Calibration of Silicon Drift Detectors for the SIDDHARTA-2 Experiment

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The SIDDHARTA-2 (Silicon Drift Detector for Hadronic Atom Research by Timing Application) experiment is a research experiment in the field of nuclear physics, performed at the DAΦNE (Double Annular Φ Factory for Nice Experiments) collider at INFN-LNF, which aims to study strong nuclear interactions by measuring the shift and broadening of energy levels in exotic kaonic atoms [1-3].
To achieve this goal, the SIDDHARTA-2 collaboration has developed a new experimental apparatus equipped with 384 Silicon Drift Detectors (SDDs) [4-6] placed around deuterium gaseous target. The energy response of each detector must be calibrated and monitored during the experiment to reduce systematic error [7].
The poster presents a calibration method for high-precision X-ray spectroscopy measurements of kaonic deuterium using the SDDs.

Kaonic atom

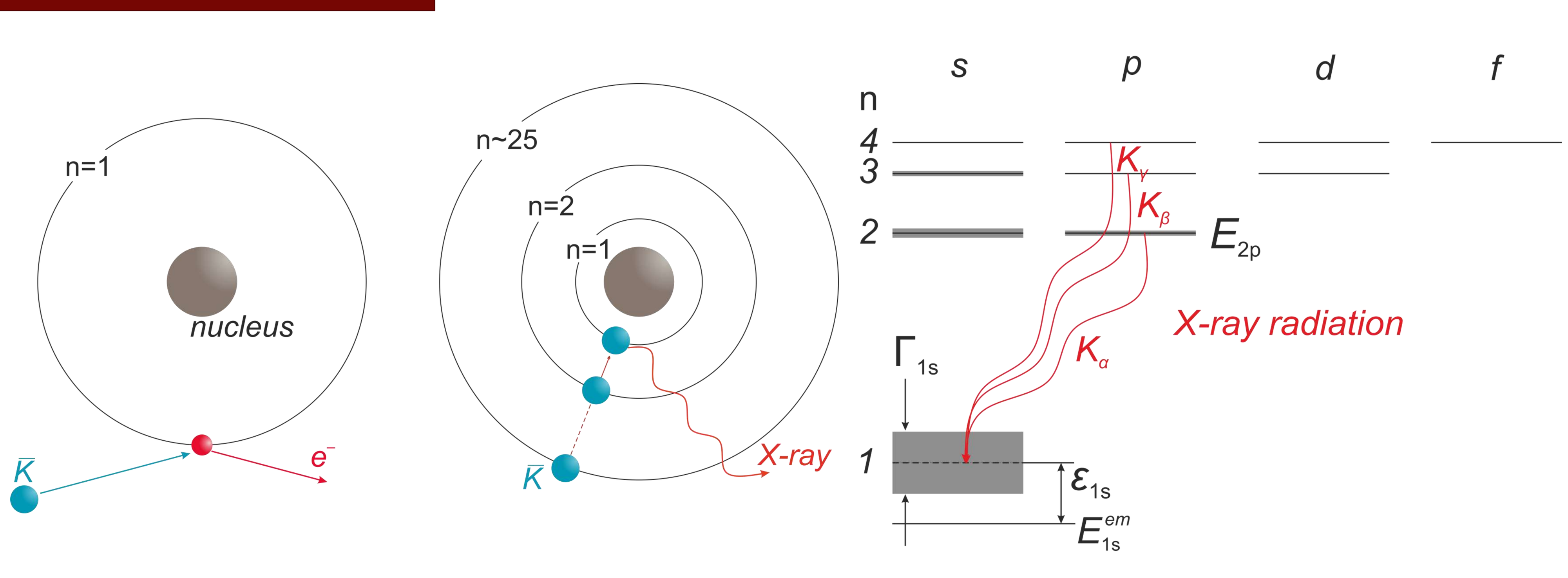
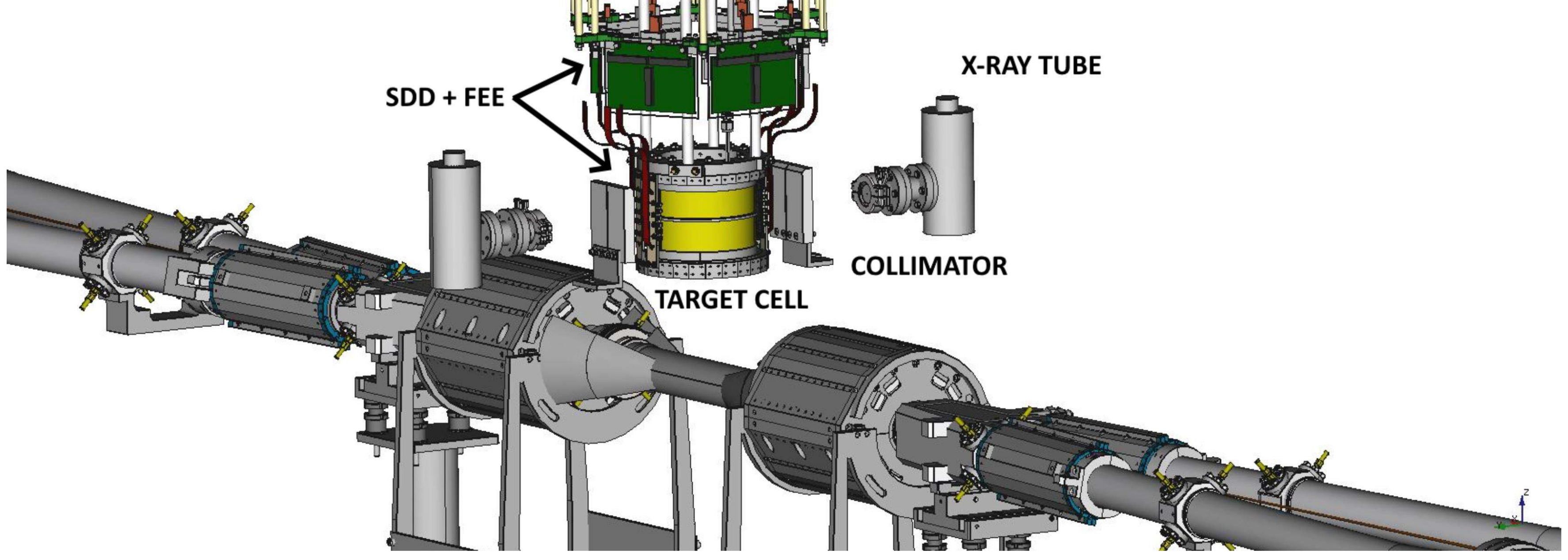


Fig. 1. Left and centre: a kaonic atom is formed when a negative kaon $\bar{K}$ is captured by a nucleus, replacing an electron in an excited orbit [1-3,8].
Right: the kaonic atom de-excites to lover states via various cascade processes, emitting radiation in the X-ray domain. When the fundamental, 1s, level is reached, a strong interaction between the kaon and the nucleus takes effect, which induces a shift of the level compared to the pure QED value and its broadening (due to the kaon absorption by the nucleus). The experimentally determined shift (ε) and width (Γ) are related to the s-wave scattering lengths at threshold [3].

Calibration system

Fig. 2. Illustration of the SIDDHARTA-2 calibration configuration [7].

The target cell, the SDDs with the Front-End-Electronic (FEE) and the X-ray tubes are placed above the DAΦNE beam line.



Silicon Drift Detector

Fig. 3. Picture of the SIDDHARTA-2 silicon drift detectors 2×4 array screwed on the aluminium block. The red rectangle defines the active area (5.12 cm²) of the device given by the eight cells of 0.64 cm² each [4].

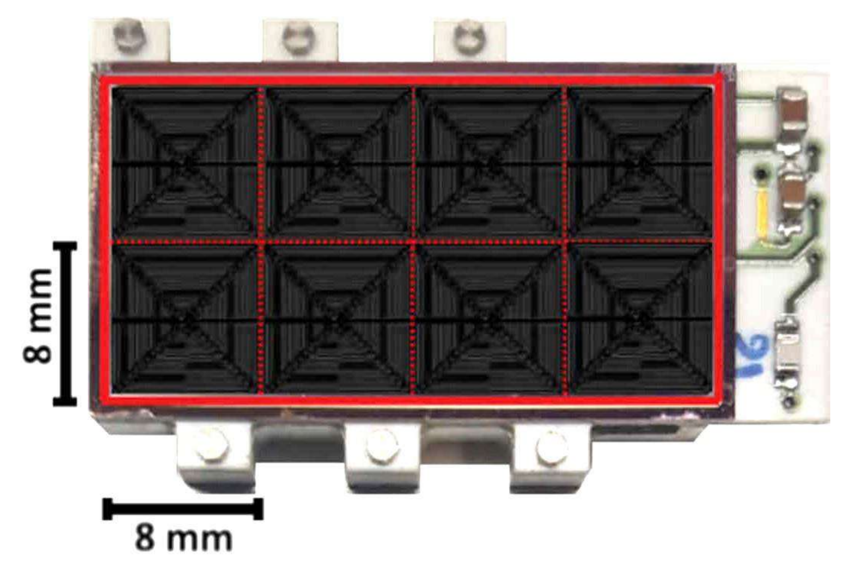
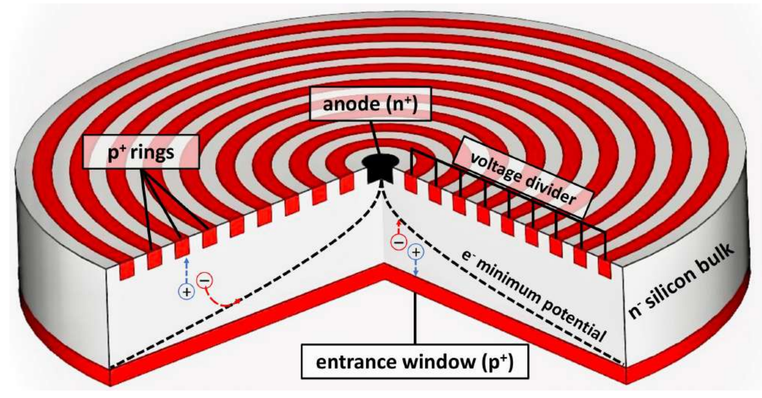


Fig.4. Cross section of a cylindrical silicon drift detector. The radiation entrance window for the ionizing radiation is the non-structured backside of the device [7].



Calibration method

The energy response function of the detector is predominantly a Gaussian curve for every fluorescence X-ray peak. However the response has a low energy component due to the incomplete charge collection and electron-hole recombination. Thus, the total peak fit function is formed by two contributions: Gaussian function (the main contribution to the peak shape) and tail function (an exponential function to reproduce the incomplete charge collection).
Only the Ti K_α and Cu K_α peaks are exploited to calibrate the detectors, since they have the highest signal-to-background ratio.
To interpolate the calibration points, whose coordinates are the theoretical and the experimental values of each single K_α peak, a 1st degree polynomial function has been used. The slope of the function corresponds to the gain of the examined system, in terms of eV/ch.

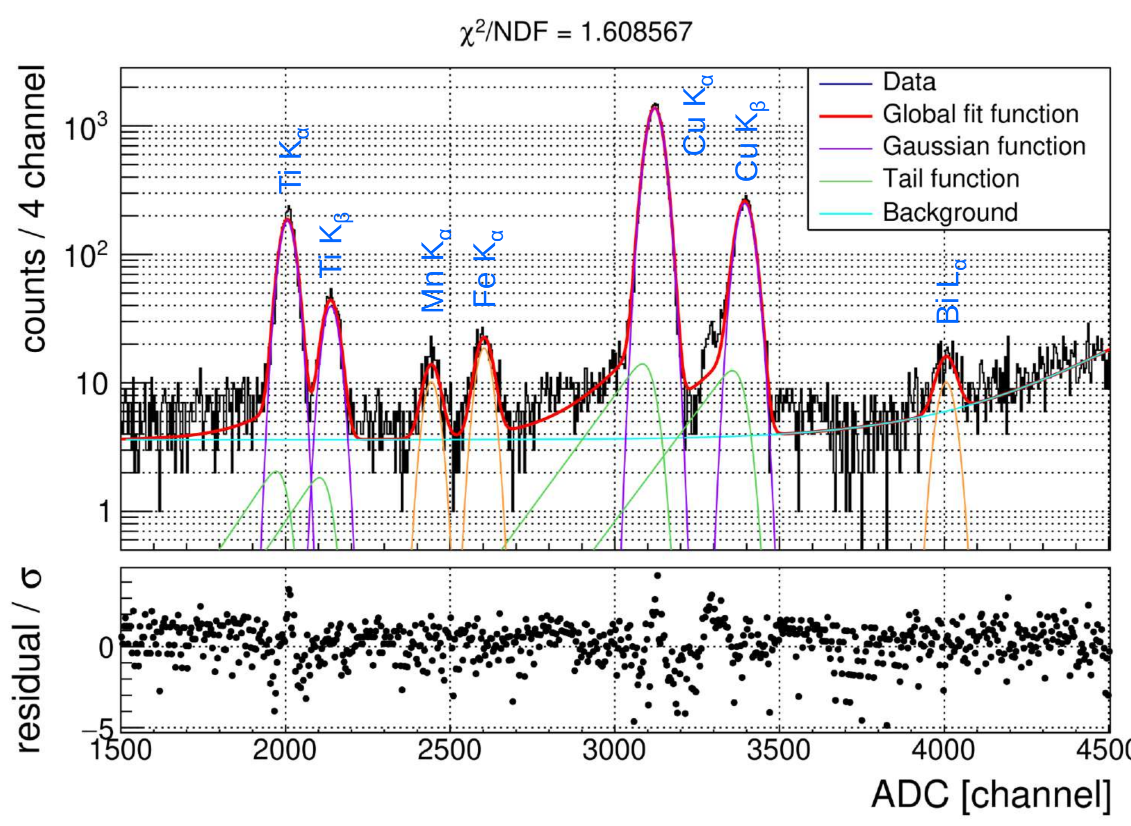


Fig. 5. Calibration spectrum for a single SDD in arbitrary units given by ADC. Highlights of the various contributions to the fit function are shown.

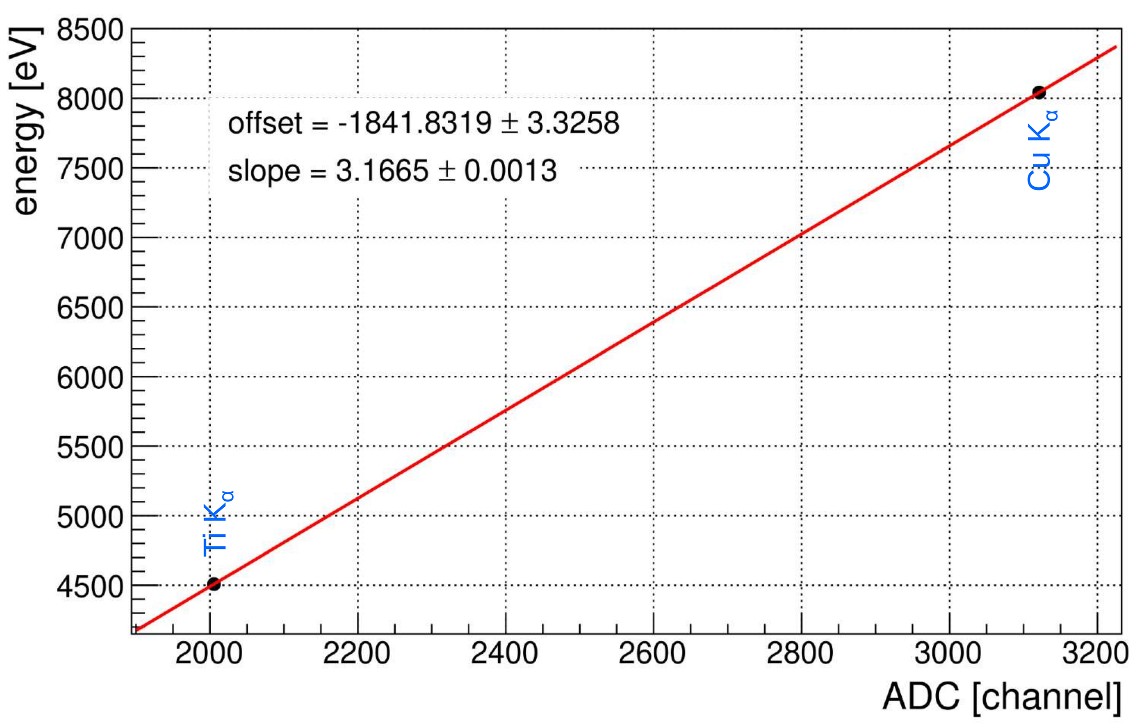


Fig. 6. Calibration function to determine the ADC-to-eV conversion. Linear interpolation of the experimental K_α peak positions versus the theoretical energies of the transitions.

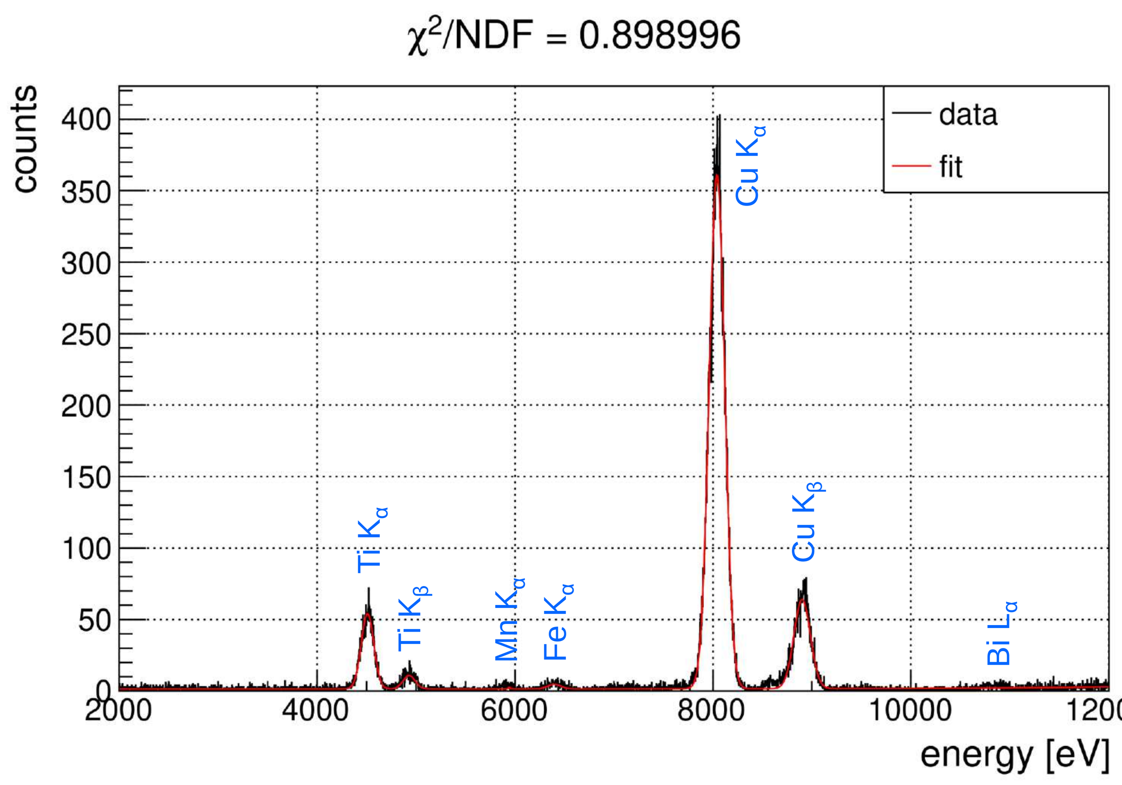


Fig. 7. Obtained energy spectrum.

[1] M. Miliucci *et al.*, *Il Nuovo Cimento* **44 C** (2021) 152. [2] C. Curceanu *et al.*, *Few-Body Syst.* **62** (2021) 83. [3] C. Curceanu *et al.*, *Acta Phys. Polon.* **B 51** (2020) 251.
[4] M. Miliucci *et al.*, *Meas. Sci. Technol.* **33** (2022) 095502. [5] M. Miliucci *et al. Meas. Sci. Technol.* **32** (2021) 095501. [6] M. Miliucci *et al.*, *Condens. Matter* **6** (2021) 47.
[7] F. Sgaramella *at al.*, arXiv:2201.12101. [8] M. Bazzi *et al.*, Proceedings of HYP 2006, 189.