

# Summary

The present PhD thesis addresses the development and testing of advanced materials for particle accelerators. Recent projects, such as CERN's HL-LHC and FCC-hh, aim to enhance the collision rates of particle beams, demanding materials capable of withstanding extreme conditions while adhering to strict operational requirements, such as ultra-high vacuum compatibility, high electrical conductivity, radiation resistance, and cost-effective mass production.

Materials like nuclear-grade graphite and carbon-carbon composites, historically used for collimator components, are expected to be inadequate for future accelerators. Consequently, research has focused on composites combining graphite with high-temperature-resistant metals, such as Molybdenum-Graphite (MoGr), Chromium-Graphite, and Copper-Graphite.

Due to limitations in existing testing technologies, novel experimental methods are required to reproduce the extreme conditions faced by these materials. The present work investigates the possibility of using high-energy laser beams as an alternative to particle beams.

Experimental work was conducted at the PHELIX facility in Germany, where various materials for accelerator's collimators were irradiated with high-energy lasers. Diagnostic tools, including high-speed camera, PDV system, and high-resolution micro-CT, captured real-time mechanical responses and detailed post-mortem damage of the specimens.

Data from the experimental campaign informed the development of material models. For R4550 graphite, existing dynamic test data guided the calibration of a Steinberg-Guinan model and tabulated Equation of State.

A novel numerical procedure linking Radiation-Hydrodynamic simulations to finite element analyses was developed to predict laser-material interactions. This approach was validated using aluminum and copper before applying it to graphite-

based materials. Simulations closely matched experimental observations, confirming the robustness of the R4550 model under laser-induced conditions.

MoGr was also modelled, leveraging its predominant graphite composition and experimental insights. Adjustments to its spall strength parameter improved simulation accuracy for thicker samples, revealing its lower spall strength compared to isotropic graphite.

This thesis establishes a framework for characterizing and modelling advanced collimator materials using high-energy laser beams. The versatile R4550 graphite model demonstrates potential adaptability for other graphite-based composites, including CrGr and CuGr, advancing the development of materials for next-generation particle accelerators.