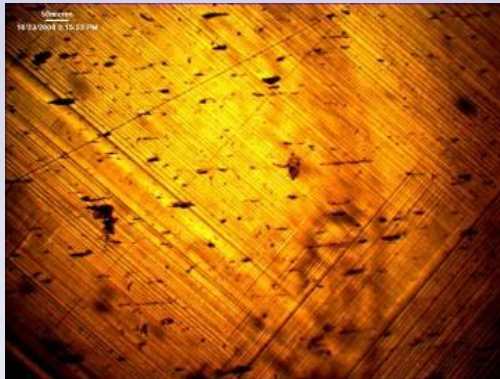
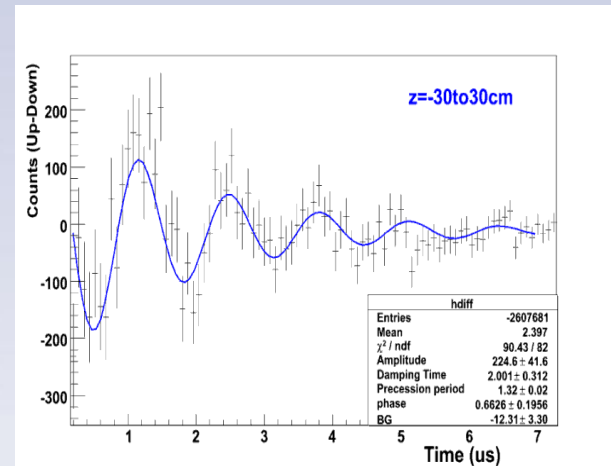


# Physics 403 Modern Physics Laboratory

Spring 2015  
*Eugene V Colla, Liang Yang*



Ferroelectric domains in BaTiO<sub>3</sub>

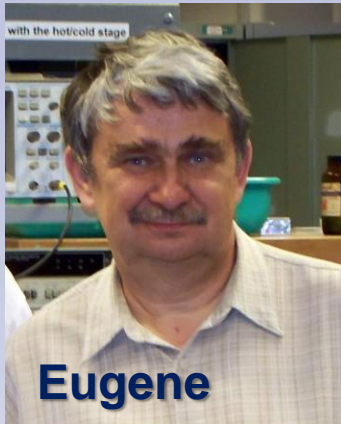


Spin-precession of stopped cosmic ray muons



# Physics 403 Modern Physics Laboratory

Spring 2015, Teaching Team



**Eugene**

**Instructors:**

Eugene V Colla [kolla@illinois.edu](mailto:kolla@illinois.edu)

Liang Yang [liangyg@illinois.edu](mailto:liangyg@illinois.edu)



**Liang**



**Jack**

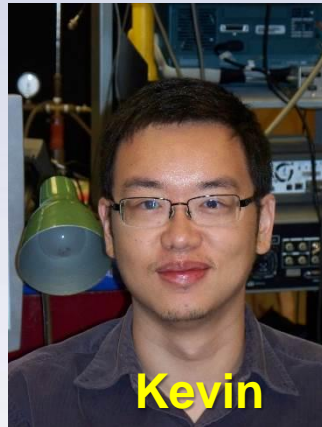
**Laboratory  
Specialist:**

**Jack Boparai**

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**Andrey**



**Kevin**



**Yakov**



**Rebecca**

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**Support from Kwiat  
research group**



[illinois.edu](http://illinois.edu)

# Outline

- I. Goals of the course
- II. Teamwork / grades / expectations from you
- III. Syllabus and schedule
- IV. Your working mode
  - In class and “after hours” access
  - Safety, Responsibility
  - Home and away computing
- V. *Take a Lab tour !***
- VI. Let's get started
  - electronic logbooks
  - digital scopes

# Course Goals. Primary goals:

- **Learn how to “do” research**
  - Each project is a mini-research effort
  - How are experiments actually carried out ?
    - The procedures aren't 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
  - Use of modern tools and modern analysis and data-recording techniques



# Course Goals. Primary goals:

- **Learn how to document your work**
  - Online - **electronic logbook \***
  - Online – saving data and projects in student area in server
  - Using traditional paper logbooks
  - Making an analysis report
  - Writing **formal reports**
  - Presenting your findings **orally**



# Course Goals. Secondary goals:

- **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 additional insight to understand advanced courses you have taken
  - Some are just too new to be discussed in textbooks



# The Experiments

- **Nuclear / Particle (NP)**

- Alpha particle range in gasses

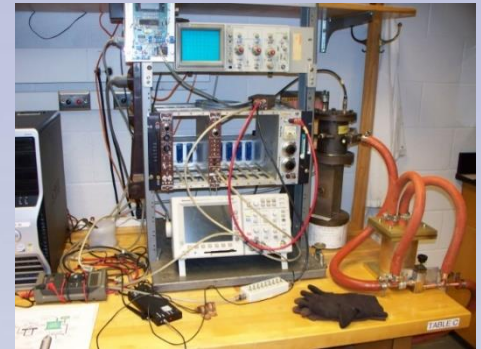
- Cosmic ray muons:

- Lifetime, capture rate, magnetic moment

- Angular correlations in nuclear decay

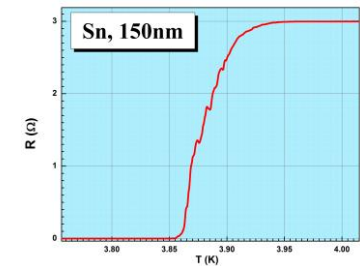
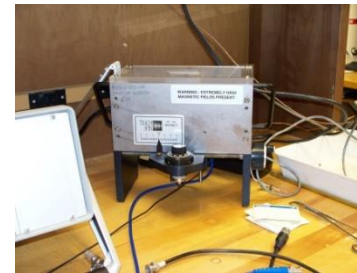
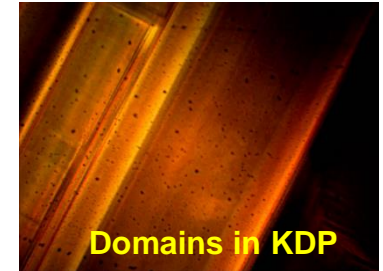
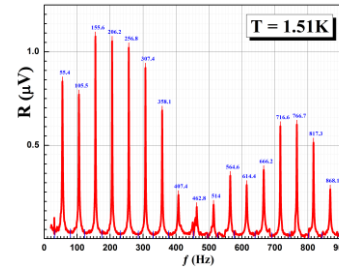
- Angular distribution of cosmic rays

- $\gamma$  - rays spectroscopy (**new**)



# The Experiments

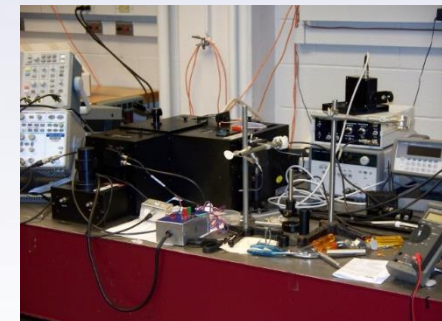
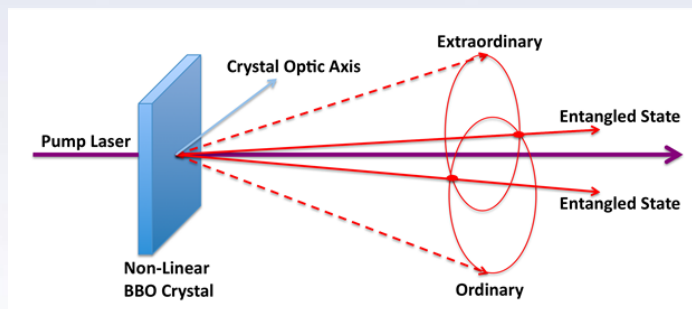
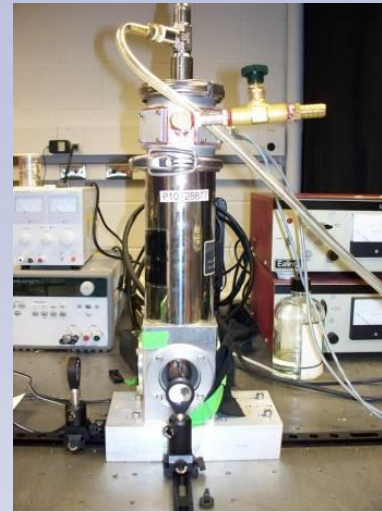
- **Condensed Matter (CM)**
  - Superconductivity
  - Tunneling in superconductors
  - 2<sup>nd</sup> sound in <sup>4</sup>He superfluid state
  - Ferroelectrics and ferroelectric phase transition
  - Pulsed NMR
  - Calibration of temperature sensors
  - Special Tools:
    - Vacuum film deposition
    - Atomic Force Microscope
    - Polarizing microscope





# The Experiments

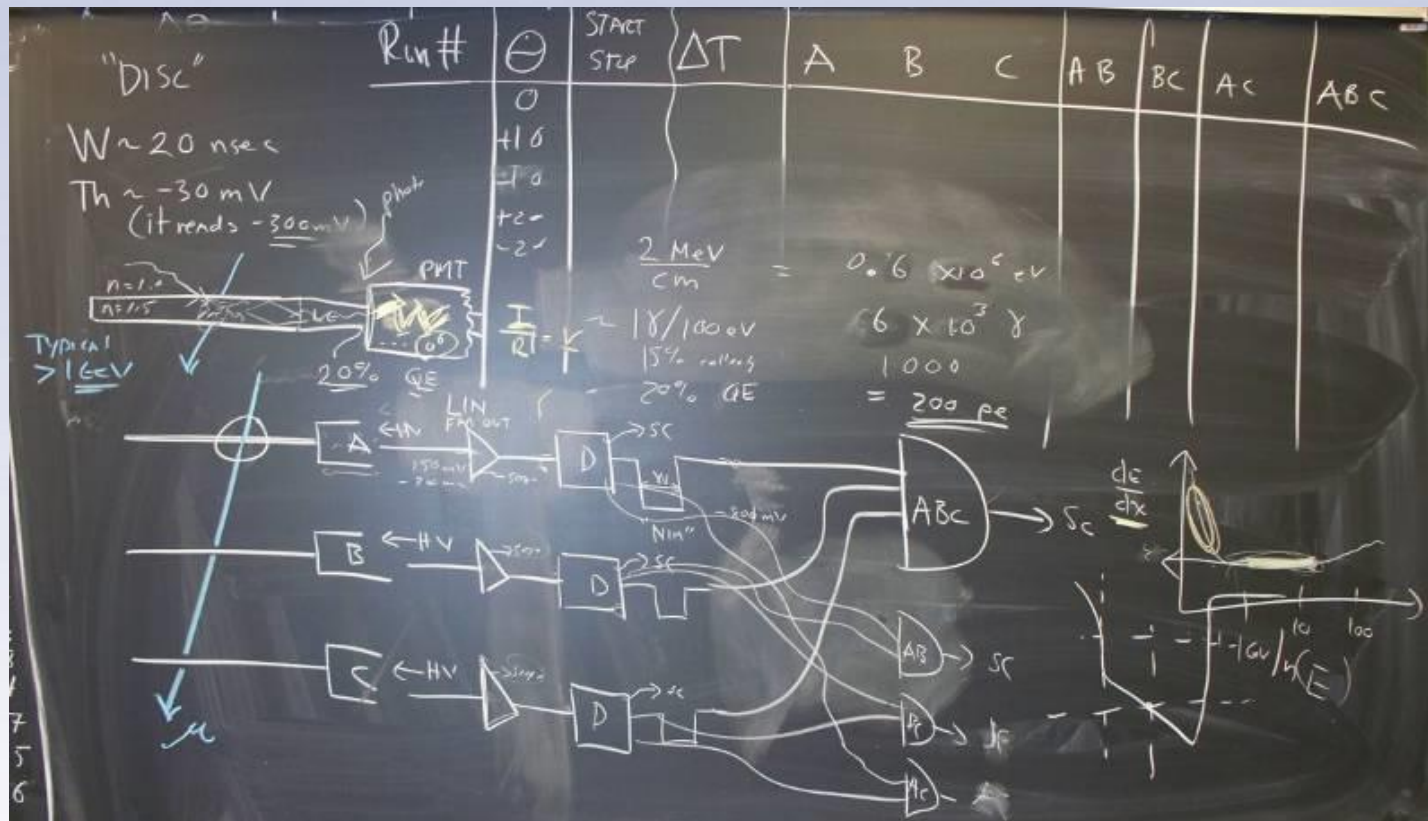
- Atomic / Molecular / Optics
  - Optical pumping of rubidium gas
  - Berry's phase
  - Quantum erasure
  - Quantum Entanglement
  - Fluorescence spectroscopy





# The “manuals”

- Many are just guides
- A few purchased experiments have “real” manuals
- We serve as your guides ... like real research



# Grading: Distribution of “1000” points

Item	Points
<b>Expt. documentation:</b> elog reports, shift summaries, plot quality; paper logbooks	<b>180 Total</b> 60 / cycle
<b>Formal reports:</b> physics case, quality of results, depth of analysis, conclusions	<b>600 Total</b> 100 / report
<b>Oral reports:</b> motivation, organization of presentation; fielding questions	<b>225 Total</b> 75 / oral
Total	1005
<b>Effective point total will be</b>	<b>1000 ← grade</b>

The grading scale will be a percentage out of “1000” :

Letter grading scale is approximately **97% = A+**, **93% = A**, **90% = A-**, **87% = B+**, **83% = B**, **80% = B-**, etc

You can **RESUBMIT one lab report** to improve your grade (deadline for resubmissions May, 7 – reading day).



# Submission of Lab-Reports

- Due dates as on syllabus at midnight
- The reports should be uploaded to the server:
- <https://my.physics.illinois.edu/courses/upload/>
- Accepted MS-Word or PDF



# Absences / Late Reports

- If you are sick, let Eugene by email. Don't come in and get others sick. We are working side-by-side in a close environment for many hours.
- You can “make up” the time with arrangements and you can have access to the rooms. We will be accommodating.
- Policy for late reports
  - You can have **ONE “late ticket” for a “free”** delay of up to **3** business days, but you must tell us you are using the ticket
  - Reports are due at midnight on the date shown on the syllabus. After that we will charge:
    - 5 points for up to 1 week late. 10 points for up to 2 weeks late.
    - After that, it's too late.



# Syllabus

## Cycles

	Date	Day	Activity	Comment	Due	Note
1	1/20	Tues	Orientation	About Phy403 (ec)		
2	1/22	Thurs	Cycle 1-1			
3	1/27	Tues	Cycle 1-2	OriginPro Intro (ec)		
4	1/29	Thurs	Cycle 1-3	Elog Comments (ec/ly)		
5	2/3	Tues	Cycle 1-4	Written Reports (ec)		
6	2/5	Thurs	Cycle 1-5		Rotate	
7	2/10	Tues	Cycle 1-6	Error analysis (ly)		
8	2/12	Thurs	Cycle 1-7		C1-Ex1(2.13.15)	
9	2/17	Tues	Cycle 1-8	Oral Reports/Talks(ec/ly)		
10	2/19	Thurs	Cycle 2-1		Rotate	
11	2/24	Tues		ORALS Cycle 1		
12	2/26	Thurs	Cycle 2-2			
13	3/3	Tues	Cycle 2-3	Optical spectroscopy (Kevin)	C1-Ex2 (3.4.15)	
14	3/5	Thurs	Cycle 2-4			
15	3/10	Tues	Cycle 2-5	Measuring Temp (ec)	Rotate	
16	3/12	Thurs	Cycle 2-6			
17	3/17	Tues	Cycle 2-7	Noise (mw)	C2-Ex1 (3.18.15)	
18	3/19	Thurs	Cycle 2-8			
	3/21			Spring Break		
19	3/31	Tues	Cycle 3-1	Lock-in Amps and FT(ec)	Rotate	
20	4/2	Thurs				
21	4/7	Tues	Cycle 3-2	ORALS Cycle 2	C2-Ex2 (4.8.15)	
22	4/9	Thurs	Cycle 3-3			
23	4/14	Tues	Cycle 3-4	Ferroelectricity (ec)		
24	4/16	Thurs	Cycle 3-5		Rotate	
25	4/21	Tues	Cycle 3-6	High Energy Physics (ly)	C3-Ex1 (4.22.15)	
26	4/23		Cycle 3-7			
27	4/28	Tues	Cycle 3-8	Entanglement		
28	4/30	Thurs		Working Day / Catch-up		
29	5/5	Tues		ORALS Cycle 3		
	5/7			READING DAY	C3-Ex2 (5.7.15)	



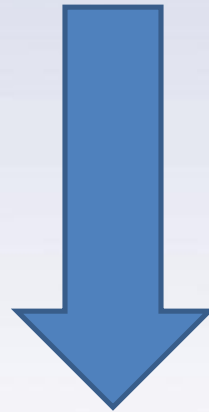


# Assignment of experiments

**3 cycles with 2 experiments**

**→ teams change after each cycle**

**→ joint team reports and oral presentations**



	NP	CM	Atomic + CM	Optics
	A. Cosmic Muon Stand i. Muon lifetime ii. Capture rate iii. Magnetic moment B. Alpha range C. Gamma Gamma D. Cosmic angular distribution	A. Ferro 1 B. Ferro 2 (imaging) C. 2 <sup>nd</sup> sound of <sup>4</sup> He D. pNMR E. Hysteresis loops F. Tunneling G. AFM H. T calibration	A. Optical pumping B. Superconductivity C. Mutual inductance	A. Quantum Table i. Berry's phase ii. Quantum erasure iii. Entanglement B. Florescence spectroscopy
	<b>Liang, Matthew</b>	<b>Eugene</b>	<b>Eugene , Andrew, Liang</b>	<b>Kevin and TA's from Kwiat Lab</b>
<b>C1-1</b>	1,2 3,4 5,6	7,8 9,10 11,12; 13,14	15,16 21,22	17,18 19,20
<b>C1-2</b>	1,2 3,4 5,6	7,8 9,10 11,12; 13,14	17,18 19,20	15,16 21,22
<b>C2-1</b>	15,18 16,17 19,22; 20,21	1,3 4,5 6,2	8,9 11,14	7,10 12,13
<b>C2-2</b>	15,18 16,17 19,22 20,21	1,3 4,5 6,2	7,10 12,13	8,9 11,14
<b>C3-1</b>	7,9 8,10 11,13; 12,14	15,17 16,18 19,21; 20,22	2,3	1,5 4,6
<b>C3-2</b>	7,9 8,10 11,13; 12,14	15,17 16,18 19,21; 20,22	1,5	4,6 2,3



# Safety is your responsibility !

Hazards: *high voltage, radioactive sources, cryogens, chemical materials*

In class work and “after hours” access & work requires responsible conduct with regards to

(I) safety/hazards and with

(II) equipment

Discuss potential hazards at the beginning of each experiment with an instructor or TA

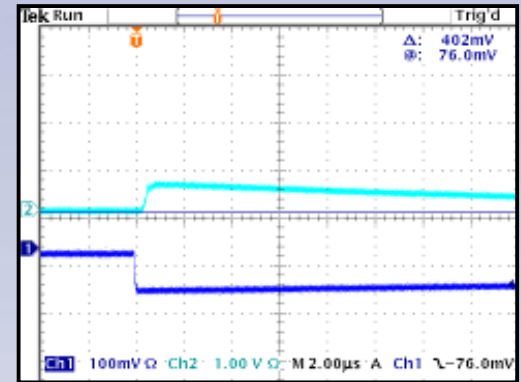
When in doubt stop and ask

Problems after hours: **217 493 1576** (Eugene's cell)



# How to record data (1)

- Work together
- Write down the equipment used
- Make a diagram of the setup
- Note the settings of dials, switches, gauges
- Take a digital photo if appropriate
- Use a software drawing program to make a detailed sketch
- You will almost always look at some signals with a scope.
  - Record a representative trace using the Scope



# How to record data (2)

- When you have come to an intermediate stopping point, take a few minutes and summarize the recent steps
  - Use the eLog (see next).
  - Write down what you did in real sentences.
  - Provide enough detail that you can reconstruct later what you did!
- Plan your plots and analysis as you go.
  - How will you look at the data later?
  - Do you have enough information?
  - Did the equipment perform as expected?





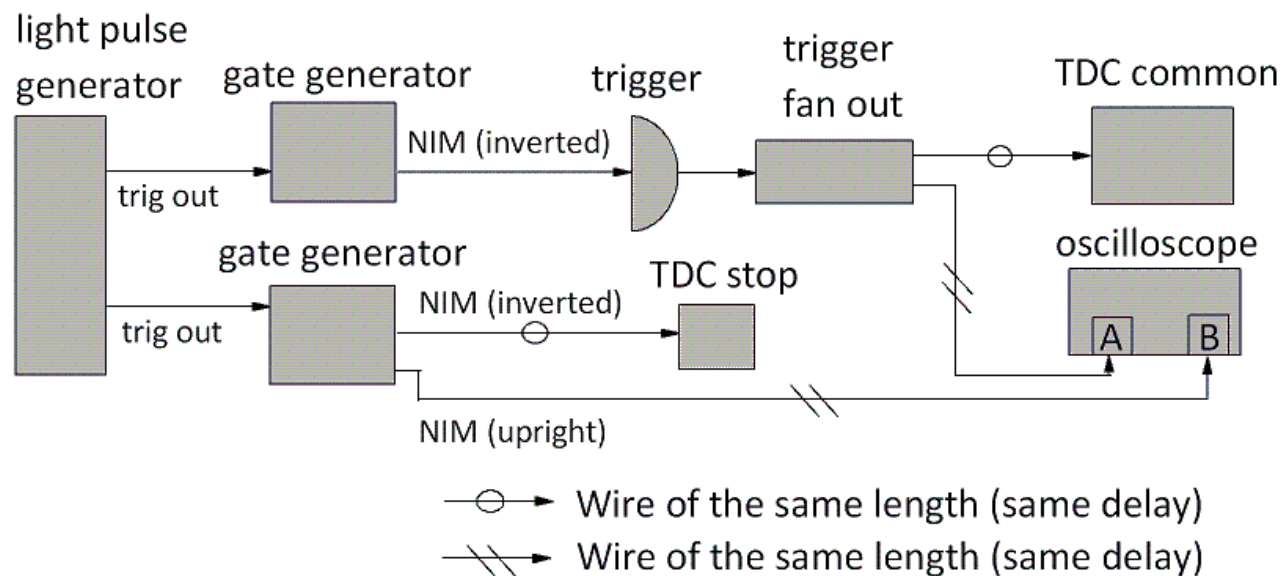
# An Example of Well Organized eLog Record

<http://elog.npl.illinois.edu/ModPhysLabSpring2009/111>

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 width set



2-4:00 pm

Processed data from aluminum run00041.


Talked to Jason about fitting parameters and what plots should look like.

Looked at old elogs to see some examples of plots already made by students. One was found in Spring2008.

4-5:00 pm



# How to record data (3)

- Many experiments require you to “change and measure” something by hand
    - Make a table in a paper logbook for this
    - Double check points periodically to establish reliability
    - Be prepared to state your measurement uncertainty
    - Make a “quick sketch” of your results by hand; then, enter the data in an electronic table and make a final plot
      - Do you have enough points?
      - Do you have any obvious anomalies?
      - You can repeat points but do not throw them out.
-  Use other measurements to check reliability

# How to record data (4)

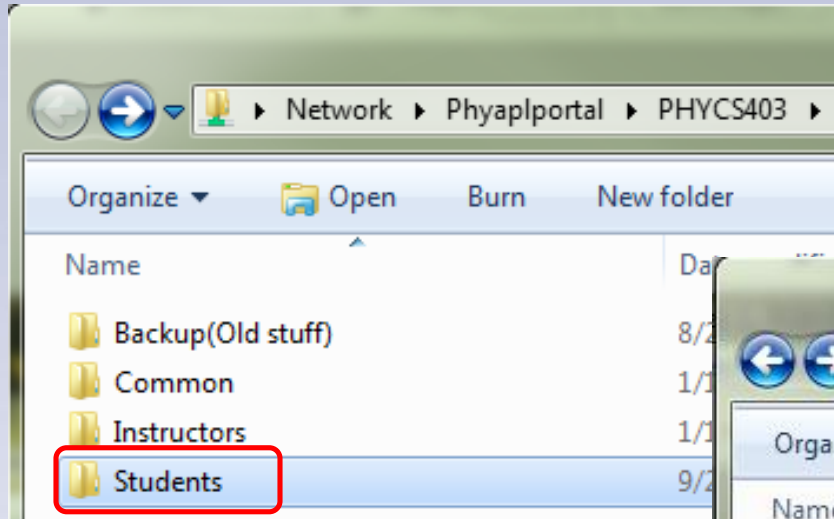
- Many experiments have built-in, computer-based data acquisition (DAQ)
  - You will not have time to fully understand the DAQ, but
- Be sure you know functionally what it is doing – ask
- A good idea is to make test measurements of something you know
  - Because it's “automatic” don't be fooled into thinking it's “correct.” DAQ will provide you with data even if the experiment **goes wrong** and the computer is doing the work.
  - As before, anomalies? enough points? uncertainties?
  - You will often get a **built-in “online” plot of the results**. Don't think that is the end of the game. But, look at the results !



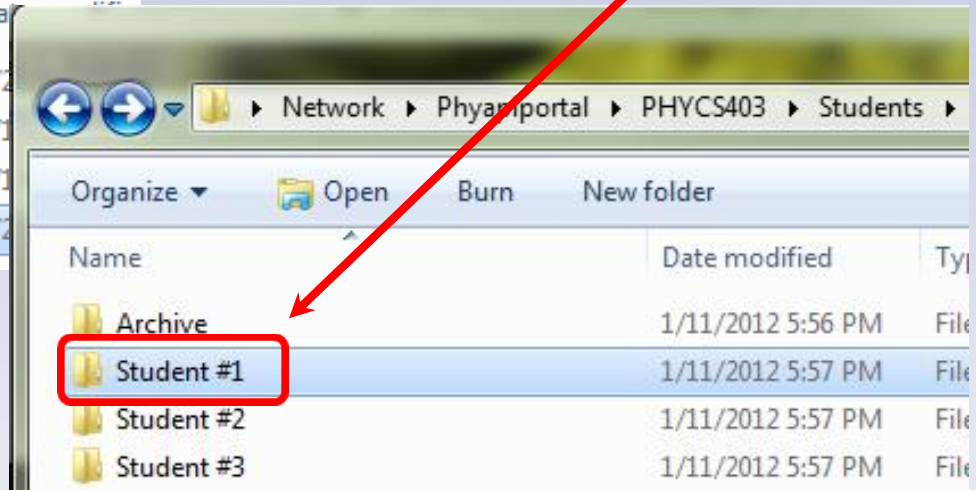
# Where to exchange, store and retrieve course information.

## (i) Your data, projects, tables etc

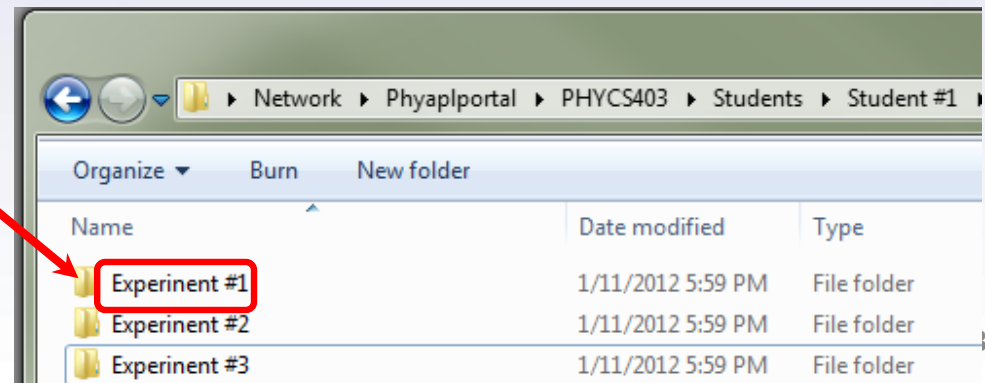
- \\engr-file-03\PHYINST\APL Courses\PHYCS403



**Make your own folder and put your work there**



**Store all experiment related materials in corresponding folder**

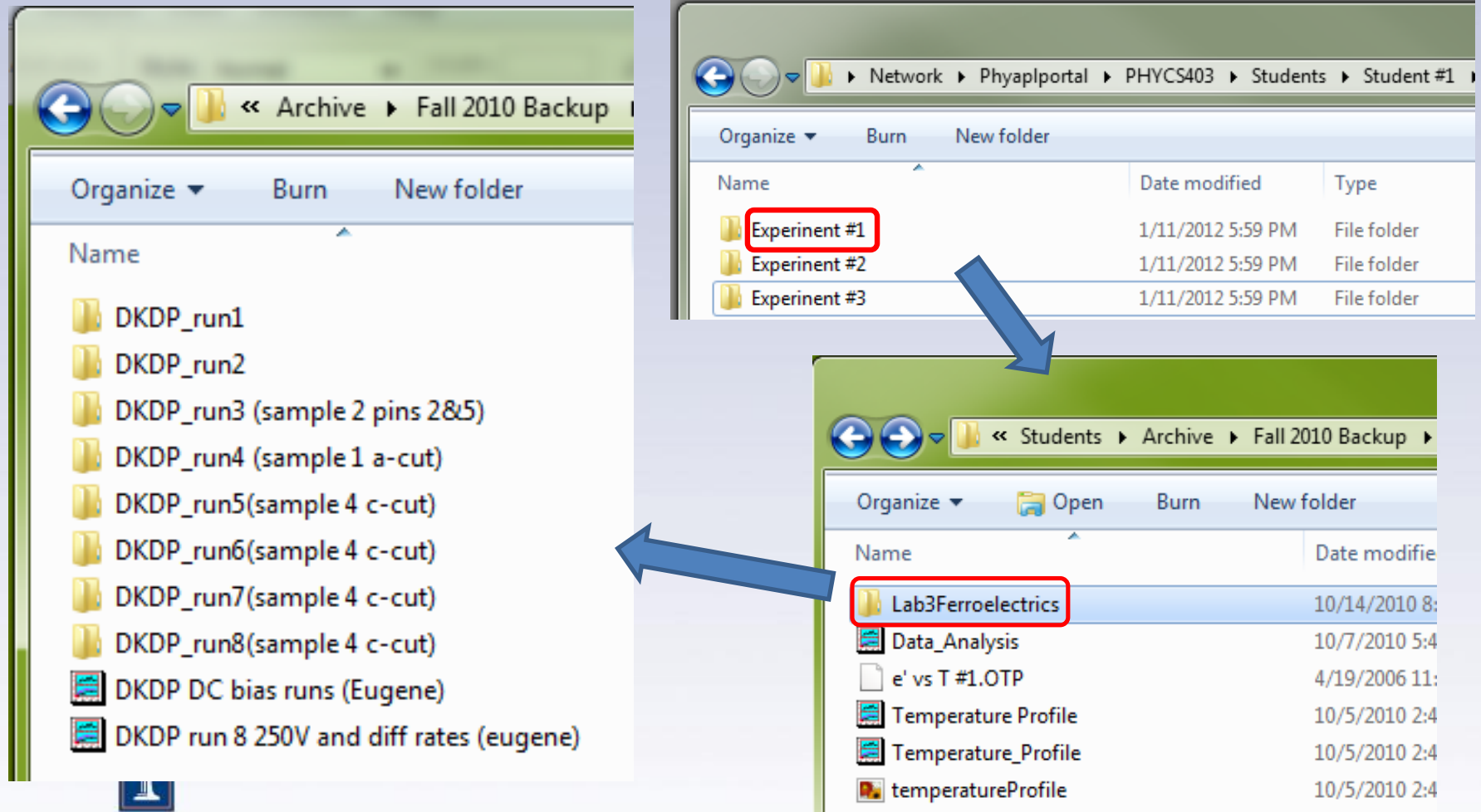


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# Where to exchange, store and retrieve course information.

## *(i) Your data, projects, tables etc*

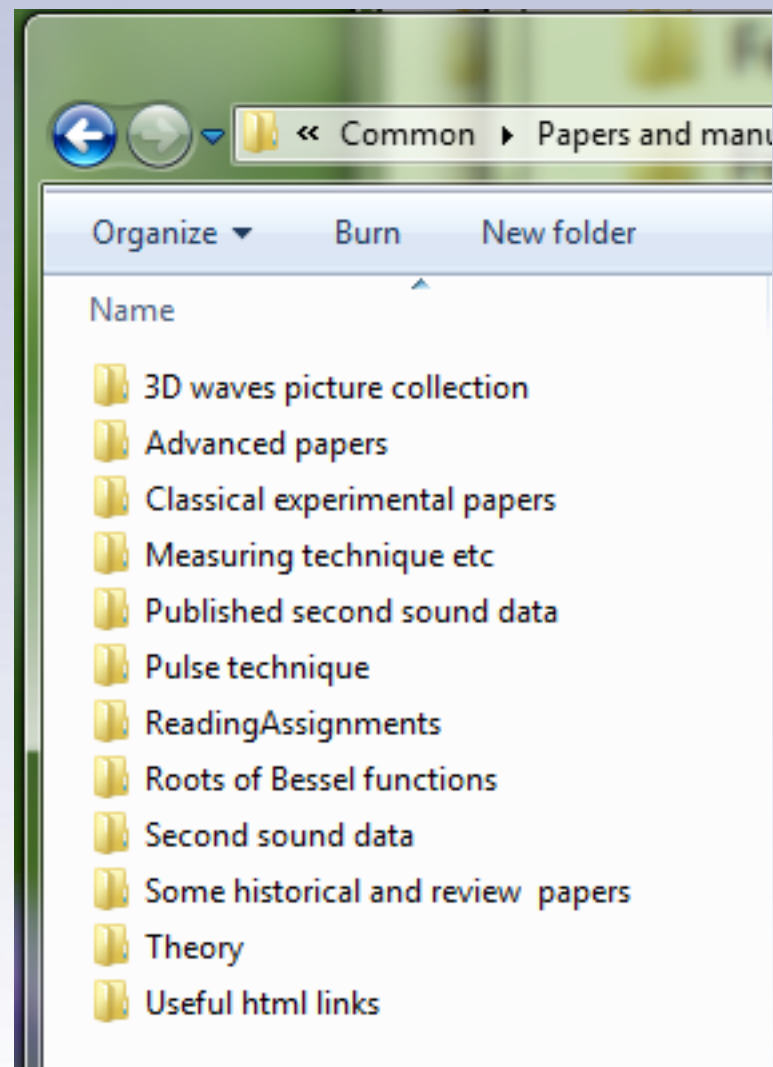
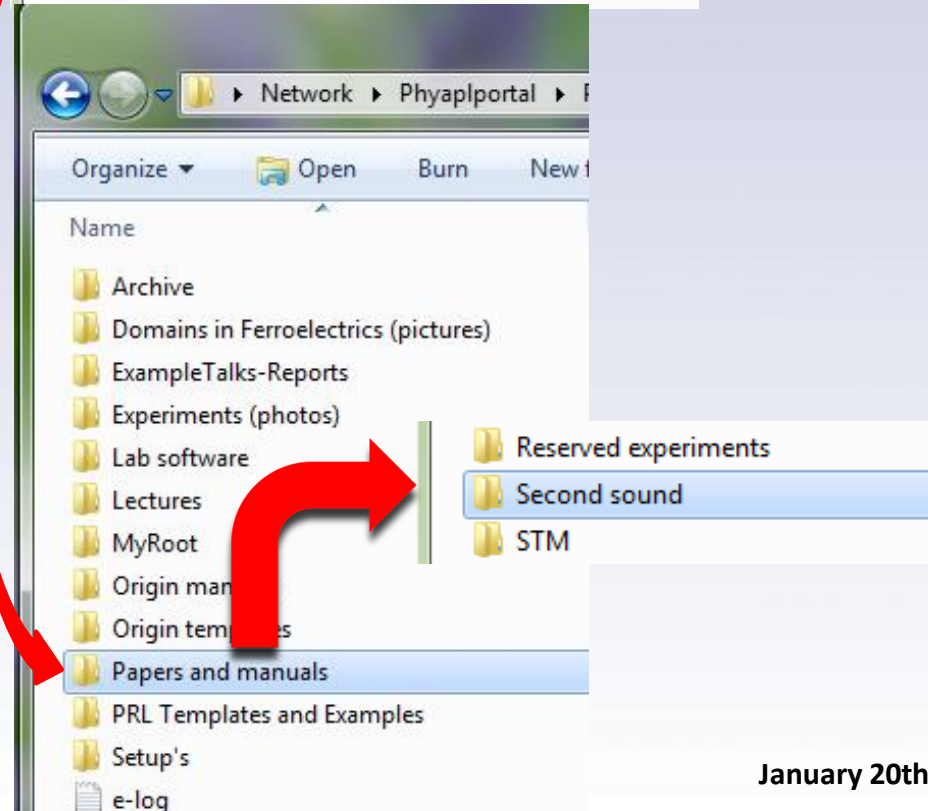
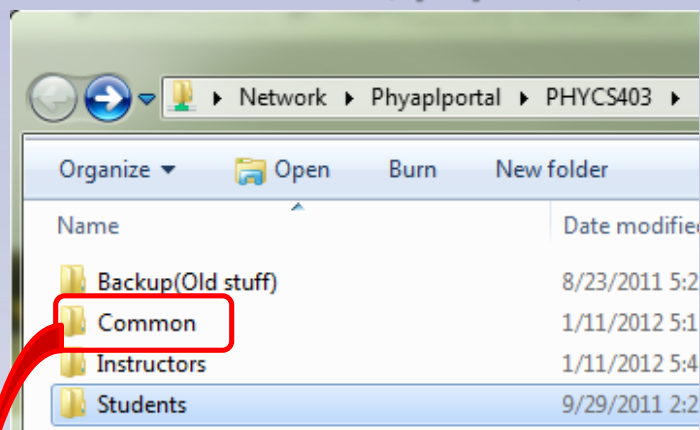
An example of the “smart” structure of folders containing the raw data and data analysis projects





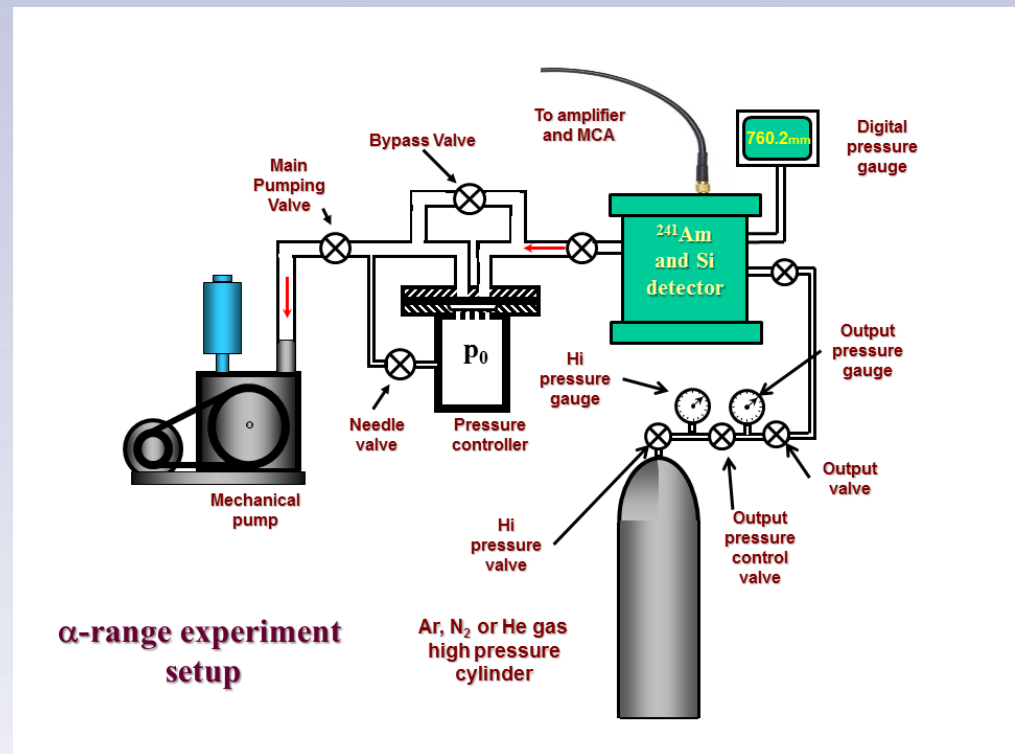
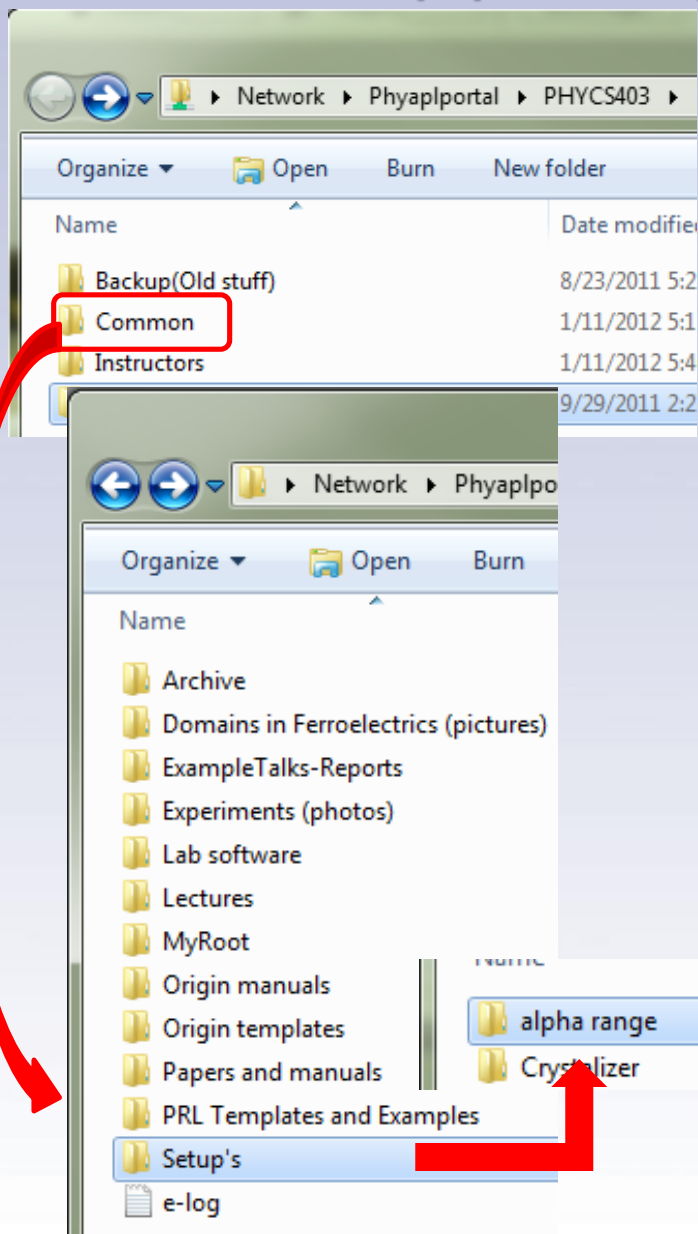
# Where to retrieve course information.

*Manuals, papers*, setup diagrams and other useful materials



# Where to retrieve course information.

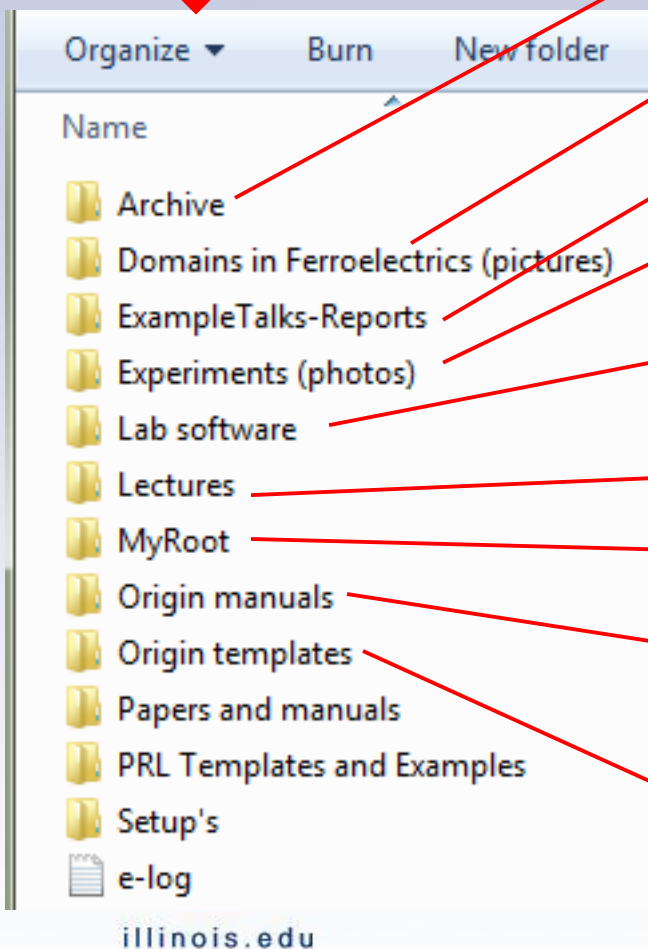
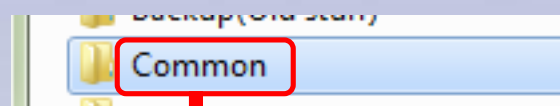
Manuals, papers, *setup diagrams* and other useful materials



α-range experiment setup diagram

# Where to retrieve course information.

Manuals, papers, setup diagrams and *other useful materials*



**Some old stuff (not very useful)**

**Sample pictures of ferroelectric domains**

**Examples of report and oral presentation**

**Pictures of the setups of the experiments**

**Software including DAQ software for different experiments. Newest version of Origin is also there**

**P403 lecture notes**

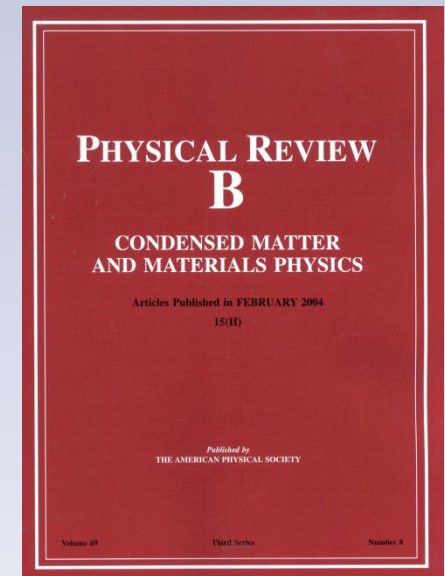
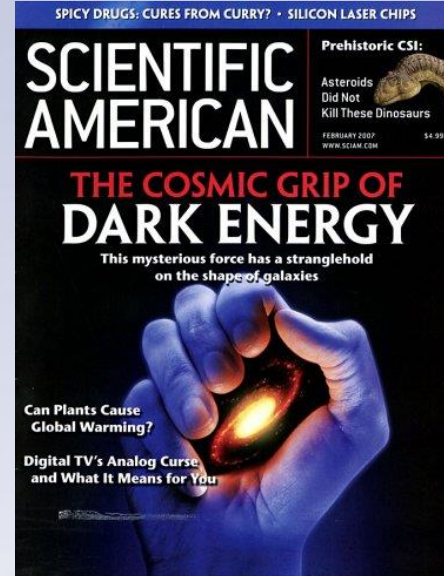
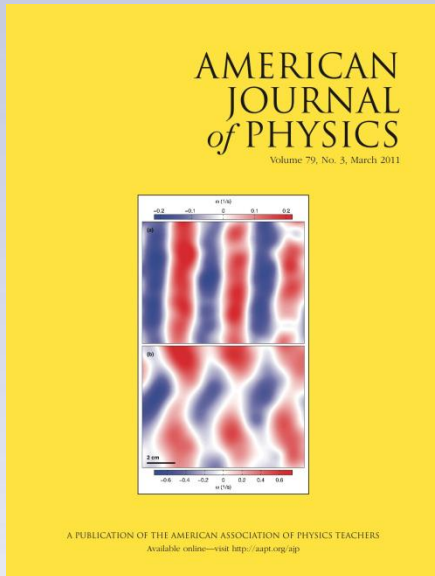
**C++ scripts for Root**

**Origin manuals + a very compressed version written by Eugene**

**Origin templates (how to use them will be discussed in next lecture)**

# “Journal club”

This is a new proposed activity for Physic 403 course  
and it will be presented by Professor **Robert Clegg**



<http://ajp.aapt.org/#mainWithRight>

<http://www.nature.com/nature/index.htm>

<http://www.scientificamerican.com/>

<http://publish.aps.org>  
or <http://prola.aps.org/>



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# e-logs: ... *First A brief tour* ...

<http://elog.npl.illinois.edu/phys403/>

## How to use it

- Pause and summarize your work at natural stopping points in the action. This is useful for particular findings and measurement sequences.
- Along the way, save data, plots, scope shots to a temporary folder on your desktop.
- Near the end of the class, make a “**Shift Summary**” providing a rather complete overview of the highlights of your work. There, you can upload your plots, scope shots, etc. and describe the data



# Entering the e-Log ...

*(at this point, you need to work on a computer)*

## Registering as a new user

- Go to

<http://www.npl.illinois.edu/elog/modphys/Modern+Physics+Laboratory+Fall+2011+Semester/>

- Click "[Register as new user](#)" on the bottom right

- Fill in information for login name, Full Name, e-mail address, and password  
**PASSWORD IS NOT SECURE, DO NOT USE A "SENSITIVE" PASSWORD**

- Click "Save" in the upper left hand corner



# e-logs: About using it ...

- Navigating the E-Log
- The e-log user guide can be found at <http://midas.psi.ch/elog/userguide.html>
- The Main Page
  - The main page shows a summary of the last 100 entries in reverse order (newest at top).
  - ID, Date, Author, Experiment, Post Type, or Subject can be clicked to sort by that category.
  - Full|Summary|Threaded change the way the main page is shown (default is Summary).
  - The menu bar contains several options:
    - New: Create a new post
    - Find: Search for a post
    - Login: Login as a new different user
    - Logout: Logout the current user
    - Help: As simple help page (not very useful)
    - HelpELCode: A help page on using the E-Log code when making posts

# e-logs: Making a post ...

- **Create a New Post**
- **To create a new post, click "New" from the menu bar.**
- **Fill in the Author, Experiment, Post Type, and Subject**
  - **If the post is written by more than one person, use a comma separated list.**
  - **Be sure the Author name is the same you used when registering so that you can edit/delete the post if necessary.**
  - **If you need a new Experiment or Post Type, click the button "Add Experiment" or "Add Post Type".**  
**The large blank area is for the Text portion of the post**



# e-logs: Making a post ...

- Towards the button is the Encoding option.

"ELCode" translates the post using E-Log code, refer here for instructions on it's use.

"plain" makes the post in plain text with no formatting.

"HTML" translates the post according to HTML standards.

- Attachments can be made in the attachment section.

Any file less than 10MB can be attached to the post.

Certain file types such as png, jpeg, gif, and txt will be shown at the bottom of the post.

To display figures in-line, see the ELCode Help Page

When finished click "Submit"

The "Suppress Email notification" box can be unchecked if you

would like the entire class to receive an e-mail informing them that your post has been submitted. In general, leave this box checked.



# Analyzing Data with *ORIGIN* or *ROOT*

- We aim to point you toward two powerful, professional analysis tools:
- **ORIGIN** (commercial; CM, AMO, bio, ...)

## – Motivations

- Very powerful and flexible
- No necessary to have experience with C++
- It's also free for you ; current available version is Origin Pro v. 8.6
- **ROOT** (CERN + users; nuclear, particle physics)

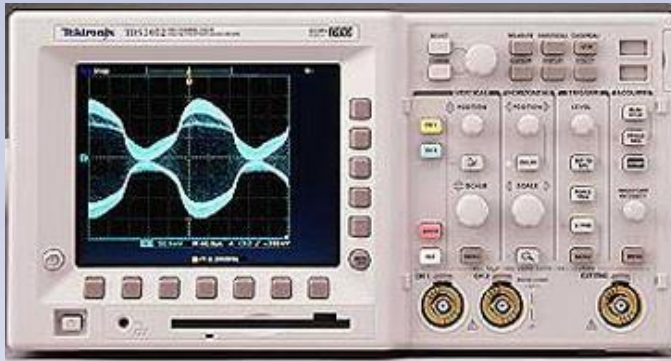
## – Motivations

- Fantastically flexible
- Outputs pub-quality plots in any format
- Relatively easy to do complex tasks, like non-linear least-squares fitting, Monte-Carlo, etc.
- World community of users contributing
- IT'S FREE ! You can download the whole thing to your PC under Linux, Windows, or MAC OS
- We provide a starter kit with a suite of tools
- Lots of tutorials exits

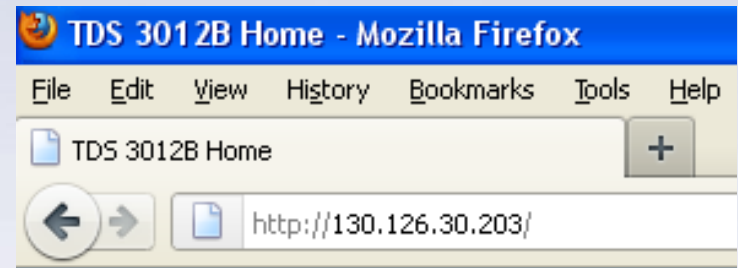
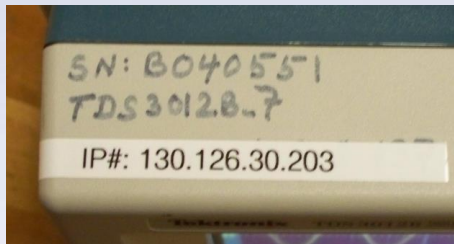




# Digital scopes for data acquisition

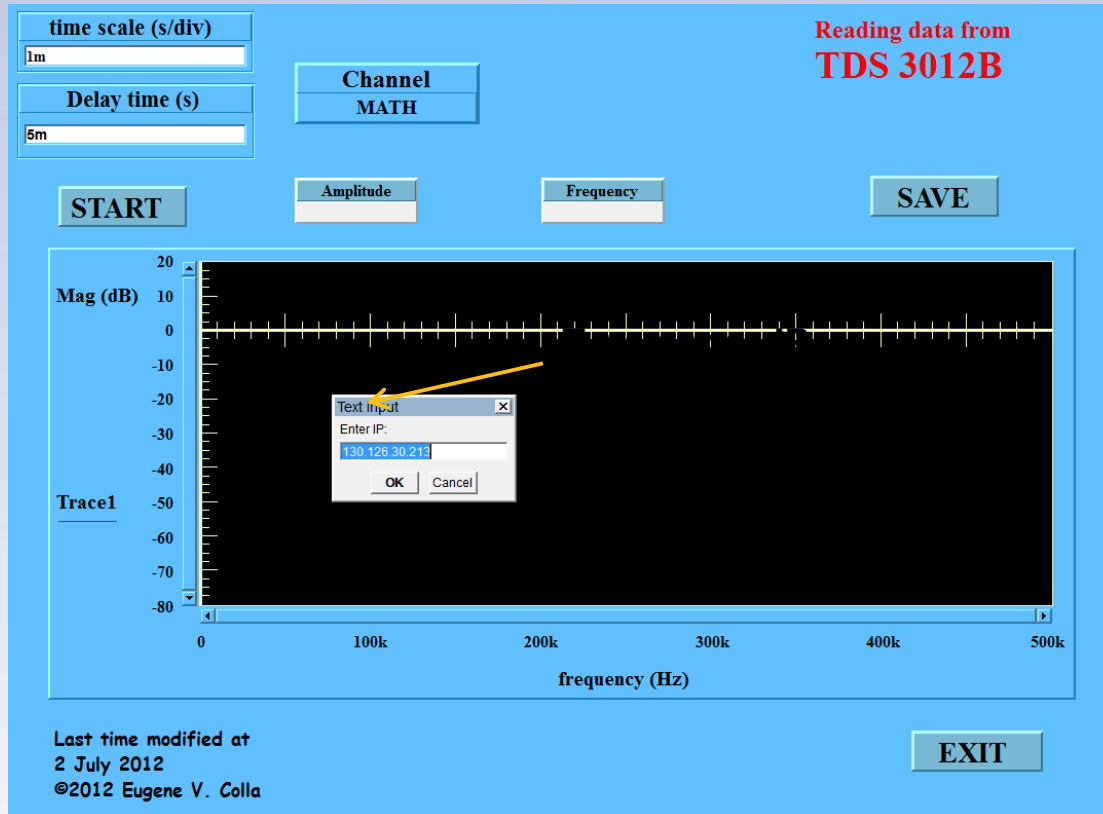


## 1. Using browser and scope IP address



# Digital scopes for data acquisition

\\engr-file-03\PHYINST\APL Courses\PHYS403\Common\Lab software\Tektronix 3012b\TDS3012 datataker#2(delay+IP address+binary).vxe



This program will help you to take data much faster than using Tektronix site.

