**Template JRA**

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| **Work package number** | WP30 | **Start date** | 01/06/2019 |
| **Activity Type** | Joint Research Activity |
| **Work package acronym** | JRA12-SPINFORFAIR |
| **Work package title** | Spin for FAIR |

1. Work carried out and overview of progress
	1. **Project objectives**

*[Please give an overview of the project objectives for the third reporting period (June 2022 – July 2024), with regard to the overall objectives as described in the Annex 1 of the Grant Agreement and summarized below.]*

The physics potential for studies with polarized antiprotons is enormous. The flagship experiment, Drell-Yan production, in double polarized proton-antiproton annihilation, will provide direct access to the transverse spin structure of the nucleon. In this perspective the implementation of a double polarized proton-antiproton collider at the coming FAIR facility, as a long-term upgrade, would open new and unique research opportunities for spin-physics with polarized antiprotons. So far, no antiproton beams with sizeable polarization could be produced. It is the aim of the PAX Collaboration to develop an efficient method for polarizing antiproton beams by in-situ build-up in a storage ring. The only viable way to do this effectively is by “spin-filtering” by the repeated interaction of an antiproton beam with a polarized hydrogen gas target in a cooler storage ring, selectively discarding more particles in one of the two spin states. In the framework of the I3HP3 project, the PAX collaboration has successfully performed a spin-filtering measurement with protons at the COSY-ring by using a transverse polarized hydrogen target. The COSY measurement, actually a determination of the transverse spin-dependent polarization build-up cross section, proves that spin-filtering can be considered as a method to polarize a stored beam and that the interpretation of the polarization build-up mechanism in terms of the proton-proton interaction is valid. With the present JRA, PAX intends to make use of the unique environment offered by the COSY ring to transfer this method to longitudinal polarization. This point is motivated by the fact that all the different models for spin-filtering predict a significantly higher degree of polarization for the longitudinal case than for the transverse one. For the optimization of the polarization buildup it is therefore necessary to study both cases in conjunction. In addition, this approach represents the only way to obtain the relevant spin-dependent cross-sections for producing polarized antiprotons. Afterwards the PAX collaboration is ready to perform the corresponding experiments with antiprotons.

* 1. **Progress made during the reporting period towards the objectives**

*[Please describe the progress made during the third reporting period in line with your Gantt chart and the project overall tasks as described in the Annex 1 of the Grant Agreement and summarized below.]*

***Table 1.2 Progress made during the reporting period for each task***

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| ***Task 1: Siberian snake. Implementation: the natural direction of the polarization in a storage ring is vertical with respect to the beam momentum; longitudinal polarization requires the introduction of a dedicated magnet system: namely a Siberian snake by which the spin-closed orbit at the target installed in the opposite straight section and about which the stored particles precess, is oriented along the longitudinal direction*** |
| * The first Siberian Snake commissioning beam time took place in March 2020 at the COSY Storage Ring. The test evidenced that the solenoidal field, acting quadratically on the betatron tunes, introduces a strong phase space coupling creating a tune split around the νx − νy = 0 resonance, inhibiting the possibility of operating the ring in this region of the phase space. The νx = νy is essential for the obtainment of the long beam lifetime conditions required for the spin-filtering experiment.
* Subsequently, progresses were made in understanding the effect on the beam dynamics caused by the presence of the soleonidal magnetic field. The available way to compensate for the effect of the solenoid in COSY is to modify the quadrupoles strength. This in turn affects the betatron tunes linearly, requiring dedicated simulations with the MAD- X model of COSY. At the time of the first Siberian Snake commissioning test, the model did not include the necessary coupled ion optics yet and the tunes compensation required several iterations, resulting in a time consuming process.
* Dedicated developments have been initiated in view of second commissioning test. The option of installing skewed quadrupole magnets in the COSY beam line, in order to compensate the tune shift caused by the solenoidal field, has also been investigated.
* The long shutdown due the COVID pandemic, combined with the budget restrictions causing a reduction of the available beam time at the COSY ring and its premature shutdown at the end of 2023, did not allow the completion of the physics program.
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| ***Task 2: Measurements and Data Interpretation: two sets of measurements are foreseen. The first is devoted to the measurement of the target polarization with the twofold goal of commissioning the new detection system and to provide an absolute calibration for the target polarimeter. The second is represented by the longitudinal spin-filtering measurements at COSY*** |
| * The detector, with two of the planned four quadrants assembled, has been commissioned with an unpolarized proton beam and a polarized deuterium target demonstrating that it can be used for the low-energy spin-physics experimental program at COSY.
* After the first commissioning, the missing two quadrants have also been assembled, while the electronics, the cooling system and the data acquisition have been adapted to the full detector scheme. A test bench has been set up in the IKP-2 Pax laboratory, and an acquisition of cosmic rays data with a fully assembled detector was scheduled before the Covid-19 crisis began.
* Operations were resumed in the second half of 2021, when the data taking started and the commissioning of the detector with cosmic rays has been successfully completed.
* The final detector commissioning, as well as the beam polarization measurement, was planned together with the final Siberian Snake commissioning, taking into account the beam availability at the COSY facility and the PAX interaction point availability, now occupied by the RF Wien Filter needed for the EDM precursor experiment performed by the JEDI collaboration, whose schedule was heavily affected by the pandemic as well.
* As for Task, the long shutdown due the COVID pandemic, combined with the budget restrictions causing a reduction of the available beam time at the COSY ring and its premature shutdown at the end of 2023, did not allow the completion of the physics program
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**1.3 Highlights of significant results**

*[Include an overview of the project results towards the objectives in line with the structure of the Annex 1 to the Grant Agreement*.*]*

1. Critical Implementation risks and mitigation actions

**2.1 Risk materialization**

*[Provide the information on the project risks described in Annex 1 to the Grant Agreement*.*]*

1. The performance of the longitudinal spin-filtering test is conditional to the commissioning of the Siberian snake in COSY (low)

Whether the risk has materialized? (Yes/No)

1. The performance of the longitudinal spin-filtering test is conditional to the accomplishment of the beam and polarization lifetimes in the ring (low)

Whether the risk has materialized? (Yes/No)

1. The performance of the longitudinal spin-filtering test is conditional to the commissioning of the detector (low)

Whether the risk has materialized? (Yes/No)

**2.2 Risk-mitigation measures applied**

*[Please indicate whether the risk-mitigation plan described in Annex 1 to the Grant Agreement and corresponding to the risk number was applied in the reporting period*.*]*

1. The Siberian snake has been tested on a test bench. Should a first commissioning test in COSY not be successful, additional beamtime will be asked to complete the task and to learn how to properly operate the system.

Whether the risk-mitigation plan was applied? (Yes/No)

1. The proper conditions for spin-filtering test have been already accomplished for the test with transverse polarization. Should the conditions not be accomplished, a revision of the COSY vacuum system will be required.

Whether the risk-mitigation plan was applied? (Yes/No)

1. The detector has been already commissioned on a test bench. If the first commissioning present some problems, additional beamtime will be asked.

Whether the risk-mitigation plan was applied? (Yes/No)

**2.3 Comments/new risk-mitigation measures proposed**

*[Provide any significant comments on the risks encountered and the mitigation plan applied. Give any unforeseen risks encountered during the reporting period and not mentioned above*.*]*

3. Deviations from Annex 1 (Description of Action) and Annex 2 (Estimated budget for Action) (if applicable)

**3.1 Deviations from planned objectives and tasks, and their impact on the progress of the work package**

*[Explain the reasons for deviations, the consequences and the proposed corrective actions.]*

**3.2 Deviations between actual and planned person months**

*[Explain deviations between actual and planned person-months. If applicable, propose corrective actions.]*

1. Deliverables and milestones tables

**4.1 Deliverables**

*[Please list all the deliverables due in this reporting period, as indicated in Annex I.*

*Deliverables must also be accompanied by a short report (deliverable description and technical documentation, such as photo, list of publications, etc.), so that the European Commission has a record of their existence.]*

***Table 4.1 List of deliverables***

| **Deliverable No.** | **Deliverable name** | **Lead Beneficiary** | **Nature** | **Dissemination level[[1]](#footnote-1)** | **Delivery month from Annex I** | **Delivered****(yes/no)** | **Actual delivery month** | **Comments** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
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*In case a deliverable has been delivered in the reporting period and a report exists in the Participant Portal, you can indicate “uploaded report” in correspondence of a deliverable*

**No Deliverables in the RP3 (months 37-62)**

**4.2 Milestones**

*[Please complete the table if milestones are specified in Annex I.*

*Milestones will be assessed against specific criteria and performance indicators as defined in Annex I.]*

***Table 4.2 List of milestones***

| **Milestone number** | **Milestone name** | **Lead beneficiary** | **Delivery month from Annex I** | **Delivered****(yes/no)** | **Actual delivery month** | **Comments** |
| --- | --- | --- | --- | --- | --- | --- |
| MS71 | Snake commissioned | 30 - INFN | 43 | 50% |  | See description of Task 1 |
| MS72 | Measurement of target polarization and beam polarization accomplished | 30 - INFN | 43 | 50% |  | See Description of Task 2 |

**4.3 Deliverable Reports**

*(Please provide, for each deliverable listed in Table 4.1, a brief description, including if possible some technical documentation (photos, list of publications, etc.).Use as many pages as needed per each report.)*

1. PU = Public

PP = Restricted to other programme participants (including the Commission Services).

RE = Restricted to a group specified by the consortium (including the Commission Services).

CO = Confidential, only for members of the consortium (including the Commission Services). [↑](#footnote-ref-1)