Cryomodule Magnetic Field Measurements

Jackline Koech
Supervisor: Darryl Orris

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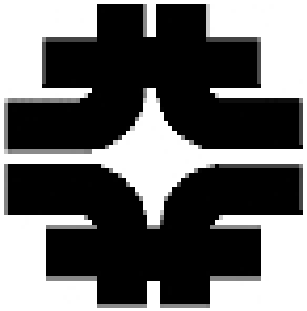
MOUNT HOLYOKE.



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?

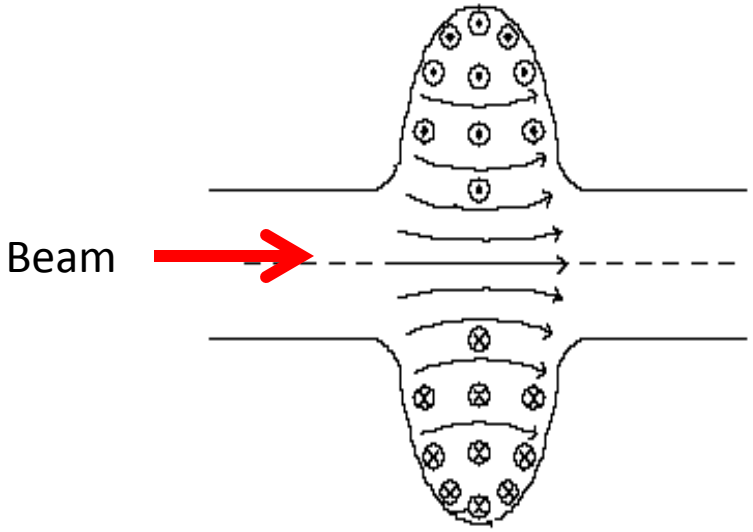
- **Superconductivity:** Zero electrical resistance of some materials at very low temperatures.
- These cavities are made of Niobium which become superconductors at a few degrees above absolute zero.

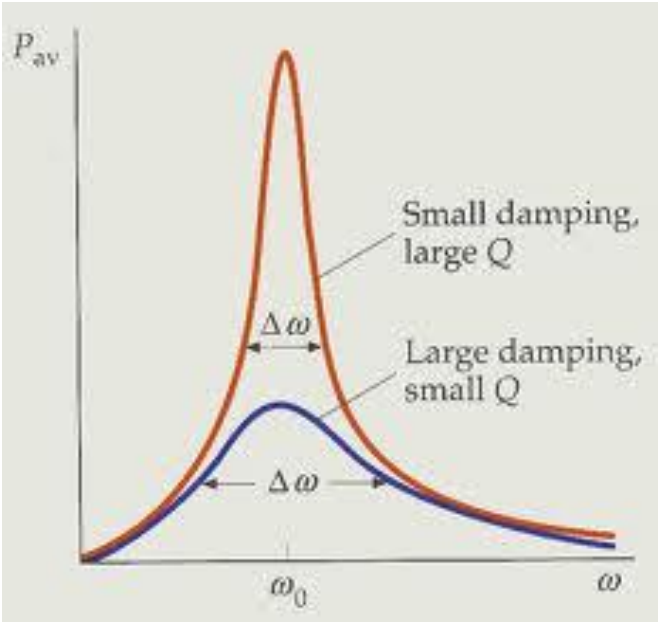
http://www.linearcollider.org/about/What-is-the-ILC/The-project

★ 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.



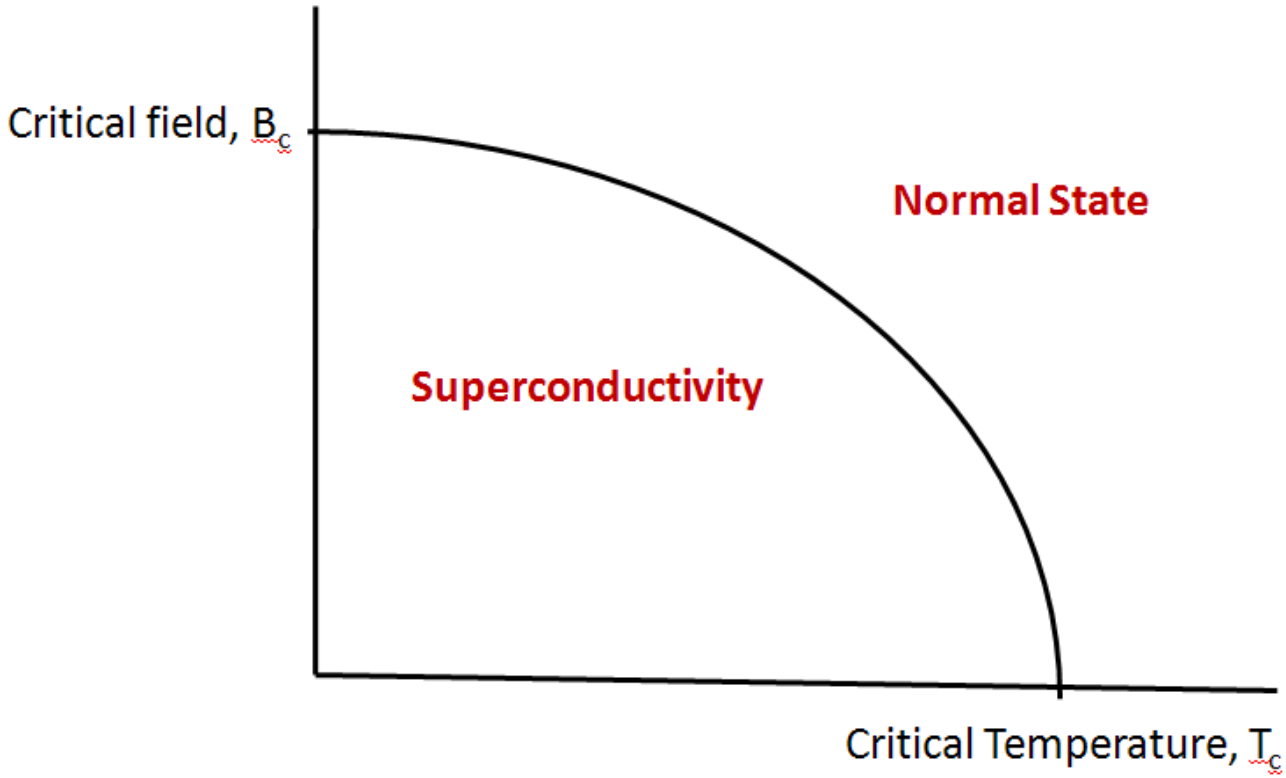


qbx6.ltu.edu

$Q \sim 10^{10} - 10^{11}$ for RF cavities

Effect of field on the cavities

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

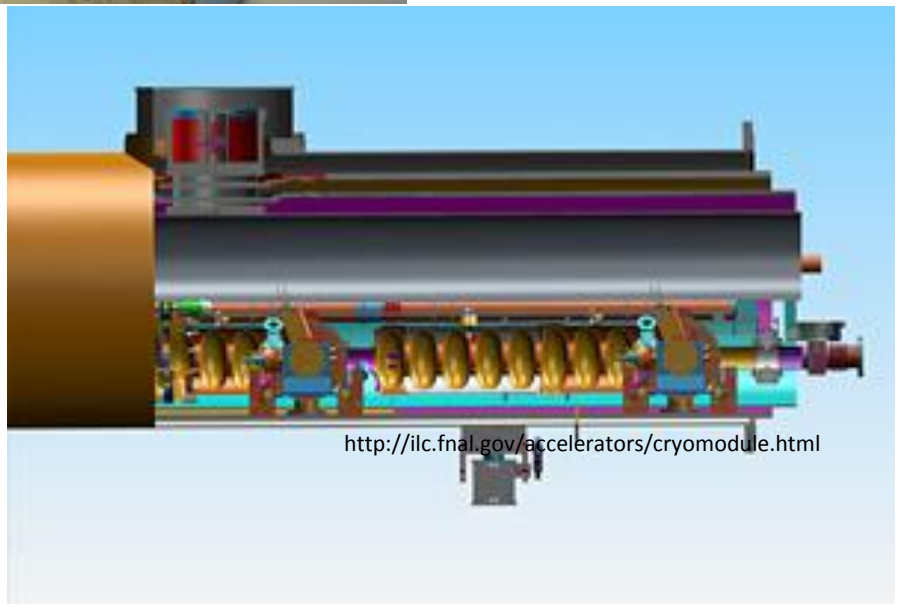


Cryomodule

1.3 GHz Vacuum vessel

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

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



An inside view of Cryomodule with the superconducting cavities

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

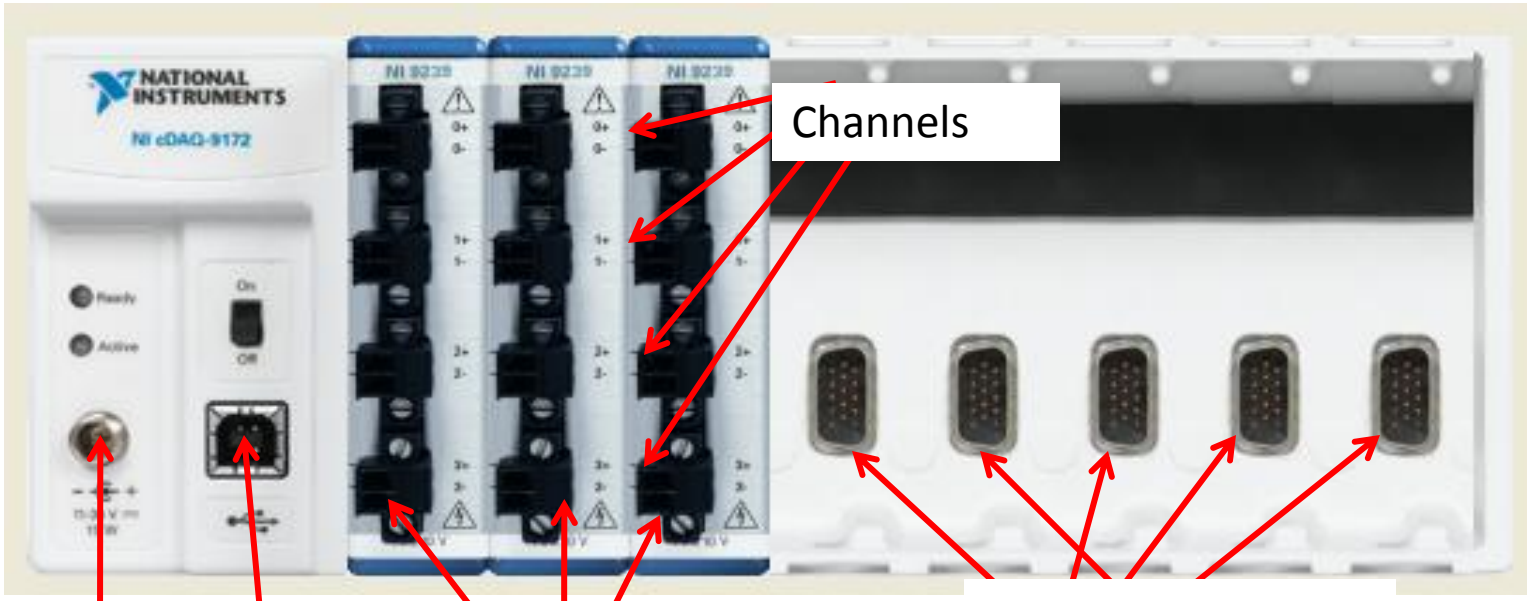
Magnetic Sensor

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

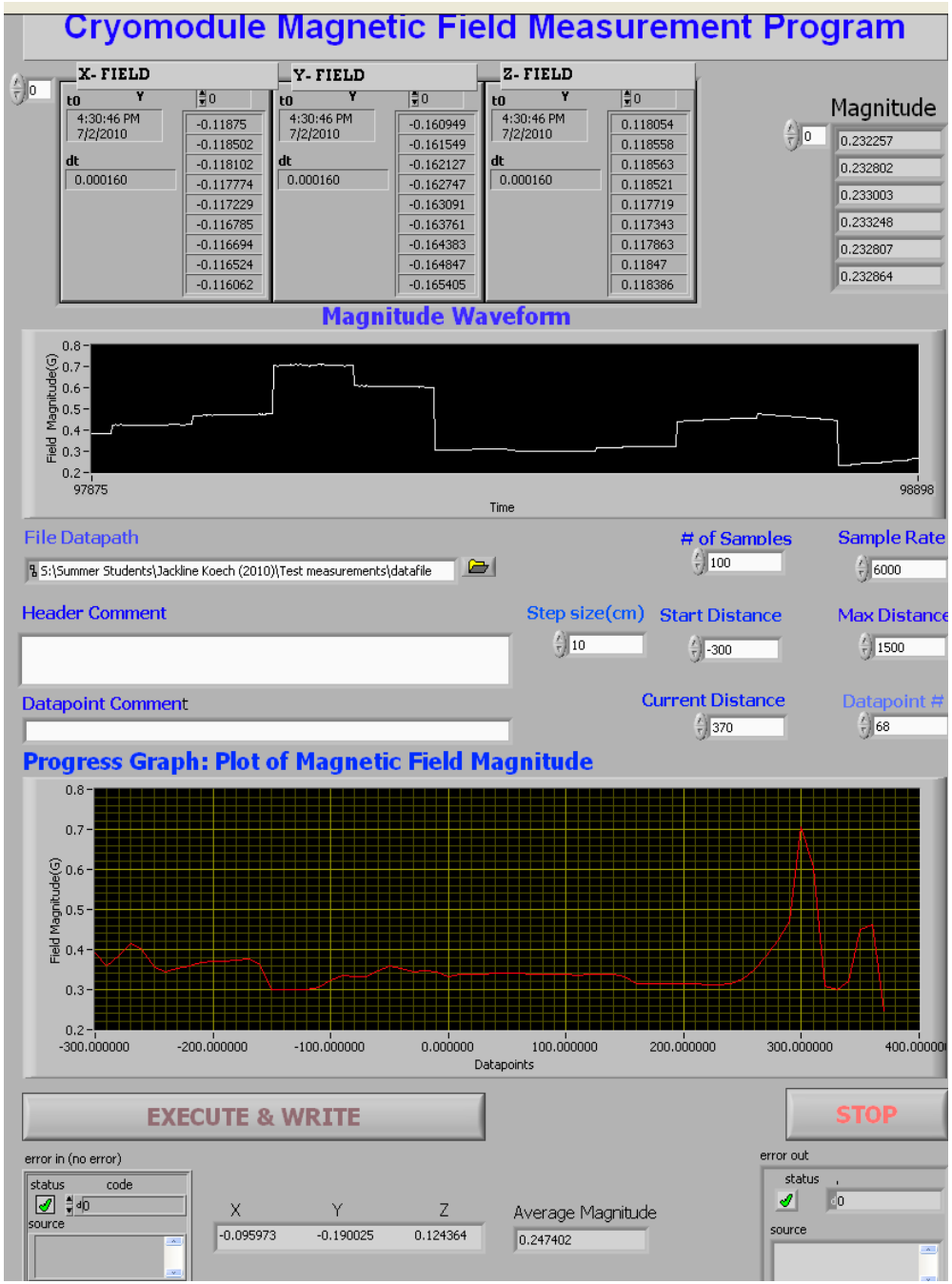


We use NI's compact chassis with 9239 modules

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

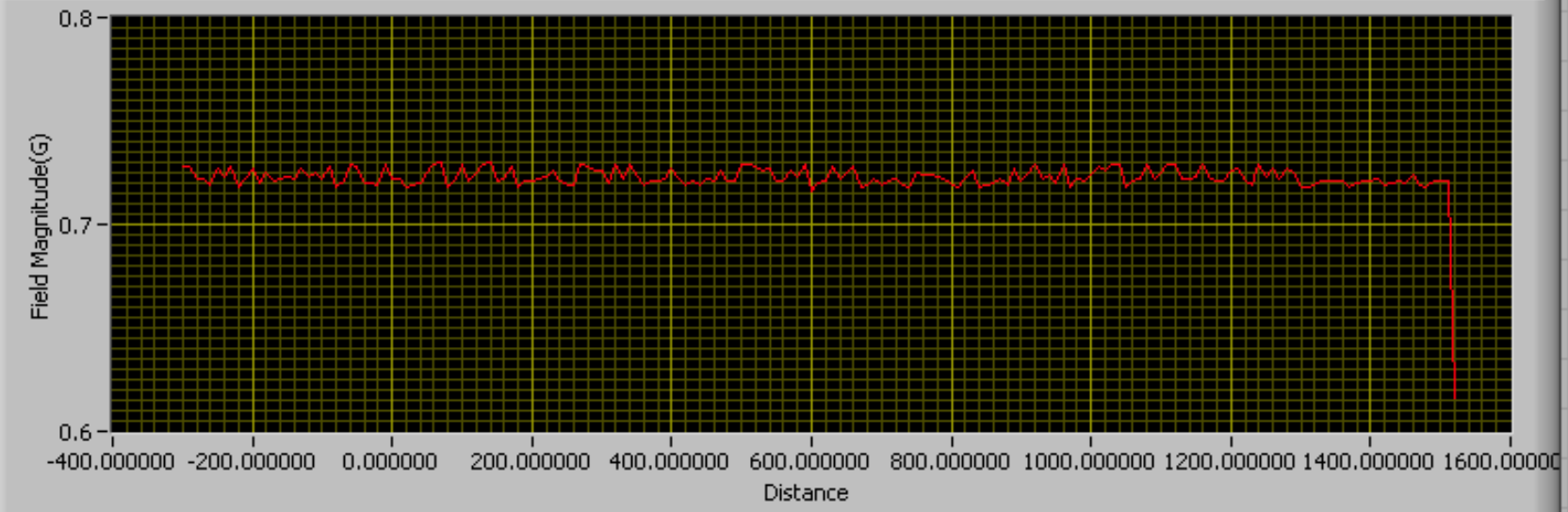
Max Distance: 1500

Datapoint Comment

Current Distance: 1500

Datapoint #: 183

Progress Graph: Plot of Magnetic Field Magnitude



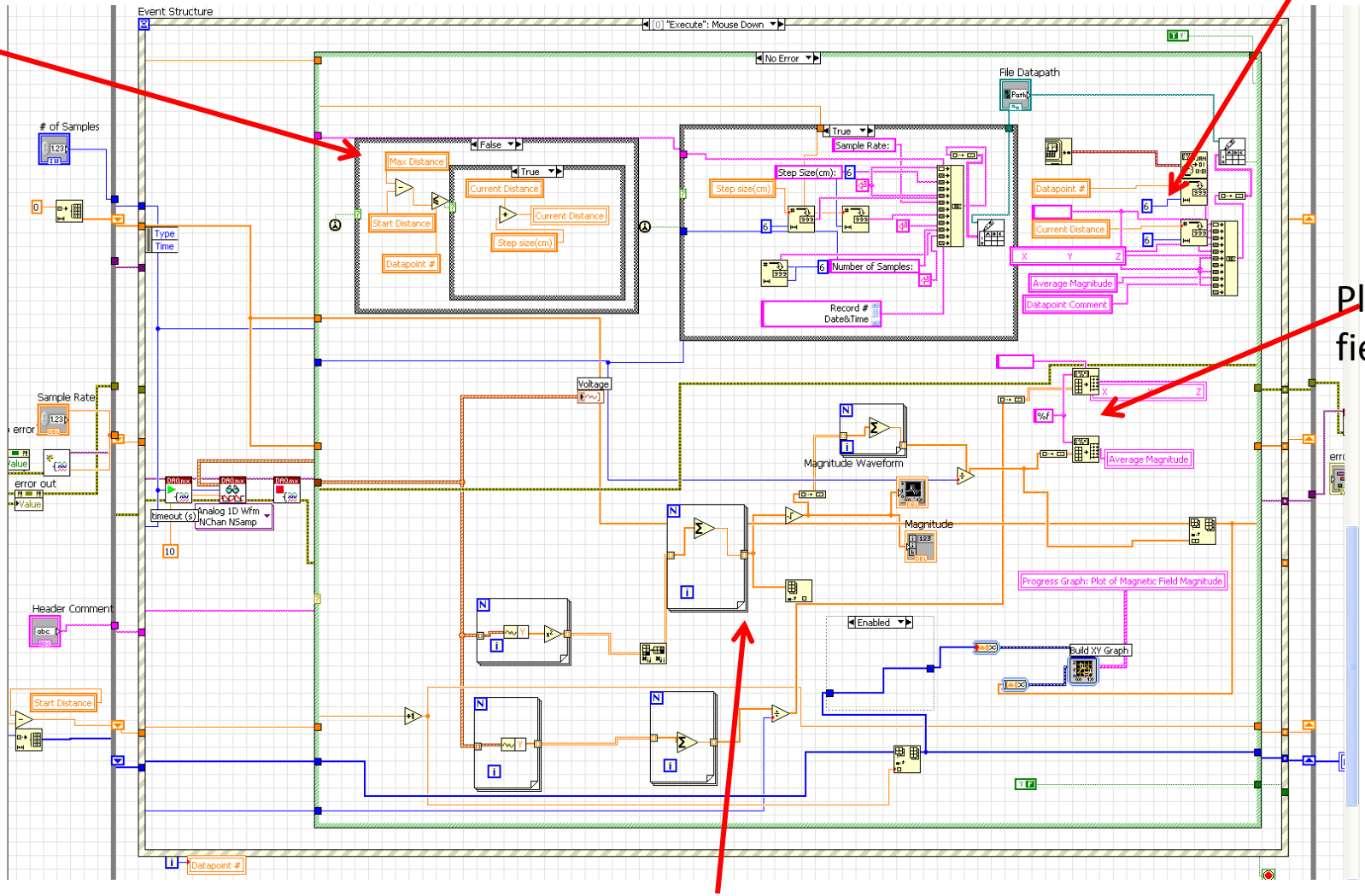
EXECUTE & WRITE

STOP

Block Diagram

Writes to file

Steps the distance



Plots field

Calculates the field averages and magnitude

Experimental Setup

Computer with the LabVIEW program

To power supply

NI-DAQ and modules

To power supply

Magnetic Sensor and Cable

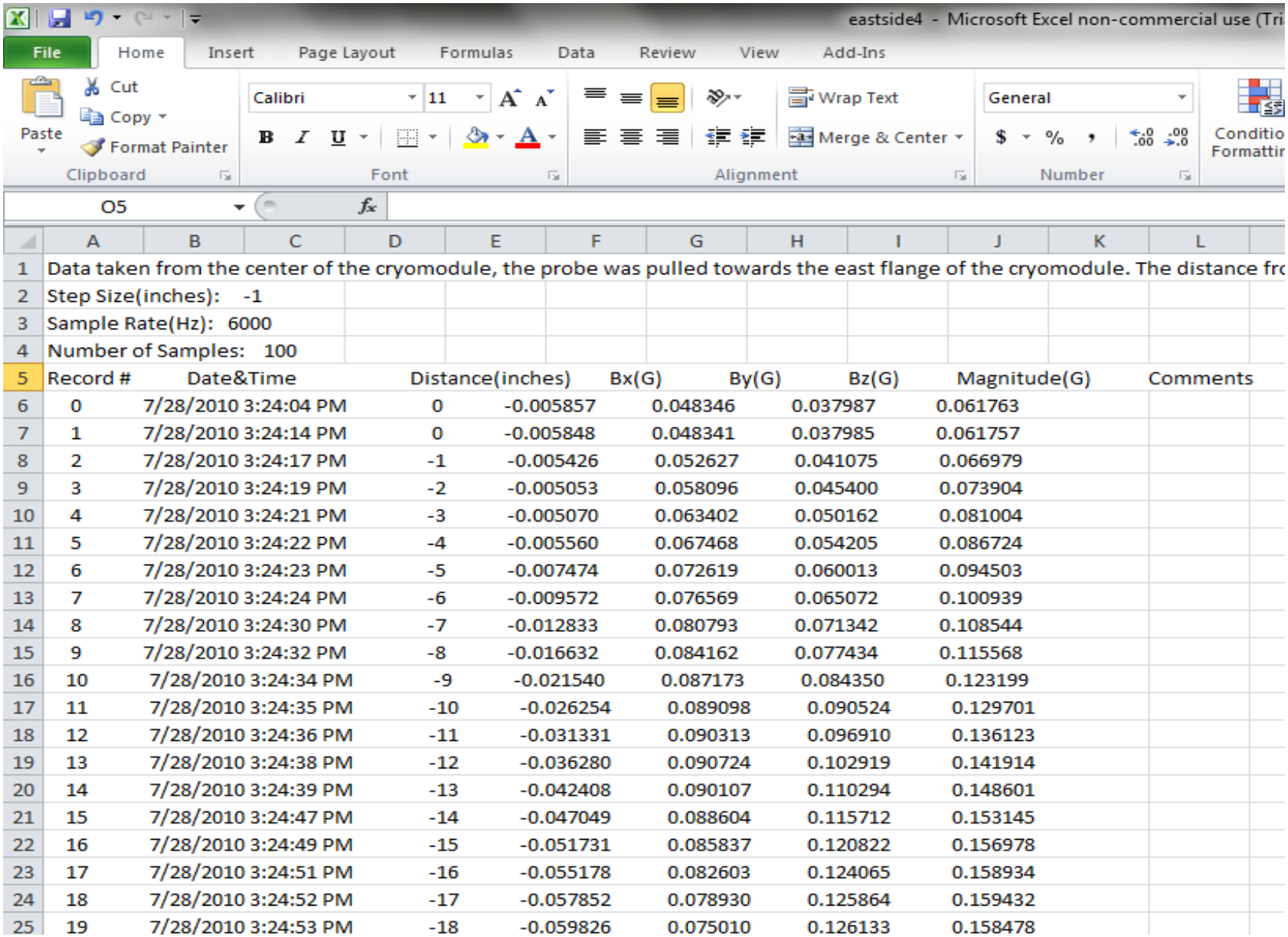
Power Supply Unit

Procedure

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

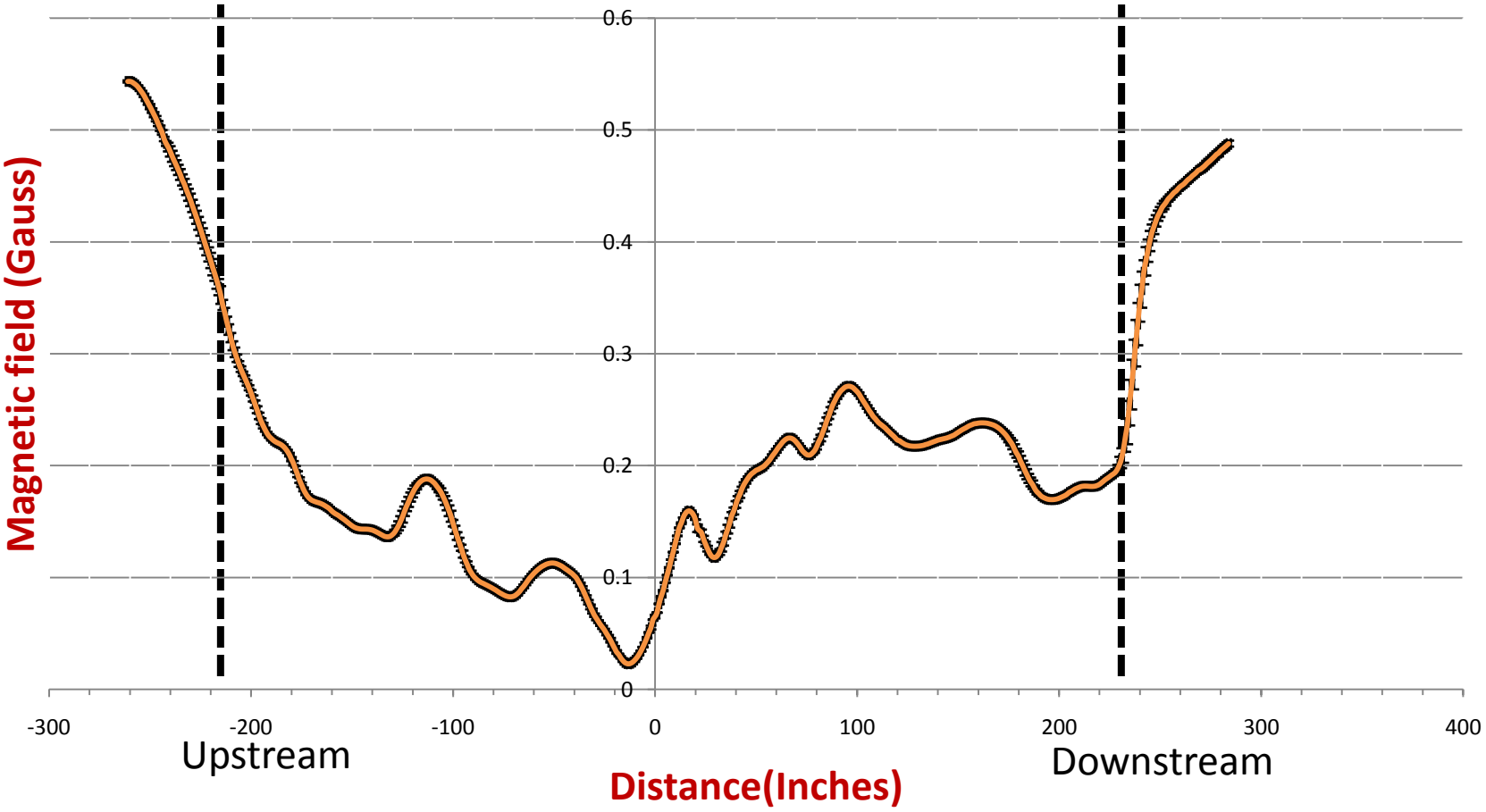
- A tape was attached to the Magnetometer to measure distance

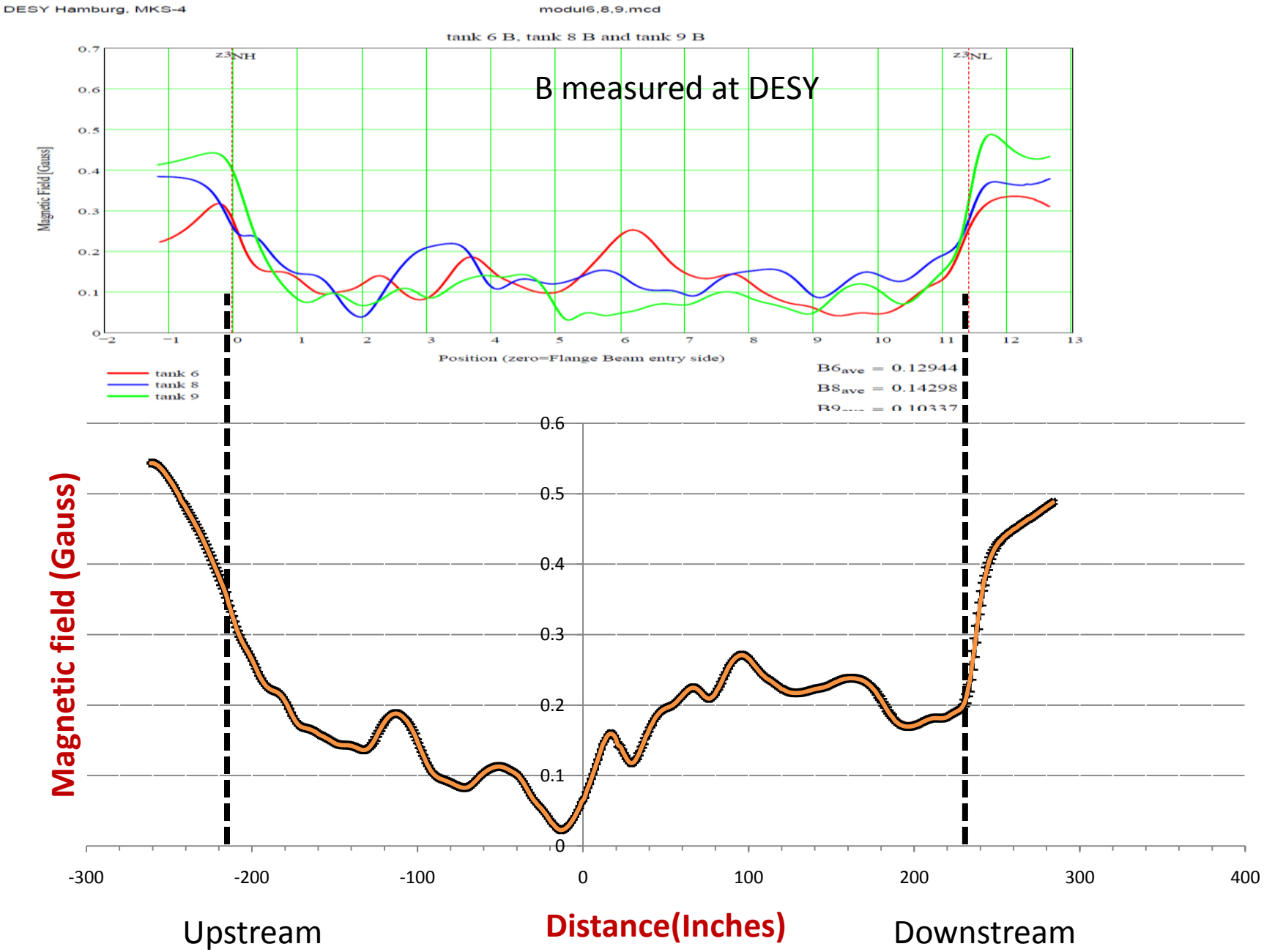
Sample Output File opened in Excel



	A	B	C	D	E	F	G	H	I	J	K	L
1	Data taken from the center of the cryomodule, the probe was pulled towards the east flange of the cryomodule. The distance fr											
2	Step Size(inches): -1											
3	Sample Rate(Hz): 6000											
4	Number of Samples: 100											
5	Record #	Date&Time		Distance(inches)	Bx(G)	By(G)	Bz(G)	Magnitude(G)	Comments			
6	0	7/28/2010 3:24:04 PM		0	-0.005857	0.048346	0.037987	0.061763				
7	1	7/28/2010 3:24:14 PM		0	-0.005848	0.048341	0.037985	0.061757				
8	2	7/28/2010 3:24:17 PM		-1	-0.005426	0.052627	0.041075	0.066979				
9	3	7/28/2010 3:24:19 PM		-2	-0.005053	0.058096	0.045400	0.073904				
10	4	7/28/2010 3:24:21 PM		-3	-0.005070	0.063402	0.050162	0.081004				
11	5	7/28/2010 3:24:22 PM		-4	-0.005560	0.067468	0.054205	0.086724				
12	6	7/28/2010 3:24:23 PM		-5	-0.007474	0.072619	0.060013	0.094503				
13	7	7/28/2010 3:24:24 PM		-6	-0.009572	0.076569	0.065072	0.100939				
14	8	7/28/2010 3:24:30 PM		-7	-0.012833	0.080793	0.071342	0.108544				
15	9	7/28/2010 3:24:32 PM		-8	-0.016632	0.084162	0.077434	0.115568				
16	10	7/28/2010 3:24:34 PM		-9	-0.021540	0.087173	0.084350	0.123199				
17	11	7/28/2010 3:24:35 PM		-10	-0.026254	0.089098	0.090524	0.129701				
18	12	7/28/2010 3:24:36 PM		-11	-0.031331	0.090313	0.096910	0.136123				
19	13	7/28/2010 3:24:38 PM		-12	-0.036280	0.090724	0.102919	0.141914				
20	14	7/28/2010 3:24:39 PM		-13	-0.042408	0.090107	0.110294	0.148601				
21	15	7/28/2010 3:24:47 PM		-14	-0.047049	0.088604	0.115712	0.153145				
22	16	7/28/2010 3:24:49 PM		-15	-0.051731	0.085837	0.120822	0.156978				
23	17	7/28/2010 3:24:51 PM		-16	-0.055178	0.082603	0.124065	0.158934				
24	18	7/28/2010 3:24:52 PM		-17	-0.057852	0.078930	0.125864	0.159432				
25	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
B measured at DESY
z3NH
z3NL
Magnetic Field [Gauss]
Position (zero=Flange Beam entry side)
tank 6
tank 8
tank 9
B6ave = 0.12944
B8ave = 0.14298
Magnetic field (Gauss)
Upstream
Distance(Inches)
Downstream

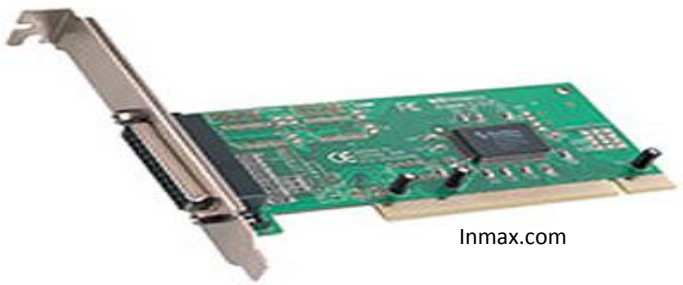
Conclusion

- 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

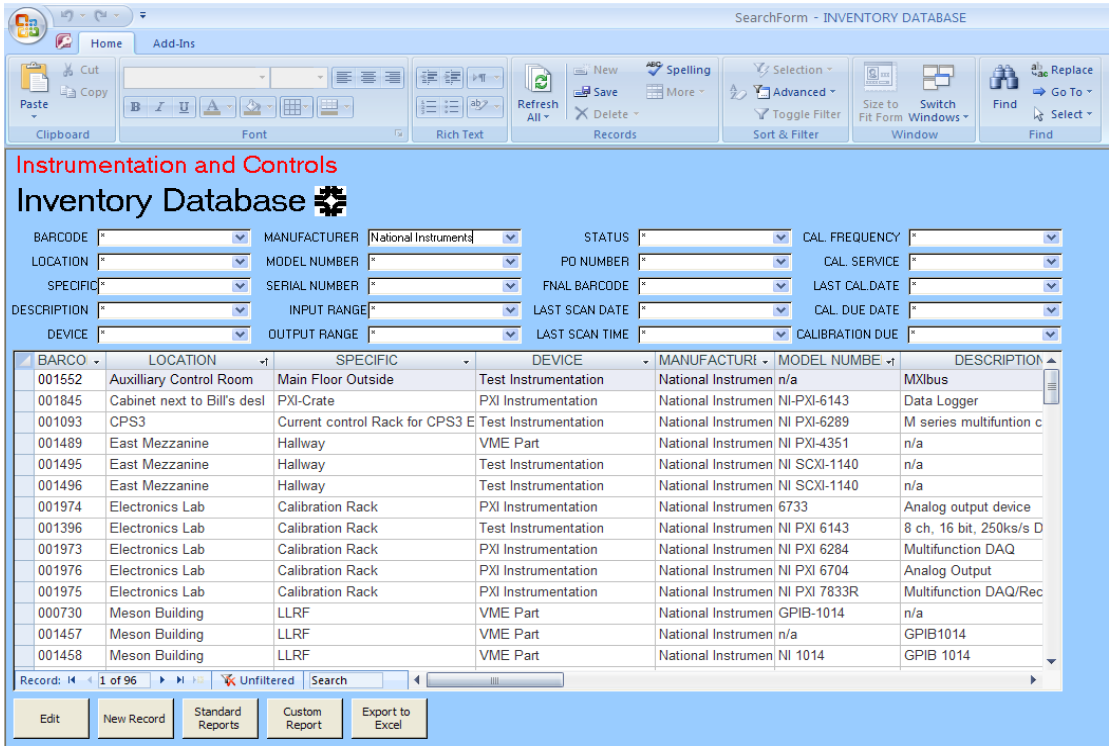
Calibrations

- 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.



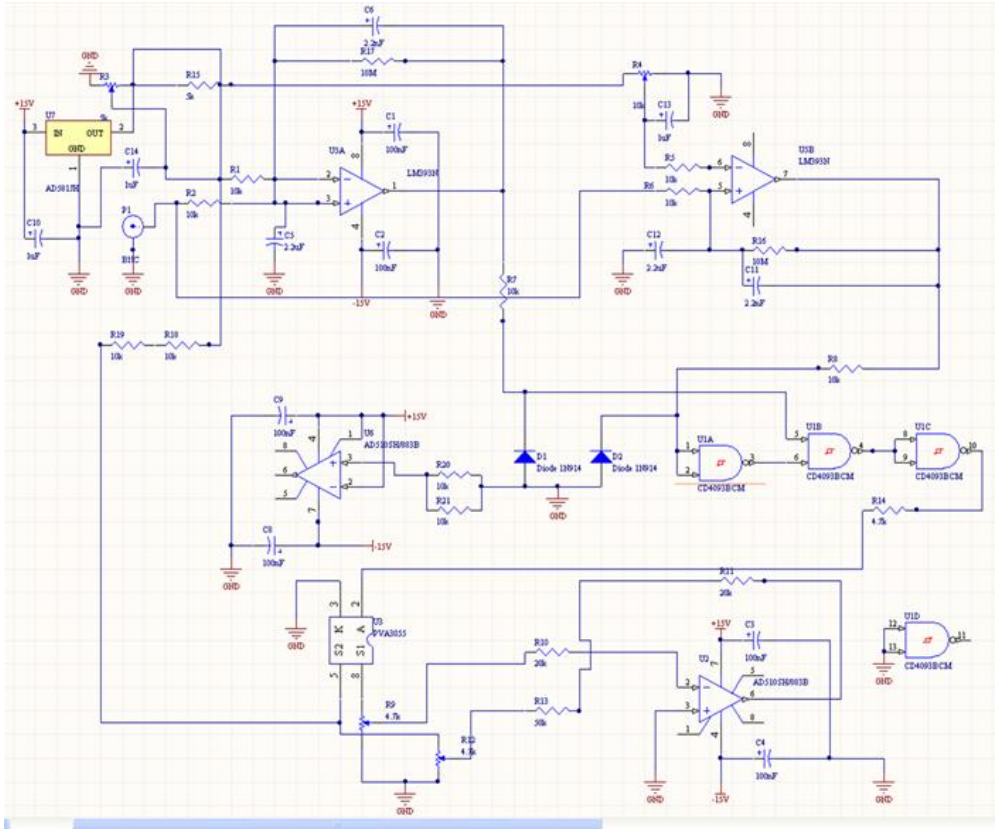
Inmax.com

PXI Card



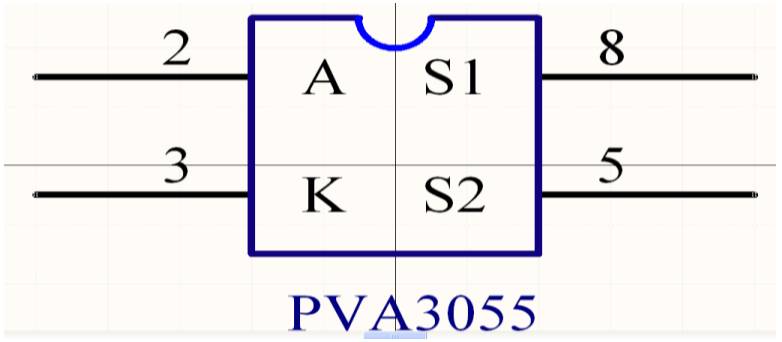
Database

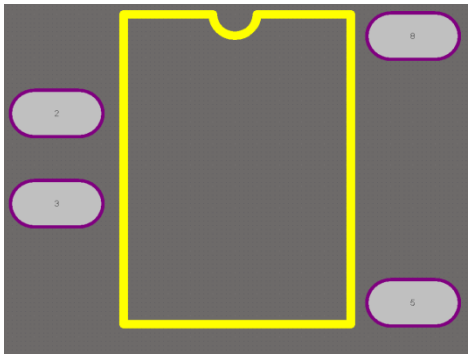
Printed Circuit Board Design using Altium Designer



Schematic of AQD variable threshold

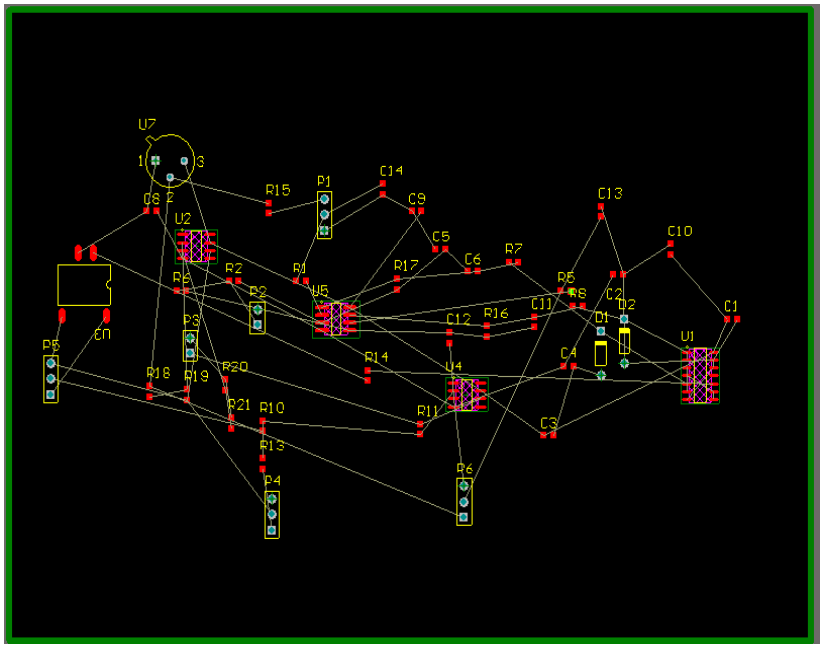
Creating components and associating them with a certain footprint.



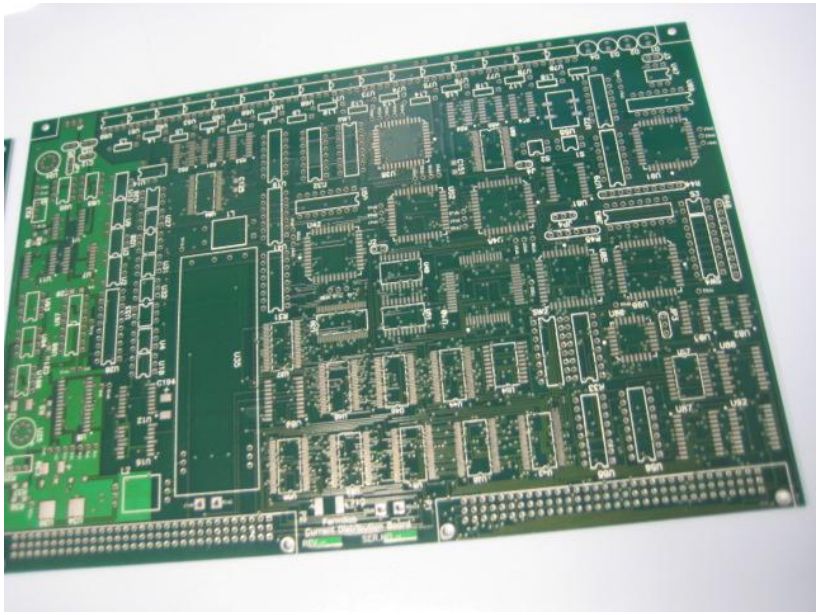


Printed Circuit Board Design

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/internationallinearcollider.html
- Ilan Ben-Zvi, *Superconducting RF Cavities for Particle Accelerators: An Introduction*, Brookhaven National Laboratory.

Thank You!

I will now take your questions.