STANFORD LINEAR ACCELERATOR CENTER

Dynamic Modeling and Simulation of LER-HER PEP II Rings

J. Fox, T. Mastorides, C. Rivetta, D. Teylteman, D. Van Winkle

- **Outline**

  - Goals
  - Modeling Issues
  - Dynamic Model
  - Validation
  - Results
  - Conclusion & Future lines

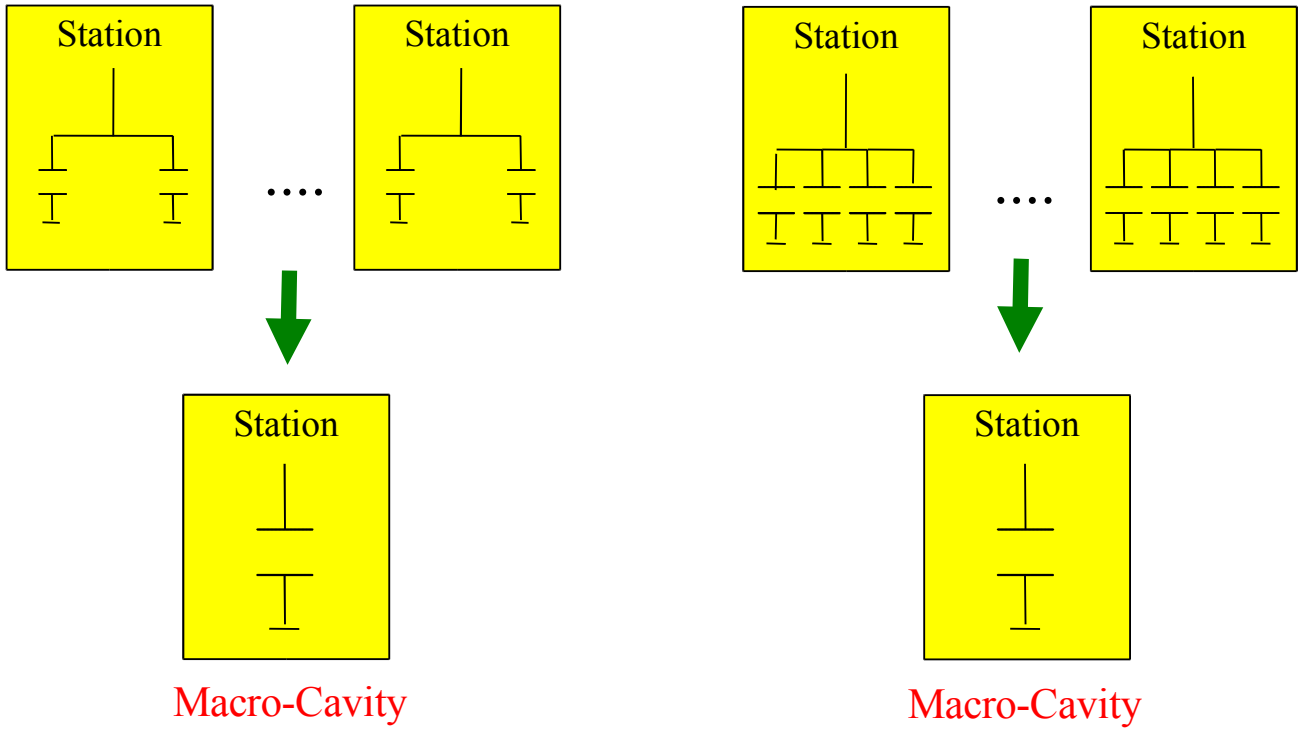
Goals

- Develop a reduced model of the LER-HER complex to analyze via simulation the interaction between RF cavity stations / LLRF feedback / Beam dynamics.
  - Predict high-current system behavior.
  - Understand LLRF limits.
  - Test stand for alternative LLRF processing techniques, including hardware and software concepts.
  - Test on-line algorithms for diagnostic.
  - Analysis of sensitivity of parameter / 'off-sets'.

Modeling Issues

- Beam dynamics in both rings is affected by N stations configured at different operating conditions.
- Stations are not equal: 2 - 4 Cavities per Klystron.
  - Detailed model - Very slow / Parameters - Compromise

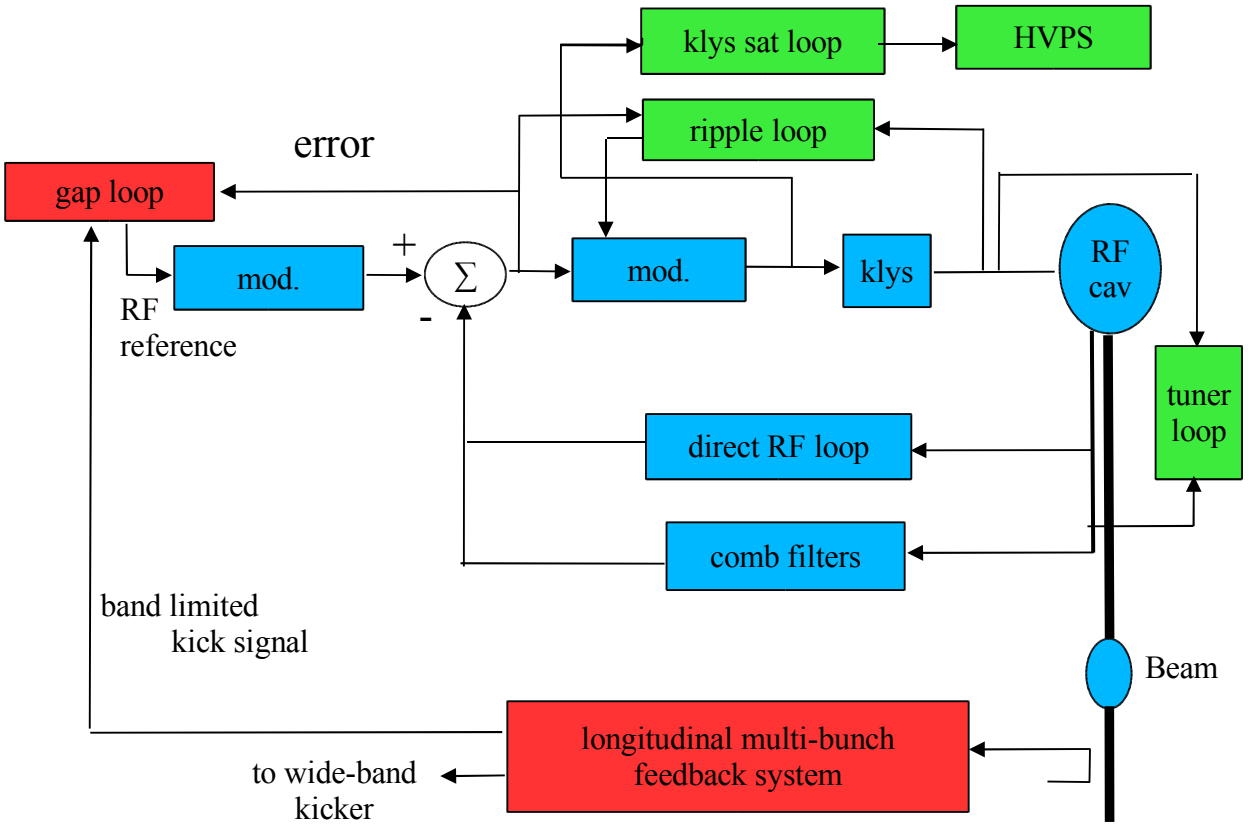
LER-HER



Modeling Issues

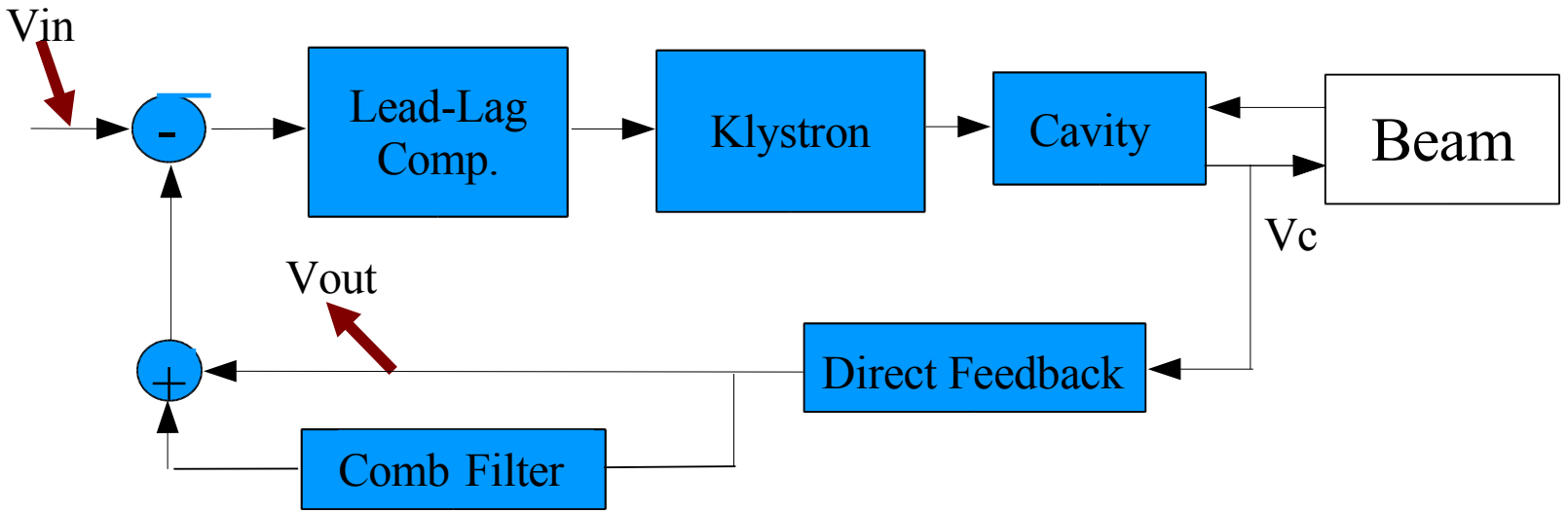
- Each station has different feedback loops operating at different 'time scale'.
  - Reduced model to improve convergence / speed
  - Slow-Fast time scale separation.
    - Slow: Blocks with time constant of several seconds/minute.
    - Fast: Include all the blocks with time constant of the order of the beams dynamic.
- Model Approach:
  - Time domain simulation (Non Linearities).
  - Macro-Cavities per 2 – 4 Cavity stations for LER-HER.
  - Linear / Non Linear Klystron.
  - Beam modeled by macro-bunches (Low Order Modes).
  - Validate parameters.

Dynamic Model



Legend
Blue – Fast Loops
Green – Slow Loops
Red – Not Implemented

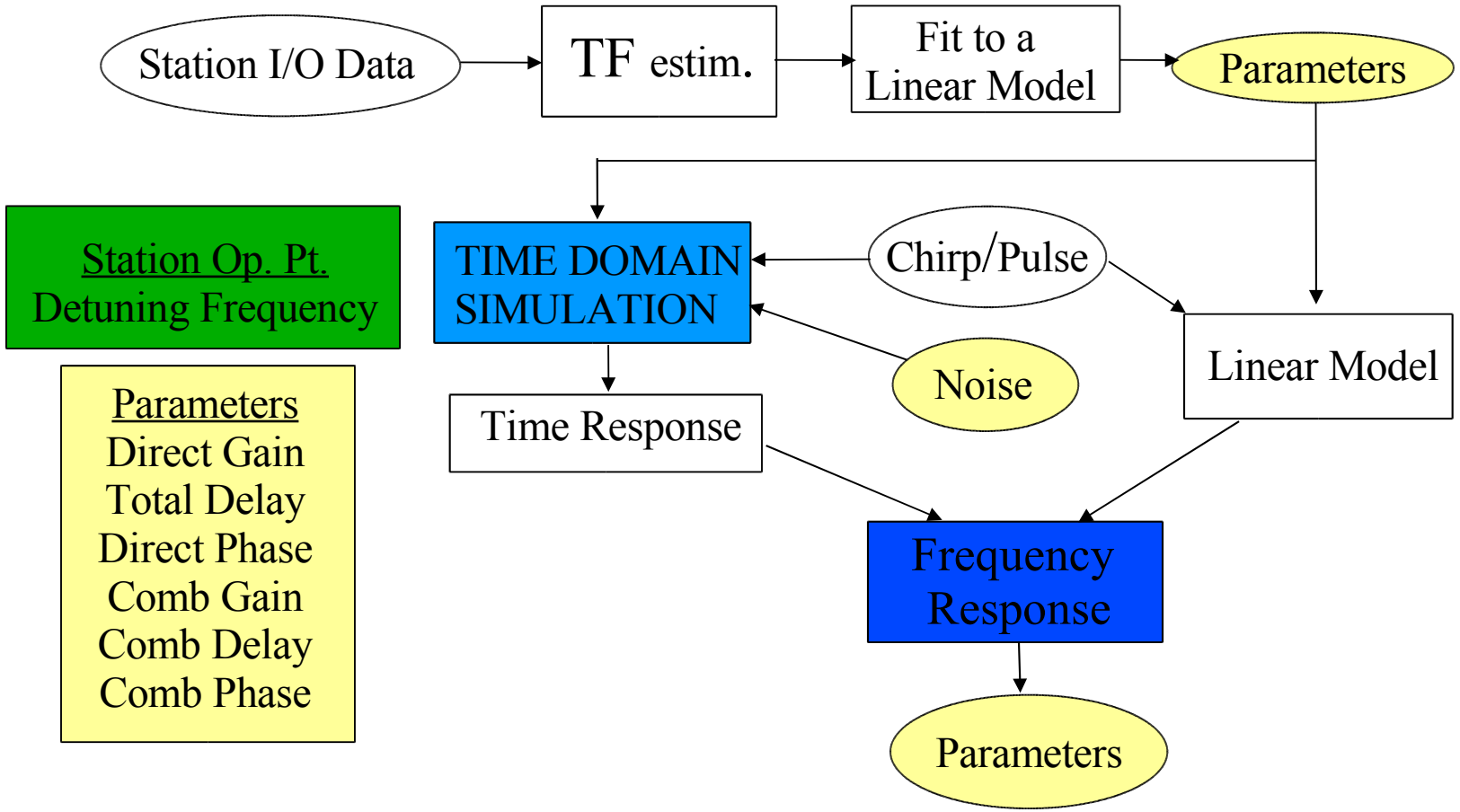
Dynamic Model



- Define the operation point of each station per ring.
- Define the parameters for the macro-cavities, feedback loops and beam to run time domain simulation.
- Estimate beam growth rates of low order modes. Analyse parameters sensitivities and performance limits.

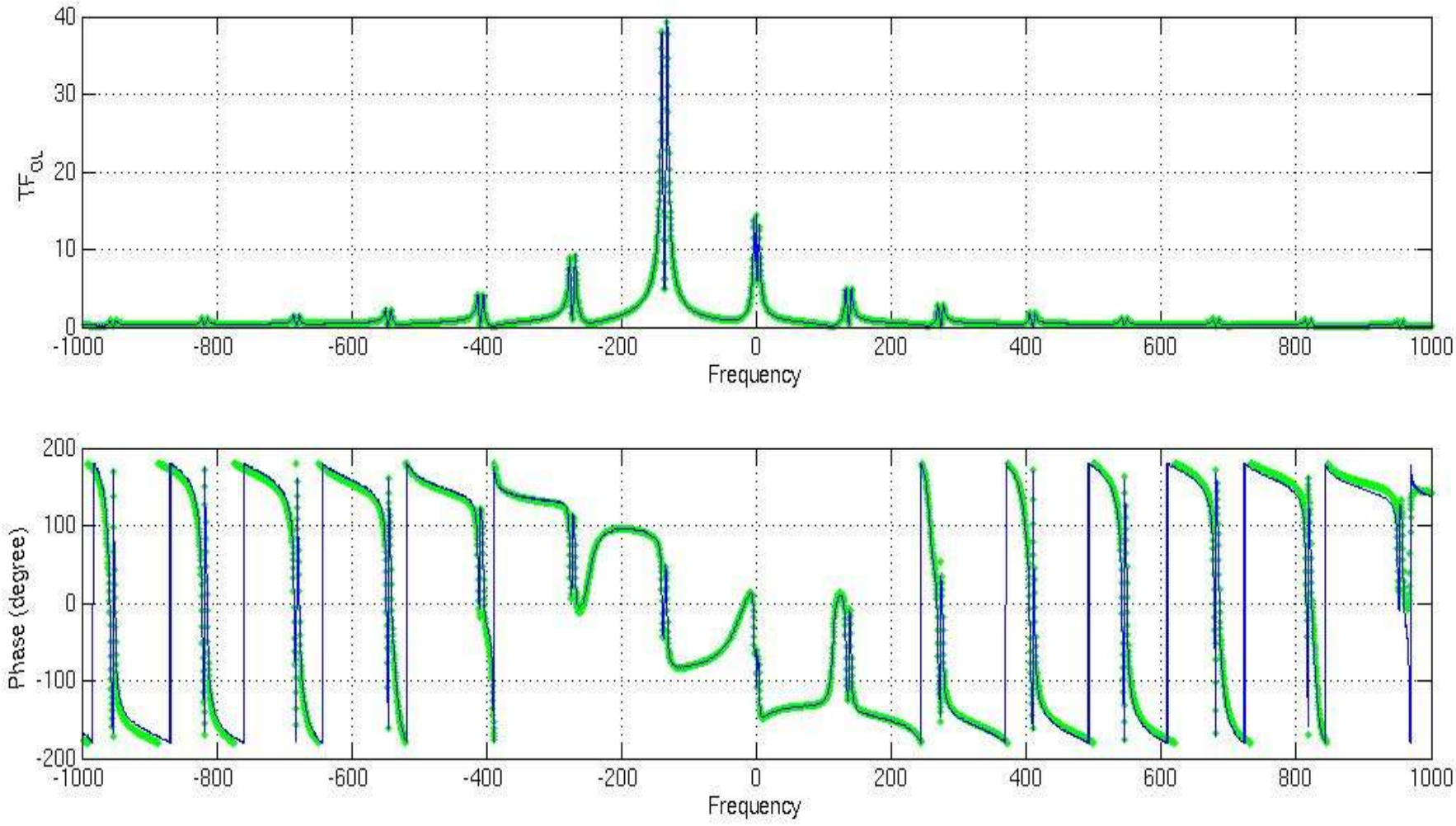
Validation

- Compare the actual "linear TF fit" measured from the station with respect to the simulation model.



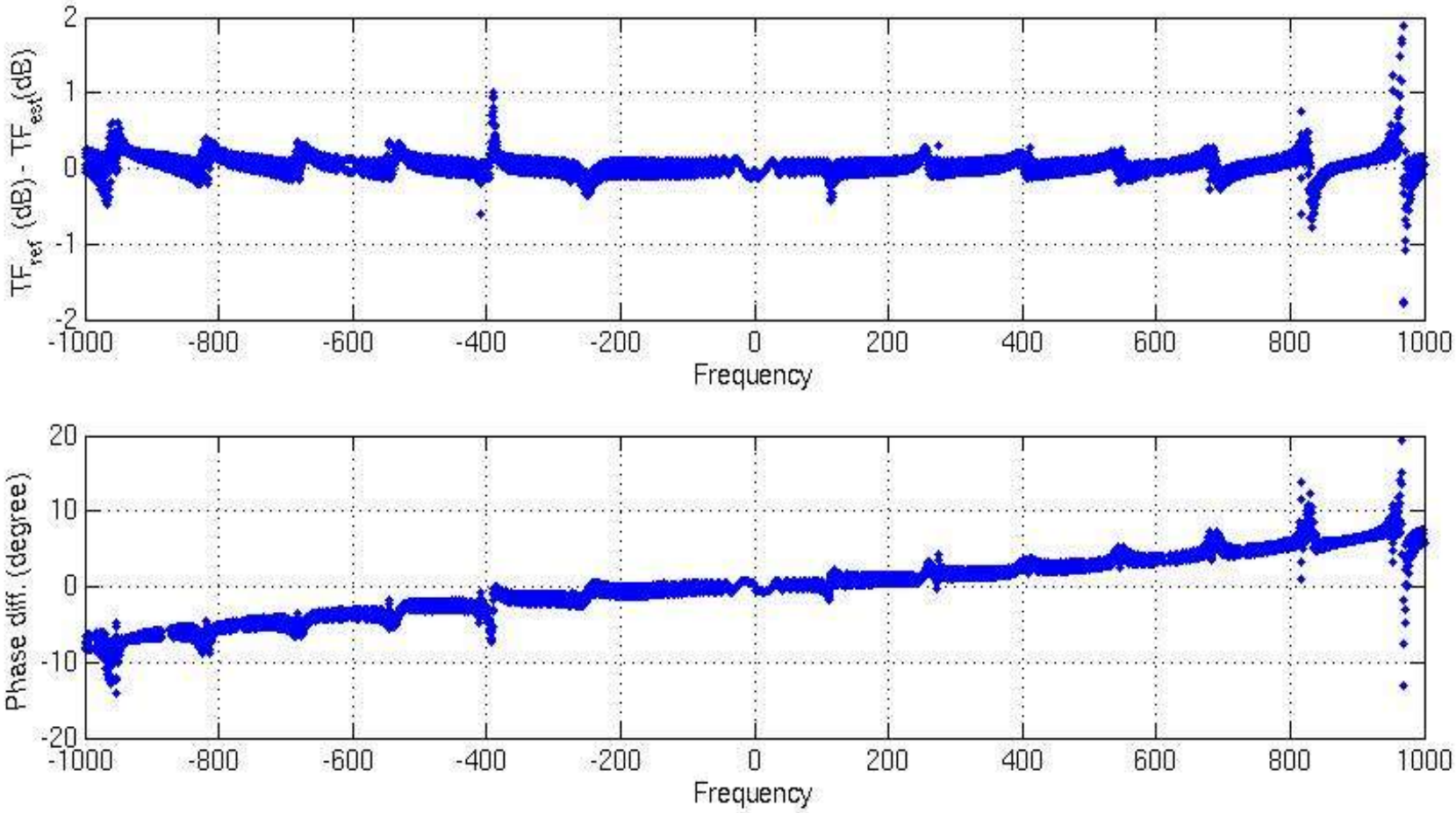
Results

- Transfer function estimate using frequency sweep – (No beam)



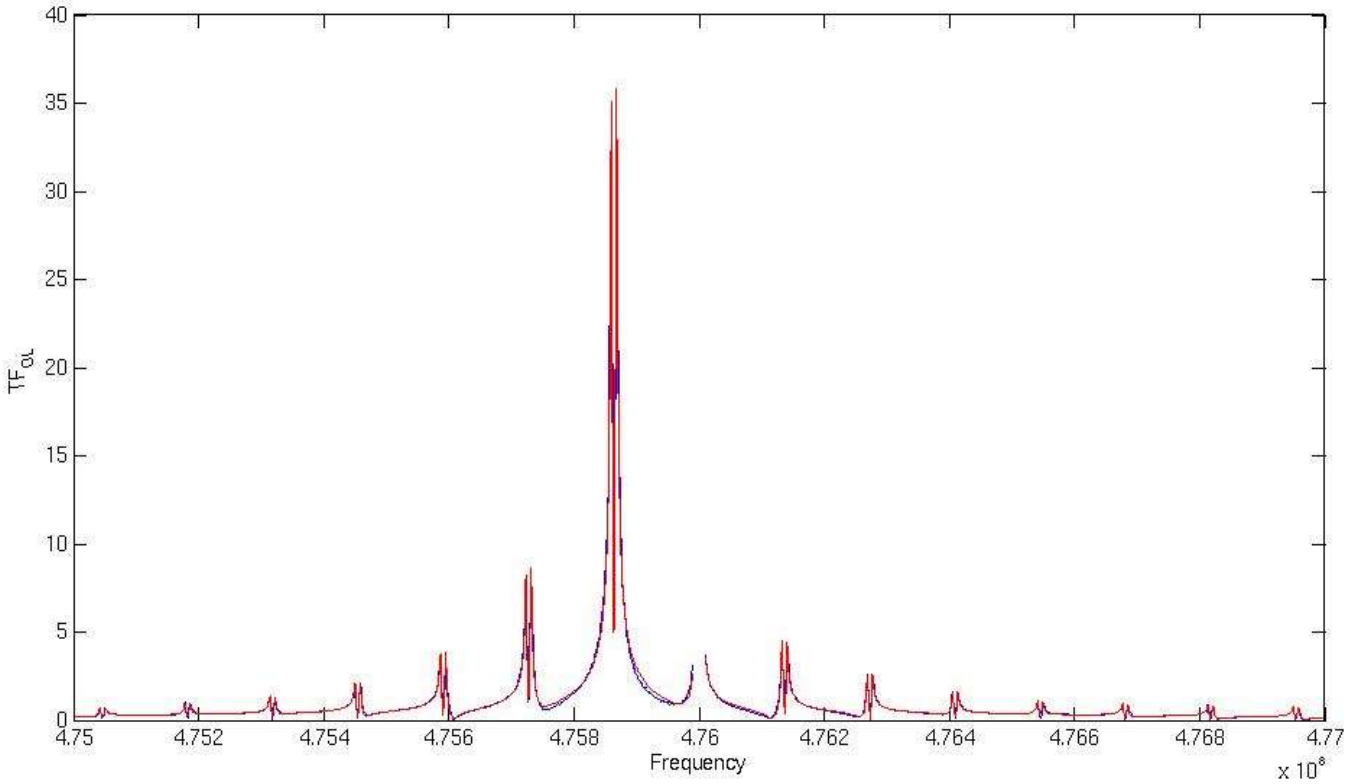
Results

- Transfer function estimate error – (Frequency sweep - No beam)



Results

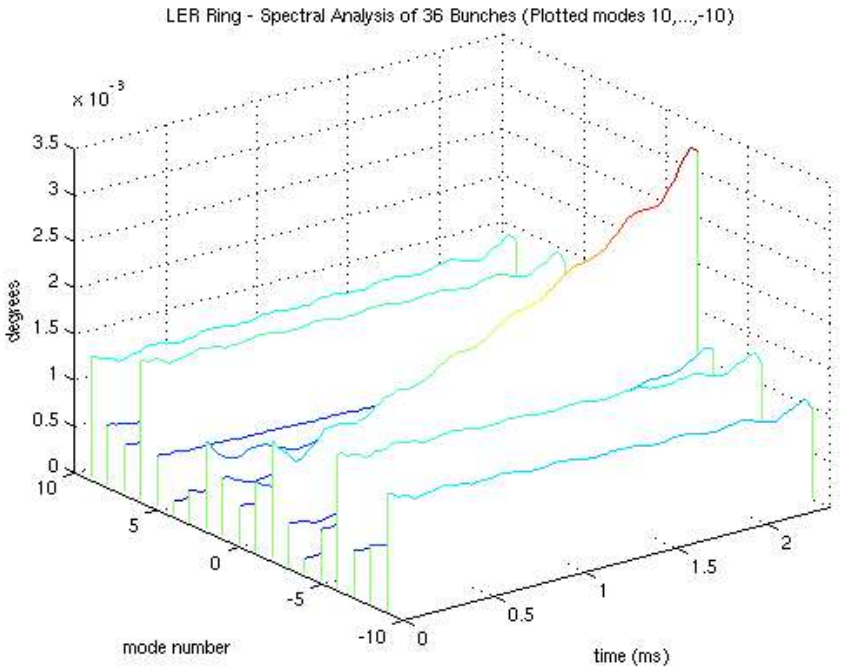
- Transfer function estimate via noise injection – (No beam)

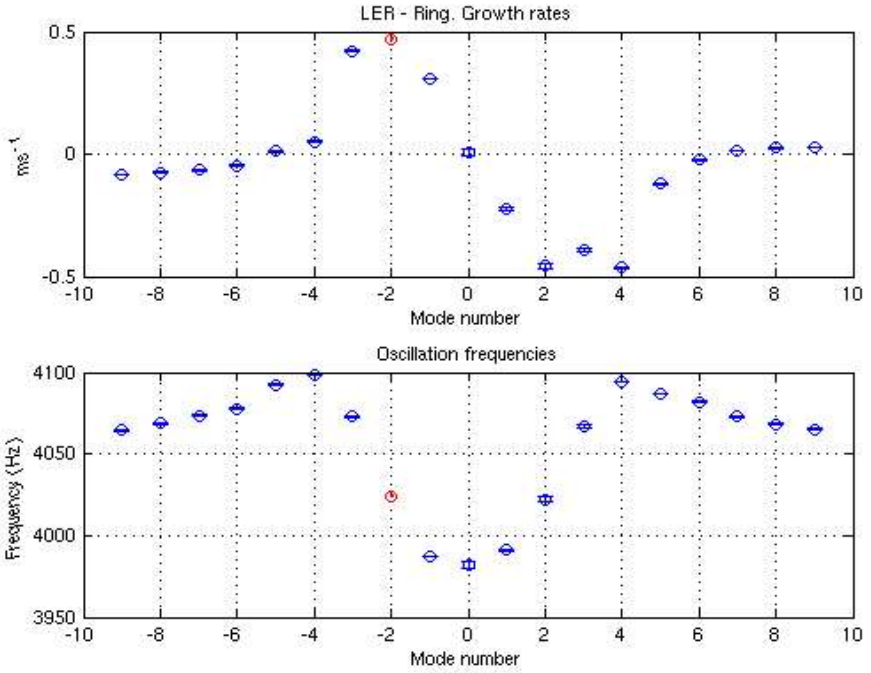


	Loaded Prms	Estimated Prms	Error %
direct gain	5.3	5.54	4.49
direct delay	3.62E-007	3.79E-007	4.87
direct phase	2.88	2.88	0.1
comb gain	0.18	0.17	4.36
comb delay	5.48E-006	5.49E-006	0.16
comb phase	0.47	0.46	3.17

Results

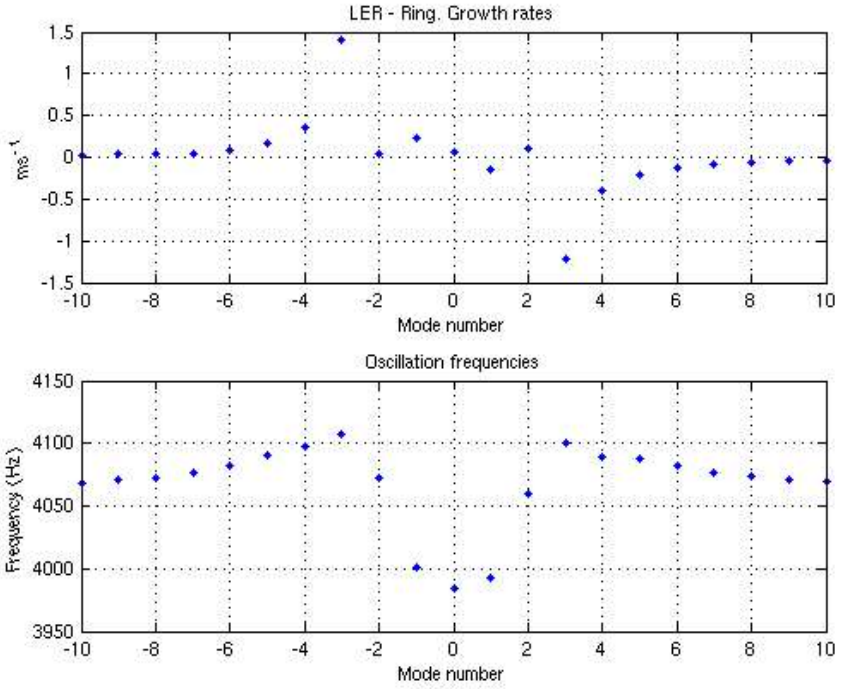
- LER Growth Rates (Vg = 4.05MV, Ib = 2000mA, 3 Active Stations (2 Cav/st.), 1 Parked Station.

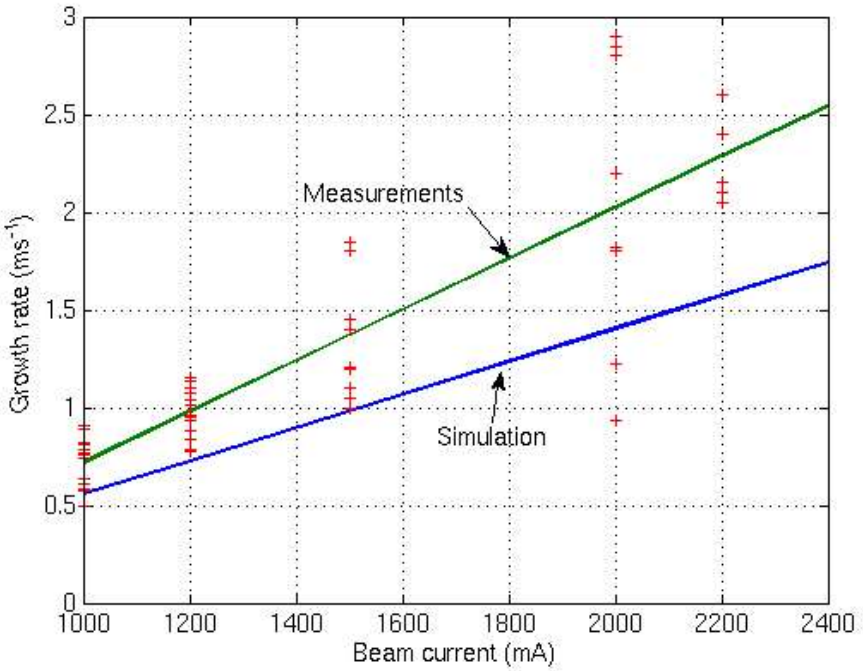




Results

- LER Growth Rates (Vg = 4.05MV, Ib = 2000mA, 3 Active Stations (2 Cav/st.), 1 Parked Station (wrong position).





Conclusions & Future Lines

- A simulation tool is being developed to predict the behavior and limits of the LER-HER complex at high beam currents. It started from previous work developed by Richard Tighe.
- The reduced model captures both the behavior of the multiple stations defining 'macro-cavities' and the low order modal behavior of the beam by 'macro-bunches'.
- HER & LER rings have included non linear klystron models.
- Good overall agreements between simulations and measurements performed at LER ring.
- Needs better understanding in the parameter definition corresponding to the macro-cavities and feedback loops.
  - Analysis of sensitivities and error bounds.
- Still in process of validation of growth rates.