Memorandum of Understanding

between

Forschungszentrum Jülich GmbH
52425 Jülich

– hereinafter referred to as JÜLICH –

and

Ministry of Education and Science of Georgia

– hereinafter referred to as MoE –

Preamble

On the occasion of the 10-year anniversary of the Georgian-German Science Bridge (GGSB), a Letter of Intent (LoI) was signed between the Ministry of Education and Science of Georgia (MoE) and Forschungszentrum Jülich GmbH (JÜLICH) (refer to Annex 1) to support and further develop their long-term scientific and educational cooperation. In this regard the foundation of so called **SMART|***Labs* (SMART is the abbreviation for Science, Medicine, Applied Research and Technology and hereafter called the "PROJECT") between a consortium of Georgian Universities (the Georgian Technical University (GTU), Ilia State University (ISU) and Tbilisi State University (TSU)) and particular JÜLICH institutes (Institute of Energy and Climate Research (IEK), Nuclear Physics Institute (IKP), Institute of Neuroscience and Medicine (INM), Jülich Center for Neutron Science (JCNS) and Central Institute of Engineering, Electronics and Analytics (ZEA)) is envisaged. JÜLICH and MoE have developed a basic understanding of the mutual demands made on the PROJECT. They now intend to enter into specific negotiations on the contracts to be concluded.

I. Subject matter of the negotiations

From the present point of view, a contractual regulation of the rights and duties concerning the following project elements is required, which should include but not be limited to the following:

1. Both parties agree on a long-term collaboration in the fields of science and education, defined in the Memorandum of Understanding (MoU) and enclosed as Annex 2.
2. In order to establish the basis for this cooperation at the currently selected (but not limited to) universities in Georgia, **SMART|***Labs* will be founded under the following intentions:
   a. each **SMART|***Lab* will be located at one of the consortium universities, which outlines the general scope of the planned topical laboratories;
   b. each **SMART|***Lab* will be headed by an outstanding young Georgian scientist returning back to Georgian science to ensure and intensify further educational and scientific exchange with scientists from JÜLICH;
   c. different **SMART|***Labs* should cooperate as much as possible whenever is seems appropriate.
3. Current ideas for **SMART|***Labs* between the consortium and JÜLICH, including the foreseen topics and partners, are given in Annex 3. This list can be extended on mutual agreement.

4. MoE considers the **SMART|***Lab* concept as a special cooperative targeted program and is willing to support these long-term (> 10 years) research projects with financial resources operated by the Shota Rustaveli National Science Foundation (SRNSF).
5. JÜLICH via its respective partner institutes, agrees to provide substantial support for the required equipment as well as the high-level and long-term cutting-edge research project.
6. The selection of the topical **SMART|***Labs* and the young Georgian scientist heading the lab will be made on mutual agreement between the Georgian host institution and JÜLICH once the financial resources are secured.

A first detailed proposal for a so called **SMART|EDM**_*Lab* is described in Annex 4. In order to become effective, the annex for the **SMART|EDM**_*Lab* as well as any future Annex 4 must be signed by the corresponding Georgian and JÜLICH partner institutions. Annexes 1-4 are part of this agreement.

II. Legally binding provisions

1. With the exception of the following provisions, no legal obligation for either of the parties can be derived from this Agreement. In particular, there is no obligation to conclude the contracts specified under I.

2. Either party shall bear its own internal and external costs incurred in connection with the negotiations and other relevant measures. Either party shall be entitled to terminate the negotiations at any time without giving reasons, provided that a declaration in writing to this effect is presented to the other party.

3. In case of failure to materialize the PROJECT or to comply with the time schedules agreed upon, the parties shall not bring forward any claim against one another, irrespective of the legal basis. This shall apply, in particular, to claims for damages or the reimbursement of costs due to failure to conclude the contract. The parties, moreover, shall not be liable for information not being provided at all, or not in good time, or being provided in a faulty manner.

4. Either party shall treat the negotiations and the contents of this MoU confidentially, unless the other party has given its prior written consent to a publication.

5. Either party shall use all and any information obtained from the other party within the framework of the discussions and negotiations exclusively for the purposes (see

Preamble) for which it has obtained such information, shall not disclose it to third parties and shall protect it like its own trade secrets. This obligation shall not apply to information that is generally known, information that has been provably derived independently by the party receiving such information, or information lawfully obtained from third parties without infringing any obligation of confidentiality. This obligation shall not be applicable either in case a party is compelled to disclose the information obtained on the grounds of legal provisions. This obligation shall be valid for a period of six *(6)* years after this Agreement has ceased to be in force.

6. Any modifications to this MoU shall be made in writing in order to become valid. The form requirement can only be waived by agreement in writing.

7. This Agreement shall enter into force on the date of signature by both parties. It shall cease to be valid upon conclusion of all contracts required for the implementation of the project and in case the negotiations are terminated, at the latest, however, on 31st of December 2021 *(31/12/2021)*. However, the provisions on confidentiality shall remain valid.

8. Should a provision of this Agreement be or become ineffective, this shall not affect the validity of the other provisions. The parties undertake to replace such ineffective provision by an effective provision as close as possible to the regulation purpose of the ineffective provision.

9. The exclusive place of jurisdiction for all disputes arising from this Agreement shall be Jülich.

Tiblisi, 07. October 2015

Ministry of Education and Sciences of Georgia	**Forschungszentrum Jülich GmbH**
Tamar Sanikidze	Sebastian M. Schmidt
Minister of Education and Science of Georgia	Board of Management of Forschungszentrum Jülich

JÜLICH
FORSCHUNGSZENTRUM

Letter of Intent
between the Ministry of Education and Science of Georgia (MoE)
and Forschungszentrum Julich GmbH (FZJ)
on a strategic partnership

The Ministry of Education and Science of Georgia (MoE) and Forschungszentrum Jülich GmbH (FZJ), Jülich (Germany) intend to support and further develop the long-term scientific and educational cooperation between a consortium of Georgian Universities (GTU, ISU, TSU) and Institutes (IEK, IKP, INM, JCNS, ZEA) of FZJ.

In order to do so, MoE and FZJ – within the "Georgian German Science Bridge (GGSB) – agree:

- To foster student exchanges by internship, Master, and PhD programs;
- To support Georgian PhD students by preparing agreements between Georgian and German universities within the so called "Cotutelle" program ;
- To support Georgian scientists in common research and in the exchange of scientific equipment;
- To promote common medium and large-scale projects within and outside Jülich, e.g., through applications by Georgian-German partners within the HORIZON2020 initiative of the European Union (EU);
- To help MoE in its intention to define and sign an updated intergovernmental science and education agreement between Georgia and Germany, and
- To formulate and sign a Memorandum-of-Understanding (MoU) between MoE and FZJ later this year.

Date:

For the Ministry of Education and Science of Georgia	For Forschungszentrum Jülich GmbH Jülich, Germany
	S. Schmidt
Tamar Sanikidze	**Sebastian M. Schmidt**
Minister of Education and Science of Georgia	Board of Management of FZJ

Annex 2

Memorandum of Understanding

between

Forschungszentrum Jülich GmbH
52425 Jülich

– hereinafter referred to as JÜLICH –

and

Consortium of Georgian Universities
Georgia

Composed of:
Ivane Javakhishvili Tbilisi State University (TSU),
Georgian Technical University (GTU),
Ilia State University (ISU)

– hereinafter referred to as GEORGIA –

Preamble

The successful scientific cooperation between JÜLICH and GEORGIA dates back to the early 1990´s with a first agreement signed in 1998. The first Memorandum of Understanding (MoU) was signed in May 2010. Based on this MoU, the mutual cooperation has been fostered within the concept of the so called "Georgian-German Science Bridge" (GGSB), supported by the Ministry of Education and Science (MoE) of Georgia, Shota-Rustaveli National Science Foundation (SRNSF) and JÜLICH.

JÜLICH and GEORIGA discussed on several occasions the opportunities for the long-term scientific and educational cooperation between a consortium of Georgian Universities (TSU, GTU, ISU) and Institutes of JÜLICH (IEK, IKP, INM, PGI/JCNS, ZEA) (hereinafter called the "PROJECT"). In these discussions a mutual agreement about the future of the PROJECT has been achieved: it is intended to further develop the cooperations and to negotiate specific agreements as outlined below.

I. Subject matter of the negotiations

From the present point of view, a contractual regulation of the rights and duties concerning the following project elements is required, which should include but not be limited to the following:

1. JÜLICH and GEORGIA agree to continue their scientific cooperation in the field of **fundamental particle and nuclear physics (**JÜLICH institute **IKP)**; this encompasses existing projects as well as future ventures, and includes the following items:

- Jülich Electric Dipole moment Investigations (JEDI):
  - performing research and development (R&D) for accelerator components and measurement equipment, in particular for the design and construction of a dedicated high efficiency polarimeter system for an electric dipole moment (EDM) search;
  - undertaking joint preparatory experiments at the Cooler Synchrotron storage ring (COSY), including a precursor EDM experiment;
  - conducting R&D work for the design of a high precision EDM storage ring for protons and deuterons.
- Facility for Antiproton and Ion Research (FAIR):

- contributing to developments for the High Energy Storage Ring (HESR) and the internal detector system PANDA;
- performing R&D for the Polarized Antiproton Experiment (PAX).

- Theory:
  - supporting the motivation, analysis and interpretation of COSY and FAIR experiments as well as the JEDI project.

On the part of JÜLICH, this cooperation will be implemented into JARA-FAME, the section "Forces and Matter Experiments" of the "Jülich-Aachen Research Alliance".

2. JÜLICH and GEORGIA agree to continue their scientific cooperation in the field of **condensed matter physics and scattering methods** (JÜLICH institutes **JCNS**, **PGI**); this encompasses existing projects as well as future ventures, and includes the following items:

- Development and microscopic understanding of novel materials and materials systems for information Technology and applications in Energy Conversion:
  - synthesis of multiferroic and magnetocaloric materials;
  - quantitative characterization with various laboratory methods;
  - detailed microscopic studies by means of Electron Paramagnetic Resonance and Neutron and X-ray scattering techniques.

- Application of Grazing Incidence Scattering techniques on thin films and nanostructured systems.

3. JÜLICH and GEORGIA agree to continue their scientific cooperation in the field of **atmospheric sciences and environment (**JÜLICH institute **IEK)**; this encompasses existing projects as well as future ventures, and includes the following items:

- Numerics of forward and inverse modelling of atmospheric models:
  - performing research and development (R&D) on the discretisation of icosahedral grids;

- performing R&D on data assimilation with adjoint atmospheric modelling, including preconditioning and minimisation for variational methods and further afield;
- performing R&D on numerical solution of stochastic differential equations of atmospheric processes.

- Development and application of specific analytical techniques for atmospheric process understanding:
  - performing R&D on enantioselective processes of chiral pollutants in the environment and atmosphere;
  - development and application of micro- and nanoanalytical techniques for studying of atmospheric trace compounds.

4. JÜLICH and GEORGIA agree to continue their scientific cooperation in the field of **medical imaging physics (JÜLICH's institute INM**); this encompasses existing projects as well as future ventures and includes the following items:

- Development and application of novel methods for quantitative magnetic resonance imaging:
  - undertaking quantitative mapping of the MRI relaxation parameters;
  - extension of quantitative mapping to include water mapping;
  - application of the developed methodologies to study pathologies such as traumatic brain injury and cancer.

- Application of non-Gaussian methods for the analysis of diffusion in the brain:
  - acquisition and possession of data to investigate non-Gaussian diffusion in the brain;
  - demonstration of the utility of these methods in clinical studies.

5. JÜLICH and GEORGIA agree to expand their cooperation towards efficiently exploiting the capacity of the **Central Institute for Engineering and Technology (JÜLICH's institute ZEA)**, applied to the fields of fundamental particle and nuclear physics, condensed matter physics, in atmospheric sciences, in medical applications and in engineering sciences (simulation and instrumentation). The main focus is to provide

opportunities for young academics to become acquainted with frontier technological processes.

6. Towards the education of students and the training of young researchers, the cooperation of scientists as well as the exchange of equipment, JÜLICH and GEORGIA agree to:

- foster student exchanges by setting up Internship-, Master-, and PhD programs together with German universities, in particular to support Georgian PhD students by preparing agreements between Georgian and German universities within the so called “Cotutelle” program;
- conduct dedicated summer and autumn lecture courses;
- organize common topical workshops and conferences to present and discuss recent results and to plan further cooperation;
- support Georgian scientists in common research and in the exchange of scientific equipment;
- initiate so called joint SMART|Lab’s project.

All details such as mutual commitments, deliverables, timelines, and resources will be specified in Annexes to this MoU, to be signed independently by each partner.

II. Legally binding provisions

1. With the exception of the following provisions, no legal obligation for either of the parties can be derived from this Agreement. In particular, there is no obligation to conclude the contracts specified under I.

2. Either party shall bear its own internal and external costs incurred in connection with the negotiations and other relevant measures. Either party shall be entitled to terminate the negotiations at any time without giving reasons, provided that a declaration in writing to this effect is presented to the other party.

3. In case of failure to materialize the PROJECT or to comply with the time schedules agreed upon, the parties shall not bring forward any claim against one another, irrespective of the legal basis. This shall apply, in particular, to claims for damages or the reimbursement of costs due to failure to conclude the contract. The parties,

moreover, shall not be liable for information not being provided at all, or not in good time, or being provided in a faulty manner.

4. Either party shall treat the negotiations and the contents of this MoU confidentially, unless the other party has given its prior written consent to a publication.

5. Either party shall use all and any information obtained from the other party within the framework of the discussions and negotiations exclusively for the purposes (see Preamble) for which it has obtained such information, shall not disclose it to third parties and shall protect it like its own trade secrets. This obligation shall not apply to information that is generally known, information that has been provably derived independently by the party receiving such information, or information lawfully obtained from third parties without infringing any obligation of confidentiality. This obligation shall not be applicable either in case a party is compelled to disclose the information obtained on the grounds of legal provisions. This obligation shall be valid for a period of five *(5)* years after this Agreement has ceased to be in force.

6. Any modifications to this MoU shall be made in writing in order to become valid. The form requirement can only be waived by agreement in writing.

7. This Agreement shall enter into force on the date of signature by both parties. It shall cease to be valid upon conclusion of all contracts required for the implementation of the project and in case the negotiations are terminated, at the latest, however, on 31st of December 2021 *(31.12.2021)*. However, the provisions on confidentiality shall remain valid. If necessary this Agreement can be extended by written agreement.

8. Should a provision of this Agreement be or become ineffective, this shall not affect the validity of the other provisions. The parties undertake to replace such ineffective provision by an effective provision as close as possible to the regulation purpose of the ineffective provision.

9. The exclusive place of jurisdiction for all disputes arising from this Agreement shall be Jülich.

Tbilisi, Gorgia, 07 October, 2015

Forschungszentrum Jülich GmbH

Prof. Dr. Sebastian M. Schmidt
Member of the Board of Directors

i.V. Prof. Dr. Hans Ströher
Director at IKP

i.V. Prof. Dr. Andreas Wahner
Director at IEK

i.V. Prof. Dr. Nadim Jon Shah
Director at INM

i.V.Prof. Dr. Thomas Brückel
Director at JCNS

i.V. Prof. Dr. Ghaleb Natour
Director at ZEA

Consortium of Georgian Universities

Prof. Dr. Merab Eliashvili
Acting Rector of Ivane Javakhishvili Tbilisi State Unversity

Prof. Dr. Archil Prangishvili
Rector of Georgian Technical University

Prof. Dr. Giga Zedania
Rector of Ilia State University

Annex 3.

Synopses of plans for

SMART|*Labs*

(SMART: **S**cience, **M**edicine, **A**pplied **R**esearch and **T**echnology)

Within the concept of the “Georgian-German Science Bridge” (GGSB), the new idea is to foster the mutual cooperation by establishing so called "**SMART|***Labs*", which should be affiliated with a consortium of Georgian universities (currently comprising , but not limited to, the Georgian Technical University (GTU), Ilia State University (ISU) and Tbilisi State University (TSU)).

SMART|*Labs*:

- Will help the emergence and further development of Georgian frontier science and future technology.
- Should be connected with a scientific or a medical question/problem and they should have a strong technological component with possible applications.
- Should comprise a small group (3-5) of scientists/engineers and students and be built around an outstanding young Georgian researcher. The group should have or establish strong ties with (at least) one international research center ("partner") to assure, e.g., access to world-leading research infrastructures. It will be advantageous to identify (a) Georgian senior scientist(s) at the partner institution to ensure communicative and administrative continuity.
- Should be supported with start-up resources (e.g. an SRNSF grant for personnel and FZJ equipment donations) to set up the *Lab* and effectively initiate its international activities. Details must be defined in separate project proposals.

Different **SMART|***Labs* could be connected in varying levels of internal cooperation to explore and exploit possible synergies (example: equipment-making by the EDM and the MRI **SMART|***Labs*).

Examples:

SMART|EDM_*Lab*

Topic:	**Science**	Search for charged particle EDMs in Storage Rings
Issue:	**Applied Research**	Polarimetry: basics (completion of the data base)
	Technology	Detector/target design, construction (+ electronics, readout)
Partner:	**Georgia - FZJ**	TSU and Institut für Kernphysik (IKP)
	Georgia	Dr. David Mchedlishvili
	FZ-Jülich	Prof. Hans Ströher, Dr. A. Kacharava, Dr. I. Keshelashvili

Benefit: Georgian scientists and students will be involved in research concerning one of the fundamental questions of contemporary science: why is there essentially only matter found in our universe and only negligible amounts of anti-matter ("The puzzle of our existence")?

The **SMART|**EDM_*Lab* (Georgian scientists and students) will take on one of the most important issues of the JEDI (“Jülich Electric Dipole Moment Investigations”)-project: 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 detector response and capabilities;
- design of the equipment;
- construction;

- installation and commissioning;
- use in the experiment.

The experience gained in this project by the Georgian group in simulations, hardware design and construction and experimental techniques, e.g., DAQ, will enable them to apply their knowledge to other science fields and to Georgian industry.

SMART| MRI_*Lab*

Topic:	**Science**	Development of techniques for magnetic resonance imaging
Issue:	**Applied Research**	Investigation of brain function and dysfunction
	Technology	Software design / construction of radiofrequency coils
Partner:	**Georgia - FZJ**	GTU and INM-4
	Georgia	Prof. Dr. Ketevan Kotetishvili (temporarily)
	FZ-Jülich	Prof. Nadim Jon Shah, PD Dr. Farida Grinberg

Benefit: Georgian scientists and students will be involved in design of novel sequences (imaging methods) for quantitative magnetic resonance imaging. These will include mapping the relaxation parameters T1, T2, and T2* as well as the proton density, M0. Moreover, developments will be undertaken in the area of diffusion imaging both from the point of view of analysis of data and well as novel methodology.

At 9.4T the design of new radiofrequency coils is also an important task; Georgian scientists and students will also gain knowledge in this area. This is particularly beneficial since only five such machines exist worldwide.

The experience gained in this project by the Georgian group in sequence design, radiofrequency hardware design and programming of novel techniques for quantitative MRI will enable them to apply their knowledge in the Georgian healthcare sector as well as in Georgian industry (characterization of materials).

SMART| AtmoSim_*Lab*

Topic:	**Science**	Development of techniques for atmospheric simulations and measurements
Issue:	**Applied Research**	Forecasting regional air quality /detection method for atm. chiral compounds
Partner:	**Georgia - FZJ**	TSU and IEK-8
	Georgia	Prof. R. Botchorishvili, Prof. B. Chankvetadze (temporarily)
	FZ-Jülich	Prof. AndreasWahner, PD Dr. Hendrik Elbern

Benefit: Georgian scientists and students will be involved in:

- Numerics of forward and inverse modelling of atmospheric models:
  - performing research and development (R&D) on the discretisation of icosahedral grids;
  - performing R&D on data assimilation with adjoint atmospheric modelling, including preconditioning and minimisation for variational methods and further afield;
  - performing R&D on numerical solution of stochastic differential equations of atmospheric processes.

- Development and application of specific analytical techniques for atmospheric process understanding:
  - performing R&D on enantioselective processes of chiral pollutants in the environment and atmosphere;
  - development and application of micro- and nanoanalytical techniques for studying of atmospheric trace compounds.

The experience gained in this project by the Georgian group will enable them to apply their knowledge in Georgia for environmental applications.

Annex 4.

<u>SMART</u>|EDM_*Lab*

Motivation for the foundation of a SMART|*Lab* within the Project

Search for Electric Dipole Moments of Protons and Deuterons in Storage Rings (srEDM)

Executive Summary of Science Case and Organizational Structure

Science:	Fundamental research: Symmetries and symmetry breaking in subatomic physics
Science Impact:	Evolution of the Universe (Matter-Antimatter Asymmetry); Physics beyond the Standard Model of Particle Physics
Jülich Project:	Search for charged particle Electric Dipole Moments in Storage Rings (srEDM)
Int. Collaboration:	JEDI (**J**ülich **E**lectric **D**ipole Moment **I**nvestigations) (http://collaborations.fz-juelich.de/ikp/jedi/)
SMART|*Lab* Issue:	Polarimetry of the proton/deuteron beam in the EDM storage ring
Technology:	Polarimeter (detector and target) design, construction (incl. electronics, readout)
Technology Impact:	Simulation and design programs, scintillation detectors for medical research
Partner:	TSU (Georgia) and Nuclear Physics Institute (IKP) (Jülich) Georgia: Dr. David Mchedlishvili (Head of lab), EDM team HEPI TSU Jülich: Prof. Hans Ströher, Dr. Andro Kacharava, Dr. Irakli Keshelashvili
Project Timeline:	Start January 1, 2017 Duration 5 years (with the option for additional 5 year extensions)
Total Budget:	For the first 5 years 450.000 € (four-hundred-and-fifty thousand Euro)

Date/Place: October 7, 2015, Tbilisi

For
Forschungszentrum Jülich (FZJ), Germany
and Institut für Kernphysik (IKP)

Sebastian M. Schmidt
Board of Management FZJ

Hans Ströher
Director at IKP

For
Shota Rustaveli National Science Foundation (SRNSF), Georgia and the Ivane Javakhishvili Tbilisi State University (TSU)

Marine Chitashvili
Director General SRNSF

Merab Eliashvili
Acting rector of TSU

Scientific Case

1. Novelty of research, goals and objectives

1.1 Topicality of the problem and research novelty

According to our present understanding, the early Universe contained the same amount of matter and antimatter and, if the Universe had behaved symmetrically as it developed, every particle would have been annihilated by one of its antiparticles. One of the great mysteries in the natural sciences is therefore why matter dominates over antimatter in the visible Universe. The breaking of the combined charge conjugation and parity symmetries (CP-violation, CPV) in the Standard Model of particle physics (SM) is insufficient to explain this and further sources of CPV must be sought. These could manifest themselves in electric dipole moments (EDMs) of elementary particles, which occur when the centroids of positive and negative charges are mutually and permanently displaced. An EDM observation would also be an indication for physics beyond the SM.

Investigations on different systems are required to pin down CPV sources and the JEDI (Jülich Electric Dipole Moment Investigations) project aims to lay the foundations for the study of new CPV mechanisms by searching for EDMs of *charged* hadrons (proton, deuteron, …) in a new class of precision storage rings. It will develop the key technologies and achieve a first directly measured EDM limit for protons and deuterons and thus provide the basis for a new European flagship research infrastructure.

The EDM measurement principle, the time development of the polarization vector subject to a perpendicular electric field, is simple, but the smallness of the effect makes this an enormously challenging project. A stepwise approach, from R&D for key-technologies towards the holy grail of a double-beam precision storage ring with counter-rotating beams, is needed. The research environment of the Forschungszentrum Jülich (Germany), including COSY, provides the optimum basis for one of the most spectacular possibilities in modern science: finding an EDM as a signal for new physics beyond the SM and perhaps explaining the puzzle of our existence.

1.2 Research subject and objectives

A new class of precision storage rings is required to search for electric dipole moments (EDMs) of charged particles with unprecedented sensitivity. It is the aim of the JEDI project to take a decisive step towards the design and construction of such a facility by establishing the required key technologies and to deliver the first directly measured EDMs for both the proton and the deuteron using the existing cooler storage ring COSY at the Forschungszentrum Jülich (FZJ).

EDMs are very small – the best current limit for the neutron is 10^{-26} e×cm – and the aim for charged particles is at least 10^{-29} e×cm. Although the measurement principle – the time development of the polarization vector subject to a perpendicular electric field – is simple, this represents an enormously challenging project due to the smallness of the expected effect. It will only be mastered through the common effort of an experienced international team of accelerator and spin-physics scientists, supplemented by mechanical and electrical engineers.

Given the history of neutron EDM searches over the past 50 years or so, it is evident that a corresponding level of sensitivity cannot be obtained in one giant leap – a stepwise approach, in which the next generation measurement is based on the expertise and technological know-how gained in the preceding one, is compulsory. The steps towards the holy grail of a charged particle EDM search, using a double-beam precision storage ring with counter-rotating beams, comprise:

1. Research and development of all the key techniques at an existing conventional single-beam storage ring. COSY, the cooler synchrotron and storage ring at the Forschungszentrum Jülich, is the ideal place for these investigations, which involve spin-coherence time optimization, precision polarimetry development, beam tracking measurements, etc.;
2. Precision spin-tracking simulations: an essential requirement for an assessment of the capabilities of the final precision ring is to provide realistic simulations, e.g., for benchmarking EDM test installations in COSY;
3. A proof-of-principle experiment: this measurement will use COSY-Jülich without major transformations except for improvements of the beam position monitor (BPM) system and the assembly of a

radiofrequency (rf) Wien-filter which (in an ideal storage ring) would induce spin rotation if an EDM exists;

4. A first direct EDM measurement (for the proton and the deuteron), again exploiting COSY-Jülich, but here upgraded with a short electrostatic deflector inside the ring. The beam chicane could be inserted in one of the straight sections of COSY. This would test one of the key techniques of the final ring and should lead to an EDM upper limit in the order 10^{-24} e×cm. It would also provide a reality check on further key items, e.g., the spin coherence time and polarimetry;
5. Conceptual design report (CDR) and technical design report (TDR) for the final dedicated storage ring, including cost estimates for building and operating the facility;
6. Construction and commissioning of the new facility for EDM searches, once funding has been secured.

The current project addresses item 1), in particular the beam polarimetry, which will determine the observable for an EDM (limit). The accelerator scientists and experimental physicists (hadron and spin physics) at the Institut für Kernphysik (IKP) at FZJ, the research environment at the center (e.g., mechanical and electronics workshops) – including the cooler storage ring COSY for polarized proton and deuteron beams as a unique asset – as well as the close connections with RWTH Aachen University (high energy physics, engineers) via the Jülich-Aachen Research Alliance (JARA, section FAME (Forces and Matter Experiments)) and the long-term successful cooperation with University of Ferrara and INFN Ferrara (Italy) and Tbilisi State University (TSU, Georgia) provide the optimal basis for one of the most spectacular possibilities in modern science: finding an EDM as a signal for new physics beyond the SM and perhaps explaining the puzzle of our existence.

2. Research methods and expected outcomes

2.1 Concept for charged-hadron EDM searches

EDMs are very small – the best current upper limit for the neutron is 10^{-26} e×cm – and the goal for charged particles in the ultimate project is 10^{-29} e×cm or even better. In spite of the simplicity of the measurement principle – following the time development of the polarization vector of particles subject to a perpendicular electric field – the smallness of the effect provides exceptional challenges, e.g., to identify and/or avoid any fake signal.

The spin precession (i.e., the motion of the polarization vector of a particle beam) in a storage ring is governed by the so-called Thomas-Bargmann-Michel-Telegdi (Thomas BMT) equation. The main challenge is that in general the spin precession due to the magnetic dipole moment (MDM) is many orders of magnitude larger than the spin precession expected from an EDM. The aim is thus to find electromagnetic field configurations where the contribution due to the MDM vanishes, i.e., where the spin vector does not precess and always points along the momentum vector in the absence of an EDM. This technique is called “frozen spin”.

For protons, with their positive anomalous magnetic moment, this can be achieved with purely electric fields for a “magic” beam momentum (p = 701 MeV/c). For particles with a negative anomalous magnetic moment (like deuterons and ^{3}He), a combination of electric and magnetic fields has to be used. In either case, a non-vanishing EDM results in a build-up of a vertical polarization component for a beam that was initially polarized in the horizontal plane. A purely electric ring for proton EDM measurements was proposed by a collaboration at Brookhaven National Laboratory (BNL, USA). A radial electric field of about 17 MV/m between field plates approximately 2 cm apart results in a ring with a bending radius of about 50 m. An alternative is to use a combined machine, with both radial electric and vertical magnetic fields. By suitable combinations of the E- and B-fields, a ring with a bending radius between 10 and 30 m could be used for protons, deuterons and ^{3}He nuclei (“all-in-one” ring). Such a ring is suggested by the JEDI collaboration at COSY.

For both options, the use of clockwise (CW) and counter clockwise (CCW) beams is mandatory. This is because the main systematic error will come from an unwanted spin precession due to the MDM in radial magnetic fields which will be indistinguishable from the EDM signal. However, a radial magnetic field causes forces in different directions for the beams in opposite directions and thus it can be controlled to a very high accuracy.

2.2 Implementation and expected impact

As already stressed, the principle of such measurements is quite simple: if an electric dipole moment exists, the spin vector, which is oriented parallel to the EDM direction, will experience a torque in an external electric field, resulting in a change in the original spin direction. This minuscule spin rotation (about 1 mrad/s for an EDM of 10^{-26} e×cm) can be determined with the help of a polarimeter (a detector to determine the spin direction). Alternatively, it might be possible to measure the tiny change of the spin precession frequency due to an EDM by comparing results with different electric field strengths. As emphasized before, the smallness of the expected effect, as well as possible background and fake contributions, will require paramount precision and utmost care.

In view of the necessary requirements, the existing cooler storage ring COSY at the Forschungszentrum Jülich, with its capability to provide polarized protons and deuterons with momenta up to 3.7 GeV/c, is an ideal starting point for a research and development programme and a first direct charged particle EDM measurement. For an ultimate precision measurement, however, a new class of dedicated storage rings is required, and these do not yet exist. At this point, COSY might be used as an injector to prepare the beams for the EDM ring. Searches for proton and deuteron EDMs have the potential to reach a sensitivity of 10^{-29} e×cm per year of running, which is at least one order of magnitude better than that which is aimed for in future neutron EDM searches.

One of the aims of the current project is to establish the required key technologies for precision EDM storage rings for protons and deuterons. Before approaching the concept and design of the final ring, the toolbox of major hardware components needs to be developed and scrutinized in test measurements. In addition, a proof-of-principle test measurement and a first direct EDM measurement will be conducted. To be successful, the project needs expertise in many different fields, ranging from accelerator and elementary particle (spin-) physics to mechanical and electrical engineering. To ensure this, the project is embedded in the recently founded JEDI collaboration at COSY, comprising more than 100 collaborators from France, Georgia, Germany, Italy, Poland, Russia, USA, and other countries, and the US-based storage ring EDM collaboration. It should be emphasized that Georgian team from TSU is already an active collaborative partner in this project.

Arguably the most important impact of this project will be the first-ever direct measurement of an EDM for charged hadrons in a storage ring, since it will determine the directions of R&D and pave the way for the (new class of) precision storage ring(s) of the future. Accelerators are the tools for discovery and innovation, not only in the fields of elementary particle, hadron and nuclear physics, but also, e.g., in medical and industrial applications. This is why all developed countries, and in particular Europe, put a lot of emphasis into the further development of accelerators, from high-energy colliders and synchrotron radiation facilities to spallation neutron sources. The physics case of the EDM project ultimately requires the design of a completely new and innovative storage ring. In order to reduce systematic errors and to identify/control fake effects, counter-rotating beams must be used. Together with the requirement of ultimate precision, these represent significant challenges. By overcoming these challenges, many innovations are to be expected, from surface treatment of electrostatic deflectors (to provide highest electric fields), shielding techniques (of external electric and magnetic fields), beam position and polarization measurement, to simulation techniques on supercomputers.

Already in the course of the initial steps – R&D, implementation of hardware into COSY, test and first EDM measurements with single beam – the complexity of the project will be a constant driver of innovation in accelerator, detection, and simulation techniques:

- Optimization of the <u>spin coherence time</u> (SCT) of the longitudinally polarized stored COSY beam accelerator (sextupole) settings;
- Design, construction, and implementation and operation in COSY of a <u>new beam polarimeter</u>, capable of continuous spin tracking with the required sensitivity and stability;
- Design, construction and implementation in COSY, as well as their use, of new high-precision <u>beam position monitors</u>;
- Design, construction and implementation in COSY of an <u>rf Wien-filter</u> to be used for the proof-of-principle demonstration measurement;
- Design, construction and implementation in COSY of an <u>electrostatic deflector</u> for the first direct EDM measurement;
- Spin-tracking <u>simulations</u> to benchmark experimental investigations and make predictions for a new hardware.

While physicists and engineers (from research centres and universities) have to collaborate during the design phase, the later construction of such a precision storage ring will inevitably also involve technologically oriented institutes such as, e.g., the Central Institute for Engineering, Electronics and Analytics (ZEA) of FZJ, and high-tech companies, e.g., for building combined E-B deflectors. An important extra impact will be the training and education of students and young researchers in a wide range of activities, simulations, hardware development, and data analysis. In addition, the existing collaborations at different levels between the core-team partners will be further developed and intensified. The project will also foster interactions within the worldwide community.

3. Additional information about the project

3.1 Feasibility and structure of the international team

The Cooler Synchrotron COSY at the Institut für Kernphysik (IKP) of Forschungszentrum Jülich has been mentioned repeatedly as the test and development machine for the JEDI-project. COSY is the state-of-the-art storage ring for polarized proton and deuteron beams. After more than twenty years of operation for hadron physics, it has essentially all of the equipment and techniques needed for spin-manipulations. Therefore, COSY is the only machine in the world where most of the necessary tests for the storage ring EDM project can be performed, including a first direct measurement of proton and/or deuteron EDMs. The accelerator scientists at IKP have a long-standing experience with the acceleration and storage of polarized beams in COSY. The group at IKP performed hadron physics experiments with polarized beams at COSY for about 15 years, using internal detector systems (ANKE, PAX and WASA). With the phasing out of the COSY hadron-physics programme at the end of 2014, most of IKP-2 scientists are now fully focused on srEDM. The central engineering institutes of FZJ (ZEA-1 (mechanics), ZEA-2 (electronics)) are IKP-2 partners in JEDI.

Within the institutional cooperation between the Forschungszentrum Jülich and RWTH Aachen University called JARA (Jülich-Aachen Research Alliance), the recently founded section FAME (Forces and Matter Experiments) is concerned with “The Fate of Antimatter”, which provides the scientific basis of the project. JARA-FAME brings together hadron (spin-) physics of IKP with the high energy physics as well as the engineering institutes of RWTH. Jülich has close scientific contacts with many of the surrounding universities in Germany (Aachen, Bochum Bonn, Cologne, Düsseldorf, Essen, Erlangen-Nürnberg, Münster, Wuppertal) and cooperates with major laboratories worldwide.

3.2 Contributions by the external partners: Georgian group

The long-term (more than 20 years) and extremely successful cooperation between the High Energy Physics Institute of Tbilisi State University (HEPI TSU) and IKP-2, e.g., for the ANKE and PAX spin physics experiments, has led to a substantial involvement of the Georgian group in the JEDI-project, in particular in the polarimetry investigations (see a photo of group members below).

Georgian group involved in JEDI project: (from left to right) M. Tabidze, D. Mchedlishvili, G. Macharashvili, Z. Bagdasarian, N. Lomidze, M. Nioradze, A. Kacharava and I. Keshelashvili

The polarimeter for the EDM Storage Ring 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. There also needs to be control of the systematic errors in detecting this change to a similar level of precision. The conditions of high efficiency (1%) and analyzing power (~0.6) are fulfilled for medium energy protons and deuterons when using a thick (few cm) carbon block onto which the beam particles are directed continuously during the experiment. Elastic scattering of the beam particles from the atomic nuclei in the carbon target will be observed in a series of detectors installed behind the target.

Feasibility studies conducted at COSY have already demonstrated this level of performance and error suppression for a carbon block mounted at the edge of the circulating beam. The goal of the working package will be the design, construction and testing of a prototype polarimeter for use in the first EDM storage ring experiment. This will comprise the following major steps:

- Development of a broad-band database for p-C and d-C scattering;
- Detector characterization;
- Polarimeter modelling and Monte Carlo simulations;
- Realization and test of a prototype.

One exciting novel project which has recently been started (by Georgian scientists working at FZJ), is to shoot small diamond pellets (size 1-100 μm) through the beam as target instead of using a bulk carbon block – this has many attractive features, like, e.g., instantly switching the target on/off and obtaining a beam profile, but it requires a new development.

A dedicated target-station in COSY for the data base measurements will be provided at the WASA place; test experiments for detectors can also use the extracted COSY beam. The group of the IKP in close collaboration with the HEPI TSU group will start to develop the polarimeter prototype and work on the new diamond pellet target system; for this purpose a new IKP-2 staff member (Irakli Keshelashvili) has been hired recently, and a cooperation with ZEA-1 (mechanical engineering of FZJ) has been started.

The Georgian team performed at COSY a series of very successful projects supported by Shota Rustaveli Science Foundation (SRNSF): "Study of spin structure of nucleon-nucleon interaction" (ST06/4-108), and "Studies of hadronic processes with formation of diproton final states in polarized experiments" (ST09/1024-4-200). Currently group is running two new projects: "Jülich electric dipole moment investigations" (DI/19/6-200/11) and "Measurement of nucleon-nucleon elastic scattering in polarization experiments" (FR/563/6-200/12). The outcome of these investigations turned out in eight very high ranked physics journal papers, 4 PhD and 4 Master thesis performed by the young participants of the project (Dr. D. Chiladze, Dr. D. Mchedlishvili, PhD Z. Bagdasarian and Master student T. Bokuchava). In autumn 2015 a new master student of GTU, Dito Shergelashvili will start to become involved into the JEDI project. It is expected that a new master student of TSU, Levan Kankadze, will visit IKP within the internship program to obtain first experience and start to be involved in scientific work at IKP/FZJ. Together with the experienced project participants (M. Nioradze, M. Tabidze, N. Lomidze, A. Kacharava, I. Keshelashvili, and G. Macharashvili), students gain a variety of skills by helping to conduct experiments in the frame of large international collaborations at Forschungszentrum Jülich. One of the main goals of the current project is to share this knowledge with a new generation of students from the Consortium of Georgian Universities (see Annex 2).

4. Description of the SMART|EDM_*Lab*

4.1 General concept of SMART|*Labs*

The idea of smart (SMART: **S**cience, **M**edicine, **A**pplied **R**esearch and **T**echnology) labs implies the establishment of relatively small, well equipped and maintained modern laboratories. Such labs are supposed to contribute in different fields of fundamental and applied science within the framework of international collaborations. 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 switch from one activity to another and be able to also contribute to neighboring directions of research and developments using its infrastructure. Therefore, smart labs need to be supplied with modern equipment and tools. These goals set additional requirements for the place where such labs will be situated, and also the technical requirements and regulations it must satisfy. Although the main purpose of the smart labs is its engagement in 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 or at universities. This will induce interest of students and motivate them to participate in ongoing projects, where they will have an opportunity to gain knowledge in modern experimental techniques and improve their skills.

4.2 Research objectives: JEDI polarimetry concept and current activity

The **SMART|EDM_***Lab* introduces a wide range of opportunities for young researchers to contribute in the ongoing JEDI project in cooperation with an international collaboration. During this long-term project many challenges should have to be overcome to achieve the goal of either reducing the upper limit 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 creation and assembly of a new, highly-efficient polarimeter and the development of a completely new type of the target, called a ballistic diamond pellet target. The proposed laboratory, which will be established in Georgia and supplied with suitable equipment (see below), will contribute in these directions by performing various tests and developments of different parts of the detector and the target systems. These activities will mainly include, but not limited to, testing scintillation crystals and photomultipliers for the polarimeter, developing data acquisition and target control electronics, performing Monte Carlo simulations and analyses of obtained test data, etc. Besides, computer modeling of the design concepts and all technological systems will be necessary. Hence, participation of engineers is also overseen in these directions.

The **SMART|EDM_***Lab* by Georgian scientists and students will take on one of the most important issues of the JEDI-project: 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 detector response and capabilities;
- Design of the equipment;
- Construction;
- Installation and commissioning;
- Use in the experiment.

The experience gained in this project by the Georgian group in simulations, hardware design and construction and experimental techniques, e.g., DAQ, will enable them to apply their knowledge to other science fields and to Georgian industry.

The general requirements for this working package were described in 3.2. The conceptual new idea of the polarimeter (suggested by the Georgian team) is shown on Figure 1. It will monitor the change of the asymmetry using the elastic scattering reaction with very high accuracy.

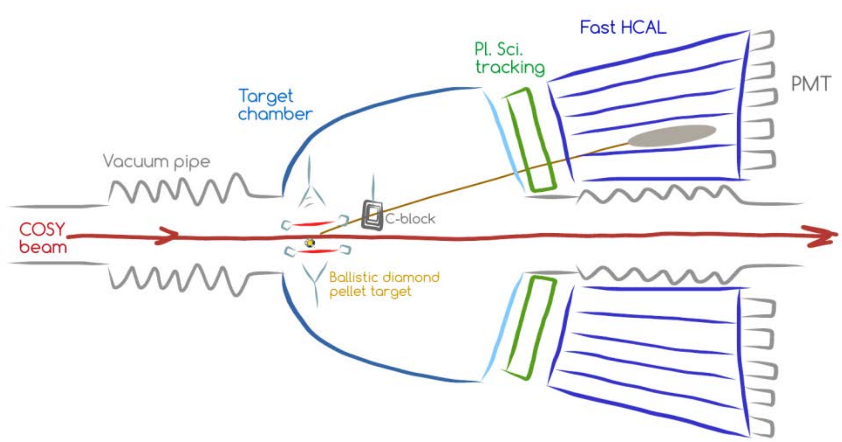


Figure 1: The sketch of the JEDI polarimeter.

The concept of the polarimeter is based on the following principle: measuring the full energy deposited in the detector by the deuterons from the elastic dC scattering process. The principle includes: (i) the best elastic reaction identification capability; (ii) 100% DAQ efficiency; (iii) full acceptance in a reasonable coverage of the maximum Figure-of-Merit (FoM) region; (iv) no magmetic/electric field, (v) long term stability (>10 years). Currently, the idea is to use a heavy nuclei crystal calorimeter to select elastically scattered deuterons (protons) from the fixed carbon target. In addition, for tracking the plastic scintillator (Pl. Sci.) array will be installed in front of hadron calorimeter (HCAL) to increase the position resolution.

The material of choice for the fast calorimeter is the novel LYSO (Lutetium-yttrium oxy orthosilicate) crystal because of its unique properties. It has very high light output (75% of that of NaI (Tl)), a fast decay time constant of 40 ns, and a very high density of 7.1 g/cm^3. The only drawback is its internal radioactivity. With a spectral endpoint below 1 MeV, there are no difficulties for the considered energy (T_d = 270 MeV). On Figure 2 the sketch of the polarimeter, covering angular range of 5º < ϑ < 25º, is shown. The inner rings of the detector indicated with lighter colors are LYSO crystals. For the outer part (marked using darker colors), where much lower count rate is expected (due to rapid fall in the elastic differential cross section), BGO (Bismuth germinate) crystals with equal density, similar light output and rather slower decay time constant can be employed.

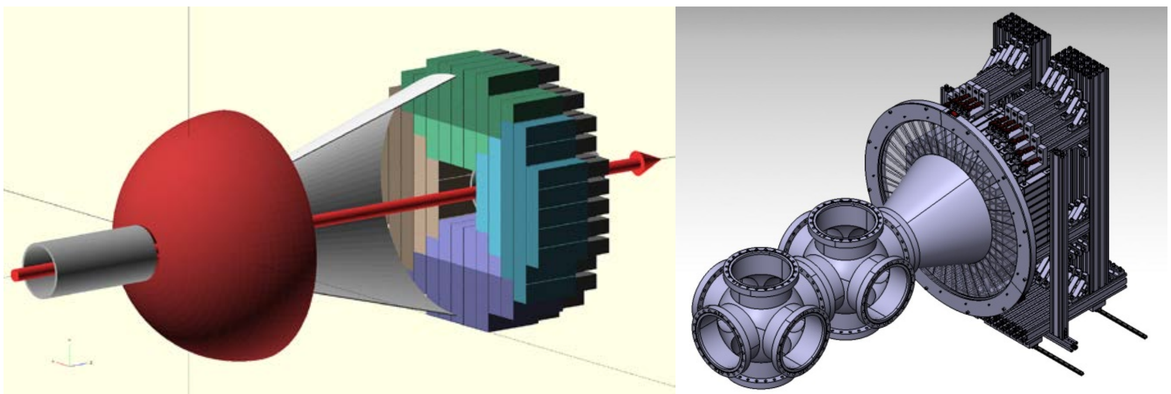


Figure 2: The GEANT simulation model of the final polarimeter (left panel) and its current engineering model (right panel).

The very first (and ongoing) step of this development program is to study the choice for the detector material. The information collected after the first measurements in lab and then at COSY 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 of the proposed measurement is shown on Figure 3. After commissioning, the setup is planned to be installed at a COSY external beam line. The crystals will be mounted on a 2D step-motor control-table that is capable of moving in the vertical direction and rotating around the vertical axis. During these tests, the deuteron beam (at five different energies: 100, 150, 200, 250, 270 MeV) will be directed towards the center of the crystal. In addition, the position sensitivity of the measured amplitude will be explored by directing the beam onto six symmetric points in one-quarter of the crystal (shown in Figure 3 panel (a)). The panel (b) of the same figure shows how the rotation of the crystal will be used to simulate different path lengths through the crystal. This information can be analyzed, and the Bragg peak function can be reconstructed. In the figure 4, the first sample of LYSO crystal with a Hamamatsu R1548-07 photomultiplier tube (PMT) and its newly developed high voltage divider is shown. This type of PMT has a rectangular input window (24x24 mm) with two independent photocathodes each of 18x8 mm and independent multiplication system. This gives the possibility to use even smaller crystals (15x30 mm) for the first ring of the detector to double the acceptance of each module. A maximum sensitivity of the PMT is exactly at the maximum of the scintillation spectrum (420 nm) of the LYSO crystal. 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 ^{22}Na source, and count rate linearity using LED pulses will be examined. Understanding the signal shape using two different types of the Hamamatsu PMT (R1548 and R1924) with two newly developed passive high-voltage dividers is planned. The very first laboratory test with cosmic rays shows a very solid signal (900 mV) for the horizontally aligned crystal (3 cm path) with about 80% of PMT Maximum HV. The front edge of the average signal was measured using one meter 50 coaxial cable to be about 800 ps, which shows the excellent timing characteristic of the LYSO crystal.

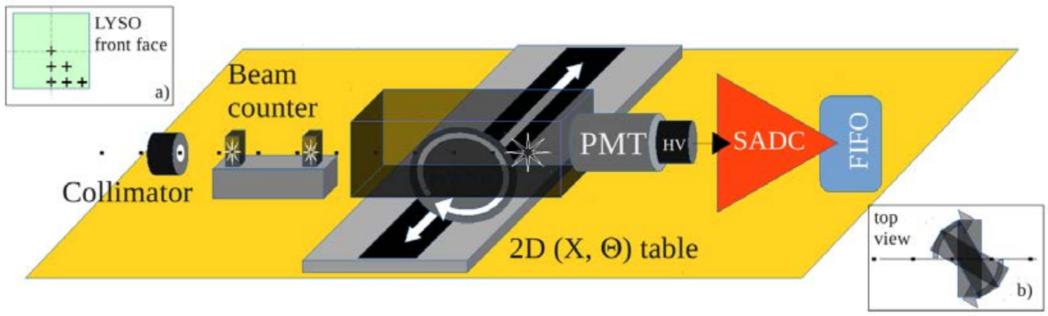


Figure 3: The test setup of the first step measurement. Panel (a) shows the front face of the LYSO crystal and the six target points where the beam will be directed. Panel (b) demonstrates the rotation of the crystal in order to study the different energy losses by the deuteron to explore the Bragg peak distribution.

Figure 4: First sample of the LYSO crystal PreLude 420 produced by Saint Gobain. The size of the crystal is 30 × 30 × 100 mm3. The Photomultiplier tube (PMT) is a Hamamatsu R1548-07.

The main objective of the step two is a precise and careful scan of the target materials near to the C. In understanding and making this step effective, an intensive Monte Carlo simulation will be needed. All the acquired information after step one will be an 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. Step three will be as an internal storage ring test of the final JEDI polarimeter concept. The main idea of step two is using extracted polarized deuteron beam for the asymmetry measurement. The extraction of the polarized deuteron beam was never widely examined at the COSY accelerator facility. At the same time, the external experiments have used high-energy polarized external proton beams. Close to our energy region of interest (270 MeV) the deuteron depolarization resonances are not expected. Moreover, the main idea of the measurement requires only the constant polarization over one cycle extraction, which can be easily obtained. During the slow extraction, the target material can be continuously switched from carbon to aluminum and back (~ 5 sec). This will allow us to measure simultaneously with polarized and unpolarized deuteron beam two main physical quantities: the differential cross section and the vector analyzing power that are the main ingredients of the F OM that is important for the material comparison. As a cross check, one can also use already measured and published vector analyzing powers at 270 MeV to confirm COSY beam polarization. All these measurements must then be repeated for the proton beam as well.

4.3 General requirements and laboratory equipment

Taking all issues mentioned above into account, the future **SMART|EDM_***Lab* should satisfy the following demands:

Required area:

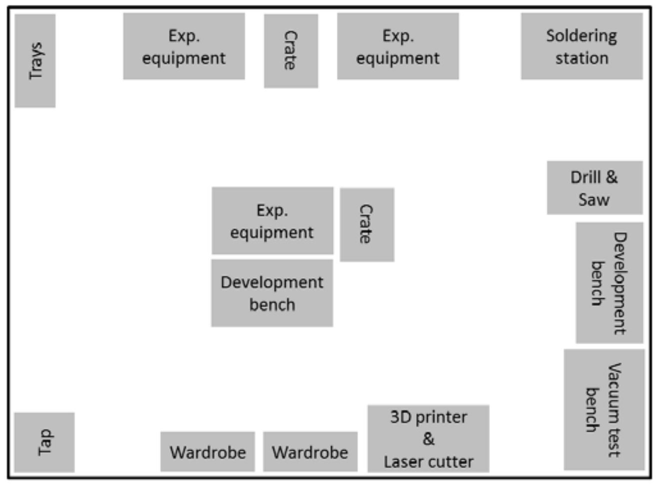
- Laboratory: 45 – 50 m^2;
- Office space: 20 – 25 m^2.

Main technical requirements for lab area:

- Light and dry room;
- Supplied with heating and air ventilation systems;
- Availability of a tap in the laboratory is highly desirable;
- Equipped with grounded mains sockets + separate grounding wire. There should be one non-interruptible power supply (UPS) dedicated for the laboratory (with minimum power of 1 KW). Thus, separate electrical lines and sockets must be provided;
- Local area network to interconnect PCs and experimental equipment (with minimum link of 100 Mbit/s) and access to the internet (unlimited, with minimum upload/download speed of 10 Mbit/s);
- Radioactive samples will be used in the laboratory. Therefore, it is absolutely necessary to satisfy the general requirements of Georgia's radioactive standards;
- The laboratory will be equipped with expensive experimental apparatus. Therefore, it should be protected by security systems.

The preliminary distribution of the laboratory area (see the sketch):

- 3 – 4 tables to place PCs and measurement equipment;
- 1 table for soldering station;
- 1 table for drilling and sawing tools;
- 1 table for 3D printer and laser cutter;
- 2 – 3 tables for new concept developments and tests;
- Lockable wardrobes, trays and safe;
- One corner for the vacuum chamber and pumping system.



4.4 Resources and budget

The main infrastructure of the laboratory is assumed to be provided by the host university (TSU). There are two additional parts for the demand of resources: personnel (see below), which will be provided by Georgia (SRNSF), and equipment: the start-up laboratory equipment with total value of **50.000 Euro** (see list of the equipment given in section 4.6) will be covered by Georgia (SRNSF). The additional demands for laboratory resources will be supplied by Forschungszentrum Jülich (IKP) as a loan or donation.

The **tentative** budget (for **5 years** period) is as follows:

• Head of lab (**PI**): 1.500 EUR per month	× 60 = 90.000 EUR
• PhD student: 21.000 GEL per year	× 3 = 63.000 GEL ≈ 25.000 EUR
• Master student(s): 15.000 GEL per year	× 5 = 75.000 GEL ≈ 30.000 EUR
• Travel money: 6.000 EUR per year (3 visits for **PI)**	× 5 = 30.000 EUR
• Other goods and services: 2.000 EUR per year	× 5 = 10.000 EUR
• Start-up equipment: 50.000 EUR	× 1 = 50.000 EUR

Total budget (SRNSF):	**235.000 EUR**
Total budget for 1st year (personnel + equipment)**:**	**57.000 + 50.000 = 107.000 EUR**

In summary, the total (**tentative**) budget for the first 5 years will be **450.000 €**, with contributions from:

➢ MoE, SRNSF:	235.000 €	Financing of the **SMART|EDM_***Lab* and its operation
➢ TSU:	60.000 €	**SMART|EDM_***Lab* infrastructure (see section 4.3)
➢ IKP of FZJ:	155.000 € (*	(* Estimated indirect contributions, comprising: The scientific project and infrastructure at FZJ (in particular access to the accelerator COSY for the EMD project), test equipment (e.g. detector components, prototype crystals, photomultipliers), detector read-out (e.g. electronics, data acquisition, trigger modules), and travel expenses of Jülich scientists to Georgia.

4.5 Personal: Principal Investigator (PI)

Dr. David Mchedlishvili

Personal details:

Date and place of birth:	March 26, 1984, Tbilisi, Georgia
Citizenship:	Georgia
Personal ID:	01022007960
Marital status:	Married
Address:	Temqa district, block IV, building 9b, app.40, Tbilisi 0197, Georgia
E-mail:	d.mchedlishvili@fz-juelich.de
Phone number:	+995322603250, +4915127018255

Education:

1990 – 1996	Secondary School # 143 Tbilisi
1996 – 2001	High school lyceum “Tamarioni”, graduated with distinction
2001 – 2005	Iv.Javakhishvili Tbilisi State University, Physics faculty, Academic Degree of Bachelor in Physics (Honours Diploma)
2005 – 2007	Tbilisi State University, Physics faculty, Graduate Study for Master Degree, Specialty - Nuclear Astrophysics
2009 – 2013	Doctorate student of faculty of Natural Sciences in TSU under the program “Spin Physics at ANKE/COSY Experiments”

Research activities:

2002	Increasing the sensitivity of Dual Focusing Mass-Spectrometer using micro channel detectors
2003	The influence of waste waters of Madneuli gold mine over the rivers Mashavera and Kazretula
2008 – 2009	Spin in nuclear physics/Polarization Experiments
2009 – 2013	Ph.D. student position at the Institute of Nuclear Physics at Forschungszentrum Juelich (currently writing Ph.D. thesis)
2013	Spokesperson of the COSY proposal (#218)
2014 – present	Post-doctoral researcher position at the Institute of Nuclear Physics at Forschungszentrum Juelich

Working experience:

2007 – 2009	High Energy Physics Institute (HEPI) of Tbilisi State University, Department of Experimental Physics
2009 – present	Research Center Juelich (FZJ), Institute for Nuclear Research (IKP)

Main activities since 2009:

Preparation and carrying out the polarised hadron experiments, statistical data analysis, Monte Carlo simulation of physical processes, testing experimental equipment and detectors, maintaining the web page of the JEDI collaboration

Publications:

2009	D. Chiladze, … D. Mchedlishvili et al. **European Physics Journal A40, 23**
2012	P. Benati, ... D. Mchedlishvili et al. **Physical Review Special Topics, Accelerators and Beams 15, 124202**
2012	D. Tsirkov, ... D. Mchedlishvili et al. **Physics Letters B712, 370**
2012	D. Mchedlishvili et al. **European Physics Journal A49, 49**
2013	S. Dymov, … D.Mchedlishvili et al. **Physics Review C88, 014001**
2013	Q. J. Ye, … D. Mchedlishvili et al. **Physics Review C87, 065203**
2013	D. Mchedlishvili et al. **Physics Letters B726, 145**
2013	V. Shmakova, D. Mchedlishvili, S. Dymov et al. **Physics Letters B726, 634**
2014	D. Oellers, ... D. Mchedlishvili et al. **Nuclear Instruments and Methods in Physics Research A759, 6**
2014	Z. Bagdasarian, ... D. Mchedlishvili et al. **Physical Review Special Topics, Accelerators and Beams 17, 052803**
2014	M. Papenbrock, ... D. Mchedlishvili et al. **Physics Letters B 734, 333**
2014	Z. Bagdasarian, ... D. Mchedlishvili et al. **Physics Letters B 739, 152**
2014	B. Gou and D. Mchedlishvili et al. **Physics Letters B 741, 305**
2015	S. Dymov, ... D. Mchedlishvili et al. **Physics Letters B 744, 391**
2015	D. Eversmann, ... D. Mchedlishvili et al. **Physical Review Letters 115, 094801**

Conference series:

2010	A. Kacharava, … D. Mchedlishvili et al. **European Physics Journal, Web of Conferences 3, 05004**
2011	D. Mchedlishvili et al. **Journal of Physics 295, 012099**
2011	D. Mchedlishvili **- PoS (STORI'11) 040**. URL: http://pos.sissa.it/

Participation in scientific projects:

2007 – 2009	Georgian National Science Foundation (GNSF), ST06/4-108, as **assistant**
2010 – 2013	Shota Rustaveli National Science Foundation, ST09-1024-4-200, as **main participant**
2012 – 2014	Shota Rustaveli National Science Foundation, DI/19/6-200/11, as **main participant**
2013 – 2016	Shota Rustaveli National Science Foundation, 31/91, as **main participant**
2015 – 2018	Shota Rustaveli National Science Foundation, 13/6, as **main participant**

Participation in international conferences:

2010	19^{th} International Spin Physics Symposium (SPIN 2010), Jüelich, Germany
2011	8th International Conference on Nuclear Physics at Storage Rings (STORI'11), Frascati, Italy

2012	5th Georgian-German School and Workshop in Basic Science (GGSWBS'12), Tbilisi, Georgia
2013	Symmetries and Spin (SPIN-Praha-2013), Prague, Czech Republic – **Invited talk**
2013	Physics in the LHC era, Tbilisi, Georgia

Participation in internal meetings:

2009	4th COSY-FFE workshop, Bad Honnef, Germany
2011	75th annual meeting of the DPG *(Deutsche Physikalische Gesellschaft)* and DPG spring meeting, Bonn, Germany
2012	76th annual meeting of the DPG and DPG spring meeting, Mainz, Germany
2012	7th COSY-FFE workshop, Bad Honnef, Germany
2013	77th annual meeting of the DPG and DPG spring meeting, Dresden, Germany

Computer skills:

Linux, MS Windows, MS Office, C++, CERN ROOT, Matlab, Multisim, Hardware and System repair

Languages:

Georgian (Native)
English: Spoken, Written (Fluent)
Russian: Spoken, Written (Fluent)

4.6 Preliminary list of laboratory equipment

Device	Recommende	Price (EUR)	N	Total	Purpose	comment
Linux based PC		1.500,00	2	3000	For data aquisition and slow control	
24 Inch Monitor		300,00	2	600		
19 Inch Rack		1.500,00	1	1500	Crate holder	
NIM Crate	Wiener	5.290,00	1	5290		
CAMAC Crate	Wiener	5.649,00	1	5649		
6U VME Mini Crate	Wiener	3.090,00	1	3090		
SADC Struck	Struck	8.940,41	1	8940.41	250MS/s sampling ADC for PMT readout	
SiPM / MPPC - semicon-photosensors	KETEK PM6660T	195,00	3	585	6x6 mm Silicom PM for pl. scintillator readout	
Oscilloscope	Tektronix MDO3022	3.831,80	1	3831.8	fast measurement of detector signals	at least: 2ch., BW 200MHz, 2GS/s, ...
Signal Generator	Tektronix AFG3102C	5.485,90	1	5485.9	Simulating detector signal	
Power suppl	Hameg HMP2020	1.270,92	2	2541.84	Power supply for general purpose	
Power supply	Hameg HMP4040	2,125.44	1	2125.44	Power supply for general purpose	
Soldering Station	Weller WSD 121 Set	387,00	2	774	Usefull for changing or enhancing electronic	
3D Printer	Renkforce RF1000	1.999,00	1	1999	For prototyping needs	
Filament plastic 3 mm	Renkforce	32,99	10	329.9		
CAMAC Controller	Wiener CC-USB	5.140,00	1	5140		
FPGA development	Xilinx Basys3	136,25	2	272.5		
Pmod RS23	Digilent	20,12	2	40.24		
Pmod USB	Digilent	20,12	2	40.24		
Pmod DA3	Digilent	42,06	2	84.12	DSP - Digital Signal Processing	
Pmod AD1	Digilent	33,83	2	67.66	DSP	
Pmod AD2	Digilent	22,86	2	45,72	DSP	4 channel 12-bit A/D
Raspberry pi	R Pi 2 model B		5			
Arduino	Starter Kit		5			
Multimeters						

Total: ~ 49.000 EUR

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