Cryomodule Magnetic Field Measurements

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08/03/2010

Overview

1. Cryomodule field measurements

- Introduction
  - Motivation
  - Why measure the field?
- Tools & Methods
  - Measurement Program
  - Experimental setup
- Data, Discussion and Conclusion

2. Calibrations

3. Printed Circuit Boards Design

Introduction

International Linear Collider(ILC)

Will make use of Superconducting Radio Frequency Cavities.

http://www.crystalinks.com/internationalinearcollider.html

What are the Superconducting RF cavities?

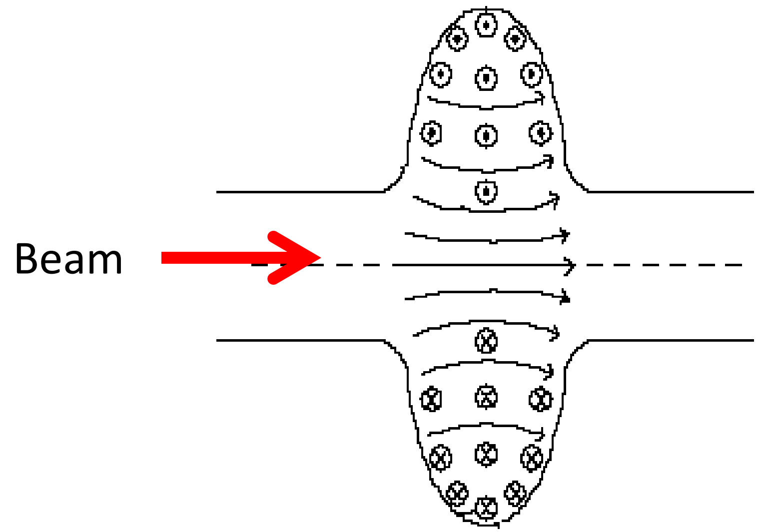
- **Superconductivity:** Zero electrical resistance of some materials at very low temperatures.
- These cavities are made of Niobium which become superconductors at a few degrees above absolute zero.

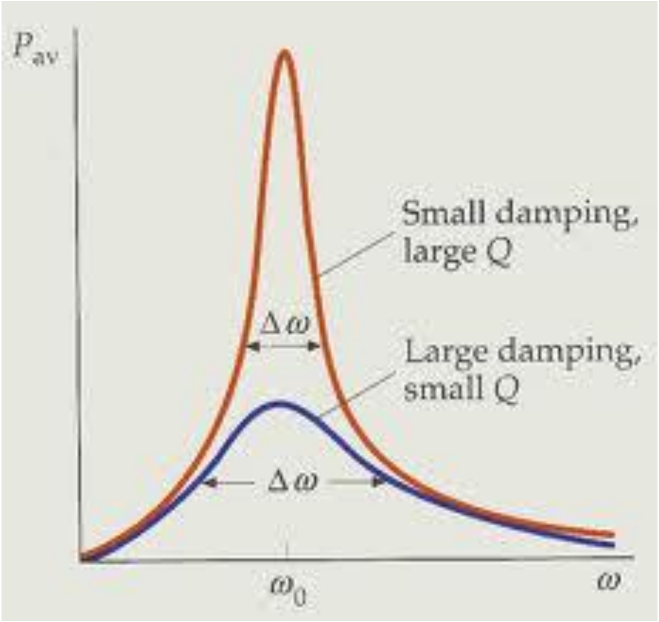
http://www.linearcollider.org/about/What-is-the-ILC/The-project

★ **High acceleration gradient**

How does it accelerate beams?

- SCRF technology is a resonant system
- A standing wave is set up in the cavity where the electric field is in the direction of the beam. Charged particles entering the cavity get accelerated.



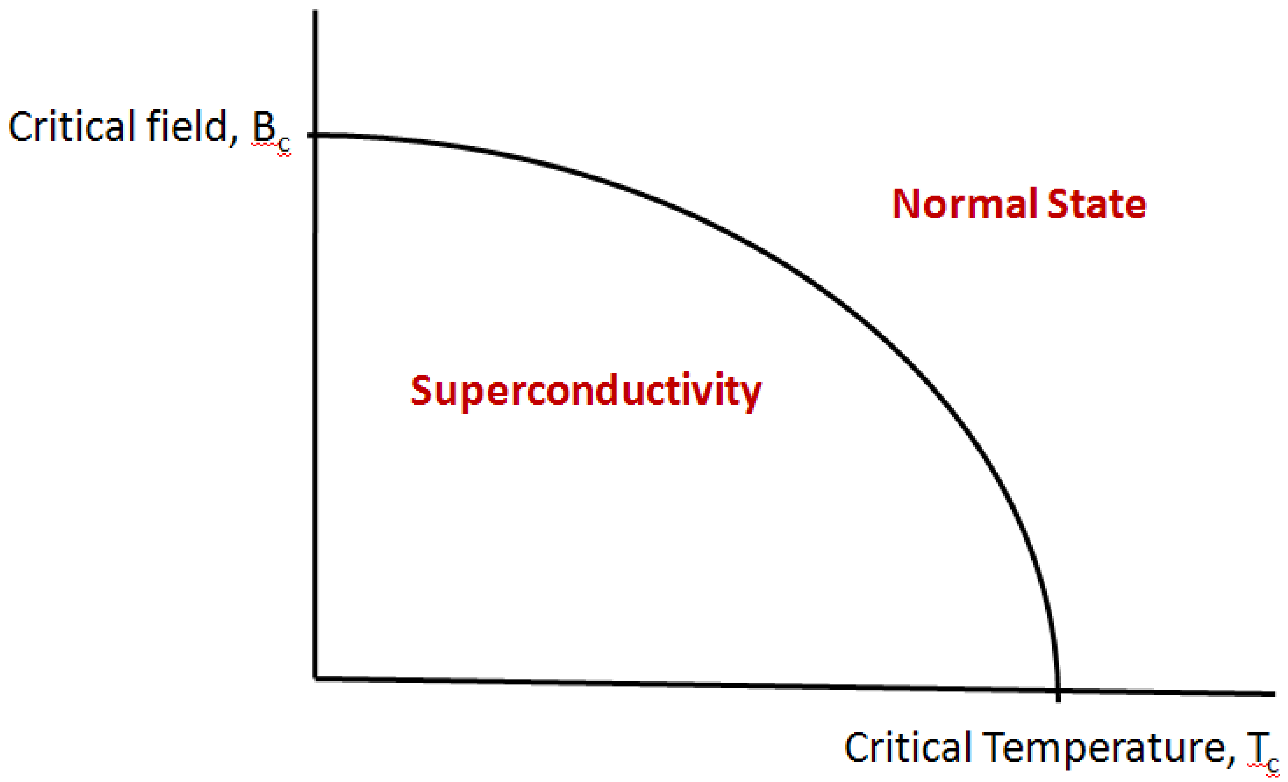


qbx6.ltu.edu

Q ~ 10^{10} – 10^{11} for RF cavities

Effect of field on the cavities

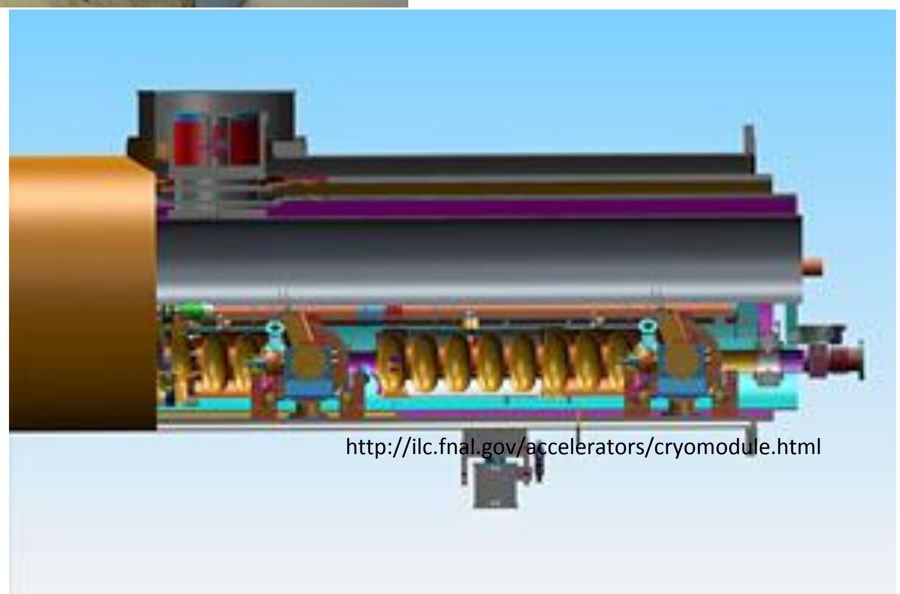
- The main two limitations of superconducting RF cavities are field emission and quenching



Cryomodule

1.3 GHz Vacuum vessel

- Vacuum vessel provides magnetic shielding which reduces the field to about 10-20uT.



An inside view of Cryomodule with the superconducting cavities

- **We need to measure the field inside the cryomodule to ensure that the field is within some acceptable limits.**

Objectives

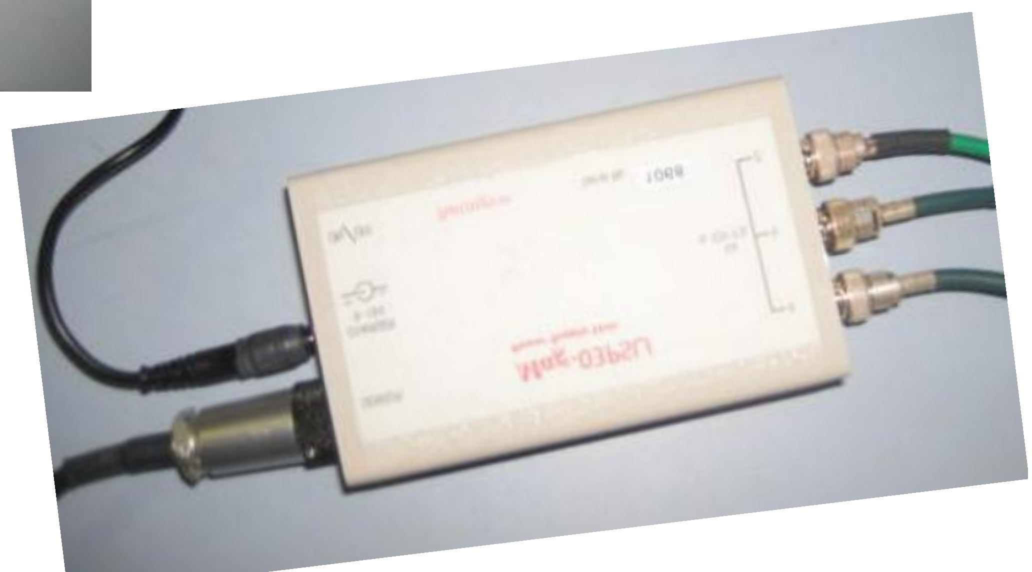
- Develop a LabVIEW program that will facilitate field measurements inside the cryomodule.
- Test the program and check the measurements' consistency with those taken at DESY, the German center for Particle Physics research.

Tools

Magnetic Sensor

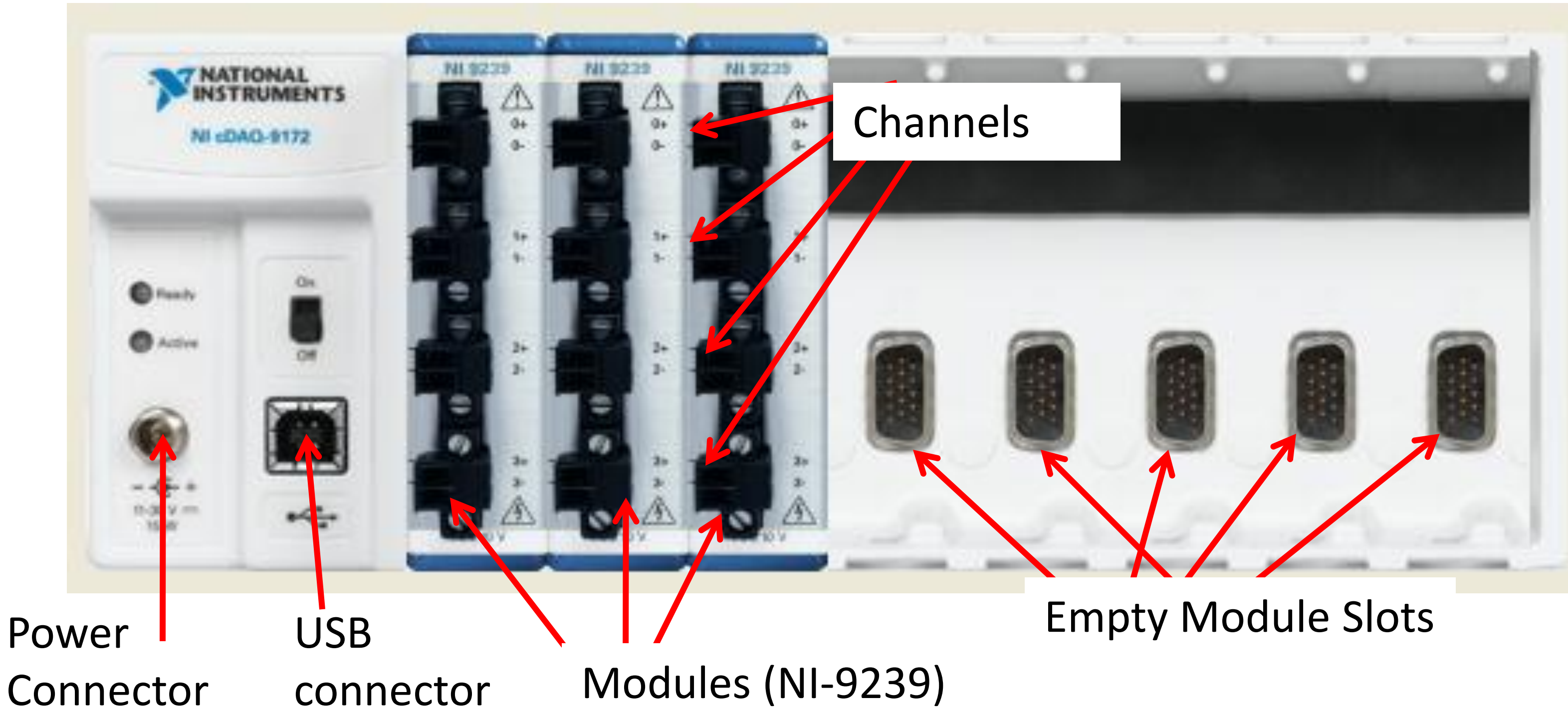
We use Bartington's three-axis magnetometer Mag-03MC1000 , attached to a Power Supply Unit, Mag-03PSU via a 10m cable.

Measures the field in the X, Y and Z directions



Power Supply Unit

NI cDAQ-9172 & NI- 9239



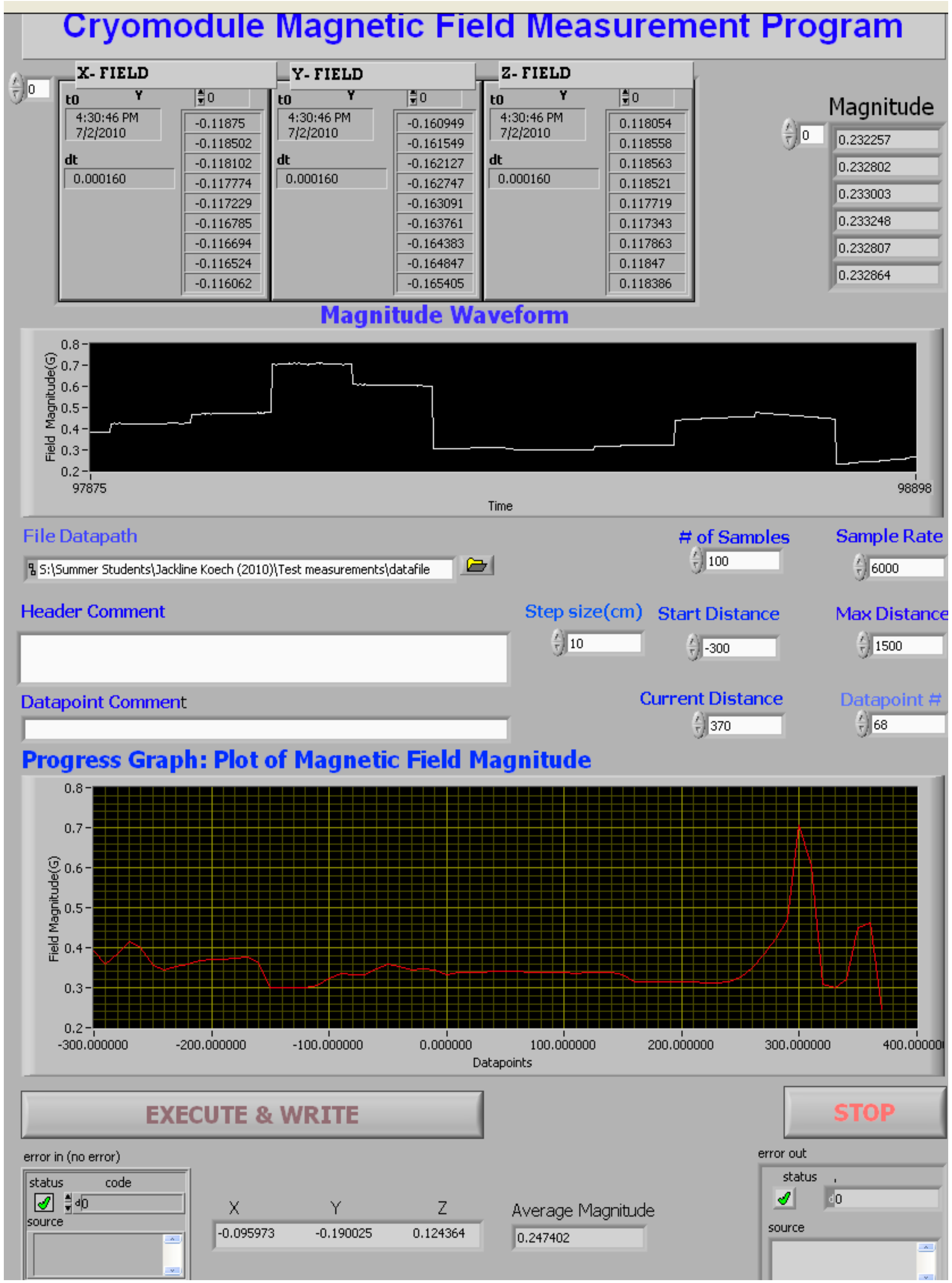
We use NI's compact chassis with 9239 modules

Field Measurement program

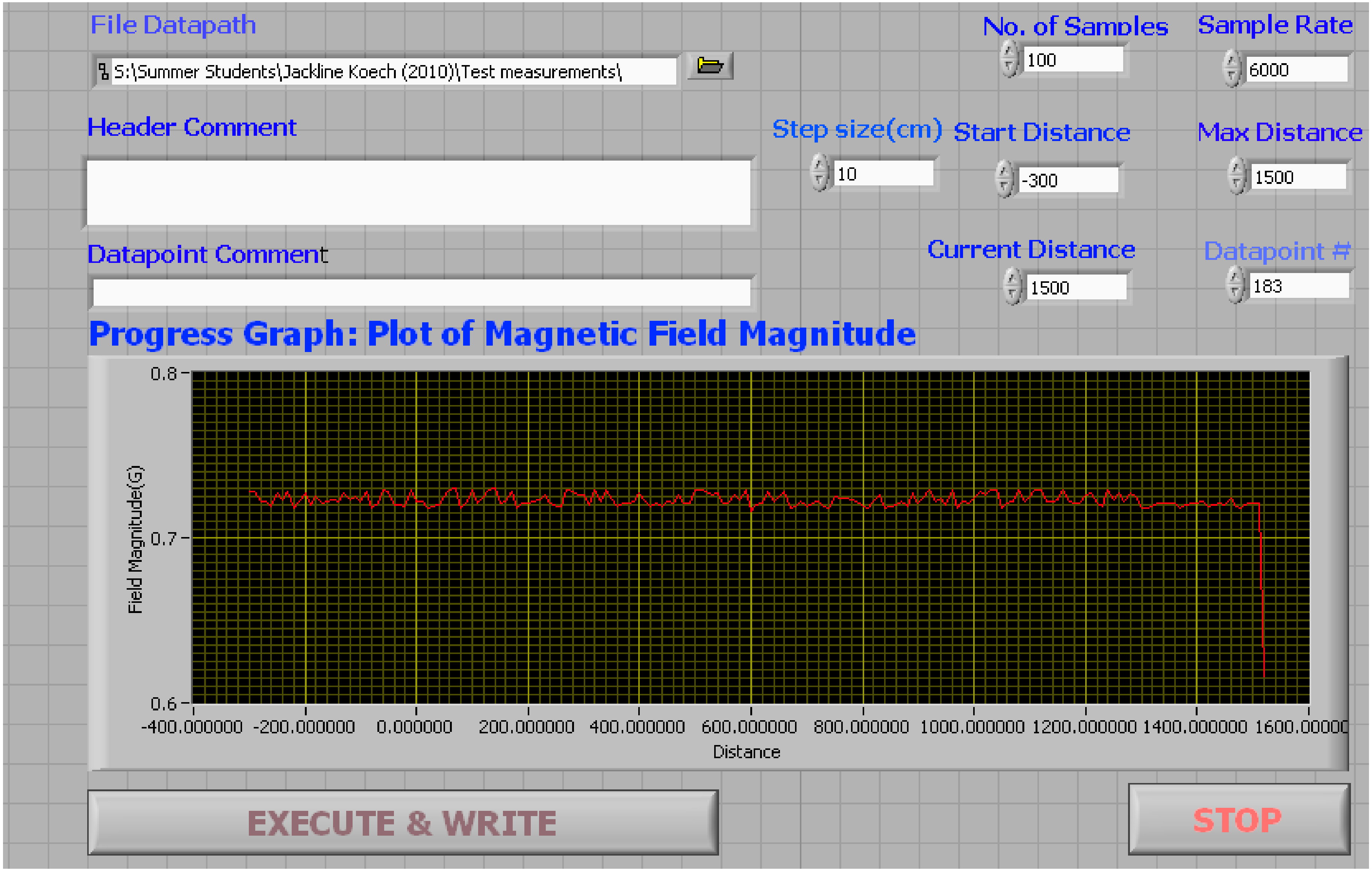
- Written in LabVIEW

- LabVIEW programs are called Virtual Instruments(VIs) and have front panels and a block diagrams

Front Panel



- Reads X, Y and Z fields, calculates magnitude and its average over many sample points.
- Plots field at the different data points as the sensor is moved along the Cryomodule
- Outputs a file

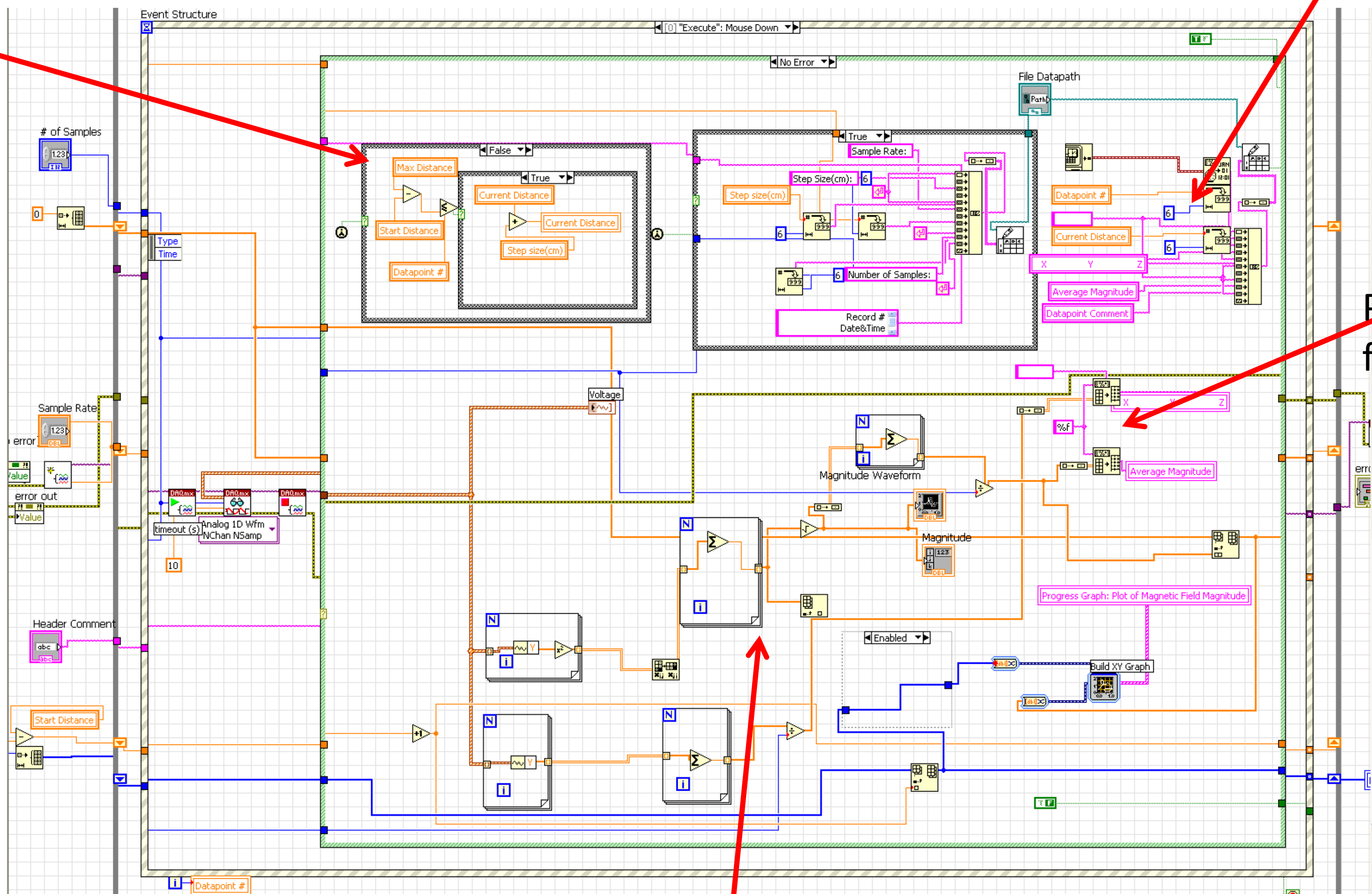

File Datapath
S:\Summer Students\Jackline Koech (2010)\Test measurements\
No. of Samples
100
Sample Rate
6000
Header Comment
Step size(cm)
10
Start Distance
-300
Max Distance
1500
Datapoint Comment
Current Distance
1500
Datapoint #
183
Progress Graph: Plot of Magnetic Field Magnitude
Field Magnitude(G)
0.8
0.7
0.6
-400.000000
-200.000000
0.000000
200.000000
400.000000
600.000000
800.000000
1000.000000
1200.000000
1400.000000
1600.00000
Distance
EXECUTE & WRITE
STOP

Block Diagram

Steps the distance

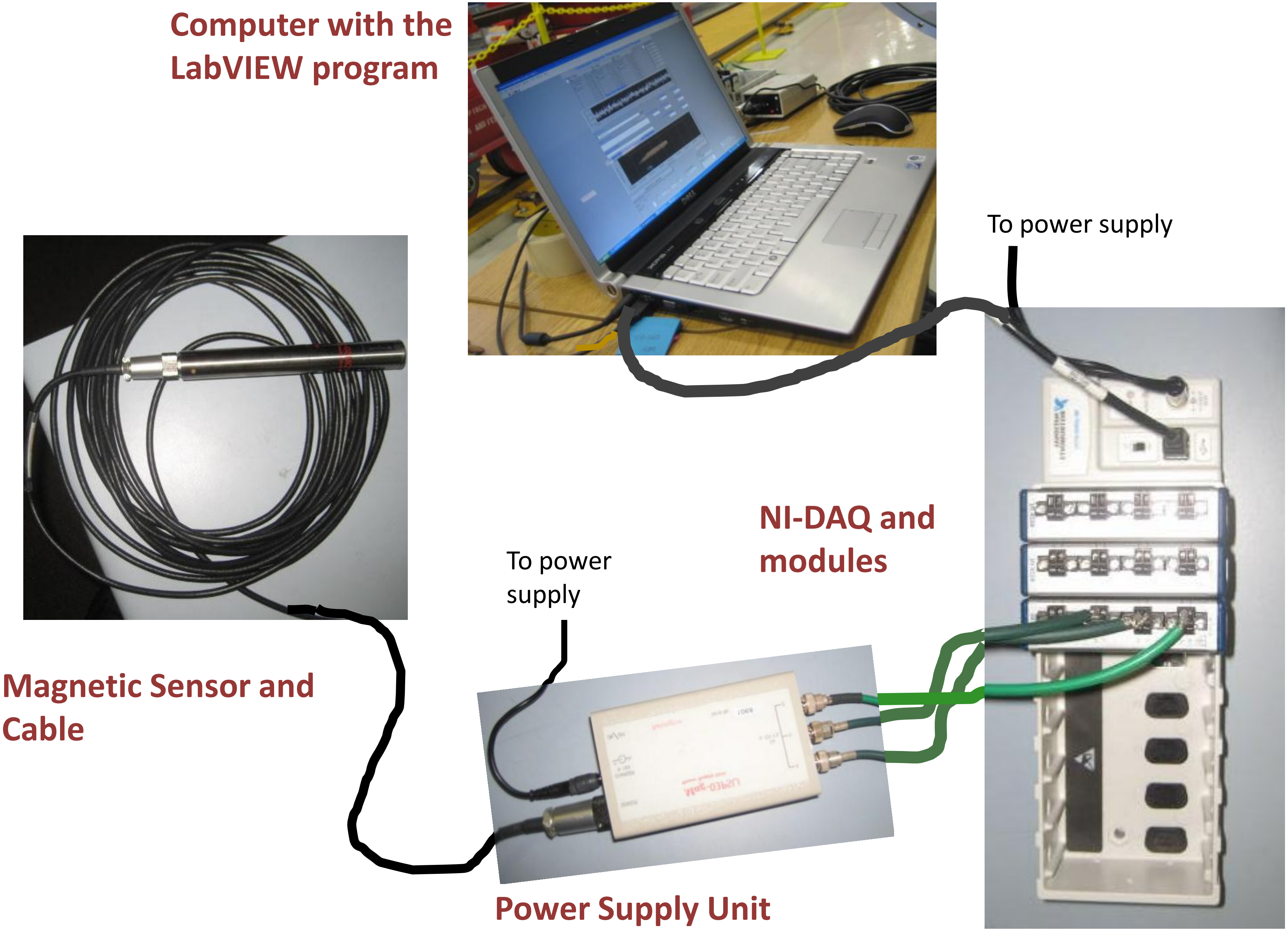
Writes to file

Plots field



Calculates the field averages and magnitude

Experimental Setup



Procedure

- Aluminum channel with wooden support. The Magnetometer was supported by a G-10 probe holder that slides along the channel.

- A tape was attached to the Magnetometer to measure distance

Sample Output File opened in Excel

Data taken from the center of the cryomodule, the probe was pulled towards the east flange of the cryomodule. The distance frc

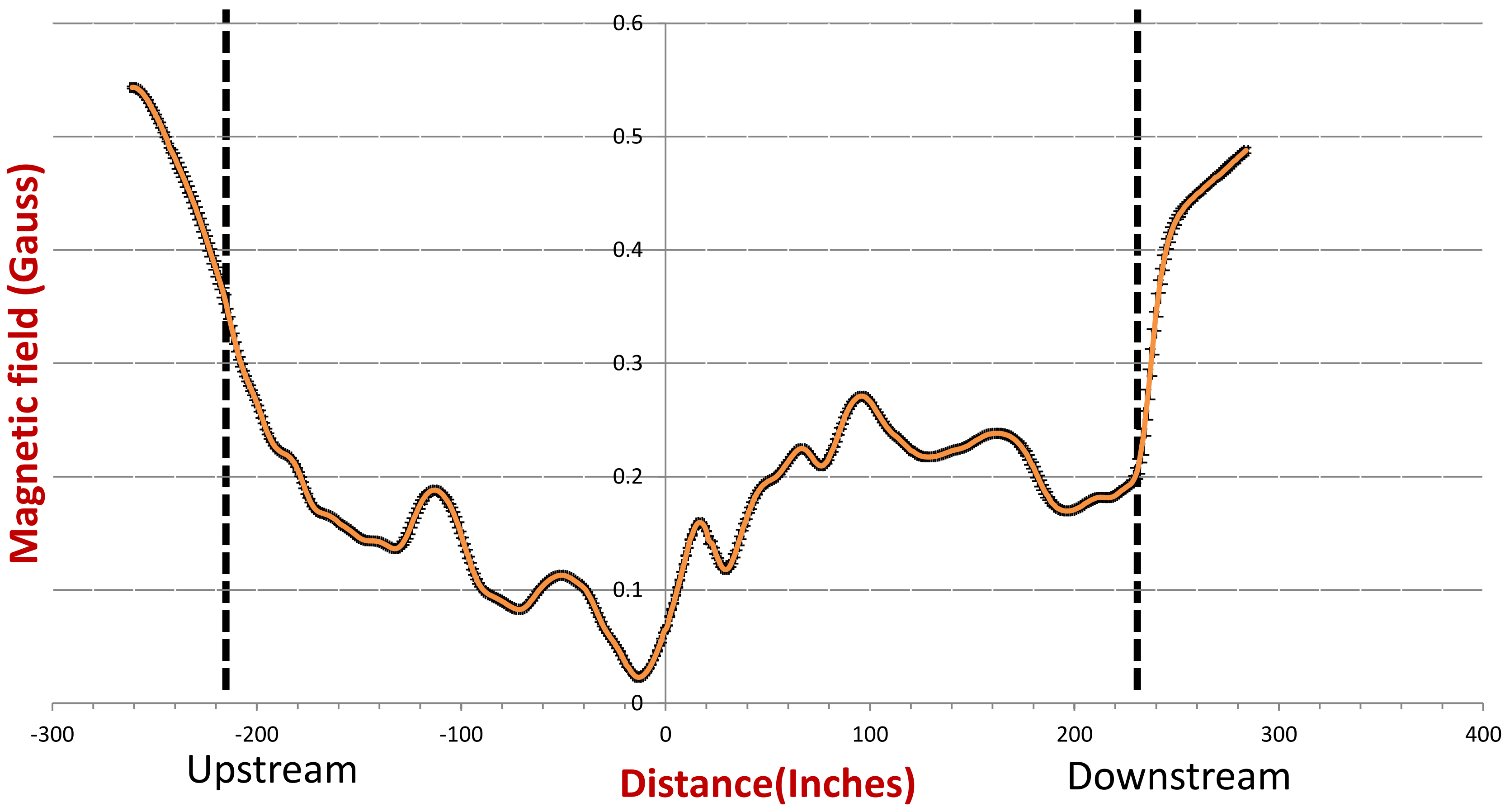
Step Size(inches): -1

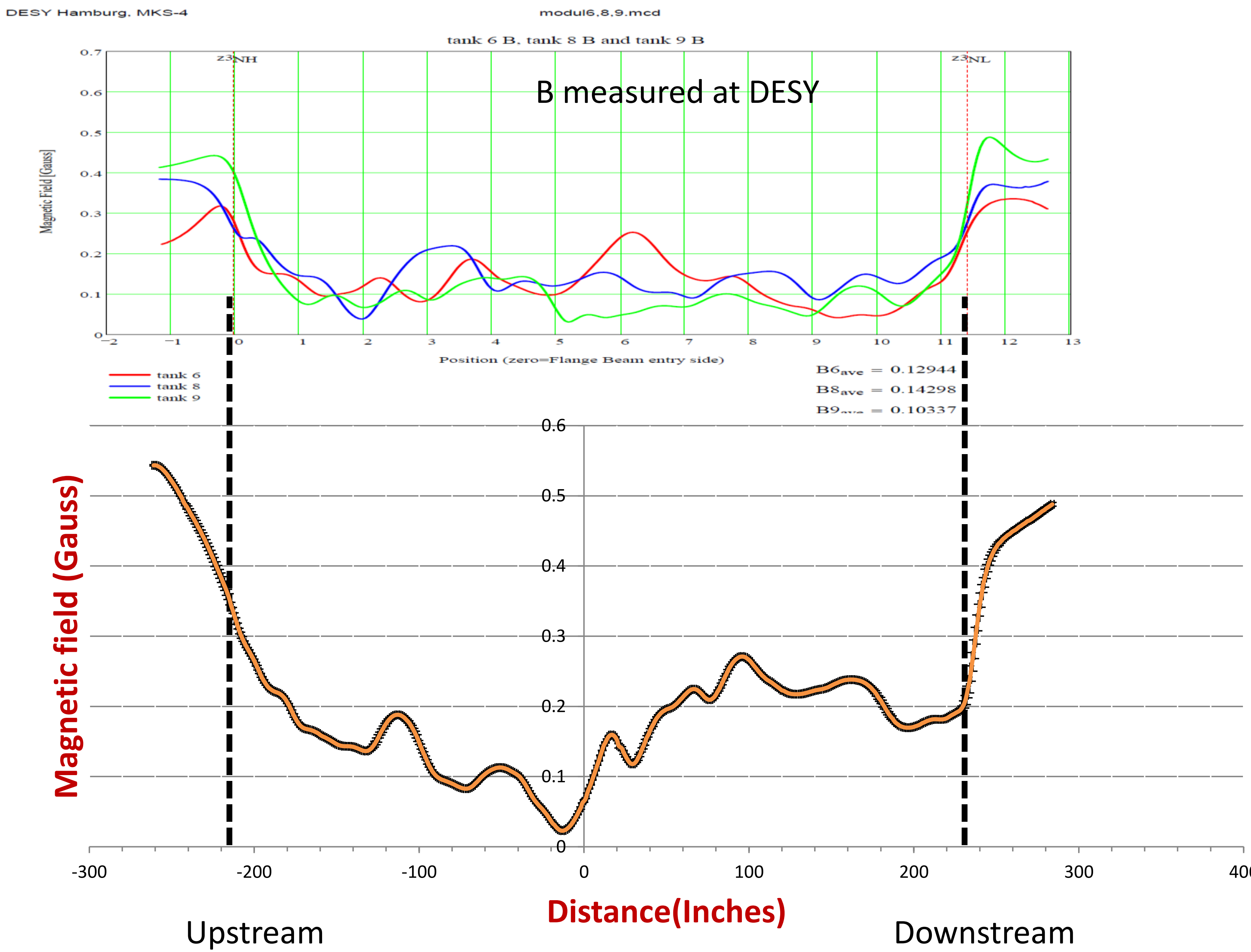
Sample Rate(Hz): 6000

Number of Samples: 100

Record #	Date&Time	Distance(inches)	Bx(G)	By(G)	Bz(G)	Magnitude(G)	Comments
0	7/28/2010 3:24:04 PM	0	-0.005857	0.048346	0.037987	0.061763	
1	7/28/2010 3:24:14 PM	0	-0.005848	0.048341	0.037985	0.061757	
2	7/28/2010 3:24:17 PM	-1	-0.005426	0.052627	0.041075	0.066979	
3	7/28/2010 3:24:19 PM	-2	-0.005053	0.058096	0.045400	0.073904	
4	7/28/2010 3:24:21 PM	-3	-0.005070	0.063402	0.050162	0.081004	
5	7/28/2010 3:24:22 PM	-4	-0.005560	0.067468	0.054205	0.086724	
6	7/28/2010 3:24:23 PM	-5	-0.007474	0.072619	0.060013	0.094503	
7	7/28/2010 3:24:24 PM	-6	-0.009572	0.076569	0.065072	0.100939	
8	7/28/2010 3:24:30 PM	-7	-0.012833	0.080793	0.071342	0.108544	
9	7/28/2010 3:24:32 PM	-8	-0.016632	0.084162	0.077434	0.115568	
10	7/28/2010 3:24:34 PM	-9	-0.021540	0.087173	0.084350	0.123199	
11	7/28/2010 3:24:35 PM	-10	-0.026254	0.089098	0.090524	0.129701	
12	7/28/2010 3:24:36 PM	-11	-0.031331	0.090313	0.096910	0.136123	
13	7/28/2010 3:24:38 PM	-12	-0.036280	0.090724	0.102919	0.141914	
14	7/28/2010 3:24:39 PM	-13	-0.042408	0.090107	0.110294	0.148601	
15	7/28/2010 3:24:47 PM	-14	-0.047049	0.088604	0.115712	0.153145	
16	7/28/2010 3:24:49 PM	-15	-0.051731	0.085837	0.120822	0.156978	
17	7/28/2010 3:24:51 PM	-16	-0.055178	0.082603	0.124065	0.158934	
18	7/28/2010 3:24:52 PM	-17	-0.057852	0.078930	0.125864	0.159432	
19	7/28/2010 3:24:53 PM	-18	-0.059826	0.075010	0.126133	0.158478	

Field magnitude measured in lab




DESY Hamburg, MKS-4
modul6,8,9.mcd
tank 6 B, tank 8 B and tank 9 B
z3NH
z3NL
B measured at DESY
Magnetic Field [Gauss]
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−2
−1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Position (zero=Flange Beam entry side)
tank 6
tank 8
tank 9
$B6_{ave} = 0.12944$
$B8_{ave} = 0.14298$
$B9_{ave} = 0.10337$
Magnetic field (Gauss)
0.6
0.5
0.4
0.3
0.2
0.1
0
-300
-200
-100
0
100
200
300
400
Distance(Inches)
Upstream
Downstream

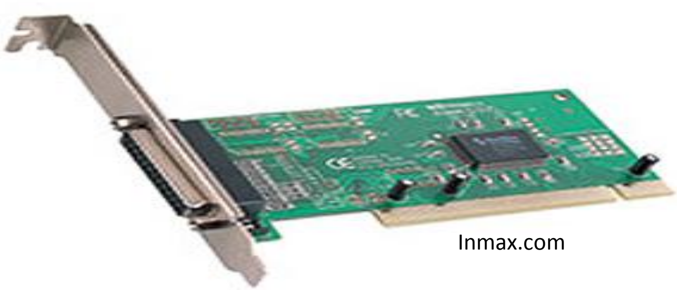
Conclusion

- We have been able to develop a program that facilitates efficient Magnetic field measurements inside the cryomodule.

- Our measurements are consistent with measurements done on a similar cryomodule at DESY

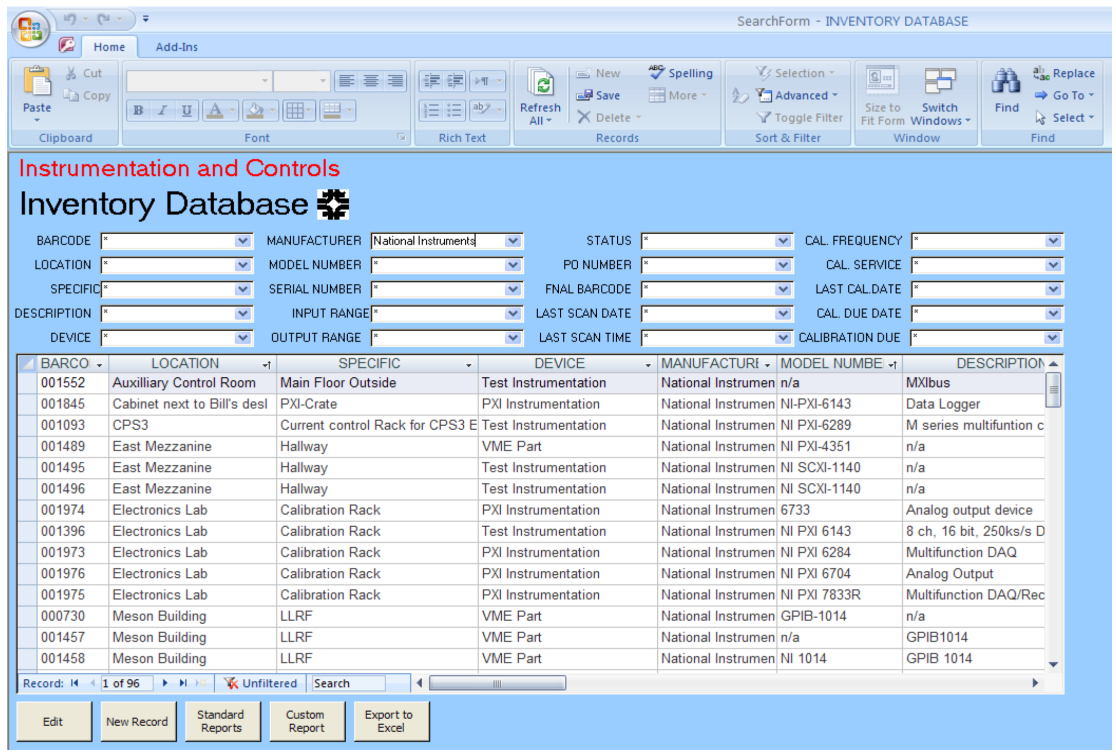
Calibrations

- We did voltage/current calibration of instruments used for testing superconducting and conventional magnets, mostly PXI cards.
- LabVIEW program run on the PXI computer platform.



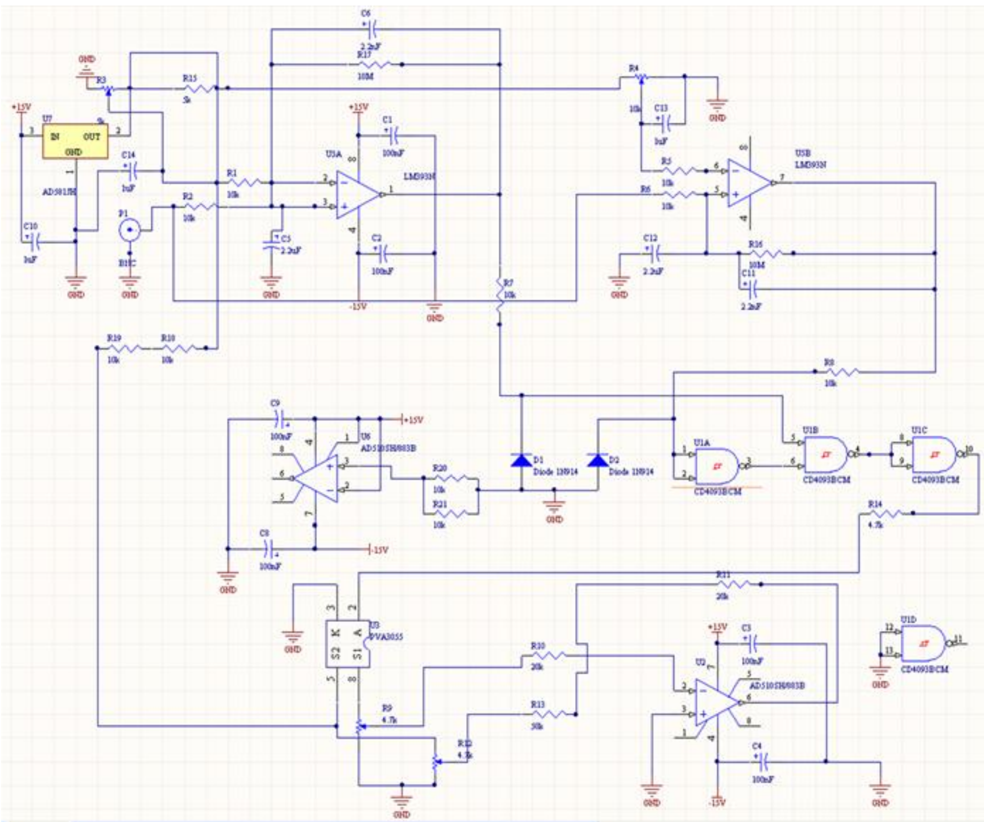
Inmax.com

PXI Card

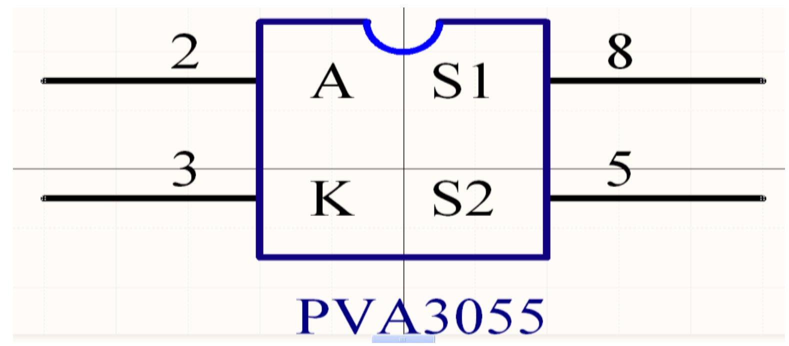


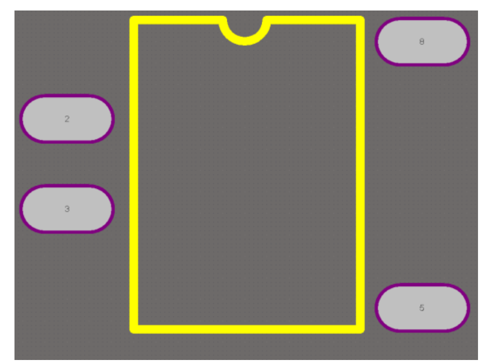
Database

Printed Circuit Board Design using Altium Designer



Creating components and associating them with a certain footprint.

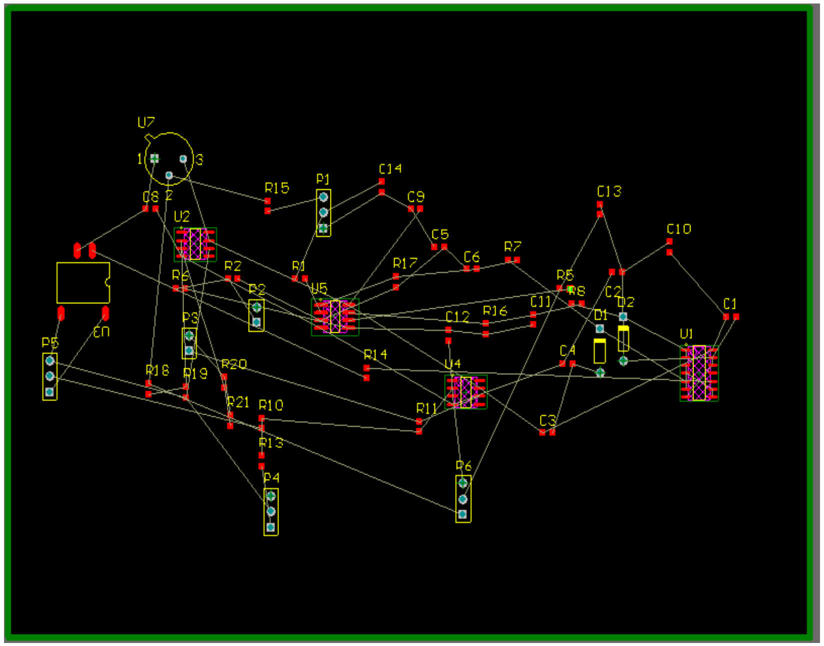




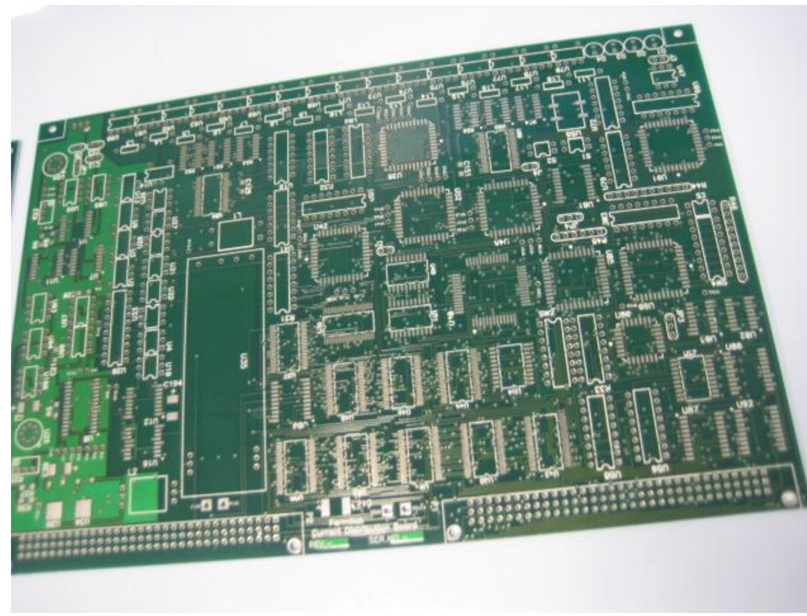
Schematic of AQD variable threshold

Printed Circuit Board Design

Schematic >PCB layout>printing PC Boards



PCB layout



Current distribution board
- Andrzej

Acknowledgements

- Fermilab SIST committee
- Supervisor: Darryl Orris
- Mentor: Mayling Wong
- Dr James Davenport.
- Andrzej Makulski, Roger Nehring
- Technical Division employees

References

- http://www.linearcollider.org/about/What-is-the-ILC/The-project
- http://www.crystalinks.com/internationalinearcollider.html
- Ilan Ben-Zvi, *Superconducting RF Cavities for Particle Accelerators: An Introduction*, Brookhaven National Laboratory.

Thank You!

I will now take your questions.

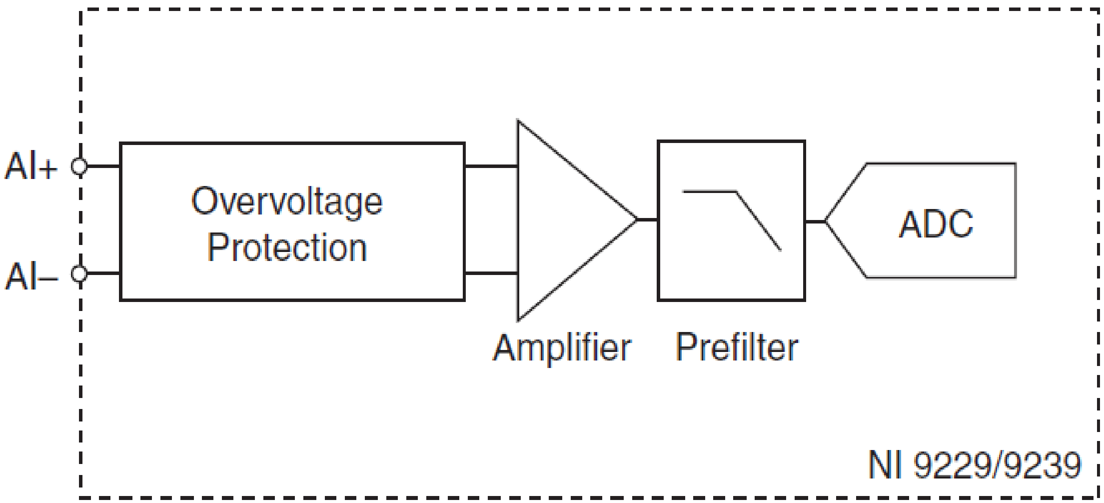
Extra slides

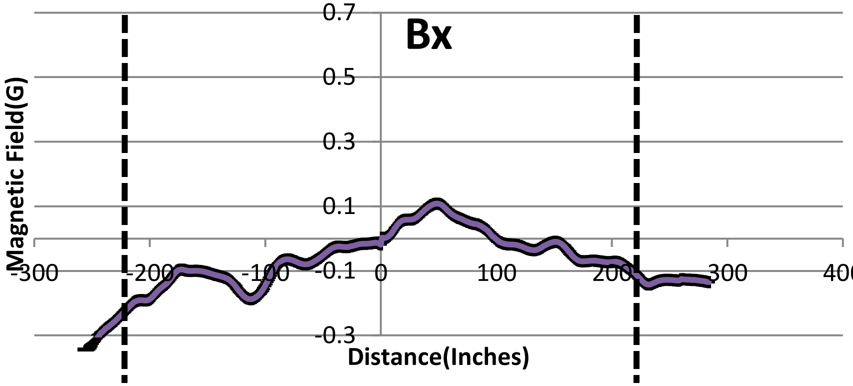
$$Q = \frac{w}{\Delta w}$$

Input Circuitry for One Channel of the NI-9239

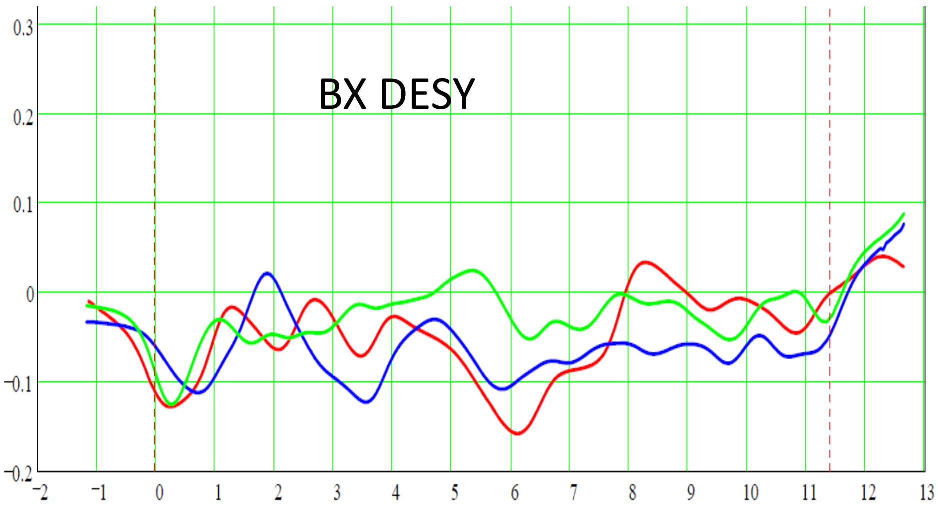
4 channel, 24 bit simultaneous Channel to Channel Isolated Analog input modules. Each Channel provides an independent signal path and ADC. NI 9239 uses a combination of analog and digital filtering to provide an accurate representation of in-band signals while rejecting out-of-band signals.

Ni.com



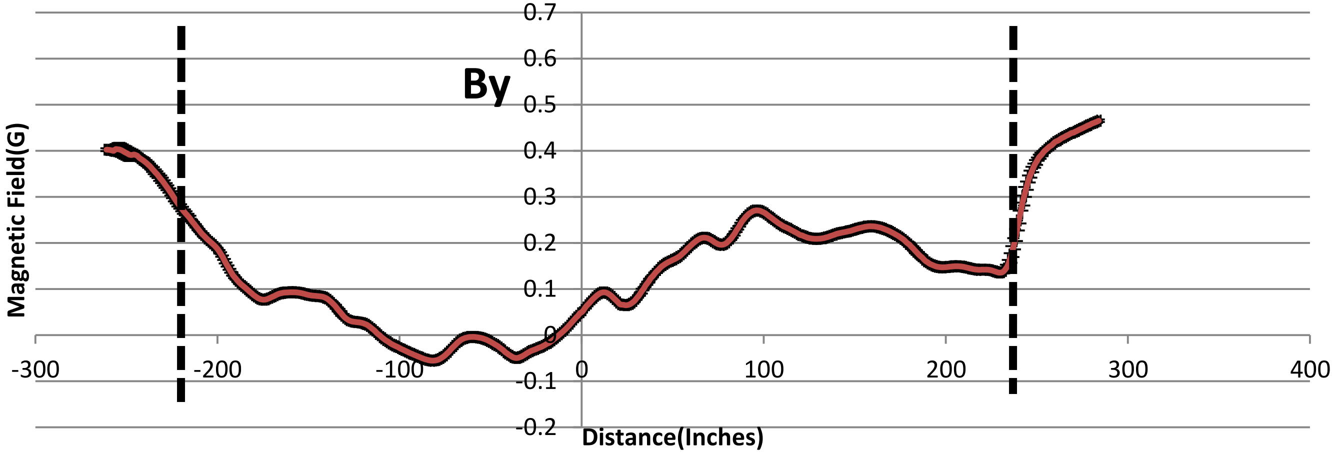


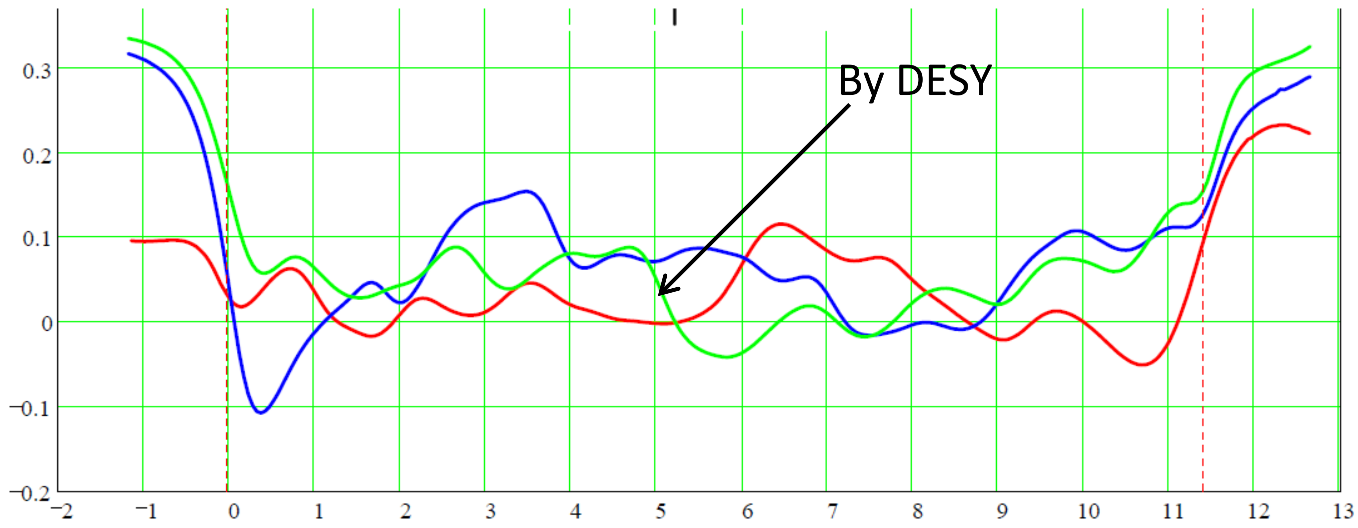
Bx
Magnetic Field(G)
Distance(Inches)
0.7
0.5
0.3
0.1
-0.1
-0.3
-300
-200
-100
0
100
200
300
400



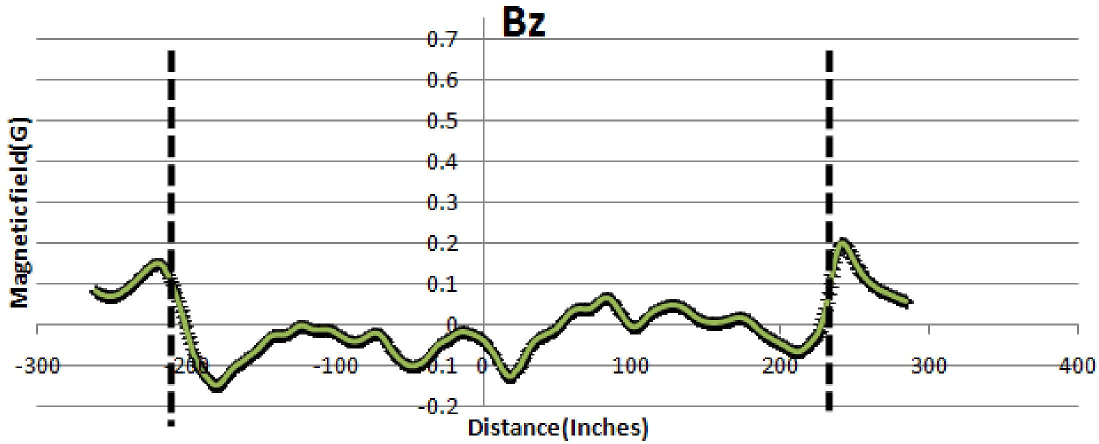
BX DESY
0.3
0.2
0.1
0
−0.1
−0.2
−2
−1
0
1
2
3
4
5
6
7
8
9
10
11
12
13

By

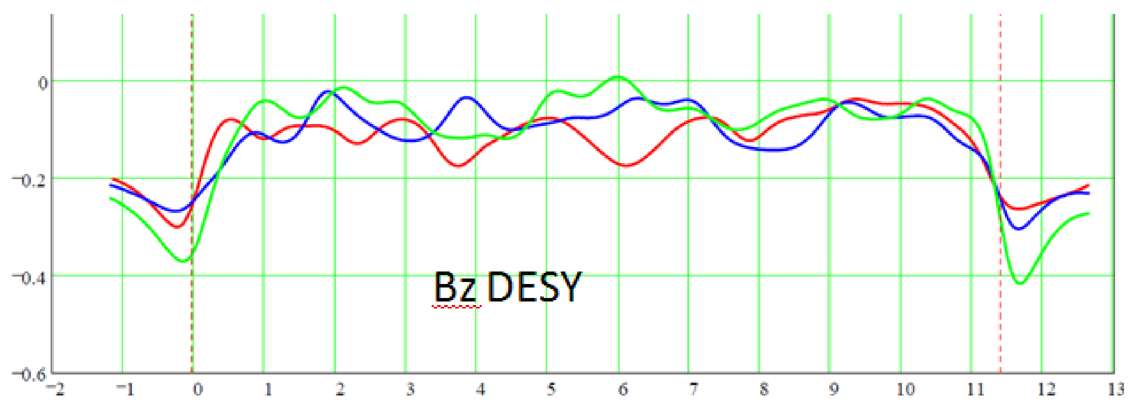

By
Magnetic Field(G)
Distance(Inches)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-300
-200
-100
0
100
200
300
400


By DESY
0.3
0.2
0.1
0
−0.1
−0.2
−2
−1
0
1
2
3
4
5
6
7
8
9
10
11
12
13

Bz

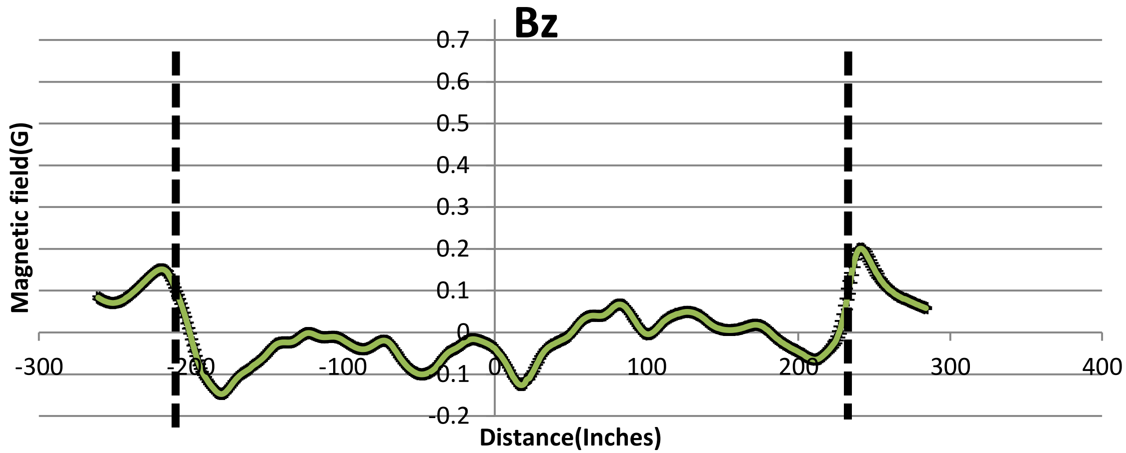


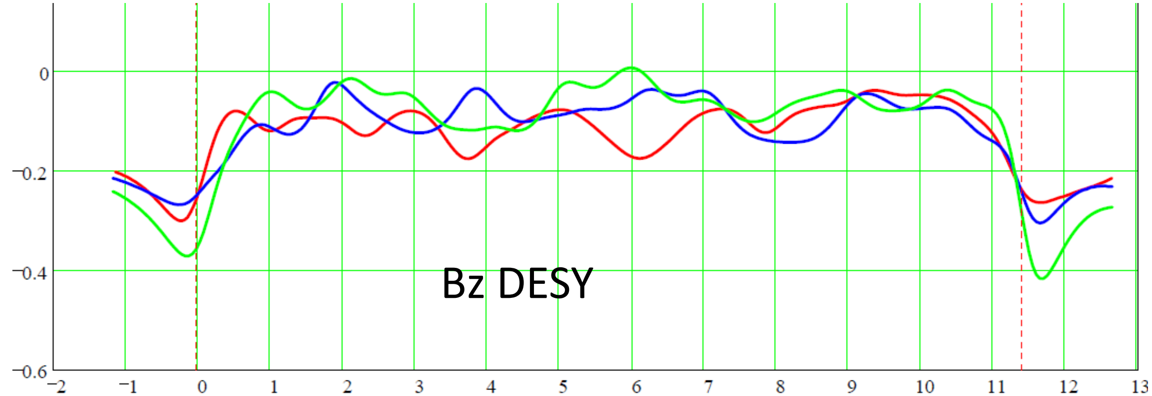
Bz
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-300
-200
-100
0
100
200
300
400
Magneticfield(G)
Distance(Inches)



0
−0.2
−0.4
−0.6
−2
−1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Bz DESY

Bz


Bz
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-300
-200
-100
0
100
200
300
400
Magnetic field(G)
Distance(Inches)


0
−0.2
−0.4
−0.6
−2
−1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Bz DESY