Simulation of THz Spectra

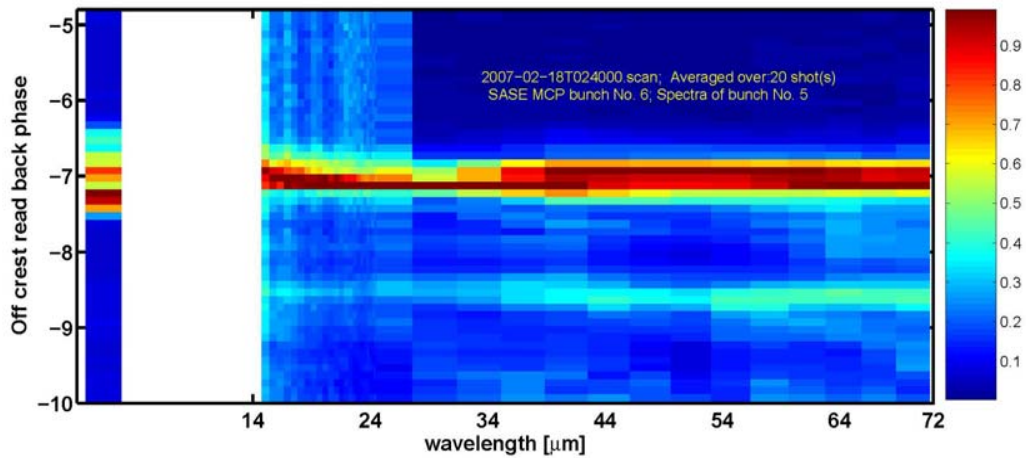
Bolko Beutner, DESY

XFEL Beam Dynamics Meeting 28.04.2008

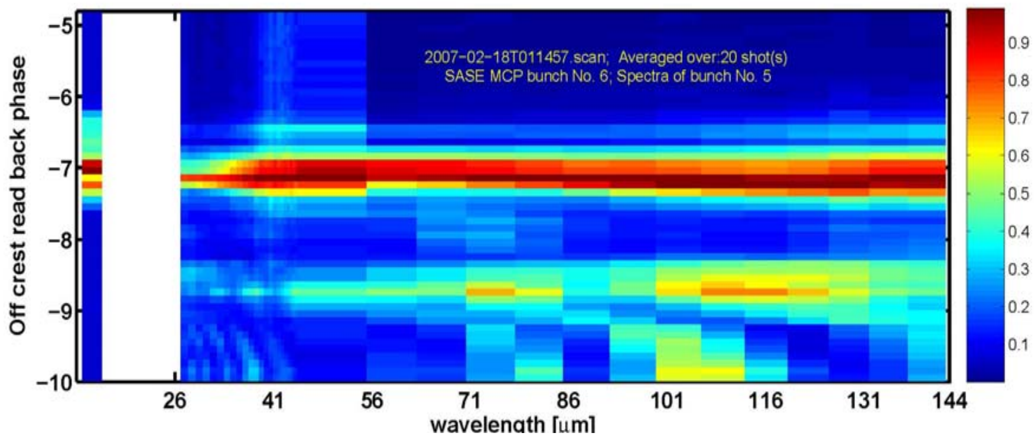
Introduction

THz spectra and their dependence on ACC1 phase were measured

- Strong changes of power for less than a degree phase change
- Patterns in the spectra for high off crest phases
- Structures in the range of a few ten micron

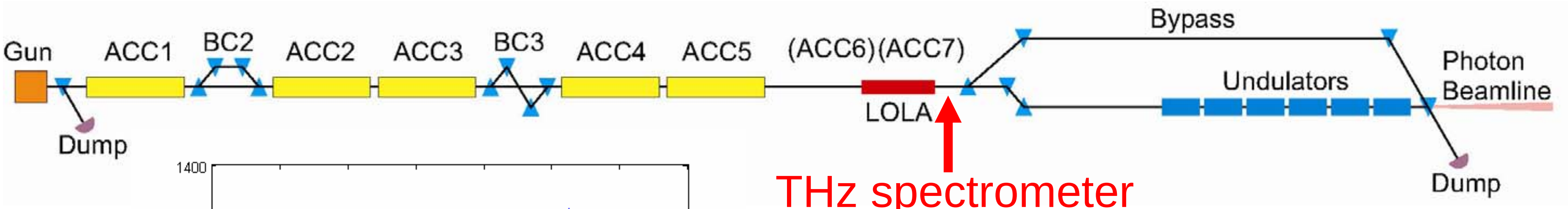


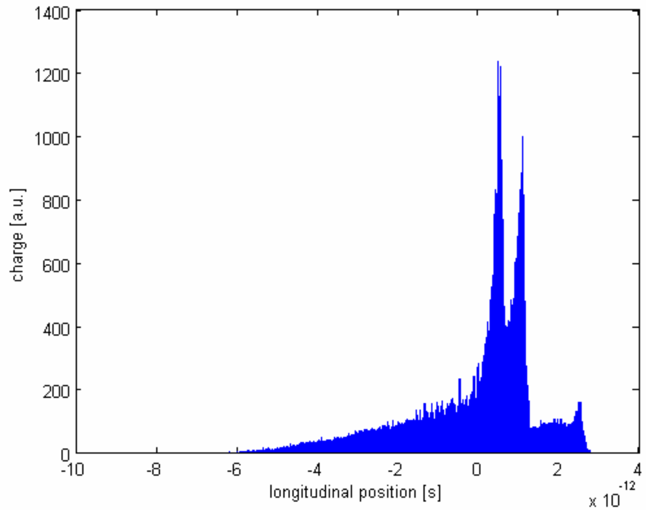
H. Delsim-Hashemi



Introduction

- To understand the features of the spectra start-to-end simulations (thanks to M. Dohlus) for FLASH are used
- Spectra are generated from the longitudinal charge profiles for different ACC1 phases
- THz spectrometer response is generated from these spectra



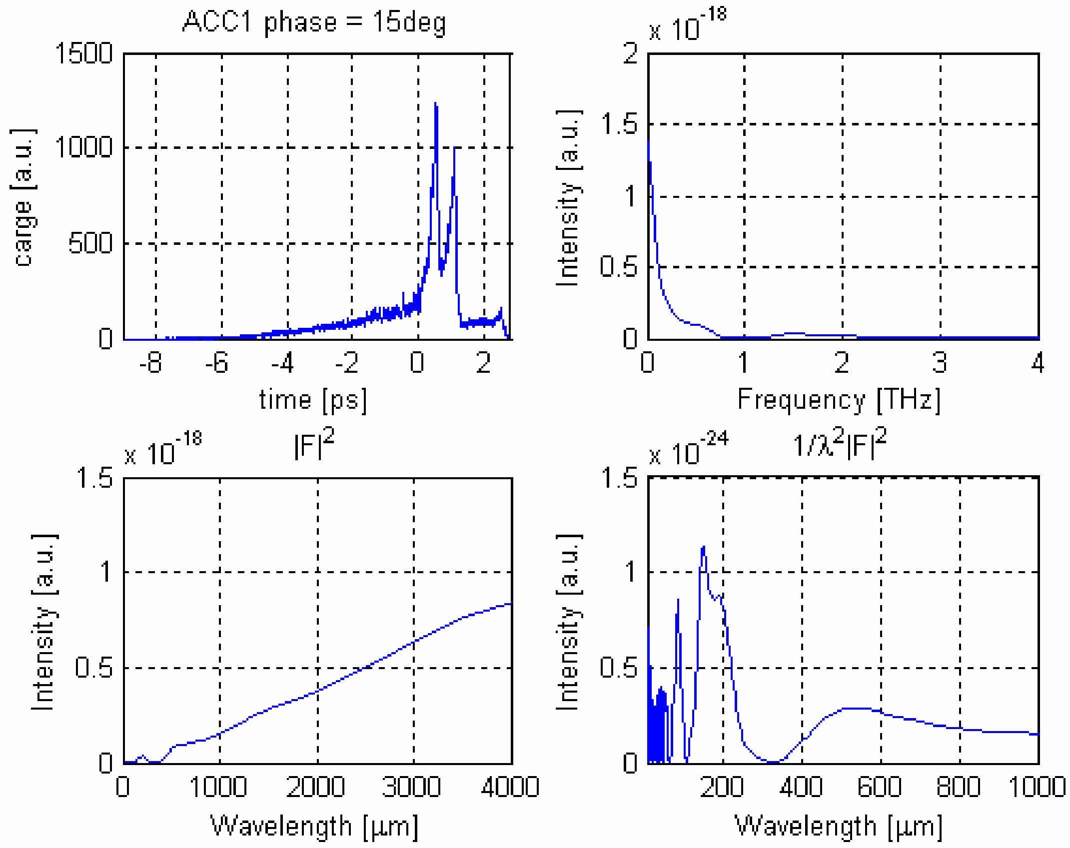


Procedure Overview

- From the Fourier transform of the longitudinal charge profile one calculates the Form factor, the wavelength spectrum, and the spectrometer response

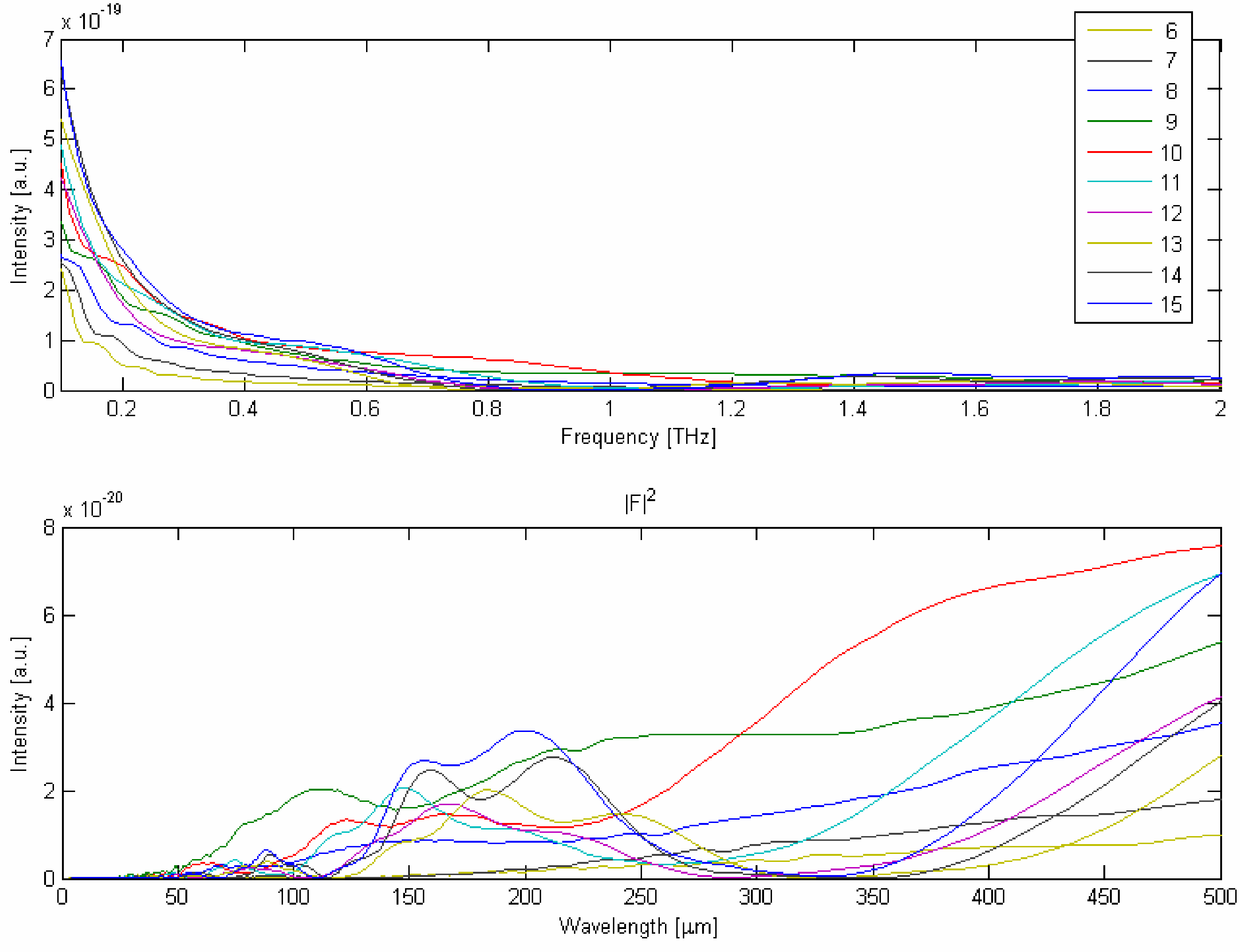
$$\frac{dU_N}{d\omega} \propto |F(\omega)|^2$$

$$\frac{dU_N}{d\lambda} \propto \frac{1}{\lambda^2} |F(\lambda)|^2$$



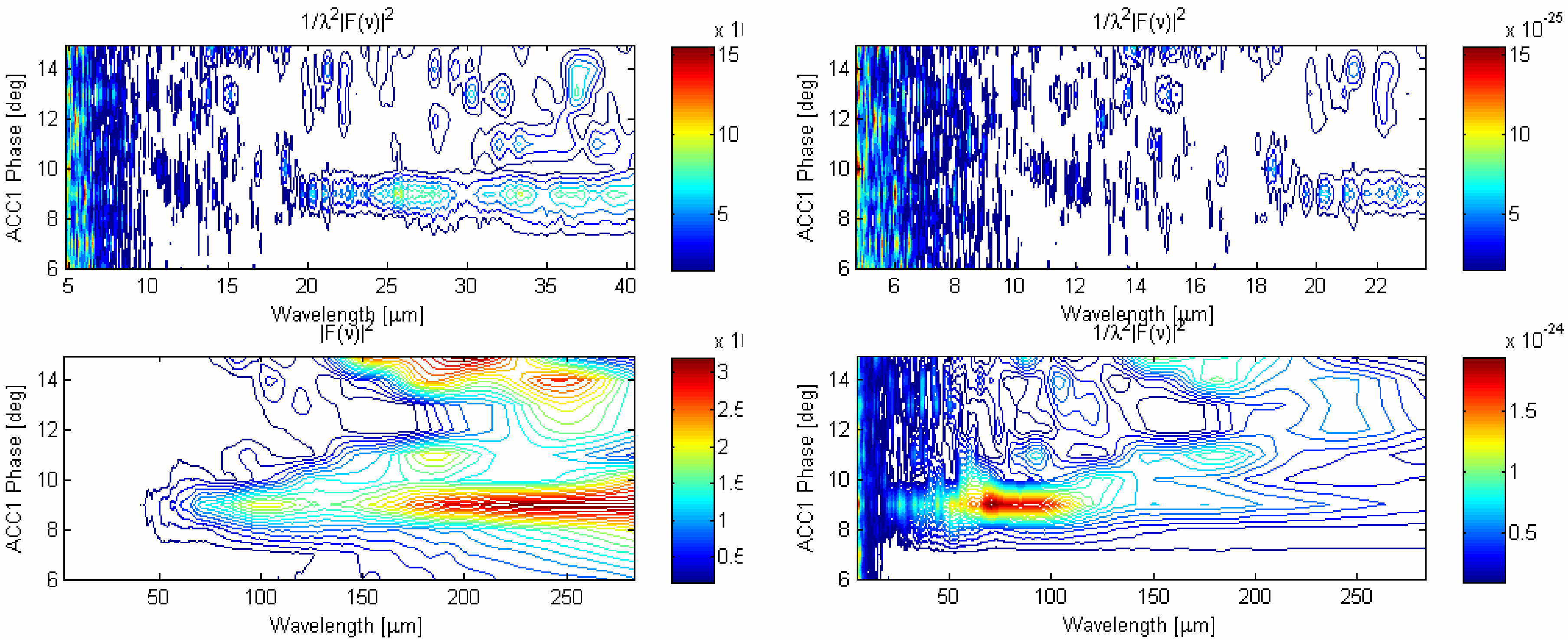
Simulated Form factors

ACC1 Phase



ACC1 Phase scan

- Steep changes of spectra with ACC1 phase (only 1 deg steps in simulations)
- Substructure for off crest phases higher than about 10 deg
- Noise below about 20 micron

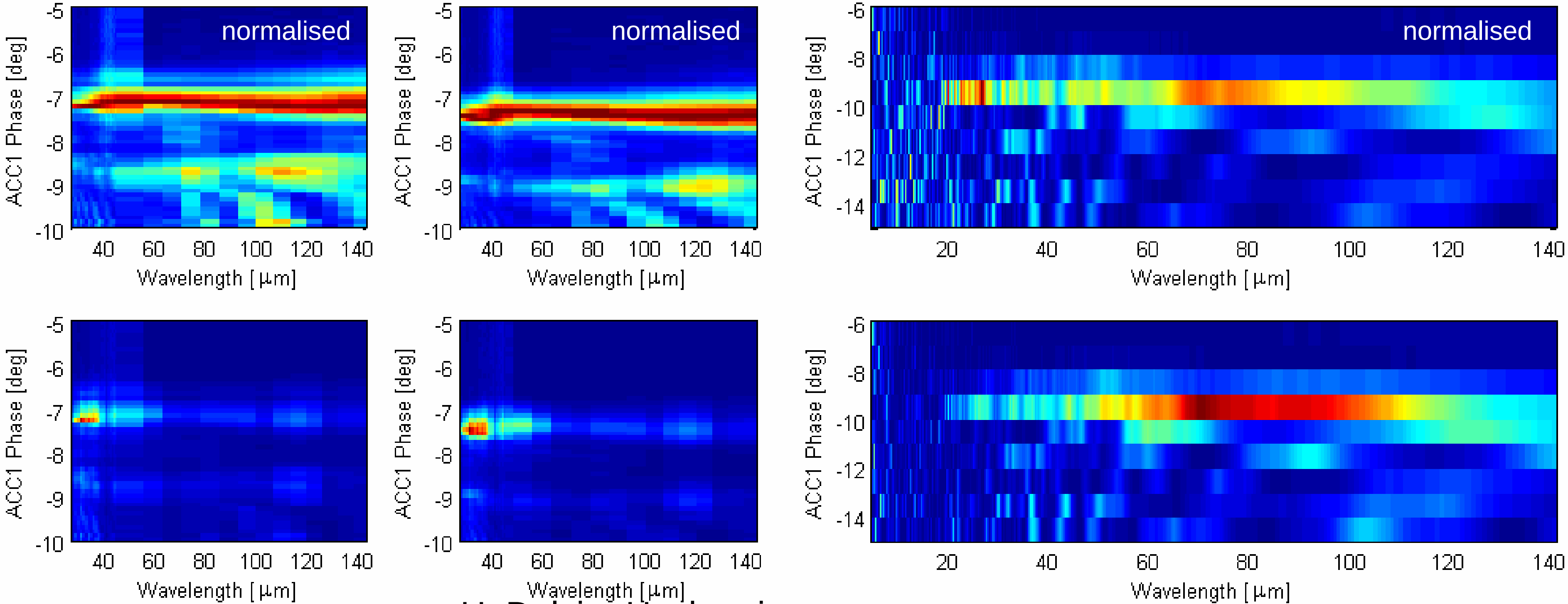


Comparison with measurements

- Phase shift between simulations and measurements of about 2deg or additional features at ~7deg in measurements
- simulations were not set up to match measurements (ACC1 gradient and BC bending angles might be slightly different)

measurements

simulations normalised

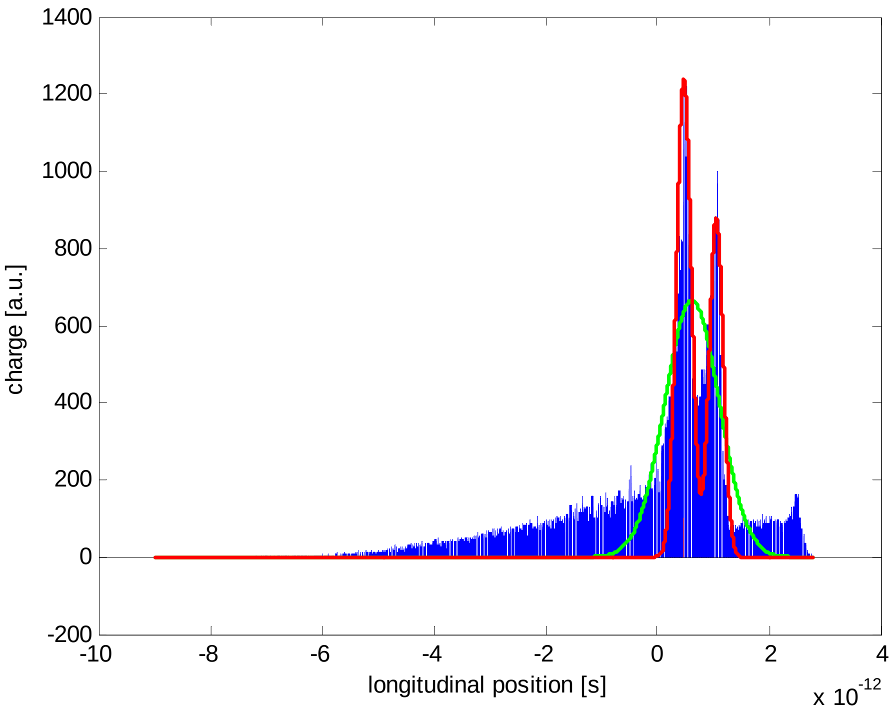


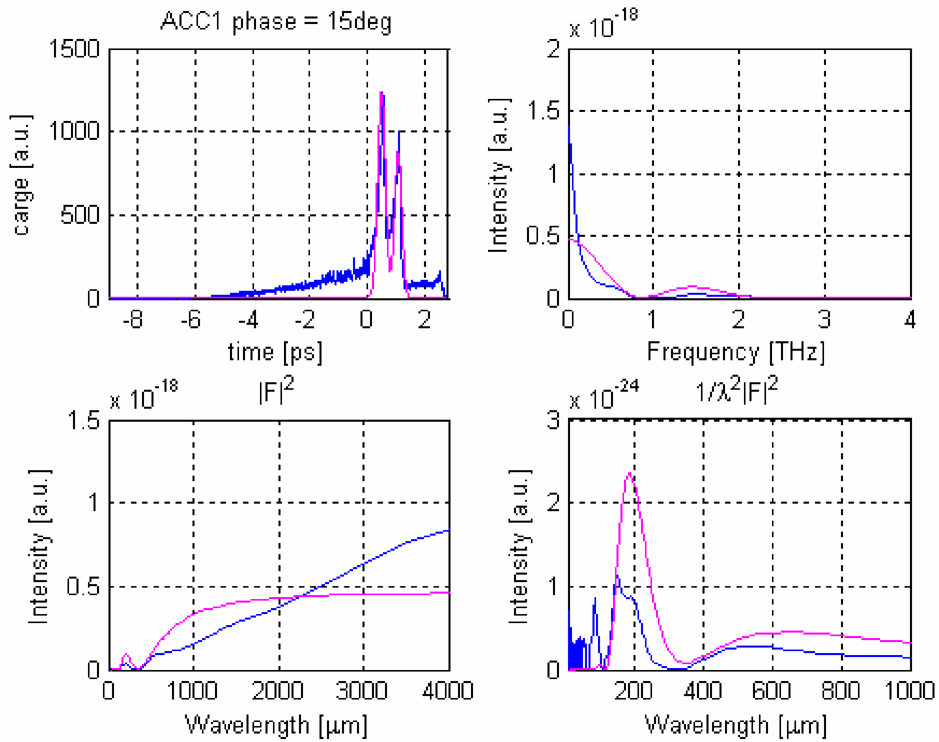
H. Delsim-Hashemi

Double spike structure

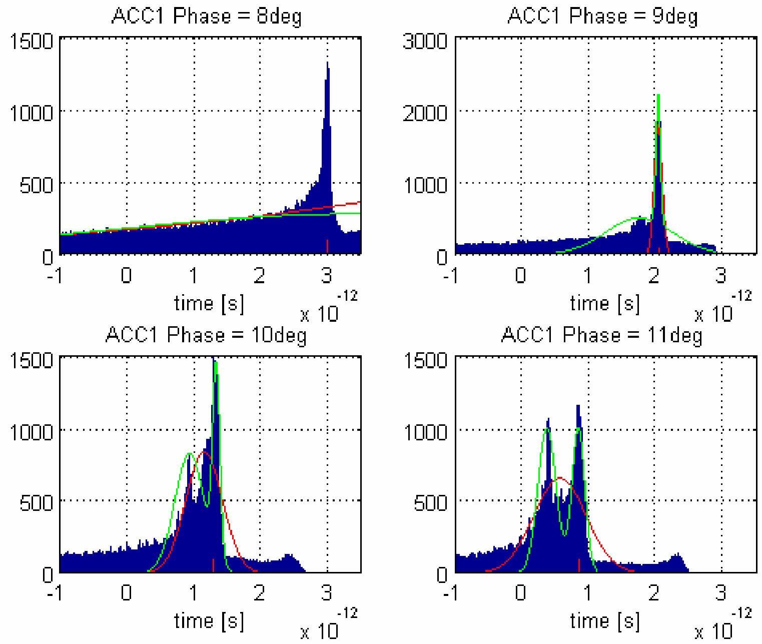
- Double spike structures after about 9 deg off crest
- Double Gaussian is fitted to charge profile and used for spectra generation

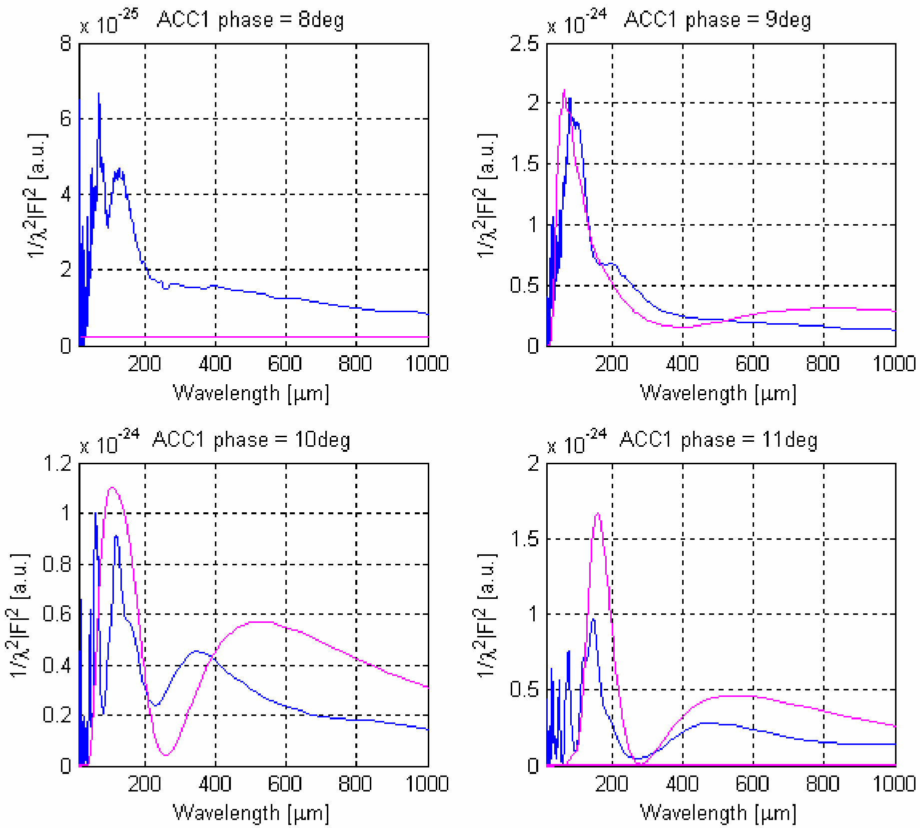
s2e Double Gaussian





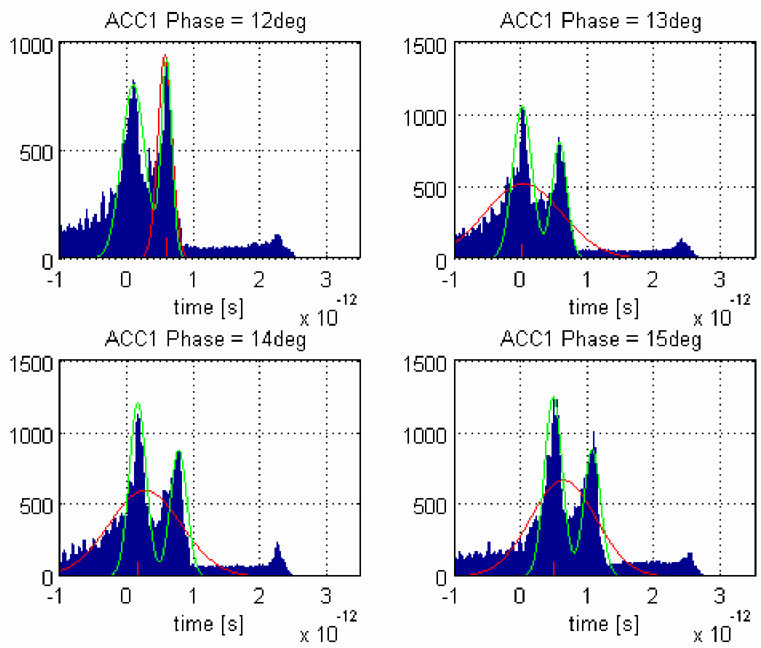
Comparison with double Gaussian I

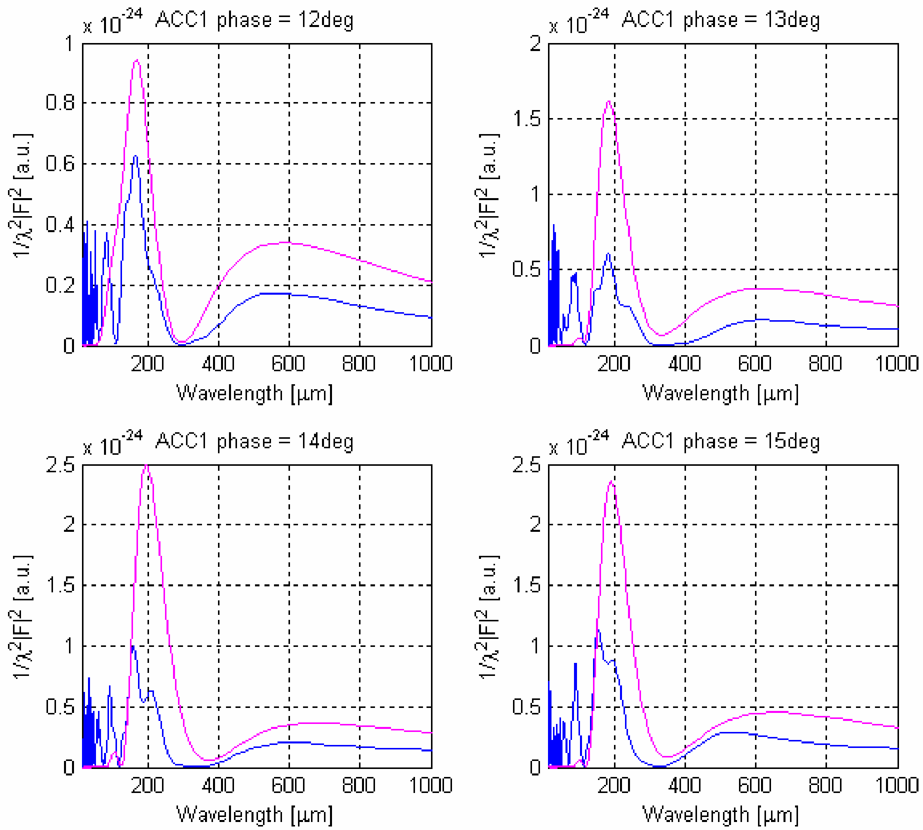




- No proper fit at 8 deg (no double spike)
- Double Gaussian is not the best choice at 10 deg

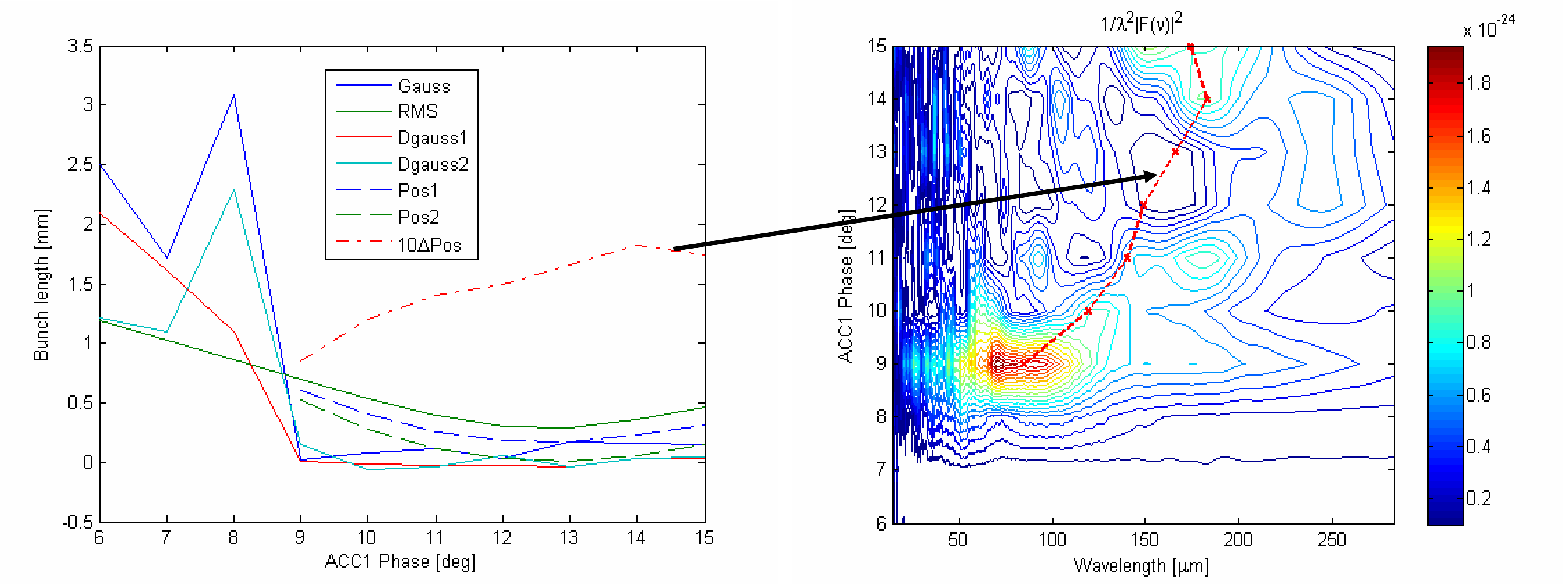
Comparison with double Gaussian II





- Agreement of coarse structure between double Gaussian and Simulations
- For Phases higher than 12 deg the spike in the spectrum is reduced for real data (effects of third spike?)

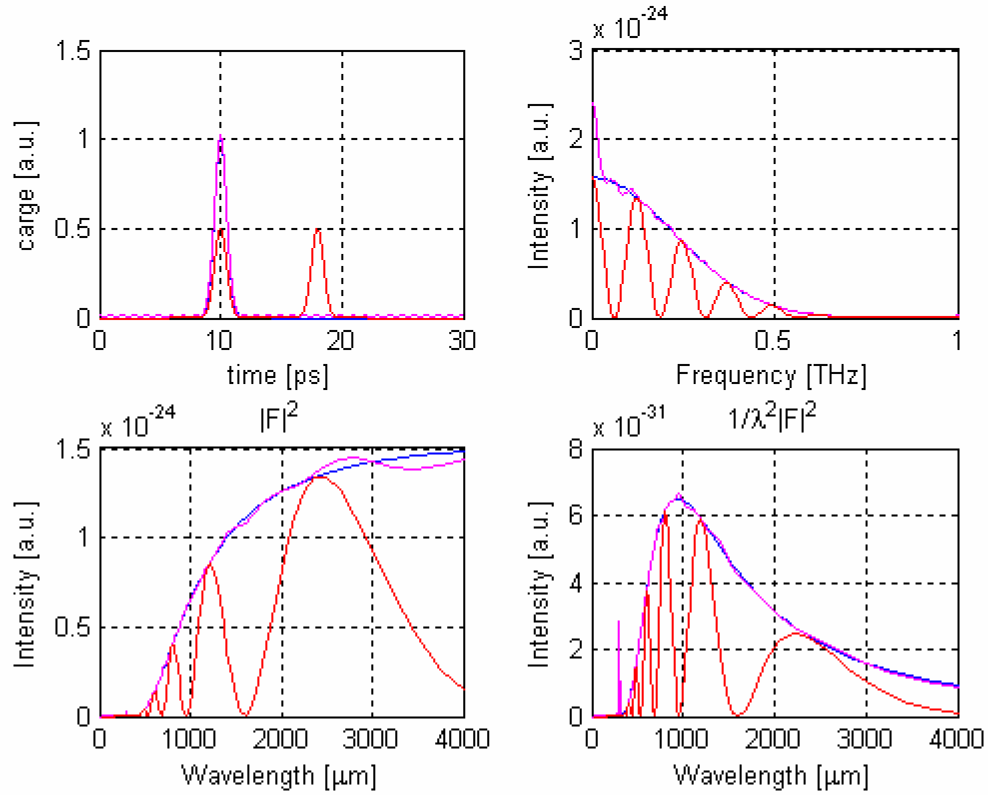
Correlations with bunch dimensions



- Spike separation is compared with the wavelength spectrum
- Some correlations are visible

Toy model

- Simple structures build from Gaussians are used for qualitative understanding
- Small scale modulations lead to a sharp signal at the wavelength
- Two Gaussians gives rise to substructure in the spectrum



Gaussian (sigma = 0.5ps)

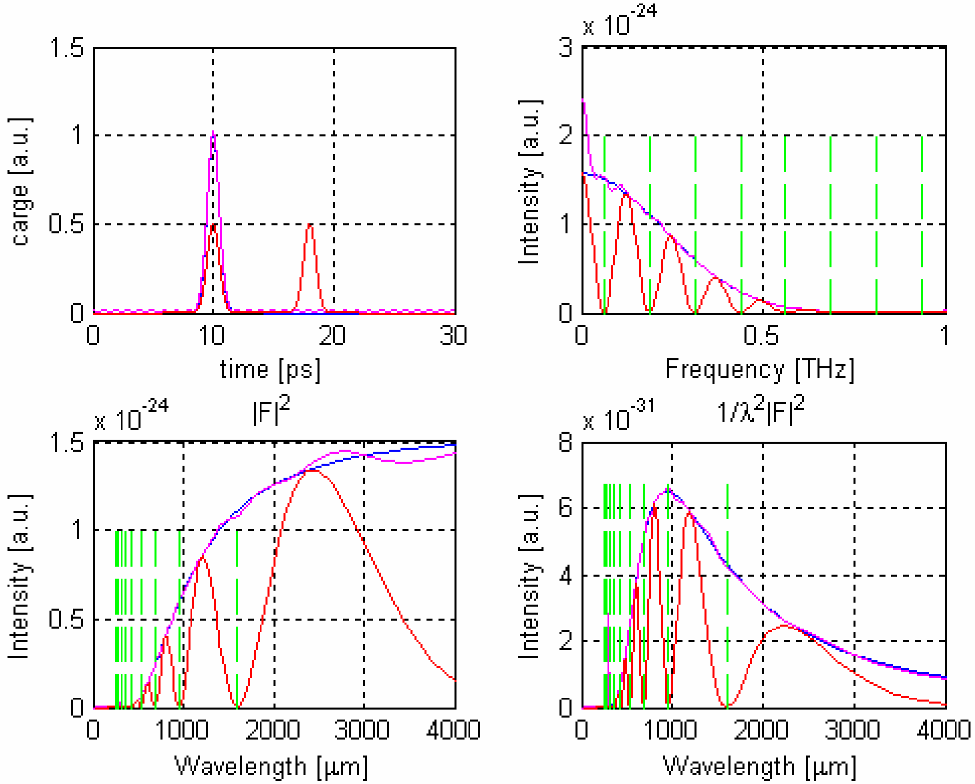
Gaussian with sine (lambda = 1ps/300um)

two half Gaussians (Delta s = 8ps)

Substructure

- Minima are caused by destructive interference between the radiation of the two spikes

  => position of minima corresponds to spike separation



$$\varphi(\Delta t) = 2\pi \frac{\Delta t}{T}$$

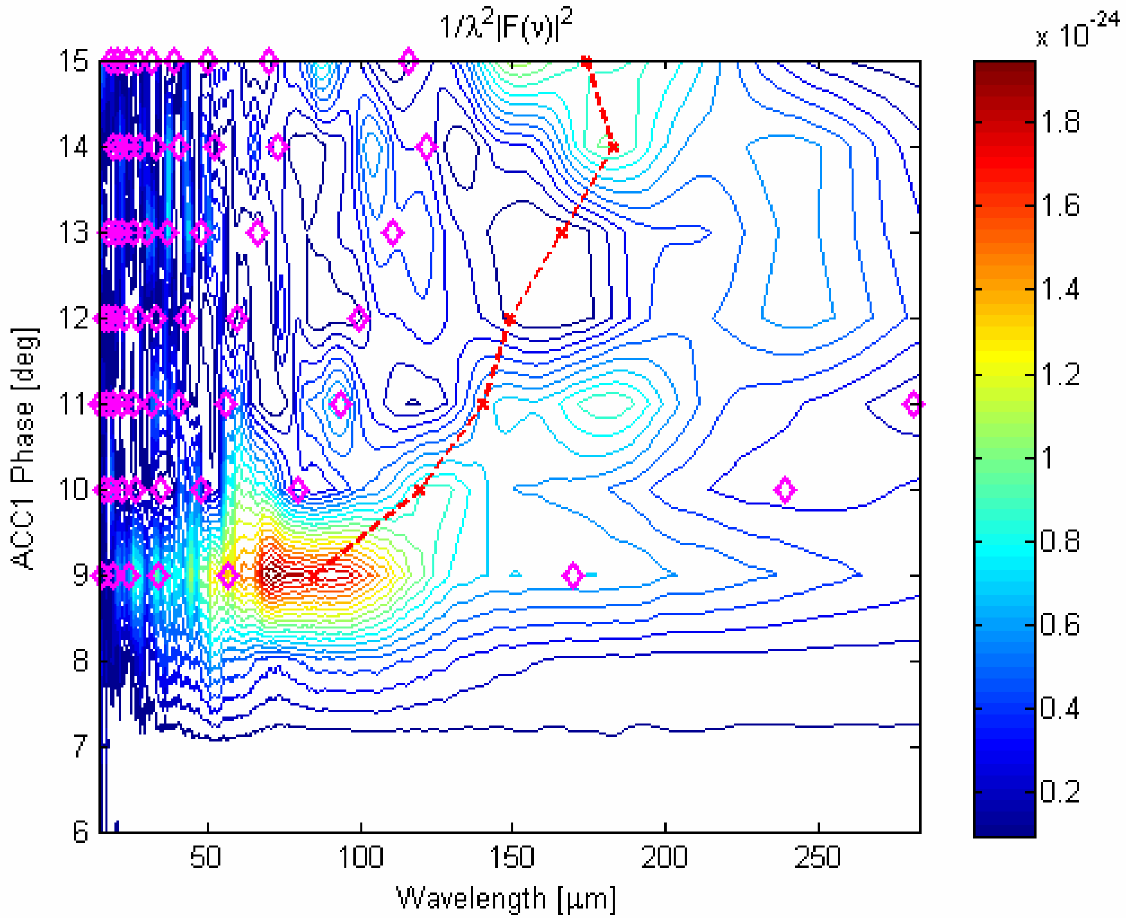
$$\varphi \stackrel{!}{=} (2n-1)\pi$$

$$\nu_n = \frac{1}{T} = \frac{2n-1}{2\Delta t}$$

$$\lambda_n = \frac{\Delta t c}{n - 1/2}$$

Comparison with Spectra

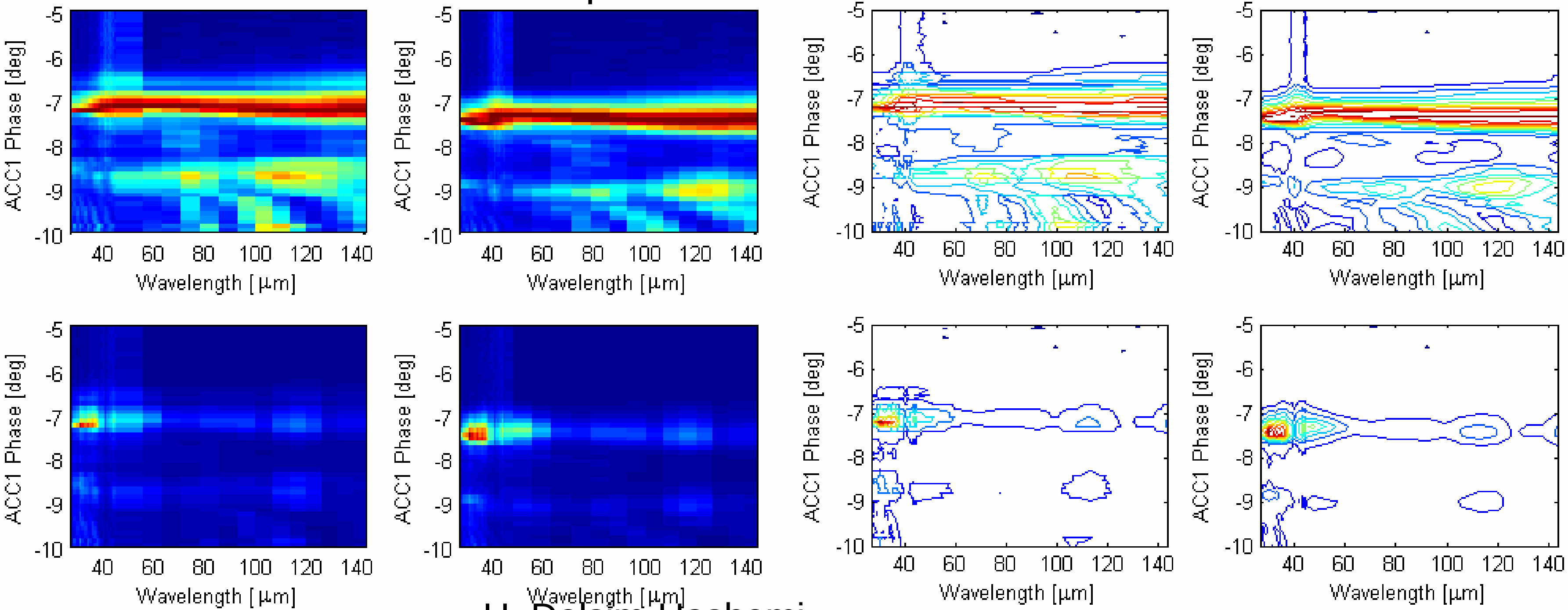
- Spike separation from the double Gaussian fit is used to estimate minima position



Substructure in measurements I

- For ACC1 phase offsets higher than ~8deg minima patterns exist in measured spectra
  => indications for double spike structure
- Qualitative correspondence to estimated pattern

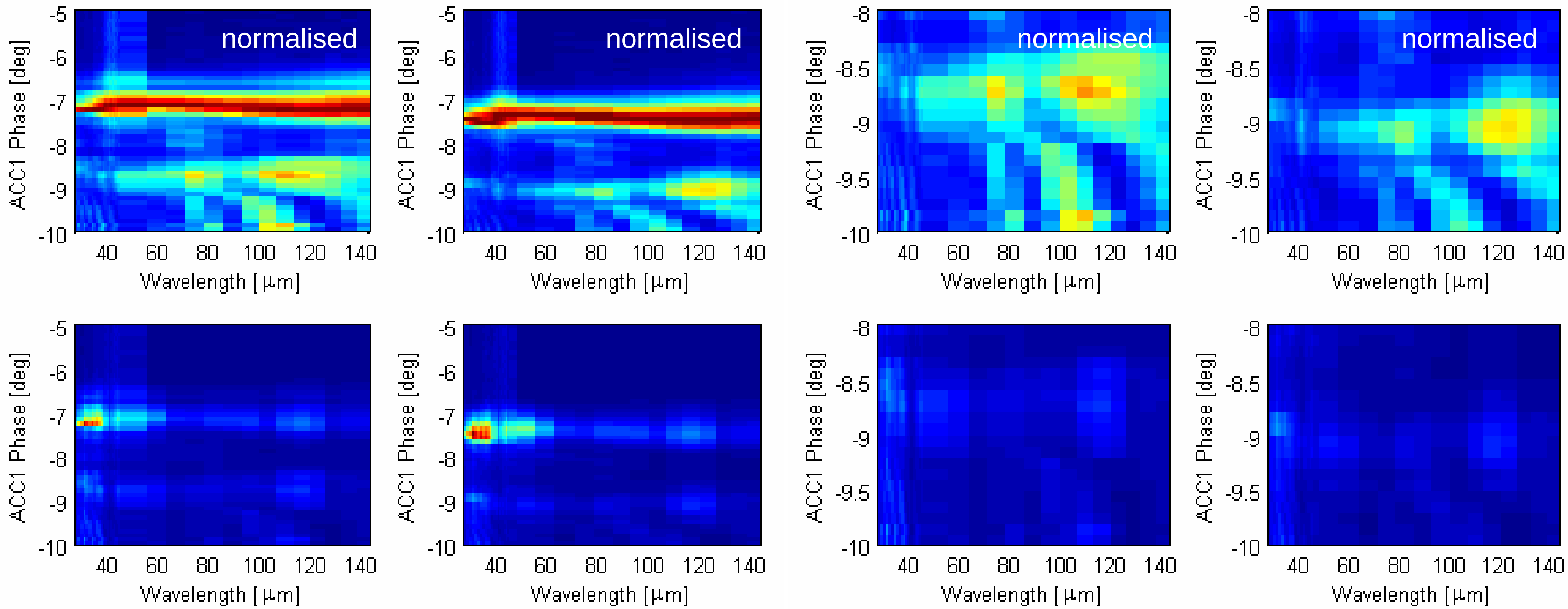
two different measured spectra



H. Delsim-Hashemi

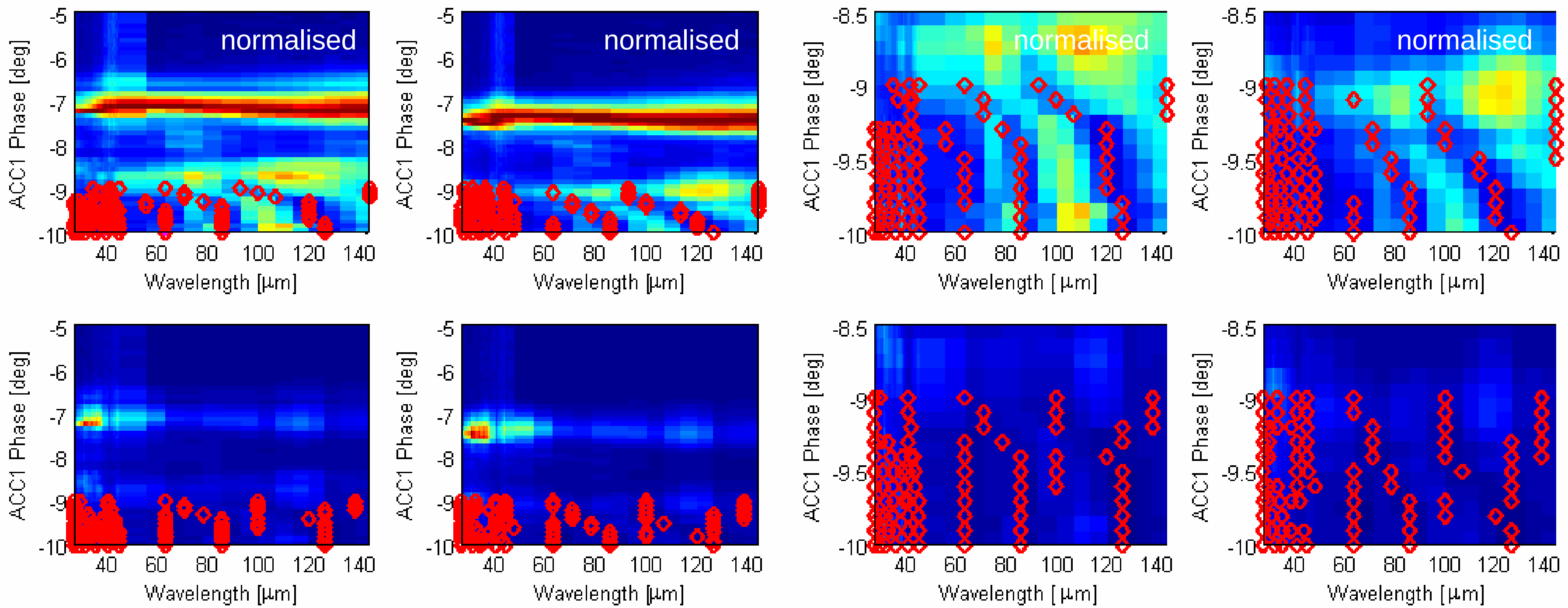
Substructure in measurements II

- Minima structure in the phase range from 9 to 10 deg are determined and used for a estimation of spike separation Δt using a linear fit to $\lambda_n = \frac{\Delta t c}{n - 1/2}$



Substructure in measurements III

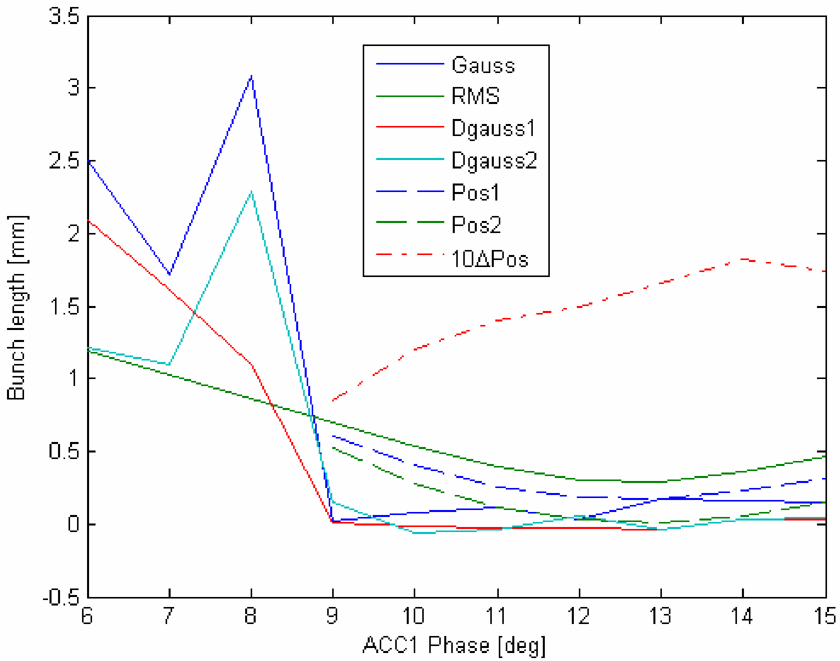
- Minima structure in the phase range from 9 to 10 deg are determined and used for a estimation of spike separation Δt using a linear fit to $\lambda_n = \dfrac{\Delta t c}{n - 1/2}$



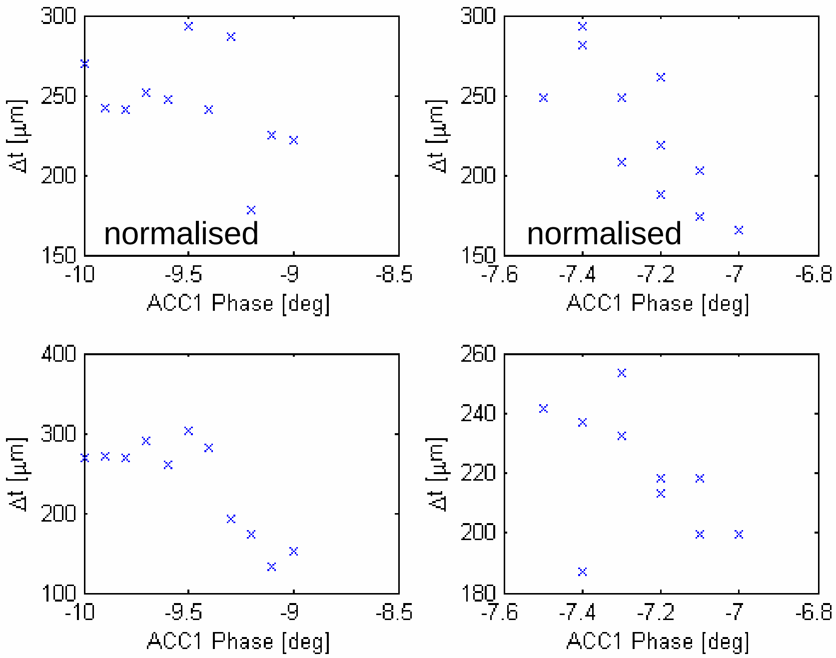
Comparison with Simulations

- Estimated spike separation from ~150 to ~300 micron
- Simulations go from ~100 to ~150 micron
- Simulations are not specifically set up to match measurements (RF and BC settings)

simulations



measurements



Summary

- Steep increase of THz signal for small phase changes is reproduced in simulations
- Phase shift or additional feature at ~7 deg in measurements

- Qualitative understanding of substructure induced by double spikes
- Estimation of double spike structure from spectra is possible (no detailed error analysis yet)

- Simulations give no reliable information on micro bunching (<20 micron)

Next Steps

- Detailed analysis of measured double spike spectra
- Complete analysis of old and recent measured phase scan data

- more detailed start to end simulations
  - finer phase steps
  - Setup of simulations to match measurements
- Extract spike separation from simulated spectra to crosscheck the analysis procedures
- Comparison with micro bunching simulation models (<20 micron)

- Decomposition of charge profiles in more than two Gaussians (Delsim-Hashemi)