V. Ravindran

Curriculum Vitae

The Institute of Mathematical Sciences
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Personal Information

Nationality Indian   Date of Birth 9th October, 1965

Research Interests

- Yang-Mills theory, QCD, Higgs physics, Collider Physics Phenomenology
- Quantum field theory techniques: multi-leg, multi-loop computations in QCD
- Soft gluon resummation, infra-red structure of QCD multi-loop amplitudes
- Spin and model identification at the Large Hadron Collider (LHC)
- Parton shower and matching using aMC@NLO

Technical Skills

Language C, Fortran, Mathematica, Maple, FORM
Packages QGRAF, FIRE, LITERED, Reduze 2, Gnuplot

Education

1982–1985 **Bachelor of Science (Physics major)**
Voorhees college, University of Madras, Vellore 632 001, India

1985–1987 **Master of Science (Physics)**
Govt. Arts College, University of Madras, Thiruannamalai, India

1987–1993 **Ph. D. (Theoretical Physics)**
Institute of Mathematical Sciences, Chennai 600 113, India

Work Experience

1994–1995 **PDF**, Tata Institute of Fundamental Research, Mumbai
1996–1997 **PDF**, Physical Research Laboratory, Ahmedabad
1997–1999 **PDF**, DESY, Zeuthen, Germany
1999–2000 **Faculty (Fellow D)**, Harish-Chandra Research Institute, Allahabad
2000–2001 **Faculty (Reader E)**, Harish-Chandra Research Institute, Allahabad
2001–2004 **Faculty (Asso.Prof F)**, Harish-Chandra Research Institute, Allahabad
2004–2010 **Faculty (Asso.Prof G)**, Harish-Chandra Research Institute, Allahabad
2010–2012 **Faculty (Prof H)**, Harish-Chandra Research Institute, Allahabad
2012–NOW **Faculty (Prof H)**, The Institute of Mathematical Sciences, Chennai

Fellowships and Awards:

- JSPS Visiting Scientist at KEK, Japan from 01-11-2006 to 30-12-2006
- FOM Associate Fellow at Lorentz Institute, The Netherlands from 01-06-2006 to 30-08-2006
- FOM Associate Fellow at Lorentz Institute, The Netherlands from 01-05-2007 30-07-2007
- Elected as Fellow of Indian Academy of Science in 2012.

Guiding experience:

- Ph.D. Students (completed):
  - Anurag Tripathi, completed in 2009
  - Manoj Mandal, completed in 2015
  - Maguni Mahakhud , completed in 2015
  - Taushif Ahmed , completed in 2016
  - Narayan Rana , completed in 2016
- Co-guided a Ph.D. Student: Neelima Agarwal, completed in 2011.
- Ph.D. Students:
  - Prasanna Kumar Dhani (completing in 2017)
  - Pulak Banerjee (completing in 2017)
  - Amlan Chakaraborty
  - Puja Mukherjee
  - A.H. Ajjath

Summary of Major Contributions:

The Higgs boson is the corner stone of the Standard Model and its discovery at the LHC is the most fundamental one in physics. My work on predicting its cross section within perturbative QCD has played the most important role in the discovery. Using the state-of-the-art quantum field theoretic techniques, I had shown that QCD effects can increase the cross section by factor of two reducing the theoretical uncetainty significantly. This paper is the "renowned paper" on hep-spires and also cited by all the publications from LHC, CERN on the Higgs boson. I had also developed an elegant framework that can provide preditions for the inclusive and semi-inclusive observables for Higgs boson as well as Drell-Yan productions at three loop level in QCD in the threshold limit which belong to the most precise results available till today in the collider physics studies, recently appeared as "two papers in Physical Review Letters". My works on "Characterisation of Higgs boson" and di-leptons/bosons production are widely used by the CMS/ATLAS collaborations at the LHC.

Impact of the works on HEP Experiments:

- The study of the properties of the Higgs boson has been going on at the LHC. Our next to leading order (NLO) predictions for the differential distributions and next to next to leading order (NNLO) predictions for the total cross section for the Higgs production have been used by both Tevatron and LHC experimental groups for their analysis of Higgs searches.
- Leptonic and photonic final states in hadron colliders provide useful informations in the search of new physics. The bounds on the new physics model parameters can be obtained from the experimental data in these channels provided precise predictions are available from the theory. Any such analysis requires what is called K-factor that parameterizes the potential higher order QCD effects which are often large at present collider energies. Our predictions for K-factors are being used by both CDF at the Tevatron and CMS at the LHC to set search limits on the parameters in extra dimension models such as ADD and RS.

Highlights of my Recent Works:

My current research focuses mainly on perturbative aspects of Quantum Chromodynamics (QCD) and its application to high energy scattering processes. This involves deeper understanding of perturbative structure of multi-loop and multi-leg QCD amplitudes which constitute the higher order QCD radiative corrections to various observables at hadronic colliders such as Tevatron at Fermi lab and Large Hadron Collider (LHC) at CERN. In these hadron colliders, the incoming states being protons and/or anti-protons, QCD plays an important role in the production mechanism of particles in the Standard Model (SM) as well as in any physics beyond the Standard Model (BSM).

- **Higgs production at NNLO and beyond:** I have been working on the impact of higher order QCD effects to various SM processes such as Drell-Yan and Higgs boson productions at hadron colliders. We have computed next to leading order (NLO) QCD corrections to differential distributions $d^2\sigma/dp_T/dy$ and NNLO QCD corrections to total cross section for the Higgs production at Tevatron and LHC. Using these results we estimated the theoretical uncertainties by comparing the K-factors and the variation with respect to the mass factorization/renormalization scales with the results obtained by lower order calculations. These estimates have already played important role at Tevatron and in particular at the LHC to discover Higgs boson. We also found that the total cross section is dominated by the soft and virtual gluons. This is of interest for the resummation of large corrections which occur near the boundary of phase space. Such corrections have already been taken into account for these studies through various resummation methods.
- **Higgs Characterisation:** Effective field theory approach is one the powerful methods to study the characterisation of the Higgs boson discovered at the LHC. Given that there are large number of higher dimensional operators, a systematic approach in a automated framework is essential. Using MadGraph 5 and aMC@NLO, we have incorporated relevant higher dimensional opertors along with next to leading order QCD effects to study spin and parity properties of the Higgs boson.
- **Infra-red pole structure of QCD amplitudes:** Our two loop computation on the quark and gluon form factors in $SU(N)$ gauge theory elucidates the origin of the second order infra-red single pole terms and they are found to be equal to the second order singular

part of the anomalous dimension plus a universal function. This observation on the single pole structure of the form factors completes the challenging problem of understanding the infra-red structure of such amplitudes. Based on this, it is now possible to understand the complete infra-red structure of multi-parton amplitudes in $SU(N)$ gauge theories and similar studies have been extended to non-perturbative regions of conformally invariant theories using AdS/CFT correspondence.

- **Soft gluon resummation and N^3LO results:** The infra-red structure of QCD amplitudes supplemented with renormalisation group invariance provides useful guidance to compute the dominant QCD effects, namely soft gluon corrections to various observables. In this context, I have determined the soft distribution functions to N^3LO level for DIS, hadro-production in e^+e^- collisions, Drell-Yan and Higgs production processes using mass factorisation theorem and the perturbative results that are known upto three loop level in QCD. Using these distributions I have obtained threshold enhanced QCD corrections as well as the exponents of resumed cross sections beyond two loop level for various inclusive processes. The results are found to reduce various scale uncertainties making the predictions stable.
- **NLO QCD corrections for BSM physics:** Models of extra dimensions have dominated the theoretical literature on physics beyond the standard model. Existing collider studies of the effects of gravitons have been done at the Born level in QCD. It is important to incorporate NLO QCD corrections to these processes in order to quantify the size of the effects and to see how robust the leading order estimate of the cross-section is with respect to these corrections. We have investigated the quantitative impact of the QCD corrections for searches of extra dimensions at hadron colliders. We have computed these effects for several important reactions that are now used to study these models at Tevatron and at the LHC. They include processes such as Drell-Yan, Di-photon, WW and ZZ productions where the gravitons appear at propagator level and also processes where real gravitons are emitted along with photon/W/Z. We found that at the LHC ($\sqrt{S} = 14TeV$) the K-factors for all these processes are rather large ($K = 1.6$), indicating the importance of accounting for these QCD corrections in the experimental search for TeV-scale gravity. Our predictions are more suited for the analysis since they are less sensitive to unphysical scales namely renormalisation and factorisation scales. Our approach has been extended to other BSM searches such as R-parity violation SUSY, unparticles etc at colliders. We have also successfully completed a first NNLO QCD computation for the resonant production cross section of neutral/charged slepton at the hadron colliders. First results on two loop QCD radiative corrections to graviton mediated processes in both ADD and RS models are also obtained by us.

- **Higher orders with Parton Shower:** Combining fixed order perturbative results and the parton shower Monte Carlo (PS) can cover most of the kinematical regions in order to consistently include resummation in the collinear limit and also allow us to study more exclusive final states and provide predictions as realistic as possible to the experimental situations. One can also include various hadronisation models to simulate final state configurations. Recently, using aMC@NLO which uses MC@NLO formalism and FKS subtraction methods in the MadGraph framework, we have studied di-lepton, di-vector boson signals at the LHC in both ADD and RS models upto NLO in QCD with parton showering to obtain various kinematic distributions.

List of Ten Best Publications

1. NNLO corrections to the total cross-section for Higgs boson production in hadron hadron collisions,
   V. Ravindran, J. Smith, W. L. van Neerven,
   Nuclear Physics B665, (2003), 325 .

2. Next-to-leading order QCD corrections to differential distributions of Higgs boson production in hadron-hadron collisions,
   V. Ravindran, J. Smith, and W.L. van Neerven,
   Nuclear Physics B634, (2002), 247.

3. Higher-order threshold effects to inclusive processes in QCD,
   V. Ravindran,
   Nuclear Physics B752,(2006),173 .

4. Next to leading order QCD corrections to the Drell-Yan cross section in models of TEV-Scale gravity, Prakash Mathews, V. Ravindran, K. Sridhar, W.L. van Neerven,
   Nuclear Physics B713, (2005) 333 .

5. A framework for Higgs characterisation,
   P. Artoisenet, P. de Aquino, F. Demartin, R. Frederix, S. Frixione, F. Maltoni, M.K. Mandal, P. Mathews, K. Mawatari, V. Ravindran,
   JHEP 1311 (2013) 043.

6. Mellin moments of the next-to-next-to leading order coefficient functions for the Drell-Yan process and hadronic Higgs-boson production,
   J. Blümlein and V. Ravindran,
   Nuclear Physics B716, (2005), 128 .

7. Two Loop Corrections to Higgs Production,
   V. Ravindran, J. Smith, W.L. van Neerven,
   Nuclear Physics B704, (2005) 332.

8. Diphoton signals in theories with large extra dimensions to NLO QCD at hadron colliders,
   M. C. Kumar, Prakash Mathews, V. Ravindran and A. Tripathi,
   Physics Letters B 672 (2009) 45.

9. On Sudakov and soft resummations in QCD,
   V. Ravindran,
   Nuclear Physics B746, (2006),58.

10. Drell-Yan Production at Threshold to Third Order in QCD,
    T. Ahmed, M. Mahakhud, N. Rana and V. Ravindran,
    Phys. Rev. Lett. 113 no. 11, (2014) 112002.