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The STAR array for high sensitivity (n, γ) cross-section measurements at the cern n_toF facility

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Historically, innovations in detection techniques and advances in high-quality pulsed neutron beams have led to fascinating discoveries in stellar nucleosynthesis and subsequent refinements of theoretical models of stellar structure and galactic chemical evolution.

The n_TOF collaboration has been advancing innovative (n, γ) experimental setups aimed at achieving high sensitivity for challenging isotopes with low neutron capture cross sections and/or highly radioactive, while keeping possible systematics, such as dead time and pile-up corrections, under control [Bal24]. In 2022, a new state-of-the-art (n, γ) experimental setup was commissioned at n_TOF EAR2 [Weiss15], consisting of an array of nine sTED units [Alc24] arranged in a cylindrical configuration close to the target, two conventional large-volume C6D6 detectors, and one LaCl₃(Ce) detector [Bal23a,Ler23]. This setup enabled a significant improvement in terms of detection sensitivity and covered neutron-energy range.

Further improvements could be attained with the use of a new scintillation material replacing the liquid C6D6. Recent advancements in solution-growth methods for trans-stilbene crystals have enabled the production of high-purity deuterated stilbene (stilbene-d12) crystals. With their favorable properties with respect to liquid C6D6, such as higher density, excellent n/ γ discrimination, larger light yield, and reduced chemical risks, deuterated stilbene presents a promising alternative to liquid C6D6 scintillators. Their solid-state form allows for thinner encapsulation, eliminates the need for expansion volumes, and removes the requirement for a borosilicate quartz window for optical coupling. Additionally, they can be more easily coupled to photosensors, thereby facilitating the use of Silicon photomultipliers and further reducing the material budget per detector. These factors contribute to lowering the intrinsic neutron sensitivity of the detection device, thereby enhancing systematic accuracy in nuclei or neutron energy regions where elastic scattering dominates. Such developments will enable superior detection sensitivities in radiative neutron-capture cross-section measurements and they will open the possibility for (n,n) and (n,n') measurements over broad neutron-energy ranges and will reduce neutron-induced backgrounds [Bal23b].

Driven by this motivation, we present a conceptual design study for a future Stilbene-d12 Detector Array, referred to as STAR, primarily aimed at (n, γ) measurements of very small and/or radioactive samples at CERN n_TOF EAR2. Conceptualization, MC design and Initial experimental results with a stilbene prototype will be presented at the time of the workshop.

[Alc24] V. Alcayne et al., Radiat.Phys.Chem. 217 (2024) 111525

[Bal23a] J. Balibrea-Correa et al: EPJ Web Conf. 279 (2023) 06004

[Bal23b] J. Balibrea-Correa et al; CERN-INTC-2023-034 ; INTC-I-254. - 2023.

[Bal24] J. Balibrea-Correa et al: Nucl.Instrum.Meth.A 1064 (2024) 169385

[Ler23] J. Lerendegui-Marco et al: <https://arxiv.org/abs/2310.15714>

[Weiss15] C. Weiss et al., NIM-A 799, 90-98 (2015)

Abstract

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