Dispersion Effects on SASE at FLASH

- SASE dependence on e^- trajectory
- SASE vs e^- energy for different dispersion scenarios
- SASE spectrum dependence on dispersion

Measurements done 11 & 15 October 2008 (total=1shift)
Simulations done with Genesis 1.3

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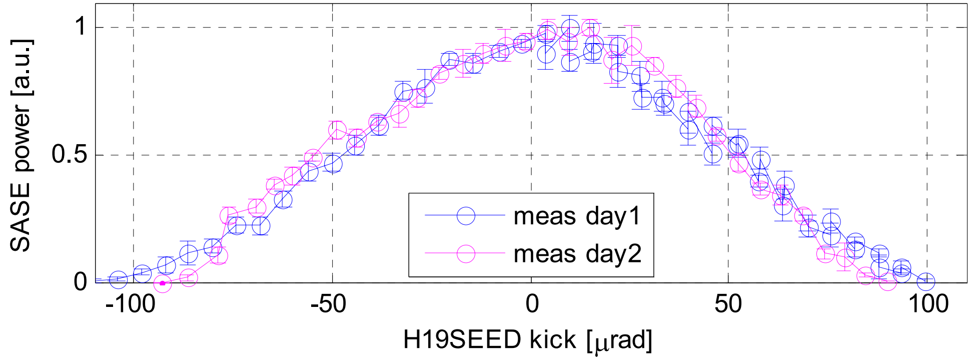
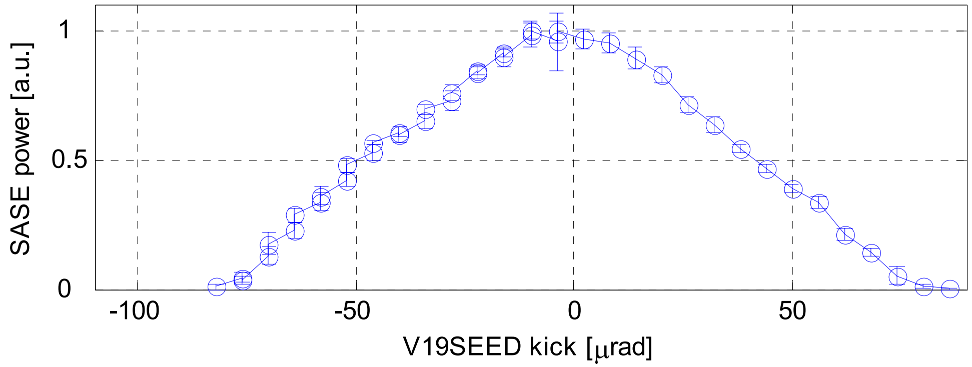
FEL Beam Dynamics Meeting
24 of November of 2008, Hamburg

SASE dependence on electron trajectory Measurements

Measurements are averaged over 100 shots
SASE energy taken by MCP detector (maximum around 20 μJ)





day1: 450MeV
day2: 495MeV

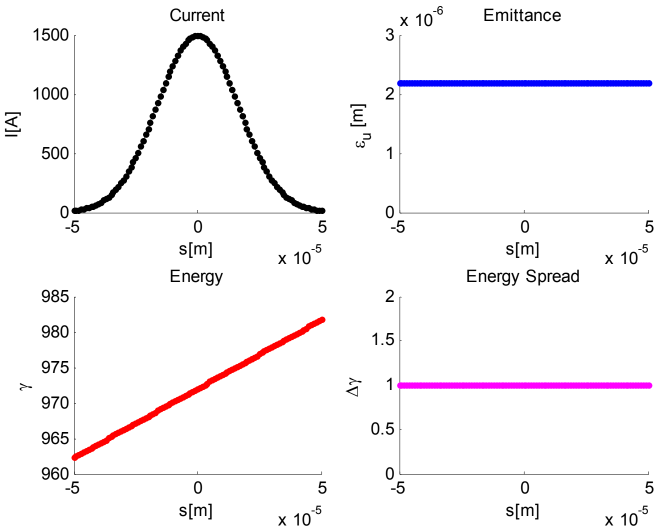
- FWHM: 100-105 μrad (x) / 90 μrad (y)

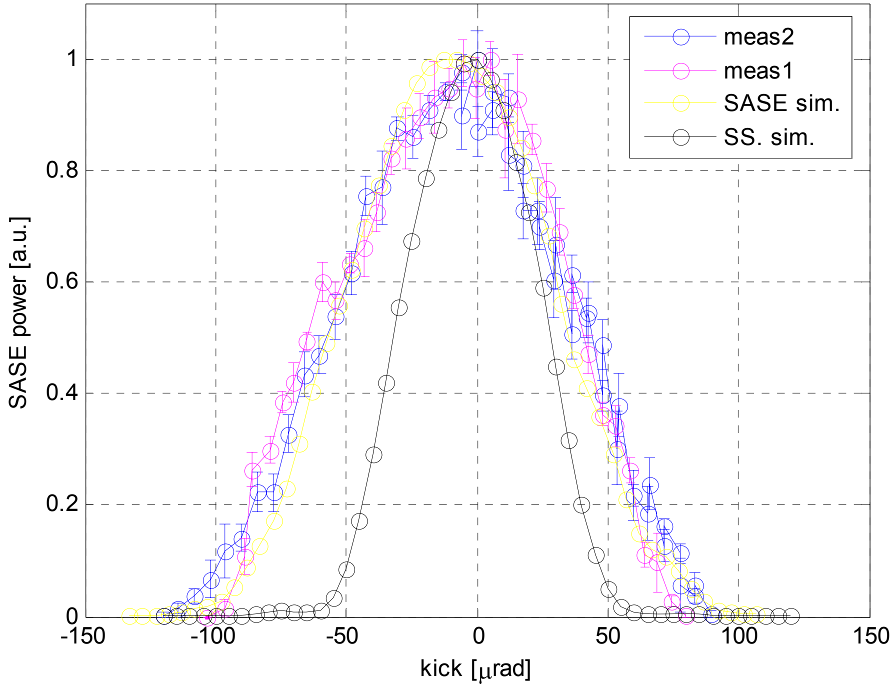
(x>y because e^- wiggling motion in the undulator is in x?)

- Good reproducibility between different days

SASE dependence on electron trajectory
Simulations vs measurements

Idea: finding a “reasonable” input e^- beam for Genesis with an orbit sensitivity as in reality.





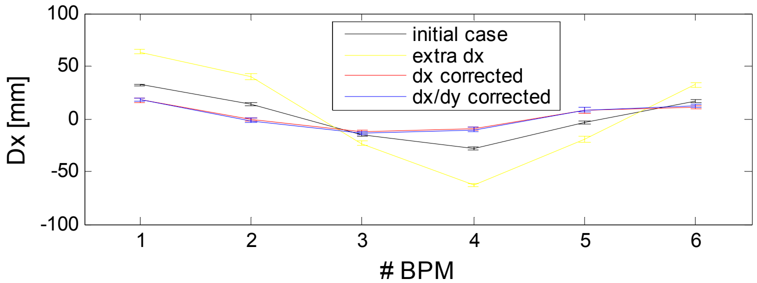
SASE simulations
Bunch length = 100e-4m
Gaussian current profile (Imax=1.5 KA)
Energy chirp of ±1%
Rest of conditions constant along the bunch:
ε_u=2.2 μm, matched optics

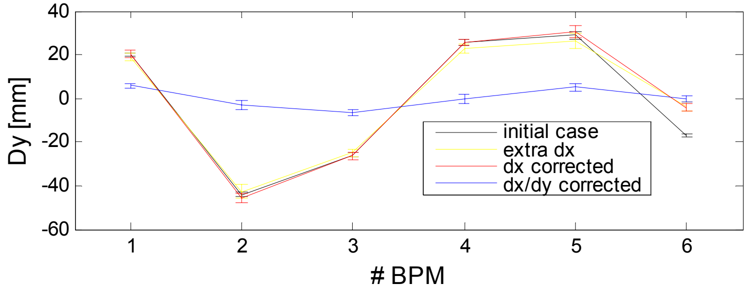
Steady state simulations (SS): 1 single λ
Time-dependent: bandwidth

Good agreement

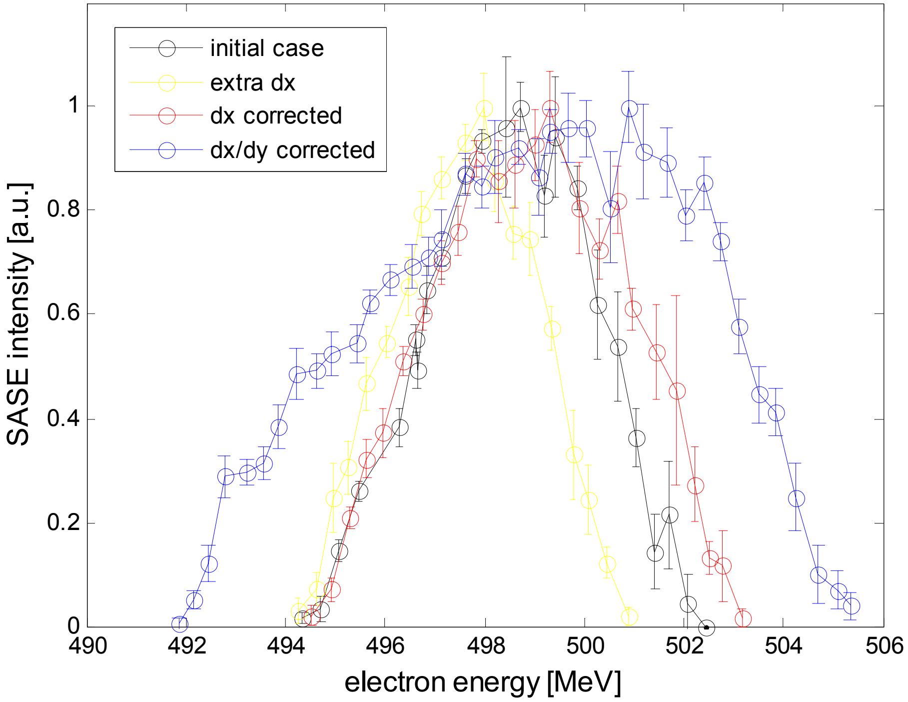
SASE energy vs electron energy Measurements

Energy change by varying ACC456 gradient
Measurements averaged over 100 points





rms dispersion	dx	dy
initial case	22mm	30mm
extra dx	48mm	28mm
dx corrected	12mm	31mm
dx/dy corrected	11mm	5mm



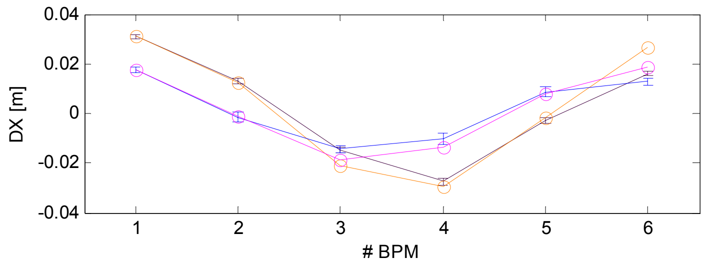
FWHM goes from **0.82** to **1.72%** after correcting dispersion in both planes ☺

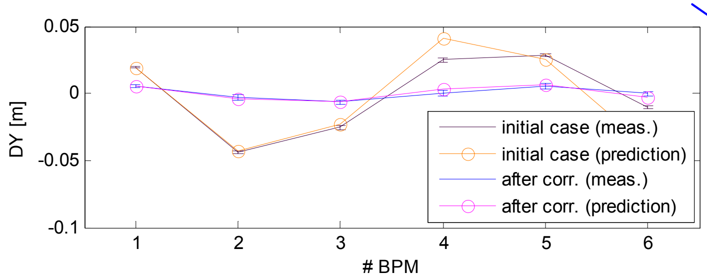
SASE energy vs electron energy Simulations

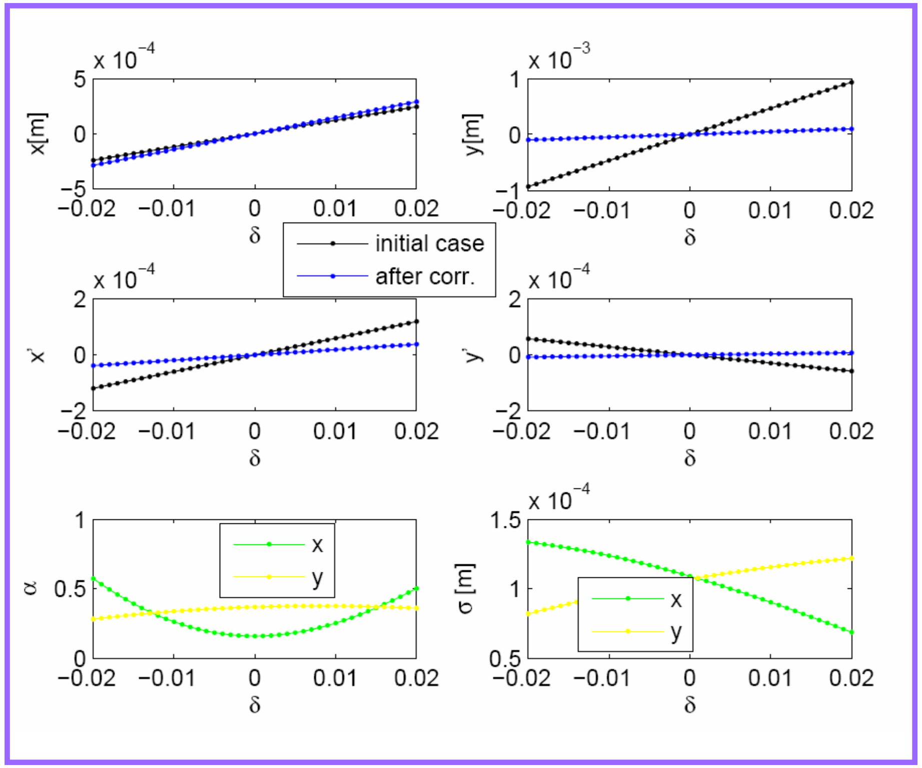
Considered effects: -Orbit changes according to dispersion functions
-Optics changes (magnets were not scaled)

From the dispersion measurement, the dispersion functions at the entrance of the undulator can be derived:
D(s) = D(s0)*R11(s)+D'(s0)*R12(s)

	Initial situation	After correction
dx	12 mm	14 mm
dx'	6.0 mrad	1.9 mrad
dy	47 mm	5 mm
dy'	-2.9 mrad	0.4 mrad



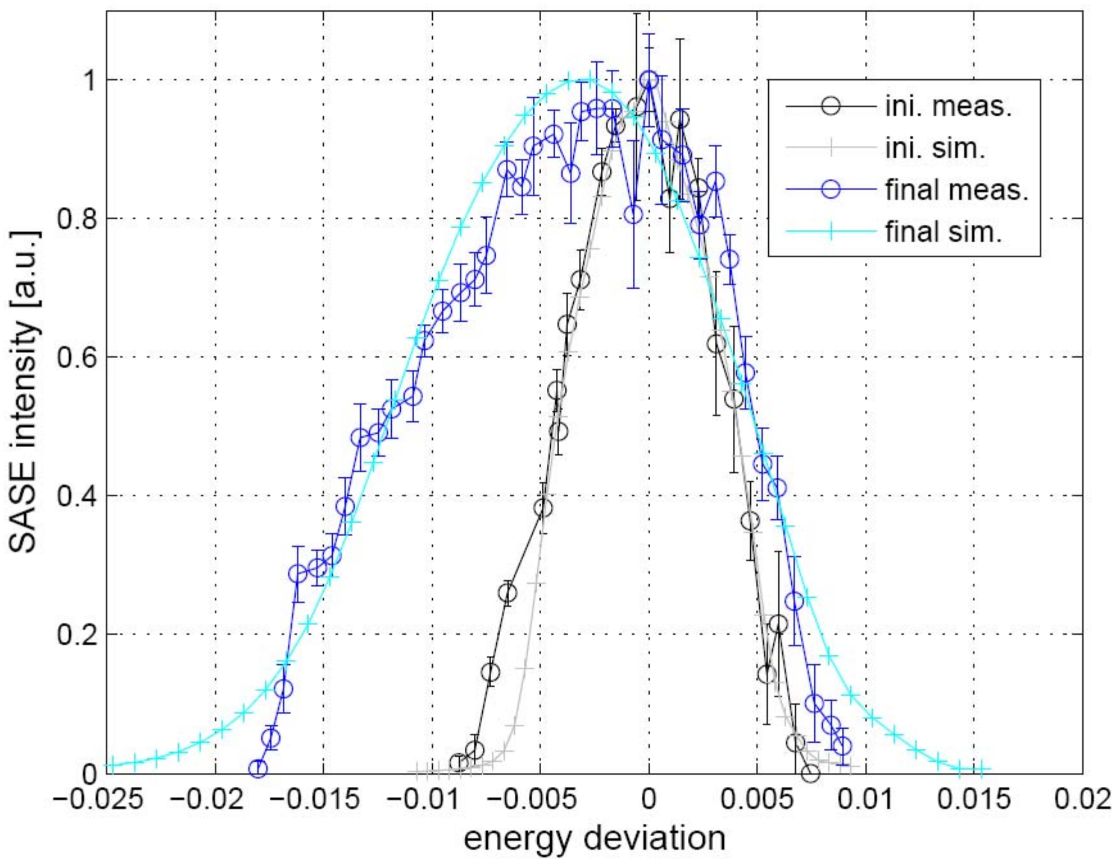




Same beam conditions as before

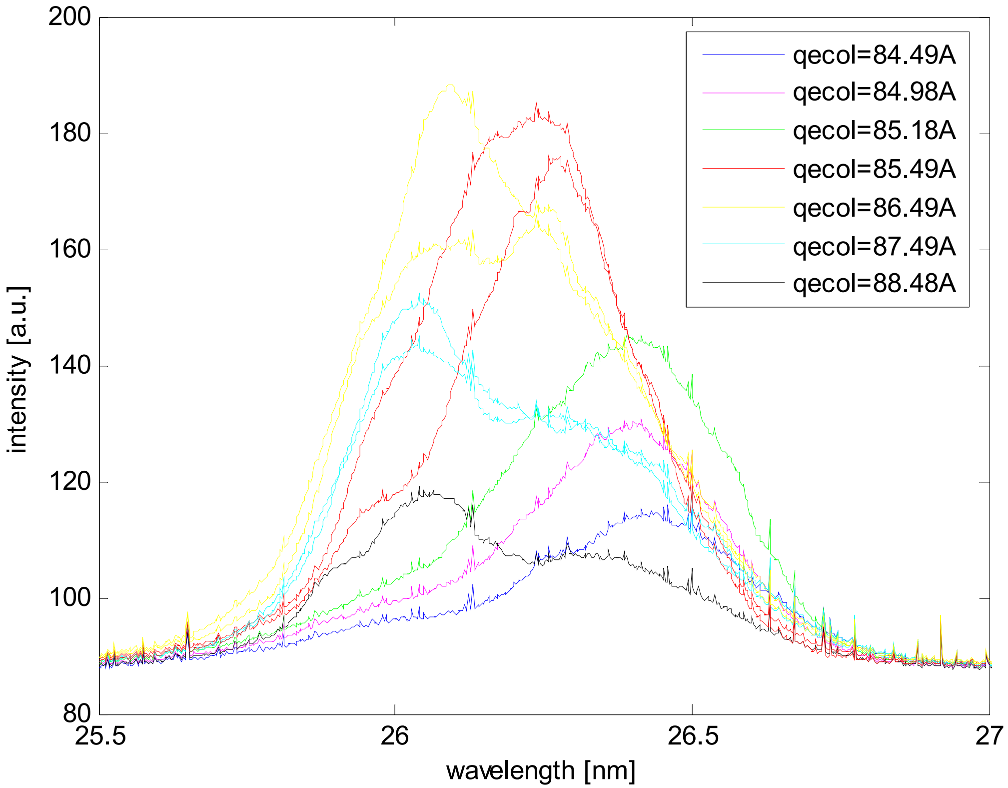
No dispersion generated inside the undulator

SASE energy vs electron energy
Simulations vs measurements

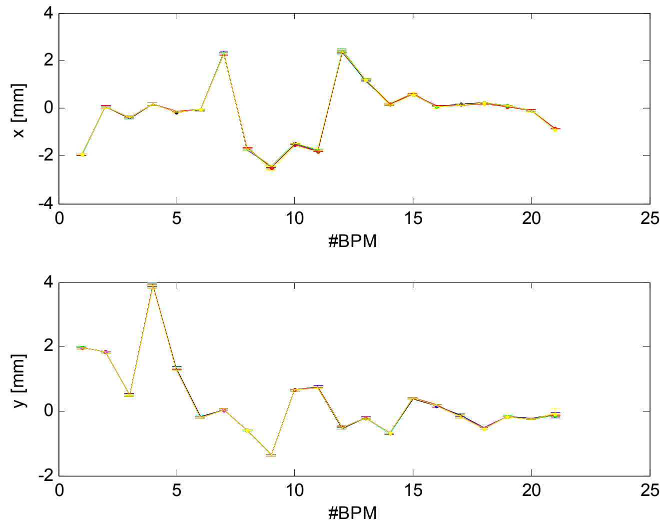


Good agreement

SASE spectrum vs dispersion Measurements



- Every measurement averaged over 200 shots
- Dispersion generated by varying QECOL current
- Centroid orbit along the undulator kept constant



Widest spectrum and maximum power without dispersion

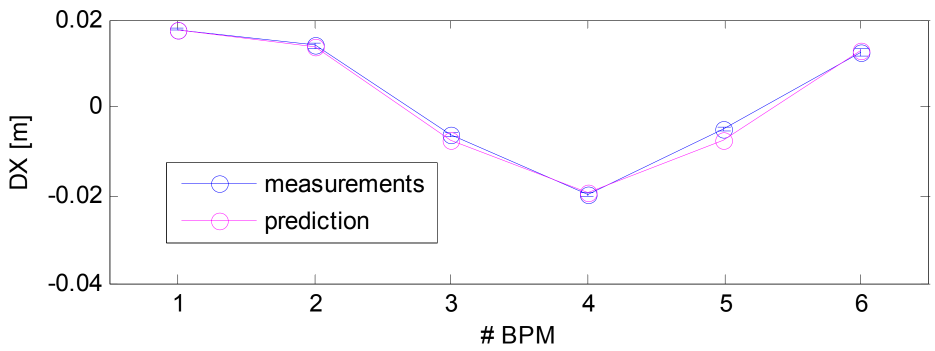
Effects depend on the dispersion sign ↑QECOL→ ↓ λ

(but not symmetrically): ↓QECOL→ ↑ λ

Dispersion generated when changing Q3/5ECOL current

Decrease of 0.5 A decrease
(0.6% of the current)

Rms dispersion in the undulator: 15 mm



Dispersion functions at the undulator entrance	
dx	0.7 mm
dx’	4.7 mrad

→ No dispersion generated inside the undulator

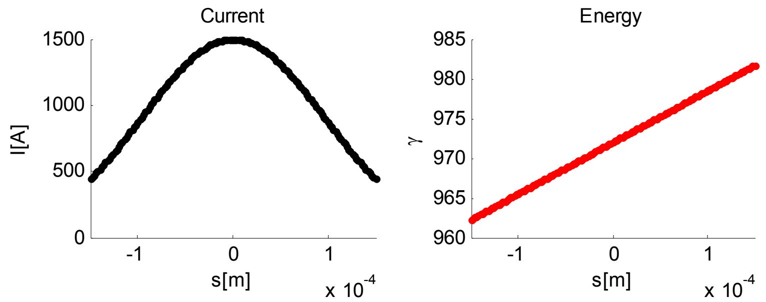
SASE spectrum vs dispersion Simulations

Effect of the dispersion to SASE spectrum depends on the initial correlation between transverse coordinates and energy. In general we have the following relation:

$$u = u_0 + \eta_u \cdot \frac{\Delta p}{p} + \tau_u \cdot \frac{\Delta p}{p}^2 + \cdots$$
$$u' = u'_0 + \eta'_u \cdot \frac{\Delta p}{p} + \tau'_u \cdot \frac{\Delta p}{p}^2 + \cdots$$

Introducing dispersion changing Q3/5ECOL current, a linear component η_u is added

SASE simulations

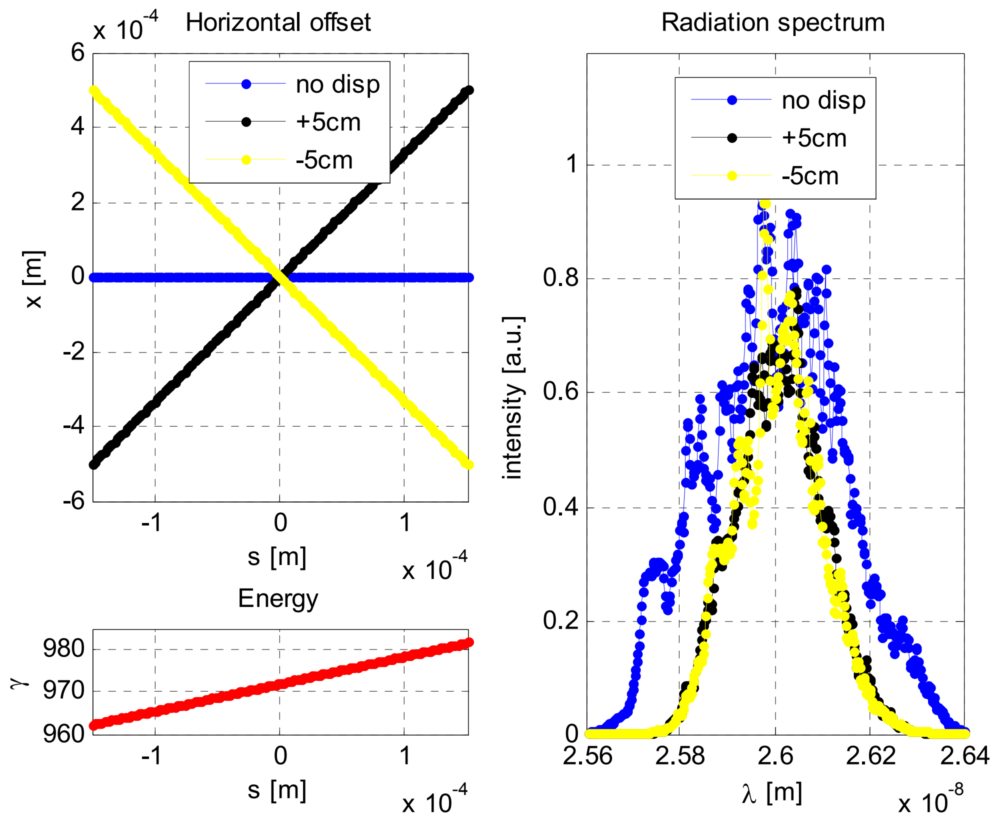


Similar beam conditions as before
Bunch length increased to 300e-4m
Current increased for the head and the tail

Analysis restricted to horizontal offset x and the impact of Dx
Considered dispersions: [0 +5cm -5cm]

SASE spectrum vs dispersion Simulations

No initial correlation x-energy / no off-set

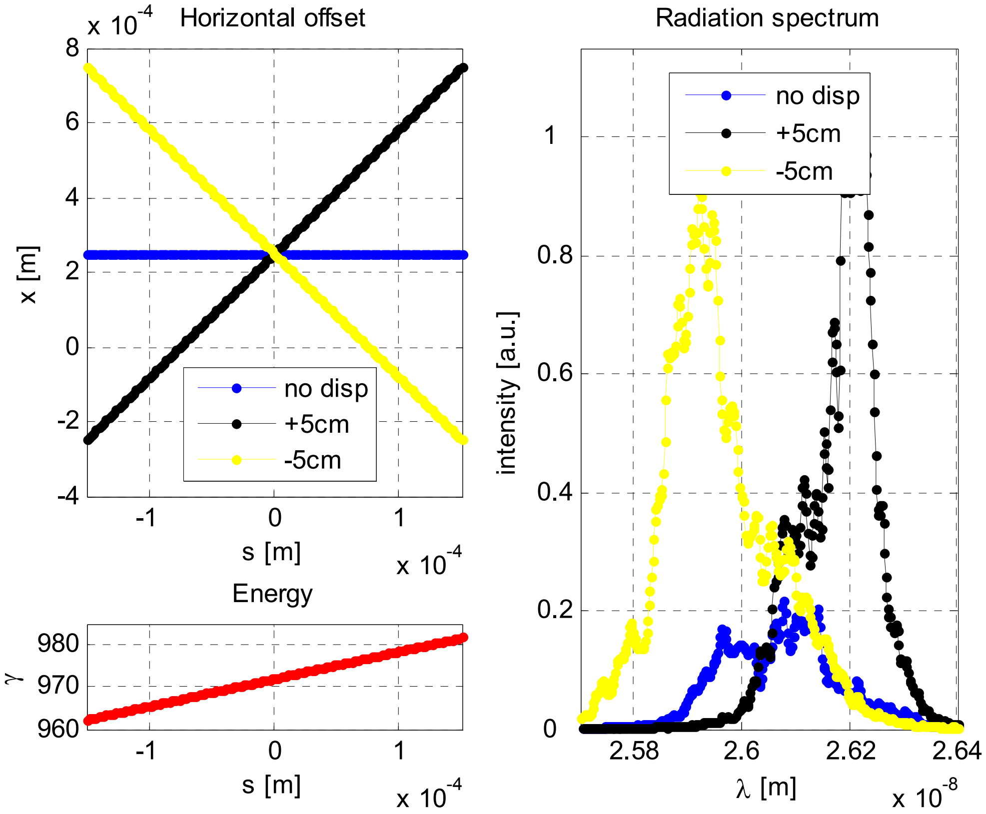


- The spectrum becomes narrower
- Central wavelength does not change

Eduard Prat, DESY

SASE spectrum vs dispersion
Simulations

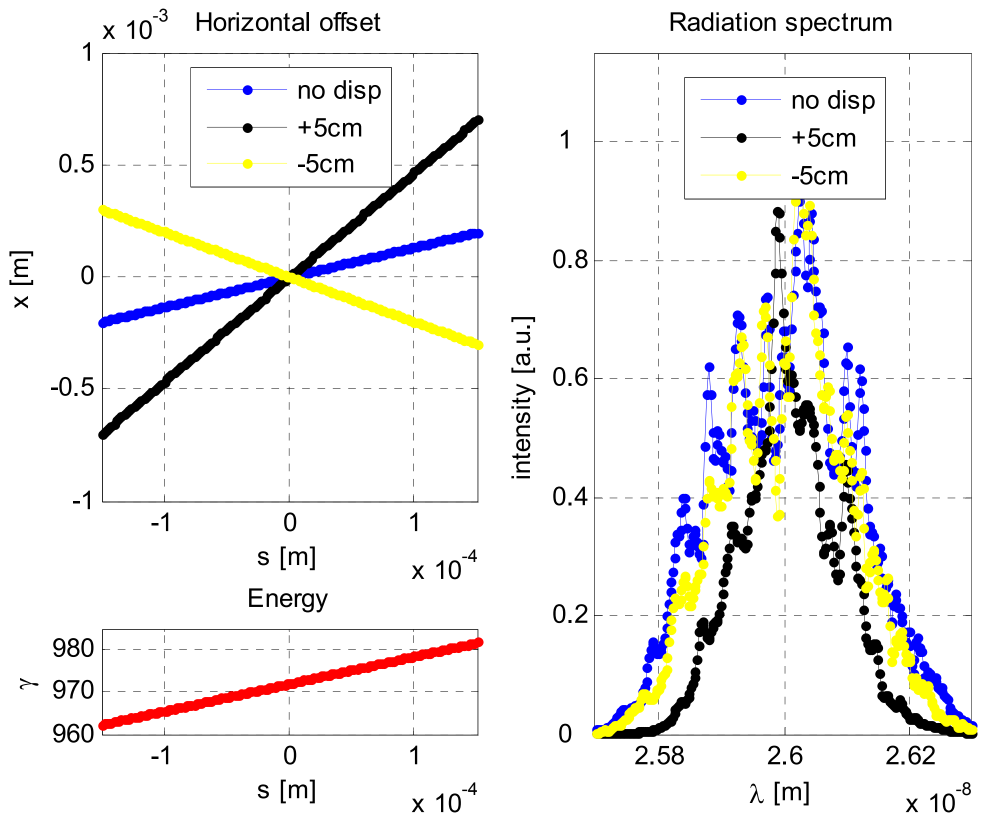
No correlation x-energy / non-zero off-set (+250 μm)



- Central wavelength depends on the dispersion sign

SASE spectrum vs dispersion
Simulations

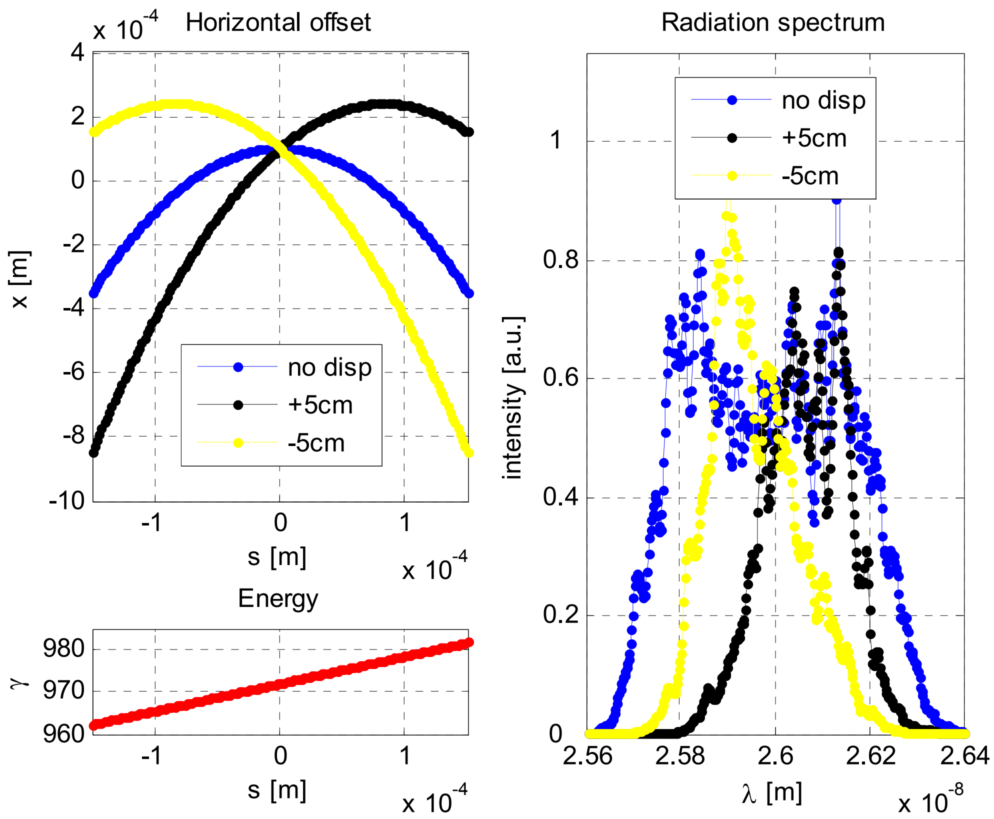
Initial linear correlation x-energy



- Effect to the spectrum width depends on the final correlation (can be narrower or wider)
- Central wavelength does not change

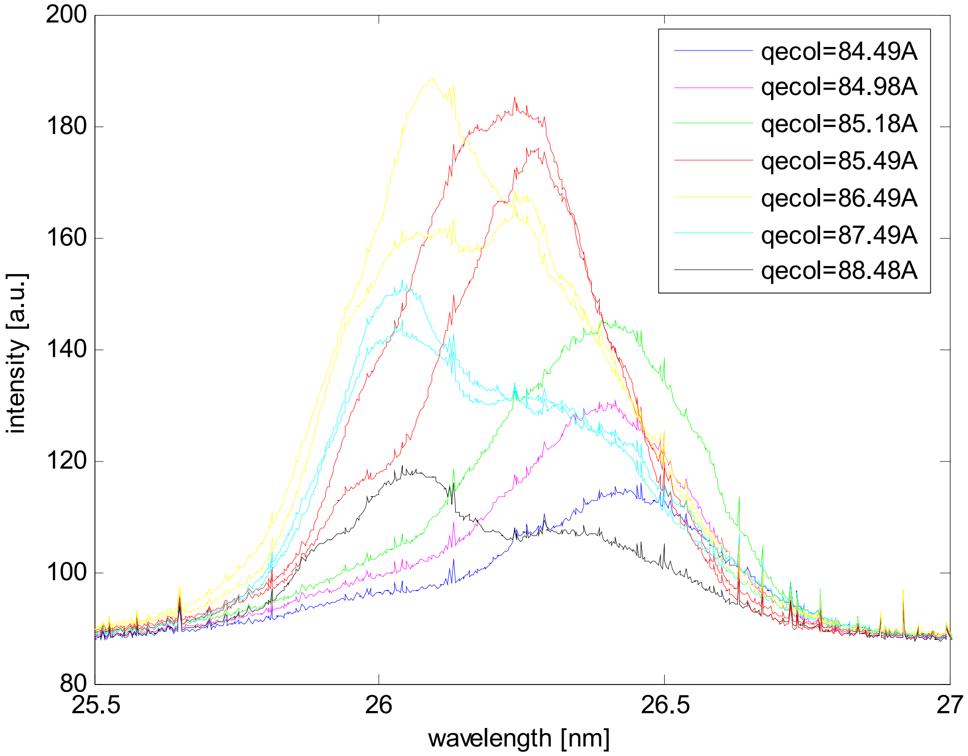
SASE spectrum vs dispersion Simulations

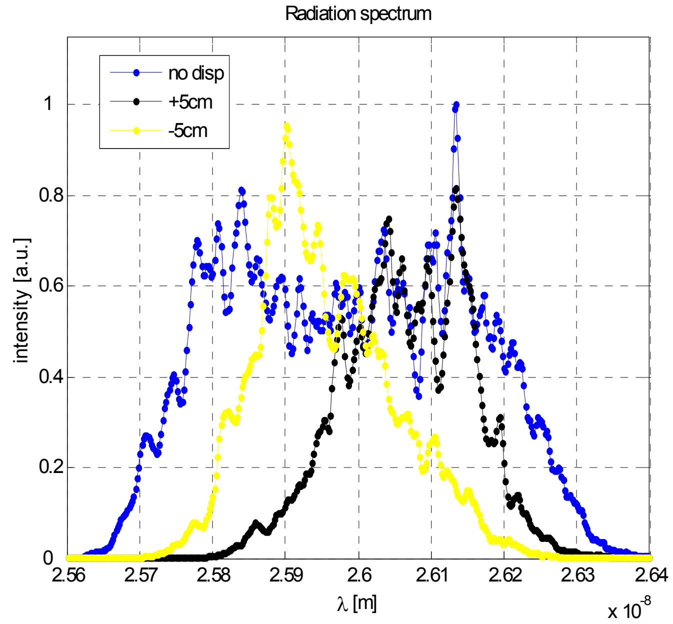
Initial quadratic correlation x-energy



- The spectrum becomes narrower
- Central wavelength depends on the dispersion sign

SASE spectrum vs dispersion
Measurements





Linear + quadratic initial u-u'/energy correlation?
Simulations are ongoing…

Summary – Next steps

Summary

- Dispersion correction improves sensitivity of SASE to electron energy

- Introducing dispersion narrows the SASE spectrum and changes the central wavelength. An initial quadratic correlation u/u'-energy explains qualitatively the measurements.

Next steps

- Fully simulate SASE wavelength vs dispersion (compare required initial u-u'/energy correlation with s2e simulations / measurements)

- Repeat the measurements: see reproducibility, try to introduce dispersion with steerers in the MATCH section instead of QECOL.