CURRICULUM VITAE

DAMIANO TOMMASINI
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Gender: male
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Education and research position

- **PostDoc (ESR)** *May 2012 - May 2013*
  Early Stage Researcher fellowship in the field of particle physics at the LHC, given by the Marie Curie Initial Training Network LHCPhenoNet at the University of Debrecen and INR, Debrecen, Hungary
- **Ph.D.** *Feb. 2009 - March. 2012*
  Ph.D. in theoretical physics at the "Università degli Studi di Firenze".
  Project title: *"QCD effects on Higgs Boson production and decay at Hadron colliders"*;
  Supervisor: Dr. Massimiliano Grazzini.
- **ESR** *Mar. 2011 - Aug. 2011*
  Early Stage Researcher fellowship in the field of particle physics at the LHC, given by the Marie Curie Initial Training Network LHCPhenoNet at the "University of Zürich".
- **Master degree** *Oct. 2006 - Sept. 2008*
  Master degree in theoretical physics at the "Università degli Studi di Milano Bicocca";
  Thesis: *"Problemi statistici sulle distribuzioni delle galassie",*
  i.e. "Statistical problems on the distribution of galaxies";
  Supervisors: Prof. Luigi Galgani, Prof. Guido Chincarini and Dr. Andrea Carati.
  Graduation 10 July 2008. Degree: 104/110.

Research Activity

1) *Higgs boson and QCD phenomenology at high energy colliders*

My research interests are mostly focused on Higgs boson and phenomenology of perturbative QCD at hadron and lepton colliders.

Higgs phenomenology at hadron colliders

One of the major goals of the current high-energy physics program at the LHC is the study of the standard model Higgs boson (or its equivalent in theories beyond the Standard Model), and the examination of its properties. The dominant mechanism for Higgs boson production at hadron colliders is gluon-gluon fusion. Since the dynamics of this process is controlled by strong interactions, the study of the QCD radiative corrections is necessary to obtain accurate theoretical predictions.

The total cross section for Higgs boson production by gluon fusion has been computed up to the next-to-next-to-leading order (NNLO) in QCD perturbation theory and the calculation has been consistently improved by adding the soft-gluon logarithmic contributions up to the next-to-next-to-leading logarithmic accuracy (NNLL).

This total cross section is an ideal quantity and it is never really measured. Since detectors have always a finite acceptance, to properly take into account the kinematic cuts applied in the experimental analysis, more exclusive calculations are actually needed.

In particular, one of the most useful observables is the transverse momentum (q_T) distribution of the Higgs boson. When $q_T \sim m_H$ (where m_H is the mass of the Higgs boson), fixed order calculations are theoretically justified because the QCD perturbative series is controlled by the small expansion parameter $\alpha_S(m_H)$. On the contrary, in the small q_T region ($q_T \ll m_H$), the convergence of the fixed-order expansion is spoiled, since the coefficients of the perturbative series are enhanced by powers of large logarithmic terms $\alpha_S^n \log^m(m_H^2/q_T^2)$. These terms are due to the emission of soft gluon radiation and they have to be re-summed to all orders, to obtain reliable predictions. The resummation has been performed up to next-to-next-to-leading logarithmic accuracy (NNLL), and the result has been matched to the fixed order NLO result valid at large transverse momenta. The calculation is implemented in the publicly available numerical program `HqT`.

In the first version of `HqT` some approximations were implemented at the NNLL+NLO order. In the first part of my PhD I have been working to write a new version of the code which now includes the exact value of the NNLO hard-collinear coefficients $\mathcal{H}_N^{H^{(2)}}$. I have evaluated the explicit expressions of these coefficients in Mellin space and implemented them in the code, together with the recently derived value of the NNLL coefficient $A^{(3)}$. In this updated version of the program we have implemented the exact dependence on the resummation scale, which allows a more reliable estimate of the theoretical uncertainties. We have used the new program to present updated predictions for the Higgs spectrum at the Tevatron and the LHC and to perform a detailed study of the theoretical uncertainties. We found that, in a wide region of transverse momenta, the size of the scale uncertainties is considerably reduced going from NLL+LO to NNLL+NLO accuracy. The program is widely used by the experimental collaborations at the Tevatron and the LHC to correct the Higgs q_T spectrum obtained through Monte Carlo simulations [1].

The program `HqT` provides predictions for the inclusive q_T spectrum of the Higgs boson, and it cannot be directly used to study the Higgs boson decay products. In the second part of my PhD I have extended the program `HqT` including the full kinematical information on the Higgs boson and its decay products. I have explicitly considered the decay into electroweak particles (i.e. two photons or two vector bosons into four leptons), that are the most important for the Higgs boson searches at hadron colliders. The calculation is implemented in a new Monte Carlo program named `HRes`, that allows us to retain the full kinematical information of the decay products, including also the effects of geometrical acceptance cuts. The `HRes` code and the related paper are published [2].

QCD jet cross section by subtraction at the NNLO accuracy

High energy particle collisions frequently lead to final states with hadronic jets. Jet observables can be used for precision studies, since their large production cross sections allow measurements with high statistical accuracy. Some examples include: the determination of the QCD coupling α_s, from jet rates and event shapes in electron-positron annihilation; the measurement of gluon parton distribution functions (and also α_s) in deep inelastic lepton-hadron scattering into two (plus one) jets; the determination of parton distributions in hadron-hadron scattering from single jet inclusive production and vector boson plus jet production.

The relevant observables are often measured with experimental precision of a few percent or better, thus theoretical predictions with the same level of accuracy are necessary. This usually requires the computation of next-to-next-to-leading order (NNLO) corrections in perturbative

QCD. One of the main bottlenecks of the straightforward application of QCD perturbation theory at NNLO is the following. Due to the presence of infrared (IR) singularities, the finite higher-order corrections are sums of pieces which are separately divergent in 4 space-time dimensions. These IR singularities must be regularized and canceled before any numerical computation may be performed. The most common approach for handling IR singularities at next-to-leading order (NLO) accuracy is the subtraction method: after regularizing all contributions by dimensional regularization, one builds subtraction terms that simultaneously cancel both the kinematical singularities in real emission phase space integrals and the explicit poles in one-loop virtual corrections. Since the IR singularity structure of QCD amplitudes is universal, i.e. process and observable independent, such subtraction terms can be defined in general. In recent years, a lot of efforts have been made to extend the subtraction method to NNLO accuracy. In this case, the calculation is much more complicated and, in broad terms, any proposed subtraction scheme must address two quite distinct difficulties. First, one must define subtraction terms that properly regularize the real emission phase space integrals. Second, one must combine the integrated form of these counterterms with the virtual contributions, canceling the IR divergences of the loop matrix elements. From the point of view of mathematical rigor, this cancellation must be local, i.e. it must happen pointwise in phase space. Furthermore, from a practical point of view, the full locality of the subtraction scheme is also important to ensure good numerical efficiency of the algorithm. Finally, the construction should be universal (process and observable independent), otherwise tedious adaptation of the algorithm to every specific problem becomes necessary.

The construction of a general subtraction scheme with fully local counterterms requires a lot of careful analytical calculations. In order to spare some work, various approaches have been proposed to NNLO calculations. During my first Post-doc in Debrecen, I am working on the subtraction scheme proposed by Gábor Somogyi, Zoltán Trócsányi and Vittorio del Duca in 2006. I am focusing on actual numerical implementation of subtraction terms for the double-virtual contribution to the total rates and event shapes in the process $e^+e \to 3jets$ (useful to analyze LEP data or new data that could be collected in future lepton colliders). Our first aim is to check the various subtraction terms both analytically and numerically. Once that all the required subtraction terms are known, they can be implemented in a Monte Carlo code. This is the main task I am focusing on in this period. In the future, also the double-real, mixed real-virtual and double-virtual corrections shall be included in order to obtain physical predictions concerning the process under investigation. Although double-real and mixed real-virtual contributions have already been implemented in a (private) numerical code, this is not yet fully satisfactory. Moreover, double-virtual contributions have not been implemented yet. Therefore, there is still work to do in order to have a complete and satisfactory version of the numerical code, including all the relevant terms.

2) *Quantum gravity and related cosmological observables*

My second research interest is focused on the phenomenology of possible effects predicted by theories of quantum gravity. Such effects could be observed as time delays on astronomic particles.

The Lorentz Invariance Violation (LIV) arises in various frameworks and theories of quantum gravity. In the context of quantum gravity, spacetime may have a non-trivial structure and physical laws may show deviations around the Planck energy scale. Thus, LIV effects may become substantial in the case of high energy particles and, in recent years, there has been growing interest on such a topic. In particular, the analysis of the time-of-flight of astronomical particles provides model independent tests, that are viable since astronomical sources provide high energy particles propagating along large cosmological distances, that could amplify the small LIV effects.

The use of cosmological sources to gain insight into possible modifications of the particles time-of-flight (due to LIV), requires a careful consideration of the universe cosmological expansion of the Universe, because such phenomenology is expected to be dependent on the cosmological model. Within the LIV phenomenology, massless particles may have energy-dependent speeds, and thus high energy particles may arrive earlier or with a delay, compared to low energy particles emitted at the same instant. It is thus important to predict such LIV effects taking into account different cosmological models, to predict delays that will be tested by current and future experiments.

In collaboration with Orlando Luongo we focused on the so-called Hořava model, which has recently attracted particular interest. First, we fixed the free parameters of the model through the Supernovae Ia test, in the Friedmann-Robertson-Walker Universe, then we predicted the correspondent time delays. Finally we compared the results with the similar ones, obtained in the ΛCDM scenario and also with the Modified Chaplygin Gas Model. We have found deviations in the various models at both low and high redshift that could be experimentally measured [3].

Statement of research interests

My research interests mainly concern theoretical and phenomenological aspects of quantum field theory applied to elementary particle physics. In particular, my current efforts are mostly devoted to the study of electron-positron collision with three jets in the final state. My PhD activity has been mostly focused on precision calculations for Standard Model Higgs boson production and decay. Another research interest concern the estimate and prediction of possible Lorentz invariance violation effects on high energy cosmic particles. During my undergraduate thesis I also worked on cosmology and in particular on the matter distribution in the Universe.

I am interested in all the fundamental aspects of high energy physics, both in the Standard Model and Beyond. A very interesting signal has been recently observed by the experiments at the LHC collider. This signal is compatible with a Higgs boson signal, but further experimental data and related analyses are needed to clarify the spontaneous symmetry breaking mechanism. More generally, we are living in an interesting era for the physics of elementary particles, and new phenomena are hopefully going to be observed.

As I wrote in the "Research activity" section, I worked on precision phenomenology for the Higgs boson production and decay at hadron colliders and I published an update on the numerical program `HqT` and the new code `HRes`. There is still room for improvements in that codes, and in future I will work in order to include further perturturbative corrections and to extend the code including other Higgs decay modes.

I am currently working on the subtraction technique at the NNLO accuracy for the process $e^+e^- \to 3jets$. I am expecting to complete the computation of double-virtual contribution for the differential cross section of such a process and in the future I will continue this work in order to include also the double-real emission and the mixed real-virtual contributions to this calculation. Implementing all of the results in a Monte Carlo code is a very interesting and useful goal, in order to improve the analyses of the experimental data collected at LEP or new data that could be collected in future lepton colliders.

In general, I am particularly interested in working on Higgs boson phenomenology, perturbative QCD, higher order calculations and numerical tools. I will continue to work on the projects I have been working in the past and present years, but I am also interested and open to new projects with different collaborations.

Publications

- **Articles in peer-reviewed journals**

1 D. de Florian, G. Ferrera, M. Grazzini and D. Tommasini, "Transverse-momentum resummation: Higgs boson production at the Tevatron and the LHC," JHEP **1111** (2011) 064 [arXiv:1109.2109 [hep-ph]].

2 D. de Florian, G. Ferrera, M. Grazzini and D. Tommasini, "Higgs boson production at the LHC: transverse momentum resummation effects in the H->2gamma, H->WW->lnu lnu and H->ZZ->4l decay modes," JHEP **1206** (2012) 132 [arXiv:1203.6321 [hep-ph]].

3 O. Luongo and D. Tommasini, "Cosmological measurements of Lorentz invariance violation at the Lifshitz point," Int. J. Mod. Phys. D **21** (2012) 1250070.

- **Reports**

  S. Dittmaier, S. Dittmaier, C. Mariotti, G. Passarino, R. Tanaka, S. Alekhin, J. Alwall and E. A. Bagnaschi *et al.*, "Handbook of LHC Higgs Cross Sections: 2. Differential Distributions," arXiv:1201.3084 [hep-ph].

- **Proceedings**

  D. de Florian, G. Ferrera, M. Grazzini, D. Tommasini, "Higher order QCD predictions for the Higgs pT distribution," QCD and High Energy Interactions, Moriond, France, March 10 - 17 2012

- **Articles/reports in preparations**

  1 "Handbook of LHC Higgs Cross Sections: 3 Higgs Properties".

  2 D. Tommasini, "Parton level event generators for High Energy Physics: optimizing the integration algorithms does not necessarily imply an optimization of the histogramming procedure".

  3 O. Luongo and D. Tommasini, "Dark energy as a network interacting fluid with grid configuration"

Talks

- "The transverse-momentum distribution of the Higgs boson at the Tevatron and the LHC", at the conference "IFAE 2011", Perugia, Italy, April 27th 2011
- "Higgs boson production at the LHC: transverse momentum resummation and decay in two photons", at Institut fur theoretische physik, Universität Zürich-Irchel, June 28th 2011
- "QCD effects on Higgs boson production and decay at Hadron colliders", at the conference "LHCphenonet Annual Meeting 2012", Durham, United Kingdom, March 22nd 2012
- "QCD effects on Higgs boson production and decay at Hadron colliders", at the University of Debrecen and Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen, Hungary, May 22nd 2012
- "Updates on the Higgs boson production and decay at the LHC: transverse momentum resummation effects in the H to 2photons, H to WW to $l\nu l\nu$ and H to ZZ to 4l decay modes", at the workshop "Hp2", Munich, Germany, September 4th 2012
- "Updates on the theoretical predictions for the Higgs boson production and decay distributions", at the conference "LHCphenonet Mid-Term Meeting 2012", Ravello, Italy, September - 17th 2012

Conferences, workshops and schools

- School: "SIGRAV School in Cosmology and INFN Formation School", Florence, Italy, January 26 - 31 2009.
- School: "IV Parma International School of Theoretical Physics", Parma, Italy, August 31 - September 4 2009.
- Workshop: "XVIII International Workshop on Deep-Inelastic Scattering and Related Subjects", Florence, Italy, April 19 - 23 2010.
- School: "4th Summer School on THE PHYSICS OF LHC", Martignano (Lecce), Italy, June 14 - 19 2010.

- School: "CTEQ-MCnet School 2010", Lauterbad (Black forest), Germany, July 26 - August 4 2010.
- Workshop: "The 3rd International Workshop on High Precision for Hard Processes at the LHC", Florence, Italy, September 14 - 17 2010.
- Conference: "Kick-off meeting of the LHCPhenoNet Initial Training Network", Valencia, Spain, January 31 - February 4 2011
- Workshop: "ATLAS NLO MC mini-workshop", Geneva, Switzerland, March 31 2011
- Conference: "IFAE 2011", Perugia, Italy, April 27 - 29 2011
- Conference: "Higgs Cross Sections for the LHC", BNL (New York), USA, May 4-6 2011
- Conference: "Higgs Hunting 2011", Orsay (Paris), France, July 28-30 2011
- Workshop: "High-energy QCD after the start of the LHC", Florence, Italy, September 5 - October 21 2011
- Workshop: "The Zurich Phenomenology Workshop: Higgs search confronts theory", Zurich, Switzerland, January 9-11 2012
- Conference: "LHCphenonet Annual Meeting 2012", Durham, United Kingdom, March 19 - 22 2012
- Conference: "LHCPhenoNet Mid-Term Meeting", September 16-20 2012, Ravello, Italy
- Workshop: "HP2: High Precision for Hard Processes", Munich, Germany, September 4 - 7 2012
- Workshop: "Johns Hopkins 36th Workshop", Florence, Italy, October 16 - 19 2012
- Workshop: "7th meeting of the LHC Higgs Cross Section WG", CERN Geneva, Switzerland, December 5-6 2012
- Workshop: "Zurich Phenomenology Workshop 2013: Particle Physics in the LHC Era", Zurich, Switzerland, January 7-9 2013

Languages

Italian (native), English (good).

Computer skills

- *Operating systems:* Linux and Windows.
- *Programming:* Fortran, C.
- *Software:* LaTeX, Mathematica and Office.

References

These persons are familiar with my professional qualifications:

Main referees

Dr.	Massimiliano Grazzini	e-mail:	grazzini@physik.uzh.ch
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Other referees

Dr. Stefano Catani	e-mail:	stefano.catani@fi.infn.it
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Autorizzo il trattamento dei dati personali ai sensi del D. lgs. 196/03

I hereby authorize the treatment of personal data according to the Italian Personal data Protection Code, Legislative Decree no. 196/2003 June 2003