Northern Illinois University

EEX-based methods towards nanometer-scale modulation and brightness enhancement

Buse Naz Temizel Ozdemir

LINAC 2026

Emittance Exchange Based Methods

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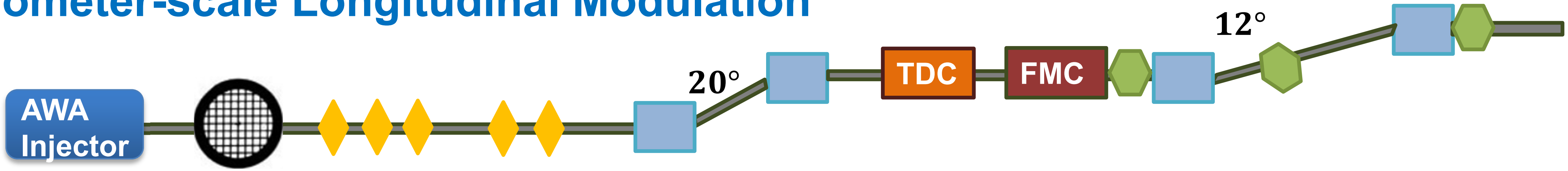
- Explore the limits of longitudinal modulations achievable with EEX beamlines.

Nanometer-scale Longitudinal Modulation



Emittance Exchange Based Methods

- Generate high-frequency bunch trains from transverse modulations using EEX.
- Explore the limits of longitudinal modulations achievable with EEX beamlines.
- Explore methods for enhancing radiation brightness for a given beam.

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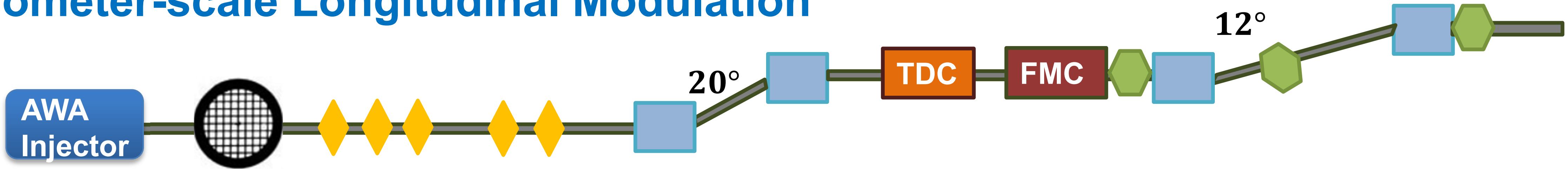
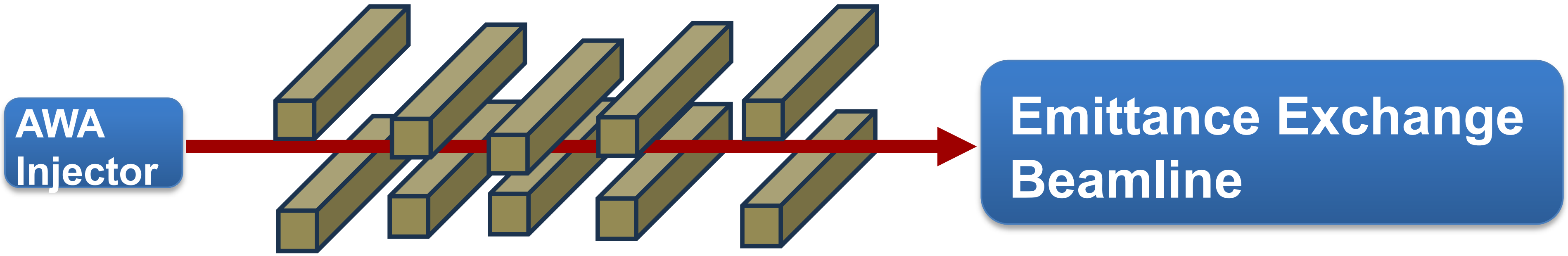
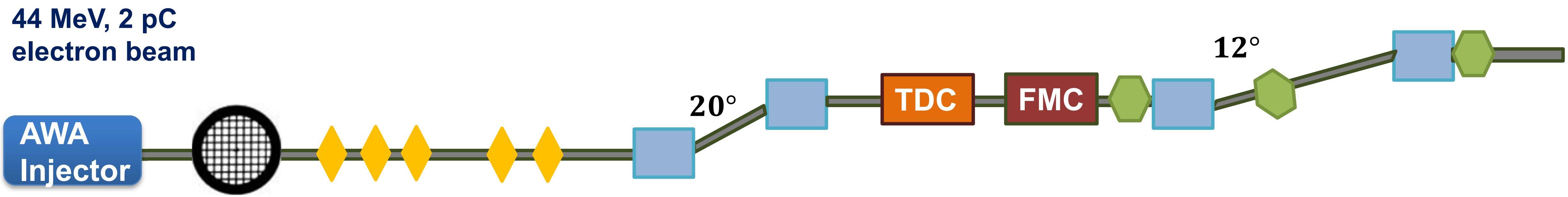


Sawtooth Correlation with Transverse Wigglers



Approach for Generating nanometer-scale Modulation

Goal: generate **nanometer-scale** longitudinal density modulation using emittance exchange (EEX) beamline at the Argonne Wakefield Accelerator



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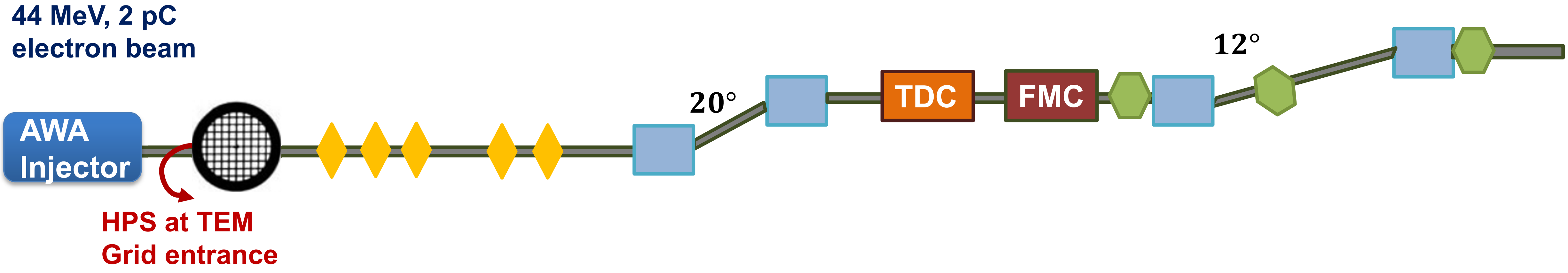

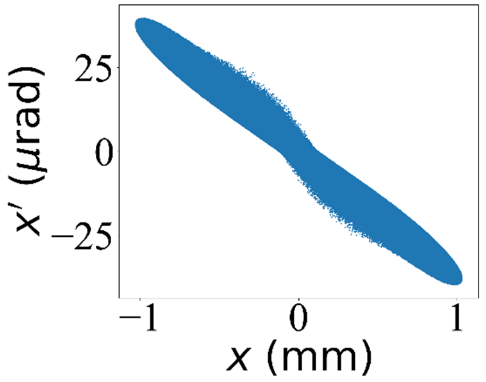

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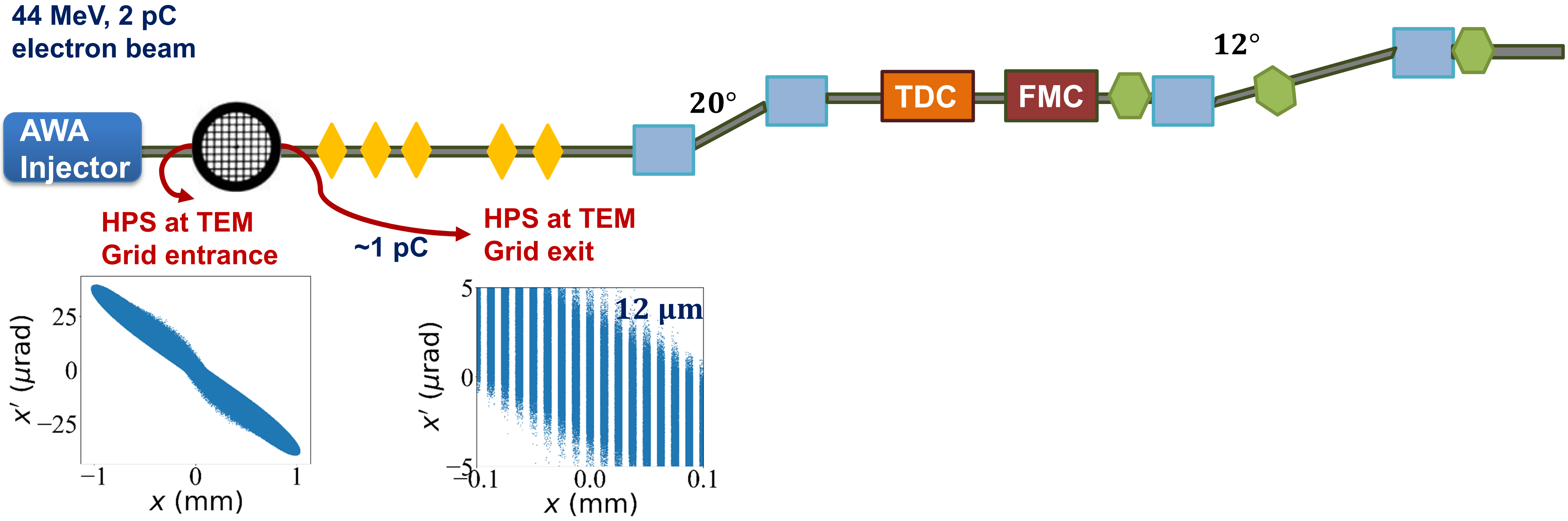

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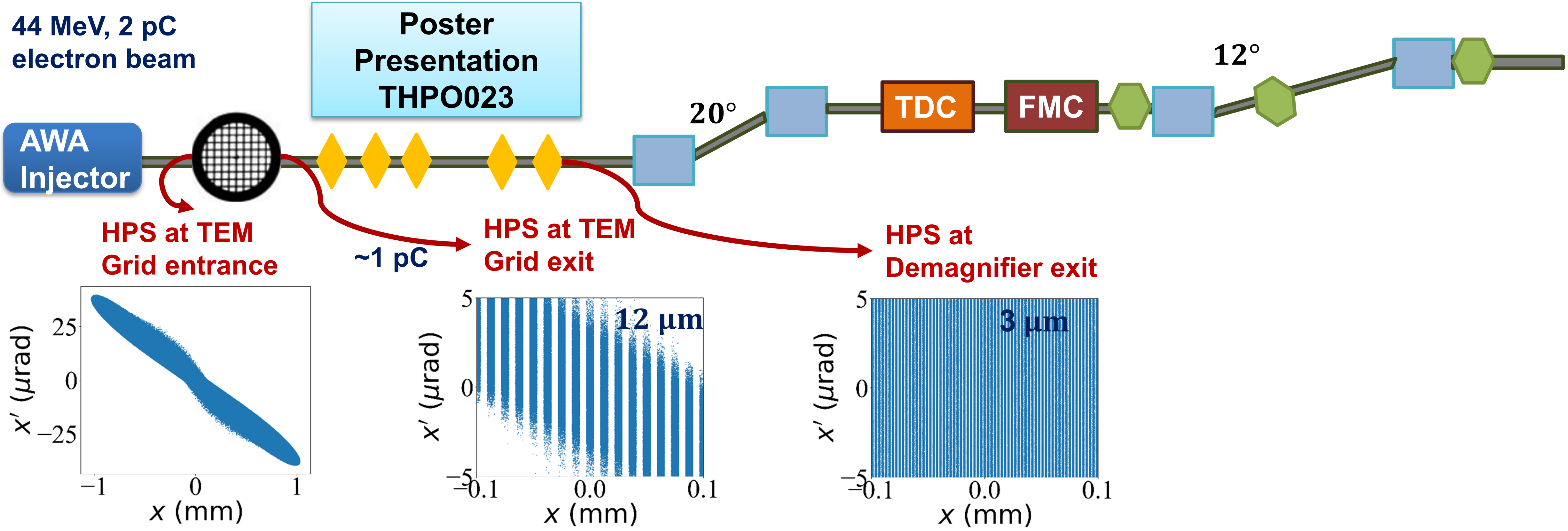

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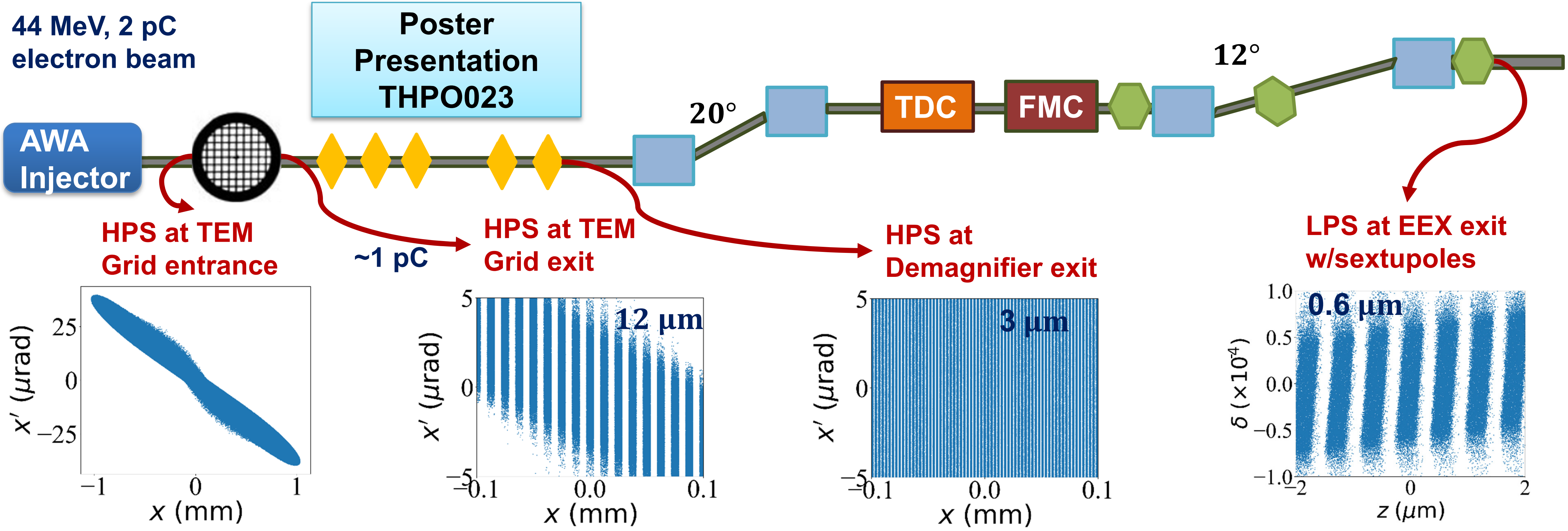
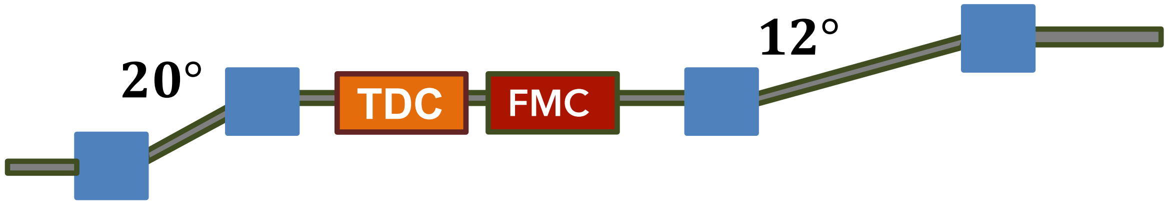
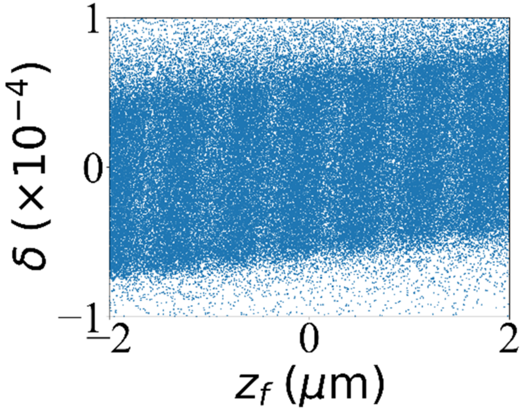


Second-order Correction



LPS at EEX Exit
w/o sextupoles



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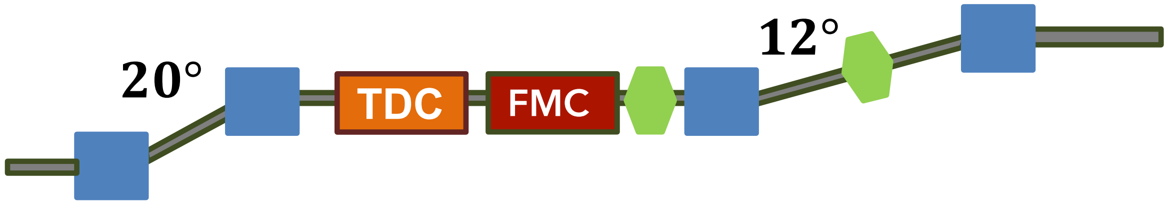

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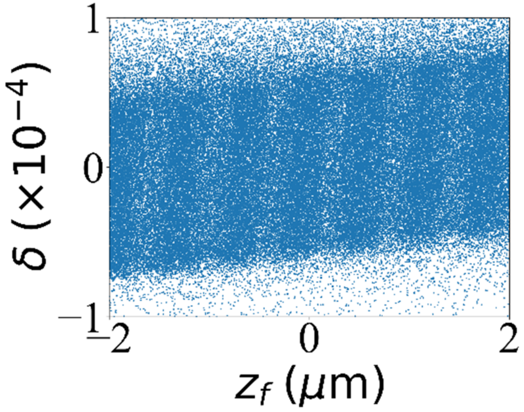

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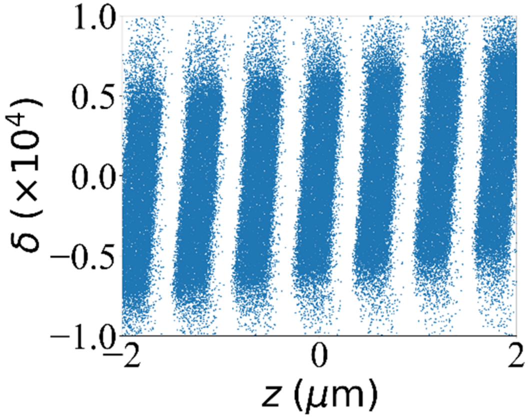

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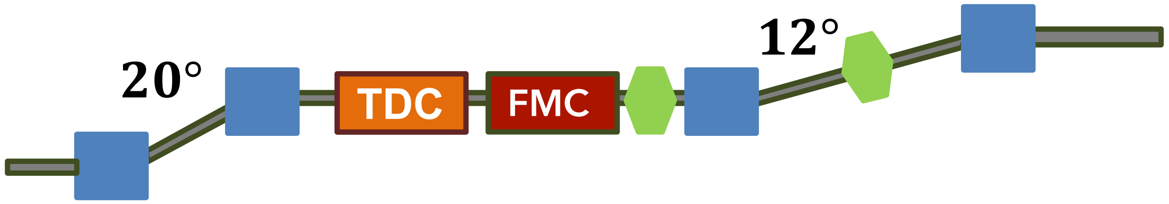

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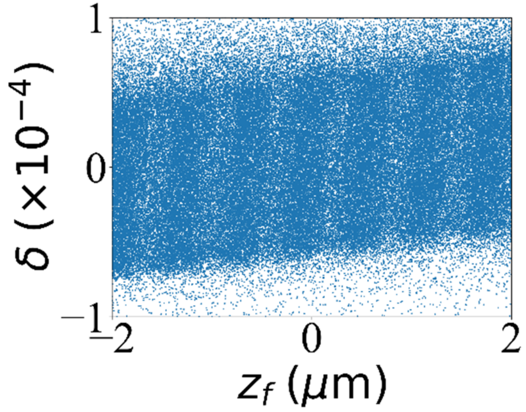

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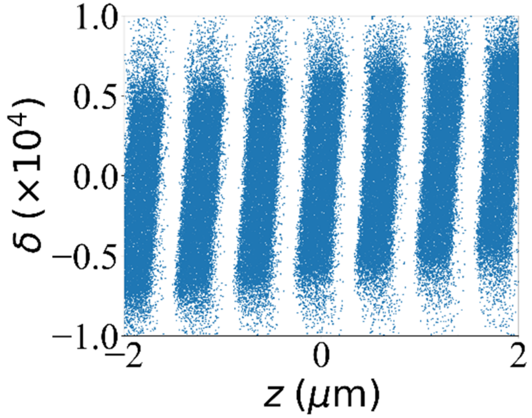
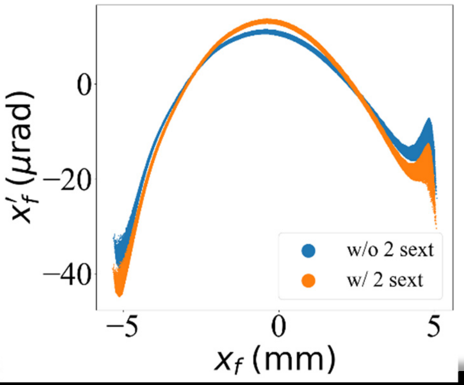


HPS at EEX exit (Nonlinear Only)



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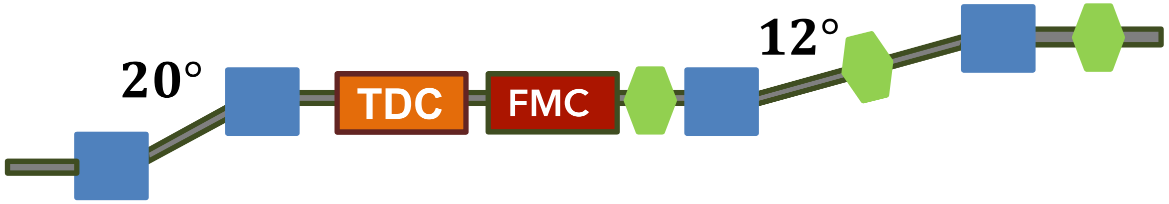
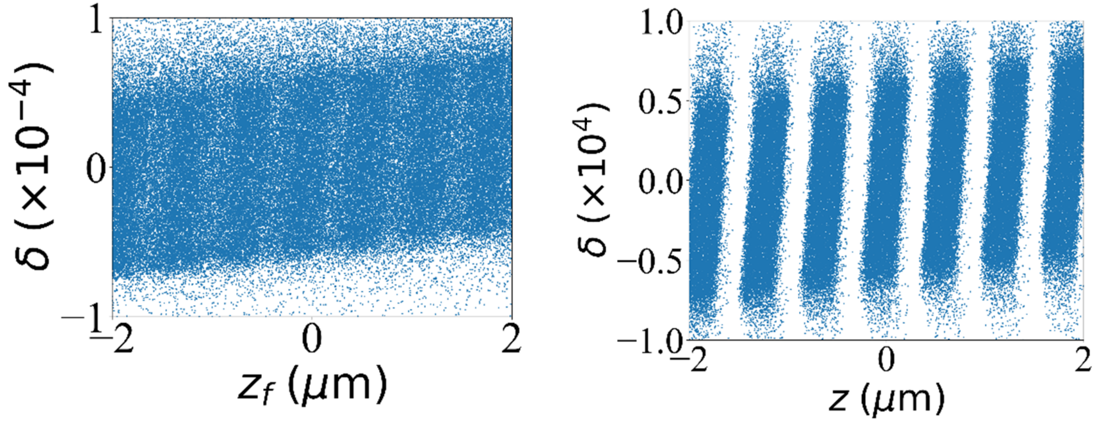


- Corrected washed-out modulation with upstream two sextupoles.
- Correcting LPS with two sextupoles cause horizontal emittance growth.
- Exit sextupole provides dual functionality: horizontal emittance recovery and RF curvature compensation.

LPS at EEX Exit w/o sextupoles

LPS at EEX Exit w/sextupoles



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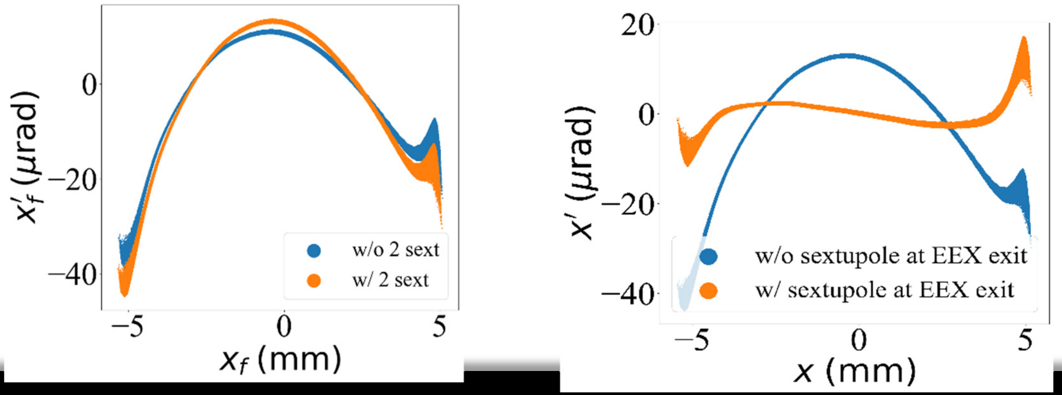
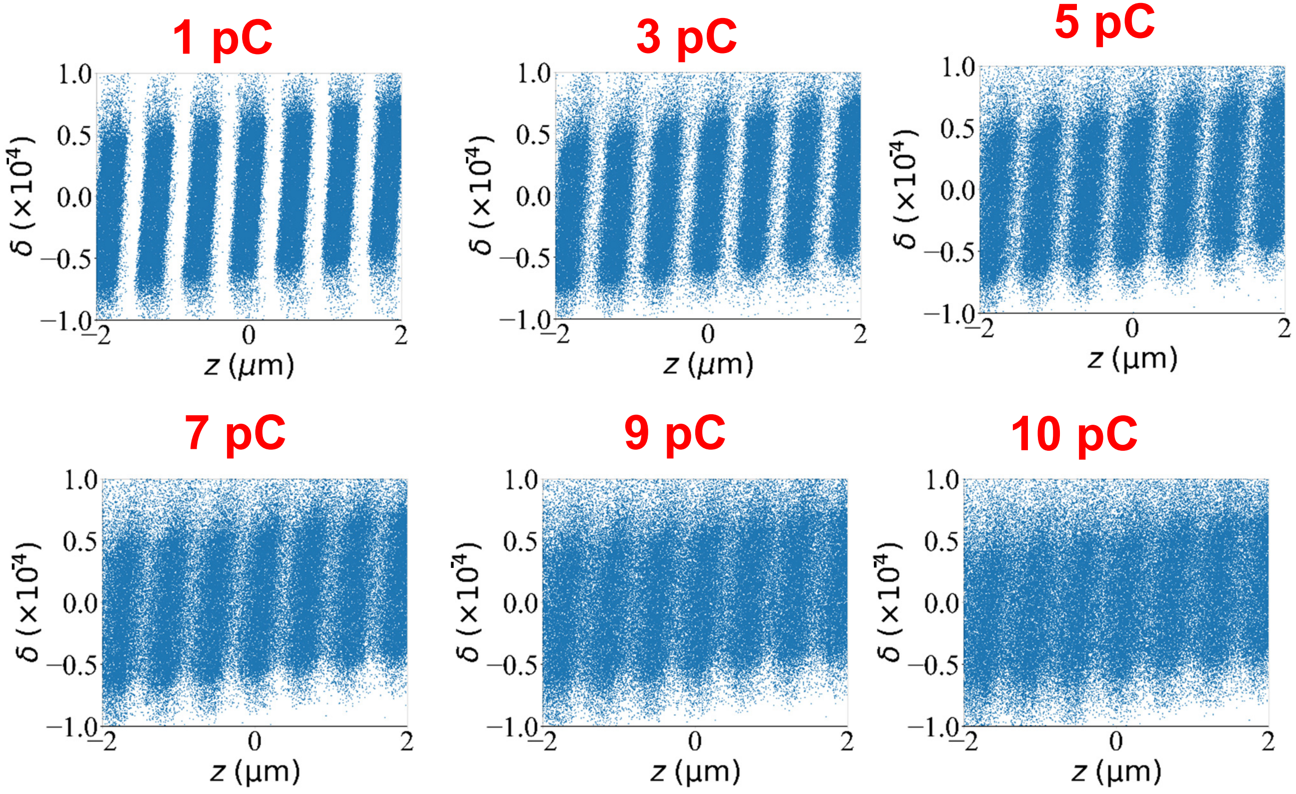


Effect of Beam Charge on Bunching Factor and LPS

LPS for different charge levels



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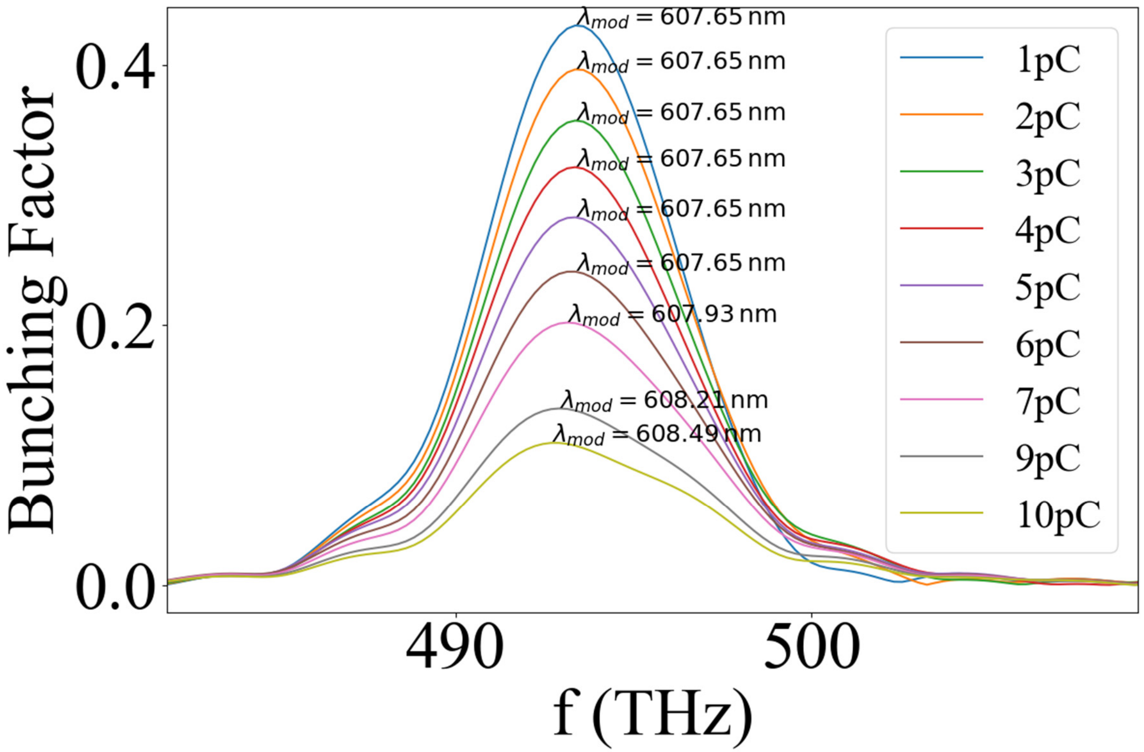
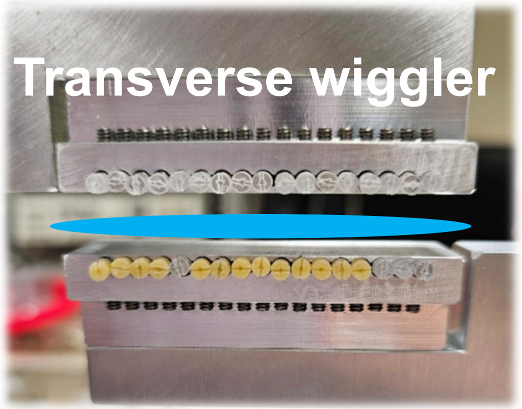


CSR has effect on the longitudinal modulation

Sawtooth Correlation Method



$$B_y \approx -2B_r \cos\left(\frac{2\pi}{\lambda_u} x\right) \exp\left[-\frac{\pi g}{\lambda_u}\right]$$

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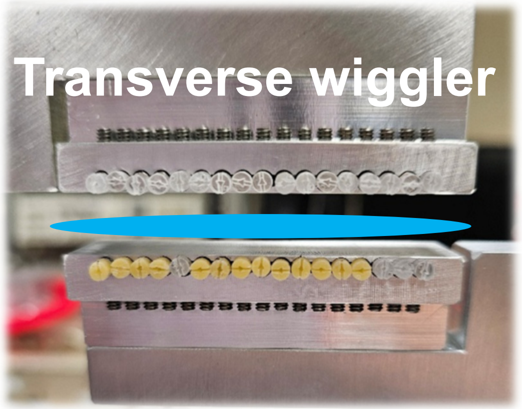

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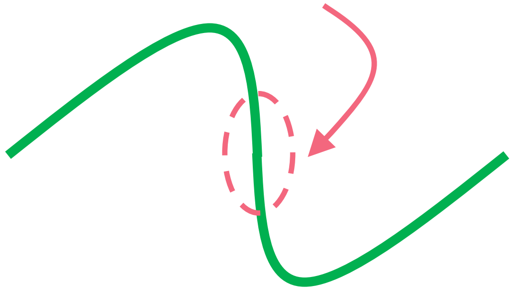
Single sine curve:

only linear parts really contribute on the peak



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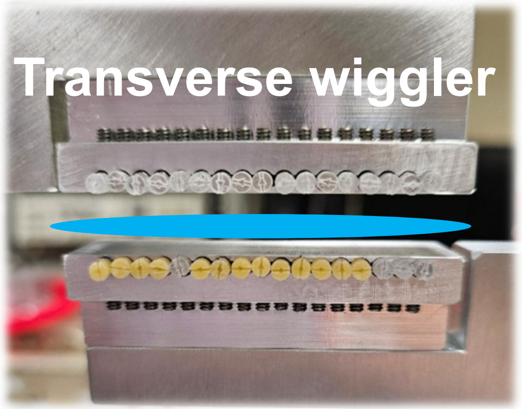

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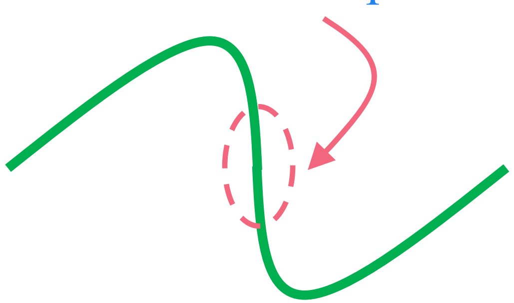

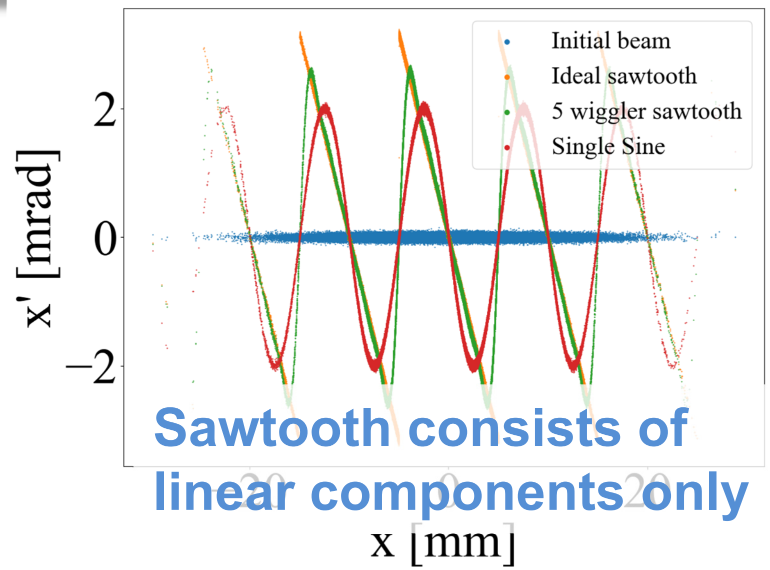

Sawtooth consists of linear components only

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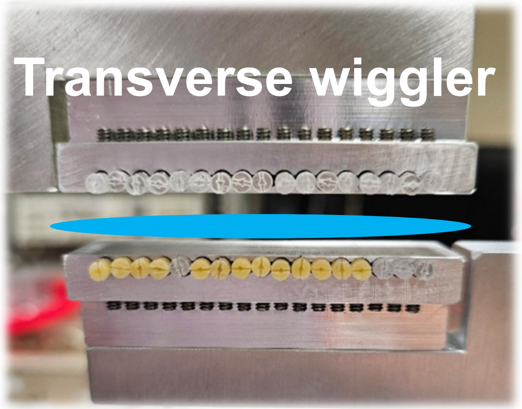

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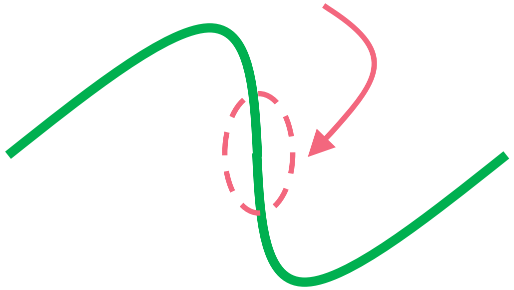

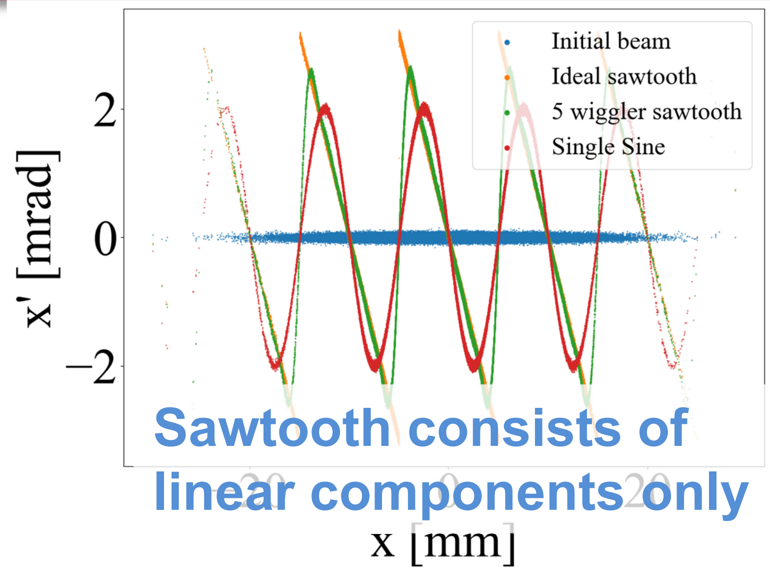

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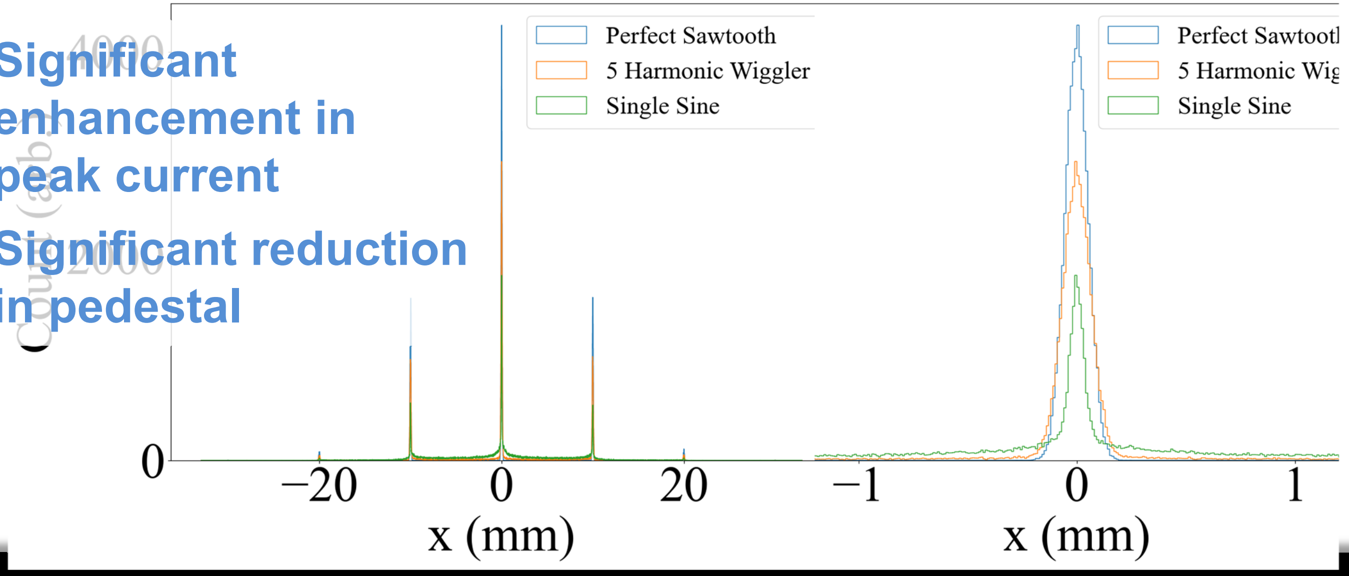
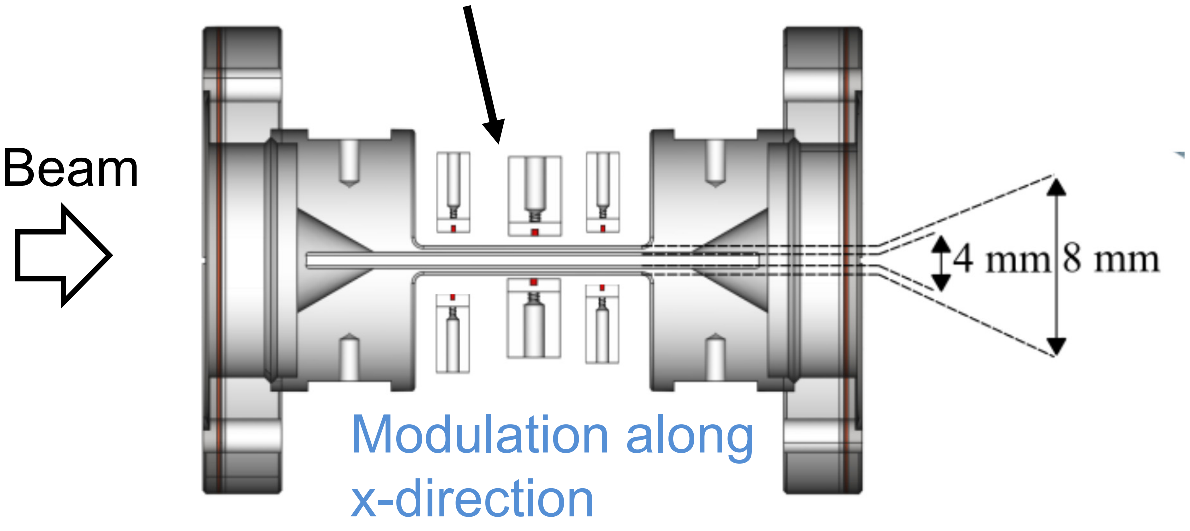


Significant enhancement in peak current

Significant reduction in pedestal

Preliminary S2E Simulation Results

Wigglers will be placed over a vacuum chamber



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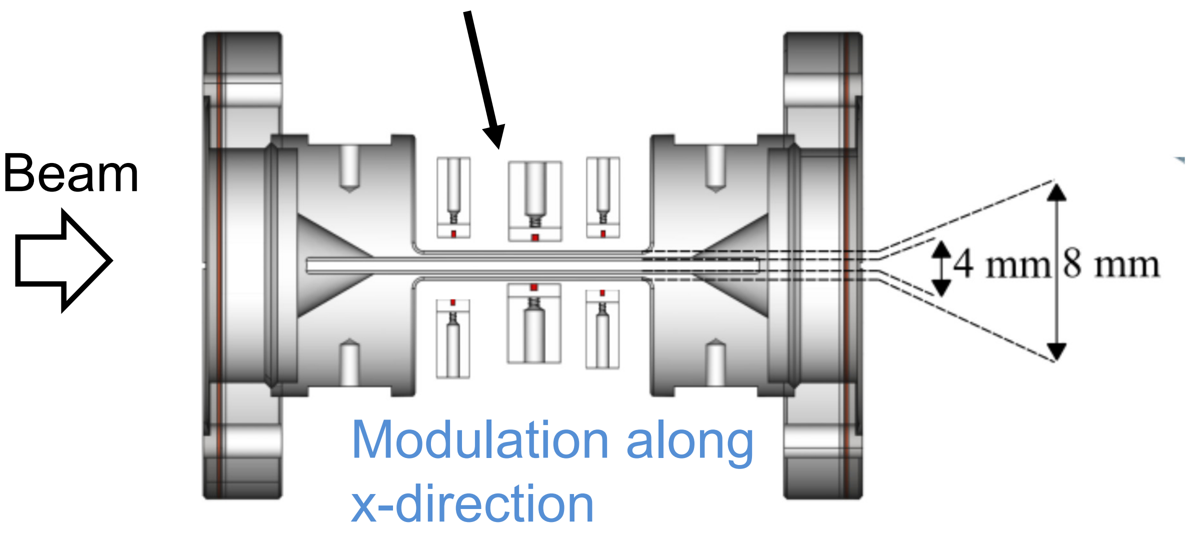

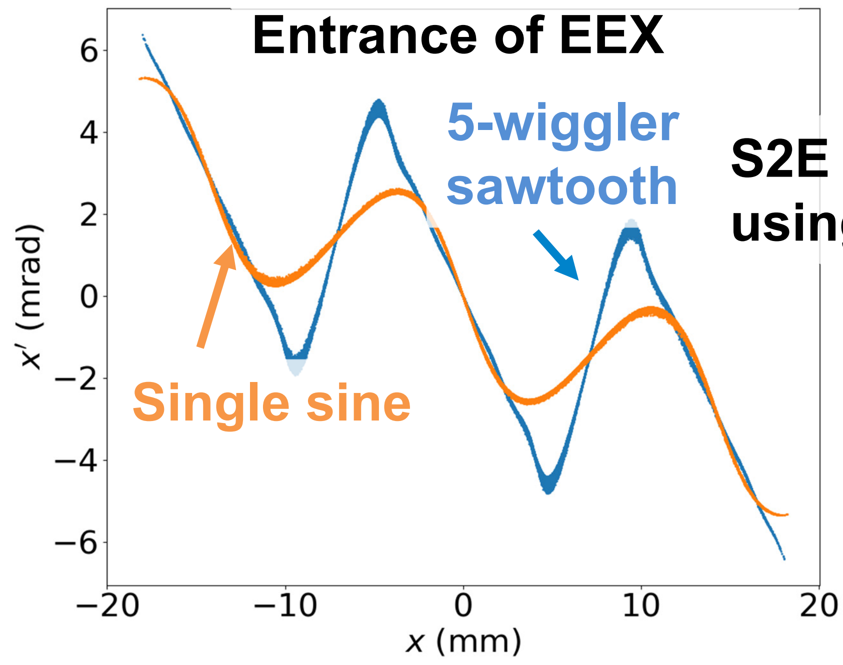

S2E simulation using AWA beamline

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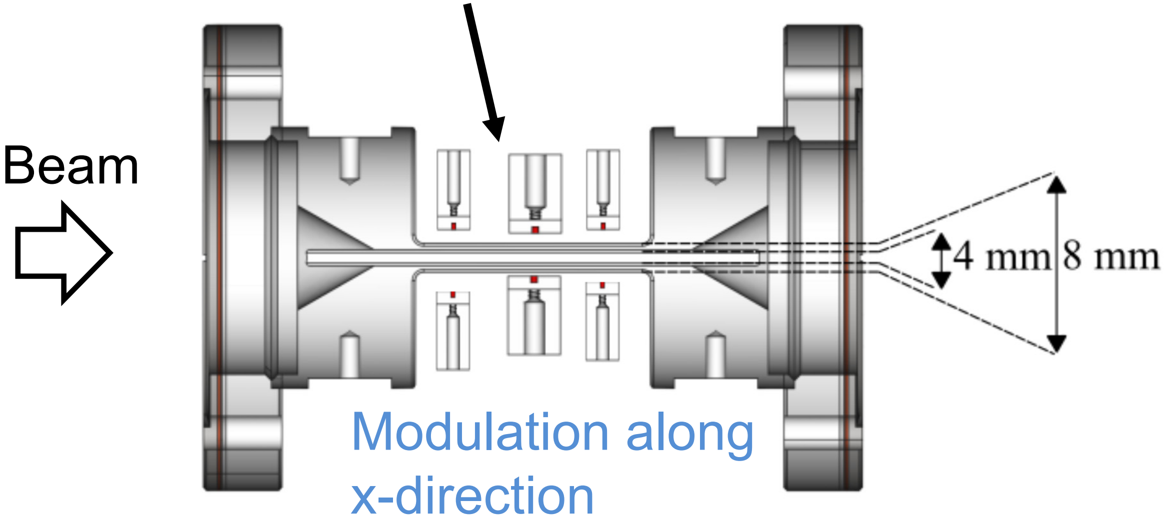

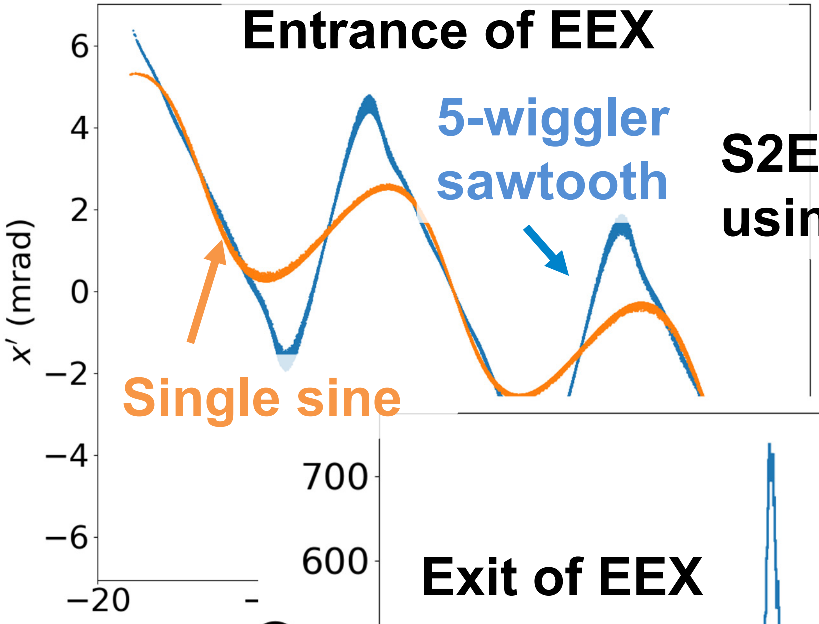

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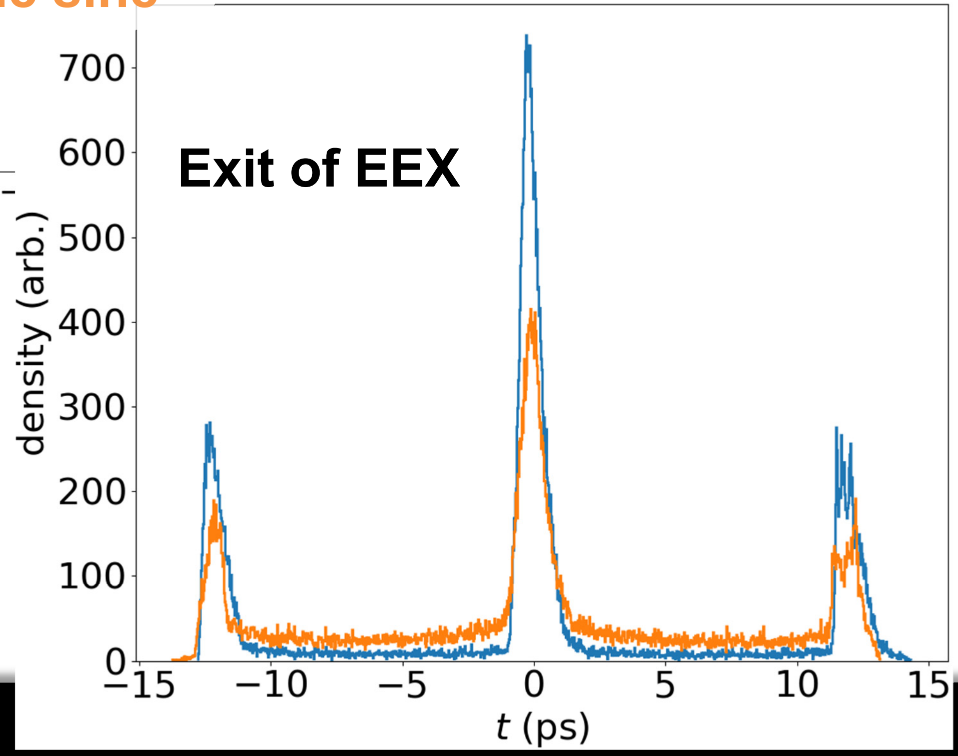

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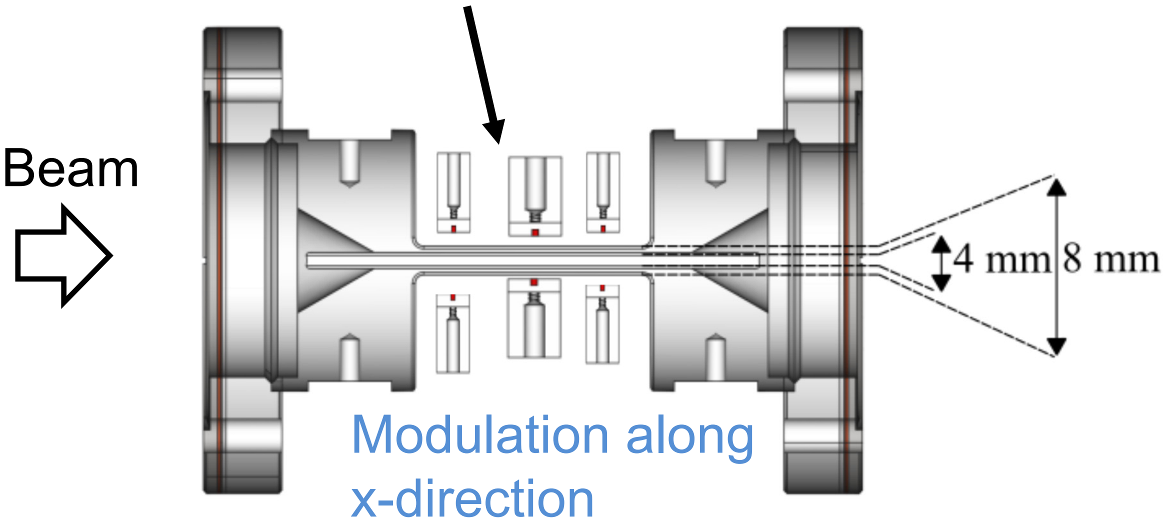

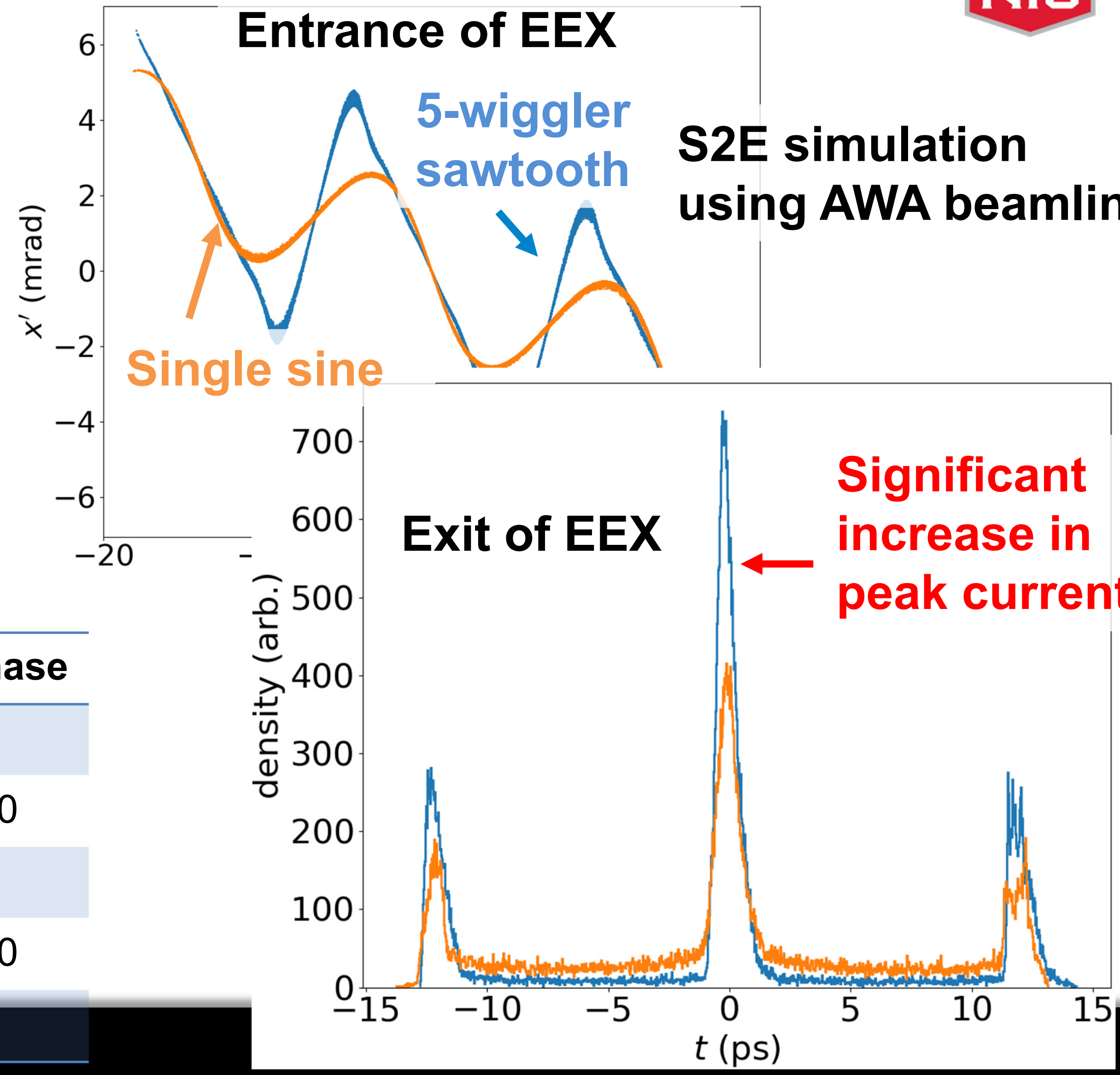

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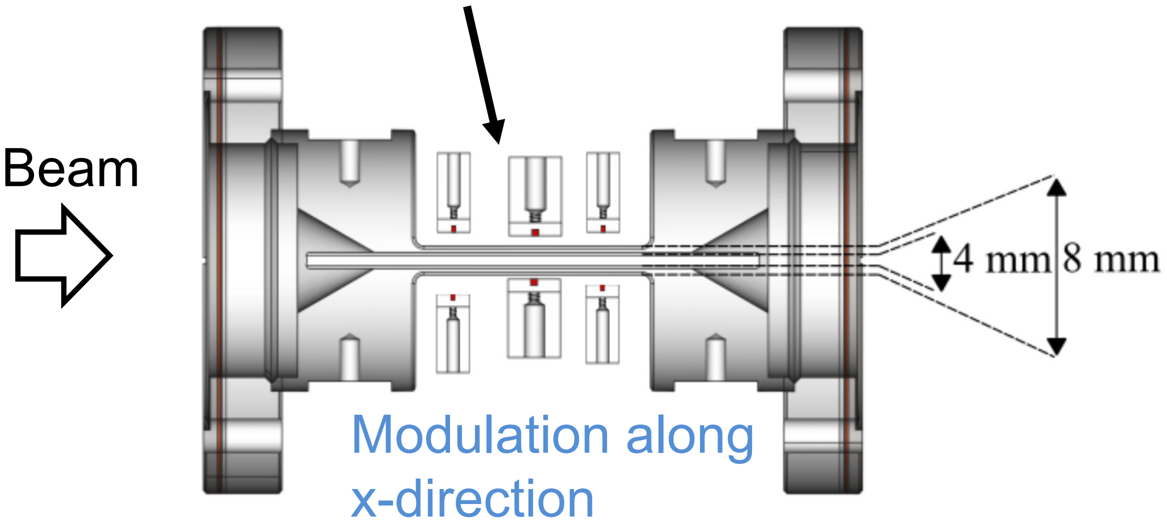

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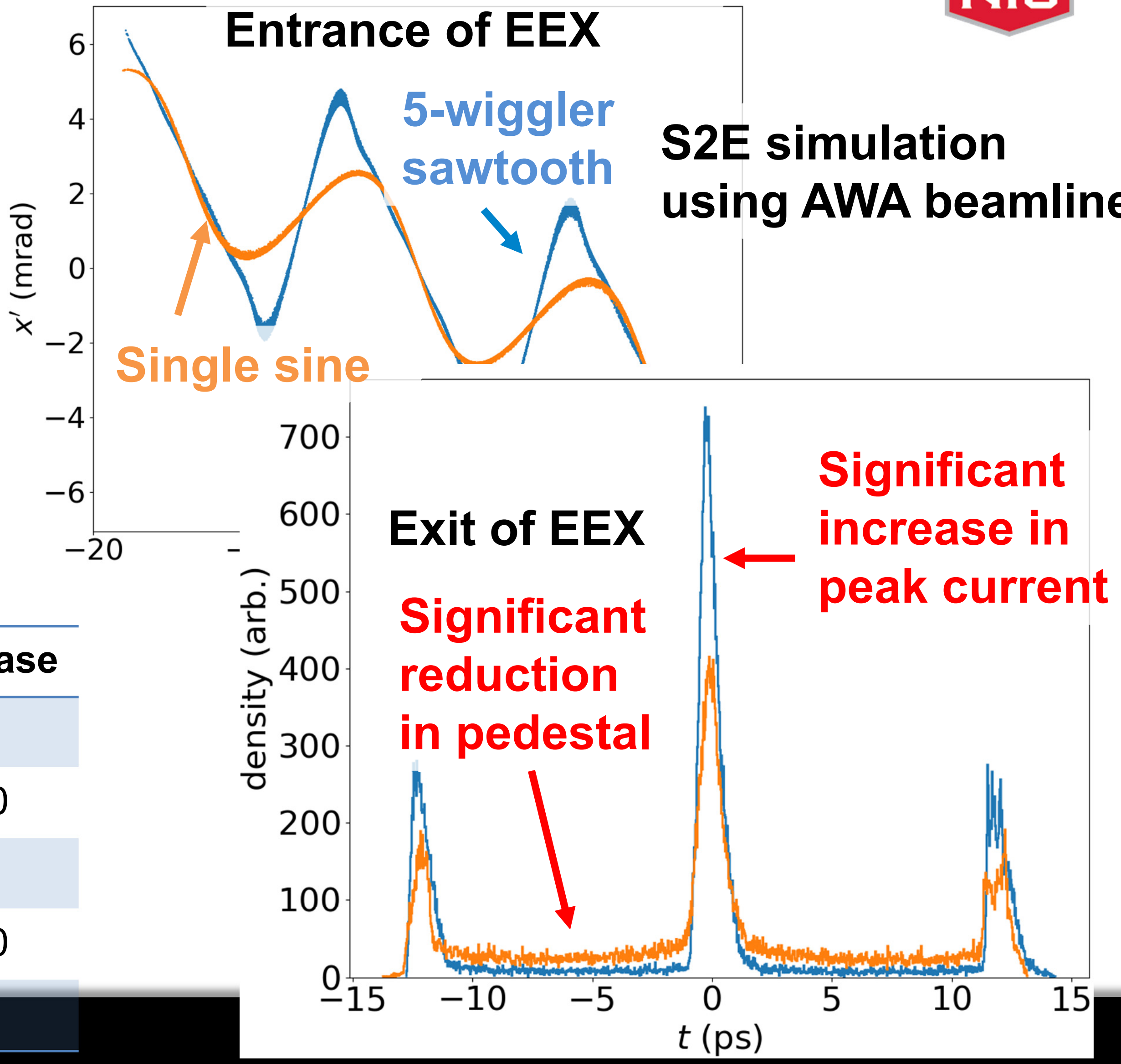

S2E simulation using AWA beamline

Summary

Nanometer-scale modulation

- Nanometer-scale longitudinal modulation is investigated using a TEM grid and quadrupole demagnifier.
- Sextupole magnets are used to mitigate second-order effects in simulations.

Sawtooth Correlation

- Sawtooth modulation is investigated as a method for increasing peak current.

The feasibility of both approaches is studied through AWA beamline simulations.