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Capabilities, Opportunities, and Challenges of the STAR Facility: A New X-ray Source for Material Analysis

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The STAR (Southern Europe Thomson back-scattering source for Applied Research) facility is situated at the University of Calabria in Rende (CS), Italy. The construction phase concluded in 2023, and it is currently in the commissioning phase. It will serve as a user facility catering to the R&D community for comprehensive studies of various forms of matter, encompassing biological, organic, and inorganic materials, through the utilization of micro tomography techniques on two distinct beamlines. Designed in the vein of large-scale user facilities like Synchrotrons, STAR operates as a "user facility" accessible to researchers. Access to its laboratories will be managed through a "call for proposals" process followed by a thorough evaluation of applications by a scientific panel. The facility is structured into three levels: the first level hosts the source with beamlines, providing primary X-ray generation and manipulation capabilities. The second level comprises six laboratories (e.g., sample preparation, modelling and simulation, prototyping, spectroscopy and microscopy, biological sample treatment, mechanical characterization of materials), facilitating detailed investigations on various materials. Finally, the third level consists of a network of existing university laboratories, complementing STAR's infrastructure and fostering collaborative research endeavours.

Enclosed within a 2.5 m wall bunker, the STAR source operates on the Inverse Compton Scattering mechanism, enabling the generation of high-quality X-rays through the interaction of a relativistic electron bunch with an IR laser picosecond pulse with a repetition rate of 100 Hz. The resulting X-rays possess critical attributes for material analysis; they feature a source size of a few tens of microns, polarization, quasi-

monochromaticity with minimal photon beam divergence, and continuous tunability up to 350 keV by adjusting the electron energy. This wide range of energies can pose hurdles regarding detector efficiency and radiation damage. Detecting X-rays across such a wide energy range requires detectors with high efficiency and sensitivity. Achieving consistent detection efficiency across the entire energy spectrum can be challenging, especially considering the potential for radiation damage to detector materials over time. Moreover, due to the inherent energy-angle correlation, the radiation field produced by STAR exhibits a transverse gradient in intensity and spectral distribution at a given distance from the interaction point. This presents a significant challenge for imaging techniques like tomography, as uniform energy distribution is pivotal to ensure consistent contrast and resolution throughout the reconstructed images. Additionally, the X-ray flux can peak at approximately 10^{11} photons per second within a 10% bandwidth, accompanied by pulse lengths in the picosecond range. These very short, very intense, pulses of X-rays can pose significant troubles for single-photon counting detectors due to their high count rates, ultra-fast timing requirements, and potential for pile-up artifacts, necessitating specialized detector designs and careful experimental considerations to ensure accurate photon counting.

This presentation will serve as an invitation to developers and testers of X-ray detectors, offering an overview of the capabilities, opportunities, and challenges inherent in the STAR Facility's cutting-edge X-ray source for material analysis. The aim is to inspire the audience to explore the potential for collaboration and innovation, inviting them to leverage the STAR Facility as a platform for testing their detector solutions and proposing novel advancements in the field of X-ray detection technology.

References:

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