Implementation Agreement

between

Ministry of Education and Science of Georgia (MoE),
Shota Rustaveli National Science Foundation (SRNSF),
Ivane Javakhishvili Tbilisi State University (TSU)

– hereinafter referred to as GEORGIA –

and

Forschungszentrum Jülich GmbH

– hereinafter referred to as JÜLICH –

on the foundation of a **SMART|EDM**_*Lab* within the project:

Search for Electric Dipole Moments using Storage Rings (srEDM)

1. Preamble

On the occasion of the visit of a German delegation from Forschungszentrum Jülich (JÜLICH) in Tbilisi (Georgia) in October 2015, a Memorandum of Understanding (MoU) was signed between GEORGIA and JÜLICH on the long-term collaboration in the fields of science and education within the framework of the Georgian-German Science Bridge (GGSB). In order to establish the basis for this cooperation at universities in Georgia, both parties agreed on the foundation of so called SMART|Labs. The Georgian Ministry of Education and Science (MoE) considers the SMART|Lab concept as a special cooperative targeted and long-term (>10 years) program and will support such labs with financial resources, which will be operated by the Shota Rustaveli National Science Foundation (SRNSF). The science case, research objectives, organizational structure and total budget of the first proposed project, the **SMART|EDM_*Lab***, has been discussed and approved last year (see Annex 4. of the MoU). Within the current document, a description of work-packages, deliverables and time-line for this project is outlined.

2. Subject matter of the agreement: SMART|EDM_*Lab*

2.1 General concept and motivation

The idea of SMART|Labs (SMART: **S**cience, **M**edicine, **A**pplied **R**esearch and **T**echnology) implies the establishment of relatively small, well equipped and maintained modern laboratories in Georgia. Such labs are supposed to contribute in different fields of fundamental and applied science within the framework of a particular international collaboration. The main objectives of such labs can be few at a time and they may change dynamically. The laboratory and its staff should be able to efficiently change from one activity to another and be able to also contribute to neighboring directions of research and developments, making use of its infrastructure. Therefore, smart labs need to be supplied with modern equipment and tools. These goals involve additional constraints for the place where such labs will be situated as well as for the technical requirements and regulations it must satisfy. Although the main purpose of SMART|Labs lies in its contributions to research projects, by involving a young generation of (Bachelor, Master and PhD) students, it will also induce a large educational impact. The best sites for such laboratories will thus be near to or at universities. This will inspire the interest of students and motivate them to participate in ongoing projects with the chance to gain knowledge in modern experimental techniques and so improve their skills.

Based on these boundary conditions it was agreed among the consortium of Georgian universities that the first **SMART|EDM**_*Lab* will be situated at Tbilisi State University (TSU) and will function in close collaboration with the group of physicists from the High Energy Physics Institute (HEPI TSU), which have a long-term (more than 20 years) successful cooperation with the Institute for Nuclear Physics (Institut für Kernphysik, IKP) of Forschungszentrum Jülich in spin physics experiments at COSY, including the ongoing JEDI project (Jülich Electric Dipole moment Investigations). The Georgian researcher, Dr. David Mchedlishvili, has been identified as the principal investigator (PI) and head of the laboratory.

2.2 Research objectives

The **SMART|EDM**_*Lab* introduces a wide range of opportunities for its members, in particular the young researchers, to contribute to the JÜLICH based srEDM-project in cooperation with the international JEDI collaboration (It should be mentioned that srEDM has recently received a prestigious ERC Advance Grant by the European Research Council.). During this long-term project many scientific and technological challenges must be mastered to achieve the goal of reducing the upper limit for an electric dipole moment (EDM) of fundamental particles or even finding a finite EDM value. The most important goals for this precision measurement, where the **SMART|EDM**_*Lab* will significantly contribute, comprises the design, construction and assembly of a new highly-efficient polarimeter (a particle detection system based on inorganic scintillator material) and the development of a completely new type of the target, the so called Jülich ballistic Diamond pellet Target (JuDiT). The proposed laboratory, which will be established at TSU and supplied with suitable equipment, will contribute to both activities by performing tests and developments of different parts of the detector and the target systems. These activities will include, but are not limited to, testing scintillation crystals and modern photomultipliers for the polarimeter, developing data acquisition and target control electronics, performing Monte Carlo simulations and analyzing test data. In addition, computer modeling of the design concepts and all technological systems will be necessary. Hence, the participation of engineers is also foreseen.

The **SMART|EDM**_*Lab* by Georgian scientists and students will take on one of the most important issues of the srEDM-project within the framework of the JEDI collaboration: polarimetry. One aspect concerns the completion of the required data base by planning, performing and analyzing experiments at COSY-Jülich, the second pillar comprises all parts of the polarimeter-target-detector development:

- Detector and target concept, including electronics and readout;
- Simulations of the detector response and deduction of its capabilities;
- Design of the equipment of the polarimeter;
- Construction of the device;
- Installation and commissioning;
- Use in the experiment.

The experience gained in this project by the Georgian group in terms of simulations, electronics development, hardware design and construction, experimental techniques and data analysis, will enable them to apply their knowledge to other science fields and to Georgian industry.

2.3 Work packages (WP)

The following section presents the overview of the work packages foreseen for the srEDM-project with the three major deliverables:

- key technologies (next-generation calorimeter);
- EDM measurements (proof-of-principal experiment at COSY), and
- developments towards the PET (positron-emission tomography) application systems for medical diagnostics.

It must be emphasized that all the activities will require the combined effort of many colleagues at the **SMART|EDM**_*Lab*, Forschungszentrum Jülich and the complete JEDI-collaboration. This is a technologically challenging project, which also requires significant mechanical and electronic engineering expertise: this know-how is available in the Central Institute for Engineering, Electronics and Analytics (ZEA) of JÜLICH, more specifically in ZEA-1 (Engineering and Technology) and ZEA-2 (Electronic Systems).
Detailed information about the WPs is provided in the Annex 1.

2.4 Deliverables and time-line

The project duration is 5 years starting January 01 2017. Possible further project phases will be discussed and agreed upon in due time.

- 1st year: new concept for next-generation equipment: calorimeter & target;
- 2nd & 3rd year: building, assembling and demonstrating functionality of the polarimeter elements, as well as readout development;
- 4th & 5th year: conducting the proof-of-principle experiment for EDM search at COSY, medical applications (e.g. development towards the PET diagnostics);
- 1st to 5th year: educational components (e.g. gain skills to perform Master and PhD theses);
- 2nd to 5th year: publications in high-impact journals, conference talks and proceedings.

2.5 Project budget and reporting[1]

Total budget for the first 5 years will be 450.000 Euro, with a contribution from SRNSF – 235.000 Euro, from JÜLICH – 155.000 Euro, and from TSU – 60.000 Euro.
The tentative Foundation's budget for the 5 years period is as follow:

- Head of lab (PI) – 1.500 Euro (60 months - 90 000 Euro)
- PhD student – 21.000 GEL per year (3 years – 63.000 GEL/25.000 Euro)
- Master student(s) – 15.000 GEL per year (5 years – 75.000 GEL/30.000 Euro)
- Travel money – 6.000 Euro per year (3 visits for PI) (5 years – 30.000 Euro)
- Other goods and services for the research purposes (different from the overhead)– 2.000 Euro (5 years – 10.000 Euro)
- Start-up equipment – 50.000 Euro

PI's salary and scholarship for the Master and PhD students for a 6 months period will be transferred to their private bank account; travel, start-up equipment and other goods and services money will be transferred to the TSU's treasury account's special sub code, after the end of the reporting period, the remaining grant will be retained to the TSU treasury account (see Annex 2 for the detailed annual budget).

[1] JULICH and TSU will define their budget distribution, this implementation agreement foresees only SRNSF budget

Dr. David Mchedlishvili, the PI from the Georgian side, will be responsible for the progress and coordination of the work packages ongoing in the frame of the **SMART**|EDM_*Lab*. TSU will be responsible for the requesting and reporting to SRNSF about financial aspects, including, e.g., travel, jointly PI and TSU are responsible for the required man power (Master and PhD students). The PI and the TSU present following documents to the Foundation:

- Annual financial statement and progress report to the SRNSF according to the project timelines 21 days upon the end of the calendar year;
- PI and TSU Scientific-research Institute for High Energy Physics submits to the Foundation acceptance letter, which is the precondition for the scholarship transfer to the PhD and Master students
- Annual budget in July of each year, for the first year – till December 15, 2016
- A three-years-progress-report about completed work and an agenda for the following two remaining years, which is the precondition for the project extension.

2.6 Selection process of Master and PhD students

Master and PhD students are selected from the Iv. Javakhishvili Tbilisi State University, Georgian Technical University, Ilia State University, Agricultural University of Georgia or any other Georgian university (by mutual consent of JÜLICH and this university) to ensure their internship at a SMART|Lab. The selection result is signed by the TSU and subsequently submitted to the Foundation by the PI.

Participating Georgian universities, JÜLICH and the PI define number and budget of Master and PhD students annually. TSU and PI submit to the Foundation an acceptance letter for the Master and PhD students' candidacy till December 15 each year.

The potential beneficiary of the program should submit to the PI an electronic version and a hard copy of his/her application in English and in Georgian language.

The internship for PhD students is granted for a period up to 3 years and for Master students up to 2 years with a possible extension up to 6 months each. The extension of the internship should be agreed among the Foundation and JÜLICH and based on the formal request of the universities/research institutes involved in good time beforehand. In case of extension, the Foundation shall not be liable for providing any additional grant.

3. Exchange of knowledge

3.1. The Partners shall exchange their Expertise and Work Results inasmuch as such exchange is required for the execution of the Agreement and inasmuch as they can legally dispose of such Expertise and Work Results.

3.2. Parties shall act in accordance with paragraph 7 (Rights of Use) of this Agreement in cases for protective rights, applications for protective rights or know-how are part of the exchanged information.

4. Confidentiality

4.1 Either Partner shall keep in confidence any Expertise and Work Results obtained from the other Partner under Item 5 and is only entitled to publish such Expertise and Work Results if the other Partner has given its prior written consent.

4.2 The obligation to confidentiality does not exist or is not applicable inasmuch as

a. such Expertise and Work Results can be taken from sources generally available;
b. such Expertise and Work Results were state of the art or knowledge of the receiving Partner prior to receipt;
c. such Expertise and Work Results are rightfully made available to the receiving Partner from a third source without any obligation of confidentiality.
d. the dissemination of Expertise and Work Results is required by an order of a competent court or administrative agency.

4.3 Before either Partner uses any such Expertise and Work Results of the other Partner without maintaining confidentiality, it shall notify the other Partner in writing and demonstrate that one of the above cases is applicable. Item 8 of this Agreement is not affected by this provision.

5. Publications

5.1 Inasmuch as the Partners do not jointly publish the Work Results, any Publications by either Partner on the other Partner's Work Results require the latter's prior written consent. Consent may only be refused for good cause; it is deemed to be given unless the Partner has objected within one month from the written inquiry. In all other respects, the Partners shall reach agreement concerning Publications.

5.2 Publications should refer to the Partners' cooperation and, at either Partner's request, should name said Partner's staff members involved in deriving the Work Results.

6. Work Results

6.1 Either Partner shall own the Work Results arising on its side.

6.2 Either Partner shall make provisions for being entitled to dispose of its Work Results.

6.3 The Partner shall inform each other of their patent applications without delay.

6.4 The Partners shall jointly seek patent protection for Joint Inventions. The Partners shall form a community of part owners (Bruchteilsgemeinschaft). Subject to the limitations set out in paragraph 6.5 and 6.6, each Partner is free to dispose of its share. The disposal of the joint patent in full requires consent of all part owners. The costs shall be borne by the Partners according to their shares in Inventions unless agreed otherwise.

6.5 If a Partner wishes to sell its share to a third party, it shall make an offer for sale under the same conditions to the other Partner first. The Partner may accept the offer and demand the transfer of the share within three months. In case more than two parties hold the joint patent and are interested in the acquisition of the share, the share is to be offered to them in equal parts unless agreed otherwise.

6.6 Inasmuch as either Partner is not interested in a protective right, it shall offer its rights to the other Partner for transfer, inasmuch as it is legally and actually able to do so. The transfer of rights shall be provided for in a separate agreement. Such offer is to be made early enough to enable the other Partner to take any action required for safeguarding such rights within given statutory periods, especially within the 12-month period to be observed for patent applications claiming priorities. If more than two parties hold the joint patent, the share is to be offered to each Partner in equal parts. The rejection of an offer of transfer is deemed to constitute consent with the abandonment of the patent.

7. Right of Use

7.1 The Partners shall grant each other a free, non-exclusive right to use their Work Results for the execution of the Contract, inasmuch as they are legally in a position to do so.

7.2 Moreover, the Partners shall grant each other a free, irrevocable, non-exclusive right to use Work Results for research and development including contract research. As far as the exercise of this right requires the use of Partner's Expertise the Partners shall grant each other a free, irrevocable, non-exclusive right to such Expertise for research and development including contract research.

7.3 With regard to a right to use their Work Results and Expertise for commercial purposes the Partners will undertake separate negotiations. As far as a right to use a Partner's Expertise is required for the commercial use of own or joint Work Results a Partner is only entitled to refuse the conclusion of a license agreement at market conditions if it has legitimate reasons to do so.

7.4 Sublicensing by one Partner requires the prior written consent of the other Partner. Such consent may not be withheld unreasonably.

8. Own commercial use of Joint Work Results

If a Partner uses Joint Inventions and related protective rights for its own commercial purposes it shall pay the other Partner a fee in the amount of a license fee at market conditions for the use of the Partner's share.

9. Liability, Warranty

9.1 The Partners shall not be mutually liable for and shall hold each other harmless against any personal, material and property damage incurred by the other, its staff members or agents in executing the Contract, unless such damage has been caused willfully or by gross negligence or unless such damage is covered by insurance protection.

9.2 The Partners will not assume any mutual warranty that Expertise, Work Results, documents and items made available in executing the Contract are correct, useful and complete and can be used without infringing third party rights. Either Partner shall inform the other Partner about conflicting third-party rights as soon as they obtain such knowledge.

9.3 None of the Partners is responsible for the enforceability of the protective rights covered by this Contract.

10. Validity and Termination

The provisions of the Memorandum of Understanding from 7th of October, 2015 are applicable.

11. Jurisdiction / Choice of law

The provisions of the Memorandum of Understanding from 7th of October, 2015 are applicable.

Date/Place: August 29th, 2016, Tbilisi, Georgia

For Forschungszentrum Jülich GmbH, Jülich, Germany

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Prof. Dr. Dr. h.c. mult. Sebastian M. Schmidt
Board of Directors

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i.V. Prof. Dr. Dr. h.c. mult. Hans Ströher
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For Ministry of Education and Science, Tbilisi, Georgia

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Manana Mikaberidze
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Acting Rector

Annex 1: Work packages (WP) with the deliverables

WP-1: Beam polarimetry (calorimeter development)

The conceptual new idea of the polarimeter (as suggested by the Georgian team) has been described in the signed MoU document. The polarimeter will be based on the measurement of the full energy deposited in the detector by the deuterons from the elastic dC scattering process. This basic principle requires: (i) elastic reaction identification capability; (ii) close to 100% DAQ efficiency; (iii) full acceptance in a reasonable coverage of the maximum Figure-of-Merit (FoM) region; (iv) no magnetic/electric field, and (v) long term stability (>10 years). Currently, the idea is to use a heavy nuclei crystal calorimeter to select elastically scattered deuterons from the fixed carbon target. In addition, for tracking a plastic scintillator array will be installed in front of the hadron calorimeter to increase the position resolution.

The material of choice for the fast calorimeter is the so called LYSO (Lutetium-yttrium oxy orthosilicate) crystal because of its unique properties. The complete polarimeter will consist of individual detectors arranged in rings around the beam. The inner rings of the detector are LYSO crystals. For the outer part, where much lower count rates are expected, BGO (Bismuth germanate) crystals of nearly equal density, similar light output and rather slower decay time constant can be employed. The first, already started step of this development program is to study the characteristics of the LYSO detector material, as a hadron calorimeter. The information collected after the first measurements in the laboratory and later at the COSY beam will provide essential input for the development of the simulation code using the GEANT4 toolkit. Simulations currently on-going are based on scarce data for this kind of material. The test setup for the foreseen measurements is under preparation. Some parameters of the LYSO crystal will be studied in the lab prior to the measurements with the COSY beam. The values of its response to cosmic rays, the absorption length measurements using a ^{22}Na source, and the count rate linearity using Light pulses will be examined. After commissioning, the setup is planned to be installed at an external beam line of COSY. The crystals will be mounted on a 2D step-motor control-table that is capable of moving the setup in the vertical direction and rotating it around the vertical axis. During these tests, the deuteron beam will be directed towards the center of the crystal. Understanding the signal shape using two different types of the Hamamatsu PMT's with two newly developed passive high-voltage dividers is also planned.

The main objective of the next step is a precise and careful scan of the target materials close to carbon. In understanding and making this step effective, intensive Monte Carlo simulations will be needed. All the acquired information after step one will be used as input of the GEANT4 simulation code. Like step one, the step two will also utilize the COSY external beam, which gives us the advantage to tag every incoming deuteron. The main idea of step two is using extracted polarized deuteron beam for the asymmetry measurement. Step three will be as an internal storage ring test of the final JEDI polarimeter concept.

WP-2: Beam polarimetry (target development)

A key challenge for the srEDM project is the provision of a sensitive and efficient method to determine the tiny change of the beam polarization direction – JuDiT (Jülich ballistic Diamond pellet Target) will provide the essential and groundbreaking technique: two highly innovative shooter/catcher systems of the beam-polarimeter. These will precisely and repeatedly maneuver a single solid diamond pellet (diameter 10-100 µm) as the target through the circulating beam inside the storage-ring vacuum. Elastic scattering of the beam particles on carbon nuclei will provide the polarimetry reaction. JuDiT, in combination with the polarimeter detector, will enable to push the EDM sensitivity level by orders of magnitude in a future dedicated storage ring – including a possible pioneering EDM discovery. The very first use will be made in a deuteron precursor EDM-experiment in the existing storage ring COSY Jülich. The new idea for the beam-target part of the polarimeter, a precision-controlled motion of a micro-object, requires various highly innovative solutions for the technical challenges and a lot of effort to actually realize JuDiT and to bring it in operation in the vacuum conditions of a storage ring. The details are given in the JuDiT-proposal, recently submitted for an ERC consolidator grant in framework of the HORIZON 2020 program of the European Union.

WP-3: Polarimeter-target-detector assembly and test

After the successful completion of tests for the individual elements of the new detector system (WP-1 and WP-2), the group will embark on the step-by-step assembly and test of the whole polarimeter setup. The Monte-Carlo model of the polarimeter has shown that a modular assembly with a standardized aluminium support structure is the optimal solution. Such a construction allows building the polarimeter with a varying number of crystals up to the final optimal configuration. In addition, such a simple construction makes it easy to set up the polarimeter in two or more different places in the storage ring in order to monitor the spin rotation. The main building blocks of the polarimeter are the LYSO crystal modules. The size of these modules is such as to stop the elastically scattered deuterons or protons and measure their total energy and time with high precision. The current engineering drawing (detector and the target chamber) together with the supporting system was shown and discussed in Annex 4. of the MoU.

WP-4: First EDM measurements using COSY

A storage ring charged hadron EDM-search has never been conducted and, given the potential impact of such measurements, a demonstration of the method, i.e., the storage of a polarized beam with large spin coherence time and the application of an E×B field such that no Lorentz-force acts on the particles (a "magic rf Wien filter"), must be conducted as a first step. During last year, a prototype rf E×B dipole has been successfully commissioned and tested at COSY. The force due to a radial magnetic field is cancelled by a vertical electric one. In this configuration, the dipole fields form a Wien filter that directly rotates the particles' polarization vector. It was verified that the device can be used to continuously flip the vertical polarization of a 970 MeV/c deuteron beam without exciting any coherent beam oscillations. For a first EDM-experiment the rf E×B dipole in Wien-filter mode will be rotated by 90° around the beam axis. This configuration will be used for systematic investigations of sources for false EDM signals. The magic rf Wien filter will allow us to perform a polarization build-up experiment. The planned (and then fully tested) polarimeter must operate continuously with high efficiency and high polarization sensitivity (analyzing power) so that polarization rotations of the beam as small as a µrad may be detected if they happen within a time of about 1000 s. Since we are using a magnetic machine (COSY), the direction of the spin of the particles is not frozen. In order for this technique to work, the frequency of the rf Wien filter must be locked to the spin motion. This will be accomplished by dedicated feedback systems. Using the rf E×B Wien filter, we are aiming at a first measurement of the deuteron EDM, which will serve as proof-of-principle measurement for the storage ring EDM technique. The SMART|EDM_*Lab* group of Georgian physicists will take part in conducting this experimental program at COSY and make significant contribution into the data analysis.

WP-5: Applications (for medical diagnostics)

The **SMART|EDM**_*Lab* is not only pursuing research and development for the srEDM project, but it also has in mind possible applications: one obvious route is to exploit the LYSO detectors and its advanced readout for medical diagnostics. Modern medical imaging technologies sit at the intersection of a variety of disciplines including physics, informatics, medicine, and engineering. Much of the driving force behind recent advances has come from an understanding of the physics of imaging and its application. For instance, the physics of particle detectors and the chemistry of radiotracers have led to the development of positron emission tomography (PET) while nuclear magnetic resonance is the technique underpinning magnetic resonance imaging (MRI). In order to exploit these opportunities, however, new techniques need to be developed based on novel components and materials. The physics of PET employing photomultiplier tubes (PMT) is well understood and is a mature technology. Unfortunately, given the requirements of space and MR-compatibility, PMTs are non-starters since they do not work in strong magnetic fields and they have been replaced by semiconductor photodetectors in commercial MR-PET systems. In particular, the need for MR-compatibility drove the development of silicon photomultiplier (SiPMs). The development of novel, magnetic-field-insensitive detector concepts based on these novel components is the key element of the work together with INM (Institute of Neuroscience and Medicine) of JÜLICH: here the **SMART|EDM**_*Lab* could make a significant contribution. This might eventually lead to a new-generation PET scanner.

Annex 2: Detailed Budget of SRNSF

Expenses	years	Total (EUR)	1st year (EUR)	2nd year (EUR)	3rd year (EUR)	4th year (EUR)	5th year (EUR)
Head of lab (PI): 1.500 EUR per month	5 (60 months)	90.000	18.000	18.000	18.000	18.000	18.000
PhD student: 21.000 GEL per year	3	25.000	8.333	8.333	8.334		
Master student(s): 15.000 GEL per year	5	30.000	6.000	6.000	6.000	6.000	6.000
Travel money (3 visits for PI): 6.000 EUR per year	5	30.000	6.000	6.000	6.000	6.000	6.000
Other goods and services: 2.000 EUR per year	5	10.000	2.000	2.000	2.000	2.000	2.000
Start-up equipment: 50.000 EUR	1	50.000	50.000				
		235.000					