Beam-Based Alignment of Electromagnet Quadrupoles

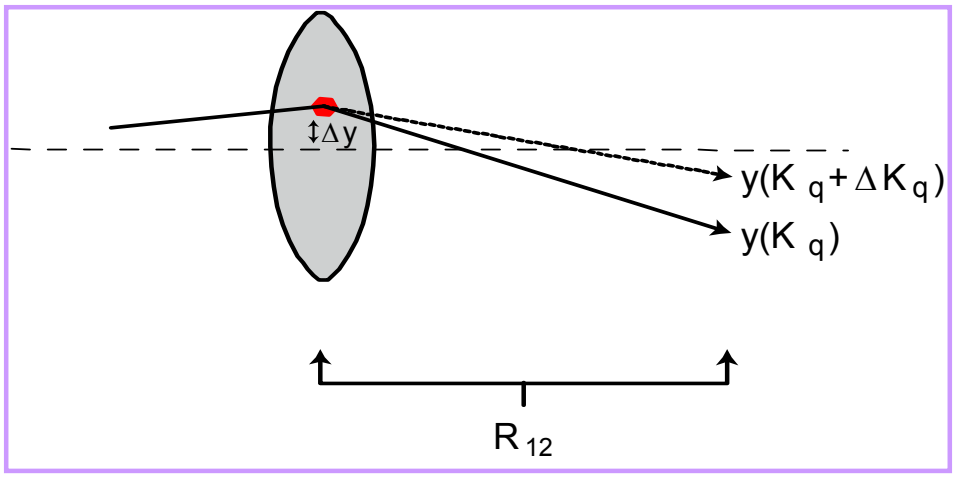
Quadrupole shunting: measure the orbit variation as a function of quadrupole excitation, fit magnet offset from beam.

Accuracy: limited by quadrupole center motion during strength variation.

Measurements of prototype quad center show better stability than specifications.

Quadrupole Shunting:

Changing the strength of a misaligned quad changes the orbit downstream



Accuracy Limit:

If quadrupole center moves during shunting, beam position fit converges on wrong answer

Maximum change in center position during measurement

$$x_{error} \approx \Delta x_{max}\left(1-\left|\frac{K_q}{\Delta K_q}\right|\right)$$

Error in fitted beam-to-quadrupole offset

Fit Error Expression for Quad Strength Scan Towards Zero Current

Maximum fractional change in quadrupole strength during measurement

NLC Prototype Magnet:

NLC specifications call for Δx_{max} ~ 1 μm. The prototype has achieved Δx_{max} ~ 0.5 μm