DFG-RSF Cooperation: Joint German-Russian Project Proposals in all fields of science
(funding period 2022-2024)

0. Core data

Title of the Research Project

Spin transparency as a new approach to precision tests of fundamental symmetries in polarization experiments at colliders and storage rings: theory and experiment

Project Partners

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Project Summary

The search for new physics beyond the Standard Model is at the forefront of particle physics. Precision experiments on the spin of particles form a promising path to a major discovery. Experiments are in preparation to search for electric dipole moments of protons and deuterons. Such a dipole moment would demonstrate the violation of the CP- and T-symmetries and would shed light on the anomalously large baryon asymmetry of the universe. Axion-like particles, an interesting candidate for the unexplained dark matter in the universe, would introduce oscillating dipole moments, which could be detected in spin experiments. In the same category is the search for the semi-strong CP- and T-violation in hadronic interactions, where one looks for T-violating effects at the part-per-million level. Another domain of precision spin experiments is the long-

standing spin-crisis of the nucleons, where the hitherto poorly known tensor structure function of deuterons is moving into focus.

All aforementioned projects require stringent control of the spin orientation in storage rings, flexibility in the orientation of the spins, and long spin coherence times. With our project SpinTra we will develop a new method to control the spin in a storage ring and to align it in any desired direction. This method was proposed by Yury Filatov and collaborators. He is also the Russian PI of the project. We will work out the theoretical foundations, verify the concept with numerical simulations, built the required hardware, install it in the COSY ring at FZ Jülich, and demonstrate the feasibility with a proof-of-principle experiment.

If successful, the method can be applied to enhance the science potential of the electron-Ion Collider eIC at the Brookhaven Laboratory in the US, Nuclotron-based Ion Collider fAcility NICA in Russia, the Electron-ion collider in China (EicC), or the semi-electric and all-electric storage rings for the search for electric dipole moments.

The transnational collaboration between the Russian groups at MIPT and the German groups at RWTH Aachen University and the Forschungszentrum Jülich is essential for the success of the projects. The MIPT groups contribute their expertise on the theory aspects and they will built the hardware for the proof-of-principal. The German groups provide the COSY facility, a unique facility for such an experiment, and their experience in the conduction of high-precision spin experiments.

Key words

Which describes the aspects of this project: (please select by filling “ v ”)

Mathematics, Computer and Systems Science;
v Physics and Space Science;
Chemistry and Materials Science;
Biology and life sciences;
Medicine;
Agricultural sciences;
Earth Sciences;
Humanities and Social Sciences;
Engineering Sciences;

Project Description

1 Starting Point

1.1 State of the art and preliminary work

1.1.1 Motivation

Our project SpinTra is motivated by the search for new physics beyond the Standard Modell (SM), which is among most debated issues in particle physics [1]. The SM is well known to be incomplete in several aspects. A particular deficit is the failure to explain the disappearance of the anti-matter throughout the evolution of the universe. The SM predictions for the baryon asymmetry of the universe, i.e. the difference in the amount of matter and antimatter in the universe, is by many orders of magnitude smaller than the experimental observation [2]. It is generally believed that this deficit can only be resolved, if new sources of CP- and T-violation are discovered.

Spin experiments play a particularly important role in the quest for new physics, as exemplified by the enormous activity in the search for the electric dipole moments (EDM) of neutral and charged particles [3]. However, this is not the only problem that can be addressed by spin experiments. Since the 1980’s, there remains the unresolved problem of the spin structure of nucleons. Still another example of novel spin physics aspect for storage ring experiments is a search for axion-like particles, suggested by the Peccei-Quinn solution of the strong-CP puzzle [4,5]. The search for the semistrong CP- and T-violation [6,7,8] requires high precision polarization experiments and is still a long way [9] from an *experimentum crucis.* Experiments on the spin of particles in storage rings can make a decisive contribution to these quests.

1.1.2 State of the art

The invention of the Siberian snake by A. Kondratenko (member of SpinTra) and S. Derbenev [10] has revolutionized spin physics at high-energy accelerators and opened the way to experiments with longitudinally polarized protons. An important boost to spin physics came from the spin crisis in deep inelastic scattering (DIS), which for almost four decades remained one of topical mysteries in particle physics. The longitudinally polarized protons and deuterons are imperative for the spin crisis experiments at the electron-ion collider eIC to be constructed at BNL [11] and for the related search for the gluon polarization in nucleons at the NICA collider in Dubna [12]. For the reason of very small magnetic anomaly, no practical solution has been found so far to preserve any desired frozen orientation of relativistic deuterons at the interaction point.

1.1.2.1 Search for EDMs

Since decades various experimental groups are searching for EDMs in neutral systems [3]. The most sensitive experiments are carried out on polarized neutral atoms and neutrons. If immersed in a strong electric field the coupling of the EDM to the field will rotate the spin of the objects. With an improved understanding of the spin dynamics in storage rings experiments on charged particle with highly competitive sensitivities become accessible.

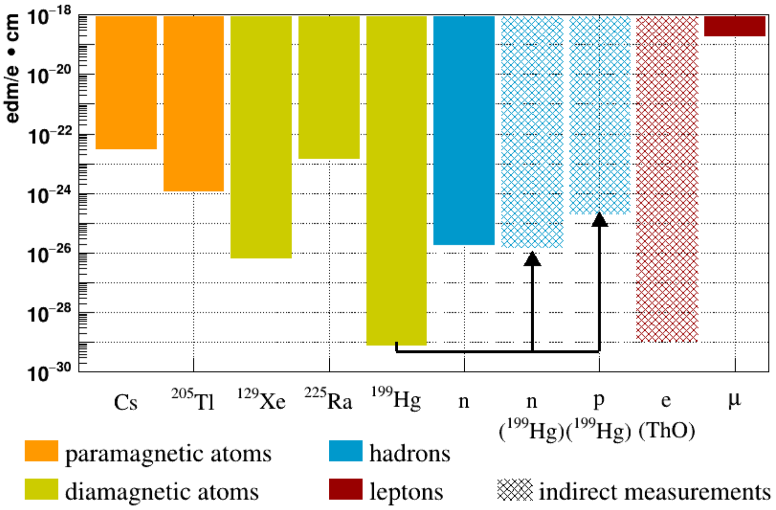

Figure 1: Current limits on EDMs of various objects.

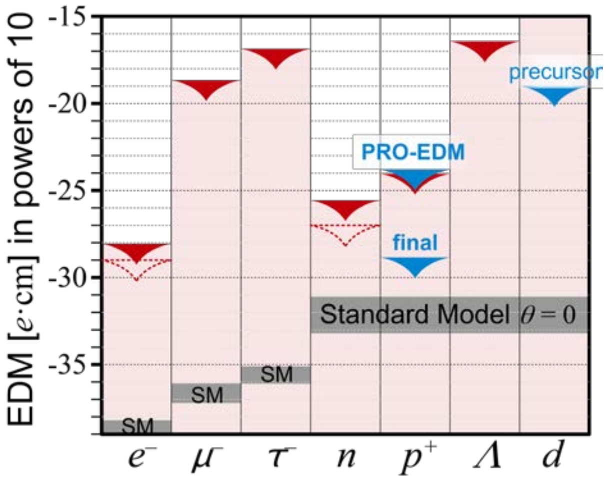

Figure 2: The red arrows indicate the current limits on EDMs of neutral systems, the red dashed arrows the expected improvements for the next decade. The blue arrows show the projected sensitivity of the storage ring experiments. The grey bars indicate the SM predictions.

1.1.2.2 The spin crisis of the nucleons and the gluon polarization

The finding that valence quarks carry only about one third of the helicity of the polarized proton has become known as the spin crisis. The contribution of polarized gluons and sea quarks to the momentum sum rule remains one of the most debated issues. The spin experiments at NICA shall focus on signatures of gluon polarization in production of prompt photons and open charm [11]. The double longitudinal polarization deep inelastic scattering at eIC [12] has the potential to improve the sensitivity to the gluon polarization drastically.

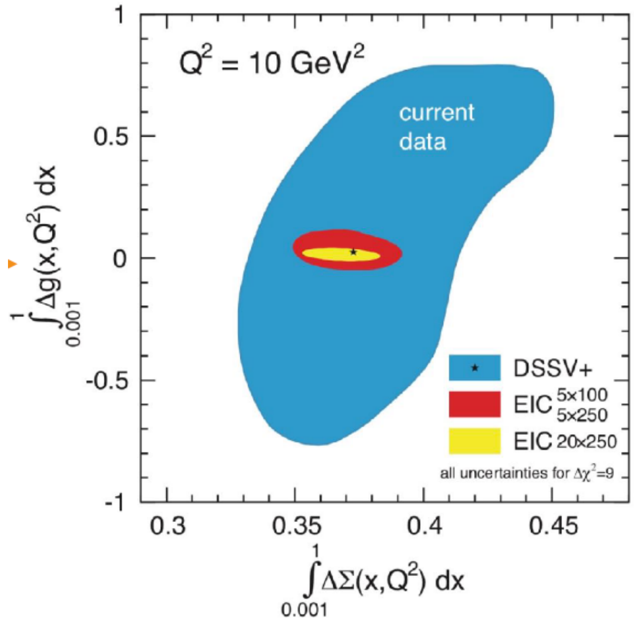

Figure 3: Projected sensitivity to the number of polarized gluons in protons in polarized DIS at eIC vs. the current data (DSSV+ fit, blue area).

1.1.2.3 Dark matter: The search for Axions

An axion-field was proposed by Peccei and Quinn to solve the strong CP-problem of the SM. The axion itself is an interesting candidate for the unexplained dark matter in the universe. Unfortunately, we know very little about the potential mass of the particle. Experiments have to cover many decades of masses in their search. For low axion masses, polarization experiments in storage rings promise the highest sensitivity. An axion field would couple to the spin of the particles in the ring and induce an oscillating EDM [4,5]. The figure shows the sensitivity to axions with various methods.

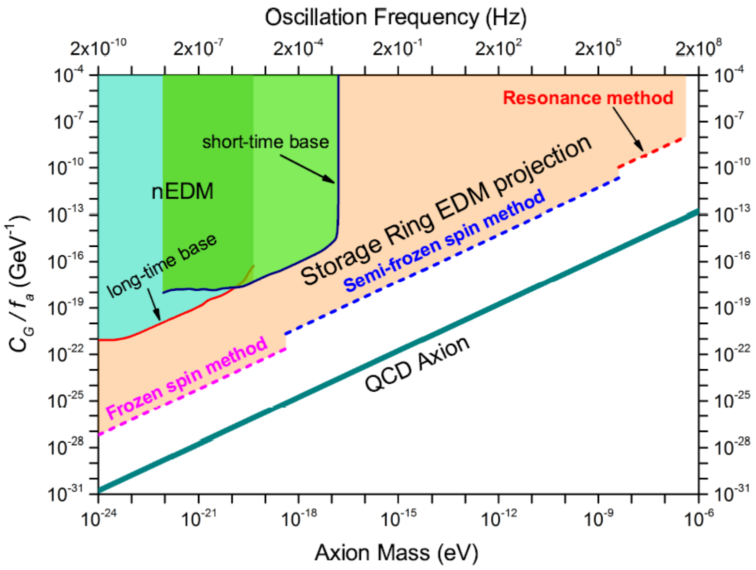

Figure 4: Sensitivity of the search for oscillating EDMs to axion fields.

1.1.3 Preliminary work

A novel technique for the control of particle spins in storage rings was proposed [13]. It is called spin transparency (ST). It constitutes an efficient, highly flexible method to control the beam polarization in storage rings from the acceleration to stable operation and to manipulate the spin direction in real time during the experiments. The basic ideas of the ST method were first formulated by the Russian team members in the process of the design of the figure-8 booster and collider synchrotrons of the Medium-energy Electron-Ion Collider (MEIC) project at Jefferson Lab [14]. Later on, it was applied in the design of the racetrack rings with two solenoidal snakes of the Nuclotron-based Ion Collider fAcility (NICA) [15].

In the ST regime, the integral effect of spin rotations in the ring elements is compensated within each single particle turn, i.e., the spin transfer matrix for a single turn is unity, so that any spin orientation is reproduced turn-by-turn. The magnetic lattice of the synchrotron becomes “transparent" to the spin. This implies that the particles are in an integer spin-tune resonance. The spin motion in such a situation is highly sensitive to small perturbations of the fields along the orbit. This high sensitivity threatens the stability of the beam polarization, but it allows implementing a simple and efficient spin control system. A spin navigator, which is a flexible device consisting of elements with weak constant or quasi-stationary fields rotating the spins about a desirable direction by a small angle, will be used. The strength of the applied spin navigator must be sufficient to compensate for perturbations of spin rotations associated with the imperfections of the magnetic structure and beam emittances.

The ST technique allows one to:

- control the polarization by weak magnetic fields, not affecting the orbital dynamics
- maintain stable polarization during an experiment,
- set any required polarization direction at any orbital location in a storage ring,
- change the polarization direction during an experiment,
- do frequent coherent spin flips of the beam to reduce experimental systematic errors,
- carry out ultra-high precision experiments.

The ST technique will significantly expand the potential of future experiments with polarized beams at COSY, at the electron-Ion Collider (eIC) at the Brookhaven Laboratory in the US, NICA in Russia, Electron-ion collider in China (EicC), and other facilities.

Experimental verification of the ST technique with protons at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven has been suggested [16]. In this case, a scheme with two identical helical Siberian snakes would be applied. At the ultrarelativistic energies of RHIC, it is preferable to use the spin navigators with weak transverse magnetic fields with field integrals, which are essentially constant vs. energy.

The preliminary analytical studies and numerical simulations confirm stable spin orientation with spin navigators. Still the experimental test of the approach is indispensable. The same integer spin-tune mode will be used for the spin crisis experiments at eIC and the gluon polarization experiments at NICA and it is behind the all-electric, frozen-spin EDM storage rings, aiming to detect proton EDMs down to 10^{-29} e cm [17,18].

The JEDI (Jülich Electron Dipole moment Investigations) collaboration with long-term active participation of members of the present project from RWTH and Russian Institutes, is the world leader in charged particle EDM searches. It works with the COSY ring at the Institute of Nuclear Physics (IKP) at the Forschungszentrum Jülich. With its excellent instrumentation, it is a unique facility in the world for precision spin physics. The measurement of the spin precession frequency for deuterons to 10 decimal places [19], the routine operation with a spin coherence time of about 1000 s [20], the development of a radio-frequency (RF) Wien filter as a spin rotator [21], the first determination of the orientation of the stable spin axis and of systematic effects from ring imperfections [22], the beam-based alignment of the ring lattice [23], and the resonance tune mapping approach [24] are among the record-breaking JEDI results in EDM-related studies. JEDI is preparing a precursor experiment on the search for the deuteron EDM to be executed at COSY in 2021.

So far JEDI remained a unique source of experimental input on the spin dynamics in storage rings. JEDI is at the heart of a design of a next-generation prototype ring (PTR) for EDM searches [18]. Suggested by the CPEDM (Charged Particle EDM) Collaboration, the PTR will be the first all-electric ring with polarized counter-rotating beams, as well as the first hybrid ring with combined electric and magnetic bending in ST frozen spin mode for studies of spin dynamics in new regimes. Eventually, the PTR will pave the way to the all-electric, frozen-spin (zero spin-tune) storage ring with counter-rotating protons of momentum 700 MeV/c, the ultimate facility to search for the proton EDM with a sensitivity down to 10^{-29} e cm [17,18].

The project team has a solid expertise in accelerator physics and spin dynamics in storage rings. The major ideas behind the ST mode were worked out theoretically and partially tested in numerical simulations to justify further exploration. Still, more theoretical work is called upon in both spin-orbit dynamics at integer spin tune, especially spin coherence time in the new regime, and in theoretical understanding of the deuteron tensor polarization effects in the deuteron EDM experiments.

Weak though gravitational interaction is, in storage rings the gravity pull of Earth has to be compensated for by focusing fields in the ring [25,26,27]. For particles, rotating in the all-electric ring, the compensating vertical electric field is tantamount to the unwanted radial magnetic fields. Rotations of the magnetic moment in this field will produce a fake EDM signal. This gravity induced fake EDM signal can be separated by comparison of spin rotations of counter-rotating beams. It can serve as a standard candle to control the ring performance [28]. The recently found general relativity effect is a sizable geometric magnetic field in pure electrostatic systems residing on the rotating Earth [28]. Further scrutiny of gravity effects in searches for the EDM is called upon.

Closely related to the frozen longitudinal spin in low energy EDM rings is the search for axion-like particles in the domain of masses and couplings complementary to what can be probed in non-accelerator experiments worldwide [4,5].

These three cases are connected by many aspects of spin-orbit dynamics in the vicinity of integer spin-tune resonances. There is a pressing need to develop a detailed theory of spin-orbit coupling in this unexplored domain of spin dynamics.

Tensor polarization distinguishes spin dynamics of deuterons from protons and there are prediction for tensor structure functions [29] to be tested at eIC. An update of these more than 20-year-old predictions based on vastly improved understanding of diffractive DIS is called upon. Our collaboration will address the impact of tensor polarization on the EDM experiments with deuterons and the possibilities of utilizing tensor polarization for the control of frozen spin in the EDM storage ring. Here one of the open issues is the co-magnetometry for globally frozen longitudinal asymmetry. Elaboration of the RF Wien filter approach to this problem is in progress, and a possibility of using different rotations of the vector and tensor polarizations [30] for the polarimetry purposes is being studied.

The COSY ring of IKP remains unique storage ring for spin physics and in the foreseeable future there will be no competitors to COSY as s testing ground of ST and spin navigator ideas. In principle, there is a possibility to test the ST mode directly in the Nuclotron, foreseen to operate as injector of polarized protons and deuterons into NICA. However, before completion of the MPD (Multi-Purpose Detector) program at the end of the 2020's, the Nuclotron will exclusively be run as an injector of heavy ions.

1.2 Project-related publications

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1.2.1 Articles published by outlets with scientific quality assurance, book publications, and works accepted for publication but not yet published.

F. Abusaif,.., A. Axentev,…,N. Nikolaev,.., Y. Senichev,.., A. Stahl et al., Storage Ring to Search for Electric Dipole Moments of Charged Particles – Feasibility Study, arXiv:1912.07881, to be published as CERN Yellow Report

1.2.2 Other publications, both peer-reviewed and non-peer-reviewed

None

2 Objectives and work programme

2.1 Anticipated total duration of the project

January 2022- December 2024 / 36 months

2.2 Objectives

The principal objective of this project is the development of the spin transparency (ST) approach to provide precision spin control for storages rings. This includes all theoretical aspects as well as a proof-of-principle of the approach with the COSY storage ring.

The objectives include:

- The compilation of an adequate model of spin-orbit coupling in this hitherto unexplored domain applicable to the proton and deuteron spin structure experiments at NICA/JINR and eIC/BNL and in the CPEDM program for the prototype and the ultimate all-electric ring EDM ring.
- The development of concepts to support arbitrary spin orientations at the interaction point of the experiments with the possibility to maintain the longitudinal polarization of modest to ultrarelativistic energy deuterons at the eIC, where the conventional Siberian Snake approach is impractical. This is of prime importance for the eIC program of polarized deep inelastic scattering.
- The verification of the suppression of unwanted lattice imperfection effects by multiple spin flips as required to minimize systematic effects on precision polarization variables.
- Development and realization of a polarimetric measurement of the longitudinal spin polarization in a ring with frozen spin.
- Conceptual work on the compensation of the gravity pull and potential geometric spin phase background effect in the EDM signal at all-electric EDM magic storage rings
- Operation of the COSY ring near an integer spin resonance, demonstrating the feasibility of the ST approach.
- Development and construction of spin navigators and their installation in the COSY ring.
- Proof-of-principle of the ST approach with the COSY ring.

2.3 Work programme including proposed research methods

2.3.1 Work programme

Our project SPINTRA aims at a first-ever experimental test of the ST approach with protons in the COSY storage ring, taking advantage of the unique performance of COSY as a spin physics oriented storage ring. Our experiment wiil complement the experimental studies of the spin coherence time for protons, which are imperative for the design of the proton EDM rings. As such, the project will be a natural new addition to the JEDI and CPEDM research programs (several members of our project are members of JEDI and CPEDM). The experiment in 2023 will use horizontal polarization of 108 MeV protons with a spin-tune $G\gamma=2$. Four weeks of beam time will be requested. The in-plane magnetic field of the steerer magnets will be used for the spin navigation. This program will be an extension to the integer spin tune of the beam bump diagnostics of spin rotations by imperfection magnetic fields, currently under scrutiny by JEDI collaboration at COSY. In the four-week run in 2024, we plan to complement the spin navigators by weak field solenoids.

The preparation of experimental studies of the ST regime requires extensive theoretical studies of spin-orbit coupling in the vicinity of the integer spin-tune resonance. Maintenance of stable polarization in this regime is a hitherto unexplored domain of spin dynamics as the conventional wisdom was to cross the resonance as fast as possible. In this task a principal tool will be the technique of response functions [31,32]. Here of prime concern will be ST resonances induced by the ring imperfection fields. The response functions will be input for the operation of spin navigators to compensate for the unwanted effects. The response function technique was already successfully applied to explain the strength of the spin resonance induced by the RF dipole in the COSY ring [33]. Furthermore, the impact of imperfection fields in the COSY ring on spin rotations has been studied experimentally by the JEDI collaboration. Methods for spin-tune mapping and spin resonance-tune mapping have been developed. The latter will be a basic approach behind the precursor search for the deuteron EDM scheduled for 2021 [34]. A beam-based alignment of magnetic elements in COSY was developed recently by the JEDI collaboration with strong participation of the RWTH team [23]. This will be of particular significance for SpinTra. The analysis of the ST resonance strengths, caused by the orbital emittance of the beam, will be based on averaging of second order effects in spin perturbations [35]

A spin-flip system is required for the precisie isolation of polarization observables. Its design will be based on adiabatic invariants of the spin evolution in cyclic accelerators [36]. These analytic methods will be verified by the state of the art quasi-simplectic spin tracking, based upon Runge-Kutta integration of the Lorentz equations for the orbital motion and of the Thomas-BMT equations for the spin motion. The advantage of such integrators, slow though they are, is their model independence provided the fringe fields are known to the desired accuracy. We are planning to use mainly the ZGOUBI code developed at BNL [37]. Our collaboration members have an extensive experience of ZGOUBI based simulations in the design of the spin-flip system for the collider JLEIC [38] at Jefferson-Lab.

While the vector polarizations of protons and deuterons share the same evolution in magnetic fields, the behavior of the tensor polarization of deuterons in the ST regime, and especially at ST resonances, is one of the open issues. On the one hand, understanding the dynamics of tensor polarization is required for the measurement of the tensor structure function of deuterons in deep inelastic electron-deuteron scattering at eIC. Members of our collaboration contributed predictions of the tensor structure function [29] to be tested at eIC. On the other hand, new methods are needed for the determination and control of the tensor polarization of ultrarelativistic stored deuterons [30]. The theoretical analysis of tensor polarimetry will be one of the tasks within the SpinTra project. Besides that, we need to explore the impact of tensor polarization in the precision EDM experiments at CPEDM PTR and beyond.

One of the open issues for the frozen-spin EDM rings is a polarimetry of longitudinal polarization, which cannot be measured directly. We will study the option of a periodic sideways swipe of beam polarization by the RF Wien filter operated at frequencies close to the revolution frequency. Such swipes can provide single-bunch self-contained comagnetometry of the beam. Longitudinal asymmetry and elaboration of the Wien filter approach to this problem is in sight. The dedicated analysis of possible fake EDM signal from the geometric magnetic field, including a potential geometric phase in pure electrostatic storage rings, is called upon. It will be a part of our project.

The COSY ring of IKP, with its excellent instrumentation for spin physics, is viewed by the collaboration as a unique facility for experimental tests of the ST and spin navigator ideas.

The following timetable is anticipated:

2022*: The principal task will be the technical design of the spin navigators for the manipulation of the in-plane polarization of protons in the COSY ring.*

The studies in 2022 will include

- theoretical evaluation of the strength of ST spin resonance at spin-tunes equal to $2,3$, and 4 induced by ring imperfections and by orbital emittances;
- analysis of the impact of synchrotron oscillations on the spin dynamics;
- development of a description of spin-orbit coupling and spin-tracking simulations of the spin dynamics in the ST regime;
- formulation of technical specifications on magnetic elements of the COSY ring to be used as spin navigations;
- development of methods of polarimetry of tensor polarization of stored ultrarelativistic deuterons.

2023*: The principal task will be the construction of a spin flip system for the ST regime.*

The collaboration studies in 2023 will include

- analysis of the requirements on the spin navigator fields for the preservation of polarization during multiple spin flips;
- development of spin-orbit aspects of spin flip in the ST regime;
- spin tracking simulations of spin flips in the ST regime;
- precursor experiment on the spin-navigator driven stabilization of the in-plane polarization of protons at COSY (four week preparatory stage during machine maintenance time followed by four weeks of experimentation);
- the analysis of the experimental data from the precursor experiment for optimization of the final ST and spin navigator experiment;
- theoretical studies of the impact of geometrical magnetic fields on spin dynamics in electrostatic storage rings;
- development of self-contained single-bunch comagnetometry of frozen longitudinal polarization in all electric magic ring.

***2024**: the principal task will be the experimental tests of the ST at integer spin tunes at COSY*

The collaboration studies in 2024 will include

- numerical simulations of compensation of imperfection effects on the spin coherence time in the ST regime;
- final SPINTRA experiment to test the ST regime with solenoidal spin navigators and operation of the multiple spin-flip system in the ST regime at COSY;
- analysis of the impact of tensor polarimetry in precision searches for EDM.

2.3.2 Milestones and deliverables

We will structure the project along the following milestones (MS) and deliverables (DL):

MS1	Spin model	Dec. 2022	Full spin model in the ST regime of COSY
DL1	Navigator specs	Sept. 2022	Technical specifications of magnetic elements in COSY
MS2	Tensor polariztaion	Dec. 2022	Concepts of tensor polarimetry of stored deuterons
DL2	Publication	Dec. 2022 - June 2023	Publications on the theory of tensor polarimetry in colliders
MS3	Experiment	Spring 2023	Test of ST with available infrastructure at COSY
MS4	Polarimetry of frozen spin	Dec. 2023 - June 2024	Concepts of polarimetry of frozen spin of protons in magic energy EDM rings
DL3	Publication	Dec. 2023 - June 2024	Publication on the theory of frozen spin polarimetry
DL4	Publication	Dec. 2023 – June 2024	Publication of the results of the precursor ST experiment
MS5	Spin in gravity	Dec. 2023	Theoretical description of the gravity effects in frozen-spin, magic energy EDM rings
DL5	Publication	Dec. 2023 – June 2024	Publications on the general relativity effects in frozen-spin, magic energy EDM rings
MS6	Experiment	Spring 2024	Final ST experiment at COSY
DL6	Publication	Dec. 2024	Publication of the results of the project

2.4 Added value of international cooperation

Our project is closely related to the international effort to construct a dedicated EDM storage ring with sensitivity to the proton EDM down to 10^{-29} e cm. The JEDI collaboration conducts experimental studies of the related systematic effects required for design of the CPEDM prototype ring PTR. The partners of the project are cooperating as members of JEDI collaboration and as partners of the newly formed CPEDM collaboration. The cooperation between RWTH and IKP on these projects is integrated into the Jülich-Aachen Research Alliance (JARA). A. Stahl is founding member and director of the JARA section FAME (Forces And Matter Experiments) which studies CP violation and the baryon asymmetry of the Universe. IKP-2 of FZJ and MIPT have a long tradition on cooperation (MIPT-FZJ collaboration agreement of 15.08.2015, prolonged on 24.06.2020 for 5 years). It is supported through the strategic partnership of the Helmholtz Association with Russian institutes within the protocol of 12.03.2009 of the Commission of Scientific and Technology Cooperation between Germany and Russian Federation.

The planned cooperation will generate a substantial amount of added value through the combination of the expertise on modelling of spin dynamics within the Russian groups with the expertise on spin experiments by the German groups and the access to COSY, the unique experimental facility for spin experiments. The basic idea of the spin transparency and spin navigator approach was developed by the MIPT partners (Yu. Filatov and A. Kondratenko). It can only be tested through the cooperation with the German partners. Through the collaboration, we will provide a new method for the manipulation and control of the beam polarization in storage rings. We will push the readiness level of this method from a basic idea to a suitable method. The new method will extend the science case of several large-scale projects beyond COSY, namely eIC, NICA, EicC, and RICH.

3 Bibliography concerning the state of the art, the research objectives, and the work programme

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4 Relevance of sex, gender and/or diversity

All partners are open to people independent of their sex, gender or other cultural background. We especially promote the participation of female scientists in the project on all stages of their career. Special programs to support female scientists exist at RWTH and IKP. The institutes take measures to increase the participation of female scientists in their program.
Within the SpinTra project, with only a travel budget, the potential to support female scientists or scientists of diverse background is limited.

5 Supplementary information on the research context

5.1 Ethical and/or legal aspects of the project

5.1.1 General ethical aspects

The project addresses question of fundamental research on the universe. No ethical conflicts are expected.

5.1.2 Descriptions of proposed investigations involving experiments on humans or human materials

None

5.1.3 Descriptions of proposed investigations involving experiments on animals

None

5.1.4 Descriptions of projects involving genetic resources (or associated traditional knowledge) from a foreign country

None

5.1.5 Descriptions of investigations involving dual use research of concern, foreign trade regulations

None

5.2 Data handling

The results of the project and the major technical aspects will be published in international scientific journal, reported at international conferences and will be publicly available as electronic arXiv articles. Access to the full data of the project will be granted upon request. This data includes the technical drawings and other documents on the spin navigators and the source code for the spin modelling.

5.3 Other information

None.

6 People/collaborations/funding

6.1 Employment status information

Yury Filatov, employed in a permanent position by MIPT
Achim Stahl, employed in a permanent position by RWTH

6.2 First-time proposal data

None

6.3 Composition of the project group

Russian partner MIPT:

1. Yury N. Filatov (Principal Investigator), leading scientist, head of accelerator physics laboratory, Moscow Institute of Physics and Technology (MIPT), permanent position
2. Anatoliy M. Kondratenko, senior scientist of accelerator physics laboratory, MIPT, head of Science and Technique Laboratory “Zaryad”, permanent position
3. Nikolai N. Nikolaev, professor, chair of problems of theoretical physics, MIPT, and principal scientist, head of high energy physics division of the Landau Institute of Theoretical Physics, Russian Academy of Sciences, permanent position
4. Mikhail A. Kondratenko, research scientist of accelerator physics laboratory, MIPT, research scientist of Science and Technique Laboratory “Zaryad”, permanent position
5. Yuri V. Senichev, professor, chair of astrophysics, MIPT and leading scientist, Institute of Nuclear Research, Russian Academy of Sciences, permeanent position
6. Evgenii D. Tsyplakov, graduate student, MIPT
7. Alexander E. Aksentev, junior scientist, Institute of Nuclear Research, Russian Academy of Sciences, permanent position
8. Alexey A. Melnikov, PhD student, MIPT
9. Artur L. Shilov, graduate student, MIPT
10. Irina L. Gurileva, engineer, Baldin-Veksler Laboratory of High Energy Physics, JINR, permanent position

German partner RWTH:

1. Achim Stahl (Principle Investigator), chair of 3. Physikalisches Institut, RWTH.
2. Karim Laihem (Senior scientist), 3. Physikalisches Institut, RWTH.
3. Andreas Lehrach, professor of accelerator physics, 3. Physikalisches Institut, RWTH.
4. Jörg Pretz, professor of experimental physics, 3. Physikalisches Institut, RWTH.
5. Achim Andres, graduate student, RWTH.
6. Maximilian Vitz, graduate student, RWTH.
7. N.N., master students, RWTH.

6.4 Researchers in Germany with whom you have agreed to cooperate on this project

1. Frank Rathmann, senior scientist, IKP FZJ
2. Andreas Lehrach, senior scientist, IKP FZJ
3. Jörg Pretz, senior scientist, IKP FZJ
4. Alexander Nass, experimentalist, IKP FZJ
5. Volker Hejny, experimentalist, IKP FZJ

6. Ralf Gebel, interim director, accelerator department, IKP FZJ
7. Vsevolod Kamerdzhiev, IKP FZJ

6.5 Researchers abroad with whom you have agreed to cooperate on this project

1. I.A. Koop, Budker Institute of Nuclear Physics, Novosibirsk, Russia
2. A.J. Silenko, Bogoliubov Laboratory of Theoretical Physics, JINR, Dubna, Russia
3. Y.N. Uzikov, Dzhelepov Laboratory of Nuclear Physics, JINR, Dubna, Russia
4. S. N. Vergeles, Landau Institute of Theoretical Physics, Chernogolovka, Russia
5. O. V. Teryaev, theory coordinator of the NICA project, Bogoliubov Laboratory of Theoretical Physics, JINR, Dubna, Russia
6. A.D. Kovalenko, research director, Baldin-Veksler Laboratory of High Energy Physics, JINR, Dubna, Russia
7. I.N. Meshkov, Baldin-Veksler Laboratory of High Energy Physics, JINR., Dubna, Russia
8. P. Lenisa, Ferrara University and INFN Ferrara, Italy

6.6 Researchers with whom you have collaborated scientifically within the past three years

JEDI collaboration: http://collaborations.fz-juelich.de/ikp/jedi/collaboration/members.shtml?type=other

6.7 Project-relevant cooperation with commercial enterprises

None.

6.8 Project-relevant participation in commercial enterprises

None.

6.9 Scientific equipment

The Russian team will have access to all facilities, including workshops and computing centers, available at Joint Institute of Nuclear Research, Moscow Institute of Physics and Technology, Institute of Nuclear Research of the Russian Academy of Sciences and Landau Institute for Theoretical Physics.
The COSY storage ring at IKP FZJ will be available for the experimental program of the project including the entire infrastructure necessary for the project.
Laboratories, workshops and computing infrastructure will be available at sites of MIPT, RWTH, and IKP.

6.10 Other submissions

None.

7 Requested modules/funds

7.1 MIPT Moscow

The project will be funded Russian partners request total funding of 18 Mln RUR for 3 years, 6 Mln RUR per year for duration of the project from January 2022 to December 2024. It will be used as a contribution to the personnel listed in section 6.3. By rules of the Russian Science Foundation, that will cover the overheads and personal funding:
Overheads: 1.8 Mln RUR
Personnel funding: 16.2 Mln RUR

7.2 RWTH Aachen

The project will be funded on the German side to a large extent from own resources. We request, however, a travel budget for all the necessary travel within SpinTra. The Russian partners will not apply for any travel. Their request is focused on personnel. The partners have no budget available, which could be used to cover the travel expenses.

7.2.1 Funding for direct project costs

7.2.1.1 Travel

The collaboration will communicate through modern methods of e-mails, web-based platforms, phone-, and videoconferences. However, some personal contact is still necessary. Most of the exchange is focused on the regular collaboration meetings organized yearly. We ask for a budget for bidirectional travel.

A special need arises in SpinTra from the two beam-times at COSY. We ask for travel both for the preparation (3 week) of the machine development and beam-times as well as for their conduction (5 weeks).

	Participants	Cost per travel	Total
1st beam time (1 month)			**15000** €
Flights	6	600 €	3600 €
Guest house	6	1000 €	6000 €
Per diems	6	900 €	5400 €
2nd beam time (1 month)			**15000** €
Flights	6	600 €	3600 €
Guest house	6	1000 €	6000 €
Per diems	6	900 €	5400 €
Collaboration Meetings			**9900** €
Flights	9	600 €	5400 €
Hotel (70€/night)	9	350 €	3150 €
Per diems	9	150 €	1350 €
German participant to Russia			**6600** €
Flight	6	600 €	3600 €
Hotel (70€/night)	6	350 €	2100 €
Per diems	6	150 €	900 €
Total			**46500** €

8 Signature

Aachen, December 12th, 2020

Prof. Dr. Achim Stahl