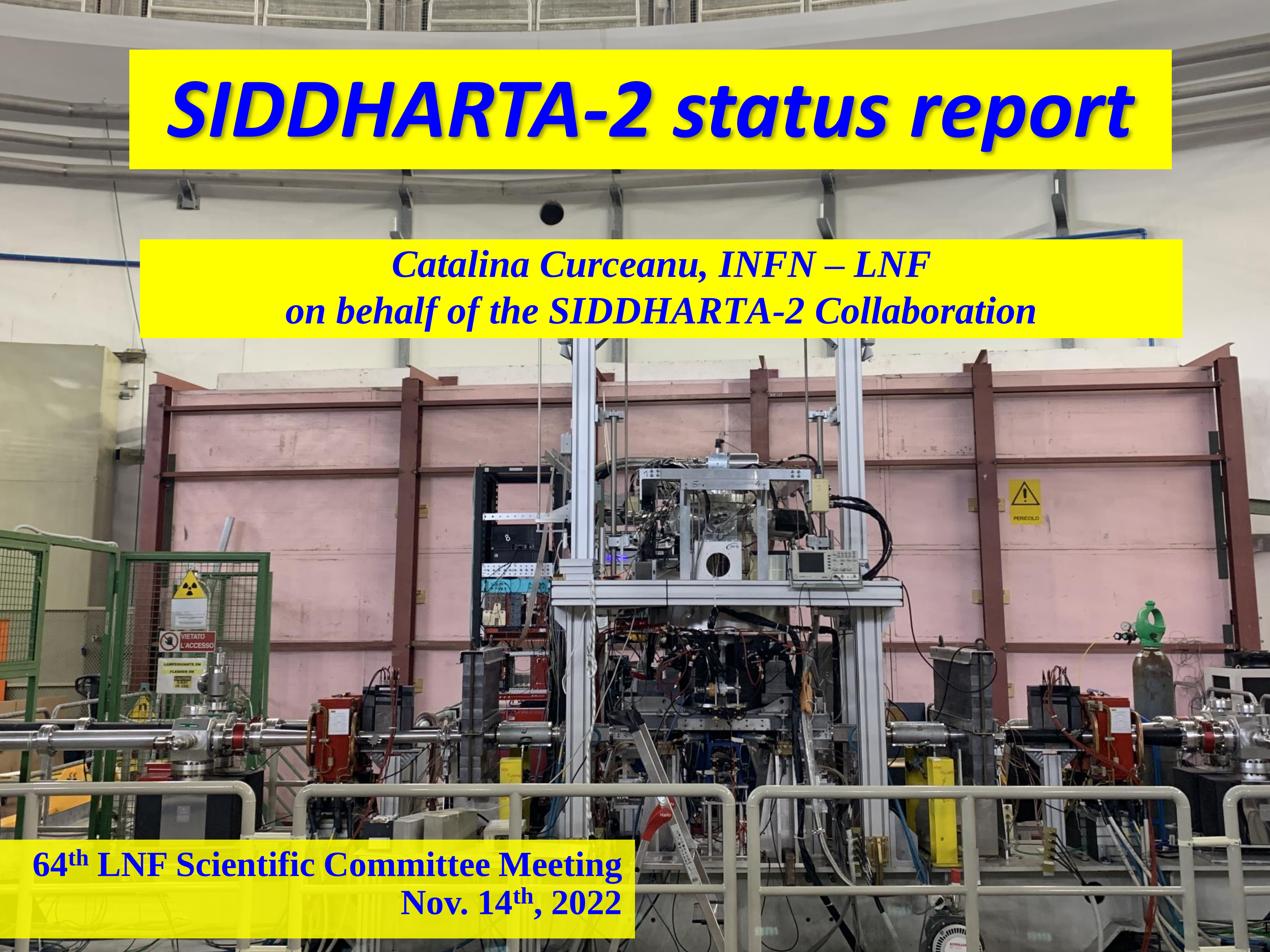
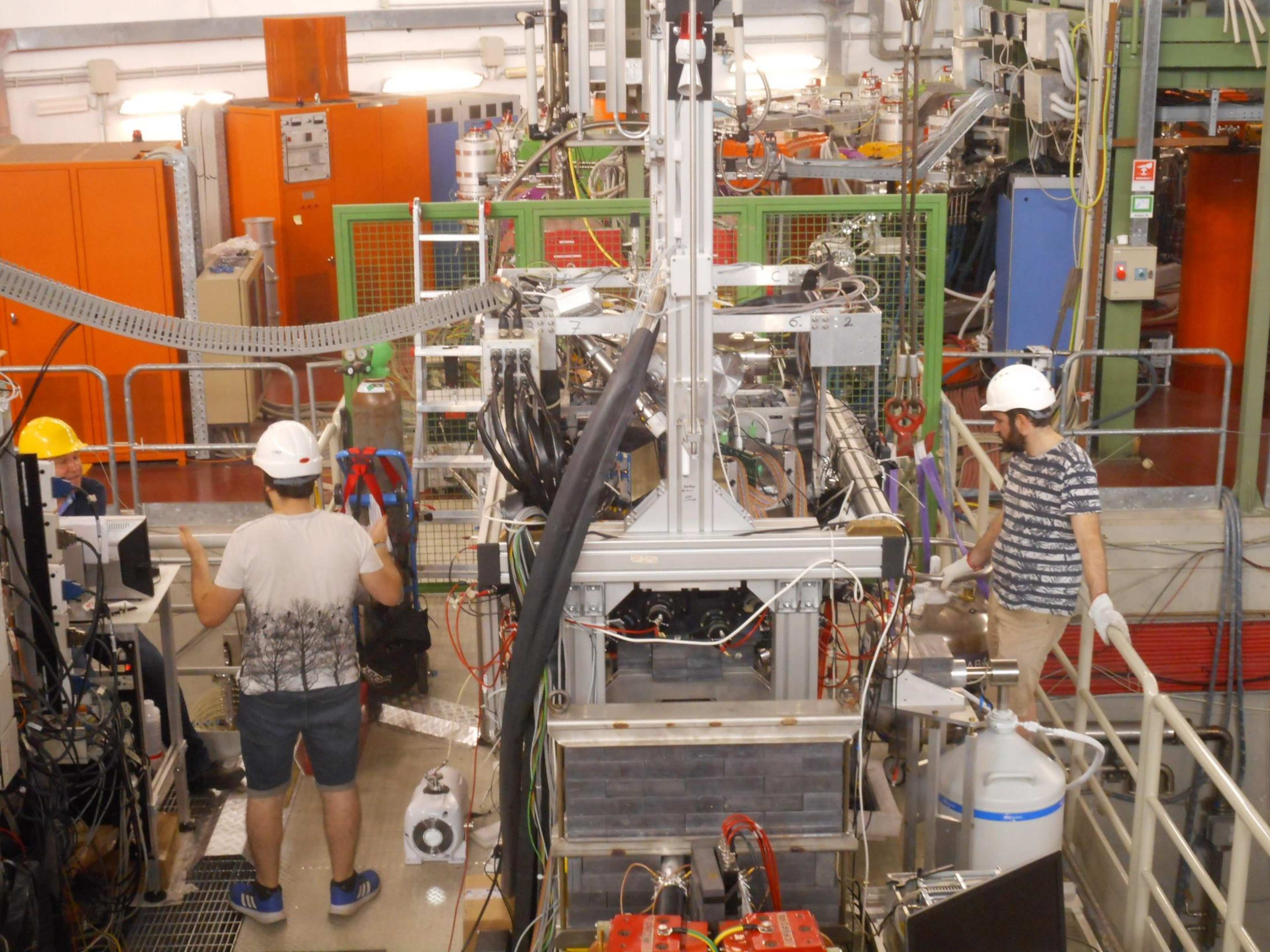
SIDDHARTA-2 status report

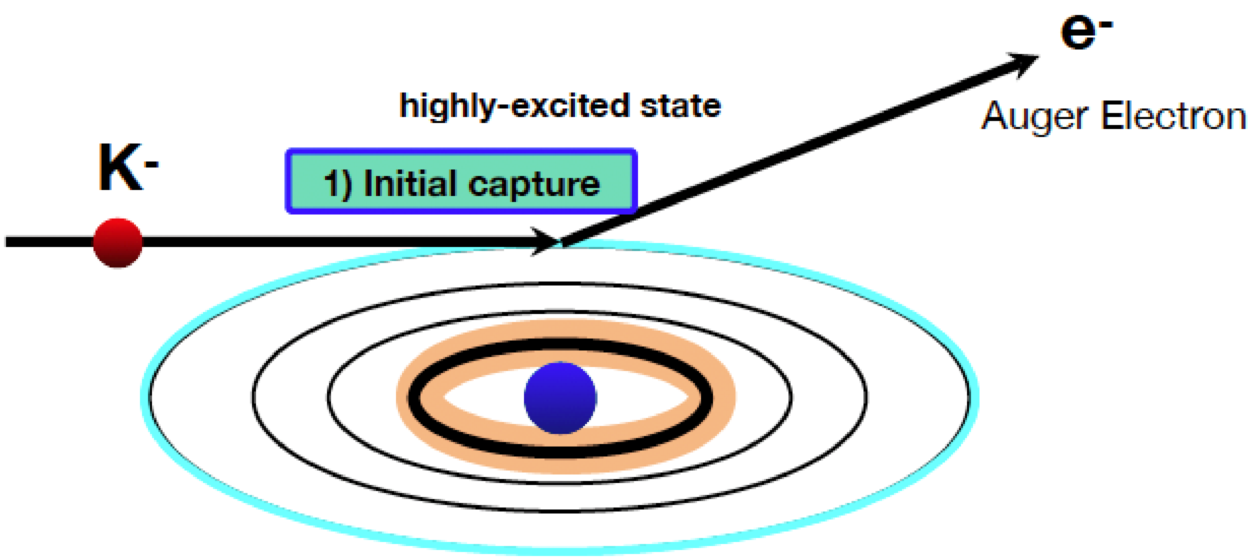
Catalina Curceanu, INFN – LNF
on behalf of the SIDDHARTA-2 Collaboration



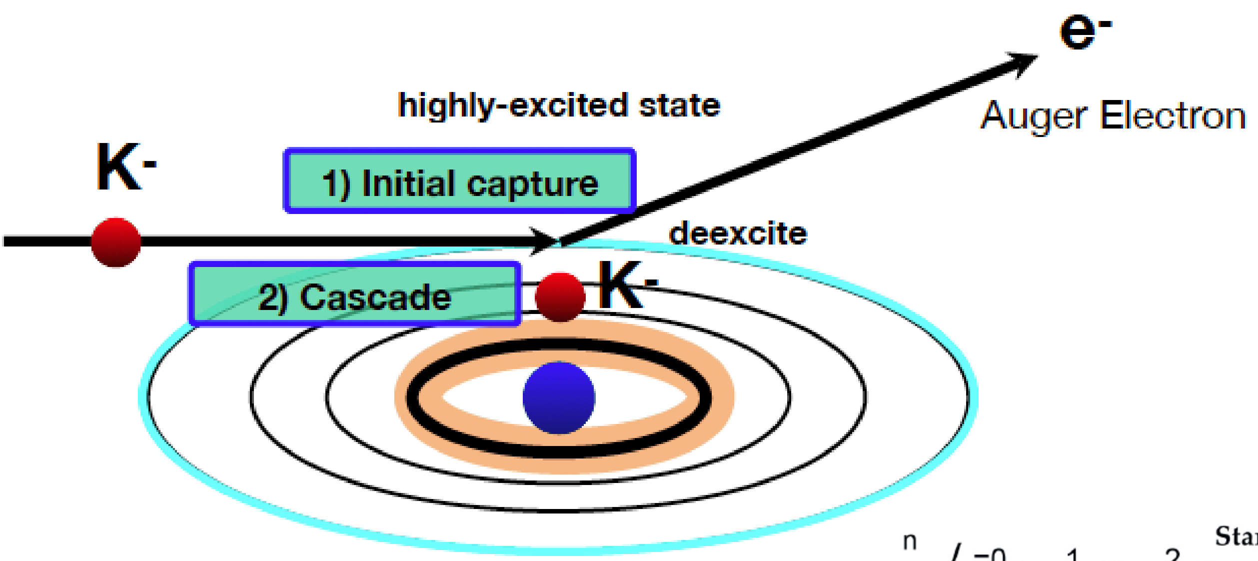
64th LNF Scientific Committee Meeting
Nov. 14th, 2022

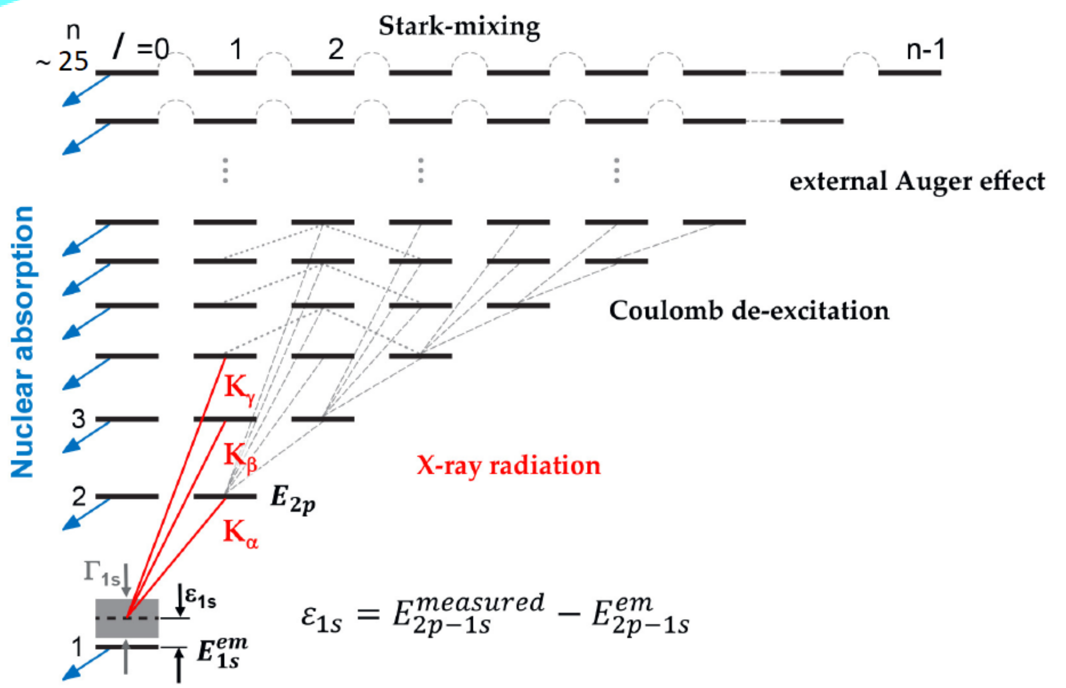


Kaonic atom Formation

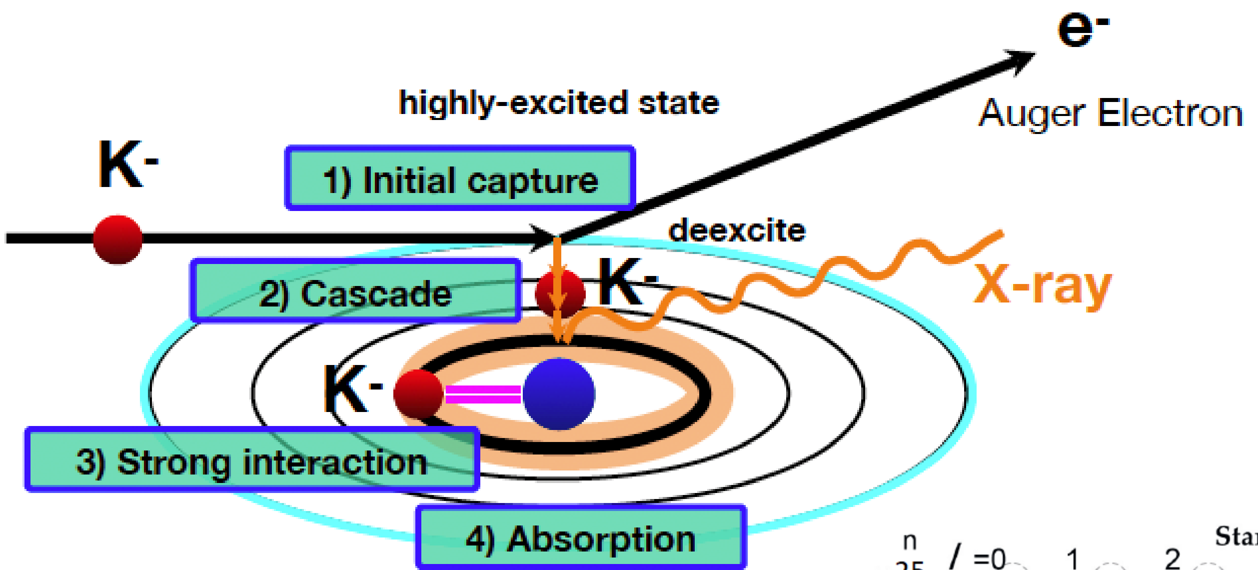


Kaonic atom Formation

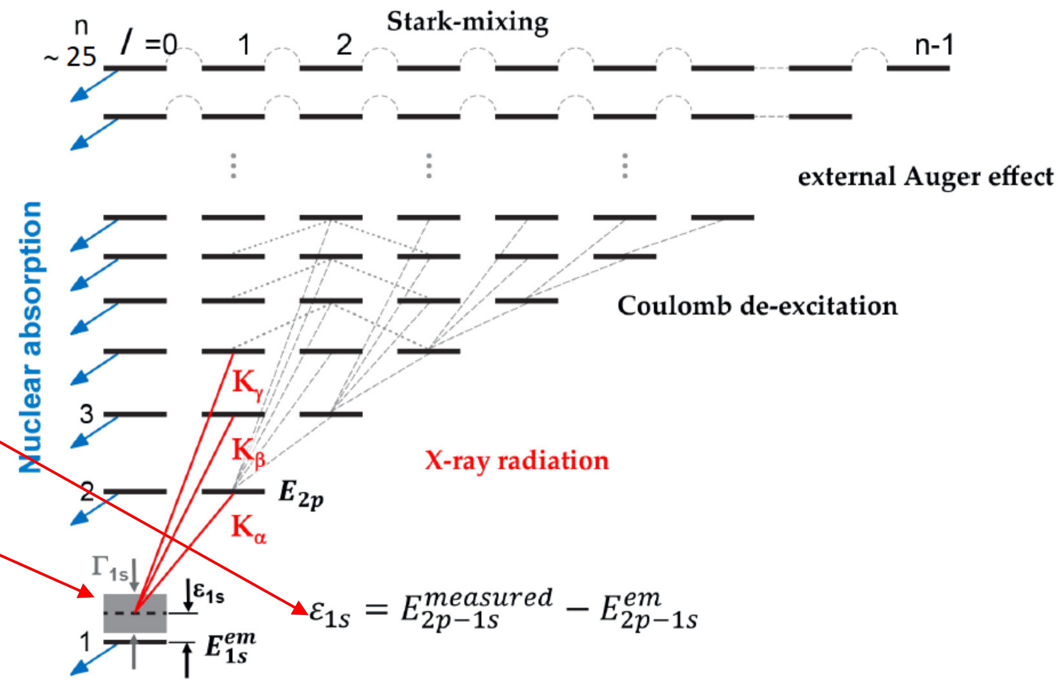




Kaonic atoms and the QCD effects



Width Γ and shift ε obtained by measuring the X-rays emitted



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

SIDDHARTA-2 Scientific Goal

To perform the *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.

SIDDHARTA-2 Scientific Goals

To perform the *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.

Analysis of the combined measurements of kaonic deuterium and kaonic hydrogen

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

(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

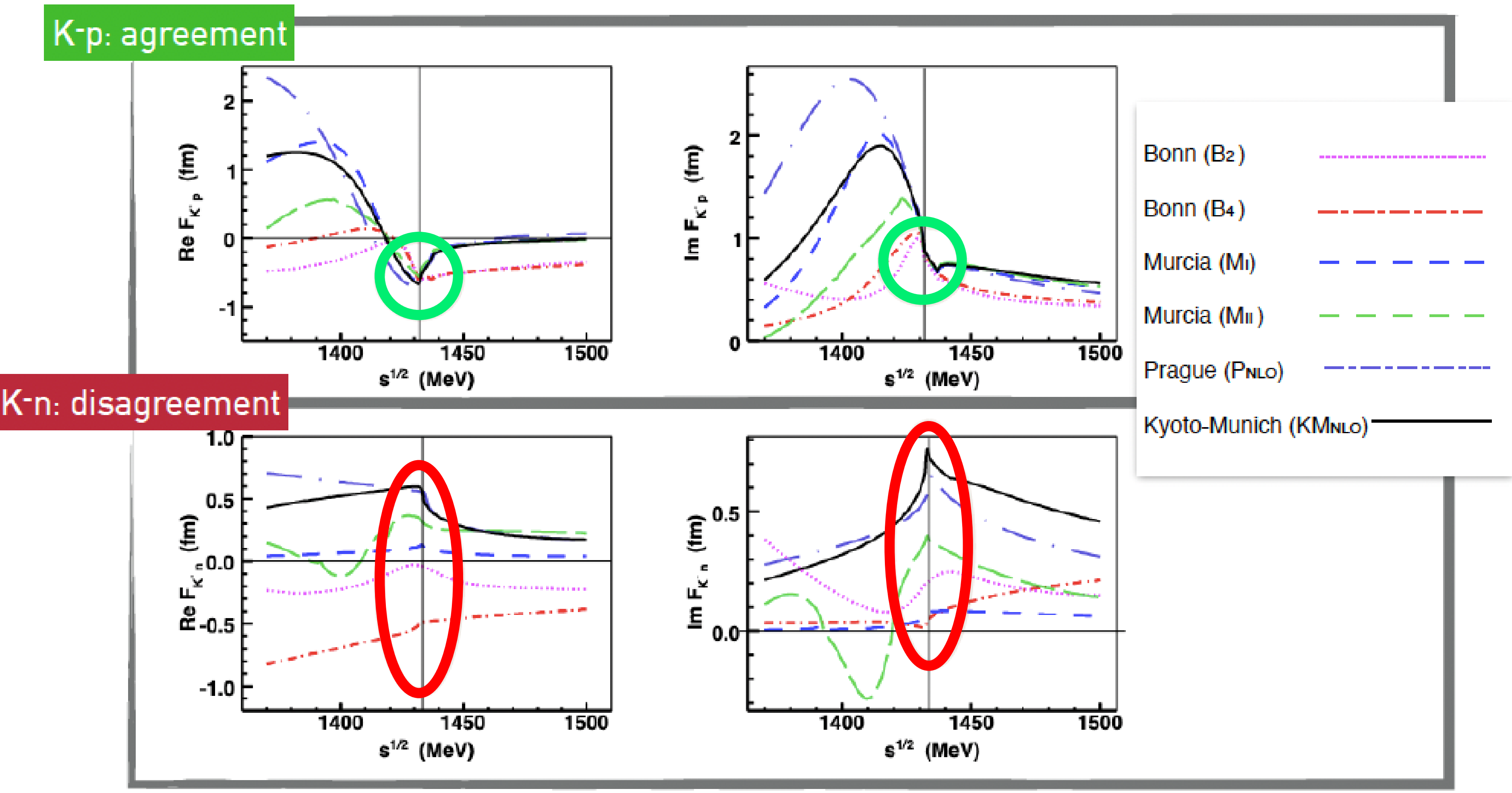
$$a_{K^-p} = \frac{1}{2}[a_0 + a_1]$$
$$a_{K^-n} = a_1$$

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

completely solve Isospin-dependent K-N scattering length

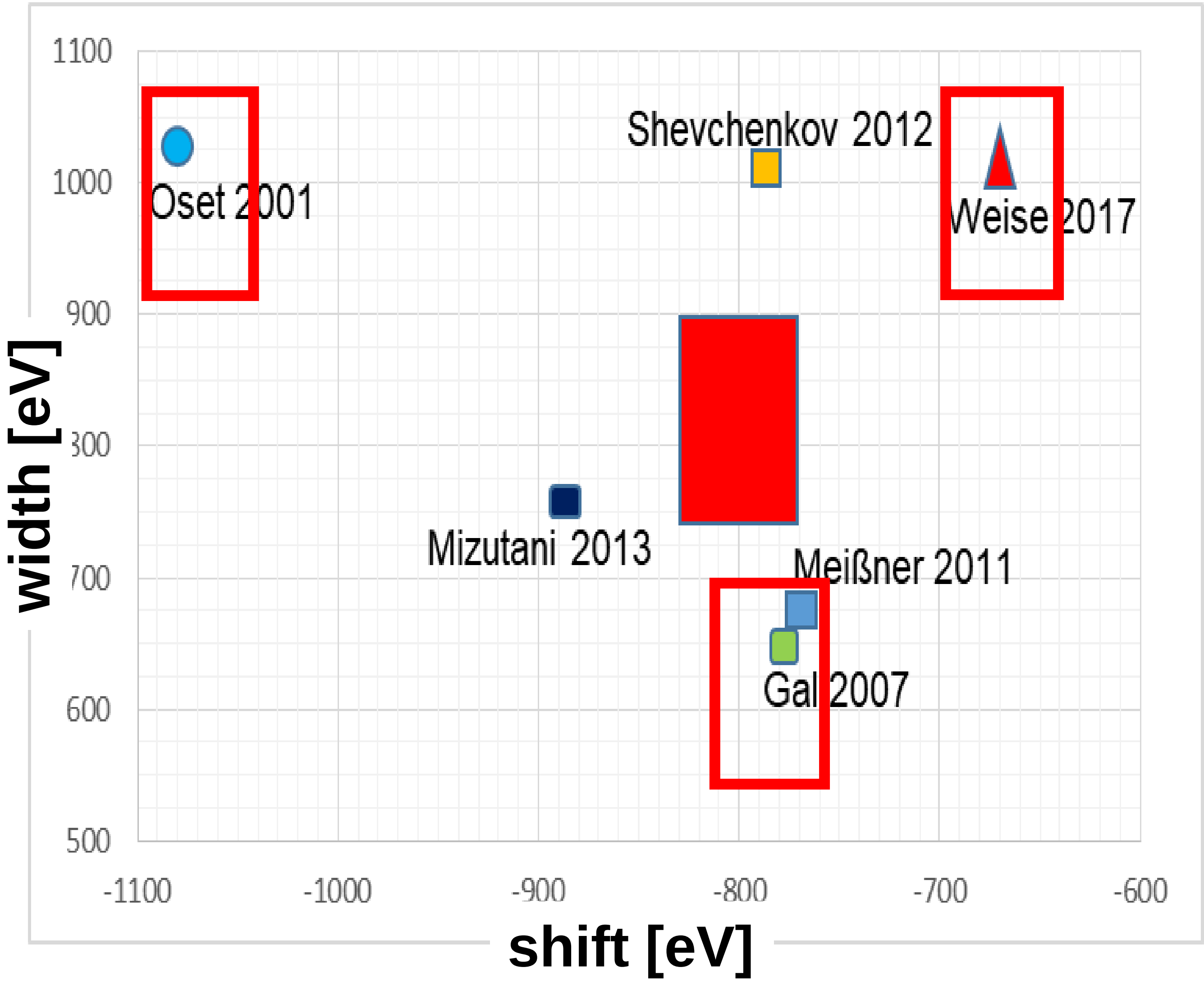
Other kaonic atoms measurements: QCD; QED

Kaonic atoms – scattering amplitudes



A. Cieplý, M. Mai, Ulf-G. Meißner, J. Smejkal, https://arxiv.org/abs/1603.02531v2

SIDDHARTA-2 kaonic deuterium at DAΦNE



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- Publications since last SC
- 63rd SciCom recommendations
- SIDDHARTINO/SIDDHARTA-2 runs outcomes
- Activities towards SIDDHARTA-2 optimization and restart of the run (end Feb 2023)
- HPGe & CdZnTe Detectors: test runs for light and heavy kaonic atoms (kaon mass)
- Future plans

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Publications since last SC

1. D. Sirghi et al., New measurements of kaonic helium-4 L-series X-rays yields in gas with the SIDDHARTINO setup, Nucl. Phys. A, Available online 31 October 2022, 122567
2. M. Miliucci et al., Towards the first kaonic deuterium measurement with the SIDDHARTA-2 experiment at DAFNE, Nuovo Cim.C 45 (2022) 6, 205 – best talk SIF 2021
3. A. Khreptak et al., Studies of the linearity and stability of Silicon Drift Detectors for kaonic atoms X-ray spectroscopy, accepted in Acta Physica Polonica A
4. M. Miliucci et al., Large area silicon drift detectors system for high precision timed x-ray spectroscopy, Measur.Sci.Tech. 33 (2022) 9, 095502
5. F. Sgaramella et al., Measurements of kaonic atoms transitions from solid targets by SIDDHARTA-2, ready to be submitted to EPJ A
6. M. Miliucci et al., High precision Kaonic Deuterium measurement at the DAΦNE collider: the SIDDHARTA-2 experiment and the SIDDHARTINO run, Rev.Mex.Fis.Suppl. 3 (2022) 3, 0308081
7. F. Sirghi et al., Status and perspectives for low energy kaon-nucleon interaction studies at DAΦ\PhiΦNE: from SIDDHARTA to SIDDHARTA-2, PoS PANIC2021 (2022) 200

Publications since last SC

8. A. Scordo et al., HAPG mosaic crystal Von Hamos spectrometer for high precision exotic atoms spectroscopy, PoS PANIC2021 (2022) 195
9. M. Skurzok et al., Investigation of the low-energy K−K^-K− hadronic interactions with light nuclei by AMADEUS, Int.J.Mod.Phys.E 31 (2022) 08, 2240001
10. F. Sgaramella et al., The SIDDHARTA-2 calibration method for high precision kaonic atoms x-ray spectroscopy measurements, Phys.Scripta 97 (2022) 11, 114002
11. F. Napolitano et al., Kaonic atoms at the DAΦNE collider with the SIDDHARTA-2 experiment, Phys.Scripta 97 (2022) 8, 084006

+ other 4 articles submitted awaiting reviews and other 4 articles in preparation

Marlene Tuechler: Best Poster award

8th International Symposium on Symmetries in Subatomic Physics (SSP2022)

SSP2022

29 August 2022 to 2 September 2022
Europe/Vienna timezone

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- Confirmed Speakers
  - Poster prize
- Registration
- Conference fee
- Contribution List
- Book of Abstracts

Poster prize

SSP2022 is a conference supported by NuPECC who granted funding for two poster prizes awarded on Thursday (01.09.2022) after the morning session.

The winners are:

Alexander Boeschoten (Van Swinderen Institute, Groningen) for the poster titled:

Understanding of Systematic Effects in eEDM Searches with diatomic molecules

and

Marlene Tüchler (Stefan Meyer Institute, Vienna) for the poster titled:

Kaonic Atom X-Ray Spectrocopy with the SIDDHARTA-2 Experiment

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63rd LNF Scientific Committee Meeting

SIDDHARTA-2 is presently collecting data with a helium target to commission the detector and the aim is to collect 100 pb^{-1} with the deuterium target in 2022 before the summer stop. At least 500 pb^{-1} (up to a maximum of 700 pb^{-1}) are required in 2023 to complete the physics programme with the deuterium target. Considering the running time (at least 200 days) necessary to achieve the above targets at the present luminosity production rate, the proposed actions and interventions are a worthwhile investment.

63rd LNF Scientific Committee Meeting

Recommendations DAΦNE - BTF/LINAC - SIDDHARTA-2:

• DAΦNE should aim at reaching 100 pb^{-1} before the summer closure. During 2023 additional 700 pb^{-1} should be delivered.

• To this end, the SC supports an immediate action to improve the DAΦNE luminosity and backgrounds, as proposed by the DAΦNE team. Ideally this should take place during the helium run of SIDDHARTA-2, in order to then profit from the maximum luminosity for the K-d run.

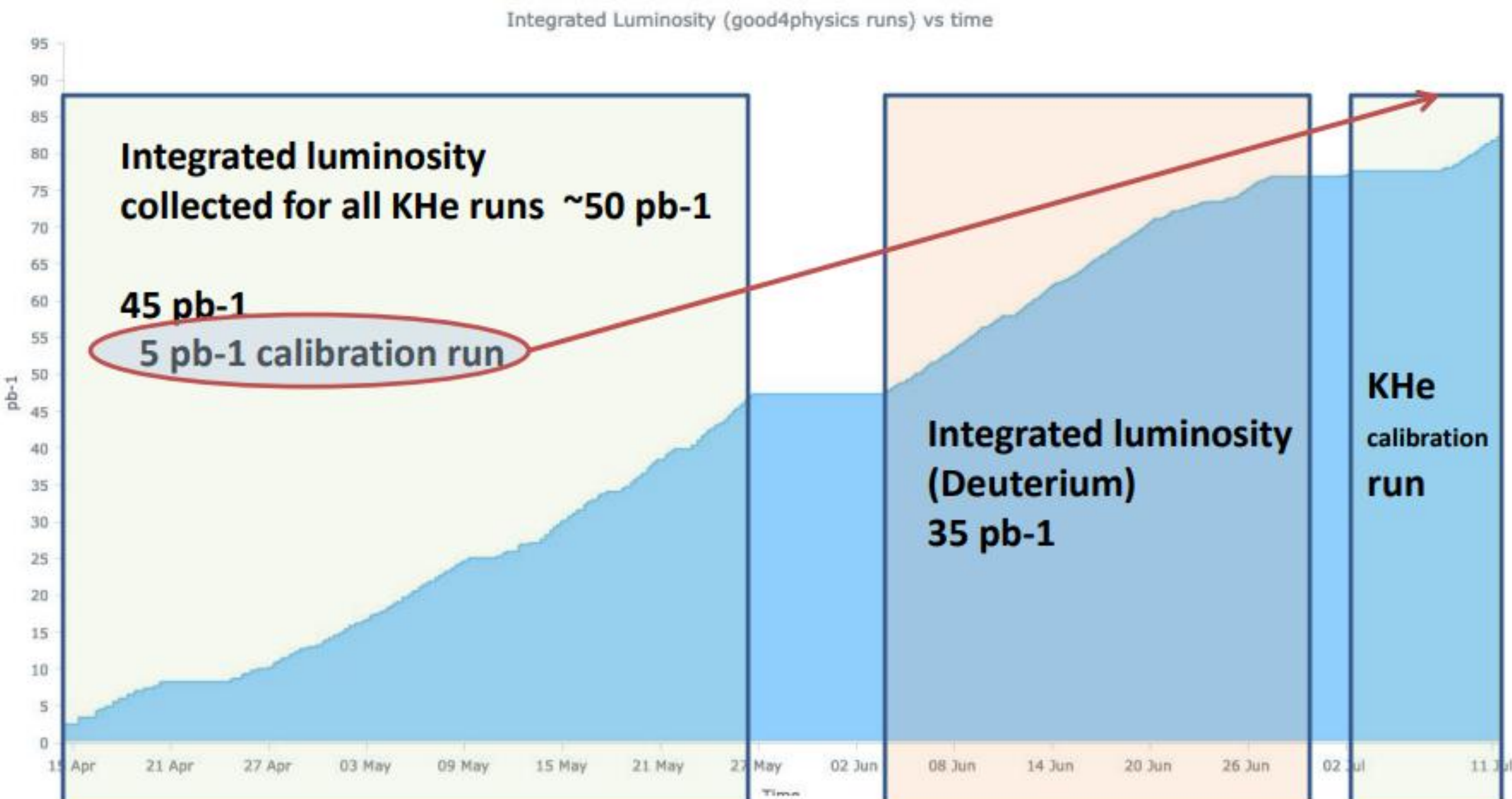
Summary of runs since last SC:

- Finalization optimization run with Kaonic Helium: end of May 2022 – total integrated luminosity 45 pb^{-1}

- **Run with kaonic deuterium: 2 – 14 June 2022: about 35 pb^{-1}**

- Post run calibration with kaonic helium: about 5 pb^{-1}

Integrated luminosity summary



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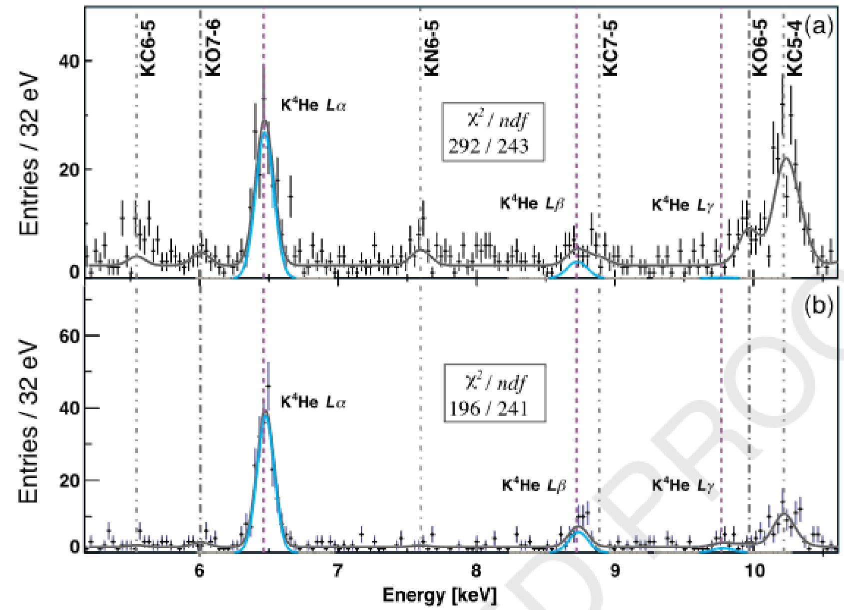
www.elsevier.com/locate/nuclphysa

New measurements of kaonic helium-4 L-series X-rays yields in gas with the SIDDHARTINO setup

D.L. Sirghi [a,b,c,*], H. Shi [d], C. Guaraldo [a], F. Sgaramella [a,**], C. Amsler [d], M. Bazzi [a], D. Bosnar [e], A.M. Bragadireanu [c], M. Carminati [f,g], M. Cargnelli [d], A. Clozza [a], G. Deda [f,g], L. De Paolis [a], R. Del Grande [a,h], L. Fabbietti [h], C. Fiorini [f,g], M. Iliescu [a], M. Iwasaki [i], J. Marton [d], M. Miliucci [a], P. Moskal [j], F. Napolitano [a], S. Niedzwiecki [j], H. Ohnishi [k], K. Piscicchia [b,a], Y. Sada [k], A. Scordo [a], M. Silarski [j], F. Sirghi [a,c], M. Skurzok [j], A. Spallone [a], K. Toho [k], M. Tüchler [d,l], O. Vazquez Doce [a], J. Zmeskal [d], C. Yoshida [k], C. Curceanu [a]



. 2. X-ray kaonic helium-4 spectra measured by SIDDHARTINO for: (a) 0.82 g/l target gas density; (b) 1.90 g/l target gas density. The kaonic helium-4 peaks L_α, L_β and L_γ are shown. Several kaonic atom X-ray lines produced in the Kapton foils are also shown: Kaonic Carbon 6 → 5, Kaonic Oxygen 7 → 6, Kaonic Nitrogen 6 → 5, Kaonic Carbon 7 → 5, Kaonic Oxigen 6 → 5, Kaonic Carbon 5 → 4 transitions. The solid line shows the fit function of the spectrum. The blue line shows the L series L_α, L_β and L_γ kaonic helium-4 components. (For interpretation of the colors in the figure(s), the reader is referred to the web version of this article.)

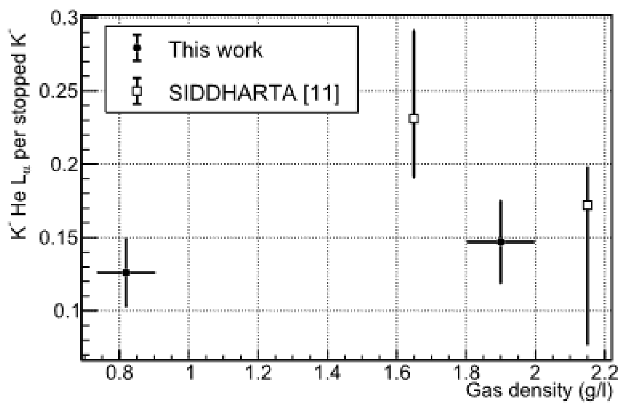
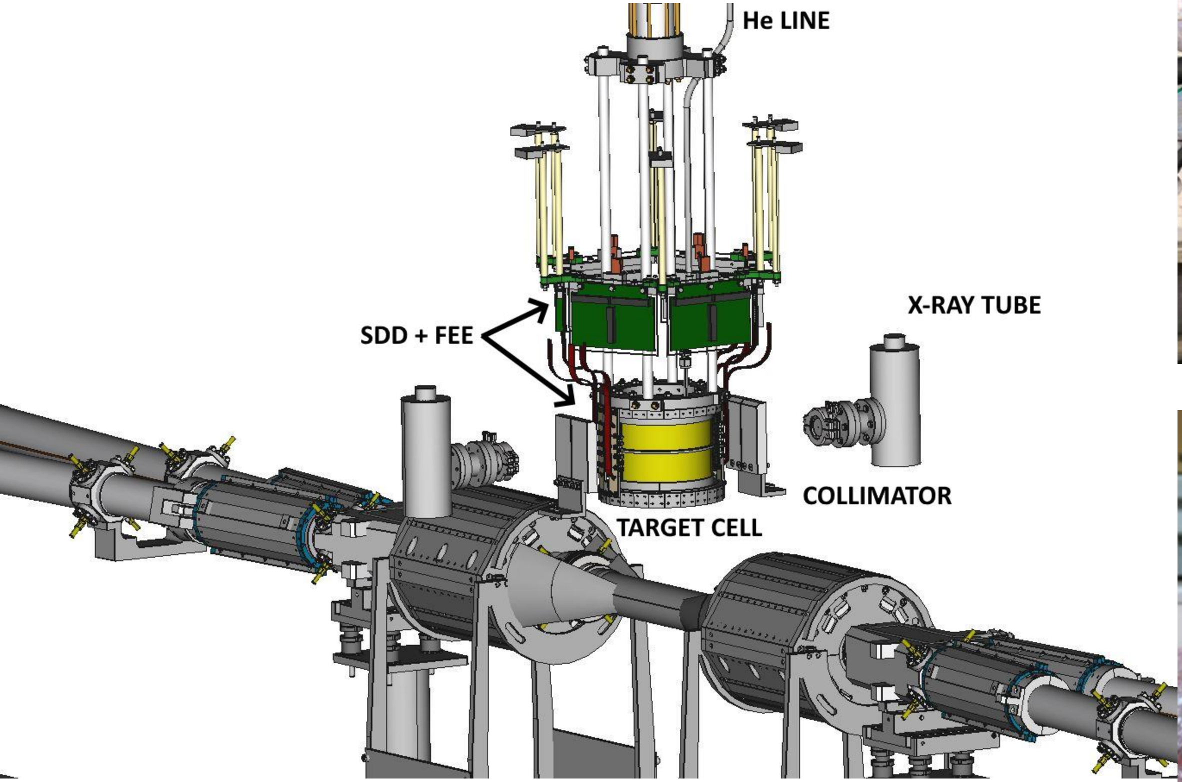


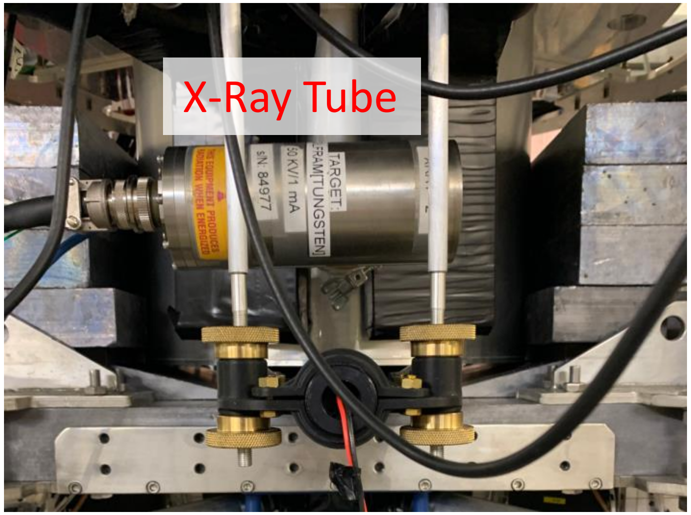
Fig. 3. The L_α X-ray yield of K^{-} ^{4}He as function of the target density from all gaseous target measurements: this work (filled dots) and SIDDHARTA [16] (hollow squares).

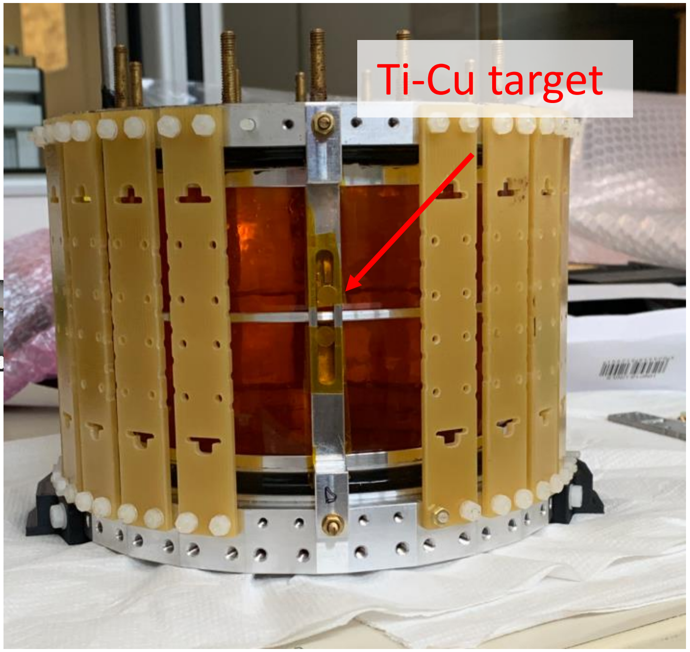
SIDDHARTA-2
Data Analysis Report

- Silicon Drift Detectors calibration spectra analysis
- Apply trigger, veto, cross talk -> clean spectrum!
- Kaonic deuterium preliminary analysis
- SIDDHARTA-2 kaonic helium run results
- Surprise: Kaonic helium first measurement of the M (n=3) lines (and coincidence with L-lines)

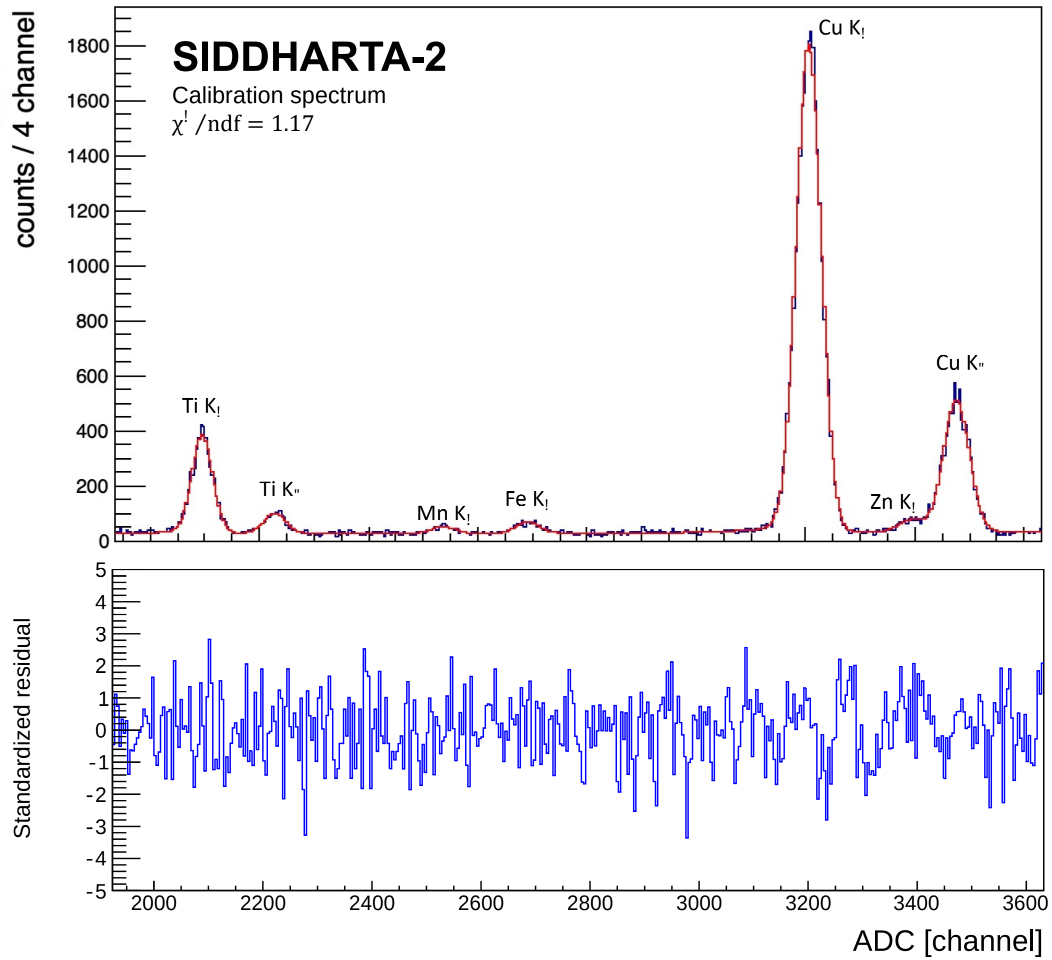
SDD Calibration: 384 SDDs
(6xSIDDHARTINO)

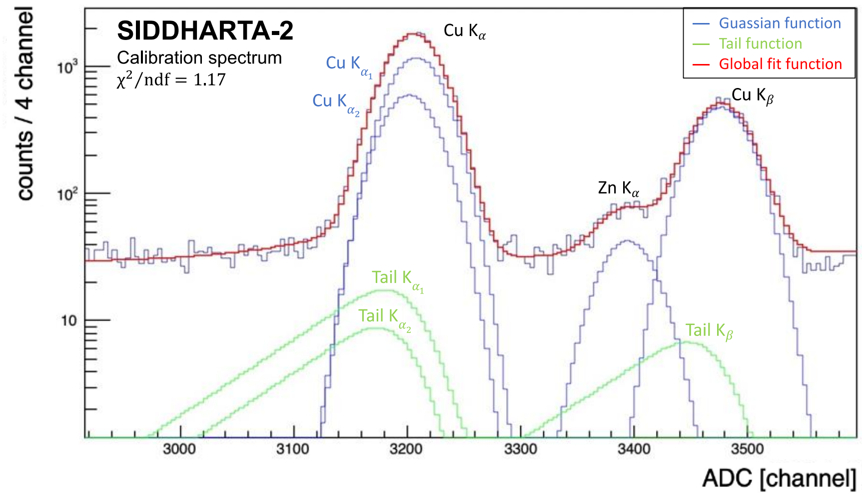






SDD Calibration





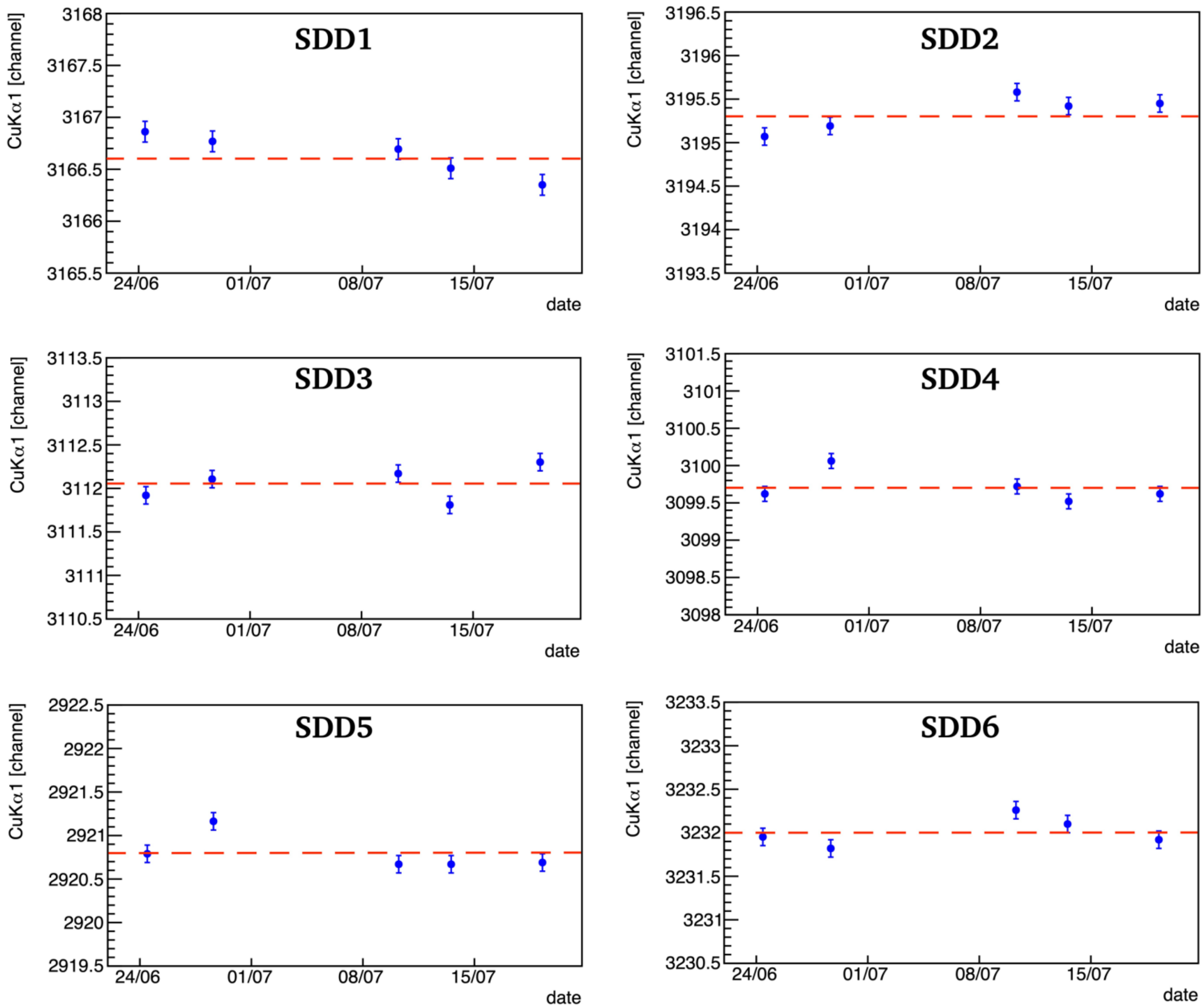
$$Gauss\ func.:\ H_G \cdot e^{\frac{-(x-x_0)^2}{2\sigma^2}}$$

$$\sigma = \sqrt{FF \cdot E \cdot \epsilon + \frac{noise^2}{2.35^2}}$$

$$Tail\ func.:\ H_T \cdot e^{\frac{x-x_0}{\beta\sigma}+\frac{1}{2\beta^2}} \cdot erfc\left(\frac{x-x_0}{\sqrt{2}\sigma}+\frac{1}{\sqrt{2}\beta}\right)$$

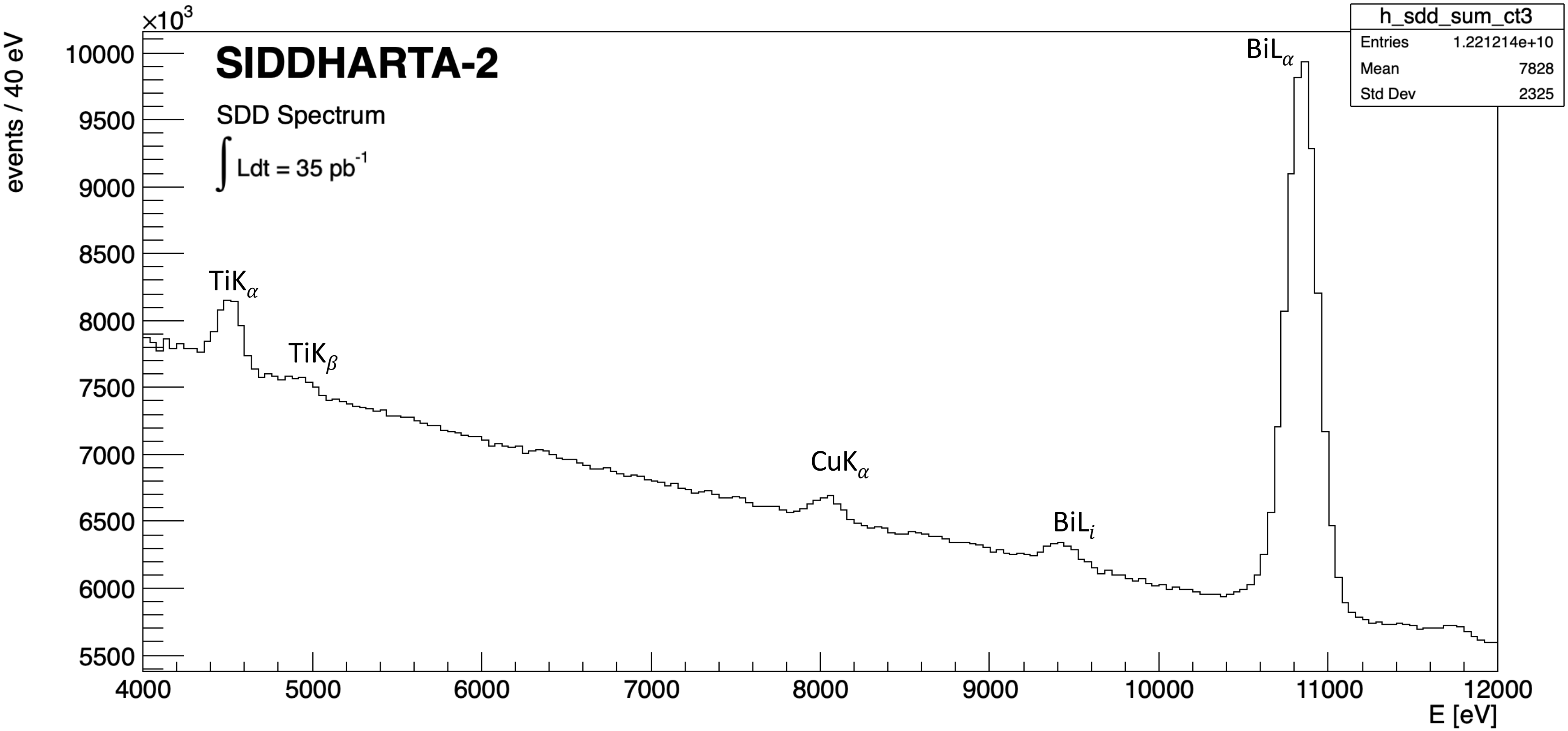
F Sgaramella et al 2022 Phys. Scr. 97 114002

SDD Calibration - Stability



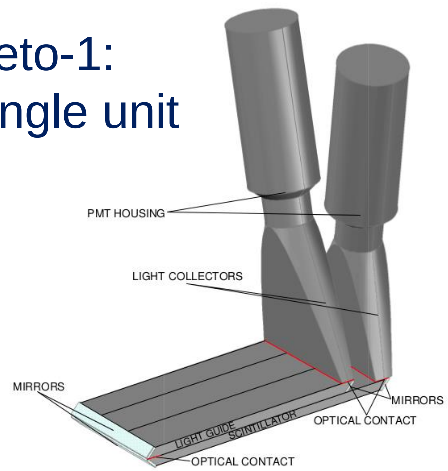
F Sgaramella et al 2022 Phys. Scr. 97 114002

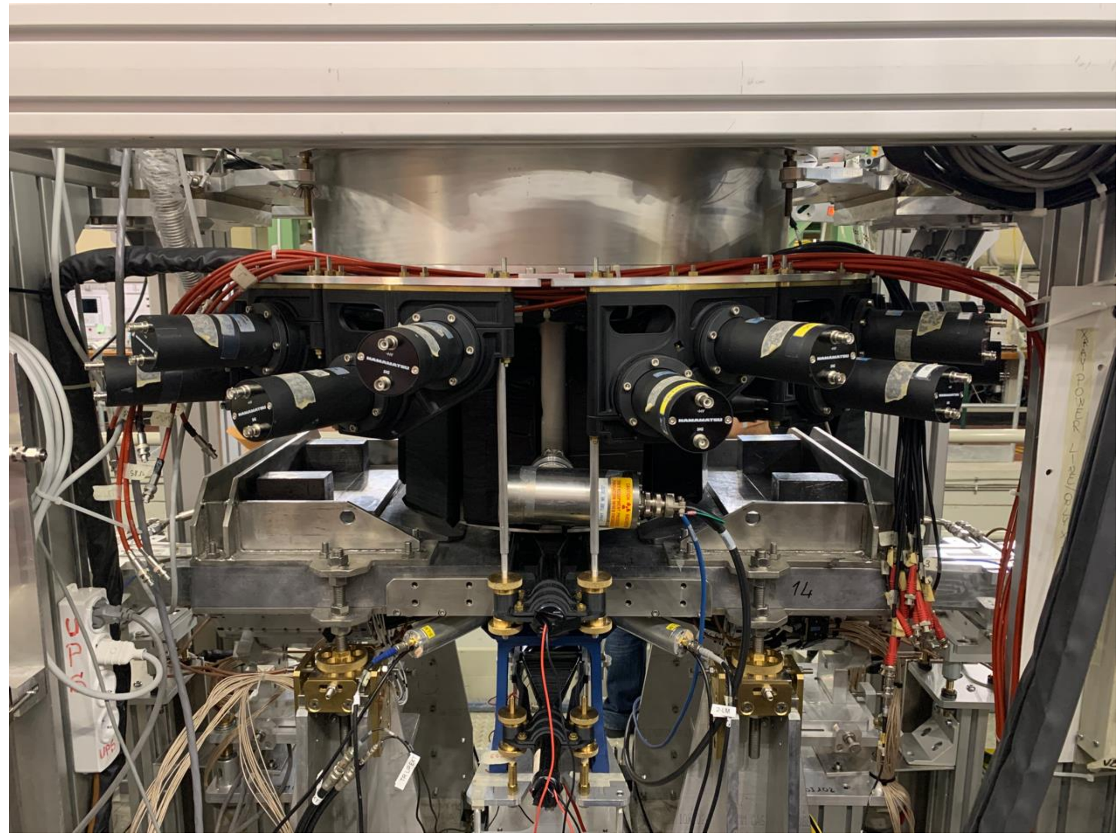
SIDDHARTA-2 Kaonic deuterium SDDs energy spectrum



SIDDHARTA-2
Veto-1 system

Veto-1:
single unit

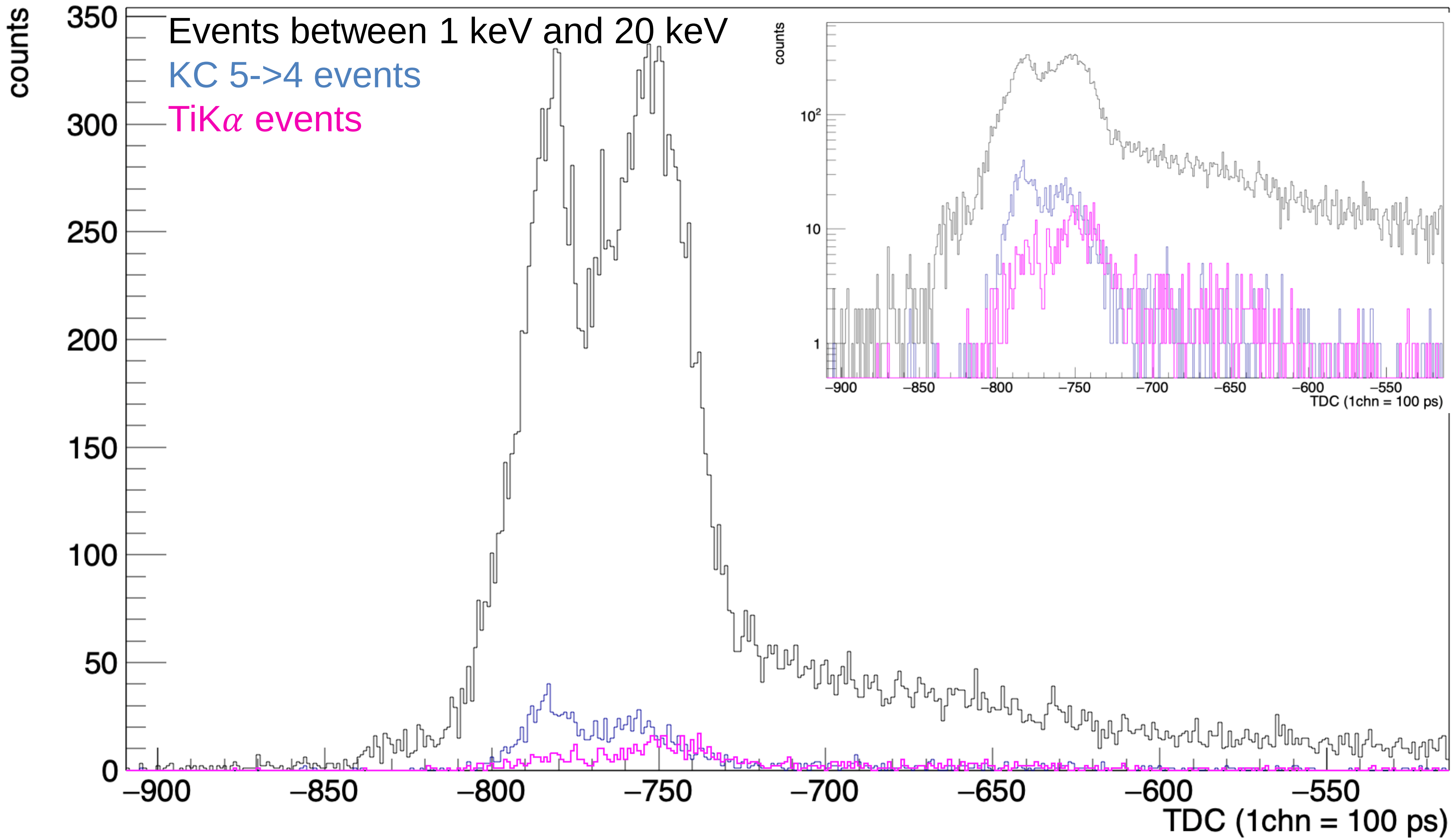




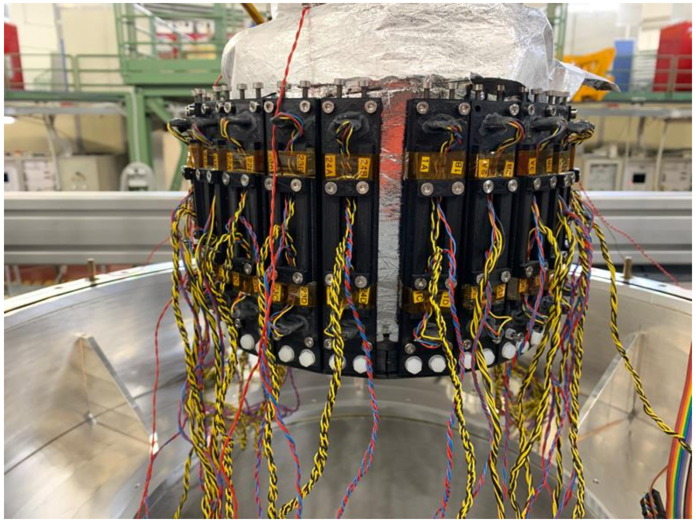
Veto-1 system installed around the vacuum chamber

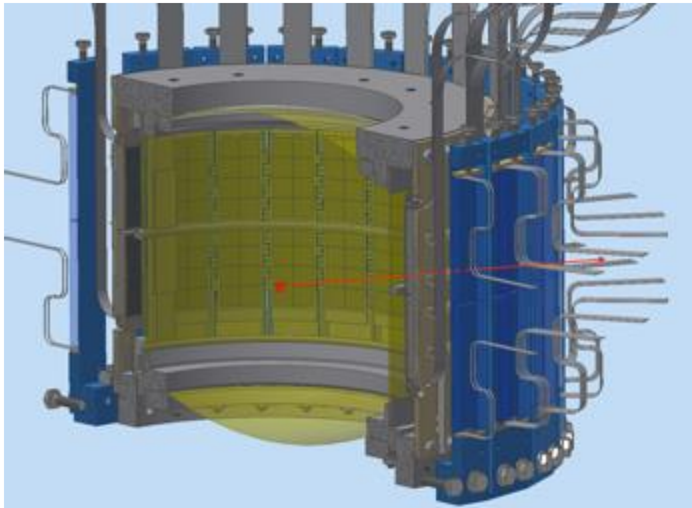
M. Bazzi et al, 2013 *JINST* **8** T11003

Veto 1 TDC mean time spectrum

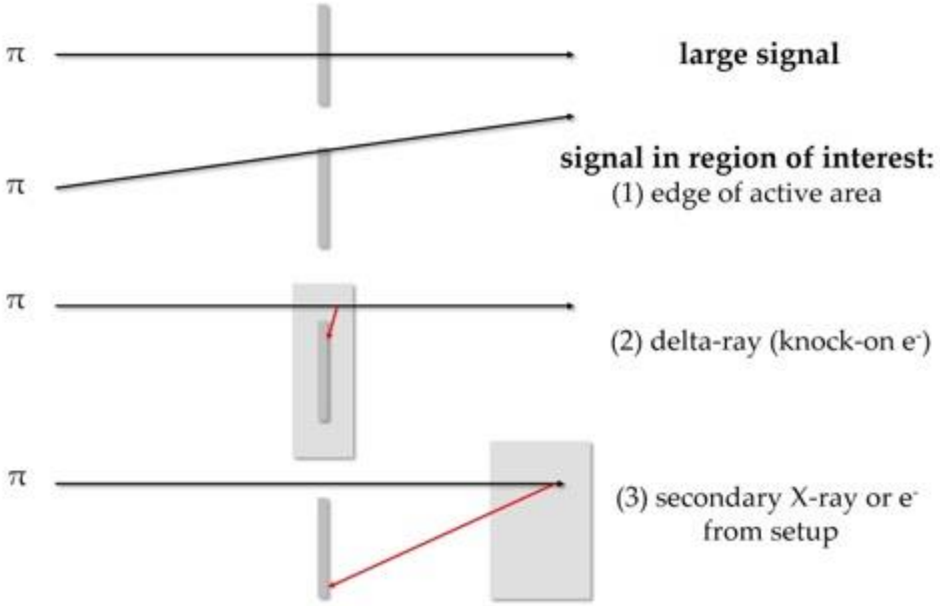


SIDDHARTA-2
Veto-2 system

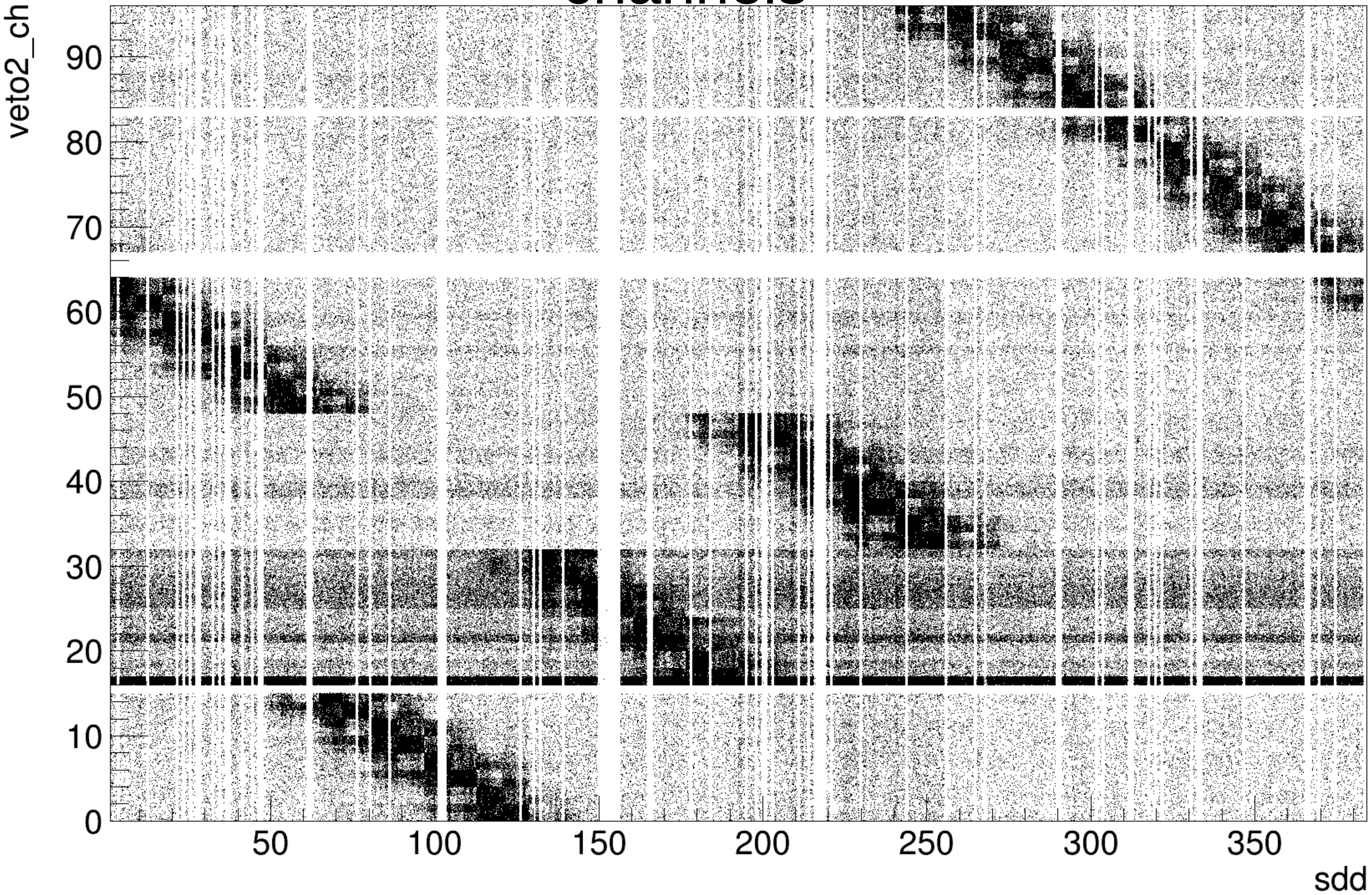




Working principle of veto-2 system

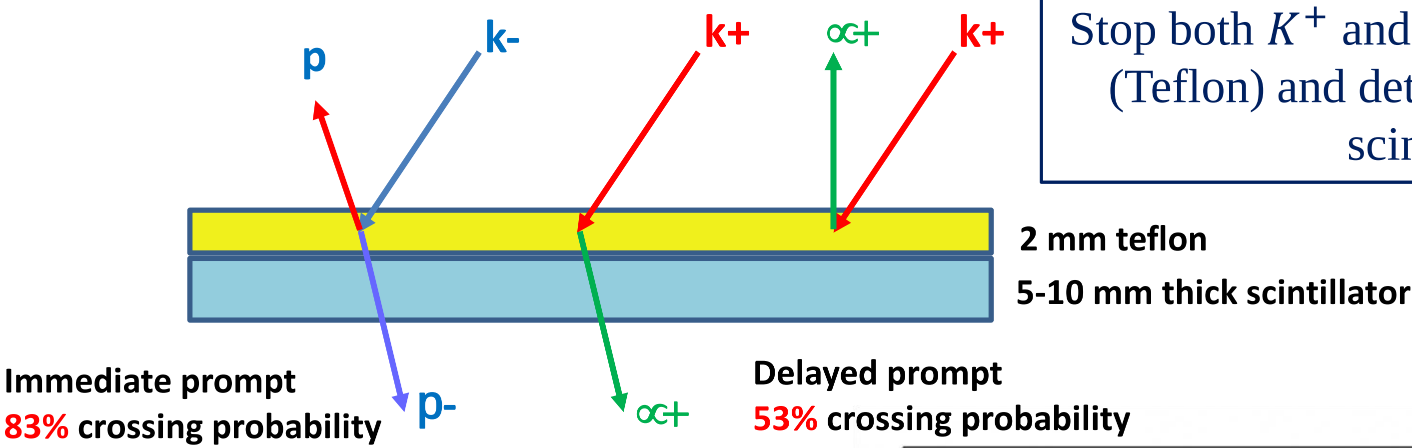


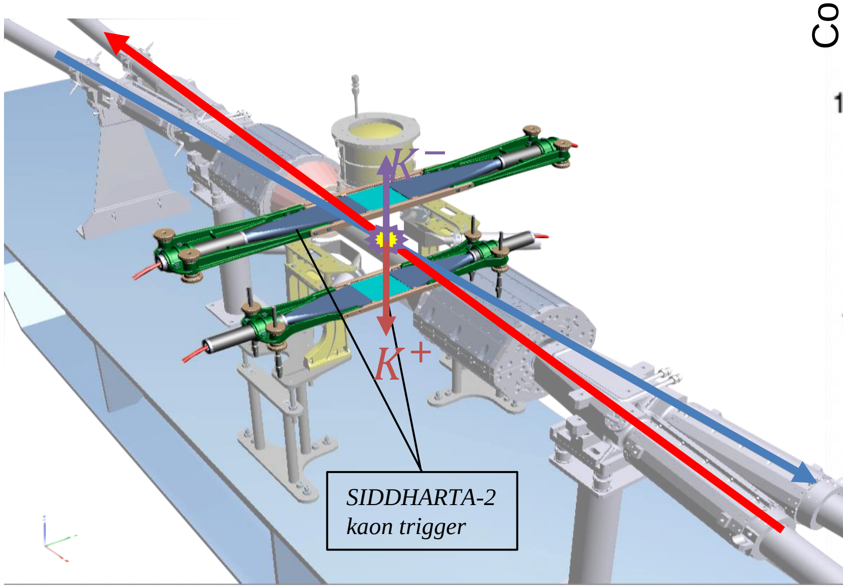
Correlation between veto2 and SDD channels

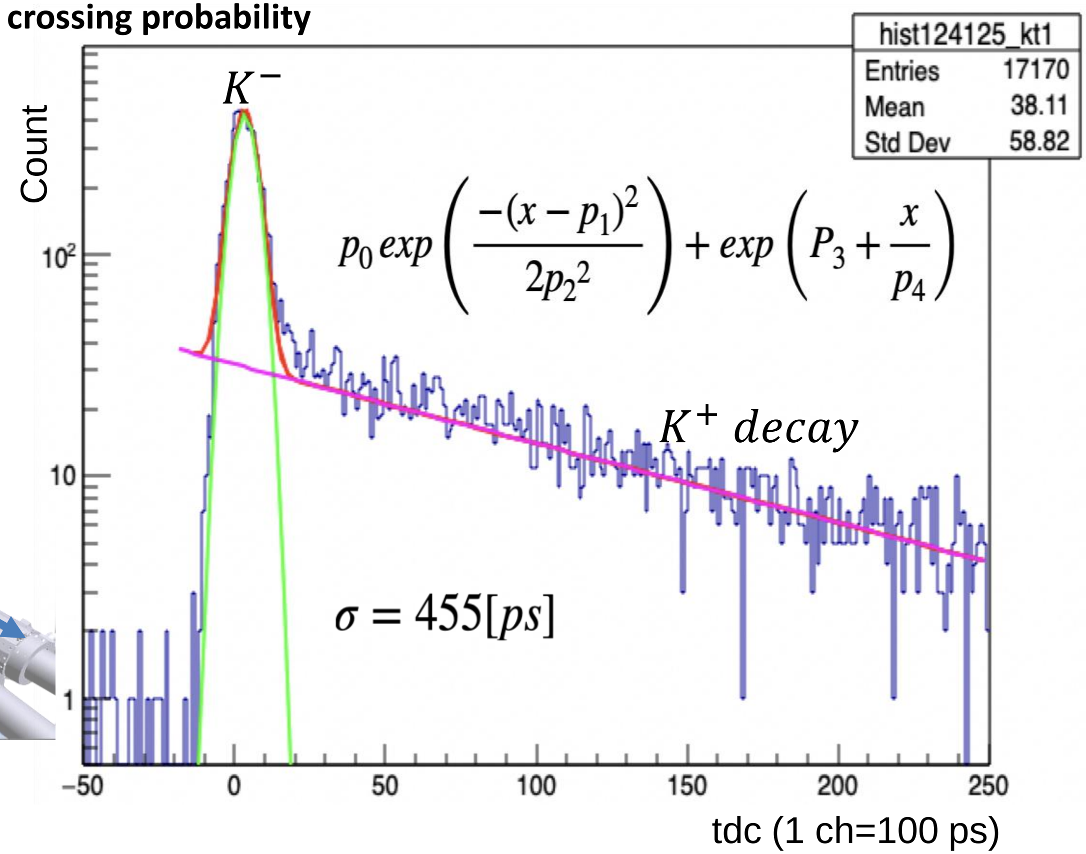


Kaon charge identification

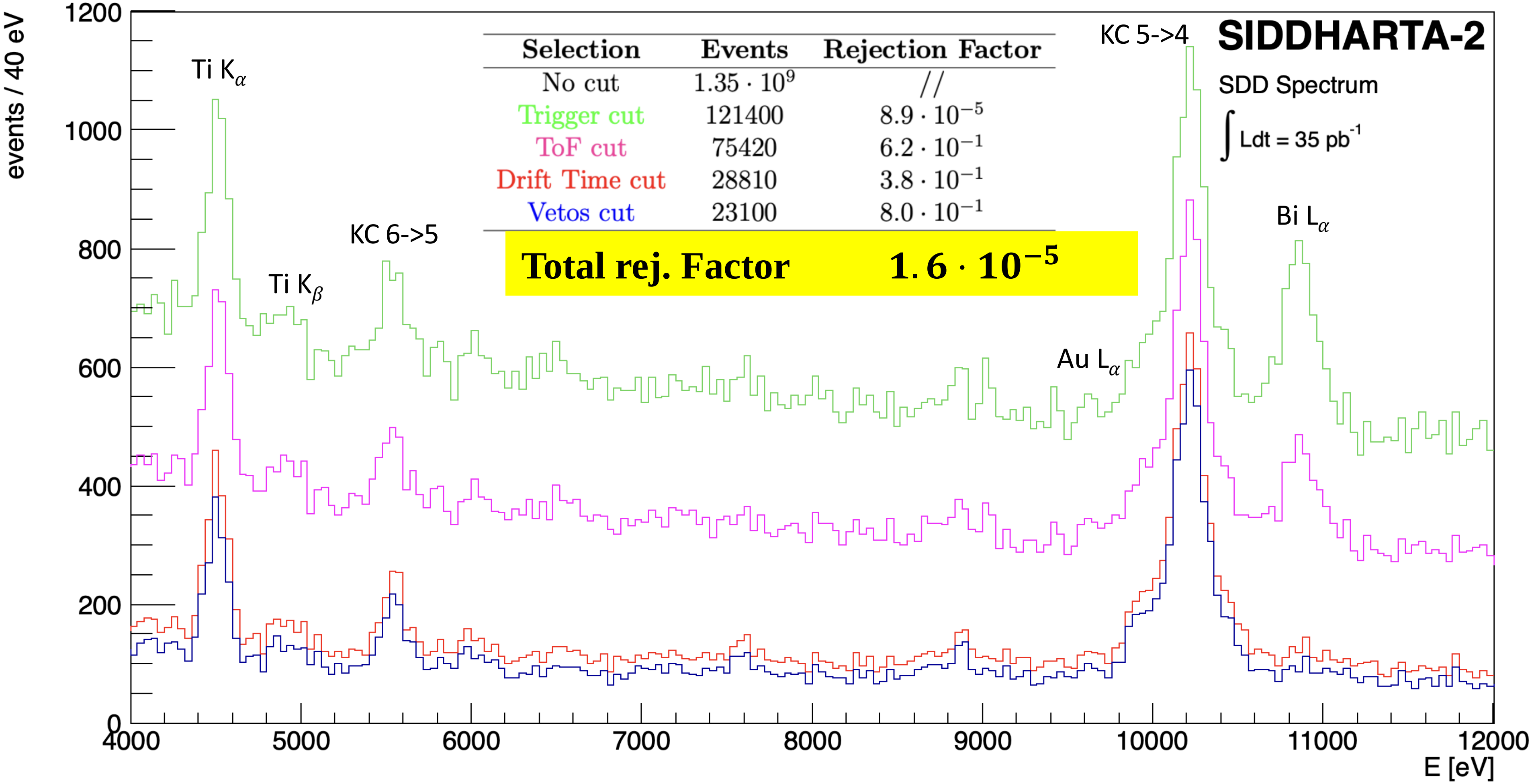
Stop both K^+ and K^- in a passive layer (Teflon) and detect secondaries in a scintillator







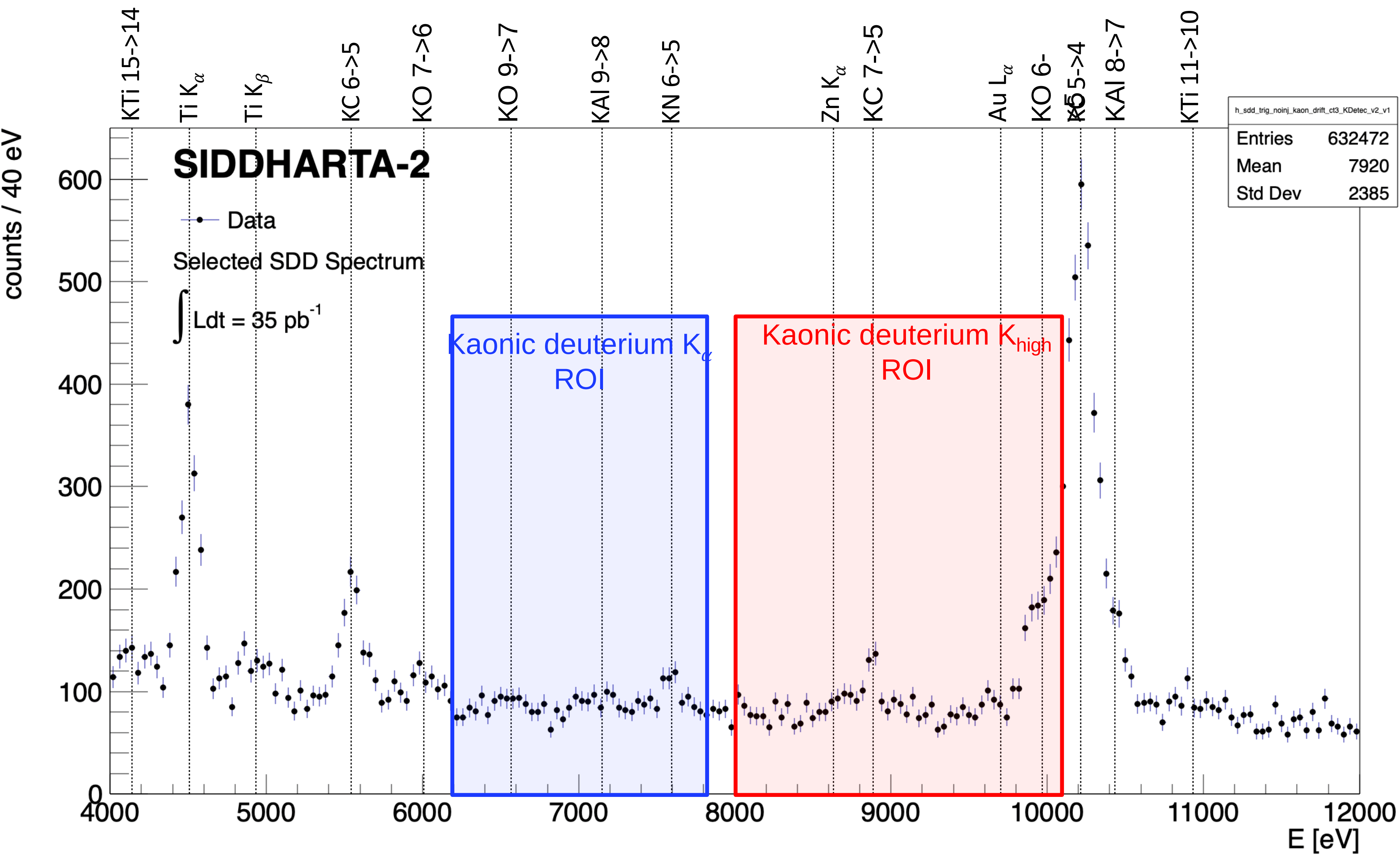
SIDDHARTA-2 Kaonic deuterium background reduction



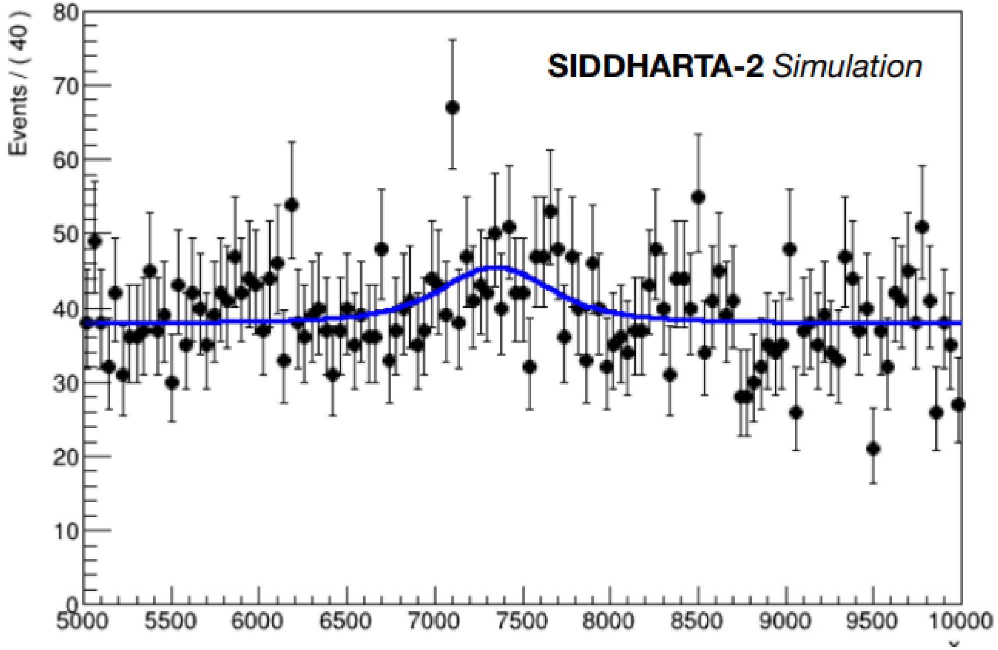
Selection	Events	Rejection Factor
No cut	$1.35 \cdot 10^9$	//
Trigger cut	121400	$8.9 \cdot 10^{-5}$
ToF cut	75420	$6.2 \cdot 10^{-1}$
Drift Time cut	28810	$3.8 \cdot 10^{-1}$
Vetos cut	23100	$8.0 \cdot 10^{-1}$

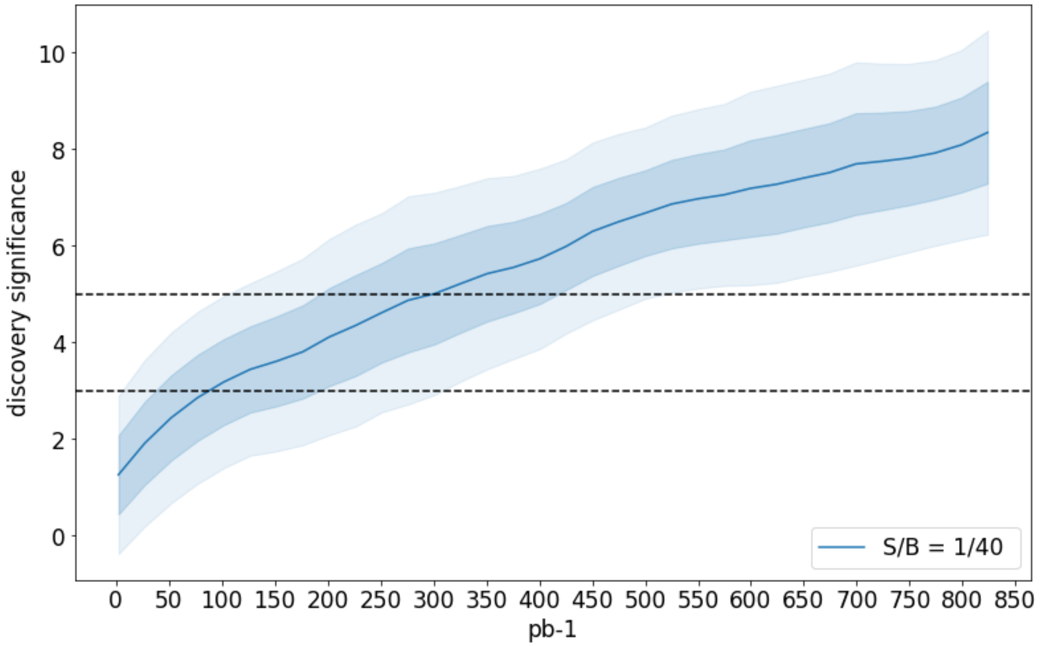
Total rej. Factor $\mathbf{1.6 \cdot 10^{-5}}$

SIDDHARTA-2 Kaonic deuterium



$35 pb^{-1}$ SIDDHARTA-2 Kaonic deuterium MCarlo



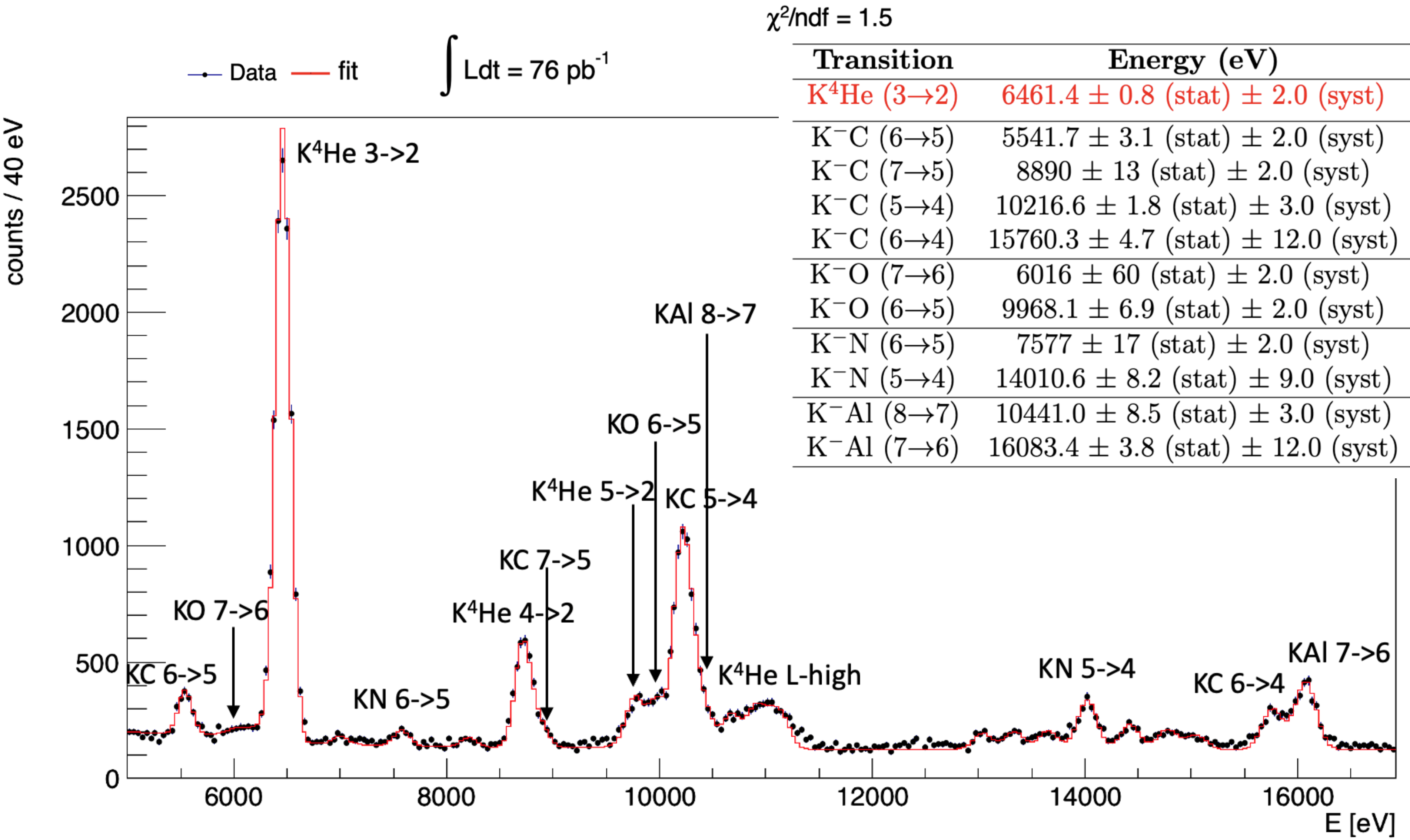


SIDDHARTA-2 outcomes:

Kaonic ^{4}He Run

+ Other kaonic atoms from solid targets

SIDDHARTA-2 and SIDDHARTINO:
sub-1 eV precision! -> article



Transition	Energy (eV)
K^4He (3→2)	6461.4 ± 0.8 (stat) ± 2.0 (syst)
K^-C (6→5)	5541.7 ± 3.1 (stat) ± 2.0 (syst)
K^-C (7→5)	8890 ± 13 (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)	6016 ± 60 (stat) ± 2.0 (syst)
K^-O (6→5)	9968.1 ± 6.9 (stat) ± 2.0 (syst)
K^-N (6→5)	7577 ± 17 (stat) ± 2.0 (syst)
K^-N (5→4)	14010.6 ± 8.2 (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)

SIDDHARTA-2 and SIDDHARTINO
Kaonic atoms from soldid targets -> article

Transition	Energy (eV)
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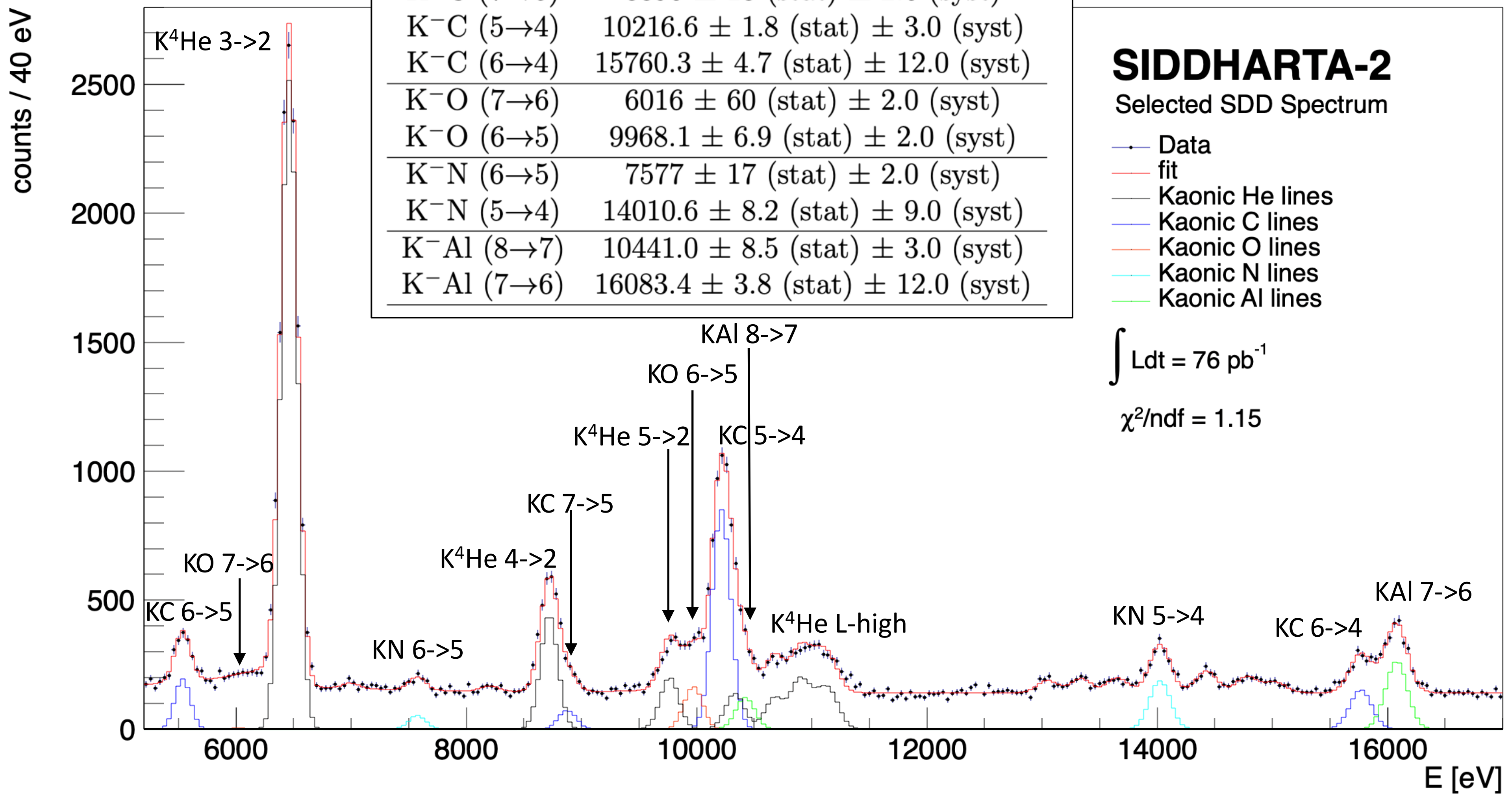
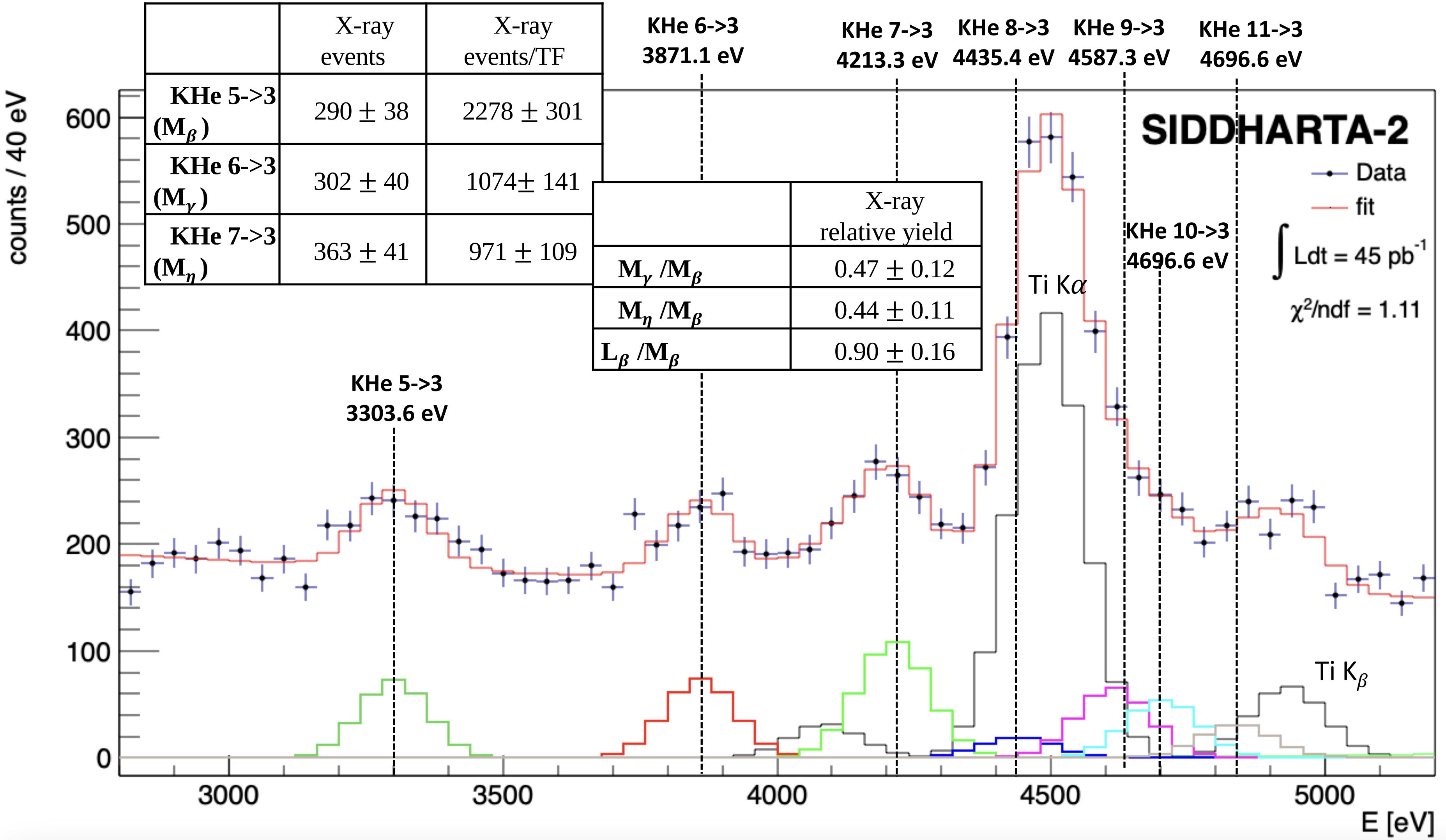


SIDDHARTA-2 Kaonic ^{4}He SURPRISE

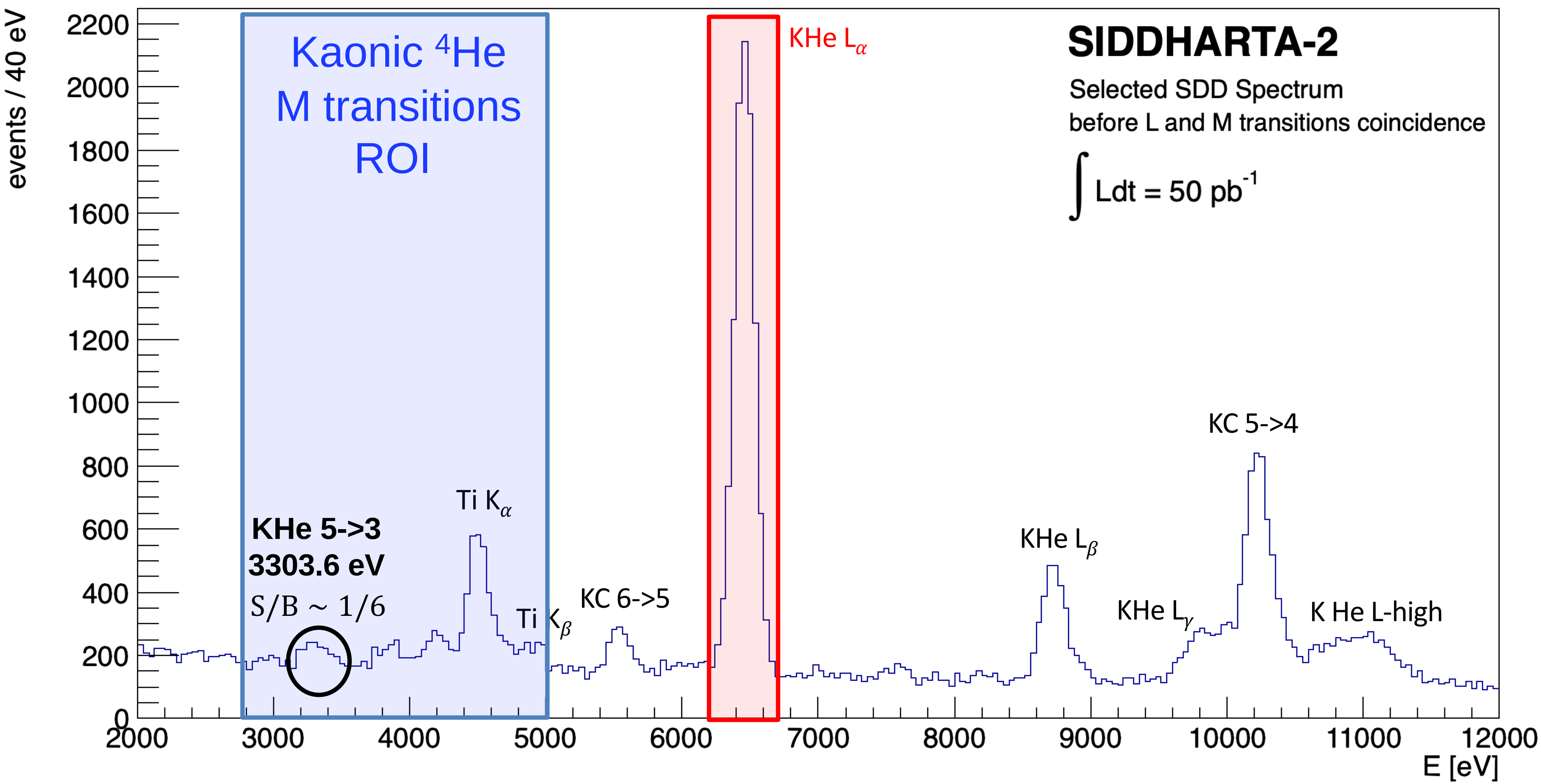
First measurememt M-line transitions – article

	X-ray events	X-ray events/TF
KHe 5->3 (M_β)	290 ± 38	2278 ± 301
KHe 6->3 (M_γ)	302 ± 40	1074± 141
KHe 7->3 (M_η)	363 ± 41	971 ± 109

	X-ray relative yield
M_γ / M_β	0.47 ± 0.12
M_η / M_β	0.44 ± 0.11
L_β / M_β	0.90 ± 0.16

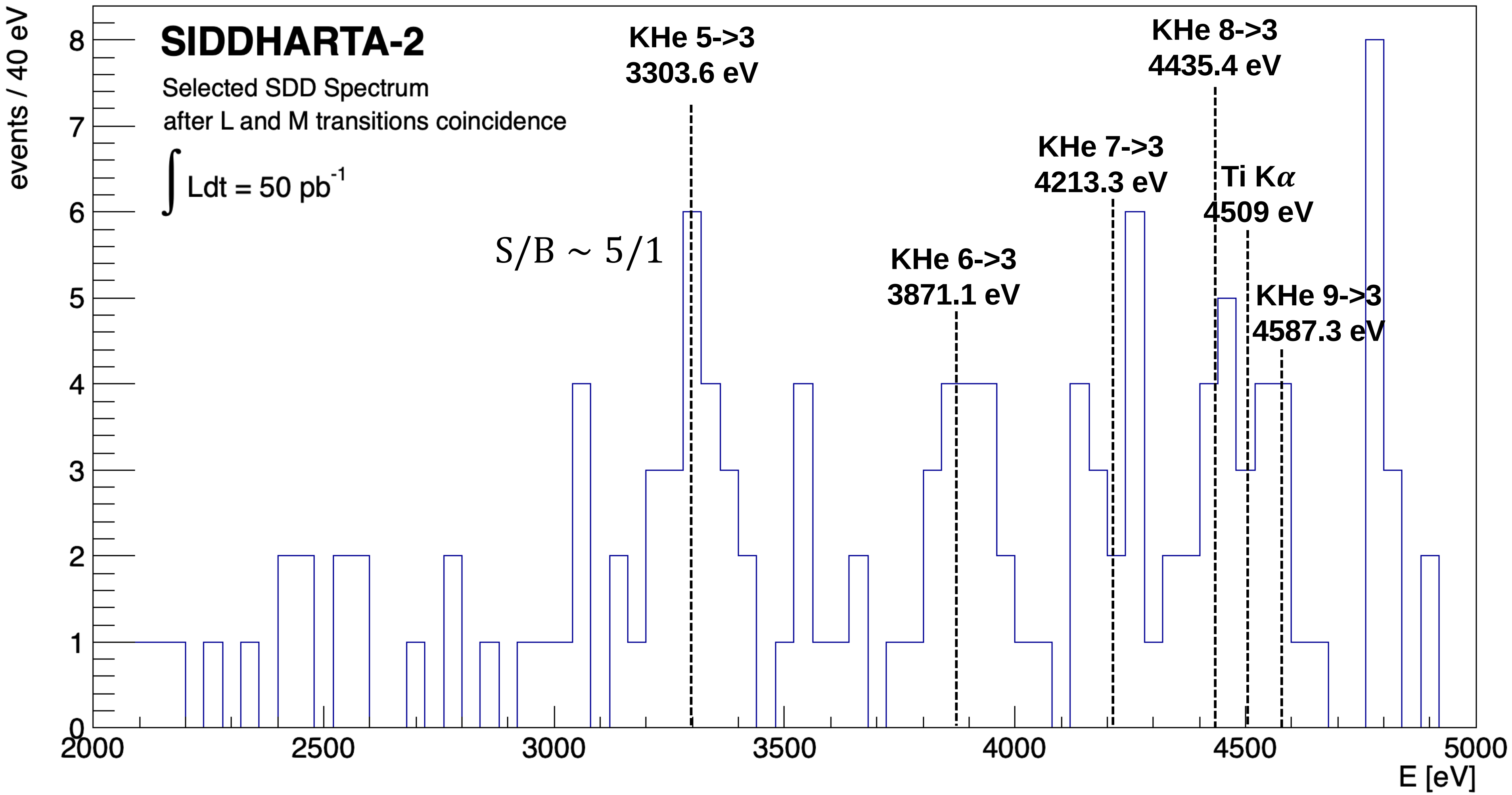


SIDDHARTA-2 Kaonic ^{4}He
coincidence between L and M transitions



S/B improved factor > 30

Feasibility test for future kaonic atom measurements (kaonic ^{4}He fundamental level) - article



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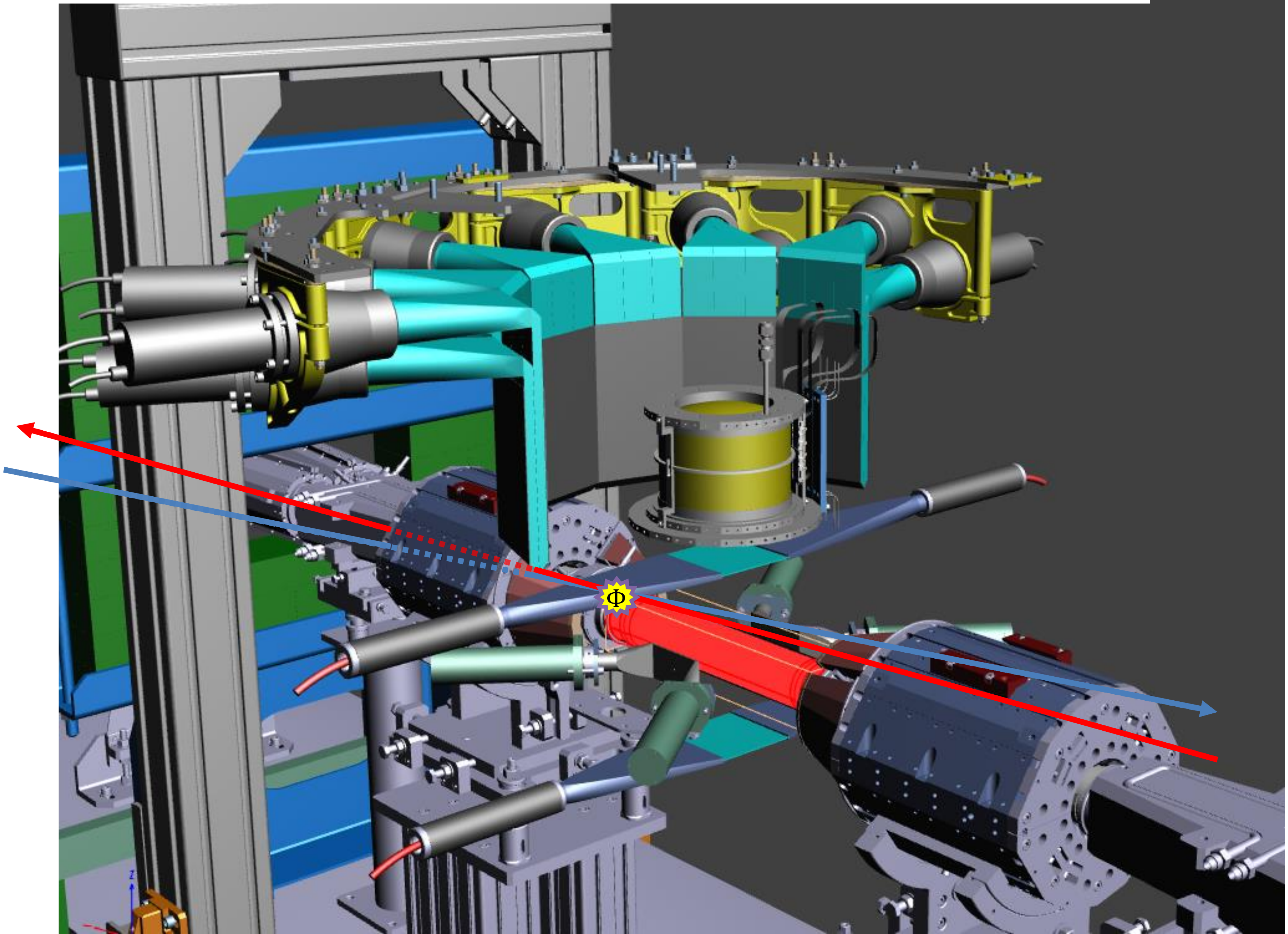
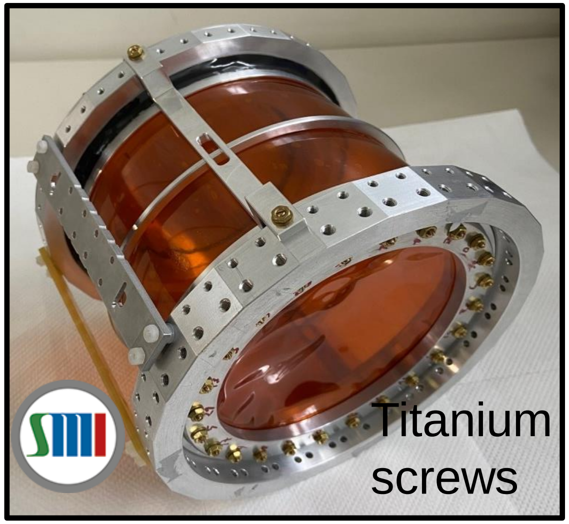
SIDDHARTA-2 setup



Optimize the SIDDHARTA-2 setup

(Sept. 2022 – February 2023)

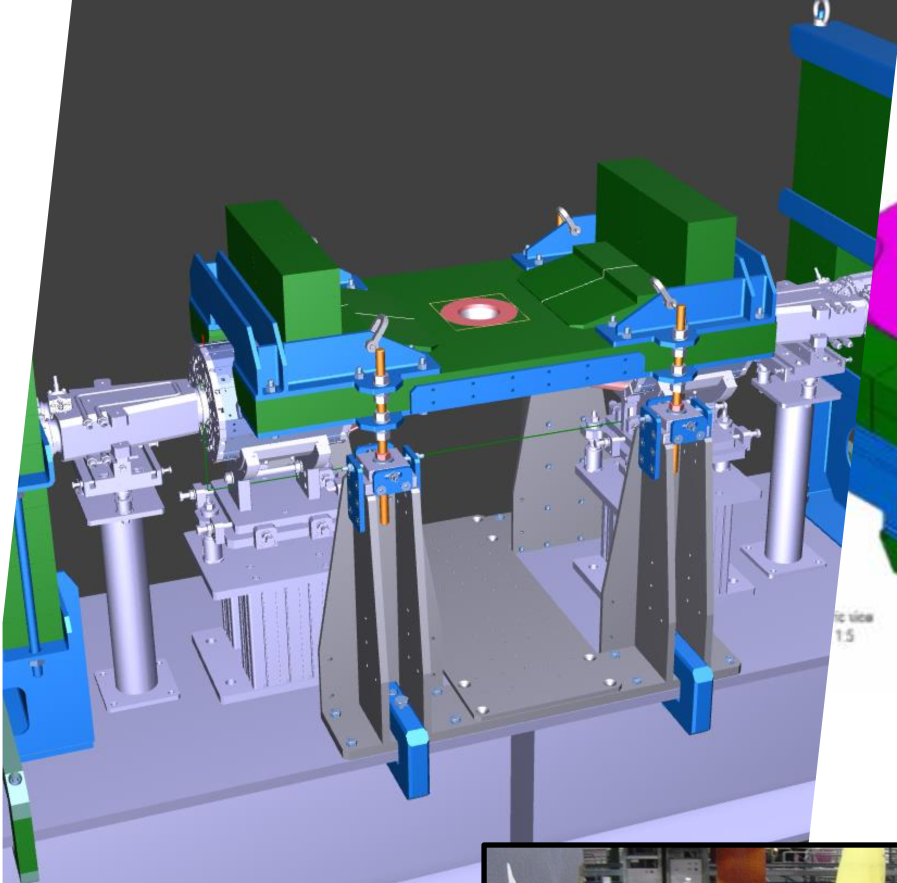


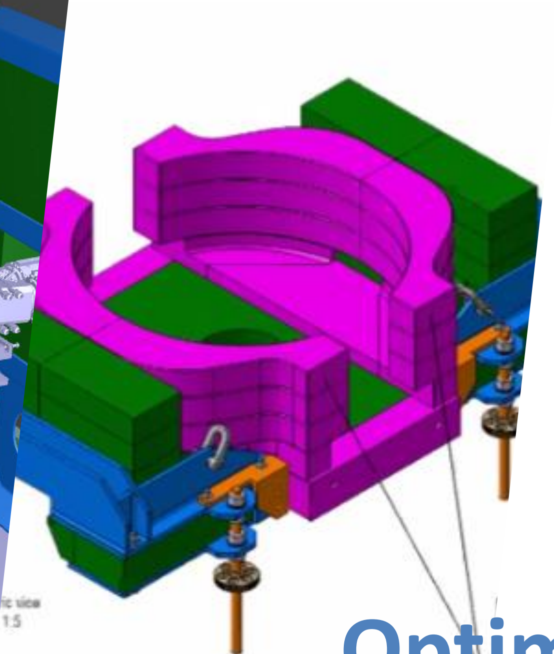
- ✓ **UHMWPE – new entrance windows material**
  for target super-strong form of polyethylene, would eliminate both Nitrogen and Oxygen contamination

- ✓ **Reinforced shielding around the setup**

- ✓ **Add new vero system (veto3)**

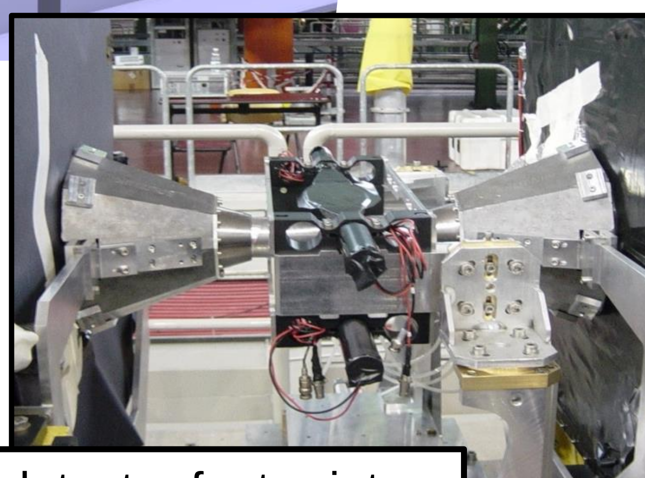
- ✓ **Work with DAFNE to reduce background**

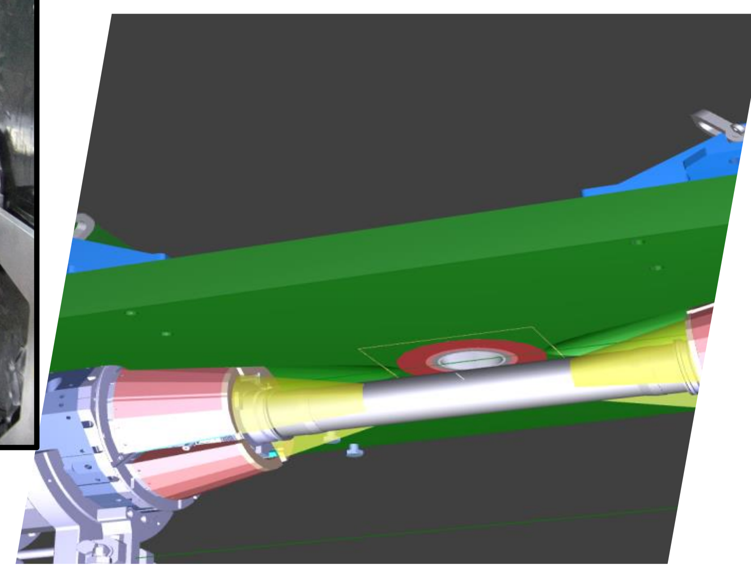




Improve the lateral shielding around the vacuum chamber

Optimize the SIDDHARTA-2 setup

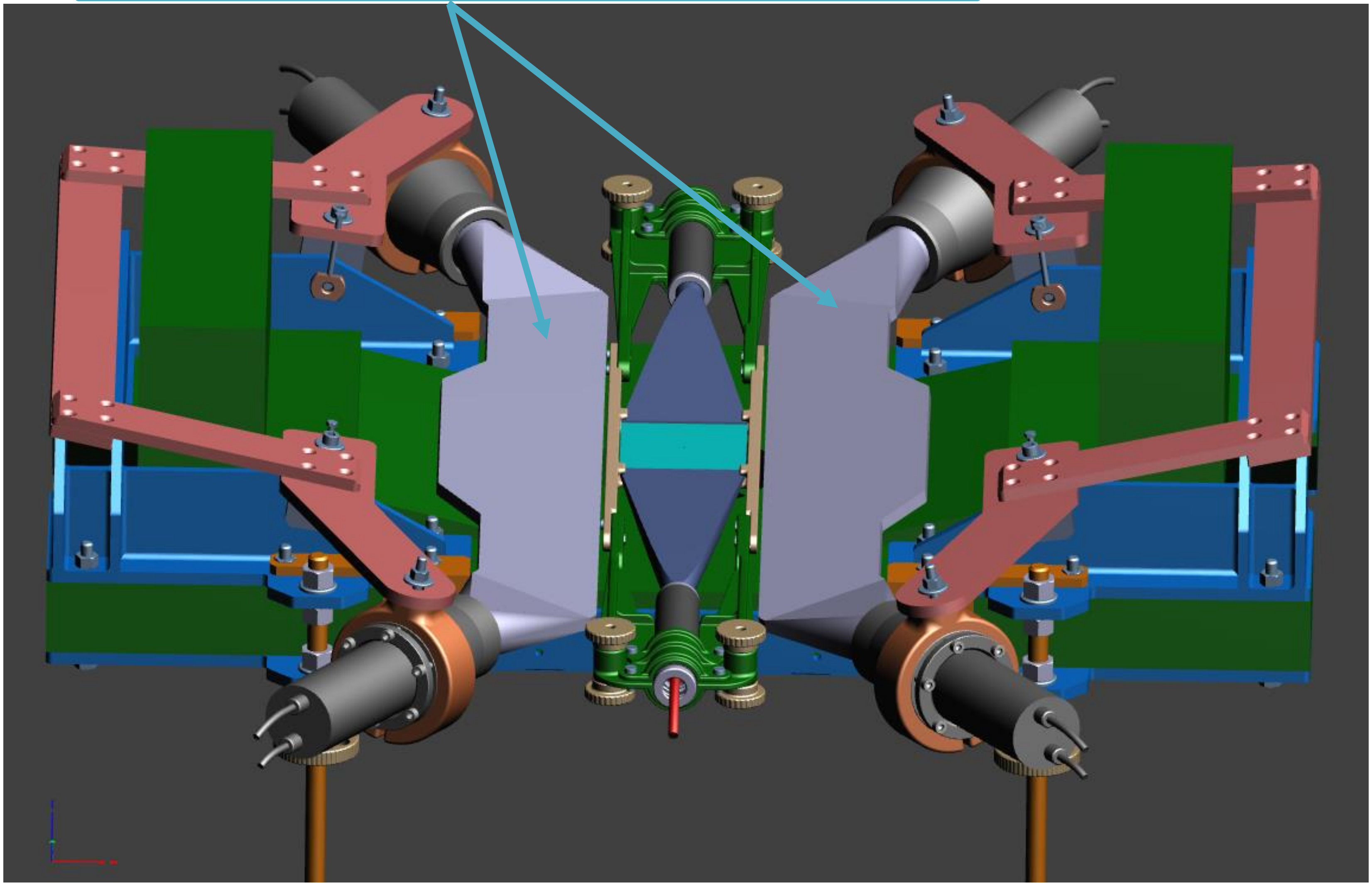




DAΦNE luminosity detector foot-print replaced by special re-design shielding

Optimize the SIDDHARTA-2 setup

VETO system adds – VETO3 below the setup



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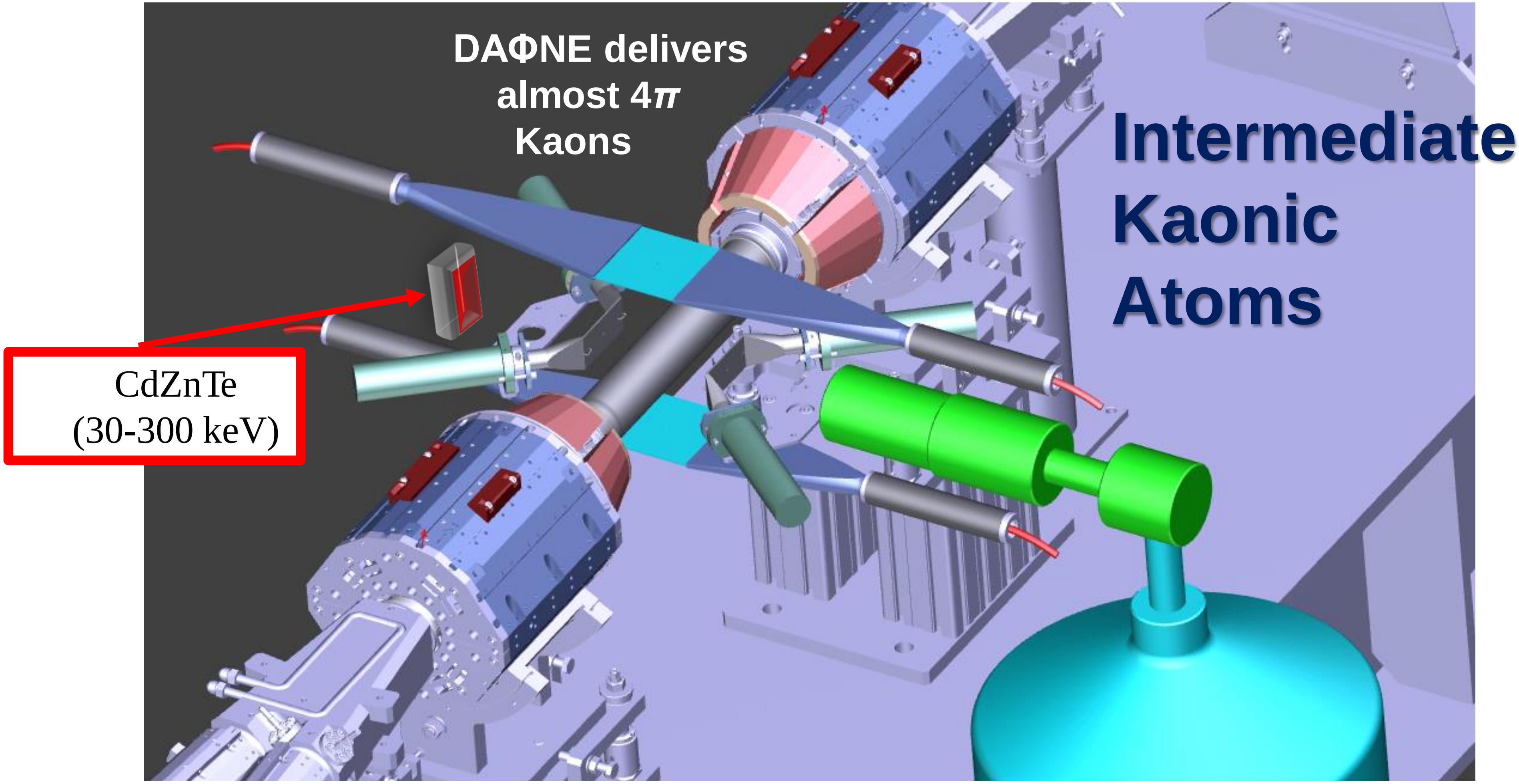
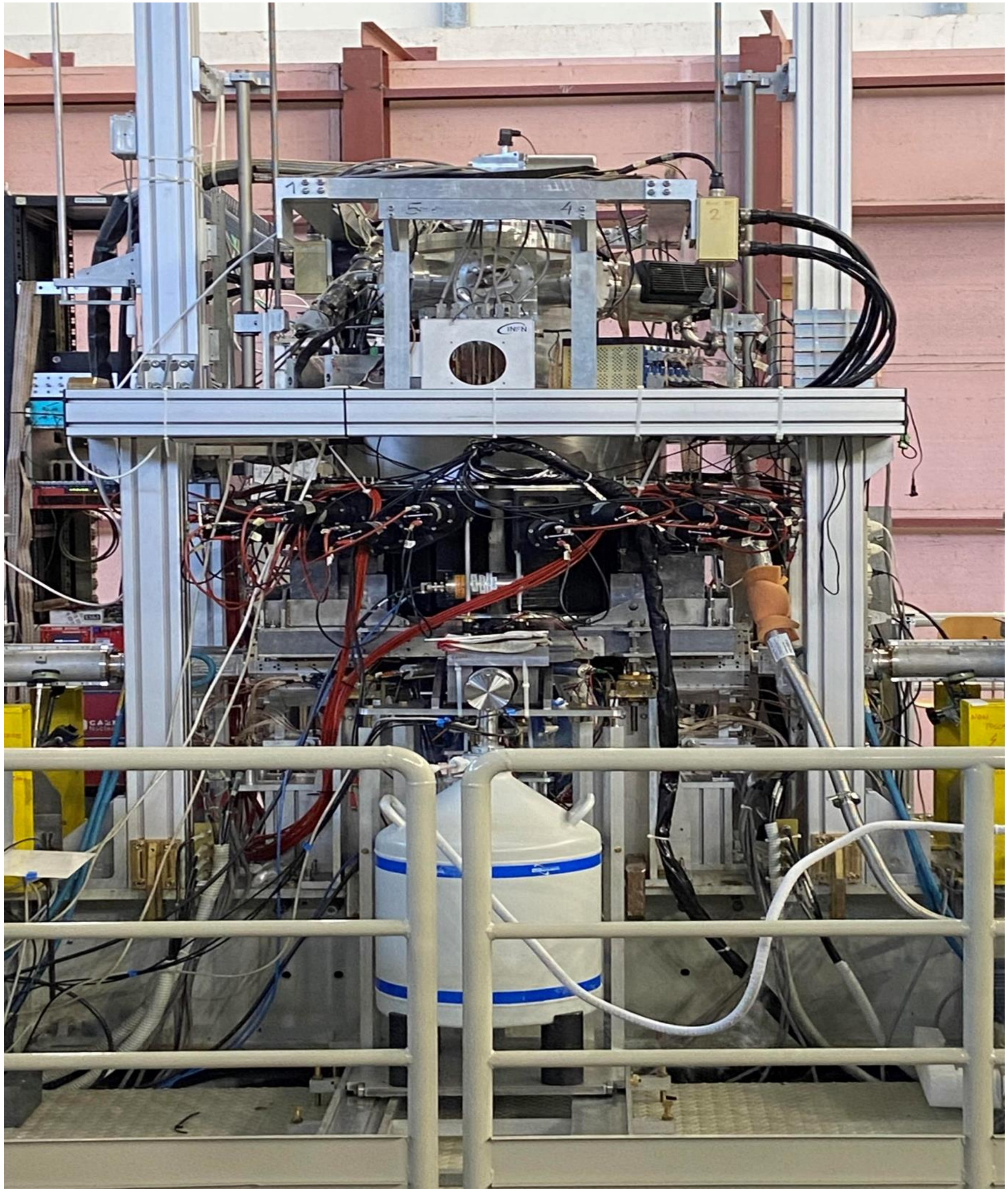
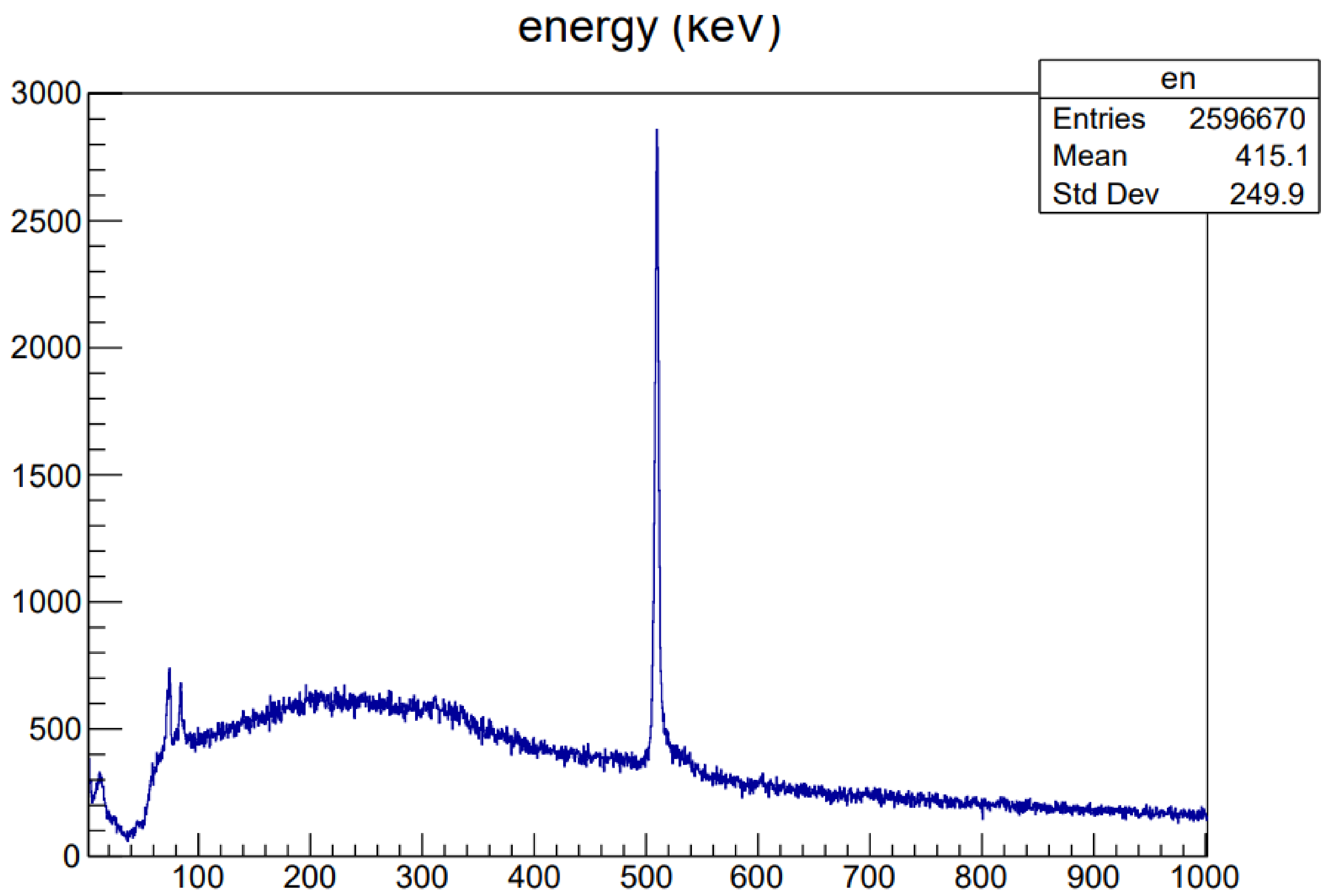
Take advantage of “free space” in DAΦNE



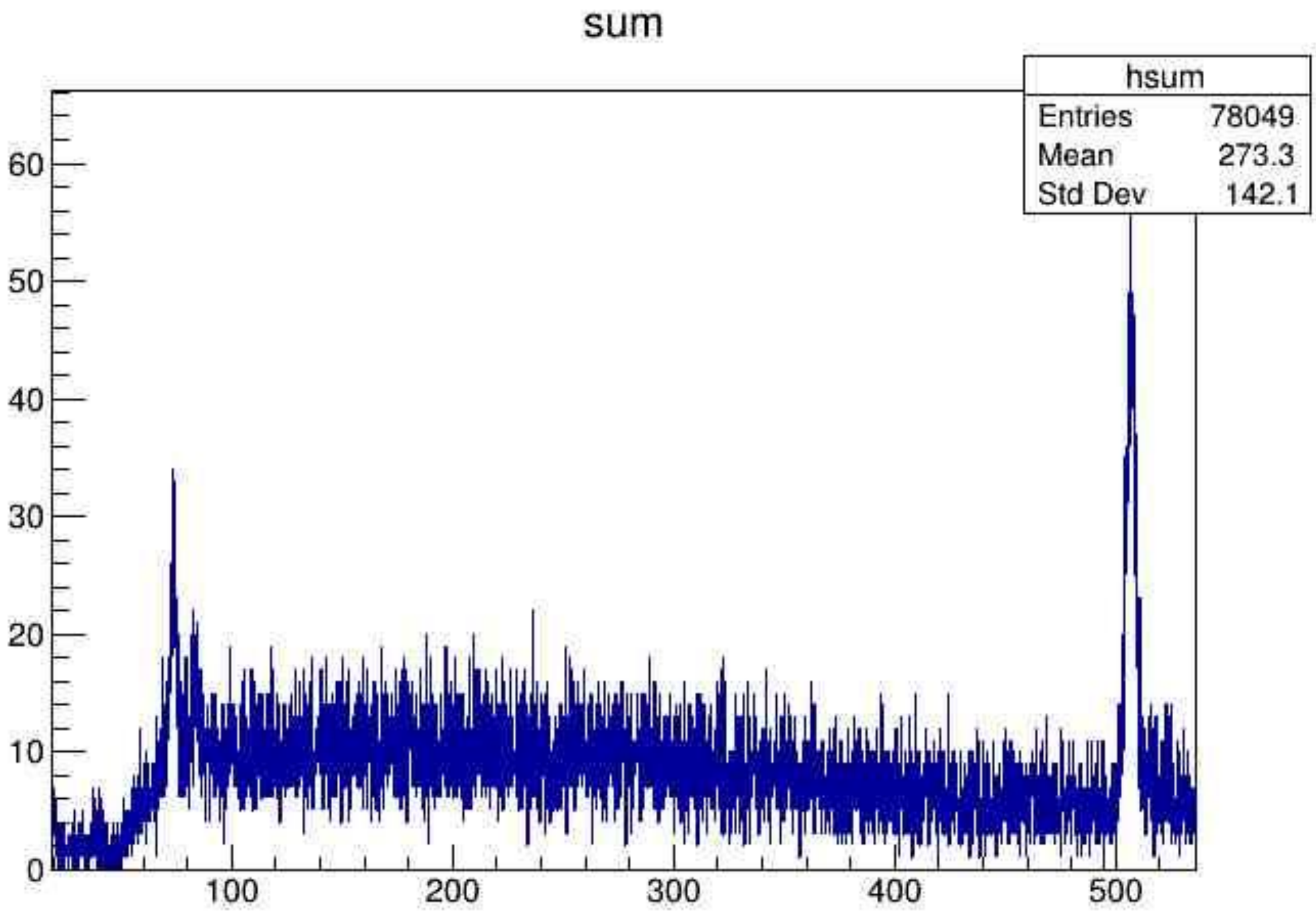
Present
status



First HPGe spectrum (we plan a technical paper)



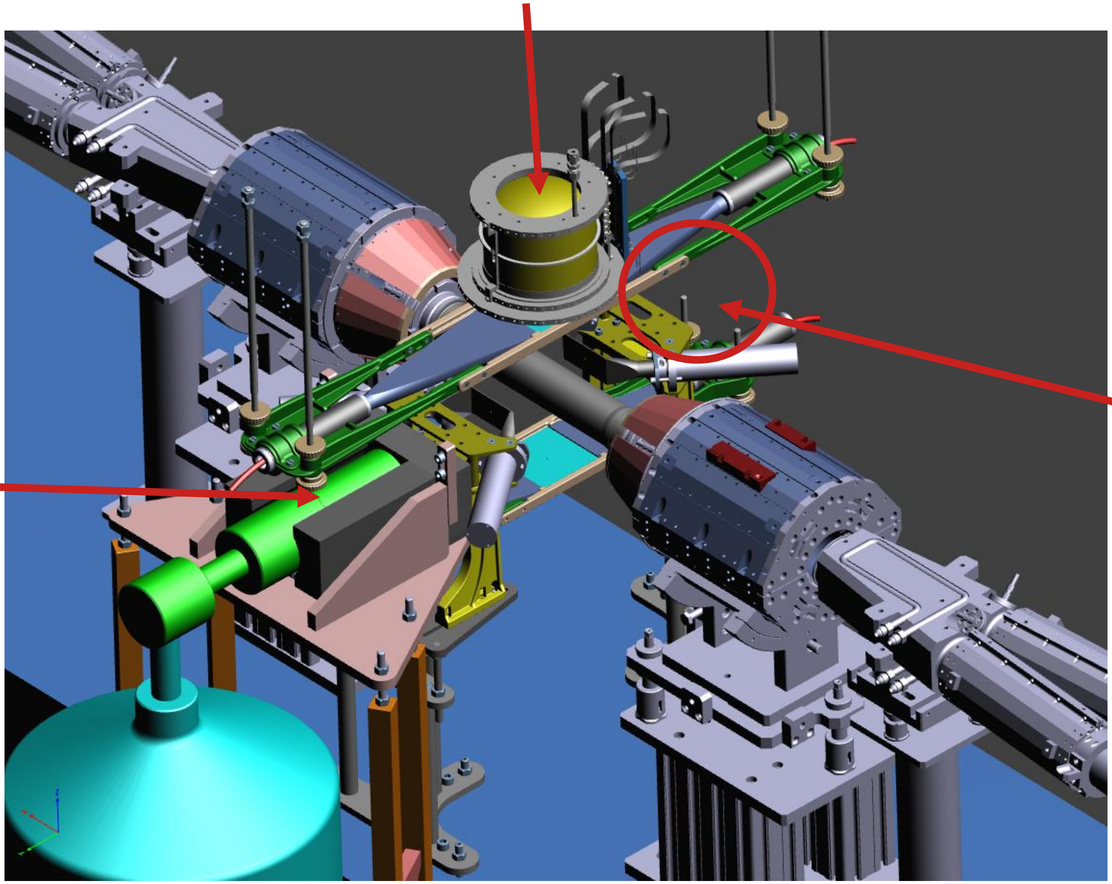
Measurements – 2 days
data analyses ongoing (kaonic lead – see last SC)



Intermediate-mass kaonic atoms' spectroscopy with CZT detectors: Exploiting DAFNE

HPGe
(0,1-1 MeV)

Heavy Kaonic
Atoms



CdZnTe
(30-300 keV)

Intermediate
Kaonic Atoms

DAΦNE delivers almost 4π K^-

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

Intermediate-mass kaonic atoms' spectroscopy with CZT detectors: physics goals and motivations

E. Friedman et al. / Nuclear Physics A579 (1994) 518–538

Table 1
Compilation of K^- atomic data

Nucleus	Transition	ϵ (keV)	Γ (keV)	Y	Γ_u (eV)
He	$3 \to 2$	-0.04 ± 0.03	–	–	–
		-0.035 ± 0.012	0.03 ± 0.03	–	–
Li	$3 \to 2$	0.002 ± 0.026	0.055 ± 0.029	0.95 ± 0.30	–
Be	$3 \to 2$	-0.079 ± 0.021	0.172 ± 0.58	0.25 ± 0.09	0.04 ± 0.02
^{10}B	$3 \to 2$	-0.208 ± 0.035	0.810 ± 0.100	–	–
^{11}B	$3 \to 2$	-0.167 ± 0.035	0.700 ± 0.080	–	–
C	$3 \to 2$	-0.590 ± 0.080	1.730 ± 0.150	0.07 ± 0.013	0.99 ± 0.20
O	$4 \to 3$	-0.025 ± 0.018	0.017 ± 0.014	–	–
Mg	$4 \to 3$	-0.027 ± 0.015	0.214 ± 0.015	0.78 ± 0.06	0.08 ± 0.03
Al	$4 \to 3$	-0.130 ± 0.050	0.490 ± 0.160	–	–
		-0.076 ± 0.014	0.442 ± 0.022	0.55 ± 0.03	0.30 ± 0.04
Si	$4 \to 3$	-0.240 ± 0.050	0.810 ± 0.120	–	–
		-0.130 ± 0.015	0.800 ± 0.033	0.49 ± 0.03	0.53 ± 0.06
P	$4 \to 3$	-0.330 ± 0.08	1.440 ± 0.120	0.26 ± 0.03	1.89 ± 0.30
S	$4 \to 3$	-0.550 ± 0.06	2.330 ± 0.200	0.22 ± 0.02	3.10 ± 0.36
		-0.43 ± 0.12	2.310 ± 0.170	–	–
		-0.462 ± 0.054	1.96 ± 0.17	0.23 ± 0.03	2.9 ± 0.5

Element	Transition	E (keV)
$K^{12}C$	3-->2	63
$K^{12}C$	4-->2	85
$K^{12}C$	5-->2	95
$K^{12}C$	6-->2	101
$K^{12}C$	7-->2	104
$K^{12}C$	4-->3	22
$K^{12}C$	5-->3	32
$K^{12}C$	6-->3	38
$K^{12}C$	7-->3	41

Element	Transition	E (keV)
$K^{32}S$	4-->3	161
$K^{32}S$	5-->4	74
$K^{32}S$	6-->4	115
$K^{32}S$	7-->4	139
$K^{32}S$	8-->4	155
$K^{32}S$	9-->4	166
$K^{32}S$	10-->4	174

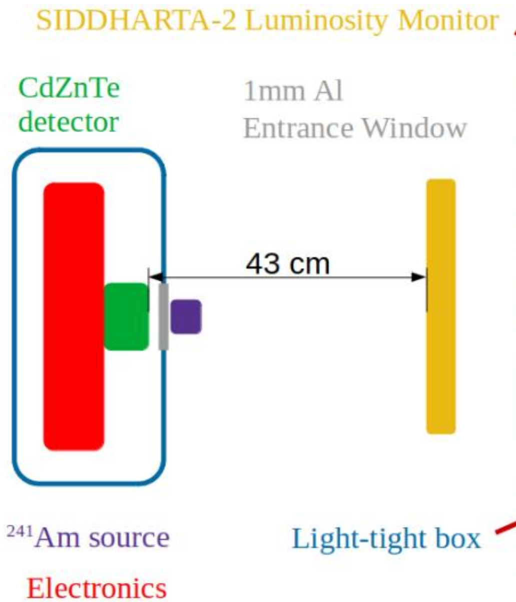
Element	Transition	E (keV)
$K^{27}Al$	3-->2	302
$K^{27}Al$	4-->3	106
$K^{27}Al$	5-->3	155
$K^{27}Al$	6-->3	181
$K^{27}Al$	7-->3	197
$K^{27}Al$	8-->3	208
$K^{27}Al$	5-->4	49
$K^{27}Al$	6-->4	76
$K^{27}Al$	7-->4	91
$K^{27}Al$	8-->4	102
$K^{27}Al$	9-->4	109
$K^{27}Al$	10-->4	114

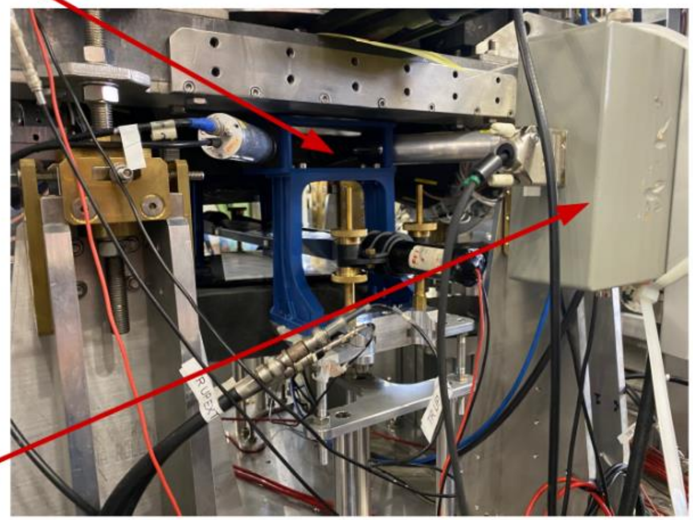
Examples :
KC(3→2), KAl(3→2), KS(4→3):
with
precisions < 20 eV (ε) and <40 eV (Γ)

Measurements of several parallel transitions to provide new inputs for cascade calculations & QCD & QED

Intermediate-mass kaonic atoms' spectroscopy with CZT detectors:
First ever tests of a CZT prototype on a collider 3 days in June

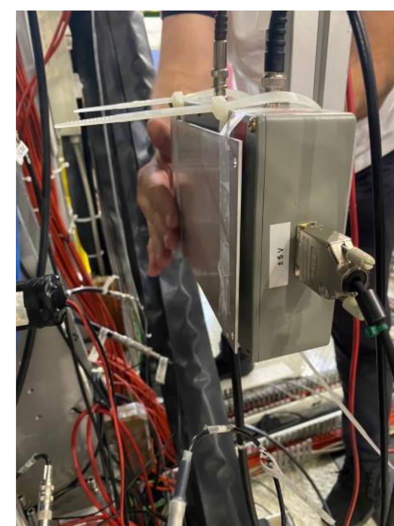
Goal: background and resolution assessment in machine environment



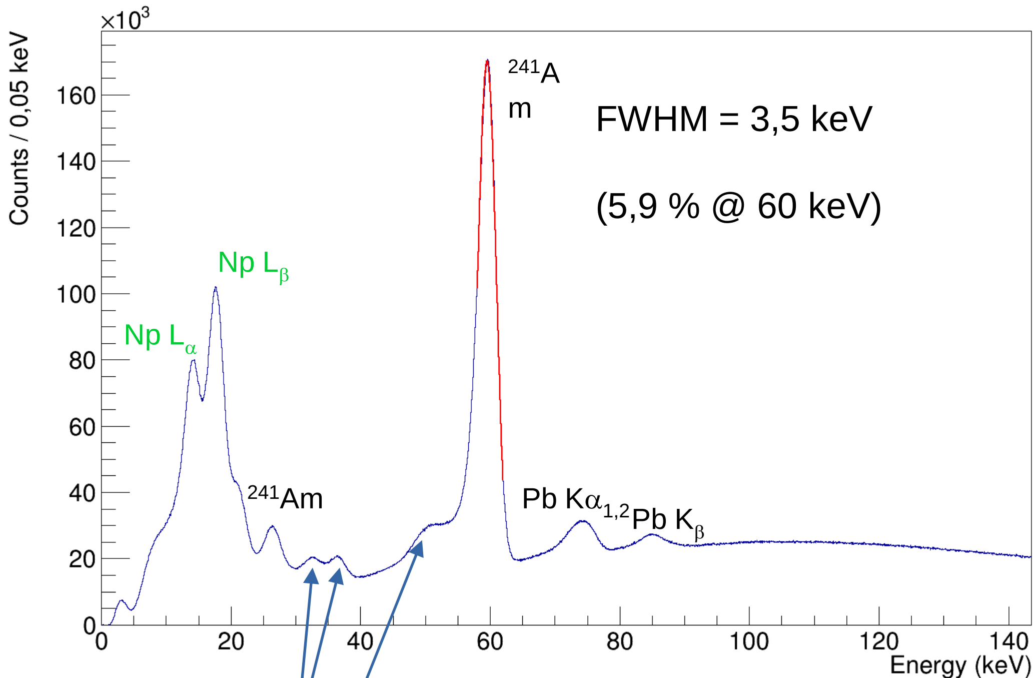


22/06/2022:

First prototype installed in DAΦNE with the help of Palermo Team



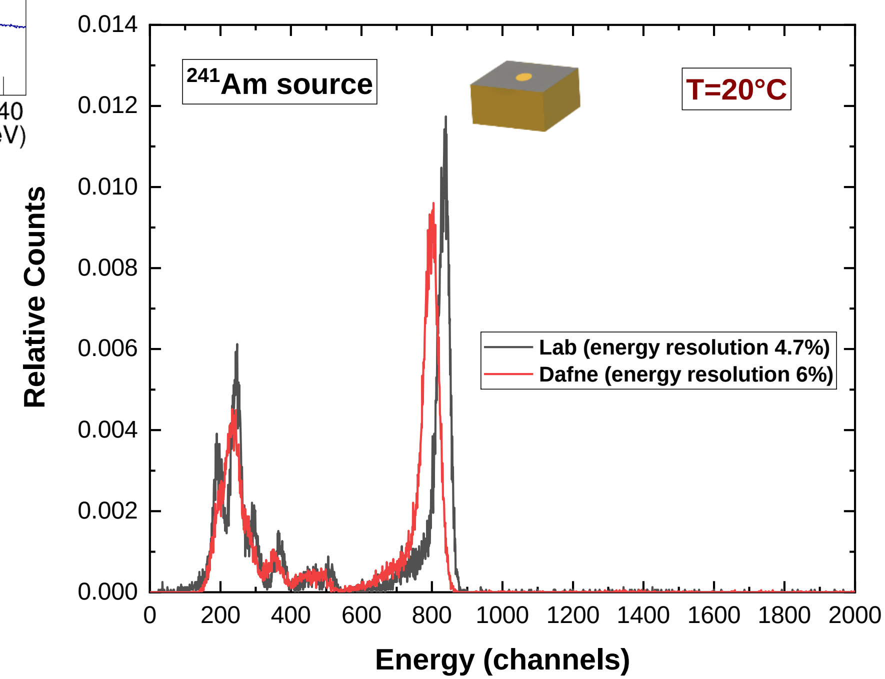
Intermediate-mass kaonic atoms' spectroscopy with CZT detectors: Main Results and achievements



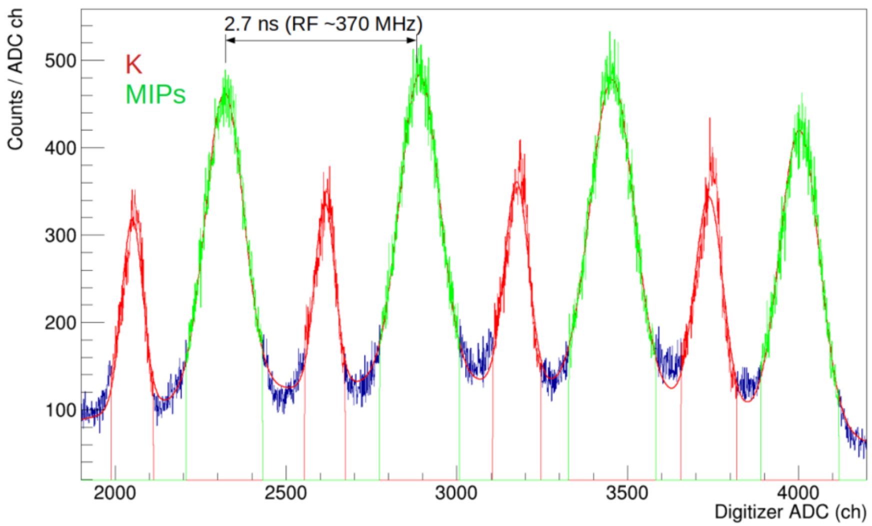
Element	K-shell absorption energy (keV)	Fluorescent lines	Energy of fluorescent lines (keV)	λ_{CdZnTe} (µm)
Cd	26.7	$K\alpha_1$	23.17	116
		$K\beta_1$	26.10	161
Zn	9.7	$K\alpha_1$	8.54	8.4
		$K\beta_1$	9.57	11.4
Te	31.8	$K\alpha_1$	27.47	69
		$K\beta_1$	31.00	95

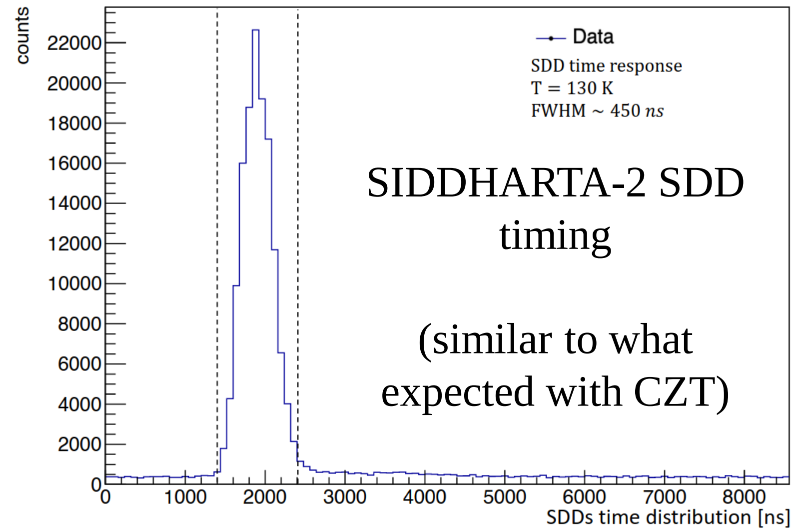
Good resolutions are confirmed

Small worsening only due to 30 m long cables in DAFNE (to be modified in the future)

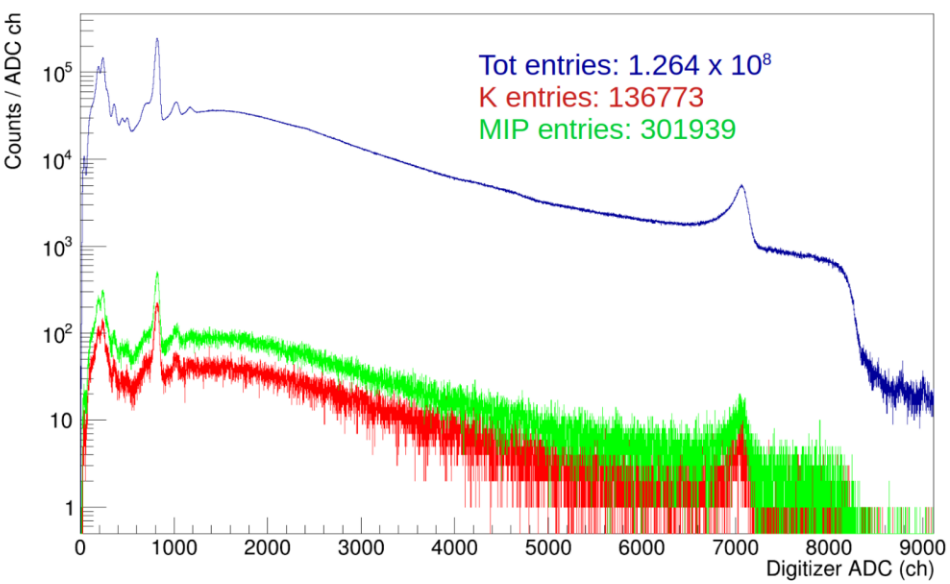


Intermediate-mass kaonic atoms' spectroscopy with CZT detectors: Testing background rejection





Request	Events	Rejection factor
No request	1.26×10^8	1
K^-_{TAC}	136359	3×10^2
$K^-_{TAC}, \Delta T < 1\,\mu s$	1096	1.15×10^5
$K^-_{TAC}, \Delta T < 500$ ns	605	2.08×10^5
$K^-_{TAC}, \Delta T < 300$ ns	374	3.33×10^5
$K^-_{TAC}, \Delta T < 100$ ns	124	1.02×10^6



CdZnTe will allow for FWHM< 100 ns timing peak

Rejection factors ~10^6 can be expected

Intermediate-mass kaonic atoms' spectroscopy with CZT detectors: First 3 papers

Springer Nature 2021 LaTeX template

New opportunities for kaonic atoms measurements from CdZnTe detectors

L. Abbene[1], M. Bettelli[2], A. Buttacavoli[1], F. Principato[1], A. Zappettini[2], C. Amsler[3], M. Bazzi[4], D. Bosnar[5], M. Bragadireanu[6], M. Cargnelli[3], M. Carminati[7], A. Clozza[4], G. Deda[7], L. De Paolis[4], R. Del Grande[8,4], L. Fabbietti[8], C. Fiorini[7], I. Friščić[5], C. Guaraldo[4], M. Iliescu[4], M. Iwasaki[9], A. Khreptak[4], S. Manti[4], J. Marton[3], M. Miliucci[4], P. Moskal[10,11], F. Napolitano[4], S. Niedźwiecki[10,11], H. Ohnishi[12], K. Piscicchia[13,4], Y. Sada[12], F. Sgaramella[4], H. Shi[3], M. Silarski[10,11], D. L. Sirghi[4,13,6], F. Sirghi[4,6], M. Skurzok[10,11], A. Spallone[4], K. Toho[12], M. Tüchler[3,14], O. Vazquez Doce[4], C. Yoshida[12], J. Zmeskal[3], A. Scordo[4*] and C. Curceanu[4]

Submitted to EPJ_ST

sensors

MDPI

Article

Potentialities of a digital quasi-hemispherical CdZnTe detector for kaonic atoms X-ray spectroscopy.

Antonino Buttacavoli[1], Fabio Principato[1], Gaetano Gerardi[1], Manuele Bettelli[2], Andrea Zappettini[2], Alessandro Scordo[3], Catalina Curceanu[3], and Leonardo Abbene[1,*]

[1] 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.);
[2] 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.);
[3] INFN-LNF, Istituto Nazionale di Fisica Nucleare-Laboratori Nazionali di Frascati, Frascati, 00044 Roma, Italy
* Correspondence: leonardo.abbene@unipa.it

Received: date; Accepted: date; Published: date

In preparation

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Project timeline – future plan

SIDDHARTA-2 Kd run: run 1 (requested 400 pb^{-1})
run 2 (400 pb^{-1}) with optimized components

Start of the data taking
kaonic deuterium
SIDDHARTA-2 run

SIDDHARTA-2
setup preparation
till end February '23

Start Run1
SIDDHARTA-2
and
HPGe and CdZnTe
setups parasitic test

From early March to
July 2023

DAΦNE summer
shutdown

Continue with Run2
SIDDHARTA-2
Kd
HPGe

as soon as
possible!
Autumn 2023
or 2024

SIDDHARTA-2 K-d measurement

achievable precision

*Kaonic deuterium run in **2023/4***

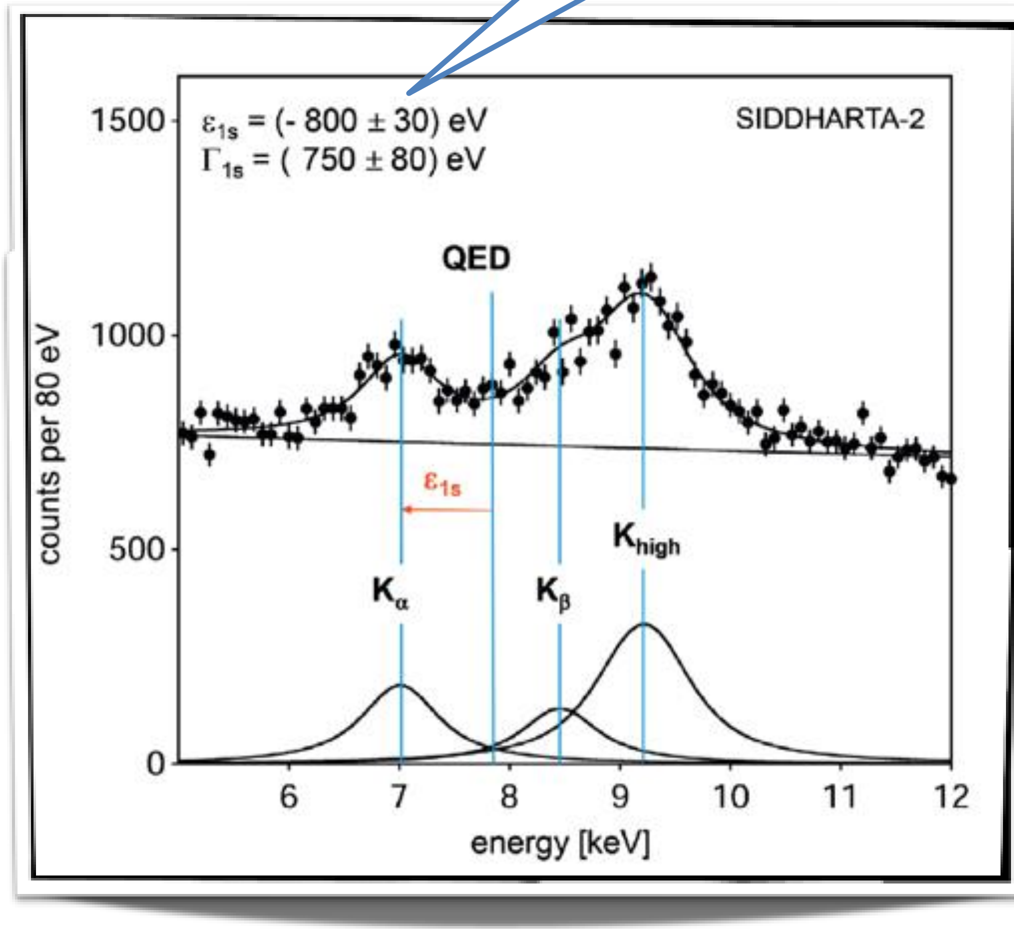
*Monte Carlo for an integrated luminosity of **800 pb^{-1}***

to perform the first measurement of the strong interaction induced energy shift and width of the kaonic deuterium ground state (similar precision as K-p) !

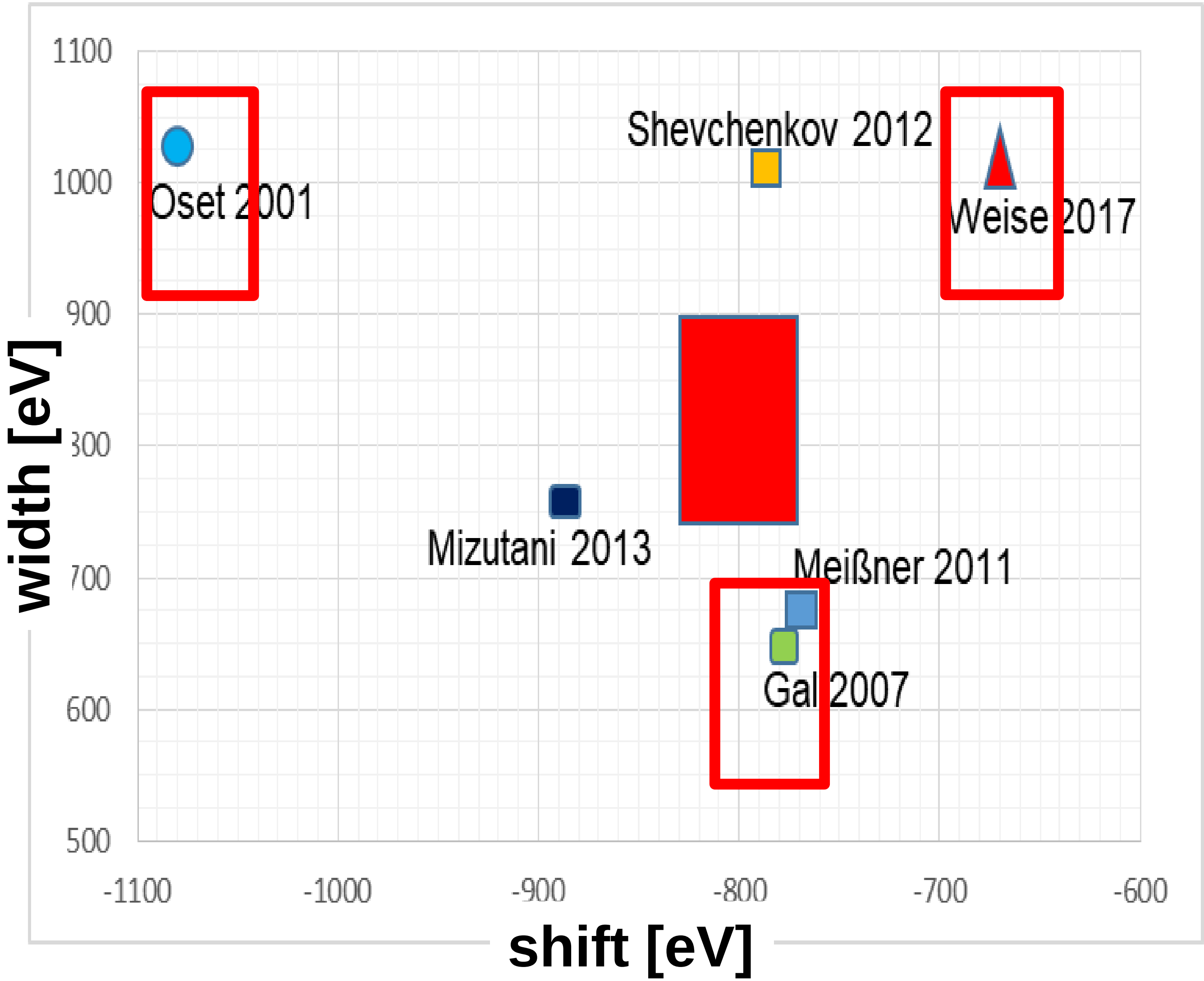
When significative?

Depends on yield (unknown)

Not less than 500 pb^{-1}

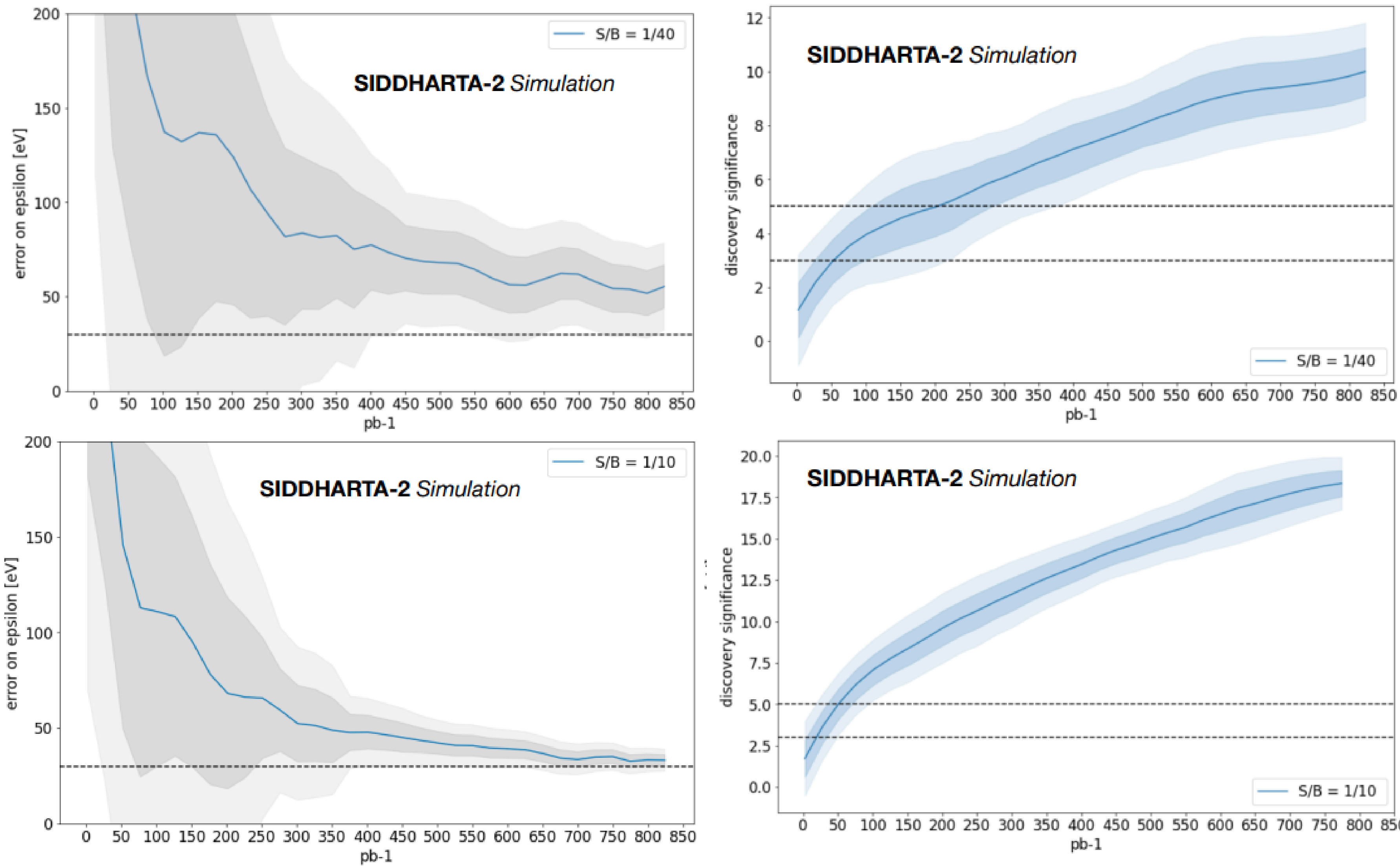


SIDDHARTA-2 kaonic deuterium at DAΦNE



Precision and significance

Precision on shift



Conclusions

- **The first SIDDHARTA-2 run has been concluded successfully: optimization of setup; run with Khe; technical run with Kd**

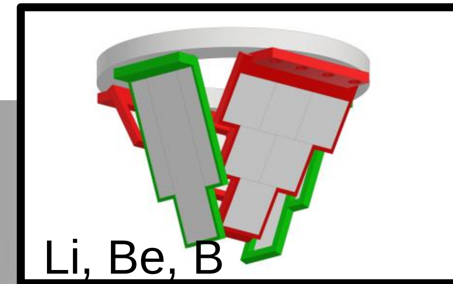
- **In particular we: we performed the most precise KHe measurement in gas and the measurement of yields at lowest density; first M-lines observation ever; kaonic atoms from solid targets**

- **11 articles were published/submitted since the last Sci Com – important scientific outcome, 4 are in preparation**

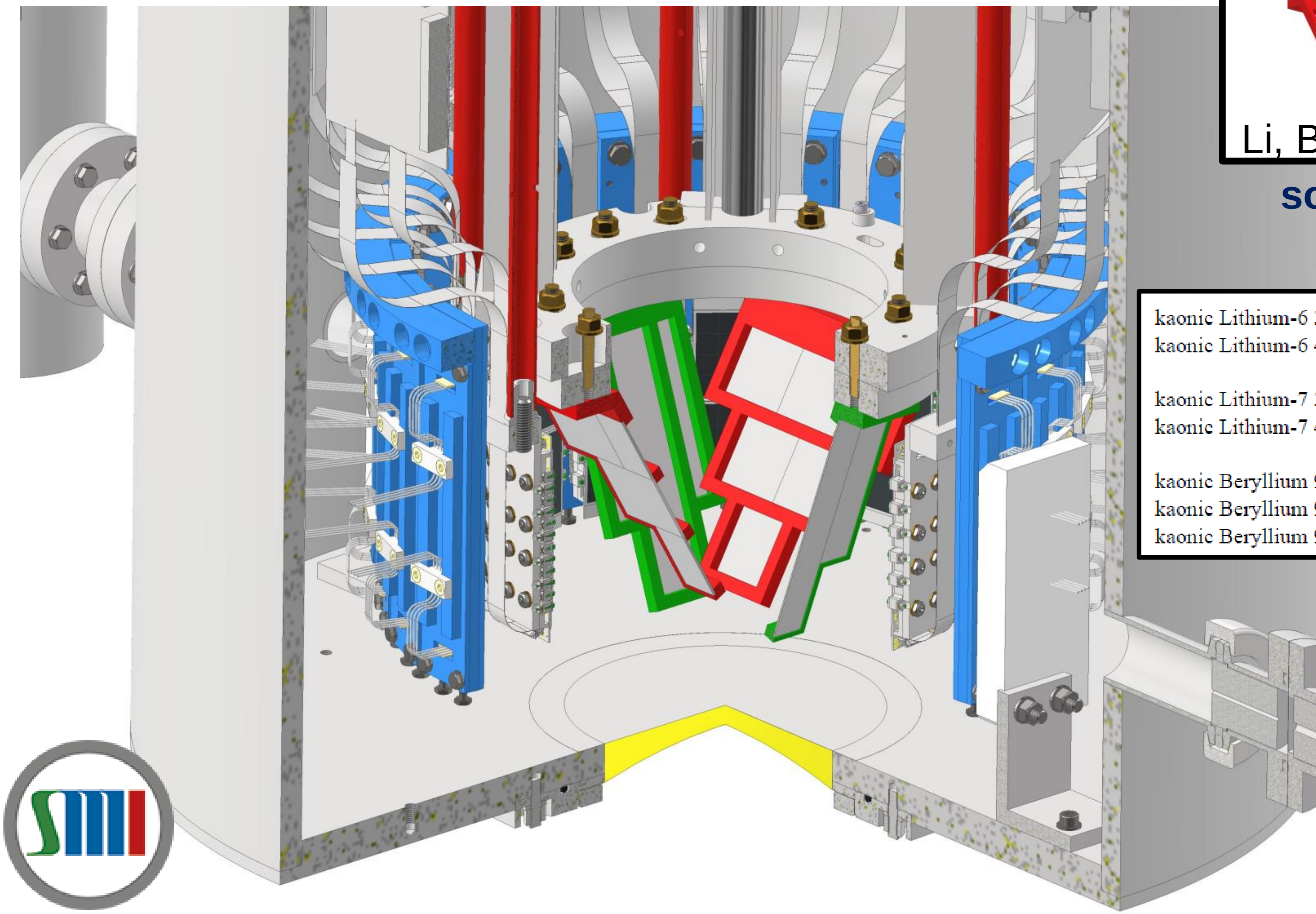
- **We are ready and very motivated to start the SIDDHARTA-2 (forst) Kd measurement as soon as possible**

- **We put forward proposal for solid targets measurements with SIDDHARTA-2 setup for 100-150 pb^{-1} after Kd run - @SC62 as well as future measurements proposal**

SDD 1mm development - Solid targets



solid targets



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

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

Kaonic atoms

Kaon-nuclei interactions (scattering and nuclear interactions)

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

Dark Matter studies

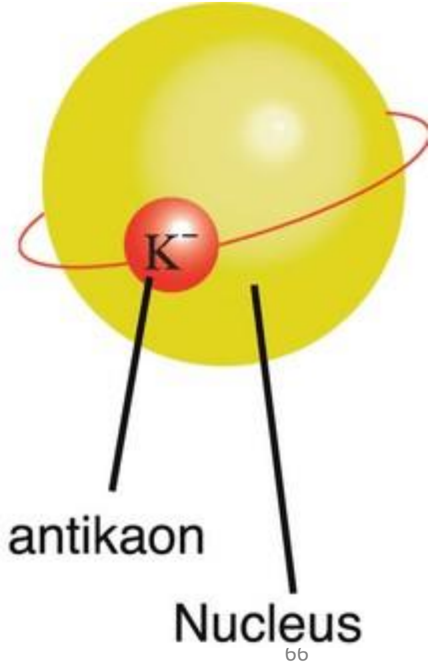
The equation of state of dense matter: Stiff, soft, or both? Astron.Nachr. 340 (2019) 1-3, 189

Astrophysics
EOS Neutron Stars

EXtensive Kaonic Atoms research:

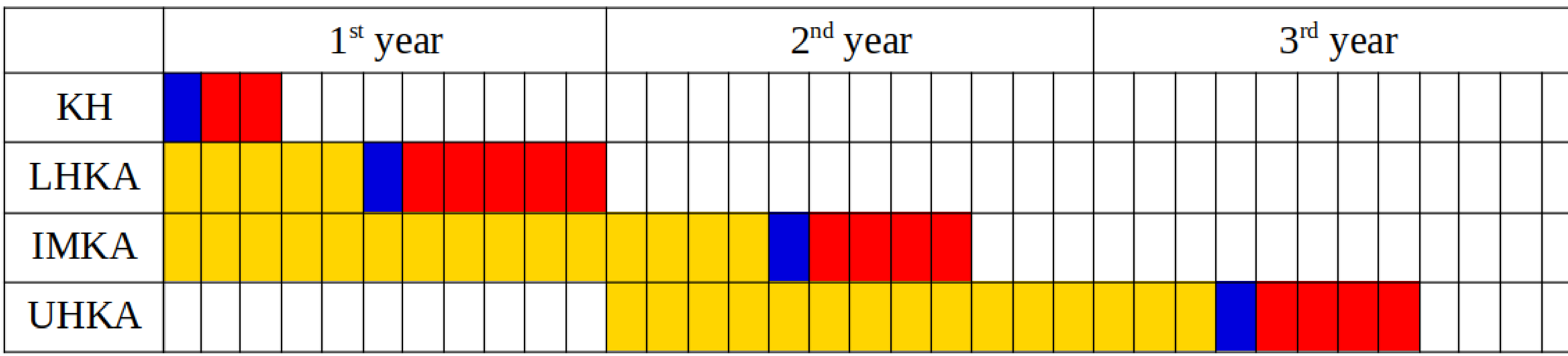
from LIthium and Beryllium to Uranium

EXKALIBUR



Gantt chart – possible implementation of the kaonic atoms measurements

Total integrated Luminosity:
200 + 400 (200) + 400 (200) + 400 pb^{-1}



Preparation of the experiment

Installation and commissioning

Data taking

Part of the SIDDHARTA-2 collaboration

Thank you!


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

In Conclusion, we propose to perform fundamental Physics at the strangeness frontier at DAΦNE studies:

High Precision Kaonic Atoms Measurements on DAΦNE:

The strangeness Mendeleev table

We presented a program for performing unique measurements of kaonic atoms along the periodic table to contributing to understand physics going from the strong interaction (symmetry breaking) to neutron stars, and from Dark Matter to Physics Beyond Standard Model, setting LNF in forefront of these studied.

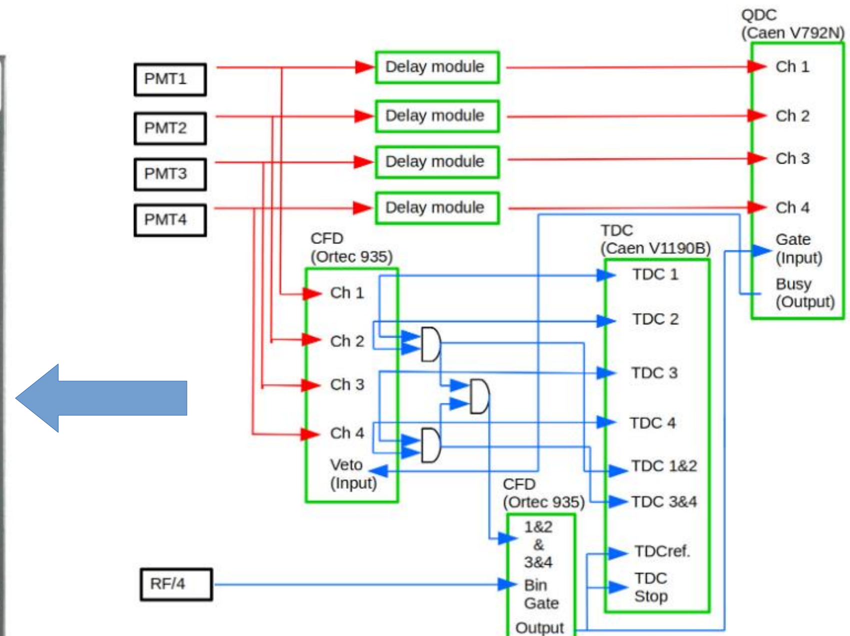
A strong international community is putting forward this realistic and feasible programme in particular in terms of the required integrated , that can be delivered within the upcoming 3-5 years, with support from National and European projects.

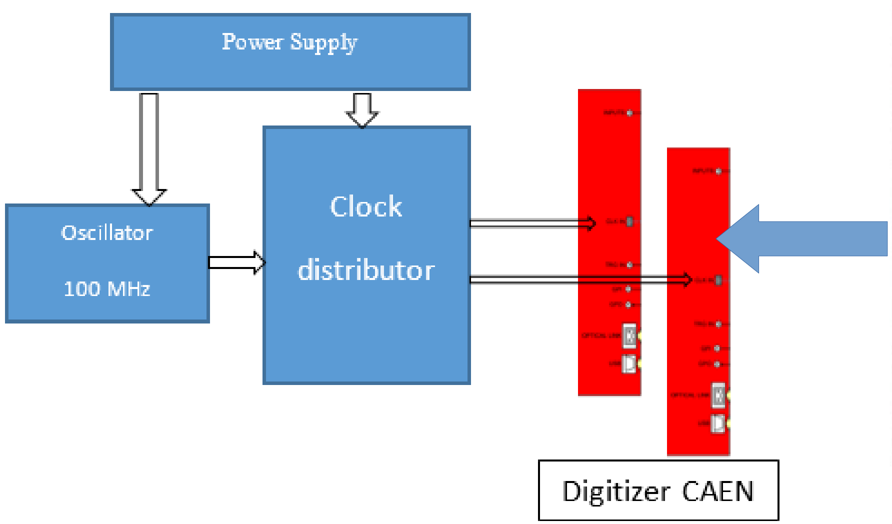
Intermediate-mass kaonic atoms' spectroscopy with CZT detectors: DAQ logic and synchronization with SIDDHARTA-2 LM

Signals from the SIDDHARTA-2 Luminometer have been processed with a Time to Analog Converter (TAC)

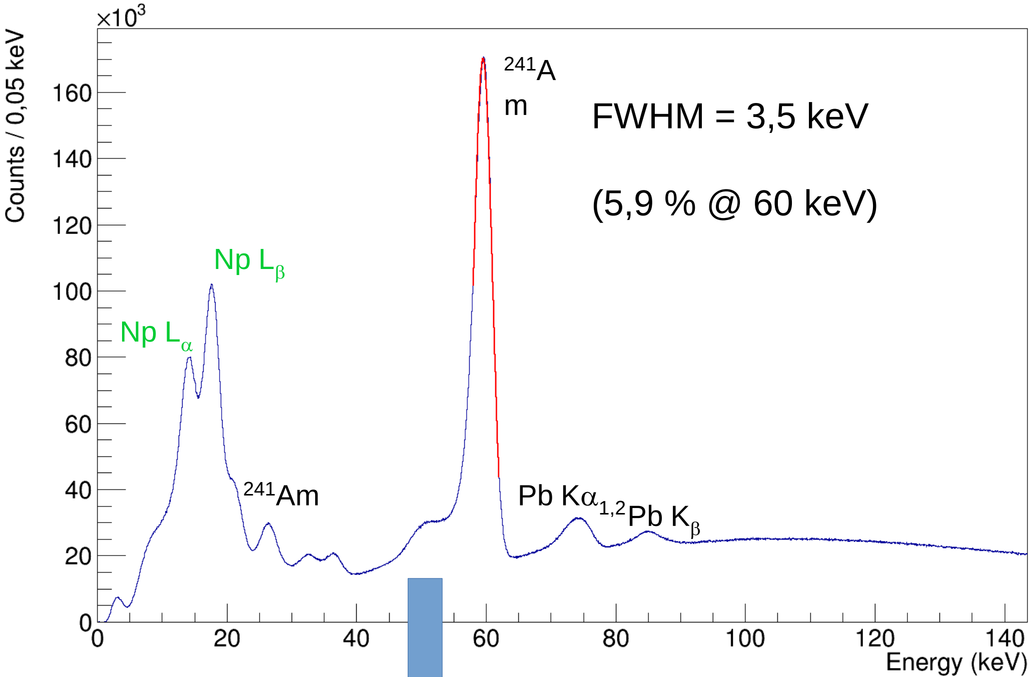
2 Digitizers CAEN DT5724-16 used to acquire both CZT & TAC events

Time correlation with a Clock Distributor (custom from Palermo Team)



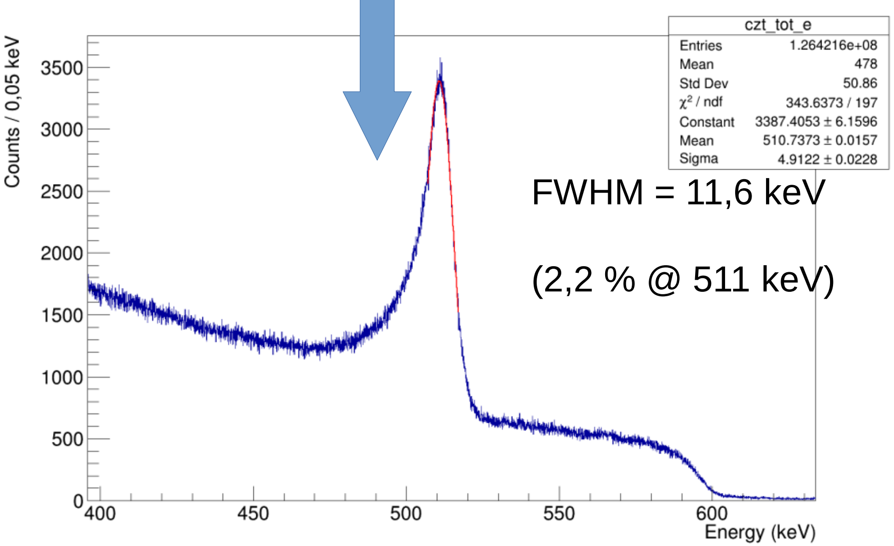


Intermediate-mass kaonic atoms' spectroscopy with CZT detectors: Main Results and achievements



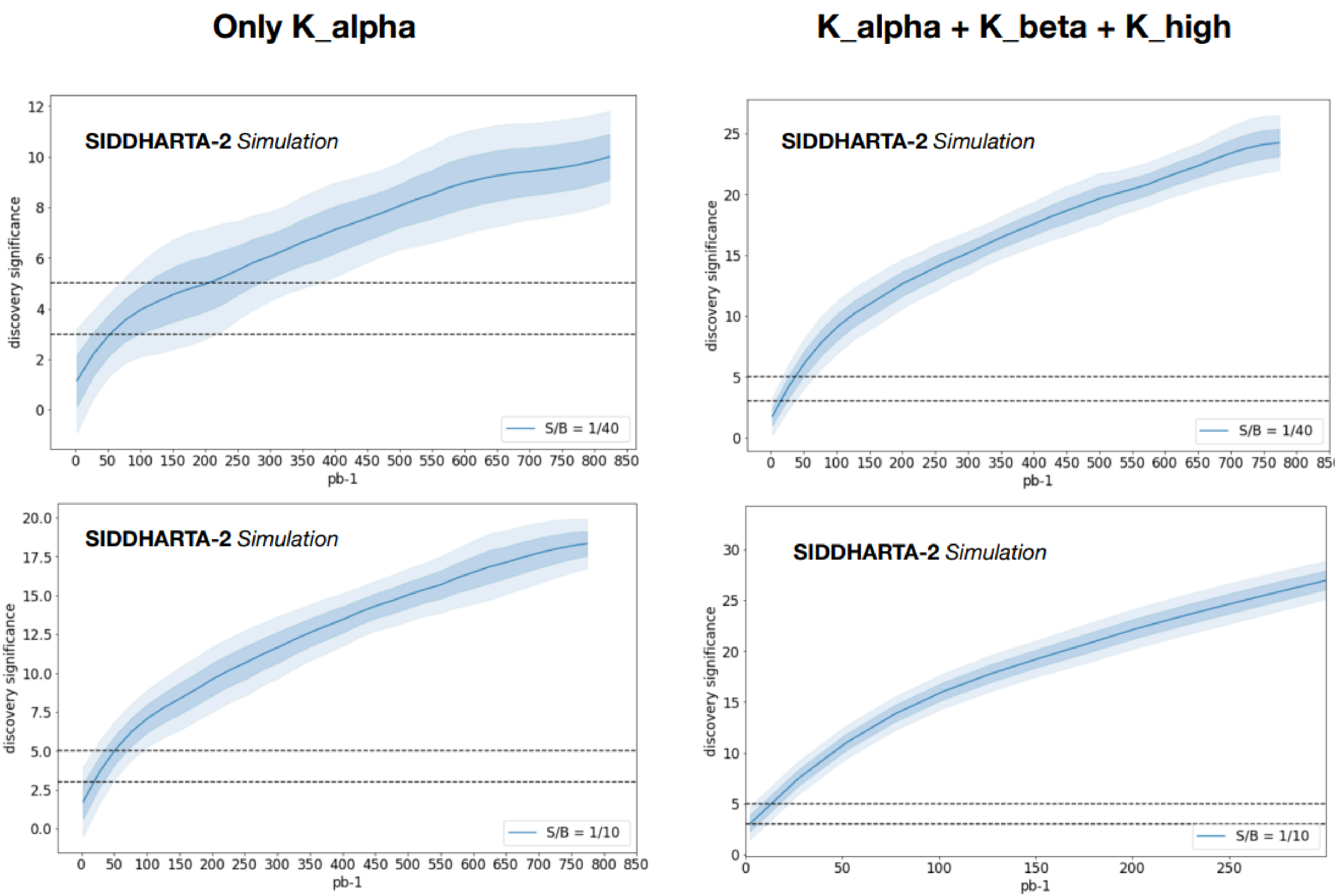
Spectra has been calibrated using Np, A and Pb peaks (E < 100 keV)

e+e- annihilation peak (511 keV) found in the exact position

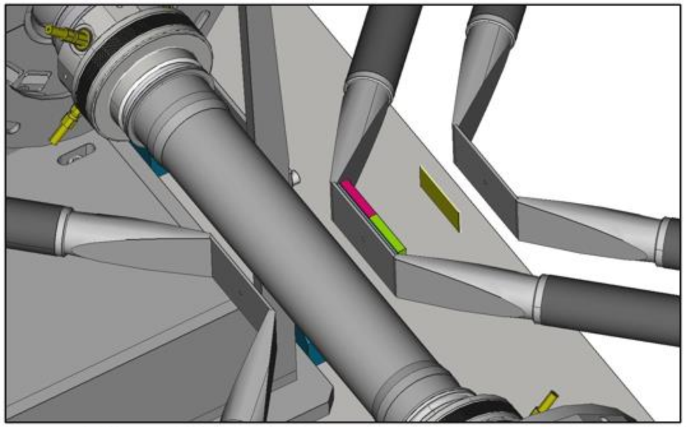


Linearity is preserved over a wide energy range

Expected signal sensitivity for SIDDHARTA-2 Deuterium Measurement



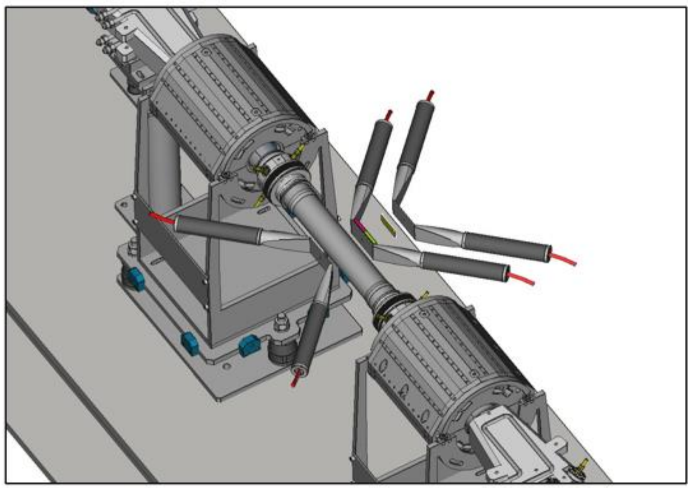
Intermediate-mass kaonic atoms' spectroscopy with CZT detectors: 2023 plans

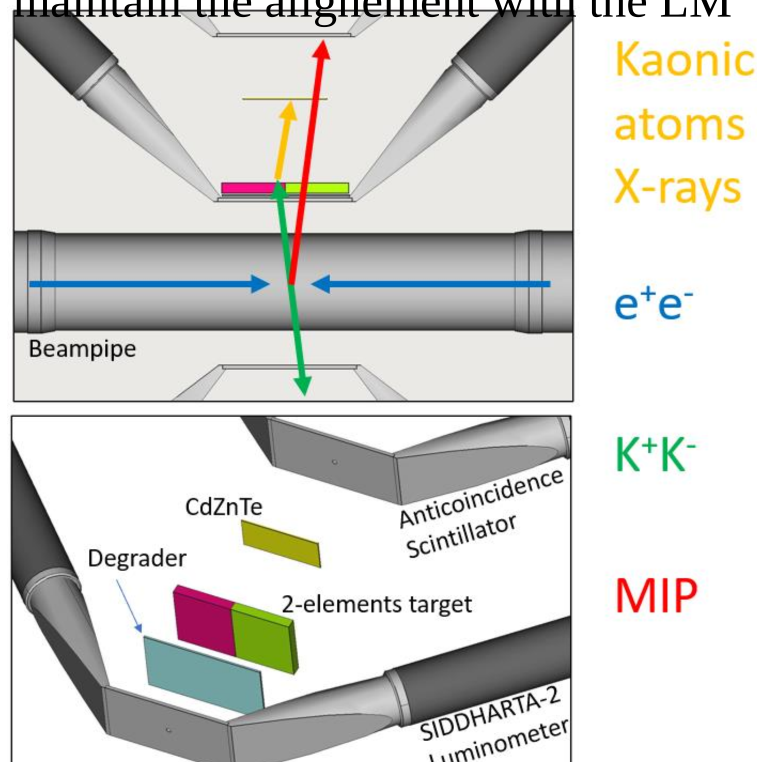


A new run is foreseen in 2023 to measure intermediate-mass kaonic atoms' transitions

Improvements:

Detecting surface : 1 $cm^2 \rightarrow 10\ cm^2$
Degrader and geometry tuned with GEANT4 MC
Mechanical setup to maintain the alignement with the LM





Fast, handy and significant physics measurements with very low costs and human efforts

Operation plan for 2022
(in agreement with LNF Management)

7 April
Started collision for SIDDHARTA-2 RUN

7 April – 27 May
KHe runs
Integrated luminosity KHe: 45 pb-1

Simultaneously we carried out further debugging of the trigger and luminometer, degrader optimization
Veto systems calibration

2 June
Collider mode
SIDDHARTA-2 RUN for Kd

11 July
END of collider mode

2 June – 6 July
First Kaonic deuterium RUN – full setup
Integrated luminosity (Deuterium): 35 pb-1

7 July – 11 July
KHe calibration run (~5 pb-1)
Energy scan

2023