Project[1] Number: 734303

Project Acronym: NEWS

Project title: New WindowS on the universe and technological advancements from trilateral EU-US-Japan collaboration.

Periodic Technical Report

Part B

Period covered by the report: from [01/07/2017] to [30/06/2019]

Periodic report: 1st

[1] The term 'project' used in this template equates to an 'action' in certain other Horizon 2020 documentation

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

NEWS coordinates the research activity of about 100 researchers from 13 European Research Institutions (INFN (IT), HZDR (DE), Polytechnic of Milano (IT), University of Genova (IT), University of Pisa (IT), University of Stockholm (SE), Royal Institute of Technology in Stockholm (SE), CNRS (FR), University of Perugia (IT), University of Rome La Sapienza (IT), European Gravitational Observatory (IT), University of Napoli Federico II (IT), Dalarna University (SE)), 3 small enterprises (Prisma Electronics (GR), Clever Operation (FR), Impex HigTech (DE)), which participate in experimental research initiatives in collaboration with 15 research Institutions in US, Japan, Russia and Hong Kong (NINS-NAOJ (JP), NASA (US), FNAL (US), Stanford University (US), Caltech (US), ICRR (JP), University of Missouri (US), MIT (US), Iowa State University (US), Hiroshima University (JP) Texas A&M (US), Hong Kong University (HK), Tomsk Polytechnic University (RF), JLAB (US)) and 1 enterprise (Faraday Technology (US)). Most of the research activity and researchers are part of large international collaborations involved in the gravitational wave search and study (Virgo, Ligo and Kagra), astroparticle (Fermi-LAT), astrophysics (IXPE), particle physics experiments and particle accelerators developments at the FNAL Muon Campus (Muon (g-2) and Mu2e). NEWS promotes international and inter-sectorial collaborations by means of secondments of personnel to enhance the European contribution to the mentioned international collaborations. The duration of the project is four years (July 1, 2017 – June 30, 2021), which will allow the European Research Institutions to take leading roles in these international collaborations.

In the field of gravitational waves (WP2 and WP3), NEWS researchers participate in the Virgo, LIGO and KAGRA Collaborations. They have built the largest gravitational wave observatories in the world in US and Italy and are providing leading contribution also to the development of the KAGRA observatory in Japan. The recent first observation of gravitational waves has inaugurated the era of gravitational wave astronomy. By exploiting the km-long laser interferometers located thousands of kilometre apart, LIGO and Virgo and the future KAGRA exploit the physical properties of light and space-time itself to detect gravitational waves and probe their astrophysical properties. NEWS researches participate in the Large Area Telescope Collaboration (WP4), which built and now operates the principal scientific instrument on the Fermi Gamma Ray Space Telescope spacecraft launched in the year 2008. The LAT is a high-energy gamma-ray telescope and has recorded more than one billion photons uniformly and continuously over the whole sky and released the most complete catalogue of more than three thousand sources. The observations of Fermi are fundamental to pursue a multi-messenger study of the cosmos that combines photons with other “messengers” like cosmic rays, neutrinos and gravitational waves. This strategy in astronomical searches will soon be enriched by X-ray polarization measurements (WP5): a new generation of space-borne telescopes based on a new class of detectors is being developed by the NEWS researchers within the IXPE Collaboration for a NASA mission planned for the year 2021. In the next few years the FNAL Muon Campus (WP6) will provide the most intense pulsed muon-beams, which are among the cleanest probes when searching for new phenomena beyond the Standard Model of fundamental interactions. NEWS researchers participate in the Muon (g-2) and Mu2e Collaborations. The goal of the Muon (g-2) experiment is to solve the puzzle originated by the existing 3 standard deviations discrepancy between the value of the muon anomaly predicted in the Standard Model and the measurement performed by the E-821 Collaboration at Brookhaven. Muon (g-2) aims for a precision of 0.14 parts per million on the muon anomaly, which corresponds to a factor of 4 improvement with respect to the Brookhaven measurement to provide a 5 deviations discrepancy from the existing theoretical prediction if the experimental measurement of the muon anomaly remains unchanged. Mu2e will search for the Charged Lepton Flavour Violating neutrinoless, coherent muon conversion to an electron in the field of a nucleus, with four orders of magnitude improved sensitivity with respect to previous experiments. The observation of this process would be an unambiguous evidence of new physics beyond the Standard Model. In order to perform particle physics experiments, advanced superconducting technologies for particle accelerators are developed (WP7). FNAL is world-leader in the design of high-field magnets and RF cavities for future accelerators, with tight collaborations with Research Institutions and industries in Europe and US. Superconducting technologies have wide applications also in the field of particle detectors (WP8), and NEWS researchers are developing bolometers and micro-calorimeters used in cosmology, astrophysics and particle physics experimental searches.

Dissemination and Outreach (WP9), Transfer of Knowledge, networking, training of involved personnel (WP10) are also fundamental with a lot of effort dedicated by NEWS researchers to these initiatives. This has generated an intense transfer of knowledge among participants and visibility of the project towards the scientific community and the general public. Overall, NEWS is progressing as planned, with almost all tasks progressing as expected and the planned deliverables and milestones completed in time.

1.1 Objectives

NEWS promotes and reinforces the collaboration between European, American and Japanese research institutions involved in some of the most important research projects in fundamental physics. In the last few years NEWS researchers have given leading contributions to the development of cutting-edge physics experiments capable of opening news windows in the exploration of the universe and the study of particle physics. They are now involved in the data analysis of these experiments, as well as in new experimental challenges which require substantial technological advancements.
LIGO and Virgo collaborations have built the largest gravitational wave observatories to detect gravitational waves and probe their sources. The first observation of a signal from a merging black hole system has inaugurated the era of gravitational wave astronomy. NEWS objectives in this field include the study of gravitational wave events, and the accurate localization of the gravitational wave sources that is necessary to perform the study of potential gamma-ray counterparts (multi-messenger approach), and the design of the future third generation gravitational wave detectors. Several crucial aspects connected to second and third generation gravitational wave detectors will be studied: seismic noise attenuation in a cryogenic environment, quantum noise reduction using squeezed states of light, thermal noise reduction using silica and sapphire fibres, and development of advanced control techniques to perform the subtraction of gravity gradient noise.
The Large area Telescope collaboration operates a gamma-ray telescope on-board the Fermi Gamma Ray Space Telescope mission and has revolutionized our view of the gamma-ray universe, by increasing the number of known sources, unveiling new classes of gamma-ray emitters, and probing particle acceleration and electromagnetic emission in space with unprecedented detail. Fermi is also the reference all-sky gamma-ray monitor for the follow-up searches for electromagnetic counterparts of gravitational wave source. NEWS objectives include the publication of the 4th catalogue of stationary gamma ray emitters as measured in Fermi data, as well as the publication of the 2nd catalogue of gamma ray transients (gamma ray bursts) that are also interesting as electromagnetic follow-up of gravitational wave events, and the definition of the Fermi legacy archive. The multi-messenger astronomical observations will soon be enriched by X-ray polarization measurements. The new NASA mission IXPE (Imaging X-Ray Polarimeter Explorer), developed by NEWS researchers, will

measure the polarization of X-rays form cosmic sources and probe the laws of physics in the condition of extreme gravitational and electromagnetic fields. NEWS objectives are to deliver a fully functional space-grade set of Gas Pixel Detectors and associated data acquisition system for the IXPE mission, and to define and implement the necessary science analysis tools.
A complementary approach to probe the Universe on is also provided by particle accelerators built and operated in earth-based laboratories. FNAL provides the cleanest probes to search for physics beyond the Standard Model of particle physics. The Muon (g-2) experiment measures the muon anomalous magnetic moment with unprecedented precision. NEWS objective is to contribute to the Muon (g-2) data taking and analysis to solve the existing discrepancy between the value predicted in the Standard Model and the measurement performed by the E-821 Collaboration at Brookhaven. Mu2e will search for the neutrino-less coherent muon conversion to an electron in the field of an aluminium nucleus that would be the unambiguous evidence of new, unknown physics. NEWS objectives include the construction of the Mu2e electromagnetic calorimeter and the development of the Mu2e simulation and computing infrastructure. This laboratory approach requires the development of advanced superconducting technologies for high-field magnets employed in particle accelerators. NEWS objective is to contribute to the international effort led by FNAL and CERN to design 16-tesla superconducting magnets for future accelerators. Superconducting technologies can also be exploited to develop detectors, for example transition-edge sensors (TES) that are cryogenic particle detectors that exploit temperature-dependent resistance of the superconducting phase transition. NEWS objective in this field is to contribute to the study of new superconducting materials.

1.2 Explanation of the work carried per Work Package.

WP1 "Ethics Requirements": The ethics cleared.

WP2 "Gravitational Wave (GW) Physics". Lead Beneficiary: INFN; Coordinators: M. Razzano (UNIPI), E. Majorana (INFN), N. Robertson (CALTECH).

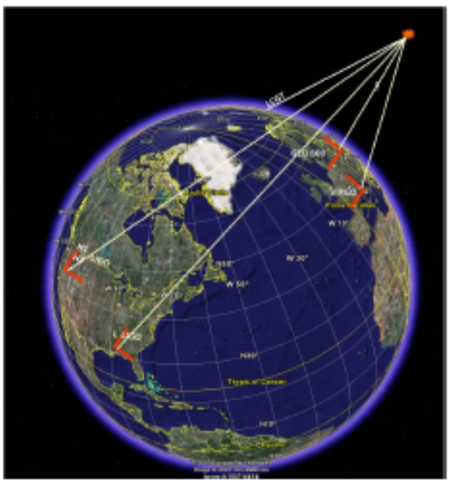
The first detection of gravitational waves (GW), made in September 2015 by the LIGO and Virgo collaborations, has opened a new way to study the cosmos. In particular, thanks to GW we can probe astrophysical sources that do not emit electromagnetic radiation, such as black holes. In fact, the first signals detected by LIGO and Virgo were produced by the coalescence of two black holes, i.e. their spiralling and subsequent merger into a single black hole. In summer 2017, Virgo has joined the LIGO detectors network in the second observation run (O2) and the Era of GW physics based on multi-detector signal localization was started. O2 has provided extraordinary achievements. These include the triple black hole coalescence observation and the multi-messenger star coalescence observation (GW170817) through the direct detection of a GW signal and the detection of the electromagnetic counterparts. Three researchers of the LIGO-Virgo collaboration have been awarded the 2017 Nobel Prize in Physics for the first observation of gravitational waves. WP2 activities are focused on extracting the maximum amount of physics results from the GW data alone and in combination with electromagnetic observations (EM), in a fully multi-messenger perspective. Furthermore, WP2 is also dedicated to exploring the science cases and international network for the third generation of GW detectors that are planned for starting observations during the 2020's. In the following we report on the status of WP2 activities related to the secondments done so far.

The birth of gravitational wave astrophysics. The first detection of GW has been possible because the LIGO and Virgo detectors are now in their *advanced* stage, i.e. they have been entirely upgraded in order to reach a sensitivity of ten times that of the previous generation. This means they can probe a volume a thousand of times larger, thus increasing the number of accessible sources by the same factor. LIGO started its first observation run (O1) in 2015, and Virgo started operations in August 2017, joining LIGO in a single international network of GW detectors. During this second observing run (O2), LIGO and Virgo detected a new signal on August 17 (GW170817), the first one produced by the coalescence of two neutron stars. This event also produced an electromagnetic (EM) emission that was observed first at the high energies by the Fermi and INTEGRAL missions, and later by the ground-based observatories in the optical and infrared range. A later emission was also detected at X rays and radio bands. This event marked a new era of multi-messenger observations, where the EM and GW observations are combined to get a complementary and more detailed perspective on astronomical sources.

Figure 2.1: (Left) Multi-messenger approach for the electromagnetic follow-up of Gravitational Wave detection; (Right) Gravitational wave and electromagnetic emission of GW170817 as observed by Fermi-LAT and INTEGRAL missions.

O2.1: Establish a network for the search of electromagnetic counterpart to gravitational waves. One or the main objectives of the WP2 is focused on building a network for searches of EM counterparts from GW sources. We are now working in two main directions related to the improvement of GW detection techniques and to the study of joint scenarios of GW and EM detections, that continue a series of works that we have already done (e.g. Patricelli, Razzano, et al, 2016).

Status: on track no major delays



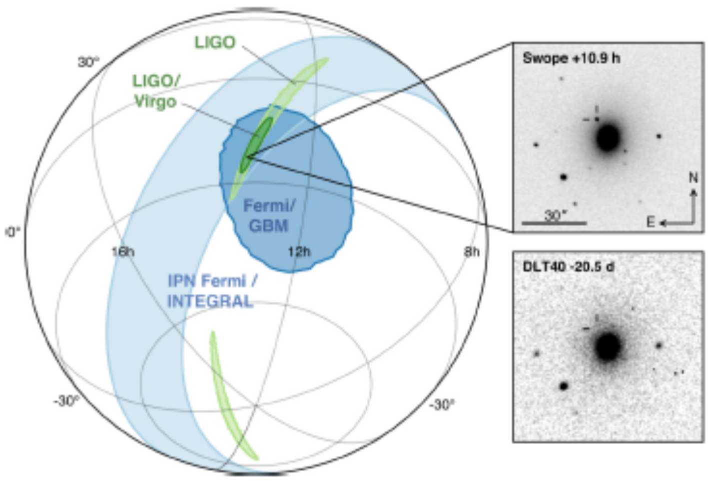


Figure 2.2: (Left) Gravitational wave localization using a network of detectors; (Right) Localization of gravitational waves, gamma rays and optical calculated for the event GW170817.

O2.2: Reduce the localization latency and increase the localization accuracy of GW events. A key aspect of multi-messenger observations is to provide a quick alert every time LIGO and Virgo detect a GW signal. These alerts are distributed to the astronomical communities and contain the parameters of the GW sources, including the best estimate of the localization (Figure 2.1 and 2.2). Improving this localization will thus be crucial to support the low-latency production of GW alerts. LIGO and Virgo are investing lots of effort to develop localization code that can be used to provide precise and fast localization region in a low-latency regime. This effort is becoming more and more important since with the improvement in sensitivity also the number of events has significantly increased. Recently, the LIGO and Virgo have published the GWTC-1, the first catalogue of GW events detected during O1 and O2 that includes ten binary black hole events and one binary neutron star merger (GW170817). Furthermore, LIGO and Virgo are moving toward the release of gravitational wave data through the Gravitational Wave Open Science Centre (https://www.gw-openscience.org).
In order to improve the localization, a detailed knowledge of the detectors and of their background noise is fundamental. Therefore, INFN and UNIPI secondments are focused on the detector characterization. Due to the commissioning of Virgo for O3, part of this work has been necessarily developed at the Virgo site in Pisa (Italy), but with the start of O2 (April 2019), Virgo researchers are now more focused on data taking and a data analysis in collaboration with LIGO. This collaboration will be strengthened by the secondments at US Partners. INFN and UNIPI are developing detector characterization work focused on non-transient noise in collaboration with CALTECH, and with transient noise in collaboration with the University of Missouri to study how noise reduction based on advanced techniques can impact the localization accuracy. Since the University of Missouri has been included as a new Partner only recently, secondments from UNIPI to the University of Missouri were started only in July 2019.
We have achieved deliverable D2.2 "Gravitational Wave Event Localization Code" in due time in June 2019 (M24), more details are included in the associated Report.
Status: slight delay and on track for RP2

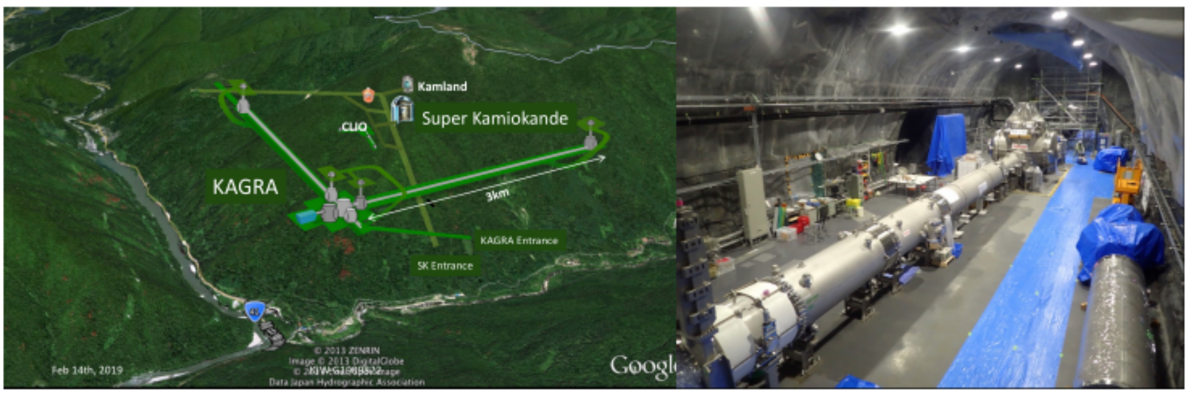


Figure 2.3: (Left) Location of the new Gravitational Wave interferometer KAGRA in Japan; (Right) View of the KAGRA tunnel.

O2.3: Develop a collaboration network for third generation detectors. EU official collaboration with KAGRA (Figure 2.3) had started several years ago in the context of FP6 with the ET project, delivering the first conceptual design of a 3rd Generation (3G) detector in 2011 (Einstein Telescope) and was pursued with EU ELiTES FP7 M. Curie Grant no. 295153. In that context a strong impulse to the implementation of KAGRA was provided, since such a detector is worldwide intended as the necessary step towards 3G detectors and, specifically towards ET, being characterized by cryogenic test masses and underground installation. Given the timescale of 15 years needed to finalize and operate 2G detectors, the 3G scenario, whose site and configuration will be reasonably decided by 2022, is such that, a long observation term will be spent using 2G detectors (in their Advanced+ configuration), in parallel to one or two 3G detectors under development and with low sensitivity. The first step is to accomplish two lines of the following roadmap:

- Assess the advantage of using cryogenics;
- Assess the advantage of using VIRGO like seismic isolation system in the underground.

Both the items above pass through a tight collaboration with KAGRA in Japan. Note that skipping the short test at the end of the last Observational Run O3, during which the presence of the fourth detector will serve to prepare the coincidence pipelines, two stages can be foreseen:

- Long runs O4 and O5 with two LIGO, VIRGO and KAGRA, namely with 4 or 5 detectors, provided the plan to construct LIGO-India;
- Beyond 2025, towards 3G.

Clearly, the role played by KAGRA is crucial, as a bridge whose path is directed both to the next future, the GW network, and the long-term future, 3G. In principle, by combining four or more detectors, the sky locus of constant time delay is a unique intersection in the sky produced by the intersection of the annuli obtained by each pair of detectors (S. Chatterji, et al. Coherent network analysis technique for discriminating gravitational-wave bursts from instrumental noise *Phys Rev D* 74:082005, 2006). In this context KAGRA Face-to-Face meetings and KAGRA workshops have been attended to delineate a common development of the detectors. Not only WP3 was the object of the meetings but also WP2, as the features of the upgrades under study (Y. Michimura et al., Particle swarm optimization of the sensitivity of a cryogenic gravitational wave detector *Phys. Rev.* **D** 97, 122003 2018) strongly depend on the science case/configuration aimed by KAGRA in the panel of four-partner network. Indeed, the coordinated timeline of the network operation, due to the very different state of implementation of the five detectors (including LIGO India), might force the Japanese collaboration to make relevant choices. Without further developments, cryogenic test-mass payloads might result more easily adaptable to high power configuration (high frequency) than to low frequency performance, as it could seem at a first glance. The same situation is about to appear concerning 3D. Different past developments, different technical features and quite different administration environments have brought to significantly different devices as Cosmic Explorer and Einstein Telescope. Remarkably, those 3G detectors claim high sensitivity at low frequency, for which KAGRA experience would be crucial. Hence in 2018, the network deal including KAGRA has been strongly conditioned by the upgrades to be scheduled in the immediate future in a LIGO, AdVirgo+ and especially for KAGRA+ (E. Majorana, Senior INFN researcher, was involved in those activities).

Further activity has been dedicated to study some fundamental aspects related to GW observation and polarization models. The adoption of a 5-vector formalism, developed by the Virgo collaboration and well assessed in the context of current pipelines to analyze continuous wave sources, has motivated an increased collaboration with CALTECH (M. ISI,

A. Weinstein, G. Intini), which constitutes a seed towards a future fruitful scientific production.
Status: on track no major delays

O2.4: Collaborate with LIGO on digital preservation of GW data. The data samples produced by LIGO and Virgo are made public and released to the community. Secondments have also been devoted to include Virgo in this data access that before these actions was guaranteed only through the LIGO Open Science Center (LOSC). During 2018, we have worked to a full upgrade of the site, that also integrates Virgo data, and that is now publicly available as Gravitational Wave Open Science Center (GWOSC), accessible at www.gw-astronomy.org. This upgrade is the first of many actions focused at improving the website access. Among the future actions is a full revision of the underlying database of the dataset and a full translation of the website in various languages, in order to spread even more the access to these data.

New Partners inserted with the Amendment of Grant Agreement AMD-734303-75.
University of Missouri (US). INFN, UNIPI and the University of Missouri are collaborating to develop innovative data analysis techniques based on machine learning applied to detector characterization to improve detector sensitivity and boosting the capability of low-latency gravitational wave detection and localization. Secondments from UNIPI have started in 2019.
Massachusetts Institute of Technology (US). INFN, UNIPI, CNRS and MIT are collaborating to develop new methods for the multi-messenger inference of the properties of gravitational wave events and on the study of the third generation interferometric gravitational wave detectors. MIT is also involved in tests of gravity, data analysis for ring-down of balck holes and high-accuracy parameter estmate. Secondments will start in late 2019 and early 2020.
University of Hong Kong (HK). INFN, UNIPI and the University of Hong Kong are developing a collaboration in the context of multi-messenger analysis of cosmic sources and the design of third generation of gravitational wave detectors. Secondments will start in late 2019 and early 2020.

We expect to achieve the future deliverable D2.1 “Roadmap for third generation detectors” (M36) and milestones in due time.

Status: on track no major delays

WP3 “Gravitational Wave Detectors”. Lead Beneficiary: UNIPG; Coordinators: H. Vocca (UNIPG), E. Calloni (UNINA).

WP3 is dedicated to the development of experimental techniques for the 2nd and 3rdgeneration gravitational-wave detectors. Work is in progress to study new cryogenic detectors, requiring specific solutions to extract the heat transferred by the laser beam to the mirrors; improved techniques to subtract the noise due to local gravity gradients, which require networks of seismic sensors to monitor the environment; quantum noise reduction using squeezed states of light; new silicon and sapphire fibers to reduce thermal noise; new control techniques of the interferometer, as well as more advanced off-line noise cancellation algorithms to be implemented in the software. The collaboration of the EU Institutions is with CALTECH in the US, NAOJ and ICRR in Japan. Although the upgrades of the existing interferometers (VIRGO in Italy, LIGO in US and KAGRA in Japan) towards the third observation run (O3), started on April 1, 2019, required an intense participation of the personnel, the secondments for WP3 started in summer 2017 from UNIPG, UNINA, CNRS, EGO, INFN and UNIPI to CALTECH, NAOJ and ICRR and increased rapidly in 2018 on the above mentioned R&D activities. As the commissioning activity for the O3 preparation has ramped down and the O3 run started, the R&D activities and secondments are further ramping up.

The main Objectives and related activities of WP3 are the following:

O3.1: Test the frequency dependent squeezing on a full-scale prototype, before using this technique in the Advanced detectors.

The context: The design sensitivity of 2G gravitational-wave detectors is limited in a large fraction of the spectrum by the quantum nature of the light used for the measurement. The use of squeezed vacuum states, where the squeezing ellipse angle depends on the frequency (*frequency dependent squeezing*) is a promising technique to achieve a broadband quantum noise reduction. Such frequency dependence of the squeezing angle can be achieved by reflecting a frequency-independent squeezed state by a high finesse detuned cavity, known as *filter cavity*. The implementation of ~100 m scale filter cavities is planned in the near-term Virgo, LIGO and KAGRA upgrades.

The project: We are developing a 300 m prototype quantum filter cavity (the longest under construction) using the TAMA facility at the National Astronomical Observatory of Japan. This full-scale prototype aims to demonstrate for the first time a squeezing ellipse rotation at a frequency below 100 Hz, as required to obtain an optimal quantum noise reduction in Virgo, LIGO and KAGRA. The experiment is composed of two main parts: the frequency independent vacuum squeezed source and the filter cavity (Figure 3.1).

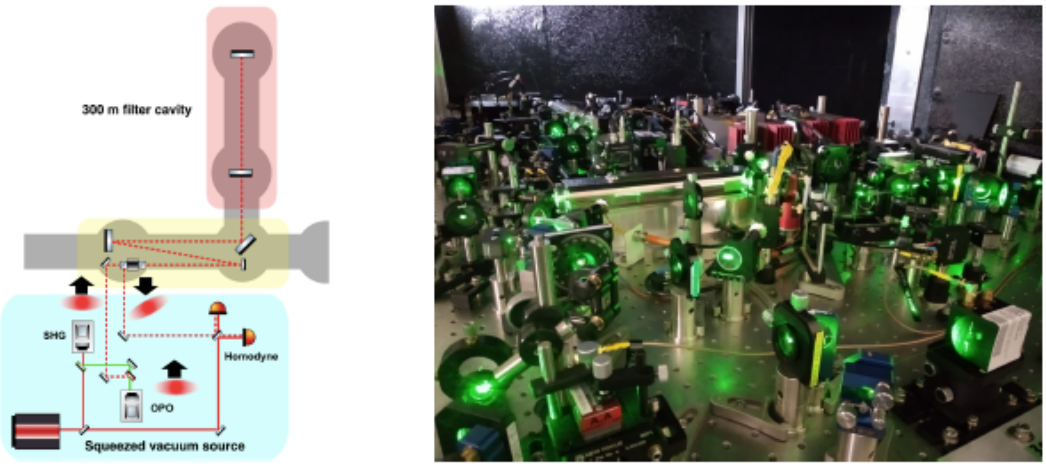


Figure 3.1: (Left) Schematic representation of the developed prototype; (Right) View of the optical bench.

Status of the squeezed vacuum source: the integration of the squeezing bench has been completed at the end of 2018. The main components are a second harmonic generator (SHG) that produces the green pump beam to feed the optical parametric oscillator (OPO), which produces the squeezed vacuum. A homodyne detector is also installed to characterize the squeezing. In February 2019, a first squeezing measurement has been performed. Currently a 5 dB of squeezing starting from few tens of Hz have been obtained. The squeezing source is now being further upgraded and stabilized in view of the injection in the filter cavity.

Status of the filter cavity: it is a 300 m Fabry-Perot cavity composed of two mirrors

suspended with a double pendulum. The finesse of the cavity has been set to ~4500 in order to obtain the squeezing rotation at the desired frequency. The cavity integration, as well as that of the injection path (also composed by suspended mirrors) has been completed in 2017 and the control of the cavity has been achieved (by using a muti-wavelength technique). A first double feedback acting on both mirrors and laser frequency has been performed, in order to reduce the frequency shifts at low frequency and ease the squeezing injection.
Next steps: The next step, planned for fall 2019, is to inject the squeezing in the cavity, and measure the rotation of the ellipse.

Status: on track no major delays

O3.2: Develop a subtraction scheme for non-stationary gravity gradient noise. The mitigation of terrestrial gravity noise, also known as Newtonian Noise (NN), is one of the foremost challenges to improve low-frequency sensitivity of ground-based gravitational-wave detectors. At frequencies above 1 Hz, it is predicted that gravity noise from seismic surface Rayleigh waves is the dominant contribution to NN in surface detectors, and may still contribute significantly in future underground detectors. Noise cancellation based on a coherent estimate of NN using data from a seismometer array was proposed in the past and we are presently developing both the theory and the deployment parts of the sensors to test the efficiency of sensor array for the noise cancellation. In particular within this Task we have achieved the deliverable D3.2 “Specification for a Tilt-meter” in June 2019 (M24), corresponding to the realization and test of a high sensitivity tilt-meter to complete the sensor array. The tilt-meter has been designed, built, tested and also installed in Virgo to be used within the run O3 started in April 2019. The robustness of the instrument has been proven in a 10-day continuous run, where the tilt-meter has continuously acquired data with no human intervention. The tilt-meter has shown capability of lock recovery after earthquakes maintaining the correct sensitivity. The sensitivity has been proved by posing the tilt-meter on a 6-degree of freedom seismic attenuation platform and the sensitivity proved has been satisfactory of the order of 10^{-11} rad/sqrt(Hz) in the 10-40 Hz measurement band.

Status: on track no major delays

O3.3: Study of silica and sapphire materials for third generation monolithic suspensions. The silica suspensions have demonstrated their capability in achieving the sensitivity to the desired level for O3, but for the third-generation detectors the challenge is to lower the thermal noise of the suspensions even more. For this reason, one possible strategy is to develop cryogenic suspensions using sapphire or silicon as the material for the whole monolithic suspension. The KAGRA experiment, that will probably join LIGO and Virgo during the last period of O3, has already realized and installed sapphire suspensions for its cavity mirrors. The design and realization of these suspensions has been possible with a strong interaction between the LIGO and Virgo groups that developed the silica suspensions in the present detectors. Thanks to the NEWS project few scientists and technicians have been seconded to Japan to share their experience realizing the mechanical components to assemble the sapphire suspension and transferring their know-how on the silicate bonding and on the suspension strategy to build the first prototypes tested in ICRR and KEK and then the real suspensions installed in the KAGRA interferometer.

While the tests on the sapphire suspensions are going on for the possible upgrades of KAGRA in the next years, an intense activity is on-going to develop a first prototype of a silicon monolithic suspension. The possibility to use mirrors and the monolithic components in silicon is a very attractive alternative for the next evolutions of the GW detectors. The use of silicon instead of sapphire has many advantages form the point of view of its production, machining, mechanical properties and in terms of costs. In the ICRR laboratories a strong collaboration is going on to measure the mechanical and thermal properties of silicon mirrors (Figure 3.2) and in the next year a first silicon suspension prototype will be realized and tested both at room and cryogenic temperatures. These tests in Japan, thanks to a number of secondments of UNIPG researchers and technical staff at NINS-NAOJ and ICRR, are strategic because they are one of the most important assets to strongly increase the collaboration between the Japanese community of KAGRA and the Virgo one in view of the European 3G detector "Einstein Telescope" and have been the key to push on the signature of an agreement between KAGRA and ET that has been celebrated during the "KAGRA, Virgo and 3G detectors workshop" in February 2019.

Status: on track no major delays

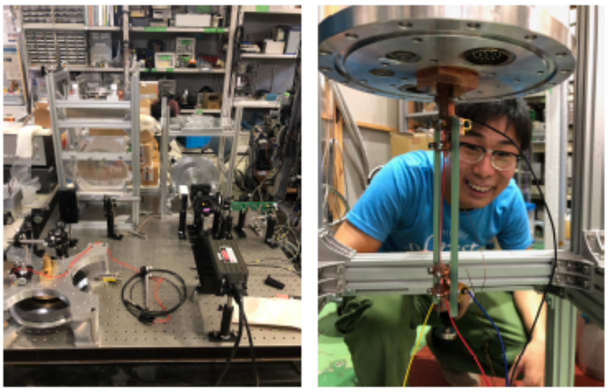


Figure 3.2: (Left) Facilities realised at ICRR by the UNIPG group, to test the mechanical properties of Silicon bulks; (Right) A silicon fiber installed into a cryostat in KEK, in collaboration between ICRR/KEK and UNIPG, to measure silicon thermal properties at cryogenic temperature.

O3.4: Study of payload and seismic suspension systems for cryogenic facilities: the cryogenic environment that it is foreseen for the third generation GW detectors poses specific problems to the attenuation system and to the mirror payload. A significant effort has been dedicated to assist the finalization of an activity that was started in 2014, during the characterization of KAGRA cryostats and the design of the present payloads. Indeed, this is crucial in order to properly exploit the potentiality of a seismically quiet site (underground), provided that the payload is hosted by a very complex mechanical structure whose internal modes are sustained by the residual seism at the underground floor. Upon such a base, KAGRA designed an ancillary suspension dedicated to attenuate the heat link connecting the payload to the test mass has been characterized (at Earthquake Research Inst. Tokyo) and then installed at the site. This implementation, which strongly connects KAGRA experience to ET designing, was pursued by KAGRA in collaboration WP3 (in continuity with the completed EU project ELiTES).

Another KAGRA development theme in the context of NEWS is the great opportunity to design dedicated sensors for payload control to be used in a cryogenic environment. They could be used to better characterize both the cryostat and the suspended payload. Remarkably, and after many scientific exchanges between EC and Japanese scientists, also KAGRA uses Optical Levers, although still under optimization. The overall perspective of testing in an real underground site hosting an interferometer, very low noise sensors, is very exciting at any level in the context of NEWS: to damp seismic suspension system, to control the payload, to inspect cryostat dynamics, and, finally, to study residual environmental noise, so relevant for both KAGRA (approaching O3) and future 3G detectors. Also, silicon bulks, as test masses, and fibers and strips as suspension elements, have started to be investigated and will be tested in the near future, before the completion of the final milestone foreseen for the next 12 months.

Status: on track no major delays

O3.5: Implementation of advanced control techniques for second and third generation gravitational wave detectors. Although at 10 Hz (bottom of the detection bandwidth), the seismic noise in underground sites is two orders of magnitude smaller than on the surface, between 150 mHz and 2 Hz the resonant modes of the isolation stages are sustained (recently verified with KAGRA), hence active control has to be used to damp the suspension chain. Concerning mirror control, the standard practice applied in every interferometer is the hierarchical control, usually meant to minimize the reinjection of control noise close to test masses. The controllers are designed according to Nyquist-like techniques. Since the beginning, Virgo adopted static sensor-actuator diagonalization, in order to obtain a set of single-input single-output (SISO) systems [44]. Later, in Advanced Virgo, also a multivariable design approach, based on optimal predictive regulators, was partially applied. This new approach has the advantage of being a user-independent and completely automatic design process, with the possibility to optimize the feedback performance for both the mixed and diagonal term elements of the sensor/actuator transfer function matrix. Such a technique will be further developed.

A remarkable difference between ground-based and underground installations concerning seismic suspension, and overall control strategies, should be outlined. While on the surface, local/global recombination is needed to circumvent environmental noise contamination on control sensors, as done in Virgo with the Inverted-Pendulum-Global-Control (P. Ruggi), in the underground the main issue is the intrinsic electronic noise (readout) of sensors involved in the control. A significant work, compliant with KAGRA needs can be developed in the framework of NEWS.

We have achieved deliverable D3.2 “Specification for a Tiltmeter” in due time (M24) and we expect to achieve the future deliverable D3.1 “Design of cryogenic seismic filter” (M36) and milestones in due time.

Status: on track no major delays

WP4 “Fermi-LAT Data Analysis”. Lead Beneficiary: INFN; Coordinators: S. Cutini (INFN), M. Pesce-Rollins (INFN), S. Digel (STANFORD).

The Large Area Telescope (LAT) is the principal scientific instrument on the Fermi Gamma Ray Space Telescope spacecraft (Figure 4.1). The Fermi spacecraft was launched into a near-earth orbit on 11 June 2008. The LAT is an imaging high-energy gamma-ray telescope covering the energy range from about 20 MeV to more than 300 GeV. The LAT's field of view covers about 20% of the sky at any time, and it scans continuously, covering the whole sky every three hours. The Work Package 4 (WP4) is dedicated to the Fermi-LAT data analysis, in particular the development of the 4th Fermi LAT gamma-ray source catalogue, searches of ElectroMagnetic (EM) counterparts to Gravitational Waves, dark matter searches and to define and implement a legacy data archive of the Fermi mission. The general scientific progress for the deliverables of the WP4 over the first two years of NEWS has been successful and also thanks to the secondments much work has been completed. Secondments are proceeding smoothly since summer 2018 from OCK, KTH and INFN to STANFORD, ICRR, and TEXAS A&M.

Status: on track no major delays

Figure 4.1: (Left and centre) The Fermi satellite before being launched; (Right) Launch of the Fermi satellite.

O4.1: Compile the 4th FERMI-LAT gamma-ray source catalogue.
INFN and KTH secondments to STANFORD. INFN researchers have worked on refining the software tools to analyse the 96-month dataset and publish the 4FGL catalogue. After 8 years of operations, and three catalogues published with 1, 2, and 4 years of data respectively, NEWS researchers have contributed to develop the most complete catalogue of stationary gamma ray emitters detected by Fermi-LAT. The analysis components have been updated, and the new analysis package, published in June 2018 and indicated as “Pass 8” has been used, with increased acceptance, and angular and energy resolution. The reconstruction algorithms have been revisited for finding source seeds and for cross-matching 4FGL with catalogues at other wavelengths to define source association. More details are reported in D.4.1 “Analysis Package for LAT 4th Catalogue” (June 2019).
Status: on track no major delays

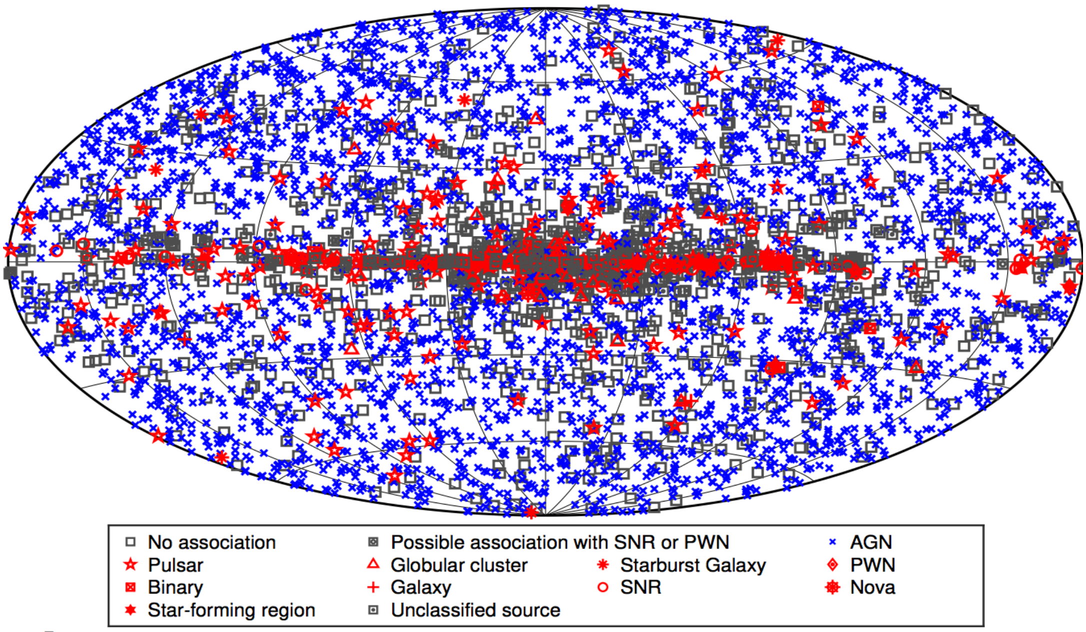


Figure 4.2: Aitoff projection of 4FGL sources as identified in Fermi-LAT data. All AGN classes are plotted with the same blue symbol for simplicity. Other associations to a well-defined class are plotted in red. Un-associated sources and sources associated to counterparts of unknown nature are plotted in black.

O4.4: Establish a network for searches of electromagnetic counterparts to Gravitational Waves. INFN and KTH researchers are contributing also to the development of fast and automated follow-up searches in Fermi gamma-ray data to the gravitational wave triggers. (D4.2), which has become extremely interesting after the first detection of two colliding neutron stars through gravitational waves and light on August 17, 2017. The LAT collaboration has implemented such a pipeline and every time a GW event is detected, the Fermi-LAT collaboration receives an alert that triggers the search of electromagnetic (EM) signals coincident with the GW event. Due to the fact that the EM source resulting from the merging of two neutron stars is a short GRB, the signal in >30 MeV gamma-rays can be fairly weak thus necessitating an in-depth sensitivity study. Thus, the INFN to STANFORD secondments have allowed working on sensitivity studies for the likelihood analysis performed with the LAT pipeline. In particular, estimating the number of trials from Monte Carlo studies of the analysis and the estimate of the sensitivity in order to be able to obtain a better upper limit of the flux in the case of a non-detection during the follow-up searches. The former task has been important because during the follow-up searches the pipeline performs a larger number of analyses over the sky, thus it becomes necessary to know how the number of trials scale with the number of analysis completed in non-independent regions of interest in the sky. Understanding how these two quantities scale allows us to provide a better estimate of the post-trial significance of the detection. The latter study has been also performed via Monte Carlo simulations of a grid of sources in different locations in the sky with varying fluxes therefore allowing to create a HEALPIX map of the source sensitivity. Such a map is imperative in the case of a non-detection during a follow-up search.

Status: on track no major delays

O3.4: Extend real time searches and alerts for gammay-ray transients (Gamma Ray Bursts).

OCK secondments to ICRR. Gamma-ray bursts (GRBs) are linked to the most powerful explosions in the known universe, where large amounts of energy are released as radiation in the MeV and GeV range. However, the mechanisms for producing this high-energy radiation are as yet unknown. Fermi-LAT has made significant advances regarding observational results in this energy range. The work done so far has been focused on the second Fermi-LAT catalogue of GRBs (D4.1). The catalogue is based on a search for high-energy emission (>100 MeV) from almost 4000 triggers made by other instruments. It comprises 186 GRBs, which is the biggest sample to date of GRBs detected in this energy range (Figure 4.3). For each GRB, a standardized analysis is performed, allowing properties such as duration, temporal evolution, spectrum and energetics to be studied. The behaviour of the high-energy emission can then be compared to that at lower energies, as well as used to test theoretical predictions. The work on the second Fermi-LAT GRB catalogue has been completed and the results were published in June 2019.

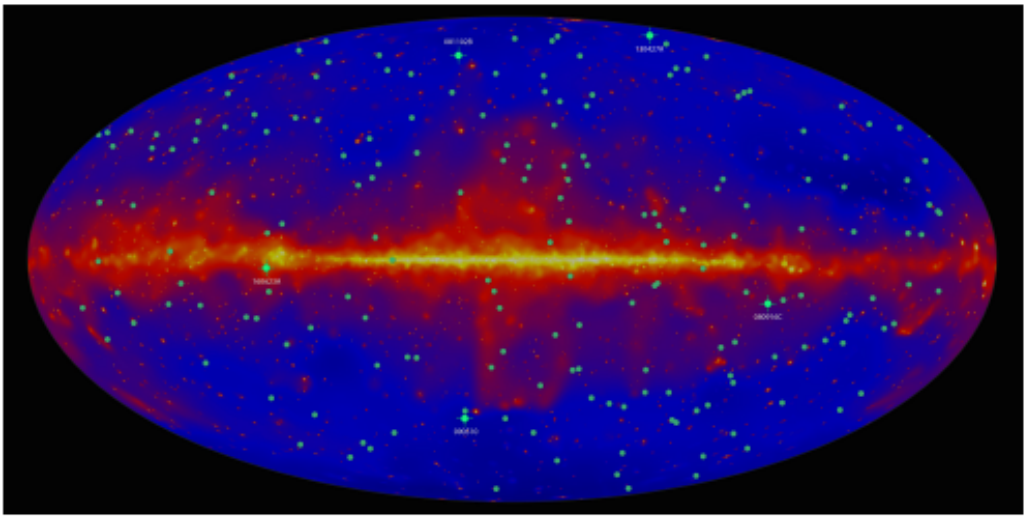


Figure 4.3: Gamma-Ray sky as it appears at energies above 10 billion electron volts. The plane of our Milky Way galaxy runs along the middle of the plot. Brighter colours indicate brighter gamma-ray sources. Green dots show the locations of 186 Gamma-Ray Bursts observed by the Large Area Telescope (LAT) during its first decade.

Already now, it is clear that the results of the analysis are a major step forward from previous studies. Particularly important has been the new Pass 8 event analysis package, which has allowed fainter events to be detected, this giving a more complete sample. Combined with the development of a new detection algorithm, the detection efficiency has improved by over 50% if compared to the first LAT GRB catalogue. This is especially important in the context of searching for counterparts to gravitational wave events, as the detection algorithm used for GRBs forms the basis of the pipeline used for GW follow-up searches (D4.2). The next step will be to develop theoretical models for systematic testing against all GRBs detected by the Fermi-LAT. Traditional approaches have involved applying analysis and models to individual GRBs. While this is still relevant in some cases, the large sample of the second GRB catalogue means that population studies are now possible for the first time. In particular, the number of LAT-detected GRBs with redshift is now over 35, meaning that studies of the energetics directly in the rest-frame of the source can be done. In the second half of the NEWS project, we aim to use the results from the Fermi-LAT GRB catalogue to systematically test emission models. We have also discussed cross-referencing LAT data with other catalogues (such as the Japanese CALET detector), particularly searching for sub-threshold detections. These efforts would tie strongly to the search for electromagnetic counterparts to gravitational wave detections. Finally, discussions have recently begun on how to build a legacy archive for the GRB results, with easily accessible results and standardised analysis provided for every LAT-detected GRB (D4.3).

HOG secondment to STANFORD. The purpose is to work on various aspects of variability in blazars (relativistic jets associated with supermassive black hoes) based on Fermi-LAT data. One of the aims will be to study the rms-flux relation for gamma-ray blazars, which provides the means to distinguish between additive and multiplicative stochastic variability processes. Such analysis has been essential for studies of accretion disks and can be expected to play a similar role in understanding what physical processes leads to the dramatic variability seen in relativistic jets of blazars. In a second project, a study of relations between optical and gamma- ray variability in blazars as seen by TESS and Fermi-LAT will be performed. Both projects will take advantage of recent work to produce the 4th Fermi-LAT source catalogue (4FGL) (D4.1).

Status: on track no major delays

O3.2: Constrain WIMP Dark Matter through indirect searches in gamma rays.

OCK Secondment to TEXAS A&M. Dwarf spheroidal satellite galaxies of the Milky Way are considered ideal targets to search for traces of dark matter annihilation in the nearby Universe. The analysis of the expected signals requires a careful determination of the amount of dark matter within these systems, by calculating the so-called J-factor. This quantity provides a normalisation to the predicted annihilation signal of dark matter and thus has a central role in searches for dark matter with the Fermi-LAT. The goal of the secondment to Texas A&M is to update the search for dark matter in dwarf spheroidal galaxies with the Fermi-LAT. The most important ingredient is the novel determination of the crucial J-factor exploiting novel data and improved modelling as well as data analysis algorithms that we developed. The standard approach for calculating the J-factor of a dwarf galaxy entails analysing the motion of stars inhabiting it. However, the general formula used is typically adopted under some strong assumptions on the kinematic state of the system, such as its internal equilibrium and spherical symmetry. Moreover, the common statistical procedure to estimate J involves fitting the observations with a likelihood. It is customary to adopt a Gaussian for the measured stellar velocity distribution. This approximation does not fully reflect the complex dynamics of stars within dwarf galaxies. An alternative is to instead derive the velocity distribution of the stellar population, starting from a physical model of the dwarf galaxy.

We will exploit newly available data and novel data analysis techniques building a physical model for the velocity distribution of stars orbiting within dwarf satellites galaxies. This quantity can be derived through a careful modelling of these systems and provides a correct definition of the predicted stellar velocities, which is directly comparable with observations. The implementation of this velocity distribution model within a frequentist fitting scheme of the observed stellar kinematics provides a new, physically and statistically consistent approach to quantify the abundance of dark matter in dwarf galaxies. Its application on measured stellar motions resolved in dwarf galaxies of the Milky Way will produce estimates of the J-factor of these systems. This newly determined J-factors will then be used in combination with an analysis of Fermi-LAT data to arrive at novel constraints on (or detection of) the particle properties of dark matter.

New Partners inserted with the Amendment of Grant Agreement AMD-734303-75.
Hiroshima University (JP). Hiroshima University is deeply involved in Fermi-LAT data analysis and in the development of X-ray polarimetry for astrophysical measurements. KTH is collaborating on the study of astrophysical transient sources, such as gamma-ray bursts and the electromagnetic counterpart of gravitational wave events, with a focus on timing/spectral analyses of Fermi-LAT data. In the field of X-ray polarimetry the collaboration is dedicated to the study of the instrumentation for new missions. Secondments will start in late 2019 or early 2020.
Texas A&M University (US). OCK and Texas AM are collaborating on the Fermi-LAT data analysis especially in the study of the nature of dark matter, that is one of the main open questions in astrophysics. Secondments for several months from OCK to Texas AM have started in 2019.

We have achieved deliverable D4.1 "Analysis Package for LAT 4th Catalogue" in due time (M24) and we expect to achieve the future deliverables D4.2 "Automatic pipeline for gamma-ray follow-up of gravitational wave triggers" and D4.3 "Fermi Data Legacy Archive" (M48) and milestones in due time.

Status: on track no major delays

WP5 "X-ray Polarimetry". Lead Beneficiary: UNIPI; Coordinators: L. Baldini (UNIPI), L. Latronico (INFN), B. Ramsey (NASA).

In January 2017, NASA selected the Imaging X-ray Polarimetry Explorer (IXPE) mission proposal based on Gas Pixel Detectors (GPD) coupled to custom CMOS readout ASICs, placed at the focal plane of X-ray grazing optics (Figure 5.1). NASA's decision represents a tremendous success of the, more than ten year long, R&D activity led by the NEWS researchers at INFN and UNIPI. IXPE adoption for the NASA's next Small Explorer Mission implies an acceleration of the work schedule, with an accelerated pace typical of SMEX missions, characterized by a 5 year span from adoption to launch and 2 years of nominal operations.

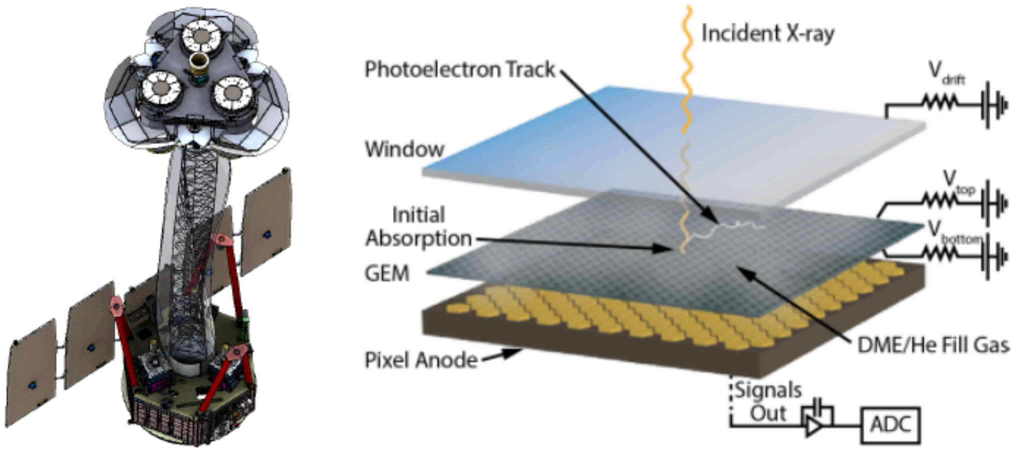


Figure 5.1: (Left) Schematic representation of the satellite employed for the IXPE mission; (Right) Working principle of the Gas Pixel Detector (GPD), the direction of the photoelectron track provides information useful to measure the X-ray polarization.

The Mission Critical Design Review (M-CDR), which is the programmatic milestone signalling the final go/no go for the production of the flight hardware, was successfully held at the Ball Aerospace (Boulder, Colorado) on June 25-27, 2019, and IXPE has now officially entered the qualification and production stage. Shortly after the M-CDR, NASA has selected SpaceX of Hawthorne, California, to provide launch services for the mission, and IXPE is currently targeted to launch in April 2021 on a Falcon 9 rocket from Launch Complex 39A in Florida.
The status of all technical achievements, in terms of Objectives and Deliverables, is now far beyond the expectations from the schedule reported in the original NEWS proposal, as a consequence of the IXPE mission adoption by NASA. Conversely, as the INFN and UNIPI team is highly committed to provide the mission with the necessary Gas Pixel Detectors and their associated services within the IXPE aggressive schedule, secondments to NASA have started in 2018 but have been so far sporadic and limited to short mission-level events, with a well-defined plan to significantly increase travels from the fall 2019 and early 2020 to support the telescope calibrations and prepare for science exploitation.
All WP5 objectives strongly benefit from the boost of activities induced by the IXPE mission adoption, and reflected in the advanced state of the project documentation accumulated to support the Instrument Critical Design Review within the Italian Space Agency, responsible for the delivery of the IXPE mission focal plane to NASA. Particularly: the first two goals of producing flight candidate detectors and electronics have been largely surpassed, as the first flight detector unit has been integrated and qualified, and the other three can also be considered complete, since a first, complete release of all the relevant software packages, that fully supports the mission objectives, was distributed to the IXPE Collaboration and is routinely used to support the mission hardware integration and test as well as the definition of the mission observing profile.
Below is a specific report for each objective.

O5.1 - Build a fully functional lab prototype of a GPD for the focal plane of an X-ray polarimetric: the INFN and UNIPI team completed 6 engineering/qualification models (EM/QM) that were used to support the qualification of the IXPE GPD design for space, along with 8 flight models, covering the full set of detectors necessary for the mission (3 + 1 spare) with large margin. One flight GPD has been already integrated in the proto-flight Detector Unit (DU), which has completed the environmental tests and is now ready to start the calibration campaign; the second flight detector unit is currently being integrated. One GPD EM is being delivered to MSFC for the first combined tests with the EM X-ray optics.
Status: progressing well

O5.2 - Study and design the basic components of a space-grade data acquisition system for the GPD: in collaboration with a high-heritage industrial partner selected through a public tender, the team has designed and produced a full-scale breadboard, 3 engineering models and 4 flight models (covering the entire set for the mission) of the back-end electronics for the detector units. The first flight set has been already integrated in the DU FM1, while the engineering model has been used for the verification of electromagnetic compatibility.
Status: progressing well

O5.3 - Optimize event reconstruction and classification: a stable version of the simulation and reconstruction gpdrecon software package is maintained through a distributed software repository and routinely used by the italian team (and the international Collaboration at large) to perform acceptance and performance studies of the flight GPDs. Updates will be explored, particularly in the area of machine learning techniques applied to improve track reconstruction and measurement of its polarimetric features.
Status: progressing well

O5.4 - Implement an observation-simulation framework for the X-ray polarimetry explorers: a stable version of the high level telescope simulator (ixpeobsim) is maintained through the software repository and routinely used by the international collaboration to perform sensitivity studies of astrophysical source observations
Status: progressing well

O5.5 - Define and implement science analysis tools for the X-ray polarimetry explorers: the data format for all simulated and reconstructed events is now compliant with the HEASARC standards and a science tools package implementing standard astrophysical analyses, e.g. spectral and polarimetric fits and light curves, has been distributed internally to the collaboration. Updates and full documentation support are envisaged future developments.

Similarly, the deliverables and milestone of the project are well advanced, specifically:
D5.1 Design Report of a Space Grade GPD and Associated Data Acquisition System (M36) - delivered with the Instrument CDR documents

- I2C-IAPS-ISE-REP-002 Instrument Design Report
- I2C-OHBI-ISE-REP-007 Detector Unit BEE Electrical Design Report

D5.2 - Simulation and Science Analysis Framework for X-Ray Polarimetry (M48): although a fully functional version is already in production within the IXPE International Collaboration, since improvements are foreseen as the mission progresses, the formal delivery

is set with the most mature software package available at the time of the proposed milestone in the NEWS proposal.
MS6 Gas Pixel Detector Prototype (M24) - achieved, since many GPD detectors have been built and qualified.
INFN and UNIPI researchers have extremely important Collaboration-level responsibilities: Luca Baldini is the Italian Co-PI of the project and convener of the Science Analysis and Simulation Working Group, Luca Latronico is the Detector Unit Project Responsible Scientist, Carmelo Sgro is responsible of the Detector Assembly, Integration and Verification and Test, Alfredo Manfreda is the Coordinator of the Offline Software Group.

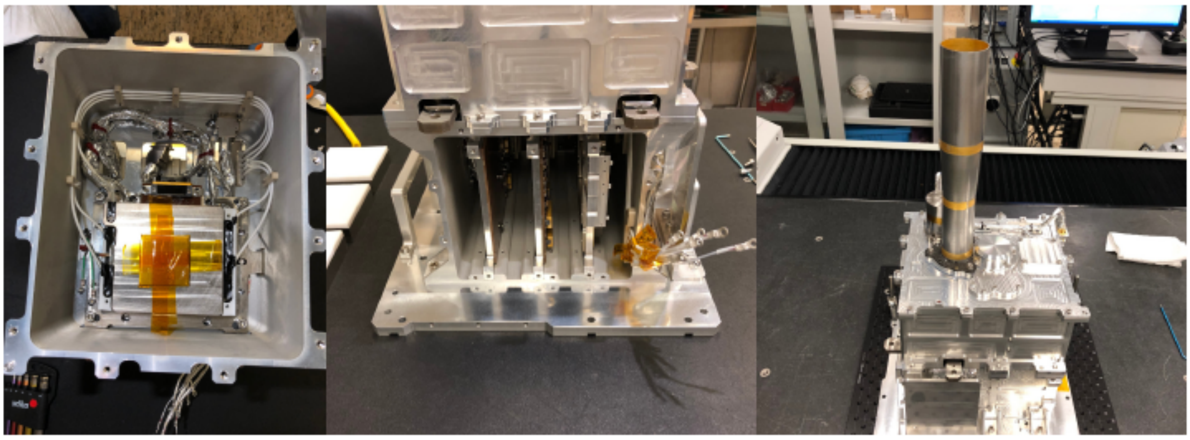


Figure 5.2: (Left) The Gas Pixel Detector installed in the first detector unit; (Centre) The detector unit back-end electronics, including low-voltage, high-voltage and data-acquisition boards; (Right) The first detector unit fully assembled.

As we move forward, the mission schedule foresees a number of formal deliveries from Italy to the United States, and those set the stage for the secondment plan for the second part of the program. Particularly:

- GPD Engineering Model, delivered in August 2019;
- Detector Unit FM1, to be delivered in December, 2019;
- Complete instrument (Detector Units FM2–4 and Detector Service Unit), to be delivered in March 2020.

The DU FM1 will undergo an end-to-end calibration along with its X-ray mirrors at MSFC. The remaining detector units and the Detector Service Unit (the onboard-computer) will be delivered to Ball Aerospace for the integration with the spacecraft. A specific plan for support with INFN and UNIPI personnel is attached to each of these deliveries, and will drive the secondment plan for the next two years. Particularly, in the fall of 2019 and through 2020, INFN and UNIPI are expected to support:

- the incoming and test, as well as the calibration activities, of the GPD EM at MSFC (Huntsville, AL);
- the end-to-end calibration of the flight telescopes at MSFC (Huntsville, AL);
- the integration of the instrument with the spacecraft at Ball Aerospace (Boulder, CO).

In addition, as the activities related to the production of the flight hardware ramp down toward the end of 2019, we expect a significant fraction of the INFN and UNIPI researchers to shift their focus on the development of the tools for high-level Science analysis, and we envision part of the secondment program in this context.

Status: progressing well

WP6 "FNAL Muon Campus Experiments". Lead Beneficiary: INFN; Coordinators: I. Sarra (INFN), V. Giusti (UNIPI), S. Di Falco (INFN).

In the next few years the FNAL Muon Campus will provide the most intense pulsed muon beams, which are among the cleanest probes when searching new phenomena beyond the Standard Model of fundamental interactions. NEWS researchers are involved in the Muon (g-2) and Mu2e experiments. The goal of the Muon (g-2) experiment at FNAL is to solve the puzzle originated by the existing 3.7 standard deviation discrepancy between the value of the anomalous muon magnetic moment predicted in the Standard Model and the measurement performed by the E821 Collaboration at Brookhaven. The expected accuracy will provide more than 5 standard deviations discrepancy from the existing theoretical prediction if the central value remains unchanged. Mu2e will search for the Charged Lepton Flavour Violating (CLFV) neutrinoless, coherent muon conversion to an electron in the field of a nucleus, with four orders of magnitude improved sensitivity with respect to previous experiments. The observation of lepton flavor violation in the neutral lepton sector, named "neutrino oscillations", was accommodated by an ad hoc modification of the Standard Model, but no mechanism within the model allows for a measurable rate of CLFV. The observation of CLFV would be an unambiguous evidence of new physics. NEWS researchers are deeply involved in several aspects of these endeavours. Secondments are running smoothly and we expect a vigorous increase in the fall 2019 and early 2020 for Muon (g-2) data taking and analysis and Mu2e development and construction activities. We expect to achieve future deliverables and milestone in due time (M36, and M48).

Status: on track no major delays

O6.1 and O6.2: Develop analysis tools and measure the muon anomalous magnetic moment at the Muon (g-2) experiment. The measurements of the electron and muon anomalous magnetic moment provide a deep insight into the quantum structure of elementary particles and have been a milestone for the development of the Standard Model. The Dirac theory predicts that the gyromagnetic ratio for an elementary particle with spin 1/2 is exactly 2. However, Quantum Electrodynamics (QED) predicts that the contribution due to virtual diagrams in which photons and other particles are emitted and reabsorbed is not negligible. These diagrams modify the effective magnetic momentum and therefore the coupling between the particle and an external magnetic field. The electron and muon anomaly can be theoretically predicted with great accuracy and thus a discrepancy with the experimental value can reveal the existence of physics beyond the Standard Model. Although the muon anomaly can be measured less precisely than the electron one, mostly due to the particle lifetime, a new particle contributing to the anomaly in a virtual correction has an effect proportional to the square of the electron or muon mass. Therefore the muon anomaly is more sensitive to New Physics contributions.

The current best experimental measurement form the E821 experiment at Brookhaven shows a 3.7 standard deviations discrepancy from the theoretical prediction. The Muon (g-2) experiment at FNAL (E989)) is designed to measure the muon anomaly with an uncertainty 4 times smaller than the E821 measurement.

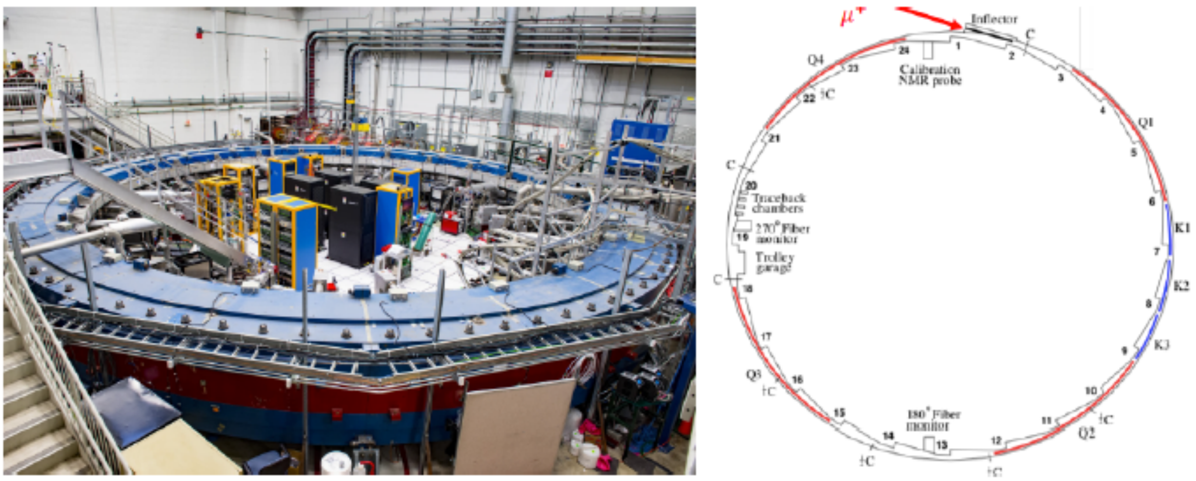


Figure 6.1: (Left) Photograph of the ring of the Muon (g-2) experiment at FNAL; (Right) distribution of the 24 calorimeter stations along the ring of Muon (g-2).

FNAL experiment uses the same experimental technique with improved statistical and systematic uncertainty (Figure 6.1). FNAL will collect an increased 20x data sample and improve the systematic error by a factor 3x by exploiting the improved calorimeter calibration system developed by NEWS researchers. The E989 experiment at FNAL has been largely built on the legacy of E821. The 14-m diameter superconducting coils from E821 storage magnet were moved from Brookhaven to FNAL. Performing the experiment at FNAL provides a number of advantages, including the ability to produce more muons and to eliminate the pion background contamination of the muon beam injected into the storage ring, which was a major limiting factor for E821 at BNL. The upgraded linear accelerator and booster ring structure at FNAL allow delivering proton pulses (8 GeV, $4x10^{12}$ proton/pulse, 1.3 s pulse separation) impinging on the production target. The secondary positive pion beam is focused with a pulsed lithium lens into the transport beam line which accepts positive pions with a momentum spread of ±0.5% around 3.11 GeV/c, In the transport beam line and in the delivery ring section the decay-in-flight of the pion beam generates a polarized muon beam due to the V-A structure of the weak current. The 10 times longer flight distance at FNAL compared to BNL allows the residual hadron contamination in the muon beam to decay away before it reaches the muon storage ring. This essentially eliminates the so-called hadron flash in the positron calorimeters after muon beam injection which was a major source of background for the BNL experiment. Muons circulate in the storage ring decaying with a lifetime of 64 microsecond. The high-energy positron from the muon decay is emitted preferentially along the spin direction, again because of the V-A structure of the weak current. Twenty-four individual calorimeter stations, each consisting of an array of 6x9 PbF_2 crystals are spaced equidistantly around the inner radius of the storage ring in order to capture the emitted positrons (Figure 6.1, Right). Each crystal in individually instrumented with silicon photomultipliers (SiPM) to detect the Cherenkov light generated by the high-energy positrons.

A sophisticated laser system developed by NEWS researchers is used to calibrate in energy and to align in time the response of the 1296 crystals. This is of paramount importance as the single largest systematic error in the BNL experiment was the calorimeter gain stability. Thanks to the laser system and to the new calorimeter, the budget for this error will be reduced by a factor of 6. Straw tracker stations are operated in front of two positron calorimeters to allow for the precise reconstruction of the positron flight path and the muon beam distribution. The FNAL E989 experiment started taking data in February 2018. After few months of commissioning, the first real data started to accumulated in April 2018, which allowed to reach a raw integral number of positrons of 16 billions, approximately of the same size as the total sample of the BNL experiment, by the end of Run I in July 2018 (Figure 6.2, Right). In early 2019 the experiment continued data taking for Run II that ended in July 2019. Data taking will restart in October 2019 for Run III. Data analysis is currently in progress. Four different groups, 2 from US Institutions, 1 from Shanghai, and 1 from Europe (Italy+England) including NEWS researchers, are independently analyzing the data with the common goal of publishing a measurement with an uncertainty at the same level as the BNL experiment by the year 2020 (Figure 6.2, Left).

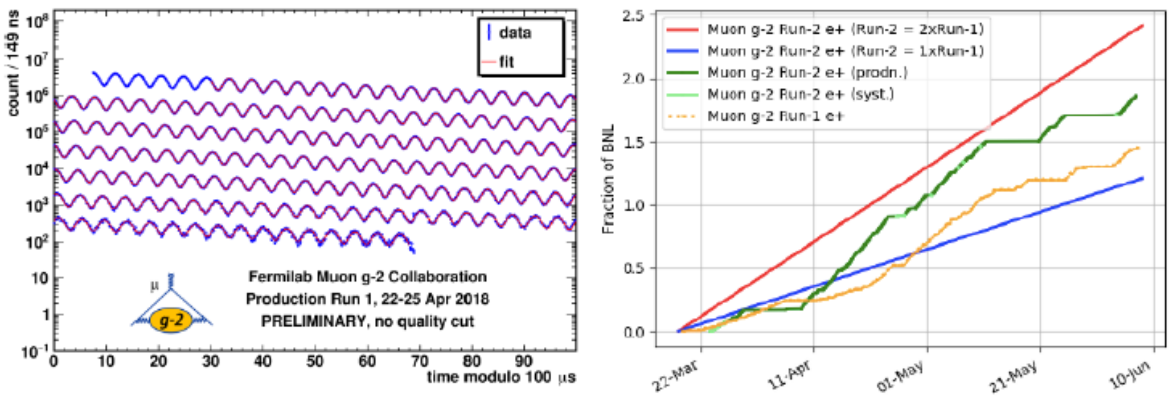


Figure 6.2: (Left) “Wiggle Plot” as measured in the Muon (g-2) data that gives the number of measured positrons in a certain direction as a function of time; (Right) Progress of Muon (g-2) data taking, yellow line is Run I data, green line is Run II data terminated in June 2019; blue and right lines are extrapolations for Run II from Run II respectively for performance identical to Run I and twice as Run II.

There are several steps towards this goal. Each of the four groups has published the documentation describing the analysis method and the assessment of the systematic error; in May 2019 the documentation has been reviewed by internal referees that have written reports with questions for the authors; In May 2019 during the Muon (g-2) Physics Week organized at Isola d’Elba (Italy) by INFN, the Collaboration has thoroughly reviewed the work of the analsys groups, which has been a major step towards unblinding. The current goal is to perform the final unblinding in September 2019, before the start of Run 3, and tu submit the first physics paper by the calendar year. This physics paper will be a major achievement, since it may confirm of disproof the 3.7s discrepancy between theory and the E821 experiment measurement. INFN researchers are providing a leading contribution to the European analysis group and to the experiment’s data taking, which includes calorimeter calibration, estimate of the systematic uncertainty due to muon beam losses related to the lost muons effect which consists of muon disappearance generated by the interactions of the muon beam with the residual beam gas or beam pipe. INFN researcher with major responsibilities in Muon (g-2) include Franco Bedeschi, member of the Institutional Board and of the Speakers

Committee, Antonio Gioiosa, coordinator of the Slow Control of the entire experiment, Marco Incagli, coordinator of the European data analysis groups, Graziano Venanzoni, member of the Institutional Board and chair of the Publication Committee and Run Coordinator, and Michele Iacovacci, member of the Institutional Board.

NEWS contribution would be significantly strengthened by including the University College London group, that is already extremely active in data taking and analysis, as a new beneficiary.

Status: on track no major delays

O6.3 and O6.4: Develop Mu2e simulation and offline analysis software. The Mu2e offline software comprises code for simulation, calibration, reconstruction, analysis and event display; it also includes code to characterize the quality of results delivered by the reconstruction code when it is run on simulated events. At the present stage of the development, there are only simulated events but the reconstruction code is being written so that it will work, as is, on experimental data, once they are available. Studies undertaken to date include characterizing the joint spatial, temporal and momentum-space population of the particle fluxes entering the Detector Solenoid, including the muon flux and the fluxes of all interesting background species; understanding how these fluxes depend on the designs of the magnetic field, the production target, and the collimators; computing realistic distributions of non-signal hits in the detector subsystems; computing the efficiency for reconstructing conversion electrons in the presence of the non-signal hits; computing the power of the detector to reject signal-like backgrounds produced by non-signal processes; computing the radiation and heat loads on elements of the apparatus; and redoing all of the above for variants on the design of the experiment. For these studies, Mu2e has developed several software packages, simpler codes permitted a fast start to many critical studies but did not have all the features needed for development of hit based reconstruction code. The **art** based offline software is now widely used along with the MARS code, which is fundamental when precision information about low energy neutrons is required. The **art** infrastructure software includes a framework, an event-data model, a persistency mechanism, run-time configuration, management of the state of random number engines, message logging, configurable responses to exceptions, and tools for the management on singleton-like entities such as geometry and conditions data. It also includes the tools to manage access to data-bases, file catalogs and the GRID workflow managements tools. The system can be used for all purposes, from the lowest level non-real-time task in the trigger/DAQ system through to final analysis; the steps in between include software triggers, reconstruction, calibration, filtering/skimming of data sets, and simulation. MARS is a Mont Carlo code for inclusive and exclusive simulation of three-dimensional hadronic and electromagnetic cascades, muon, heavy-ion and low-energy neutron transport in accelerator, detector, spacecraft and shielding components in the energy range from a fraction of an electron volt up to 100 TeV. Mu2e uses MARS configured so that it uses the MCNP package for low momentum neutrons, which is considered the best calibrated code for simulation of neutrons, in particular neutrons with low kinetic energy. Mu2e is performing detailed simulations of the experimental area and detectors to study radiation levels. These studies inform the requirements for shielding, for radiation safety and for the radiation hardness of electronics. For example, the Cosmic Ray Veto, which provides the veto to cosmic muons, is particularly sensitive to neutron background. INFN, UNIPI and HZDR researchers are thus performing a comparative study of alternative materials to build the radiation shields. The analysis is performed with Monte Carlo numerical codes (e.g.

MCNP6) suitable to simulate the neutron transport through matter. At high energy the neutron capture cross section is generally small, thus a proper neutron shield has to efficiently degrade the neutron energy to values low enough for the neutrons to be absorbed. However, at the same, the shield has to stop the photons that can be produced by the absorption reactions. In general, an efficient neutron slowing down is obtained through elastic scatterings with low-mass elements (e.g. a collision with a hydrogen nucleus halves, on average, the neutron energy. Finally, a suitable shielding for photons can be provided by elements with high density and high atomic number. We have performed a preliminary set of simulations to evaluate the performance of four materials (four species of concrete) with different percentages of hydrogen content. As a first approach, we have assumed a mono-directional and mono-energetic neutron beam striking on a slab shield from one side and we have estimated the fraction of neutrons emerging from the other side. We have also determined the energy spectrum of such neutrons. We have assumed the impinging neutron beam energy in the range 1 eV – 100 MeV and the slab thickness in the range 10 cm – 100 cm. Our results show that if the energy of the impinging neutrons is below 1 MeV, a reduction of the amount of neutron emerging from the shield can be achieved by increasing the hydrogen content of the material. If the neutron energy is increased, increasing the hydrogen content is not advantageous. For 100 MeV neutron energy the effect is negligible. For high-energy neutrons, the effect of reducing the concrete density is not compensated by having a higher hydrogen content. As a matter of fact, at high energy the elastic scattering cross section drops to very low values and in such condition exploiting non elastic reactions may be more efficient. For neutron energy above 10 MeV, the non-elastic cross section of Cu, Fe, Ni, W, Bi and Pb is larger than the H elastic scattering cross section. Due to health hazards, Pb cannot be taken into consideration. Given the high density and atomic number, the mentioned elements are interesting also for photon shielding. We have performed a second set of simulations assuming a more complex geometry and composition of the shields. In particular, the originally monolithic concrete slab has been divided in two 100 cm thick layers. To test the impact of the non-elastic reactions on the shielding, the first 20 cm of the two concrete layers have been replaced with bismuth (Bi), tungsten (W) or AISI-316 stainless steel (SS). Moreover, to efficiently remove the thermal neutrons a 0.32 cm thick sheet of Flex-Boron has been added after each layer. We have limited this analysis to the two neutron energy values of 10 MeV and 100 MeV. We have found that due to the high non-elastic cross section, W is very efficient in shielding high-energy neutrons. However W cost is high: a W alloy, with 93% by weight W, is currently quoted at 100 dollars/kg. Stainless Steel is less effective than W but much cheaper. For 100 MeV impinging neutrons, the transmission of a shield made of regular concrete is reduced by a factor better than 25 by adding 20 cm of W to each layer, and by a factor better than 5 by adding 20 cm of Stainless Steel. Borated concrete (1% by weight of B_4C) reduces the neutron transmission by only 15% with respect to regular concrete and adding 20 cm of Stainless Steel to each layer increases the effect to a factor of 5. Barite (without boron) concrete reduces neutron transmission by a factor of 3 with respect to regular concrete and adding 20 cm of Stainless Steel to each layer increases the effect to a factor of 12. In case a concern arises about the fraction of thermal neutrons, when using regular or barite concretes that do not have boron, a possible solution is adding a borated rubber like the FlexBoron. We plan to continue working on these studies to finalize the design of the shielding system of the entire Mu2e experiment.

Status: on track no major delays

O6.5 Build the Cesium Iodide (CsI) crystal calorimeter for Mu2e and Simulation and design the upgraded radiation hard calorimeter for Mu2e-II.

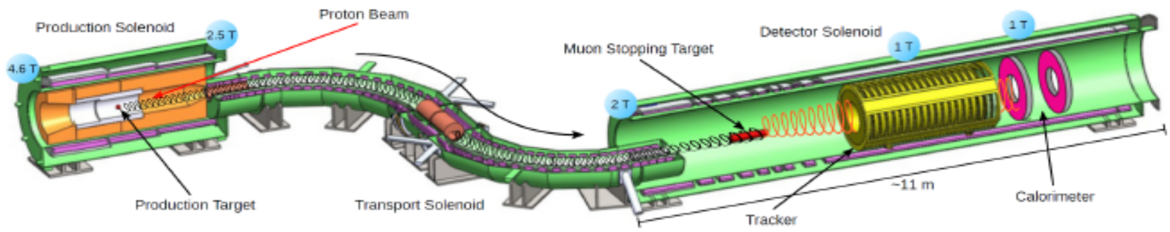


Figure 6.3: Schematic representation of the Mu2e apparatus. Backward-going pions produced by the 8 GeV proton beam are captured and decay into muons transported through a bent solenoid to a series of thin aluminium discs where they stop. The electron produced in the muon decay or capture is measured by the straw tracker and by a pair of crystal calorimeters in the shape of hollow cylinders to let the low momentum electrons go through undetected. The cosmic ray veto surrounding the detector solenoid, the absorbers inside the detector solenoid, and the extinction and stopping target monitor are not shown.

One of the primary functions of the Mu2e calorimeter (Figure 6.3) is to provide a redundant set of measurements to complement the tracker information and minimize the level of backgrounds to the search of the electron produced in the muon coherent conversion in the field of the Aluminium nucleus. To detect the 100 Mev electrons, the calorimeter design uses undoped Cesium Iodide crystal arranged in two matrices with the shape of annular disks. Each CsI crystal is read out by two large-area solid-state photodetectors (SiPM) that are preferred to standard photomultipliers since the calorimeter operates in a 1 T magnetic field (Figure 6.4). The front-end electronics servicing the SiPM is mounted next to the SiPM on the rear side of each disk, voltage distribution, slow control and data acquisition electronics are hosted in 10 custom crates place on the external lateral surface of each disk (Figure 6.5 and 6.6).

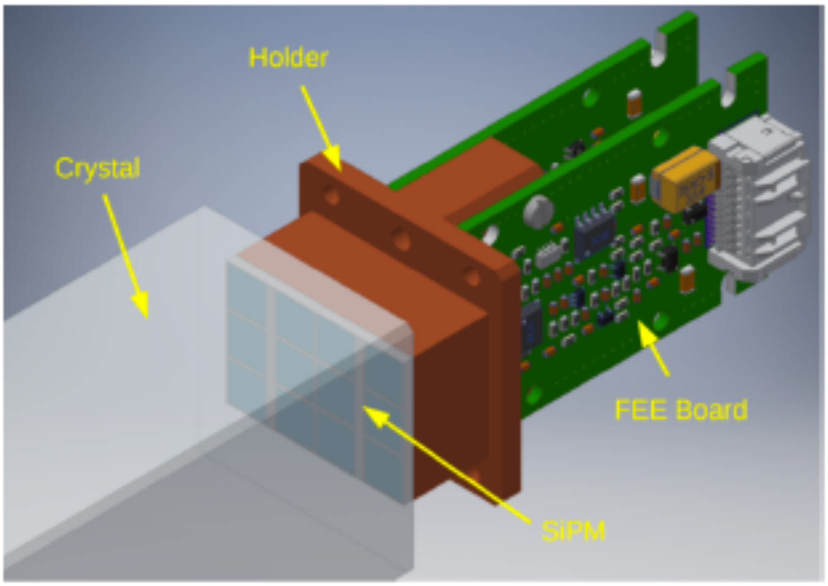


Figure 6.4: CAD model of one front-end unit, composed of one Cesium Iodide crystal readout by two SiPM and two front-end electronics boards.

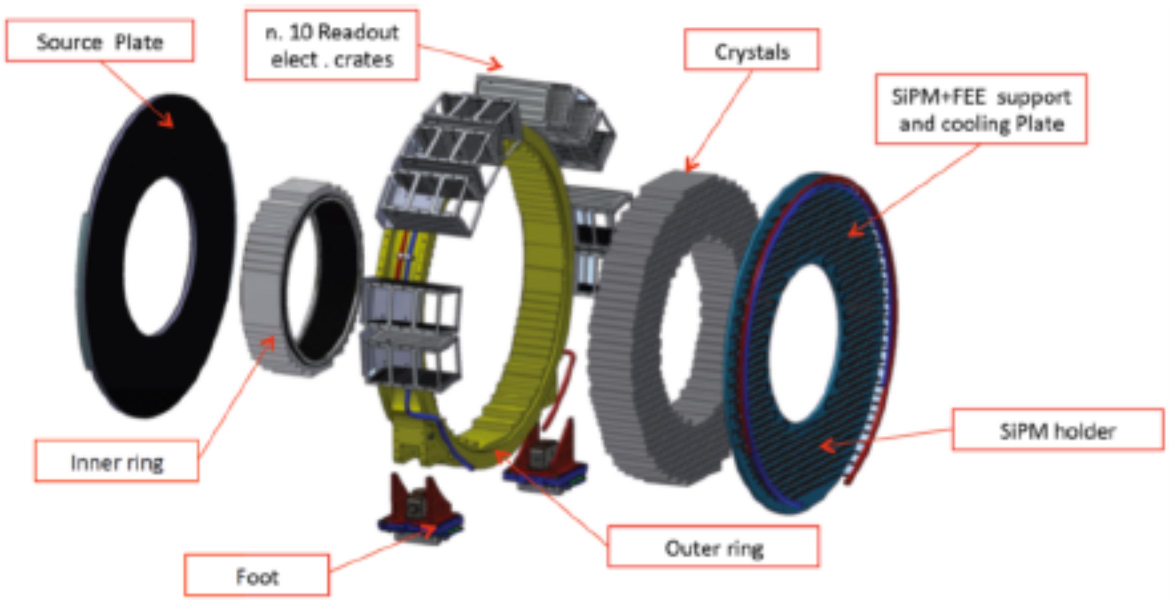


Figure 6.5: Exploded CAD model of one disk of the Mu2e electromagnetic calorimeter.

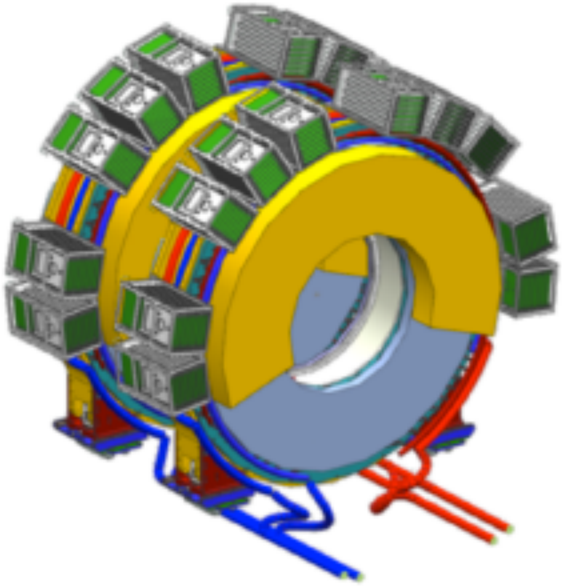


Figure 6.6: CAD model of the entire Mu2e calorimeter, including the two disks and the 20 custom crates that host the voltage distribution, slow control and DAQ boards.

After several years of R&D coordinated by INFN, UNIPI, HZDR, CALTECH and FNAL researchers involved in NEWS, the design of the calorimeter has been almost completed and detector construction is going to begin in the next few months. INFN has purchased the CsI crystals and photosensors that have been delivered to FNAL, along with the components of the mechanical structure that are expected between the last few months of 2019 and early 2020. Front-end and DAQ electronics is expected at FNAL for early 2020. Detector assembly will take place in 2020 and 2021 and will involve about 30 INFN staff, including researchers and technical staff. INFN researchers have major responsibilities in the Mu2e calorimeter project. Stefano Miscetti is the project coordinator, Fabrizio Raffaelli and Fabio Happacher are the Technical Coordinators of the mechanical assembly, Elena Pedreschi, Ivano Sarra and Franco Spinella are the Technical coordinators of electronics installation and detector grounding, Daniele Pasciuto is responsible of detector quality control, Simona Giovannella is responsible of the CsI crystals installation, Eleonora Diociaiuti and Matteo Martini are responsible of the photosensors installation, Raffaella Donghia is responsible of the cabling, Carlo Ferrari is responsible of the laser calibration system, Luca Morescalchi is responsible of the digital electronics testing, Simone Donati, Fabio Happacher are members of the Mu2e Institutional Board, Simona Giovannella is chair of the Mu2e Publication Committee, Stefano Miscetti and Raffaella Donghia are member of the Mu2e Executive Board.

Also in this case NEWS contribution would be significantly strengthened by including the University College London group, that is already extremely active software and detector development, as a new beneficiary.

NEWS researchers are also working on the Mu2e-II detector upgrades. The CsI crystal electromagnetic calorimeter developed for Mu2e will not be adequate for the level of radiation expected for Mu2e-II. The plan for Mu2e-II is to use Barium Fluoride (BaF_2) scintillating crystals. BaF_2 has a fast light emission (1 ns) at a wavelength of 220 nm, but also a large slow component (600 ns) above 280 nm that is incompatible with operation in the Mu2e high event rate and has to be suppressed. A new kind of Avalanche PhotoDiode (APD), blind above 280 nm and highly efficient in the deep UV region, will be developed. INFN and

CALTECH will design a solar-blind interference filter with an atomic layer deposition technique on silicon, which is a challenging technology. INFN and UNIPI are currently working on the design of the DAQ electronics of the calorimeter. The heart of the DAQ system is the digitizing system. Digitizing systems are challenging but widely used devices, Since they create the interface between analog sensors and digital DAQ systems they can thus be employed in a vast number of electronic devices and applications, including particle physics experiments, nuclear, space, medical and industrial applications. The sampling rate, the dynamic range and the operating environment are the most significant discriminating parameters for such challenging devices. Fast multichannel digitizers are produced by several companies and are already commercially available. The problem is that commercial devices operate mostly in conventional environments, while devices used in particle physics experiments have to withstand challenging radiation levels and magnetic fields. Our goal is to develop a 20-channel, 200 Msample/s, 12-bit digitizer which can withstand an approximate level of 30 krad of Total Irradiation Dose (TID), 10^{11} neutron fluence (1 MeV eq (Si)) and 1 tesla of magnetic field. Regarding radiation tolerance, the electronic components can be qualified using HZDR irradiation infrastructure and a detailed Monte Carlo simulation will be performed to estimate the exposure parameters. The gamma-ELBE facility at HZDR provides a high-intensity Bremsstrahlung photon field for irradiation studies and an accurate simulation of the apparatus can be performed: from the Ni radiator for the photon production to the optimal irradiation position and beam energy. A first prototype of the digitizer has been irradiated at the gELBE facility in June 2018 using a low total integrated dose. No performance degradation of the prototype was observed. The irradiation tests will be repeated in 2019 with the new prototype of the digitizing system, designed using improved radiation hard components. The prototype will be exposed to a higher total integrated dose and beam energy than in 2018. An active radiometer system based on RadFETs will be used to perform an accurate measurement of the delivered dose in real-time. The six most sensitive components of the digitizing system (i.e. FPGA, DC-DC converter, ADC, jitter-cleaner, low-dropout regulator and digital translator) will be tested n terms of permanent damage and efficiency loss of the components as a function of the delivered photon dose. In particular, we will test the re-programmability of the FPGA, the FPGA performance degradation (i.e. longer internal delays_ as function of dose, the current variation due to possible latch-up events, the DC-DC converters efficiency degradation as a function of dose, and the performance of the low-dropout regulators. The Monte Carlo simulation shows that with an electron beam energy of 15 MeV, the absorbed dose in silicon is > 2.5 krad/h at 100 micro-Ampere current, provided that the electron beam spot on the Nb target foil is 0.5 cm. The required dose of 100 krad could therefore be accumulated in about 6 hours per component, assuming an average of 100 micro-Ampere current. For the most critical components the qualification will be done at 150 krad. Further irradiation tests will be performed with photons and neutrons at the ENEA research centers at Casaccia and Frascati. Further tests in high magnetic field, of the order of 1 tesla, will be performed at the INFN –LASA laboratory.

We expect to achieve the future deliverables D6.1 “Measurement of the Muon Anomalous Magnetic Moment at Muon (g-2)”, D6.2 “Mu2e Simulation and Reconstruction Code” (M36), and D6.3 “Construction of the CsI Crystal Calorimeter for Mu2e and Simulation and Design of upgraded BaF2 Crystal Calorimeter for Mu2e-II” (M48) and milestones in due time.

Status: on track no major delays

WP7 "Advanced Superconducting Technology for Particle Accelerators". Lead Beneficiary: POLIMI; Coordinators: S. Franz (POLIMI), S. Farinon (INFN), E. Barzi (FNAL).

O7.1: Construct the superconducting magnets of Mu2e experiment. In the Mu2e experiment the generation and transport of the muon beam is controlled through magnetic fields generated by two superconducting solenoids: the Production Solenoid (PS) and the Transport Solenoid (TS). The detectors, placed after the aluminium target, are placed in the magnetic field generated by a third superconducting solenoid: the Detector Solenoid (DS). The design and building of these three magnets is critical for the Mu2e experiment. Each one has peculiar requirements and represents a challenge to the current available technologies. The conductors of the three magnets were chosen on the basis of the very long experience acquired with superconducting detector magnets for high energy experiments along last 40 years and consisting of Rutherford cables coextruded in pure Al stabilizer.

The TS solenoid. The S-shaped Transport Solenoid is composed of three straight sections separated by two toroidal sections. In these sections the muon beam produced in PS would be moved to the off-axis DS magnet. In order to avoid trapped particles, the field gradient is negative everywhere by default. The magnetic path of the TS will be controlled by 52 coils, arranged in 27 modules, electrically connected in series, so as only one power supply would feed the entire system. The splices between them need to have good electrical resistance as well as good mechanical strength. The conductor is a classic Rutherford Al stabilized cable with a critical current of 6 kA at 5T and 4.2 K.

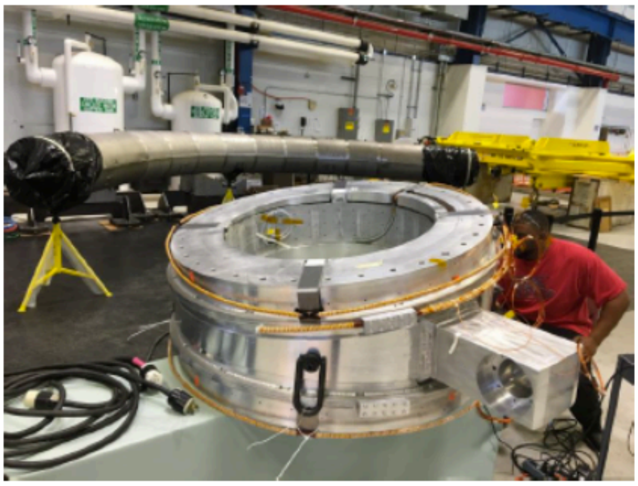


Figure 7.1: (Left) The first superconducting unit of the Mu2e Transport Solenoid composed of one single module delivered to FNAL in 2018 from ASG Superconductor in Genova (Italy); (Right) The second unit composed of two modules delivered to FNAL in 2019.

INFN role. In the first phase of the development INFN has been involved in the design and construction of a prototype module (including two coils). The design has been based on the concept of shrink-fitting, i.e., the individual coils are mechanically supported, against Lorentz forces, by an Al-alloy shell integrated through a shrink-fitting operation involving a whole module. The soundness of this approach has been proved by the successfully cryogenic test of the prototype. Soon after the prototype test, the contract for the module construction has been awarded by FNAL to ASG Superconductor in Genova (Italy) with the active collaboration of INFN in the industrial follow-up. INFN has been also in charge of the conductor qualification of all the Mu2e SC conductors through critical current, joint resistance and study of conductor damages due to construction induced stress. Two test stations have been involved in the characterization of the Mu2e conductors. The critical current of the conductors was mostly obtained involving the biggest magnet of the laboratory, i.e. the facility Ma.Ri.S.A. (acronym of Magnet for Researches in Applied Superconductivity). It is a solenoid magnet generating 6T in a bore of $500\ mm$ bore diameter, in which the conductor samples were tested using a transformer method. For other tests (transfer length and joint resistance) a smaller split coil superconducting magnet was used. After measuring the critical currents of samples (more than 40) extracted from the lengths used for in Mu2e solenoids (TS and DS), INFN has performed studies for evaluating the impact of conductor deformation during the construction (bending and twisting) on electrical transport properties. As an example a double twisting of the TS conductor does not cause any degradation of the critical current. The bending of the TS conductor could cause some limited degradation if the bending radius is in the order of 25 mm radius hard way. The contract for the construction of the 27 modules, to be later assembled and integrated into the cryostat at FNAL was awarded by FNAL to ASG Superconductors. The construction plan has been delayed due to some design changes and some difficult procurements of the Al-alloy mechanical structures. Presently all the 52 coils of the TS have been constructed; they are integrated into the Al-alloy mechanical structures (shells), as soon as they become available. The first unit (composed of a single module) has been delivered to FNAL and successfully tested in 2018 (Figure 7.1). The second unit (2 modules) has been delivered at FNAL and tested in 2019. The test of most units will be started in the second half of 2019 and through 2020. The first secondments at FNAL have started in 2019 and are mostly planned for 2020.

Status: on track no major delays

O7.2: Use advanced superconducting technologies for high-field magnets for particle accelerators. A second objective with INFN and FNAL as main actors is related to the development of superconducting technologies for high field magnets to design and build a 16 Tesla Nb3Sn accelerator dipole. For INFN this activity is still at a preliminary step and secondments at FNAL have started in 2019 and will be useful for training of personnel. The challenge for high field Nb_3Sn superconducting magnets is to push the design limit of these magnets to their superconducting potential (or Short Sample limit). To design and build a 16 Tesla Nb_3Sn superconducting dipole, the design limit needs to be at least 17 Tesla. Within the cos-theta magnet geometry, i.e. the same design used in the Tevatron at FNAL and at LHC at CERN, a number of strain management options were investigated. First, the U.S. Magnet Development Program (MDP) has developed a Nb_3Sn dipole demonstrator with a 15 Tesla design limit for a post-LHC pp Collider. The magnet design is based on 60-mm aperture 4-layer shell-type coils, graded between the inner and outer layers to maximize the magnet performance. The cable in the two innermost layers has 28 strands 1.0 mm in diameter and the cable in the two outermost layers has 40 strands 0.7 mm in diameter. Both cables have been developed and fabricated at FNAL in long lengths using RRP Nb_3Sn wires produced by Bruker-OST. An innovative mechanical structure based on aluminium I-clamps and a thick stainless steel skin is used to preload the brittle Nb_3Sn coils and support large Lorentz forces at high fields. The maximum field for this design is limited at 15 Tesla due to mechanical considerations. The first magnet assembly was done with lower coil pre-load to minimize the risk of coil damage during assembly. Then conceptual designs and analyses were performed for a 4-layer coil also based on a 60 mm cold aperture, but with a 17 Tesla design limit. To achieve this limit, a strain management mechanical solution was developed, that makes use of winding into slots and with adequate spacers. To readily test the winding concept, plastic parts were produced using 3D printing technology. Also, a mechanical structure of 630 mm outer diameter for testing at FANL was developed and analysed. In parallel, a modelling effort was invested in investigating why high field accelerator magnets made of Nb_3Sn typically have long trainings and are limited at 90% of their short sample limit at best. This means that the conductor current is at 60% or less of its critical value. Homogeneous finite element models are typically used for the complex system that includes coils, wedges, poles, yoke, rods, keys, shoes, fillers, shell, etc. Since homogeneous models do not allow determining stress and strain distribution, a more accurate sub-modelling of the composite structure was performed. This is extremely important for Nb_3Sn performance since state-of-the-art high critical current wires of this superconductor are particularly sensitive to strain. Sub-modelling was applied to a 10-stack test, where a stack of impregnated Rutherford cables is compressed along the x, y and z directions, one at a time, both at room temperature and at 4.2 K, to obtain the mechanical properties of the composite sample. Sub-modelling also allows identifying critical areas of maximum equivalent Von Mises stress and strain. Deliverable 7.1 “16 Tesla Dipole Designed” has been submitted in due time in June 2019 (M24).

Status: on track no major delays

O7.3 Optimize state-of-the-art electrochemical deposition techniques. An electro-chemical deposition technique, which had been collaboratively developed by FNAL and POLIMI, to produce superconducting Nb_3Sn films on Nb substrates, was reproduced at FNAL. Advantages of electroplating are simplicity, accurate control, and low costs. The process includes three deposition steps: in Step 1, a seed Cu layer of a few micrometer is deposited on the Nb substrate; in Step 2, a Sn layer of thickness that is about double that of the desired final thickness of Nb3Sn is deposited, and finally in Step 3, a Sn containing layer of Cu is deposited. Up until Fall 2018, using the above system, several superconducting Nb_3Sn films of thickness between a couple of micrometer to 25 mm were obtained on Nb rectangular substrates of 0.3 mm to 0.5 mm thickness, as well as on Nb disc substrates of 2 inch diameter. The latter samples are to be used in the Jefferson Laboratory (USA) surface impedance measurement facility, which is made of a TE011 cavity with a demountable endplate, where a disc sample can be placed. For adhesion, thickness control and uniformity, most parameters of the electro-plating process were studied and optimized, including:

* Bath composition and anode materials for each of the three deposition steps;
* Current densities, deposition times, stirring rates, and cathode and anode relative orientation in DC mode;
* Current densities, deposition times, stirring rates, cathode and anode relative orientation, pulse frequencies, and duty cycles in pulsed mode.

The pulsed mode was chosen for all the three deposition steps starting from sample No. 4.

The Nb substrate roughness requirements were also studied by applying the coating process to substrates having different surface roughness values, which were measured using a confocal microscope. The roughness range studied was between (0.2±0.1) mm for electro-polished Nb samples up to (1.1±0.2) mm for rolled Nb sheets. It was found that for the best adhesion of the deposited layers a roughness of about 1 mm is needed, which means that the original Nb surface to be coated will not need any prior electro-polishing. The heat treatment cycle used in argon atmosphere and having 700°C of maximum temperature was the same as in the original process. Total deposition times of up to one hour for the three steps produce Nb_3Sn thickness values of up to 10 mm. After reaction, the samples were characterized both in-house

and at other labs using a Scanning Electron Microscope (SEM) and Electron Probe Microanalysis (EPMA), transport test of critical current $I_c(B)$ up to 14 Tesla to determine the upper critical field μ_0H_{c20} as a free parameter in the $I_c(B)$ data fitting, resistive and inductive critical temperature T_{c0}, as well as SQUID measurements of the lower critical field $H_{c1}(4.2K)$. Critical temperature of 17.5 to 17.6K, lower critical fields of 600 Oe, and upper critical fields larger than 23 Tesla were consistently obtained. The electroplating technique was scaled-up to 3D surfaces using simple Nb cylinders of one inch diameter, obtained by shaping 0.3 mm thick Nb sheets. The anode was a cylindrical rod of 1 cm diameter. Adequate current densities, deposition times, and pulse frequencies were searched for, until the process was successful.
One POLIMI researcher has been seconded at Tomsk Polytechnic University in 2019 to develop the technique for the electrodeposition of tin coatings onto niobium specimens, as a preparatory step to the alloying treatment, to be carried out by pulsed electron beams to form Nb-Sn alloys.
Tin electrodeposition was carried onto niobium specimens (1.5 cm × 1.5 cm × 100 µm). Two types of electrolytic baths were used: stannate baths (alkaline) and sulphuric baths (acidic) are simple in their formulation. Baths were formulated without additives.

Salt used	$Na_2[Sn(OH)_6]$	NaOH	$SnSO_4$	H_2SO_4	Cathodic c.d.	Voltage	T
	(g/l)	(g/l)	(g/l)	(g/l)	(A/dm2)	(V)	(°C)
Stannate	66-110	12-15			1-2.5	3-4.5	70-80
Sulphuric			10-50	50-200	1-10	2-4	15-30

The two formulations allowed depositing semi-bright layers, with good adhesion to niobium substrate, of pure tin of thickness ranging from 5 – 20 µm. The tin layers deposited will be alloyed with niobium substrates by using intense pulsed beam of electrons. The main difficulty of this treatment is quite evident, and it is related to the large melting temperature difference between the two metals: Sn 232°C and Nb 2480°C. This second treatment will be carried out in a further secondment period.
One POLIMI researcher has been seconded at Jefferson Laboratory in 2019 to work on the electrochemical synthesis of Nb_3Sn coatings, consisting in the electrodeposition of a Cu/Nb/Sn/Cu multilayer followed by heat treatment to induce the formation of the Nb_3Sn phase by solid diffusion. Indeed, the heat treatment also develops a Cu-Sn surface layer, which needs to be removed to exploit the underlying Nb_3Sn superconducting film. In particular, the POLIMI researcher has worked on characterizing the Cu-Sn phase and on finding and developing a suitable removal process in order to bring to the surface the Nb_3Sn layer.

New Partners inserted with the Amendment of Grant Agreement AMD-734303-75.
Iowa State University (US). A tight collaboration is being developed by INFN, UNIGE and FNAL also with the Ames Laboratory at the Iowa State University, a world-class laboratory for the development of new superconducting materials. This is relevant both for WP7 and WP8. Iowa State University has been inserted as a new Partner and two UNIGE researchers have been seconded for several months in 2018.
Tomsk Polytechnic University (RF). Given the long-standing experience of Tomsk Polytechnic University in the magnetron sputtering sources and techniques for the deposition of metals, alloys and compounds on targets, POLIMI is interested in testing the possibility to produce metallic films by magnetron sputtering and carrying out electron beam melting to

produce surface alloys on niobium and tin. The goal is to obtain a Nb_3Sn film in a totally unexplored way, with a potential improvement in manufacturing time, reliability and costs.
Jefferson Science Associates LLC (US). Jefferson Laboratory collaborates with FNAL and POLIMI in the development of advanced superconductor technology for particle accelerators. One POLIMI researcher has been seconded at Jefferson Laboratory in 2019.

Milestone MS9 "Mu2e Transport Solenoid Constructed" (M20) has been postponed. We have achieved deliverable D7.1 "16 Tesla Dipole Designed" in due time (M24) and we expect to achieve the future deliverable D7.2 "Nb_3Sn Deposition Technique Optimised on Niobium and Copper" (M48) and milestones in due time.

Status: on track no major delays

WP8 "Advanced Superconducting Technology for Particle Detectors". Lead Beneficiary: UNIGE; Coordinators: F. Gatti (UNIGE), M. De Gerone (INFN), E. Barzi (FNAL).

O8.1 and O8.2: Characterize new superconducting materials to develop new particle detectors. Work is in progress at UNIGE to study new materials, new responsive systems where a small change of an extrinsic thermodynamic variable, for example temperature, pressure, or magnetic field, determines an intrinsic phase change. Alloys and compounds can exhibit strong field-, temperature-, or pressure-controlled reactions, which can be tuned by chemistry, crystallography, and processing. These characteristics can be exploited to develop sensors and smart materials important to develop new particle detectors. We are studying materials manifesting specifically clear or compelling examples (or combinations) of superconductivity, strongly correlated electrons, quantum criticality, and exotic, bulk magnetism. In particular, our efforts are dedicated to understanding and controlling FeAs-based superconductors and searching for new examples of novel, or high temperature, superconductivity. This includes working both on developing theoretical models as well as in laboratory tests. The experimental work consists in developing and growing crystals, performing measurements of microscopic, thermodynamic, transport and spectroscopic properties, as well as the electronic structure in extreme conditions of pressure, temperature, magnetic field and resolution. Theoretical work includes developing transport models, understanding thermodynamic and spectroscopic properties using state-of-the-art phenomenological approaches to superconductors and modern-quantum many-body theory. With the secondments at Iowa State University in 2018 we have worked on T8.1 and T8.2, we have identified and investigated a new ternary compound forming with approximate chemical stoichiometry 2:3:4 *i.e.* $LaZn_{1.5}Sn_2$. We have determined its crystal structure and exact stoichiometry: we have found its structure to be a derivative of the tetragonal $CaBe_2Ge_2$-type showing substantial disorder and defects. We have found this compound to form also by all the light rare earth elements (R = Ce, Pr, Nd). The $LaZn_{1.5}Sn_2$ compound is superconductor with $T_c = 5.5$ K. The presence of superconductivity in a disordered compound is unexpected since superconductivity is uncommon in heavily disordered phases, as the crystallographic disorder promotes breaking of Cooper pairs, usually destroying superconductivity. Therefore, this new superconductor may represent the "parent" compound of a new class of superconductors, whose T_c may be properly tuned and possibly increased by atomic substitution or by applying physical pressure. This is part of the necessary R&D to develop new Transition-Edge Sensors (TES) that exploit the strongly temperature-dependent resistance of the superconducting transition. The goal is to develop an Antenna-Coupled TES with very small heat capacity and working in the 10 mK temperature range to achieve a sufficient sensitivity for 100 GHz single photon thermal detection.

New Partners inserted with the Amendment of Grant Agreement AMD-734303-75.
Iowa State University (US). As mentioned in the previous section, a tight collaboration is being developed by INFN, UNIGE and FNAL also with the Ames Laboratory at the Iowa State University, a world-class laboratory in the development of new superconducting materials. This is relevant both for WP7 and WP8. Iowa State University has been inserted as a new Partner and two UNIGE researchers have been seconded for several months in 2018.

We expect to achieve the future deliverables D8.1 “Single Photon Detector at 100 GHz Study” (M42) and D8.2 “Data from CMB Telescope of the Antenna Couple TES Bolometer” (M48) in due time.

Status: on track no major delays

WP9 “Dissemination and Outreach”. Lead Beneficiary: UNIPG; Coordinators: F. Cottone (UNIPG), C. Oppedisano (INFN), C. Luongo (INFN).

O9.1: Promote the communication between the scientific community and the general public to increase the science awareness. Aiming at promoting the programme, disseminating its activities and maximizing its outcome, the NEWS researchers participated in a large number of Outreach and Dissemination initiatives. These include, but are not limited to, the European Researchers’ Night, with initiatives for the general public audience, exhibits, seminars, games for kids, organized locally by each participating Research Institution. Thematic events are also organized by single Institutions, taking inspiration from similar initiatives from, or with the direct collaboration of researchers from the Partners from United States and Japan. Only some of them are mentioned in what follows (or below).
In the field of gravitational wave physics, events including seminars given by Prof. Barry Barish (Nobel Laureate, 2017) and Prof. Takaaki Kajita (Nobel Laureate, 2015) have been organized in Italy by Prof. Helios Vocca (INFN, UNIPG). Virgo researchers have maintained and possibly enriched their strong tradition of outreach activities directed towards high school students and the general public. In July 2017, the Science Show performance named “Waves Hunters” was held and attracted more than 300 people on gravitational wave research on one of the main square of Gubbio city in occasion of the Gubbio Sience Festival. They organized guided tours of the Virgo site (Pisa, Italy) on a weekly or a bi-weekly basis. In June 2017, Dr. Gianluca Gemme (INFN), Italian national coordinator of the Virgo experiment, gave the seminar “Gravitational astronomy: dawn of a new science” for the general public at the Cultural Association “Ciclo Arte e Scienza” in Montecatini Terme. In September 2017, the European Reseachers’ Night event supported by the SHARPER project was held at the same time in Perugia, Palermo, Ancona, Cascina and Bruxelles. In this occasion, Prof. Helios Vocca (UNIPG) and Massimiliano Trevisan (PSIQUADRO) presented the Gravitational Waves science through interactive demos. In September 2017, OCK and KTH participated in the annual event “Day and night of Astronomy” in Stockholm, with observations of the sky. In October 2017, the Nobel Prize in Physics was assigned to Rainer Weiss, Barry C. Barish and Kip S. Thorne for the discovery of gravitational waves, which has inspired many events dedicated to gravitational waves. In October 2017 the European Gravitational Observatory

(EGO) organized a press conference to present new discoveries in the field of gravitational astronomy. A video connection with the simultaneous press conference organized by the Virgo-LIGO Collaboration at the National Science Foundation in Washington was available. In February 2018, the seminar "The Music of Gravitational Waves" was given by Dr. Francesco Cottoneto to a public of professors of Scientific Higher Schools at UNIPG within the program of the Italian National Plan for Scientific University Courses 2018. Between March 2018 and April 2018, the Association "Palazzo Blu: Arte e Cultura" in Pisa, in collaboration with UNIPI and INFN, organized the series of events for the general public "Valuable knowledge: discovering the talents of the city of Pisa". The first event was organized by Prof. Massimiliano Razzano, Dr. Diego Passuello and Dr. Carlo Bradaschia and was dedicated to the presentation of the Virgo experiment at the EGO site in Cascina. In August 2018, OCK and KTH organized the Conference "Time for accretion" in Sweden. In September 2018, EGO, UNIPI and INFN organized a one full-day event for the general public at the Virgo Laboratory. Several researchers spent the entire day with the public, tours of the laboratory were available, and, in the evening, members of the "Association of the amateurs astronomers" of Pisa and Cascina organized observations of planets with their telescopes. In September 2018, OCK and KTH participated in the annual "Day and night of Astronomy", with observations of the sky. In January 2019, EGO, UNIPI and INFN organized a Conference dedicated to Machine Learning applications to gravitational wave s, geophysics, and robotics, within the COST Action (CA17137). The focus was on the development of innovative techniques for the rapid analysis of data, which will be vital in gravitational wave astronomy, on specific topics such as control and feedback systems for next-generation detectors, noise removal, data analysis and data-conditioning tools. The COST Action aims at creating a broad network of scientists for four different areas of expertise, i.e. gravitational wave physics, geophysics, computing science and robotics, with a common goal of tackling challenges in data analysis and noise characterization. In February 2019 EGO contributed to the organization of a Workshop on observatory synergies for astroparticle physics and geoscience, in Paris, in collaboration with several European research Institutions, including the Institut de Physics du Globe de Paris, and the Italian National Institute of Geophysics and Volcanology. The aim of the workshop was exploring the possible common grounds and combining the scientific expertise of both fields to promote original interdisciplinary research and education projects. In February 2019, UNIPG, INFN, EGO and KAGRA organized a workshop in Perugia (Italy) to promote a more active collaboration within the international scientific community involved in gravitational wave physics to strengthen the bridge between second generation gravitational wave detectors, like Advanced Virgo and Advanced LIGO, and the third generation gravitational wave observatories, like Einstein Telescope and Cosmic Explorer. The workshop explored possible synergies between KAGRA, Virgo and third generation observatories consolidating the long-standing collaboration tradition between the corresponding scientific communities. In February 2019, UNIRO, in collaboration with the European Physical Society, organized a Conference on gravitation to discuss aspects of classical and quantum gravity, including general relativity tests, and gravitational waves from the experimental, theoretical and data analysis points of view. With the beginning of the new joint LIGO – Virgo data taking O3 started on April 1, 2019, LIGO and Virgo are providing public alerts delivered shortly after the detection of credible transient gravitational waves candidates. This strategy aims to facilitate follow-up observations by other telescopes and enhance the extraordinary potential of multi-messenger observation, but also that areto get involved science enthusiasts interested in receiving alerts and real-time data products related to gravitational-wave events. For the Researchers' Night in September 2019, INFN, EGO and UNIPI are organizing seminars for the general public and visits to their laboratories.

In the field of astroparticle physics, in 2017, thematic master-classes have been organized by INFN Departments in Bari, Perugia, Torino and Trieste for high-school students who were involved in a full immersion activity consisting of lessons on gamma astronomy and Fermi-LAT data analysis with a discussion of the findings like an international scientific collaboration. In 2018, several initiatives have been taken for the general public. These initiatives were within the frame of the ten-year celebration of Fermi-LAT successful operation and included an artistic exhibit by Luca Pozzi both at CERN (Geneva) and in Bologna (Italy). The event was in collaboration with the European Space Agency and offered the occasion for an international competition for illustrators. In March 2018, UNIPI and INFN organized the Fermi-LAT Collaboration Meeting in Pisa: the meeting lasted for 1 week and included a thorough discussion of Fermi-LAT scientific achievements and the ten-year Fermi-LAT operation celebration. In September 2018, UNIPI and INFN organized the event "From the quark to the Universe" for the students and the general public in Pisa, with an introductory seminar by Prof. Massimiliano Razzano, Prof. Walter Del Pozzo and Prof. Ettore Vicari (Director of the Department of Physics)) on the open problems in particle physics, astronomy and astrophysics. In November 2018, UNIRO organized the "International Cosmic Day 2018", in collaboration with European research Institutions and FNAL through the Quarknet network in US. A few hundred students participated in the event at UNIRO and researchers have shown the performance of a chamber in detecting cosmic muon tracks and delta electrons produced in the collision of muons with the gas atoms present in the chamber.. In the framework of an Italian governmental program, high school students have been involved in Fermi-LAT data quality monitoring and in the preparation of material for outreach and dissemination activities.

NEWS researchers are also extremely active also in the organization of Summer Schools. In 2017, 2018 and 2019 UNIPI, INFN and FNAL researchers have organized the annual Summer School "Summer Students at FNAL and other US Laboratories", a 9-week internship for Physics, Engineering, Computer Science and Materials Science Master students. This is the evolution of the INFN-DOE Summer Students program at FNAL, which was started by INFN in 1984 and since then has hosted approximately 550 students (on average 25 students/year in the last few years) from more than 20 Italian and some European universities. Interns are hired for 9 weeks by FNAL and pursue a Training Program under the supervision of a FNAL scientist. The students' training programs span from data analysis to design, simulation and construction of particle detectors and accelerator components, R&D on superconductive elements, theory of accelerators, and analysis of astrophysical data. Since 2010, with the support of the Italian National Institute of Astrophysics and the Italian Space Agency, 28 additional students were hosted in other US laboratories and universities, including Stanford and Caltech, with training programs mostly dedicated to astrophysics space science. INFN organizes also internship programs for Master students at LIGO Laboratories on gravitational wave physics and detectors and at STANFORD mostly on astroparticle, including Fermi-LAT data analysis. Since 2015 UNIPI endorsed these internship programsin US as one of his own Summer Schools coordinated by Prof. Simone Donati. The interns are enrolled as UNIPI students for the duration of the internships. They are required to write summary reports and upon positive evaluation by a UNIPI board, students are acknowledged 6 ECTS credits. NEWS researchers have organized seminars at UNIPI and INFN before the beginning of the internships in US, and also seminars and visits to the FNAL laboratories for the FNAL interns in August 2017, 2018 and 2019. Reports about the UNIPI Summer School have been given at the XXXIX International Conference on High Energy Physics at Seoul in 2018, and the 2019 Meeting of the American Physical Society Division of Particles and Fields at Boston in 2019.

Also the new Twitter account H2020_NEWS has been created in 2019 to inform the general public of the NEWS achievements.
In the field of pure dissemination to the scientific community, NEWS researchers widely publish the results of their searches in physics and instrumentation journals and organize and participate in specialized international conferences and workshops. We have achieved and expect to achieve future deliverables in due time (M9, M12, M21, M24, M33, M36, M45, M48).

Status: on track no major delays

Work Package 10 "Transfer of Knowledge". Lead Beneficiary: UNINA; Coordinators: R. De Rosa (UNINA), E. Pedreschi (INFN), R. Sia (CLEVER).

O10.1 and O10.2: Achieve maximum transfer of knowledge among participants and increase the quality of research and the competitiveness of participants. The NEWS programme plans for a significant Transfer of Knowledge through the participation of the involved researchers in seminars, trainings, and specialised conferences, as well as Research-Industry Transfer of Knowledge through the direct involvement of non-Academic personnel in the research activities of the Academic partners, and the participation to common Research Projects.
The first NEWS General Meeting has been organized at INFN and UNIPI in conjunction with the Fermi-LAT Collaboration Meeting (March 2018). In celebration of the 10-year successful operation of Fermi-LAT, the Collaboration has organized an Open Day with seminars and lectures on all aspects of the Fermi mission including but not limited to the: conceptual design, development of the science case, building the international team, path to mission approval, detector development and operation in space. The event represented an interesting opportunity for multi-disciplinary training of the NEWS researchers. NEWS researchers have also attended trainings organized by Institutions not involved in NEWS on topics of interest to their career development. We have achieved, and expect to achieve, future deliverables in due time (M9, M21, M33, M45). The second NEWS General Meeting will be held again at INFN in the fall 2019 and work is currently in progress to organize a series of seminars and training for the researchers.
For WP5 "X-ray Polarimetry", the development of the IXPE mission has required a huge Transfer of Knowledge between academic research Institutions and industry. This involves all IXPE components: from radiation sensors to housing mechanics, readout electronics and associated mission services as thermal control systems, data acquisitions, storage and filtering systems. The Transfer of Knowledge between UNIPI, INFN and several companies with long-standing experience in space technology is continuous. This involves the manufacturing technologies for the Gas Pixel Detectors (GPD) development with Oxford Instruments (OI). This company was part of the original NEWS proposal as a Beneficiary but could not sign the Grant Agreement since it was acquired by Hitachi High-Technologies. INFN, UNIPI and OI have defined the procedures for assembling, conditioning and qualifying the leak-tight, sensitive gas cells of the GPDs, starting from INFN integration of the parts and going through a final custom bake-out thermal cycle and gas filling procedure operated at OI with INFN supervision. INFN is also collaborating with OHB-Italia for the design and qualification of flight electronics for biasing, control and readout of the GPDs. INFN has designed the layout and firmware of the key electronic boards necessary to operate the GPD, namely the core GPDBoard hosting the readout ASIC interfaced to the gas cell, and the external Low Voltage, Data Acquisition, and backplane boards. OHB-Italia optimized the design by adopting ECSS

space standards for the PCB design, selecting the components, qualifying the boards and producing the engineering model and flight models of all the electronic boards required by the mission. INFN and UNIPI are collaborating with several engineering companies to perform the structural and thermal qualification of the mechanical structures of the focal plane detectors and involved services. INFN designed the mechanical structures and validated the structural properties against the expected environmental loads, by flowing down the requirements to the supplier of the sub-unfits, some of which are based on specific technologies which required specific verification for the IXPE application. This applies to the thermal control system which uses proprietary Graphic Fiber Thermal Strap technology owned by the US company Technologies Application Inc. (TAI), to the stray-light collimator designed by INFN in collaboration with DTM Technologies, the mechanical housings of the sensors and electronics designed by INFN and manufactured by Tecno Alarm SRL, and qualification for flight through dedicated thermal-vacuum and vibration tests performed by the specialized companies BPS and SERMS.

CLEVER OPERATION researchers have been seconded at UNIPI and INFN in 2018 and 2019 for a total period of six months. Secondments were devoted mostly to WP 10, but training and research activities were performed also on WP6. CLEVER Researchers have had regular meeting and discussions with UNIPI and INFN personnel. They were trained and participated in the research activity of the IXPE group, with a focus on the FMECA (Failure Mode, Effects and Criticality Analysis). The FMECA is performed to systematically identify potential failures in instrument, unit and sub-unit level and to assess their effects in order to define mitigation actions, starting with the highest-priority ones related to failures having the most severe consequences. The failure modes identified are classified according to the severity of their consequences. They were also trained and participated in the research activities of the Mu2e group, including the design and development of the electromagnetic calorimeter, its readout electronics and data acquisition mainly the digitization system, which has challenging requirements in terms of performance and radiation tolerance. CLEVER researchers have developed and optimized the DAQ of the semi-automated test station used at FNAL to test the SiPM performance: gain, operational voltage, dark current, photo-detection efficiency, and homogeneity of the response. They contributed to preparation of the irradiation tests of the digitizing system, which were performed at the Helmholtz Zentrum Dresden Rossendorf (HZDR) irradiation facility in June 2018. They also worked on the performance characterization and troubleshooting of the digitizing system prototype, which included testing of one full readout channel consisting of one sensor module (formed of a Cesium Iodide scintillation crystal coupled to a SiPM array), front-end electronics, and the digitizing system. The system functioned successfully and was a major step towards the implementation of a full-scale 20-channel system. Moreover, CLEVER performed a preliminary study of the innovation potential and impact of the digitizing system designed by INFN researchers from different perspective: societal, scientific and technological potential, as well as preliminary market analysis. In collaboration with UNIPI and INFN researchers CLEVER submitted the proposal “INTENSE” (H2020-MSCA-RISE-2018) which received financial support (GA 822185, started January 2019). CLEVER, UNIPI and INFN researchers also submitted proposals to the ATTRACT Call in 2018, which did not receive financial support, and are continuously working to submit proposals that are intended to bring this innovative technology to different markets and applications such as medical, industrial, transportation, space and research.

INFN and UNIPI researchers are performing significant Transfer of Knowledge in the field of radiation hard electronics developed for Mu2e towards the company CAEN S.P.A. (Viareggio Lucca, Italy) as part of the project PRIMIS “PRedIctive MaIntenance in hoStile environment” which has been financed with 1.9 million euro by the Regione Toscana in 2018 within the

POR-FESR 2014-2020 program of Regione Toscana. CAEN is interested in expanding their competences and catalogue in the area of radiation resistant digitizing systems and power supplies. In 2019 INFN and UNIPI researchers received the financial support (25 keuro) from INFN for their project “HAMLET: High bAndwidth commercial digitizer for hostile EnvironmenT” through the INFN competitive call “Research for Innovation 2020” dedicated to the Transfer of Knowledge from INFN to private companies. CAEN and CLEVER had submitted Letters of Interests to INFN for HAMLET for an external participation.

Status: on track no major delays

WP 11 “Management”. Lead Beneficiary: INFN; Coordinators: S. Donati (INFN), S. Giovannella (INFN), M. Punturo (INFN).

O11.1, O11.2 and O11.3: Ensure the efficient organization of the project and supervise secondments and monitor activities to achieve the deliverables. NEWS Management and Scientific Boards have been appointed at the Kick-Off Meeting (July 2017) and are regularly meeting on approximately a 3-month basis to monitor scientific and administrative progress. A new website has been created for the programme (risenews.df.unipi.it) and regularly updated. It has been used to make relevant NEWS information available for both the general public, in the public section of the website, and for the programme’s participants, in the restricted section. Also the Twitter account H2020_NEWS has been created.
In January 2018, an Amendment to the Grant Agreement has been established in order to include a new Beneficiary (HOGSKOLAN DALARNA in Sweden) and a new Partner (Institute for Cosmic Ray Research at the University of Tokyo, ICRR, in Japan). Several researchers from several beneficiaries have already been seconded at ICRR for several months.
The first annual General Meeting had been organized and was held at INFN-Pisa and UNIPI in March 2018. The Mid-Term review has been organized at INFN and UNIPI in March 2019, and also the second annual General Meeting will be organized at INFN in the fall 2019.
In April 2019, an Amendment to the Grant Agreement has been established in order to include several new Partners (University of Missouri (US), Massachusetts Institute of Technology (US), Tomsk Polytechnic University (RF), Iowa State University (US), Hiroshima University (JP), Texas A&M University (US), the University of Hong Kong (HK), Jefferson Science Associate LLC (US)). Several researchers from several Beneficiaries have already been seconded at these new Partners.
As an example of new financial resources generated by NEWS, with the objective of providing support to the Japanese parallel participation to NEWS activities, the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) approved a Core-to-Core (C2C) programme from FY2018 to FY2022 by the Japanese Society for the Promotion of Science (JSPS). The corresponding Japanese funding of 18,000,000 yen per year (summing up to 90,000,000 yen for five years) is allocated to support the expenses of their travels toward the European and American Institutions involved in NEWS.

The Table below reports the complete list of Deliverables that shows we have achieved and expect to achieve future deliverables in due time.

DELIVERABLE NUMBER	DELIVERABLE RELATIVE NUMBER	TITLE	DUE DATE	DUE DATE IN MONTHS	STATUS in system	Comment on progress and planning deviations
21	D11.1	Kick-Off Meeting	01/08/2017	1	APPROVED	Completed
23	D11.3	NEWS web site	01/12/2017	5	APPROVED	Completed
1	D1.1	NEC - Requirement No. 1	01/01/2018	6	APPROVED	Completed
20	D10.1	Trainings	01/04/2018	9	SUBMITTED	Completed
18	D9.2	Workshop Day/Open Day	01/04/2018	9	SUBMITTED	Completed
22	D11.2	General Meetings	01/04/2018	9	SUBMITTED	Completed
19	D9.1	Summer Students at US Laboratories	01/07/2018	12	SUBMITTED	Completed
24	D11.4	First Progress Report	01/07/2018	12	APPROVED	Completed
26	D11.6	Mid-Term Meeting	04/03/2019	18	SUBMITTED	Completed
3	D2.2	Gravitational Wave Event Localization Code	01/07/2019	24	SUBMITTED	Completed
14	D7.1	16 Tesla Dipole Designed	01/07/2019	24	SUBMITTED	Completed
5	D3.2	Specification for a Tiltmeter	01/07/2019	24	SUBMITTED	Completed
6	D4.1	Analysis Package for LAT 4th Catalogue	01/07/2019	24	SUBMITTED	Completed
12	D6.2	Mu2e Neutron Transport Simulation and Reconstruction Code	01/07/2020	36	PENDING	On-track
4	D3.1	Design of cryogenic seismic filter	01/07/2020	36	PENDING	On-track
16	D8.1	Single Photon Detector at 100 GHz Study	01/07/2020	36	PENDING	On-track
11	D6.1	Measurement of Muon Anomalous Magnetic Moment at Muon (g-2)	01/07/2020	36	PENDING	On-track
15	D7.2	Nb3Sn Deposition Technique Optimised on Niobium and Copper	01/07/2020	36	PENDING	On-track
2	D2.1	Roadmap for third generation detectors	01/07/2020	36	PENDING	On-track
9	D5.1	Design Report of a Space Grade GPD and Associated Data Acquisition System	01/07/2020	36	PENDING	On-track
25	D11.5	Second Progress Report	01/07/2020	36	PENDING	On-track
7	D4.2	Automatic pipeline for gamma-ray follow-up of gravitational wave triggers	01/07/2021	48	PENDING	On-track
13	D6.3	Construction of the CsI crystal calorimeter for Mu2e and Simulation and Design of upgraded BaF2 Crystal Calorimeter for	01/07/2021	48	PENDING	On-track

		Mu2e-II				
8	D4.3	Fermi Data Legacy Archive	01/07/2021	48	PENDING	On-track
17	D8.2	Data from CMB Telescope of the Antenna Coupled TES Bolometer	01/07/2021	48	PENDING	On-track
10	D5.2	Simulation and Science Analysis Framework for X-Ray Polarimetry	01/07/2021	48	PENDING	On-track

In the following are reported some selected publications and presentations at International Conferences. Of these, those that are directly relevant to the project are cited appropriately for the EU funding and also the project confirms that they are fully open access according to the Grant Agreement Articles defining these requirements:

- B.P. Abbot et al., "Low-latency Gravitational-wave Alerts for Multimessenger Astronomy during the Second Advanced LIGO and Virgo Observing Run", Astrophys. Journal 875 (2019) no.2, 161.
- A. Albert et al., "Search for Multimessenger Sources of Gravitational Waves and High-energy Neutrinos with Advanced LIGO during its First Observing Run, ANTARES, and IceCube", Astrophys. Journal 870 (2019) no.2, 134.
- E. Burns et al., "A Fermi Gamma-ray Burst Monitor Search for Electromagnetic Signals Coincident with Gravitational-Wave Candidates in Advanced LIGO's First Observing Run", Astrophys. Journal 871 (2019) no.1, 90.
- E. Capocasa et al. "Measurement of optical losses in a high-finesse 300 m filter cavity for broadband quantum noise reduction in gravitational-wave detectors", Phys. Rev. D98 (2018) no.2 022010.
- T. Akutsu et al., "First cryogenic test operation of underground km-scale gravitational-wave observatory KAGRA", 2019, arXiv:1901.03569 [astro-ph.IM].
- T. Akutsu et al., "KAGRA: 2.5 generation interferometric gravitational wave detector", Nature Astronomy 3 (2019) 35-40.
- T. Akutsu et al., "The status of KAGRA underground cryogenic gravitational wave telescope", 2017, arXiv:1710.04823.
- The Fermi-LAT Collaboration, "The Fourth Catalogue of Active Galactic Nuclei Detected by the Fermi Large Area Telescope", arXiv:1905.10771 [astro-ph.HE].
- M. Ajello et al., "A Decade of Gamma-Ray Bursts Observed by Fermi-LAT: The Second GRB Catalogue", The Astrophysicsl Journal, Volume 878 (2019), no. 1, 52.
- D. Tak et al., "High-energy emission from GRBs: The second Fermi-LAT Gamma-Ray Burst Catalogue", Gamma Ray and Related Astrophysics in the Gavitational Wave Era, 13-17 May 2019, Nanjing, China.
- M. Yassine et al., "High-energy emission from GRB: The second Fermi-LAT Gamma-Ray Burst Catalogue", European Week of Astronomy and Space Science (EWASS), 24-28 June 2019, Lyon, France.

- E. Bissaldi et al., “High-energy emission from GRBs: 10 years with Fermi-LAT”, Proceedings of the International Cosmic Ray Conference (ICRC), 25 July – 1 August 2019, Madison, USA.
- M. Axelsson et al., “High-energy emission from GRBs: A decade of Fermi-LAT observations”, Proceedings of the Conference Gamma-Ray Bursts in the Gravitational Wave Era, 28 October – 1 November 2019, Yokohama, Japan.
- A. Anastasi et al., “Muon (g-2) calibration system data flow”, Nucl. Instrum. Meth. A936 (2019) 335-336.
- A. Driutti et al., “The calibration system of the Muon (g-2) experiment”, Nucl. Instrum. Meth. A936 (2019) 98-101.
- A. Anastasi et al., “The laser calibration system of the Muon (g-2) experiment at Fermilab” arXiv:1906.08432 [physics.ins-det].
- A. Anastasi et al., “The monitoring electronics of the laser calibration system in the Muon (g-2) experiment”, Nucl. Instrum. Meth. A936 (2019) 372-373.
- M. Incagli et al., “Measuring the muon precession frequency in the E989 Fermilab Muon (g-2) experiment”, Proceedings of the European Physical Society – High Energy Physics EPS – HEP Conference 2019, July 10-17 2019, Ghent, Belgium.
- N. Atanov et al., “Mu2e calorimeter readout system”, Nucl. Instrum. Meth. A936 (2019) 333-334.
- E. Pedreschi et al., “The Digitizer ReAdout Controller (DIRAC) of the Mu2e electromagnetic calorimeter at Fermilab”, Proceedings of the TWEPP 2019 Topical Workshop on Electronics for Particle Physics”, 2-6 September 2019, University of Santiago di Compostela, Spain.
- L. Morescalchi et al., “High Statistics Characterization of Mu2e Calorimeter Silicon PhotoMultipliers with an Automated Test Station”, Proceedings of the 2019 IEEE Nuclear Science Symposium and Medical Imaging Conference”, 26 October – 2 November 2019, Manchester, UK.
- E. Diociauti et al., “The muon -> electron conversion and the Mu2e experiment at Fermilab”, Proceedings of the European Physical Society – High Energy Physics EPS – HEP Conference 2019, July 10-17 2019, Ghent, Belgium.
- E. Barzi et al., “The Science Training Program for Young Italian Physicists and Engineers at Fermilab”, Proceedings of the 12th International Conference on Education and Development, INTED 2018, Valencia (Spain), March 5-7, 2018, arXiv:1908.01899 [physics.ed-ph].
- C. Luongo et al., “The Italian Summer Students Program at Fermi National Accelerator Laboratory and other US Laboratories”, Proceedings of the XXXIX International Conference on High Energy Physics, ICHEP 2018, Coex, Seoul, Korea, 4-11 July, 2018, arXiv:1908.01900 [physics.ed-ph].
- S. Donati et al., “The Italian Summer Students Program at Fermilab and other US Laboratories”, Proceedings of the 2019 Meeting of the Division of Particles and Fields of the American Physical Society, July 29 – August 2, 2019, Northeastern University, Boston, (USA).
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1.3 Impact

NEWS provides fundamental support to the research activity of about 100 researchers that are collaborating with American and Japanese research institutions in many areas of fundamental research in physics, gravitational wave astronomy and detectors, particle detectors for space and advanced technologies for high-intensity accelerator beams. Most of these research activities are developed by large international collaborations, as for example LIGO and Virgo, KAGRA, Fermi-LAT, Muon (g-2) and Mu2e, and are financed by national funding agencies, as for example the Italian National Institute of Nuclear Physics, the French Centre National de la Recherche Scientifique, the Italian Space Agency, the Italian Institute of Astrophysics, the Swedish K. A. Wallenger Foundation, the Swedish Research Council and the National Space Board. The problem is the limited funding generally available for travelling that does not allow European researchers to have the necessary permanence at the US and Japanese laboratories (LIGO, FNAL, KAGRA) where the experimental facilities they have contributed to design and build are located. NEWS provides a solution to this problem and through extended secondments allows European researchers to take leading roles in these research activities and receive a world-class training. This is fundamental to enhance the career perspectives especially of Early Stage Researchers but also of Experienced Researchers at all levels. The participation of non-academic partners in NEWS provides a beneficial transfer of knowledge that reinforces the European industrial innovation capacity. The role of the European research institutions in these international collaborations is thus significantly strengthened and the prospects of future partnerships strongly increased. In particular, NEWS researchers have successfully developed new initiatives that have resulted in financed projects, as for example “INTENSE: particle physics experiments at the high intensity frontier, from new physics to spin-offs. A cooperative Europe – United States – Japan effort” (H2020-MSCA-RISE-2018, GA 822185), “PRIMIS: PRedIctive MaIntenance in hoStile environment” financed by the Italian Regione Toscana in 2018 within the POR-FESR 2014-2020 program of Regione Toscana, “HAMLET: High bAndwidth commercial digitizer for hostile EnvironmenT” financed by the INFN competitive call “Research for Innovation 2020” dedicated to the Transfer of Knowledge from INFN to private companies. Also, NEWS researchers at the European Gravitational Observatory (EGO), the University of Pisa and INFN have promoted the new European Project “REINFORCE” (GA 872859) dedicated to Citizens’s Science and coordinated by EGO.

Concerning gender balance, the fraction of female researchers participating in NEWS is only about 20 % of the total. This is independent of NEWS, since it is due to the researchers population in the participant institutions. This improved at the level of Work Package co-Leaders and Scientific Board composition, with a fraction above 30 %.

Through an intense dissemination and outreach activity, NEWS has a beneficial impact on the entire scientific community, as well as the general public, especially the younger generations of European students in scientific and technological disciplines. In particular, NEWS researchers have an intense participation in international conferences to present their results and publish their scientific results on specialized journals and reviews. They also participate actively in many well-established outreach initiatives.

2. Update of the plan for exploitation and dissemination of result (if applicable)

There is no significant update concerning the plan for exploitation and dissemination of results. This part of the project will be the focus of the WP dealing with these issues according to the discussions at the MTM and as well following the grant agreement DoA.

3. Update of the data management plan (if applicable)

NEWS does not participate in the Open Research Data Pilot in Horizon 2020.

4. Follow-up of recommendations and comments from previous review(s) (if applicable)

At the MidTerm Review (Pisa, March 2019) there were no significant comments, except some concern about secondments starting at a slower than expected rate. The reasons for this initial delay and the plans for the next two years the have been widely explained in Section 5 of this Report.

5. Deviations from Annex 1 and Annex 2 (if applicable)

Table 5.1 shows that until August 2019 (M26) a total of 152 Person Months (PMs) of secondments have been planned and 103 PMs have been started. Hence the starting rate is 66.0% (starting rate = started/planned). Of these, 77.51 PMs were completed, representing hence a completion rate of 49.7% (completion rate = completed/planned). This is accounted for as secondments that have started at a slower rate than originally anticipated for several reasons. As the programme started on the 1st of July 2017, it was not simple for many institutions (which were in a learning process about the programme's administrative planning) to plan a significant number of secondments to be executed "immediately" during the same summer season (2017) or in the following semester. A large fraction of the NEWS researchers had already ongoing University teaching duties and this has not allowed them to be seconded extensively at the beginning of the programme.

Researchers involved in Virgo-LIGO (WP1, WP2) have been intensively involved in the upgrades of the Virgo interferometer towards the third observation run (O3) planned for April 2019 and which will see Virgo and LIGO interferometers taking data jointly again. This has required an intense participation of the personnel and has limited the number of first secondments. There was absolutely no space for distracting researchers form the Virgo commissioning: a delay of Virgo commissioning would have an extremely negative impact on the field, with the only European interferometer not joining the US interferometers (LIGO) in O3. As the Virgo commissioning activity for the O3 preparation ramps down, R&D activities will ramp up rapidly and the rate of secondments will steadily increase. Several Beneficiaries have recently hired several new PhD students and postdocs that will be seconded between the end of 2019 and 2020.

As a result of the IXPE mission's outstanding approval by NASA, which will significantly boost the NEWS scientific and societal outcome and outreach, the researchers involved in the construction of the X-ray polarimeter (WP5) have started their secondments at a slower rate than originally expected. At the moment of the Grant Agreement Preparation (2017), the IXPE mission was only a proposal and the secondments were planned to study its feasibility. The IXPE mission was then approved for launch by NASA, which is an extraordinary success of the INFN and UNIPI teams, laying a solid and impressive ground foundation for all subsequent efforts and programmes. As the involved INFN and UNIPI researchers have been fully committed to the construction of the detectors, there was absolutely no space for distracting them from the X-ray polarimeter construction: a minimal delay of the schedule approved by NASA could have resulted in the IXPE mission cancellation. As a consequence,

secondments at NASA have been postponed to the second part of the NEWS programme and will therefore be mainly dedicated to the detectors' commissioning, launching and operating the mission planned for 2020, with several INFN and UNIPI researchers fully committed and with important operational responsibilities.
WP6 is mainly focussed on the Fermilab Muon (g-2) experiment data taking and Mu2e detectors constructions, there are about 40 INFN researchers and several technical staff involved, with major responsibilities at Collaboration level. The presence at Fermilab of the INFN researchers involved in Muon (g-2) will significantly increase in autumn 2019 and through 2020 with the beginning on the new data taking of the experiment. In Mu2e INFN is responsible of the construction of the Cesium Iodide (CsI) crystal calorimeter, in collaboration with FNAL, and CALTECH. The design of the detector has required several years of R&D and is now very close to completion. A large fraction of the detector components, including the mechanical structure, the CsI crystals, the photosensors, electronics and cables, have been and will be delivered to FNAL in the next few months. The plan is to proceed with detector assembly in 2020 that will require a significant presence at FNAL of INFN researchers that have major responsibilities as previously mentioned.
WP7 and WP8 are mainly focussed in the development of advanced superconducting technologies for particle accelerators and detectors. Secondments have started in 2018 from UNIGE to the University of Iowa (US) and in 2019 from INFN to FNAL and POLIMI to Tomsk Polytechnic (RF) and Jefferson Laboratory (US) and are proceeding smoothly.
In 2018 and 2019 several Beneficiaries have hired new Postdocs and PhD students that will be seconded for a significant part of their time as part of their training. All involved personnel is reported in Table 5.2.
We have not accumulated significant delays in the activities and deliverables foreseen in the Grant Agreement. There has been only a delay on Work Package 7 "Advanced superconducting technology for particle accelerators" which depends on the schedule of FNAL and the Italian company ASG Superconductors. ASG has to build the superconducting coils for the FNAL Mu2e beamline with FNAL and INFN personnel technical support. ASG has accumulated a delay of approximately one year. This will have no significant impact on the Mu2e schedule since data taking is planned for 2022. The impact on NEWS is that the INFN secondments planned for the superconducting coils integration at FNAL have been postponed and have started in 2019. Milestone MS9 "Mu2e Transport Solenoid Constructed" (M20) has been postponed as well. This potential delay is not expected to have a considerable effect on the overall progress of the programme since it is counted for in the programme's risk analysis and contingency plan. Table 5.1 reports the secondment progress updated at M26.

Table 5.1: Summary of NEWS secondments as planned, started and completed by the Beneficiaries (updated at August 2019, M26).

Sending Organisation Short Name	Total planned DoA (RM)	Total encoded and started (RM)	Total encoded and executed (RM)	Starting Implementation rate (started/planned) (%)	Completed Implementation rate (executed/planned) (%)	Comment (deviation, catch-up plan, reshuffling, etc.)
CLEVER	7	6	5.91	85.7 %	84.4 %	Reshuffling
CNRS	7	7	4.81	100 %	68.7 %	Reshuffling
EGO	5	2	1.00	40.0 %	20.0 %	Reshuffling
INFN	72	36	24.79	50 %	34.4 %	Reshuffling
KTH	2	1	1.03	50 %	51.5 %	Reshuffling
OCK	9	12	11.3	133.3 %	125.6 %	Reshuffling
Prisma	3	0	0	0 %	0 %	Reshuffling

UNIGE	14	7	5.60	50 %	40 %	Reshuffling
UNINA	5	1	0.23	20 %	4.6 %	Reshuffling
UNIPG	18	17	13.01	94.4 %	72.3 %	Reshuffling
UNIPI	8	7	4.13	87.5 %	51.6 %	Reshuffling
UNIRO	2	1	1	50 %	50 %	Reshuffling
HOG	0	1	0.13	+100 %	+13 %	Reshuffling
HZDR	1	0	0	0 %	0 %	Reshuffling
Impex	0	0	0	-	-	Reshuffling
POLIMI	3	5	4.57	166.7 %	152 %	Reshuffling
	156	103	77.51	66.0 %	49.7 %	

Table 5.2: Seconded personnel, including names and roles in the organizations with elaboration on the catch up plan for RP2. A separate document will be uploaded in the PPGMS with full RP2 catch up plan (Gantt Chart).

Sending Organisation Short Name	Name of Researcher	Role in Organization	Start Month	Work Package	Total expected months
CLEVER					
	Radia Sia	President	12	5,6	
	Nabil Menaa	Researcher	9	5,6	
	Engineer (to be hired)	Researcher	36	6	20
CNRS					
	Eric Chassande-Mottin	Research Director	9	2,3	
	Marc Eisenmann	PhD Student	10	2,3	
	Pierre Prat	Research Engineer	10	2,3	
	Matteo Barsuglia	Research Director	13	2,3	
	C. Nguyen	Researcher	30	2,3	14
EGO					
	Irene Fiori	Researcher	22	3	
	Franco Carbognani	Researcher	12	3	
	Camilla De Rossi	Researcher	29	3	
	Marco Ciardelli	Researcher	32	3	
	Staff Engineers	Researchers	36	3	11
INFN					
	Francesco Fidecaro	Professor	9	2,3	
	Annalisa Allocca	Postdoc	9	2,3	
	Ettore Majorana	Senior Researcher	12	2,3	
	Federico Paoletti	Technical Staff	21	3	
	Francesco Brighenti	Researcher	24	2	
	Giancarlo Cella	Researcher	36	2	
	Andrew Miller	Postdoc	26	2,3	
	Matteo Bischi	Phd Student	29	3	
	Carmelo Sgro	Researcher	10	5	
	Elisabetta Cavazzutti	Researcher	10	4,5	
	Luca Baldini	Associate Professor	13	4,5	
	Melissa Pesce-Rollins	Researcher	13	4,5	
	Milos Kovacevic	Postdoc	36	4,5	
	Michela Negro	Postodoc	23	4,5	
	Michele Pinchera	Researcher	36	5	
	Leonardo Lucchesi	PhD Student	33	5	
	Hikmat Nasimi	PhD Student	36	5	

	Alberto Manfreda	Postdoc	26	5	
	Luca Latronico	Senior Researcher	33	5	
	Chiara Oppedisano	Researcher	33	5	
	Alessandro Paggi	Postdoc	33	5	
	Riccardo Ciolini	Associate Professor	36	6	
	Stefano Di Falco	Researcher	20	6	
	Simone Donati	Associate Professor	20	6	
	Carlo Ferrari	Researcher	8	6	
	Valerio Giusti	Associate Professor	28	6	
	Andrea Marini	Postdoc	36	6	
	Luca Morescalchi	Postdoc	27	6	
	Elena Pedreschi	Researcher	36	6	
	Fabrizio Raffaelli	Research Director	23	6	
	Franco Spinella	Senior Researcher	20	6	
	Antonio Gioiosa	Postdoc	27	6	
	Caterina Bloise	Research Director	36	6	
	Eleonora Diociaiuti	Postodoc	36	6	
	Raffaella Donghia	Postdoc	30	6	
	Simona Giovannella	Senior Researcher	24	6	
	Dariush Hampai	Researcher	32	6	
	Fabio Happacher	Researcher	30	6	
	Matteo Martini	Associate Professor	30	6	
	Stefano Miscetti	Research Director	21	6	
	Daniele Pasciuto	PhD Student	30	6	
	Ivano Sarra	Researcher	31	6	
	AnnaMaria Zanetti	Researcher	31	5	
	Giovanni Tassielli	Postdoc	34	6	
	Franco Bedeschi	Research Director	34	6	
	Andrea Fioretti	Researcher	23	6	
	Carlo Gabbanini	Senior Researcher	34	6	
	Marco Incagli	Senior Researcher	20	6	
	Alberto Lusiani	Researcher	32	6	
	Graziano Venanzoni	Senior Researcher	32	6	
	Elia Bottalico	PhD Student	35	6	
	Paolo Girotti	PhD Student	35	6	
	Matthias Smith	Postdoc	11	6	
	Diego Cauz	Associate Professor	32	6	
	Michele Iacovacci	Associate Professor	34	6	
	Stefano Mastroianni	Researcher	34	6	
	Giovanni Cantatore	Senior Researcher	36	6	
	Giuseppe Di Sciascio	Senior Researcher	36	6	
	Atanu Nath	Researcher	36	6	
	Matteo Sorbara	Researcher	36	6	
	Technical Staff	Technical Staff	32	6	
	Chiara Vignoli	Senior Researcher	21	7	
	Francesco Puosi	Postdoc	30	2.3	160
KTH					
	Rupal Basak	Researcher	4	4	
	Mark Pearce	Professor	37	4,5	
	Mozsi Kiss	Researcher	34	4,5	
	Rakhee Kushwah	Researcher	37	4,5	
	Nirmal Iyer	Researcher	36	4,5	

	Theodor-Adrian Stana	Researcher	36	4,5	13
	Zaynep Acuner	Researcher	32	4,5	
	Bjorn Ahlgren	Researcher	31	4,5	
OCK					
	Nils Hakansson	PhD Sudent	4	4	
	Magnus Axelsson	Researcher	8	4	
	Andrea Chiappo	PhD Student	23	4	16
Prisma					
	Adamantia Soukoulia	Engineer	30	5,6	
	Paraskevas Kouris	Engineer	30	5,6	
	Konstantinos Tsourapas	Engineer	30	5,6	
	Despoina Xafi	Engineer	30	5,6	9
UNIGE					
	Pietro Manfrinetti	Researcher	15	7,8	
	Alessia Provino	Researcher	15	7,8	
	Flavio Gatti	Associate Professor	36	7,8	27
UNINA					
	Fabio Garufi	Researcher	9	3	
	Luciano Errico	PhD Student	32	2,3	
	Enrico Calloni	Associate Professor	36	2,3	8
UNIPG					
	Helios Vocca	Associate Professor	1	3	
	Antonfranco Piluso	Technical Staff	2	3	
	Flavio Travasso	Researcher	12	3	
	Damiano Aisa	Technical Staff	18	3	
	Mateusz	Bawaj	25	3	30
UNIPI					
	Massimiliano Razzano	Associate Professor	7	2,3	
	Davide Caiulo	Researcher	8	6	
	Francesco Di Renzo	PhD Student	21	2,3	
	Walter Del Pozzo	Associate Professor	32	2	
	Danny Laghi	PhD Student	29	2	
	Giulia Pagano	PhD Student	34	2	
	Gregorio Carullo	PhD Student	34	2	
UNIRO					
	Giuseppe Intini	PhD Student	3	2,3	
	S. Di Pace	Researcher	30	2,3	
	V. Mangano	Researcher	30	2,3	3
HOG					
	Stefan Larsson	Researcher	10	4	2
HZDR					
	Anna Ferrari	Researcher	33	6	
	Stefan Mueller	Researcher	33	6	6
Impex					
	Engineer (to be identified)		36	3	1
POLIMI					
	Massimiliano Bestetti	Associate Professor	13	7	
	Federico Morini	PhD student	25	7	10

New Request of Amendment to the Grant Agreement (September 2019) as part of catch up plan for RP2 to boost secondment implementation.

We plan to insert a new Beneficiary: the University College London (UK), PIC 999975620, starting on January 1, 2020.

The UCL muons group consists of two academics (Gavin Hesketh and Becky Chislett), one engineer (Erdem Motuk) and three PhD students (Gleb Lukicov, Sam Grant and Dominika Vasilkova). The group is heavily involved in the analysis of the data from the Muon (g-2) experiment (WP6) in order to measure the spin precession frequency as part of the "Europa" effort (a combination of analysers from the UK and Italy (INFN)). On UCL side there is a strong emphasis on measuring systematic uncertainties using the straw tracking detectors. They provide information about the beam distribution and motion, which are crucial for understanding the acceptance as well as the energy and pitch corrections and the associated systematics. They are also used to cross check the pileup in the calorimeters and the gain changes as well as to cross check the muon loss systematic.

For Mu2e (WP6) UCL is working on the data acquisition system for the experiment using the art-DAQ framework and the subsequent unpacking and processing of the data into human readable format for analysers, which matches that coming from the simulation. This effort will then be incorporated into the main Mu2e software. The group will also contribute towards developing the GEANT4 simulation prior to the start of data taking and incorporating the detector systems. The resulting code will be used to develop analysis tools to be used on both data and simulation in anticipation of the final result. As the UK is providing the stopping target monitor (STM) for the experiment there will be a particular focus on producing the necessary code to cross calibrate the rates observed in the calorimeter and straw trackers to that seen in the STM. The results of this are crucial to understanding how what the calorimeters see is related to the observations of the other detector systems, underpinning the ability to produce a final result.

UCL plans to use about 20 months of Secondment at Fermilab that would be reshuffled from other Beneficiaries.

5.1 Tasks

There are no significant tasks not fully implemented, critical objectives not fully achieved and/or not being on schedule.