Curriculum Vitae et Studiorum

Name

Carlo Oleari

Date and place of birth

8 January 1966

Nationality

Italian

Address for correspondence

Dipartimento di Fisica "G. Occhialini"
Università di Milano-Bicocca
Piazza della Scienza, 3
20126 Milano
ITALY

e-mail: carlo.oleari@mib.infn.it
Tel. : +39-02-64482530
Fax. : +39-02-64482582

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

2014–present	From 1/10/2014, *"Professore Associato, settore concorsuale 02/A2 - fisica teorica delle interazioni fondamentali"* in the Department of Physics, University of Milano-Bicocca, Milan, Italy.
2006–2014	From 1/10/2006, *"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

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

2015–present	*Lecturer* in “Theory and phenomenology of the fundamental interactions” and “Elements of Theoretical Physics: Special Relativity and Advanced Quantum Mechanics”, undergraduate courses for the fourth- and third-year students in Physics, at the Università di Milano-Bicocca.
2014–2015	*Lecturer* in “Theory and phenomenology of the fundamental interactions” and “Advanced Quantum Field Theory”, undergraduate courses for the fourth-year students in Physics, at the Università di Milano-Bicocca.
2010–2014	*Lecturer* in “Theory and phenomenology of the fundamental interactions”, undergraduate course for the fourth-year students in Physics, at the Università di Milano-Bicocca.
2007–2010	*Lecturer* in “Quantum Mechanics”, undergraduate course for the third- and fourth-year students in Physics,at the Università di Milano-Bicocca.
2006–2013	*Lecturer/Teaching Assistant* in “Math for Physics”, undergraduate course for the second- and third-year students in Physics, at the Università di Milano-Bicocca.
2006–2010	*Lecturer* in “Introduction to Quantum Mechanics”, undergraduate course for the third-year students in Physics, at the Università di Milano-Bicocca.
2004–2006	*Lecturer* in “Fundamental interactions and the Standard Model: introduction to QCD”, graduate course for the Ph.D students, at the Università di Milano-Bicocca.
2002–2003	*Tutor* in the second-year courses in Physics, University of Durham.
1999–2000	*Tutor* in the third-year courses in Physics, University of Durham.
1994–1998	*Lecturer/Teaching Assistant* in “Fundamental Physics” (mechanics, thermodynamics, kinetic theory of gases, classical electrodynamics and optics), undergraduate course for the first- and second-year students of the Engineering Faculty, at Politecnico di Milano and Como (9 courses of 40 hours each).

Public lectures

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

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

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

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

Professional activities

2009–2014	Theory contact person of the "Higgs boson production in vector-boson fusion" working group in the *LHC Higgs Cross Section Working Group* project.
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.
2004–present	Organizer of the seminars for internal and external speakers in the Department of Physics, Università di Milano-Bicocca, Milan, Italy.
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's activities

I act as referee for the following journals:

- Journal of High Energy Physics
- Nuclear Physics B
- Physical Review D
- Physical Review Letters

Schools and conferences

- "Problemi attuali di Fisica Teorica", Cortona, Italy, 22–25 May 1996.
- "V Seminario Nazionale di Fisica Teorica", Parma, Italy, 2–13 September 1996.
- Visiting student in the Theory Division, CERN, Geneva, Switzerland, 1997.
- "Theory of LHC Processes Workshop", CERN, Geneva, Switzerland, 9–13 February 1998.
- "1$^{\text{st}}$ General Meeting of the Network on QCD and Particle Structure" and "3$^{\text{rd}}$ UK Phenomenology Workshop on Hera Physics", Durham, United Kingdom, 20–25 September 1998.
- "Annual UK Theory Winter Meeting", Rutherford Appleton Laboratory, Oxford, United Kingdom, 16–18 December 1998.
- "Standard Model Physics (and more) at the LHC", CERN, Geneva, Switzerland, 14–22 January 1999.
- "XXXIV Rencontres de Moriond. QCD and High Energy Hadronic Interactions", Les Arcs, France, 20–27 March 1999.
- "International School of Subnuclear Physics, 37$^{\text{th}}$ Course, Basics and Highlights in Fundamental Physics", Erice, Italy, 29 August–7 September 1999.
- "International Workshop QCDNET 99. 2$^{\text{nd}}$ European QCD-network Workshop", Firenze, Italy, 15–18 September 1999.
- "UK Phenomenology Workshop on Collider Physics", Durham, UK, 19–24 September 1999.
- "VII International Workshop on Advanced Computing and Analysis Techniques in Physics Research", Fermilab, Batavia, IL, USA, 16–20 October 2000.
- "Thinkshop^2: top-quark physics for Run II & beyond", Fermilab, Batavia, IL, USA, 10–12 November 2000.
- "Workshop on the Future of Higgs Physics", Fermilab, Batavia, IL, USA, 3–5 May 2001.
- "Pheno 2001 Symposium", Madison, WI, USA, 7–9 May 2001.
- Visitor at Fermilab, Batavia, IL, USA, with the summer visitor program, 21 May–3 June 2001.
- "Snowmass 2001: the Future of Particle Physics", Snowmass, CO, USA, 30 June–21 July 2001.
- "CTEQ Meeting", Argonne National Laboratory, Argonne, IL, USA, 26–27 October 2001.

- “XXXVII Rencontres de Moriond”, Les Arcs 1800, France, 16–23 March 2002.
- “IFAE 2002: Incontri sulla Fisica delle Alte Energie”, Parma, Italy, 3–5 April 2002.
- “Pheno 2002 Symposium”, Madison, WI, USA, 22–24 April 2002.
- “LoopFest”, Brookhaven National Laboratory, Upton, NY, USA, 9–10 May 2002.
- “Annual Theory Meeting”, Durham, UK, 16–18 December 2002.
- “Monte Carlo at Hadron Colliders Workshop”, Durham, UK, 14–17 January 2003.
- “Particle Physics 2003”, Durham, UK, 14–16 April 2003.
- “Workshop: Physics at TeV Colliders”, Les Houches, France, 26 May–6 June 2003.
- “CERN Workshop on Monte Carlo tools for the LHC”, CERN, Geneva, Switzerland, 7 July–2 August 2003.
- “Electroweak Radiative Corrections to Hadronic Observables at TeV Energies”, Durham, UK, 11–15 September 2003.
- “Annual Theory Meeting”, Durham, UK, 18–20 December 2003.
- “Collider Workshop 04”, Santa Barbara, CA, USA, 7 March–3 April 2004.
- “LoopFest III”, Santa Barbara, CA, USA, 1–3 April 2004.
- “IFAE 2004: Incontri sulla Fisica delle Alte Energie”, Torino, Italy, 14–16 April 2004.
- “DIS 2005”, Madison, WI, USA, 27 April–1 May 2005.
- “Pheno 2005 Symposium”, Madison, WI, USA, 2–4 May 2005.
- “Workshop: Physics at TeV Colliders”, Les Houches, France, 11–20 May 2005.
- “New Frontiers in Subnuclear Physics”, Milan, Italy, 12–17 September 2005.
- “Workshop sui Monte Carlo, la fisica e le simulazioni a LHC”, Frascati, Italy, 27–29 February 2006.
- “DIS 2006”, Tsukuba, Japan, 19–25 April 2006.
- “Workshop on Collider Physics”, Argonne National Laboratory, Argonne, IL, USA, 8–12 May 2006.
- “CTEQ Meeting”, Argonne National Laboratory, Argonne, IL, USA, 12 May 2006.
- “Pheno 2006 Symposium”, Madison, WI, USA, 15–17 May 2006.
- “Workshop sui Monte Carlo, la fisica e le simulazioni a LHC”, Frascati, Italy, 29–30 May 2006.

- “CTEQ School 2006”, Rhodes, Greece, 1–9 July 2006.
- “Workshop: high precision for hard processes at the LHC”, Zürich, Switzerland, 6–9 September 2006.
- “Workshop sui Monte Carlo, la fisica e le simulazioni a LHC”, Frascati, Italy, 23–25 October 2006.
- “IV Workshop Italiano sulla Fisica di ATLAS e CMS”, Bologna, Italy, 23–25 November 2006.
- “Fisica in ‘vivo’ ”, Milano, Italy, 13–14 March 2007.
- “Pheno 2007 Symposium”, Madison, WI, USA, 7–9 May 2007.
- “Physics at TeV Colliders”, Les Houches, France, 17–23 June 2007.
- “RADCOR07”, Firenze, Italy, 1–5 October 2007.
- “V workshop italiano sulla fisica *pp* ad LHC”, Perugia, Italy, 30 January–2 February 2008.
- “Pheno 2008 Symposium”, Madison, WI, USA, 28–30 April 2008.
- “GDR Supersymétrie”, LAL Orsay, Paris, FRANCE, 3–4 December 2008.
- “CMS Advanced Monte Carlo Use and Tuning Strategies”, CERN, Geneva, Switzerland, 15–16 December 2008.
- “Workshop on Higgs Boson Phenomenology”, Zürich, Switzerland, 7–9 January 2009.
- “IFAE 2009: Incontri sulla Fisica delle Alte Energie”, Bari, Italy, 15–17 April 2009.
- “Physics at TeV Colliders”, Les Houches, France, 8–26 June 2009.
- “SM and BSM physics at the LHC Search”, CERN, Geneva, Switzerland, 3–28 August 2009.
- “MC4LHC readiness”, CERN, Geneva, Switzerland, 29 March–1 April 2010.
- “1st LHC Higgs Cross Section Workshop”, Freiburg, Germany, 12-13 April 2010.
- “Loops and Legs in Quantum Field Theory”, Wörlitz. Berlin, Germany, 25-30 April 2010.
- “LoopFest IX”, Stony Brook University, NY, USA, 21-23 June 2010.
- “2nd LHC Higgs Cross Section Workshop”, CERN, Geneva, Switzerland, 5-6 July 2010.
- “3rd LHC Higgs Cross Section Workshop”, Bari, Italy, 4-5 November 2010.

- “ATLAS NLO MC mini-workshop”, CERN, Geneva, Switzerland, 30-31 March 2011.
- “Physics at TeV Colliders”, Les Houches, France, 30 May-8 June 2011.
- “The Th-LPCC summer Institute on LHC Physics”, CERN, Geneva, Switzerland, 8-13 August 2010.
- “NLO and parton showers miniworkshop”, CERN, Geneva, Switzerland, 27-28 February 2012.
- “Standard Model @ LHC 2012”, Copenhagen, Denmark, 10-13 April 2012.
- “6th LHC Higgs Cross Section Workshop”, CERN, Geneva, Switzerland, 24-25 May 2012.
- “Higgs Hunting 2012”, Orsay, France, 18-20 July 2012.
- “TH/LPCC Institute on SM at the LHC”, CERN, Geneva, Switzerland, 1-5 October 2012.
- “MC generators and future challenges, a joint ATLAS/CMS/LPCC workshop”, CERN, Geneva, Switzerland, 19-21 November 2012.
- “Particle physics in the LHC era”, Zürich, Switzerland, 7–9 January 2013.
- “VI Workshop Italiano sulla Fisica p-p a LHC”, Genova, Italy, 8–10 May 2013.
- “Physics at TeV Colliders”, Les Houches, France, 3 May-12 June 2013.
- “Atlas Higgs working group (N)NLO MC and tools workshop for LHC run 2”, CERN, Geneva, Switzerland, 16-17 December 2013.

Invited talks

- “Next-to-leading-order corrections of heavy-flavour jets in e^+e^- collisions and fragmentation functions” at *Heavy Flavour Working Group Meeting*, ETH-Höggerberg, Zürich, Switzerland, 21–22 November 1997.
- “α_s^2 corrections to the production of heavy quarks” at *NaLep, X Meeting on LEP Physics*, Napoli, Italy, 15–17 April 1998.
- “Hadronization effects in the fragmentation function of e^+e^- into massive quarks”, Rutherford Appleton Laboratory, Oxford, UK, 4 November 1998.
- “Heavy-quark fragmentation functions in e^+e^- annihilation and hadronization effects”, DAMTP, Cambridge, UK, 19 February 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.

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

- “Sudakov resummation in prompt-photon hadroproduction”, at *International Workshop QCDNET 99.* 2^{nd} *European QCD-network Workshop*, Firenze, Italy, 15–18 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.

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

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

- “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.

- “Two loop QCD corrections to massless $2 \to 2$ scattering processes”, Università di Torino, Italy, 9 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 Milano, Italy, 11 April 2001.

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

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

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

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

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

- “Higgs production plus two jets via gluon fusion: LHC and VLHC”, Brookhaven National Laboratory, Upton, NY, USA, 6 February 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.
- “Challenges in the calculation of NNLO scattering processes”, at *IFAE 2002: Incontri sulla Fisica delle Alte Energie*, Parma, Italy, 3–5 April 2002.
- “Next-to-next-to-leading order scattering processes: present and future”, at *LoopFest*, Brookhaven National Laboratory, Upton, NY, USA, 9–10 May 2002.
- “Higgs + 2 jets via gluon fusion: LHC and VLHC”, Università degli Studi, Milan, Italy, 19 December 2002.
- “Kinematical limits on Higgs boson production via gluon fusion in association with jets”, DESY-Theorie, Hamburg, Germany, 12 February 2003
- “Kinematical limits on Higgs boson production via gluon fusion in association with jets”, Oxford, UK, 6 March 2003
- “Higgs boson production via gluon fusion and weak-boson fusion: high-energy limits at LHC and VLHC”, Cambridge, UK, 13 May 2003
- “NLO corrections for Higgs boson production via weak-boson fusion”, Les Houches, France, 31 May 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.
- “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 to Higgs boson production via weak-boson fusion: signal and backgrounds”, Manchester, UK, 24 October 2003.
- “Higher order calculations in QCD”, *ATLAS plenary physics meeting*, CERN, Geneva, Switzerland, 26 February 2004.
- “QCD corrections to Higgs production: signal and backgrounds”, SLAC, Menlo Park, USA, 3 March 2004.
- “NLO QCD corrections to W and Z production via vector-boson fusion” at *LoopFest III*, Santa Barbara, CA, USA, 1 April 2004.
- “Higher order calculations in QCD”, at *IFAE 2004: Incontri sulla Fisica delle Alte Energie*, Torino, Italy, 14 April 2004.
- “Higher order calculations in QCD”, DAPNIA/SPP, CEA Saclay, France, 14 June 2004.
- “Higher order calculations in particle theory”, Universitaet Karlsruhe, Karlsruhe, Germany, 18 November 2004.

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

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

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

- “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 and di-boson production”, Università degli Studi, Bologna, Italy, 8 March 2006.

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

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

- “QCD corrections to Higgs and vector-boson production”, at *DIS 2006*, Tsukuba, Japan, 21 April 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 di-boson production”, at *Pheno 2006 Symposium*, Madison, WI, USA, 16 May 2006.

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

- “QCD for New Physics Discovery”, at the meeting “Fisica in ‘vivo’ ”,Milano, Italy, 13–14 March 2007.

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

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

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

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

- “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”, University of Wisconsin, Madison, WI, USA, 22 February 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”, NIKHEV, Amsterdam, The Netherlands, 4 April 2008.

- “Matching NLO Calculations with Parton Shower: the POsitive-Weight Hardest Emission Generator”, UCL, Louvain-la-Neuve, Belgium, 7 April 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”, Università degli Studi, Torino, Italy, 18 September 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”, at *GDR Supersymétrie*, LAL Orsay, Paris, France, 4 December 2008.

- “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.

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

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

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

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

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

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

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

- "Higgs boson production in VBF", at *1st LHC Higgs Cross Section Workshop*, Freiburg, Germany, 12-13 April 2010.
- "Shower Monte Carlo + NLO: POWHEG" at *Loops and Legs in Quantum Field Theory*, Wörlitz. Berlin, Germany, 26 April 2010.
- "POWHEG", Università degli Studi, Torino, Italy, 9 June 2010.
- "Shower Monte Carlo + NLO: POWHEG" at *LoopFest IX*, Stony Brook University, NY, USA, 21 June 2010.
- "Higgs boson production in POWHEG" at *ATLAS NLO MC mini-workshop* , CERN, Geneva, Switzerland, 31 March 2011.
- "The POWHEG BOX", at *Physics at TeV Colliders*, Les Houches, France, 12 June 2011. Les Houches, 3 June 2011.
- "Matching NLO Calculations with Parton Shower: the POWHEG generator", MPI, Munich, 31 January 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", Università Roma Tre, Roma, Italy, 21 June 2012
- "MC tools and NLO Monte Carlos", at *Higgs Hunting 2012*, Orsay, France, 18 July 2012.
- "Status and Future plans for POWHEG", at *MC generators and future challenges, a joint ATLAS/CMS/LPCC workshop*, CERN, Geneva, Switzerland, 19 November 2012.
- "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.
- "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.
- "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.
- "Recent developments in Monte Carlo tools for the LHC", Universitaet Mainz, Mainz, Germany, 26 June 2013.
- "HVJ and $gg \to HZ$ with the POWHEG BOX", CERN, Geneva, Switzerland, 18 December 2014.
- "Angular coefficients in Z and W production with the POWHEG BOX", CERN, Geneva, Switzerland, 24 February 2015.

- "VV + jets and the POWHEG BOX", at *Multi-Boson Interactions 2016*University of Wisconsin, Madison, WI, USA, 24 August 2016.
- "NLO QCD+EW corrections for HV and HV+jet in the POWHEG BOX RES", CERN, Geneva, Switzerland, 29 June 2017.
- "NLO QCD+EW corrections for HV and HV+jet in the POWHEG BOX RES", CERN, Geneva, Switzerland, 29 January 2018.

Research activity and interests

Power Corrections

In gauge theories in general, and in Quantum Chromodynamics (QCD) in particular, there are Feynman graphs whose value grows as the factorial of the order of the perturbative expansion in the strong coupling constant α_s: the so called renormalons. The resulting perturbative series is then divergent and, if one wants to give meaning to this series, one has to interpret it as an asymptotic expansion. As a consequence, there is an uncertainty in the value of the sum of the series which is of the order of (negative in QCD) powers of the energy scale E that governs the process. For example, at LEP I energies ($E \sim 90$ GeV), these terms affect the shape variables at the order of 1%, limiting the precision measurement of α_s.

P. Nason and I investigated the supposed universality of the power-correction terms in infra-red and collinear-safe shape variables. In the soft-radiation limit, the limit that gives rise to infrared renormalons in QCD, we demonstrated the equivalence of two shape variables: the C parameter and $\sin^2\eta$. In addition, we found that the squared invariant mass of the heavy jet, M_H^2, acquires a power-correction contribution enhanced by the presence of a logarithm of E. For this reason, this shape variable suffers from large non-perturbative corrections and it is not suited to be used in the extraction of α_s.

Heavy Quarks

The R_b problem, that is the discrepancy between the theoretical prediction and the measured value of the fraction of Z bosons that decay into a $b\bar{b}$ pair, challenged the physics community for some time. We [1, 2, 3] investigated the effect and magnitude of a dynamical systematic error, coming from the correlation of single and double tagging of b quarks. 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. More precision tests of the Standard Model performed at LEP subsequently gave a value for R_b in agreement with the theoretical value.

In addition, the sensitivity of such measurements reached a level that it was compelling to investigate the relevance of heavy-quark mass corrections in the determination of α_s from event shape variables. For this reason, we [2] computed 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. We produced a benchmark of values for some shape variables such as thrust, C parameter and the energy-energy correlation, and for the three-jet fractions according to the E, EM, JADE and DURHAM schemes, for a wide range of mass values [4]. The resulting Monte Carlo (MC) program has been extensively used by members of the ALEPH, DELPHI and OPAL Collaborations in the study of quark-mass effects at LEP.

Very recently, the SLD Collaboration has produced new data on the measurement of angle-dependent B-$\overline{B}$ energy correlations in $Z^0 \to b\bar{b}$ events. A Brandenburg, P. Nason and I [5] have introduced and defined a new shape variable that carries information on the angular and energy correlations between the two final b-quarks, and we have suggested the SLD Collaboration to measure the quantity described by this new variable. We have demonstrated that, in the definition of this shape variable, large logarithms of the ratio of the mass of the final quark over the centre-of-mass energy cancel out, so that this variable has a well-behaved perturbative expansion in α_s. We have studied the theoretical uncertainties due to the renormalization-scale dependence and the quark-mass definition and we have addressed the question of which mass definition should be used for this variable. In addition, we have produced some tables of our results that can be used in a fit to the data to measure α_s at next-to-leading order.

Heavy-Quark Fragmentation Function 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 appearance of potentially large logarithms of the form $\log(m/E)$, where E is the total center-of-mass energy. The presence of these large terms, multiplying the expansion coefficient of the perturbative series, α_s, may invalidate the expansion itself. In order to obtain reliable estimation of physical quantities, we resummed these large logarithms to all orders in perturbative QCD, and we matched the resummed calculation with the fixed-order one [6], in order to have a differential cross section that is valid both when $E \gg m$ and when $E \sim m$.

- the hadronization of the final massive quark (typically into D and B mesons), and in general all the low-energy phenomena that cannot be computed in a perturbative framework. It has become customary in the scientific literature to parametrize all these effects with a one- or more-parameter function (Peterson et al. function, Euler function, ...). Since we expect this function to be universal (it describes the last stage of hadron formation and it is then independent of the hard-scattering part of the reaction), it can be extracted from one process, such as e^+e^- annihilation, and used in another. In fact, our results [7, 8, 9] were used in the fitting of tagged charm-photoproduction data at HERA to directly determine the gluon distribution function inside a proton.

The more recent data for B production from the ALEPH and SLD Collaborations were fitted too, and, while showing a bad χ^2 for the one-parameter Peterson et al. function, they confirmed the fact that the contribution of non-perturbative effects is less important than in D-meson production [10].

In refs. [11, 12], we have compared the QCD theoretical predictions for heavy flavoured mesons fragmentation spectra in e^+e^- annihilation with data from CLEO, BELLE and LEP. We have included several effects in our calculation: next-to-leading order (NLO) initial conditions, evolution and coefficient functions. Soft-gluon effects are resummed at next-to-leading-log accuracy. A matching condition for the crossing of the bottom threshold in evolution is also implemented at next-to-leading order accuracy [13]. Important initial-state electromagnetic radiation effects in the CLEO and BELLE data have been accounted for.

Our findings can be summarized in the following:

- With reasonably simple choices of a non-perturbative correction to the fixed-order initial condition for the evolution, the data from CLEO and BELLE can be fitted with remarkable accuracy.
- The fitted fragmentation function, when evolved to LEP energies, does not however represent fairly the D^* fragmentation spectrum measured by ALEPH. Large non-perturbative corrections to the coefficient functions of the meson spectrum are needed in order to reconcile CLEO/BELLE and ALEPH results.
- We have tabulated the non-perturbative parameters extracted from the fits to e^+e^- fragmentation data for D/D^* and B mesons, so that they can be employed in the theoretical predictions for the production of charmed and bottomed mesons in hadron-hadron, photon-hadron and photon-photon collisions.

Sudakov Resummation in Prompt-Photon Hadroproduction

Prompt-photon production in fixed-target experiments is our main source of information on the gluon parton density at large x, the fraction of energy carried by the initial parton. This same region is relevant for hadron colliders in production phenomena at very high transverse momenta, and thus its understanding is crucial in order to disentangle possible signals of new physics from the QCD background.

For example, a particularly interesting problem emerged in the past few years in the production of high-transverse-energy (E_T) jets at the Tevatron. An excess over the QCD prediction has been reported by the CDF collaboration, for jets with $E_T \gtrsim 350$ GeV. Both jet cross sections and direct-photon cross sections at high transverse energy are affected by soft-gluon effects. In both cases, these effects should be understood in order to be able to claim a discrepancy with QCD predictions. In particular, these effects can be very important in the direct-photon case, since the typical E_T values probed are much smaller than in the case of jet production at the Tevatron, and therefore the size of the running coupling α_s at the relevant scales is bigger.

S. Catani, M.L. Mangano, P. Nason, W. Vogelsang and I [14, 15] computed some phenomenological effects of soft-gluon resummation, at next-to-leading-log level, in the fixed-target hadroproduction cross-section for prompt photons, and we made a comparison with the data collected by the E706 and UA6 Collaborations. While the agreement of the resummed cross section with the data is not yet satisfactory, the tendency of the resummed cross section is to get closer to the measured data, giving a better χ^2.

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

Accurate perturbative calculations beyond leading order in QCD are an important ingredient in improving our understanding of jet production in current and future high-energy collider experiments at the Tevatron, at Fermilab, and at the Large Hadron Collider (LHC), at CERN. At present, next-to-leading order calculations have become standard and are used to make comparisons with experimental data.

To date, these comparisons have been limited by both experimental and theoretical uncertainties at the 10% level. However, improvements in detector technology, as well as the expected large increases in the luminosity of the colliding particles, should significantly improve the quality of the experimental data and will require more accurate theoretical calculations either to claim new physics or to refine our understanding of the Standard Model (SM).

The theoretical prediction may be improved by including the next-to-next-to-leading order (NNLO) perturbative contributions. There are several reasons for why this step is vital in reducing the theoretical uncertainties:

- the dependence from the unphysical renormalization and factorization scales is going to be reduced;
- the presence of an additional hard parton gives rise to better matching between the partonic and the hadronic final state;
- double radiation from one of the incoming partons or single radiation from both of the two incoming partons creates more complicated transverse-momentum patterns for the final state partons, and may provide a better and more theoretically motivated description of the data, without the need of an intrinsic transverse momentum for the parton in the incoming hadron;
- the need of power correction contributions to event shape variables is going to be reduced, since part of the $1/E$ contributions (where E is the high energy scale of the process) will be taken into account by the NNLO term.

The full NNLO prediction for $2 \to 2$ QCD scattering processes requires the knowledge of the two-loop $2 \to 2$ matrix elements as well as the contributions from the one-loop $2 \to 3$ and tree-level $2 \to 4$ processes. At large transverse energies, $E_T \gg m_{\text{quark}}$, the quark masses may be safely neglected and we, therefore, focus on the scattering of massless partons.

Techniques for computing multi-particle tree amplitudes for $2 \to 4$ processes, and the one-loop $2 \to 3$ parton processes are well understood, and for many QCD processes they are known and available.

The evaluation of the two-loop $2 \to 2$ contributions for QCD processes has been a challenge for the past few years [16]. This was mainly due to a lack of knowledge about planar and crossed double-box integrals that arise at two loops, from the point of view of both the tensor reduction and the analytic evaluation of the corresponding master integrals.

In fact, it is well known in the literature that tensor integrals can be related to scalar integrals with higher powers of the propagators in higher space-time dimension D. The problem is then moved to the computation of generic scalar integrals and the goal is to express them in terms of a finite set of master integrals, whose analytic expression as a function of the kinematic variables of the process and of the dimension D is known.

C. Anastasiou, E.W.N. Glover and I [17], using recurrence relations obtained by integration-by-parts identities, reduced the topology called pentabox to simpler ones, and we gave the analytic expression of these integrals. These master integrals were computed with the quite recent negative-dimension method [18, 19] that was used to study massive one-loop integrals by analytically continuing the Feynman integral to negative dimensions and to negative powers of the propagators. In this way, we obtained the general solutions for massless one-loop box integrals with zero or one massive external leg and with arbitrary powers of propagators and we evaluated the two-loop box integrals which are one-loop insertions to one-loop box graphs.

A more challenging problem was the derivation of the reduction procedure for the two-loop crossed box with light-like external legs and the evaluation of the corresponding master integrals [20, 21]. This problem was the unresolved issue in the tensor reduction of matrix elements for two-loop $2 \to 2$ scattering processes. We made use of recurrence relations obtained by integration-by-parts and Lorentz-invariance identities to express integrals with different powers of the propagators as a function of two master crossed boxes, plus simpler topologies. We explicitly gave the equations that relate the two master integrals in different dimensions and the analytic expansion in terms of $\epsilon = (4-D)/2$ of the missing master integral.

All the ingredients for the computation of physical matrix elements for QCD massless partons in $2 \to 2$ scattering were then available.

Furthering the pioneering work of Z. Bern, L.J. Dixon and A. Ghinculov, who completed the two-loop calculation of physical $2 \to 2$ scattering amplitudes for the QED processes $e^+e^- \to \mu^+\mu^-$ and $e^+e^- \to e^+e^-$, we studied 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 [22, 23, 24], quark-gluon [25] and gluon-gluon [26] scattering.

In these papers, we presented analytic expressions for the infrared pole structure (that ultimately cancels against contributions from the $2 \to 3$ and $2 \to 4$ processes), which agrees with that anticipated by S. Catani, as well as the finite remainder of the amplitudes squared. The matrix elements were renormalized in the $\overline{\mathrm{MS}}$ scheme, and we performed the calculation using the conventional dimensional regularization, treating the external particles in D dimensions, with 2 degrees of freedom for fermions and $D-2$ degrees of freedom for gluons.

Electroweak Symmetry Breaking and Higgs boson

The LHC is generally regarded as the collider that will enable the direct observation of the Higgs boson, the remnant of the mechanism believed responsible for electroweak symmetry breaking and fermion-mass generation, and the last unobserved particle of the Standard Model.

Furthermore, the LHC promises complete coverage of Higgs boson-decay scenarios, including general Minimal Supersymmetric Standard Model (MSSM) parameterizations, and even invisible Higgs boson decays.

Observation of a resonance in some expected decay channel is, however, only the beginning of Higgs boson physics. Continuing efforts will include the search for more than one Higgs boson, as predicted e.g. by the two-Higgs doublet models, of which the MSSM is a subset. At least as important as the discovery, is the detailed study of the properties of the Higgs-like resonance: determination of all the quantum numbers and couplings of the state. These include the gauge, Yukawa and self couplings as well as the charge, color, spin and CP quantum numbers.

It is then of primary importance the study of the production channels that allow the extraction of these properties (signal) and of the relative background that can hide or mimic the signal itself.

Gluon fusion and weak-boson fusion (WBF) are expected to be the most copious sources of Higgs bosons in pp collisions at LHC. Weak-boson fusion, $qq \to qqH$ via t channel W or Z exchange, characterized by two forward quark jets, has very small QCD radiative corrections. T. Figy, D. Zeppenfeld and I [27, 28] have computed these NLO corrections and we have shown that, for jet distributions, they are of the order of 5 to 10% in most cases, but reaching 30% occasionally. The remaining scale uncertainties range from the order of 5% or less for distributions to below $\pm 2\%$ for the Higgs boson cross section in typical weak-boson fusion search regions. We have implemented a fully-flexible partonic Monte Carlo program, that can be easily interfaced with a LO hadronic Monte Carlo, like the recent version of `HERWIG`.

Since the NLO QCD corrections are modest, not only when considering inclusive quantities, but also when considering jet distributions, Higgs boson production in WBF is an ideal place for the extraction of HWW and HZZ couplings.

On the other hand, NLO QCD corrections to the inclusive gluon-fusion cross section are known to be large. Because the lowest-order process is loop induced, a full NNLO calculation would entail a three-loop computation, which presently is not feasible. In the intermediate Higgs-mass range, which is favored by the present electroweak precision data, the Higgs boson mass m_H is small compared to the top-quark (m_t) pair threshold and the large-m_t limit promises to be an adequate approximation.

The production of a Higgs boson accompanied by two jets via gluon fusion, while part of the inclusive Higgs boson signal, constitutes a background when trying to isolate the HWW and HZZ couplings in the WBF process. A precise description of this background is needed in order to separate the two major sources of $H + 2$ jet events. In addition, one has to find characteristic distributions and the relative cuts to apply, in order to distinguish between the WBF contribution and the gluon fusion one.

To derive these cuts and to assess the validity of the $m_t \to \infty$ limit, we computed the gluon-fusion cross section, including all finite m_t corrections, coming from top-quark triangle-, box- and pentagon-loop diagrams in an analytic framework [29, 30, 31, 32]. We studied the renormalization- and factorization-scale dependence of the resulting $H + 2$ jet cross section, and we discussed phenomenologically important distributions at the LHC. As expected, the large-m_t limit provides an excellent approximation to the full m_t dependence only when the Higgs boson mass is small compared to the top-pair threshold. The large-m_t limit is found to break down for $m_H > m_t$ and when jet transverse momenta become large ($p_{Tj} \gtrsim m_t$). However, large dijet invariant masses do not invalidate the $m_t \to \infty$ limit as long as the Higgs boson mass and the jet transverse momenta are less than the top-quark mass.

Another interesting limit that we have investigated is the high-energy limit, reached in two different configurations: (a) when the Higgs boson is centrally located in rapidity between the two jets, and very far from either jets and (b) when the Higgs boson is close to one jet in rapidity, and both of these are very far from the other jet [33, 34]. In both cases the amplitudes factorize into impact factors or coefficient functions connected by gluons exchanged in the t channel. Accordingly, we computed the coefficient functions for the production of a Higgs boson from two off-shell gluons, and the impact factors for the production of a Higgs boson in association with a gluon or a quark jet, including the full top-quark mass dependence.

We have found good agreement between the exact calculation, in the high-energy regime, and the approximated expressions built using the simpler form factors.

Up to date, the $m_t \to \infty$ and the high-energy limits are the only two approximations that could be used to extend the leading order calculation (it is a leading-order calculation, even if it is a one-loop one) to a NLO level. In fact, the exact NLO calculation for Higgs boson plus two jets via gluon fusion is nowadays unfeasible, having to deal two-loop diagrams not yet evaluated in the literature.

MSSM and Higgs Boson Production

We are now working on the extension of the $H + 2$ jet calculation to the Minimal Supersymmetric Standard Model (MSSM). Most of the work has been devoted to the calculation of the sfermion contribution running in the pentagon, box and triangle loops that appear at leading order in the Higgs boson plus two jet production. The substitution of the fermion in the loop with a sfermion (scalar particle) does not introduce any tensor structure in the numerator of the loop integrals or any color structure not already present in the SM case. In fact, while now the sfermionic propagator does not carry any tensor structure, the vertex squark-antisquark-gluon carries a tensor structure linearly dependent on the loop momentum.

For this reason, we have used the same procedure outlined in ref. [30] to express the full MSSM amplitude in terms of finite scalar pentagons, boxes, triangles and of the finite part of self-energy integrals.

Our final goal is to combine the SM result with the MSSM one and to compute distributions and cross sections in different regions of the parameter space, to establish the relevance of the MSSM contribution with respect to the SM one. In fact, Higgs boson coupling to sbottom quark may be enhanced by a $\tan\beta$ factor (the ratio of the two vacuum expectation values) and could give rise to a sizable contribution to the SM one.

QCD corrections to multiple boson production via vector-boson fusion

In order to measure all the properties of the Higgs boson, a detailed knowledge of both the signal and the background processes has to be achieved.

- The production of W or Z bosons in association with two jets is an important background to the Higgs boson search in vector-boson fusion (VBF) at the LHC. The purely electroweak component of this background is dominated by vector-boson fusion, which exhibits kinematical distributions very similar to the Higgs boson signal. In addition, these processes are important since one would like to exploit W and Z production via VBF as calibrating processes for Higgs boson production, namely as a tool to understand the tagging of forward jets or the distribution and veto of additional central-jet activity. The precision needed for Higgs boson studies then requires the knowledge of NLO QCD corrections for Wjj and Zjj production as well. D. Zeppenfeld and I [35] have computed these corrections to W and Z boson production via vector-boson fusion and we have shown that the QCD corrections are modest, increasing the total cross sections by about 10%. Remaining scale uncertainties are below 2%. Corrections of the order of a few percent have been found for distributions too.

- Together with single vector-boson production, pair production too forms an irreducible background for VBF Higgs searches.

  - In ref. [36], we have consider what is commonly referred to as W^+W^- production via vector-boson fusion (with subsequent leptonic decay of the W's), or, more precisely, $e^+\nu_e\, \mu^-\bar{\nu}_\mu + 2$ jets production in proton-proton scattering, 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. We have computed the next-to-leading order QCD corrections to this process, at order $\alpha^6\alpha_s$. The QCD corrections that we have found are modest, changing total cross sections by less than 10%. Remaining scale uncertainties are below 2%.
  - In addition, vector-boson fusion processes allow to distinguish a light Higgs boson scenario from strong weak-boson scattering. In refs. [37, 38], we have then 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 have 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 at order $\alpha_s\,\alpha^6$. The corrections to the integrated cross sections were found to be modest, while the shapes of some kinematical distributions change appreciably at NLO. Residual scale uncertainties typically are at the few percent level.
  - Finally, in refs. [39, 40], we have completed 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. [41] we have 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 $pp \to W^\pm W^\mp W^\pm$ have been considered in [42, 43, 44]. 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, called `VBFNLO` [45, 46, 47], that provides a fully-flexible next-to-leading order partonic simulation, with the possibility to interface the LO order results to a shower Monte Carlo generator, producing events at the hadron level.

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 (hadronization). 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 have been 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. [48], and further implemented in the `POWHEG BOX` code [49, 50]. 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 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 two interfaces: to `MadGraph4` [51], that automatically builds the Born (with its spin and color-correlated amplitudes) and the real contributions, and to `GoSam` [52], that builds the virtual term.

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 resonances. 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 from other independent groups. The ones to which I collaborated are the following:

- Single vector-boson production (W and Z) with decay [53]
- Single-top production in the s- and t-channel [54]
- Higgs boson production in gluon fusion [55]
- Higgs boson production in vector-boson fusion [56]
- Vector boson plus one jet production with decay (W/Z + 1 jet) [57]
- Jet pair production [58, 59, 60]
- $Wb\bar{b}$ production [61]
- Higgs boson production plus one and two jets [51]
- $HW^{\pm}/HZ$ + 0 and 1 jet [52]
- Three-jet production [62]
- $t\bar{t}$ and Wt production and decay including non-resonant and interference effects [63]

- NLO QCD+EW predictions for HV and HV +jet production including parton-shower effects [64]

- NLO QCD+EW predictions for HV and HV +jet production including parton-shower effects [64]

- A theoretical study of top-mass measurements at the LHC using NLO+PS generators of increasing accuracy [65]

Multi-scale Improved NLO and merging samples

Perturbative QCD calculations depend on unphysical renormalization and factorization scales through potentially large logarithmic corrections. In addition, 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. [66], we have applied `MiNLO` to $H/W/Z$ + 1 jet production (Bj in short), and we have investigated the accuracy of the results. We have shown 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 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 have been applied to HV + 1 jet [52], that allowed us to produce a sample with NLO accuracy both for inclusive HV production and for inclusive HV + 1 jet quantities.

We have also applied `MiNLO` to $Wb\bar{b}j$ production [67], with massive final-state b quarks, and where we have performed a detailed c omparison with the $Wb\bar{b}$ code and with up-to-date experimental results.

Reports and Proposals

I have contributed to several reports and proposals:

- ACAT and Snowmass reports:
  - Advanced computing and analysis techniques in physics research [68]
  - Physics at future hadron colliders, Snowmass [69]
- Les Houches reports:
  - Physics at TeV colliders. Proceedings, Euro Summer School, Les Houches, France [70]

  - Higgs working group: Summary Reports [71, 72, 73]
  - A Proposal for a standard interface between Monte Carlo tools and one-loop programs [74]
  - The SM and NLO Multileg Working Group: Summary report [75]
  - The SM and NLO Multileg and SM MC Working Groups: Summary Report [76]
  - The Tools and Monte Carlo working group Summary Report [77]
  - Update of the Binoth Les Houches Accord for a standard interface between Monte Carlo tools and one-loop programs [78]
  - 9th Les Houches Workshop on Physics at TeV Colliders (PhysTeV 2015) Les Houches, France, June 1-19, 2015 [79]

- LHC Higgs cross section handbooks:
  - Handbook of LHC Higgs Cross Sections: 1. Inclusive Observables [80]
  - Handbook of LHC Higgs Cross Sections: 2. Differential Distributions [81]
  - Handbook of LHC Higgs Cross Sections: 3. Higgs Properties [82]
  - Handbook of LHC Higgs Cross Sections: 4. Deciphering the Nature of the Higgs Sector [83]

- What Next reports:
  - What Next: White Paper of the INFN-CSN1 [84]
  - The Standard Model from the LHC to future colliders: a contribution to the Workshop "What Next" of INFN [85]

- Other reports
  - Physics at a 100 TeV *pp* collider: Standard Model processes [86]

List of publications

[1] P. Nason and C. Oleari, *Momentum correlations in $Z^0 \to b\bar{b}$ and the measurement of R_b^0*, *Phys.Lett.* **B387** (1996) 623–628, [hep-ph/9607347].

[2] P. Nason and C. Oleari, *Next-to-leading order corrections to the production of heavy flavor jets in e^+e^- collisions*, *Nucl.Phys.* **B521** (1998) 237–273, [hep-ph/9709360].

[3] P. Nason and C. Oleari, *Next-to-leading order corrections to momentum correlations in $Z^0 \to b\bar{b}$*, *Phys.Lett.* **B407** (1997) 57–60, [hep-ph/9705295].

[4] C. Oleari, *Next-to-leading order corrections to the production of heavy flavor jets in e^+e^- collisions*, hep-ph/9802431.

[5] A. Brandenburg, P. Nason, and C. Oleari, *On a possible measurement of α_S from $B\bar{B}$ correlations in Z^0 decay*, *Nucl.Phys.* **B667** (2003) 394–410, [hep-ph/0304272].

[6] P. Nason and C. Oleari, *On the fragmentation function for heavy quarks in e^+e^- collisions*, *Phys.Lett.* **B418** (1998) 199–208, [hep-ph/9709358].

[7] P. Nason and C. Oleari, *A Fixed order calculation of the heavy quark fragmentation function in e^+e^- collisions*, *Phys.Lett.* **B447** (1999) 327–330, [hep-ph/9811206].

[8] P. Nason and C. Oleari, *A Phenomenological study of heavy quark fragmentation functions in e^+e^- annihilation*, *Nucl.Phys.* **B565** (2000) 245–266, [hep-ph/9903541].

[9] C. Oleari, *On the extraction of nonperturbative effects in the fragmentation functions of heavy quarks in e^+e^- annihilation*, hep-ph/9905344.

[10] K. Anikeev, D. Atwood, F. Azfar, S. Bailey, C. Bauer, *et. al.*, *B physics at the Tevatron: Run II and beyond*, hep-ph/0201071.

[11] M. Cacciari, P. Nason, and C. Oleari, *A Study of heavy flavored meson fragmentation functions in e^+e^- annihilation*, *JHEP* **0604** (2006) 006, [hep-ph/0510032].

[12] M. Cacciari, P. Nason, and C. Oleari, *Power-suppressed effects in heavy quark fragmentation functions*, *eConf* **C0601121** (2006) E005, [hep-ph/0607022].

[13] M. Cacciari, P. Nason, and C. Oleari, *Crossing heavy-flavor thresholds in fragmentation functions*, *JHEP* **0510** (2005) 034, [hep-ph/0504192].

[14] S. Catani, M. L. Mangano, P. Nason, C. Oleari, and W. Vogelsang, *Sudakov resummation effects in prompt photon hadroproduction*, *JHEP* **9903** (1999) 025, [hep-ph/9903436].

[15] C. Oleari, *Results in next-to-leading log prompt photon hadroproduction*, *J.Phys.* **G26** (2000) 627–630, [hep-ph/9912206].

[16] C. Oleari, *Challenges in the calculation of next-to-next-to-leading order scattering processes*, hep-ph/0205184.

[17] C. Anastasiou, E. N. Glover, and C. Oleari, *The two loop scalar and tensor pentabox graph with lightlike legs*, *Nucl.Phys.* **B575** (2000) 416–436, [hep-ph/9912251].

[18] C. Anastasiou, E. N. Glover, and C. Oleari, *Scalar one loop integrals using the negative dimension approach*, *Nucl.Phys.* **B572** (2000) 307–360, [hep-ph/9907494].

[19] C. Anastasiou, E. N. Glover, and C. Oleari, *Application of the negative dimension approach to massless scalar box integrals*, *Nucl.Phys.* **B565** (2000) 445–467, [hep-ph/9907523].

[20] C. Anastasiou, T. Gehrmann, C. Oleari, E. Remiddi, and J. Tausk, *The Tensor reduction and master integrals of the two loop massless crossed box with lightlike legs*, *Nucl.Phys.* **B580** (2000) 577–601, [hep-ph/0003261].

[21] C. Oleari, *The Tensor reduction and master integrals of the two loop massless crossed box*, hep-ph/0011384.

[22] C. Anastasiou, E. N. Glover, C. Oleari, and M. Tejeda-Yeomans, *Two-loop QCD corrections to the scattering of massless distinct quarks*, *Nucl.Phys.* **B601** (2001) 318–340, [hep-ph/0010212].

[23] C. Anastasiou, E. N. Glover, C. Oleari, and M. Tejeda-Yeomans, *Two loop QCD corrections to massless identical quark scattering*, *Nucl.Phys.* **B601** (2001) 341–360, [hep-ph/0011094].

[24] C. Anastasiou, E. N. Glover, C. Oleari, and M. Tejeda-Yeomans, *One loop QCD corrections to quark scattering at NNLO*, *Phys.Lett.* **B506** (2001) 59–67, [hep-ph/0012007].

[25] C. Anastasiou, E. N. Glover, C. Oleari, and M. Tejeda-Yeomans, *Two loop QCD corrections to massless quark gluon scattering*, *Nucl.Phys.* **B605** (2001) 486–516, [hep-ph/0101304].

[26] E. N. Glover, C. Oleari, and M. Tejeda-Yeomans, *Two loop QCD corrections to gluon-gluon scattering*, *Nucl.Phys.* **B605** (2001) 467–485, [hep-ph/0102201].

[27] T. Figy, C. Oleari, and D. Zeppenfeld, *Next-to-leading order jet distributions for Higgs boson production via weak boson fusion*, *Phys.Rev.* **D68** (2003) 073005, [hep-ph/0306109].

[28] T. Figy, C. Oleari, and D. Zeppenfeld, *QCD corrections to vector boson fusion processes*, *Nucl.Phys.Proc.Suppl.* **135** (2004) 9–13, [hep-ph/0407066].

[29] V. Del Duca, W. Kilgore, C. Oleari, C. Schmidt, and D. Zeppenfeld, *Higgs + 2 jets via gluon fusion*, *Phys.Rev.Lett.* **87** (2001) 122001, [hep-ph/0105129].

[30] V. Del Duca, W. Kilgore, C. Oleari, C. Schmidt, and D. Zeppenfeld, *Gluon fusion contributions to H + 2 jet production*, *Nucl.Phys.* **B616** (2001) 367–399, [hep-ph/0108030].

[31] V. Del Duca, W. Kilgore, C. Oleari, C. Schmidt, and D. Zeppenfeld, *Higgs production plus two jets at hadron colliders*, *PoS* **HEP2001** (2001) 133, [hep-ph/0109147].

[32] C. Oleari and D. Zeppenfeld, *Higgs plus two jet production at LHC and VLHC*, *eConf* **C010630** (2001) E404, [hep-ph/0110338].

[33] V. Del Duca, W. Kilgore, C. Oleari, C. Schmidt, and D. Zeppenfeld, *The High-energy limit of H+2 jet production via gluon fusion*, hep-ph/0203156.

[34] V. Del Duca, W. Kilgore, C. Oleari, C. Schmidt, and D. Zeppenfeld, *Kinematical limits on Higgs boson production via gluon fusion in association with jets*, *Phys.Rev.* **D67** (2003) 073003, [hep-ph/0301013].

[35] C. Oleari and D. Zeppenfeld, *QCD corrections to electroweak $\ell\nu_\ell jj$ and $\ell^+\ell^- jj$ production*, *Phys.Rev.* **D69** (2004) 093004, [hep-ph/0310156].

[36] B. Jager, C. Oleari, and D. Zeppenfeld, *Next-to-leading order QCD corrections to W^+W^- production via vector-boson fusion*, *JHEP* **0607** (2006) 015, [hep-ph/0603177].

[37] B. Jager, C. Oleari, and D. Zeppenfeld, *Next-to-leading order QCD corrections to Z boson pair production via vector-boson fusion*, *Phys.Rev.* **D73** (2006) 113006, [hep-ph/0604200].

[38] B. Jager, D. Zeppenfeld, and C. Oleari, *QCD corrections to vector boson pair production via weak boson fusion*, *Acta Phys.Polon.* **B38** (2007) 797–804, [hep-ph/0608272].

[39] G. Bozzi, B. Jager, C. Oleari, and D. Zeppenfeld, *Next-to-leading order QCD corrections to W^+Z and W^-Z production via vector-boson fusion*, *Phys.Rev.* **D75** (2007) 073004, [hep-ph/0701105].

[40] G. Bozzi, B. Jager, C. Oleari, and D. Zeppenfeld, *Vector boson pair production via vector boson fusion at NLO QCD*, *J.Phys.Conf.Ser.* **110** (2008) 042006, [arXiv:0710.1572].

[41] B. Jager, C. Oleari, and D. Zeppenfeld, *Next-to-leading order QCD corrections to W^+W^+jj and W^-W^-jj production via weak-boson fusion*, *Phys.Rev.* **D80** (2009) 034022, [arXiv:0907.0580].

[42] F. Campanario, V. Hankele, C. Oleari, S. Prestel, and D. Zeppenfeld, *QCD corrections to charged triple vector boson production with leptonic decay*, *Phys.Rev.* **D78** (2008) 094012, [arXiv:0809.0790].

[43] B. Jager, G. Bozzi, C. Englert, D. Zeppenfeld, C. Oleari, *et. al.*, *Weak boson scattering at the Large Hadron Collider*, *PoS* **RADCOR2009** (2010) 057, [arXiv:1001.2649].

[44] D. Zeppenfeld, G. Bozzi, F. Campanario, C. Englert, V. Hankele, *et. al.*, *NLO QCD corrections to processes with multiple electroweak bosons*, *PoS* **RADCOR2009** (2010) 017, [arXiv:1002.0292].

[45] K. Arnold, M. Bahr, G. Bozzi, F. Campanario, C. Englert, *et. al.*, *VBFNLO: A Parton level Monte Carlo for processes with electroweak bosons*, *Comput.Phys.Commun.* **180** (2009) 1661–1670, [arXiv:0811.4559].

[46] K. Arnold, J. Bellm, G. Bozzi, M. Brieg, F. Campanario, *et. al.*, *VBFNLO: A Parton Level Monte Carlo for Processes with Electroweak Bosons – Manual for Version 2.5.0*, arXiv:1107.4038.

[47] K. Arnold, J. Bellm, G. Bozzi, F. Campanario, C. Englert, *et. al.*, *Release Note – Vbfnlo-2.6.0*, arXiv:1207.4975.

[48] S. Frixione, P. Nason, and C. Oleari, *Matching NLO QCD computations with parton shower simulations: the POWHEG method*, *JHEP* **0711** (2007) 070, [arXiv:0709.2092].

[49] S. Alioli, P. Nason, C. Oleari, and E. Re, *A general framework for implementing NLO calculations in shower Monte Carlo programs: the POWHEG BOX*, *JHEP* **1006** (2010) 043, [arXiv:1002.2581].

[50] C. Oleari, *The POWHEG-BOX*, *Nucl.Phys.Proc.Suppl.* **205-206** (2010) 36–41, [arXiv:1007.3893].

[51] J. M. Campbell, R. K. Ellis, R. Frederix, P. Nason, C. Oleari, *et. al.*, *NLO Higgs boson production plus one and two jets using the POWHEG BOX, MadGraph4 and MCFM*, *JHEP* **1207** (2012) 092, [arXiv:1202.5475].

[52] G. Luisoni, P. Nason, C. Oleari, and F. Tramontano, *$HW^{\pm}/HZ$ + 0 and 1 jet at NLO with the POWHEG BOX interfaced to GoSam and their merging within MiNLO*, *JHEP* **1310** (2013) 083, [arXiv:1306.2542].

[53] S. Alioli, P. Nason, C. Oleari, and E. Re, *NLO vector-boson production matched with shower in POWHEG*, *JHEP* **0807** (2008) 060, [arXiv:0805.4802].

[54] S. Alioli, P. Nason, C. Oleari, and E. Re, *NLO single-top production matched with shower in POWHEG: s- and t-channel contributions*, *JHEP* **0909** (2009) 111, [arXiv:0907.4076].

[55] S. Alioli, P. Nason, C. Oleari, and E. Re, *NLO Higgs boson production via gluon fusion matched with shower in POWHEG*, *JHEP* **0904** (2009) 002, [arXiv:0812.0578].

[56] P. Nason and C. Oleari, *NLO Higgs boson production via vector-boson fusion matched with shower in POWHEG*, *JHEP* **1002** (2010) 037, [arXiv:0911.5299].

[57] S. Alioli, P. Nason, C. Oleari, and E. Re, *Vector boson plus one jet production in POWHEG*, *JHEP* **1101** (2011) 095, [arXiv:1009.5594].

[58] S. Alioli, K. Hamilton, P. Nason, C. Oleari, and E. Re, *Jet pair production in POWHEG*, *JHEP* **1104** (2011) 081, [arXiv:1012.3380].

[59] S. Alioli, J. R. Andersen, C. Oleari, E. Re, and J. M. Smillie, *Probing higher-order corrections in dijet production at the LHC*, *Phys.Rev.* **D85** (2012) 114034, [arXiv:1202.1475].

[60] P. Nason and C. Oleari, *Generation cuts and Born suppression in POWHEG*, arXiv:1303.3922.

[61] C. Oleari and L. Reina, *$Wb\bar{b}$ production in POWHEG*, *JHEP* **1108** (2011) 061, [arXiv:1105.4488].

[62] A. Kardos, P. Nason, and C. Oleari, *Three-jet production in POWHEG*, *JHEP* **1404** (2014) 043, [arXiv:1402.4001].

[63] T. Ježo, J. M. Lindert, P. Nason, C. Oleari, and S. Pozzorini, *An NLO+PS generator for $t\bar{t}$ and Wt production and decay including non-resonant and interference effects*, *Eur. Phys. J.* **C76** (2016), no. 12 691, [arXiv:1607.0453].

[64] F. Granata, J. M. Lindert, C. Oleari, and S. Pozzorini, *NLO QCD+EW predictions for HV and HV +jet production including parton-shower effects*, *JHEP* **09** (2017) 012, [arXiv:1706.0352].

[65] S. Ferrario Ravasio, T. Ježo, P. Nason, and C. Oleari, *A Theoretical Study of Top-Mass Measurements at the LHC Using NLO+PS Generators of Increasing Accuracy*, arXiv:1801.0394.

[66] K. Hamilton, P. Nason, C. Oleari, and G. Zanderighi, *Merging H/W/Z + 0 and 1 jet at NLO with no merging scale: a path to parton shower + NNLO matching*, *JHEP* **1305** (2013) 082, [arXiv:1212.4504].

[67] G. Luisoni, C. Oleari, and F. Tramontano, *$Wb\bar{b}j$ production at NLO with POWHEG+MiNLO*, *JHEP* **04** (2015) 161, [arXiv:1502.0121].

[68] M. Fischler, E. Boos, D. J. Broadhurst, S. Eidelman, S. Groote, *et. al.*, *Summaries of recent computer-assisted Feynman diagram calculations*, .

[69] U. Baur, R. Brock, J. Parsons, M. Albrow, D. Denisov, *et. al.*, *Physics at future hadron colliders*, *eConf* **C010630** (2001) E4001, [hep-ph/0201227].

[70] S. Balatenychev, G. Belanger, F. Boudjema, A. Cottrant, M. S. Carena, *et. al.*, *Theoretical developments*, .

[71] **Higgs Working Group** Collaboration, D. Cavalli *et. al.*, *The Higgs working group: Summary report*, hep-ph/0203056.

[72] **Higgs Working Group Collaboration** Collaboration, K. Assamagan *et. al.*, *The Higgs working group: Summary report 2003*, hep-ph/0406152.

[73] N. Adam, T. Aziz, J. Andersen, A. Belyaev, T. Binoth, *et. al.*, *Higgs Working Group Summary Report*, arXiv:0803.1154.

[74] T. Binoth, F. Boudjema, G. Dissertori, A. Lazopoulos, A. Denner, *et. al.*, *A Proposal for a standard interface between Monte Carlo tools and one-loop programs*, *Comput.Phys.Commun.* **181** (2010) 1612–1622, [arXiv:1001.1307].

[75] **SM and NLO Multileg Working Group** Collaboration, J. Andersen *et. al.*, *The SM and NLO Multileg Working Group: Summary report*, arXiv:1003.1241.

[76] **SM AND NLO MULTILEG and SM MC Working Groups** Collaboration, J. Alcaraz Maestre *et. al.*, *The SM and NLO Multileg and SM MC Working Groups: Summary Report*, arXiv:1203.6803.

[77] J. Butterworth, A. Arbey, L. Basso, S. Belov, A. Bharucha, *et. al.*, *The Tools and Monte Carlo working group Summary Report*, arXiv:1003.1643.

[78] S. Alioli, S. Badger, J. Bellm, B. Biedermann, F. Boudjema, *et. al.*, *Update of the Binoth Les Houches Accord for a standard interface between Monte Carlo tools and one-loop programs*, *Comput.Phys.Commun.* **185** (2014) 560–571, [arXiv:1308.3462].

[79] J. R. Andersen *et. al.*, *Les Houches 2015: Physics at TeV Colliders Standard Model Working Group Report*, in *9th Les Houches Workshop on Physics at TeV Colliders (PhysTeV 2015) Les Houches, France, June 1-19, 2015*, 2016. arXiv:1605.0469.

[80] **LHC Higgs Cross Section Working Group** Collaboration, S. Dittmaier *et. al.*, *Handbook of LHC Higgs Cross Sections: 1. Inclusive Observables*, arXiv:1101.0593.

[81] S. Dittmaier, S. Dittmaier, C. Mariotti, G. Passarino, R. Tanaka, *et. al.*, *Handbook of LHC Higgs Cross Sections: 2. Differential Distributions*, arXiv:1201.3084.

[82] **LHC Higgs Cross Section Working Group** Collaboration, S. Heinemeyer *et. al.*, *Handbook of LHC Higgs Cross Sections: 3. Higgs Properties*, arXiv:1307.1347.

[83] **LHC Higgs Cross Section Working Group** Collaboration, D. de Florian *et. al.*, *Handbook of LHC Higgs Cross Sections: 4. Deciphering the Nature of the Higgs Sector*, arXiv:1610.0792.

[84] A. Andreazza *et. al.*, *What Next: White Paper of the INFN-CSN1*, *Frascati Phys. Ser.* **60** (2015) 1–302.

[85] S. Forte *et. al.*, *The Standard Model from the LHC to future colliders: a contribution to the Workshop "What Next" of INFN*, arXiv:1505.0127.

[86] M. L. Mangano *et. al.*, *Physics at a 100 TeV pp collider: Standard Model processes*, arXiv:1607.0183.

Milano, 8 Maggio 2018

Carlo Oleari