First results of micro-bunching and COTR experiments at FLASH

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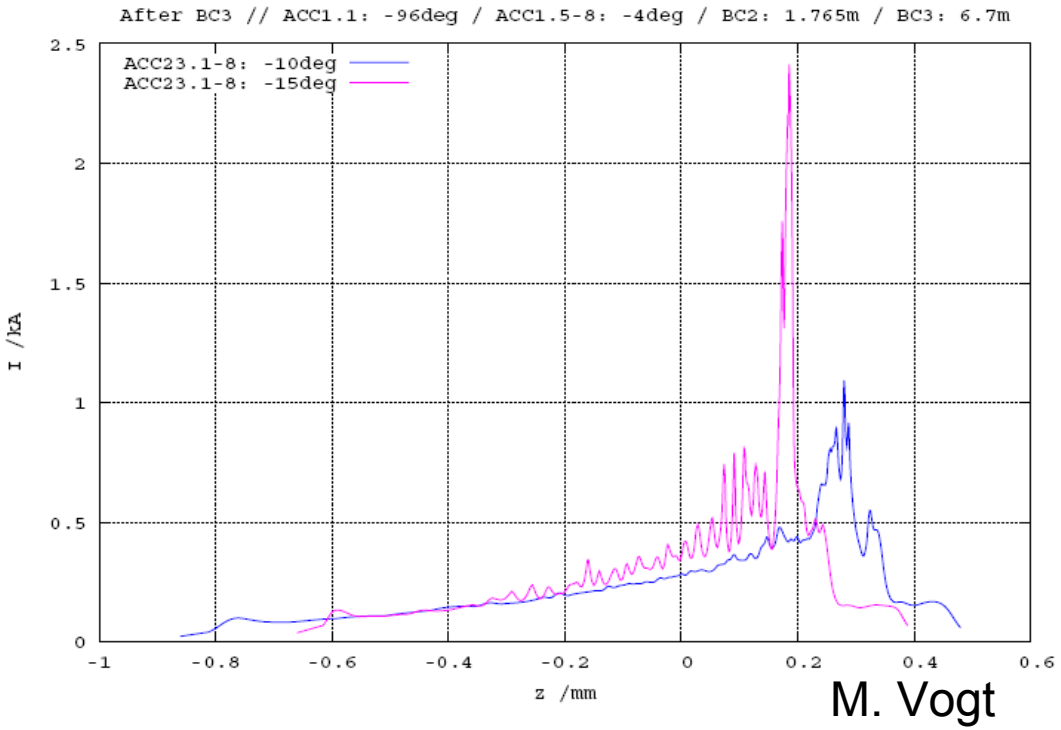
Introduction

- Micobunching instabilities are predicted to have a strong effect on FEL like XFEL or 3rd harm. FLASH – no experiments are done at FLASH so far…
- Velocity bunching can be used to simulate some beam properties of the 3rd harm. System (linear long. Phase space)
- ACC23 as a “knob” to turn microbunching “on and off”
- Microbunch structure can be used for COTR studies



M. Vogt

Goals

Microbuning Instability

- Observation of microbunch (~ 10 um) structure on the bunch with the THz spectrometer
- Observation of instbilities at LOLA
- Studies on possible beam break up

Coherent Optical Transition Radiation

- COTR in “microbunching mode” (OTR screens / LOLA)
- COTR in standard compression (OTR screens)
- Charge dependence

Machine Settings

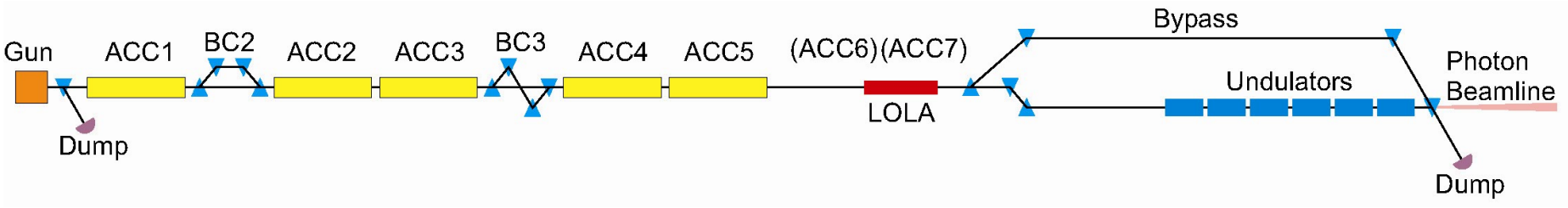
ASTRA/CSRTrack Simulations by M. Vogt

velocity bunching ->

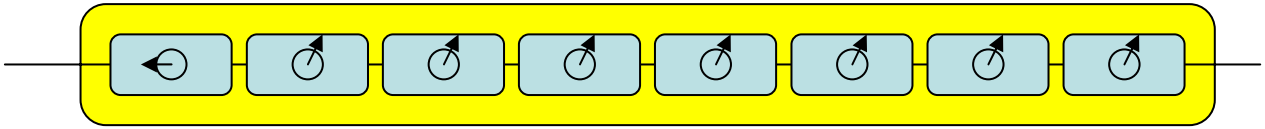
RF Gun	Phi = -0.55 deg	E_max = 44 MeV/m	Q=1nC
ACC1.C1	Phi = -83.00 deg	E_max = 25.35 MeV/m	
ACC1.C2-8	Phi = -2.00 deg	E_max = 37.00 MeV/m	=> <E_out> = 129.3 MeV
BC2	rho = 1.765 m	theta = 16.49 deg	lim: 15-21deg
	=> R56= 0.149	=> I = 57.666 A	
ACC2-3	Phi = -15 deg	E_max = 30.70 MV/m	=> <E_out> = 373.6 MeV
BC3	rho = 6.200 m	theta = 4.64 deg	lim: 1.7-5.4deg
	=> R56= 0.07329	=> I = 47.2674 A	
ACC4-6	Phi = 0 deg	E_max = 26.65 MV/m	=> <E_out> ca. 680 MeV

Experiments at FLASH

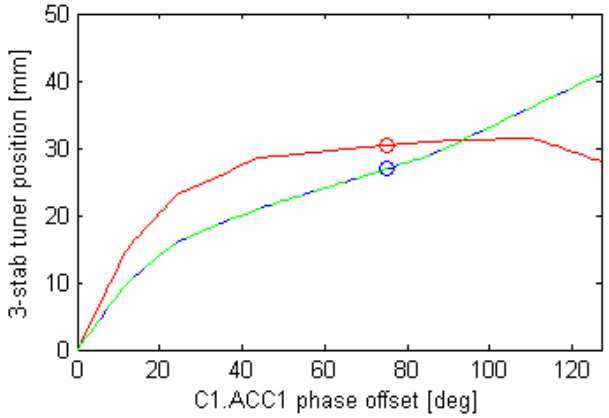
- Setup of velocity bunching (including bunch length measurements)
- ACC23 phase scan in microbunching mode (vb on)
  - LOLA
  - THz
  - OTR18ACC7
- Beam Focus on OTR screens in standard comprssion (vb off)
  - ACC1 phase scan BC2 compression / OTR10DBC2

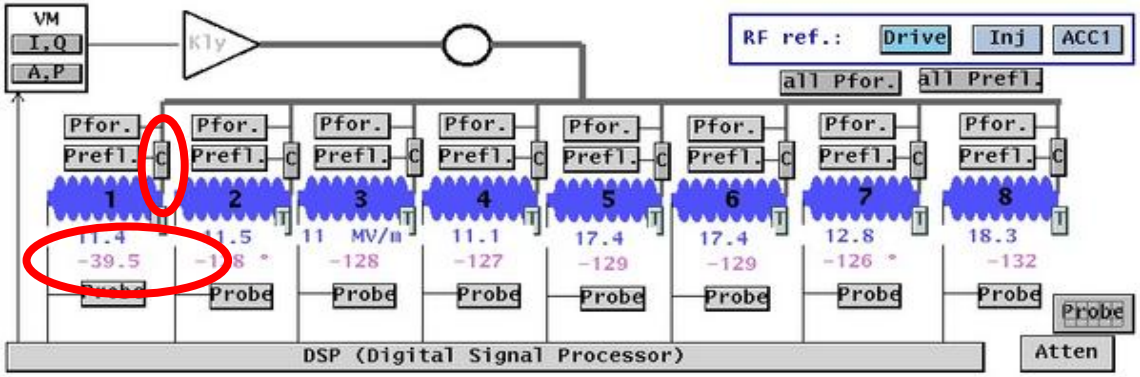


Velocity Bunching



- 3-Stab waveguide tuners are used to shift phase offsets of single cavitites
- Tuner positions are taken from pre-measured curves
- Q of the cavities are kept within reasonable limits by tuning of the middle stab position
- Final phase offsets differ slightly from the intended ones but are measured with the RF probes





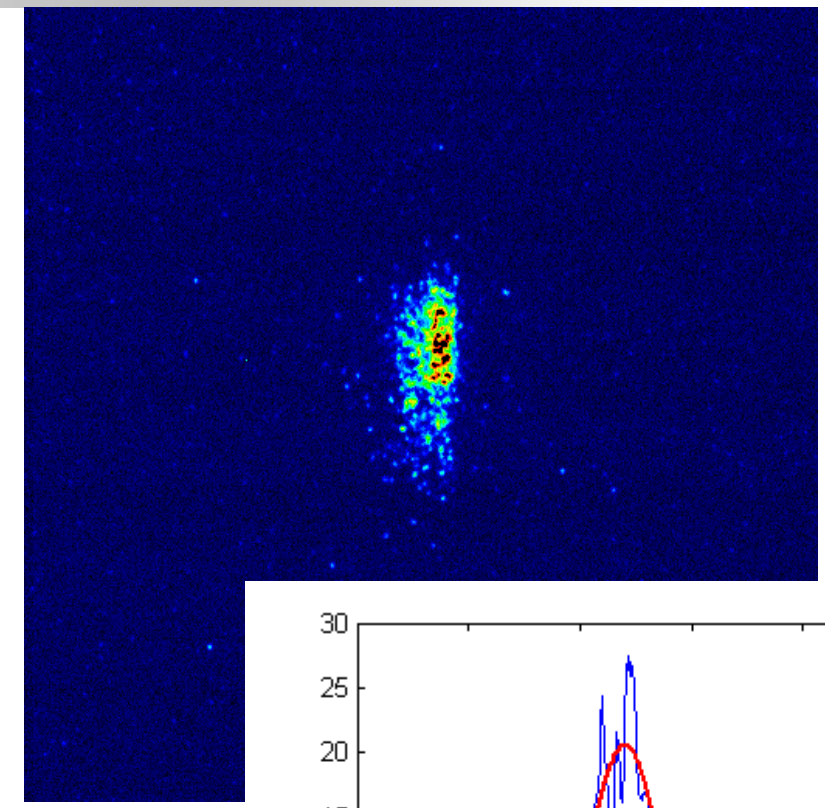
Streak Camera

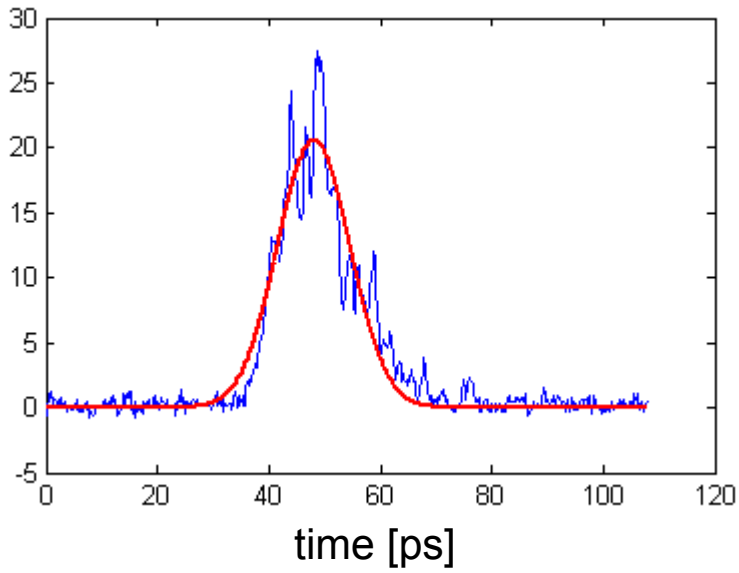
Sychrotron radiation from the 4th dipole in BC2 is transported to TOSYLAB via an optical beamline.

A Hamamatsu streak camera is used to measure synchrotron radiation pulse length and thus the bunch length.

A 540 nm±40 nm wavelength filter was used suppress resolution limitation by optical dispersion.

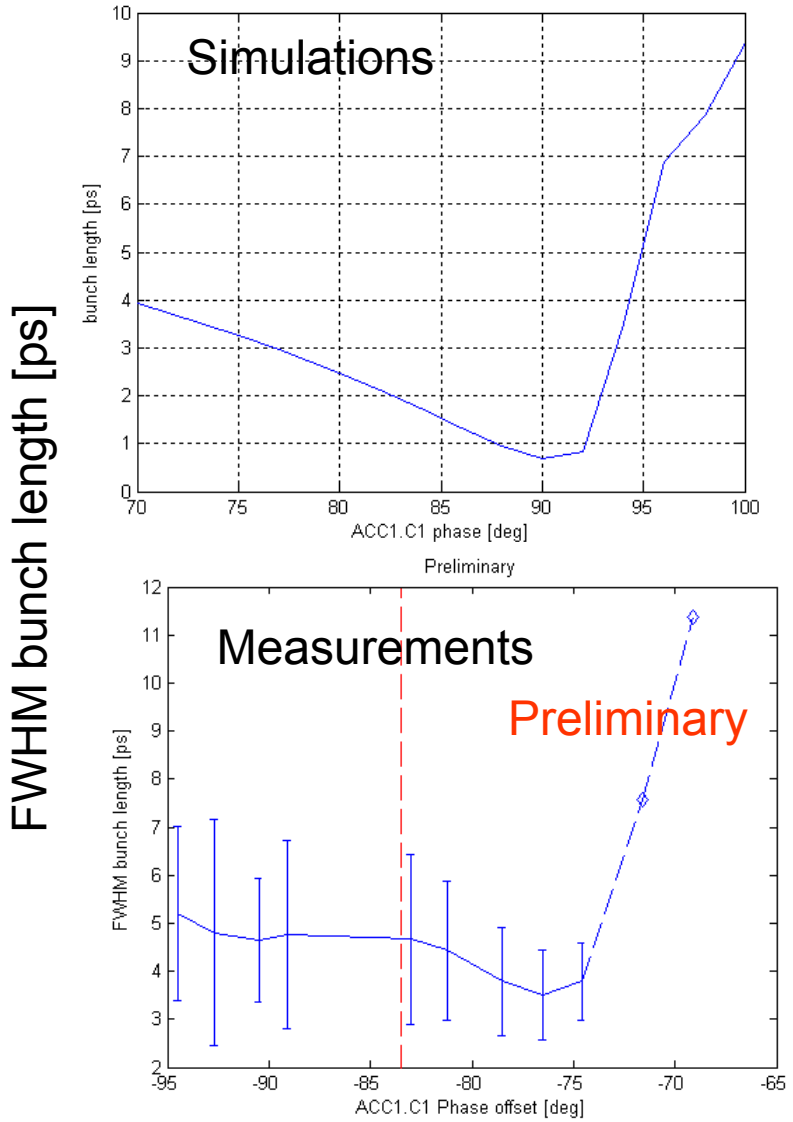
Resolution limit expected around 1 ps.





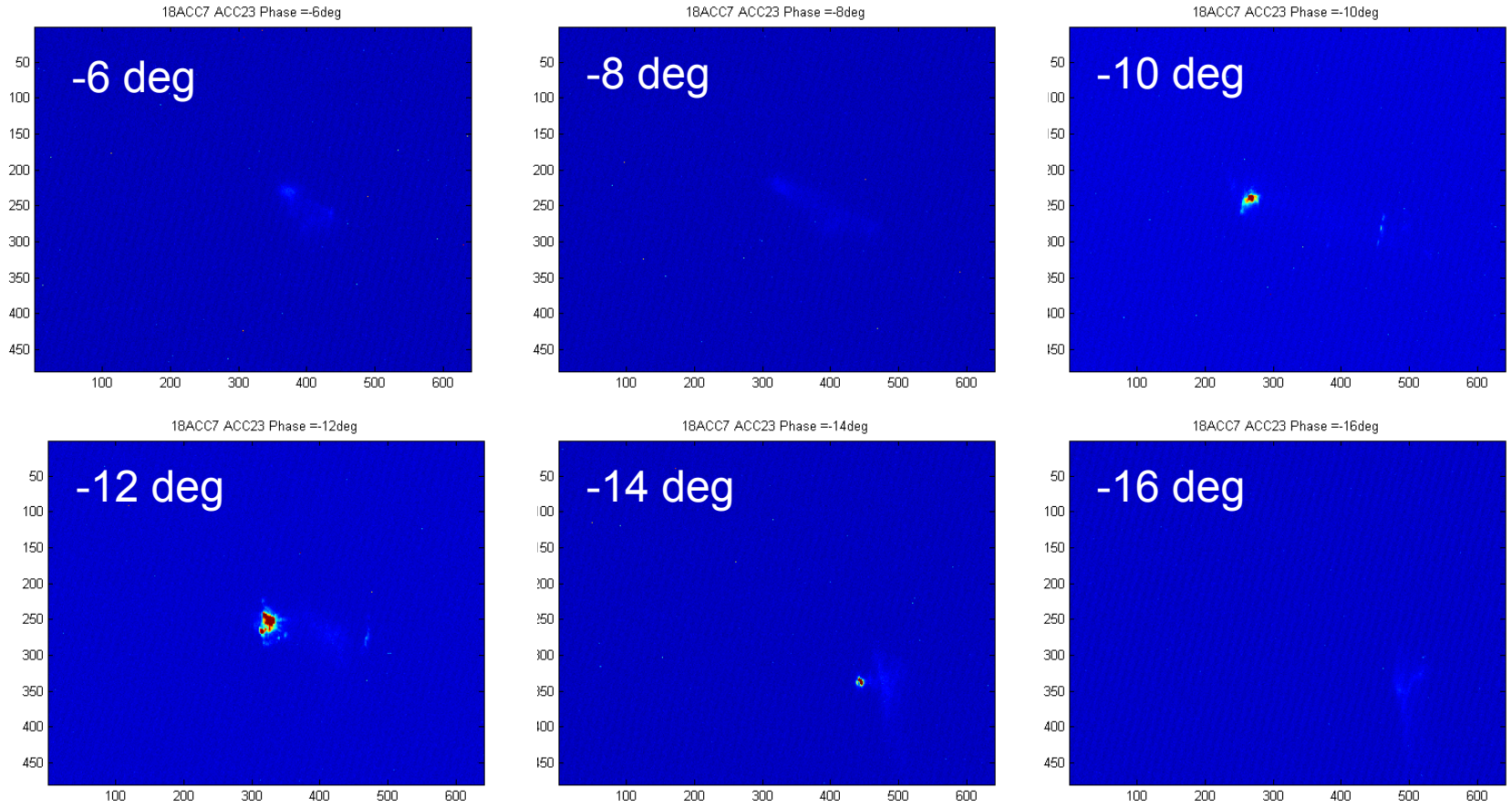
VB Setup

- Bunch length measurements to set up velocity bunching
- Comparison with simulated bunch length data
- Working point set with respect to shortest bunch length



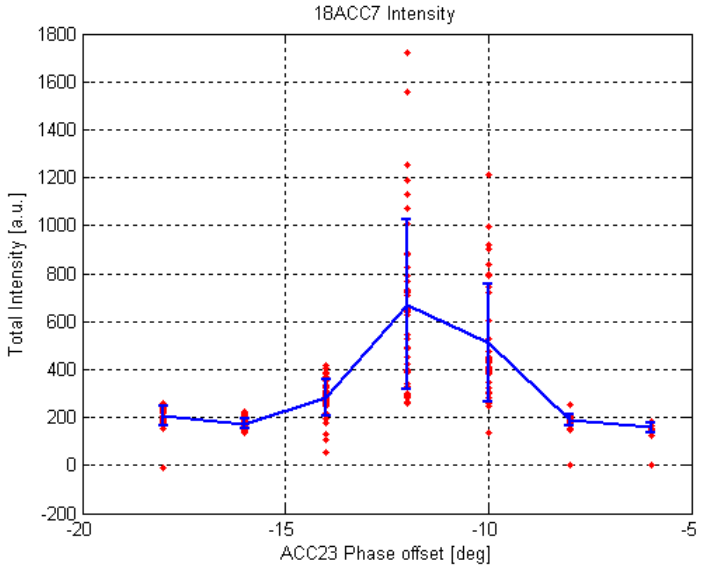
18ACC7

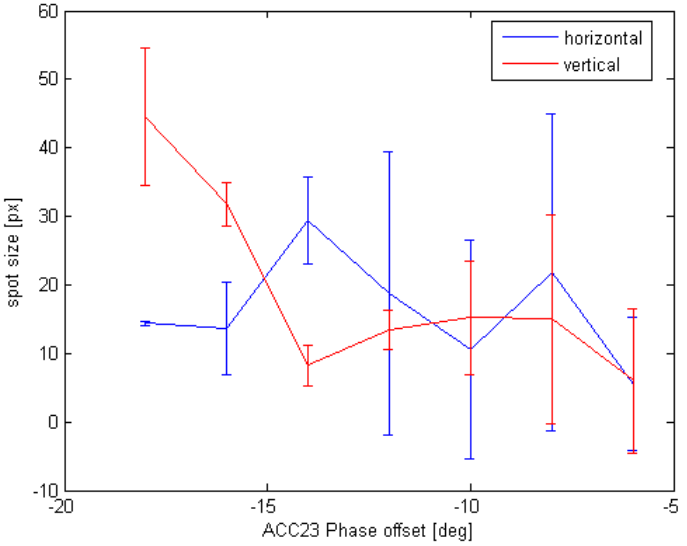
- ACC23 phase scan in “microbunching mode”



18ACC7

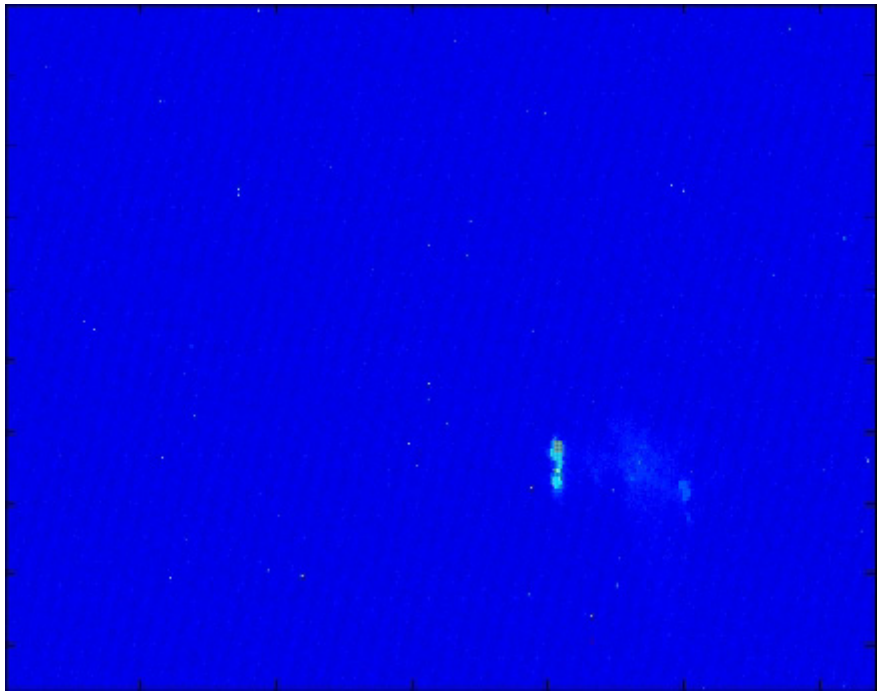
- Strong intensity increase around 13 deg off crest in ACC23
- Strong fluctuations
- Beam size determination is hard due to spiky structure





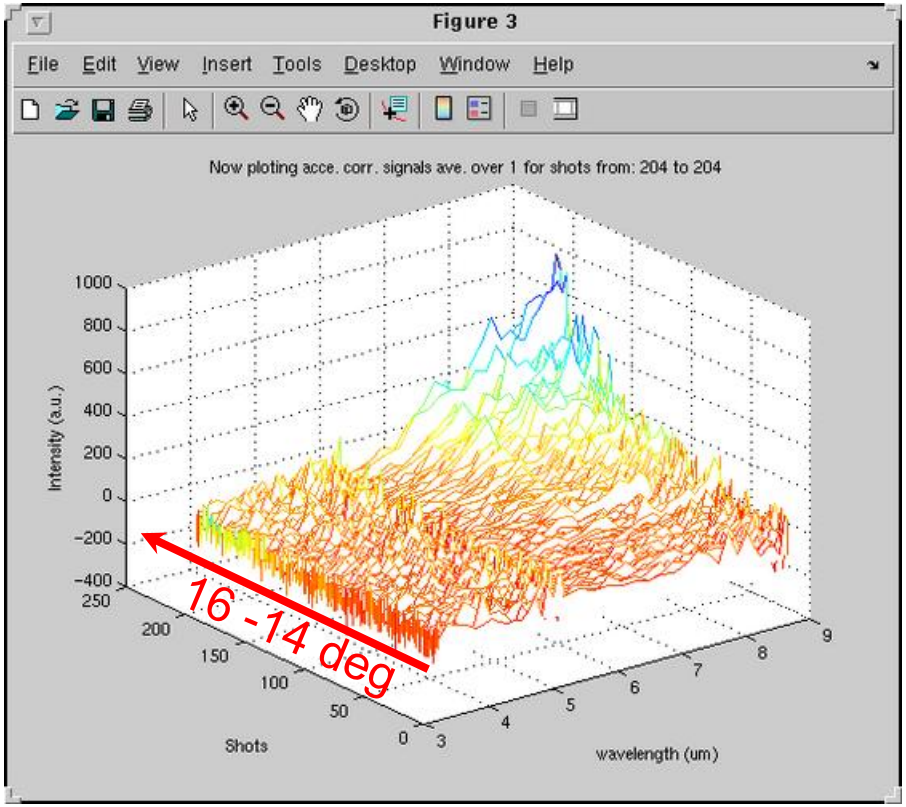
Beam Breakup

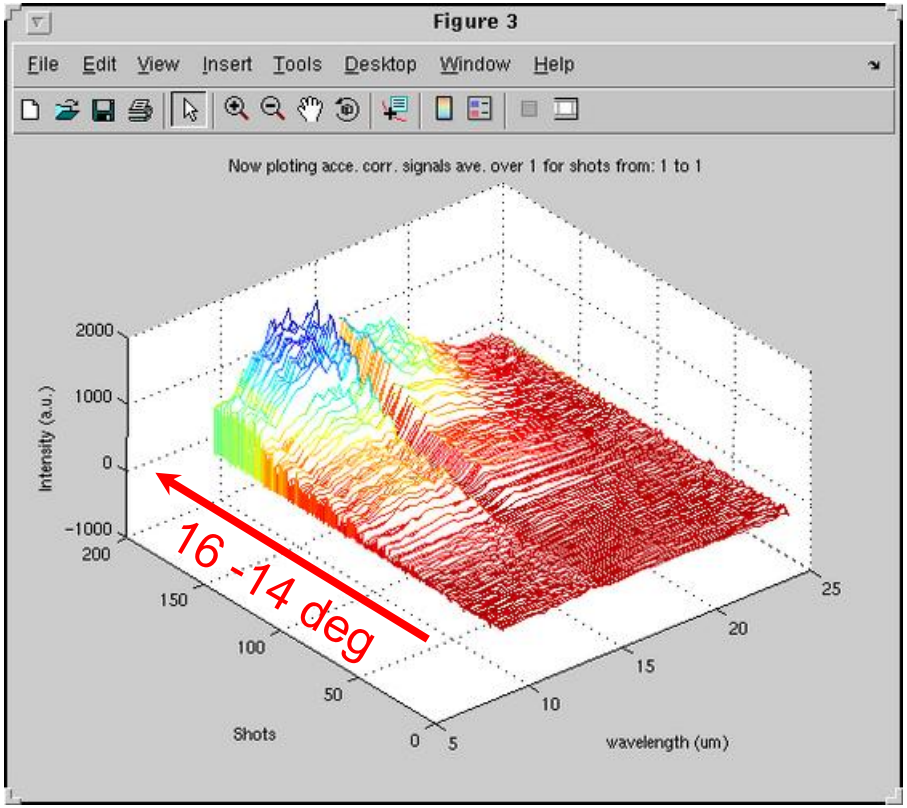
- 13.3 deg in ACC23 – 100 shots



THz Spectra

- Phase scan ACC23 16deg -> 14 deg in ~0.1 deg steps
- Strongest contribution in 8-25um range

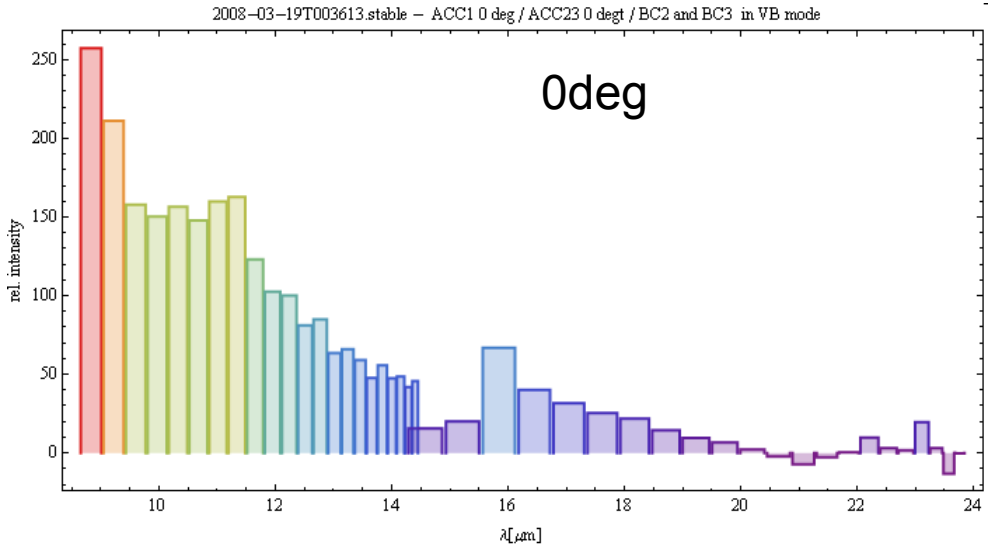


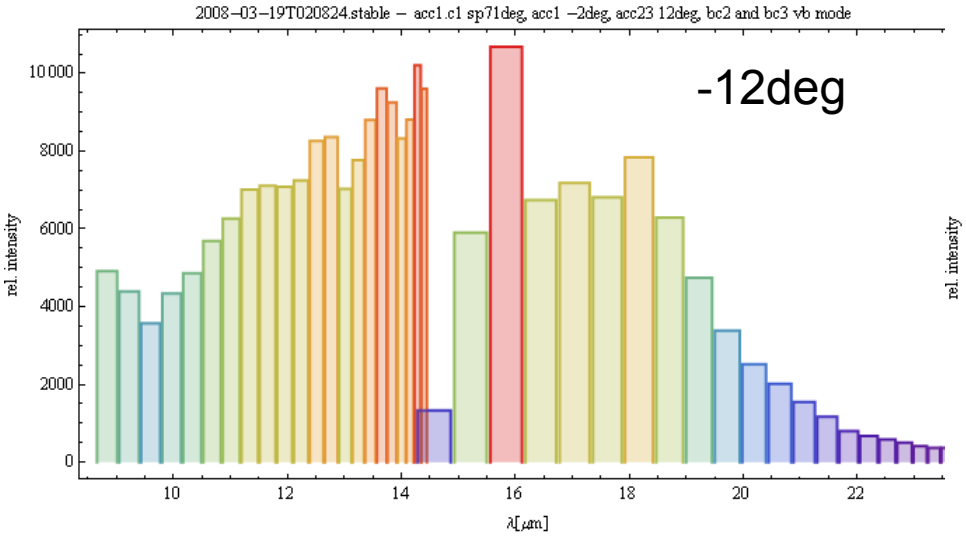


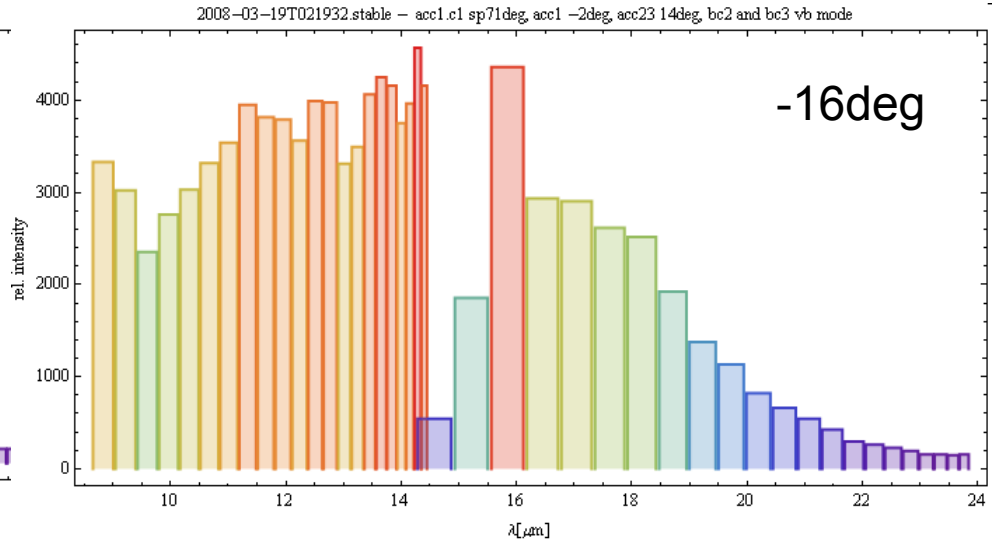
“Microbunching” ?

- ACC1.C1 vb mode
- ACC1.C2-C8 -2deg
- ACC23 scan

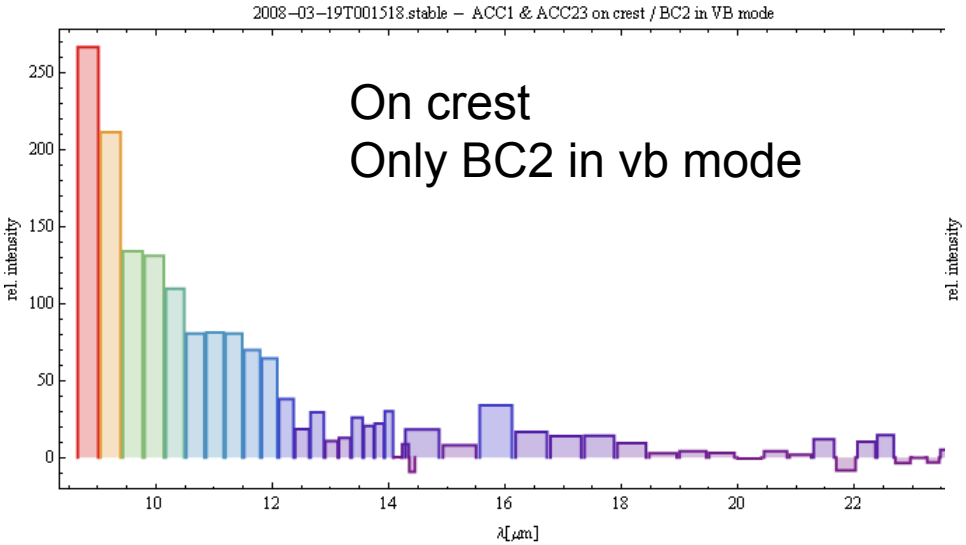
- Strong signals in predicted “microbunchig mode”

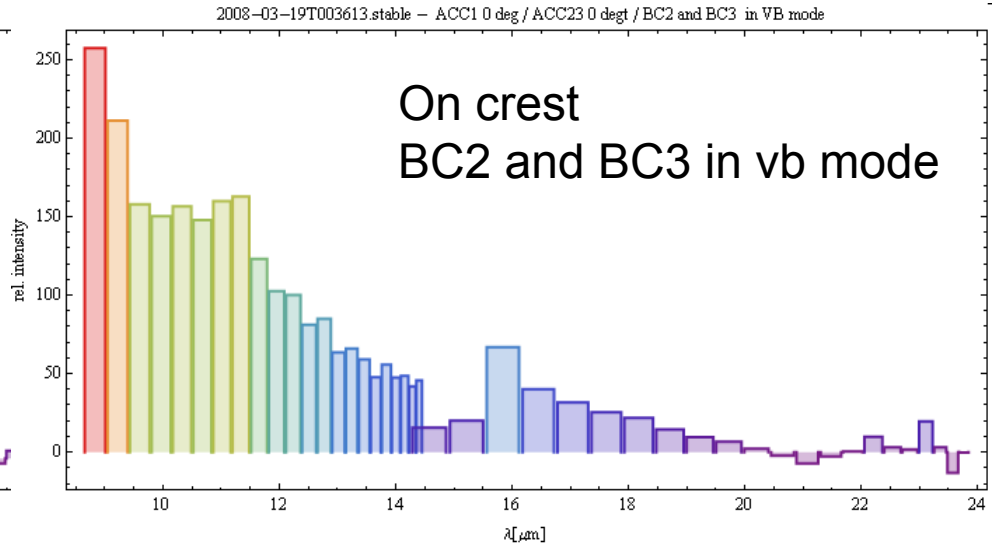


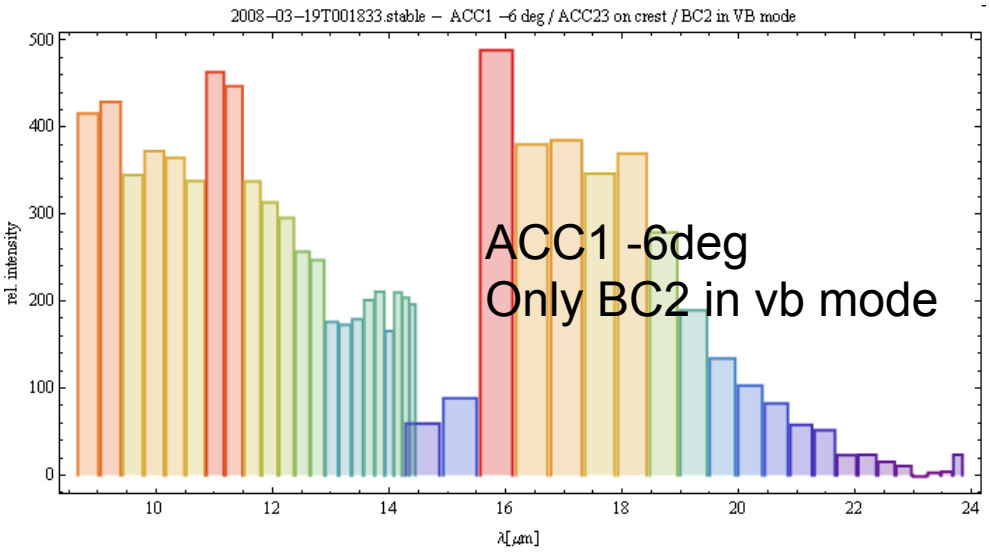




“no microbunching”?



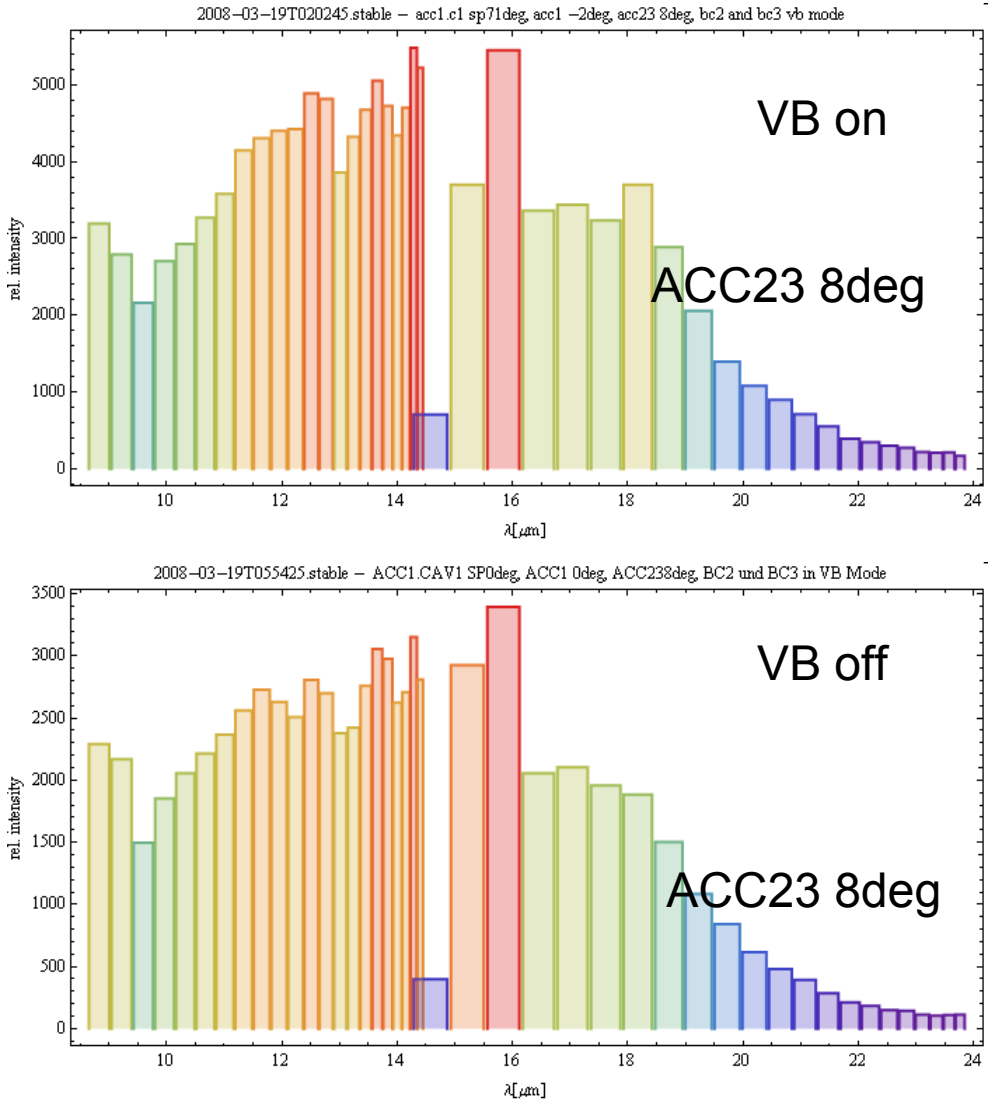




- Structure in the 8-25um range
- Low intensity compared to the “microbunching mode”

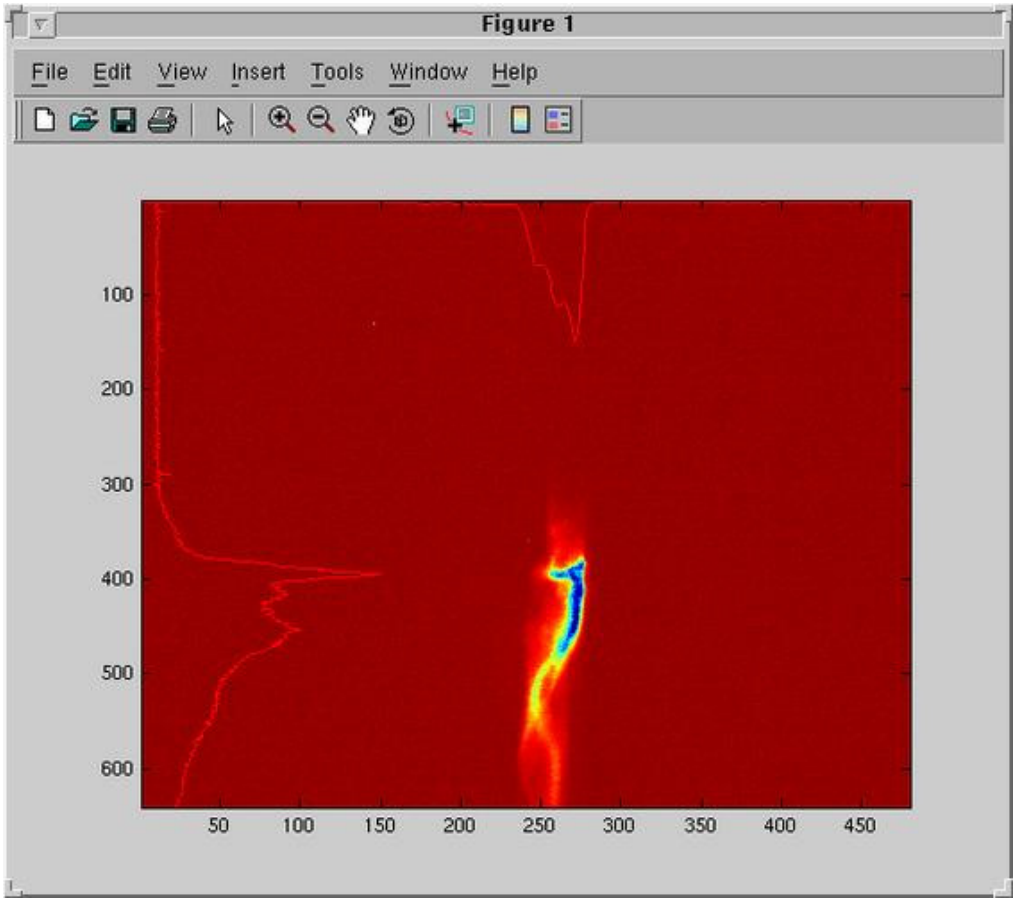
VB on and off

- Similar structure with and without VB
- Strongest THz signal at ACC23 8 deg offcrest in non vb mode (~12 deg in vb mode)
- Maximum signal lower than in vb mode

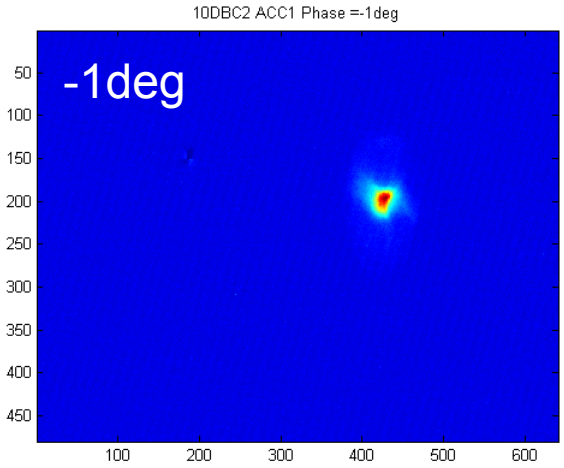


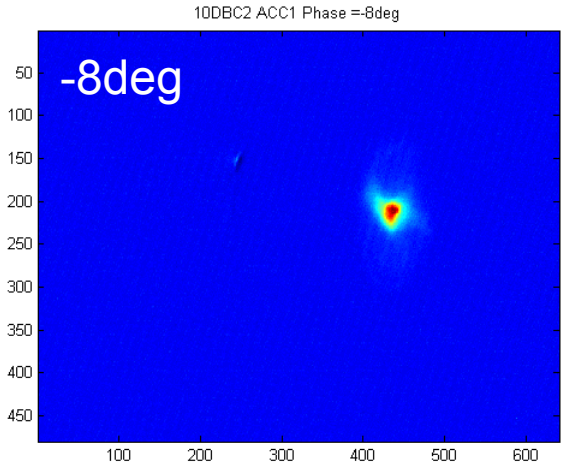
Spike of Tail ?

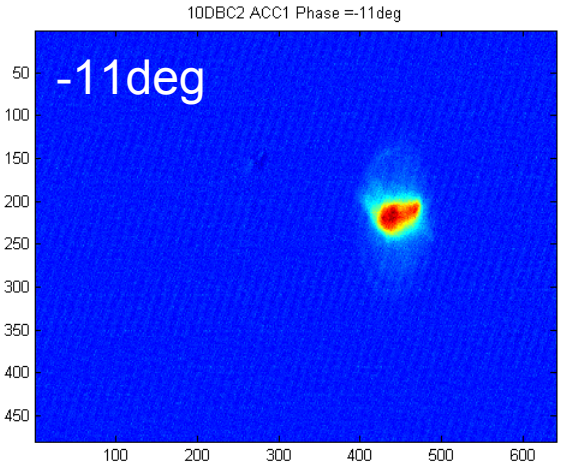
- Widening of beam spike
- Distortion of the whole bunch
- Strong machine jitter complicates analysis
- Not completely analysed yet….

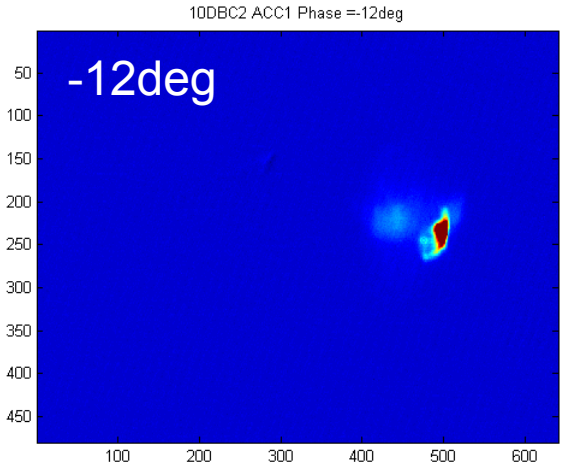


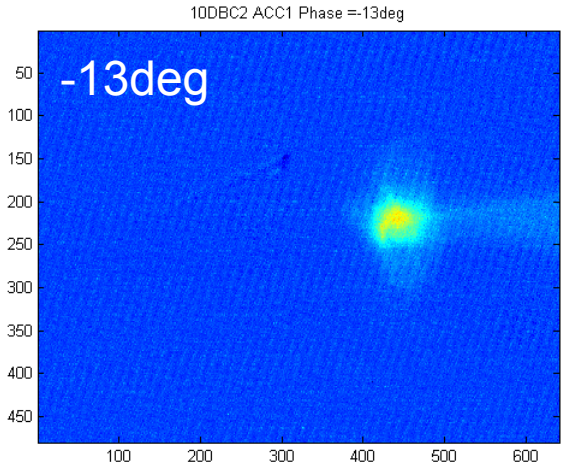
COTR in standard compression?

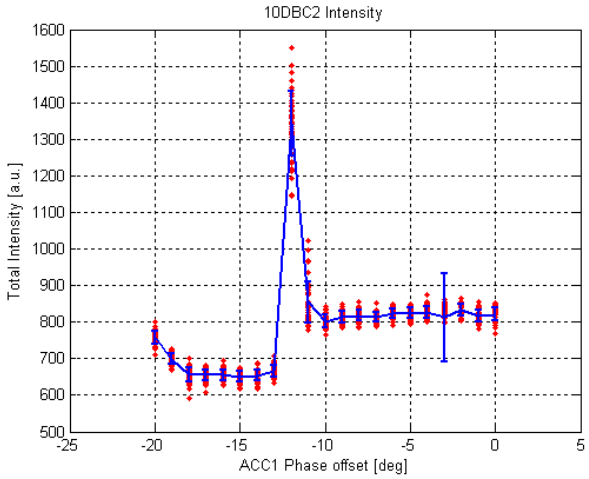




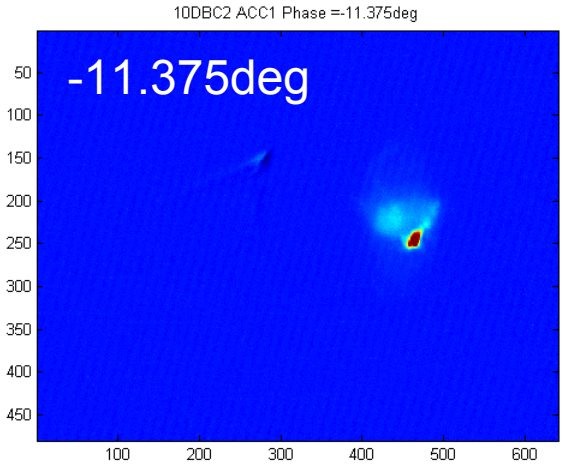


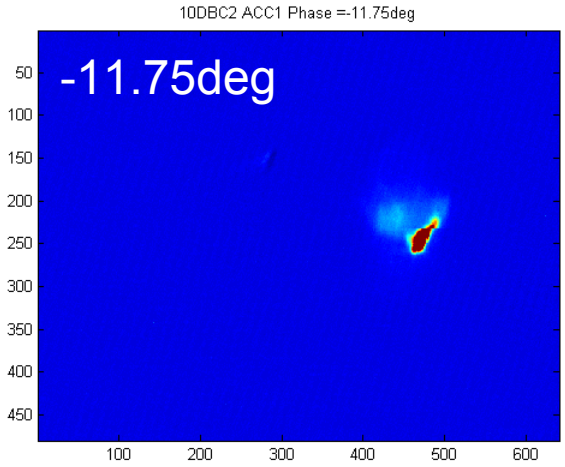


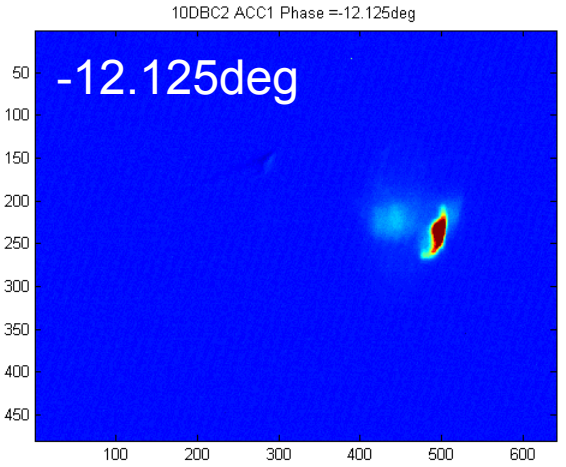


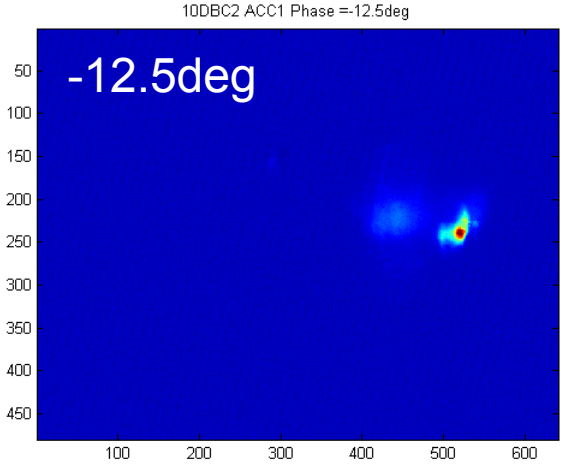


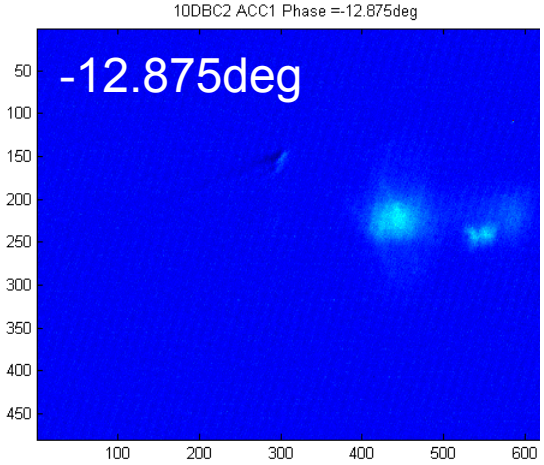
COTR in standard compression?

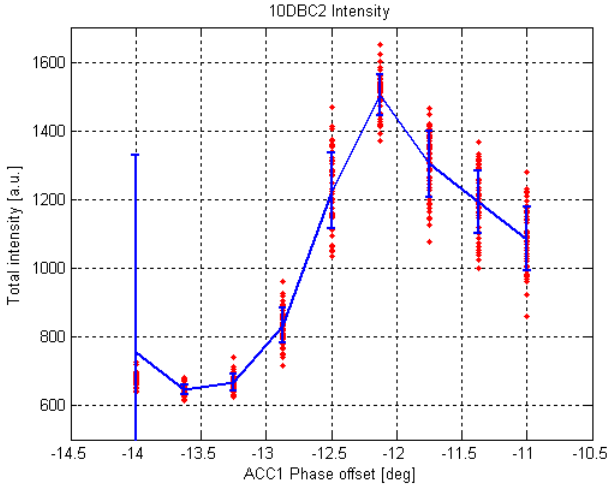






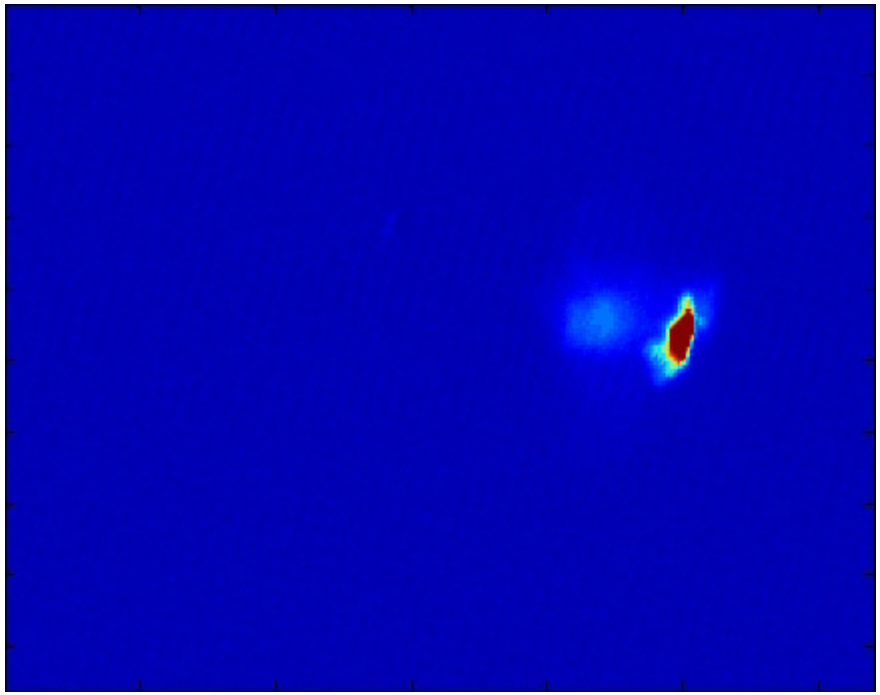




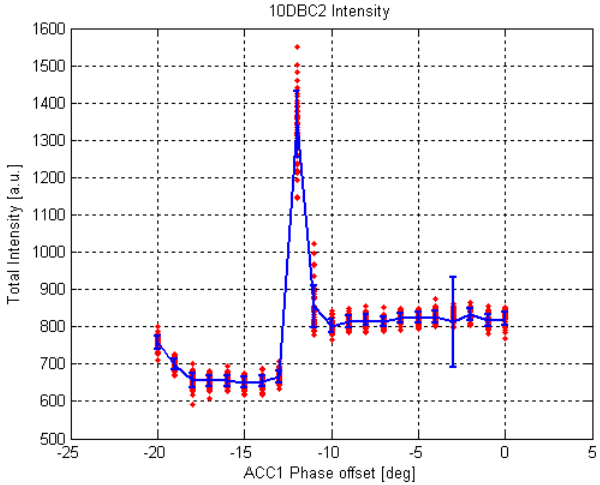


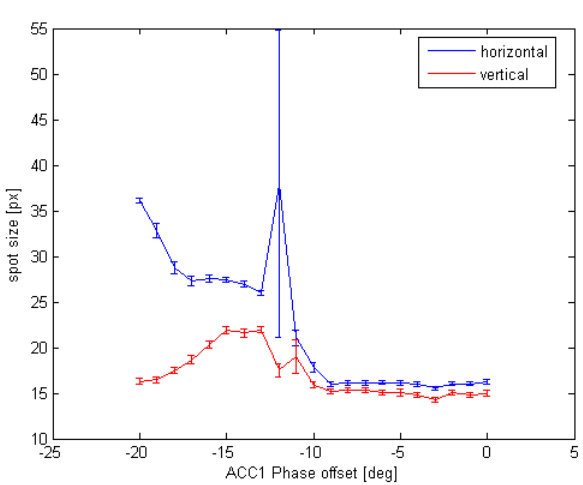
Fluctuations

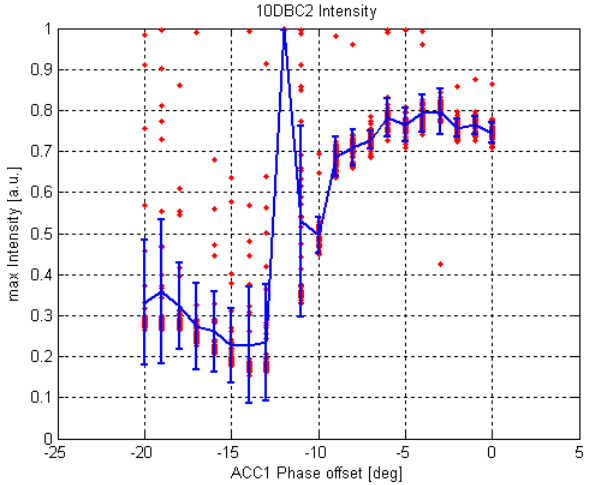
- ACC1 phase 12.125 deg



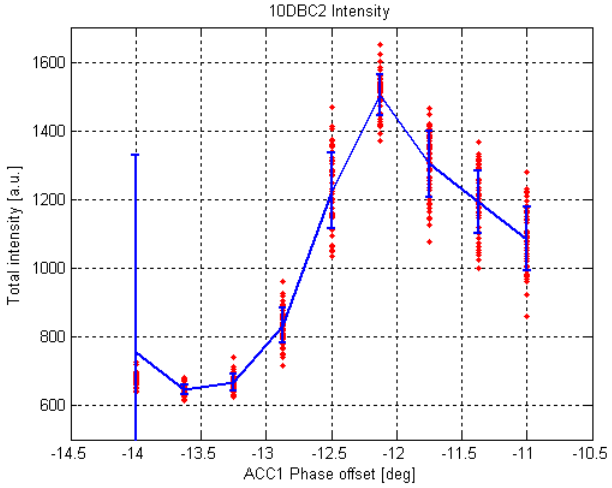
Summary

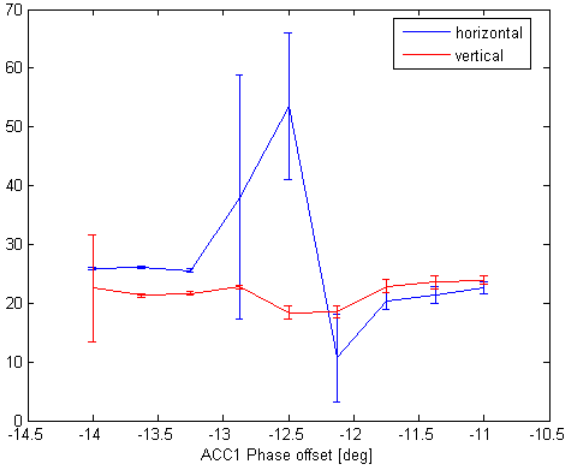


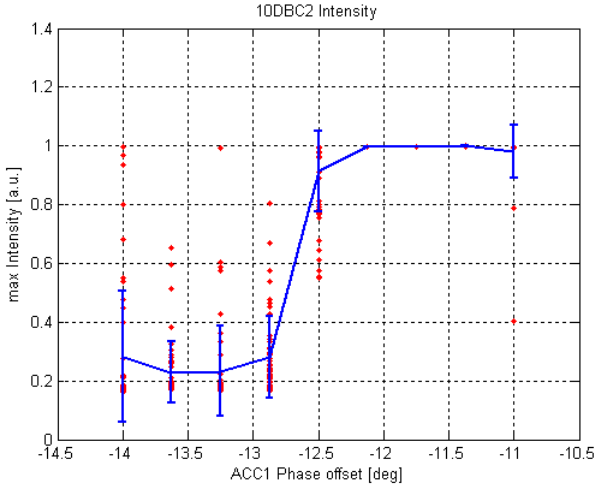




Increased spot size at “full compression” and a peak in maximum intensity

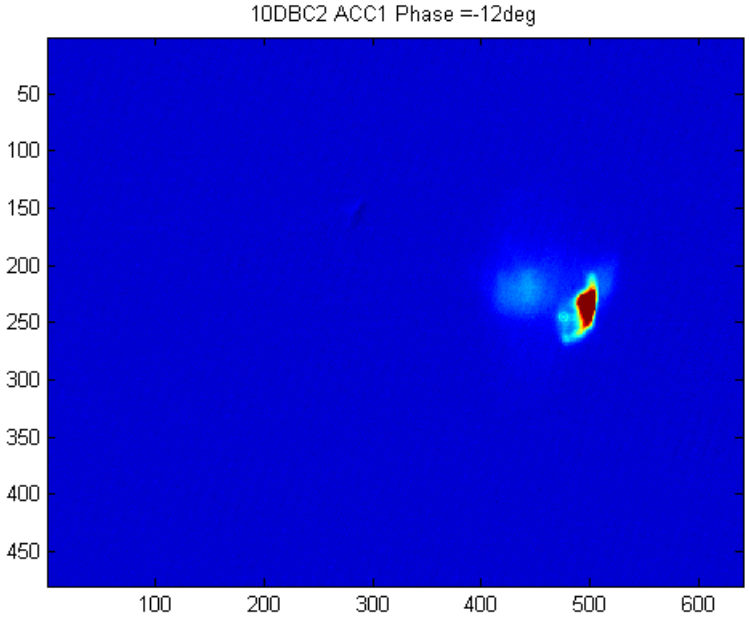


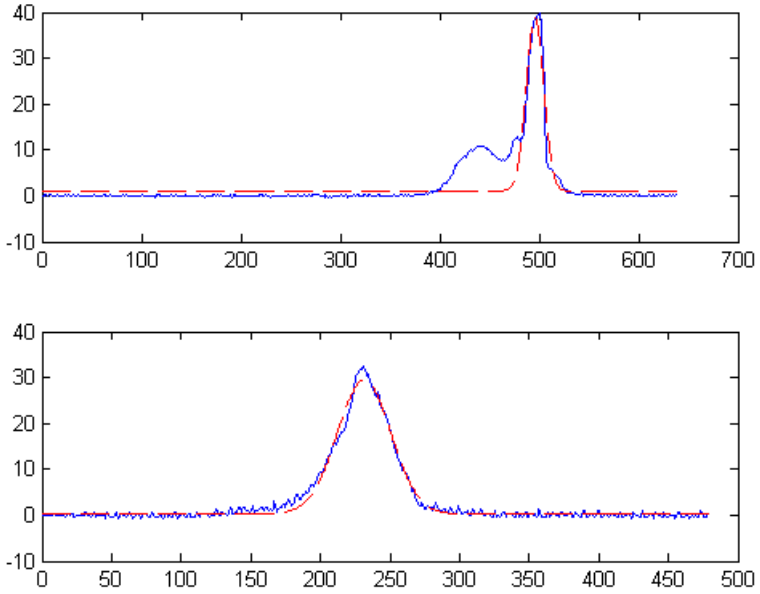




Transverse Structure

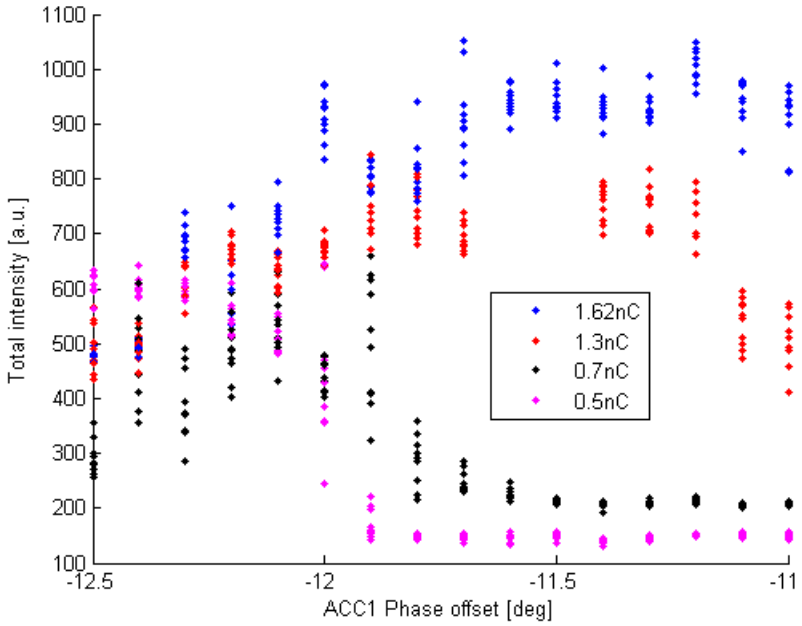
- Bright spot horizontally separated from the beam centre
  - ⇒ Spot size?
  - ⇒ High intensity in narrow region

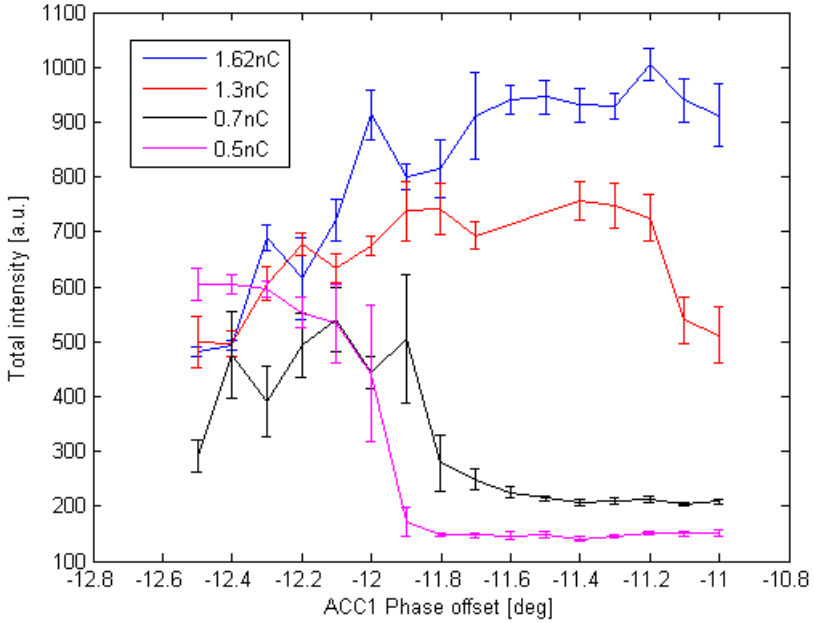




Charge Dependence

- Charge dependence study of OTR/COTR radiation
- Sharp increase of total intensity in low charge regime
- More flat intensity for high bunch charges
  - higher transverse emittance
  - uncorr. energy spread
- Similar Fluctuations in all cases





Summary

- Observation of strong THz signals in predicted “microbunching mode”
- Transverse beam breakup in “microbunching mode”
- COTR radiation in “microbunching mode”

- Indications for COTR in standard compression
- Studies on charge dependence of OTR/COTR radiation

Next Steps

- Further data analysis
  - LOLA images
  - Detailed analysis of the THz spectra
  - More detailed image analysis

- Simulations
  - Start to end simulations with all known machine parameters during the measurements
  - Studies on transverse beam breakup

Thank you for your Attention

and

Special thanks to V. Ayvazyan, M. Huening, O. Grimm, B. Schmidt, S. Wesch, C. Behrens, H. Delsim-Hashemi.