# Kursanalys - KTH[1]

Formulär för kursansvarig.
Kursanalysen utförs under kursens gång.
Nomenklatur: F – föreläsning, Ö – övning, R – räknestuga, L – laboration, S – seminarium)

## KURSDATA Obligatorisk del [2]

| Kursens namn | Kursnummer |
|---|---|
| Teoretisk partikelfysik | SI2400 |
| **Kurspoäng och poäng fördelat på exam-former** | **När kursen genomfördes** |
| 7,5 högskolepoäng (INL1, 4,5 högskolepoäng och TEN1, 3 högskolepoäng) | Läsåret 2018/2019 (period 4) |
| **Kursansvarig och övriga lärare** | **Undervisningstimmar, fördelat på F, Ö, R, L, S** |
| Professor Tommy Ohlsson<br>Dr. Sofiane Boucenna<br>Marcus Pernow | 13 x 2 h föreläsningar<br>7 x 2 h seminarier |

| | |
|---|---|
| **Antal registrerade studenter** | 22 |
| **Prestationsgrad efter 1:a examenstillfället, i %** | 83,6 |
| **Examinationsgrad efter 1:a examenstillfället, i %** | 72,7 |

## MÅL

**Ange övergripande målen för kursen**

Efter fullgjord kurs skall du kunna:
- känna till och beskriva partikelfysikens standardmodell.
- beräkna sönderfallssannolikheter och spridningstvärsnitt med hjälp av relativistisk kinematik.
- använda symmetrier för att begränsa S-matrisens form, t.ex. isospinn, diskreta symmetrier och rumtidssymmetrier.
- redogöra för och beskriva hadronernas statiska egenskaper utifrån kvarkmodellen.
- känna till grunddragen i den elektrosvaga teorin.
- ha kännedom om hur djupt inelastisk spridning påvisar existensen av kvarkar i nukleonerna.
- känna till grundläggande neutrinofysik och beskriva neutrinooscillationer.

**Ange hur kursen är utformad för att uppfylla målen**

Kursen är utformad så att föreläsningar och seminarier samt egna självstudier ska leda till att studenterna kan lösa skriftliga inlämningsuppgifter samt svara på teorifrågor och därmed uppfylla målen för kursen.

## Eventuellt deltagande i länkmöte före kursstart

**Synpunkter från detta**

-

## Kursens pedagogiska utveckling I

**Beskriv de förändringar som gjorts sedan förra kursomgången. (Berätta även för studenterna vid kursstart)**

* De skriftliga hemuppgifterna omorganiserades och förändrades något jämfört med föregående år.
* Examinationen vad avser teorifrågor skedde genom muntliga tentamina istället för närvaro och ”quizzes”.
* Seminarierna utformades mer som övningar.

## Kontakt med studenterna under kursens gång

1 Instruktioner till kursanalysformulär sist i dokumentet
2 Rektors beslut: http://www.kth.se/info/kth-handboken/II/12/1.html

| Studenter i årets kurs-nämnd: | Namn | E-post (lämnas blank vid webbpublicering) |
|---|---|---|

| | |
|---|---|
| **Resultat av formativ mittkursenkät** | - |
| **Resultat av kursmöten** | - |

## Kontakt med övriga lärare under kursens gång

**Kommentarer**

-

## Kursenkät; teknologernas synpunkter Obligatorisk del [3]

**Att komma ihåg:**
1) Uppmana, mha kursnämnden, till ifyllande av kursenkät i anslutning till / just efter slutexaminationen
2) Delge kursnämnden enkäten
3) Publicera enkäten under en kortare tid

| | |
|---|---|
| **Period, då enkäten var aktiv** | 2019-05-21 – 2019-06-07 |
| **Frågor, som adderades till standardfrågorna** | What is your overall impression of the course?<br>How would you rate the difficulty of the course?<br>Has there been much overlap with other courses?<br>How were the homework problems?<br>How were the oral examination?<br>How did you find the quizzes as a form of examination?<br>What is your opinion about the course description and the administration of the course?<br>How was the course literature?<br>How were the lectures? (Sofiane Boucenna)<br>How were the seminars? (Marcus Pernow)<br>Please, enter any further comments and opinions about the course: |
| **Svarsfrekvens** | 50 % |
| **Förändringar sedan förra genomförandet** | - |
| **Helhetsintryck** | Enligt kursenkäten svarade samtliga av studenterna (förutom en) att de var positiva eller mycket positiva med kursen i sin helhet. En övervägande majoritet av studenterna (90 %) ansåg att kursens svårighetsgrad var hög. |
| **Relevanta webb-länkar** | http://courses.theophys.kth.se/cgi-bin/evaluation/results/evaluation_showresults?command=showresults&evaluationid=212 |

## Kursansvarigs tolkning av enkät

| | |
|---|---|
| **Positiva synpunkter** | Samtliga studenter (förutom en) svarade att Sofianes föreläsningar var mycket bra eller bra. En övervägande majoritet av studenterna svarade att Marcus seminarier (övningar) var mycket bra. Se bilaga. |
| **Negativa synpunkter** | Se bilaga. |

[3] Rektors beslut: http://www.kth.se/info/kth-handboken/II/12/1.html

| | |
|---|---|
| **Var kursen relevant i förhållande till kursmålen?** | - |
| **Syn på förkunskaperna** | - |
| **Syn på undervisningsformen** | - |
| **Syn på kurslitt/kursmaterial** | - |
| **Syn på examinationen** | Samtliga studenter svarade att inlämningsuppgifterna var svåra. Angående de muntliga tentamina var studenternas åsikter mer spridda, dvs. de tyckte att de muntliga tentamina var alltifrån lätta till mycket svåra. |
| **Speciellt intressanta kommentarer** | Se bilaga. |

## Synpunkter från övriga lärare efter avslutad kurs

| | |
|---|---|
| **Vad fungerade bra** | - |
| **Vad fungerade mindre bra** | - |
| **Vad fungerade mindre bra** | - |

## Resultat av kursnämndsmöte efter examination

| | |
|---|---|
| **Studenternas sammanfattn.** | - |
| **Förslag till förändringar** | - |
| **Länk till kursnämndsprot.** | - |

## Kursansvarigs sammanfattande berättelse

| | |
|---|---|
| **Helhetsintryck** | Jag är nöjd med utfallet av kursen. Det var ungefär samma antal studenter som följde kursen den här gången som under föregående kursomgång. |
| **Positiva synpunkter** | Se bilaga med resultat av kursenkät. |
| **Negativa synpunkter** | Se bilaga med resultat av kursenkät. |
| **Syn på förkunskaperna** | - |
| **Syn på undervisningsformen** | - |
| **Syn på kurslitt/kursmaterial** | - |
| **Syn på examinationen** | Jag är på det stora hela nöjd med hur examinationen har fungerat och har inga planer på att göra några förändringar tills nästa kursomgång. |

## Kursens pedagogiska utveckling II Obligatorisk del [4]

| | |
|---|---|
| **Hur förändringarna till denna kursomgång fungerade** | Jag tyckte att förändringarna till denna kursomgång fungerade bra. |
| **Förändringar som bör göras inför nästa kursomgång** | Jag tycker inte att det är nödvändigt att införa några större förändringar tills nästa kursomgång. Förändringar i schemat kommer dock att göras tills nästa kursomgång, dvs. placeringen av föreläsningar och övningar ändras. |

## Övrigt

**Kommentarer**

Bilagor:
1. Kurs-PM: SI2400 Theoretical Particle Physics
2. Obligatoriska hemuppgifter [Homework Problems #1-#3 in SI2400 Theoretical Particle Physics, 7.5 credits - Spring 2019, Period 4]
3. Resultat av: Theoretical Particle Physics, SI2400, vt 2019

[4] Rektors beslut: http://www.kth.se/info/kth-handboken/II/12/1.html

**Instruktioner till kursanalysformulär**

1) Kursanalysformuläret fylls i interaktivt; fälten expanderar automatiskt.
2) Fyll i fälten inom en månad efter kursens slut. (Viktigt krav från KTH!)
   Skicka sedan till studierektor (som vidarebefordrar till prefekt och programansvarig).
3) Försök att ge så kompletta uppgifter som möjligt.
   Tänk på att kursanalysen är ett hjälpmedel inte bara för teknologerna, utan även för Dig som lärare.
4) Med ”prestationsgrad” avses antalet presterade poäng hittills på kursen (inlämningsuppgifter, projektuppgifter, laborationer etc.) dividerat med antalet möjliga poäng för de registrerade studenterna. Med ”examinationsgrad” avses antalet studenter av de registrerade, som klarat samtliga kurskrav. Kurssekreteraren hjälper gärna till här.
5) Kontakten med studenterna:

- Etablera kursnämnd under kursens första vecka (minst två studerande, gärna genusbalanserad).
- Lämplig bonus till kursnämndsdeltagarna är fri kurslitteratur.
- Om kursnämnd ej kan etableras, skall sektionens studienämndsordförande (SNO) kontaktas genast (se www.ths.kth.se/utbildning/utbildningsradet.html för kontaktuppgifter).
- Kursnämnden skall sammanträda under kursens gång, exempelvis i halvtid. Har mittkursutvärdering genomförts, skall den diskuteras då.
- Kursnämnden skall även ha ett möte efter det att studenterna har besvarat kursutvärderingen och kursnämndens studenter fått tillgång till resultaten. Undantaget är kurser i period fyra, där mötet bör ske direkt efter examinatioinen är avslutad för att analysen skall vara klar innan sommaren.
- Under det avslutande kursnämndsmötet bör studenterna föra protokoll. Detta protokoll skall kursansvarig få senast en vecka efter mötet.
- Det är kursansvarigs ansvar att kalla till kursnämndsmöten.

**Slutligen, tänk på:**

- det är viktigt att kursanalysen tydligt *visar utvecklingen av kursens kvalitet* från ett läsår till nästa.
- möjligheten att lägga ut kursanalysen på kurshemsidan.
- spara kursanalysen till förberedelsearbetet inför nästa kursomgång.

# SI2400 Theoretical Particle Physics

"Theoretical Particle Physics" will give the students fundamental knowledge about the systematics and reactions of particles within the framework of the so-called Standard Model.

**Credits:** 7.5 **Level:** 2 **Grading:** A, B, C, D, E, Fx, F

**Time:** Period 4 (Lectures 26h and seminars 14h, which will be given in English.)

**Lecturer:**
Dr. Sofiane Boucenna
E-mail: boucenna@kth.se

**Examiner:**
Prof. Tommy Ohlsson
Telephone: 08-7908261 E-mail: see bottom of page

**Seminar teacher:**
Marcus Pernow
E-mail: pernow@kth.se

## Aim

After completion of the course you should be able to:

- know and describe the standard model of particle physics.
- compute decay rates and cross-sections with help of relativistic kinematics.
- use symmetries to restrict the form of the S-matrix, for example, isospin, discrete symmetries, and spacetime symmetries.
- give an account of and describe the static properties of the hadrons from the quark model.
- know the basic principles of the electroweak theory.
- have knowledge about how deep inelastic scattering shows the existence of quarks in the nucleons.
- know about basic neutrino physics and describe neutrino oscillations.

## Syllabus

Introductory survey. Conservation laws. Basic reaction theory. Feynman diagrams. Lorentz invariance. One particle states. Binary reactions. Determination of mass. Scattering theory (the S-matrix, decay rate, scattering cross-section). Symmetries. Time-reversal. Space-reflection. Charge conjugation. Determination of spin and parity of particles. Isospin. Strangeness. The quark model. Color. Hadron spectroscopy. Quarkonium. Electroweak interaction of quarks. The Higgs mechanism. Deep inelastic scattering. Neutrino physics. Neutrino oscillations.

## Prerequisites

The following courses are mandatory:

- Special Relativity Theory

- Advanced Quantum Mechanics

The following course is recommended:

- Relativistic Quantum Physics

# Program

- Program of lectures and seminars.

# Requirements

Hand in assignments (INL1; 4.5 hp) and a theory exam (TEN1; 3 hp).

## Examination

The examination of the course will be a combination of homework problems and a theory exam. There will be three mandatory sets of homework problems during the course. These will be distributed and should be handed in according to the following scheme:

| Homework problems | Out | In |
|---|---|---|
| Set #1 | Lecture 5 (March 28, 2019) | April 11, 2019 |
| Set #2 | Lecture 9 (April 11, 2019) | April 29, 2019 |
| Set #3 | Lecture 13 (May 8, 2019) | May 22, 2019 |

The theory exams (read: oral exams) will take place after or around the last lecture of the course. Each exam will take approximately 20 minutes. The time for the exam will be agreed upon between the student and the lecturer, but the student is obliged to take contact with the lecturer.

## Grading

The different grades are: A, B, C, D, E, Fx, and F. The grades will be awarded according to the following scheme:

### Homework problems (INL1)

| Grade | Homework problems |
|---|---|
| F | < 40% of all problems correct |
| E | ≥ 40% of all problems correct |
| D | ≥ 60% of all problems correct |
| C | ≥ 70% of all problems correct |
| B | ≥ 80% of all problems correct |
| A | ≥ 90% of all problems correct |

In addition, you need to obtain at least 40 % on each homework problem set in order to obtain a passing grade (E or higher). If you obtain a total result of more than 40 %, but do not fulfill this criterion, you will be given the grade Fx and a chance to make a completing task for the grade E.

### Theory exam (TEN1)

The theory exams are graded P (pass) or F (fail).

**Final grade**

When you have passed both parts of the course (INL1 and TEN1), you will obtain a final grade. The final grade will be the same as your grade on the homework problems (INL1).
For PhD students, the different grades are: P (pass) and F (fail).

# Required reading

There is a course book:

- D. Griffiths, *Introduction to Elementary Particles*, Wiley (2008)

Other books that can be used:

- W.N. Cottingham and D.A. Greenwood, *An Introduction to the Standard Model of Particle Physics*, 2nd ed., Cambridge (2007)
- F. Halzen and A.D. Martin, *Quarks and Leptons*, Wiley (1984)
- Q. Ho-Kim and X.-Y. Pham, *Elementary Particles and Their Interactions - Concepts and Phenomena*, Springer (1998)
- A. Seiden, *Particle Physics - A Comprehensive Introduction*, Addison-Wesley (2005)
- H. Snellman, *Elementary Particle Physics*, KTH (2004)
- M. Thomson, *Modern Particle Physics*, Cambridge (2013)

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Senast uppdaterad: 2019-02-19
Sidansvarig:
*Tommy Ohlsson <tohlsson@kth.se>*

# SI2400 Theoretical Particle Physics

## Program of the lectures

[In the *literature* description, 'G' refers to suggested chapters from D. Griffiths' "Introduction to elementary particle physics" and 'T' refers to suggested chapters from M. Thomson's "Modern Particle Physics". Supplementary material on the internet could be referred to during the course.]

- **Lecture 1:** General Introduction.
  *Literature:* G1-3; T1-2
- **Lecture 2:** Decays and cross-sections.
  *Literature:* G6; T2
- **Lecture 3:** Introduction to QED.
  *Literature:* G7; T5
- **Lecture 4:** electron-electron annihilation.
  *Literature:* G7; T6
- **Lecture 5:** electron-proton scatterings.
  *Literature:* G8; T7-8
- **Lecture 6:** The quark model.
  *Literature:* G9; T8-9
- **Lecture 7:** Weak interactions I.
  *Literature:* G10; T11
- **Lecture 8:** Weak interactions II.
  *Literature:* G10; T12
- **Lecture 9:** Electroweak unification.
  *Literature:* G10; T15
- **Lecture 10:** The Higgs mechanism.
  *Literature:* G11; T17
- **Lecture 11:** The Standard Model.
  *Literature:* G11; T16
- **Lecture 12:** Beyond the Standard Model: neutrino masses.
  *Literature:* T13
- **Lecture 13:** Beyond the Standard Model: open questions.

## Program of the seminars

The seminars (7 x 2h) will consist of discussions between the students and the seminar teacher.

## Literature

Suggested references:

- D. Griffiths, *Introduction to Elementary Particles*, Wiley (2008)
- M. Thomson, *Modern Particle Physics*, Cambridge (2013)

Additional references:

- F. Halzen and A.D. Martin, *Quarks and Leptons*, Wiley (1984)
- W.N. Cottingham and D.A. Greenwood, *An Introduction to the Standard Model of Particle*

*Physics*, 2nd ed., Cambridge (2007)
- Q. Ho-Kim and X.-Y. Pham, *Elementary Particles and Their Interactions - Concepts and Phenomena*, Springer (1998)
- A. Seiden, *Particle Physics - A Comprehensive Introduction*, Addison-Wesley (2005)
- H. Snellman, *Elementary Particle Physics*, KTH (2004)

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Senast uppdaterad: 2019-02-20
Sidansvarig:
*Tommy Ohlsson <tohlsson@kth.se>*


Theoretical Physics

# Homework Problems #1
## SI2400 Theoretical Particle Physics, 7.5 credits
## Spring 2019

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**Deadline:** April 11, 2019 @ 17:00
**Teachers:** Dr. Sofiane Boucenna (`boucenna@kth.se`)
Marcus Pernow (`pernow@kth.se`)
**Examiner:** Prof. Tommy Ohlsson (`tohlsson@kth.se`)

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1. Basics: Natural Units, Relativistic kinematics, and Conservation laws:

   - (1 pt) The decay width of the Higgs boson in natural units is $\Gamma_H \approx 6$ MeV. What is the corresponding lifetime in S.I. units? Compare with the lifetime of the muon.
   - (1 pt) Can a photon decay to two muons in vacuum? Explain your reasoning.
   - (2 pts) Calculate the amplitude for the u-channel of the process $H_1, H_1 \to H_2, H_2$ (via $S$) in the scalar theory.
   - (2 pts) Draw the lowest order Feynman diagrams involving $\tau$ in QED.
   - (2 pts) Show that for the decay $a \to 1, 2$ the momenta of either 1 and 2 in the centre-of-mass frame are

$$p_{1,2} = \frac{1}{2m_a}\sqrt{(m_a^2 - (m_1 + m_2)^2)(m_a^2 - (m_1 - m_2)^2)} \tag{1}$$

2. QED:

- (2 pts) Show that the photon propagator is the origin of the $1/\sin^4(\frac{\theta}{2})$ dependence of the Rutherford cross section for $ep \to ep$ scattering (consider QED with the additional vertex: $p\bar{p}\gamma$, where $\bar{p}$ is the anti-proton. Assume that the proton is elementary.)
- (2 pts) Can you easily obtain the cross-section of the process $e^+e^- \to e^+e^-$ from the result of $e^+e^- \to \mu^+\mu^-$ ? If yes: give the result, if no: why not?
- Consider scattering of electrons with $\pi^\pm$ pions (note that pions are spin-0 particles, and ignore their substructure.)
  - (2 pts) Consider the process of electron–pion scattering: $e^+\pi^- \to e^+\pi^-$. Draw its leading order Feynman diagram(s) and write down the expression for the amplitude $\mathcal{M}$ using the Feynman rules.
  - (2 pts) Perform the "averaging over initial spins and sum over final spins" to compute $\langle|\mathcal{M}|^2\rangle$.
  - (2 pts) Determine the differential cross-section $\frac{d\sigma}{d\Omega}$ for this process in the pion rest-frame.

Theoretical Physics

# Homework Problems #2
## SI2400 Theoretical Particle Physics, 7.5 credits
## Spring 2019

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**Deadline:** April 29, 2019 @ 17:00
**Teachers:** Dr. Sofiane Boucenna (`boucenna@kth.se`)
Marcus Pernow (`pernow@kth.se`)
**Examiner:** Prof. Tommy Ohlsson (`tohlsson@kth.se`)


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1.
- (2 pts) Calculate the cross-section of the process $u_R d_R \to u_R d_R$ in the $s$-channel considering only the weak interactions.
- (2 pts) Explain why the $\tau$ lepton branching ratios are observed to be approximately:
  $\mathrm{BR}(\tau^- \to e^- \nu_\tau \overline{\nu_e})$: $\mathrm{BR}(\tau^- \to \mu^- \nu_\tau \overline{\nu_\mu})$: $\mathrm{BR}(\tau^- \to \nu_\tau + \text{hadrons}) \approx 1 : 1 : 3$.
- (2 pts) In the textbook (Griffiths) the ratio of pion decay rates $\Gamma(\pi^- \to e^- \, \overline{\nu}_e)/\Gamma(\pi^- \to \mu^- \, \overline{\nu}_\mu)$ is shown to be suppressed because of parity violation in weak interactions. What would change if you consider the weak interaction to be vectorial?

2. $Z$ decays:

   Consider the decays of the $Z$ boson in the electroweak theory.

   - (2 pts) Draw the relevant diagram and calculate the partial decay width of the $Z$ boson into a generic pair of fermions (at tree-level). Assume the $Z$ boson is much heavier than any of the fermions.
   - (3 pts) Calculate the total decay rate of the $Z$ into electrically charged particles (experimentally visible in colliders). Use $M_Z = 92$ GeV and $\sin^2\theta_W = 0.23$.
   - (2 pts) Use the value of the total decay width reported by the Particle Data Group (`pdg.lbl.gov`) to calculate the number of neutrinos in the Standard Model.
   - (3 pts) We now consider a hypothetical extension of the Standard Model with one additional generation of leptons with masses much smaller than the $Z$ boson mass. What can you say about this model? What if they are heavier than the $Z$ boson?
   - (2 pts) Repeat the previous part if instead the additional fermions are neutral under all the symmetries of the Standard Model.


Theoretical Physics

# Homework Problems #3
## SI2400 Theoretical Particle Physics, 7.5 credits
## Spring 2019

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**Deadline:** May 22, 2019 @ 17:00
**Teachers:** Dr. Sofiane Boucenna (`boucenna@kth.se`)
Marcus Pernow (`pernow@kth.se`)
**Examiner:** Prof. Tommy Ohlsson (`tohlsson@kth.se`)

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[Use the Particle Data Booklet whenever necessary to get the experimental values of relevant parameters. State clearly what value you used in the calculation.]

1. A neutrino detector is positioned at a distance $L$ from a neutrino source (e.g. nuclear reactor) of mean energy $E = 3$ MeV.

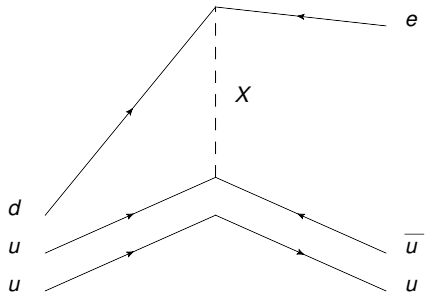
   - (2 pts) Assuming the oscillation involves the second and third neutrino mass eigenstates, at what $L$ would the oscillation probability reach its first maximum?
   - (3 pts) At $L = 1$ km, the experimentalists found that $P_{ee} \equiv P(\nu_e \to \nu_e) = 1.01 \pm 0.04$. Show that $P_{ee} \approx 1 - \sin^2 2\theta_{13} \sin^2 \Delta_{23}$, with $\Delta_{23} \equiv \Delta m^2_{23} L/(4E)$. (hint: neglect what is negligible.)
   - (2 pts) In the limit of large splitting between the second and third mass eigenstates (i.e., $|\Delta m^2_{23}| \gg E/L$) in the previous question, simplify $P_{ee}$ and obtain an expression for $\sin^2 \theta_{13}$ as a function of $P_{ee}$. Show that $\sin^2 \theta_{13} \propto (\Delta m^2_{23})^{-2}$ in the opposite limit, $|\Delta m^2_{23}| \ll E/L$.

2.
- (2 pts) What are the possible decays of the Higgs boson in the Standard Model (limit the answer to 2 body decays)?
- (3 pts) Show that the decay rate of the Higgs boson to two charged fermions is

$$\Gamma_{H\to f\bar{f}} = N_c \frac{G_F}{\sqrt{2}} \frac{M_f^2 M_H}{4\pi} \left(1 - 4\frac{M_f^2}{M_H^2}\right)^{3/2} ,$$

  where $G_F$ is Fermi's constant, $M_{f,H}$ is the mass of the fermion and Higgs, and $N_c$ the number of color degrees.
- (2 pts) *Estimate* the total decay width of the Higgs. What are its 3 largest branching ratios?

3. Leptoquarks are hypothetical bosons that can couple quarks to leptons, arising in various Beyond Standard Model scenarios. Consider a model in which the proton decays as $p \to e^+\pi^0$, a process that is mediated by the leptoquark $X$ as shown in the diagram.




- (2 pts) Using dimensional analysis, estimate the decay rate of the proton in terms of the leptoquark mass $M_X$ and coupling $g_X$. (The actual decay rate also involves a numerical factor involving powers of $(2\pi)$, etc. You may assume this factor to be around $10^{-3}$.)
- (2 pts) The Super-Kamiokande detector in Japan is looking for proton decay in a tank containing 50 kilotons of water. Over the last 20 years, no such process has been observed. Use this information to put a constraint on $M_X$ and $g_X$. Plot your result in the $M_X$-$g_X$ plane.



# Resultat av: Theoretical Particle Physics, SI2400, vt 2019

Status: Avslutad
Publicerad under: 2019-05-21 - 2019-06-07
Antal svar: 11
Procent av kursdeltagarna som svarat: 50%
Kontaktperson: Tommy Ohlsson

## What is your overall impression of the course?

11 svarande

| | | |
|---|---|---|
| Very positive | 6 | 54% |
| Postive | 4 | 36% |
| Negative | 1 | 9% |
| Very negative | 0 | 0% |

*- Good lecturer and good seminars! (Very positive)*
*- It was a really good introductory course to theoretical particle physics, very interesting. (Very positive)*

## How would you rate the difficulty of the course?

11 svarande

| | | |
|---|---|---|
| Very high | 0 | 0% |
| High | 10 | 90% |
| Low | 1 | 9% |
| Very low | 0 | 0% |

*- Difficult subject. (High)*
*- I'd rather say correct (High)*
*- It was easy to follow, but difficult to think about. The difficulty was*

*adequate, in my opinion (High)*
*- I would say medium/normal difficulty. (Low)*

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## Has there been much overlap with other courses?

11 svarande

| | | |
|---|---|---|
| Far too much overlap | 1 | 9% |
| Some overlap, but it was useful to go over the topics again | 8 | 72% |
| Mostly unnecessary overlap | 1 | 9% |
| No overlap | 1 | 9% |

*- Most of the topics had already been covered. (Far too much overlap)*
*- Just enough to make the bridge between what we already knew and what we were learning (Mostly unnecessary overlap)*

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## How were the homework problems?

11 svarande

| | | |
|---|---|---|
| Very difficult | 0 | 0% |
| Difficult | 11 | 100% |
| Easy | 0 | 0% |
| Very easy | 0 | 0% |

*- Interesting, required some research (Difficult)*
*- Often not clear what was expected in the question. (Difficult)*
*- Probably the worst part of the course. The way the questions were formulated were too ambiguous, and the fact that the teachers said nothing about it didn't help. Sometimes we really were not looking for help in doing the problems, just a clearer way of saying the question, on many of them we just couldn't understand what was being asked (Difficult)*

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## How was the oral examination?

11 svarande

| | | |
|---|---|---|
| Very difficult | 2 | 18% |
| Difficult | 5 | 45% |
| Easy | 4 | 36% |
| Very easy | 0 | 0% |

*- Difficult but ok. (Difficult)*

*- Reflective of the topics covered in the lectures. (Easy)*
*- I studied for it and felt prepared, so it was easy for me. It is a good way of checking if you actually knew what you were doing or if you just copied the homework from someone else. (Easy)*

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## What is your opinion about the course description and the administration of the course?

11 svarande

| | | |
|---|---|---|
| Very good | 2 | 18% |
| Good | 6 | 54% |
| Poor | 2 | 18% |
| Very poor | 1 | 9% |

*- The website felt like it had been written by someone other than the people teaching the course, although this was barely a problem. Why not just use Canvas? (Poor)*

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## How was the course literature?

10 svarande

| | | |
|---|---|---|
| Very good | 2 | 20% |
| Good | 5 | 50% |
| Poor | 3 | 30% |
| Very poor | 0 | 0% |

*- Griffiths was outdated. I mostly used the Thomson book. (?)*
*- enjoyed the spontaneous style and historical perspective (Very good)*
*- Good, but it would have been easier to have one book and follow it's notations. (Good)*
*- The course literature felt outdated, and it often lacked simple formulas required to solve the homework problems, which were very difficult to find elsewhere (the spin-0 vertex on the first hw, the spin-1 completeness relation on the second homework). Also, Griffiths rundown on the types of particles is weaved into a history lesson which he himself says can be skipped or skimmed, which set me back a little at the beginning of the course. Overall, the book solid/average (Poor)*

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## How were the lectures (Sofiane Boucenna)?

11 svarande

| | | |
|---|---|---|
| Very good | 6 | 54% |

| | | |
|---|---|---|
| Good | 4 | 36% |
| Poor | 0 | 0% |
| Very poor | 1 | 9% |

*- Some of the best lectures I've attended. Sofiane was very enthusiastic about the topic, and did a really good job at conveying that enthusiasm. The lectures were all very interesting and clear, it was an incredibly inspiring way to learn about the topic (Very good)*
*- Excellent lectures! (Very good)*
*- Good, but sometimes we did not have time to go through everything in the lecture plan. (Good)*
*- However, there was a lot of focus on explaining the basic ideas, which we already knew from previous courses. (Good)*
*- Good but at most times it was hard to keep up and I wold prefer that the lectures would follow the book a little bit more. (Good)*

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## How were the seminars (Marcus Pernow)?

11 svarande

| | | |
|---|---|---|
| Very good | 9 | 81% |
| Good | 2 | 18% |
| Poor | 0 | 0% |
| Very poor | 0 | 0% |

*- Marcus was always open for questions and never dodged the difficult ones, even when it wasn't obvious. He was incredibly helpful, especially when it came to understanding mathematical details that were overlooked in the lectures. He explained things in a very clear way. If anything, I feel we didn't interact as much as we could with him, which is our loss (Very good)*

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## Please, enter any further comments on the course below.

*- The grading of the second homework seemed incredibly harsh compared to the first one. It came as a gut-shot to many of us whom thought our solution style would be sufficient to receive a high grade after the first homework. It is not that the grading was strict I am complaining about, it is that the grading apparently became much stricter after one was lulled into a false sense of confidence.*
*- Encourage the students to work more in groups in for example the seminars.*
*- A great course, but as the major energy has to be put on solving problems it becomes hard to at the same time take the time to think about the material to learn as much as possible and to be ready for the oral exam.*

*- want to thank both of your cooperation through the course. I think that my knowledge on Fundamental Physics expecially in understanding the intricasies of the nature of the Particles and theie interactions has broadened with this course and certainly with much more mathematical foundation added to it. I enjoyed the course thoroughly even though I had to miss few lecture as it overlapped with other 2 courses that I took this period. Please continue doing the same in the coming semesters as well. All the best.*

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Avbryt | Exportera data till annat program

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