

**Dr. Costas G. PAPADOPOULOS**

**Curriculum Vitae**

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## 1 Personal data

**Surname** Papadopoulos  
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**Father's name** Georgios  
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## 2 Professional Experience

### Positions

*Current:*

February 2008 - today NCSR 'Democritos', Director of Research.

*Previous:*

September 1999 - February 2008 NCSR 'Democritos', Senior Researcher.

May 1996 - August 1999 NCSR 'Democritos', Researcher.

May 1994 - May 1996 Research Associate, Physics Department,  
Durham University, United Kingdom and  
unpaid Associate, Theory Division, CERN.

March 1992-April 1994 Fellow at CERN Theory Division, Geneva.

1989-1992 Post-doctoral position in NCSR 'Democritos', Athens.

1985-1989 Teaching assistant in University of Athens.

### Professional experience - Distinctions

February 2019 - June 2019 CERN Scientific Associate.

November 2015 - January 2016 CERN Corresponding Associate.

July-September 2014  
& March-May 2015 Hungarian Academy of Sciences: "MTA Distinguished  
Guest Scientists Fellowship Programme"

April 2015 Elected full professor of Mathematical Physics, HOU

November 2014 - February 2015 CERN Corresponding Associate.

March 2013 - August 2013 ETH Academic Guest

June 2012 - February 2013 CERN Scientific Associate.

May, August - September 2003 Visiting Professor, Durham University

August 2002 - November 2003 CERN Scientific Associate.  
and Marie Curie Fellow, cat 40.

June 2001 - September 2001 CERN Corresponding Associate.

June 1998 - September 1998 CERN Corresponding Associate.

## Education

- 1973-1979 Ιωνίδειος Πρότυπος Σχολή Πειραιώς (Secondary School of Excellence).
- 1979-1984 B.A. (Πτυχίο) of Physics, University of Athens.
- 1984-1985 Post-graduate courses in 'DEA de Physique Theorique', Ecole Normale, Paris.
- 1985-1986 Post-graduate courses in NCSR 'Demokritos', Athens.
- 1989 PhD in Theoretical Physics, University of Athens.

## Languages

Beyond Greek, I have a good knowledge of French and English.

# 3 Scientific work and research expertise

## Research Experience and Expertise

- My research work covers a large area of theoretical high-energy physics with emphasis to particle physics phenomenology. I am the author of 156 publications, in international refereed journals and conference proceedings, including CERN Yellow Reports. According to the INSPIRE database there are 14,310 citations, h-index: 50 (date: 14/2/2022) <sup>1</sup>.

Major achievements include the development of recursive equation approach to scattering amplitudes calculation and the resulting HELAC-PHEGAS computational system, the establishment of the OPP method to calculate virtual one-loop corrections along with the HELAC-NLO framework for arbitrary NLO QCD calculations, and the introduction of the Fermion-loop scheme for the consistent description of scattering involving unstable particles in perturbation theory.

In the last years, I am working on NNLO higher-order corrections, introducing novel methods for calculating multi-loop Feynman integrals and extending the OPP method at two loops.

- I have participated in international working groups (see also my publication list) set up either to study the physics potential or to assist, from the theoretical part, the physics analysis of large scale experiments: LEP200, LHC and ILC (the International Linear Collider project) – FCC (The Future Circular Collider project).
- I have developed the underlying theoretical and methodological approaches as well as the computer programmes for a number of computational tools, including ERATO, ERATO-LQ, HAAG, and notably the HELAC-PHEGAS system. These novel methods and tools allow the detailed study of arbitrary scattering process and

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<sup>1</sup>More detailed information in section 13.

played, play and will play a crucial role in the physics analysis of large scale experiments like LEP, LHC and ILC/FCC.

- I have participated, as scientist in charge, in many research projects funded by the European Union and the Greek General Secretariat for Research and Technology. I have also coordinated one of the largest collaboration on theoretical particle physics in Europe, the *HEPTOOLS Network*, that includes 17 research teams, from 16 Research centers and 47 Universities worldwide.

A synopsis of my research work is presented in section 11.

## 4 Administrative experience

### Administrative experience

I have been participated as:

1. Since 11/2017 till 1/2019, Acting Director of INPP, NCSR-D. As Acting Director I have taken the following initiatives:
  - I have organised the Institute's annual two-day meeting, where the members of INPP had the opportunity to present their research work, the funded programs in which they participate and their future plans (<https://indico.cern.ch/event/680759/>).
  - In order to in-depth review all research projects of the INPP, namely Nuclear Physics, High-Energy Physics and KM3, I have organised several informal meetings, where all members of the corresponding projects participated and we had the opportunity to analyse in-depth the research achievements, the funding needs, the commitments and the future plans.
  - In order to secure the re-opening of the application for funding of the INPP from the KRIPIS-II programme, I implemented all necessary formal procedures and I coordinated the setup of the corresponding proposal, achieving the necessary merit-based consensus from all participating researchers.
  - The implementation of the necessary selection procedure for three new researcher positions currently under evaluation and the opening of new positions, one in experimental high-energy physics and one in theoretical high-energy physics.
  - The development of collaborations of the INPP with other Institutes in NCSR-D. In this framework, I have organised with the Institute of Informatics and Telecommunications (IIT) a one-day workshop on "Big Data and Deep Learning Techniques" (<https://indico.cern.ch/event/705941/>).

- The brainstorming review with the members of Governing Board of NCSR-D of the activities of INPP at CERN, in order to best exploit the existing, as well as any potential new resources, in funding and personnel, and to promote efficient outreach activities concerning the presence of INPP at CERN.
- The addressing of severe pending issues related to the Delta-Vereniki deployment vessel and the Nestor Institute infrastructure.
- The coordination of the design and the implementation of the new website of INPP.

The aim is to strengthen the academic life of the Institute and establish a collaborative spirit among the researchers of INPP, in order to achieve an objective and merit-based evaluation and support of the research activities, in the framework of an unbiased and in-depth scientific dialogue.

2. Since 9/2017, I have been appointed as Deputy Director of INPP from the Governing Board of NCSR-D based on the proposal of the Scientific Council (ΕΣΙ) of the Institute.
3. Since 2017, member of the Advisory Committee for Scientific matters, NCSR-D.
4. Member elected of the Advisory Board of the Institute of Nuclear Physics, 2000-2002, 2012-2014, 2016-2017.
5. Appointed by the Ministry of Development, as member of the CERN Greek Committee, 2005-2009.
6. Deputy member of the Research Management Committee of NCSR- Demokritos (Επιτροπή Ερευνών), 2005-2008.
7. Appointed by the Secretary General of Research and Technology, as expert, in the Greek delegate to the 7th Framework Programme (FP7) of the European Commission, 'People' (ex. Marie-Curie Actions), 2006-2009.
8. During my appointment as acting president of the Association of Greek Researchers (ΕΕΕ), 2005-2007, I had the opportunity to get acquainted in-depth with the Greek research system and to appreciate the relative importance of NCSR-D and INPP within it.

## 5 Academic Experience

1986 - 1989 I have participated in laboratory exercises and teaching in University of Athens, as teaching assistant.

- 1989 - 1991 I have organized a post-graduate tutorial on high-energy phenomenology at NCSR ‘Democritos’, and I have supervised the PhD work of Dr. O. Korakianitis ( PhD thesis: ‘Phenomenology of and beyond the Standard Model of particle interactions at high energies’, February 1993, University of London) as well as the first stages of the work of Dr. K. Philippides ( PhD from New York University, 1995, NY, USA).
- 1995 I have participated in the Annual Summer School organized by NCSR ‘Democritos’, giving two lectures on ‘Recent developments in Elementary Particle Physics’
- 1996 - 1997 I have organized and taught the one-semester course on ‘Computational techniques in high-energy phenomenology’. This course has been offered for the first time in Greece. It is now part of the graduate school programme of the Department of Applied Mathematics and Physical Sciences, National Technical University of Athens.
- 2001-2003 Teaching ‘Introduction to Physical Sciences’, at the Hellenic Open University.
- 2003-2017 Teaching ‘Quantum Physics’, at the Hellenic Open University. The course is composed by three units: Quantum Mechanics, Nuclear Physics and Elementary Particle Physics.
- 2017-2018 Teaching ‘Mathematical Physics’, at the Graduate School, Advanced Studies in Physics, at the Hellenic Open University.
- PhD/MSc I have supervised or participated in the supervision (member of the PhD advisory and examination committees) of the following PhD Students:

**O. Korakianitis**, February 1993, University of London, PhD, *Phenomenology of and beyond the Standard Model of particle interactions at high energies*, advisor: Prof. A. Love.

**K. Philippides**, May 1996, New York University, PhD, *Quantum Loop Contributions to form factors and universal corrections of the Standard Model*, advisor: Prof. A. Sirlin.

**Y. Contogiannis**, 2001, University of Athens, PhD, *Theory of critical fluctuations in the quark matter*, advisor: Prof. N. Antoniou.

**P. Draggiotis**, November 2002, Katholieke Universiteit Nijmegen (KUN), The Netherlands, PhD, *QCD Explosion: enumeration and computation of QCD processes*, scholarship NCSR, advisors: R. Kleiss and C.G.Papadopoulos (co-promotor).

**A. Kanaki**, June 2003, National Technical University of Athens, PhD, *The effective action approach to Higher order corrections*, scholarship NCSR, advisor: C.G.Papadopoulos.

**D. Noucios**, 1999-2002, National Technical University of Athens, un-completed, *NLO QCD corrections for arbitrary partonic scattering processes*, scholarship NCSR, unfinished, advisor: C.G.Papadopoulos.

**E. Petrakou**, March 2006, National Technical University of Athens, Master Thesis, *Study of the MSSM and the Susy QED*, advisor: C.G.Papadopoulos.

**A. Lazopoulos**, Katholieke Universiteit Nijmegen (KUN), The Netherlands, PhD student, PhD appointed in 2005, advisors: R. Kleiss and C.G.Papadopoulos (co-promotor). Thesis title "Quasi Monte-Carlo error estimates", 2007

**A. Vlachos**, National Technical University of Athens, PhD student, scholarship NCSR, co-advisor: C.G.Papadopoulos.

**I. Malamos**, University of Athens & Radboud University Nijmegen, PhD student, scholarship NCSR, co-advisor: C.G.Papadopoulos. Thesis title "Reduction of one and two loop Amplitudes at the Integrand level", 2011.

**N. Davis**, University of Athens, PhD student, scholarship NCSR, co-advisor: C.G.Papadopoulos. Thesis title "Searching for the chiral critical point of quark matter in relativistic ion collisions", 2015.

**A. Chatzistavrakidis**, National Technical University of Athens, PhD student, scholarship NCSR-D, member of the 3-member advisory committee along with G.Zoupanos and G.Koutsoumbas, and member of the examination committee. Thesis title "Higher-dimensional unified gauge theories with extra dimensions based on compact, continuous or non-commutative, spaces", PhD approved July 2010.

**A. Kardos**, University of Debrecen, Hungary, PhD student, Early Stage Researcher, HEPTOOLS. Thesis title "Top predictions at high precision for the LHC", 2012.

**N. Syrrakos**, SEMFE, NTUA, "Two-loop Master Integrals with the differential equations method" ΣΕΜΦΕ, Ε.Μ.Π. ως κύριος επιβλέπων (μαζί με τον καθ. Ν. Τράκα). Thesis title "Υπολογισμός Master Integrals δύο βρόχων με την μέθοδο των διαφορικών εξισώσεων", starting date 6/2018.

**D. Canko**, Physics Department, NKUA, "Two-loop scattering amplitudes" Τμήμα Φυσικής, Ε.Κ.Π.Α, ως κύριος επιβλέπων. Thesis title "Υπολογισμοί πλατών σχέδασης δύο βρόχων", starting date 6/2018.

**B. Παπαδάκης**, ΕΑΠ, ΠΣΦ, Διπλωματική Εργασία: "Το Σωματίδιο Higgs και το Πρόβλημα των Μαζών των Στοιχειωδών Σωματιδίων", 12-5-2019. <https://apothesis.eap.gr/handle/repo/41192>



**B. Γρίσπος**, ΕΑΠ, ΠΣΦ, Διπλωματική Εργασία: “ΦΑΙΝΟΜΕΝΟ CASI-MIR: ΠΡΟΣΦΑΤΕΣ ΕΞΕΛΙΞΕΙΣ ΚΑΙ ΠΡΟΟΠΤΙΚΕΣ”, 29-9-2019.

<https://apothesis.eap.gr/handle/repo/44195>

**N. Tsolis**, ΕΜΠ, ΣΕΜΦΕ, Διπλωματική Εργασία: “Υπολογισμός ολοκληρωμάτων Feynman τάξεως δύο βρόχων”, 6-7-2020.

<http://dx.doi.org/10.26240/heal.ntua.19058>

I have been participating also in the examination committee of **Dr. Andreas van Hameren**, **Dr. Marcel van Kessel** and **Dr. Irene Niessen**, at the University of Nijmegen, Netherlands, **Dr. Valentin Jonathan Hirschi** at EPFL, Switzerland, **Dr. Alice Maria Donati** at the University of Granada, Spain and in the thesis evaluation committee of **A. Primo** at the University of Padova, Italy.

Post-Doc I have supervised/I am supervising the post-doctoral research of:

**A. van Hameren**, January 2001 - March 2004.

**M. Worek**, December 2003 - November 2005.

**P. Draggiotis**, November 2004 - November 2006.

**G. Ossola**, April 2006 - April 2008.

**A. Cafarella**, October 2006 - October 2008.

**G. Bevilacqua**, December 2008 - December 2010.

**C. Wever**, July 2013 - June 2015.

**D. Tommasini**, July 2013 - June 2015.

**H. Frellesvig**, August 2014 - July 2017.

I have participated in academic personnel selection committees at Greek Universities.

### Development of educational material

I have developed the educational material entitled “Quantum Mechanics”, consisting of 16 hours of webcast (2004-2005) and 16 hours of webcast for “Quantum Field Theory (2007-2008) as well as hypertext for “Particle Physics” (2008) and multiple-choice questions for “Nuclear Physics” (2008).

## 6 Research programs

I participate (or participated) in the following programs:

1. “ Μελέτη διορθώσεων ανώτερης τάξης στο πλαίσιο της κβαντικής χρωμοδυναμικής και εφαρμογές στα πειράματα Υψηλών Ενεργειών του LHC ” (QCD higher-order corrections and applications for LHC), ΕΔΒΜ, acting as scientist in charge, 2020-2022

2. Υπολογισμός πλατών σχέδασης δύο βρόχων (Two – loop Amplitude Calculations Based on Intergrand Reduction), ΕΛΙΔΕΚ, acting as scientist in charge, 2019-2022.
3. **Cost Action** OC-2016-2-21139 "Unraveling new physics at the LHC through the precision frontier", member of the management committee, 2017-2021.
4. **Marie Curie Actions Initial Training Networks (ITN)**, 'The Higgs quest - exploring electroweak symmetry breaking at the LHC', **HiggsTools**, acting as scientist in charge of the Greek Node, 2014-2017.
5. **Excellence Project**, ΑΡΙΣΤΕΙΑ-I, 'Higher Order Calculations and Tools for High Energy Colliders', **HOCTools**, acting as scientist in charge, 2012-2015.
6. **ΚΡΗΠΙΣ Project**, 'Εξερευνώντας το Ορατό και Αόρατο Σύμπαν με επιταχυντές και καινοτόμους ανιχνευτές', **ΟΡΑΣΤ**, acting as member of the main research team, 2012-2015.
7. **Thales Project**, 'BEYOND THE STANDARD MODEL: Theoretical Elementary Particle Physics and Cosmology under the light of LHC', **BSM-LHC**, acting as member of the main research team, 2012-2015.
8. **Thales Project**, 'SEARCHES FOR NEW PHYSICS AT TEVATRON, LHC AND BEYOND', **DIBOSON**, acting as member of the main research team, 2012-2015.
9. **Thales Project**, 'Development and Applications of Novel Instrumentation and Experimental Methods in Astroparticle Physics', **ASTRONEU**, acting as member of the main research team, 2012-2015.
10. **Marie Curie Research Training Network**, 'Tools and Precision Calculations for Physics Discoveries at Colliders', **HEPTOOLS**, acting as Network Coordinator, 2006-2010.
11. **Marie Curie Host Fellowships for Transfer of Knowledge (TOK)**, 'Algorithms and Tools for multi-particle production and higher order corrections at high energy colliders', **ALGOTOOLS**, scientist in charge, 2005-2009.
12. General Secretariat for Research and Technology, **Poland-Greece bilateral**, 'Advanced computer techniques for theoretical calculations and development of simulation programs for high energy physics experiments', scientist in charge, 2004-2007.
13. EPAN, '**Participation of Greek teams in International Organizations**', Greece-CERN, NCSR-Demokritos, participant, 2004-2006.

14. General Secretariat for Research and Technology, programme: '**Research Excellence**', Physics at the LHC', participant, 2002-2004.
15. **Development Host Fellowships**, 'Multi-Particle Processes And Higher Order Corrections', scientist in charge, 2002-2006.
16. General Secretariat for Research and Technology, **PLATON: Franco-hellenic bilateral collaboration project**, participant, 2002-2004.
17. **Research Training Network**, 'Particle physics phenomenology at high energy colliders', coordinator of the Greek node, 2000-2005.
18. **Marie Curie Individual Fellowship**, 'Multi-Particle Processes At High Energy Colliders', fellow, 2002-2003.
19. Πειραματική και Φαινομενολογική μελέτη των αντιδράσεων  $e^+e^-$  στον επιταχυντή LEP II του CERN - ΔΗΜΟΕΡΕΥΝΑ, (Experimental and Phenomenological study of  $e^+e^-$  collisions at LEP-II), NCSR 'Democritos' program '**Demo-research**', scientist in charge, 1999-2001.
20. **PENED-GGET**, E345, participant, 1996.
21. EEC Program, **Human Capital and Mobility**, participant, CHRXCT930319.
22. EEC Program, **Science**, participant, SC1-CT92-0792.
23. EEC Program, **Science**, participant, SC1-CT91-0729.
24. **British Council, Athens-Durham**, participant, 1991-1993.
25. Bilateral Program between Greece (NRCPS 'D') and Germany (DESY), participant.

## 7 Schools-Conferences-Workshops

- 1986 Paris-Meudon Colloquium on Superstrings, Paris.
- 1986 \* 1st Congress of the Greek Society for the Study of High Energy Physics (GSSHEP), Athens.
- 1987 ICTP Spring School on Superstrings, Trieste, Italy.
- 1988 \* 2nd Congress of GSSHEP, Athens.
- 1988 Les Houches School on 'Strings, Fields and Critical Phenomena', Les Houches, France.
- 1989 \* 3rd Congress of GSSHEP, Athens.
- 1989 3rd Hellenic School on Elementary Particles, Corfou, Greece.
- 1990 \* 4th Congress of GSSHEP, Athens.

- 1990 International School on Elementary Particle Physics, Ioannina, Greece.
- 1990 \* ECFA Large Hadron Collider Workshop, Aachen, Germany.
- 1991 \* 5th Congress of GSSHEP, Thessaloniki, Greece.
- 1992 \* 6th Congress of GSSHEP, Athens, Greece.
- 1993 \* 7th Congress of GSSHEP, Iraklion, Greece.
- 1993 \* Workshop on future electron-positron colliders, Annecy, France.
- 1993 \* Recontres de Moriond, Electroweak interactions and Unified theories, Les Arcs, France.
- 1994 \* 8th Congress of GSSHEP, Athens, Greece.
- 1994 \* LEP II Workshop, 1st meeting of Standard Model Group.
- 1995 \* LEP II Workshop, 1st meeting of WWG couplings Group.
- 1995 \* LEP II Workshop, 2nd meeting of WW Group.
- 1995 \* LEP II Workshop, 2nd meeting of WWG couplings Group.
- 1995 \* LEP II Workshop, 3d meeting of WW Group.
- 1995 \* Next Linear Collider Workshop, April 4, CERN.
- 1995 \* LEP II Workshop, 3d meeting of WWG couplings Group.
- 1995 \* LEP II Workshop, 4th meeting of WW Group.
- 1996 \* 10th Congress of GSSHEP, Ioannina, Greece.
- 1996 \* Linear Collider Workshop, February, Hamburg, Germany.
- 1996 \* Linear Collider Workshop, November, Hamburg, Germany.
- 1997 \* Physics at LEP2, Oxford University, United Kingdom.
- 1997 \* Joint Particle Phenomenology meeting, Chalkidiki, Greece.
- 1997 \* XVIII int. symposium on lepton-photon interactions, Hamburg, Germany.
- 1997 \* 2nd meeting on high-energy phenomenology (EEC network), September, Nijmegen, The Netherlands.
- 1998 12th GSSHEP Conference, Athens.
- 1998 LHC Workshop, CERN, Geneva, Switzerland.
- 1998 \* Meeting of the DELPHI Working group on TGC measurements, Athens, Greece.
- 1999 LHC Workshop, CERN, Geneva, Switzerland.
- 1999 \* MiniLEP2 Workshop, CERN, Geneva, Switzerland.
- 1999 WW99 International Workshop on WW physics at LEP2, Creta, Greece.
- 2000 \* Padua Conference on the Linear Collider project.
- 2000 Investing in Europe's Human Research Potential, October 4-7, Crete, Heraklion.
- 2000 European Young Scientist Forum in the Pan-European Conference on Science and technology - Prospects for the 21st century, Gdansk, Poland, October 7-9.
- 2000 \* VII International Workshop on Advanced Computing and Analysis Techniques in Physics Research, Fermilab, USA, October 16-20.
- 2001 \* 'Physics at Colliders' network meeting, Granada, Spain, March 1-4.

- 2001 \* CPP2001, Automatic Calculation for Future Colliders, November 28-30, 2001, Tokyo Metropolitan University, Japan.
- 2002 \* 'Physics at Colliders' network meeting, April 9-11, 2002, Grey College, United Kingdom.
- 2003 \* 'The 4th ECFA/DESY Workshop on Physics and Detectors for a 90-800 GeV Linear e+e Collider', 1-4 April at NIKHEF
- 2003 \* 'CERN Workshop on Monte Carlo tools for the LHC' July 7 -Aug 1 2003.
- 2003 'Electroweak Radiative Corrections to Hadronic Observables at TeV Energies' 11th-15th September 2003 Grey College, University of Durham.
- 2003 \* 'ECFA LC Workshop" Montpellier, France, 13-16 November.
- 2004 Annual meeting of the HSSHEP, Chios, 1-4 April.
- 2004 \* Particle physics phenomenology at high energy colliders, final meeting of the European Union Network, Montpellier, France, September 26-27
- 2005 \* 10th International Workshop on Advanced Computing and Analysis Techniques in Physics Research (ACAT 05), Zeuthen, Germany, 22-27 May 2005
- 2005 \* XXIX International Conference of Theoretical Physics Ustron, 8-14 September 2005, Poland
- 2005 QMUL Workshop From Twistors to Amplitudes 3 - 5 November, Queen Mary, University of London
- 2006 \* HEP2006: Recent Developments in High Energy Physics and Cosmology, April 13-16, 2006, Ioannina, Greece
- 2006 \* DIS2006, XIV International Workshop on Deep Inelastic Scattering, 20/4/2006 - 24/4/2006, International Congress Center EPOCHAL Tsukuba, Japan. (*invited talk*)
- 2006 \* Loops and Legs in Quantum Field Theory April 23 -28, 2006 Eisenach, Germany
- 2006 \* MONTE CARLOS FOR THE LHC, Workshop on the tools for LHC event simulation, CERN, July 17-26, 2006.
- 2006 \* HP<sup>2</sup> Workshop, 6-9 September, 2006, High Precision for Hard Processes at the LHC, ETH, Zurich, Switzerland. (*invited talk*)
- 2006 \* International Linear Collider (ILC) Workshop (ILC-ECFA and GDE Joint Meeting) Valencia, 6-10 November 2006. (*invited talk*)
- 2007 \* Cracow Epiphany Conference on Precision Physics and Monte Carlos for LHC, 4 - 6 January 2007, Cracow, Poland. (*invited talk*)
- 2007 \* Physics at TEV Colliders, Les Houches, 11-29 June 2007. (*invited talk*)
- 2007 \* 8th International Symposium on Radiative Corrections APPLICATION OF QUANTUM FIELD THEORY TO PHENOMENOLOGY Florence, Italy, October 1-5, 2007 . (*invited talk*)
- 2007 \* The Galileo Galilei Institute for Theoretical Physics (GGI), Advancing Collider Physics: from Twistors to Monte Carlos, October 1-21, 2007 . (*invited talk*)
- 2008 \* Loops and Legs 2008, April 20 -25, 2008 Sondershausen. (*invited talk*)
- 2008 \* HEPTOOLS Training event, May 29 to may 30, Nijmegen, The Netherlands. (*invited lectures*)

- 2008 \* TOOLS 2008, Tools for the New Physics and its Background, June 30th to July 4th at the Max-Planck-Institut für Physik, Munich, Germany. (*invited talk*)
- 2008 \* High Precision for Hard Processes at the LHC, 7-10 October, 2008, Buenos Aires, Argentina. (*invited talk*)
- 2009 \* Computer Algebra and Particle Physics 2009, 29 March to 3 April 2009, DESY-ZEUTHEN, Germany. (*invited lectures*)
- 2009 \* The 2009 Europhysics Conference on High Energy Physics 16-22 July 2009 Krakow, Poland. (*invited talk*)
- 2009 \* HEPTOOLS: Third Annual Meeting 30/11-1/12 2009 HEPHY, Vienna. (*invited talk*)
- 2010 \* MC4LHC readiness 29/3-1/4 2010 CERN, Geneva. (*invited talk*)
- 2010 \* Loops and Legs in Quantum Field Theory 25/4-30/4 2010 Woerlitz, Germany. (*invited talk*)
- 2010 \* Loopfest IX: Radiative Corrections for the LHC and Lepton Colliders 21/6-23/6 2010 Stony Brook, USA. (*invited talk*)
- 2010 \* QCD at the LHC, 27 September - 1 October, Trento, Italy. (*invited talk*)
- 2010 \* School and Workshops on the Standard Model and Beyond - Cosmology August 29 - September 5, 2010, Corfu, Greece (*invited talk*)
- 2011 \* Heavy Particles at the LHC, 5-7 January 2011, ETH Zurich, CH. (*invited talk*)
- 2011 \* The Harmony of Scattering Amplitudes, 13 June - 8 July 2011, KITP, University of California Santa Barbara, USA. (*invited talk*)
- 2011 The TH-LPCC Summer Institute on LHC Physics, August 1-7, 2011, CERN, CH.
- 2012 \* "High Precision for Hard Processes" (HP2) September 4 - 7, 2012, Munich, Germany. (*invited talk*)
- 2012 \* Summer School and Workshop on the Standard Model and Beyond September 8 - 17, 2012, Corfu, Greece
- 2013 The Lastis Symposium 2013, Nature at the energy frontier June 3 - 6, 2013, Zurich, Switzerland
- 2013 \* LHCphenonet Summer School September 7 - 12, 2013, Crakow, Poland (*invited talk*)
- 2014 \* LoopFest XIII New York City College of Technology (City Tech) June 18-20, 2014, Brooklyn, NY, USA (*invited talk*)
- 2014 \* Workshop "Prospects and Precision at the Large Hadron Collider at 14 TeV", and the conference "HP2: High Precision for Hard Processes" September 2014, Firenze, Italy (*invited talk*)
- 2015 \* "HOCTools NNLO meeting", January 2015, Athens, Greece
- 2015 \* First Annual Meeting of ITN HiggsTools, April 2015, Freiburg, Germany. (*invited talk*)
- 2015 \* UCLA Radcor-Loopfest conference, June 2015, Los Angeles, USA (*invited talk*)
- 2016 \* Loops and Legs conference, April 2016, Leipsig, Gemany (*invited talk*)
- 2016 \* QCD@LHC, August 2016, Zurich, Switzerland (*invited talk*)
- 2016 \* "High Precision for Hard Processes" (HP2), September 2016, Buenos Aires, Argentina, (*invited talk, presented by C. Wever*)

- 2017 \* HEP 2017: Recent Developments in High Energy Physics and Cosmology, April 2017, Ioannina, Greece, (*invited talk*)
- 2017 \* Third HiggsTools Annual Meeting and Young Editors School in Torino, May 2017, Torino, Italy, (*invited talk*)
- 2017 \* LHC and the Standard Model: Physics and Tools, June-July 2017, Geneva, Switzerland, (*invited talk*)
- 2017 MIAPP: Mathematics and Physics of Scattering Amplitudes, August 2017, Munich, Germany
- 2017 \* RADCOR, 24-29 September 2017, St. Gilgen, Austria
- 2018 \* Mini workshop: Precision EW and QCD calculations for the FCC studies: methods and techniques, 12-13 January 2018, CERN
- 2018 PARTICLEFACE 2018, 26-28 February, Valencia, Spain
- 2018 \* Loops and Legs in Quantum Field Theory, April 29 to May 4, 2018 St. Goar, Germany
- 2018 \* Physics at the LHC and Beyond, 16-27 July, 2018 CERN, Geneva, Switzerland
- 2018 \* High Time for Higher Orders: From Amplitudes to Phenomenology, 13-24 August, 2018 Mainz, Germany
- 2018 \* High Precision for Hard Processes (HP2 2018), 1-3 October, 2018 Freiburg, Germany
- 2018 \* Amplitudes in the LHC era, The Galileo Galilei Institute for Theoretical Physics, 15-27 October, 2018 Firenze, Italy
- 2019 \* 11th FCC-ee workshop: Theory and Experiments, 8-11 January, 2019 CERN
- 2019 RADCOR 2019 – 14th International Symposium on Radiative Corrections: Applications of Quantum Field Theory to Phenomenology 9 -13 September 2019, Avignon, France
- 2019 MathemAmplitudes 2019: Intersection Theory & Feynman Integrals 18-20 December, 2019, Padova, Italy
- 2020 \* 3rd FCC Physics and Experiments Workshop, CERN, Geneva, Switzerland
- 2020 PARTICLEFACE 2020: Working Group Meeting and Management Committee Meeting, Krakow, 11-13 February 2020, Poland
- 2021 Cracow Epiphany Conference, ON FUTURE OF PARTICLE PHYSICS, 7-10 January 2021, Crakow.
- 2021 \* 15th International Symposium on Radiative Corrections (RADCOR) XIX Workshop on Radiative Corrections for the LHC and Future Colliders (LoopFest), May 17 – 21, 2021, Florida State University, Virtual Conference
- 2021 \* Amplitudes 2021, Niels Bohr Institute in collaboration with Penn State University, August 16-20, 2021
- 2021 HEP2021 Conference, HSSHEP and AUTH, June 16-19, 2021

where \* means contribution by relevant work presentation.

## 8 Conference Organization

- 1994 Organizer of the 1st annual meeting on high energy phenomenology, 9-10 June, National Technical University of Athens, Athens.
- 1997 Convenor of the Trilinear Gauge Couplings Group of the Phenomenology Workshop on LEP2 Physics, 14-18 April, Physics Department, Oxford, UK.
- 1997 Organizer of the 2nd annual meeting on high energy phenomenology, 26-28 September, University of Nijmegen, The Netherlands.
- 2004 Organizer of the annual meeting of HSSHEP 1-4 April, University of Aegean, Greece.
- 2004 Meeting Of The European Network 'Physics At Colliders', 26-27 Sep 2004, Montpellier, France, Editor.
- 2006 Loops and Legs 2006, April 23 -28, 2006 Eisenach, Germany: Member of the International Programme Committee.
- 2007 HEPTools, Annual meeting, November, 26-27, 200, Athens, Greece.
- 2008 Graduate School in Physics at Colliders, January, 2008, Torino, Italy.
- 2008 Loops and Legs 2008, April 20 -25, 2008 Sondershausen, Germany: Member of the International Programme Committee.
- 2009 HEPTOOLS, Second Annual meeting, 9-12 March 2009, Lisbon, Portugal: Coordinator.
- 2009 XXVII Workshop on recent Developments in High Energy Physics and Cosmology, ΕΕΣΦΥΕ, 21-23 May 2009, NCSR-D, Athens, Greece: Organising Committee (Chairman). <https://indico.cern.ch/event/55216/>
- 2009 Fourth Graduate School in Physics at Colliders On the eve of the LHC, 29/6-3/7 2009, Turin, Italy: International Advisory Board.
- 2009 School and Workshops on the Standard Model and Beyond - Standard Cosmology August 31 - September 6, 2009: Member of the International Programme Committee.
- 2009 HEPTOOLS, Third Annual meeting, 30/11-1/12 2009, Vienna, Austria: Coordinator.
- 2010 Loops and Legs in Quantum Field Theory, 25/4-30/4 2010 Woerlitz, Germany: Member of the International Programme Committee.
- 2010 School and Workshops on the Standard Model and Beyond - Standard Cosmology August 29 - September 5, 2010, Corfu, Greece: Member of the International Programme Committee.
- 2014 Summer School and Workshop on the Standard Model and Beyond September 3 - 14, 2014, Corfu, Greece: Member of the Organizing Committee.



- 2015 Summer School and Workshop on the Standard Model and Beyond September 1 - 11, 2015, Corfu, Greece: Member of the Organizing Committee.
- 2016 Summer School and Workshop on the Standard Model and Beyond August 31 - September 12, 2016, Corfu, Greece: Member of the Organizing Committee.
- 2017 Summer School and Workshop on the Standard Model and Beyond September 2 - September 28, 2017, Corfu, Greece: Member of the Organizing Committee.
- 2018 PARTICLEFACE 2018 February 26 - 28, 2018, Valencia, Spain: Member of the Scientific Programme Committee.
- 2018 Workshop on the Standard Model and Beyond August 31 - September 9, 2018, Corfu, Greece: Member of the Organizing Committee.
- 2019 HEP 2019 - Conference on recent Developments in High Energy Physics and Cosmology, April 17 - 20, 2019, NCSR-D, Athens, Greece: Member of the Organizing Committee.
- 2019 Workshop on Connecting Insights in Fundamental Physics: Standard Model and Beyond, August 31 - September 9, 2019, Corfu, Greece: Member of the Organizing Committee.
- 2021 Workshop on the Standard Model and Beyond, August 29 - September 8, 2021, Corfu, Greece: Member of the Advisor Committee.

## 9 Invited talks and visits

1. University of Athens, Greece.
2. NRCPS 'Democritos', Athens, Greece.
3. CERN, Geneva, Switzerland.
4. Ecole Polytechnique, Palaiseau, France.
5. Ecole Normale Supérieure, Paris, France.
6. LAPP, Annecy, France.
7. University of Crete, Iraklion, Greece.
8. University of Thessaloniki, Greece.
9. DESY, Hamburg, Germany.
10. University of Ioannina, Greece.
11. National Technical University of Athens.
12. University of Durham, United Kingdom.
13. University of Minnesota, Minneapolis, MI, USA.
14. New York University, New York, NY, USA.
15. City College of New York, New York, NY, USA.
16. Northeastern University, Boston, Mass, USA.
17. DRAL, Didcot, United Kingdom.

18. Catholic University of Nijmegen, The Netherlands.
19. Argonne National Laboratory, IL, USA.
20. University of Torino, Italy.
21. Desy-Zeuthen, Berlin, Germany.
22. Max-Plank Institute, Munich, Germany.
23. ETH, Zurich, Switzerland.
24. NIKHEF, Amsterdam, Netherlands.
25. Institute of Nuclear Physics PAN, Krakow, Poland.
26. CMS, Monte Carlo Generator meeting (26/4/07), CERN, Geneva, Switzerland.
27. ATLAS, Monte Carlo Generator meeting (4/6/07), CERN, Geneva, Switzerland.
28. University of Warsaw (23 March 2009), Warsaw, Poland.
29. Stanford University, SLAC National Accelerator Laboratory, USA.
30. Institute for Advanced Study, IAS, Princeton, NJ, USA.
31. NICPB, Tallinn, Esthonia.
32. University of Debrecen, Debrecen, Hungary.
33. University of Padova, Padova, Italy.

## 10 Other activities

### Evaluator-Reviewer

I have reviewed numerous articles for international peer-review journals, including Physics Letters B, Nuclear Physics B, Computer Physics Communications, Zeitschrift für Physik, JHEP, EPJ, etc. I have evaluated many research proposals (GSRT, NSF, CUNNY,  $E\Delta BM$ , EU H2020, etc.).

### Scientific Organizations

I am member of the following Societies:

1. Greek Physical Society.
2. Hellenic Society for the Study of High Energy Physics (HSSHEP), elected member of the board, 2003-2006.
3. Association of Greek Researchers (EEE), elected member of the board, 2003-2005, and acting president of the board, 2005-2007.
4. Marie Curie Fellowship Association.

# 11 Synopsis of research work

## Preamble

The current and future experiments at high-energy colliders, such as LHC, which is currently delivering very important results, FCC (the Future Circular Collider project) or ILC (the International Linear collider project), it is expected to be a significant and unprecedented step forward in the exploration of nature at the deepest level. Particle physics phenomenology consists the theoretical basis for the successful completion of these experiments.

Particle physics phenomenology is a well established scientific field with a significant impact in high-energy physics both in the direction of providing accurate theoretical predictions, based on modern mathematical methods and tools, in order to reveal the physics content of experimental data, as well as in triggering new ideas in particle theory research, with a common ground to produce new scientific knowledge.

## Research interests

My publications cover a broad area of particle physics and they can be classified as follows:

- Development of the methodological background of Quantum Field Theory

Publications<sup>2</sup>: [98] [97] [92] [91] [90] [89] [88] [84] [76] [75] [74] [73] [72] [70] [69] [68] [66] [65] [64] [63] [57] [54] [53] [45]

Reliable and accurate theoretical predictions require the development of the methodological background of Quantum Field Theory (QFT). A significant contribution in this direction was the development of recursive equations, more specifically the Dyson-Schwinger equations approach, to compute scattering amplitudes. Recursive equations allow not only to compute multi-leg tree-order amplitudes but also to address higher-order corrections.

The discovery of the on-shell recursive equations, related to certain topological string theories, and the understanding of their relation to the Dyson-Schwinger equations opened new interesting frontiers in the field.

A breakthrough contribution is represented by the work on the reduction of one-loop amplitudes at the integrand level, which allows the computation of multi-leg scattering amplitudes beyond tree order. The method which is nowadays known as OPP, featuring the initials of the authors (Ossola, Papadopoulos and Pittau), resulted to what has been named as the NLO revolution, and is used routinely in current calculations and automated computational tools for LHC.

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<sup>2</sup>the numbering refers to the publication list, section 12

In the last years my research activity focus on scattering amplitudes beyond one loop. Introducing novel ideas, such as the simplified differential equations approach, we were able to complete the most advanced calculation in multi-leg multi-loop frontier, namely the family of planar two-loop five-point Master Integrals. Extending the OPP method beyond one loop the aim is to establish the methodological framework for NNLO calculations of arbitrary scattering processes, which are necessary to match the anticipated experimental accuracy in the next decades.

- Study of unstable particles in perturbation theory and renormalisation

Publications: [60] [42] [38] [34]

The consistent treatment of unstable particles, such as  $W^\pm$ ,  $Z$ , in the framework of perturbation theory is the subject of a vast literature.

The so-called Fermion-Loop scheme, based on contributions from closed fermionic loops in the scattering amplitude, at any order of the perturbative expansion, offers a consistent, with respect to the gauge symmetry, treatment of unstable particles. Adopting the appropriate renormalisation scheme, the so-called complex pole scheme, consistent and reliable theoretical predictions are possible and this solution is routinely used in current calculations.

Reliable predictions for scattering amplitudes with unstable particles are of primary importance for the physics analysis in  $e^+e^-$  and hadronic colliders.

- Phenomenological studies of electroweak and strong interactions

Publications: [96] [95] [94] [93] [87] [86] [85] [83] [82] [81] [80] [79] [77] [71] [67] [62] [61] [58] [55] [50] [48] [47] [46] [44] [41] [39] [37] [25] [26] [21] [16] [18] [15] [11]

In this group of publications we study the predictions of generic quantum field theories for scattering processes. This requires the calculation of scattering amplitudes at tree order as well as in higher orders of perturbation theory, and at the same time efficient Monte-Carlo integration techniques over the multi-dimensional phase space.

- Four-fermion ( $+\gamma$ ) and six-fermion production in  $e^+e^-$  collisions

Developing the methodological framework to compute scattering amplitudes as well as efficient algorithms for phase-space integration and simulation. Study of NLO corrections.

The reliable theoretical description of such processes allows the study of the properties of vector bosons, their interactions with the electromagnetic field and their self-interactions at LEP-II and beyond (ILC, FCC).

- Processes with hadronic jets in  $pp$  and  $p\bar{p}$  collisions

Developing the theoretical framework and the corresponding computational tools (HELAC, PHEGAS, HAAG, JETi), we are able to study multi-jet production (2-8 jets), as well as several scattering processes, such as  $W$ +jets,  $Z$ +jets,  $nV$ +jets and Higgs production. These calculations allow to study important parameters of the theory, such as the mass and the width of  $W$ ,  $Z$  and Higgs, as well as the trilinear Higgs couplings that are directly related to the  $SU(2)$  symmetry breaking Higgs mechanism.

– Higher-order corrections

Based on the OPP method and the developed computational tools, such as HELAC-NLO, HELAC-1LOOP, HELAC-DIPOLES, CutTools, OLO we are able to provide predictions for several scattering processes at NLO accuracy, which were not feasible before. Many processes have been studied, including  $pp \rightarrow t\bar{t}b\bar{b}$ ,  $pp \rightarrow t\bar{t} + 2 \text{ jets}$ , that are necessary for top quark and Higgs physics.

• Phenomenology beyond the Standard Model

Publications: [51] [40] [22] [17] [10] [7] [4] [2] [1]

Despite the fact that Standard Model describes well all experimental data, it fails to account for other phenomena, for instance the fermion mass hierarchy problem. Many alternative theories have been proposed in order to address some of the open problems. The most important of them are supersymmetry, grand-unified theories, compositeness, etc. In addition, string theory offers a consistent description of gravity. In this group of publications we study phenomenological predictions of such theories and their confrontation to experimental data.

• Multi-particle production – the large multiplicity limit of QFT

Publications: [59], [56], [43], [35], [32] [31], [30], [29], [28], [27], [23],

Processes with multi-particle production are of special interest from a theoretical and experimental point of view. From the experimental point of view, high-energy colliders, such as the LHC, provide enough energy to produce many particles in the final state. From the theory point of view, the large multiplicity limit challenges the applicability of perturbative expansion. Issues related to the onset of non-perturbative effects and the consistent description of multi-particle production in QFT, are studied in this group of publications.

• Phase transitions in hadronic matter, intermittency and chaotic dynamics

Publications: [49], [36], [33], [24], [20], [19], [14], [9], [8]

The confinement of quarks and gluons into hadrons as well as the onset of quark-gluon plasma, is studied in the framework of phase-transition theory. In multi-

particle production processes the statistical description provides a better approximation. An interesting point is the relation of this description with the chaotic dynamics, where the emergence of fractal geometry is well studied. The intermittency effects appearing in experimentally measured moments of the distribution of hadrons in rapidity space are related to the statistical description of the system.

- Studies of more general interest

Publications: [78] [52] [13] [12] [5] [6] [3]

In these publications a number of studies related to different subjects, such as the quantisation of gravitational field, the string theory, the  $2D$  conformal field theories, the study of discrepancies in quasi-random generators, and the derivation of path integrals in polar coordinates, are presented.

### Collaboration with experimental groups

A very important aspect of my research work is the development of collaborations with experimental groups, in order to better serve the scientific objectives of our community. This collaboration has been achieved with many experimental groups from DELPHI, ALEPH, L3 and OPAL, concerning the physics of anomalous gauge boson couplings during the LEP-II era. Collaborations have been also developed during the LHC era, concerning the physics of the HL-LHC, the associated multi-jet production, the trilinear Higgs couplings, the compositeness signals, etc. An other aspect of my research activities refers to the ILC – International Linear Collider and the FCC – Future Circular Collider project. The ILC project focus on the physics of a linear electron-positron collider, with energies from about 100 GeV to 2 TeV, whereas the FCC project refers to a circular collider with collision energies up to 100 TeV in proton-proton mode: my participation in physics studies in both projects, was and it is still active.

## 12 Publication List

### 12.1 Journal Articles

- [98] Dhimiter D. Canko, Costas G. Papadopoulos, and Nikolaos Syrrakos. “Analytic representation of all planar two-loop five-point Master Integrals with one off-shell leg”. In: *JHEP* 01 (2021), p. 199. DOI: 10.1007/JHEP01(2021)199. arXiv: 2009.13917 [hep-ph].
- [97] Costas G. Papadopoulos and Christopher Wever. “Internal Reduction method for computing Feynman Integrals”. In: *JHEP* 02 (2020), p. 112. DOI: 10.1007/JHEP02(2020)112. arXiv: 1910.06275 [hep-ph].

- [96] A. Abada et al. “FCC Physics Opportunities: Future Circular Collider Conceptual Design Report Volume 1”. In: *Eur. Phys. J. C* 79.6 (2019), p. 474. DOI: 10.1140/epjc/s10052-019-6904-3.
- [95] A. Abada et al. “FCC-ee: The Lepton Collider: Future Circular Collider Conceptual Design Report Volume 2”. In: *Eur. Phys. J. ST* 228.2 (2019), pp. 261–623. DOI: 10.1140/epjst/e2019-900045-4.
- [94] A. Abada et al. “FCC-hh: The Hadron Collider: Future Circular Collider Conceptual Design Report Volume 3”. In: *Eur. Phys. J. ST* 228.4 (2019), pp. 755–1107. DOI: 10.1140/epjst/e2019-900087-0.
- [93] A. Abada et al. “HE-LHC: The High-Energy Large Hadron Collider: Future Circular Collider Conceptual Design Report Volume 4”. In: *Eur. Phys. J. ST* 228.5 (2019), pp. 1109–1382. DOI: 10.1140/epjst/e2019-900088-6.
- [92] Hjalte Frellesvig and Costas G. Papadopoulos. “Cuts of Feynman Integrals in Baikov representation”. In: *JHEP* 04 (2017), p. 083. DOI: 10.1007/JHEP04(2017)083. arXiv: 1701.07356 [hep-ph].
- [91] Costas G. Papadopoulos, Damiano Tommasini, and Christopher Wever. “The Pentabox Master Integrals with the Simplified Differential Equations approach”. In: *JHEP* 04 (2016), p. 078. DOI: 10.1007/JHEP04(2016)078. arXiv: 1511.09404 [hep-ph].
- [90] Costas G. Papadopoulos, Damiano Tommasini, and Christopher Wever. “Two-loop Master Integrals with the Simplified Differential Equations approach”. In: *JHEP* 01 (2015), p. 072. DOI: 10.1007/JHEP01(2015)072. arXiv: 1409.6114 [hep-ph].
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- [88] G. Bevilacqua et al. “HELAC-NLO”. In: *Comput. Phys. Commun.* 184 (2013), pp. 986–997. DOI: 10.1016/j.cpc.2012.10.033. arXiv: 1110.1499 [hep-ph].
- [87] M. V. Garzelli et al. “ $t \bar{t} W^{+-}$  and  $t \bar{t} Z$  Hadroproduction at NLO accuracy in QCD with Parton Shower and Hadronization effects”. In: *JHEP* 11 (2012), p. 056. DOI: 10.1007/JHEP11(2012)056. arXiv: 1208.2665 [hep-ph].
- [86] M. V. Garzelli et al. “ $Z^0$  - boson production in association with a top anti-top pair at NLO accuracy with parton shower effects”. In: *Phys. Rev. D* 85 (2012), p. 074022. DOI: 10.1103/PhysRevD.85.074022. arXiv: 1111.1444 [hep-ph].
- [85] Adam Kardos, Zoltan Trocsanyi, and Costas Papadopoulos. “Top quark pair production in association with a Z-boson at NLO accuracy”. In: *Phys. Rev. D* 85 (2012), p. 054015. DOI: 10.1103/PhysRevD.85.054015. arXiv: 1111.0610 [hep-ph].

- [84] Ronald H. P. Kleiss et al. “Counting to One: Reducibility of One- and Two-Loop Amplitudes at the Integrand Level”. In: *JHEP* 12 (2012), p. 038. DOI: 10.1007/JHEP12(2012)038. arXiv: 1206.4180 [hep-ph].
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- [82] Giuseppe Bevilacqua et al. “Complete off-shell effects in top quark pair hadroproduction with leptonic decay at next-to-leading order”. In: *JHEP* 02 (2011), p. 083. DOI: 10.1007/JHEP02(2011)083. arXiv: 1012.4230 [hep-ph].
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### 12.4 PhD Thesis

Title in Greek: ”Μελέτη παραγωγής αδρονικών πιδάκων στα πλαίσια μη καθιερωμένων προτύπων”

Title in English: ’Jet production beyond the Standard Model’,

PhD Thesis, University of Athens, Physics Department, June 1989.

Advisory Committee: Prof. N. Antoniou, (main advisor), Prof. C. Kourkoumelis and Prof. S. Vlassopoulos.

<http://dx.doi.org/10.12681/eadd/44635>

## 13 Citations

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