ATF2

Magnets

Status Report on New Magnets being procured for the ATF2 beamline

Cherrill Spencer, Magnet Designer
and member of ATF2 Magnet Group

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Overview of magnet status report

- **Three Final Focus dipoles**, B1,B2 & B5: designed by Spencer, made and measured at IHEP, Beijing, delivered to KEK ~ 3 weeks ago
- **Two Final Doublet quads** : QD0 & QF1. Old FFTB quads: aperture been increased, working on improving multipole content- solution been found
- **Two Final Doublet sextupoles**: SD0 & SF1: old FFTB sextupoles, solid wire coils. Have added water-cooled copper plates to reduce their temperature rise
- **Three Final Focus sextupoles**: old SLC water-cooled sextupoles, about to be refurbished and re-measured.
- **Some vibration measurements** on the QD0 & “SD0”

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One of the Dipoles made at IHEP in IHEP measurement lab. Data shown here is IHEP data.

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4 hour thermal test results on #2, running at 175 amps

ATF2 DEA Dipole 2# Thermal Test@175.03A

Date 10/25/2007

Ambient Temperature( ) 23

Temps measured by infra-red “gun” thermometer- not so precise

		Temperature( )					
Num.	Time	top coil	bottom coil	terminal	input LCW line	Output LCW line	Voltage (V)
1	9:50	16.4	16.3	16.2	16.3	14.6	0
2	9:55	17.4	19.5	16.4	16.3	16.2	6.2935
3	10:05	17.4	23.6	18.3	17.3	18.4	6.4195
4	10:15	17.9	23.3	17.4	17.9	19.7	6.4231
5	10:25	18.1	23	18.1	17.1	19.7	6.4174
6	10:35	17.6	23.2	16.4	16.4	/	6.4104
7	10:45	18.3	23.6	16.8	17.7	/	6.4198
8	10:55	17.9	23.9	18.4	18.6	/	6.4277
9	11:05	18.7	24.1	20.4	19.3	/	6.4386
10	11:35	18.7	24.4	21.2	19.4	/	6.4476
11	12:05	19.8	25.6	20.3	20	23.6	6.4573
12	12:35	19	25.2	20.6	20.5	23.8	6.456
13	13:05	19.4	25.3	20.3	19.8	23.9	6.455
14	13:35	19.3	25.1	19.8	19.6	23.8	6.463
15	14:05	19.2	25.2	20.1	20.2	23.8	6.4699

From increase in voltage across terminals calculate the average delta T of coils : 7.1° C

ATF2 DEA Dipole 3# Water Cooling Check

Water pressure drop (Kg/cm^2)	Water Flow (liter/minute)		
	1	2	3
6.0	1.2	1.24	1.22

Water flow predicted to be 1.2 l/m at delta P of 6Kg/cm^2

Magnet Alignment- described by Ms Li in her report

- Used laser Alignment measuring apparatus to adjust movement platform (XY) of SSW by alignment people.
- Alignment of magnet and Wire position with respect to the alignment target measured using the level and the transit.
- Comment from Spencer: I interpreted the statement above to mean they had used the 2 alignment reference plates on top of the core to align the stretched wire with the magnet; but apparently I was wrong – they used their own alignment targets. One on the stage carrying the stretched wire and one in the dipole gap – see next 2 slides for photos and descriptions.

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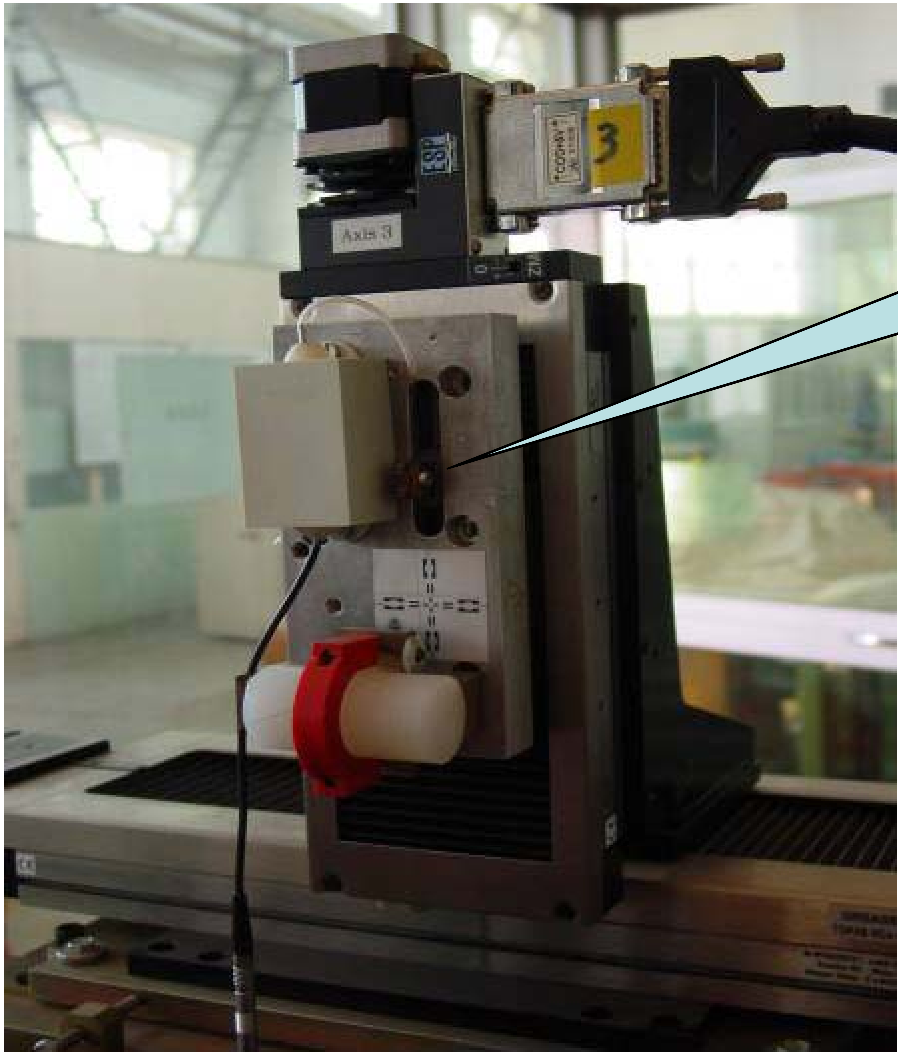
Laser alignment for the platforms that move and hold stretched wire



laser reflector for laser tracker

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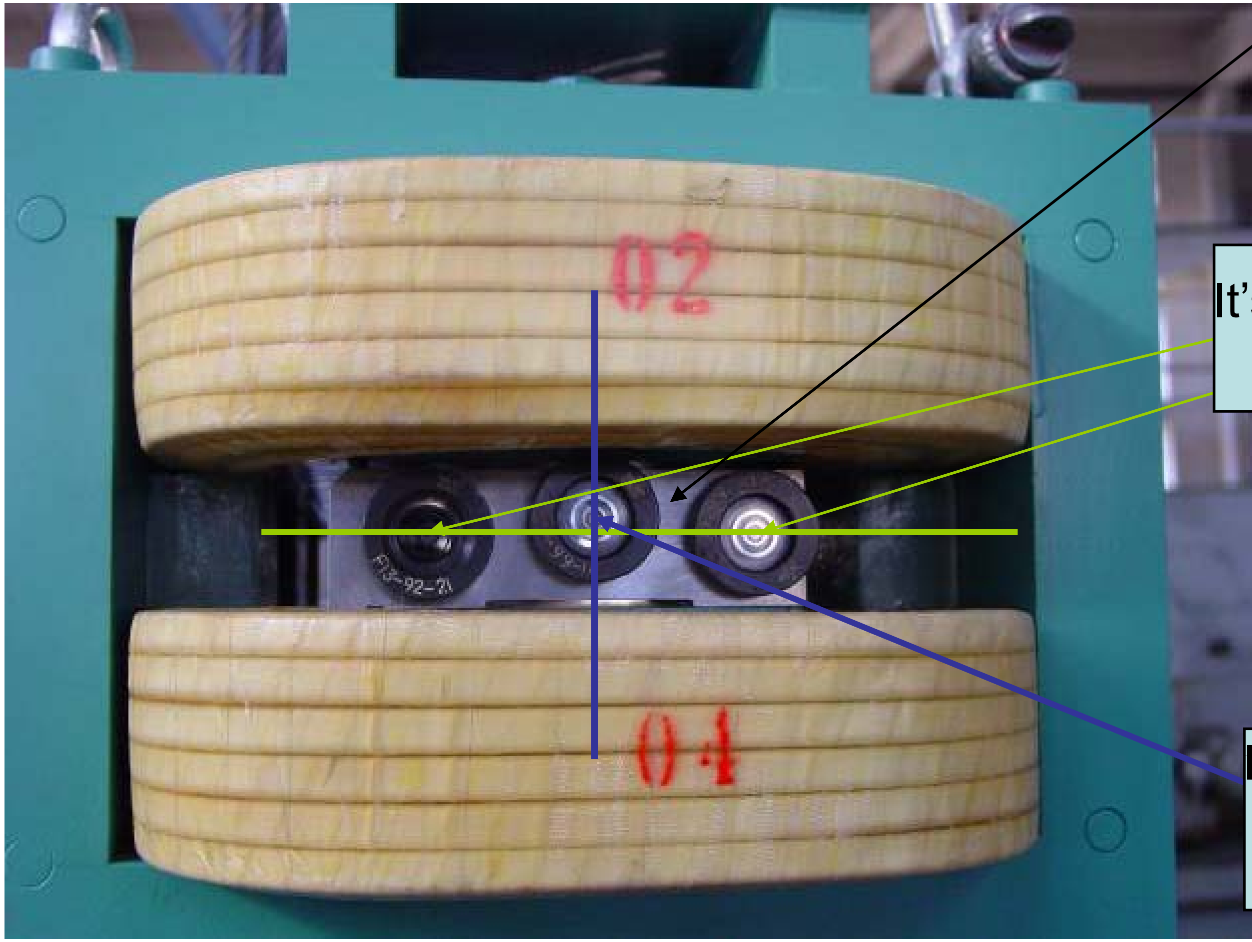
Optics alignment target: to adjust the support (and position) of the magnet by using a level and the transit to ensure wire is at mechanical center of the dipole.



Alignment target, set at each end

It's for the middle plane Using level.

Same optical target used to set up Hall probe

It's for the mechanical center of the magnet poles using transit.

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Stretched Wire Measurement System

- Single Stretched Wire (SSW) system used at BEPCII for the superconducting magnets measurement- made by DESY and lent to IHEP.
- A stretched wire is moved across the magnetic field, Synchronic movement of the wire on both sides. It is 2.9 m long
- CuBe wire, a diameter of 0.125 mm.
- Voltage induced in wire is integrated during movement.
- Knowing
  - Length of wire; time it takes to move a step; distance of movement, one can calculate from Lorentz Law :
  - Voltage induced= speed of movement * length of wire* B (perp to wire motion)
  - There are no calibration constants in this SSW method
- So measure the Integrated field strength of dipoles.
- Angle of dipoles.
- Accuracy.
- 10^{-4} for fields.
- Once a year one calibrates one's volt meter and checks integrator

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Magnetic Measurements done on DEA #2

- Four times standardization cycle from 0A-175A-0A.
- A computer program controls the standardization and setting of the current.
- Maximum current = 175 amps.
- Minimum current= 0.0015 amps.
- Ramp rate = 3.2 amps per second.
- Pause times at top and bottom = 30 seconds.
- Set of measurement currents:

  75,85,95,105,115,125,135,145,155,165,175 amps.

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The Integrated Field Measurement Results, from stretched wire; only dipole #2 measured with stretched wire:

Current(A)	BL[T.m]
74.978	0.107290
84.970	0.121638
94.985	0.135888
104.983	0.150169
114.976	0.164433
124.966	0.178669
134.976	0.192718
144.973	0.206832
154.966	0.221066
164.980	0.235292
174.970	0.249631

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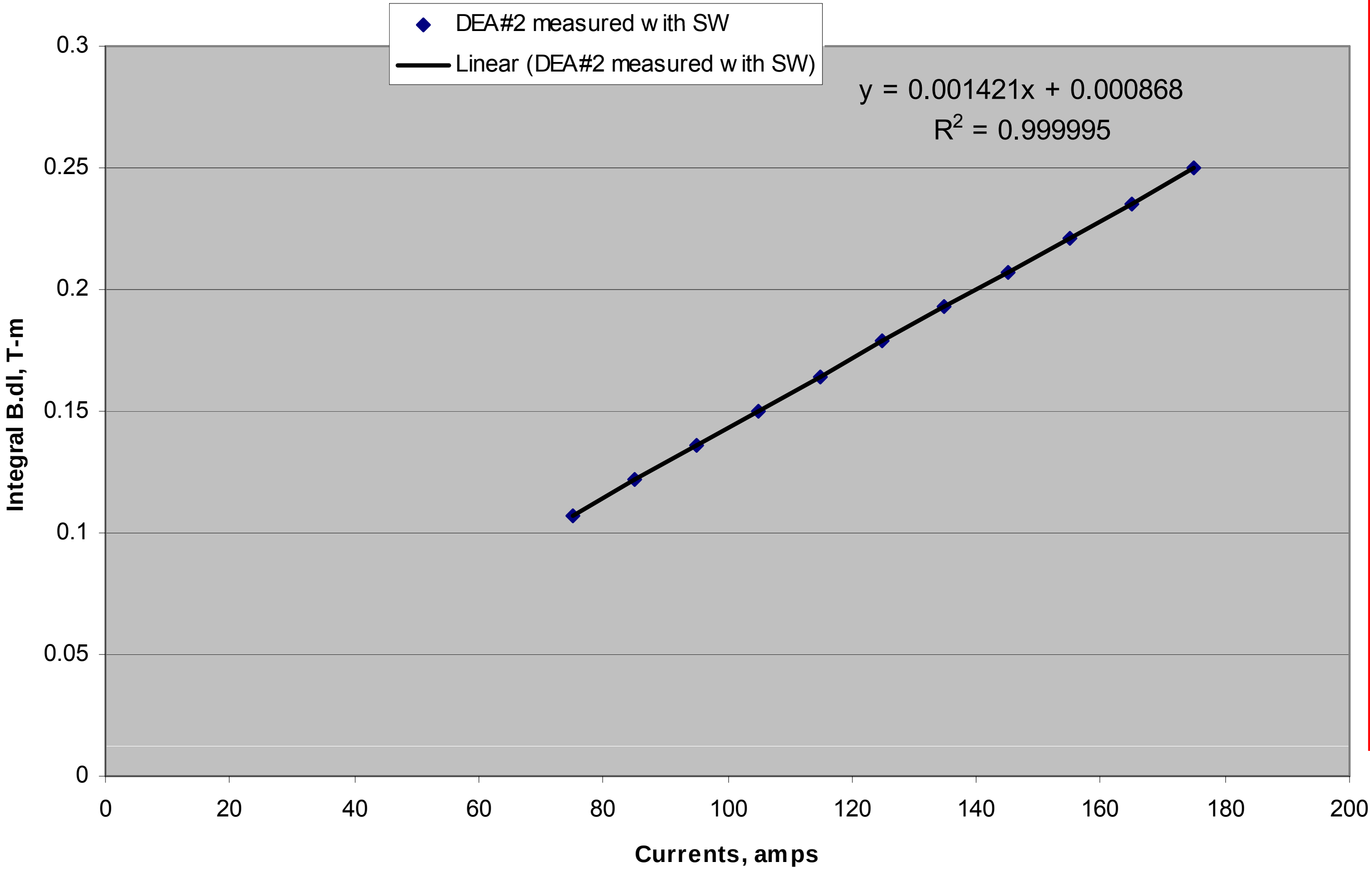
DEA dipole #2 measured with stretched wire to get ∫B.dl at various currents



B1's req'd ∫B.dl = 0.2334T-m.

From linear plot calculate I will be 163.6 amps to produce 0.2334 T-m.

Cherrill predicted 162.3 amps

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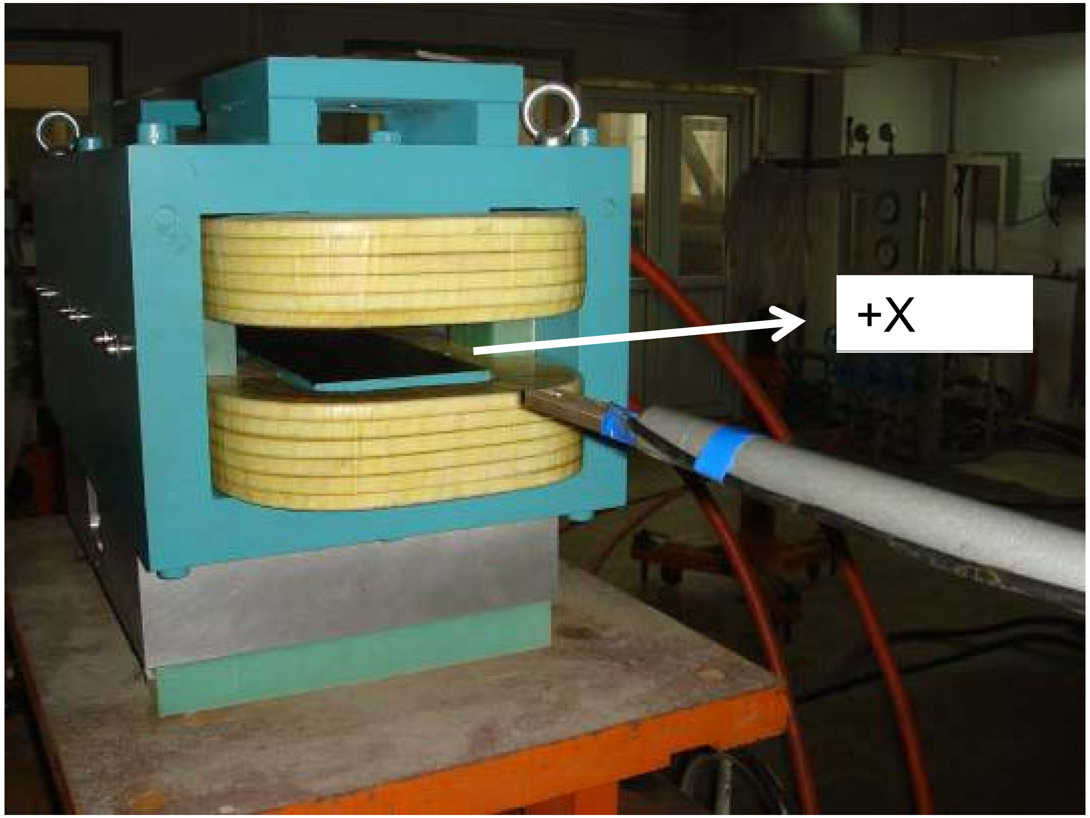
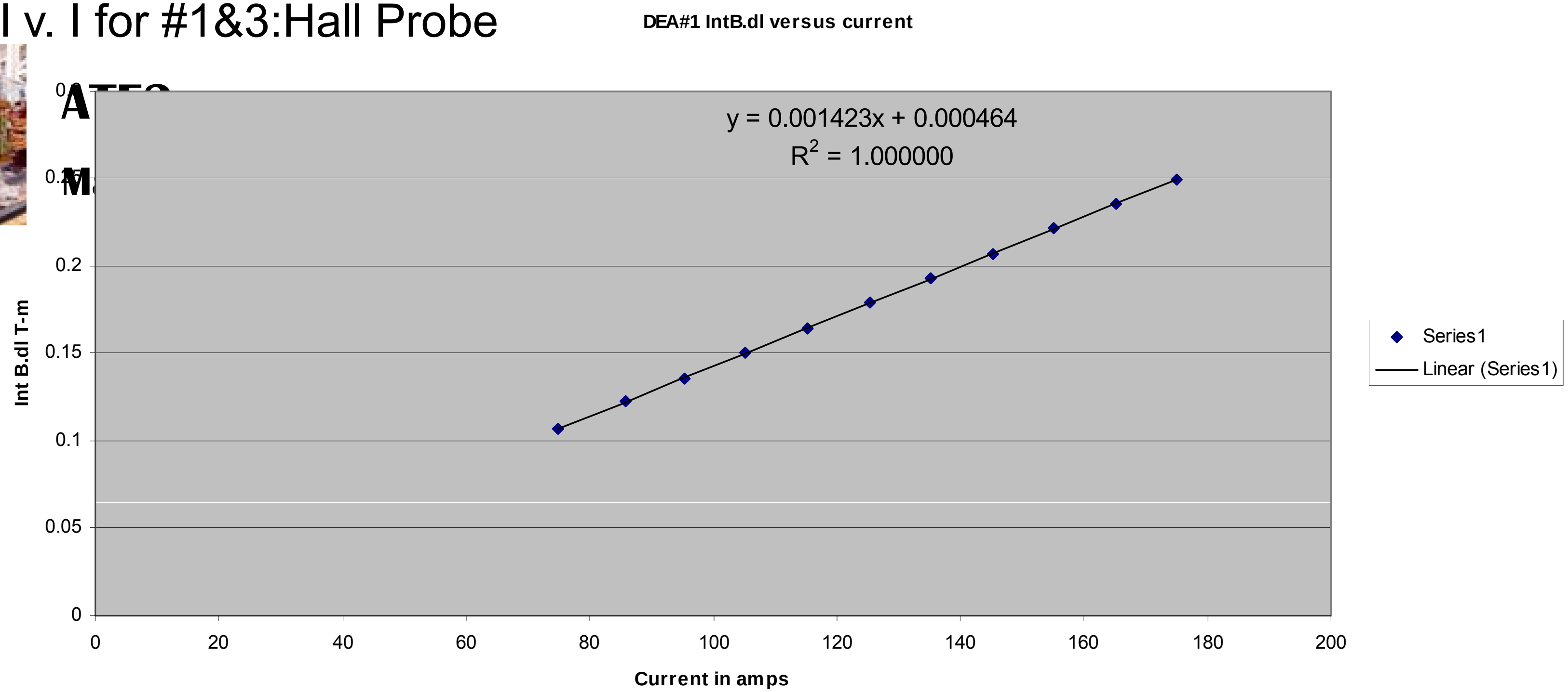
Hall probe (group 3) about to be inserted into DEA dipole at IHEP

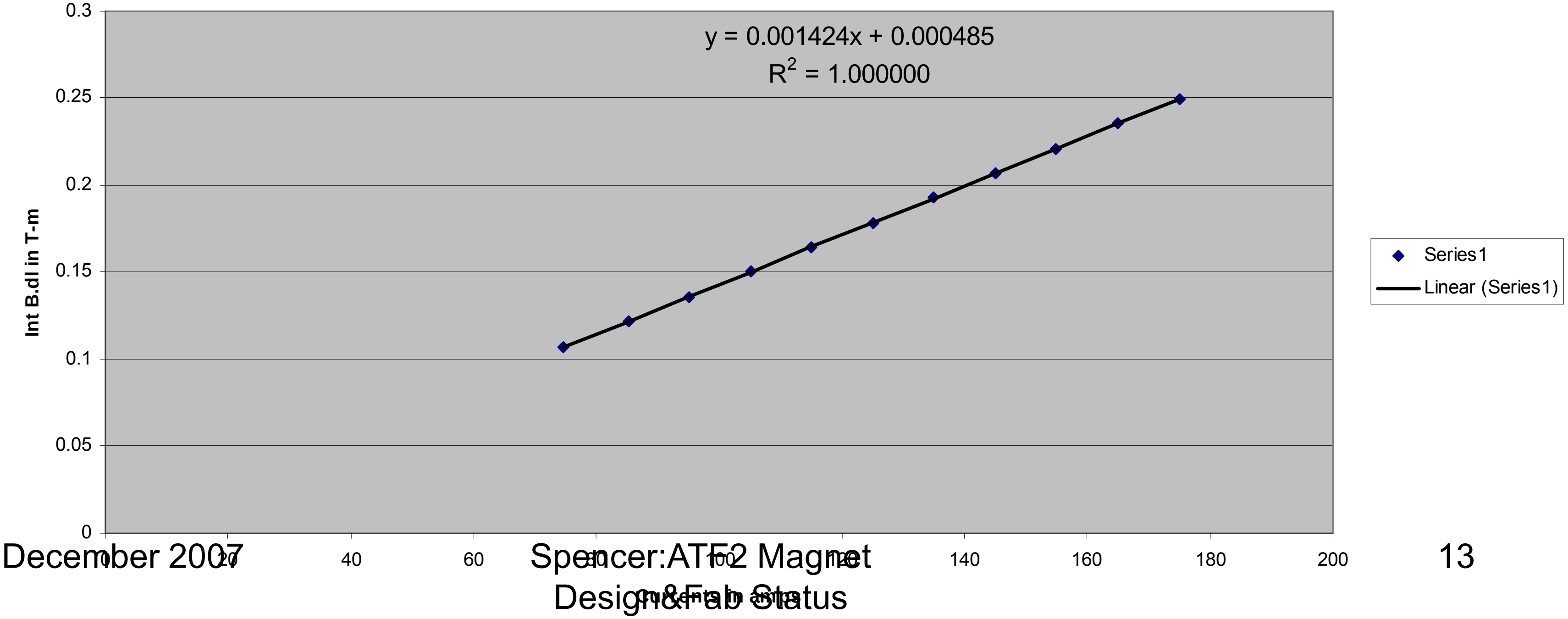


IntB.dl v. I for #1&3:Hall Probe

#1



#3



Remarkable agreement in the integrated strengths of the 3 dipoles

- Study 3 plots in previous 2 slides- look at the linear equations made by fitting to the integrals versus currents.
- See very similar slopes & constants. Even though #1 and #3 were measured by scan along Z of Hall Probe and #2 by stretched wire.
- Hall probe scan was from -45 cm to + 45 cm through the gap at X=Y=0- Cherrill has studied the raw data and it is satisfactory

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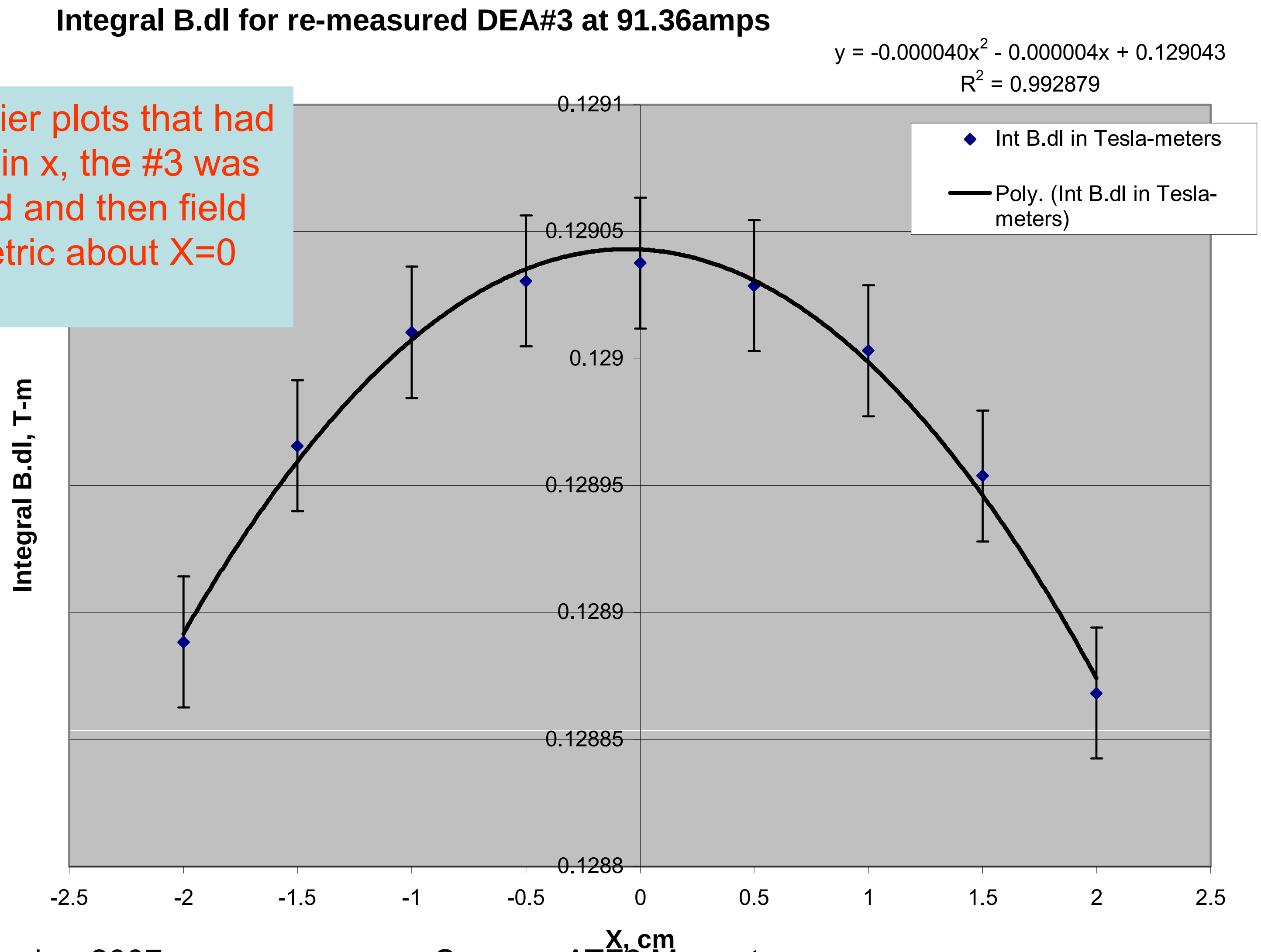
To judge quality of field –look for higher multipoles, by measuring IntB.dl v X

After earlier plots that had an offset in x, the #3 was re-aligned and then field is symmetric about X=0 line.



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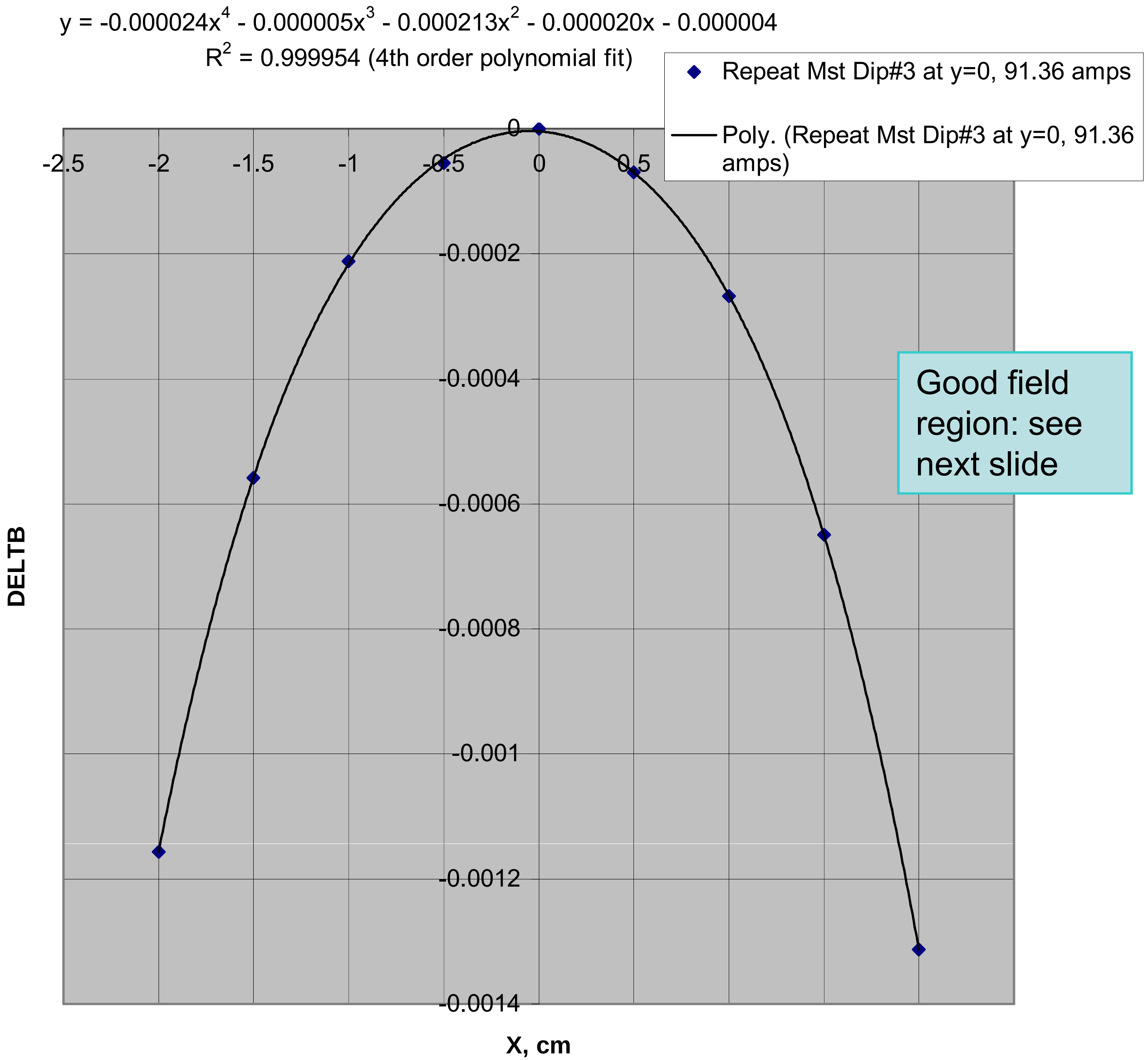
DEA dipole #3 measured on X,Y,Z grid to calculate the sextupole etc components

Calculate DELTB=

(∫B.dl at X - ∫B.dl at X=0)

∫B.dl at X=0

Plot DELT versus X in cm, fit with a 4th order polynomial. Coefficient of X^2 is the sextupole component/dipole: 2.1×10^{-4} which is $< 2.5 \times 10^{-4}$



Use “good field region” as a way of defining quality of field

- Above method of fitting a polynomial to Taylor expansion of the field is one way of evaluating the field quality. (Spencer can provide references to this technique)
- Another way is to quote how wide the “good field” region should be. If sext/dipole at 1 cm is to be < $< 2.5 \times 10^{-4}$, is same as saying, that Delta B.dl/(B.dl at X=0) must not drop by more than 2.5×10^{-4} within +-1 cm around X=0 (assuming all the fall-off is caused only by the sextupole component in the field).
- Study the previous and next graphs to see this is true.

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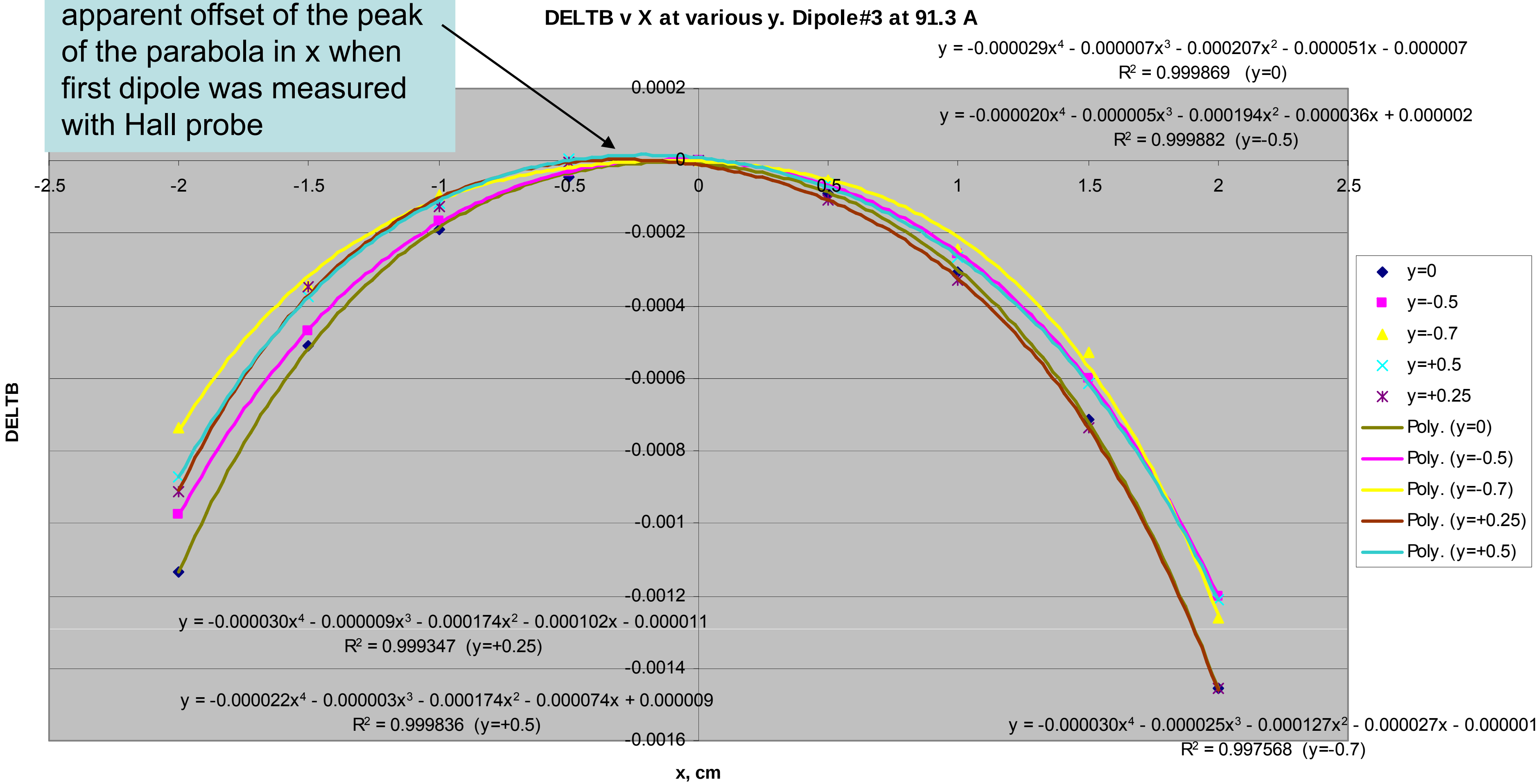
DELTB at 5 different y heights- can extract the skew sextupole from this data set

Concern about the apparent offset of the peak of the parabola in x when first dipole was measured with Hall probe



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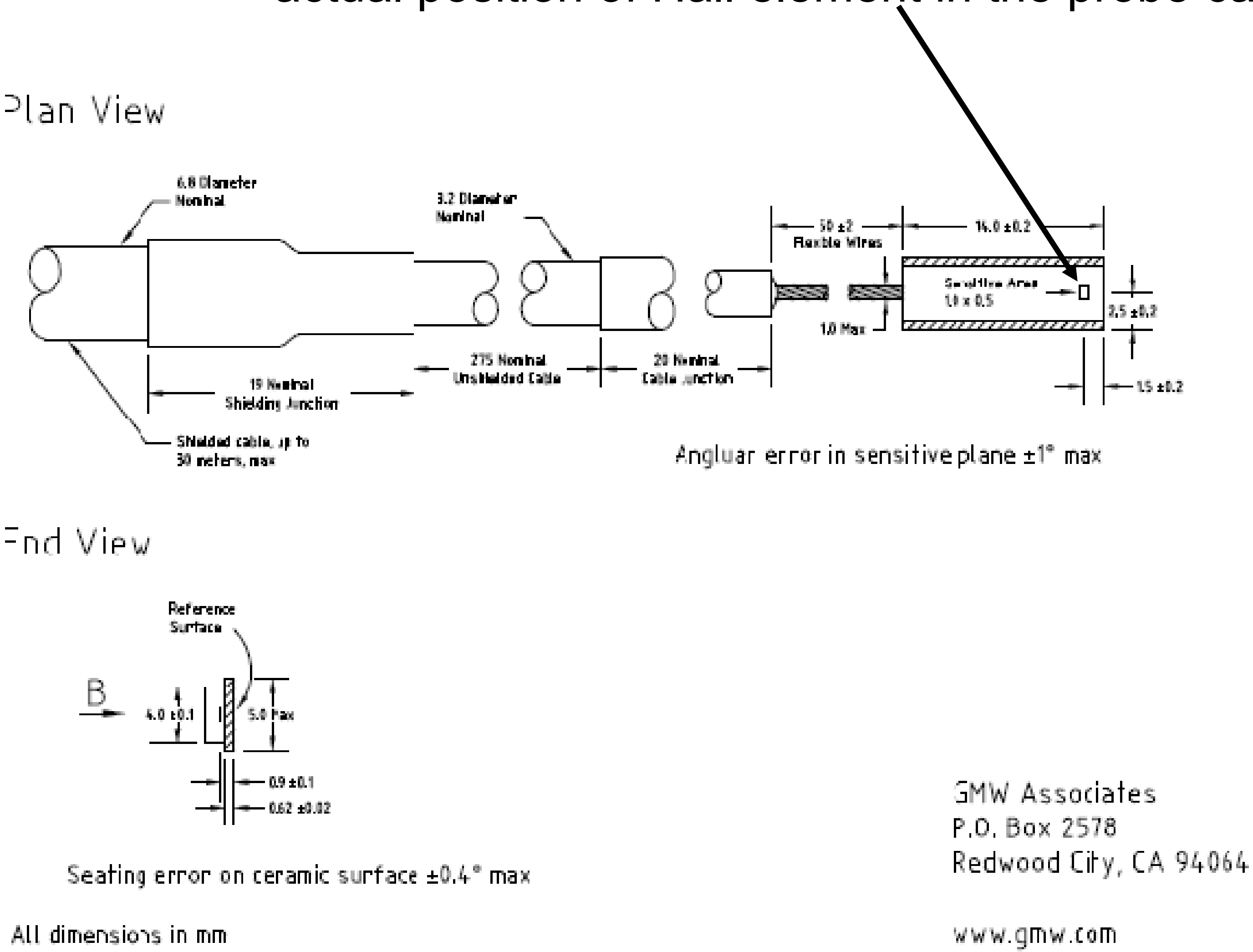
Spencer's explanation for the initial offset in X of the Int B.dl data taken by the Hall Probe: did not account for actual position of Hall element in the probe case



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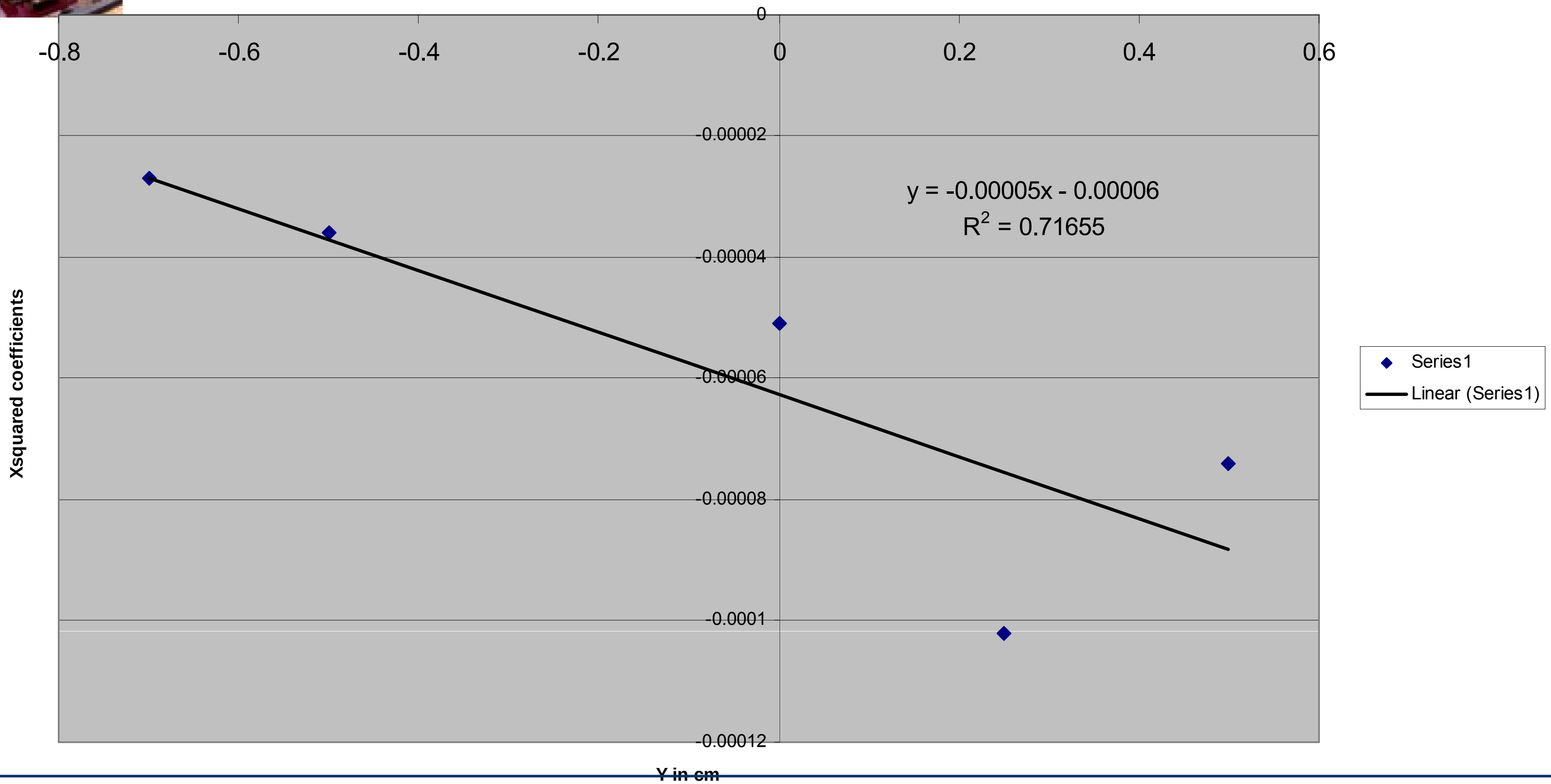
Make 4th order fits to DELTB (slide#20)and take the coefficients of the x^2 terms and plot them v. Y



$-1/2(\text{slope of above line})\ 1^2 = (a_2/b_0)$ [Spencer can provide workings that show this]

Result: skew sextupole/dipole = 2.5×10^{-5} : smaller than value Kuroda proposed the other week: 4.55×10^{-4}. All 3 dipoles have similarly small skew sextupoles

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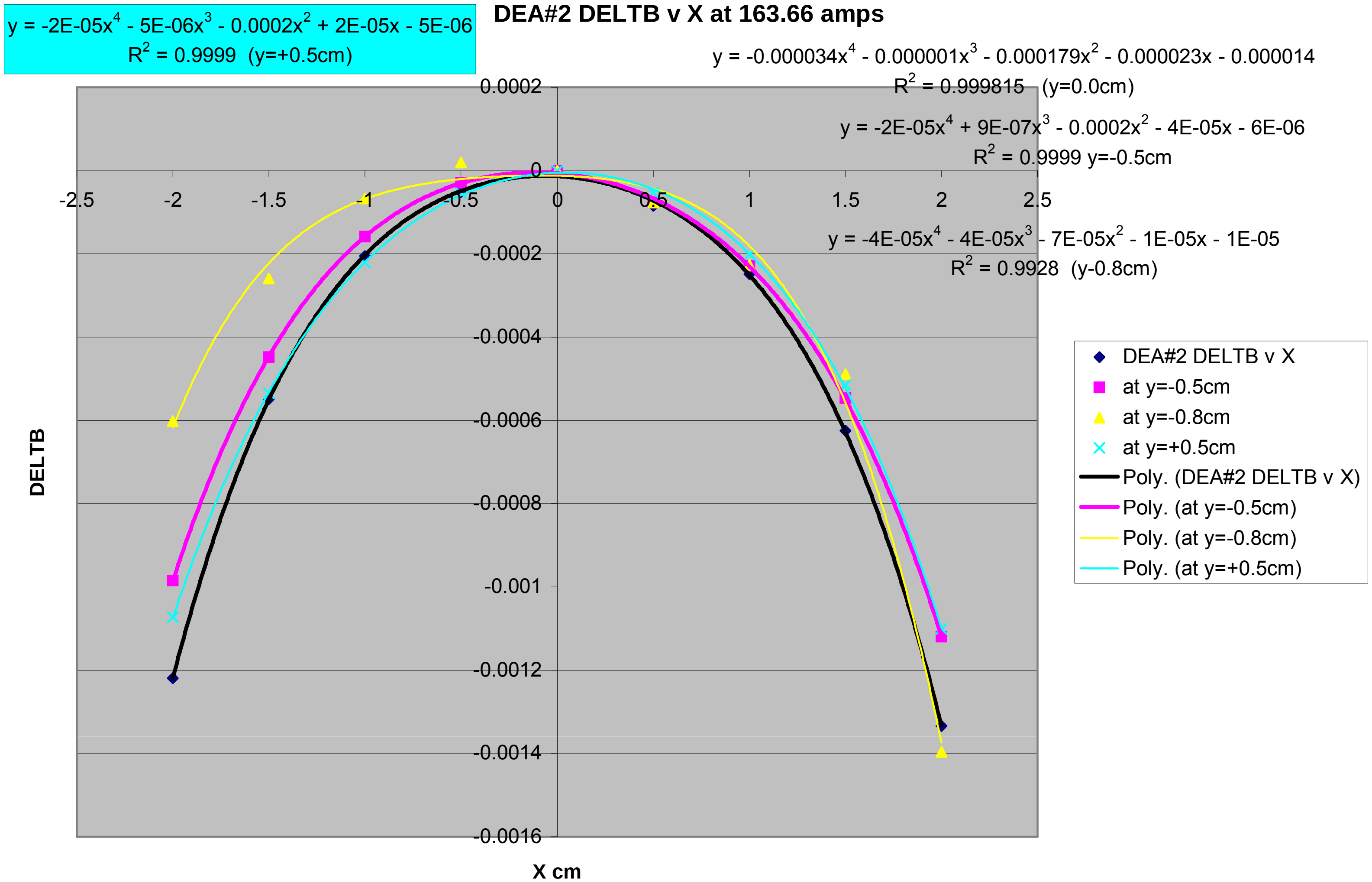
The dipole #2 was measured last – all offset problems gone away.



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Reproducibility of Hall probe-judge from Integral B.dl measurements

- On DEA #3- measured IntB.dl at x=0, then, X= -2,-1.5,-1,-0.5,0,0.5, 1.0,1.5, 2.0 cm.
- Compared the 2 IntB.dl measurements at X=0:
- Difference was 0.005% of 2nd measurement
- As I wrote above – the consistency of the integrated strengths at the same currents on different dipoles could not occur if there were systematic errors occurring in the measurements.

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Calculate the effective length from the data

- Divide the integrated strength at a current by the B field at center of gap at same current.
- Find L(effective) = 62.21 cm (for each dipole)
- Cherrill had predicted (using rule of thumb : L eff = core length + gap) : 61.28 cm
- So actual effective length is slightly longer- probably effect of the racetrack shape of the coils- their straight section sticks out a little beyond the core

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Spencer's Conclusion having looked at all IHEP data and the raw Hall probe data [their LCW system not available again until Dec20th]

- I have looked at all the data from all 3 dipoles, I have just shown a subset in this presentation. Based on all the data I proposed that :
- The 3 DEA dipoles made and measured by IHEP are meeting all our requirements: mechanical, thermal, integrated strength at expected currents and field quality and therefore
- I TOLD IHEP on 29th November TO SHIP THEM to KEK as soon as convenient (with the 2 spare coils). They made a shipping crate that I reviewed by photo and sketch and I OK'd crate.

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Shipping crate with 3 DEA dipoles in it: each held down to a steel frame which is attached to the crate bottom

I hope we will see these 3 dipoles during our tour of ATF2 this afternoon.

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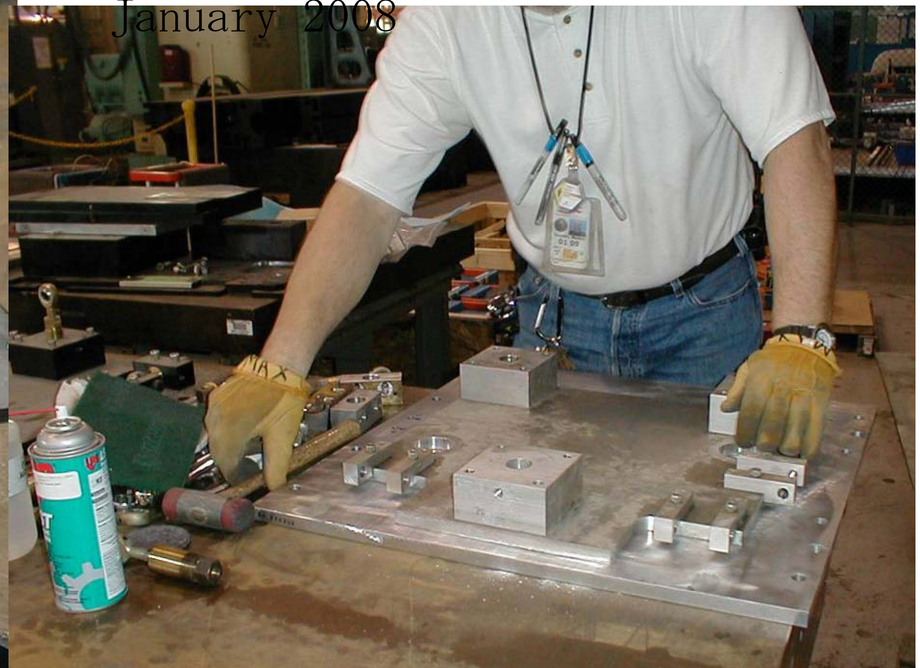
Adjustable supports for the 3 DEA dipoles : old SLC T-1 style supports

Have scavenged 3 old “T-1” X,Y,Z adjustable mounts from SLC. Have been cleaned & refurbished (new screws). Will be shipped to KEK in early January 2008



Summary of required FD quad parameters

- QF1 and QD0 requirements:
- Definition of K1 :

  Gradient = K1 x Brho / Effective length

  At 1.3 GeV, Brho = 4.3363 Tesla-meter

Latest requirements are:

- QF1 K1 = 0.737 and QD0 K1= -1.351
- Integrated strengths: QF1: 3.1959 Tesla; QD0: 5.8584 T
- New aperture: 50.00 mm diameter ; Eff L= 0.475 m;
- Aperture had to to be 50mm to match S band BPM
- Predicted : 127.9 amps to reach QD0 strength, actually 132.1 amps, well within 150 amp limit of power supply
- Thermal test: LCW temperature increase is ~1.5C with 2.5gpm total water flow- as required.

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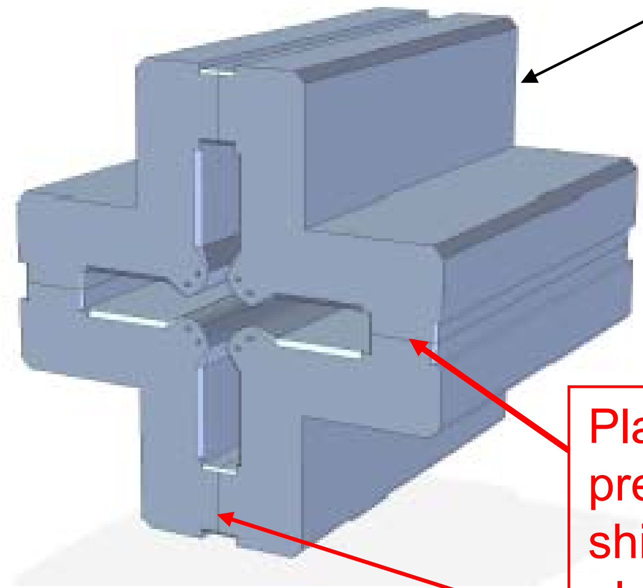
Chosen method for enlarging the "QC3" quad's bore diameter

Dimensions of shims:

10.607mm thick
58.09mm wide
450.00mm long

Shim will be low carbon steel, ground to 0.0005" (0.0127mm) flatness.

Tolerances on width& length: +/-0.127mm



QC3's solid steel core, made from 4 equivalent pieces

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

Spencer reckons split planes were made to 0.02mm flatness & 0.02mm perpendicularity

Close up view of modified quad

Shim
added at
split plane

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Compare predictions of multipole content with tolerances from James Jones & S. Kuroda

Magnet Name	Tolerance 6 pole/quad At r=1cm	Tolerance 12 pole/quad	POISSON Prediction 12pole/quad	Tolerance 20pole/quad	POISSON Prediction 20pole/quad
QF1	9.5×10^{-5}	2.46×10^{-4}	1.86×10^{-3}	1.19×10^{-3}	4.18×10^{-6}
QD0	5.26×10^{-5}	3.08×10^{-3}	1.86×10^{-3}	5.98×10^{-1}	4.18×10^{-6}

ABOVE TABLE IS FOR A 50mm diameter bore with a shifted poletip that was originally designed for a 35mm diameter bore.

Tightest 12pole/quad tolerance is for QF1 and POISSON model predicts the 12-pole will be about 8 times larger.

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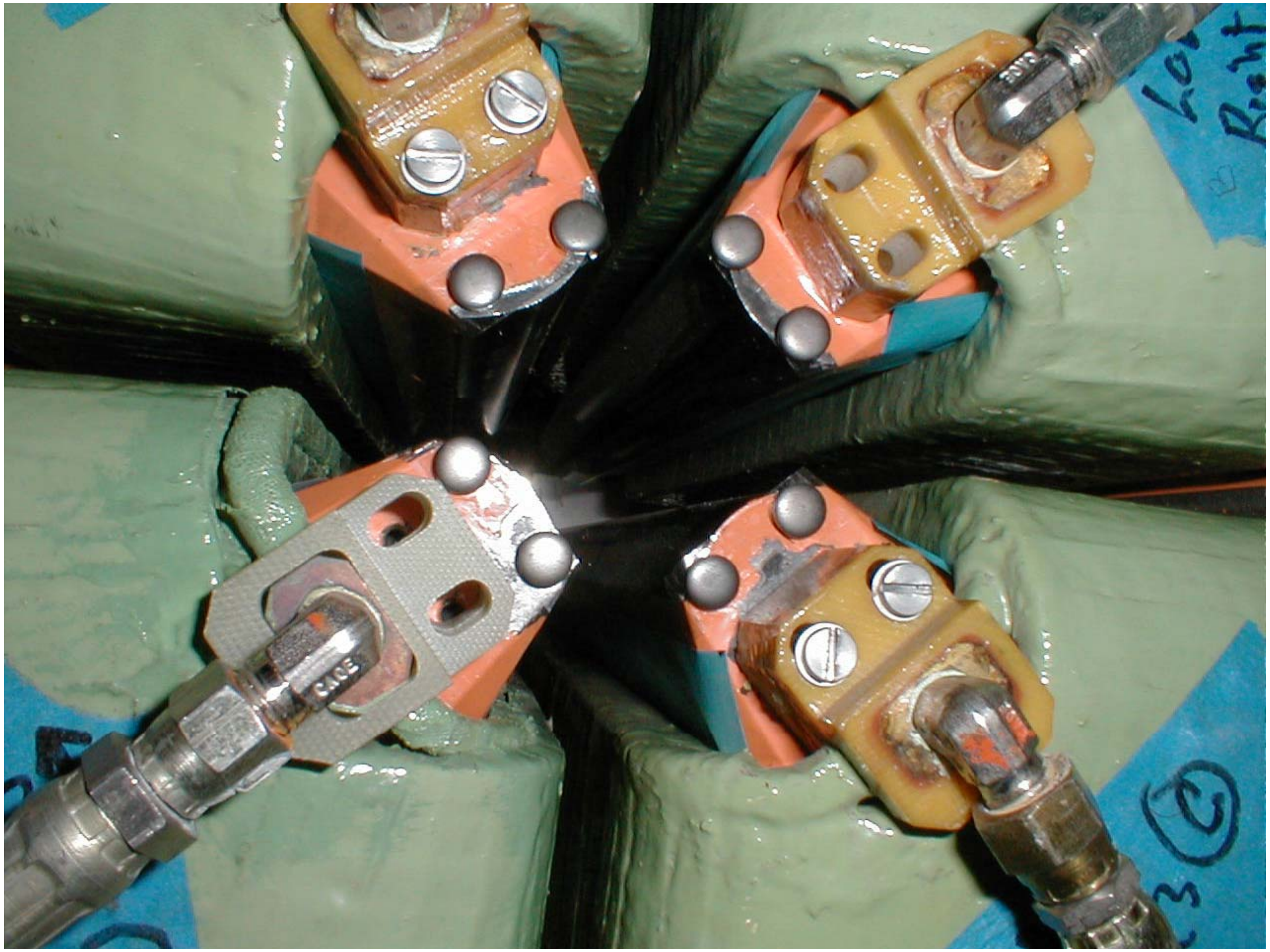
Modified quad, with 50mm aperture on rotating coil measurement stand at SLAC

L4 geophone placed for vibration tests (see later)

Fully bucked rotating coil, to measure integrated harmonics and integrated strength

Some 12.7mm steel buttons stuck on poletip ends: to reduce 12-pole



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Mag measurements with 50mm bore at 2 diff. currents. RED values:>Jones & Kuroda tols

Magnet Name	6 pole/quad At r=1cm	8-pole /quad	10-pole /quad	12pole/quad	20pole/quad
Without buttons : QDO	0.038	0.011	0.0190	0.173	0.00057
With ~0.5" buttons:QD0	0.019	0.015	0.005	0.12 Lowest poss	0.00022
QDO tolerances,%	0.0053	0.016	0.11	0.31	59.8
Without buttons: QF1	0.038	0.011	0.0190	0.173	0.00057
With ~ 0.5" buttons: QF1	0.019	0.020	0.005	0.16	0.00022
QF1 tolerances	0.0096	0.010	0.025	0.0246	0.12

Percentages of quad strength at radius = 1cm. Asked Glen White if via his dynamical simulation he could loosen any tolerances?

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New multipole tolerances based on latest dynamics simulations

- Realised that the button method was not going to reduce the12-pole content below about 0.16% of the quad.
- Buttons caused other multipoles to get larger
- Could not get sextupole content close to very low tolerance (maybe apparatus error too big)
- Asked Glen White to run his beam simulation program with the multipoles we could achieve
- Conclusion: a 0.02% sextupole could be tolerated, but the 12 pole had to be < 0.05% in both QD0 and QF1
- Have to find a new way to reduce the 12pole

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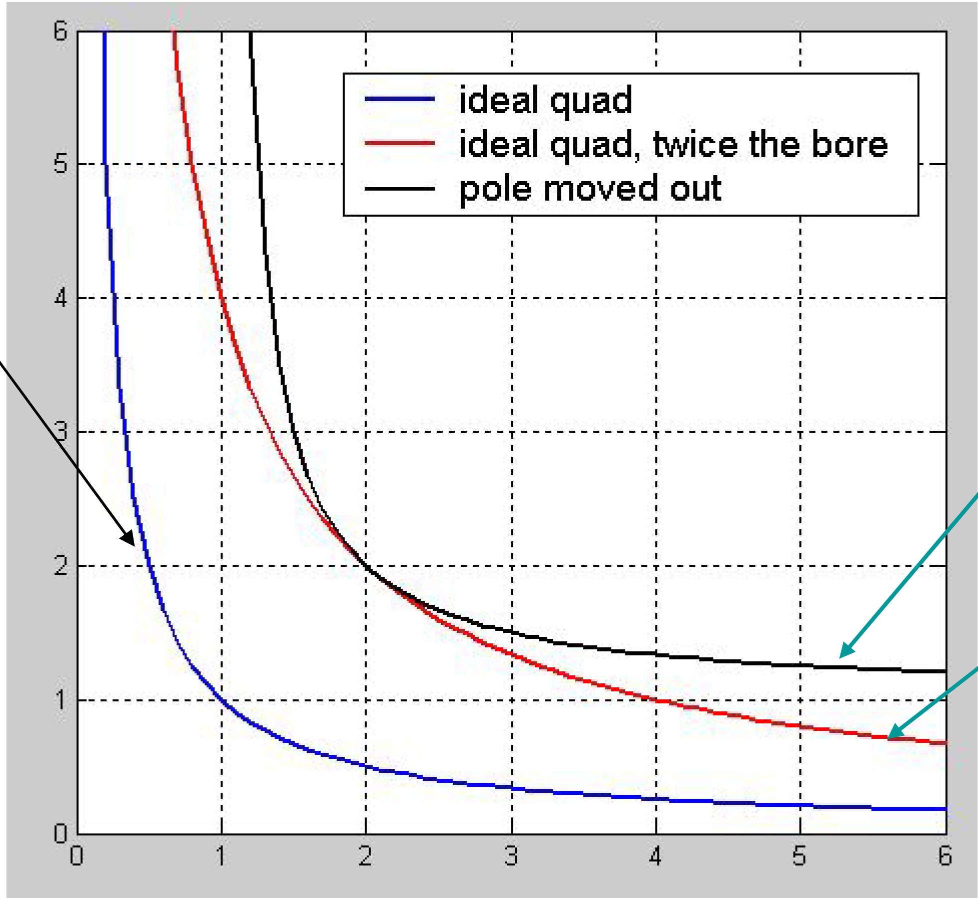
What affect does shifting the hyperbolic poletip have on the multipole components?

In a real quad the hyperbola is truncated about here to make room for the coils.

So all real quads have some 12-pole component mixed in.



This section of the poletip is “missing” more material than it would if the pole had been machined back. This leads to higher 12-pole content in the shifted case.

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One core quadrant of a FD quad

5 small holes already exist in the poletip sides- could we use these to attach a new piece of steel all along the pole?

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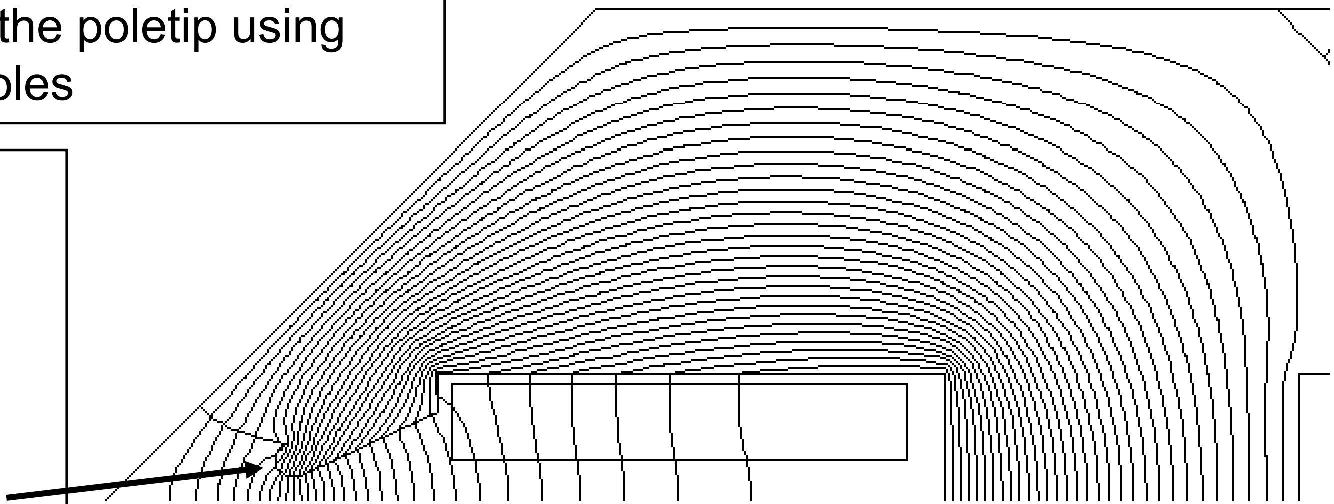
Decided to modify the edges of the poletips - all along length of pole

Poletips have 5 existing holes placed along their length.

Could attached a “side” shim to the poletip using these holes

CROSS SECTION THROUGH 1/8th of FD QUAD IN POISSON MODEL

Using POISSON modelling program tried various different shapes , this one gave 0.019%.



BUT would have been difficult & expensive to fabricate these shims

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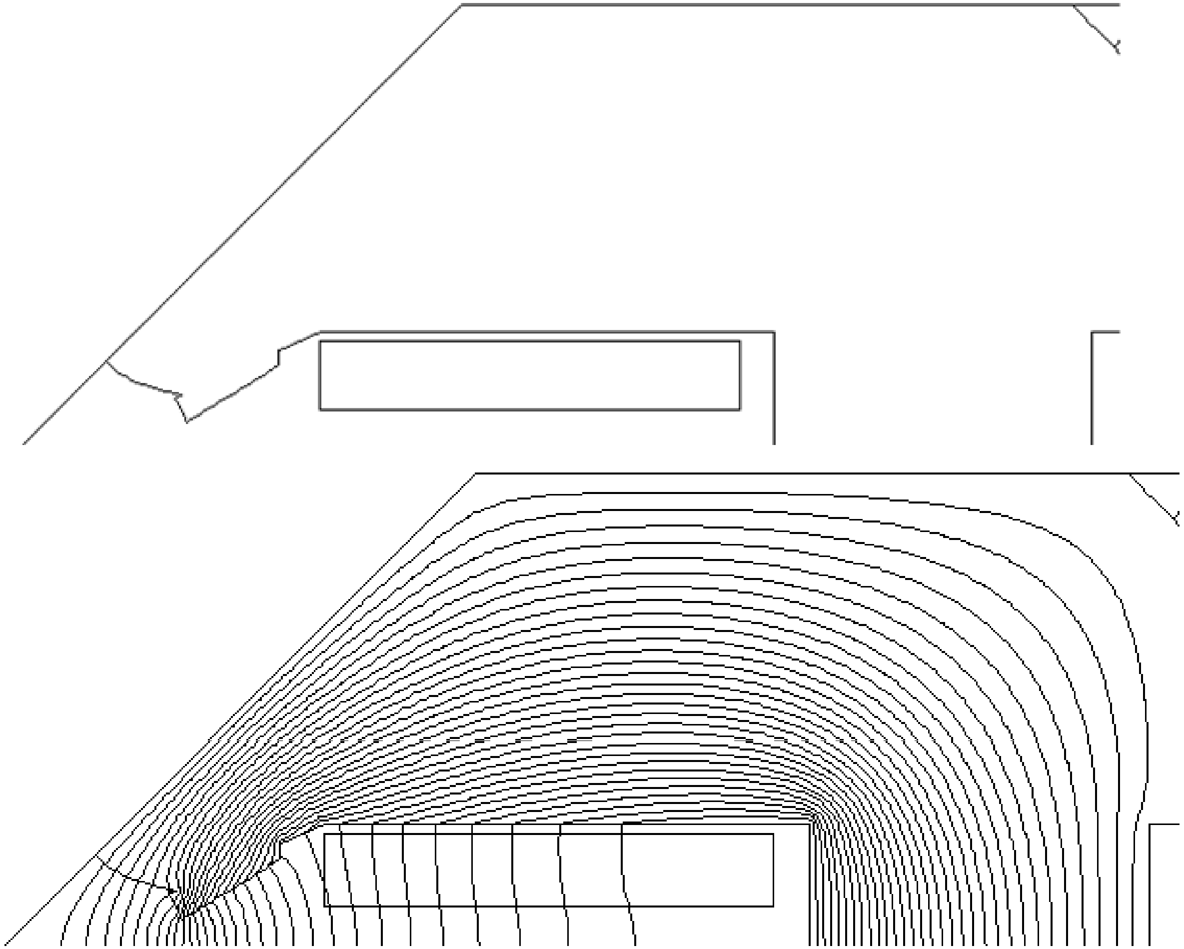
Tried different shapes that would make shims easier to fabricate



This shape gives

12pole/quad = 0.02% at 1cm

Better than Glen's revised tolerance of 0.05%

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Paper model of new side-shims showing where they will go

Shim is 5.2mm thick. Low carbon steel [C1010]

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Cross-sectional view of new side-shim : to reduce 12-pole

Width of shim carefully chosen so does not interfere with adjacent coil [which vary a little in size from coil to coil]

Request to fabricate 16 shims been submitted to SLAC shops.

Will be made in January, Steel in house.

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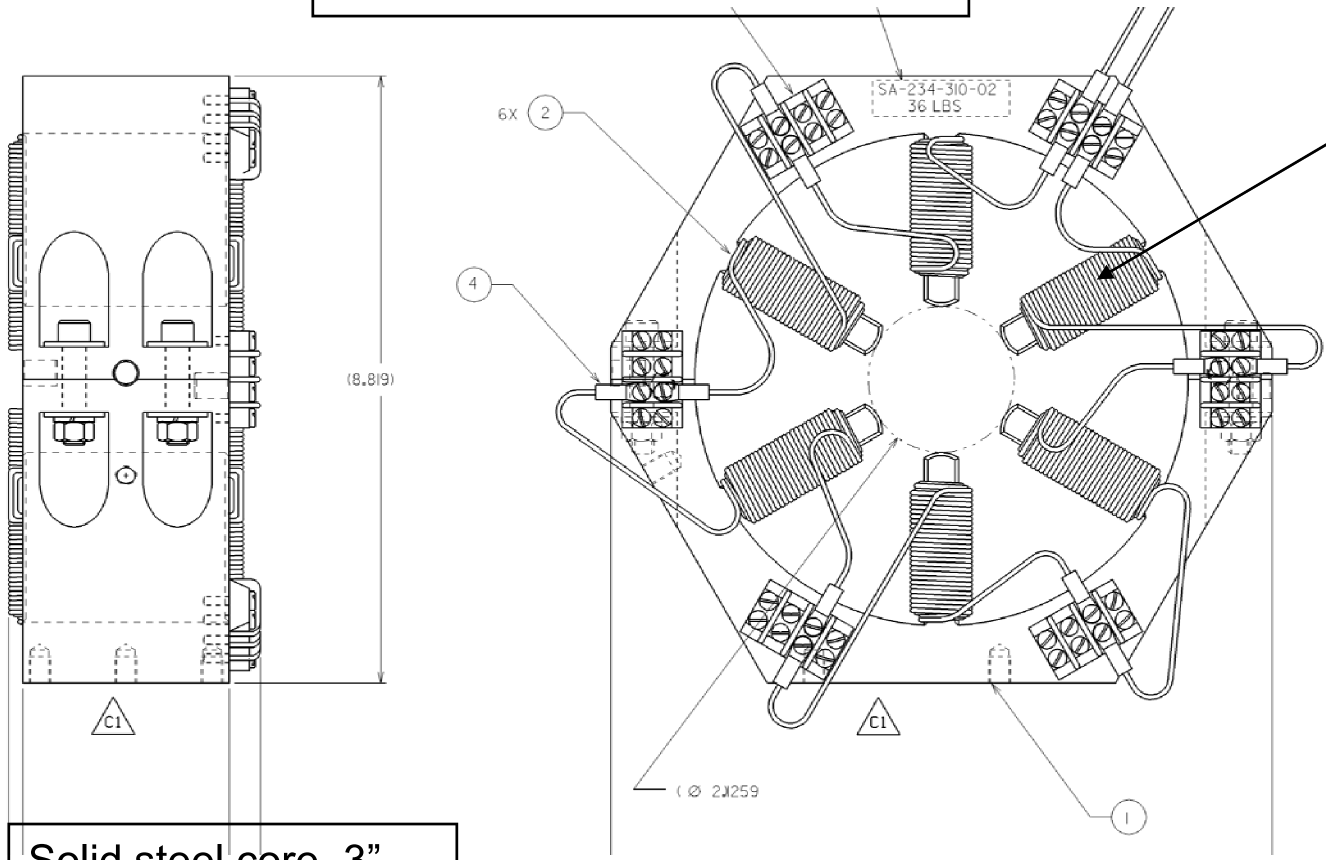
CHOICE FOR FD sextupoles: Old FFTB sextupole "2.13SX3.00". Two were in ATF extraction line, then removed as not needed there anymore.

Bore diameter: 2.1259" = 54mm



Solid steel core, 3" long = 76.2mm

#14 round solid wire coils, 3 layers, 87 turns total. Previously ran this sextupole at 8 amps and measured how hot they and rest of magnet got- see next slides.

From old mag mst estimate about 3.6A for SF1 and ~6.5 A for SD0 to reach required ∫S.dl

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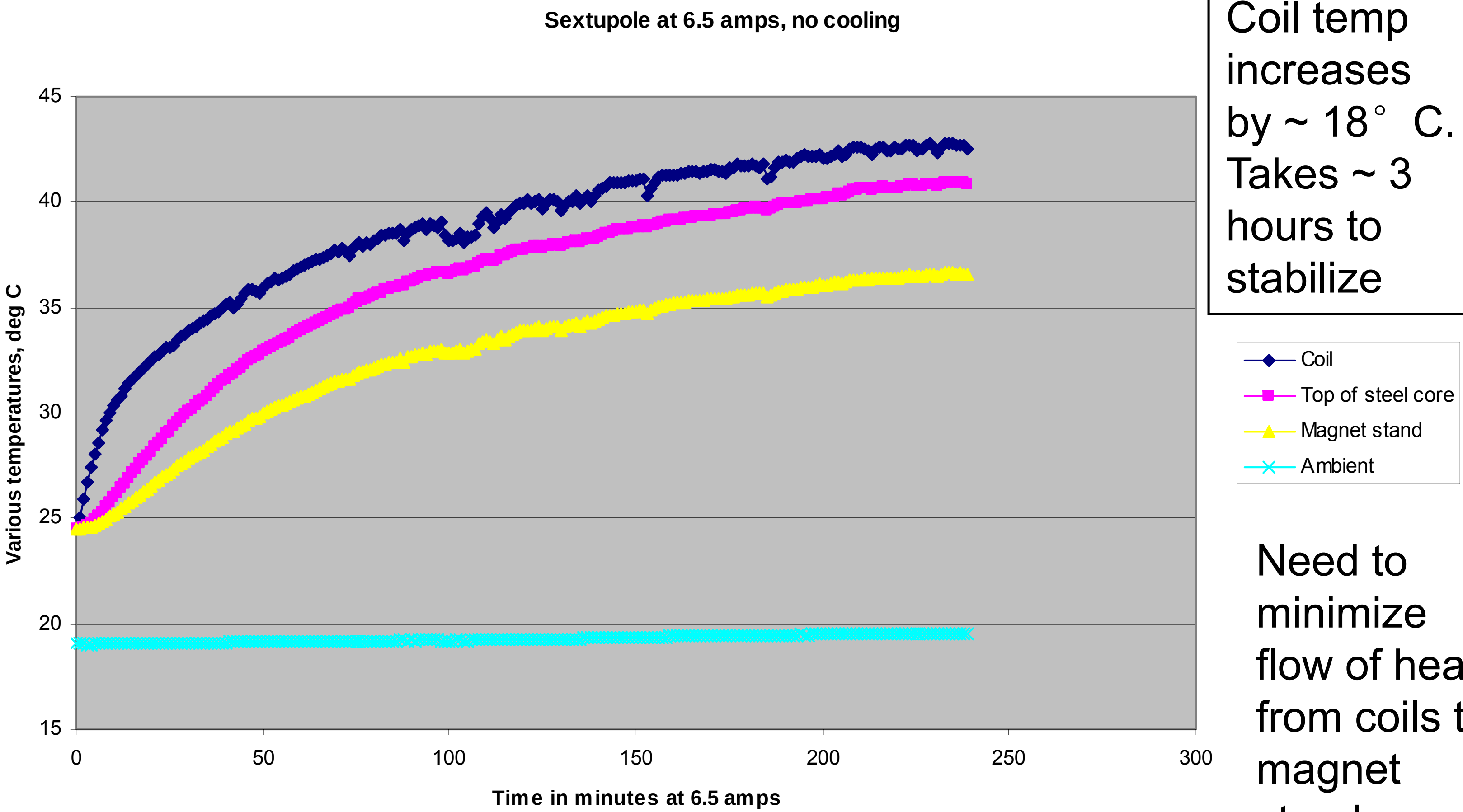
Old FFTB sextupole running at 6.5 amps



Coil temp increases by ~ 18° C. Takes ~ 3 hours to stabilize

Need to minimize flow of heat from coils to magnet stand

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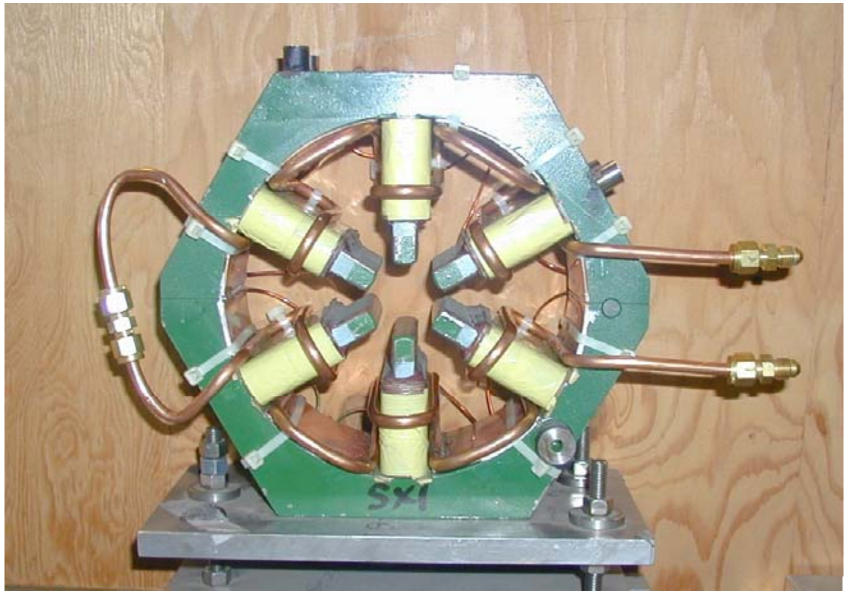
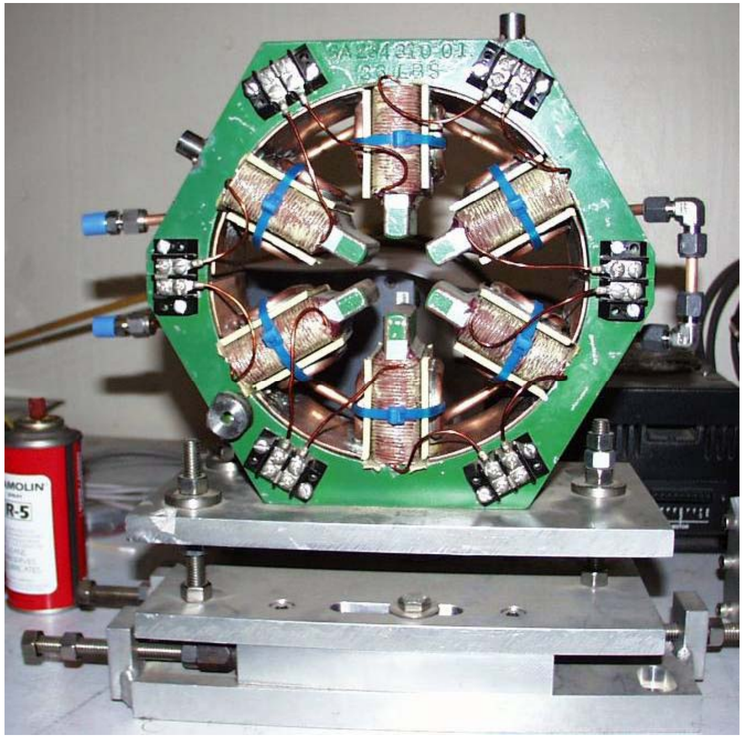
Added external cooling: copper pipes and some copper plates



The cooling circuit is one assembly and it all slides into the magnet from one side.
The circuit can be split into 2 separate parts when the magnet is split.



2nd version: copper plates on sides of coils, under copper pipes

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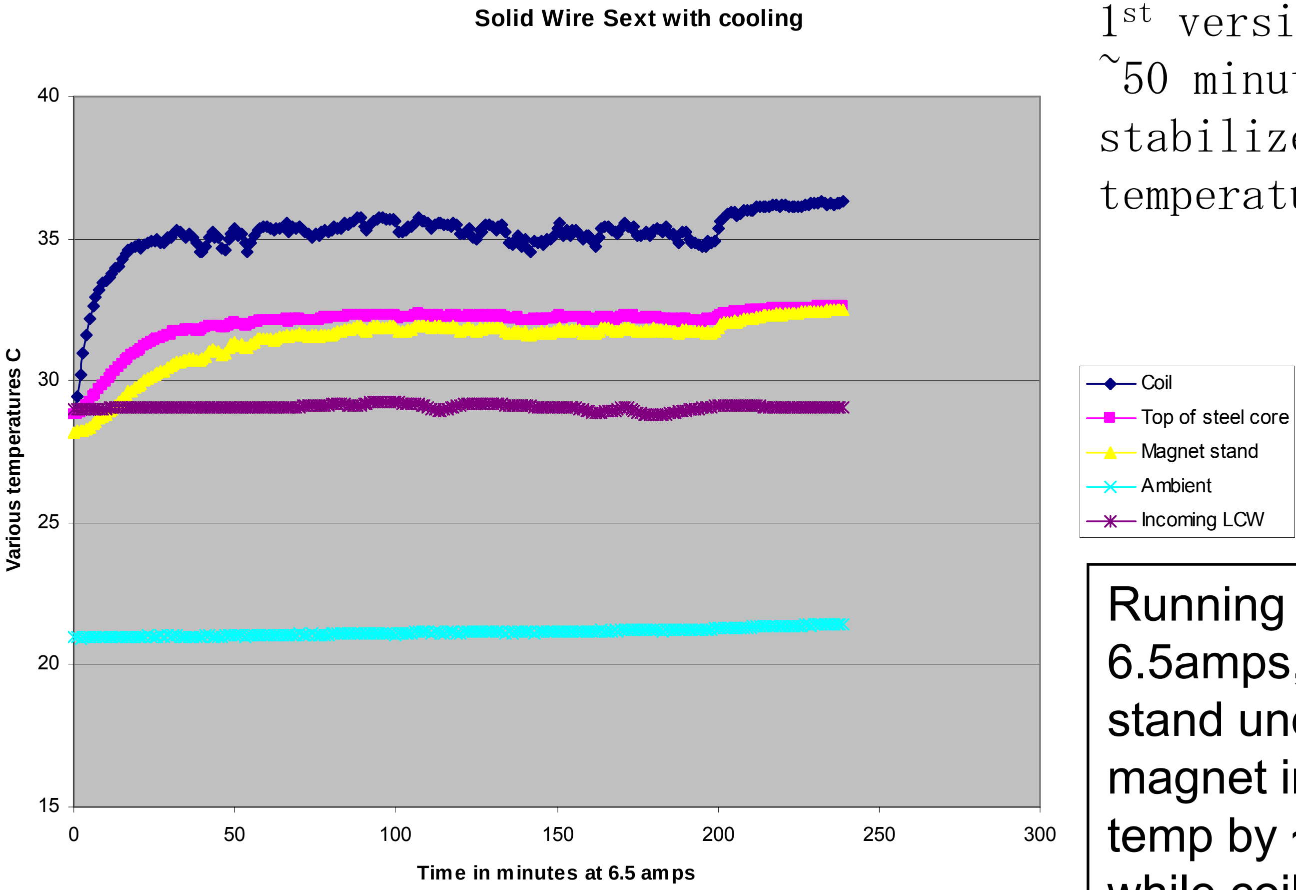
Have loops of copper tubing pressed onto coil surfaces & copper sheets on inside of outer core ring. ~ 1gpm LCW passing thro' loops

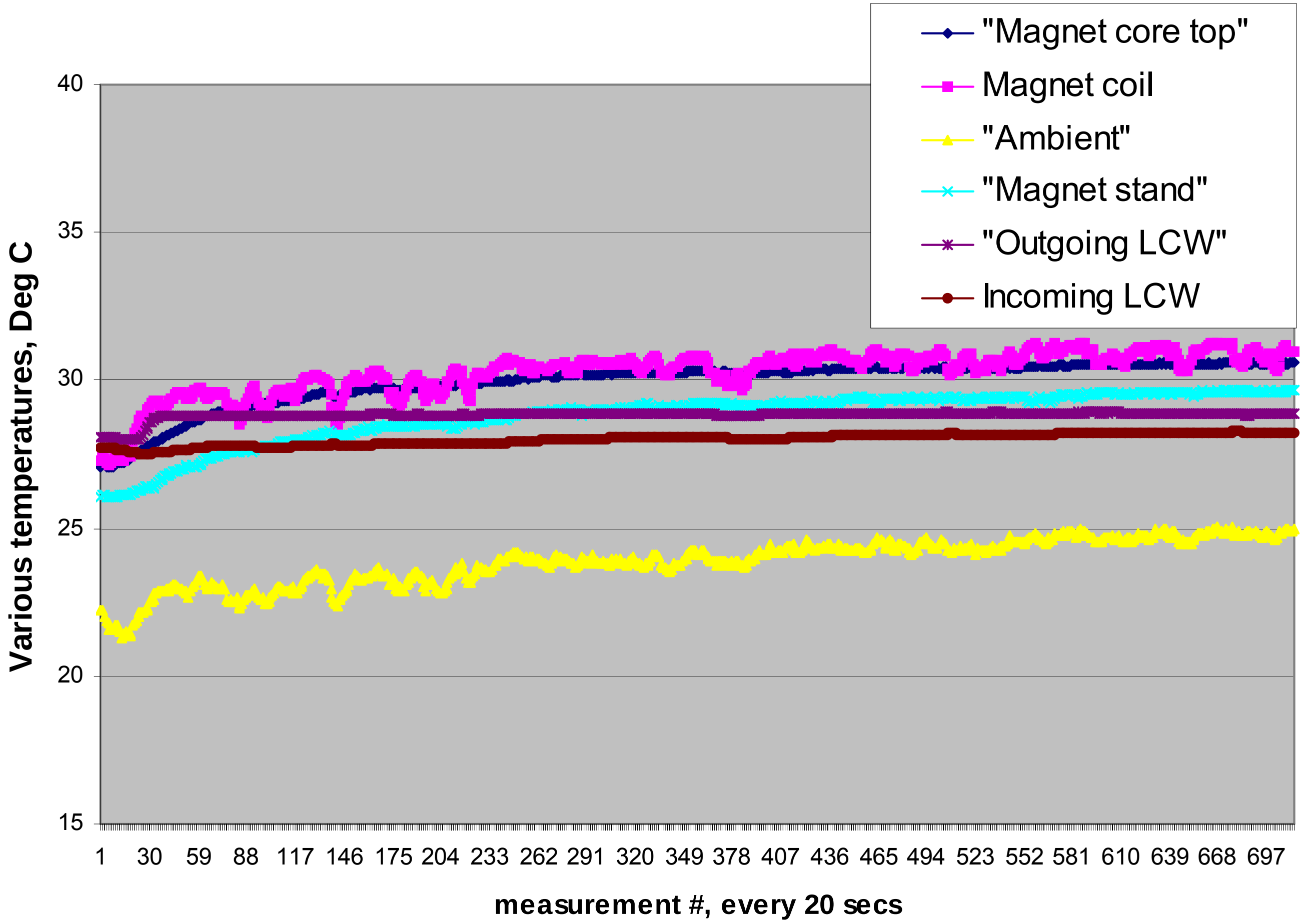


1st version: took ~50 minutes to stabilize temperature

Running at 6.5amps, magnet stand under magnet increases temp by ~3° C while coil increases by ~7° C

2nd version : more cooled plates

Solid wire sextupole, with improved cooling plates, run for 4 hours at 6.5 amps



Temperature stabilizes in about 30 minutes

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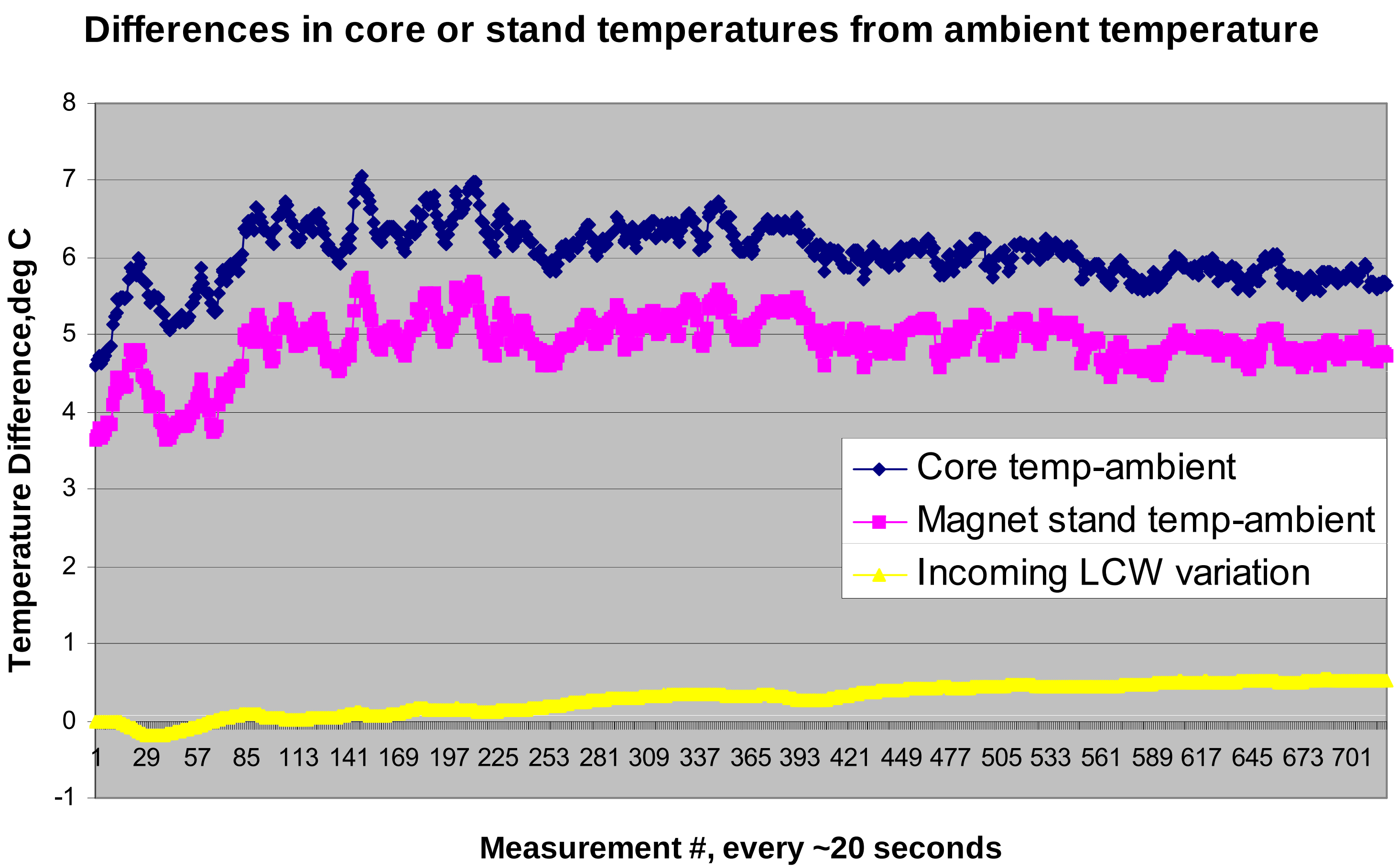
Ambient temperature was increasing during test, so subtract ambient and re-plot



Core & magnet stand temps increase by < 2 C over 4 hour run at 6.5 amps

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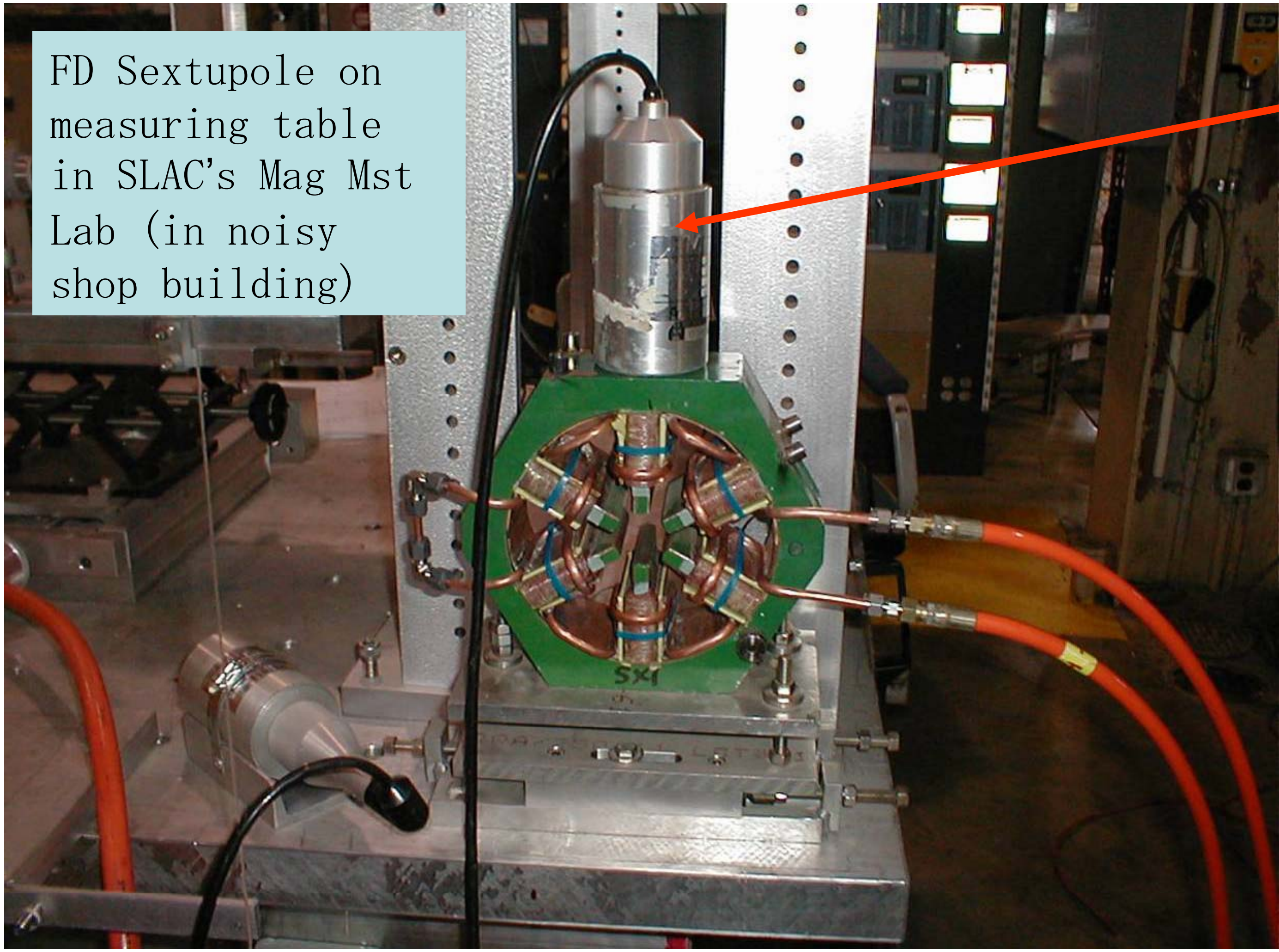
Vibration measurements : to see affect of cooling water (only)

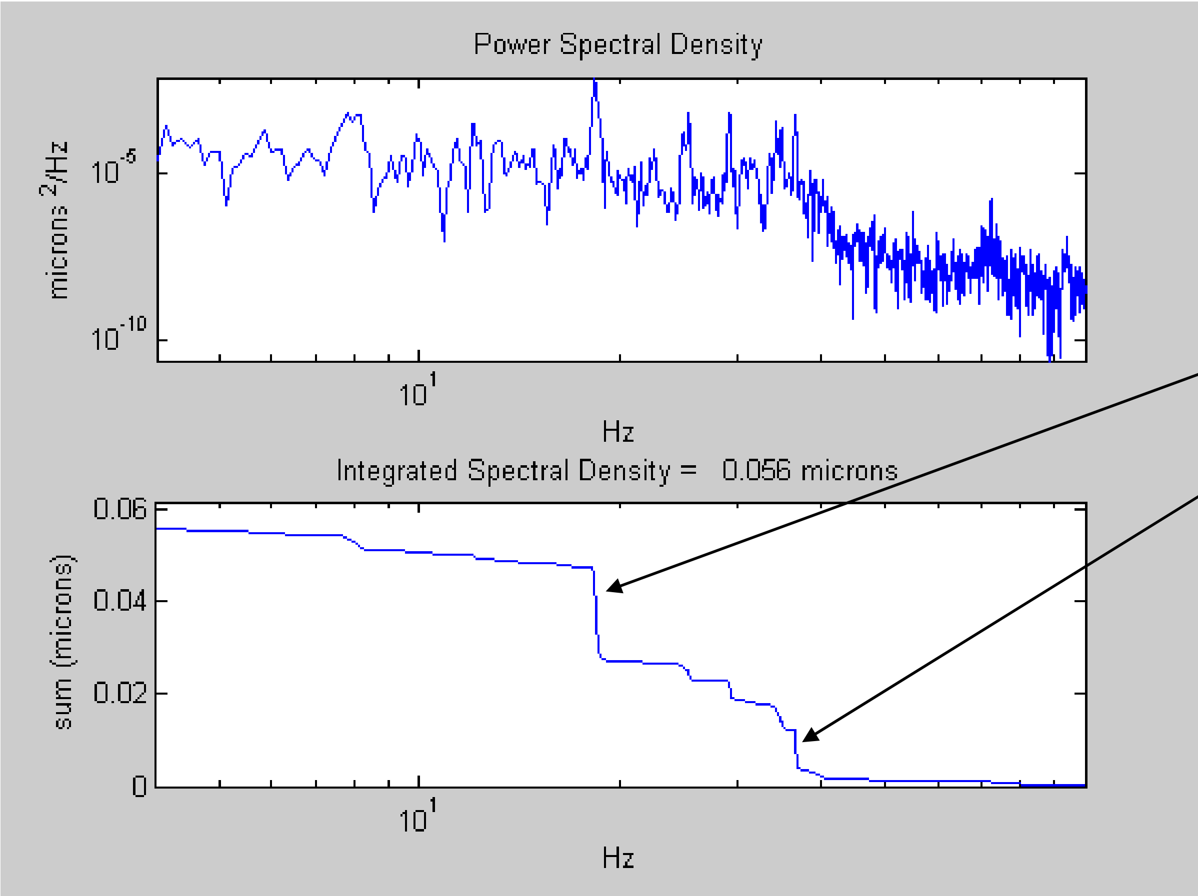


MarkL4 geophone.

Measures vibrations between 4 and 100 Hz.

Took data for 16 seconds: water off and then water on at required flow rate.

FD quad measured with LCW off . Hoses are connected to water system.



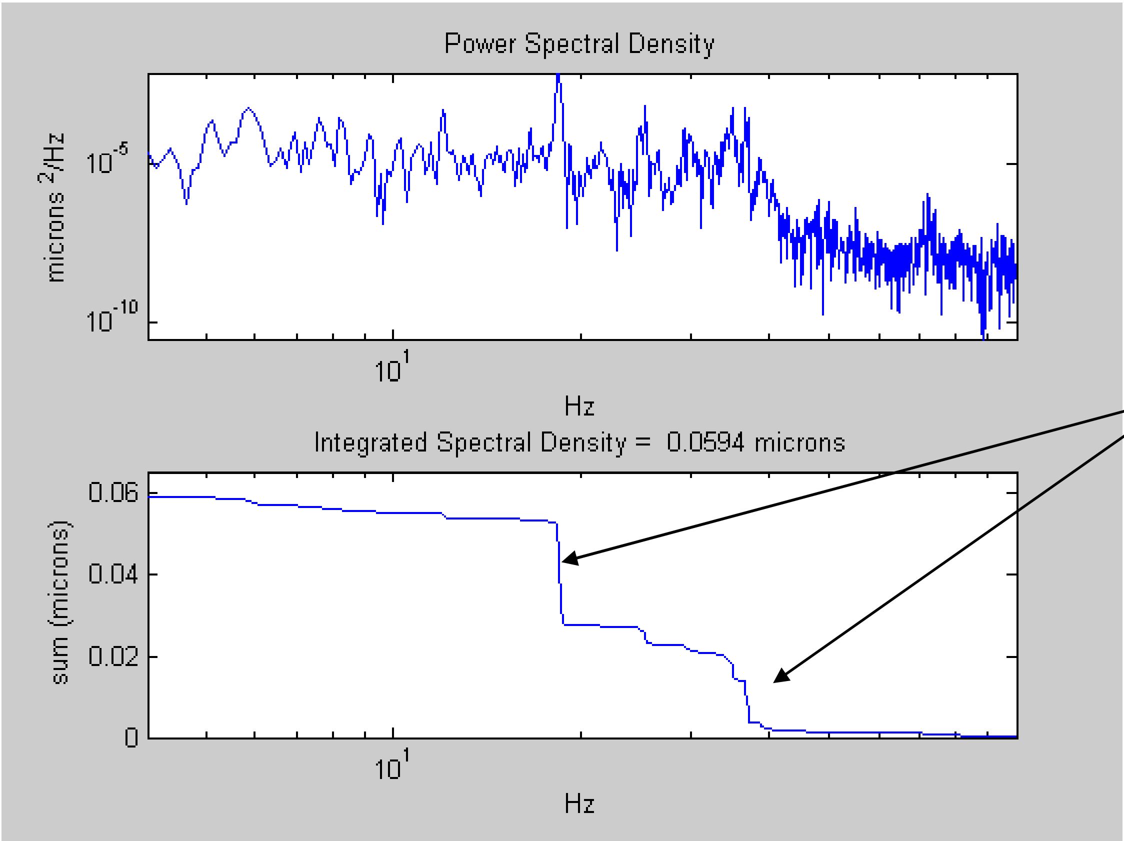
Overall vertical "movement" is 56 nanometers.

Noticeable frequencies are ~19 Hz and ~ 33 Hz

ATF2

Magnets

FD quad measured with LCW on at 2.8 gpm total. Similar data for sextupole



Measured vertical "movement" is 59.4 nanometers.

A 2nd measurement showed 54 nm with water on.

19Hz & 33Hz oscillations are there.

Later- measured the large table under the quad- it had 19Hz effect. So the 33Hz signal was present for both quad & sextupole, water On and Off.

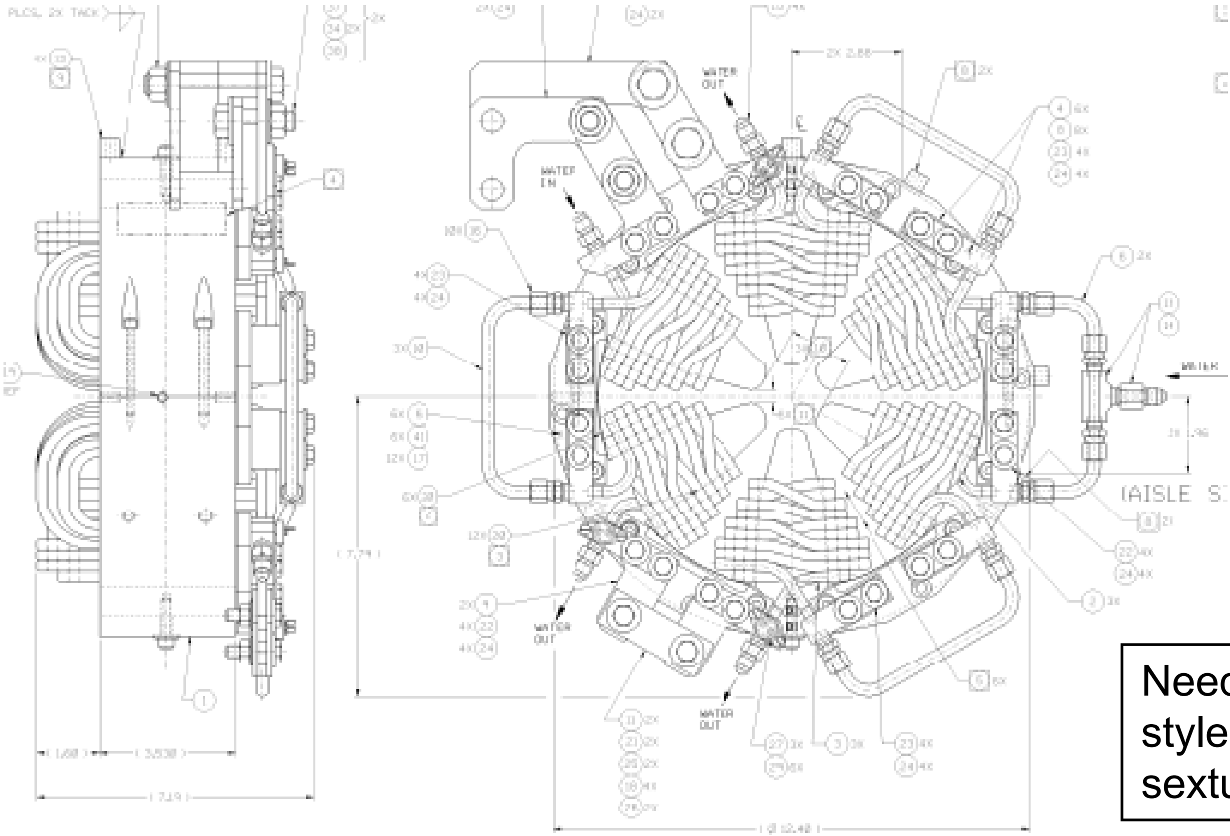
Style of existing SLC FF sextupole, 4 of which acquired (with much effort) for the ATF2

Style name= 1.625SX3.53

Bore diameter= 41.28 mm

Core length =89.66mm

26 turns of 0.255" sq hollow Cu conductor per coil



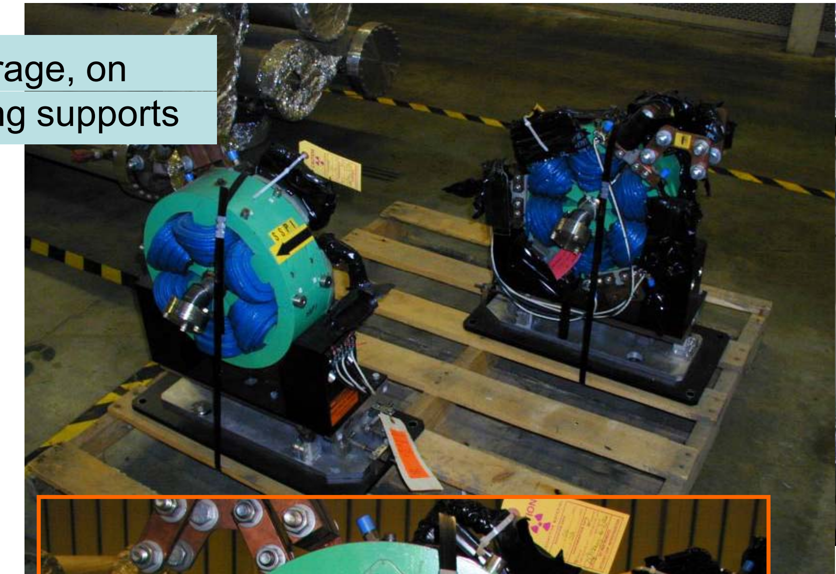
Need 3 of this style for FF sextupoles

ATF2

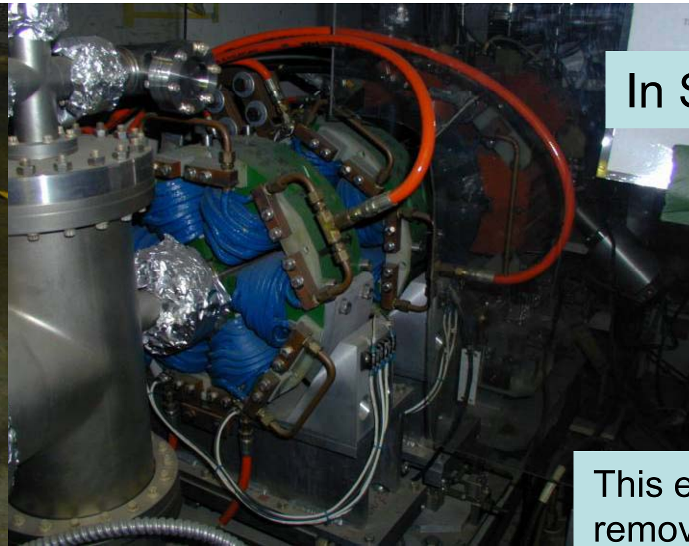
Magnets

Photos of the SLC "SX3" style sextupoles we will be using for ATF2 sextupoles

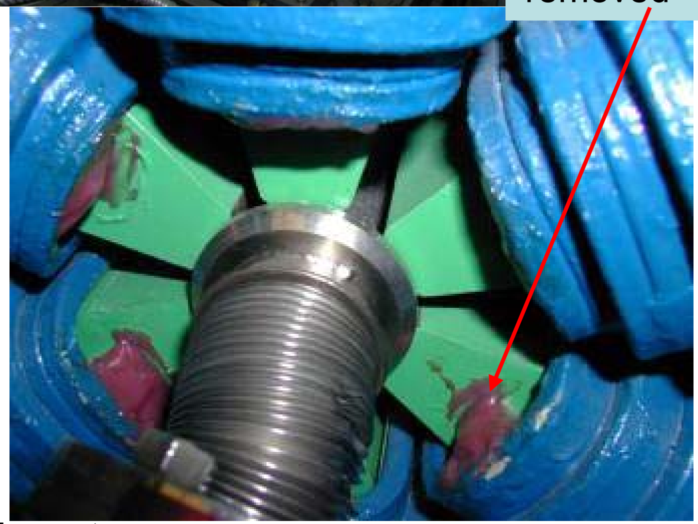
In storage, on existing supports



In SLC FF



This epoxy will be removed



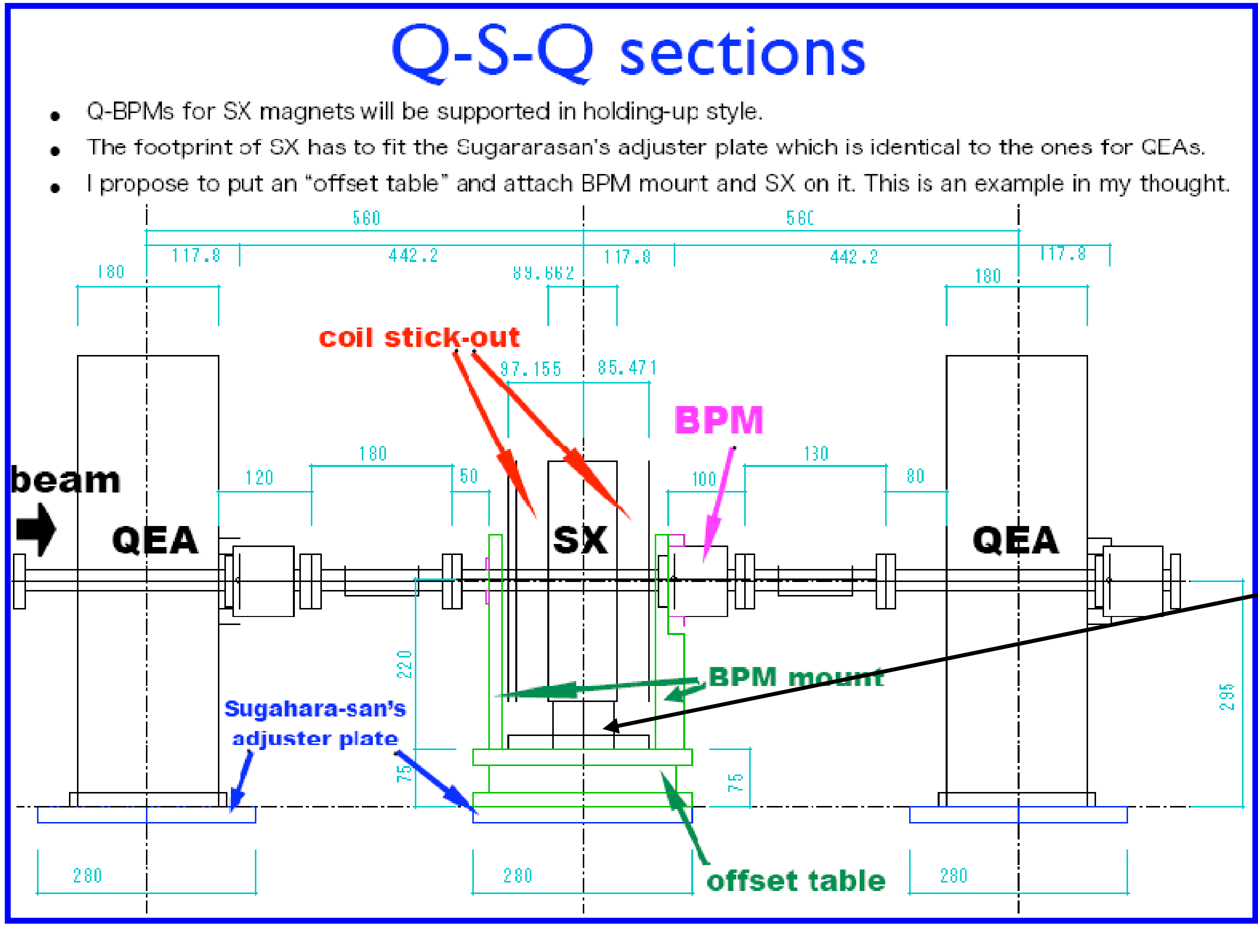
Remaining Issue with the FF sextupoles

- The 3 magnets for the FF sextupoles do not need any modification- will be refurbished and re-measured.
- But their existing supports do not fit in with height of concrete block etc
- A special adaptor will be used to match the BPM to the sextupole’s end. BPM has to be held up too.- see next slide

ATF2

Magnets

Proposal from Honda-san in August 2007



Honda-san proposes to make the green items.

This leaves some support under the sextupole to be designed and made-represented by these black lines here. We will discuss how to proceed tomorrow.

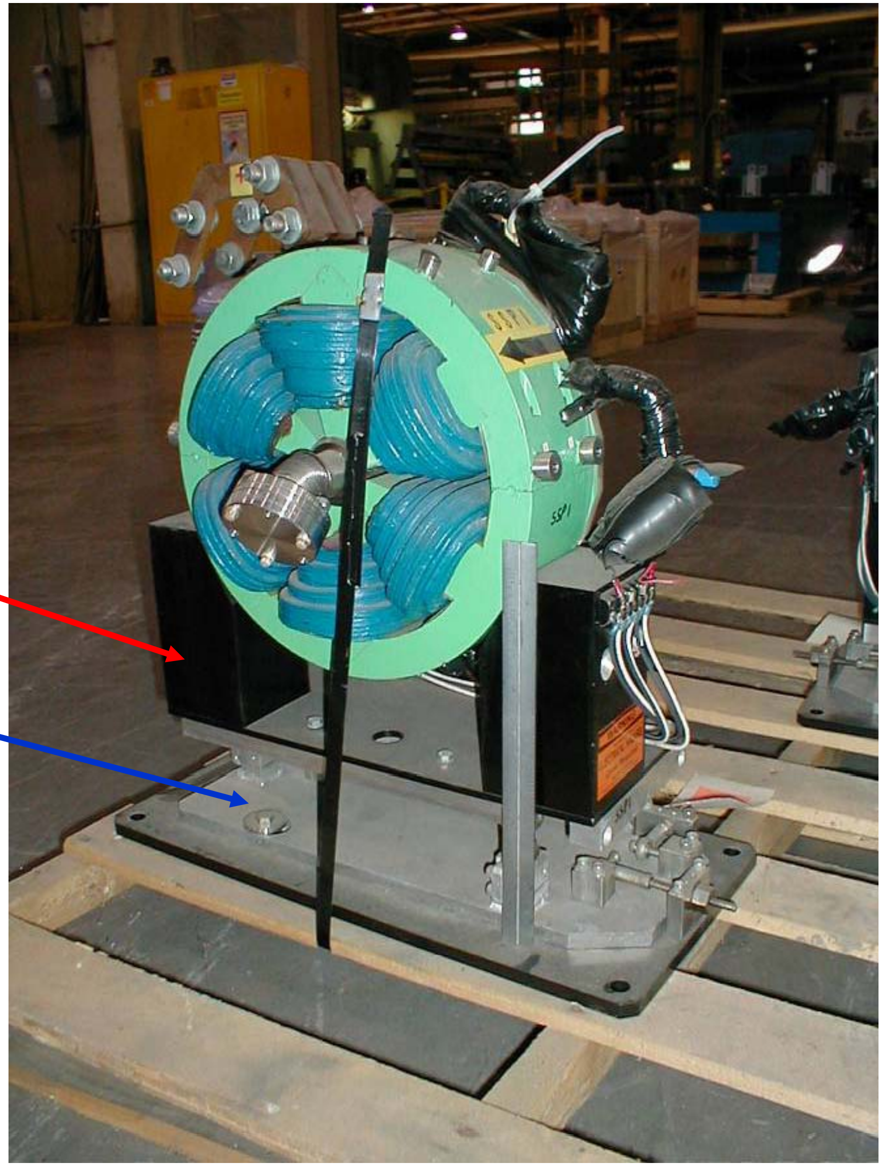
ATF2

Magnets

This is a spare sextupole waiting to be re-furbished for ATF2.

This support is too tall.

This T1 support will not be used



ATF2

Magnets

Remaining issues we are working on

- Extra supports for FD quads and FFD sextupoles to get them to correct beam height- LAPP will design and fabricate
- Alignment procedures for all the “re-used” magnets – have been working with Sugahara - san on procedure to use existing SLAC tooling ball installation holes & fiducialization data with the KEK alignment target
- Compatibility of QD0 with MONALISA