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
Primary. Each project is a mini-research effort

Step 1. Preparing:
- Sample preparation
- Wiring the setup
- Testing electronics

Preparation of the samples for ferroelectric measurements
Courtesy of Emily Zarndt & Mike Skulski (F11)

Step 2. Taking data:
If problems – go back to Step 1.

Standing waves resonances in Second Sound experiment
Courtesy of Mae Hwee Teo and Vernie Redmon (F11)
Physics 403. The goals of the course.

Primary. Each project is a mini-research effort

Step 3. 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

Step 4. Writing report and preparing the talk

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°.

 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 $\tau_\mu = 2.322 \pm 0.0832 \mu s$, yielding $G_F = (1.132 \pm 0.02087) \times 10^{-5} \text{ GeV}$. These results are fairly in line with the accepted muon lifetime of $2.197 \mu s$ and Fermi constant of $1.166 \times 10^{-5} \text{ GeV}$, 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 intermediate mass between the mass of an electron and a neutron, muons are different...
The procedures are not all written out
The questions are not in the back of the chapter
The answers are not in the back of the book
You will have to learn to guide your own activities
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

Making an analysis report, Writing formal report

Presenting your findings orally

Phase Transitions in Barium Titanate
Mae Hwee Teo and Noble Redmon
University of Illinois at Urbana-Champaign
10.5.2011

Abstract
Barium titanate is a ferroelectric, a unique type of material which exhibits polarization in the absence of a coercive field. As the name suggests ferroelectrics are similar in phenomena to 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
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"

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

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

1951. Rudolf Ludwig Mössbauer “for his researches concerning the resonance absorption of gamma radiation…”
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\textsuperscript{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
• **Nuclear / Particle (NP)**
  – Alpha particle range in gases
  – Cosmic ray muons:
  – Angular correlations in nuclear decay
  – Angular distribution of cosmic rays
  – Mössbauer spectroscopy

• **Atomic / Molecular / Optics (AMO)**
  – Optical pumping of rubidium gas
  – Berry’s phase
  – Quantum erasure
  – Quantum Entanglement
  – Florescence spectroscopy
Ferro1

(1) Sample preparation

(2) Samples on the cryostat stage

(3) Results: Temperature dependence of the dielectric constant of barium titanate
domains in tetragonal phase of BaTO
Second sound

Velocity of the second sound in $^4$He

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<th>$T_p$ (K)</th>
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- Lee & Koblesky (2010)
- Pellam (1948)
- Theoretical Fit of Experimental Data

Idea of the experiment

$T = 1.57K$

Final result

Raw data

To lock-in
Muon counting

Main stock of scintillators

Muons precession in magnetic field

Wiring

Courtesy of Deniz Köksal, Emily Zarndt
**Optical pumping**

Energy transitions of Rb$^{85}$ 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

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<tr>
<th>Item</th>
<th>Points</th>
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<tr>
<td><strong>Expt. documentation</strong>: elog reports, shift summaries, plot quality; paper logbooks</td>
<td>180 Total 60 / cycle</td>
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<tr>
<td><strong>Formal reports</strong>: physics case, quality of results, depth of analysis, conclusions</td>
<td>600 Total 100 / report</td>
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<tr>
<td><strong>Oral reports</strong>: motivation, organization of presentation; fielding questions</td>
<td>225 75 / oral</td>
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<td><strong>Effective point total will be</strong></td>
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## Syllabus

### Cycles

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Physics 401 Spring 2013 19
### Assignment of experiments:

**3 cycles with 2 experiments**

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

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<thead>
<tr>
<th>Cycle</th>
<th>Date</th>
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*Matthias*

*Eugene*

*Eugene + Zack*

*TA from Kwiat group (A) Robert Clegg (B)*
• Total 24 seats (Fall) and 12 (Summer) (23 in Summer 2016)
• The course is more appropriate for juniors and seniors
• Prerequisite: Credit or concurrent registration in P486.
• Instructor Approval Required