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UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"

# Workshop on Determination of Fundamental QCD Parameters

## September 30 – October 4, 2019

## ICTP-SAIFR, São Paulo, Brazil

*Talks*

**Precision determination of short distance top mass**

Aditya Pathak

(University of Vienna)

Top mass has been measured at the LHC with sub-percent accuracy with an experimental uncertainty less than a GeV. However, there is an additional theoretical ambiguity of O (1 GeV) due to lack of precise knowledge of the top mass renormalization scheme encoded in the parton shower Monte Carlo simulations that drive the measurement. I will describe our effort to calculate precision top jet mass spectrum, including the use of soft drop grooming, that allows one to obtain a theoretical precision at very high accuracy while keeping track of the top mass scheme and accounting for corrections due to hadronization and the underlying event. The cross section has the potential to achieve the required kinematic sensitivity competitive with other theory-data based comparison methods, such as the total top cross section.

**Quark mass determination by the Fermilab Lattice, MILC, and TUMQCD collaborations**

Aida El-Khadra

(University of Illinois Urbana-Champaign)

I will discuss the recent determination by the Fermilab Lattice, MILC, and TUM QCD collaborations of the up, down, strange, charm, and bottom quark masses based on a four-flavor lattice QCD calculation.

# Towards charm and bottom quark masses with five-loop accuracy

Andreas Maier

(DESY Zeuthen)

Thanks to sum-rule determinations at next-to-next-to-next-to-leading order, the masses of the charm and the bottom quark are known within an uncertainty of better than one percent. However, an even higher precision is needed to match Higgs coupling measurements at next-generation lepton colliders. I report on an ongoing project to determine quark masses from a relativistic sum-rule analysis at five-loop order and show first results for the moments of the polarisation function.

**Inclusive top quark pair production cross section at lepton colliders: Matching of threshold and continuum**

Angelika Widl

(University of Vienna)

A major goal of future linear colliders are high precision measurements of the top quark mass and width from the inclusive top quark pair production cross section. Calculations of the cross section have separately focused on the production threshold and the continuum in the past and have reached high precision (NNNLO in the continuum and NNLL as well as NNNLO at threshold). However, for measurements at future linear colliders the intermediate region between threshold and continuum is also relevant, e.g. for determinations of the top quark mass from radiative events. In this talk we present a matched cross section, which smoothly connects the threshold with the continuum. We discuss the matching procedure as well as the effect of the choice of massscheme on the intermediate region and the continuum. By considering different orders of the matching, we show that it is consistent and accurately describes the intermediate region.

**Charm and bottom quark masses from heavy quarkonium**

Antonio Pineda

(Universitat Autònoma de Barcelona)

We will review determinations of the charm and bottom quark masses from heavy quarkonium.

Attilio Cucchieri

(Instituto de Física de São Carlos – USP)

**Determination of quark masses from QCD sum rules**

Cesareo Dominguez

(University of Cape Town)

Precision determinations of light and heavy-quark masses from QCD sum rules are reviewed. Emphasis is on recent results achieving high precision by invoking Cauchy theorem in the complex squared energy plane, leading to QCD finite energy sum rules. Current results are in good agreement with those from Lattice QCD.

**Quark mass determinations from BMW collaboration**

Christian Hoelbling

(Universität Wuppertal)

I will discuss the status of light and strange quark mass determinations from the BMW collaboration. A special focus will be on quark mass ratios.

**Probing the strong coupling and nonperturbative effects with angularities**

Christopher Lee

(Los Alamos National Laboratory)

Some of the most precise determinations of the strong coupling come from event shapes (such as thrust and C-parameter) in electron-positron collisions. Event shape distributions can be predicted to high accuracy in QCD perturbation theory. Physical distributions are modified by nonperturbative hadronization effects. The leading such contributions can be shown to depend on a single universal quantity which shifts the first moment. Both perturbative resummation and nonperturbative effects must be accounted for to determine alpha_s reliably, but doing so typically yields values for alpha_s lower than many other determinations. Angularities are a larger class of event shapes defined with a tunable parameter that controls the scales in the resummed factorized prediction as well as the size of the nonperturbative shift, essentially by varying the size of the jets that dominate the peak of the angularity distribution. They thus provide a way to tune the relative contribution of perturbative and nonperturbative contributions and a sensitive probe of alpha_s and the leading nonperturbative shift. We review developments in event-shape based determinations of alpha_s and the prospects for angularities to aid in this endeavour.

**Precision QCD at the LHC**

Daniel de Florian

(ICAS – Universidad Nacional de San Martin)

We consider the exteThe first years of running of the CERN LHC marked a real milestone in particle physics with the discovery of the long sought Higgs boson. The LHC is delivering a wealth of high-quality data at an increased centre-of-mass energy, which, so far, shows and impressive agreement with the expectation from the Standard Model (SM) without clear evidence for new physics signals.

In general, the key word for indirect physics searches for the next years will be precision, since new physics could manifest itself through small deviations from SM behavior. In this talk I will present the state of the art theoretical (QCD and SM) toolkit for precision physics at the LHC with some emphasis on the impact of uncertainties on the fundamental QCD parameters.nsion of the CMW soft-gluon effective coupling in the context of soft-gluon resummation for QCD hard-scattering observables beyond the next-to-leading logarithmic accuracy.

**Infrared Parton Shower Dynamics and the Top Quark Mass**

Daniel Samitz

(University of Vienna)

We show that using an infrared cutoff in the parton shower evolution for massive quarks implies that one employs a short-distance mass scheme, i.e. a mass scheme that does not have the O(Lambda_QCD) renormalon contained in the common pole mass renormalization scheme. Interestingly, this short-distance mass scheme is the pole of the heavy quark propagator in the presence of the infrared cutoff. Our analysis considers an angular ordered shower based on coherent branching and is based on jet masses. In this context we determine explicitly the relation of this short-distance mass to the pole mass. An essential prerequisite to control the quark mass scheme in a parton shower is that it has next-to-leading logarithmic precision. The basis of our analysis is (a) an analytic solution of the parton shower evolution and (b) that the infrared cut of the angular ordered shower can be implemented into analytic calculations in the framework of SCET. Numerical comparison to the Herwig event generator confirms our analytic results. The outcome of our analysis proves that the top quark mass parameter contained in multi-purpose event generators is in general not the pole mass.

**Fundamental Parameters from Electroweak Fits**

Jens Erler

(Universidad Nacional Autónoma de México)

Results of global electroweak fits within the Standard Model and beyond will be presented with special emphasis on heavy quark masses and alpha_s.

**Determination of the QCD coupling constant from the static energy and the free energy**

Johannes Weber

(Michigan State University)

I present two determinations of the strong coupling constant . The first one is from the static energy at three-loop accuracy using new lattice data at small lattice spacings, and thus, reaches very short distances. I present a comprehensive and detailed estimate of the error sources that contribute to the uncertainty of the final result, $\alpha_s(M_Z) = 0.11660 ^{+0.00110}_{-0.00056}$. The second determination is based on lattice data for the singlet free energy at finite temperature at even smaller distances from which I obtain $\alpha_s(M_Z) = 0.11638^{+0.00095}_{-0.00087}$.

**Use of recent high-precision R(s) data in the determination of alpha_s**

Kim Maltman

(York University & University of Adelaide)

I provide details of two analyses employing recent high-precision results for R(s), obtained from a sum of exclusive mode cross-sections up to s=4 GeV^2. The first is a determination of alpha_s analogous to that using hadronic tau decay data where the access to higher s leads to reduced theoretical systematics, the second an investigation of certain assumptions about the behavior of the OPE for the current-current correlators employed in many of the tau-based determinations of alpha_s in the literature.

**Heavy quark masses from QCD sum rules**

Pere Masjuan

(Universitat Autònoma de Barcelona)

We determine the heavy quark masses from QCD sum rules of moments of the vector current correlator calculated in perturbative QCD. Only experimental data for the charm and bottom resonances below the continuum threshold are needed in our approach, while the continuum contribution is determined by requiring self-consistency between various sum rules, including the one for the zeroth moment. Existing data from the continuum region can then be used to bound the theoretical error. Special attention is given to the question how to quantify and justify the uncertainty.

**Strong coupling constant and heavy quark masses in ( 2+1 )-flavor QCD**

Peter Petreczky

(Brookhaven National Laboratory)

I will present a determination of the strong coupling constant and heavy quark masses in (2+1)-flavor QCD using lattice calculations of the moments of the pseudo-scalar quarkonium correlators at several values of the heavy valence quark mass with Highly Improved Staggered Quark (HISQ) action. We determine the strong coupling constant in the MSbar scheme at four low-energy scales corresponding to mc, 1.5mc, 2mc, and 3mc, with mc being the charm quark mass. The novel feature of this analysis is that up to eleven lattice spacings are used in the continuum extrapolations, with the smallest lattice spacing being 0.025 fm.

**alpha_s from tau decay**

Santiago Peris

(Universitat Autònoma de Barcelona)

I will p I will review the present situation regarding the determination of $\alpha_s$ from tau decay, including recent developments related to the expected behavior of the Operator Product Expansion and its associated Duality Violations. resent an analysis of both hadronic tau decay and e^+e^- -> hadrons data leading to a determination of the value of $\alpha_s$ below the charm quark mass.

**Test of OPE on the Euclidean lattice**

Shoji Hashimoto

(KEK – Tsukuba)

We use short- and mid-distance lattice correlators and other observables to test the perturbation theory and operator product expansion in QCD. They include correlators in the momentum space, those in the coordinate space as well as the Dirac eigenvalue spectrum.

**The Strong Coupling from Low Energy Physics**

Tomasz Korzec

(Universität Wuppertal)

We map out the scale dependence of a strong coupling over a wide range of energies non-perturbatively using Monte-Carlo simulations of lattice QCD. This allows us to determine QCD's Lambda parameter very accurately, using low energy hadronic experiments as inputs. Perturbation theory enters the calculation only at very high energies, where it is shown to be reliable. This is made possible by a suitable choice of finite-size coupling, based on the gradient flow, and by a finite size scaling technique, that guarantees very controlled continuum extrapolations at every energy scale. At last, we explore a possible improvement of the traditional method, in which the scale dependence of the coupling is constructed entirely in the computationally far less demanding pure Yang-Mills-Theory, while still yielding the full QCD result. The method is based on the theory of decoupling.

**From sum-integrals to continuum integrals and back**

York Schroeder

(Universidad Bío-Bío)

Within finite-temperature quantum field theory, the evaluation of vacuum-type sum-integrals plays a central role in the determination of equilibrium observables, such as the free energy (or pressure) of a thermal system.

As has been repeatedly observed in the past, many two-loop sum-integrals can be decomposed into one-loop factors, allowing for analytic solutions in the space-time dimension d.

In this talk, I sketch a recent proof that this decomposition is generic, and give an algorithm that constructs this decomposition for any massless bosonic two-loop vacuum sum-integral. A number of related insights into a special class of two-loop massive vacuum integrals are discussed along the way.

**alpha_s determination from static QCD potential**

Yuichiro Kiyo

(Juntendo University)

We aim precision alpha_s determination from static QCD potential with a renormalon subtraction and lattice QCD data. Our method provides a well convergent perturbative static QCD potential, which can be compared with lattice QCD data for the static Wilson line. In this talk I would like to discuss the renormalon subtraction and give the detail analysis for the matching between perturbative and lattice QCD static potentials.

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***Posters***

**Electrodynamics in the thooft gauge, a Heisenberg approach**

Gabriel Brandão de Gracia

(Institute of Theoretical Physics (IFT-Unesp))

This article is devoted to describe the ’t Hooft gauge electrodynamics by means of non-pertubative methods. The point is that this specific gauge choice introduces a non- linear photon field self interaction. So, this model is constructively analysed in a BRST framework in analogy to the non-Abelian cases. Finally, we show that the asymtoptic transverse photon modes are the same as that of the linear gauge well known case since just the non-physical longitudinal sector get renormalized by such gauge self interaction. Then, the physical gauge independence is explicitly verified.

**Two-loop beta function in Yang-Mills theory from the Implicit Regularization perspective**

Adriano Lana Cherchiglia

(Universidade Federal do ABC)

The Large Hadron Collider is testing the Standard Model of Elementary Particles (SM) to an unprecedented level. The data collected so far, however, does not show any significant deviation to the predicted value in the SM implying that corrections due to New Physics, if present, will surely be small. Therefore, it is highly demanded to increase the level of accuracy of the SM predictions, in order to allow any significant deviation to be promptly detected. In this scenario, the High Energy theoretical community has embraced the task to move the precision frontier further. Among the different proposals, the development of new regularization schemes proves to be a viable alternative. In this context, the main aim would be the development of a minimal set of algebraic manipulations to render a given physical process finite, allowing the remaining terms to be treated numerically. In this scenario, we have developed a method, called Implicit Regularization, which has been proved to comply with BPHZ theorem as well as abelian gauge symmetry, to arbitrary loop order. Aiming for an automatization of the method at NNLO and further investigations in a non-abelian theory, in this work we have computed the two-loop correction to the beta function of the Yang-Mills theory. We sketch the main pieces of the computation and present a careful comparison with other regularization schemes.

**The fermion-boson vertex and its impact on Dynamical Chiral Symmetry Breaking**

Luis Albino Fernández Rangel

(IFT - UNESP)

Isela Melany Higuera Angulo

(Instituto de Física y Matemáticas of the Universidad Michoacana de San Nicolás de Hidalgo)