ATF2

Magnets

Status Report on the ATF2 “Final Doublet” magnets: 2 quads and 2 sextupoles.

Progress since my report of 27th March 2008

26th May 2008

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Member of ATF2 Magnet Team

With fine assistance of SLAC Mechanical Technicians,

Magnetic Measurement Group & John Amann

QF1 ready to be put into shipping crate, 24 Apr 08

Requirements for the final doublet quads:

QF1: K1= .737

∫G.dl = 3.1959 Tesla

Bore diameter = 50mm

QD0: K1 = -1.351

∫G.dl = -5.85837 Tesla

Bore diameter = 50 mm

Effective lengths < 0.48m

Measured effective length = 0.4651 meters

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Chosen method for enlarging an old SLAC "QC3" quad's bore diameter

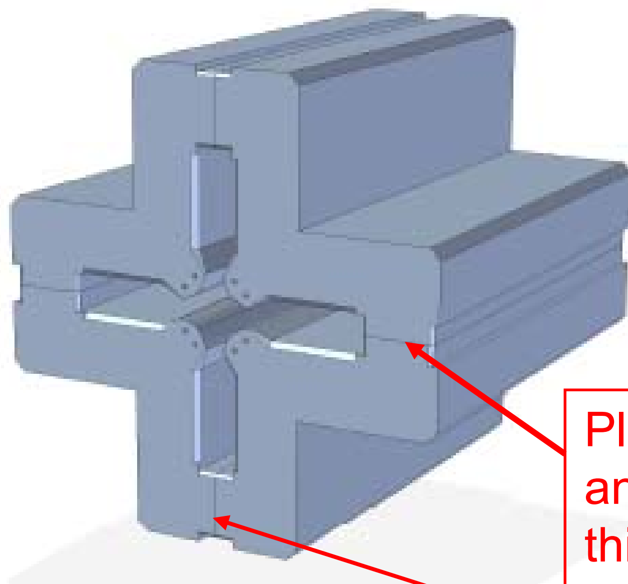
from 35mm to 50mm

Hyperbolic pole-tip is moved, along a radius, further out than it's equation says it should be.

$XY = r^2/2$.

Consequence: the 12-pole component increases, ~17 times predicts POISSON.

ATF2 has very tight tolerances on the multipoles in QD0 & QF1



Shim is low carbon steel, ground to 0.0005" flatness

Placed a very flat and precise thickness shim in each split plane to "explode" the quad and enlarge the bore diameter.

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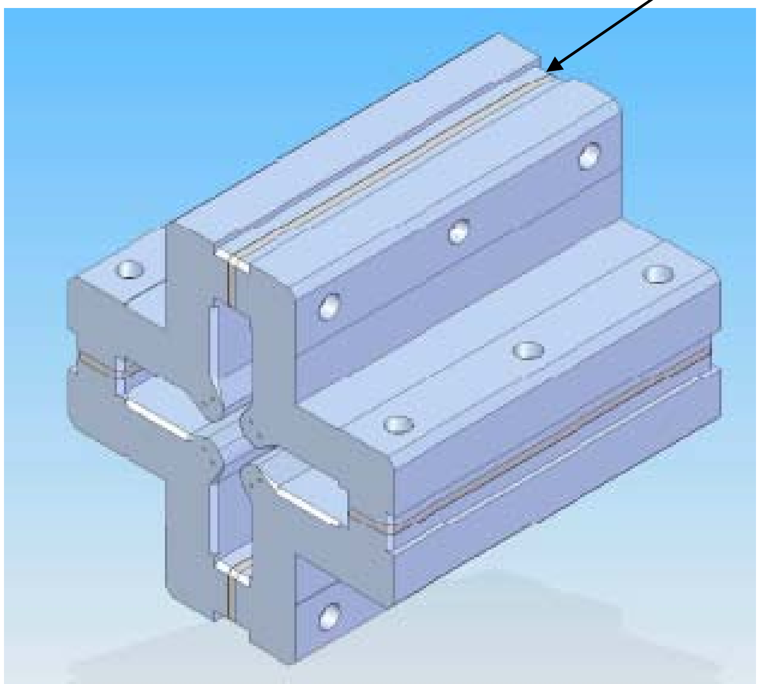
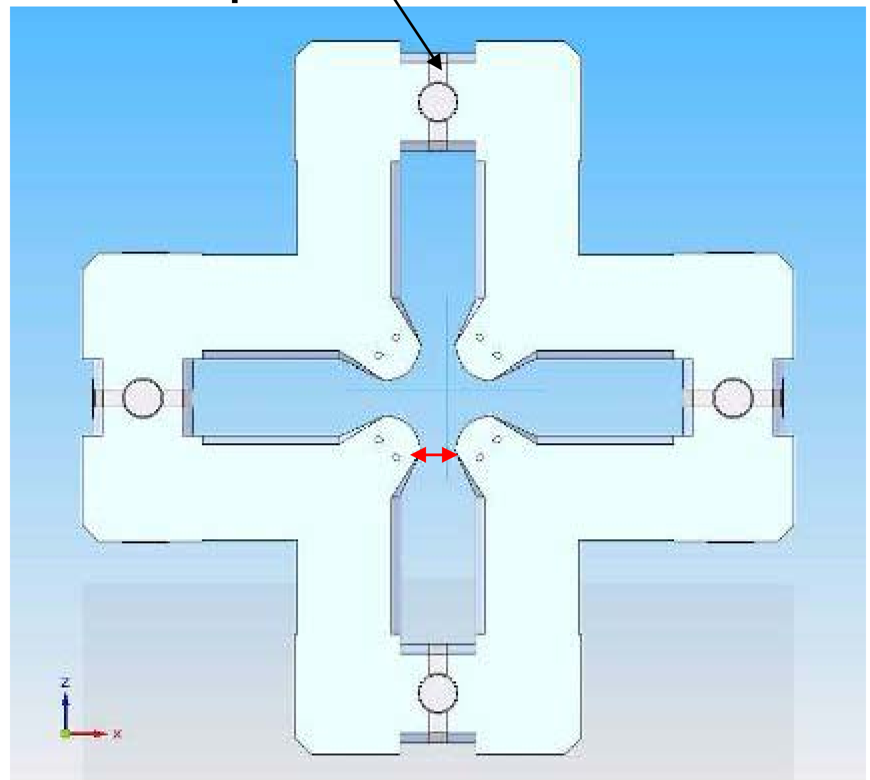
Drawings of the modified core with ground shims in place





Sextupole component is very sensitive to poletip being at wrong radius or the poletip being offset "azimuthally"

INITIAL GOAL :Adjacent pole distances (red arrow above) "gaps" adjusted, by moving quadrants, to be same to +/- 0.013mm. Many efforts, but not possible to achieve this with 4 bore diameters & 8 gaps values simultaneously on both quads- see later

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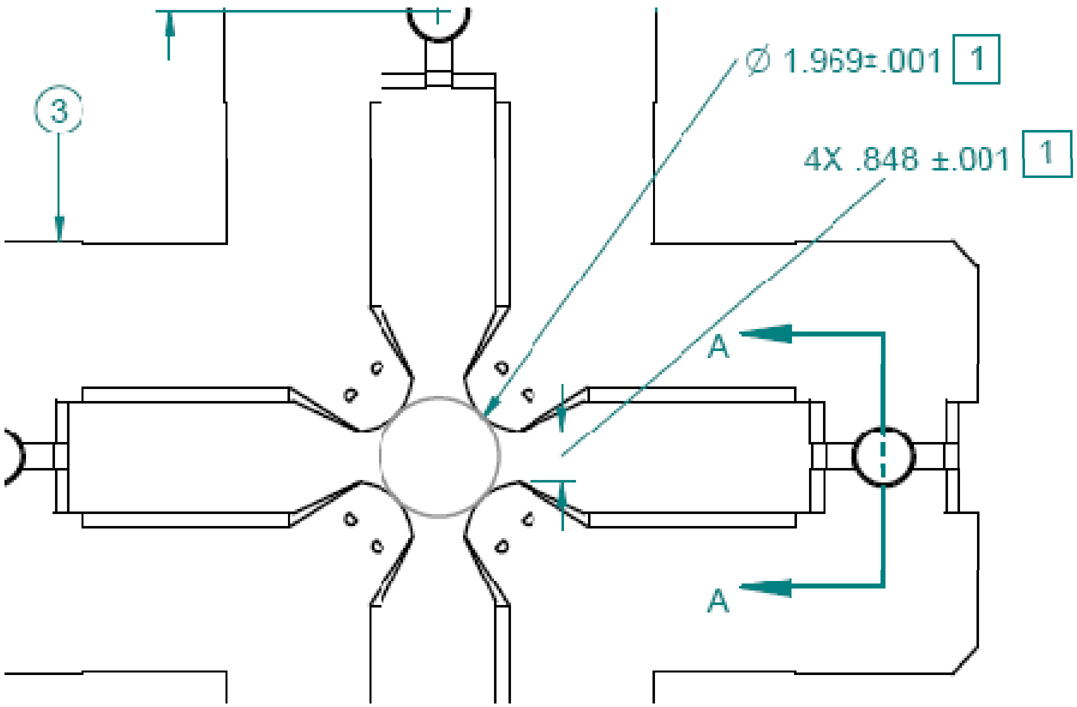
In order to achieve the very small multipoles : specification for the bore diameters and gaps between the ends of the adjacent hyperbolas

Units = inches



In fact the actual value of the gaps is less important than their being the same to within +/-0.001”.

We predicted that to achieve the very small sextupole component requirement the equivalency of the gap values would need to be:

approx <+/- 0.0005”

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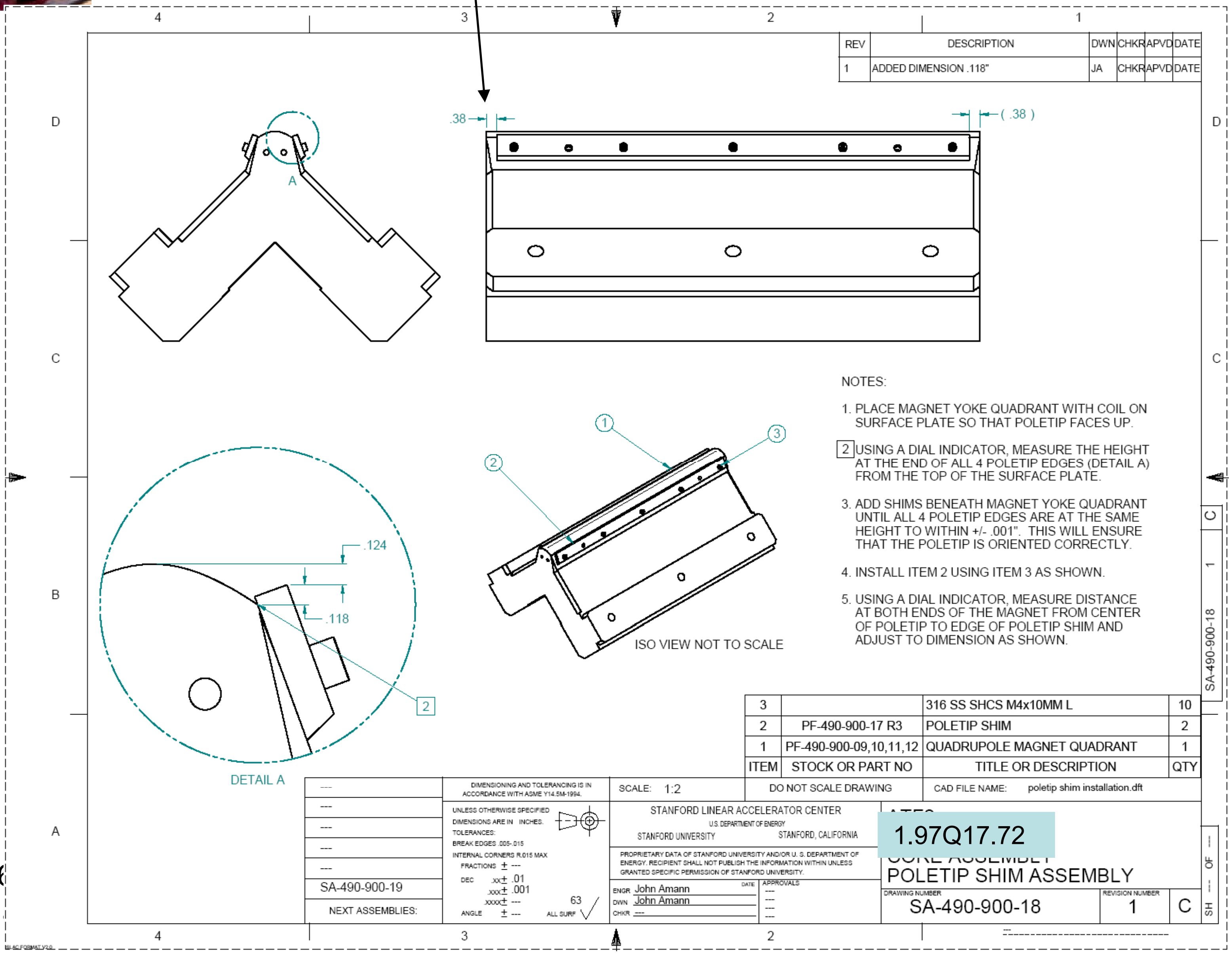
So I designed some pole-side shims to reduce the 12 pole. Shims have to be shorter than pole so can access end of hyperbolic poletip for QC of gaps



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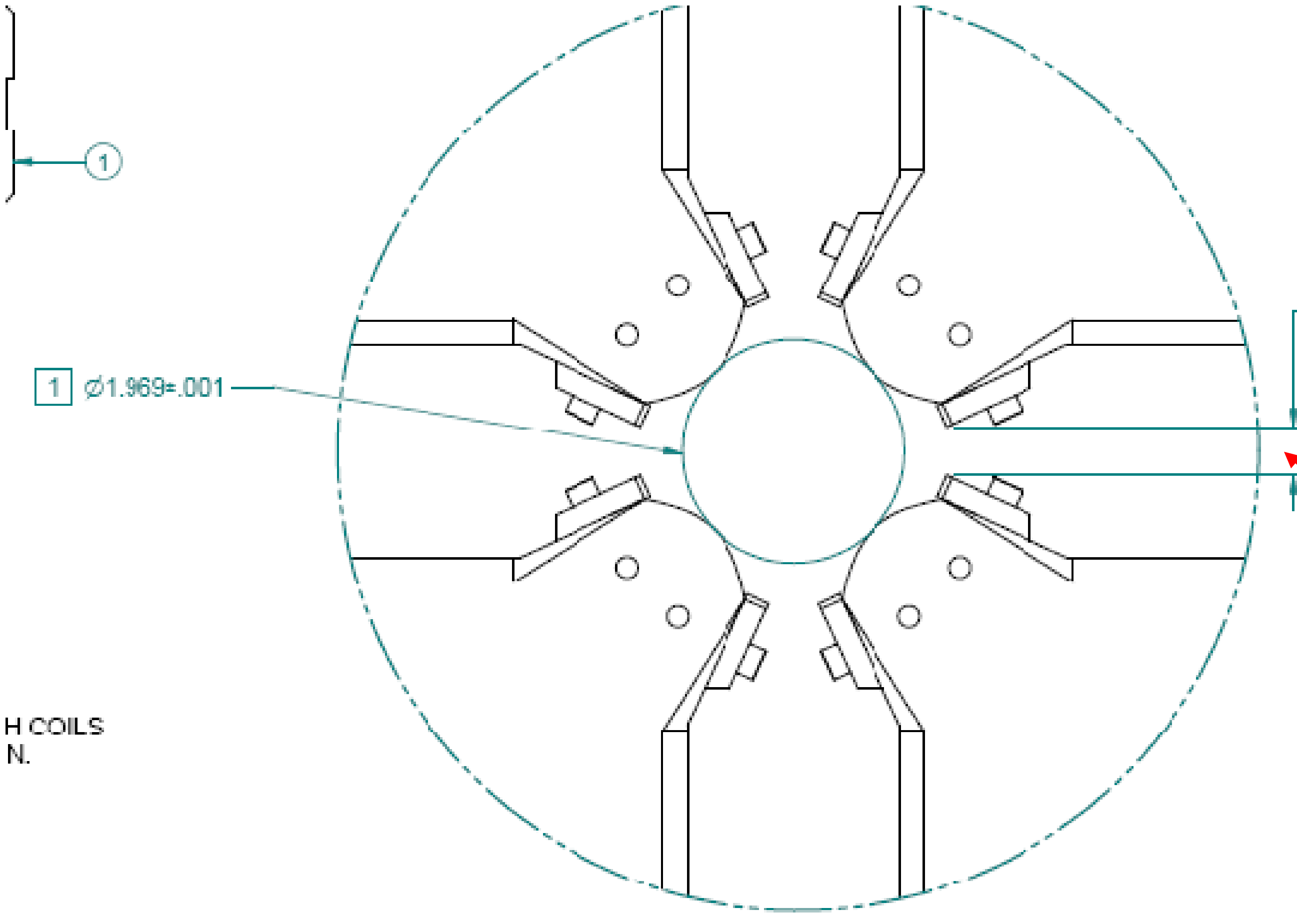
Specification for the gap distances between the pole-side shims: found to *not* be a reliable measurement for determining if the 4 poles were symmetric as in slide 5



The variation in shim-to-shim distance was *not* a reliable guide to the variation in the distance between the ends of the hyperbolae.

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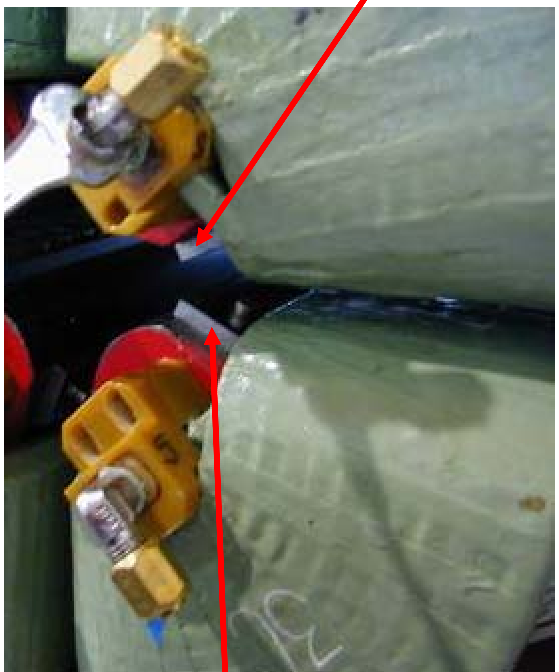
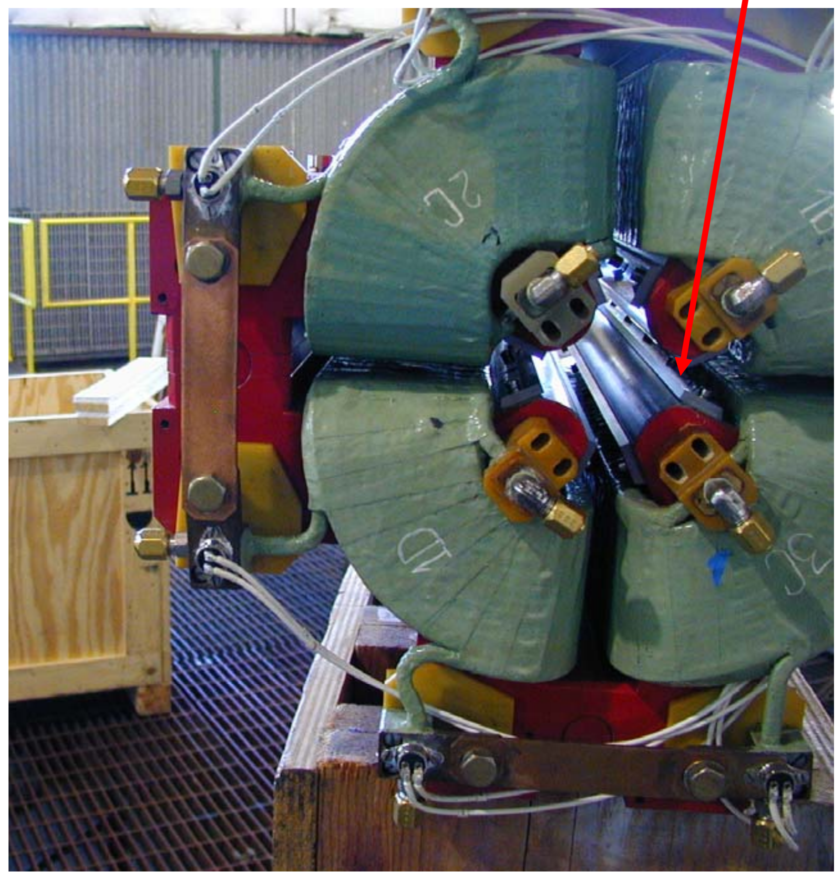
Photos showing the pole-side shims on QF1. They have been pinned into proper position.



These shims are a little shorter than the poles, so a gauge block can be inserted between the ends of the poletips, to measure the gap between them.



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Worked with mechanical technician to improve adjacent poles' & diameters' symmetries

- Dowel pin holes adjusted then main bolt [holding 4 quadrants together] torque settings adjusted iteratively, distances and aperture diameters re-measured, until best values achieved
- Tried several mechanical configurations, measuring multipoles after each try, repeat until good enough.
- The spot size at the IP is very sensitive to the sextupole components in QD0 and QF1
  - The unwanted sextupole is mostly a skew sextupole, it affects the spot size. We kept improving the adjacent pole distance symmetry. The pole gaps in QF1 have some final asymmetry, ~0.12 mm : QD0 final gap asymmetry was 0.025mm.
  - See slide 13 for measurements of the final multipoles

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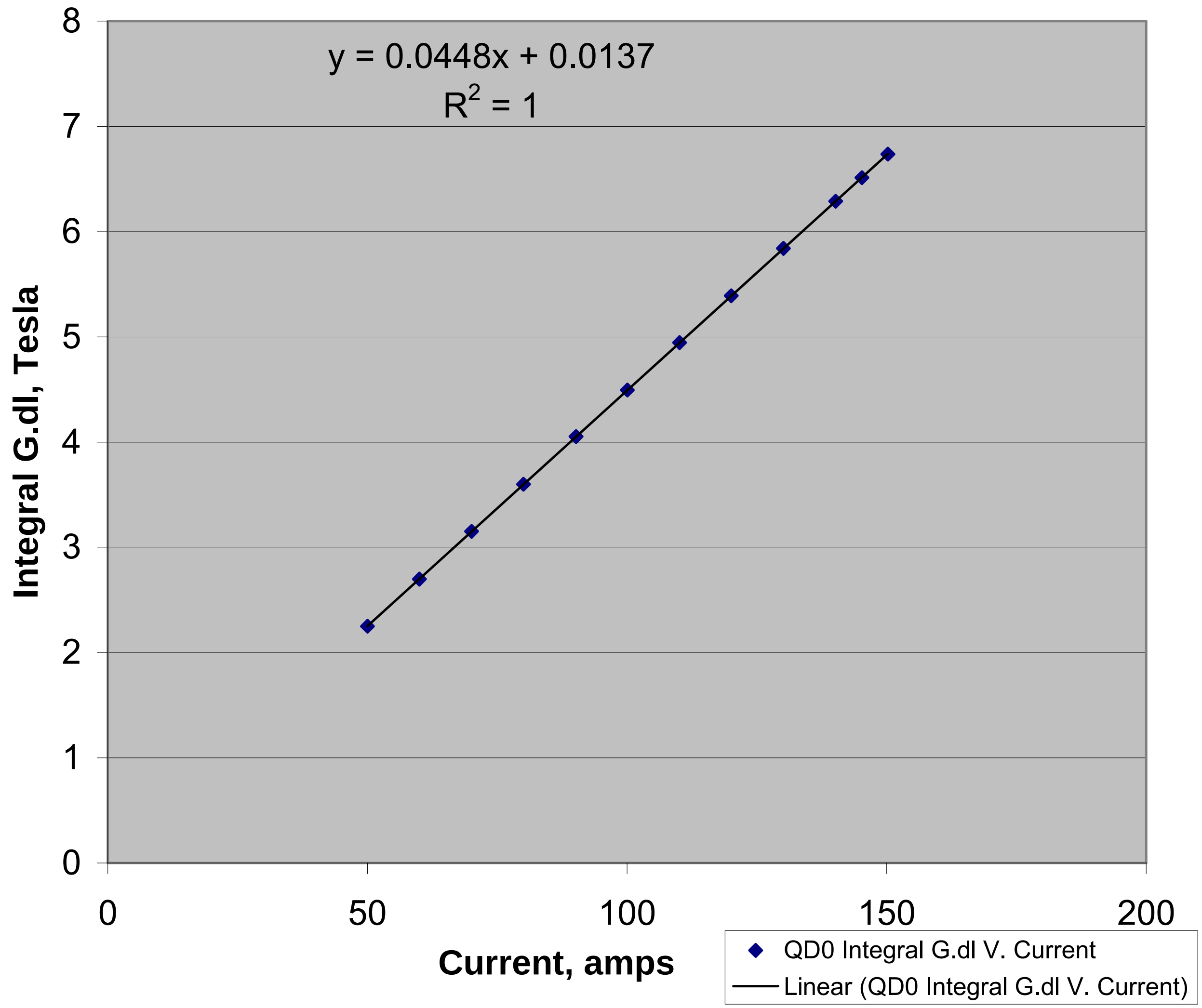
QD0 in final mechanical config. $\int G.dl$ v. I
measured at SLAC with rotating coil

QD0 final integral strength measured up to 150 amps



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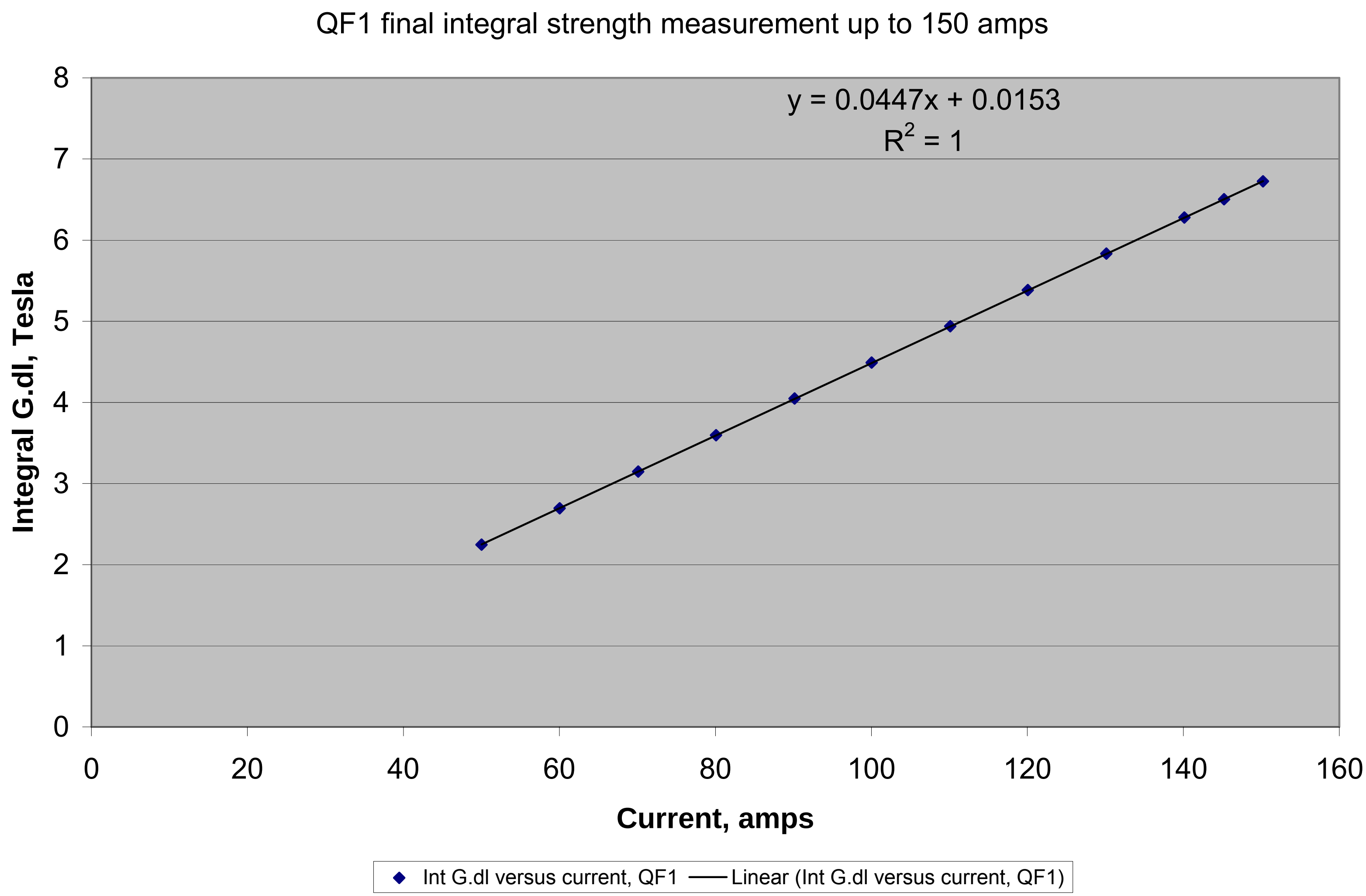
QF1 integrated strength measured by SLAC rotating coil set-up between 50 and 150 amps. Final mech. config.



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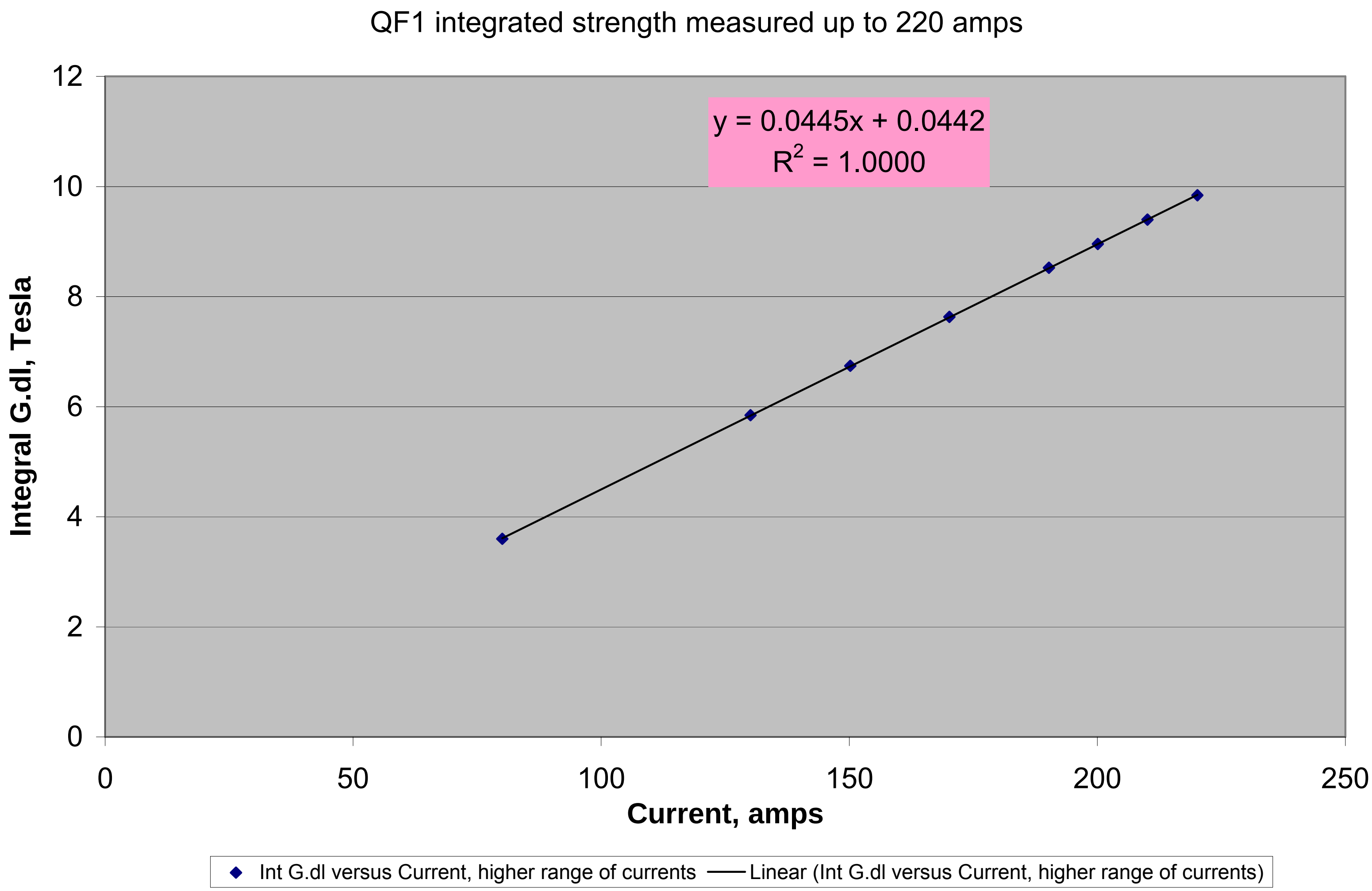
QF1 integrated strength measured between 80 & 220 amps



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Final Multipole Measurements on both FD quads at r=1cm, in %

Magnet Name	Sextupole/ quad	Octupole/quad	10pole/quad	12pole/quad	20pole/quad
Tolerance (tightest)*	<0.03	<0.025	<~0.01	<0.05	<0.12
QD0 at 132.2 amps	0.0255	0.0052	0.007	0.036	0.0027
QF1 at 77.5 amps	0.0274	0.0058	0.0128	0.036	0.0027

* Multipole tolerances arrived at by many iterations between magnet engineer and beam dynamics experts. E.g. original sextupole tolerance was too small to be measured even. If keep below quoted tolerances will have acceptable beam spot size- see next slide.

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Magnetic measurements also measure the angle of the first south pole of any multipole, relative to horizontal axis

- The multipole angle measurements indicate there is significant *skew* sextupole mixed in with the normal sextupole.
- Glen White has modelled the beam passing through QF1 & QD0 [mean and rms from 100 seeds]:
  – 36.7 +/- 0.4 nm spot with perfect quads -> 42 +/- 4 nm with these multipoles, and no re-tuning
  – Glen is confident that when the FD sextupoles strength and roll (using their magnet movers) are adjusted to compensate for the unwanted sextupoles in QF1 & QD0 then the spot size will be restored.

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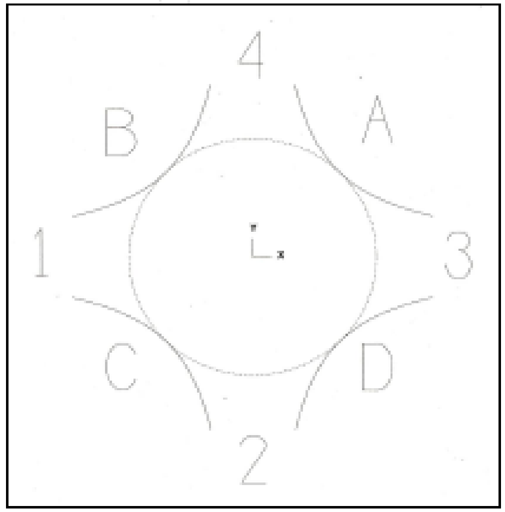
Measured Diameters and Adjacent Pole Gaps on QF1: final values measured on a CMM at SLAC & gauge blocks at LAPP

The 4 diameters are within 0.00073” [0.0185mm] of each other- this is very good.

But the gaps vary by up to 0.00476”, this is ~2 times the desired variation. We tried many different bolt torque settings to reduce this variation but could not manage it AND keep the diameters within 0.001”.



The diameters and gaps in the table were measured on a CMM, precise to 0.00001”.

These values agreed with our SLAC gauge block measurements, precise to 0.0001” [0.00254mm].

Units=Inches

Side	Pole Dist A-C	Pole Dist B-D	Gap 1	Gap 2	Gap 3	Gap 4
Downstream End (+Z)	1.96975	1.97028	0.84895	0.85155	0.85360	0.85062
Upstream End (-Z)	1.97016	1.96955	0.84858	0.85141	0.85334	0.85114

Units= mm

SLAC data

LAPP data

No-lead end Downstream	50.032 50.03	50.045 50.07	21.563 21.57	21.629 21.62	21.681 21.68	21.606 21.60
Lead end Upstream	50.042 50.03	50.027 50.03	21.554 21.56	21.626 21.62	21.675 21.66	21.619 21.62

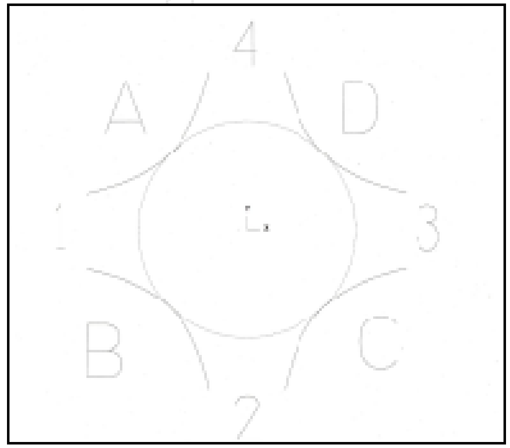
After air shipping to France, gaps measured again with gauge blocks precise to 0.01mm

ATF2 Magnets

Measured Diameters and Adjacent Pole Gaps on QD0: final values measured on a CMM at SLAC and with gauge blocks at LAPP

The 4 diameters are within 0.00086" of each other- this is very good.

The gaps vary by up to 0.00091", this is better than the desired variation of +/-0.001". The sextupole is a *little* less in QD0 than in QF1. Indicating less dependence of the sextupole on the gap variation than we predicted.



The diameters and gaps in the table were measured on a CMM, precise to 0.00001". These values agreed with our gauge block measurements , precise to 0.0001" [0.00254mm].

Units = inches

Side	Pole Dist A-C	Pole Dist B-D	Gap 1	Gap 2	Gap 3	Gap 4
Downstream End (+Z)	1.96992	1.96906	0.85141	0.85105	0.85170	0.85079
Upstream End (-Z)	1.96933	1.96988	0.85130	0.85103	0.85176	0.85137

NOTE-names of poles, A,B,C,D are in different positions on QD0 to QF1.

Units = mm
SLAC data
LAPP data

No-lead end Downstream	50.036 50.04	50.014 50.02	21.626 21.62	21.617 21.61	21.633 21.64	21.610 21.61
Lead end Upstream	50.021 50.02	50.035 50.03	21.623 21.63	21.616 21.60	21.635 21.63	21.625 21.62

After air shipping to France, gaps measured again with gauge blocks precise to 0.01mm

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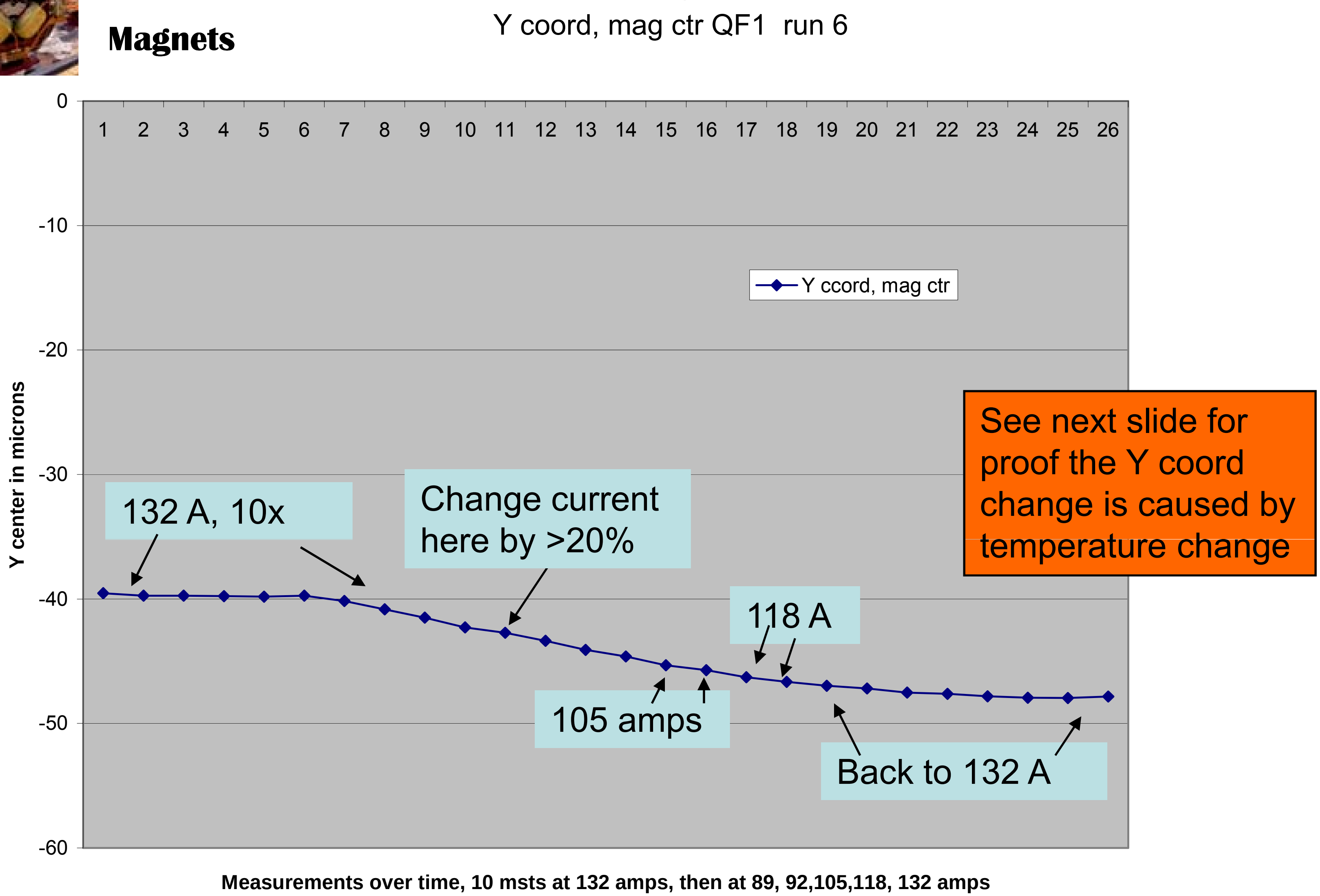
Mimic a beam based alignment set of currents, measure Y coord of magnetic center at each current



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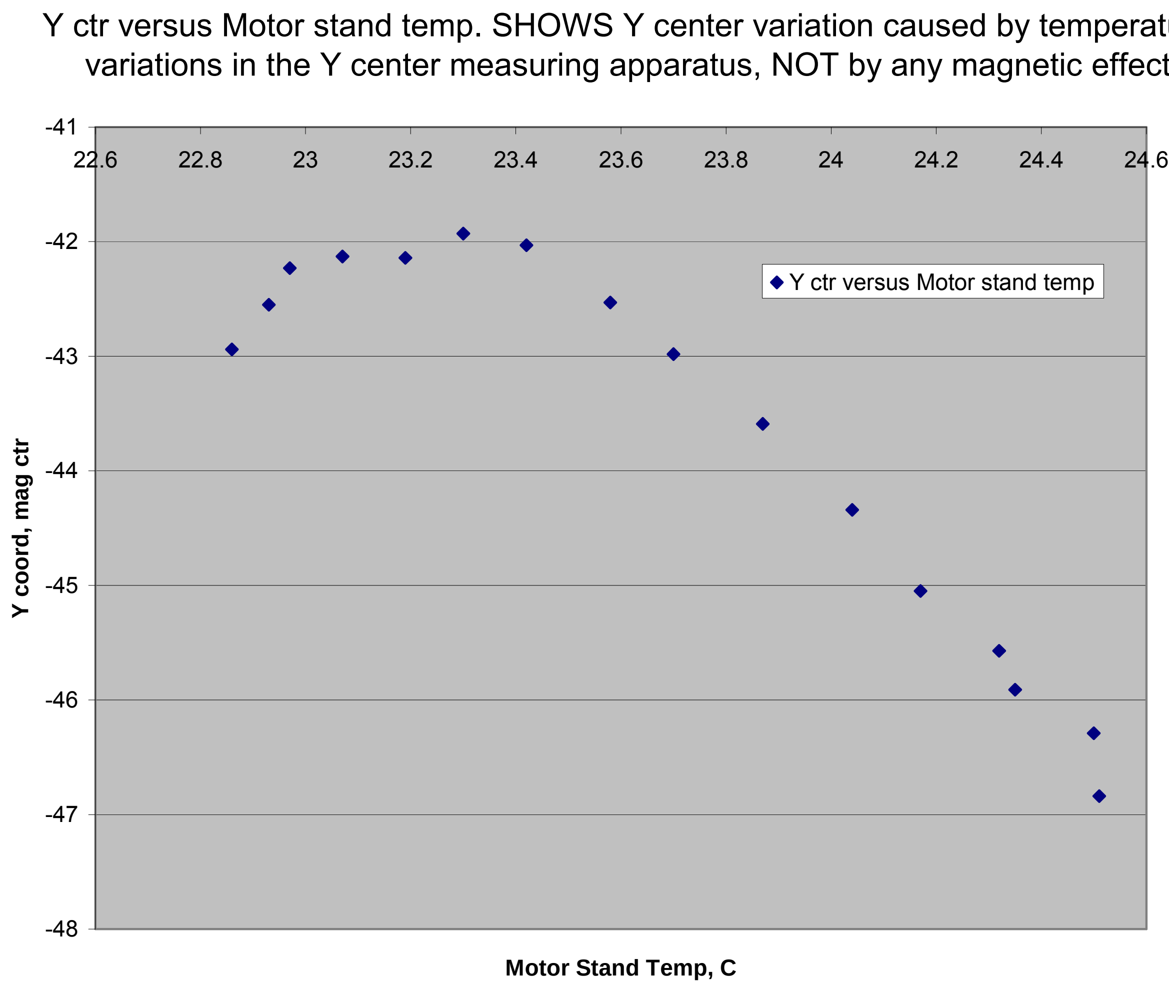
Y coord of magnetic center (microns) variation caused by temperature variation in supports of the rotating coil.

X center coord hardly varies during this sequence.



Rotating coil is moving during the run- makes it look like magnetic center is moving, but it is not!

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Mimic making small changes in FD quad currents around nominal I

- Start with I= 132 amps, measure integrated strength, then change current in this sequence: 131,131,132,133,133,132,132 amps and measure integrated strength at each current with rotating coil
- Result: integrated strength varies by, at most, + 0.045%-- quite acceptable

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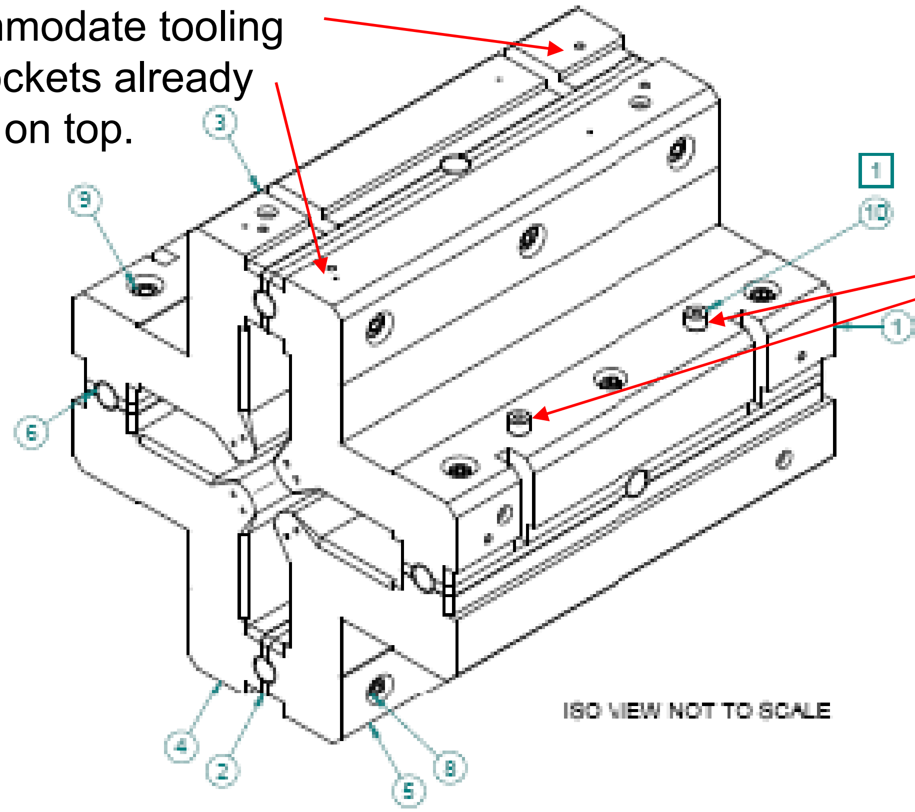
Tooling Ball sockets added & fiducialization has been done

Some holes to accommodate tooling ball sockets already drilled on top.

Top of quads kept clear so MONALISA can be installed later

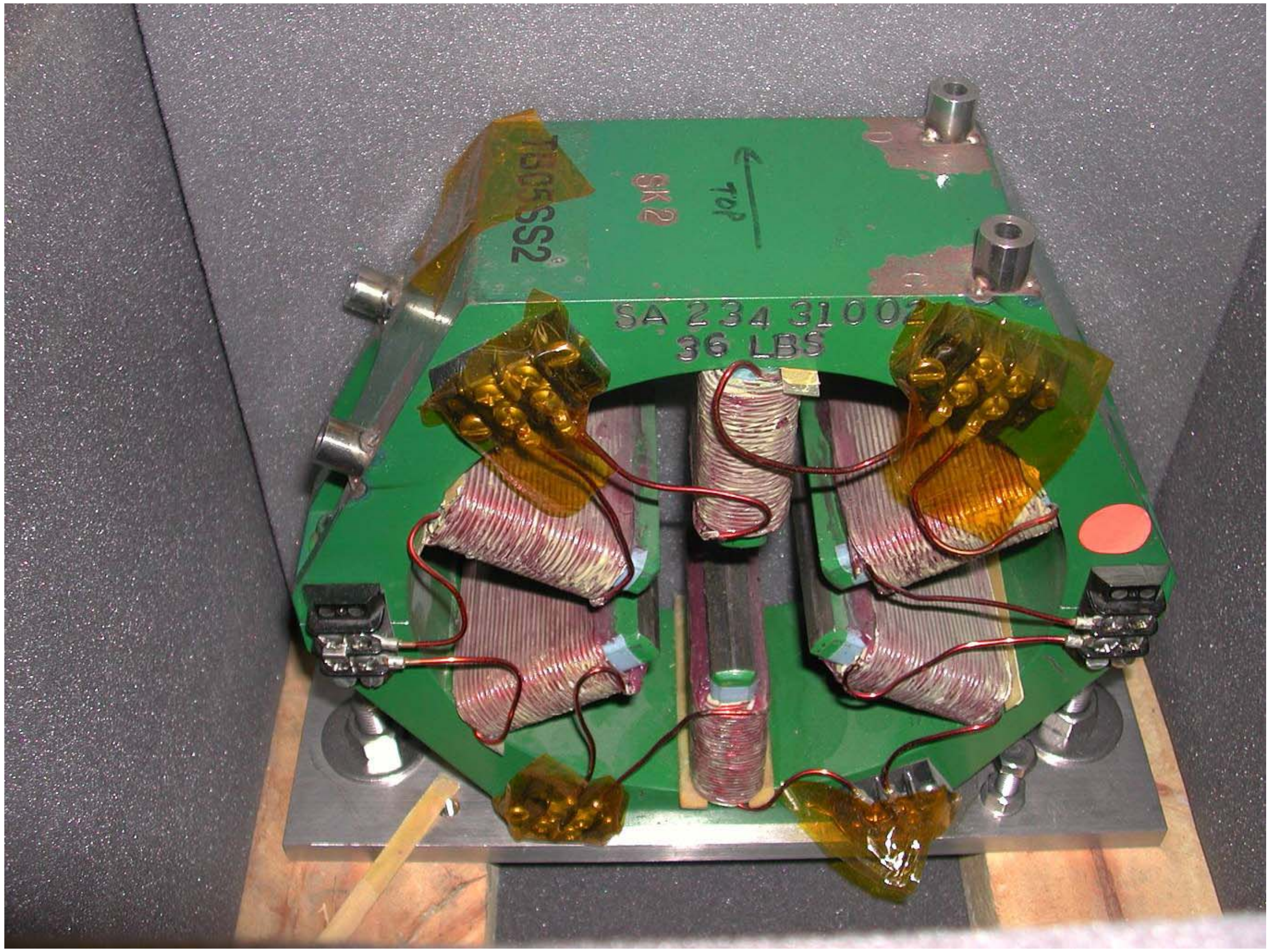


Tooling ball sockets tack welded to various surfaces.

Fiducialization: worked out where tooling balls are relative to mechanical center.

Data will be sent to KEK soon.

An old FFTB sextupole which is now an ATF2 FD sextupole- 2 now at LAPP



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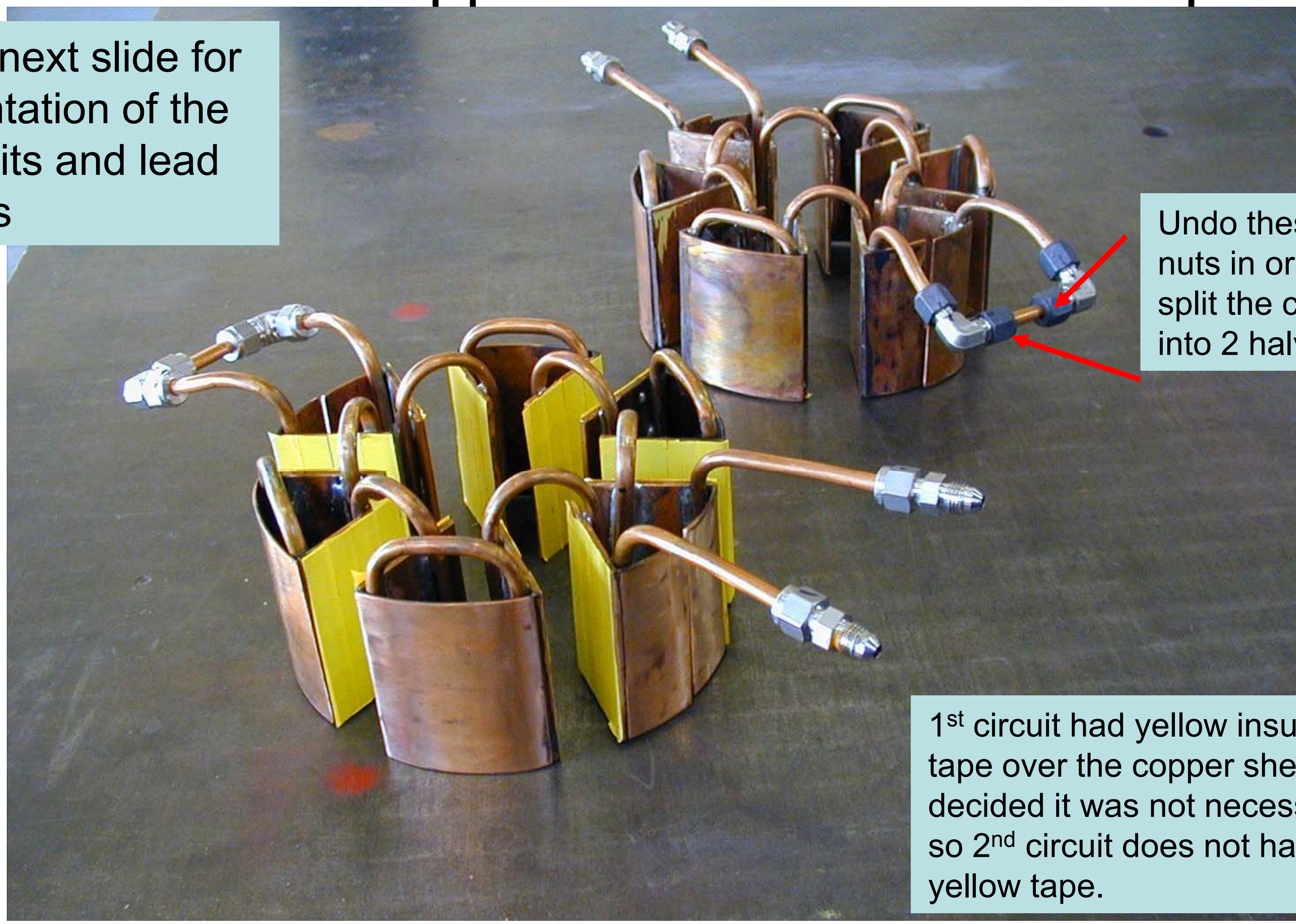
The 2 cooling circuits developed to slip over the coils of the FD sextupoles- shipped to LAPP at end of April.



See next slide for orientation of the circuits and lead pipes

Undo these nuts in order to split the circuit into 2 halves.

1st circuit had yellow insulating tape over the copper sheets, decided it was not necessary, so 2nd circuit does not have yellow tape.

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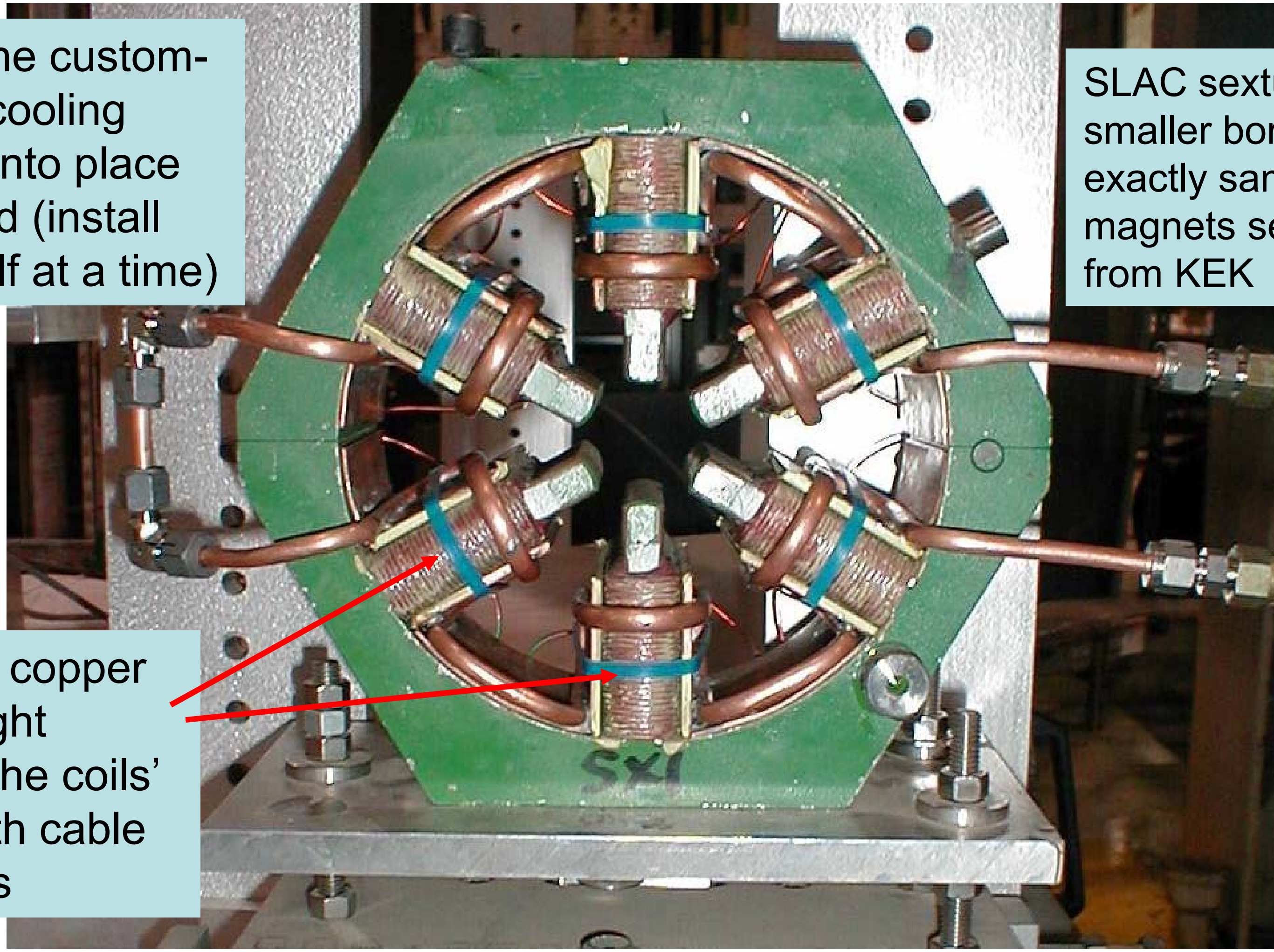
Photo of cooling circuit installed on a similar sextupole at SLAC



Push the custom-made cooling circuit into place by hand (install one half at a time)

SLAC sextupole has smaller bore, otherwise exactly same as magnets sent to LAPP from KEK

Hold the copper plates tight against the coils' sides with cable tie-wraps

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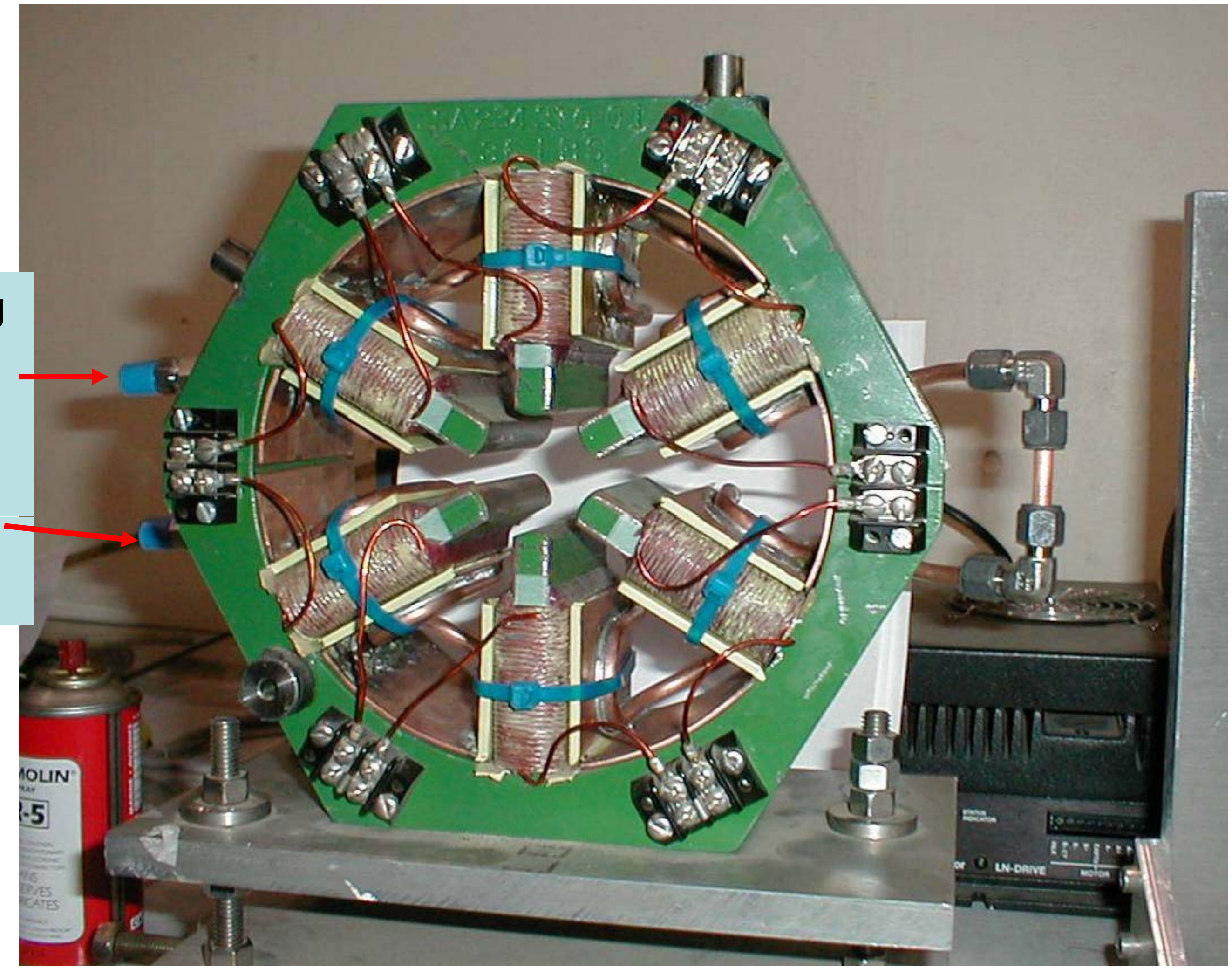
Photo of the electrical terminal end of a sextupole with the cooling circuit installed

Synflex cooling hoses hook up to these 2 fittings via swivel couplings on hose ends



Previously proved that these cooling circuits will keep these sextupoles cool enough.

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Conclusions on the ATF2 FD magnets designed, prepared & measured by Spencer et al at SLAC; shipped to LAPP at end of April, 2008

- Two FD quads have
  - met their ∫G.dl requirements with small enough Δtemperature
  - met their stringent multipole requirements;
  - their magnetic center behavior during beam based alignment is acceptable
  - their ∫G.dl behavior during 1 amp variations around the operating current is acceptable
  - Detailed instructions will be provided to KEK to re-assemble the quads after splitting to install the SBPMs- so mechanical symmetry is regained and multipoles kept within specs
- Two FD sextupoles have
  - Met their integrated strength requirements [use old data from when they were measured at SLAC many years ago]
  - Met their thermal behavior requirements with new cooling circuits