Studies of Quantum-Chromo-Dynamics with Collider Experiments

Prof. Dr. Otmar Biebel

Lecture:

Tuesday	8:30 - 10:00 Uhr	Seminar Room H206
Tuesday	14:15 - 15:00 Uhr	Seminar Room H206

Tutorial:

Tuesday	15:00 - 15:45 Uhr	Seminar Room H206

Begin: Lectures: 21. April 2020
Tutorial: 21. April 2020

Topics of the Lecture

- Introduction, Motivation
- Quark Model of Hadrons
- Colour Charge and QCD
- Discovery of the Gluon, Gluon Spin
- asymptotic Freedom
- α_S Measurements
- Triple-Gluon-Coupling, Colour Factors
- Quark Mass Effects
- Quark-Gluon Differences
- Modelling of QCD Reactions
- Power Corrections
- Fragmentation Functions
- Colour Coherence Effects
- Proton and Photon Structure Functions
- at low scales: DGLAP vs. DLLA vs. BFKL

on the web:

`http://www.physik.uni-muenchen.de/lehre/vorlesungen/sose_20/A_QCD_at_collider/index.html`

Literature/Books

A small selection of books:

• Perkins	Introduction to High Energy Physics	Addison Wesley
• Griffith	Introduction to Elementary Particles	Wiley&Sons
• Halzen, Martin	Quarks & Leptons	Wiley&Sons
• Ellis, Stirling, Webber	QCD and Collider Physics	Cambridge University Press
• Dissertori, Knowles, Schmelling	Quantum Chromodynamics	Oxford University Press
• Renton	Electroweak Interactions	Cambridge University Press
• Particle Data Group	`http://pdg.lbl.gov`	

and many more!

Details on Topics of the Lecture

1. Introduction, Motivation
   (a) Quark Model of Hadrons:
   anomalous magnetic moment, mesons and baryons octett, structure of $SU(3)_{\text{flavour}}$, problem of Ω^- baryon
2. Establishing QCD
   (a) Colour Charge and QCD:
   experimental evidence for colour charge, structure of $SU(3)_{\text{colour}}$, differences and similarities of QCD and QED
   (b) Discovery of the Gluon, Gluon Spin:
   Jet structure in $e^+e^- \rightarrow q\bar{q}$, 3-jet structure for discovery of the gluon, Ellis-Karliner angle for gluon spin, phase space of 3-parton final states
   (c) asymptotic Freedom:
   Vacuum polarisation (QED vs. QCD), consequences of renormalisation, 3-jet rate R_3 vs. centre of mass energy, asymptotic freedom
   (d) α_S Measurement:
   completely inclusive observables, inclusive obervables (event shares), renormalisation scale uncertainty, collinear and infrared divergencies of 3-jet cross section, resummation vs. fixed order in α_S: NLLA vs. NLO, results for $\alpha_S(M_Z)$
   (e) Triple-Gluon-Coupling, Colour Factors of QCD:
   Colour factors and quark-gluon and gluon-gluon interaction, angular correlations (e.g. Nachtmann-Reiter angle) to identify triple-gluon coupling, principle of jet algorithms, measurements of colour factors

3. Identification and Impact of Partons
   (a) Quark Mass Effects:
   finite quark mass and 3-parton phase space, dead-cone effect, identification methods for flavour of primary quark, α_S and effects of finite quark masses, running quark mass, measurement of b-quark mass at $\sqrt{s} \equiv M_Z = 91\,\text{GeV}$
   (b) Quark-Gluon Differences:
   identification of quark and gluon jets, differences between quark and gluon jets Čerenkov effect, Transition Radiation, Landau distribution, δ electrons
4. Non-perturbative Regime of Strong Interaction
   (a) Modelling of QCD Reactions:
   parton shower, hadronisation models, Altarelli-Parisi splitting functions, string and cluster and tube hadronisation models
   (b) Power Corrections:
   principle effect of hadronisation on event shape variables
   (c) Fragmentation Functions:
   parton fragmentation functions, scaling of fragmentation functions, longitudinal and transverse fragmentation functions, DGLAP equation
   (d) Colour Coherence Effects:
   colour coherence, angular ordering of gluon radiation, fragmentation at small $x \equiv 2E_{\text{hadron}}/\sqrt{s}$, colour coherence and heavy quarks, string and drag effect (inter jet effects of colour coherence)
   (e) Proton and Photon Structure Functions:
   meaning of structure functions, (Bjorken-) scaling, pardon densities in the proton (valence and sea quarks, gluons), interpretation of proton and photon structure using DGLAP evolution equation, scaling violation
   (f) DGLAP vs. DLLA vs. BFKL:
   deep inelastic scattering at small x_{Bj}, diffraction and rapidity gaps, pomeron, resummation properties of DGLAP, DLLA, BFKL, experimental evidence for BFKL evolution

5. Open Issues of QCD
   (a) Confinement
   (b) Quark-Gluon-Plasma
       (i.e. quarks & gluon in a deconfined phase)
   (c) Glueballs
   (d) Proton Spin