Radiation detectors for present and future kaonic atoms' measurements at DAΦNE

"EXOTICO: EXOTIc atoms meet nuclear COllisions for a new frontier precision era in low-energy strangeness nuclear physics"

A. Scordo, Trento (ECT*), 18/10/2022

Why (again and still) kaonic atoms?

402 C.J. Batty et al. / Physics Reports 287 (1997) 385–445

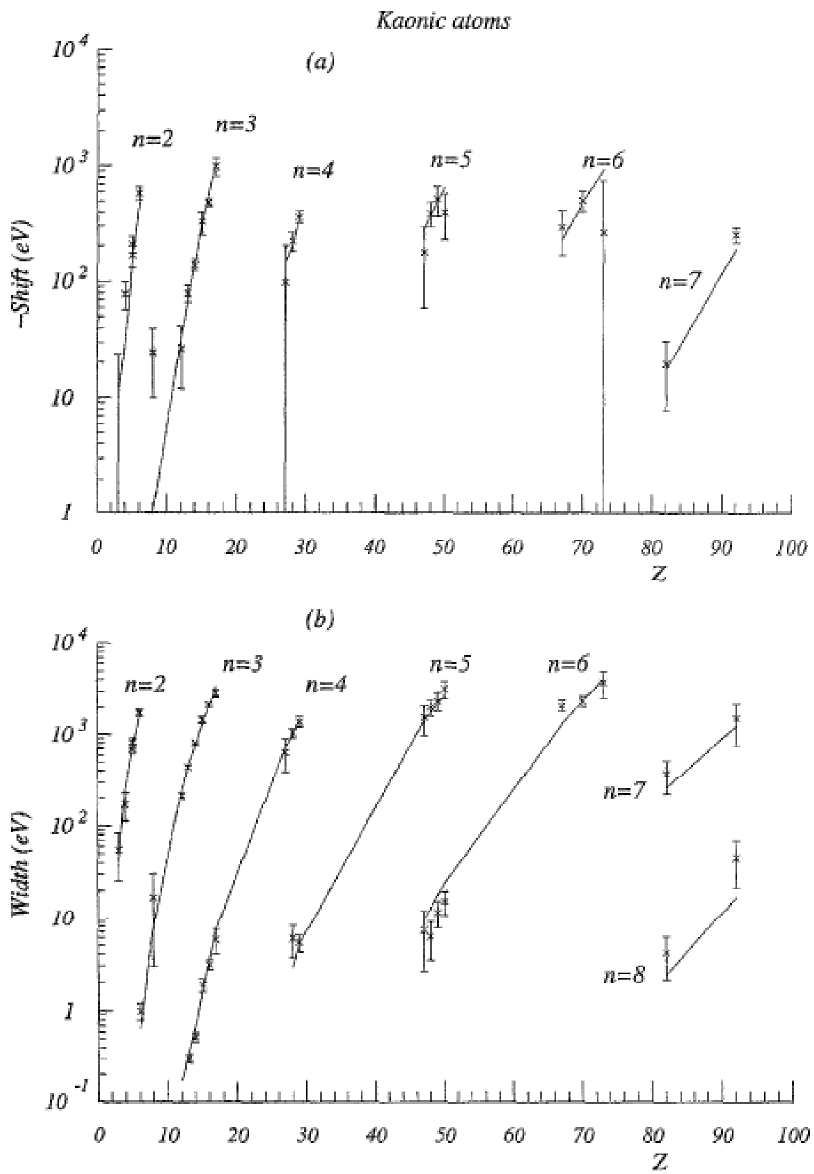


Fig. 7. Shift and width values for kaonic atoms. The continuous lines join points calculated with the best-fit optical potential discussed in Section 4.2.

Except for the most recent measurements at DAΦNE and JPARC on KHe and KH, the whole knowledge on kaonic atoms dates back to 1970s and 1980s

These data are the experimental basis for all the developed theoretical models

These theoretical models are used to derive, for example:

- KN interaction at threshold
- KNN interaction at threshold
- Nuclear density distributions
- Possible existence of kaon condensates
- Kaon mass
- Kaonic atoms cascade models

Why (again and still) kaonic atoms?

E. Friedman et al. / Nuclear Physics A579 (1994) 518–538 521

Table 1
Compilation of K^- atomic data

Nucleus	Transition	ϵ (keV)	Γ (keV)	Y	Γ_u (eV)	Ref.
He	3→2	−0.04 ±0.03	–	–	–	[15]
		−0.035±0.012	0.03 ±0.03	–	–	[16]
Li	3→2	0.002±0.026	0.055±0.029	0.95±0.30	–	[17]
Be	3→2	−0.079±0.021	0.172±0.58	0.25±0.09	0.04±0.02	[17]
^{10}B	3→2	−0.208±0.035	0.810±0.100	–	–	[18]
^{11}B	3→2	−0.167±0.035	0.700±0.080	–	–	[18]
C	3→2	−0.590±0.080	1.730±0.150	0.07±0.013	0.99±0.20	[18]
O	4→3	−0.025±0.018	0.017±0.014	–	–	[19]
Mg	4→3	−0.027±0.015	0.214±0.015	0.78±0.06	0.08±0.03	[19]
Al	4→3	−0.130±0.050	0.490±0.160	–	–	[20]
		−0.076±0.014	0.442±0.022	0.55±0.03	0.30±0.04	[19]
Si	4→3	−0.240±0.050	0.810±0.120	–	–	[20]
		−0.130±0.015	0.800±0.033	0.49±0.03	0.53±0.06	[19]
P	4→3	−0.330±0.08	1.440±0.120	0.26±0.03	1.89±0.30	[18]
S	4→3	−0.550±0.06	2.330±0.200	0.22±0.02	3.10±0.36	[18]
		−0.43 ±0.12	2.310±0.170	–	–	[21]
		−0.462±0.054	1.96 ±0.17	0.23±0.03	2.9 ±0.5	[19]
Cl	4→3	−0.770±0.40	3.80 ±1.0	0.16±0.04	5.8 ±1.7	[18]
		−0.94 ±0.40	3.92 ±0.99	–	–	[22]
		−1.08 ±0.22	2.79 ±0.25	–	–	[21]
Co	5→4	−0.099±0.106	0.64 ±0.25	–	–	[19]
Ni	5→4	−0.180±0.070	0.59 ±0.21	0.30±0.08	5.9 ±2.3	[20]
		−0.246±0.052	1.23 ±0.14	–	–	[19]
Cu	5→4	−0.240±0.220	1.650±0.72	0.29±0.11	7.0 ±3.8	[20]
		−0.377±0.048	1.35 ±0.17	0.36±0.05	5.1 ±1.1	[19]
Ag	6→5	−0.18 ±0.12	1.54 ±0.58	0.51±0.16	7.3 ±4.7	[19]
Cd	6→5	−0.40 ±0.10	2.01 ±0.44	0.57±0.11	6.2 ±2.8	[19]
In	6→5	−0.53 ±0.15	2.38 ±0.57	0.44±0.08	11.4 ±3.7	[19]
Sn	6→5	−0.41 ±0.18	3.18 ±0.64	0.39±0.07	15.1 ±4.4	[19]
Ho	7→6	−0.30 ±0.13	2.14 ±0.31	–	–	[23]
Yb	7→6	−0.12 ±0.10	2.39 ±0.30	–	–	[23]
Ta	7→6	−0.27 ±0.50	3.76 ±1.15	–	–	[23]
Pb	8→7	–	0.37 ±0.15	0.79±0.08	4.1 ±2.0	[24]
		−0.020±0.012	–	–	–	[25]
U	8→7	−0.26 ±0.4	1.50 ±0.75	0.35±0.12	45 ±24	[24]

The available data on “lower levels” have big uncertainties

Many of them are actually UNmeasured

Many of them are hardly compatible among each other

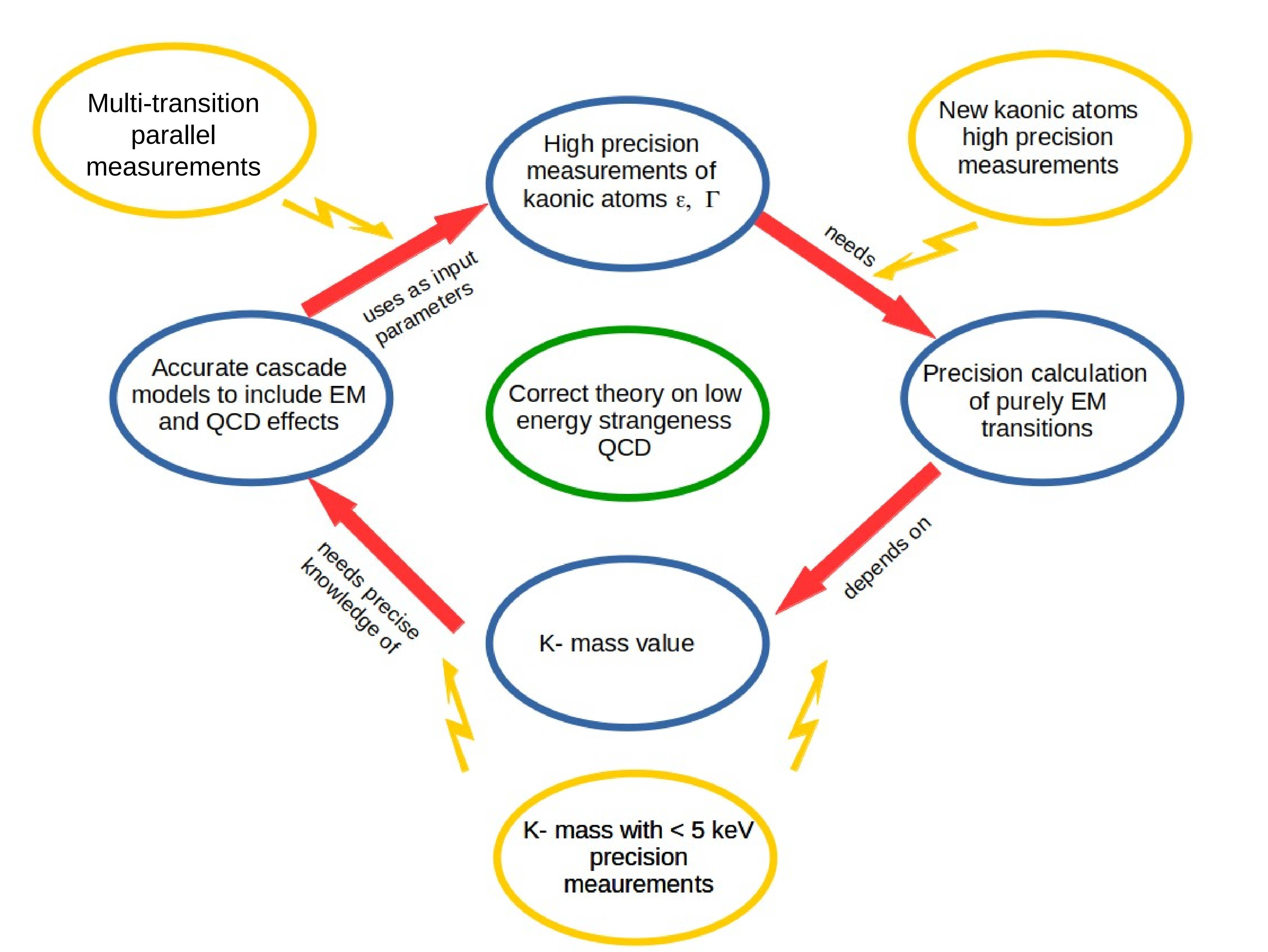
Relative yields with upper levels are not always measured

Absolute yields are basically unknown (except for few transitions)

The REmeasured ones have been proved WRONG

This situation would already be a proper justification for new measurements

What more can we learn from new measurements?



What more can we learn from new measurements?

"Fundamental Physics at the strangeness frontier at DAΦNE" Workshop

INFN-LNF - ONLINE, 25-26/02/2021

80 participants from more than 20 different institutes

Several "strange" topics covered and intense discussion showing that the physics case and the community are strong and sparkling

Focused on DAΦNE, the BEST facility in the world for low energy strangeness experiments

Summary

- Significant progress in understanding kaonic atoms, converging on multinucleon interaction with the nucleus.
- 35-40 years old data have yielded beyond expectations.
- High quality measurements for L=1 kaonic states in ^{3,4}He, ^{6,7}Li, ^{9}Be, ^{10,11}B and ^{12}C could allow for few-body approaches, connecting to the density dependence in heavier kaonic atoms.
- It is high time for new experiments.

I wish to thank Avraham Gal and Nir Barnea for meetings and discussions.

This work is supported by the European Union Horizon 2020 research and innovation programme under grant agreement No. 824093.

Conclusions: kaonic atoms calculations

- The microscopic K^-NN model was applied in the calculations of kaonic atoms
- Preliminary results:
  - data are best described by $K^-N + K^-NN$ potentials based on Pauli blocked BCN amplitudes
  - $K^-N + K^-NN$ potentials supplemented by a phenomenological term describing 3 and 4 nucleon processes
  - fit to the data suggests that Re$(K^-N + K^-NN)$ should be more attractive and Im$(K^-N + K^-NN)$ should be less absorptive
- EXPERIMENT:
  - It would be desirable to revise some kaonic atom data
  - More data on 3N and 4N absorption fractions are needed

Still….The Kaon Mass Puzzle….

FPSF, LNF February 25-26, 2021

Kaon masses. Why are they important?

Claude Amsler

Stefan Meyer Institute, Vienna, Austria

and

Simon Eidelman (Speaker)

Budker Institute of Nuclear Physics SB RAS, Novosibirsk, Russia
and Lebedev Physical Institute RAS, Moscow, Russia

The most precise (incompatible) measurements date back to 1988 and 1991

Kaon mass precision impacts not only in low energy strangeness QCD

For example, D and J/ψ is affected

FPSF, LNF February 25-26, 2021

Introduction

- The $\pi^{\pm}$ mass accuracy is 1.2×10^{-6}, while for $K^{\pm}$ it is 20 times worse, 2.6×10^{-5}. The same accuracy has been achieved for the K^0 mass.
- The D^0-meson mass is restricted by the accuracy of $m(K^{\pm})$ and $m(K^0)$. In turn, masses of excited charmed mesons for which direct measurements are not precise, $D_1(2420)^0, D_2^*(2460)^0$ and $D_{s1}(2536)^{\pm}$, are precisely determined from a fit of measured masses and mass differences for D^0, $D^{\pm}$ and $D_s^{\pm}$.
- Knowledge of kaon masses affects our understanding of the $\chi_{c1}(3872)$ ($X(3872)$) nature - the first of X, Y, Z states, discovered by Belle in 2003. Its current explanation – a mixture of regular $c\bar{c}$ and $D^0\bar{D}^{*0}$ molecule. How close is $m(\chi_{c1}(3872))$ to the $D^0\bar{D}^{*0}$?
- The whole mass scale for charmed hadrons comes from the J/ψ and $\psi(2S)$: $3096.900 \pm 0.002 \pm 0.006$ MeV and $3686.099 \pm 0.004 \pm 0.009$ MeV measured by KEDR in Novosibirsk
  V.V. Anashin et al., Phys. Lett. B749 (2015) 50

Errors can be improved with high precision measurements of "high n levels" of kaonic atoms

Motivations & Scientific case

The main disagreement is between the two most recent and precise measurements (x-ray energies from kaonic atoms):

m_K=493.696±0.007 MeV

A.S. Denisov et al.

JEPT Lett. 54 (1991)558

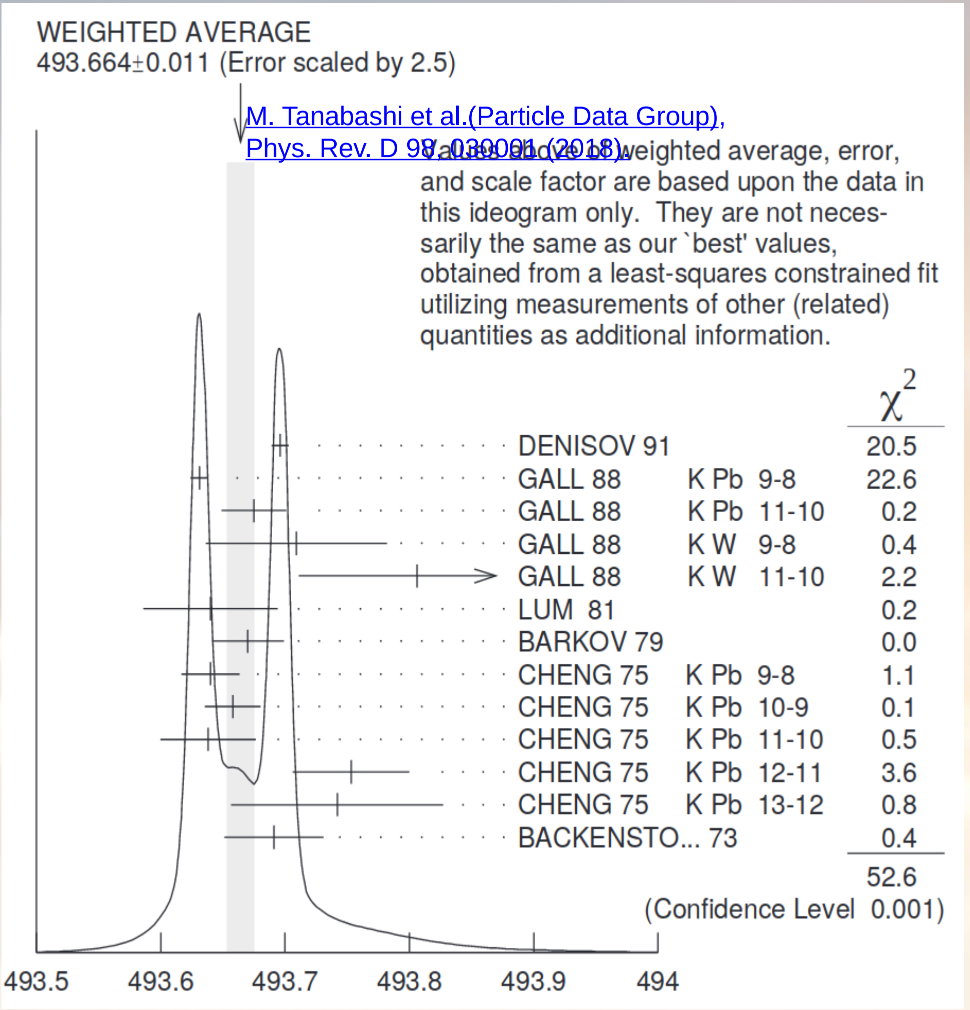
K^- ^{12}C, crystal diffraction spectrometer (6.3 eV at 22.1 keV), 4f-3d

m_K=493.636±0.011 MeV

K.P. Gall et al.

Phys. Rev. Lett. 60 (1988)186

K^-Pb, K^-W; HPGe detector, **K^-Pb (9 -> 8),** K^-Pb (11 -> 10), K^-W (9 -> 8), K^-W (11 -> 10)



This puzzle could be addressed, together with the renewal of the kaonic atoms database, again with the recent advancements in radiation detectors.

TES, Bragg Spectrometers, HPGe, SDD, and CdZnTe

Transitions: energies and widths…which detector?

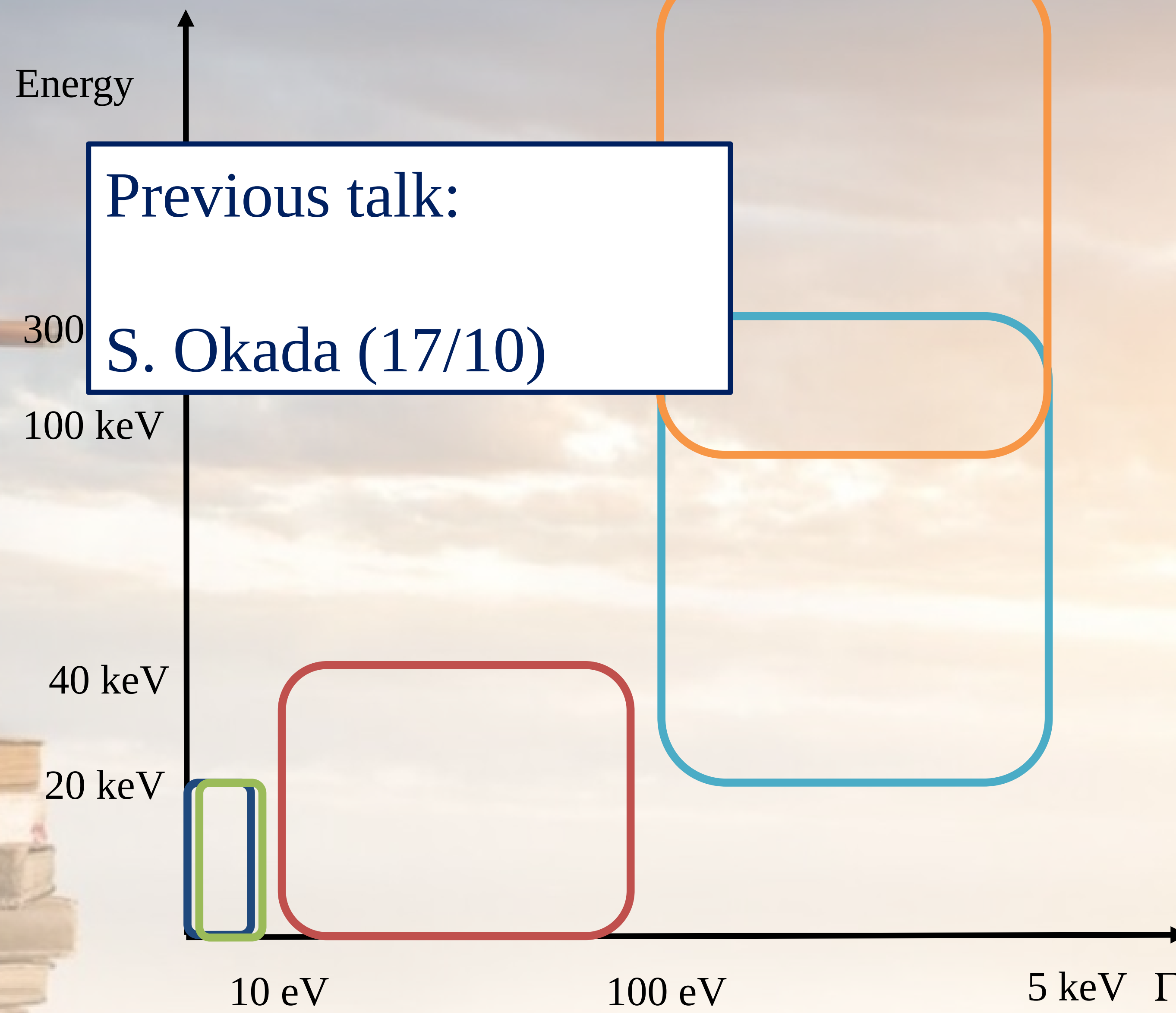
Crystal spectrometers:
- High resolution
- Low efficiency
- 0-20 keV range

~~…calorimeters~~
- ~~acce…~~
- ~~…ult calibration~~

SDDs
- 100 eV max resolution
- 4-40 keV range
- High efficiency

Cd(Zn)Te
- 20-300 keV range
- FWHM / E ~ %
- High efficiency
- Room Temperature

HPGe
- 100-1000 keV range
- FWHM / E ~ %
- High efficiency
- Cooling needed



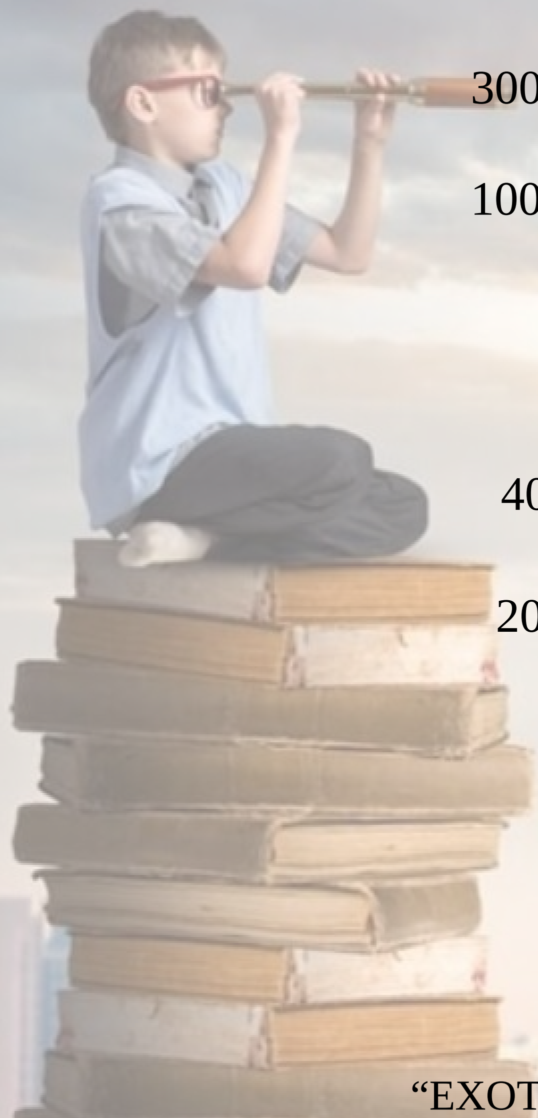
Previous talk:

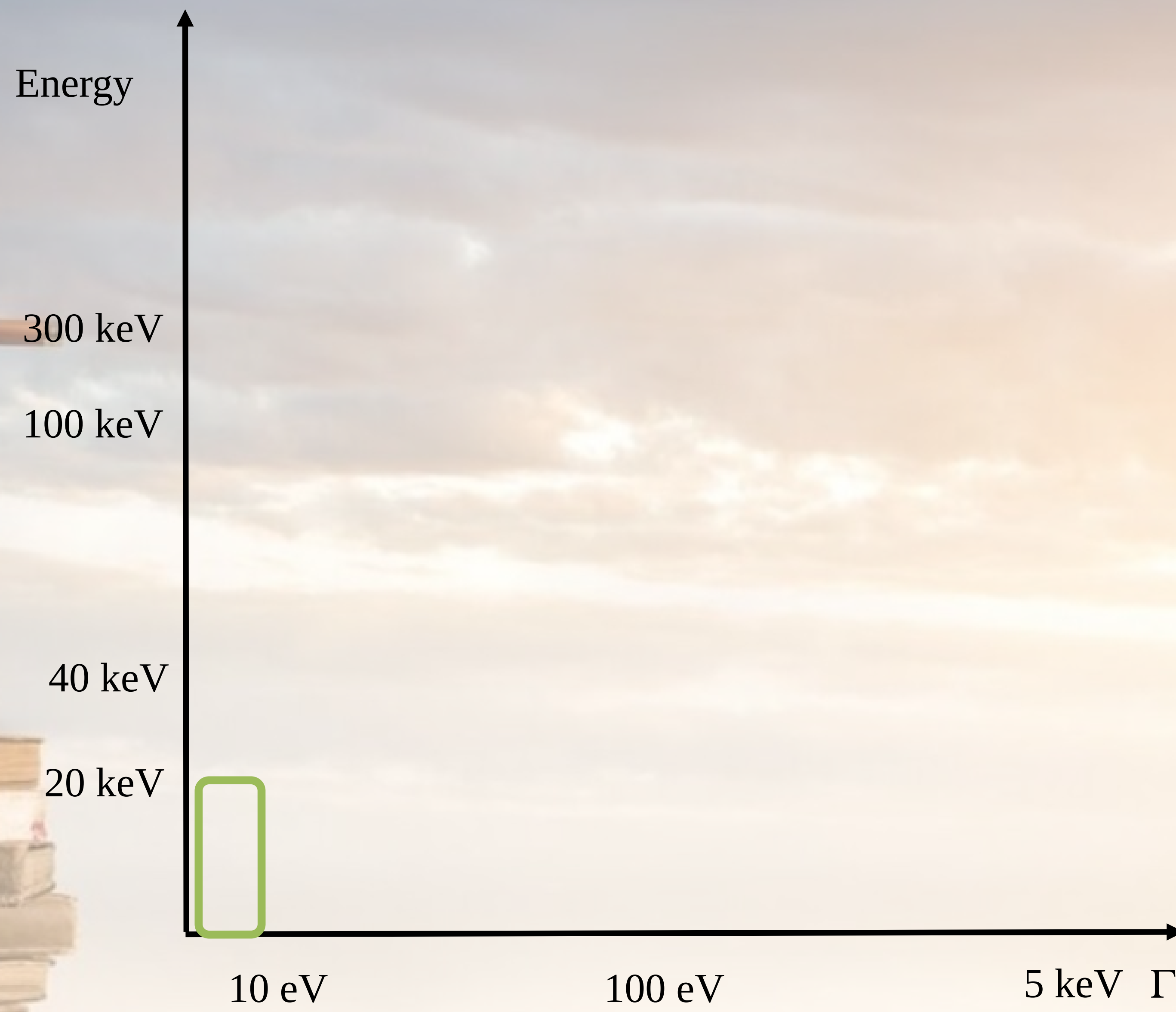
S. Okada (17/10)

Transitions: energies and widths…which detector?

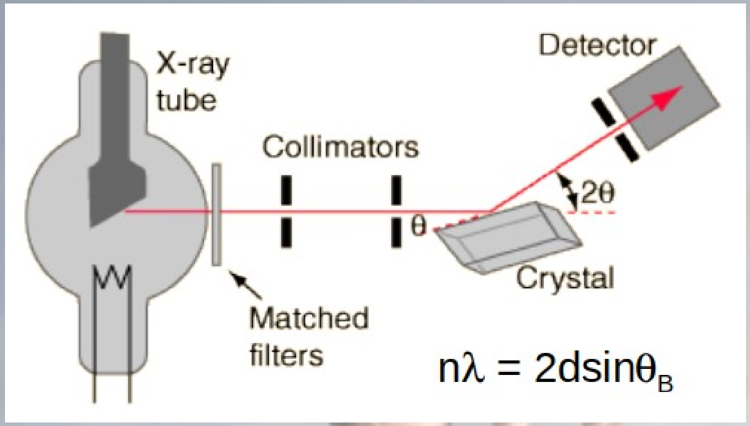
Crystal spectrometers:

- High resolution
- Low efficiency
- 0-20 keV range





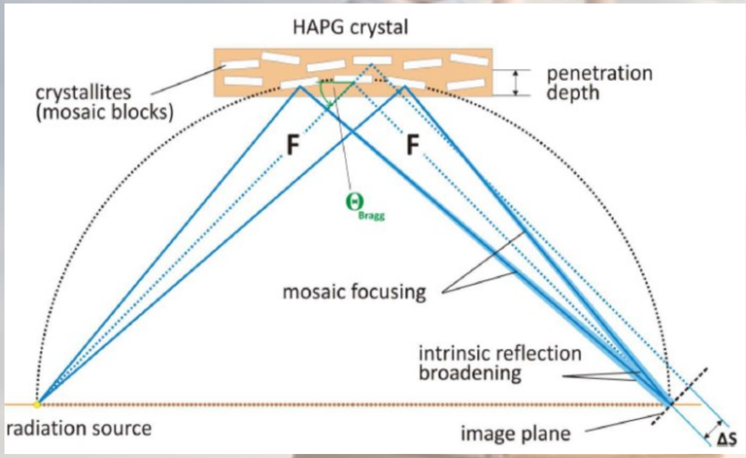
Bragg spectrometers

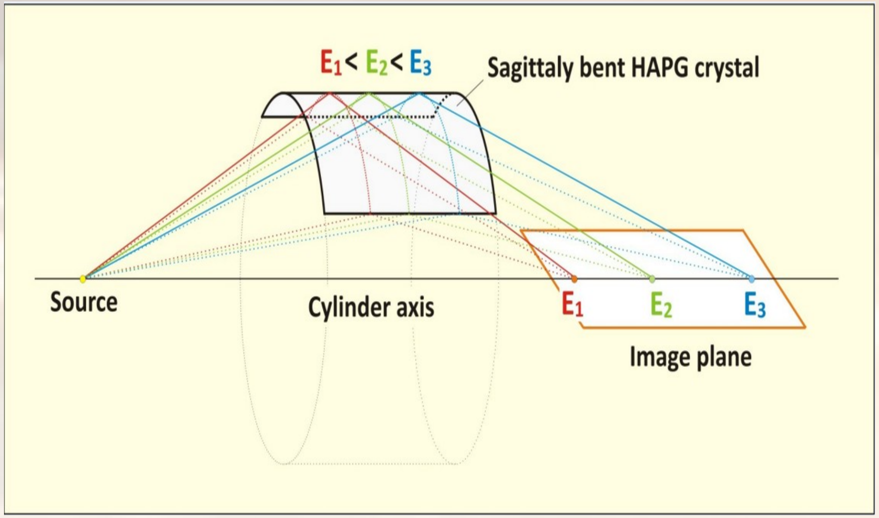


Photons of different energies are reflected in different positions

With a crystal and a position detector, energy spectra with ultra-high resolution can be obtained

For monochromatic sources, also directionality could be tested





Von Hamos geometry and mosaic crystals can improve collection efficiency

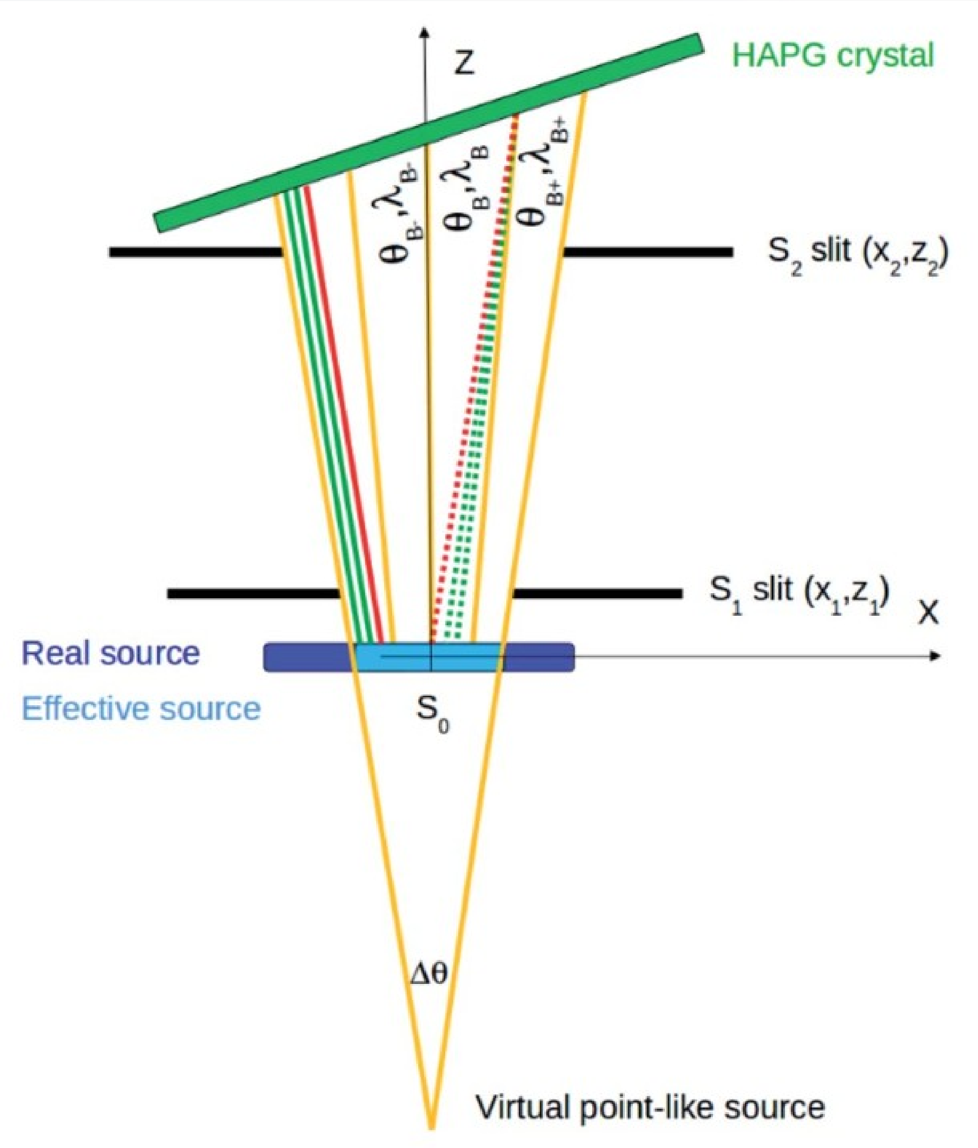
FWHM of few eV with NO COOLING

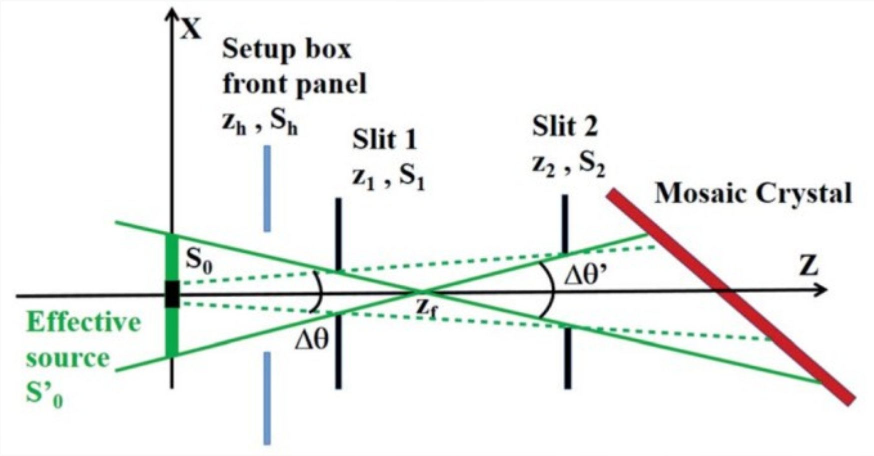
Energy range between 1-20 keV
(n=1, depending on the crystal)

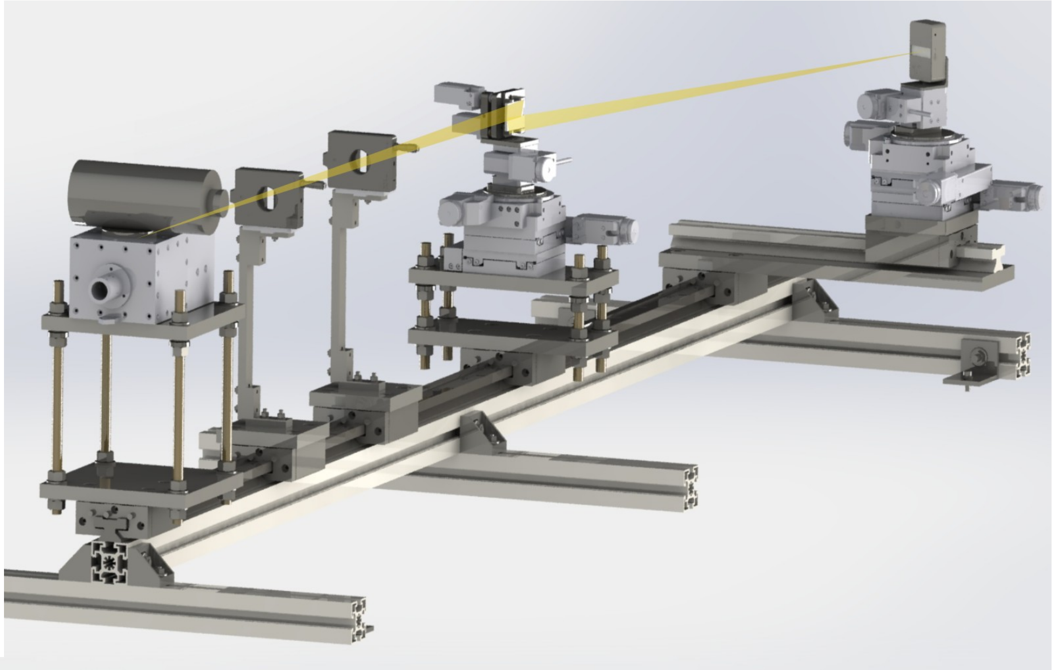
Extremely low efficiencies (solid angle)

Bragg spectrometers: VOXES

Spectrometer developed under CSN5 Young Researcher Grant (2016-2018)





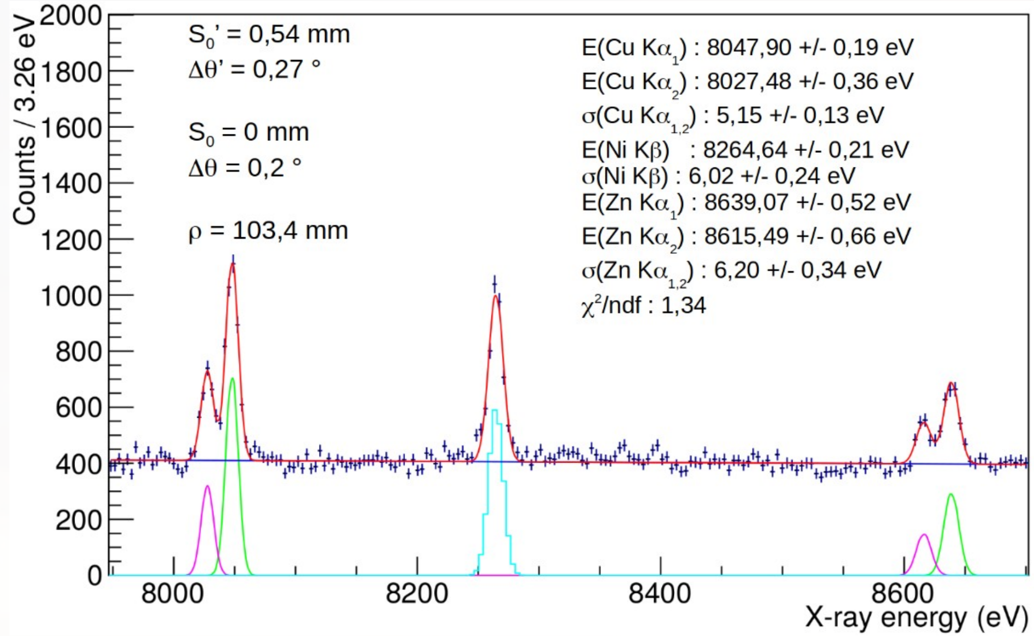


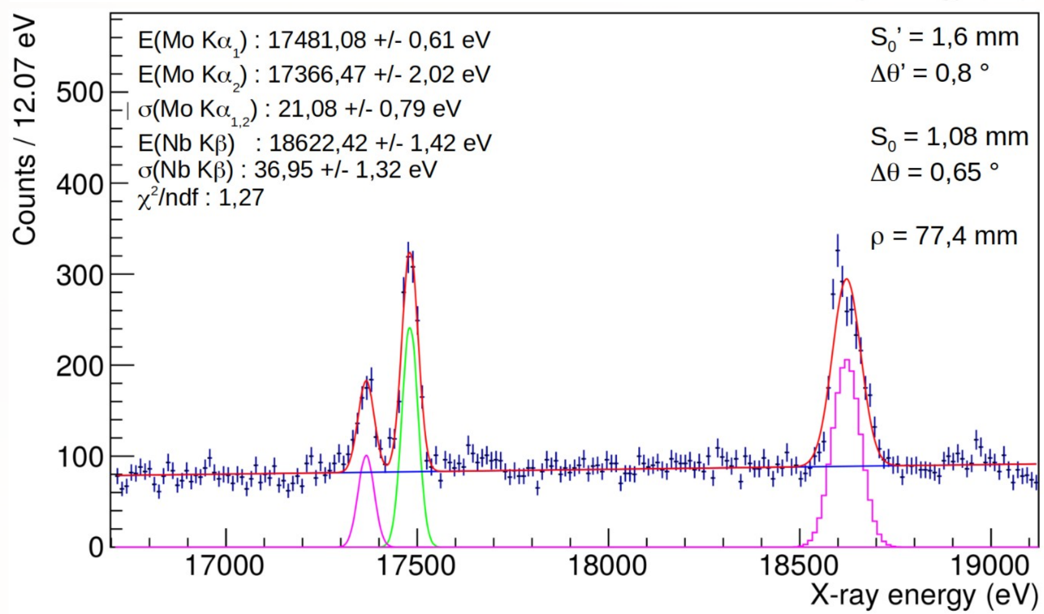
Bragg spectrometers: VOXES

High precision measurements with VOXES in LNF Lab

Table 3 Best achieved resolutions and precisions summary.

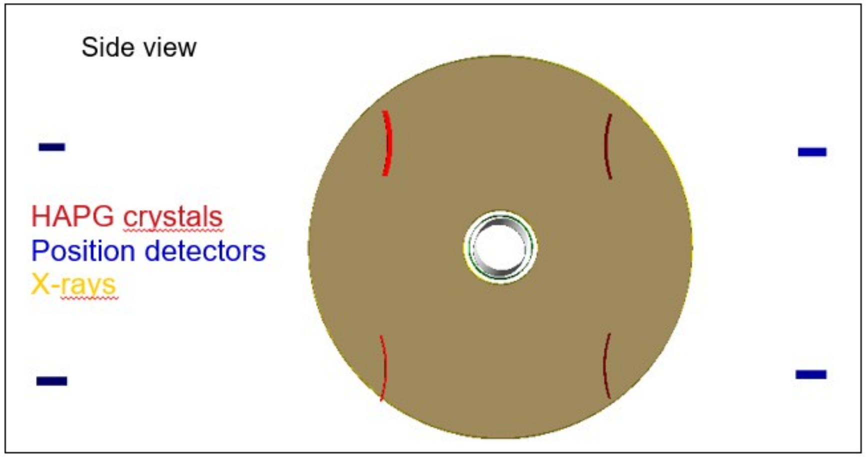
Element	$\rho_c\,(mm)$	Parameter	value (eV)	$S_0'/\Delta\theta'\,(mm,^\circ)$
		$\sigma(K\alpha_{1,2})$	$4,17\pm0,16$	0,3/0,24
	77,5	$\delta(K\alpha_1)$	0,11	0,6/0,44
		$\delta(K\alpha_2)$	0,18	0,6/0,44
		$\sigma(K\alpha_{1,2})$	$4,05\pm0,13$	0,3/0,18
Fe	103,4	$\delta(K\alpha_1)$	0,09	0,7/0,34
		$\delta(K\alpha_2)$	0,13	0,7/0,34
		$\sigma(K\alpha_{1,2})$	$4,02\pm0,08$	1,1/0,60
	206,7	$\delta(K\alpha_1)$	0,1	1,2/0,70
		$\delta(K\alpha_2)$	0,15	1,2/0,70
		$\sigma(K\alpha_{1,2})$	$6,8\pm0,07$	0,3/0,16
	77,5	$\delta(K\alpha_1)$	0,07	0,6/0,32
		$\delta(K\alpha_2)$	0,1	0,6/0,32
		$\sigma(K\alpha_{1,2})$	$4,77\pm0,05$	0,3/0,16
Cu	103,4	$\delta(K\alpha_1)$	0,04	0,7/0,32
		$\delta(K\alpha_2)$	0,07	0,7/0,32
		$\sigma(K\alpha_{1,2})$	$3,60\pm0,05$	0,8/0,60
	206,7	$\delta(K\alpha_1)$	0,04	1,1/0,70
		$\delta(K\alpha_2)$	0,07	1,1/0,70
		$\sigma(K\alpha_{1,2})$	$5,15\pm0,13$	0,5/0,27
Cu	103,4	$\delta(K\alpha_1)$	0,10	0,6/0,22
		$\delta(K\alpha_2)$	0,21	0,6/0,22
		$\sigma(K\beta)$	$6,02\pm0,24$	0,5/0,27
Ni	103,4	$\delta(K\beta)$	0,13	0,6/0,22
		$\sigma(K\alpha_{1,2})$	$6,20\pm0,34$	0,5/0,27
Zn	103,4	$\delta(K\alpha_1)$	0,26	0,6/0,22
		$\delta(K\alpha_2)$	0,42	0,6/0,22
		$\sigma(K\alpha_{1,2})$	$21,1\pm0,8$	1,6/0,80
Mo	77,5	$\delta(K\alpha_1)$	0,6	1,6/0,80
		$\delta(K\alpha_2)$	2,0	1,6/0,80
		$\sigma(K\beta)$	$36,9\pm1,3$	1,6/0,80
Nb	77,5	$\delta(K\beta)$	1,3	1,6/0,80

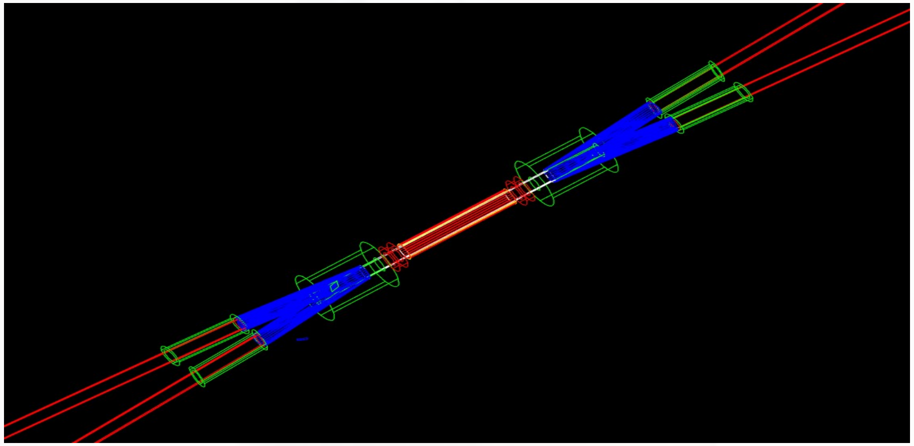


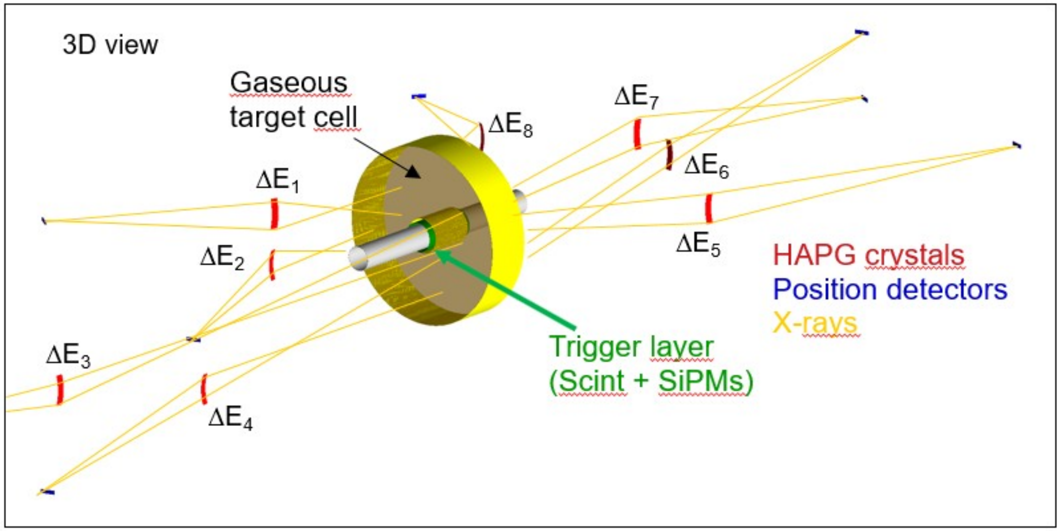


VOXES: (possible) applications in DAΦNE

A new setup including several spectrometer arms could allow for new and very precise measurements of kaonic atoms transitions both from solid and gaseous targets

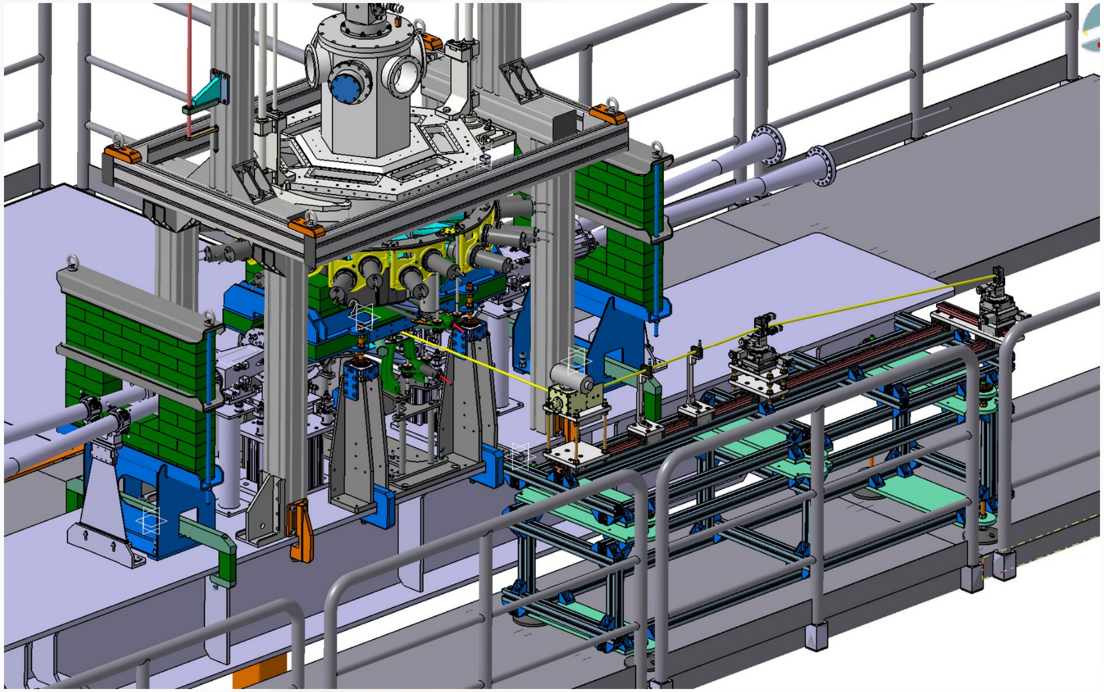


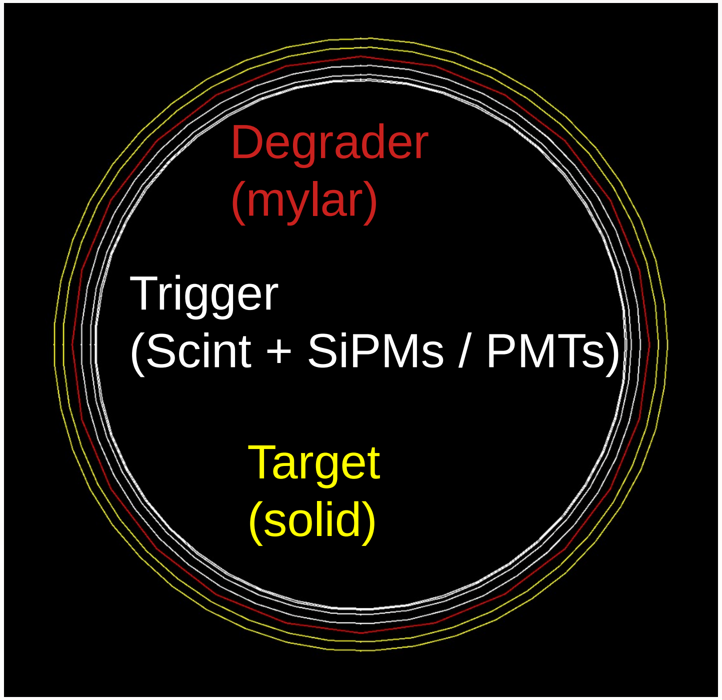


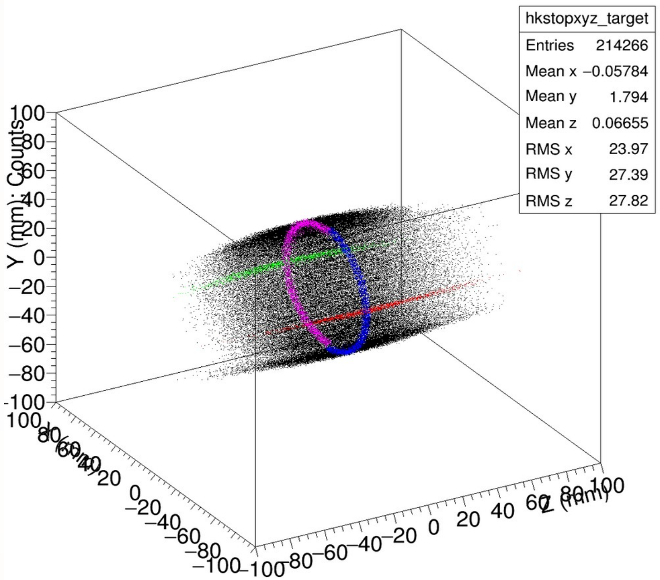


VOXES: (possible) applications in DAΦNE

A new setup including several spectrometer arms could allow for new and very precise measurements of kaonic atoms transitions both from solid and gaseous targets

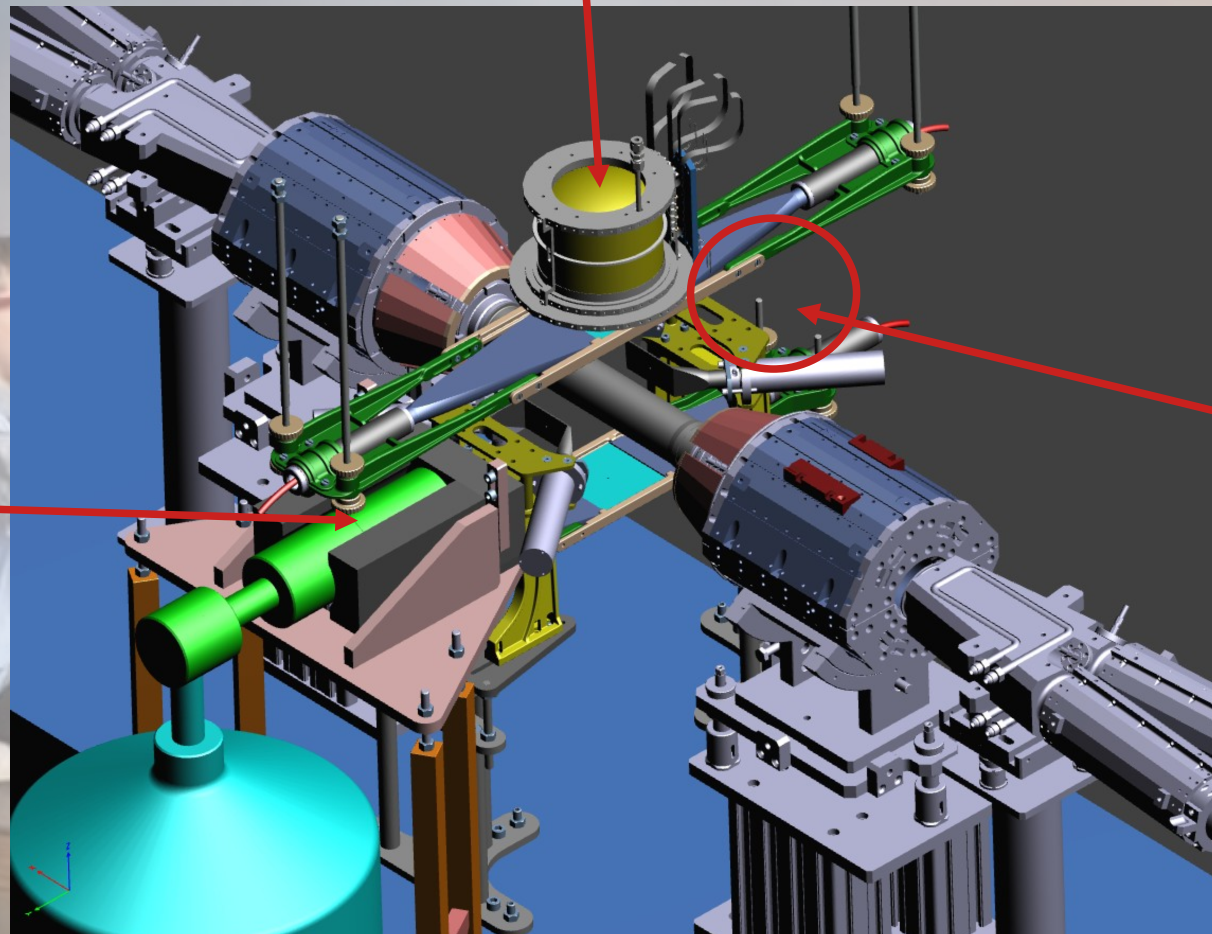






Exploiting DAΦNE

SDDs (4-15 keV) - Light Kaonic Atoms



HPGe
(0,1-1 MeV)

Heavy Kaonic
Atoms

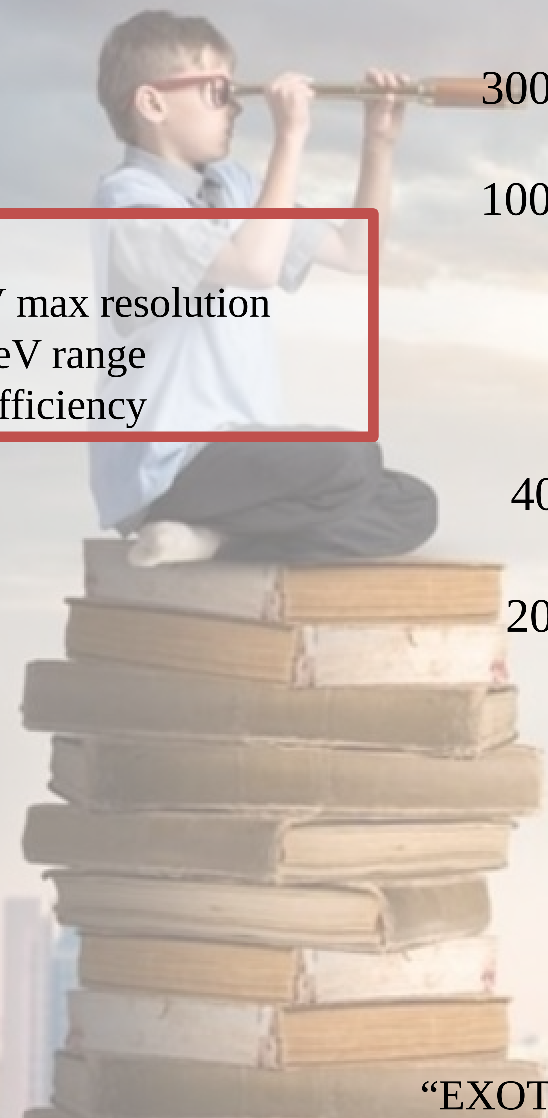
CdZnTe
(30-300 keV)

Intermediate
Kaonic Atoms

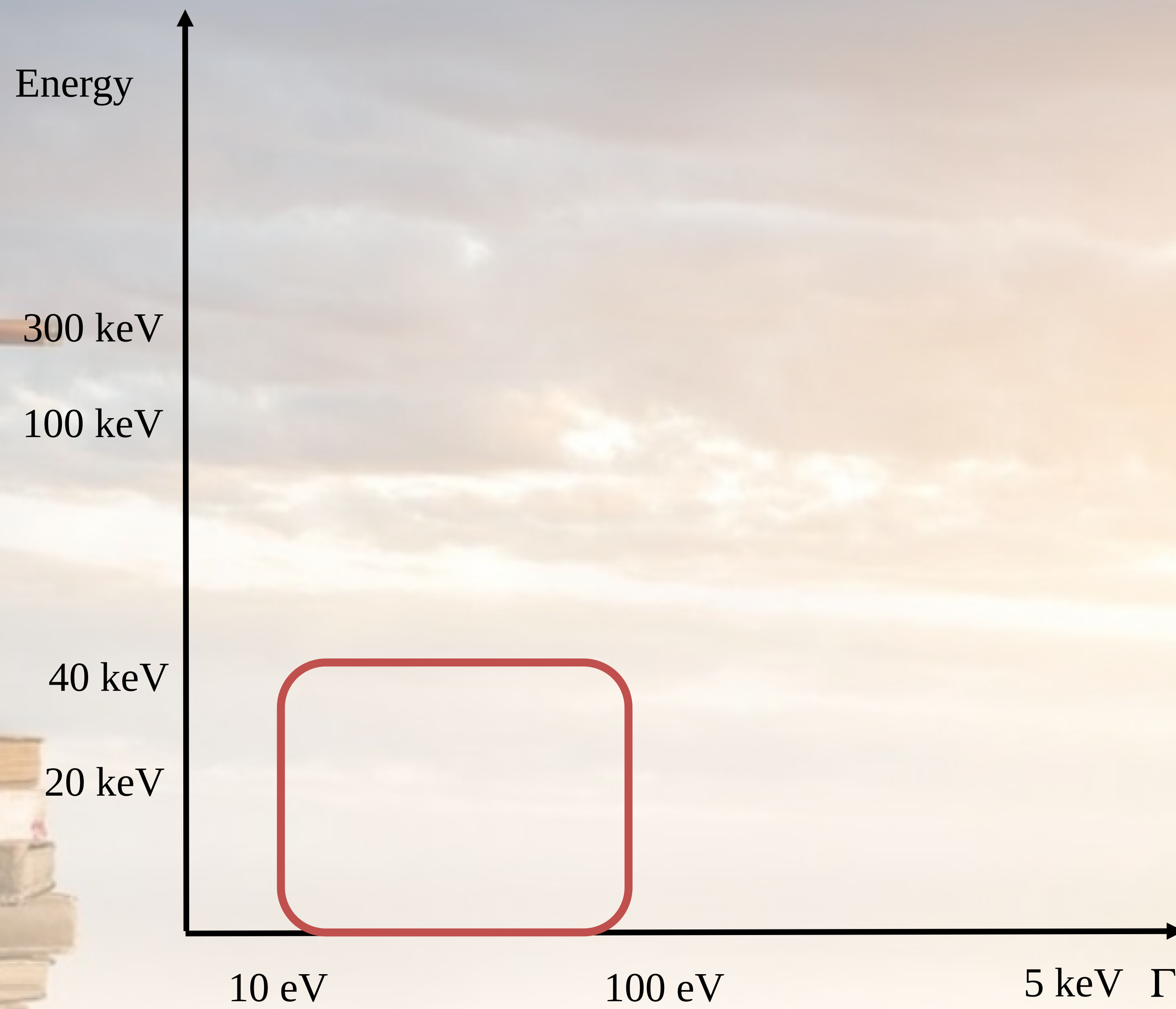
DAΦNE delivers almost 4π K^-

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

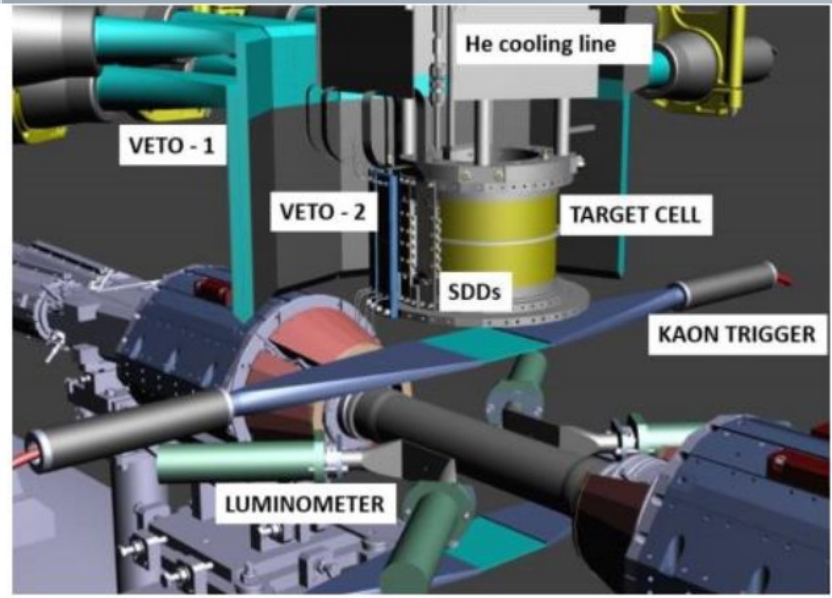
Transitions: energies and widths…which detector?



SDDs
- 100 eV max resolution
- 4-40 keV range
- High efficiency



SDD: present and future at DAΦNE



SIDDHARTA-2 is now running with 450 μm thick SDDs

Assumptions
signal: shift - 800 eV
width 750 eV
density: 5% (LHD)
detector area: 246 cm^2

K¬ʌ yield: 0.1 %
yield ratio as in K~p

Previous talks:

F. Sirghi (17/10)
F. Sgaramella (18/10)

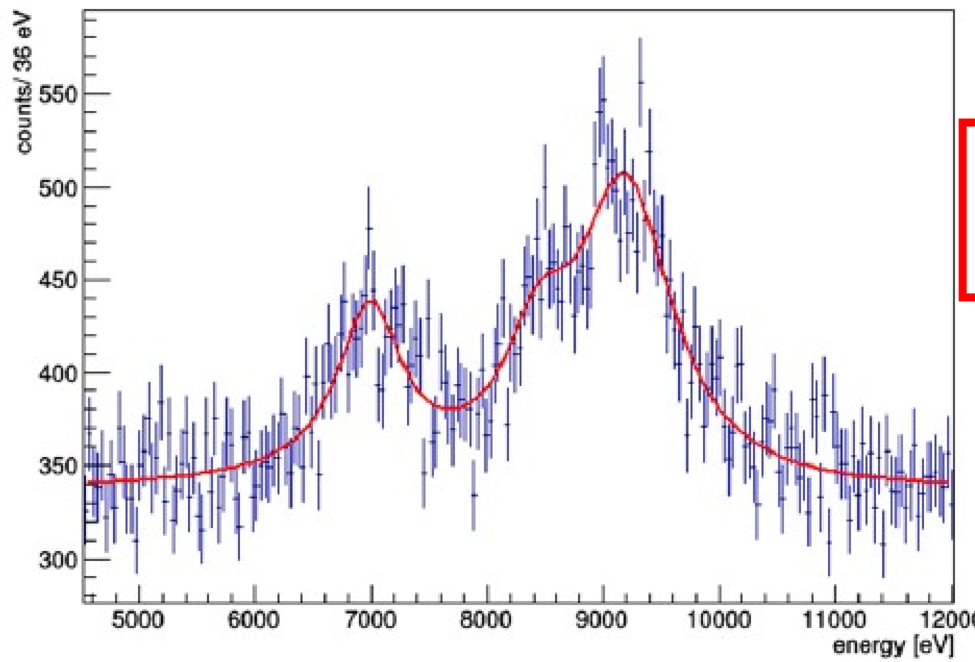


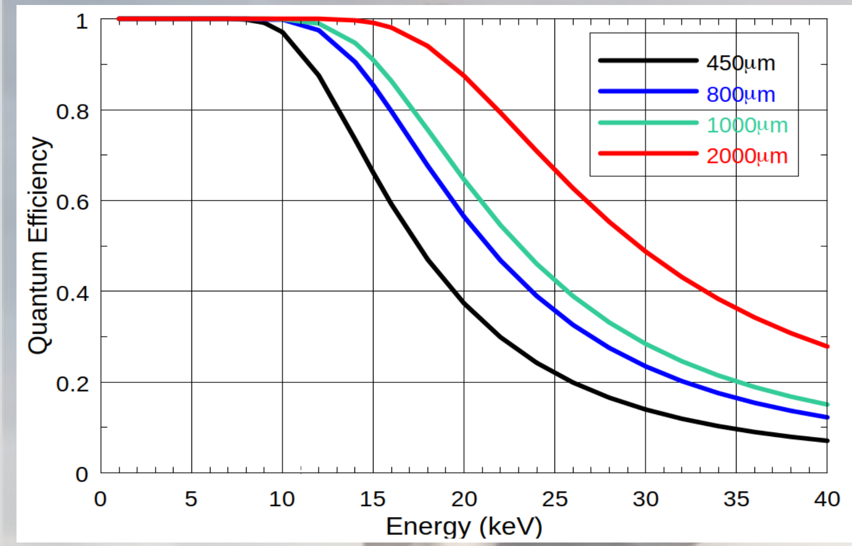
Figure 21: The simulated spectrum of K^-d for SIDDHARTA-2 for 800 pb^{-1} (the K_α line is at 7 keV, while from 8 to 10 keV there is the K-complex)

Expected:
$\Delta\varepsilon(1s)$ = 30 eV
$\Delta\Gamma(1s)$ = 70 eV

SDD: present and future at DAΦNE

Kaonic Helium transitions on 1s level would be accessible (very difficult):

$K^3He(2 \rightarrow 1)$: 33 keV
$K^4He(2 \rightarrow 1)$: 35 keV



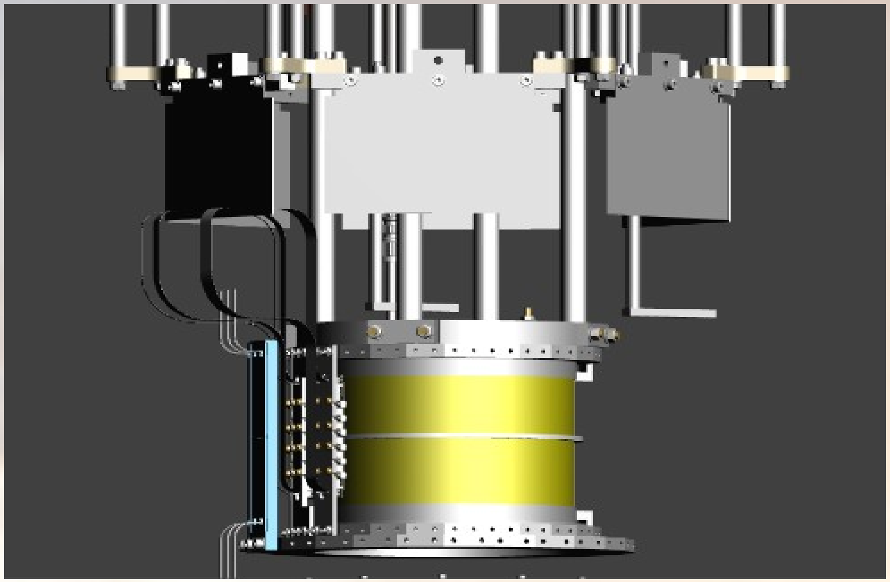
Feasibility:

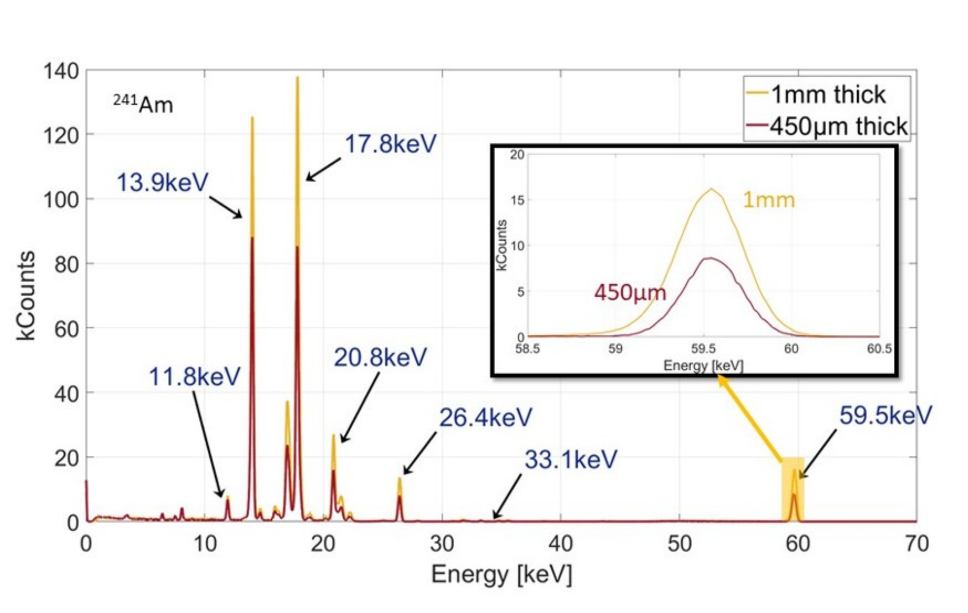
1-2 mm SDDs already financed by INFN CSN3

Electronics is similar to SIDDHARTA-2 SDDs

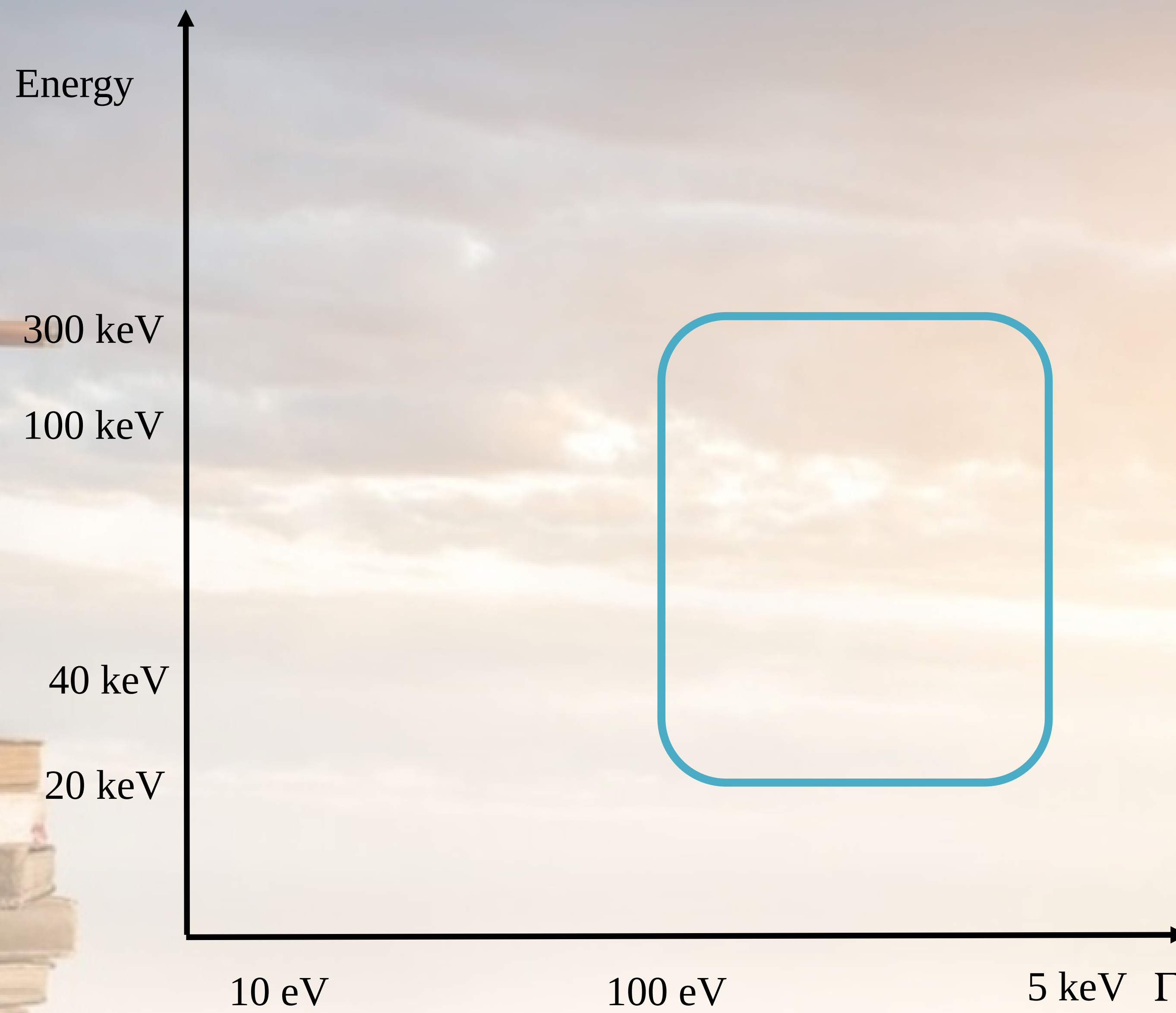
800µm and 1mm SDDs prototypes already produced by FBK for ARDESIA (INFN)

SIDDHARTA-2 – like setup with 1-2 mm thick SDDs





Transitions: energies and widths…which detector?



Cd(Zn)Te
- 20-300 keV range
- FWHM / E [illegible] %
- High efficiency
- Room Temperature

Advanced ultra-fast solid STate detectors for high precision RAdiation spectroscopy : ASTRA

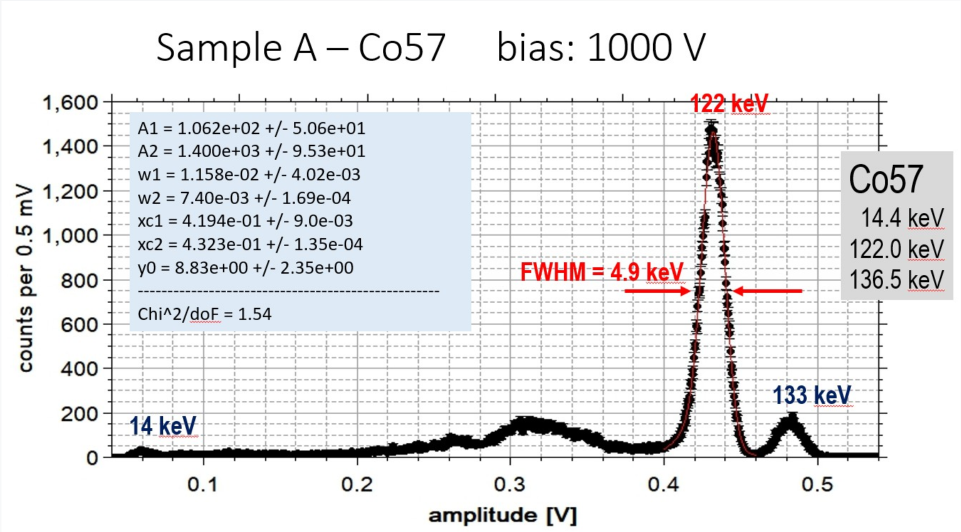
Organization legal name	Short name	Activity leader
Austrian Academy of Sciences, Stefan Meyer Institute, Austria	OEAW	**J. Zmeskal**
Istituto Materiali per Elettronica e Magnetismo, CNR, Parma, Italy	CNR	A. Zappettini
Jagiellonian University, Krakow, Poland	UJ	P. Moskal
Laboratori Nazionali di Frascati (LNF) – INFN, Italy	INFN	A. Scordo
Politecnico Milano, Dipartimento di Elettronica, Italy	POLIMI	C. Fiorini
University of Zagreb, Croatia	UNIZG	D. Bosnar

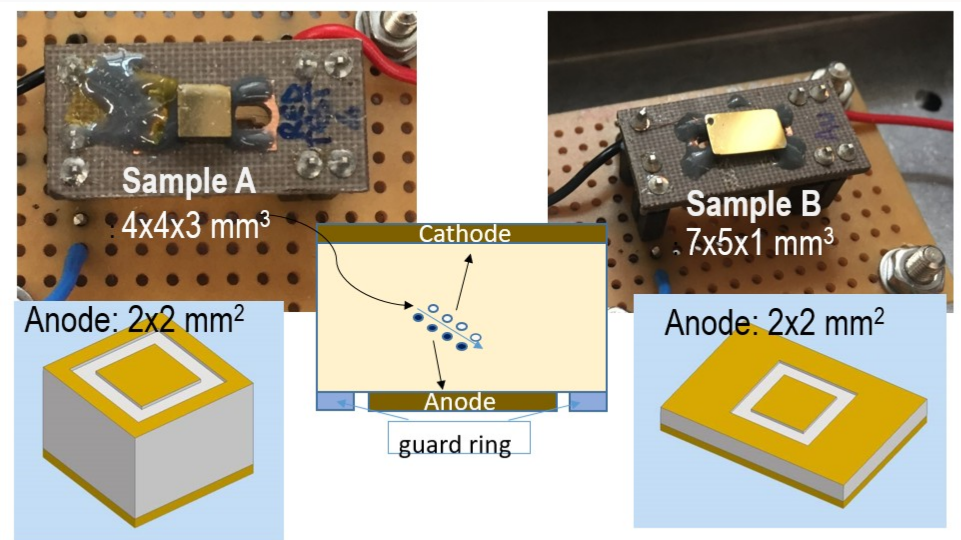
The main objective of the ***ASTRA*** project is to develop beyond state-of-art ultra-fast CdZnTe/CdTe radiation detector systems for high-precision measurements of gamma- and X-ray events in a broad energy range, **few keV to MeV**.

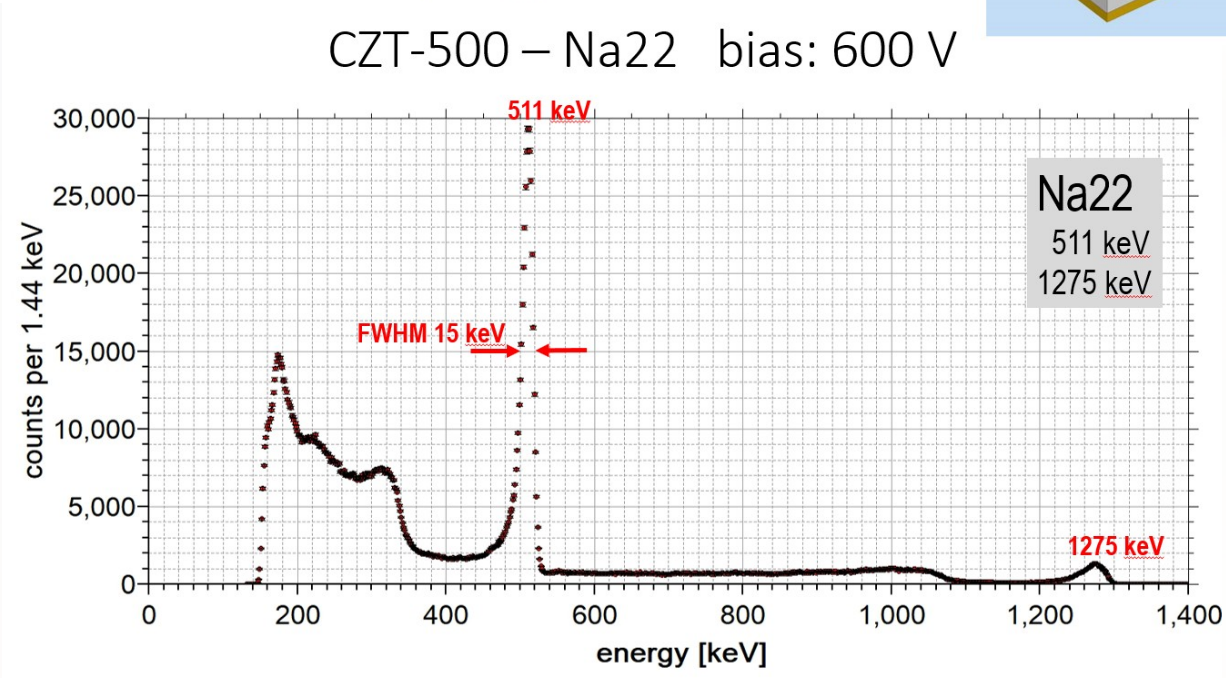
ASTRA: first outcomes

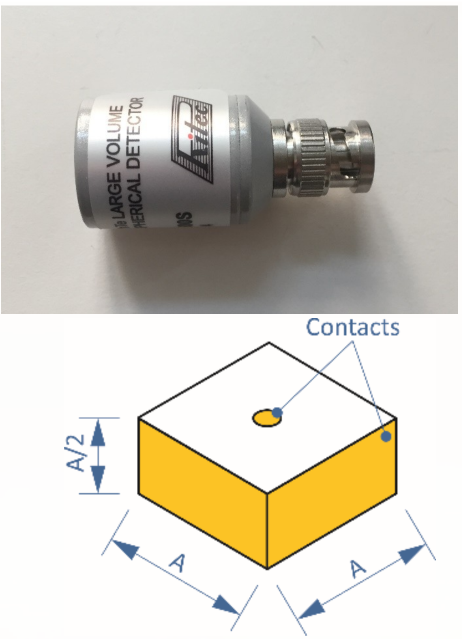
Advanced ultra-fast solid **ST**ate detectors for high precision **RA**diation spectroscopy : **ASTRA**

First prototypes of Cd(Zn)Te delivered by JRA8-ASTRA (STRONG-2020) and tested





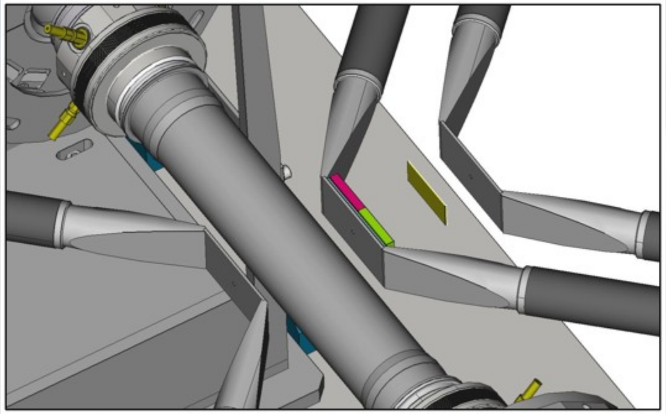


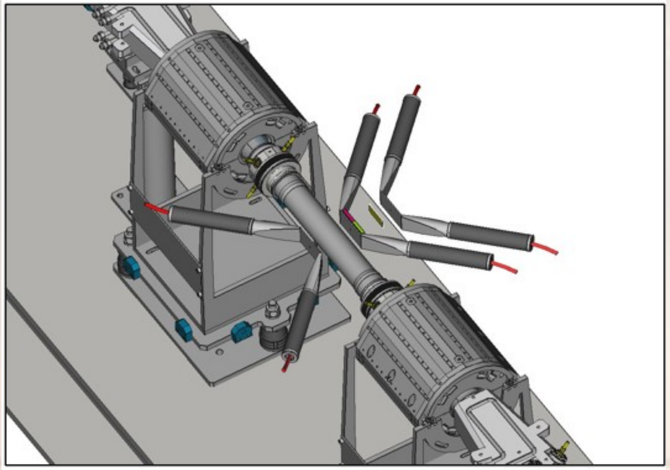


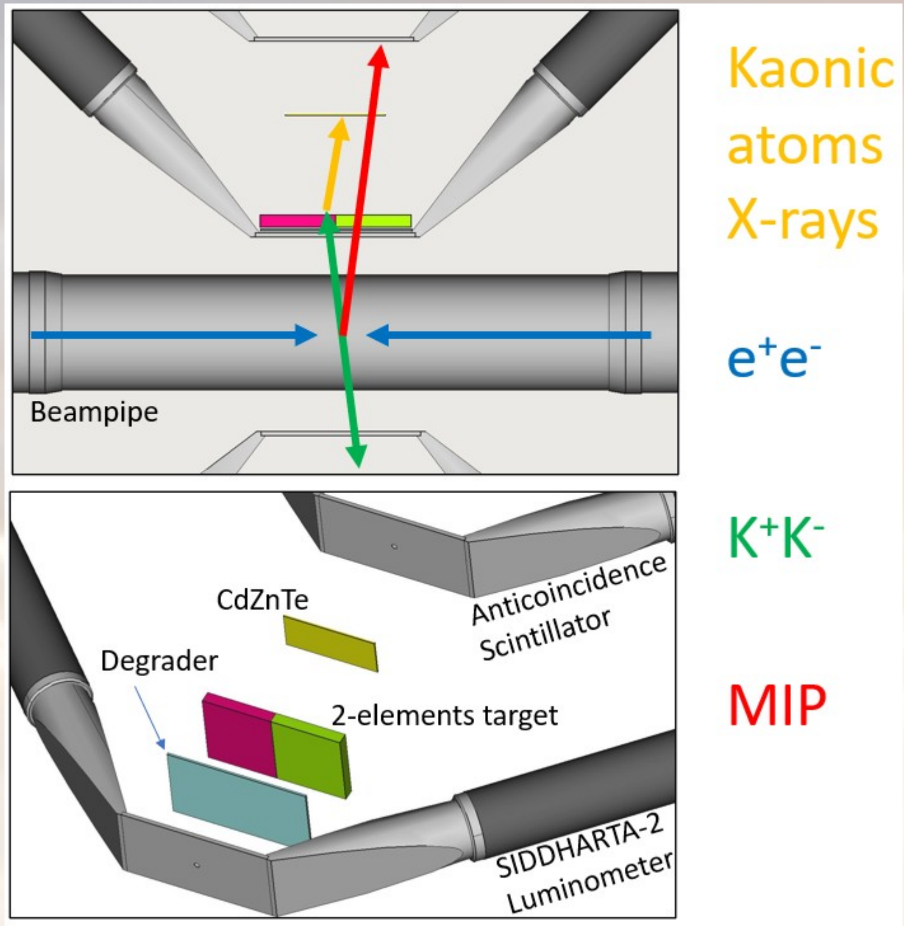
CZT: proposal for new measurements at DAΦNE

Detector Key Points:

- High efficiency in the 20-100 keV region
- Reasonable efficiencies up to 300 keV
- Good resolution (FHWM/E ~ %)
- Fast response and time resolution (< 50 ns)
- No need for cooling
- Compact readout and installation package







Feasibility:

CdTe (and also CdZnTe) detectors developed in the JRA8-ASTRA (STRONG-2020) project

Further prototypes will be available by mid 2023

CZT: proposal for new measurements at DAΦNE

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 → 2	−0.04 ± 0.03	–	–	–
		−0.035 ± 0.012	0.03 ± 0.03	–	–
Li	3 → 2	0.002 ± 0.026	0.055 ± 0.029	0.95 ± 0.30	–
Be	3 → 2	−0.079 ± 0.021	0.172 ± 0.58	0.25 ± 0.09	0.04 ± 0.02
^{10}B	3 → 2	−0.208 ± 0.035	0.810 ± 0.100	–	–
^{11}B	3 → 2	−0.167 ± 0.035	0.700 ± 0.080	–	–
C	3 → 2	−0.590 ± 0.080	1.730 ± 0.150	0.07 ± 0.013	0.99 ± 0.20
O	4 → 3	−0.025 ± 0.018	0.017 ± 0.014	–	–
Mg	4 → 3	−0.027 ± 0.015	0.214 ± 0.015	0.78 ± 0.06	0.08 ± 0.03
Al	4 → 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 → 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 → 3	−0.330 ± 0.08	1.440 ± 0.120	0.26 ± 0.03	1.89 ± 0.30
S	4 → 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^{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

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

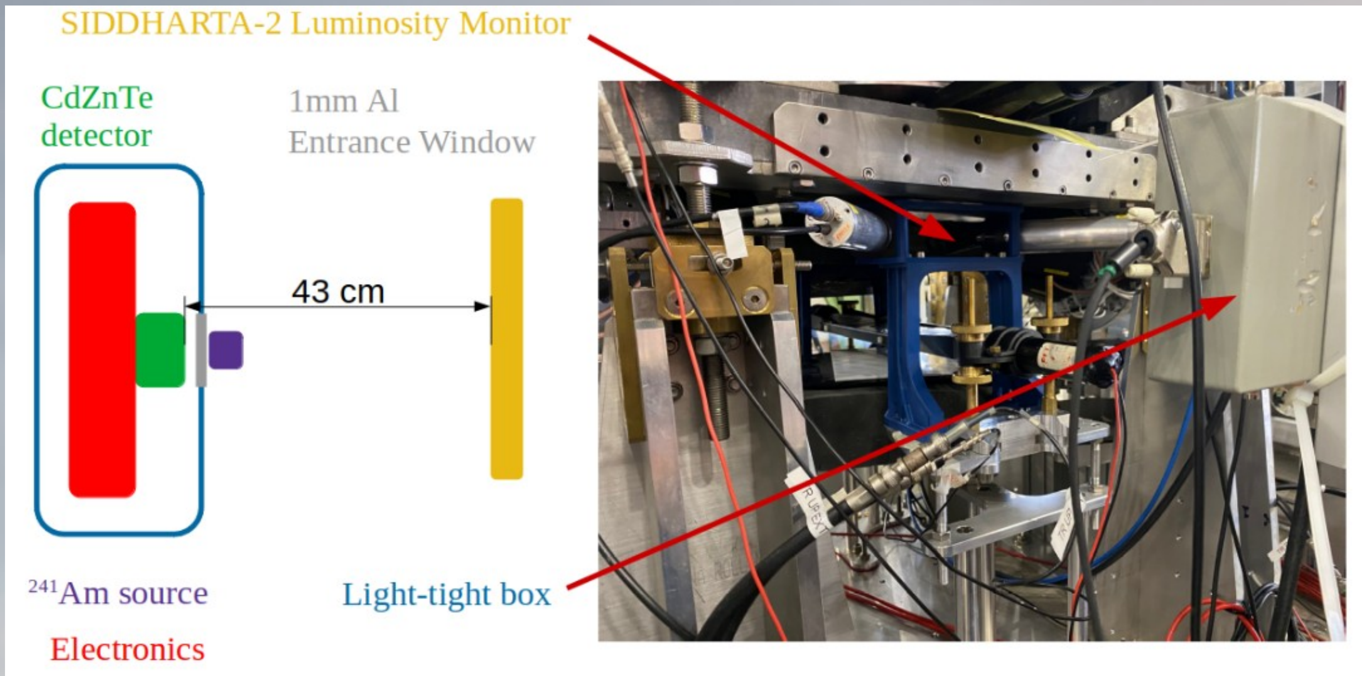
KC(3→2), KAl(3→2), KS(4→3):

Precisions < 20 eV (ε) and <40 eV (Γ) are reachable in few months

Measurements of several parallel transitions ⇒ new inputs for cascade casculations

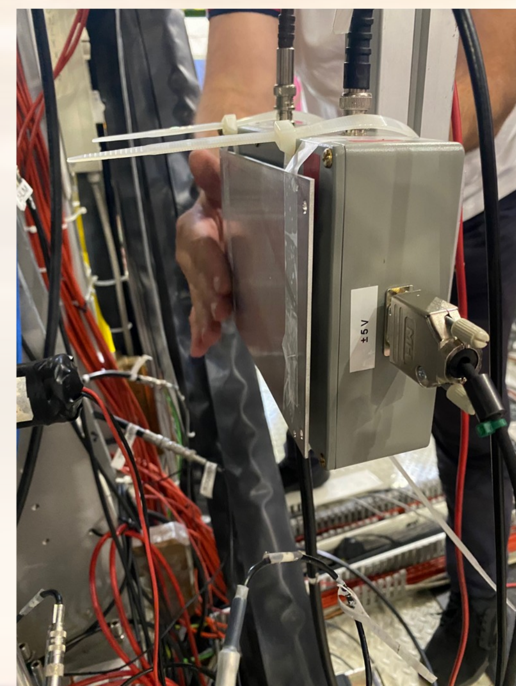
CZT: first tests @ DAΦNE

Goal: background and resolution assessment in machine environment (first time)

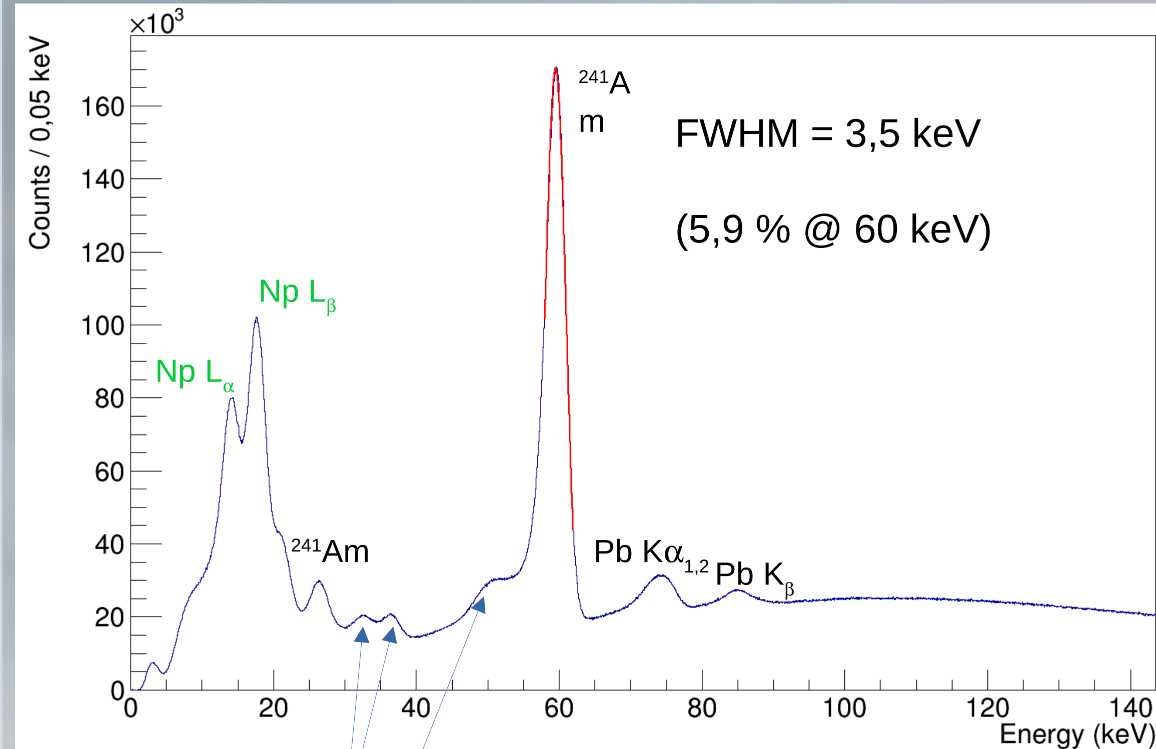


22/06/2022:

First prototype installed in DAΦNE to check “on beam” response and possible issues

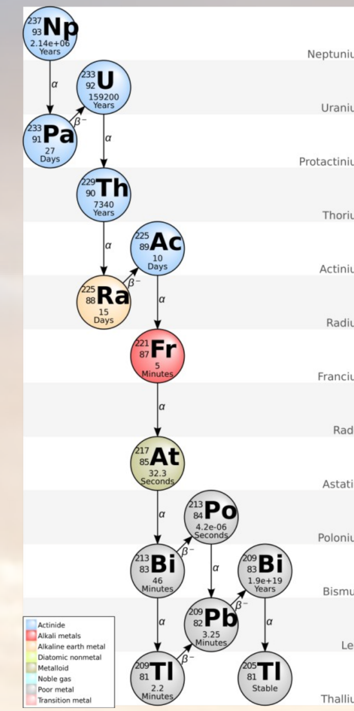


CZT: first tests @ DAΦNE



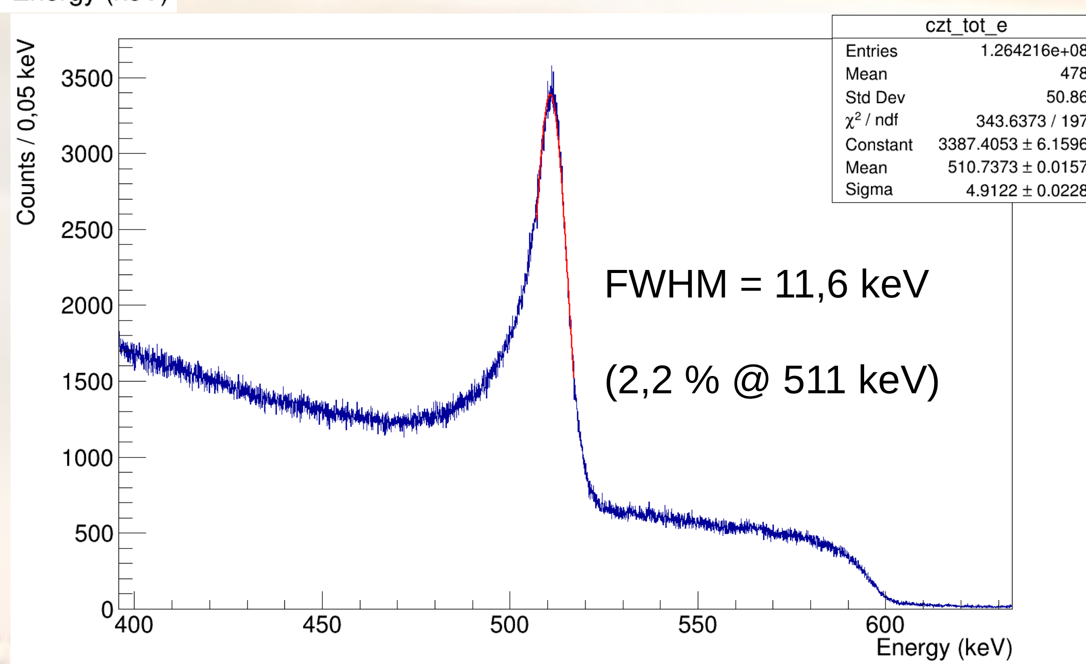
Np peaks (X-rays) from decay of ^{241}Am

Good energy resolution confirmed "on beam"

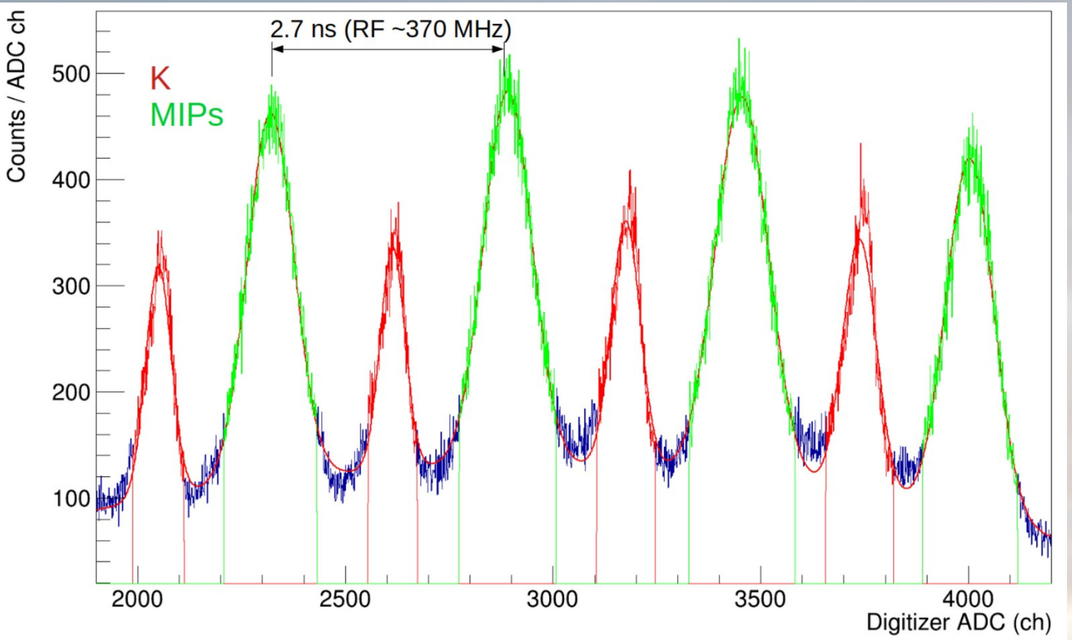


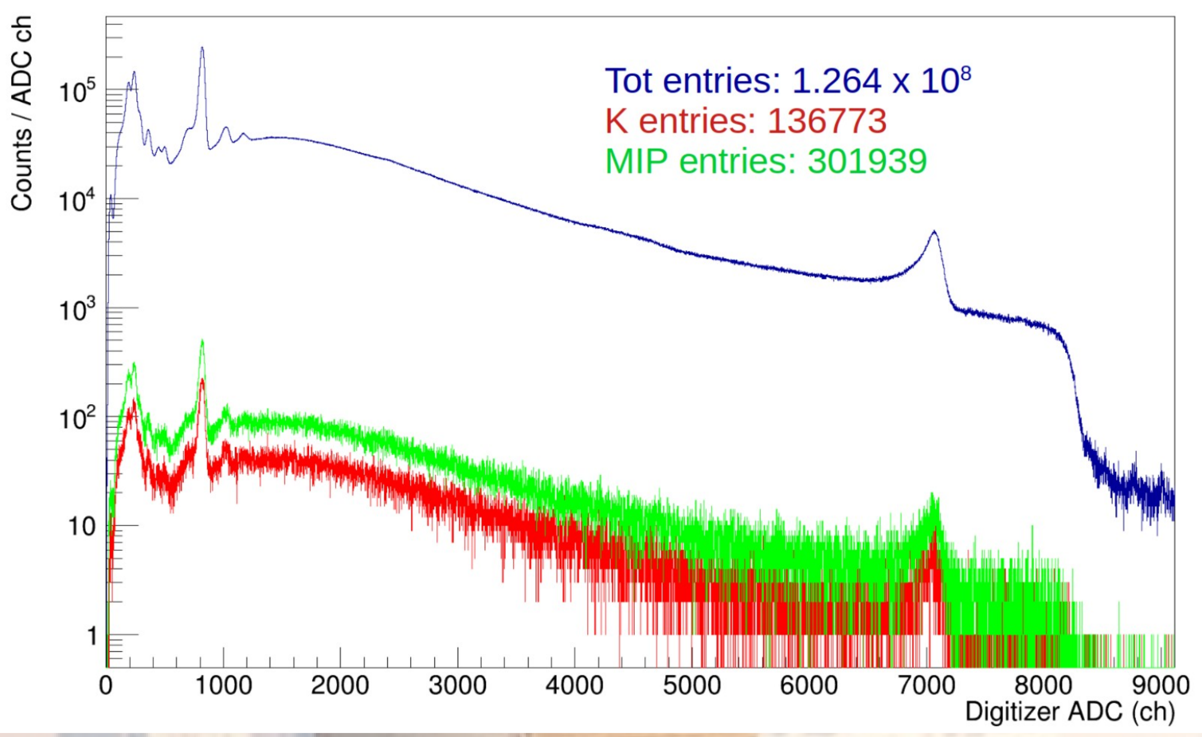
Element	K-shell absorption energy (keV)	Fluorescent lines	Energy of fluorescent lines (keV)	λ_{CdZnTe} (μm)
Cd	26.7	$K\alpha_1$	23.17	116
		$K\beta_1$	26.10	161
Zn	9.7	$K\alpha_1$	8.54	8.4
		$K\beta_1$	9.57	11.4
Te	31.8	$K\alpha_1$	27.47	69
		$K\beta_1$	31.00	95

Also linearity "on beam" is preserved



CZT: first tests @ DAΦNE





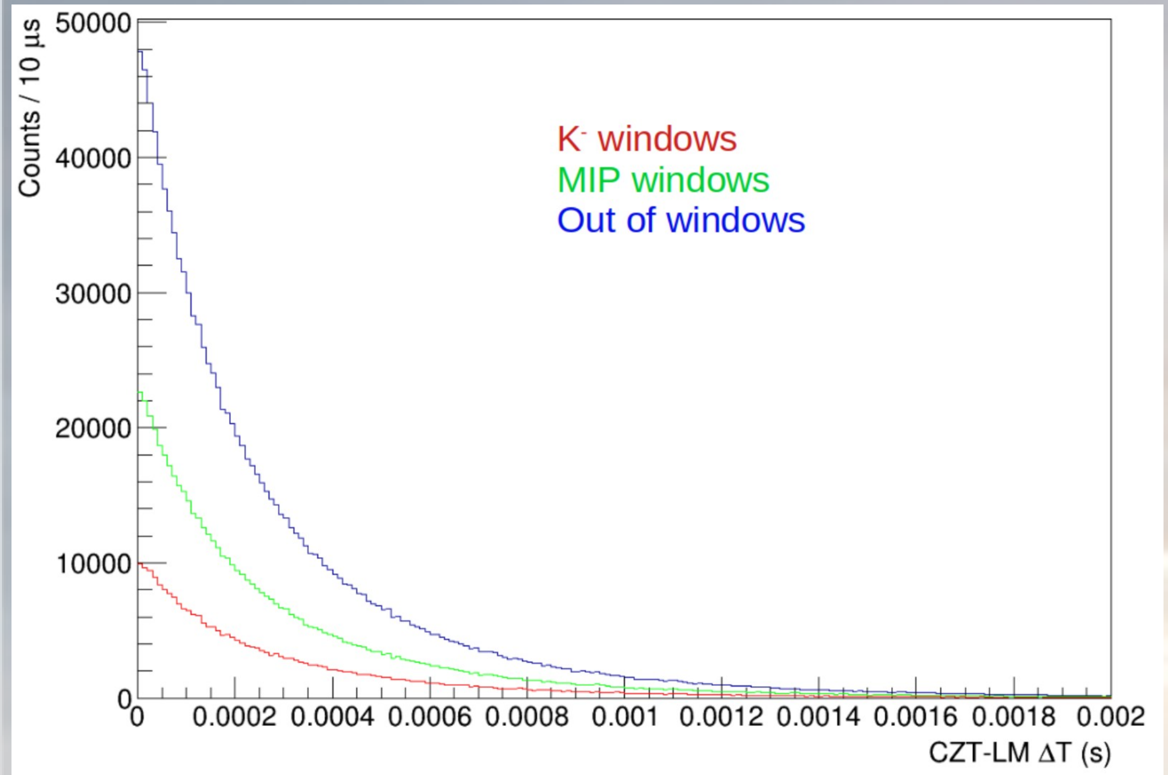
K / MIPs peaks are very well separated with the SIDDHARTA-2 Luminometer

Processing with TAC preserves time resolution and discrimination capabilities

RF/4 is used, causing 4 K/MIPs structures

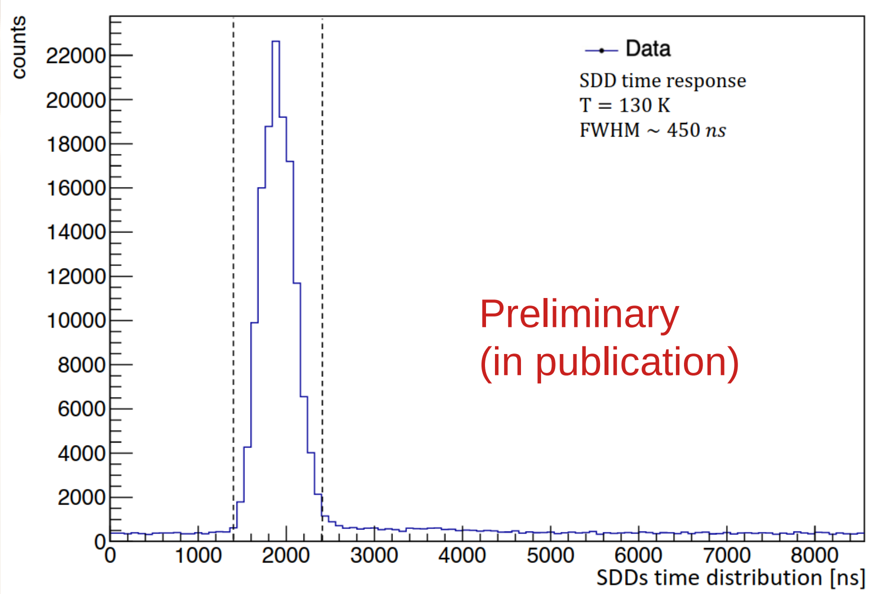
The request of a TAC signal before a hit on CdZnTe leads to a ~ 10^{-3} background rejection factor

CZT: first tests @ DAΦNE



^{241}Am events occur with a time difference up to 2 ms, which is exactly what expected from the 500 Hz rate of the source

For kaonic atoms events, like in SIDDHARTA-2 Drift Time, one expects a peak over a flat background

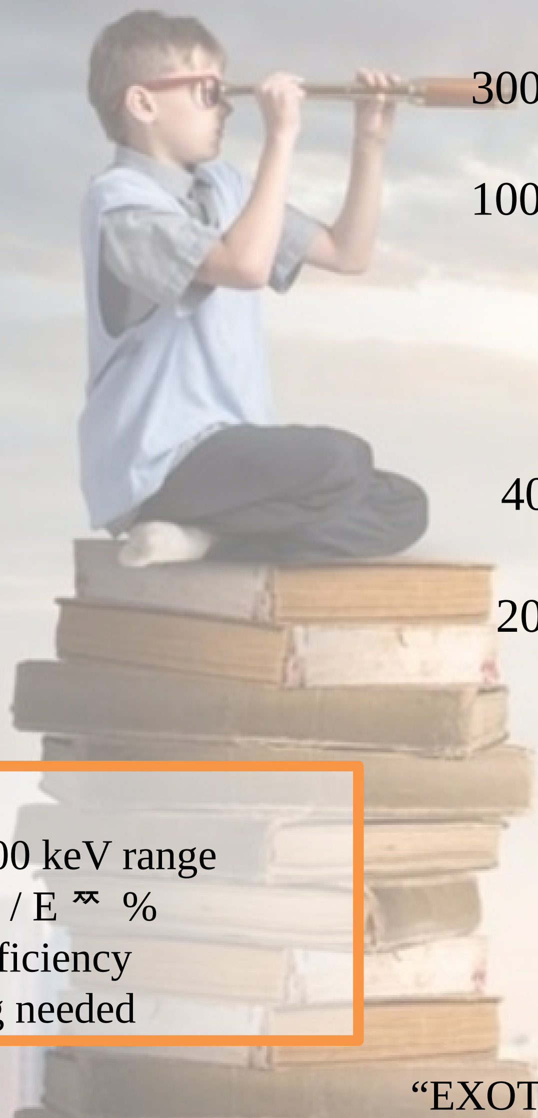


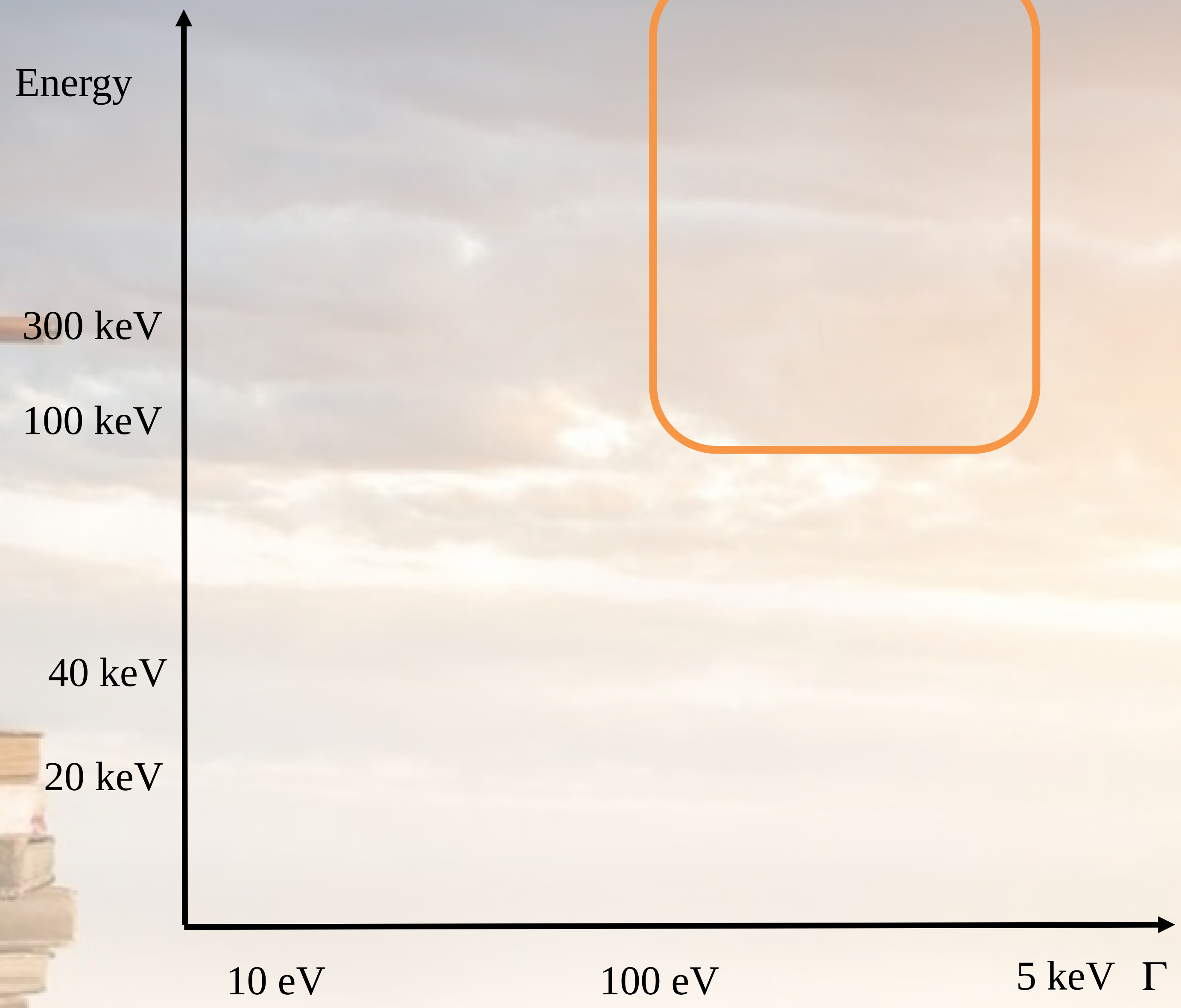
Request	Events	Rejection factor
No request	1.26×10^8	1
K^-_{TAC}	136359	3×10^2
$K^-_{TAC}, \Delta T < 1\,\mu s$	1096	1.15×10^5
$K^-_{TAC}, \Delta T < 500$ ns	605	2.08×10^5
$K^-_{TAC}, \Delta T < 300$ ns	374	3.33×10^5
$K^-_{TAC}, \Delta T < 100$ ns	124	1.02×10^6

CdZnTe will allow for FWHM ~ 100 ns timing peak

Rejection factors ~10^6 can be expected

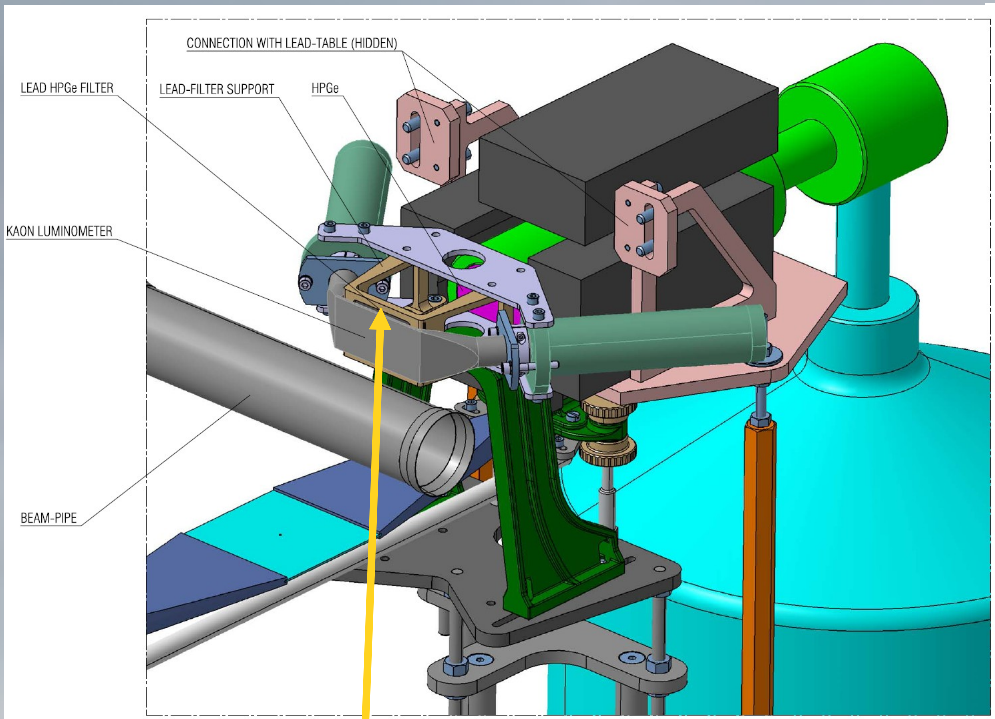
Transitions: energies and widths…which detector?

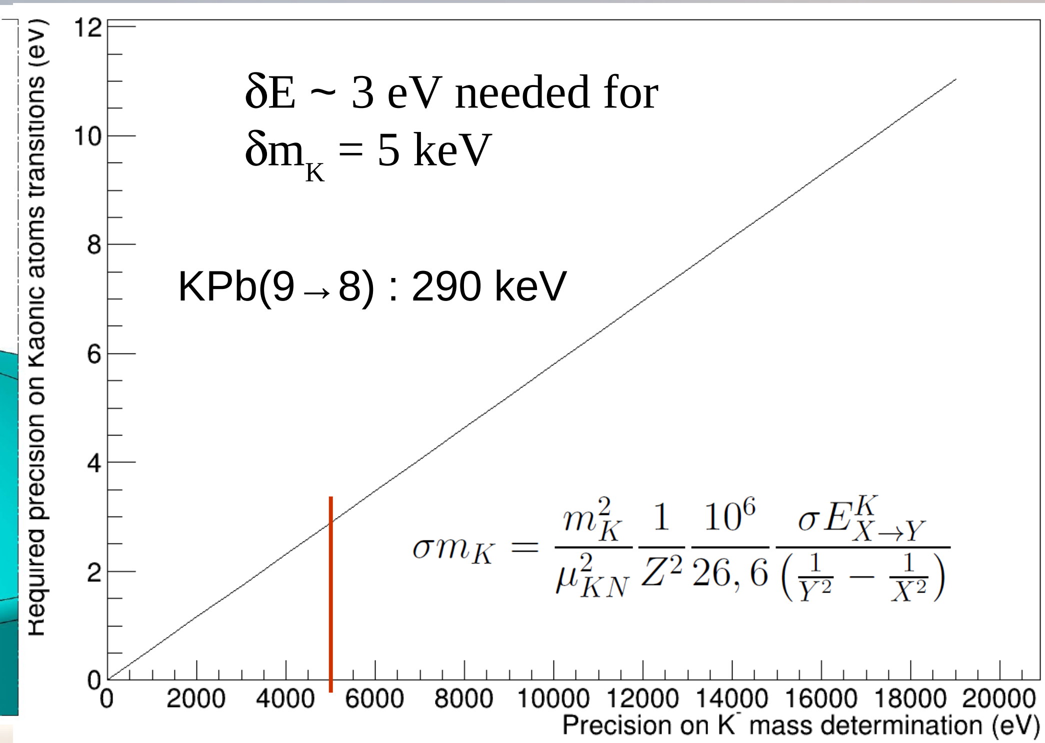




HPGe
- 100-1000 keV range
- FWHM / E ≈ %
- High efficiency
- Cooling needed

New Kaon Mass measurement with HPGe





Pb target just behind
the SIDDHARTA-2 luminometer,
which is used as trigger

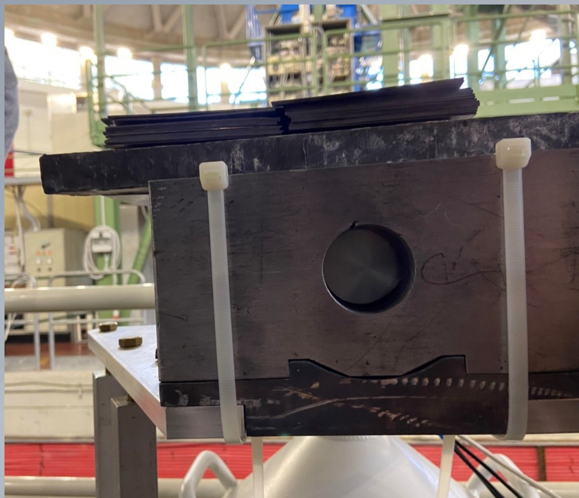
Resolutions (FWHM)
obtained with ^{60}Co, ^{133}Ba sources :

0.870 keV @ 81 keV
1.106 keV @ 302.9 keV
1.143 keV @ 356 keV
1.167 keV @ 1330 keV

HPGe detector provided by the group of the University of Zagreb (Croatian Science Foundation project 8570)

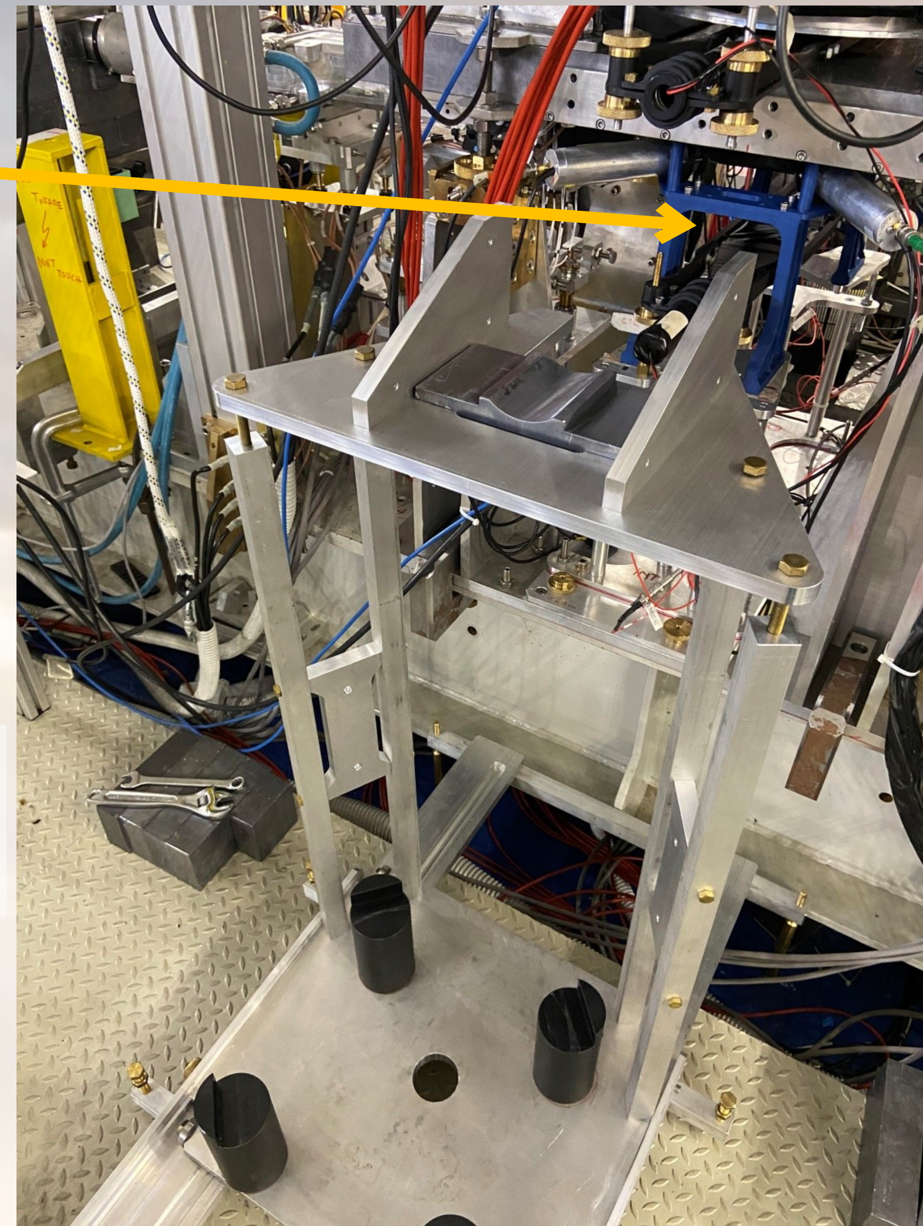
Recent activities and achievements

Installation of HPGe structures and preliminary shielding



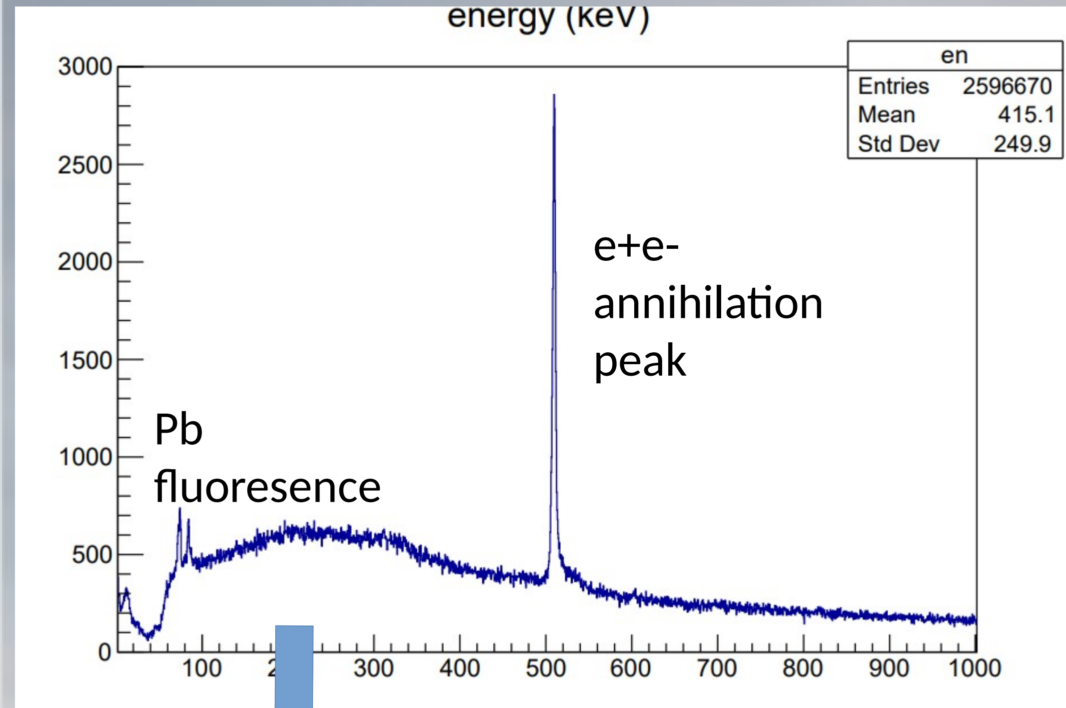
Pb target support behind luminomiter

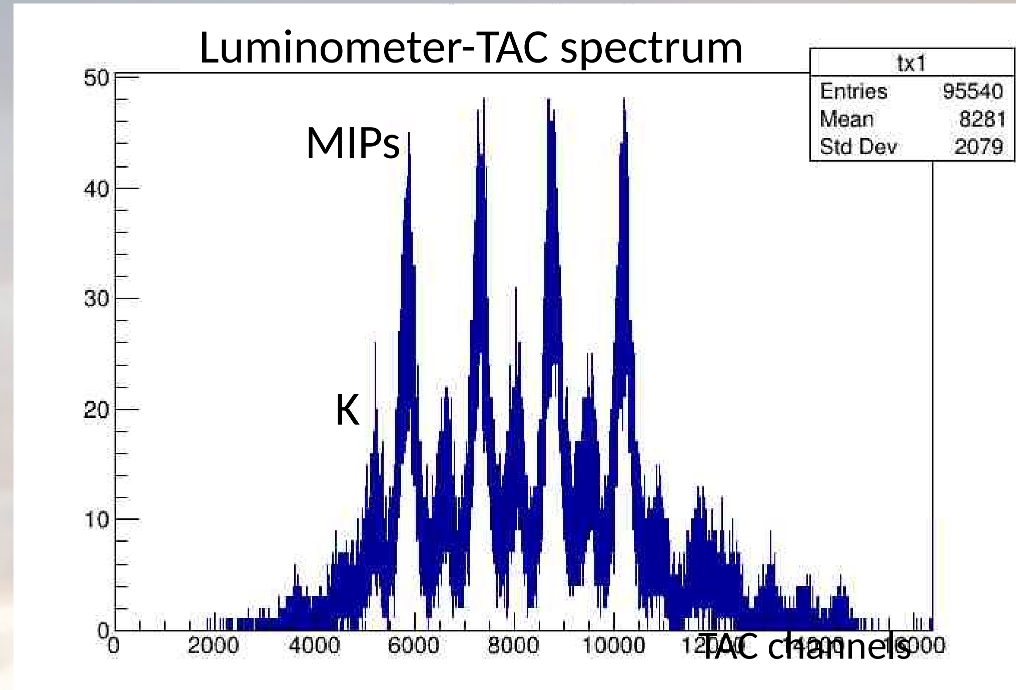
Ge refilling procedure to be done each 7-10 days



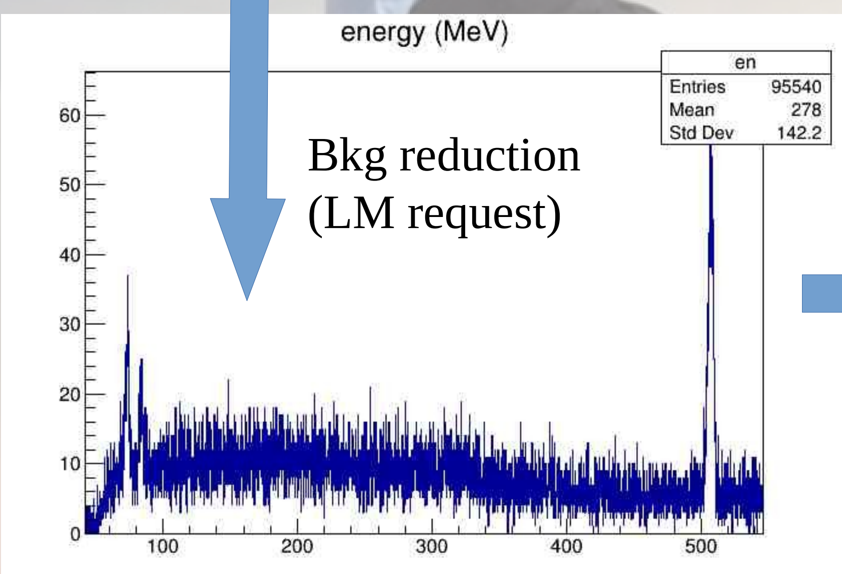
Recent activities and achievements

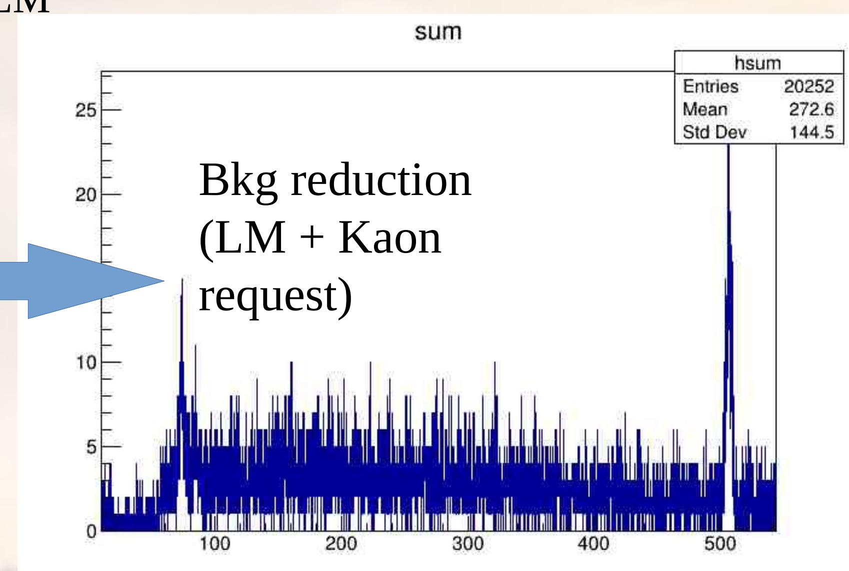
First overall spectrum (Technical paper in preparation)





LM signal processed with a Time to Analog Converter (TAC) to select events on HPGe in coincidence with K- in the LM





CONCLUSIONS

- Kaonic atoms measurements are still strongly demanded in the nuclear physics (and not only) community
- DAΦNE is a unique facility in the world to perform such kind of measurements
- There is a plethora of fundamental kaonic atoms transition lines to be measured, with different detectors and techniques
- Many measurements and tests can be carried on in parallel with SIDDHARTA-2
- New experiments with new setups can be proposed (some already have)
- Joint effort between thereticians (ask, calculate, support, approve, endorse) and experimentalists (build strong teams and improve know-how) is crucial