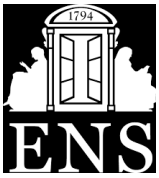
Université Pierre et Marie Curie - Paris 6

Laboratoire de Physique Théorique et Hautes Énergies (LPTHE)

Laboratoire de Physique Théorique Ecole Normale Supérieure (LPTENS)

"Séminaires Internationaux de Recherche de Sorbonne Universités"



Workshop on Multi-loop Calculations: Methods and Applications

Wednesday 7 and Thursday 8 of June 2017

Wednesday June 7		
9:00 - 12:30	Wednesday morning	
	9:00 (*5'*)	Welcome speech by **Matteo Cacciari** (FRIF director)
	9:10 (*40'*)	**John Gracey** (Liverpool U.) "Connecting quantum field theories across the dimensions via large N"
	9:55 (*40'*)	**Konstantin Chetyrkin** (Hamburg U.) "R-, R^{-1}- and R^*-operations and multiloop RG calculations"
	10:40 (*20'*)	Coffee break
	11:00 (*40'*)	**Vladimir Kazakov** (LPTENS, Paris) "Conformal Feynman graphs from integrable chiral CFT"
	11:45 (*40'*)	**Dmitry Chicherin** (Prisma, Mainz U.) "Yangian Symmetry of Fishnet Graphs"
12:30 - 14:30	Lunch	
14:30 - 18:30	Wednesday afternoon	
	14:30 (*40'*)	**David Broadhurst** (Open U., UK) "L-series from Feynman diagrams with up to 22 loops"
	15:15 (*40'*)	**Erik Panzer** (Oxford U.) "6-loop ϕ^4 theory in $4-2\epsilon$ dimensions"
	16:00 (*20'*)	Coffee break
	16:20 (*40'*)	**Peter Marquard** (DESY, Zeuthen) "4-loop mass relations and 5-loop anomalous dimensions in QCD"
	17:00 (*25'*)	**Bernd Kniehl** (Hamburg U.) "Fate of the universe: gauge independence and advanced precision"
	17:30 (*25'*)	**Oleg Veretin** (Hamburg U.) "3-loop massive tadpoles and the polylogarithms up to weigth 6"
	18:00 (*25'*)	**Andrey Pikelner** (Hamburg U.) "Towards four-loop Standard Model renormalization in the gaugeless limit"
19:00	Workshop dinner	

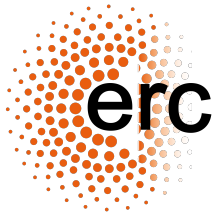
Thursday June 8		
9:10 - 12:30	Thursday morning	
	9:10 (*40'*)	**Tomáš Lučivjanský** (Košice U., Slovakia) "Survey of multi-loop calculations in stochastic dynamics and fully developed turbulence"
	9:55 (*40'*)	**Luminita Mihaila** (Heidelberg U.) "Chiral behavior within the Gross-Neveu-Yukawa model at three loops"
	10:40 (*20'*)	Coffee break
	11:00 (*40'*)	**Johannes Henn** (Prisma, Mainz U.) "Surprising simplicity of massive scattering amplitudes"
	11:45 (*40'*)	**Oliver Schnetz** (Erlangen-Nuremberg U.) "7 loops ϕ^4"
12:30 - 14:30	Lunch	
14:30 - 17:45	Thursday afternoon	
	14:30 (*40'*)	**Vladimir Smirnov** (SINP, Moscow) "Evaluating multiloop Feynman integrals by differential equations"
	15:15 (*40'*)	**Dmitri Kazakov** (JINR, Dubna) "UV Divergences and RG Equations in Non-renormalizable Theories"
	16:00 (*20'*)	Coffee break
	16:20 (*40'*)	**Pierre Vanhove** (IPhT, Saclay) "Higher-loop monodromy relations"
	17:00 (*40'*)	**Lev Lipatov** (INP, St. Petersburg) "Effective actions for high energy scattering amplitudes in QCD and gravity"
End of the Workshop		

Practical information:

- all talks will take place in Amphi Charpak, tower 22, level SB/RC,
- lunch breaks will take place in tower 13, 5th floor,
- the workshop dinner will take place in Zamansky Tower, 24th floor,
- the secretaries office is located in LPTHE, tower 13-14, 4th floor.

Amphi Charpak, tour 22, niveau SB/RC

Université Pierre et Marie Curie BP 126, 4, place Jussieu, 75252 Paris Cedex 05



Abstracts

L-series from Feynman diagrams with up to 22 loops

David Broadhurst

Open University

The Open University, Milton Keynes MK7 6AA, UK

Beyond 3 loops, polylogarithms no longer suffice for the QED contributions to the magnetic moment of the electron. At 4 loops, one encounters an L-series of a modular form of weight 4. I shall report on L-series that similarly result from Feynman diagrams with up to 22 loops. A salient feature is the existence of intricate quadratic relations between Feynman integrals, encoded by Betti and de Rham matrices that generalize Legendre's quadratic relation between elliptic integrals.

Yangian Symmetry of Fishnet Graphs

Dmitry Chicherin

PRISMA Cluster of Excellence

Johannes Gutenberg University, 55099 Mainz, Germany

We consider an all-loop conformal Yangian symmetry of fishnet graphs. These multipoint Feynman graphs correspond to several interesting observables in the integrable massless bi-scalar field theory in four dimensions. The on-shell graphs constitute the full set of planar amplitudes, and the off-shell graphs describe single-trace correlators. The Yangian is realized as the monodromy matrix acting on the boundary of fishnet graphs that provides a number of differential equations for them. We also discuss generalizations for graphs with fermions and for scalar graphs in three and six dimensions.

R-, R^{-1}- and R^*-operations and multiloop RG calculations

Konstantin Chetyrkin

II Institut fur Theoretische Physik, Universitat Hamburg

Luruper Chaussee 149, 22761 Hamburg, Germany

We discuss the current status of the multiloop RG calculations and methods in QCD and general gauge theories in connection to the classical Bogolyubov-Parasiyuk R-operation and its generalizations (R^{-1} and R^*-operations).

Connecting quantum field theories across the dimensions via large N

John Gracey

Theoretical Physics Division, Department of Mathematical Sciences, University of Liverpool

P.O. Box 147, Liverpool, L69 3BX, United Kingdom.

We review the large N method of computing critical exponents in a universal theory in d spacetime dimensions. These exponents are connected with the renormalization group functions of various quantum field theories such as $O(N)$ ϕ^4 theory and Quantum Chromodynamics whose perturbative series have been extended in recent years. The ultraviolet completion of these theories is also discussed. For instance we show that the six and eight dimensional QCD renormalization group functions are consistent with the underlying universal theory. We also introduce an infinite set of new universal theories which derive from new solutions within the large N formalism of Vasil'ev et al and involve higher derivative kinetic terms. The ultraviolet completions of the first few new threads are constructed and shown to be consistent with the new large N critical exponents in d dimensions.

Surprising simplicity of massive scattering amplitudes

Johannes Henn

PRISMA Cluster of Excellence

Johannes Gutenberg University, 55099 Mainz, Germany

We consider a model of massive scattering amplitudes in $N = 4$ super Yang-Mills, which is analogous to light-by-light scattering. Working at the planar level, we provide the full three-loop amplitudes. We then derive various asymptotic expansions in physically interesting regimes, many of which are exactly known, or governed by integrability. We find a surprisingly simple structure in the Regge limit, and suggest a simple form of the first power-suppressed terms.

UV Divergences and RG Equations in Non-renormalizable Theories

Dmitry Kazakov

Joint Institute for Nuclear Research (JINR)

Joliot-Curie 6, 141980 Dubna, Moscow region, Russia

It is well known that in renormalizable theories the UV divergences (high-energy asymptotics) are governed by the renormalization group equations. However, the R-operation is valid in any local field theory irrespectively of renormalizable it is or not. As it follows from the Bogoliubov-Parasiuk theorem the counter terms are always local. This very statement applied to non-renormalizable theories allows one to construct the counter terms and to write down the RG equations. We consider this procedure

on example of $D = 8$ SUSY gauge field theory. This choice though looking rather complicated in fact is essentially simplified using the modern spinor-helicity formalism. To be more specific we consider the four-point amplitude on shell in the planar limit. We construct the RG equations in the leading approximation and solve them analytically in the ladder approximation. We consider then the subleading approximation for the same diagrams. This allows us to get explicitly the all loop leading and subleading divergences. Then we trace the scheme dependence of the obtained counter terms.

The conclusion is surprisingly straightforward: the construction of the counter terms in renormalizable and non-renormalizable theories is just the same. The only difference is that while in renormalizable theories all UV divergences are absorbed into a single dimensionless coupling and the scheme dependence is reduced to the definition of this coupling, in non-renormalizable case this dimensionless coupling is constructed of the original gauge coupling multiplied by a kinematical factor like the Mandelstam variables s, t or u in our case. The interpretation of this observation remains still unclear.

Conformal Feynman graphs from integrable chiral CFT

Vladimir Kazakov

Laboratoire de Physique Théorique Ecole Normale Supérieure (LPTENS)

Departement de Physique de l'ENS, Ecole Normale Superieure, Paris

We review the computation of special class of integrable planar multi-loop graphs generated by recently proposed bi-scalar CFT. The theory is obtained as a particular, double scaling limit of weakly coupled and strongly twisted N=4 SYM. In the planar limit, it is dominated by fishnet-type graphs related to integrable conformal spin chain. We present the computation of wheel-type graphs defining the anomalous dimension of BMN vacuum type operator in the bi-scalar theory and give explicit results for multi-frame wheels with 3 spokes (generalizing the 1- and 2-frame cases known in the literature). We will briefly discuss preliminary results of computation of 3- and 4-point functions in bi-scalar theory.

Fate of the universe: gauge independence and advanced precision

Bernd Kniehl

II Institut fur Theoretische Physik, Universitat Hamburg

Luruper Chaussee 149, 22761 Hamburg, Germany

We perform a manifestly gauge-independent analysis of the vacuum stability in the Standard Model (SM) including two-loop matching, three-loop renormalization group evolution, and pure QCD corrections through four loops. Exploiting our knowledge of the Higgs-boson mass, we derive an upper bound on the pole mass of the top quark by requiring that the SM be stable all the way up to the Planck mass scale and conservatively

estimate the theoretical uncertainty. This bound is compatible with Monte Carlo mass quoted by the Particle Data Group at the 1.3 sigma level. We also briefly discuss cosmological consequences of this finding.

Effective actions for high energy scattering amplitudes in QCD and gravity

Lev Lipatov

Theoretical Physics Department, Petersburg Nuclear Physics Institute,

Orlova Roscha, Gatchina, 188300, St. Petersburg, Russia

We discuss the effective actions for the high energy scattering in QCD (including its supersymmetric generalizations) and gravity. They describe the interactions of reggeized gluons and gravitons with usual partons and are local in corresponding particle rapidities. The corresponding Euler-Lagrange equations are derived and used for finding effective reggeon vertices in these models including the integral kernel for the BFKL equation.

Survey of multi-loop calculations in stochastic dynamics and fully developed turbulence

Tomáš Lučivjanský

Safarik University in Košice, Institute of Physics, Department of theoretical physics and astrophysics

in collaboration with Michal Hnatič and Juha Honkonen

Renormalization group has been successfully applied in the statistical physics and provides a very efficient computational tool for calculation of universal quantities. Selected recent contributions concerning the rapidly developing domain of stochastic field theory are reviewed and fundamental differences between models: static model, their dynamic counterparts and non-equilibrium are discussed in this survey. We concentrate on the role of multi-parameter expansion in regulators of dimensional and analytic renormalization. A special attention is devoted to the role and properties of the minimal subtraction scheme. In the end, relevant problems and future goals are proposed.

4-loop mass relations and 5-loop anomalous dimensions in QCD

Peter Marquard

Deutsches Elektronen Synchrotron (DESY)

Platanenallee 6, Zeuthen, Germany

The anomalous dimensions of QCD govern its fundamental properties. We present results for the conversion formulas between heavy quark masses defined in the MSbar

and on-shell scheme and various short distance masses. Furthermore, we present results for the full renormalization of QCD in the MSbar scheme at 5-loop order.

Chiral behavior within the Gross-Neveu-Yukawa model at three loops

Luminita Mihaila

Institut für Theoretische Physik, Universität Heidelberg

Philosophenweg 16, 69120 Heidelberg, Germany

In this talk, we report on the calculation of the critical exponents in 4-epsilon dimensions for general number of fermion flavors at three-loop order within the bosonized version of the Gross-Neveu model – the Gross-Neveu-Yukawa model. Furthermore, we apply the computed series for the critical exponents and their Padé approximants to several phase transitions of current interest and present a comparison with the results of other analytical and numerical methods.

6-loop ϕ^4 theory in $4-2\epsilon$ dimensions

Erik Panzer

All Souls College, University of Oxford

OX1 4AL Oxford, UK

In a joint effort with Mikhail Kompaniets, we extended the perturbative renormalization of ϕ^4 theory to six loops. In the first part, I will sketch some of the techniques used in this calculation; focussing on the integration with hyperlogarithms (due to Francis Brown) and the subtraction of subdivergences through local, factorizable counterterms (as suggested by Francis Brown and Dirk Kreimer). Then I will comment on the results, and in particular I will address the asymptotic behaviour of the perturbative series, as well as the resummation of critical exponents.

Towards four-loop Standard Model renormalization in the gaugeless limit

Andrey Pikelner

II Institut fur Theoretische Physik, Universitat Hamburg

Luruper Chaussee 149, 22761 Hamburg, Germany

We report recent progress in calculation of four-loop beta functions and anomalous dimensions within the gaugeless limit of Standard Model. Numerical impact of higher order corrections and its application to the Standard Model vacuum stability analysis will also be discussed.

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7 loops ϕ^4

Oliver Schnetz

Department Mathematik, Emmy-Noether-Zentrum

FAU Erlangen-Nurnberg, Cauerstr. 11, 91058 Erlangen

We report on a recent attempt to calculate renormalization group functions of dimensionally renormalized ϕ^4 theory in the minimal subtraction scheme at loop order 7. The approach is different from the former momentum space calculations which provided results up to 6 loops. We use position space and the theory of graphical functions in combination with generalized single-valued hyperlogarithms (with some input from parametric integration by F. Brown and E. Panzer).

Evaluating multiloop Feynman integrals by differential equations

Vladimir Smirnov

Skobeltsyn Institute of Nuclear Physics

Moscow State University, 119991, Moscow, Russia

Differential equations are used to evaluate master integrals for several families of Feynman integrals. Analytical results are obtained for all the master integrals of two families of massless Feynman integrals with two external momenta on the light cone associated with three-point four-loop non-planar graphs. Using these results, the four-loop contributions to the photon quark and Higgs quark form factors involving two closed fermion loops are analytically evaluated. A four-loop conformal integral, i.e. an integral over four four-dimensional coordinates, is evaluated by turning to its dimensionally regularized version and applying differential equations for the set of the corresponding 213 master integrals. An analytical result is obtained also for a three-loop coordinate-space integral which place the central role in the three-loop computation of the conformal four-point correlation function in the so-called bi-scalar CFT, an integrable four-dimensional theory obtained in a special limit of twisted N=4 SYM.

Higher-loop monodromy relations

Pierre Vanhove

Institut de Physique Théorique

CEA, IPhT, F-91191 Gif-sur-Yvette, France

Using a string based construction we derive an higher loop extension of the tree level kinematic relation between colour ordered amplitudes in open string theory and quantum field theory. We will discuss the consequences of these relations at one-loop order and outline some interesting consequences at higher-loop order.

This talk is based on work done and in progress with Piotr Tourkine and Alexandre Ochirov.

3-loop massive tadpoles and the polylogarithms up to weigth 6

Oleg Veretin

II Institut fur Theoretische Physik, Universitat Hamburg

Luruper Chaussee 149, 22761 Hamburg, Germany

In this talk we will discuss high precision numerical evaluation of Feynman diagrams with masses using differential equations. Solutions are constructed as formal series in small expansion parameter. An asymptotic behavior of expansion coefficients and technique for acceleration of the summation are reviewed.
