THz Driven Deflection and Tomographic Retrieval of Bunch Parameters

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Terahertz Acceleration Group - https://www.thzag.uk/

Motivation

- THz Deflection Experiment using 100 keV Electron Gun

- Work towards THz Compressor and THz Acceleration

- What other useful information can we extract from these measurements?

- Can Tomography techniques be applied to data we already have?

THz Deflection - Experimental Overview

- 100 keV Electron gun set up combined with THz pulses generated using an amplified laser system

- Electrons and THz pulse generated using same laser pulse giving inherent synchronization

MCP

100 keV Electron Gun

DLW

THz Source
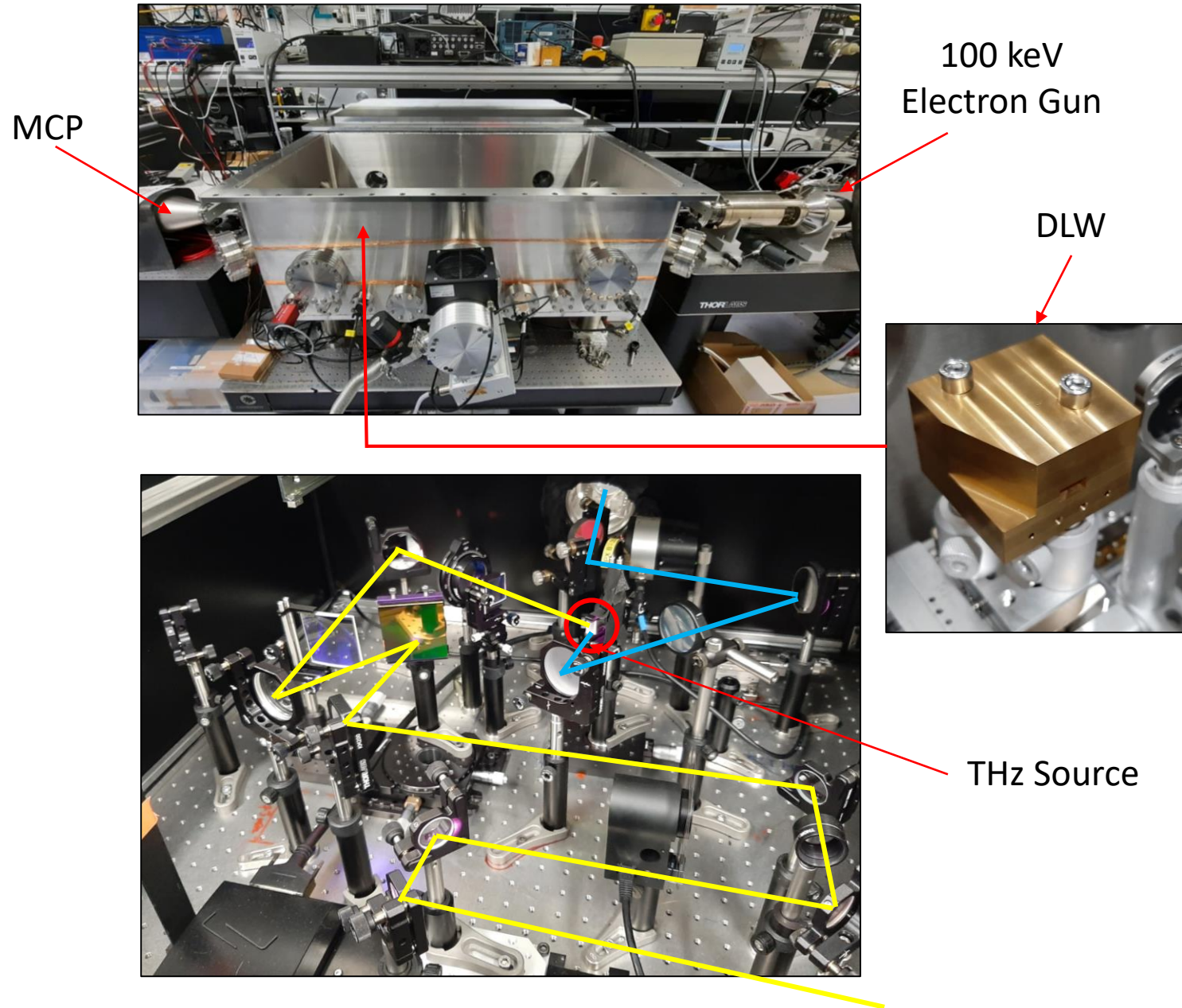
THz Deflection – Measurements

- Electron bunch spatial profile measured using MCP detector

- Electrons focused through a DLW with copropagating THz pulse

- THz pulse used to deflect electrons in y

- Relative arrival time of THz pulse scanned

- 'deflectogram' built from the measured y-projections at different time delays
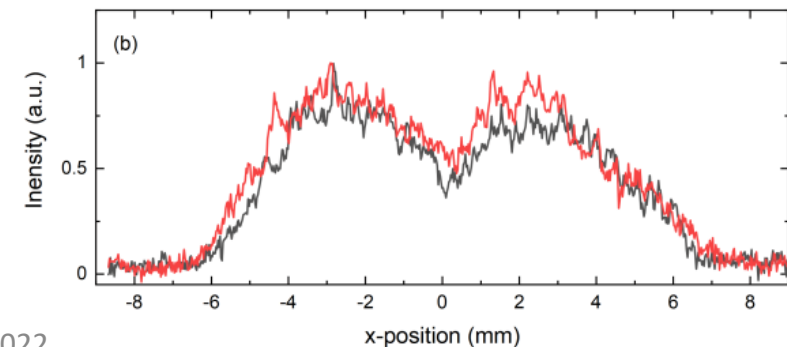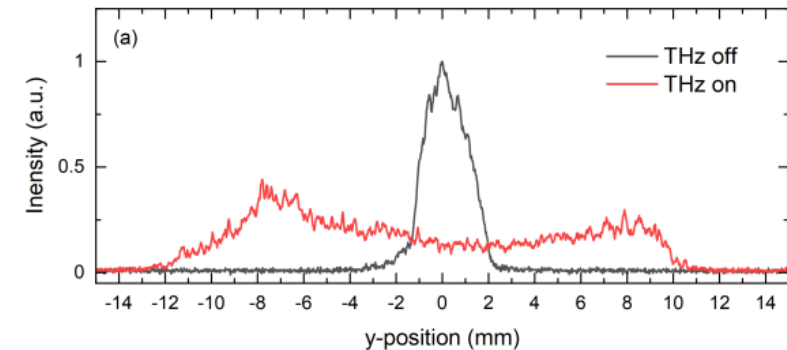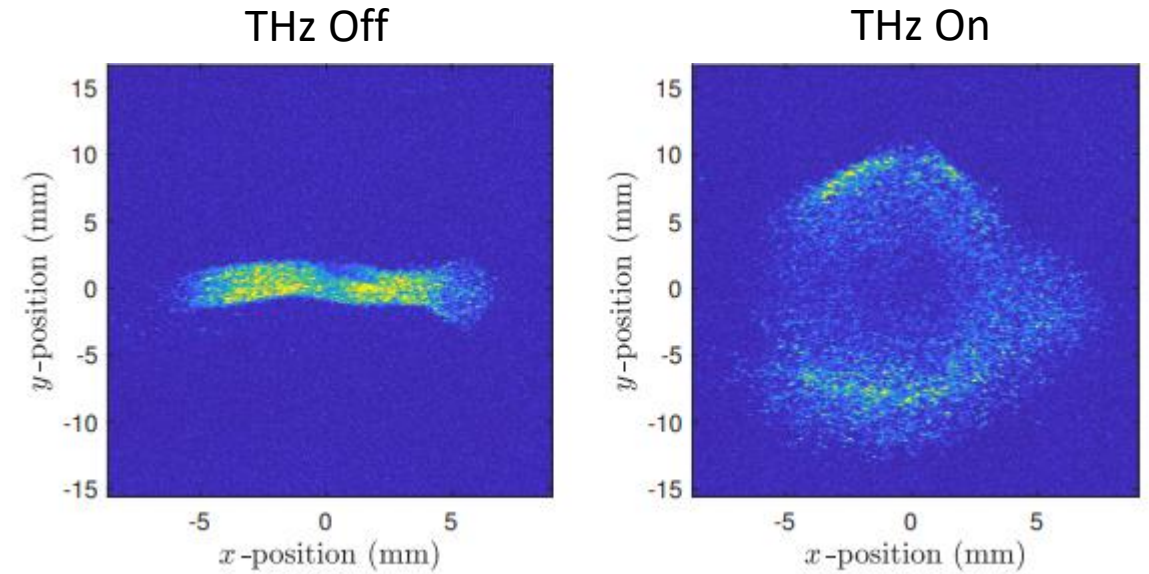
THz Deflection – Deflectogram Measurements

- F_{THz} – 0.38 THz

- Peak Deflecting Field Strength – 1.1 MV/m
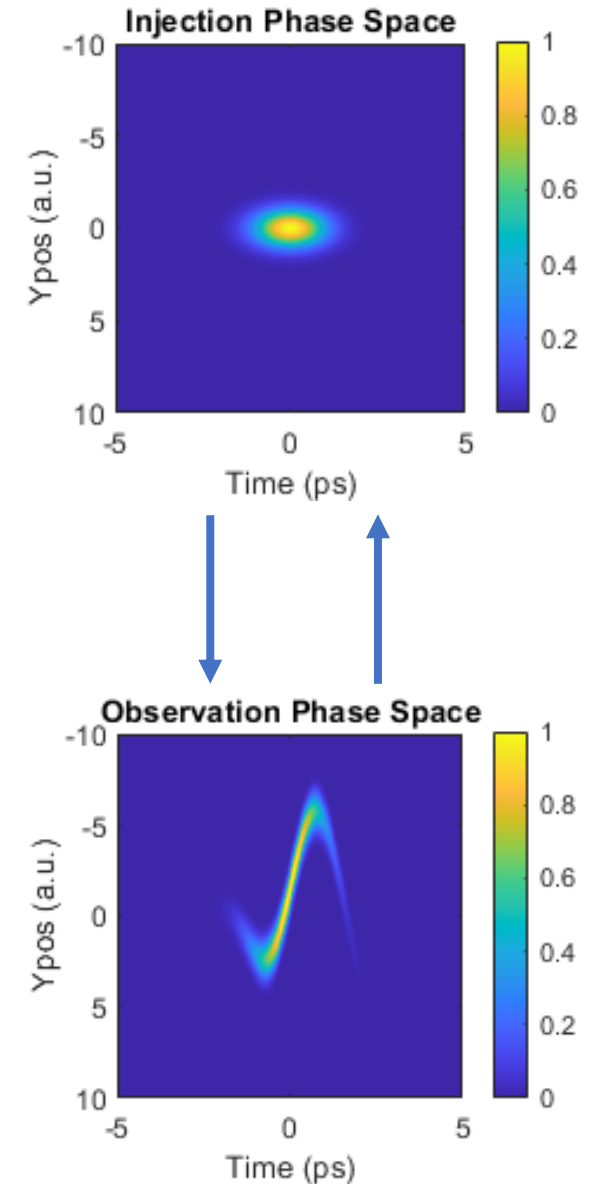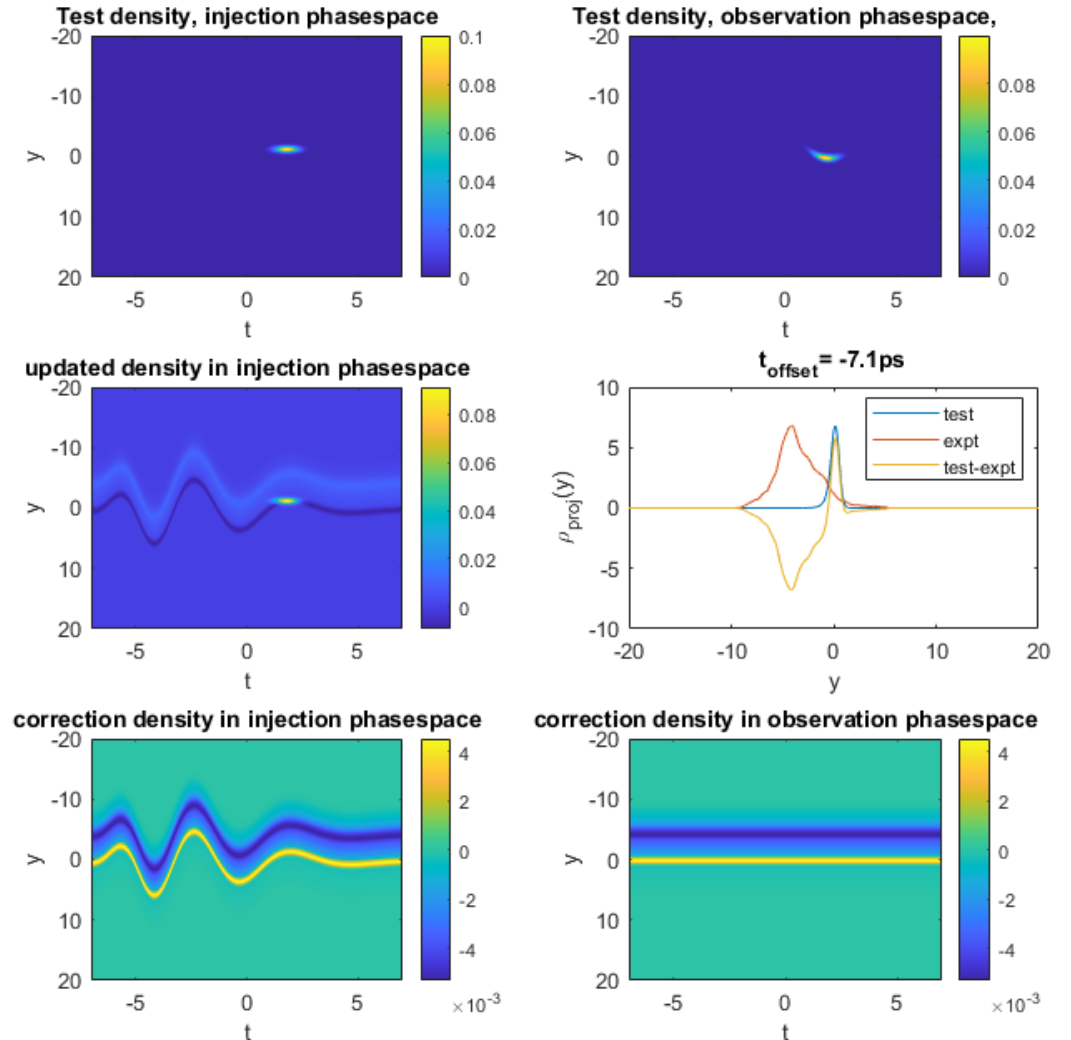
- Estimated bunch duration – 3.5 ps
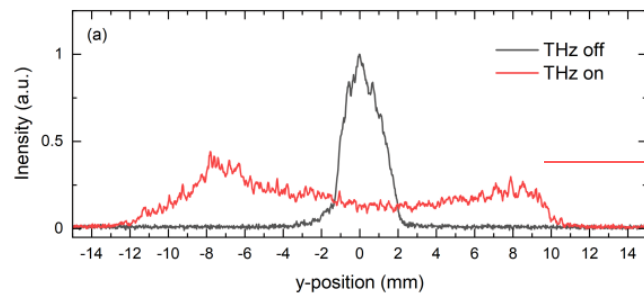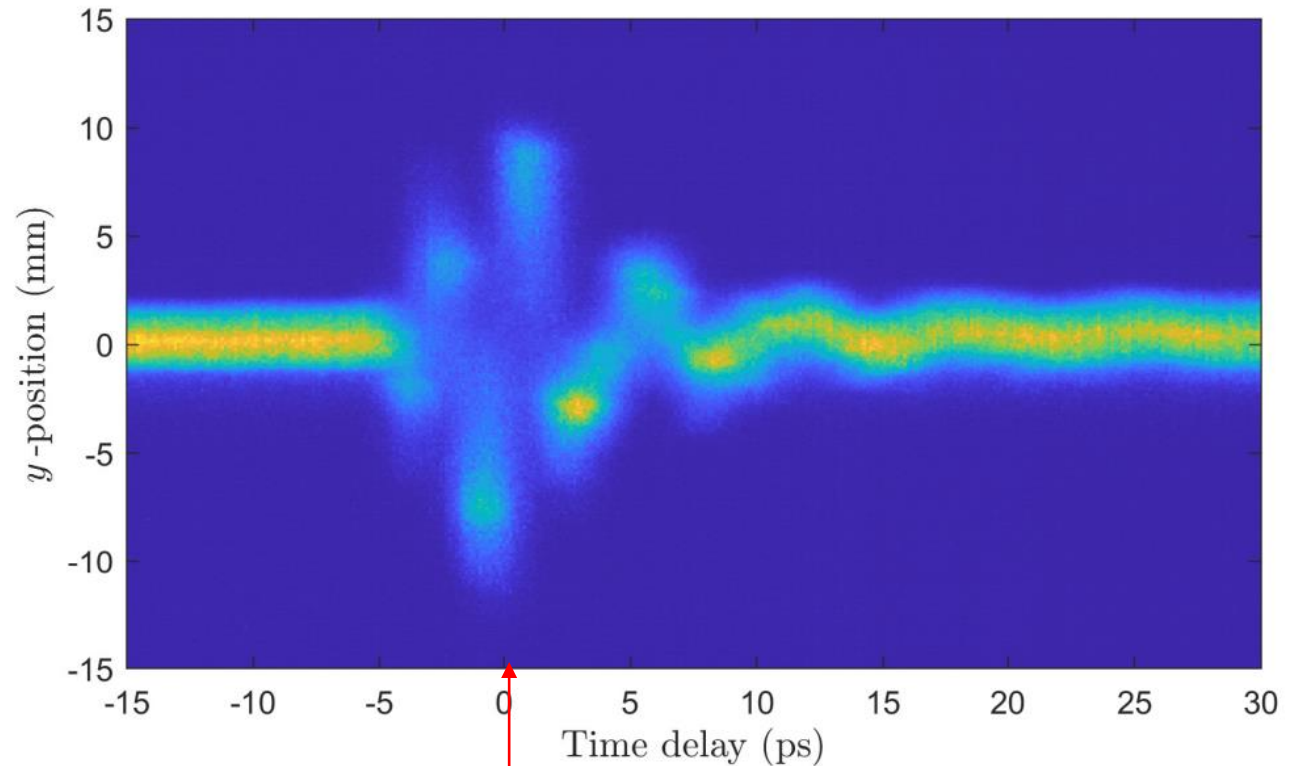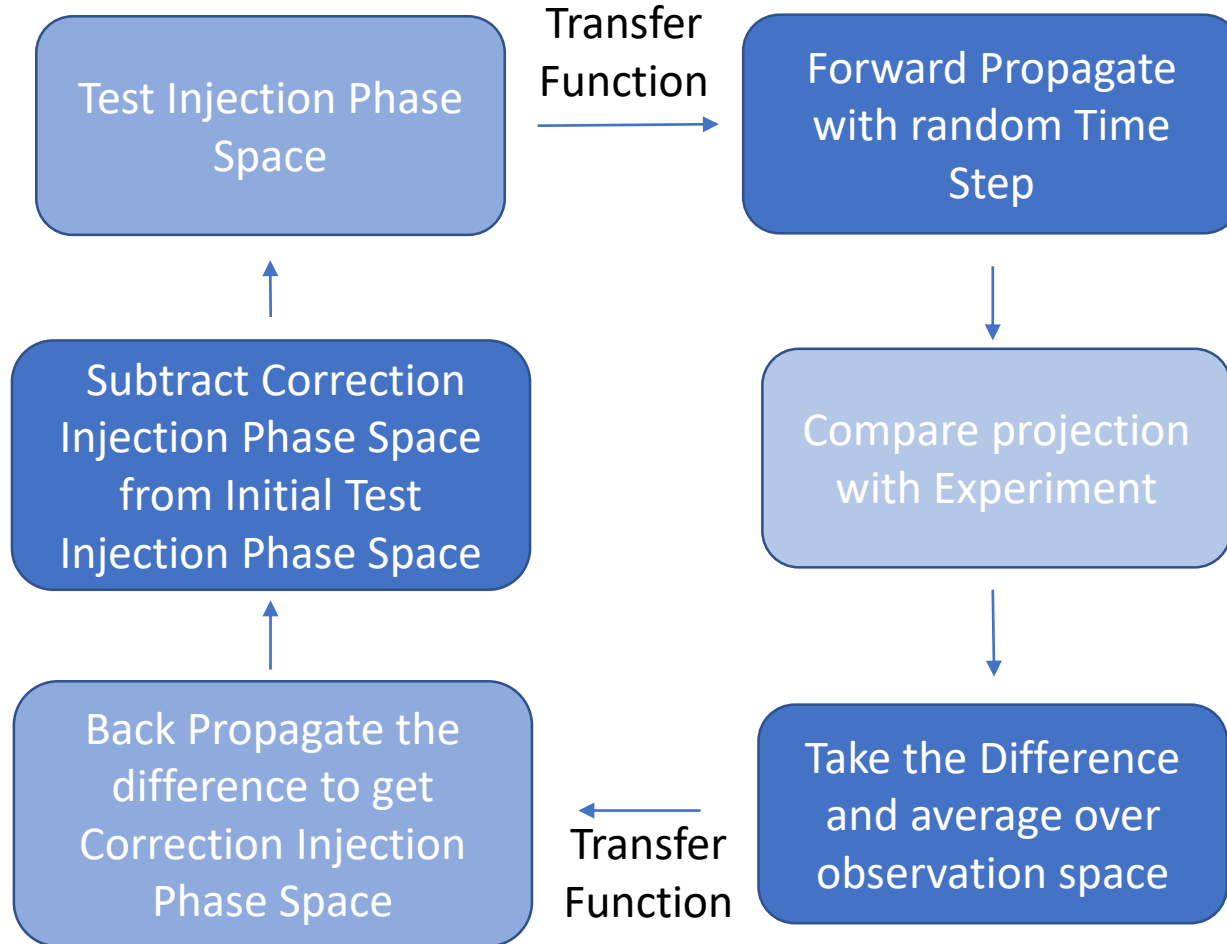
Why Tomography?

- Tomographic reconstruction techniques enable a 2-dimensional profile to be retrieved from a series of 1-dimensional projection measurements

- Established technique – used for longitudinal and transverse phase space measurements

- In our case, series of y-projections at different Δt

- Attempt to retrieve $\rho(y,t)$ from series of $\int \rho(y,t)dt$ measurements

Transfer Function

- Transfer Function is key to successful retrieval

- Describes the transformation of input to observed

- Currently using simple transfer function

- Assume uniform interaction across DLW structure

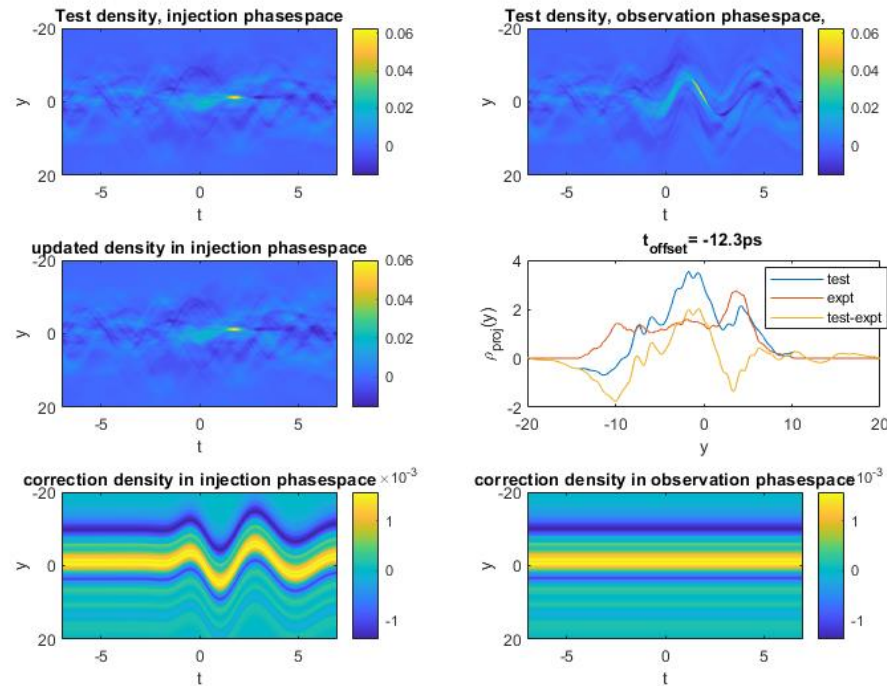- Simulations are underway to give improved transfer function
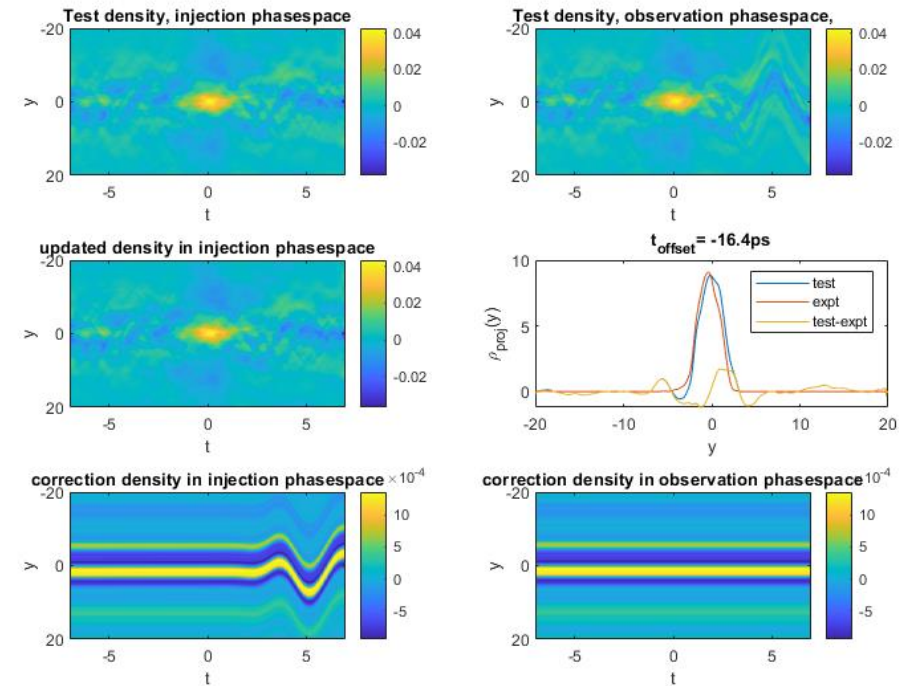
Tomography Retrieval Algorithm

Test Injection Phase Space

Transfer Function →

Forward Propagate with random Time Step

Subtract Correction Injection Phase Space from Initial Test Injection Phase Space

Compare projection with Experiment

Back Propagate the difference to get Correction Injection Phase Space

← Transfer Function

Take the Difference and average over observation space

Test density, injection phasespace

Test density, observation phasespace,

updated density in injection phasespace

t_{offset} = -7.1ps

test
expt
test-expt

correction density in injection phasespace

correction density in observation phasespace

Tomography Retrieval Algorithm
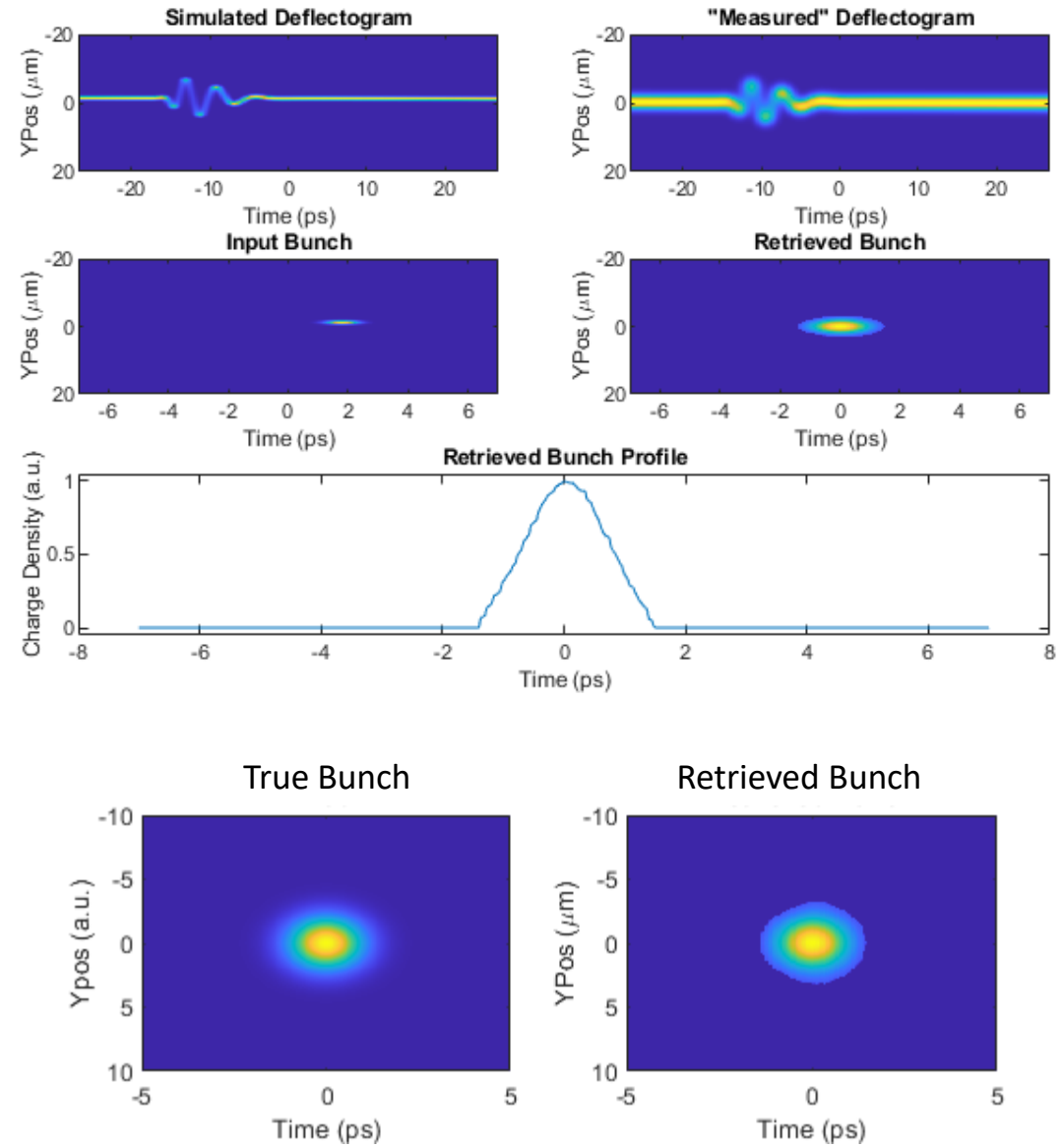
50 Iterations

500 Iterations

'Ideal' Test Case Results

- Start with simulated data

- Artificial deflectogram generated using known initial conditions

- Tomography retrieval used to estimate initial conditions from artificial deflectogram
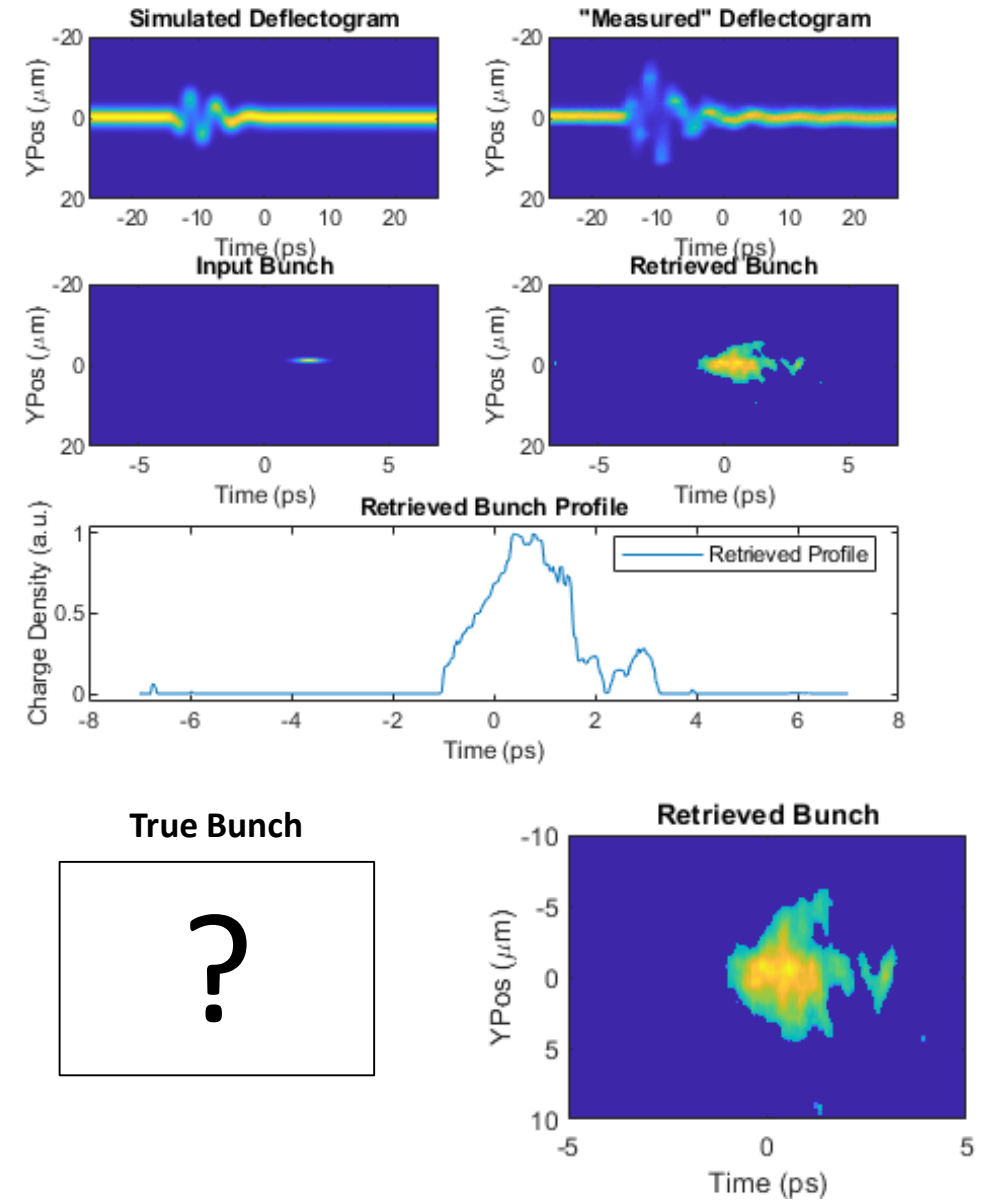
- Good agreement

Complex Test Case Results

- Does this still work for more complex initial conditions?

- Started with a more complex bunch profile consisting of three distinct sections

- Still good agreement
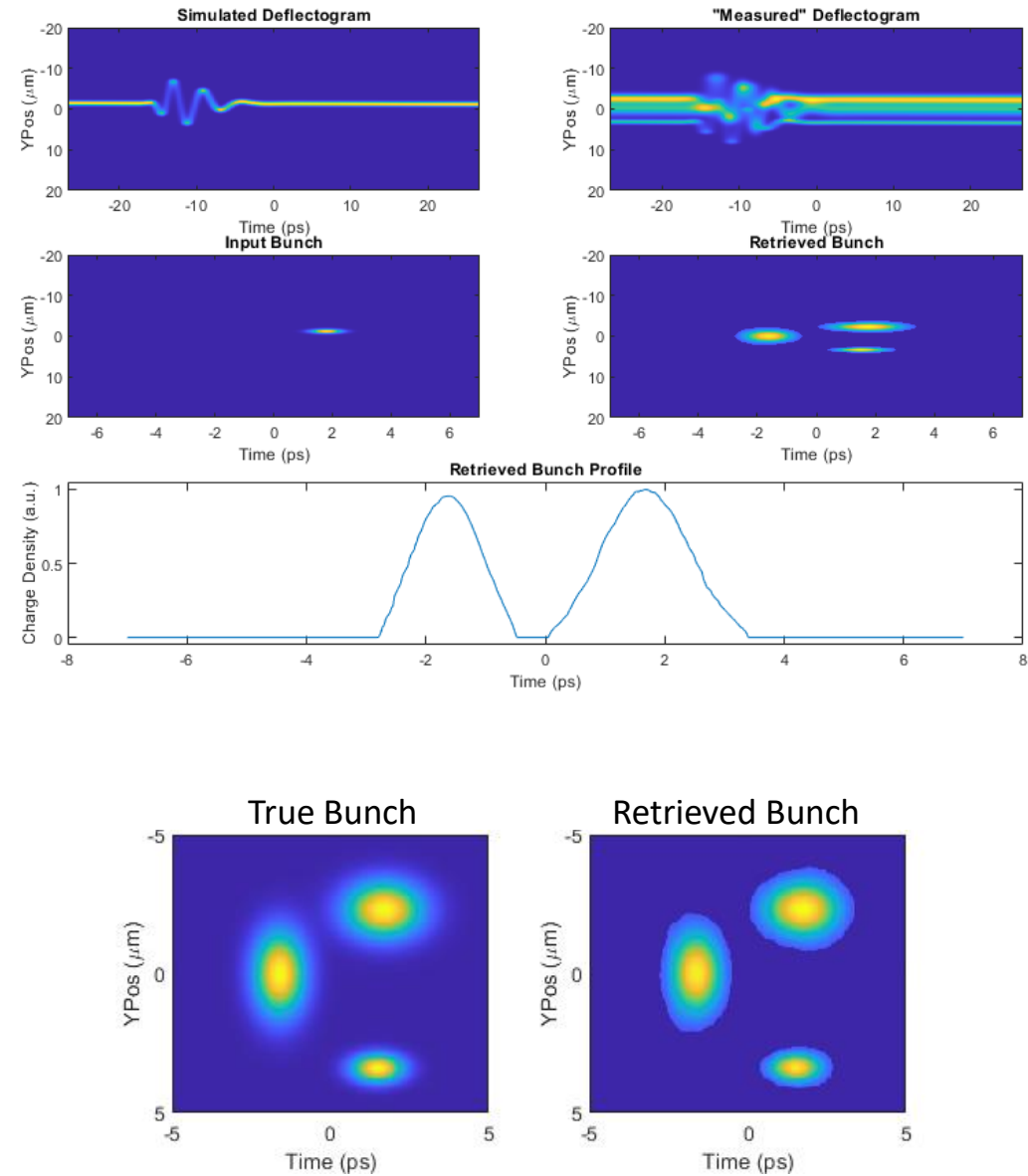
Real Data – THz Deflection

- Experimentally measured deflectogram

- Initial conditions are unknown

- Attempt to retrieve through Tomographic retrieval

Conclusions + Future Work

- Successfully measured THz-Driven Deflection of Electrons

- Promising attempts to determine bunch length through tomographic methods

- To get full longitudinal phase space measurements, need some energy resolution on measurements

- Future experiments looking at THz acceleration, and the addition of an energy spectrometer before the MCP detector will enable this