UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

Modern Experimental Physics

Introduction for Physics 401 students

Spring 2019
Eugene V. Colla

illinois.edu

Outline

- Goals of the course
- Experiments
- Teamwork
- Schedule and assignments
- Your working mode

Physics 403. The goals of the course.

- **Primary:** **Learn how to “do” research**
  - ❖ Each project is a mini-research effort
  - ❖ How are experiments actually carried out
  - ❖ Use of modern tools and modern analysis and data-recording techniques
  - ❖ Learn how to document your work
- **Secondary:** **Learn some modern physics**
  - ❖ Many experiments were once Nobel-prize-worthy efforts
  - ❖ They touch on important themes in the development of modern physics
  - ❖ Some will provide the insight to understand advanced courses
  - ❖ Some are just too new to be discussed in textbooks

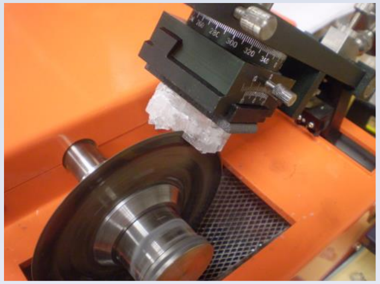
Physics 403. The goals of the course.

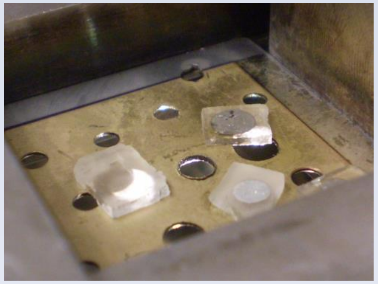
Primary. Each project is a mini-research effort

Step1. Preparing:

- Sample preparation
- Wiring the setup
- Testing electronics

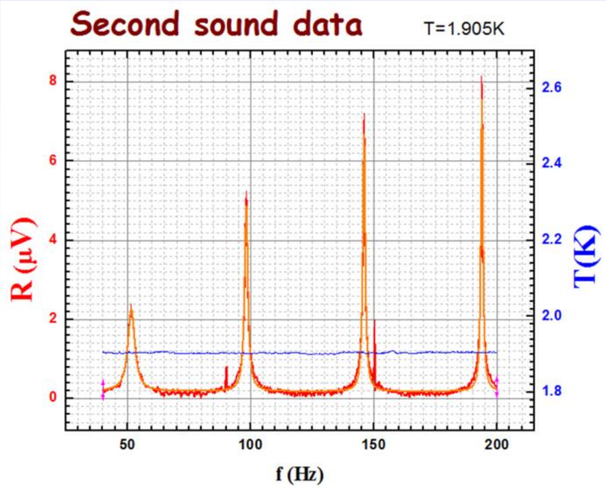
Step2. Taking data:
If problems – go back to Step 1.





Preparing the samples for ferroelectric measurements

Courtesy of Emily Zarndt & Mike Skulski (F11)



Standing waves resonances in Second Sound experiment

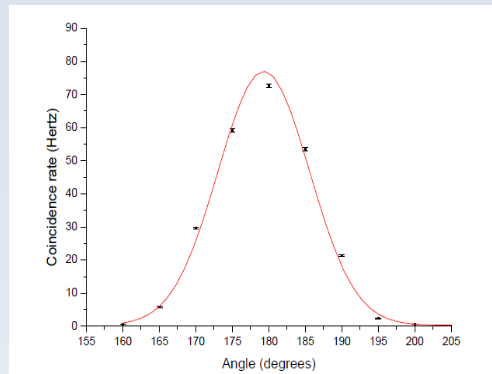
Courtesy of Mae Hwee Teo and Vernie Redmon (F11)

illinois.edu

Physics 403. The goals of the course.

Primary. Each project is a mini–research effort

Step3. Data Analysis
If data is "bad" or not enough data point – go back to Step 2



Plot of coincidence rate for 22Na against the angle between detectors A and B. The fit is a Gaussian function centred at 179.30° with a full width at half maximum (FWHM) of 14.75°.

Courtesy of Bi Ran and Thomas Woodroof

Step4. Writing report and preparing the talk

Cosmic Ray Muon Lifetime Measurement

Author#1 and Author#2
September 15, 2011

Abstract

Over the course of two months, this experiment aims to observe and analyze the decay process of cosmic muons. During this portion of the experiment, our group set-up the experimental apparatus, acquired the first set of data, roughly measured the muon lifetime, and calculated the Fermi constant G_F. From this first run of data, the muon lifetime was measured as $\tau_\mu = 2.322 \pm 0.08332\ \mu s$, yielding $G_F = (1.132 \pm 0.02087) \times 10^{-5}\ GeV$. These results are fairly in line with the accepted muon lifetime of $2.197\ \mu s$ and Fermi constant of $1.166 \times 10^{-5} GeV$, and suggest that the first cycle of the experiment was successful.

Theory

Muons were first discovered by the Carl D. Anderson and Seth Neddermeyer at Caltech, in 1936. During their study of cosmic radiation, muons were noticed by the different curvature they follow when compared to any other charged particle when applied a magnetic field. First assumed to be a meson with an interme-

Range of alpha particles in gas

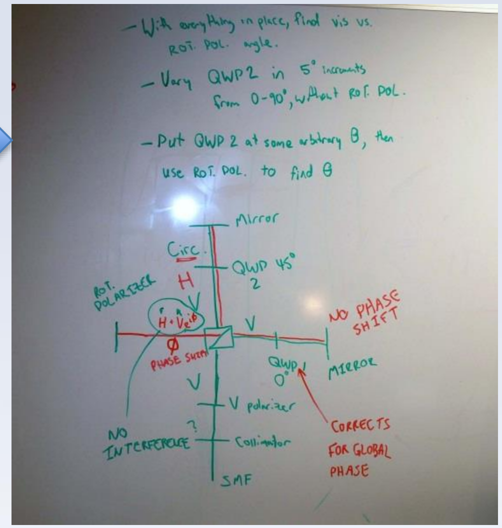
Author #1 and Author#2

illinois.edu

Physics 403. The goals of the course.

Primary. How are experiments actually carried out ?

The procedures are not all written out



The questions are not in the back of the chapter

Physics 401 Expt 44 Page 16/16 Microwave Cavities

REPORT

Include data and sample calculations for each part of the experiment. Include data analysis where necessary. Discuss briefly about your results and observations in each part.

1. Part I: (a) What is your wavelength in the slotted line? (b) What is the oscillator frequency? (c) What is the per cent uncertainty obtained from your measurement?

2. Part II: (a) What are the values of c for both the TE_{101} and TE_{102} modes? (b) Estimate the per cent uncertainties for the c.

The answers are not in the back of the book

Example 1.8 Installing a Carpet

A carpet is to be installed in a room whose length is measured to be 12.71 m and whose width is measured to be 3.46 m. Find the area of the room.

Solution If you multiply 12.71 m by 3.46 m on your calculator, you will see an answer of 43.9766 m². How many of these

You will have to learn to guide your own activities

illinois.edu

Physics 403. The goals of the course.

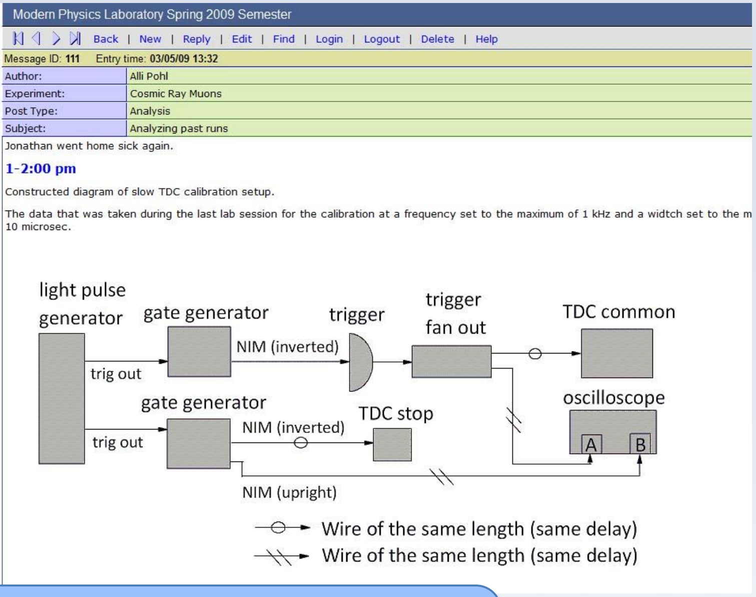
Primary. Use of modern tools and modern analysis and data-recording techniques

- Lock-in amplifiers
- Digital scopes
- Precise DMM's
- Multichannel analyzers
- Cryogenic equipment
- Temperature controllers
- Sample preparation equipment
- Microscopes
- Modern optical equipment
- etc.

Physics 403. The goals of the course.

Primary. Learn how to document your work

On line. Electronic logbook


Modern Physics Laboratory Spring 2009 Semester

Back | New | Reply | Edit | Find | Login | Logout | Delete | Help

Message ID: 111 Entry time: 03/05/09 13:32

Author:	Alli Pohl
Experiment:	Cosmic Ray Muons
Post Type:	Analysis
Subject:	Analyzing past runs

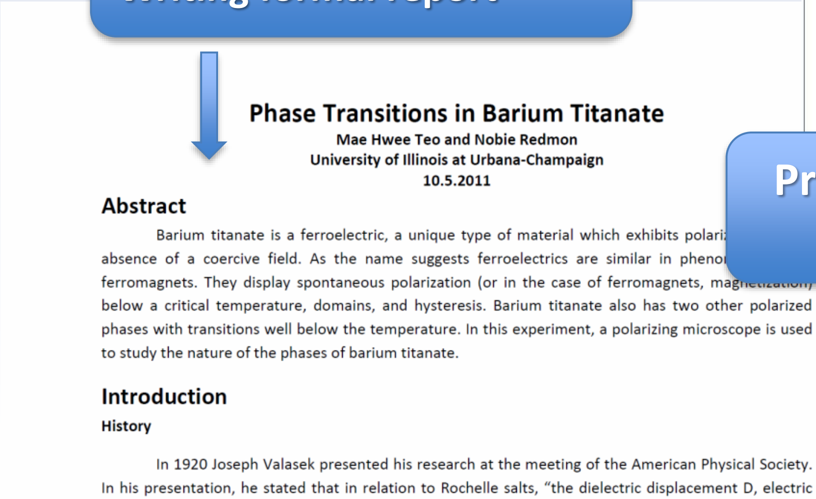
Jonathan went home sick again.

1-2:00 pm

Constructed diagram of slow TDC calibration setup.

The data that was taken during the last lab session for the calibration at a frequency set to the maximum of 1 kHz and a widtch set to the m
10 microsec.

Making an analysis report, Writing formal report


Phase Transitions in Barium Titanate

Mae Hwee Teo and Nobie Redmon
University of Illinois at Urbana-Champaign
10.5.2011

Abstract

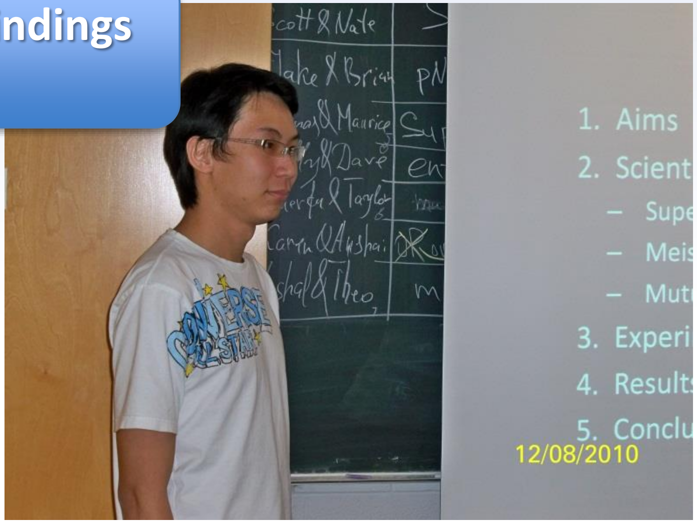
Barium titanate is a ferroelectric, a unique type of material which exhibits polari[...] absence of a coercive field. As the name suggests ferroelectrics are similar in pheno[...] ferromagnets. They display spontaneous polarization (or in the case of ferromagnets, magnetization) below a critical temperature, domains, and hysteresis. Barium titanate also has two other polarized phases with transitions well below the temperature. In this experiment, a polarizing microscope is used to study the nature of the phases of barium titanate.

Introduction

History

In 1920 Joseph Valasek presented his research at the meeting of the American Physical Society. In his presentation, he stated that in relation to Rochelle salts, "the dielectric displacement D, electric

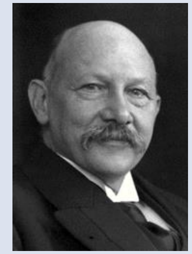
Presenting your findings orally



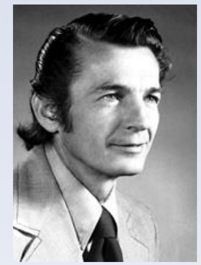
Physics 403. The goals of the course.

Secondary: Learn some modern physics

Many experiments were once Nobel-prize-worthy efforts

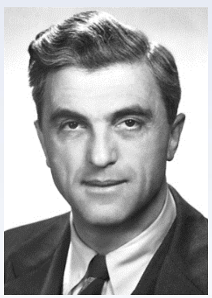


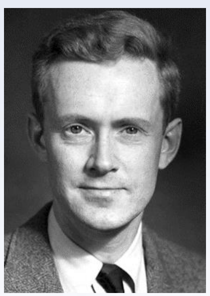
1913. Heike Kamerlingh Onnes
"for his investigations on the properties of matter at low temperatures which led, inter alia, to the production of liquid helium".



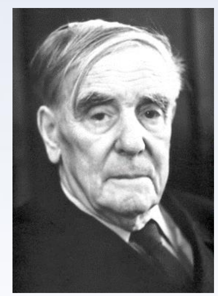
1973. Ivar Giaever
"for their experimental discoveries regarding tunneling phenomena in semiconductors and superconductors, respectively"

1986. Gerd Binnig
"for their design of the scanning tunneling microscope"

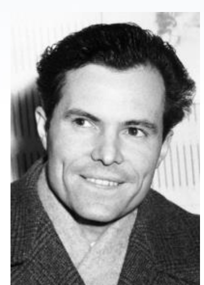




1952. Felix Bloch and Edward Mills Purcell
"for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith"



1976. Pyotr Leonidovich Kapitsa
"for his basic inventions and discoveries in the area of low-temperature physics"

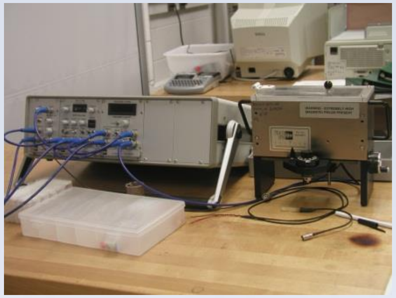


1961. Rudolf Ludwig Mössbauer
"for his researches concerning the resonance absorption of gamma radiation and his discovery in this connection of the effect which bears his name."

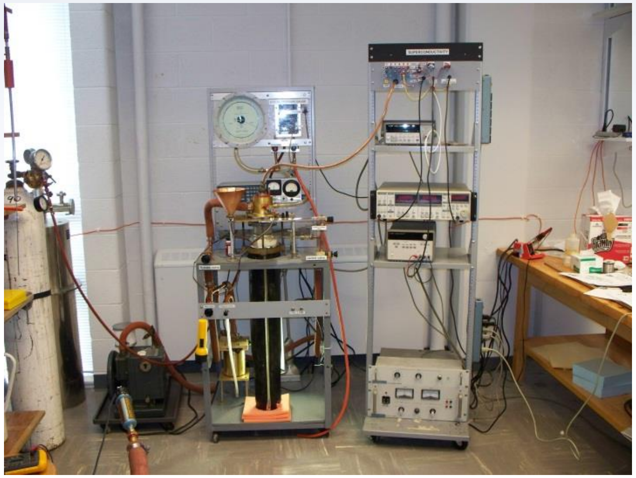
illinois.edu

Physics 403. Experiments

All experiments are divided in three main groups: Condensed Matter (CM), Nuclear/ Particle Physics (NP), Atomic/Molecular/Optics (AMO)



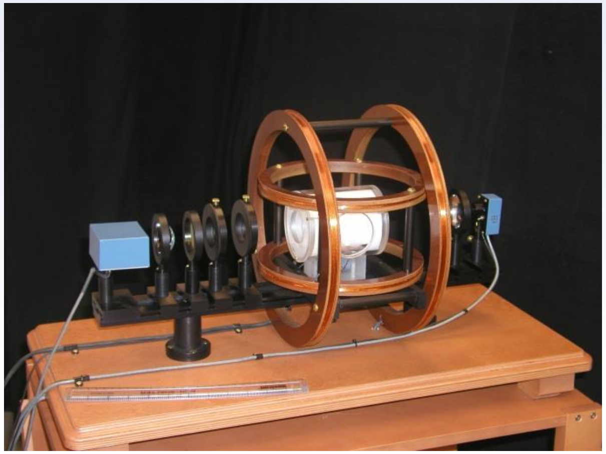
- ## Condensed Matter (CM)
  - Superconductivity
  - Tunneling in superconductors - new
  - Contactless detecting of the superconductivity. Penetration depth.
  - 2^{nd} sound in He4 superfluid state
  - Ferroelectrics and ferroelectric phase transition. Dielectric and pyroelectric study (Ferro1)
  - Optical Investigation of the ferroelectric phase transition and domain formation (Ferro2)
  - Polarization of the ferroelectrics. Hysteresis loops (Ferro3) –new
  - Low temperature thermometry. Sensors calibration.
  - Pulsed NMR
  - Special Tools:
    - Vacuum film deposition
    - Atomic Force Microscope
    - Polarizing microscope



Physics 403. Experiments

- **Nuclear / Particle (NP)**
  - Alpha particle range in gasses
  - Cosmic ray muons:
  - Angular correlations in nuclear decay
  - Angular distribution of cosmic rays
  - Mössbauer spectroscopy
  - γ-rays spectroscopy

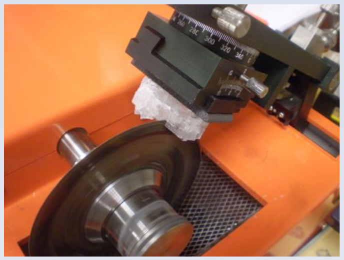
- **Atomic / Molecular / Optics (AMO)**
  - Optical pumping of rubidium gas
  - Berry's phase
  - Quantum erasure
  - Quantum Entanglement
  - Florescence spectroscopy

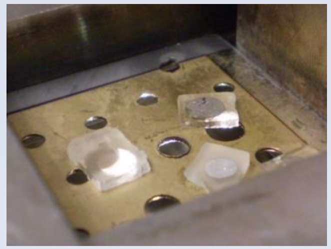


Physics 403. Experiments. Examples.

Ferro1

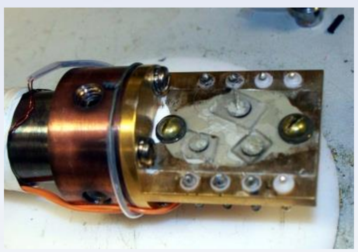
(1)





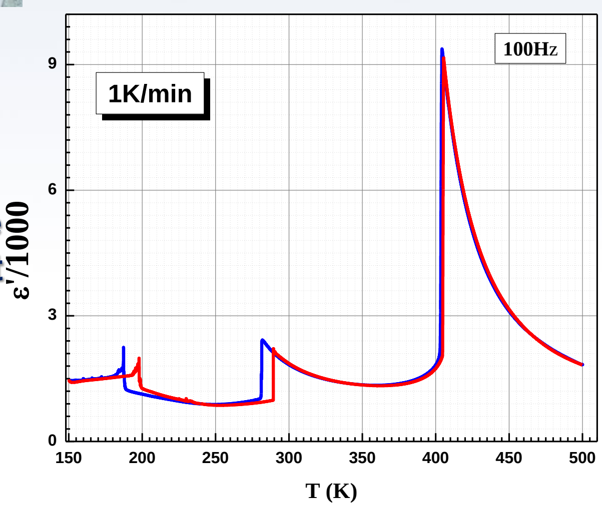
Sample preparation

(2)



Samples on the cryostat stage

(3) Results: Temperature dependence of the dielectric constant of barium titanate

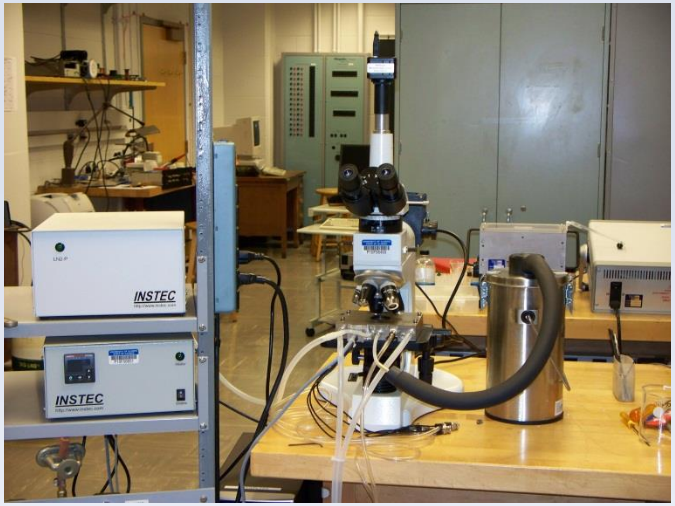


setup

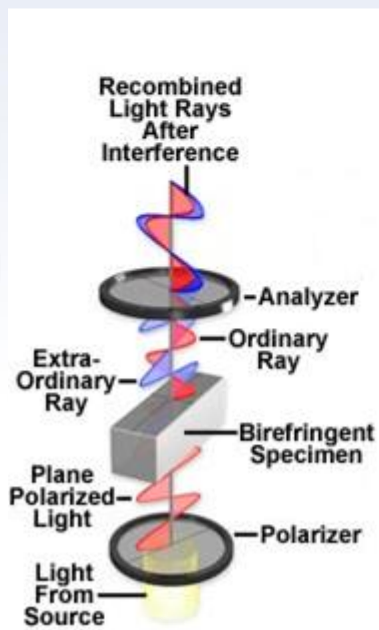
Physics 403. Experiments. Examples.

Ferro2

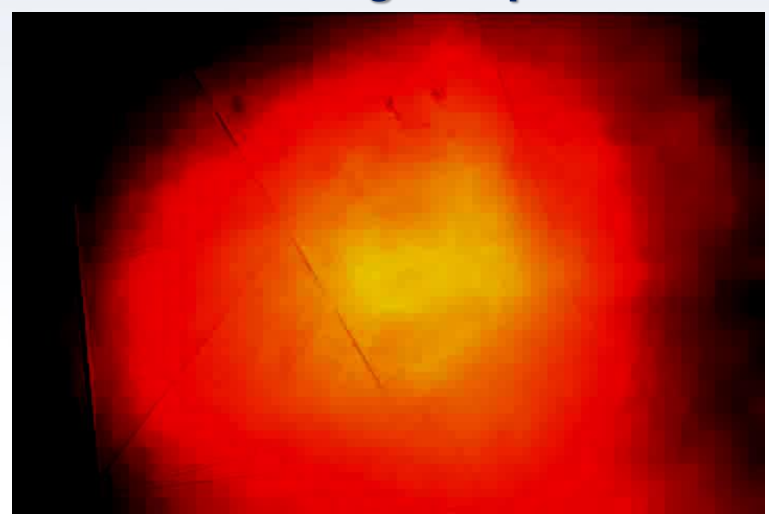
Setup



Idea of operating



Domains in tetragonal phase of BaTO

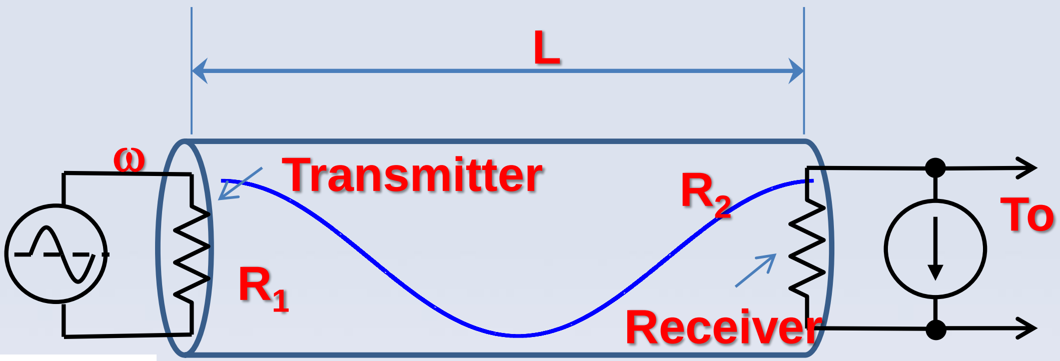


Courtesy of Dave Grych and Thomas Hymel (F10)

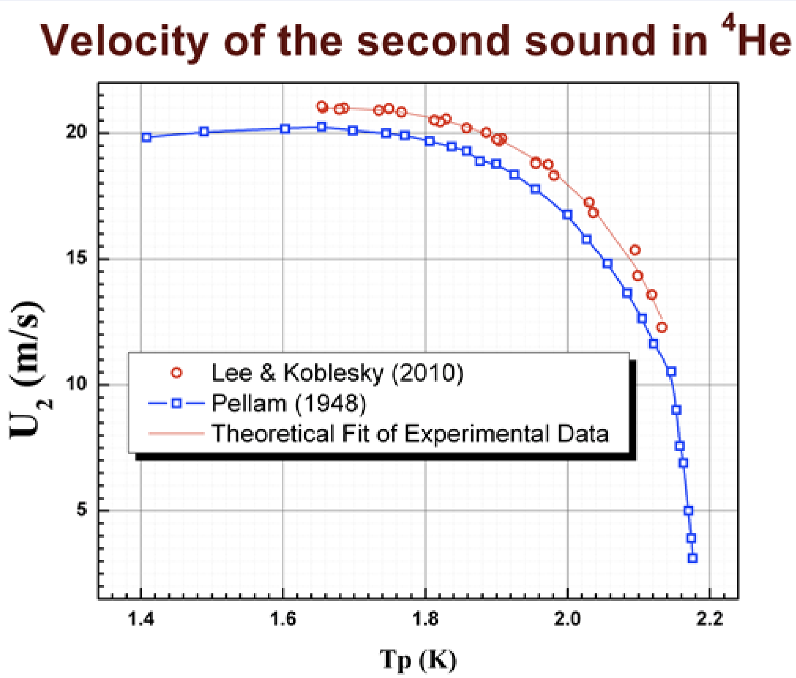
illinois.edu

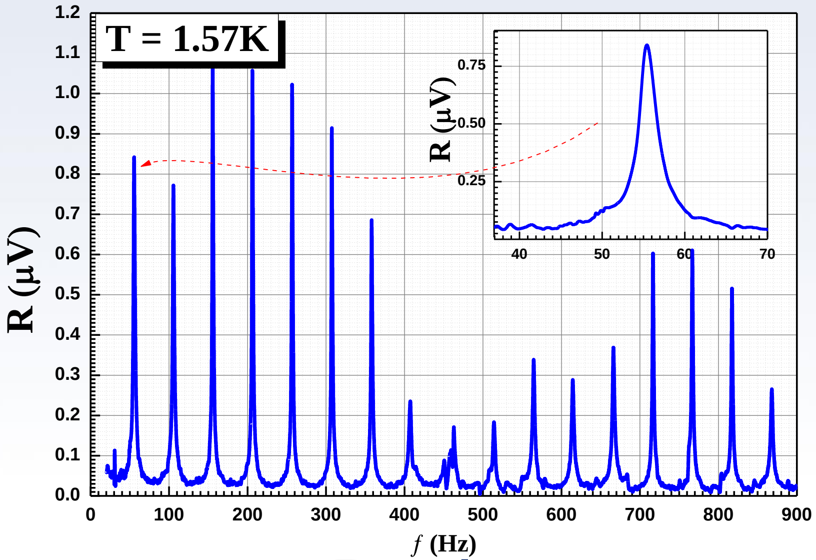
Physics 403. Experiments. Examples.

Second sound



Idea of the experiment T<2.17K

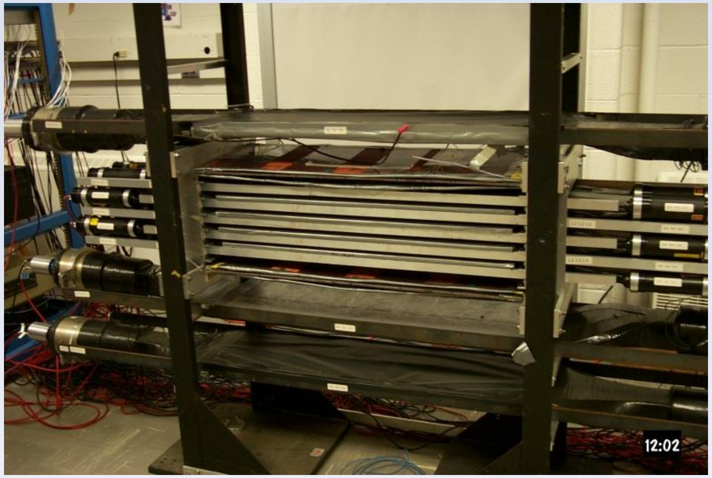




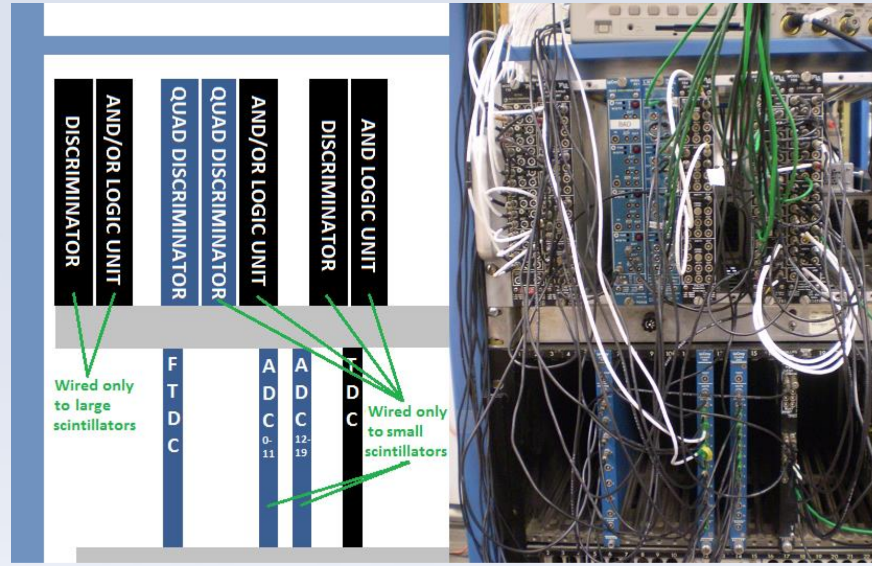
Final result **Raw data**

Physics 403. Experiments. Examples.

Muon counting

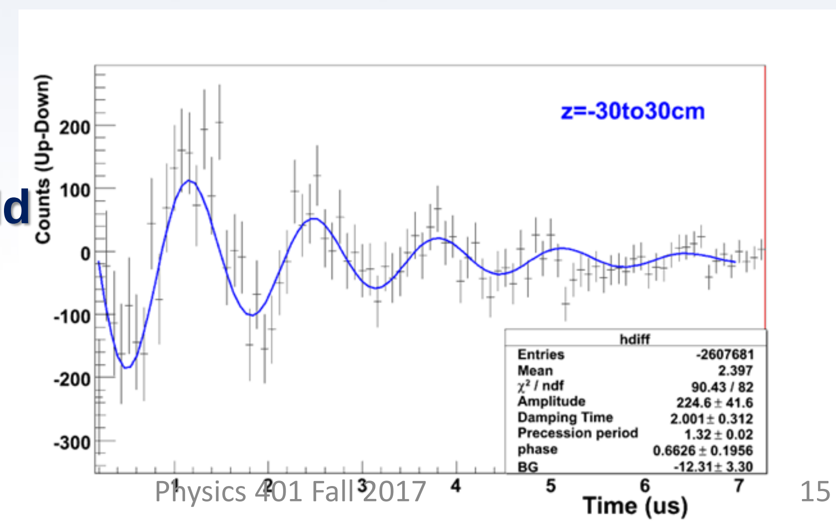


Main stock of scintillators



Wiring
Courtesy of Deniz Köksal, Emily Zarndt

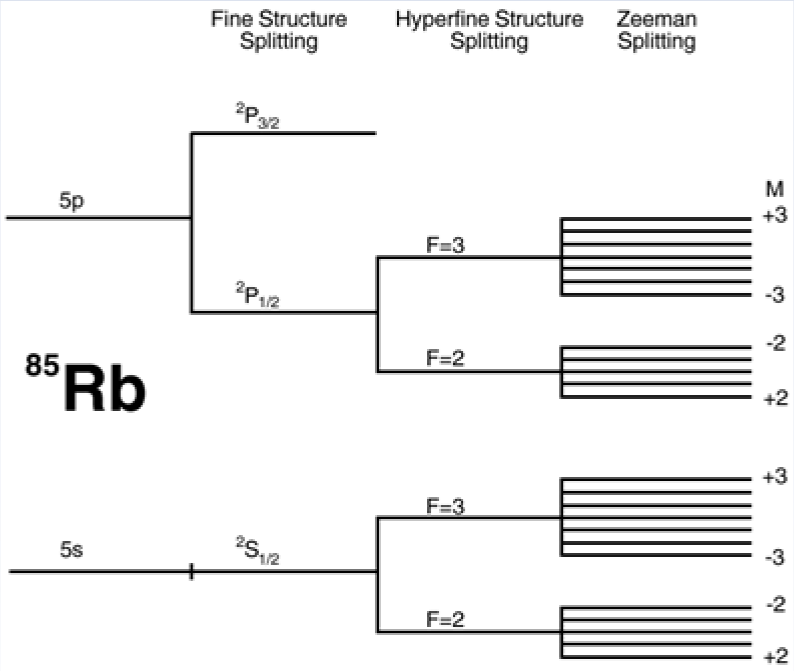
Muons precession in magnetic field

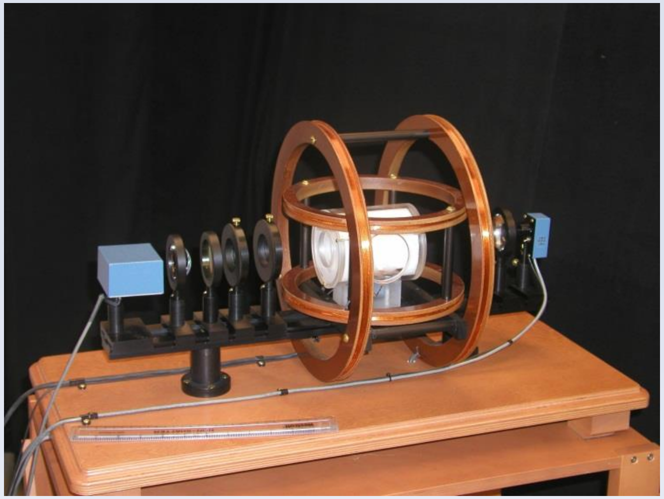


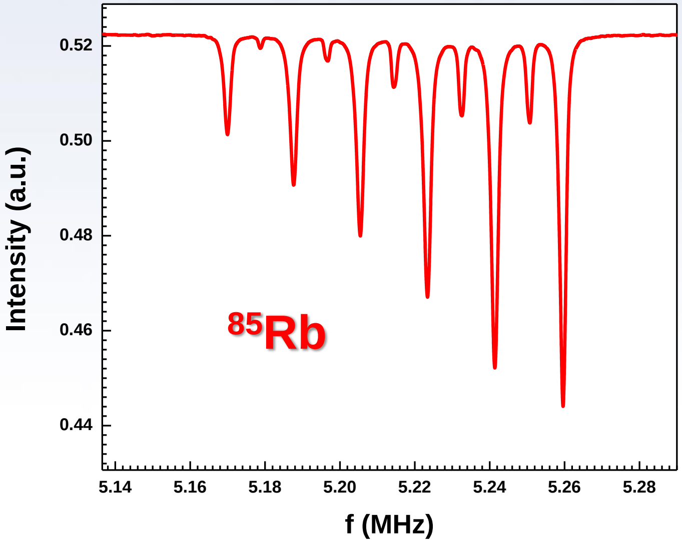
illinois.edu

Physics 403. Experiments. Examples.

Optical pumping



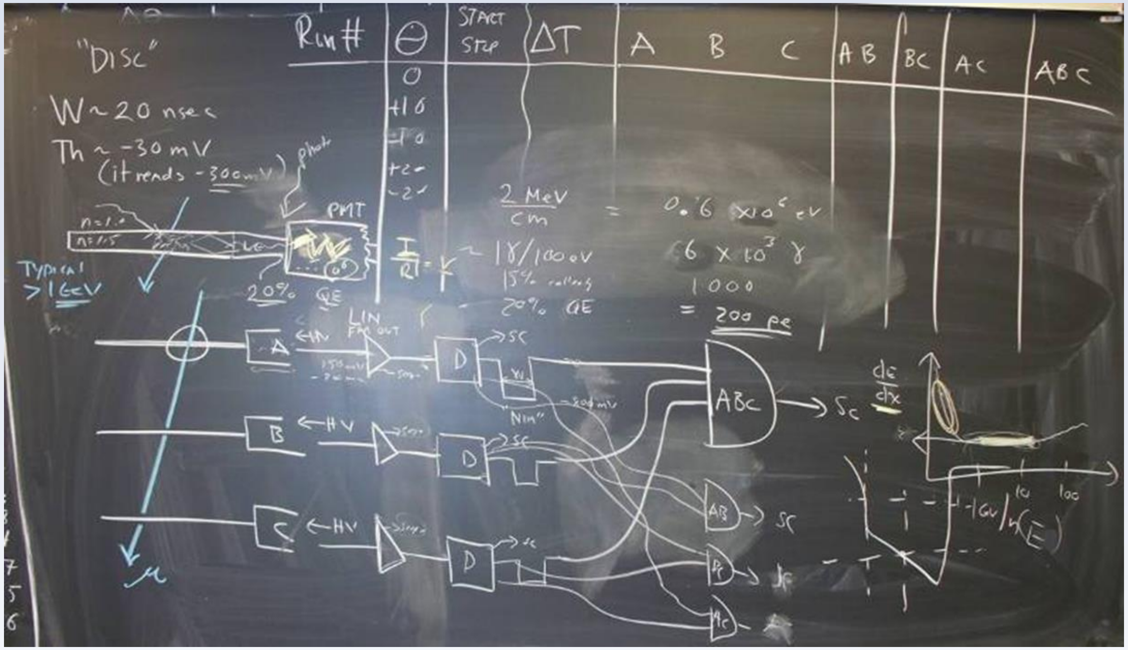




Energy transitions of Rb85 for 10.8 G. Double quantum transitions can be seen and occur when two photons are simultaneously absorbed. Courtesy of Natasha Sachdeva (S2011)

The "manuals".

- Many are just guides
- A few purchased experiments have "real" manuals
- We serve as your guides … like real research



An example of Lab manual

Assignments and grading (Fall or Spring)

Item	Points
Expt. documentation: elog reports, shift summaries, plot quality; paper logbooks	180 Total 60 / cycle
Formal reports: physics case, quality of results, depth of analysis, conclusions	600 Total 100 / report
Oral reports: motivation, organization of presentation; fielding questions	100 50/ oral
Final oral presentation: (final exam)	120
Total	**1000**

Syllabus

Cycles

Class	Date	Day	Activity	Comment	Due	Note
1	8/23	Tues	Orientation	About Phy403 (mgp)		
2	8/25	Thurs	Cycle 1-1			
3	8/30	Tues	Cycle 1-2	OriginPro Intro (ec)		
4	9/1	Thurs	Cycle 1-3	Elog Comments (mgp)		
5	9/6	Tues	Cycle 1-4	Written Reports (mgp)		
6	9/8	Thurs	Cycle 1-5		Rotate	
7	9/13	Tues	Cycle 1-6	Basic ErrorAnalysis (mgp)		
8	9/15	Thurs	Cycle 1-7		**C1-Ex1**	
9	9/20	Tues	Cycle 1-8	Oral Reports / Talks		
10	9/22	Thurs	Cycle 2-1		Rotate	
11	9/27	Tues		**ORALS Cycle 1**		
12	9/29	Thurs	Cycle 2-2			
13	10/4	Tues	Cycle 2-3	Root Analysis Intro (mgp)	**C1-Ex2**	
14	10/6	Thurs	Cycle 2-4			
15	10/11	Tues	Cycle 2-5	Data & Ethics (mgp)	Rotate	
16	10/13	Thurs	Cycle 2-6			
17	10/18	Tues	Cycle 2-7	Lock-in Amps (ec)	**C2-Ex1**	
18	10/20	Thurs	Cycle 2-8			
19	10/25	Tues		**ORALS Cycle 2**		
20	10/27	Thurs	Cycle 3-1		Rotate	
21	11/1	Tues	Cycle 3-2	Measuring Temp (ec)	**C2-Ex2**	
22	11/3	Thurs	Cycle 3-3			
23	11/8	Tues	Cycle 3-4	Quark Structure of Hadrons (mgp)		
24	11/10	Thurs	Cycle 3-5		Rotate	
25	11/15	Tues	Cycle 3-6	Ferroelectricity (ec)	**C3-Ex1**	
26	11/17	Thurs	Cycle 3-7			
				Thanksgiving Break		
27	11/29	Tues	Cycle 3-8	Entaglement		
28	**12/1**	**Thurs**		**Working Day / Catchup**		
29	**12/6**	**Tues**		**ORALS Cycle 3**		
	12/8			**READING DAY**	**C3-Ex2**	

illinois.edu

Assignment of experiments:

3 cycles with 2 experiments

- → teams change after each cycle
- → joint team reports and oral presentations

Cycle	Date	Nuclear / Particle A. Cosmic Muon Stand i. Muon lifetime ii. Capture rate iii. Magnetic moment B. Alpha range C. Gamma Gamma D. Cosmic angular distribution Matthias	Condensed Matter A. Ferro 1 i. BaTiO3 ii. KDP / DKDP iii. Relaxor or unknown B. Ferro 2 (imaging) C. 2nd sound of ⁴He D. pNMR Eugene	Atomic + CM A.Optical pumping B.Superconductivity i. Indium, Tin, Lead ... ii. Mutual inductance Eugene + Zack	Optics A. Quantum Table i. Berry's phase ii. Quantum erasure iii. Entanglement B. Florescence spectroscopy TA from Kwiat group (A) Robert Clegg (B)
C1-1	8.26-9.7	A-1,2 B-3,4	A-5,6 C-7,8 D-9,10	A-11,12	A-13,14
C1-2	9.10-9.21	A-3.4 C-1.2	B-7,8 C-5,6 B-9,10	B-13,14	A-11,12
C2-1	9.23, 9.30-10.7	A-8,11 B-10,13	A-1,12 C-3-14	A-2,5	A-7,4 B-6,9
C2-2	10.12 - 10.21	A-10,13 C-8,11	B-3-14 D-1,12	B-7,4	A-6,9 B-2,5
C3-1	10.28 -11.9	A-5,12 B-7,14 C-6,9	A-2,4 C-11,13	A-1,3	A-8,10
C3-2	11.11 - 11.17, 11.30	A-7,14 B-6.9 C-5.12	B-11,13 C-2,4	B-8,10	A-1,3

Physics 403. Summer 2019 and Fall 2019

- **Total 26 seats**
- **The course is more appropriate for juniors and seniors**
- **Prerequisite: Credit or concurrent registration in P486.**
- **Instructor Approval Required**