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Improving the Lecture Format

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Introduction

This project is about improving the lecture format, to improve learning of students during the class. This implies also introducing more activation during the class. Another focus during this project is in improving the final assessment, by ensuring better alignment with the lectures and activities learning goals. I use my block 3 course on experimental nuclear and particle physics for this (see description in practical part, page 211). It is the first time I am officially responsible for the course so this allows me to take some decisions about improvements of the course. To verify how well the goals of this project have been met, at the end of the course the students will be asked their opinion about this more "active" approach to teaching via an anonymous questionnaire. The students' performance at the final exam and my personal impressions on the exam will be used as well.

During this project, the support and advice received during the supervised sessions by the department and educational supervisor have been invaluable, and have improved significantly my teaching methods and my view on teaching. I would like to thank Bob and Jens for this.

Theoretical part

Having responsibility for a course is rewarding and challenging. As one says: "With great power comes great responsibility". Several months before the course starts, the basis of a good work with the course have to be laid down, by writing very clearly what are the Intended Learning Outcomes (ILOs) of the course, and what the specific content of the course (the curriculum) should be. One could say that this project really started when I had to write down the description of the course, and this really drove the whole design of the course (activities, exam, curriculum . . .).

Once the ILOs are clearly formulated, the next step is how to do the teaching, so that the ILOs can be achieved and the students learn what I want them to learn. The success of the last step in the course, the exam, is extremely connected to this second step, and therefore I felt that the exam should also be part of the project.

Although the course comprises both lectures and laboratories (addressing declarative and functioning knowledge respectively), I will devote my effort in this project to the lectures, so development of declarative knowledge. It is mainly declarative knowledge that is tested during the final exam too. Functioning knowledge is mainly assessed during the laboratory exercises itself and during the students presentations of their laboratory exercises results, although some questions regarding functioning knowledge can be asked during the final exam too.

I will start with a review of some theoretical ideas about how teaching can be improved. The main inspiration has been "Teaching for quality learning at university", by J.Biggs and C.Tang, and various literature referenced in it. These ideas have been the guiding lines for the improvements I have tested during my course, as described on page 211 onwards.

Teaching/learning activities for declarative knowledge

In my own words, a student has a good declarative knowledge on a subject when he/she has acquired a deep understanding of a subject, and is therefore able to explain it clearly to others both at a simple level (to non-experts) but also at a deep level (to experts in the field). As an example, in my course about detector devices for elementary particles, a student with good declarative knowledge should be able to explain the basic principles of a detector for elementary particles, but also elaborate on the pros and cons of the design of a particular detector described in a scientific report. This is basically the ILO for declarative knowledge I set for my course.

The situation where the students acquire declarative knowledge is typically denoted with the name "lecture". Most often a lecture is identified with a method of teaching, where students listen and the teacher talks. This is not really optimal for learning. A lecture should instead be seen as a situation where students are learning, using different methods or activities (Biggs and Tang; 2007, pp. 104–134). To improve lectures, the following points are important:

1. Lectures are to be seen as situations in which different teaching / learning activities (TLAs) can be organized, according to the ILOs of the course. This will keep the mind of the students active and engaged in what they are being taught, and therefore help them learn it for good.
2. The focus of a lecture should be on what the students are doing. A teacher should constantly study its class, and according to its size and composition, understand how students are best activated and engaged in the subject, and whether they are learning or not.

The motivation is simple, although apparently difficult to recognize by many (me included): people do not really learn something, unless they have really tried to understand it their-selves first, in an active way (not just listening) and unless they think it is relevant to them (the last point will be taken up again in the next section).

Alternating activities during a lecture, as opposed to long monologue lectures, has also to do with the way we learn. Studies show that effective learning dramatically decreases after 10-15 minutes, and that a rest or change in activity roughly at this time interval will bring the effective learning up to its full power. The long-term retention of concepts covered during a lecture is also dramatically increased if some review happens at the end of the lecture. Various examples of TLAs are suggested in (Biggs and Tang; 2007, pp. 104–134), some of which I have picked up for this project, as described in the practical part (211).

An advantage in small classrooms like the one I describe for my course below, is that they can easily become very interactive, so that the lecture really becomes a conversation. The teacher needs to be ready to answer basically any question, and sometimes improvise if a new point of view is brought up in the discussion. So this type of lecture can be extremely inspirational, and students can learn tremendously, but the teacher needs to prepare for this. The teacher gets also enormous feedback about the students' level of understanding during such interactive lecture. It is also very important for engaging students in learning during a lecture, and actually one of the basic principles of University teaching, that lecturers bring in their own research experience and bring to life the subjects that are being taught by putting them in the context of current research in the field. This adds invaluable content to what the students learn during a lecture.

Assessment

It is a well-known fact that what students decide to learn during a course is largely driven by the knowledge required at the exam. Therefore, if a course has some ILOs, then the best way to ensure that students will achieve those is by focusing the final exam format and content around those, making this clear to the students during the course. This is a very powerfull way of getting them more engaged in learning activities during the lectures. Since ILOs drive the TLAs, of course, then it is clear that the TLAs used during the lectures will help the students learn and prepare for the exam at the same time.

Should one try to assess students' level of knowledge and understanding during the course, before the final exam (when it could be too late)? The answer is yes, absolutely, as long as it is seen as giving/receiving feedback rather than a judgement (Biggs and Tang; 2007, pp. 163–194). It is especially valuable to the teacher, to get feedback about the status of the students' learning and eventually tune the teaching method and the lecture content. In a small class like the one I have, this can be achieved by encouraging questions during the lecture, or going from group to group during problem solving and answering questions.

Another point regarding the exam worth further consideration is how grades are assigned. A method of assessing students which is in line with the course and activities and more fair to the students is the criterion-referenced assessment: students are assessed based on how well they have meet the ILOs specified for the course. This is a relatively new way of looking at exam grading, therefore quite interesting to test. It requires the teacher to ensure alignment between the ILOs, the TLAs in the lectures and the format and content of the final exam, of course, but it is the most fair way to assess students, in my opinion.

The final assessment requires also a good deal of preparation from the teacher point of view, before the exam starts (Biggs and Tang; 2007, pp. 163-216). Three steps should be distinguished: setting the criteria for assessing the student, selecting the evidence that would be relevant to place final assessment, making a judgement about to which extent the criteria have been met. Only by following these three steps the students will be graded in absolute (not relative to each other) and most fairly.

Practical part: Course on experimental particle and nuclear physics

Improving the lecture format

As mentioned in the introduction, this year I decided to work on improving and increasing TLAs during lectures, keeping in mind the ILOs of the course. I have 9 students (1 girl). In addition, sometimes a PhD student (girl) joins the lecture, but she is not registered for the exam. In this section I describe the improvements I tried to introduce, and the results of this, as seen from my point of view. In the final section (page 216), the opinion of the students is reported and compared to what I concluded.

Improvements on lecture layout

The course has a block structure, therefore each week one half day of lectures and one full day, divided in morning lectures and afternoon laboratories. For the project I focus on the lectures. Teaching for several hours can be very tiring both for the students and the teacher, and without any form of feedback of how much students are learning during those hours, and without any activity to challenge their curiosity and make them think about what they are learning, I believe that effective learning will be low during lectures. So for a lecture, I typically prepare for:

1. Breaks after each hour.
2. During each hour there should be at least once an activity (TLA) with the students in the form of questions, problem or exercise. Students are grouped two by two (some prefer to be alone) when they need to discuss and prepare the solution. Attention is paid on how to pair some of the students (after couple of lectures is easier, because one knows the students better)
3. Split the lecture subjects into a few self-contained parts, which fit well within the planned breaks.
4. At the beginning and at the end of the lecture, explain respectively what we are going to learn and what we have learnt, respectively. This will focus more the students, they know why they are learning what I tell them, and the summary at the end helps them cross check if they have understood or not (and eventually ask questions).

5. Point out clearly during the lecture where the material can be looked up. Lectures' slides are always available after the lecture on the course web-side (I do intentionally after the lecture because in the slides there is also the detailed explanation of the solution to the exercises or problems we do in class).
6. Always be ready to interrupt the lecture to answer questions and also to have a brief discussion with the students about a subject. During the lecture, move around and closer to the students, to welcome questions and encourage interaction.

I find that with careful preparation – needed to stay on time and at the same time cover 1.-6. – and a few trials, this organization of the lecture time helps a lot students learning. They are all very attentive, and engaged, and they also feel they are in safe hands, so to say. The class is very interactive, quite different from last year. I also feel, at the end of the class, I know how much the students have learnt, due to the interaction happening in class.

Improvements on activation during the lecture

Concerning the TLA used during the lecture, I have at least one extended activity in the form of a problem or exercise, where students work in groups (2 maximum). This lasts about an hour. During the rest of the lecture, I then use briefer activities in the form of questions (answer by raising hand for yes/no, or direct questions depending on the class mood/subject of the moment). A typical problem will look like the one shown in Appendix B. The problem is presented very briefly at the beginning of a lecture. The students are told that this problem resembles very much what they will have to solve for the exam.

Now they know the goal of what they are going to hear from me in the next hour or so: the tools, concepts, for how to solve then this problem. When the problem is then represented to them later on, they will solve it by using what I just taught them (if additional knowledge is need from previous lectures, then at least the basic formulas are reproduced on the problem sheet, as in page 5 of the example).

Students in the class are quite different, so the questions range from easy to difficult, and there are a few different ones, see problem in Appendix B, page 4: students are first asked to use a formula they just learnt in class to calculate the resolution of the tracking detector. Then they are asked to look at this number, and look at the quantity they need to measure with this detector (?z, shown in page 1 and during the lecture) and argue if this is good or not. Then they are asked to argue more generally about the layout of the detector (this requires putting more than one concept learnt in the lecture together), etc.... I think this helps learning a lot, towards the ILOs of the course, because this puts the "sterile" concepts of resolution, design etc of a detector in the context of the physics goals of the experiment, and makes them understand why they are really important. Also, due to the different levels of questions, all students will be able to answer something, and there is also something challenging for the better students. During this activity, I make sure to go around and check on every group, since solving this type of problem sparks lots of questions, which need to be answered promptly for the students to progress.

When the time to discuss the solution comes, I gather the transparencies with the answers and make sure the groups go each through at least one of their answers. I ask students to present their results using hand-written transparencies. I find this method of solving problems very useful, it puts them in charge of their own results and they theirselves like this. It also helps them learn how to explain their results. I also tend to add some concluding remarks, putting again what we have learnt in the problem in the context of current research, and giving additional relevance to the subject. Then one really sees the students' eyes sparkling...

Another type of problem proposed in class was more visual, see appendix C: students were presented with computer pictures of particle collisions from an experiment at CERN, and were asked to identify the particle types according to the information provided by the picture. Then each student would have a turn to say his/her opinion on one picture at least, and we discussed all together the reply. This problem raised a lot of discussion and questions during the lecture, and made the students during the lecture very very active and engaged.

The introduction of this problem solving activity has been very successful in my opinion, although at start not all students participated with the same level of commitment, but this has changed while we went along with the course. I think they learnt a lot this way. They learnt some of the concepts I wanted them to learn, without me telling them but simply by discussing and arguing on the problem. They also learnt better a concept described only briefly in the lecture by using it in a real problem. They learnt much more that if I had presented the same concepts, with all the answers given already.

Additional improvements

Additionally, I decided to devote two lectures "situations" to two new activities: one day trip to a modern particle physics laboratory (DESY, near Hamburg) and one half day of students' presentations of their lab results on a laboratory experiment of choice.

The trip allows to actualize, to make more concrete and real and hopefully interesting the subject of the course. Modern particle physics detectors are huge, and cannot be brought to the classroom or laboratory. So discussing them in the lectures can result a bit sterile. I believe this trip activity has been very interesting, and useful, to put concepts learnt in class into context of modern research, and all students participating in the course have confirmed this. This really fulfilled one of the purposes of university teaching, to bring current research topics into the lectures (or rather, lectures to the research place).

The presentations are useful for me (and for the students) as formative assessment on the students' level of understanding of the theory behind the laboratory exercise and on the ILO of "explaining" (declarative knowledge), which is an important part of the final exam. During one group's presentation the other students are encouraged to ask questions to them, while we teachers act as moderators and try to intervene as little as possible. The presentation in itself is also useful preparation for the exam, where students are asked to present in 15'-20' answers to the exam questions typically on an experiment's design report or scientific paper. I was amazed by the enthusiasm and the good level of preparation of each group. Peer-students posed lots of questions, and I hardly had to intervene. This activity was, in my opinion, a success.

Improving the final assessment

First of all, the format of the exam: I personally consider that declarative knowledge, involving abilities like "explain", "argue", "analyse", etc. . . is best addressed by an oral exam, with assignment and both students presenting and teacher asking questions. Oral examination is more complex – the teacher receives more inputs of different types, and needs to draw down some clear rules of how to grade what – so it needs more preparation, but is also the best in my opinion. The format is: 15'-20' of presentation of the student, on answers to a problem assigned two working days before, see appendix D. Then, questions from the teachers (me and a couple of colleagues who helped with the teaching and labs). The students have picked a problem among many (each problem is assigned a number, and they pick a number randomly), and to each problem a teacher is assigned, and he/she will then be the one starting with the questions, and only after he/she is done the other co-teachers can ask more. This should diminish confusion and fear for the student (1 against 3) , as we discuss with him/her one by one, and his attention is then focused on one person at a time.

This year I decided to test two important changes:

1. I decided that we should follow the criterium-referenced assessment, and assign grades according to which extent the student has reached the ILOs for the course. After some discussion with the collegues participating in the examining committee, we agreed on what described in Appendix E.
2. To make sure I can fulfill this quite ambitious goal of sticking to the criteria above for grading, I prepare a set of easy, medium and difficult questions on various subjects of the curriculum, so that I have them ready for the different cases. Eg. I have a student oscillating between grade 2 and 4, then I have a few easier questions to ask, to see if the student has at least read and digested to some level the curriculum or not. The difficult questions (some of them open or divergent questions) are e.g. useful in the case one is uncertain between grade 10 and 12 for a student, and wants to see if the student has acquired confidence enough to attempt an original answer.

1. and 2. allow me more easily to assign an absolute grade to the students, and to provide each student with a clear explanation of why they got the grade they got.

I think that this exam format fit quite well the course changes I implemented this year. Maybe students' presentations could be shortened, by preparing problems slightly shorter, since some students indeed went beyond the time assigned. There should always be enough time for questions from the teachers, to collect enough "evidence" to assign the grade fairly to all students. Besides this, the more careful preparation before the exam from my side, and making sure to collect enough information during the exam by asking questions with the focus of understanding how well students have really understood one subject, paid off. I felt I could assign with good confidence grades to the various students. Students scored rather high, with three 12 and three 10 and two students coming for re-exam (so still to be assigned) and one (Erasmus) who decided to return to France earlier than expected.

Unfortunately one professor moved at last moment the exam for his course one day after mine, so some students attending both felt they could not cope with exams so close in time, hence the reexam cases. This range of grades can be expected since this is a last year course, so many good students attend the course. Maybe the grades obtained are high also because students indeed learnt quite a bit during the lectures and were more ready for this type of exam. Students presentations were in general excellent, many students added material self found on the internet, and the format and depth of the explanation of the solutions was very satisfactory. My overall impression was that students acquired declarative knowledge on the subjects covered in the course at the level I had aimed to.

Feedback from the students

So far I focused on what the results of this project are (outcome of improvement of activities and exam), as seen from my point of view. But what about what the students thought of it? To gather some information, I decided to prepare an anonymous questionnaire, asking for feedback on lecture format, teaching activities, and exam preparation. I distribute the questionnaire during the second last lecture, to have also a chance to use the last lecture for additional needed explanations to students. The statistics is low (only 10 students) but some useful information can nonetheless be drawn from the answers (appendix F).

Looking at the Lecture questionnaire, one can see that students clearly believe that the lectures help them in achieving the ILOs of the course and support learning, and have enough opportunity to get feedback during the lecture, for example asking questions. It also seems that the short breaks devoted to discussions two and two are enough. The format of the presentation (with slides) is ok, but students seem to like also a more personalized format by using blackboard, probably because it also slows down the pace of the lecture, so for next year I will try to use more this as well. In general, this result matches the impression I got myself of the students' opinion, during class, so this shows that this structure of lecture was appreciated on average, and it also shows that I got the correct feedback during class.

Looking at the Teaching Activity questionnaire, one can see that students believe both exercises and problems, solved in groups, help them learning, and that the feedback (institutionalization) on the solutions to the problems are clearly covered in class. So the feedback on having this type of activation in class is definitely positive, and matches well again the impression I got during the interaction with the class. It also seems that the type and length of problems and exercises proposed is appropriate, so probably one can continue with this in the next years.

Looking at the Exam questionnaire, and remembering that this questionnaire was filled before the end of the course, one can see that students think that both the lecture slides and the book are important to prepare for the exam, confirming the results on the Lecture questionnaire, that lectures help them learn the ILOs of the course. It also seems like the student might like to do more problems similar to the exam in class (consistent still with the result in the TA questionnaire), and that they like to be able to ask further questions during preparation for the exam (something I encouraged them to do during the last lecture). One important message I got from this questionnaire, and tried to compensate for in the last lecture, is that students are not completely sure what to expect for the exam. I was a bit surprised by this, given how I had introduced some of the problems solved in class. Anyway, I devoted part of the last lecture to remind them that the problems we had in class are very similar to the exam questions, and reassuring them of the important point to focus on (in answer also to the E7 response).

5. Conclusions

The goal with this project is to improve learning during lectures and improve exam format and execution, basically introducing additional activities during the lectures hours and ensuring alignment of the lectures and exam with the ILOs of the course. Taking inspiration from the book by Biggs and Tang (2007), and reflecting on several of the points brought up in chapters 7, 9 and 10, I decided to implement some of the ideas into my course this year.

I believe that the changes I introduced during this course have been welcomed by the students, and have helped them learning and performing well at the exam. This is confirmed both by the exam results but also by the response to the questionnaire distributed towards the end of the course.

A Appendix: Course ILOs and assessment

Master level, Block 3, February-April 2009, 7.5 ECTS

Goals:
The purpose of this course is for the students to learn how subatomic particles are detected in modern physics experiments and how data from a particle detector is analyzed to measure the basic properties of subatomic particles. An introduction to particle accelerators will be given as well.

ILOs:
1. After following this course, the students have a theoretical understanding of how modern detectors for subatomic particles function, all the way from the physical processes in the detector sensors to the final energy and momentum determination of a particle.
2. know the basic principles of how to operate a particle detector and collect the data, using cosmic rays or radioactive samples as sources of particles.
3. know how to simulate data from a particle detector, or how to visualize and analyse experimental data from particle detectors, with the help of computer programs bases on C++ language.

Assessment:
The grade 12 is given to a student who at the exam has shown clear understanding of all theoretical and experimental aspects covered in the course, and in addition has demonstrated the skills listed in the ILOs above during the laboratory and computing exercises.
Students will be provided, a few days before the exam, with a publication about a recently proposed experiment, and a set of questions regarding the publication. The answer to these questions will constitute the basis of a 15 minutes presentation the students will give on the subject, on the day of the exam. The presentation will be followed by questions on the material presented, or more generally on the material presented during the lectures or discussed during the laboratory exercises.

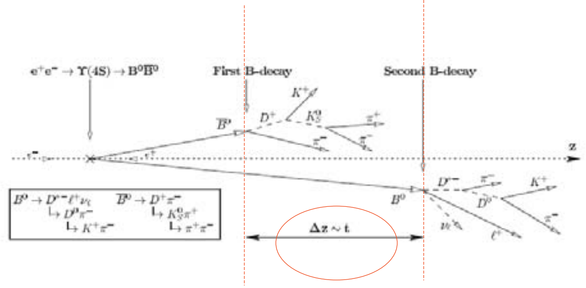
ILO nr 1. is focused on declarative knowledge, nr. 2 and 3 are focused on functioning knowledge. Laboratory sessions and reports are used for nr. 2 and nr. 3, and activity of the students in the laboratory (plus some questions during the exam) are used for assessing functioning knowledge.
The project focuses on nr. 1, and declarative knowledge.

B Appendix: Example of problem to solve in class

On the following pages is an example of a problem to solve in class.

Babar measure the amount of matter transforming into antimatter

Measuring $\Delta z = t$ precisely is very important



B0 can transform into <u>B0</u> along the way (phenomenon called mixing)

$$\frac{N_{B0} - N_{\underline{B0}}}{N_{B0} + N_{\underline{B0}}} \quad != 0 \text{ and depends on time t}$$

Babar goal is also to measure various very rare decays of B mesons
This requires extremely good momentum resolution, to clean up
the signal from background

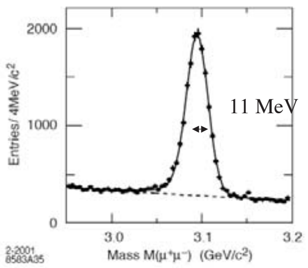
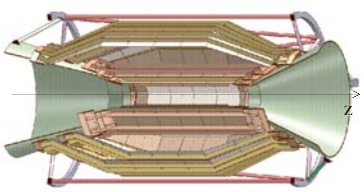


Figure 47. Reconstruction of the decay $J/\psi \to \mu^+\mu^-$ in selected $B\overline{B}$ events.

In decays like
B-> pi pi pi pi
or so, the momentum
of each decay particle
can go down to
~10 MeV
-> momentum resolution
challenge

SILICON VERTEX DETECTOR



Layer/ view	Radius (mm)	R-O pitch (μm)	Floating strips	Strip length (mm)
1 z	32	100	1	40
1 φ	32	50-100	0-1	82
2 z	40	100	1	48
2 φ	40	55-110	0-1	88
3 z	54	100	1	70
3 φ	54	110	1	128
4 z	91-127	210	1	104
4 φ	91-127	100	1	224
5 z	114-144	210	1	104
5 φ	114-144	100	1	265

- Given the pitch, what is the spatial resolution? And the angular resolution (roughly) ?
- Does the resolution fullfil the requirement for measuring precisely the decay distance Δz between the two B mesons?
-to measure Δz=t precisely, should we rely on all layers ?

-Use the answers before to motivate the structure shape and the number and position of layers of silicon detector.

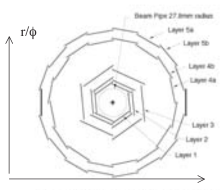
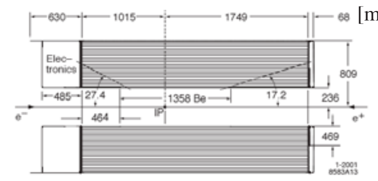


Figure 18. Schematic view of SVT: transverse sec-

DRIFT CHAMBER



re 28. Longitudinal section of the DCH with principal dimensions; the chamber center

40 wires, B= 1.5 Tesla

Parameter	Values
Mixture He : C_4H_{10}	80:20
Radiation Length	807 m
Primary Ions	21.2/cm
Drift Velocity	22 μm/ ns
Lorentz Angle	32°
dE/dx Resolution	6.9%

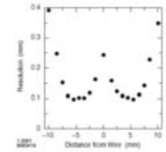


Figure 37. DCH position resolution as a function of the drift distance in layer 18, for tracks on the left and right side of the sense wire. The data are averaged over all cells in the layer.

Remember

P_T (GeV) =0.3 B(Tesla) r (m)

$\sigma_{PT} / P_T = \sigma_x P_T \sqrt{(720*(N+4))} / (B L^2)$

$\sigma_{PT} / P_T |_{ms} = 0.045 / (B \sqrt{(L X_0)})$

Does this geometry fullfill requirement on:

- reconstruct particles with p_T^{min} = 60 MeV? (If not, what other detector can be used for this?)
- providing momentum resolution < 1% for relevant range of B decay products ?

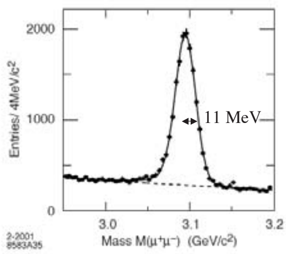


Figure 47. Reconstruction of the decay $J/\psi \to \mu^+\mu^-$ in selected $B\overline{B}$ events.

How do you calculate the mass of J/psi, if what you can measure is the two muons from its decay (assume m_muon=0) ?

How do you calculate the error on the mass of J/psi?

Justify roughly the width of the mass peak observed in fig 47

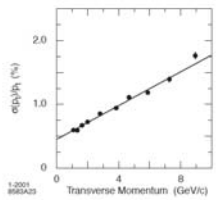


Figure 46. Resolution in the transverse momentum p_t determined from cosmic ray muons traversing the DCH and SVT.

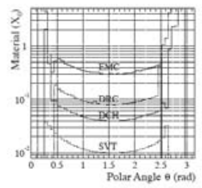
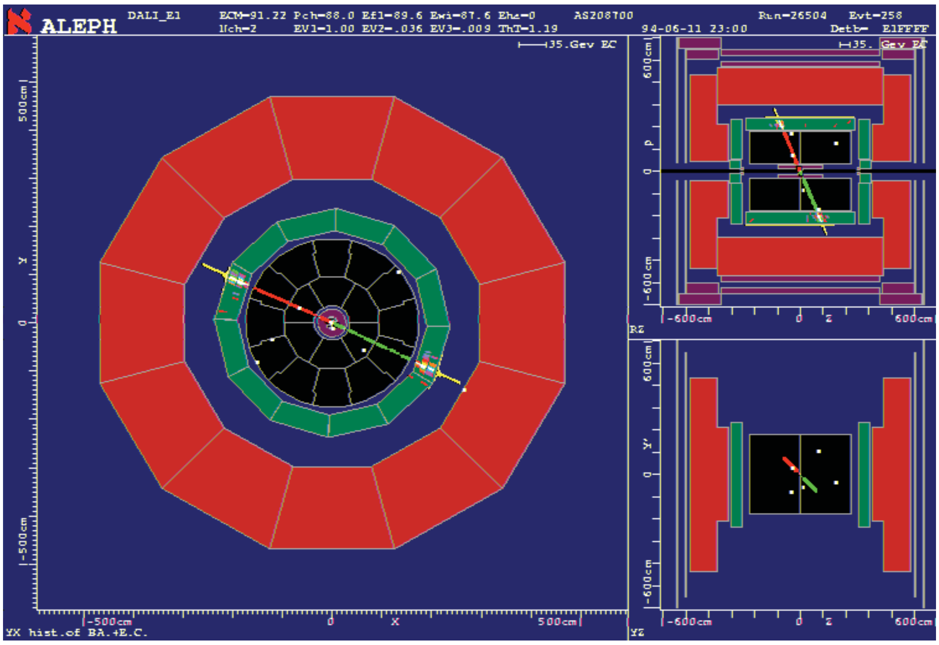


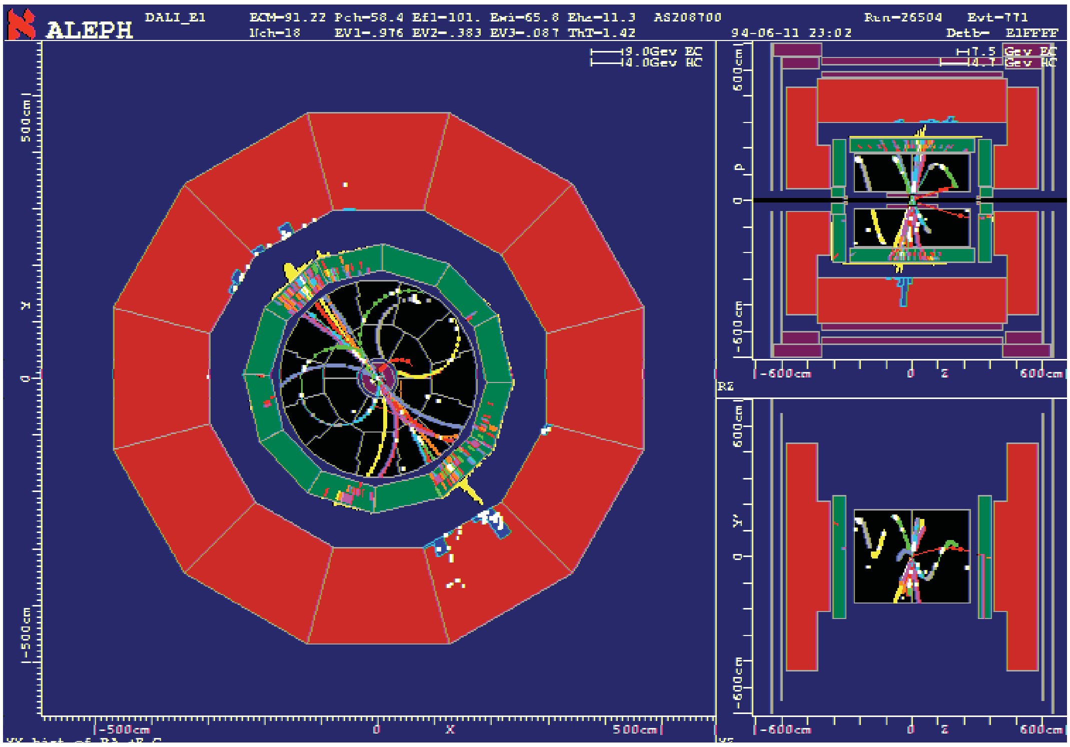
Figure 3. Amount of material (in units of radiation lengths) which a high energy particle, originating from the center of the coordinate system at a polar angle θ, traverses before it reaches the first active element of a specific detector system.

What are the pros and cons of the BaBar tracking detector (silicon plus drift chamber) ?

Any suggestions for improvements?

C Appendix: Example of problem to solve in class





D Appendix: Example of one exam problem

Take-Home exam
Experimental particle and nuclear physics
Question 6

The LHC-B detector

Answer the following in about 20 minutes (use Technical Proposal and Reoptimized TDR reports – please return after exam) :

- Justify the choice of spectrometer layout and detector components of LHC-B, in view of the physics goals of the experiment (see sect. 1,2 of the Technical Proposal)

- Explain why LHC-B has two RICH detectors, what is their purpose and give arguments for the choice of radiator and of location of these detectors in the overall LHC-B layout

- The initial design of LHC-B (as in Technical Proposal) had one fundamental flaw, which lead to a complete review and optimization of the detector (see Reoptimized TDR). Which one?

- Describe the Silicon Vertex Detector in LHC-B. In particular explain what are the main factors driving the decision on : support structures, orientation of strips , pitch size , temperature operation , location with respect to beam line. Finally, explain the behaviour with momentum of the space resolution on the impact parameter of tracks (i.e. the distance of closest approach to the interaction point) , as shown in fig. 7.15, page 46, of the Technical Proposal.

- The $B^0 \rightarrow \psi K^0$ is one of the important decays to be observed at LHC-B, to deepen our understanding of CP violation. ψ decays in either 2 muons or 2 electrons , while K^0 decays into 2 charged pions. So one looks for events containing either $\mu^+\mu^-\pi^+\pi^-$ or $e^+ e^- \pi^+\pi^-$. As you can see in fig.15.8, page 150, of the Technical Proposal, the resolution in the mass reconstructed from $\mu^+\mu^-$ or from $e^+ e^-$ is quite different. Try to motivate the difference, keeping in mind which detector components are relevant for the reconstruction of the two final states.

E Appendix: Description of assessment criteria

Grade 12 : fulfills the ILOs of the course.
For declarative knowledge ILOs, it means

- the student can explain very well the solutions to the problem assigned, and the solutions are all correct.
- The student shows clear understanding and overview of the subject when answering the questions after the presentation. Both general questions to probe all curriculum, and more specific questions on presentation, to see if the student can analyse problem from a new or different point of view, and has really understood what he has presented.
- no hesitations.

Grade 10 : fulfills the ILOs of the course with only minor flaws.
For declarative knowledge ILOs, it means

- the student can explain the solutions to the problem, and the solutions are all correct.
- when asked to analyse the problem from another point of view, hesitates and possibly cannot answer all question, but at least attempts to draw a reasonable answer.
- The student can answer general questions on the curriculum taught.
- Some hesitations

Grade 7 : fulfills the ILOs of the course, but with some flaws.
For declarative knowledge ILOs, it means

- the student is not able to answer all questions in the problem assigned, or not all correctly (maximum 20-30% is lacking). Clearly lacks an overview of the subject.
- when questioned on various parts of the curriculum, can answer some questions with confidence, and some others less confident.
- various hesitations.

Grade 4: fulfills the ILOs of the course with big flaws.
For declarative knowledge ILOs, it means

- the student is not able to answer all questions in the problem assigned, or can answer all but not all correctly (maximum 50% is lacking). Clearly lacks an overview of the subject
- when asked general questions on various parts of the curriculum, can answer only a few questions with confidence.
- many hesitations

Grade 2: barely fulfills the ILOs of the course.
For declarative knowledge ILOs, it means

- the student can answer some questions in the problem assigned correctly, but only a few.
- when asked general questions on the curriculum, answers with very little confidence, but some answers are correct.
- mostly hesitating.

F Appendix: Student evaluation

Answers can be : Series 1 = I agree , Series 2 = I don't know , Series 3 = I disagree

Lecture:

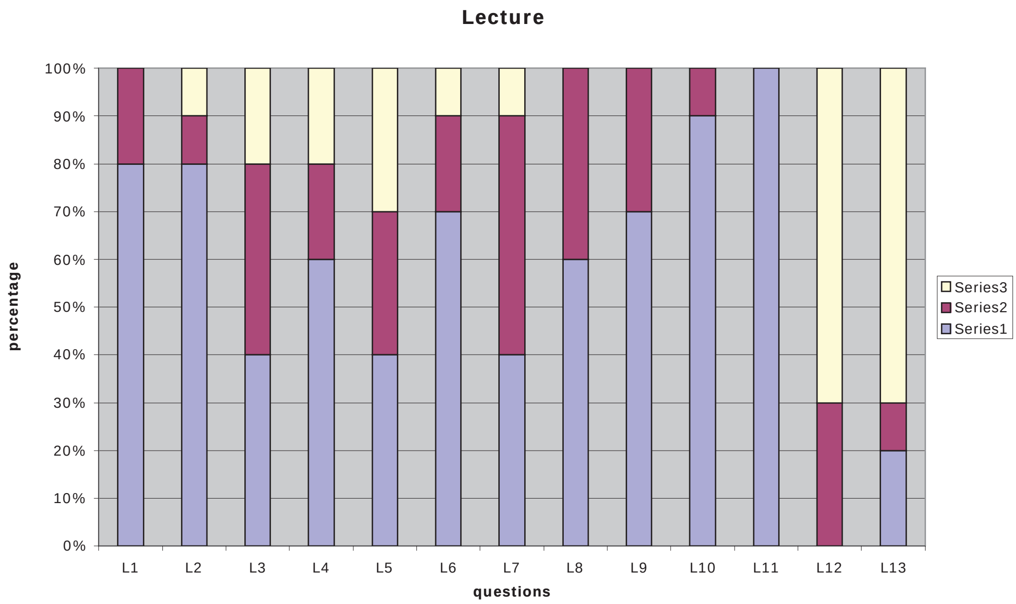
L1: The curriculum of this course is clearly presented in the lecture
L2: The slides support well what the teacher is explaining in the lecture.
L3: The format of the slides makes it easy to follow the lecture.
L4: In the slides, text and figures are well balanced so following the lecture is easy.
L5: I like slide presentation.
L6: I like blackboard presentation
L7: References to book or other material needed for preparation to the exam are clearly indicated in the slides.
L8: Goals of the lecture are clearly presented.
L9: Use of the pointer helps to focus on what is taught during the lecture
L10: The lecture helped me understand better the subjects I am supposed to learn for the exam.
L11: During the lecture, I have enough opportunity to ask questions
L12: During the lecture, I would like more breaks where we can discuss two and two
L13: The teacher speaks too fast

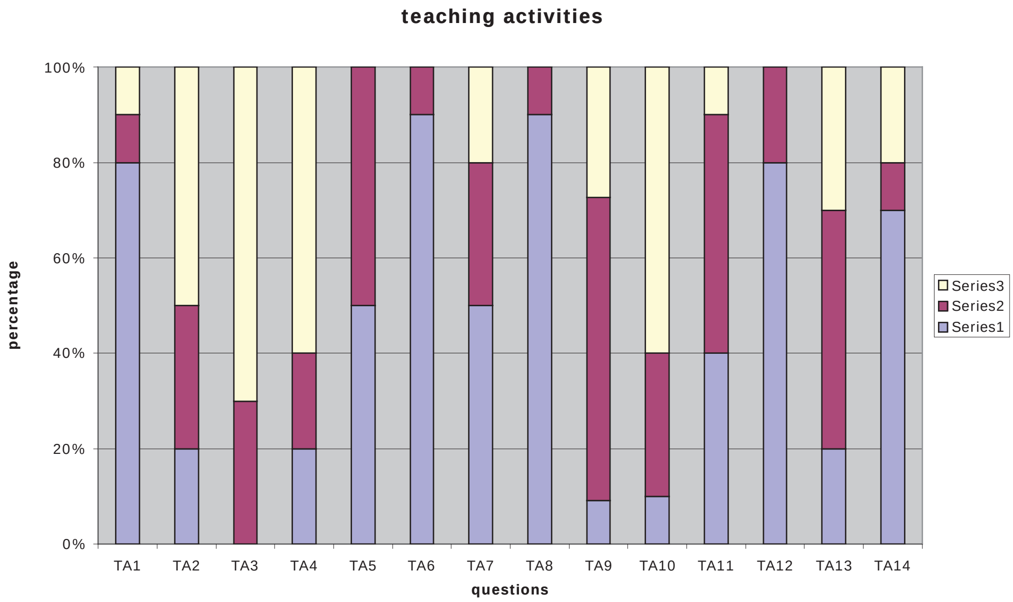
Teaching Activities:

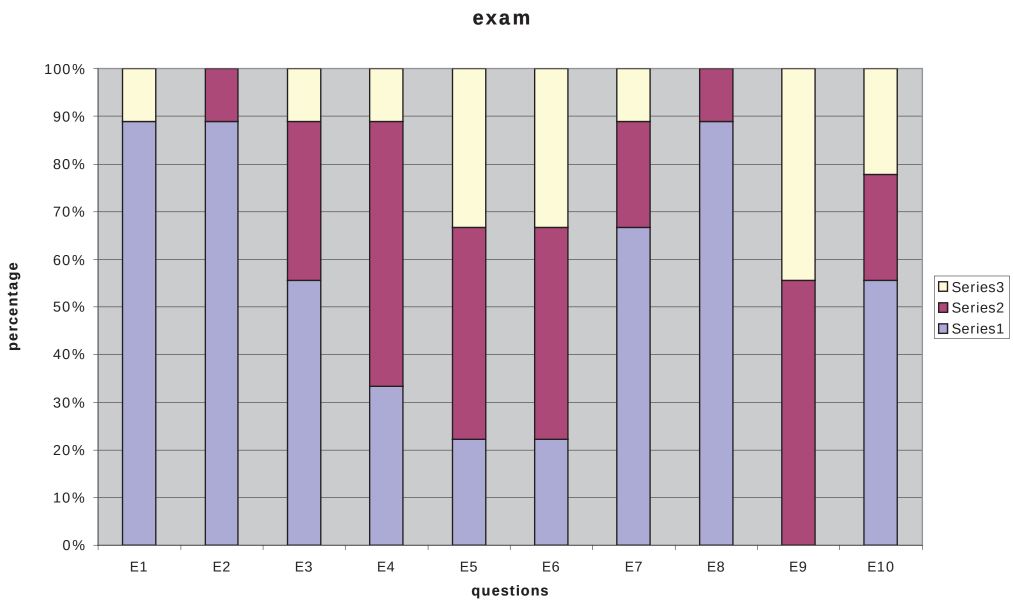
TA1: The exercises (calculations) help me learn better what is taught in the lecture
TA2: I would like more exercises during the lecture
TA3: I would like longer exercises during the lecture
TA4: I would like no exercises during the lecture
TA5: The exercises are clearly formulated.
TA6: The explanation of the exercise's solution is clear and helpfull.
TA7: I like when I am given the opportunity of explaining the solution to the exercise.
TA8: A problem (requires calculation but also some other knowledge gathered during the lecture or in lectures before e.g. BaBar or SuperKamiokande xample) helps me learn better what is taught in the lecture.
TA9: I would like more often problems in the lecture.
TA10: I would not like problems during the lecture.
TA11: The problems are clearly formulated.
TA12: The explanation of the problem's solution is clear.
TA13: It is difficult to solve a problem during the lecture, I need more time
TA14: I like to work in groups on a problem.

Exam:

E1: I use the recommended book to prepare
E2: I use the slides to prepare
E3: I use material online, beyond what suggested, to prepare
E4: I like the book suggested for the course
E5: I wish I was given more material to read, for preparing for the exam
E6: I know what I am expected to know for the exam
E7: I like a part of the last lecture devoted to explain more about the exam requirements
E8: I like the opportunity to come and ask questions to the teachers while I prepare
E9: Two days to prepare for one paper is not enough
E10: I would like to be given more exam-type problems during the course, to train







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