1. Explanation of the work carried out by the beneficiaries and Overview of the progress

1.1 Objectives

The following part gives the descriptions of the objectives as fixed in the Description of the Action (DoA) and explains how the project has progressed towards these objectives during the first Reporting Period. The objectives are organized around the following three pillars: low- and high-energy frontier studies, and instrumentation as defined in the Grant Agreement (GA).

As stated in the GA, the objectives of this Action are to federate leading experimental and theoretical groups in EU in order to carry out new fundamental and applied research studies at the frontier of our current knowledge of the strong interaction, the force that binds together quarks and gluons and, ultimately, forms the visible baryon matter of our universe. The underlying quantum field theory that describes the strong interaction, quantum chromodynamics (QCD), has an extremely rich dynamical content (asymptotic freedom, confinement, approximate chiral symmetry, non-trivial vacuum topology…). This translates into a very diverse many-body phenomenology at various limits: at high temperatures the Quark-Gluon-Plasma (QGP), at large quark densities the colour superconductivity, at very low parton fractional momenta the colour glass condensate (CGC), etc. Also, many of the fundamental parameters of the Standard Model (SM) like the strong coupling constant, the quark masses, the matrix elements of the Cabibbo-Kobayashi-Maskawa mixing (CKM) are also directly connected to QCD. A good understanding of the interaction between light-, heavy-quarks, and gluons is crucial for searches of physics beyond the SM. The study of QCD is mostly carried out through electron-positron (e+e-), lepton-proton (e-p, mu-p), electron-nucleus (e-A), protonproton (p-p), antiproton-proton, proton-nucleus (p-A), antiproton-nucleus and nucleus-nucleus (A-A) collisions at low (<20 GeV) and high (>20 GeV) center-of-mass (c.m.) energies in world-class experimental facilities for which Transnational Access (TA) is requested.

The detailed progress towards concrete objectives of each thematic field achieved during the second Reporting Period is presented in the table below.

Objective	Results
Low-Energy frontier	
JRA - Precision Tests of the Standard Model (PrecisionSM) Precise determination of the muon anomalous magnetic moment (g-2)μ; extraction of the CKM matrix element Vud from beta decay, and of the weak mixing angle from	Studies of lepton anomalous momenta have received a very strong boost during this second reporting period by the release of the first experimental data from the Muon g-2 experiment at Fermilab that confirmed the discrepancy with SM at the 4.2 sigma level. This discrepancy relies on theoretical input from hadronic physics, in which two approaches are employed: dispersion relations (considered in this WP) and lattice QCD (considered in WP17 of STRONG-2020). This WP actively participated in the interpretation of the experimental results,

parity-violating electron scattering (PVES)	organizing one workshop, and produced one white paper, providing essential contributions to this worldwide effort to pin down experimental and theoretical uncertainties in a coordinated way. Concerning Task 1, the progress has also been very remarkable, achieving sizable reductions in the hadronic uncertainties in Vud and Vus (factors from 2 to 10) and a more precise evaluation of the uncertainties on beta decays that depend on nuclear structure corrections. Contributions to two white papers and one workshop have been realized, as well as three other papers. An important milestone has been an in-person workshop dedicated to weak neutral current interactions with nuclei relevant for the determination of the weak mixing angle, as well as nuclear properties like the difference between the proton distribution and neutron distribution in nuclei. It has been achieved and organized at the MITP in Mainz, on May 23-27, 2022.
NA - Proton Radius European Network (PREN) Address the "proton-radius puzzle" via combined data-theory analyses of new results in atomic spectroscopy and very-low momentum transfer (Q2) lepton-proton elastic scattering at various energies	During this second reporting period, this network has organized regular remote meetings to discuss the recent developments. In addition, there have been short time visits by postdocs at different groups. Several new hydrogen spectroscopy experiments have been set up at various laboratories all over the network. A full in-person meeting was so far excluded due to the pandemic situation. Such a meeting recently took place in June 2022, in Paris. The Network has organized several public lectures. Scientific progress in terms of experimental and theoretical results has been published.
NA - LatticeHadrons (LatticeHadrons) Development of combined software, data sharing, and methodologies in lattice QCD theory across Europe for hadron spectroscopy and structure, hadrons under extreme conditions, hadrons in the SM and beyond, and novel numerical algorithms and computing for lattice hadron physics	During the second reporting period, no in-person visits and exchanges were possible due to the pandemic. However, several activities have been carried out. On the one hand, a new platform LaVA has been devised and agreed via the web systems of ECT*. On the other hand, several workshops have taken place, such as a thematic workshop in June 2021, a thematic workshop in hybrid mode in Galileo Galilei institute in 2022, and another one in software development organized in June 2022. Three other workshops are being planned.

JRA-Light-and heavy-quark hadron spectroscopy (HaSP) Development of a common data-theory analysis framework to determine exotic hadrons properties by fitting new experimental data to lattice QCD and effective-field-theory predictions	This has been a very productive WP during the second reporting period, with an excellent progress in all tasks. Regarding the list of achievements, Task 1 was devoted to the further development and applications of effective field theories for the study of exotic hadrons employing hadronic degrees of freedom (tetraquarks, low lying negative parity isoscalar hyperons, Tcc+ states, effective range expansion for narrow near-threshold resonances), effective field theories for singular NN interactions, effective field theories for conventional states (doubly heavy baryons, Λ baryon spectrum), light meson dynamics (πK and $\bar{K}$N Interactions), as well as heavy quarks in matter and finite temperature. Moreover, hadron decays have been thoroughly studied, such as weak decays involving low-lying scalar mesons, heavy hadron decays or heavy baryon decays to find BSM physics, together with the study of exotics through inclusive and semi-inclusive decays of heavy-quark hybrids, triangle singularities and tetraquarks. As for Task 2, the list of achievements includes the determination of the strong coupling constant, the study of jets and other nuclear observables, as well as lattice QCD calculations of nuclear systems, the study of atomic nuclei and neutron matter, and the use of dispersive methods for the study of light resonances. Also, heavy-quark, hybrid and tetraquark potentials have been computed by the Hadron Spectrum collaboration, whereas the FASTSUM collaboration has worked on the in-medium quarkonium evolution. With regards to Task 3, light exotic mesons, charmonium and strangeonium, have been studied thoroughly, as well as low-lying scalars and strange mesons. Finally, within Task 4 on baryon spectroscopy, new experimental data on photo- and electro-induced meson production on protons and deuterons has been reported with a significant contribution from participating institutions in STRONG-2020. As for milestones and deliverables, the HaSP general workshop and school (milestones MS54 and MS55) have been delayed taking advantage of the six months extension of the project due to the pandemic. The deliverable D25.2 (report) will be achieved once the HaSP workshop takes place in September 2022.

NA - QCD physics at GSI/FAIR (FAIRnet) Multi-prong improved data selection plus distributed physics analysis for rare signal events under high background conditions in anti-p-p, anti-p-A, and A-A collisions for the PANDA and CBM experiments at the future FAIR facility	Design of hardware has progressed well, with a new ASIC for readout of the Silicon Strip Detectors for PANDA. A prototype has been delivered and is being tested after some delays. Another prototype, an AMC board for high-speed data collection, was also delivered with some delays and is being tested. A paper on reconstruction algorithm for EMC spectrometer of PANDA has been published. Concerning CBM, a full-system test setup was described in the first reporting period, and the detector has been extended now in all subsystems.
NA-Strange Hadrons and the Equation-of-State of Compact Stars (THEIA) Address the "neutron stars hyperon puzzle" through combined theoretical and experimental studies of (anti)hypernuclei and bound strange-meson systems produced in hadronic collisions at various c.m. energies	There has been an excellent progress towards the objectives, both experimental and theoretical, with different groups working for the different objectives. As for Task 1, significant progress has been made for hypernuclei $^{3}{}_{\Lambda}H$ and $^{4}{}_{\Lambda}H$, as well as for determining the existence of a neutral A=3 hypernucleus nnΛ, from the experimental and theoretical point of view. With regards to Task 2, the PANDA Phase-one program including the possible measurement of antihyperons in nuclei has been recently published. For Task 3, important experimental advances have been performed at DAFNE with the SIDDHARTA-2 setup, as well as with AMADEUS. As for Task 4 on the role of a mini antiproton-proton collider at FAIR for strangeness nuclear physics, this one is left for the upcoming period. For Task 5 on annual workshops, the HYP2022 conference took place in Prague, whereas two web-seminars with weekly talks have been held online. All deliverables and milestones have been achieved, although there has been delays due to the COVID-19 pandemic at MAMI and also FAIR. Related to the pandemic, only conference fees for three online meetings occurred, so the budget was not spent. A risk-mitigation plan was put in place adding a new deliverable, the development and implementation of a hypernucleus database for the whole community. This new deliverable implied the transfer of 25% of the budget from Travel to Personnel costs.
High-Energy Frontier	
VA - Automated perturbative NLO calculations for heavy ions and quarkonia (NLOAccess)	It has to be underlined that in terms of usage and achievements, the VA exceeds the initial objectives and expectations.

Extension of the MadGraph automated on-line code for the novel computation of perturbative QCD cross sections in high-energy hadronic collisions at next-to-leading-order accuracy, using meson and heavy-ion beams, and for quarkonia final-states.	During the second reporting period, the NLOAccess team has updated the IT resources. The access has also been successfully tested and is now allowing the usage of modern compilers. A major landmark was met with the integration of MADGRAPH5aMC@NLO with a two-step running, which allows code reuse. The number of registered users increased from 89 to 247 since the former report, with a significant participation of PhD and Master students. About 40 related presentations were delivered and several reviews or articles including predictions made using the NLOAccess portal were published in nuclear and particle physics journals. The International Assessment Board (IAB) with a balanced composition (theorists and experimentalists from EU and non-EU institution) meets and provides feedback regularly.
VA - Virtual Access to 3DPartons (3DPartons) Development of a new combined framework to extract generalized (GPDs) and transverse momentum-dependent (TMDs) parton distributions, with higher-order fixed and twist corrections, from fits to experimental e-p and p-p data	Central workhorse is a common webpage for the distribution of analysis and fitting software packages, which has been continuously improved, updated and enlarged during the second reporting period. New fitting procedures and new experimental observables have been added in the software libraries. The access to the web page and the usage of the web page is monitored by dedicated web analytics software. For the assessment of the work done in this WP, a dedicated Assessment Board has been created. This board consist of eight experts of the related fields of theoretical physics, analysis of experimental data and software development. During the reporting period, a constant update and increase of the libraries accessible through the web page has been performed. A certain trend is to write new application in python code instead of previously commonly used C++. In spite of the pandemics and the general slowing-down of activities throughout the world, the access to the facility remained stable during the second period. Similarly to what was observed during the first period, the connections originated mostly from the United States (213), France (133), Poland (73) and China (58). The physics programmes for future electron-ion colliders EIC in the US and EICC in China rely heavily on the developments made accessible in this WP.
JRA- Generalized Parton Distributions (GPD-ACT)	During this second reporting period, several analyses have been finalized and published, while others are underway, as well as

Extraction of GPDs from new high-precision QCD analyses of novel high-statistics e-p and p-p measurements at fixed-target and collider energies.	detector developments and deployment. Tasks are organized by two experimental facilities (Jefferson Lab–TJNAF) and COMPASS at CERN, and one theory-phenomenology. Two analyses at TJNAF have been published in Phys. Rev. Lett. and another one is underway. The construction of the NPS spectrometer is completed and is being installed to take data in 2023. Three analyses of COMPASS data are underway and will be finished in the coming months, one of them finds tension with previous data that is being studied. Two other analyses have been finished, one of them already published. On the phenomenological side, almost ten articles have been published, which is quite impressive.
JRA - 3D structure of the nucleon in momentum space (TMD-neXt) Extraction of unpolarized and polarized TMDs and parton fragmentation functions (FFs) from new high-precision QCD analyses of novel high-statistics measurements at e+e-, e-p and p-p at fixed-target and collider energies.	During this second reporting period, several experimental and theoretical analyses have been released and the WP progressed well, despite some small delays mostly due to the lockdown of experimental facilities related with COVID-19. This WP has released: i) preliminary analysis of unpolarized and polarized DY data from COMPASS, as well as DY data at the LHC by the CMS collaboration; ii) a new extraction of the quark TMD from a global analysis, an extraction of the quarks Sivers function, as well as theoretical developments for the TMD fragmentation functions; iii) theoretical implementations to determine the gluon TMDs. Finally, experimental work has been performed and data taking is still ongoing for COMPASS and CLAS.
JRA - Challenges for next generation DIS facilities (next-DIS) Development of new Monte Carlo tools and studies of benchmark channels, for e-A collisions at future deep-inelastic experiments. Optimisation of associated detector designs for high-resolution tracking, vertexing, photon, and PID.	During this second reporting period, new studies to a Timepix-based tagger for the EIC were developed. Also, other related developments that will lead to a prototype have been achieved. Two other prototypes have been developed and tested using a hybrid device made of MicroMegas and GEM amplification. The characterization of these prototypes demonstrates their agreement with the specifications for the TPC for future colliders. Another prototype to investigate the critical aspects of the proposed dRICH has been successfully commissioned at the CERN test-beam facility and data analysis is ongoing. Another test-beam campaign will take place in fall 2022. The third technology under consideration – MAPS for tracking – also experienced significant progress during this reporting period. This technology is developed in collaboration with the ALICE ITS3 project.

NA - Small-x Physics at the LHC and future DIS experiments (Small-x) Extraction of high-precision nuclear parton distribution functions through global fits including the latest LHC p-A and A-A data. Extension of current gluon-saturation calculations to NLO accuracy with resummation corrections, for observables with three jets and with heavy-quarks. Calculation of multi-particle correlations issuing from initial-state PDF effects to separate them from final-state hydrodynamic effects in small systems	During this reporting period, a new nuclear parton distribution function (nPDF) set, EPPS21, has been released. This is one of the main highlights of this WP. Also, analyses of the potential of future experiments to distinguish between linear and non-linear regimes of QCD have been published. Quite impressive progress has also been performed in NLO computations in the framework of the Color Glass Condensate (CGC), with more than 10 articles released. A related activity on TMDs at small-x, also including non-linear effects in a slightly different approach, has also provided very important results including resummation and NLO calculations. Moreover, this WP has produced studies and important results on multi-particle correlations, leading to five publications. Overall, the progress in this WP is excellent, and many physics results have been produced during this period.
JRA - Fixed Target Experiments at the LHC (FTE@LHC) Development of novel gas-target techniques to be able to carry out the most energetic fixed-target collisions ever performed in the laboratory, using the LHC beams at ALICE and LHCb. Evaluation of the novel expected constraints on PDFs at high-x in the proton and nucleus, parton spin dynamics, as well as QGP properties via unique quarkonia measurements.	All the three main tasks, i.e. i) feasibility studies in ALICE; ii) Gas-target developments in LHCb; iii) Phenomenological and theoretical studies; made a significant progress for both the investigation and the implementation of a fixed target experiment and programme at the LHC. The progress made related to the feasibility studies in ALICE corresponds to the integration of a solid target internal to the beampipe in ALICE, which materializes in the form of a conceptual design report made available as an internal note. A target position compatible with the access and intervention to internal detectors was proposed. Fast and full simulations were performed to evaluate the consequence of material budget (found neglectable) to the main forward detector, if specific conditions are respected. Tracking detector performance was evaluated in the fixed target (displaced primary vertex) mode using dedicated software (including improved algorithm) compatible with the latest framework (O2) of the experiment. Assessments for track, weakly decaying hadron and open-charm secondary vertex reconstructions were made.

	At LHCb, not only the design and construction but also the installation of the unpolarized gas target were completed. Temperature control and monitoring, which are essential for luminosity determination, are integrated to the LHCb data acquisition and the LHC system. The analysis of collected data related to the first standalone tests on gas (atomic hydrogen) polarization, performed using a dedicated storage cell, is ongoing. The design of the new polarised gas target is proceeding well and is completed for most of its parts. Full simulations provide relevant information about the detector data-taking performance. Corresponding software were included in the new LHCb framework, and several key channels were studied for hard processes in p-A and Pb-A collisions. On the phenomenological and theoretical part, next-to-leading order (NLO) corrections for eta_c yields were computed, as well as NLO-corrected to LO cross-section for eta_c, eta_b and chi_c for collisions energies above 20 GeV in the center of mass relevant for the fixed-target programme at the LHC.
NA - Quark-Gluon-Plasma characterisation with jets (Jet-QGP) Development of novel experimental and theoretical techniques for jet physics in A-A collisions, providing a reference implementation of jet interactions in a QGP via a full heavy-ion Monte Carlo event generator. Definition of new observables and development of new tools with increased sensitivity to the physical mechanisms involved in jet-QGP interactions.	The first task of this theory/phenomenology/inter-experiment NA is completed with selecting the JEWEL event generator as a well-defined reference implementation for jet-QGP dynamics. Its second task is to identify jet substructure observables sensitive to specific scales/features of jet-QGP interaction: using machine learning techniques, three variables (jet width, one-subjettiness and the dynamical grooming k_T) have been identified to be the most sensitive, albeit strongly correlated. Once the ongoing studies are complete, the report on the survey of observable corresponding to Deliverable D14.3 and expected for month 36 should be made available, with a delay of 3 months (i.e. moving MS16 to month 39).
NA - Quark-Gluon Plasma characterisation with heavy flavour probes (Hf-QGP)	In spite of the pandemic, several papers, virtual and (later) hybrid meeting and/or workshops have been held with an overall very good progress towards the objectives.

Extraction of QGP transport coefficients from new high-precision theoretical calculations and experimental measurements of the production of open and closed heavy flavour (HF) quarks in A-A collisions at the LHC. Accurate measurements of total c-cbar, b-bbar cross sections in p-p, p-A and A-A collisions. Development of a new data-theory interface to compare event-by-event experimental results to MC predictions	As for Task 1 on open heavy flavor, the assessment of the numerical models from the Catania, Frankfurt, GSI and Nantes groups that describe the dynamical variables of open heavy flavor has been accomplished and delivered, with several papers already published. With regards to Task 2 on hidden heavy flavor, a significant progress has been made for the instrumental tool that can be used for a systematic comparison of Monte Carlo theory models and experimental results (the deliverable D18.4). However, the pandemic has delayed its completion due to lack of work force. To solve this issue, the hiring of the expected new postdoc positions has been delayed in the theory group or diluted in a few shorter-term positions in the experimental groups, ensuring the necessary manpower for the rest of the project. And for Task 3, due to the COVID-19 pandemic restrictions, the schedule of the three foreseen theory workshops has been adjusted, so that the second and third workshops will take place in 2022 and 2023, respectively. As for deliverables, D18.4 on Theory database was delivered on time, and D18.3 on a paper on LHC activities is moved to month 48.
JRA - Inter-experiment combination of heavy-ion measurements at the LHC (LHCCombine) Combination of key LHC (ALICE, ATLAS, CMS, LHCb) measurements in p-p, p-A, and/or A-A collisions to achieve high-precision constraints on nuclear PDFs, QGP properties, SM parameters, and/or searches of physics beyond the SM. Examples include gauge bosons and jets differential cross sections to constrain nPDF, light-by-light scattering to constrain new physics searches, open charm or bottom hadron cross	The objective of this JRA is to define a common structure for LHC experiments in order to improve communication channels between them in the field of heavy-ion studies and establish an LHC data-combination working group exploiting their complementary capabilities. Despite the complicated context during the second reporting period, the progress made by the WP is remarkable, with no deviations from planned objectives. A total of 14 meetings addressing the objectives of the project were held, with 7 of them during the second reporting period. Several important achievements are underlined, including the establishment of a heavy-ion working group within the LHC Physics Center at CERN and combination work from the WP being presented at the largest conference (Quark Matter 2022) in the field.

sections to determine QGP transport coefficients	
Instrumentation	
JRA - Micropattern Gaseous Detectors for Hadron Physics (MPGD_HP) Development of new gas detectors with improved capabilities in tracking, charged particle identification, photon detection, and timing in the picosecond region, capable of operating under very high beam intensity conditions.	The GEM-TPC for FOPI was the first larger-scale TPC operated without gating grid. It provided the prototype for the upgrade of the ALICE TPC with GEM detectors, which was finished in 2021 and will operate in heavy-ion collisions with a rate up to 50 kHz starting the fall 2022. Possible applications of high-rate TPCs include the Crystal Barrel experiment at ELSA (Bonn) and the tagged DIS Experiment at Thomas Jefferson National Accelerator Facility (Virginia, USA), aiming to measure pions and kaons structure functions in the valence regime using the 12 GeV beam. An active-target TPC without charge amplification will be the main device for measurements of the proton charge radius using a high-energy muon beam at the AMBER experiment at CERN SPS. A modular hybrid (Micromegas+ THGEM) Photon Detector prototype has been designed and built. This WP has seen impressive progress within all tasks during this second reporting period. The limited access to laboratories due to COVID-19 has delayed the experimental activities, and a mitigation plan has been applied to minimize the impact. The WP had a small deviation within task 4 (study of multi-channels 10x10cm² prototypes), due to technical difficulties as well as lack of manpower. This situation has caused a delay, the prototype designs are still not finalized, and the production would not begin before summer 2022. This should not however be a problem thanks to the extension of STRONG-2020. The deliverable D32.1 is on time, as well as all the milestones (MS80, MS81, MS82).
JRA - Tracking and Ions Identifications with Minimal Material budget (TIIMM) Development of new silicon detectors based on Monolithic Active Pixel Sensors (MAPS) for high-precision tracking, and energy loss measurement	Four different designs of the second prototype (TIIMM-1) stemmed from the tests of the first prototype (TIIMM-0). These designs were completed in November 2021 and submitted for fabrication in January 2022. The fabrication at the silicon foundry is going well and the sensors are expected to be delivered in June 2022, corresponding to a 3 months delay with respect to the initial schedule. TIIMM-0 was tested in laboratory without particle beam. Its control functionalities were validated and the performance of the front-end electronics investigated. The detector data acquisition system is being

for advanced particle identification.	developed: the testing board has been submitted for manufacturing, while the firmware and data acquisition software are under development. An electronic board to interface the acquisition system based on the Terasic ADC-SoC type daq cards, and the electronic boards on which the four different types of sensors will be bonded have been designed. Delays due to COVID-19 will be managed within the project.
JRA - Advanced ultra-fast solid STate detectors for high precision RAdiation spectroscopy (ASTRA) Development of beyond state-of-art radiation detectors based on semiconductors able to perform high-precision measurements of X-ray and gamma-ray photons in different environments and conditions.	A first detector prototype made of CdZnTe has been built on the basis of simulations. The read-out system for both the low-energy (10-100 keV) and high-energy (10 keV-MeVs) prototype were developed (deliverable D26.1 and D26.3), and the detectors were tested at SMI (milestones MS57 and MS59). Long-term stability tests as well as studies of the temperature dependence of the energy resolution are ongoing. A specific design of both low- and high-energy detector setup to be installed at DAFNE is being developed to perform first test measurements under beam condition and to study kaonic atoms. COVID-19 has caused a 2 months delay in some tasks, which will be compensated by the end of the project.
JRA - Cryogenic Polarized Target Applications (CryPTA) Production of polarized nucleon targets (at the prototype level) using solid state materials combined with superconducting high-field magnets and the Dynamic Nuclear Polarization method.	In 2021, the dilution cryostat was designed and built by our Russian collaboration partners for future measurements of double polarization observables at the ELSA accelerator facility in Bonn. In 2022, a new "internal holding coil" has been designed for the new dilution cryostat. They developed a concept for a holding coil, in which a solenoid is coupled with a dipole coil (Milestone MS64). The two racetracks of the dipole field are produced like our solenoids in a wet winding technique. However, initial test developments showed an unacceptable, inhomogeneous adhesive distribution on the insides of the racetracks. With an improved winding device (winding core and wire guide), a more uniform adhesive distribution in the coil package is to be achieved. An optimized winding core has been designed to achieve a more uniform adhesive distribution in the coil package, which will be applied to produce a satisfactory test magnet this year. All magnets developed and already built as part of the CryPTA project were intended for installation and use in new dilution refrigerator. The cryostat was built by the "Cryogenic Department of JINR (Dubna)" and has already been

	delivered in parts. However, due to the current political developments and the resulting measures, the further construction and commissioning of the device has been postponed indefinitely. In order to test the coils already built, we are rapidly advancing the construction of a new 4He evaporation refrigerator for systematic test measurements. The shielding behavior of the high-temperature superconductors in a cylindrical geometry was investigated, and the milestone MS65 was reached. New ideas and concepts for a second improved version of the polarized active target insert have been developed and reported. The current European political situation has forced the group to produce some mechanical part locally. Due to the involvement and strong constraints in other projects (FAIR phase 0 commissioning), the consortium member "HIM JGU-Mainz" has left this JRA.
JRA - Cryogenically cooled particle streams from nano- to micrometer-size for internal targets at accelerators (CRYOJET) Development of cryogenically-cooled cluster/pellet/microjet sources to be used as targets in a variety of collision setups (storage ring experiments, electron accelerators, or laser-driven hadron accelerators).	Significant advances have been made in the production technique for monolithic copper cluster nozzles, which could be manufactured industrially for the first time with the full-required nozzle length. The formation of hydrogen and argon cluster beams was investigated and highest hydrogen cluster target thicknesses are regularly available. Numerical simulations on the cluster evaporation in vacuum have been developed and compared with data from experiment, leading to a good understanding of the vacuum situation for experiments using cluster/pellet target beams. Shadowgraphy measurements of hydrogen clusters have been performed, which allowed to determine the maximum size of clusters at different stagnation conditions, which is relevant for future hadron physic experiments as well as for laser-cluster interactions. New diagnostic tools for the investigation of droplet beam properties have been developed. The bench test setup for the real-time pellet tracking system has been extended so that it can be used with a complete measurement level of up to four detection modules (DMs) and a dummy target. COVID-related delay has caused the realization of one risk. The mitigation plan has been applied, but a task has to be modified.

JRA - Spin for FAIR (SPINFORFAIR) Optimization of the polarization of protons and antiprotons beams and targets for the GSI/FAIR storage ring	Some progress has been made in understanding the complex beam dynamics due to the presence of a high magnetic field, thus the snake field. At the time of the first Siberian Snake commissioning, this model did not include the necessary coupled optics, and further developments have been done to be ready for the next commissioning. The possibility of installing skewed quadrupole magnets in the COSY beam line, in order to compensate the tune shift caused by the solenoidal field, is also being investigated. After the first detector commissioning with two installed quadrants, which resulted in the first target polarization measurement, 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. Preliminary analysis results have been produced (task 2). The final detector commissioning, as well as the beam polarization measurement, will follow the final Siberian Snake commissioning, taking into account the beam availability at the COSY facility. A risk has materialized (The performance of the longitudinal spin-filtering test is conditional to the commissioning of the Siberian snake in COSY), but the group has managed the risk migration very well, and has studied the issue in detail. The COVID-19 emergency, coupled with the severe budget restrictions imposed by the FZJ management, has affected the COSY schedule, not allowing at the moment to make any predictions about the possible implementation of the experiment in the storage ring. This will have repercussions on the plan for the longitudinal spin-filtering test (MS74). Additional delays due to COVID-19 will be absorbed within the project extension.
JRA - Polarized Electrons, Positrons and Polarimetry (P3E) Optimization of high-intensity polarized electron and positron beam sources, and full design of the	Following extensive theoretical studies of positron production and simulations within the Geant4 framework, polarized positron production was fully characterized and optimized for initial electron beam energies of interest at JLab (10 MeV, 100 MeV, 1000 MeV). A first conceptual design of the positron source was elaborated and implemented into the General Particle Tracer (GPT) framework. The challenge of the positron

Hydro-Møller polarimeter detector using high-voltage monolithic active pixel sensors (HV-MAPS).	production target has been investigated using ANSYS simulations to evaluate the reliability of a design based on a rotating target. The Hydro-Møller simulation is being used to optimize the magnetic chicane and the detector setup in order to achieve a suitably high signal-to-background ratio for the detection of Møller electron pairs. The latest version of the MuPix HV-MAPS pixel sensor, MuPix11 has been submitted to the foundry and is expected back in summer 2022, allowing for beam tests at MAMI in autumn. Delays due to COVID-19 (personnel hiring and experimental activities) will be managed within the project extension.