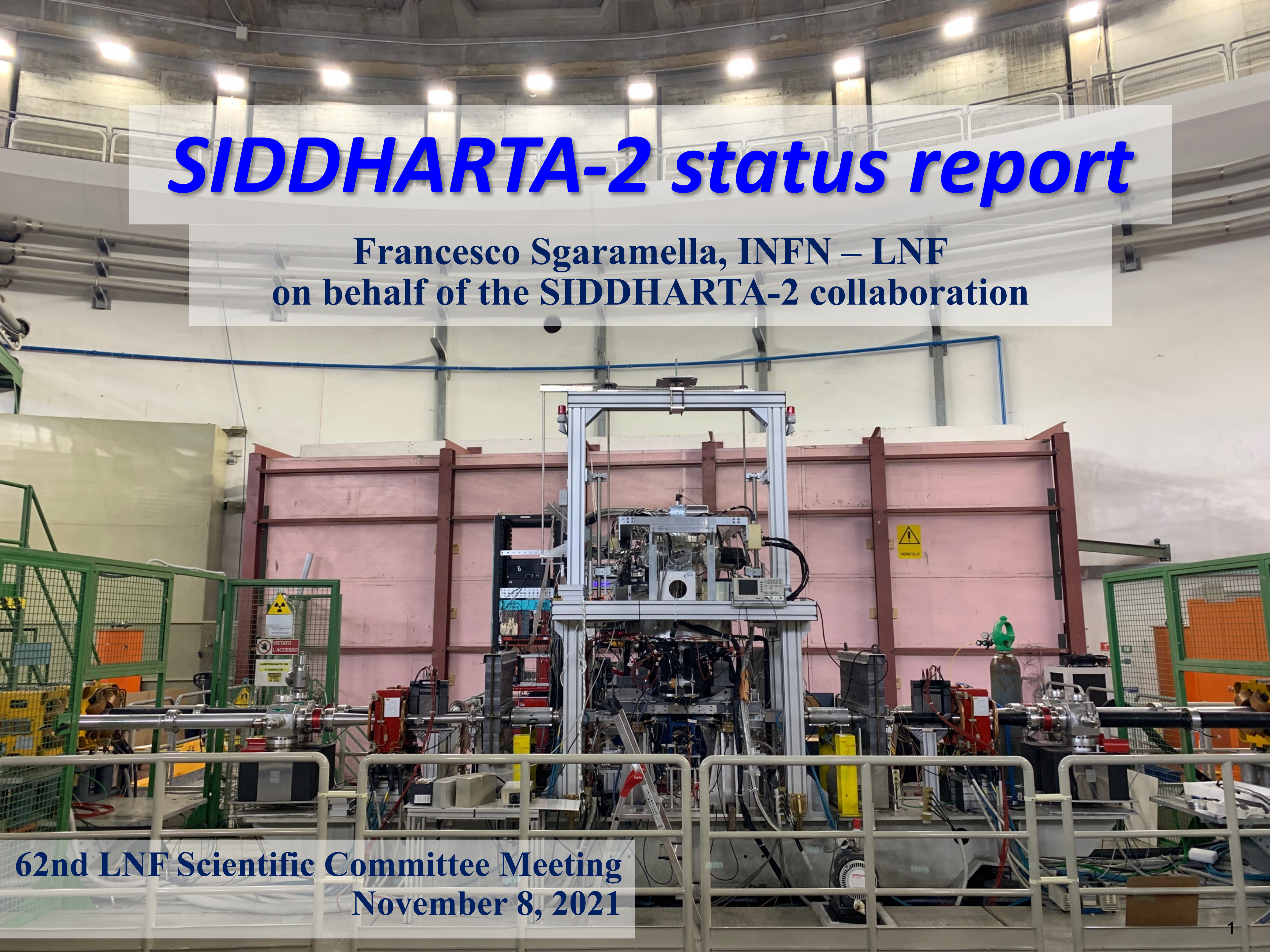
SIDDHARTA-2 status report

Francesco Sgaramella, INFN – LNF
on behalf of the SIDDHARTA-2 collaboration



62nd LNF Scientific Committee Meeting
November 8, 2021

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

Contents

- Publications since last SC
- 61st SC recommendations
- SIDDHARTINO run outcomes
- Activities in DAΦNE – full SIDDHARTA-2 installation
- HPGe Detector: test run for kaonic lead (kaon mass)
- Future plans

Publications since last SC

1. M. Miliucci et al., Silicon Drift Detectors system for high precision light kaonic atoms spectroscopy, Meas. Sci. Technol. 32 (2021).

2. M. Miliucci et al., Low energy kaon-nuclei interaction at DAΦNE:The SIDDHARTA-2 experiment, Il Nuovo Cimento 44 C (2021).
   Selected communication at 106° SIF Congress (best presentation: Marco Miliucci) for with publication on Rivista de il Nuovo Cimento.

3. C. Curceanu et al, Kaonic Atoms Measurements at DAΦNE: SIDDHARTA-2 and Future Perspectives, Few Body Syst. 62, 4 (2021).

4. M. Miliucci et al., Silicon Drift Detectors spectroscopic response during the SIDDHARTA-2 Kaonic Helium run at the DAΦNE collider, arXiv:2111.01572, submitted to Condensed Matter.

5. M. Miliucci et al., HIGH PRECISION KAONIC ATOMS X-RAY SPECTROSCOPY AT THE DAΦNE COLLIDER: THE SIDDHARTA-2 EXPERIMENT (submitted to RAP Conference Proceedings)

Publications since last SC

6. A. Scordo et al, Efficiency measurements and simulations of a HAPG based Von Hamos spectrometer for large sources, J. Anal. At. Spectrom., 2021, JAAS, 2021, 36, 2485 – 2491, doi: 10.1039/D1JA00214G.

7. A. Scordo et al, VOXES: a new HAPG mosaic crystal based Von Hamos spectrometer for millimetric sources, RAP conference proceedings, VOL. 6, PP. 1–5, 2021.

8. M. Miliucci et al., Silicon Drift Detectors Technology for High Precision Light Kaonic Atoms Spectroscopic Measurements at the DAΦNE Collider, in print on AIP-CP.

9. V. De Leo et al, Reflection efficiency and spectra resolutions ray-tracing simulations for the VOXES HAPG crystal based Von Hamos spectrometer, arXiv:2111.01572, submitted to Condensed Matter.

10. Kaonic Helium measure: shift and width, *in preparation.*

11. Yield kaonic helium in gas, *in preparation.*

61st LNF Scientific Committee Meeting

<u>*Recommendations SIDDHARTA*</u>

- "**Controlling the background is a critical aspect of this experiment** and the committee would like to see the details of **the interventions planned by SIDDHARTA**/DAFNE for moving towards the aimed -for background level. The committee would appreciate getting this written feedback by the end of June."

This was one of our main goals in the SIDDHARTINO run, up to its end (18 July) – report sent by LNF Director *Report on the Dafne-Siddharta operation May-July 2021* together with a competitive measurement of kaonic helium

Project timeline – since last SciCom

61st LNF SciCom

2021, May

Software and hardware optimization back. reduction

SIDDHARTINO optimization run

2021, June

Different combinations of the degrader thickness and different gas density

SIDDHARTINO K-^{4}He run

2021, 24 June – 18 July

Analysis of the SIDDHARTINO data.
Start SIDDHARTA-2 Installation

Start SIDDHARTA-2 installation: mechanics

2021, August

Installation of SDD, veto and electronics.
Update of the DAQ....

SIDDHARTA-2 Installation and tests

2021, September -October

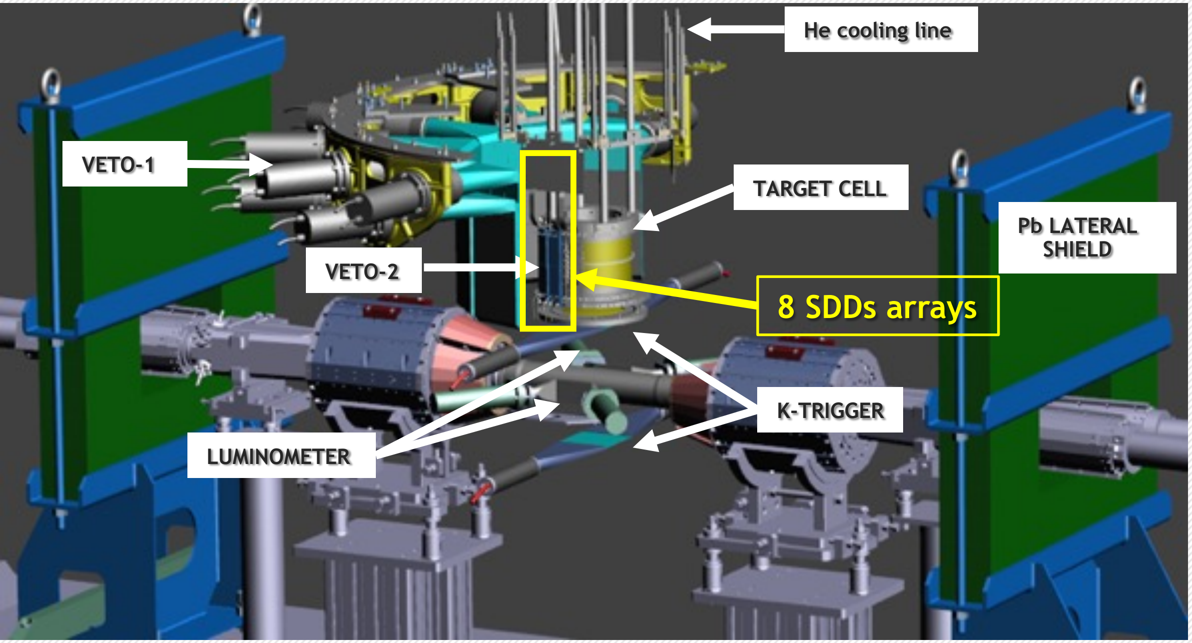
Ready for run

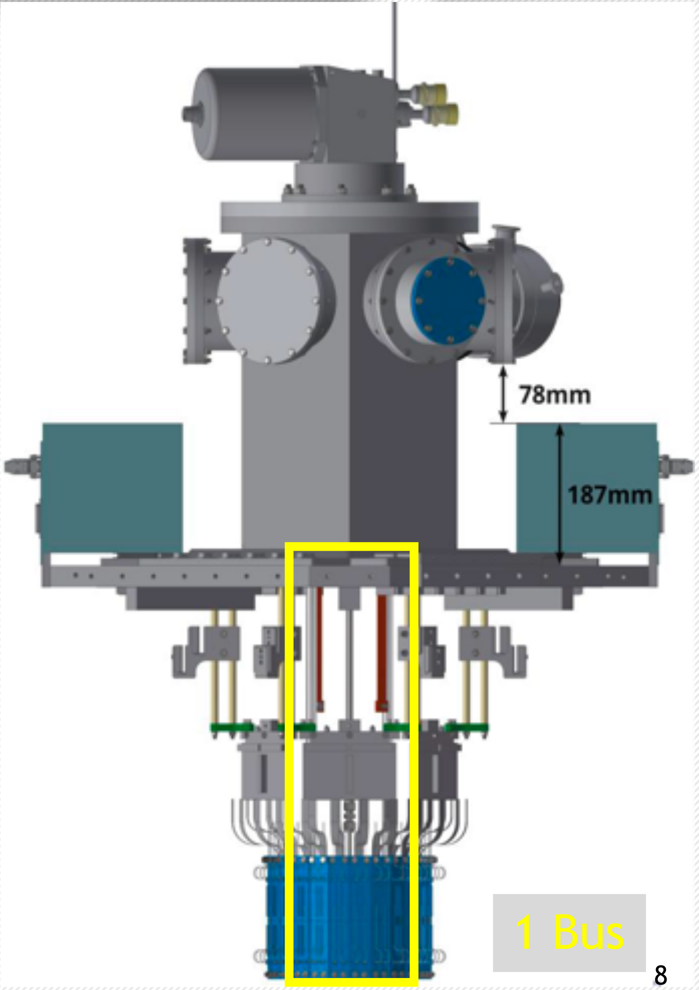
62nd LNF SciCom

2021, November

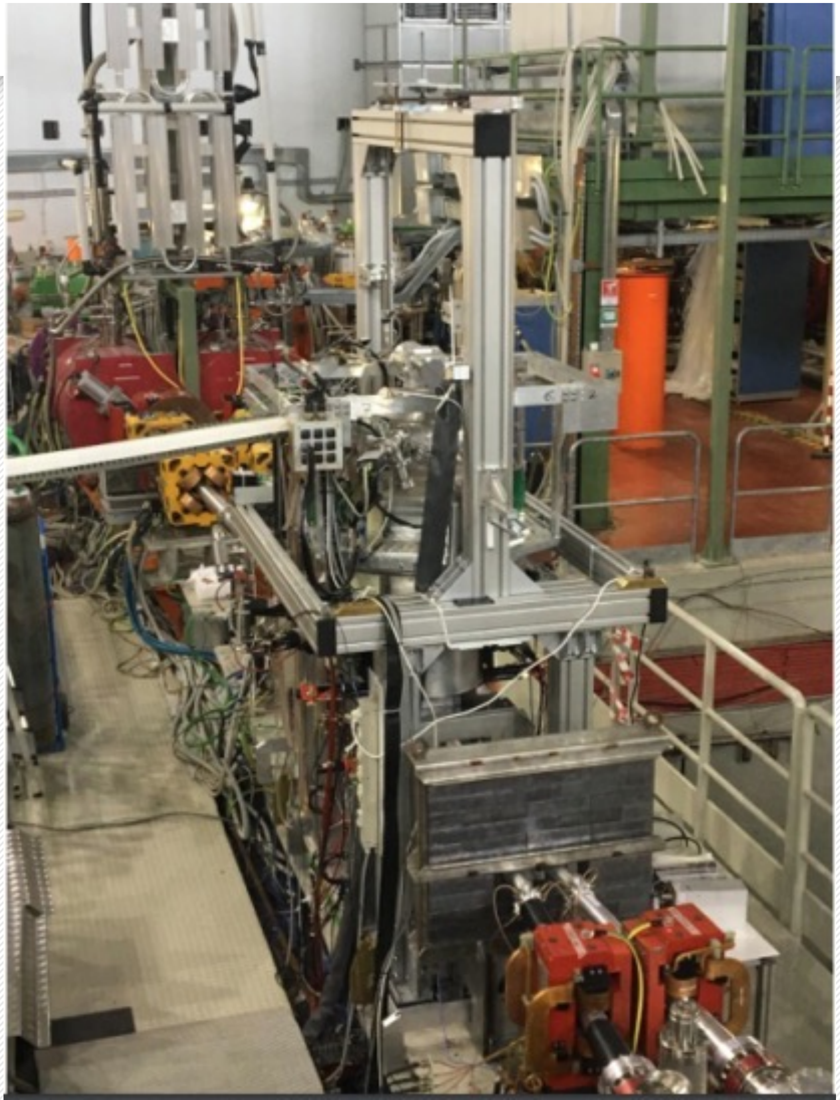
SIDDHARTINO run

Schematic representation of SIDDHARTINO setup





SIDDHARTINO setup (1/6 SDDs)



* Phase 1 with SIDDHARTINO:

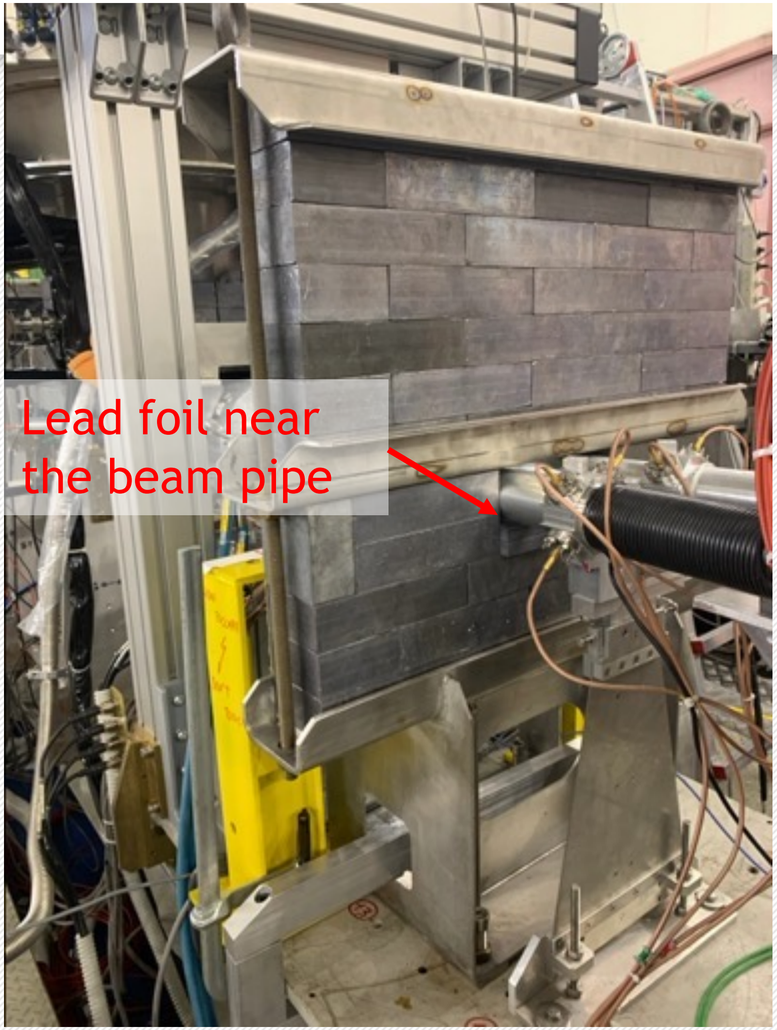
during the commissioning of DAΦNE:

optimization with the SIDDHARTINO setup

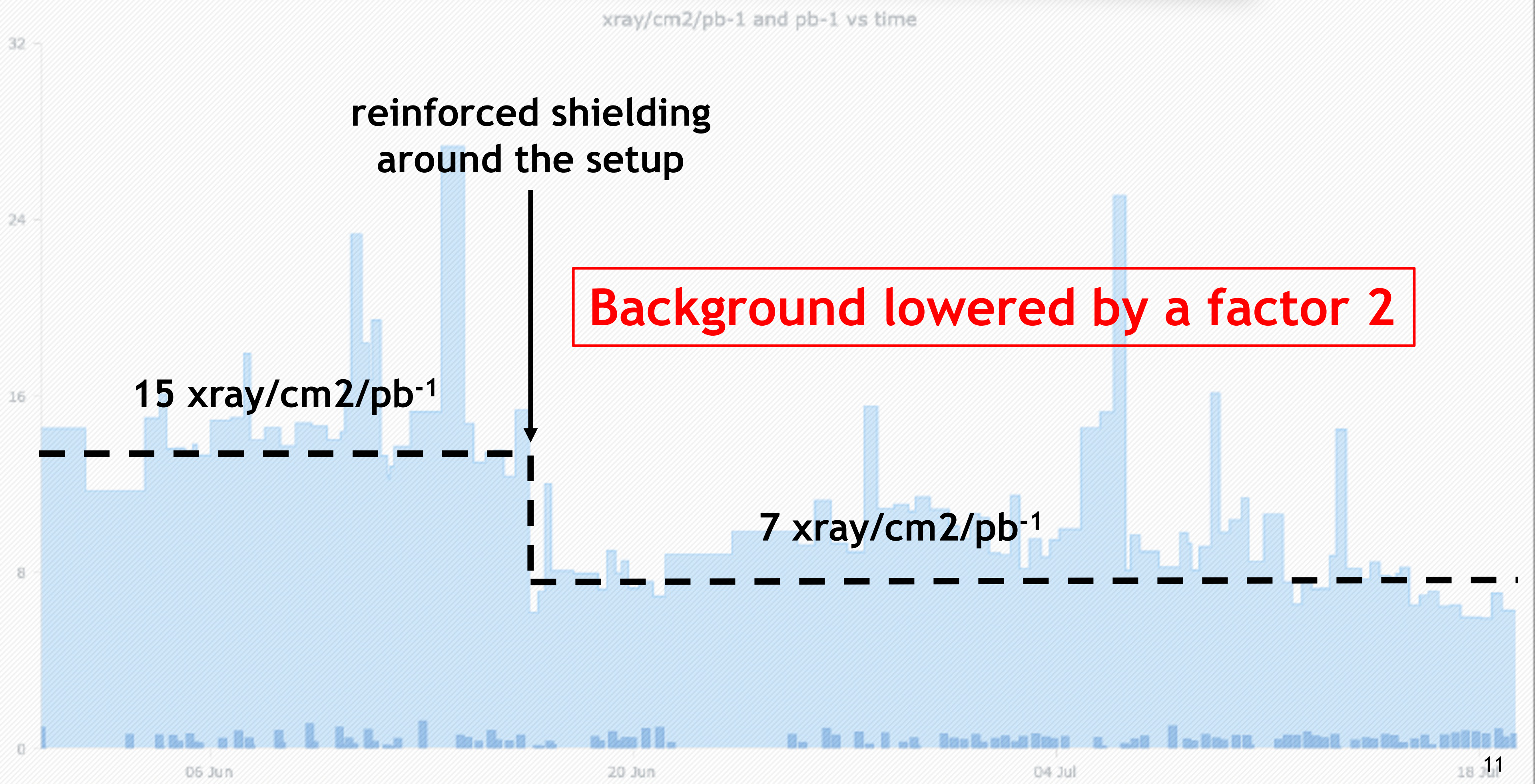
for the K-^{4}He measurement

(with 8 SDD arrays)

Back. reduction: reinforced shielding around the setup



SIDDHARTINO - xray/cm2/pb^{-1}

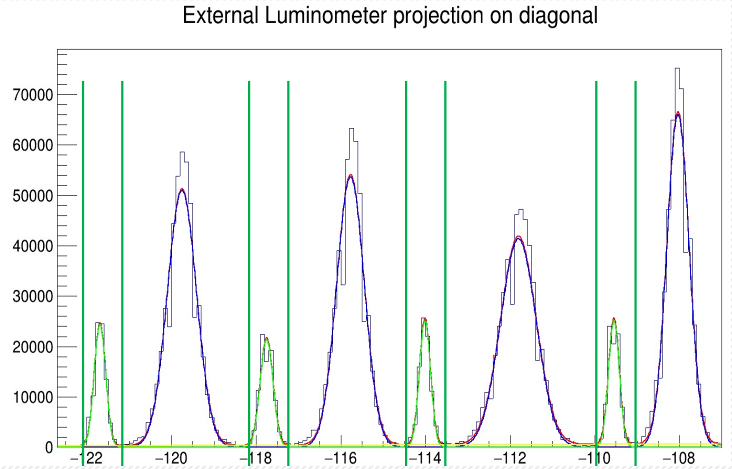


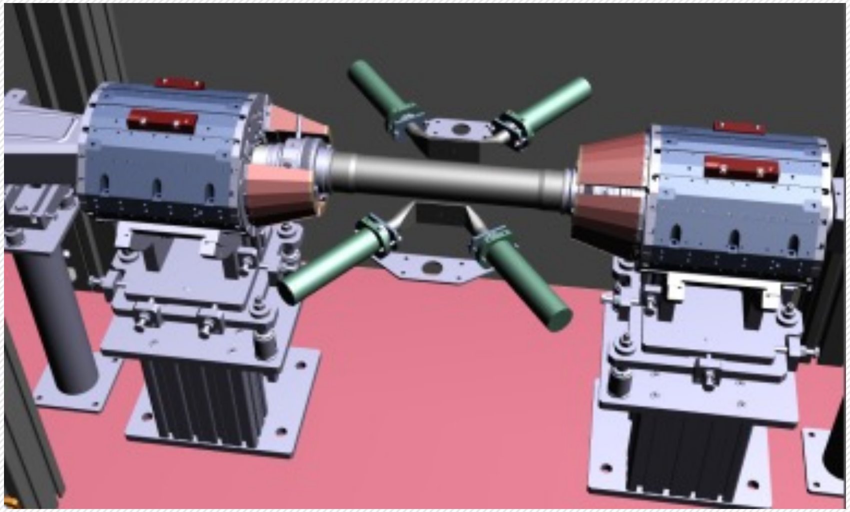
Luminosity measurement to monitor also background

- **Luminosity detector:**

- SIDDHARTA-2 luminometer used for back: kaons/MIPS

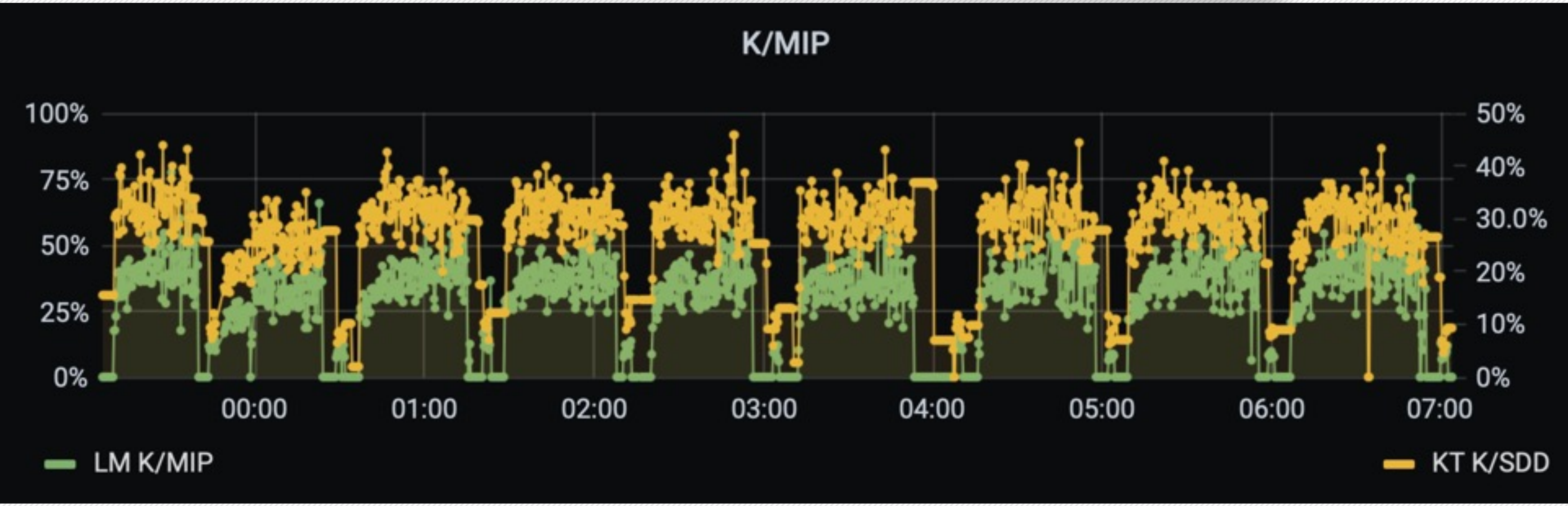
- luminosity delivery





Back to plastic scintillators in coincidence with RF/4 signal

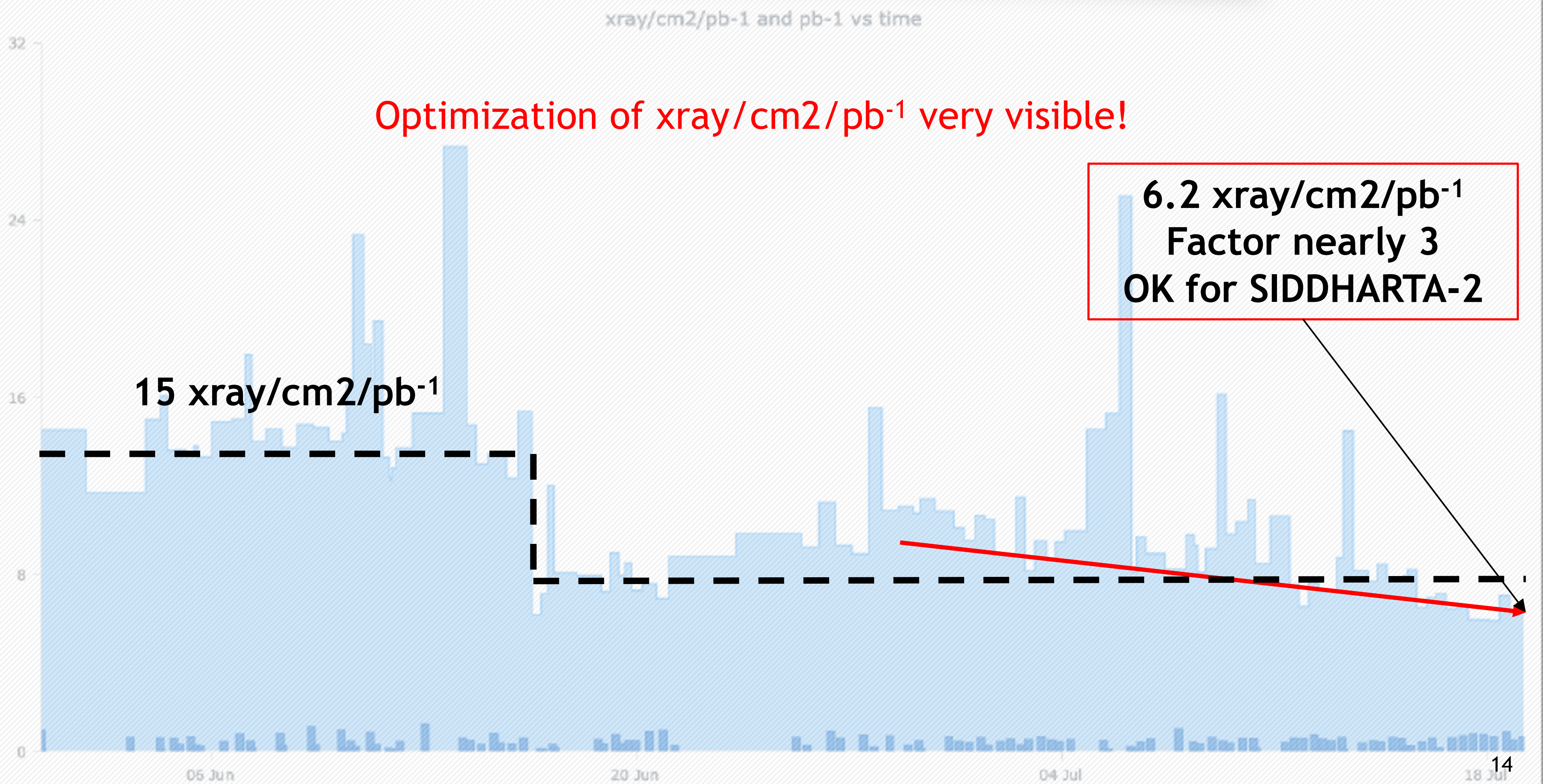
Background levels monitor



Background levels were monitored online by a counter based on Kaon/Mip rate and a second based on Kaon/SDD rate.

Shared with the DAΦNE staff to optimize the background

SIDDHARTINO - xray/cm2/pb^{-1}



SIDDHARTINO data - Integrated Luminosity

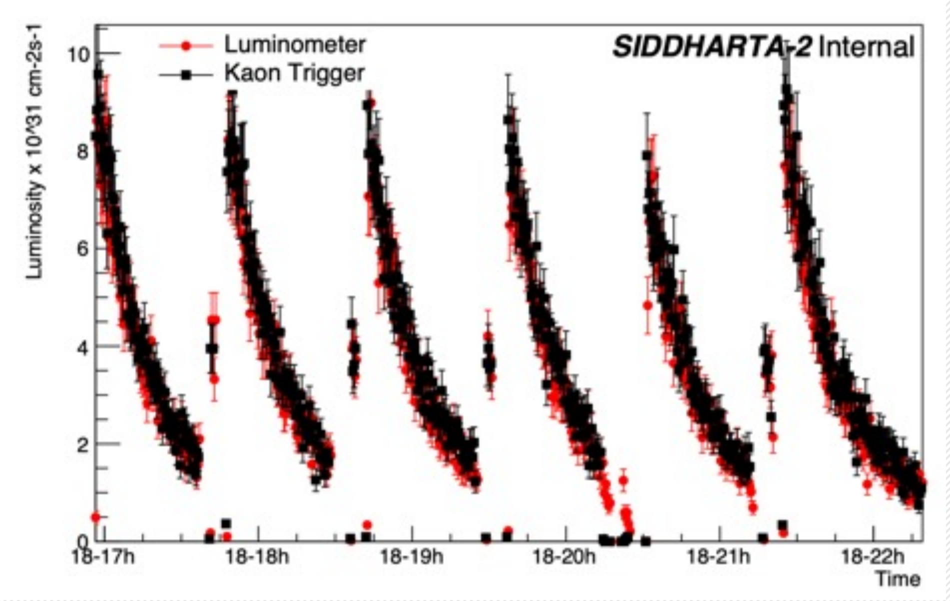
Total integrated luminosity: 54 pb^{-1}

Optimization run: 24 pb^{-1}

Trigger, DAQ, SDD optimization

Kaonic ^{4}He run: 30 pb^{-1}

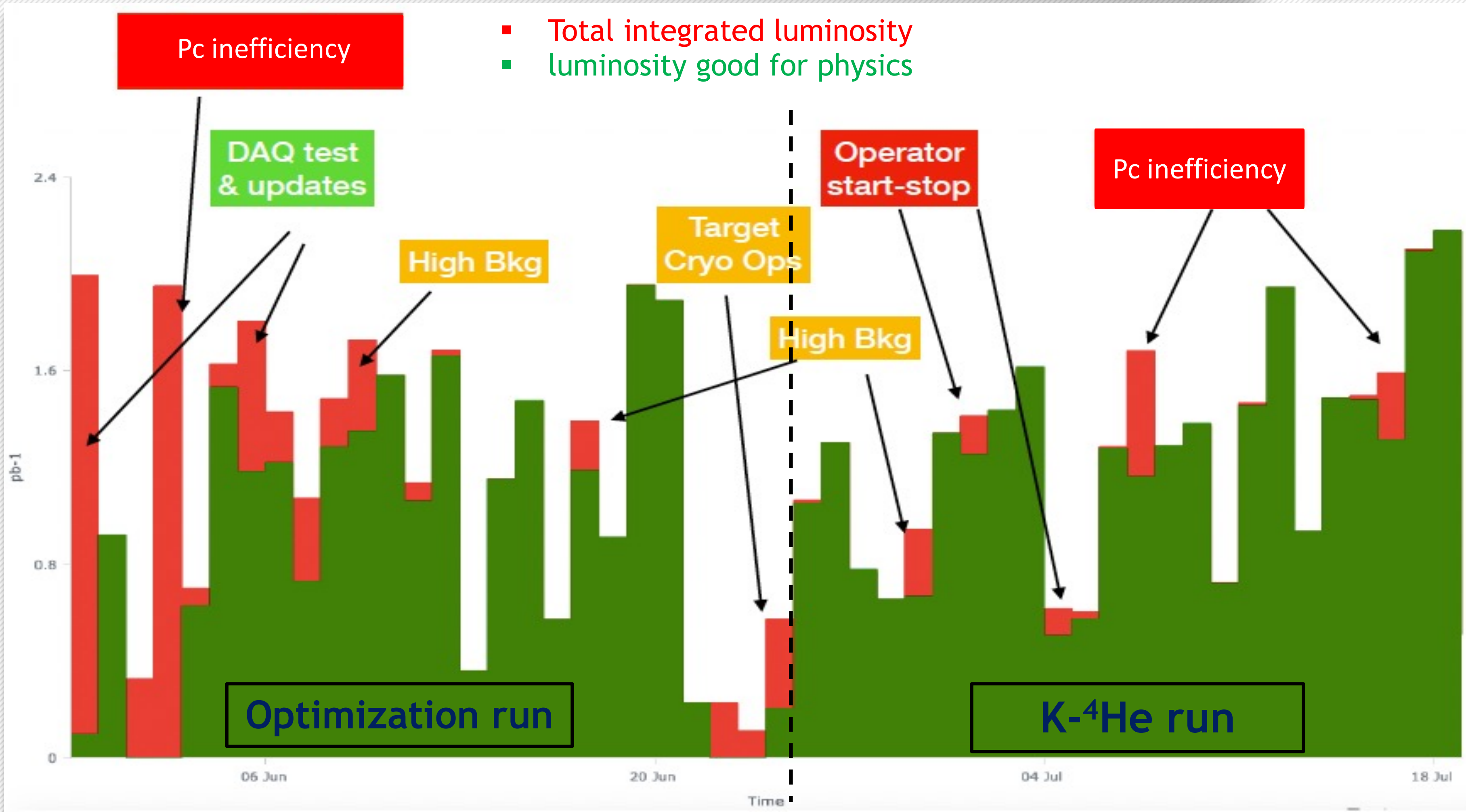
Degrader optimization, low and high ^{4}He density measure



Kaon monitor and Luminometer measure at the end of SIDDHARTINO run

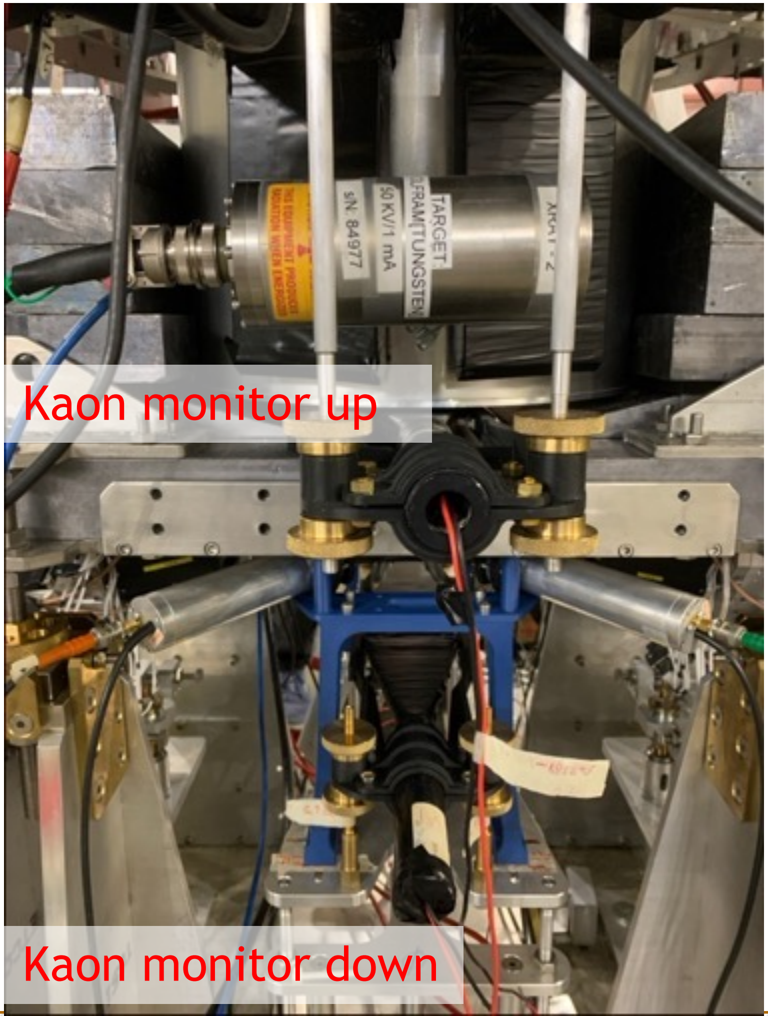
SIDDHARTINO - Integrated Luminosity

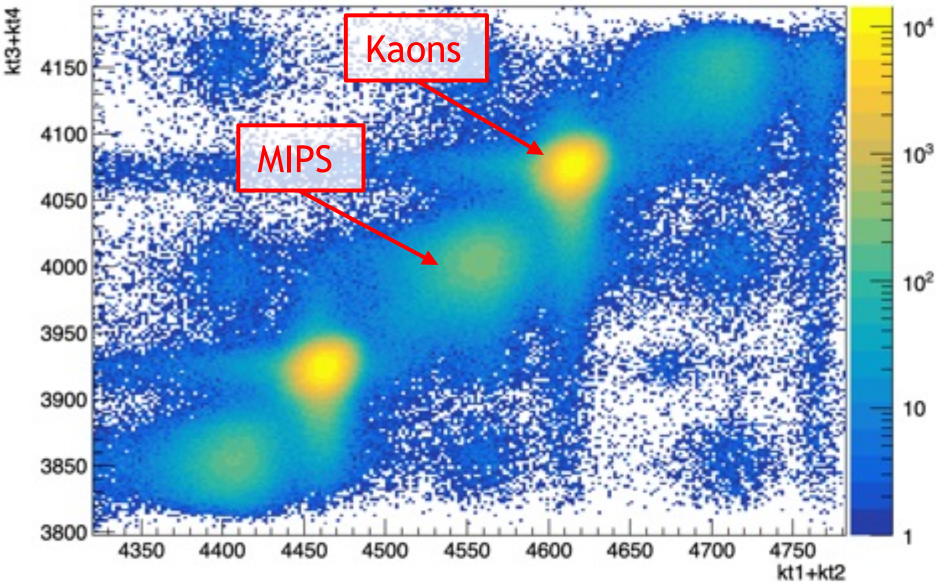
86% total efficiency
>95% for K^4He good runs

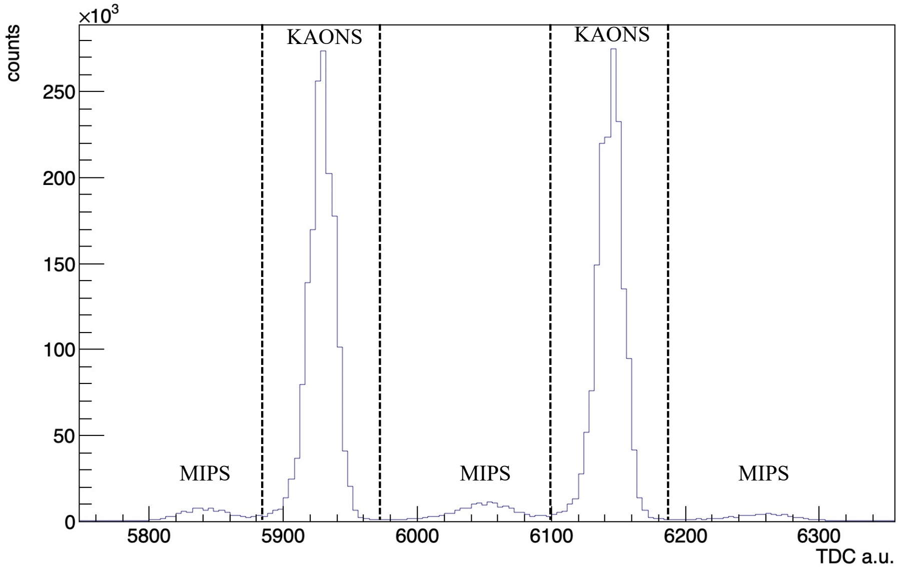


SIDDHARTINO – Optimization Run

Trigger time window optimization



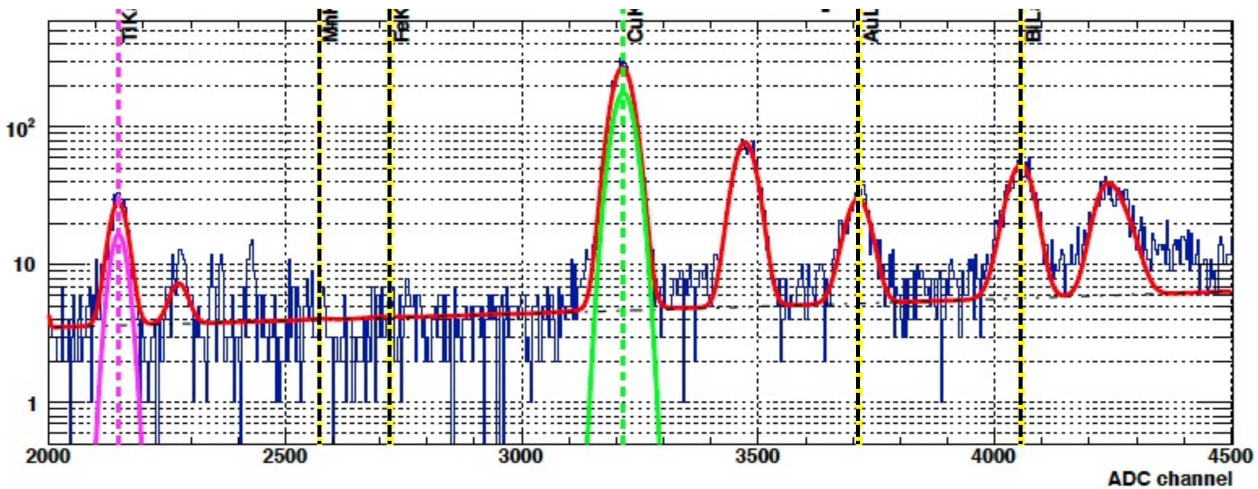




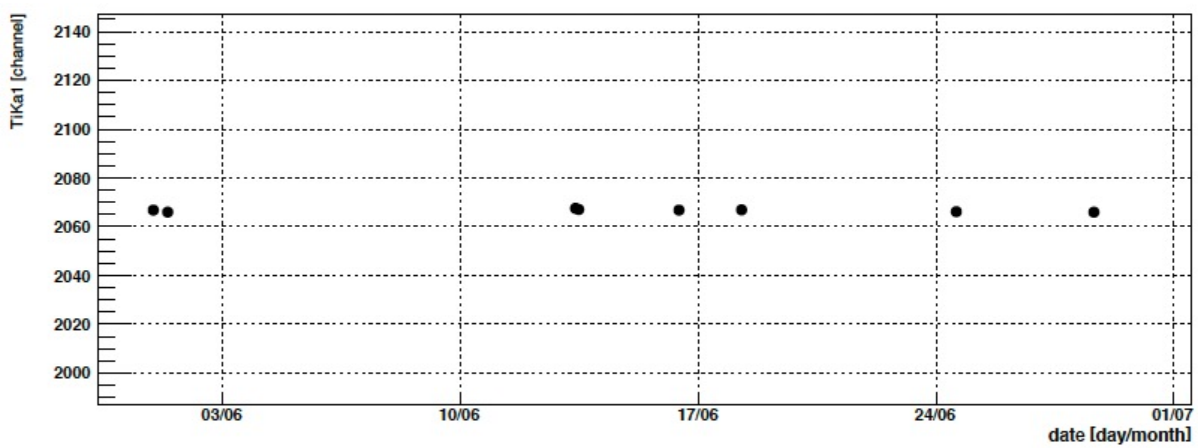
SIDDHARTINO – Optimization Run

SDD calibration and energy response

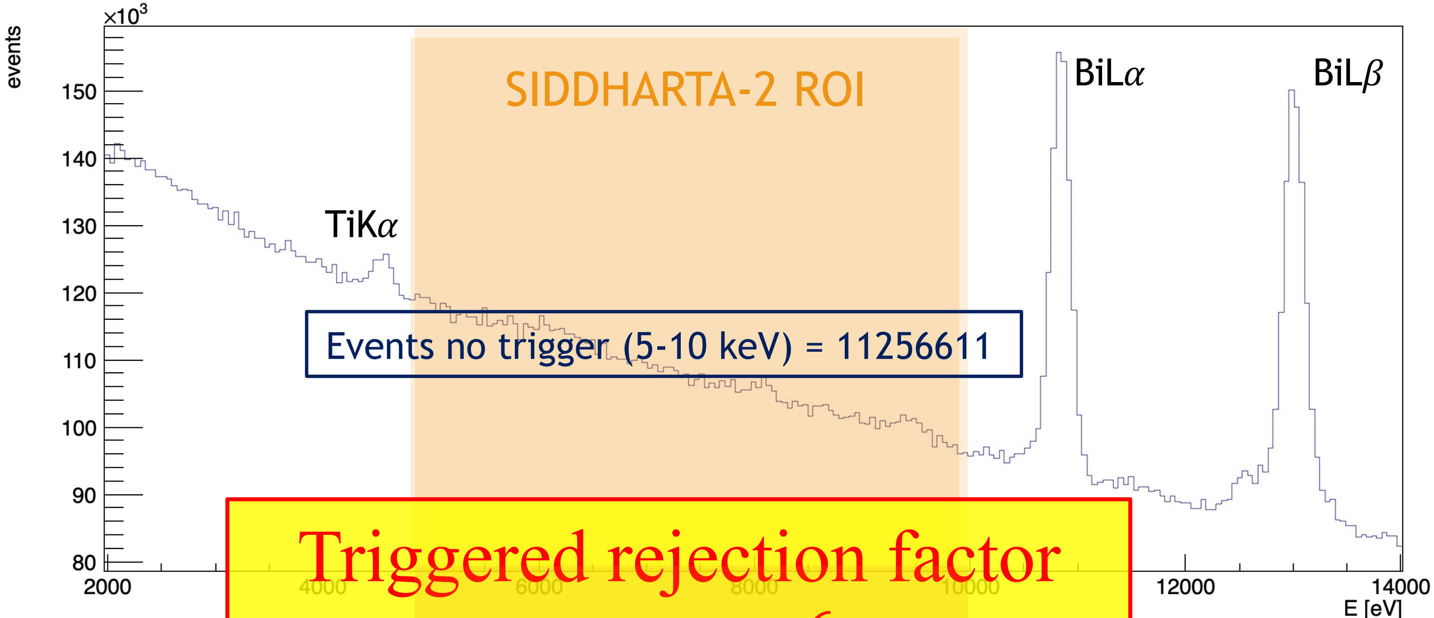
SDD calibration run



SDD Stability

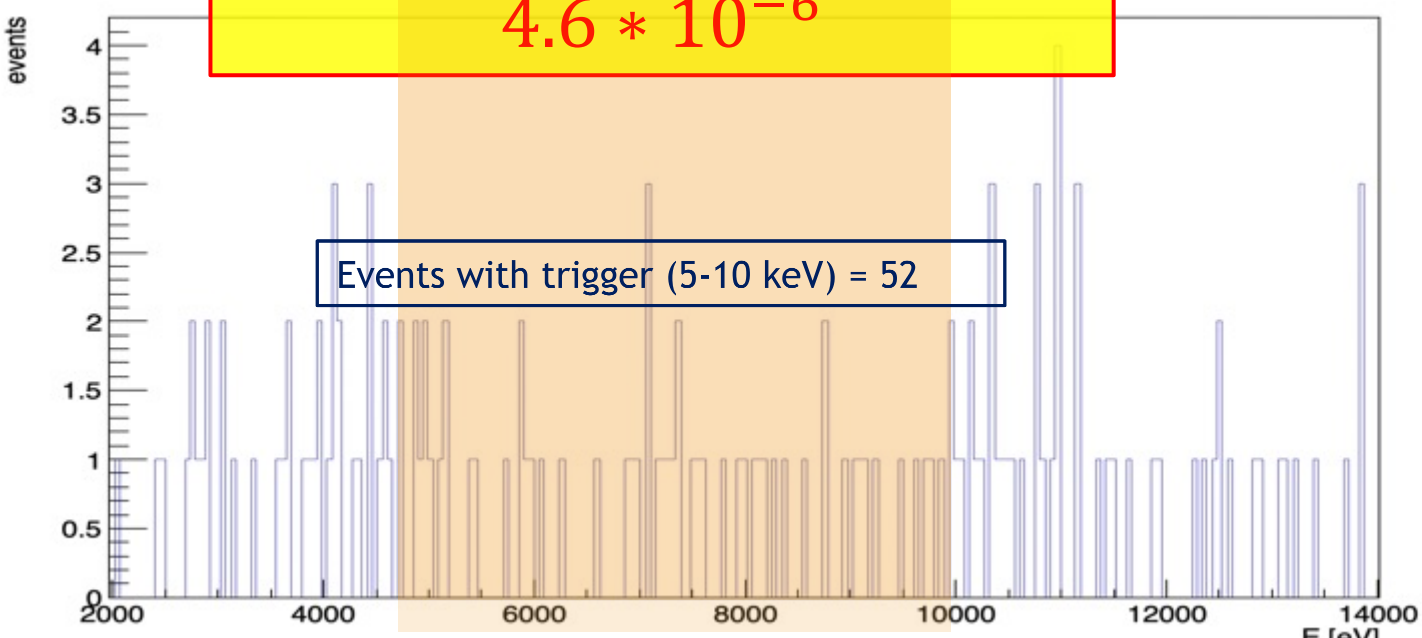


Trigger rejection factor



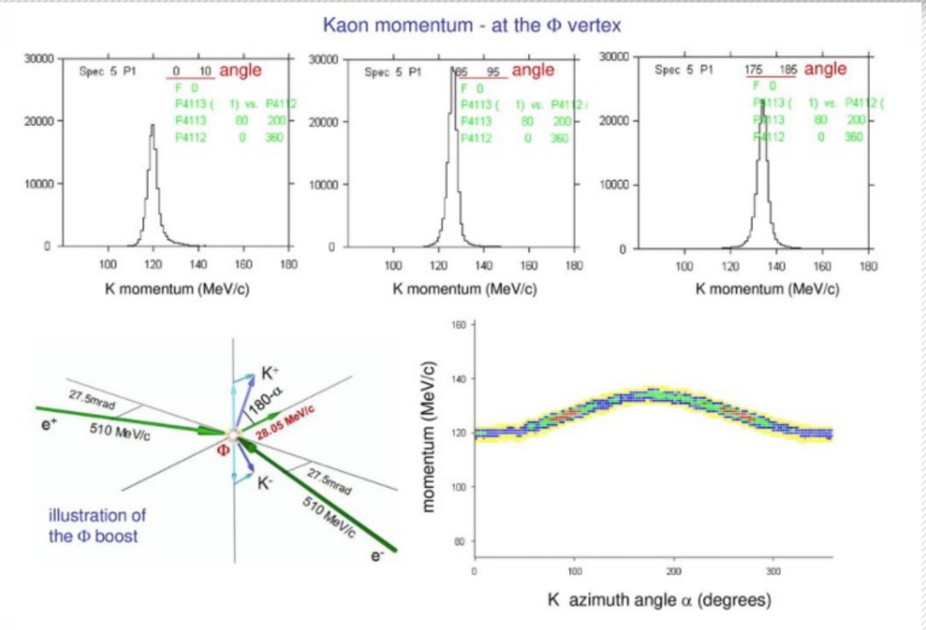
Sum of all SDDs after individual calibration

Triggered rejection factor $4.6 * 10^{-6}$

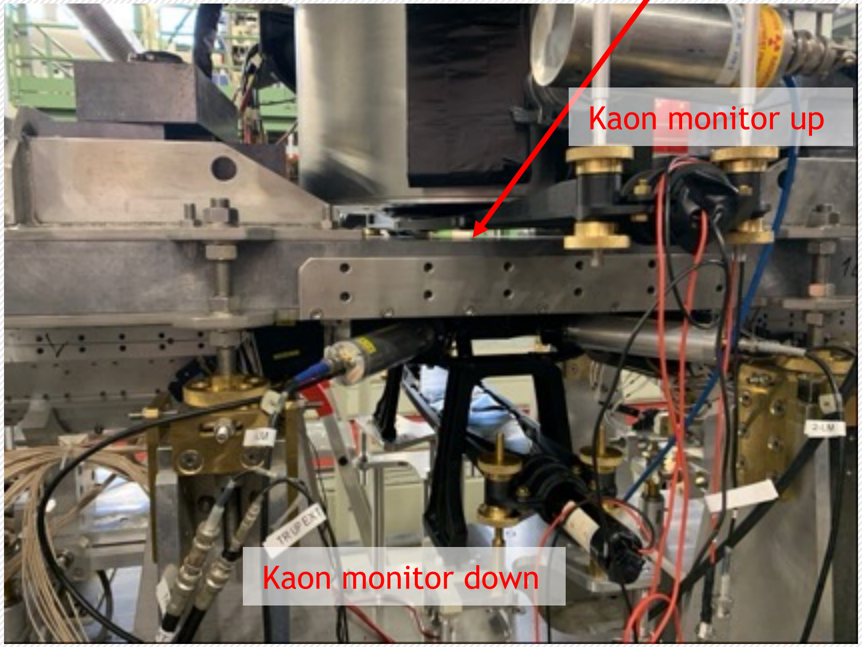


Sum of all SDDs after trigger cut

Degrader Optimization

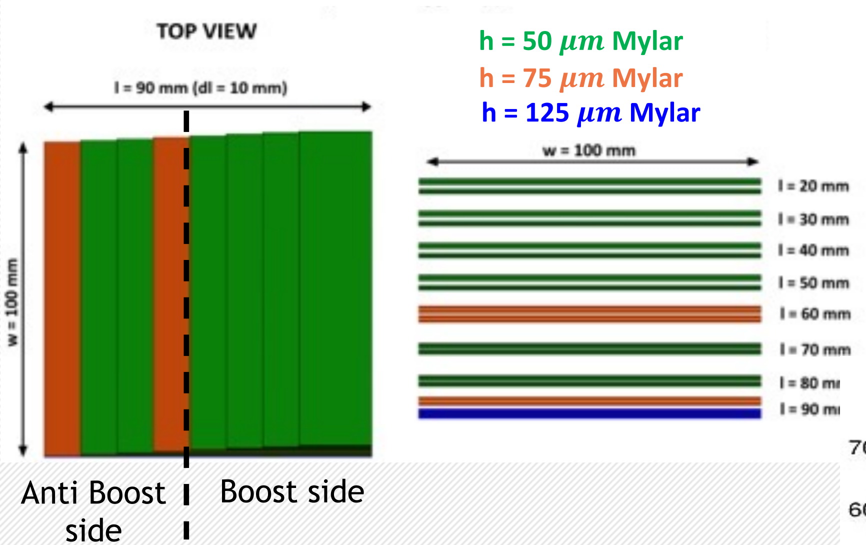


the degrader is composed of mylar foil (micron) and is placed below the kaon monitor up



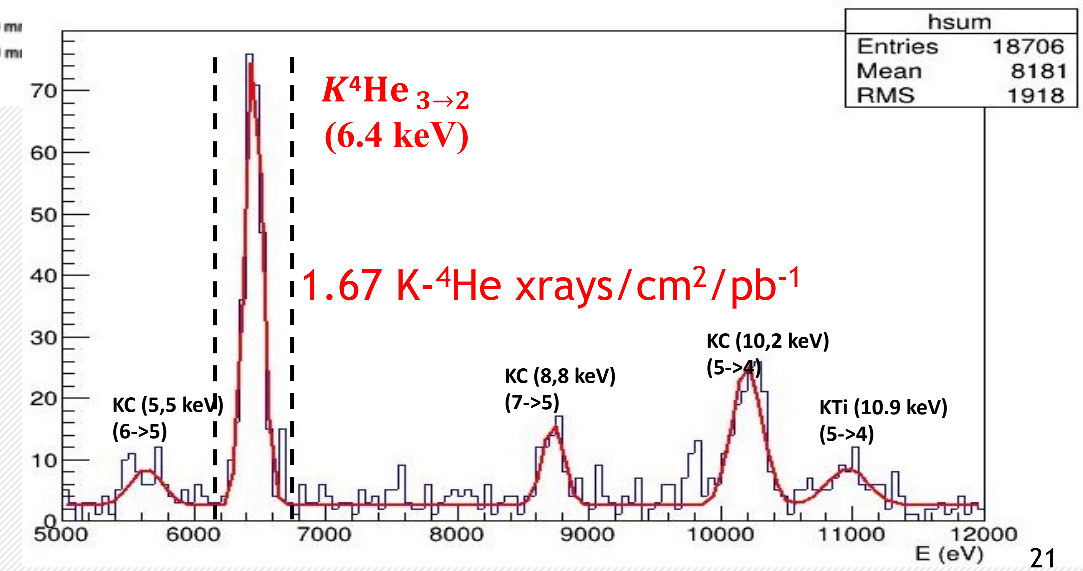
Degrader thickness optimization is fundamental to maximize the number of stopped kaons in the target

Degrader-1: middle thickness 550 μm



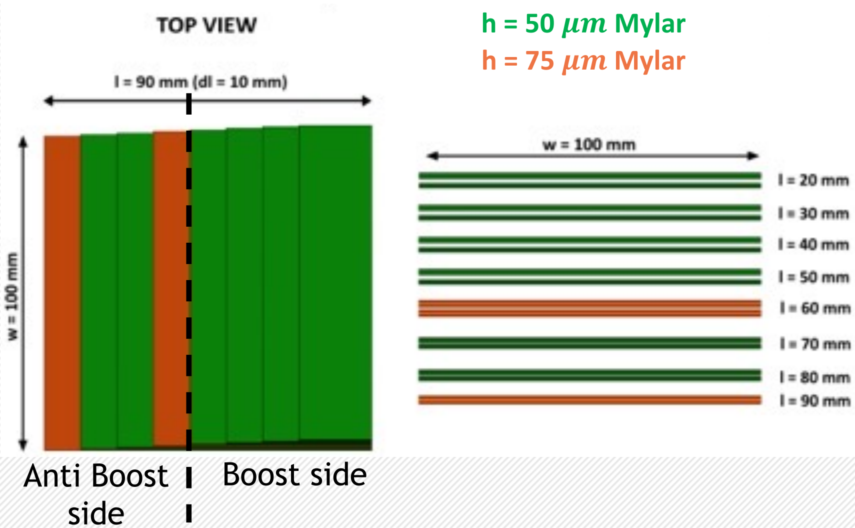
Degrader

Luminosity integrated = 6.758 pb^{-1}



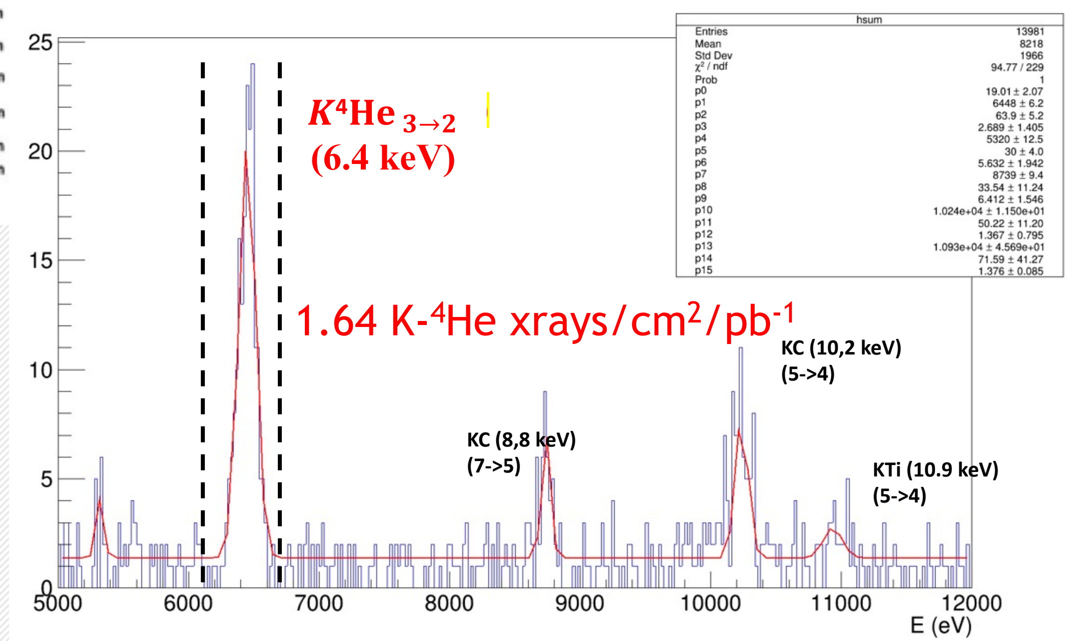
Degrader-2: middle thickness
425 μm

SIDDHARTINO DEGRADER #2 (8 step $-$ 125 μm)



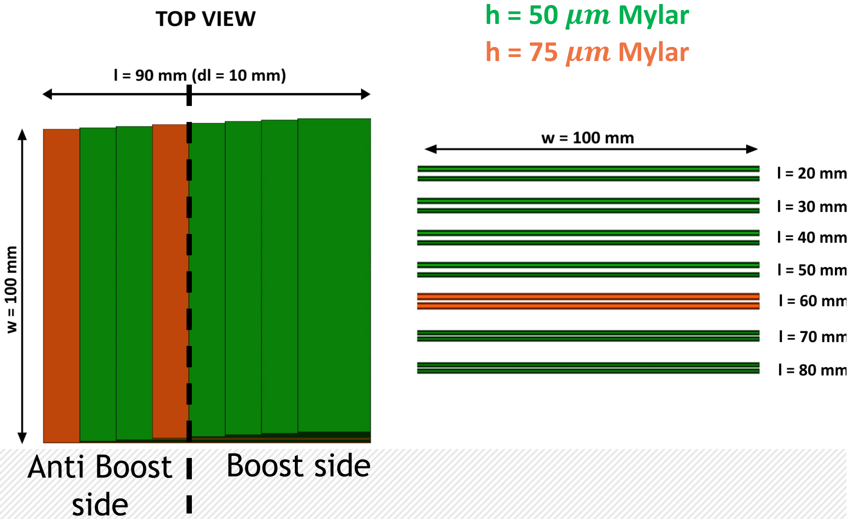
Degrader

Luminosity integrated = 4.577 pb^{-1}



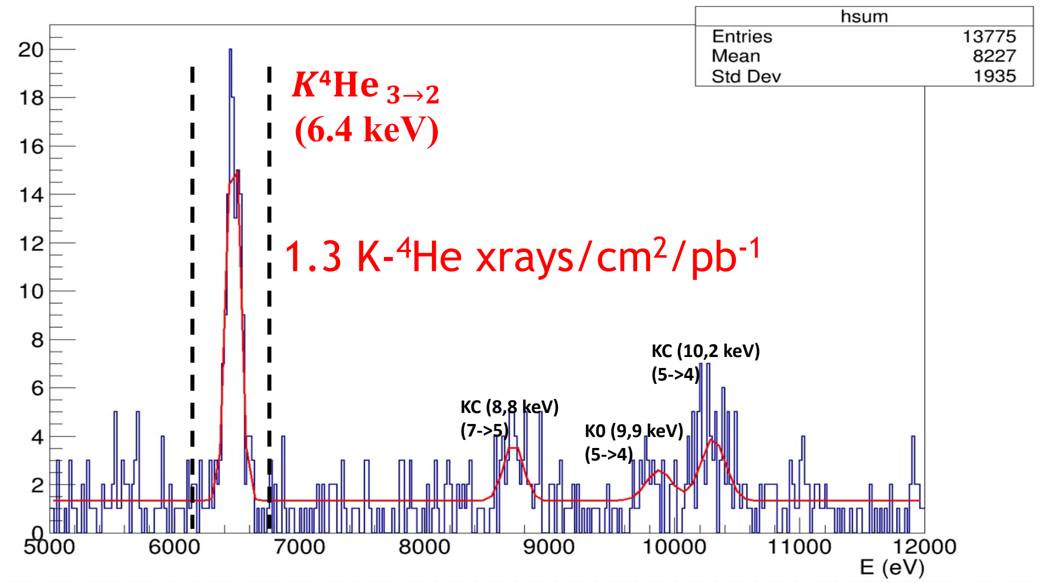
Degrader-3: middle thickness 350 μm

SIDDHARTINO DEGRADER #3 ($\mathbf{8\ step - 125\ \mu m\ - 75\ \mu m}$)



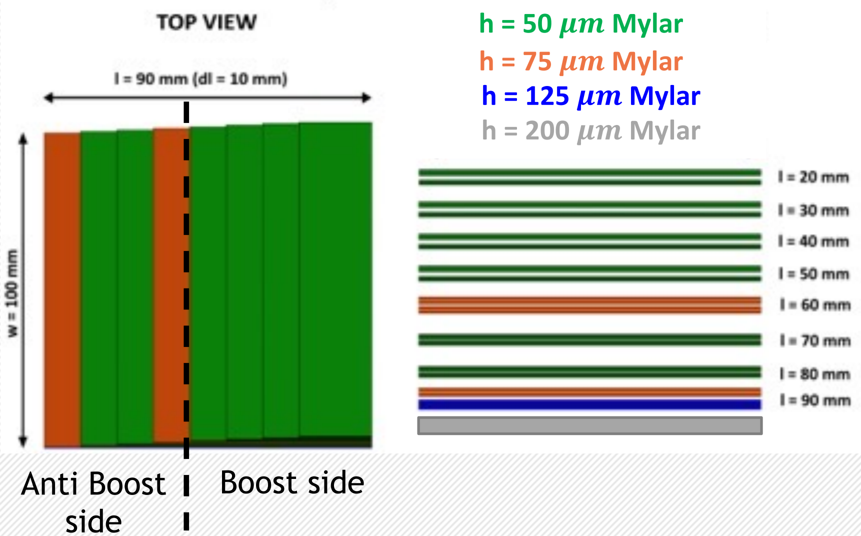
Degrader

Luminosity integrated = 5.219 pb^{-1}



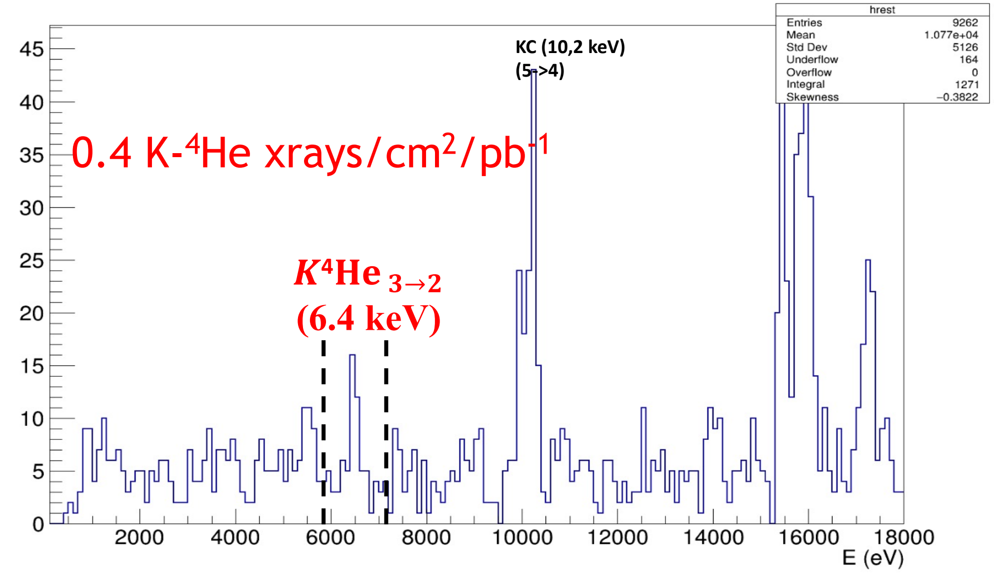
Degrader-4: middle thickness 750 μm

SIDDHARTINO DEGRADER #4 (8 step + 200 μm)

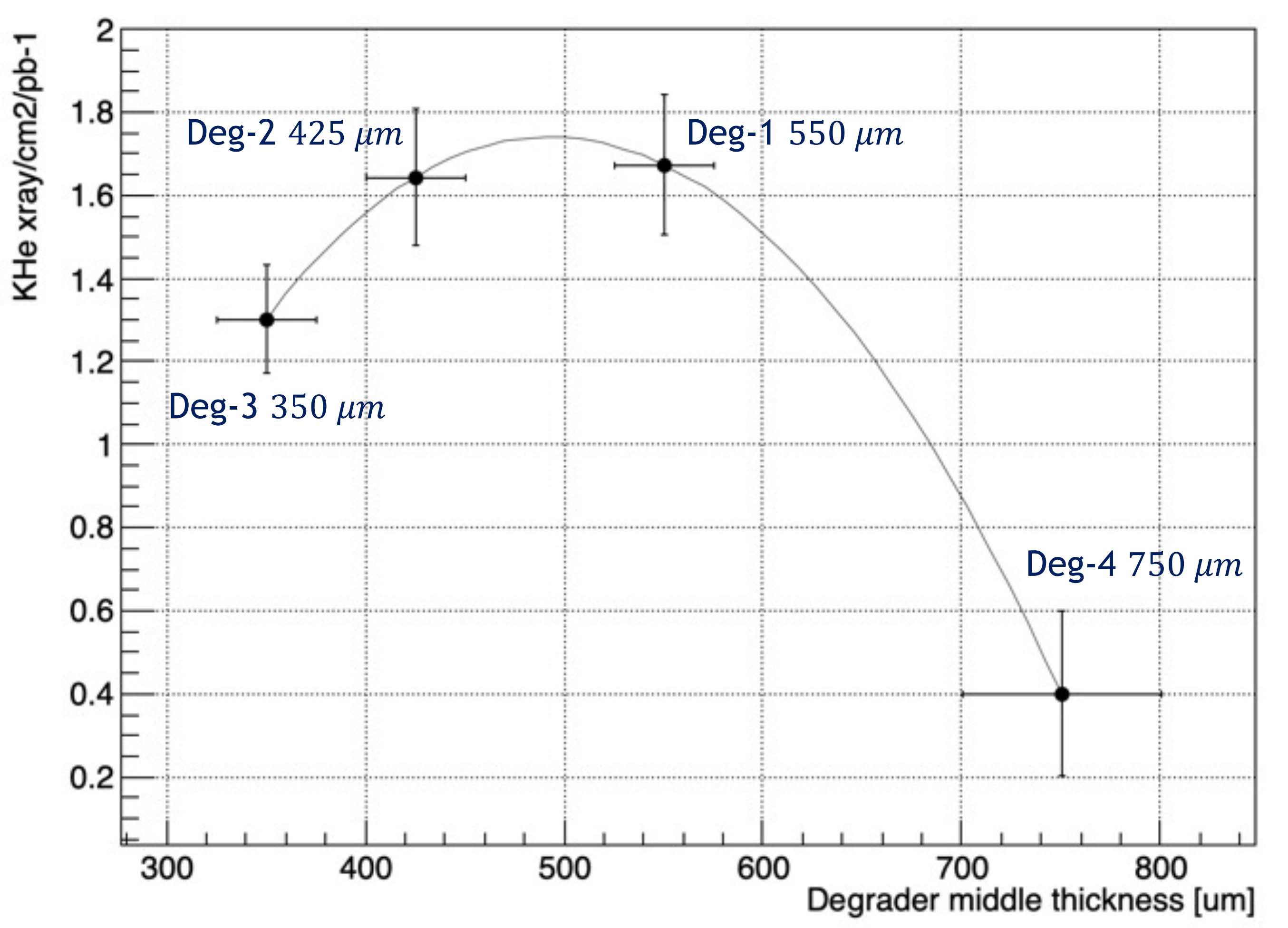


Degrader

Luminosity integrated = 4.753 pb^{-1}

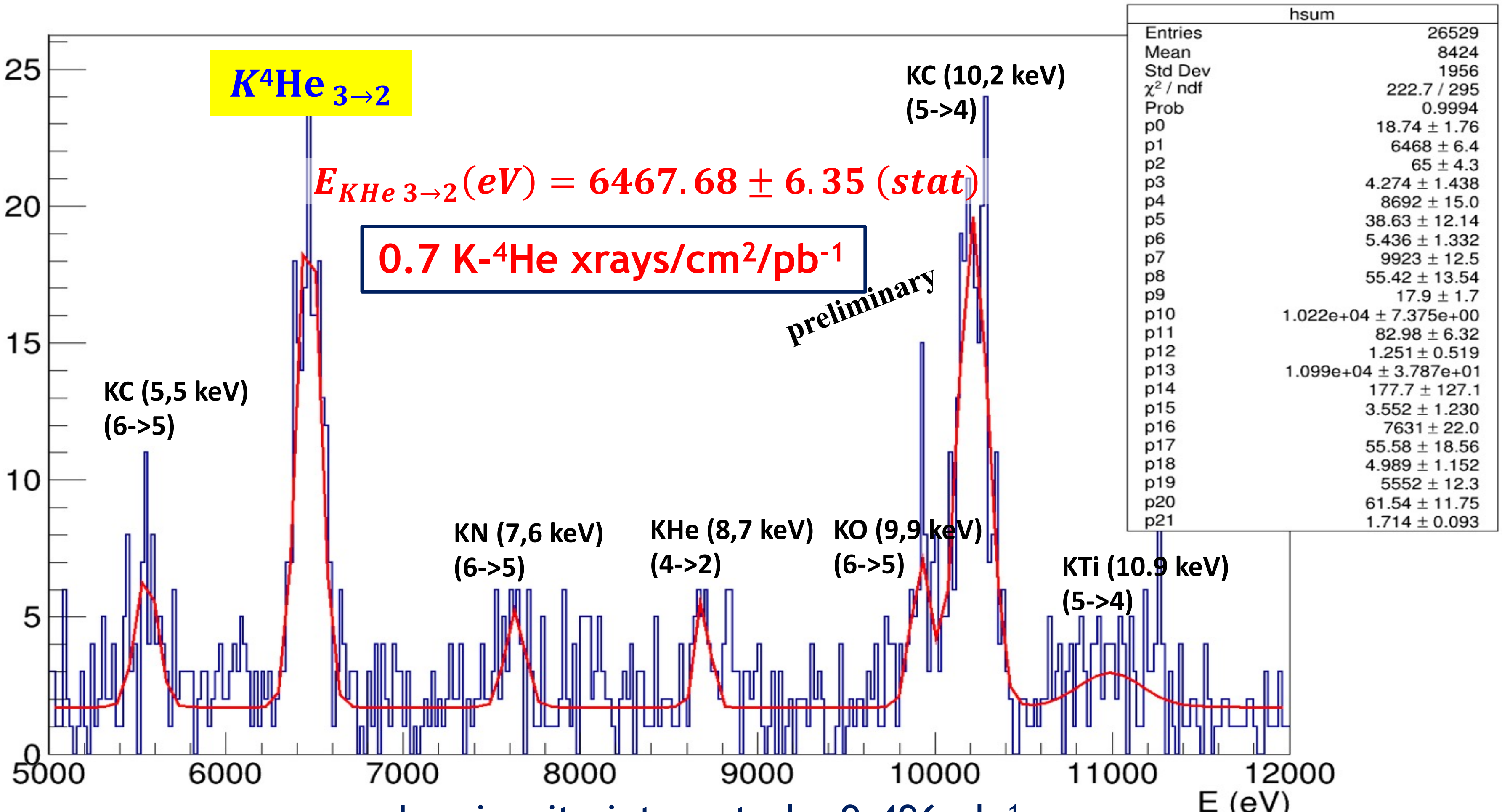


Degrader Curve



SIDDHARTINO - K-^{4}He run

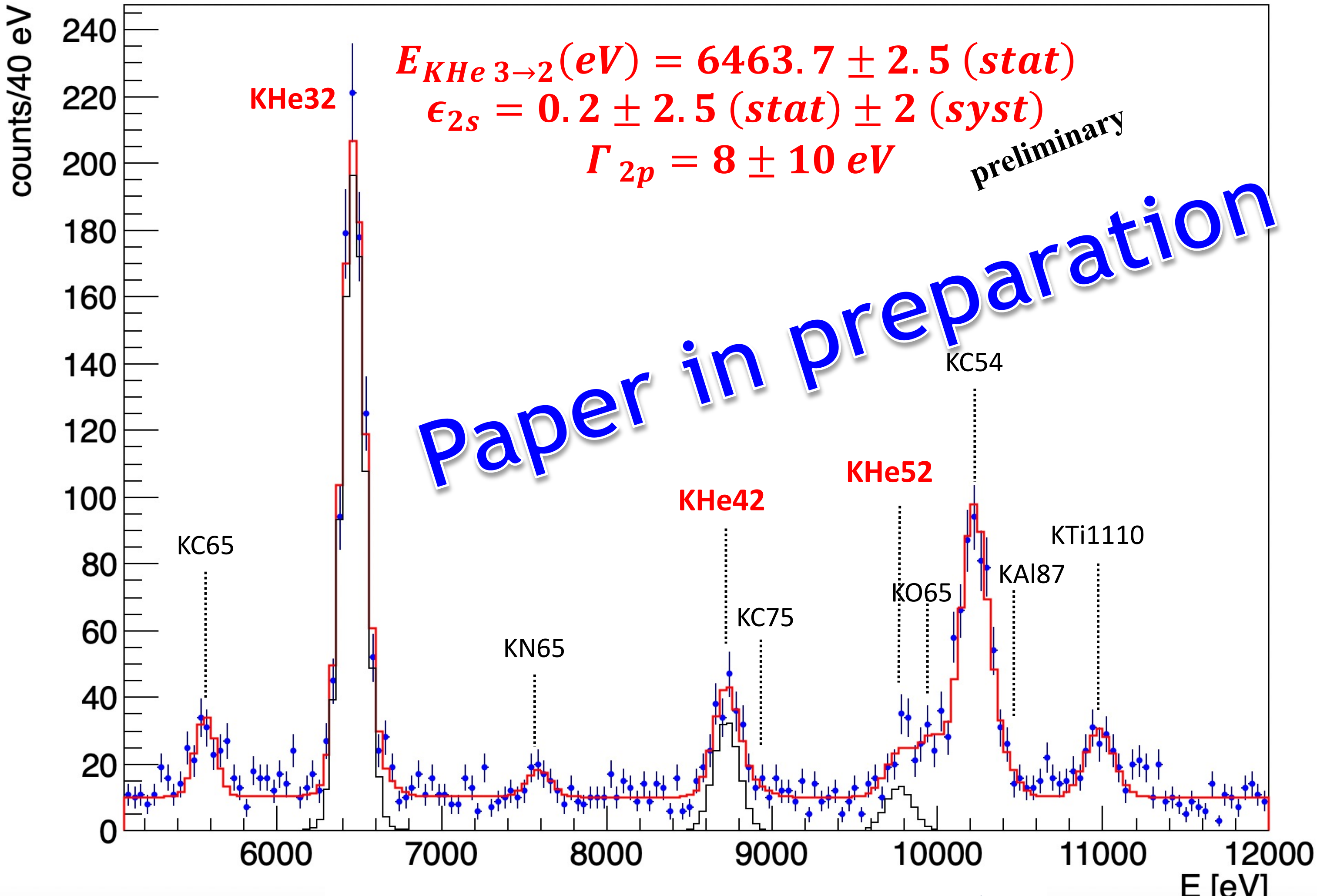
K-^{4}He low density run: 0.75% liquid helium density -> **yields at lowest measured density analyses undergoing -> paper**



Luminosity integrated = 9.496 pb^{-1}

SIDDHARTINO - K-^{4}He run

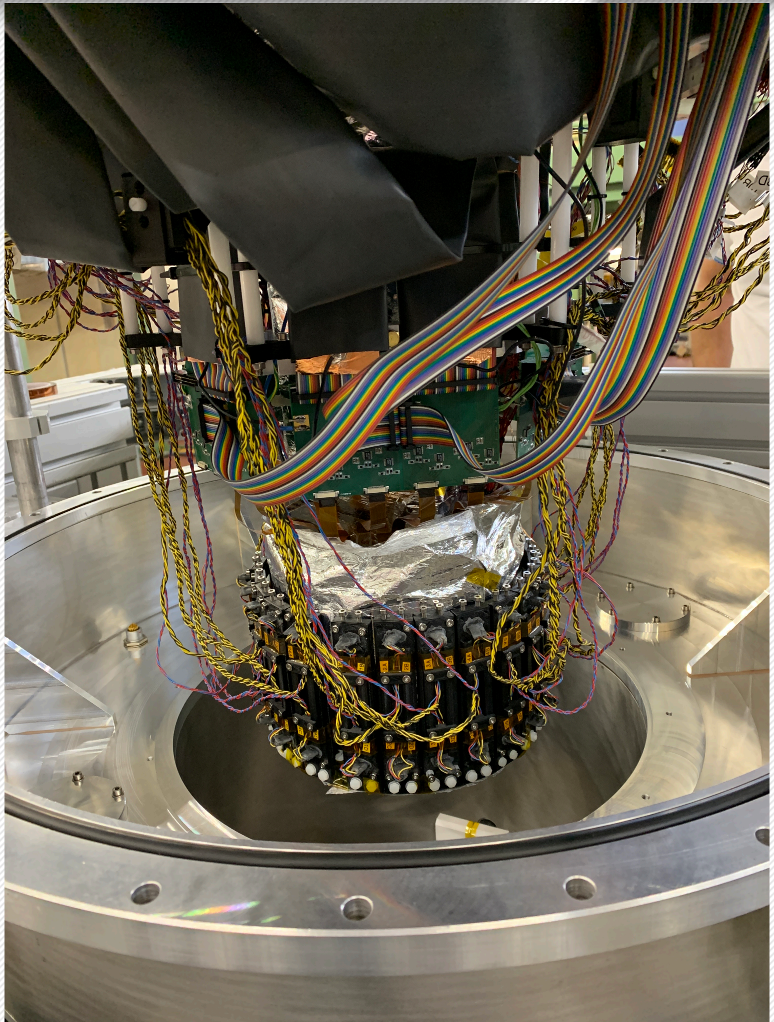
K-^{4}He shift and width:
the most precise measurement in gas!



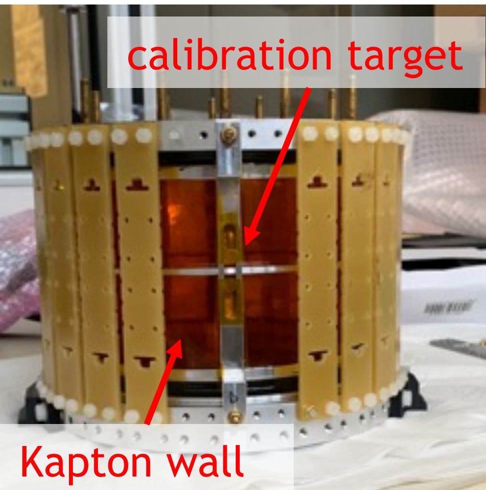
Luminosity integrated = 26.05 pb^{-1}

Report on main activities in DAΦNE towards **SIDDHARTA-2**

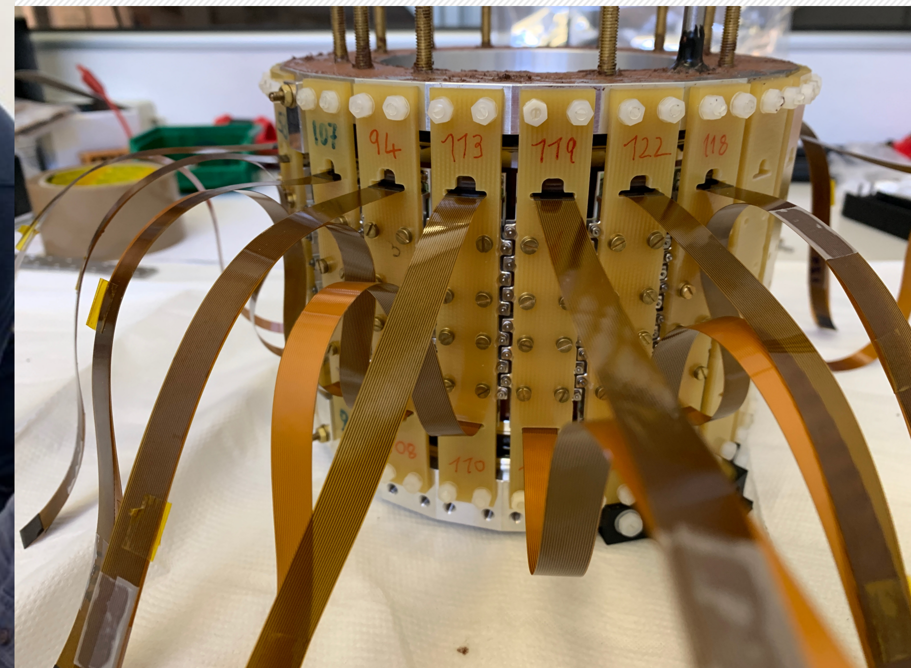
- **SDD detectors installation**
- **Veto-2 installation**
- **Front-end electronic installation**
- **Veto-1 installation**



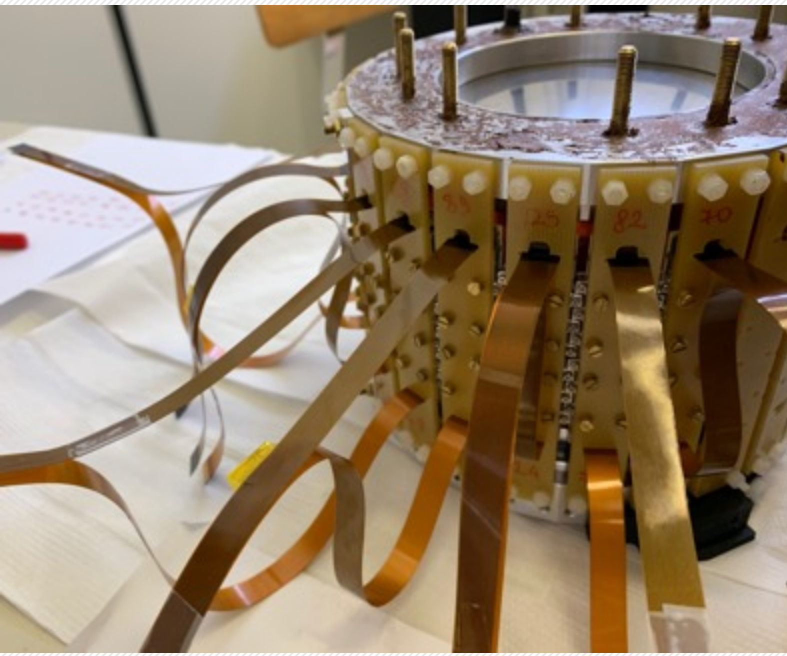
SDD installation



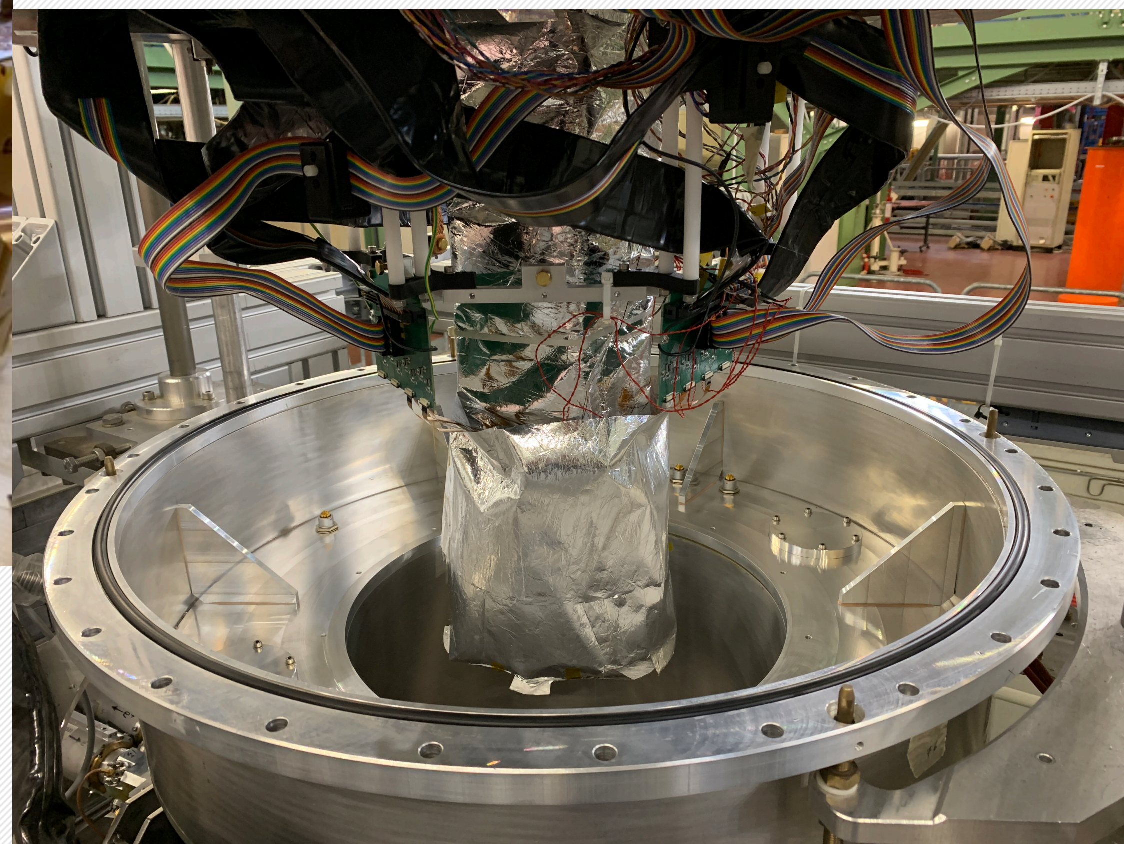
SDD installed around the target



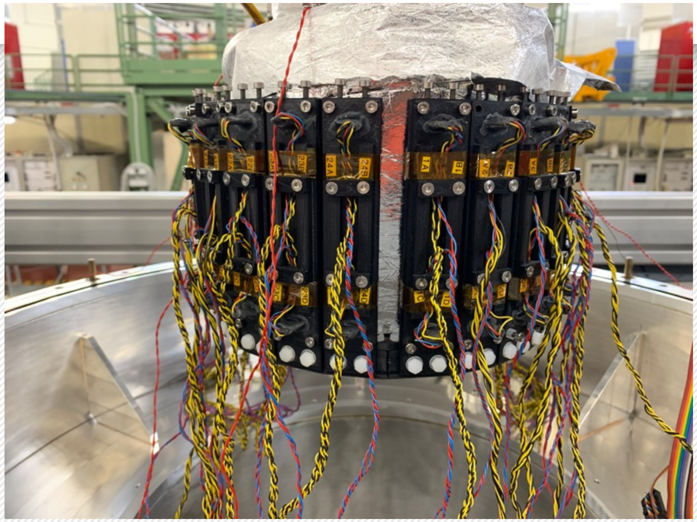
SDD installation

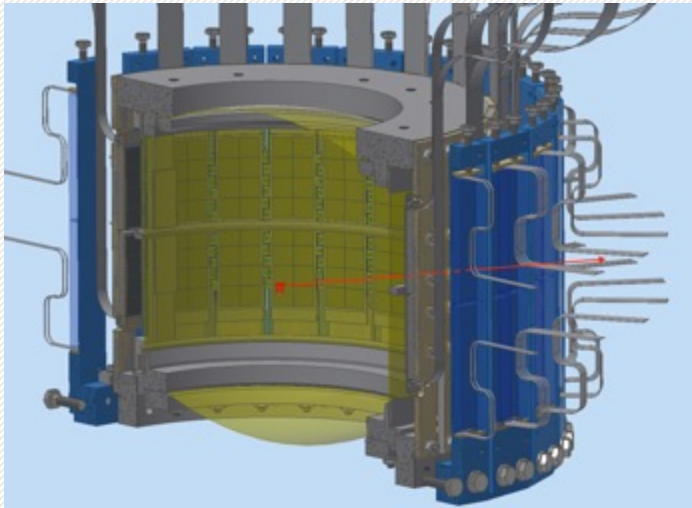


Wrap for thermal isolation

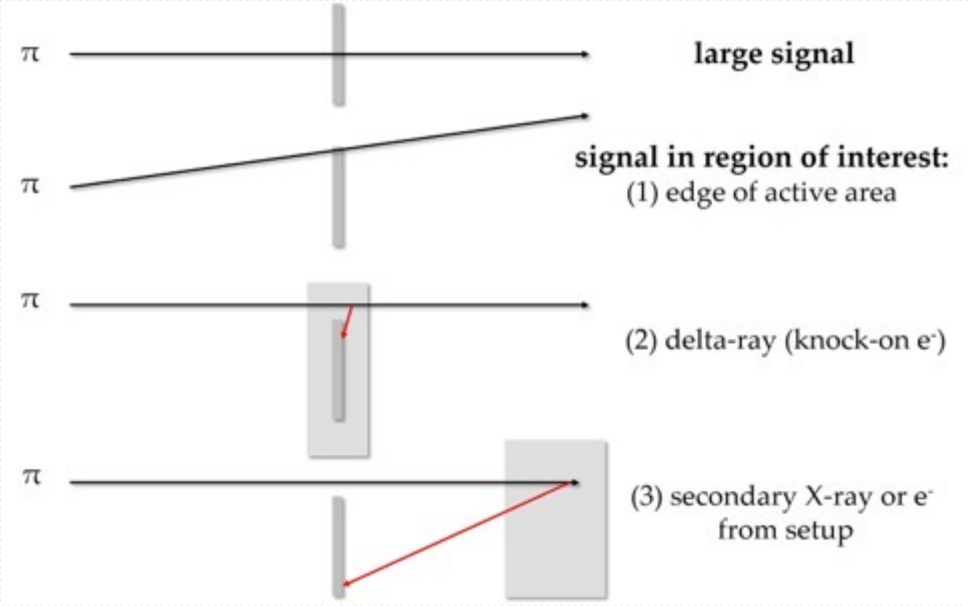


Veto-2 installation

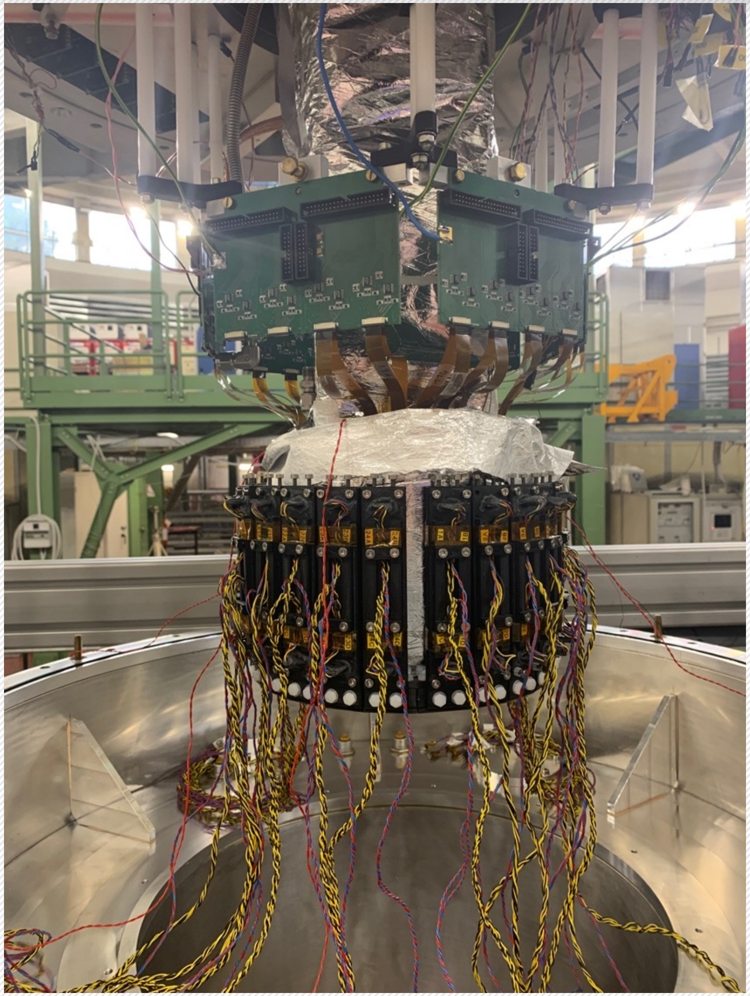




Working principle of veto-2 system



Veto-2 installation

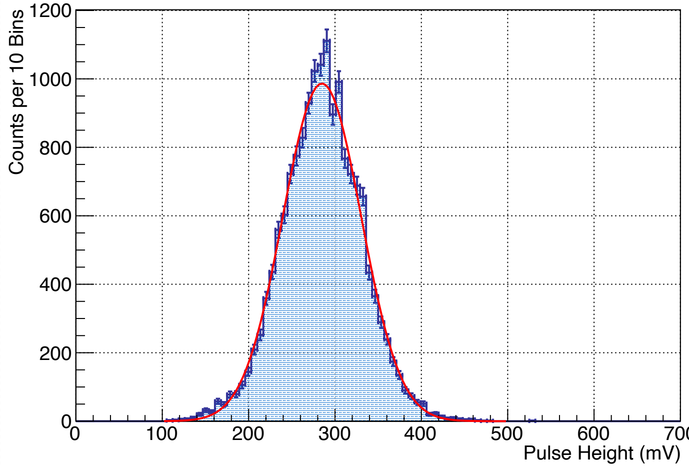


- The installation of veto 2 has been completed and the correct operation of each unit has been verified

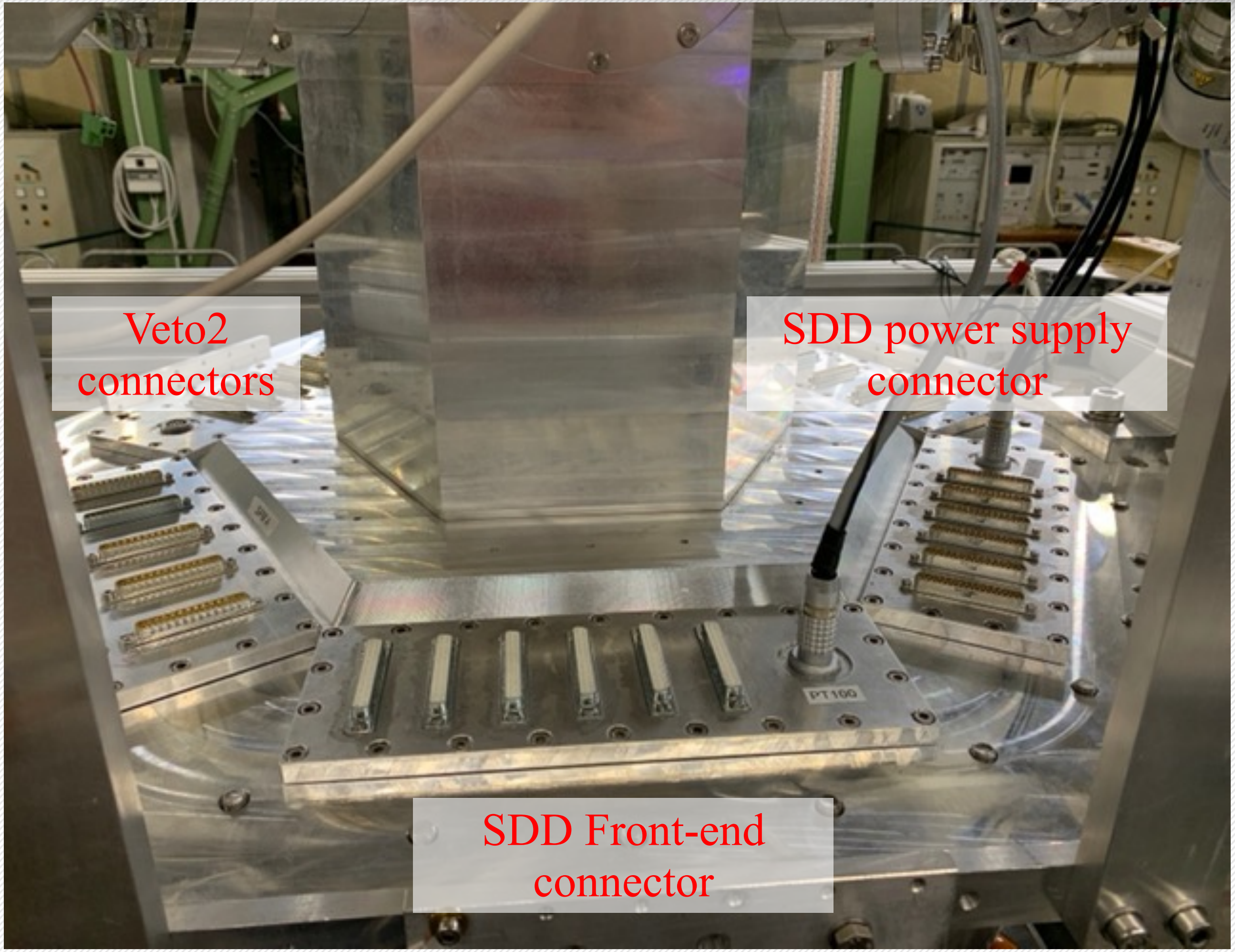
- Each veto-2 unit is equipped with an LED that will allow to calibrate and verify the correct functioning of the system with and without beams

Veto-2 single unit

Veto-2 Calibration spectrum



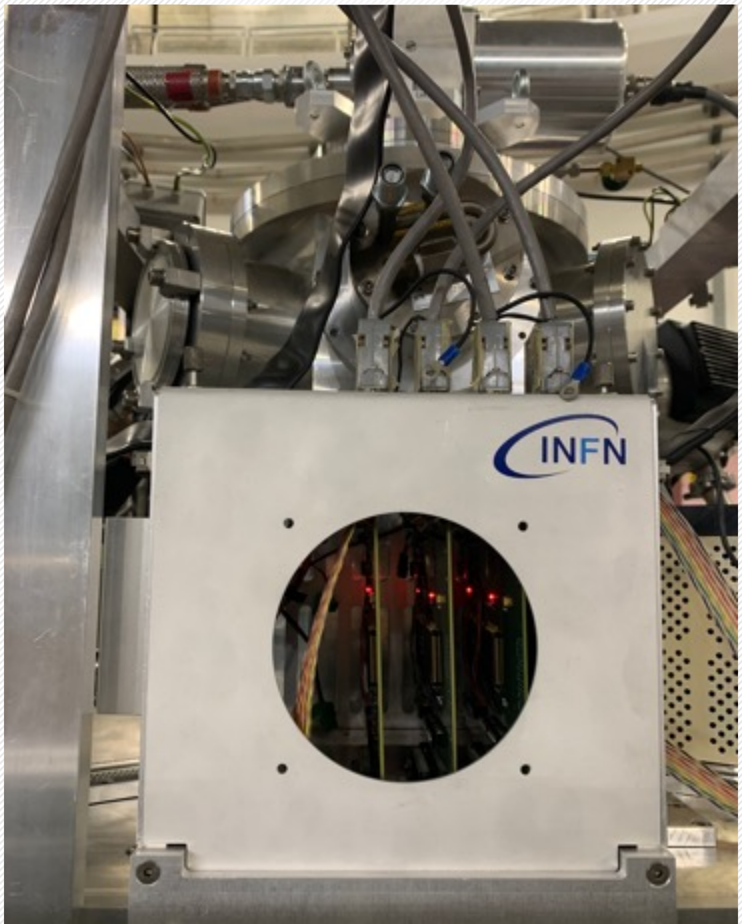
Front-end electronics installation



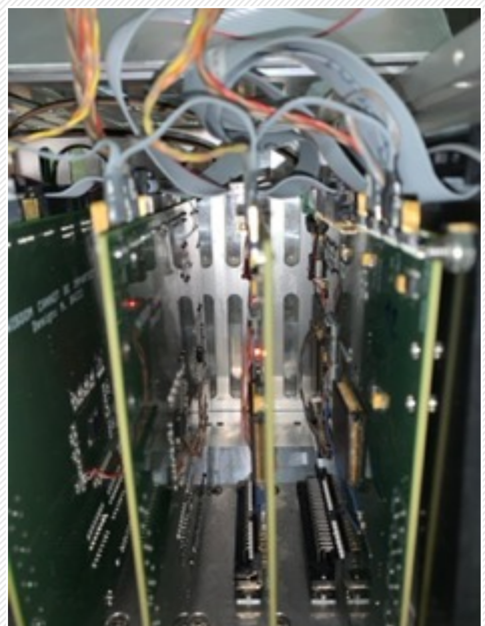
SIDDHARTA-2 setup before the installation of electronic components

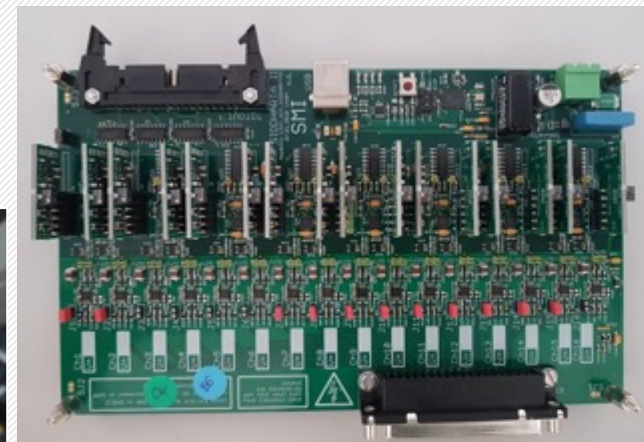
Front-end electronics installation

Electronic Box



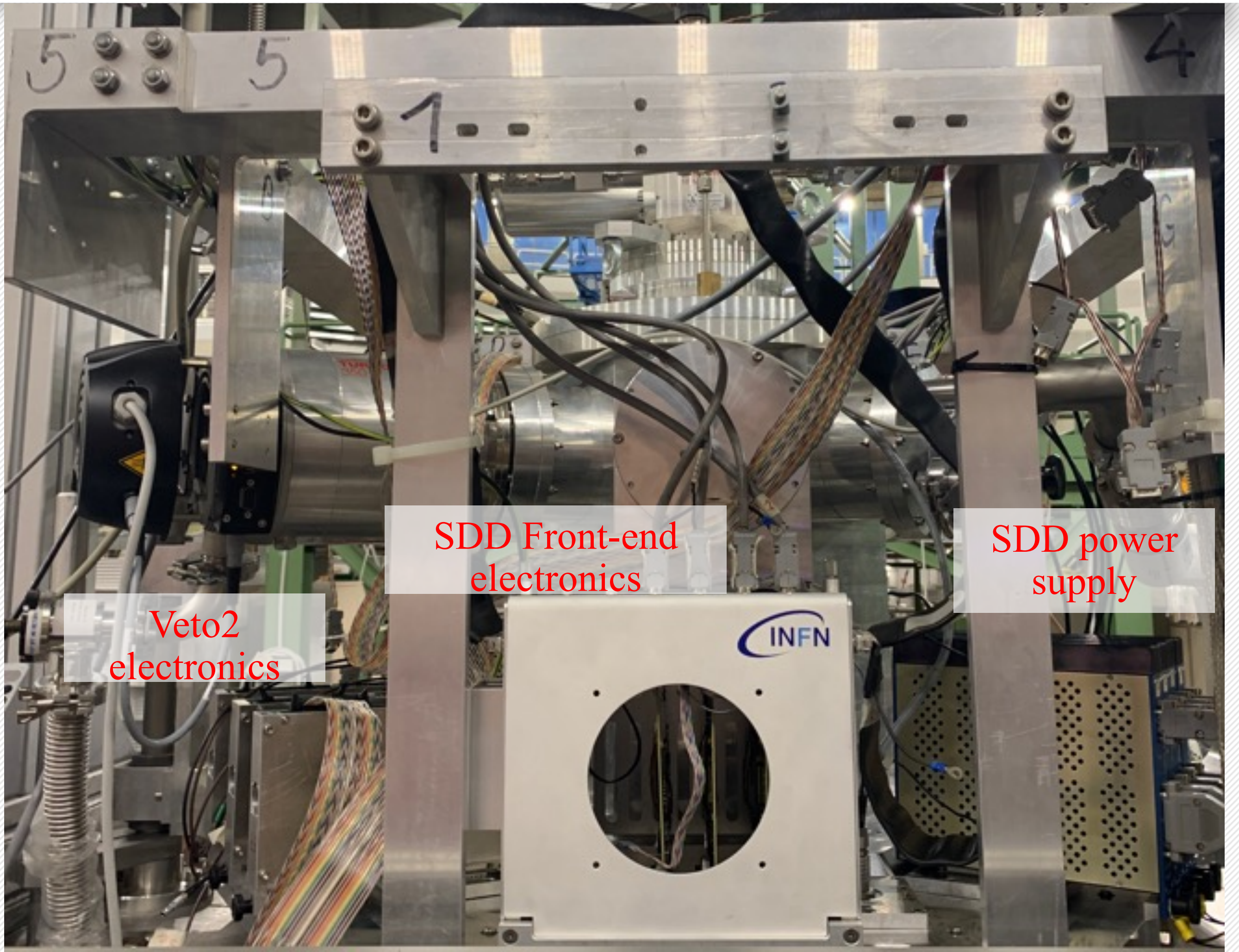
SDD Front-end
electronics



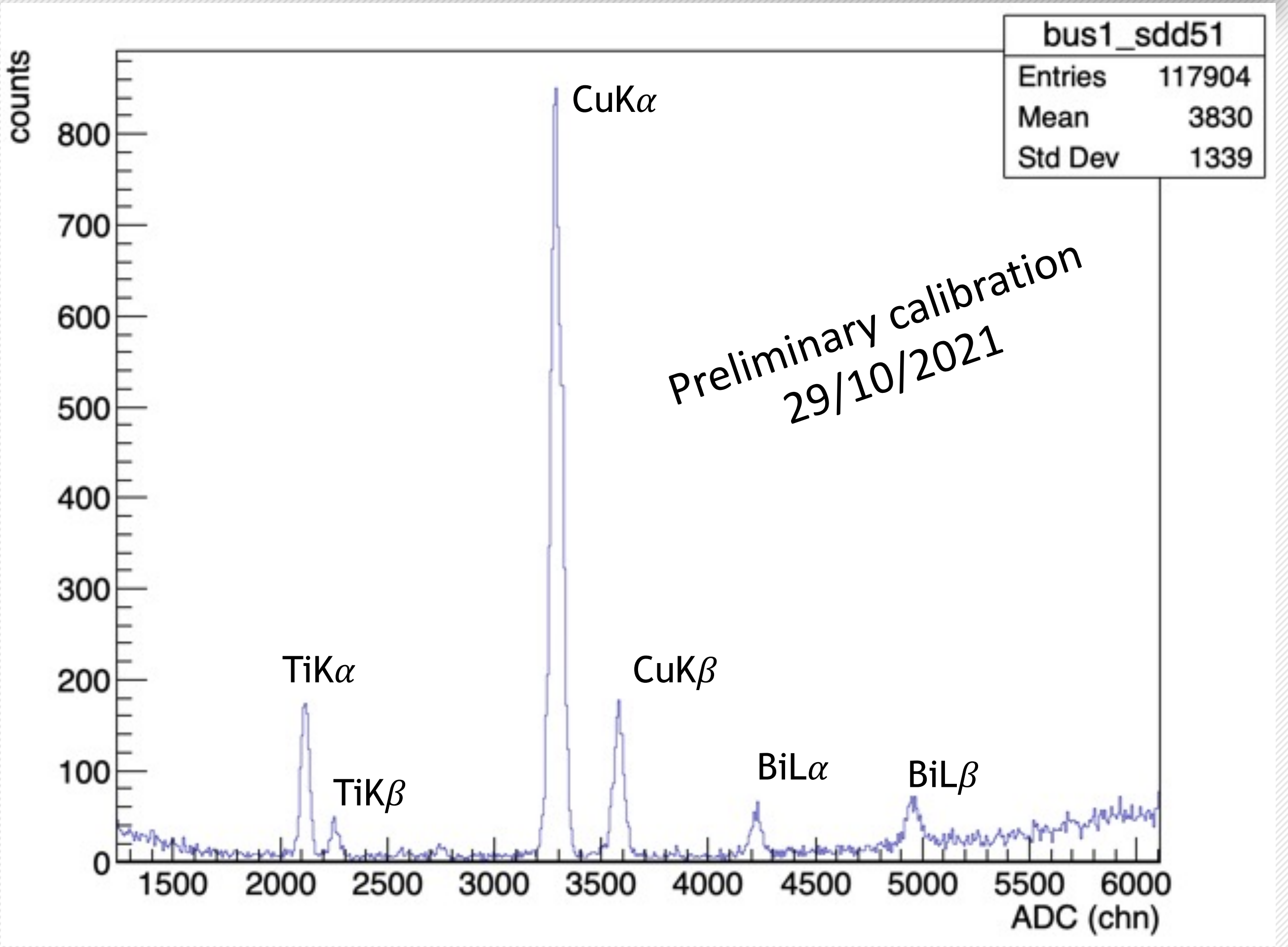


Veto-2
Front-end electronics

Front-end electronics installation

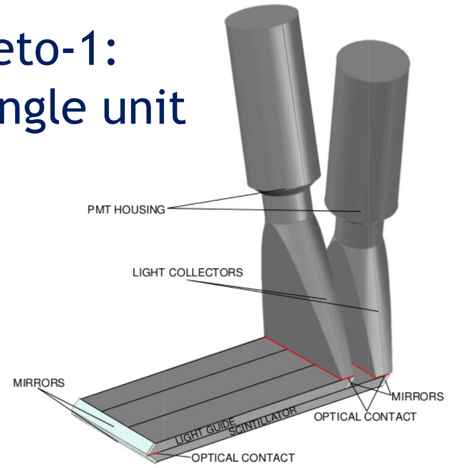


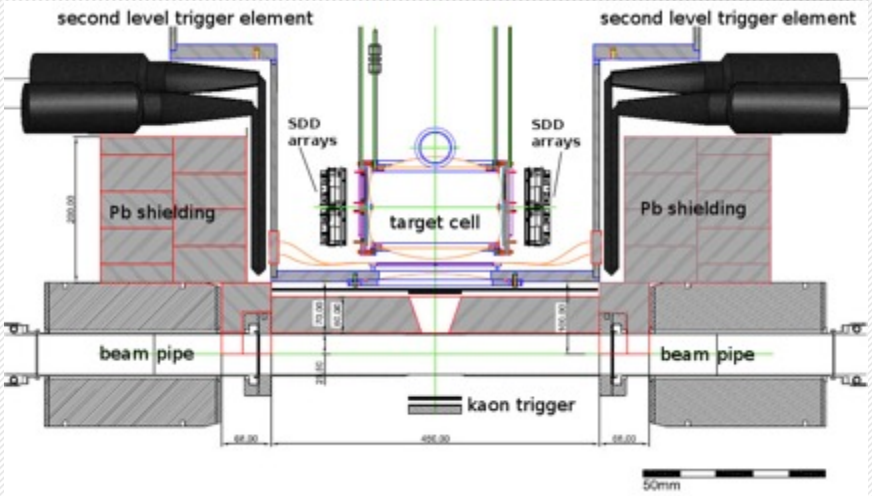
SDD calibration spectrum acquired with SIDDHARTA-2



Veto-1 system installation

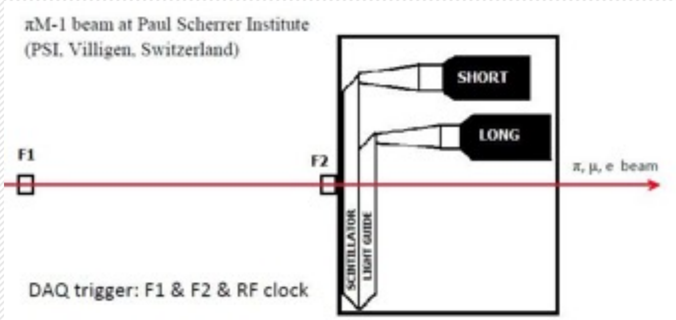
Veto-1: single unit





Drawing of the veto-1 elements placed around the vacuum chamber

Working principle of veto-1 system



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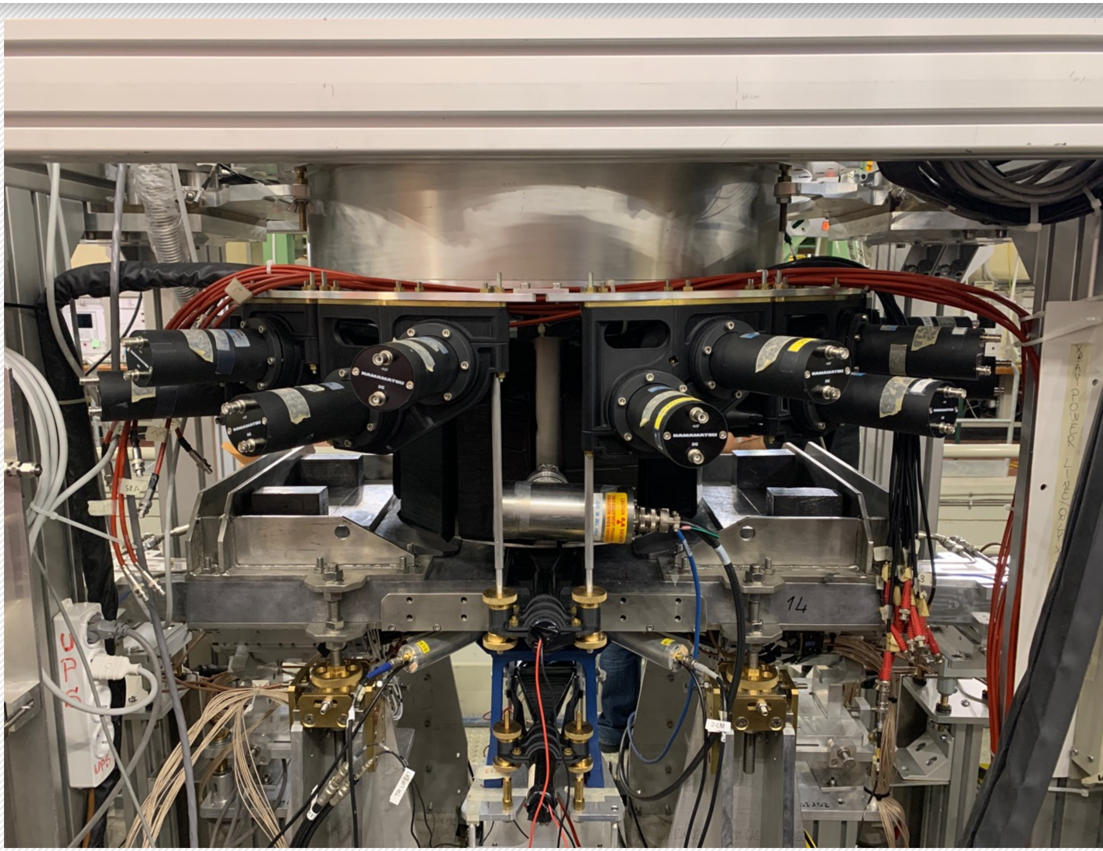
Veto-1 system installation

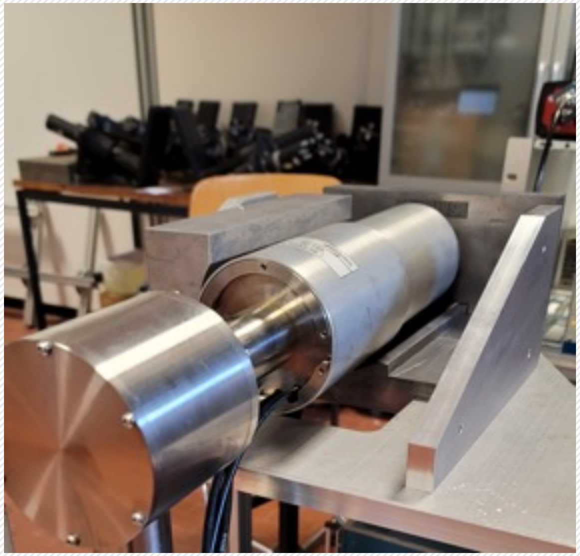


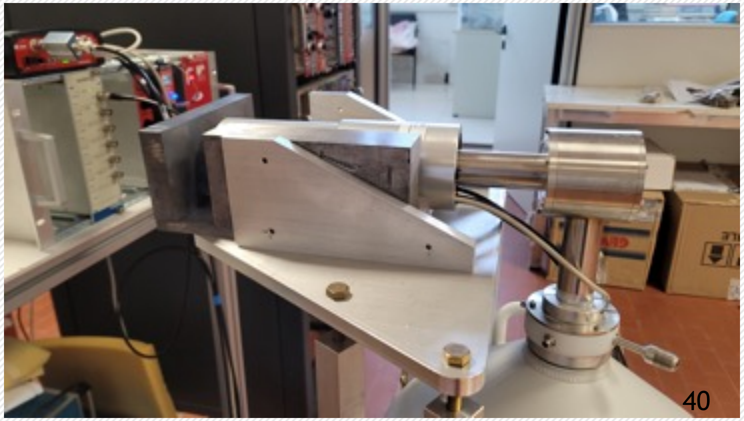
Veto-1 system installed around the vacuum chamber

SIDDHARTA-2 setup
Ready for Run

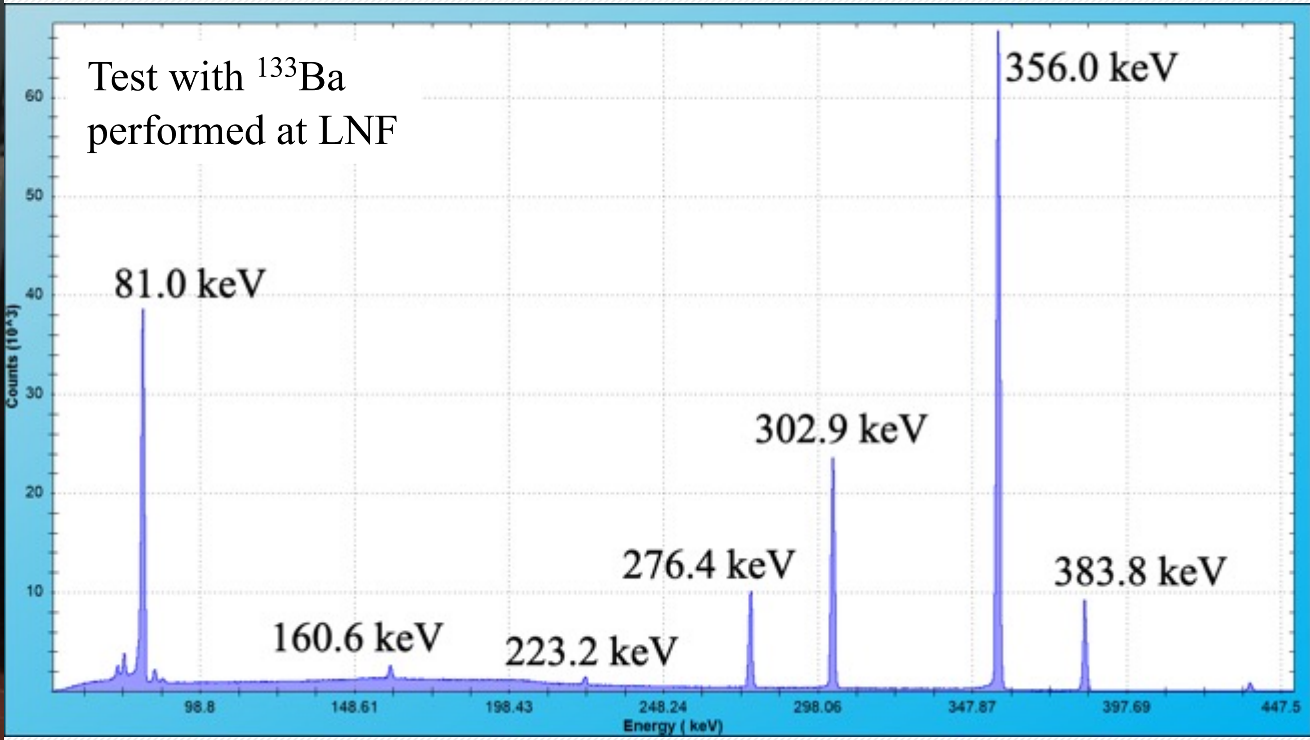
HPGe - feasibility test for the kaonic lead measurement

- HPGe detector available, Funded by University of Zagreb Croatian Science Foundation project 8570
- The HPGe has been transported to LNF from Zagreb
- Completed the installation of the support structure and the lead shielding

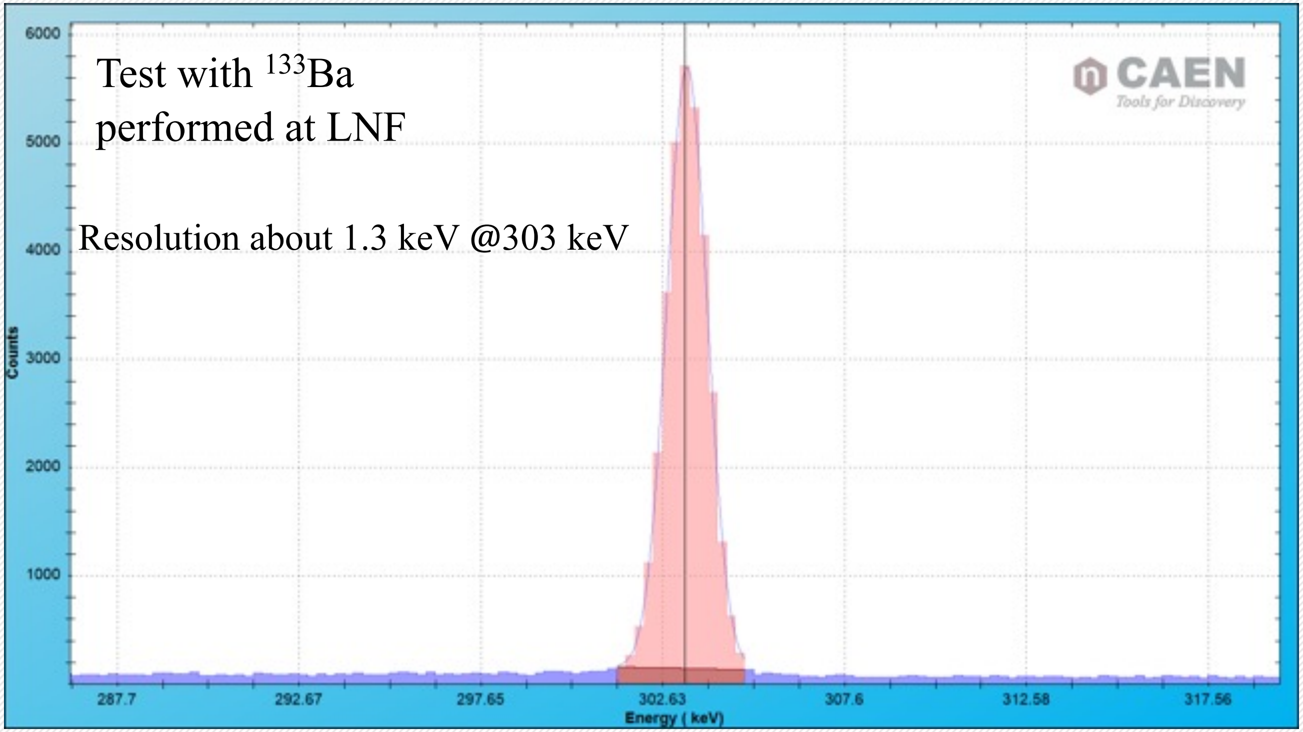




HPGe - feasibility test for the kaonic lead measurement

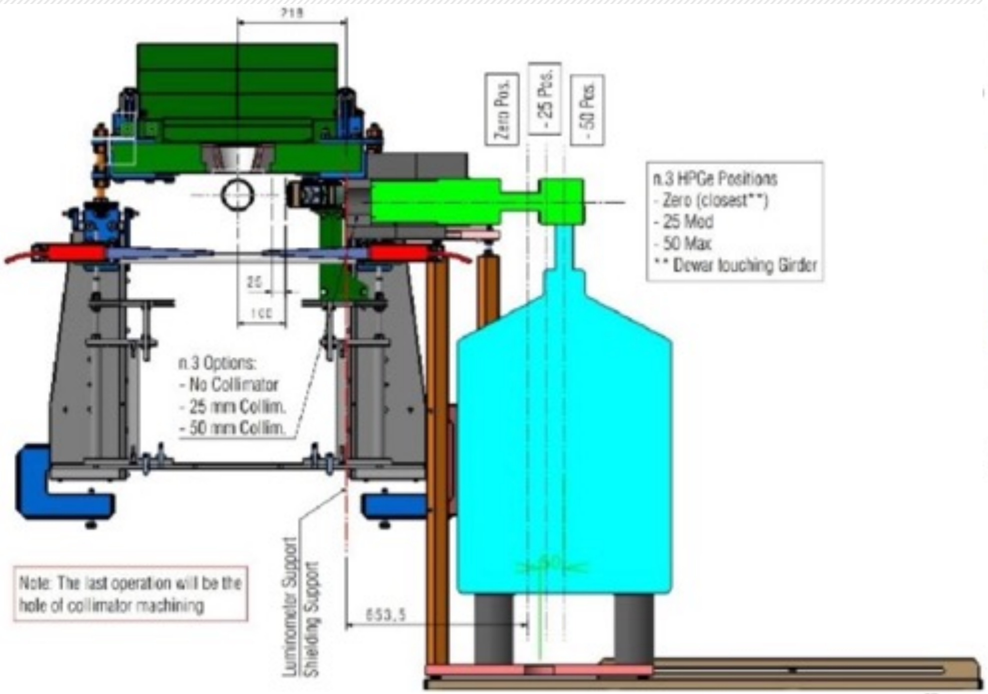


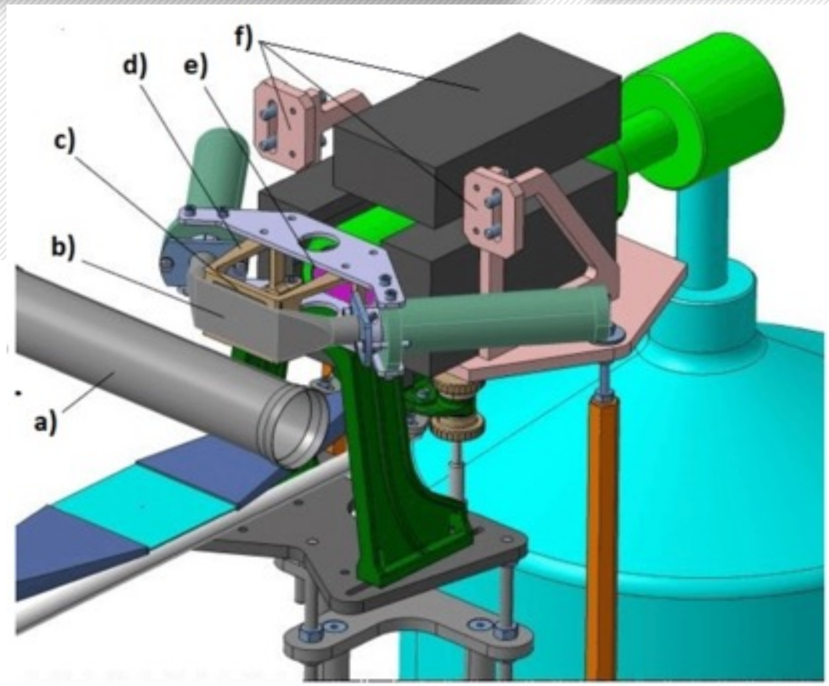
HPGe - feasibility test for the kaonic lead measure



HPGe - feasibility test for the kaonic lead measurement

schematic representation of the apparatus, that will be installed in the DAΦNE hall





The layout of the HPGe setup: (a) beam pipe, (b) luminometer, (c) target, (d) target holder, (e) active part of the HPGe detector, (f) lead shielding with the holder (figure done by C. Capoccia, LNF).

HPGe detector ready to be install in the DAΦNE hall

Project timeline - future

SIDDHARTA-2 Kd run: run 1 (300 pb^{-1})
run 2 (500 pb^{-1}) with optimized components

Start of the data taking with ^4He to check run condition with respect to SIDDHARTINO run

Installation of SIDDHARTA-2 setup

2021, September - October

Start Run SIDDHARTA-2 and HPGe parasitic test

2021, November

DAΦNE shutdown for winter holiday

2021, December

Continue the run SIDDHARTA-2

Kd

HPGe

2022, from January through all 2022

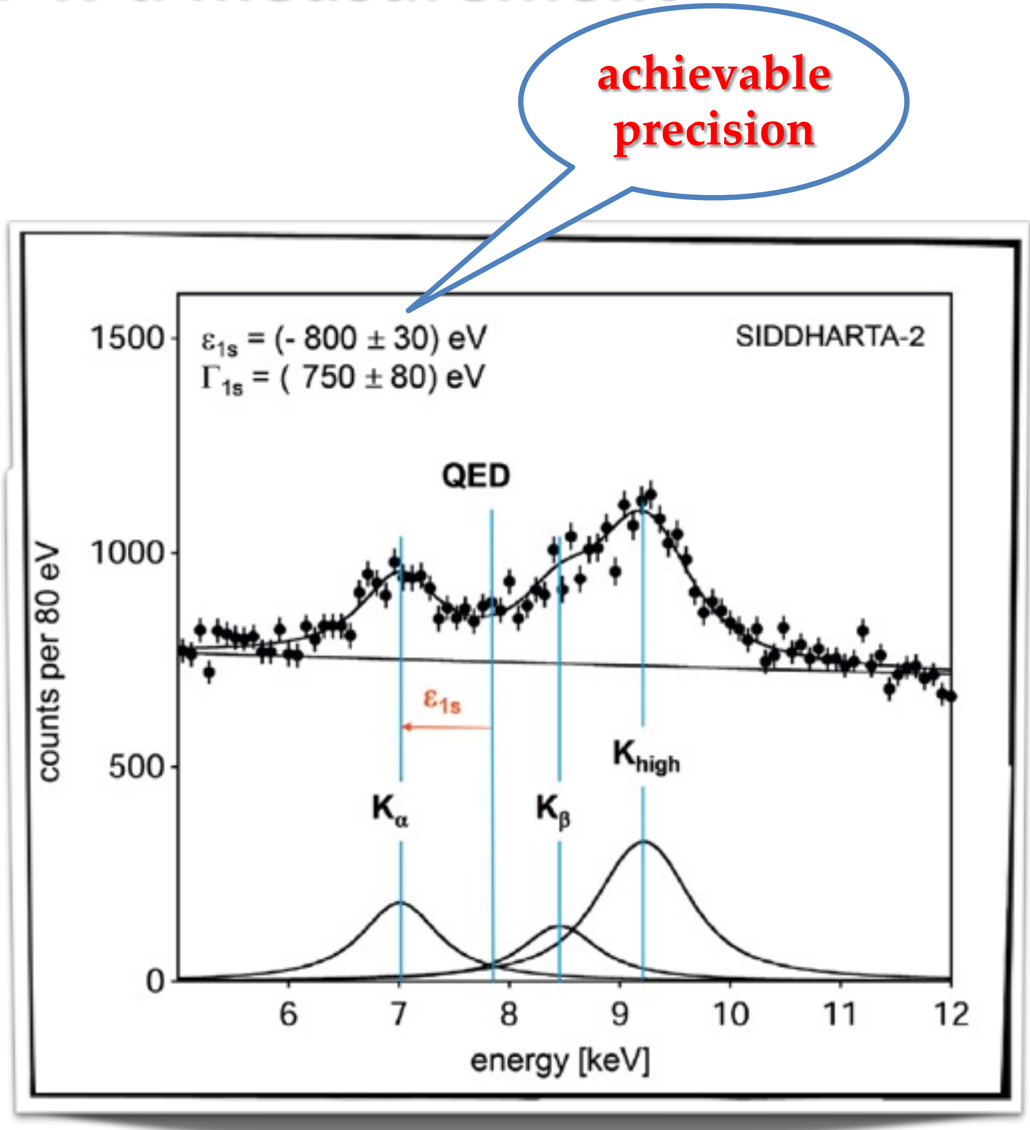
SIDDHARTA-2 K-d measurement

Kaonic deuterium run in (all)

2022

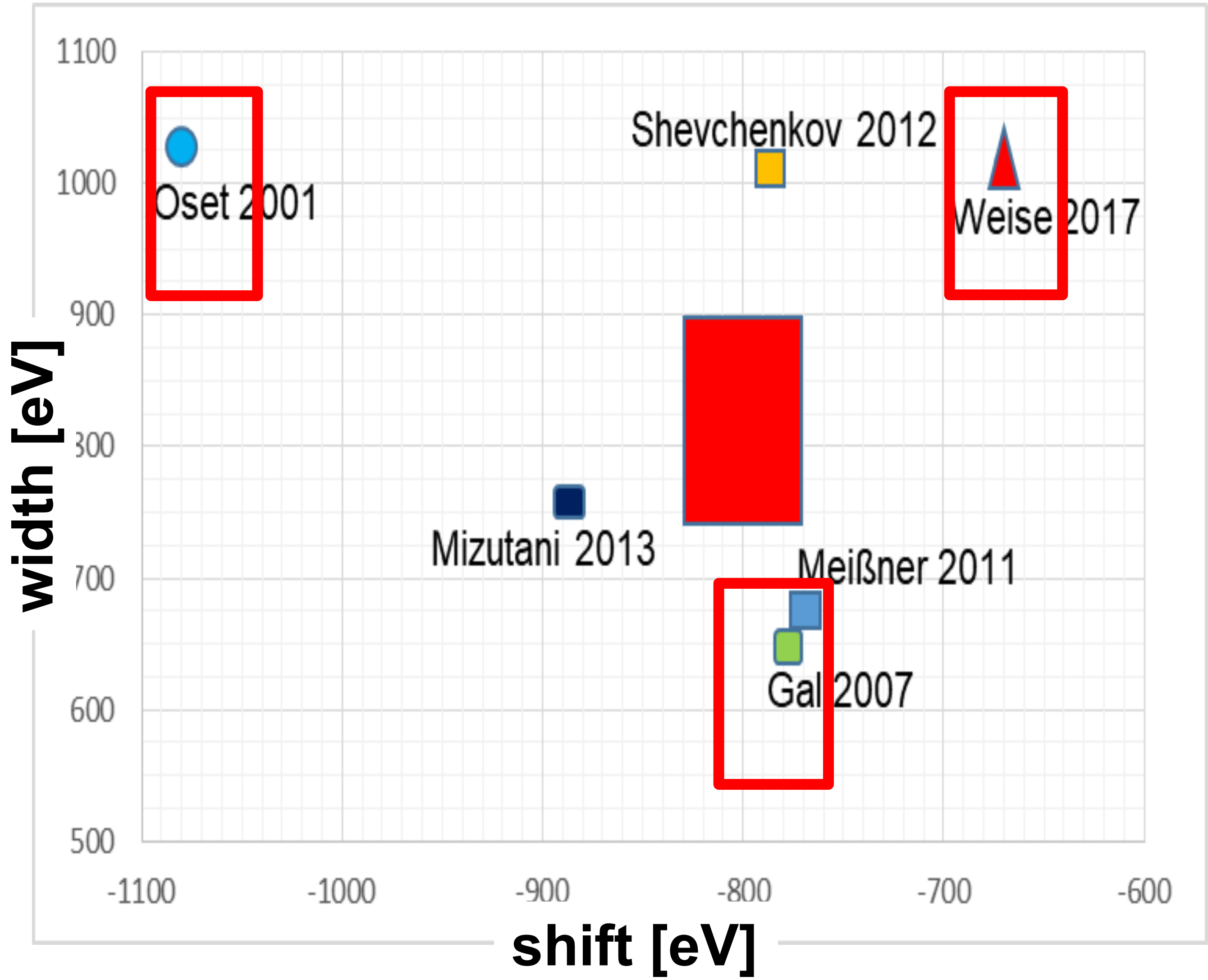
Monte Carlo for an integrated luminosity
of 800 pb^{-1}

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) !

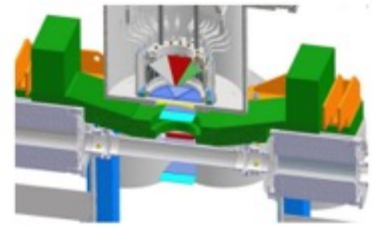


Significant impact in the theory of strong interaction with strangeness

SIDDHARTA-2 kaonic deuterium at DAΦNE



We anticipate the request for an extension of run with same setup with solid targets



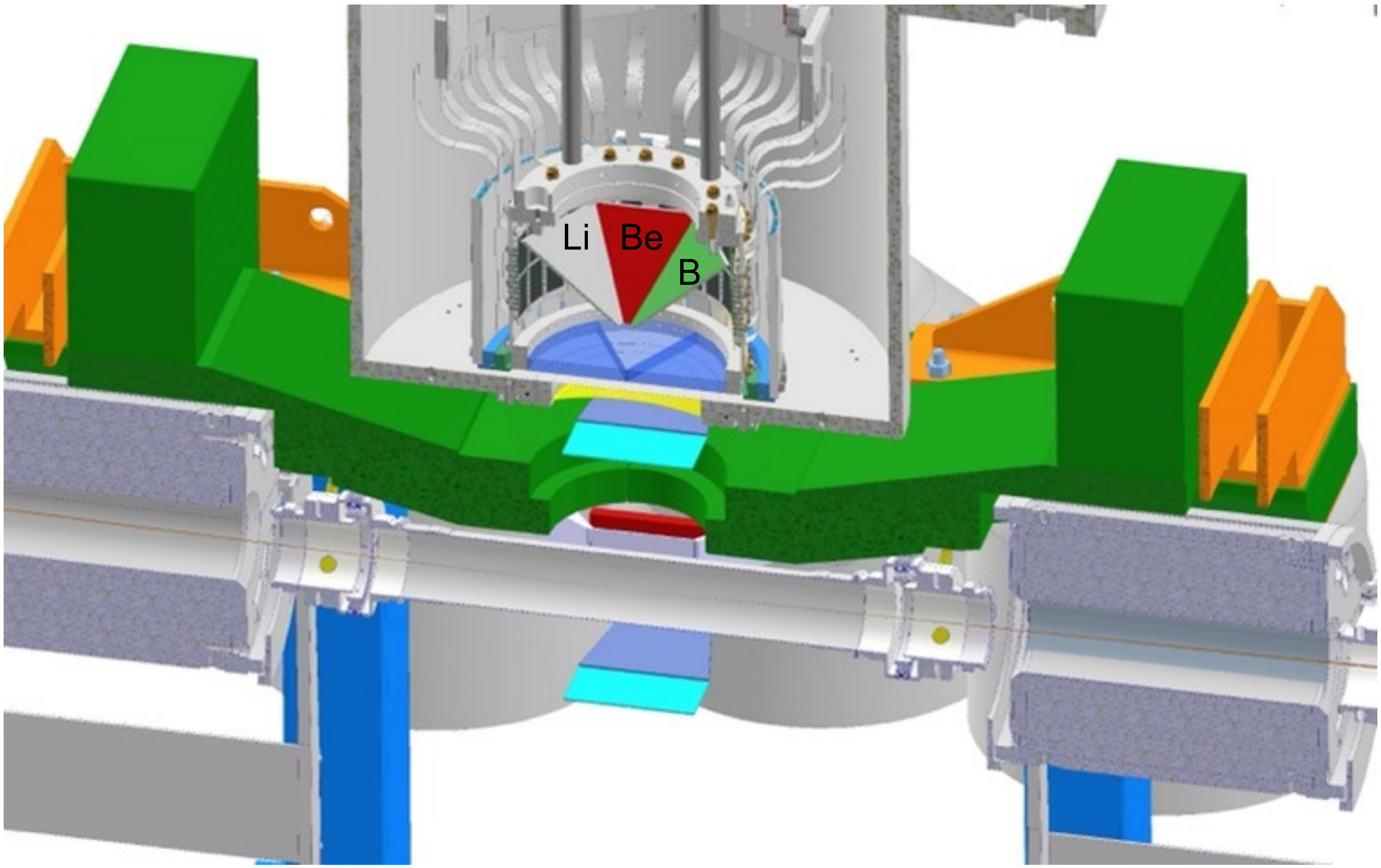
Light Kaonic Atoms Measurements with SIDDHARTA-2 after Kd run

July 2021

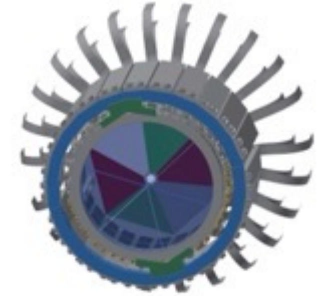
The SIDDHARTA-2 Collaboration

https://www.lnf.infn.it/esperimenti/siddharta/Kaonic-atoms-post-Kd-SIDDHARTA_final.pdf

Use of present SDDs: Solid target system for light kaonic atoms: e.g. **Li – Be - B financed by INFN Nuclear physics (gr 3) as first step towards Future (see Curceanu talk)**



Solid target system for light kaonic atoms: e.g. Li – Be – B



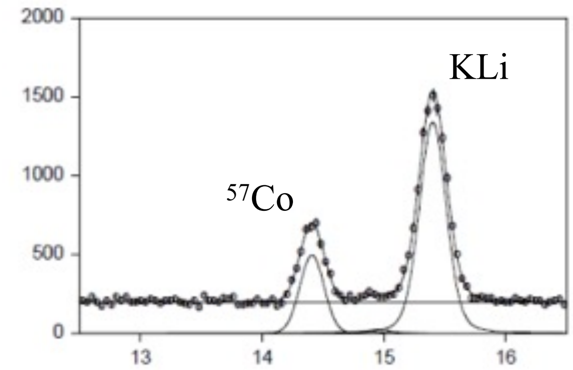
kaonic Li-transitions

3-2	**~15 keV**
4-2	~21 keV
5-2	~23 keV
4-3	**~ 5 keV**
5-3	**~ 8 keV**
6-3	**~ 9 keV**
5-4	**~2.5 keV**
6-4	**~ 4 keV**

15-JUL-21
C:/simul/sidino/MC-KLI-10K.XAT

Spec 1
mc-kli-10k

Range: 13.400 16.300 0.000 0.000
Exclude: 0.000 0.000 0.000 0.000
ChiSq 79.7 NPnt 72 DoF 63 CQ/DoF 1.2651



	P	A00= 207.4 +- 36.0	B00= -0.7043 +- 2.4632	C00= 0.0000 fixed	
Co57	V	Int01= 3078.0 +- 81.0	Pos01= 14.4084 +- 0.0028	LG01= 0.0000 fixed	Sig01= 0.0991 +- 0.0024
KLi	V	Int02= 10064.8 +- 183.1	Pos02= 15.4010 +- 0.0016	LG02= 0.0498 +- 0.0082	Sig02= 0.0991 cpl. Sig01
Y_Ka1	V	Int03= 135.0 +- 37.5	Pos03= 14.9564 cpl. Pos01	LG03= 0.0000 fixed	Sig03= 0.0991 cpl. Sig01
Y_Ka2	V	Int04= 67.4965 cpl. Int03	Pos04= 14.8814 cpl. Pos01	LG04= 0.0000 fixed	Sig04= 0.0991 cpl. Sig01

The energy spectra of light kaonic atom transitions for Li, Be and B targets below 17 keV can achieve a precision below 2-3 eV, for an integrated luminosity of **about 150 pb^{-1}** (including calibrations and test).

We anticipate the request of this additional run post-SIDDHARTA-2

Conclusions

- Despite the difficult period, we have been able to follow our plan and Sci Com recom. and perform our activities along the schedule @SC61
- In particular we: understood and (together with DAΦNE) succeed to reduce backg such as to start SIDDHARTA-2 run; performed the most precise KHe measurement in gas and the measurement of yields at lowest density
- About 10 articles were published - important scientific outcome, 2 are in preparation
- We are ready and very motivated to start the SIDDHARTA-2 planned first Kd measurement
- We put forward proposal for solid targets measurements with SIDDHARTA-2 setup for 100-150 pb^{-1} after Kd run


Luca de Paolis Ph.D. in physics
eccellente qualità con lode
September 2021
4) X-ray transitions measured by E62 at J-PARC
Luca De Paolis
Tutors:
INFN

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

SPARE

New results of K-^{4}He 2p level shift

$E_{e.m.} = 6463.5 \pm 0.2$ eV

$E_{exp} = 6463.6 \pm 5.8$ eV

$$\Delta E = E_{exp} - E_{e.m.} = 0 \pm 6(\text{stat}) \pm 2(\text{syst})\ \text{eV}$$

Published in PLB 681(2009) 310-314

More date on K-^{4}He 2p level shift

$$\Delta E = E_{exp} - E_{e.m.} = +5 \pm 3(\text{stat}) \pm 4(\text{syst})\ \text{eV}$$

$$K^{-4}\text{He}:\Gamma_{2p} = 14 \pm 8(\text{stat}) \pm 5(\text{syst})\ \text{eV}.$$

for a very first look at a possible isotope shift between kaonic3He and4He

Published in PLB 697(211) 199

New K^4He results by KEK PS E570

PLB 653 (2007) 387

Transition	$3d \to 2p$	$4d \to 2p$	$5d \to 2p$
Measured energy (eV)	6466.7 ± 2.5	8723.3 ± 4.6	9760.1 ± 7.7
EM calc. energy (eV) [15]	6463.5	8721.7	9766.8

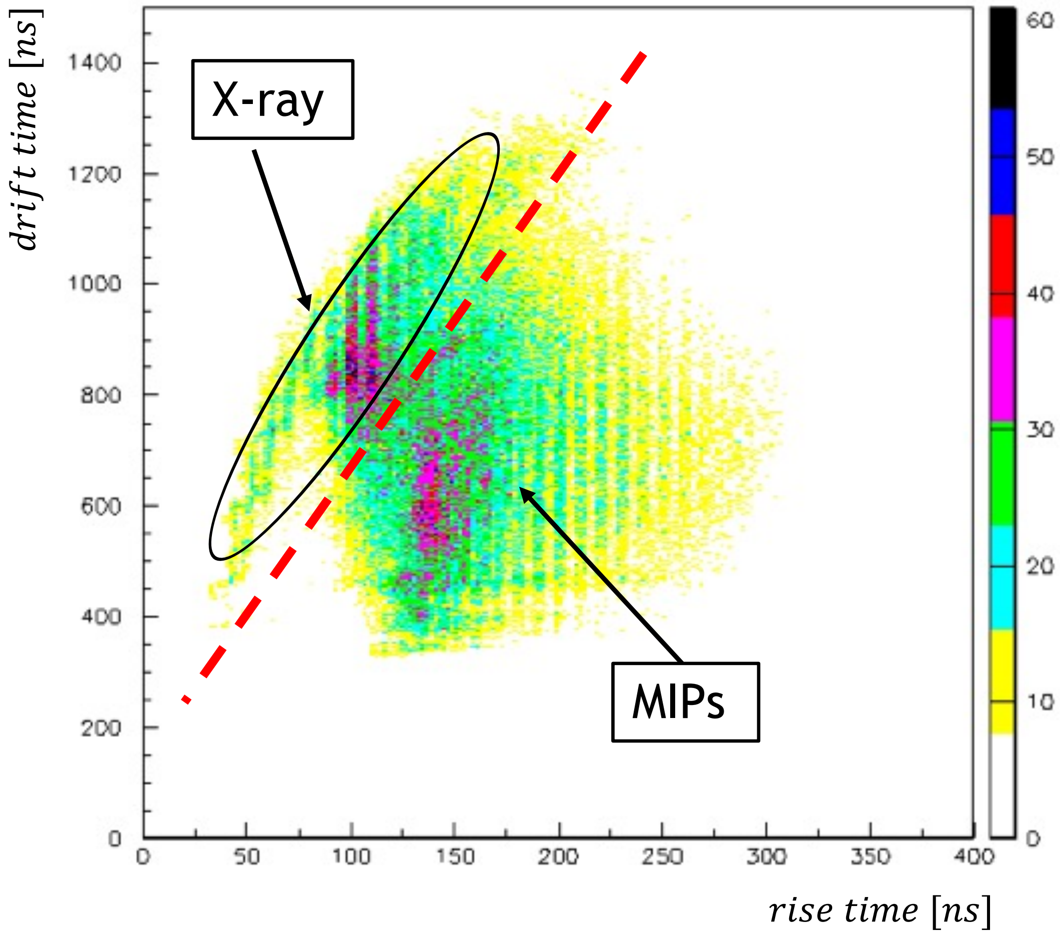
ΔE (eV)	Ref.
-41 ± 33	Wiegand *et al.* [5]
-35 ± 12	Batty *et al.* [6]
-50 ± 12	Baird *et al.* [7]
-43 ± 8	Average of above [1,7]
$+2 \pm 2$ (stat) ± 2 (syst)	Okada *et al.* [10]
0 ± 6 (stat) ± 2 (syst)	This work

ΔE_{2p} =2±2(stat.)±2(syst.) eV)

SIDDHARTA's results is consistent with the results obtained by E570 experiment

"kaonic helium puzzle" solved

Laboratory activity



Discovered a correlation between rise time and drift time for the x-ray

New technique to distinguish x-rays from MIP

we are studying the feasibility of applying this technique to the SIDDHARTA-2 experiment

M. Iliescu et al, IEEE VOL. 70, 2021. DOI 10.1109/TIM.2021.3068149

Laboratory activity