The MI Wide Aperture Quadrupole (WQB) Project

David Harding and Weiren Chou

2 November 2006

Outline

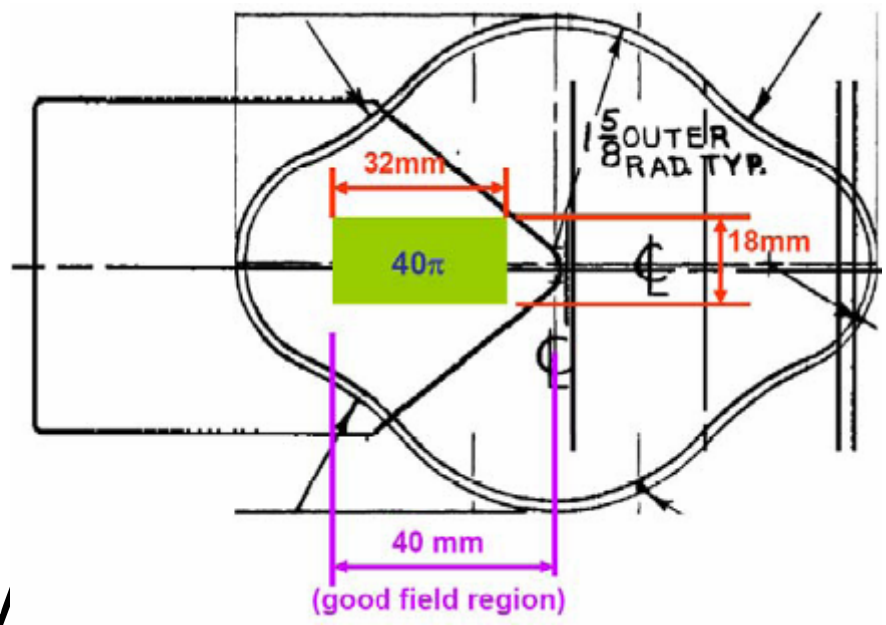
- Dave
  - Design
  - Construction
  - Measurements
- Weiren
  - Installation
  - Operation
  - Performance

TD Credits

- Vladimir Kashikhin
- John Carson
- Bill Robotham
- Jim Jablonski
- Hank Glass
- Mike Tartaglia
- Joe DiMarco
- Linda Alsip
- John Zweibohmer
- Mark Thompson
- Jamie Blowers
- Dennis Gaw
- TJ Gardner
- Bill Robatzek
- Technicians galore

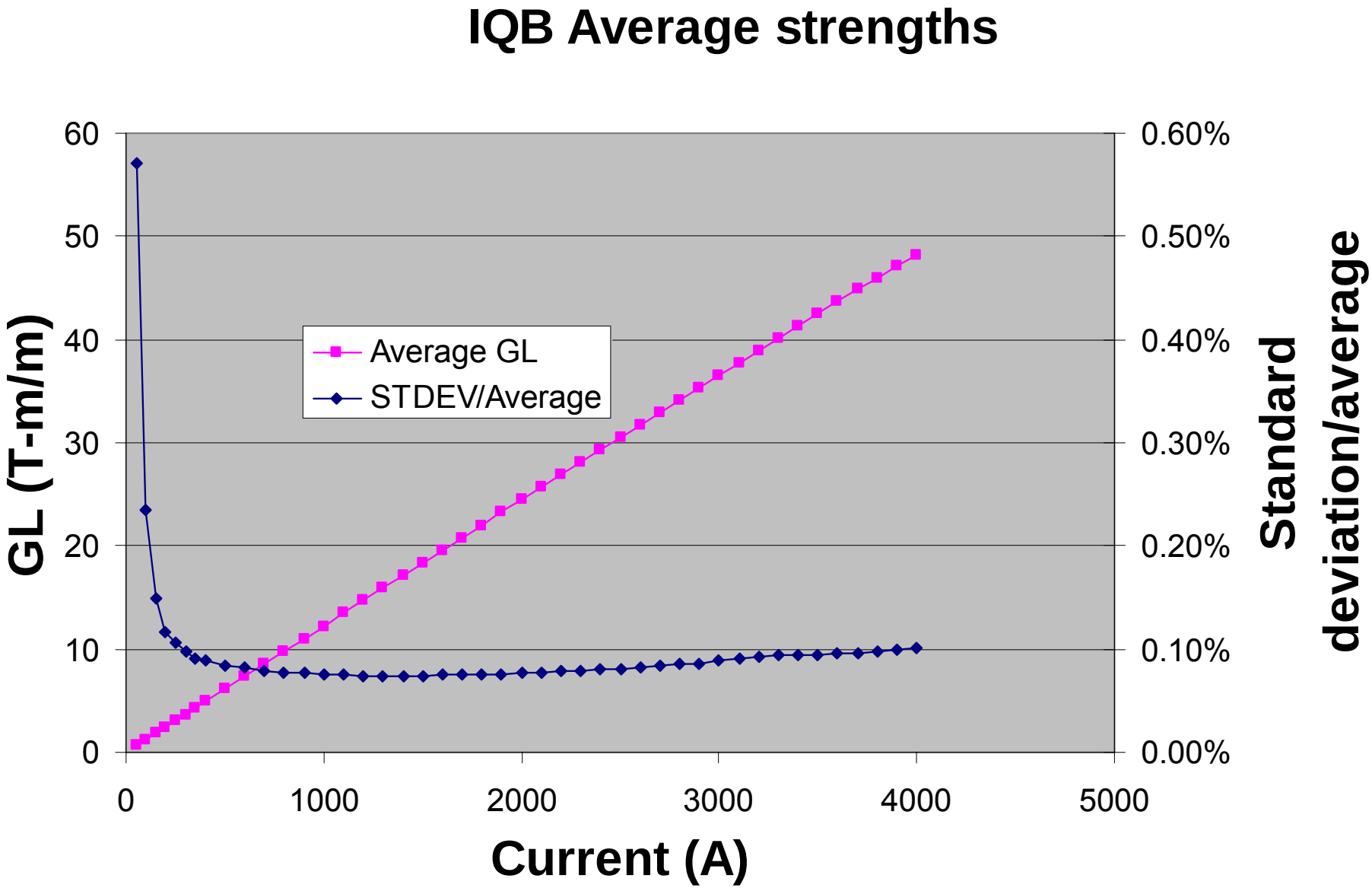
The Problem

- Injection and extraction are always tight spots.
- Main Injector cut corners here.
- With NuMI intensity rising, the quads were becoming unpleasantly activated.

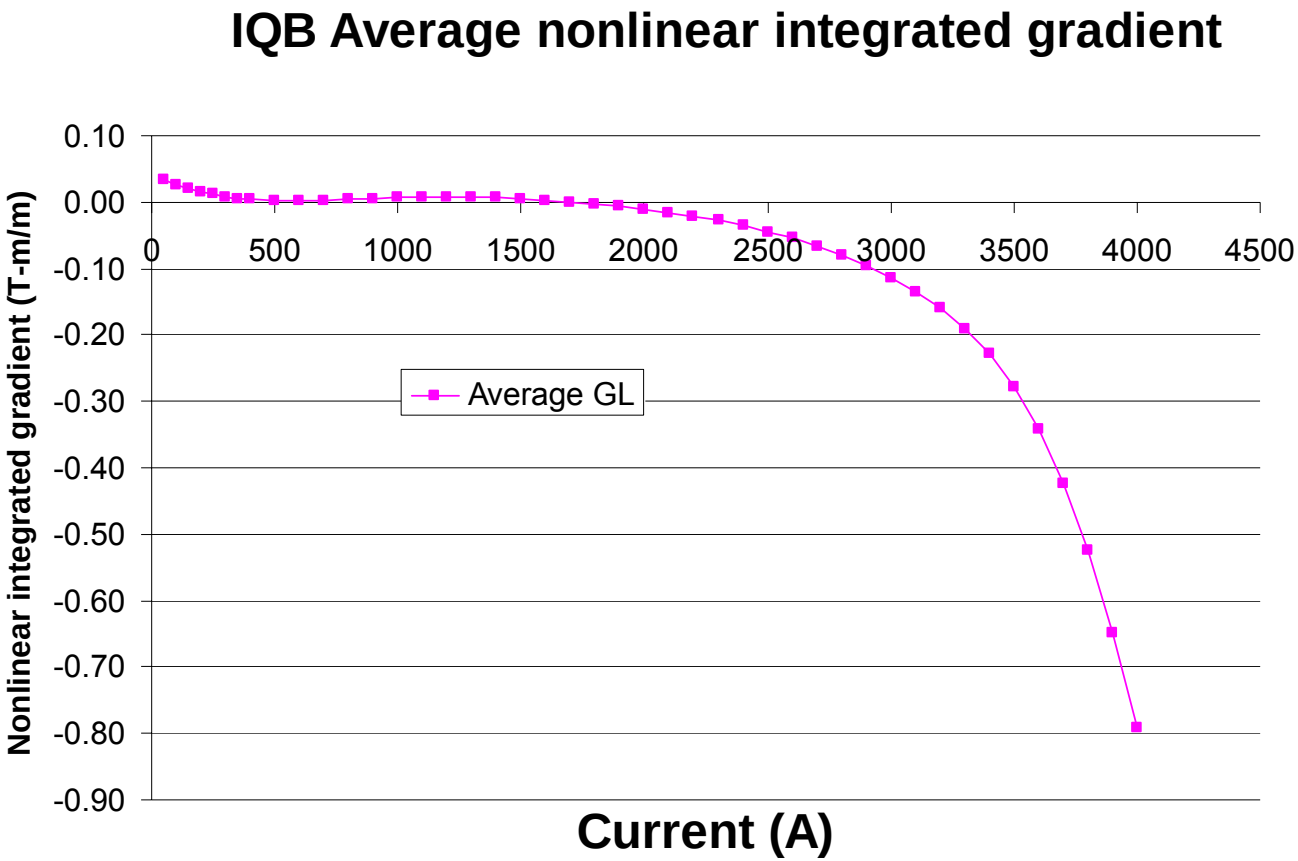


The Specification

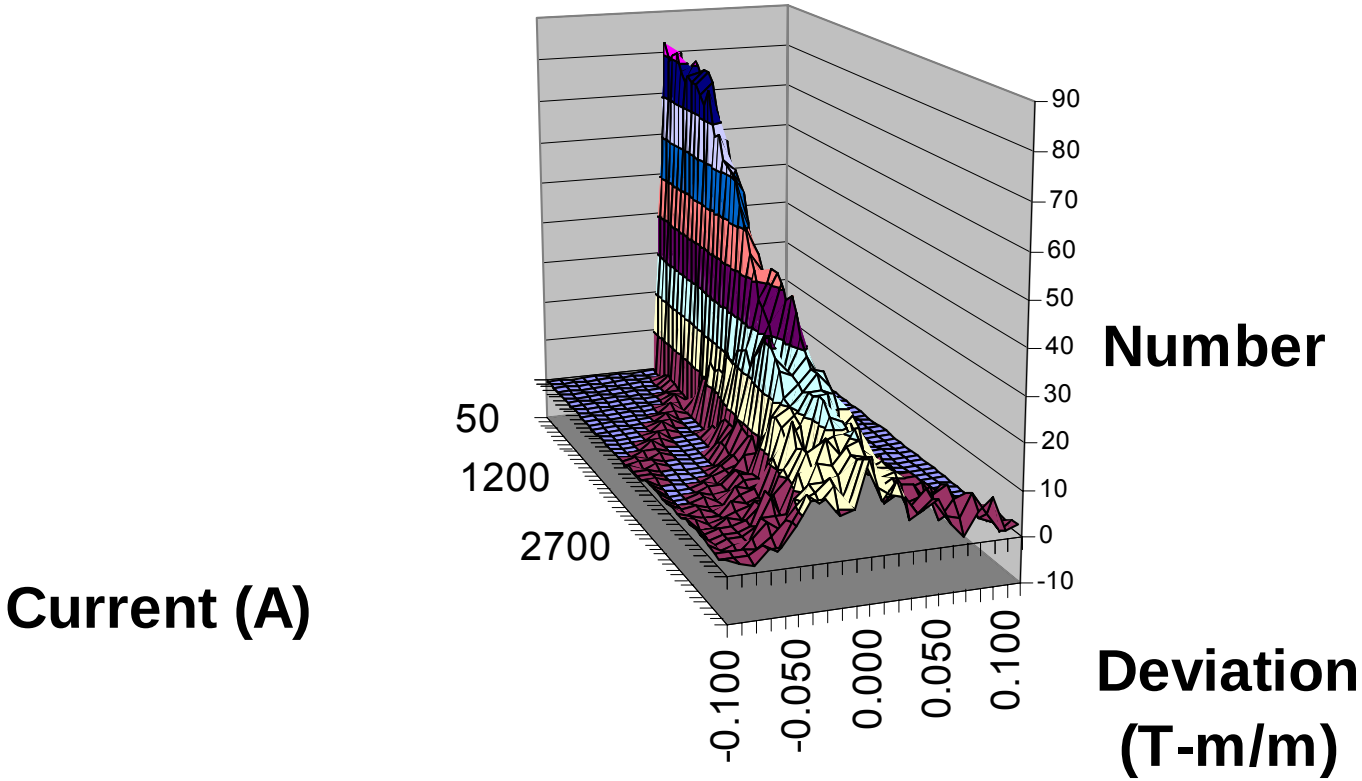
- Same integrated gradient at all currents
- Same length
- Larger aperture


IQB Average strengths
GL (T-m/m)
Standard deviation/average
Current (A)
Average GL
STDEV/Average
0
10
20
30
40
50
60
0.00%
0.10%
0.20%
0.30%
0.40%
0.50%
0.60%
0
1000
2000
3000
4000
5000

IQB performance



Frequency of deviations from mean



Number of turns

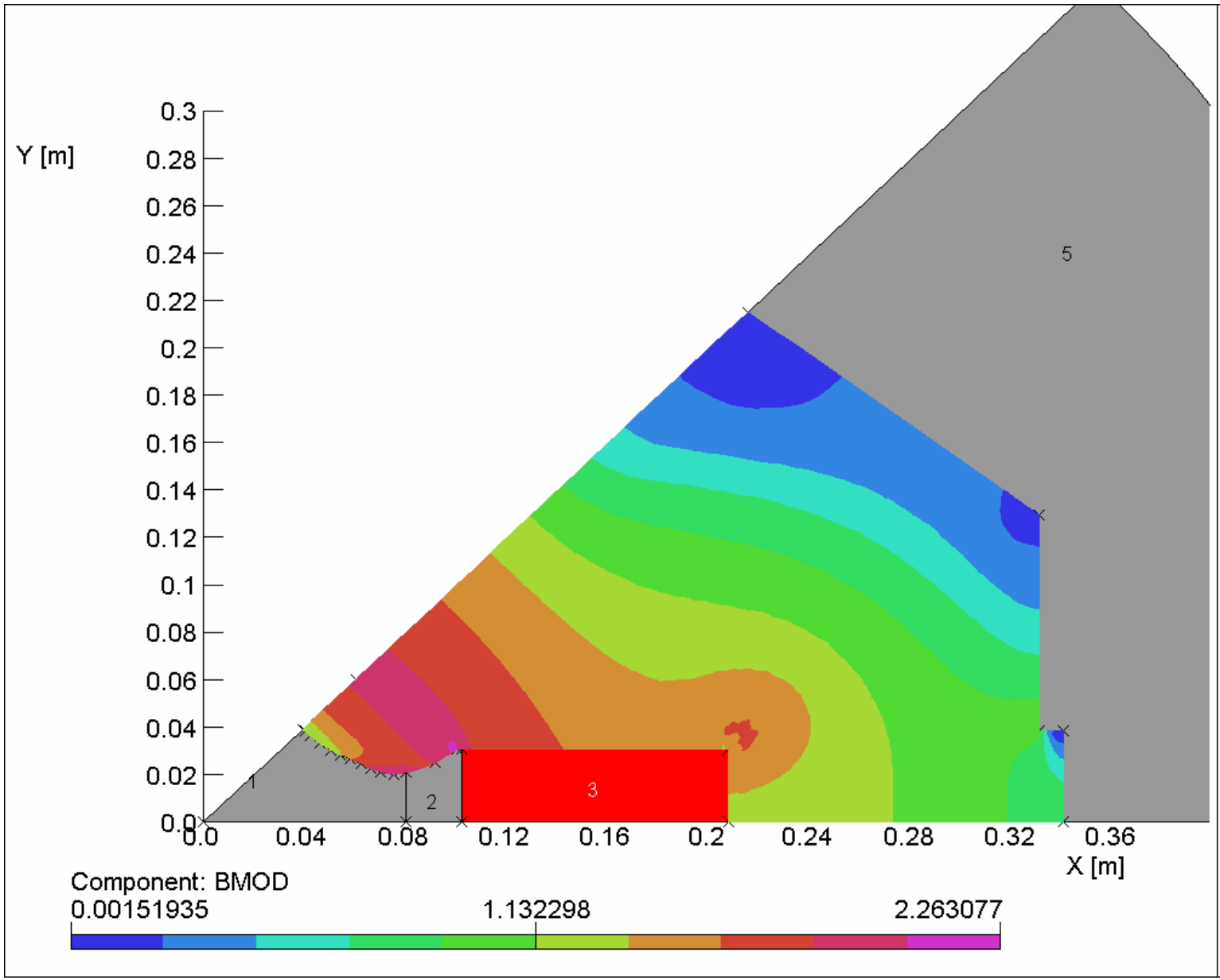
$$G = \frac{\mu_0 \mathrm{NI}}{r^2 / 2}$$

N	R (mm)	B pole (T)
4	41.73	1.23
5	46.66	1.37
6	51.11	1.50
7	55.21	1.62
8	59.02	1.73

Gradient 20.78 T/m (3600 A)

Steel

- More or less silicon?
  - More → lower remanent field
  - Less → high saturation field



UNITS

Length	: m
Flux density	: T
Field strength	: A m^{-1}
Potential	: Wb m^{-1}
Conductivity	: S m^{-1}
Source density	: A m^{-2}
Power	: W
Force	: N
Energy	: J
Mass	: kg

PROBLEM DATA

WQB_050404.st
Quadratic elements
XY symmetry
Vector potential
Magnetic fields
Static solution
Scale factor = 1.0
6958 elements
14123 nodes
7 regions

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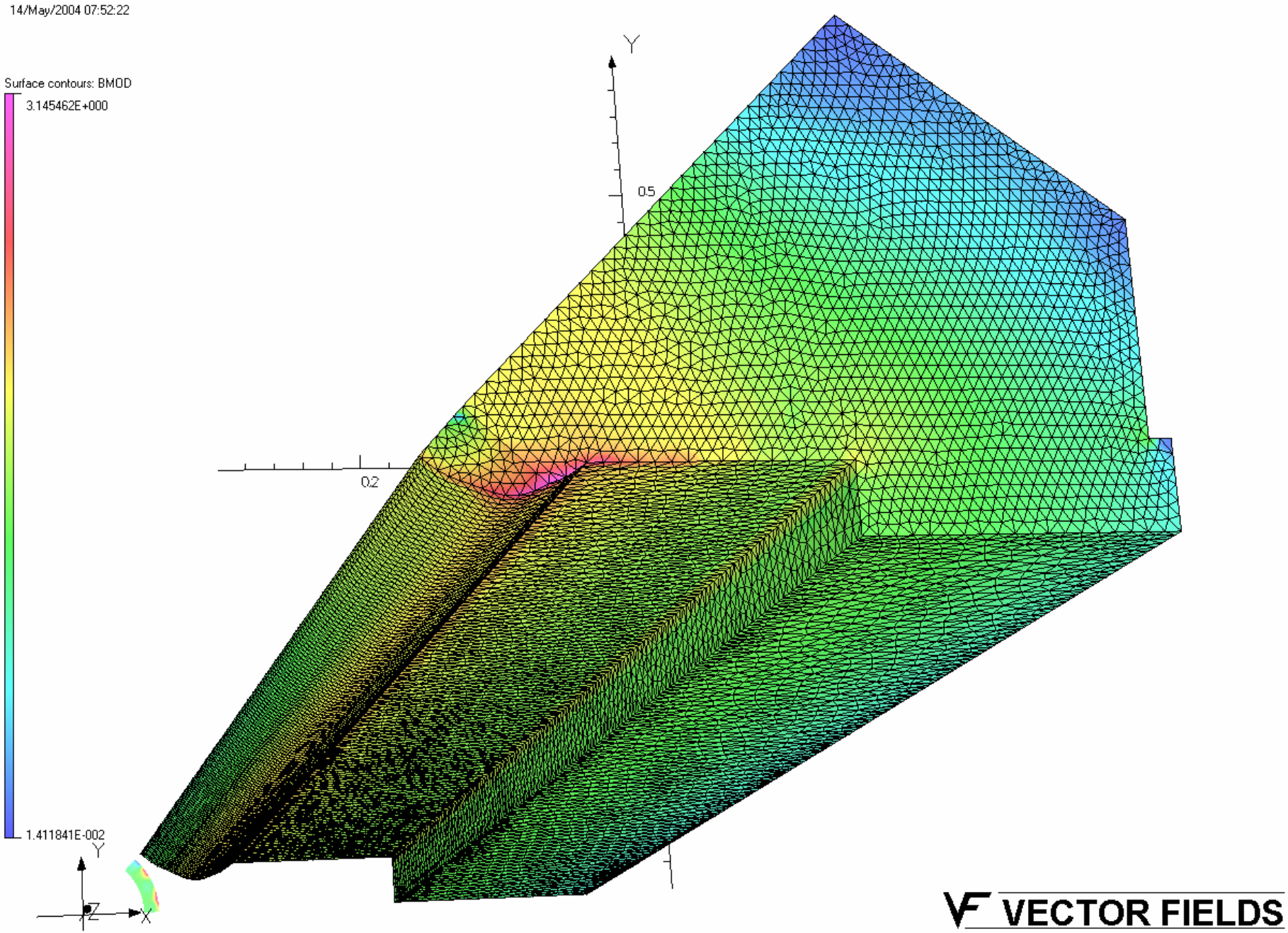
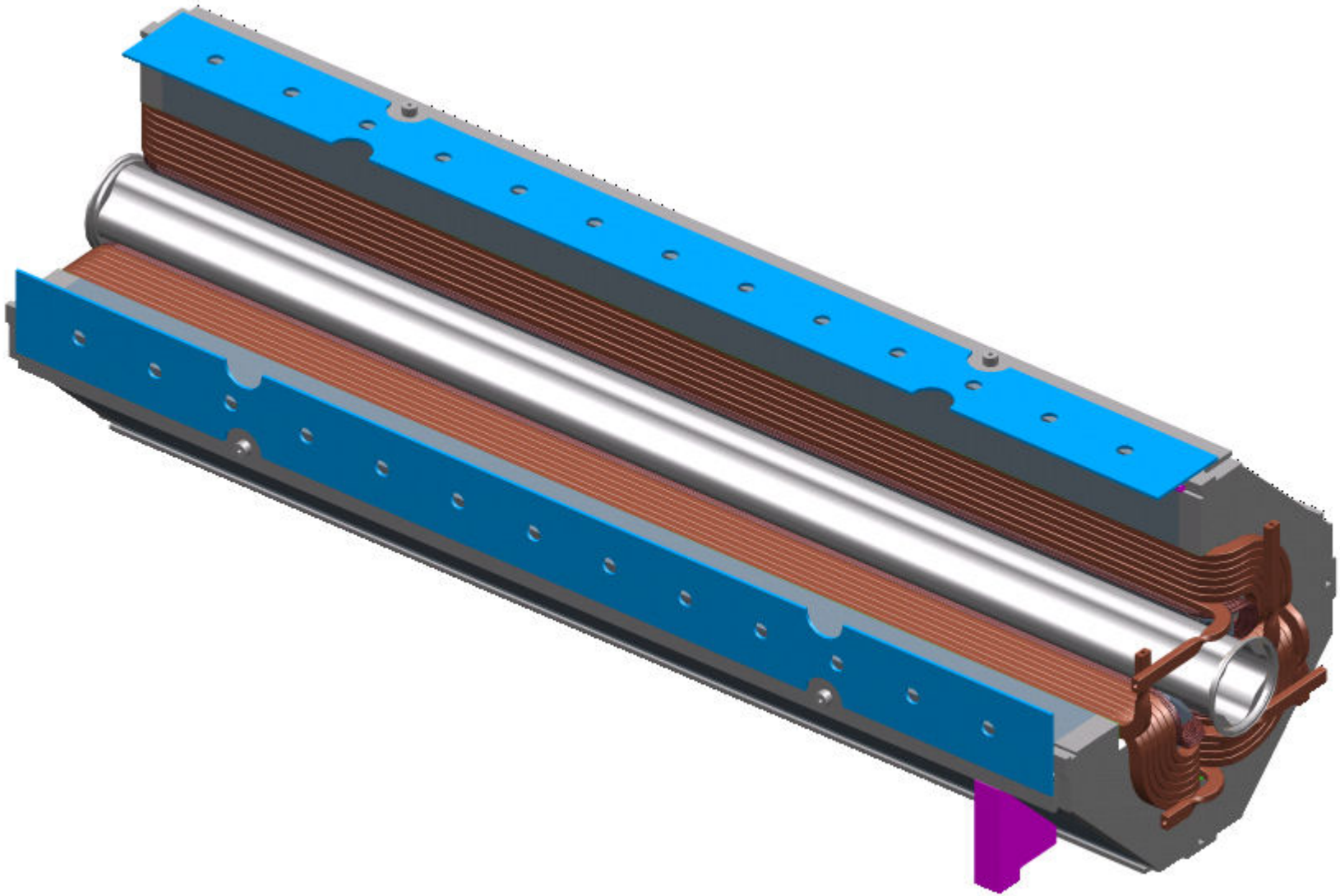
OPERA-2d
Pre and Post-Processor 9.000

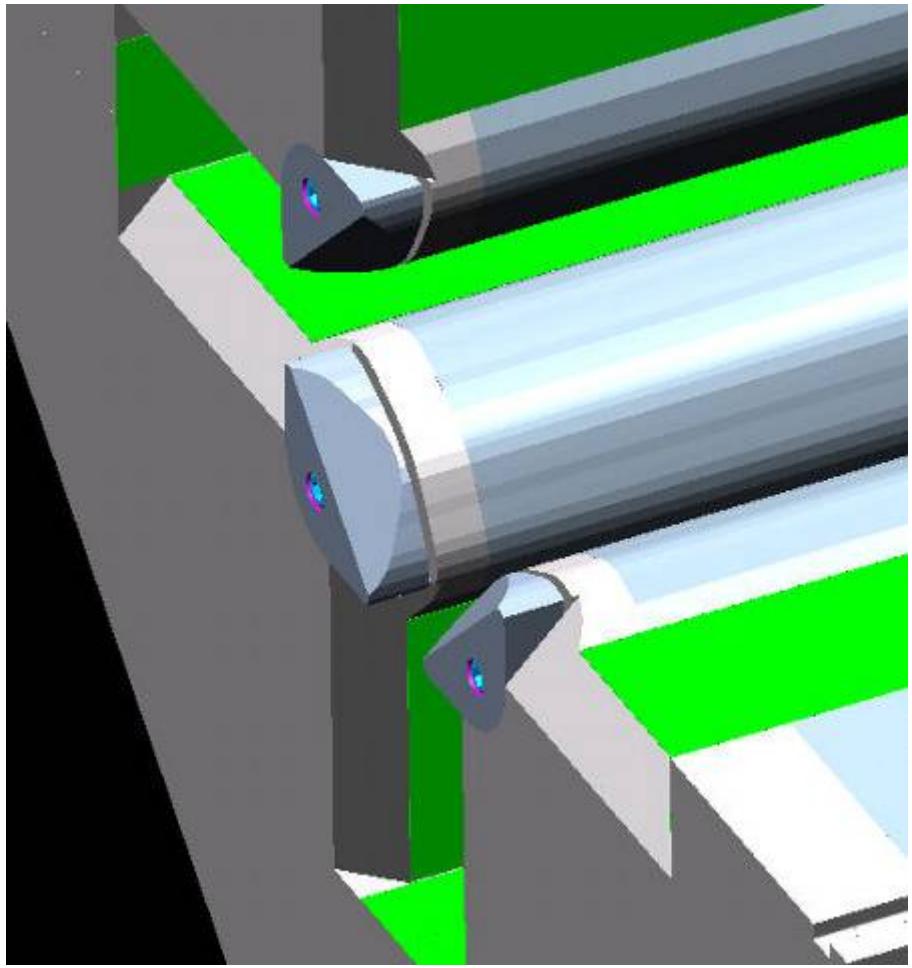

14/May/2004 07:52:22
Surface contours: BMOD
3.145462E+000
1.411841E-002
Y
0.5
0.2
Y
Z
X
VECTOR FIELDS



Hedge I

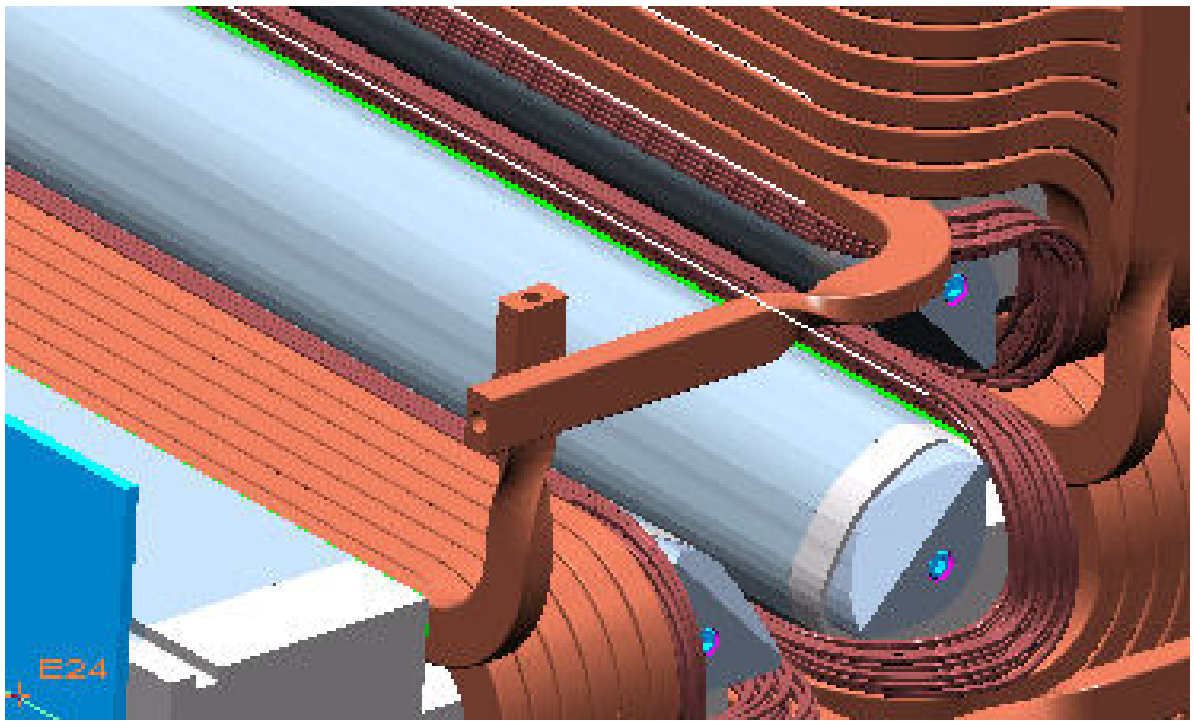
- Removable end pieces + shims
  - Adjust pole length
  - Adjust pole end profile

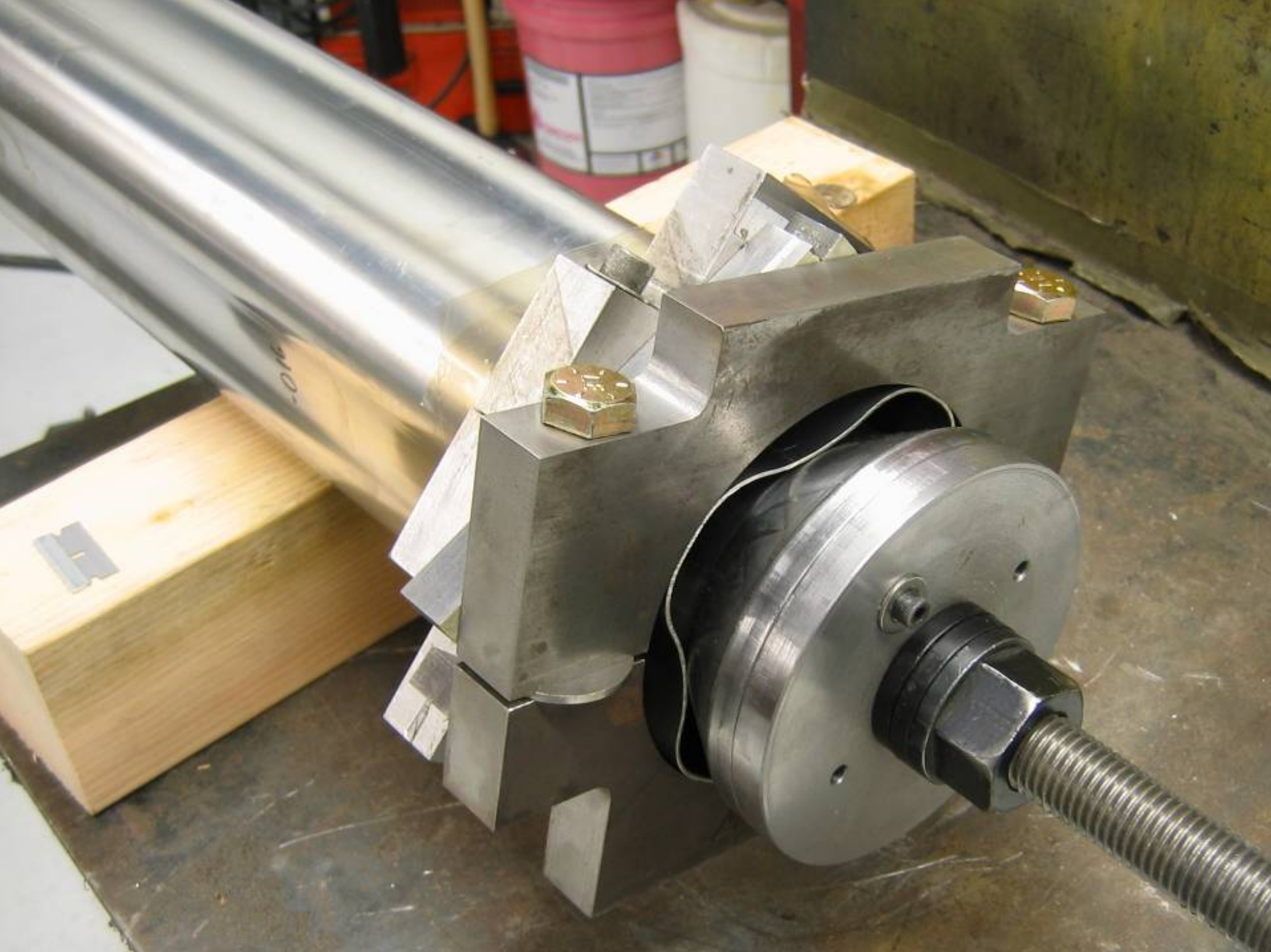
- Right the first shot



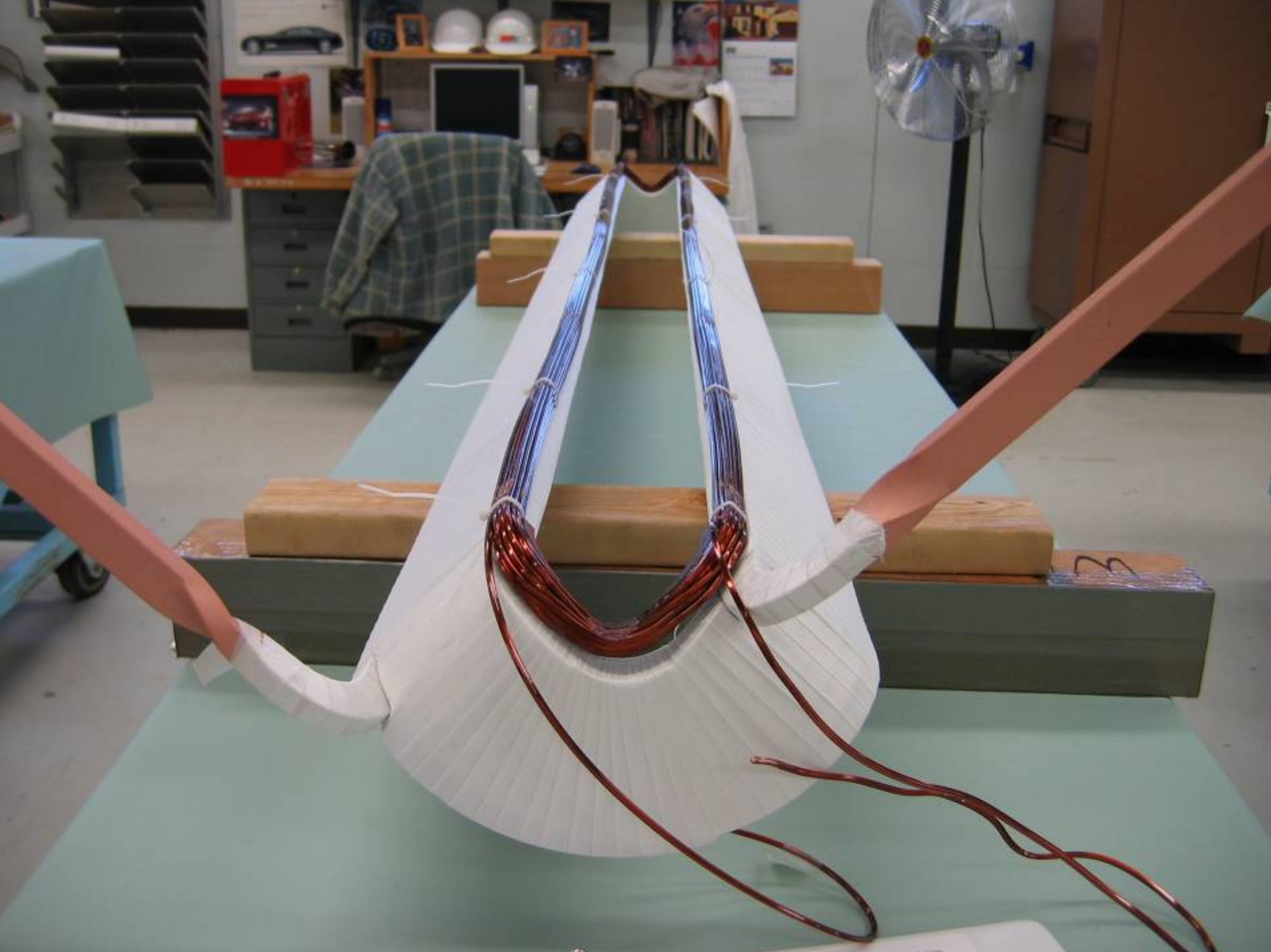
Hedge II

- Add trim coils to adjust ±2% at full excitation
  - Low current *vs*. high inductance (self and mutual)
  - 18 turns, 28 A
- Important

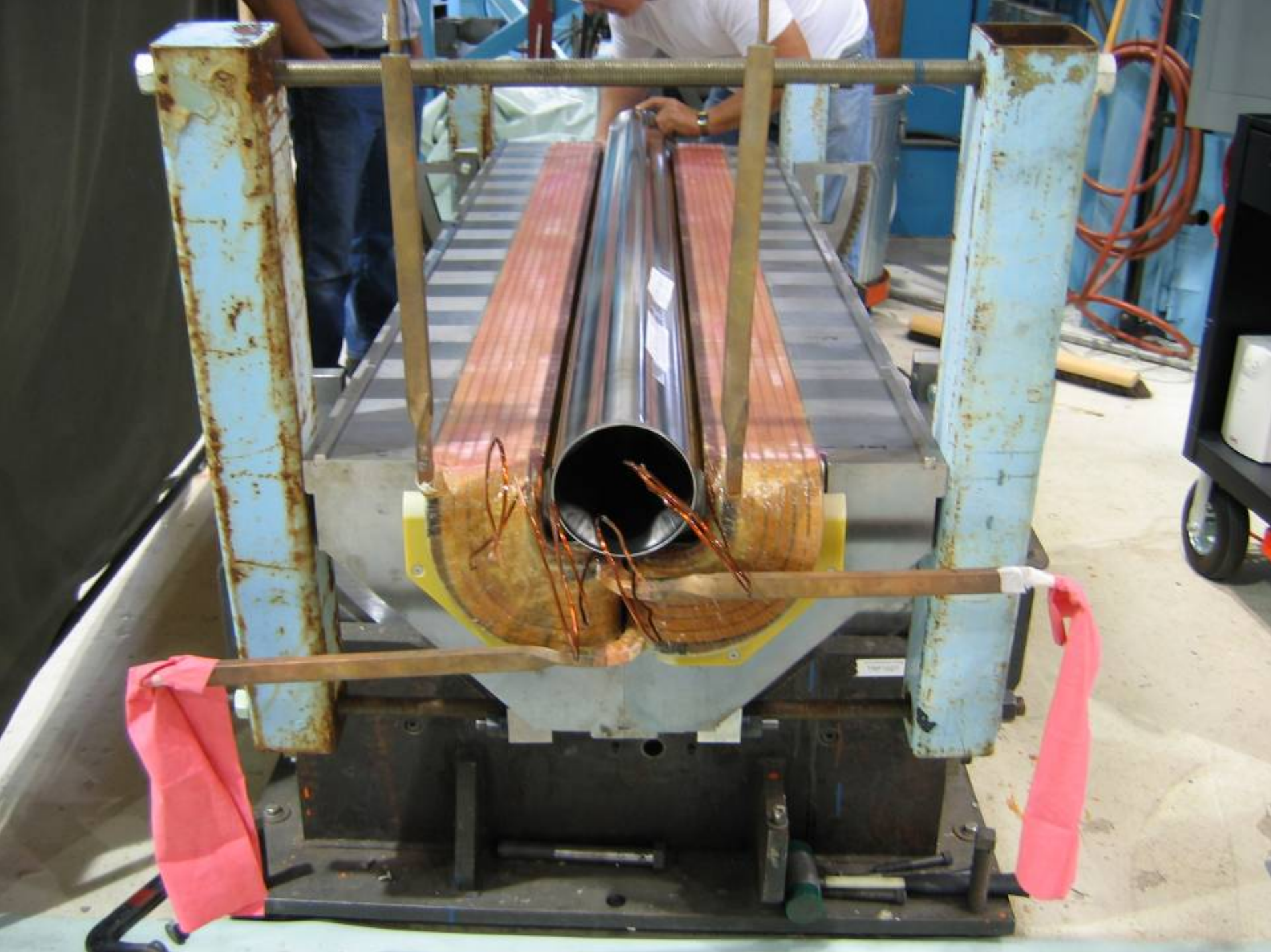




4055



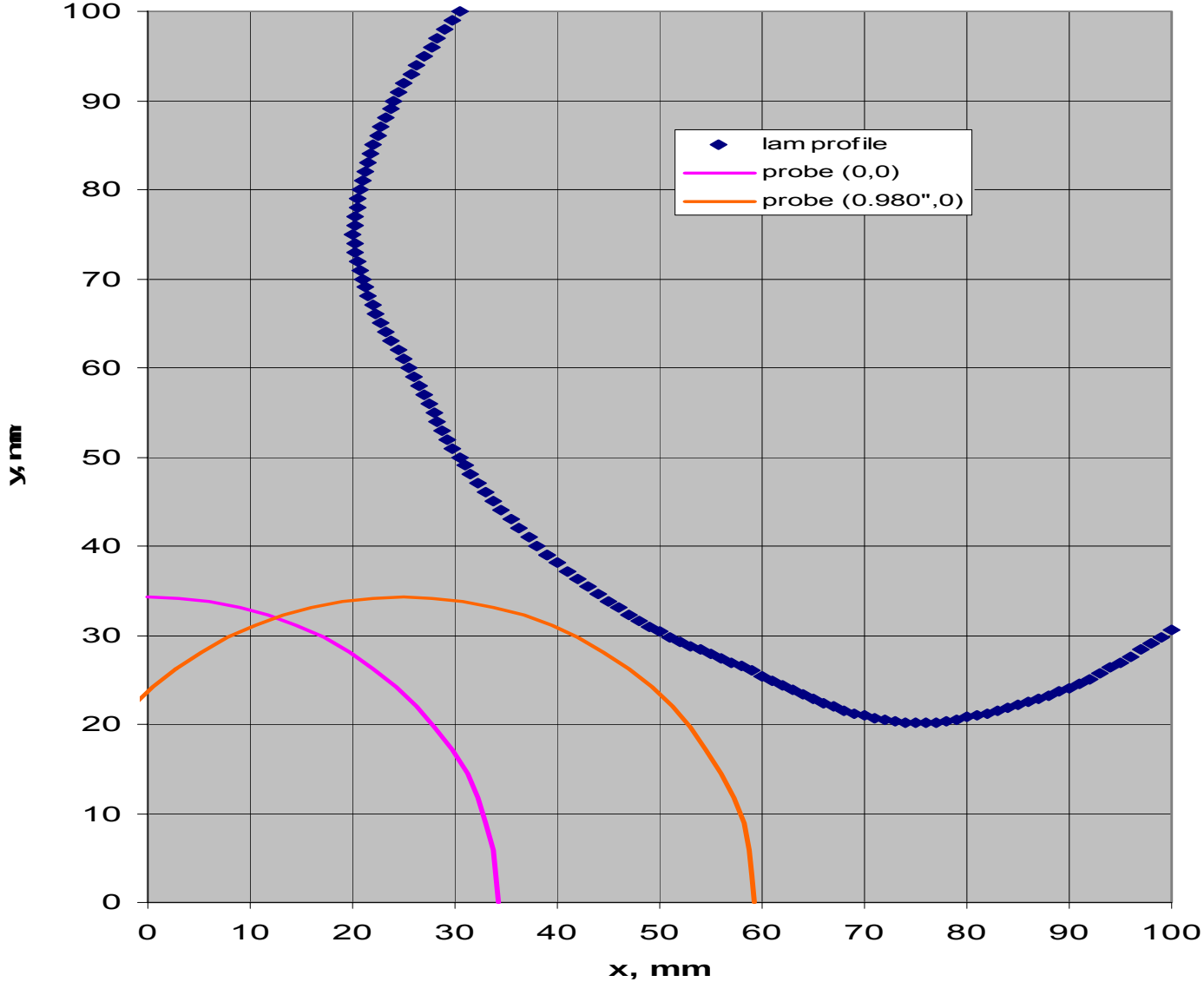
EMERGENCY
EYEWASH STATION
STOP



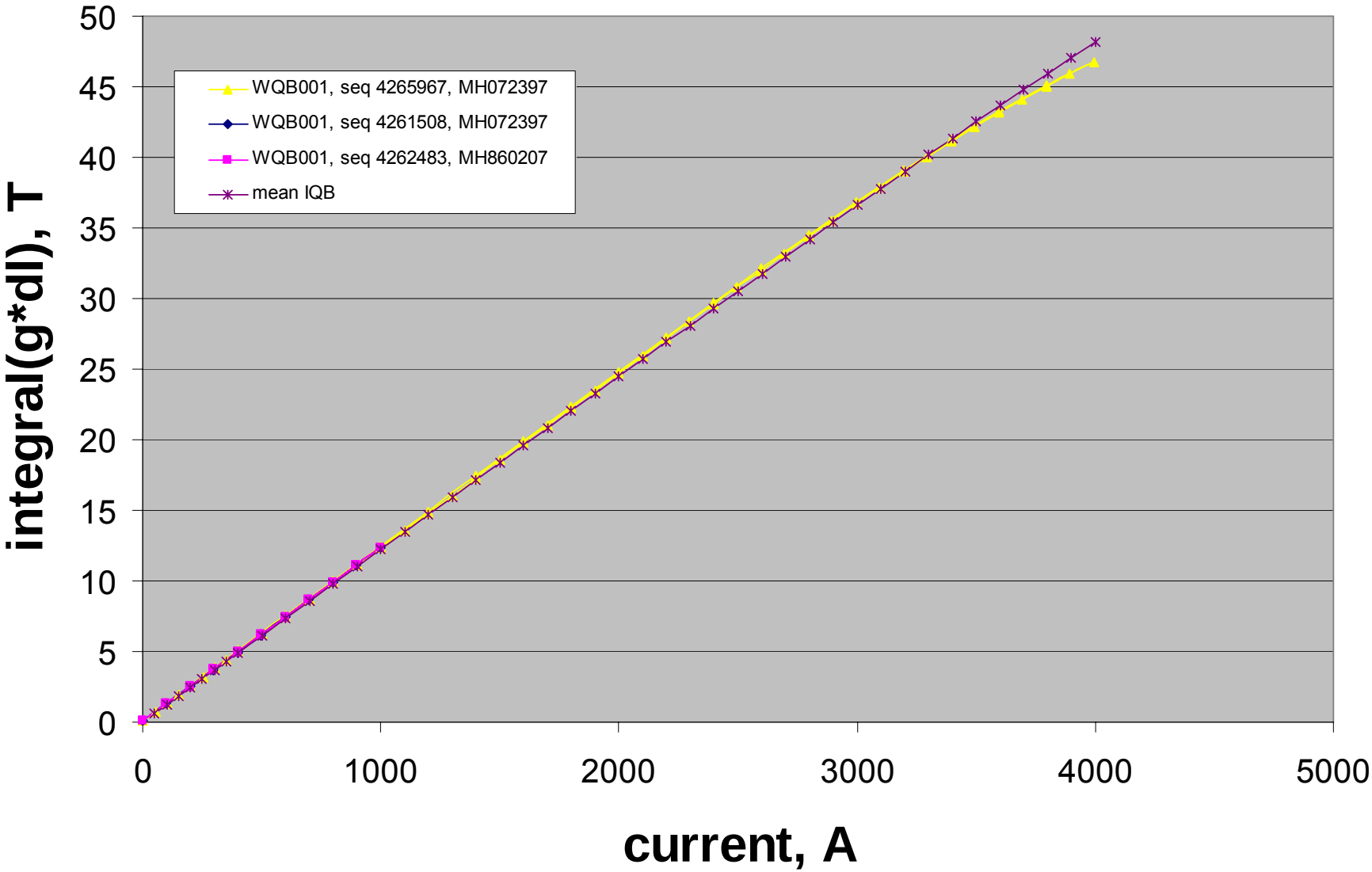
CRANE
SHUT OFF

NO STEP
NO STEP
NO STEP
Wide Aperature Quadrupole
WQB006
Wt: 12000 lbs
Quadrant #1
Quadrant #2
Quadrant #3
Quadrant #4

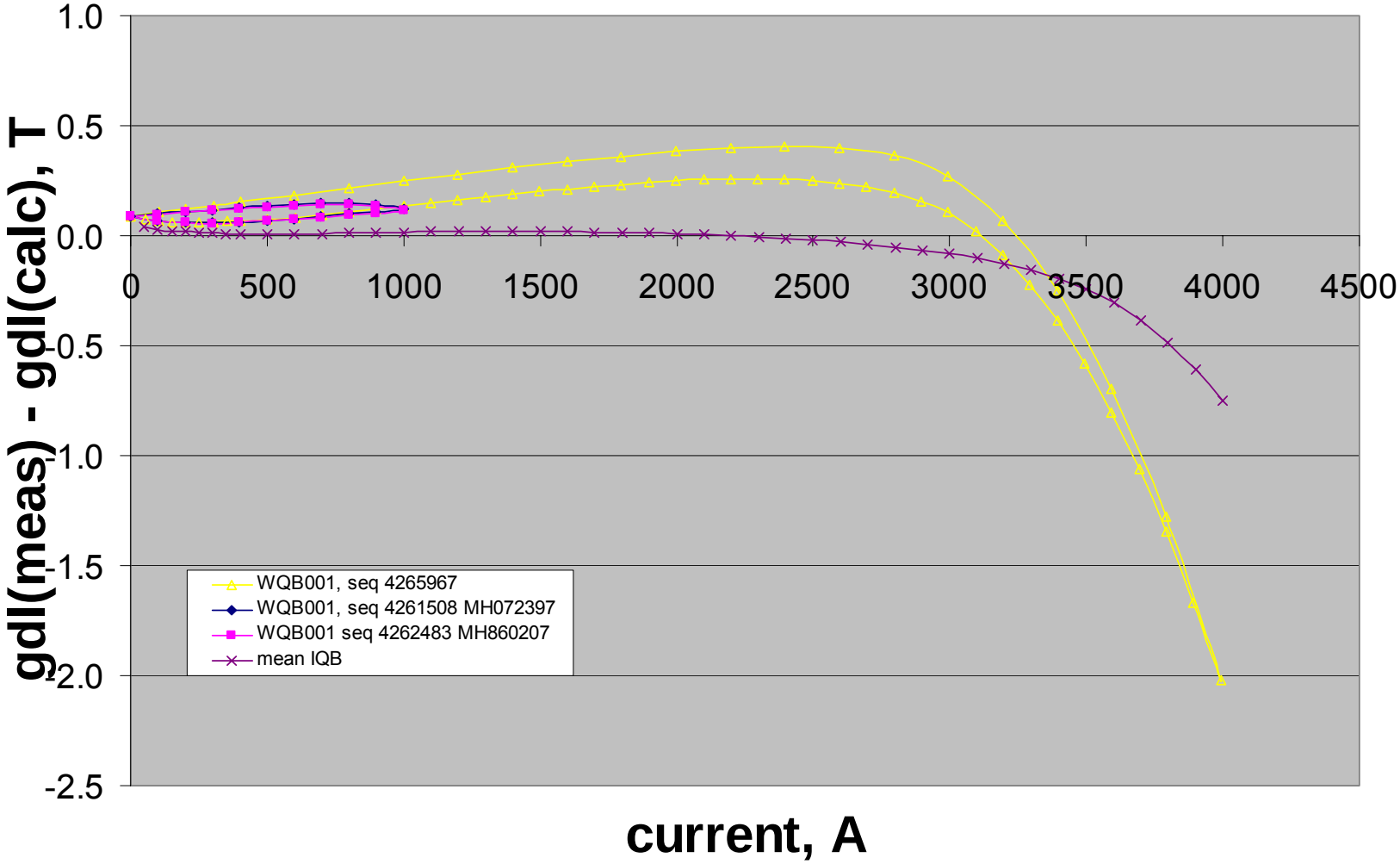
WQB lam profile
Morgan probe MH940701 (r = 34.32 mm)



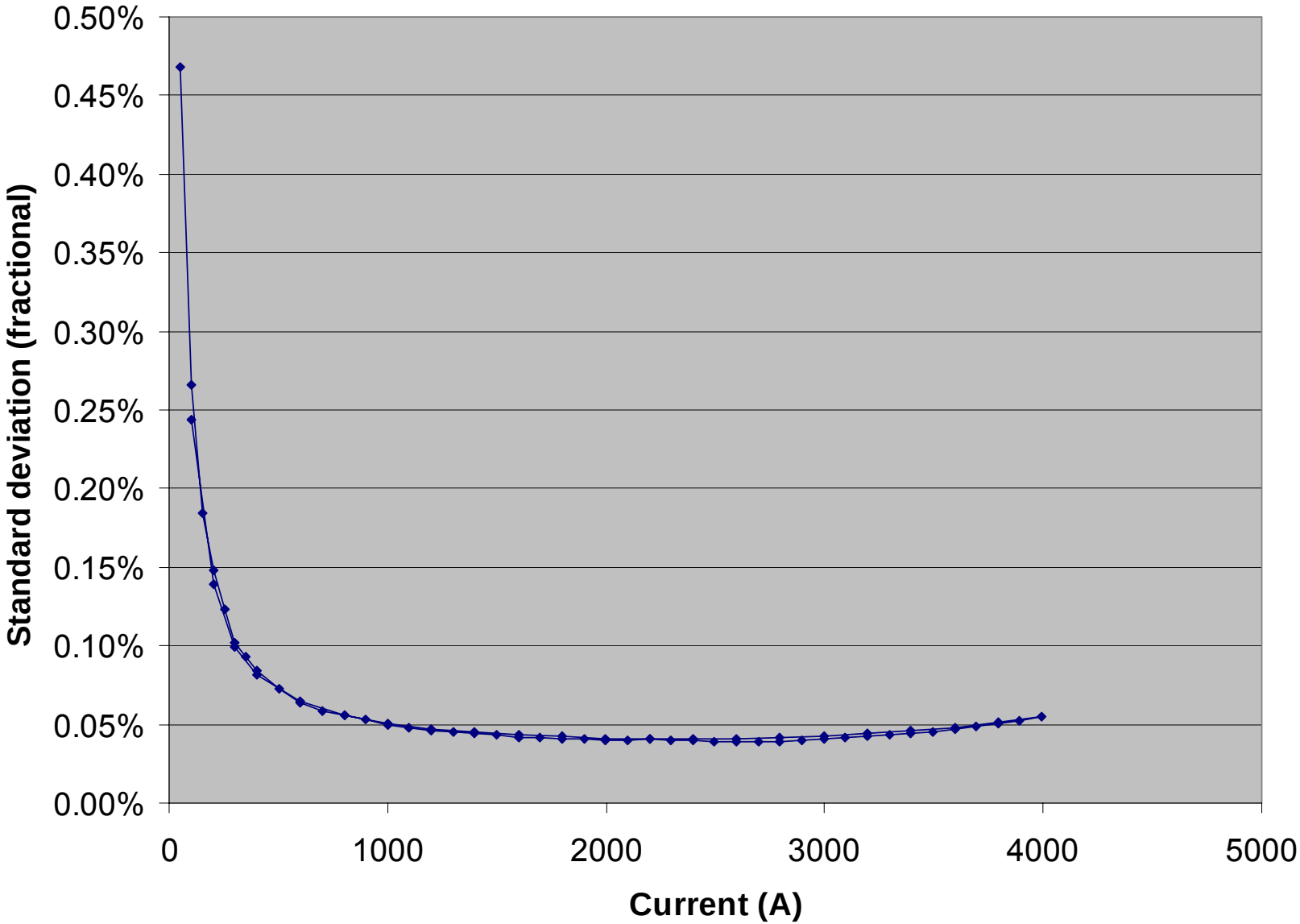
WQB001 strength (rotating coil)



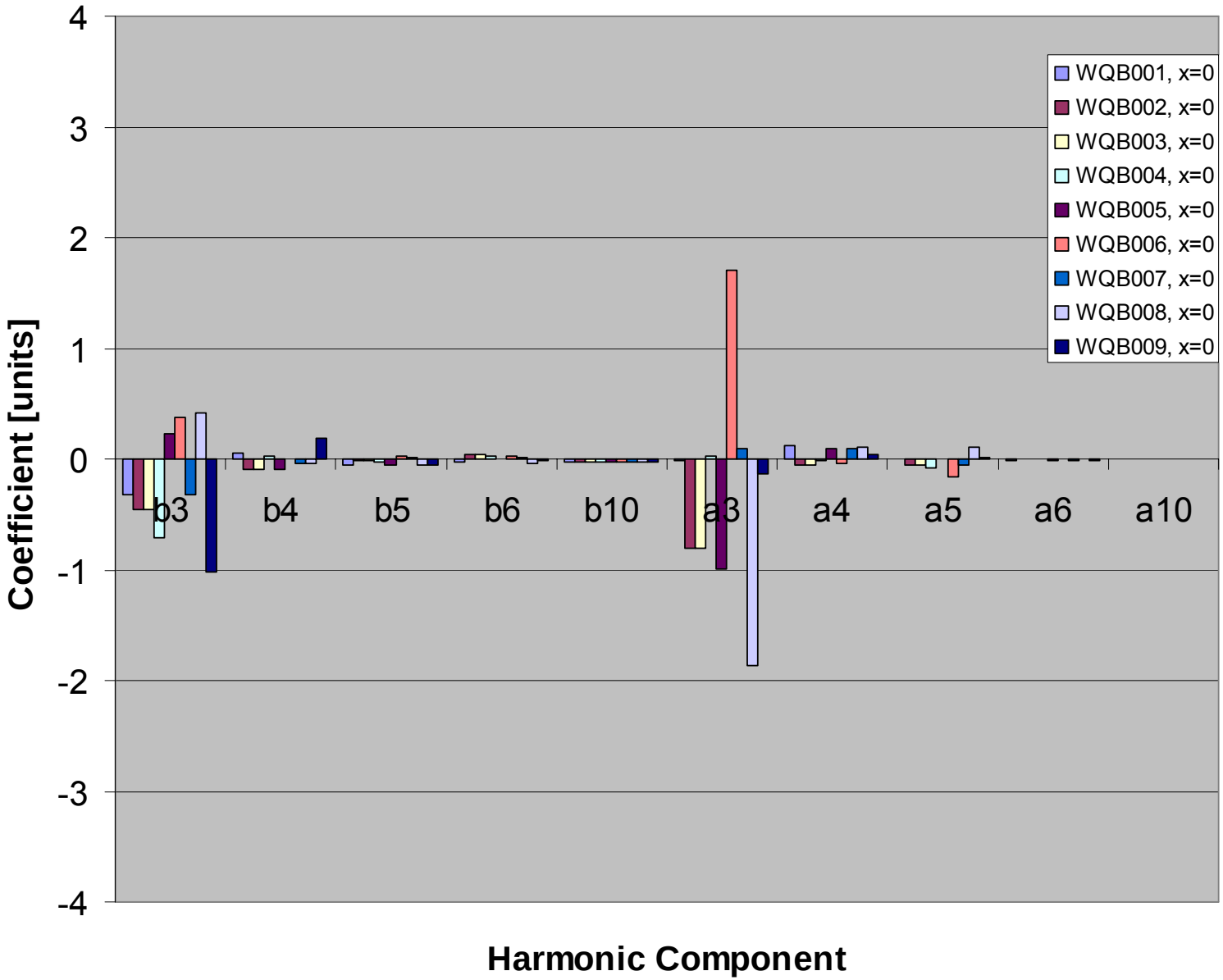
WQB001 nonlinear part of strength
(relative to mean IQB TF = .01222 T/A)

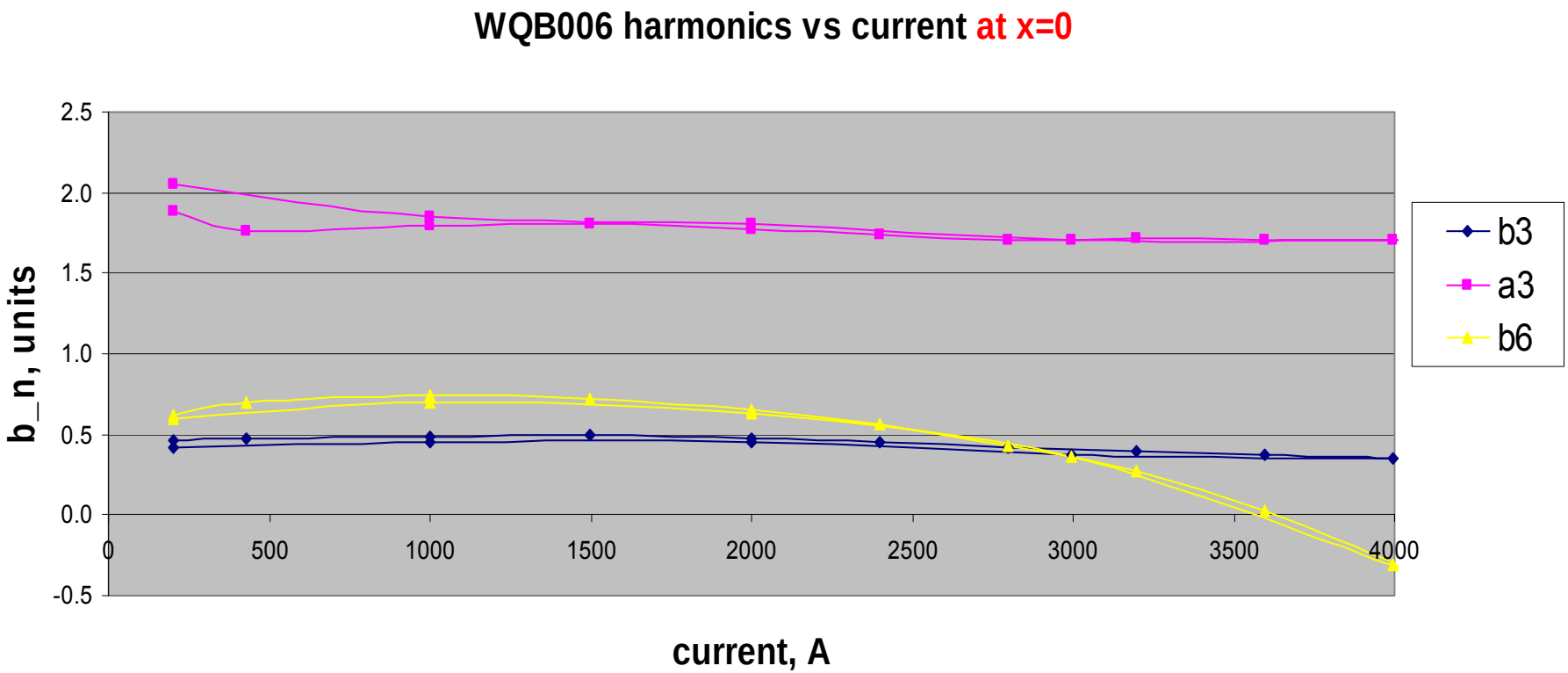


All WQB magents STDEV/average

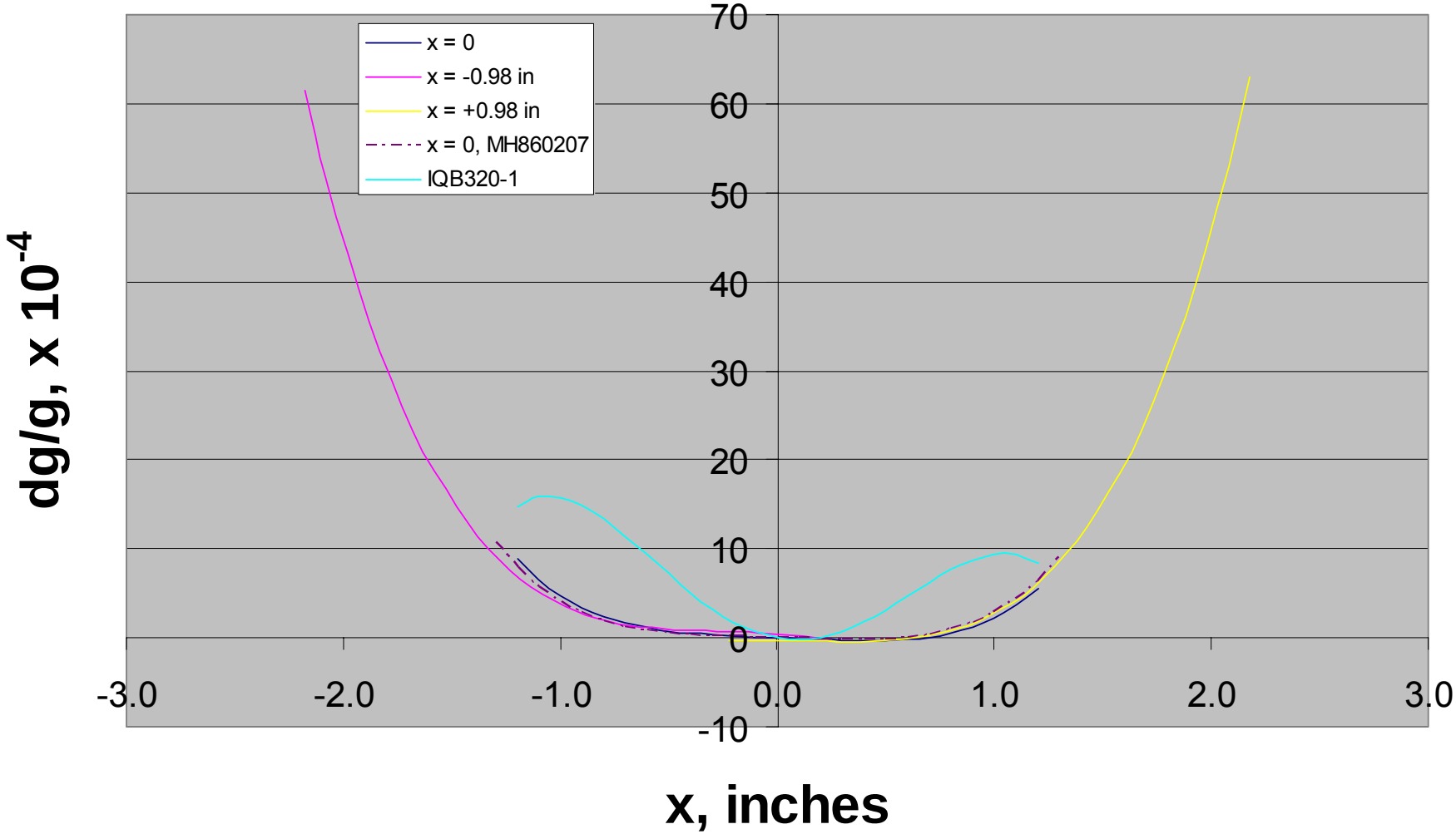


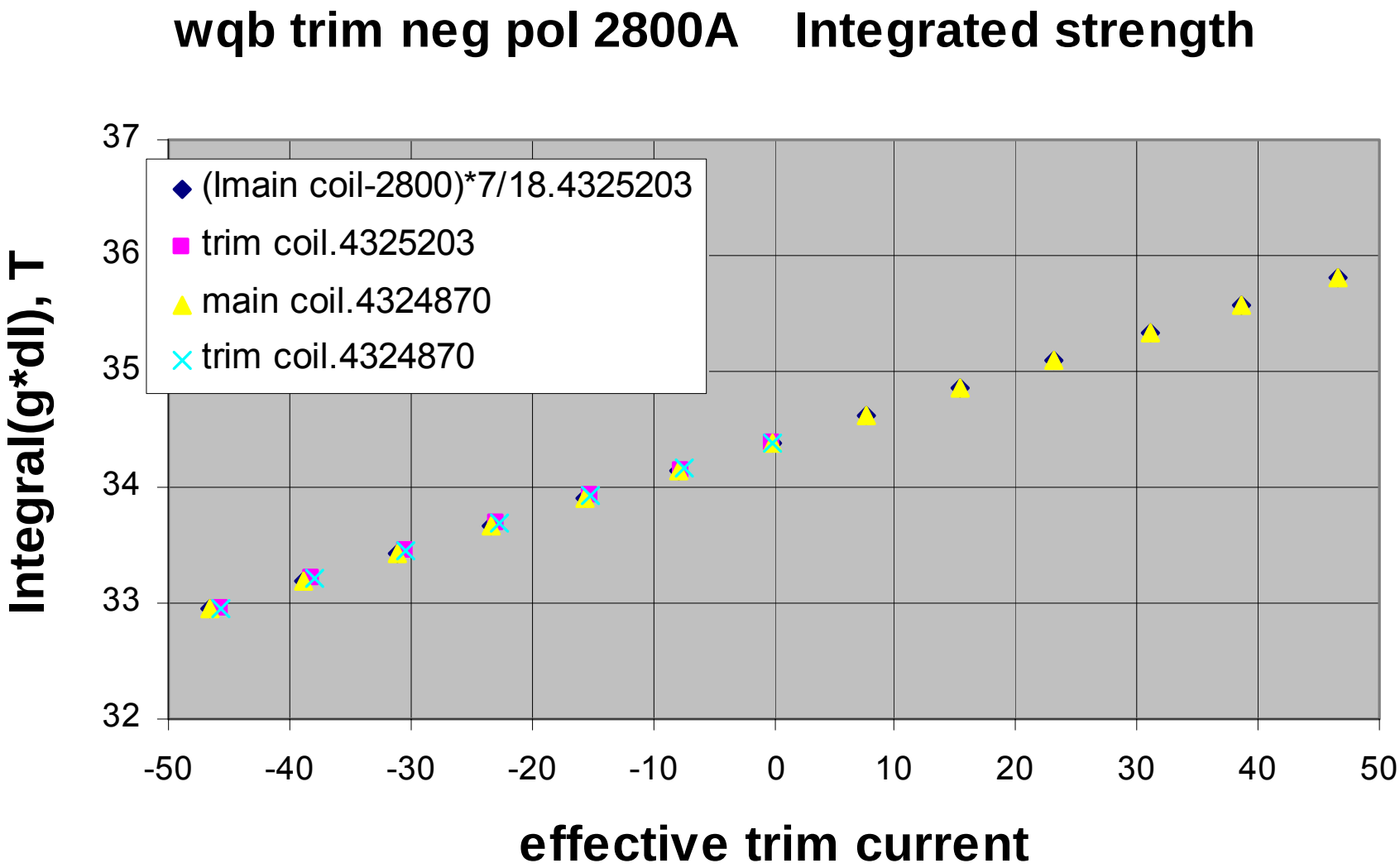
WQB Production Harmonics, I=3600A, x=0"




WQB006 harmonics vs current at x=0
b_n, units
current, A
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0
500
1000
1500
2000
2500
3000
3500
4000
b3
a3
b6

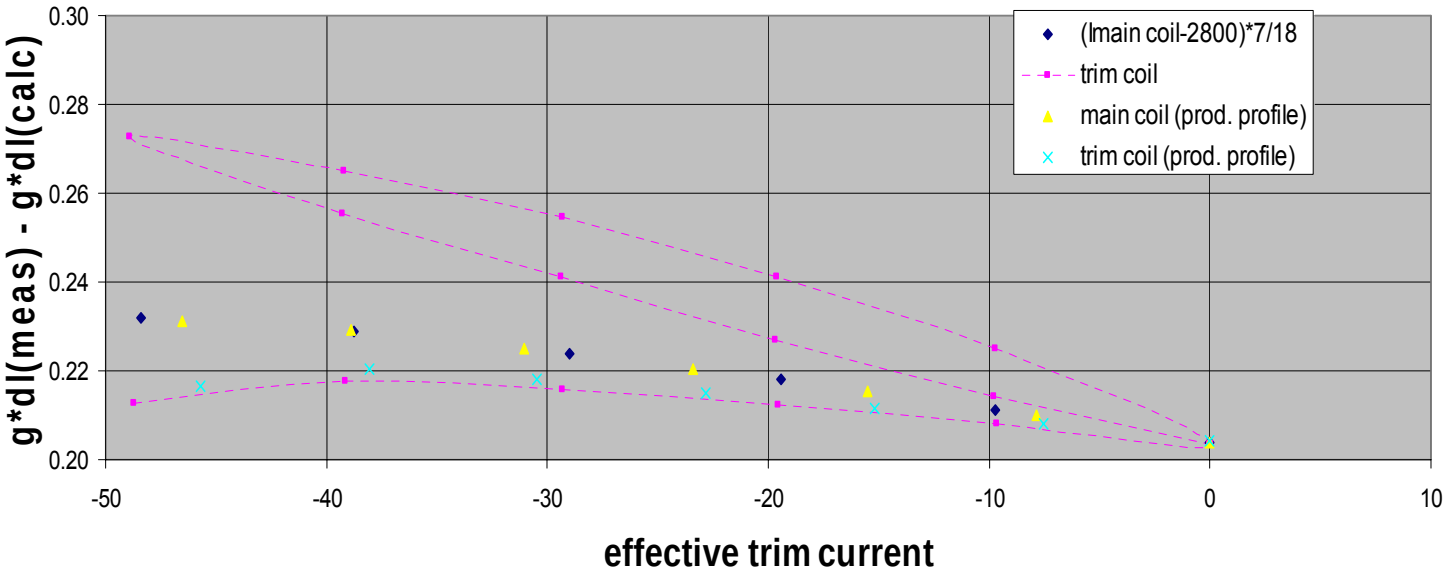
WQB001-0 gradient shape at 1000 A



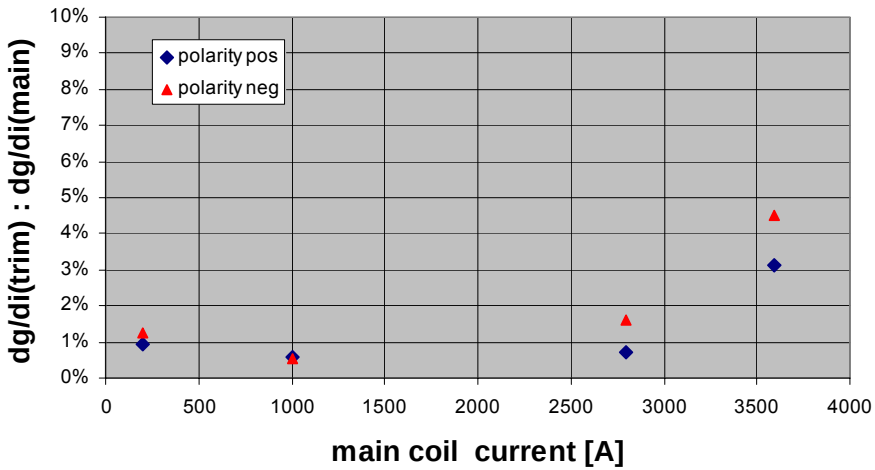

wqb trim neg pol 2800A Integrated strength
(Imain coil-2800)*7/18.4325203
trim coil.4325203
main coil.4324870
trim coil.4324870
Integral(g*dl), T
37
36
35
34
33
32
-50
-40
-30
-20
-10
0
10
20
30
40
50
effective trim current

wqb trim neg pol 2800A non-linear strength

compare trim loop to "production" profile



WQB003-0 percent anomaly



WQB
Magnet