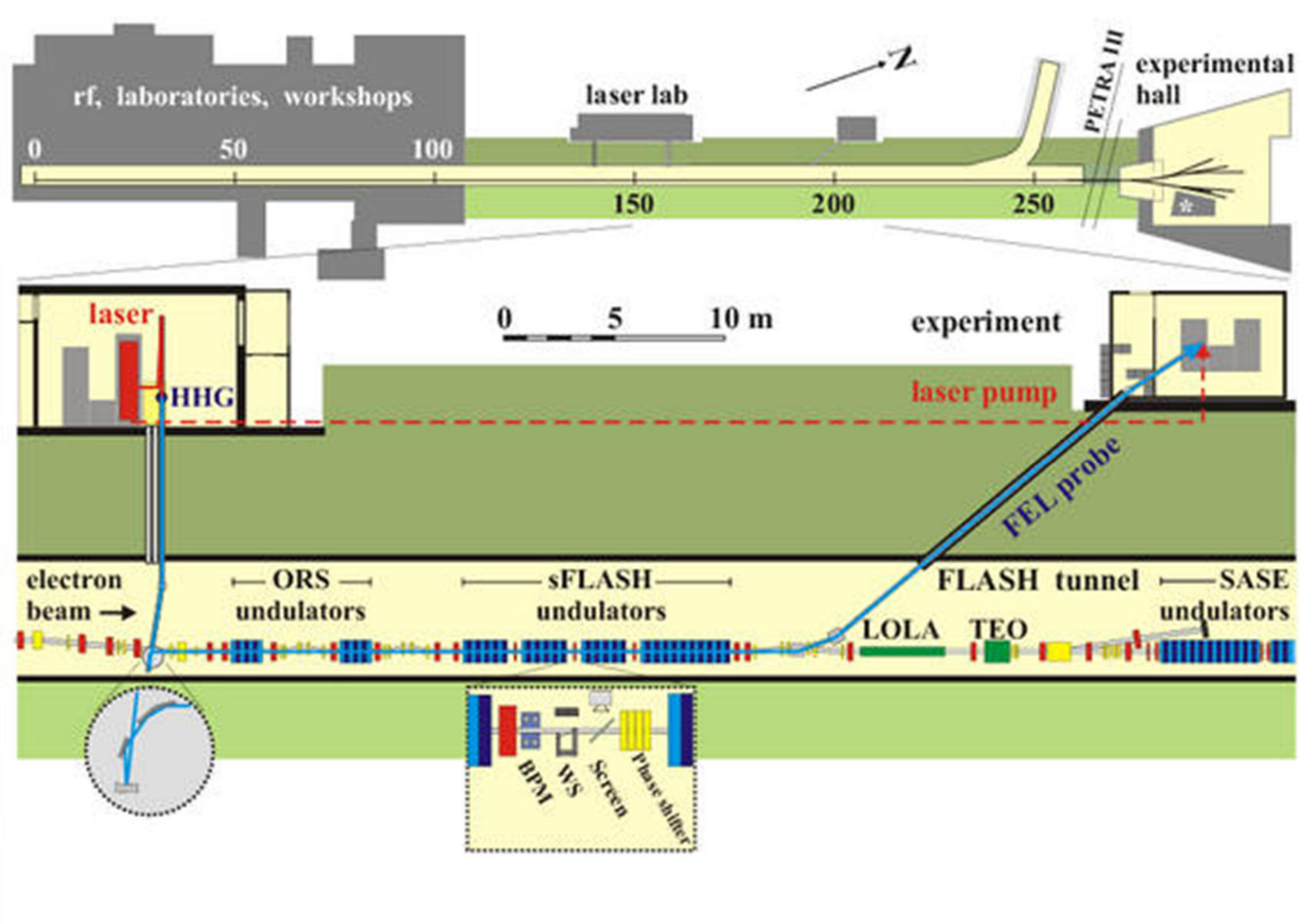
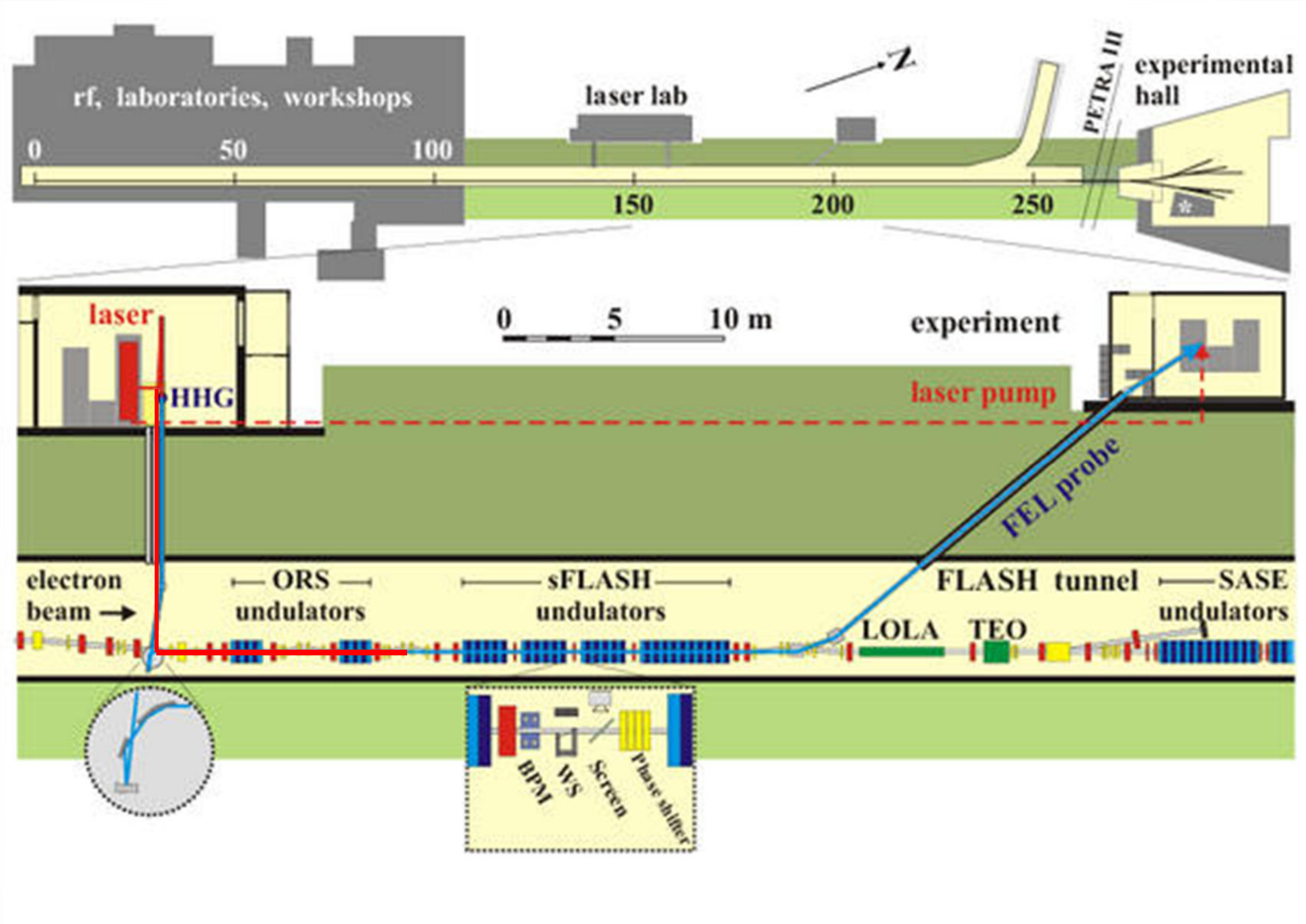
Progress towards EEHG at FLASH in 2012

Holger Schlarb, DESY
Peter Salen, Peter Van der Meulen, Stockholm University
Kirsten Hacker*, Shaukat Khan, TU Dortmund
Gergana Angelova Hamberg, Volker Ziemann, Uppsala University
Armin Azima, University of Hamburg

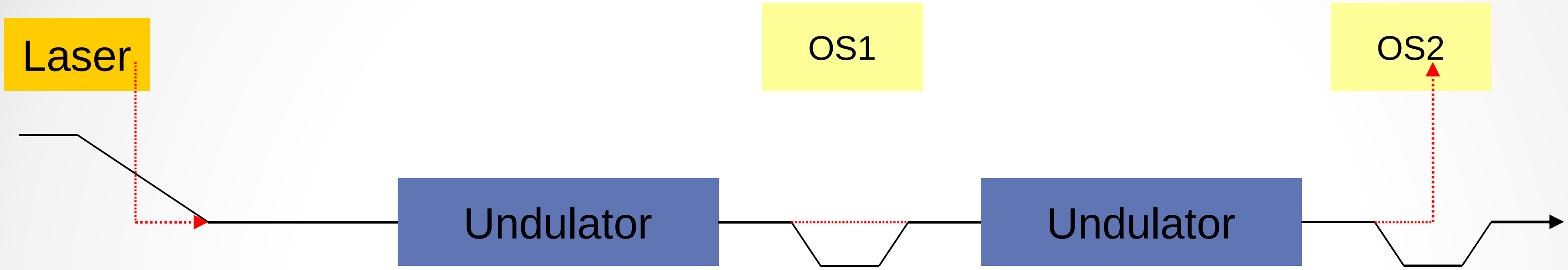
ORS and sFLASH



ORS and sFLASH

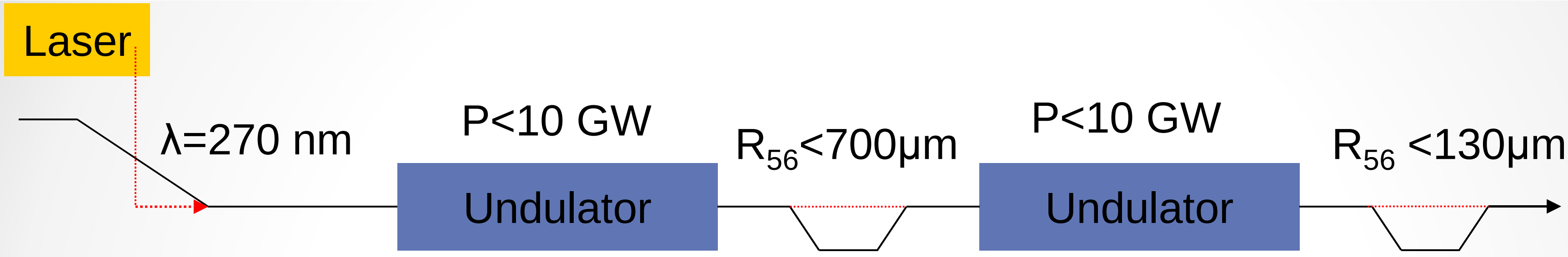


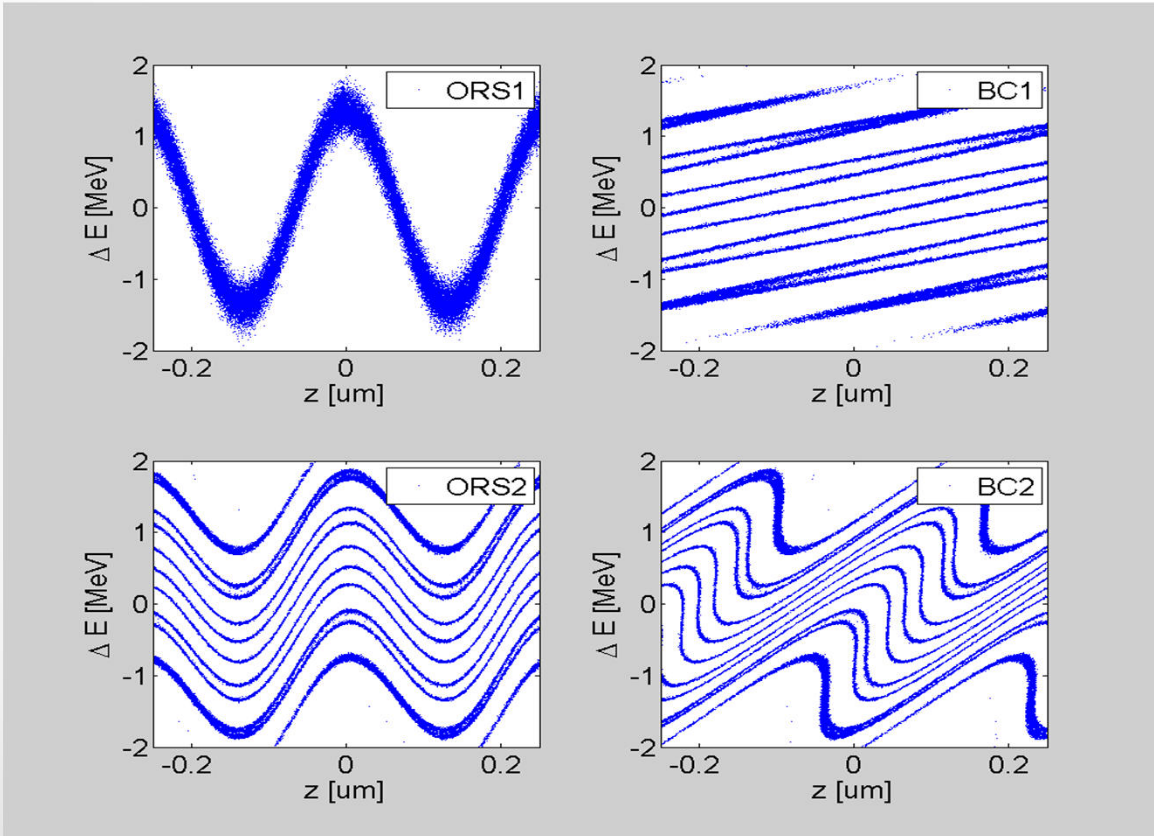
Agenda for 2012



- Laser Timing Diagnostic
- Optical Replica method 1
- Optical Replica method 2
- EO sampling with a FROG
- Beam slicing with 4 um OPA
- Echo-seeding

Echo-seeding in Jan 2012

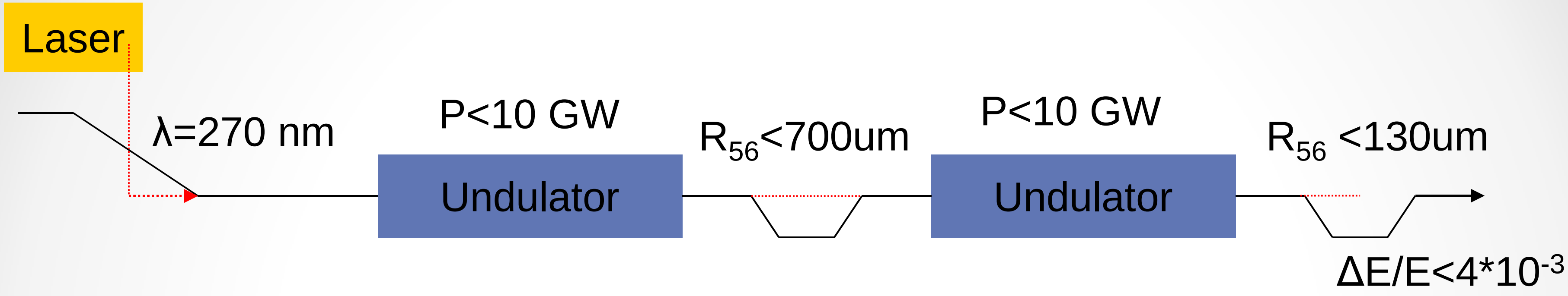




ΔE/E<4*10^{-3}

1-D particle tracking
With Matlab

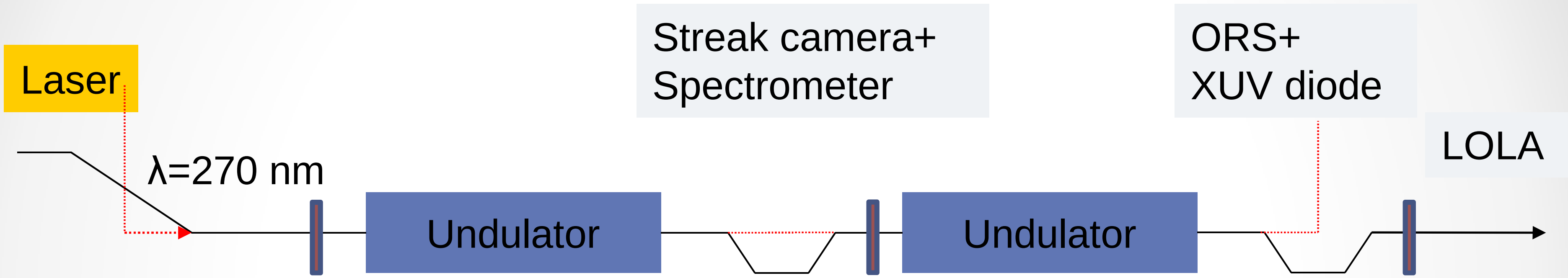
Other EEHG schemes



facility	E_0 (GeV)	$R_{56}^{(1)}$ (mm)	$R_{56}^{(2)}$ (mm)	λ(nm)
FERMI FEL2	1.2	8.2	0.35	4
FERMI FEL2	1.2	2.5	0.12	10
FLASH II	1.2	5.2	0.09	4
FLASH II	0.7	1.1	0.06	13
FLASH I ORS	1.15	0.7	0.03	14
FLASH I ORS	0.7	0.6	0.05	14

-FERMI FEL2 [250 MW]
-FLASH II [1.5 GW]
-FLASH I ORS [10 GW]

EEHG diagnostics

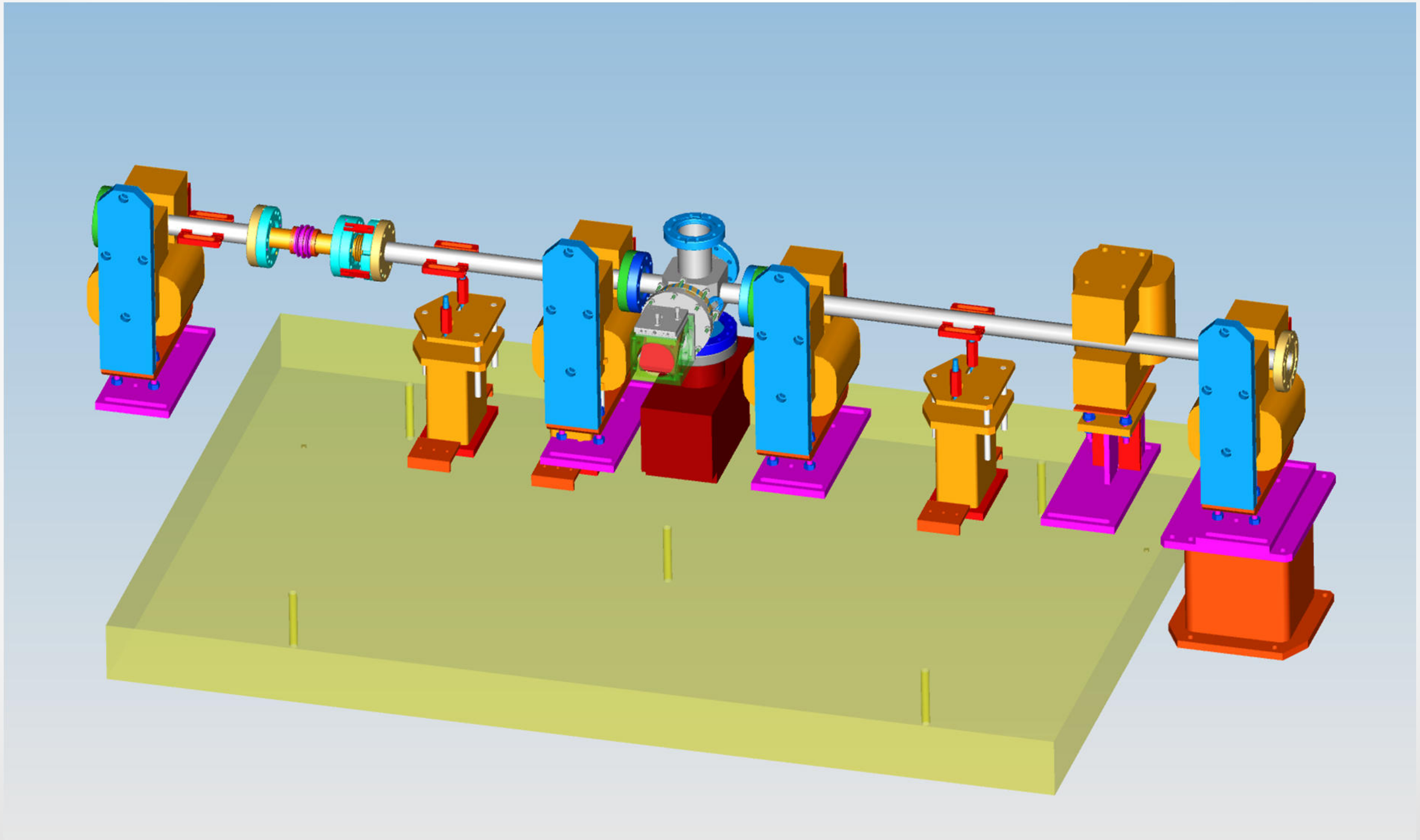


- YAG/OTR screens for transverse overlap
- Streak camera for (ps) longitudinal overlap
- LOLA (check for energy spread changes -> bunching)
- ORS for longitudinal overlap and profile
- sFLASH undulators & spectrometer

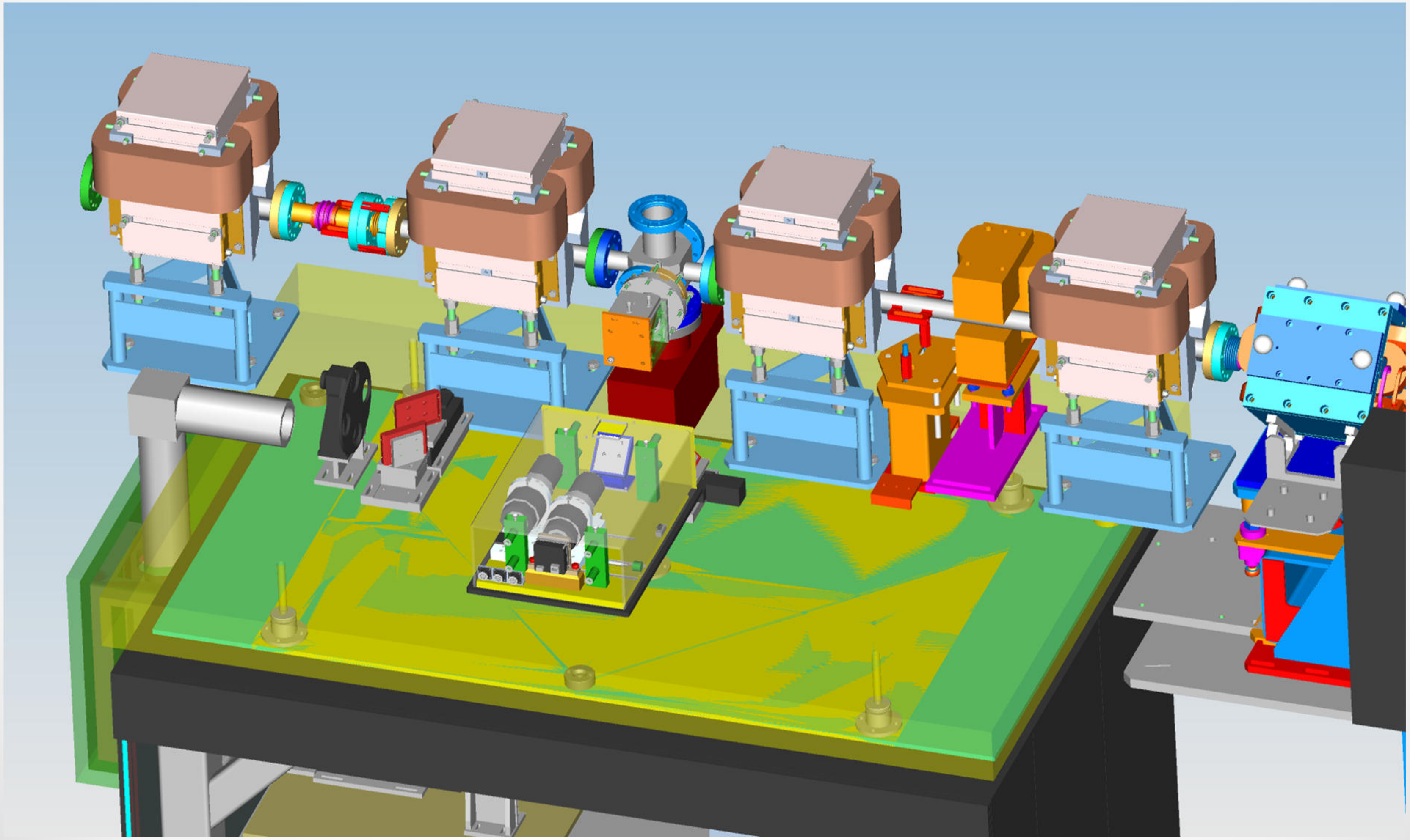
Experiment checklist:

- ✓ 30 mJ 800 nm laser
- ✓ undulators and chicanes
- ✓ laser/e-beam diagnostics
- ▪ Stronger dipoles in 1st ORS chicane
- ▪ In-vacuum transport for laser beam
- ▪ Tripler for 800 nm -> 270 nm
- ▪ Telescope to control laser waist
- ▪ Motorized steering mirrors

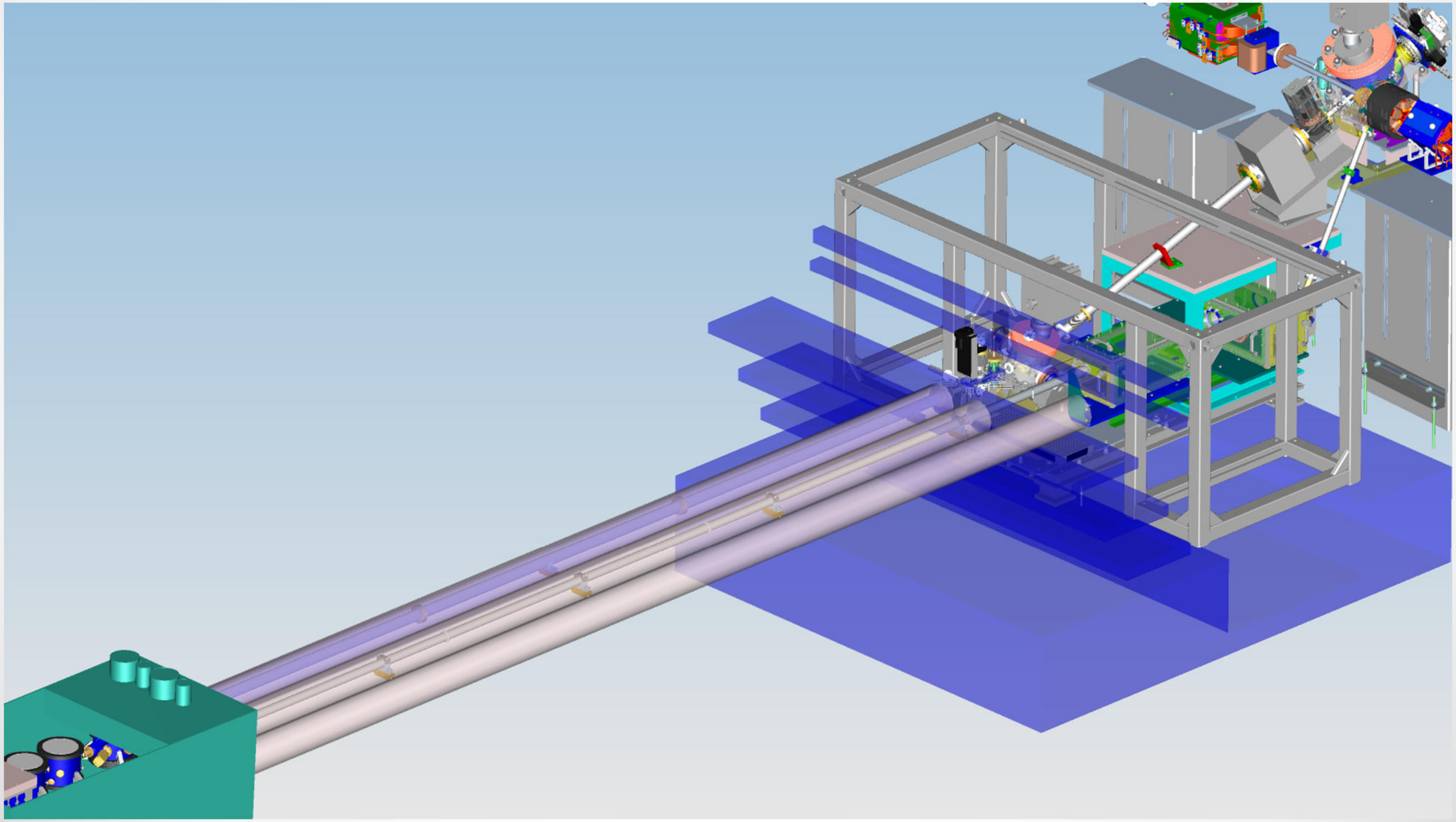
Chicane Upgrade: Before



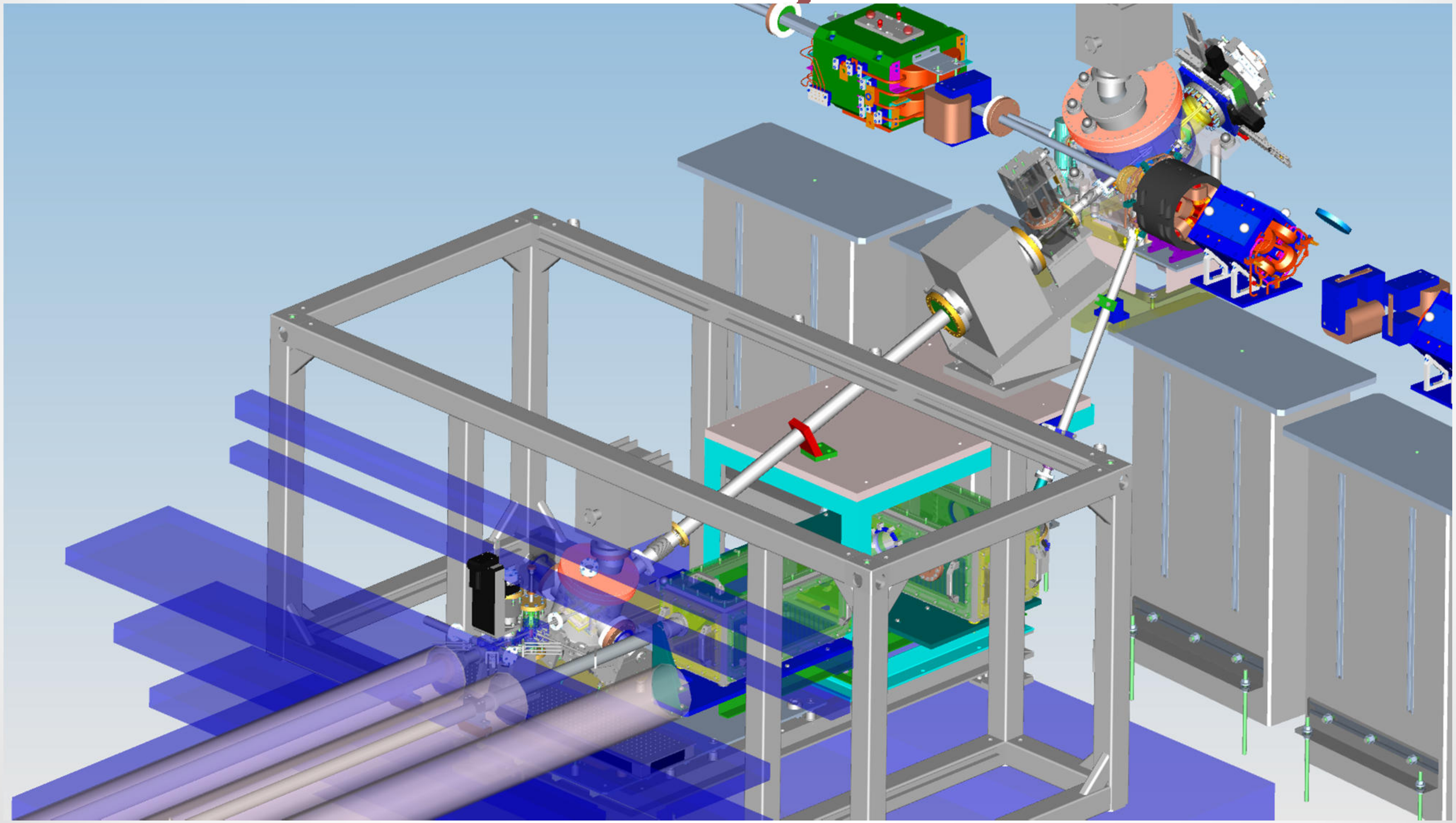
Chicane Upgrade: After



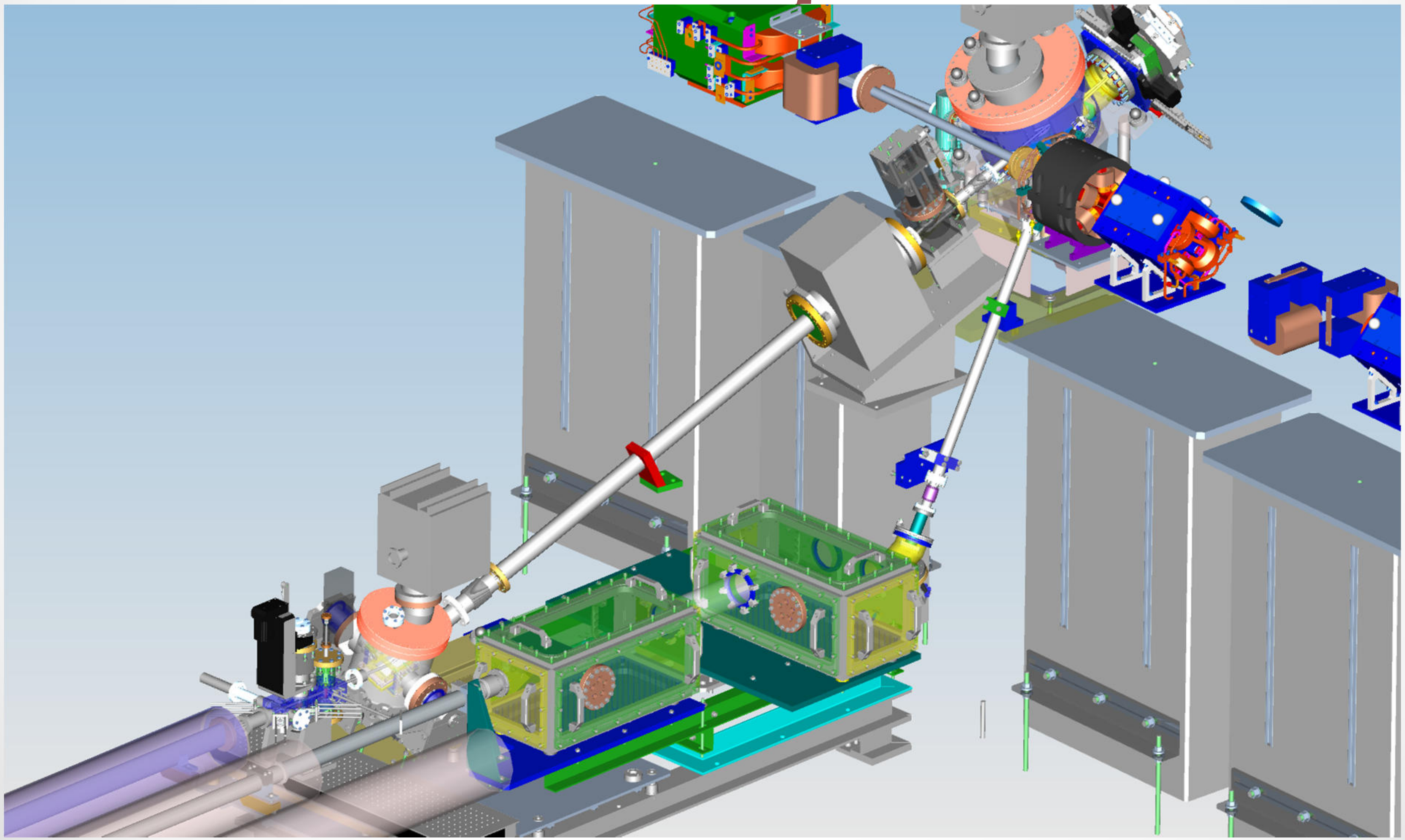
Laser Transport Line



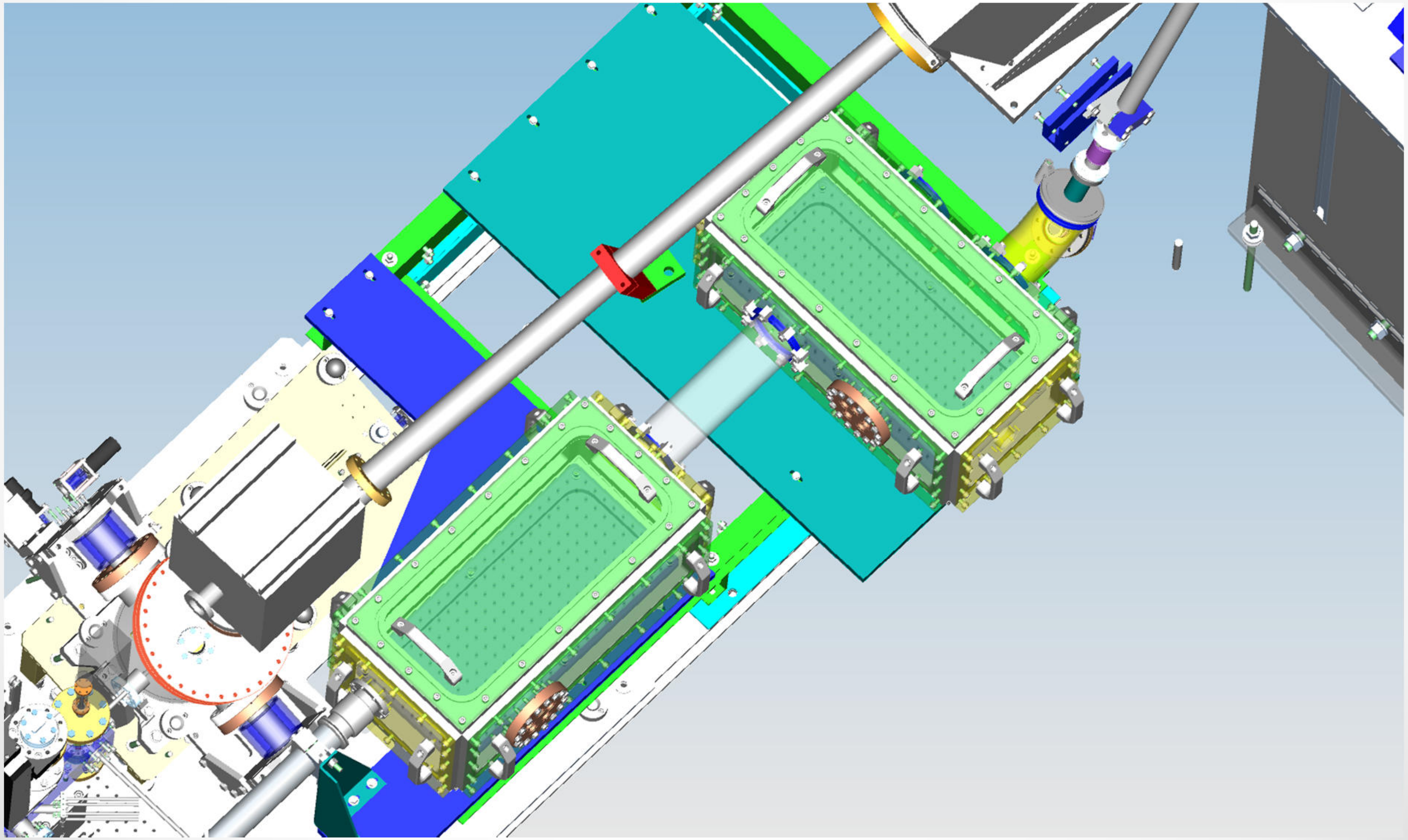
Laser Transport Line



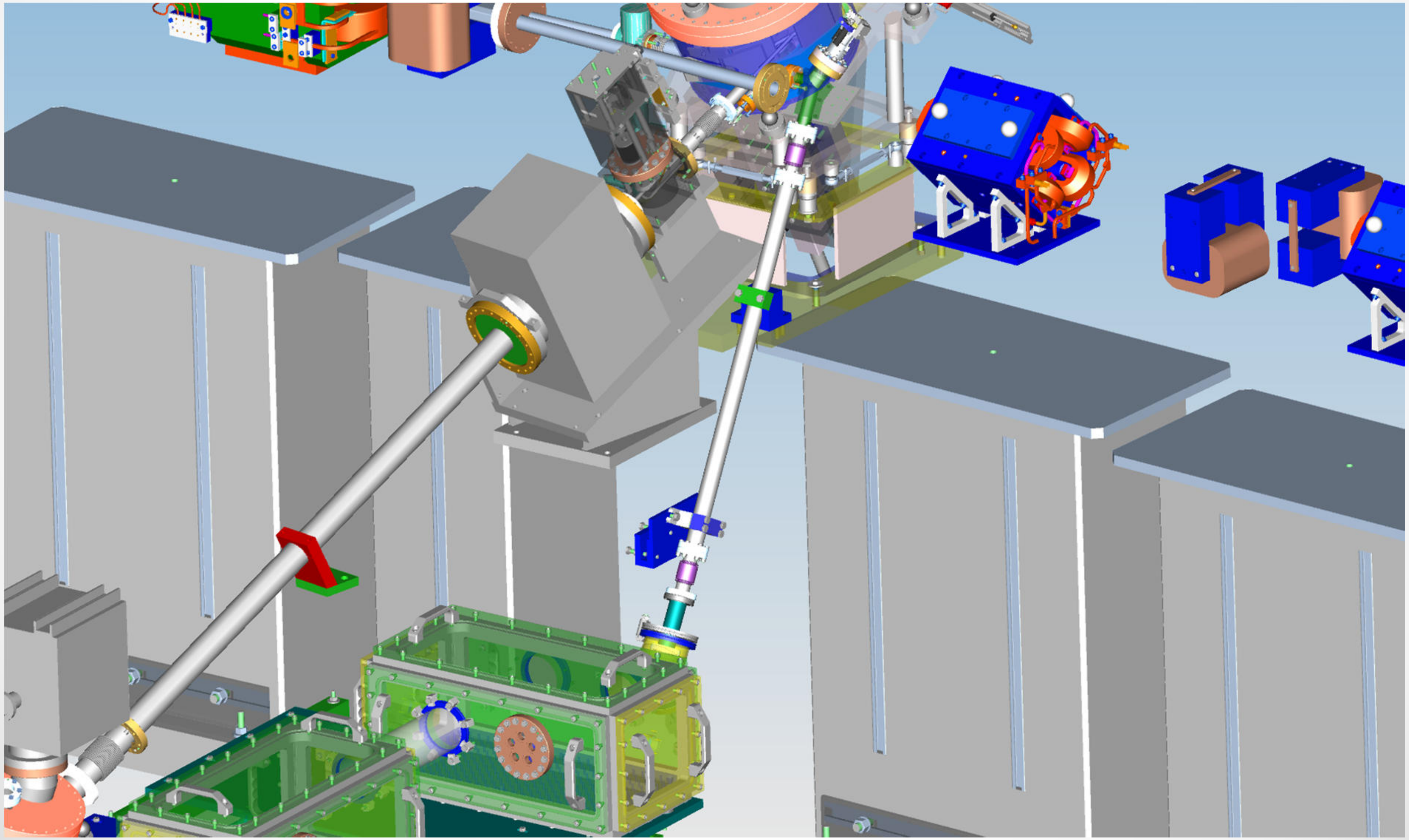
Laser Transport Line



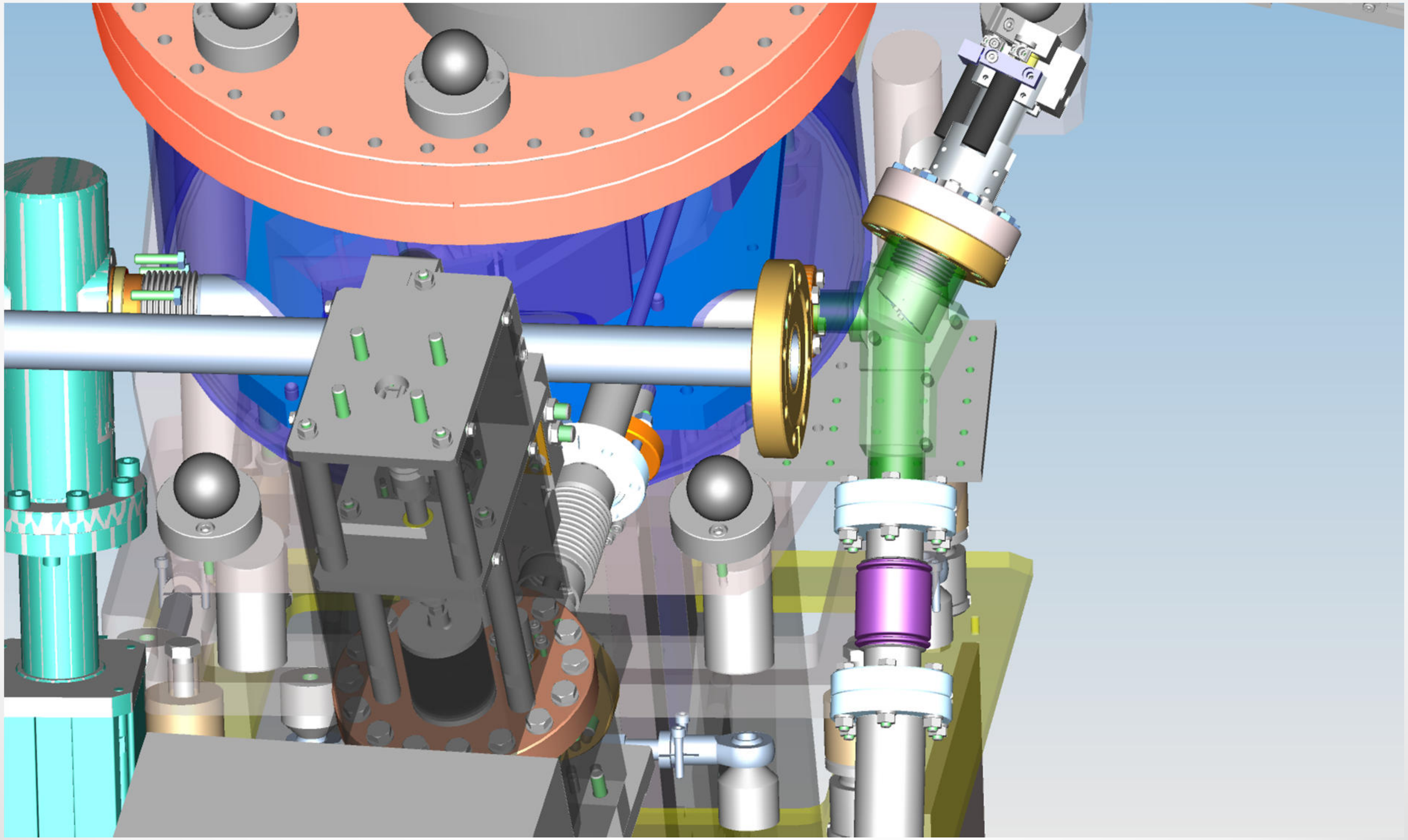
Laser Transport Line



Laser Transport Line



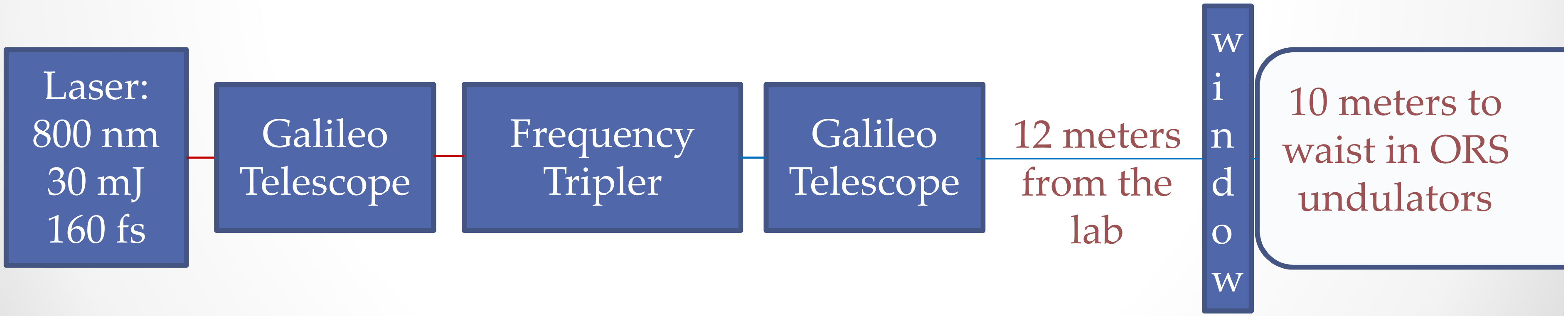
Laser Transport Line



In-vacuum laser transport

"B integral"
Nonlinear phase shift
Should be <1

$$B = \frac{2\pi}{\lambda} \int n_2 \ell(z) dz$$



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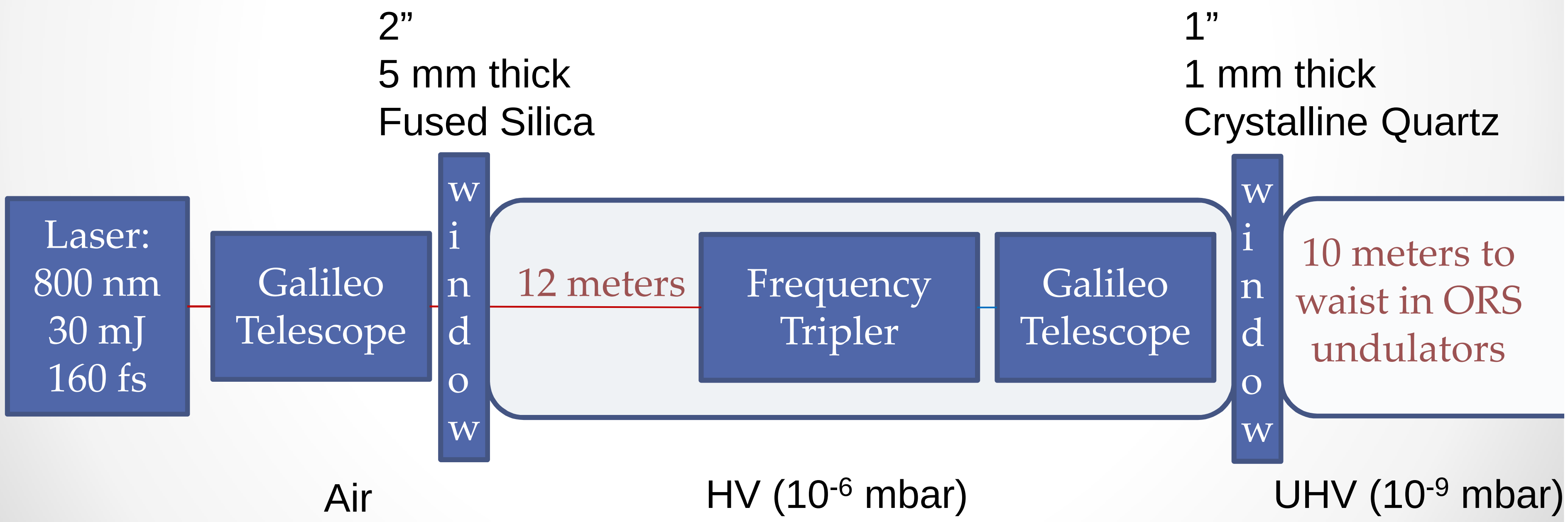
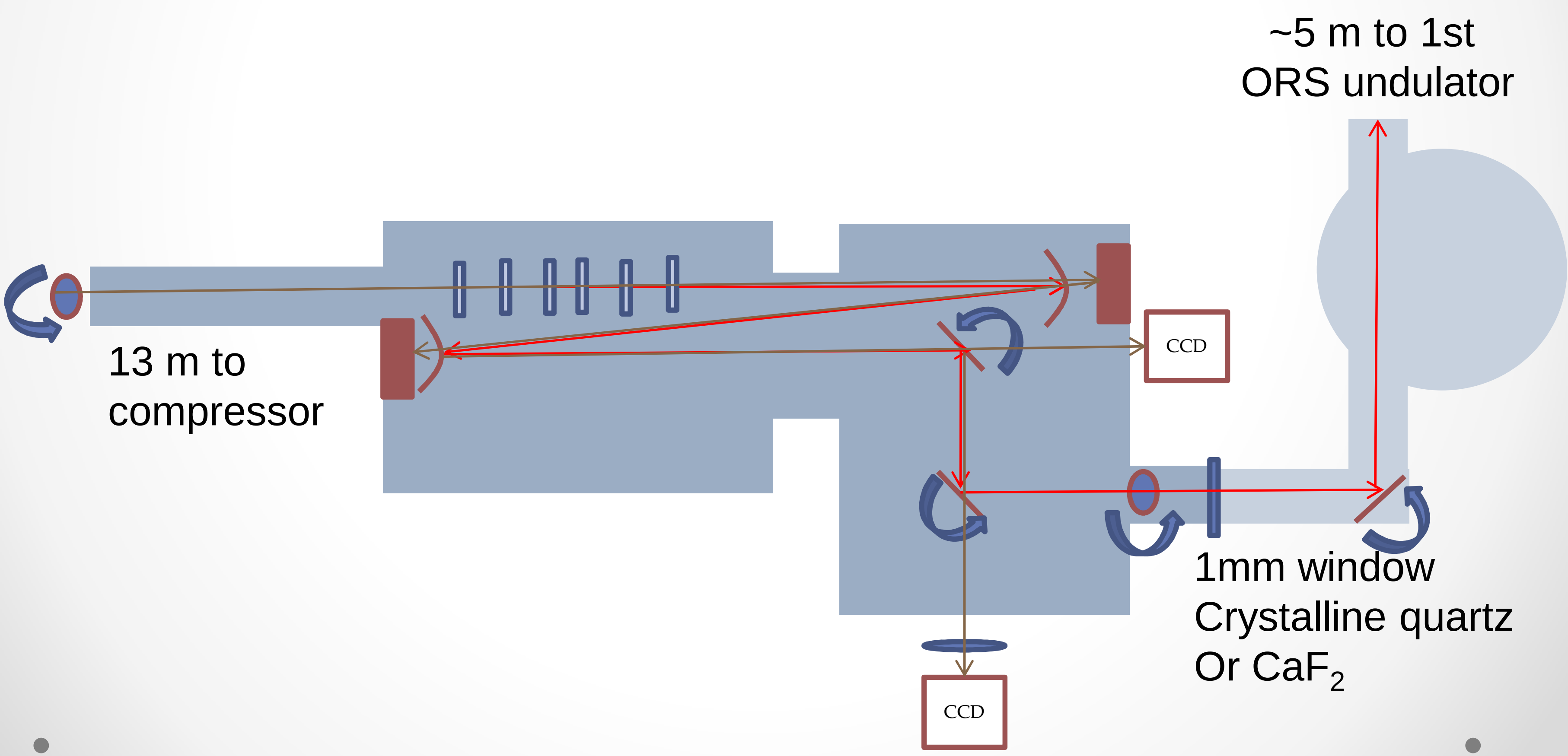
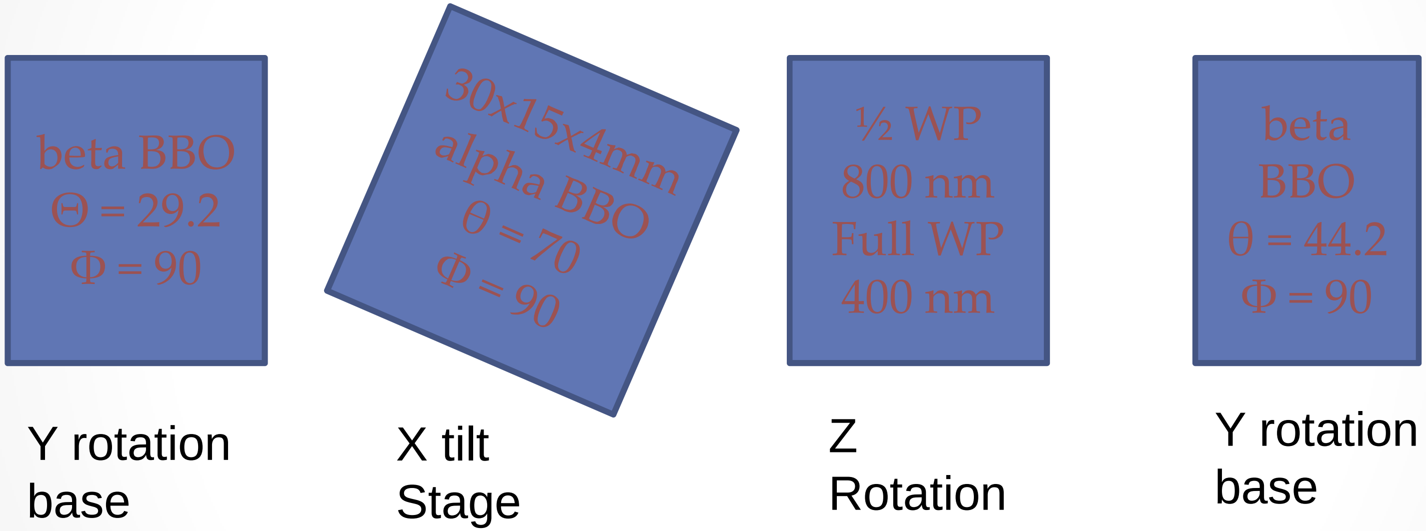


In-vacuum laser path



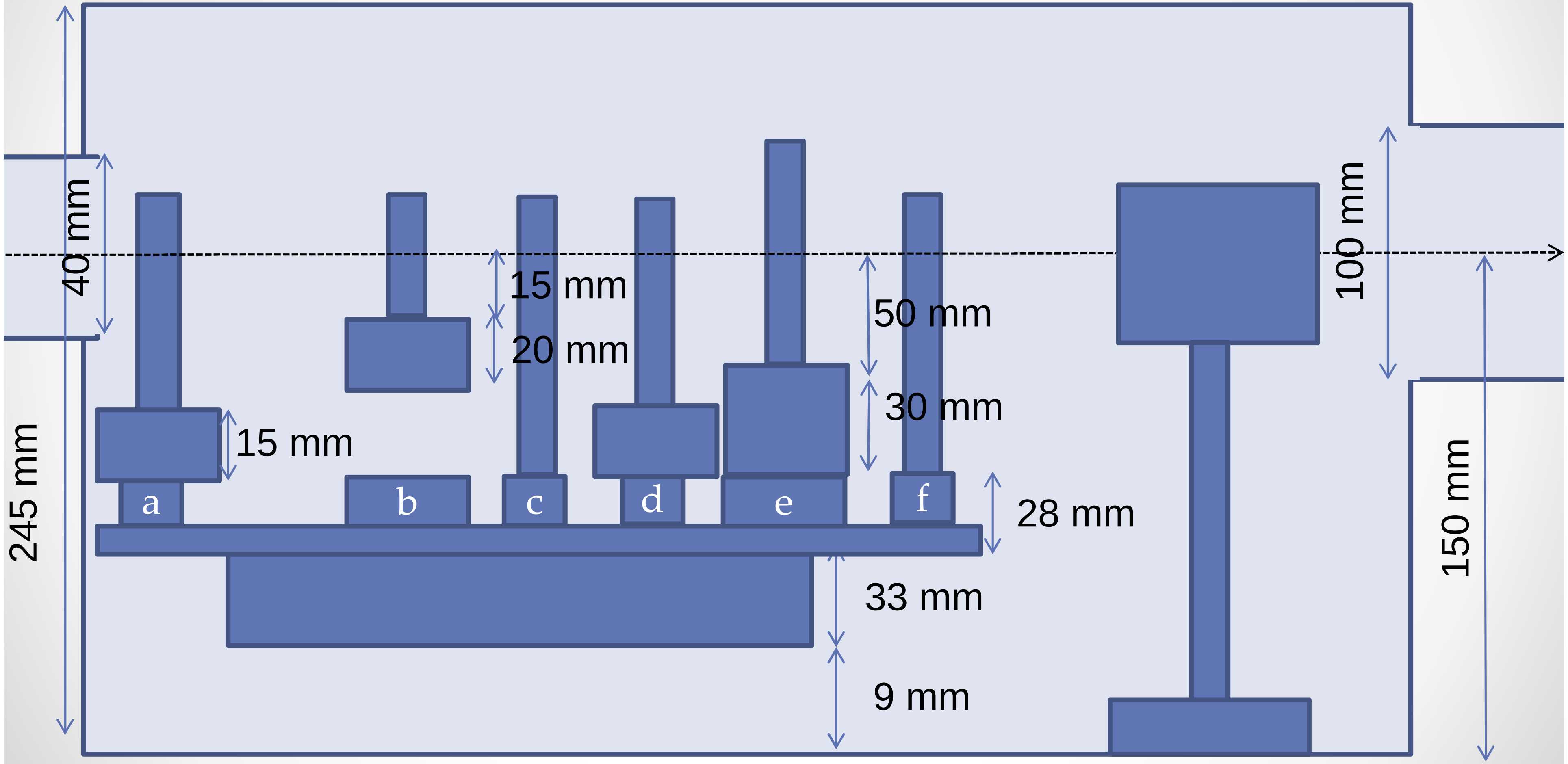
Frequency Tripler

A la Armin

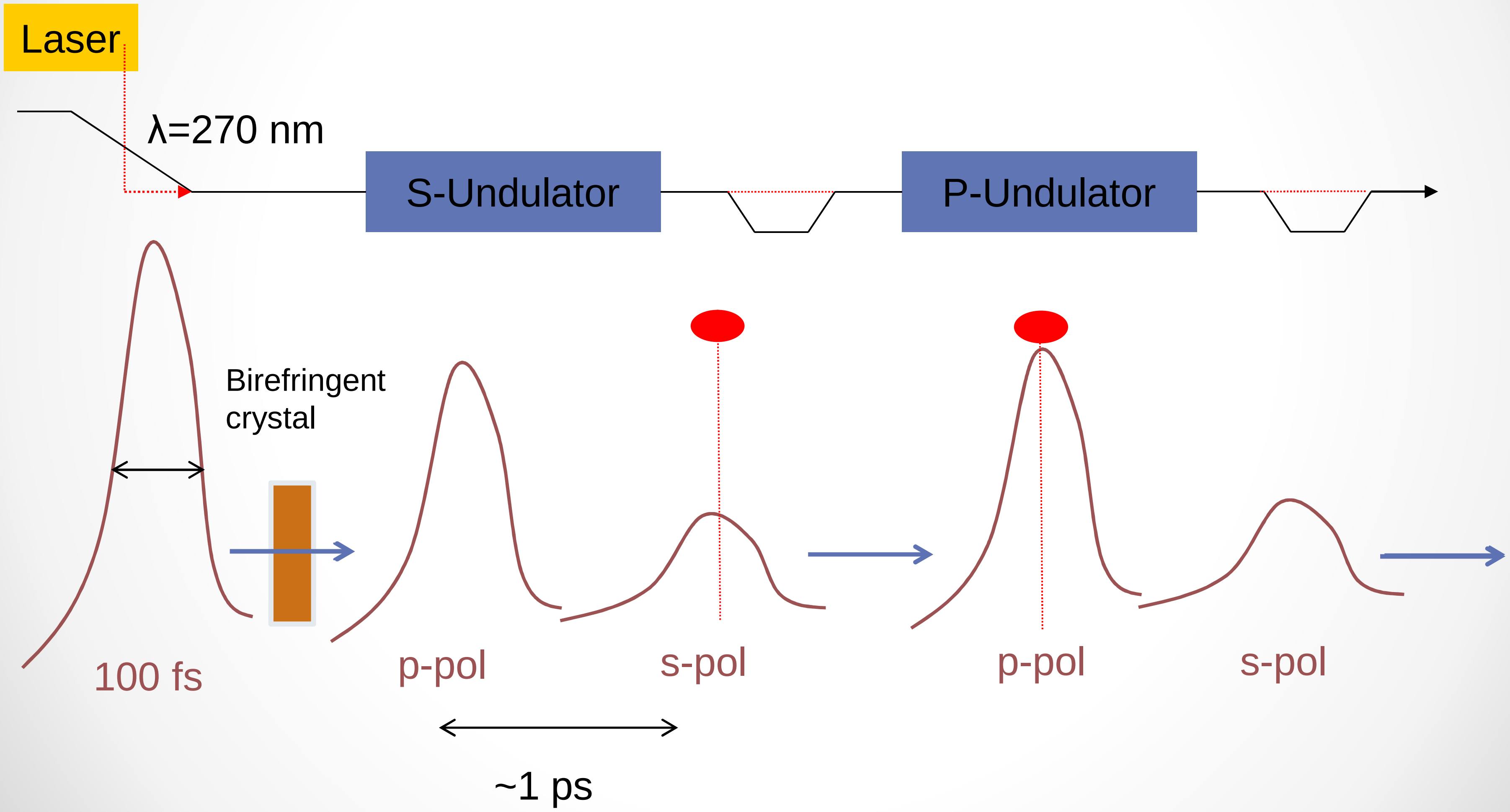


- -21 mm clear aperture
- -Mechanics from Standa
- -Crystals from EKSMA
- -Arrives in September

Side-view of 1st box

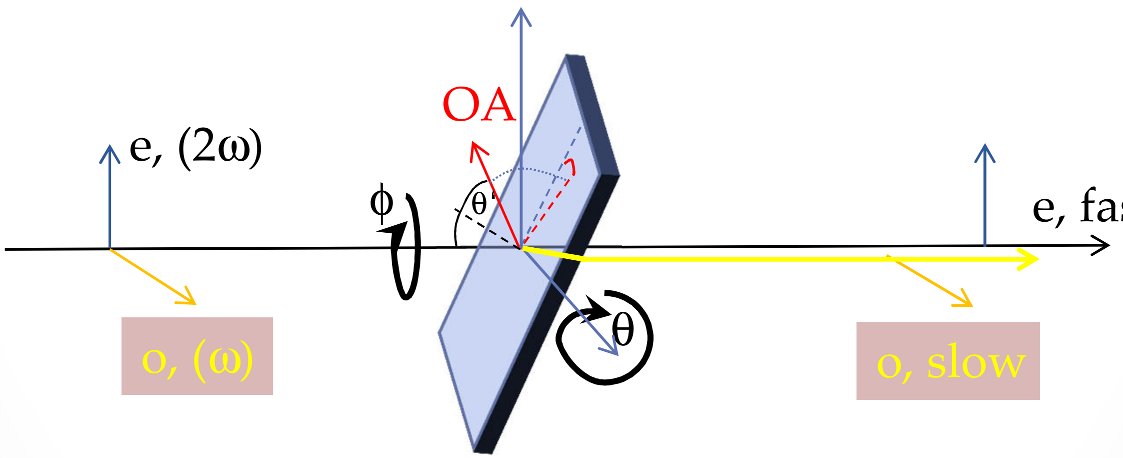


EEHG with one laser

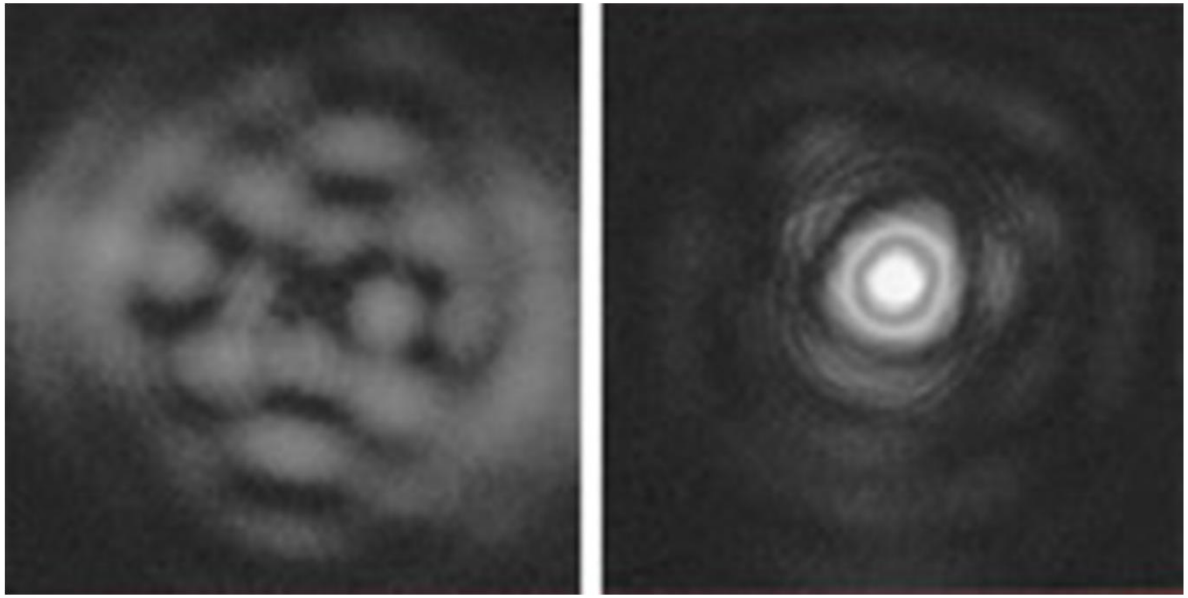


Laser Power Control

Birefringent uniaxial negative crystal with optical axis (OA)



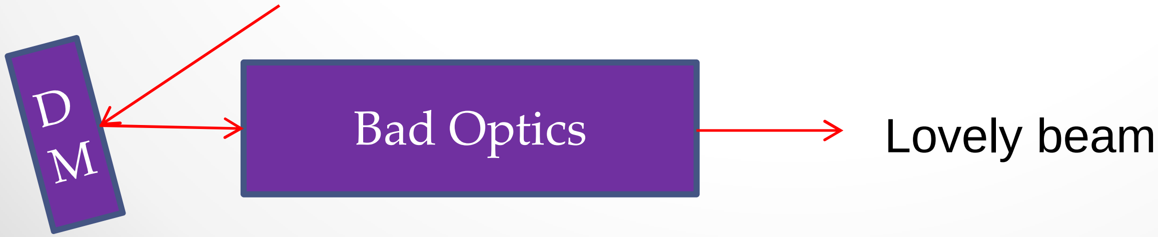
Laser Wavefront Control



Before

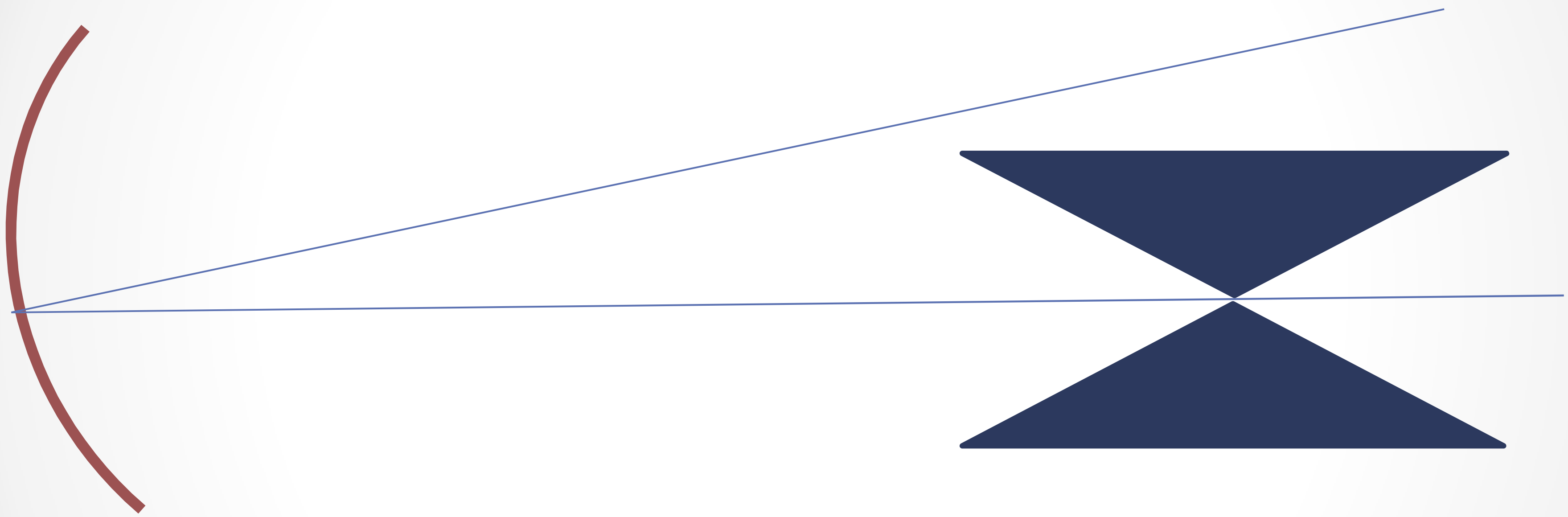
After

Large-scale distortions => Adaptive optics



Laser Wavefront Control

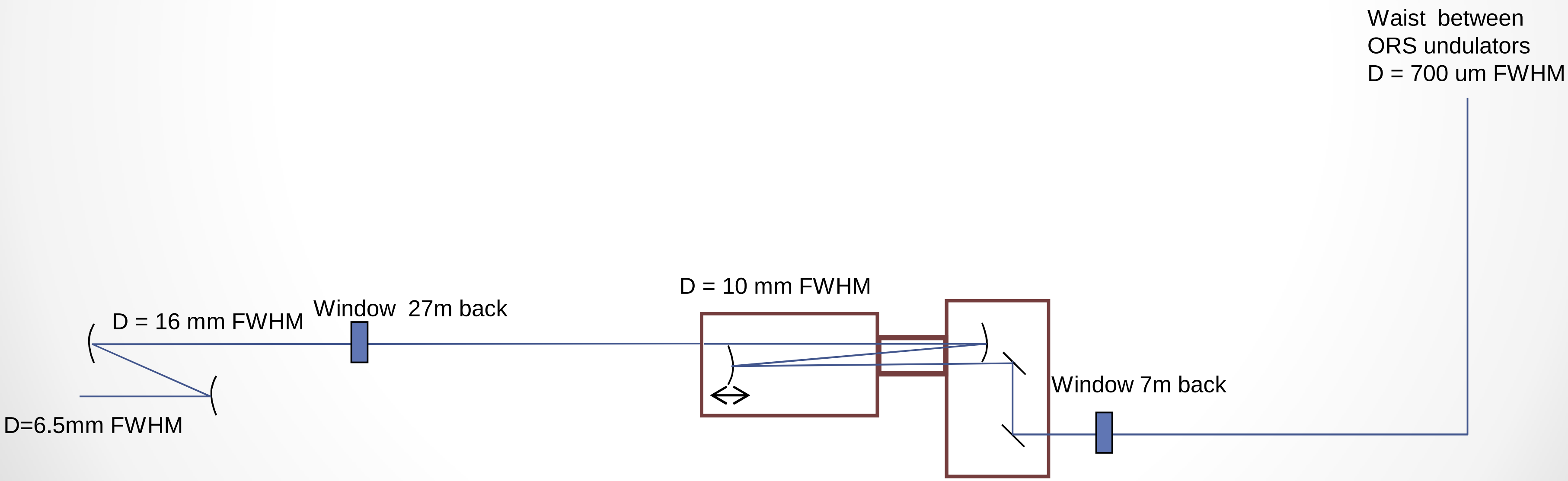
Microscopic distortions =>Spatial filter



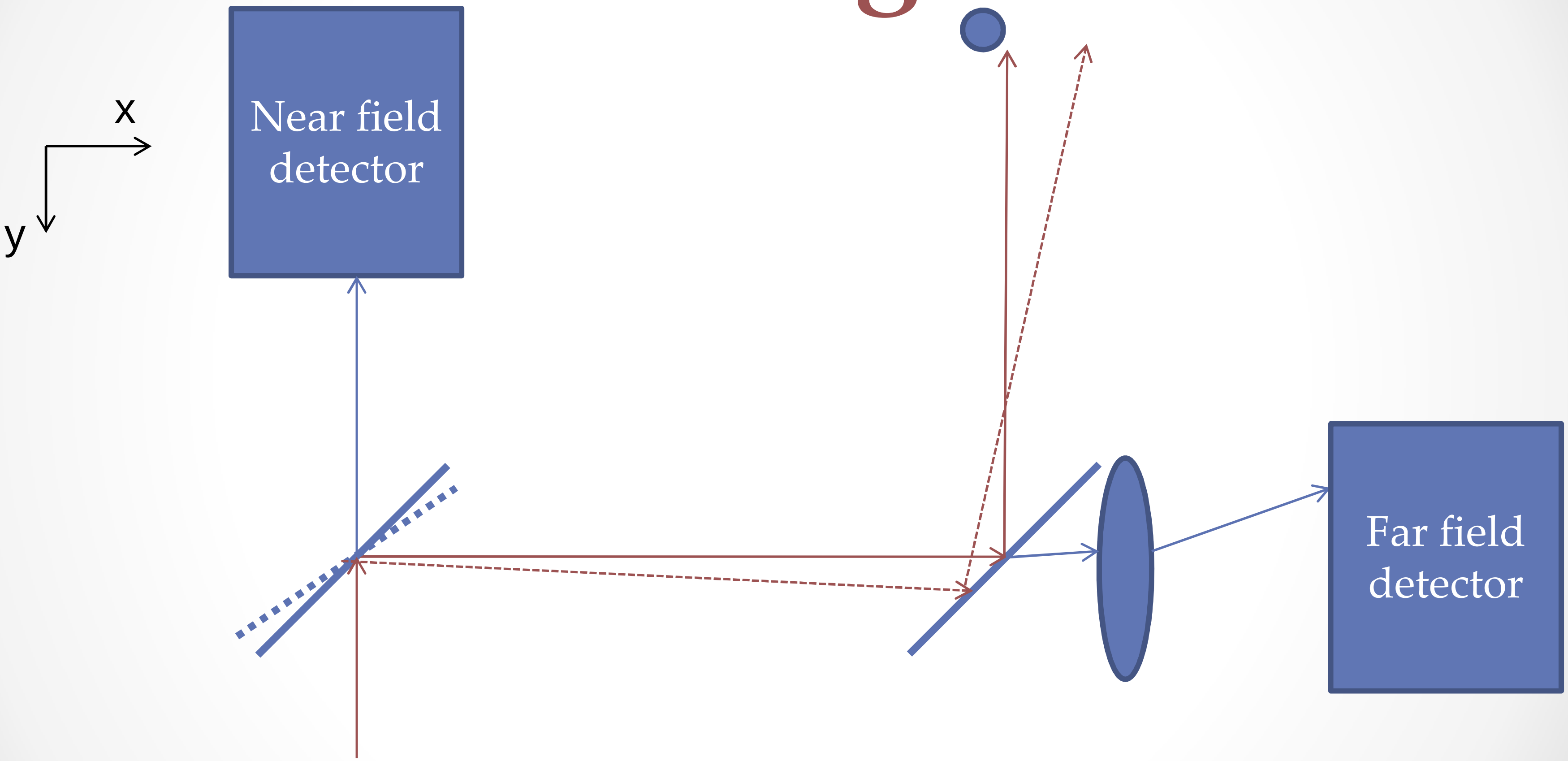
Dielectric conical filtering hole at diffraction limit
-50% losses
-intensity jitter increases due to pointing jitter
-pointing jitter -> fast steering feedback

Laser Waist Control

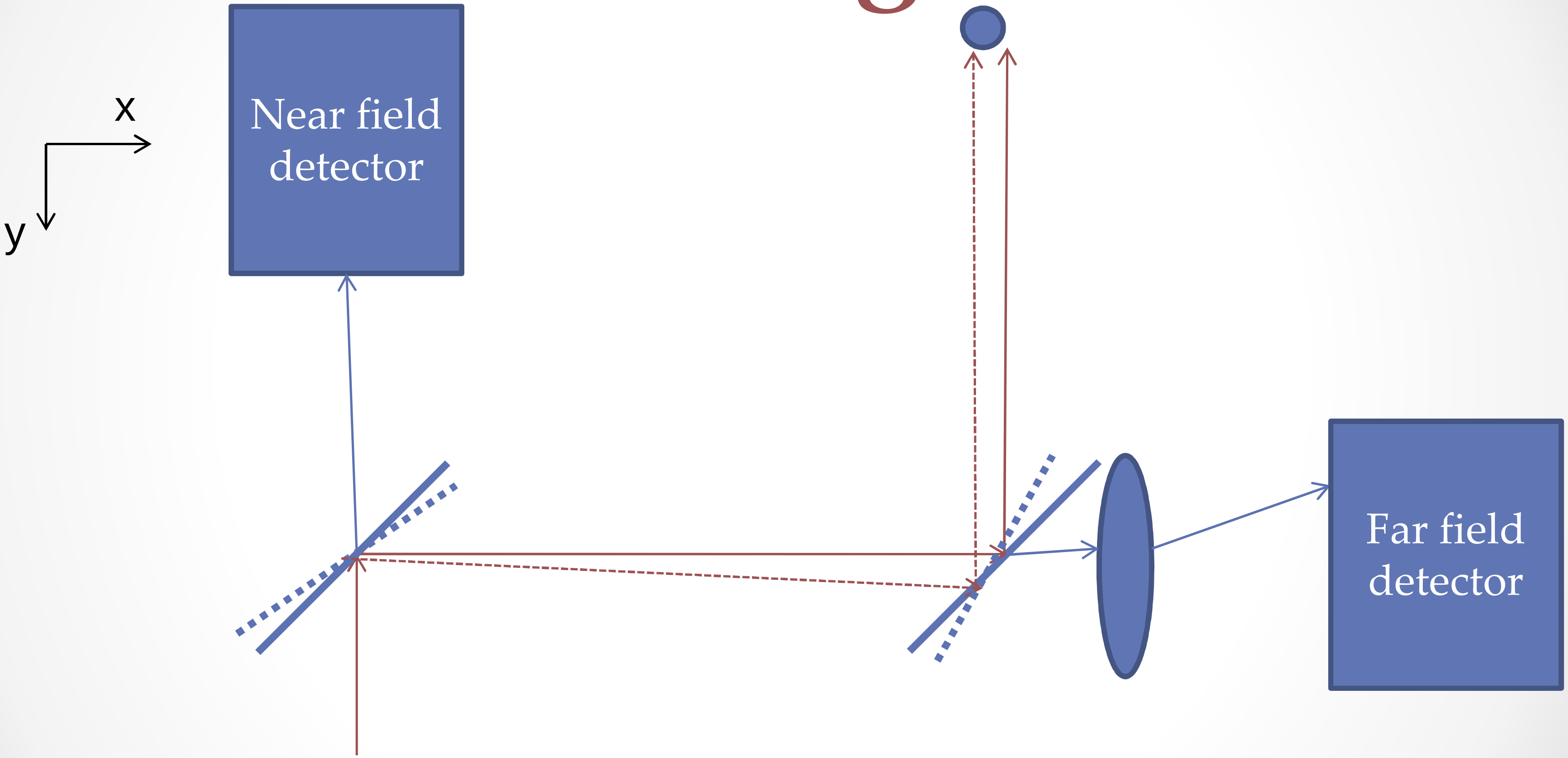
- 10 mm waist in tripler
- 700 um waist in between undulators



Laser Steering Control



Laser Steering Control



Experiment checklist:

- ✓ 30 mJ laser
- ✓ undulators and chicanes
- ✓ laser/e-beam diagnostics
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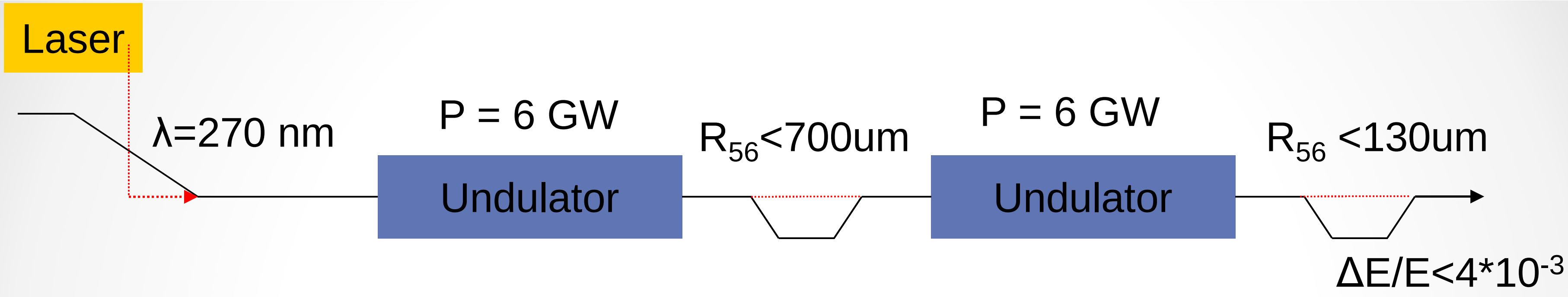
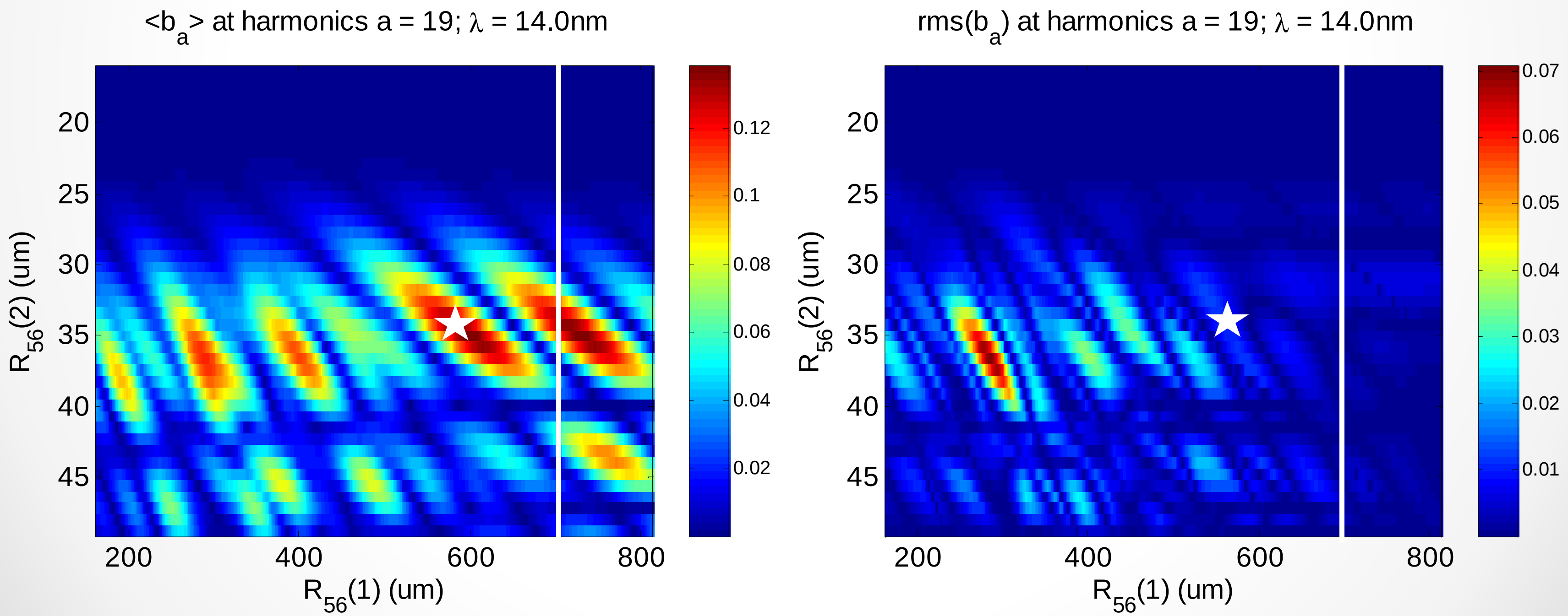
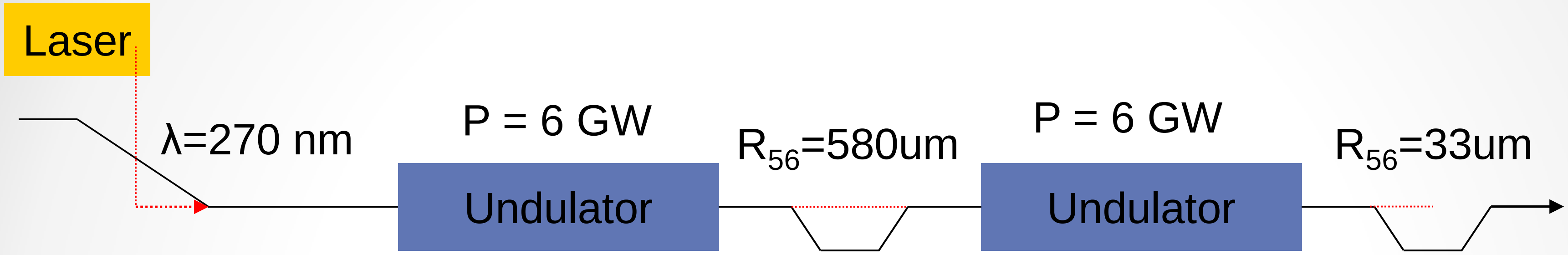
14 nm @ 1.15 GeV

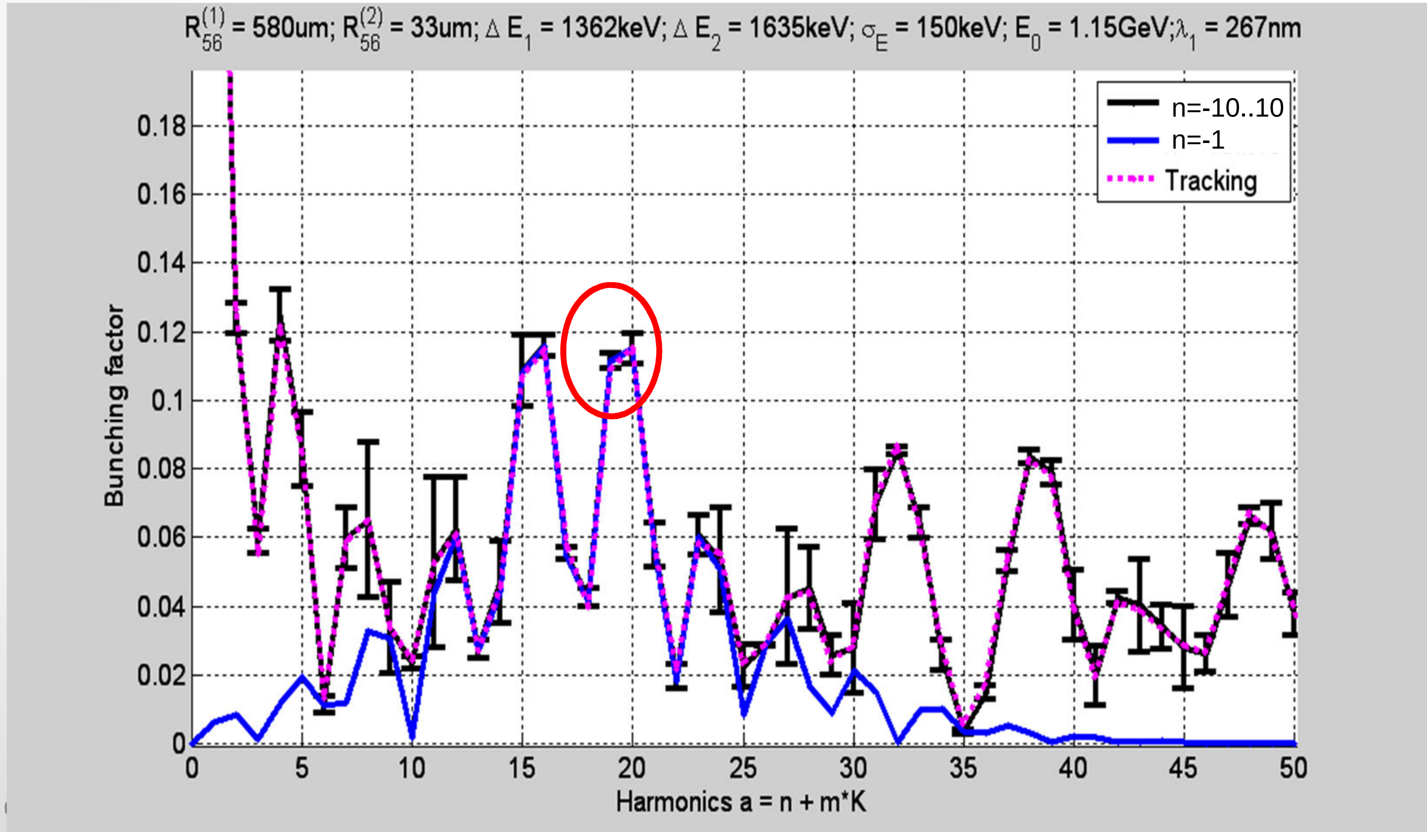

Laser
λ=270 nm
P = 6 GW
Undulator
R56<700um
P = 6 GW
Undulator
R56 <130um
ΔE/E<4*10-3


<ba> at harmonics a = 19; λ = 14.0nm
rms(ba) at harmonics a = 19; λ = 14.0nm
R56(2) (um)
20
25
30
35
40
45
200
400
600
800
R56(1) (um)
0.12
0.1
0.08
0.06
0.04
0.02
0.07
0.06
0.05
0.04
0.03
0.02
0.01

14 nm @ 1.15 GeV



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



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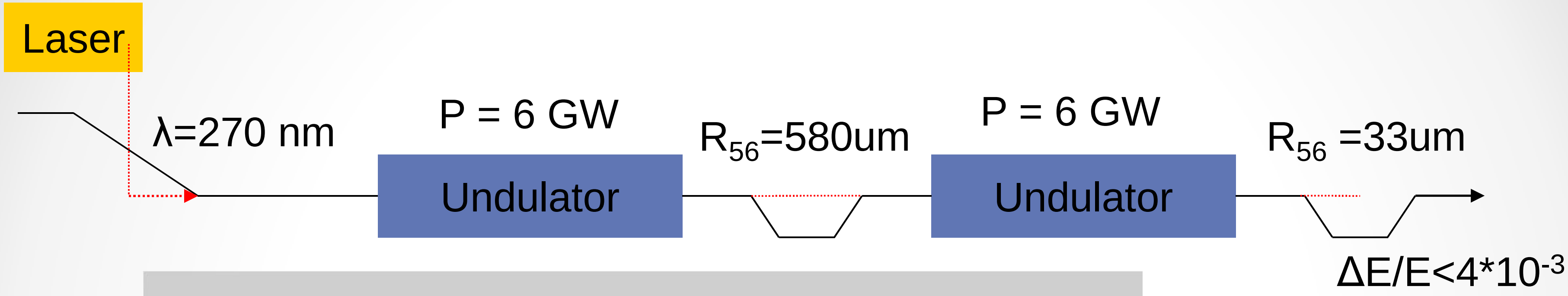
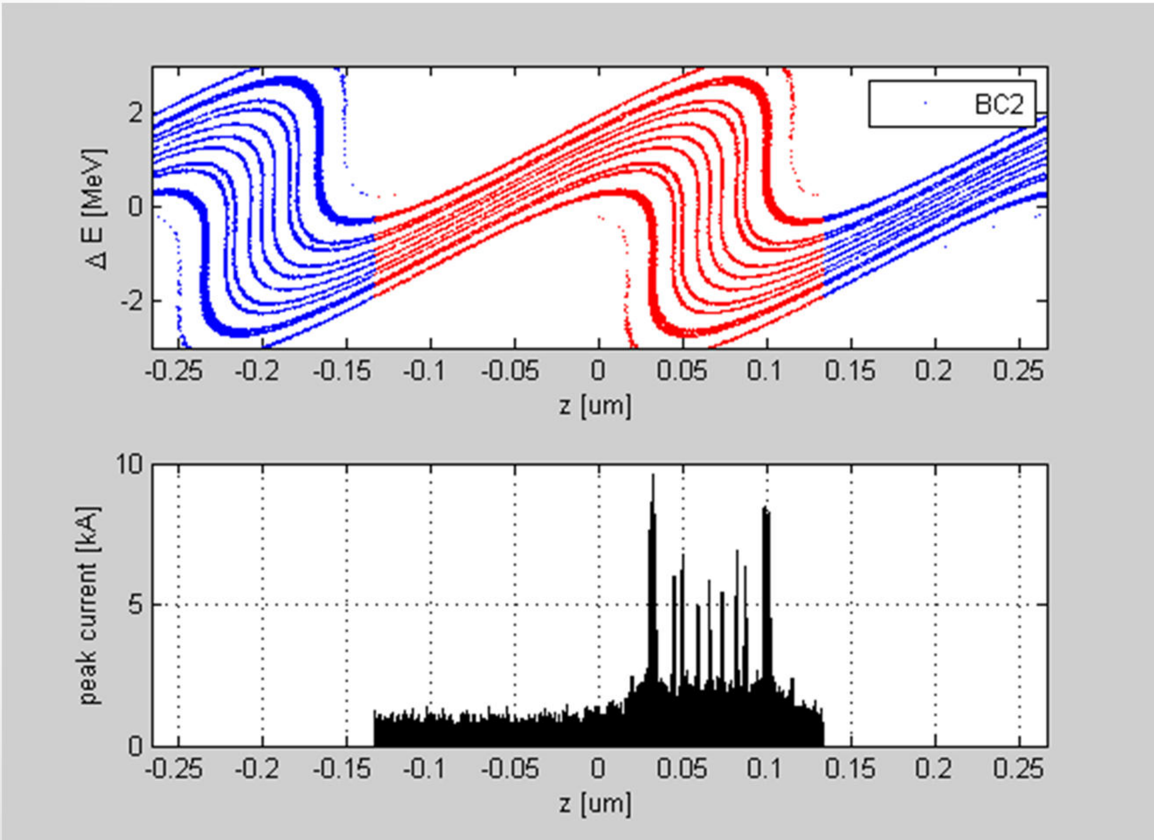
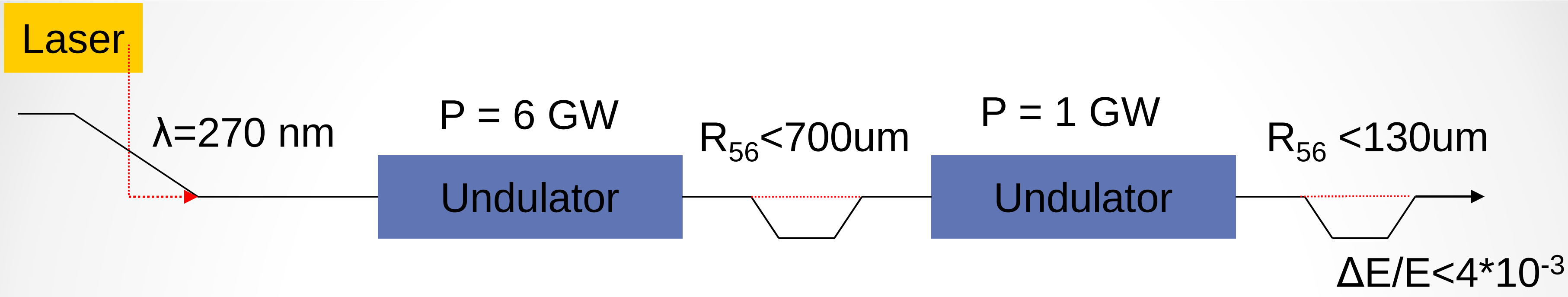


Laser
λ=270 nm
P = 6 GW
Undulator
R56=580um
P = 6 GW
Undulator
R56 =33um
ΔE/E<4*10-3



BC2
Δ E [MeV]
2
0
-2
-0.25
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
z [um]
peak current [kA]
10
5
0
-0.25
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
z [um]

14 nm @ 1.15 GeV


Laser
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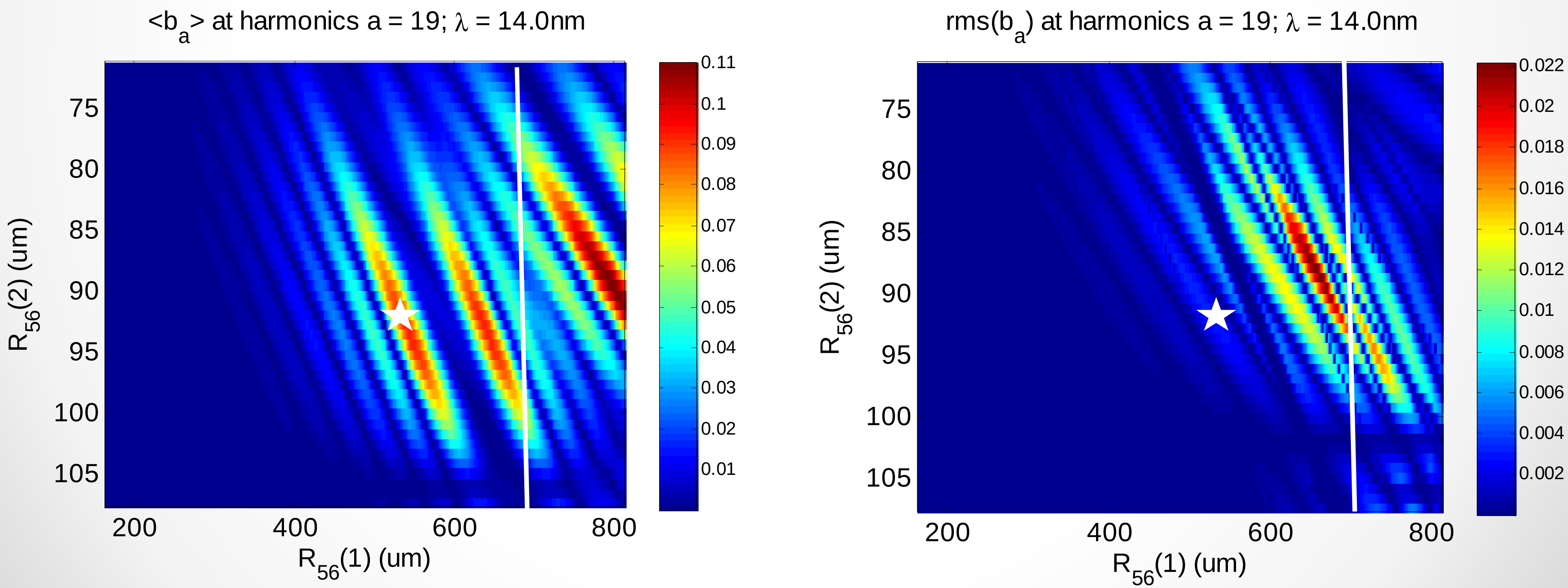
Undulator
R56<700um
P = 1 GW
Undulator
R56 <130um
ΔE/E<4*10-3


<ba> at harmonics a = 19; λ = 14.0nm
R56(2) (um)
R56(1) (um)
rms(ba) at harmonics a = 19; λ = 14.0nm
R56(2) (um)
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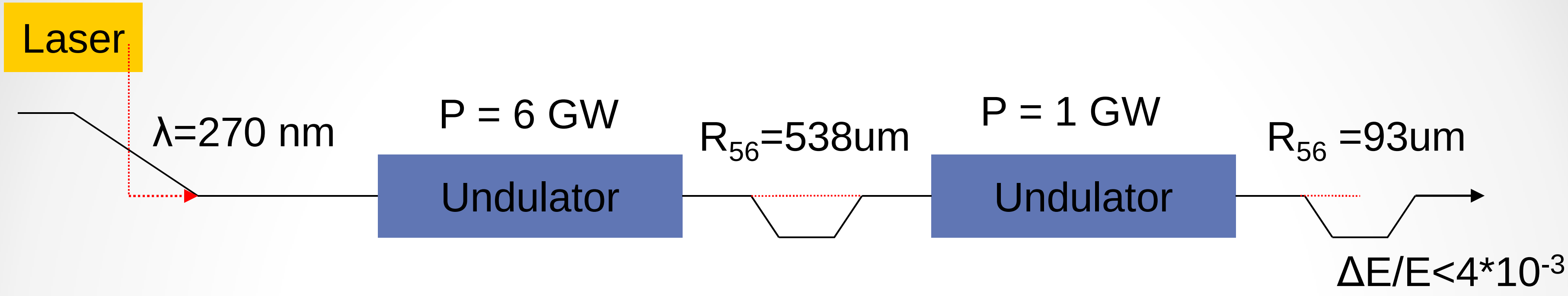
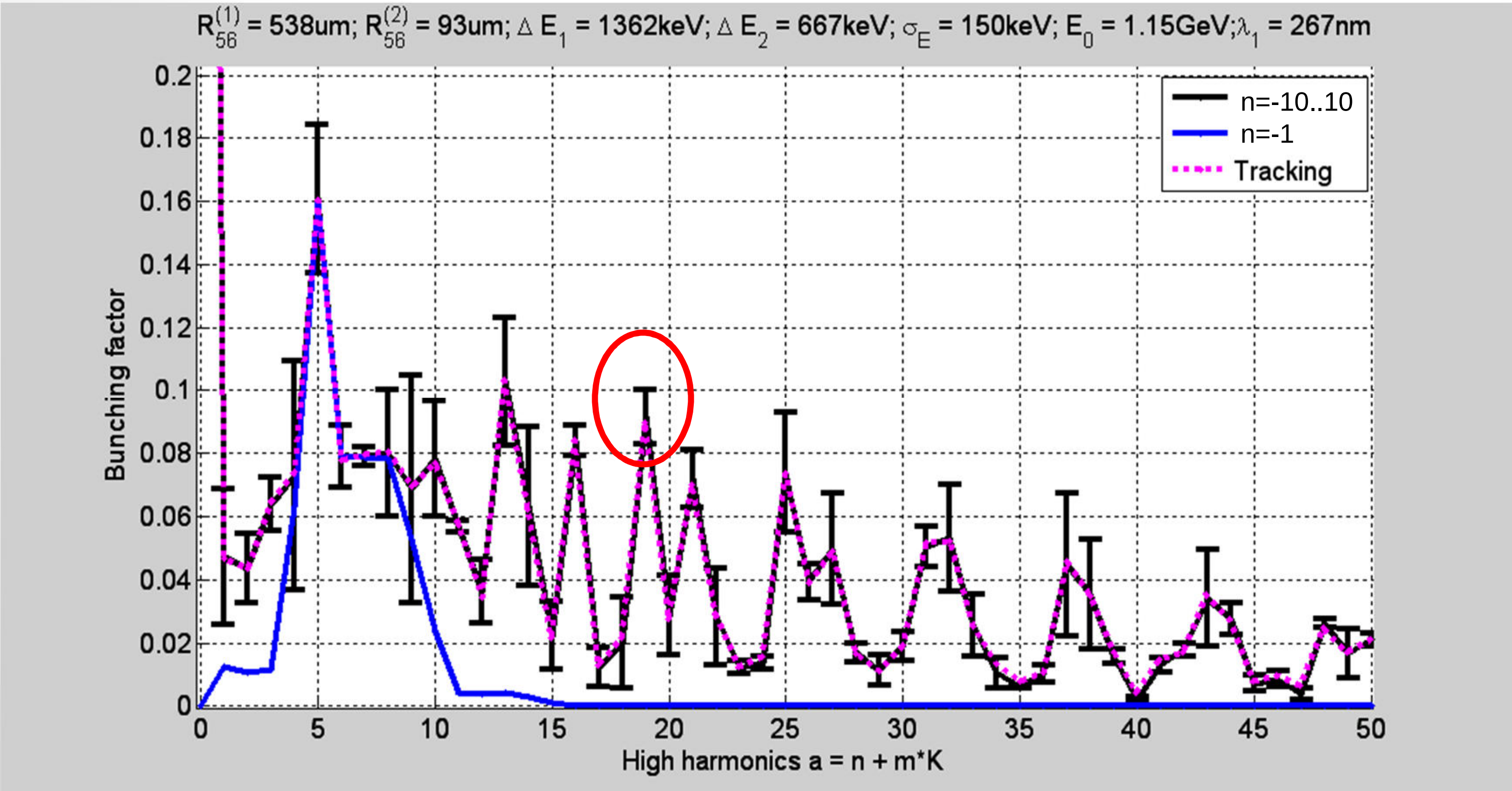
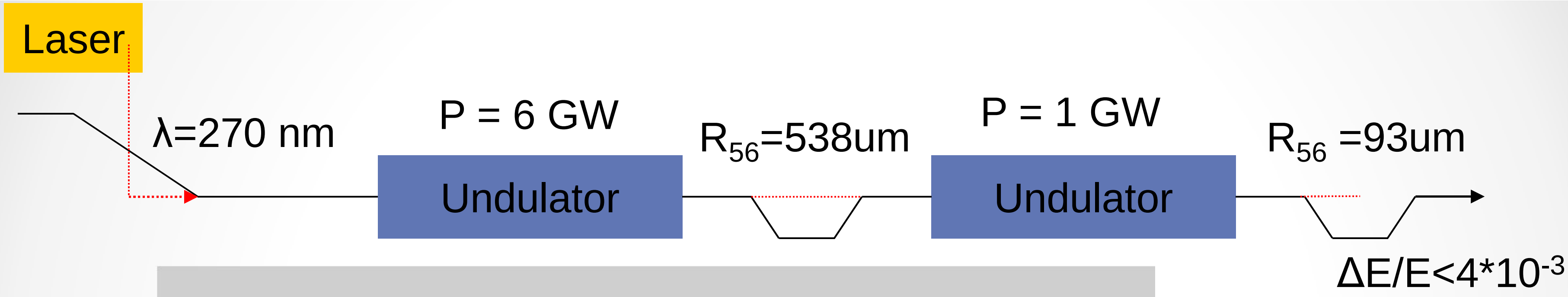
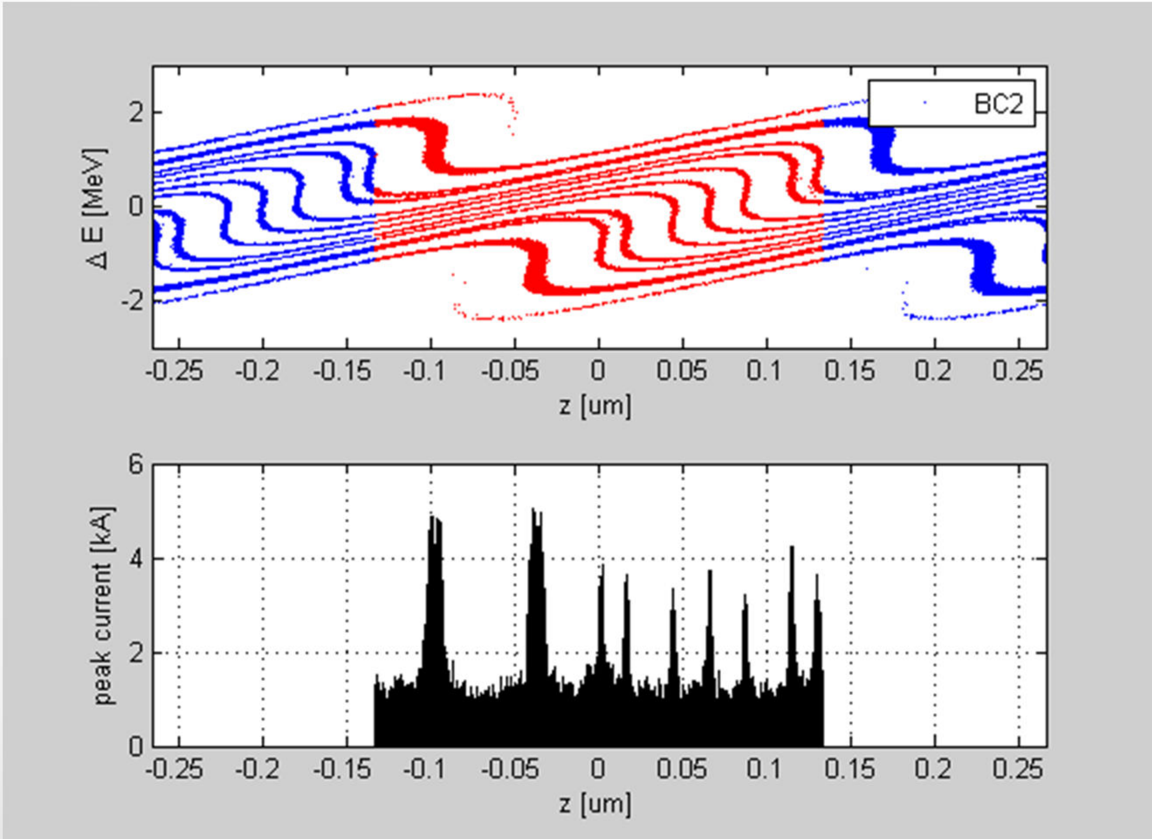
14 nm @ 1.15 GeV


Laser
λ=270 nm
P = 6 GW
Undulator
R56=538um
P = 1 GW
Undulator
R56 =93um
ΔE/E<4*10-3


R56(1) = 538um; R56(2) = 93um; Δ E1 = 1362keV; Δ E2 = 667keV; σE = 150keV; E0 = 1.15GeV;λ1 = 267nm
Bunching factor
High harmonics a = n + m*K
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
5
10
15
20
25
30
35
40
45
50
n=-10..10
n=-1
Tracking

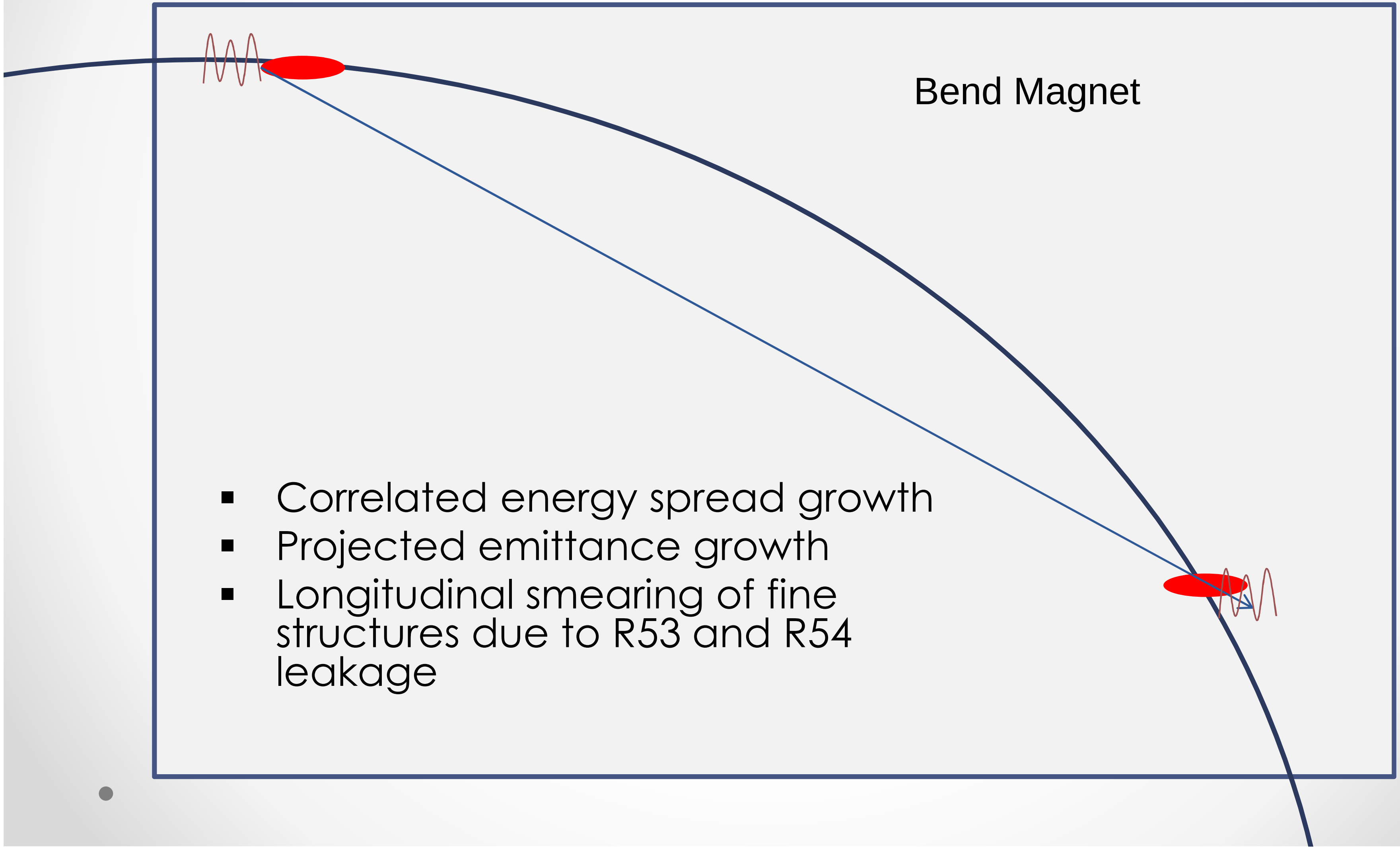
14 nm @ 1.15 GeV


Laser
λ=270 nm
P = 6 GW
Undulator
R56=538um
P = 1 GW
Undulator
R56 =93um
ΔE/E<4*10-3


BC2
Δ E [MeV]
z [um]
peak current [kA]
z [um]

CSR wakes

Coherent Synchrotron Radiation

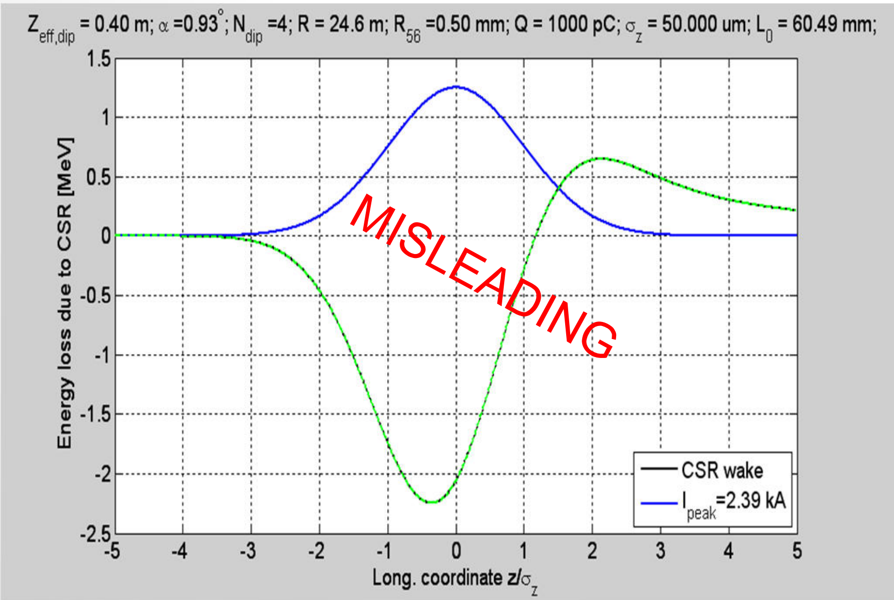


- Correlated energy spread growth
- Projected emittance growth
- Longitudinal smearing of fine structures due to R53 and R54 leakage

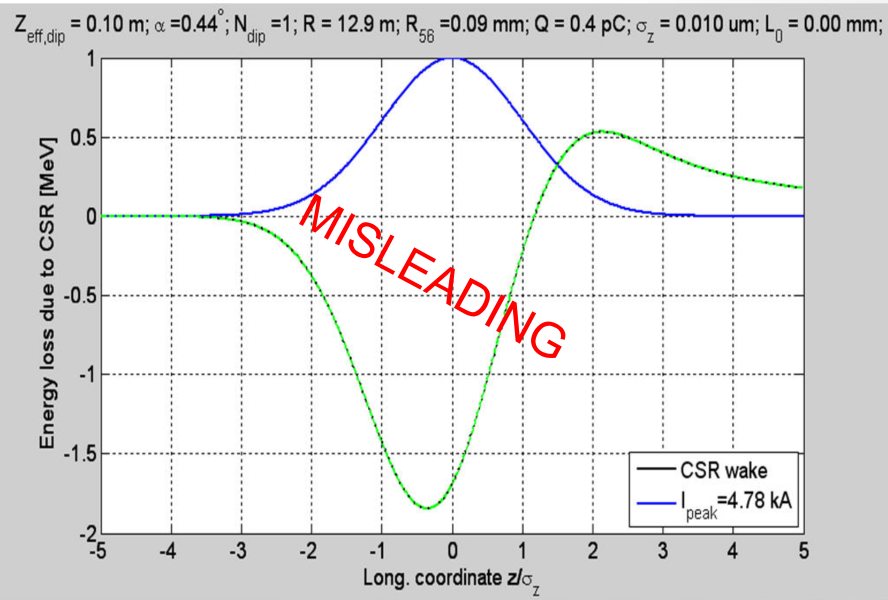
CSR wakes

Coherent Synchrotron Radiation

1-D macro bunch
In first chicane

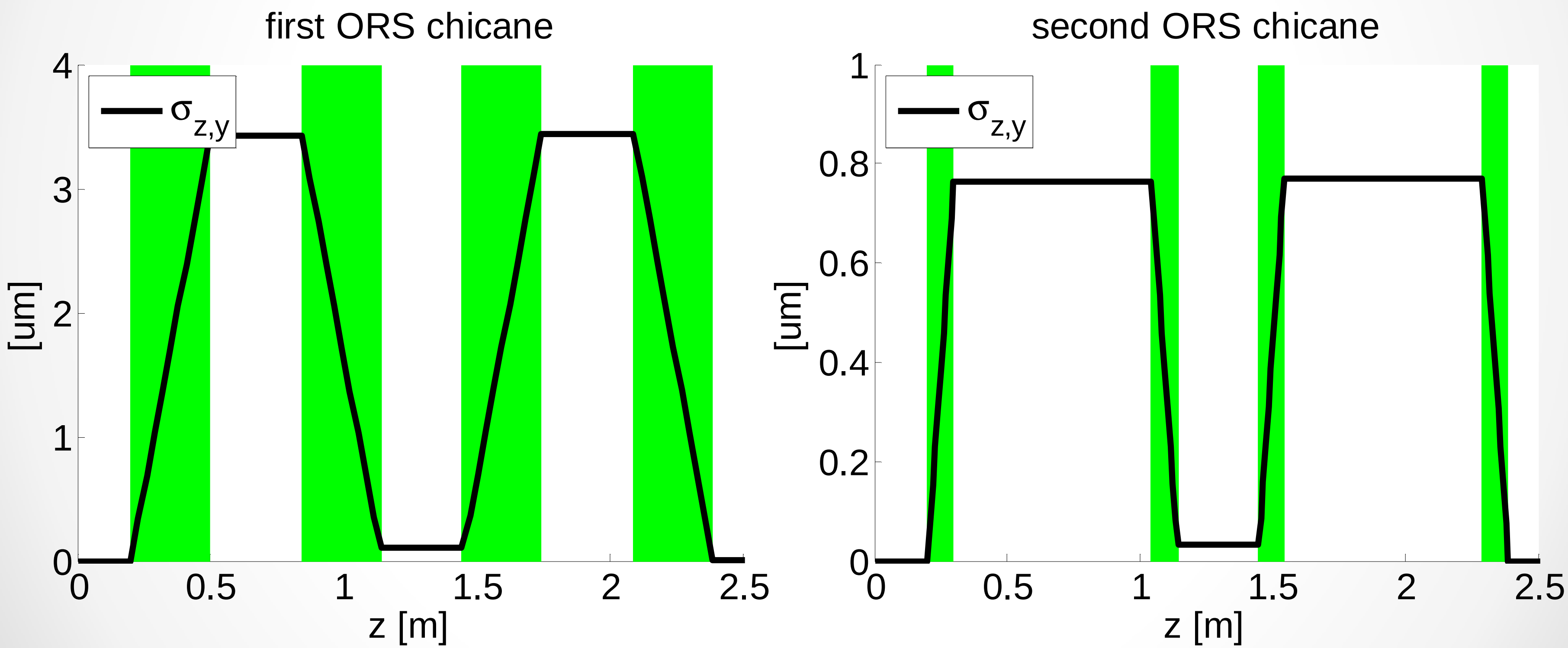


1-D micro bunch
In last chicane



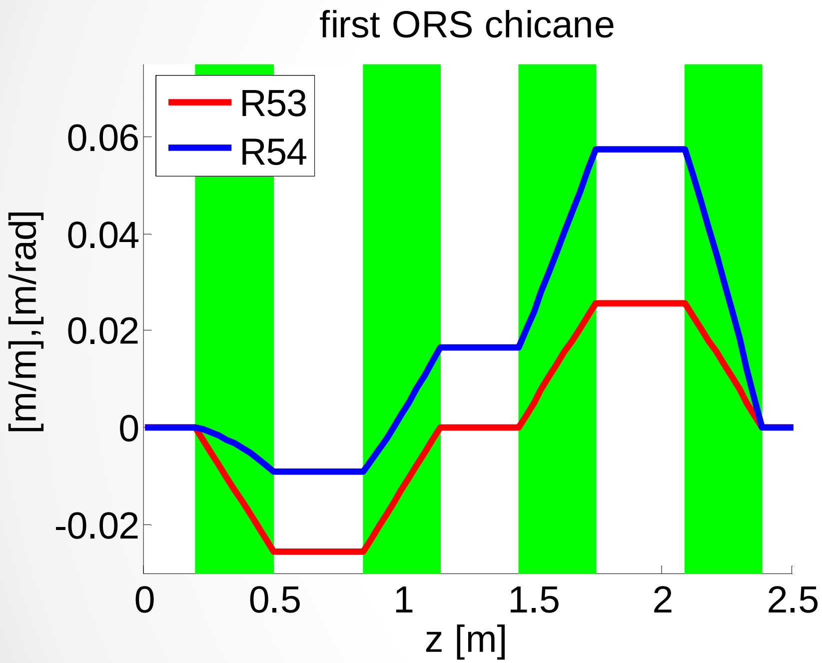
R_{53} & R_{54} smearing out spikes

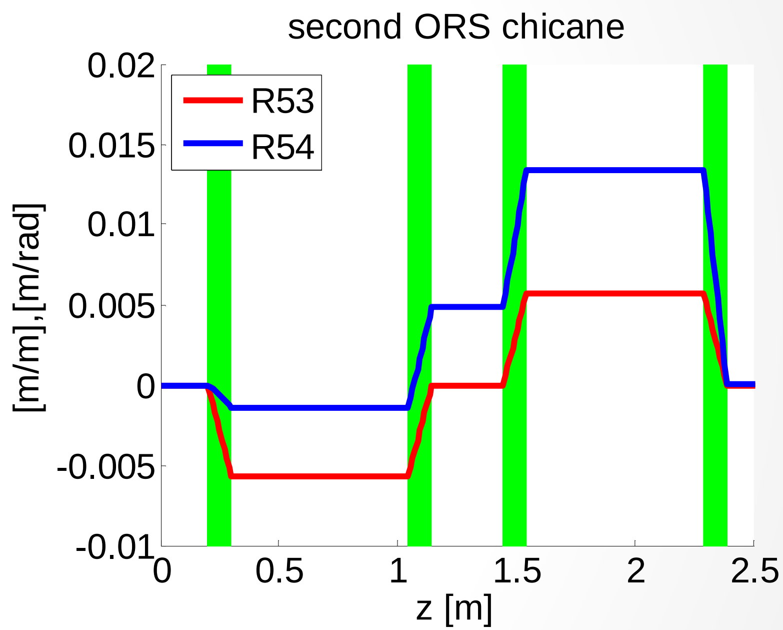
$\sigma_{z,y}^2 = R_{53}^2 \sigma_y^2 + R_{54}^2 \sigma_{y'}^2$



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

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





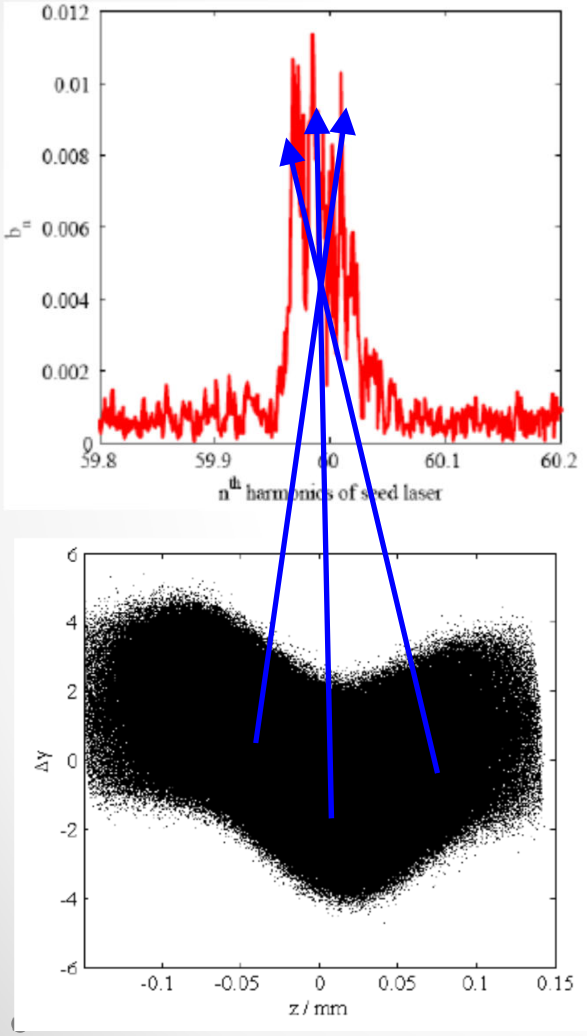
$\sim \exp(k^2 R_{53}^2 \sigma_y^2/2)$

$\Rightarrow$ 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%

CSR -> bunching factor

ORS EEHG wakes are same magnitude as FLASH II wakes for 20th harmonic scheme



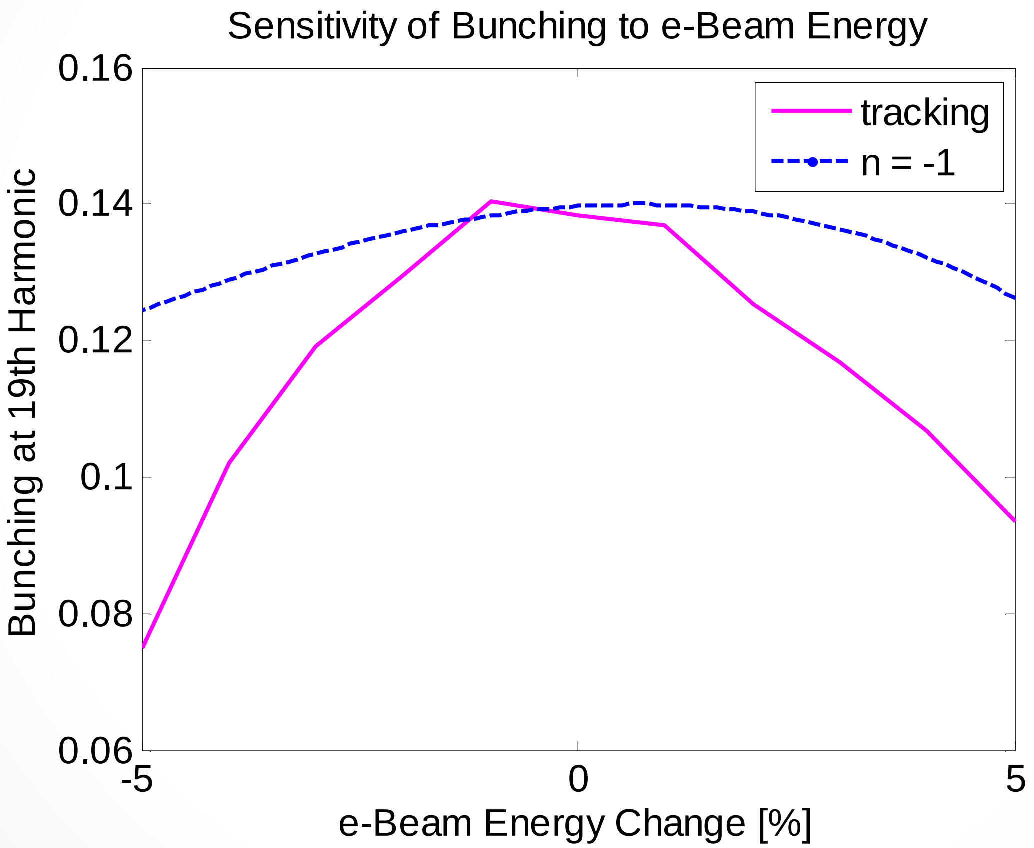
CSRtrack/Elegant=> 50% reduction in bunching

Interpretation?
R53, R54 leakage or something else?

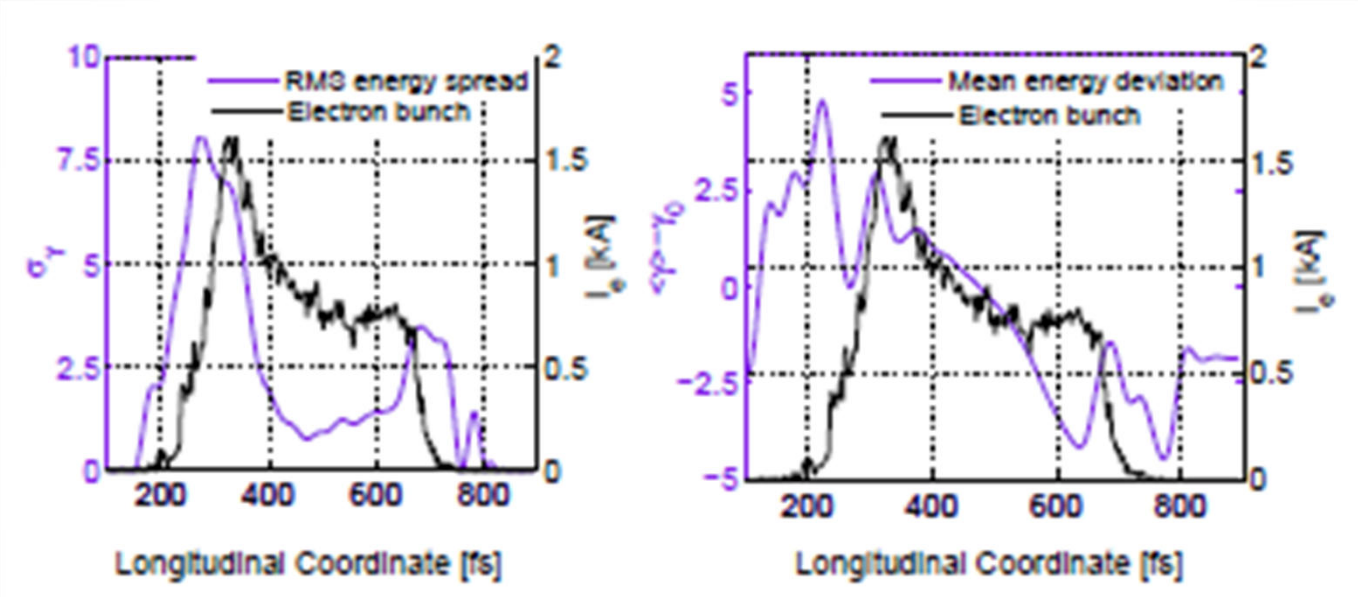
"different parts of the electron beam shift to different microbunching wavelength.
Thus, the projected microbunching bandwidth is broadened and the bunching factor is degraded."

Plot from Deng
FEL beam dynamics seminar
Dec 06

Beam Energy Sensitivity



Actual Electron Beam

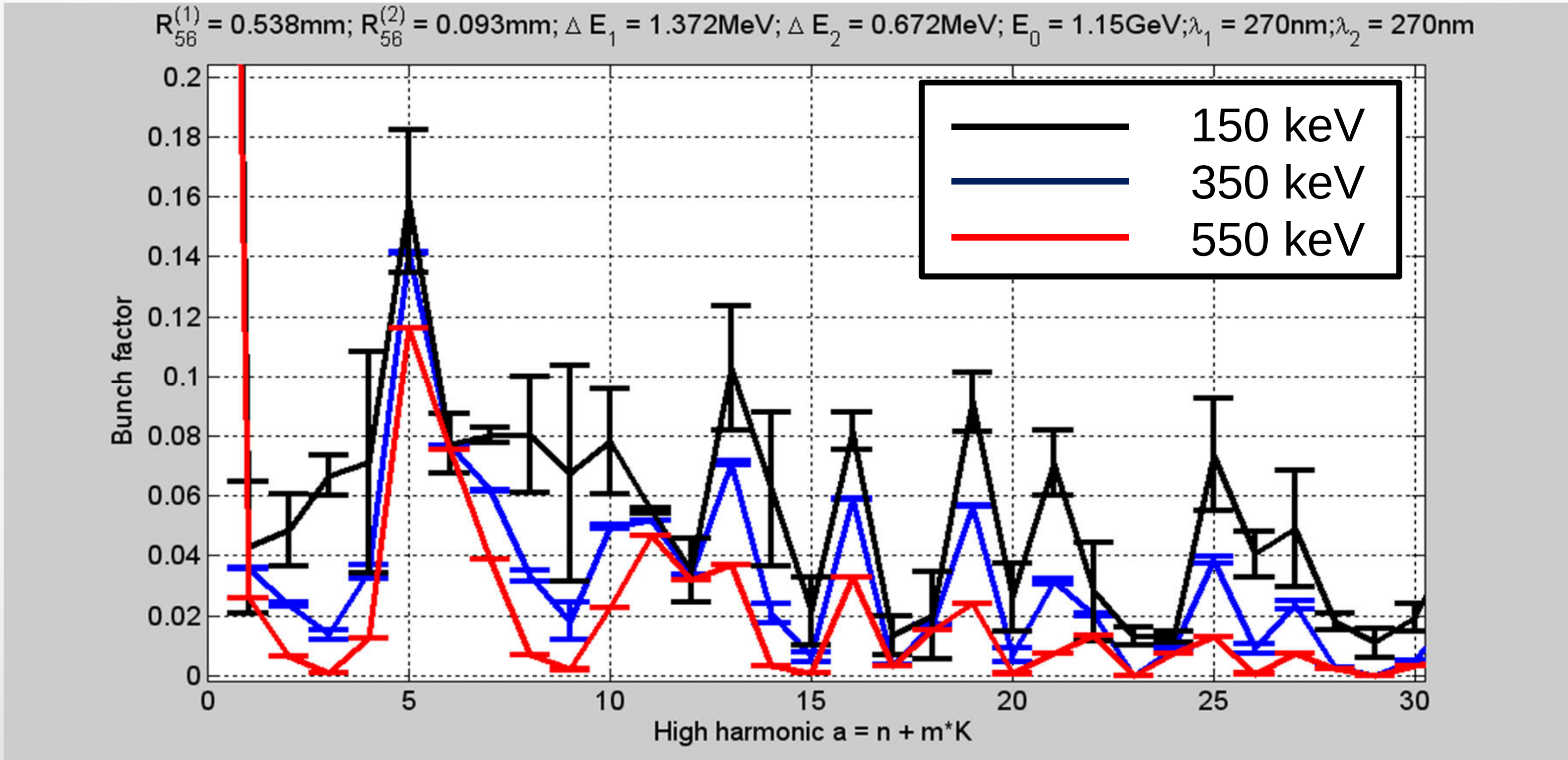


FEMTOSECOND RESOLVED DETERMINATION OF ELECTRON BEAM AND XUV SEED PULSE TEMPORAL OVERLAP IN sFLASH*

R. Tarkeshian†, A. Azima, J. Bödewadt, F. Curbis, M. Drescher, M. Mittenzwey, T. Maltezopoulos, H. Delsim-Hashemi, V. Miltchev, J. Rönsch-Schulenburg, J. Rossbach, Hamburg University, Hamburg, Germany
K. Honkavaara, T. Laarmann, H. Schlarb, S. Schreiber, DESY, Hamburg, Germany
R. Ischebeck, PSI, Villigen, Switzerland

Large Slice Energy Spread

Lower bunching factor
Lower peak current
Lower phase sensitivity



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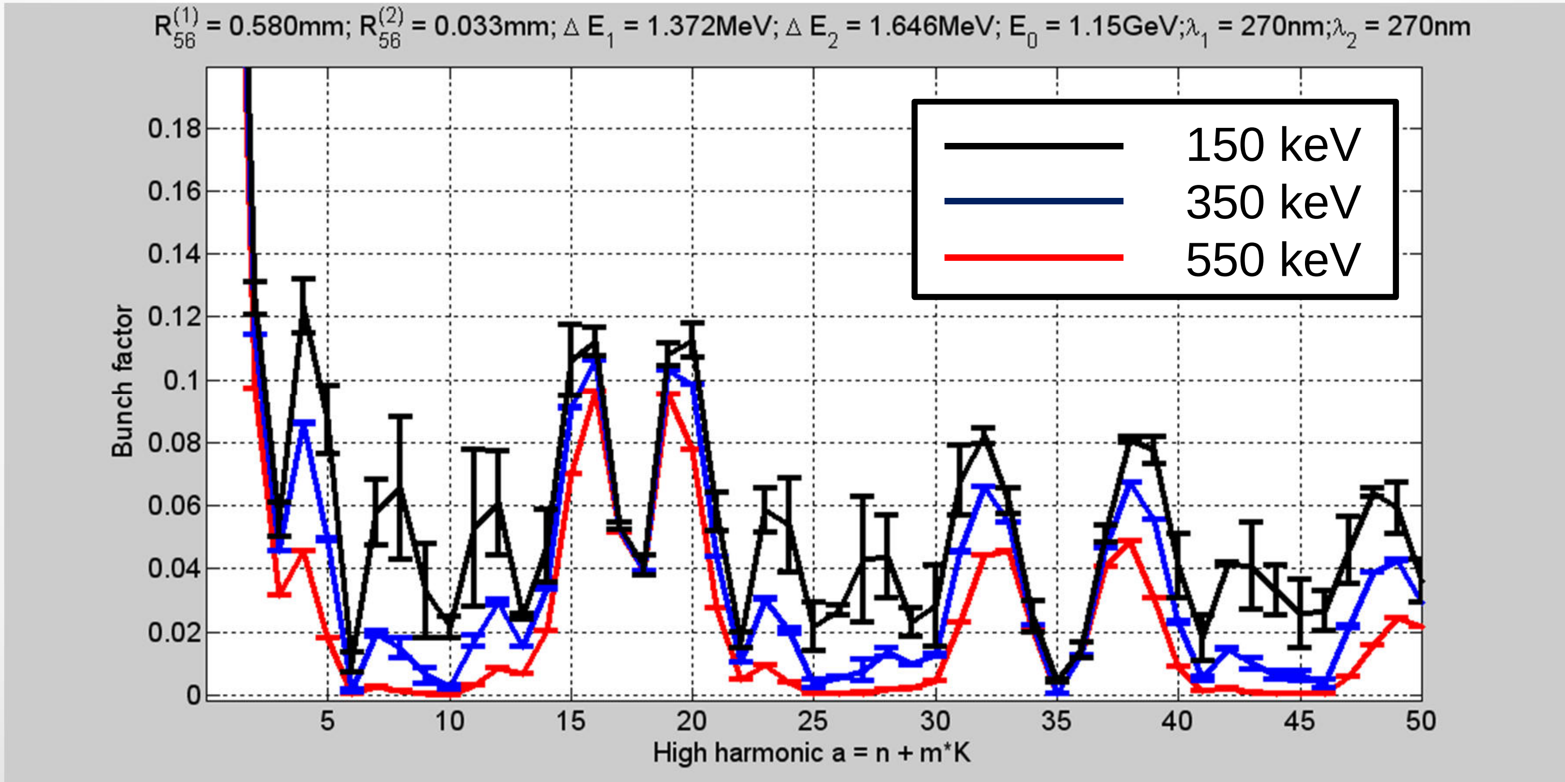
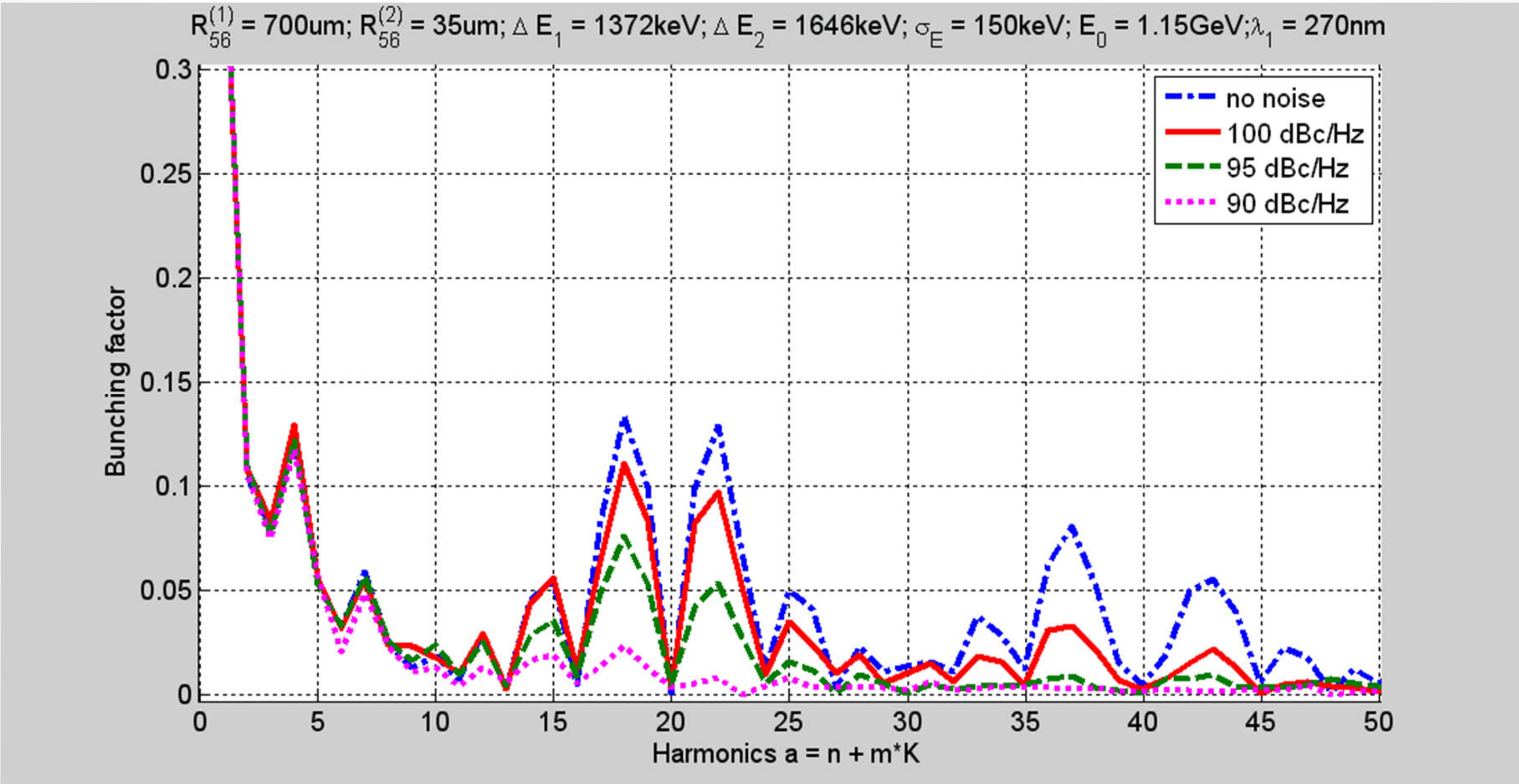


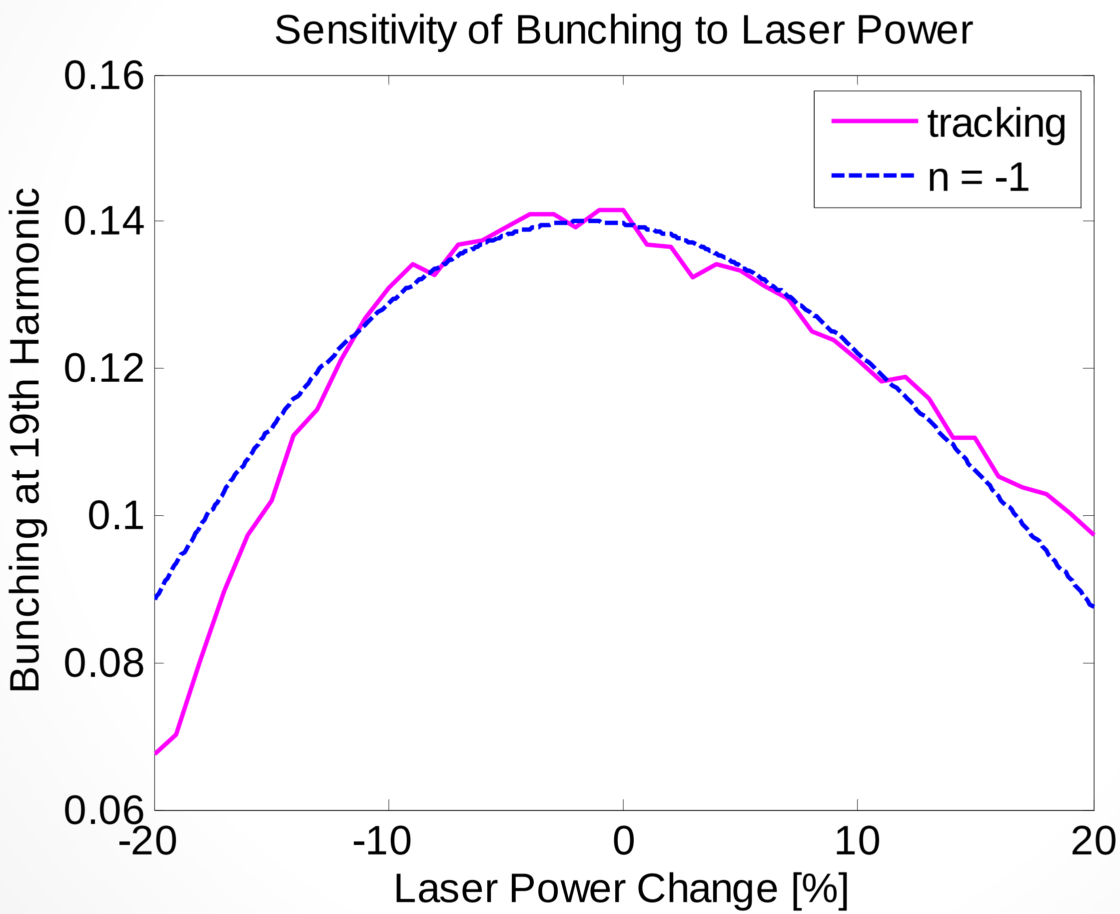
Phase Noise Sensitivity

All seeding schemes
Same rule?

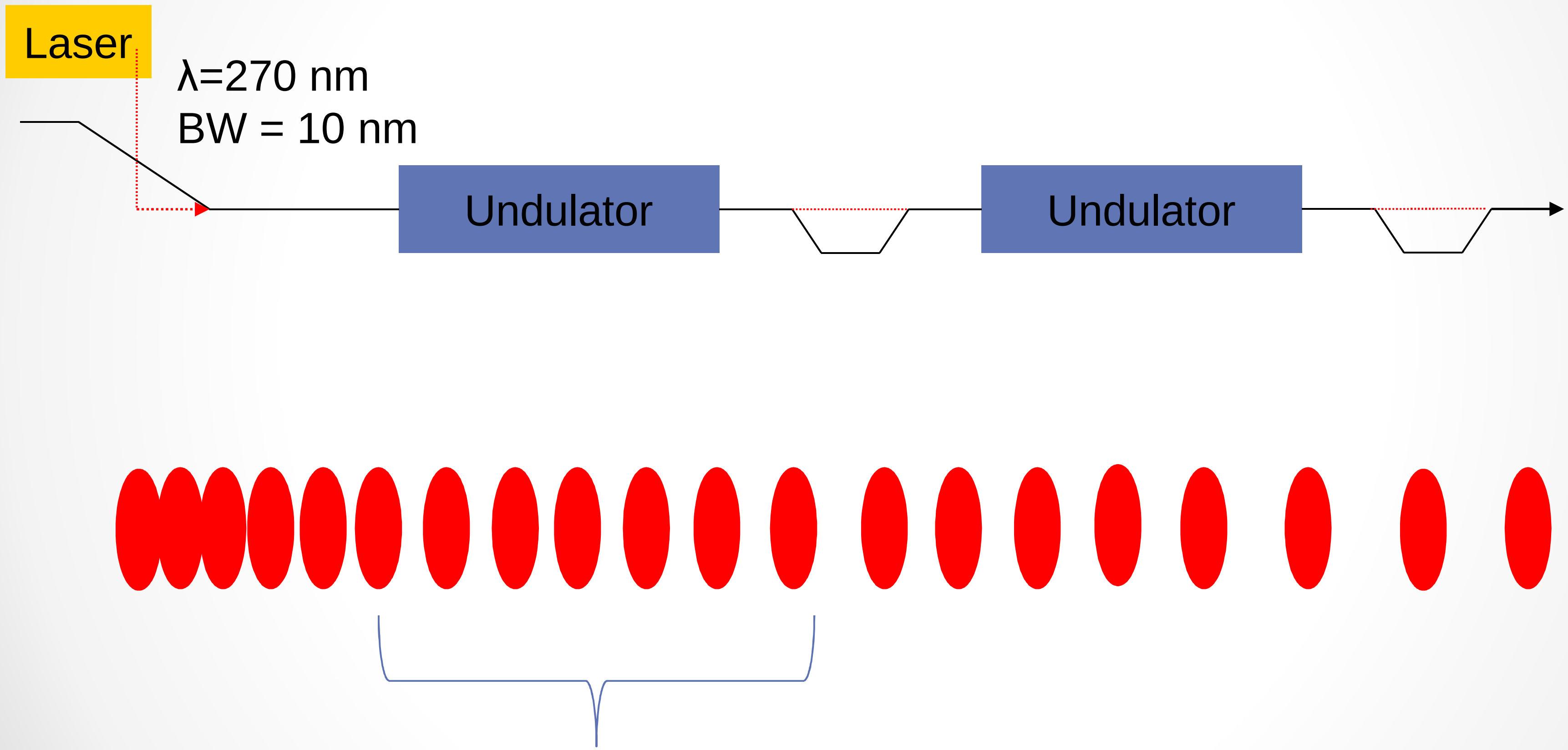
$$\left(\frac{P_s}{P_n}\right)_{out} = \frac{1}{n^2}\left(\frac{P_s}{P_n}\right)_{in}$$



Laser Power Sensitivity



EEHG with chirped laser pulse

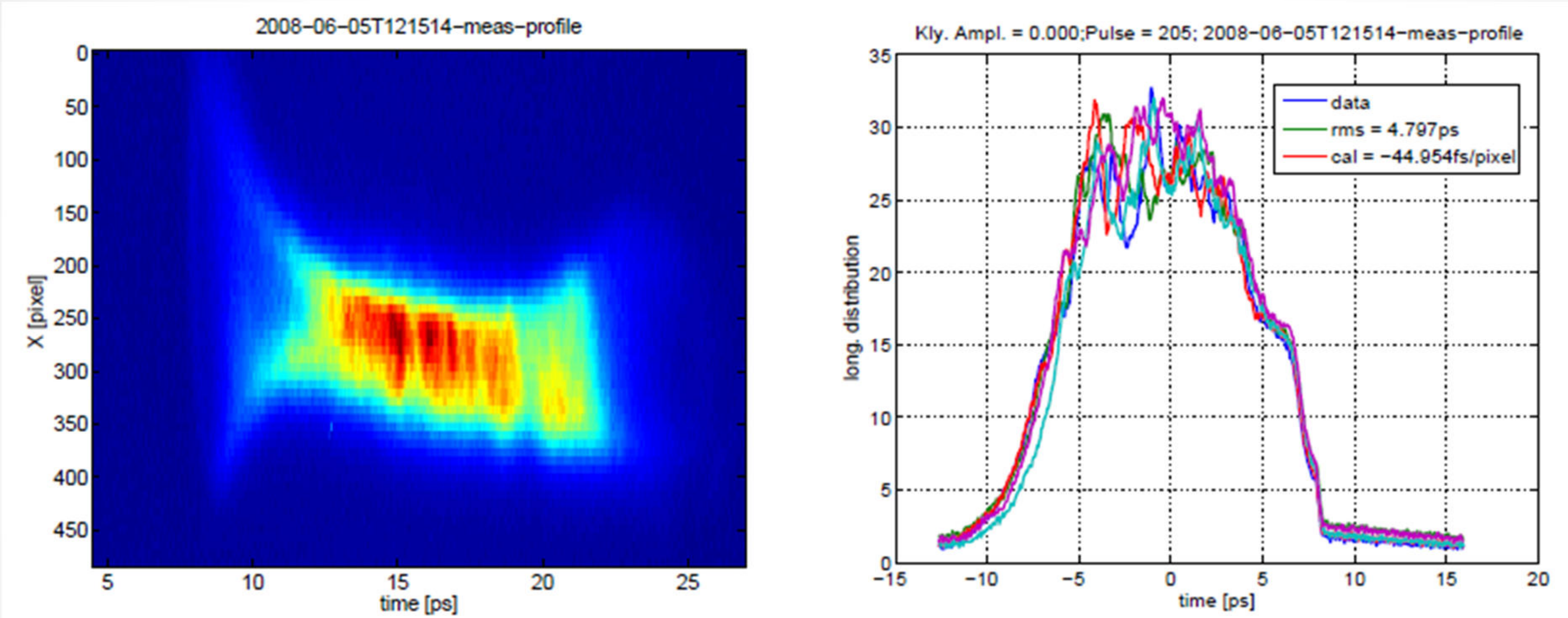


Bandwidth of bunching <5% > bandwidth of undulator radiation 1%

=>

Only a slice of the beam lases

Incoming Microbunches



screen image of streaked electron bunch

longitudinal projection

Form factor in visible is ~0.01

BUT!

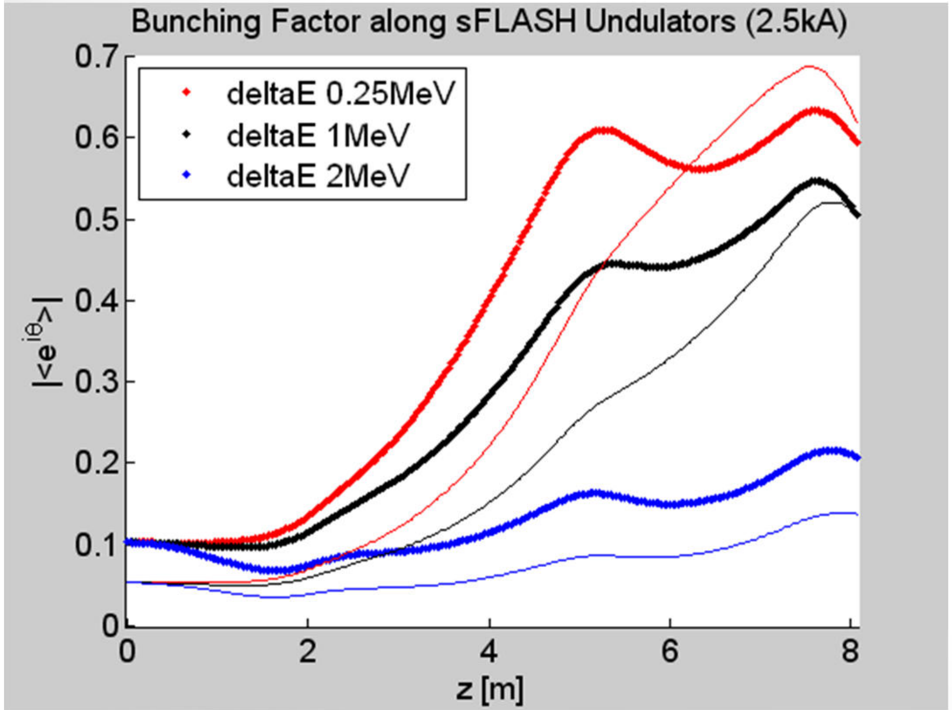
Structures smaller than 600 nm are smeared out in dogleg

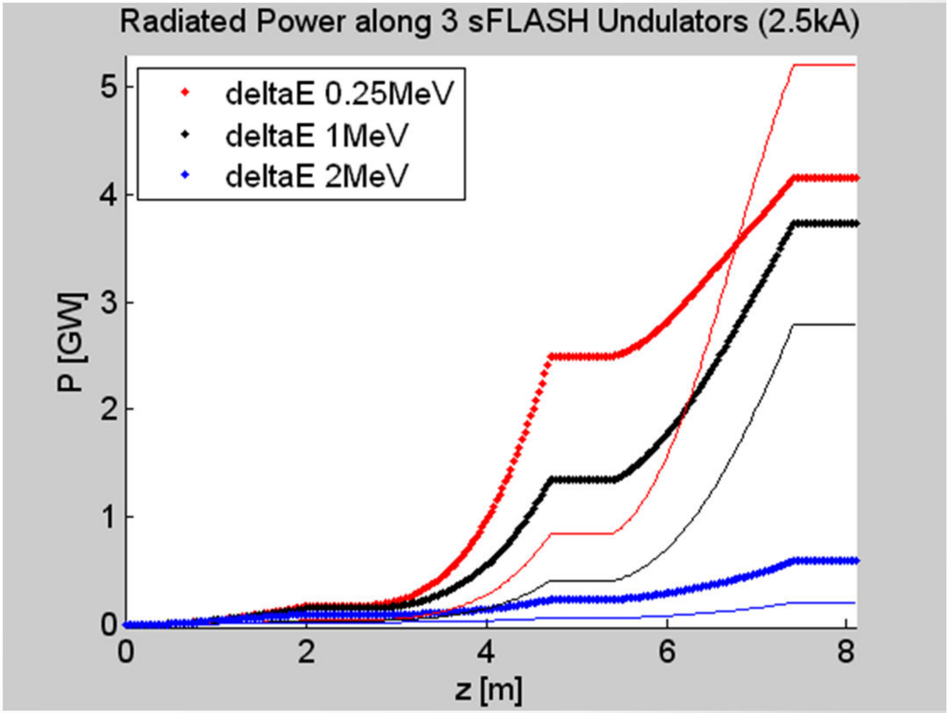
Image courtesy of H. Schlarb via S. Wesch

GENESIS

Through the first 3 sFLASH undulators

red solid line	I_{peak}=2.5 kA	σ_E=250 keV (rms)	bunching=0.05
black solid line	I_{peak}=2.5 kA	σ_E=1000 keV (rms)	bunching=0.05
blue solid line	I_{peak}=2.5 kA	σ_E=2000 keV (rms)	bunching=0.05
red dotted line	I_{peak}=2.5 kA	σ_E=250 keV (rms)	bunching=0.10
black dotted line	I_{peak}=2.5 kA	σ_E=1000 keV (rms)	bunching=0.10
blue dotted line	I_{peak}=2.5 kA	σ_E=2000 keV (rms)	bunching=0.10





GENESIS

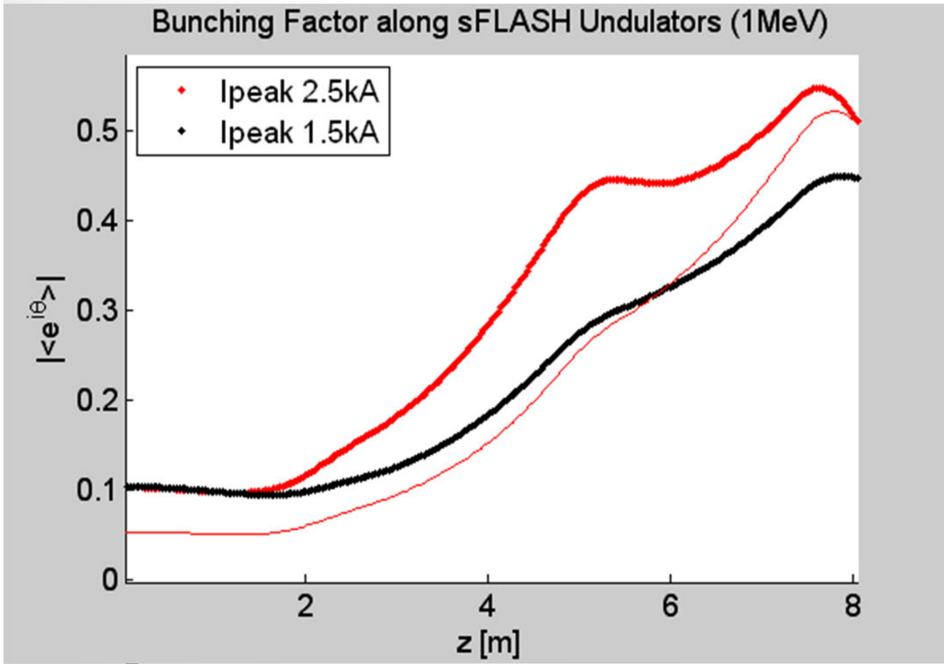
Through the first 3 sFLASH undulators

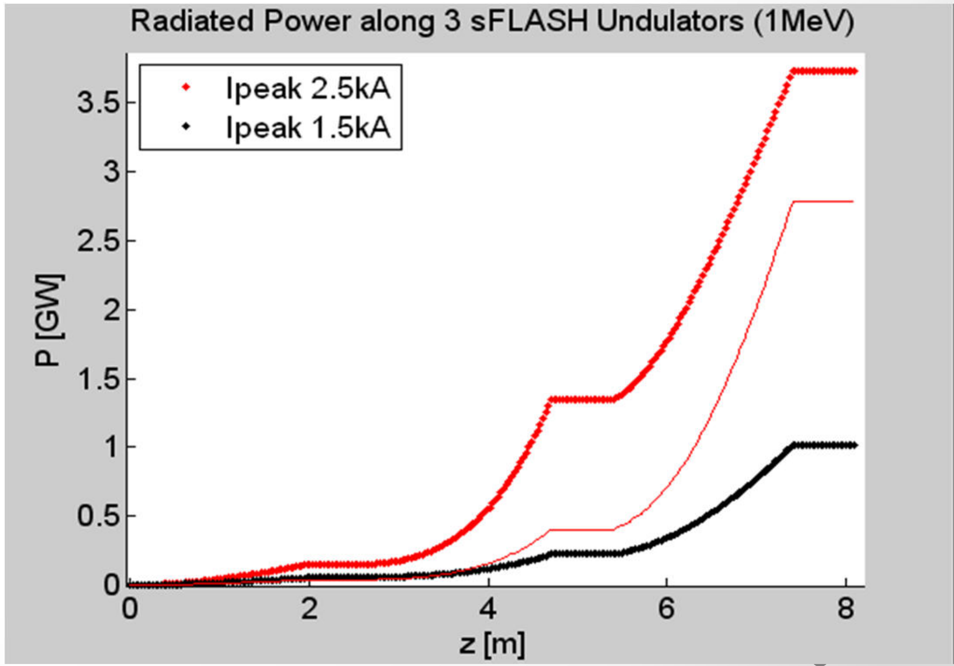
I_{peak}=2.5 kA σ_E=1000 keV (rms) bunching=0.05

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



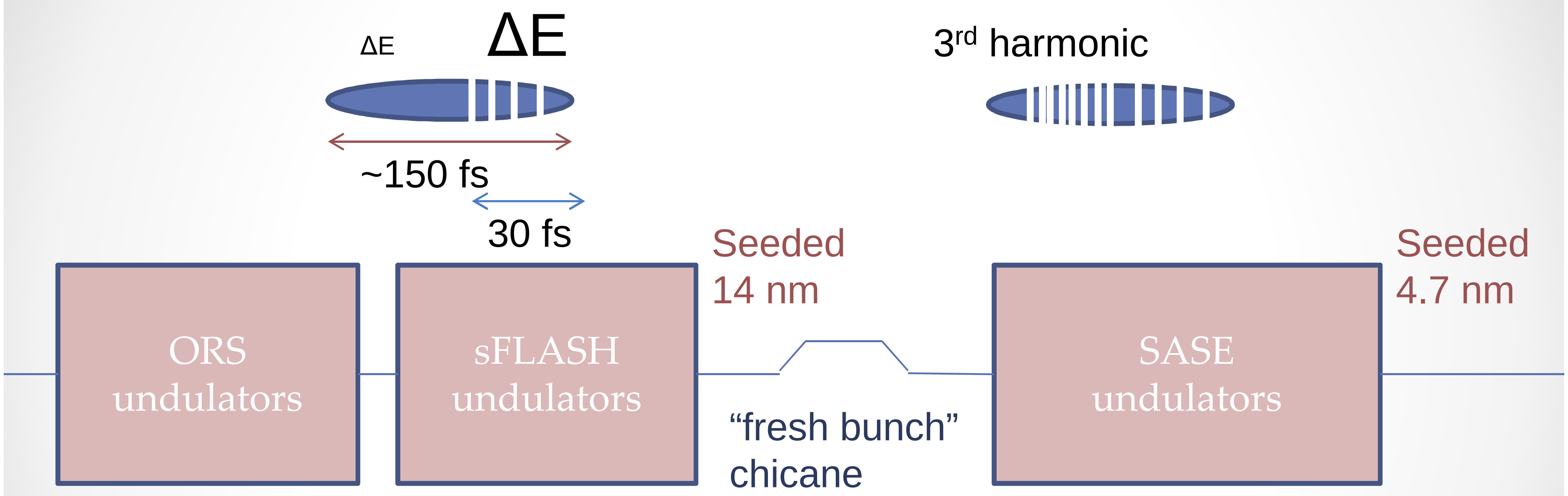


Conclusion

- ✓ All hardware except for the adaptive mirror has been ordered
- ✓ Studies imply that the experiment can be conducted with realistic machine parameters
- Installation Oct-Dec 2011
- Execution Jan-Sept 2012

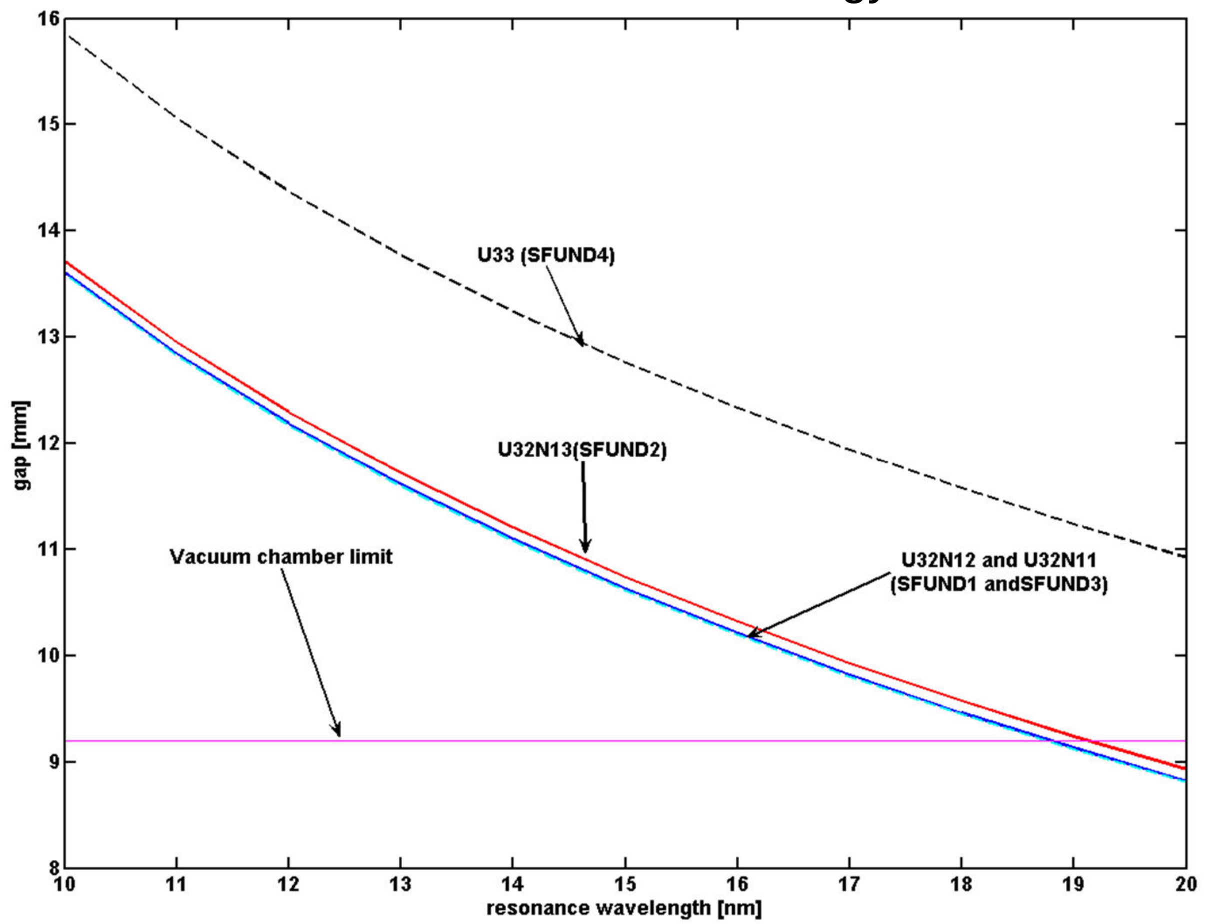
Thank you for your time

EEHG + HGHG


ΔE
ΔE
~150 fs
30 fs
3rd harmonic
Seeded
14 nm
Seeded
4.7 nm
ORS
undulators
sFLASH
undulators
"fresh bunch"
chicane
SASE
undulators

EEHG with sFLASH undulators

For 1GeV beam energy



Plot courtesy of Delsim-Hashimi