Wake Field Monitor characterization in CLEAR

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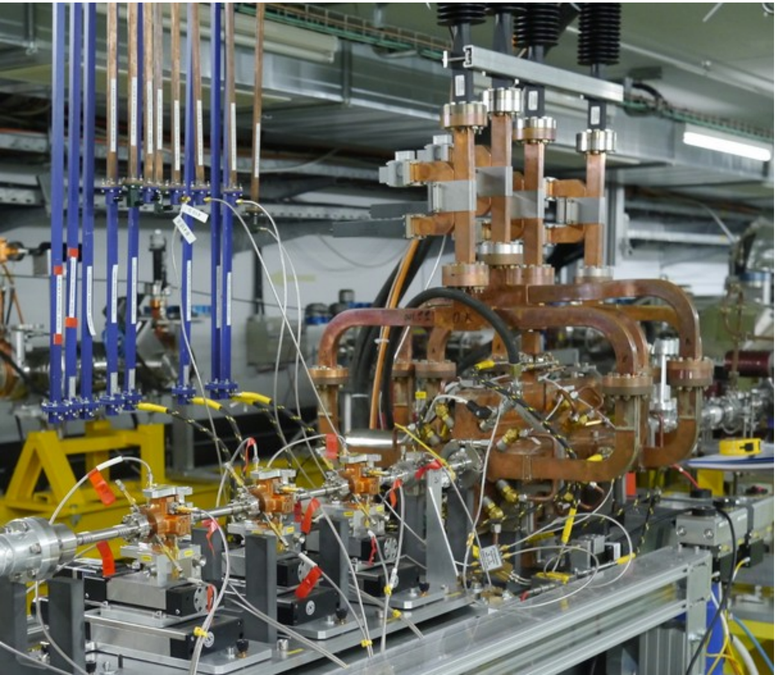
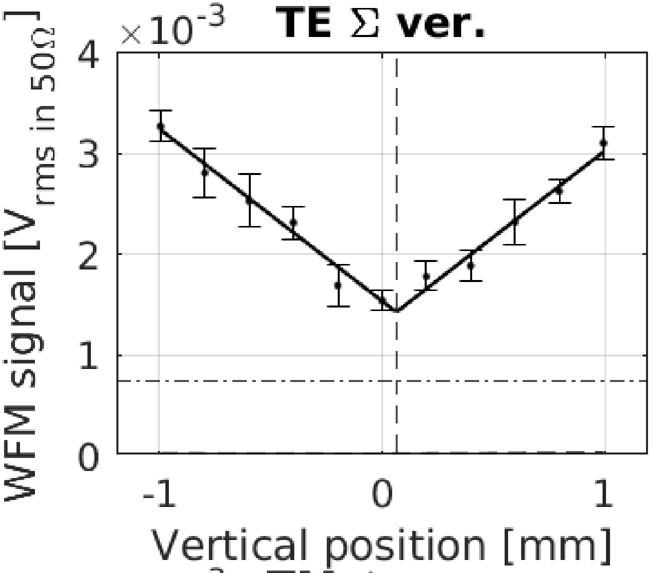
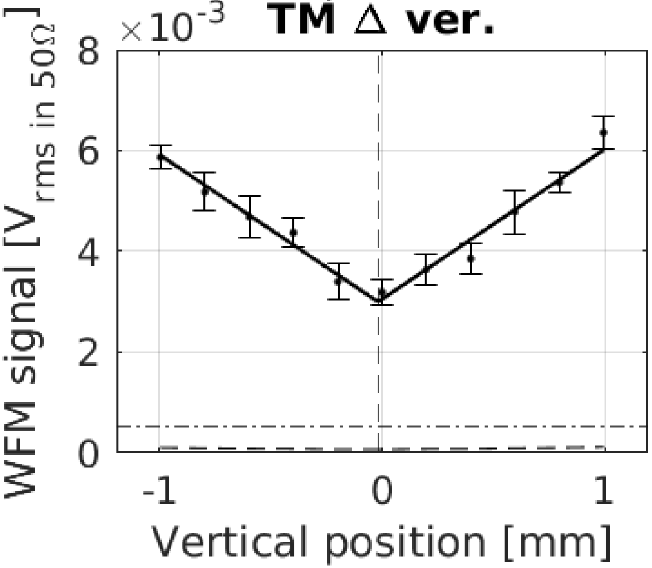
CLIC RF meeting

21/10/2020

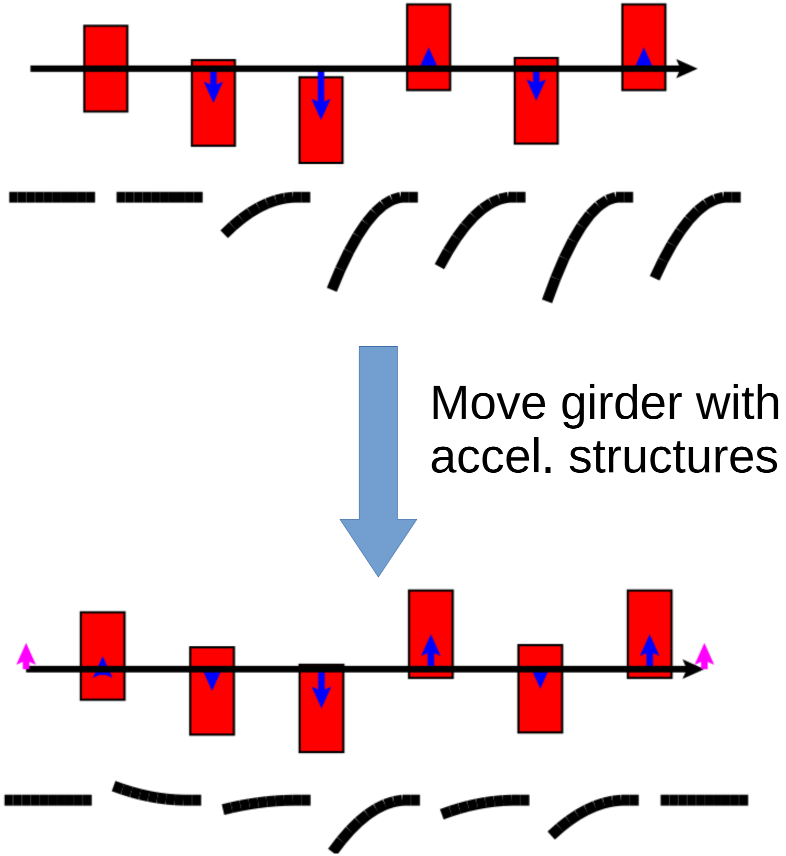




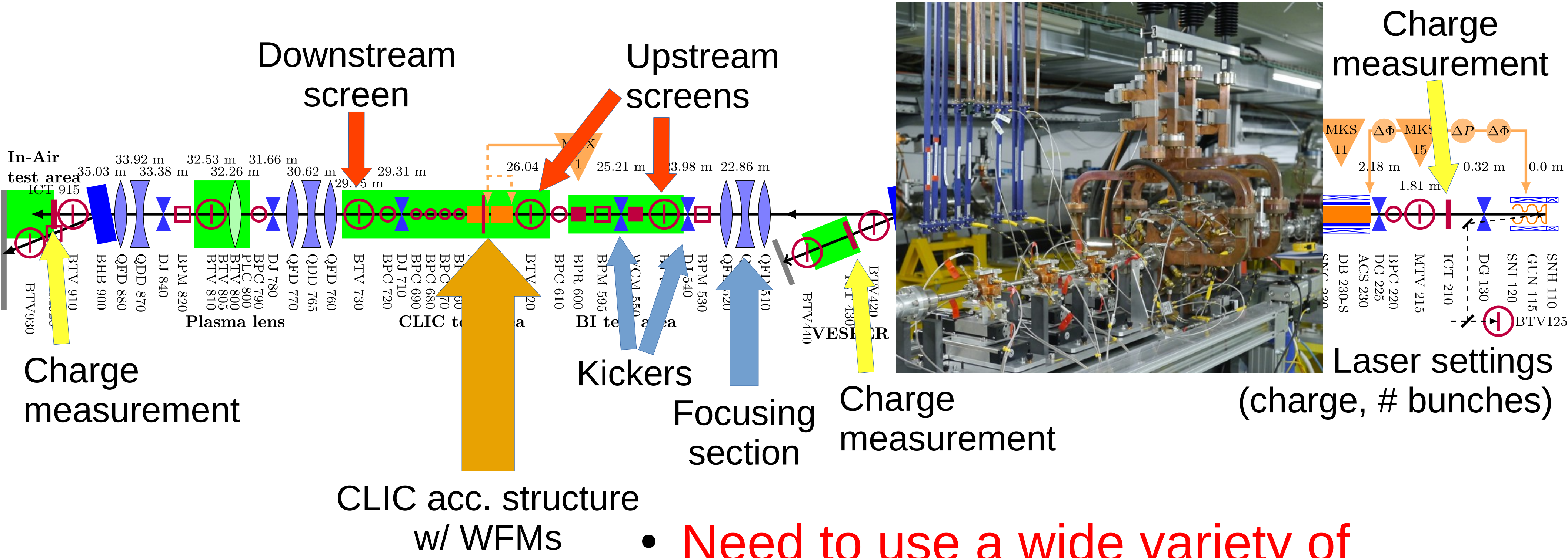


Idea of CLIC WFMs

- Align accelerating wrt. beam
  => Reduce wake field kick
- For CLIC luminosity target:
  Need alignment better than 3.5 µm
- Must show that this is feasible
  and develop hardware and algorithms
  - Characterize a similar setup in CLEAR, study resolution, sensitivity with different train lengths etc.



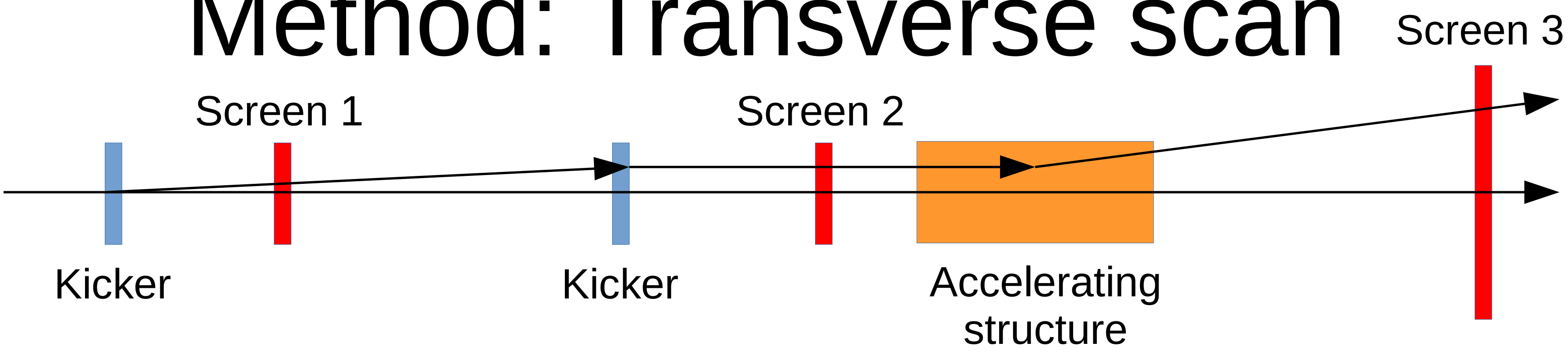
Installation in CLEAR tunnel



Also:
Radiation monitors (3),
Inductive BPM sum (soon),
RF deflector

- Need to use a wide variety of available instruments and devices
- Strict demands for beam properties
  - Both control and measurement

Method: Transverse scan



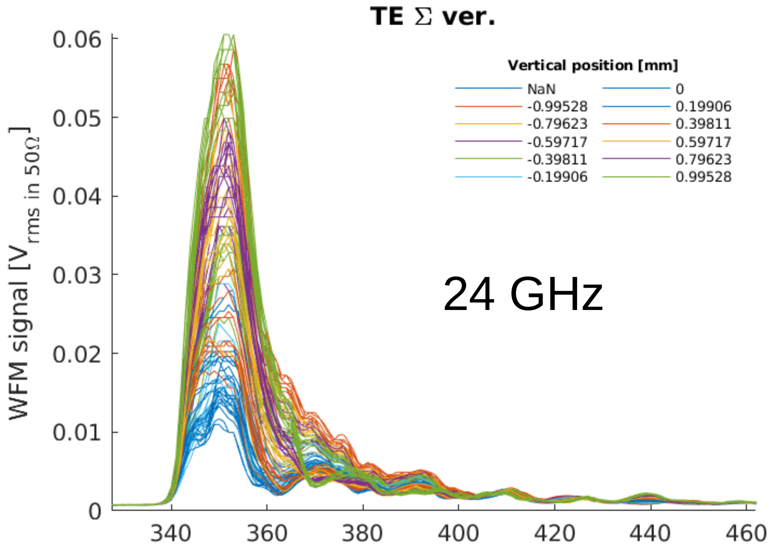
- Scan beam position vs. structure,
  observe WFM signal & kick as function of beam transposition
- While structure is equipped with a mover,
  this has not been reliable to operate
- Rather use the two upstream kickers to transpose the beam
  - Magnet strengths were carefully measured with beam;
    parallelism and calibration confirmed with low-charge beam on screen 2 & 3

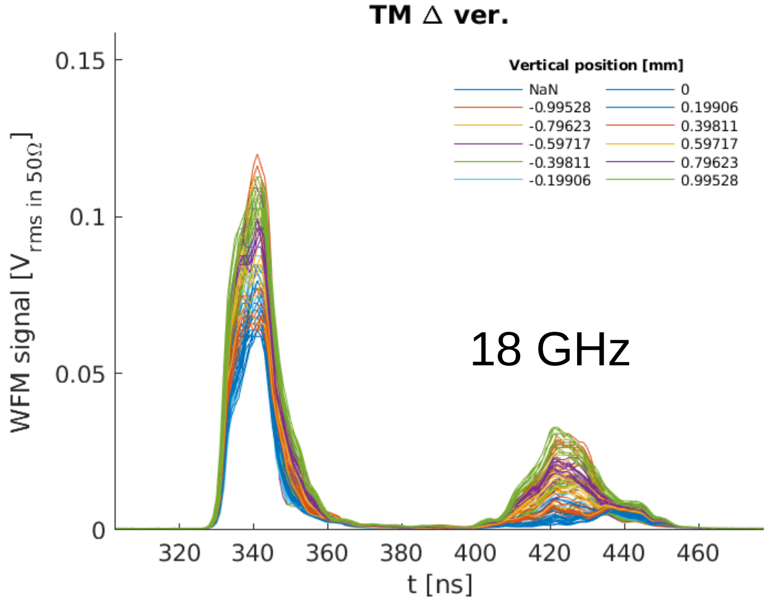
Measured signals

- We measure the power within a given frequency band
- Signal amplitude is given as

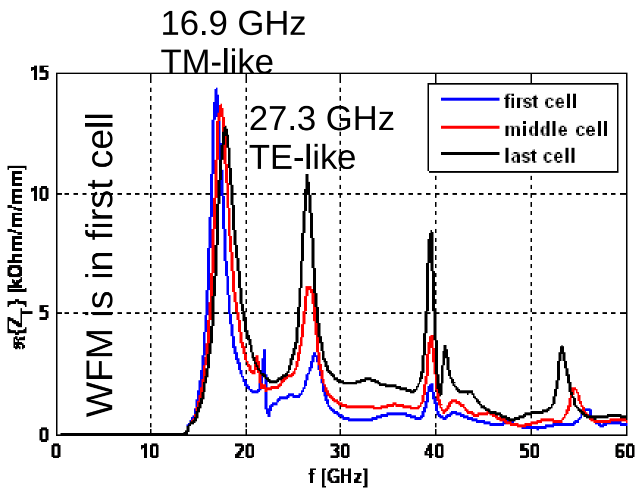
$$V_{\mathrm{rms}}[\mathrm{V}] = \sqrt{10^{\frac{P[\mathrm{dBm}]}{10}}[\mathrm{mW}] \cdot 10^{-3} \cdot 50[\Omega]}$$

- This is the estimated voltage on the input of the log-detector, given the power P
  - After antennas, hybrids, waveguides, filters, etc.
- Proportional to the field in the structure at the given frequency





Signal generation in acc. structure



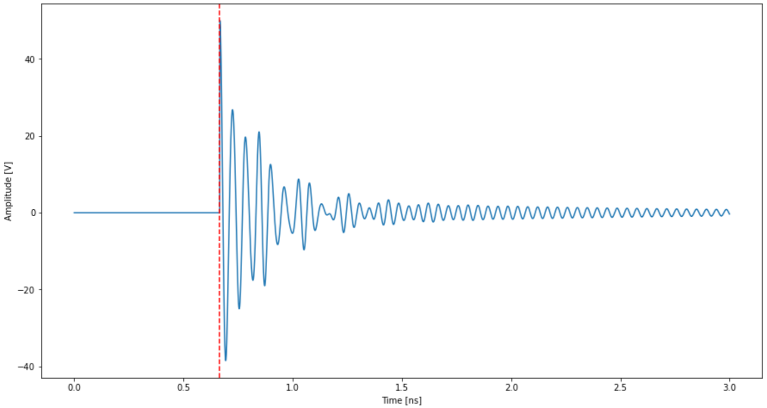
- Each bunch excites multiple modes
  - These then ring down quickly (Q ~ 10 due to damping)
  - Antennas pickup the field
- Can describe signal as sum of signals from each mode, generated by each bunch (or slice of a bunch):

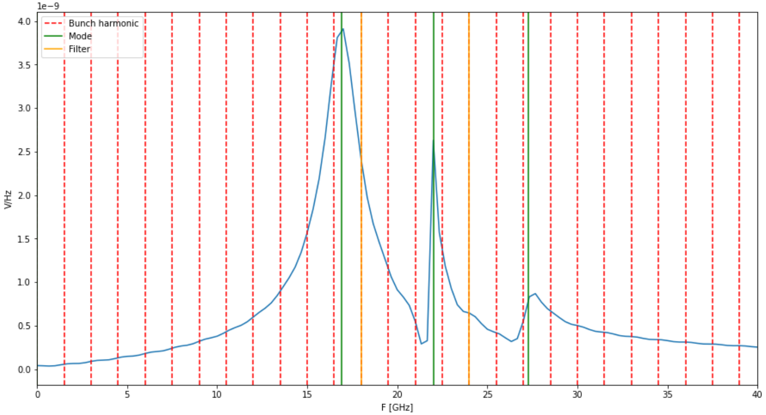
$$V(t) = \sum_{modes\, i} \Re\left[\sum_{bunches\, j} Q_j * A_i \exp\left(\boldsymbol{i}\, 2\pi f_i (t-t_j) - \frac{2\pi f_i (t-t_j)}{2Q_j}\right)\right]$$

- In CLEAR, bunches arrive at 1/(1.5 GHz) intervals

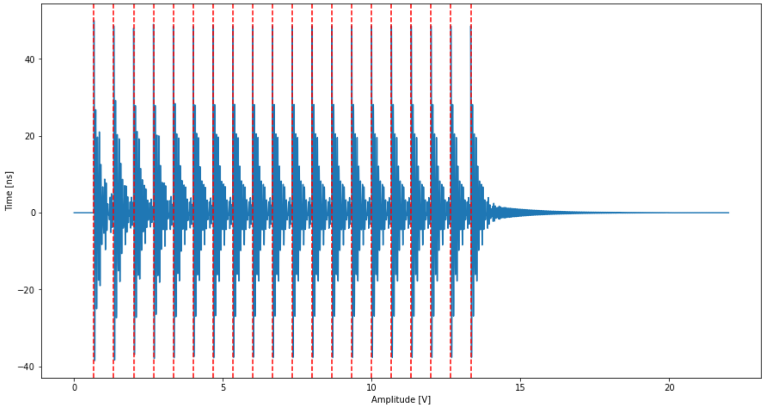
Bunch harmonics toy model

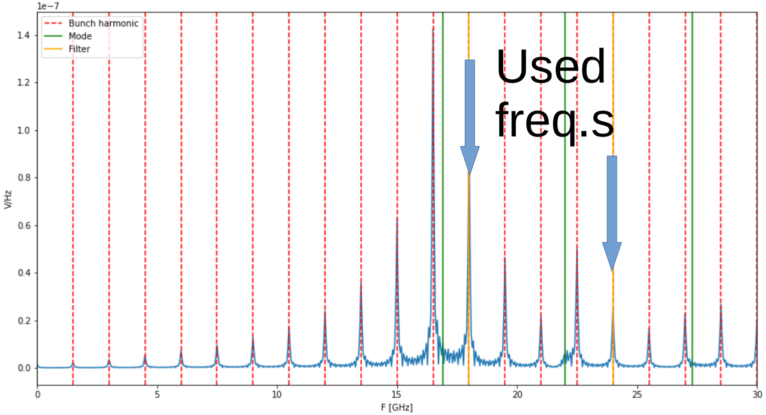
- Single bunch:





- 20 bunches:





Pickups

- The structure is equipped with 8 antennas, 2 on each WG from the first regular cell
- Each pair is connected to a hybrid, and Σ / Δ signals are sent to the gallery
- The “TE” pickups are mostly expected to see in-phase signals (Σ)
- The “TM” pickups are mostly expected to see 180° out of phase signals (Δ)

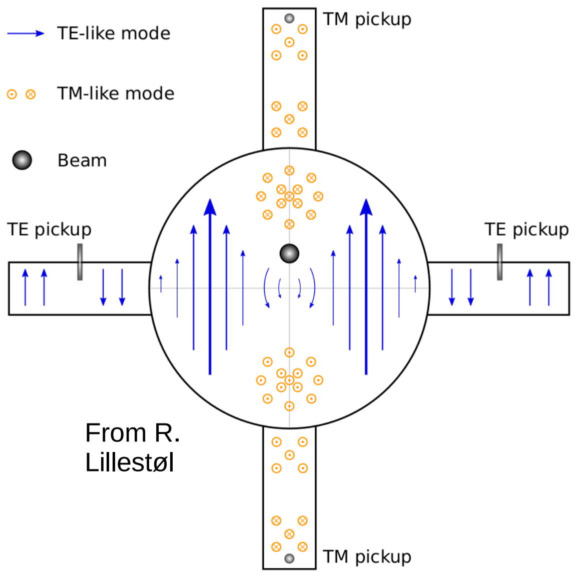
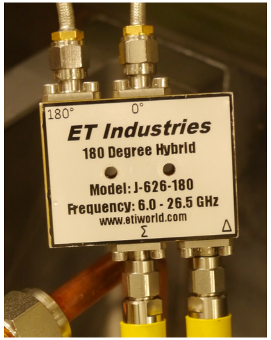
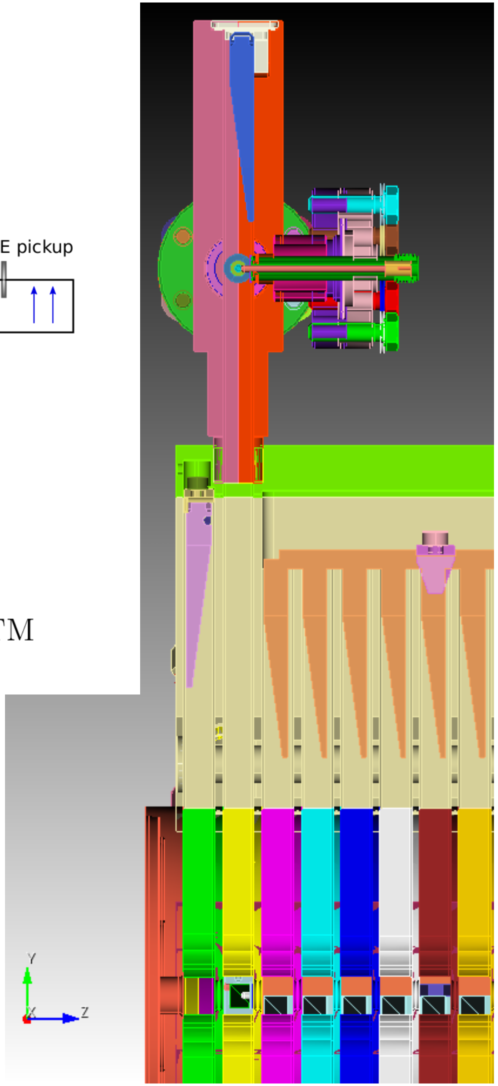


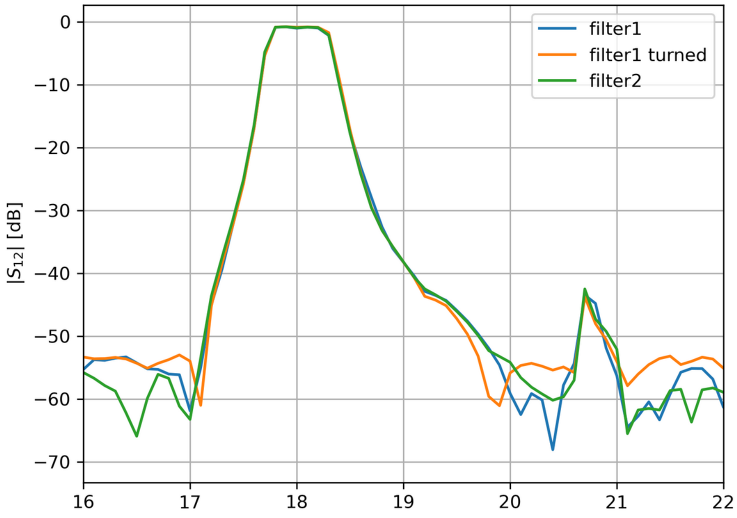
Figure 5: Field map of TE and TM

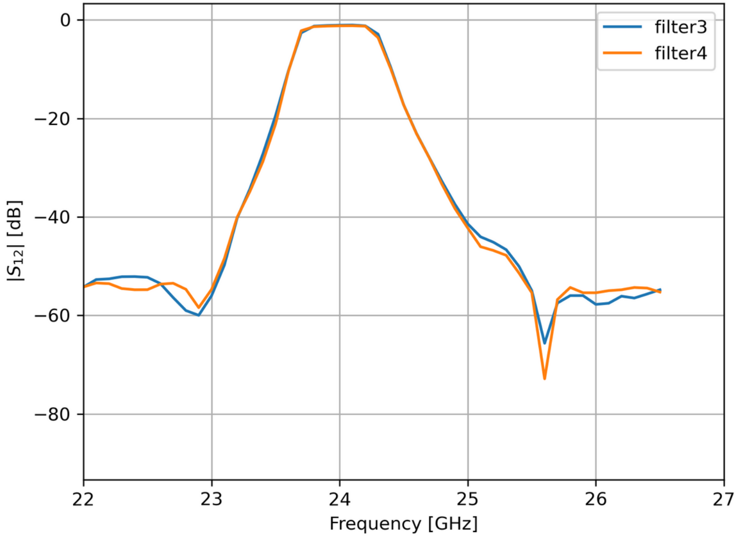




Freq. filters

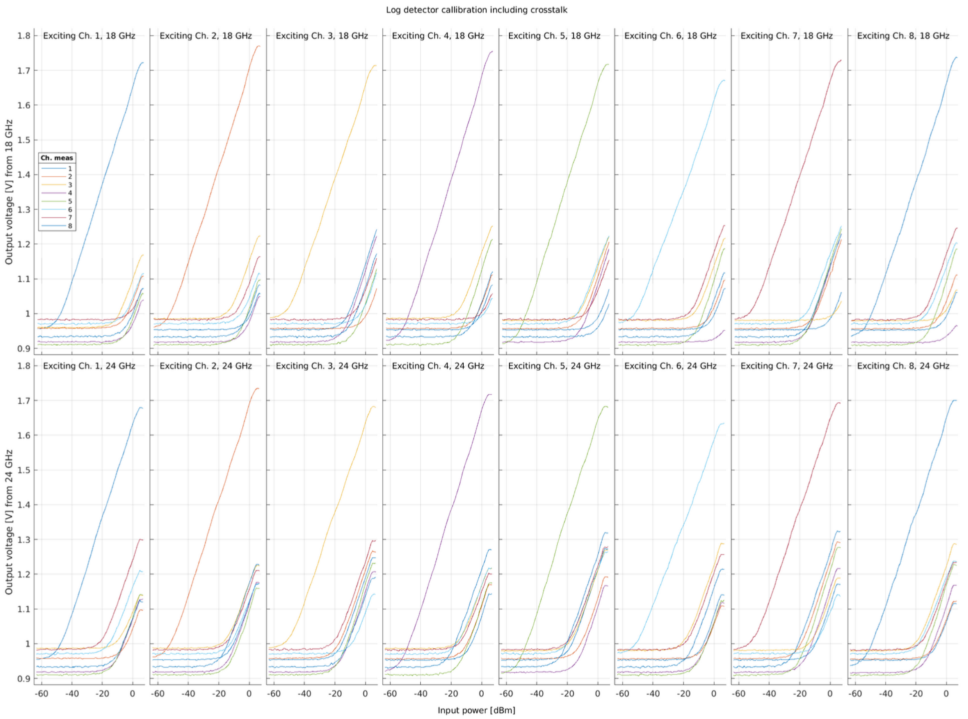
- A total of 8 Σ / Δ signals are sent to the gallery:
  - 2 planes * 2 frequencies * (Σ / Δ)
- Passed through filters
  - TM: 18 GHz
    (17.8 to 18.3 “flat top”)
  - TE: 24 GHz
    (23.7 to 24.3 “flat top”)

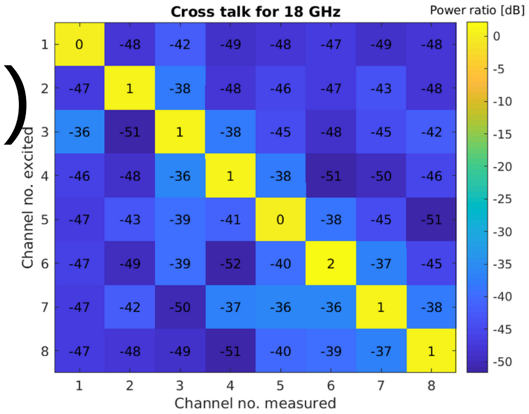


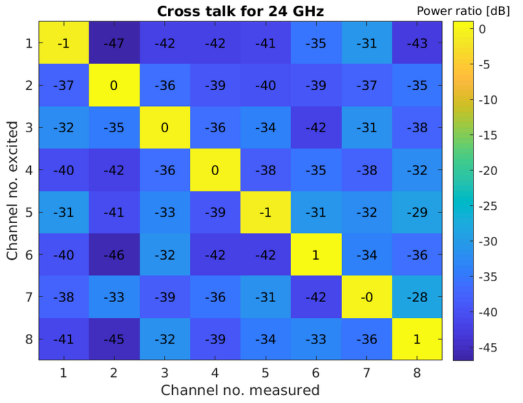


Log. power detector

- Converts freq. filtered power signal to voltage
  - Calibration needed
  - Fit linear curve P(V)
- Wide dynamic range
- Low cross-talk (~20 dB)
- Based on Analog Devices HMC662LPE

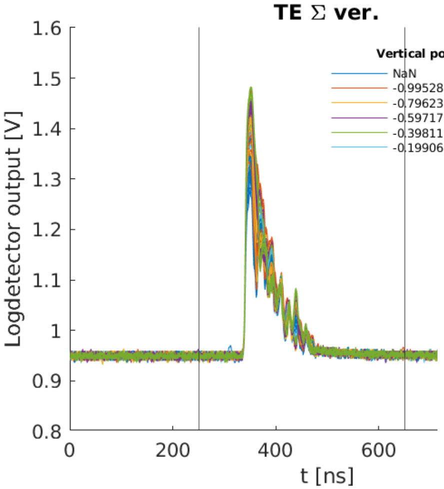




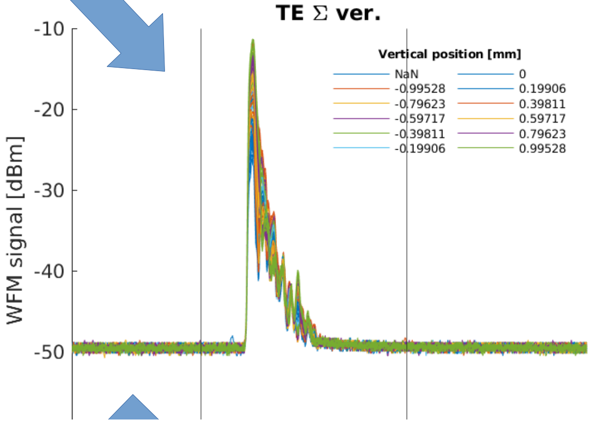


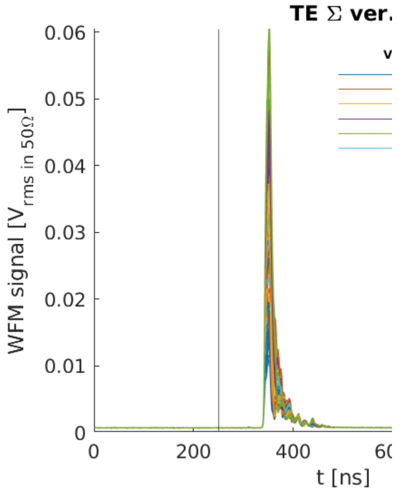
From V_{out} [V] → P(t) [dBm] → V_{in} [V_{rms} (50Ω)]

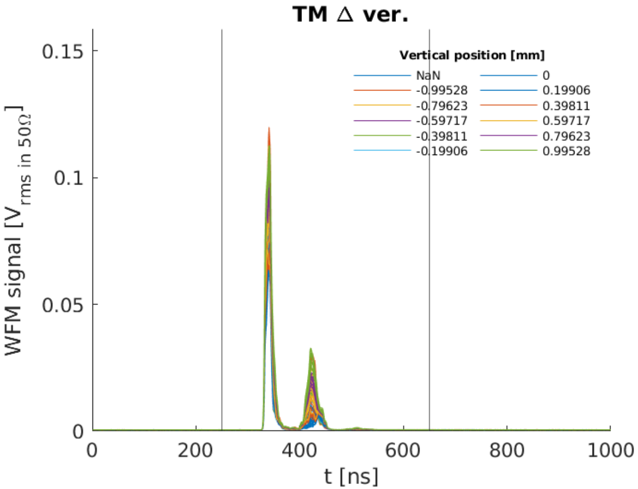
- Need to turn the V(t) from the log detector into a position signal
- Currently done by averaging in window
- Done separately for each signal
- Need to deal with reflections, varying train lengths, etc.



Calibration polynomial

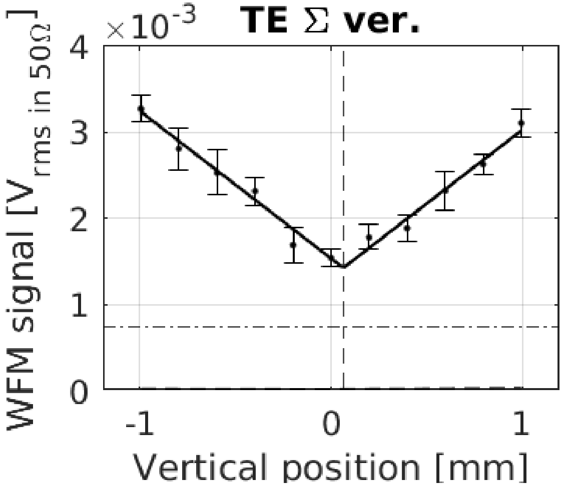






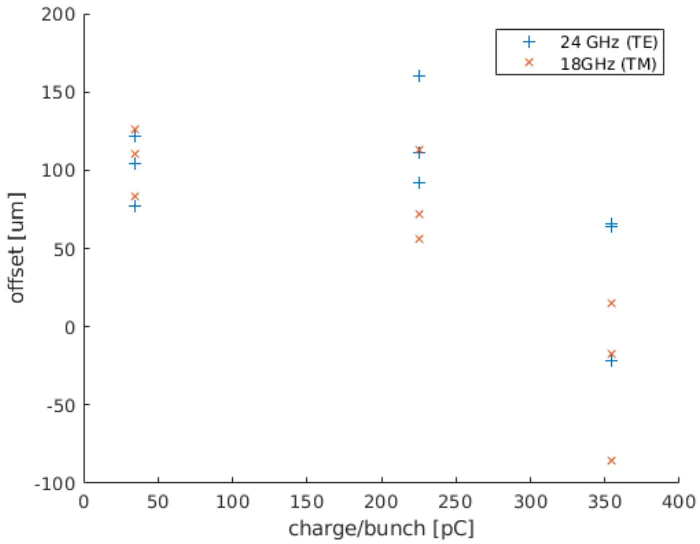
Average

& Fit V

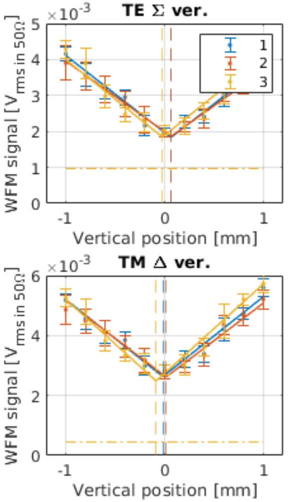


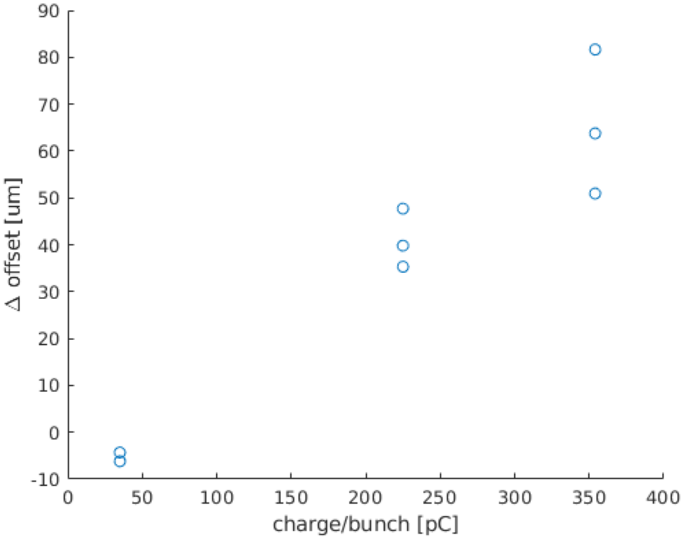
Center comparison between modes

- Expect to measure same beam offset with TE, TM
  - Not exactly the the same
- Each mode shows repeatable results
- Discrepancy occurs when changing beam setup (Here: Charge)
- Different modes with different offsets (fabrication)?
  - Tuning is not done symmetrically



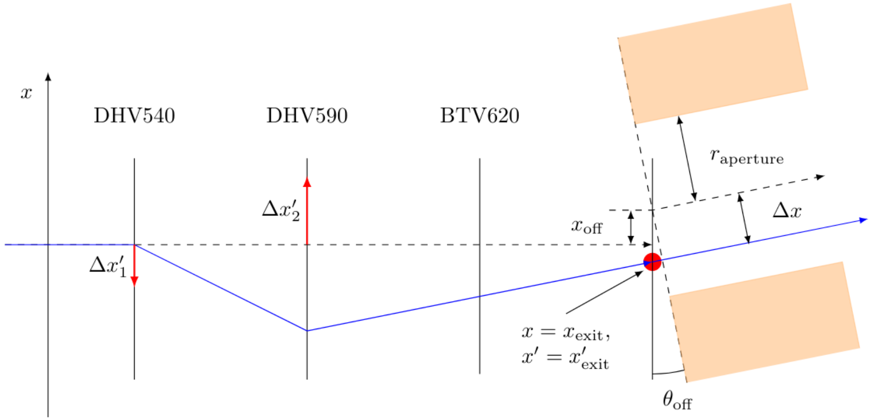
20 bunches, 354 pC/bunch

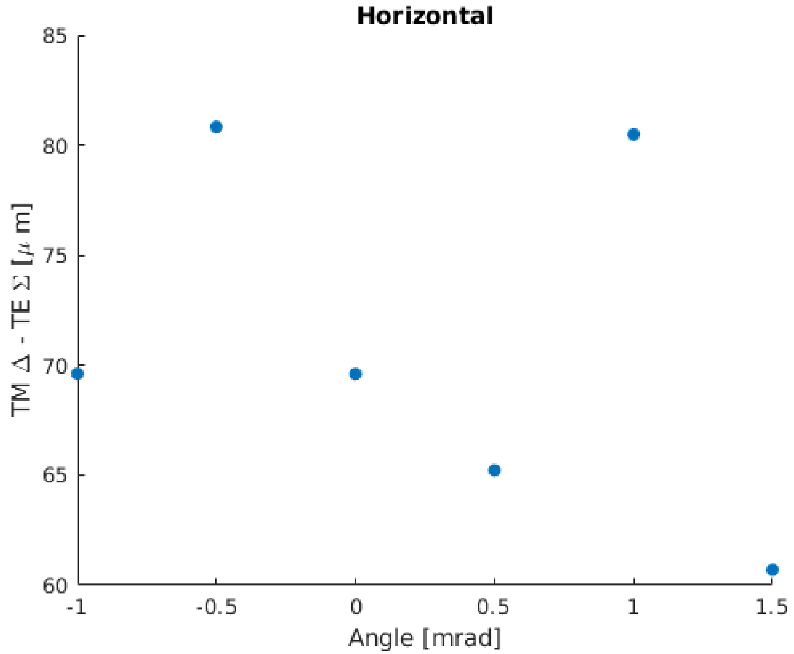




Effect of beam angle

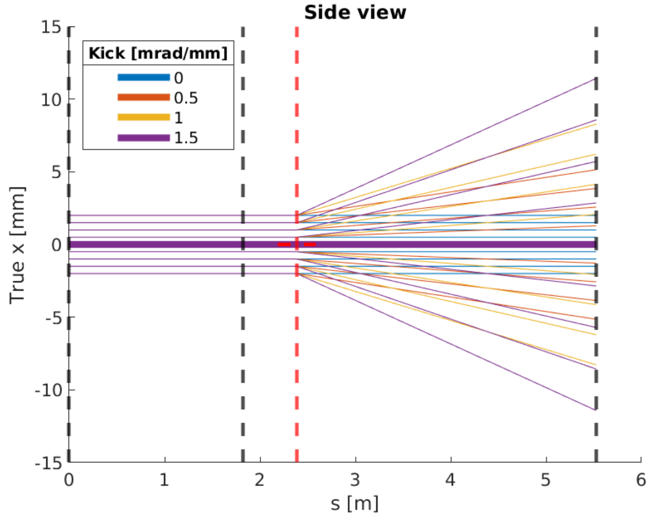
- Can use bump to create an angle on top of displacement
- If center discrepancy caused by frequencies traveling down the structure, would expect to see an effect
- **No effect observed**



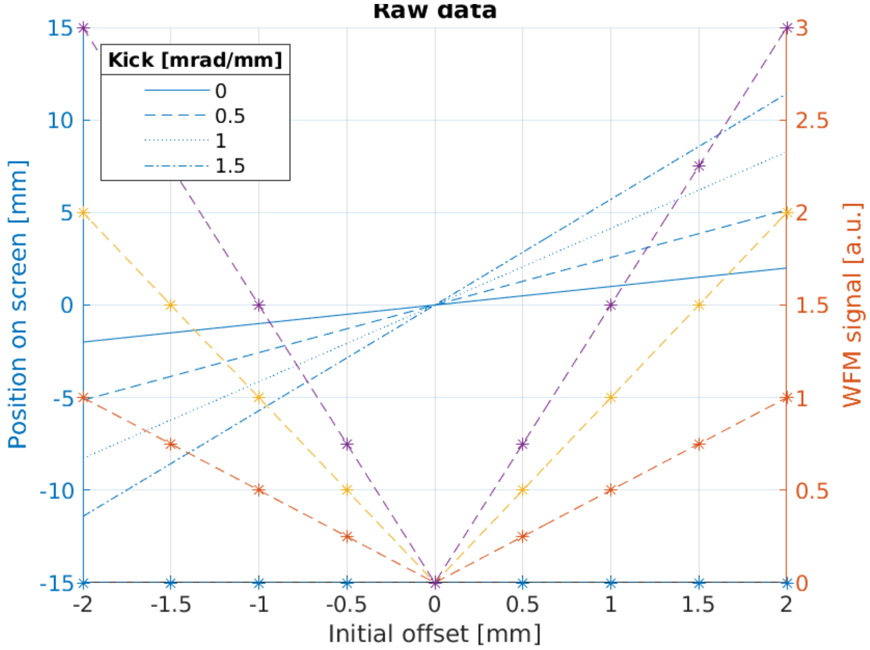


Center comparison between WFM and kicks

- Purpose of WFMs:
  Center the structure to minimize the kick
- Need relationship between WFM center and kick center (same or constant offset?)
- Find this by comparing WFMs and kicks

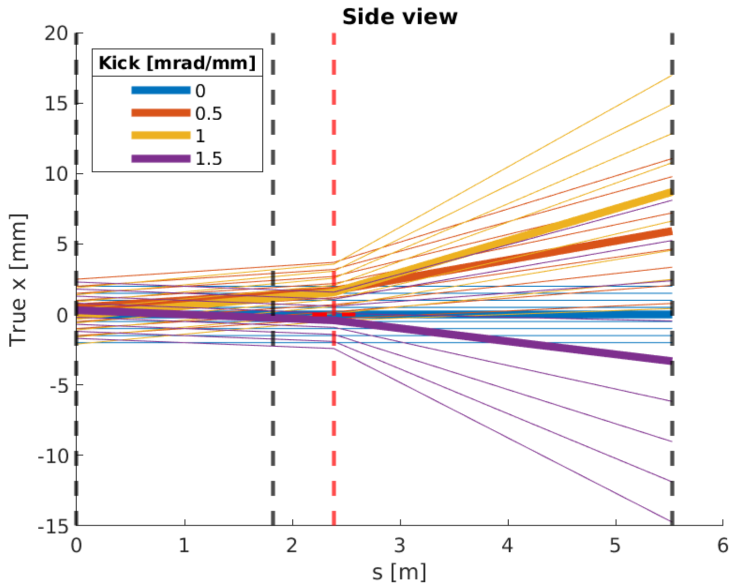


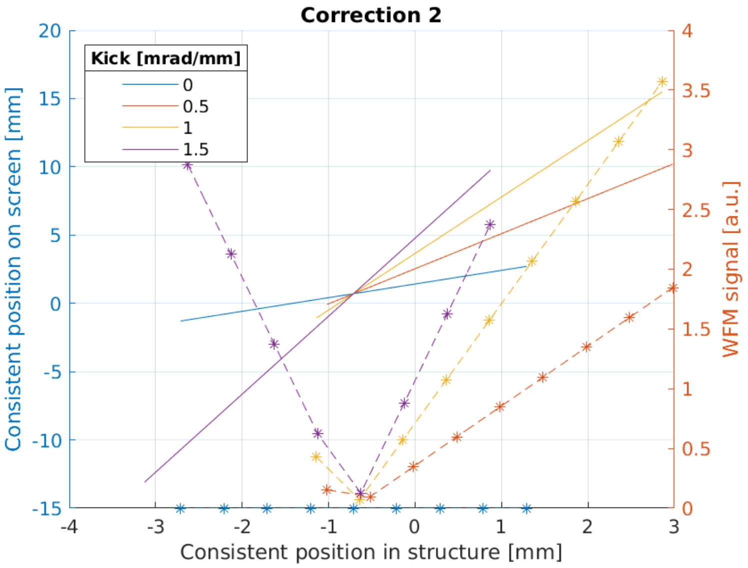
PLOTS:
"IDEAL WORLD" TOY MODEL



Estimation and correction for initial trajectory params

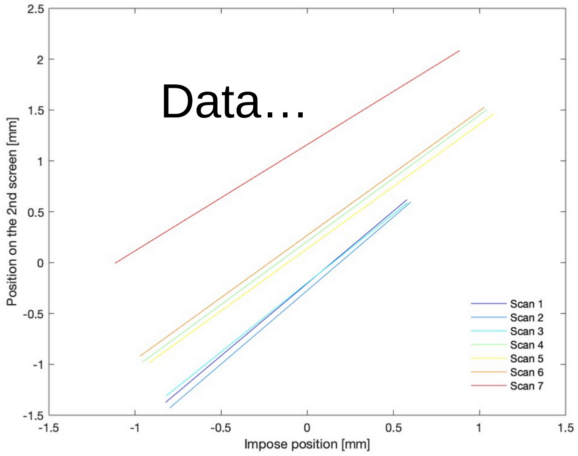
- In reality:
  - Screens are misaligned
  - Initial beam position & angle changes when changing charge
  - Screens have finite resolution
- Need to be able to correct for this
- Found correction scheme that works in simulation:
  - Measure initial beam angle and offset with first 2 screens
  - Correct for shift on last screen and in structure

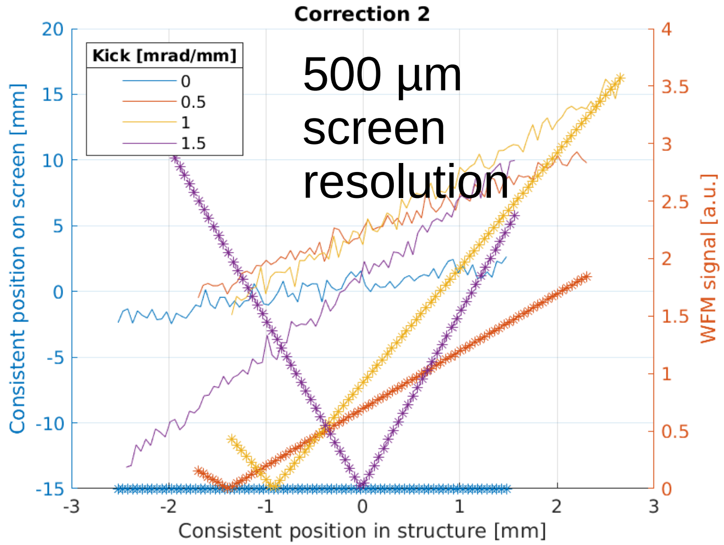


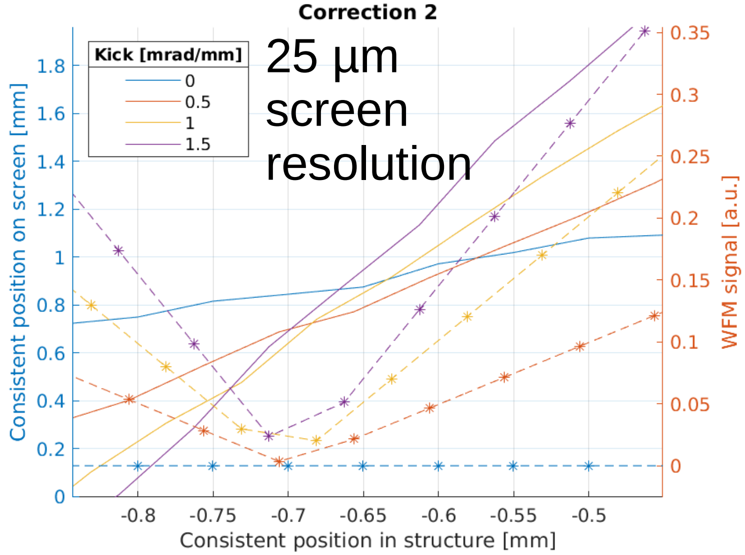


Effect of screen resolution

- Method relies on good estimate of initial trajectory
- This requires good measurements upstream of structure
- Not yet working well







Conclusions

- Work on characterization of WFMs are proceeding, but is difficult
  - Stringent demands of beam quality, losses, charge measurement etc.
- Center discrepancy between TE and TM on the order of 100 µm
  - Not caused by beam angle
- Cross talk in log detector not an issue
- **Still: Understanding of system is steadily increasing**

Outlook

- Improved camera resolution in screen 2,
  are commissioning screen 1
- Working on simulations to probe hypotheses
  - Hikmet: CST Simulation of WFM signals
  - Toy model:
    - Will probe effect of mode displacement and bunch displacement
    - Test methods for best V(t) signal treatment
- Applying improved analysis codes and calibrations
  to “old” data