PROCEEDINGS OF SCIENCE

Kaonic atoms measurements at DAΦNE by SIDDHARTA

SIDDHARTA Collaboration: M. Bazzi[a], G. Beer[b], L. Bombelli[c], A.M. Bragadireanu[a,d], M. Cargnelli[e], G. Corradi[a], C. Curceanu (Petrascu)[a], A. d'Uffizi[a], C. Fiorini[c], T. Frizzi[c], F. Ghio[f], B. Girolami[f], C. Guaraldo[a], R.S. Hayano[g], M. Iliescu[a,d], T. Ishiwatari[e], M. Iwasaki[h], P. Kienle[e,i], P. Levi Sandri[a], A. Longoni[c], V. Lucherini[a], J. Marton[e], S. Okada[a], D. Pietreanu[a], T. Ponta[d], A. Rizzo[a], A. Romero Vidal[*a], A. Scordo[a], H. Shi[g], D.L. Sirghi[a,d], F. Sirghi[a,d], H. Tatsuno[g], A. Tudorache[d], V. Tudorache[d], O. Vázquez Doce[a], E. Widmann[e] and J. Zmeskal[e]

[a] *INFN, Laboratori Nazionali di Frascati, Frascati (Roma), Italy*
[b] *Dep. of Phys. and Astro., Univ. of Victoria, Victoria B.C., Canada*
[c] *Politecnico di Milano, Sez. di Elettronica, Milano, Italy*
[d] *IFIN-HH, Magurele, Bucharest, Romania*
[e] *Stefan-Meyer-Institut für subatomare Physik, Vienna, Austria*
[f] *INFN Sez. di Roma I and Inst. Superiore di Sanita, Roma, Italy*
[g] *Univ. of Tokyo, Tokyo, Japan*
[h] *RIKEN, The Inst. of Phys. and Chem. Research, Saitama, Japan*
[i] *Tech. Univ. München, Physik Dep., Garching, Germany*

E-mail: `Antonio.RomeroVidal@lnf.infn.it`

The SIDDHARTA experiment performed in 2009 precision measurements of kaonic atoms transitions, in particular of kaonic helium and kaonic hydrogen, at the upgraded DAΦNE collider. The measurements were performed using triggered X-ray detectors, namely large area Silicon Drift Detectors, which were developed in the framework of the collaboration. The experiment will be presented, together with preliminary results of the data analyses.

XLVIII International Winter Meeting on Nuclear Physics, BORMIO2010
January 25-29, 2010
Bormio, Italy

*Speaker.

 http://pos.sissa.it/

PoS(BORMIO2010)035

1. Introduction

The SIDDHARTA experiment aims to study the Kaon-nucleon strong interaction in kaonic atoms produced at *DAΦNE*, in particular in the kaonic hydrogen (K-H) and kaonic deuterium (K-d).

The method is based on the measurement of the X-rays emitted in the de-excitation processes of the kaonic atoms. The strong interaction leads to a shift ΔE of the fundamental $1s$ energy level compared to the value calculated from electromagnetic interaction only, and a broadening Γ due to the absorption of the kaon by the nucleus. These quantities can be obtained by comparing the measured energies of the X-ray transitions to the $1s$ level to the purely QED calculated values. SIDDHARTA improved the previous K-H measurements done by DEAR [1] and KpX [2] at KEK, and permormed the first ever K-d measurement.

A precise measurement of the ΔE and Γ for the K-H and K-d would provide a very valuable information for a better comprehension of the low energy QCD in the strangeness sector. In particular, it will allow to determine the antikaon-nucleon isospin dependent scattering lengths [3].

2. The SIDDHARTA experimental setup

The SIDDHARTA setup [3] was installed in the e^+e^- interaction point of the *DAΦNE* collider in autumn 2008. The setup is divided in three parts: a kaon detector, an X-ray detection system, and a cryogenic target. In figure 1 an overview of the setup is shown.

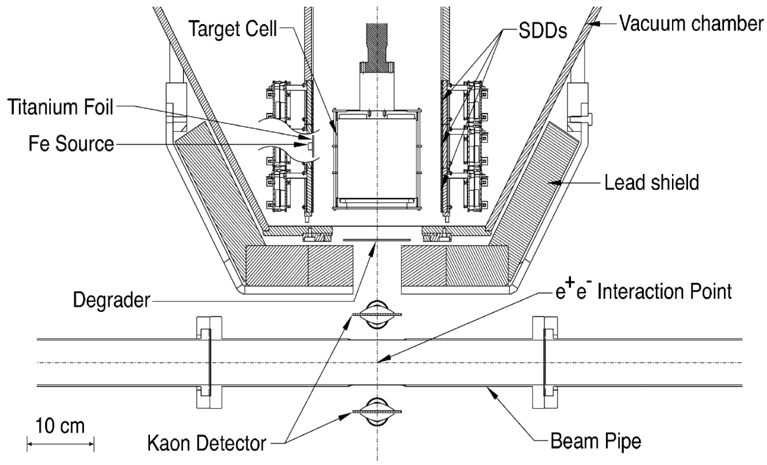

Figure 1: The SIDDHARTA setup; the Fe source was used during KHe measurement for calibration purpose; it was taken away for the K-H measurement.

The target cell is cylindrical with a radius of 6 cm and a height of 12 cm built in Kapton, 75 μm thick. It was filled with gas at a temperature of 27 K and a pressure of 1 bar. The bottom of the vacuum chamber has a circular window made of a Kapton foil, through which kaons enter in the target cell. An energy degrader, installed on the bottom of the vacuum chamber, was adjusted in thickness to optimize the number of kaons stopped inside the target. It had a step-like shape to compensate the ϕ boost effect caused by a finite crossing angle of the electron and positron beams.

The K^+K^- pairs produced by ϕ decay were detected by a kaon detector [4]. This detector consists of two scintillators installed above and below the beam pipe at the interaction point. Each scintillator has a size of 152×72 mm^2, and a thickness of 1.5 mm. Two fast photomultipliers (Hamamatsu R4998) were optically coupled to the ends of each scintillator.

In this detector, charged kaon pairs were well identified by their time of flight. The slow kaon pairs are clearly separated from fast minimum ionizing background particles (MIPs), due to excellent time resolution ($\sim$ 100 ps FWHM) and to the use of stable clock pulses (380 MHz RF) delivered by $DA\Phi NE$. A correlation of the time difference on the two scintillators is shown in figure 2. The K^+K^- pair production events are clearly indicated. The ratio of kaon coincidences to MIPs during the measurements was about 20:1.

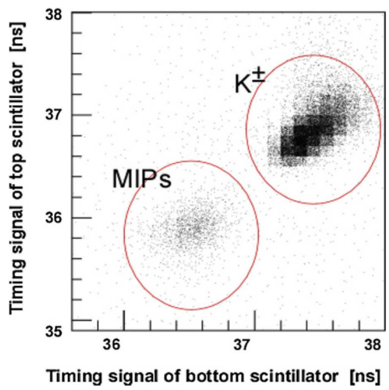

Figure 2: Timing spectrum of the two scintillators in the kaon detector. The time difference between the clock signals delivered by $DA\Phi NE$ and the coincidence of the two scintillators is shown. The K^+K^- and MIPs coincidence events are marked in the figure.

The X-rays were detected using recently-developed large area SDDs having an active area of 1×1 cm^2 and a thickness of 450 μm [5][6]. After detailed performance tests, 144 SDDs were installed surrounding the target cell. The SDDs were cooled to a temperature of 170 K with a stability of $\pm 0.5K$.

X-ray signals in the SDDs were read out using a specially designed data acquisition system. Energy data of all the X-ray signals detected by the SDDs were recorded. In addition, time differences between the coincidence signals in the kaon detector and X-ray signals in the SDDs were recorded using a clock with a frequency of 120 MHz, whenever the coincidence signals occurred within a time window of 6 μs.

The SDD data are categorized as one of two types: one type contains X-ray events uncorrelated with the kaon coincidence ("self-trigger data"), and the other type contains X-ray events correlated with the kaon coincidence ("coincidence data"), which provides kaonic atom X-ray energy spectrum with a very high background suppression.

Two Ti and Cu foils were installed in a place close to the target cell to monitor the stability of the SDD X-ray detection system. Using the K_α lines of Ti (4.5 keV) and Cu (8.0 keV) activated by background particles, a dedicated stability check and energy calibration has been performed.

3. SIDDHARTA measurements and preliminary results

SIDDHARTA took data in 2009 with 4 different targets: ^4He, ^3He, H_2 and d. The data analyses for all these targets are ongoing. In what follows, we briefly present preliminary results for K ^4He and K-H. The kaonic helium measurements to the 2p-level (L-series) with ^4He were used to optimize the degrader, but proved to be very competitive.

In figure 3 we presents the kaonic helium preliminary result, giving a measurent of: $\Delta E = 0 \pm 6$ (stat) $\pm$ 2 (syst). More details are given in paper [7].

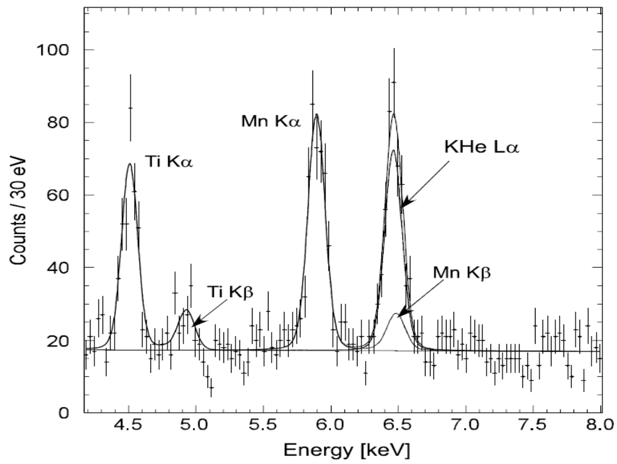

Figure 3: Energy spectrum of the kaonic ^4He X-rays. The kaonic ^4He L_α line is seen at 6.4 keV.

Figure 4 shows the K-H X-ray energy spectrum selected by the triple coincidence timing events for partial statistics. The two peaks at 4.5 and 5.5 keV correspond to the Ti fluorescense lines, coming from the Ti foil, wich is activated by the kaons and background; and to the Kaonic-Carbon 6 -> 5 (at 5.5 keV) X-ray transitions, produced at the target walls.

The other two broad peaks are the kaonic hydrogen K_α line ($5.8-6.4keV$ region) and the $K_{complex}$ (K_β ...) line (7.0 – 9.0 keV region).

The analysis is ongoing in order to extract the ΔE and the Γ with a precision better than DEAR [1].

4. Conclusions

The SIDDHARTA experiment performed in 2009 precision measurements of kaonic helium (3 and 4) and kaonic hydrogen. It performed as well the first ever exploratory measurement of the kaonic deuterium.

DAΦNE proved to be an ideal "kaonic atoms" factory.

Presently, data analyses are ongoing. In parallel plans for an upgrade of the experimental setup and an enriched scientific case for the near future are being considered.

5. Acknowledgements

We acknowledge the support of the European Community-Research Infrastructure Integrating

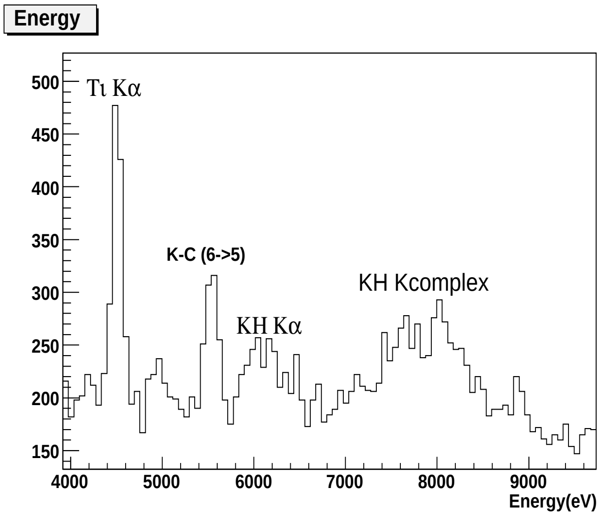

Figure 4: Kaonic hydrogen X-ray spectrum for events in coincidence with the kaon detector. $Ti\ K_\alpha$ and K_β lines are seen at 4.5 and 5.0 keV. Also the Kaonic-Carbon 6 -> 5 line is seen at 5.5 keV. The broad peaks between 5.8 and 9.0 keV correspond with the kaonic hydrogen K_α and $K_{complex}$ lines.

Activity "Study of Strongly Interacting Matter" (acronym HadronPhysics2, Grant Agreement n. 227431) under the Seventh Framework Programme of EU.

References

[1] G. Beer et al., Phys. Rev. Lett. 94 (2005) 212302.

[2] M. Iwasaki et al., Phys. Lett. 78 (1997) 3067.

[3] J. Zmeskal, Progr. Part. Nucl. Phys. 61 (2008) 512.

[4] V. Lucherini, et al., Nucl. Instrum. Methods A 496 (2003) 315.

[5] P. Lechner, et al., Nucl. Instrum. Methods A 458 (2001) 281.

[6] C. Fiorini, et al., Nucl. Instrum. Methods A 568 (2006) 322.

[7] M. Bazzi, et al., Physics Letters B 681 (2009) 310-314.