# Teaching: Bunch length measurement with TDS.m

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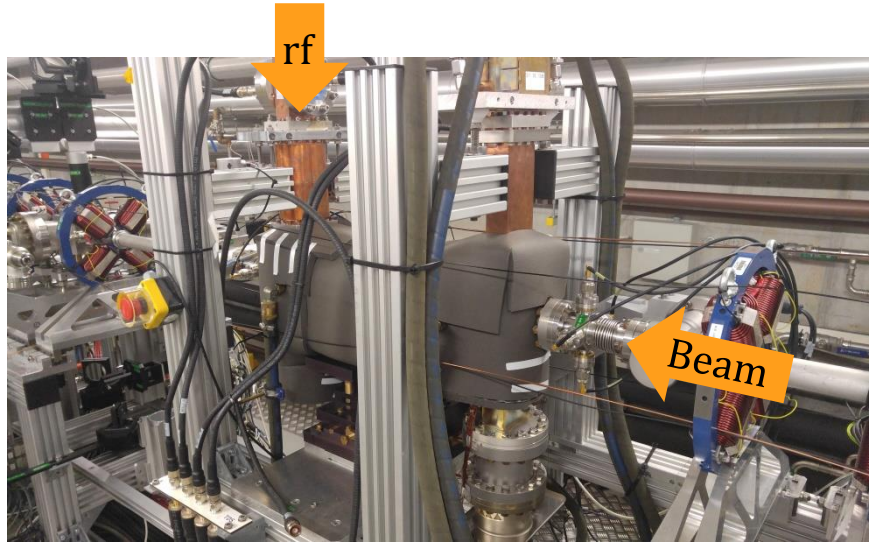
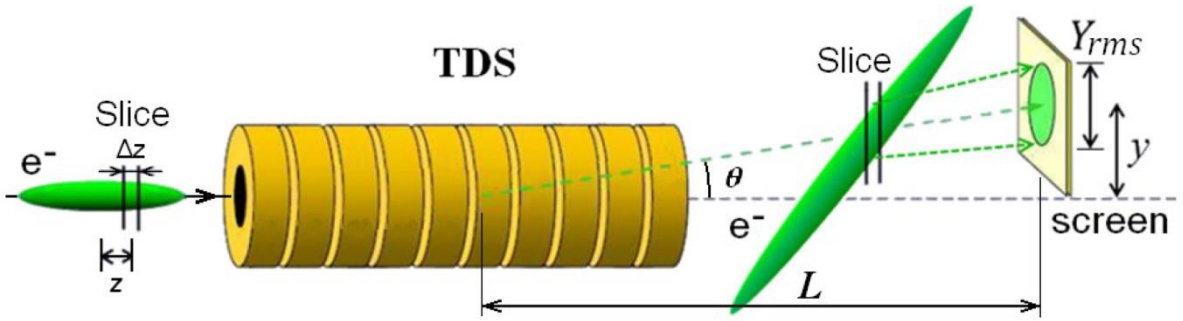
# Transverse deflecting structure (TDS)

## Short summary

- To measure temporal properties
  - Bunch profile (length and shape)
  - Slice emittance
  - Long. phase space (*z, E*)
- Works like streak camera
- @ PITZ: Streak in **vertical** plane




PITZ TDS




D. Malyutin, PhD thesis (2014)

TDS specs

| | | |
|---|---|---|
| RF Frequency | 2997 MHz | |
| Power | 2.11 MW | = 93.3 dBm |
| Deflecting Voltage | 1.7 MV | |
| Pulse Length | 3 µs | ≙ 3 bunches |
| Length | 0.533 m | |
| Phase advance per cell | $2\pi/3$ mode | |
| Number of cells | $14 + 2$ | |

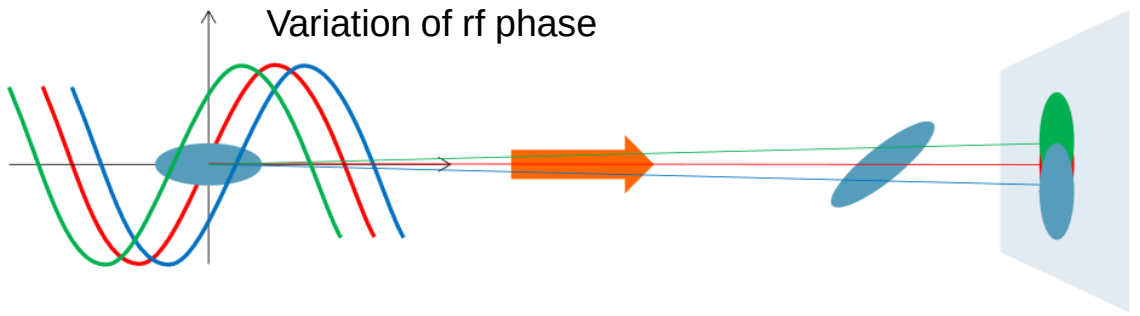
# TDS calibration

## Find streak parameter experimentally

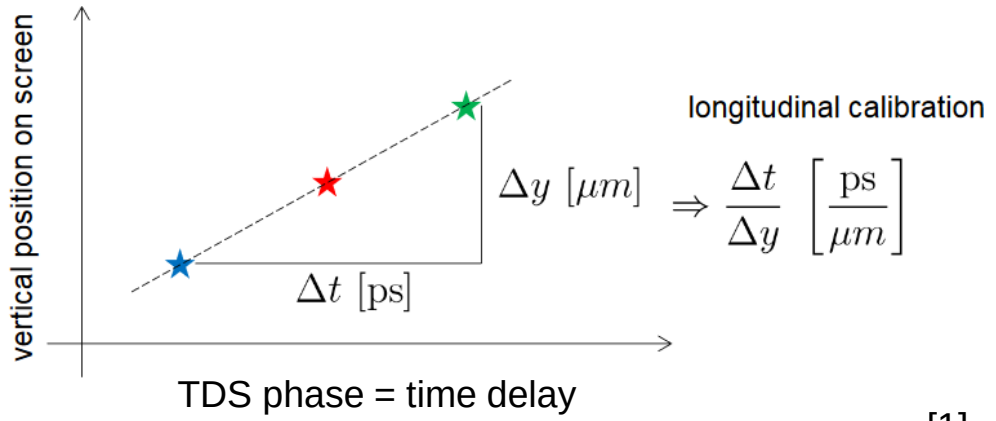
- Streak parameters is mapping parameter: y = S * z
- Different rf phases lead to different net streak
- Change of mean position vs change of TDS phase
- Slope gives streak parameter (bottom right)

- Done at **both** rf phases
  - Sometimes different streak parameter for each slope

Change of position




[1]



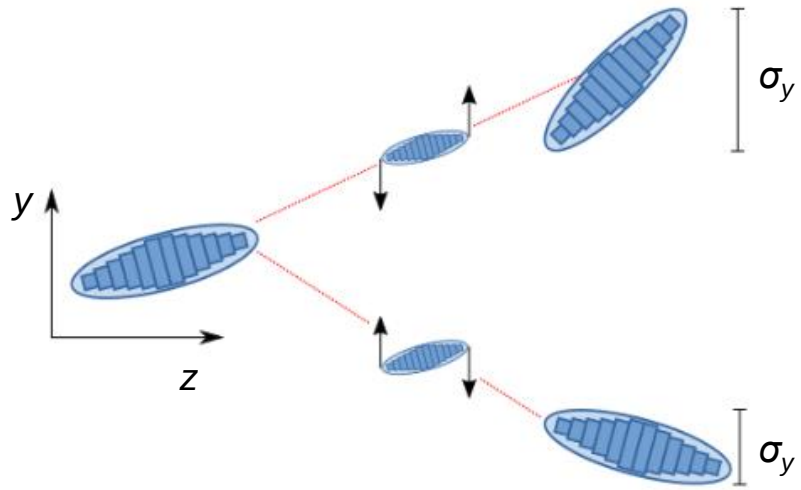

[1]

[1] B. Beutner, Operator Training ‘TDS operation’ (2019)

# Pre-streaked beam

## Initial beam tilt from steering (in dipoles and quadrupoles)

- Initial *y*-*z* correlation leads to strange results
  - Beam seems to have different length at each TDS rf slope
  - Possible solution: Improve transport (reduce dipole strength, go centred through quadrupole magnets)




Different size at each slope [1]

[1] B. Beutner, Operator Training ‘TDS operation’ (2019)

# TDS LLRF GUI

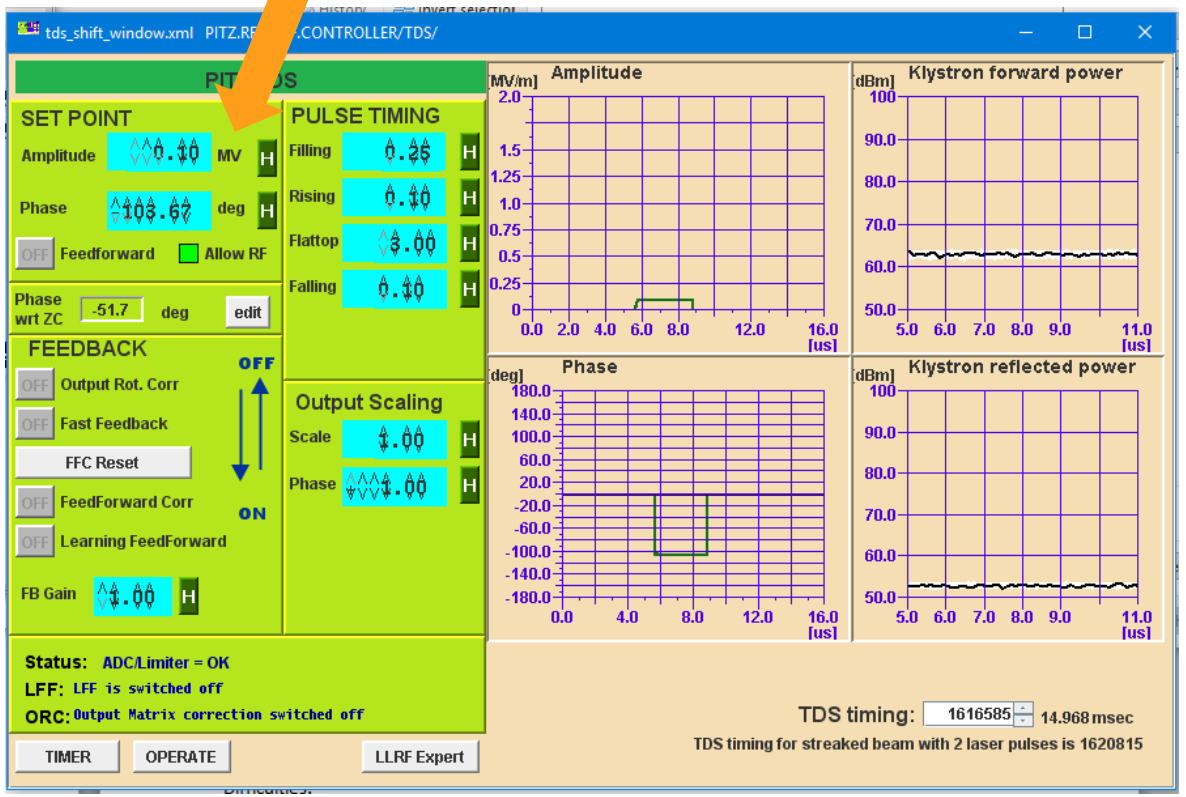
## tds_shift_window.xml

- Use manual in control room to turn RF5 on & off
- Other than gun and booster:
  - Feedforward can be turned on and off rapidly
  - Keep feedbacks **off**

Phases changes with Amplitude SP

Turned on and off without reducing Ampl. SP

Keep FB's off



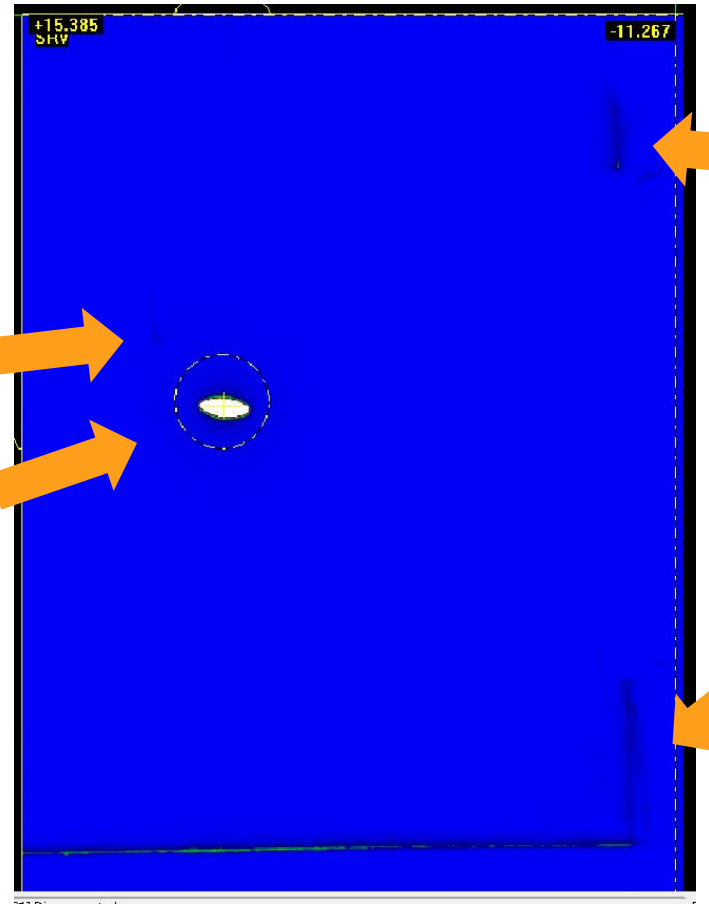
# Bunch length measurement

## How to prepare the beam for bunch length measurements

- Keep the TDS off at beginning
- Use quadrupoles to focus beam vertically (small $y_{rms}$) on screen (usually PST.Scr1)
- Usually Q9 and Q10 are used (they are closest)
- Steer beam to vertical centre of screen

- Note: Beam will be saturated, hence use 1 bunch and 0 gain
- Using camera unbinned helps

PST.Scr1 (LYSO)

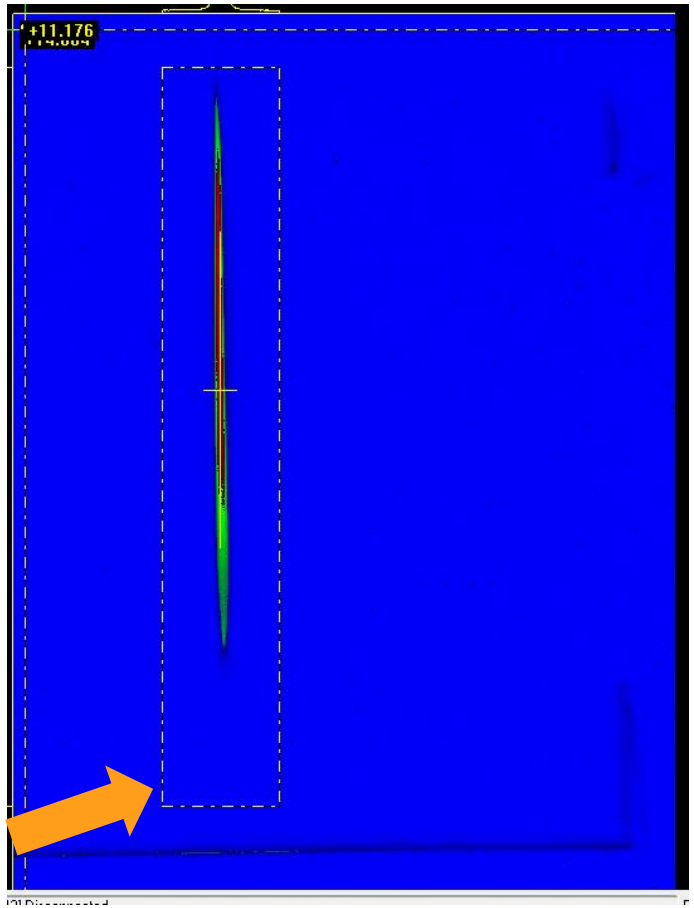


# Bunch length measurement

## How to prepare the beam for bunch length measurements

- TDS power so that beam is strongly streaked (keep margins for phase scan)
- Centre position same as unstreaked beam
  - Almost zero-crossing phase
- High signal, but no saturation
  - Up to three bunches
  - Gain up to 23
- Adjust power for phase range
  - Range: zero crossing +- 3 deg
  - Stepsize: 1-2 deg step

PST.Scr1 (LYSO)




Margin for phase scan

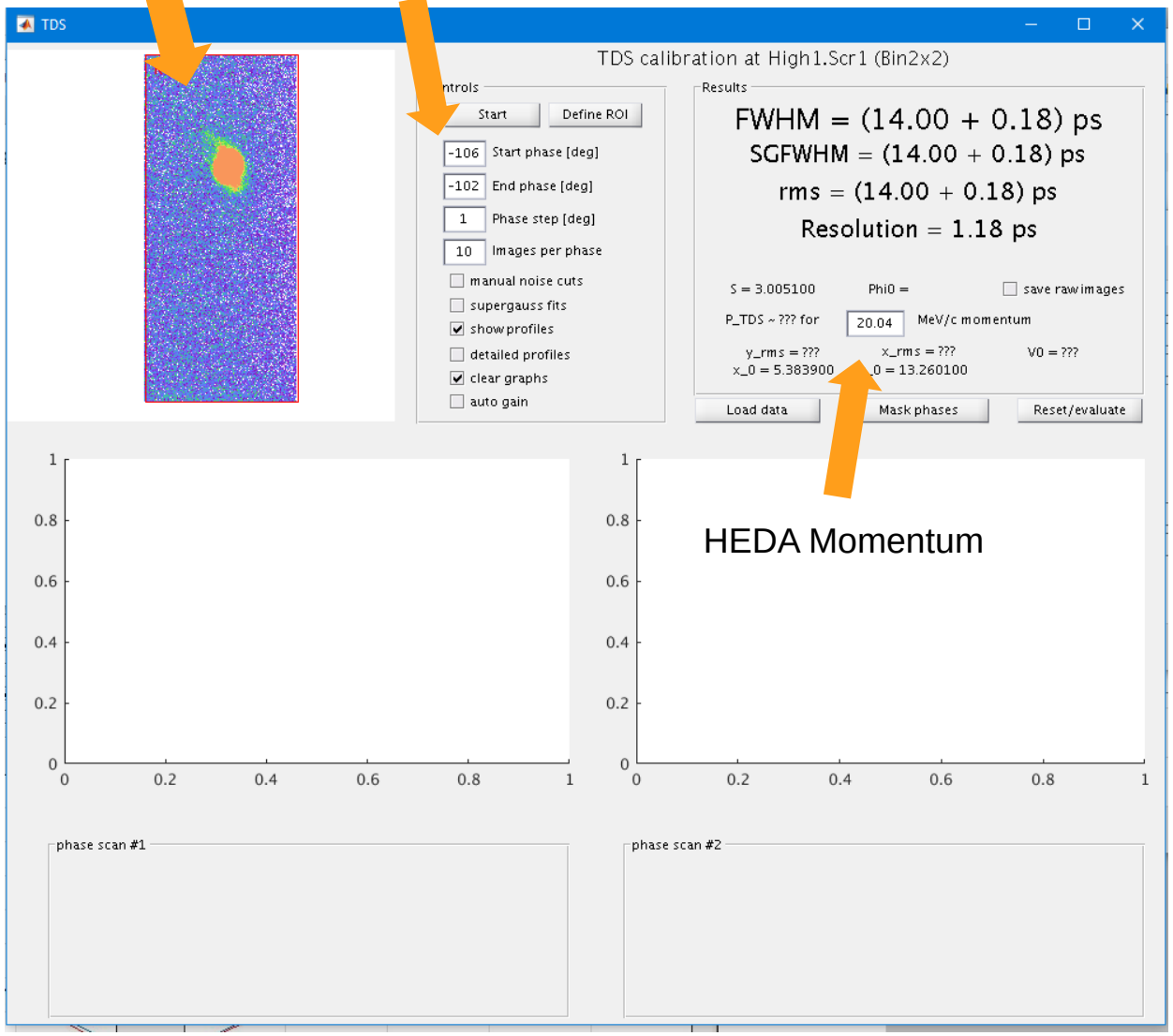
# TDS.m

## Measure the bunch length

- PITZ GUI > tools > ‘Open Matlab 16b with Standard Measurement Scripts’ > TDS.m
- Select used camera (PST.Scr1 (bottom))
- Select region of interest (ROI) big, cut out reflection from edge
- Type in phase range (and momentum)
  - Phase = zero crossing +- 3 deg
  - Phase step = 1-2 deg
- Click ‘Start’ to start scan
- Adjust number of pulses and gain (prompt shown)

H1.S1 as example

Phase range



# TDS.m

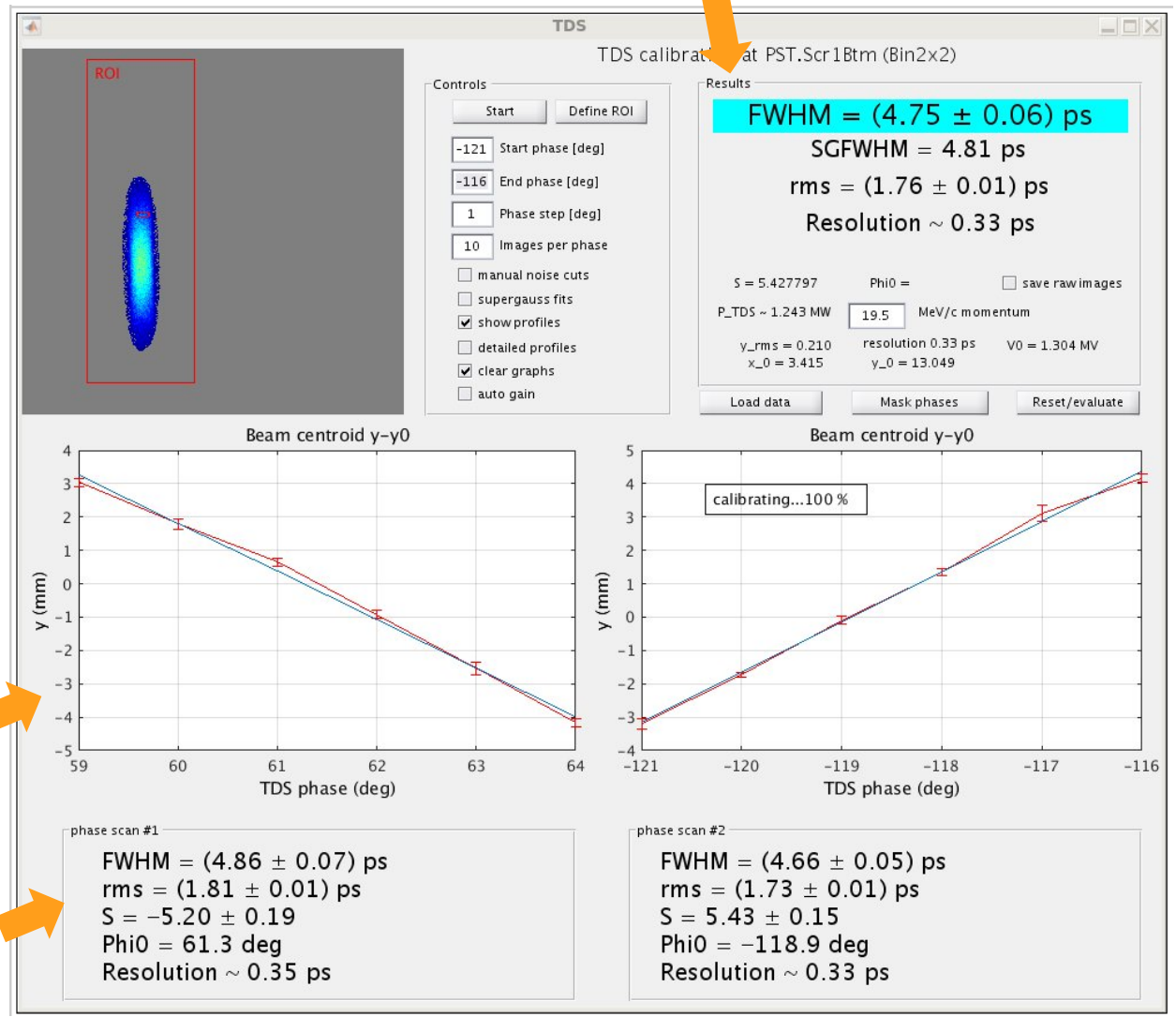
## Measure the bunch length

- Print TDS GUI into logbook (shows results)
- Top rigth:
  - FWHM: averaged FWHM from both slopes
  - SGFWHM: FHWM of supergaussian fit
  - Rms: rms bunch length
  - Resolution = Unstreaked beam size * streak parameter
    - 1 ps resolution should be upper limit
    - ~ 0.2 ps resolution is lower limit

Summary of results

Phase scan

Values for this slope

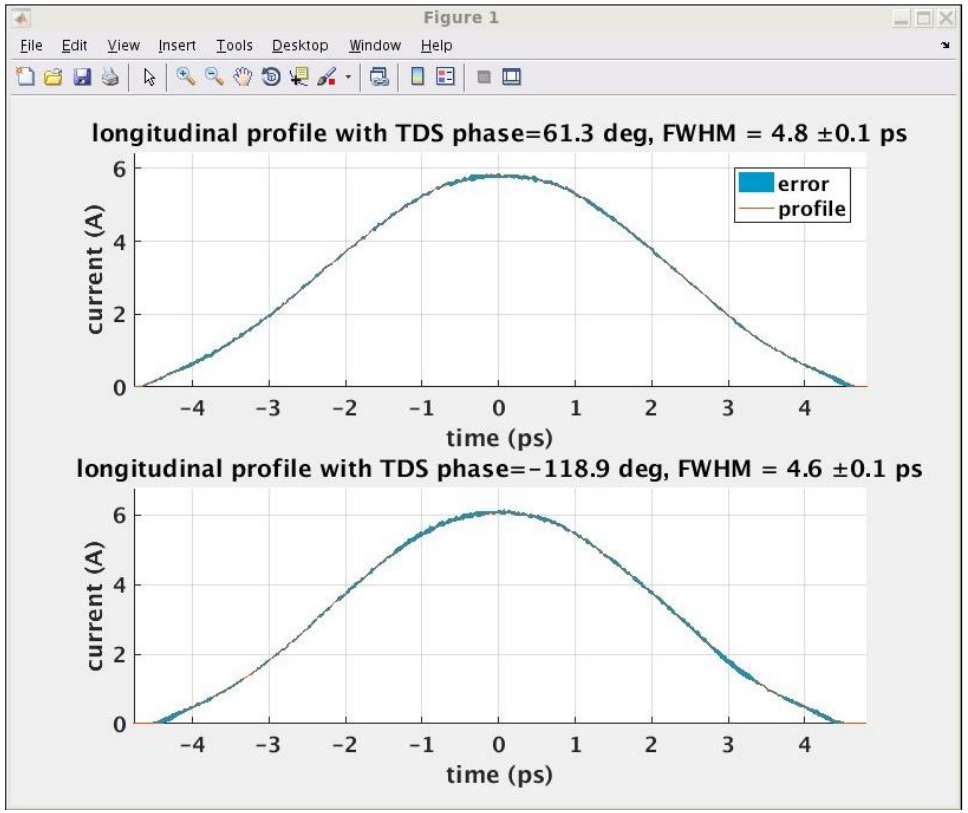


# TDS.m

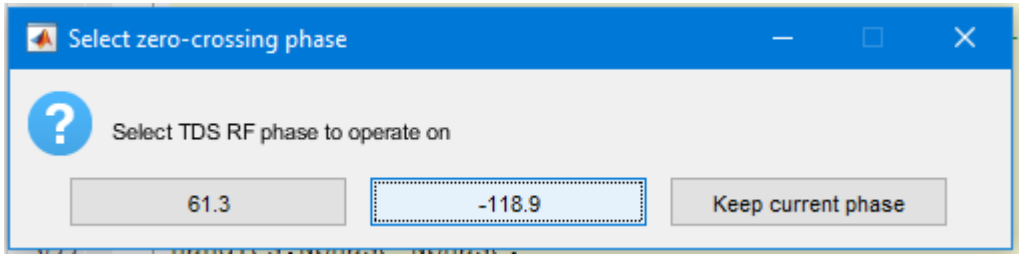
## Measure the bunch length

- Print Bunch profiles into logbook
- Data saved automatically
- Select zero-crossing phase to keep

Bunch profiles



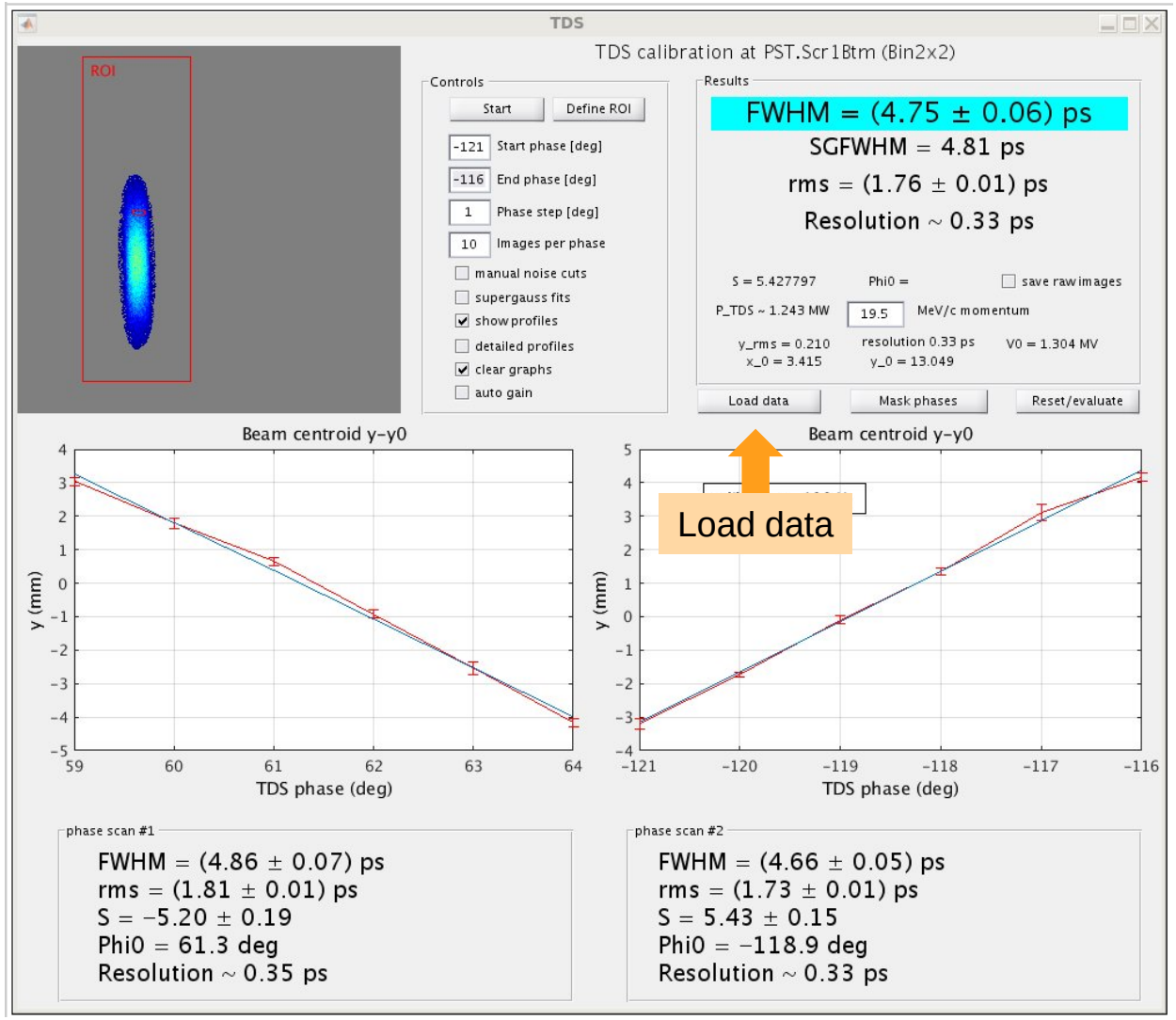

Select the zero-crossing phase (or current phase) of the TDS



# TDS.m

## Reanalyse data in TDS.m

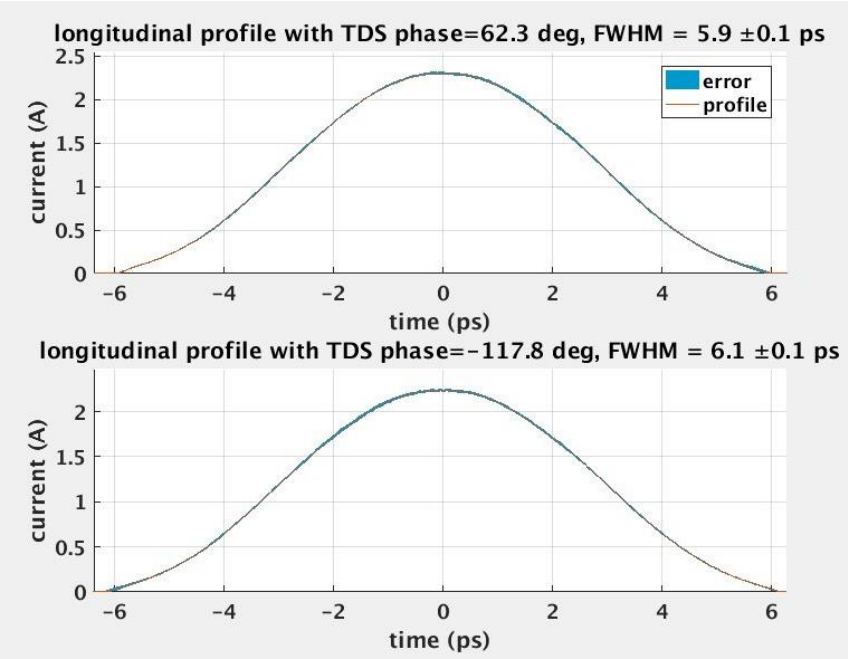
- Loads old (saved) data to TDS.m
- Problems occur with older data:
  - Use older Matlab version
- It's possible to mask certain phases in phase scan
  - Right-click onto unwanted phase
- 'Reset/evaluate' for recalculation

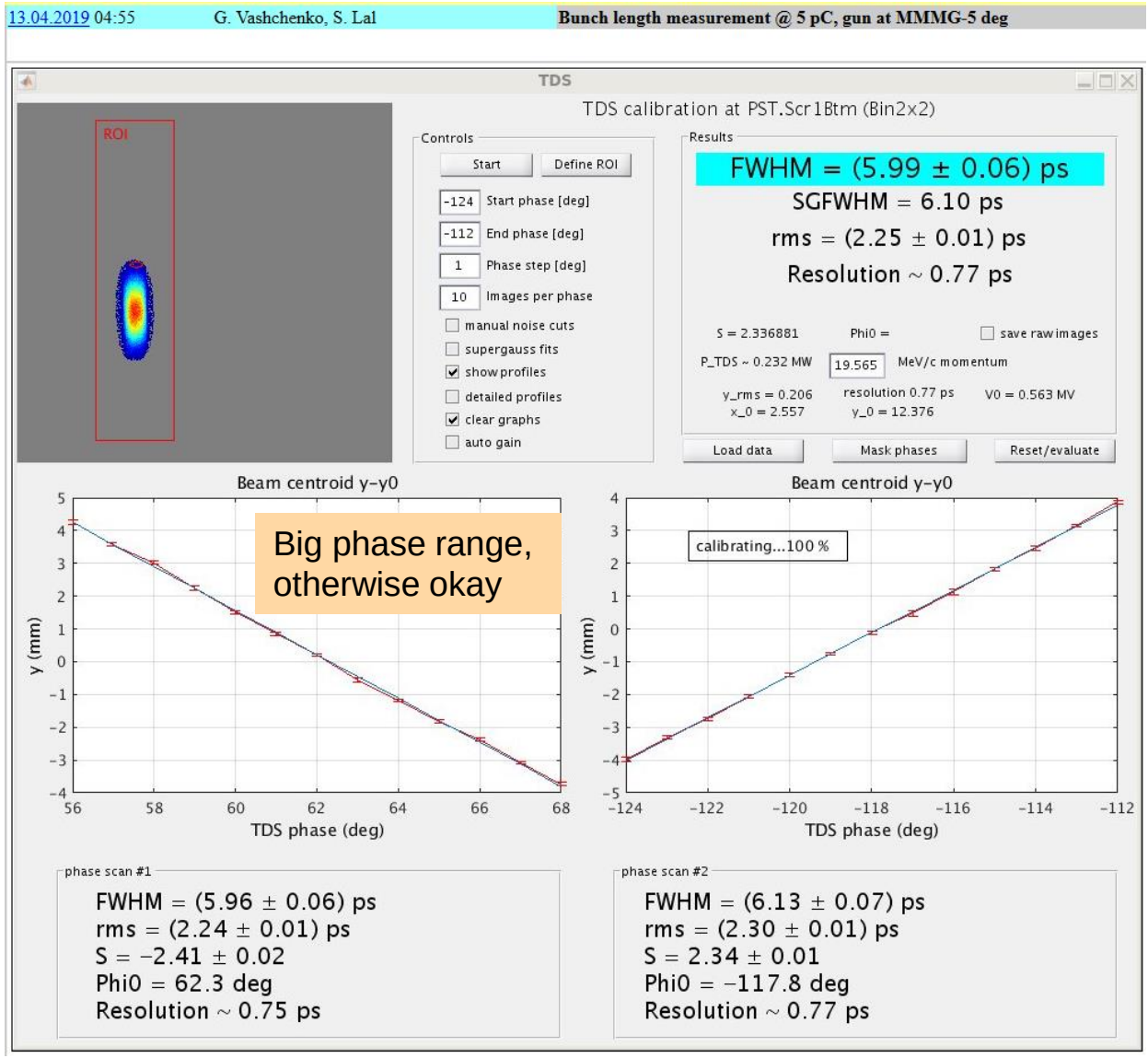


# Laser shape measurement

## Use TDS.m as alternative for OSS

- TDS acts as alternative for OSS measurements
  - Chose low charge (~ 5 pC)
  - If gun @ XFEL Gradient (6.3 MeV/*c*):
    - Gun Phase = -10 deg w.r.t. MMMG phase
- Do bunch length measurement (see figures)



# Other remarks

- Sometimes it fails (noisecut issue): Change focusing, camera gain, number of pulses
- When encountering this error: Save images from video client, print error message into logbook, email me
- Different bunch length at each slope: Reduce overall steering, check trajectory through quadrupoles
- (Some) information found in PITZ Wiki (measurement procedures)
- Open work:
  - Observe error with noisecut (breaking script) – change was done
  - Check calculation of resolution
  - Calculation of bunch profile at fixed phase (currently from different phases)
  - Plot Gaussian and SG fit next to bunch profile (XFEL request)
  - Add information where bunch head and bunch tail are
  - Improve documentation, put manual into wiki