# Booster AC meas. with SW

- First attempt was with SSW (Single Stretched Wire) (2001).
- Resolution was not good enough
  - Gain for integrator had to accommodate full 1000A unbucked dipole signal with large loop – need to resolve fractions of a unit at 100A
- Timing issues
  - Integrator trigger out used to begin dmm triggering – observed phasing issues when looking even at dipole transfer function

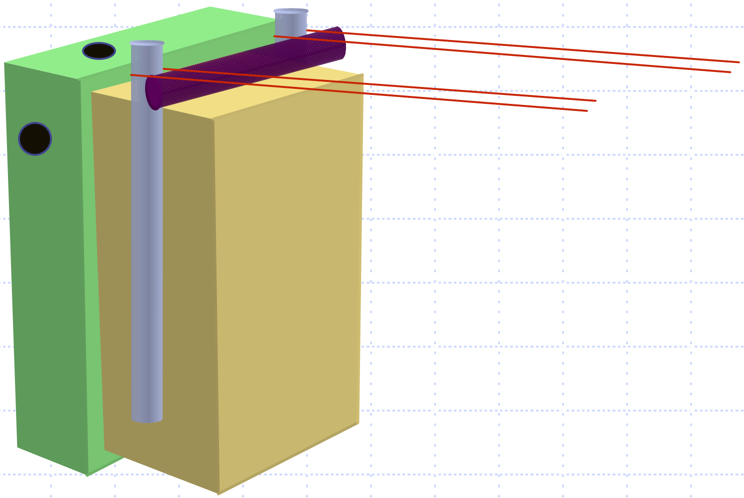
# Booster AC meas. with SW, 2003

- Two wire loops separated by fixed distance which buck each other (gradient probe).
- Wire loop size defined by precision quartz rods; distance between loops defined by gauge block.
- Integral measurement scanning across aperture.

# Schematic

Fixture to be mounted on each stage. Loops buck each other → measure gradient.

A second (stationary) set can be mounted off the base plate of the SSW stage units so that gradient is also bucked and reference gradient is available.



# Booster AC measurements with SW

- SW gradient fixtures mounted on SSW stages, translated across aperture with AC measurements at each position.
- Simultaneously sample current, gradient, and bucked gradient changes due to ramping (use 3 similar devices 3458's or PDI's (internal triggering with external sync from power supply)).
- Normalize the measure flux changes in bucked (i.e. moving–fixed) combination with the (fixed) gradient flux change (obtain change in gradient normalized by reference gradient).
- Assemble normalized $\Delta$flux vs x-position "snap-shot" at each current (might also normalize to current change) – fit to extract field coefficients during each snap-shot.
- Stationary fixtures could be mounted near center so that gradient would be bucked as well as dipole. In principle bucking should be very good.

# Harmonics

- Flux in reference gradient winding (sampled)

$$B_0(I)\frac{b_1(I)}{R}DWL_m$$

- Flux in moving winding

$$B_0(I)\frac{b_1(I)}{R}DWL_m - B_0\frac{b_2(I)}{R^2}2xDWL_m + \ldots$$

- Bucked flux (sampled)

$$B_0(I)\frac{b_2(I)}{R^2}2xDWL_m + \ldots$$

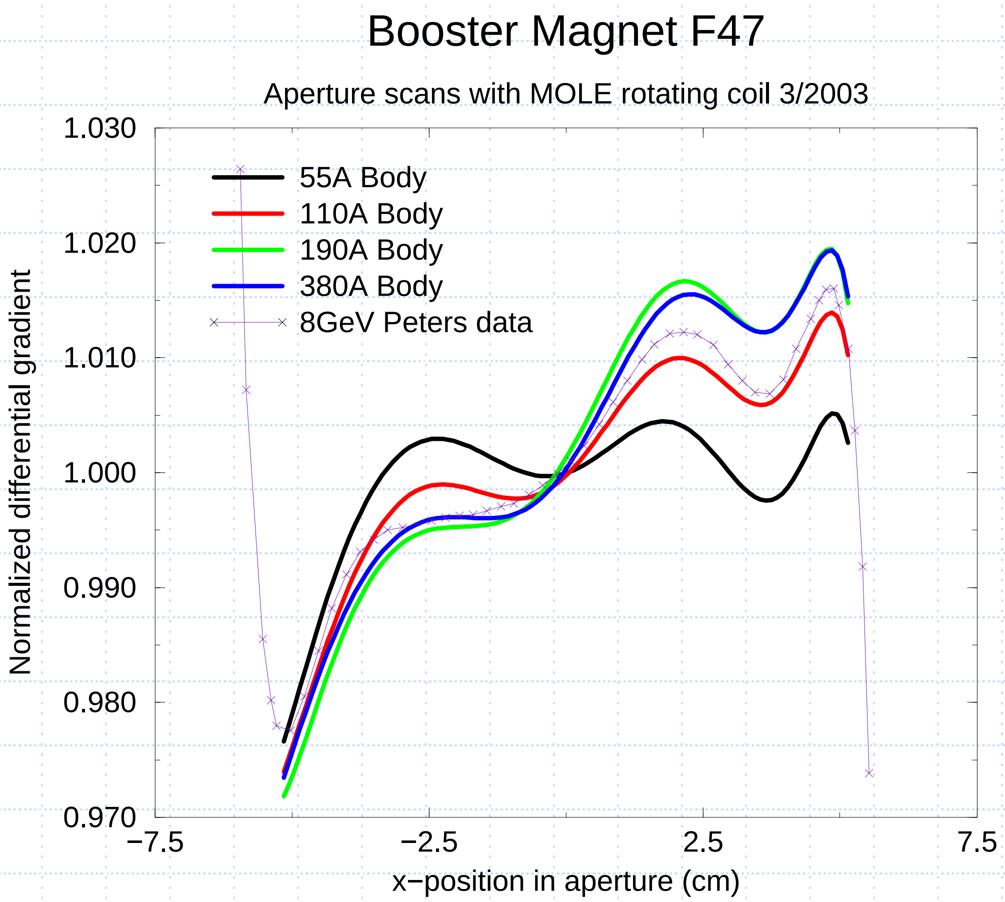
- Bucked flux normalized to reference gradient

$$\frac{b_2(I)}{R\,b_1(I)}2\,x + \ldots$$

D distance between loops,

W is width of loops

# Sample DC data




- Need to measure changes in gradient across aperture. Resolution should be better than ~0.1%. Gradient is ~6% of dipole => need to resolve better than 0.5 units.

# Challenges

- Common to SW and fixed coil methods
  - Flux signal small (need to resolve 2e-8 Vs/in/ms for SW)
  - Current signal small (need to resolve 1.5μV/ms)

  - (fitting/integration could help above two)
  - (mitigate flux resolution with bucking and current by sampling reference gradient winding)

- Wire effects (vibration, sag – should be small)

# Flux signal

Dipole TF ~0.7 T/kA

Gradient TF ~0.04T/in/kA

0.1% of gradient TF is 4e-5 T/in/kA

Ramp rate ~30kA/s (100 to 1000A) ➔ 30A/ms

To resolve 0.1% of gradient, have to measure

Flux change in 1 msec = B * dI/dt*$\Delta$t * A =

= 4e-5T/in/kA * 30kA/s *0.001s * (0.005m *3m) =

= 2e-8 Vs/in (near pdi resolution limit)

(Voltage is 2e-5V; probably better to use 3458 DMM – at 1kHz

6 digits resolution, noise level =?)

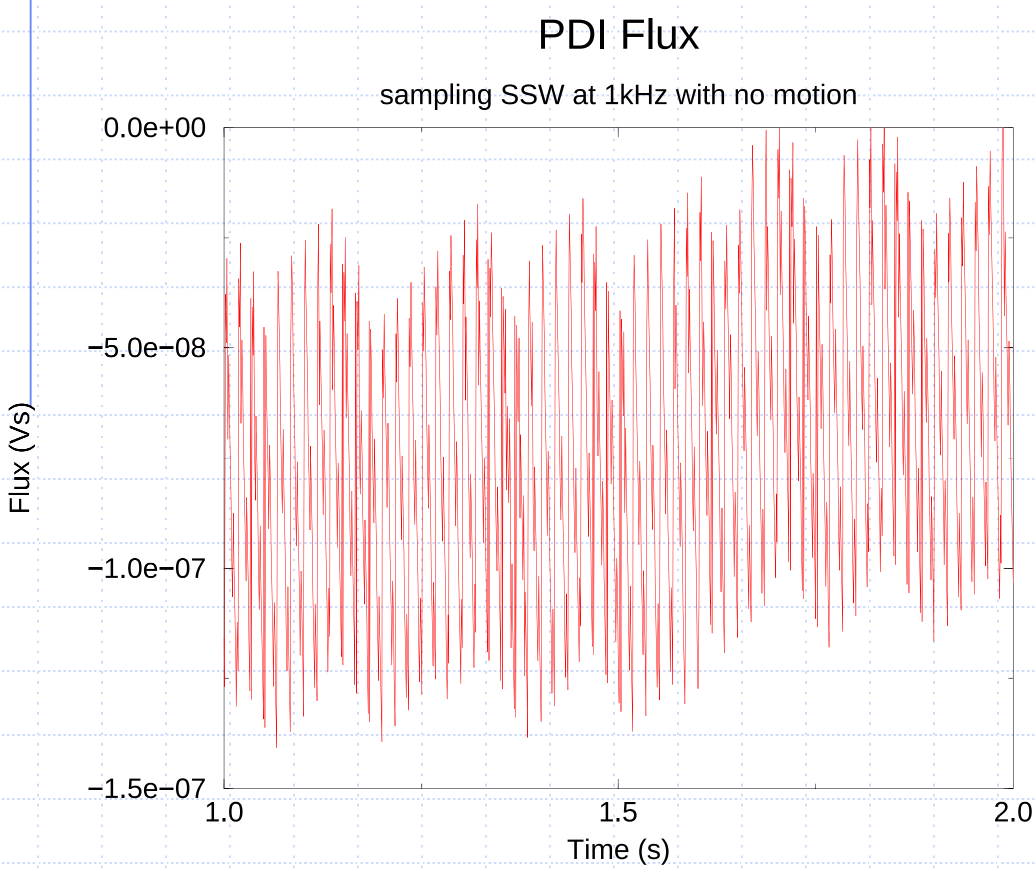
# Current signal

Ramp rate ~30kA/s (100 to 1000A) ➔ 30A/ms (with 1kHz sampling)

Need 0.5units accuracy in normalized flux measurement➔ measure 30A to within 0.0015A ➔ 1.5μV (if 1000A/V shunt) (can use fitting to help achieve current accuracy)

0.0015A * 1s/30000A ➔ 0.05μs synchronization repeatability of trigger start at different positions needed if want to make measurement without current normalization

# PDI noise




Main noise is 60Hz

# Wire effects

- Vibration – loop ~5mm, frequency 40-50Hz (500 or 850g tension) – stay away from 45Hz!
- Vibration amplitude with 18m wire is typically ~1μm (LQXB01). This would be 2units of a 5mm loop, but with 3.5m wire, amplitude should be smaller (depends on magnitude of mechanical vibration in E4R). Should be helped by statistics as well.
- Sag 100-200μm (850 or 500g tension). Differences in sag would only pick up skew terms. Since skew terms and different loop areas from wire sag are small, these should be negligible.