MASTER THESIS PROJECTS @ IFAE'S THEORY GROUP

TITLE: Higher-order behaviour of gluonium correlation functions

PROJECT DESCRIPTION: Available results for gluonium correlation functions in QCD perturbation theory show that they are perturbatively very badly behaved, meaning that higher-order QCD corrections turn out rather large. This is for example seen in the scalar and pseudoscalar gluonium correlators which are known to fourth and third order respectively. On the other hand, recently, a novel definition of the QCD coupling was proposed, which allows to parametrise the scheme dependence of alpha_s by a single parameter C. Furthermore, it was noticed that exploiting the C-dependence of the coupling, the perturbative behaviour of correlation functions which carry a global factor of alpha_s to some power, like the scalar and pseudoscalar correlators, could be substantially improved. Since also gluonium correlators carry a quadratic global factor of the coupling, the proposal is to investigate if their perturbative behaviour could also be improved by employing the C-scheme coupling. The corresponding behaviour can also be tested in the large-beta_0 approximation, which is available for both gluonium correlation functions.

CONTACT PERSON: Matthias Jamin

TITLE: Dispersive approach to the electron and muon anomalous magnetic moment the meaning of the alpha/2pi correction

PROJECT DESCRIPTION: Understanding Quantum Electrodynamics calls for having more insight and physical intuition behind QED calculations. As Feynman once said, we have no way to get a general idea of the result of a calculation to be expected. For example, for the first QED correction to the anomalous electron moment, the famous alpha/2pi correction, we do not have a physical picture by which we can easily see that the correction is indeed alpha/2pi, we do not even know why the sign is positive (other than computing it). This considerations of course translates as well to the second-order calculation, and so on.

Is there any general idea of what is contained in each correction? Along these lines, is there any physical intuition on how a calculation for the anomalous electron moment would translate into the muonic or tauonic counterpart?

In this project we will explore the role of dispersion relations for the electromagnetic interaction vertex calculated using the analytic properties of Feynman graphs in perturbation theory together with the exact Thomson limit of the Compton scattering of photons by electrons.

In this case, an intuitive view of the result, modulus and sign, can be easily gained and the relation between different lepton moments explored.

CONTACT PERSON: Pere Masjuan

TITLE: Unitary constraints on Dalitz plot distributions: separating the wheat from the chaff Resonance contributions versus non-resonance backgrounds

PROJECT DESCRIPTION: The Dalitz-plot distributions (DP) characterises the physics region of a particular 3-body decay in terms of the invariant masses of its final state. The distribution of the population of experimental events on the Dalitz region given raise to the DP reveals the presence of 2-particle resonances formed in any of the three pairs of particles. The analysis of DP in B decays is difficult because involves the presence of many structures in a large range of available energy. The large mass of the B meson in contrast to the low mass of the particle in the final state (pion, kaon, eta) allow the intermediate states to undertake rescattering and eventually yield resonance states.

One of the most used technics in experimental studies for B decays is the isobar model understood as a superposition of Breit-Wigner (BW) resonances. BWs, however, when superposed, break unitary and modify the phase motion of the distribution with potential errors obviated in practice.

In this project, we shall explore the constraints imposed by unitary, analyticity, and crossing symmetry in 3-body decays with important rescattering effects. In this respect, we foresee to produce a model-independent method for analysing DP and test the viability of the recent discovered resonances in DPs. This methodology will be important as well for studying CP asymmetries already observed in in 3-body decays.

CONTACT PERSON: Pere Masjuan

TITLE: Regge trajectories in the baryon sector a test of the diquark content on baryon spectroscopy

PROJECT DESCRIPTION: Baryons are composite subatomic particles made up of three quarks, which participate in the strong interactions of the Standard Model. The most familiar baryons are the protons and neutrons that make up most of the mass of the visible matter in the universe. The way how the quarks inside baryons interact among themselves to give raise to their mass is still an open question. Any model explaining this process has to face the proliferation of baryon resonances in the light-quark sector observed in spectroscopy.

One of the most successful scenarios based on old String Theory ideas considers the baryon made up of a diquark system interacting with the third split-apart quark.

In this project we propose to explore the spectroscopy induced by such ideas making use of Regge trajectories, a classification of particles in terms of internal quantum numbers and mass, and contrast it with the state-of-the-art spectroscopy studies collected in the Particle Data Tables.

This study should allow us to conclude whether the diquark model explored recently in the context of AdS/QCD theories holds and whether the standard quark model is enough for

describing the zoo of baryon resonances.

CONTACT PERSON: Pere Masjuan

TITLE: Regge trajectories in the baryon sector a test of the diquark content on baryon spectroscopy

PROJECT DESCRIPTION: The Landau-Yang theorem states that due to the conservation of C-parity (charge conjugation) a stationary state with spin-1 cannot decay into two photons. Its application to the recently measured 125GeV mass particle decaying into two photons ruled out the possibility that such particle is a spin-1 state. The Landau-Yang theorem, however, requires explicit and implicit assumptions. When they are avoided, the possibility of a spin-1 particle decaying into two photons will not be prohibited and this may have implications for calculations of observables for which high precision is required.

In particular, when either the spin-1 particle or the photons are off-shell, are virtual, the transition is possible. This can have implications in phenomenological studies of photon photon scattering cross sections at low and high energies.

In this project, we shall explore the assumptions given raise to the Landau-Yang theorem, consider the cases where such result can be avoided and study the implications for the e+e- to e+e- pi+ pi- amplitude.

CONTACT PERSON: Pere Masjuan

TITLE: Bootstrap method as a noise filtering for experimental data how unitary constraints improve the determination of fundamental constants

PROJECT DESCRIPTION: It is a common practice in particle physics to extract the value of fundamental constants of nature after a fit to a given set of experimental data. The experimental uncertainty induces an error on the determination of the constant. The same happens when studying structure functions, form factors, or scattering amplitudes using a particular parameterization which coefficients must be fitted to experimental results.

Physical amplitudes respect basic properties such as unitary, analyticity, and crossing symmetry, and one can wonder whether the experimental data one should use do as well respect such fundamental constraints.

In this project, we will explore the statistical method of bootstrapping to design a method which should yield a noise filtering for experimental data. In cases where experimental uncertainties overpass the unitary constraints, after applying the noise filtering method, one should expect smaller final uncertainties in the determination of constants and structure functions.

We will then explore the method of noise filtering using the bootstrapping technic to study the hadronic vacuum polarization function of a heavy quark and the pseudoscalar meson

transition form factor.

CONTACT PERSON: Pere Masjuan

TITLE: Phenomenological determination of the pi0-eta-eta’ mixing from V→P gamma decays

PROJECT DESCRIPTION: Based on a simple model for the dipole transitions of vector mesons V (V=rho, omega, phi) into pseudoscalar mesons P (P=pi0, eta, eta’), the mixing among these pi0, eta and eta’ mesons will be investigated comparing the predicted decay widths with the most recent experimental data on these decays. The precision of the latest data might make possible to fit the pi0-eta and pi0-eta’ mixing angles for the first time using these decays. Their precise observation would allow not only to test the size of isospin-breaking effects in these decays but also to make better predictions on observables including these mixing angles.

CONTACT PERSON: Rafel Escribano
