PROCEEDINGS OF SCIENCE

The SIDDHARTA-2 experiment: preparation for the first kaonic deuterium measurement

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The SIDDHARTA-2 experiment aims to perform the first measurement of the kaonic deuterium 2p → 1s x-ray transitions. The apparatus is presently installed at the interaction region of the DAΦNE electron-positron collider at the National Laboratories of Frascati (LNF-INFN), in Italy. Kaonic deuterium and kaonic hydrogen 2p → 1s x-ray transitions measurements, the latter one already performed by the SIDDHARTA collaboration, allow the determination of antikaon-nucleon scattering lengths. A description of the SIDDHARTA-2 apparatus in preparation for the kaonic deuterium measurement is provided in this paper.

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1. Introduction

The x-ray spectroscopy of light kaonic atoms allows the experimental investigation of the strong interaction between the kaon and the nucleus at low energies [1]. A kaonic atom is formed when a K^- is stopped in a dedicated target and captured in an atomic system due to the electromagnetic interaction with the nucleus. The captured K^- replaces an electron in a highly excited atomic level and initiates an electromagnetic cascade process that could bring it to the innermost atomic level, in which the kaon-nucleus strong interaction produces a shift and a broadening of the energy level that can be extracted with dedicated x-ray spectroscopy measurements. In 2009, the SIDDHARTA experiment measured the kaonic hydrogen 2p $\rightarrow$ 1s transition, extracting the energy shift and width of the 1s kaonic hydrogen atomic level due to the strong kaon-proton interaction [2]. This measurement, added to the kaonic deuterium 2p $\rightarrow$ 1s transition measurement, will allow to extract the antikaon-nucleon scattering lengths, not directly accessible otherwise due to the $\Lambda(1405)$ resonance just below the threshold and the strong coupling to the $\pi\Sigma$ channel [1, 3]. The SIDDHARTA-2 experiment aims to measure, for the first time, the kaonic deuterium 2p $\rightarrow$ 1s transition in 2023/4 at the DAΦNE electron-positron collider [4], a Φ factory located at the National Laboratories of Frascati, in Italy. The SIDDHARTA-2 apparatus, presently installed at the Interaction Region (IR) of the DAΦNE collider, is presented in this paper.

2. The SIDDHARTA-2 apparatus

The SIDDHARTA-2 apparatus is presently installed at the Interaction Region (IR) of the DAΦNE collider, in Frascati. The target consists of a cylindrical cell (144 mm in diameter and 125 mm in height) with walls made of a two-Kapton layer (150 μm thick) and aluminium supports. The target gas is fluxed inside the cylindrical cell. Outside, 384 Silicon Drift Detectors (SDDs) laterally surround the cylindrical target, for x-ray detection. SDDs provide a resolution of $157.8 \pm 0.3(stat)^{+0.2}_{-0.2}(syst)$ eV at 6.4 keV ($K^-{}^4He$, 3d $\rightarrow$ 2p transition energy [5, 6]). Outside the cylindrical target and surrounding the SDDs, plastic scintillators read by pairs of Silicon Photo-Multipliers (SiPMs) are placed and used as a veto system for external background identification (VETO-2). The target cell, the SDDs and the VETO-2 are placed inside a vacuum chamber, which is kept at a pressure below 10^{-5} mbar. SDDs are cooled at about 120 K by a closed-cycle helium refrigerator system. Radially, outside the vacuum chamber, a second veto system consisting of 12 plastic scintillators read by pairs of Photo-Multipliers (PMTs) is installed for further external background reduction. Two plastic scintillators read by PMTs are placed one below and one above the DAΦNE Interaction Point (IP) and used to discriminate the back-to-back kaons directed to the SIDDHARTA-2 target, based on the time-of-flight (Kaon trigger system). A luminometer, consisting of two plastic scintillators read by pairs of photomultipliers, is placed on the horizontal side of the IP. A schematic drawing of the SIDDHARTA-2 apparatus is shown in Fig. 1. More detailed information on the elements of the SIDDHARTA-2 apparatus can be found in [3, 7]. The SIDDHARTINO experiment, consisting in a reduced SIDDHARTA-2 apparatus with only 64 SDDs installed, performed a precise measurement of gaseous K^--^{4}He transitions to the 2p level [8, 9], thus confirming the expected performances, the excellent background rejection capacity of the SIDDHARTA-2 apparatus, and the validity of the data selection and analysis procedure [10].

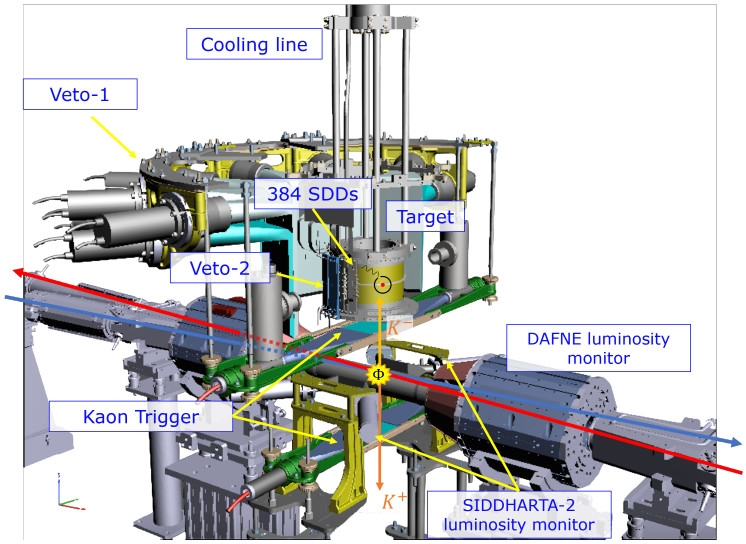

Figure 1: A schematic drawing of the SIDDHARTA-2 apparatus installed at the DAΦNE Interaction Region at the INFN National Laboratories of Frascati.

3. Conclusions and future perspectives

The SIDDHRATA-2 experiment is presently installed at the DAΦNE e^-e^+ collider (see Fig. 2), and is ready to perform the first measurement of kaonic deuterium 2p → 1s x-ray transitions. The data-taking campaign will start in 2023. The preliminary measurements performed by SIDDHARTINO and SIDDHARTA-2 on kaonic ^{4}He proved the high efficiency of the apparatus and the validity of the data analysis procedure.

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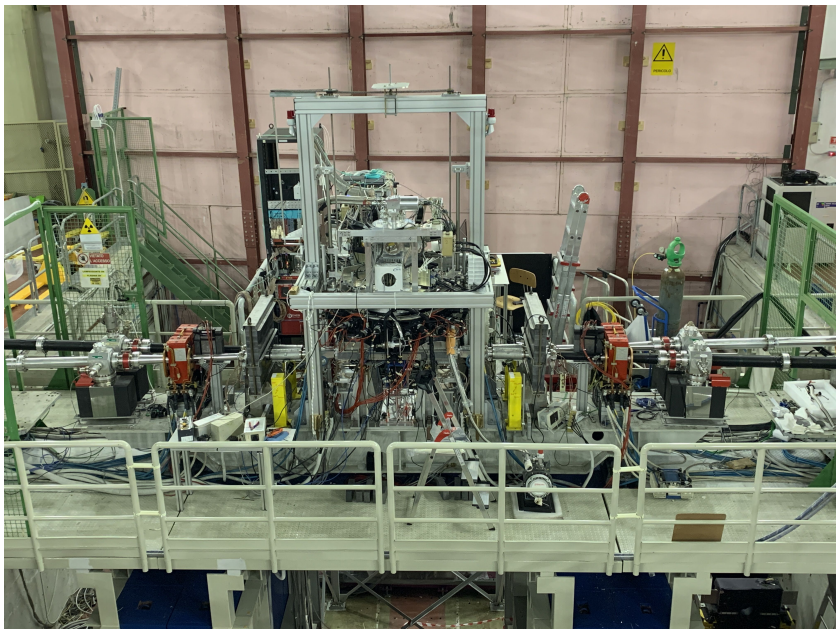

Figure 2: Picture of the SIDDHARTA-2 experiment presently installed in the DAΦNE Φ factory, at the National Laboratories of Frascati (LNF-INFN), in Italy.

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