Writing Scientific Reports Using LaTeX*

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(Dated: July 22, 2021)

This part, the abstract is an essential part of a scientific paper—often the only component freely viewable from search engines. It should briefly summarize the background, the purpose, the method, and most importantly, the quantitative results with errors. Based on those, a conclusion may be drawn. In this paper, we present a LaTeX template for formal reports in PHY4803L. It is based on the REVTeX document class from the American Physical Society—a standard for the Physical Review journals as well as many others. Your paper should demonstrate your mastery of the entire experiment. It should be neat in appearance with correct English. It should be concise; four single-spaced pages including figures should suffice. Not included in the four-page limit, appendices can be used to present data that is summarized in the main body, for derivations referred to in the main body, and for answers to questions posed in the experimental guides.

1. INTRODUCTION AND THEORY

The introduction typically places the current work in context with prior work and explains what new physics is involved and why the article is worth reading. For your articles, use one or more paragraphs to succinctly explain the motivation, purpose and relevant background to the experiment. This should be done at a level so that another lab student could follow your development.

A full theory section should not normally be needed for our advanced lab experiments. So use the introduction to present the main physics variables and formulas you will use. Trace their origin to the physics involved. Don't provide derivations, but do describe what new assumptions are needed. Formulas involving measurement conversions, instrument settings or other apparatus details should be relegated to the apparatus and experiment section.

Here we will use the introduction to discuss technical writing issues.

One resource for developing into a strong technical writer is the UF Reading and Writing Center[1]. Students can even receive free consultations on their written reports through this office!

An important part of your education as a physicist is learning to use standard tools for sharing your work with others. In Advanced Lab, we will instruct you in the use of LaTeX for writing scientific papers in a widely accepted professional style. Articles submitted for publication in a professional journal must be suitably formatted according to the journal guidelines. Physical Review Letters and many others adhere to the Physics Review Style and Notation Guide. The REVTeXhomepage has additional reference material.

The source files[1] for this document may be used as a template for your Advanced Lab papers. Spending a few hours studying and altering the sample-paper.tex and sample-paper.bib files will allow you to develop sufficient mastery of LaTeX to easily generate all manner of technical documents. Specific instructions for compiling LaTeX documents on Windows operating systems are contained in the appendices.

The writing process involves at least three distinct steps: prewriting or outlining, drafting, and revising or editing. Given the tight time constraints in Advanced Lab, students are advised to begin the drafting process **before** finishing their lab sessions [2]. Most of the first draft can be accomplished during the latter sessions of an experiment.

The essence of expository writing is the communication of understanding through a clear and concise presentation of predominately factual material.[3, 4] Most people cannot compose successful expository prose unless they put the need to communicate foremost among their priorities. Two things predominate in generating understanding in the reader:

Organization: The reader must be provided with an overview or outline, know how each fact fits into that overall picture, and must be specifically alerted about any especially important fact. Furthermore, the facts must be presented in a logical order—so that fact 17 is not important for understanding fact 12.

Depth: Bearing in mind the preexisting knowledge of the reader, the writer must budget the length of discussion allotted to each topic in proportion to its importance.

Writing a journal-like article for the lab report is great practice for improving your technical writing. Thus we

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[1] http://www.phys.ufl.edu/courses/phy4803L/sample-paper.zip

urge you to concentrate on your overall presentation, not only on the facts themselves. We strongly recommend that you:

1. Base your report on an outline.

2. Begin each paragraph with a topic sentence which expresses the main area of concern and the main conclusion of the paragraph. Put less important material later in the paragraph.

Point 2 is frequently absent in novice reports; topic sentences are your mechanism for telling the reader what is under discussion and where it fits into the overall picture. You can check your topic sentences by reading them in order, i.e., omit all the following sentences in each paragraph; this should give a fair synopsis of your paper.

If you are writing up results you obtained with a partner, use we for work performed together and I for work performed alone. Use the past tense for your procedure and analysis, and the present for your results. "LiF xray diffraction angles *were* measured to $\pm 0.2°$ and *are* consistent with an FCC lattice with a spacing $a_0 = (4.035 \pm 0.014)\,\text{nm}$." Note that units are in normal (not math) fonts; the source file shows how to make this happen while inside the LaTeX math mode.

Lastly: Remember to proofread your paper for spelling and grammar mistakes. Few things are as offensive to a reviewer as careless writing and such mistakes will count against you!

2. APPARATUS AND EXPERIMENT

With reference to one or more figures, this section describes the apparatus and procedures that give rise to the raw data. Also discuss the data's random errors and the sources and sizes of possible systematic errors. Include here critical observations of any noteworthy issues associated with the apparatus.

The apparatus figure should contain a block diagram or schematic of the equipment and perhaps include the most important signal processing steps. The figure should be referenced and placed as early as possible in this section.

Place additional information within the figures or in their captions to help you stay within the four page limit. **Example first sentence of an experimental section:** The experimental apparatus consists of a specially prepared chemical sample containing $^{13}\text{CHCl}_3$, an NMR spectrometer, and a control computer, as shown in Fig. 1.

3. ANALYSIS AND RESULTS

This section should demonstrate how the raw data lead to the main results. Make a complete estimate of the uncertainties in your results—both random and systematic.

In some cases, it is proper to put data and analysis in the experiment section, particularly if it is more about
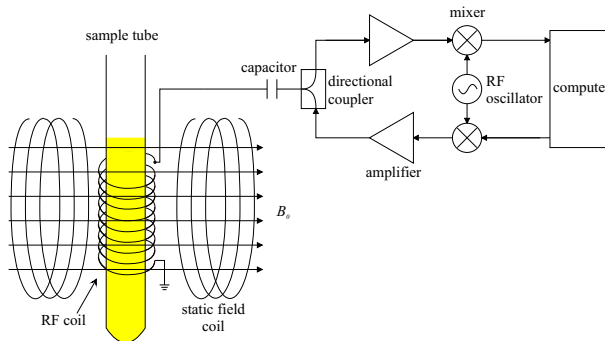

FIG. 1: Figures should be inserted into the text in their natural positions. Command options can be used to crop, scale, or rotate the figure. The size of this graphic was set by the width command. The aspect ratio defaults to 1.0 if the height is not also set. When creating figures, choose large font sizes in graph labels and other figure information; the figure should be legible when scaled to fit in a single column. This part—the caption—should be clear and comprehensible. Use the caption to elaborate on specific issues, features, complications, or operating procedures. Adapted from [5, 6].

the apparatus and its parameters than about the main physics of the experiment. And in some cases, it is proper to describe procedures in this section. When it aids the logical flow of the paper, keep procedures, data, analysis, and results together.

Either here or in the previous section, be sure to display representative raw data. Where there is an abundance of data, consider using an appendix to present it. See, for example, Fig. 5.
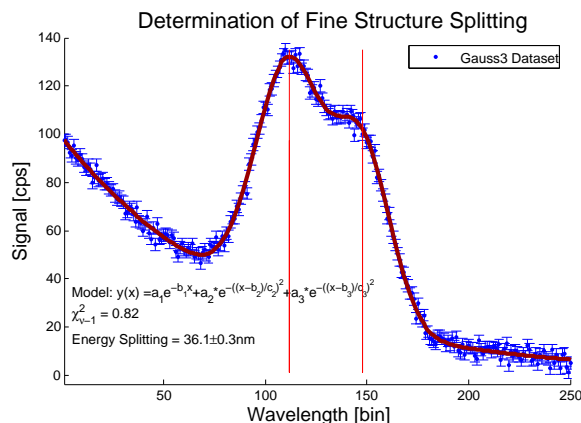

FIG. 2: Sample figure describing a set of data, fit procedures and results. Use the caption space to provide more details about the fitting procedure, results or implications if you do not have sufficient room in the main body of text.

Often the raw data are analyzed in a specific way that needs to be clearly communicated to the reader. For example, the peak positions in a spectrum may be required.
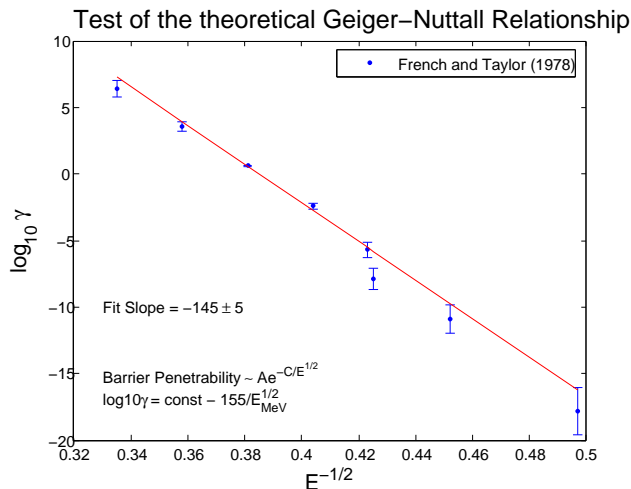
FIG. 3: Sample figure showing overall physical relationship you set out to test.

A graphic demonstrating a typical fit result, functional model, and reduced χ^2 is shown in Fig. 2. Finally, there should be a graph or table which summarizes the experimental data, and which conveys the primary findings of the laboratory exercise. For example, the Geiger-Nuttall relationship as shown in Fig. 3 or Table I containing results of xray spectra analyses.

TABLE I: An example table with footnotes. Note that several entries share the same footnote. Always use a preceding zero in the data you record in tables. **Always display units**. Inspect the LaTeX input for this table to see exactly how it is done.

	r_c (Å)	r_0 (Å)	κr_0		r_c (Å)	r_0 (Å)	κr_0
Cu	0.800	14.10	2.550	Sn[a]	0.680	1.870	3.700
Ag	0.990	15.90	2.710	Pb[a]	0.450	1.930	3.760
Tl	0.480	18.90	3.550				

[a]Here's the first, from Ref. [7].

Additional graphics, such as Figure 2, should be well thought out and crafted to maximize their information content while retaining clarity of expression. Try to avoid the temptation to inundate the reader with too many graphics. It is worth spending some time thinking of how best to present information rather than just creating graph after graph of uninformative data.

4. CONCLUSIONS

Summarize and discuss the findings of the experiment. Report all your results with appropriate significant digits,

units, and uncertainties, e.g., $Q = (2.12 \pm 0.06) \times 10^{10}$ disintegrations s^{-1}. When appropriate, compare your results with theoretical expectations or other experimental values with respect to the standard deviations of the quantities involved. Make suggestions for improvements and describe additional experiments that could be attempted with this or an improved apparatus. Be adventurous with your suggestions.

It is worth mentioning here some thoughts on **ethics and writing in science**.

When you read the report of a physics experiment in a reputable journal (e.g., Physical Review Letters) you can generally assume it represents an honest effort by the authors to describe exactly what they observed. You may doubt the interpretation or the theory they create to explain the results. But at least you trust that if you repeat the manipulations as described, you will get essentially the same experimental results.

Nature is the ultimate enforcer of truth in science. If subsequent work proves a published measurement is wrong by substantially more than the estimated error limits, a reputation shrinks. If fraud is discovered, a career may be ruined. So most professional scientists are very careful about the records they maintain and the results and errors they publish.

In keeping with the spirit of trust in science, Advanced Lab instructors will assume that what you record in your lab book and report in your written and oral presentations is exactly what you have observed.

Using other people's words without acknowledgement is a serious intellectual crime and possible causes for dismissal from the University. The appropriate way to incorporate an idea which you have learned from a textbook or other reference is to study the point until you understand it and then put the text aside and state the idea in your own words. Fabrication or falsification of data and using the results of another person's work without acknowledgement are offenses of similar gravity.

One often sees, in a scientific journal, phrases such as "Following Bevington and Melissinos [5, 7] ..." This means that the author is following the ideas or logic of these authors and not their exact words. If you do choose to quote material, it is not sufficient just to include the original source among the list of references at the end of your paper. If a few sentences or more are imported from another source, that section should be

> indented on both sides or enclosed in quotes, and attribution must be given immediately in the form of a reference note.[5]

If you have any question at all about attribution of sources, please see the course instructor. The University has produced an with additional information about how to avoid plagiarism.
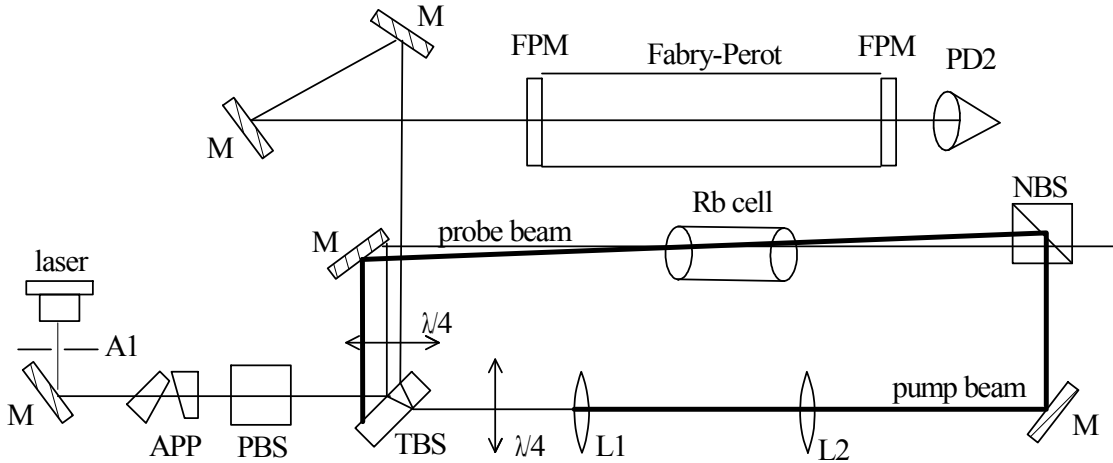
FIG. 4: This is a two-column figure using the `figure*` environment. Two column figures can't be on the first page and LaTeX often has trouble with their placement.

5. BIBLIOGRAPHY REMARKS

Bibliographies are very important in Advanced Lab papers. Beyond the requisite citation of source material, they provide evidence of your literature research beyond the experimental guides. Literature searches, appropriate references to other research, and bibliographies are an integral part of experimental research. Bibliographic entries are made within a separate '.bib' file which gets attached during the process of building a final PDF document. See the bibliography file sample-paper.bib (included in the zip file) for details on several types of bibliographic entries and their required and optional fields.

6. TYPESETTING MATHEMATICS

One of the great powers of LaTeX is it's ability to typeset all manner of mathematical expressions. While it does take a short while to get used to the syntax, it will soon become second nature. Numbered, single-line equations are the most common and are usually referenced in the text; e.g., see Eq. 1.

$$\chi_+(p) \lesssim [2|\mathbf{p}|(|\mathbf{p}| + p_z)]^{-1/2} \begin{pmatrix} |\mathbf{p}| + p_z \\ px + ip_y \end{pmatrix}. \quad (1)$$

Occasionally, long equations which span more than one line of a two-column page may be required. A good solution is to split-up the equation into multiple lines and label all with a single equation number, like in Equation 2. See the LaTeX file to see how this is done.

$$\sum |M_g^{\mathrm{viol}}|^2 = g_S^{2n-4}(Q^2) \ N^{n-2}(N^2 - 1)$$
$$\times \left(\sum_{i<j} \right) \sum_{\mathrm{perm}} \frac{1}{S_{12}} \frac{1}{S_{12}} \sum_\tau c_\tau^f. \quad (2)$$

It is often useful to group related equations to denote their relationship, e.g., in a derivation. Enclosing single-line and multiline equations in `\begin{subequations}` and `\end{subequations}` will produce a set of equations that are "numbered" with letters, as shown in Equations. (3a) and (3b) below:

$$\left\{ abc123456abcdef\alpha\beta\gamma\delta1234556\alpha\beta \frac{1\sum_b^a}{A^2} \right\} \quad (3a)$$

$$\mathcal{M} = ig_Z^2(4E_1E_2)^{1/2}(l_i^2)^{-1}(g_{\sigma_2}^e)^2\chi_{-\sigma_2}(p_2). \quad (3b)$$

Note how you can also create a reference to Eqs. 3, i.e., all subequations, by proper location of the `\label` command that creates the references.

Mathematics can also be placed directly in the text using delimiters: $\vec{\psi_1} = |\psi_1\rangle \equiv c_0|0\rangle + c_1|1\rangle\chi^2 \approx \prod\sum \left[\frac{y_i - f(x_i)}{\sigma_i} \right]^2 |\psi_1\rangle \sim \lim_{\mu\to\infty} p(x;\mu) \geq \frac{1}{\sqrt{2\pi\mu}} e^{-(x-\mu)^2/2\mu} P(x) \ll \int_{-\infty}^x p(x')dx' a \times b \pm c \Rightarrow \nabla\hbar$.

[1] *University of florida reading and writing center*, URL http://www.at.ufl.edu/rwcenter/.

[2] R. DeSerio, *Title of the lab manual/experiment*, http://this.is.the.url.of.the.lab.manual.pdf (20xx, year the manual was last updated), Phy 4802L, Department of

Physics, University of Florida.

[3] J. P. Leslie C. Perelman and E. Barrett, *The Mayfield Handbook of Technical and Scientific Writing* (Mayfield, 1998), URL https://web.mit.edu/21.guide/www/home.htm.

[4] D. Pritchard, *Junior lab written report notes* (1990).

[5] A. Melissinos, *Experiments in Modern Physics* (Academic Press, 1966).

[6] A. Melissinos and J. Napolitano, *Experiments in Modern Physics* (Academic Press, 2003), chap. 5, pp. 179–184, 2nd ed.

[7] P. Bevington and D. Robinson, *Data Reduction and Error Analysis for the Physical Sciences* (McGraw-Hill, 2003).

Appendix A: OVERLEAF LaTeX COMPILER

While you are welcome to create your own local LaTeX installation, it is recommended and much easier to use UF's free Overleaf LaTeX site for preparing your manuscripts. Information on using the site can be found at https://www.overleaf.com/edu/ufl.

Start by creating a new Overleaf project and then create new .tex and .bib files or upload existing ones from your computer, along with any needed figures. You may also upload all files together as a .zip package. Select the main .tex file to edit it and click on the Recompile to compile it into a finished .pdf file. For creating this LaTeX document, upload . This .zip has the following files:

sample-paper.tex   The main LaTeX paper.

sample-paper.bib   The text file where reference information is located.

figure files   The files sample-fig1.pdf through sample-fig5.pdf files are PDF-viewable figures requested in the sample-paper.tex file. They can be created with the PDFCreator printer available on the lab computers.

sample-paper.pdf   This is the PDF file created by the LaTeX compiler.

bare-paper.tex   A nearly bare second main file that can be used as a starting template.

Appendix B: Miscellaneous

The `\bibliography{sample-paper}` command (just before the appendices) generates the bibliography at that point in the document. It invokes the 'bibtex' macro package that reads in the bibliography file 'sample-paper.bib' allowing citation references to be resolved.

All computer output can be saved directly into a PDF format by printing to the doPDF printer driver. For Mac computers you can use the Save As PDF option. If the output is a full 8.5×11 inch PDF page, and you only want an area, it can be cropped when inserted into the LaTeX file. See the source file for the syntax. This has been done on Fig. 4. This figure uses the two-column `figure*` environment for a figure that needs the extra width.
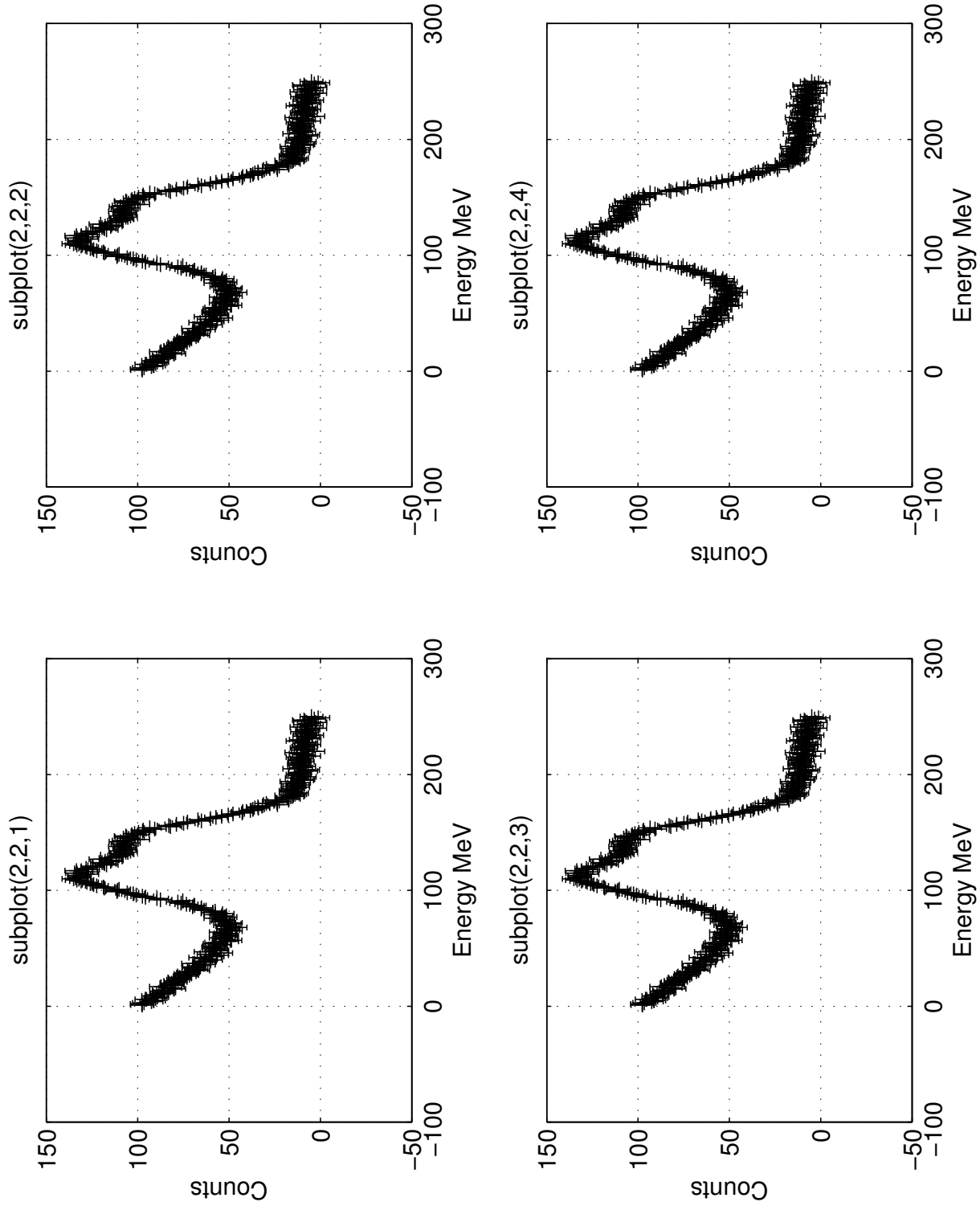
FIG. 5: For very large plots where important detail might be lost if too compressed, it can be convenient to use the 'turnpage' environment for displaying in landscape mode. e.g., any experiment where a data set is acquired at several angular positions (21cm, e/m, Rutherford) or is time varying (Physics of Alpha Decay and Pulsed NMR.) These full page graphics are usually best kept in appendices so as not to impede the flow of the paper. Note that large tables can also be presented in this landscape environment if desired