Design of Various ATF2 MAGNETS: STATUS REPORT to ATF2 Project Meeting, KEK, May 30th 2006

Cherrill Spencer, SLAC
Member of ATF2 Magnet Team

ATF2

Magnets

ATF2 Magnet Styles to Be Designed & Fabricated

- 14 final focus quads + 6 matching section quads + 8 extraction quads
  - All made from one design, called "QEA", design completed last summer
  - 28 magnets + 1 spare been fabricated by IHEP, Beijing. Being measured at IHEP and KEK: Masuzawa will report on their measurements in this session
- 5 final focus sextupoles - in design, need your feedback on my design suggestion
- 3 final focus bends - in design, need your feedback on my design suggestion
- 2 final doublet quads – design has been chosen
- 2 final focus octupoles – need to get requirements!

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FF sextupoles: requirements

- K2L values provided , bore aperture > 32mm, suggested effective length 0.2m
- K2L = (Gradient´ x L eff) / (B x rho)
  - (B x rho) of 1.3 GeV beam = 43.3633
  - Gradient´= (2 x B at poletip) / (bore radius)^{2}
- Names of 5 sextupoles: SF6, SF5, SD4, SF1, SD0
- K2L values range from 0.84 to 14.34
- Look for existing sextupoles to use to save time and money. K2L values can be satisfied with variety of Leff & radii
- Have found 2 styles of existing SLC sextupoles. Designed & made by me in 1993 for the final focus optics upgrade of SLC.

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Suggested design for SF6,SF5,SF1 & SD0

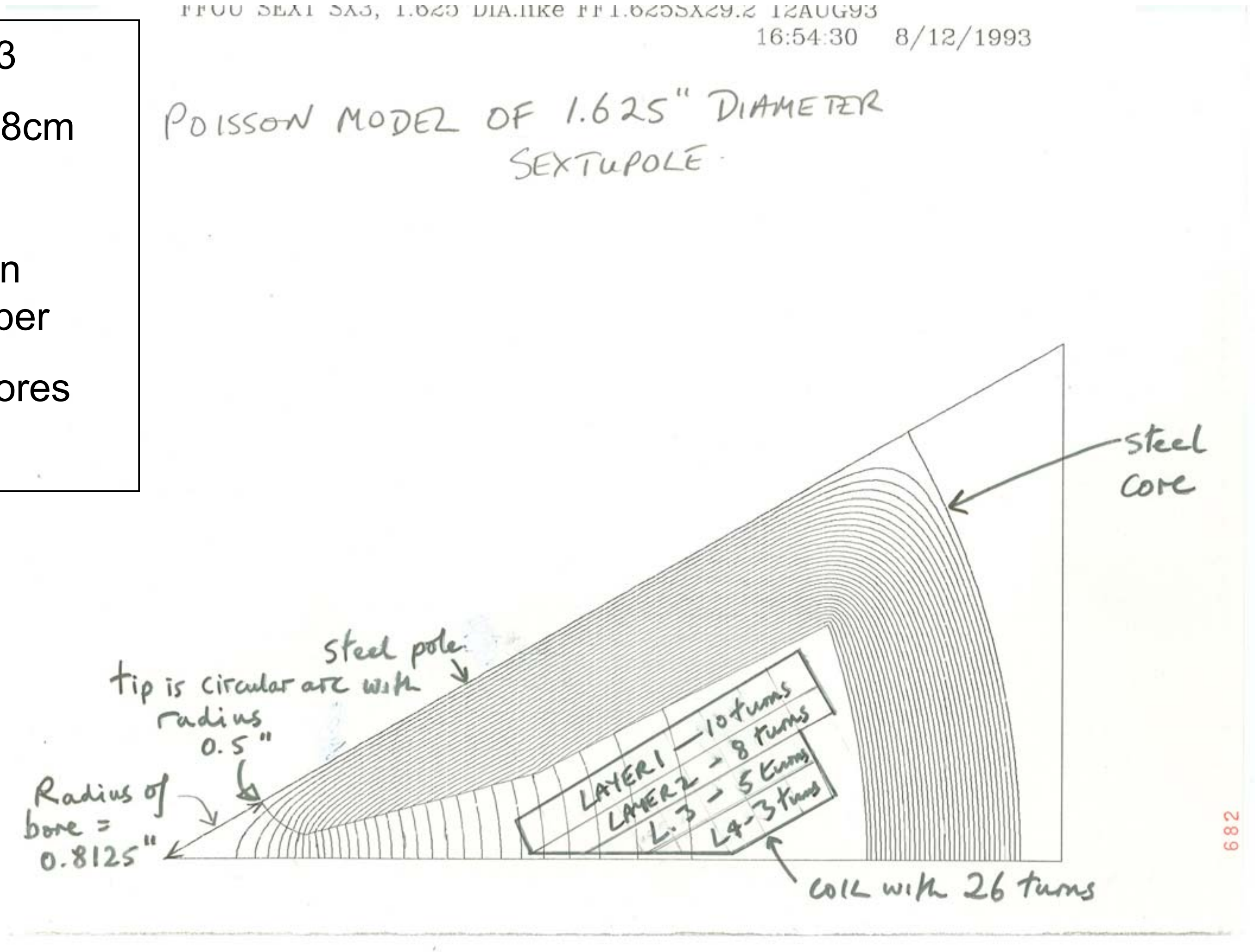
"SX3" : 1.625SX3.53

Bore radius = 2.0638cm

L eff = 0.1m

Water cooled 26 turn coils, 0.255"sq Copper

Solid C1008 steel cores



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Suggested design for SD4 (strongest ATF2 FF sextupole)

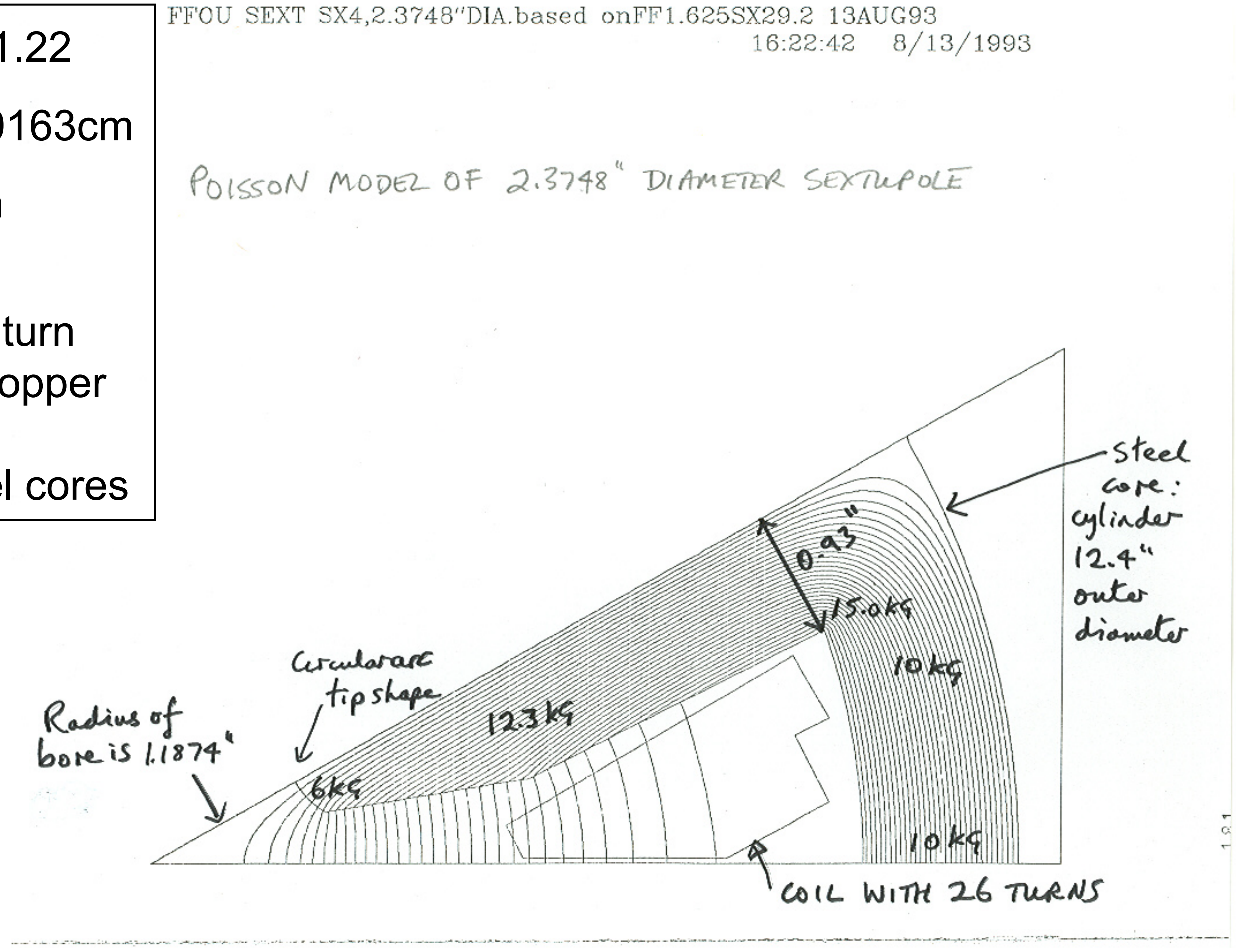
“SX4” 2.375SX11.22

Bore radius = 3.0163cm

Eff length = 0.3m

Water cooled 26 turn coils, 0.255”sq Copper

Solid C1008 steel cores



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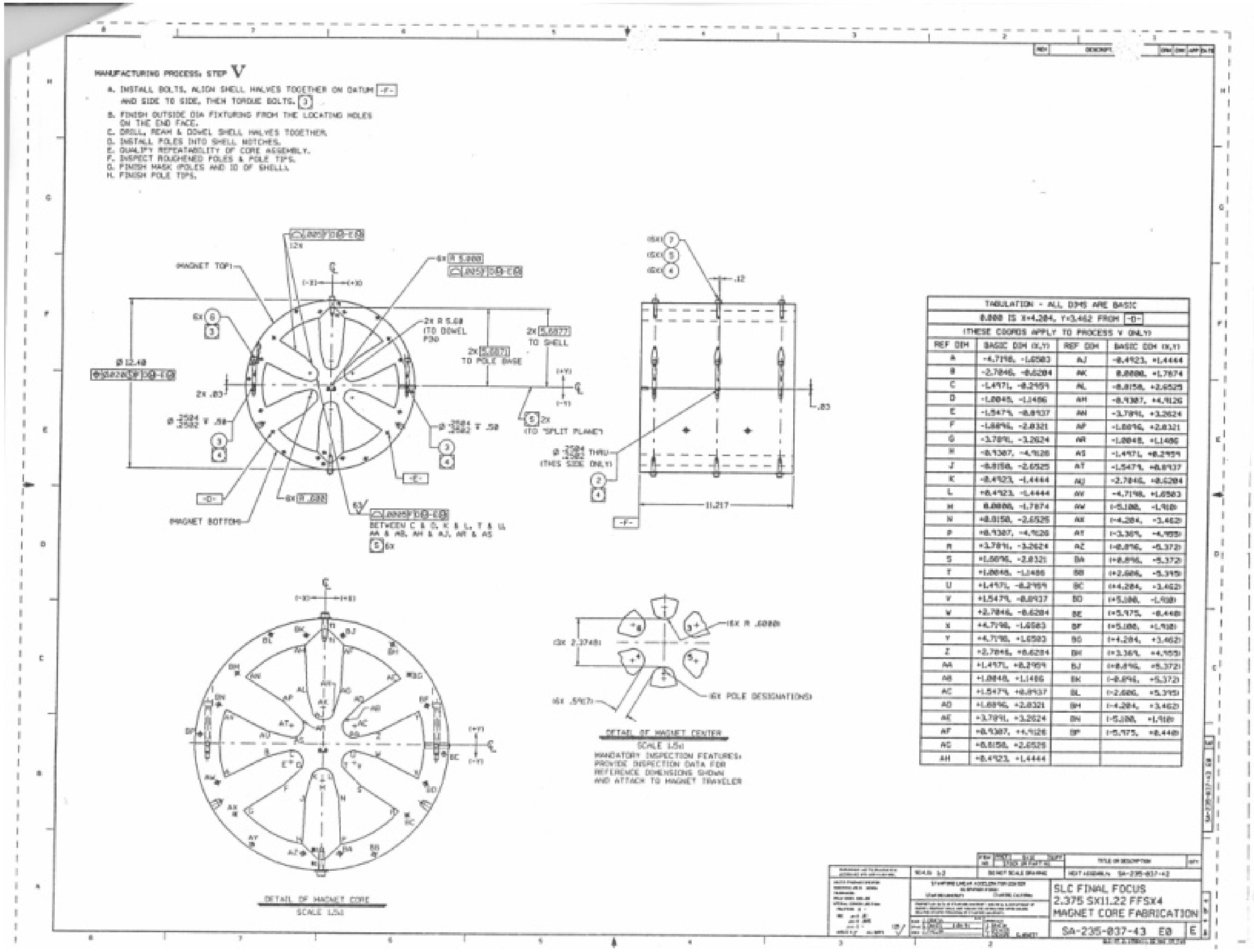
Solid steel sextupole core: tight tolerances on steel machining leading to low multipoles



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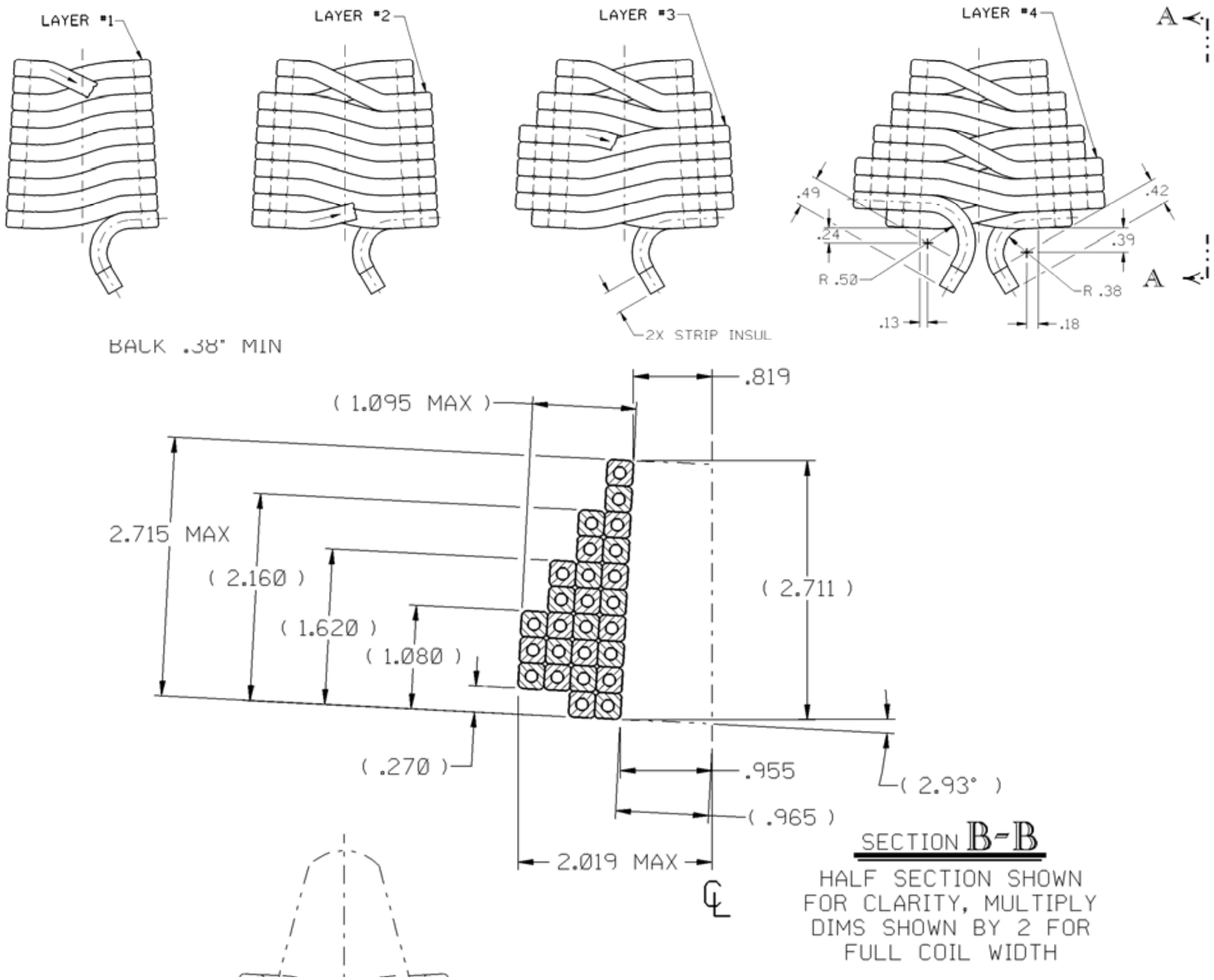
26 turn water cooled coils, can run up to 195 amps



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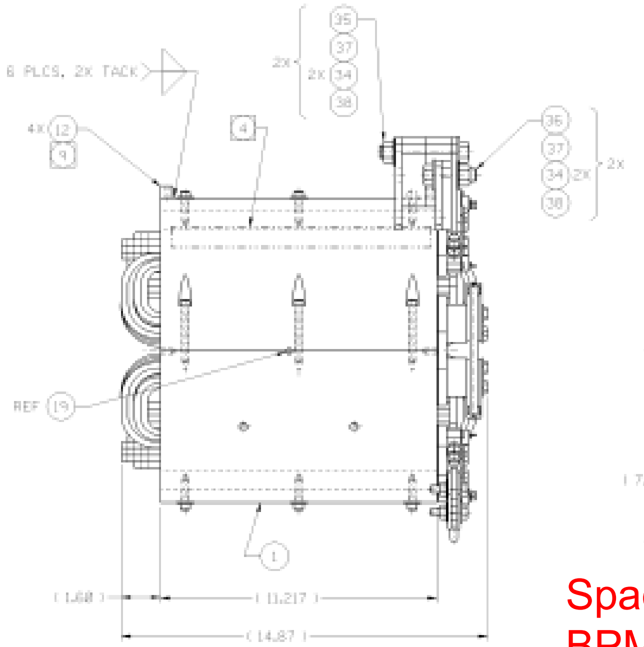
Assembly drawing of “SX4” style.

SX3 has similar profile, overall length is 18.26cm

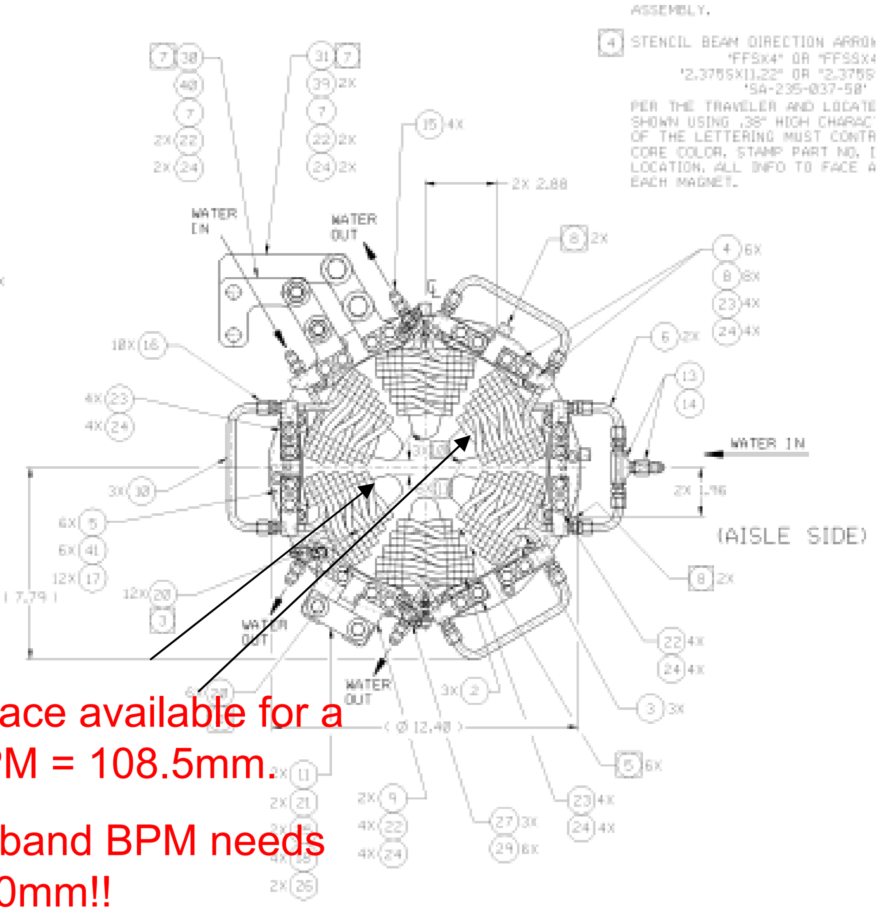
Magnet Weights: SX3 ~ 56 kg

SX4 ~ 146 kg



Overall length 37.85cm

BEAM DIRECTION



Space available for a BPM = 108.5mm.

S band BPM needs 190mm!!

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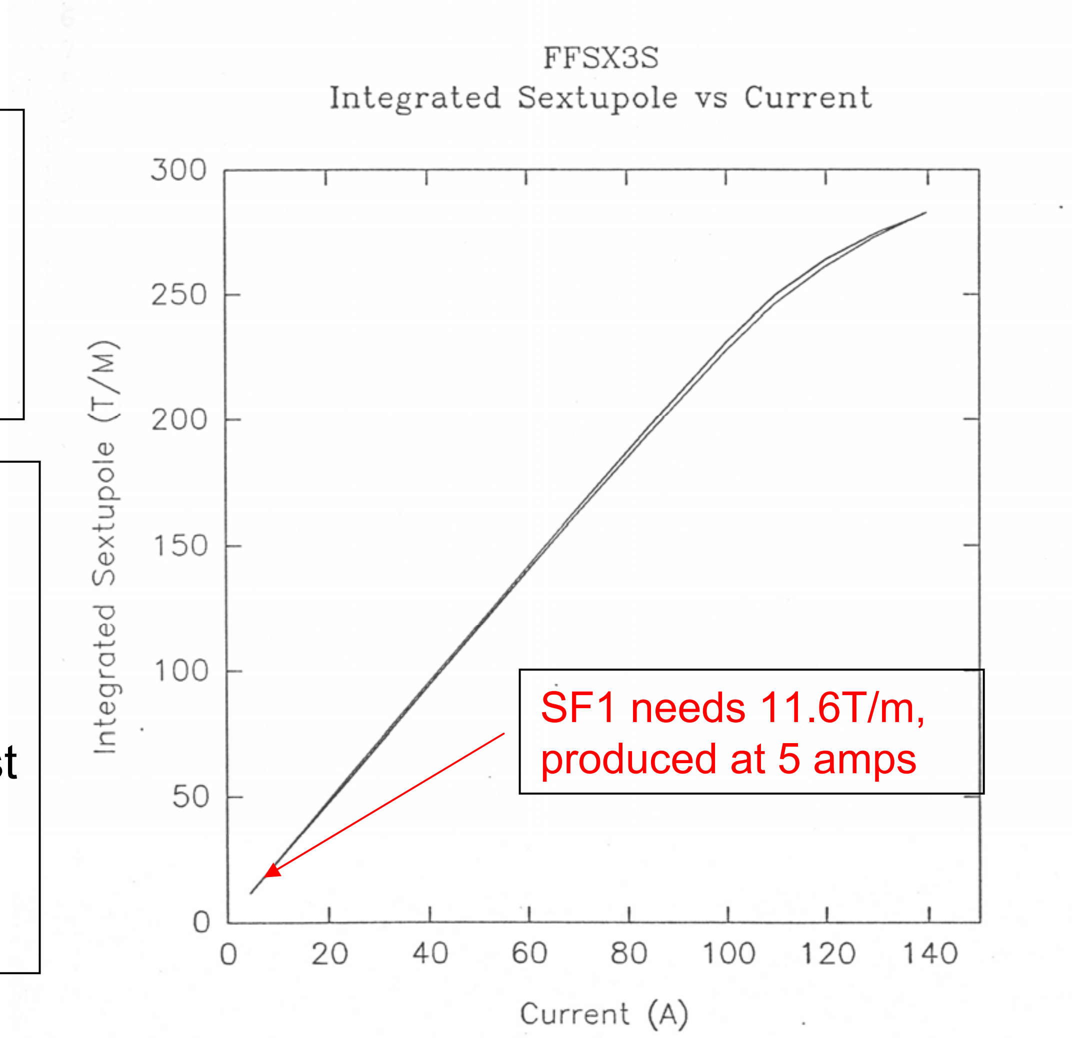
Magnets

Measured strength of SX3: used in a 55GeV SLC beam line.

Integrated gradients of the SX3 style can reach much higher than we need at ATF2

4 SX3 and 4SX4 magnets exist- sitting, unused in the SLC final focus.

I have made request to take 4 SX3 and 1 SX4 magnets- waiting on the reply



Implications of required strengths using existing SX3 and SX4 magnets

- Scaling down to ATF2 required strengths: the currents needed for 4 shorter sextupoles range from ~1.7 to 15.6 amps. Resistance of SX3 = 0.033 ohms, so voltages range from 0.056 to 0.5 volts. Do these I and V needs fit in with power supplies being considered?
- SX4 style used for SD4 : 30 amps & 2 volts.
- If these voltages are too small, we can change the coils for new design with fewer turns and smaller conductor (higher resistance/m). Even so, voltages still small: 0.4 to 1.2 v, and currents range from 3.4 to 31 amps.
- Need to decide if can use these old magnets or not.

Multipole tolerances for the sextupoles. Comparison with actual multipoles.

- Do the suggested old SLC sextupoles meet the multipole tolerances? Were all measured at SLAC in 1993 by rotating coil system
- What are the multipole tolerances? Table 3.7 in ATF2 proposal gives list, some ambiguity in units.
  - 18 pole is first allowed multipole, table 3.7, normal component at r=1cm: 18-pole/6-pole =0.306; 8-pole/6 pole= 0.0066
- SX3 data, measured at 1.535cm, scaled to 1 cm
  - highest octupole/sext= 0.002 at 1cm: OK
  - Highest 18-pole/sext = 0.0002 at 1cm : OK
- SX4 data, measured at 1.535cm scaled to 1cm
  - Highest octupole/sext = 0.0016 at 1cm : OK
  - Highest 18-pole/sext =0.00006 at 1cm : OK
- Conclusion: Multipole tolerances MET (need to check table 3.7)

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Requirements for the 3 FF bends

- B1,B2 and B5 (B3and B4 disappeared!)
- Integral B.dl with 1.3 GeV beam   Sextupole/dipole at 1cm, 2% beam blow-up
  - B1 1.881 kG-m $<1.2 \times 10^{-3}$
  - B2 1.513 kG-m $<2.62 \times 10^{-4}$
  - B5 2.215 kG-m $<2.55 \times 10^{-4}$
- Suggested effective length = 0.8m
- Suggested full gap >=32 mm
- In order to save time and money I have searched for existing magnets (none) and existing design with full set of drawings: found a PEPII injector dipole

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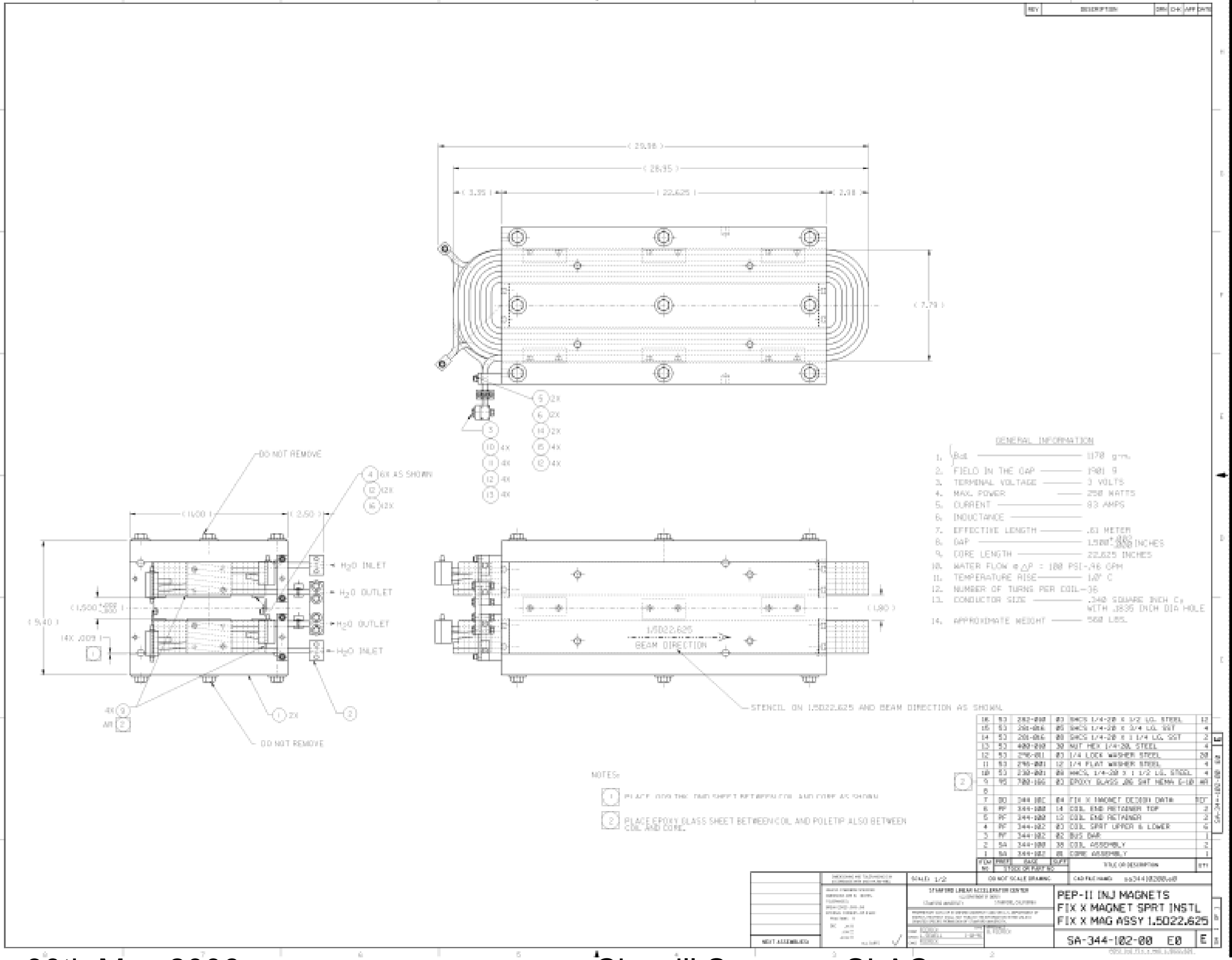
Suggestion for the FF bends: ”1.5D22.625”, use the PEPII drawings. Will have to build 3 dipoles.



Eff. L = 0.61m instead of 0.8m

Gap is 38.1mm instead of 32mm

Overall length = 73.5cm

Integrated strength range is acceptable

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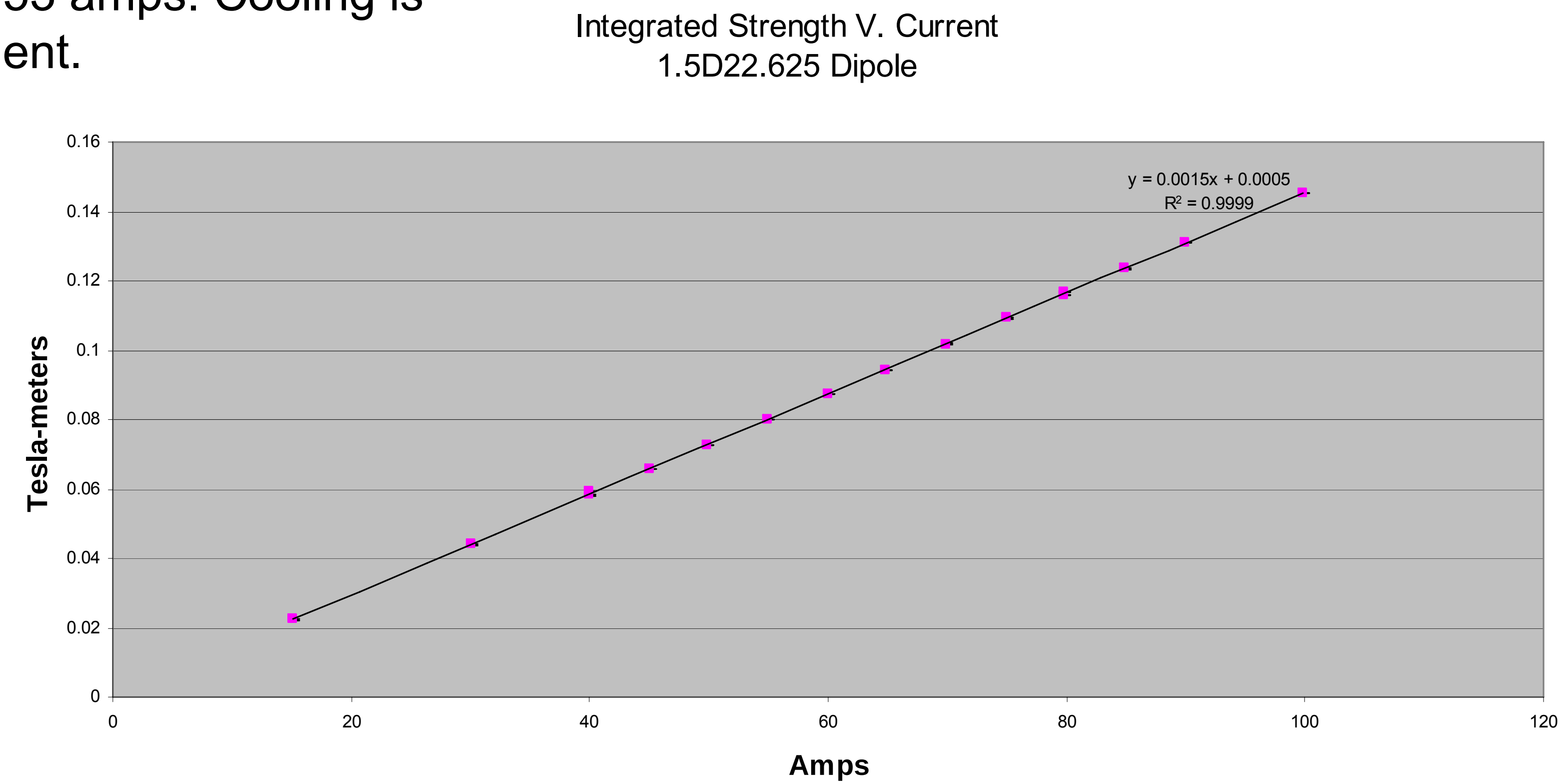
Measured integrated strength: up to 100 amps, but can be run at higher currents

Range of currents needed: 104-153 amps. Cooling is sufficient.



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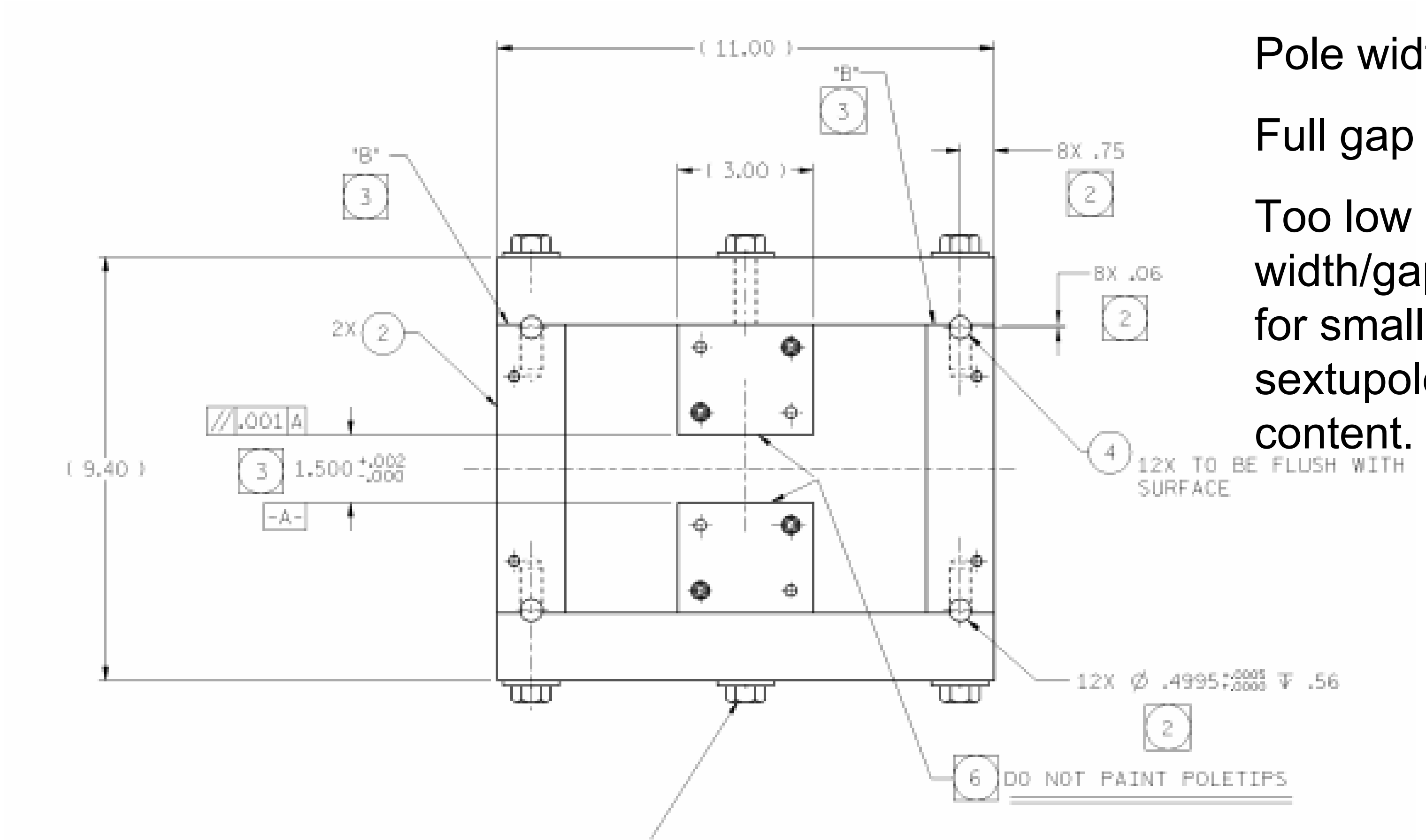
Does this design meet multipole tolerances? Look at measurements.



Pole width = 3”

Full gap = 1.5”

Too low width/gap ratio for small sextupole content.

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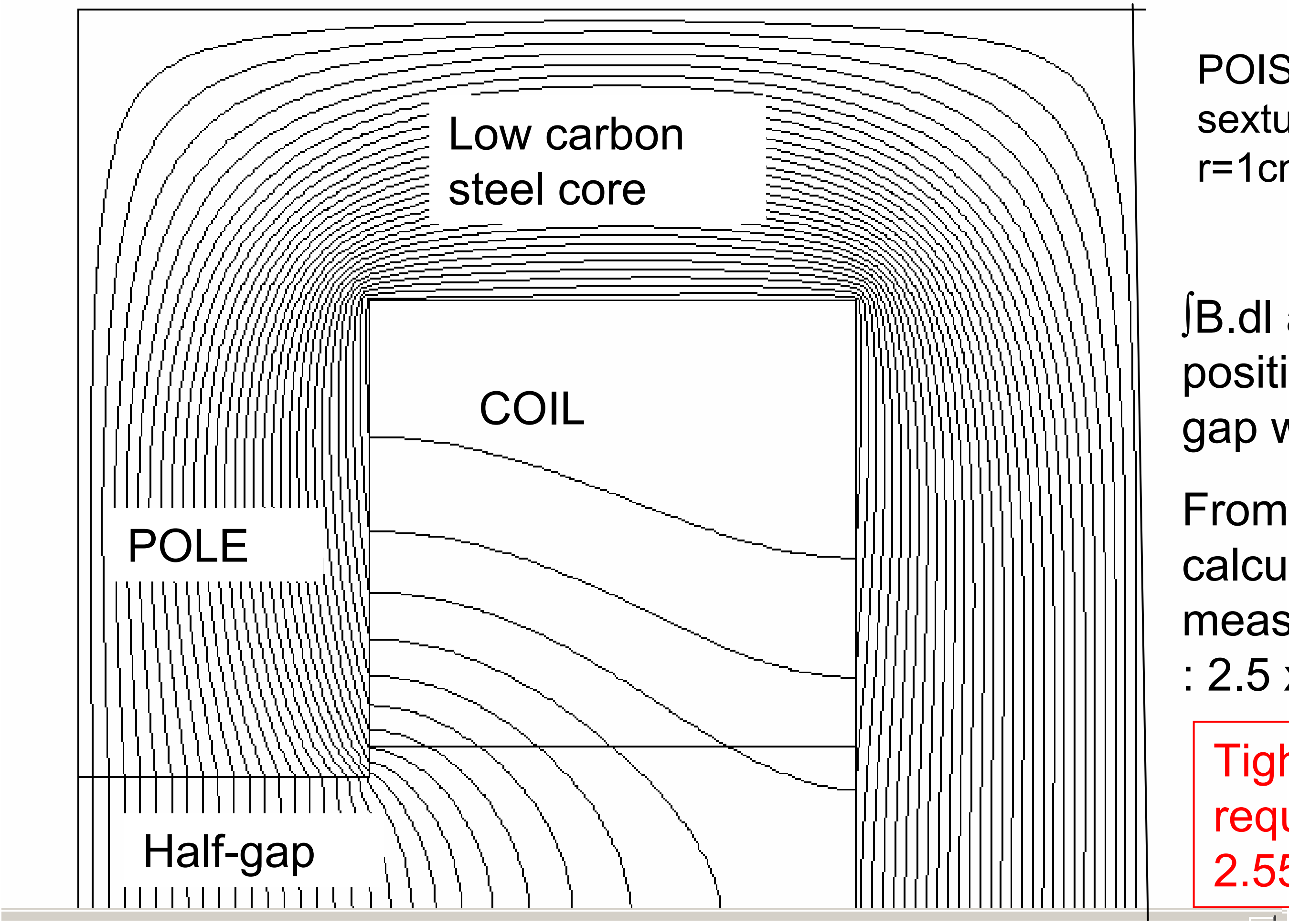
2-D POISSON model of this dipole. Top right-hand corner modeled



POISSON predicts sextupole/dipole at r=1cm : 1.52×10^{-3}

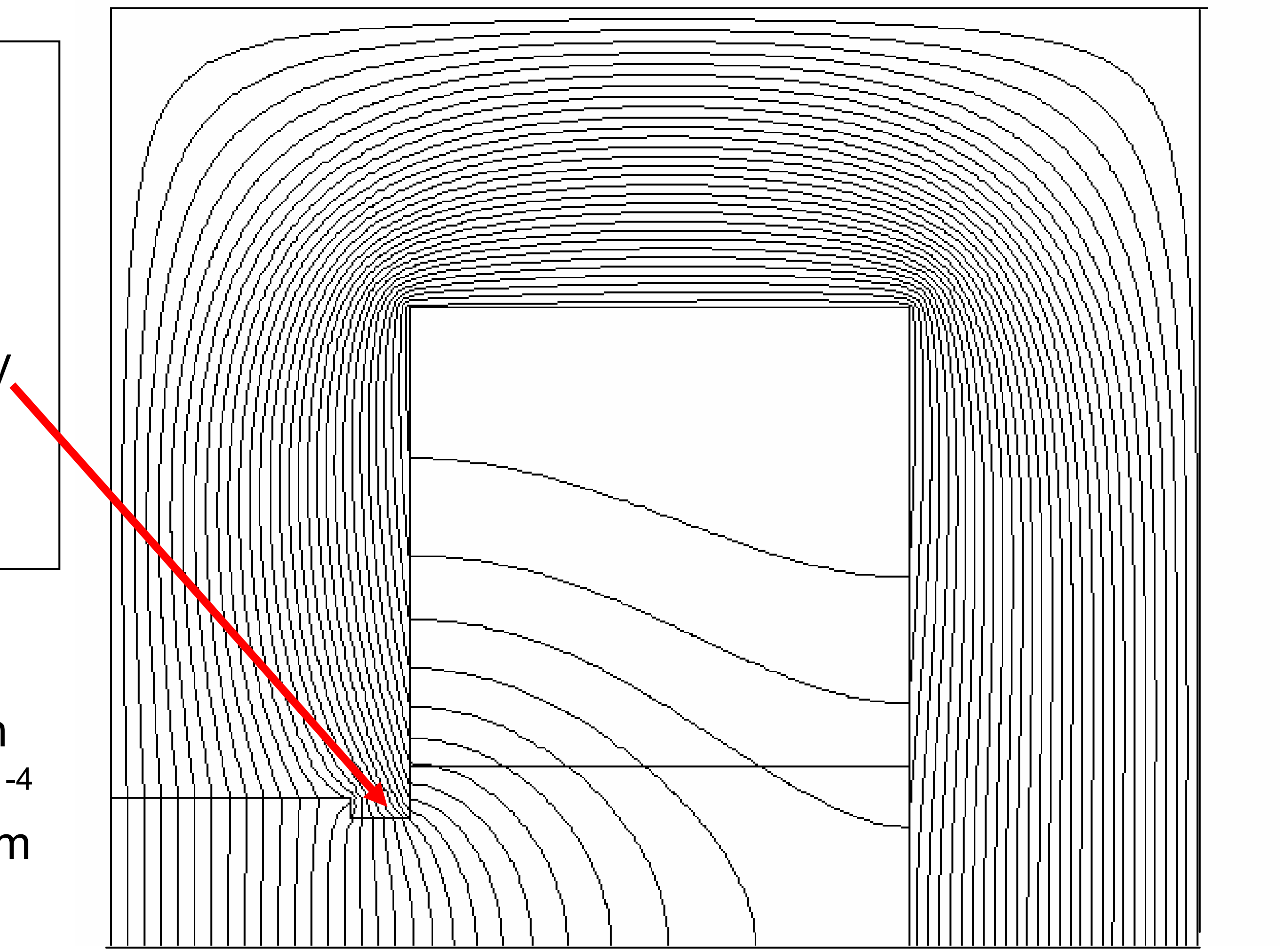
∫B.dl at many X positions across the gap were measured.

From this data can calculate the measured sext/dipole : 2.5×10^{-3} at 1cm

Tightest sext/dipole requirement is 2.55×10^{-4}

Sextupole is ~ 10 times too large: try modifying ends of poletip to reduce it

Add a small shim at end of poletip and see effect on sextupole content: tried 3 different shapes (on Saturday last) and not yet found one that reduces sextupole.



I think the poletip is just not wide enough to reach the 2.5×10^{-4} level, there is no shim shape that will help

How to proceed with the design of the 3 FF bends?

- I will try some other pole end shapes- but I am doubtful I can find a shape that reduces the sextupole in such a narrow poletip (compared to gap).
- So, will have to make a new design from scratch– will choose the coil parameters so the power requirements fit in with high-availability power supply concept.

At February 2006 ATF2 project meeting my design suggestion for Final Doublet Quads was accepted

- 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
- QD0 K1= -1.351
- Using the "QC3" style FFTB quad [1.38Q17.72]
- Aperture: 35.06mm diameter ; Eff L= 0.4675m;
- Gradients: QF1: 6.834 T/m; QD0 :12.533 T/m

Two old FFTB quads: 1.38Q17.72. being removed this week from FFTB

- FFTB “QC3” style = 1.38Q17.72. Made in Protvino, Russia, 1991
- Bore = 1.38” = 35.06mm; Core length = 17.72” = 45.009 cm
- Effective length= 46.762 cm
- Water cooled coils, 0.255” sq hollow Cu conductor; Solid steel core
- Maximum current capability: ~320 amps
- Needed for nominal specs: between 70 and 132 amps
- Residual radioactivity is essentially zero

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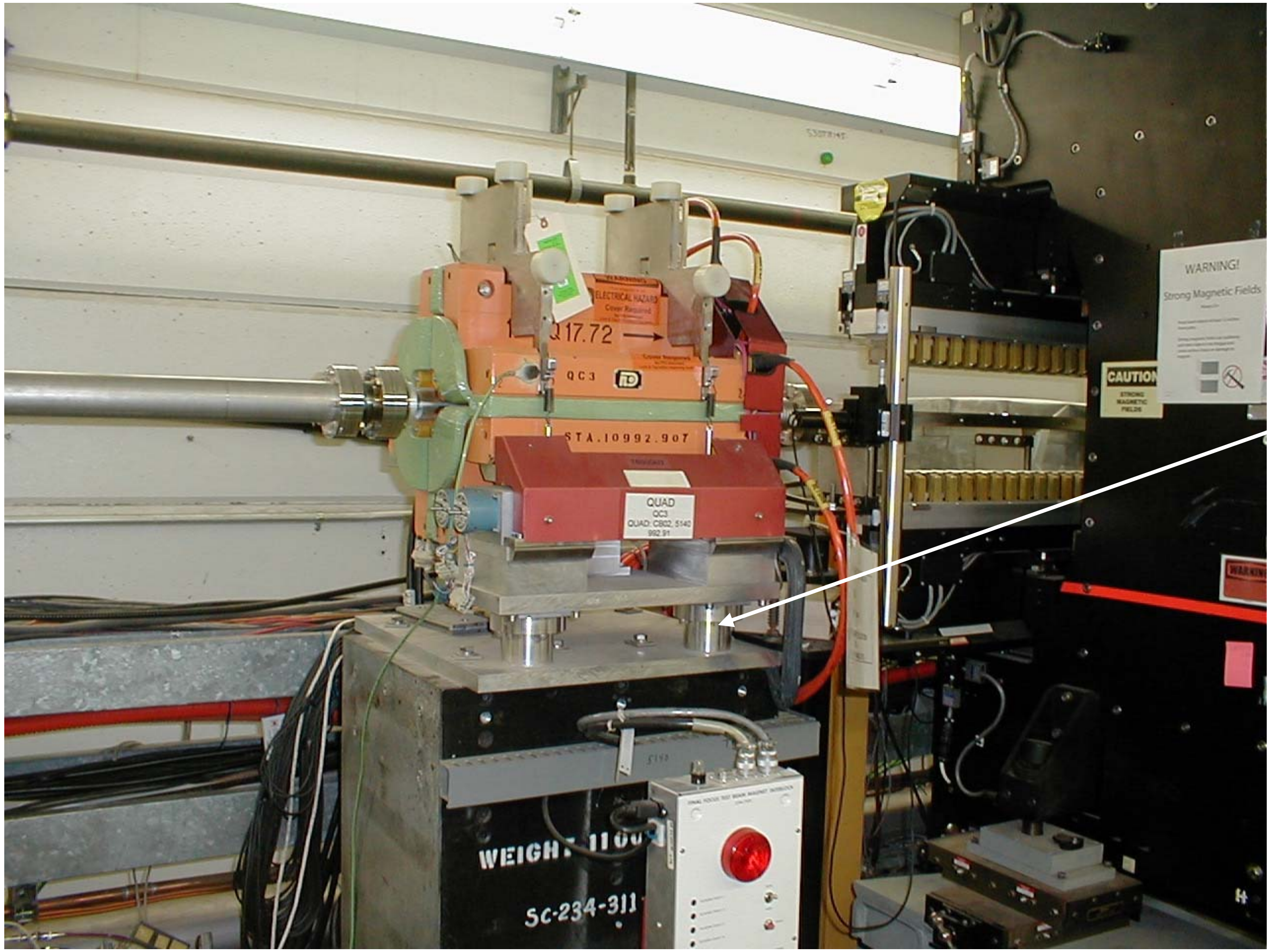
FFTB “QC3” in SLAC FFTB beamline
Sitting on a SLAC magnet mover



This support can be re-designed to be ~8cm less tall, so magnet center at desired height.

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Field quality of the 1.38Q17.72: is it good enough to be an ATF2 final doublet?

- All FFTB quads designed and made in Russia in 1991
- Magnetic measurements made in Protvino, Russia and SLAC
- Sextupole multipole has the tightest tolerance.
- Latest information from Kuroda-san:

  (Normal) Sextupole/quadrupole: <~ 5 x 10^{-4} at radius =10 mm

Sextupole only measured in Russia. I have (in my old folders) data at 250 amps : 2.1 x 10^{-4} at r= 10mm

12 pole measured in Russia and at SLAC.

Tolerance for 12 pole/quad: < 2.5 x 10^{-4}.

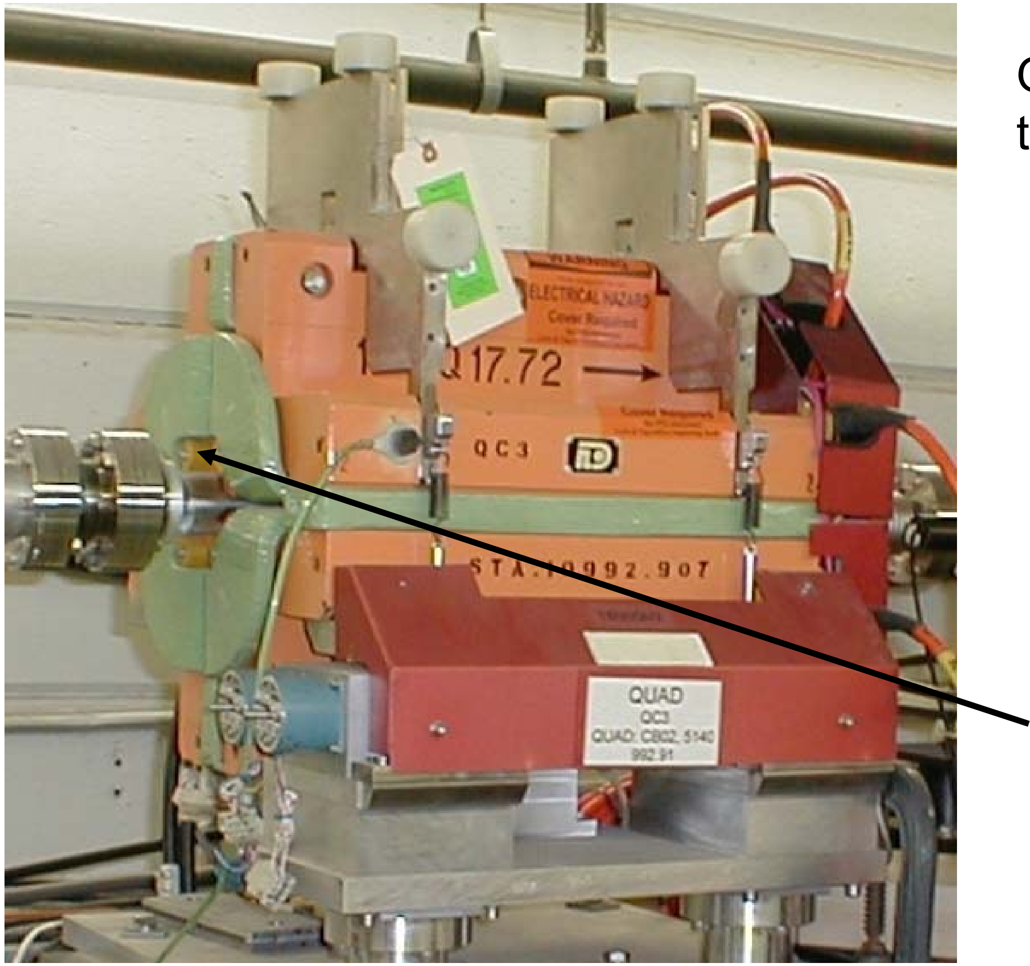
At 189 amps 12pole/quad <~ 4 x 10^{-4} at radius =10 mm

So – field quality looks to be close and will re-measure at SLAC in next few months- try to get the normal and skew components.

What about possible vibrations from water flowing in coils?

- With a delta water pressure of 80 psi (same as other ATF2 quads) the water velocity would be 6.2 ft/sec
- When this quad measured for its vibration in 2000 its water velocity was 8.9 ft/sec and the vibration measured was ~<2nm
- See LCC-0036 Technical Note by R.J.Fenn et al
- So, no concern about extra vibrationd induced by cooling water flow.

Information about physical size of 1.38Q17.72 quadrupole



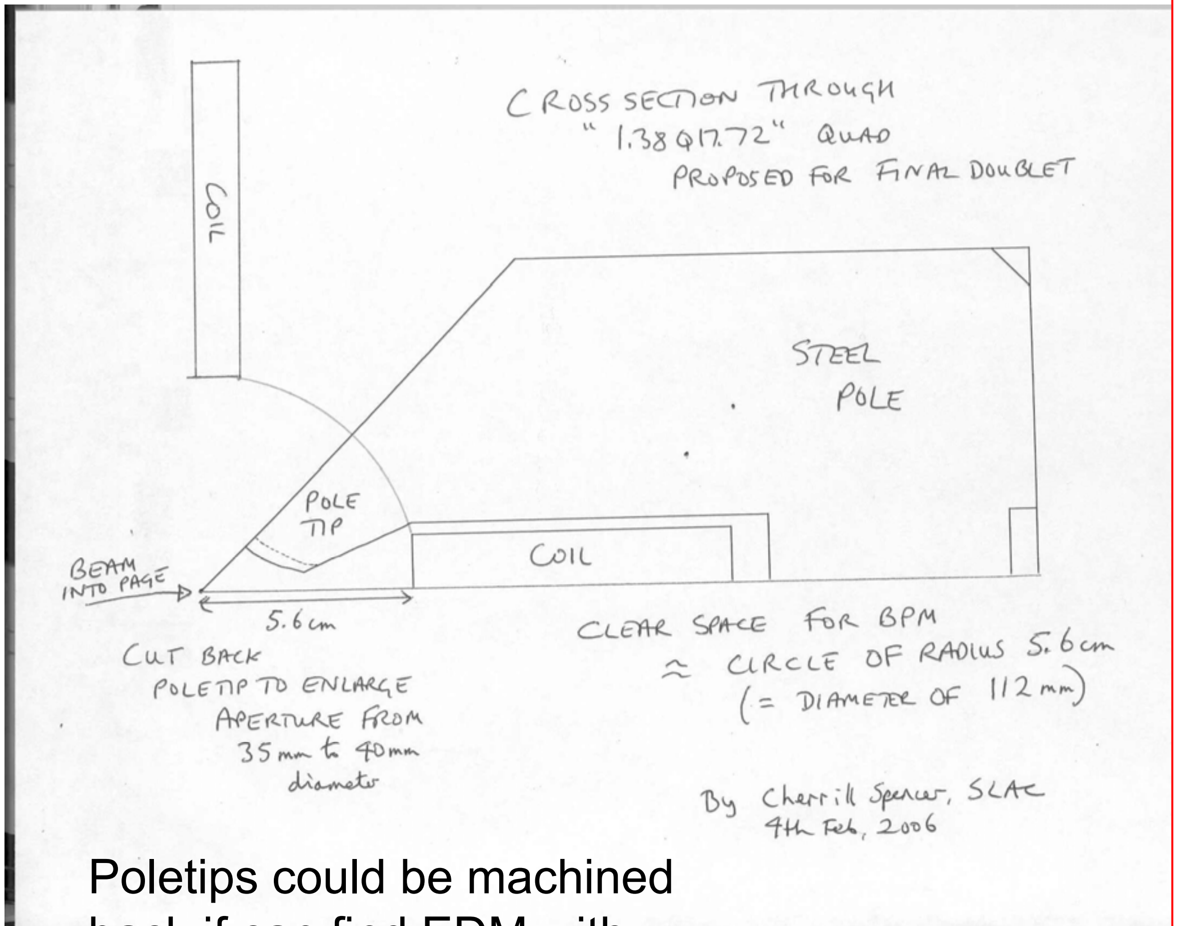
Overall length (including terminals at on end) = 51 cm

Weight of magnet = 400 Kg

Also note– has a set of 4 trim coils; one around each back leg

Look at coil ends- is there enough space for BPM?

Space available for a BPM in the 1.38Q17.72 quad



Poletips could be machined back if can find EDM with >17.8” length capacity

In Feb 2006 understood needed ~110mm clear space for some BPM- could satisfy.

Today I learn a different BPM is being considered which is 190mm – much too large to be attached directly to core end. Can an adapter be used?

Maybe the 35 mm aperture needs to be enlarged?