# Transverse Impedance Distribution Measurements Using the Response Matrix Fit at APS

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Acknowledgements
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# Procedure description

- The beam sees the transverse impedance as defocusing quadrupole whose strength depends on the beam current
- At APS we use the response matrix fit method for measurement of beta functions along the ring
- We use this method to measure beta functions for different beam currents, then we calculate local phase advance changes with beam current, then we determine the transverse impedance

# Response matrix fit (LOCO)

- Orbit response matrix is the change in the orbit at the BPMs as a function of the changes in the steering magnets
- The response matrix is defined by the linear lattice; therefore it can be used to calibrate the linear optics
- Accelerators have a large number of steering magnets and precise BPMs, so response matrix measurement generates a very large array of precise data
- The idea of the analysis is to adjust all variables upon which the response matrix depends in a computer model until the model response matrix best fits the measured response matrix

# Response matrix analysis

The measured response matrix depends on the following parameters:

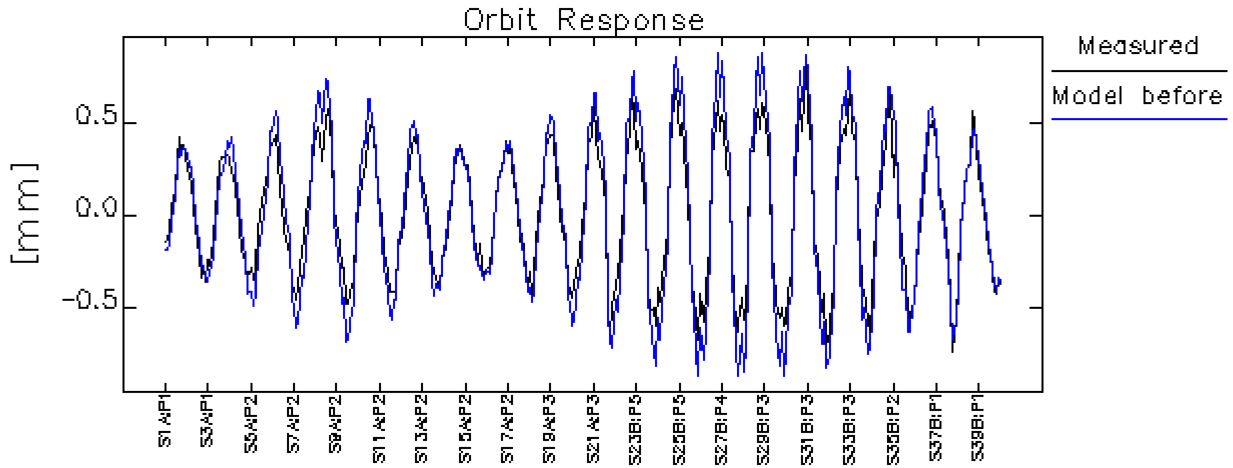
- Quadrupole gradients
- Steering magnet calibrations
- BPM gains

} Main parameters

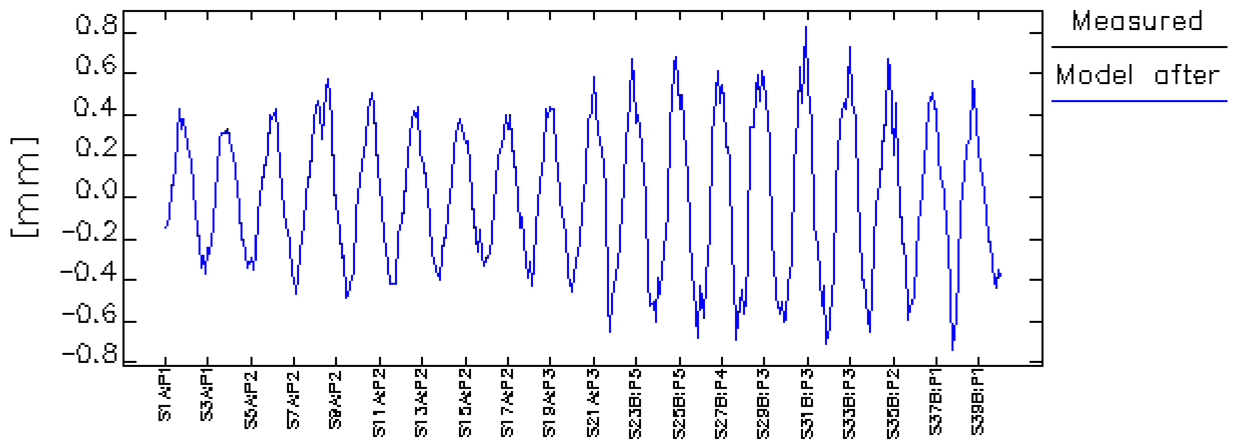
- Energy shift associated with steering magnet change
- BPM nonlinearity
- Steering magnet and BPM longitudinal positions

Totally, we vary about 1,400 variables to fit 32,000 elements of the response matrix

# Measurements and fitting

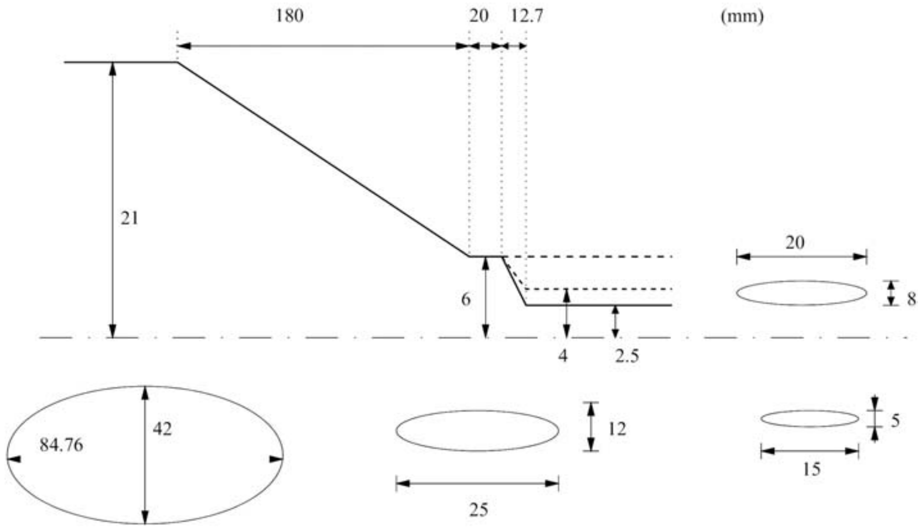



Typical rms error before the fit: 80 μm



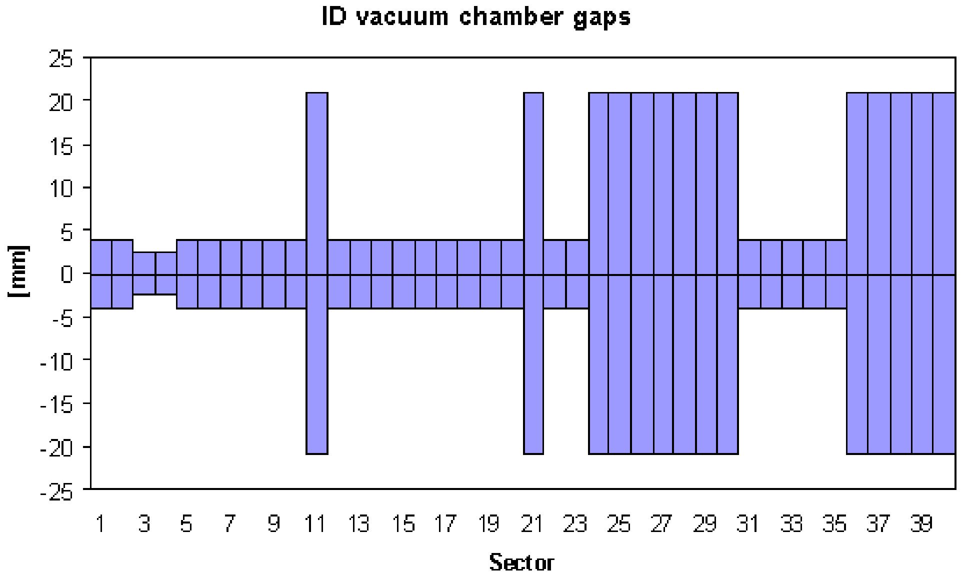

Typical rms error after the fit: < 2 μm

# Vertical impedance sources



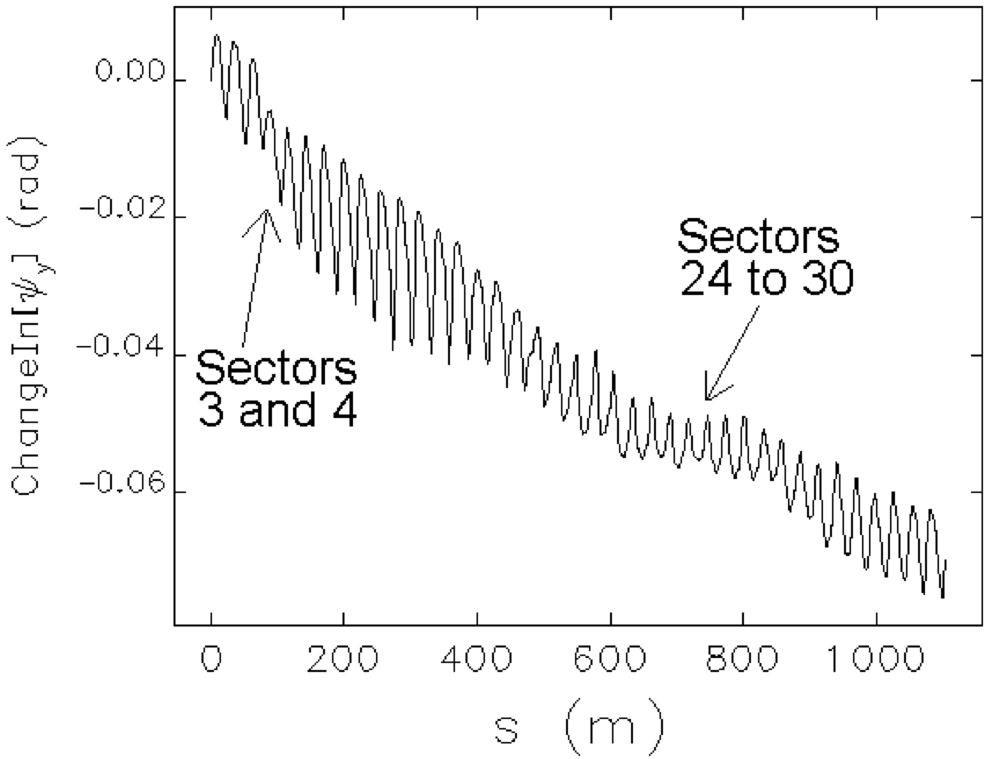

Geometry of the transition between large- and small-gap vacuum chambers

Locations of the small-gap ID vacuum chambers; each ID chamber is 5-m long aluminum extrusion



# Measurements

In order to obtain the change in focusing with the beam intensity, we measure the response matrices for different beam currents, analyze them to get beta functions, and then compare the local phase advances.

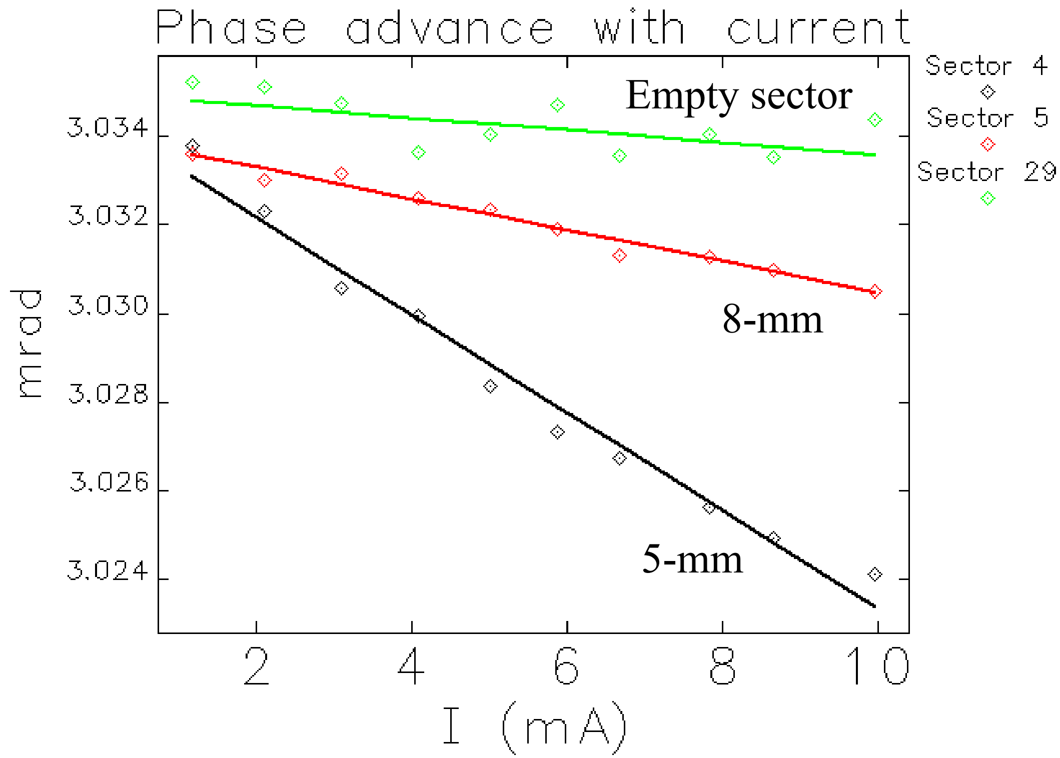



Betatron phase advance difference between 10 mA and 1 mA

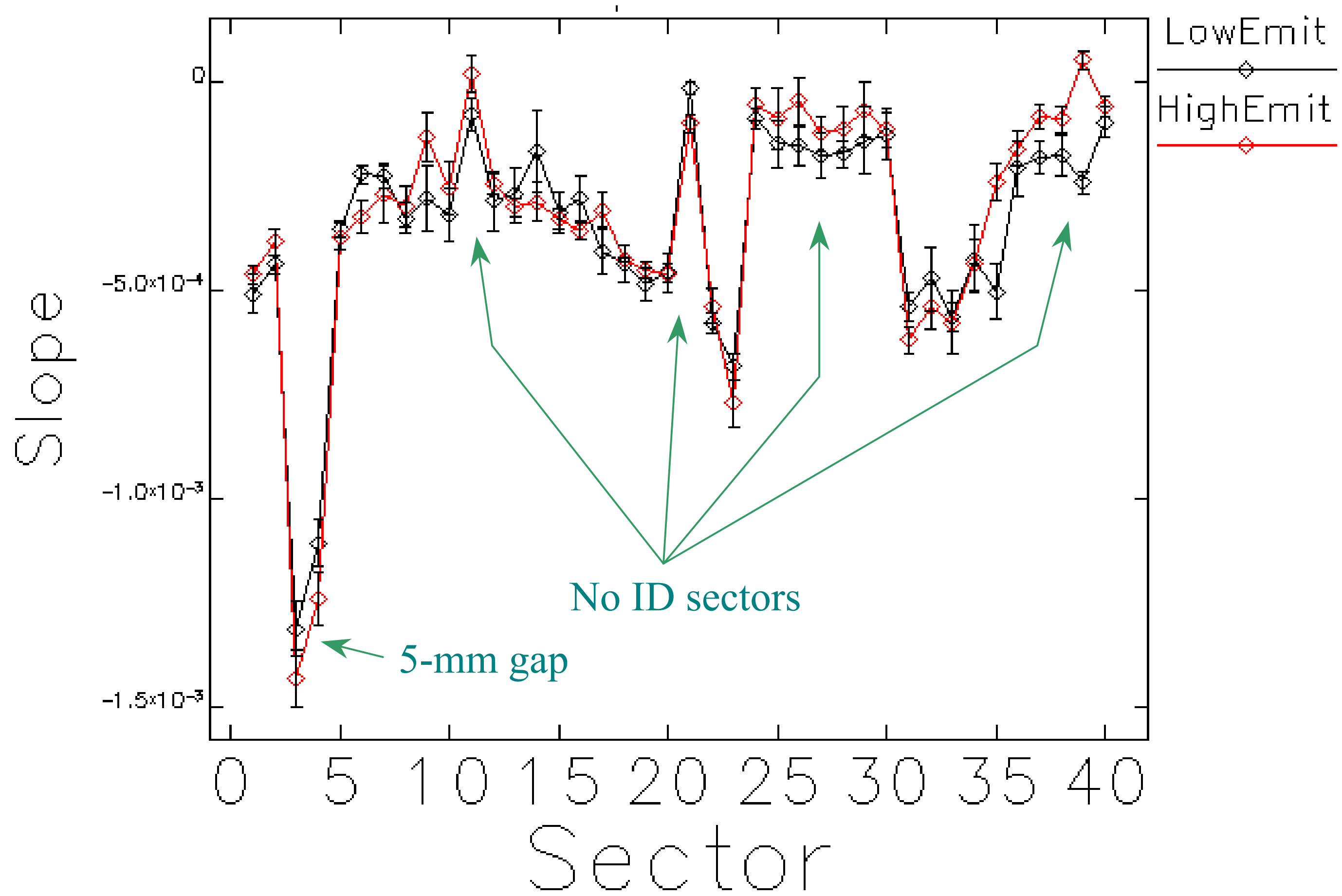
# Measurements

To get the local distribution of the impedance, we analyze the phase-advance changes sector by sector.

Typical phase-advance slopes for sectors with 5-mm, 8-mm and 42-mm-gap vacuum chambers are shown below.



# Vertical betatron phase slope distribution



# Vertical impedance calculation

For a particular component, the effective impedance can be found from measured slopes of the phase advance:

$$Z_{eff}^{i} = \frac{E/e\,\sigma_s}{R\beta_i}\frac{d\mu}{dI}$$

| | Units | High emittance | Low emittance |
|---|---|---|---|
| $d\mu/dI_{no\ ID}$ | $A^{-1}$ | -0.09 | -0.14 |
| $d\mu/dI_{8mm}$ | $A^{-1}$ | -0.39 | -0.40 |
| $d\mu/dI_{5mm}$ | $A^{-1}$ | -1.33 | -1.21 |
| $Z_{noID}^{eff}$ | kΩ/m | 3.5 | 4.1 |
| $Z_{8mm}^{eff}$ | kΩ/m | 31 | 34 |
| $Z_{5mm}^{eff}$ | kΩ/m | 126 | 138 |
| $Z_{total}^{eff}$ | MΩ/m | 1.1 | 1.2 |

# Conclusion

- Vertical effective impedance distribution has been determined using the response matrix fit
- It was found that the small-gap ID vacuum chambers contribute the most to the storage ring vertical impedance
- The actual values of the vertical impedance of the chambers with different gaps were determined
- The results compare well with the impedance model (tomorrow posters RPPB001-004) and with the earlier measurements using local orbit bumps (PAC2001 by L. Emery)