FLASH2020+

Progress Review Meeting

FLASH2020+ Seeding Progress

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With contributions from FLASH2020+ Team

Hamburg, March 8th, 2024

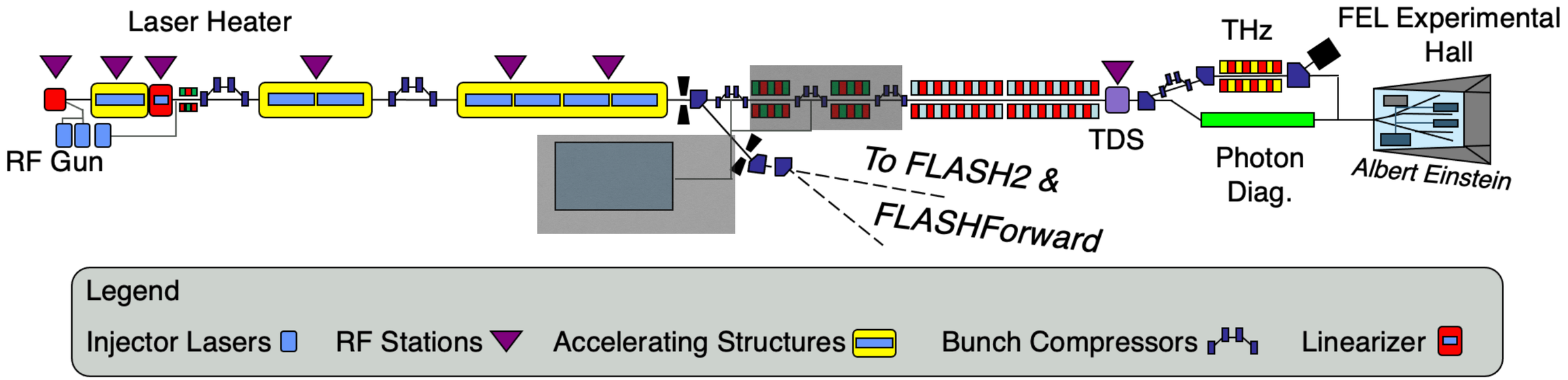
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

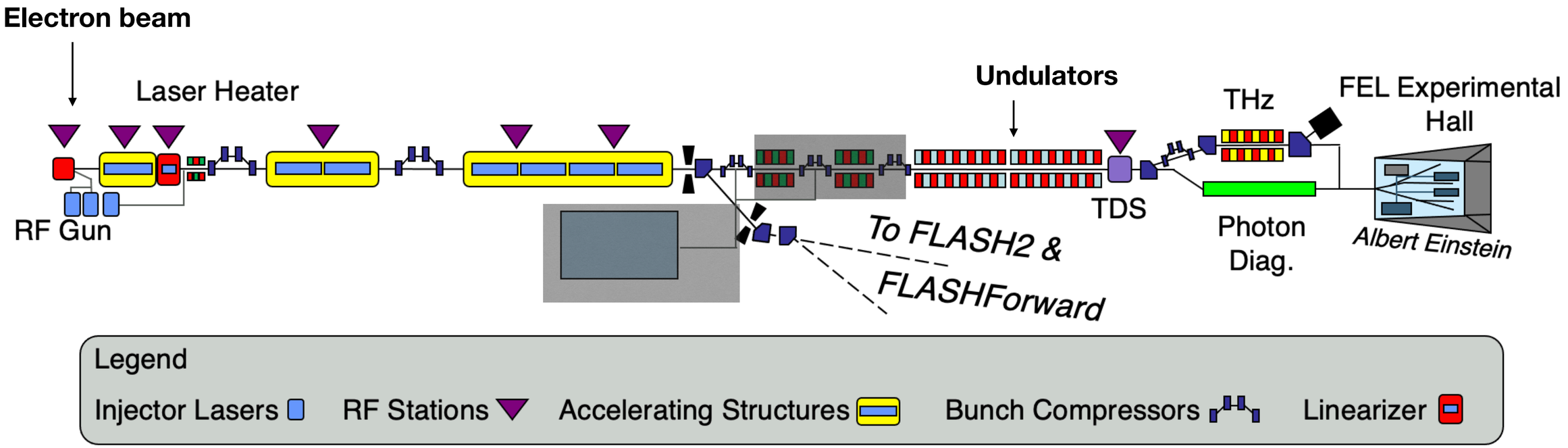
FLASH2020+ Seeding Progress:

Spectrometer Repair
EEHG Simulations
CSR Studies
Updates from Workshops and Meetings

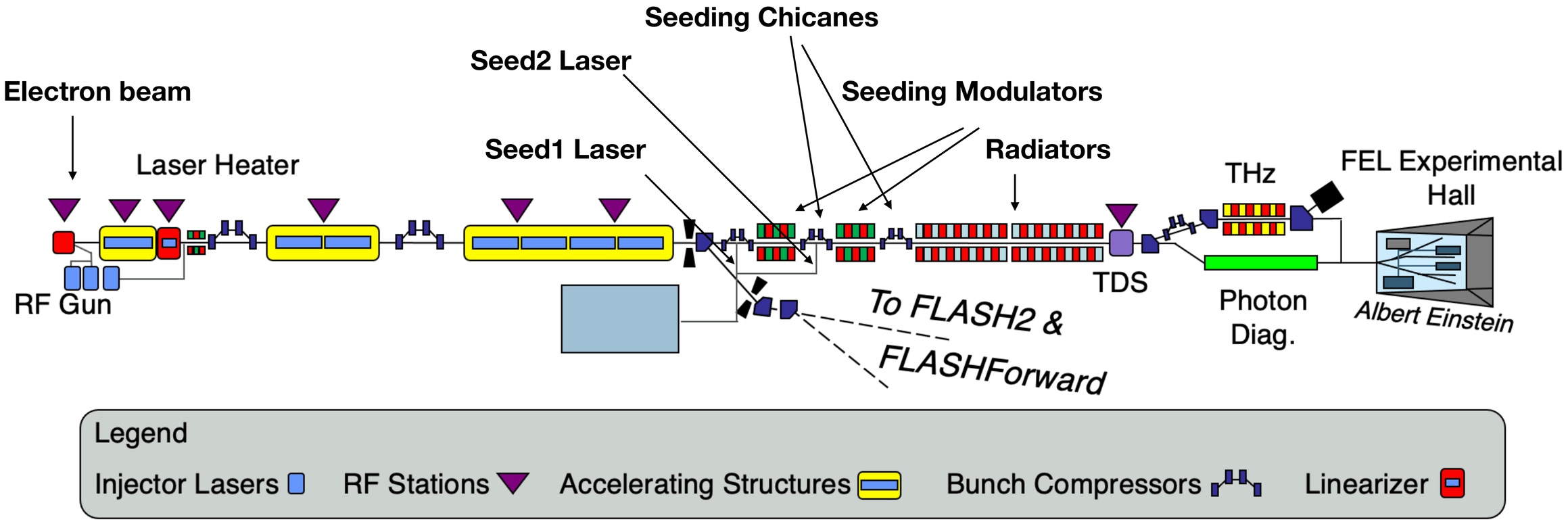
Upgrading FLASH1 to an external seeding scheme heightens the demand for sophisticated simulations and sensitive diagnostics.



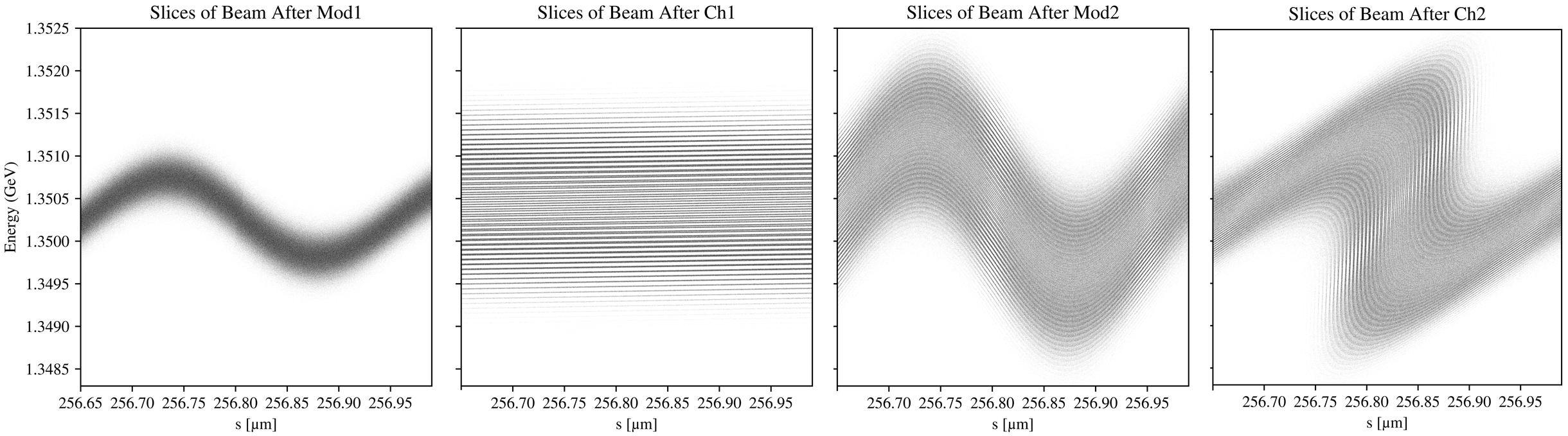
1) SASE


Electron beam
Laser Heater
RF Gun
Undulators
TDS
THz
Photon Diag.
FEL Experimental Hall
Albert Einstein
To FLASH2 &
FLASHForward
Legend
Injector Lasers
RF Stations
Accelerating Structures
Bunch Compressors
Linearizer

1) SASE to external seeding means more complex setup



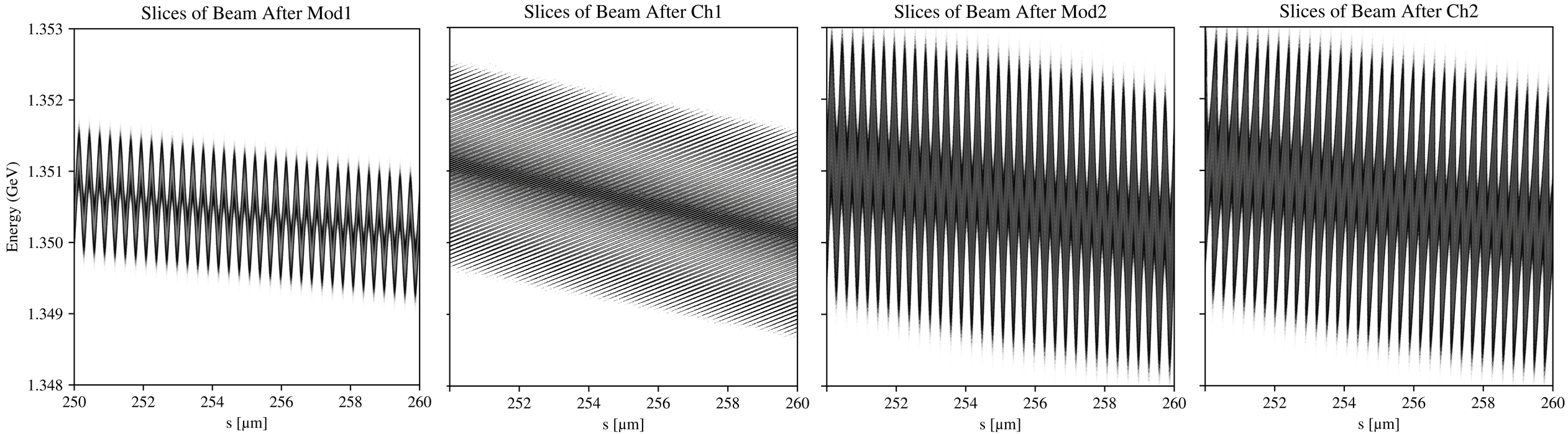
2) Sophisticated manipulation of beam dynamics renders the setup more susceptible to instabilities.



~ 0.5 micron

2) Sophisticated manipulation of beam dynamics renders the setup more susceptible to instabilities.

Puts constraints on seeding design (dispersive sections, laser parameters, …) and Machine stability (i.e., compression, timing, …)



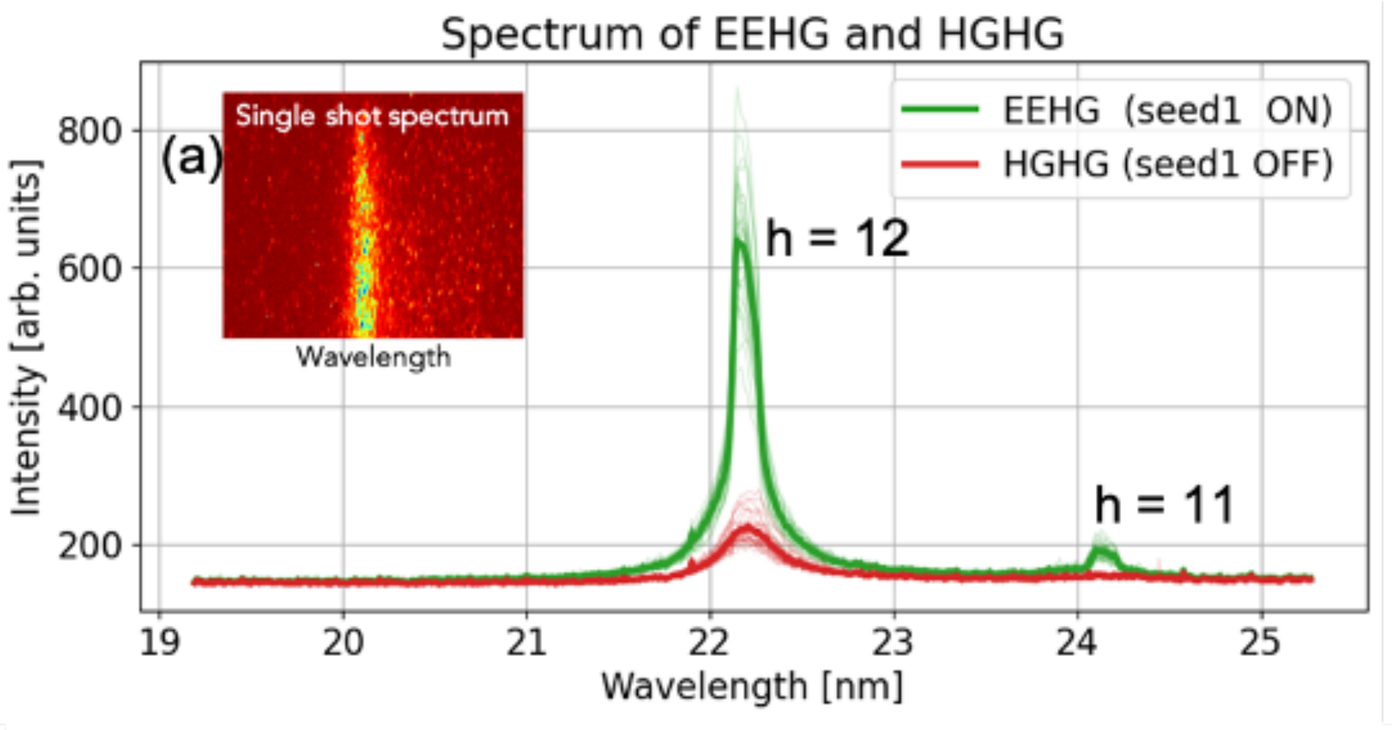
10 micron

3) Detecting and characterizing an FEL pulse near the Fourier limit is challenging, highlighting the necessity for additional technical rigor and precision.

Spectrometer

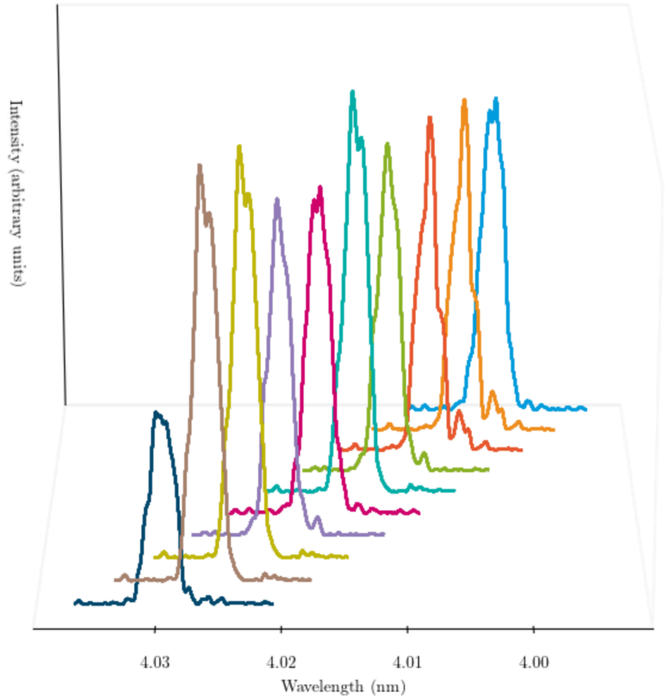
Already an essential tool in characterizing SASE (where optimization is done with GMD, MPC, and Screens)

Essential for optimizing Seeding Setup

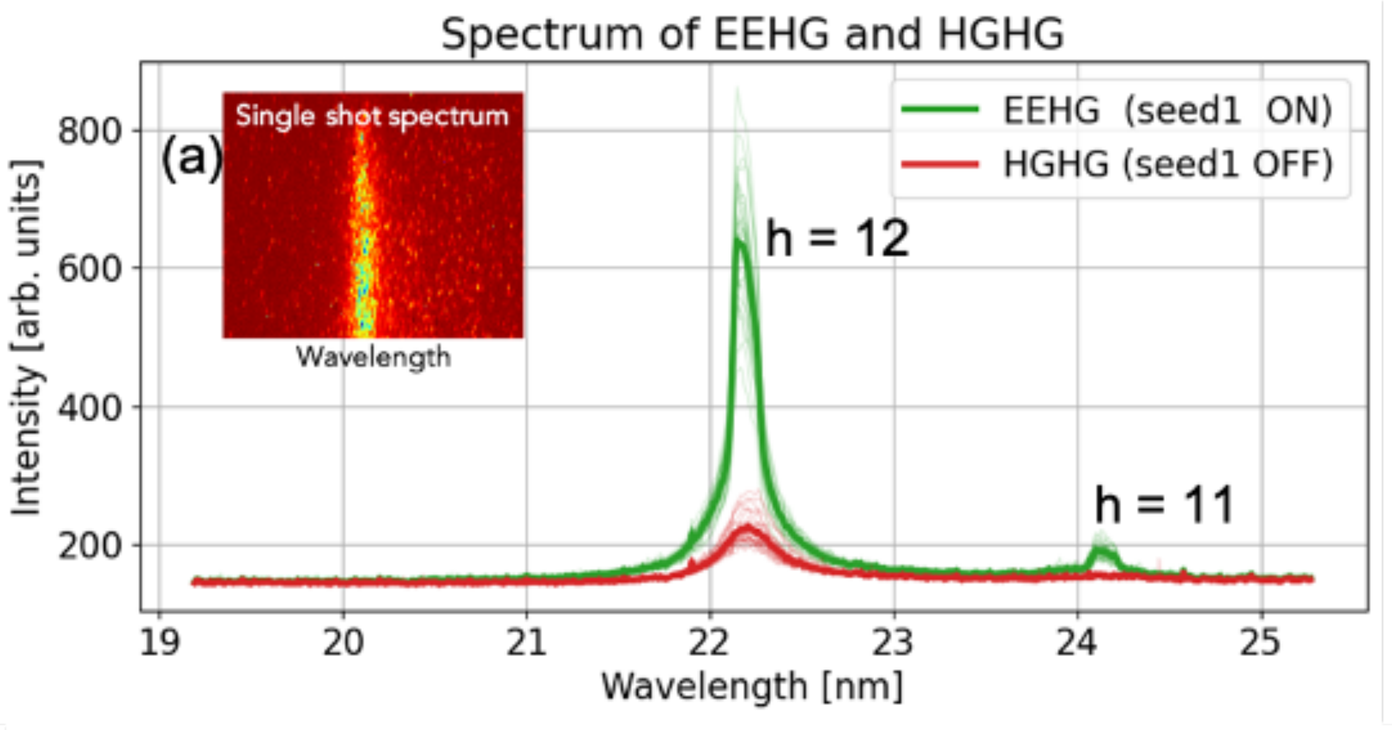


Leveraging Dual Methodologies for Progress

Simulation Studies and optimization



Beam Time Measurements, Analysis, and Studies



FLASH2020+ Seeding Progress:

Spectrometer Repair

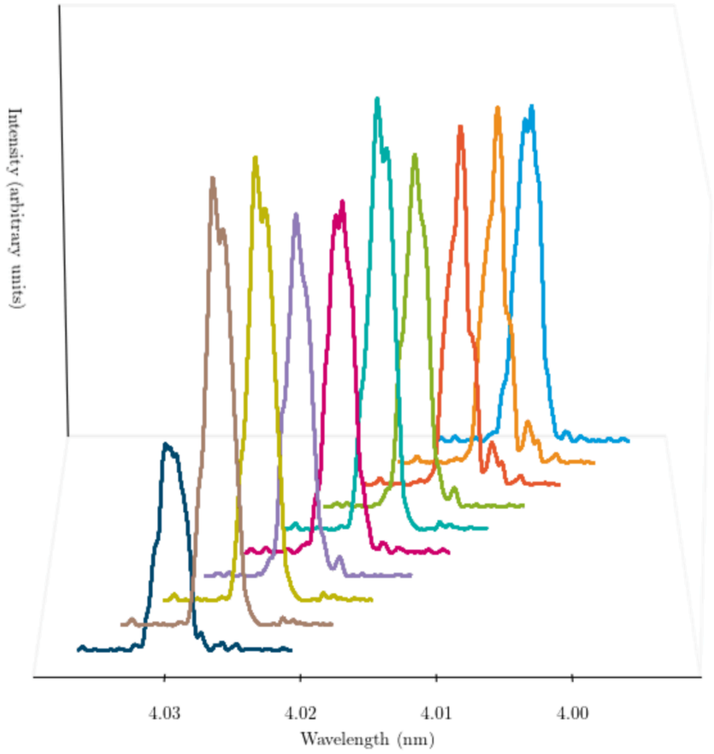
EEHG Simulations

CSR Studies

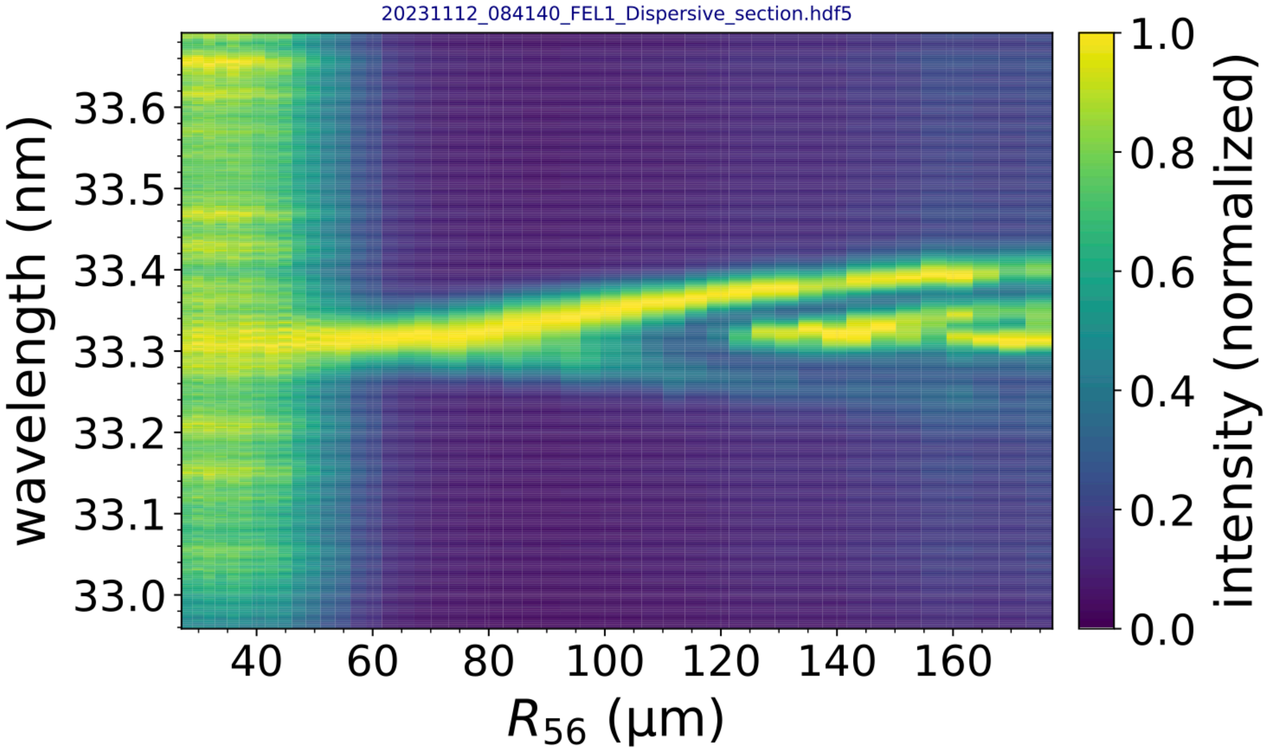
Updates from Workshops and Meetings

Both Simulations and Experiments emphasize that the spectrometer is essential for successful seeding setup and studies.

The spectrum of 4nm EEHG from the last round of Simulation Optimization

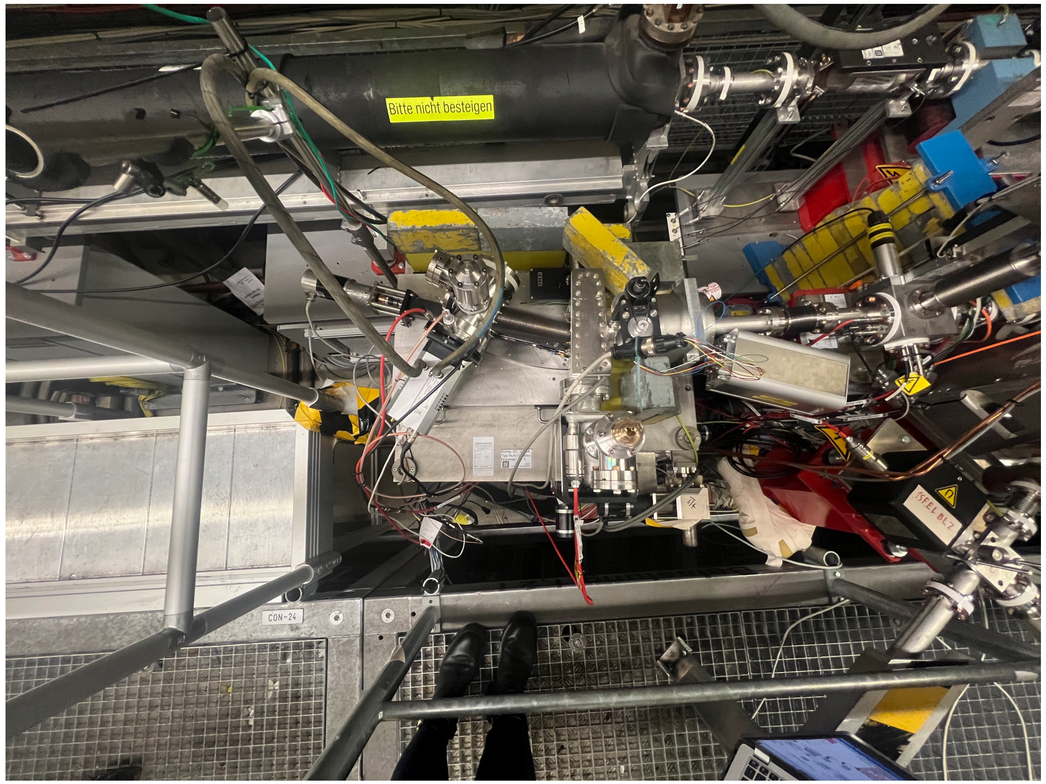


From E. Allaria et al. Spectrum From a Dispersion scan at FERMI



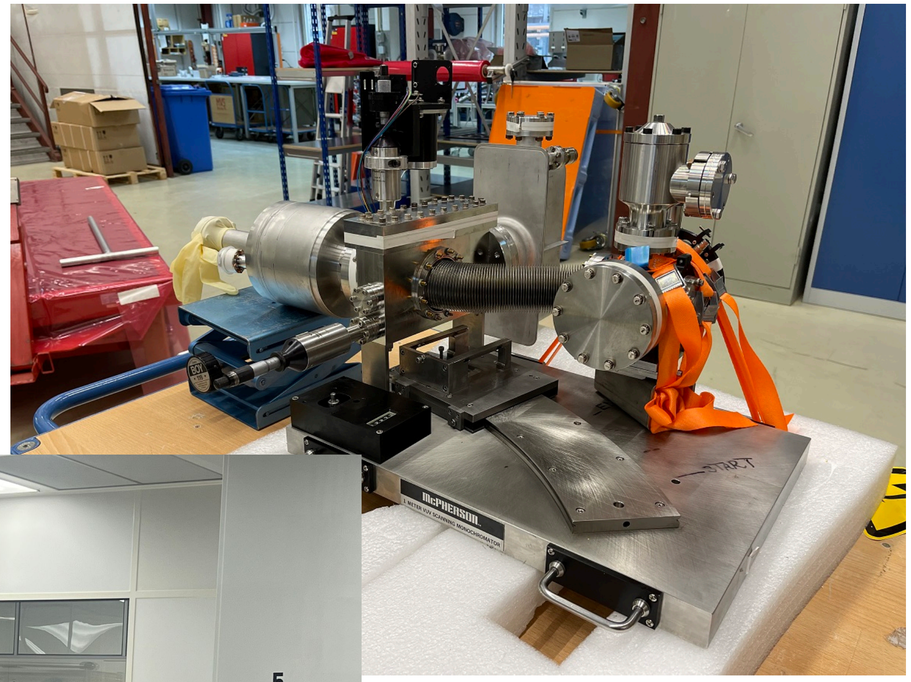
Spectrometer Repair both a challenge and worthwhile investment

- Clean room setup and beamline venting: 1-2 day(s)
- Repair work and testing: About a week
- Installation time: 2 days



Challenging in project mode, would be significantly more problematic in user operations mode

Repair of the spectrometer was possible help from many colleagues



Many thanks to colleagues
Antonio Wagner,
Silke Mogk,
Sven Ackerman
Karsten Harries,
Peter Toedten, Karsten Klose,
Giso Marquart, Dominic Lotter, and more

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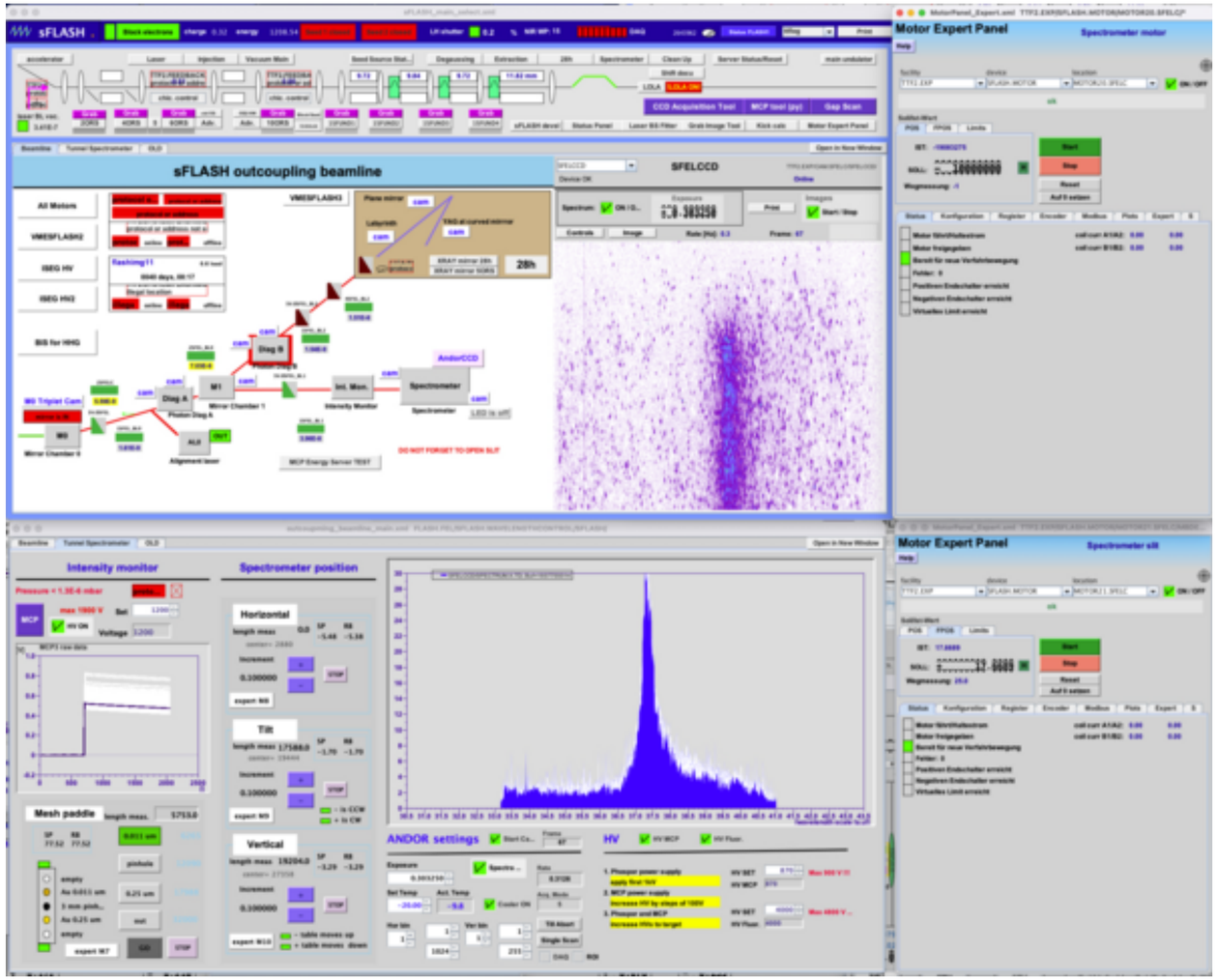
Installed and Tested: SASE (from Xseed undulators on spectrometer)



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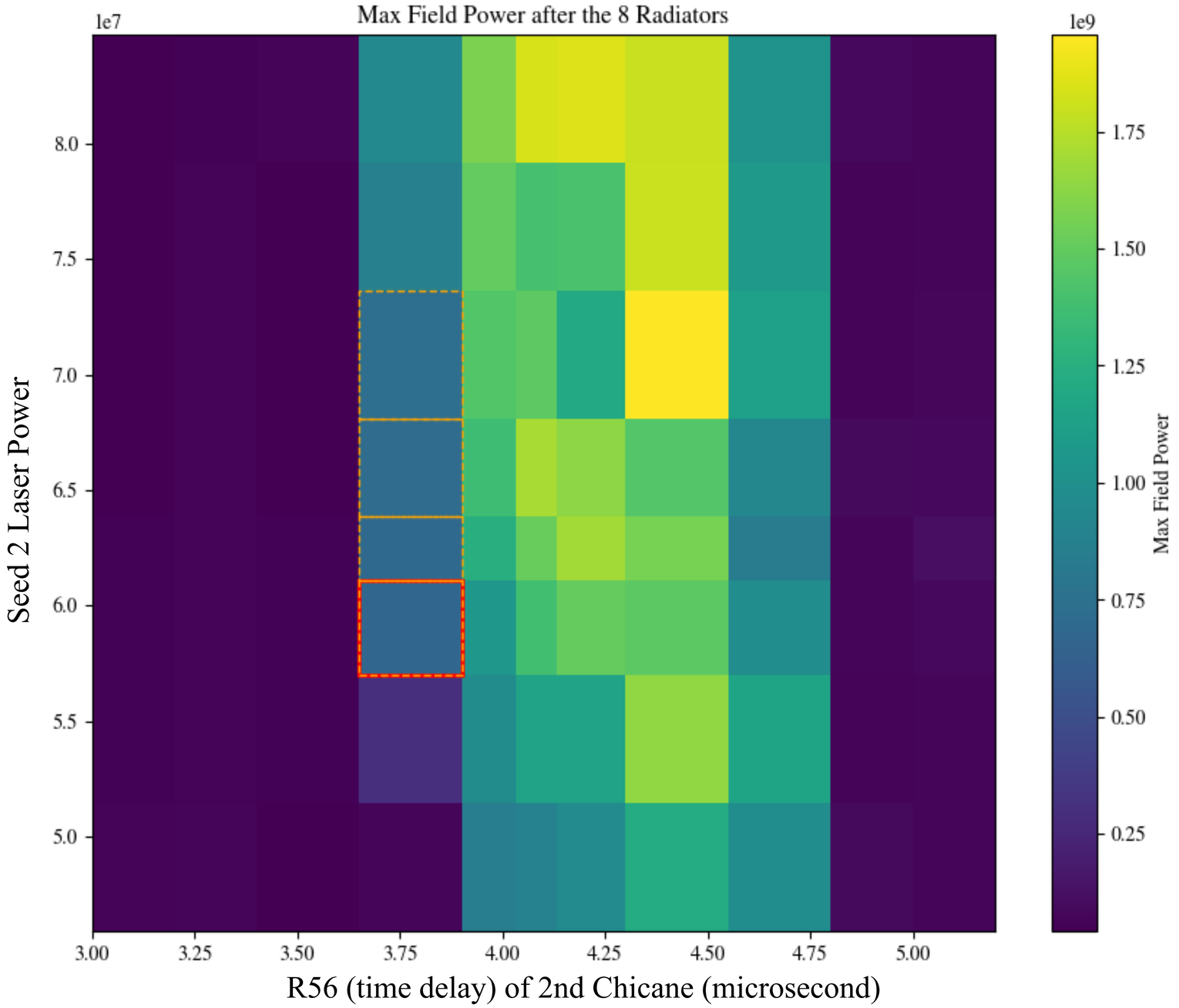
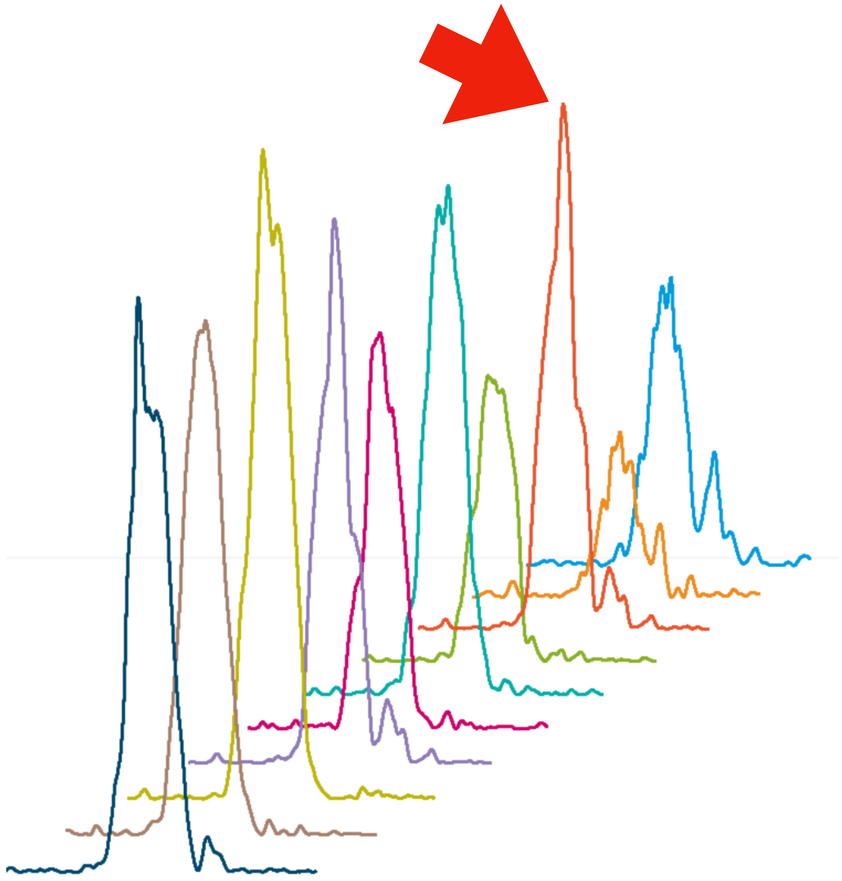
Simulation Studies are in good agreement with theory.

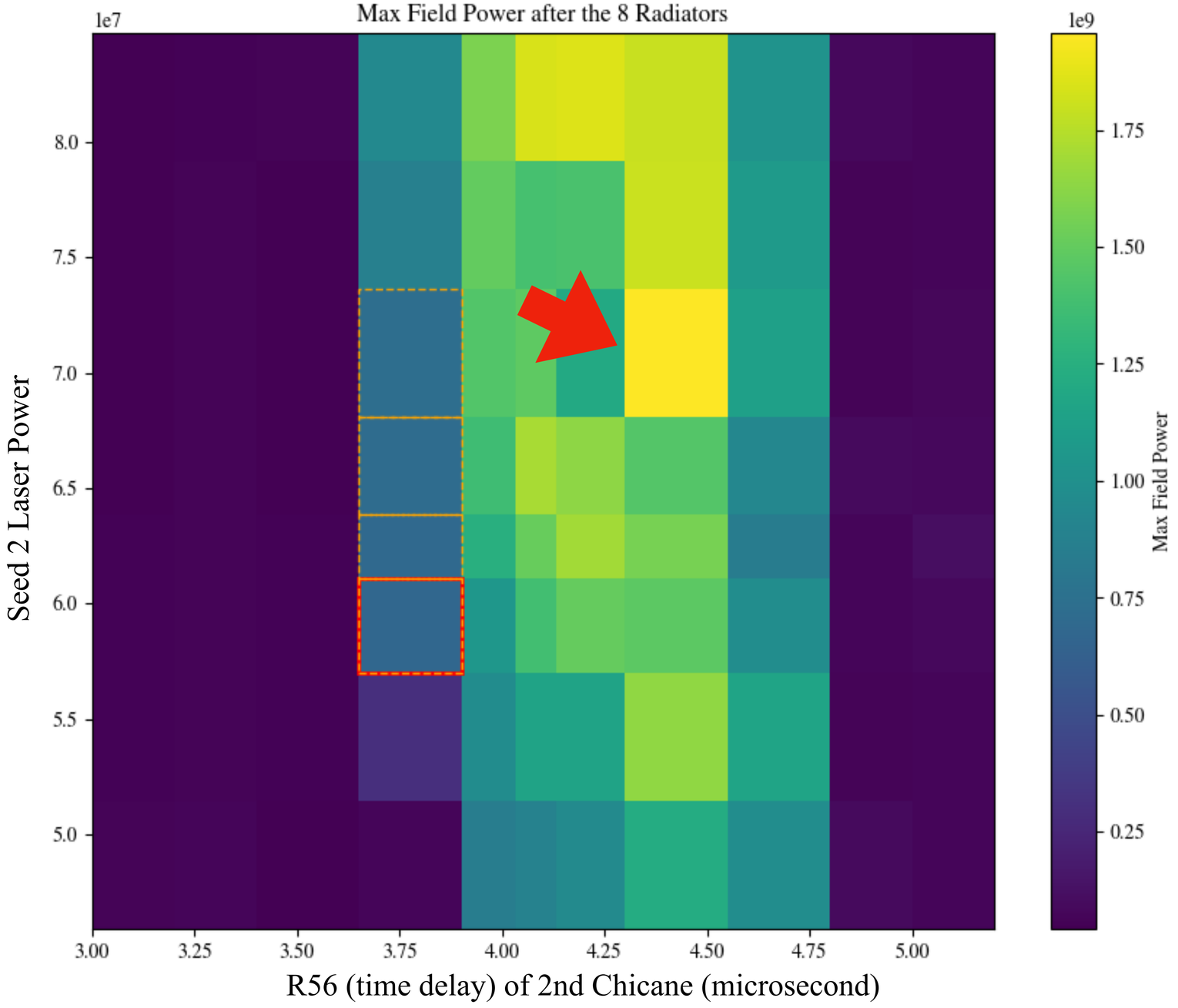
They have given us a good idea of how to optimize

Especially at high harmonics, the metric for optimization plays an important role.

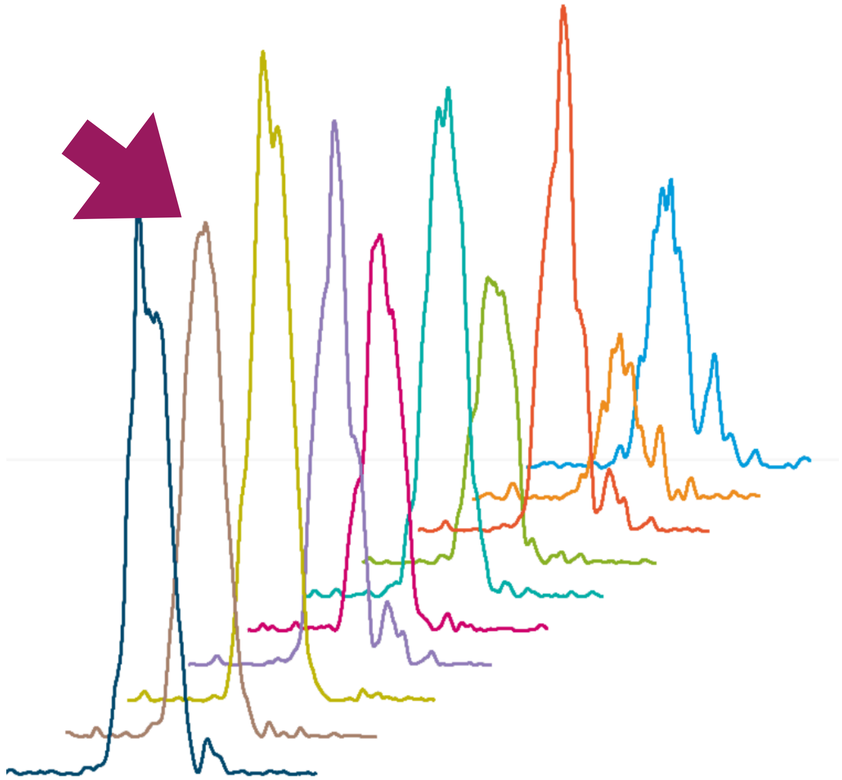


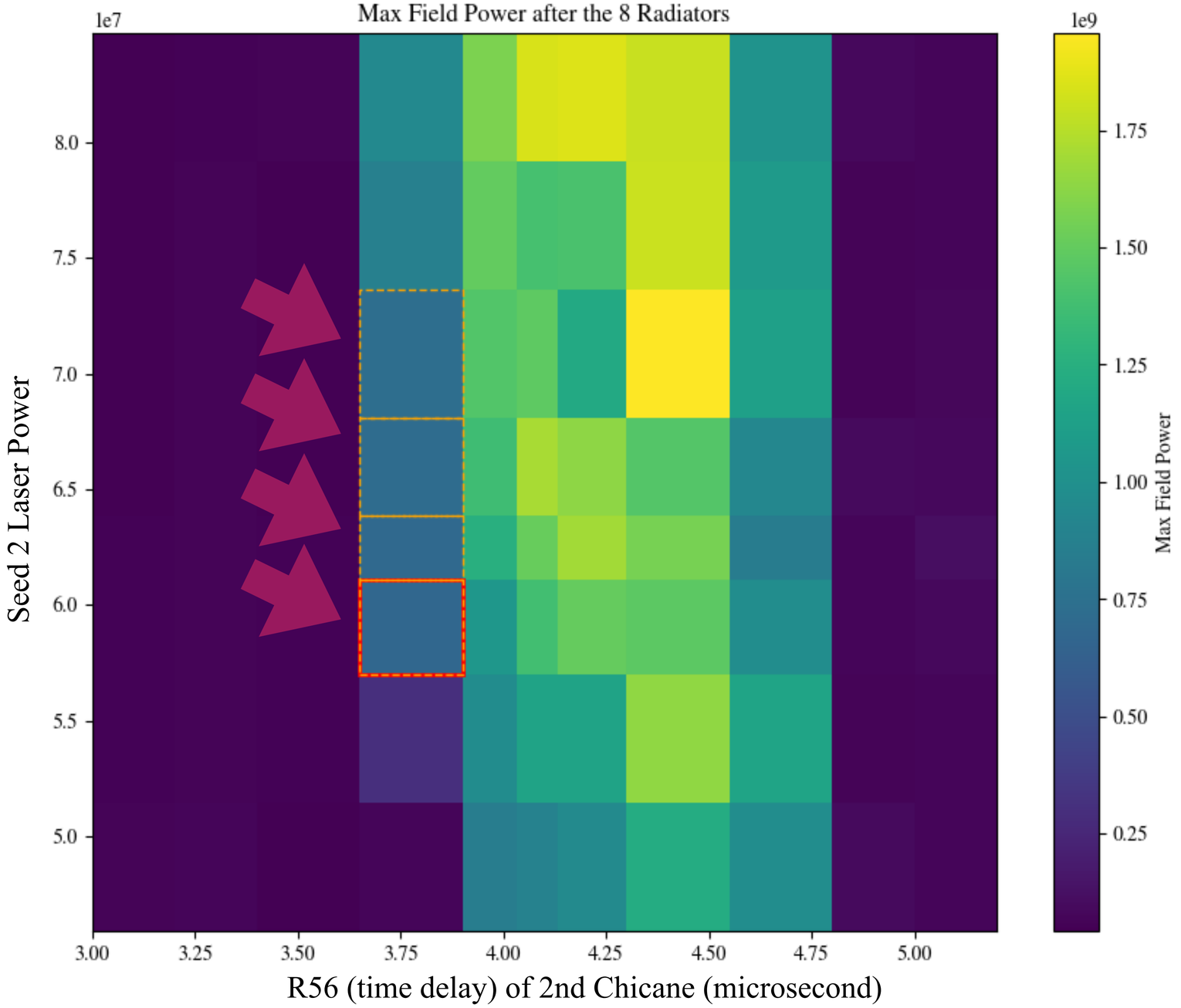
The highest power might not give the best EEHG spectrum.



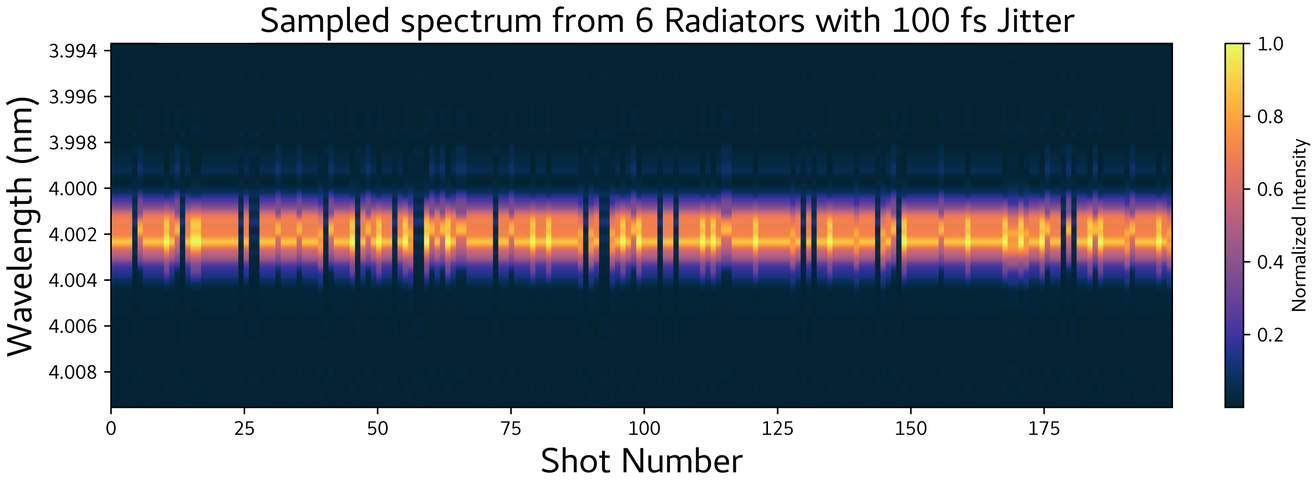


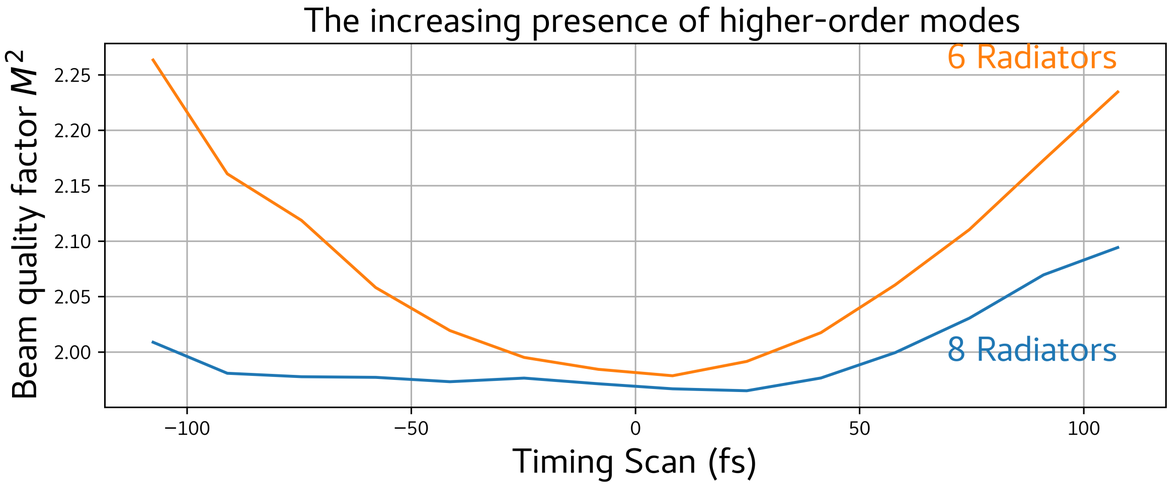
Reducing modulation in 2nd Modulator can significantly reduce high harmonics.

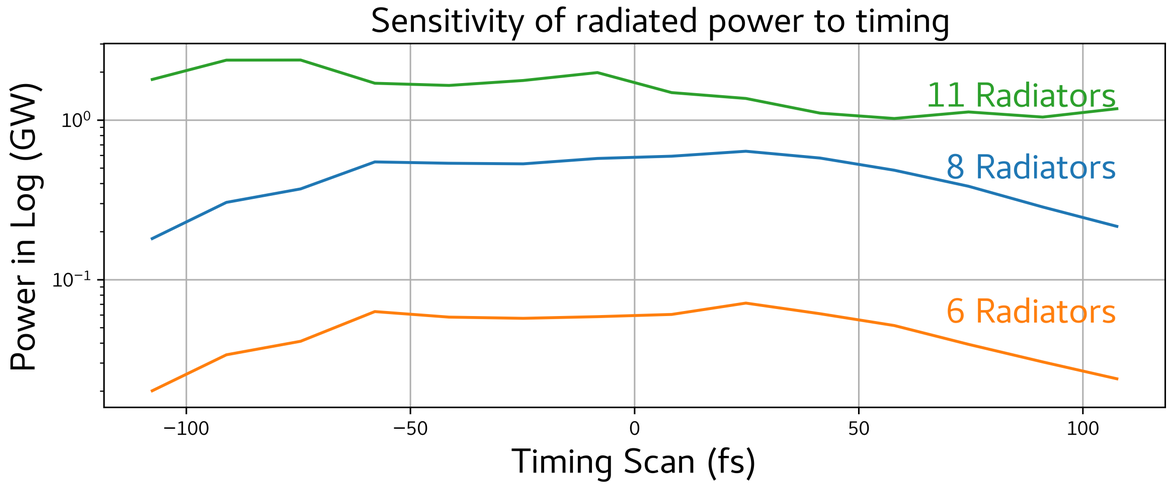


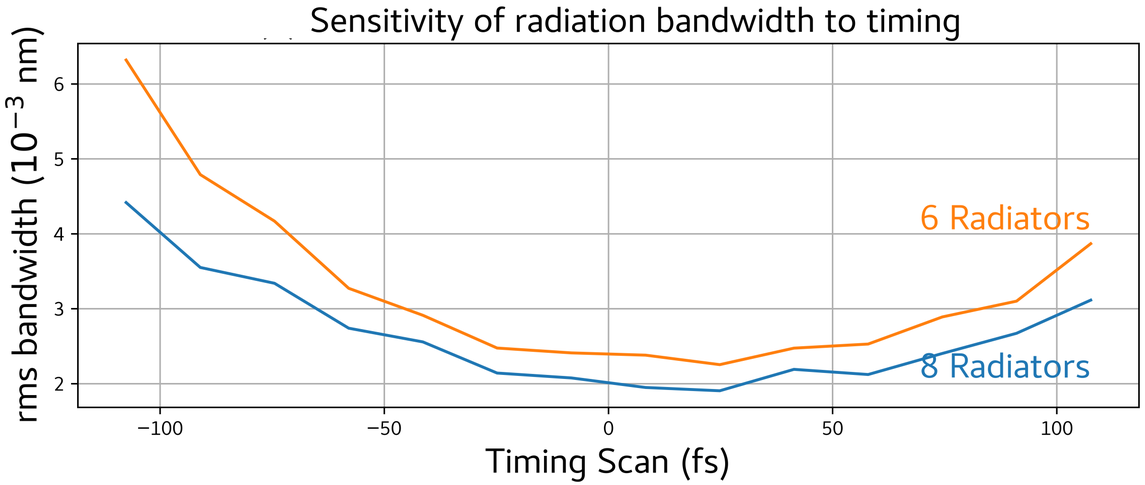


EEHG setup is robust around an optimized point









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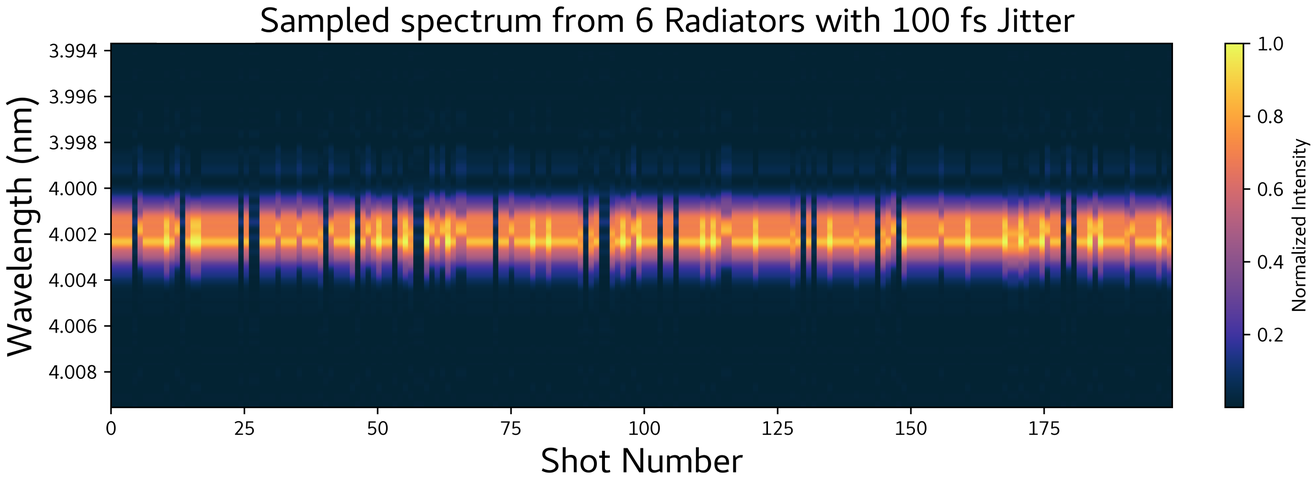
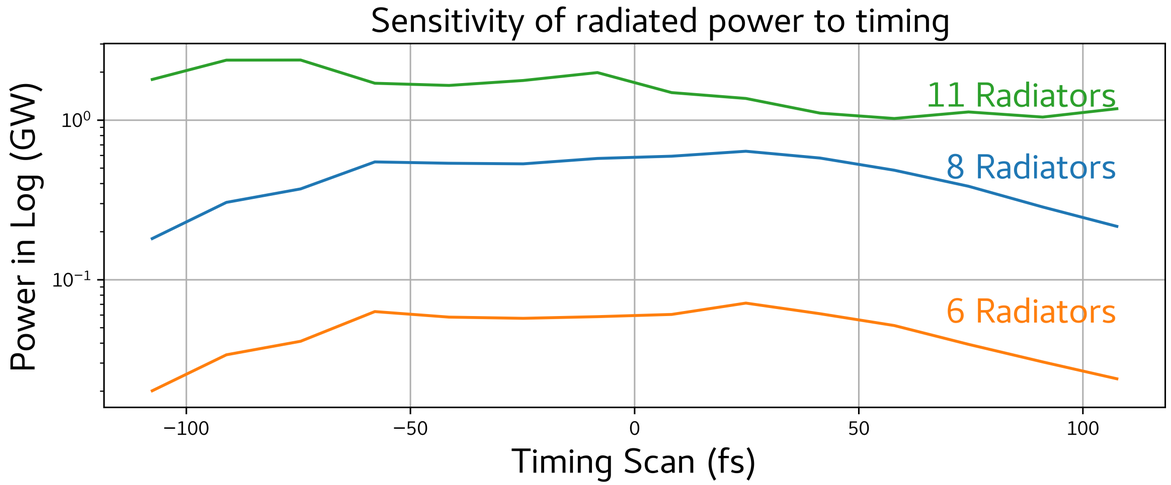
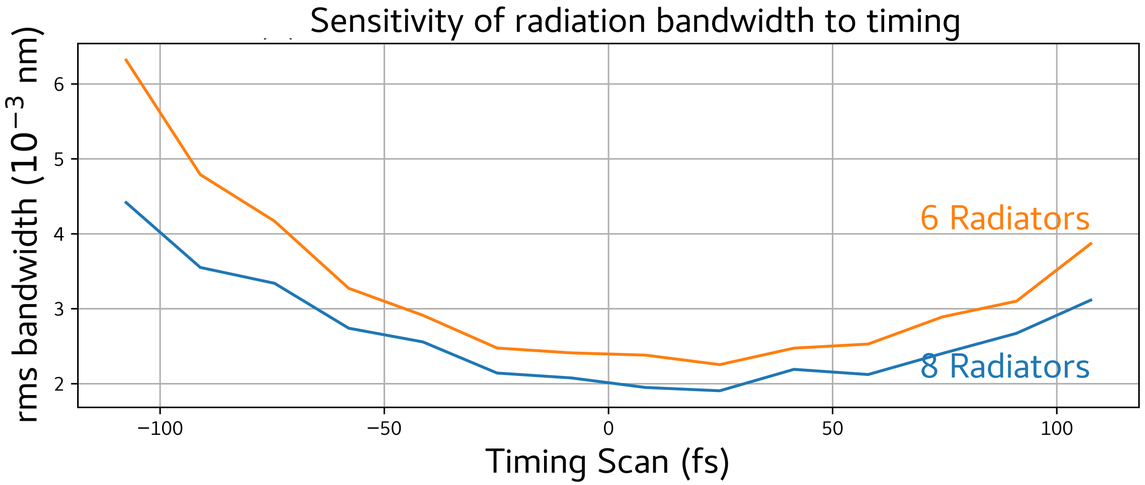


After optimization, bandwidth can tolerate ~40 fs in jitter, and Power can tolerate ~ 80 fs.

Reported laser jitter is 40fs





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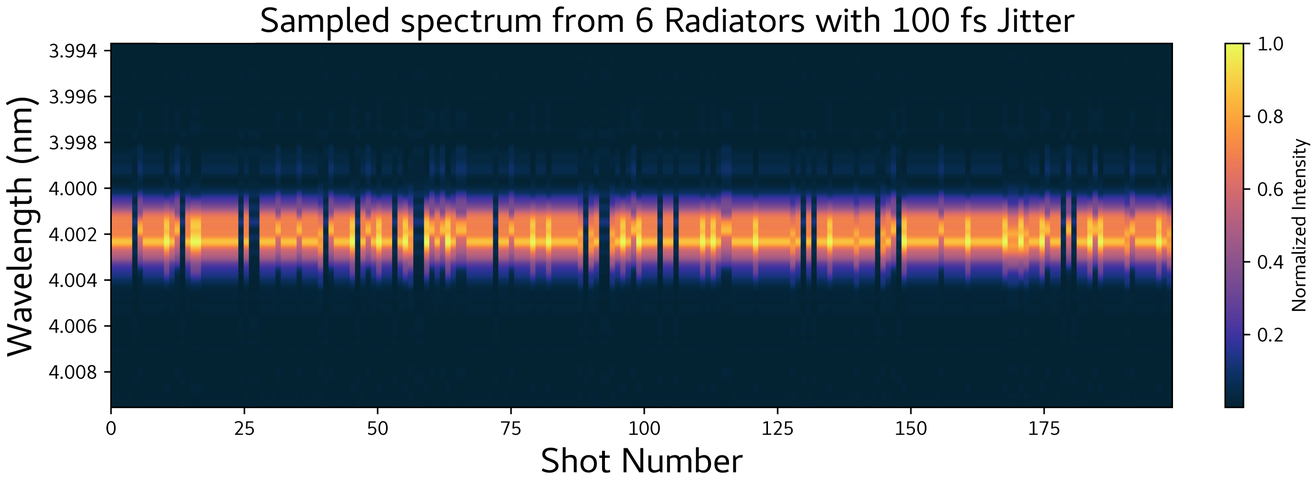

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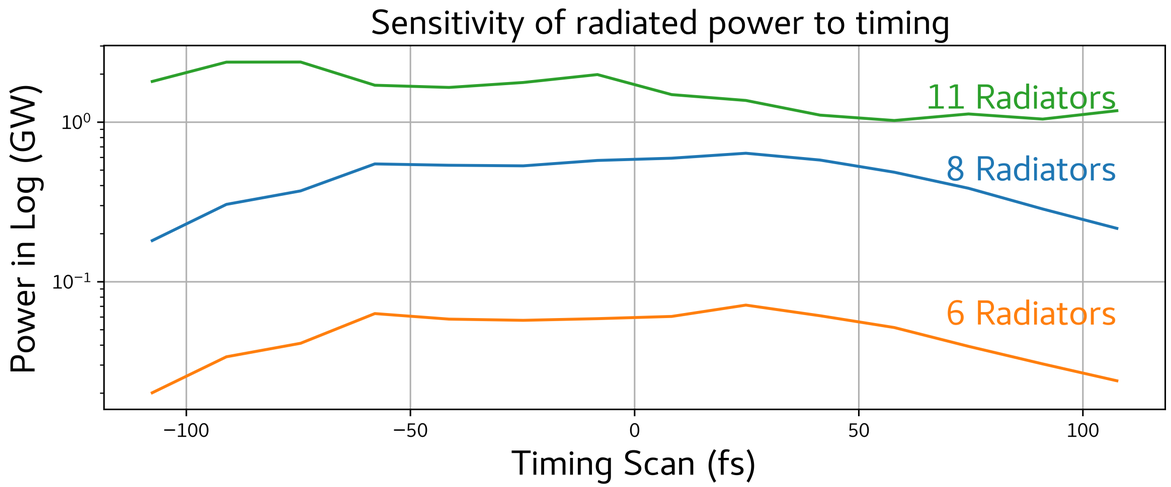

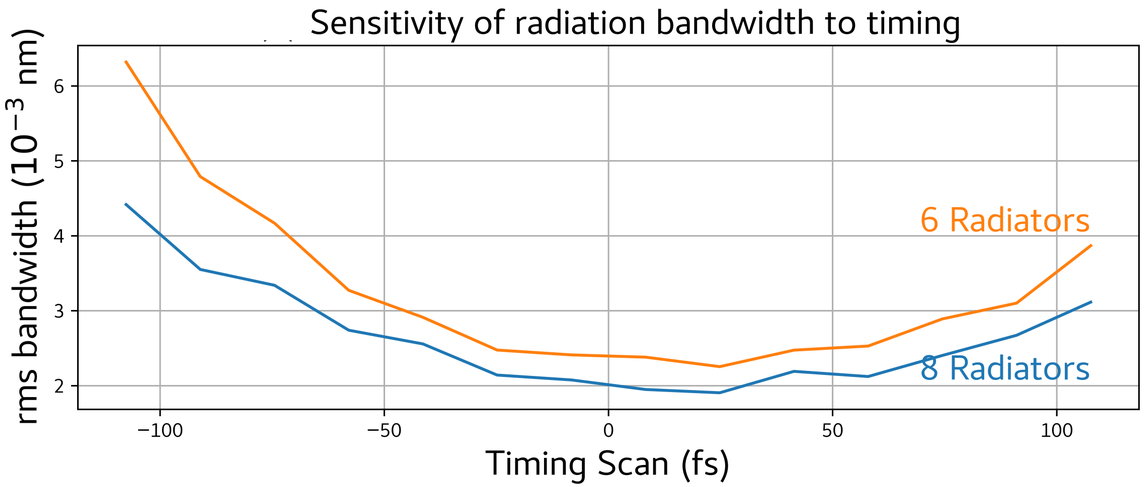

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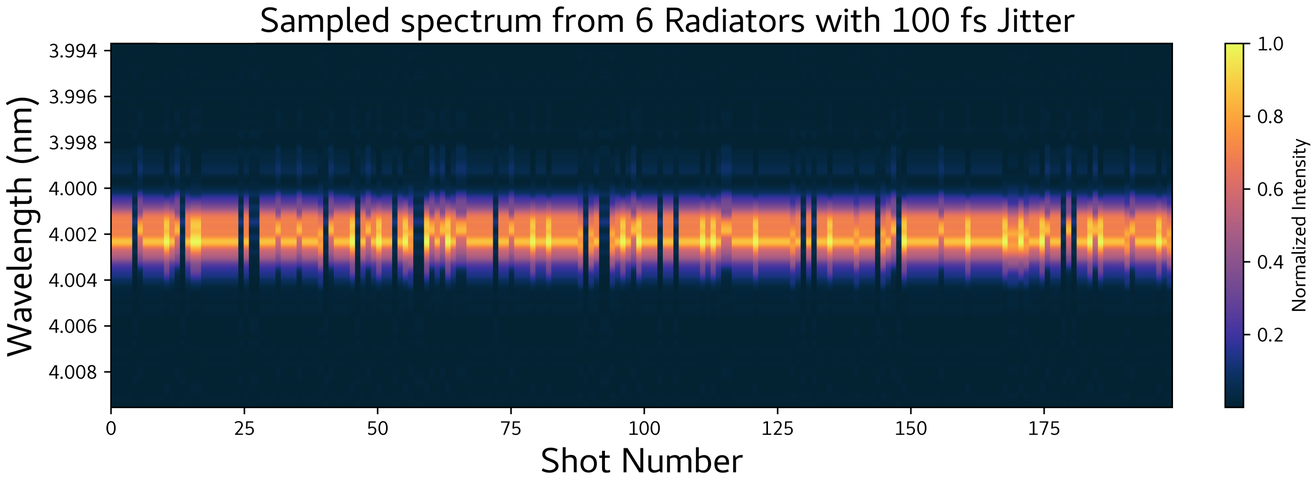

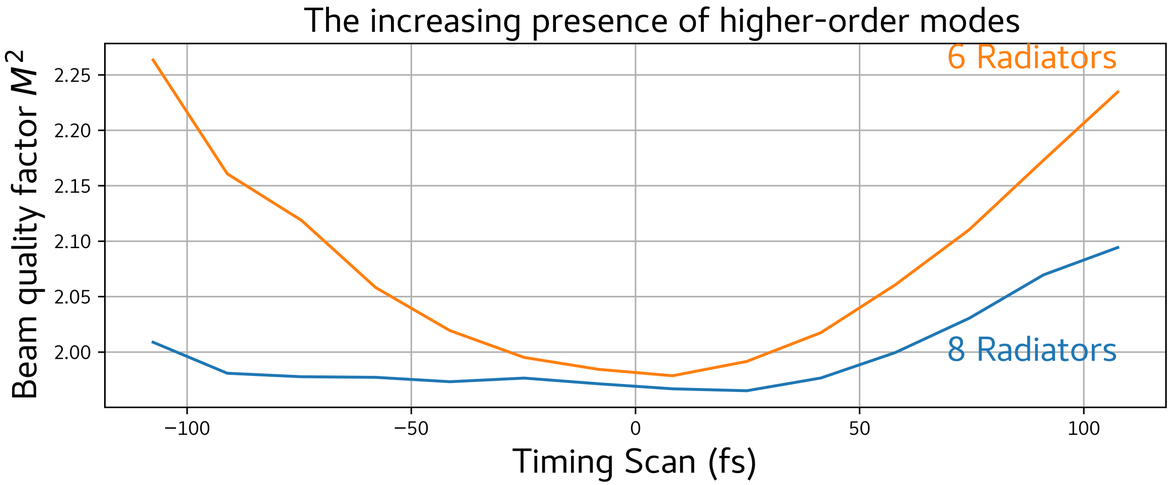

In the circularly polarized case, the beam quality factor remains ~2 for +/- 20fs

When we can afford more undulators, it will be even better.

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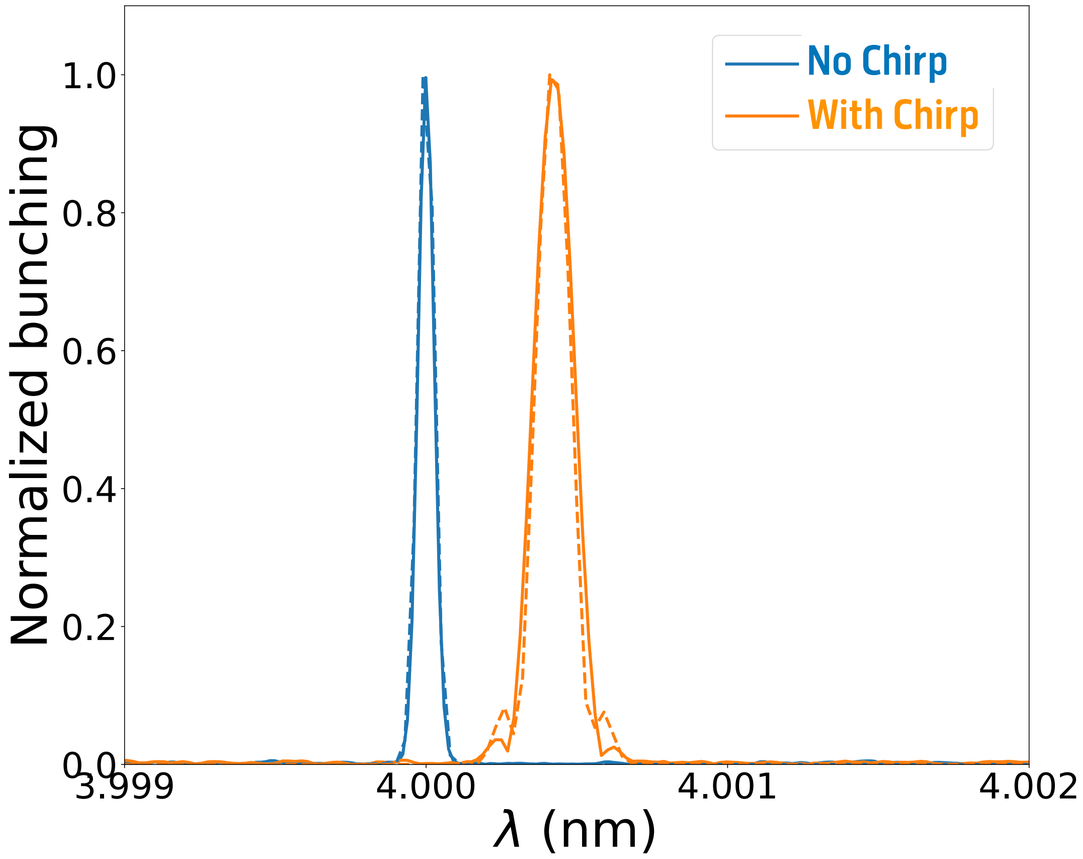
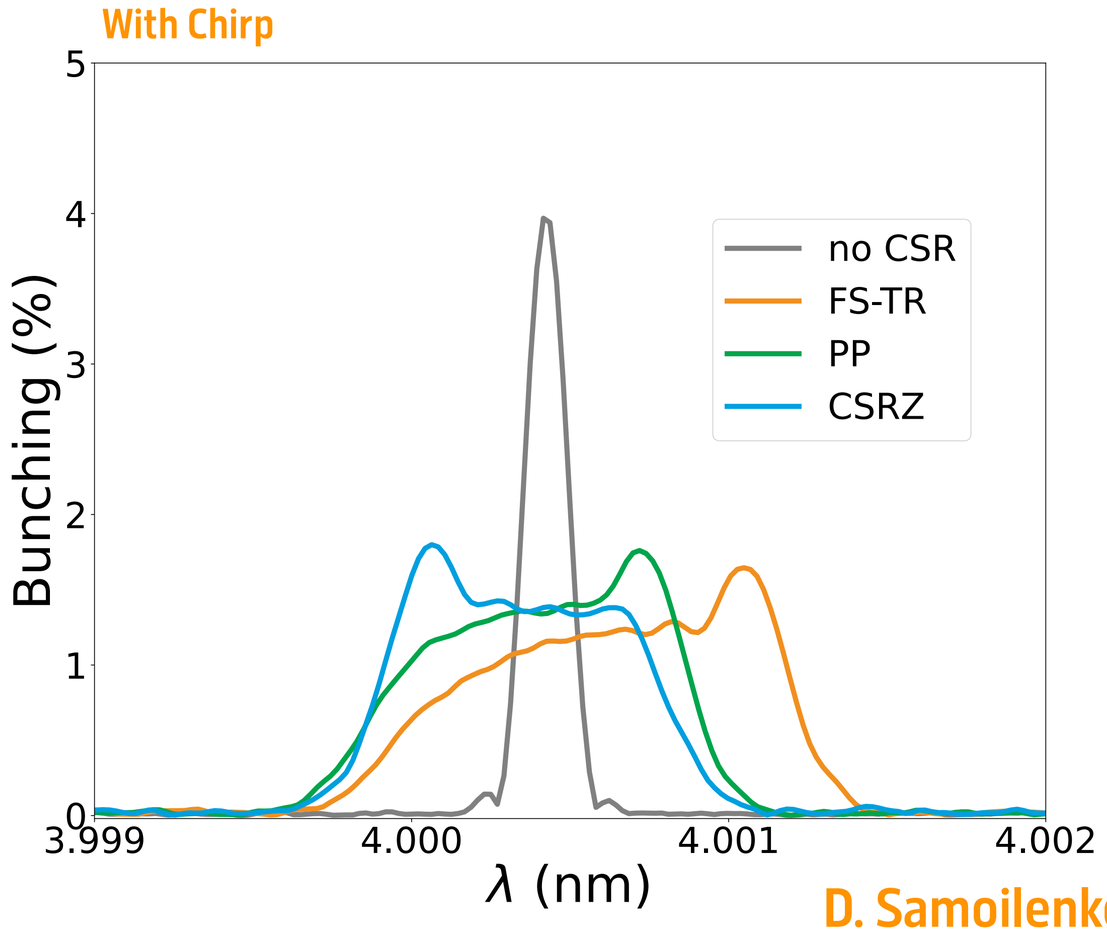
Studying Coherent Synchrotron Radiation Wakefields in the first seeding chicane give valuable insights for optimizing seeding.





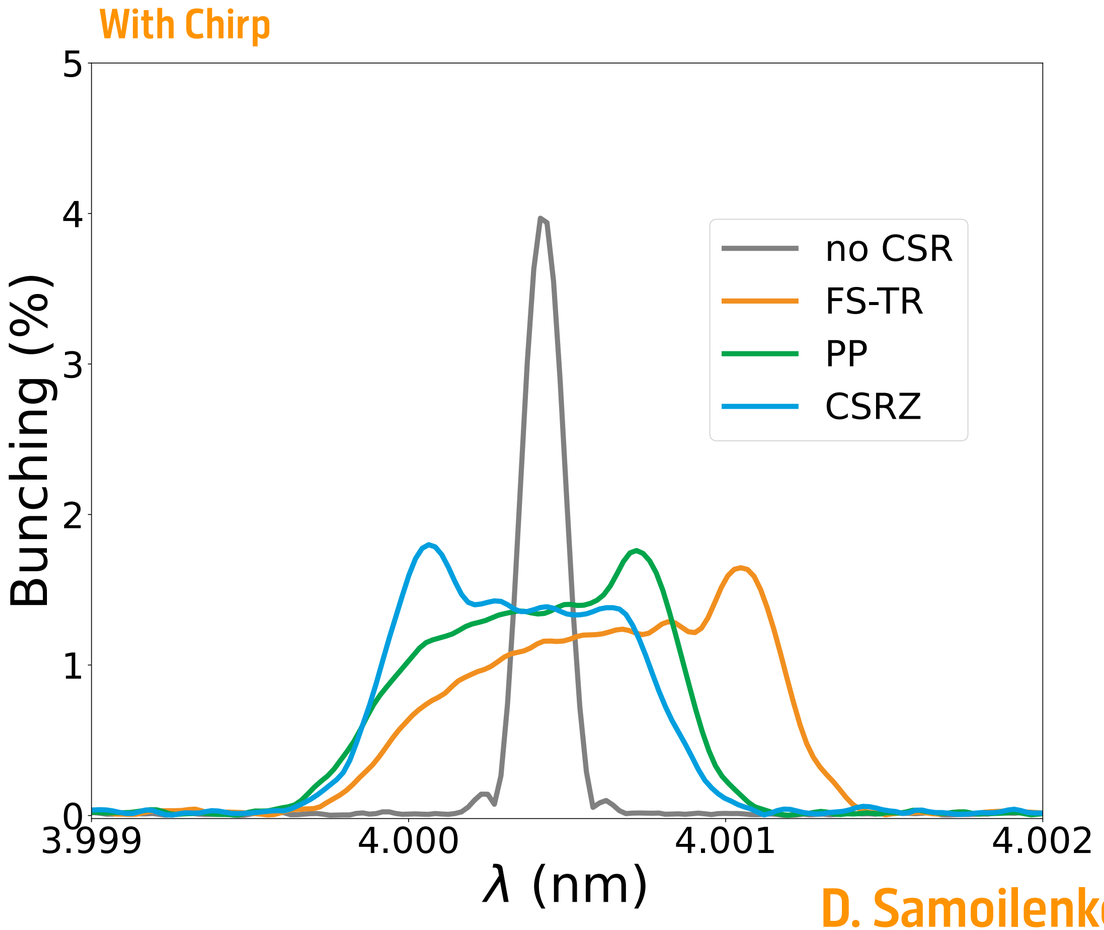
D. Samoilenko

Studying Coherent Synchrotron Radiation Wakefields in the first seeding chicane give valuable insights for optimizing seeding.

Included CSR models with transient and shielding effects

With chirp and no chirp

With different numbers of particles (macro particle weight)



D. Samoilenko

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Recap of Meetings and Workshops

✱ **Users meeting**

- **Machine People to Photon People:**
  - **The ideal first experiment does not rely heavily on wavelength scan**

- **Photon People to Machine People:**
  - **3rd harmonic of 4nm is appealing for several studies**

☑ **Optimizing tapering archives 1% 3rd harmonic**

✱ **Simulation and Software development and workshop**
- **Our software and simulation tools can support us well**
- **Discussion and collaboration with FERMI, INFN, Pulsar, Lund University, …**

Summary FLASH2020+ Seeding Progress:

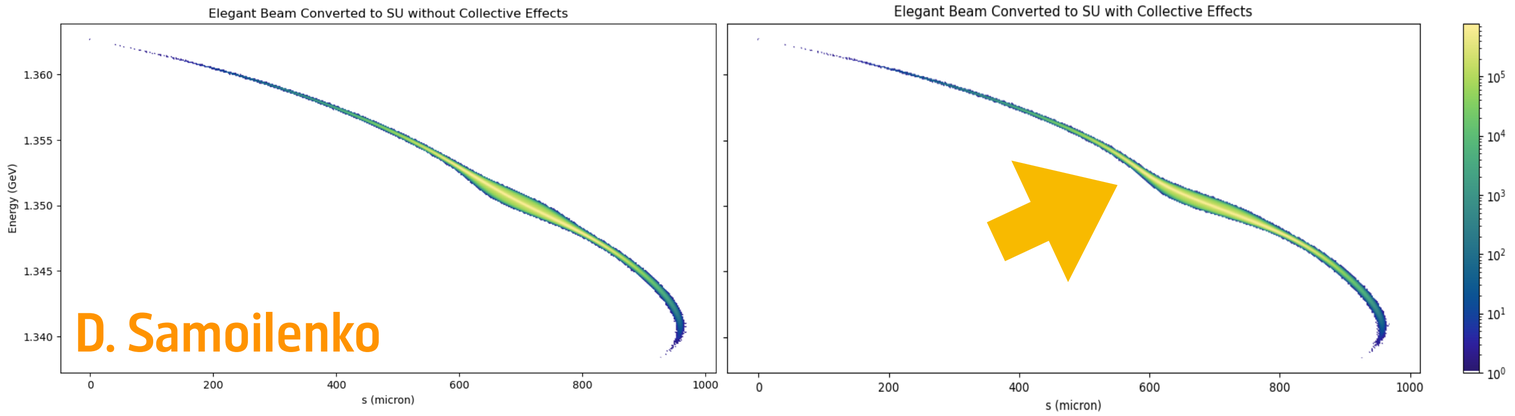
Summary and Future Plans

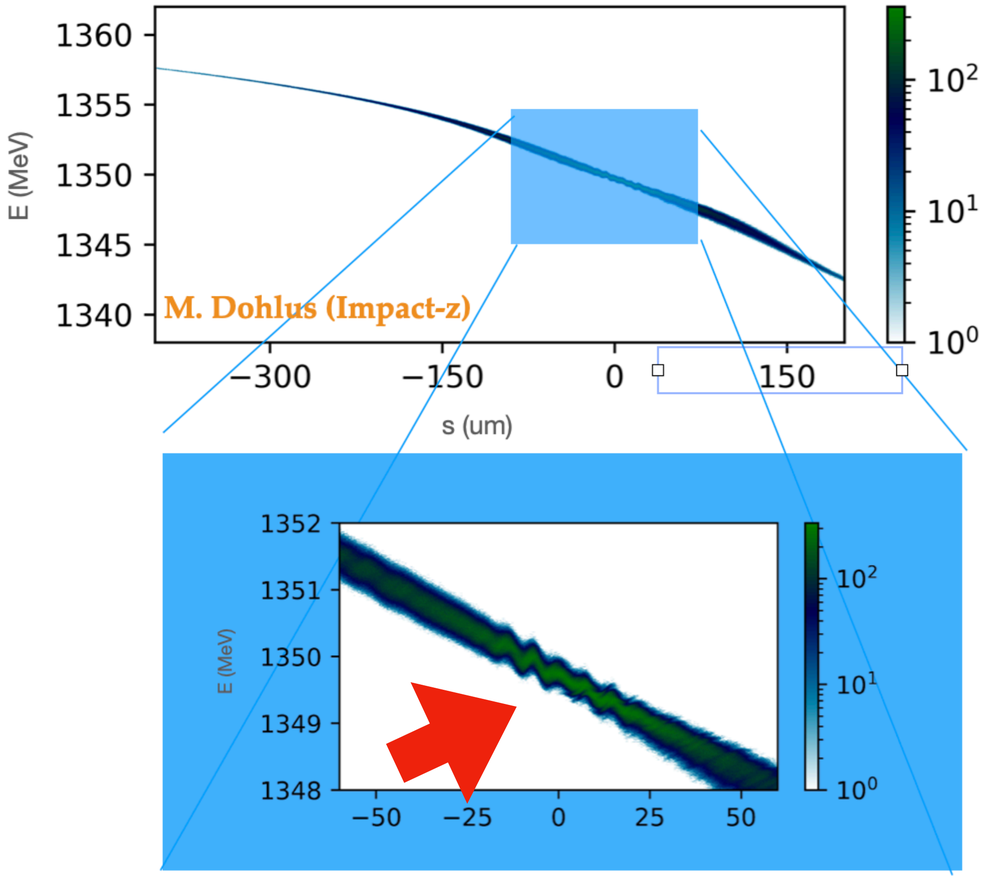
- Addressed seeding challenges effectively through simulations, experiments, or both.
- We are applying new insights strategically post-upgrade.
- Despite the complexity, successful implementation is achievable.
- We are planning the first user experiment for FLASH2020+ to ensure a productive and exciting initial operation phase.

BaCk Up SlIdeS

Sophisticated manipulation of beam dynamics renders the setup more susceptible to instabilities.

What kind of instabilities have we considered?



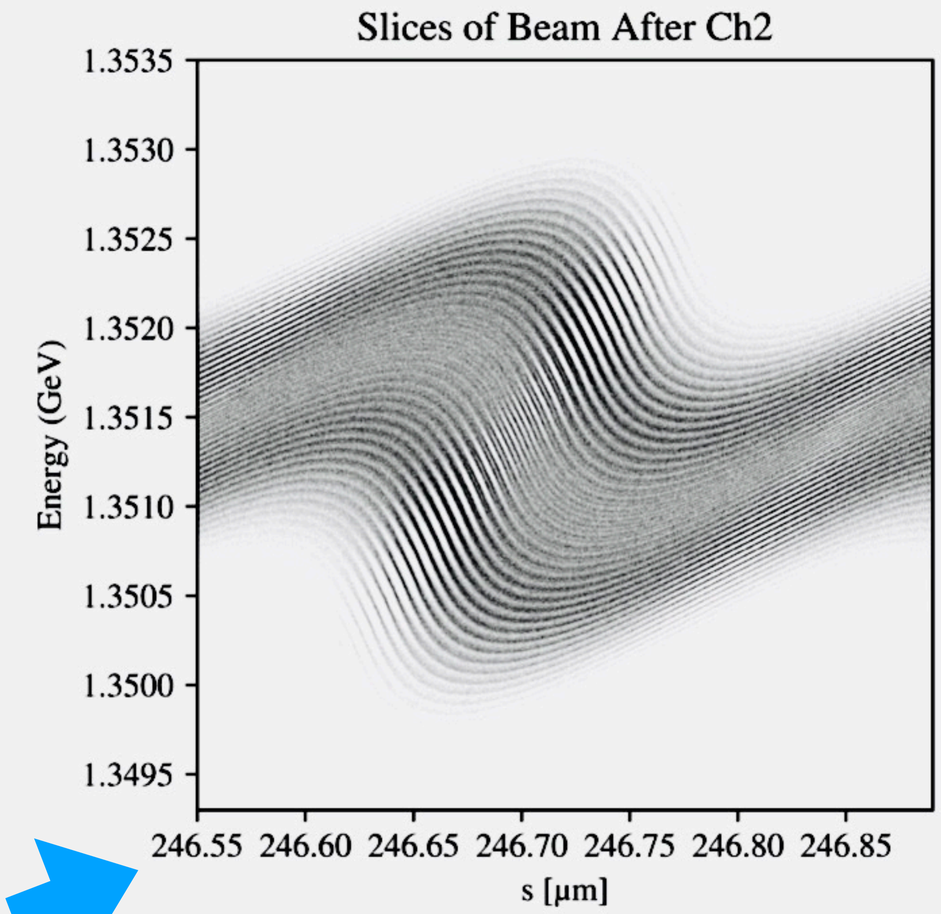


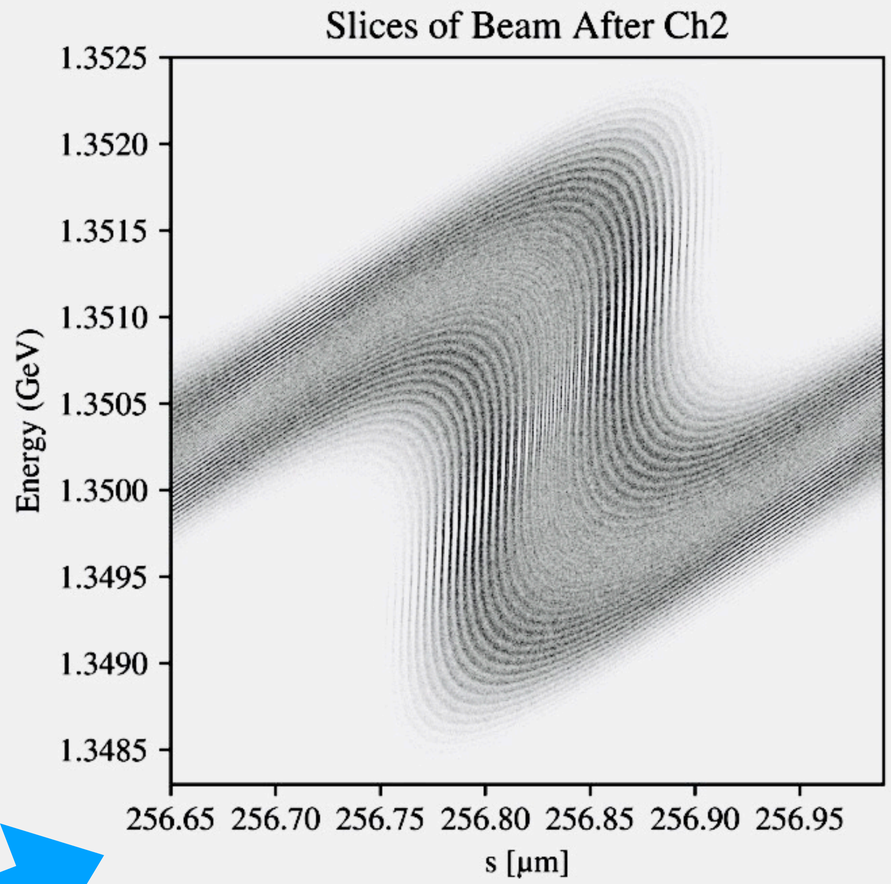
Large Oscillations in the beam profile with a period of 50 microns

Small oscillations with period of a few microns

What does 40 fs of jitter look like in the phase space?

Chirp-induced Energy Spread

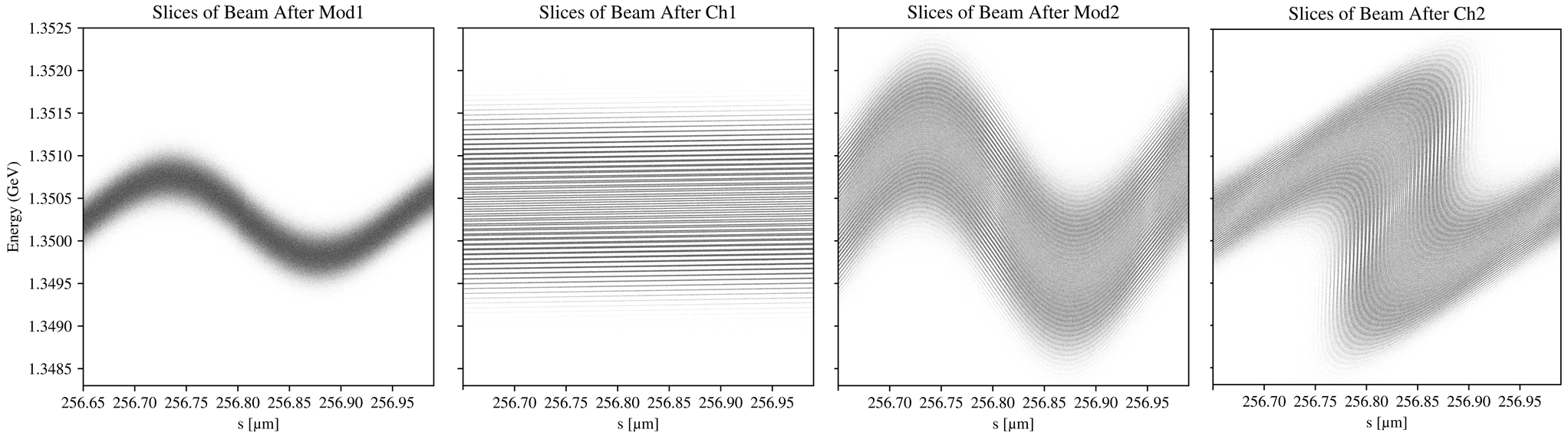




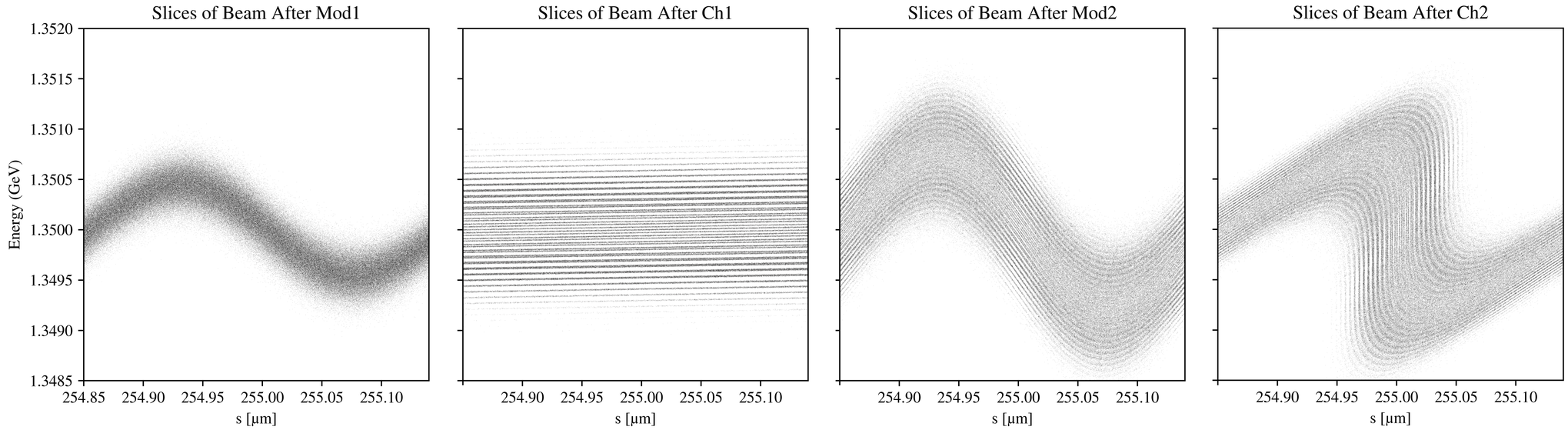
A shift of 10 microns ~ 30 fs

What are the main consequences of chirp?

Chirp



No chirp



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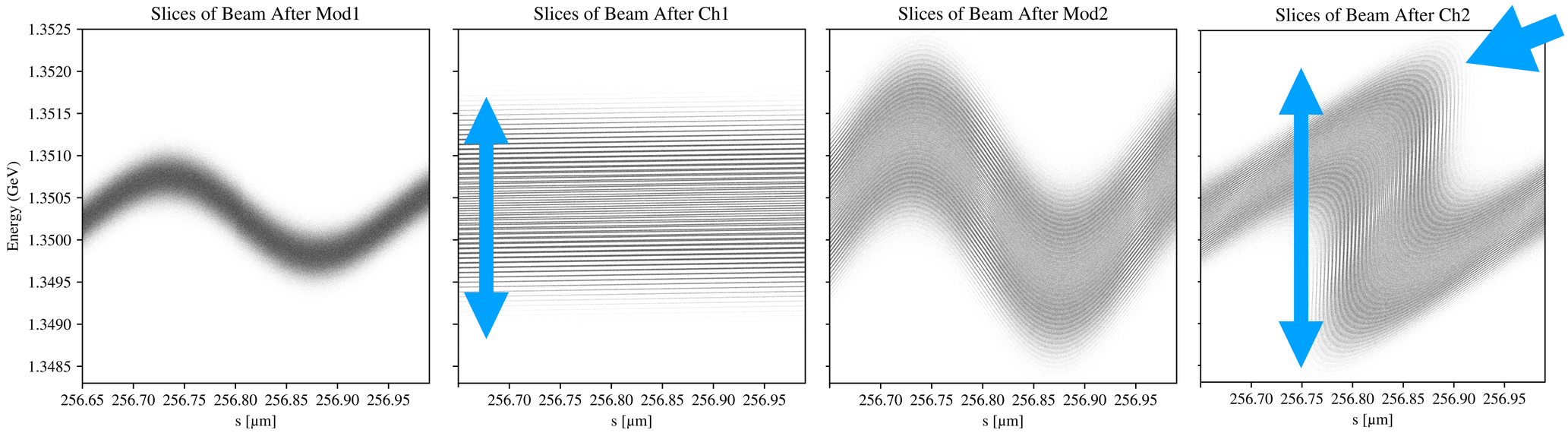

No chirp