Direct Wakefield measurement of CLIC accelerating structure in FACET

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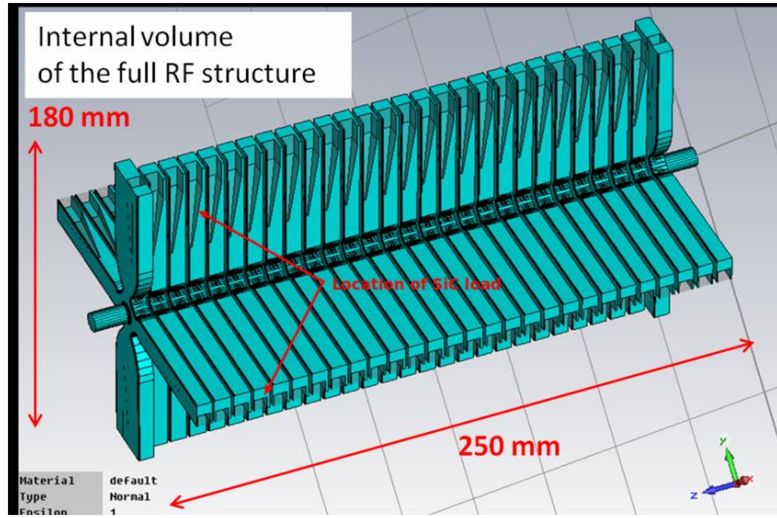
Experiment history and participant

- 2010.07.15: Letter of intent to SAREC for a program of measurements for the CLIC study at the FACET facility
- 2011.04.05: Recommendation from SAREC for submitting a proposal for the experiment at FACET
- 2011.10.14: Proposal is submitted to SAREC
- 2012.01.31: Proposal is presented at SAREC review
- 2012.04.18: Proposal is accepted by SAREC and experiment has got a number: E-208
- 2013.02.13: Delay of positrons at FACET. No positrons in 2013. ☹
- 2014.01.18: Good news on positrons. Positrons commissioned in 2014. ☺
- 2014.06.__: Structure prototype has been shipped to SLAC
- 2014.11.27-2014.12.03: Measurements has been done successfully!!!

Name	**PI**	**Type of User**	**Insituition**
E. Adli		On-site	SLAC
G. De Michele		On-site	CERN
A. Grudiev	Yes	Remote	CERN
A. Latina		On-site	CERN
D. Schulte		Remote	CERN
W. Wuensch		Remote	CERN
Hao Zha		On-site	CERN

Transverse long-range Wakefield in CLIC-G structure

Structure name	CLIG-G TD26cc
Work frequency	11.994GHz
Cell	26 regular cells+ 2 couplers
Length (active)	230mm
Iris aperture	2.35mm - 3.15mm



transverse long-range wakefield calculation using Gdfidl code:

Peak value :

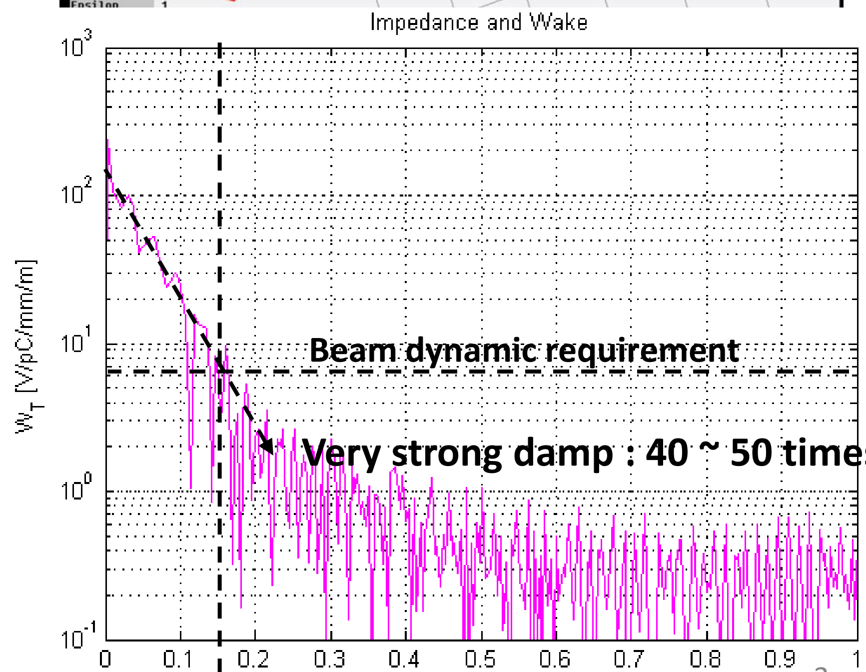
250 V/pC/m/mm

At position of second bunch (0.15m):

5~6 V/pC/m/mm

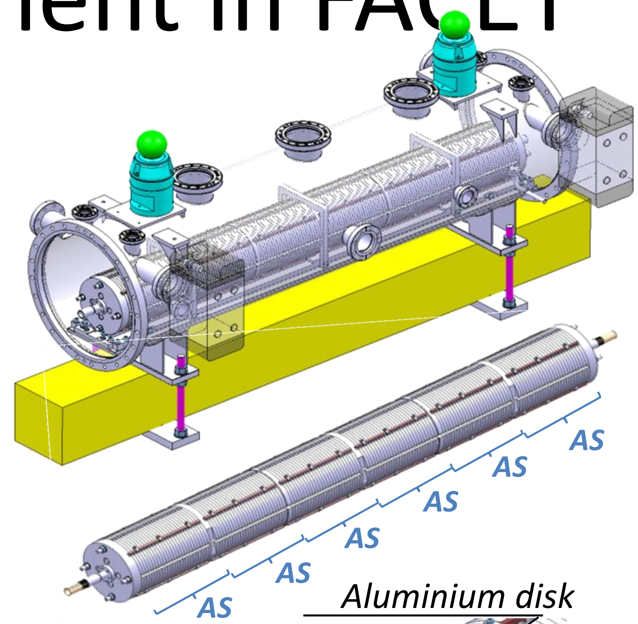
Beam dynamic requirement:

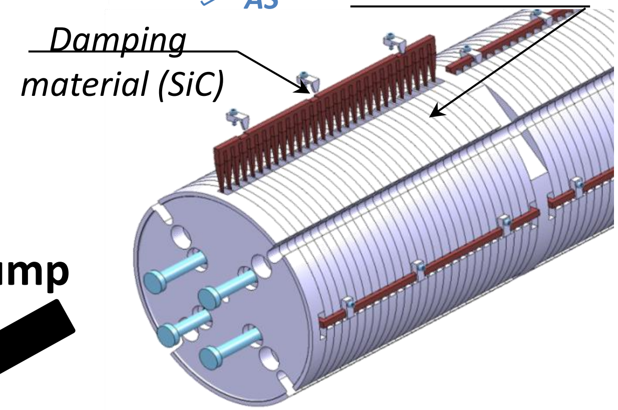
< 6.6 V/pC/m/mm

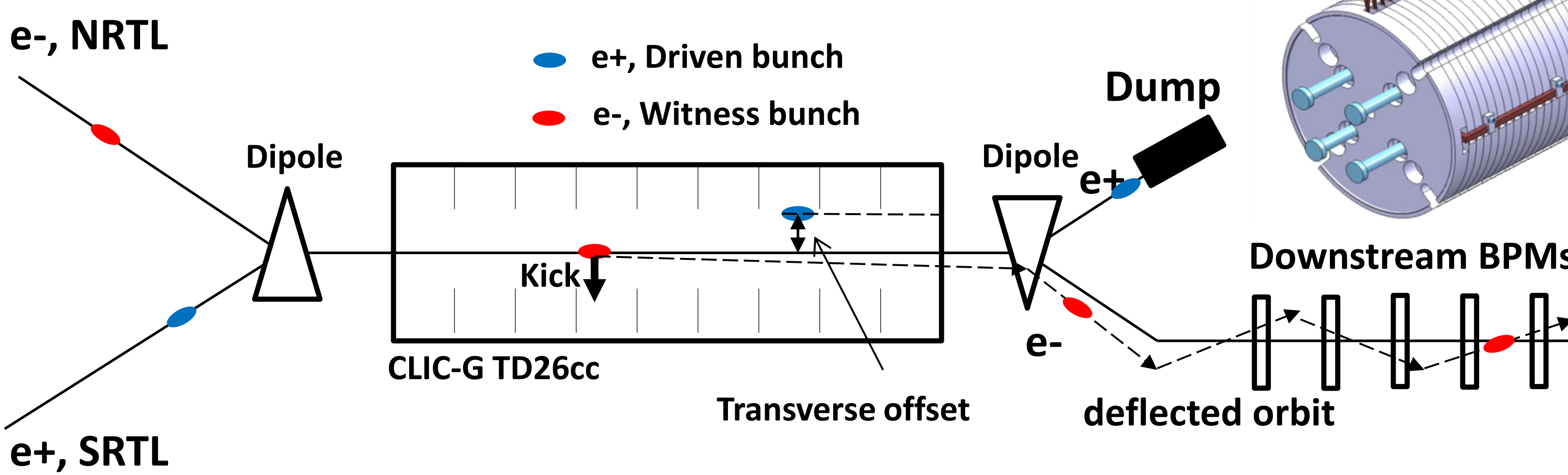


Direct wakefield measurement in FACET

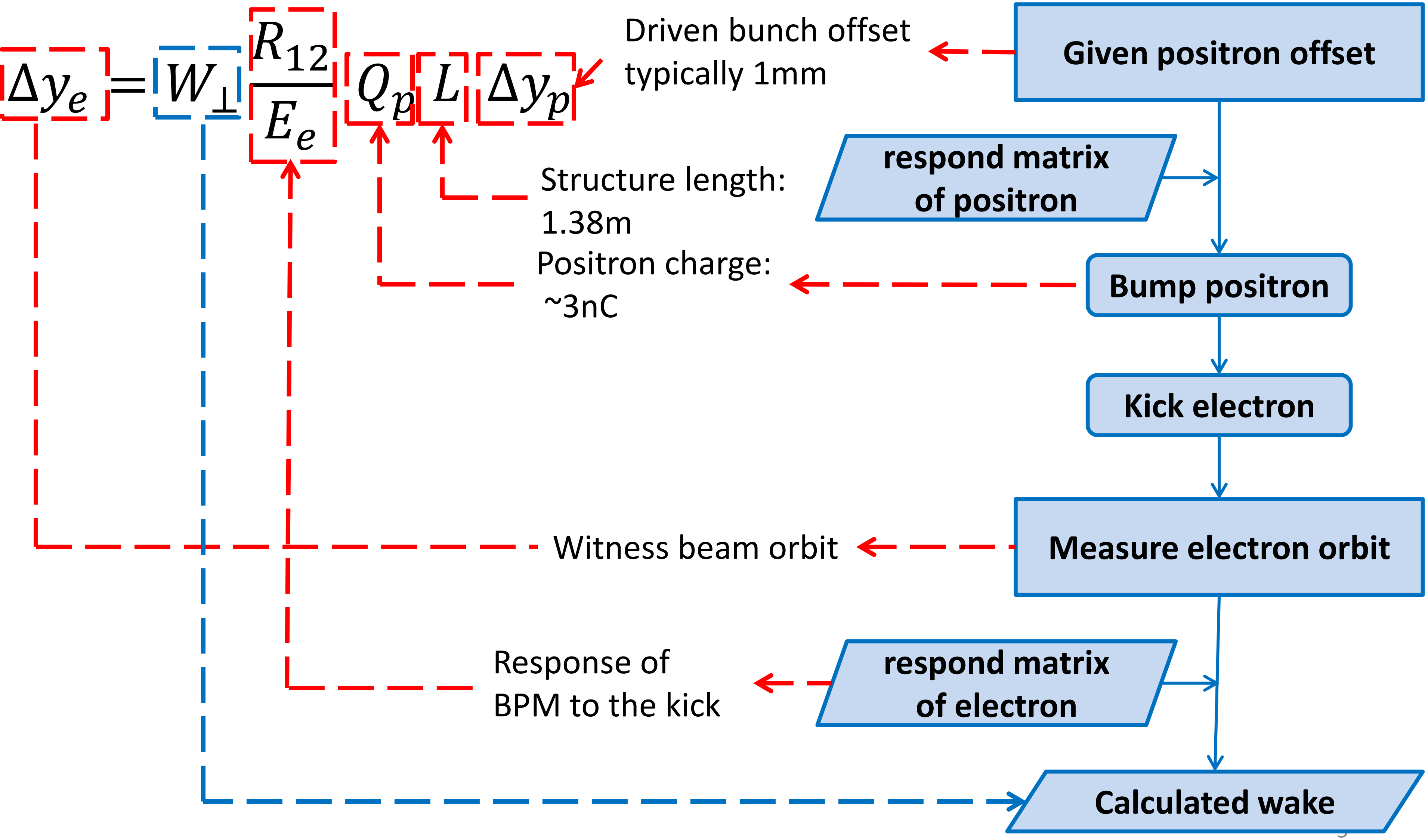
- Prototype structure are made of aluminium disks and SiC loads (clamped together by bolts).
- 6 full structures, active length = 1.38m
- FACET provides 3nC, 1.19GeV electron and positron.
- RMS bunch length is near 0.7mm.
- Maximum orbit deflection of e- due to peak transverse wake kick (1mm e+ offset): 5mm, BPM resolution: 50um







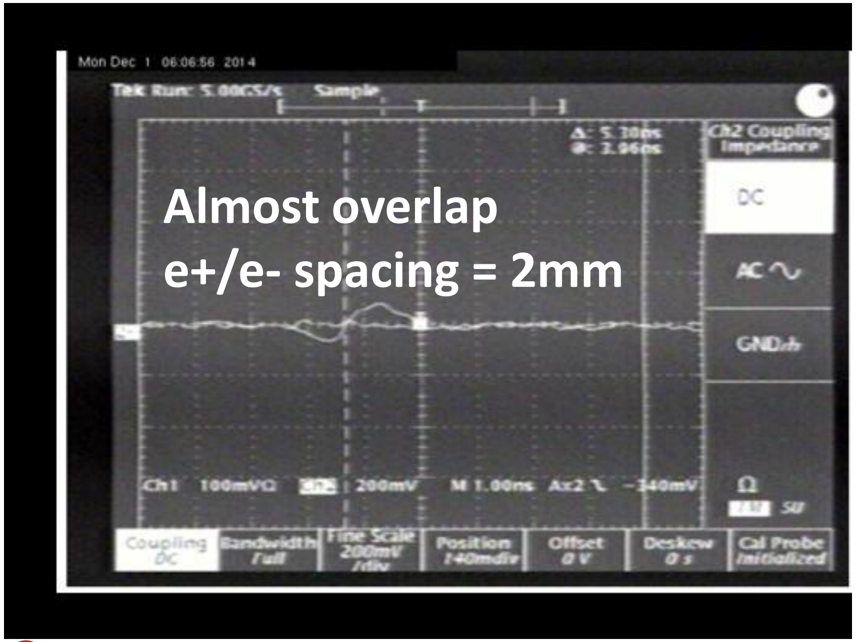
Procedure of measurement

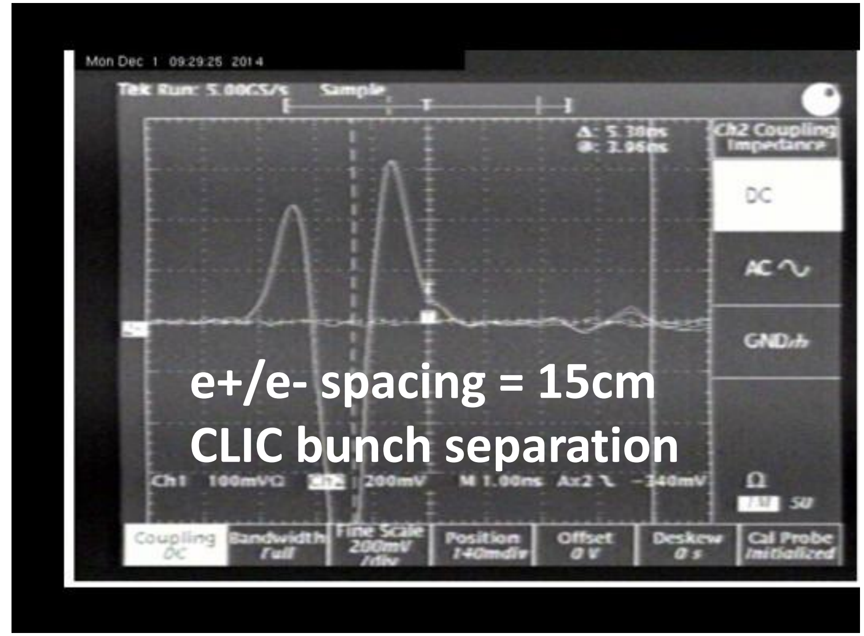


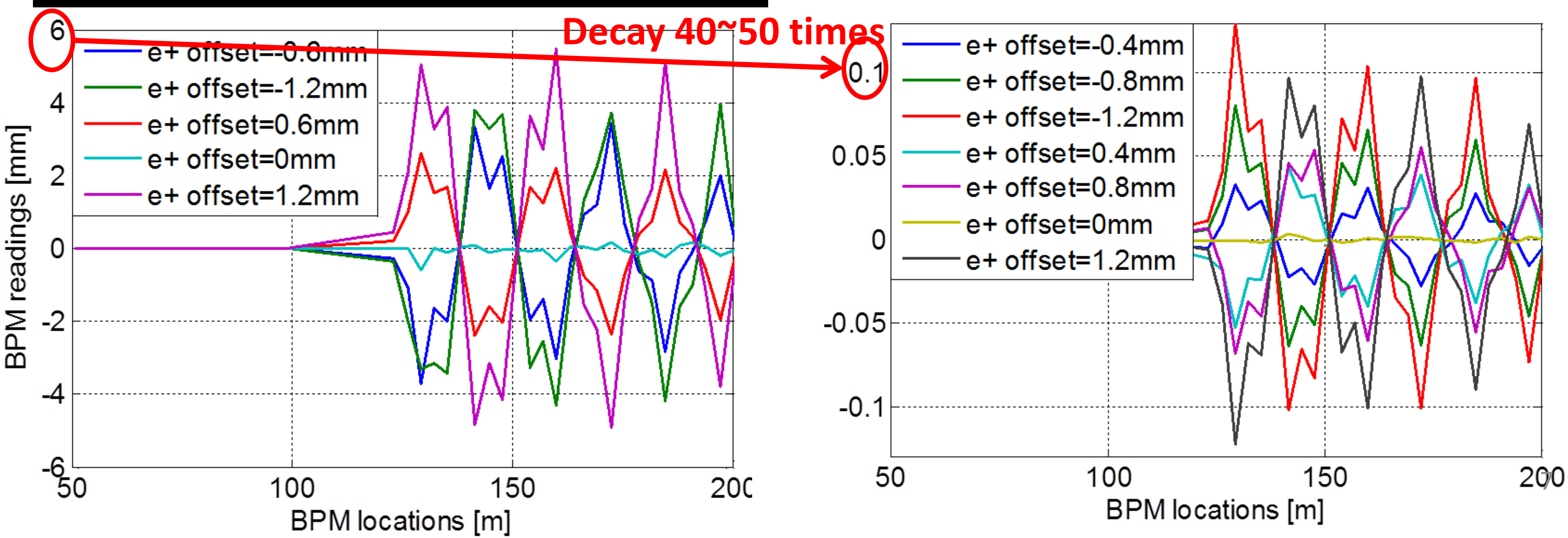
Measurement in FACET

- Before we measured deflect orbit:
  - Measure the response matrix of e+: in order to bump orbit of driven bunch with given offset.
  - Measure the response matrix of e-: in order to calculate the absolutely value of wake kick.
  - Dispersion free correction: decrease e- orbit jitter due to energy jitter.
- We measure:
  - 252 points in time-domain wake potential (by changing e+/e- timing);
  - Each point with 5~7 e+ offset.
  - Each offset we take data of 100 shots.

Measurement in FACET

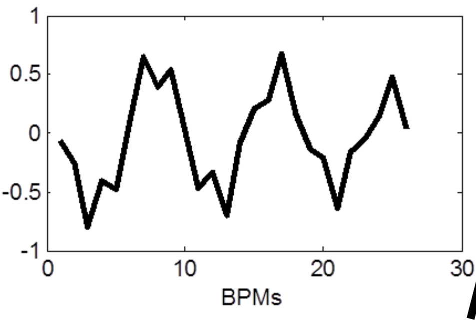


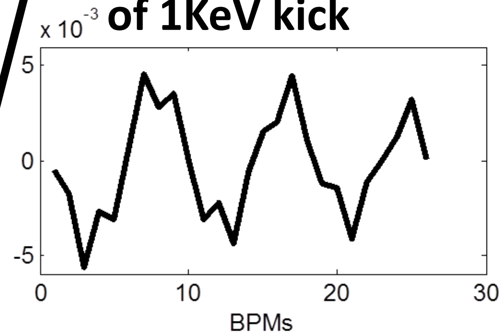




Wakefield analysis

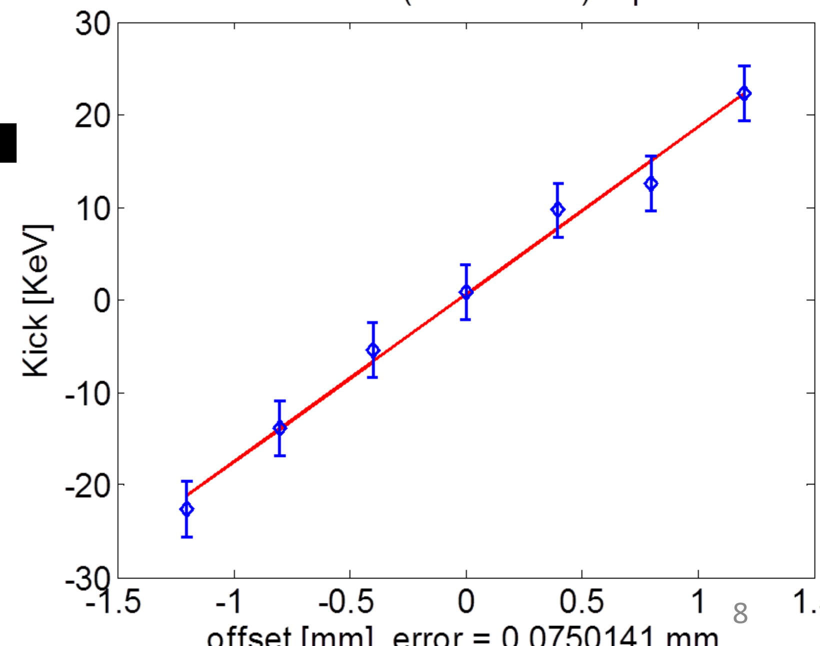
Deflected Orbit [mm] / **Response orbit [mm] of 1KeV kick**

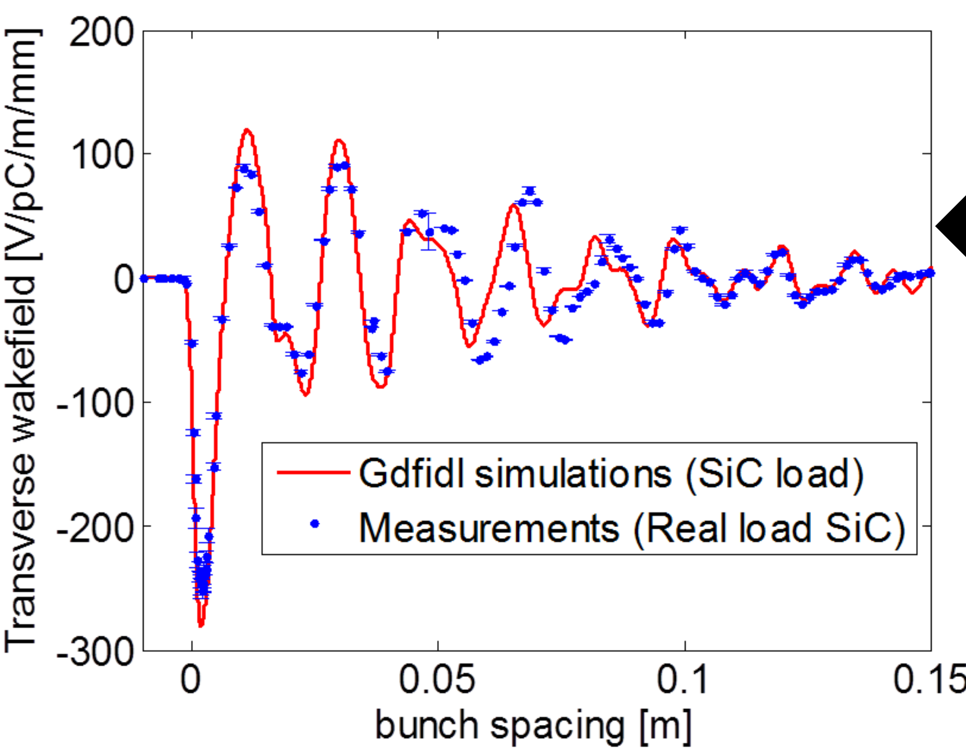




One point	Shot 1	… …	Shot 100	
Offset 1	*kick11*	… …	*Kick1,100* →	$\overline{k_1}$
Offset 2	*kick21*	… …	*Kick2,100* →	$\overline{k_2}$
⋮	⋮	…⋮…	⋮	⋮
Offset 7	*kick71*	… …	*Kick7,100* →	$\overline{k_7}$

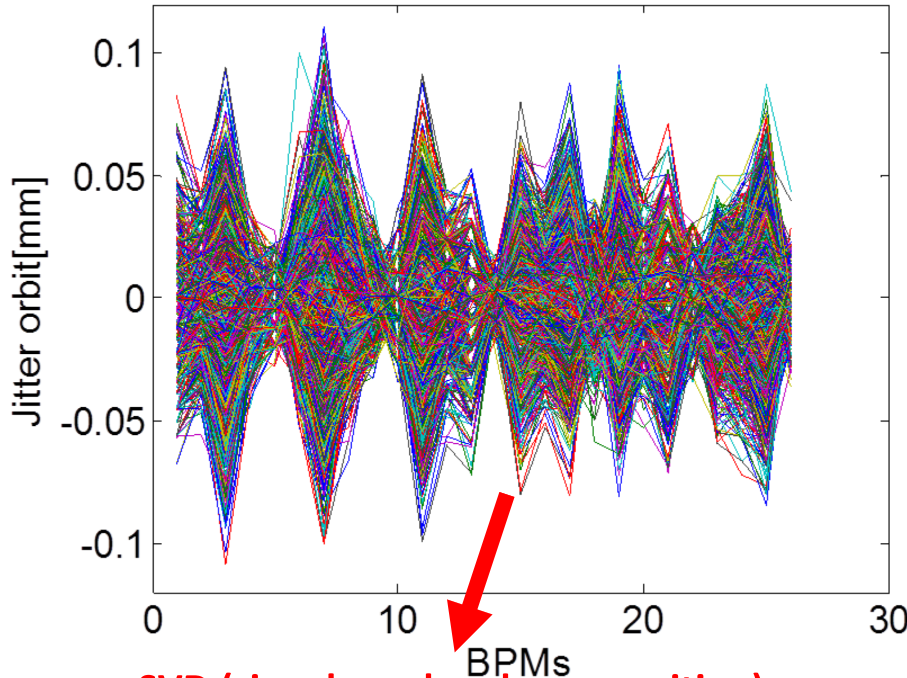
Wake = 4.80112 (+-0.174073) V/pC/m/mm



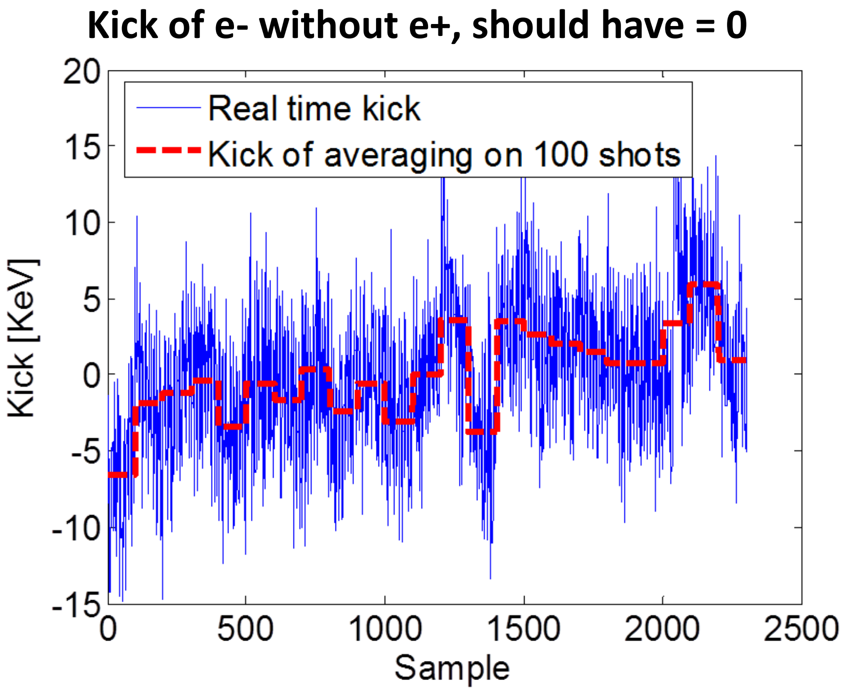


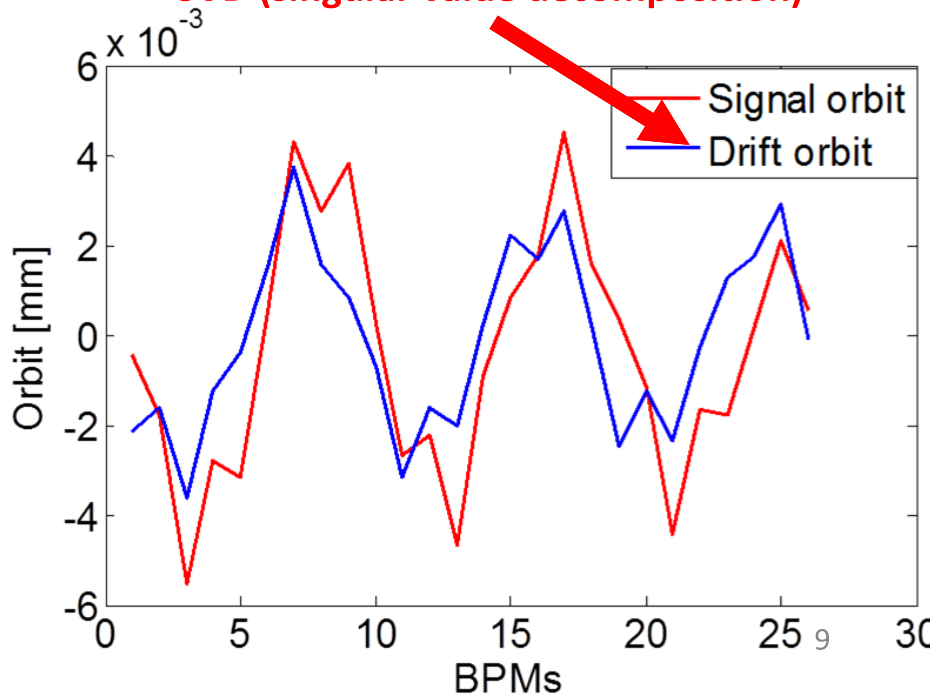
Slow beam orbit drift

- Averaging on 100 shots removes fast jitter.
- Slow **random drift** of e- orbit is observed (2 ~ 5KeV equivalent)
- This limits the minimum resolution of results by **0.5 V/pC/m/mm**.



SVD (singular value decomposition)

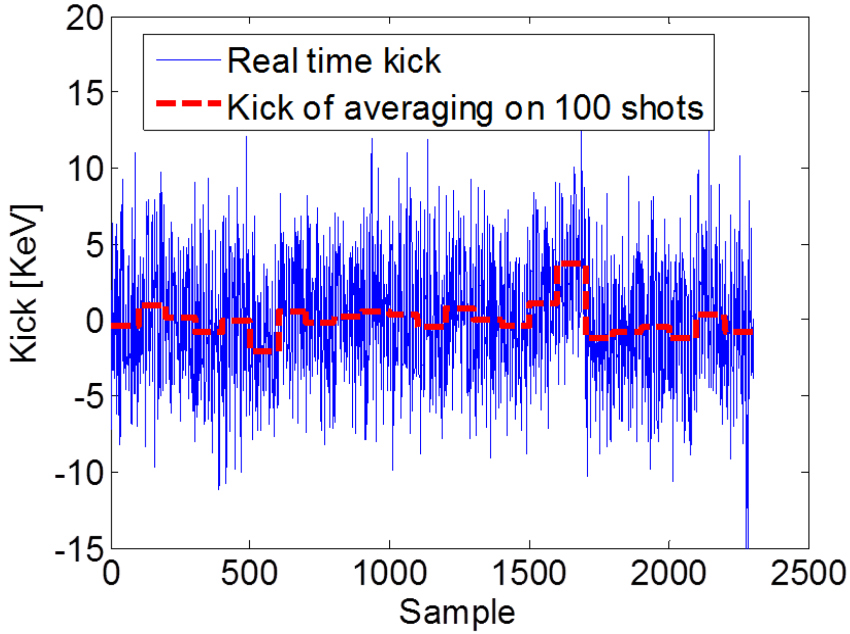




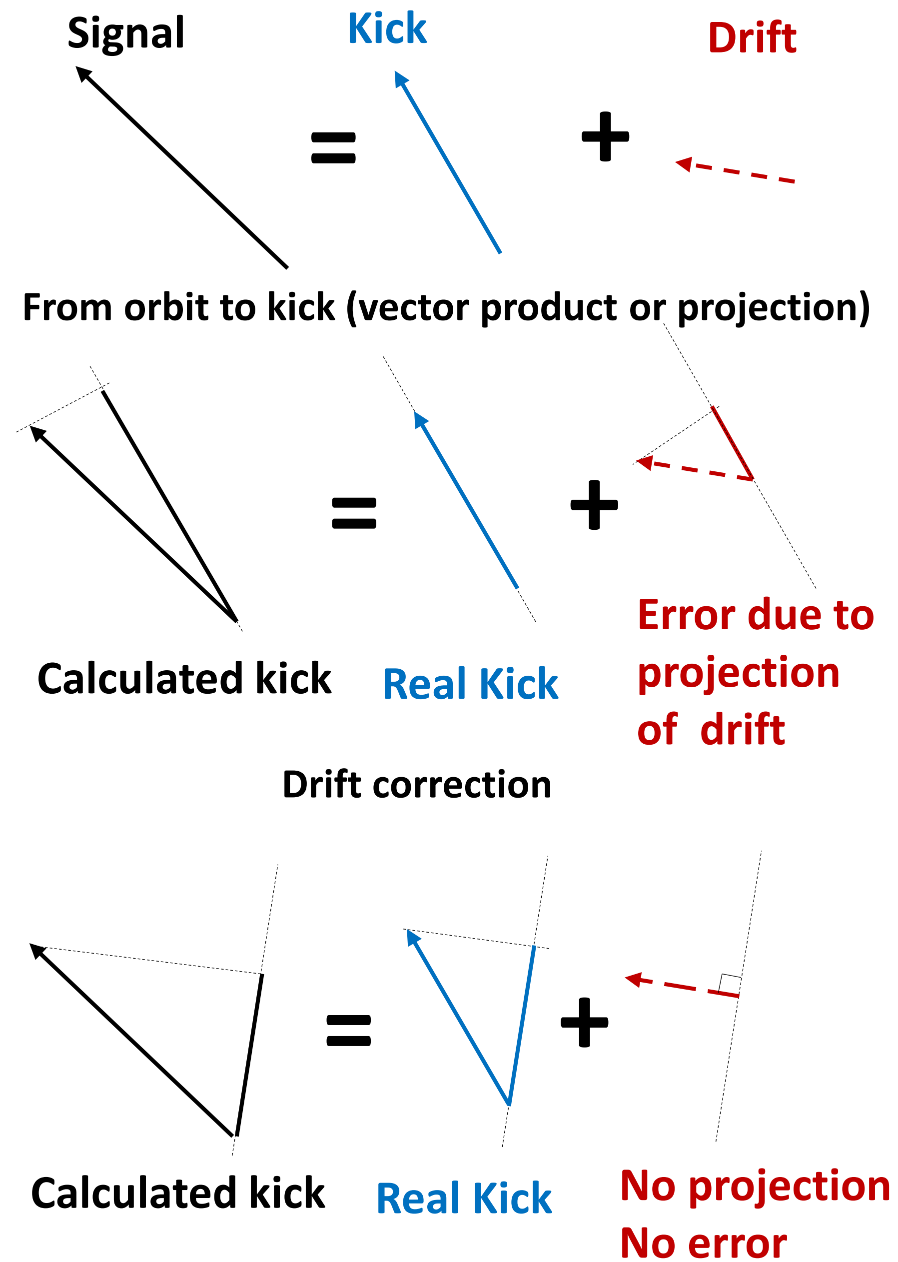
Slow drift correction

- Use SVD to identify drift mode (or drift source)
- Use linear algebra to remove drift modes from orbit.
- Can remove 2 modes (1 betatron oscillation + 1 dispersion)

Orbit of e- without e+, should have no kick



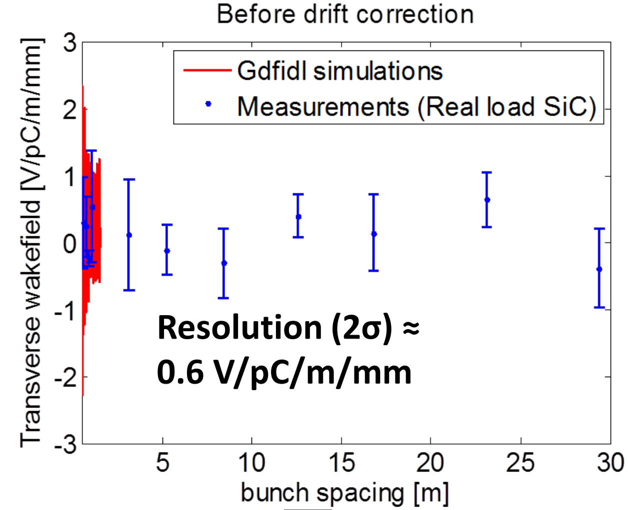
Orbit decomposition

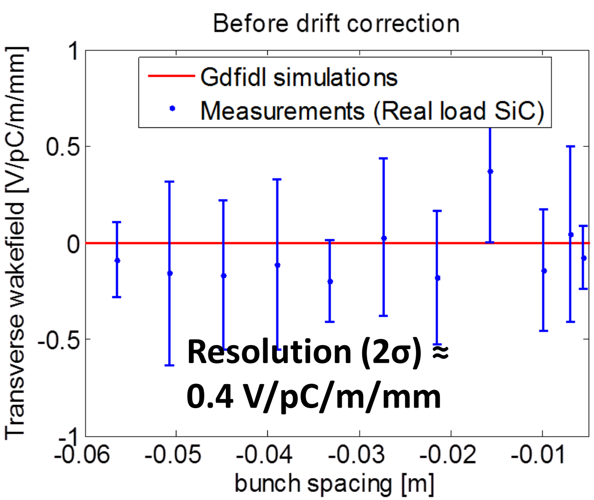


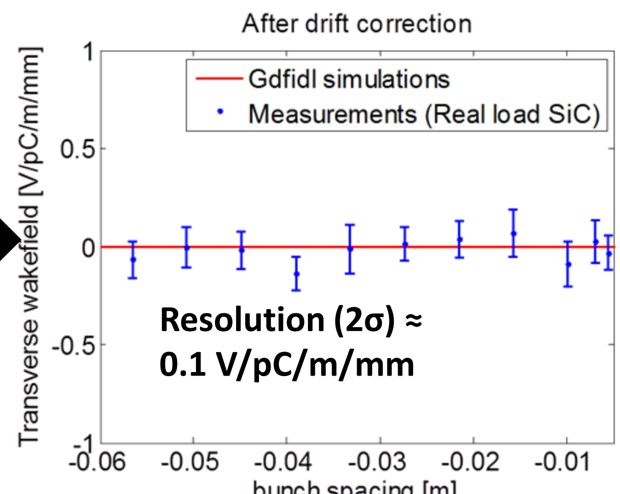
After drift correction

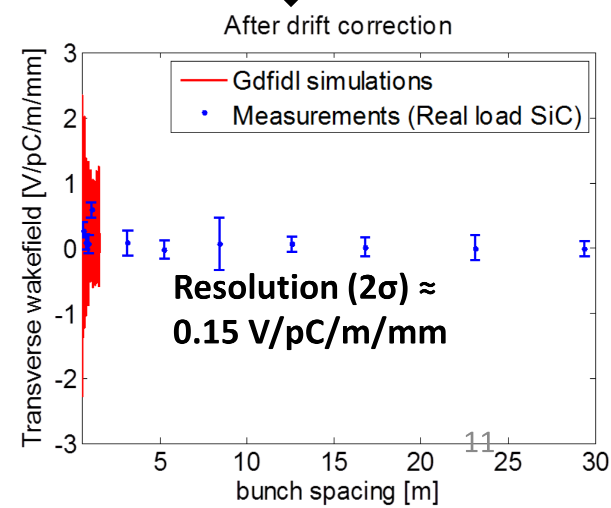
- This drift correction is used for when wakefield kick is zero or very weak (achieve **0.1 V/pC/m/mm** resolution).
- Drift correction will not be used for strong wakefield kick because of:

- Orbit drift is much smaller than deflected orbit, signal noise ratio is already very high.
- It will change the calculated wake by a certain ratio, means for strong kick the error will increase.



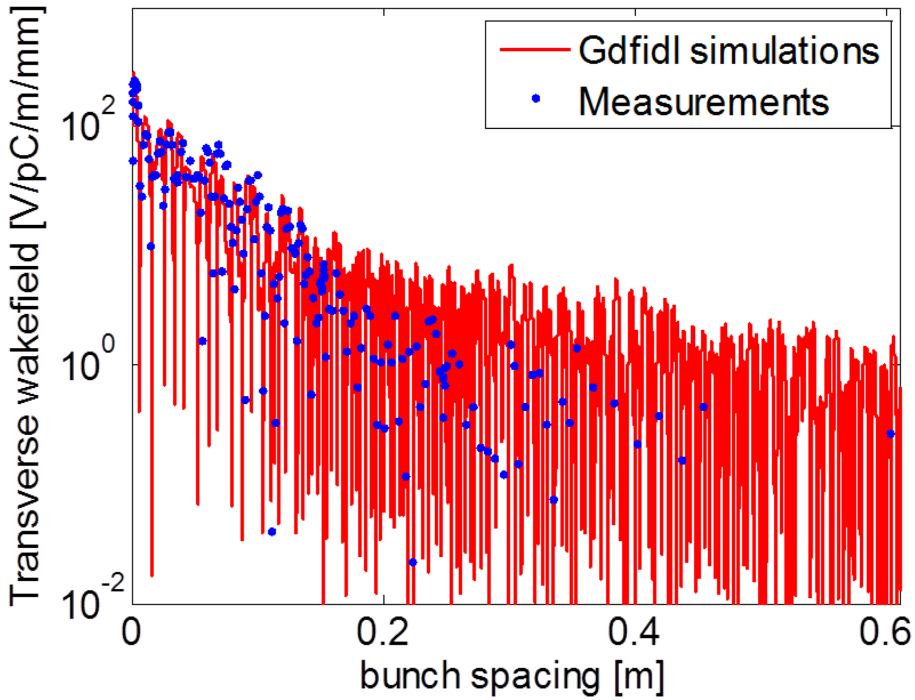


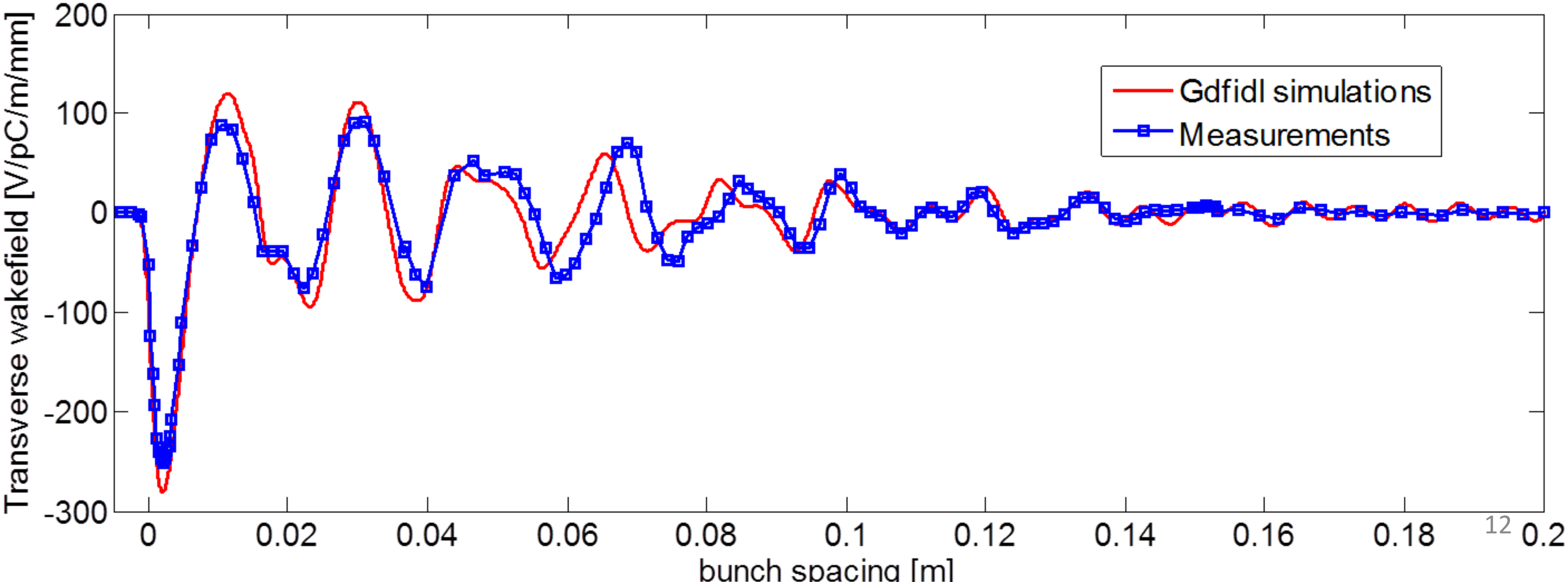




Final results

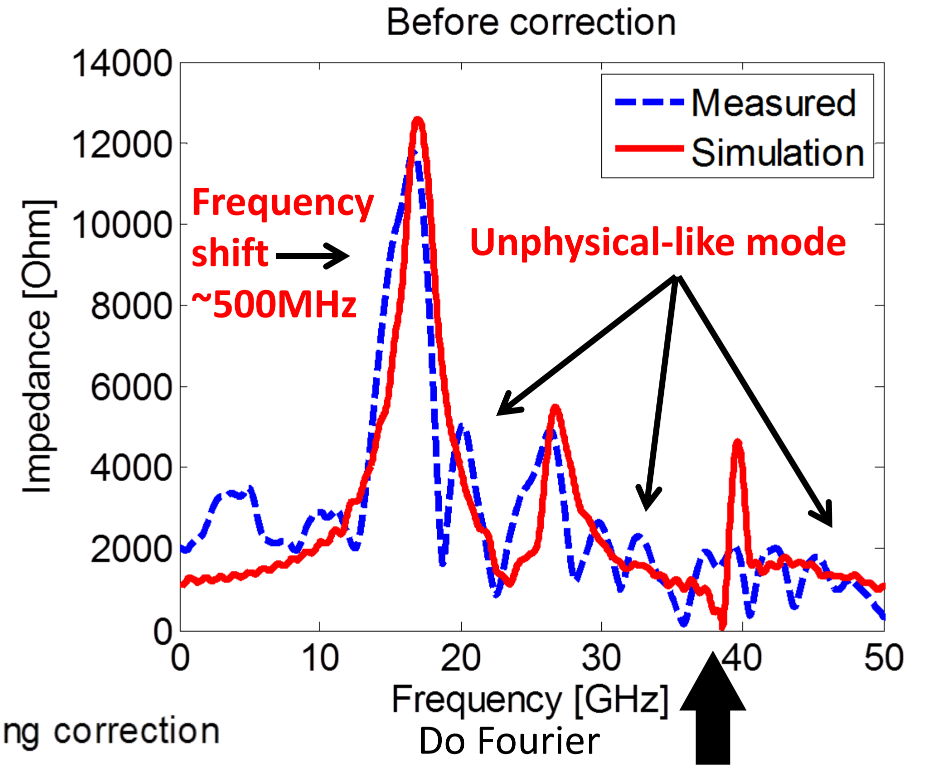
- We measure the absolutely wakefield value, peak value 10% lower than simulations.
- Wake potential at second bunch seperation = 4.5V/pC/m/mm.
- Decay faster than simulation.

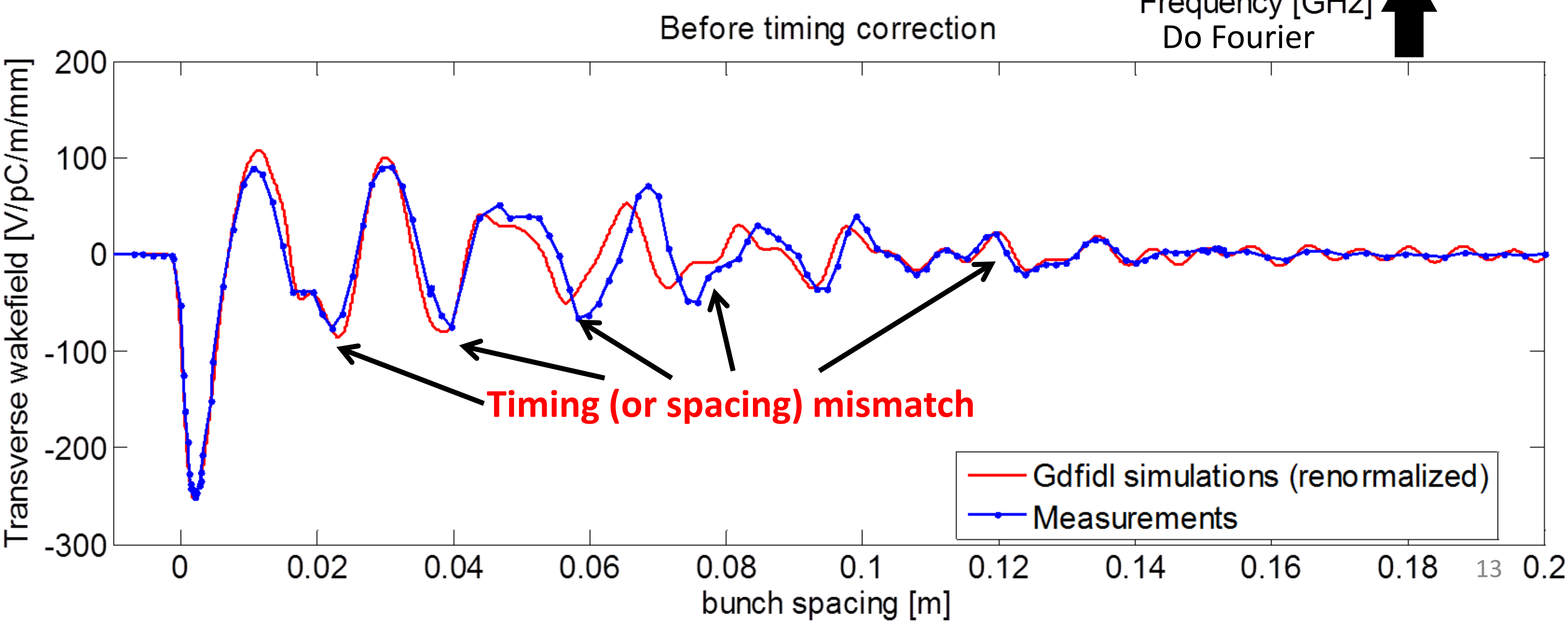




Timing shift

- There is a timing shift in the measurements.
- Should coming from the phase calibration (confirmed from SLAC people)



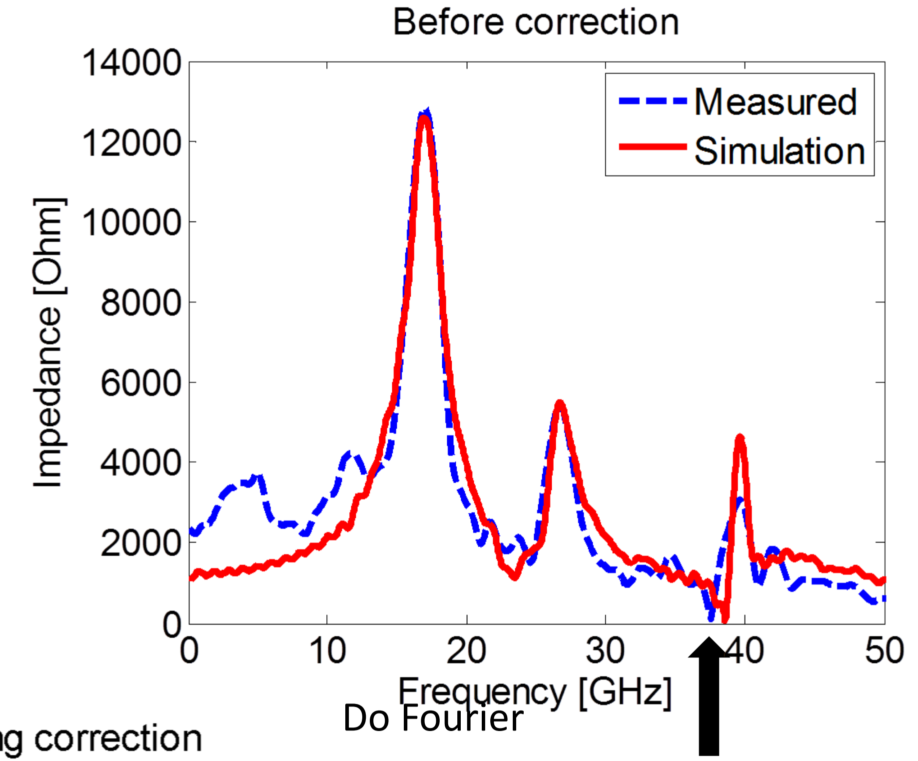


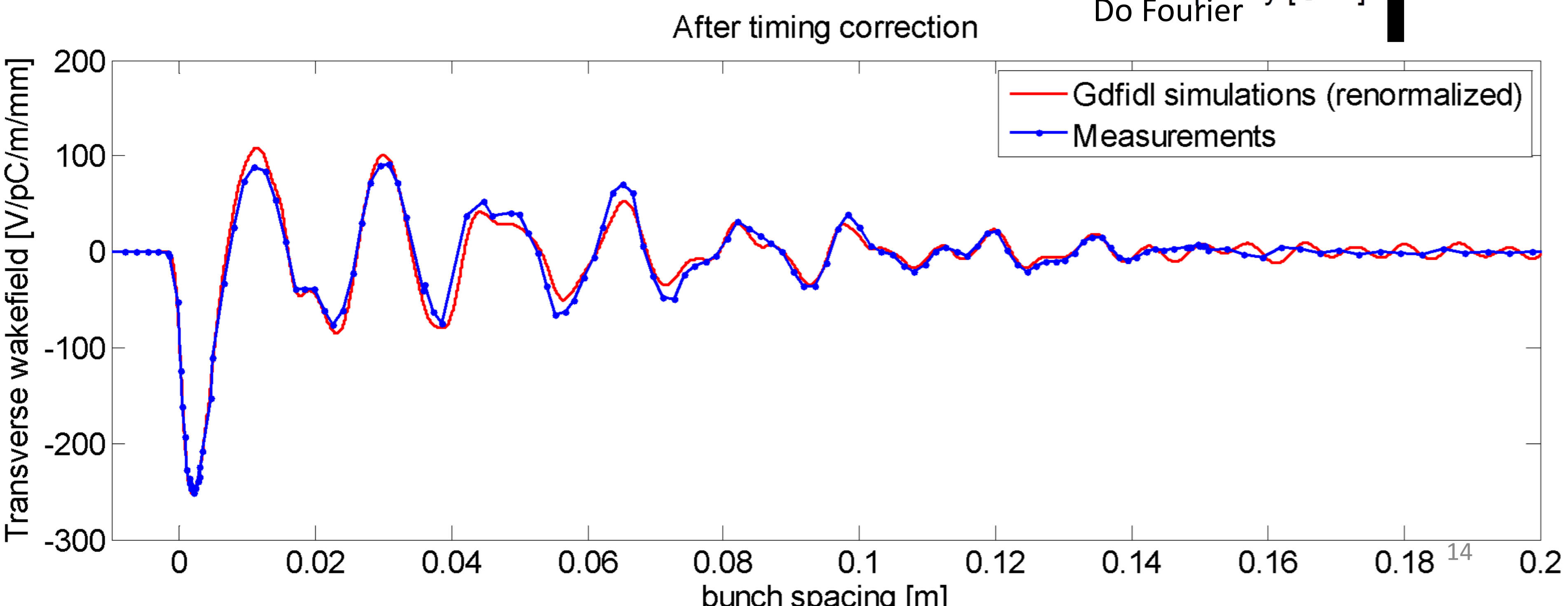
Timing shift

- Artificially apply timing correction:

*2mm *sin(phase of positron).*

- Spectrum looks normal after correction.
- Need to have more study





Conclusion

- We successfully measured the absolutely long-range transverse wakefield potential in CLIC-G TD26cc.
- The results show expedited attenuation of HOMs, and meet the BD requirement.
- After applying lots of tools (DFS, SVD, etc.), we manage to get very accurate results (Resolution: 0.1~3 V/pC/m/mm).
- Artificially adjust the timing shift will have more physical results, and the shift like to be a real effect. This need to be further confirmed and studied.

Acknowledgement

- We thank Paul Scherrer Institute (PSI) financially support the prototype manufacturing through FORCE 2011 funding.
- We would give great thank to Giovanni De Michele for the preparation of the prototype and experiments.
- We thank Anastasiya Solodko by the hard work of engineer design and fabrication of the prototype .
- We thank SLAC people: Christine Clarke, Jerry Yocky, Nate Lipkowitz and all the operators’ great help during the measurements.