Contribution ID: **416** Type: **Presentazione orale**

Recent Advances in Ultra-High Vacuum Shape Memory Alloy Connectors for Particle Accelerators

Thursday 3 September 2026 09:45 (15 minutes)

Shape memory alloy (SMA)-based pipe coupling systems for ultra-high vacuum (UHV) applications in particle accelerators have been developed at CERN in collaboration with University of Calabria. These SMA couplers are designed for room-temperature UHV systems and offer a compact, rapid, and cost-effective alternative to conventional joining technologies. Owing to their bolt-free configuration, the couplers can be remotely installed and removed through controlled temperature variations, significantly reducing radiation exposure for technical personnel.
The functional performance of SMA joints with different geometries and dimensions has been experimentally assessed in terms of leak tightness, mounting, and dismounting behavior. In parallel, dedicated investigations were conducted at CERN to evaluate the evolution of the mechanical and functional properties of SMAs under particle irradiation.
SMA-based connections enable the realization of highly compact joints that can be assembled and disassembled with minimal or no operator intervention. These unique characteristics distinguish the proposed technology from currently available permanent and removable pipe coupling solutions, such as welded joints and bolted flanges. As a result, SMA couplers offer significant advantages for several high-technology fields, including high-energy physics, nuclear fusion, aerospace, and oil and gas applications.
Recently, SMA couplers were installed for the first time in an operating accelerator, specifically as bi-metallic titanium/stainless steel transition joints for the vacuum dump windows of the Large Hadron Collider at CERN. Furthermore, a new generation of SMA-based connectors for beam position monitors (BPMs) has been developed, tested, and validated for Elettra Sincrotrone Trieste and Brookhaven National Laboratory, and is currently being further developed for future CERN accelerator facilities involving copper/stainless steel bimaterial connections.

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Session Classification: Meccanica dei Materiali

Track Classification: Meccanica dei Materiali