Curriculum Vitae et Studiorum

Name

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Nationality

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Education and qualifications

1998	**Ph.D. in Theoretical Physics**, 5 May 1998 Dipartimento di Fisica, Università degli Studi di Milano. Title of the thesis: "Next-to-Leading-Order Corrections to the Production of Heavy-Flavour Jets in e^+e^- Collisions" Tutor: Dr. Paolo Nason
1995	**State Exam** for the Engineering Qualification 1st Session in 1995, with full marks (100/100)
1994	**Degree in Electronic Engineering**, 25 July 1994 Politecnico di Milano with full marks (100/100 cum laude). Title of the thesis: "Positron lifetime spectra: comparative studies of data analyzing methods" Supervisor: Prof. Alfredo Dupasquier (Politecnico di Milano)

Professional experiences

2020–present	Full Professor, *"Professore Ordinario, settore concorsuale 02/A2 - Fisica Teorica delle Interazioni Fondamentali (ssd FIS/02)"* in the Department of Physics, University of Milano - Bicocca, Milan, Italy.
2014–2019	Associate Professor, *"Professore Associato, settore concorsuale 02/A2 - Fisica Teorica delle Interazioni Fondamentali (ssd FIS/02)"* in the Department of Physics, University of Milano - Bicocca, Milan, Italy.
2006–2014	Researcher, *"Ricercatore Universitario, settore scientifico-disciplinare FIS/02"* in the Department of Physics, University of Milano - Bicocca, Milan, Italy.
2004–2006	*Research Fellow* in the Department of Physics, University of Milano - Bicocca, Milan, Italy, with a 3 years grant within the program "Rientro dei cervelli".
2002–2003	*Research Fellow* in the Department of Physics, University of Durham, Durham, UK, with a PPARC Advanced Fellowship of 5 years.
2000–2002	*Postdoctoral Research Associate* in the Department of Physics, University of Wisconsin, Madison, USA.
1998–2000	*Postdoctoral Research Assistant* in the Department of Physics, University of Durham, Durham, UK, with a INFN fellowship of 2 years ("Concorso a n. 7 borse di studio post-doctoral per fisici teorici. Bando n. 6585/97").
1997	CERN Theory Division, Visiting Scientist (5 months).

Awards and Honors

2014	Italian National Scientific Qualification as Full Professor ("Abilitazione Scientifica Nazionale, prima fascia") in theoretical physics, *Settore concorsuale 02/A2 - Fisica Teorica delle Interazioni Fondamentali, settore scientifico disciplinare FIS/02 - Fisica Teorica Modelli e Metodi Matematici*
2004	"Rientro dei cervelli": grant for four-year research activity in the Department of Physics, Università di Milano - Bicocca, Milan, Italy.
2002	PPARC Advanced Fellowship, UK. Grant for five-year research activity in the Department of Physics, University of Durham, Durham, UK.
2001	DPF Snowmass Fellowship, American Physics Society, USA.
1998	INFN Fellowship ("Concorso a n. 7 borse di studio post-doctoral per fisici teorici. Bando n. 6585/97"), Italy. Grant for two-year research activity in the Department of Physics, University of Durham, Durham, UK.

Teaching experiences

Unless otherwise stated, all courses were held at the Physics Department of the University of Milano - Bicocca.

Bachelor courses

- *"Elements of Theoretical Physics"*, *"Special Relativity"*
  2015–present, third-year students
- *"Quantum Mechanics"*
  2007–2010, third-year students
- *"Math for Physics"* (complex analysis, linear operators, Fourier transform)
  Lecturer/Teaching Assistant
  2006–2013, second- and third-year students
- *"Introduction to Quantum Mechanics"*
  2006–2010, third-year students
- *Tutor* in Physics, University of Durham
  2002–2003, second-year students
- *Tutor* in Physics, University of Durham
  1999–2000, third-year students
- *"General Physics II"* (electromagnetism, geometrical optics)
  Lecturer/Teaching Assistant
  1994–1998, second-year students of the Engineering Faculty, at Politecnico di Milano and Como
- *"General Physics I"* (mechanics, thermodynamics, kinetic theory of gases)
  Lecturer/Teaching Assistant
  1994–1998, first-year students of the Engineering Faculty, at Politecnico di Milano and Como

Master courses

- *"Theory and phenomenology of the fundamental interactions"*
  2010–present
- *"Numerical methods for theoretical physics"*
  2015–2017
- *"Advanced Quantum Field Theory"*
  2014–2015

- *"Advanced Quantum Mechanics"*
  2007–2010

Ph.D. courses

- *"Fundamental interactions and the Standard Model: introduction to QCD"*
  2004–2006

Public lectures

- "Matching NLO Calculations with Parton Shower: the POWHEG generator", lectures give at LAPTh, Annecy, France, 29 November–1 December 2011.

- "Introduction to Electroweak theory and Higgs boson physics at the LHC", lectures given at the *Galileo Galilei Institute*, Firenze, Italy, 24–26 September 2007.

- "Heavy-Quark Production", lecture given at the *CTEQ School 2006*, Rhodes, Greece, 2 July 2006.

- "Higgs physics at the LHC", lectures given at *The physics of LHC*, Martignano, Lecce, Italy, 20–25 May 2004.

Outreach - Third Mission

- "Introduction to theoretical physics", from special relativity and quantum mechanics, to quantum filed theory and general relativity, for an audience of 400 students at the University of Milano - Bicocca, 5 March 2019.

- "Theoretical physics", a colloquial presentation on theoretical physics today, status and unresolved puzzles, organized by AISF (Associazione Italiana Studenti di Fisica), open to the general public, 18 December 2018, Milano.

- Responsible of the "Alternanza scuola-lavoro" project in the theory group at the Physics Department of the University of Milano - Bicocca: an 80-hour project for high-school students, 4–15 June 2018.

- Presentation of the movie "Il senso della bellezza - arte e scienza al CERN" by Valerio Jalongo, and discussion about "Physics today", for an audience of 300 high-school students, Cinema del Borgo, Bergamo, 27 February 2018.

- "Quantum Chromo Dynamics for New Physics Discovery", talk given to the winners of the Italian Physics Olympiads (Olimpiadi Italiane della Fisica), 3 May 2007, Milano.

Supervision

- **Postdocs**

I have mentored several postdocs:

- Keith Murray Hamilton, 2009–2011, INFN grant
  Now Associate Professor at University College London
- Adam Kardos, 2012–2014, INFN grant
  Now postdoc at the University of Debrecen
- Tomáš Ježo, 2014–2016, University of Milano - Bicocca grant
  Now postdoc at the University of Zurich.
- Leandro Cieri, 2017-2019, INFN grant
  Winner of a postdoc Horizon 2020 Marie Sklodowska-Curie grant of 3 years, starting in Fall 2019

- **Ph.D. students**

I have supervised three Ph.D. students:

- Federico Granata, "Electroweak and strong next-to-leading-order corrections to HV and HVj production at hadron colliders", 2017
  Now working "on conception and organization of dissemination activities of scientific culture", at the University of Milano - Bicocca
- Silvia Ferrario Ravasio, "Top-mass observables: all-orders behaviour, renormalons and NLO + Parton Shower effects", 2018
  First postdoc at the University of Durham, Durham, UK. Second postdoc at the University of Oxford, UK.
- Marco Rocco, "Power corrections in a transverse-momentum cut for colour-singlet production at NLO and NNLO in QCD", 2020

I have co-supervised two Ph.D. students:

- Emanuele Re, "Next-to-leading-order QCD corrections to shower Monte Carlo event generators: single vector-boson and single-top hadroproduction", 2009
  Now permanent researcher at CNRS (CR1)
- Simone Alioli, "Matching next-to-leading-order QCD calculations with shower Monte Carlo simulations: single vector boson and Higgs boson productions in POWHEG", 2009
  Now Associate Professor at the University of Milano - Bicocca

- **Master theses**

I have supervised 7 Master theses:

- Marcello Rossi, 2013
- Martina Gandini, 2013
- Federico Granata, 2013
- Silvia Ferrario Ravasio, 2015
- Loris Farina, 2020
- Alessandro Gavardi, 2019
- Filippo Belloni, 2021

- **B.Sc. final projects**

  I have also supervised 16 B.Sc. final projects.

Academic activities

- Member of the Ph.D. School in Physics at the University of Milano - Bicocca
- Member of the VBSCan COST Action
- Member of the Ph.D. award committee at the University of Milano - Bicocca in 2018 and 2019
- Member of the selection committee for 6 postdoc positions in theoretical physics, in 2018, at the University of Milano - Bicocca
- Member of the admission committee to Master of Science, at the University of Milano - Bicocca, 2015–2018
- Member of the Ph.D. evaluation committee at the University of Zurich in 2017
- Member of the selection committee for 1 postdoc position in theoretical physics, in 2018, INFN, sez. Pavia
- Member of the selection committee for 1 postdoc position in theoretical physics, in 2008, 2011 and 2016, INFN, sez. Milano - Bicocca
- Member of the Ph.D. award committee at the University of Pavia in 2015
- Member of the selection committee for 4 postdoc positions in 2013, at the University of Milano - Bicocca ("Assegno tipo A")
- Member of the selection committee for 1 postdoc position in theoretical physics, in 2013, at the University of Milano - Bicocca ("Assegno tipo B")
- Member of the selection and admission committee for a Ph.D. in Physics in 2009, at the University of Milano - Bicocca
- Member of the selection committee for 1 postdoc position in theoretical physics in 2007, at the University of Parma

Professional activities

2019–2020	National Coordinator of the INFN network QFT@Colliders (Coordinatore nazionale dell'Iniziativa Specifica dell'INFN QFT@Colliders)
2018–present	Coordinator of the theory group in the Department of Physics, Università di Milano - Bicocca.
2016–2017	Principal Investigator of the PWHG-RES project for the use of 0.25 million core hours of the High Performance Computing of LISA (Interdisciplinary Laboratory for Advanced Simulation), at CINECA.
2009–2014	**Theory contact person** of the "Higgs boson production in vector-boson fusion" working group in the *LHC Higgs Cross Section Working Group*, at CERN.

Organization of conferences and workshops

2004–present	Co-organizer of the seminars of the phenomenology group for internal and external speakers in the Department of Physics, Università di Milano - Bicocca, Milan, Italy.
2018	Local co-organizer of *IFAE 2018*, Milan, Italy, 4–6 April 2018.
2009	Organizer and convener of the parallel session "Electroweak and QCD physics" at *IFAE 2009*, Bari, Italy, 15–17 April 2009.
2007	**Organizer** and **convener** of the second *Parma International School in Theoretical Physics*, University Campus, Parma, Italy, 3–8 September 2007.
2002–2003	Organizer of the seminars for internal and external speakers in the Department of Physics, University of Durham, Durham, UK.
2002	Organizing committee for "Pheno 2002 Symposium", Madison, WI, USA, 22–24 April 2002.
2001	Organizing committee for "Pheno 2001 Symposium", Madison, WI, USA, 7–9 May 2001.

Referee activities

I act as referee for the following journals:

- Physical Review Letters (I.F. 8.8)
- Journal of High Energy Physics (I.F. 5.5)
- Physical Review D (I.F. 4.4)
- Physics Letters B (I.F. 4.3)
- Nuclear Physics B (I.F. 3.3)

Services to national funding agencies

- Reviewer for ANVUR, Italy
- Reviewer for MIUR, Italy

Invited talks

- "NLO+parton shower QCD+EW corrections in the associated production of a Higgs and a vector boson, in a resonance-aware framework", CERN, Geneva, Switzerland, 29 January 2018.

- "NLO QCD+EW corrections for HV and HV+jet in the POWHEG BOX RES", CERN, Geneva, Switzerland, 29 June 2017.

- "VV + jets and the POWHEG BOX", at *Multi-Boson Interactions 2016* University of Wisconsin, Madison, WI, USA, 24 August 2016.

- "Angular coefficients in Z and W production with the POWHEG BOX", CERN, Geneva, Switzerland, 24 February 2015.

- "HVJ and $gg \to HZ$ with the POWHEG BOX", CERN, Geneva, Switzerland, 18 December 2014.

- "Recent developments in Monte Carlo tools for the LHC", Universitaet Mainz, Mainz, Germany, 26 June 2013.

- "Progressi teorici nei calcoli di Modello Standard e strumenti di generazione MC", at *VI Workshop Italiano sulla Fisica p-p a LHC*, Genova, Italy, 9 May 2013.

- "Merging H/W/Z + 0 and 1 jet at NLO with no merging scale", at *Particle physics in the LHC era*, Zürich, Switzerland, 7 January 2013.

- "Status and Future plans for POWHEG", at *MC generators and future challenges, a joint ATLAS/CMS/LPCC workshop*, CERN, Geneva, Switzerland, 19 November 2012.

- "MC tools and NLO Monte Carlos", at *Higgs Hunting 2012*, Orsay, France, 18 July 2012.

- "Matching NLO Calculations with Parton Shower: the POWHEG generator", Università Roma Tre, Roma, Italy, 21 June 2012

- "NLO Monte Carlo Tools for Higgs Physics at the LHC", at *Standard Model @ LHC 2012*, Copenhagen, Denmark, 10 April 2012.

- "Matching NLO Calculations with Parton Shower: the POWHEG generator", MPI, Munich, 31 January 2012.

- "The POWHEG BOX", at *Physics at TeV Colliders*, Les Houches, France, 12 June 2011.

- "Higgs boson production in POWHEG" at *ATLAS NLO MC mini-workshop* , CERN, Geneva, Switzerland, 31 March 2011.

- "Shower Monte Carlo + NLO: POWHEG" at *LoopFest IX*, Stony Brook University, NY, USA, 21 June 2010.

- "POWHEG", Università degli Studi, Torino, Italy, 9 June 2010.

- "Shower Monte Carlo + NLO: POWHEG" at *Loops and Legs in Quantum Field Theory*, Wörlitz, Berlin, Germany, 26 April 2010.

- "Higgs boson production in VBF", at *1st LHC Higgs Cross Section Workshop*, Freiburg, Germany, 12-13 April 2010.

- "Status of POWHEG BOX", at *MC4LHC readiness*, CERN, Geneva, Switzerland, 30 March 2010.

- "The POWHEG BOX", at *RWTH*, Aachen, Germany, 9 July 2009.

- "Towards the POWHEG BOX", at *Physics at TeV Colliders*, Les Houches, France, 12 June 2009.

- "QCD and EW summary talk" at *IFAE 2009: Incontri sulla Fisica delle Alte Energie*, Bari, Italy, 17 April 2009.

- "NLO + Parton Shower: POWHEG" at *IFAE 2009: Incontri sulla Fisica delle Alte Energie*, Bari, Italy, 16 April 2009.

- "NLO + Parton Shower: POWHEG" at Scuola Normale Superiore, Pisa, Italy, 24 March 2009.

- "NLO + Parton Shower: POWHEG and Higgs boson production in gluon fusion" at *Workshop on Higgs Boson Phenomenology*, Zürich, Switzerland, 8 January 2009.

- "Matching NLO Calculations with Parton Shower: introduction and POWHEG status report", at *CMS Advanced Monte Carlo Use and Tuning Strategies*, CERN, Geneva, Switzerland, 15 December 2008.

- "Matching NLO Calculations with Parton Shower: the POsitive-Weight Hardest Emission Generator", at *GDR Supersymétrie*, LAL Orsay, Paris, France, 4 December 2008.

- "Matching NLO Calculations with Parton Shower: the POsitive-Weight Hardest Emission Generator", Th. Colloquium, CERN, Geneva, Switzerland, 26 November 2008.

- "Matching NLO Calculations with Parton Shower: the POsitive-Weight Hardest Emission Generator", Università degli Studi, Torino, Italy, 18 September 2008.

- "New Developments in Perturbative QCD", plenary talk at *Pheno 2008 Symposium*, University of Wisconsin, Madison, WI, USA, 30 April 2008.

- "Matching NLO Calculations with Parton Shower: the POsitive-Weight Hardest Emission Generator", UCL, Louvain-la-Neuve, Belgium, 7 April 2008 .

- "Matching NLO Calculations with Parton Shower: the POsitive-Weight Hardest Emission Generator", NIKHEV, Amsterdam, The Netherlands, 4 April 2008.

- "Matching NLO Calculations with Parton Shower: the POsitive-Weight Hardest Emission Generator", KITP, Santa Barbara, CA, USA, 6 March 2008.

- "Matching NLO Calculations with Parton Shower: the POsitive-Weight Hardest Emission Generator", University of Wisconsin, Madison, WI, USA, 22 February 2008.

- "Matching NLO Calculations with Parton Shower: the POsitive-Weight Hardest Emission Generator", Fermilab, Batavia, IL, USA, 21 February 2008.

- "Matching NLO Calculations with Parton Shower: the POsitive-Weight Hardest Emission Generator", at *RADCOR07*, Firenze, Italy, 4 October 2007.

- "Parton Shower + NLO: a POsitive-Weight Hardest Emission Generator", at *Physics at TeV Colliders*, Les Houches, France, 23 June 2007.

- "Parton Shower + NLO: a POsitive-Weight Hardest Emission Generator", at *Pheno 2007 Symposium*, Madison, WI, USA, 7 May 2007.

- "QCD corrections to Higgs and vector (di-)boson production", Università degli Studi, Firenze, Italy, 3 April 2007.

- "QCD for New Physics Discovery", at the meeting "Fisica in 'vivo' ",Milano, Italy, 13–14 March 2007.

- "QCD corrections to vector-boson fusion processes", at *Workshop: high precision for hard processes at the LHC*, Zürich, Switzerland, 6 September 2006.

- "QCD corrections to Higgs and di-boson production", at *Pheno 2006 Symposium*, Madison, WI, USA, 16 May 2006.

- "QCD corrections to Higgs and production of di-bosons", at *Workshop on Collider Physics*, ANL, Argonne, IL, USA, 11 May 2006.

- "QCD corrections to Higgs and vector-boson production", at *DIS 2006*, Tsukuba, Japan, 21 April 2006.

- "Heavy-Quark Fragmentation Functions in e^+e^- Collisions", at *DIS 2006*, Tsukuba, Japan, 21 April 2006.

- "QCD corrections to Higgs production: signal and backgrounds" Université Catholique de Louvain, 6 April 2006.

- "QCD corrections to Higgs and di-boson production", Università degli Studi, Bologna, Italy, 8 March 2006.

- "NLO and NNLO: status and progresses", at *Workshop sui Monte Carlo, la fisica e le simulazioni a LHC*, Frascati, Italy, 27 February 2006.

- "QCD corrections to Higgs production: signal and backgrounds", at *Pheno 2005 Symposium*, Madison, WI, USA, 2 May 2005.

- "QCD corrections to Higgs production: signal and backgrounds", Fermilab, Batavia, IL, USA, 17 March 2005.

- "Precision calculations for hadron collider physics", University of Edinburgh, UK, 20 December 2004.

- "Higher order calculations in particle theory", Universitaet Karlsruhe, Karlsruhe, Germany, 18 November 2004.

- "Higher order calculations in QCD", DAPNIA/SPP, CEA Saclay, France, 14 June 2004.

- "Higher order calculations in QCD", at *IFAE 2004: Incontri sulla Fisica delle Alte Energie*, Torino, Italy, 14 April 2004.

- "NLO QCD corrections to W and Z production via vector-boson fusion" at *LoopFest III*, Santa Barbara, CA, USA, 1 April 2004.

- "QCD corrections to Higgs production: signal and backgrounds", SLAC, Menlo Park, USA, 3 March 2004.

- "Higher order calculations in QCD", *ATLAS plenary physics meeting*, CERN, Geneva, Switzerland, 26 February 2004.

- "NLO QCD corrections to Higgs boson production via weak-boson fusion: signal and backgrounds", Manchester, UK, 24 October 2003.

- "Summary talk of the Higgs boson working group", at *CERN Workshop on Monte Carlo tools for the LHC*, CERN, Geneva, Switzerland, 11 July 2003.

- "NLO QCD corrections for Higgs boson production in weak-boson fusion processes", at *CERN Workshop on Monte Carlo tools for the LHC*, CERN, Geneva, Switzerland, 9 July 2003.

- "NLO corrections for Higgs boson production via weak-boson fusion", Les Houches, France, 31 May 2003.

- "Higgs boson production via gluon fusion and weak-boson fusion: high-energy limits at LHC and VLHC", Cambridge, UK, 13 May 2003

- "Kinematical limits on Higgs boson production via gluon fusion in association with jets", Oxford, UK, 6 March 2003

- "Kinematical limits on Higgs boson production via gluon fusion in association with jets", DESY-Theorie, Hamburg, Germany, 12 February 2003

- "Higgs + 2 jets via gluon fusion: LHC and VLHC", Università degli Studi, Milan, Italy, 19 December 2002.

- "Next-to-next-to-leading order scattering processes: present and future", at *LoopFest*, Brookhaven National Laboratory, Upton, NY, USA, 9–10 May 2002.

- "Challenges in the calculation of NNLO scattering processes", at *IFAE 2002: Incontri sulla Fisica delle Alte Energie*, Parma, Italy, 3–5 April 2002.

- "Challenges in the calculation of next-to-next-to-leading order scattering processes", at *XXXVII Rencontres De Moriond*, Les Arcs 1800, France, 16–23 March 2002.

- "Higgs production plus two jets via gluon fusion: LHC and VLHC", Brookhaven National Laboratory, Upton, NY, USA, 6 February 2002.

- "Challenges in two loop QCD massless $2 \to 2$ scattering processes", Argonne National Laboratory, Argonne, IL, USA, 12 November 2001.

- "Higgs production via gluon fusion: LHC and VLHC", CTEQ Meeting, Argonne National Laboratory, Argonne, IL, USA, 26–27 October 2001.

- "Higgs + 2 jets via gluon fusion: LHC and VLHC", Snowmass, CO, USA, 30 June–21 July 2001.

- "Challenges in two loop QCD massless $2 \to 2$ scattering processes", Snowmass, CO, USA, 30 June–21 July 2001.

- "Production of a Higgs boson accompanied by two jets via gluon fusion", at *Workshop on the Future of Higgs Physics*, Fermilab, Batavia, IL, USA, 3–5 May 2001.

- "Two loop QCD corrections to massless $2 \to 2$ scattering processes", CERN, Geneva, Switzerland, 20 April 2001.

- "Two loop QCD corrections to massless $2 \to 2$ scattering processes", Università di Milano, Italy, 11 April 2001.

- "Two loop QCD corrections to massless $2 \to 2$ scattering processes", Università di Parma, Italy, 10 April 2001.

- "Two loop QCD corrections to massless $2 \to 2$ scattering processes", Università di Torino, Italy, 9 April 2001.

- "Progress towards $2 \to 2$ scattering at NNLO: $q\overline{q} \to q'\overline{q}'$ and $q\overline{q} \to q\overline{q}$", Fermilab, Batavia, IL, USA, 7 December 2000.

- "Tensor reduction and master integrals of the two-loop crossed box", at *ACAT 2000*, Fermilab, Batavia, IL, USA, 16–20 October 2000.

- "One and two-loop scalar integrals using the negative-dimension approach", at *UK Phenomenology Workshop on Collider Physics*, Durham, UK, 19–24 September 1999.

- "Phenomenology and results in next-to-leading-log prompt-photon hadroproduction", at *UK Phenomenology Workshop on Collider Physics*, Durham, UK, 19–24 September 1999.

- "Sudakov resummation in prompt-photon hadroproduction", at *International Workshop QCDNET 99. 2nd European QCD-network Workshop*, Firenze, Italy, 15–18 September 1999.

- "Scalar one-loop integrals using the negative-dimension approach", at *International School of Subnuclear Physics*, Erice, Italy, 29 August–7 September 1999.

- "On the extraction of non-perturbative effects in the fragmentation functions of heavy quarks in e^+e^- annihilation", at *XXXIV Rencontres De Moriond*, Les Arcs, France, 20–27 March 1999.

- "Heavy-quark fragmentation functions in e^+e^- annihilation and hadronization effects", DAMTP, Cambridge, UK, 19 February 1999.

- "Heavy-quark fragmentation functions in e^+e^- annihilation and hadronization effects", DAMTP, Cambridge, UK, 19 February 1999.

- "Hadronization effects in the fragmentation function of e^+e^- into massive quarks", Rutherford Appleton Laboratory, Oxford, UK, 4 November 1998.

- "α_s^2 corrections to the production of heavy quarks" at *NaLep, X Meeting on LEP Physics*, Napoli, Italy, 15–17 April 1998.

- "Next-to-leading-order corrections of heavy-flavour jets in e^+e^- collisions and fragmentation functions" at *Heavy Flavour Working Group Meeting*, ETH-Hönggerberg, Zürich, Switzerland, 21–22 November 1997.

Research activity and interests

In the following, I present the historical evolution of my research career, from the oldest to the most recent subjects.

Heavy-quark production at e^+e^- colliders

At the beginning of LEP activity, and for a few years, the measured fraction of the Z boson decaying rate into a $b\bar{b}$ pair, over the total rate, was in slight disagreement with respect to the theoretical prediction. We investigated the effect and magnitude of a dynamical systematic error, coming from the correlation of single and double tagging of b quarks [97, 95, 93]. The error we found was a few per cent of the measured quantity, and, since the computation was performed up to order α_s^2, it could not justify the disagreement with the experimental value.

LEP performed so well that the precision at which several shape variables were measured reached a level that it was compelling to investigate the impact of mass power corrections, due to the presence of heavy quarks. This led us to compute the next-to-leading-order (NLO) differential cross section for the process $e^+e^- \to Z/\gamma \to Q\overline{Q}+X$, where Q is a heavy quark and we implemented it in a Monte Carlo generator [96, 93] that has been extensively used by the ALEPH, DELPHI and OPAL collaborations in the study of quark-mass effects at LEP.

We also proposed the definition of a new shape variable, with well-behaved perturbative expansion in α_s, that carries information on the angular and energy correlations between the two final b-quarks [65].

Heavy-quark fragmentation functions and hadronization

Every attempt to make a comparison between data and the computed fragmentation-function for the production of a heavy quark of mass m in the process $e^+e^- \to Z/\gamma \to Q+X$ has to face two additional problems: the presence of large logarithms of the ratio m/E, where E is the total center-of-mass energy, that can invalidate the perturbative expansion, and non-perturbative effects, due to the hadronization of the final massive quark into hadrons. To tackle the first issue, we resummed the large logarithms to all orders in perturbative QCD, and matched the resummed calculation to the fixed-order one [94], with the purpose of having a differential cross section valid for all possible values of the ratio m/E. We parametrized the effects of hadronization into a universal non-perturbative fragmentation function, that we extracted with fits to the D and B meson data, in e^+e^- annihilation [92, 91, 89, 70, 60, 59, 56]. The results we obtained were used in the fits of tagged charm-photoproduction data at HERA, in order to directly determine the gluon distribution function inside a proton.

Two-loop matrix elements in the scattering of $2 \to 2$ massless QCD partons

The comparison of experimental data with calculations at NLO has become a standard at the LHC. For several quantities, next-to-next-to-leading order (NNLO) accuracy is mandatory, and large efforts have been done, and are done, in order to reach this goal for several total and differential cross sections. One of the main ingredients for NNLO calculations are the virtual contributions computed, at least, at two loops.

In a series of pioneering papers, we showed that the two-loop $2 \to 2$ matrix elements for QCD scattering processes could be computed using recurrence relations obtained by integration-by-parts and Lorentz-invariance identities of the Feynman integrals, and reduced to scalar master integrals [88, 87, 85, 84, 83]. We could then compute the $\mathcal{O}\left(\alpha_s^4\right)$ contributions arising from the interference of two-loop and tree-level graphs for the QCD processes of quark-quark [82, 81, 80], quark-gluon [78] and gluon-gluon [77] scattering. These results are now part of fixed-order Monte Carlo generators for the study of dijets production at NNLO.

Higgs boson production in the SM and the MSSM

After the direct observation of the Higgs boson at the LHC, the measure of its quantum numbers and couplings (the gauge, Yukawa and self couplings as well as the charge, color, spin and CP properties) is of primary importance in order to confirm its role in the electroweak symmetry-breaking mechanism. It is then mandatory the study of the production channels, that allow the extraction of these properties (signal), and of the corresponding backgrounds, that can hide or mimic the signal itself.

Gluon fusion and vector-boson fusion (VBF) processes are the most copious sources of Higgs bosons in pp collisions at LHC. Due the crucial role of the measure of the HWW and HZZ couplings in the understanding of the electroweak symmetry-breaking mechanism, we computed the NLO corrections to Higgs boson production in vector-boson fusion [64, 61] and Higgs boson plus two jets, in gluon fusion, keeping the exact dependence on the top-quark mass [75, 74, 72, 71]. This last calculation turned out to be very challenging, since we had to compute one-loop Feynman diagrams with up to five massive propagators. We also computed limiting expressions of the exact one, for a Higgs boson centrally located in rapidity between the two jets, and very far from either jets, and for when it is close to one jet in rapidity, and both of these are very far from the other jet [68, 66].

We also produced results in the framework of the Minimal Supersymmetric Standard Model (MSSM) and studied the Higgs boson coupling to sbottom quark, running in the loops, and its interference with the SM contribution.

QCD corrections to single and multi-boson production via vector-boson fusion

Single and multi-boson final states are not only important *per se*, but also since they are background processes to Higgs boson production and to many new-physics scenarios. The knowledge of the differential cross sections for these processes need to be known with the highest possible accuracy.

For these reasons, we computed NLO QCD corrections to several vector-boson fusion processes:

- The production of W or Z bosons in association with two jets [63].
- $e^+\nu_e\,\mu^-\bar{\nu}_\mu$ + 2 jets [58], with all resonant and non-resonant Feynman diagrams and spin correlations of the final-state leptons included, in the phase-space regions which are dominated by t-channel electroweak-boson exchange.
- In refs. [57, 55], we considered the channels $W^+W^- \to ZZ$ and $ZZ \to ZZ$ as part of electroweak Z boson pair production in association with two tagging jets. We computed the NLO QCD corrections to the cross sections for $pp \to e^+e^-\,\mu^+\mu^- + 2$ jets and $pp \to e^+e^-\,\nu_\mu\bar{\nu}_\mu + 2$ jets via vector-boson fusion, up to order $\alpha_s\,\alpha^6$.
- In refs. [54, 52], we presented the calculation of the NLO QCD corrections to $pp \to e^+\nu_e\,\mu^+\mu^-$ + 2 jets and $pp \to e^-\bar{\nu}_e\,\mu^+\mu^-$ + 2 jets, final states of VBF W^+Z and W^-Z production, respectively, and in ref. [44] we provided results for W^+W^+jj and W^-W^-jj production too.
- QCD corrections to charged triple vector-boson production with leptonic decay $pp \to ZZW^\pm$ and $pp \to W^\pm W^\mp W^\pm$ were considered in refs. [48, 40, 39]. Triple vector-boson production processes are of particular interest because they are sensitive to quartic electroweak couplings and they are a Standard Model background for many new-physics searches, characterized by several leptons in the final state.

All these processes have been collected into a single program, `VBFNLO` [47, 30, 25], a fully-flexible NLO partonic generator for VBF physics, that is currently used in VBF studies.

NLO + parton shower Monte Carlo generators

The truncation of the perturbative series at next-to-leading or next-to-next-to-leading order yields the best available results for sufficiently inclusive observables, in kinematic regions where higher-order corrections are not enhanced (in this case, resummation techniques should be used). However, in many cases, a more exclusive description of final states and/or a wider kinematic coverage are needed.

For the description of exclusive hadronic final states, perturbative calculations have to be combined with a model for the conversion of partonic final states into hadrons. Existing hadronization models are in remarkably good agreement with a wide range of

data, after tuning of the model parameters. However, these models operate on partonic states with high multiplicity and low relative transverse momenta, which are obtained from a parton shower or dipole-cascade approximation to QCD dynamics and not from fixed-order calculations.

In the last decade, two successful algorithms, that consistently merge NLO calculations with parton-shower effects, were proposed and developed: `MC@NLO` and POWHEG. The POWHEG method (POsitive-Weight Hardest Emission Generator), proposed by P. Nason in 2004, was presented with full details in ref. [53], and further implemented in the `POWHEG BOX` code [38, 35]. Since then, the `POWHEG BOX` has become one of the main tools used by the experimental collaborations at the LHC for full shower simulations. The `POWHEG BOX` is an automatic tool that, given a few basic ingredients, turns a next-to-leading, fixed-order calculation, into a NLO + parton shower simulation.

A user can provide the Born, real and virtual contributions, or can benefits of three interfaces: to `MadGraph4` [27], that automatically builds the Born (with its spin and color-correlated amplitudes) and the real contributions, to `GoSam` [22], that builds the virtual terms, and to `OpenLoops` [12], with the possibility to compute electroweak (EW) NLO corrections too.

In addition, it allows for electromagnetic shower, for quick reweighting of events for simulations at different scales and with different parton distribution functions and it correctly deals with the production of radiation from resonances [12]. The current release of the code can run on a multi-core framework, so that the generation of events can be very fast.

Several processes, in the Standard Model and beyond, have been implemented in the `POWHEG BOX`, both by the original collaboration and by other independent groups. The ones to which I collaborated are the following:

- Single vector-boson production (W and Z) with decay [49]
- Single-top production in the s- and t-channel [43]
- Higgs boson production in gluon fusion [46]
- Higgs boson production in vector-boson fusion [42]
- Vector boson plus one jet production with decay (W/Z + 1 jet) [34]
- Jet pair production [33, 28, 23]
- $Wb\bar{b}$ production [31]
- Higgs boson production plus one and two jets [27]
- $HW^{\pm}/HZ$ + 0 and 1 jet [22]
- Three-jet production [19]
- $Wb\bar{b}j$ production [17]

- $t\bar{t}$ and Wt production and decay, including non-resonant and interference effects [12]. The correct treatment of the generation of radiation from resonance decay products requested a complete "restyling" of the `POWHEG BOX`, that now has become `POWHEG BOX RES`.

- NLO QCD+EW predictions for HV and HV + jet [10], where the virtual corrections are implemented both exactly and in the leading-log approximation, where only the leading and subleading contributions from electroweak Sudakov logarithms are retained.

Multi-scale Improved NLO and merging samples

Perturbative QCD calculations depend on unphysical renormalization and factorization scales through potentially large logarithmic corrections. Theoretical errors are usually estimated by varying the scales by a factor of 2 around their central values, often determined a posteriori. `MiNLO`, acronym of Multi-scale Improved NLO, gives a prescription on how to assign the factorization and renormalization scales, and on how to partially resum the large logarithmic terms into Sudakov form factors.

In ref. [24], we applied `MiNLO` to $H/W/Z$ + 1 jet production (Bj in short), and we investigated the accuracy of the results. We showed that, by slightly modifying the `MiNLO` procedure, we could have a result that is NLO accurate for inclusive B distributions and NLO accurate for inclusive B + 1 jet distributions, at the same time. We then managed to generate a sample of events with this extended accuracy, without the need of actually merging two different samples, and without the need of an unphysical merging scale.

In addition, we showed that we could generate the first sample with NNLO + parton shower accuracy, with little effort.

The same `MiNLO` modifications applied to Bj production were applied to HV + 1 jet [22], that allowed us to generate events with NLO accuracy both for inclusive HV production and for inclusive HV + 1 jet quantities.

We also applied `MiNLO` to $Wb\bar{b}j$ production [17], with massive final-state b quarks, and we performed a detailed comparison with the $Wb\bar{b}$ code and with up-to-date experimental results, since there are disagreements among different calculations, done in different approximations.

Top-mass studies

The abundant production of top pairs at the LHC provides an opportunity for detailed studies of top-quark properties, for tests of the Standard Model in the top sector, and for measurements of fundamental parameters such as the top-quark mass. With the Higgs boson mass now known with high precision, the W-boson and top-quark masses have become strongly correlated, and an accurate determination of both would lead to a SM test of unprecedented precision. It has been shown that in the Standard Model as is (i.e. assuming no new physics effects up to the Planck scale), the vacuum is stable

if the top mass is below 171 GeV (i.e. very close to its present value), metastable up to 176 GeV, and unstable above this value.

The top mass cannot be defined in terms of the mass distribution of the system of its decay products: since the top quark is a colored object, no final-state particle system can be unambiguously associated with it. On the other hand, the top mass is certainly related to the mass distribution of the system of objects arising from top decay, i.e. hard leptons, neutrinos and hard, b-flavoured hadronic jets. The mass distribution of this system can be computed and measured, and the top mass enters this computation as a parameter. By extracting its value from a fit to the measured distributions, we are unavoidably affected by theoretical errors that must be carefully assessed. In particular, these errors will depend upon the accuracy of the modelling of these distributions. For these reasons, we studied the theoretical uncertainties in the determination of the top-quark mass using next-to-leading-order generators interfaced to parton showers that have different levels of accuracy, and we found very different results depending upon the adopted shower model [9, 4].

We also studied the all-orders behavior and renormalon effects on top-mass observables. We found that the reconstructed mass is affected by linear renormalons in any renormalization mass scheme, and the total cross section, when selection cuts are introduced, is affected by jets-related linear renormalons in any mass scheme [7].

Reports and Proposals

I have contributed to several reports and proposals:

- ACAT and Snowmass reports:
  - Advanced computing and analysis techniques in physics research [73]
  - Physics at future hadron colliders, Snowmass [79]
- Les Houches reports:
  - Physics at TeV colliders. Proceedings, Euro Summer School, Les Houches, France [76]
  - Higgs working group: Summary Reports [69, 62, 50]
  - A Proposal for a standard interface between Monte Carlo tools and one-loop programs [41]
  - The SM and NLO Multileg Working Group: Summary report [37]
  - The SM and NLO Multileg and SM MC Working Groups: Summary Report [26]
  - The Tools and Monte Carlo working group Summary Report [36]
  - Update of the Binoth Les Houches Accord for a standard interface between Monte Carlo tools and one-loop programs [20]
  - 9th Les Houches Workshop on Physics at TeV Colliders (PhysTeV 2015) Les Houches, France, June 1-19, 2015 [14]

- LHC Higgs cross section handbooks:
  - Handbook of LHC Higgs Cross Sections: 1. Inclusive Observables [32]
  - Handbook of LHC Higgs Cross Sections: 2. Differential Distributions [29]
  - Handbook of LHC Higgs Cross Sections: 3. Higgs Properties [21]
  - Handbook of LHC Higgs Cross Sections: 4. Deciphering the Nature of the Higgs Sector [11]
- What Next reports:
  - What Next: White Paper of the INFN-CSN1 [15]
  - The Standard Model from the LHC to future colliders: a contribution to the Workshop "What Next" of INFN [16]
- Monte Carlo Community input to European Strategy Update
  - Monte Carlo event generators for high energy particle physics event simulation [6]
- Other reports
  - Physics at a 100 TeV pp collider: Standard Model processes [13]

List of publications

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Le dichiarazioni rese nel presente curriculum sono da ritenersi rilasciate ai sensi degli artt. 46 e 47 del D.P.R. 445/2000.

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