

# SIDDHARTA-2: STATUS REPORT

Catalina Curceanu and Francesco Sgaramella  
on behalf of the SIDDHARTA-2 collaboration  
66<sup>th</sup> Scientific Committee Meeting – 8<sup>th</sup> November 2023

# SIDDHARTA-2 COLLABORATION

## Silicon Drift Detectors for Hadronic Atom Research by Timing Application

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

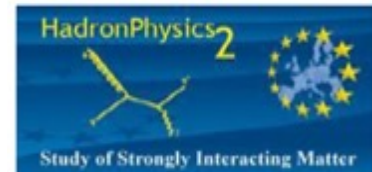
ELPH, Tohoku University

Univ. of Palermo, Italy

IMEM-CNR, Parma, Italy

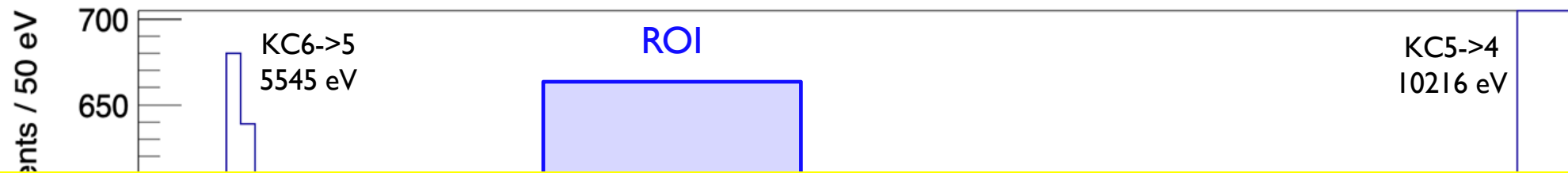


Istituto Nazionale di Fisica Nucleare  
Laboratori Nazionali di Frascati

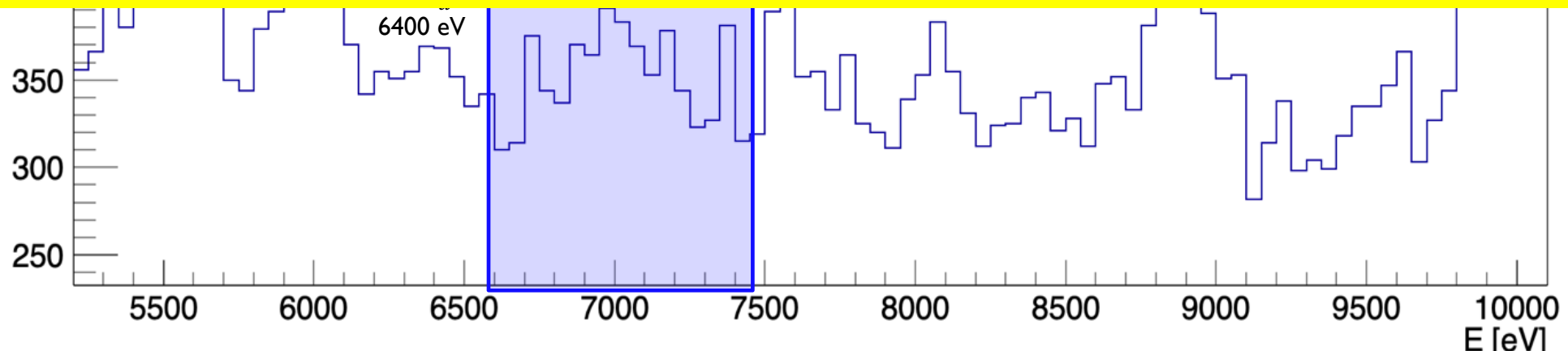


# The Kaonic deuterium measurement – Very Preliminary results

First Kd spectrum, May – July 2023, integrated luminosity 200 pb<sup>-1</sup> (including injections)



*We are very grateful to DAΦNE team and accelerator division, to INFN, Gr 3, LNF management and Director and applaud these achievements which set a solid ground for the ongoing kaonic deuterium first measurement ever and other kaonic atoms measurements!*



# Publications since last SciCom – May 2023

- 1) *C. Curceanu et al.*, Kaonic atoms at the DAFNE collider: a strangeness adventure, *Front.in Phys.* 11 (2023) 1240250
- 2) *L. Abbene et al.*, Potentialities of CdZnTe Quasi-Hemispherical Detectors for Hard X-ray Spectroscopy of Kaonic Atoms at the DAΦNE Collider, *Sensors* 23 (2023) 17, 7328
- 3) *L. De Paolis et al.*, The KAMEO proposal: Investigation of the E2 nuclear resonance effects in kaonic atoms, *Nuovo Cim.C* 46 (2023) 3, 59
- 4) *M. Skurzok et al.*, A review of the low-energy  $K^-$ -nucleus/nuclei interactions with light nuclei AMADEUS investigations, *Front.in Phys.* 11 (2023) 1237644
- 5) *K. Piscicchia et al.*, First Simultaneous  $K^-p \rightarrow (\Sigma^0/\Lambda) \pi^0 \rightarrow (\Sigma^0/\Lambda)\pi^0$  Cross Sections Measurements at 98 MeV/c, *Phys. Rev. C* 108 (2023) 055201
- 6) *S. Wycech and K. Piscicchia*, Pionization: A method to study the nuclear surface, *Phys. Rev. C* (2023) 108, 014313
- 7) *M. Tuchler et al.*, The SIDDHARTA-2 Veto-2 system for X-ray spectroscopy of kaonic atoms at DAΦNE, JINST, accepted

# Publications since last SciCom – May 2023

- 8) *L. De Paolis et al.*, The measurements of E2 nuclear resonance effects in kaonic atoms at DAFNE; the KAMEO proposal, submitted to EPJ Web conf
- 9) *F. Sirghi et al.*, Kaonic atoms with SIDDHARTA-2 at the DAFNE Collider, submitted to EPJ Web conf
- 10) *F. Sgaramella et al.*, First measurement of kaonic helium-4 M-series transitions, e-Print:2310.20584, submitted to Journal of Phys. G
- 11) *A. Scordo et al.*, CdZnTe detectors tested at the DAΦNE collider for future kaonic atoms measurements , arXiv:2310.15062, submitted to NIM A
- 12) *F. Sirghi et al.*, SIDDHARTA-2 apparatus for kaonic atoms research on the DAΦNE collider, to be submitted to NIM

**+3 articles in preparation**

**> 10 invited talks in International Workshops and Conferences**

**First simultaneous  $K^-p \rightarrow \Sigma^0\pi^0, \Lambda\pi^0$  cross section measurements at 98 MeV/c**

Kristian Piscicchia,<sup>1,2</sup> Magdalena Skurzok<sup>3,4,\*</sup> Michael Cargnelli,<sup>5</sup> Raffaele Del Grande,<sup>6,2</sup> Laura Fabbietti,<sup>6,7</sup> Johann Marton,<sup>5</sup> Pawel Moskal,<sup>3,4</sup> Àngels Ramos,<sup>8</sup> Alessandro Scordo,<sup>2</sup> Diana Laura Sirghi,<sup>2,9,1</sup> Oton Vazquez Doce,<sup>2</sup> Johann Zmeskal,<sup>2,5</sup> Sławomir Wycech,<sup>10</sup> Paolo Branchini,<sup>11</sup> Filippo Ceradini,<sup>12,11</sup> Eryk Czerwiński,<sup>3,4</sup> Erika De Lucia,<sup>2</sup> Salvatore Fiore,<sup>13,14</sup> Andrzej Kupsc,<sup>15,10</sup> Giuseppe Mandaglio,<sup>16,17</sup> Matteo Martini,<sup>2,18</sup> Antonio Passeri,<sup>11</sup> Vincenzo Patera,<sup>14,19</sup> Elena Perez Del Rio,<sup>3,4</sup> Andrea Selce,<sup>12,11</sup> Michał Silarski,<sup>3,4</sup> and Catalina Curceanu<sup>2</sup>

cross section at  $p_{K^-} = 98 \pm 10$  MeV/c

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

AMADEUS (analyses of KLOE data with support of KLOE collaboration)

**Record:** cross sections at the lowest energy ever and improving the relative errors of about one order of magnitude w.r.t any other measurement

# Contents

- 65<sup>th</sup> Scientific Committee recommendations and our related actions
- Kaonic Deuterium run: status and future plans
- (More) Scientific outcomes: highlights
- Updates on HPGe and CdZnTe detectors and preliminary results
- Request for supplementary run: light kaonic atoms (Li - Be - B) measurements with 1 mm SDDs
- Future plans: EXKALIBUR

# 65<sup>th</sup> Scientific Committee recommendations

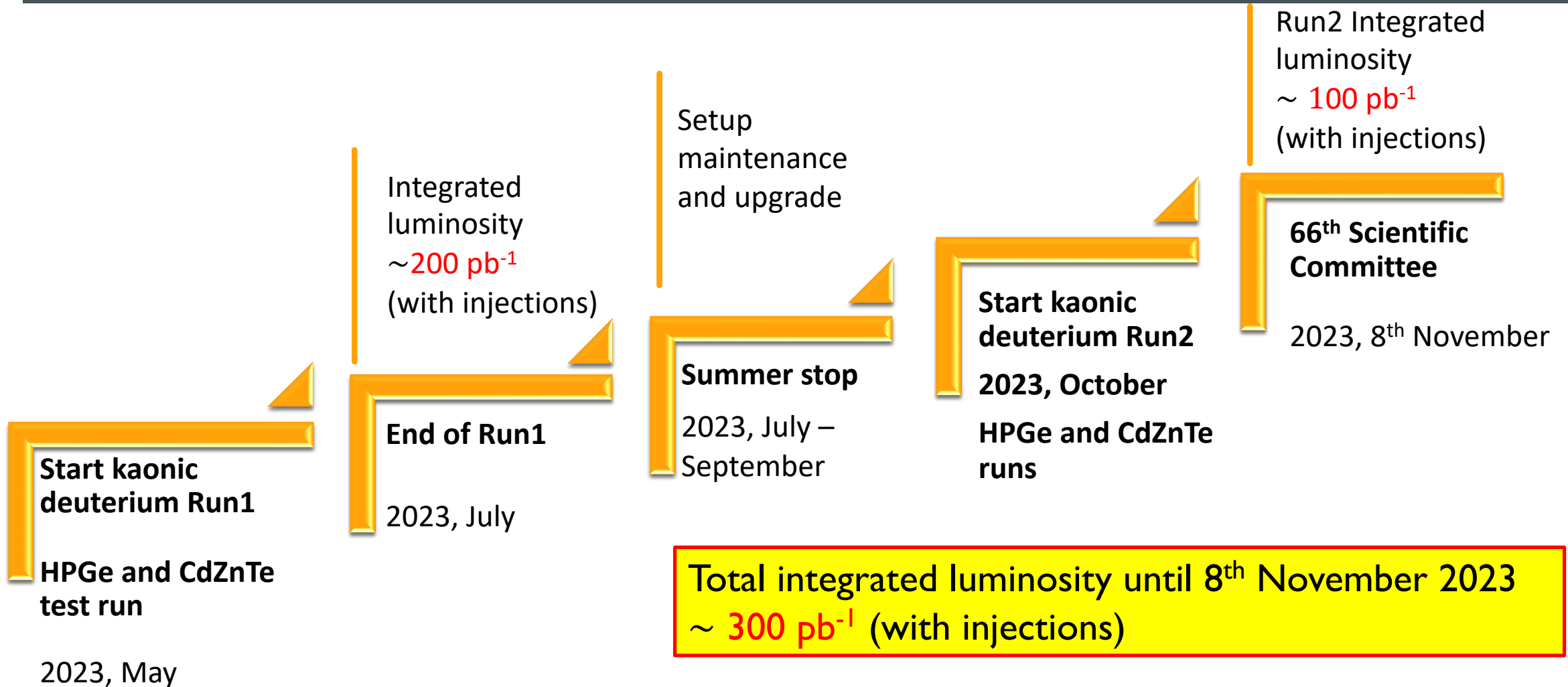
## Recommendations for SIDDHARTA-2:

- The SC encourages the collaboration to move swiftly and decisively to the **Kd data taking in two runs this year**, with the aim of taking advantage of the maximum integrated luminosity attainable in 2023.
- To **complete the quality studies of the data recorded during injection time**, with the aim of obtaining valuable additional Kd data.
- Keep the usual maintenance and upgrading duties in signal/background reduction, as well as the coordinated effort with the DAΦNE team to study reinforcement options for the shielding (by removing, reshaping, or displacing the luminometers close to the SIDDARTHA setup).
- During runs 1 and 2 undertake data acquisition with the **satellite HPGe and CdZnTe detectors**, minimizing the interference with the Kd data taking.



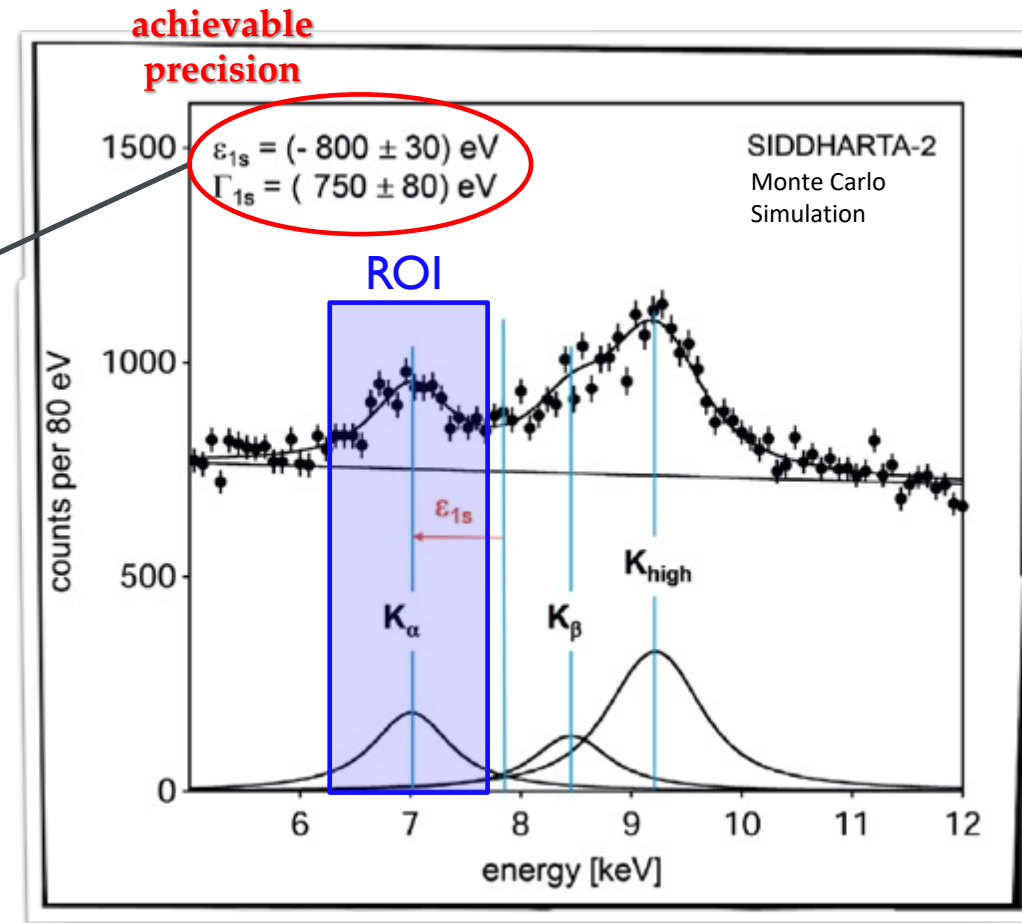
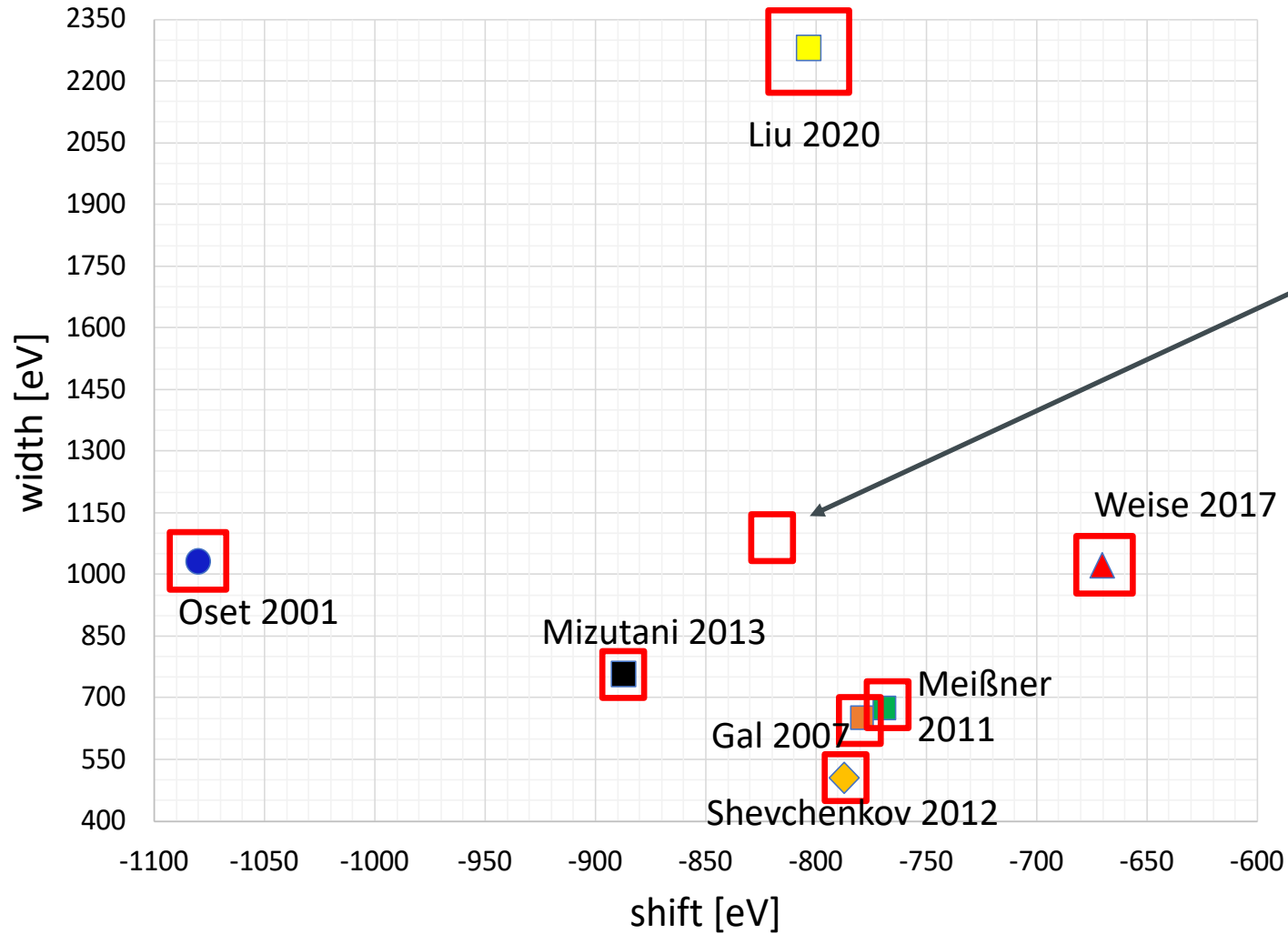
# The kaonic deuterium measurement – Timeline

- First run with SIDDHARTA-2 optimized setup for  $200 \text{ pb}^{-1}$  integrated luminosity: May – July 2023 - **completed**
- Second run Autumn – Winter 2023 goal: estimated  $200\text{-}300 \text{ pb}^{-1}$  ongoing
- Third run 2024 – goal:  $300\text{-}400 \text{ pb}^{-1}$
- Calibration runs: Kaonic He; Kaonic Ne; ....  $50\text{-}100 \text{ pb}$



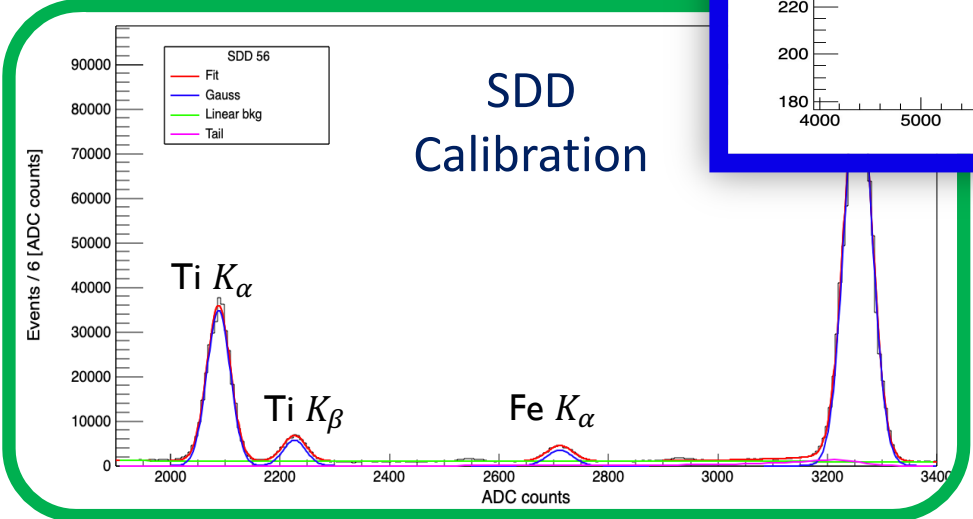
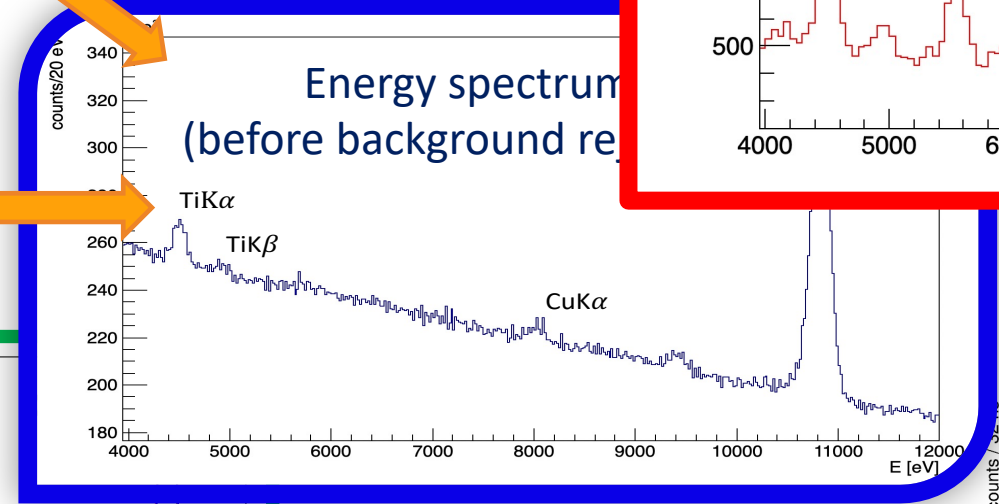
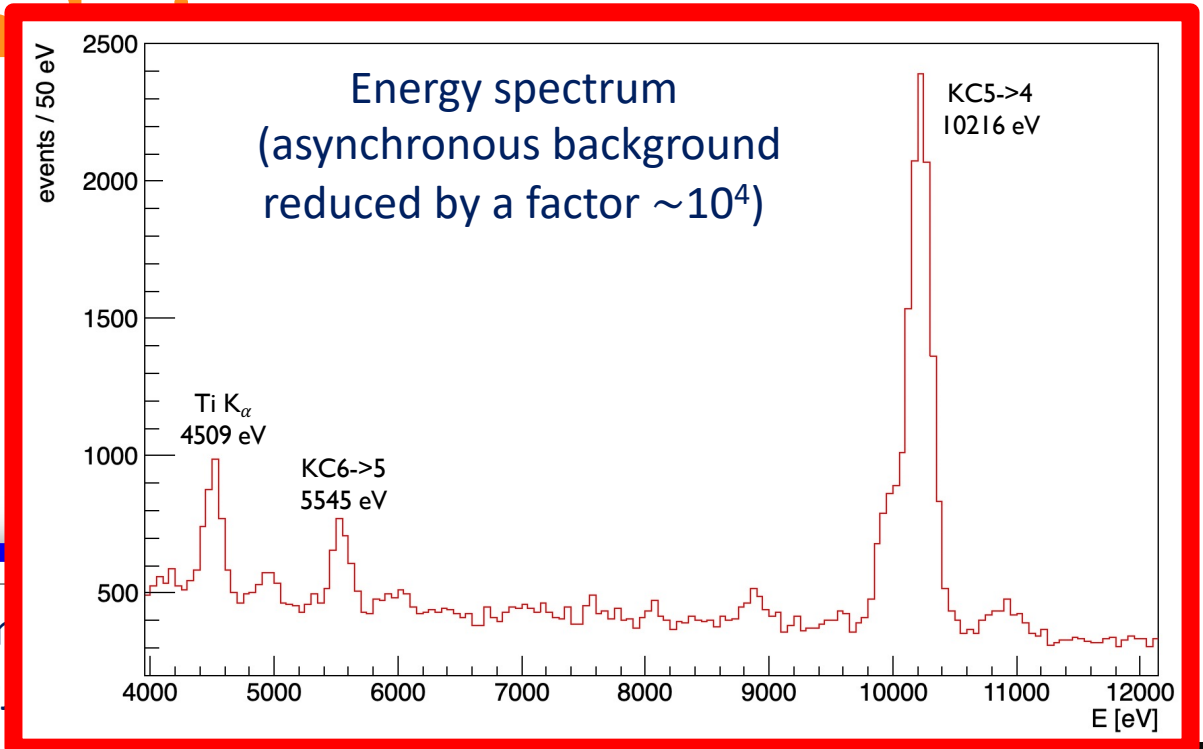
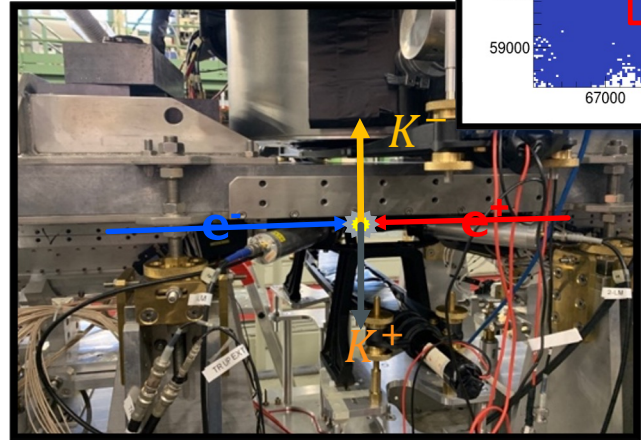
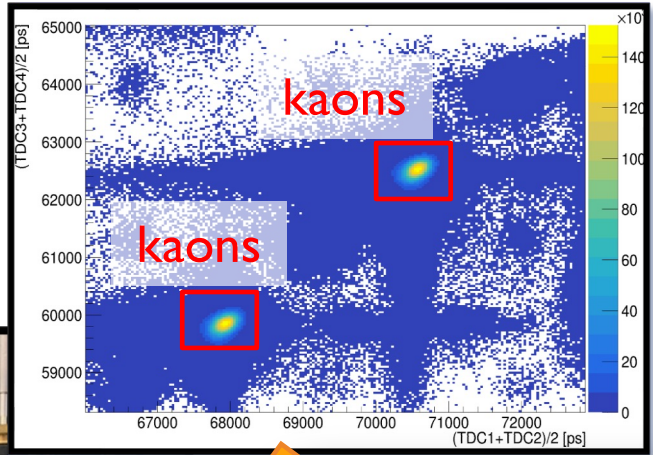
# Kaonic deuterium shift and width (Theoretical predictions)

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.

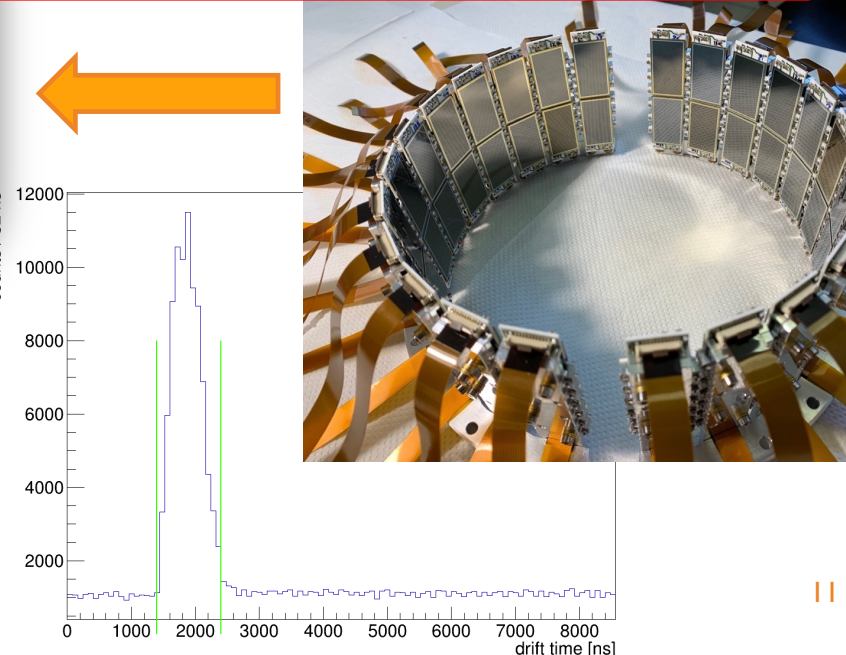


# Kaonic deuterium – Run1 data analysis

**KAON TRIGGER**

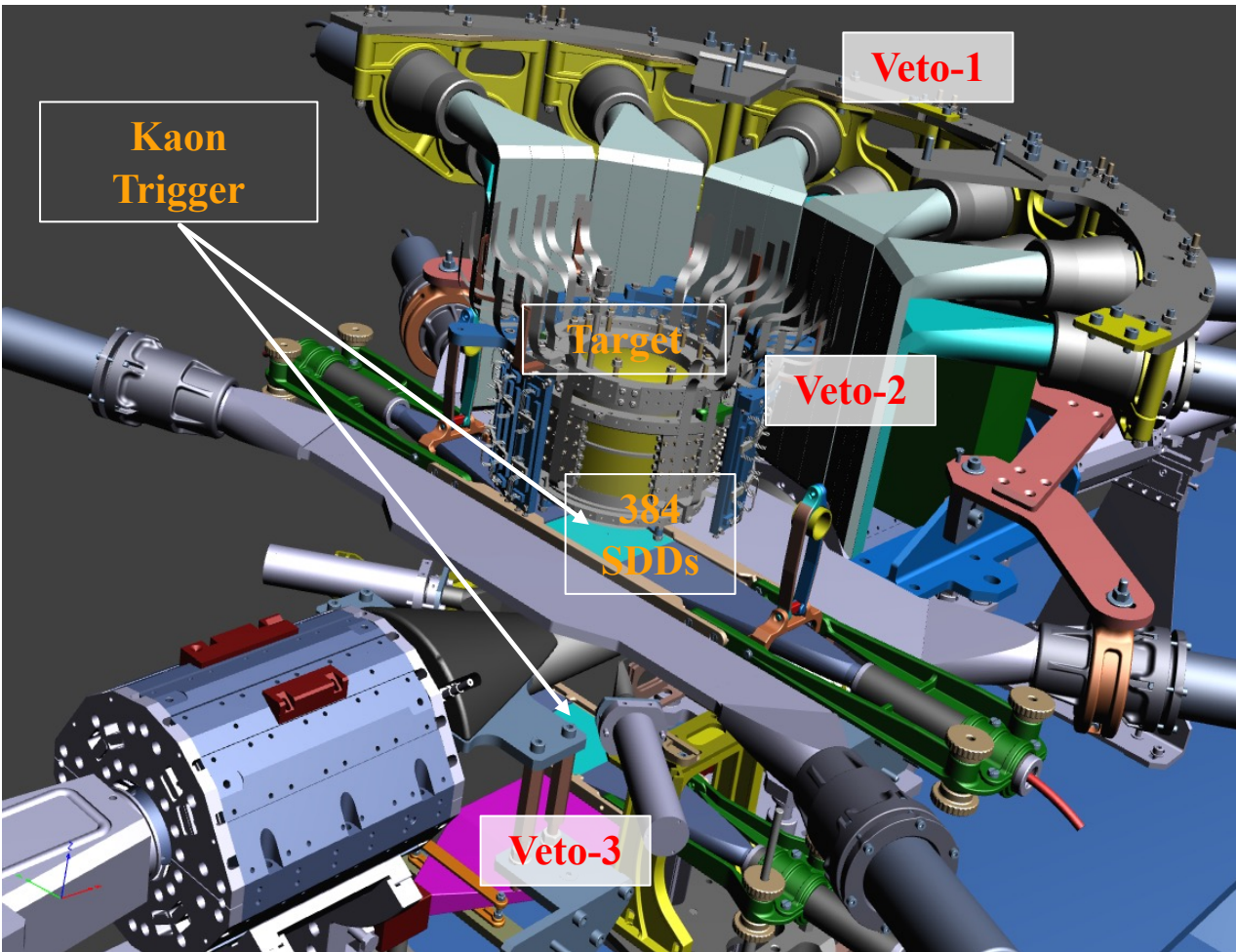


**SDDs Drift Time**



# Kaonic deuterium – data analysis – synchronous background

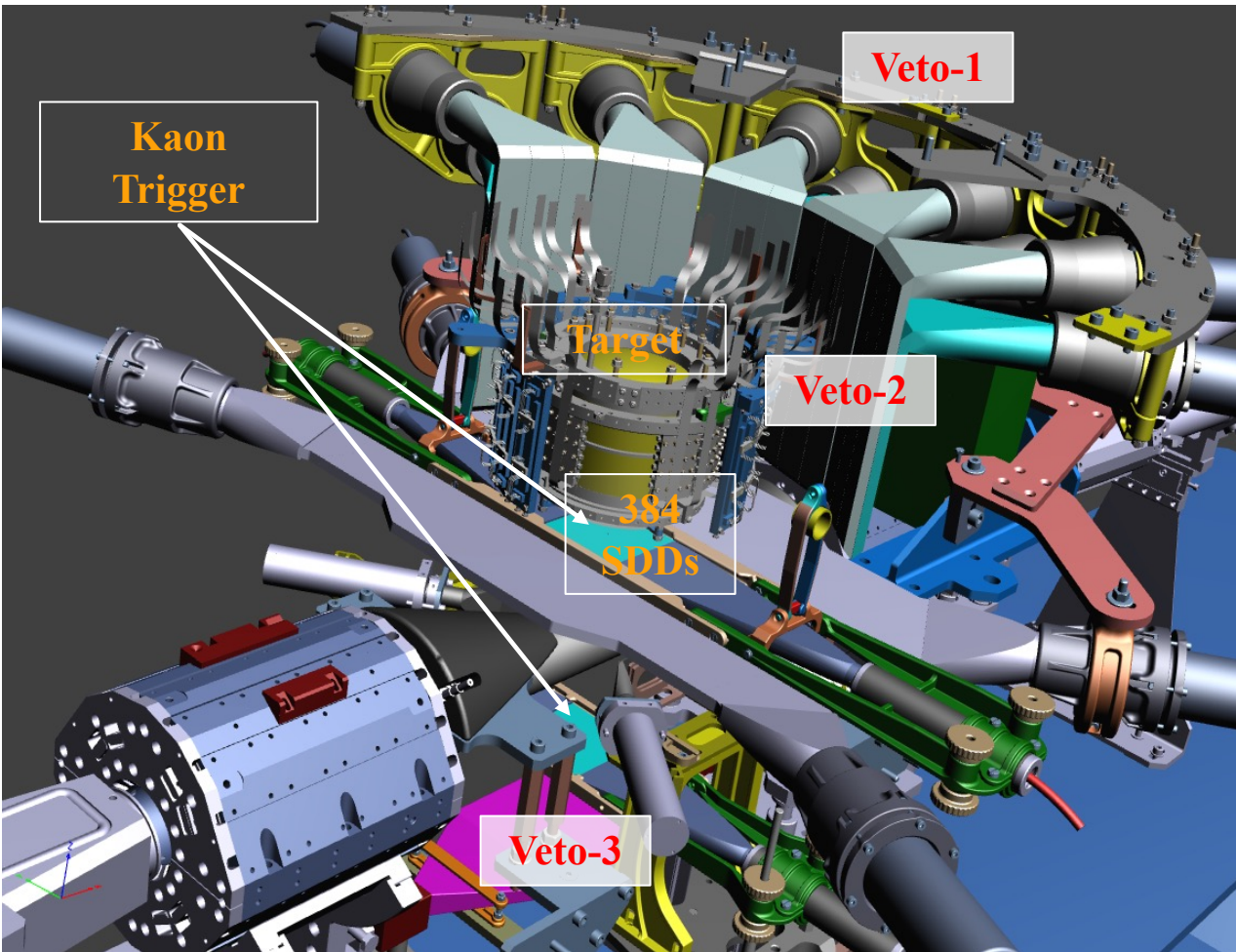
SIDDHARTA-2 Setup



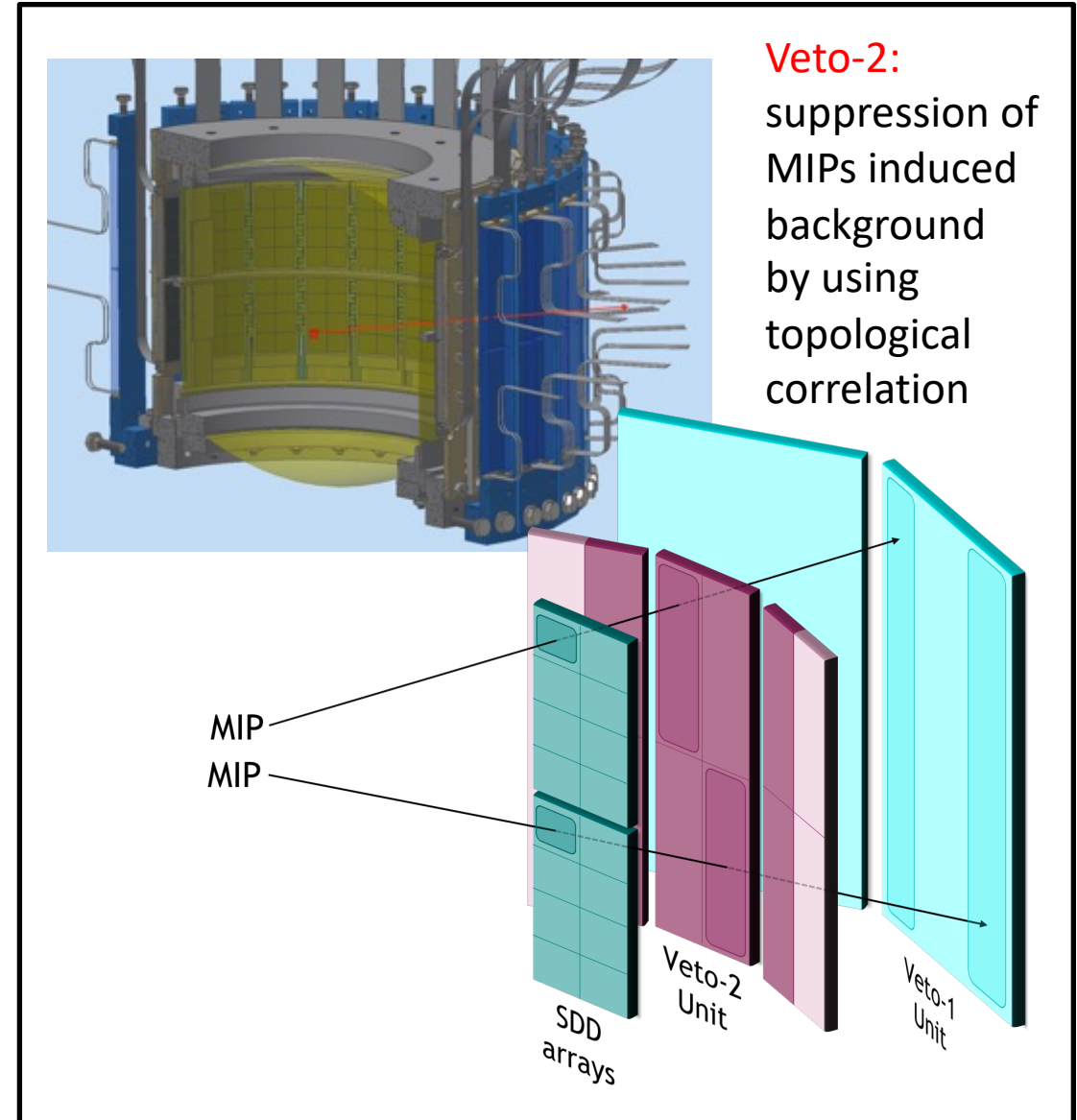
Three Veto systems for synchronous background reduction

# Kaonic deuterium – data analysis – synchronous background

SIDDHARTA-2 Setup



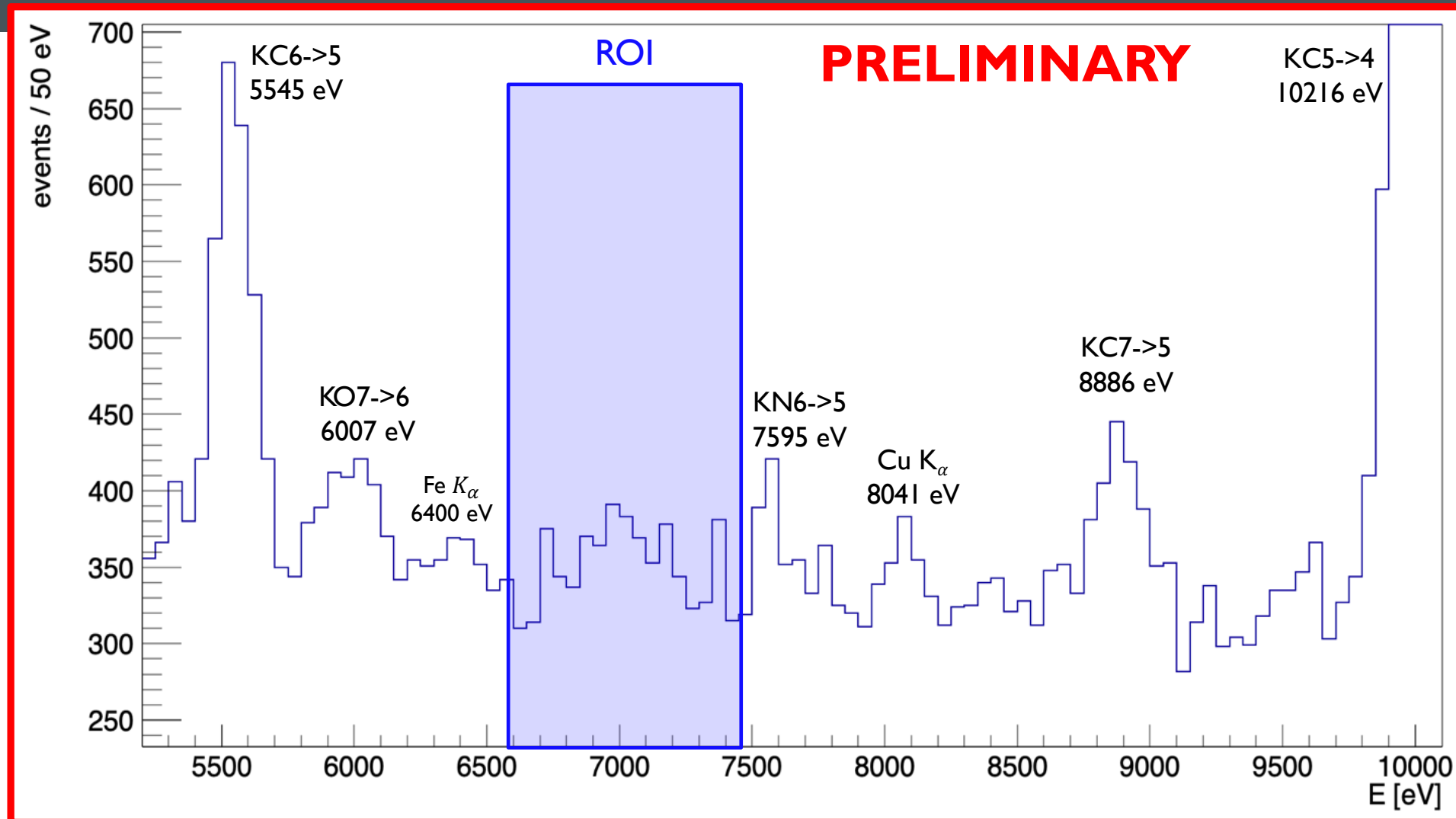
Three Veto systems for synchronous background reduction (M. Iliescu, J. Zmeskal, M. Tuchler...)



M. Tuchler et al., The SIDDHARTA-2 Veto-2 system for X-ray spectroscopy of kaonic atoms at DAΦNE, JINST, accepted

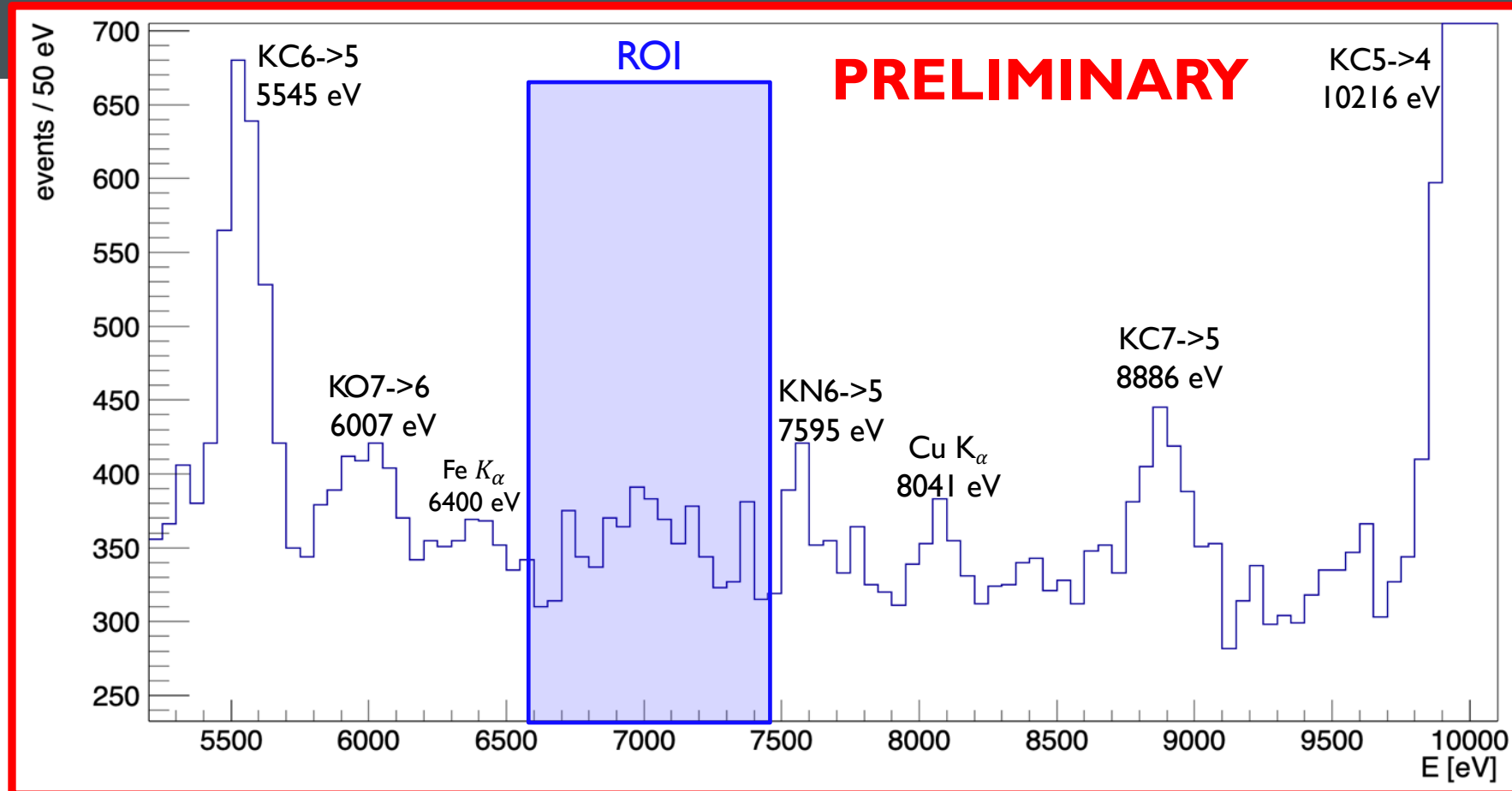
# Kaonic deuterium preliminary results (F. Sgaramella)

First run, May – July 2023, integrated luminosity  $200 \text{ pb}^{-1}$  (with injections)



# The Kaonic deuterium measurement – Preliminary results

First run, May – July 2023, integrated luminosity  $200 \text{ pb}^{-1}$  (with injections)



Next Steps:

Refined  
calibration

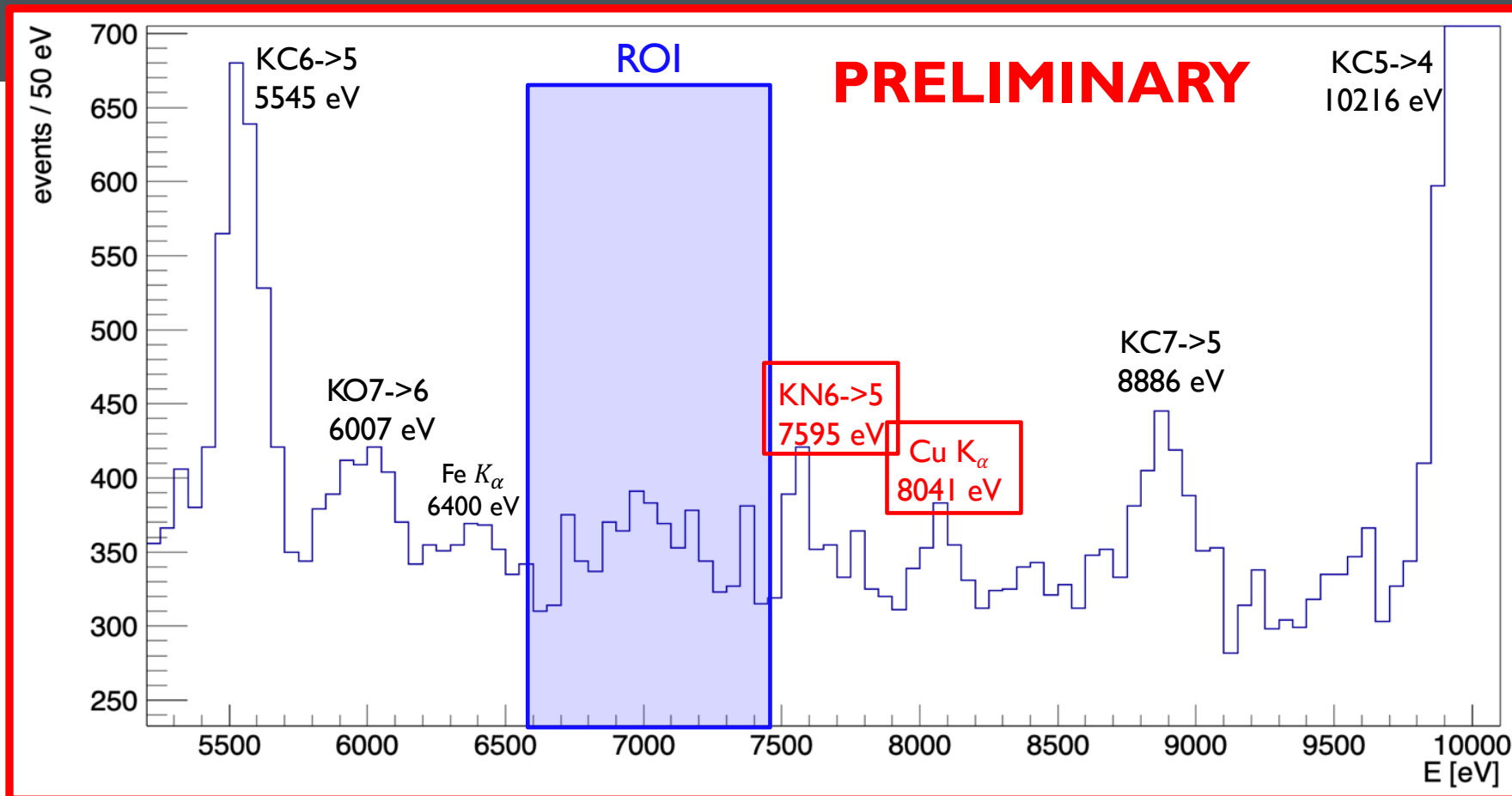
Veto-1  
Veto-3

Injection  
selection

Data  
Analysis

# The Kaonic deuterium measurement – Preliminary results

First run, May – July 2023, integrated luminosity  $200 \text{ pb}^{-1}$  (with injections)



Next Steps:

Refined calibration

Veto-1  
Veto-3

Injection selection

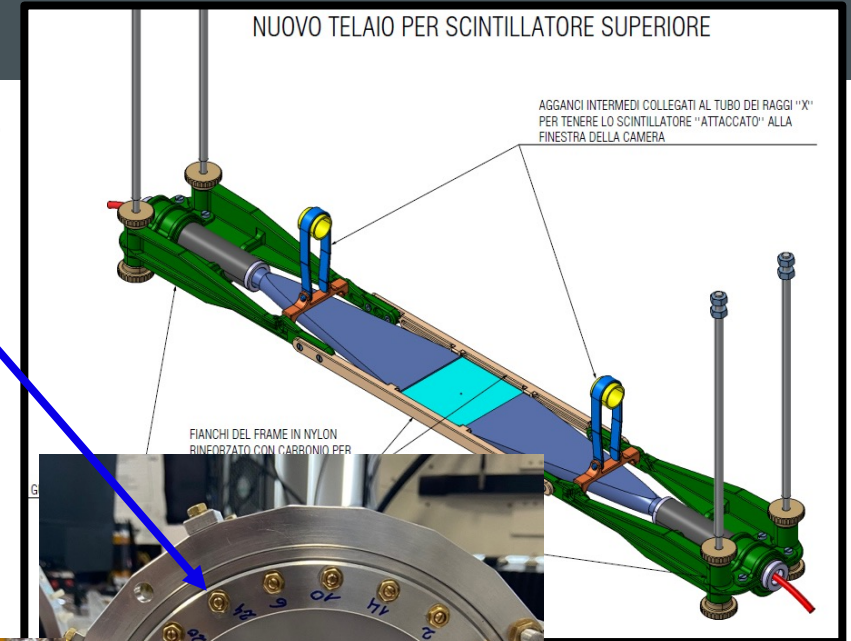
Data Analysis



# SIDDHARTA-2 setup (F. Sirghi, Technical Coordinator)

Optimization of the SIDDHARTA-2 setup during the summer stop of DAΦNE (July - September)

- Replaced some of the screws with Ti ones bottom of the target behind the SDD holders
- Replaced the vacuum chamber's entrance window with a new Mylar window to remove the contamination due to Nitrogen
- Kaon trigger: redesign the support structures and replaced the scintillator
- Replaced some Veto-2 SiPMs damaged by radiation



Run2: 100 pb<sup>-1</sup> already acquired. Data analysis on going



# 65<sup>th</sup> Scientific Committee recommendations

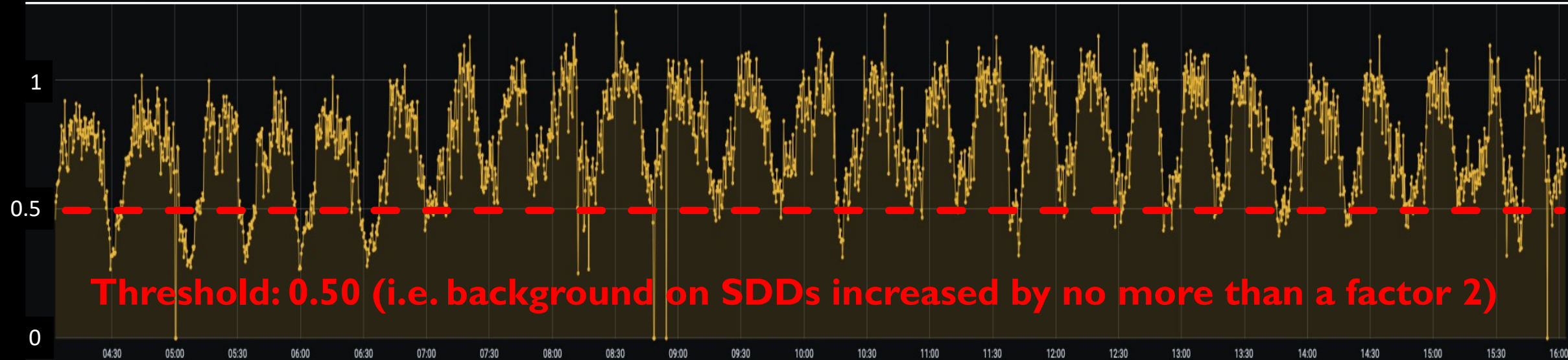
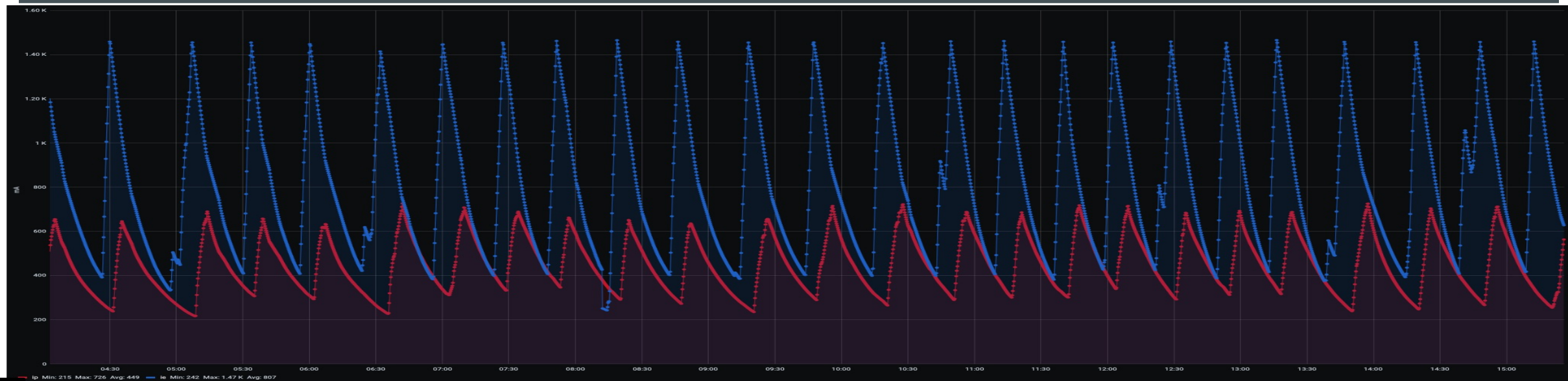
## Recommendations for SIDDHARTA-2:

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# Injections data analysis

**Kaon/SDD rate** to evaluate the background during the  $e^-e^+$  injections

Run1: 200  $\text{pb}^{-1}$  of which **70  $\text{pb}^{-1}$**  during **injections**  $\rightarrow$  **more than 50  $\text{pb}^{-1}$**  usable (under evaluation)



# Contents

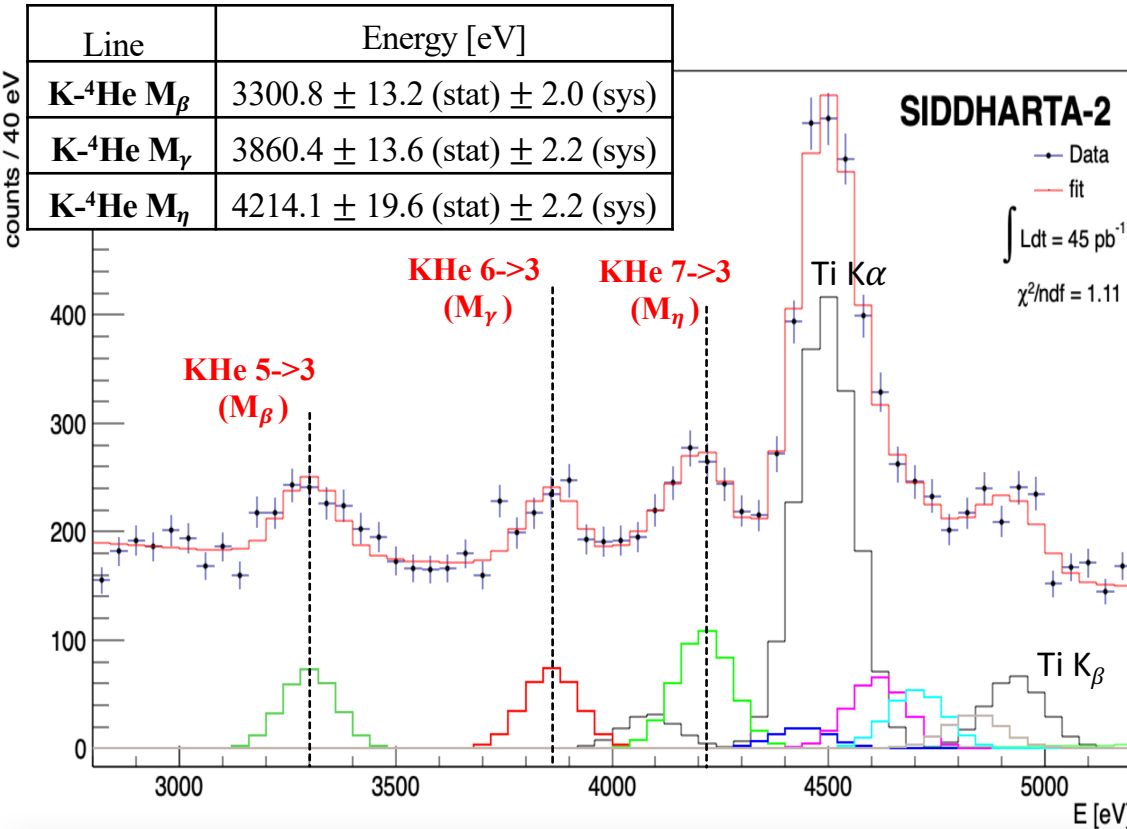
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# The Kaonic $^4\text{He}$ – M-series transitions (2022)

First observation and measurement of kaonic helium M-series transition

New experimental data for cascade models calculations

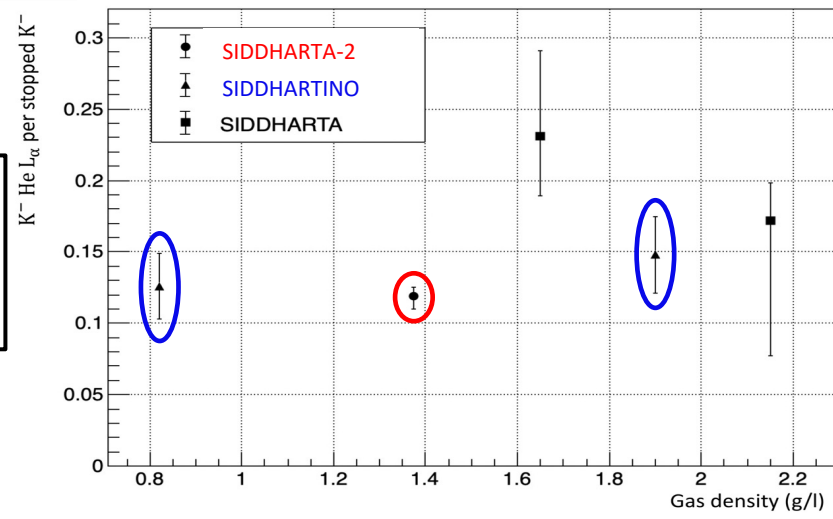
The X-ray yield is the key observable to understand the de-excitation mechanism in kaonic atoms and develop more accurate kaonic atoms cascade models.



Density	1.375 g/l
$L_{\alpha}$ yield	$0.119 \pm 0.002 \text{ (stat)}^{+0.006 \text{ (sys)}_{-0.009 \text{ (sys)}}$
$M_{\beta}$ yield	$0.026 \pm 0.003 \text{ (stat)}^{+0.010 \text{ (sys)}_{-0.001 \text{ (sys)}}$
$L_{\beta} / L_{\alpha}$	$0.172 \pm 0.008 \text{ (stat)}$
$L_{\gamma} / L_{\alpha}$	$0.012 \pm 0.001 \text{ (stat)}$
$L_{\beta} / M_{\beta}$	$0.91 \pm 0.14 \text{ (stat)}$
$M_{\gamma} / M_{\beta}$	$0.48 \pm 0.11 \text{ (stat)}$
$M_{\delta} / M_{\beta}$	$0.43 \pm 0.12 \text{ (stat)}$

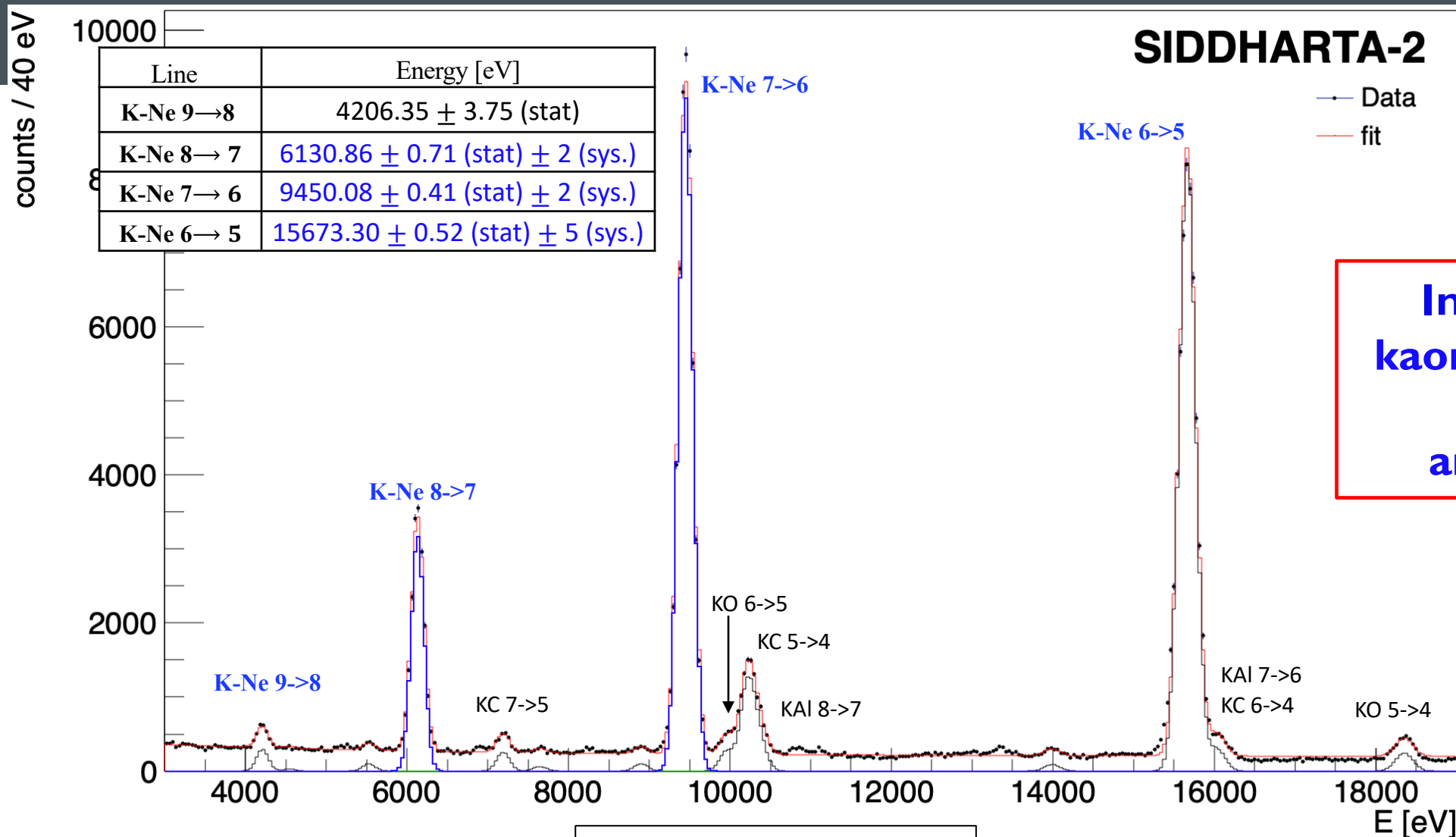
First measurement of  $\text{K}^{-4}\text{He}$  M-series transition

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



# The Kaonic Neon measurement (2023)

First measurement of kaonic neon X-ray transitions ( record of precision  $< 1$  eV )



Paper in preparation

# The (charged) Kaon mass puzzle and kaonic Neon

Kaon mass (K-Ne 8  $\rightarrow$  7 and K-Ne 7  $\rightarrow$  6) =  $493.671 \pm 0.021$  (stat) MeV  
 (stat. error  $\sim$  15 keV including the K-Ne 6  $\rightarrow$  5)

## Kaon mass discrepancy

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



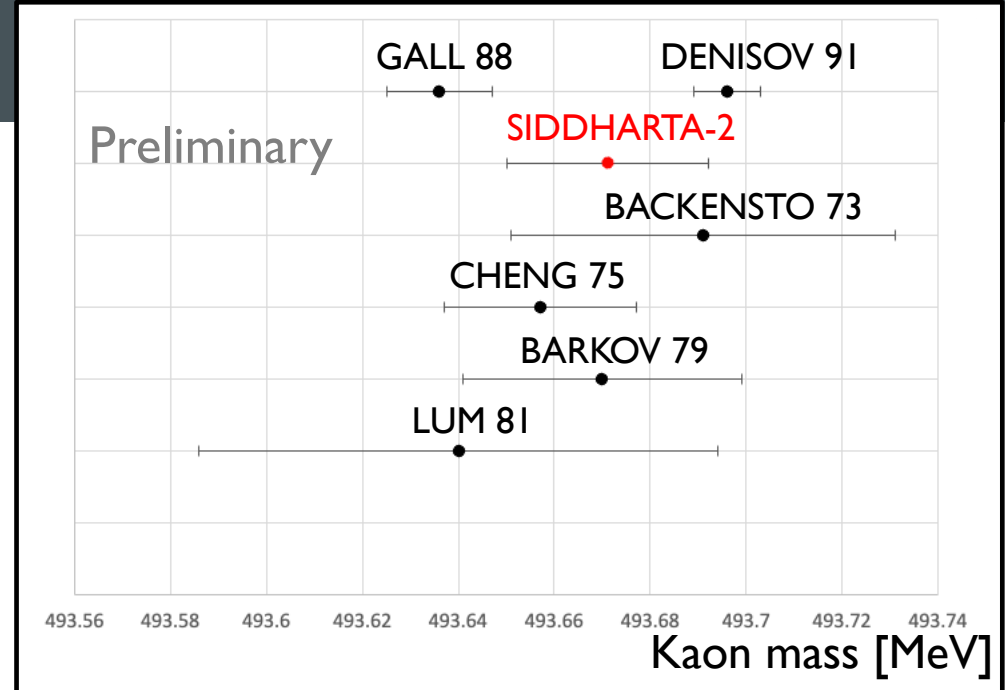
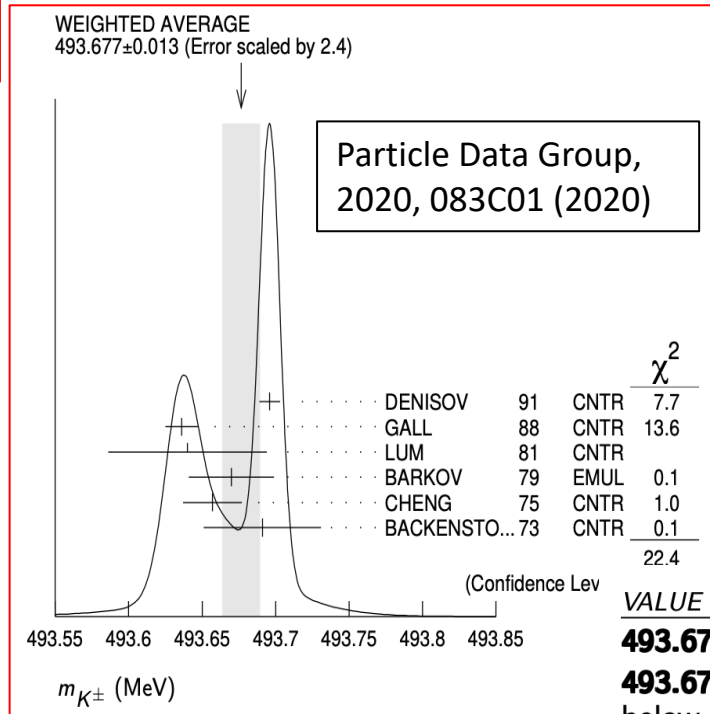
Less systematic uncertainty with respect to DENISOV 91 and GALL 88 measurements, thanks to the use of a low Z gas (Ne) target



It could solve the kaon mass discrepancy issue



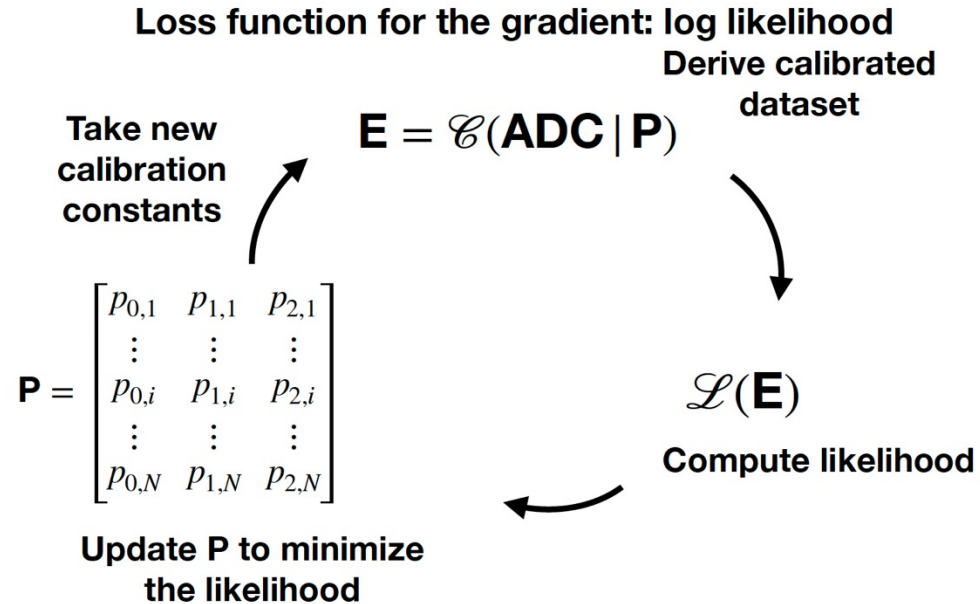
Impact on the charmonium spectrum and on all processes in which charged kaons are involved



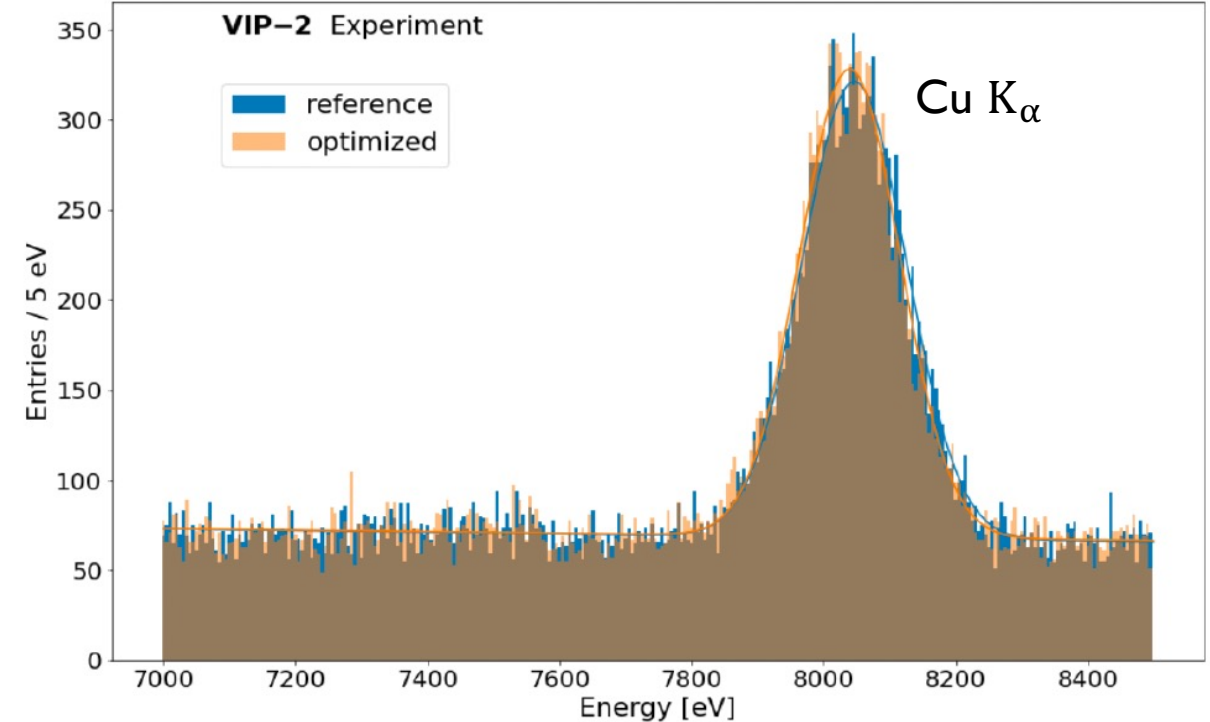
VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT
<b><math>493.677 \pm 0.016</math> OUR FIT</b>	Error includes scale factor of 2.8.			
<b><math>493.677 \pm 0.013</math> OUR AVERAGE</b>	Error includes scale factor of 2.4. See the ideogram below.			
$493.696 \pm 0.007$	<sup>1</sup> DENISOV	91	CNTR	— Kaonic atoms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

# SDD energy calibration with ML and Differential Programming

The method can correct for miscalibration improving the systematic error and the energy resolution allowing to perform high precision measurement with an accuracy below 1 eV



	Position [eV]	FWHM [eV]	$\chi^2/ndf$
Reference	$8050 \pm 1$	$185 \pm 2$	1.64
Optimized	$8048 \pm 1$	$176 \pm 2$	1.25



Fabrizio Napolitano et al 2023 Meas. Sci. Technol. in press <https://doi.org/10.1088/1361-6501/ad080a>

Fabrizio Napolitano and Simone Manti



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# Kaonic Lead Measurement at DAΦNE with HPGe

HPGe provided by Zagreb University (Croatian Science Foundation project 8570) to perform the kaonic lead measurement in parallel with the SIDDHARTA-2 kaonic deuterium measurement



- BSI HPGe detector with transistor reset preamplifier (TRP).
- DAQ based on CAEN DT578I digitizer
- Coincidence between:
  - > ch0 Luminometer
  - > ch1 HPGe signal
  - > ch2 TAC signal
- Data acquired:
  - > June-July 2023: 109.38 pb<sup>-1</sup>
  - > September-now 2023: 117.67 pb<sup>-1</sup>

# The Kaonic Lead Measurement (Zagreb Uni; Krakow, Jagiellonian Uni – Lumi)

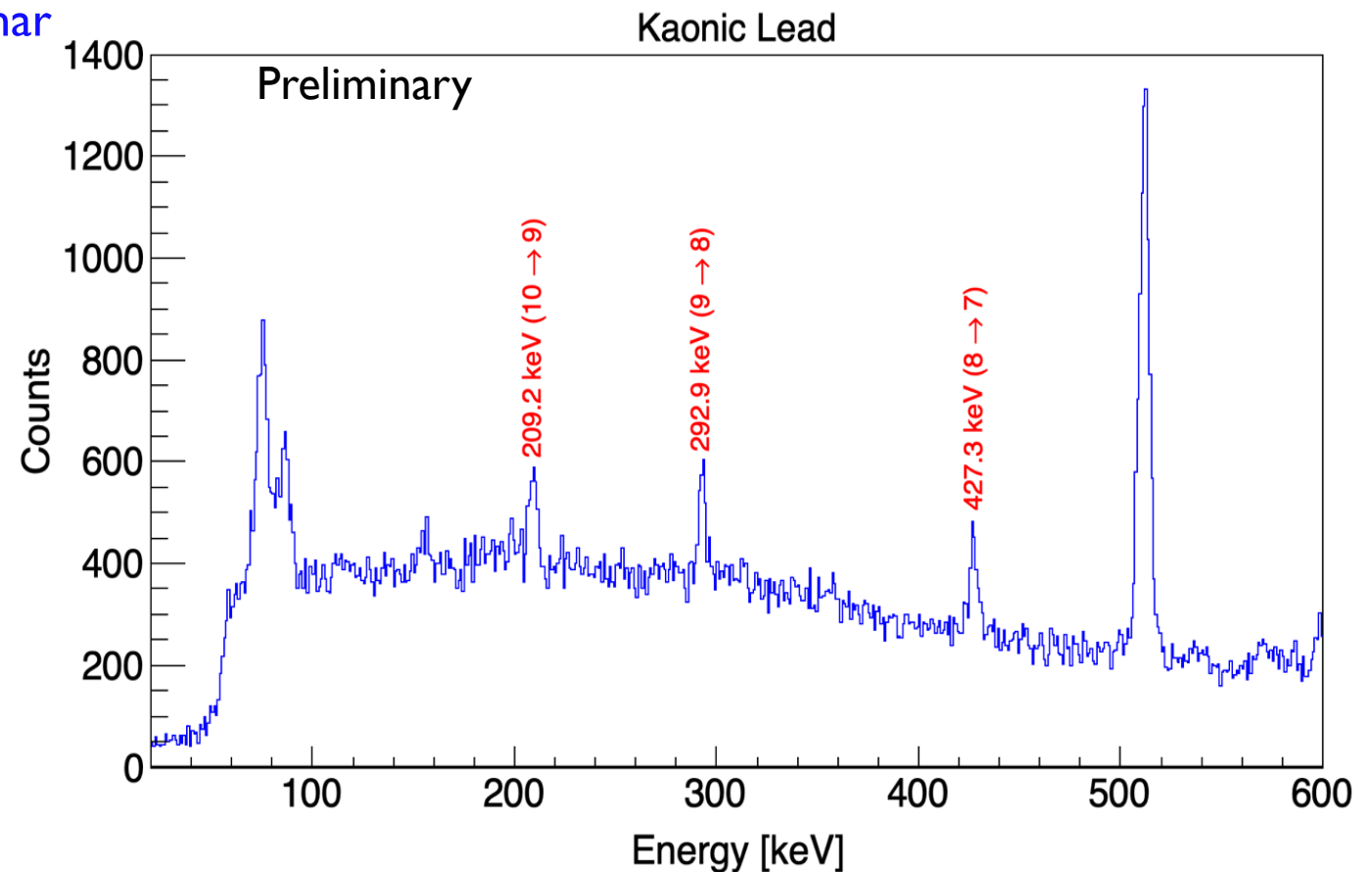
Integrated luminosity:  $109.38 \text{ pb}^{-1}$  (June – July 2023)

Preliminary analysis of June-July 2023 data (D. Bosnar and I. Friščić) :

Gaus+linear function was fitted for each peak:

- (10  $\rightarrow$  9) : 906 events in peak,  
position  $209.191 \pm 0.171 \text{ keV}$
- (9  $\rightarrow$  8) : 947 events in peak,  
position  $292.939 \pm 0.134 \text{ keV}$
- (8  $\rightarrow$  7) : 943 events in peak,  
position  $427.200 \pm 0.152 \text{ keV}$

Optimization and detailed analysis is in progress  $\rightarrow$  towards a publication



# CdZnTe detectors: first test at DAΦNE

## Detector Key Points:

High  
Fast

Find a journal Publish with us Search



L. Abbene, et al., *Sensors* 23 (2023) 17, 7328

Article

Home > The European Physical Journal Special Topics > Article

*Eur. Phys. J. Spec. Top.* **232**, 1487 (2023)

Regular Article | Published: 05 June 2023

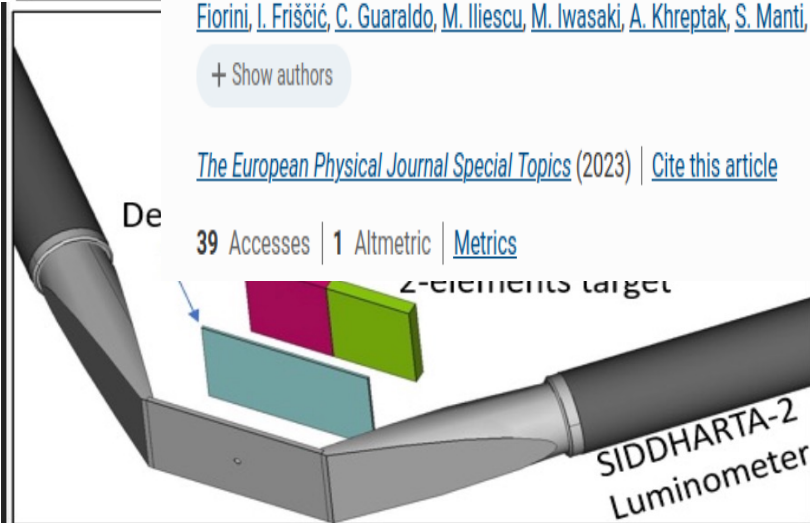
## New opportunities for kaonic atoms measurements from CdZnTe detectors

L. Abbene, M. Bettelli, A. Buttacavoli, F. Principato, A. Zappettini, C. Amsler, M. Bazzi, D. Bosnar, M. Bragadireanu, M. Cargnelli, M. Carminati, A. Clozza, G. Deda, L. De Paolis, R. Del Grande, L. Fabbietti, C. Fiorini, I. Friščić, C. Guaraldo, M. Iliescu, M. Iwasaki, A. Khreptak, S. Manti, J. Marton, ... C. Curceanu

+ Show authors

The European Physical Journal Special Topics (2023) | Cite this article

39 Accesses | 1 Altmetric | Metrics



Element	K-shell absorption energy (keV)		
Cd	26.7	$K\beta_1$	26.10
		$K\alpha_1$	8.54
Zn	9.7	$K\beta_1$	9.57
		$K\alpha_1$	27.47
Te	31.8	$K\beta_1$	31.00
			161
			8.4
			11.4
			69
			95

## Potentialities of Quasi-Hemispherical CdZnTe Detectors for Hard X-ray Spectroscopy of Kaonic Atoms at DAΦNE collider.

Leonardo Abbene<sup>1,3</sup>, Antonino Buttacavoli<sup>1,3\*</sup>, Fabio Principato<sup>1,3</sup>, Gaetano Gerardi<sup>1</sup>, Manuele Bettelli<sup>2</sup>, Andrea Zappettini<sup>2</sup>, Catalina Curceanu<sup>3</sup>, F. Sirghi<sup>3</sup> and Alessandro Scordo<sup>3</sup>

<sup>1</sup> Department of Physics and Chemistry (DiFC) - Emilio Segrè, University of Palermo, Viale delle Scienze, Edificio 18, Palermo, 90128, Italy; antonino.buttacavoli@unipa.it (A.B.); fabio.principato@unipa.it (F.P.); donato.cascio@unipa.it (D.C.); giuseppe.raso@unipa.it (G.R.); gaetano.gerardi@unipa.it (G.G.);

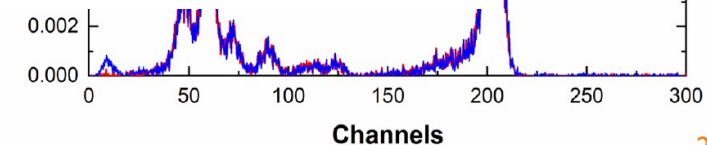
<sup>2</sup> IMEM/CNR, Parco Area delle Scienze 37/A, Parma 43100, Italy; manuele.bettelli@imem.cnr.it (M.B.); andrea.zappettini@imem.cnr.it (A.Z.);

<sup>3</sup> INFN-LNF, Istituto Nazionale di Fisica Nucleare-Laboratori Nazionali di Frascati, Frascati, 00044 Roma, Italy

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Received: date; Accepted: date; Published: date

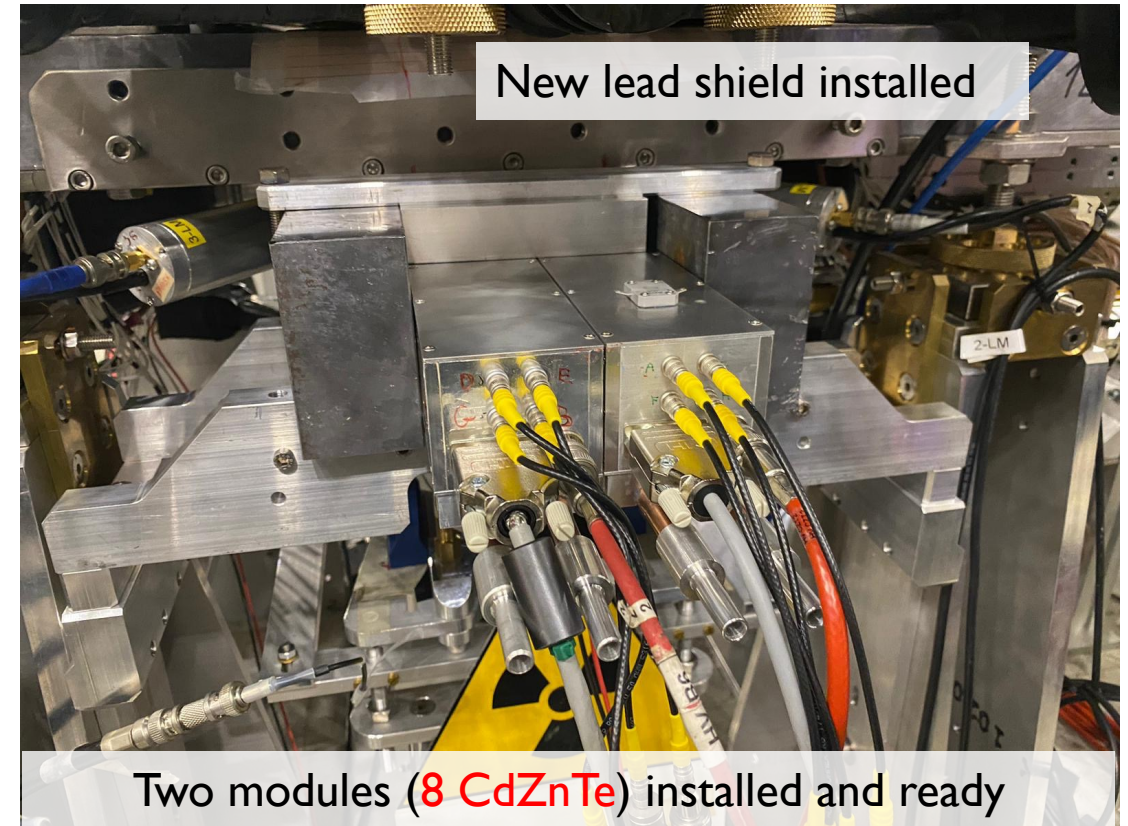
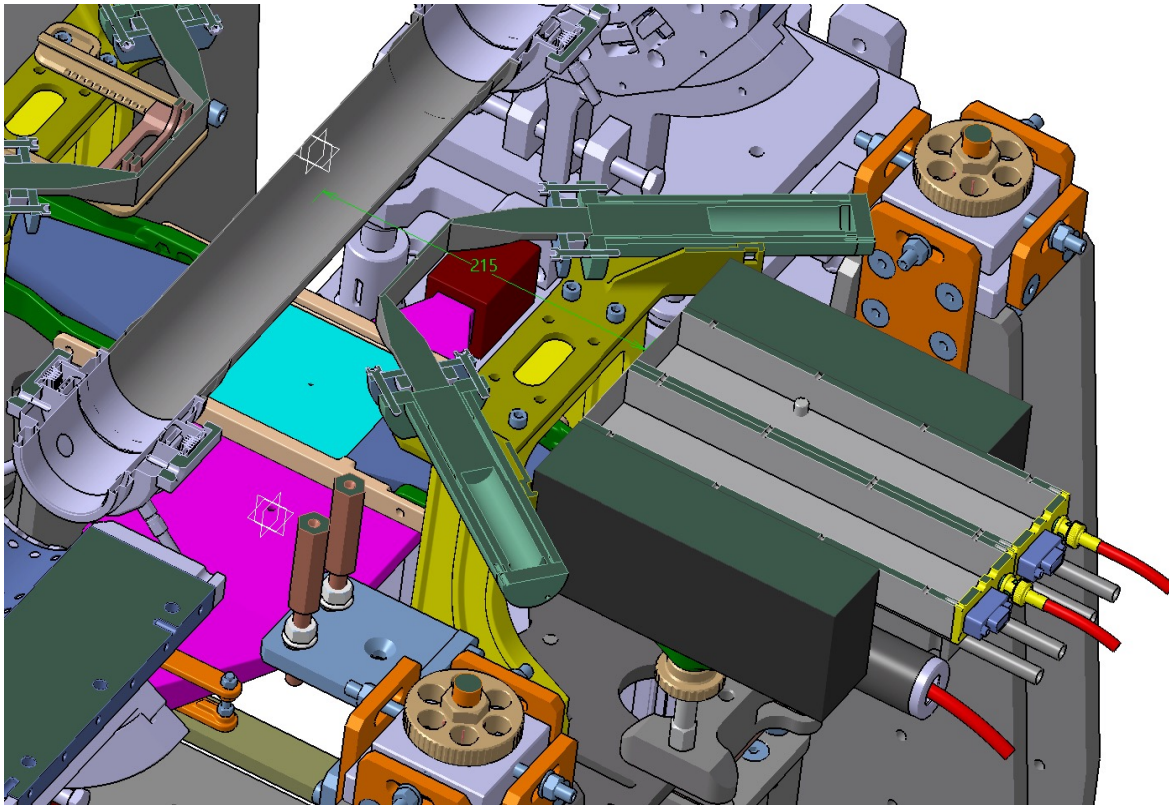
**Abstract:** Kaonic atom X-ray spectroscopy is a consolidated technique for investigations on kaon-nucleus strong interactions. Recent research activities are focusing on precise and accurate measurements of hard X rays from intermediate kaonic atoms (carbon, aluminium, sulphur). In this framework, we proposed and developed a room temperature digital spectrometer, based on a new quasi-hemispherical CZT detector, for high-resolution measurements of hard X rays from intermediate kaonic atoms (> 30 keV). The detector allows good room temperature performance, with energy resolution FWHM of 4.4 % (2.6 keV), 3 % (3.7 keV) and 1.4 % (9.3 keV) at 59.5 keV, 122.1 keV and 662 keV, respectively. The results from X-ray measurements at the DAΦNE collider at the INFN National Laboratories of Frascati (Italy) will be presented, with particular attention to the effects and the rejection of electromagnetic and hadronic background.



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DAΦNE

# CdZnTe detectors: next run with 16 cm<sup>2</sup>

16 cm<sup>2</sup> CdZnTe detectors to perform X-ray spectroscopy of **kaonic carbon and aluminium** in parallel with SIDDHARTA-2 kaonic deuterium run (L. Abbene, A. Buttacavoli, F. Principato, A. Scordo)



Two modules (8 CdZnTe) installed and ready

MCarlo: For KAl (4→3) with 10% yield we expect :  
10 (signal) ev/pb<sup>-1</sup>



Università  
degli Studi  
di Palermo

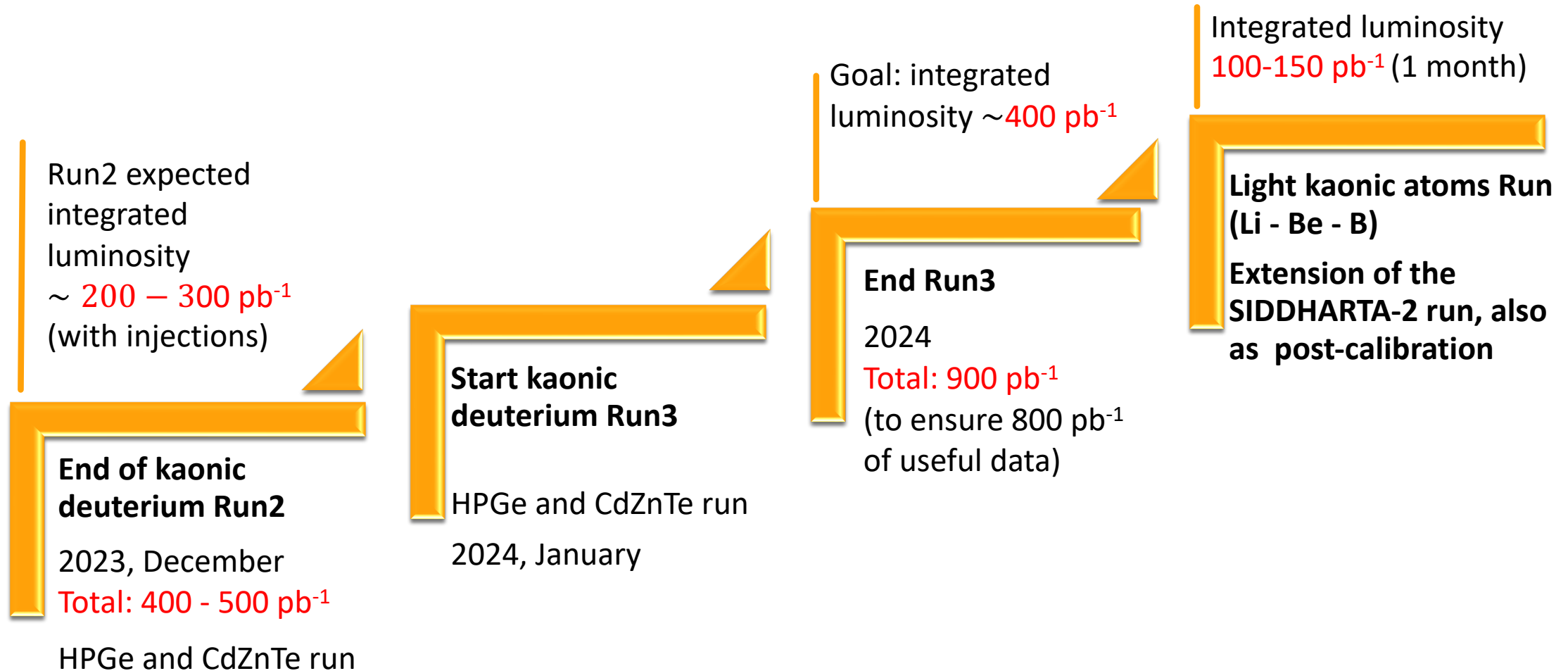
unipa



Istituto dei Materiali per l'Electronica ed il Magnetismo  
Consiglio Nazionale delle Ricerche

# Project Timeline – Future plans

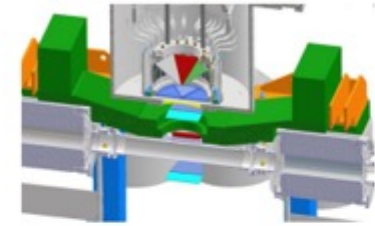
- First run with SIDDHARTA-2 optimized setup for  $200 \text{ pb}^{-1}$  integrated luminosity: May – July 2023 - **completed**
- Second run Autumn – Winter 2023 goal: estimated  $200\text{-}300 \text{ pb}^{-1}$  ongoing
- Third run 2024 – goal:  $400 \text{ pb}^{-1}$
- Calibration: solid targets – Li, B, Be –  $100\text{-}150 \text{ pb}$



**We reiterate the request for an extension of SIDDHARTA-2 run with solid targets (post calib) using also 1 mm SDDs**

The energy spectra of light kaonic atom transitions for Li, Be and B can achieve a precision below 2-3 eV, for an integrated luminosity of about 100-150 pb<sup>-1</sup>; kaon-multi-nucleon, L(1405)...

**1mm SDDs and target materials financed – construction ongoing**



**Light Kaonic Atoms  
Measurements  
with  
SIDDHARTA-2  
after Kd run**

*July 2021*

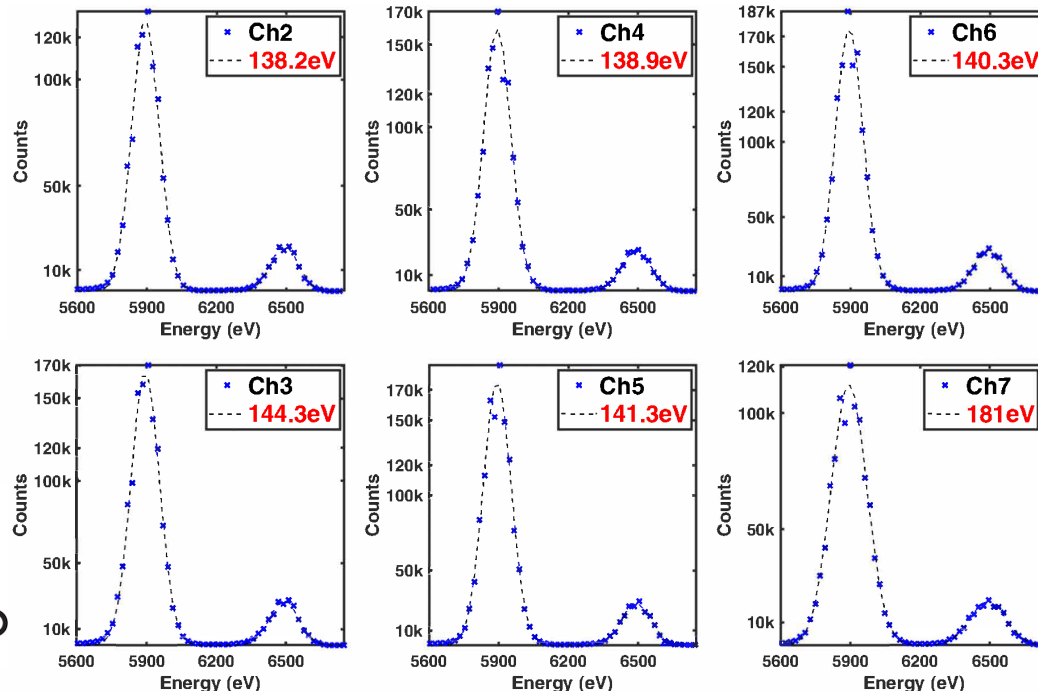
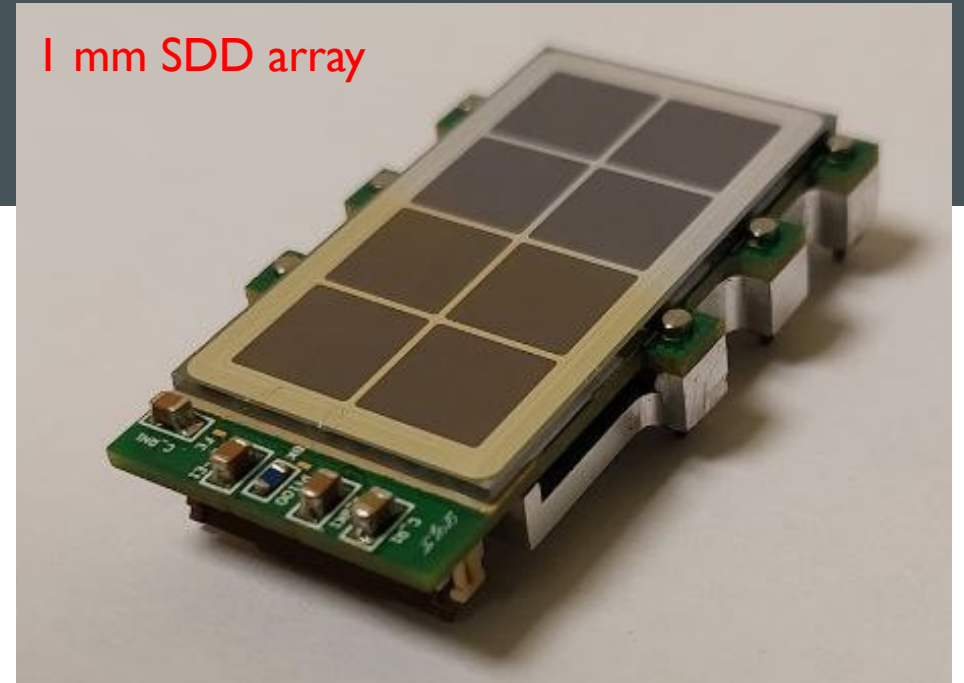
*The SIDDHARTA-2 Collaboration*



## Single SDD Module: the Prototype Design

SDD monolithic array (designed and produced by Fondazione Bruno Kessler, FBK):

- $2 \times 4$  matrix, square pixels, each one having active area of  $8 \times 8$  mm<sup>2</sup>;
- **1-mm-thick, total chip dimensions are 20 mm  $\times$  36 mm;**



Spectroscopic measurements with a first prototype with partially working channels:

- irradiation with an  $^{55}\text{Fe}$  X-ray source;
- detector temperature:  $-30^\circ\text{C}$ ;
- spectra acquired with **SFERA APP**, shaping time  $6\ \mu\text{s}$ ;
- **best energy resolution @5.9keV (Mn- $K\alpha$  peak): 138.2 eV, (channel 2).**



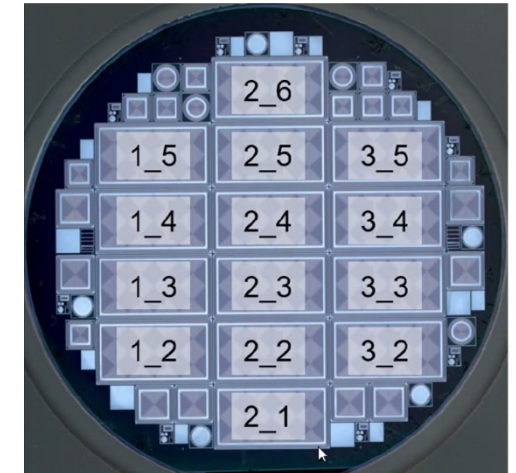
# Light kaonic atoms measurement with SIDDHARTA-2

The energy spectra of light kaonic atom transitions for Li, Be and B can achieve a precision below 2-3 eV, for an integrated luminosity of about 100-150 pb<sup>-1</sup>;

Use of present SDDs + 1mm SDDs and target materials financed – construction ongoing

## SDD 1mm detector

Multi element target (Li, Be, B) under construction  
financed by INFN (gr 3)



- Production run very successfully concluded at FBK: test of all the devices with automatic probers – **completed**
- First SDD samples delivered to PoliMi – July 2023
- Development of the new PCB and DAQ on going

kaonic Lithium-6 3-->2 transition = 15.08 keV  
kaonic Lithium-6 4-->3 transition = 5.28 keV

kaonic Lithium-7 3-->2 transition = 15.3 keV  
kaonic Lithium-7 4-->3 transition = 5.34 keV

kaonic Beryllium 9 3-->2 transition = 27.56 keV  
kaonic Beryllium 9 4-->3 transition = 9.64 keV  
kaonic Beryllium 9 5-->4 transition = 4.46 keV

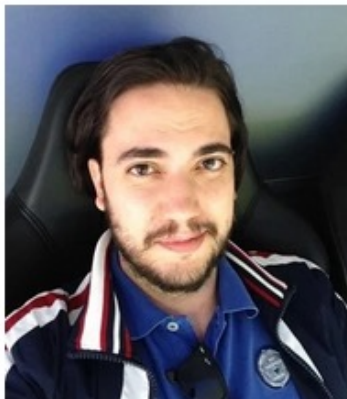
## Good news about SIDDHARTA folks:

### FRANCESCO SGARAMELLA: BEST YOUNG TALK AT HIGH PRECISION X-RAY MEASUREMENTS 2023, JUNE 2023, FRASCATI

8 August 2023

#### **Condensed Matter Best Young Researchers Presentation Award at High-Precision X-ray Measurements 2023 Conference—Winners Announced**

We are pleased to announce the winners of the Best Young Researchers Presentation Award that *Condensed Matter* (ISSN: 2410-3896) sponsored at the High-Precision X-ray Measurements 2023 conference, held from 19 to 23 June 2023, in Frascati, Italy. Congratulations to the three winners!



**Name:** Francesco Sgaramella

**Affiliation:** Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali di Frascati (INFN-LNF), Italy

**Presentation:** High-Precision Kaonic Atom X-ray Spectroscopy with SIDDHARTA-2 Experiment using the DAΦNE Collider

## Good news about SIDDHARTA folks:

**MARLENE TUECHLER:** "PROBING THE STRONG INTERACTION WITH KAONIC ATOM X-RAY MEASUREMENTS AT LOW ENERGIES", PH. D. THESIS AT VIENNA UNIVERSITY, JUNE 13TH, 2023, WITH THE HIGHEST QUALIFICATIONS



## Good news about SIDDHARTA folks:

**FRANCESCO ARTIBANI AND FRANCESCO CLOZZA**  
FROM LA SAPIENZA UNIVERSITY – FINALIZING THEIR MASTER THESES IN  
SIDDHARTA-2

PH D STUDENTS:  
FROM TOKOKU JAPAN: **TOHO KAIRO**  
PH D: **FRANCESCO ARTIBANI**



# Organized events

## Mini workshop on kaonic atoms: present status and future plans

18 July 2023  
Laboratori Nazionali di Frascati INFN  
Europe/Rome timezone

Enter your search term



ECT\*  
EUROPEAN CENTRE  
FOR THEORETICAL STUDIES  
IN NUCLEAR PHYSICS AND RELATED AREAS

## ROCKSTAR: Towards a Roadmap of the Crucial measurements of Key observables in Strangeness reactions for neutron sTARs equation of state

9–13 Oct 2023  
ECT\*  
Europe/Rome timezone

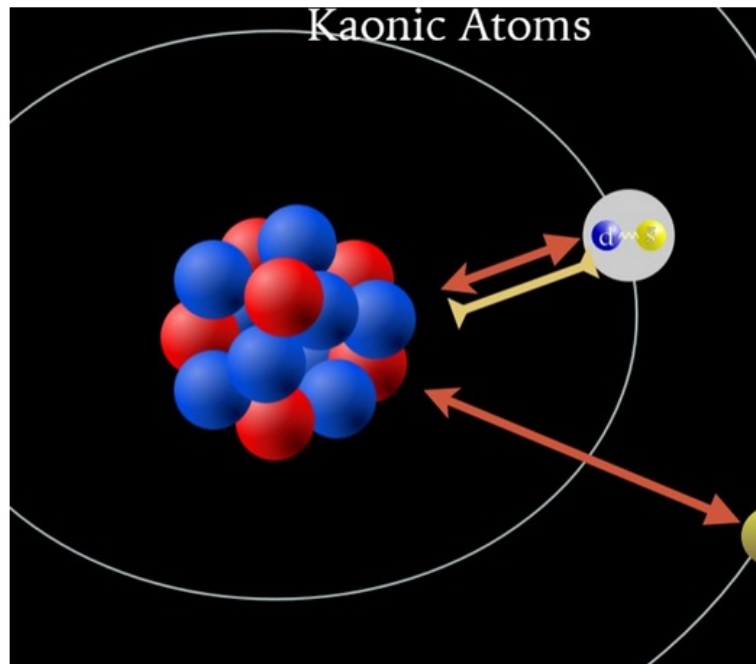
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- Overview
- Call for Abstracts
- Support
  - [✉ alessandra.tamborrino@inf.it](mailto:alessandra.tamborrino@inf.it)
  - [✉ alessandro.scordo@inf.it](mailto:alessandro.scordo@inf.it)

The mini-workshop has the aim to gather experimentalists and theorists working in the field of kaonic atoms, with particular application to kaonic atoms, to discuss the outcome of the ongoing experiments at DAFNE and plan future activities. The impact of kaonic atoms studies in particle and nuclear physics as well as in astrophysics and foundation of physics will be addressed.

The mini-workshop is organized with the support of the INFN-LNF, the Foundational Questions Institute (Grant No. FQXi-RFP-CPW-2008), the John Templeton Foundation (Grant 62099), the STROBE project (grant agreement No 824093), the MITIQO project n. A0375-2020-36647, "Gruppi di ricerca" - POR FESR Lazio 2014-2020 and FWF Austria.



- Overview
- Call for Abstracts
- Timetable
- Registration
- Contribution List
- Speaker List
- Book of Abstracts
- Participant List
- Privacy Information

Contact | Barbara Gazzoli

- [✉ staff@ectstar.eu](mailto:staff@ectstar.eu)
- [✉ gazzoli@ectstar.eu](mailto:gazzoli@ectstar.eu)



# Organized events

## KASP: Kaonic atoms between QED, QCD and beyond Standard Model physics research

28 November 2023  
Laboratori Nazionali di Frascati INFN  
Europe/Rome timezone

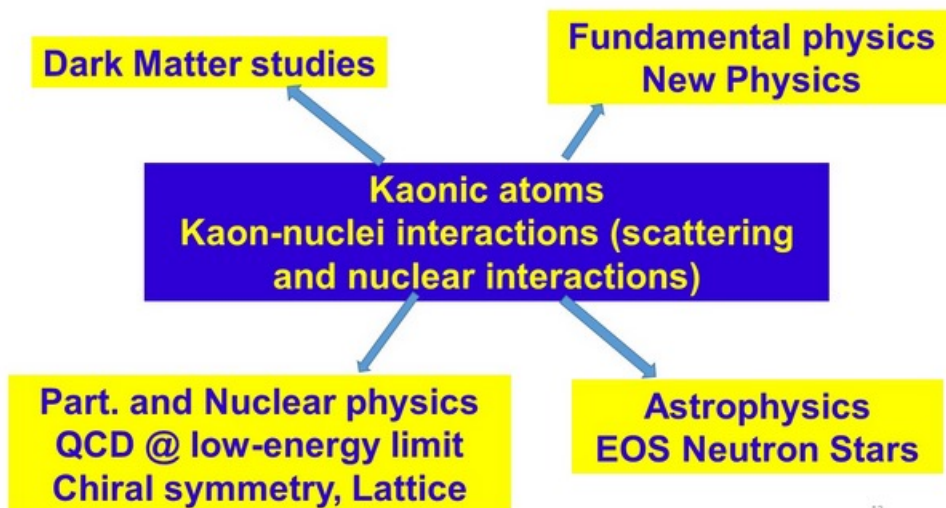
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Overview

Call for Abstracts  
Registration  
Participant List  
Internet Access  
Privacy Policy  
Safety rules  
Venue

Support

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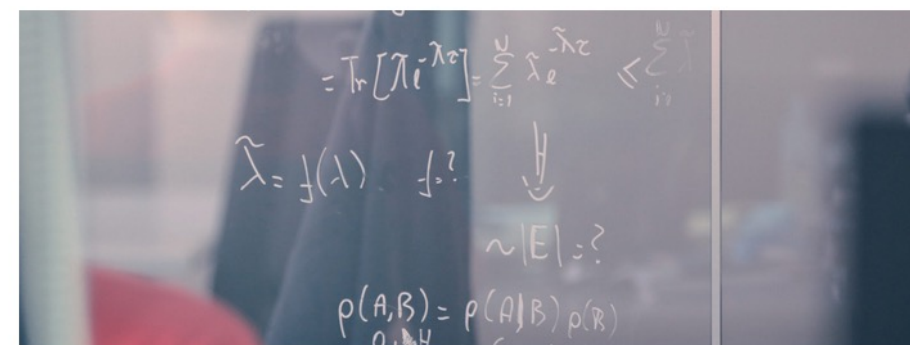
The symposium has the aim to gather experimentalists and theorists working in the field of exotic atoms, in particular in kaonic atoms, to discuss the outcome of the ongoing experiments in this sector and plan future activities. The impact of kaonic atoms studies in particle and nuclear physics, as well as in astrophysics and foundation of physics, with an excursus in beyond Standard Model physics search, will be addressed.



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## ALPACA: MODERN ALGORITHMS IN MACHINE LEARNING AND DATA ANALYSIS: FROM MEDICAL PHYSICS TO RESEARCH WITH ACCELERATORS AND IN UNDERGROUND LABORATORIES



20 November 2023 — 24 November 2023

# Contents

- 65<sup>th</sup> Scientific Committee recommendations and our related actions
- Kaonic Deuterium run: status and future plans
- (More) Scientific outcomes: highlights
- Updates on HPGe and CdZnTe detectors and preliminary results
- Request for supplementary run: light kaonic atoms (Li - Be - B) measurements with 1 mm SDDs
- **Future plans: EXKALIBUR**



# Future plans beyond SIDDHARTA-2: EXKALIBUR

proposal to perform fundamental physics at the strangeness frontier at DAFNE for a 3-years period (post-SIDDHARTA-2)

- detailed presentation at 62<sup>nd</sup> LNF Scientific Committee Meeting, November 8, 2021

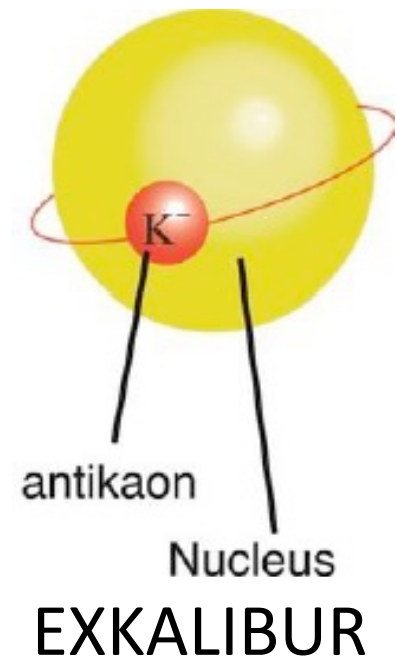
We propose to do precision measurements along the periodic table at DAFNE for:

- **Kaonic Hydrogen: 200 pb<sup>-1</sup> – with SIDDHARTA-2 setup – to get a precision < 10 eV (KH)**
- **Selected light kaonic atoms (LHKA)**
- **Selected intermediate and heavy kaonic atoms charting the periodic table (IMKA)**
- **Ultra-High precision measurements of Kaonic Atoms (UHKA)**

Dedicated runs with different types of detectors: **CZT detectors, HpGe, SDD 1mm, crystal HAPG spectrometer from VOXES project - MODULAR**

**Fundamental physics at the strangeness frontier at DAΦNE.**  
**Outline of a proposal for future measurements,**  
**C. Curceanu et al., Front.in Phys. II (2023) 1240250**  
**Members of Sci Com: [document and letters support](#)**

**EX**tensive  
**Ka**onic  
**A**toms research:  
from  
**L**ithium and  
**B**eryllium to  
**UR**anium



Letters of support for EXKALIBUR  
Fundamental physics at the strangeness frontier at the  
DAΦNE Collider

October 30, 2023

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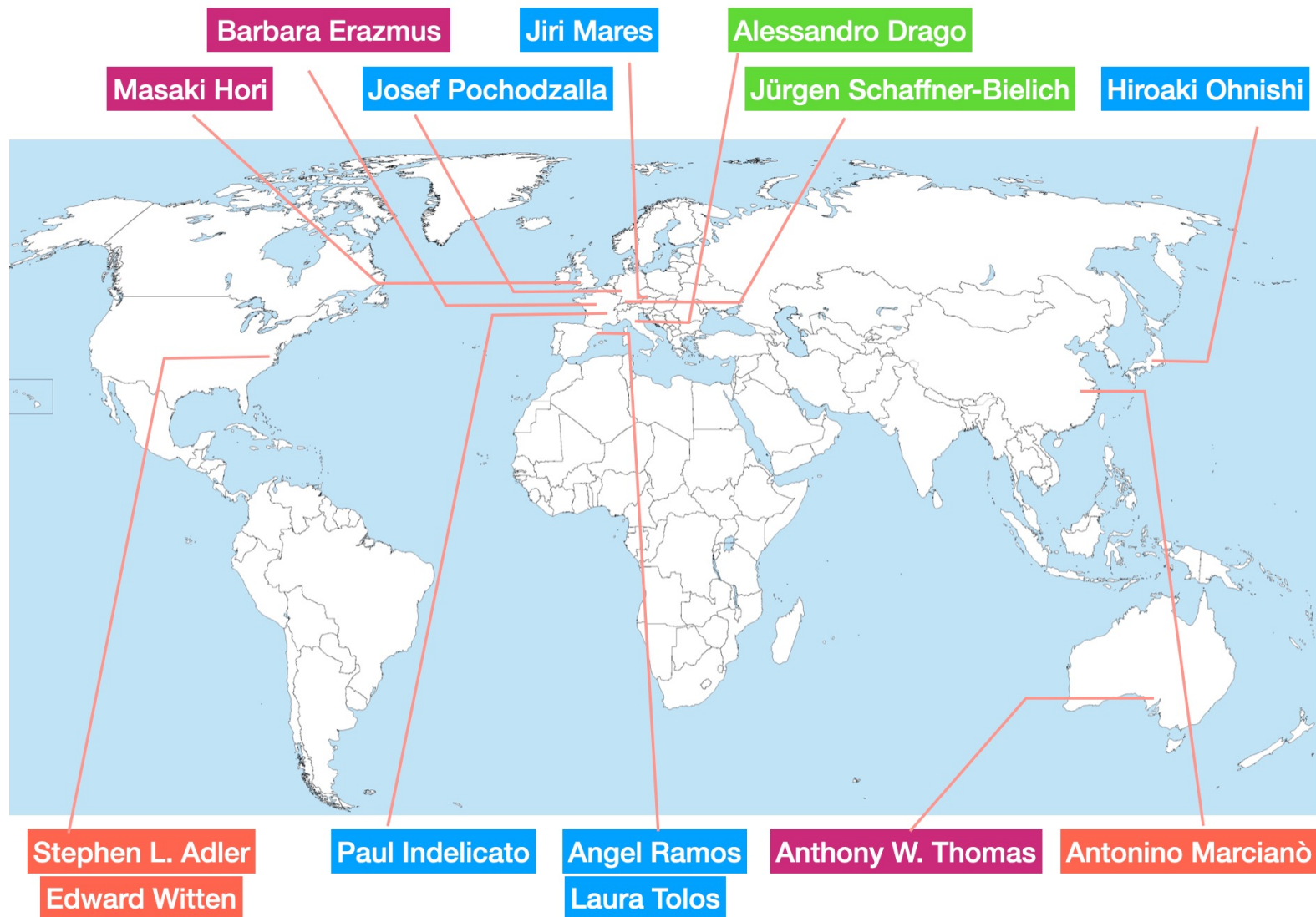
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### Nuclear Physics

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- Angel Ramos
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**Kaonic Atoms to Investigate Global Symmetry Breaking** *Symmetry* 12 (2020) 4, 547

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

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

**Fundamental physics New Physics**

### Fundamental Physics

- Edward Witten
- Stephen L. Adler
- Antonino Marcianò

### Particle Physics

- Barbara Erazmus
- Anthony W. Thomas
- Masaki Hori

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

**Dark Matter studies**

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

**Astrophysics**  
**EOS Neutron Stars**

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

### Astrophysics

- Jürgen Schaffner-Bielich
- Alessandro Drago

27 September 2023

Laboratori Nazionali di Frascati dell'INFN  
Via Enrico Fermi 40  
00044 Frascati, Roma

Dear Dr. Fabio Bossi;

Herewith our group would like to express our strong interest to carry out a new experiment in the DAΦNE collider called "Laser spectroscopy of kaonic helium and sub-ppm scale determination of the charged kaon mass". The aim of this small experiment is to synthesize metastable kaonic helium atoms using the low-energy negative kaons available at your facility, and to irradiate the atoms with high-power, high repetition rate laser beams and observe the resulting resonance of the laser-induced transition of the kaonic orbital. By comparing the results with quantum electrodynamics calculations, the kaon mass can be determined with a factor 100 higher precision than now. This is a logical extension of our previous successful experiments on antiprotonic helium atoms at CERN [*Science* 354, 610 (2016)] for which we determined the antiproton mass to a precision of  $8 \times 10^{-10}$ , and on pionic helium atoms at Paul Scherrer Institute [*Nature* 581, 37 (2020)]. The experiment will utilize the latest quantum optics techniques and will allow an exploration of quantum electrodynamics for systems that include the strange quark at heretofore unprecedented,  $10^{-7}$  scale or better precision. The kaon mass is extremely important as it currently limits the masses of other mesons such as the D mesons. Limits will be set on possible physics beyond the Standard Model, including fifth forces that may couple to strangeness. It will also become the first experiment to achieve laser excitation of an object containing the strange quark and the first one to carry out laser spectroscopy in a collider. For this experiment, DAΦNE would be operated in single-bunch mode. We are ready to apply for funding in the UK to help with this necessary accelerator R&D.

Sincerely yours,



Dr. habil Masaki Hori  
High Energy Physics Group  
Physics Department  
Imperial College London

# NEW EXPERIMENTAL PROPOSAL

Herewith our group would like to express our strong interest to carry out a new experiment in the DAΦNE collider called "Laser spectroscopy of kaonic helium and sub-ppm scale determination of the charged kaon mass". The aim of this small experiment is to synthesize metastable kaonic helium atoms using the low-energy negative kaons available at your facility, and to irradiate the atoms with high-power, high repetition rate laser beams and observe the resulting resonance of the laser-induced transition of the kaonic orbital.

The experiment will utilize the latest quantum optics techniques and will allow an exploration of quantum electrodynamics for systems that include the strange quark at heretofore unprecedented,  $10^{-7}$  scale or better precision.

# EXKALIBUR

EXKALIBUR proposes to conduct a series of **unique kaonic atom measurements** with a total integrated luminosity ranging from approximately 600 (but also 400) pb to 1500 pb. It is a feasible, comprehensive scientific program that can be executed modularly (i.e., over a few months each year) in the next 2-3 years, becoming **a global reference for research on strangeness**.

To be underlined that the program is elastic, and one can extend it from 400 pb to more than 1000, in various runs periods; **we are available for discussions and reschedule our plans function of machine and beam time availability**.

**Very significant physics measurements at the best possible machine**

# CONCLUSIONS & REQUESTS

- The first Run (Run I) of SIDDHARTA-2 Kd has been successfully; finalized Run 2 is ongoing; overall 300 pb up to now (including injections)
- We answered all issues/suggestions raised by 65<sup>th</sup> Sci Com
- We performed a preliminary analyses of first 200 pb Kd Run – very promising results!
- We finalized first KHe M-lines and KNe data analyses -> articles and test run for K mass
- We are implementing Machine Learning techniques for our data analyses – enhanced outcomes
- >10 articles were published/submitted since the last Sci Com, 3 are in preparation and > 10 invited talks
- We are ready and very motivated to continue and finalize the SIDDHARTA-2 (first) Kd measurement within summer 2024 (in parallel with test measurements with HPGe and CdZnTe)
- We plan to perform solid targets measurements with SIDDHARTA-2 (reinforced) setup for 100-150 pb<sup>-1</sup> after Kd run – as post-calibration (more infos @SC62)
- We reiterate our EXKALIBUR proposal – after SIDDHARTA-2 run – modular strangeness kaonic atoms measurements along the periodic table – support letters

*Special thanks to the accelerator, research and technical divisions, and in particular to the DAΦNE staff, to Cesidio Capoccia, and to the LNF Director*

