Hauptseminar WS14/15 15. Oktober 2015

Particle Physics and the Early Universe

1 Introduction to particle physics and cosmology

1.1 Experimental pillars of the Standard Model of particle physics

Idea: what do we know about the elementary constituents of the Standard Model and their interactions. Do not try to give a complete history of discoveries, rather focus on a few. As the Higgs-Boson is subject of a later talk, just mention it, but put focus on other constituents.

general textbook:

D.H. Perkins, Introduction to High Energy Physics

charm quark:

Nobel prize lectures:
B. Richter, From the psi to charm: The experiments of 1975 and 1976, Rev. Mod. Phys. 49, 251-266 (1977)
S. C.C. Ting, The discovery of the J particle: A personal recollection Rev. Mod. Phys. 49, 235-249 (1977)

commented original papers:
R.N. Cahn and G. Goldhaber, The Experimental Foundations of Particle Physics; Cambridge University Press, 1989

top Quark:

Allgemeinverständliche Darstellungen:
W.Hollik, Th.Müller, Das Top-Quark: sein Nachweis durch Theorie und Experiment, Physikalische Blätter 53 (1997), Nr.2;
T.M. Liss, P.L. Tipton, Der Nachweis des top-Quarks, Spektrum der Wissenschaft, 12/1997

review article:
P. C. Bhat, H. Prosper and S. S. Snyder, Top quark physics at the Tevatron, Int. J. Mod. Phys. A **13** (1998) 5113 [arXiv:hep-ex/9809011]

first experimental observation top:
Observation of top quark production in anti-p p collisions. By CDF Collaboration (F. Abe et al.). FERMILAB-PUB-95-022-E, CDF-PUB-TOP-PUBLIC-3040, ANL-HEP-PR-95-44, Mar 1995. 18pp. Published in Phys.Rev.Lett.74:2626-2631,1995 (Title changed in journal)

Observation of the top quark. By D0 Collaboration (S. Abachi et al.). FERMILAB-PUB-95-028-E, Mar 1995. 12pp. Published in Phys.Rev.Lett.74:2632-2637,1995

discovery of W and Z:

first experimental observation:
W-Bosonen:UA1: Phys. Lett. **122B** (1983) 103; UA2: Phys. Lett. **122B** (1983) 476
Z-Bosonen:UA1: Phys. Lett. **126B** (1983) 398; UA2: Phys. Lett. **129B** (1983) 130

commented original papers:
R.N. Cahn and G. Goldhaber, The Experimental Foundations of Particle Physics; Cambridge University Press, 1989

measurements establishing the SM as gauge theory:

Precision Electroweak Measurements, the LEP Electroweak Working Group, the SLD Electroweak and Heavy Flavour Groups, Physics Reports: Volume 427 Nos. 5-6 (May 2006) 257-454; `http://lepewwg.web.cern.ch/LEPEWWG/1/physrep.pdf`

1.2 The cosmological Standard Model

textbooks, e.g.:

Lars Bergström and Ariel Goobar, Cosmology and Particle Astrophysics, Springer Verlag

G. Börner, The Early Universe, Springer Verlag

summer school:

Julien Lesgourgues, An Overview of cosmology.
`http://arxiv.org/pdf/astro-ph/0409426`

Gutes kompaktes Vorlesungsskript: 'Einführung in die Kosmologie' von Jens Niemeyer.
`http://www.astro.uni-wuerzburg.de/~niemeyer/lectures/cosmo_new.pdf`

1.3 Primordial nucleosynthesis

textbooks, e.g.:

Lars Bergström and Ariel Goobar, Cosmology and Particle Astrophysics, Springer Verlag

G. Börner, The Early Universe, Springer Verlag

PDG review+references: BIG-BANG NUCLEOSYNTHESIS in K.A. Olive et al. (Particle Data Group), Chin. Phys. C, 38, 090001 (2014) and 2015 update. `http://pdg.lbl.gov/2015/reviews/rpp2014-rev-bbang-cosmology.pdf`

1.4 The cosmic microwave background

textbooks on cosmology

Wayne Hu CMB tutorials: http://background.uchicago.edu/index.html

Latest papers by the Planck Collaboration: http://www.cosmos.esa.int/web/planck/publications

2 The dominance of matter over antimatter and CP violation

Lehrbücher:
(insbesondere für Definition und Entdeckung der CP-Verletzung im KKquer-System:)
D.H. Perkins, Introduction to High Energy Physics;
F. Halzen, A.D. Martin, Quarks & Leptons

CERN summer school:
Andreas Höcker, The Violation of Symmetry between Matter and Antimatter and Matter Genesis, http://indico.cern.ch/conferenceDisplay.py?confId=a07195

Robert Cahn, CP Violation and the Matter Anti-Matter Asymmetry of the Universe, http://absuploads.aps.org/download_slides.cfm?pid=%25%2D%5E%27%2E%27%2C4%20%0A

Astrophysical observations of the dominance of matter over antimatter

nice introductory article from Scientific American, April 1998: Gregory Tarl and Simon P. Swordy, Cosmic Antimatter. http://cosmos.phy.tufts.edu/~zirbel/ast21/sciam/AntiMatter.pdf

AMS Experiment Homepage: http://www.ams02.org/

O. Adriani et al., The PAMELA Mission: Heralding a new era in precision cosmic ray physics. http://www.sciencedirect.com/science/article/pii/S0370157314002087

3 The problem of particle masses

Electroweak symmetry breaking and the discovery of the Higgs boson

textbooks:
D. Griffiths, Introduction to Elementary Particles;Wiley-VCH
P. Schmüser, Feynman-Graphen und Eichtheorien für Experimentalphysiker; Springer
I.J.R. Aitchison and A.J.G. Hey, Gauge Theories in Particle Physics; Adam Hilger LTD

generally understandable(?):
'The A4 Higgs' http://www.hep.ucl.ac.uk/~djm/higgsa.html

review articles:

The Higgs Boson in the Standard Model - From LEP to LHC: Expectations, Searches, and Discovery of a Candidate S. Dittmaier, M. Schumacher (Freiburg U.). Nov 2012. 82 pp. Published in Prog.Part.Nucl.Phys. 70 (2013) 1-54. http://inspirehep.net/record/1203324?ln=en

M. Della Negra (Imperial Coll., London), P. Jenni (CERN), T.S. Virdee (Imperial Coll., London), Journey in the search for the Higgs Boson: The ATLAS and CMS experiments at the Large Hadron Collider. http://inspirehep.net/record/1223728?ln=en

LEP final result:

Search for the standard model Higgs boson at LEP LEP Working Group for Higgs boson searches and ALEPH and DELPHI and L3 and OPAL Collaborations (R. Barate et al.). Mar 2003. 23 pp. Published in Phys.Lett. B565 (2003) 61-75.
http://inspirehep.net/record/619171?ln=en

TeVatron final (?) result:

CDF and D0 Collaborations (T. Aaltonen (Helsinki Inst. of Phys.) et al.), Higgs Boson Studies at the Tevatron, Phys.Rev. D88 (2013) 052014.
http://inspirehep.net/record/1225520?ln=en

LHC Discovery:

ATLAS Collaboration, 'Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC', Phys. Lett. B716 (2012) 1.
http://inspirehep.net/record/1124337?ln=en

CMS Collaboration, 'Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC', Phys. Lett. B716 (2012) 30.
http://inspirehep.net/record/1124338?ln=en

Properties of the Higgs boson: predictions and measurements

latest LHC results: ATLAS Collaboration, https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults

CMS Collaboration, https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIG

theoretical background: T. Plehn, http://www.thphys.uni-heidelberg.de/~plehn/pics/lhc.pdf

4 Dark matter

4.1 Astrophysical observation of dark matter

overview:
Spektrum der Wissenschaft, Oktober 2003, S44; Die Suche nach dunkler Materie

text books, e.g.:
Lars Bergström and Ariel Goobar, Cosmology and Particle Astrophysics, Springer Verlag

G. Börner, The Early Universe, Springer Verlag

introductory:
`http://www.astro.uni-bonn.de/~deboer/pdm/pdmdm.html`

lecture:
Guido D'Amico, Marc Kamionkowski, Kris Sigurdson, Dark Matter Astrophysics, arXiv:0907.1912 [astro-ph.CO].
`http://inspirehep.net/record/825460`

Planck home page:
`http://www.cosmos.esa.int/web/planck`

4.2 Particle nature of dark matter and searches for dark matter at colliders

DARK MATTER
K.A. Olive et al. (Particle Data Group), Chin. Phys. C, 38, 090001 (2014) and 2015 update.
`http://pdg.lbl.gov/2015/reviews/rpp2014-rev-dark-matter.pdf`

Stefano Profumo, TASI 2012 Lectures on Astrophysical Probes of Dark Matter, arXiv:1301.0952 [hep-ph].
`http://arxiv.org/abs/1301.0952`

Vorlesungsskript Supersymmetrie:
`http://www.physik.unizh.ch/~kmueller/text/vorlesung/susy.pdf`

summer school supersymmetry:
Stephen, P. Martin, A Supersymmetry Primer
`http://arxiv.org/pdf/hep-ph/9709356`

5 Neutrino properties

ausgezeichnete sehr aktuelle online Literatursammlung: `http://www.nu.to.infn.it`

5.1 What do we know about additional neutrinos ?

The references given essentially refer to the number of light neutrinos with SM couplings.

THE NUMBER OF LIGHT NEUTRINO TYPES FROM COLLIDER EXPERIMENTS,
K.A. Olive et al. (Particle Data Group), Chin. Phys. C, 38, 090001 (2014) and 2015 update.
`http://pdg.lbl.gov/2015/reviews/rpp2014-rev-light-neutrino-types.pdf`

Historic review before LEP:
D. Denegri, B. Sadoulet and M. Spiro, The Number Of Neutrino Species, Rev.Mod.Phys.62:1,1990.
`http://rmp.aps.org/abstract/RMP/v62/i1/p1_1`

number of light neutrino species at LEP:
Precision Electroweak Measurements on the Z Resonance, Phys.Rept. 427 (2006) 257
(arXiv:hep-ex/0509008v3)

5.2 Neutrino Oscillations and Direct Mass measurements

ausgezeichnete sehr aktuelle online Literatursammlung: `http://www.nu.to.infn.it`

C. Giunti and Chung W. Kim, Fundamentals of Neutrino Physics and Astrophysics (Oxford University Press)

5.3 Dirac or Majorana neutrinos ?

Spektrum der Wissenschaft, Oktober 2001, S ?
Neutrinomasse - und es gibt sie doch !

textbooks:
Boris Kayser, The Physics of massive neutrinos, World Sci.Lect.Notes Phys.25:1-117,1989

C. Giunti and Chung W. Kim, Fundamentals of Neutrino Physics and Astrophysics (Oxford University Press)

CERN Summer Students lectures 2013:
Boris Kayser, Neutrino physics
`http://indico.cern.ch/conferenceDisplay.py?confId=243787`

6 Extra Dimensions

Überblick Welt der Physik:
`http://www.weltderphysik.de/gebiete/theorie/jenseits-des-standardmodells/extra-dimensionen`

Overview for college students with useful images for illustration:

http://www.learner.org/courses/physics/

Überblick TeVatron: http://d0server1.fnal.gov/users/gll/public/edpublic.htm

D.J. Kapner et al., Tests of the Gravitational Inverse-Square Law below the Dark-Energy Length Scale, http://arxiv.org/abs/hep-ph/0611184

R. Franceschinia et al., LHC bounds on large extra dimensions http://arxiv.org/abs/1101.4919

Original publications which received a lot of scientific attention, but go beyond the average level of master students without specialisation on string theory:

N. Arkani-Hamed, S. Dimopoulos, G. Dvali, Phys. Lett. B 429 (1998) 263,
http://arxiv.org/abs/hep-ph/9803315v1

L. Randall, R. Sundrum, Phys. Rev. Lett. 83 (1999) 3370,
http://arxiv.org/abs/hep-ph/9905221

L. Randall, R. Sundrum, Phys. Rev. Lett. 83 (1999) 4690,
http://arxiv.org/abs/hep-th/9906064