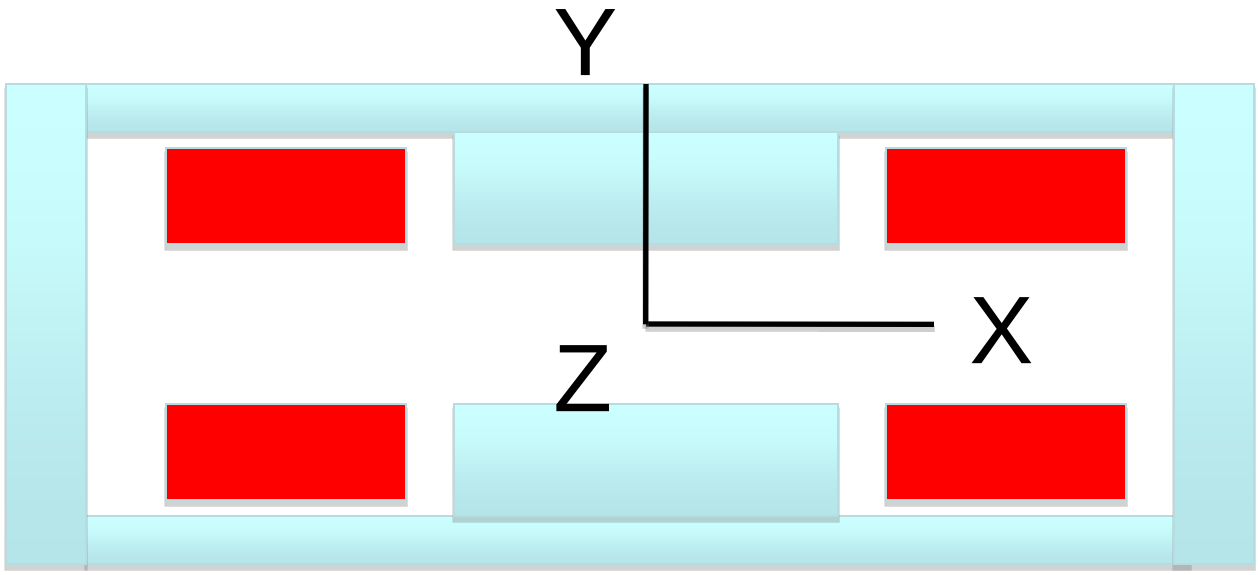
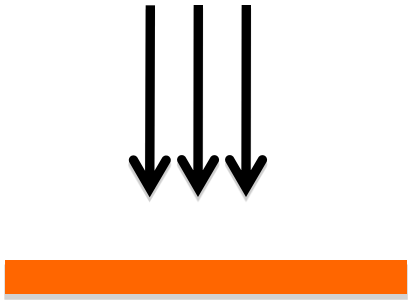
Laboratory and Computer

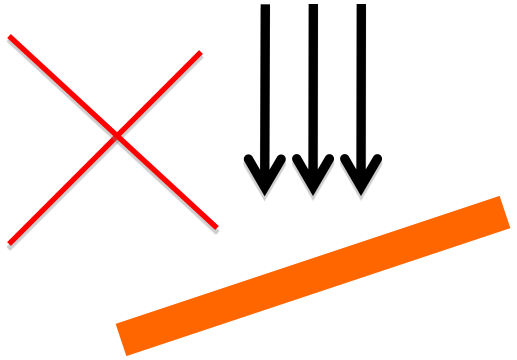
Lab 1. Measurement of Dipole Magnet

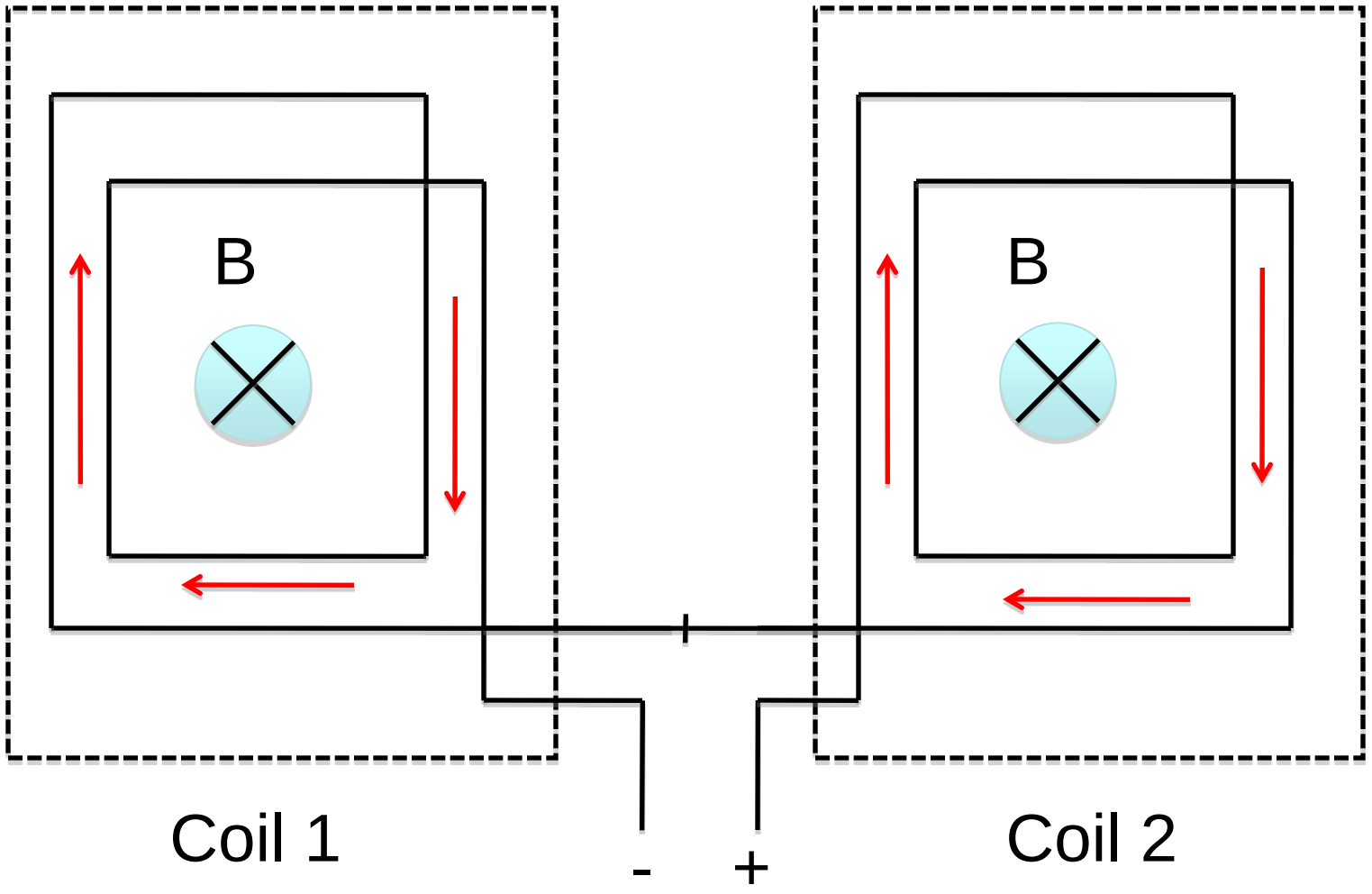
Laboratory Assignment #1

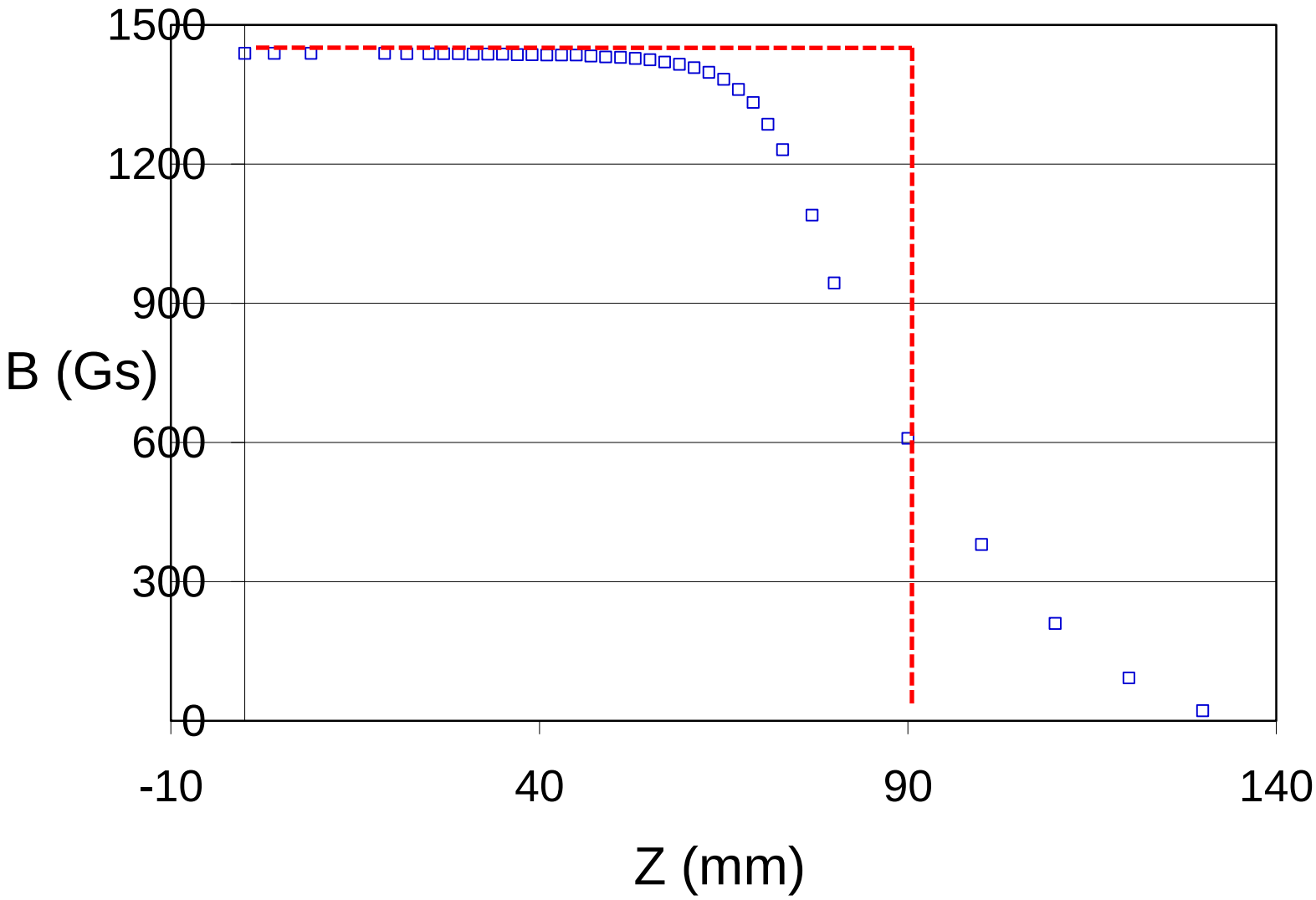
Measure magnetic fields of a dipole magnet with a Hall probe and characterize the properties of the bending magnet

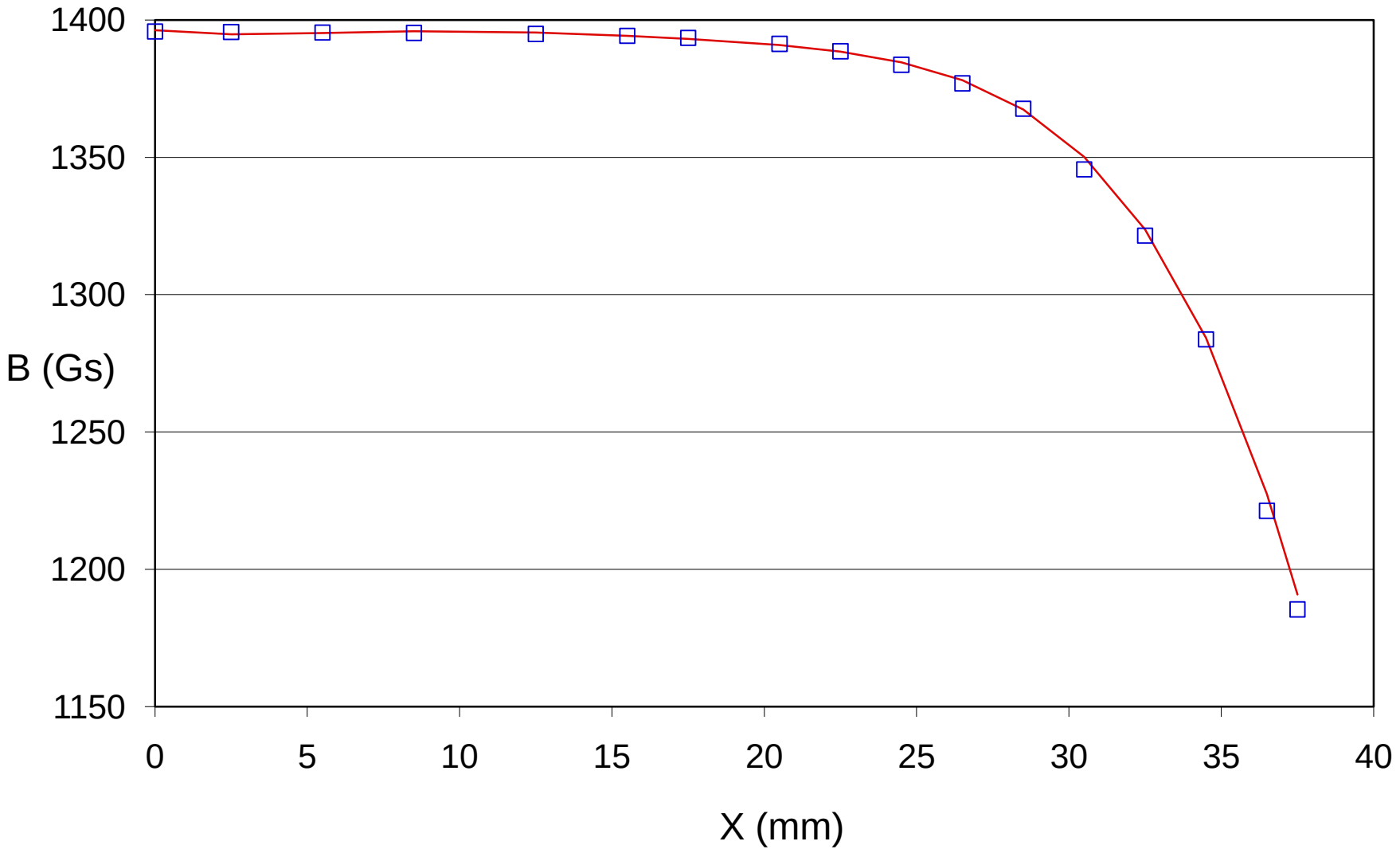

Y
X
Z

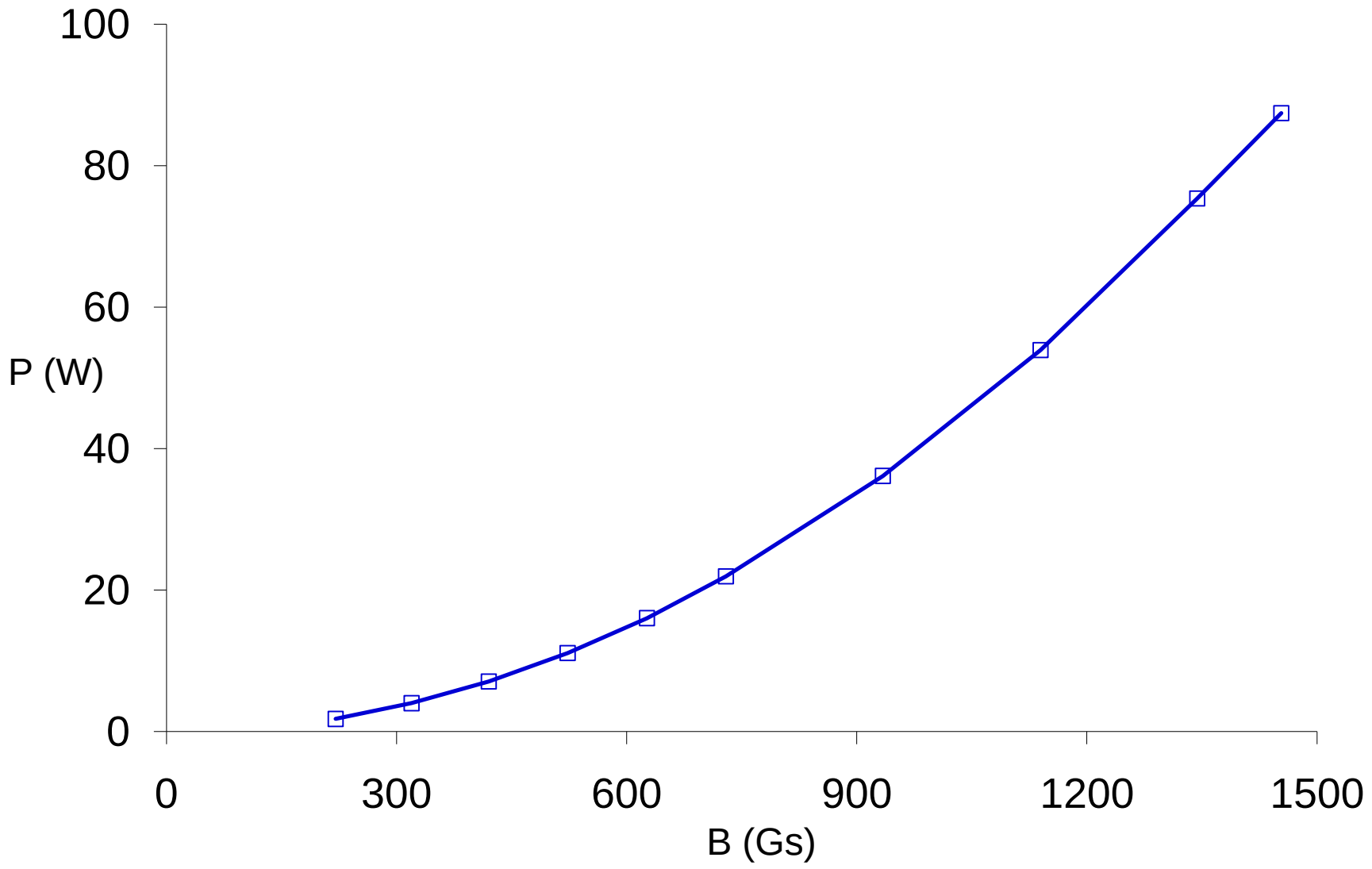


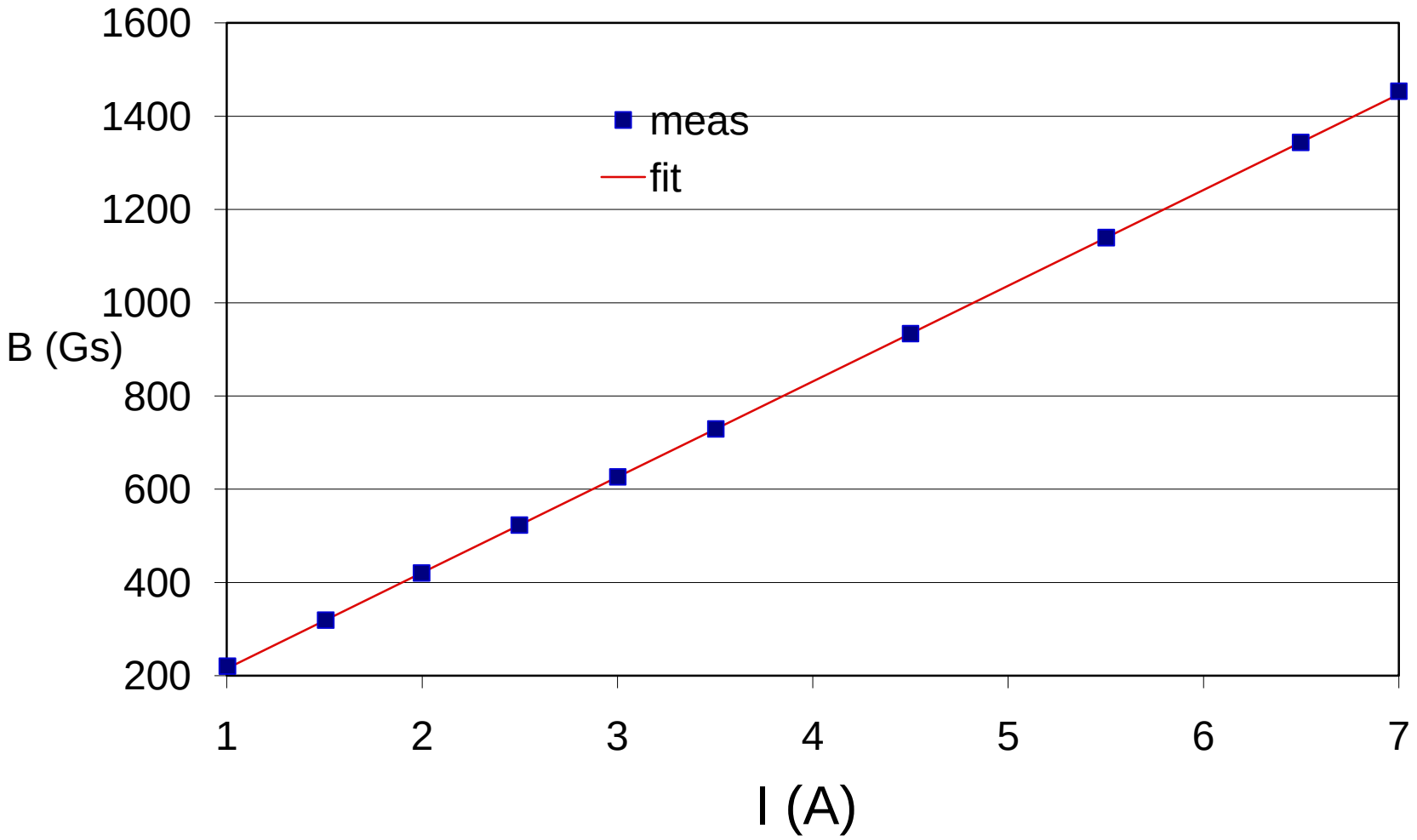



B
B
Coil 1
Coil 2
-
+


1500
1200
900
600
300
0
B (Gs)
-10
40
90
140
Z (mm)


1400
1350
1300
1250
1200
1150
B (Gs)
0
5
10
15
20
25
30
35
40
X (mm)


100
80
60
P (W)
40
20
0
0
300
600
900
1200
1500
B (Gs)

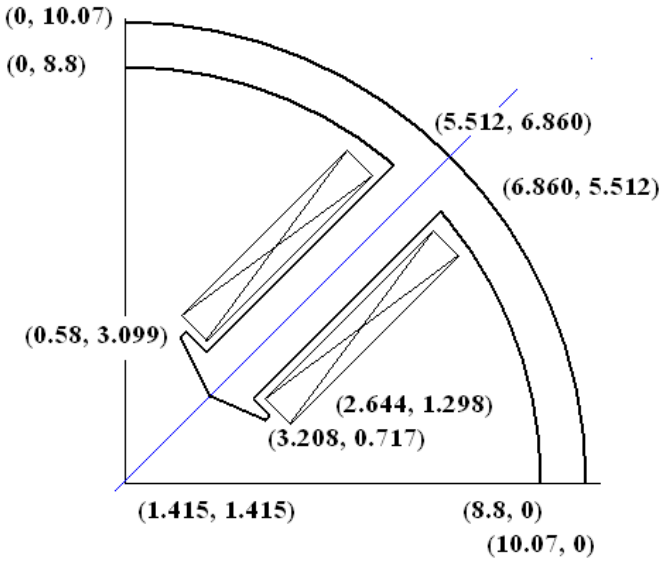


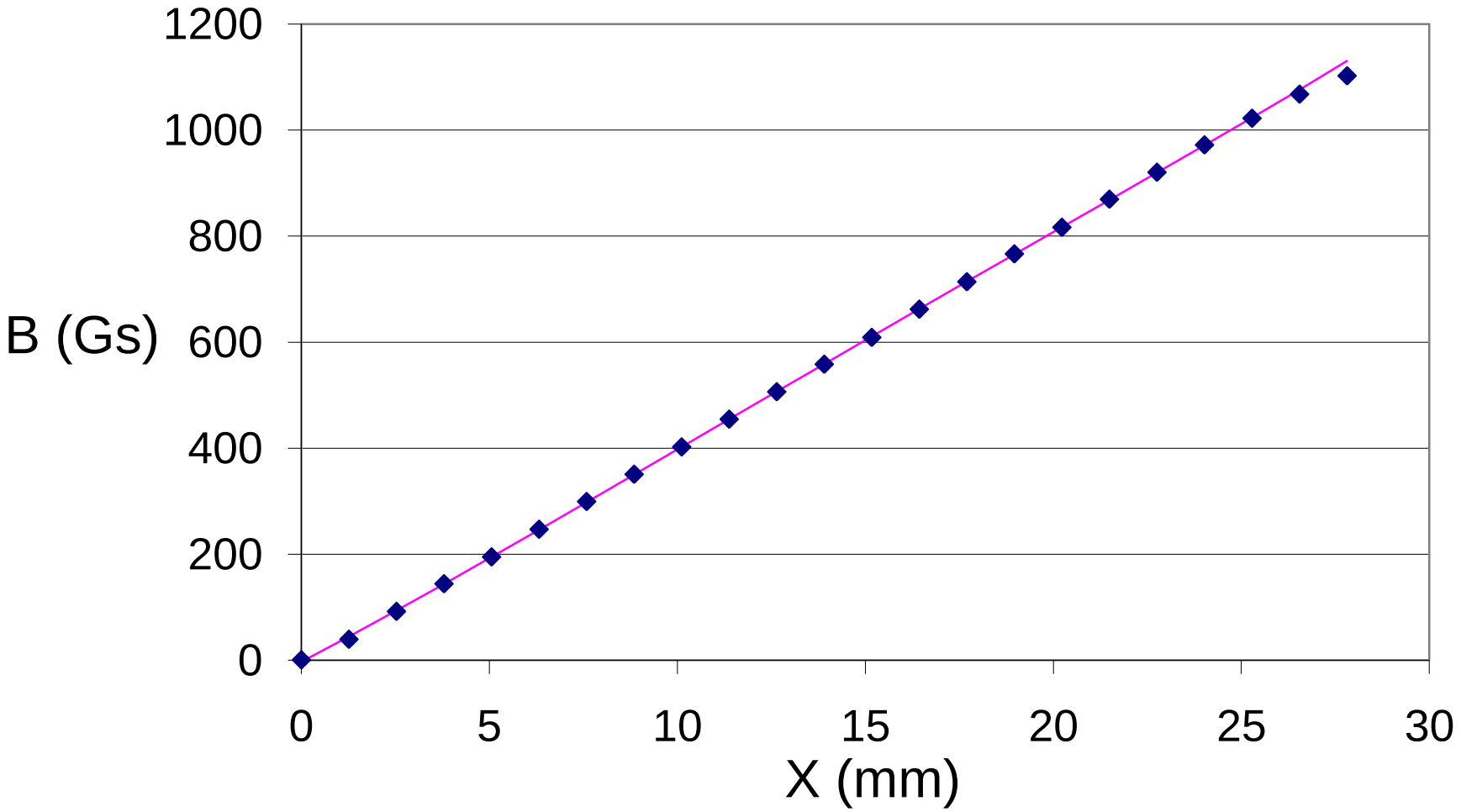
N = 237 Turns

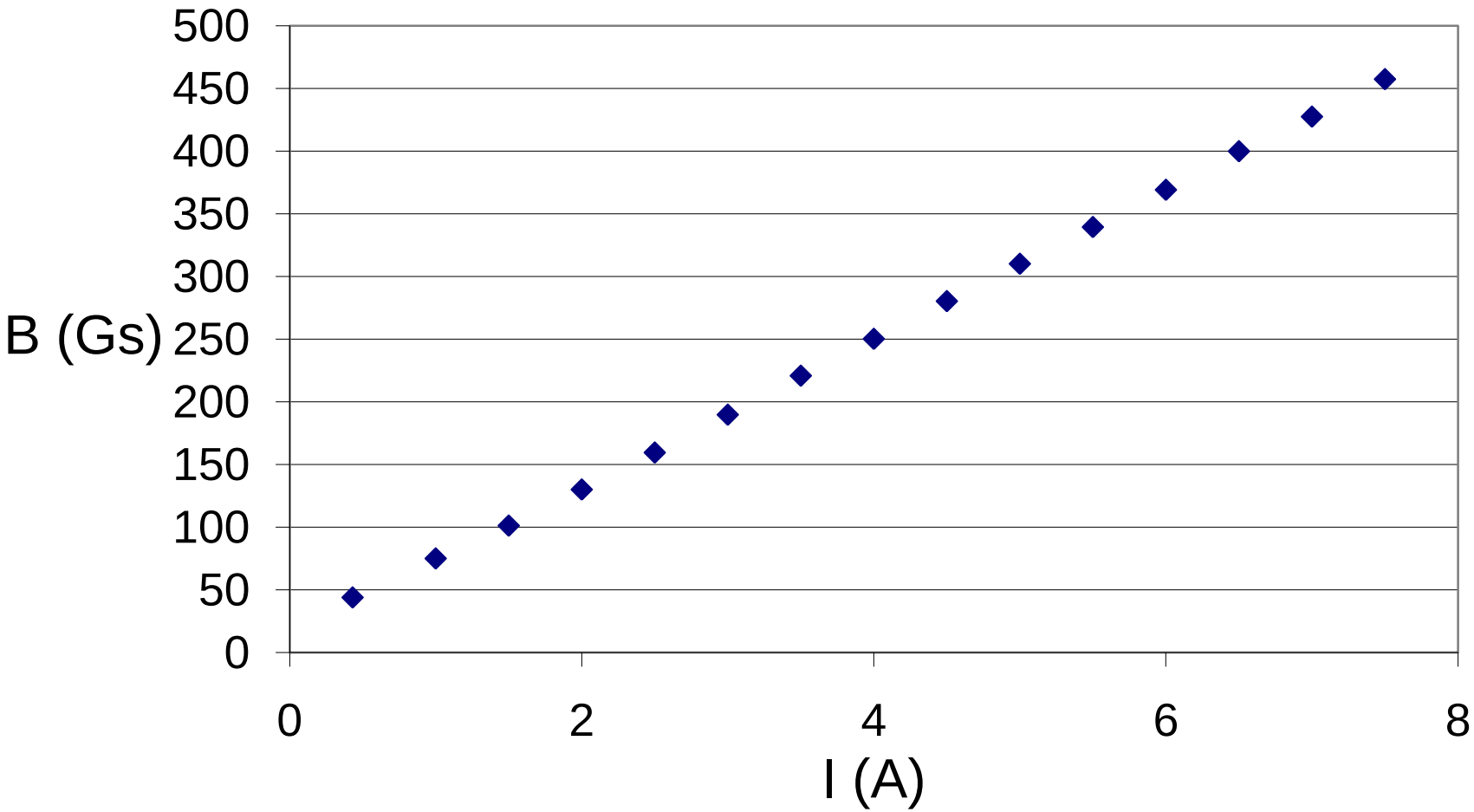
Lab 2. Measurement of Quadrupole Magnet

Laboratory Assignment #2

Measure magnetic fields of a quadrupole magnet with a Hall probe and characterize the properties of the focusing magnet




1200
1000
800
600
400
200
0
B (Gs)
0
5
10
15
20
25
30
X (mm)



N = 96

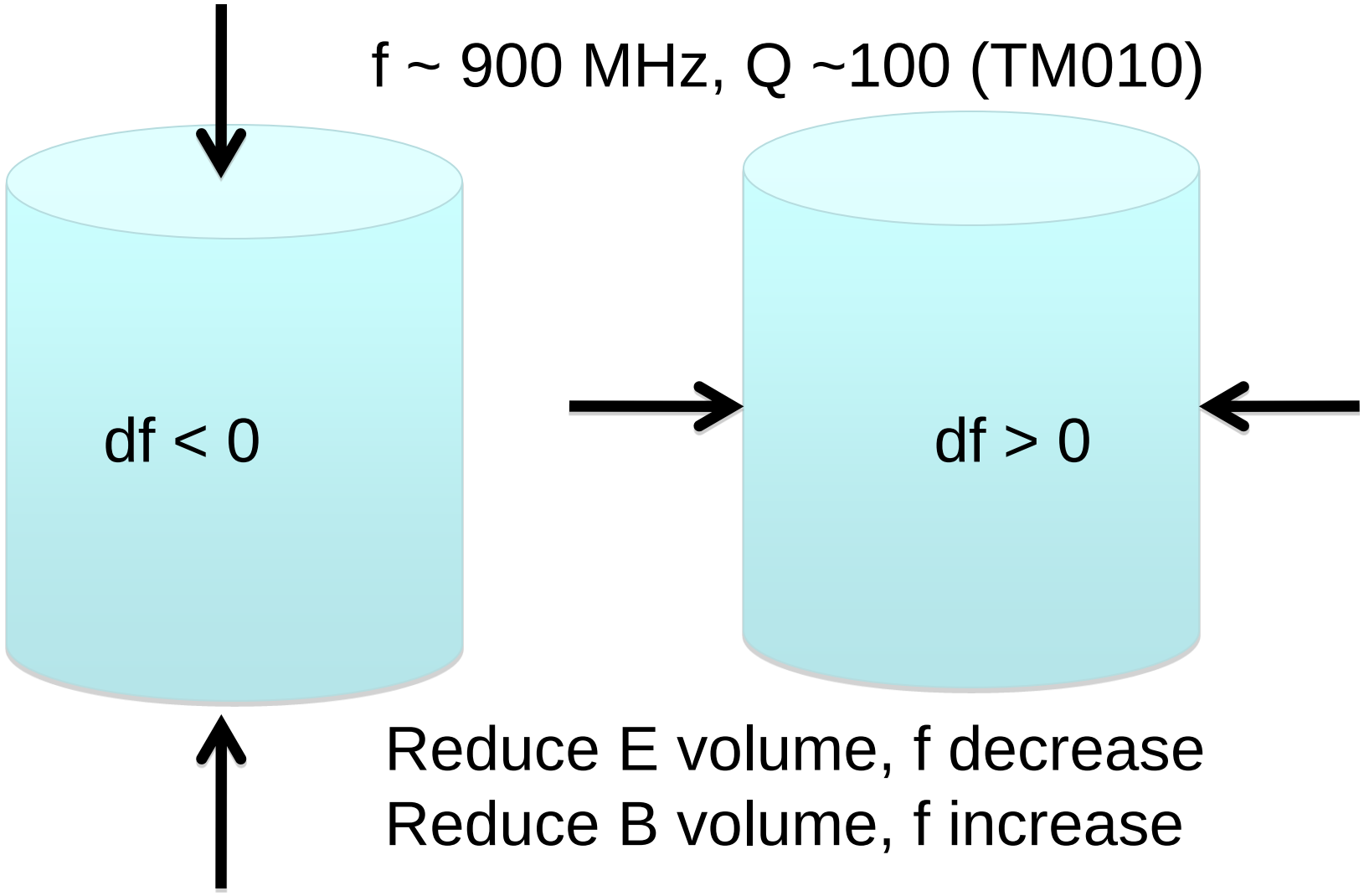
Lab 3. Measurement of RF Cavity

Laboratory Assignment #4

Measure resonant frequencies and Q-factors of RF cavities with a vector network analyzer and measure different modes and harmonics

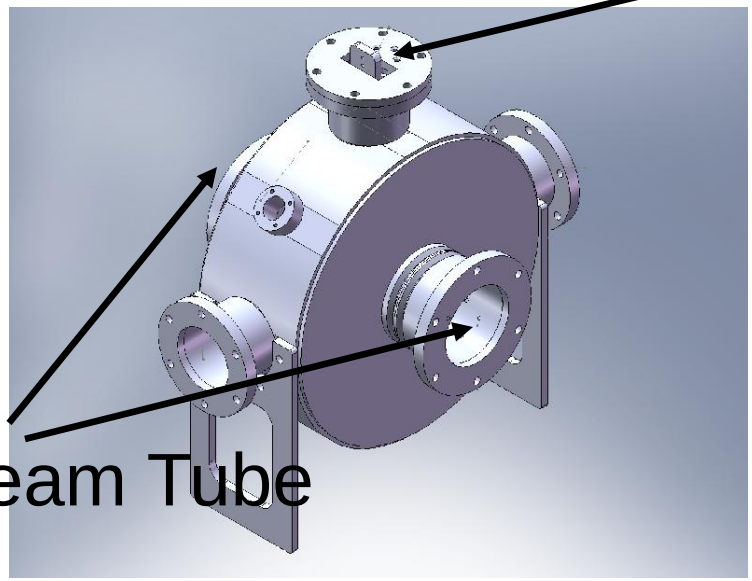
Popcorn Can

f ~ 900 MHz, Q ~100 (TM010)

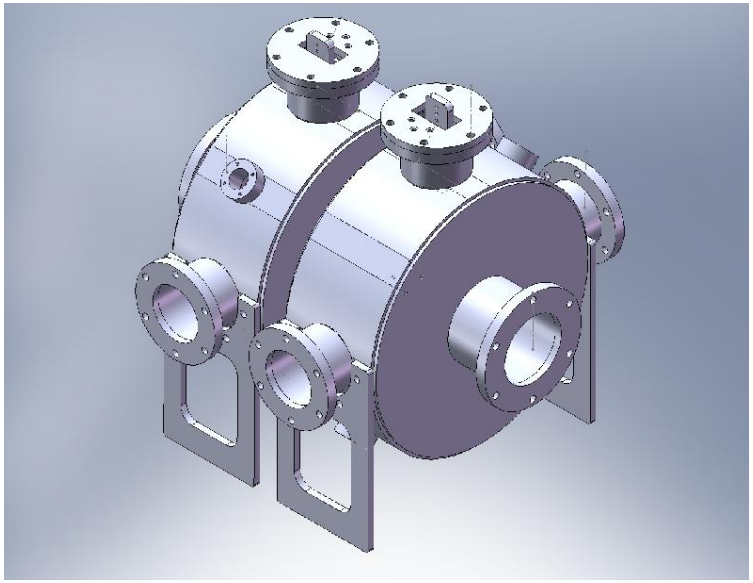


Reduce E volume, f decrease
Reduce B volume, f increase

Pillbox Cavity



Single cell



Two cell

f ~ 1 GHz (TM010), measured Q 1,000 ~10,000 Theory ~19,000. It need a narrow frequency span, no more than a few MHz, to measure a high Q cavity

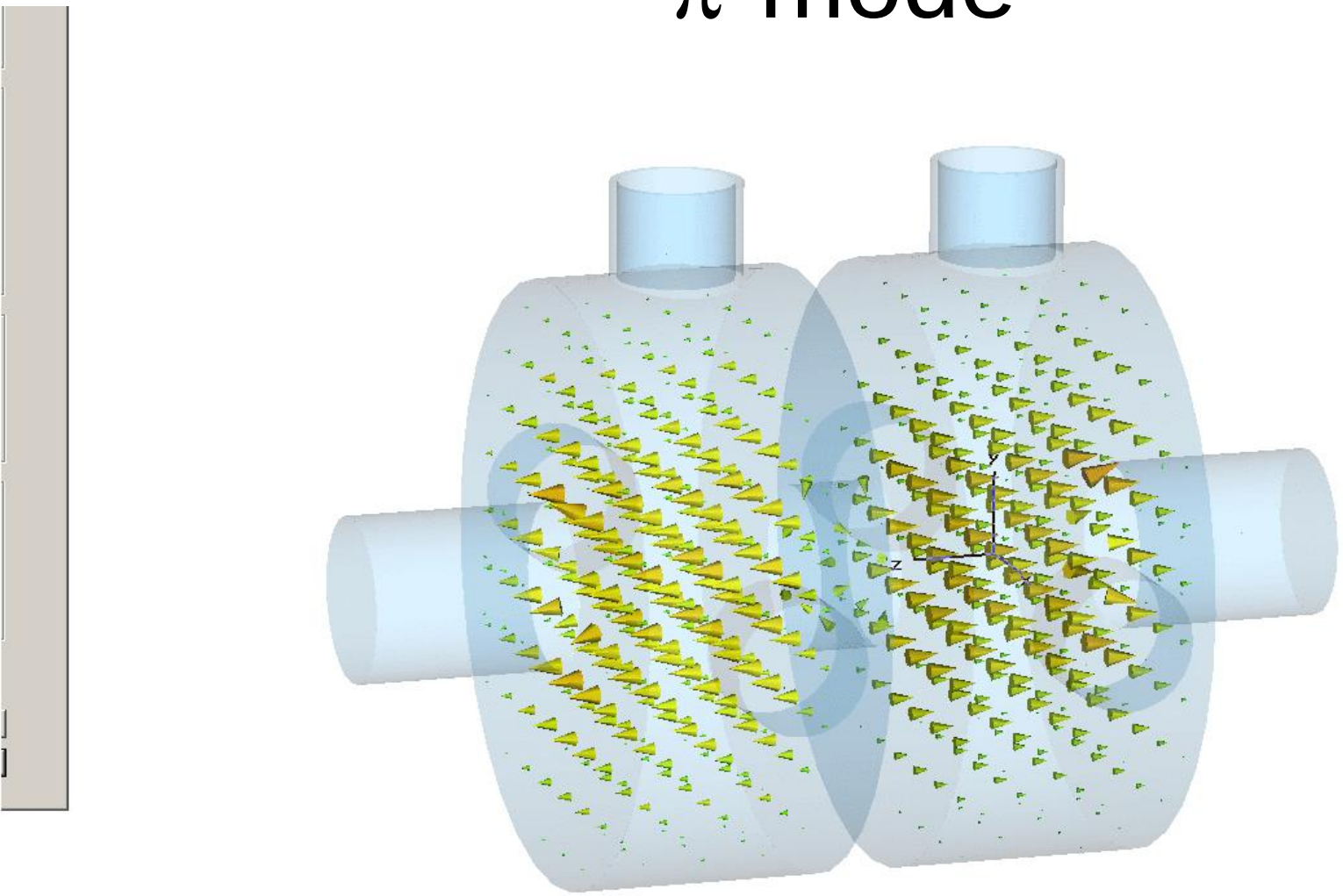
Measured quality factor lower than theory:

1)$1/Q = 1/Q_0 + 1/Q_P + 1/Q_T$
Theory gives Q_0. What we measure is Q, which also include Q_P, power coupler, and Q_T, transport pickup. Q can be increased by reducing RF coupling (increase both Q_P and Q_T)

2) Theory use pure aluminum, we fabricate with aluminum alloy

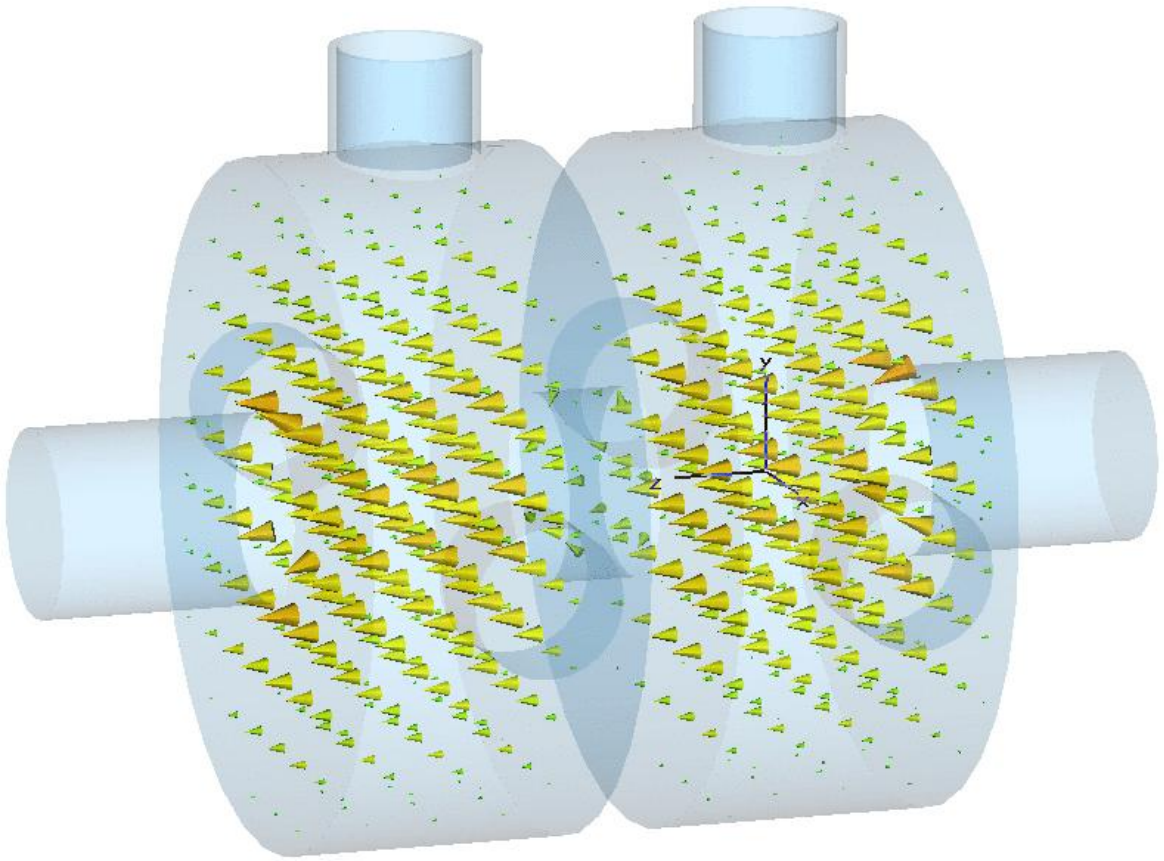
3) Surface imperfections, welding, and leaks etc

π-mode



Type = E-Field (peak)
Monitor = Mode 2
Maximum-3d = 1.56383e+007 V/m at 0.65625 / 1 / 3.125
Frequency = 1.00169
Phase = 0 degrees

0-mode



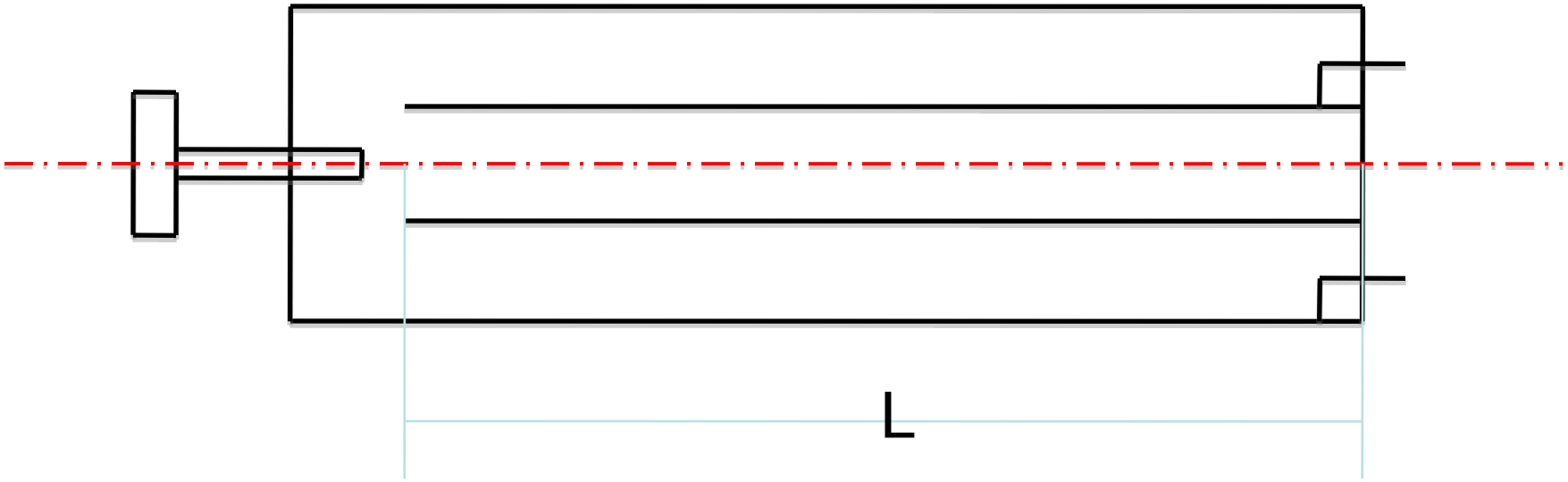
Type = E-Field (peak)
Monitor = Mode 1
Maximum-3d = 1.51525e+007 V/m at 0.65625 / 1 / -1.875
Frequency = 1.00027
Phase = 0 degrees

In a M-cell cavity, there are M passband modes because of RF coupling in all the cells.
For M passband modes of the TM010 mode,

Phase between each cell: $\frac{n}{M} \cdot \pi$ (n = 1, 2, …, M)

In particle accelerator world, you will learn that there are many different personal preferences, such as, beam emittance, index of magnet

Quarter Wave Resonator (coaxial cavity)



TEM mode, f ~ 350 MHz. Low frequency structure usually for heavy ion (low beta) acceleration

Harmonics: 1f, 3f, 5f, …

What's the difference between harmonics and modes ?

Modes TEM_r1_a1_z1, and TEM_r2_a2_z2:

If, r1 = r2, and a1 = a2, but z1 != z2 => harmonics

If, r1 != r2, or a1 != a2 => modes

For harmonics, the same field pattern exactly repeat along z axis, but modes are different

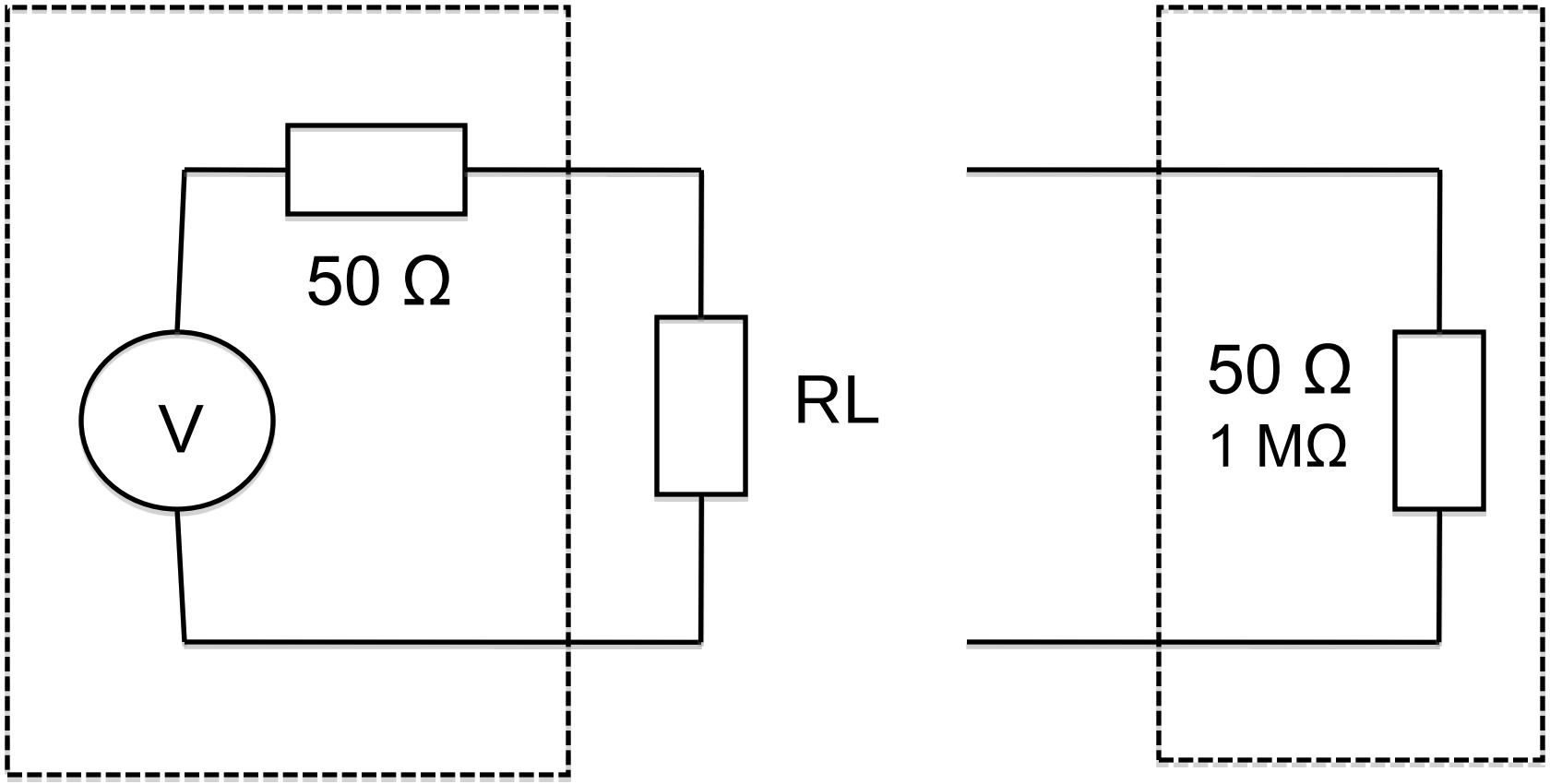
Lab 4. Measurement of BCM and BPM

Laboratory Assignment #5

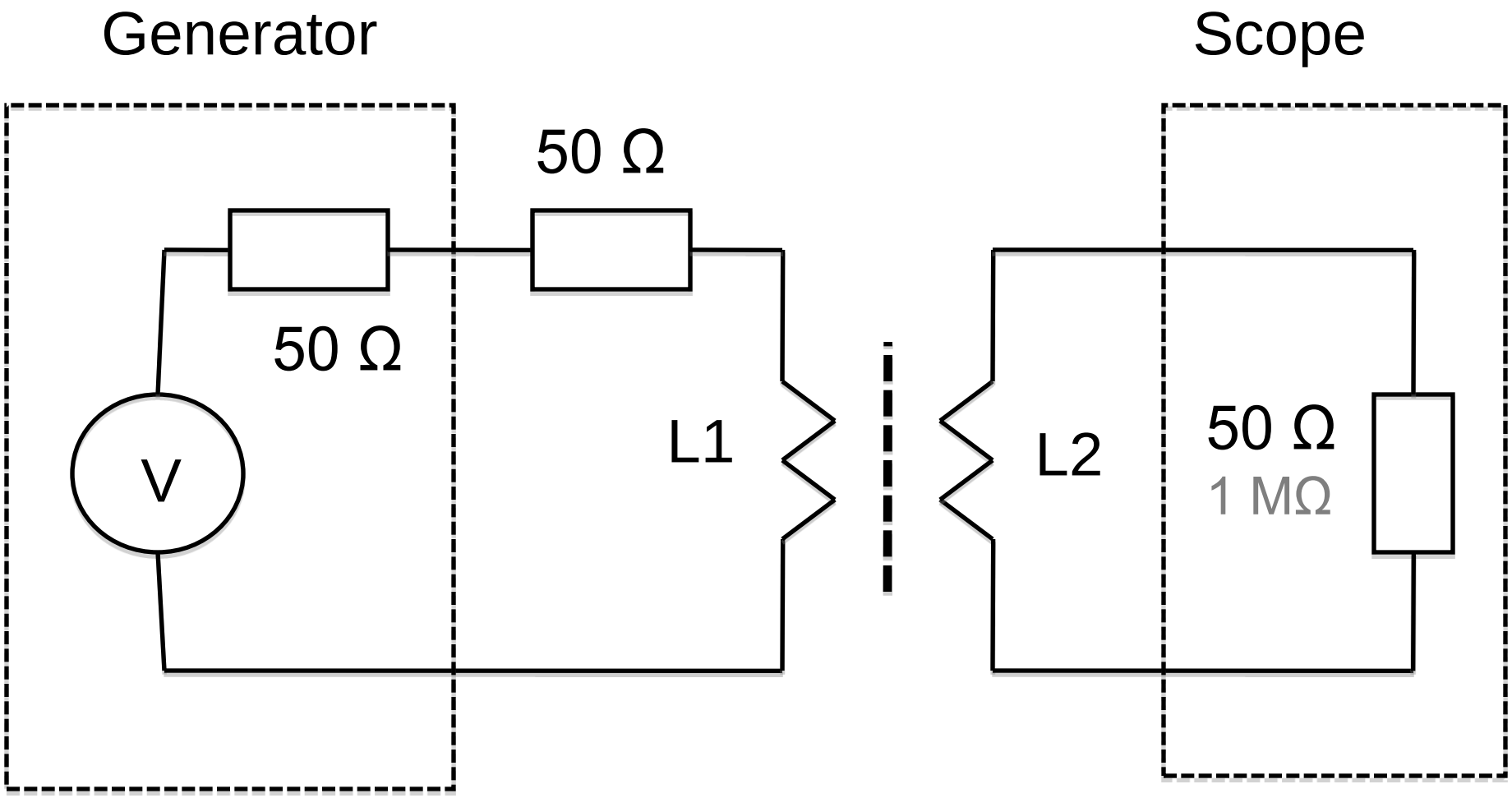
Measure and calibrate Beam Current Monitor (BCM) and Beam Position Monitor (BPM) using function generator and oscilloscope

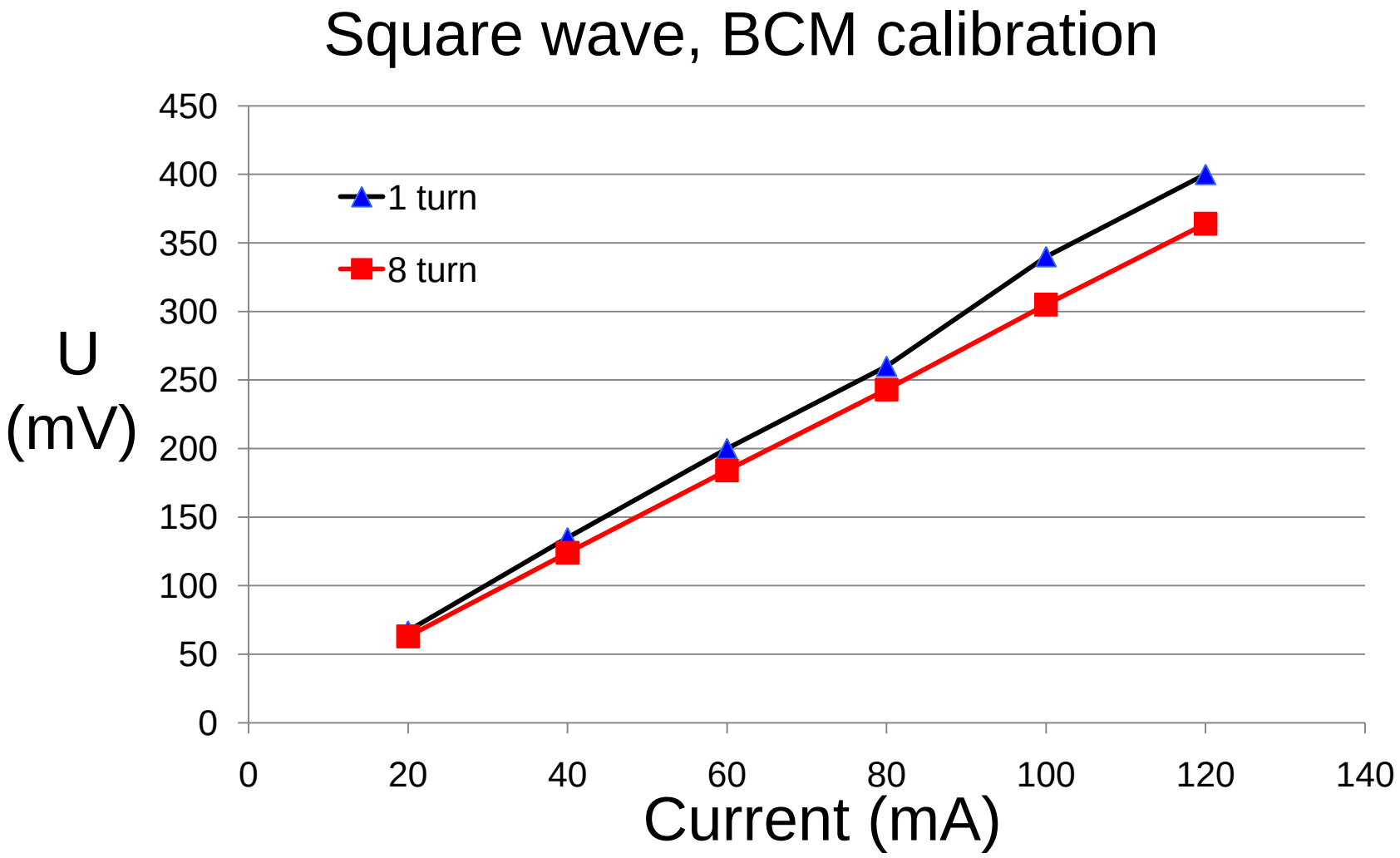
Function Generator

Scope



Your instructor can be wrong!

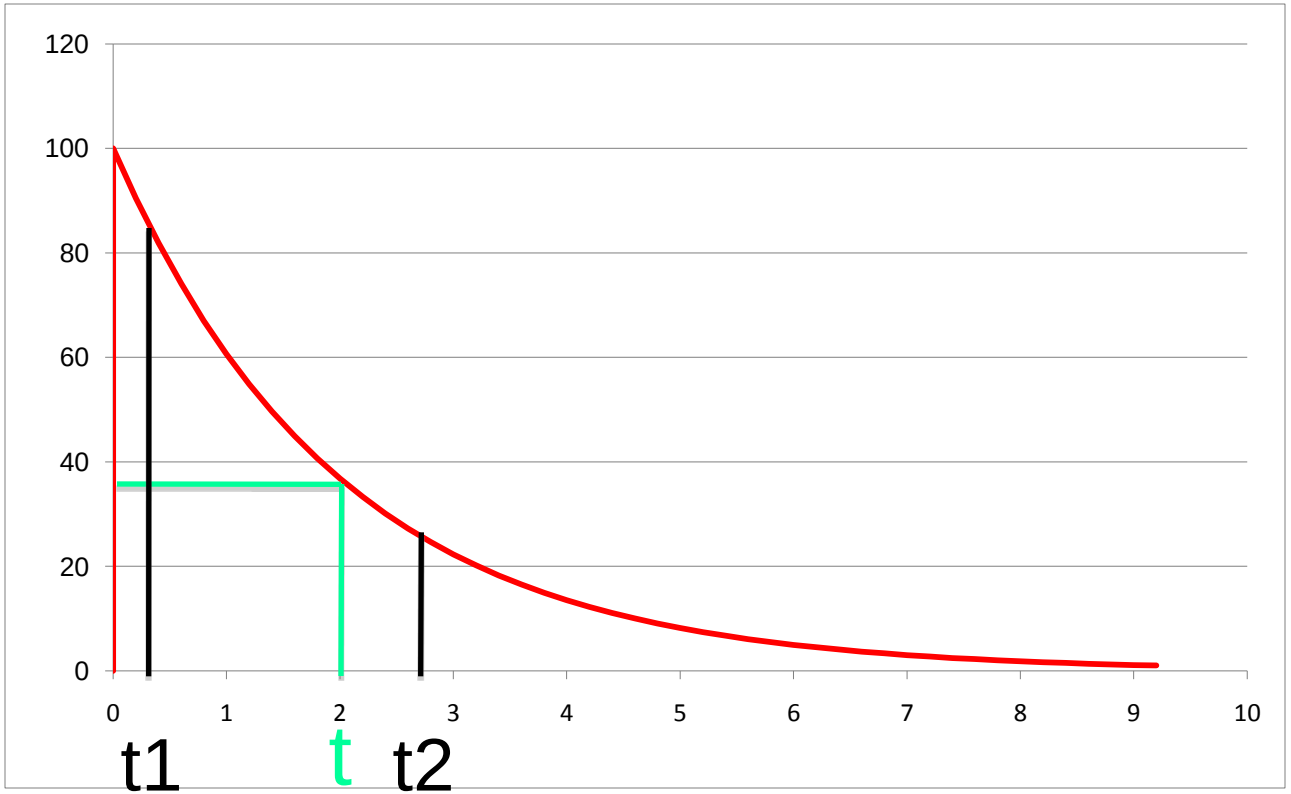

Generator
Scope
50 Ω
50 Ω
V
L1
L2
50 Ω
1 MΩ

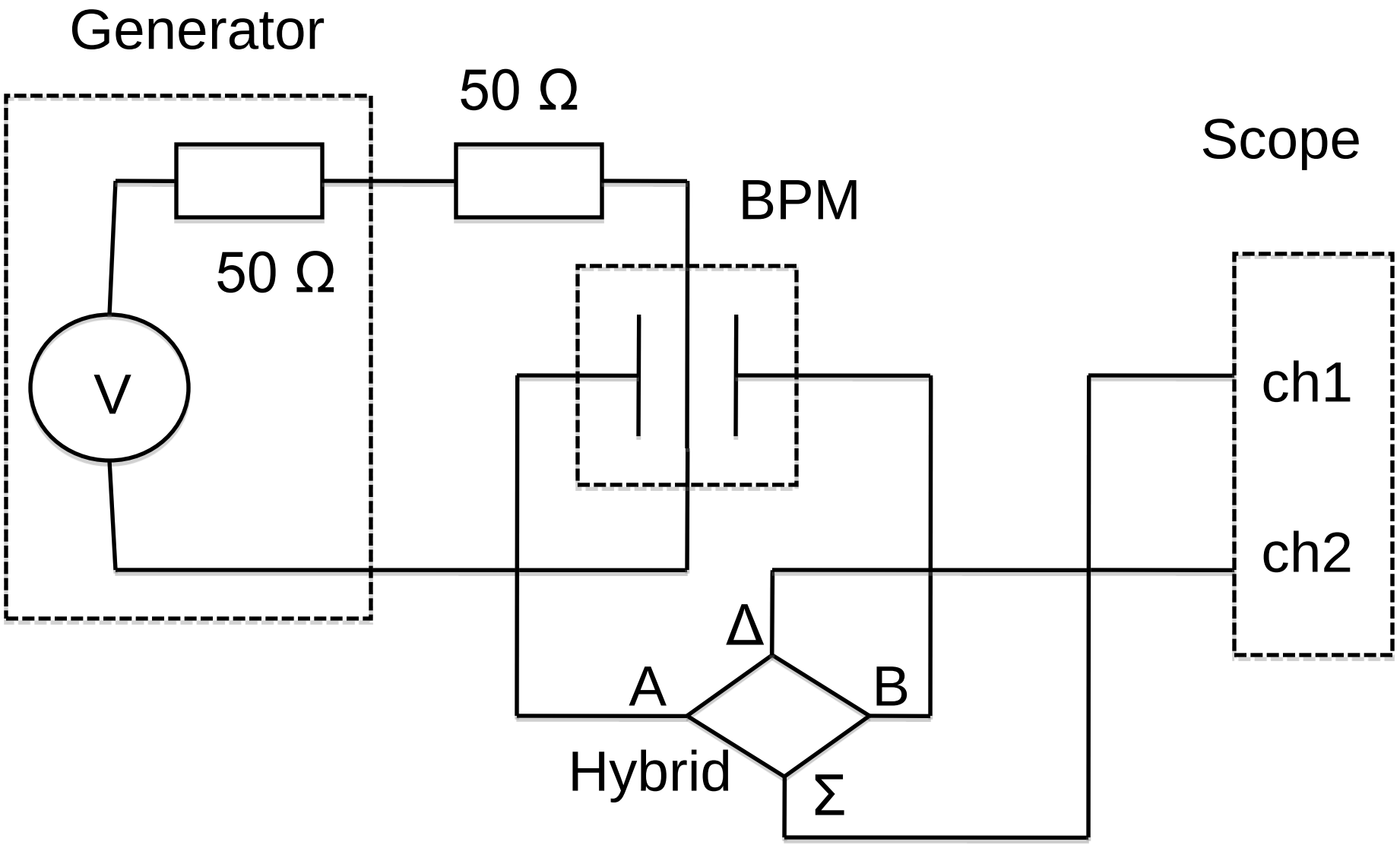

Square wave, BCM calibration
U (mV)
450
400
350
300
250
200
150
100
50
0
1 turn
8 turn
0
20
40
60
80
100
120
140
Current (mA)

Square wave, measure decay time constant

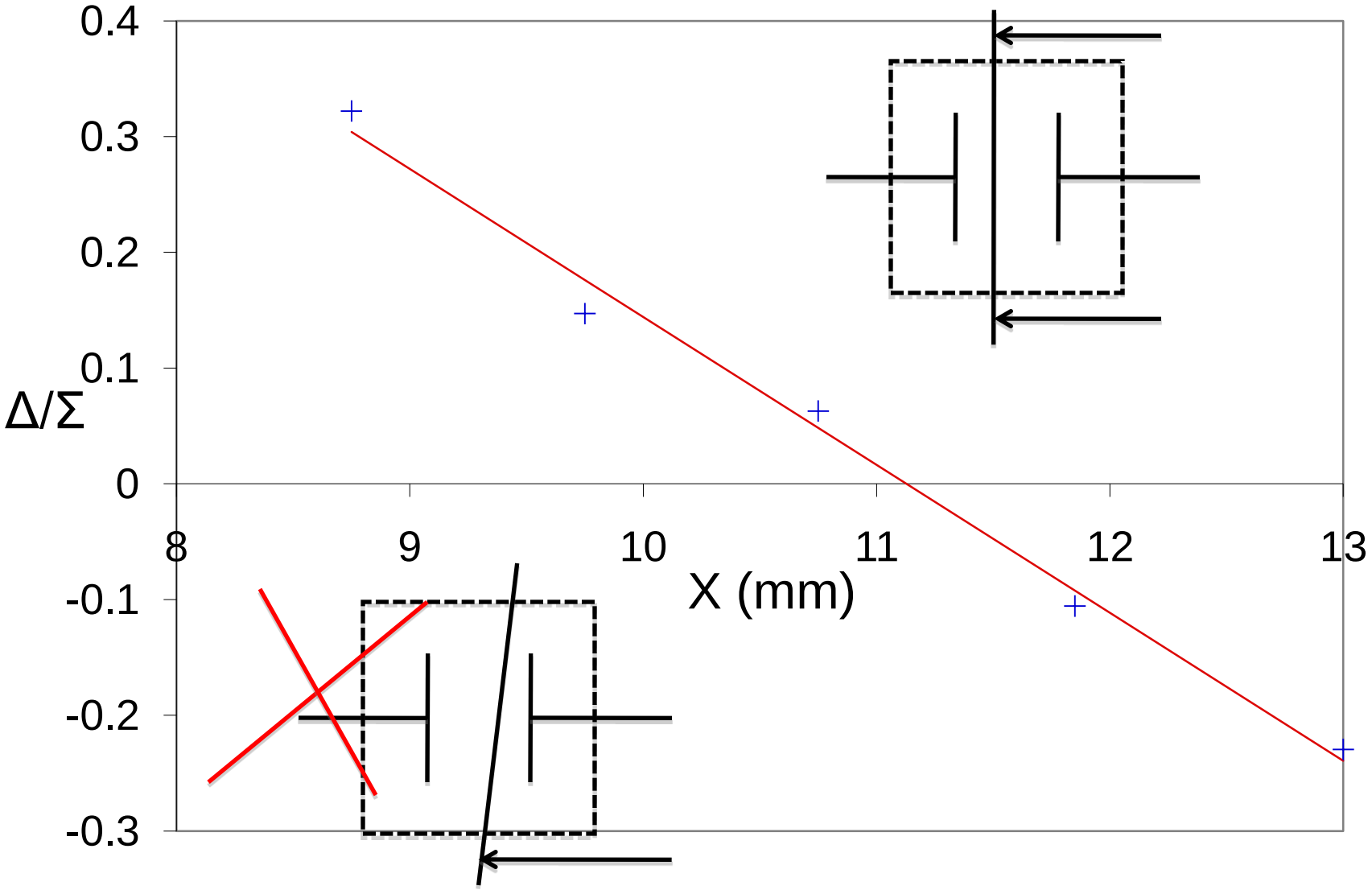
$$V = V_0 \cdot e^{-\frac{t}{\tau}}$$

$$\tau = \frac{L}{R}$$




Generator
50 Ω
Scope
BPM
50 Ω
V
ch1
ch2
Δ
A
B
Hybrid
Σ

Square wave, BPM calibration



- Don’t panic if your math is not so good as Jeff and Sarah, or your experiment skill is currently even worse than mine. In fact, I can say that many of you are way better than me, or will in the future. Particle accelerator is a very fun career, there are so many interesting things to do. But as all other jobs, it need a lot of hard works too.
- More studies are necessary if you’d like to muster any of accelerator science and techniques, e.g. magnet design and measurement, RF cavity design and measurement, beam diagnostics, accelerator physics, control, design, and project management, ion source, etc, all have special and advanced level classes. And you will learn much more from top experts in the fields.
- All your lab reports due Thursday afternoon.
- Have fun and good luck!

Laboratory and Computer

Lab 1. Measurement of Dipole Magnet

Laboratory Assignment #1

Measure magnetic fields of a dipole magnet with a Hall probe, and characterize properties of the magnet.

Com 1. Calculation of Dipole Magnet

PC Assignment #1

Calculate magnetic fields of the dipole magnet using POISSON and compare the results with Lab 1.

Lab 2. Measurement of Quadrupole Magnet

Laboratory Assignment #2

Measure magnetic fields of a quadrupole magnet with a Hall probe and characterize properties of the magnet

Com 2. Calculation of Quadrupole Magnet

PC Assignment #2

Calculate magnet fields of the quadrupole magnet using POISSON and compare the results with lab 2.

Lab 3. Measurement of RF Cavity

Laboratory Assignment #4

Measure resonant frequencies and Q-factors of RF cavities with a vector network analyzer, and measure different modes and harmonics

Com 3. Calculation of RF Cavity

PC Assignment #3

Calculate different modes and harmonics of RF cavities using URMEL.

Calculate different modes and harmonics of RF cavities using SUPERFISH.

Lab 4. Measurement of BCM and BPM

Laboratory Assignment #5

Measure and calibrate Beam Current Monitor (BCM) and Beam Position Monitor (BPM) using function generator and oscilloscope

Com 4. Calculation of Focusing Lattice

PC Assignments #4 and #5

Calculate doublet focusing

Calculate FODO lattice using ELEGANT

Details of the labs and computer simulations are in the Laboratory and Computer Assignment, with some additions.

Read all the requirements carefully, additional information of using POISSON and of RF cavity can be found in the last pages of the Assignment. Always remember: before turn on power, check the circuit one more time and make sure everything is correct; do not touch any exposed electric thread or connector when energized.

Most computer simulation tasks can be done in a very simple way: copy all the files in \USPASexamples to your own directory and modify the input files with the right parameters. More documents of POISSON and SUPERFISH are in \LANL\Docs.

In the labs and computer works, you will design and measure bending magnet, focusing magnet, RF cavity and fundamental accelerator lattices, you will also learn basic beam diagnostic instruments.

Lab and Computer Groups

Group 1

Bacchus, Ian

Baumgartner, Heidi

Benatti, Carla

Black, Rachel

Stephens, Keith

Group 2

Chen, Gary

Croke, Gary

Doty, Charles

Gardner, Matthew

Goe, Austin

Group 3

Nguyen, Chris

Okine, John

Potter, Rudolf

Prilepskiy, Yuriy

Sandip, Shrotriya

Group 4

Ballard, David

Bastaninejad, Mahzad

Coy, Robert

Hazelwood, Kyle

King, Larry

Group 5

Amar, Sokhna Bineta Lo

Blanco, Oscar

Clarken, Robert

Ndoye, Fatou

Knobloch, Jens

Group 6

Hammond, Andrew

Hatch, Chris

Johnson, Michael

Moore, Earl

Waldron, Timothy

Group 7

Salmi, Tiina-Mari

Tesfamicael, Biniam

Velev, Vesselin

Lu, Weiwei

Ripman, Benjamin

Group 8

Lighthall, Holly

Marroquin, Pilar

Michalski, Timothy

Vosmek, Ben

Lab and Computer Schedule

	18-Jan	19-Jan	20-Jan	21-Jan	24-Jan	25-Jan	26-Jan	27-Jan
Group 1	Lab 1	Com 1	Lab 2	Com 2	Lab 3	Com 3	Lab 4	Com 4
Group 2	Lab 2	Com 1	Lab 3	Com 2	Lab 4	Com 3	Lab 1	Com 4
Group 3	Lab 3	Com 1	Lab 4	Com 2	Lab 1	Com 3	Lab 2	Com 4
Group 4	Lab 4	Com 1	Lab 1	Com 2	Lab 2	Com 3	Lab 3	Com 4

Group 5	Com 1	Lab 1	Com 2	Lab 2	Com 3	Lab 3	Com 4	Lab 4
Group 6	Com 1	Lab 2	Com 2	Lab 3	Com 3	Lab 4	Com 4	Lab 1
Group 7	Com 1	Lab 3	Com 2	Lab 4	Com 3	Lab 1	Com 4	Lab 2
Group 8	Com 1	Lab 4	Com 2	Lab 1	Com 3	Lab 2	Com 4	Lab 3

Lab and computer reports are required and graded for each group – a group report, due on January 24 and on January 27.
A hard copy of Laboratory and Computer Assignment is available to each group. If you need electronic version or an additional hard copy, please ask.