Experimental Particle Physics

Understanding the measurements and searches at the Large Hadron Collider

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Cover image shows a visualization of the highest-mass dijet event, (Event 4144227629, Run 305777) recorded in 2016 by the ATLAS Experiment. The two central high-pT jets each have transverse momenta of 3.74 TeV, they have a y* of 0.38 and their invariant mass is 8.02 TeV. © CERN, reproduced with permission.

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To all my CDF and ATLAS collaborators over the years,
from whom I have learned everything!

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Preface

If you can't explain something to a first year student, then you haven't really understood it.

—Richard Feynman

My interactions with new students in experimental particle physics have led me to believe that many of them lack a broad overview of what they are doing, although they are often proficient in coding, quick in obtaining results, and fearless in presenting in meetings. Also, while there are excellent books covering theoretical aspects of collider physics, a practical guide to terminology and techniques used in the field is missing. Newcomers in the field mostly end up learning from their peers, seniors or from week-long schools, where many of the topics are covered at an insanely fast pace.

This book is an attempt to address that shortcoming. It originated from teaching a one semester-long, advanced undergraduate introduction to experimental particle physics course at the School of Physics at the University of Witwatersrand. The aim of the course was that at the end, the student should be able to digest an experimental paper, and the book follows the same philosophy.

Although in some sense a compilation, my hope is that a single book will fill the void for a one-stop resource. This can be either used as a textbook for a semester course (with the last two chapters as optional reading), or simply as required reading for a student starting in this field. Many of the exercises are designed to trigger thinking, or point to common pitfalls a beginner encounters.

Of course there are obvious shortcomings in such an effort. Many of the topics are not covered in as much detail as they merit, which is somewhat on purpose. The idea is to make beginners aware of concepts, point them to the resources, and let them take it from there. This will, hence, not be a replacement for a theoretical textbook introducing the Standard Model, but rather be complementary to it. Keeping that in mind, elaborate calculations have been avoided as much as practicable, and focus has been on introducing the commonly used analysis methods. Although I have strived hard to keep everything as general as possible, there is an overload of examples from ATLAS, and this is solely due to the fact that it was easier for me to find those.

I am heavily indebted to numerous colleagues over the years, both experimentalists and theorists, from whom I learned everything I discuss here. I would also love to hear from the community, so that subsequent editions can be improved.

First and foremost, Nabanita Mukherjee (AbbVie pharmaceuticals, formerly at Duke University, PhD in Statistics from University of Florida) helped me to write the statistics part. I cannot thank her enough for her time and patience, especially when she was going through a difficult time.

Many colleagues read the whole book or some chapters and provided invaluable suggestions. I am immensely grateful to all of them. Andy Buckley, Rick Field, Marvin Flores, Andrew Larkoski, Jong Soo Kim, Swagata Mukherjee, Tuhin Roy and Michael Spannowsky I cannot thank you enough. Danielle Wilson spent her end of second year undergraduate break reading the book, and pointed out the parts where I was not clear enough. Her review, from a non-expert perspective, helped massively. The same goes to my PHYS4029A classes of 2017 and 2018, as a large fraction of the material was fine-tuned in response to discussions in class.

During the course of writing the book, the conversations I had with Stefan von Buddenbrock, Jon Butterworth, Tasnuva Chowdhury, Valentina Cairo, Kaustuv Datta, Bruce Mellado, Debarati Roy, Xifeng Ruan, Seema Sharma and Sukanya Sinha have contributed significantly to both the content and presentation. In fact, many examples I use are motivated from the discussions we had in ATLAS, so it is only fair that I thank the whole ATLAS community. I sincerely thank Heather Russell and Frederic Dreyer for letting me use their figures. Sukanya proofread the entire book, and Stefan also helped in drawing a number of figures.

I received useful advice from many friends, and I would specifically mention Debashree Dattaray. The constant support of Nikhliesh Kar, Ramala Kar, and Nandini Kar must be acknowledged, as well as of Saswati Roy.

Finally, it would be a travesty not to thank Dan Heatley from IoP Publishing, without whose persistent push, this book would have probably never seen the light of day.

Author biography

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Deepak Kar is currently an associate professor at the School of Physics, at the University of Witwatersrand, in Johannesburg, South Africa. He is an active of the ATLAS collaboration at the Large Hadron Collider at CERN. Previously, he was a post-doctoral researcher at the University of Glasgow (2012–15), and at Technische Universität Dresden (2009–11). He completed his PhD from University of Florida in 2008, working on CDF experiment at Tevatron in Fermilab. He likes travelling, follows current affairs and sports avidly, and is a big fan of South African wines.