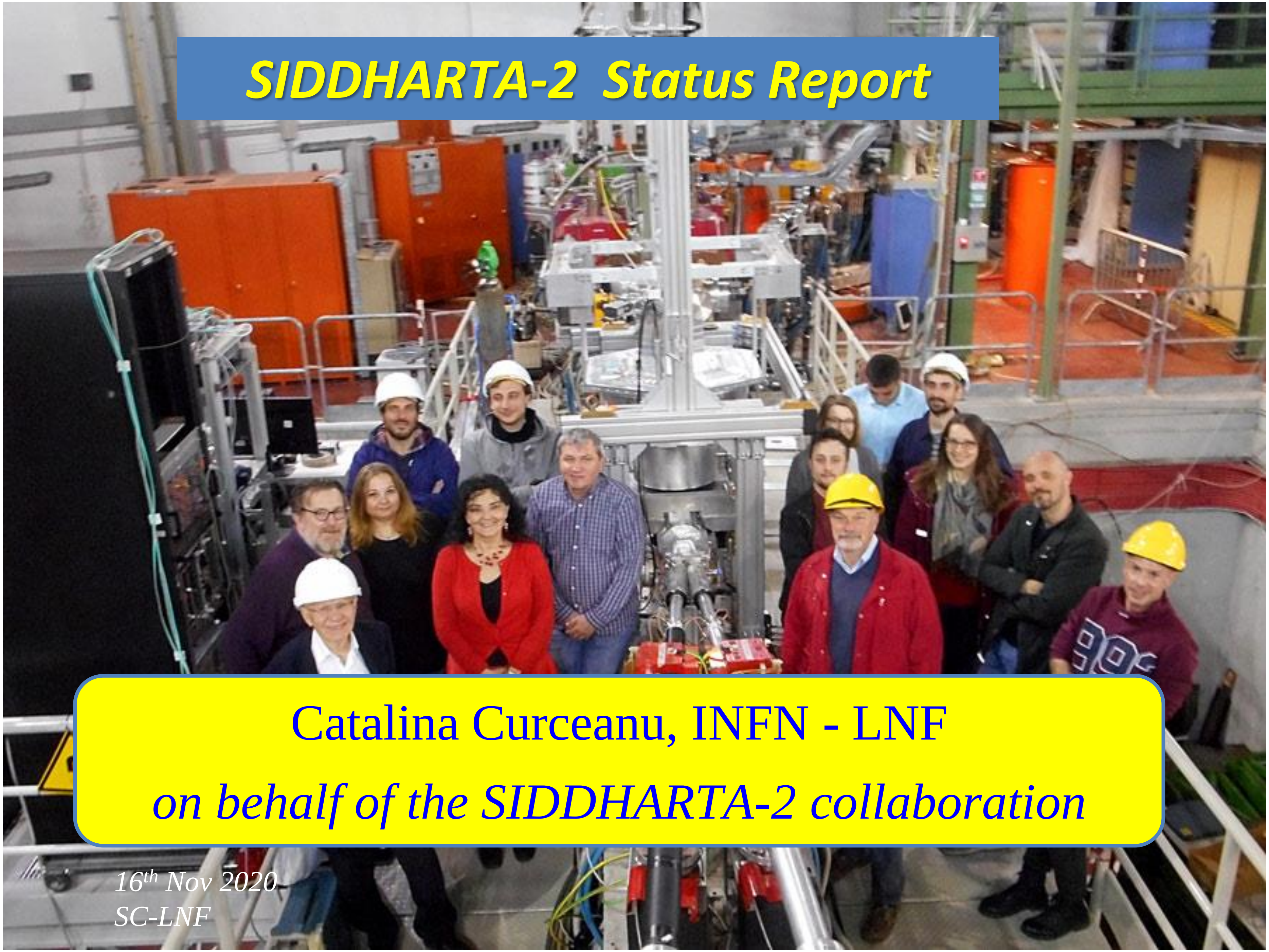
SIDDHARTA-2 Status Report



Catalina Curceanu, INFN - LNF

on behalf of the SIDDHARTA-2 collaboration

16th Nov 2020
SC-LNF

SIDDHARTA-2

SIlicon Drift Detector for Hadronic Atom Research by Timing Applications

HadronPhysics2 – Study of Strongly Interacting Matter

HadronPhysics I3 – Study of Strongly Interacting Matter

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
Helmholtz Inst. Mainz, Germany
Univ. Jagiellonian Krakow, Poland
Research Center for Electron Photon Science (ELPH), Tohoku University

STRONG-2020

Croatian Science Foundation, research project 8570

Phys.Rev.D 102 (2020) 8, 083015

On self-gravitating strange dark matter halos around galaxies

Dark Matter studies

Rev.Mod.Phys. 91 (2019) 2, 025006

The modern era of light kaonic atom experiments

Fundamental physics
New Physics

Kaonic atoms

Kaon-nuclei interactions (scattering and nuclear interactions)

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

Kaonic Atoms to Investigate Global Symmetry Breaking

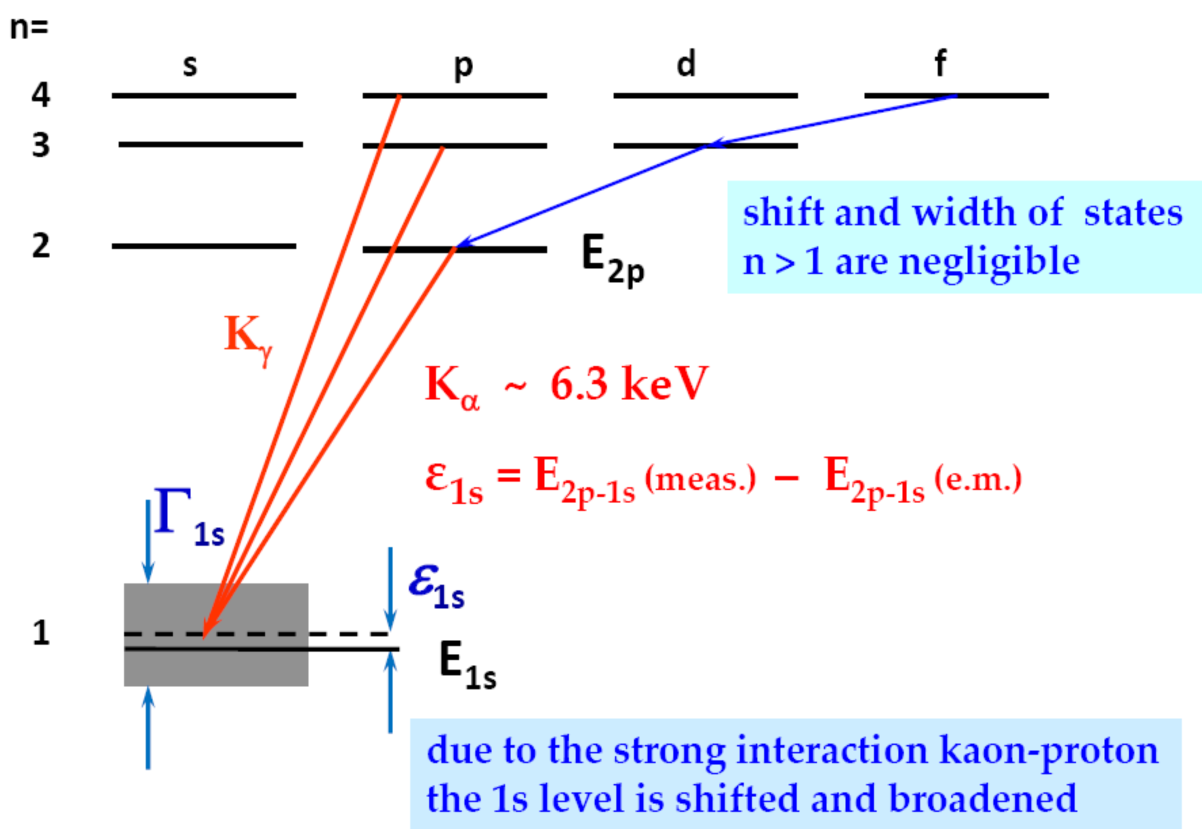
Symmetry 12 (2020) 4, 547

Astrophysics
EOS Neutron Stars

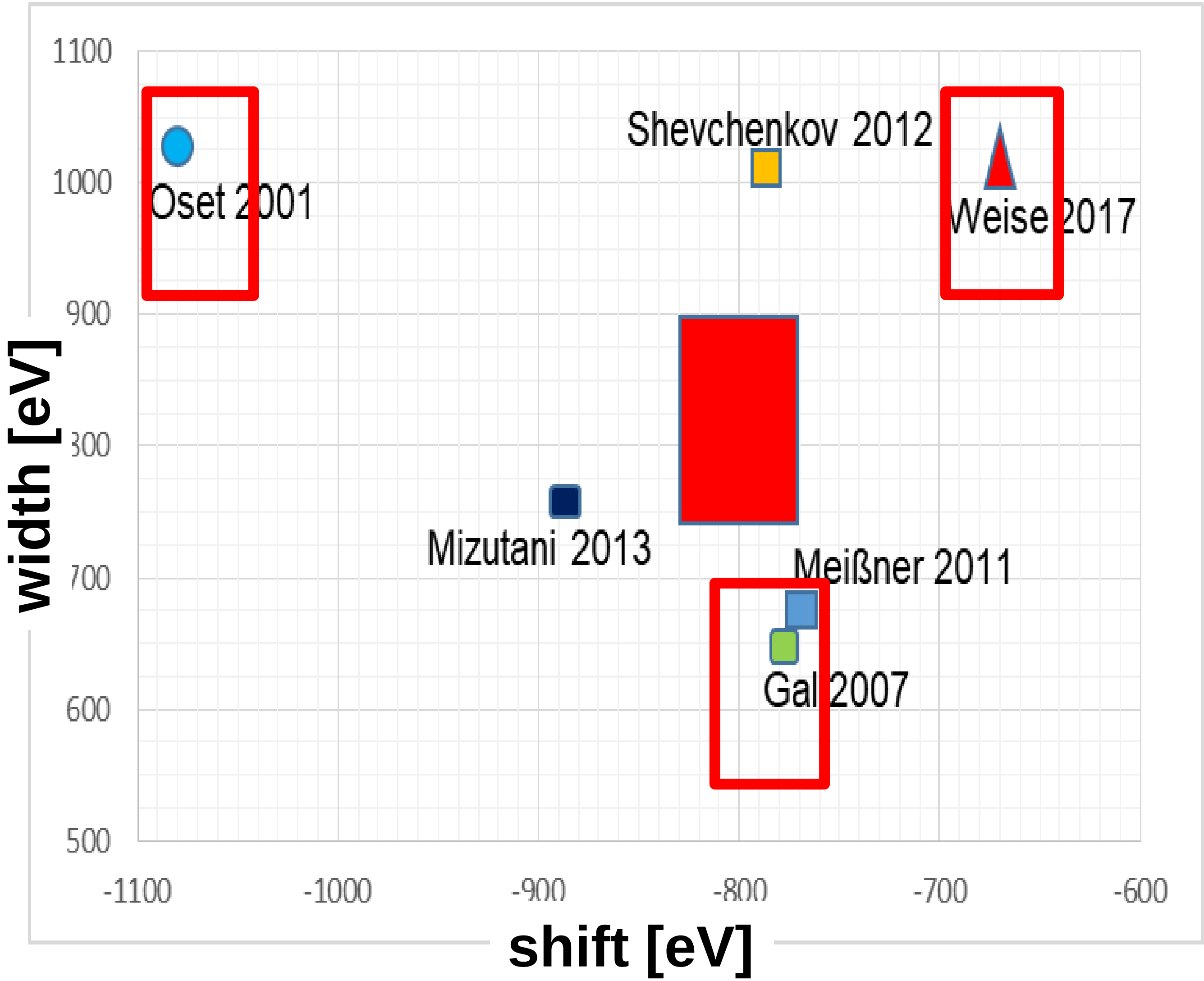
Astrophys.J. 881 (2019) 2, 122

Merger of compact stars in the two-families scenario

X-RAY TRANSITIONS TO THE 1s STATE



SIDDHARTA-2 FIRST kaonic deuterium meas.



SCATTERING LENGTHS

Deser-type relation connects shift ε_{1s} and width Γ_{1s} to the real and imaginary part of $a_{K\text{-}p}$

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

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

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

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

⇐

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

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

A very useful instrument to study the chiral and SU(3) symmetries breaking mechanisms is the measurement of X-ray transitions in kaonic hydrogen and kaonic deuterium. These measurements allow to extract the antikaon-nucleon scattering lengths, which are relevant for the calculation of the kaon-nucleon sigma terms,related to the chiral and SU(3) symmetries breaking part of the Hamiltonian…. This will fuel theoretical activities aimed to extract the kaon-nucleon sigma terms and unveil the mechanism at work in the chiral and SU(3) symmetry breaking, on which the mass of (most part) of our visible Universe depends.

Content

1) Scientific optput: articles since last SC (since May 2020)
2) Our young ones: master Student graduated; Erasmus+ training student TUM (Munich)
3) ECT* Talk and Organization of a dedicated Workshop
4) Activity in the lab -> SDDs characterization
5) Activity inside DAΦNE – towards SIDDHARTINO
6) MCarlo simulation optimization
7) Strategy revisited: plans
8) Activities towards post SIDDHARTA-2: HPGe, 1 mm SDDs & VOXES

Papers since last SC: May 2020 - now

1) Characterization of the SIDDHARTA-2 luminosity monitor, JINST 15 (2020) 10
2) Total branching ratio of the K− two-nucleon absorption in 12C, Phys.Scripta 95 (2020) 8, 084012
3) Self-gravitating strange dark matter halos around galaxies, Phys.Rev.D 102 (2020) 8, 083015
4) Studies of low-energy K− hadronic interactions with light nuclei by AMADEUS, J.Phys.Conf.Ser. 1526 (2020) 012024
5) Studies of kaonic atoms at the DAΦ\PhiΦNE collider: from SIDDHARTA to SIDDHARTA-2, J.Phys.Conf.Ser. 1526 (2020) 012023
6) The key role of the Silicon Drift Detectors in testing the Pauli Exclusion Principle for electrons: the VIP-2 experiment, J.Phys.Conf.Ser. 1548 (2020) 1, 012033
7) Silicon Drift Detectors system for high precision light kaonic atoms spectroscopy, draft ready
8) New insights into the strong interaction with strange exotic atoms, Researchoutreach.org
9) *Invitation to write a dedicated paper in Progress in Particle and Nuclear Physics*

Self-gravitating strange dark matter halos around galaxies

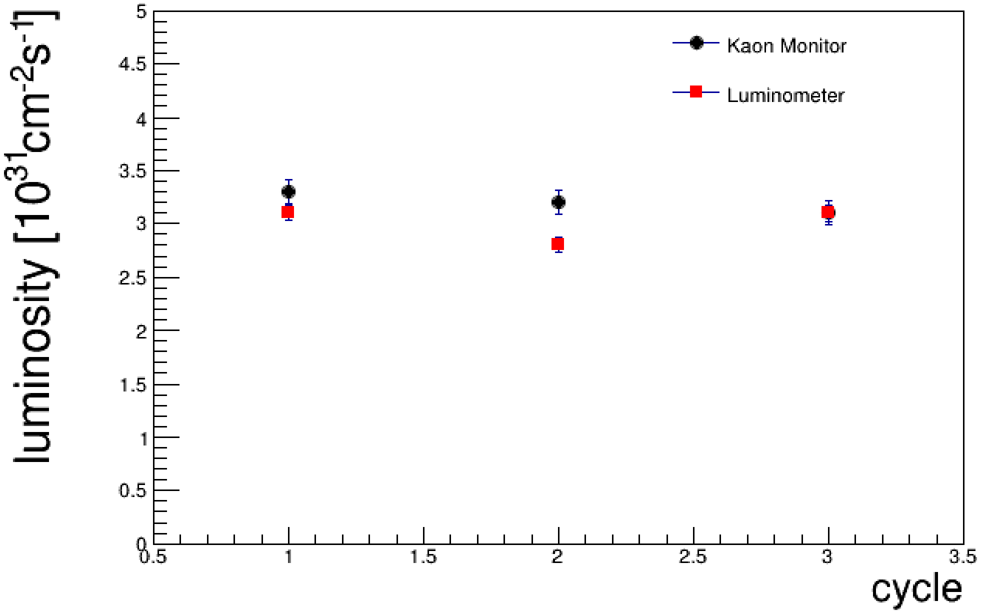
VI. CONCLUSIONS

In this paper, we proposed a possible scenario for DM's origin in the Universe based on conglomerates made of strange quark matter. These conglomerates form in the very early phases after the Big Bang, when the conditions of extreme density and temperature may favor the aggregation of strange baryonic matter in stable structures that interact only gravitationally with ordinary matter. Subsequently, when the Universe expands and cools down, the conglomerates formed in this way settle into galactic halos as "relic" DM.

SC May 2020:

Comparison: Kaon Monitor and Luminometer

Good Agreement



date [D/M/Y] | time [s] | N_K | L | L_err

16/02/2020: cycle 1 1384 3696 3.3 0.12
16/02/2020: cycle 2 1404 3634 3.2 0.12
16/02/2020: cycle 3 1317 3324 3.1 0.08

//Luminometer
16/02/2020: cycle 1 1385 4039 3.1
0.07
16/02/2020: cycle 2 1405 3753 2.8 0.07
16/02/2020: cycle 3 1317 3868 3.1
0.08

L [10^31 cm^-2 s^-1]

PRELIMINARY

Plan: paper on cross section phi

PUBLISHED BY IOP PUBLISHING FOR SISSA MEDIALAB

RECEIVED: *August 12, 2020*
ACCEPTED: *September 22, 2020*
PUBLISHED: *October 14, 2020*

Characterization of the SIDDHARTA-2 luminosity monitor

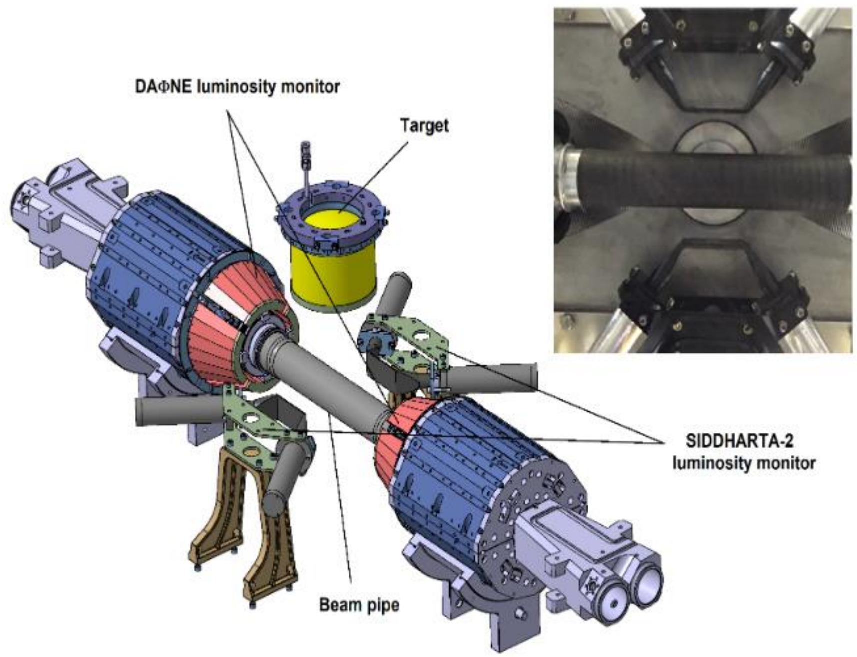


Figure 2. Schematic representation of the SIDDHARTA-2 setup with implemented luminosity monitor and the top view picture of the two installed modules (right upper corner).

Published by IOP Publishing for Sissa Medialab

Received: *August 12, 2020*
Accepted: *September 22, 2020*
Published: *October 14, 2020*

Characterization of the SIDDHARTA-2 luminosity monitor

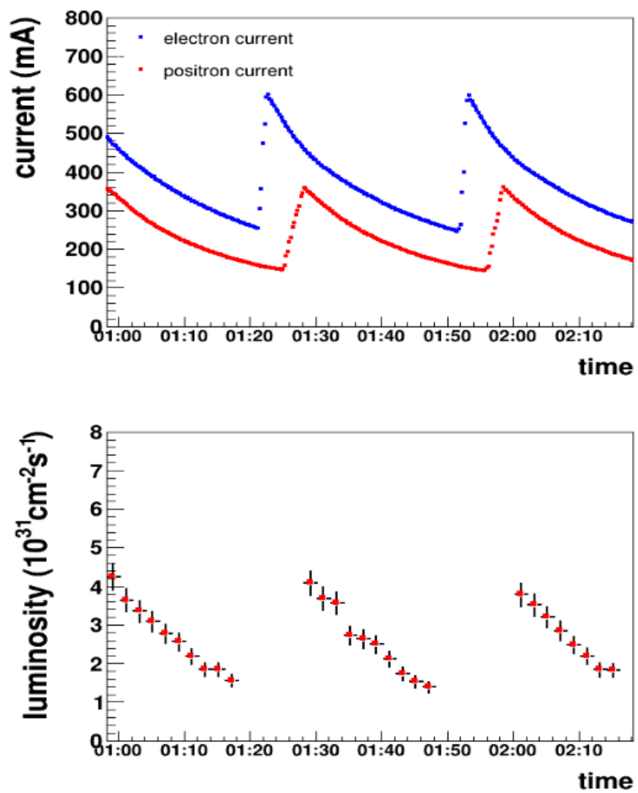


Figure 10. (upper) DAΦNE currents: electron (blue) and positron (red); (lower) measured luminosity — each point corresponds to 2 min of data taking.

Silicon Drift Detectors system for high precision light kaonic atoms spectroscopy

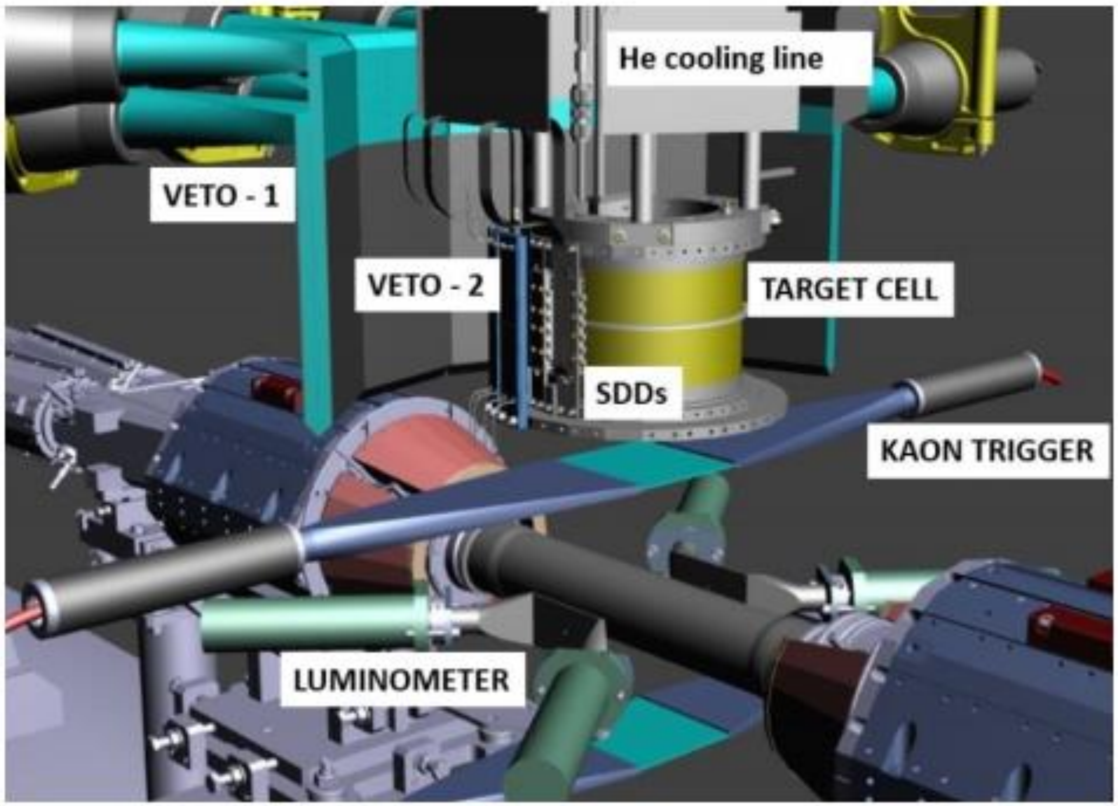
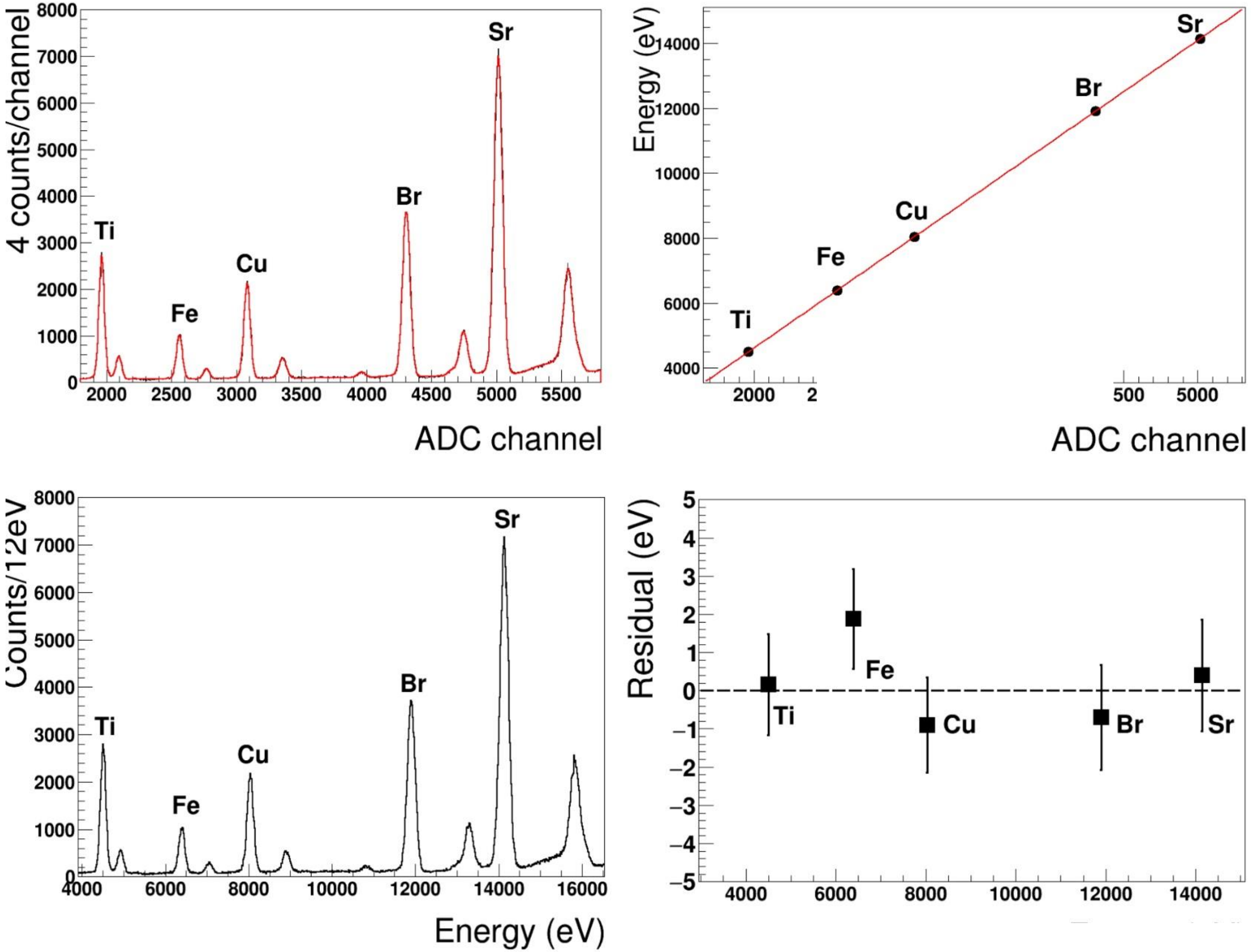


Figure 1: Schematic drawing of the SIDDHARTA-2 experiment.

Silicon Drift Detectors system for high precision light kaonic atoms spectroscopy



Paper draft ready (Marco Miliucci, Diana Sirghi, Alessandro Scordo)

research OUTREACH

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New insights into the strong interaction with strange exotic atoms

The strong interaction plays a fundamental role in our universe. The difficulty of performing precision measurements has limited our understanding of this interaction. Dr Catalina Curceanu at the National Institute for Nuclear Physics (INFN) in Frascati-Rome is leading ambitious new efforts to study and measure the strong interaction in her lab. Her team's work is centred around an intriguing form of matter in which the electrons of regular atoms are replaced by exotic strange particles named 'kaons,' and could help to explain mysteries ranging from the composition of neutron stars, to the origin of mass itself.

Download this Article

Article References

- Curceanu, C., Guaraldo, C., Sirghi, D., Amirkhani, A., Baniahmad, A., Bazzi, M., Bellotti, G., Bosnar, D., Bragadireanu, M., Cargnelli, M., Carminati, M. (2020). Kaonic Atoms to

Master Thesis: October 2020 – 110 e lode
Now: Sgaramella PhD in SIDDHARTA-2

UNIVERSITÀ DEGLI STUDI DI ROMA
"TOR VERGATA"

Università di Roma
Tor Vergata

FACOLTÁ DI SCIENZE MATEMATICHE, FISICHE E NATURALI

CORSO DI LAUREA MAGISTRALE IN FISICA

Characterization in the laboratory and DAΦNE of the SIDDHARTA-2 SDD detectors for precision kaonic atoms measurements

Relatore:
Prof. Annalisa d'Angelo

Candidato:
Francesco Sgaramella

Relatore esterno:
Dr. Catalina Curceanu
Dr. Marco Miliucci

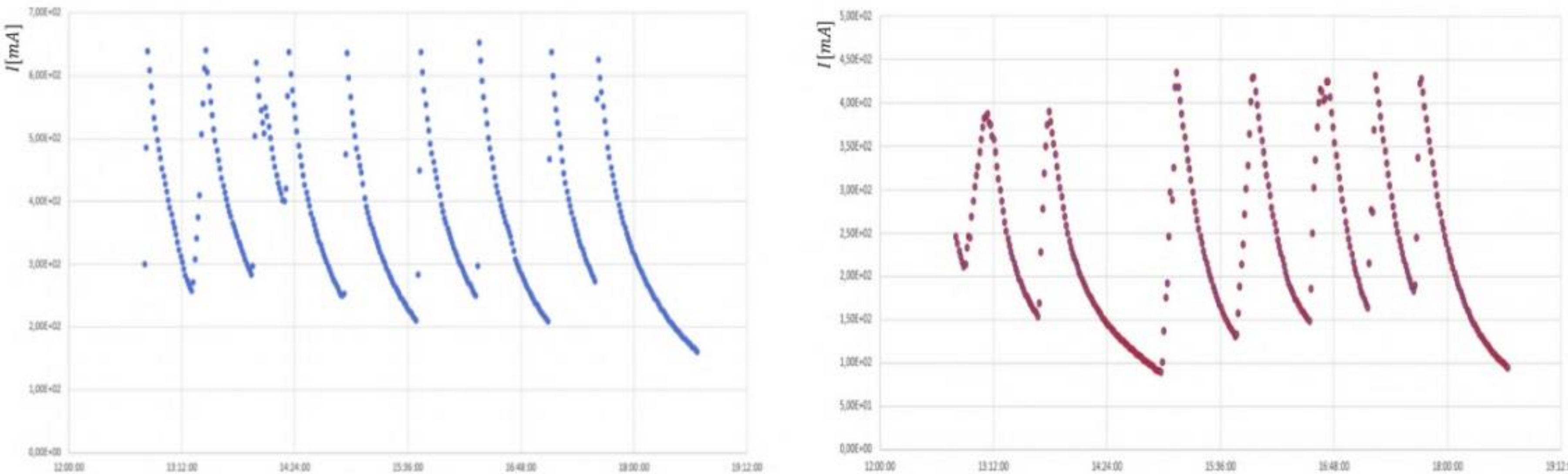


Figure 6.3: Electron beam current (blue) and positron beam current (red) in DAΦNE during the data taking.

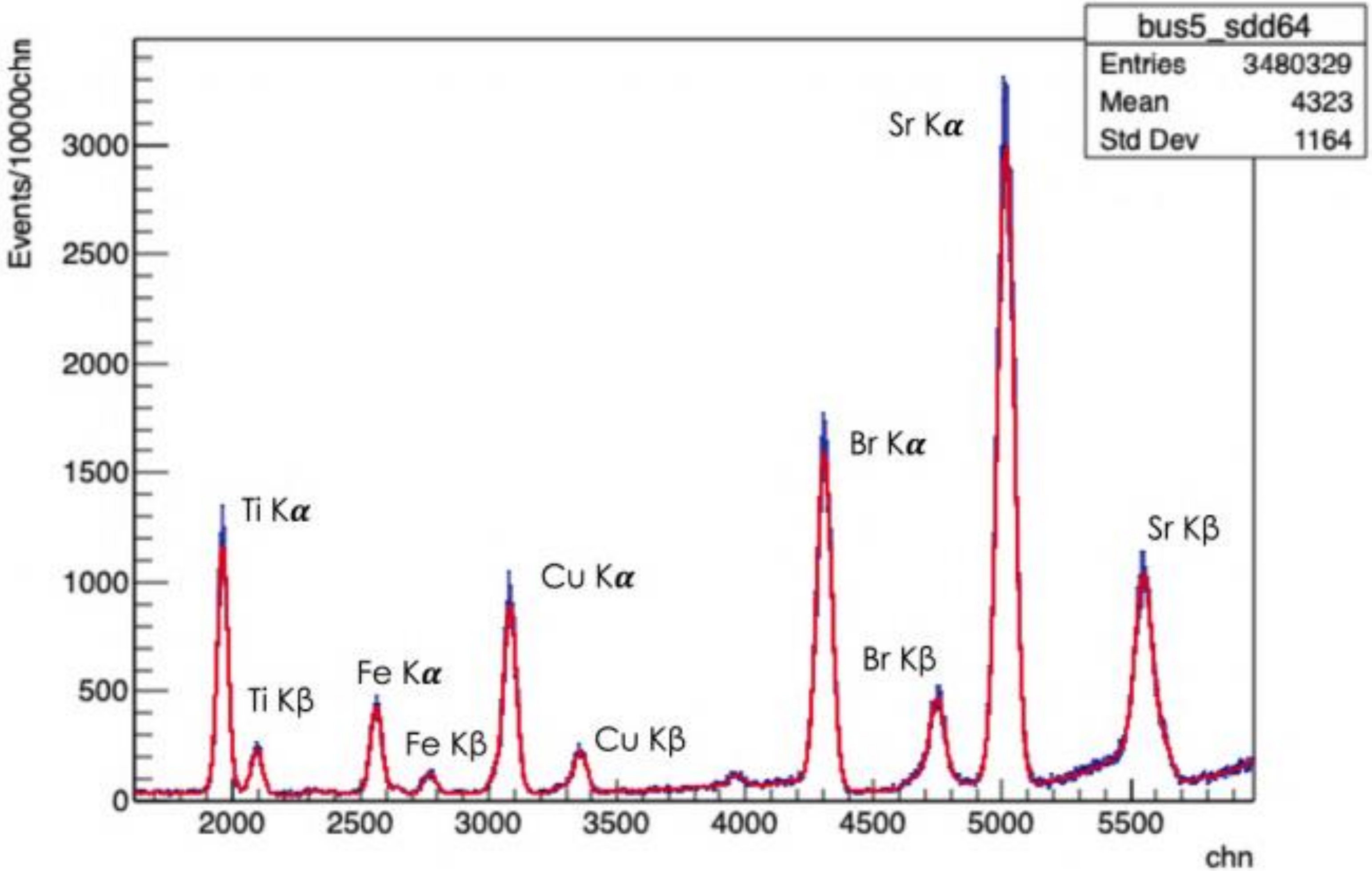


Figure 6.4: Silicon Drift Detector energy spectrum obtained with SIDDHARTINO in DAΦNE.

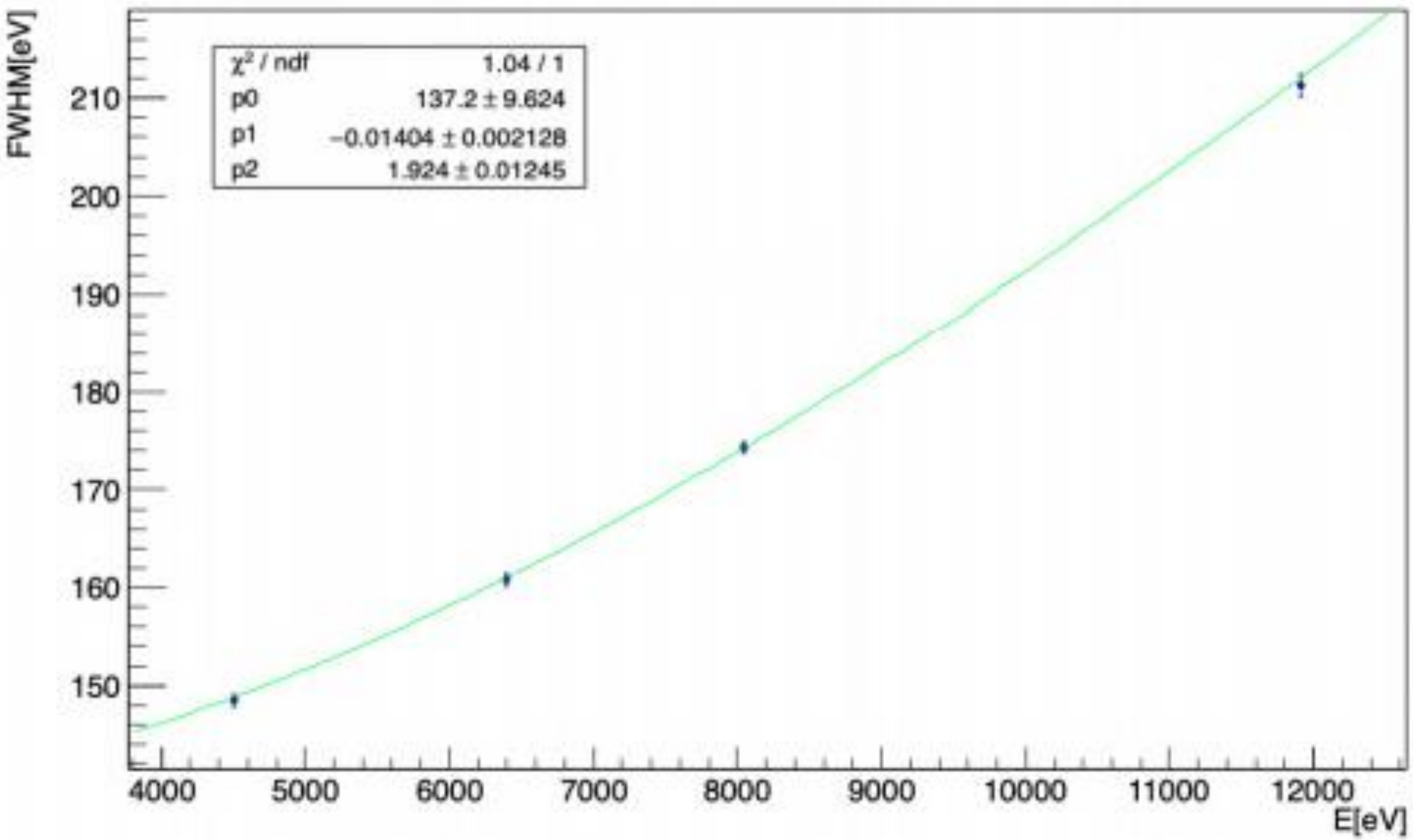


Figure 5.5: Energy resolution of an SDDs in function of the energy.

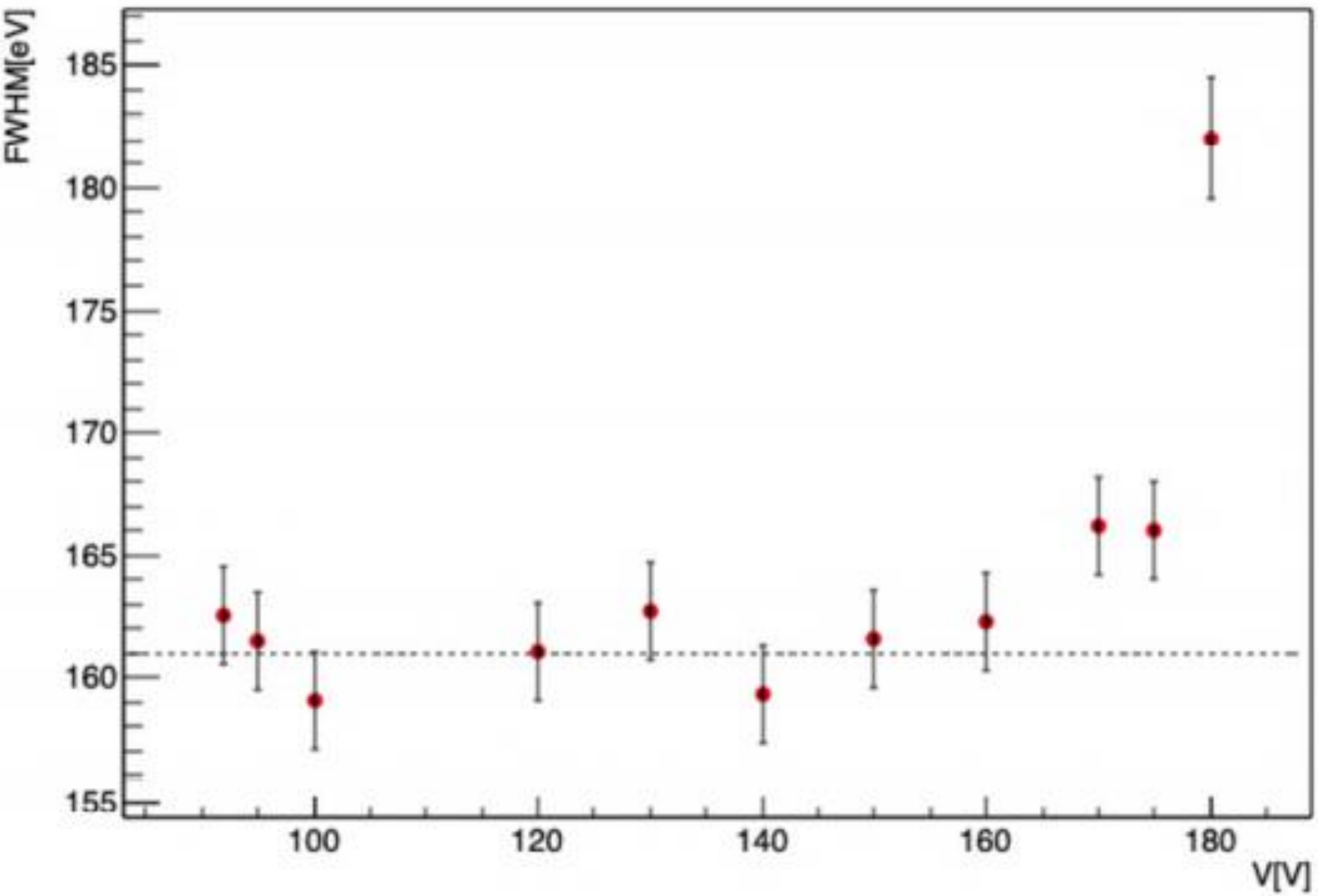
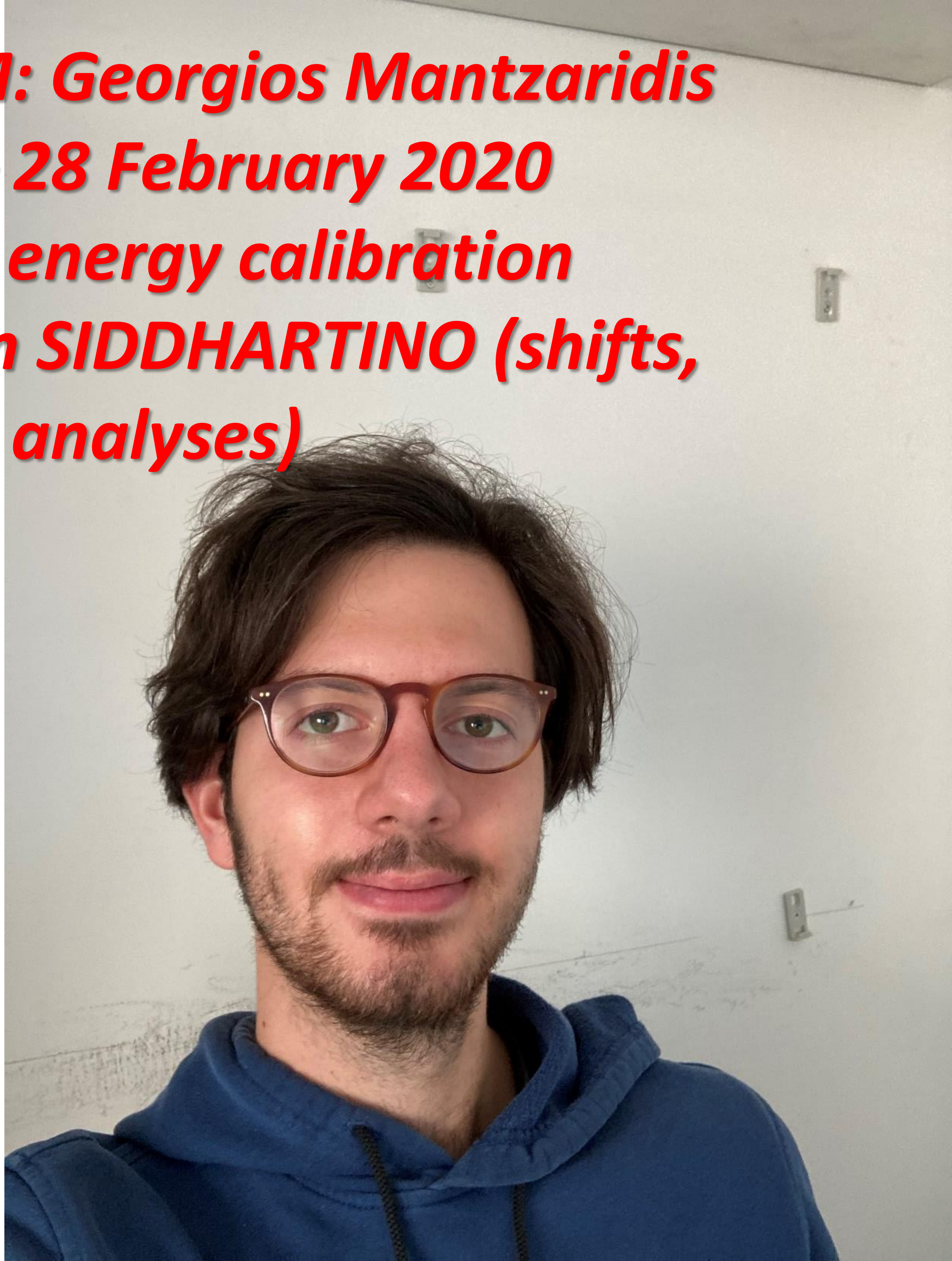


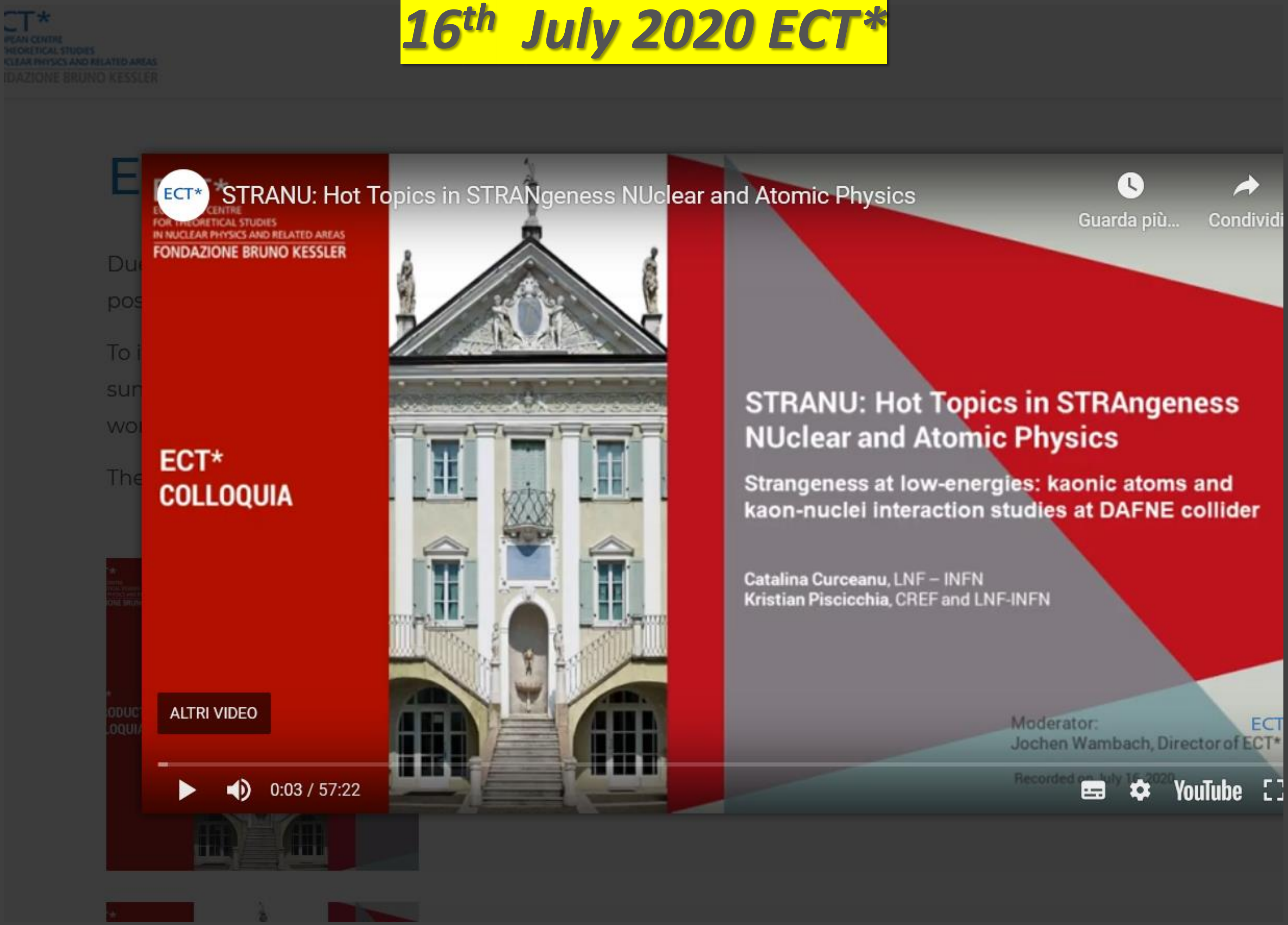
Figure 5.9: Energy resolution of the Ti K_α peak for different drift voltages.

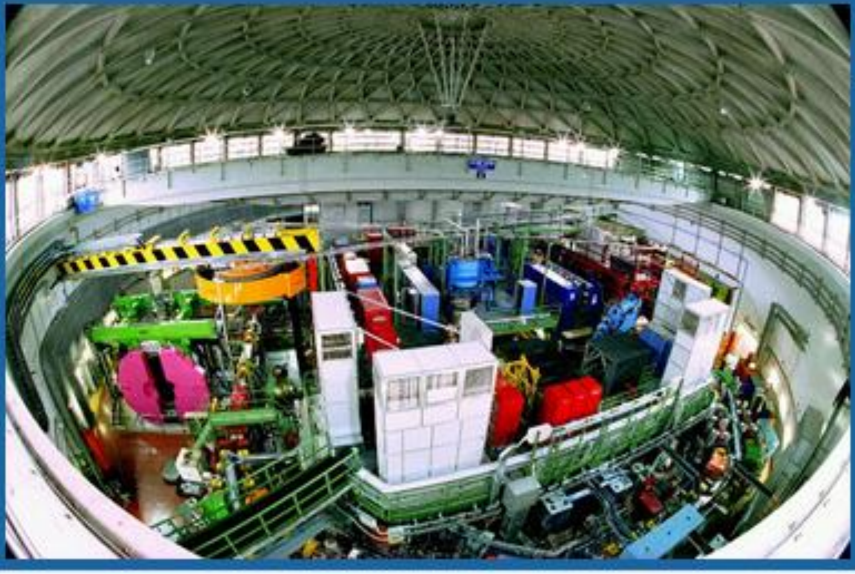
Student from TUM: Georgios Mantzaridis
15 October – 28 February 2020
Work on SDD energy calibration
Will be involved in SIDDHARTINO (shifts, data analyses)

Internships within Europe with Erasmus+



16th July 2020 ECT*





Workshop: Investigating the Universe with exotic atomic and nuclear matter

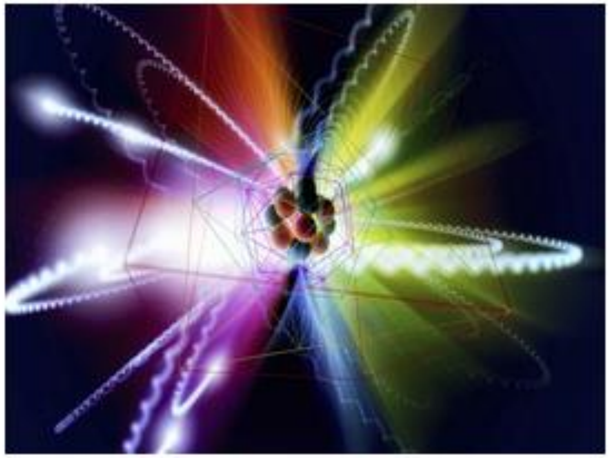
29-30 September 2020

Europe/Rome timezone

Overview
Timetable
Participant List
Registration

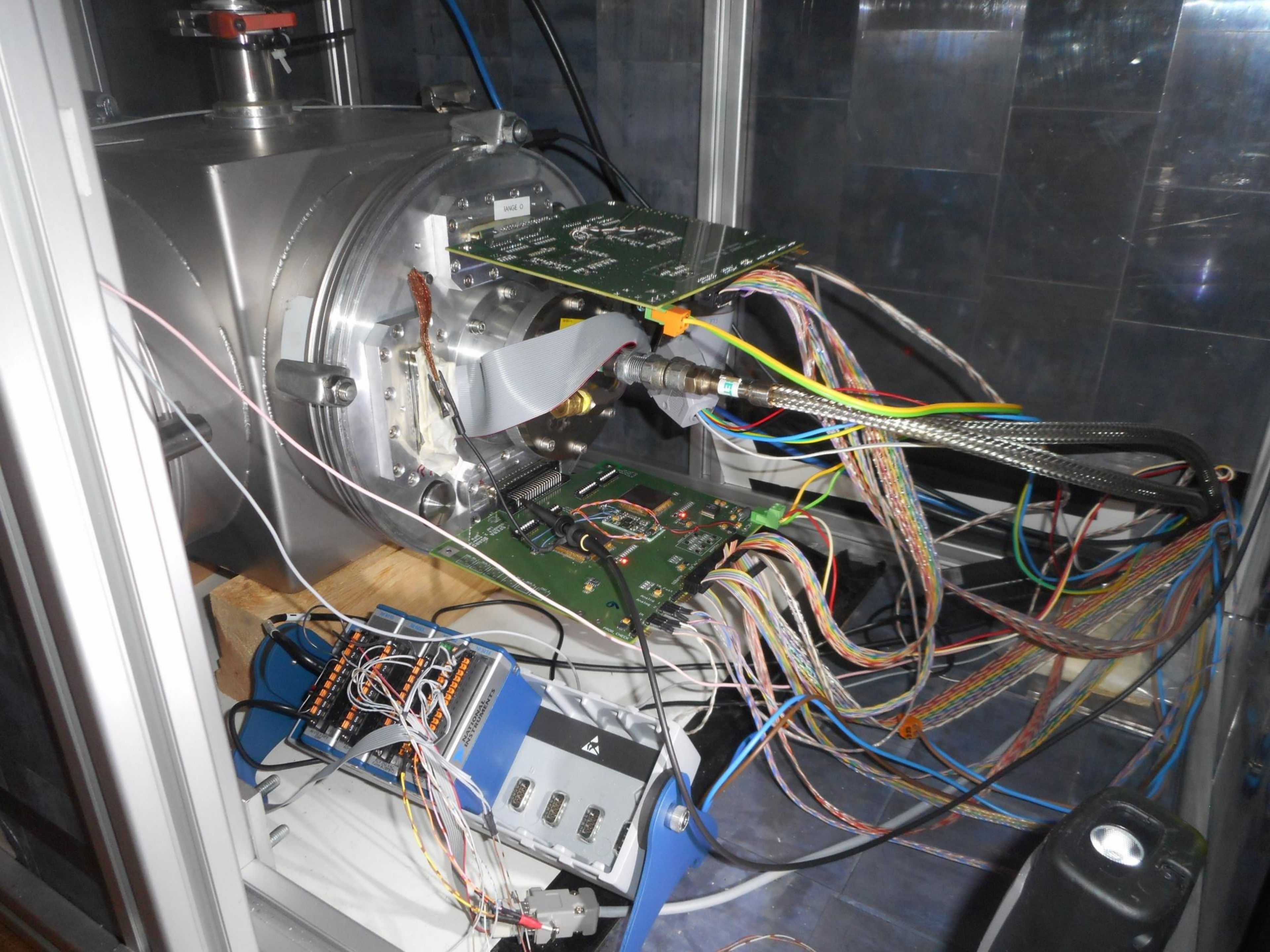
Contact

magdalena.skurzok@lnf...



The main aim of the " Investigating the Universe with exotic atomic and nuclear matter " Workshop is to discuss the theoretical and experimental hot issues related to exotic matter. In particular kaonic atoms

Activity in the laboratory


NATIONAL INSTRUMENTS

SDD characterization and refinement calibration procedure

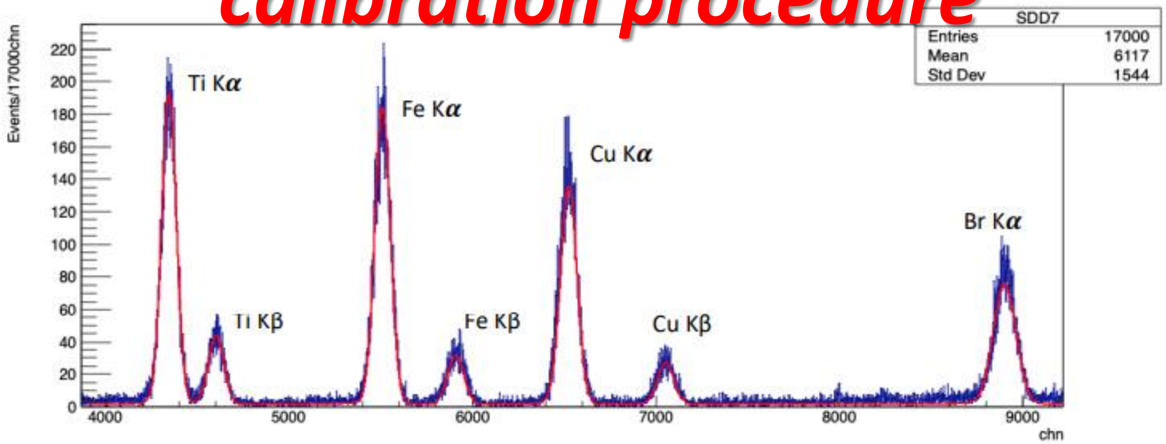


Figure 5.1: Silicon Drift Detector energy spectrum obtained with the laboratory setup.

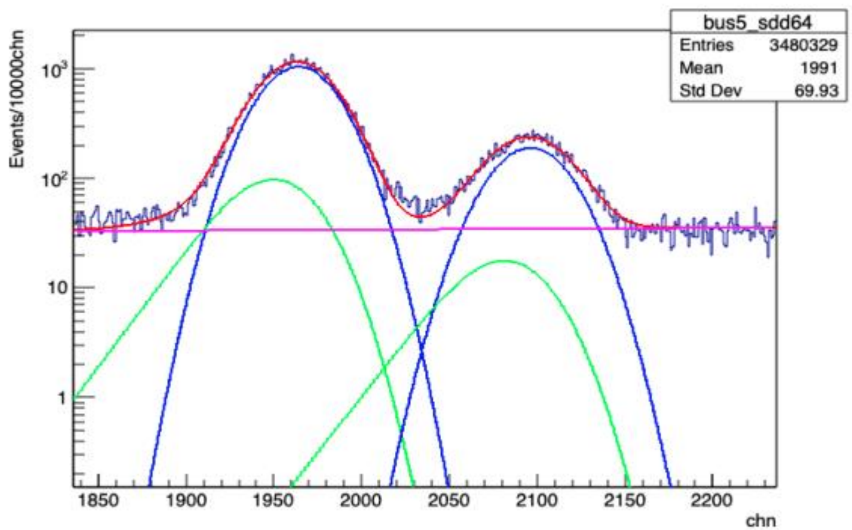
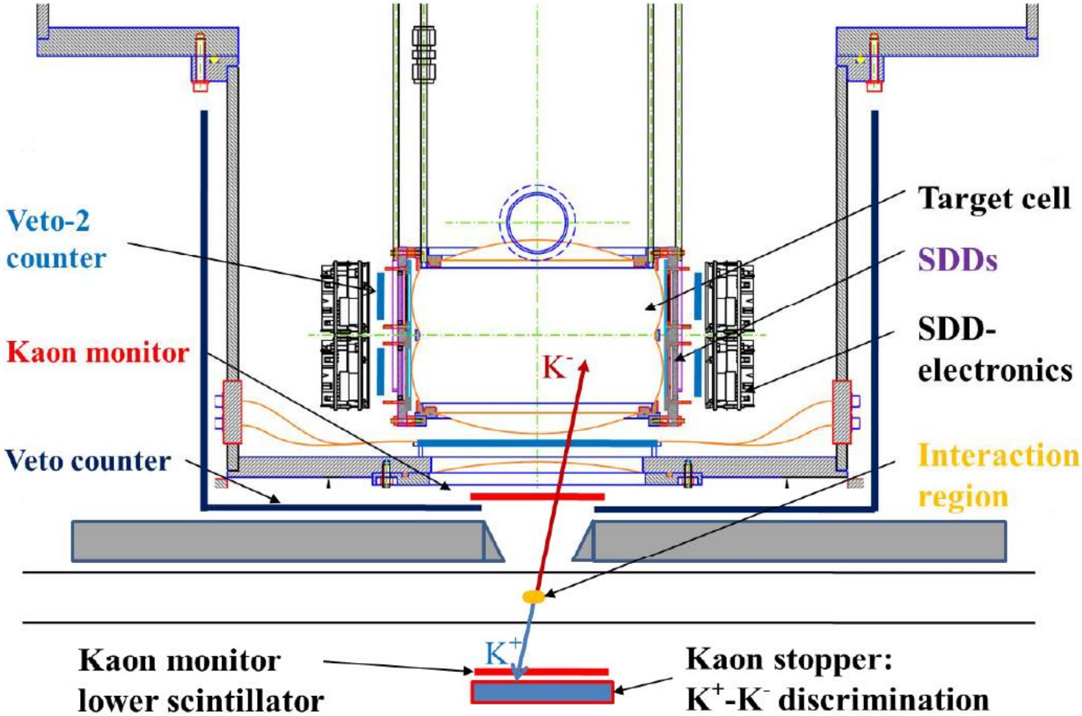


Figure 5.2: Total fit function (red) relatively to the Ti K_α and Ti K_β peaks. The Gauss (blue), Tail (green), and background (violet) contribution to the total fit are also reported.

Silicon Drift Detectors timing response for high precision kaonic atoms spectroscopy

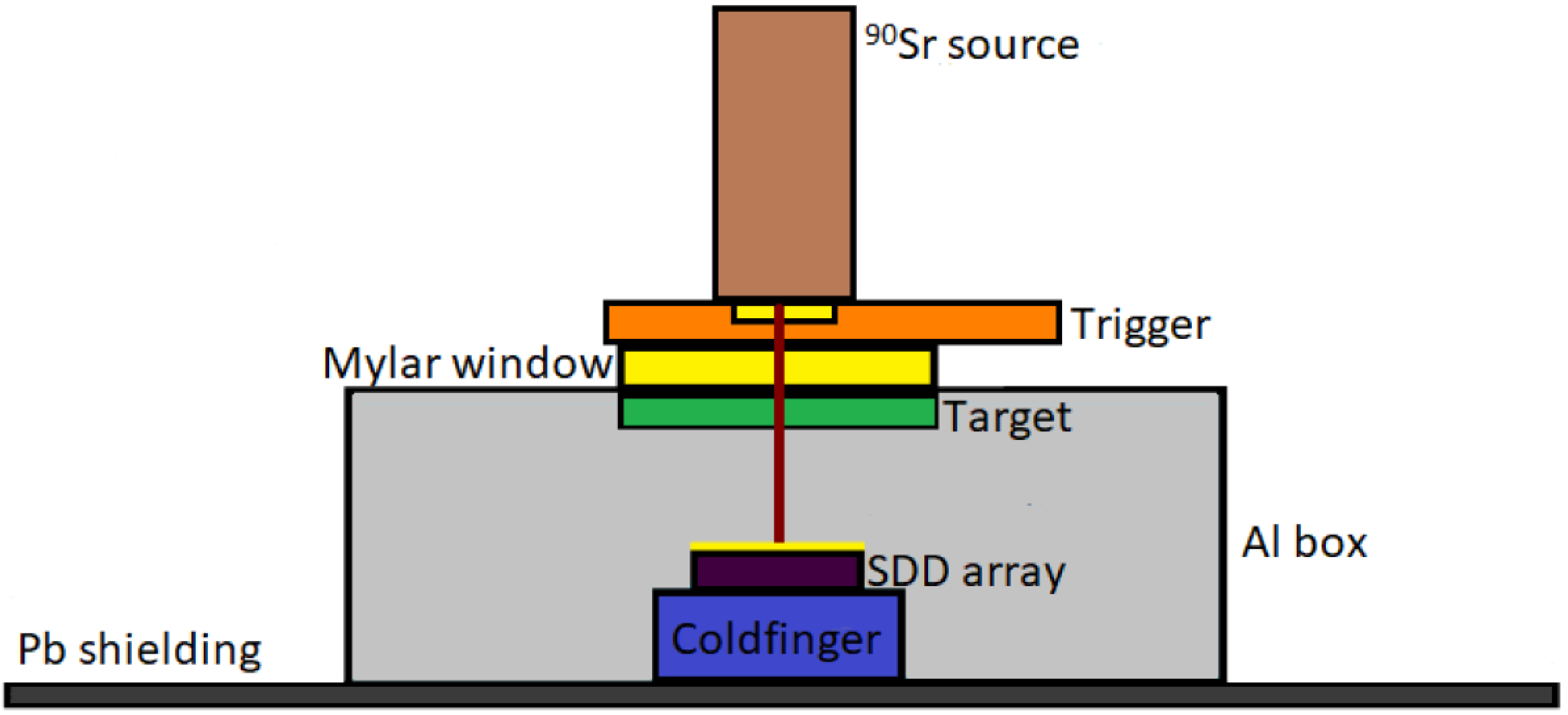
Paper in preparation



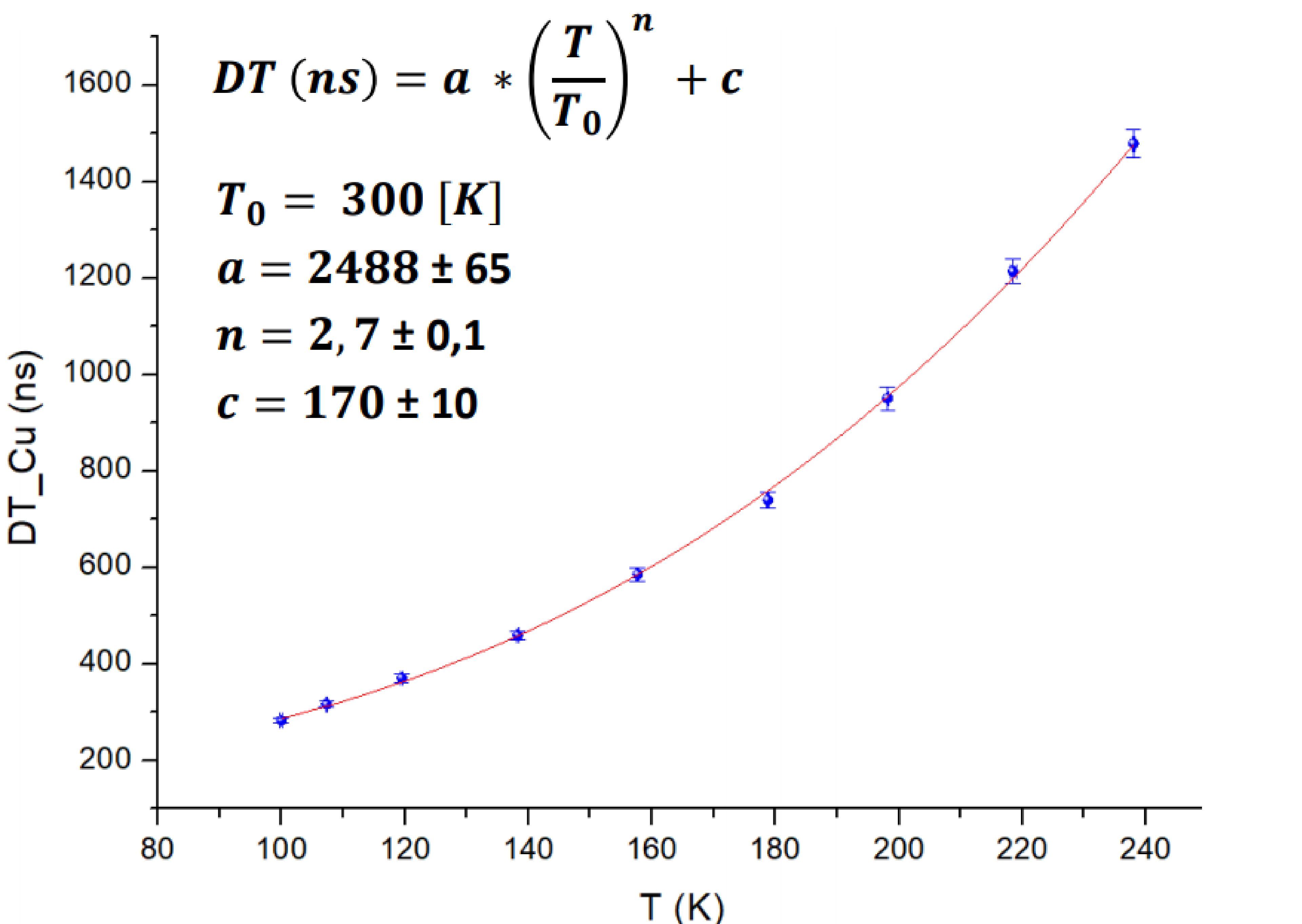
	signal	Hadronic BG	Machine BG	s/n	K_α events	significance
SIDDHARTA	1.00	1.00	1.00	1:40 *		
IP - target	1.38	1.33		1:11	6075	14
3% LHD	1.64	1.08				
geometry	1.25	0.56	0.25			
Trigger 1	0.71	0.48		1:7.6	4320	
Trigger 2	0.79	0.59	0.33	1:5.7	3415	
Trigger 3	0.98	0.73		1:4.2	3350	
K+	0.70	0.78		1:3.3	2345	
drift time 400ns			0.49	1:3.0	2345	20
total	**1.09**	**0.12**	**0.04**			**20**

Table 1: The main results of the Geant 4 MC simulation for the SIDDHARTA/K⁻d

Lab setup



^{90}Sr source
Trigger
Mylar window
Target
Al box
SDD array
Coldfinger
Pb shielding



$DT\ (ns) = a * \left(\frac{T}{T_0}\right)^n + c$
$T_0 = 300\ [K]$
$a = 2488 \pm 65$
$n = 2,7 \pm 0,1$
$c = 170 \pm 10$
DT_Cu (ns)
T (K)
1600
1400
1200
1000
800
600
400
200
80
100
120
140
160
180
200
220
240

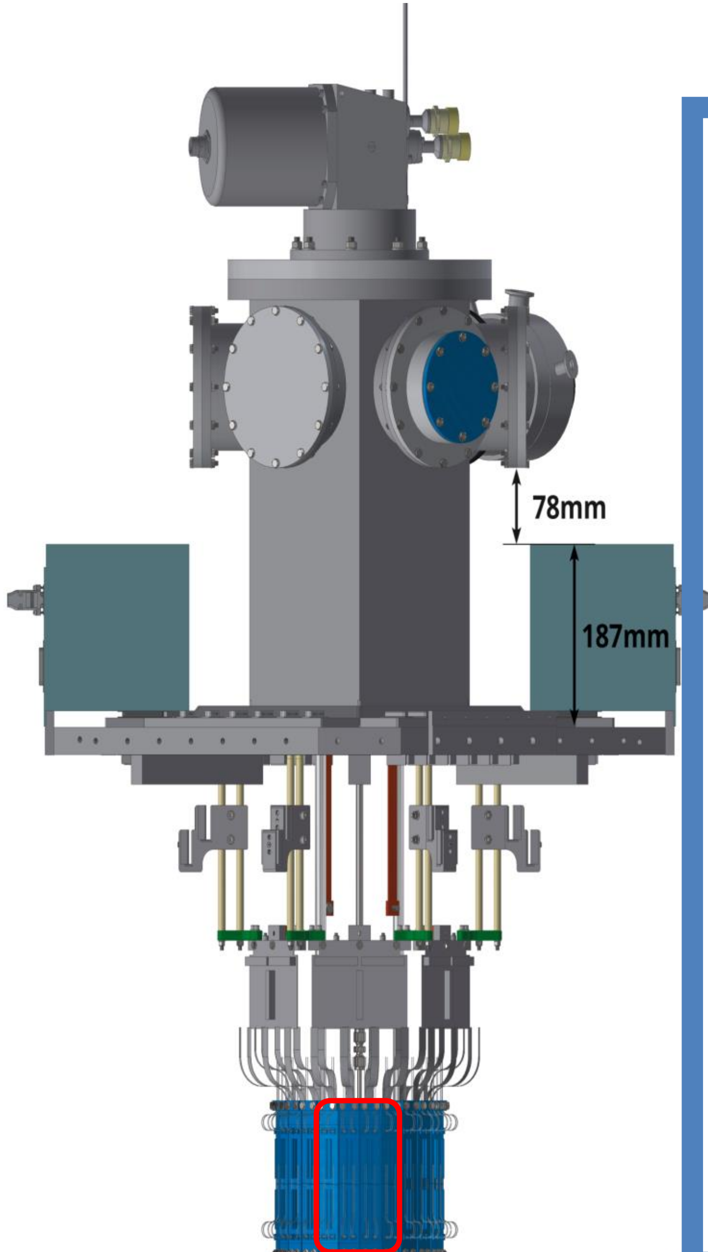
SIDDHARTA-2 - present status

We are presently in Phase 1 with SIDDHARTINO:

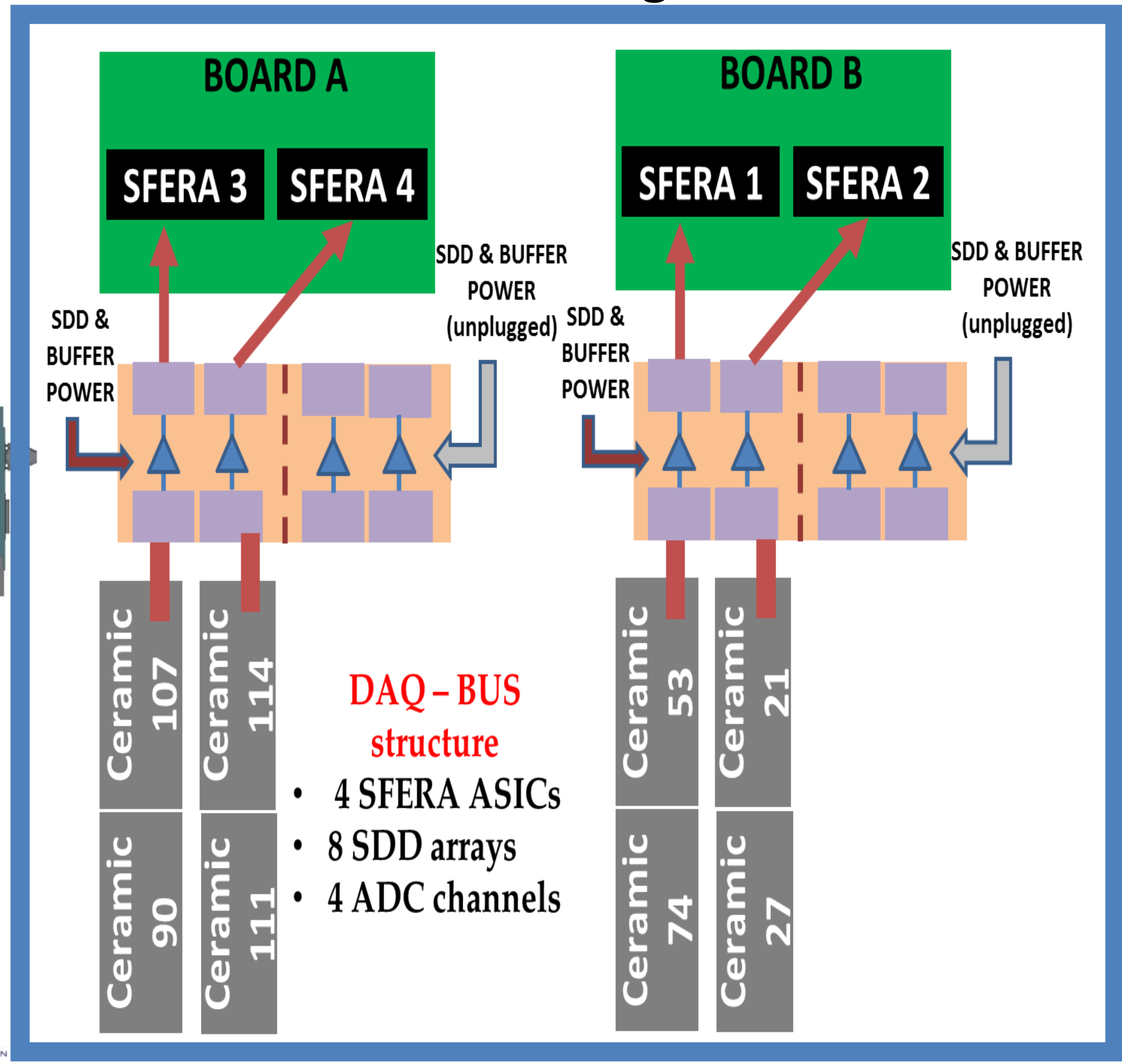
during the commissioning of DAΦNE
optimization with the SIDDHARTINO setup
for the K-^{4}He measurement
(with 8 SDD arrays)

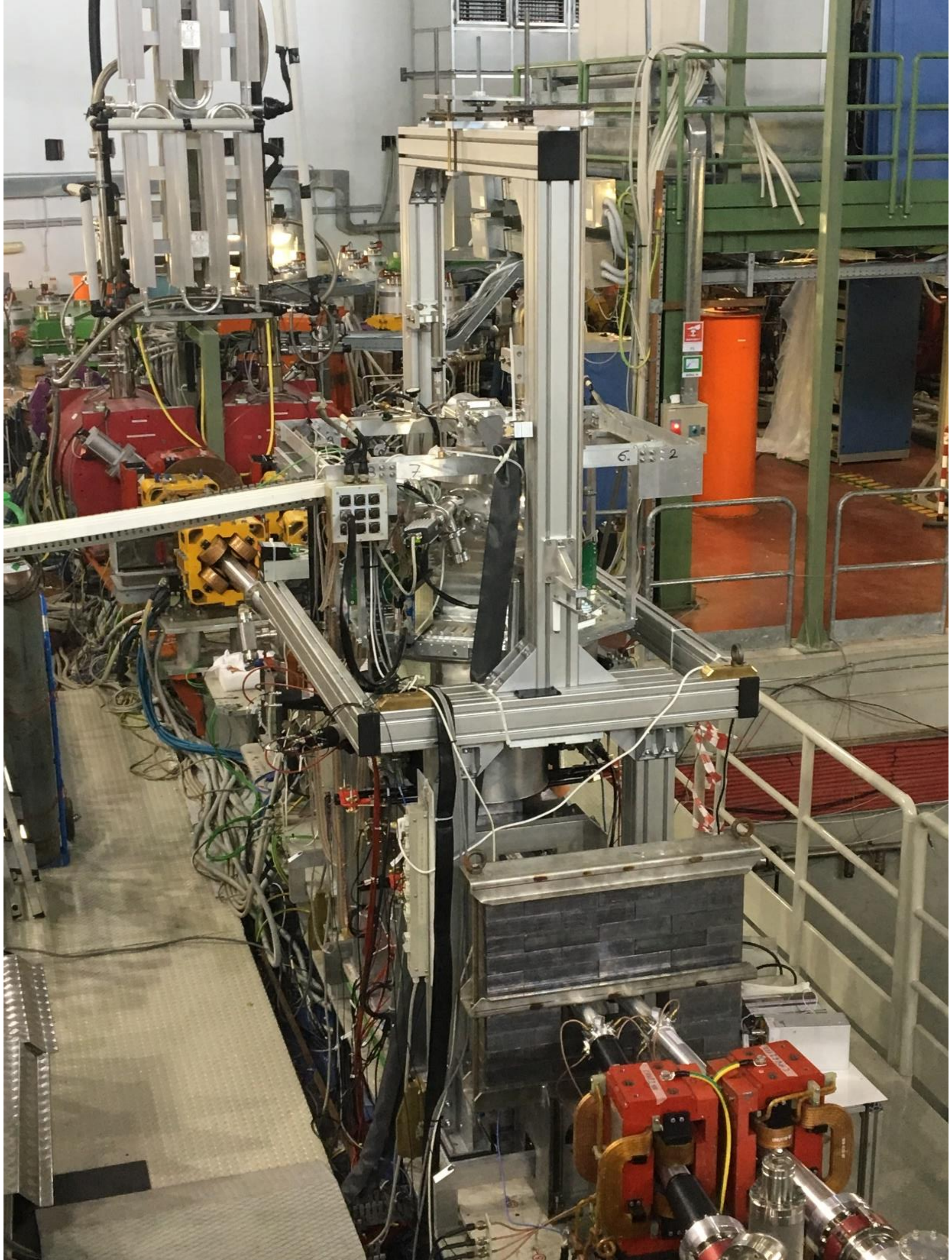
(Phase 2: Kd measurement)

SIDDHARTINO = SIDDHARTA-2 with 8 SDD's

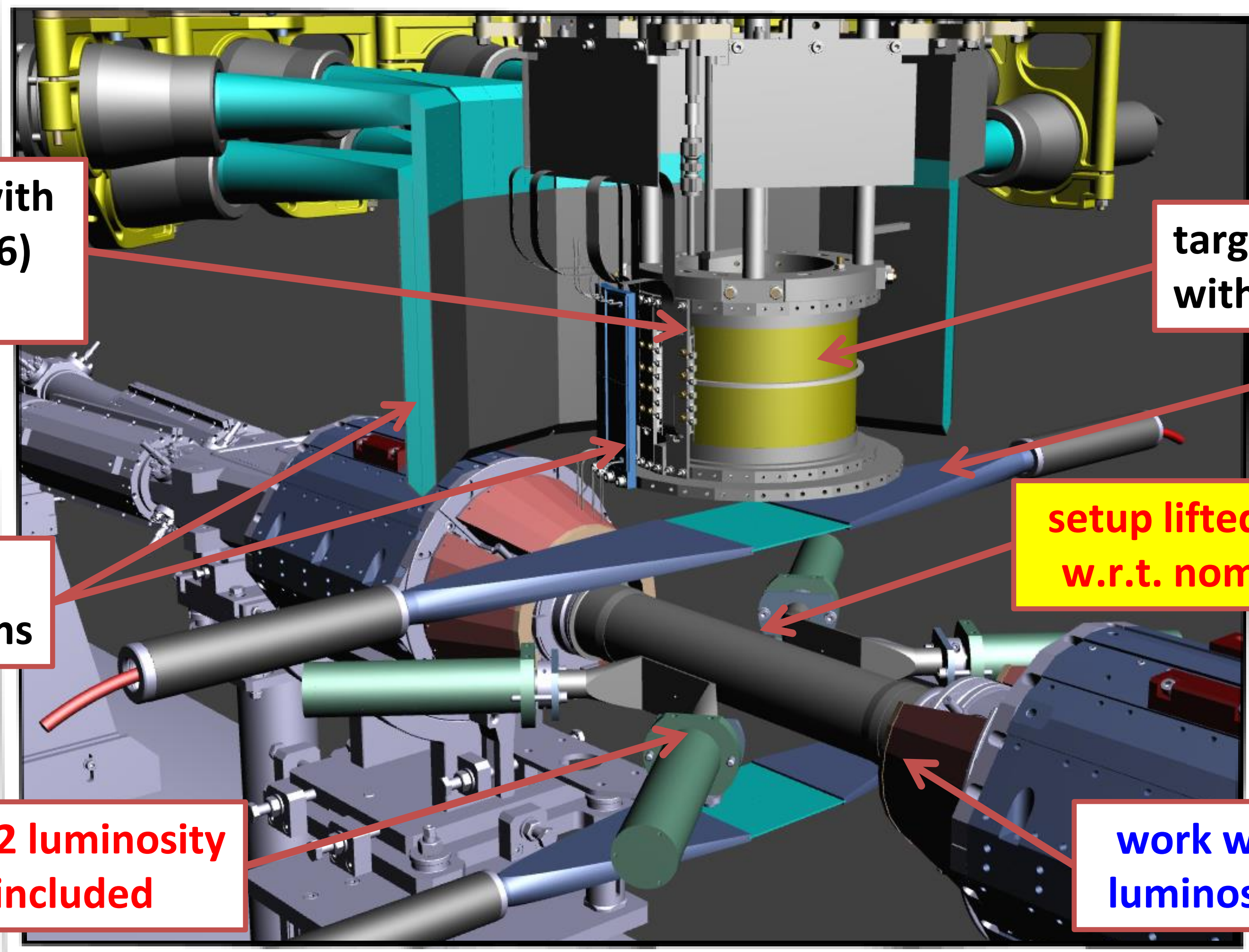


DAQ BUS configuration





SIDDHARTINO apparatus and constraints



Aim: confirm when DAΦNE background conditions are similar to those in SIDDHARTA 2009

Findings and Recommendations
SCIENTIFIC COMMITTEE 07/05/2020

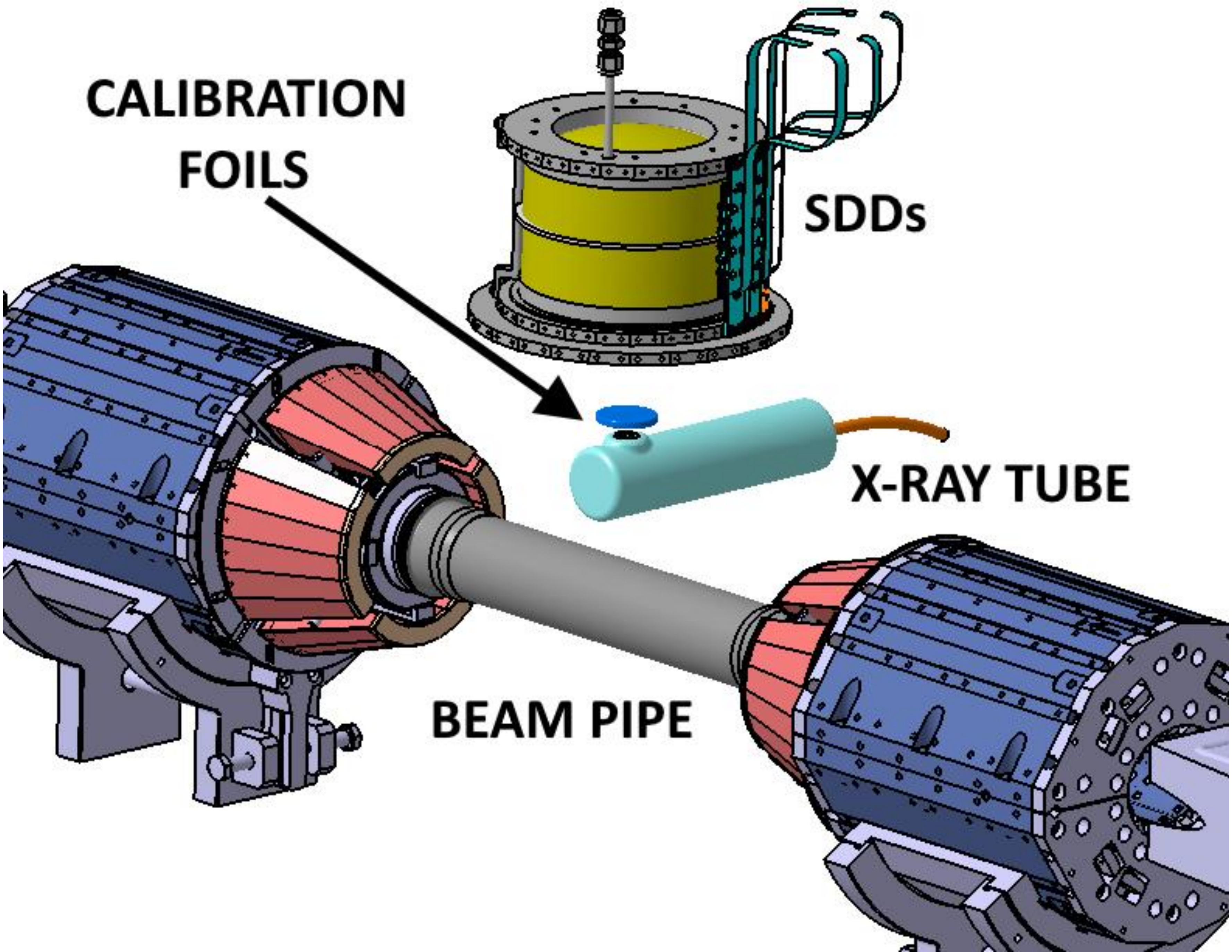
The new scenario foresees to start delivering beam for SIDDHARTINO by mid-October 2020 and let it run towards the end of the year, with the goal of optimizing the conditions to meet a S/B of at least 100/1 in the K-4He test measurement. During this commissioning period, the team plans to run parasitic tests with HPGe (High Purity Germanium detectors), which aim at contributing to a more precise measurement of the kaon mass -> Early 2021

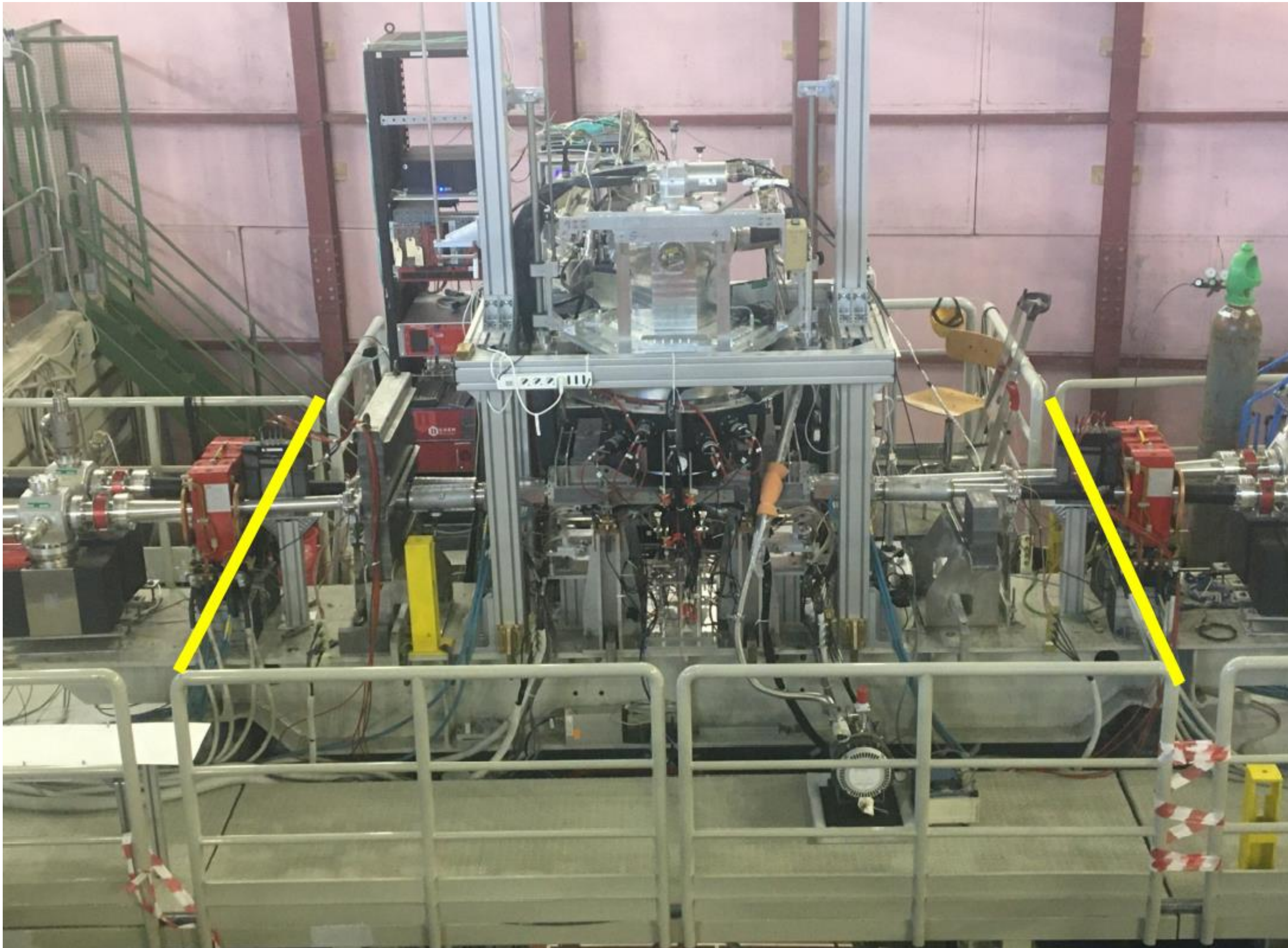
The installation of the full complement of 48 SDD arrays for Phase 2 (SIDDHARTA-2) targeting kaonic deuterium is foreseen to take place in early 2021, followed by data taking up to an estimated integrated luminosity of 800 pb-1 -> Spring 2021?

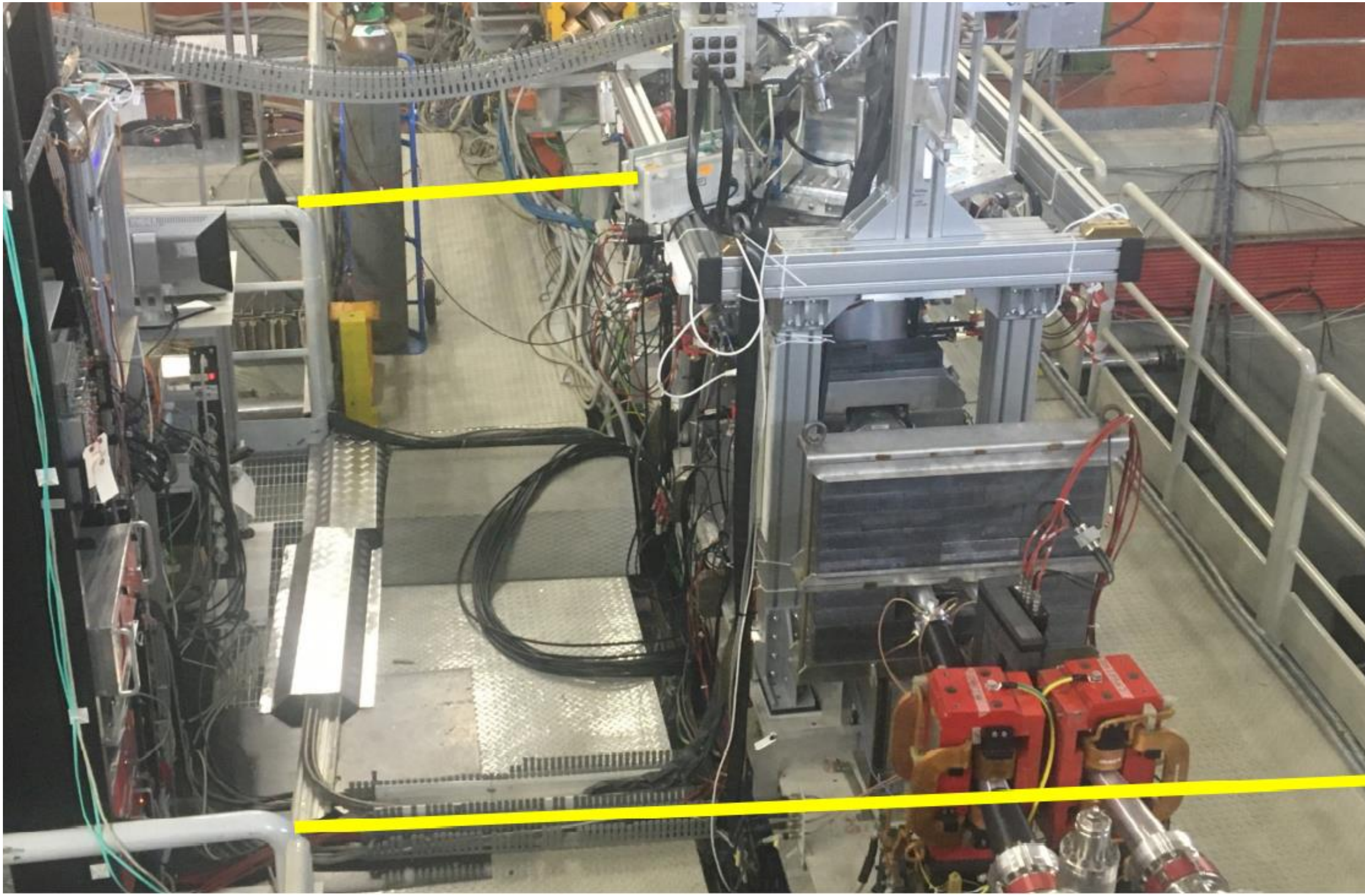
SIDDHARTINO-related activities:

- ***SIDDHARTINO area preparation for X-Ray tube use (no DAFNE interlock) -> continue work with SIDDHARTINO (no beam)***

- ***Optimization/refinement Mcarlo GEANT4 Simulation***


CALIBRATION
FOILS
SDDs
X-RAY TUBE
BEAM PIPE

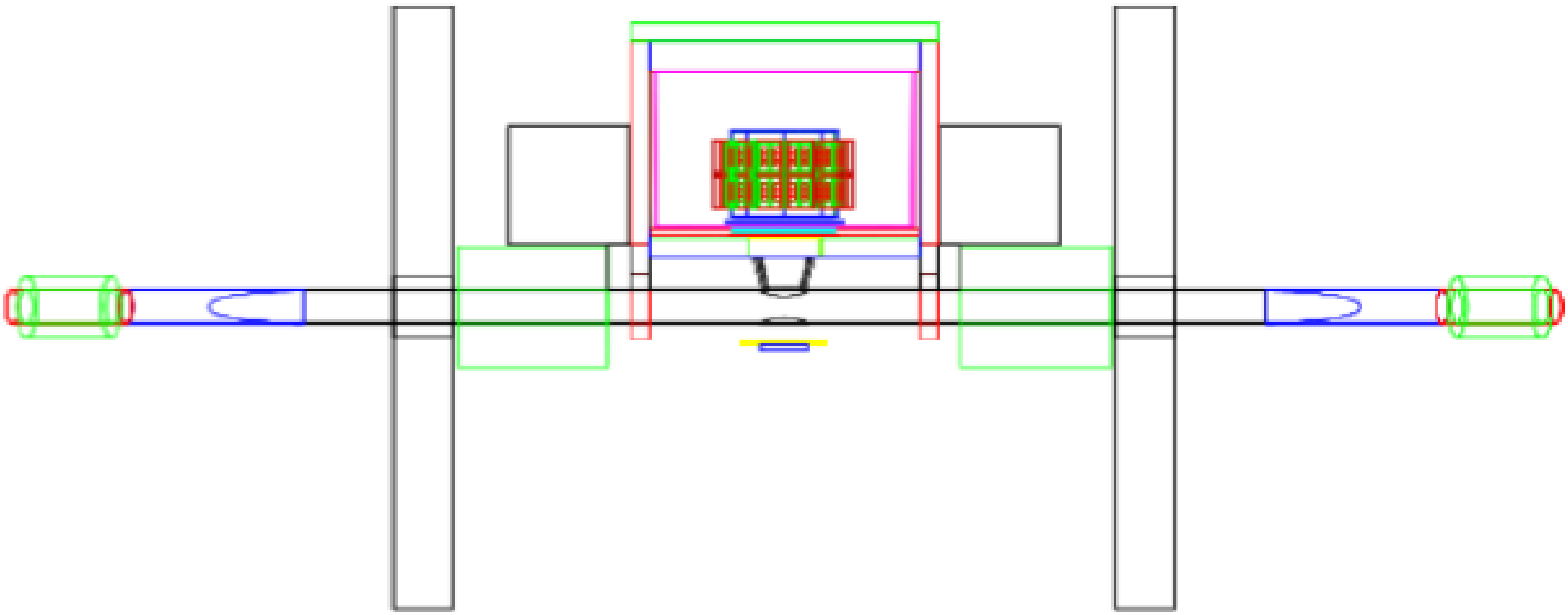


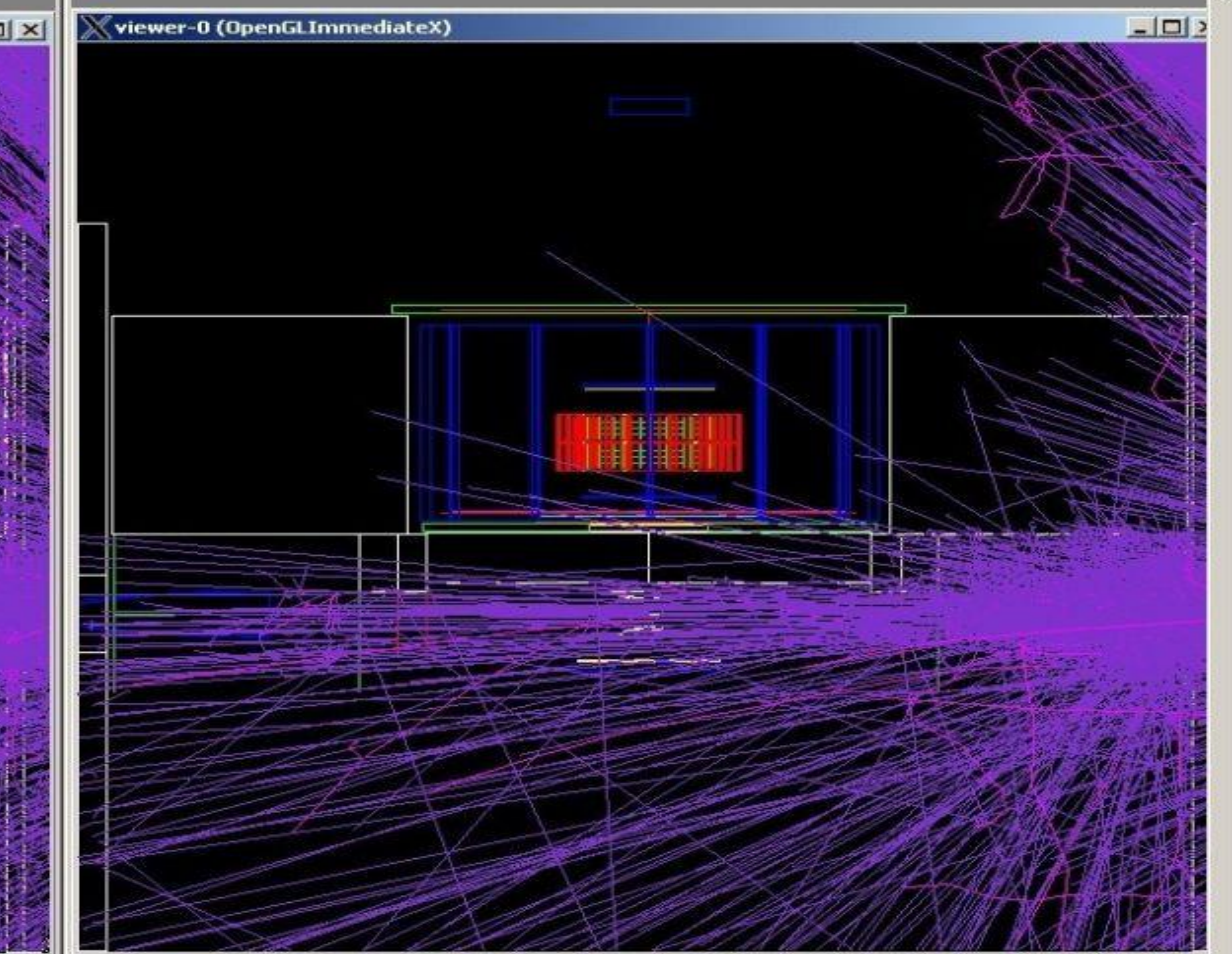



VIETATO
L'ACCESSO


13th Nov. 2020

SIDDHARTA 2 (GEANT4 MC, M. Iliescu , C. Berucci, H. Shi)



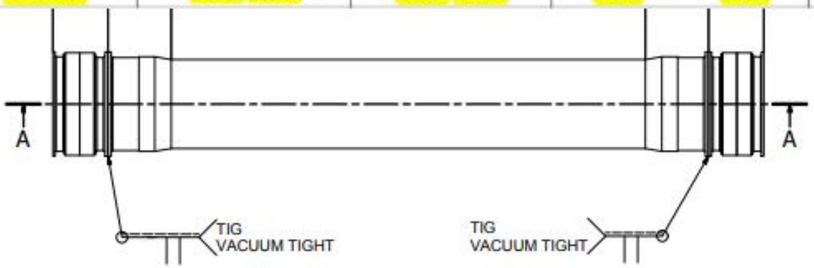

viewer-0 (OpenGLImmediateX)

SIDDHARTA-2 G4 MC

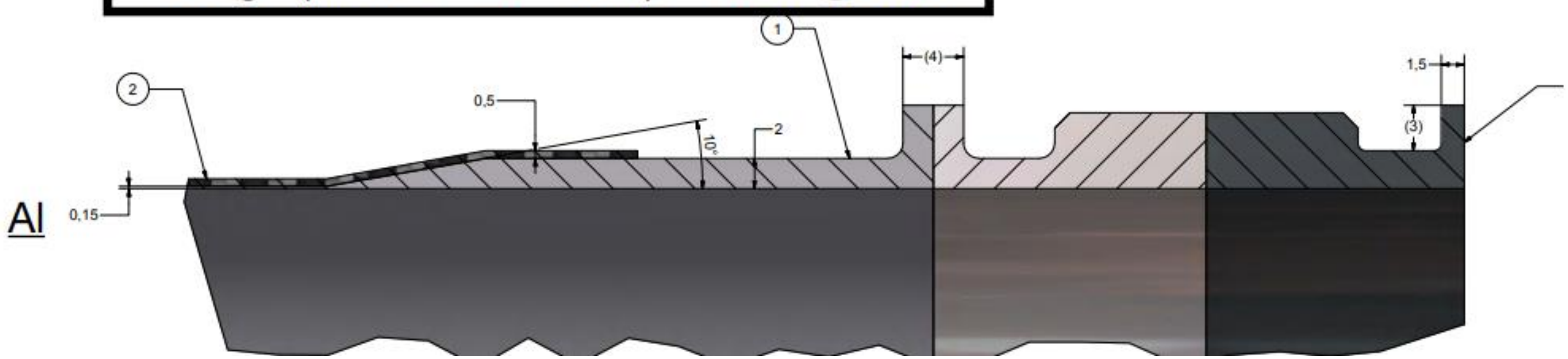
Beam pipe

1. Physica property table of Torayca® cloth

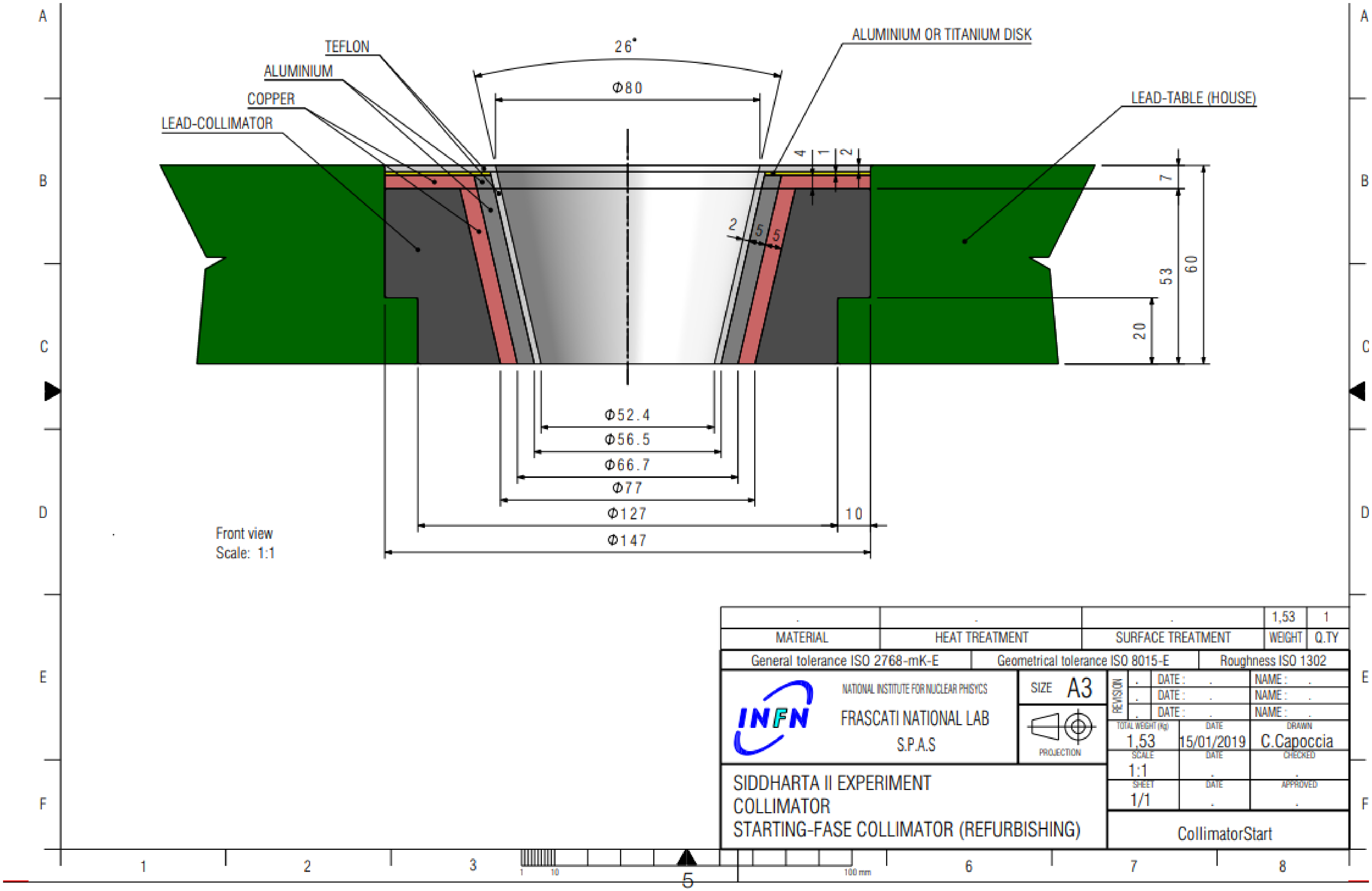
Product No.	Type	Warp	Weft	Warp density (pcs/25 mm)	Weft density (pcs/25 mm)	Weave structure	Width (cm)	Thickness (mm)	Textile weight (g/m²)
CO6142	Carbon	T300 1000	T300-1000	22.5	22.5	Plain	100	0.15	119
CO6151B	Carbon	T300B-1000	T300B-1000	17.4	17.4	Plain	100	0.11	92
CO6343	Carbon	T300 3000	T300-3000	12.5	12.5	Plain	100	0.25	198



2. 500 um Carbon fiber: Torayca CO6343
65 % carbon, 35 % Resin;
density:
198 g / (1 m^2 * 0.25 mm) = **0.792 g/ccm.**



Shielding table

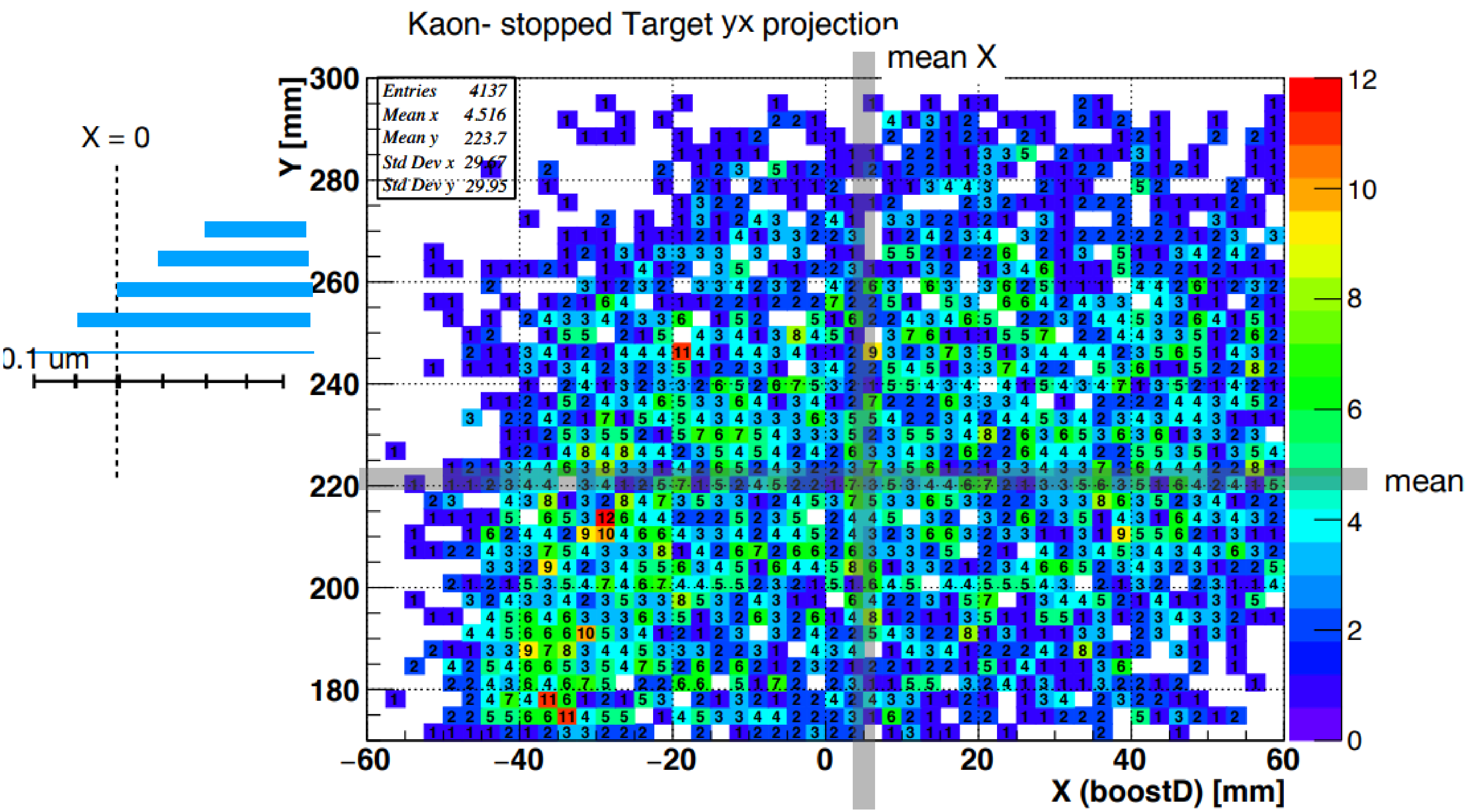


H2 gaseous target run

stopped kaon- in Target

500 k phi 0.02 LHD
0.1 um deg base ***5*** layers

4137 / 500 k = **<u>0.82 %</u>**
target stopping efficiency



SIDDHARTA-2 strategy and requests

Phase 1
SIDDHARTINO

Run with SIDDHARTINO for: optimization of run conditions (backg) verified with the measurement of K-^{4}He (8 SDD arrays)

Early 2021 (-> till end March ?)

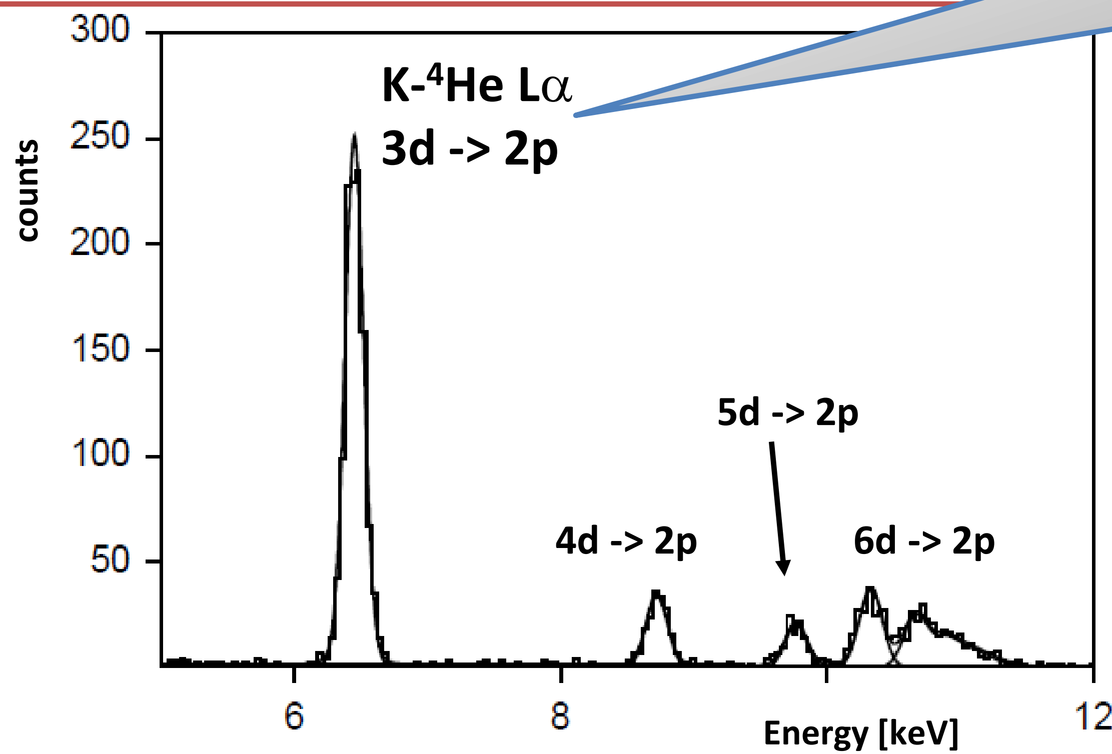
(S/B on K-^{4}He better than 100/1)

Plan – Phase1:

1) *Work with SIDDHARTINO inside DAFNE: optimization SDD, trigger, DAQ, calib….*
2) *Refine optimization of luminosity detector and cross check with DAFNE luminometer*
3) *Background reduction and optimization together with DAFNE for kaonic atoms measurements*
4) *Kaonic Helium measurement with SIDDHARTINO -> background w.r.t. SIDDHARTA and SIDDHARTA-2 for Kd goal*
   depending on DAFNE's plans (early 2021)
5) *HPGe test run in parallel with SIDDHARTINO*

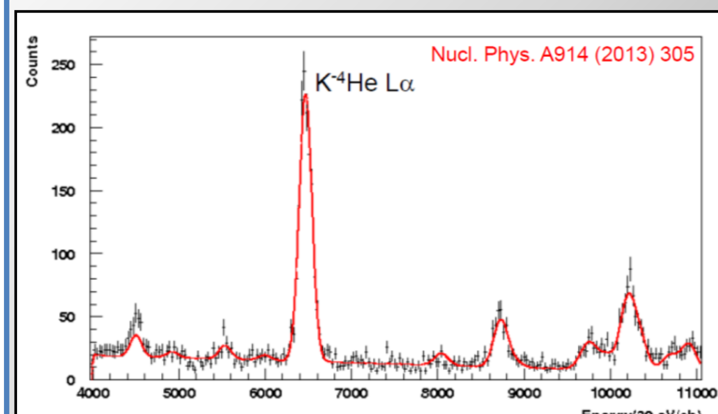
SIDDHARTINO – K-^{4}He test measurement

SIDDHARTINO expected spectrum for ~ 50 pb^{-1}
(one week of data taking in SIDDHARTA-like conditions)



About 1000 events in La peak, S/B > 100/1
(ideally should be 300/1)
Position precision :
6.452 +- 0.002 (stat) keV

SIDDHARTA measurement



S/B was 10/1 for the K-^{4}He measurement with ~ 30 pb^{-1}

SIDDHARTA-2 strategy and requests

Phase 2
SIDDHARTA-2

Setup with all the SDDs (48 SDD arrays) all 2021 (22?) and the *kaonic deuterium measurement* for a run of 800 pb^{-1}

Action plan for Kd measurement:

- **First run with SIDDHARTA-2 setup as planned (about 300 pb^{-1} integrated)**
- **Second run with optimized shielding, readout electronics and other necessary optimizations; (for other 500 pb^{-1} integrated)**

Test runs for other kaonic atoms measurements (HPGE…)

Phase-2: SIDDHARTA-2 K-d measurement

Kaonic deuterium run in (all)

2021

for S/B as 1/3:

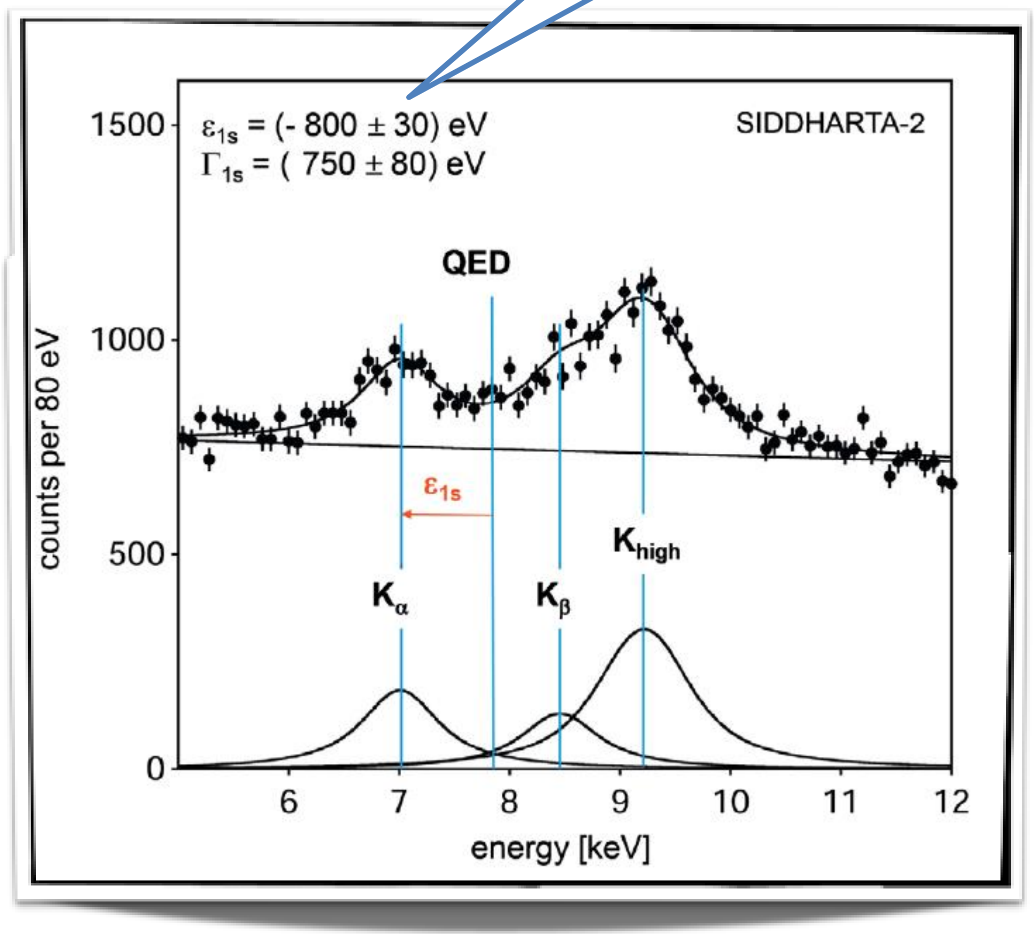
for an integrated luminosity of 800 pb^{-1}

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) !

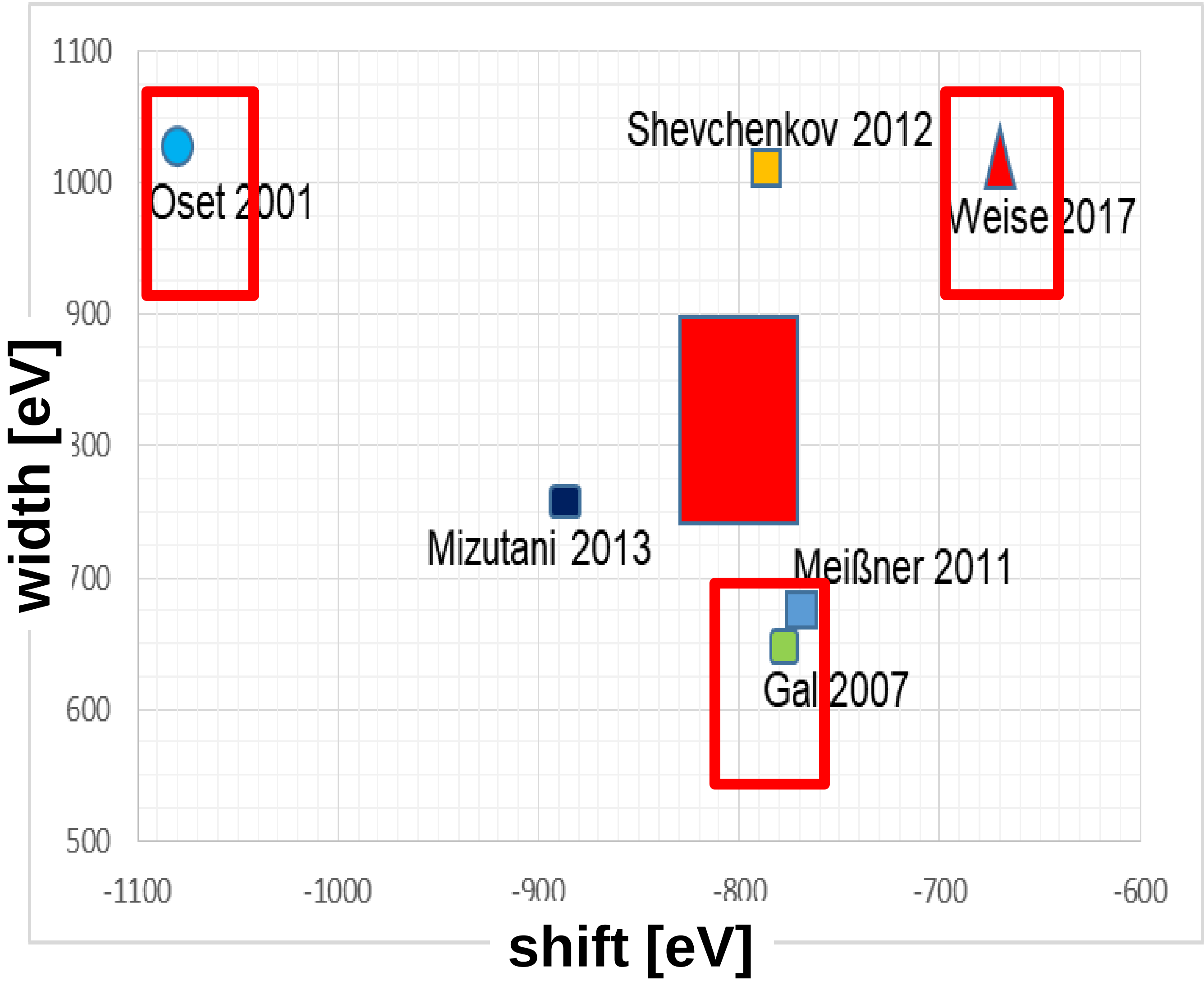
Includes:

- **veto-2 second layer**
- **Optimizations SDD, veto1**
- **Shielding, trigger….**

achievable precision



SIDDHARTA-2 FIRST kaonic deuterium meas.

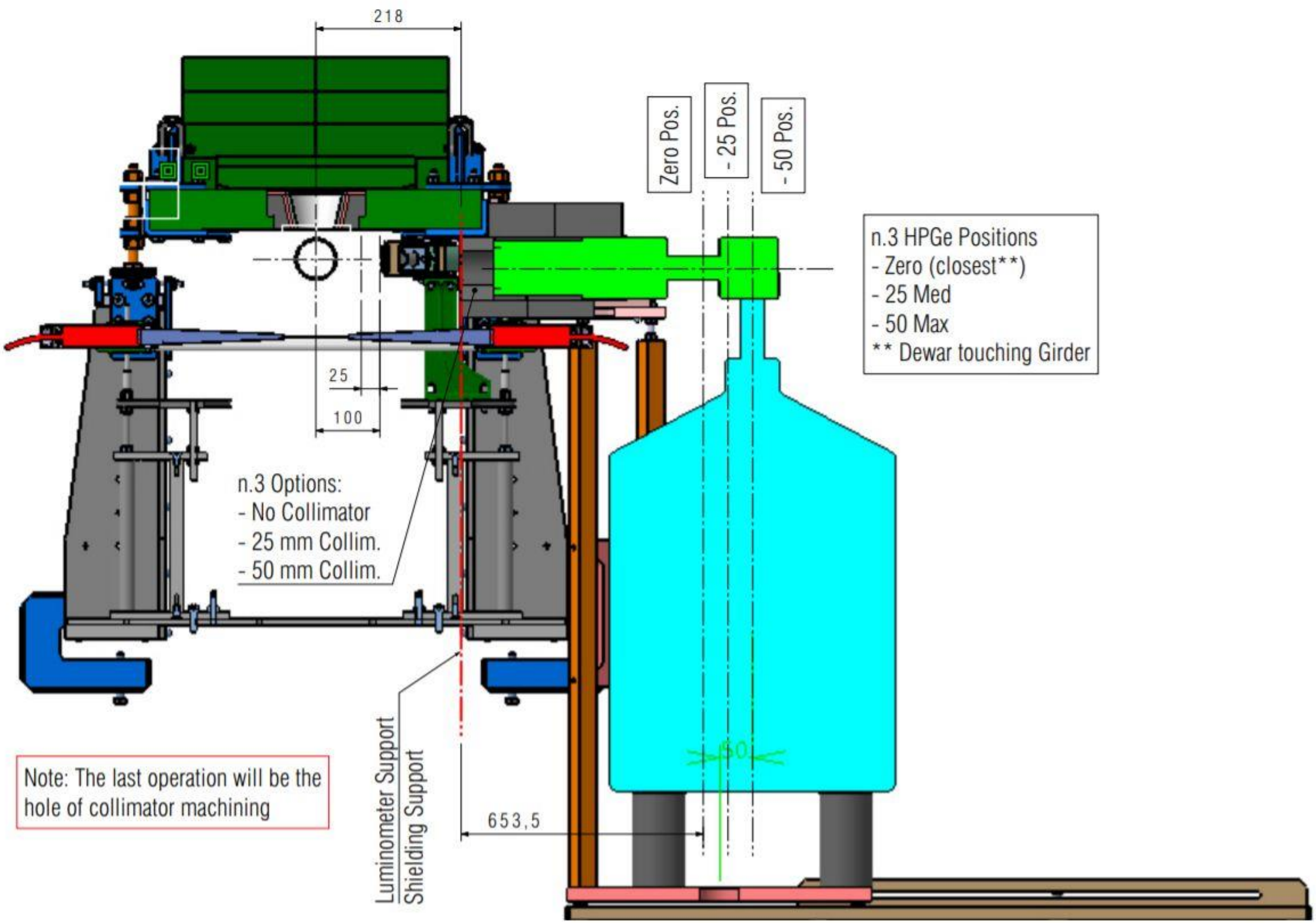


Content

1) Scientific optput: articles since last SC (since May 2020)
2) Our young ones: master Student graduated; Erasmus+ training student TUM (Munich)
3) ECT* Talk and Organization of a dedicated Workshop
4) Activity in the lab -> SDDs characterization
5) Activity inside DAFNE – towards SIDDHARTINO
6) MCarlo simulation optimization
7) Strategy revisited: plans
8) Activities towards post SIDDHARTA-2: HPGe; 1 mm SDDs & VOXES extreme precision spectrometer

Heavy kaonic atoms
(kaon mass, potential and chiral QCD)

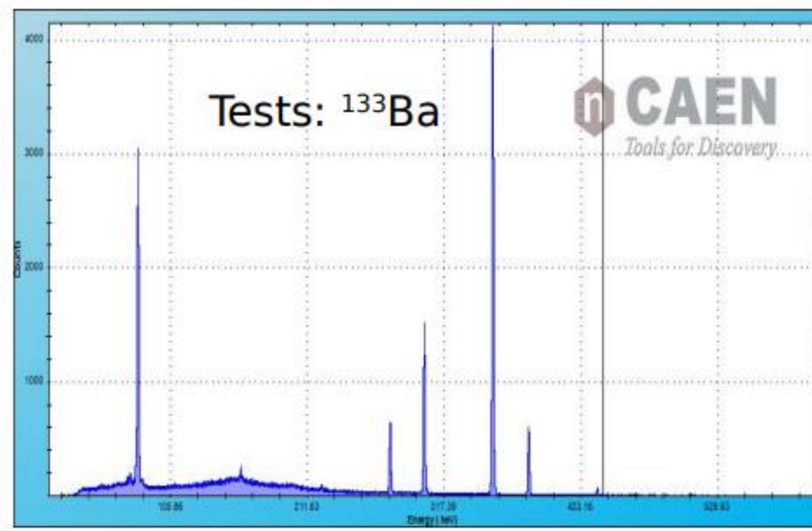
HPGe: kaonic lead for kaon mass – ready Univ. Zagreb



HPGe test run during SIDDHARTA-2

Signal from spectroscopy amplifier ~20 µs (shaping time 6 µs), restriction on the rate.

- **Digital Pulse Processing** for Pulse Height Analysis firmware , based on V.T. Jordanov et al. Nucl. Instr. Meth. A 353 (1994) 337
- **Coincidences with luminometer**



Possible rates up to 150 kHz

^{60}Co, ^{133}Ba spectra,
resolutions: 0.870 keV at 81 keV
1.106 keV at 302.9 keV
1.143 keV at 356 keV
1.167 keV at 1330 keV

Detector system ready for measurements!

HPGe test run during SIDDHARTA-2

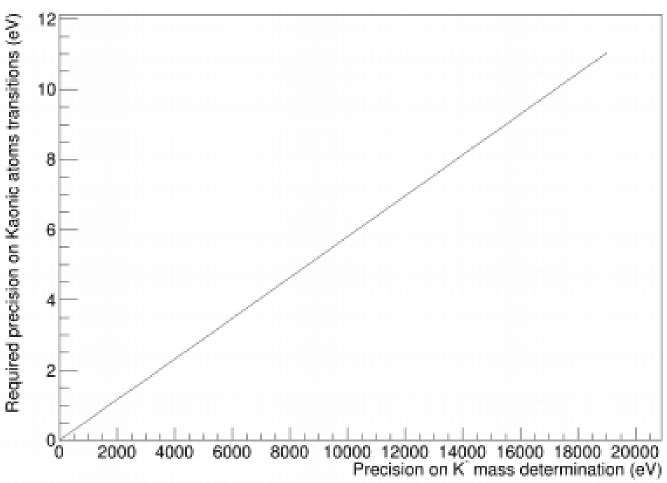
In a pure gaussian and background free spectrum, the achievable precision is

$$\text{precision(trans.)} = \frac{\sigma}{\sqrt{N}}$$

For a FWHM(302.9 keV) of 1.106 keV
N ≈ 30000 is needed for a 3 eV precision
(δm_K = 5 keV)

Considering MC
simulated (hadronic) background

N≈50.000 X-rays in the peak (291.6 kEV)
to reach the 3 eV required precision



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REVISITING THE CHARGED KAON MASS*

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(Received October 31, 2019)

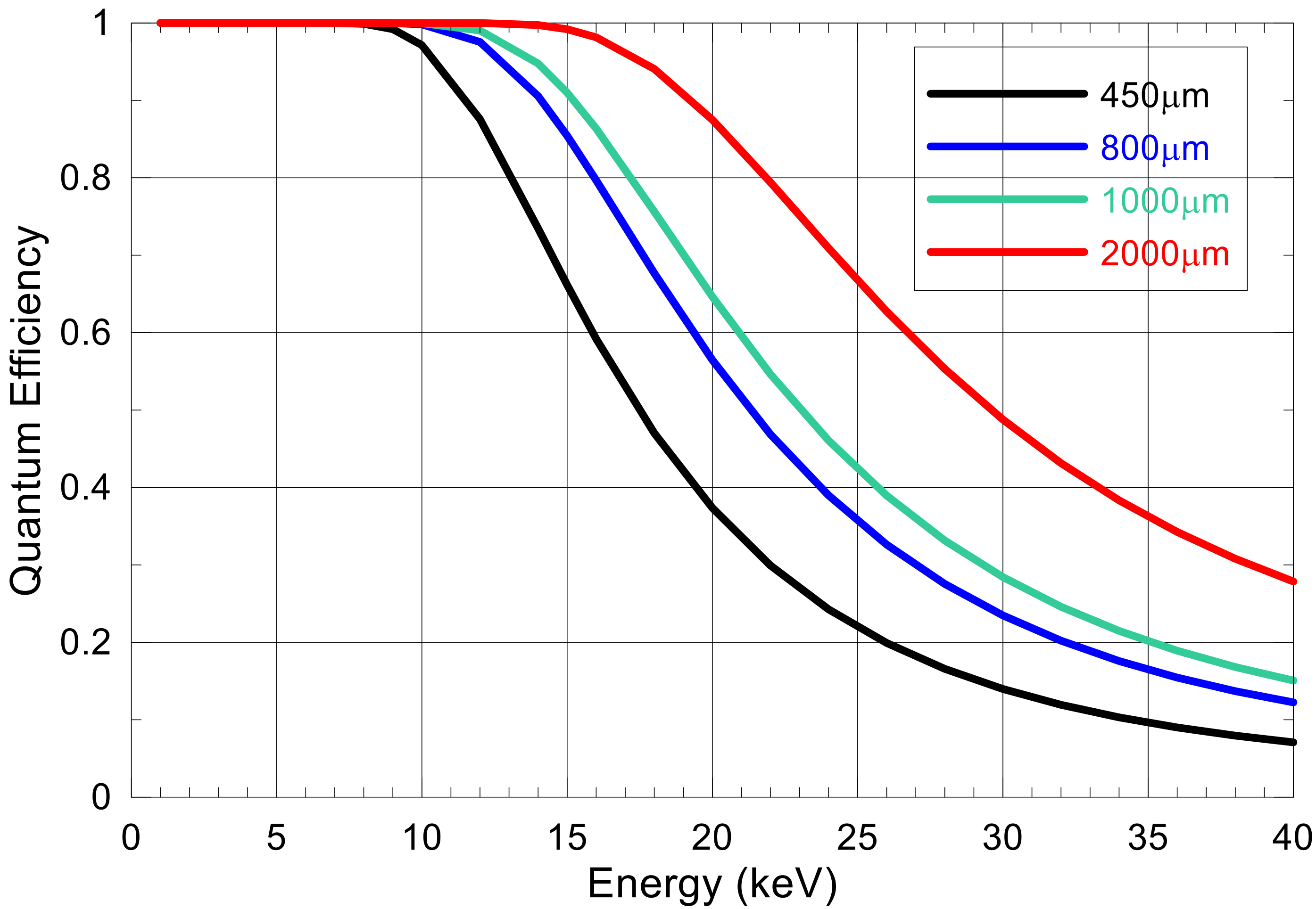
The precision of the charged kaon mass is an order of magnitude worse than the precision of the charged pion mass mainly due to two inconsistent measurements. We plan to improve this precision by determining the charged kaon mass with the requested accuracy in the measurements of X-ray transitions in kaonic atoms of selected solid targets with the HPGe detector at DAΦNE in Laboratori Nazionali di Frascati, Italy. The measurements will be performed in parallel with SIDDHARTA-2 measurements of X-ray transitions in gaseous targets. The status of the preparation of the measurements will be presented.

DOI:10.5506/APhysPolB.51.115

For the 291.6 keV transition,
with target distance from the HPGe of 115 mm, a 1,21% efficiency is expected resulting in ~4000 events / day

Intermediate mass kaonic atoms
(chiral symmetry; EOS neutron stars)

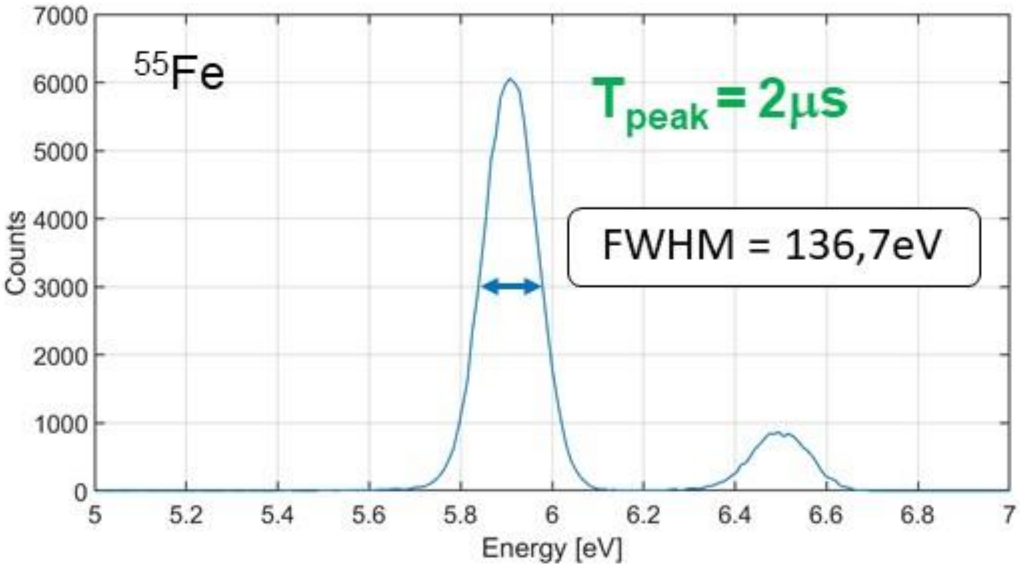
1mm SDDs for larger efficiency at E>10keV
Financed by INFN gr 3 (Nuclear Physics) - FBK

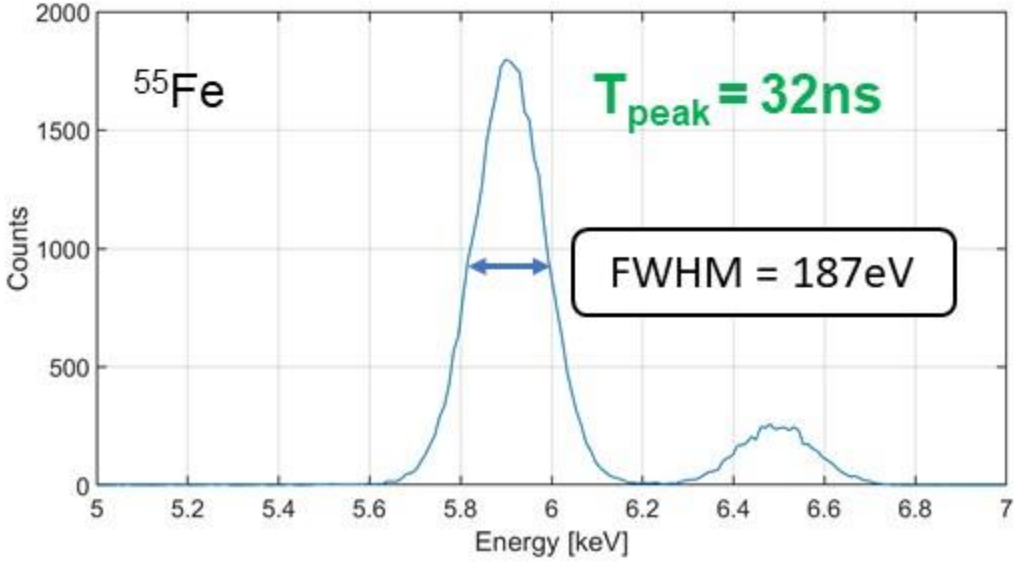


- 1-2 mm SDDs may increase x2-x4 the efficiency @30keV vs. present 450um SDDs
- 800um and 1mm SDDs prototypes already produced by FBK for ARDESIA (INFN)

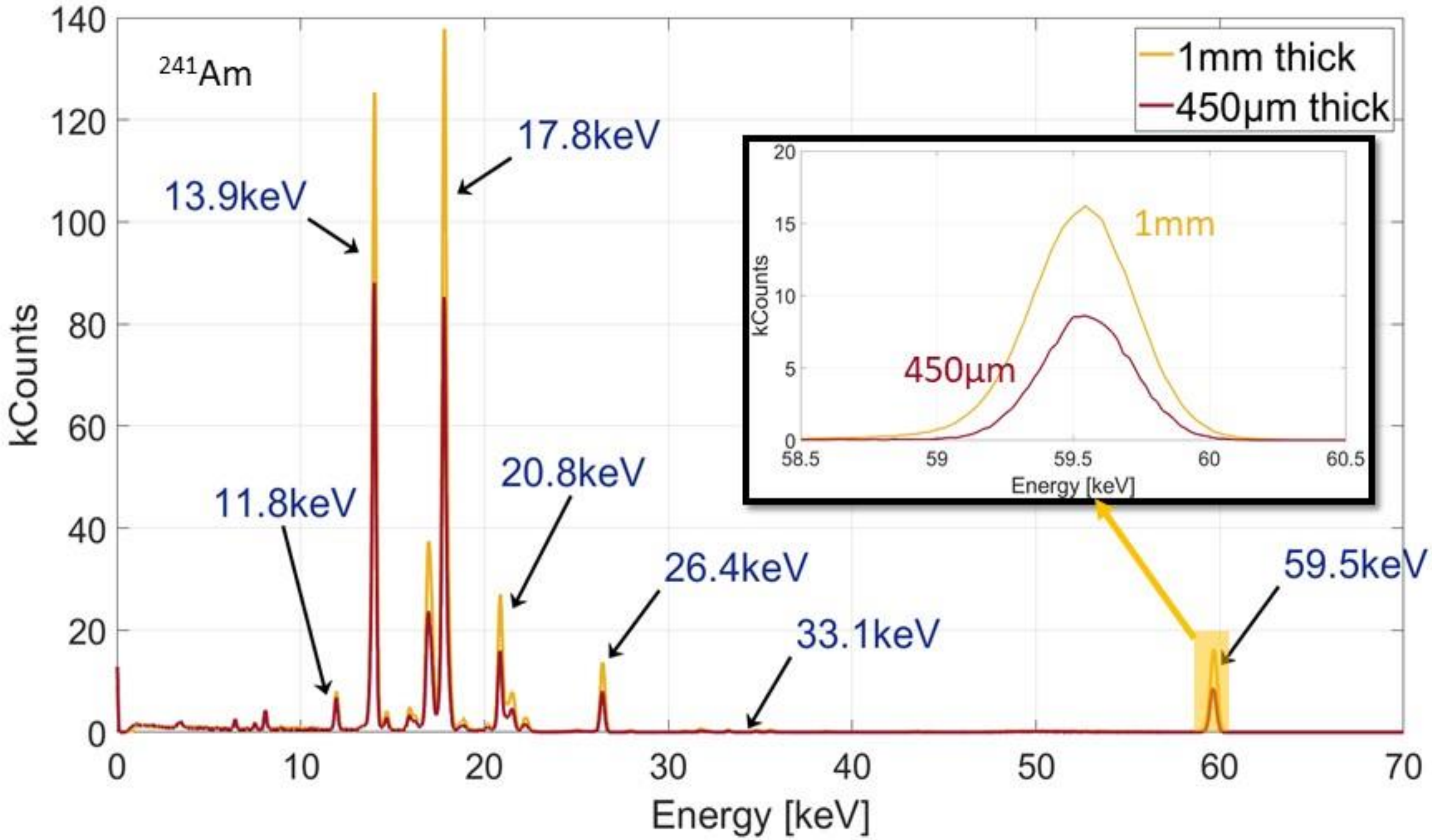
Preliminary tests on 1mm thick SDD (1)

single SDD
5x5mm^2 square
T=-40°C



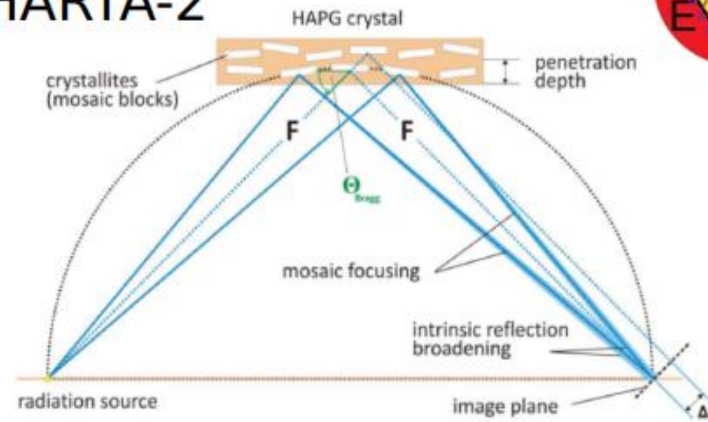


Preliminary tests on 1mm thick SDD (2)



Extreme precision kaonic atoms
(QCD precision; beyond SM?)

VOXES spectrometer test run during SIDDHARTA-2

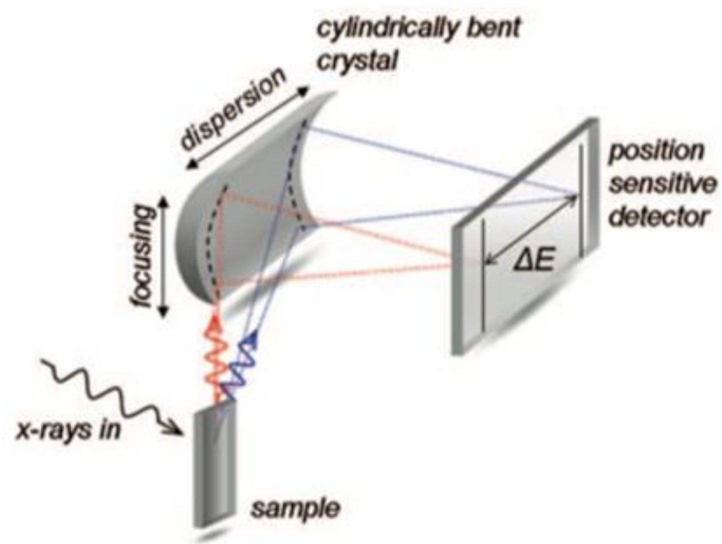


Mosaic crystal consist in a large number of nearly perfect small crystallites.

Mosaicity makes it possible that even for a fixed incidence angle on the crystal surface, an energetic distribution of photons can be reflected

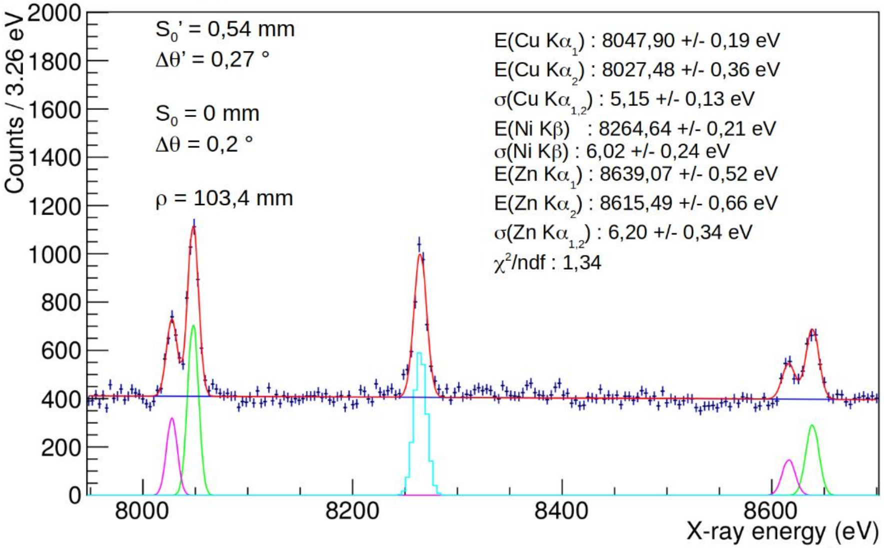
Increase of efficiency (focusing) ~ 50

Loss in resolution



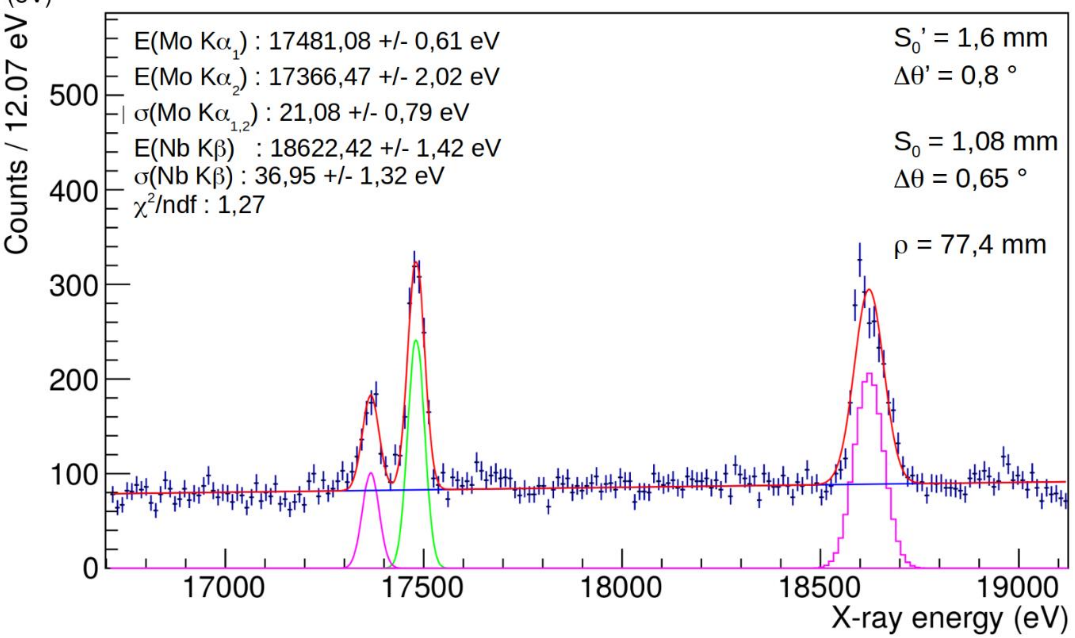
Von Hamos configuration to improve efficiency through vertical (sagittal) focusing properties of cylindrically bent crystals

Multi element spectra



700 eV dynamic range (one shot)

Resolution still at 6 eV level (σ)



>1 keV dynamic range

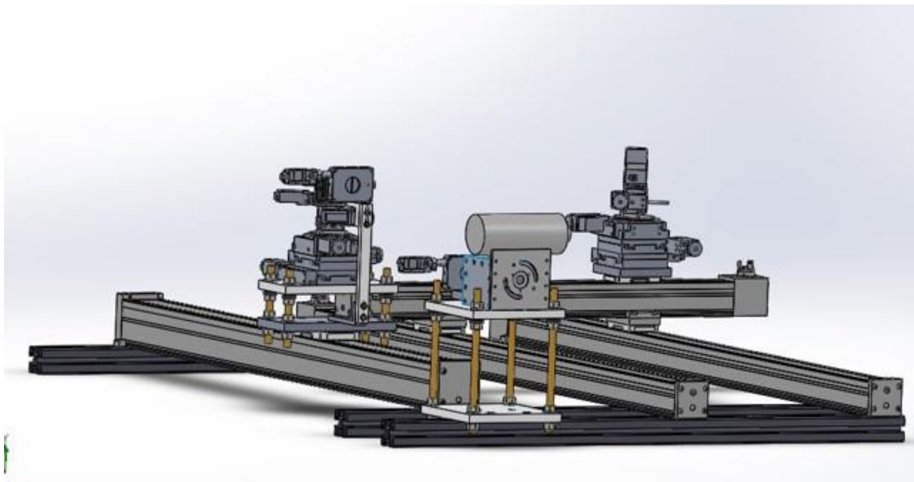
Resolution still at 1,2 ‰

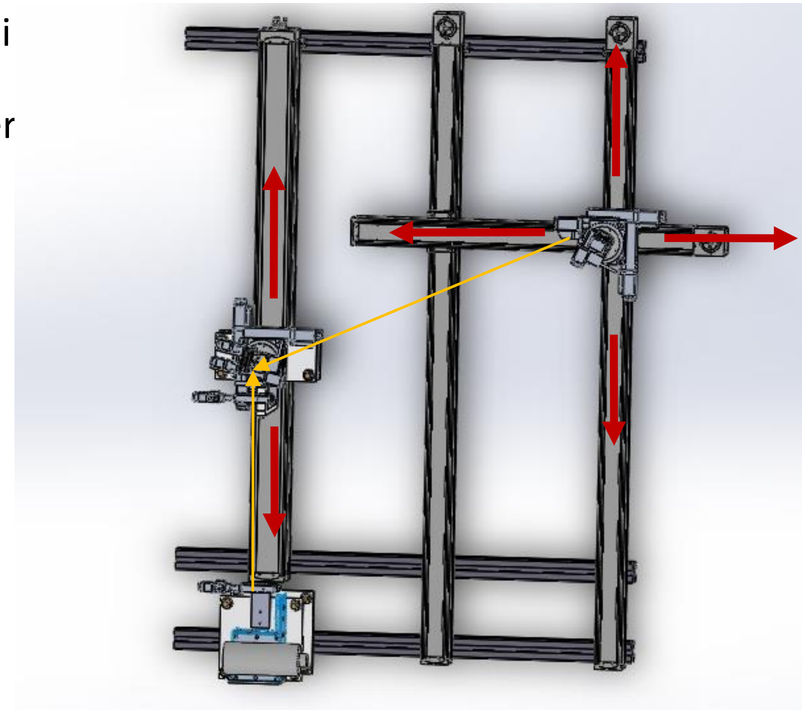
Almost 2 mm source size

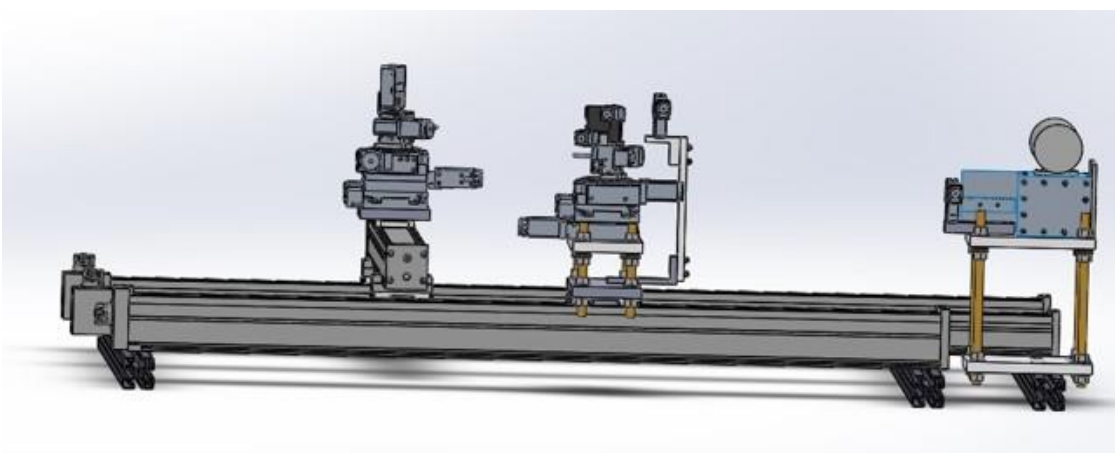
2020 Setup Upgrade

New set of motorized carriers for crystal-detector positioni

→ Possibility to remotely select the energy range of inter





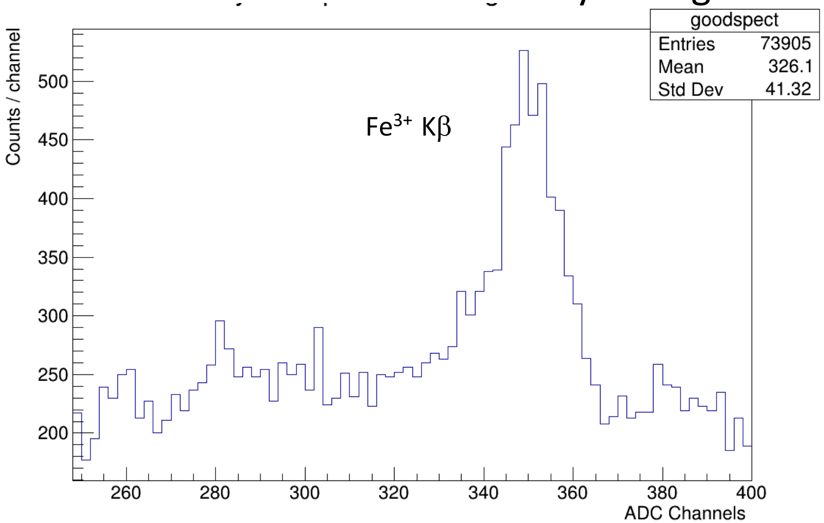


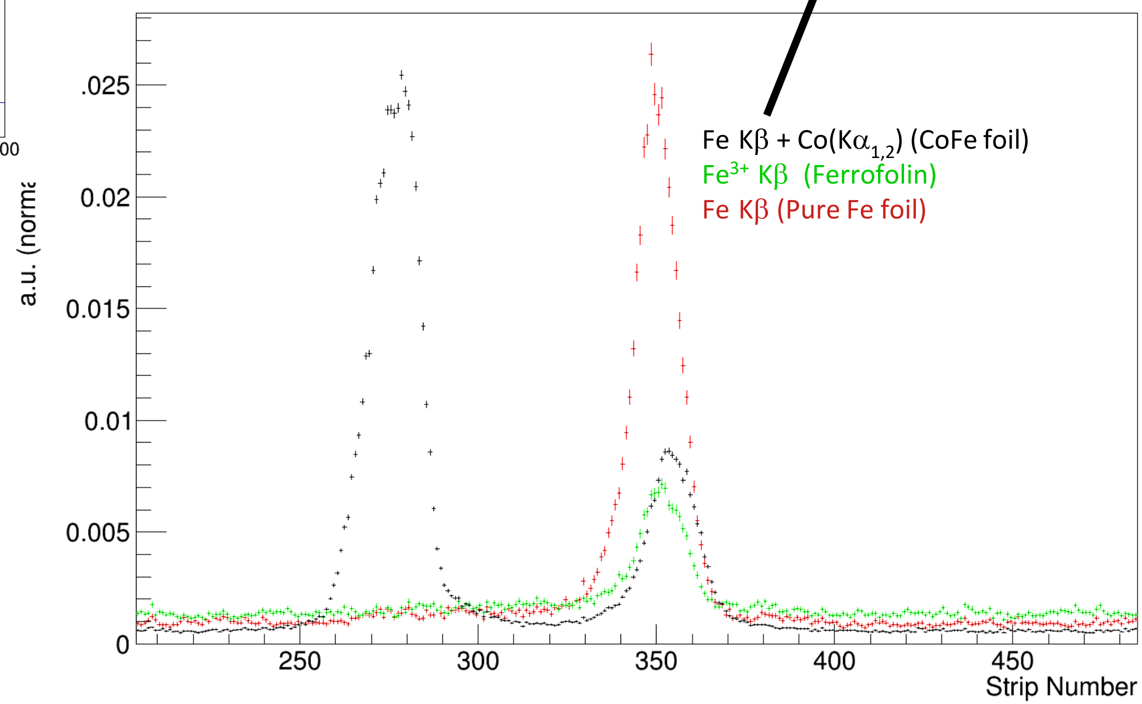
Old motorized fine positioners (XYZ, rotations and crystal tilt) are also still integrated in the new setup.

2020 tests with liquid samples

Exploratory measurements with liquid targets have also been performed recently.

Ferrofolin (mainly Fe^{3+}) liquid sample used, embedded in a 7 micron thick mylar bag





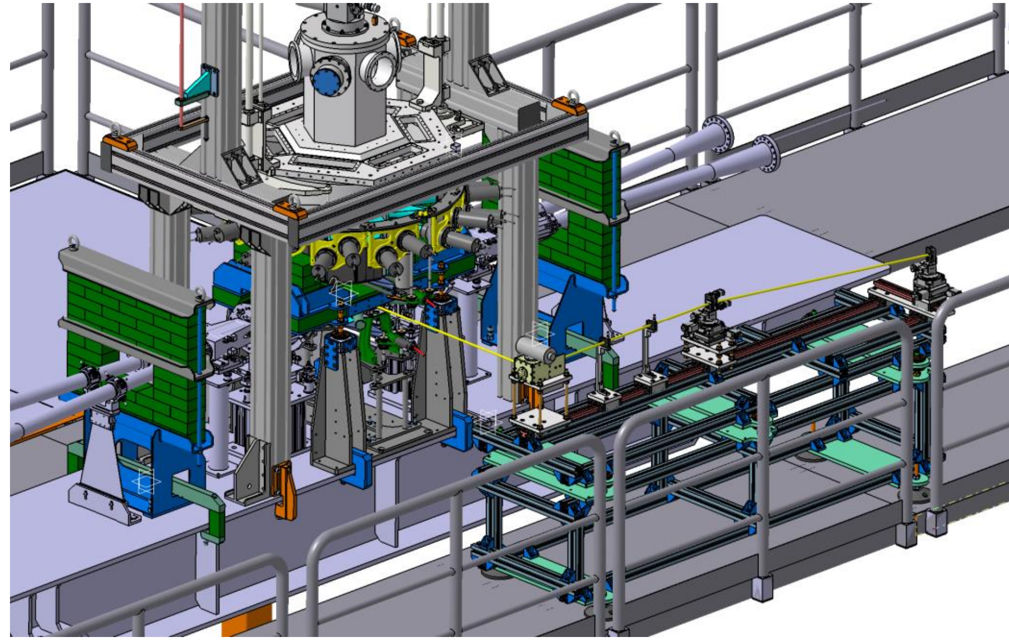
VOXES spectrometer test run during SIDDHARTA-2

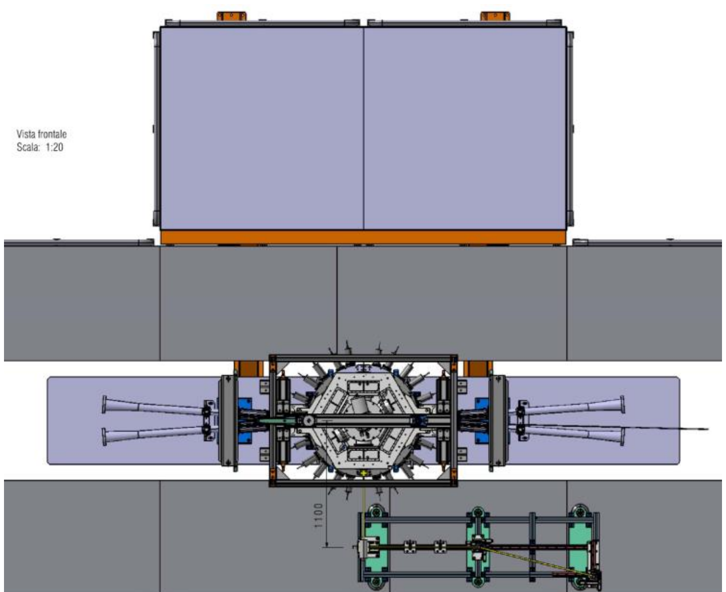
To be realized:

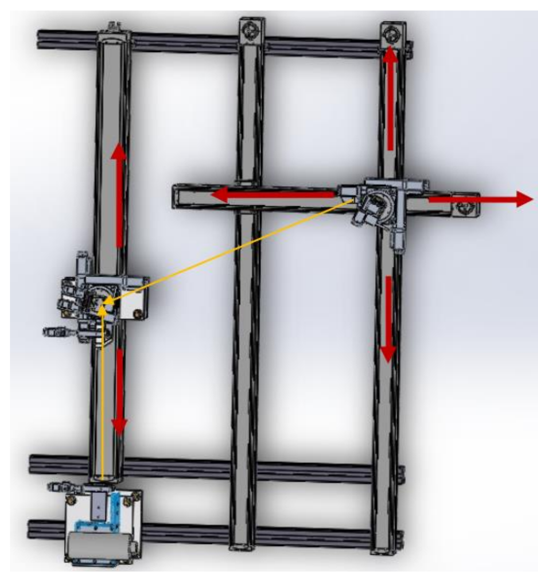
1) Shielding around Detector
2) Solid support structure

Available:

1) Multi - Crystal support structure
2) Target (Solid or Liquid/Gas)
3) Optics
4) Alignement support
5) Target box
6) Detector
7) DAQ (integ. KM)





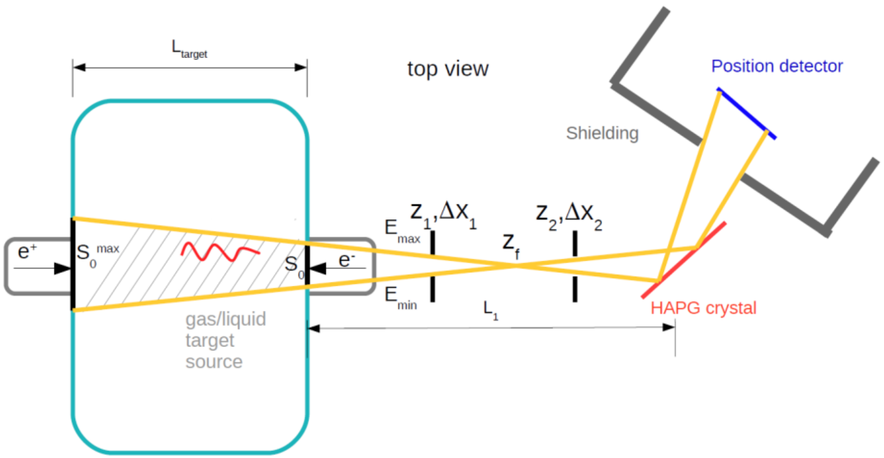


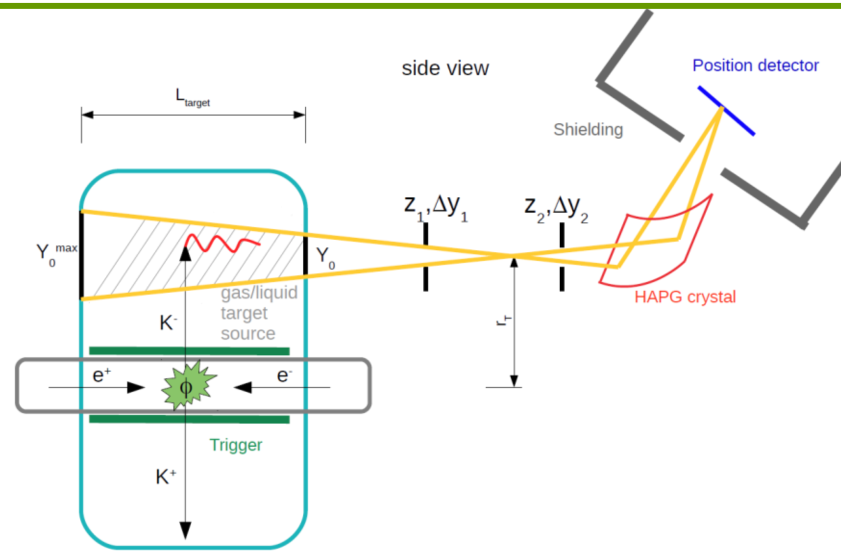
Recently upgraded with motorized carriers:

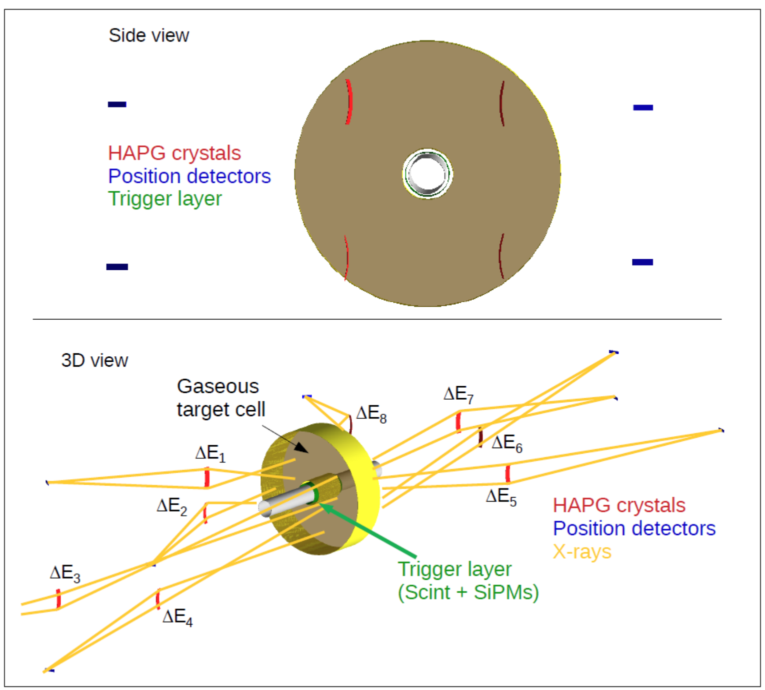
Ready for multiline measurements & onsite (online) alignement


Many thanks to the DAFNE team,
to Research and Technical Divisions
LNF Management and Services
and to INFN gr 3!
Moreover, many-many thanks to:
Cleaning staff
Bar and canteen staff!
You make life better

A possible future kaonic atoms experiment with VOXES spectrometer principle @ DAFNE







beam pipe surrounded by a cylindrical trigger system based on scintillating material read by Silicon PhotoMultipliers, and a 30 cm length, 5 cm (inner) and 40 cm (outer) radius toroidal target cell filled with a mixture of ^{3}He, ^{4}He and N

Bragg reflection on a ~ 50 cm^2 HAPG crystal using photon counting strip detectors (HPC), with 50 μm strip width, few hundreds of microns thickness and a total surface in the order of 10 cm^2

A possible future kaonic atoms experiment with VOXES spectrometer principle @ DAFNE: a numerical example

K He 3d→2p @ 6 keV

Reference: VOXES Fe solid target, 206,7 mm curvature radius HAPG crystal, S_0 of 1,1 and $\Delta\theta$ of 0,6°

Assuming:

- vertical slits dimensions of 2,6 and 26 cm,
- a target length of L_{target} = 200 mm,
- average target entrance window distance of r_T =3,5 cm from the IP,
- a starting rate of isotropically emitted K^- of $R_{DA\Phi NE}$ ~ 700 Hz (SIDDHARTA-like Luminosity L =4x10^{32} cm^{-2} s^{-1}

$$R = R^{DA\Phi NE} \times \epsilon_{geo} \times \epsilon_{stop} \times Y \times \epsilon_{geo}^{X-rays} \times \epsilon_r \times QE_{PD}$$

- ε_{geo} is the geometrical efficiency for the kaons to reach the target (2,7x10^{-5})
- ε_{stop} is the stopping efficiency in helium (> 90%)
- Y is the 3d→2p transition yield (~25%)
- $\varepsilon_{geo}^{X-ray}$ is the numerically calculated probability, for the generated X-ray, to reach the HAPG surface (~3,5%)
- ε_r is the HAPG reflection efficiency (~30%)
- QE_{PD} is the position detector quantum efficiency (>90%)

R = 4,5x10^{-5} Hz → 350 events in 100 days → δE ~ 0,2 eV (σ = 4 eV)

Calculated quantity [1]	Phenomenologica [2]	Chiral [3]
ε (K^4He)	-0,41 eV	-0,09 eV
ε (K^3He)	0,23 eV	-0,1 eV
ε (K^4He) - ε (K^3He)	-0,64 eV	0,01 eV

[1] Yamagata-Sekihara, J., S. Hirenzaki, and E. Hiyama., 2015, Private Communication.
[2] Mares, J., Friedman, E., Gal, A. 2006, Nucl. Phys. A, Vol. 770, p. 84-105.
[3] Ramos, A., Oset, E., 2000, Nucl. Phys. A, Vol. 671, p. 481-502.

Similarly, for KN(6→5): 2200 events in 100 days →δE ~ 0,08 eV (using VOXES Cu measurements)