

Early Stage Researcher Introduction

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LHCphenOnet



Appointment to Scholarship

- 1 MSci in Theoretical Physics at the University of Durham, GB, 2007
(Thesis: Orbifold Grand Unified Theories, under Dr Förste)
- 2 PhD in Theoretical High Energy Physics at Swansea University, GB, 2011
(Thesis: The Precision Parameters of Electroweak Symmetry Breaking Without a Fundamental Higgs, under Dr Piai)
- 3 In October 2011 began tenure of an ESR position in Linz, Austria at RISC.
- 4 I work under Dr Carsten Schneider in Austria and my co-advisor is Prof Johannes Blümlein in DESY, Germany.

- ① RISC works in close collaboration with LHCPHenoNet Partner DESY.
- ② RISC provides automation tools and algorithms in the form of software to aid perturbative calculations.
- ③ Most open research is within integration with respect to Feynman parameters and solving sums.

- When computing Feynman diagrams one must integrate over unknown momenta and perform integrals over Feynman Parameters.
- Some diagrams also contain sums that originate from operator insertions.
- While performing Feynman parameter integrals one frequently introduces more sums.
- Open areas of research to automate Feynman diagram computations are automated integration and summation technologies.

Research Project

New Multi-Summation Algorithm

Most of my time has been devoted to developing a new multi-summation algorithm. For example the following sum arose in a particular QCD graph,

$$\sum_{i=2}^{n+1} \sum_{j=2}^{n+2-i} \sum_{a=0}^{\infty} \sum_{b=0}^{\infty} \frac{\binom{n+2}{i} \binom{n+2-i}{j} (-1)^{i+j} B[i, j] (j+i-1)}{(j+i+a+b)(i+j+a+b-1)(j+b)(i+b)}$$

where the Harmonic numbers are abbreviated by $S_{a,\dots,b} = S_{a,\dots,b}(n)$ & $B[x, y] = \Gamma[x]\Gamma[y]/\Gamma[x+y]$.

Research Project

New Multi-Summation Algorithm

To simplify the sum one can apply my implementation to show that,

$$\begin{aligned} & \frac{2n^3 + 5n^2 + 4n - 2}{n + 1} S_2 + \left[\frac{5}{2} S_2 - \frac{n^2 + 2n + 2}{n + 1} \right] S_1^2 - 2n S_{2,1} \\ & - 2n(n + 1) \zeta_3 - S_1^3 + \frac{1}{4} S_1^4 - \frac{1}{4} S_2^2 + 2(n + 1) S_3 - \frac{1}{2} S_4 - 2S_{3,1} \\ & + [4\zeta_3 + (2n - 1) S_2 + 2S_3 - 2(n + 1) - 4S_{2,1}] S_1 + 2S_{2,1,1} \end{aligned}$$

Typically an individual Feynman diagram leads to many such sums in our project.

Secondly I work on automated integration. As an example take a textbook 1-loop QCD gluon vacuum polarisation using the 4-point vertex. The amplitude in Feynman gauge ($\xi = 1$) is,

$$ig^2 C_2(G) \int_0^1 dx \int \frac{d^d k}{(2\pi)^4} \frac{1}{(k^2 - \Delta^2)^2} g^{\mu\nu} (d-1) [k^2 + (1-x)^2 q^2]$$

for d the number of spacetime dimensions and $\Delta = -x(1-x)q^2$.

Apply integration algorithms to perform momentum and Feynman parameter integrals...

$$\begin{aligned} & - i \frac{g^2}{(4\pi)^{\frac{d}{2}}} C_2(G) q^{d-2} g^{\mu\nu} \left[\frac{1}{2} d(d-1) \Gamma\left(1 - \frac{d}{2}\right) B\left(\frac{d}{2}, \frac{d}{2}\right) \right. \\ & \left. + (d-1) \Gamma\left(2 - \frac{d}{2}\right) B\left(\frac{d}{2} - 1, \frac{d}{2} + 1\right) \right] \end{aligned}$$

We are looking at extending such standard tools and results to more difficult diagrams, such as those found at higher loops.

Training During Tenure

Of the courses offered by my institute, I have attended;

- ① Algorithmic Combinatorics
- ② Analytic Combinatorics
- ③ Computer Analysis (Symbolic Integration)
- ④ Symbolic Summation I & II
- ⑤ Computer Algebra I & II
- ⑥ Combinatorics Seminar Schedule

My institute also offers German courses which I am attending. Finally I was a local organiser of the LHCPheNet School on Integration, Summation and Special Functions in QFT.

Most of my first year was devoted to acquiring a wide range of new mathematical and programming skills. This has left me ready to make a significant impact on the RISC DESY collaboration.

In addition I have given a number of talks.

- Numerous talks to the RISC combinatorics group
- RISC-DESY Workshop
- LHCPheNoNet Durham

I have also given popular talks to the public in Linz.

I plan to begin working more closely with DESY and visit their institute to exploit the new skills I have aquired at RISC. It is expected my summation algorithm can also be used to solve summation problems in particle physics.