UNIVERSITÀ DEGLI STUDI DI MILANO

TO MAGNIFICO RETTORE OF UNIVERSITA' DEGLI STUDI DI MILANO ID CODE 4642

I the undersigned asks to participate in the public selection, for qualifications and examinations, for the awarding of a type B fellowship at **Dipartimento di Fisica Aldo Pontremoli**

Scientist - in - charge: **Prof. Alessandro Vicini**

NARAYAN RANA

CURRICULUM VITAE

PERSONAL INFORMATION

Surname	RANA
Name	NARAYAN
Date of birth	25/03/1990

PRESENT OCCUPATION

Appointment	Structure
Researcher (2018-NOW)	INFN Sezione di Milano, Milan, Italy

PAST OCCUPATION

Appointment	Structure
Postdoctoral Fellow (2016-2018)	DESY, Zeuthen, Germany

EDUCATION AND TRAINING

Degree	Course of studies	University	Year
Ph.D.	Physics	Homi Bhaba National Institute (IMSc)	2016
Master of Science	Physics	Homi Bhaba National Institute (HRI)	2013

REGISTRATION IN PROFESSIONAL ASSOCIATIONS

Date of registration	Association	City

FOREIGN LANGUAGES

Languages	level of knowledge
English	C2 (Proficient)
Bengali	Mother Tongue
Hindi	C1 (Advanced)
German, Italian	A1 (Basic)

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AWARDS, ACKNOWLEDGEMENTS, SCHOLARSHIPS

Year	Description of award
2013	CSIR-UGC NET in Physical Sciences, qualified in June 2013
2008-10	INSPIRE-SHE Fellowship for B.Sc.
2007	Merit-cum-Means Scholarship

TRAINING OR RESEARCH ACTIVITY

Description of activity

In the past years, I have been working on following research topis.

1. Mixed NNLO QCDxEW corrections to Z production at the LHC

I have obtained the most precise result till date to the inclusive production cross section of a Z boson at the LHC by computing the mixed QCDxEW corrections at NNLO with my collaborators at University of Roma Tre, University of Oxford and University of Milan.

We have computed the first analytic result for such corrections which are very important steps to obtain the mixed QCDxEW corrections to the full Drell-Yan production. We have included the complete set of contributions, with photonic and massive weak gauge boson effects, which have been computed analytically and expressed in terms of polylogarithmic and elliptic functions. To obtain them, we have to deal with two-loop virtual integrals in the double-virtual corrections, with two-body phase-space and one virtual loop integrals in the real-virtual case, and with three-body phase-space integrals for the double-real processes. In real emission cases, we use the reverse unitarity technique to transform the phase-space integrals into loop integrals satisfying the additional constraint imposed by on-shell-ness of the final-state particles. In this way, we can reduce all the integrals of all the partonic processes to the master integrals via the integration-by-parts reduction technique. The resulting master integrals are then computed solving the relevant differential equations. We present numerical results, relevant for the precision studies at the hadron colliders, which increase the accuracy of the predictions and contribute to the reduction of the QCD component of the theoretical uncertainty.

2. Higher order QCD corrections to heavy quark pair production

I have obtained the three-loop heavy quark form factors in the color-planar limit for vector, axial-vector, scalar and pseudo-scalar currents with my collaborators at DESY, Germany and RISC, Austria.

We have presented an algorithm which allows to solve analytically linear systems of differential equations which factorize to first order. The solution is given in terms of iterated integrals over an alphabet where its structure is implied by the coefficient matrix of the differential equations. These systems appear in a large variety of higher order calculations in perturbative Quantum Field Theories. We have applied this method to calculate the master integrals of the three-loop massive form factors for different currents, as an illustration. Here the solution space emerging is given by the cyclotomic harmonic poly-logarithms and their associated special constants. These form factors constitute an important part for top quark precision phenomenology. The algorithm can be applied as well to more general cases factorizing at first order, which are based on more general alphabets, iterated integrals and associated constants.

3. NNLO QCD corrections to Higgs boson pair production

I have obtained next-to-next-to leading order (NNLO) QCD corrections to the production of a pair of Higgs bosons at the Large Hadron Collider (LHC) in bottom quark annihilation with my collaborators at IMSc India, PSI Switzerland and INFN Florence.

We have computed the first results on the two-loop massless QCD corrections to the four-point amplitude $b + \bar{b} \to H + H$ in the five flavor scheme, treating bottom quarks as massless. This amplitude is sensitive to the trilinear Higgs boson coupling. Using these two loop amplitudes and exploiting the universality of the soft contributions in perturbative QCD, we have obtained the NNLO QCD effects in the soft plus virtual approximation. We have found that the inclusion of higher order terms reduces the uncertainties resulting from the unphysical renormalization and factorization scales.

4. Mixed QCDxQED corrections to Higgs boson production in bottom quark annihilation

With the increasing demand of precision at the LHC, the sub-dominant corrections to LHC processes are becoming important, specially the mixed QCD×EW corrections. As a first step, I have computed the mixed QCD×QED corrections to the production of the Higgs boson in bottom quark annihilation at NNLO level with my collaborators at IMSc India, PSI Switzerland and INFN Florence.

We have presented NNLO QED corrections to the production of the Higgs boson in bottom quark annihilation at the LHC in the five flavor scheme. We have systematically included the NNLO corrections resulting from the interference of QCD and QED interactions. We have investigated the infrared (IR) structure of the bottom quark form factor up to two loop level in QED and in QCD×QED using K+G equation. We find that the IR poles in the form factor are controlled by the universal cusp, collinear and soft anomalous dimensions. In addition, we have derived the QED as well as QCD×QED contributions to soft distribution function as well as to the ultraviolet renormalization constant of the bottom Yukawa coupling up to second order in strong coupling and fine structure constant. Finally, we have reported our findings on the numerical impact of the NNLO results from QED and QCD×QED at the LHC energies taking into account the dominant NNLO QCD corrections.

PROJECT ACTIVITY

Year	Project
2018-2020	Precise perturbative QCD predictions for Large Hadron Collider physics

PATENTS

Patent

CONGRESSES / CONFERENCES

Date	Title	Place
09.09.19–13.09.19	RADCOR 2019	Avignon, France
10.03.19-15.03.19	ACAT 2019	Saas Fee, Switzerland
10.12.18-14.12.18	DAE-BRNS HEP Symposium	Chennai, India
27.08.18-31.08.18	QCD@LHC 2018	Dresden, Germany
14.06.18-23.06.18	ISSP 2018	Erice, Sicily
29.04.18-04.05.18	LL 2018	St Goar, Germany
27.11.17-29.11.17	Physics at the Terascale	Hamburg, Germany
23.10.17-26.10.17	KMPB Conference	Zeuthen, Germany
24.09.17-29.09.17	RADCOR 2017	St. Gilgen, Austria
03.09.17-08.09.17	Matter To The Deepest	Podlesice, Poland
29.05.17-02.06.17	Future Circular Collider Week	Berlin, Germany
20.03.17-24.03.17	CAPP 2017	Hamburg, Germany
24.04.16-29.04.16	LL 2016	Leipzig, Germany
22.03.16-25.03.16	Frontiers in HEP III	Chennai, India

CONFERENCE SEMINARS

Date	Title	Place
10.09.19	NNLO mixed EW-QCD corrections to single vector boson production	RADCOR-2019, Avignon, France
29.08.19	NNLO mixed EW-QCD corrections to single vector boson production	NNPDF-&-N3PDF Meet, Varenna, Italy,
13.03.19	Three loop QCD corrections to heavy quark form factors	ACAT2019, Saas Fee, Switzerland
13.12.18	Three loop QCD corrections to heavy quark form factors	DAE-BRNS HEP Sym. 2018, Chennai, India
30.08.18	Three loop QCD corrections to heavy quark form factors	QCD@LHC 2018, Dresden, Germany
20.06.18	Multiloop computation in perturbative QCD : technological advancement and automation	ISSP, Erice, Sicily
30.04.18	Massive three loop form factors in the planar limit	LL 2018, St. Goar, Germany
28.11.17	Higher order QCD corrections to heavy quark form factors	Terascale 2017, Hamburg, Germany
25.09.17	Two-loop massive form factors for different currents up to ε2	RADCOR 2017, St. Gilgen, Austria
04.09.17	Heavy quark form factors at two-loop in perturbative QCD	MTTD-2017, Podlesice, Poland
22.03.16	Threshold cross sections for DY & Higgs productions in N3LO QCD	FHEP III, Chennai, India

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OTHER SEMINARS

1. Precision physics for the LHC and beyond
    - IOP, Bhubaneswar, India, 30th September, 2019
2. Three loop QCD corrections to massive form factors and its asymptotic behavior
    - IACS, Kolkata, India, 31st July, 2019
    - UCL, Louvain, Belgium, 18th February, 2019
3. Three loop QCD corrections to heavy quark form factors
    - Joint INFN-UNIMI-UNIMIB Pheno Seminar, Milan, Italy, 28th June, 2018
    - IMSc, Chennai, India, 15th May, 2018
4. Higher order QCD corrections to heavy quark form factors
    - SINP, Kolkata, India, 2nd November, 2017
    - IACS, Kolkata, India, 1st November, 2017
5. Threshold cross sections for Drell-Yan & Higgs productions in N3LO QCD
    - DESY, Zeuthen, Germany, 20th October, 2016
    - LAPTh, Annecy, France, 4th May, 2016
6. NNLO QCD Corrections to the Drell-Yan Cross Section in TeV-Scale Gravity
    - Saha Institute of Nuclear Physics, Kolkata, India, 11th July, 2016
    - University of Zurich, Zurich, Switzerland, May, 2016
7. Two loop QCD amplitudes for Higgs + 1 jet production in bottom quark annihilation
    - Albert Einstein Center for Fundamental Physics, Universität Bern, Bern, Switzerland, 20th July, 2015
    - Sezione di Padova, INFN, Padova, Italy, 15th July, 2015
    - Sezione di Roma, INFN, Rome, Italy, 6th July, 2015
8. Two loop amplitudes for Higgs + 1 jet production in QCD
    - The Institute of Mathematical Sciences, India, July, 2015
    - Harish-Chandra Research Institute, India, July, 2014
9. Threshold and RG improved cross-sections for Drell-Yan & Higgs productions in N3LO QCD
    - Institute for Theoretical Particle Physics and Cosmology, RWTH Aachen University, Aachen, Germany, 17th July, 2015
    - Sezione di Padova, INFN, Padova, Italy, 14th July, 2015
    - Theoretical Physics, NIKHEF, Amsterdam, The Netherlands, 9th July, 2015
    - Institut für Theoretische Teilchenphysik, KIT, Karlsruhe, Germany, 3rd July, 2015
    - Max-Planck-Institut für Physik, Munich, Germany, 1st July, 2015
    - Sezione di Firenze, INFN, Florence, Italy, 30th June, 2015

PUBLICATIONS

Books

Articles in reviews / Published articles
23. NNLO QCD×EW corrections to Z production in the qq̄ channel, Phys. Rev. D 101 (2020) 031301(R) [arXiv:1911.06200 [hep-ph]].
22. The Heavy Fermion Contributions to the Massive Three Loop Form Factors, Nucl. Phys. B 949 (2019) 114751 [arXiv:1908.00357 [hep-ph]].
21. NNLO QCD⊕QED corrections to Higgs production in bottom quark annihilation, Phys. Rev. D 100 (2019) 114016 [arXiv:1906.09028 [hep-ph]].
20. Higgs pair production from bottom quark annihilation to NNLO in QCD, JHEP 1905 (2019) 030 [arXiv:1811.01853 [hep-ph]].
19. Automated Solution of First Order Factorizable Systems of Differential Equations in One Variable, Nucl. Phys. B 939 (2019) 253-291 [arXiv:1810.12261 [hep-ph]].
18. Asymptotic behavior of the heavy quark form factors at higher order, Phys. Rev. D 99 (2019) 016013 [arXiv:1810.08943 [hep-ph]].
17. Heavy Quark Form Factors at Three Loops in the Planar Limit, Phys. Lett. B 782 (2018) 528-532 [arXiv:1807.05943 [hep-ph]].
16. The Heavy Quark Form Factors at Two Loops, Phys. Rev. D 97 (2018) 094022 [arXiv:1712.09889 [hep-ph]].
15. Three loop form factors of a massive spin-2 particle with nonuniversal coupling, Phys. Rev. D 95 (2017) 034035 [arXiv:1612.00024 [hep-ph]].
14. Konishi Form Factor at Three Loop in N = 4 SYM, Phys. Rev. D 95 (2017) 085019 [arXiv:1610.05317 [hep-th]].
13. The two-loop QCD correction to massive spin-2 resonance → qq̄g, Eur. Phys. J. C 76 (2016) 667 [arXiv:1608.05906 [hep-ph]].
12. NNLO QCD corrections to the Drell-Yan cross section in models of TeV-scale gravity, Eur. Phys. J. C 77 (2017) 22 [arXiv:1606.08454 [hep-ph]].
11. Pseudo-scalar Higgs boson production at N3LO_A + N3LL', Eur. Phys. J. C 76 (2016) 663 [arXiv:1606.00837 [hep-ph]].
10. Pseudo-scalar Higgs Boson Production at Threshold N3LO and N3LL QCD, Eur. Phys. J. C 76 (2016) 355 [arXiv:1510.02235 [hep-ph]].
9. Pseudo-scalar Form Factors at Three Loops in QCD, JHEP 1511 (2015) 169 [arXiv:1510.01715 [hep-ph]].
8. Spin-2 Form Factors at Three Loop in QCD, JHEP 1512 (2015) 084 [arXiv:1508.05043 [hep-ph]].
7. RG improved Higgs boson production to N 3 LO in QCD, [arXiv:1505.07422 [hep-ph]].
6. Higgs Rapidity Distribution in bb̄ Annihilation at Threshold in N3LO QCD, JHEP 1502 (2015) 131 [arXiv:1411.5301 [hep-ph]].
5. Higgs boson production through bb̄ annihilation at threshold in N3LO QCD, JHEP 1410 (2014) 139

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[arXiv:1408.0787 [hep-ph]].
4. Two-loop QCD corrections to Higgs → b+b+g amplitude, JHEP 1408 (2014) 075 [arXiv:1405.2324 [hep-ph]].
3. Rapidity Distributions in Drell-Yan and Higgs Productions at Threshold to Third Order in QCD, Phys. Rev. Lett. 113 (2014) 212003 [arXiv:1404.6504 [hep-ph]].
2. Drell-Yan Production at Threshold to Third Order in QCD, Phys. Rev. Lett. 113 (2014) 11, 112002 [arXiv:1404.0366 [hep-ph]].
1. Two-Loop QCD Correction to massive spin-2 resonance → 3 gluons, JHEP 1405 (2014) 107 [arXiv:1404.0028 [hep-ph]].

Congress proceedings
7. Heavy quark form factors at three loops, PoS RADCOR2019 (2019) 013.
6. NNLO mixed EW-QCD corrections to single vector boson production, Radcor 2019.
5. Three loop heavy quark form factors and their asymptotic behavior, DAE-BRNS symposium 2018.
4. Three loop QCD corrections to heavy quark form factors, ACAT 2019
3. Massive three loop form factors in the planar limit, PoS LL2018 (2018) 009.
2. Heavy quark form factors at two loops in perturbative QCD, Acta Phys.Polon. B 48 (2017) 2155.
1. Pseudo-scalar Higgs boson form factors at 3 loops in QCD, PoS LL2016 (2016) 026.

OTHER INFORMATION

I have obtained M.Sc. degree as a part of an integrated program ‘Integrated Ph.D.’ under the university ‘Homi Bhaba National Institute’. The final exam (Oral General Comprehensive Examination) for M.Sc. was held on 15.07.2013. However after bureaucratic procedures I have received the M.Sc. certificate in April, 2015.

Declarations given in the present curriculum must be considered released according to art. 46 and 47 of DPR n. 445/2000.

The present curriculum does not contain confidential and legal information according to art. 4, paragraph 1, points d) and e) of D.Lgs. 30.06.2003 n. 196.

Place and date: Gopiballavpur, India, 09/07/2020

SIGNATURE

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