Present and Future Perspective in Hadron Physics

"KAONIC ATOMS MEASUREMENTS WITH SIDDHARTA-2 AT THE DAΦNE COLLIDER"

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on behalf of the SIDDHARTA-2 collaboration

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STRONG-2020

Why Kaonic Atom?

On self-gravitating strange dark matter halos around galaxies Phys.Rev.D 102 (2020) 8, 083015

Dark Matter studies

Fundamental physics
New Physics

The modern era of light kaonic atom experiments Rev.Mod.Phys. 91 (2019) 2, 025006

Kaonic atoms
Kaon-nuclei interactions (scattering and nuclear interactions)

Kaonic Atoms to Investigate Global Symmetry Breaking Symmetry 12 (2020) 4, 547

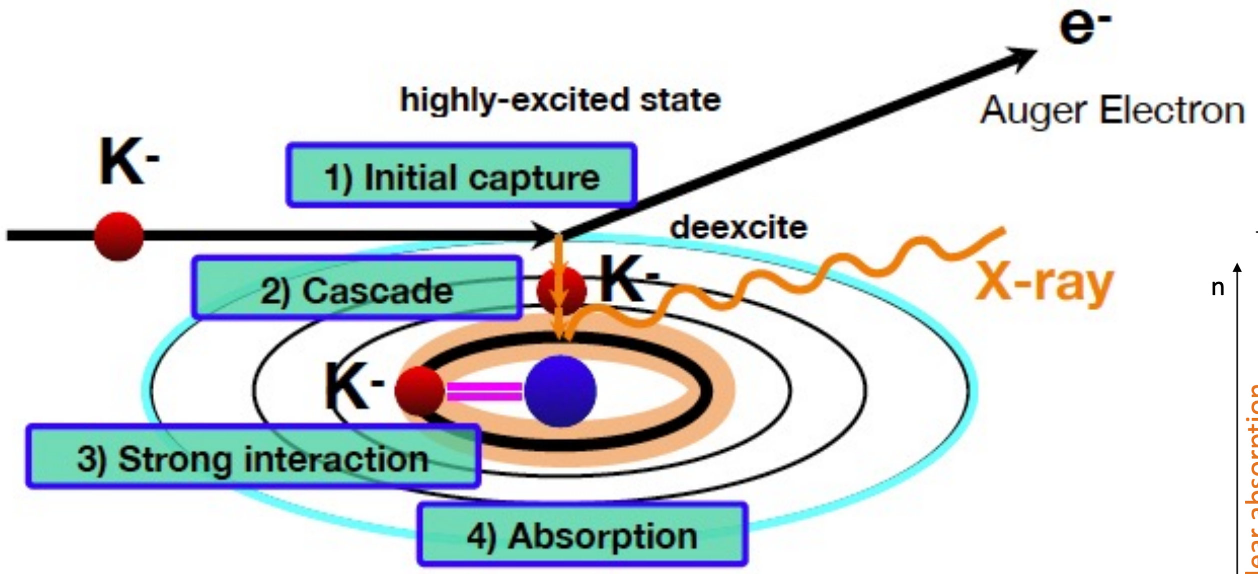
The equation of state of dense matter: Stiff, soft, or both? Astron.Nachr. 340 (2019) 1-3, 189

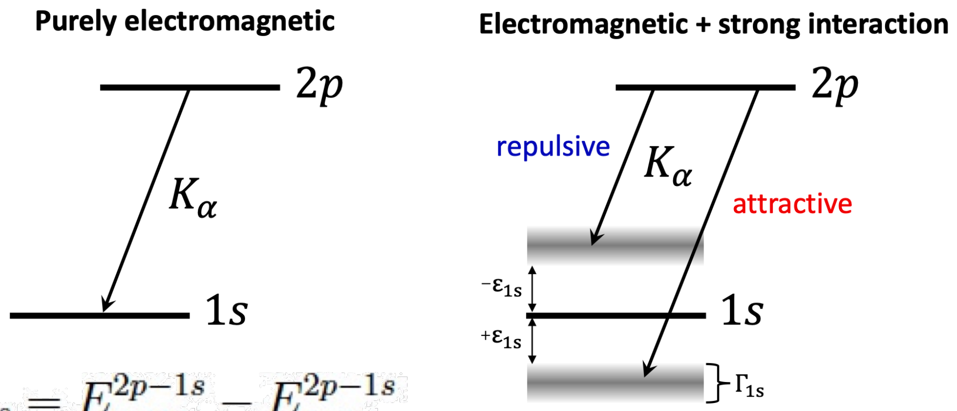
Part. and Nuclear physics
QCD @ low-energy limit
Chiral symmetry, Lattice

Astrophysics
EOS Neutron Stars

Kaonic Atoms X-ray Spectroscopy

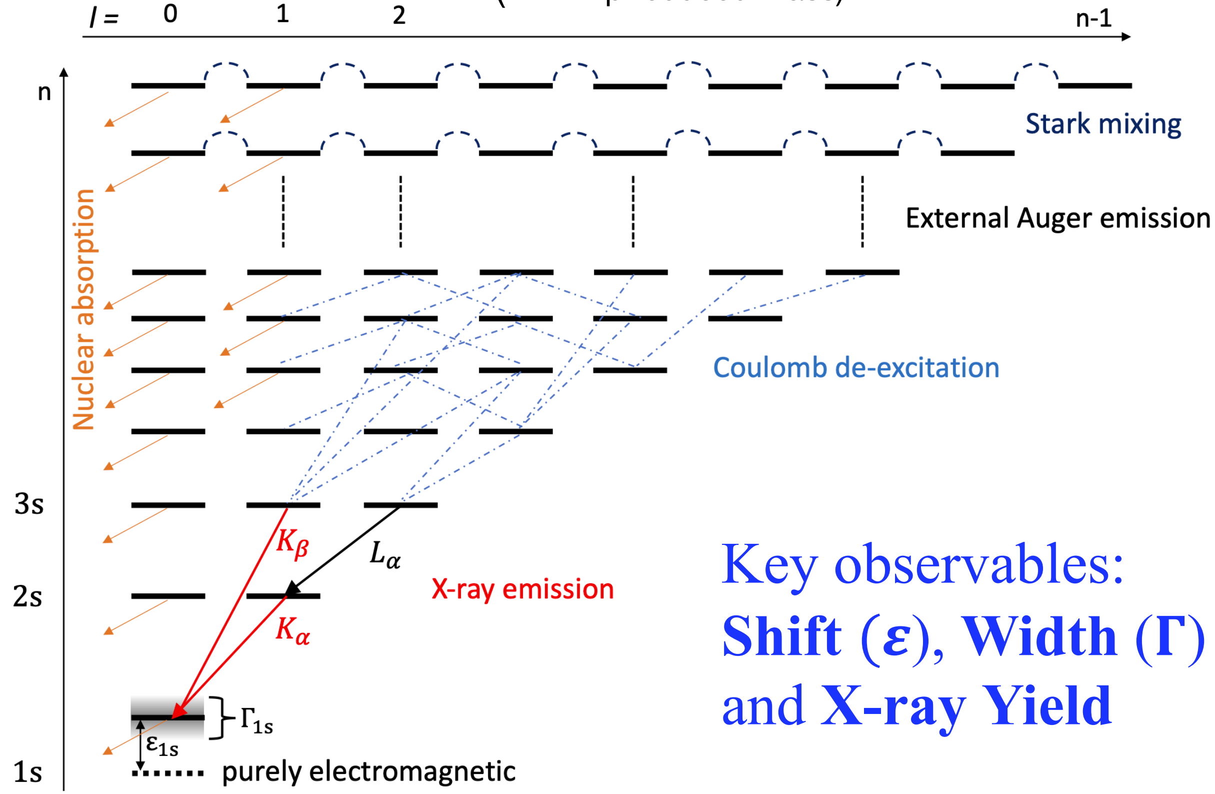
Kaonic atom formation





$$\varepsilon_{1s} = E^{2p-1s}_{\text{meas}} - E^{2p-1s}_{e.m.}$$

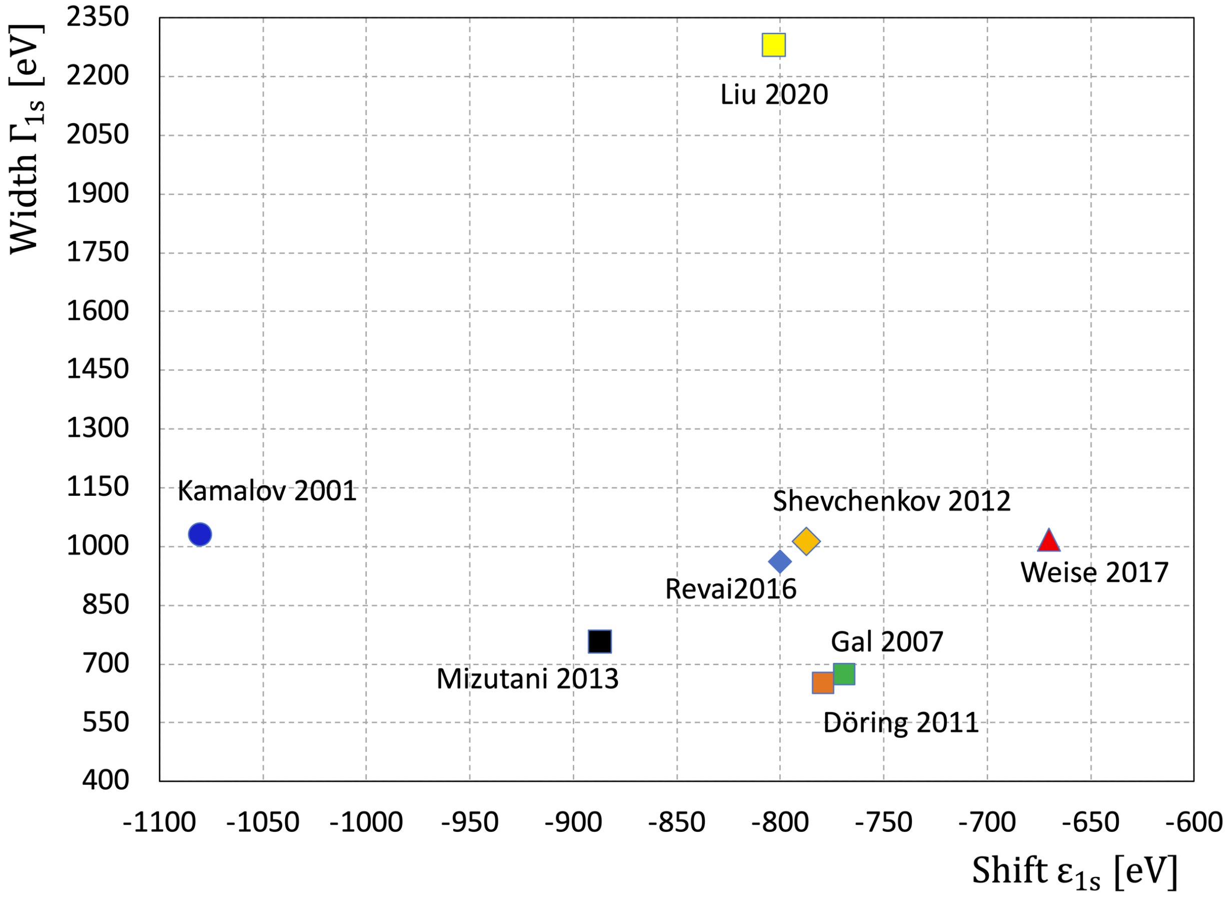
$n \sim sqrt(M^*/m_e)\, n' \sim 25$ (for K-p)
(M^* : K-p reduced mass)



Key observables:
Shift (ε), Width (Γ)
and **X-ray Yield**

The SIDDHARTA-2 Scientific goal

Scientific goal: *first measurement ever of kaonic deuterium X-ray transition to the ground state* (1s-level) such as to determine its shift and width induced by the presence of the strong interaction, providing unique data to investigate the QCD in the non-perturbative regime with strangeness.



Theoretical predictions for the kaonic deuterium 1s level shift and width

Reference	ε_{1s} (eV)	Γ_{1s} (eV)
Kamalov *et al.* (2001) [55]	-1080	1030
Gal (2007) [56]	-769	674
Döring *et al.* (2011) [57]	-779	650
Shevchenkov (2012) [58]	-787	1011
Mizutani *et al.* (2013) [59]	-887	757
Revai (2016) [60]	-800	960
Weise *et al.* (2017) [61]	-670	1016
Liu *et al.* (2020) [62]	-803	2280

The low X-rays yield has, until now, prevented the observation of 1s level transitions in kaonic deuterium.

The SIDDHARTA-2 Scientific goal

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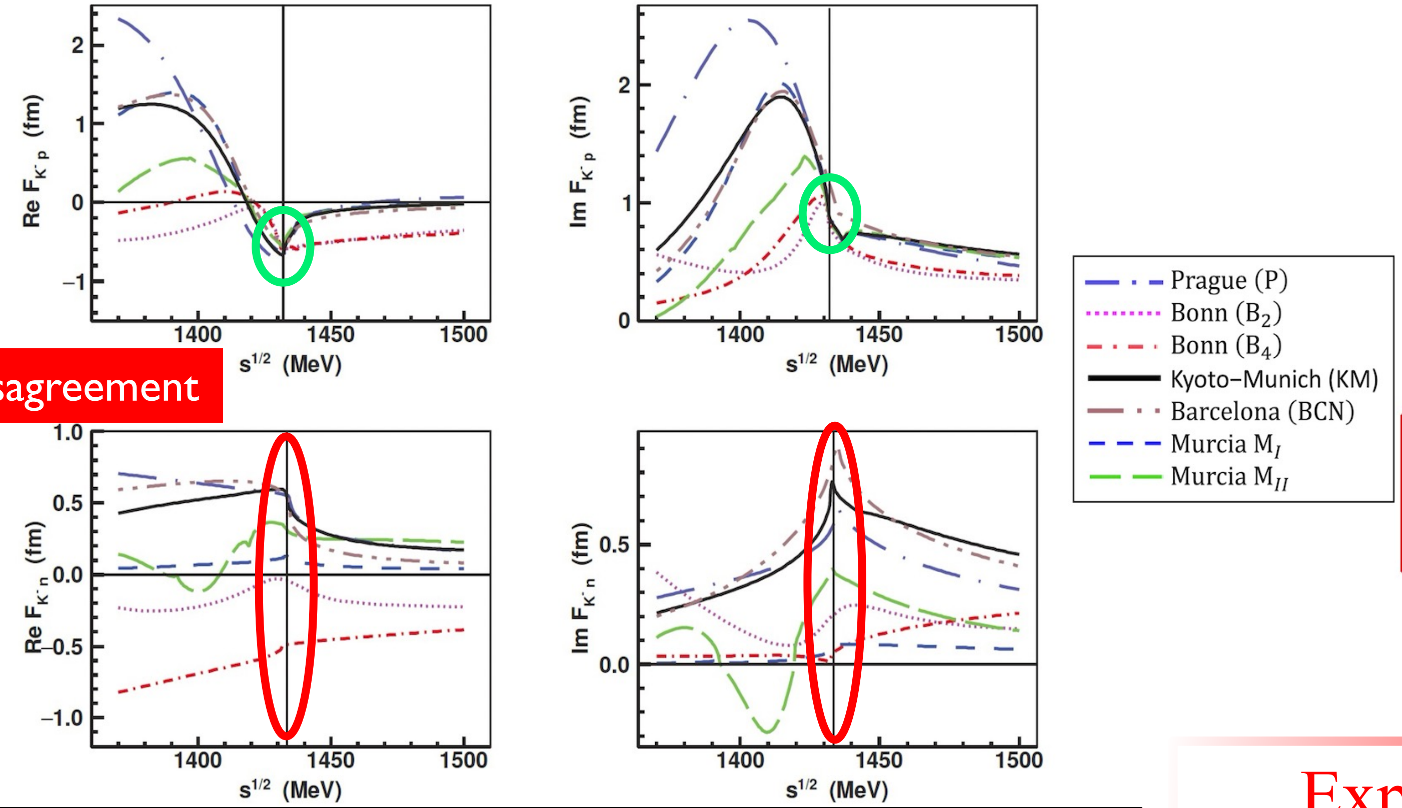
K-p: agreement → Kaonic Hydrogen

K-n: disagreement



Ciepl y, A. et al. From KN interactions to K-nuclear quasi-bound states. AIP Conf. Proc. 2249, 030014 (2020).

Combined analysis of the kaonic deuterium and kaonic hydrogen measurements

$$\varepsilon_{1s} - \frac{i}{2}\Gamma_{1s} = -2\alpha^3 \mu_c^2 a_{K^-p}\left(1 - 2\alpha\mu_c(\ln\alpha - 1)a_{K^-p}\right)$$

(μ_c reduced mass of the K^-p system, α fine-structure constant)

U.-G. Meißner, U.Raha, A.Rusetsky, Eur. phys. J. C35 (2004) 349
next-to-leading order, including isospin breaking

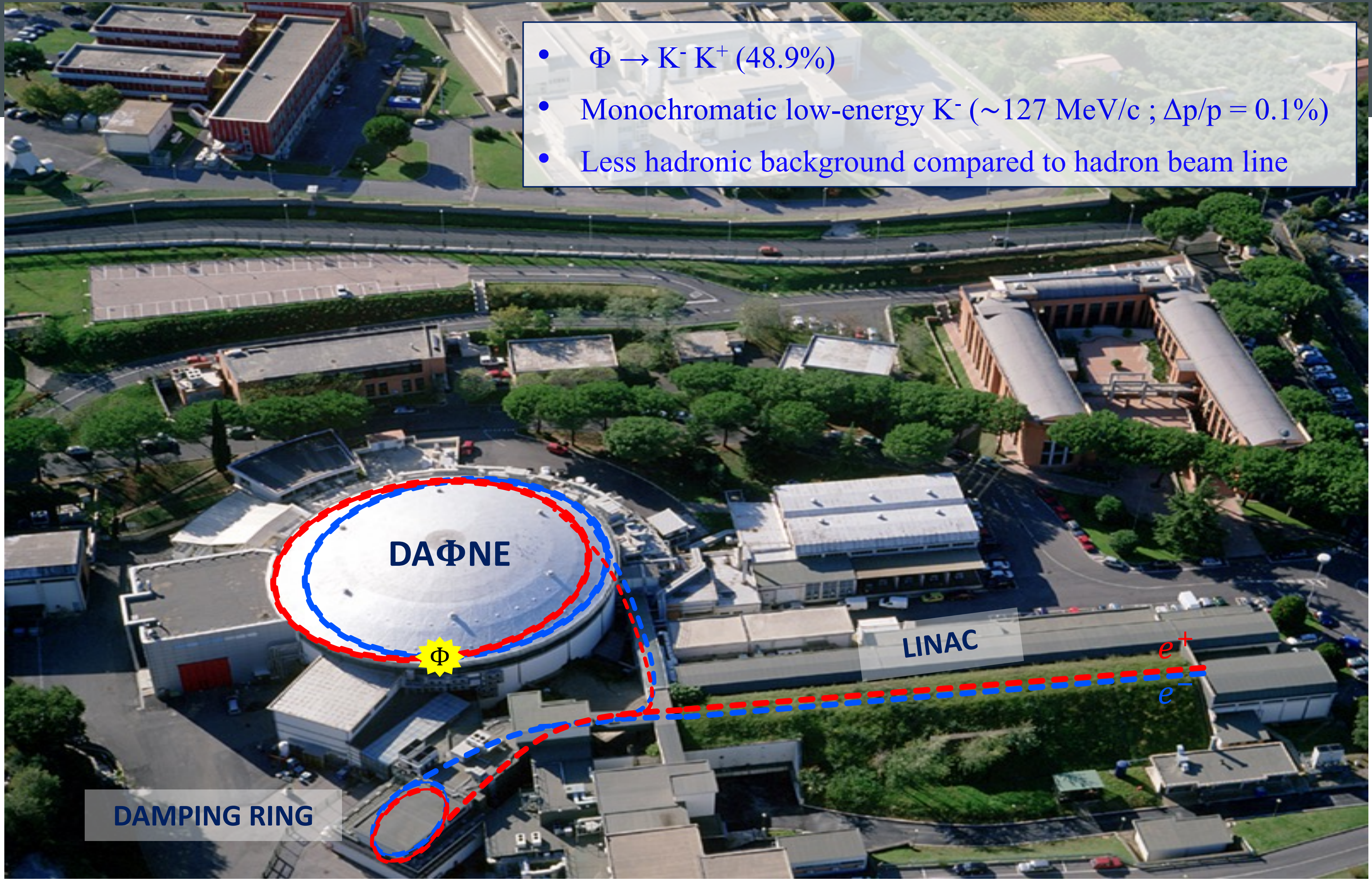
$$a_{K^-p} = \frac{1}{2}[a_0 + a_1]$$
$$a_{K^-n} = a_1$$

$$a_{K^-d} = \frac{k}{2}[a_{K^-p} + a_{K^-n}] + C = \frac{k}{4}[a_0 + 3a_1] + C$$
$$k = \frac{4[m_n + m_K]}{[2m_n + m_K]}$$

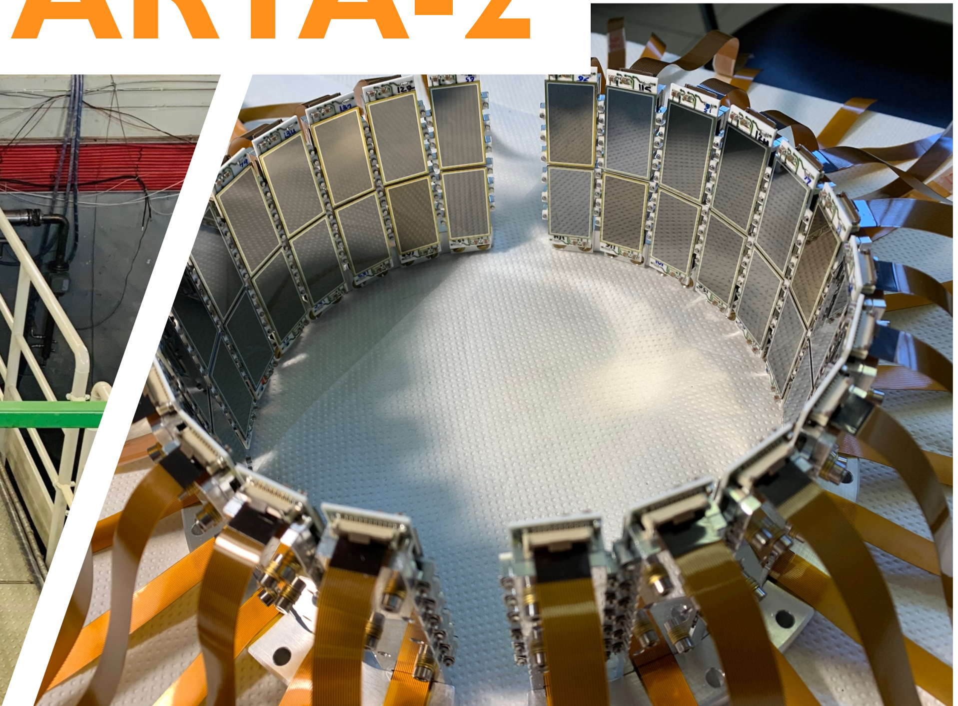
Experimental determination of the Isospin-dependent K-N scattering length

The DAΦNE collider of INFN-LNF

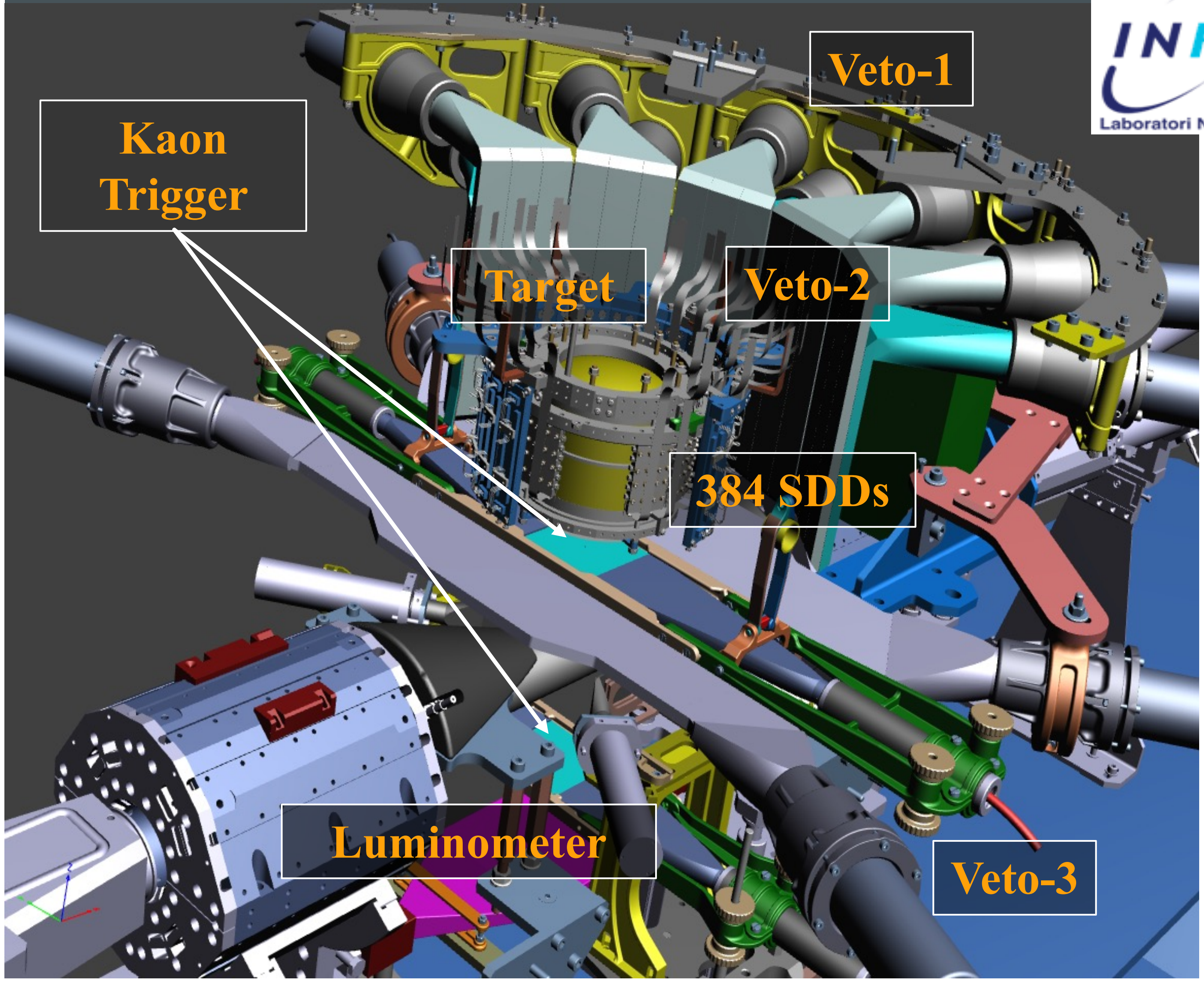
- $\Phi \rightarrow K^- K^+$ (48.9%)
- Monochromatic low-energy K^- (~127 MeV/c ; $\Delta p/p = 0.1\%$)
- Less hadronic background compared to hadron beam line



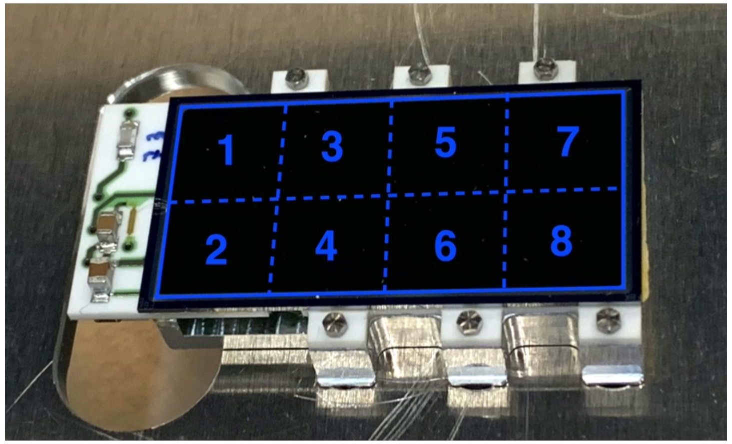
SIDDHARTA-2



The SIDDHARTA-2 setup and DAΦNE collider

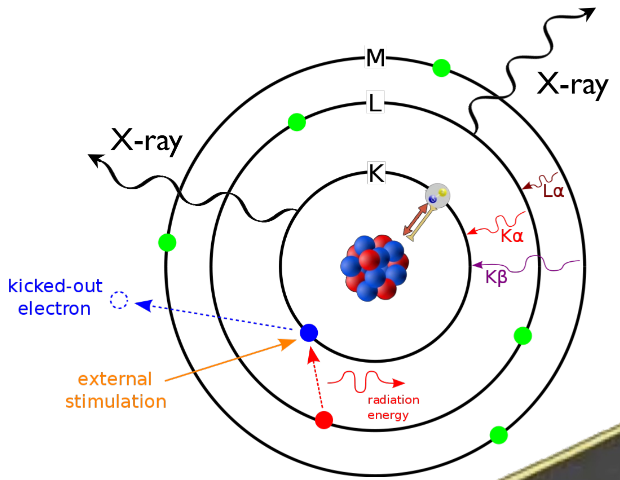


48 Silicon Drift Detector arrays with 8 SDD units (0.64 cm²)
for a total active area of 246 cm²
The thickness of 450 μm ensures a high collection efficiency for X-rays of energy between 5 keV and 12 keV



First kaonic deuterium measurement (2023 -2024)

THE ROAD TO THE FIRST KAONIC DEUTERIUM MEASUREMENT



Kaonic Neon (2023)

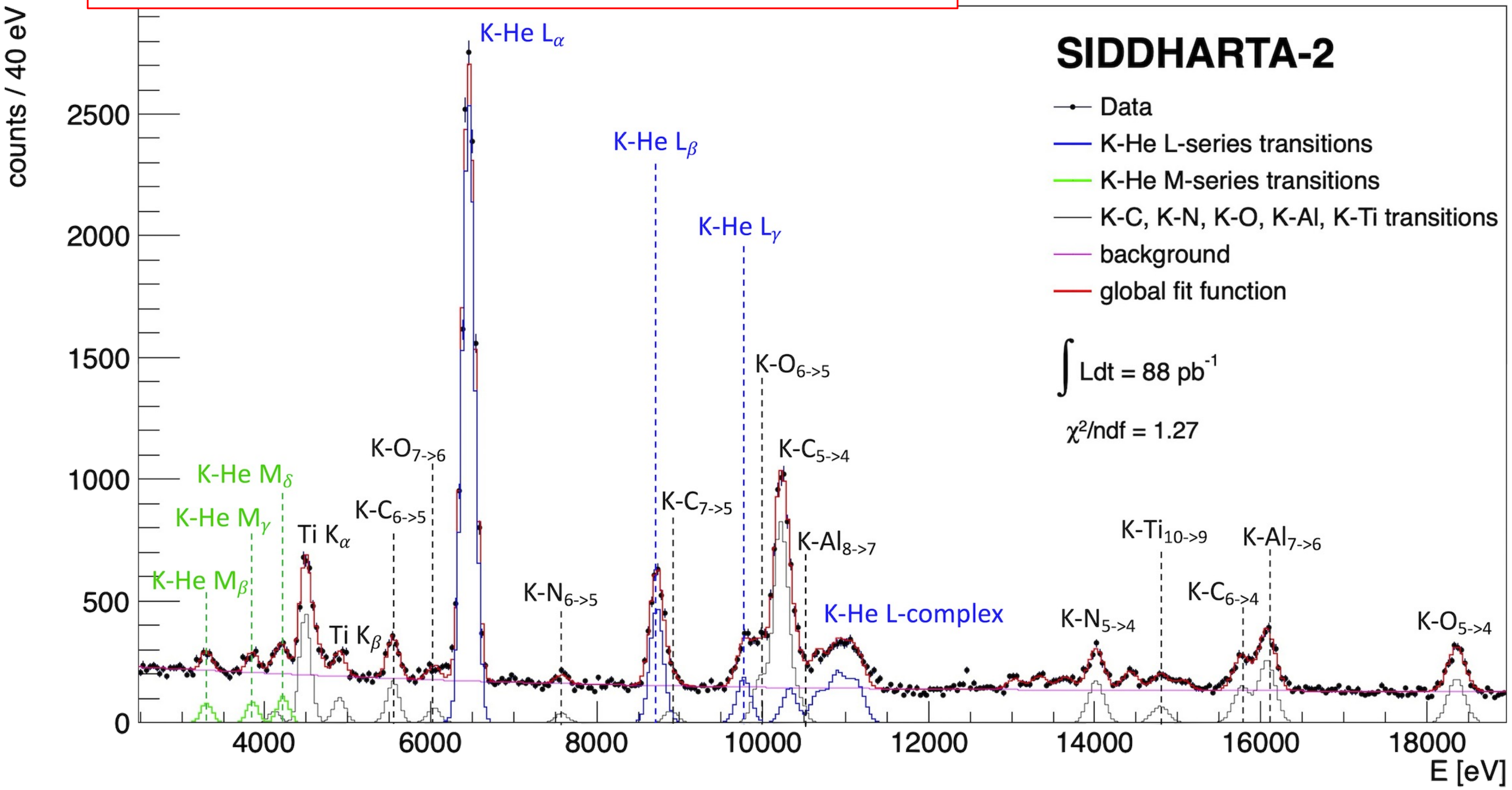
Kaonic Helium-4 (2021-2022)

The Kaonic ^{4}He measurement (2021-2022)

- Most precise measurement of kaonic helium-4 Lα in gas: 2p level energy shift and width
- First observation of kaonic helium-4 M-series transition (n→3d)
- First Measurement of high-n transition in kaonic carbon – nitrogen – oxygen and aluminium

$$\varepsilon_{2p} = E^{exp}_{3d\to 2p} - E^{e.m}_{3d\to 2p} = -1.9 \pm 0.8\,(stat) \pm 2.0\,(sys)\ eV$$
$$\Gamma_{2p} = 0.01 \pm 1.60\,(stat) \pm 0.36\,(sys)\ eV$$

→ *no sharp effect of the strong interaction on the 2p level*



new data to enrich the kaonic atoms transitions database

Transition	Energy [eV]
K^-C (6→5)	5546.0 ± 5.4 (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)	6014.8 ± 8.4 (stat) ± 2.0 (syst)
K^-O (6→5)	9965.1 ± 6.9 (stat) ± 2.0 (syst)
K^-O (5→4)	18361.1 ± 5.4 (stat) ± 12.0 (syst)
K^-N (6→5)	7581.1 ± 16.0 (stat) ± 2.0 (syst)
K^-N (5→4)	14008.0 ± 6.0 (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)
K^-Ti (10→9)	14790.3 ± 16.6 (stat) ± 9.0 (syst)

Sgaramella F., et al., 2023, Eur. Phys. J. A, 59 (3) 56

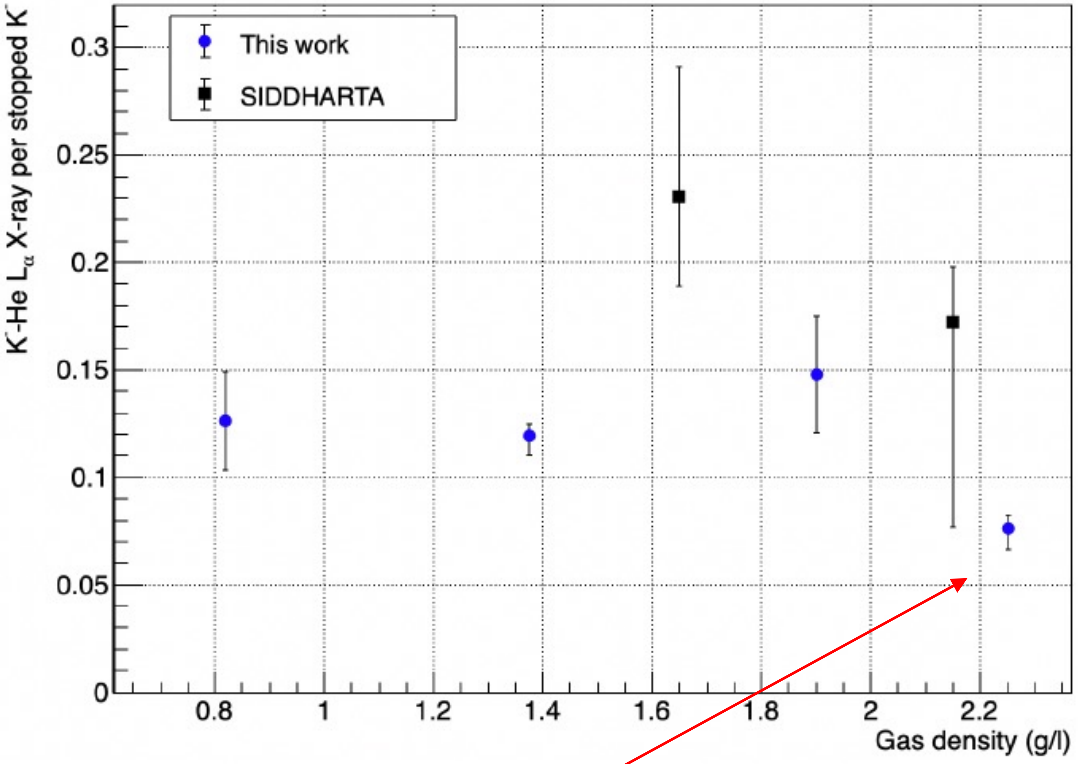
The Kaonic ^{4}He X-ray Yield (2021-2022)

New experimental data for cascade models calculations
The X-ray yield is the key observable to understand the de-excitation mechanism in kaonic atoms and develop more accurate models.

First measurement of K-^{4}He M-series transition

Study of yield density dependence for the K-^{4}He $L\alpha$ transition

Density	1.37 ± 0.07 g/l
L_α yield	$0.119 \pm 0.002\,(\text{stat})^{+0.006\,(\text{syst})}_{-0.009\,(\text{syst})}$
M_β yield	$0.026 \pm 0.003\,(\text{stat})^{+0.010\,(\text{syst})}_{-0.001\,(\text{syst})}$
L_β / L_α	0.172 ± 0.008 (stat)
L_γ / L_α	0.012 ± 0.001 (stat)
M_β / L_α	0.218 ± 0.029 (stat)
M_γ / M_β	0.48 ± 0.11 (stat)
M_δ / M_β	0.43 ± 0.12 (stat)



First observation of the stark effect in kaonic helium-4

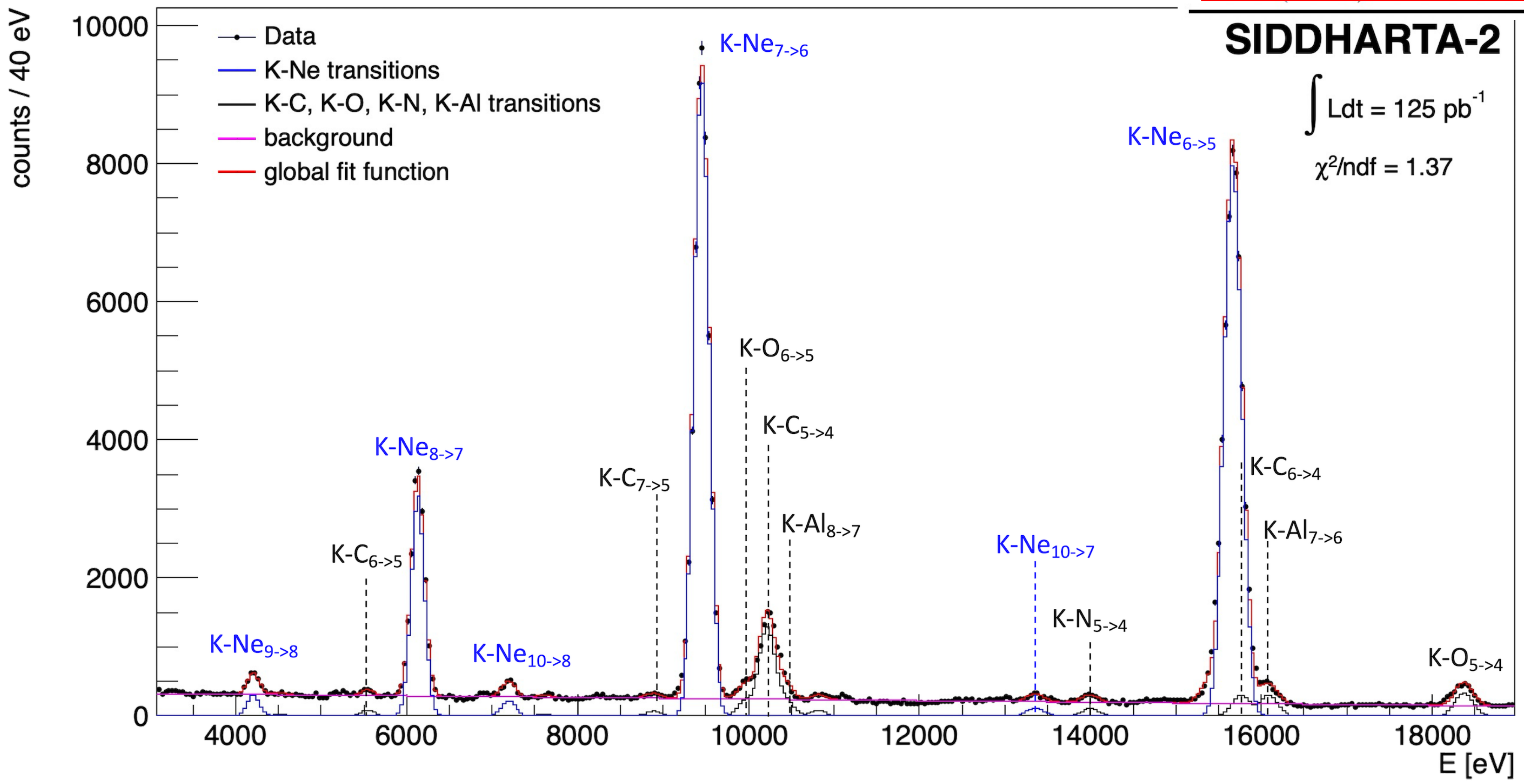
Sgaramella F., et al, 2024, *J. Phys. G: Nucl. Part. Phys.* 51 055103

Sirghi D.L., Shi H., Guaraldo C., Sgaramella F., et al., 2023, Nucl. Phys. A,1029 122567

The Kaonic Neon measurement (2023)

First measurement of kaonic neon X-ray transitions (sub eV statistical accuracy)

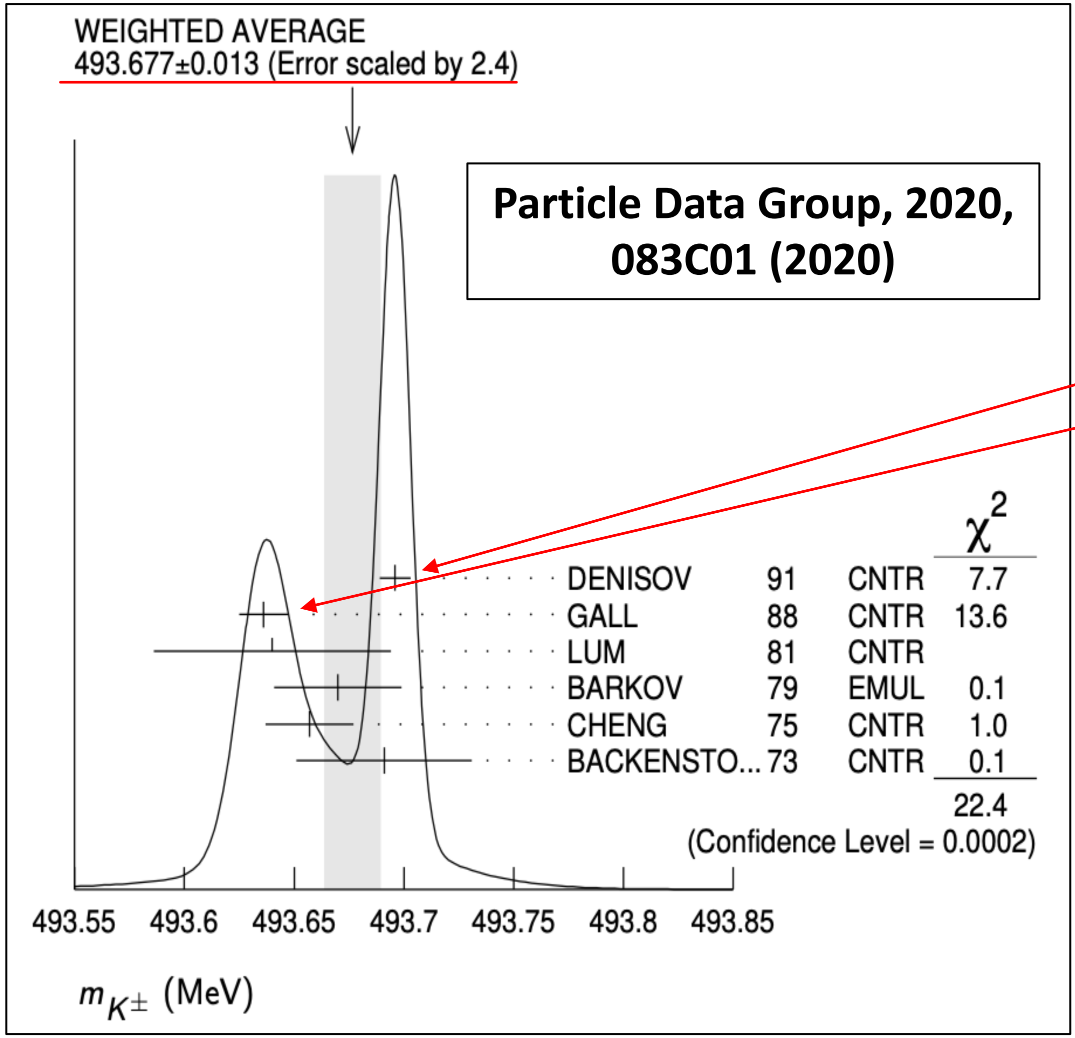
Transition	Energy [eV]
K-Ne ($9 \rightarrow 8$)	4206.35 ± 3.75 (stat) ± 2.00 (syst) eV
K-Ne ($8 \rightarrow 7$)	6130.86 ± 0.71 (stat) ± 1.50 (syst) eV
K-Ne ($10 \rightarrow 8$)	7191.21 ± 4.91 (stat) ± 2.00 (syst) eV
K-Ne ($7 \rightarrow 6$)	9450.08 ± 0.41 (stat) ± 1.50 (syst) eV
K-Ne ($10 \rightarrow 7$)	13352.20 ± 10.07 (stat) ± 3.00 (syst) eV
K-Ne ($6 \rightarrow 5$)	15673.30 ± 0.52 (stat) ± 9.00 (syst) eV



Article in preparation

The charged kaon mass puzzle

60 keV discrepancy between the two most accurate measurement



VALUE (MeV)	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
493.677±0.016 OUR FIT	Error includes scale factor of 2.8.				
493.677±0.013 OUR AVERAGE	Error includes scale factor of 2.4. See the ideogram below.				
493.696±0.007	[1] DENISOV	91	CNTR	−	Kaonic atoms
493.636±0.011	[2] GALL	88	CNTR	−	Kaonic atoms
493.640±0.054	LUM	81	CNTR	−	Kaonic atoms
493.670±0.029	BARKOV	79	EMUL	±	$e^+ e^- \to K^+ K^-$
493.657±0.020	[2] CHENG	75	CNTR	−	Kaonic atoms
493.691±0.040	BACKENSTO...	73	CNTR	−	Kaonic atoms

Large uncertainty → 26 p.p.m,

compared to charged pion:

$m_\pi = 139.57061 \pm 0.00023$ MeV, 1.6 p.p.m

The charged kaon mass puzzle

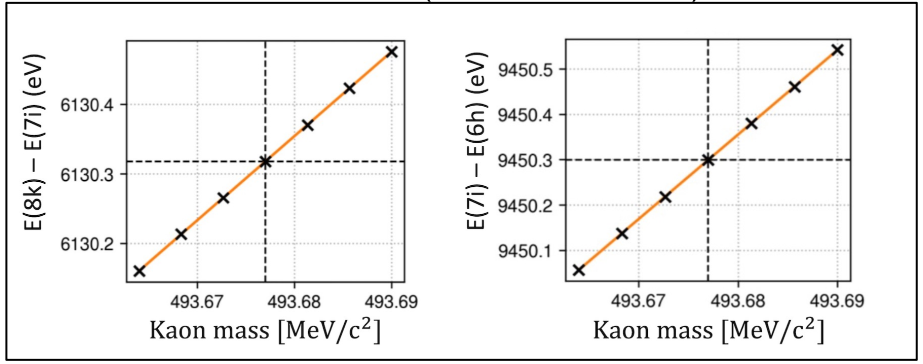
The measurement of kaonic neon high-n transitions can potentially solve the charged kaon mass puzzle

The kaonic Neon measurement to determine the K^- (K^+) mass

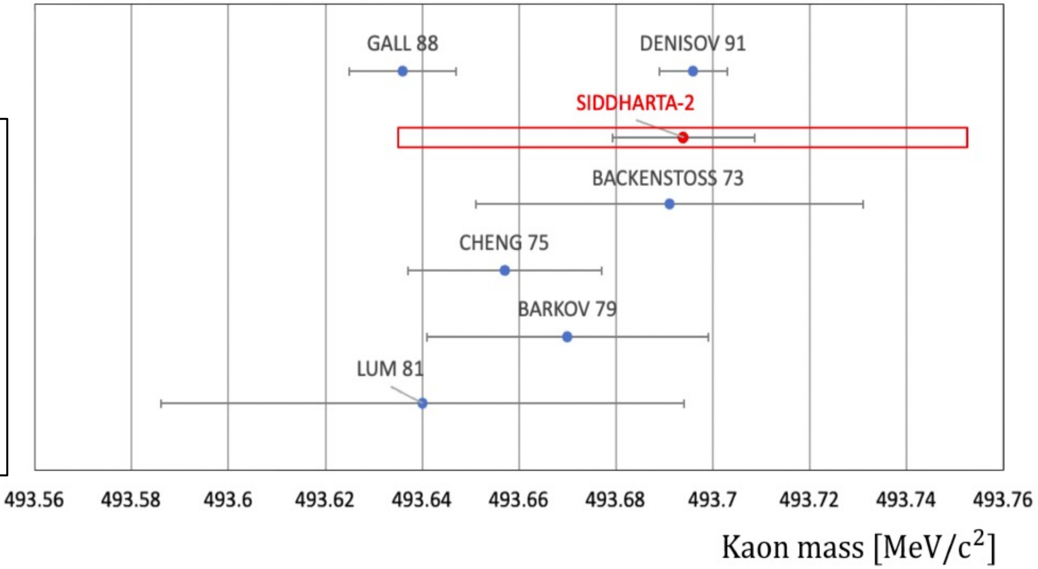
↓

Less/different systematic uncertainty with respect to DENISOV 91 and GALL 88 measurements, thanks to the use of a low Z gas target

Kaonic Ne energy transition as function of kaon mass (MCDFGME code)



Santos, J. & Parente, F. & Indelicato, Paul & Desclaux, J.. (2005). X-ray energies of circular transitions and electron screening in kaonic atoms. Physical Review A. 71.10.1103/PhysRevA.71.032501.



Measurement	Kaon mass [MeV]
DENISOV 91 [23]	493.696 ± 0.007
GALL 88 [22]	493.636 ± 0.011
LUM 81 [114]	493.640 ± 0.054
BARKOV 79 [115]	493.670 ± 0.029
CHENG 75 [116]	493.657 ± 0.020
BACKENSTOSS 73 [117]	493.691 ± 0.040
This work	493.694 ± 0.015 (stat) ± 0.060 (syst)

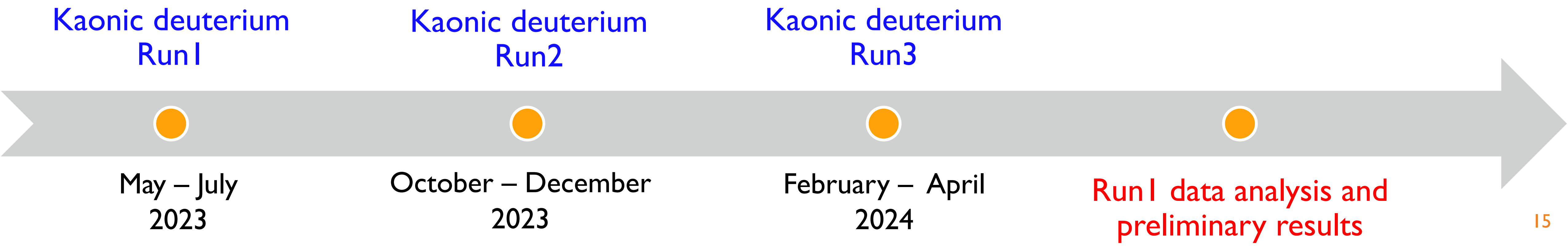
$$K - Ne(8 \to 7) = \frac{A_G}{\sqrt{2\pi}\sigma} \cdot e^{\frac{-(E-E_0)^2}{2\sigma^2}} \qquad E_0 = (m_{8\to7} \cdot K_{mass} + q_{8\to7})$$

$$K - Ne(7 \to 6) = \frac{A_G}{\sqrt{2\pi}\sigma} \cdot e^{\frac{-(E-E_0)^2}{2\sigma^2}} \qquad E_0 = (m_{7\to6} \cdot K_{mass} + q_{7\to6})$$

The first kaonic deuterium measurement (2023-2024)

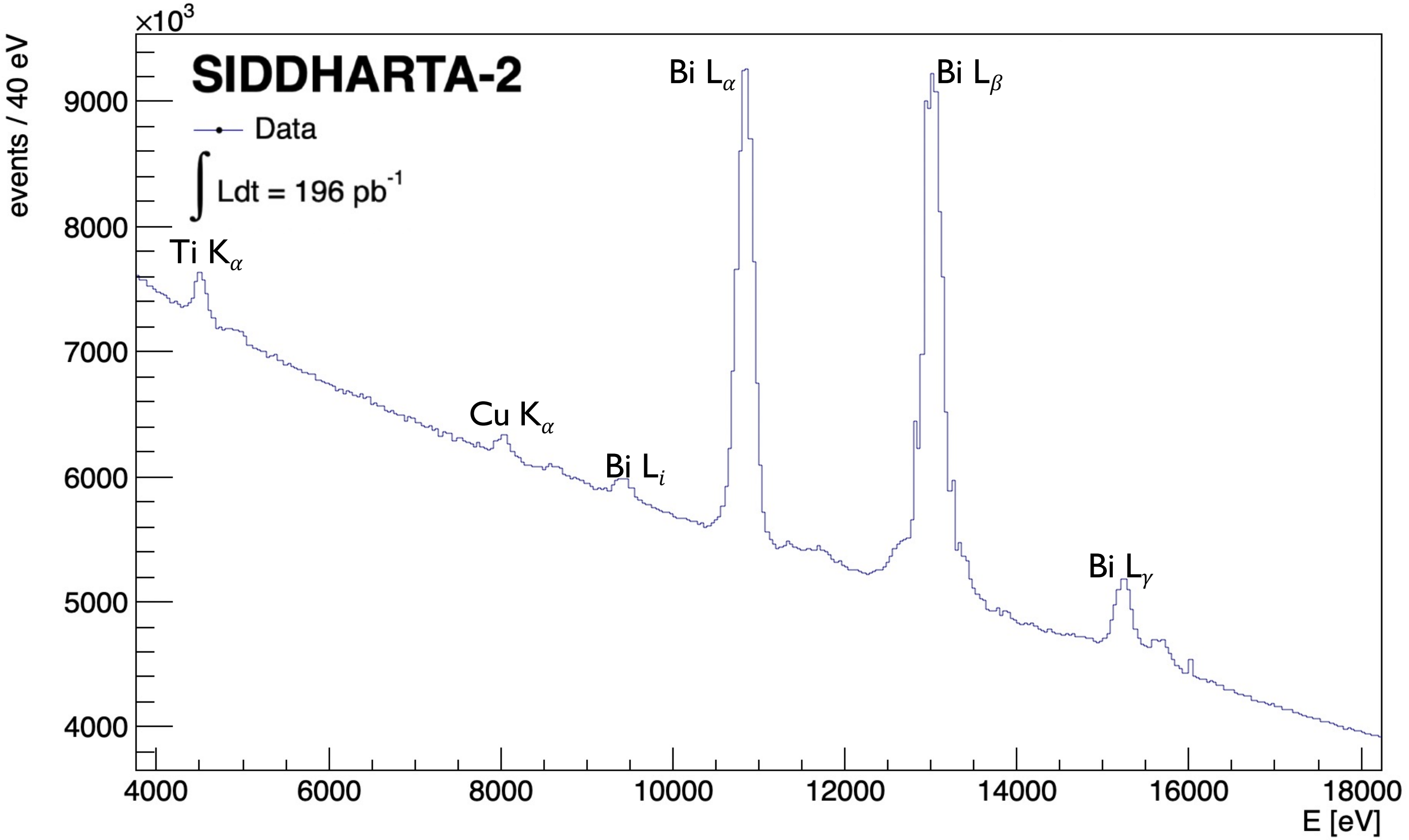
The SIDDHARTA-2 collaboration aims **to perform the first measurement of the strong interaction induced energy shift and width of the kaonic deuterium ground state with similar precision as K-p !**

- **First run** with SIDDHARTA-2 optimized setup for **200 pb^{-1}** integrated luminosity: May – July 2023
- **Second run** - October – December 2023: **344 pb^{-1}**
- **Third run** 2024 - February – April 2024: **435 pb^{-1}**



The first kaonic deuterium measurement

Inclusive energy spectrum: the continuous background and the fluorescence peaks are due to the electromagnetic (asynchronous) and hadronic (synchronous) background

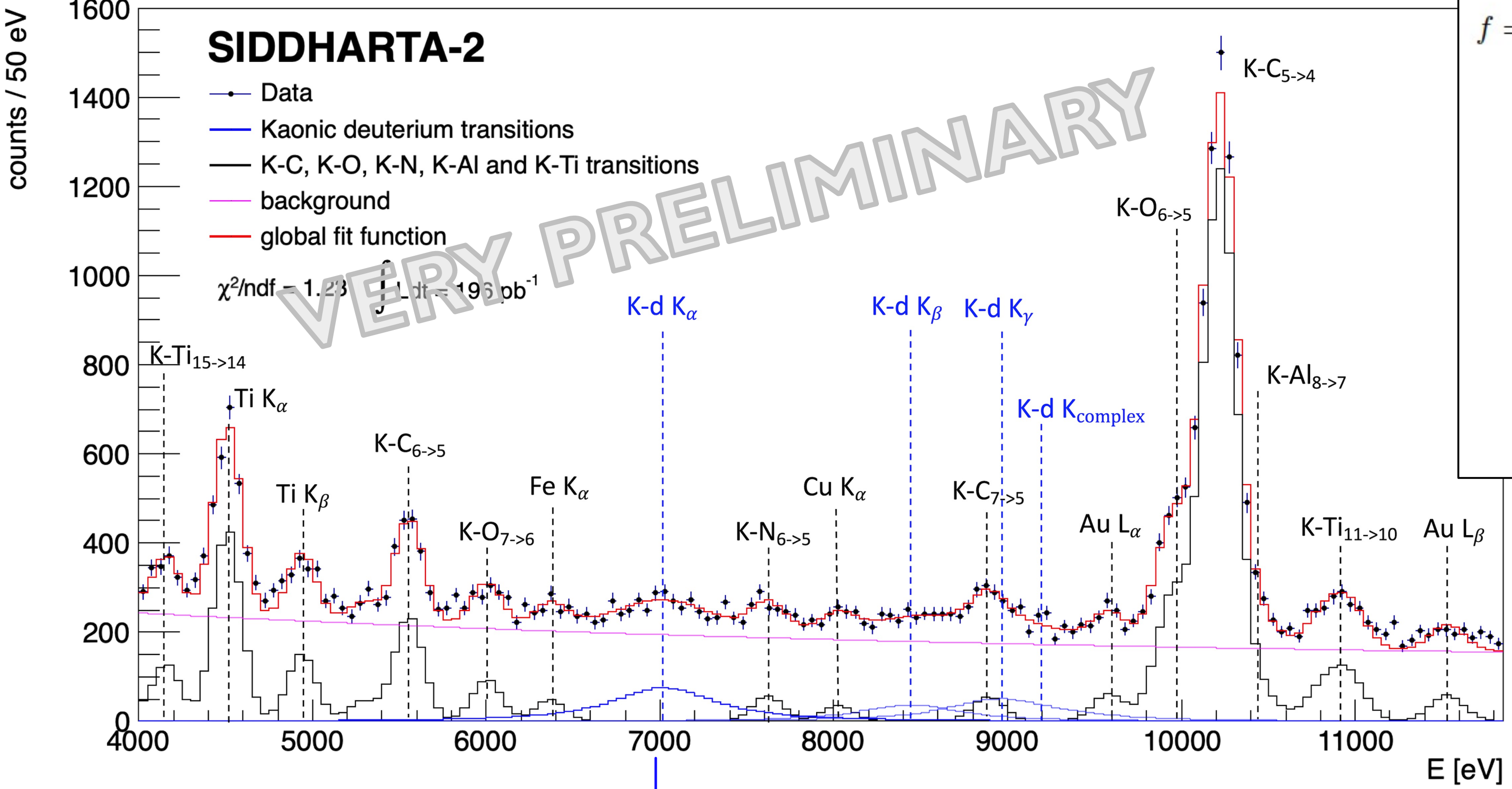


-Asynchronous background: the electromagnetic shower produced in the accelerator pipe (and other setup materials) invested by e-/e+ lost from the beam overlaps the signal; the loss rate in the interaction region reaches few MHz. The main contribution comes from Touschek effect. → Kaon Trigger and SDDs drift time

-Synchronous background, associated to kaon absorption on materials nuclei, or to other Φ decay channels. It can be considered a hadronic background.

-Spectra contamination by Xray fluorescence or by X-rays produced in higher transitions of other kaonic atoms, formed in the setup materials;
→ Veto systems

The first kaonic deuterium measurement



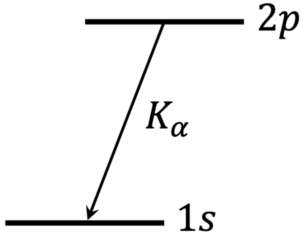
$$
\begin{aligned}
f = & \, pol_1(E) + \exp(E) + \sum_i \mathrm{Gauss}(A_{Gi}, E_i, \sigma) + \mathrm{Tail}(A_{Ti}, E_i, \beta, \sigma) + \\
& A_{\mathrm{Kd}_{2\to1}} \cdot \mathrm{Voigt}(E_{2\to1}, \sigma, \Gamma_{1s}) + \\
& A_{\mathrm{Kd}_{4\to1}} \cdot A_{rel_{3\to1}} \cdot \mathrm{Voigt}(E^{e.m.}_{3\to1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s}) + \\
& A_{\mathrm{Kd}_{4\to1}} \cdot \mathrm{Voigt}(E^{e.m.}_{4\to1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s}) + \\
& A_{\mathrm{Kd}_{4\to1}} \cdot A_{rel_{5\to1}} \cdot \mathrm{Voigt}(E^{e.m.}_{5\to1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s}) + \\
& A_{\mathrm{Kd}_{4\to1}} \cdot A_{rel_{6\to1}} \cdot \mathrm{Voigt}(E^{e.m.}_{6\to1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s}) + \\
& A_{\mathrm{Kd}_{4\to1}} \cdot A_{rel_{7\to1}} \cdot \mathrm{Voigt}(E^{e.m.}_{7\to1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s})
\end{aligned}
$$

$$
L(E) = \frac{1}{\pi} \frac{\frac{1}{2}\Gamma}{(E - E_0)^2 + \left(\frac{1}{2}\Gamma\right)^2}
$$

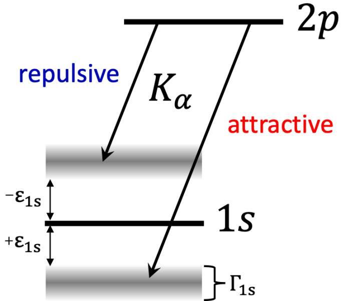
$$
\varepsilon_{1s} = E^{meas}_{2p\to1s} - E^{e.m.}_{2p\to1s} = -816 \pm 53 \text{ (stat)} \pm 2 \text{ (syst) eV}
$$

$$
\Gamma_{1s} = 756 \pm 271 \text{ (stat) eV}
$$

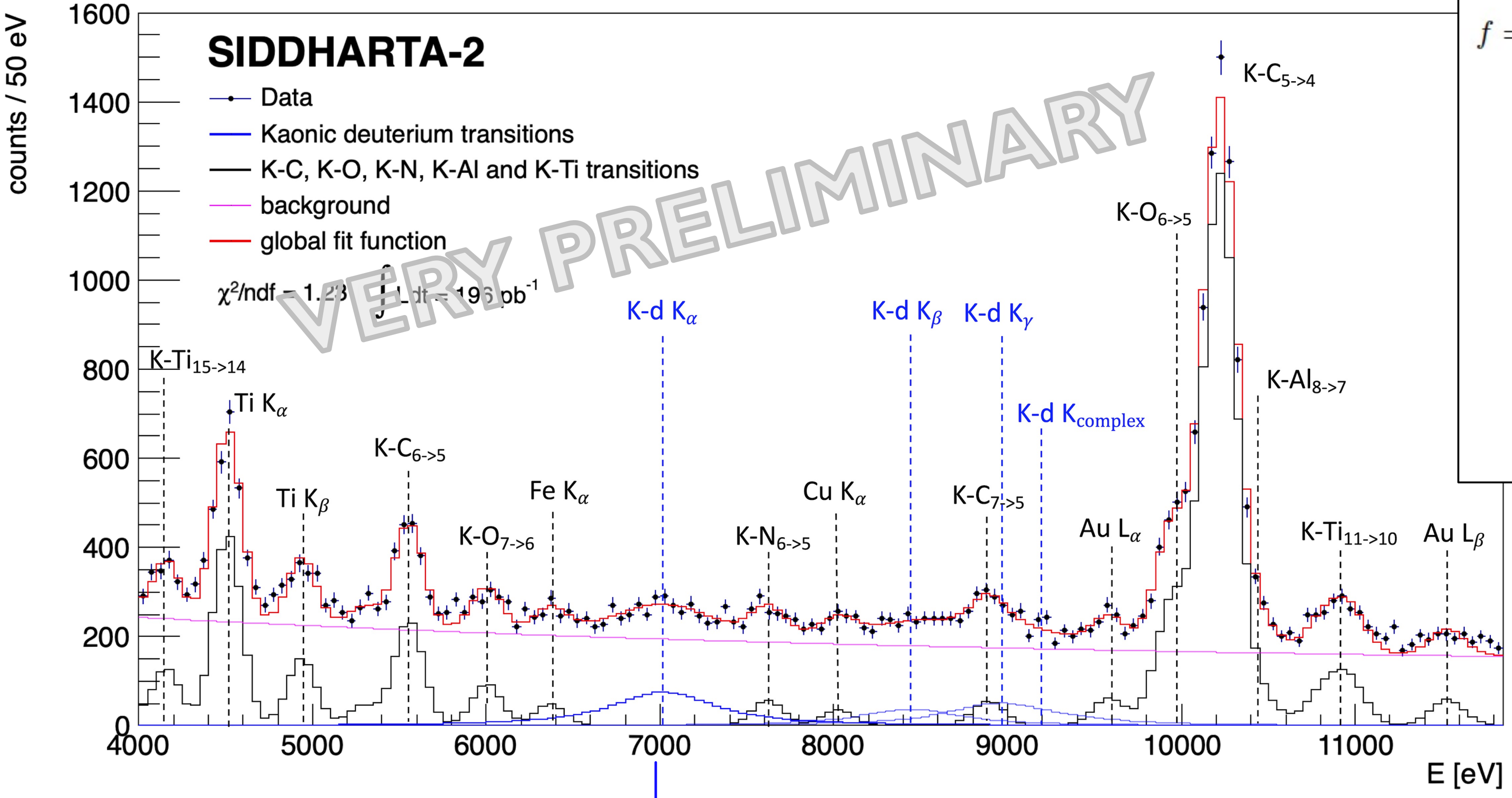
Purely electromagnetic



Electromagnetic + strong interaction



The first kaonic deuterium measurement



$$f = pol_1(E) + \exp(E) + \sum_i \mathrm{Gauss}(A_{Gi}, E_i, \sigma) + \mathrm{Tail}(A_{Ti}, E_i, \beta, \sigma) +$$
$$A_{\mathrm{Kd}_{2\to1}} \cdot \mathrm{Voigt}(E_{2\to1}, \sigma, \Gamma_{1s}) +$$
$$A_{\mathrm{Kd}_{4\to1}} \cdot A_{rel_{3\to1}} \cdot \mathrm{Voigt}(E^{e.m.}_{3\to1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s}) +$$
$$A_{\mathrm{Kd}_{4\to1}} \cdot \mathrm{Voigt}(E^{e.m.}_{4\to1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s}) +$$
$$A_{\mathrm{Kd}_{4\to1}} \cdot A_{rel_{5\to1}} \cdot \mathrm{Voigt}(E^{e.m.}_{5\to1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s}) +$$
$$A_{\mathrm{Kd}_{4\to1}} \cdot A_{rel_{6\to1}} \cdot \mathrm{Voigt}(E^{e.m.}_{6\to1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s}) +$$
$$A_{\mathrm{Kd}_{4\to1}} \cdot A_{rel_{7\to1}} \cdot \mathrm{Voigt}(E^{e.m.}_{7\to1} + \varepsilon^*_{1s}, \sigma, \Gamma^*_{1s})$$

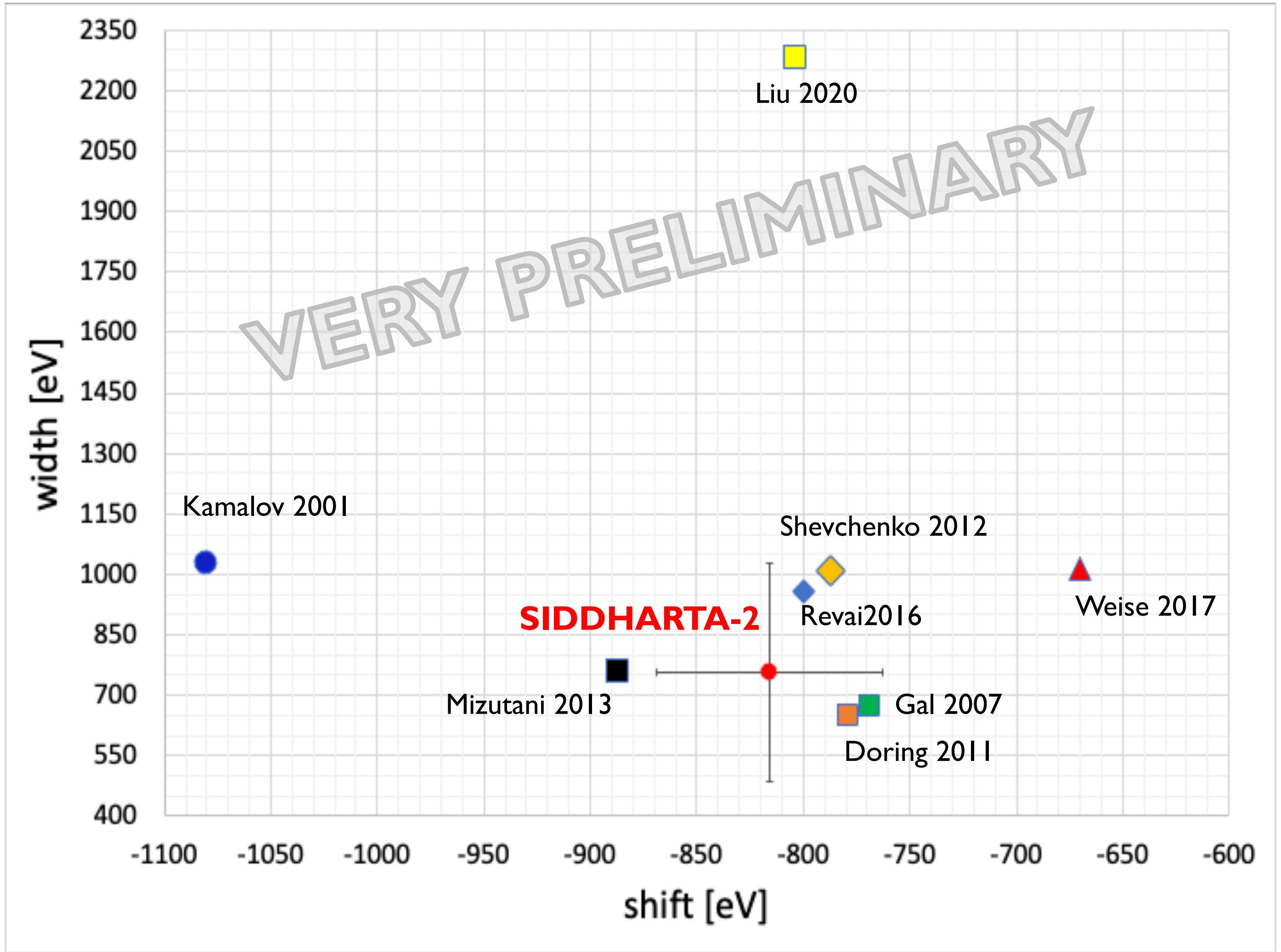
$$\varepsilon_{1s} = E^{meas}_{2p\to1s} - E^{e.m.}_{2p\to1s} = -816 \pm 53\ (\mathrm{stat}) \pm 2\ (\mathrm{syst})\ \mathrm{eV}$$
$$\Gamma_{1s} = 756 \pm 271\ (\mathrm{stat})\ \mathrm{eV}$$

"The **most important experiment to be carried out in low energy K-meson physics today** is the **definitive determination of the energy level shifts in the K−p and K−d atoms**, because of their direct connection with the physics of $\overline{\mathrm{K}}$N interaction and their complete independence from all other kinds of measurements which bear on this interaction".

R.H. Dalitz (1982)

Kaonic Deuterium Run1: preliminary result

Preliminary comparison between SIDDHARTA-2 Run1 result and the theoretical models



The analysis of the full dataset can potentially improve the statistical **accuracy by a factor 2**

(precision similar to kaonic hydrogen measurement)

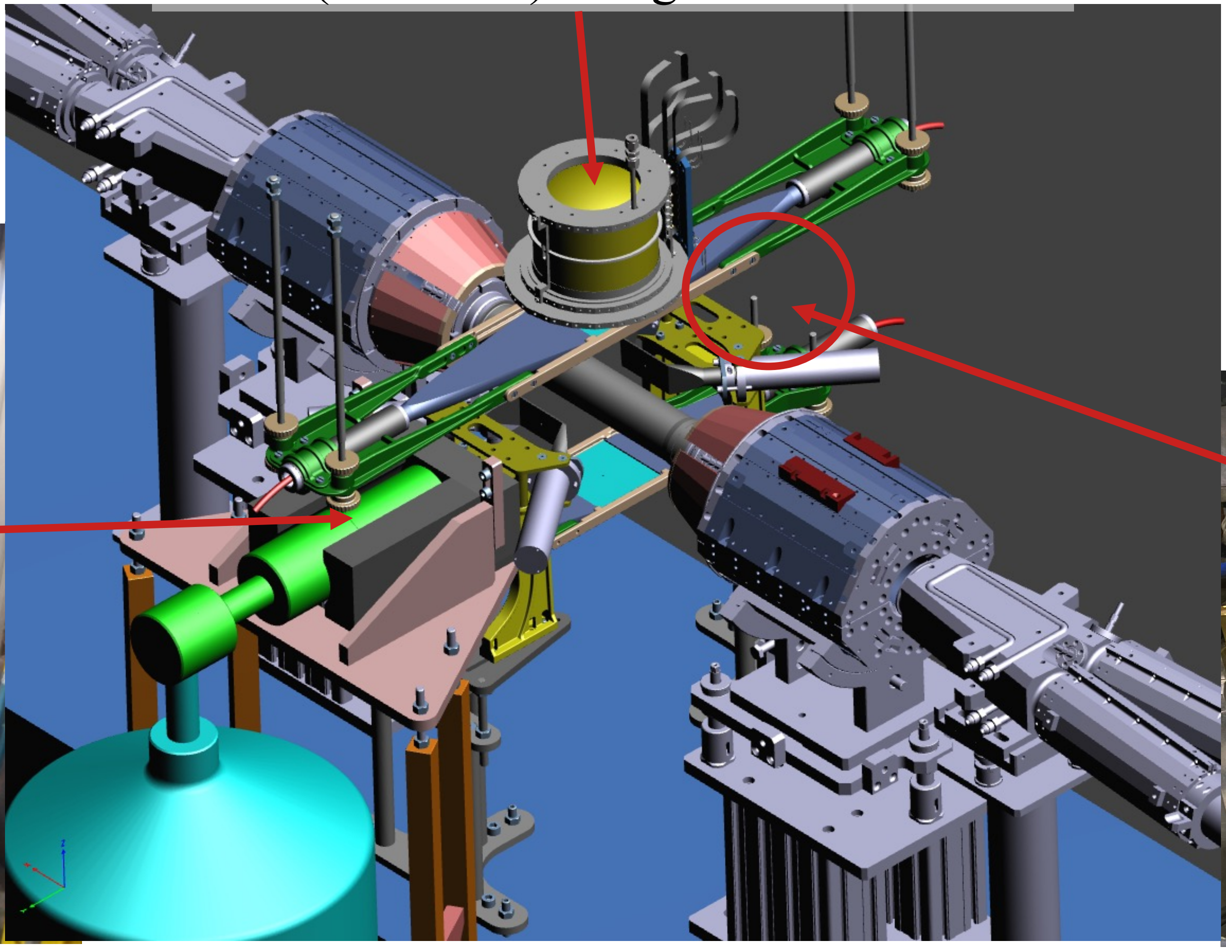
Exploiting DAΦNE

DAΦNE delivers almost 4π K^-

We want to exploit this unique beam as much as possible to perform important physics measurements

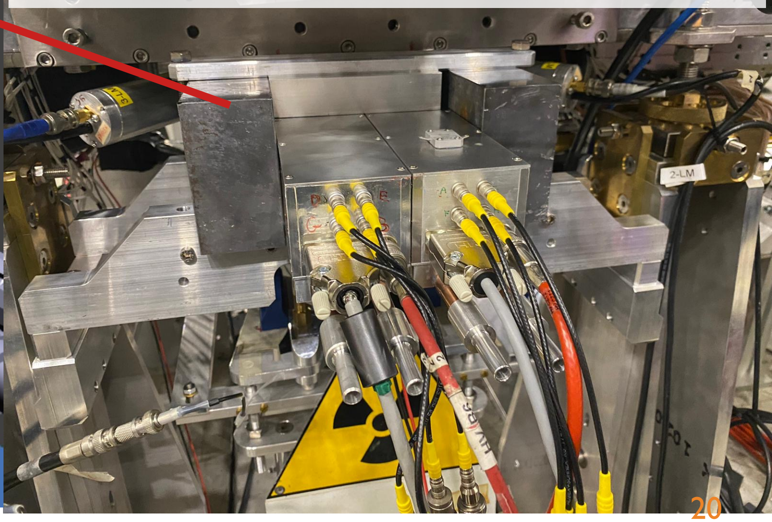
SDDs (4-15 keV) - Light Kaonic Atoms

HPGe
(0,1-1 MeV)
Heavy Kaonic Atoms



CdZnTe
(30-300 keV)
Intermediate Kaonic Atoms

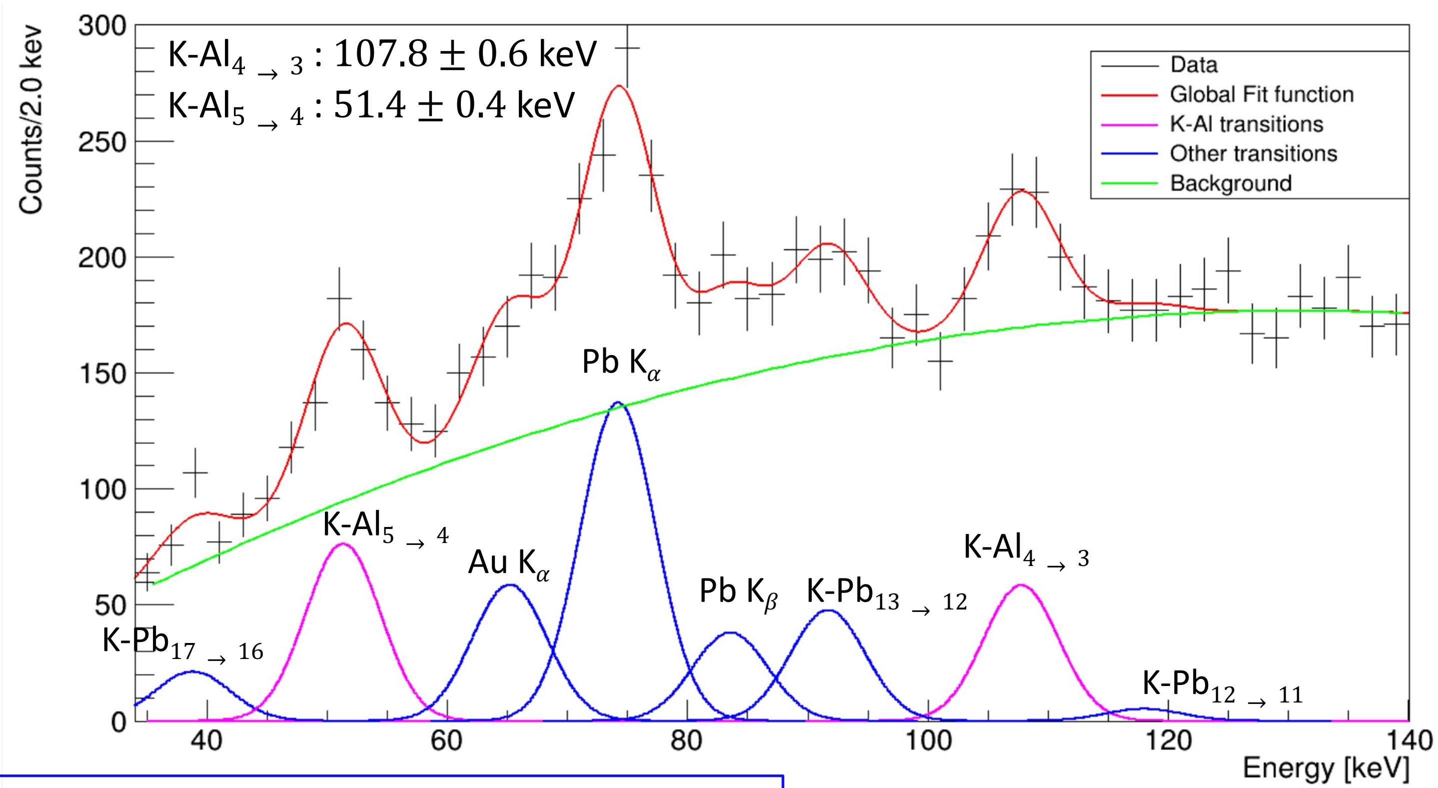
Two modules (8 CdZnTe) installed



CdZnTe detectors: test run with 8 detectors

8 cm^2 CdZnTe detectors to perform X-ray spectroscopy of kaonic aluminium in parallel with SIDDHARTA-2 kaonic deuterium run
(Advanced ultra-fast solid STate detectors for high precision RAdiation spectroscopy : ASTRA)

~ 60 pb^{-1} of data with a 2,2 mm Al target



- First kaonic atoms' spectrum measured with CZT detectors
- CZT proved to be the **perfect technology for intermediate mass kaonic atoms**, with very good "in-beam" performances during preliminary tests
- CdZnTe detectors can be easily used in parallel with already existing experiments, requiring very small space and not invasive electronics.

See A. Zappettini Talk
"CdZnTe-based radiation detectors, a breakthrough for hadron physics"

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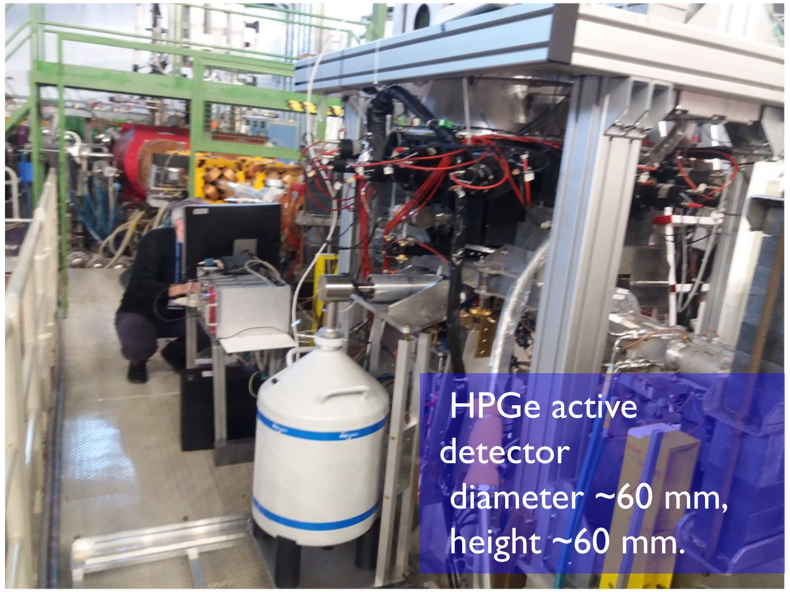
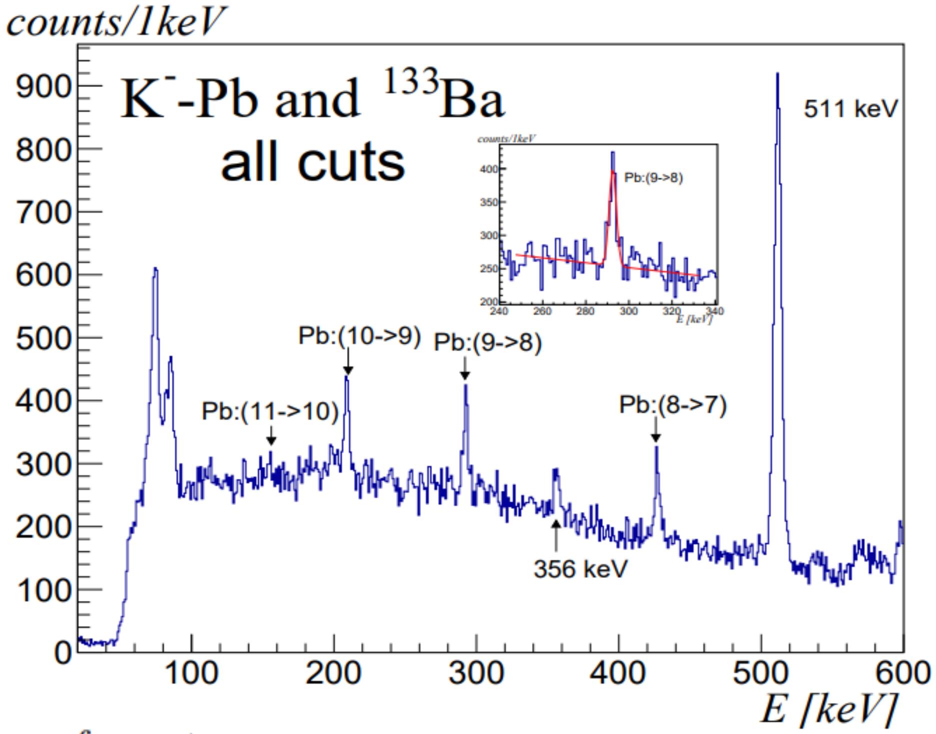
Kaonic Lead Measurement at DAΦNE with HPGe

Installed in the antiboost side of the IP to perform the kaonic lead measurement in parallel with the SIDDHARTA-2 kaonic deuterium measurement

Integrated luminosity: 109.38 pb^{-1}: subset of 40 pb^{-1} already analysed





K^--Pb transition	Peak position (keV)	Resolution (FWHM) (keV)	Number of events
$10 \to 9$	208.92 ± 0.17	3.68 ± 0.42	584 ± 30
$9 \to 8$	292.47 ± 0.17	3.97 ± 0.49	770 ± 65
$8 \to 7$	427.07 ± 0.24	4.37 ± 0.54	457 ± 45

Article submitted to Nuclear Instruments and Methods A preprint: arXiv:2405.12942

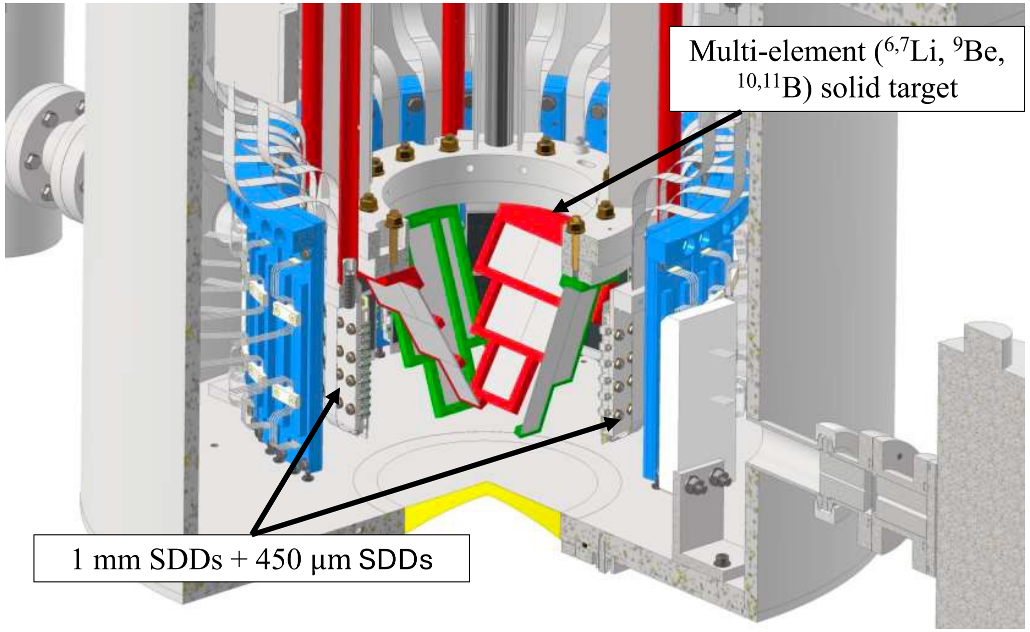
Beyond SIDDHARTA-2: EXKALIBUR

EXtensive **K**aonic **A**toms research: from **LI**thium and **B**eryllium to **UR**anium

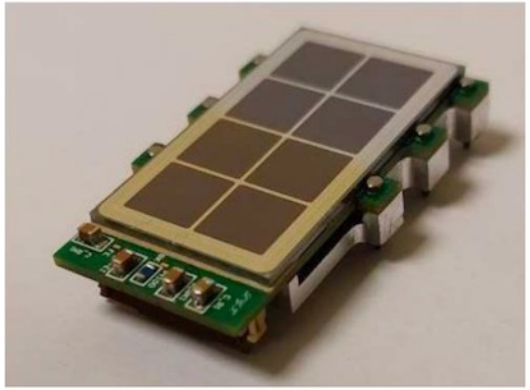
Precision measurements along the periodic table at DAΦNE for:

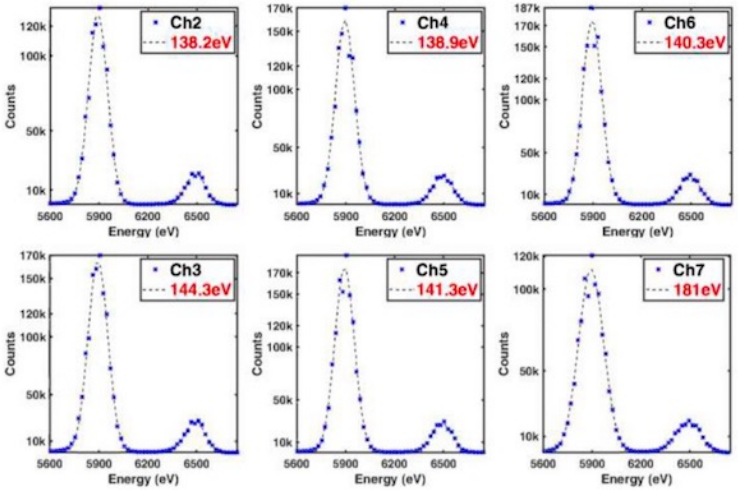
- Selected light kaonic atoms (LHKA) – Li, Be, B
- Selected intermediate and heavy kaonic atoms charting the periodic table (IMKA) – Al, C, O, S, Pb

Dedicated runs with different types of detectors: CZT detectors, HpGe, SDDs



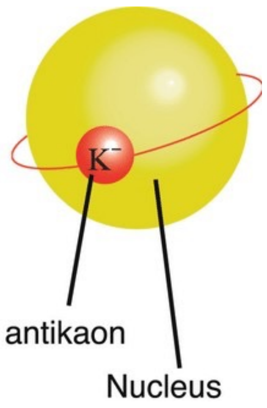
New 1mm thick SDDs have been developed to achieve a **Higher quantum efficiency needed to perform the measurement of**





EXKALIBUR

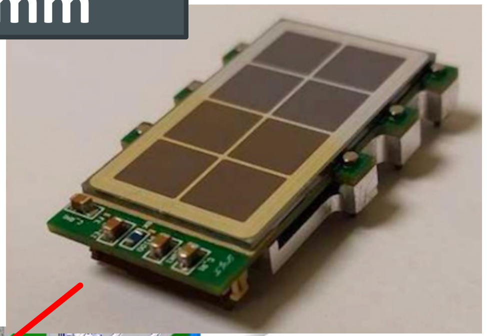
Proposal to perform fundamental physics at the strangeness frontier at DAΦNE (Italy) and JPARC (Japan)
Kaonic atoms data are the experimental basis for all the theoretical models used to derive:
KN, KNN interaction at threshold, Kaon mass, cascade models, possible existence of kaon condensates

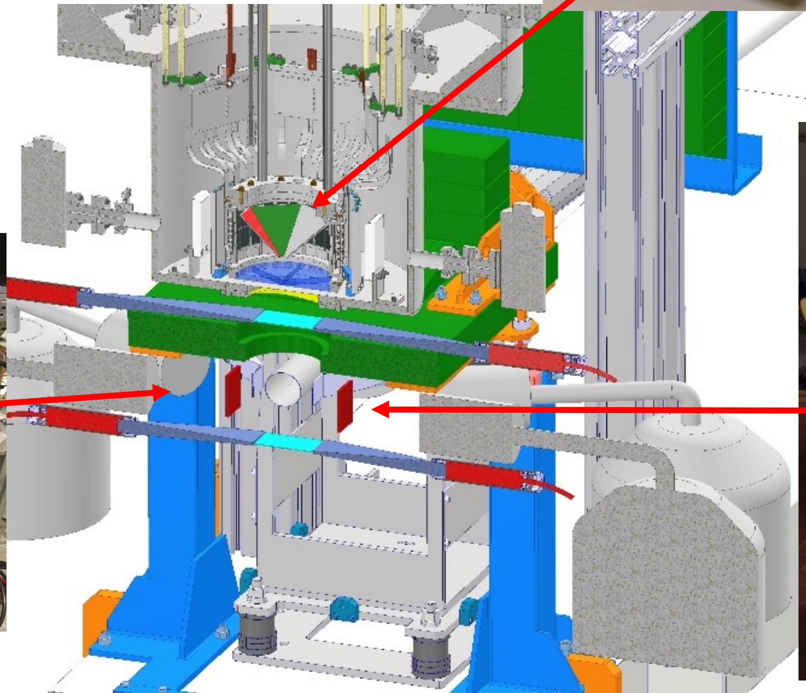


EXtensive
Kaonic
Atoms research: from
LIthium and
Beryllium to
URanium

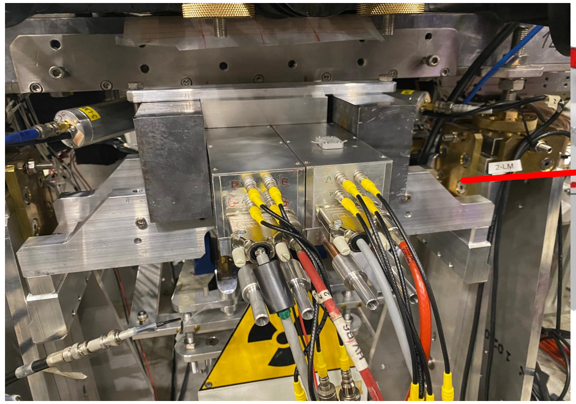
Kaonic atoms at DAΦNE collider: a strangeness adventure
C. Curceanu et al.,
doi.org/10.3389/fphy.2023.1240250

SDD 1mm

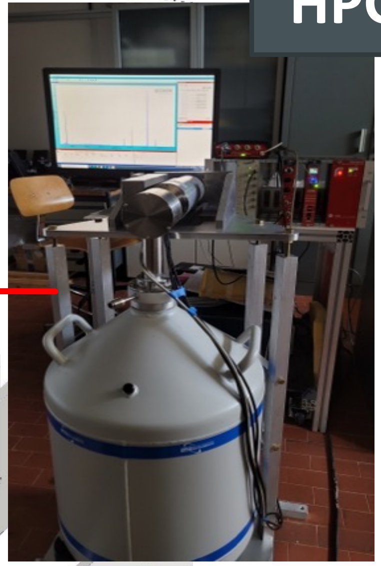




Cd(Zn)Te



HPGe

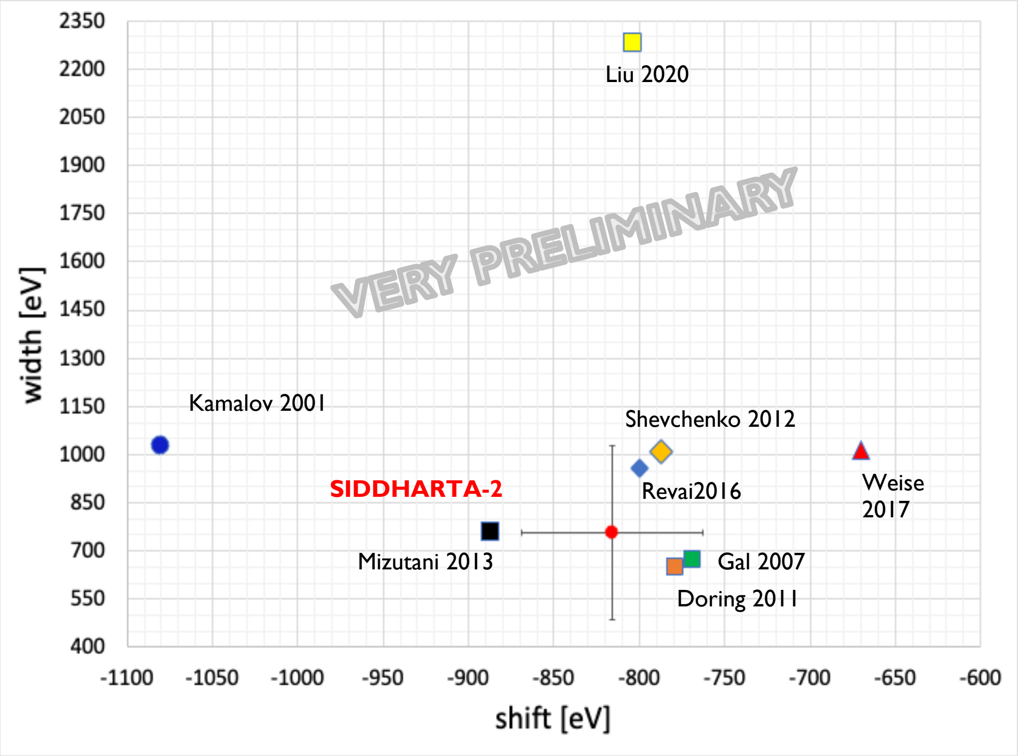


Conclusion

- **KHe L-transition measurement in gas :** J. Phys. G 49 (2022) 5, 055106
- **Kaonic helium-4 yields** L-lines in gas : Nucl. Phys. A 1029 (2023) 122567 - Nucl. Phys. A, (2023) 1029 122567
- First measurement of intermediate mass kaonic atoms: Eur. Phys. J. A 59(2023)3, 56
- **First Measurement of KHe M-lines** : J. Phys. G (2024) 51 055103
- **First Measurement of kaonic Neon** (stat. precision < 1 eV)

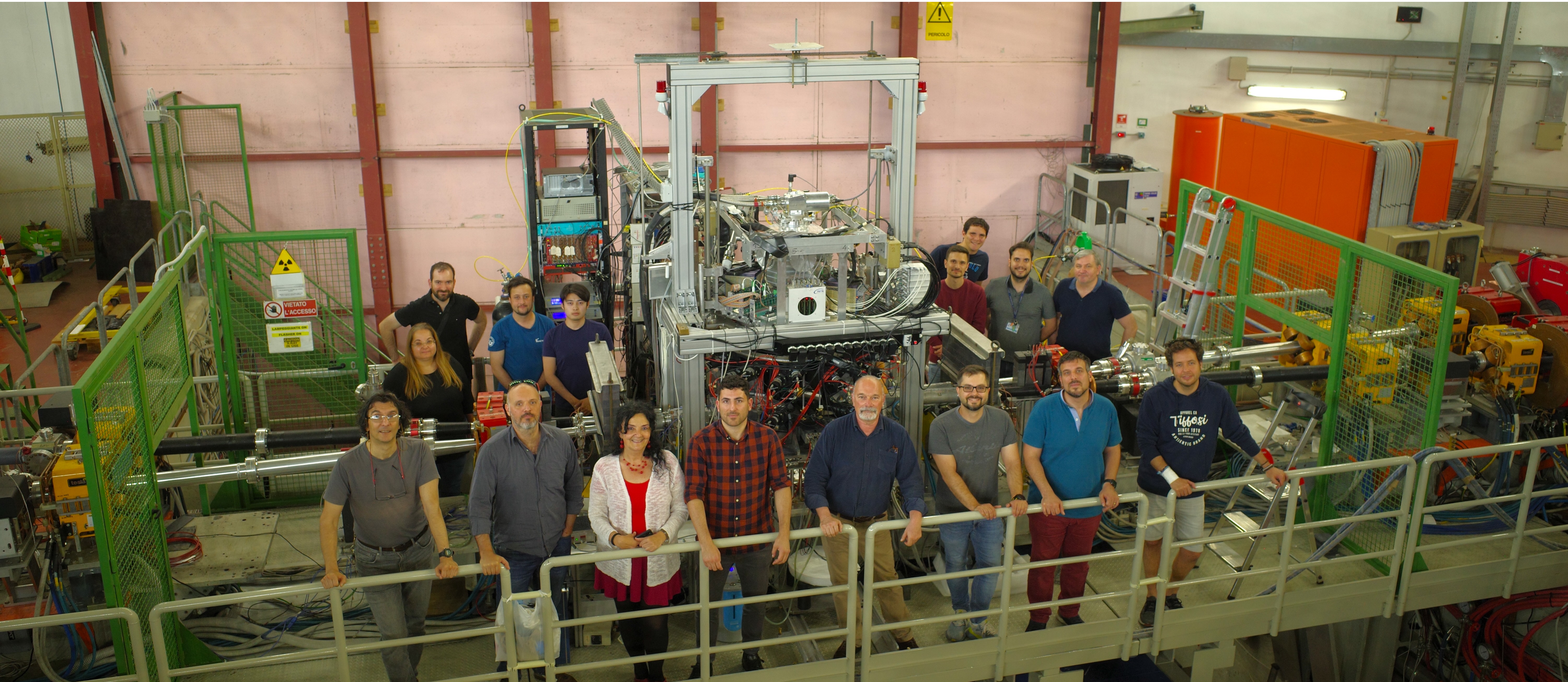
- **First measurement of Kaonic Deuterium:** preliminary analysis

$$\varepsilon_{1s} = E^{meas}_{2p\to 1s} - E^{e.m.}_{2p\to 1s} = -816 \pm 53\ \text{(stat)} \pm 2\ \text{(syst) eV}$$
$$\Gamma_{1s} = 756 \pm 271\ \text{(stat) eV}$$



- **EXKALIBUR:** new X-ray detectors (**SDDs – CZT - HPGe**) have been developed/tested to perform **kaonic atoms measurements along the periodic table** providing new experimental data to probe the **kaon-nucleus interaction**

THANK YOU



SPARE

The SIDDHARTA-2 collaboration

Silicon **D**rift **D**etectors for **H**adronic **A**tom **R**esearch by **T**iming **A**pplication

- LNF-INFN, Frascati, Italy
- SMI-ÖAW, Vienna, Austria
- Politecnico di Milano, Italy
- IFIN –HH, Bucharest, Romania
- TUM, Munich, Germany
- RIKEN, Japan
- Univ. Tokyo, Japan
- Victoria Univ., Canada
- Univ. Zagreb, Croatia
- Univ. Jagiellonian Krakow, Poland
- ELPH, Tohoku University

INFN LNF
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

HadronPhysics2
Study of Strongly Interacting Matter

STRONG-2020

HadronPhysics I3
Study of Strongly Interacting Matter

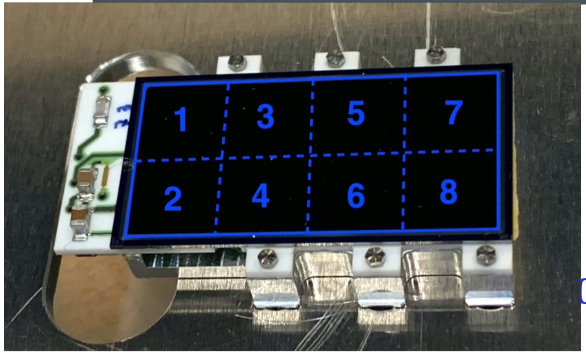
HrZZ
Croatian Science Foundation

FWF Der Wissenschaftsfonds.

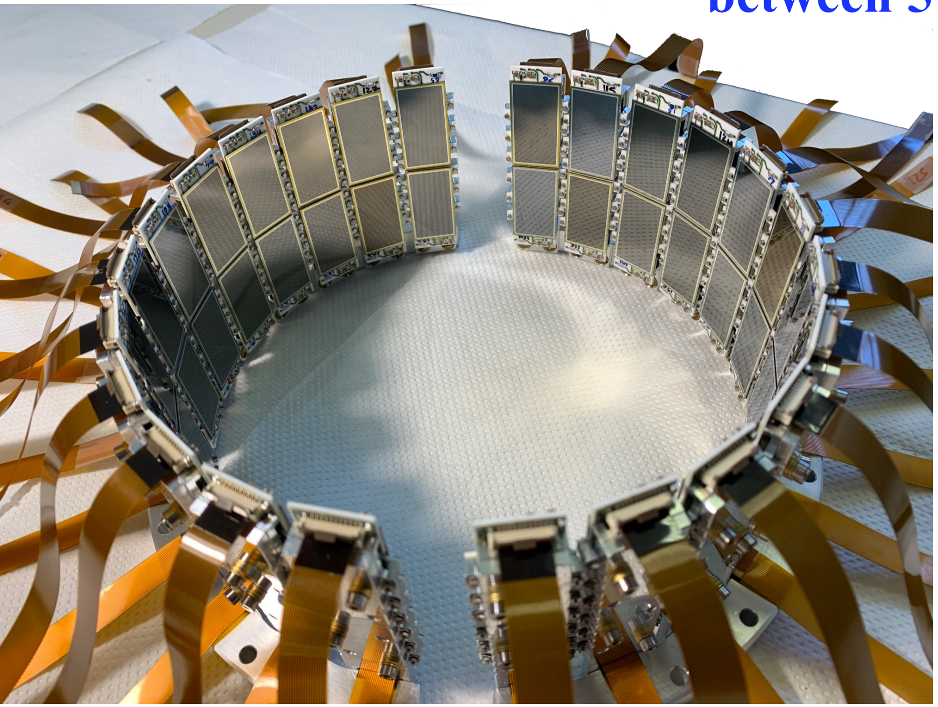
Farnesina
Ministero degli Affari Esteri e della Cooperazione Internazionale

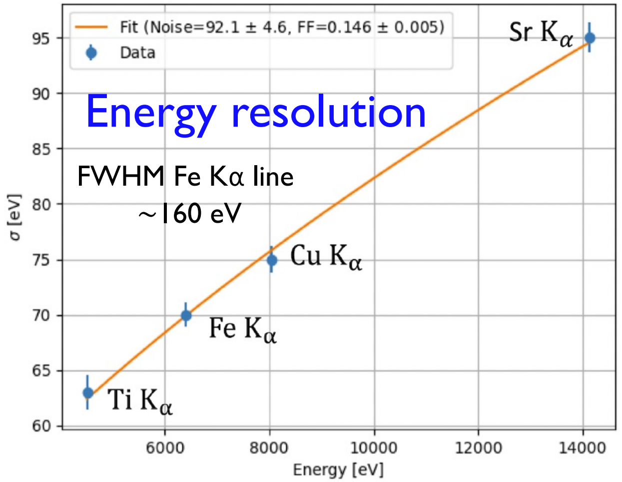
Silicon Drift Detectors

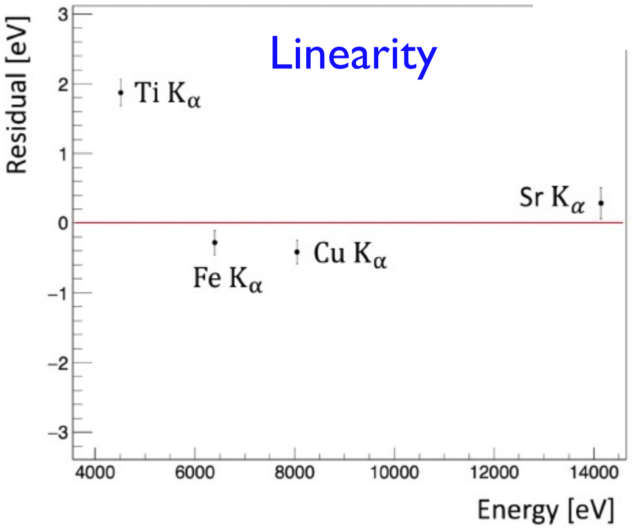
Large area Silicon Drift Detectors (SDDs) have been developed to perform high precision kaonic atoms X-ray spectroscopy

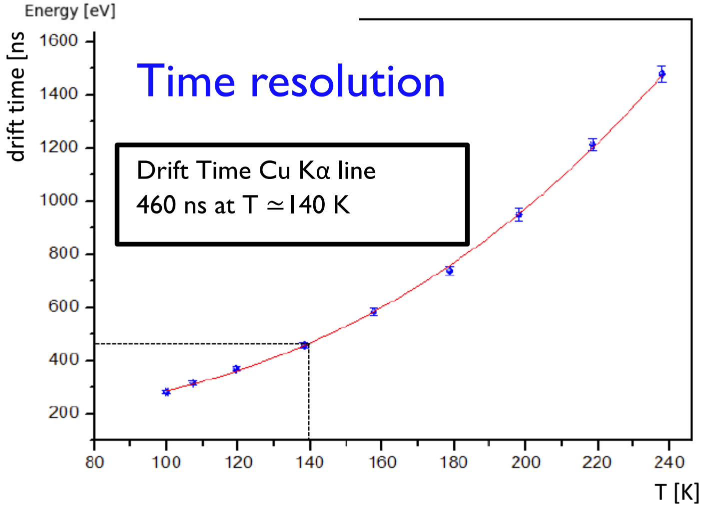


8 SDD units (0.64 cm^2)
for a total active area of 5.12 cm^2
Thickness of 450 μm ensures a high ollection efficiency for X-rays of energy between 5 keV and 12 keV

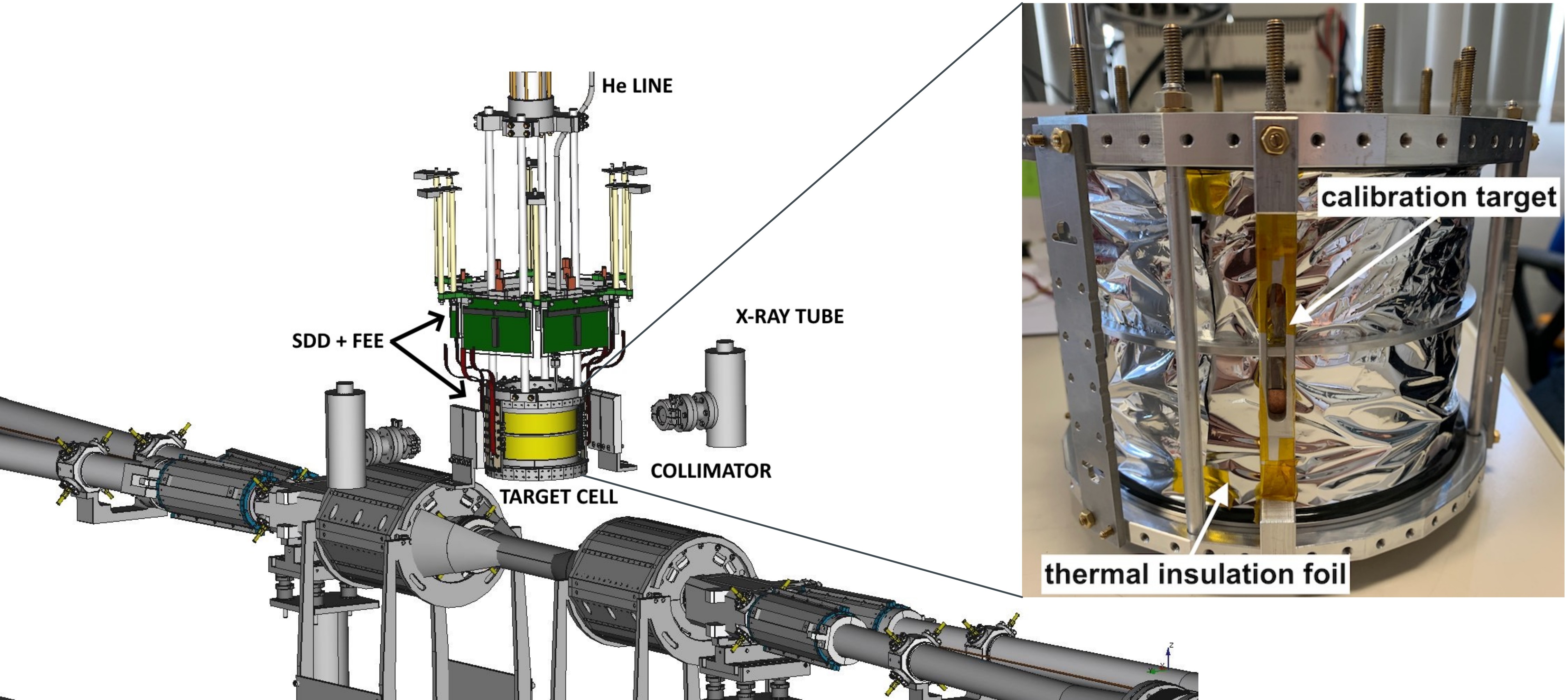




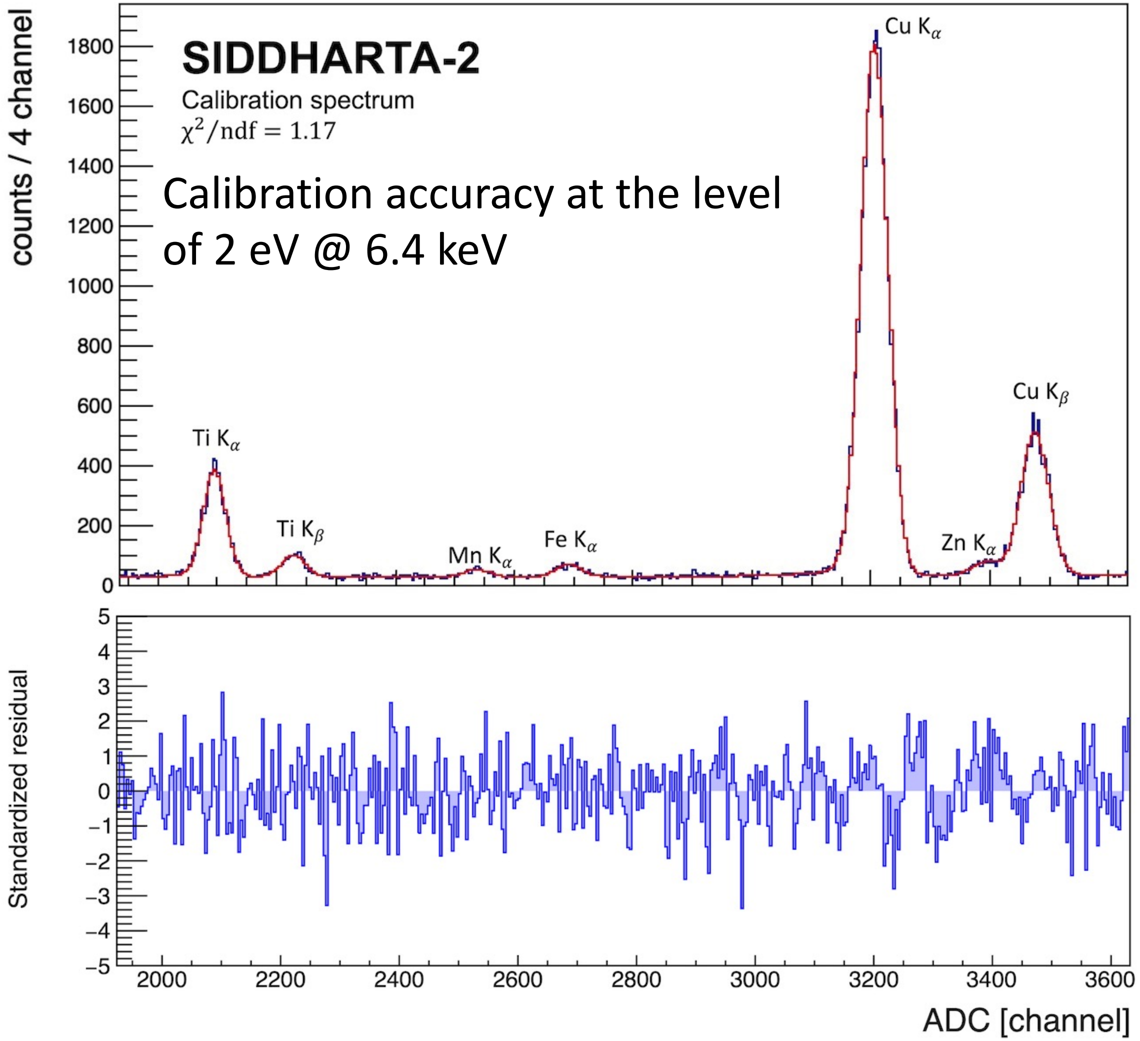




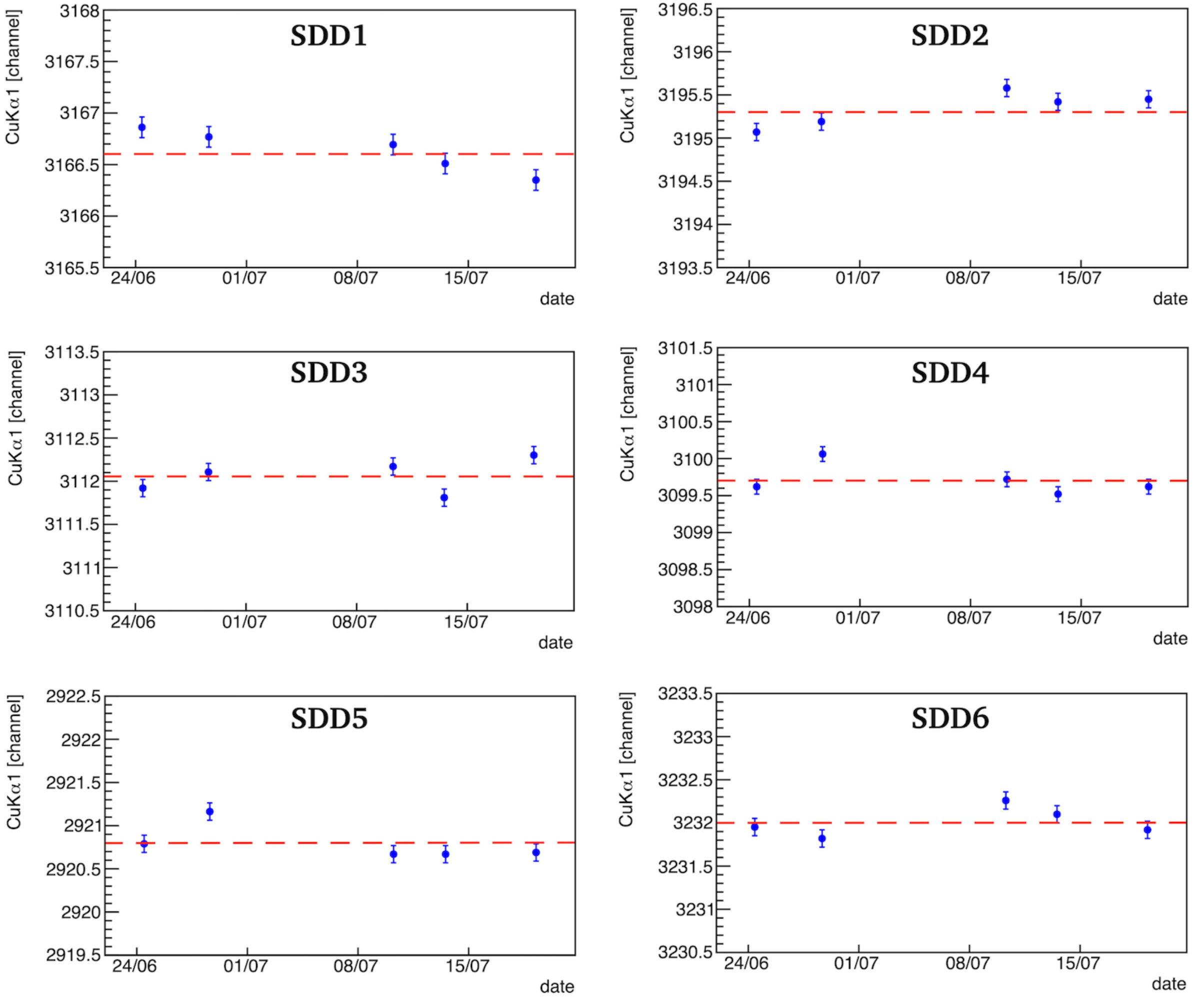
SDDs Calibration Procedure in DAΦNE



SDDs Calibration Procedure in DAΦNE

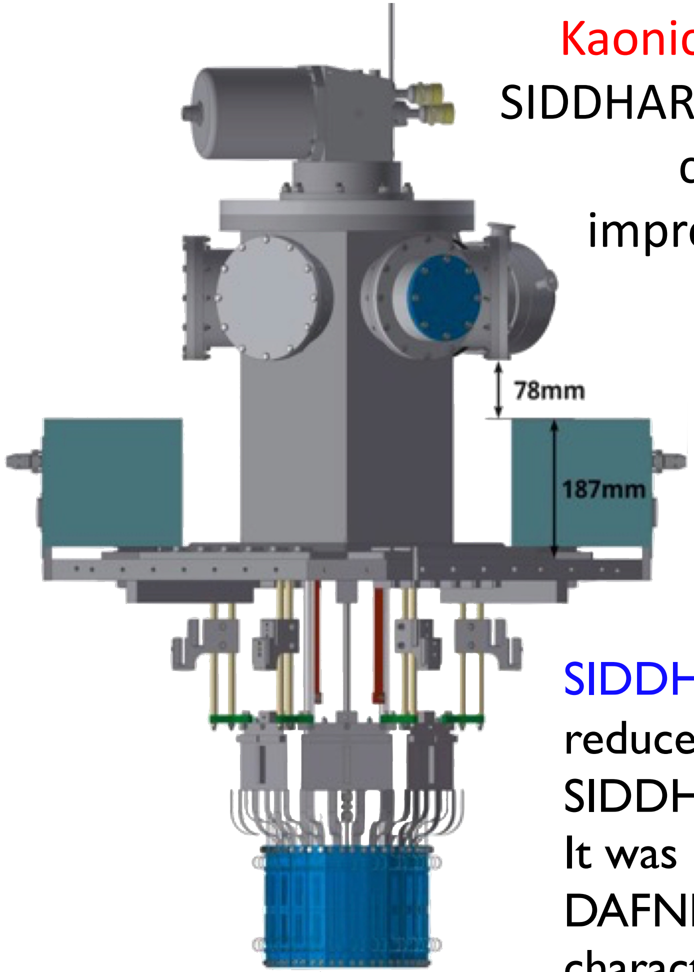


Calibration accuracy at the level of 2 eV @ 6.4 keV



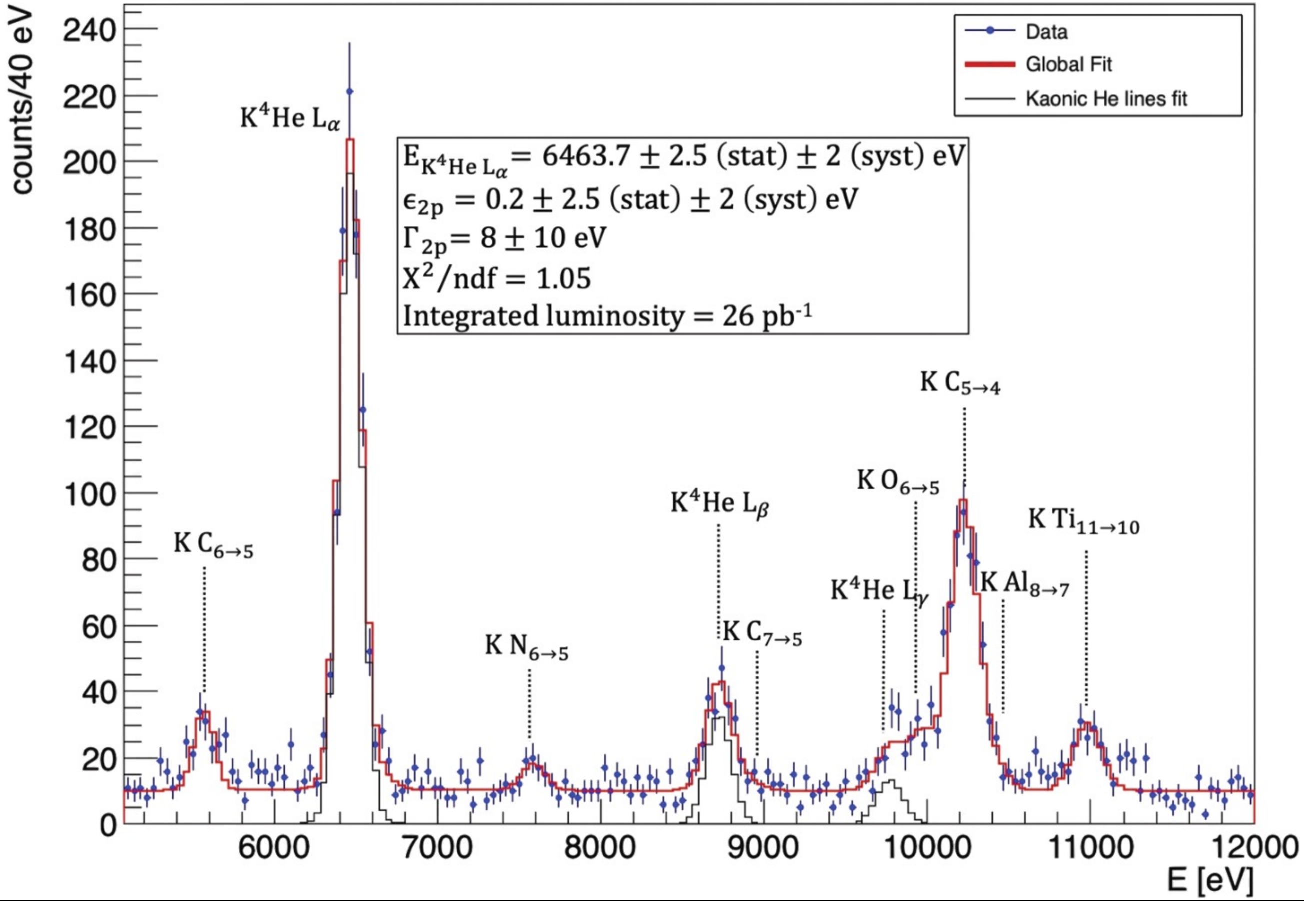
SIDDHARTINO - The kaonic ^{4}He 3d->2p measurement

Characterization of the SIDDAHRTA-2 apparatus and optimization of DAΦNE background through the kaonic helium measurement



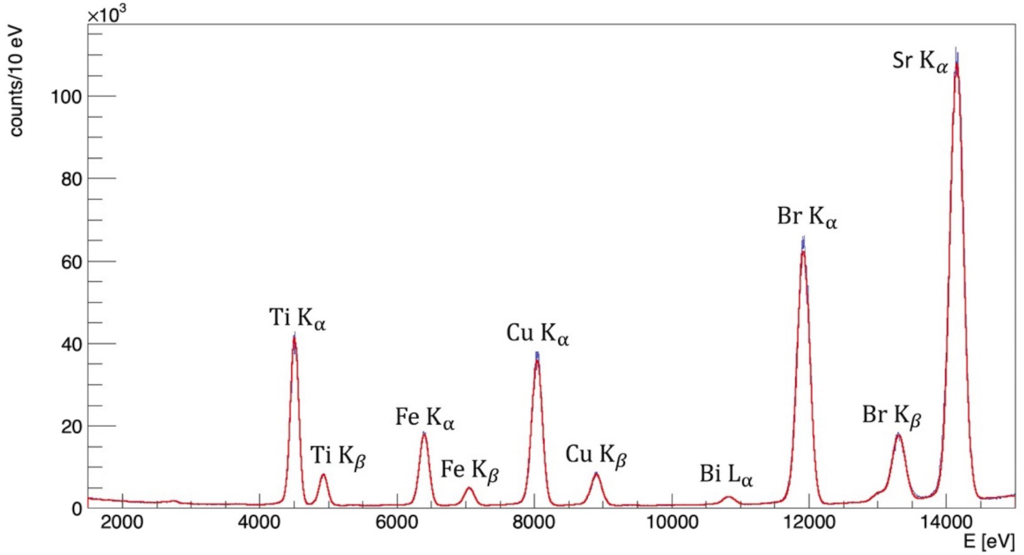
Kaonic Helium puzzle:
SIDDHARTA and KEK results confirmed,
improving accuracy

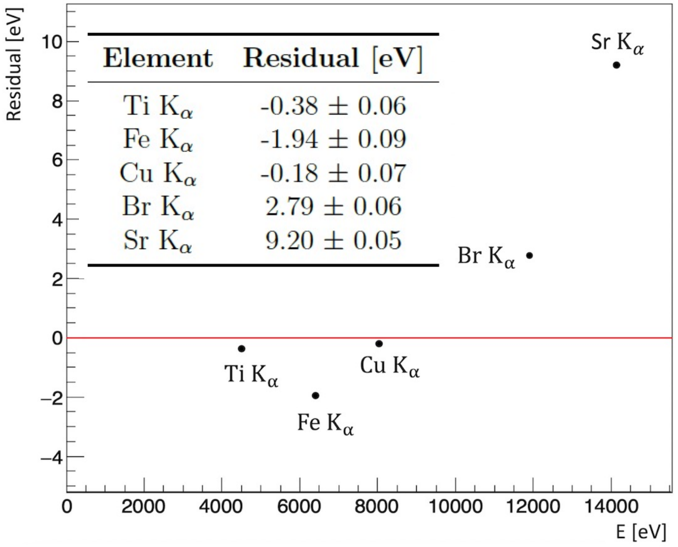
SIDDHARTINO:
reduced version of the SIDDHARTA-2 apparatus
It was used to optimize the DAFNE background and characterize the SDDs



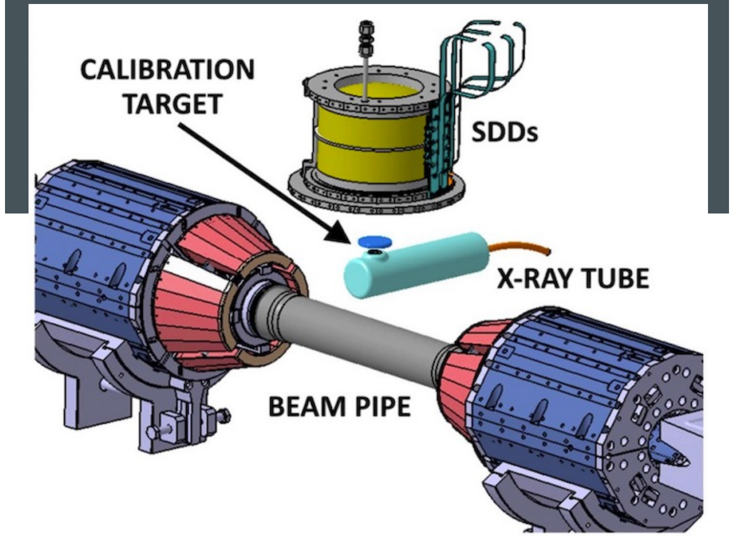
Sirghi D., Sirghi F., **Sgaramella F.**, et al., 2022, J. Phys. G Nucl. Part. Phys., 49 (5) 55106

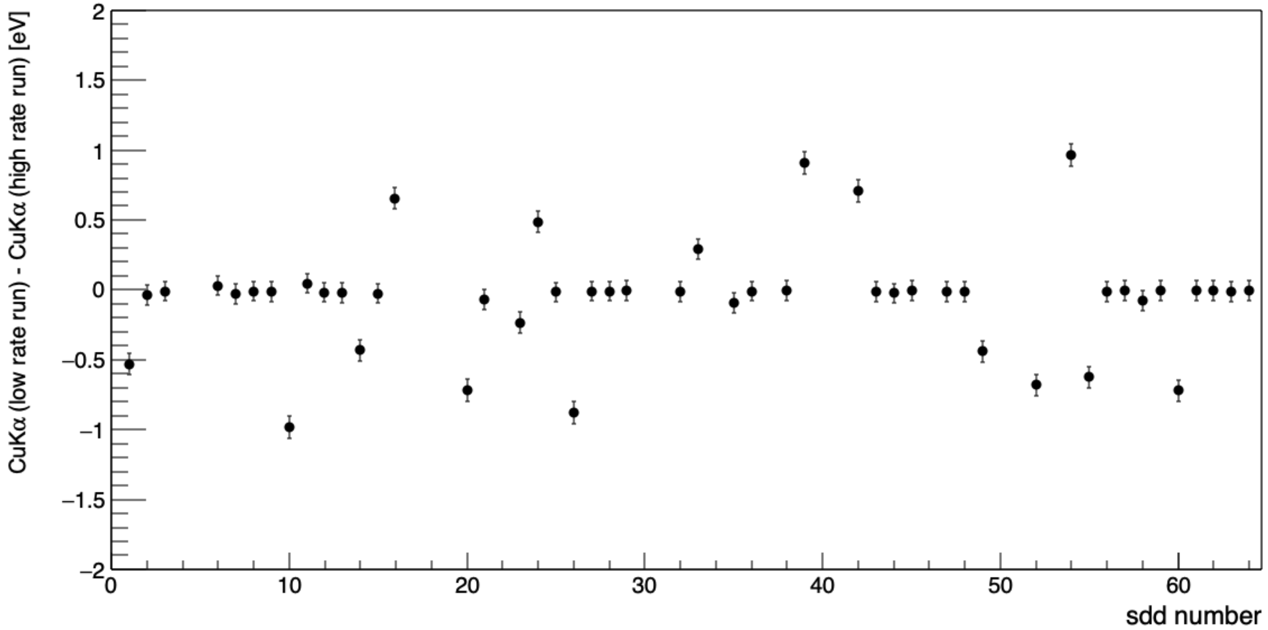
Spectroscopy Response in a High Background Environment

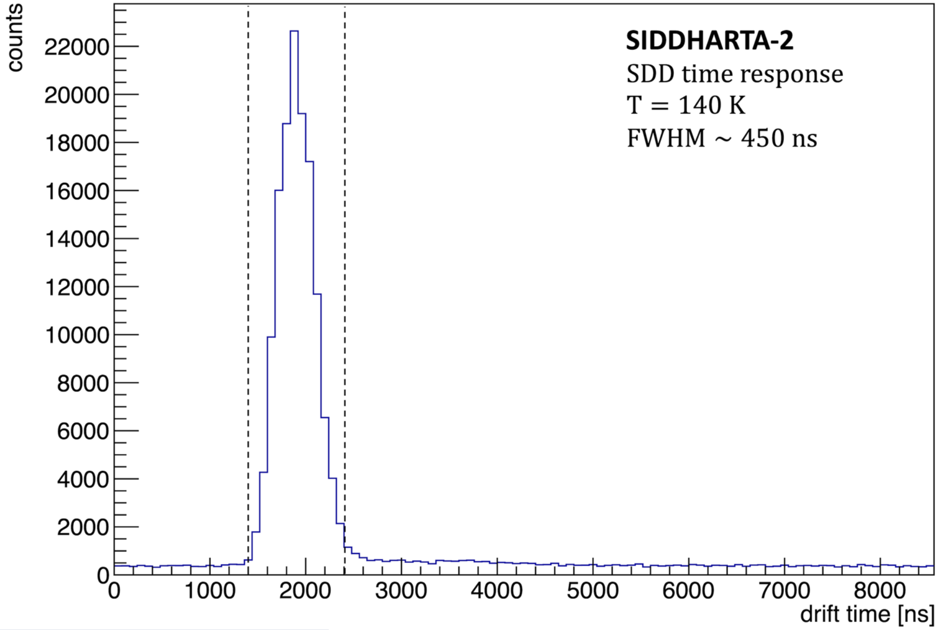




Element	Residual [eV]
Ti K_α	-0.38 ± 0.06
Fe K_α	-1.94 ± 0.09
Cu K_α	-0.18 ± 0.07
Br K_α	2.79 ± 0.06
Sr K_α	9.20 ± 0.05

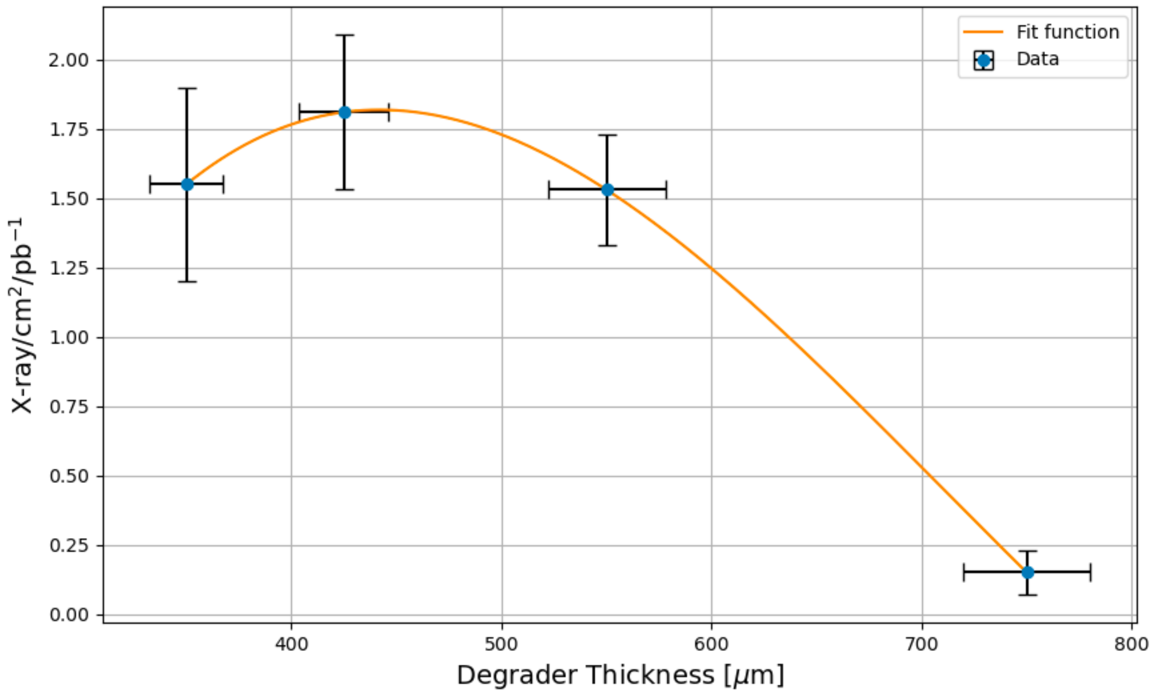


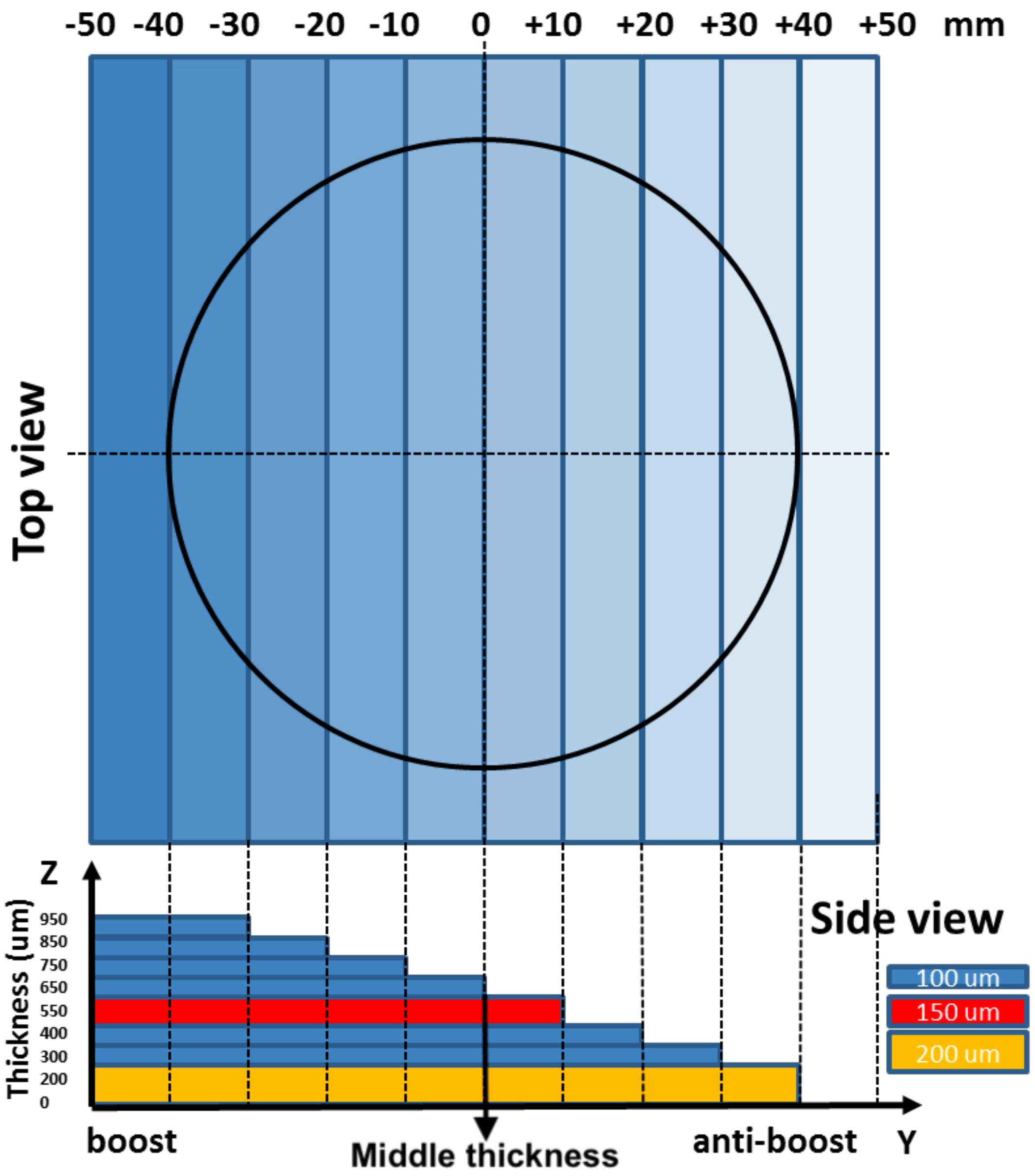




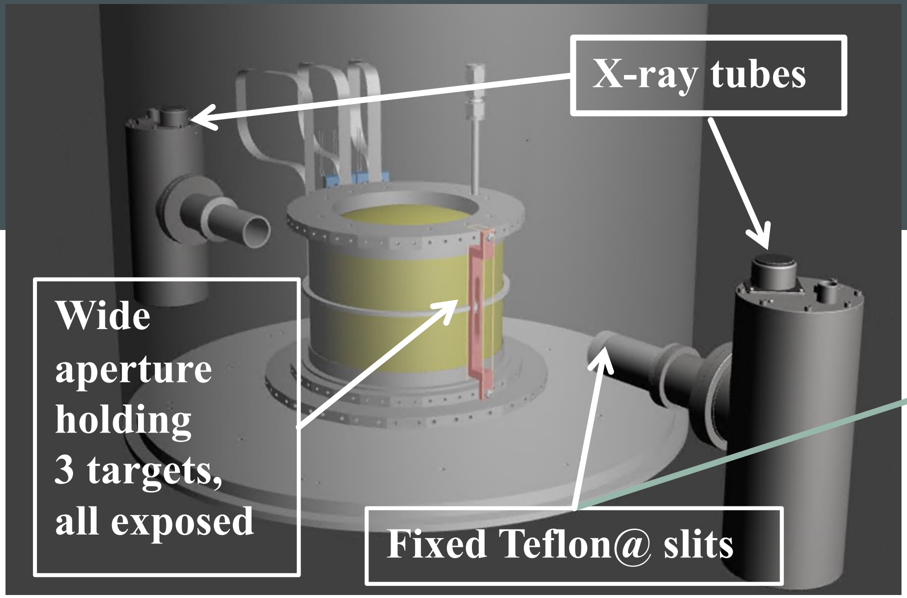
Sgaramella F., Miliucci M., et al., 2022, Phys Scr, 97 (11) 114002

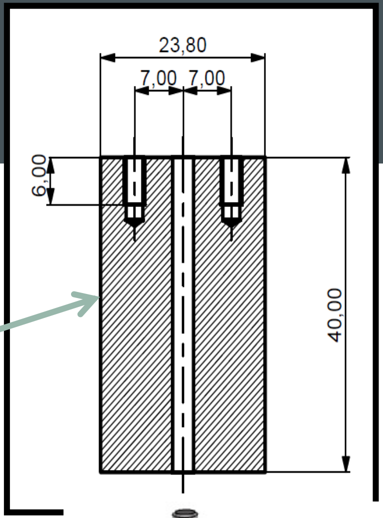
SIDDHARTINO - The kaonic ^{4}He 3d->2p measurement



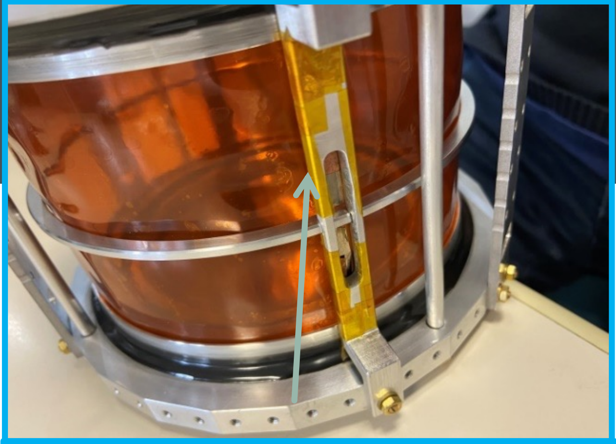


Refined calibration system : movable fluorescent foils



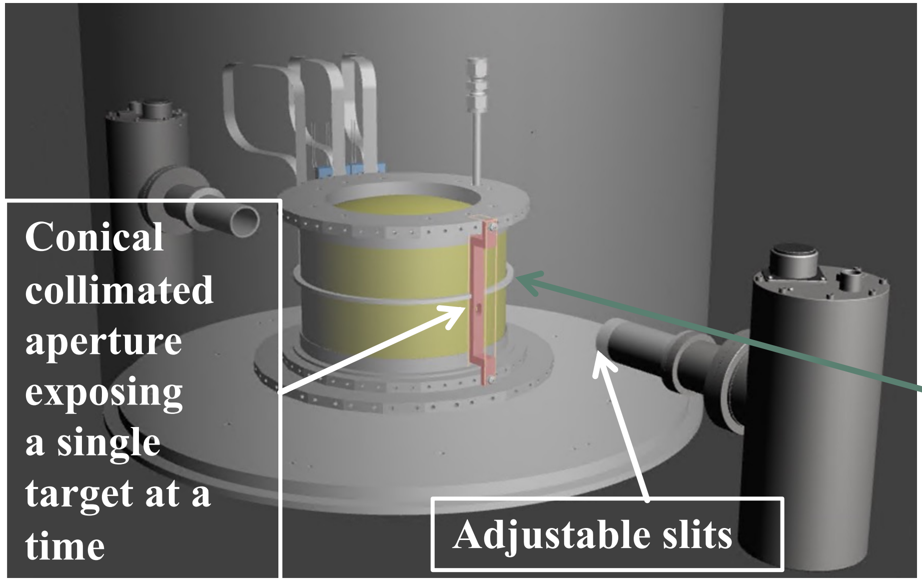


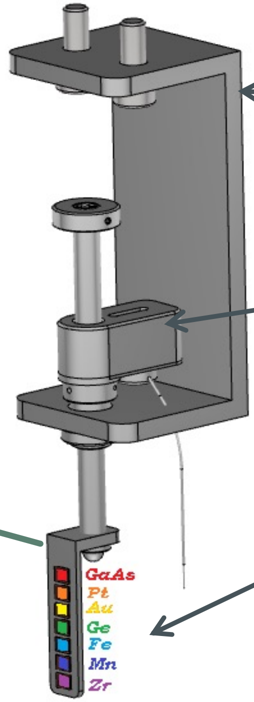
Current calibration system



Ti, Cu, Zr calibration foils holder

Upgraded calibration system





Holding structure

Actuator motor and gear box

Movable targets arm inserted behind the collimator.
Selected materials:
GaAs, Pt, Au, Ge, Fe, Mn, Zr