Luca De Paolis on behalf of the SIDDHARTA-2 Collaboration

International Conference on High Energy Physics, ICHEP 2022, Bologna

Strong-interaction investigated with kaonic atoms at the DAΦNE collider

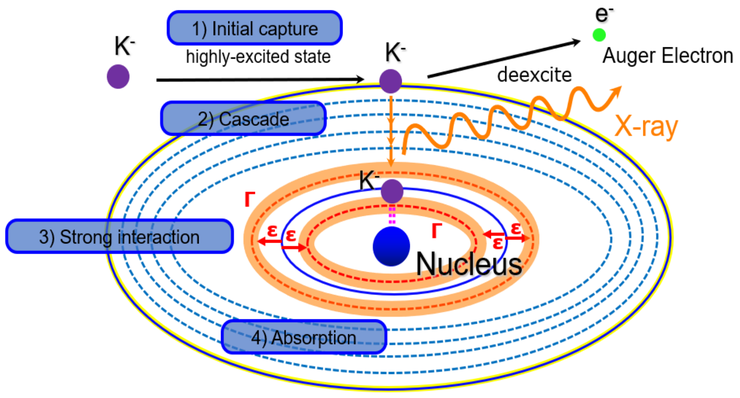
INFN Istituto Nazionale di Fisica Nucleare LABORATORI NAZIONALI DI FRASCATI

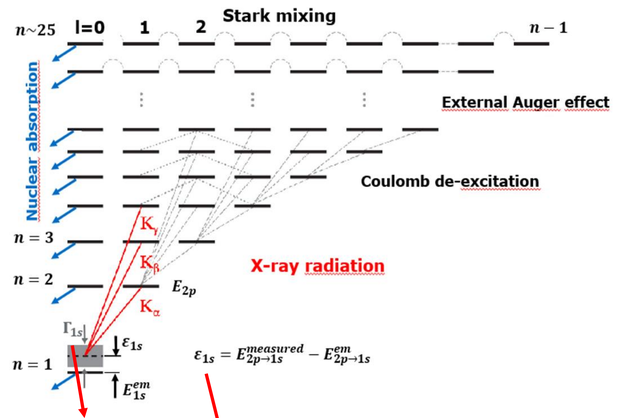
STRONG-2020

LABORATORI NAZIONALI DI FRASCATI

Kaonic atoms formation

Kaonic atoms are formed by stopping a negatively charged kaon in a target medium (e.g. H, D, He)





$$n \approx \sqrt{\frac{\mu}{m_e}} \cdot n_e$$

- μ is the reduced mass
- m_e the electron mass
- n_e is the principal quantum number of the outermost electron shell

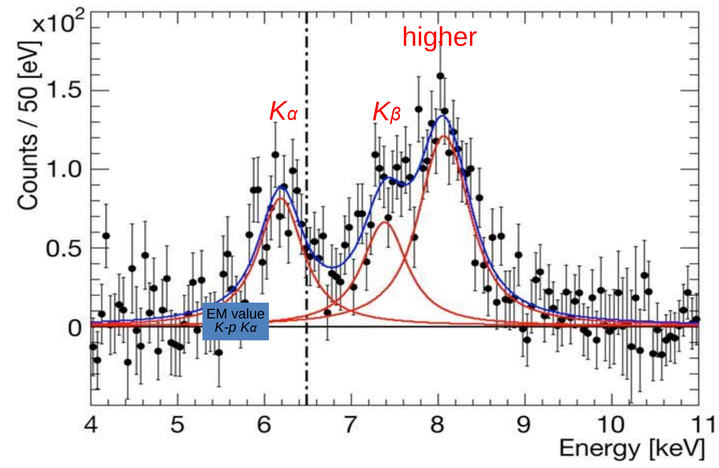
Width (Γ) and shift (ε) due to the kaon-nucleus strong interaction, obtained by measuring the X-rays emitted

C. Curceanu et al., Rev. Mod. Phys. ***91****, 025006*

THE SIDDHARTA EXPERIMENT

PERFORMED IN 2011

KAONIC HYDROGEN



$$\varepsilon_{1s}^{H} = -283 \pm 36(stat) \pm 6(syst)eV$$

$$\Gamma_{1s}^{H} = 541 \pm 89(stat) \pm 22(syst)eV$$

C. Curceanu et al., Phys. Lett. B ***704*** *(2011) 113*

SCIENTIFIC GOAL:

The measurement of shift (ε) and width (Γ) of the 1S orbital in **Kaonic Hydrogen** and **Kaonic Deuterium**, provides fundamental and unique information on kaon-proton and kaon-neutron strong interaction at low energies.

Deser-Trueman Formula

$$\varepsilon_{1s}^{H} + \frac{i}{2}\Gamma_{1s}^{H} = 2\alpha^3\mu_{\bar{K}p}^2 a_{\bar{K}p}\,(1 - 2\alpha\mu_{\bar{K}p}^2(\ln\alpha - 1)\,a_{\bar{K}p})$$

$$\varepsilon_{1s}^{D} + \frac{i}{2}\Gamma_{1s}^{D} = 2\alpha^3\mu_{\bar{K}d}^2 a_{\bar{K}d}(1 - 2\alpha\mu_{\bar{K}d}^2(\ln\alpha - 1)\,a_{\bar{K}d})$$

- $a_{\bar{K}p}, a_{\bar{K}d}$ are $\bar{K}p$ and $\bar{K}d$ scattering lengths
- $\mu_{\bar{K}p}$, $\mu_{\bar{K}d}$ are reduced masses of $\bar{K}p$ and $\bar{K}d$ systems
- $\varepsilon_{1s}^{H}, \Gamma_{1s}^{H}$ and $\varepsilon_{1s}^{D}, \Gamma_{1s}^{D}$ are energy shift and width of the 1s level in Kaonic Hydrogen and Kaonic Deuterium
- α is the fine-structure constant

$$a_{\bar{K}p} = \frac{1}{2}(a_0 + a_1)$$

$$a_{\bar{K}n} = a_1$$

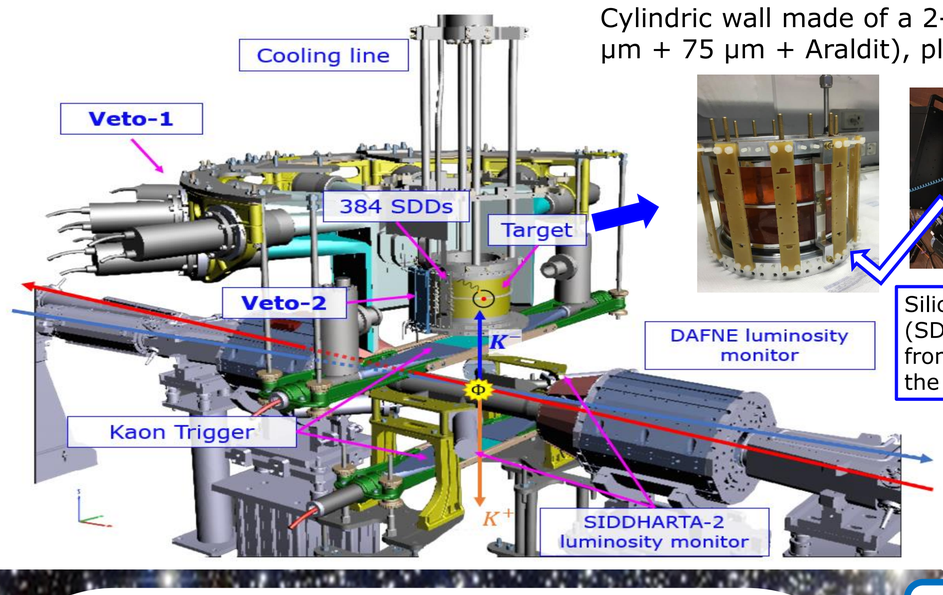
$$a_{\bar{K}d} = \frac{k}{4}(a_0 + 3a_1) + C = \frac{k}{2}\left(a_{\bar{K}p} + a_{\bar{K}n}\right) + C$$

- a_0 and a_1 are $\bar{K}N$ isospin-dependent ($I = 0,1$) lengths
- $k = \frac{4(m_N + m_K)}{2m_N + m_K}$, with m_N and m_K are respectively nucleon and kaon masses
- C is a term including all higher orders.

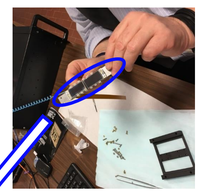
completely solve Isospin-dependent K-N scattering length

U.-G. Meißner, U. Raha, A. Rusetsky, Eur. J. Phys. C ***35*** *(2004) 349*

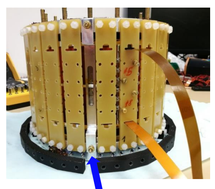
THE SIDDHARTA-2 EXPERIMENT AIMS TO MEASUREMENT OF KAONIC DEUTERIUM



Cylindric wall made of a 2-Kapton layer structure (75 μm + 75 μm + Araldit), placed on aluminum support.



Silicon Drift Detectors (SDDs) are placed 5 mm from the target wall for the x-ray spectroscopy

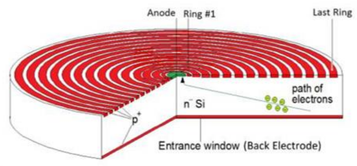


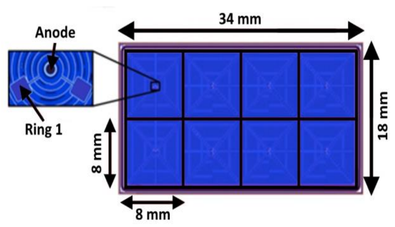
calibration foils inserted near to the SDD are activated by the X-ray tubes

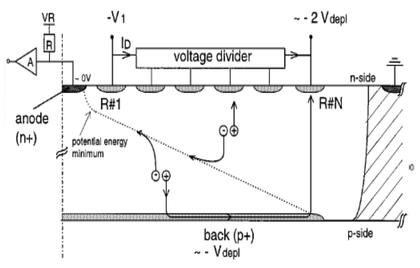
GASEOUS DEUTERIUM IS FLUXED WITHIN THE TARGET CELL

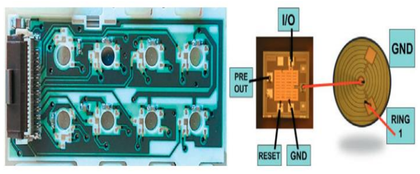
The Silicon Drift Detectors

SDD CELL CROSS SECTION

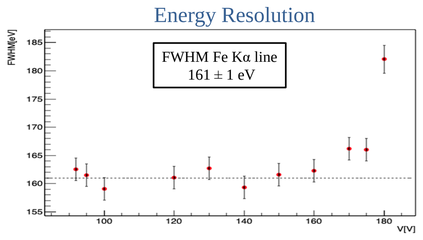






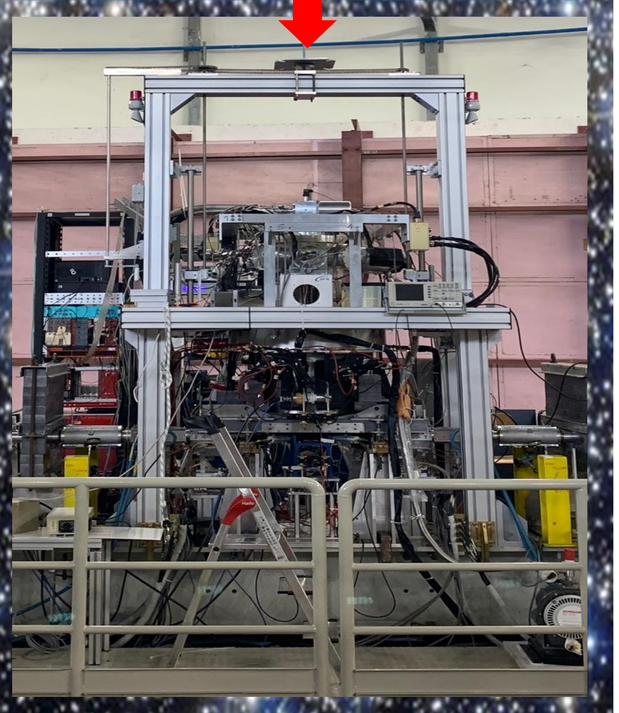


Energy Resolution



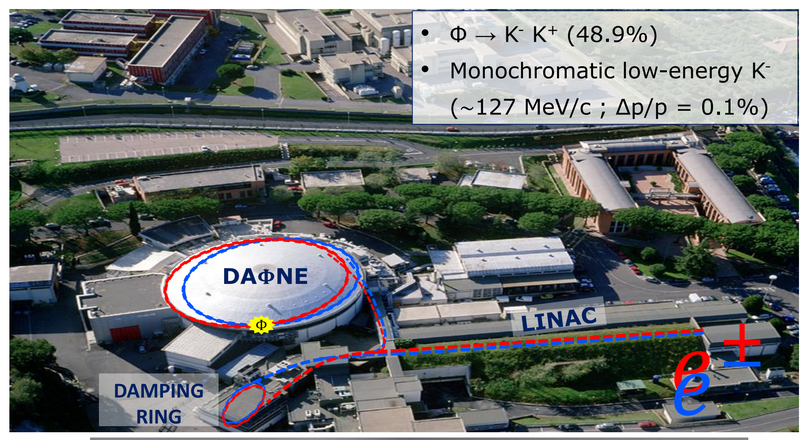
M Miliucci *et al* 2021 *Meas. Sci. Technol.* **32** 095501

SIDDHARTA-2 ACTUALLY INSTALLED AT LNF

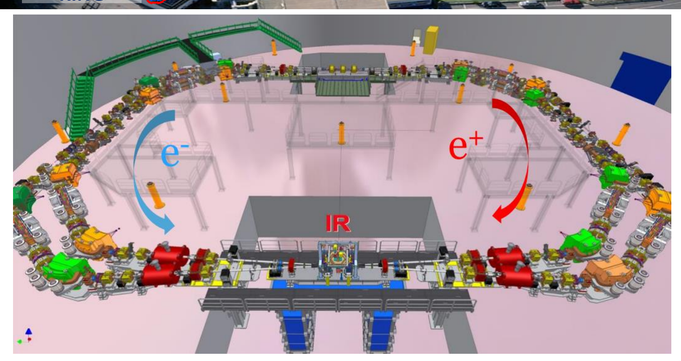


KAONIC DEUTERIUM MEASUREMENT WILL BE PERFORMED IN 2022/2023

LNF e^+e^- Accelerators complex

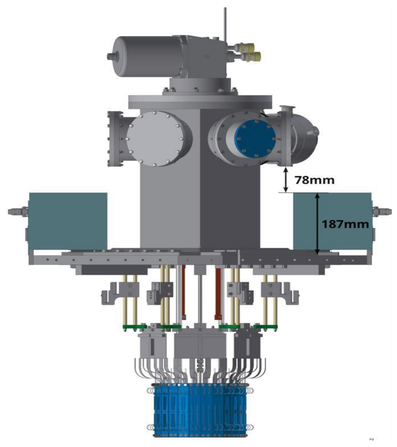


- Φ → K⁻ K⁺ (48.9%)
- Monochromatic low-energy K⁻ (~127 MeV/c ; Δp/p = 0.1%)



SIDDHARTINO

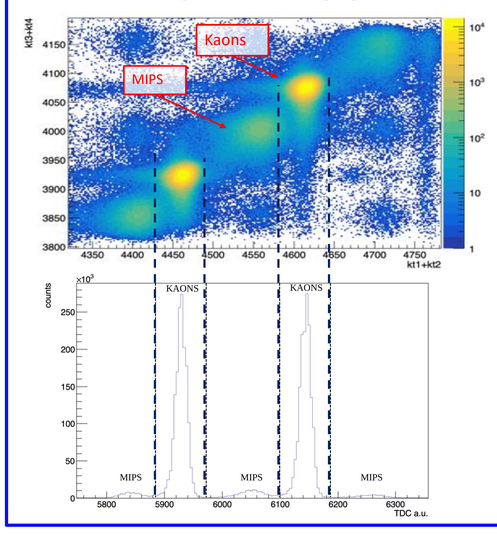
SIDDHARTINO was the phase 1 of the SIDDHARTA-2 experiment, which consisted of **1/6 of the SIDDHARTA-2 apparatus**, installed in the DAΦNE collider during the DAΦNE beams commissioning phase

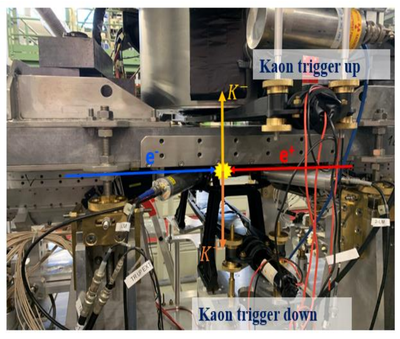


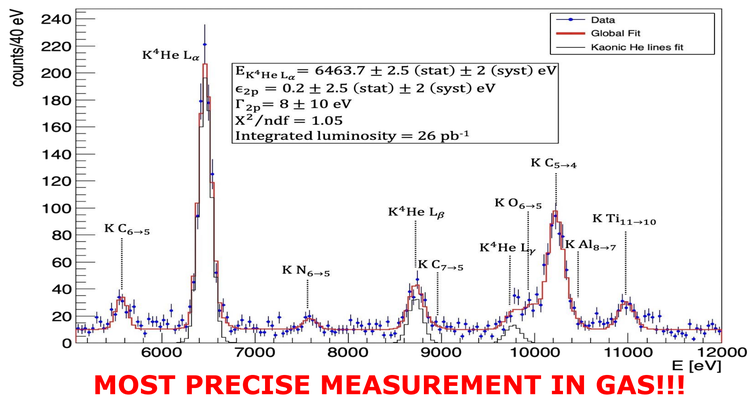
SIDDHARTINO goals:

- Evaluation of the machine background (in preparation for the K-d run) through the measurement of the shift ε_{2p} and width Γ_{2p} in kaonic Helium 4
- Tuning of the SDD detectors
- Test and tuning of the Kaon trigger

KAON TRIGGER







MOST PRECISE MEASUREMENT IN GAS!!!

Sirghi *et al* 2022 *J. Phys. G: Nucl. Part. Phys.*

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