Istituto Nazionale Fisica Nucleare - Laboratori Nazionali di Frascati

19th International Conference on Hadron Spectroscopy and Structure (HADRON 2021)

26-31 / 07 /2021

Light kaonic atoms high precision X-ray spectroscopy at the DAΦNE collider: the SIDDHARTA-2 experiment

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On behalf of SIDDHARTA-2 collaboration

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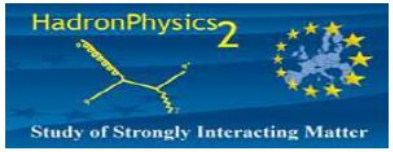
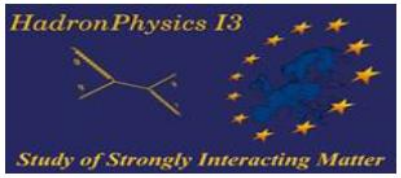
SIDDHARTA – 2

Silicon Drift Detectors for Hadronic Atom Research by Timing Application





FWF Der Wissenschaftsfonds.

Farnesina
Ministero degli Affari Esteri
e della Cooperazione Internazionale

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

STRONG-2020

Croatian Science Foundation,
research project 8570

SIDDHARTA (2) COLLABORATION

Scientific Goal

To perform precise measurements of kaonic atoms X-ray transitions to achieve unique information about QCD in the non perturbative regime in the strangeness sector not obtainable otherwise

SIDDHARTA-2 aim…

To perform the **precise measurement of kaonic deuterium** to determine X-ray transitions to the ground state (1s-level), such as to determine its shift and width induced by the strong interaction

The analysis of the **combined measurements of kaonic deuterium and kaonic hydrogen (measured by SIDDHARTA)** will allow, the extraction of the isospin dependent antikaone-nucleon scattering lengths which are **fundamental inputs of low-energy QCD effective theories.**

SIDDHARTA-2: kaonic deuterium

$$\varepsilon_{1s} + \frac{i}{2}\Gamma_{1s} = 2\alpha^3\mu^2 a_{K-p}[1 - 2\alpha\mu(ln\alpha - 1)a_{K-p} + \ldots]$$ K⁻H (SIDDHARTA,2009)

$$\varepsilon_{1s} + \frac{i}{2}\Gamma_{1s} = 2\alpha^3\mu^2 a_{K-d}[1 - 2\alpha\mu(ln\alpha - 1)a_{K-d} + \ldots]$$ K⁻d (SIDDHARTA-2,2021)

a_{K-p} and a_{K-d} : S-wave scattering lengths.

isoscalar a_0 and isovector a_1 scattering lengths

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

$$a_{K-n} = a_1$$

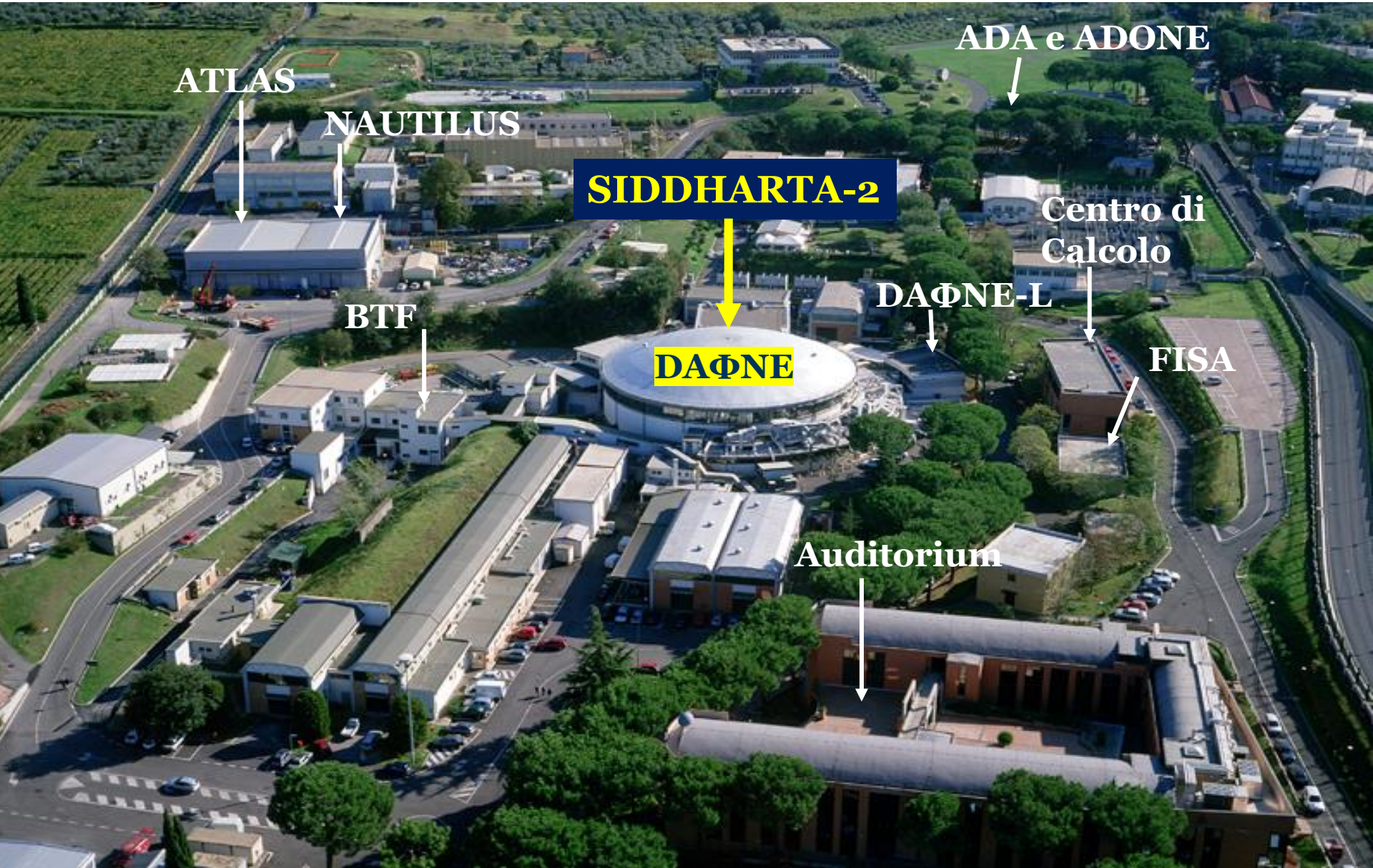
$$a_{K-d} = \frac{4[m_N + m_K]}{[2m_N + m_K]}Q + C$$

$$Q = \frac{1}{2}[a_{K-p} + a_{K-n}] = \frac{1}{4}[a_0 + 3a_1]$$

very important quantities for understanding the low energy QCD with strangeness

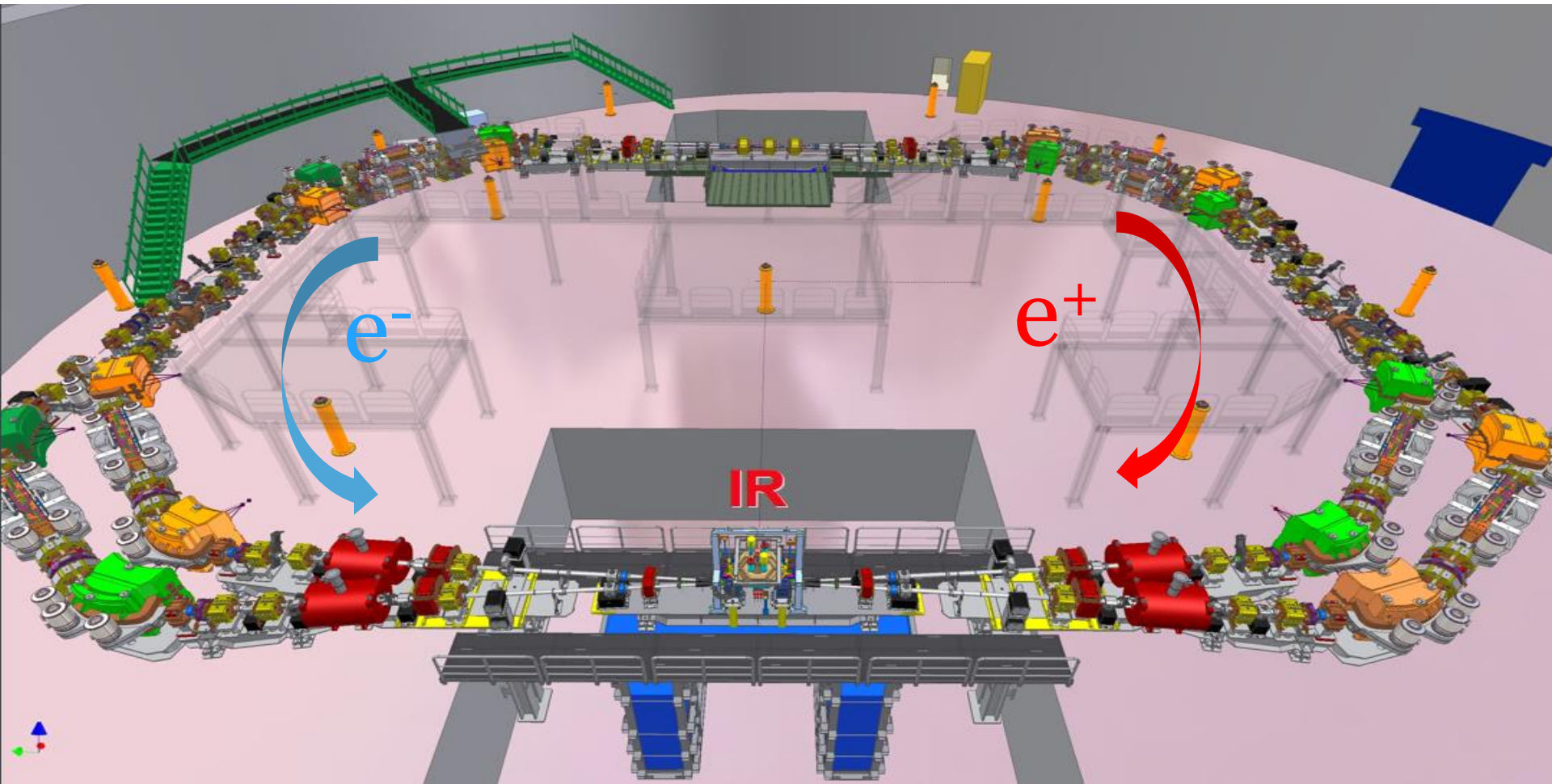
See Dr. F. Sirghi talk
30/07 h: 10.20

Laboratori Nazionali di Frascati (LNF-INFN)

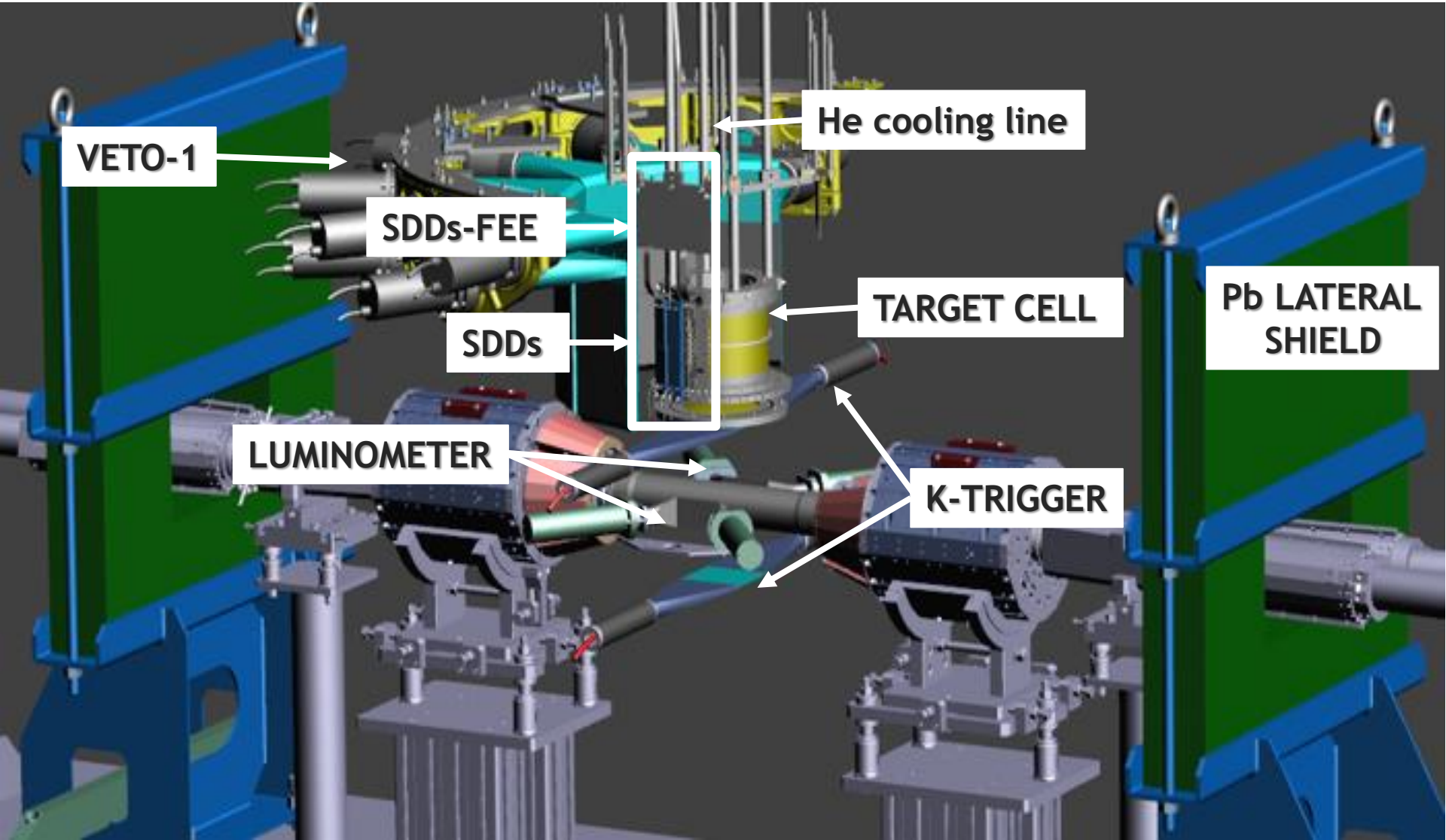


Laboratori Nazionali di Frascati (LNF-INFN)

- $\Phi \rightarrow K^- K^+$ (49.1%)
- Monochromatic low-energy K^- (~127 MeV/c ; $\Delta p/p = 0.1\%$)

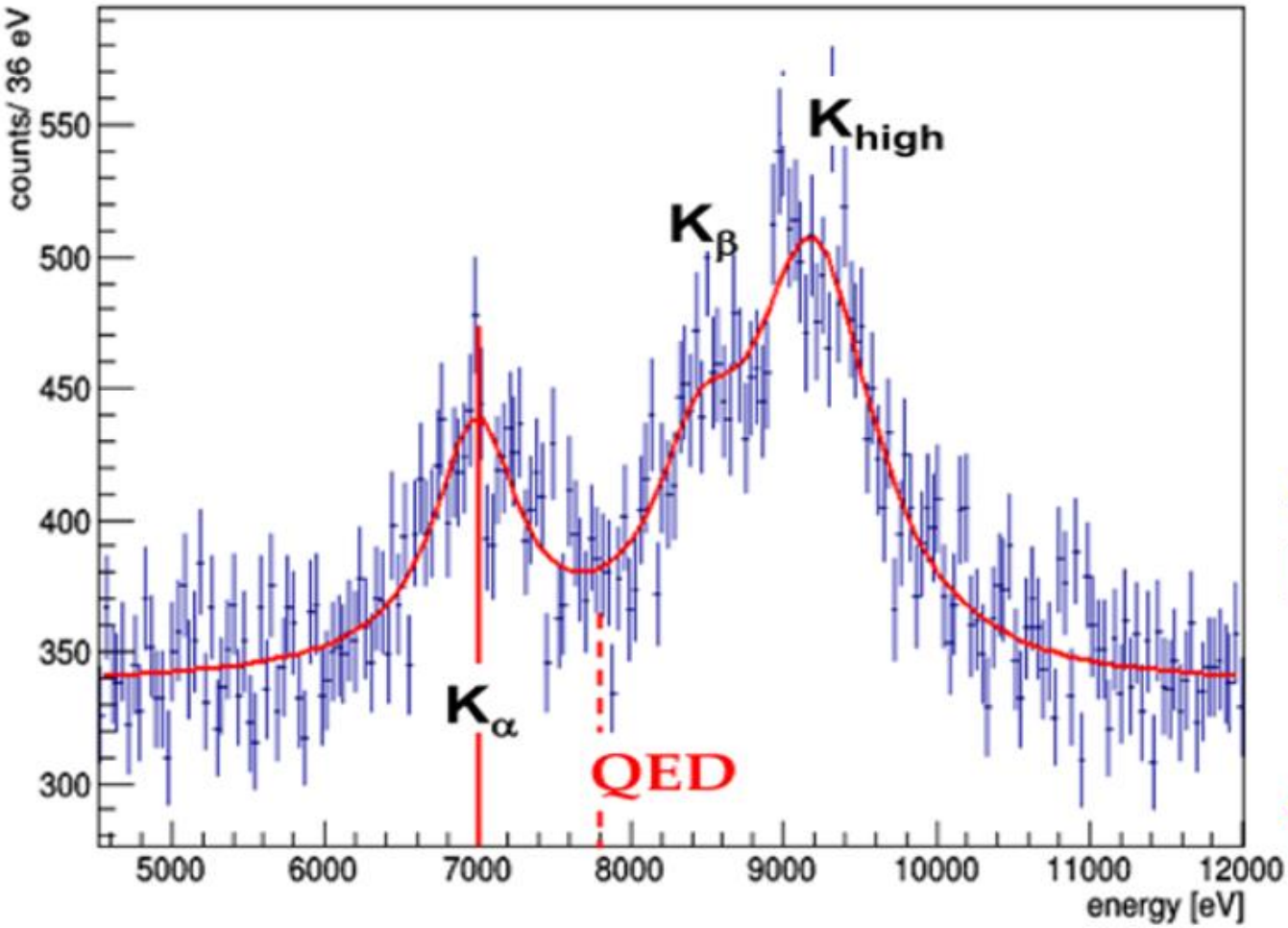


SIDDHARTA-2 experimental apparatus



SIDDHARTA-2: kaonic deuterium

KD yield < 0.1 %



$$\int L = 800 pb^{-1}$$

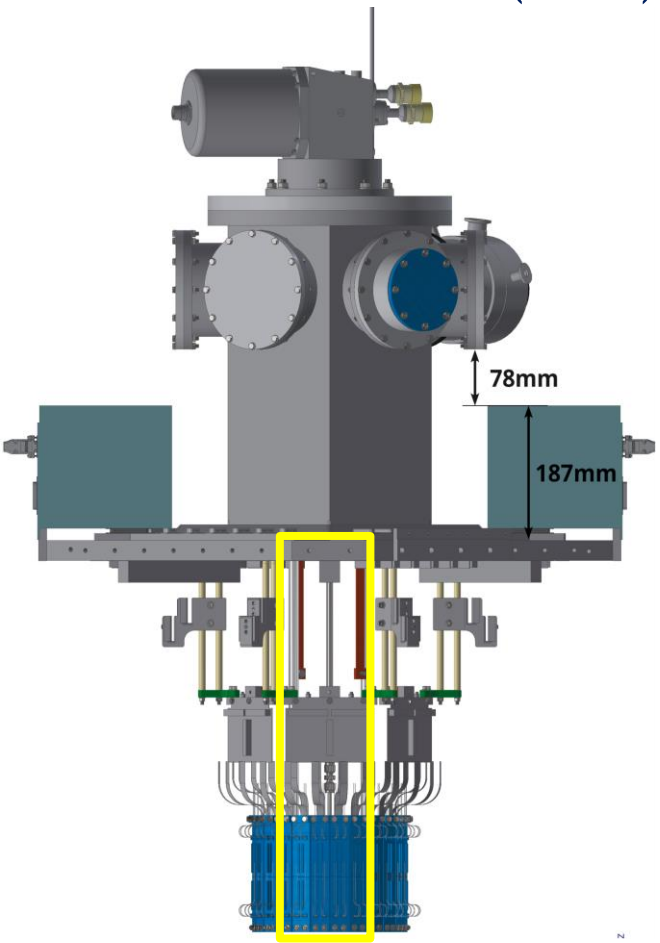
density: 3% (LHD)
detector area: 246 cm^2

$\varepsilon = -800 \pm 30$ eV
$\Gamma = 750 \pm 75$ eV

Same precision as SIDDHARTA, which gave the most precise measurement of KH so far

SIDDHARTINO - aim

1/6 of SIDDHARTA-2 (SDDs)



SIDDHARTA-2 single BUS

Measurement of K-^{4}He 3d->2p transition in preparation for the SIDDHARTA-2 data taking campaing

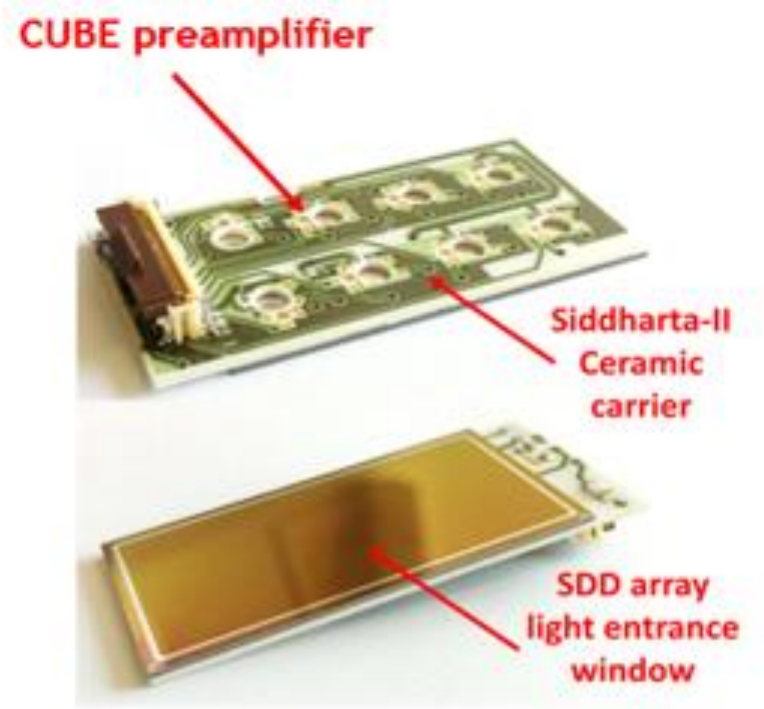
↓

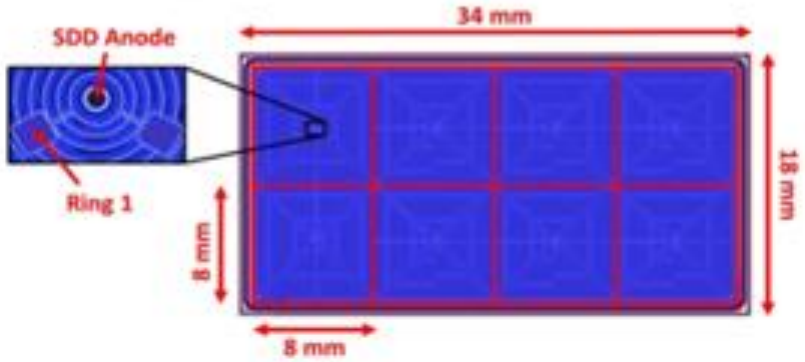
Machine commissioning
(orbits tuning, luminosity)
Evaluation of the beam quality
(background)
Detectors test
(Luminometer, Kaon trigger, SDDs)

↓

K-^{4}He 3d->2p transition precision measurement
(technical and phyisics papers)

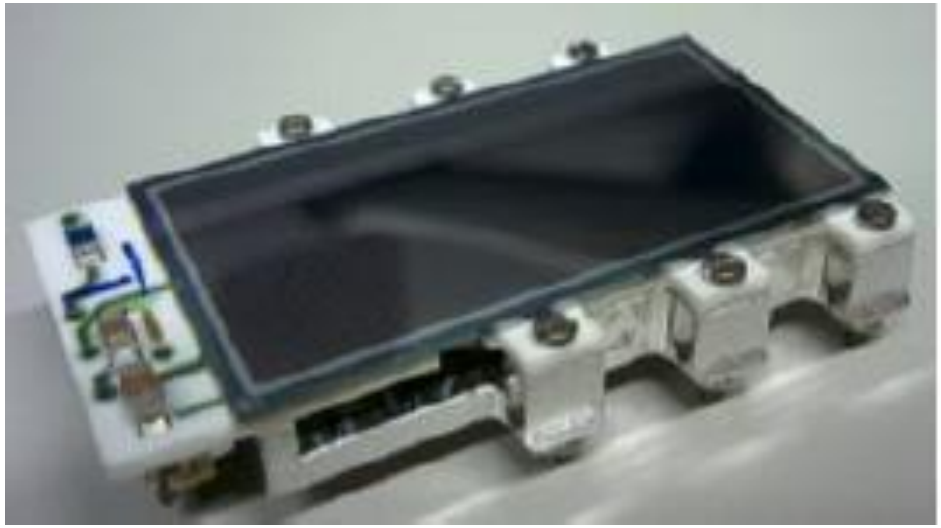
SDDs ENERGY RESPONSE



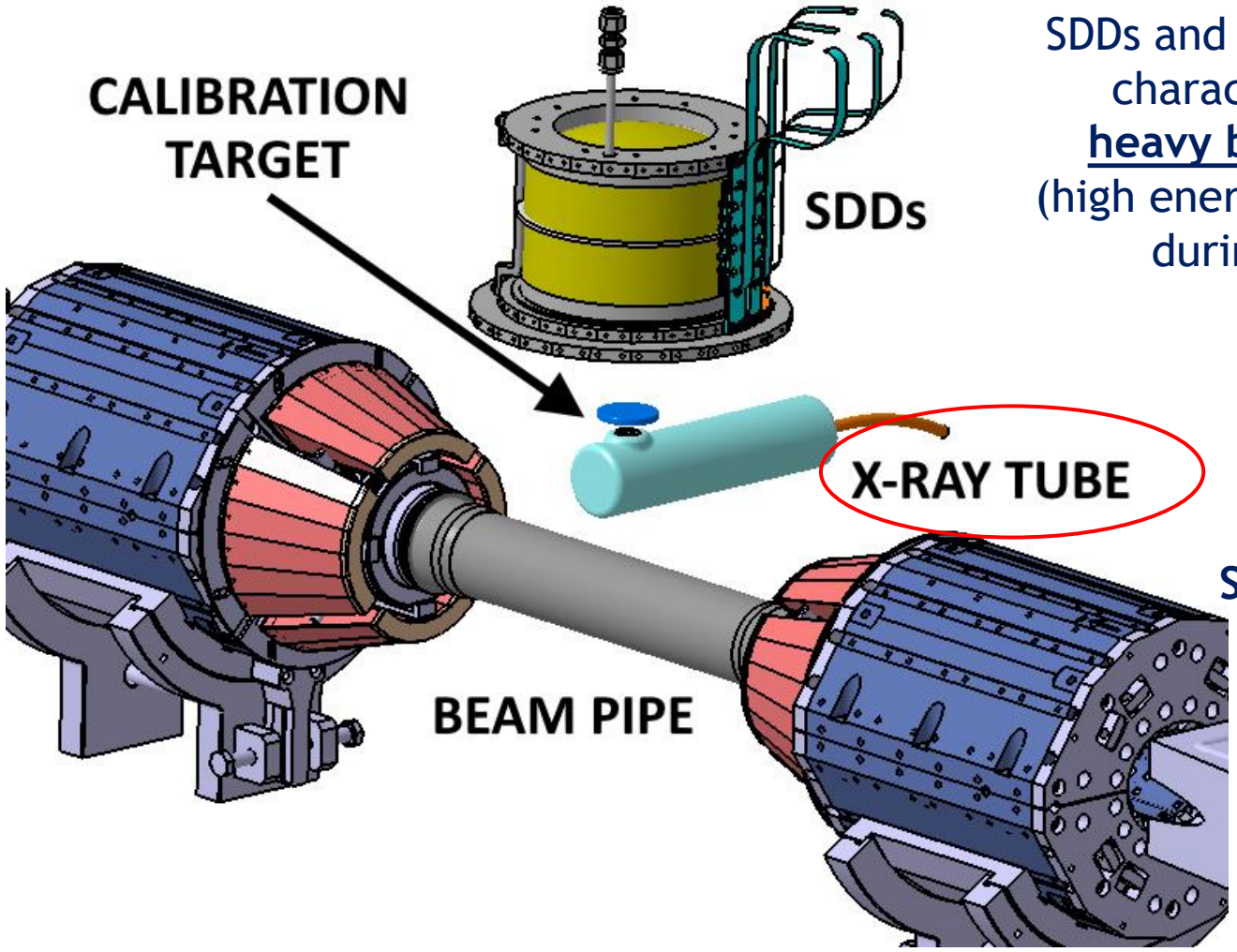


New technology of SDDs (LNF-INFN, PoliMi, FBK) for the high precision K-d measurement

8 SDD units (0.64 cm^2) for a device total active area of 5.12 cm^2



SDDs ENERGY RESPONSE

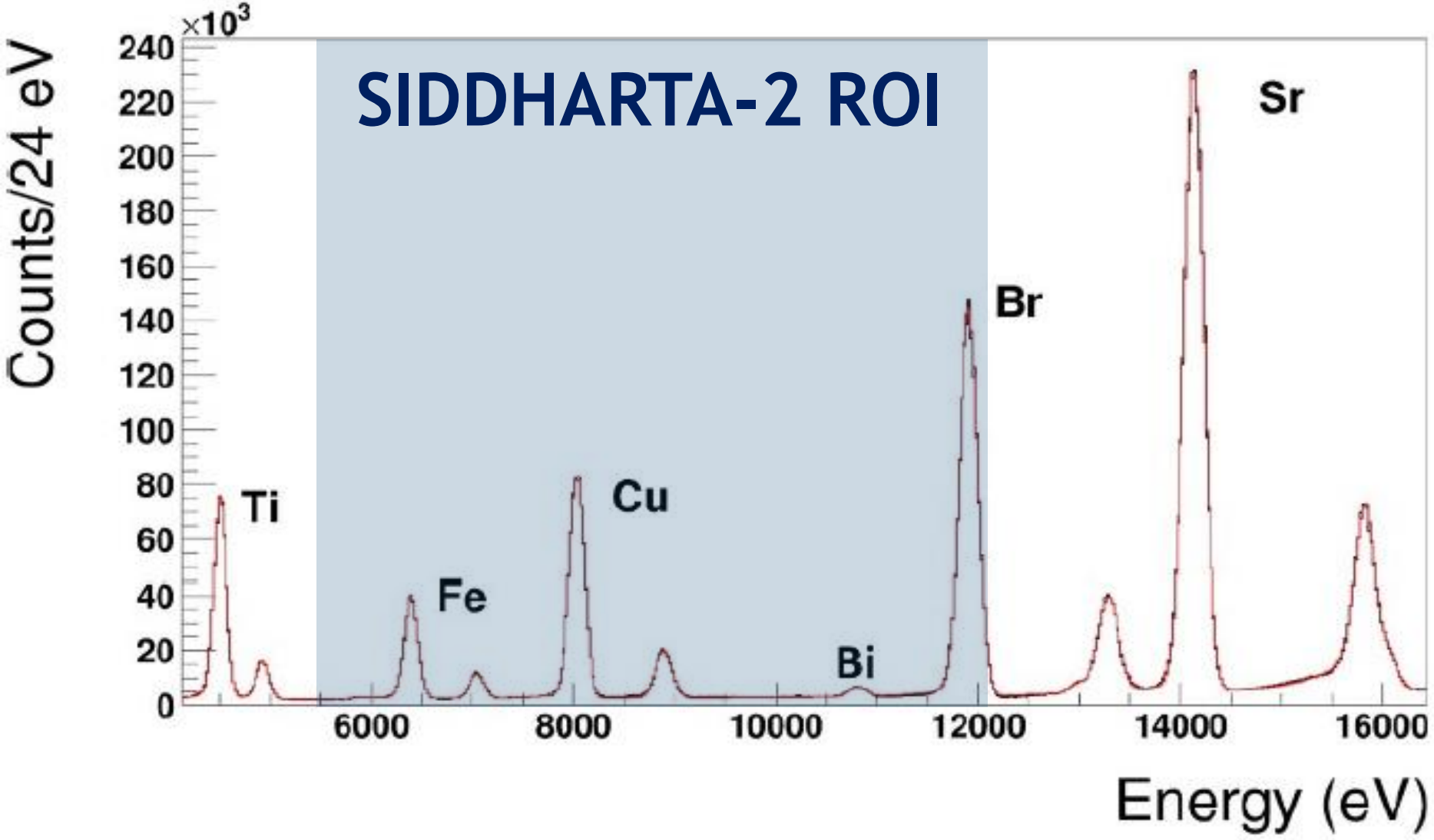


SDDs and DAQ analog/digital chain characterization in machine **heavy background conditions** (high energy particle and radiation) during the DAΦNE B.C.P

Multi-element target **Ti-Fe-Cu-Br-Sr** to include the **SIDDHARTA-2 energy range**

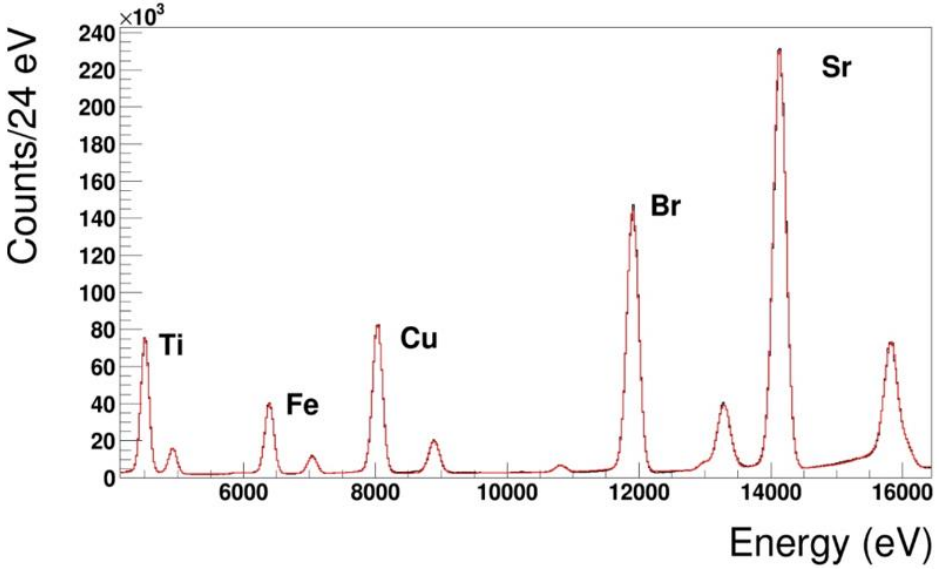
Miliucci M. et al, Silicon Drift Detectors system for high precision light kaonic atoms spectroscopy, Meas. Sci. Techn. (32), 2020

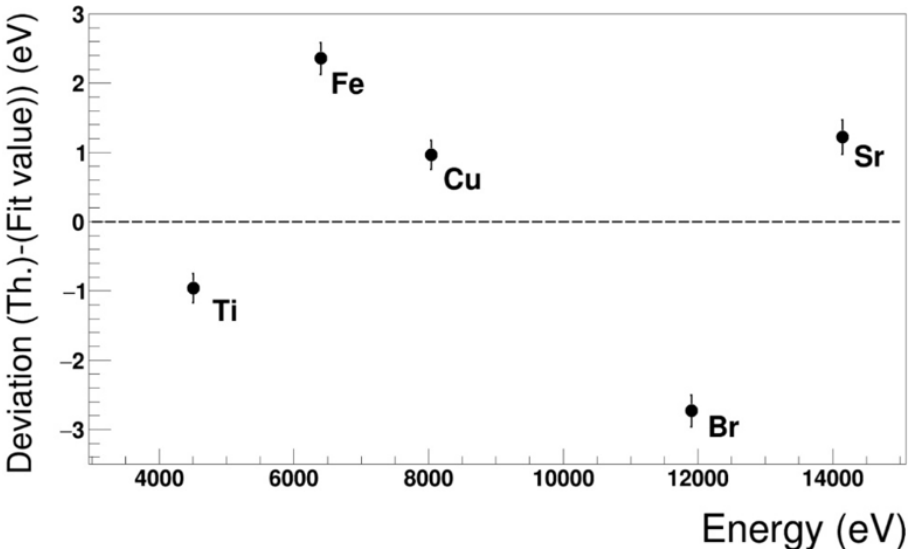
SDDs ENERGY RESPONSE



Miliucci M. et al, Silicon Drift Detectors system for high precision light kaonic atoms spectroscopy, Meas. Sci. Techn. (32), 2020

SDDs ENERGY RESPONSE



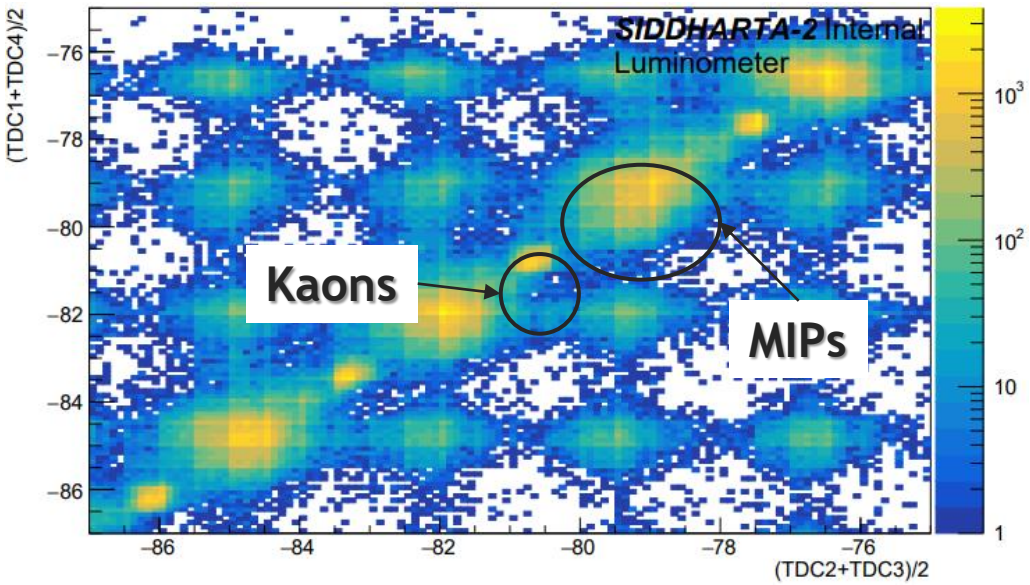


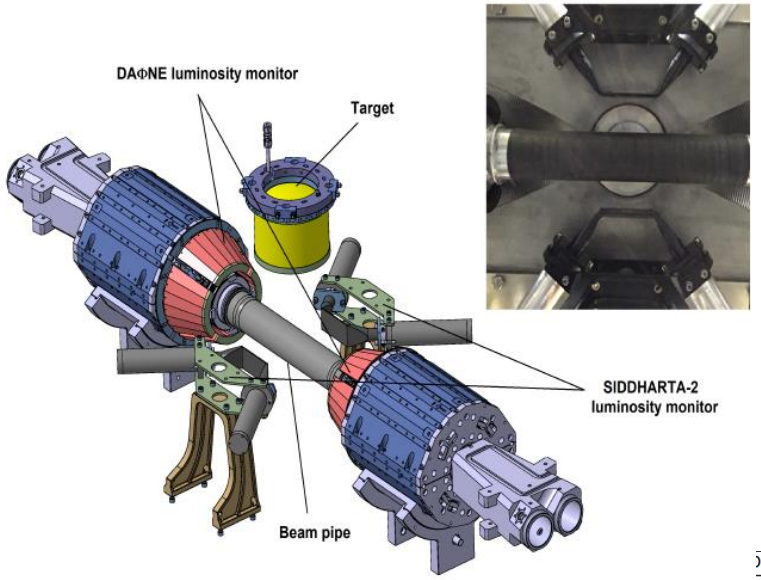
- Linear response
  -> Residuals within ± 3 eV (4-14 keV range)
  -> $\Delta E/E < 10^{-3}$ (4-14 keV)

- FWHM Fe Ka line = 157 ± 2 eV (@ 150 K)

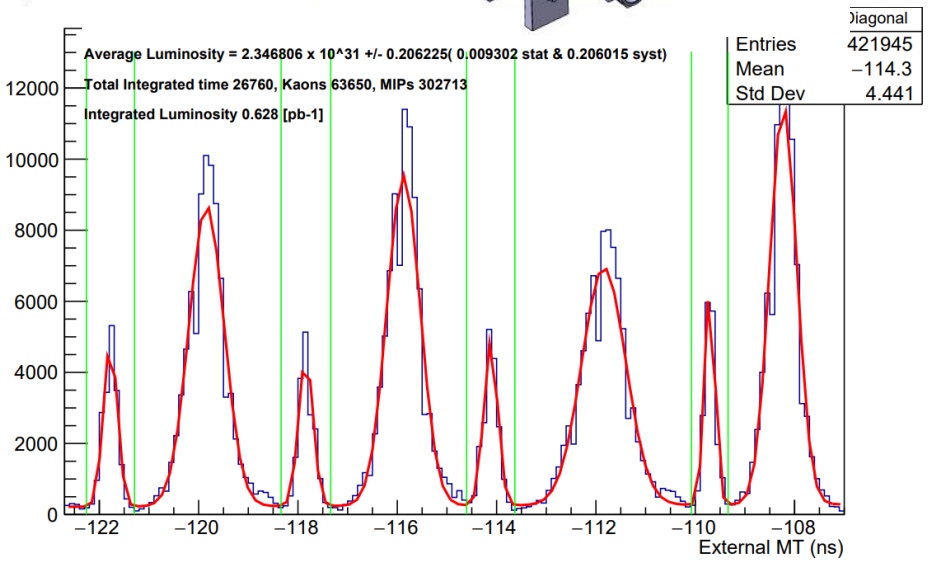
Miliucci M. et al, Silicon Drift Detectors system for high precision light kaonic atoms spectroscopy, Meas. Sci. Techn. (32), 2020

Luminosity monitor



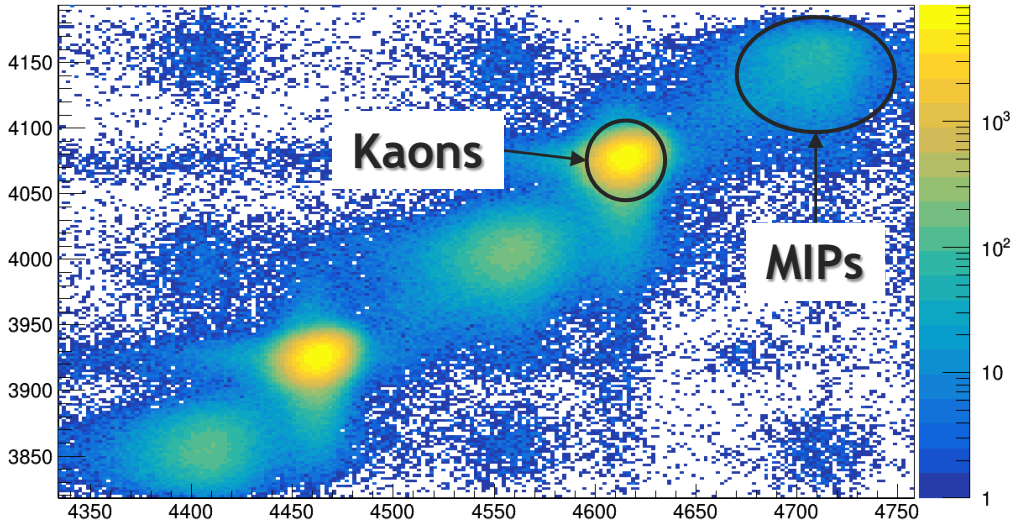


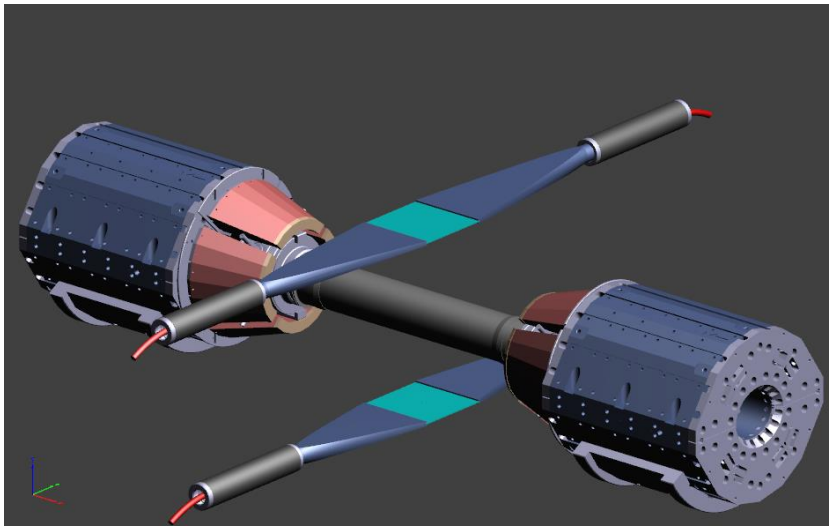
- **Measurement of the luminosity** delivered by the DAΦNE collider
- **Evaluation of beams quality** (On-line feedback from SIDDHARTA-2 to DAΦNE as Kaons/Signal)



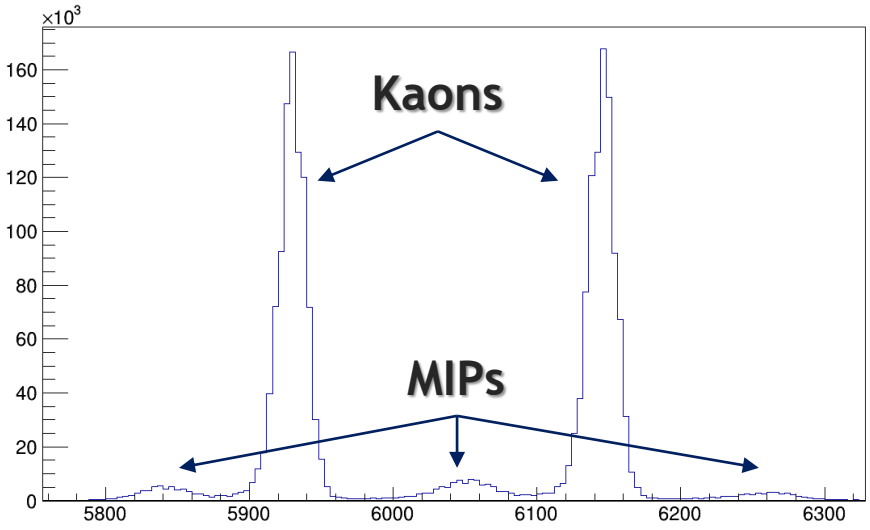
Skurzok M. et al, Characterization of the SIDDHARTA-2 luminosity monitor, JINST (15) 2020

Kaon Trigger

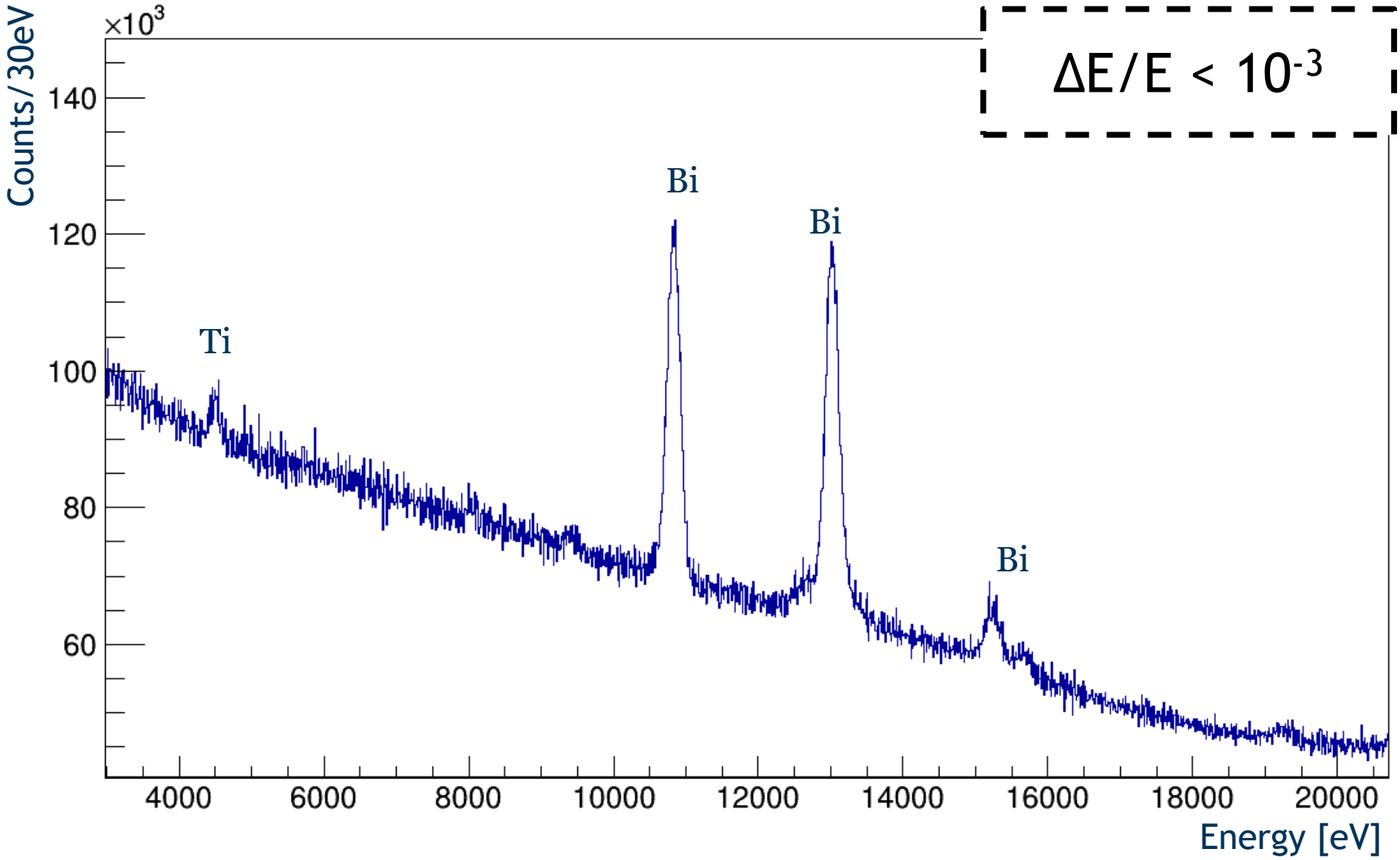




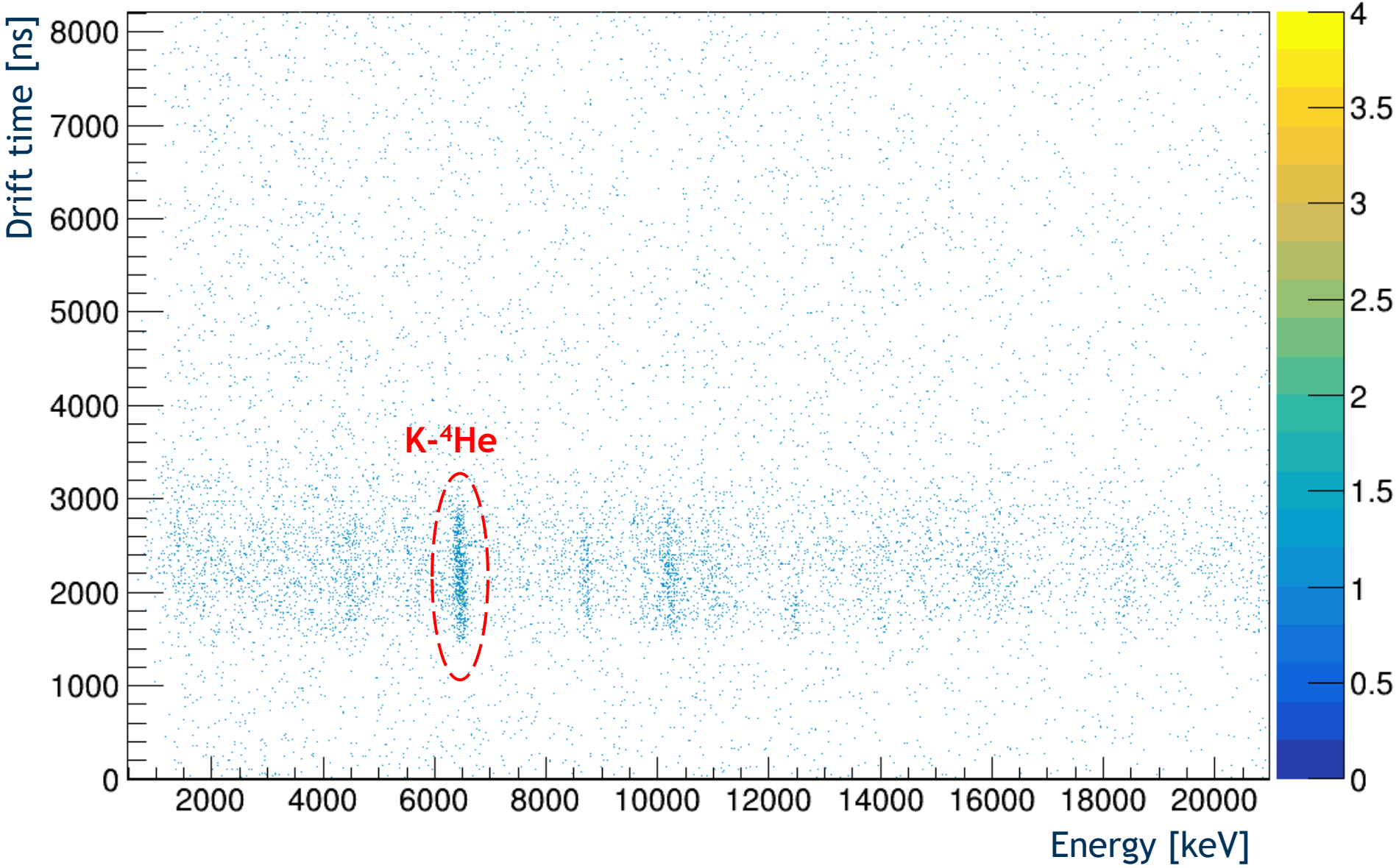
Asyncronous background rejection factor given by the K Trigger and SDDs timing response **in the order of 10^{-5}**



SIDDHARTINO RUN

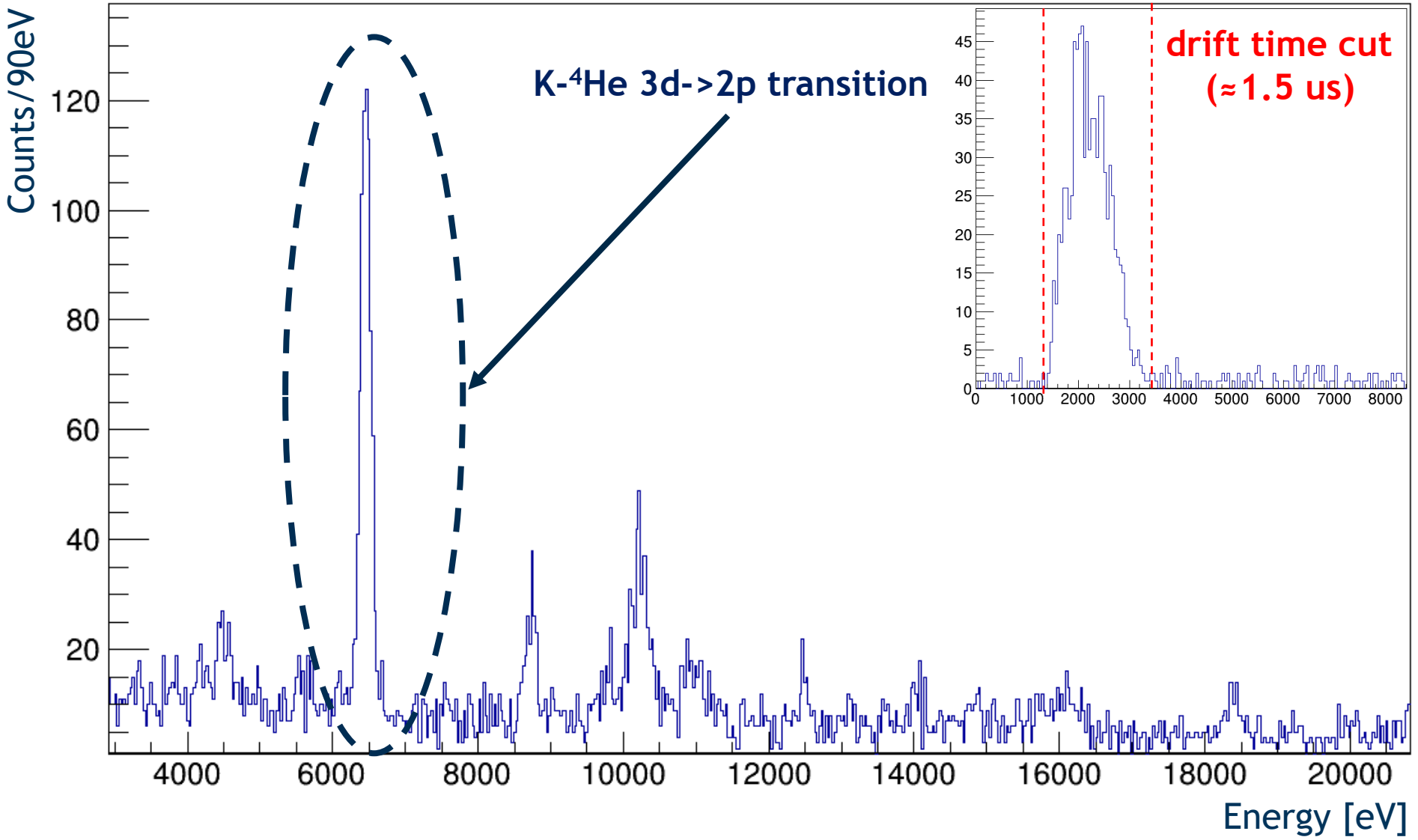


SIDDHARTINO RUN



SIDDHARTINO RUN

Integrated Luminosity = 15 pb^{-1}



SIDDHARTINO RUN

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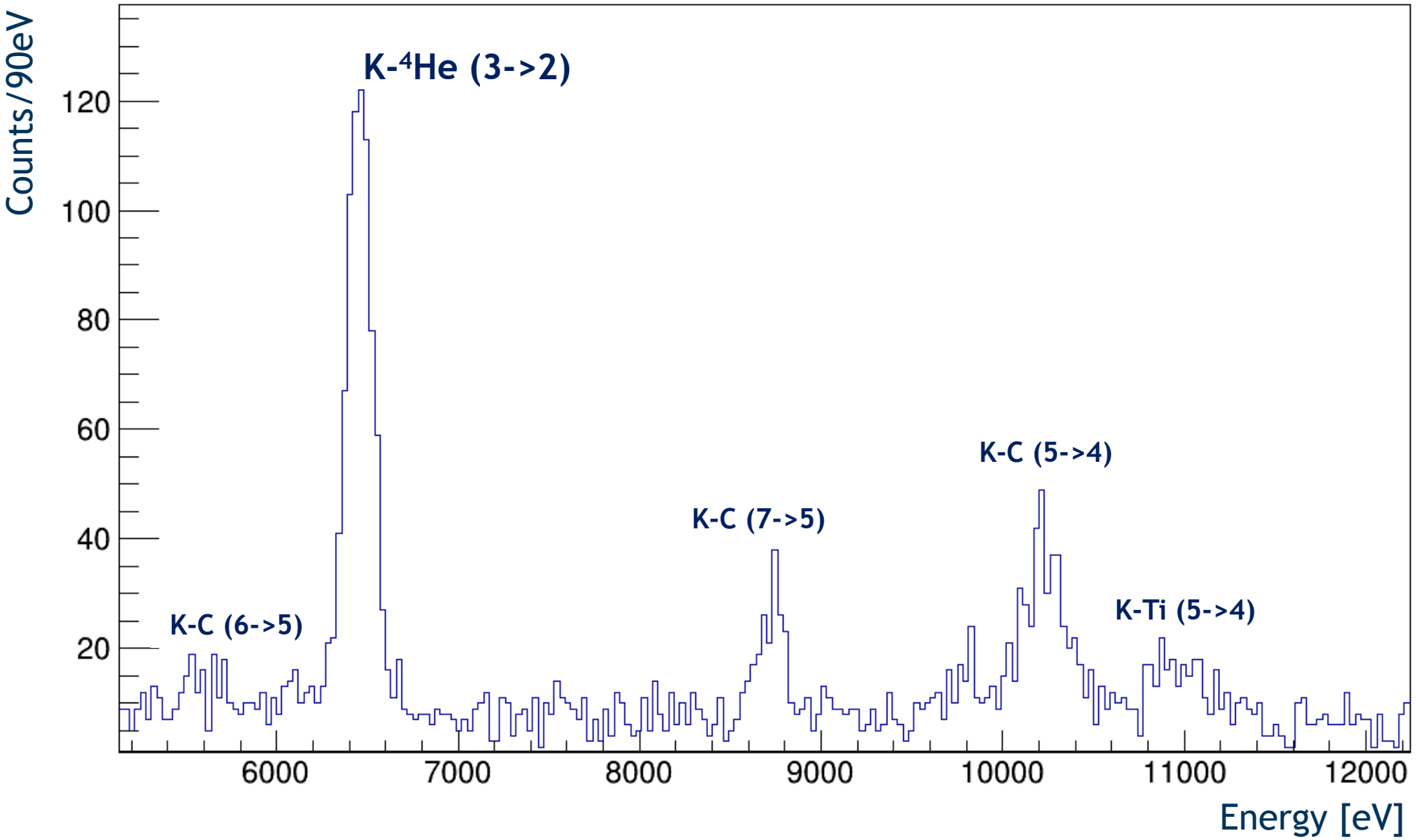

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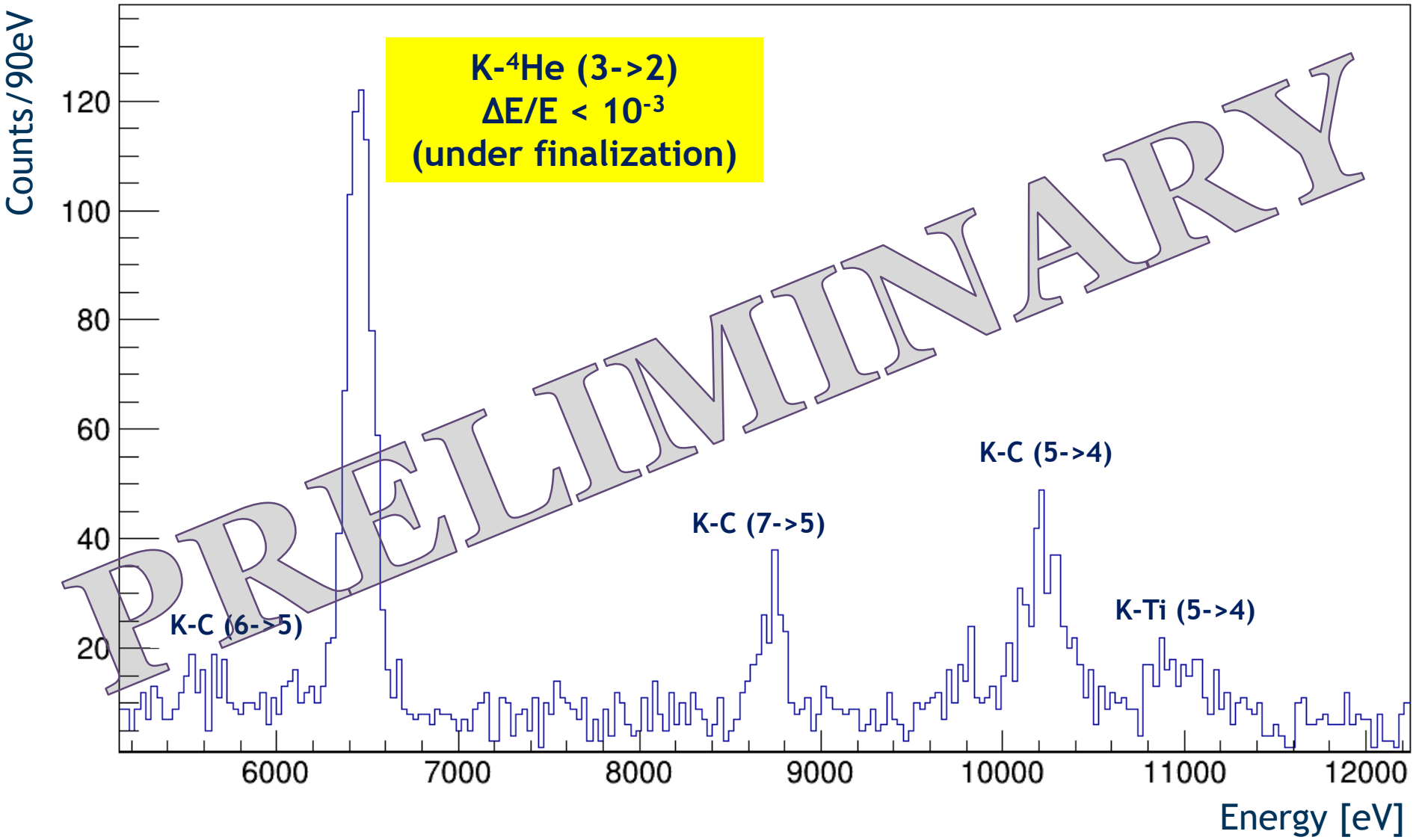

The SIDDHART(INO) RUN

- **Full and stable control of the system** spectroscopic response. SDDs analog/digital DAQ chain **performances are preserved in the heavy background of the collider** (*published papers*);
- **Linear energy response** ($\Delta E/E < 10^{-3}$ eV);
- **Asyncronous background rejection** factor $\approx 10^{-5}$;
- **K-^{4}He 3d->2p transition precision measurement** (*papers in preparation*);

READY FOR THE INSTALLATION OF THE SIDDHARTA-2 EXPERIMENTAL APPARATUS
-Autumn 2021-

Future plans

- Kaonic Helium
  - 2p -> 1s transition

- Other Kaonic atoms
  - Pioneering technology of 1mm thick SDDs

- Kaon mass:
  - High precision X-ray spectrometer - HAPG crystals (VOXES)
  - High purity Gemanium Detectors (GEKA)

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