Measuring how field quality changes when a dipole is run at very low fields compared to nominal

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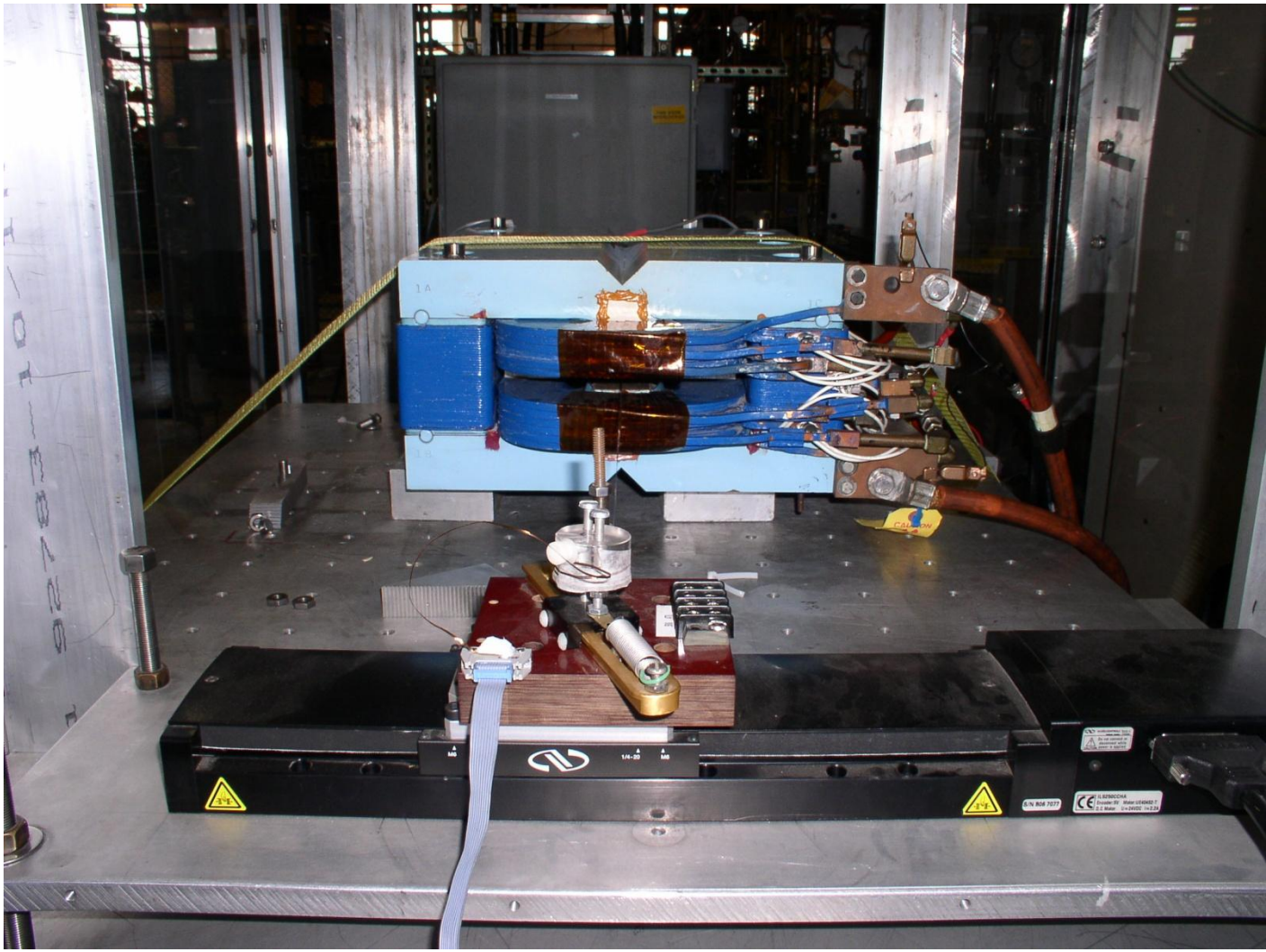
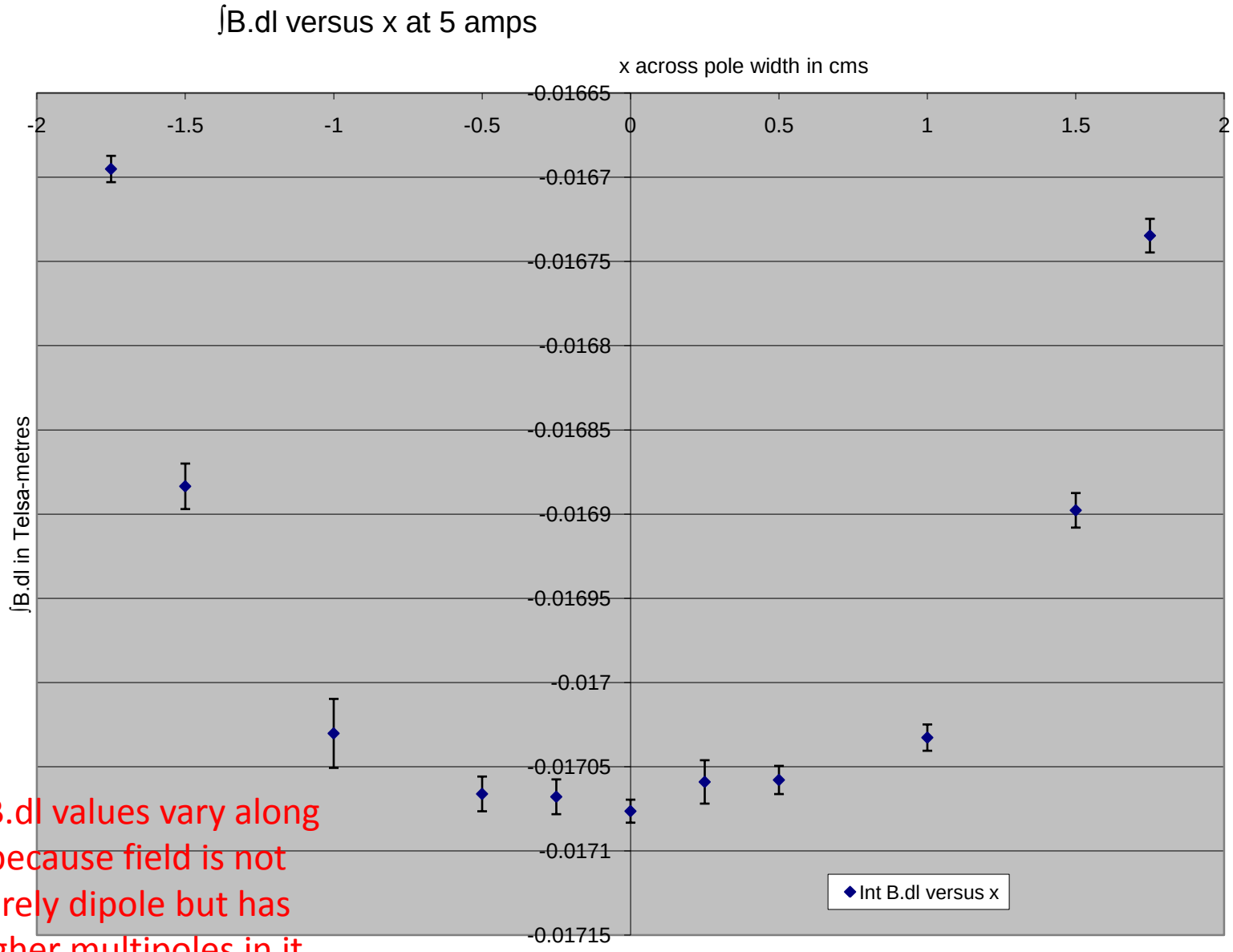
Measuring an old SLAC dipole for FACET with a stretched wire system, measures ∫B.dl across the pole tip.

Dipole parameters:
Effective length:0.4848m
Gap: 2.03cm
Pole width: 5.08cm
Nominal operating current: 116 Amps
In water cooled coils;
Solid wire trim coils run up to 8A
At 116A +4.65A in trims B(gap)= 7913 gauss
At 0.5 A on trim only, B(gap) = 55 gauss

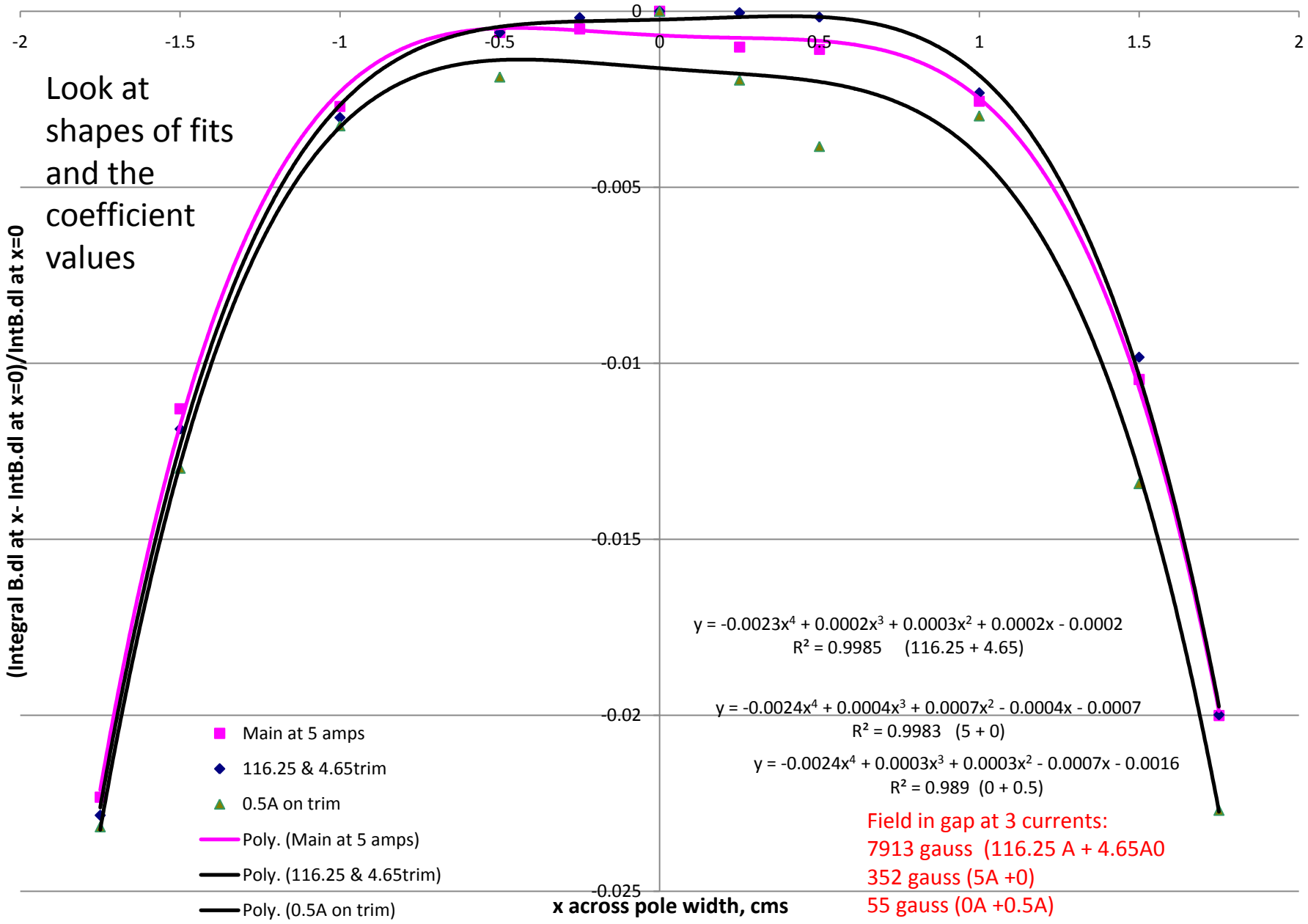




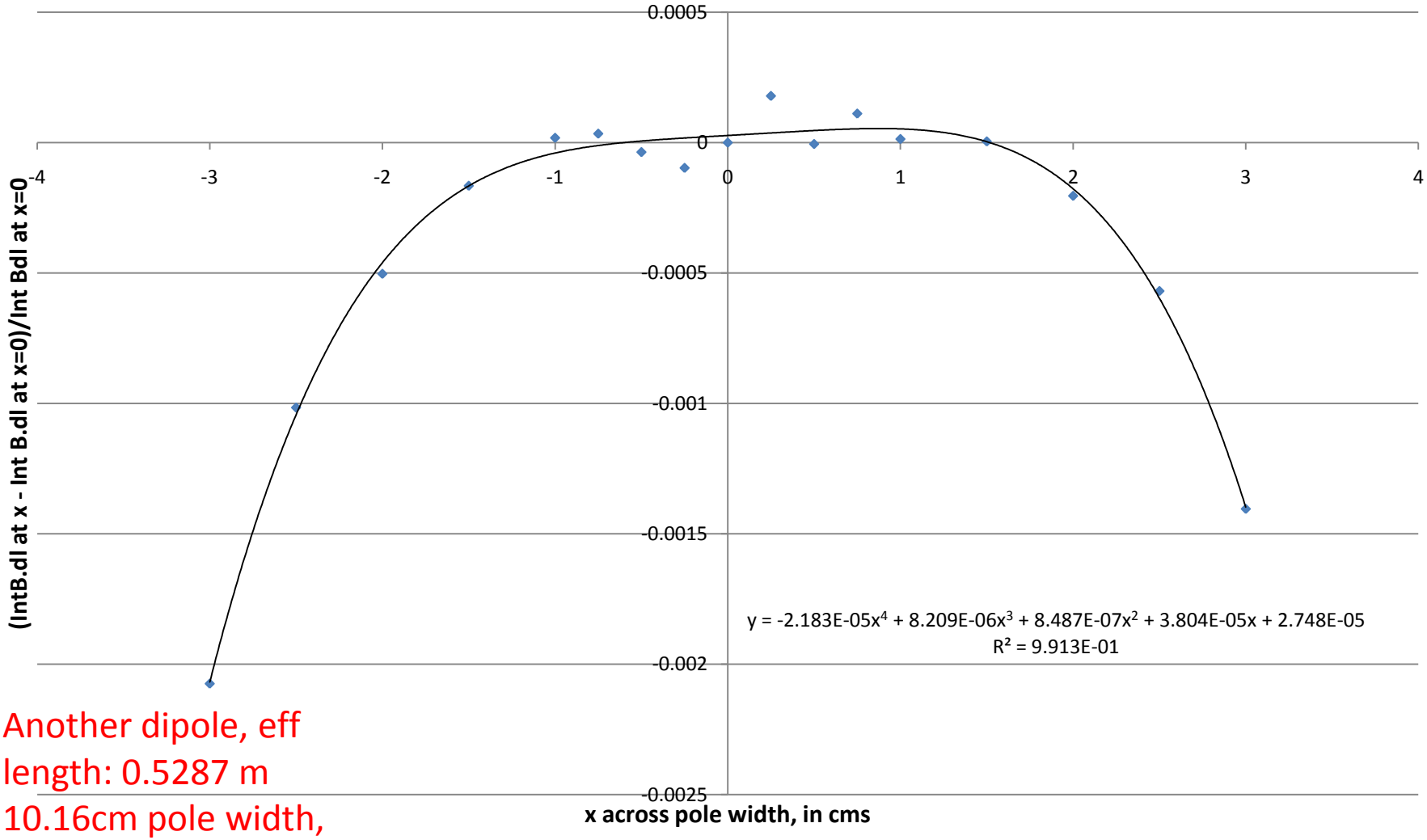
∫B.dl values vary along x because field is not purely dipole but has higher multipoles in it

Measure ∫B.dl across the pole tip at different X, compare ∫B.dl at x=0 with other x values, can estimate multipoles

- Calculate (∫B.dl at x- ∫B.dl at x=0)/ ∫B.dl at x=0
- Plot this "normalized strength" against x (centimetres)
- Fit the resulting curve with a 4^{th} order polynomial
- $y = -0.0023x^4 + 0.0002x^3 + 0.0003x^2 + 0.0002x - 0.0002$
- Coefficients of the polynomial terms are the values of the multipoles at a "radius" of 1cm compared to the dipole
  - X is the quadrupole content
  - X^2 is the sextupole content
  - X^3 is the octupole content
  - X^4 is the decapole content
- Run at wide range of currents to see how multipoles change, do they get larger at very low fields?


Look at shapes of fits and the coefficient values
(Integral B.dl at x- IntB.dl at x=0)/IntB.dl at x=0
x across pole width, cms
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
0
-0.005
-0.01
-0.015
-0.02
-0.025
Main at 5 amps
116.25 & 4.65trim
0.5A on trim
Poly. (Main at 5 amps)
Poly. (116.25 & 4.65trim)
Poly. (0.5A on trim)
y = -0.0023x⁴ + 0.0002x³ + 0.0003x² + 0.0002x - 0.0002
R² = 0.9985 (116.25 + 4.65)
y = -0.0024x⁴ + 0.0004x³ + 0.0007x² - 0.0004x - 0.0007
R² = 0.9983 (5 + 0)
y = -0.0024x⁴ + 0.0003x³ + 0.0003x² - 0.0007x - 0.0016
R² = 0.989 (0 + 0.5)
Field in gap at 3 currents:
7913 gauss (116.25 A + 4.65A0
352 gauss (5A +0)
55 gauss (0A +0.5A)

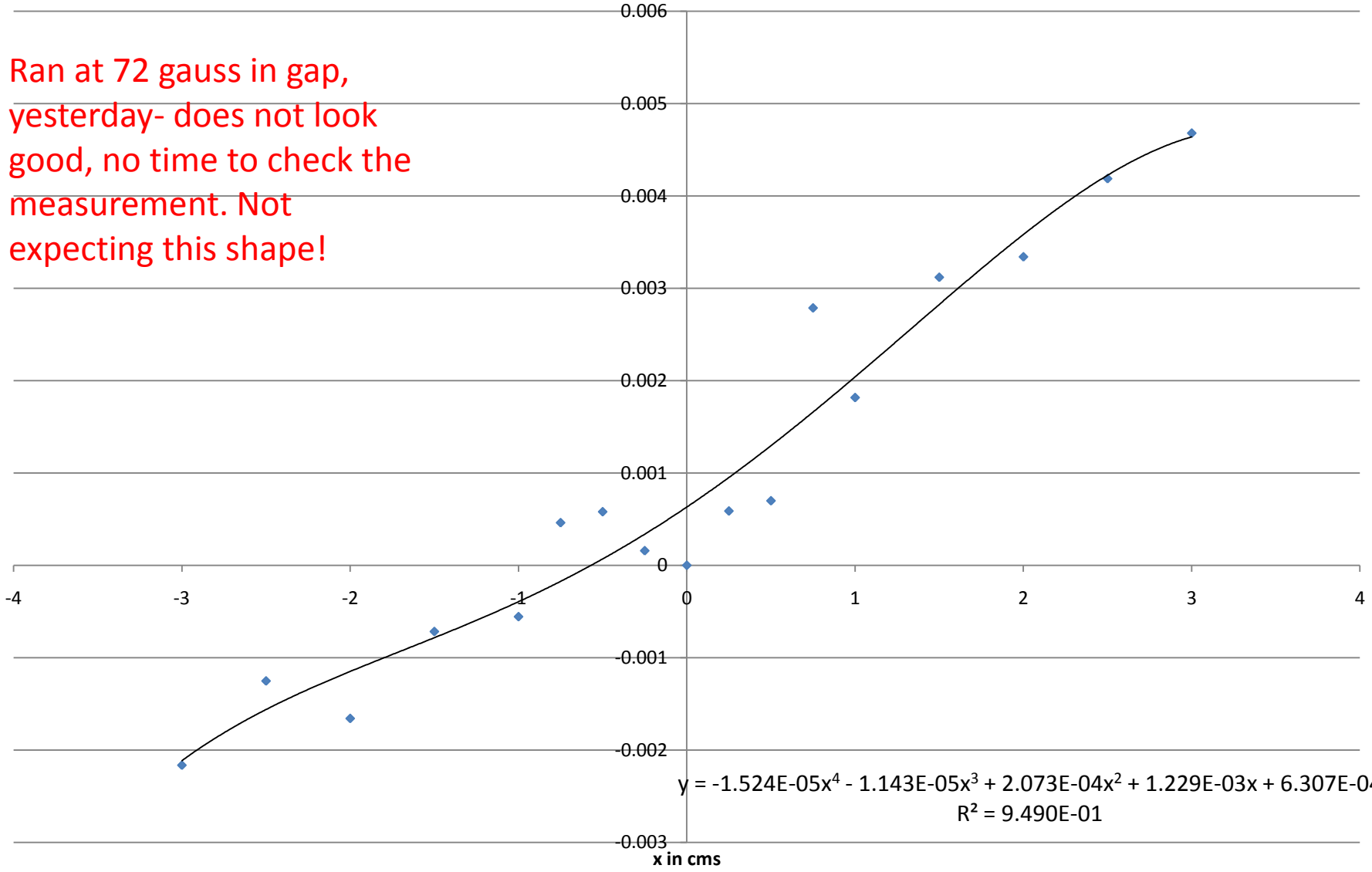
B3E dipole: Normalized Integral B.dl versus X, 460 amps on main, 8amps on trim



Another dipole, eff length: 0.5287 m
10.16cm pole width, 2.07cm gap, runs at 1.488 Tesla field in gap

Normalized Integral B.dl versus x in B3E dipole with 5A on trims

Ran at 72 gauss in gap, yesterday- does not look good, no time to check the measurement. Not expecting this shape!



Preliminary conclusions of an ongoing investigation

- These dipoles were designed to run at high fields in their gaps, so high fields in the steel
- The multipoles hardly changed when strength reduced to 1/140th of nominal (1st example)
- The BDS low field dipoles would be designed to run at very low fields and would not be run over such a wide range as shown here
- I am confident they could be designed to have good field quality.
- 25 gauss could be produced in an air-cored dipole, no need for any steel
- Will do some computer modelling and run more real dipole examples as have time