EEHG at FLASH 2012 and beyond

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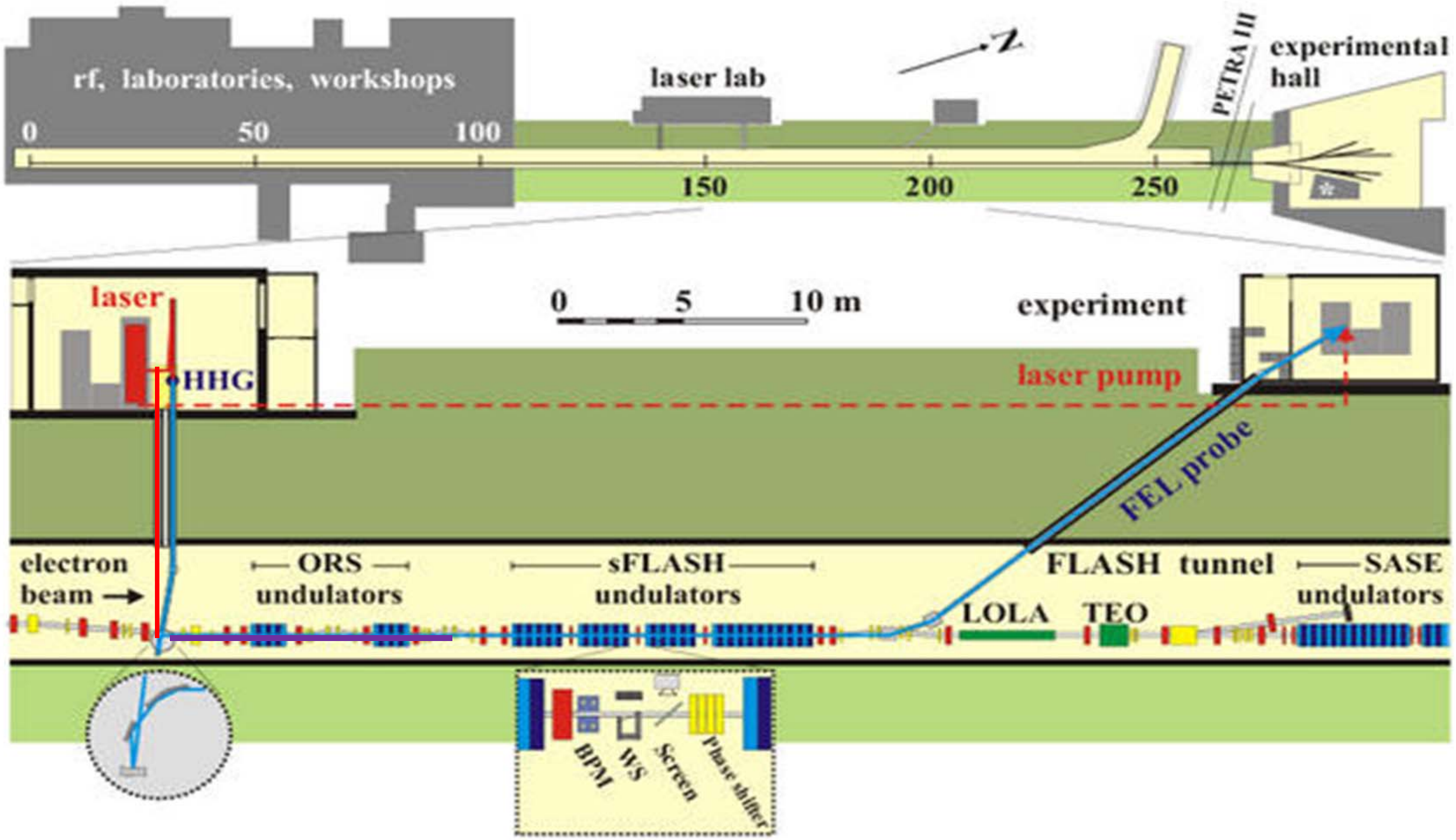
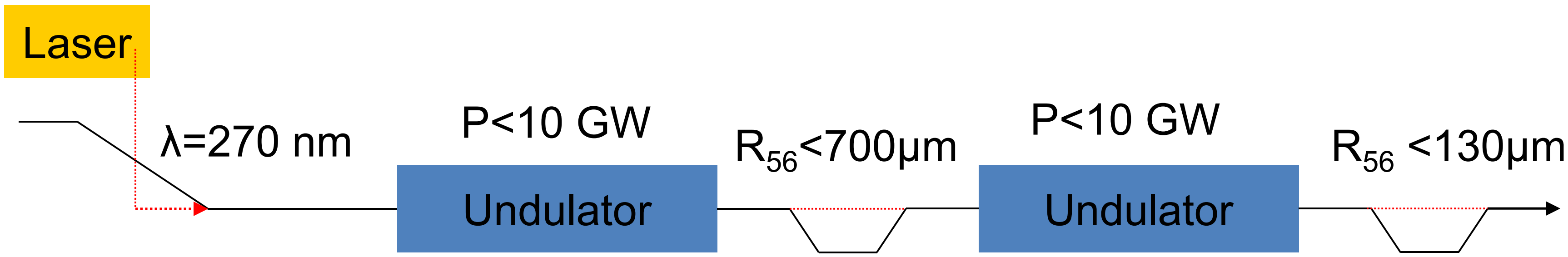
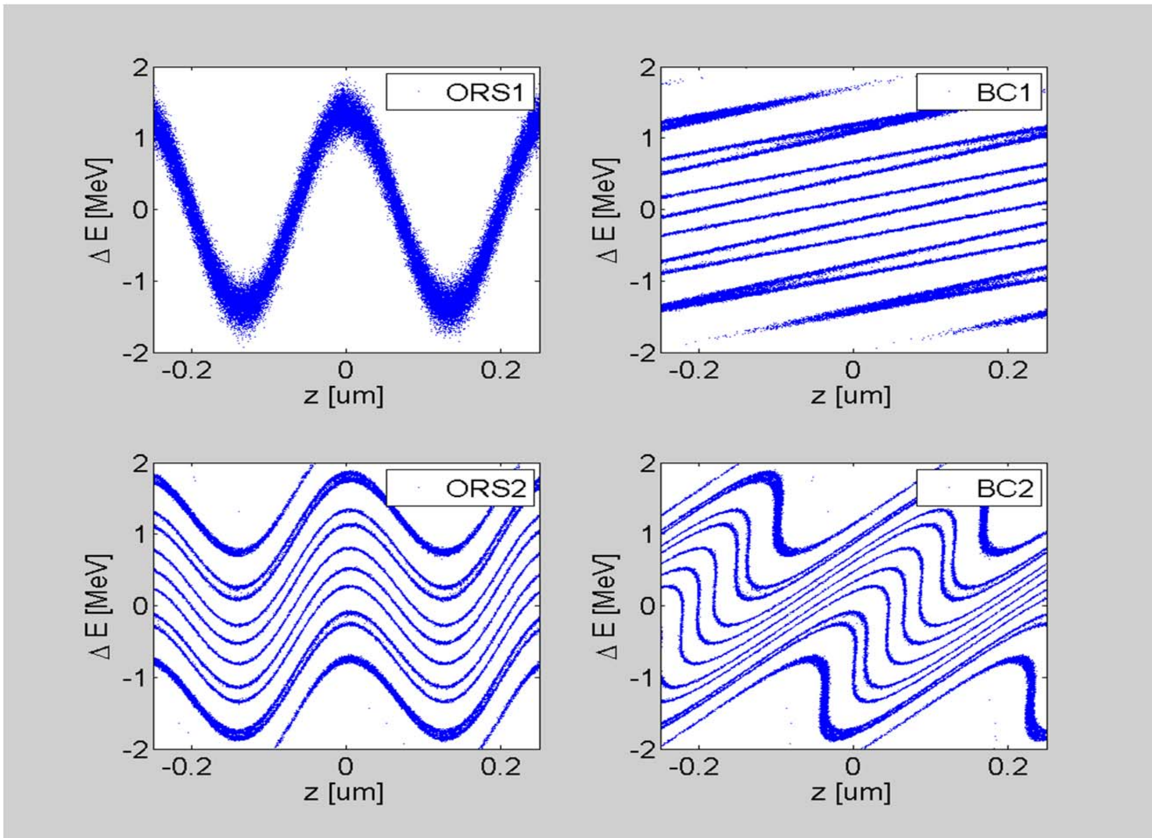
ORS and sFLASH



- sFLASH EEHG 14 nm
- SASE HGHG 4.7 nm
- sFLASH HGHG 38.5 nm simple commissioning

Echo-seeding





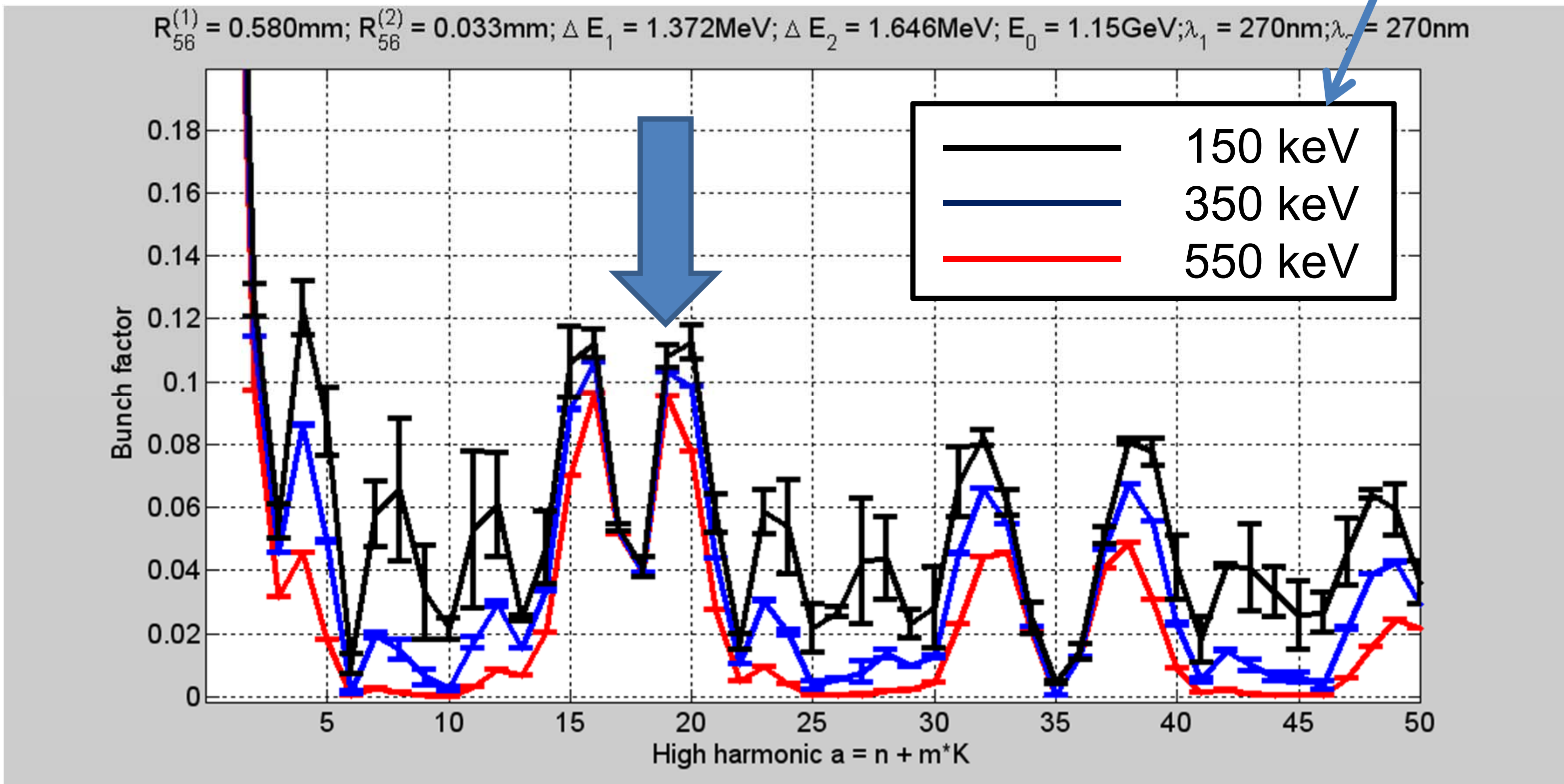
$\Delta E/E < 4*10^{-3}$

EEHG at 14 nm

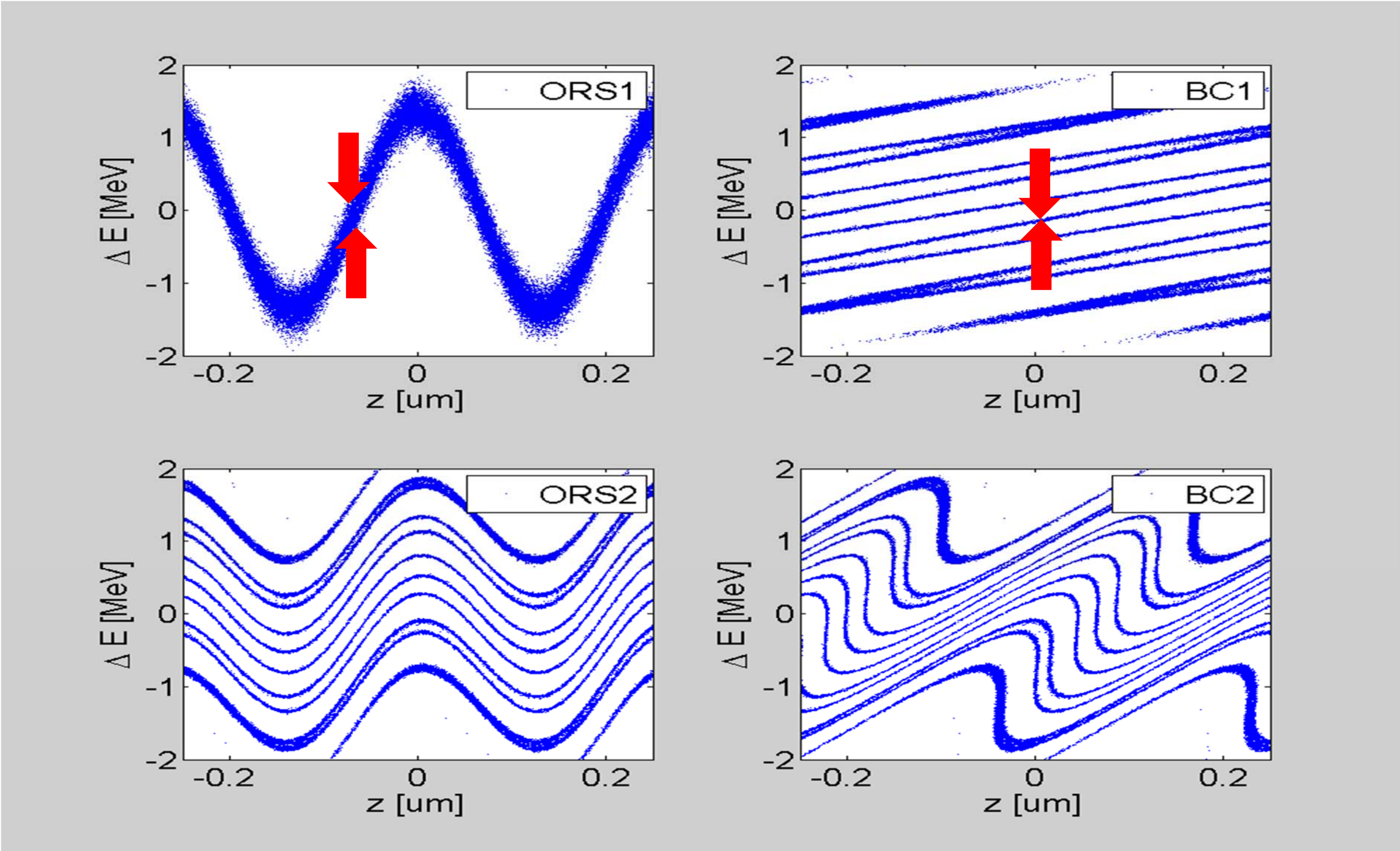
Larger laser power => larger energy spread

Lower uncorrelated energy spread sensitivity
Lower energy fluctuation sensitivity

Uncorrelated energy spread

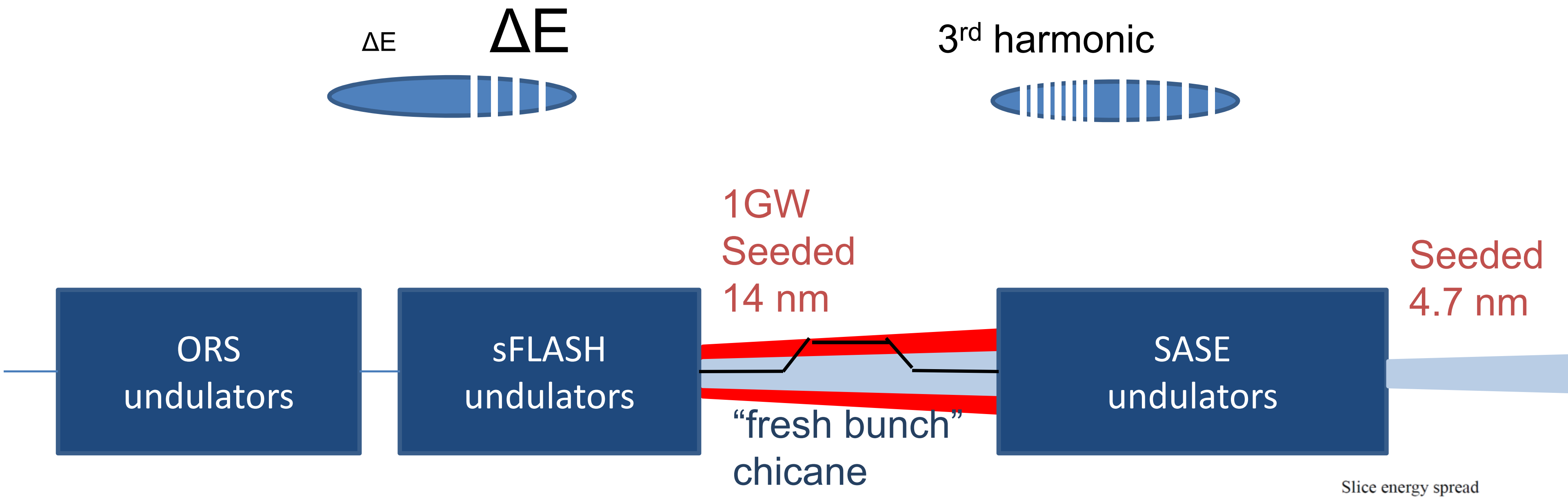


Liouville => effective cooling

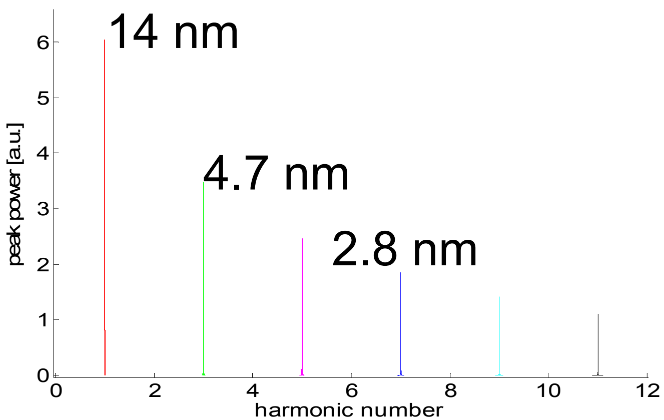


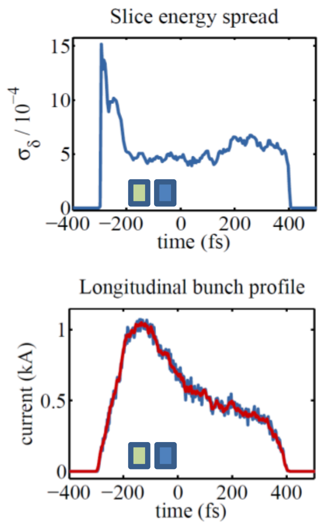
Advantage of EEHG over HGHG

Final Destination: EEHG + HGHG

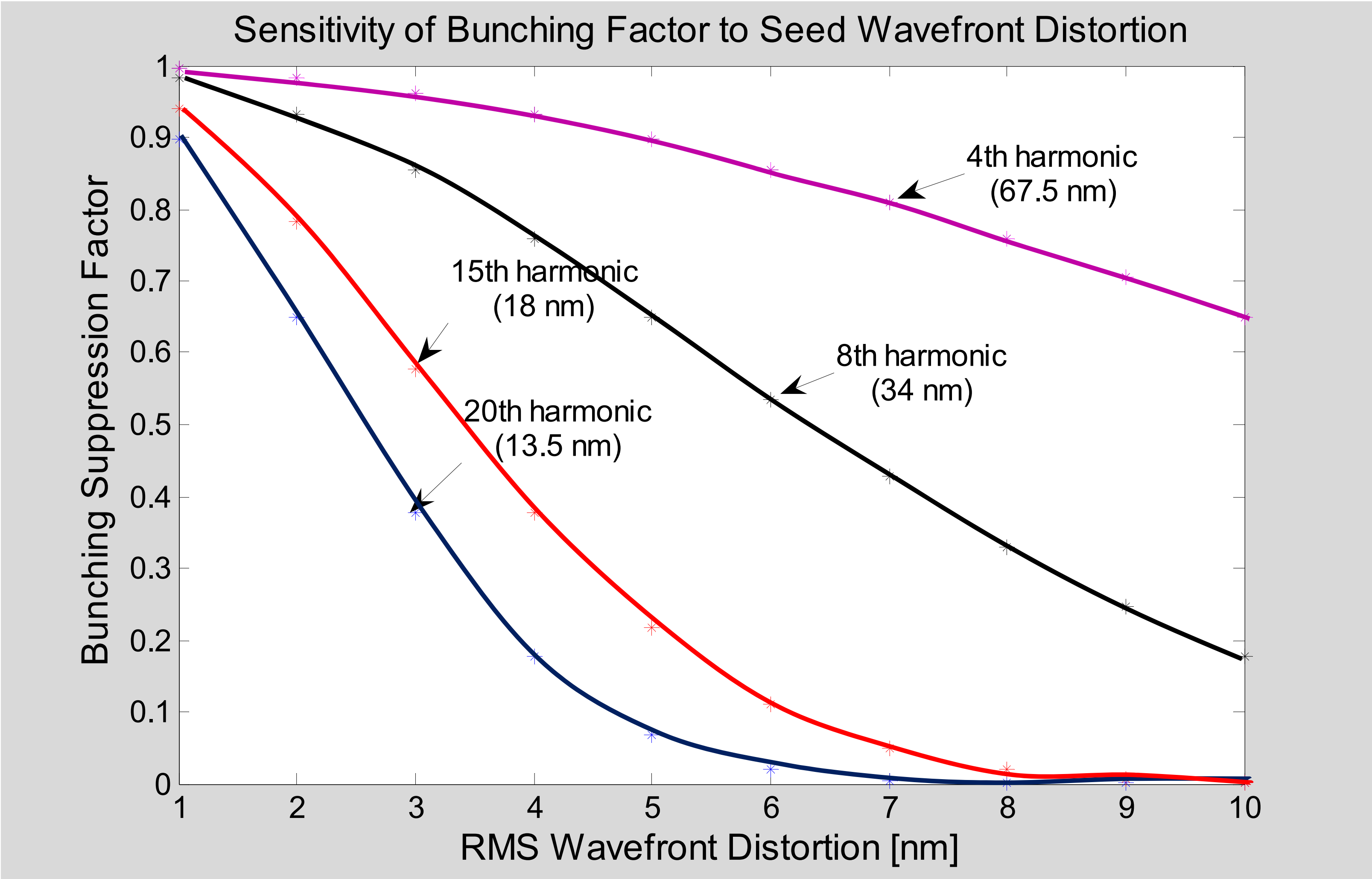


Fresh bunch technique
OR
Super-radiant regime





Wavefront distortions: biggest problem for higher harmonics

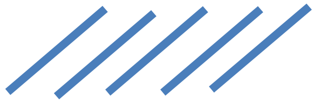
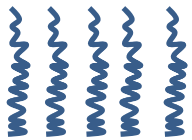


HGHG and laser wavefront

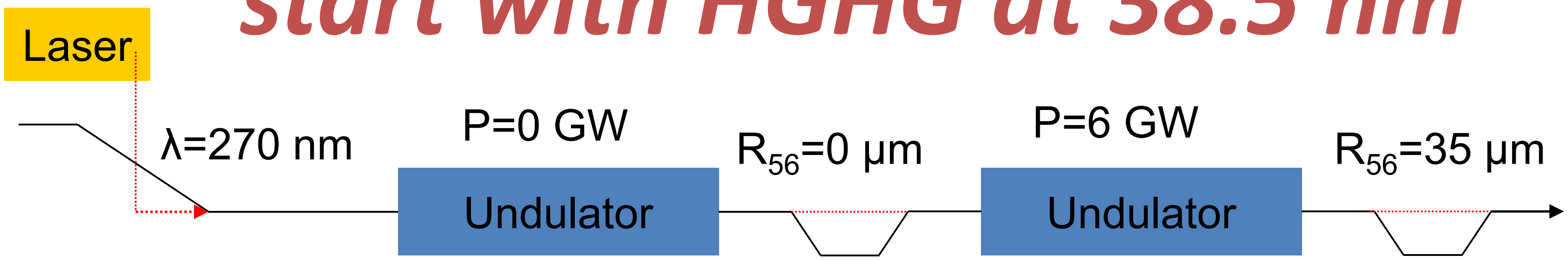
- By reaching saturation in sFLASH undulators, the wavefront is **cleaned**

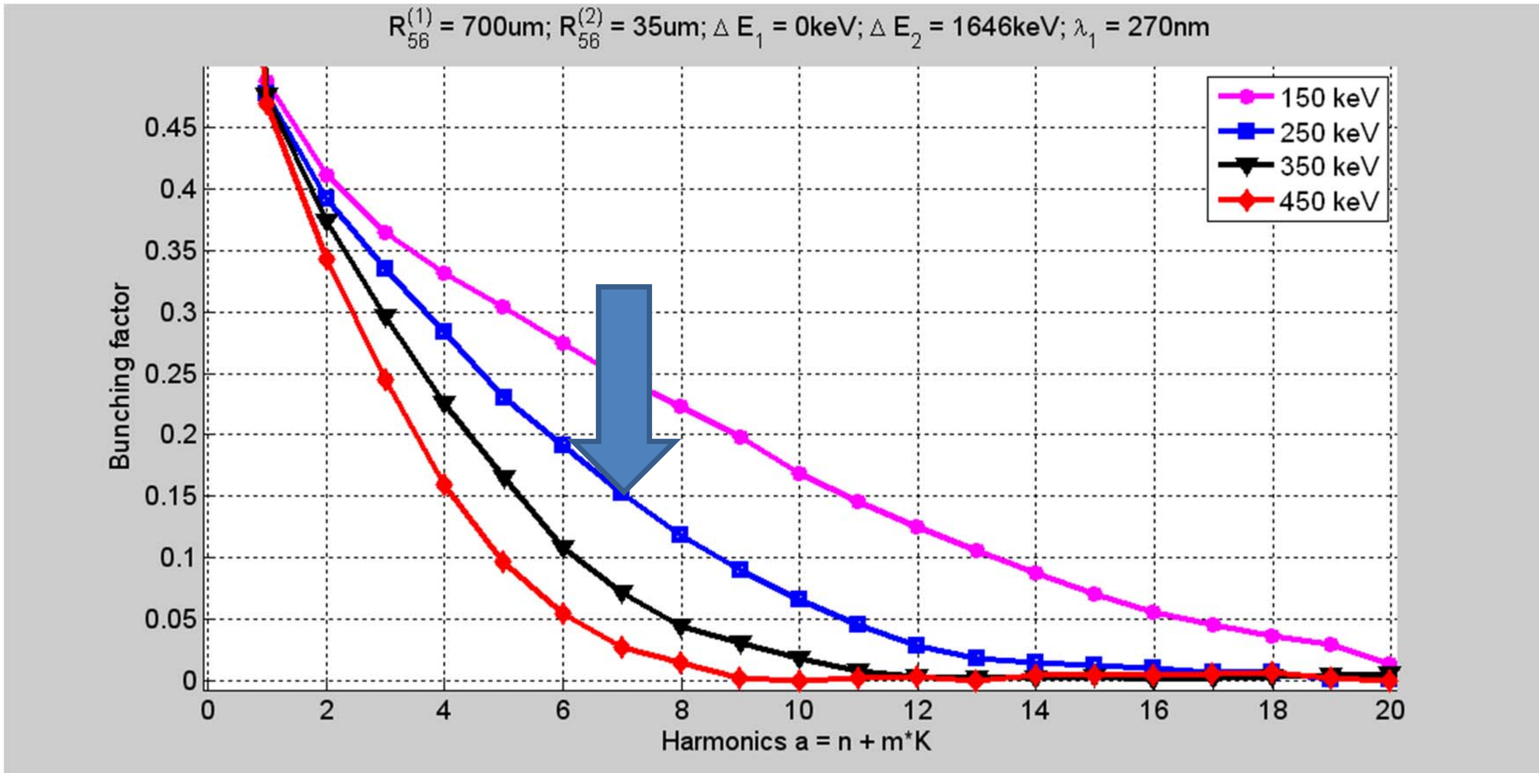
- If our laser wavefront quality is good enough for 14 nm, it is good enough for 4.7 nm

EEHG and laser wavefront

- Wavefront tilt: 
  - – Adjust magnets prior to radiator
- Lower-order deformations: 
  - – Adjust deformable mirror for 270 nm
- Higher-order deformations: 
  - – Use flatter optics or add spatial filter

Commissioning strategy: start with HGHG at 38.5 nm





Commissioning strategy

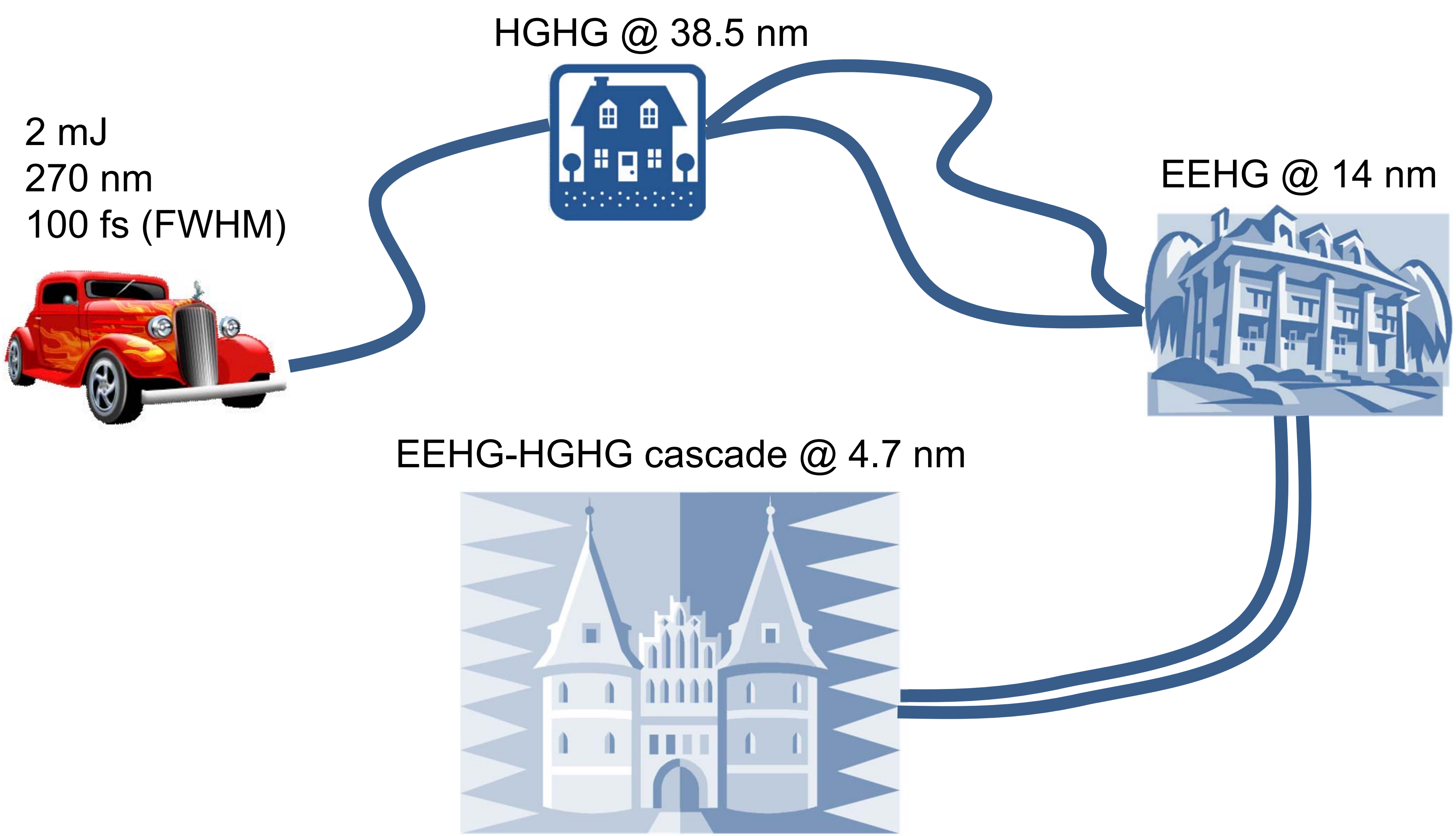
- We will only need a ***few shifts of beam time*** for calibrating our near and far-field laser beam position measurements against measurements conducted in the electron beam line with insertable screens.
- Regardless of the machine setup, we can generate a ***parasitic EEHG program*** which can use one bunch out of the bunch train
  - Requires ORS chicanes and undulators to be ON all of the time.

Summary

- We will start with an easy, already proven scheme and work our way towards seeding at 4.7 nm
- EEHG has some inherent advantages over other seeding techniques
  - Low energy spread sensitivity
  - Ease of removing effect of laser wavefront tilts
  - Easier to tune low-order wavefront distortions
  - Not as constrained in choice of harmonic
- This experiment can be conducted parasitically on an ongoing basis

Thank you for your time

Road map



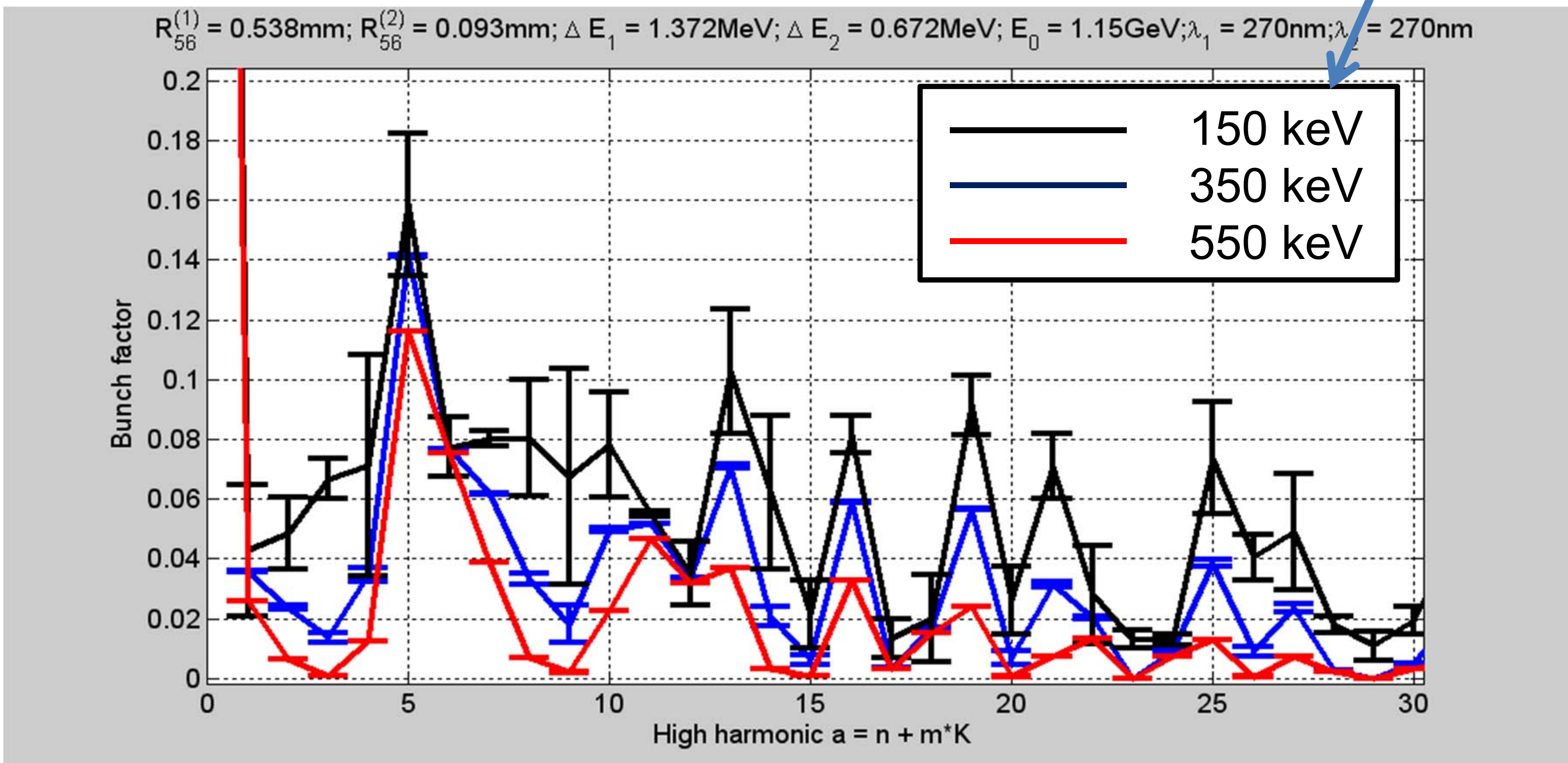
2 mJ
270 nm
100 fs (FWHM)
HGHG @ 38.5 nm
EEHG @ 14 nm
EEHG-HGHG cascade @ 4.7 nm

Route 2: hybrid EEHG-HGHG

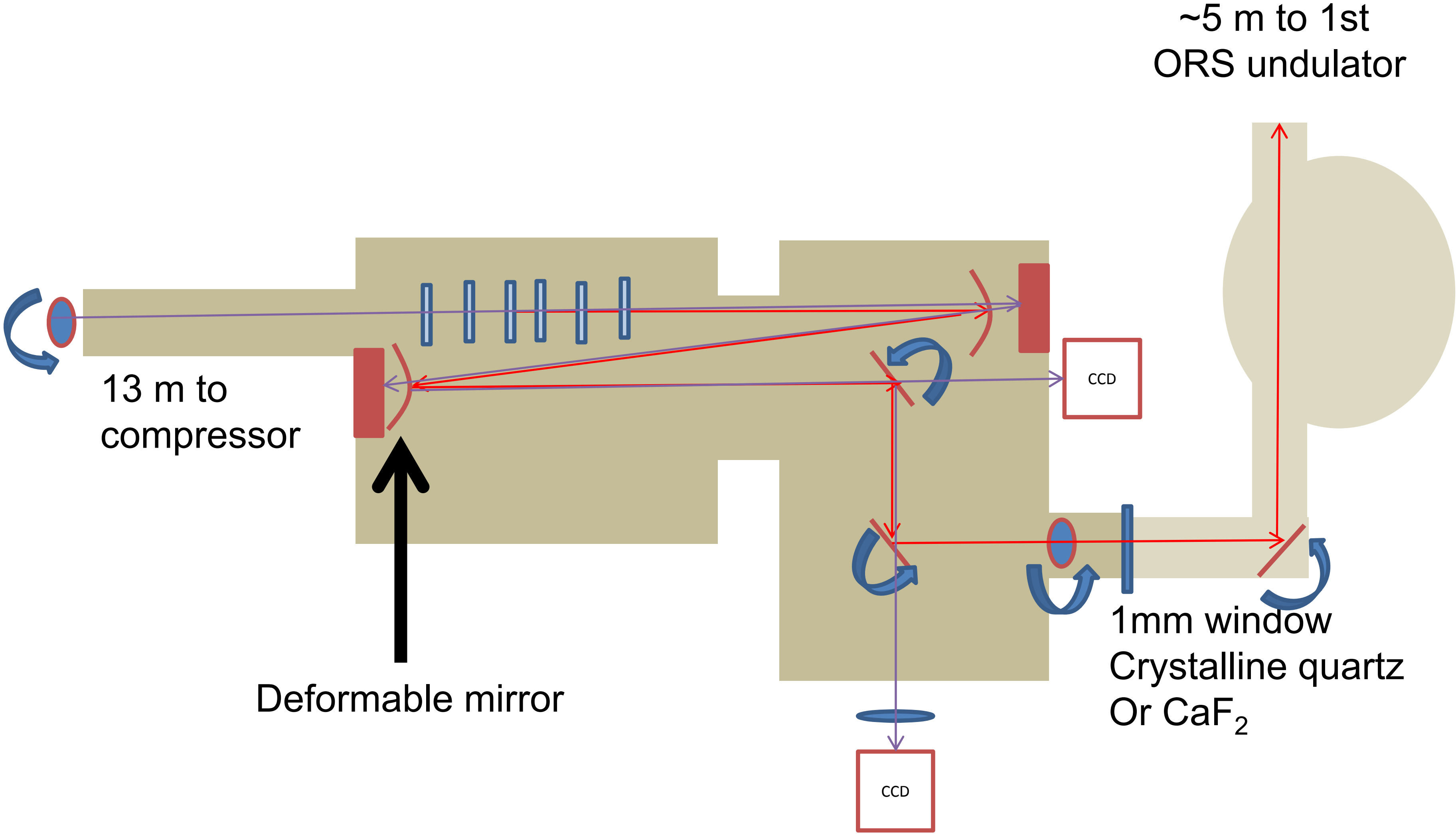
Smaller laser power => smaller energy spread

Higher uncorrelated energy spread sensitivity
Higher energy fluctuation sensitivity

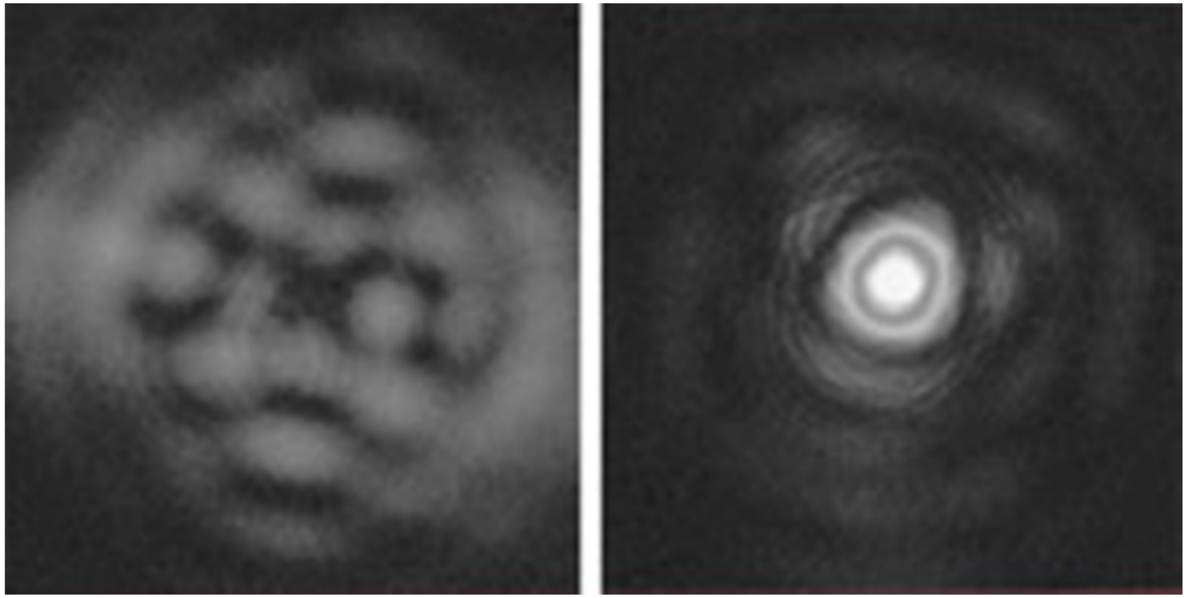
Uncorrelated energy spread



First iteration

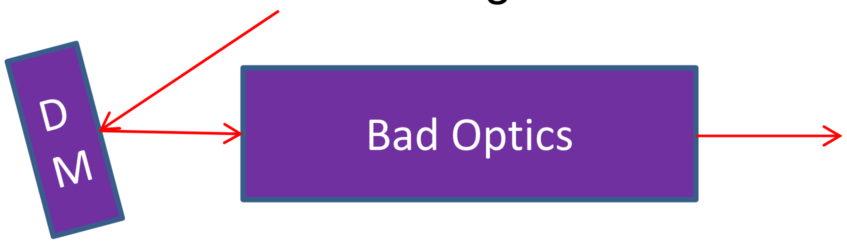


Laser Wavefront Control



Before After

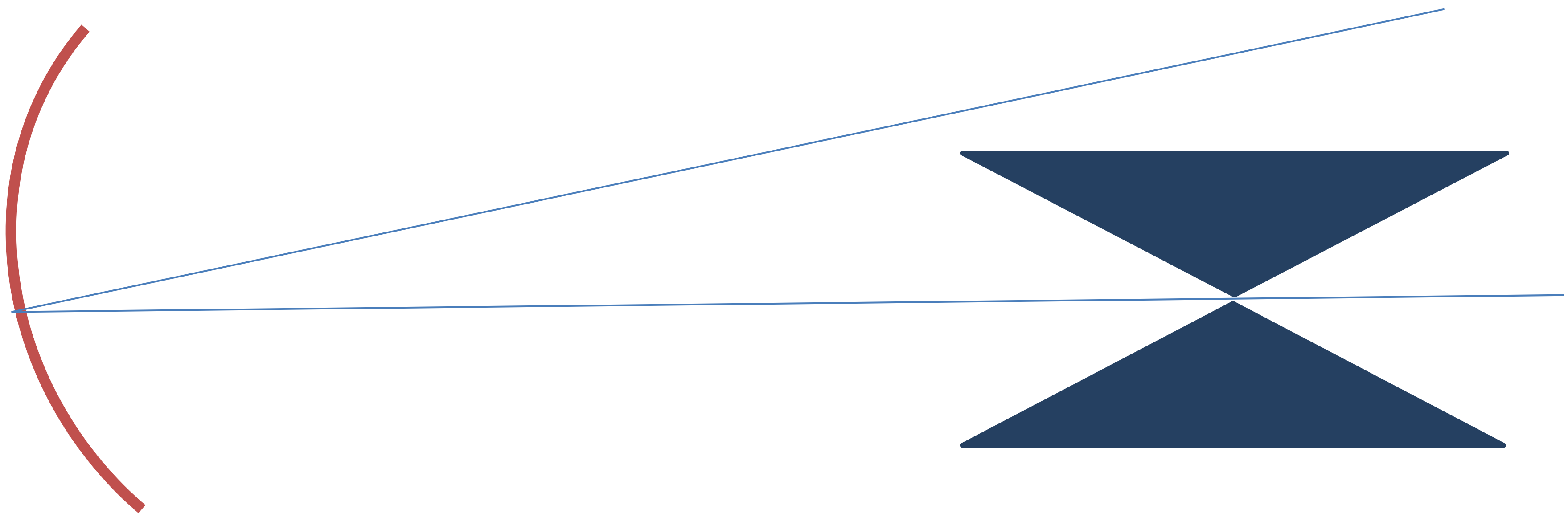
Large-scale distortions => Adaptive optics



Lovely beam

Laser Wavefront Control

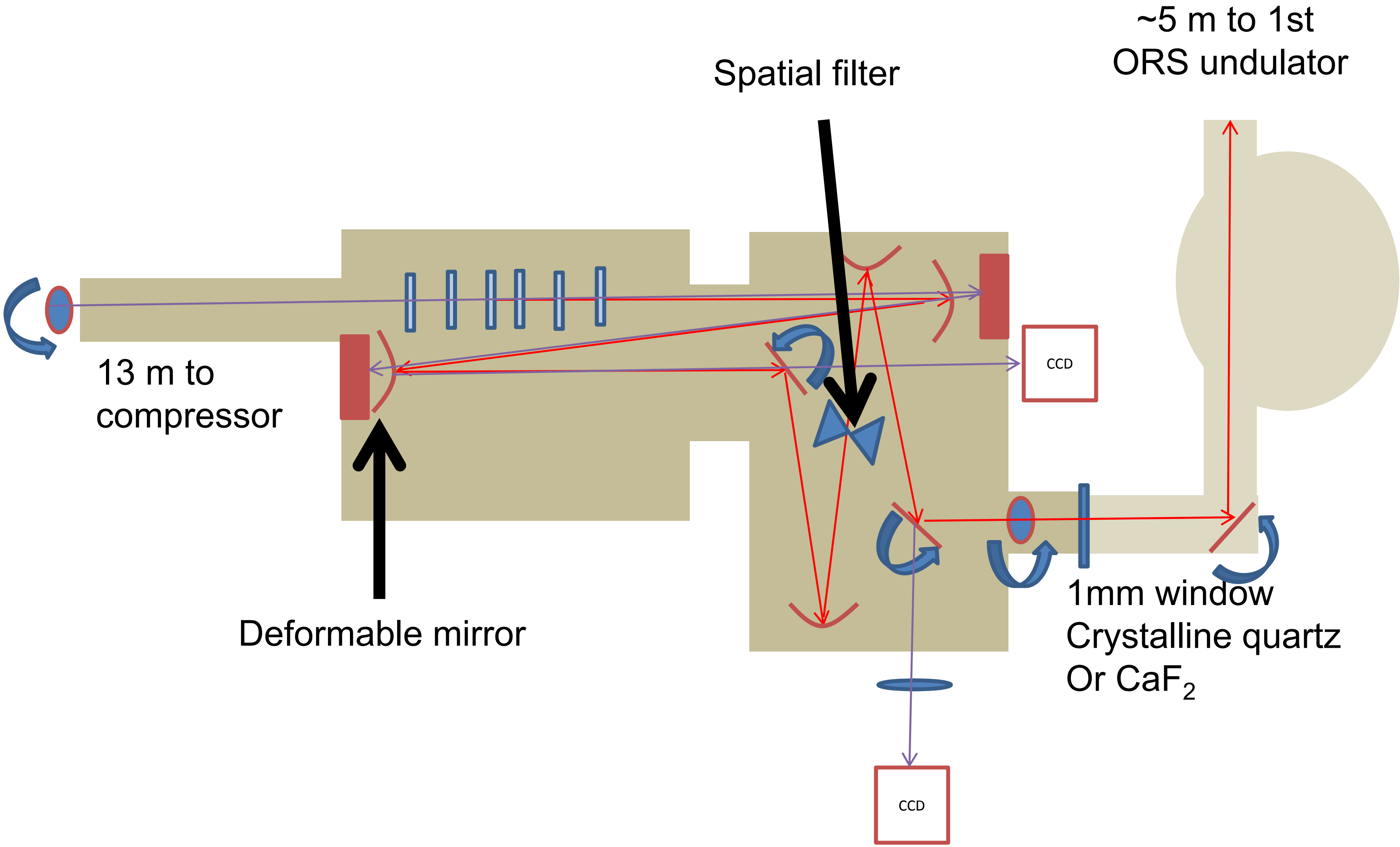
Microscopic distortions =>Spatial filter



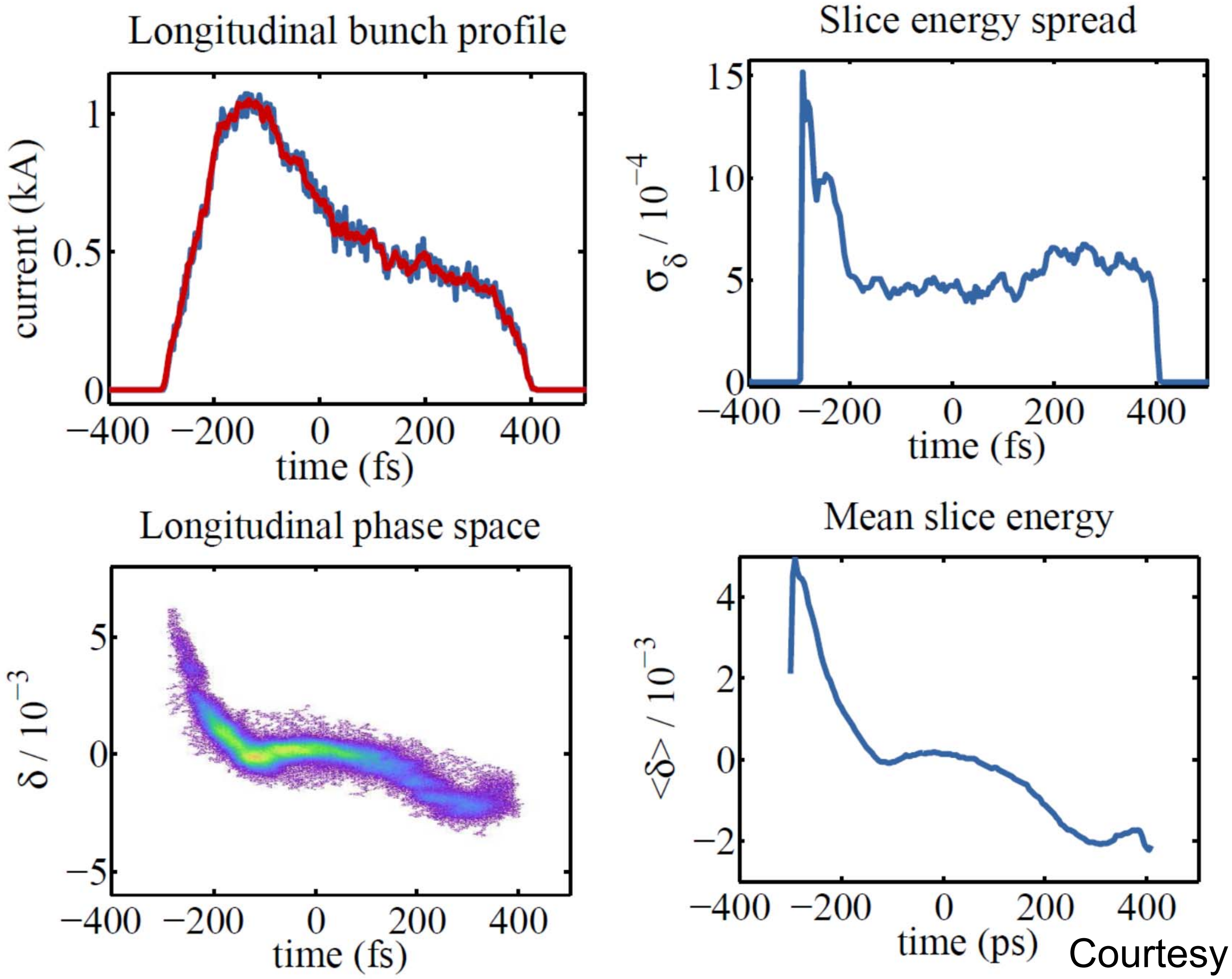
Dielectric conical filtering hole at diffraction limit

- -50% losses
- -intensity jitter increases due to pointing jitter
- -pointing jitter -> fast steering feedback

Second iteration

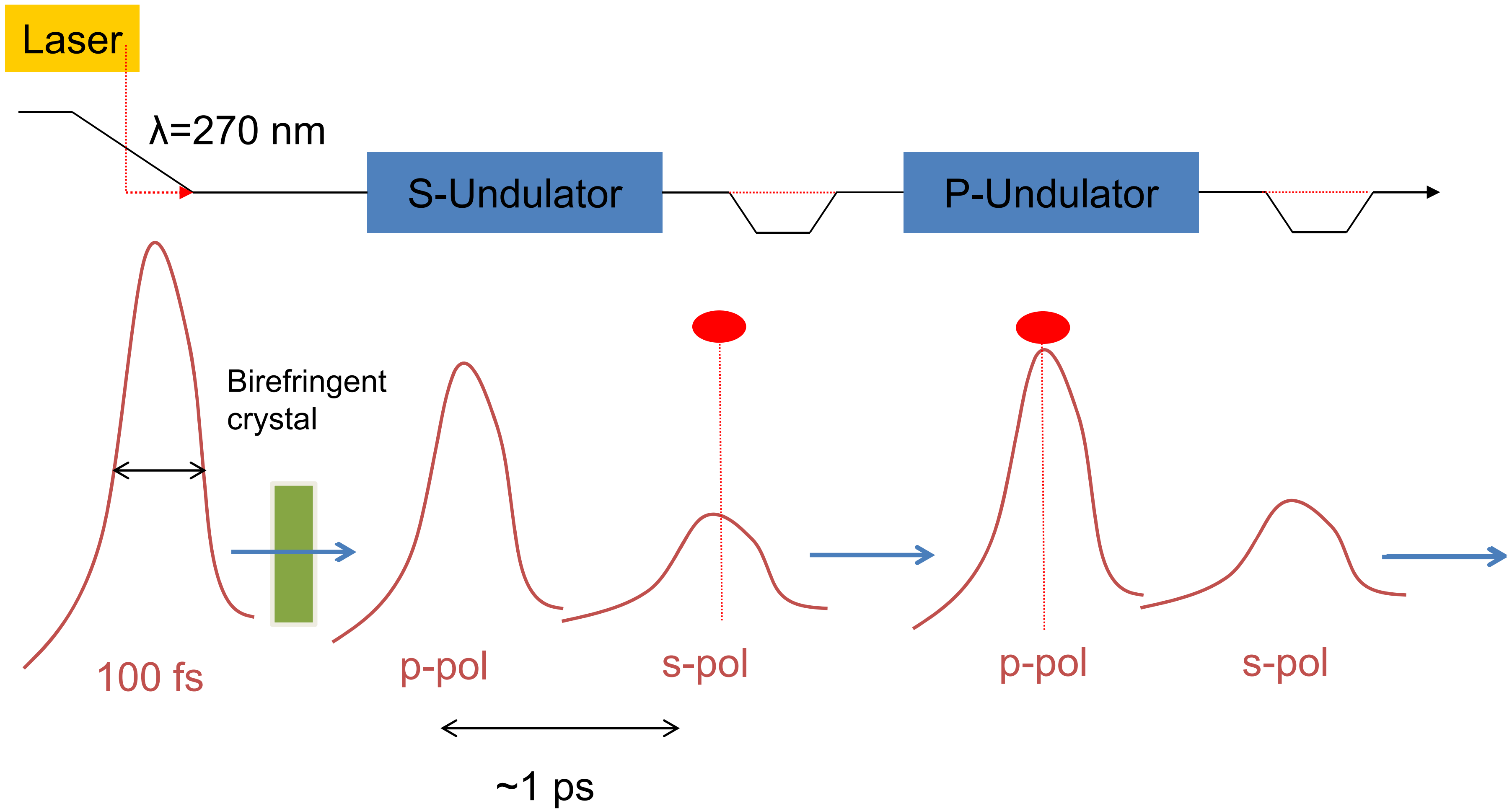


Electron beam

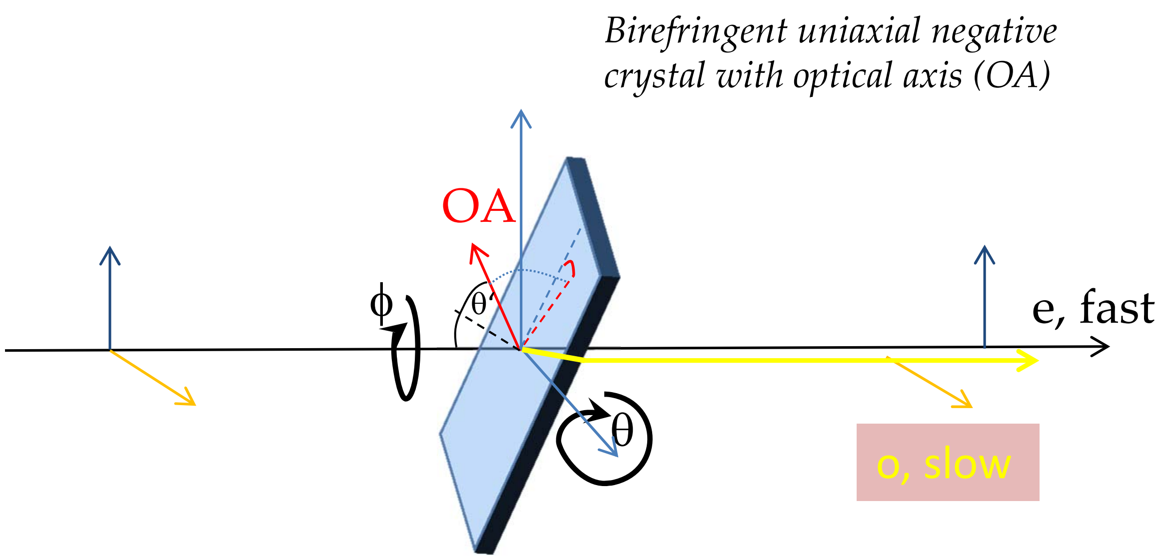


Courtesy C. Behrens

EEHG with one laser

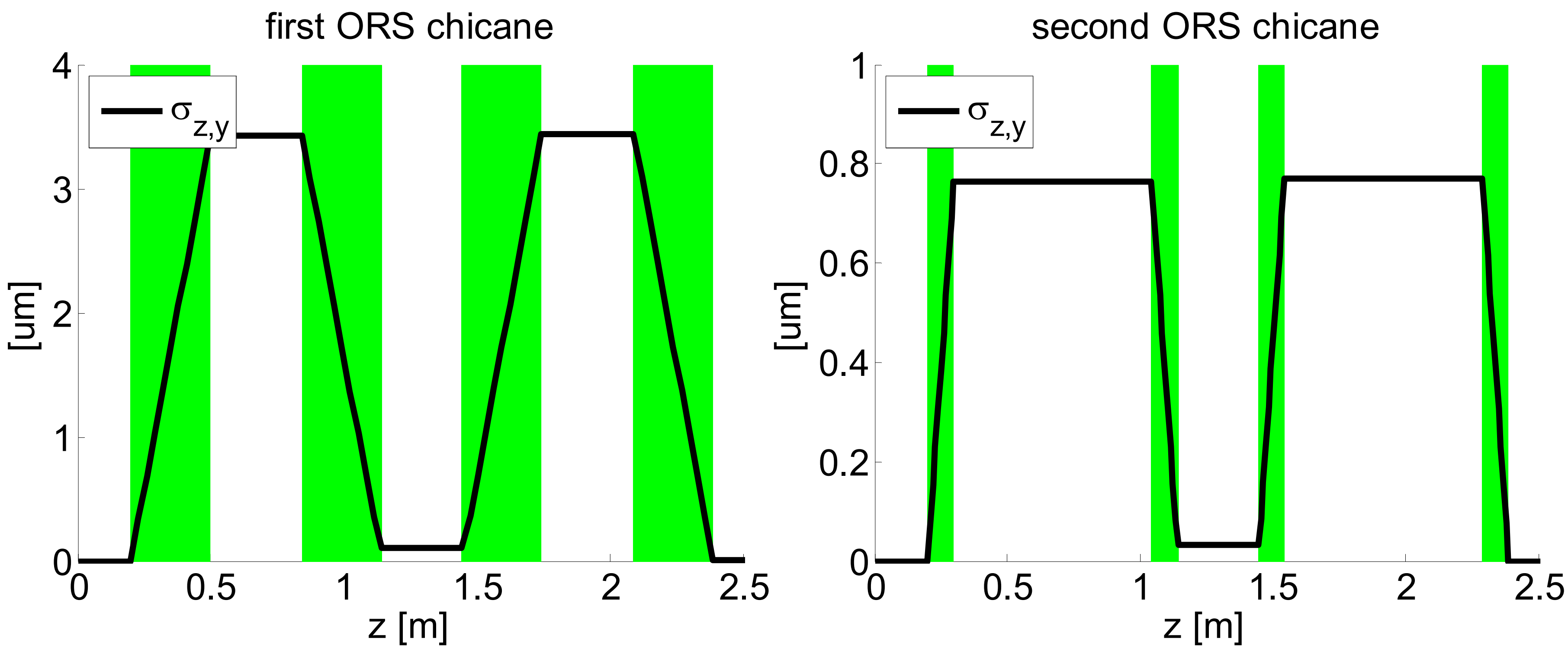


Laser Power Control



R_{53} & R_{54} smearing out spikes

$$\sigma_{z,y}^2 = R_{53}^2\,\sigma_y^2 + R_{54}^2\,\sigma_{y'}^2$$

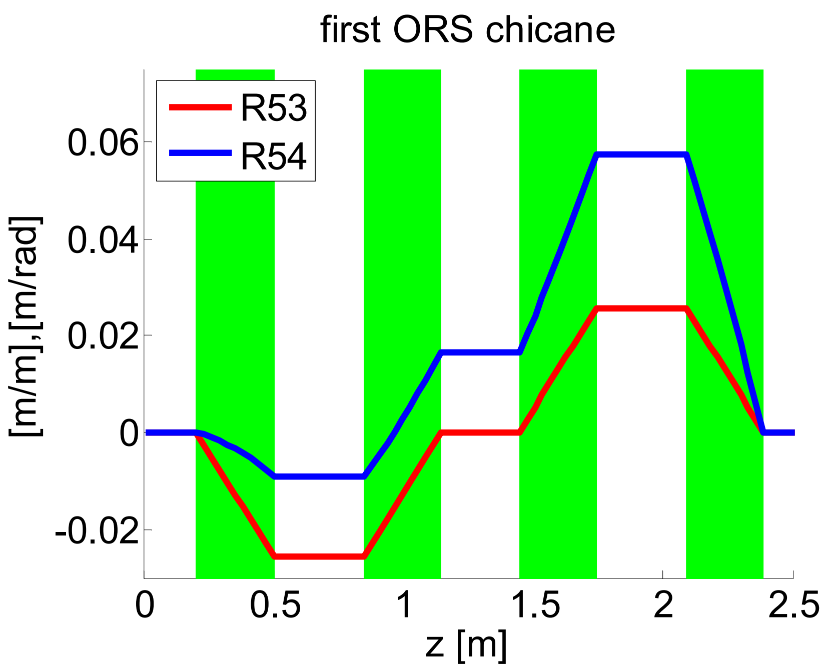


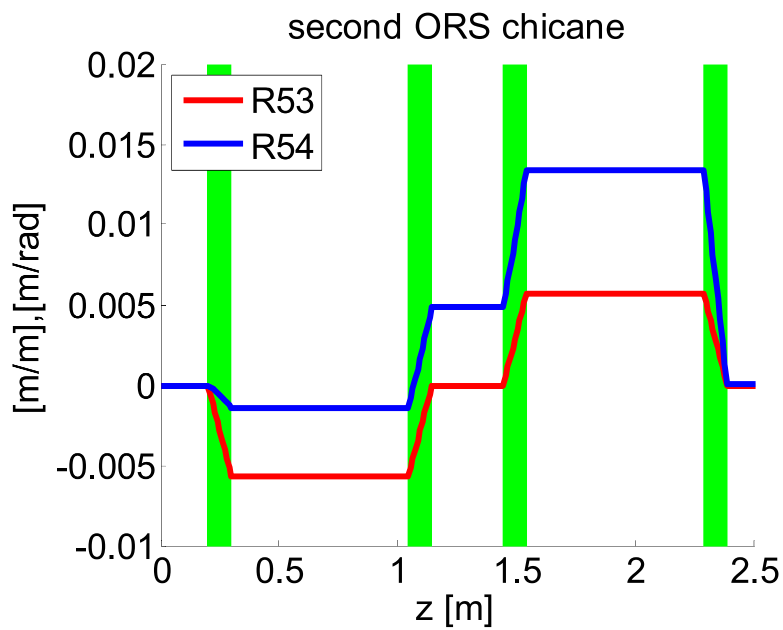
100 nm minimum

30 nm minimum

$$\sigma_{z,y} < \lambda_r/20$$

R_{53} & R_{54} leakage due to CSR



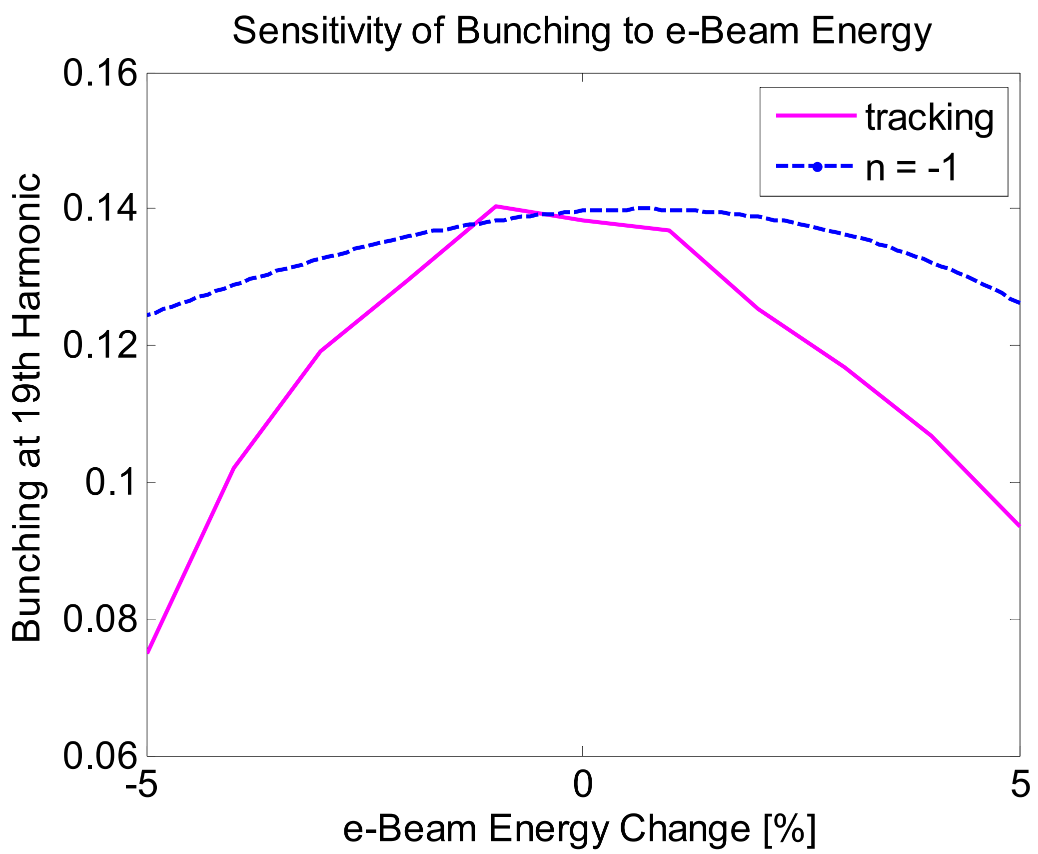


$\sim\exp(k^2 R_{53}^2 \sigma_y^2/2)$

$\Rightarrow$ Magnetic field of first chicane must be tuned to within 0.05%

$\Rightarrow$ Magnetic field of second chicane must be tuned to within 0.20%

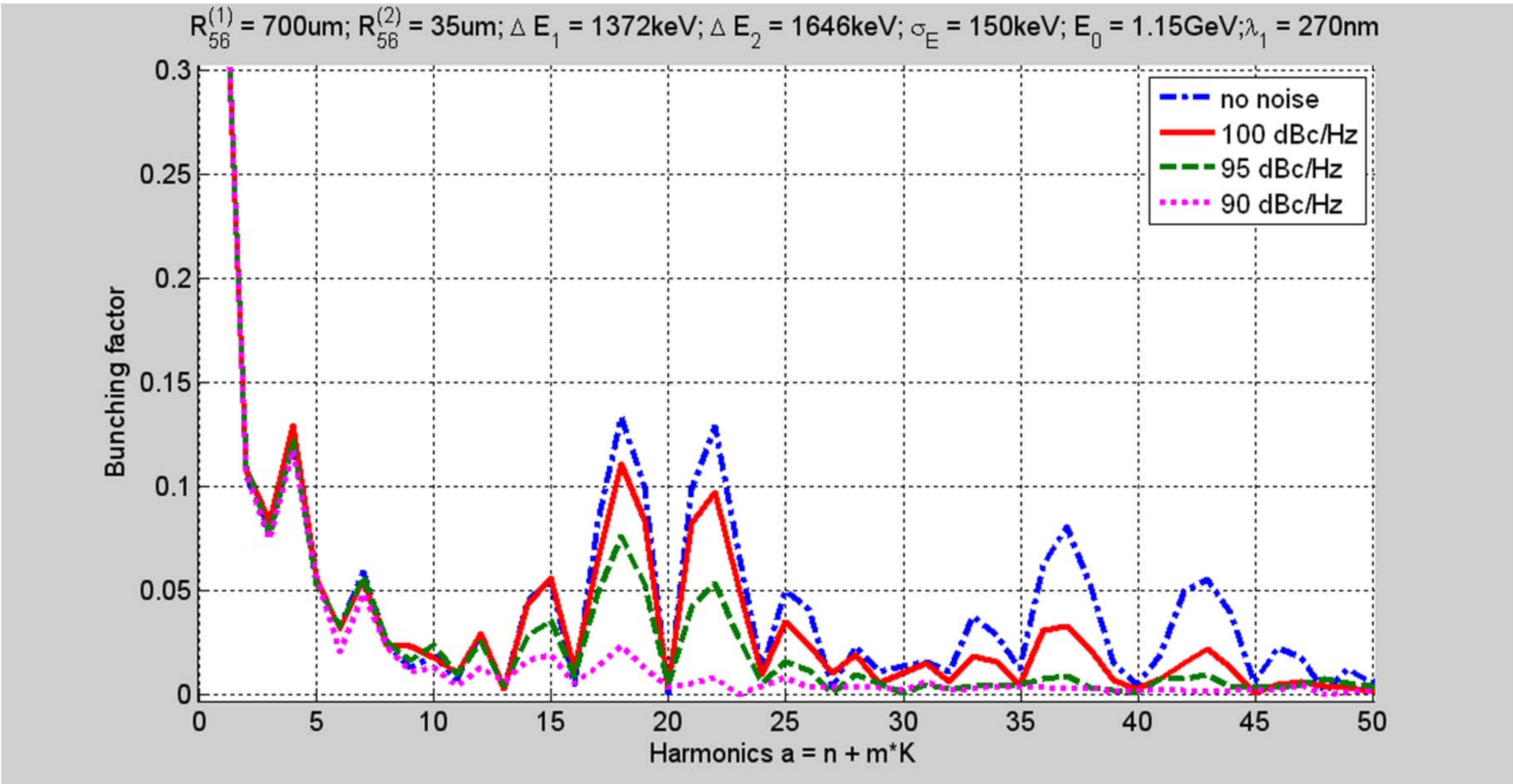
Beam Energy Sensitivity



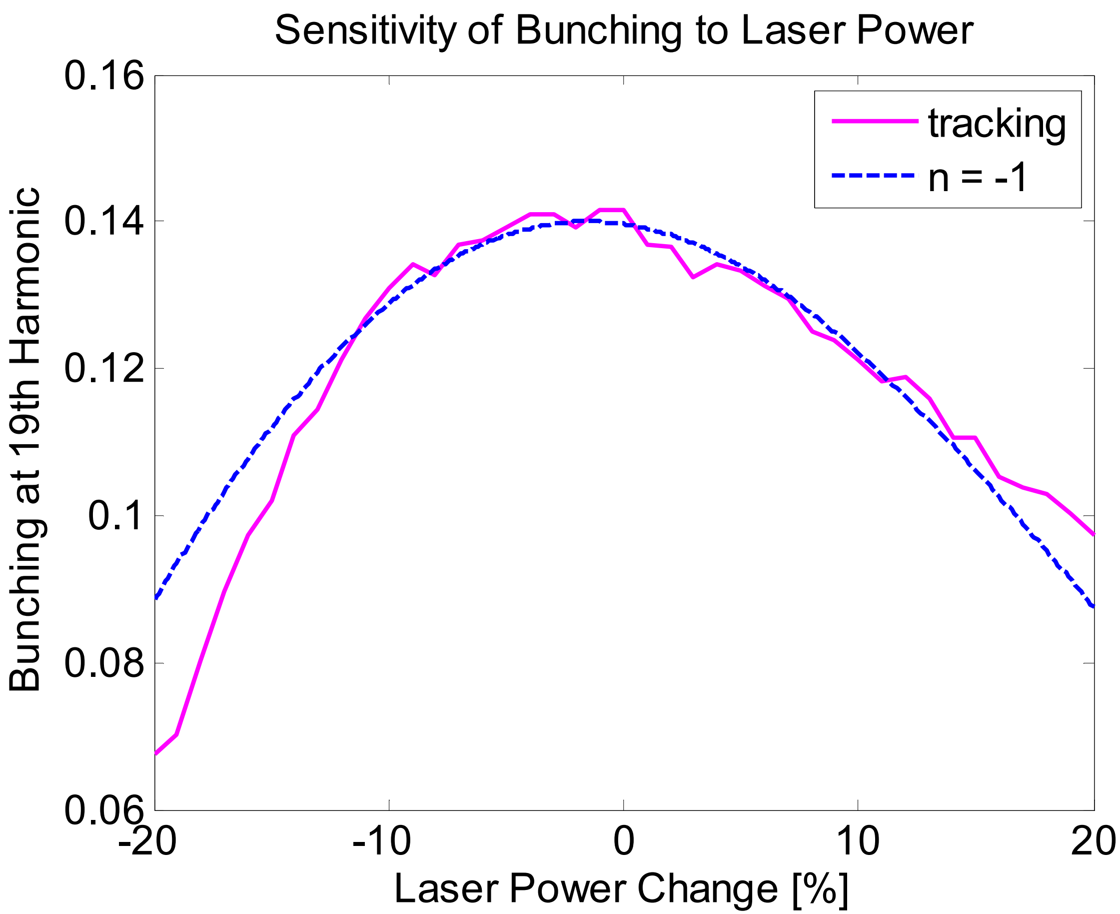
Phase Noise Sensitivity

All seeding schemes
Same rule?

$$\left(\frac{P_s}{P_n}\right)_{out} = \frac{1}{n^2}\left(\frac{P_s}{P_n}\right)_{in}$$



Laser Power Sensitivity



Incoming Microbunches

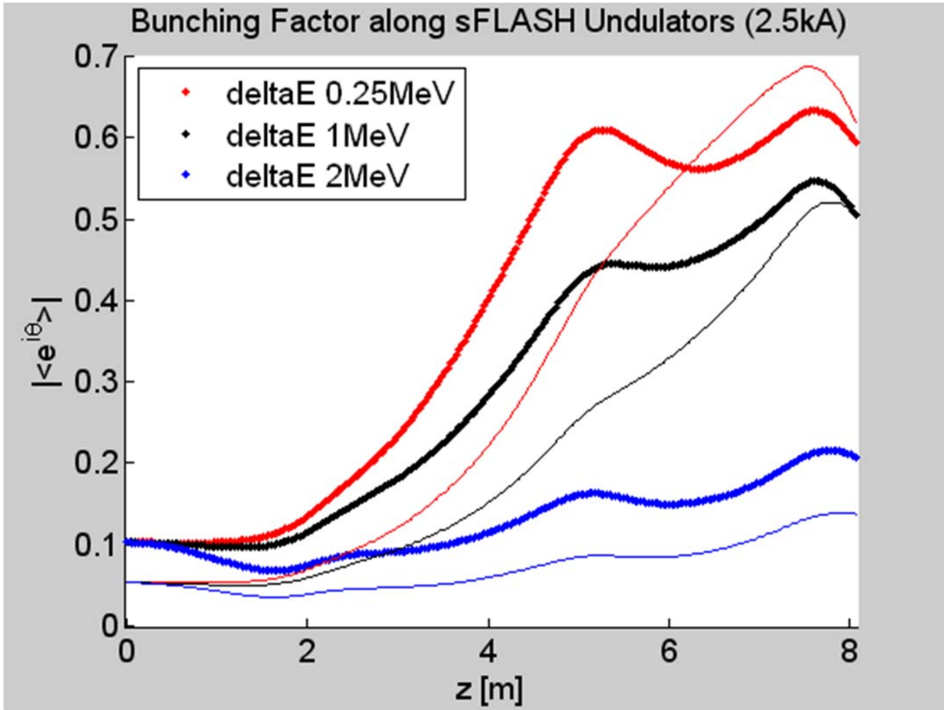
- Broadband spectrum <300 nm to 15 um (measured)
- On-crest form factor ~0.01
- Off-crest form factor much higher
- ORS undulator amplifies wavelengths from incoming microbunching spectrum
- ~~800 nm MBI could be exacerbated in ORS section~~
- ~~Constructive and destructive interference with EEHG modulation (varying from cycle-to-cycle)~~

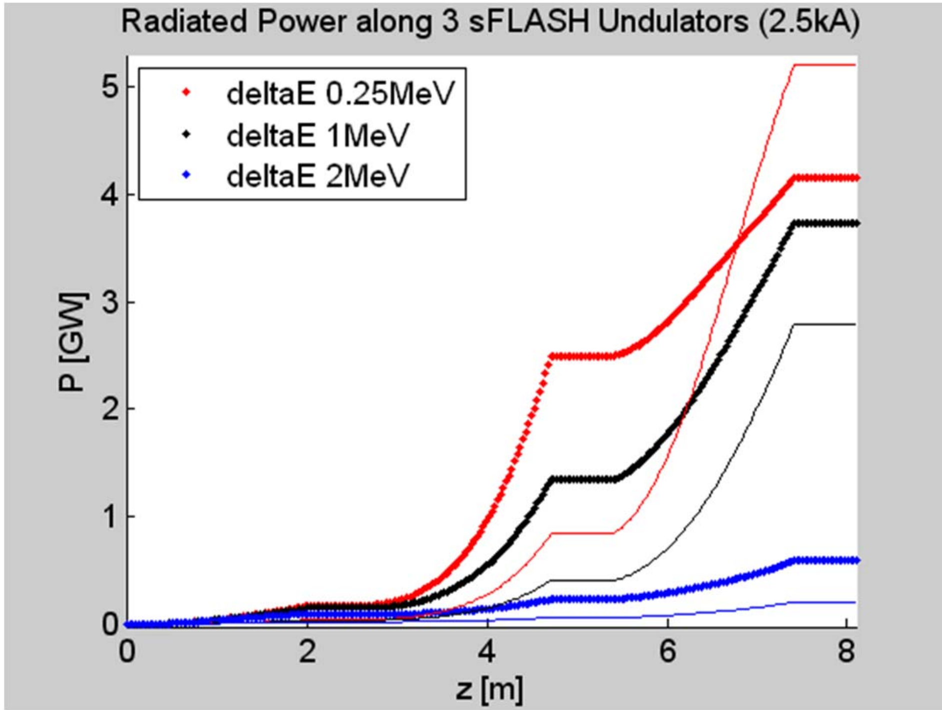
Structures smaller than 600 nm are smeared out in dogleg
&
Sub-harmonics don’t radiate on axis

GENESIS

Through the first 3 sFLASH undulators

I_{peak}=2.5 kA	σ_E=250 keV (rms)	bunching=0.05
I_{peak}=2.5 kA	σ_E=1000 keV (rms)	bunching=0.05
I_{peak}=2.5 kA	σ_E=2000 keV (rms)	bunching=0.05
I_{peak}=2.5 kA	σ_E=250 keV (rms)	bunching=0.10
I_{peak}=2.5 kA	σ_E=1000 keV (rms)	bunching=0.10
I_{peak}=2.5 kA	σ_E=2000 keV (rms)	bunching=0.10

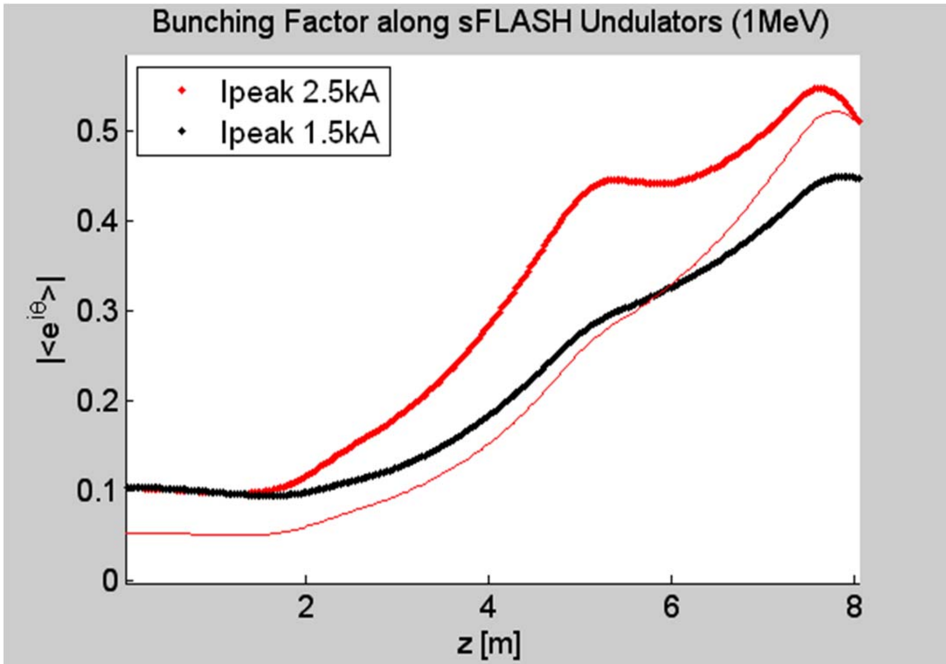


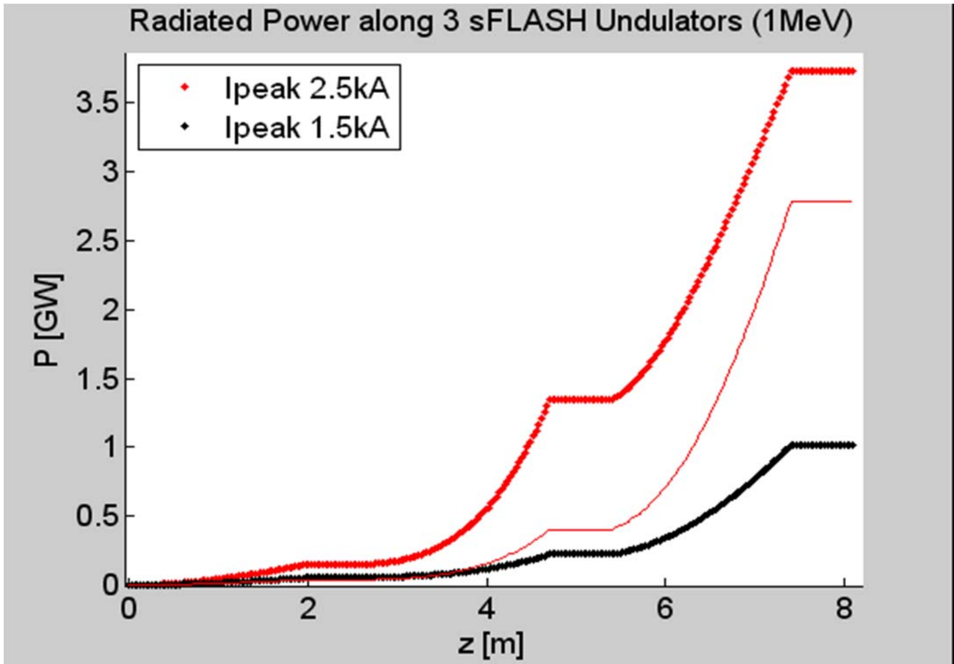


GENESIS

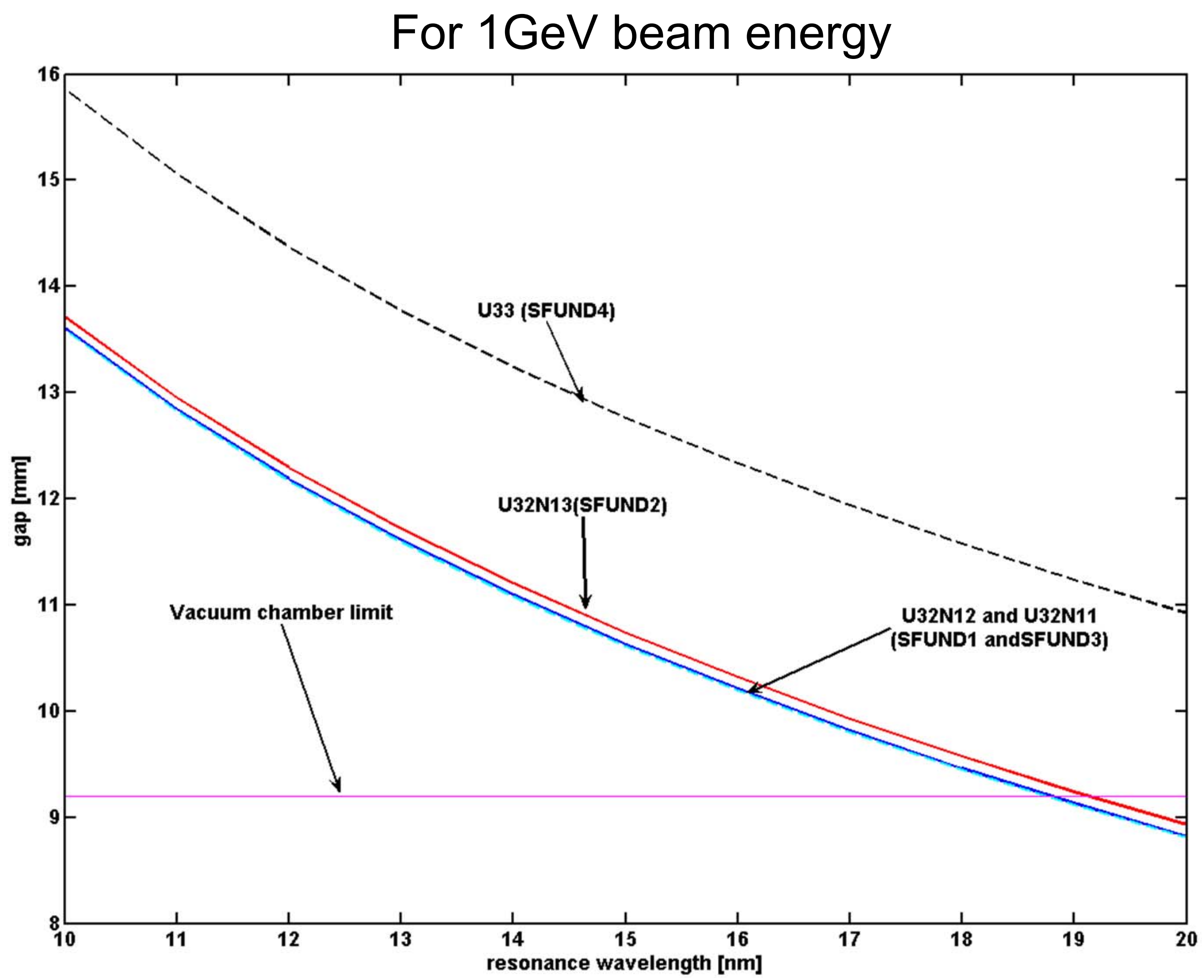
Through the first 3 sFLASH undulators

I_{peak}=2.5 kA σ_E=1000 keV (rms)   bunching=0.05
I_{peak}=1.5 kA σ_E=1000 keV (rms)   bunching=0.05
I_{peak}=2.5 kA σ_E=1000 keV (rms)   bunching=0.10
I_{peak}=1.5 kA σ_E=1000 keV (rms)   bunching=0.10





EEHG with sFLASH undulators



Plot courtesy of Delsim-Hashimi