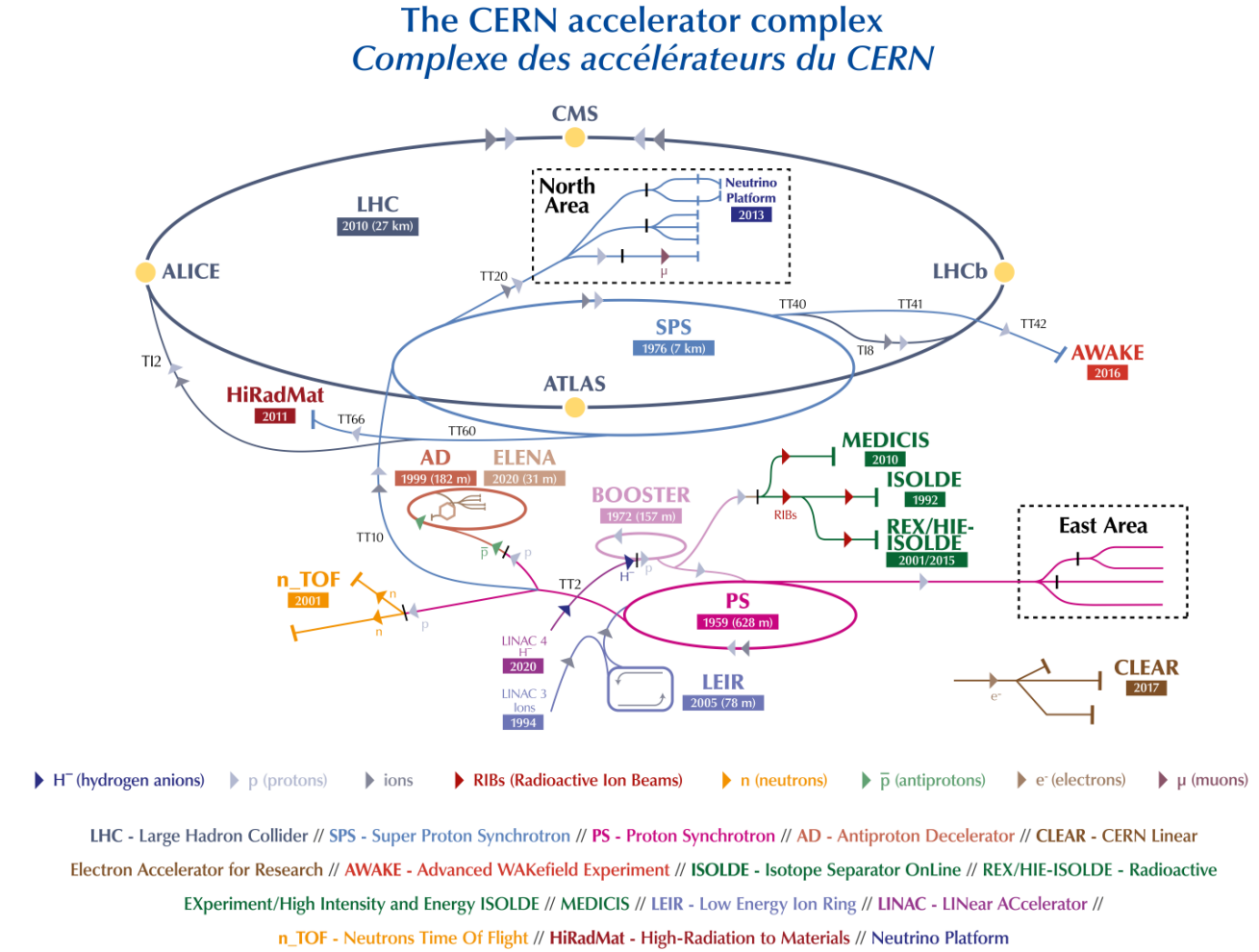
Everything I am reporting here is the result of a tremendous team effort.
None of this would have been possible without the collaboration of the CLEAR facility team and the hard work of many collaborators.

Facility Overview

clear



CLEAR operates as a user facility, but in most cases, it goes beyond simply delivering a beam according to user specifications.



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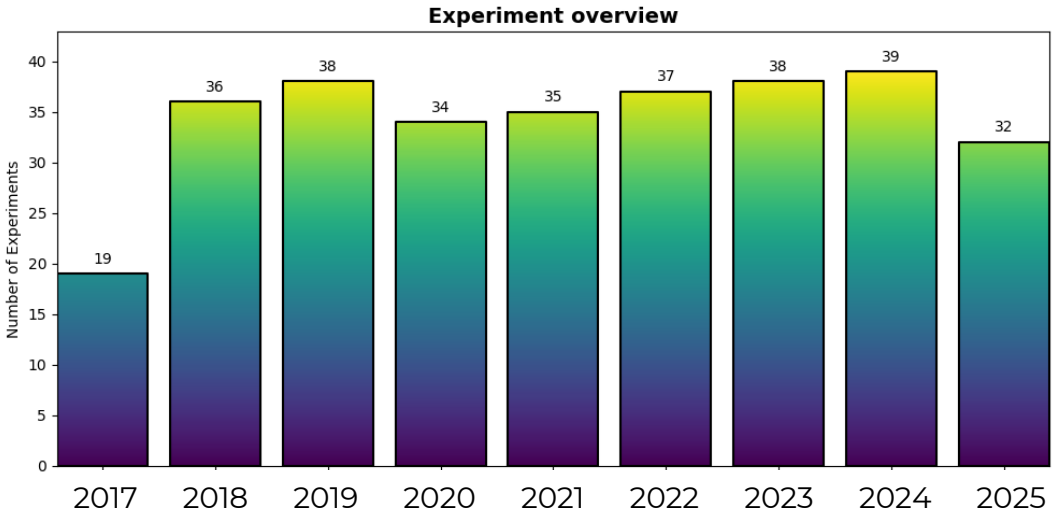
clear



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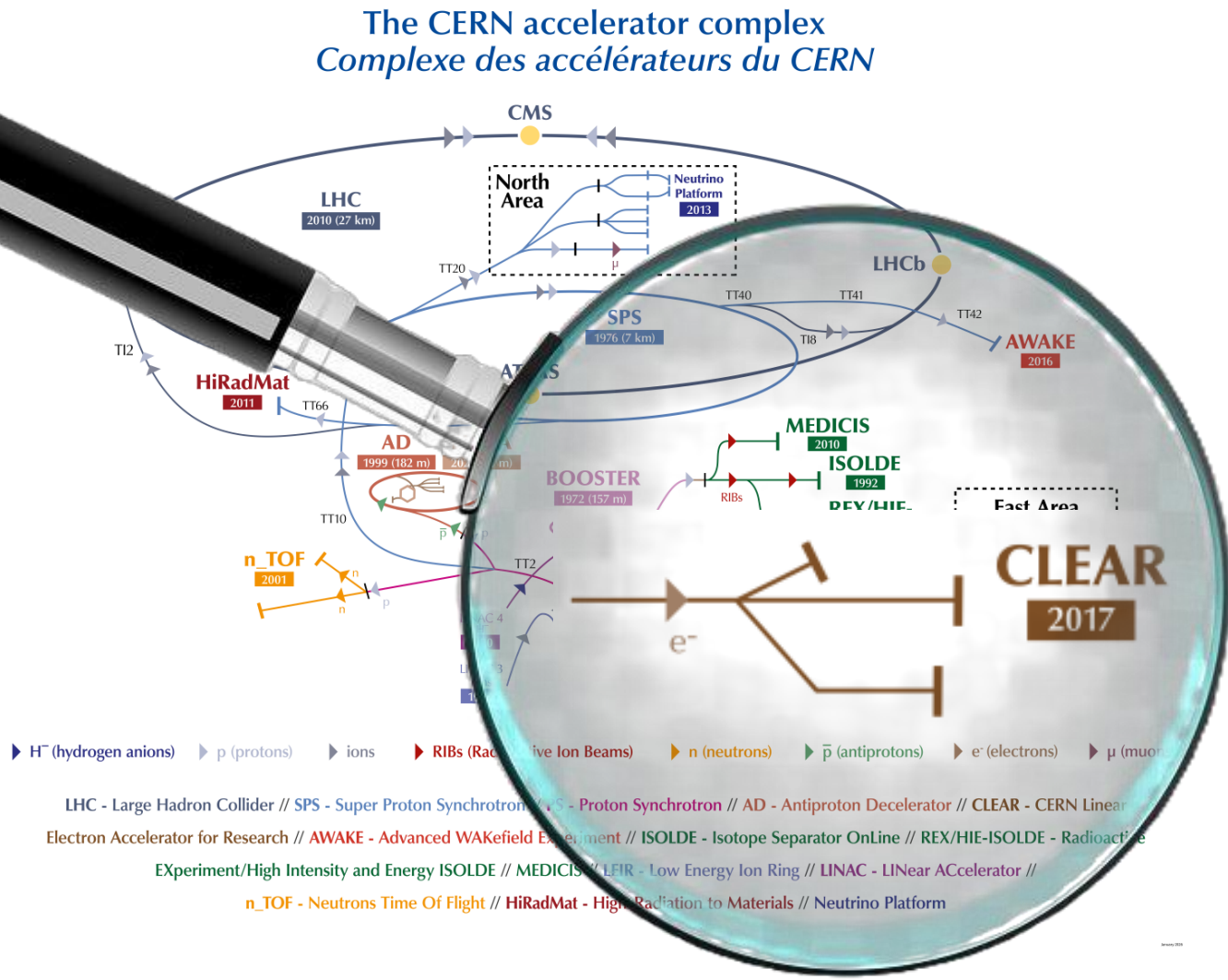
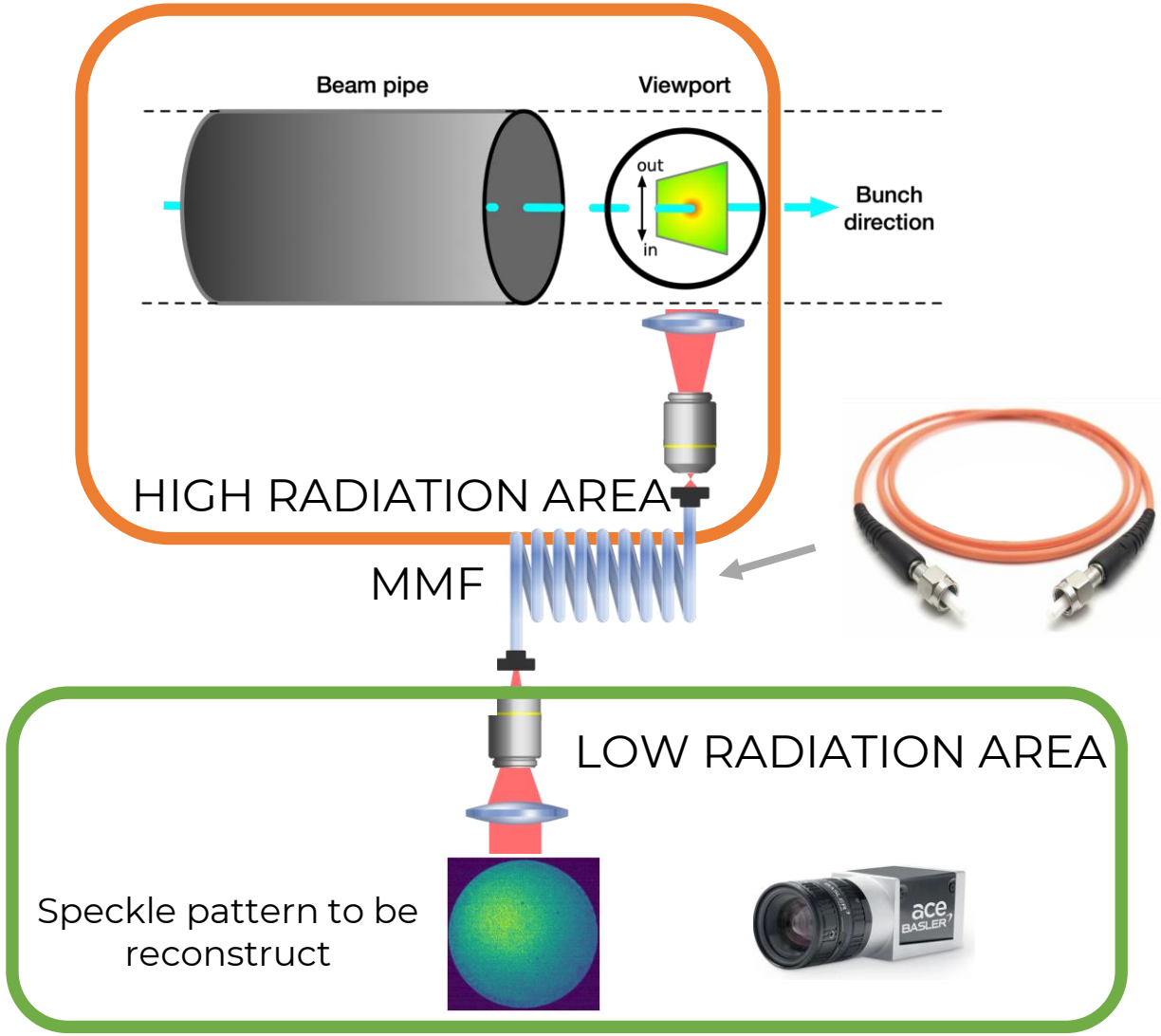


Transverse Profile Reconstruction



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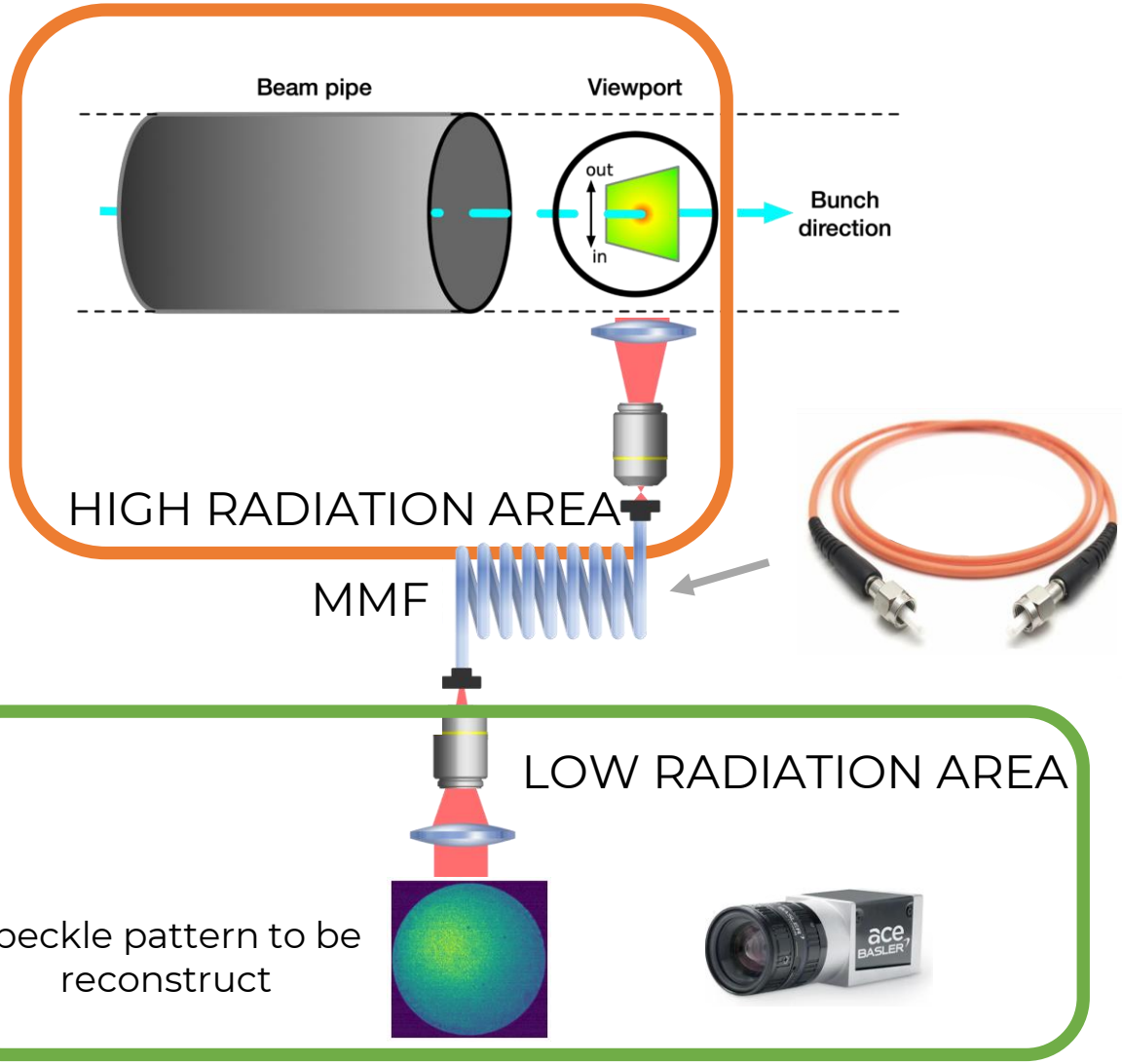
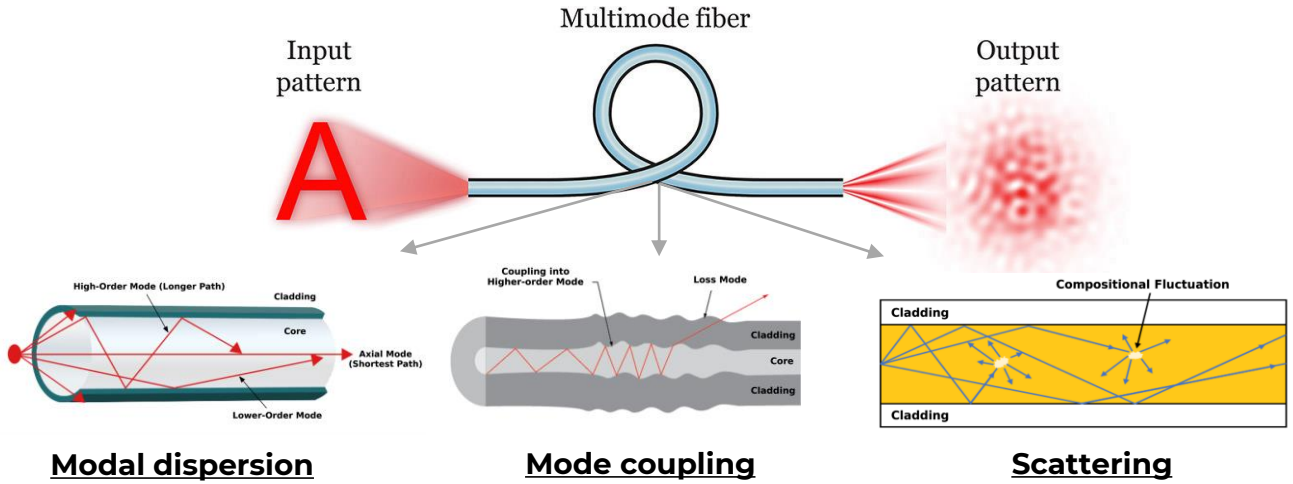
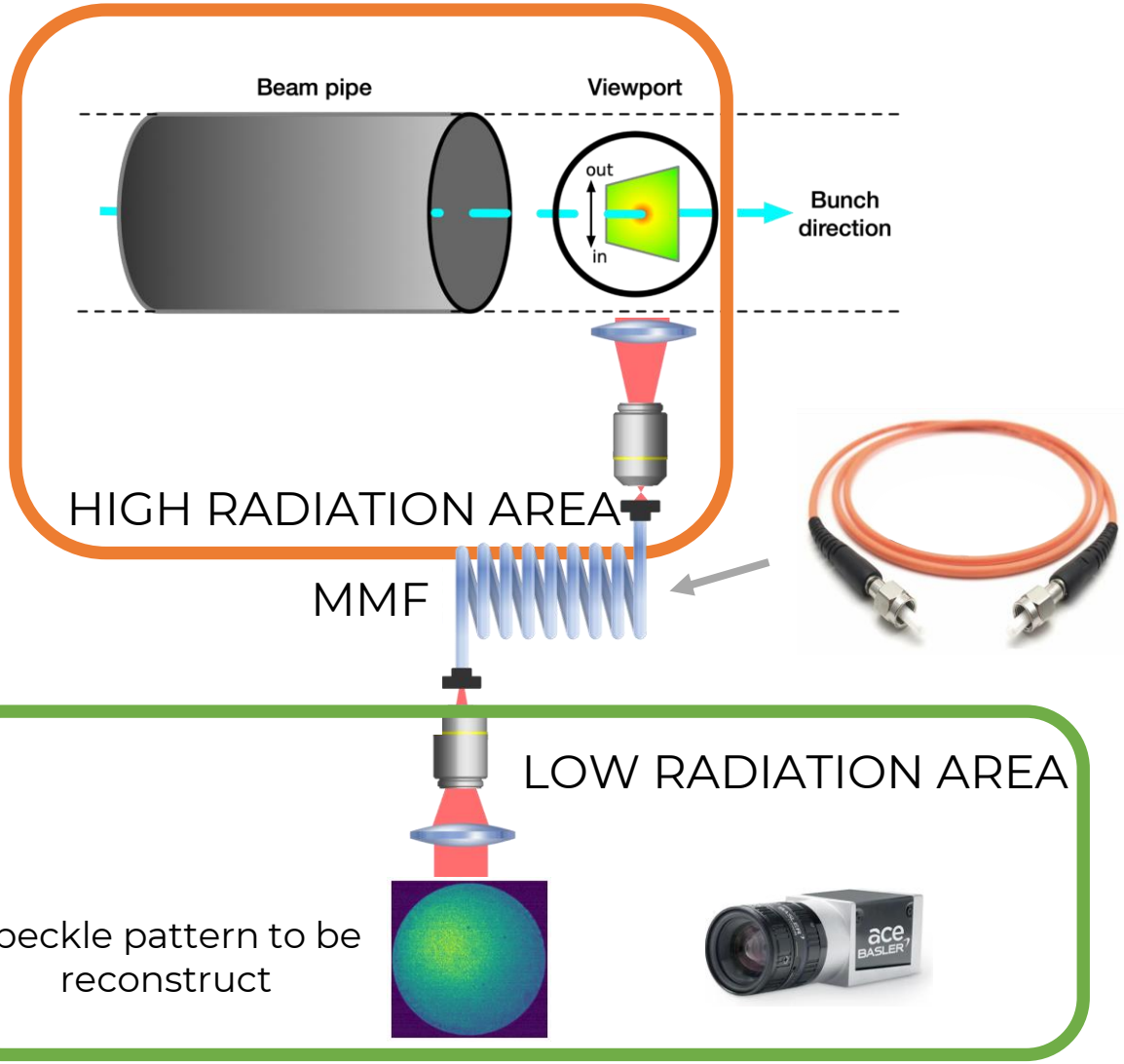
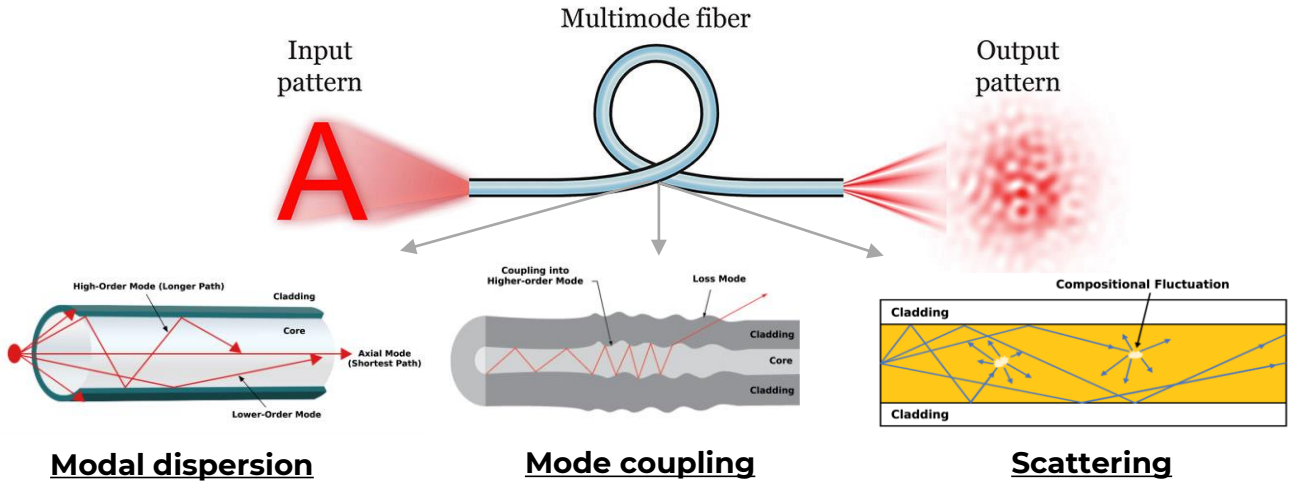




Modal dispersion **Mode coupling** **Scattering**

Transverse Profile Reconstruction





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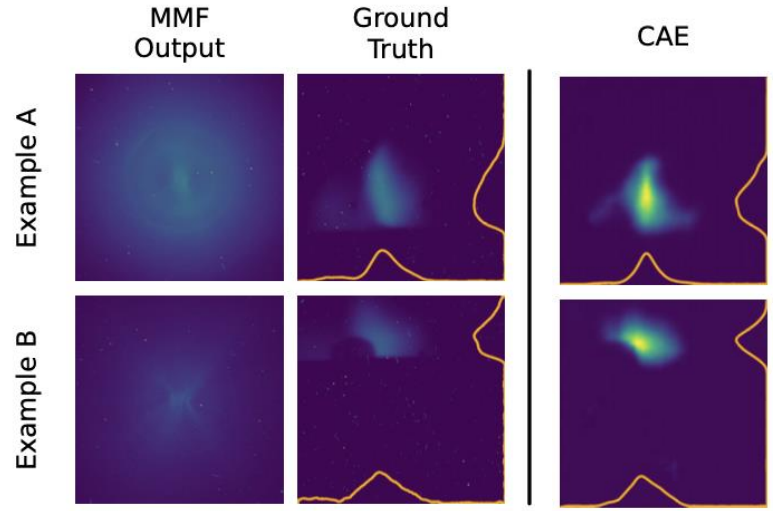
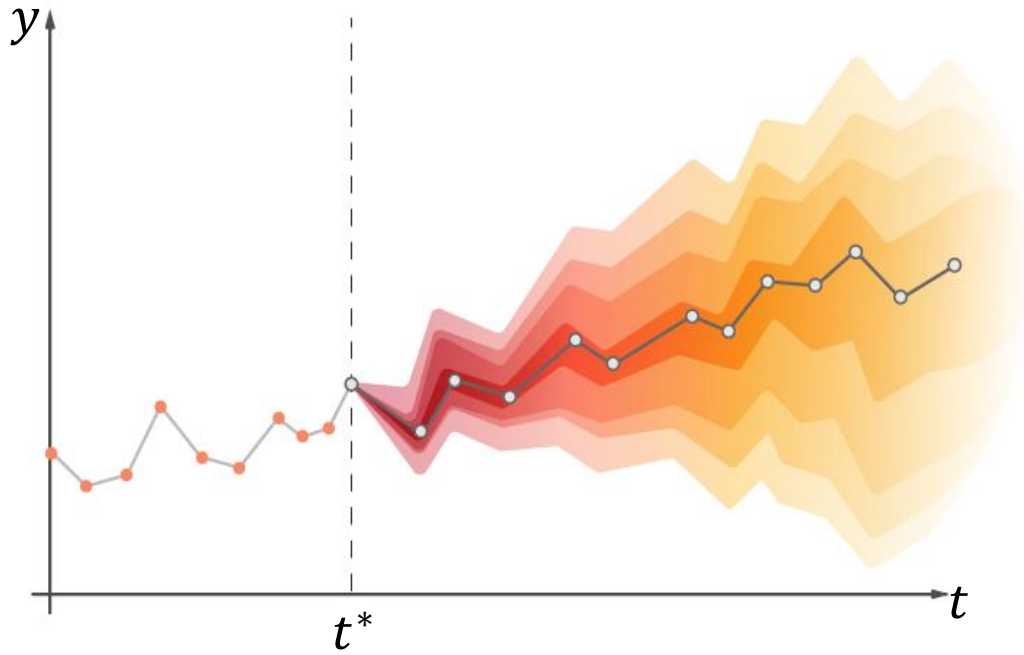


Virtual Diagnostic and Forecasting



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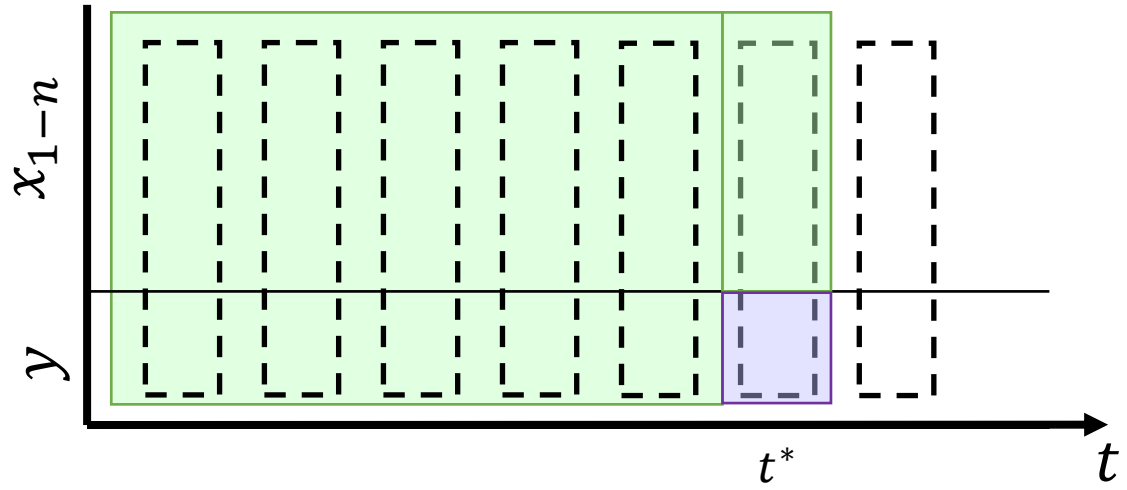
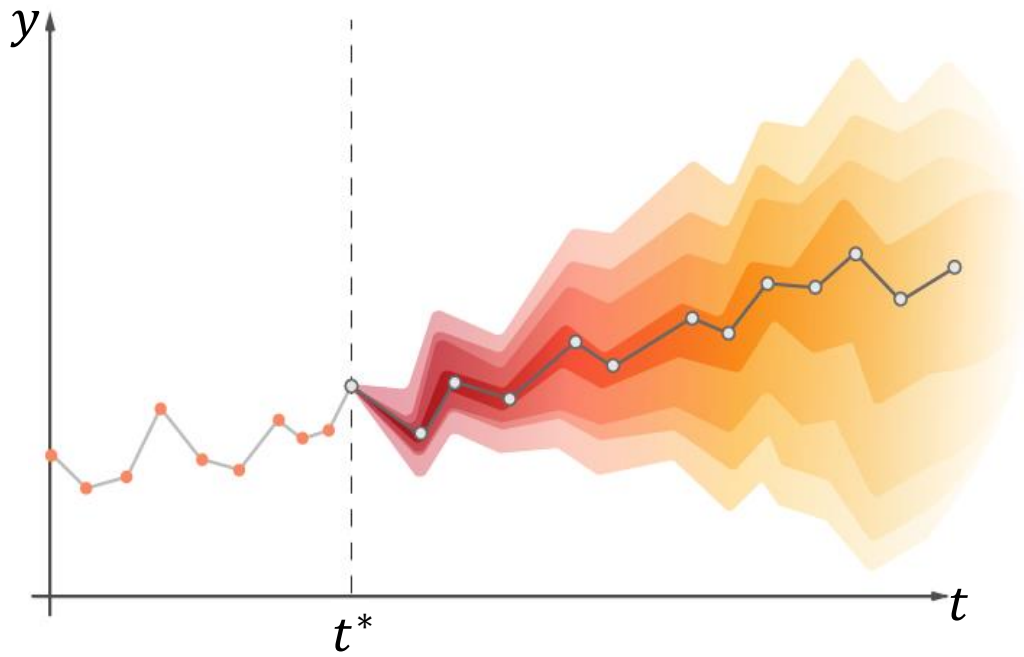
y could be any beam parameter

Virtual Diagnostic and Forecasting

A. Virtual Diagnostics: Predict y_{t^*} knowing x_{1-n} until t^*





Exogenous Features

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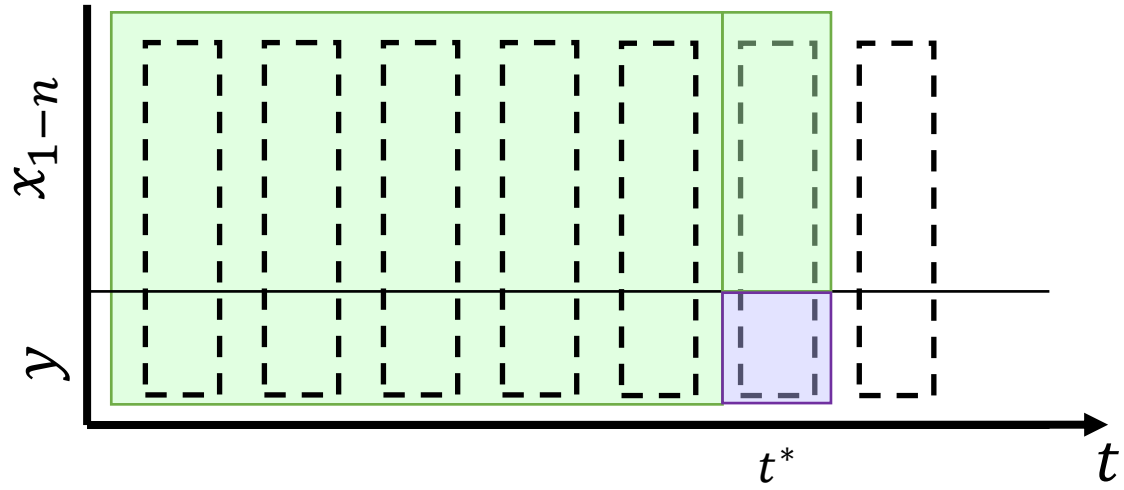

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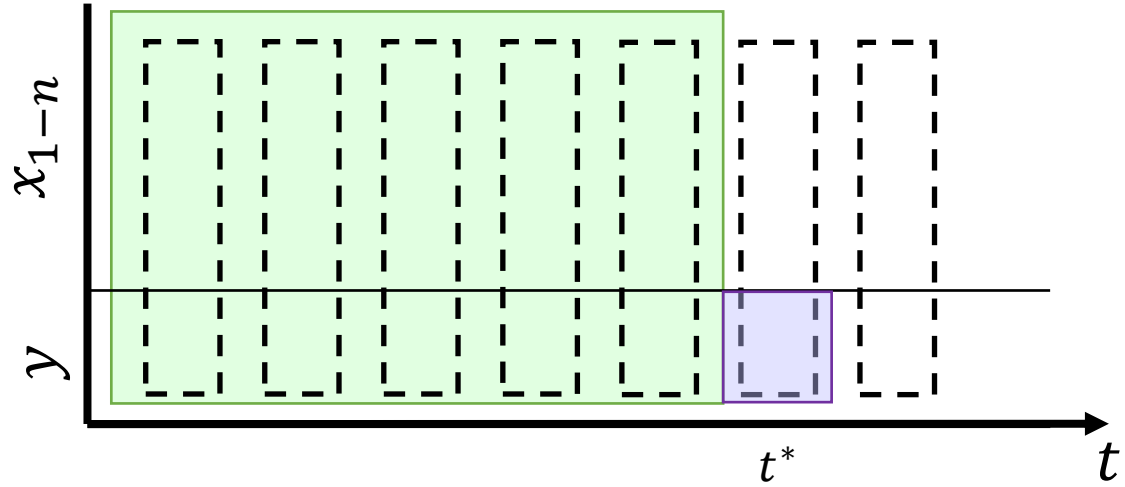

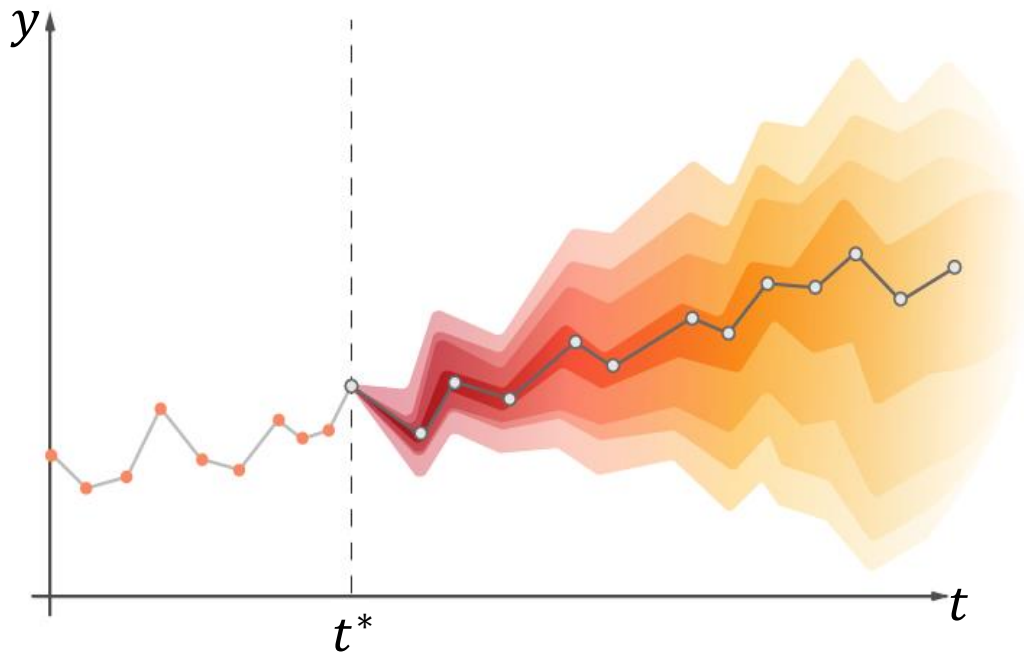

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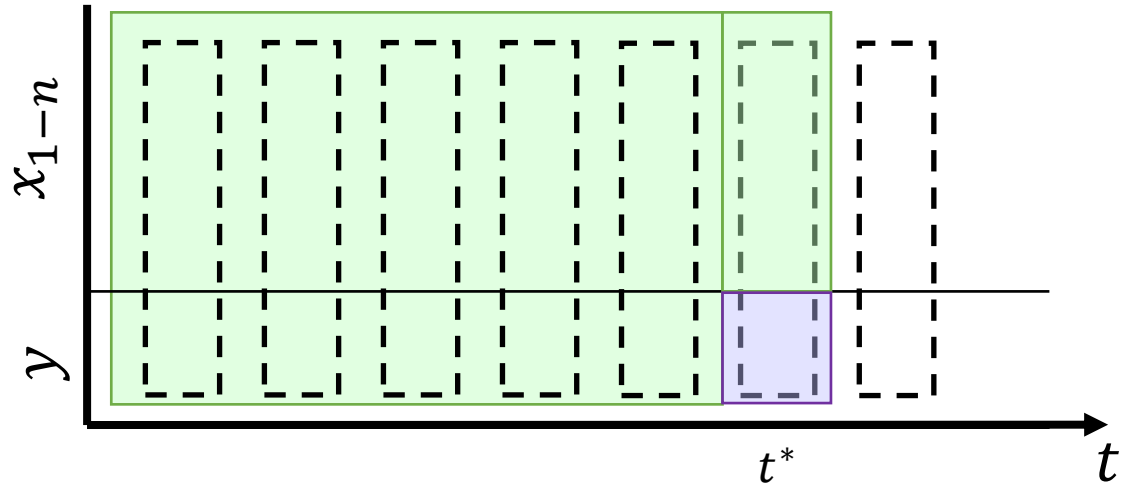

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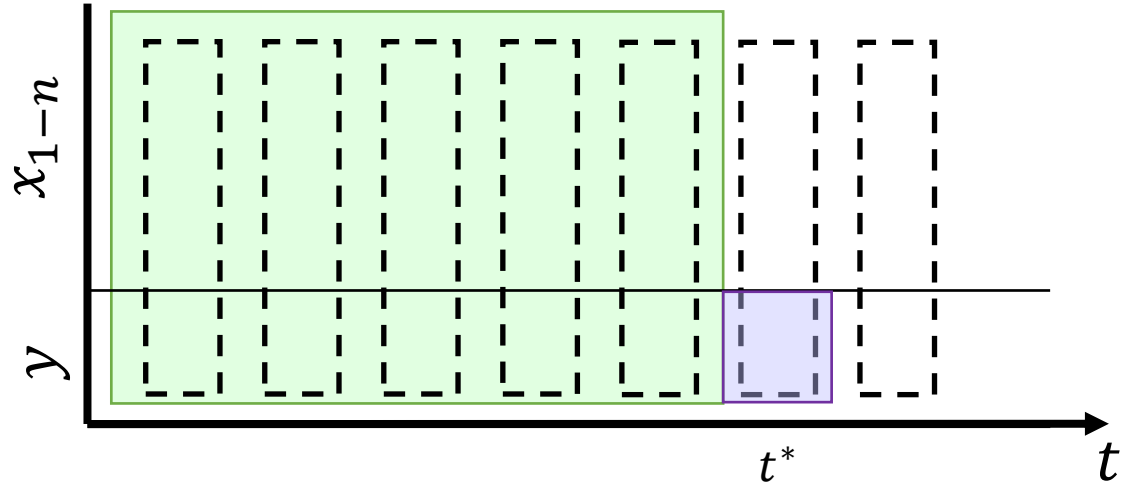
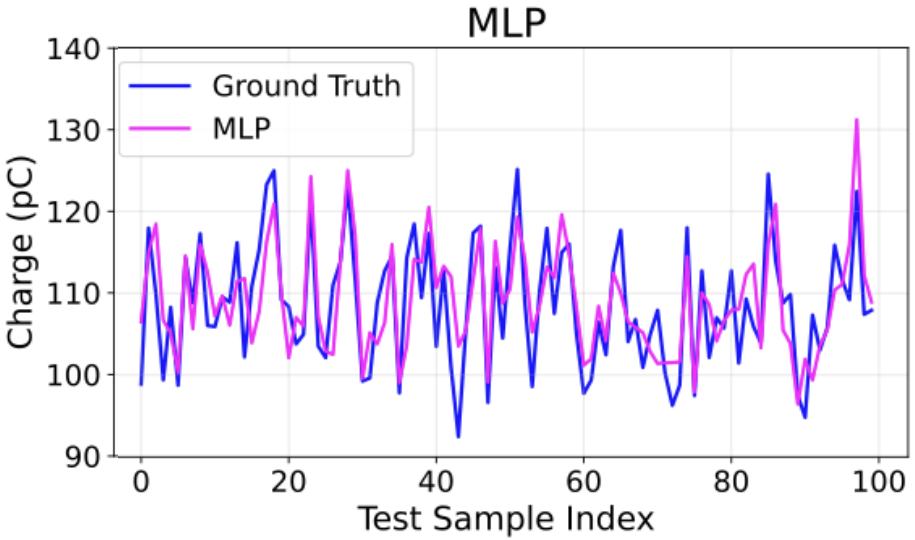
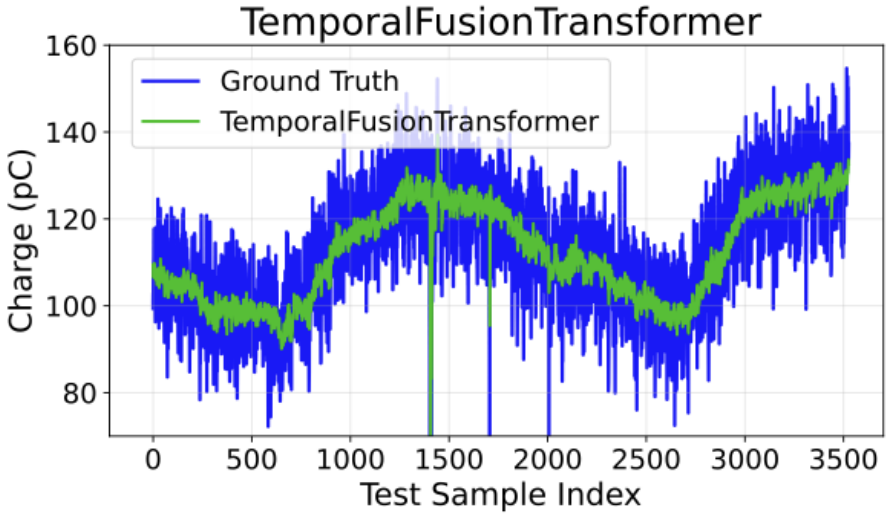
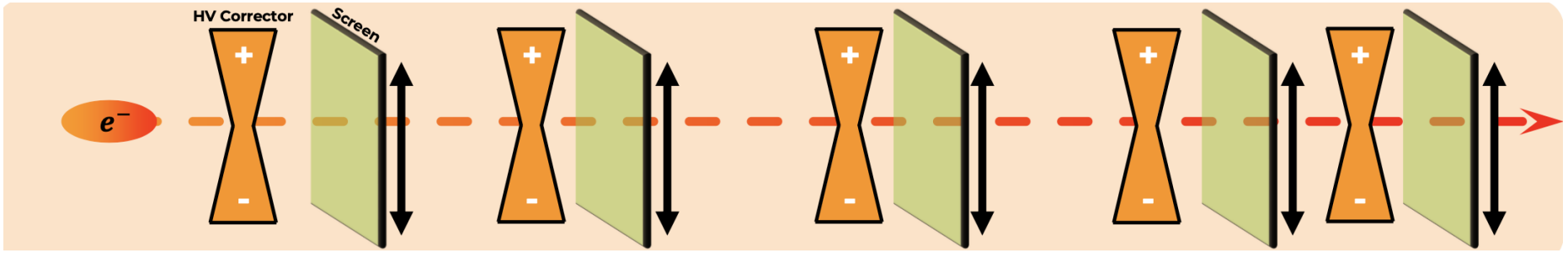


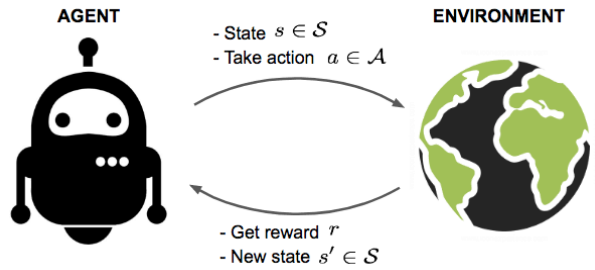




Optimization

BEAM BASED ALIGNEMENT





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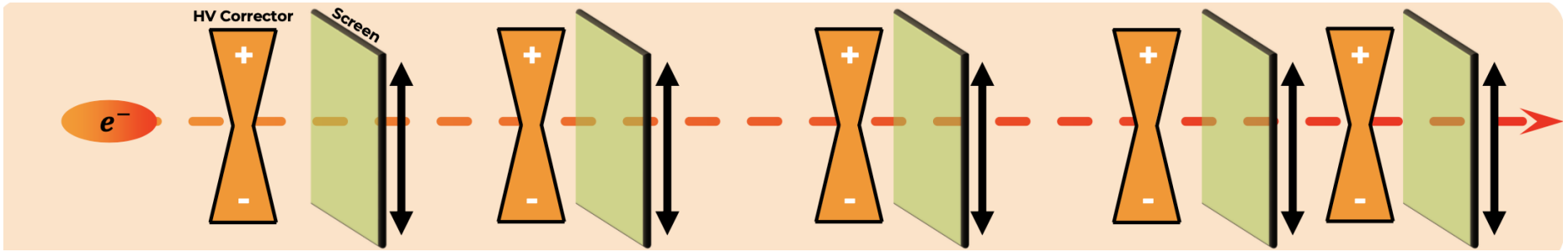
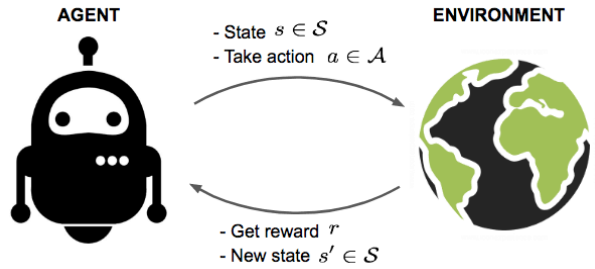
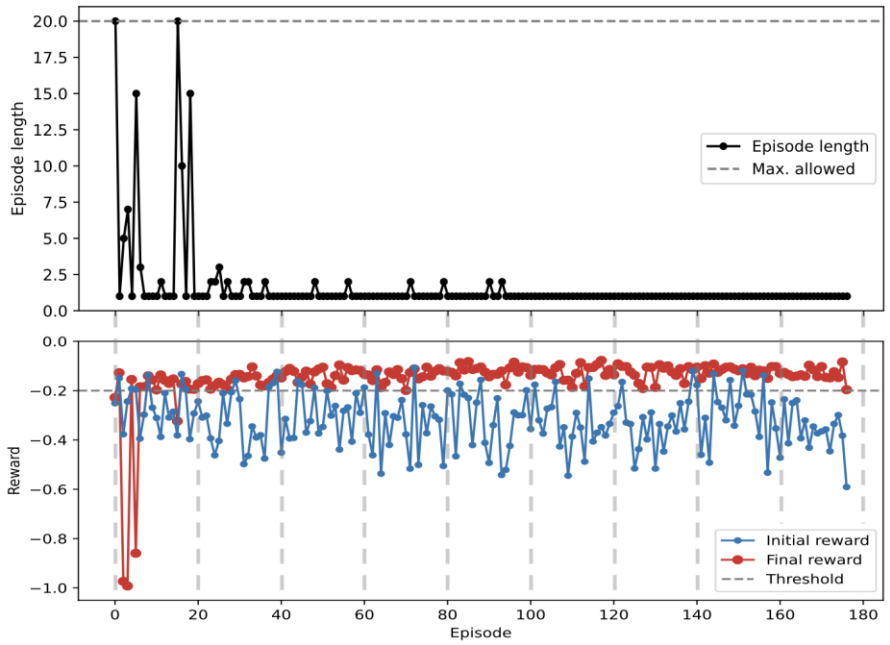
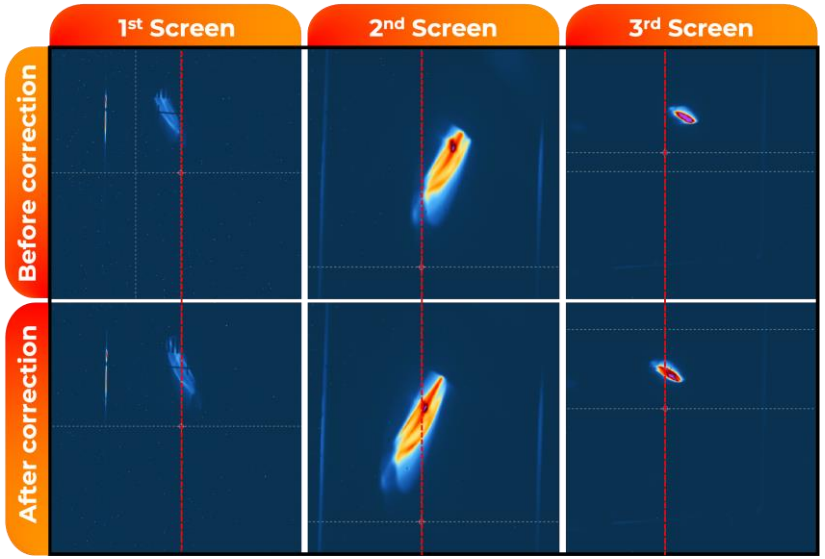








Conclusion & Outlook

- CLEAR is a unique and highly flexible testbed for a wide range of accelerator studies
- Team and facility enable rapid iteration from idea to test
- Promising results obtained across several studies; tools maturing towards operational use
- New experimental proposals are welcome from anyone with a strong idea

- Growing demand foreseen for this type of experiment / R&D study in the coming years
- Continued effort to strengthen the synergy between our studies and the wider community
- New research lines opening up — ambitious ideas becoming increasingly feasible

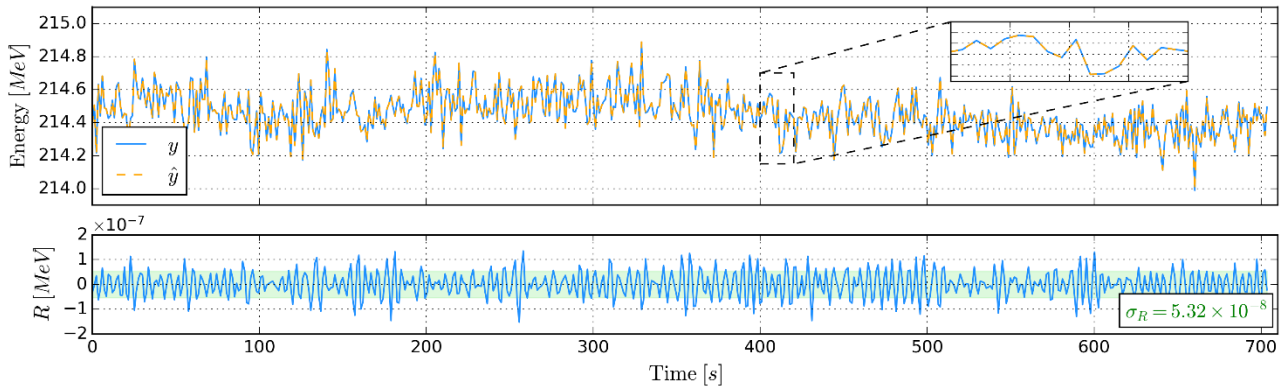
Thanks
for the attention!

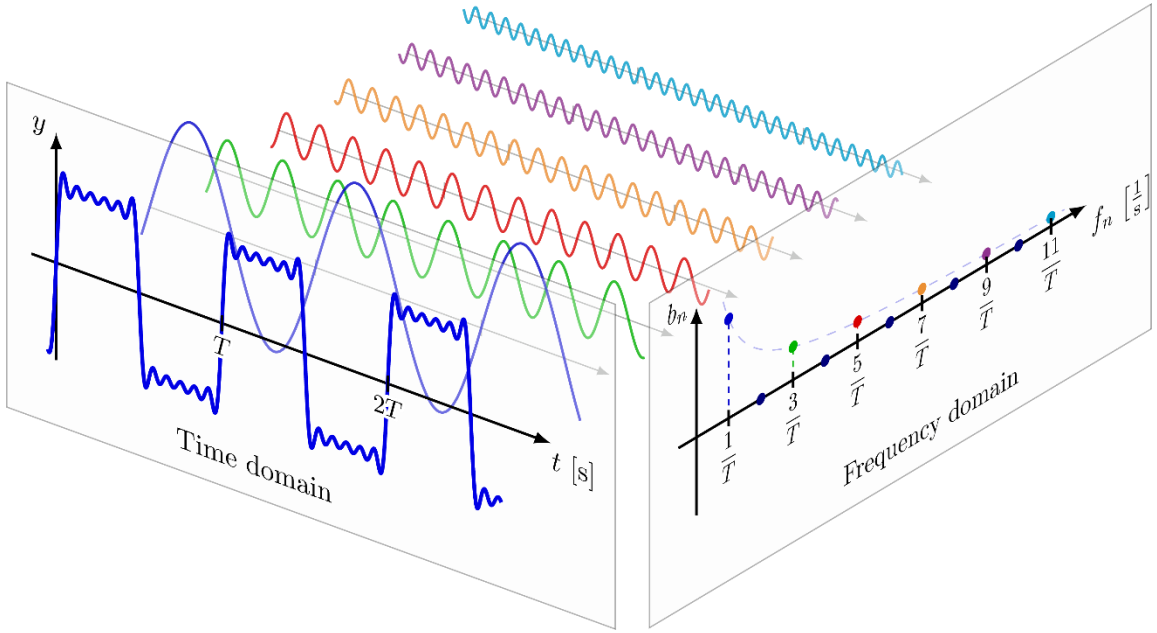
Challenges

ADDITIONAL SLIDES

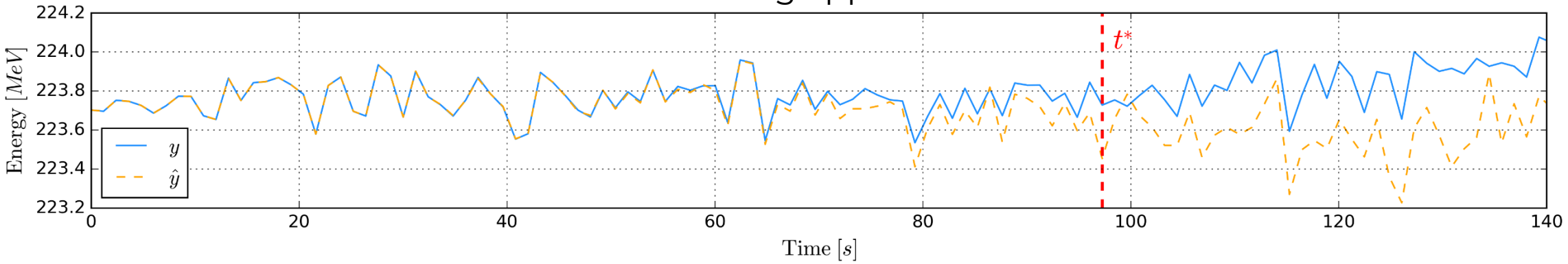
Lesson learned

Virtual Diagnostic approach





Forecasting approach



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ADDITIONAL SLIDES

Challenges

Time Series

FFT

Signal in freq

Decomposition

Band 1

Band 2

Band 3

IFFT

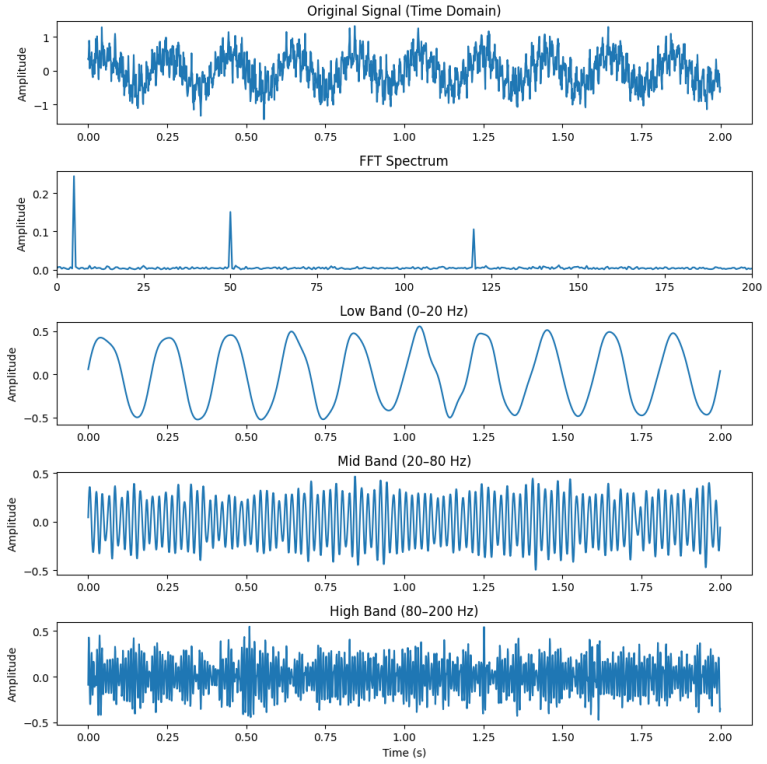
Time Series 1 - y_1

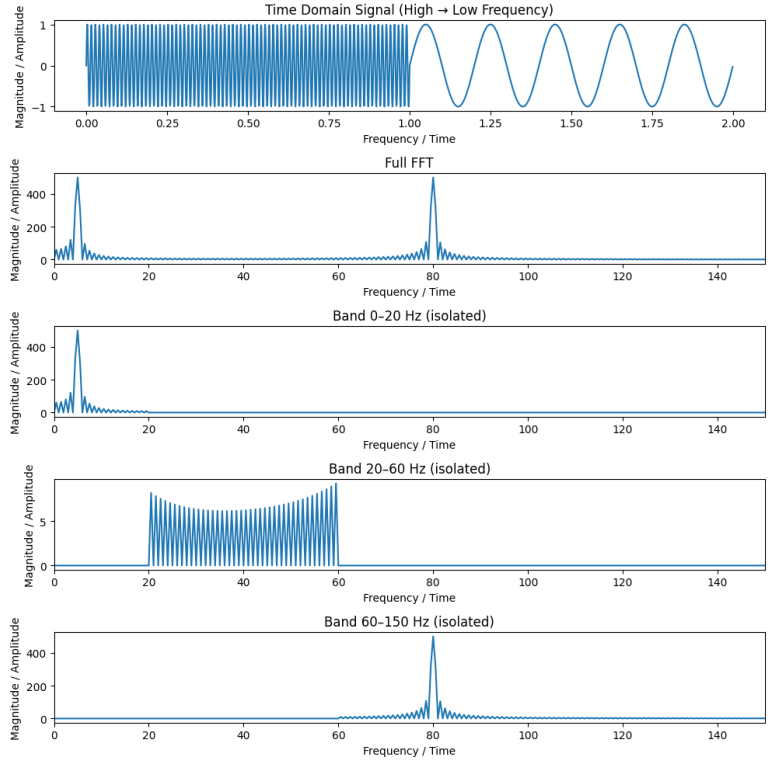
Time Series 2 - y_2

Time Series 3 - y_3

$f(X, y_n)$

Lesson learned





The FFT does not leak data, but distributes time-domain information across frequencies, so any individual band time series implicitly uses global temporal structure.

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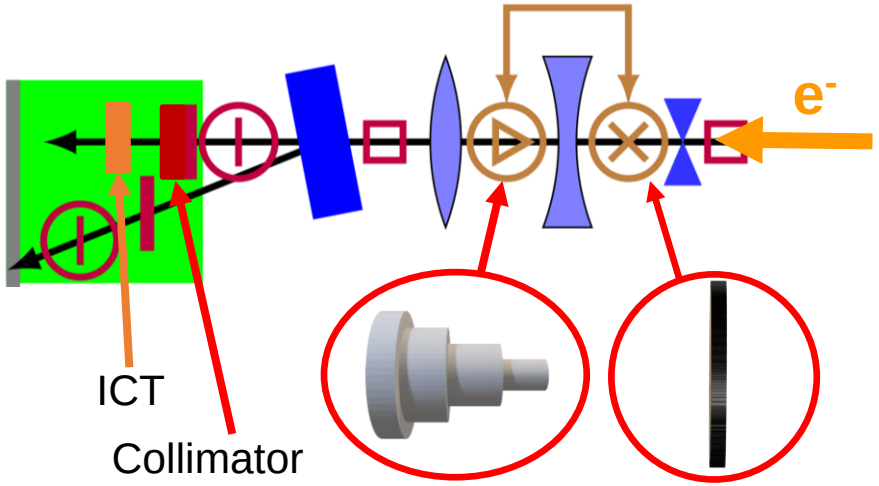
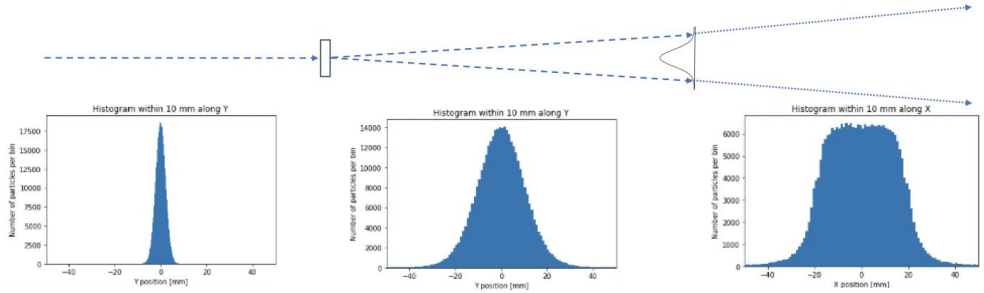
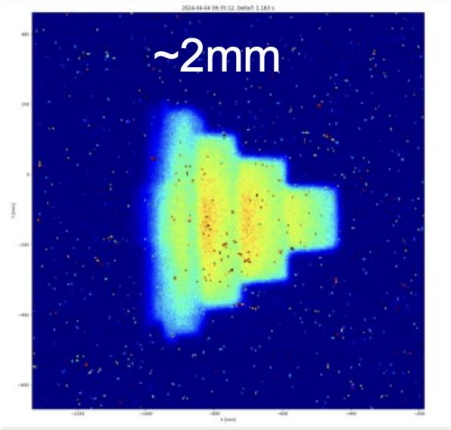
Optimization

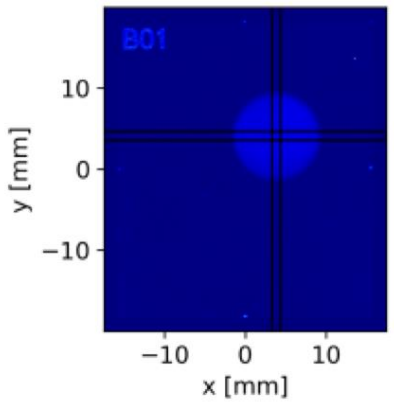
ADDITIONAL SLIDES

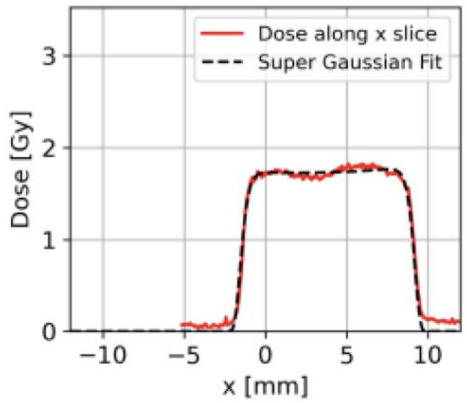
TRANSVERSE BEAM PROFILE MANIPULATION

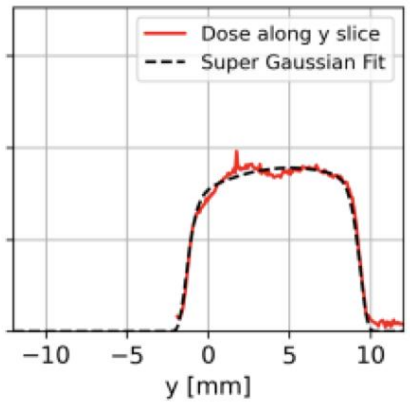






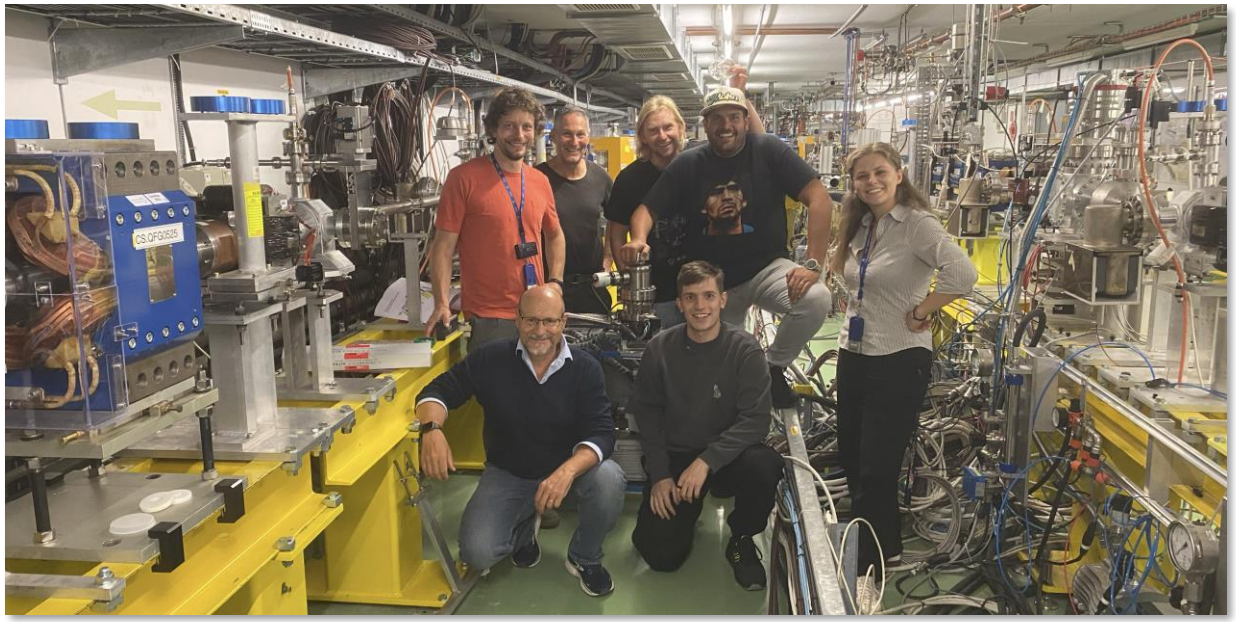






TEAM

ADDITIONAL SLIDES



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