BOOK LAUNCH

QUANTUM ENTANGLEMENT IN HIGH ENERGY PHYSICS

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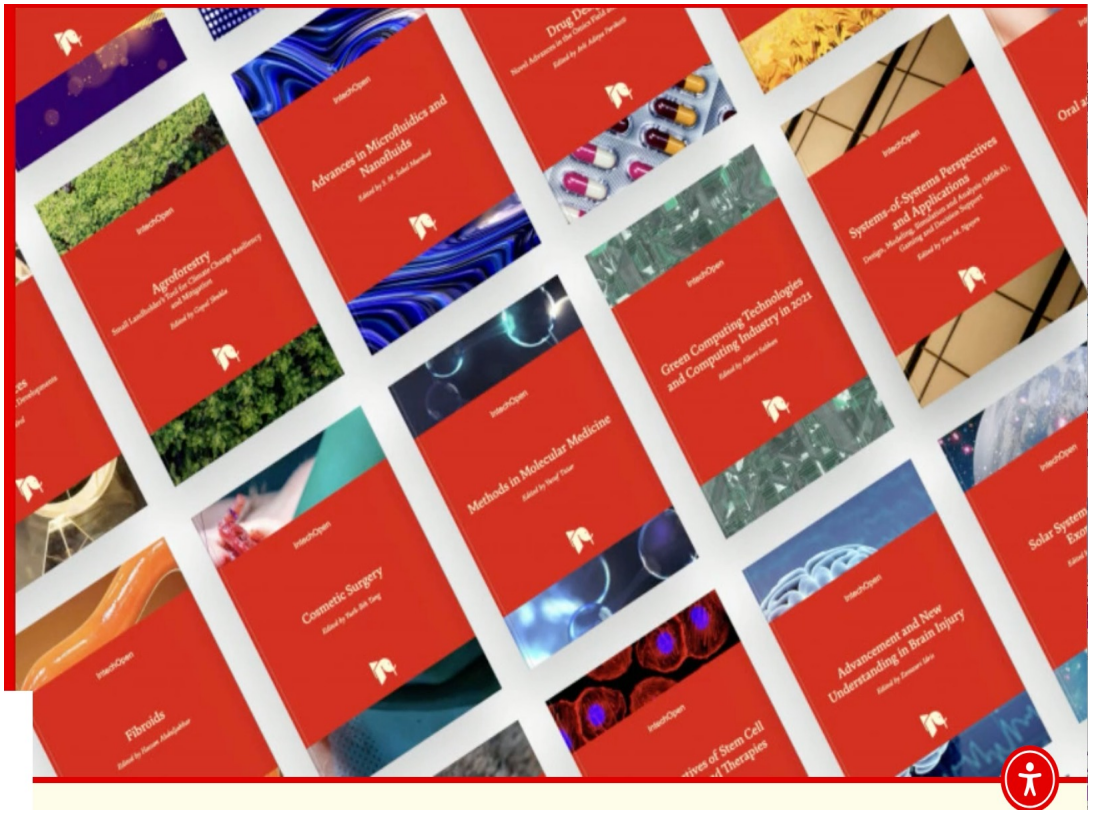

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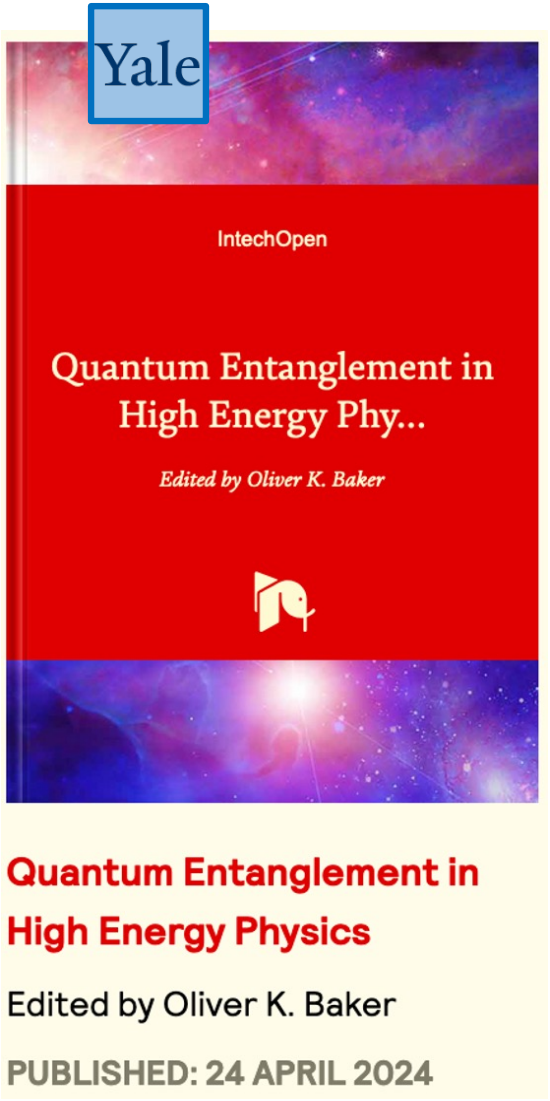

Quantum Entanglement in High Energy Physics

Edited by Oliver K. Baker

PUBLISHED: 24 APRIL 2024

Message from the IntechOpen Publishing Process Manager

IMPACT OF THIS BOOK AND ITS CHAPTERS

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- 946 chapter downloads since the Book publication on April 24th -- An impressive average of nearly 60 downloads per week.

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On the Questions of Spin and Spin Quantum Correlations in Relativistic Quantum Mechanics and Relativistic Quantum Information

- **The majority of current understanding of the quantum correlations is in the field of non-relativistic quantum mechanics. To develop quantum information and computation tasks fully, one must inevitably take into account the relativistic effects.**

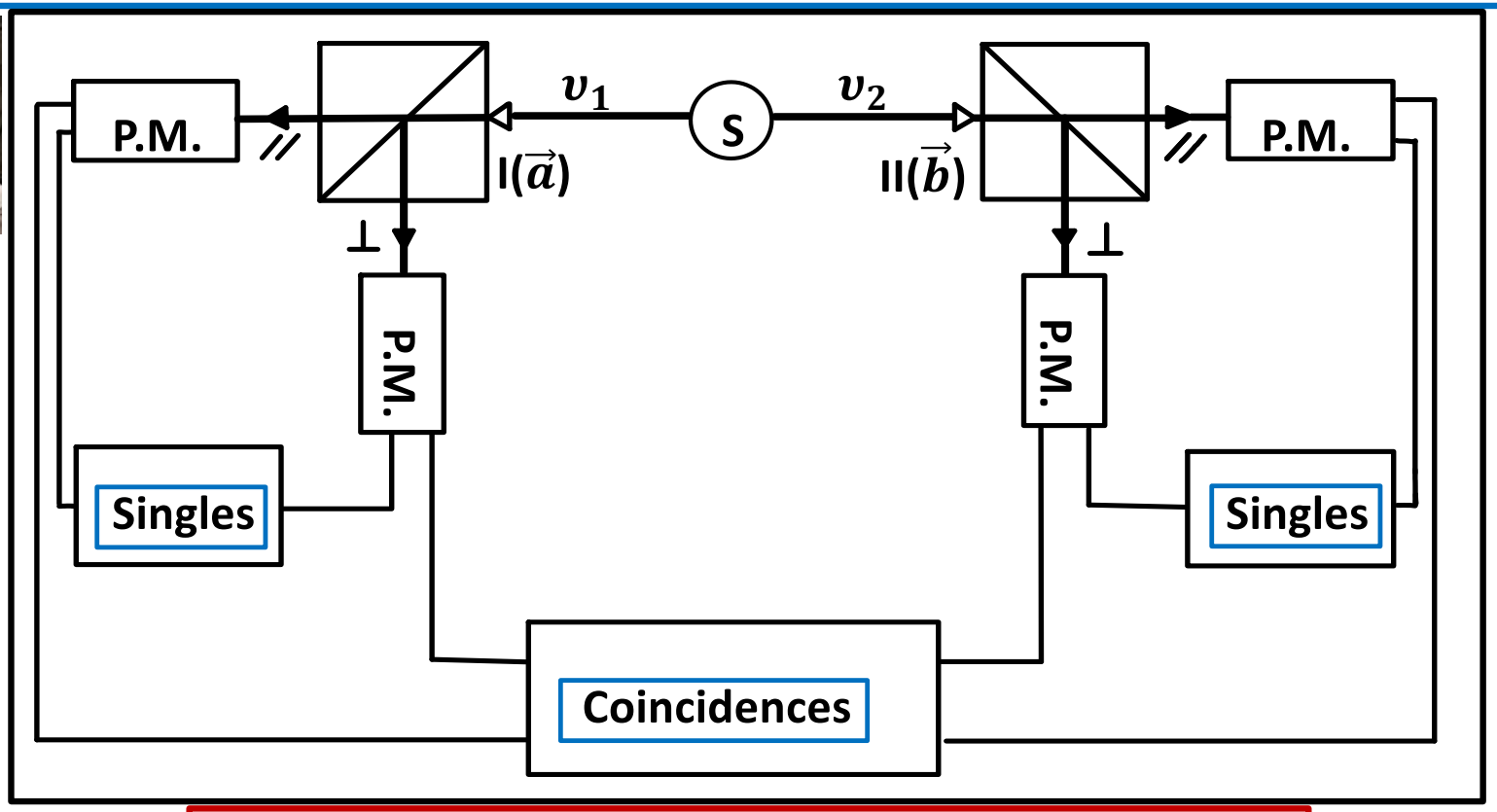
- **In this regard, the spin is one of the central tools. For this purpose, it is of paramount importance to understand and characterize fully the theory of spin in relativistic quantum information theory where the spin states act as qubit.**

- **This area is still far from being resolved. As a result, this article will explore the recent studies of the concepts of the spin and spin quantum correlations in inertial frames and some apparent paradoxes regarding this concept. We will mainly focus on the problem of characterizing the spin, reduced spin density matrices and spin quantum correlations in inertial reference frames and the apparent paradoxes involved therein.**

- **An important aspect is the use of tools of quantum field theory to extend several concepts in non-relativistic domain to relativistic one. So we analyse the development of the theory of relativistic secret sharing and a correlation measure namely the entanglement of purification.**

Alain Aspect Paper; Atomic Physics Nobel Prize, 2022

"for experiments with entangled photons, establishing the violation of Bell's inequalities and pioneering quantum information science".

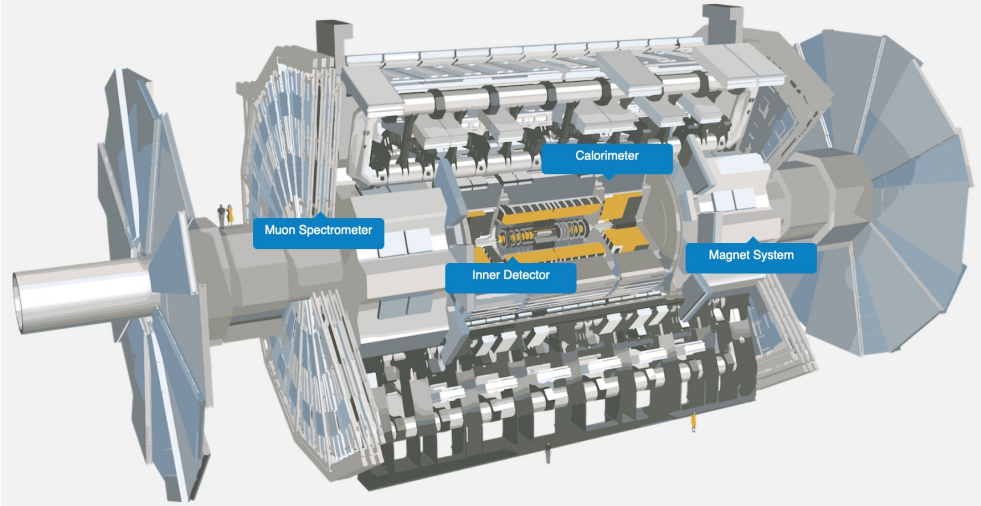


Reproduced from Fig. 2 in Phys.Rev.Lett. 49 (1982), 91-97

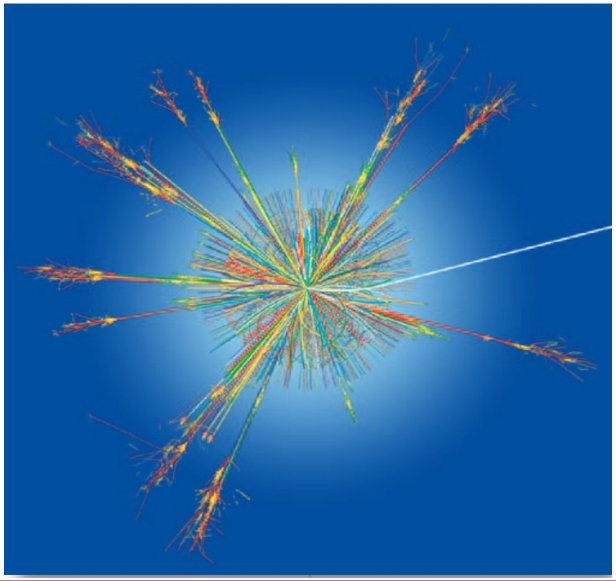
I and II are polarimeters in directions $\vec{a}$ and $\vec{b}$

COLLIDER PHYSICS AT COLLIDER ENERGIES

The ATLAS Detector



The ATLAS Collaboration



- Beam luminosity of 10^{34} cm^{-2} s^{-1} ➔ **20 collisions per bunch crossing**. ➔ **40 million bunch crossings per second**.

➔ **1 billion collisions per second**. ➔ Level 1 **trigger filters that down to about 75 000 events per second**.

➔ Level 2 trigger reduces it to about 2 000 events per second.

➔ The Event Filter then selects for permanent storage about 200 “interesting” events per second.

THEORETICAL CHAPTERS

1. Introductory Chapter: Quantum Entanglement at High Energies – Experiment, Theory, and Interdisciplinarity

By Oliver K. Baker — Yale University of USA

2. On the Questions of Spin and Spin Quantum Correlations in Relativistic Quantum Mechanics and Relativistic Quantum Information

By Shrobona Bagchi — Korea Institute of Science and Technology

3. Perspective Chapter: On Entanglement Measures – Discrete Phase Space and Inverter-Chain Link Viewpoint

By Felix A. Buot — University of San Carlos

4. Perspective Chapter: On the Contradiction between Special Relativity and Quantum Entanglement

By Yoram Kirsh — Open University of Israel

5. Phenomenology of Heavy Quark at the LHC

By Rachid Benbrik and Mohammed Boukidi — Cadi Ayyad University, Marrakech, Morocco

6. The Electromagnetic Inter-Nucleon Quark-to-Quark Bond and Its Effect on the Nuclear Force

By Nancy Lynn Bowen — Colorado Mountain College

THEORETICAL and INTERDISCIPLINARY CHAPTERS

7. Exploring Strange Entanglement: Experimental and Theoretical Perspectives on Neutral Kaon Systems

By Nahid Binandeh Dehaghani, A. Pedro Aguiar and Rafal Wisniewski

University of Porto, Aalborg University

8. Perspective Chapter: Why Do We Care about Violating Bell Inequalities?

By Christopher G. Timpson

University of Oxford

9. Perspective Chapter: Experiments in Entangled Time

By Karin Marie Fierke

University of St. Andrews

10. Entanglement in High-Energy Physics: An Overview

By Mohammed Nadir

Tampere University

11. Translational Symmetry of Intermediate Nodes and Antinodes of Entangled Particles

By Kisalaya Chakrabarti

Haldia Institute of Technology

12. Perspective Chapter: EPR Paradox – Experimental and Quantum Field Theoretical Status of Light Meson Resonances

By Alexander Machavariani

High Energy Physics Institute of Tbilisi State University

EXPERIMENTAL CHAPTERS

13. Perspective Chapter: Squeezing and Entanglement of Two-Modes Quantum X Waves

By Ali Saif M. Hassan, Waleed S.A. Hasan and Mohamed A. Shukri

University of Amran, University of Sana'a

14. Universality of Koba-Nielsen-Olesen Scaling in QCD at High Energy and Entanglement

By Yizhuang Liu, Maciej A. Nowak and Ismail Zahed

Institute of Theoretical Physics at Jagiellonian University, and Ismail Zahed from the Center for Nuclear Theory at Stony Brook University

4. Perspective Chapter; On the Contradiction between Special Relativity and Quantum Entanglement

- Demonstrations of quantum entanglement (QE), which confirm the violation of Bell's inequality, indicate that under certain conditions **action at a distance is possible**.

- This consequence seems to contradict the **relativistic principle of causality, which asserts that an effect never precedes its cause**, in any reference frame.

- By analyzing a numerical example of Bell's experiment with entangled pairs of photons, **we show how observers in two inertial reference frames can disagree about the causality relation between two events**.

- One observer claims that **event 1 is the cause of event 2**, while the other claims that **event 1 is the result of event 2**.

- **The solution we suggest to the paradox is that in entangled systems, one can find pairs of "entangled events" which have symmetrical causality relations. Each of the events can serve as a cause or as an effect, depending on the frame of reference in which they are observed.**

SOLUTIONS TO THE PARADOX – EXAMPLE

- The analysis of the ostensible contradiction between Bell's theorem and SR indicates that there is an additional possibility. In entangled systems, one can find pairs of **"entangled events"** which have symmetrical cause-and-effect relations. Each of them can appear to be the cause of the other, depending on the frame of reference in which they are observed. This fifth possibility solves the paradox which the action at a distance creates. Experimental results (e.g., [**reference** 11]) can be interpreted as supporting this suggestion.

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INTERDISCIPLINARY

critical thinking, opening minds to different points of view.

- **8. Perspective Chapter: Why Do We Care About Violating Bell Inequalities?**

By Christopher G. Timpson, Professor of Philosophy of Physics in the Faculty of Philosophy, University of Oxford

High energy experiments present an exciting new regime in which to explore the violation of Bell inequalities by nature. Bell inequality violation in high energy experiments, . . . **This is an important new regime for exploring entanglement** and Bell inequality violation, involving very different length-scales from the current state of the art in Bell experiments

- **9. Perspective Chapter: Experiments in Entangled Time**

By Karin Marie Fierke, Professor, School of International Relations, University of Saint Andrews

The purpose of this chapter is to revisit the concept, 'To See is to Break an Entanglement,' through an exploration of insights from a three-year project (2020–2023), . . . The project arose from observations that have no explanation in classical physics and sought to explore the significance of the 'quantum effects' that underpin the dynamics of a particular form of systems therapy and its potential adaptation to the analysis of global entanglements of past, present and future. **The chapter develops insights relating to entanglement, language and consciousness that arose from an 'experiment.'**

EXPERIMENTAL

- **Perspective Chapter: EPR Paradox – Experimental and Quantum Field Theoretical Status of Light Meson Resonances**
  - Written by Alexander Machavariani **Tbilisi State University,** Tbilisi, Georgia

- **In contrast to the non-relativistic formulation, relativistic quantum mechanics requires strong connection between the temporal and spatial components of coordinates according to invariance under Lorentz transformation.**
- **Besides in the relativistic approach arise additional mechanisms of entanglement which are caused by off-energy and off mass shell effects and contributions from creation and annihilation of particles in intermediate states.**

EXPERIMENT

We're making huge investments into our infrastructure for quantum research, primarily with the new Physical Sciences and Engineering Building that will continue to transform Science Hill.

August 15, 2024

Michael C. Crair,
Yale's Vice Provost for research

https://news.yale.edu/2024/08/15/full-steam-ahead-yale-research-engine-innovation?utm_source=YaleToday&utm_medium=email&utm_campaign=YT_YaleToday-Faculty_8-16-2024

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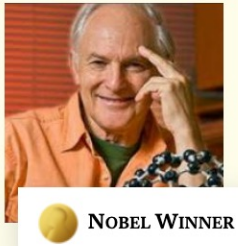

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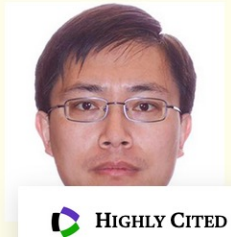

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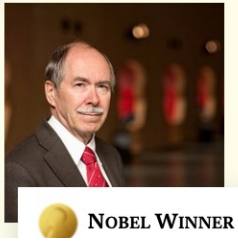

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