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Memristor-CMOS Synergy –Innovating Circuit Configurations for In-memory Computing

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Memristors, first theorized by Leon Chua in 1971 as the fourth fundamental circuit element, were experimentally realized in 2008 by researchers at HP Labs. Since then, significant progress has been made in the development of memristive devices, unlocking new opportunities for energy-efficient computing and high-density memory storage. While companies such as Knowm focus on research-driven memristor technologies, particularly in neuromorphic computing, others like Fujitsu have successfully integrated memristors into commercial ReRAM products, demonstrating their potential as viable non-volatile memory solutions. Meanwhile, companies such as Weebit are working on providing intellectual property (IP) for memristor-based structures, including memory arrays and devices compatible with CMOS technology.

The MEMPHYS project explores the integration of memristors with CMOS technology to innovate circuit architectures for in-memory computing, particularly in high-energy physics (HEP) experiments. As traditional CMOS-based trigger and data acquisition (DAQ) systems face growing challenges in power efficiency, latency, and scalability—especially in high-radiation, high-data-rate environments—MEMPHYS investigates the feasibility of memristor-based neuromorphic processing for real-time event selection directly on analog detector signals. This approach could significantly reduce data transmission bottlenecks while improving energy efficiency.

Furthermore, the project examines ReRAM-based architectures as a promising radiation-tolerant solution to enhance the reliability and reconfigurability of field-programmable gate arrays (FPGAs), essential components in modern DAQ systems. By leveraging the low-power and non-volatile nature of memristors, this research aims to develop next-generation computing paradigms. The experimental validation focuses on assessing radiation hardness, operational stability, and scalability under real-world HEP conditions. Beyond particle physics, these advancements could have broader applications in medical imaging, space instrumentation, and neuromorphic computing.

Primary author: BOCCI, Valerio (Istituto Nazionale di Fisica Nucleare)

Co-authors: DI NOLA, Alessandro (Istituto Nazionale di Fisica Nucleare); FIACCO, Davide (Istituto Nazionale di Fisica Nucleare); IACOANGELI, Francesco (Istituto Nazionale di Fisica Nucleare); Mr TARIQ, Junaid (Istituto Nazionale di Fisica Nucleare); GIORDANO, Raffaele (Università di Napoli - 'Federico II'); IPPOLITO, Valerio (Istituto Nazionale di Fisica Nucleare)

Presenter: BOCCI, Valerio (Istituto Nazionale di Fisica Nucleare)

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