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Development of a cryogenic x-ray detector and an application for kaon mass measurement

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The ASPE!CT project aims to develop a commercially viable, cryogenic detector platform. The first phase of the project will produce a cryogen-free, single-stage, adiabatic demagnetisation refrigerator for use at 300-500mK. The project aims to advance the technology into the realm of reliable, compact, black-box, touch-button devices, which can be used for a wide range of cryogenics sensors. We plan to use the detector system to make an improved measurement of the kaon mass. Though the kaon mass is an essential input for strangeness hadron physics, it is determined as an average of two largely separated measurements (~3sigma, 60 eV). We will be testing various designs of cryogenic detectors (i.e. MPT, magnetic penetration thermometer) with a view to achieving the necessary resolution (10eV or better) at ~10 keV x-ray energies created in kaonic atoms.

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1. Introduction

The ASPE!CT (Adaptable Spectrometer Enabled by Cryogenic Technology) project is an European Union collaboration of two R&D performing SME (Payr Engineering GmbH and Low Temperature Solutions UG) and the research institute Stefan Meyer Institute of The Austrian Academic of Science.

The primarily target of the project is developing a commercially viable and versatile cryogenic platform addressed to a wide range of cryogenics sensors and/or spectroscopy applications. Within the funded period, the consortium aims to advance the prototype technology into the realm of reliable, compact, black-box, touch-button devices, which can be introduced into market right after the project end.

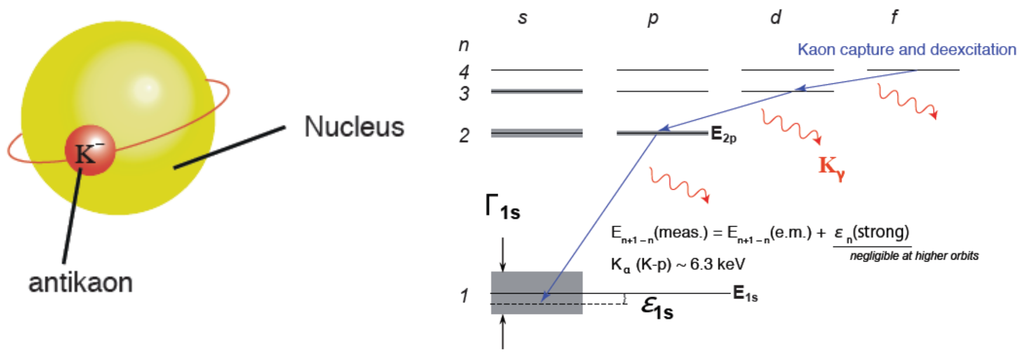
The first phase of the project will produce a special designed cryogen-free, single-stage, adiabatic demagnetization refrigerator prototype for use at sub-Kelvin temperatures. The experimental plate and the DAQ will be customized to allow the operation of an ad-hoc developed cryogenic sensor (MPT, magnetic penetration thermometer).

The cryogenic sensor will be characterized together with the ASPE!CT prototype and will be optimized to achieve a resolution of about 10eV at ~10 keV x-ray. An energies range typically created in kaonic atoms experiments. Later stages of the project should see improved count rates in an optimized experimental set-up to perform a high-resolution kaon mass measurements in a Kaon beam to be provided by the J-PARC (Tokai, Japan) or DAΦNE (Frascati, Italy).

The middle-term target is to push down the temperature range of the cost effective cooling device and to introduce continuous, high-power, low-temperature cooling and eventually to introduce in the market not only a cooling device, but a multi-purpose and robust, industrial cryogenic spectrometer operated with MPT having its own DAQ system (for example for PIXE, EDS industrial applications).

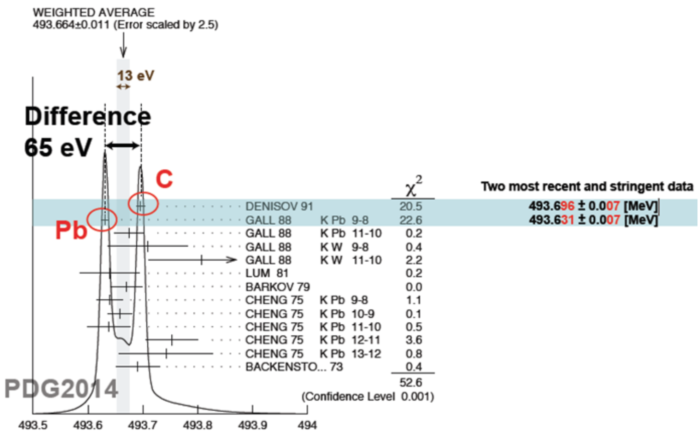
1.1 Kaonic atoms and kaonic mass

X-ray spectroscopy of kaonic atoms is an excellent tool for studying the chiral symmetry breaking with strange quarks. Kaonic atoms are QED bound systems in which the heavier, negative kaon replaces an electron. Studies of exotic mesonic atoms have provided important information on strong interaction (hadron) physics.



The negatively charged kaon is bound by the Coulomb interaction at higher orbit but also influenced by the strong interaction at lower energies.

Although the kaon mass is an essential input for strangeness hadron physics, it is currently determined as a simple average between two largely separated measurements (~3σ, 60 eV), [1] making a current estimates of the kaon mass inconclusive.



Kaon mass measurements from the 2004 Particle Data Group

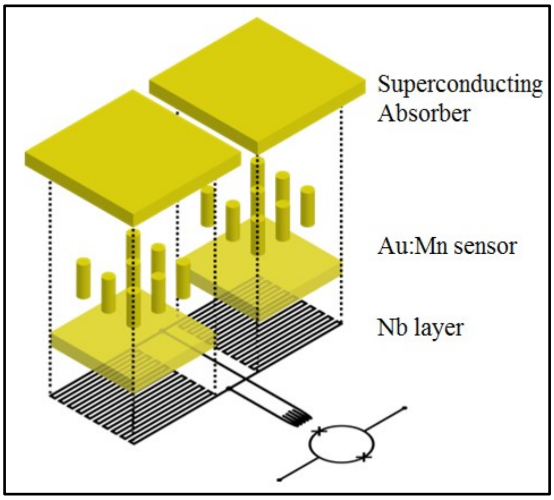
1.2 Cryogenic detector

Standard Low Temperature Detectors operate usually at about 100mK or even less. To achieve such temperature regime, complex and expensive so-called ULT devices (i.e. Dilution Refrigerators or two-stage Adiabatic Demagnetization Refrigerators) have to be purchased.

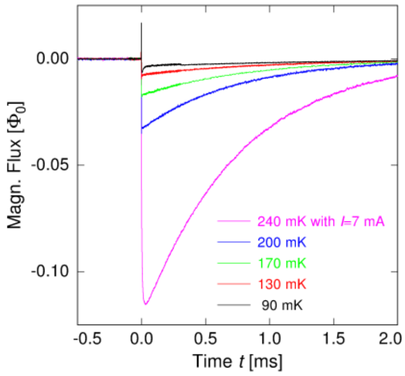
The target operating temperature of the ASPE!CT cooling device is set to be at 300-500mK or higher. With such specification the overall complexity and therefore the manufacturing costs can be reduced making the product attractive for the market.

A new detector which efficiently can be operated at 300-500mK has to be ad-hoc developed. The best choice, assuming the temperature constrains, are Magnetic Penetration Thermometers (MPT) which can be seen as a modified version of Metallic Magnetic Calorimeters (MMC) [2]. Here, the paramagnetic T-sensor is replaced with a superconductor having a sufficiently low Tc. The T-dependent flux penetration is then used as thermometer.

Compared with MMC operating at the same temperature, optimized MPT may achieve up to 10 times larger T-sensitivity. By choosing a special detector layers geometry and an accurate manufacturing procedure is possible to fabricate MPT operating at 300-500mK having a sufficient energy resolution for kaonic mass measurements. A possible MPT supplier is already identified (KIP-Heidelberg). A good MPT candidate may be a modified Al:Mn MMC detector. Activity to define the exact detector parameters and DAQ are ongoing.



MPT proposed basic design



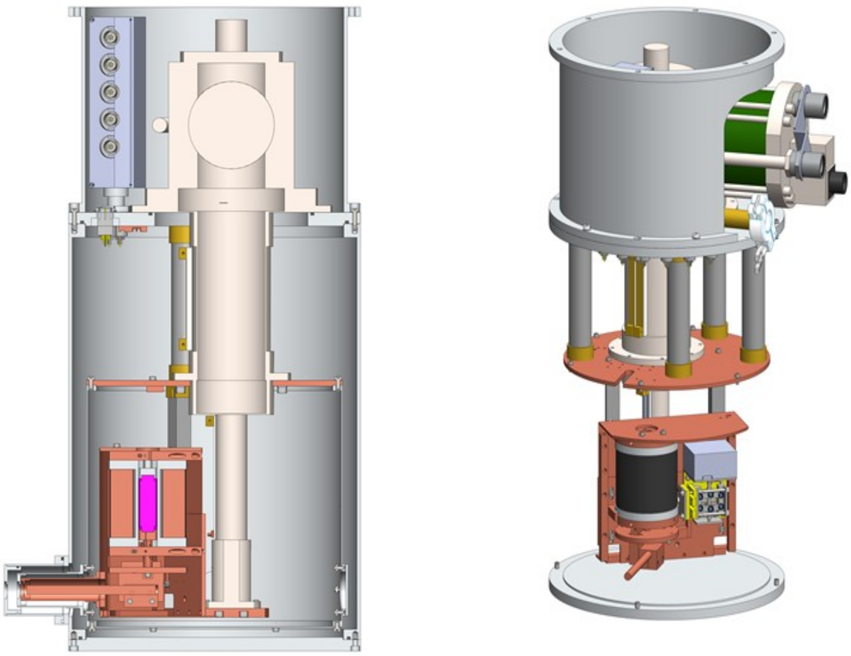
MPT Temperatures sensitivity

1.3 Cryostat

The ASPE!CT project aims to develop a commercially viable, cryogenic detector platform. The product can be classified as a cryogen-free, single-stage, adiabatic demagnetisation refrigerator (ADR).

The innovative design of the bench-top cooling device includes the use of reliable and energy efficient GM-4K mechanical cryocooler combined with a dumping system and a compact superconducting 6T magnet. By using Gadolinium Gallium Garnet (GGG) crystal as pill and optimizing the cooling parameters is possible to operate the ASPE!CT device at about 500mK for more than 48hrs with then an ADR recharge time of about 1h.

A high-level of integration, new heat-switch, magnet and electronics designs should make the cryostat robust, reliable and very easy to use.



©ASPE!CT Cooling Device

1.4 Conclusion

In the framework of a new challenging strategy, the European Union supports programs which bridge excellent science with industrial leadership. The Eurostars™ program, in particular, strongly supports international collaboration between R&D-performing SMEs and Academia with the aim to rapidly introduce into market innovative products.

The ASPE!CT project well-fit in such EU strategy and certainly creates an add-on value for each of the involved partners.

With its planned cost-effective and smart design, the ASPE!CT cooling device has good chance to meet the needs of the fast-growing market of the cryogenic spectroscopy.

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References

[1] K. A. Olive et al. (Particle Data Group), Chin. Phys. C, 38, 090001 (2014).

[2] A. Fleischmann, C. Enss, and O.M. Seidel, *Metallic magnetic calorimeters*, in Cryogenic Particle Detection, 2005, vol. 99 of the Topics in Applied Physics, ed. by C.Enss, 151-216.