KAONNIS

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1 KAONNIS: the scientific program

KAONNIS represents an integrated initiative in the field of experimental low-energy kaon-nucleon/nuclei interaction studies. Under KAONNIS the following activities are performed:

- kaonic atoms measurements by the SIDDHARTA-2 experiment
- studies of kaon-nuclei interactions at low-energies in the framework of the AMADEUS Collaboration
- participation at experiments at J-PARC (Japan) dedicated to strangeness studies
- future kaonic atoms measurements program at the DAΦNE collider

We present in what follows these scientifc lines, together with the 2022 activities and plans for 2023.

The KAONNIS activities are partially financed within the STRONG-2020 European project (grant agreement No. 824093).

2 The SIDDHARTA-2 experiment

The objective of the SIDDHARTA-2 (Silicon Drift Detector for Hadronic Atom Research by Timing Application) experiment is to perform high precision measurements of X-ray transitions in exotic (kaonic) atoms at the DAΦNE collider.

The precise measurement of the shift and width of the 1s level, with respect to the purely electromagnetic calculated values, in kaonic hydrogen and kaonic deuterium, induced by the strong interaction, through the measurement of the X-ray transitions to this level, will allow the first precise experimental determination of the isospin-dependent antikaon-nucleon scattering lengths, fundamental quantities for the understanding of the low-energy QCD in strangeness sector.

The accurate determination of the scattering lengths will place strong constraints on the low-energy K^- N dynamics, which, in turn, constraints the SU(3) description of chiral symmetry breaking in systems containing the strange quark. The implications go from particle and nuclear physics to astrophysics (the equation of state of neutron stars).

The SIDDHARTA collaboration performed the most precise measurement of kaonic hydrogen and the first exploratory study of kaonic deuterium. Moreover, the kaonic helium 4 and 3 transitions to the 2p level were measured, for the first time in gas in He^4 and for the first time ever in He^3. Presently, the SIDDHARTA-2 experiment , is under way, with the aim to measure kaonic deuterium and, as well, other types of kaonic atoms.

2.1 Before SIDDHARTA-2: the SIDDHARTA experiment

In the first decade of this century, SIDDHARTA represented a new phase in the study of kaonic atoms at DAΦNE. The previous DEAR experiment's precision was limited by a signal/background ratio of about 1/70 for the kaonic hydrogen measurement, due to the high machine background. To significantly improve this ratio, an experimental breakthrough was necessary. An accurate study of the background sources at DAΦNE was done. The background includes two main sources:

- *synchronous background*: coming from the K^- interactions in the setup materials and Φ-decay processes; it can be defined as *hadronic background*;
- *asynchronous background*: final products of electromagnetic showers in the machine pipe and in the setup materials, originating from particles lost from primary circulating beams either due to the interaction of particles in the same bunch (Touschek effect) or due to the interaction with the residual gas.

Accurate studies showed that the main background source in DAΦNE is of the second type, which points to the procedure to reduce it. A fast trigger correlated to the kaons entering into the target cut the main part of the asynchronous background. X rays were detected by DEAR using CCDs (Charge-Coupled Devices), which are excellent X-ray detectors, with very good energy resolution (about 140 eV FWHM at 6 keV), but having the drawback of being non-triggerable devices (since the read-out time per device is at the level of 10 s). A new device, which preserves all good features of CCDs (energy resolution, stability and linearity), but additionally is triggerable - i.e. fast (at the level of 1 μs), was implemented. The new detector was a large area Silicon Drift Detector (SDD), specially designed for SIDDHARTA. The development of the new 1cm^2 SDD device, together with its readout electronics and very stable power supplies, was partially performed under the Joint Research Activity JRA10 of the I3 project "Study of strongly interacting matter (HadronPhysics)" within FP6 of the EU.

The trigger in SIDDHARTA was given by a system of scintillators which recognized a kaon entering the target making use of the back-to-back production mechanism of the charged kaons at DAΦNE from Φ decay:

$$\Phi \rightarrow K^+K^- \tag{1}$$

The SIDDHARTA setup contained 144 SDD chips, 1cm^2 each, placed around a cylindrical target, filled with high density cryogenic gaseous hydrogen (deuterium or helium). The target was made of kapton, 75μm thick, reinforced with aluminium grid.

The SIDDHARTA setup was installed on DAΦNE in late summer 2008, and the period till the end of 2008 was used to debug and optimize the setup performances (degrader optimization included). The kaonic atoms measurements were done in 2009 and data analysis followed in the coming years, which produced the most precise measurement of kaonic hydrogen [1] and measurements of kaonic helium 3 [2] and kaonic helium 4 [3], [4]. Kaonic deuterium could not be measured by SIDDHARTA, since signal/background was too small.

2.2 The SIDDHARTA-2 setup

The upgrade from SIDDHARTA to SIDDHARTA-2 is relying on the following essential modifications:

- *Trigger geometry and target density*: By placing the upper kaon-trigger detector in front of the target entrance window the probability that a triggered kaon really enters the gas and is stopped there is improved. Making the detector smaller than the entry area gives away

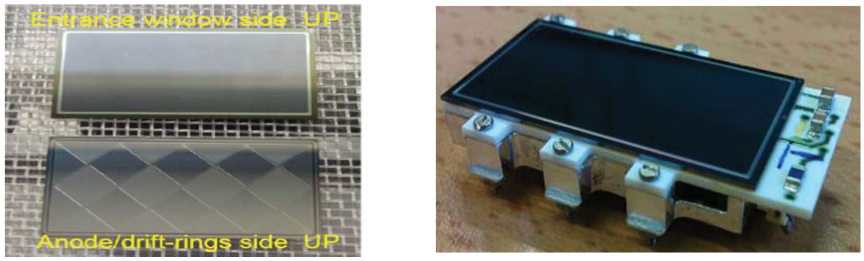

Figure 1: *The new 2 x 4 SIDDHARTA-2 SDD array together with the readout electronics.*

some signal, but suppresses efficiently the kaonic lines from "wall-stops" (kaons entering the gas volume, but passing from the inside of the target to the cylindrical walls). The number "signal per trigger" goes up, which also reduces the accidental background coming along with every trigger. We will also plan to double the gas density which enhances the gas stops and further reduces the wall-stops.

- *Active shielding*: The scintillators surrounding the target will also be used in prompt anti-coincidence if the spatial correlation of SDD and scintillator hits indicates that it originated from a pion ("charged particle veto"). An anticoincidence covering the SDD time window of about 600 ns (with the exception of the 4 ns of the gas stopping time) will reduce the accidental background. Although the scintillators have low efficiency for gammas, the abundance of secondaries from the electromagnetic showers allows a relevant reduction of accidental ("beam") background. The upper trigger scintillator has 2 functions, it is also used as an anticoincidence counter: after the kaon and eventual prompt kaon-absorption secondaries pass, it vetos beam background.

- *New SDD detectors*, produced by FBK, having a much better active/total surface ratio (about 85%, with respect to 40% in SIDDHARTA SDDs) (see Figure 1).

- *Operating SDDs at a lower temperature*: tests indicate that an improvement of the timing resolution by a factor of 1.5 is feasible by more cooling. The signal enhancement by a factor 2 to 3 is due to moving the target cell closer to the IP, by changing its shape, by a better solid angle of the SDDs and by the higher gas density. In such conditions, with an integrated luminosity of 800 pb^{-1} a precision similar to that obtained for kaonic hydrogen is reachable.

In Fig. 2. a drawing of the SIDDHARTA-2 apparatus is shown, where the main components are highlighted.

To perform both conditioning of the machine and tuning of the various components of the SIDDHARTA-2 setup, a reduced version, named SIDDHARTINO , with only 1/6 of the X-ray silicon drift detectors (SDD) was installed in 2019 in the interaction point of the DAΦNE accelerator. Due to the pandemic situation, the SIDDHARTINO run started in January 2021 and lasted until July 2021. During this period, two runs with a target cell filled with ^{4}He gas at about 1.5% and 0.8% of liquid helium density were performed to optimize various setup components, as well as to provide feedback to the machine during its commissioning phase.

The choice of ^{4}He was dictated by the high yield of the kaonic helium-4 (3d$\rightarrow$2p) transition allowing for very fast tuning. The experimental outcomes of this run already represented the first important physics results of the SIDDHARTA-2 experiment, delivering the most precise measurement of the 2p level shift and width in the gaseous target.

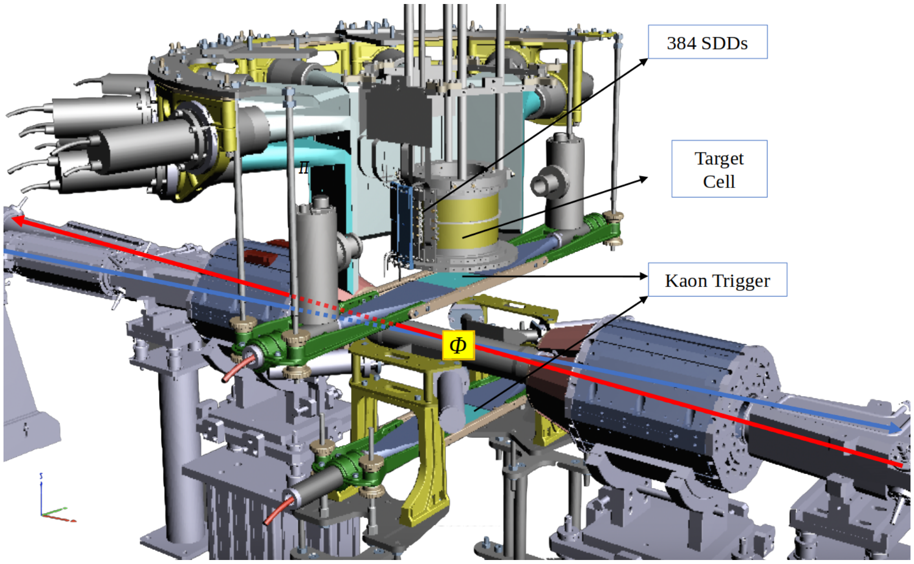

Figure 2: *Schematic view of the SIDDHARTA-2 setup.*

In the second half of 2021, the full SIDDHARTA-2 setup was installed on the DAΦNE interaction region and subsequent data taking in April - July 2022. During this period, a second test with helium (4 - 26 May 2022) before filling the target cell with deuterium, was performed. The first period of the campaign measurement dedicated to the kaonic deuterium 2p→1s transition, was done in period 03 June- 02 July 2022, and will continue in 2023/2024.

2.3 More details on 2022 SIDDHARTA-2 activities

2.3.1 Kaonic helium-4 run with SIDDHARTA-2 setup

SIDDHARTA-2 took data on DAΦNE until July 2022 and was performing, in the first part of the data taking, the helium-4 run, for the optimization of the running conditions, including SDDs background and degrader.

The increased number of SDDs, as well as the different conditions of the machine background resulting from the optimization of the instantaneous luminosity, suggested performing a second test with helium, after the SIDDHARTINO kaonic helium measurement, before filling the target cell with deuterium. This was indeed necessary to crosscheck the performances of the experimental apparatus in its full version, with a particular focus on the background rejection capabilities of the trigger system. The kaonic helium data collected in the period 04-26/05/2022 corresponds to 28 pb^{-1} of integrated luminosity.

The overall spectrum obtained without selection cut is shown in the upper pad of Fig. 4, where peaks due to the fluorescence of the various materials present in the experimental apparatus, thus not correlated in time with the beam crossing and the Φ-decay, are present.
To remove this asynchronous background, a first selection is applied using the information from the Kaon trigger; only triggered events in which two signals are detected in coincidence by the two scintillators are retained while all the others are discarded.

The effect of this selection is visible in the lower pad of Fig. 4, where the number of events is drastically reduced and the fluorescence peaks are not visible anymore, except for that from titanium which is present in the top of the target cell and is activated by kaons not stopping in

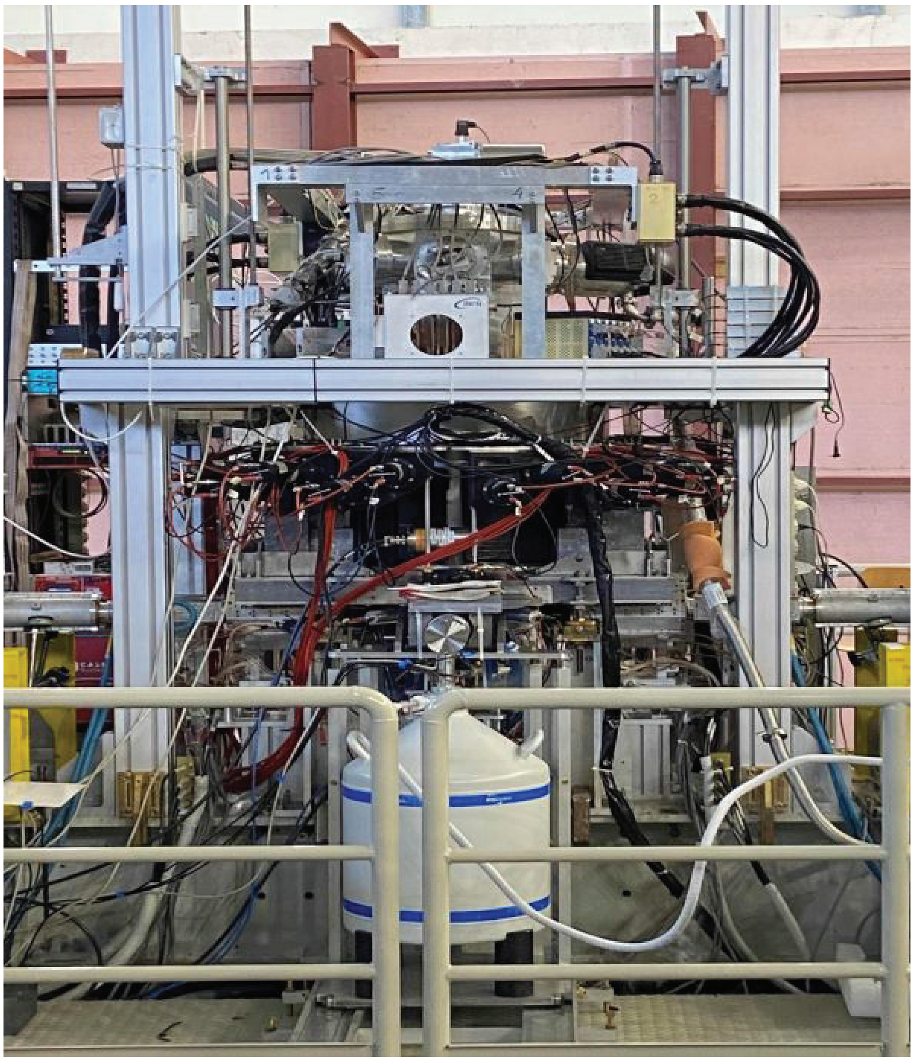

Figure 3: *Photo of SIDDHARTA-2 setup installed in DAΦNE.*

the gas. In the triggered spectrum the transitions of kaonic atoms formed in the Mylar walls of the target are visible.

The outcomes of this run confirmed the 10^5 rejection factor obtained with SIDDHARTINO 15) and allows to start the first measurement of the kaonic deuterium 2p $\rightarrow$ 1s transition, which will be performed in 2022 and 2023.

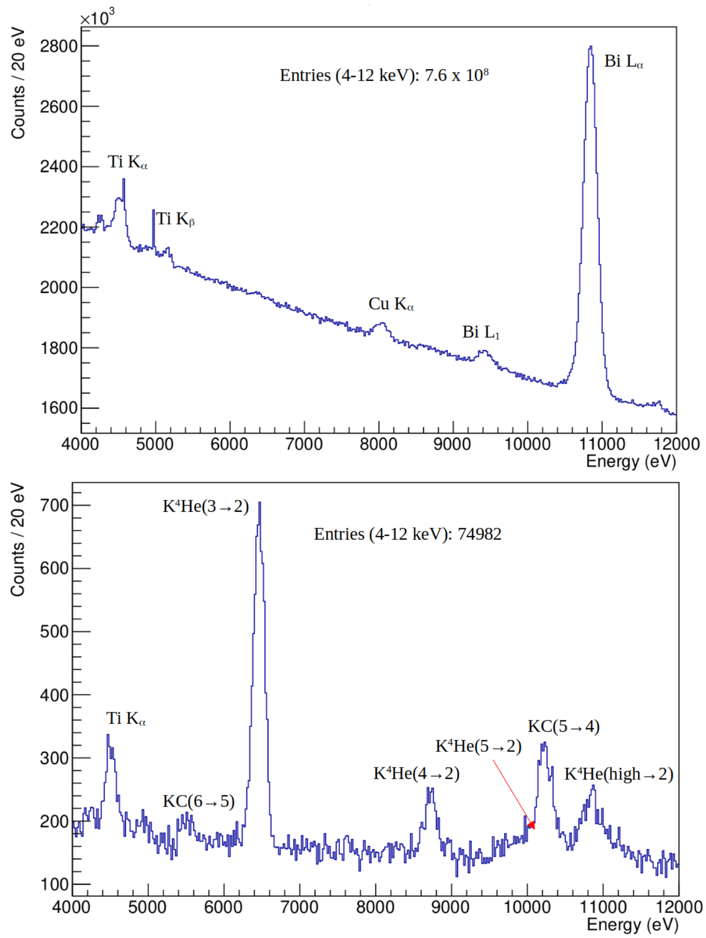

Figure 4: Spectra without (top) and with (bottom) KT selections, from which the $\simeq 10^{-5}$ rejection factor can be obtained (bottom).

2.3.2 New kaonic helium-4 L-series X-rays yields in gas

The L-series X-rays transitions of the kaonic helium-4 exotic atom were measured by SIDDHARTINO, with gaseous ^{4}He targets at densities of 1.90 g/l and 0.82 g/l, corresponding to 1.5% and 0.66%, respectively, of the liquid helium-4 density and the results were published in *Nuclear Physics A 1029 (2023) 122567.*

In Table 1, the absolute yields of the kaonic helium-4 L_α transition and the relative yields of the L_β and L_γ, corrected by detector efficiencies, obtained with the SIDDHARTINO setup are given.

Table 1: The absolute yield of the kaonic helium-4 L_α transition and the relative yields of the L_β and L_γ corrected by detectors efficiencies, obtained with the SIDDHARTINO setup.

Density	1.90 g/l	0.82 g/l
L_α yield	0.148 ± 0.027	0.126 ± 0.023
L_β/L_α	0.193 ± 0.042	0.133 ± 0.037
L_γ/L_α	0.035 ± 0.015	not detected

In Fig. 5, the absolute yields for the kaonic helium-4 L_α X-rays measured by SIDDHARTINO are plotted together with the previous SIDDHARTA results [14] in gas. The helium gas density was determined by measurements of the target gas pressure and temperature. For the higher gas density an error in the determination of pressure and temperature of $\pm 2.0\%$ and of $\pm 3.5\%$, respectively, was achieved, leading to a density error of $\pm 5\%$. While for the lower gas density, the pressure and temperature errors were determined to be $\pm 4.0\%$ and $\pm 5.1\%$, respectively, leading to a density error of $\pm 10\%$.

For the 1.90 g/l density the result of this work is consistent with the SIDDHARTA measurement done at similar gas target density [14].

From the perspective of kaonic atoms cascade models the density region covered by these two new SIDDHARTINO measurements is of great interest since, up to now, due to the absence of data, no progress has been achieved in cascade model calculations for kaonic atoms since almost twenty years [8, 9, 10, 11, 12]. In the coming years SIDDHARTA-2 collaboration will measure the transitions yields for various kaonic atoms, by also using gas targets at various densities.

These results will trigger a renaissance of the cascade calculations for exotic atoms, in particular for the kaonic atoms and a better understanding of the underlying processes and physics.

2.3.3 Intermediate mass kaonic atoms measurement

The SIDDHARTA-2 experiment performed high precision measurements of a series of intermediate mass kaonic atoms transitions, which represent the first measurements ever.

Kaonic carbon, oxygen, nitrogen and aluminium X-ray transitions in the 5-16 keV energy range were measured during the 2021 and 2022 data taking campaign, by using kaons delivered by the DAΦNE collider stopped in the setup materials.

In Fig. 6, the X-ray spectrum of the summed data for the SIDDHARTINO and SIDDHARTA-2 runs, corresponding to about 75 pb^{-1}, after the application of the event selections, is shown. The kaonic atoms signals are clearly visible. The peaks highlighted in the figure correspond to the X-ray emissions from kaonic atoms formed in the helium gas and in the components of the target cell. The energy of each kaonic atoms transition was obtained from a fit of the spectrum. Several intermediate mass kaonic atoms, such as kaonic carbon, oxygen, nitrogen and aluminium high-n transition energies are measured for the first time. The kaonic carbon, oxygen and nitrogen transitions are the result of kaons stopped in the Kapton walls, whereas the kaonic aluminium transitions were produced by kaons stopped in the top and bottom frames of the target cell.

The final results for the kaonic C, O, N and Al transitions are shown in Table 2. These results are accepted to be published in European Journal of Physics.

These new data enrich the kaonic atoms transitions database, which is used as input and as test-bed for theories and models of kaoni-nuclei interactions at low energies, a field which is still far from being fully understood. The new data added by SIDDHARTA-2 can stimulate a revival

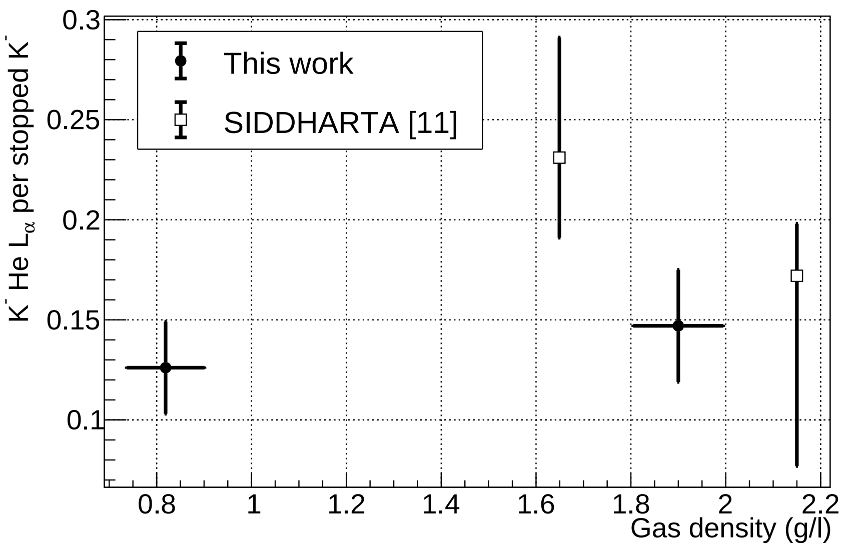

Figure 5: The L_α X-ray yield of K^- ^{4}He as function of the target density from all gaseous target measurements: this work (filled dots) and SIDDHARTA [14] (hollow squares).

Table 2: Kaonic carbon, oxygen, nitrogen and aluminium transition energies from the fit of the data in Fig. 6.

Transition	**Energy (eV)**
K^-C (6→5)	5541.7 ± 3.1 (stat) ± 2.0 (syst)
K^-C (7→5)	8890.0 ± 13.0 (stat) ± 2.0 (syst)
K^-C (5→4)	10216.6 ± 1.8 (stat) ± 3.0 (syst)
K^-C (6→4)	15760.3 ± 4.7 (stat) ± 12.0 (syst)
K^-O (7→6)	6016.0 ± 60.0 (stat) ± 2.0 (syst)
K^-O (6→5)	9968.1 ± 6.9 (stat) ± 2.0 (syst)
K^-N (6→5)	7577.0 ± 17.0 (stat) ± 2.0 (syst)
K^-N (5→4)	14010.6 ± 8.2 (stat) ± 9.0 (syst)
K^-Al (8→7)	10441.0 ± 8.5 (stat) ± 3.0 (syst)
K^-Al (7→6)	16083.4 ± 3.8 (stat) ± 12.0 (syst)

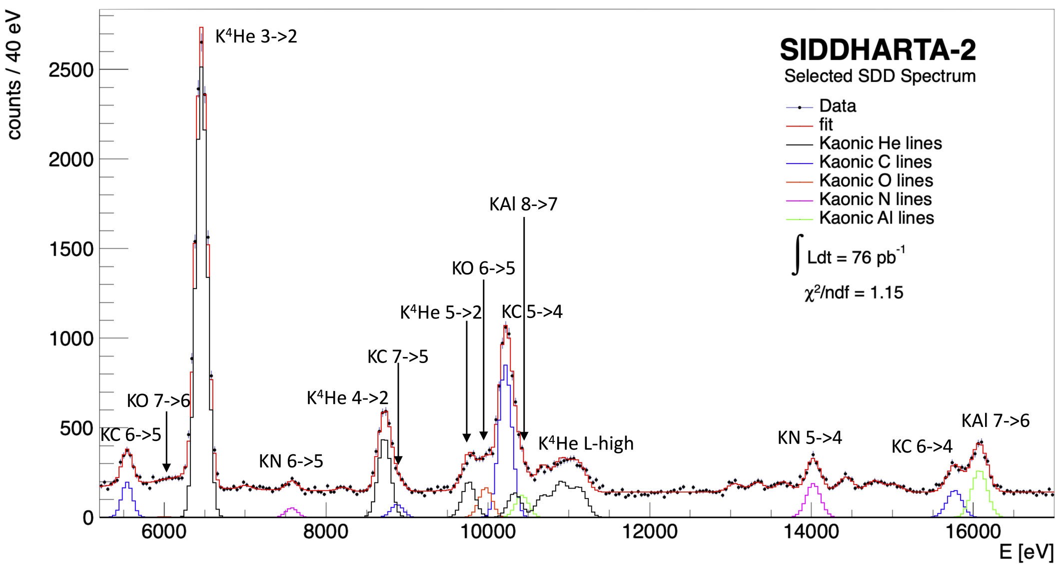

Figure 6: SDD energy spectrum and fit of SIDDHARTA-2 and SIDDHARTINO summed data after background suppression. The kaonic helium signals are seen as well as the kaonic carbon (KC), oxygen (KO), nitrogen (KN) and aluminium (KAl) signals.

of the theoretical activity in the field, towards a better understanding of the strong interaction with strangeness and of the role played by multi-nucleon absorption processes with implications extending from particle and nuclear physics to astrophysics.

The series of these measurements show the potential of DAΦNE and SIDDHARTA-2 like technologies to address high precision kaonic atoms measurements along the whole periodic table, within a future program which was put forward by the scientific community.

2.4 Plan for the SIDDHARTA-2 activities in 2023

The LNF group main activities in SIDDHARTA-2 for 2023 will be the following ones:

- optimization, debug and run with SIDDHARTA-2 setup for kaonic deuterium measurement
- Monte Carlo simulations for SIDDHARTA-2 setup and physics;
- data analysis
- run with a High Purity Germanium detector for testing the feasibility of other kaonic atoms measurements, as kaonic lead.
- consolidation of the proposal for kaonic atoms measurements beyond SIDDHARTA-2

In Figure 7 we show the kaonic deuterium simulated spectrum and expected results for an integrated luminosity of 800 pb^{-1}.

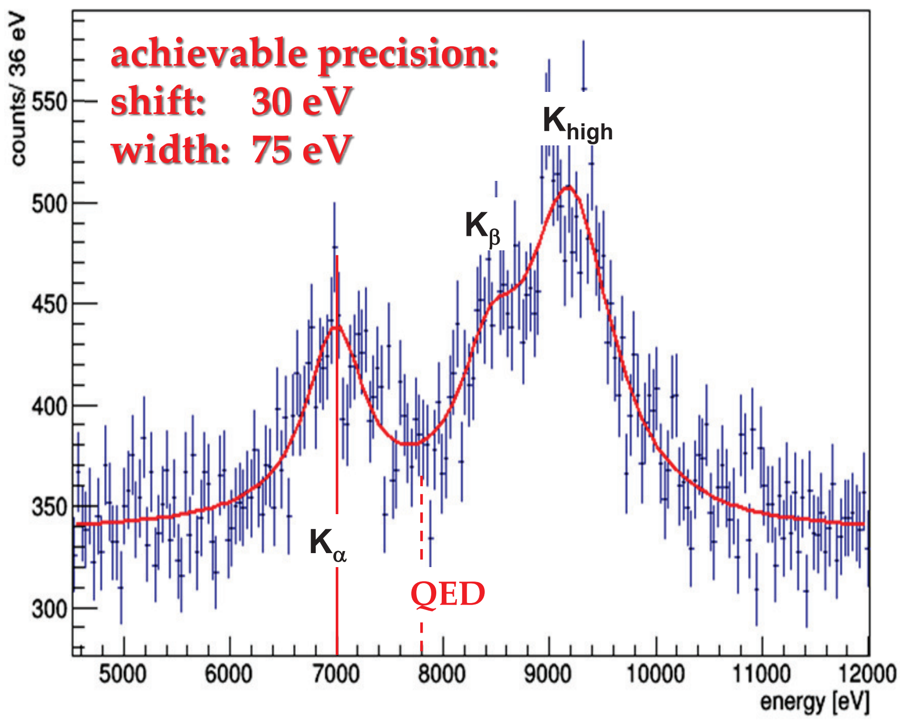

Figure 7: *Monte Carlo simulated kaonic deuterium spectrum for 800 pb^{-1}. sectors.*

3 AMADEUS: 2022

The low-energy kaon-nuclei interaction studies represent the main aim of AMADEUS. The negatively charged kaons from DAΦNE can stop inside the target or interact at low energies, giving birth of a series of processes we plan to study. Among these, a key-role is played by the production of $\Lambda(1405)$ which can decay into: $\Sigma^0\ \pi^0$, $\Sigma^+\ \pi^-$ or $\Sigma^-\ \pi^+$. We study all these three channels in the same data taking. Another important item is represented by the debated case of the "kaonic nuclear clusters", especially the and K^-pp and K^-ppn ones. We study these channels by measuring their decays to Λp and to Λd. In the same time, many other kaon-nuclei processes are investigated, either for the first time, or in order to obtain more accurate results than those actually reported in literature. Cross sections, branching ratios, rare hyperon decay processes are investigated, taking advantage of the unique kaon-beam quality delivered by DAΦNE.

In the summer of 2012 a first dedicated target, half cylinder done in pure carbon was realized and installed inside the Drift Chamber of KLOE as a first setup towards the realization of AMADEUS. The target thickness was optimized to have a maximum of stopped kaons (about 24% of the generated ones) without degrading too much the energy of resulting charged particles inside the target material. In the period of data taking a total integrated luminosity of about 90 pb^{-1} was achieved. The ongoing analysis of these data will provide new insights in the low-energy interactions of charged kaons in the nuclear matter.

Activities done in 2022:

- analysis of 2002-2005 KLOE data searching for processes generated by negatively charged kaons interacting at rest or in- fight in the setup materials (wall of the Drift Chamber and gas inside the Drift Chamber); the analyses of the K^- absorption delivering Λd and Λt final states were finalized and results are being prepared for pubblication;

- analysis of Σ^0 π^0;
- analysis of the 2012 Carbon target data;
- Monte Carlo dedicated simulations.
- During 2022 the highest precision - low-momentum - measurement of the inelastic $\mathrm{K^-p} \rightarrow (\Sigma^0/\Lambda)\,\pi^0$ cross sections, for a K^- momentum $p_K = (98 \pm 10)$ MeV/c was finalized:

  – $\sigma_{K^-p\rightarrow\Sigma^0\pi^0} = 42.8 \pm 1.5(stat.)^{+2.4}_{-2.0}(syst.)$ mb
  – $\sigma_{K^-p\rightarrow\Lambda\pi^0} = 31.0 \pm 0.5(stat.)^{+1.2}_{-1.2}(syst.)$ mb.

  With respect to previous experiments [16, 17], which extrapolated $\sigma_{K^-p\rightarrow\Sigma^0\pi^0}$ from the measurement of the the $\mathrm{K^-p} \rightarrow \Lambda\pi^0$ cross section, assuming isospin symmetry, this is the first direct simultaneous measurement of the cross sections in the isospin $I = 1$, and almost pure $I = 0$ channels. Alongside a comparable range for the kaon momentum ($\pm$10 MeV/c with respect to $\pm$12.5 MeV/c in Refs. [16, 17]) the present precision achieved in the cross section determination greatly overcomes the other low momentum measurements, providing a key input for the determination of the subthreshold $\bar{\mathrm{K}}\mathrm{N}$ scattering amplitudes and, hence, the determination of the $\Lambda(1405)$ nature, with impact on pending questions in several fields, ranging from nuclear and particle physics, to astrophysics.

3.1 AMADEUS activities in 2023

The main activities of AMADEUS in 2023 will be:

- analyses of data taken with the dedicated carbon target
- Monte Carlo dedicated simulations
- definition of the future strategy for dedicated experiment on DAΦNE and J-PARC.

Acknowledgements
The support from LNF Director, Dr. Fabio Bossi and from the DAΦNE, KLOE2 and BTF-LNF teams are gratefully acknowledged.

4 List of Conference Talks by LNF Authors in 2022

1. C. Curceanu, Stars and Cats: from exotic atoms studies to impossible atoms hunting to explore the Universe Colloquium ILL Grenoble, Grenoble, France.
2. C. Curceanu, Kaonic atoms at the DAΦNE Collider: strangeness from accelerators to the stars, Workshop on Standard Model and Beyond, Corfu, Grece.
3. C. Curceanu, All in a Thimble Strangeness in the neutron stars?, 4th Jagiellonian Symposium on advances in Particle Physics and Medicine, Krakow, Poland
4. C. Curceanu, Kaonic atoms at the DAΦNE Collider in Italy: from accelerators to the stars, UJ Particle Physics Phenomenology and Experiments Seminar (online).

5. C. Curceanu, Future plans for kaonic atoms measurements at DAΦNE, EXKALIBUR Second International Workshop on the Extension Project for the J-PARC Hadron Experimental Facility (2nd J-PARC HEF-ex WS) (online).
6. L. De Paolis, Nuclear Resonance Effects in Kaonic atoms, 108 Congresso Nazionale SIF, Milano, Italy.
7. L. De Paolis, Kaonic atoms research at the DAΦNE collider: The SIDDHARTA-2 experiment and future perspectives, International Conference on New Frontriers of Physics 2022 (ICFNP2022), Kolymbari (Grece).
8. L. De Paolis, Kaonic atoms beyond SIDDHARTA-2: future measurements and perspectives at the DAΦNE collider, European Nuclear Physics Conference 2022 (EuNPC 2022), Santiago de Compostela, Spain.
9. L. De Paolis, New possible investigation on strong interaction with kaonic atoms: the E2 nuclear resonance effect, Symposium - Nuclear E2 resonance effects in kaonic molybdenum isotopes, Frascati, Italy (online).
10. L. De Paolis, KAMEO (Kaonic Atoms Measuring nuclear resonance Effects Observables), 2nd Symposium on Nuclear E2 resonance effects in kaonic molybdenum isotopes, Frascati, Italy.
11. L. De Paolis, Nuclear Resonance effects in kaonic atoms (best poster), Quinto Incontro Nazionale di Fisica Nucleare INFN 2022, LNGS, Italy.
12. L. De Paolis, SIDDHARTA2 and future perspectives, International Workshop on QCD - Theory and experiment (QCD@Work), Lecce, Italy.
13. L. De Paolis, Strong Interaction Investigated with kaonic atoms at the DAΦNE collider (poster), International Conference on High Energy Physics 2022 (ICHEP2022), Bologna, Italy.
14. A. Khreptak, Calibration of Silicon Drift Detectors for the SIDDHARTA-2 Experiment (poster), 4th Jagiellonian Symposium on Advances in Particle Physics and Medicine, Kraków, Poland.
15. S. Manti, Cascade models for atomic transitions, Nuclear and Atomic transitions as laboratories for high precision tests of Quantum Gravity inspired models, ECT*, Trento, Italy.
16. S. Manti, Cascade models for atomic transitions, EXOTICO: EXOTIc atoms meet nuclear COllisions for a new frontier precision era in low-energy strangeness nuclear physics, ECT*, Trento, Italy.
17. F. Napolitano, High Precision Measurements of Kaonic Atoms, The Hitchhiker's Advanced Guide to Quantum Collapse Models and their impact in science, philosophy, technology and biology, Frascati, Italy.
18. F. Napolitano, Statistical Methods in Particle and Nuclear Physics, ECT* EXOTICO workshop, Trento, Italy.
19. K. Piscicchia, Low-energy kaon-nuclei interaction studies by AMADEUS, 14th International Conference on Hypernuclear and Strange Particle Physics, HYP2022, Prague.

20. F. Sgaramella, How to count kaons at DAΦNE collider? Luminometer versus Kaon Trigger, Second International Workshop on the Extension Project for the J-PARC Hadron Experimental Facility (2nd J-PARC HEF-ex WS) (online).
21. F. Sgaramella, Kaonic Atoms with SIDDHARTA-2 at the DAΦNE collider, Quinto Incontro Nazionale di Fisica Nucleare INFN 2022, LNGS, Italy.
22. F. Sgaramella, Kaonic Atoms with SIDDHARTA-2 at the DAΦNE collider, International conference on kaon physics- KAON 2022 (online)
23. F. Sgaramella, The SIDDHARTA-2 experiment for high precision kaonic atoms X-ray spectroscopy, 108 Congresso Nazionale della Società Italiana di Fisica, Milano, Itlay.
24. F. Sgaramella, Kaonic atoms X-ray spectroscopy: the SIDDHARTA-2 experiment, EXOTICO: EXOTIc atoms meet nuclear COllisions for a new frontier precision era in low-energy strangeness nuclear physics, ECT*, Trento, Italy.
25. F. Sgaramella, Kaonic Atoms with SIDDHARTA-2 at the DAΦNE collider, EuNPC 2022 - European Nuclear Physics Conference 2022, Santiago de Compostela, Spain.
26. A. Scordo, VOXES: a detection system with eV resolution for X rays in KeV range, Symposium: High precision measurements of kaonic atoms, (online).
27. A. Scordo, HAPG mosaic crystal spectrometer for precision kaonic atom spectroscopy, Second International Workshop on the Extension Project for the J-PARC Hadron Experimental Facility (2nd J-PARC HEF-ex WS) (on-line).
28. A. Scordo, Kaonic atoms beyond SIDDHARTA-2: future measurements and perspectives at the DAFNE collider, Quinto Incontro Nazionale di Fisica Nucleare INFN 2022, LNGS, Italy.
29. A. Scordo, A new life for kaonic atoms at DAΦNE: future measurements and perspectives with advanced X-ray spectroscopy techniques, RAP2022 conference, (online).
30. A. Scordo, Kaonic atoms at DAΦNE: where we are and where we go?, 4th Jagiellonian Symposium on Advances in Particle Physics and Medicine, Krakow, Poland.
31. A. Scordo, Beyond kaonic deuterium: renewing the kaonic atoms database with future measurements at DAΦNE, International workshop on "Hadron physics with kaon beam and related topics" workshop, (online).
32. A. Scordo, Radiation detectors for future kaonic atoms measurements at DAΦNE, EXOTICO: EXOTIc atoms meet nuclear Collisions for a new frontier precision era in low-energy strangeness physics, ECT*, Trento, Italy.
33. A. Scordo, Present and future kaonic atoms measurements with new generation radiation detectors, Invited seminar at the University of Zagreb, Croatia.
34. M. Skurzok, Studies of low-energy K^- - nucleus/nuclei interactions by AMADEUS, NSTAR2022: The 13th International Workshop on the Physics of Excited Nucleons, Santa Margherita Ligure, Italy.
35. M. Skurzok, Studies of low-energy K^- nucleus/nuclei interactions by AMADEUS, EXOTICO: EXOTIc atoms meet nuclear COllisions for a new frontier precision era in low-energy strangeness nuclear physics, ECT*, Trento, Italy.

36. M. Skurzok, Studies of low-energy K^--nucleus/nuclei interactions with light nuclei by AMADEUS, Second International Workshop on the Extension Project for the J-PARC Hadron Experimental Facility (2nd J-PARC HEF-ex WS), (online).
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