



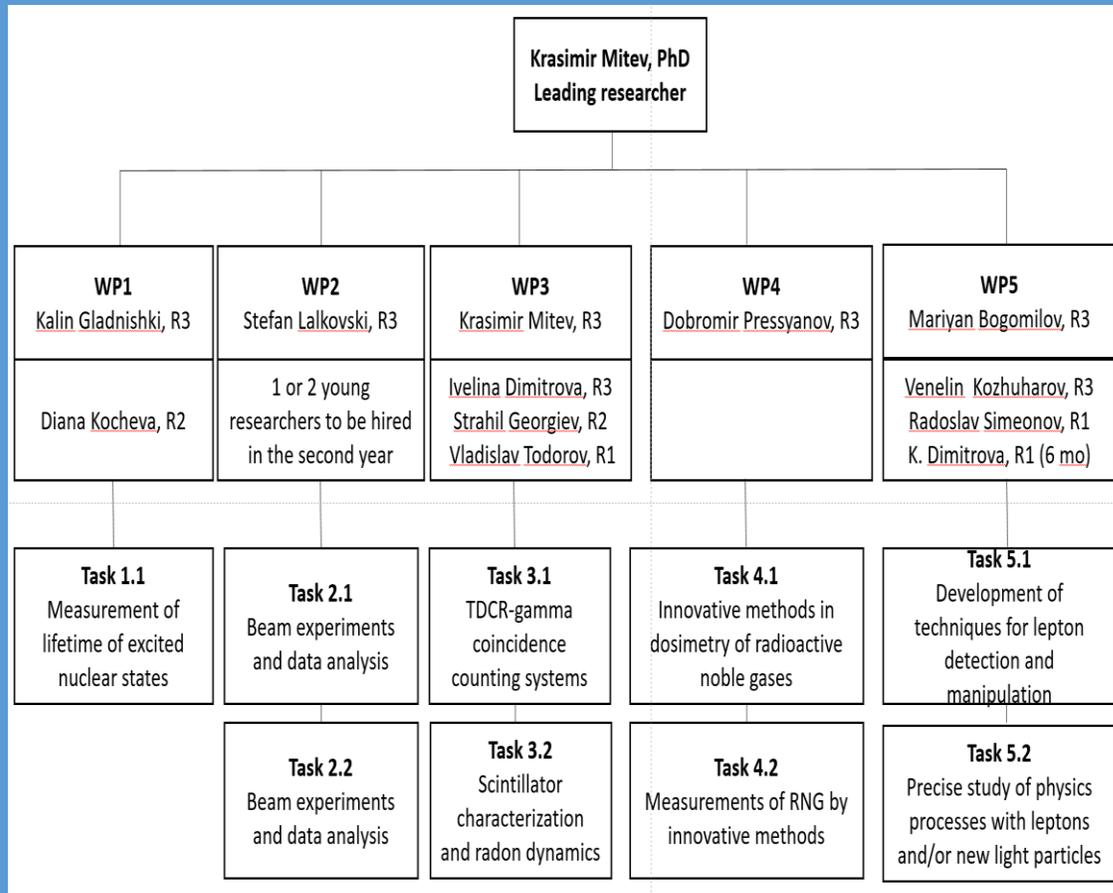
# REPORT

## ON THE ACTIVITIES OF RESEARCH GROUP “NUCLEAR” FOR THE FIRST YEAR OF THE PROJECT “SUMMIT”

*Assoc. prof. Krasimir Mitev (leading researcher), Assoc. prof. Kalin Gladnishki, Assoc. prof. Stefan Lalkovski, Prof. Dobromir Pressyanov, Assoc. prof. Mariyan Bogomilov, Assoc. prof. Venelin Kozhuharov, Assoc. prof. Ivelina Dimitrova, Assoc. prof. Strahil Georgiev, Senior assist. prof. Diana Kocheva, M. Sc. Vladislav Todorov, M.Sc. Kalina Dimitrova, M.Sc. Radoslav Simeonov*

*1<sup>st</sup> Annual Conference of the project SUMMIT, 23-24 April, Sofia, Bulgaria*

# Structure and research activities of the research group **Nuclear**



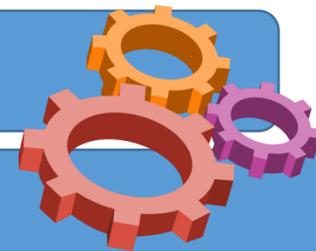
## Research directions

- Nuclear structure;
- Nuclear data;
- Radionuclide metrology and radiation measurements;
- Dosimetry, radiation protection and radioecology;
- Sub-nuclear and high energy physics and technology
  - neutrino physics
  - dark matter physics

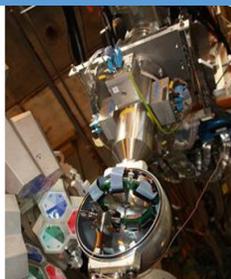
## Administrative

- The first year of the SUMMIT project was completed successfully in a spirit of good collaboration between the members of the group Nuclear.
- All the administrative necessities were timely and fully completed, including those related to completing the research staff and performing the necessary laboratory relocations.

# WP1: Nuclear Structure (Kalin Gladnishki)



ISOLDE



Experiment proposals, accepted by the Scientific Council of ISOLDE.

- Transition probabilities of low-lying excited states in  $^{210}\text{Po}$  and  $^{210}\text{Pb}$
- A Study of Seniority-2 Configurations in  $N = 126$  and  $124$  Isotonic Chains”.

Proposals, accepted by the Scientific Council of the Nuclear Research Laboratory in Magurele, Romania.

- Electromagnetic transition rates in the nucleus  $^{132,134}_{56}\text{Ba}$
- Magnetic moment of  $4+$  isomeric state in  $^{210}\text{Po}$

“Search for  $X(3)$  symmetry in  $^{190}\text{Pt}$ ”, accepted @ Cologne, Germany



Performed experiments

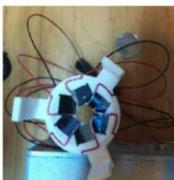
- Spectroscopy of the neutron-rich  $^{156}\text{Sm}$  in  $2n$  transfer
- Lifetime measurements in  $^{214}\text{Rn}$
- Lifetime measurements in the yrast band of  $^{162}\text{Er}$  nuclei
- Octupole Correlations in  $^{144,145}\text{Ba}$  by the Recoil Distance Doppler-shift Technique
- Probing the doubly magic shell closure at  $^{132}\text{Sn}$  by Coulomb excitation of neutron-rich  $^{130,134}\text{Sn}$  isotopes
- Single-particle structure, effective proton charge, and emerging collectivity around  $^{132}\text{Sn}$

“Lifetime measurements in  $^{214}\text{Rn}$ ”

- Fast-timing method
- ROSPHERE (mixed configuration)
  - 10  $2'' \times 2''$   $\text{LaBr}_3(\text{Ce})$ ;  $\epsilon = 1.8\%$
  - 15  $\text{HPGe}$ ;  $\epsilon = 1.9\%$

+ particle detector

SORCERER  
or  
Si detector



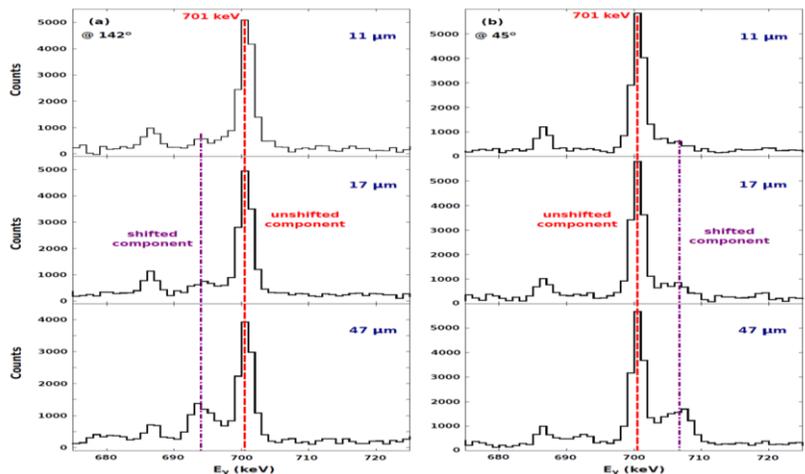
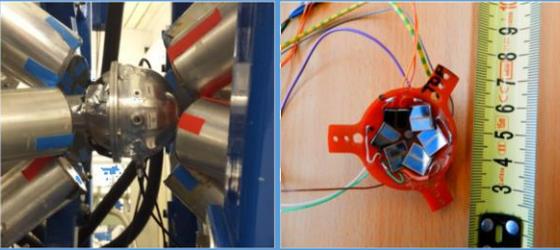
# WP1: Nuclear Structure (Kalin Gladnishki)

During the first year of the project, several data sets from previous experiments were analyzed.

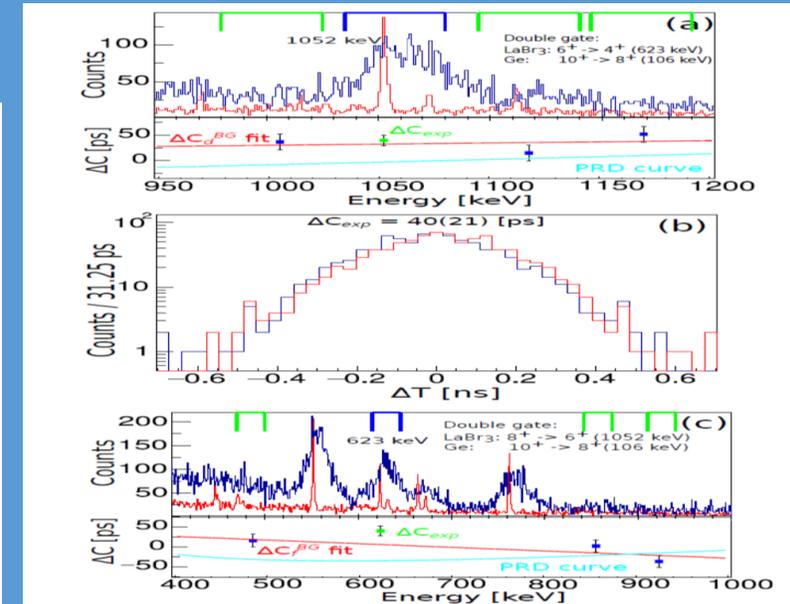
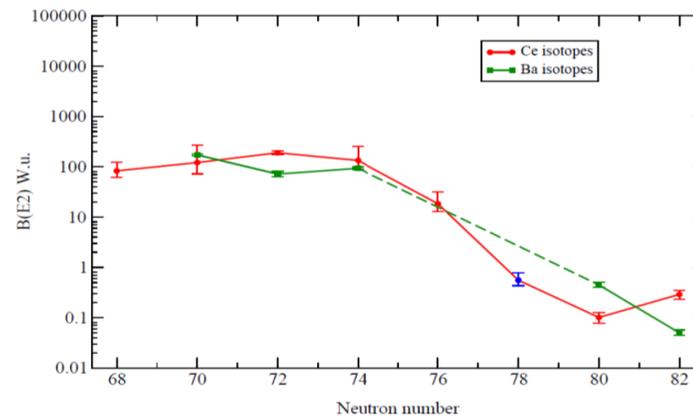
FN Tandem facility, University of Cologne

- Reaction:  $^{204}\text{Pb}(^{16}\text{O}, ^{14}\text{C})^{206}\text{Po}$ ,  $E_{\text{beam}}=84$  MeV;
- Target:  $0.6 \text{ mg/cm}^2$   $^{204}\text{Pb}$  on  $0.3 \text{ mg/cm}^2$  V backing foil;
- Stopper:  $2.0 \text{ mg/cm}^2$  V foil;
- Experimental setup:
  - 5 HpGe detectors at  $142^\circ$  and 6 HpGe detectors at  $45^\circ$ ;
  - 6 solar cells ( $10\text{mm} \times 10\text{mm}$ ) between  $115^\circ$  and  $165^\circ$ ;
- Distances: 11, 13, 17, 21, 30 and  $47 \mu\text{m}$ ;

- Study the structure of the low-lying states of  $^{206}\text{Po}$
- Experimental study of the low-lying states of  $^{205}\text{Bi}$
- Electromagnetic transition rates in the nucleus  $^{136}\text{Ce}$



## Electromagnetic transition rates in the nucleus $^{136}\text{Ce}$



## WP2: Nuclear Data (Stefan Lalkovski)

- **Core ENSDF nuclear data evaluation activities**

- $A=107$  Mass chains data compilation, evaluations and dissemination (*mass chain evaluation is completed and ready for submission*)

- **Data evaluations for monitoring applications**

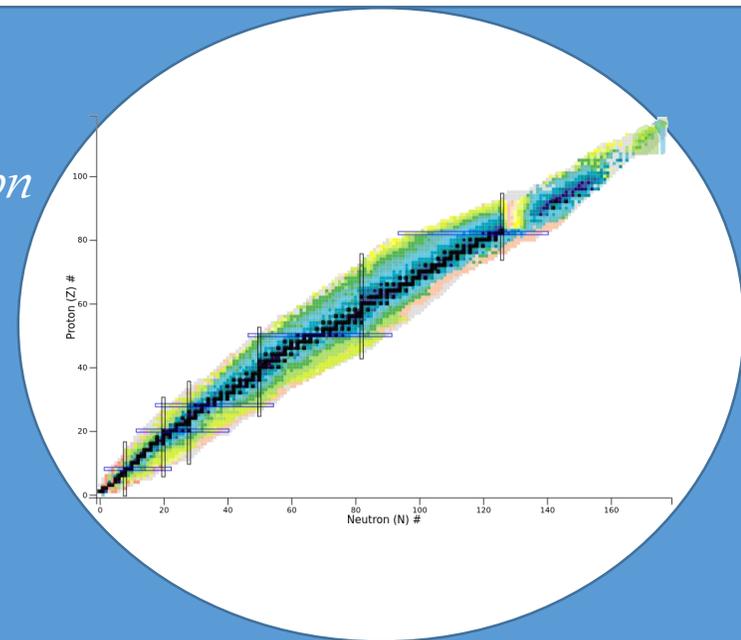
- Nuclear data evaluations for CTBTO – Adopted decay data set for  $^{144}\text{Pr}$  (*the evaluation is completed and submitted for review; reviewer report returned to the evaluator*)

- Two reviews of nuclear data evaluations for CTBTO (*work in progress*)

- **Evaluations on data for medical applications**

- $^{117}\text{Sn}$  nucleus data evaluation, comprising 22 data sets (*the evaluation is done and to be submitted for inclusion in ENSDF*)

- **Article reviews for journals**



## WP2: Nuclear Data (Stefan Lalkovski)



- **Data analysis of prior experiments**

$^{146}\text{Ce}$  beta-decay with Gammasphere (*experiment, performed at Argonne National laboratory, USA.*)

•  $^{99}\text{Rh}$  fast-timing data from RoSphere, IFIN-HH (*analysed in 2023 and published in 2024*)

- **Experiments targeted on specific phenomena**

Sub-nanosecond lifetimes of core-excited states in  $^{105}\text{Cd}$  (*experiment performed in July/August 2023 in IFIN-HH (Romania)*)

Sub-nanosecond lifetimes lifetimes in  $^{103,105}\text{Ag}$  (*experiment performed in July/August 2023 in IFIN-HH (Romania)*)

- **Proposals for future experiments**

Fast-timing in  $^{113,115}\text{Ag}$  with radioactive beams at the University of Jyvaskyla (*proposal submitted to the PAC. Awaits approval*)

Plunger in  $^{107}\text{Ag}$  (*proposal approved, the experiment is scheduled for Dec.2024*)

# WP3: Radionuclide metrology and applications (Krasimir Mitev)



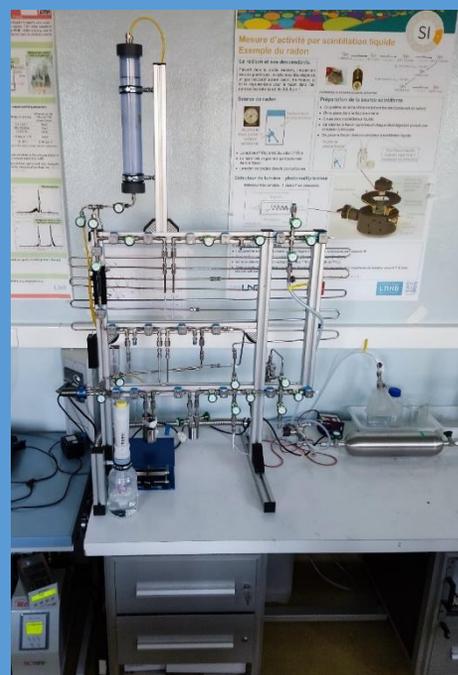
With colleagues from French primary metrology laboratory we have created the first ever radon-in-water primary standard.



The defined solid angle  $^{222}\text{Rn}$  standard

$^{222}\text{Rn}$  transfer

The new system

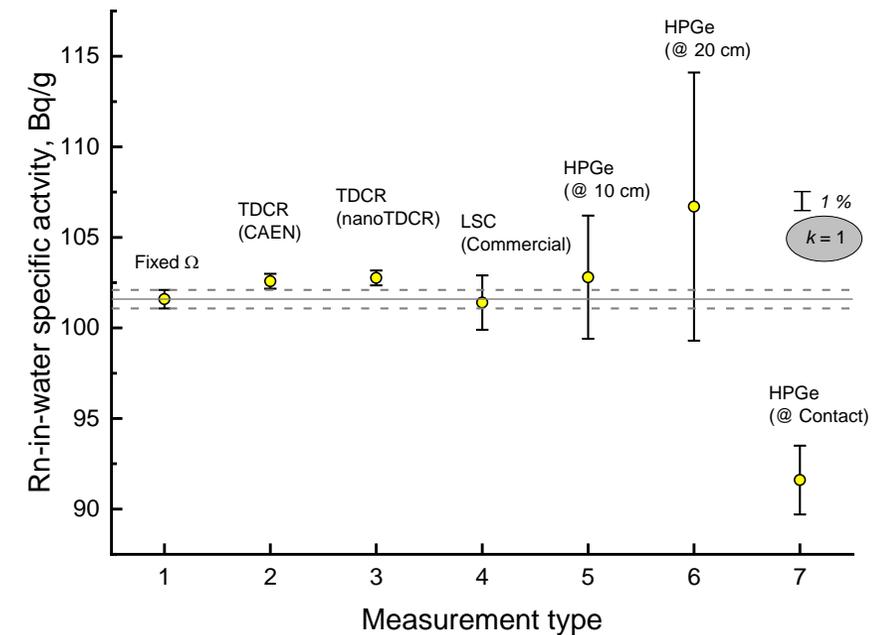


We also developed a primary standards @ SU

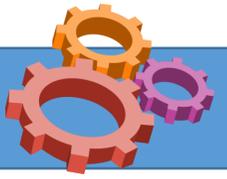


$^{222}\text{Rn}$

$^{222}\text{Rn}$ -in water traceability chain



# WP3: Radionuclide metrology and applications (Krasimir Mitev)

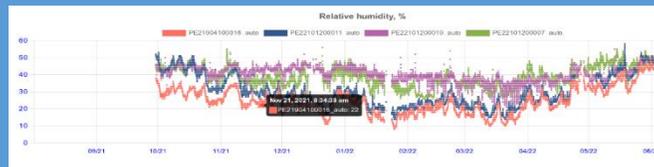
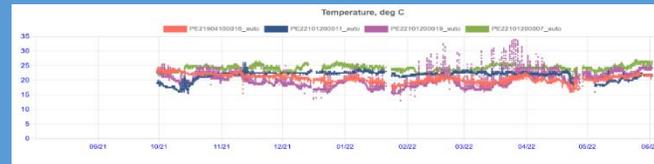
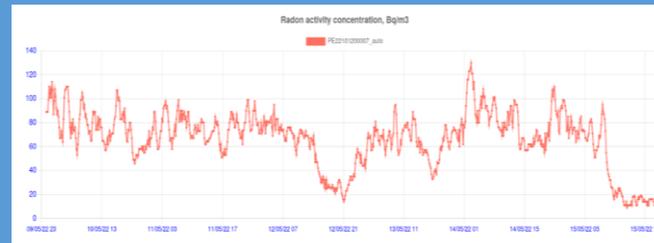


We have developed and we are operating a state of the art system for monitoring of  $^{222}\text{Rn}$  in dwellings and workplaces with electronic radon detectors.  $^{222}\text{Rn}$  measurements with 10 minutes time resolution!

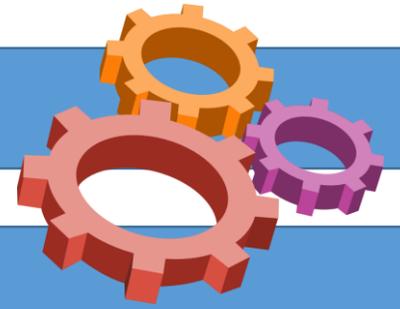


Metrological assurance (collaborations):

- French National Metrology Laboratory (LNE)
- United Kingdom Health Security Agency (UKHSA)



- The electronic monitors will provide real-time  $^{222}\text{Rn}$  data which will be very useful for active radon mitigation, development of safe indoor environment and smart heating solutions;
- There is a need of improvement of electronic radon sensors both in terms for sensitivity and time response, which will require adequate metrological assurance



## Design and study of novel methods for $^{222}\text{Rn}$ detection of unique sensitivity

- The novel detectors employ activated carbon fabrics coupled with solid state nuclear track detectors. The fabric Kynol ACC-5092-10 was identified to have high radon adsorption ability even at high humidity levels.
- The novel designs make possible to break-through in problems not tackled yet:
  - Study the fine distribution of radon concentrations in soil close to surface (including in the upper few cm close to surface) and refining estimates of the radon gradient on the surface under various circumstances;
  - Resolving problems related to free radon exhalation-rate determination.



MDAC ( $^{222}\text{Rn}$ ) of different passive detectors for exposure time of 3 months and 1 week. Current state-of-the-art in passive radon detectors is surpassed by one-two orders of magnitude.

Detector	Counted area ( $\text{cm}^2$ )	Conditions	MDAC ( $\text{Bq m}^{-3}$ )	
			3 months	1 week
Exposure:				
<i>Conventional radon detectors</i>	<i>0.5 - 1</i>	<i>Usually CR-39 placed in diffusion chambers</i>	$\geq 5$	$\geq 60$
ACC-5092-10 + LR-115/II	1	RH<50%, no temperature compensation	0.4	4.6
ACC-5092-10 + LR-115/II	1	RH>60%, no temperature compensation	1.0	11.5
ACC-5092-10 + LR-115/II	1	With temperature compensation	0.9	9.7
ACC-5092-10 + DVD	100	RH<50%, no temperature compensation	0.07	0.8
ACC-5092-10 + DVD	100	RH>60%, no temperature compensation	0.17	1.9
ACC-5092-10 + DVD	100	With temperature compensation	0.16	1.8



Possible break-through in the field:  
Gradient chamber for radon and  
thoron exhalation rates from  
surfaces

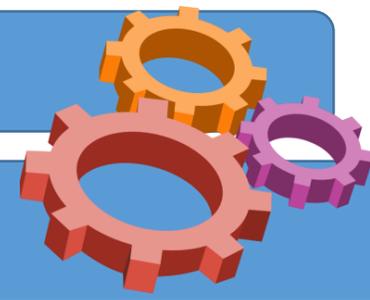
A patent application has been  
triggered

Попълва се от Патентното ведомство	 <b>ПАТЕНТНО ВЕДОМСТВО НА РЕПУБЛИКА БЪЛГАРИЯ</b>
Патентно ведомство бул. Г.М. Димитров № <b>BG/P/2024/113878</b> 04.04.2024 г.	Бул. "Д-р Г.М. Димитров" № 52, вх. Б София 1040 Тел.: +359 2 9701 321, Факс: +359 2 87 35 258 БНБ-ЦУ в лева

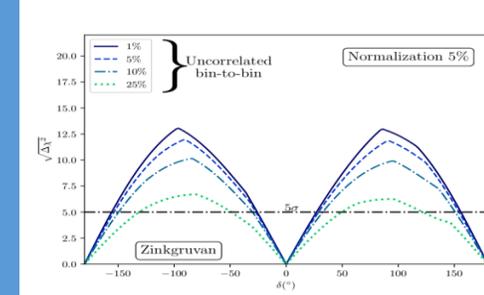
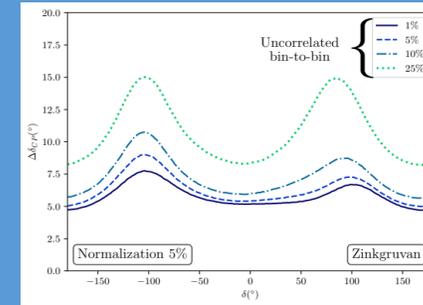
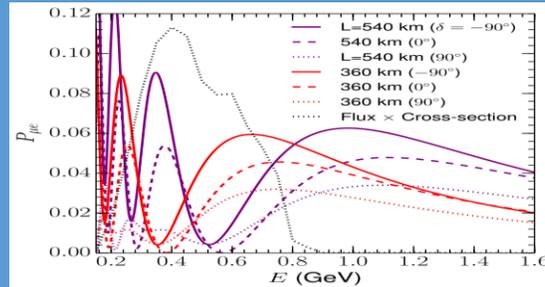
<b>ЗАЯВЛЕНИЕ ЗА ПАТЕНТ ЗА ИЗОБРЕТЕНИЕ</b>	
<b>1. НАИМЕНОВАНИЕ НА ИЗОБРЕТЕНИЕТО:</b> КАМЕРА ЗА ИЗМЕРВАНЕ НА МОЩНОСТТА НА ЕКСХАЛАЦИЯТА НА РАДОН И ТОРОН ОТ ПОВЪРХНОСТИ	
<b>2. ЗАЯВИТЕЛИ:</b>	
Име, презиме, фамилия (наименование на фирма) и <b>Софийски университет „Св. Климент Охридски“</b> ЕИК/БУЛСТАТ:0006706800015 Адрес, пощ.код: Бул. „Цар Освободител“ № 15 София 1504 Трите имена на представляващия/те ЮЛ Проф. д-р Георги Александров Вълчев, ректор	Гражданство: Седалище на фирма: България Код на страната: <b>BG</b> Телефон: е-поща: Факс:

<b>8А. ДЕКЛАРАЦИЯ ЗА ДЕЙСТВИТЕЛНИТЕ ИЗОБРЕТАТЕЛИ:</b>	
Име, презиме и фамилия: <b>Добромир Стефанов Пресиянов</b> Адрес: Ж.К. "Хаджи Димитър", бл.32, ет.6, ап.40 София 1510	Държава: България (по постоянен адр) Код на страната: <b>B   G</b> Телефон: 028161268 ; 0889 138 639 е - поща:

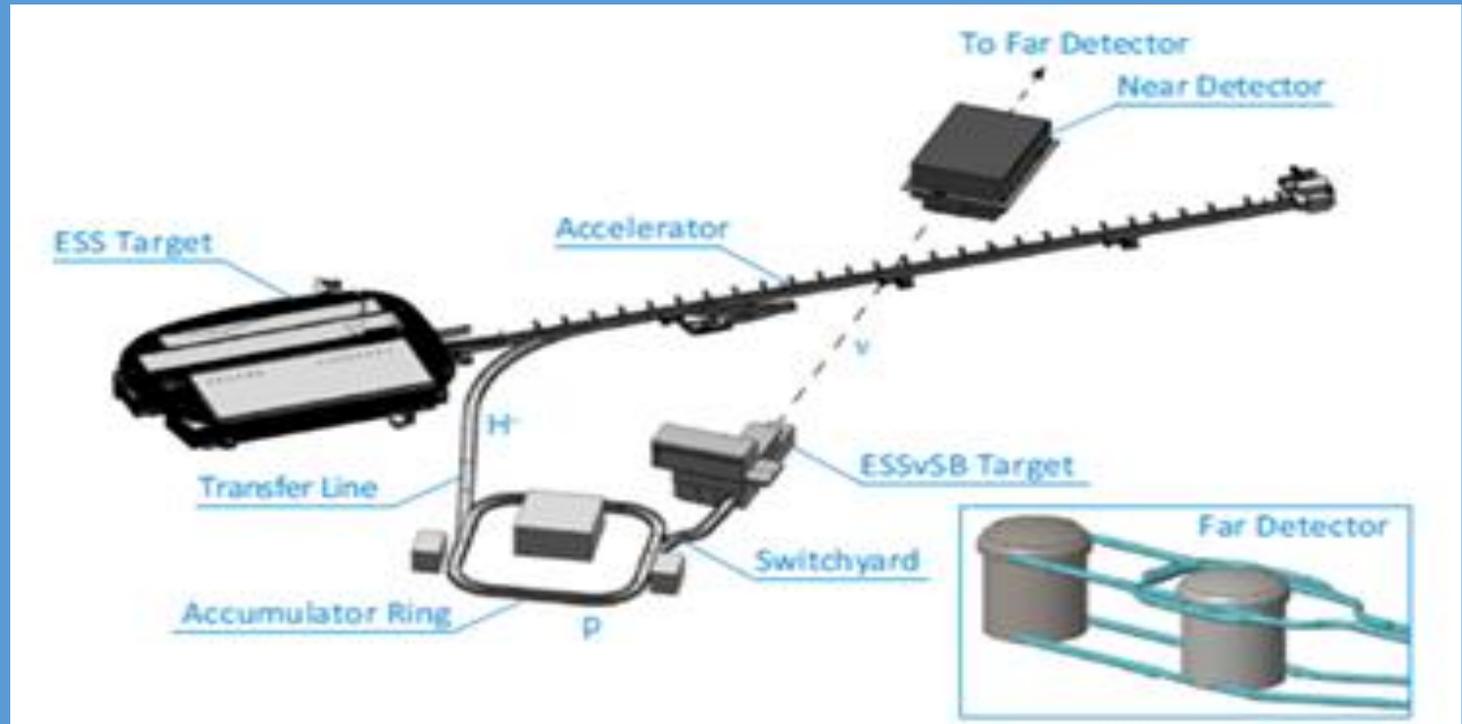
# WP5: Neutrino physics (Mariyan Bogomilov)



- The measured matter-antimatter asymmetry is ca 9 orders of magnitudes larger than what can be explained by the quark Charge-Parity (CP) violation in the Standard Model.
- A significant lepton CP violation could explain the presence of matter in Universe through leptogenesis.
  - It can be measured using neutrino oscillation in terms of the CP phase-angle  $\delta_{CP}$  with the highest precision possible.



Owing to the use of the world-uniquely high power of the European Spallation Source (ESS) linear accelerator near Lund, Sweden, the ESSnuSB project will enable a measurement of  $\delta_{CP}$  with a standard error below  $8^\circ$  for all values of  $\delta_{CP}$ .



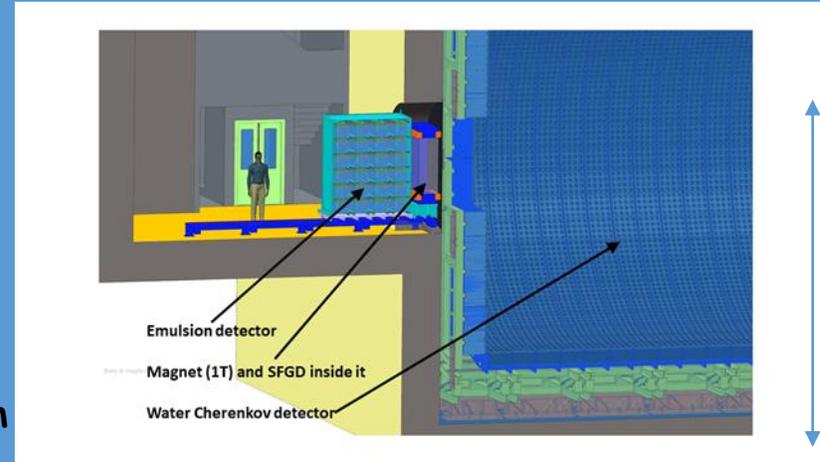
# WP5: ESSnuSB Physics Reach (Mariyan Bogomilov)



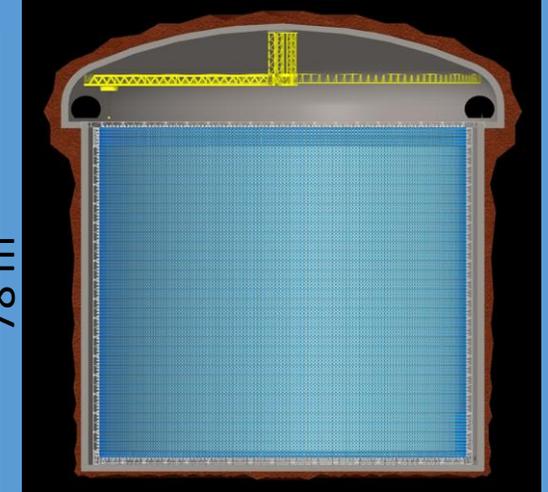
- **Using near and far detectors**
  - CP violation search
  - Precise measurement of  $\delta_{CP}$  parameter
- **Using only near detectors (50 m - 250 m)**
  - Sterile neutrino search
  - Non - standard interactions
  - Constraining Beyond Standard Models theories via neutrino - electron scattering
- **Using only far detectors (ongoing or planned non-beam study)**
  - Atmospheric neutrinos
  - Supernovae neutrinos
  - Diffuse supernovae background neutrinos
  - Geoneutrinos
  - Reactor neutrinos
  - Solar neutrinos

*We are responsible for the one of the near detectors - Scintillation tracker (SuperFGD).*

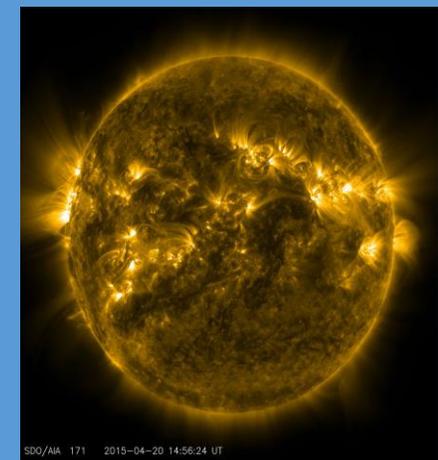
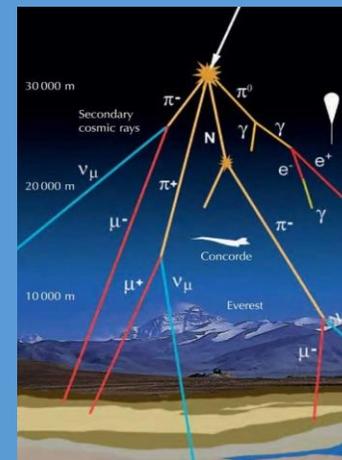
*We are coordinating the works on near detectors - development and software.*



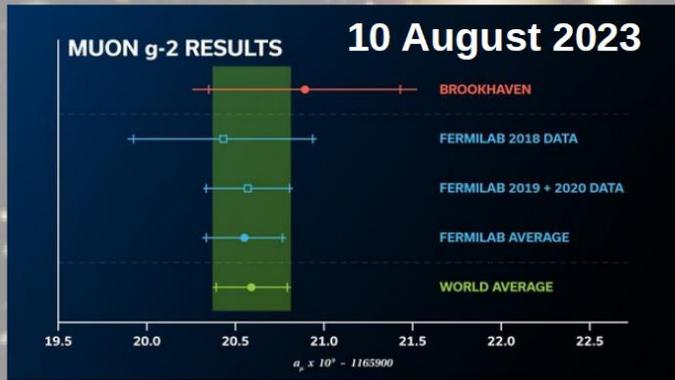
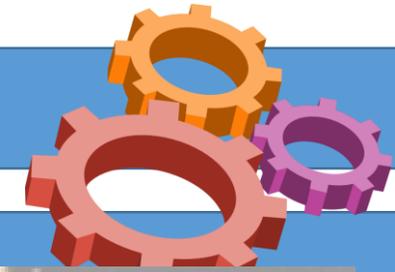
near detectors



far detector



# WP5: Uncovering Dark Matter and its interactions (Venelin Koushuharov)

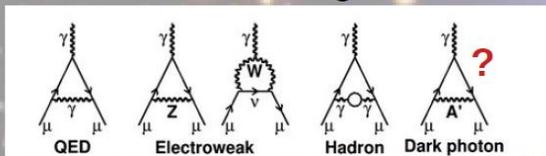


Theory:  $a_\mu = 116\,591\,810\,(43) \times 10^{-11}$

Experiment:  $a_\mu = 116\,592\,059\,(22) \times 10^{-11}$

$\Delta a_\mu = (249 \pm 48) \times 10^{-11}$

NOTE: > 5 sigma!



Coupling to SM

$\Omega_{DM} = 0.1198 \pm 0.0015$   
Production at accelerators



High intensity

Mass

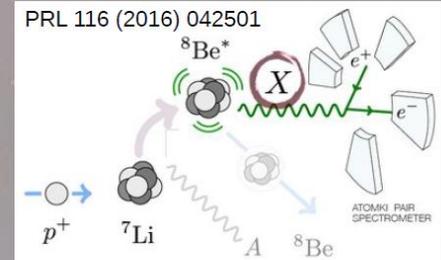
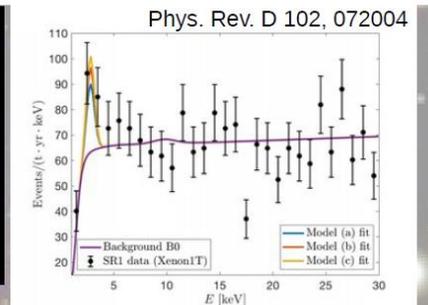
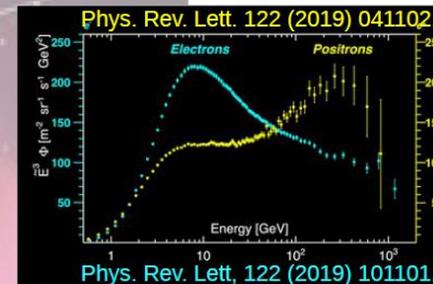
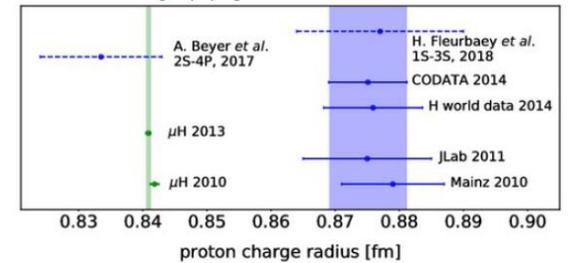
Visible sector

mediator

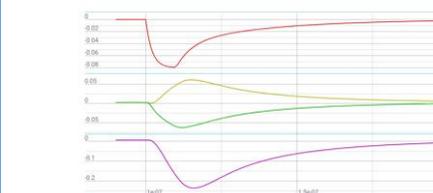
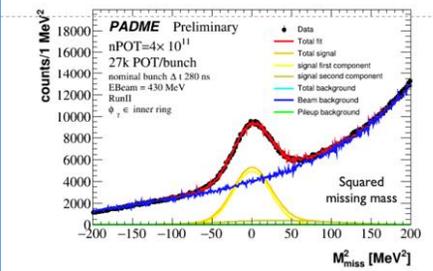
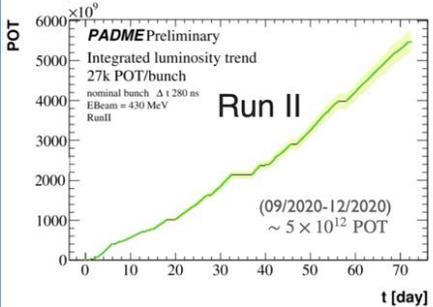
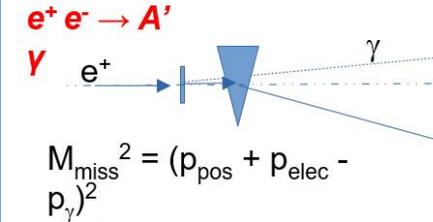
$A', a, h, HNL, ?$

Dark sector

arXiv:1011.3519 [hep-ph]



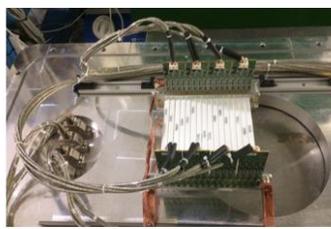
# WP5: PADME: Positron Annihilation into Dark Matter Experiment (V. Koushuharov)



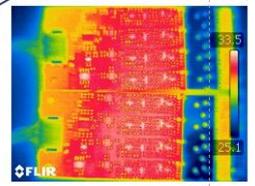
Active diamond target



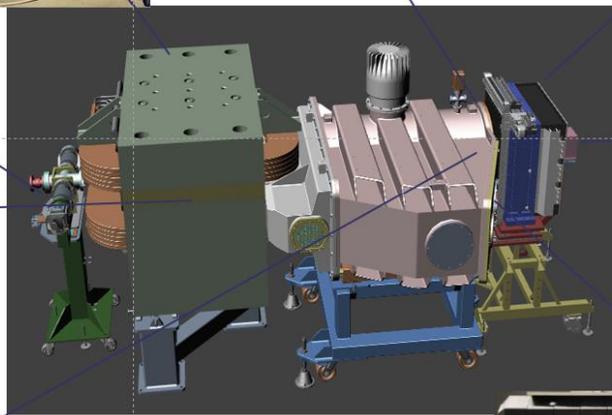
Veto scintillators



Operation of SiPM in vacuum



Dipole magnet

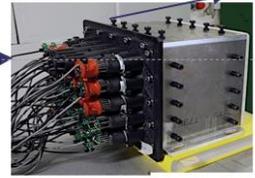
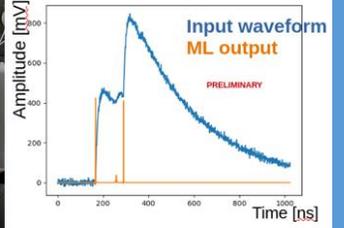
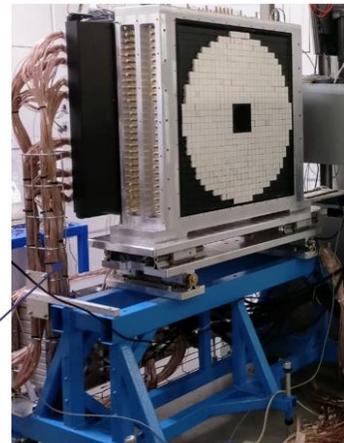


1m

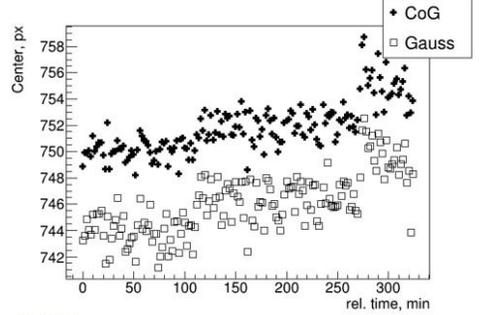


C-fiber window

BGO calorimeter

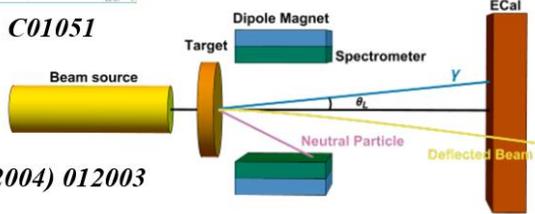


PbF<sub>2</sub> calorimeter



TimePIX3 array JINST 19 (2024) 01, C01010

And beyond:



Searching for Dark Sector @ UVX, Brasil  
*Phys. Rev. D* 108, 055030 (2023)

Detector studies in general

*J. Phys.: Conf. Ser.* 2668 (2024) 012002 (readout)  
*J. Phys.: Conf. Ser.* 2668 (2024) 012006 (new detectors)

*J. Phys.: Conf. Ser.* 2668 (2004) 012003

JINST 19 (2024) 01, C01051



## SUMMARY

The first year of the SUMMIT project was completed successfully in a spirit of good collaboration between the members of the group Nuclear. All the administrative necessities were timely and fully completed, including those related to completing the research staff of the group and performing the necessary reconstructions and laboratory relocations. This led to a smooth execution of the project without significant disturbances.

### Scientific



- 11 oral and 2 poster contributions to scientific conferences or meetings;
- 15 papers were published with acknowledgment to the SUMMIT project;
- 13 manuscripts are submitted for publications in various journals ;
- Other papers are in a process of preparation.
- One patent application



# For more interesting presentations: Tomorrow, FzF, A315, 9:30h

## Thank you for your attention!

- **S.Lalkovski et al**, Structure of the high-spin, beta-decaying state in the neutron rich nucleus  $^{146}\text{La}$ , *Physical Review C* 109, 024309 (2024),
- **S.Lalkovski, S.Kisyov, O.Yordanov**,  $j^{-1}$  anomalous states and electromagnetic transition rates in the neutron mid-shell Ag nuclei, *Acta Physica Polonica B* 55, 1-A2 (2024),
- **G.Pasqualito, ..., S.Lalkovski, ...,** Shape evolution in even-mass  $98\text{-}104\text{Zr}$  isotopes via lifetime measurements using the  $\gamma\gamma$ coincidence technique, *European Physical Journal A* 59 (2023) 276
- **B. Sabot, Ch. Dutsov, P. Cassette, K. Mitev, M. Hamel, GH. V. Bertrand, K. Lebbou, C. Dujardin**, A compact detector system for simultaneous measurements of the light yield non-linearity and timing properties of scintillators, *Scientific Reports* (2024) 14:6960
- **V. Todorov, S. Georgiev, M. Hamel, C. Dutsov, B. Sabot, I. Dimitrova, K. Mitev**, Evaluation of radon absorption and detection properties of a plastic scintillator developed for PSD measurements, *Measurement*, in press,
- **K. Mitev, B. Sabot, S. Pierre, M-C Lepy, P. Cassette**, “Towards a radon-in-water primary standard at LNHB”, *Applied Radiation and Isotopes*, 201 (2023) 111013,
- **P. Cassette, V. Todorov, B. Sabot, S. Georgiev, K. Mitev**, “Uncertainties in TDCR measurement revisited: Contribution of optical effects”, *Applied Radiation and Isotopes*, 201 (2023) 110992,
- **J. Aguilar et al.**, Search for Leptonic CP Violation with the ESSnuSBplus Project, *Letters in High Energy Physics*, LHEP-517, 2024
- **S. Bertelli et al**, Design and performance of the front-end electronics of the charged particle detectors of PADME experiment, *JINST* 19 (2024) 01, C01051,
- **S. Bertelli et al**, Beam diagnostics with silicon pixel detector array at PADME experiment, *JINST* 19 (2024) 01, C01016,
- **V. Buchakchiev et al**, Reliability evaluation of the CAEN DT5202 for high-rate data acquisition, *J. Phys.: Conf. Ser.* 2668 012006,
- **M. Naydenov**, Phenomenology of dark tensor currents, *J. Phys.: Conf. Ser.* 2668 012003
- **Veronika Arsova et al**, Multichannel SiPM test readout system for gamma ray measurements, *J. Phys.: Conf. Ser.* 2668 012002,
- **L. Angel, ..., V. Kozhuharov et al.**, Toward a search for axionlike particles at the LNLS, *Phys. Rev. D* 108 (2023) 5, 055030,