Work package number [9]	WP28	**Lead beneficiary** [10]	10 - UBO
Work package title	JRA10-Cryogenic Polarized Target Applications (CryPTA)		
Start month	1	**End month**	48

Objectives

Objectives: There are central questions that remain to be answered within the Standard Model. Examples are how the properties of strongly interacting particles can be understood from their fundamental constituents (quarks and gluons) or why these constituents are confined to these particles. Spin, a fundamental property of a particle, plays an important role in trying to understand these unresolved subjects. An ambitious spin program is therefore underway at the infrastructures ELSA (Bonn) and MAMI (Mainz), where double polarization experiments with polarized beams on polarized protons and deuterons (neutrons) targets are used to disentangle the complicated resonance spectra to learn how the elementary particles form matter. The PANDA experiment at the FAIR facility does experiments with the aim of understanding confinement, not just as a phenomenon but to comprehend it quantitatively from the theory of the strong force. New experiments exploiting high-energy antiproton and ion beams will also elucidate the generation of hadronic masses and by the use of an internal transverse polarized gas target the facility is well suited to measure single or double spin asymmetries to determine nucleon structure observables. At high energies the COMPASS experiment at CERN investigate, how the different constituents (quark flavors, gluons, sea-quarks, angular momentum) contribute to the spin of the nucleons.
Technically, the polarized nucleons for these experiments are provided by polarized solid state targets, using the method of Dynamic Nuclear Polarization (DNP) or internal Atomic Beam Source (ABS) polarized gas targets. The combination of large angular acceptance nonmagnetic detector arrangements and frozen spin polarized solid state targets equipped with internal superconducting holding coils, has led to a large number of measured double polarization observables at ELSA, MAMI and TJNAF. However, the frozen spin technique has some systematic disadvantages such as the limited beam intensity they can sustain, the time loss for repolarization and the need of a sophisticated moving system for the external superconducting magnet for DNP and the detection system. To improve this class of experiments and to overcome the drawbacks of the frozen-spin polarized target, especially to get rid of the external DNP magnet, we will optimize the small low mass internal LTS (low temperature superconducting) coils to strengthen the magnetic field for permanent DNP ("4-DNP continuous mode" target) while keeping the excellent angular acceptance and to gain the luminosity of the existing target schemes. To get access to new polarization observables it is foreseen to add additional small low mass superconducting coil schemes for individual polarization directions. In contrast to the above mentioned detector and polarized target concepts, the PANDA detector will operate with a strong longitudinal magnetic field to provide the measurement of charged particle trajectories with high resolution. To align the spins of the target nucleons in other directions than the spectrometer field orientation, it is therefore necessary to shield the polarized gas target from the magnetic field of the spectrometer coil. The development of a low mass HTS (high temperature superconducting) active or passive shielding is the first step towards a transverse polarized gas target in PANDA. A polarization or magnetic field direction off the beam axis then has to be provided by additional small superconducting coils inside the shielding tubes. In spite of the different approaches, the superconducting structures of both subtasks have similar outer dimensions and have to be as thin as possible to minimize the radiation length for penetrating particles. Our aim within the JRA is to increase the field and homogeneity of the LTS DNP-coils up to 2.5 T and to reduce the thickness of the HTS-structures towards operational prototypes and to implement for both schemes small superconducting coils for individual polarization directions under perpetration of the overall minimized thickness. State-of-the-art frozen spin targets for detection systems with full angular acceptance running at ELSA, MAMI and TJNAF use a thin, superconducting coil inside a 3He/4He dilution refrigerator either to maintain the polarization with a relaxation time in the order of several hundred hours or in future, to build up the polarization during data taking. The outgoing particles have to punch through this coil to be detected. In spite of the minimized wall thickness of the internal magnets, this limits kinematically accessible region, especially for low momentum particles. The best technical option to overcome this drawback is to detect them inside the target material itself, using a so called 'active target'. The scintillating target material has to be polarized at cryogenic temperatures and the light has to be detected with dedicated electronics adopted to these extreme conditions. A first functional prototype demonstrated in a test experiment in Mainz under beam conditions the feasibility of this technique. The third task of our JRA is the development of active polarized targets at cryogenic temperatures and the further implementation of this technology with new, improved prototypes. The overall objective of the JRA is hence to develop future key technologies for new and innovative polarization experiments using polarized targets in Europe.

Description of work and role of partners

WP28 - JRA10-Cryogenic Polarized Target Applications (CryPTA) [Months: 1-48]
UBO, JGU MAINZ, RBI
Description of work (where appropriate, broken down into tasks), lead partner and role of participants
Spokesperson: Hartmut Dutz
1. Development of low mass superconducting high field magnets. To achieve the required homogeneity (B/B < 10-4) in an internal polarizing solenoid (thin, low mass, wt ~ 2 mm) the displacement of the thin sc-wire (~ 0.2 mm) has to be less than a tenth of the wire diameter. This sets very demanding conditions on the winding technique. As first step, we will refine the winding technique for thin superconducting wires in a collaborative R&D program to reach the required magnet parameters and to build a first high field polarizing magnet. The magnet parameters will be set in due considerations of the used target dilution refrigerator and the experimental constrains of the detector set-ups at MAMI and ELSA. Then we intend to develop and design a combined low mass superconducting magnet system for DNP and to maintain the nucleon spin in any arbitrary direction for data taking. This scheme for the first time will allow to measure various (double) polarization observables in one setting and set-up at MAMI and ELSA. Recent studies and simulations have shown that the concept of the internal high field polarizing magnet is under the assumption of a given layer thickness scalable to moderate larger size solenoids (~ 30 cm). The scheme will be a major step forward for particle tracking in nonmagnetic large acceptance detector systems. For this subtasks we request staff appropriations for one Post-Doc-position, for 19 month for the leading Bonn group as well as contributions for durables and travels for the involved institutions RUB (NMR for field measurements) and CUNI (field simulations and feasibility studies for the tracking-coil application).
2. Development of low mass HTS active or passive shielding. High temperature superconductors offer new possibilities as active or passive shield for polarized nuclear gas targets. First numerical calculations in the 'Helmholtz-Institut Mainz' (HMI) have shown that high temperature super-conductors like YBCO or BSCCO are ideal materials to passively shield a strong magnetic detector field. Simulations and test with different materials and different geometries will be performed in the framework of this WP in order to find the optimum geometry and working point in terms of a transversely polarized target. The use of high temperature superconducting materials in thin cylindrical layers to shield magnetic fields is a demanding and challenging high-tech application of HTCS in terms of the sintering and machining of the superconductors in nonstandard small geometries. For this task we request appropriations for durables and consumables for the leading Mainz (HMI) group as well as contributions for travels for the involved institutions UBO and JGU Mainz (HMI) (cold tests T < 2 K are planned at the UBO low temperature magnet test facility).
3. Detection of recoil particles in active polarized targets at cryogenic temperatures. The feasibility of this technique in terms of material properties and degree of polarization has shown a promising perspective at the Institute of Nuclear Physics (IKP) in Mainz as leading institution of this sub task. A first functional prototype was used successfully for first tests in the MAMI beam with the 'Crystal Ball' detector system. However, new improved versions of the target insert have to be produced and tested in cooperation with the Joint Institute for Nuclear Research in Dubna, Russia to allow for faster cool down and higher degree of polarization. R&D activities have to be initiated together with collaborative partners from CUNI to get a more transparent, highly polarizable material and to develop the electronics for recoil particle detection at cryogenic temperatures. Another application of this technology would be to realize small scintillating detectors for cryogenic conditions. These could be placed inside the polarizing coil, very close or even in the liquid helium bath of the refrigerator, e.g. for the COMPASS experiment. For both tasks we request staff appropriations for one Post-Doc-position for 9 month for the leading IKP group and 2 month for the CUNI group as well as contributions for durables, consumables and travels for the involved institutions RUB, RBI (NMR measurements in the active target) and CUNI (material studies).

Participation per Partner

Partner number and short name	**WP28 effort**
9 - JGU MAINZ	9.00
10 - UBO	20.00
25 - RBI	3.00
Total	32.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D28.1	Prototype of a low mass, internal horizontal polarizing solenoid	10 - UBO	Demonstrator	Public	48
D28.2	Prototype of a HTSC shield for a large acceptance magnetic detector	9 - JGU MAINZ	Demonstrator	Public	48
D28.3	Prototype of a cryogenic insert with active target material	9 - JGU MAINZ	Demonstrator	Public	48

Description of deliverables

D28.1-Prototype of a low mass, internal horizontal polarizing solenoid.
D28.2-Prototype of a HTSC shield for a large acceptance magnetic detector
D28.3-Prototype of a cryogenic insert with active target material.

D28.1 : Prototype of a low mass, internal horizontal polarizing solenoid [48]

D28.1-Prototype of a low mass, internal horizontal polarizing solenoid. The first deliverable base on the realization of a thin low mass internal sc-polarizing magnet which will be implemented in the existing dilution refrigerator to complete the “4 Pi continuous mode polarized solid target” and will lead to a thin large size sc.-high field demonstrator magnet for large polarized target or comparable applications (month 48).

D28.2 : Prototype of a HTSC shield for a large acceptance magnetic detector [48]

D28.2-Prototype of a HTSC shield for a large acceptance magnetic detector. Towards a working HTSC shield the deliverable of the second task will be a prototype (demonstrator) of the simulated HTSC-shield for a large acceptance magnetic spectrometer like the PANDA-detector (month 48).

D28.3 : Prototype of a cryogenic insert with active target material [48]

D28.3-Prototype of a cryogenic insert with active target material. In this task the third deliverable will be an improved active target insert for in beam tests and lead to the operation of the active target sample at cryogenic temperatures with the Crystal Ball detector system (month 48).

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS63	High precision winding machine for thin superconducting wires	10 - UBO	9	Internal Report
MS64	Design concept of a low mass, combined field superconducting magnet system	10 - UBO	27	Internal Report
MS65	Magnet field calculations for PANDA low mass superconducting passive shielding	10 - UBO	27	Internal Report

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS66	Manufacture of prototype active targets for in beam tests	10 - UBO	27	Internal Report