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PRIN: PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE – Bando 2022
Prot. 2022T2XEFS

PART A

1. Research project title

MANTRA - Measuring Anti-Neutron: Tagging and Reconstruction Algorithm for frontier experiments

2. Duration (months)

24 months

3. Main ERC field

PE - Physical Sciences and Engineering

4. Possible other ERC field

5. ERC subfields

1.	PE2_3 Experimental particle physics with accelerators
2.	PE2_6 Nuclear, hadron and heavy ion physics
3.	

6. Keywords

nº	Testo inglese
1.	anti-neutron

	2.	clustering
	3.	calorimeters
	4.	time-of-flight
	5.	particle identification
	6.	e+e- colliders

7. Principal Investigator

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Age limits derogation

Both the PI and the substitute are under 40;

8. List of the Research Units

nº	Associated Investigator	Qualification	University/ Research Institution	Registered office (address)	Operating office (address)	e-mail address
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9 - Substitute Principal Investigator (To be identified among one of the associated investigators participating in the project).

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10. Brief description of the proposal

We propose a method to measure the energy of anti-neutrons (n-bar's) produced in high-energy physics (HEP) experiments with an energy up to few GeV. At present, large amounts of data are being collected by several high energy physics experiments, and the possibility of studying a wealth of new reactions and still unexplored reaction mechanisms could open an effective method to reliably measure their energy and kinematics be devised, exploiting at no additional cost the current experimental set-ups. The so developed method will be released as a tool exploitable for HEP community which could be used in data analysis for several kinds of measurements in which n-bar's play a fundamental role, such as nucleon and hyperon form factors, charmed mesons decays and anti-deuteron production.

Anti-neutrons are not reconstructed by the tracking systems due to their immediate annihilation, but they can produce annihilation stars in electromagnetic calorimeters (EMC) which can form self-contained hadronic showers consisting mainly of pions and hadrons resulting the inelastic interactions on the latter in the surrounding material . While neutral pions decay into two photons, which trigger electromagnetic showers completely contained in a relatively small number of EMC crystals, charged particles usually lose only a fraction of their energy and can easily escape the calorimeter. The signature from n-bar annihilation in the EMC can be distinguished from the signatures due to photons and other neutral particles due to the characteristic shape of the shower. When the n-bar annihilation products are neutral pions only, the total deposited energy can be used to determine its energy. However, if charged pions are produced the energy cannot be reconstructed only with the EMC since the shower can escape the calorimeter in the backward (backsplash) or forward direction; these particles can interact with the detectors placed before or behind the EMC, and the time signal can be used to estimate the n-bar energy.
The combination of the time information and the information from the EMC, together with the development of Artificial Intelligence

techniques, will allow the n-bar's to be identified and their energy and momentum to be measured. The developed method will be tested with experimental data from the experiments BESIII and Belle II, carried out at e+e- colliders, and will be released as a general software tool for High Energy Physics experiments with similar features, to be used in all the analyses where n-bar's detection plays a fundamental role requiring a complete reconstruction.

Thanks to the knowledge and experiences in the proponents units, on software reconstruction techniques, particles identification, n-bar physics and physics analysis techniques, together with the skills developed in different collaborations and experimental environments, we consider the finalization of the project to be feasible well within the indicated time schedule.

11. Total cost of the research project identified by items

Associated Investigator	item A.1	item A.2.1	item B	item C	item D	item E	sub-total	Total
GARZIA Isabella	0	37.500	22.500	2.000	0	2.300	64.300	**64.300**
TAMPONI Umberto	27.752	46.379	44.479	2.000	0	2.300	122.910	**122.910**
SPATARO Stefano Giovanni	43.246	37.500	48.448	2.000	0	2.300	133.494	**133.494**
Total	**70.998**	**121.379**	**115.427**	**6.000**	**0**	**6.900**	**320.704**	**320.704**

N.B. The Item B and TOTAL columns will be filled in automatically

- item A.1: enhancement of months/person of permanent employees
- item A.2.1: cost of contracts of non-employees, specifically to recruit
- item B: overhead (flat rate equal to 60% of the total personnel cost, A.1+A.2.1, for each research unit)
- item C: cost of equipment, tools and software products
- item D: cost of consulting and similar services
- item E: other operating costs

PART B

B.1

1. State of the art

While the detection and measurement of neutrons poses a difficult problem in high energy physics experiments due to their inelastic scatterings in detector materials, which prevent the extraction of a single detectable signal, anti-neutrons (n-bar's) are potentially easier to detect, since they annihilate in detectors leaving detectable signatures (an annihilation star formed by several charged and neutral hadrons). In past decades, a few experiments dealt with the detection of n-bar in the final states or the usage of low energy n-bar as probes. The FENICE experiment, dedicated to the study of nucleon form factors [1], was able to fully reconstruct n-bar's in the final state through calorimetric techniques. OBELIX (PS201) hosted a facility for the production of an n-bar beam through the CEX reaction, and could measure the momentum of each n-bar via a suitable time of flight technique. However, recent and future collider experiments are usually not optimized for the n-bar fully reconstruction, and its presence is mainly deduced from the missing mass of the event if the other particles are all reconstructed. Usually a full class of reactions are studied only indirectly by applying the isospin symmetry to analogous reactions with anti-protons (p-bar's), which however might be a too simplistic approach.

Indeed, there are several cases in which the detection of n-bar is mandatory and its kinematic cannot be determined by simple indirect methods as described in the following.
Since anti-deuterons (D-bar's) in cosmic rays can represent one of the products of dark matter annihilation [2], there is a growing interest to carefully measure their production both at hadron and lepton colliders [3]. The most widely accepted model is that D-bar's are produced through a coalescence mechanism [4,5]: a p-bar and n-bar nearby in the momentum and coordinate space bind into a D-bar, which is then detected in the experimental apparatus. Theoretical models are now quite advanced and precise [6], but their tests require to know the kinematic correlation between the two antinucleons. Usually, MonteCarlo models of the hadronization process are used as inputs to supply this information at the price of large systematic uncertainty which prevents performing stringent tests of theory. The simultaneous measurement of the n-bar and p-bar correlation function in the D-bar production would significantly reduce this uncertainty [7].

Femtoscopy techniques have been used to infer information about correlations in two-particle interactions. It was successfully exploited by ALICE to determine the proton-hyperon and hyperon-hyperon potentials [8,10], that are key inputs to the equation of

state of neutron stars [11]. So far, no direct measurement with n-bar has been performed, even though new information on the potential between n-bar and anti-hyperon would greatly improve our knowledge of the neutron matter equation of state.

Experimental results of the neutron electromagnetic form factor in the time-like region are very scarce due to the difficulties in the reconstruction. Recently, BESIII showed an oscillating feature in the electromagnetic structure of neutron [12] in the study of the e+e- → nnbar annihilation, where the two neutral hadrons in the final state were reconstructed thanks to the well known two-body kinematics. The direct detection of the n-bar would refine this analysis allowing the full identification of the final state, also in initial-state-radiation events where the kinematics is more complex.

Among other interesting cases that would highly benefit from a full n-bar reconstruction we can also mention, in passing, the study of the interaction between charmed baryons and n-bar [13,14], and the search of light charmed hypernuclei at B-factories [15].

Looking at the two recent studies by BESIII [12] and CLEO [16] involving n-bar's, in both the cases the n-bar is identified by its annihilation signature in the electromagnetic calorimeter, but no direct energy measurement has been performed; BESIII just exploited the information from its time-of-flight detector recording the hit left by the n-bar interacting on it. Several proposals have been put forward over the years, such as the HIBEAM/NNBAR program [17] for the realization of dedicated annihilation detectors.

We propose hereby to extend the seminal works by CLEO and BESIII and develop a technique to identify n-bar's and measure their energy using a combination of calorimetric and time-of-flight based measurements, of general use in a multi-purpose modern spectrometer. This will open the door to a large number of measurements in which anti-neutrons play a fundamental role, so far impossible, and it will be used to significantly improve already existing results, like those presented so far.

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2. Detailed description of the project: methodologies, objectives and results that the project aims to achieve and its interest for the advancement of knowledge, as well as methods of dissemination of the results achieved

With this project we plan to develop a general method to measure the energy of anti-neutrons combining the informations collected by an electromagnetic calorimeter (of crystal structure in our case), a detector providing a high-resolution time response (such as a time-of-flight or a fast cherenkov counter with resolution below 100 ps) located in front of it, and a muon system comprising active layers interleaved with a high Z absorber located behind it, also capable of good time resolution (below 500 ps). This detector structure is common in modern, general-purpose collider spectrometers like Belle II and BESIII. Starting from MonteCarlo (MC) simulations, we plan to verify and test the procedure using experimental data collected by BESIII and Belle II, providing a general usage algorithm suitable also for other different particle detectors with a similar structure.

Since anti-neutrons do not lose energy in tracking systems through subsequent inelastic collisions, our method relies on the detection of their annihilation on the nucleons of either the calorimeter or the timing system material. Such annihilations produce mostly high-energy pions and soft nuclear fragments. The charged pions can themselves undergo inelastic interactions with the calorimeter material, initiating a so-called hadronic shower, or leave the detector losing only energy by ionization. Neutral pions, on the other hand, decay immediately into two photons which produce electromagnetic showers in the calorimeter volume, and may be completely contained within it. If the annihilation takes place before or inside the calorimeter we expect several crystals will be interested in the shower development, which will form an asymmetric cluster with extended dimensions: typically, the 95% of the hadronic shower is contained in a cylinder with radius equal to the interaction length (the pion interaction length in CsI is about 44 cm).
Similarly, photons produce an electromagnetic shower, a cyclic process of pair production and bremsstrahlung which invest a few crystals forming a mostly symmetrical and contained cluster: in the electromagnetic shower, the 90% of the energy is contained in a cylinder with a radius equal to the Moliere radius (Rm), which corresponds to 3.5 cm for CsI scintillators.
For our project we don't consider the case in which the n-bar annihilation takes place in the muon system, but only the ones that left a signal in at least both the calorimeter and the timing detector.
The measurement of the energy of the anti-neutrons is a two-step process.
First, the n-bar annihilation must be identified. We plan to use all the available detectors to perform this task, but the electromagnetic calorimeter will be the most contributing one, discriminating the n-bar-induced shower from the one produced by photons or other hadrons.
Our aim is to study the shape of the clusters induced by n-bar's and by photons (and other possible background sources including neutrons, nearby photon pairs producing merged clusters and K0L), in order to exploit the full information by the calorimeter to distinguish between the two kinds of particles. This involves several variables commonly used for photon identification, such as total deposited energy, fraction of energy around the central crystal, lateral momentum, 2nd momentum, dispersion, Zernike polynomials, etc.. The timing of the calorimeter signals could also be included in the list, but since inorganic scintillators are slow detectors with poor time resolution we don't expect this to be a discriminant variable. Because of the huge number of parameters, we plan to use the Machine-Learning algorithms commonly adopted by the HEP community, exploring different architectures (such as GAN, CNN, etc.) to find the most effective one for the identification.
A typical design for an electromagnetic calorimeter could be represented by the BESIII setup, composed of 6240 CsI(Tl) crystals,

arranged in one barrel and two end caps, and each crystal being 28 cm long (corresponding to about 15 radiation lengths) and with a cross section of about 6 x 6 cm2, or by the Belle II one (ECL), which deploys a total of 8736 CsI(Tl) crystals with a typical dimension of 6 x 6 x 30 cm3.
Once the anti-neutron has been identified, its energy can be measured combining again the signals of all available detectors. We plan to distinguish several cases. If the n-bar annihilates only in neutral pions, either inside or in front of the calorimeter, the total shower would be contained in the electromagnetic calorimeter and the total deposited energy can be used to determine its energy. However, this occurs only in a tiny fraction of cases (about 5%), while usually, charged pions and nucleons are produced. In this case we can assume safely that part of the energy is lost because the n-bar annihilation products can escape the crystals. In these cases, our goal is to complement the calorimeter information with the time information from detectors close to the calorimeter and hit by a charged pion produced in the annihilation.
In the BESIII apparatus, a time-of-flight (TOF) system consisting of plastic scintillator bars is placed around the interaction point at a distance of about 90 cm, just before the EMC, to measure the flight time of charged particles in combination with the accelerator radio-frequency clock which provides the start time, with a resolution around 100 ps. In Belle II, a time-of-propagation (TOP) counter made of bars of fused silica covers the barrel region just before the ECL. The TOP is a novel detector concept that, measuring the timing of the Cherenkov photons with a resolution of 100 ps per photon, provides a simultaneous measurement of the Cherenkov angle and the time-of-flight of a charged particle crossing it. We plan to modify its reconstruction algorithm to provide a timing of the hadronic annihilations or backsplash events.
In case of a n-bar event, the two detectors can provide a signal when hit by a backsplash following annihilation in the calorimeter, or when the n-bar directly annihilates in their material just before the calorimeter; in the first case, the time measurement depends also on the position inside the crystal where the shower initiated, while in the second case the time signal will be prompt and more precise. In both cases, the presence of a signal by these detectors will also assist in the n-bar identification, since a photon travels much faster than a n-bar, and their component may be singled out.
If the shower develops in the forward region the charged pions escape towards the outer region, and they can be detected by the outermost detectors, i.e. the BESIII muon counter (MUC) or the Belle II KL and muon (KLM) detection system, which can also provide time measurements with a very good resolution. In this case, the time information must be elaborated taking into account the additional flight-time of the charged pions over a distance of tens of centimeters.

Of course the detection efficiency will depend on the nucleon-anti-nucleon cross sessions. These measurements both in the low (<500 MeV/c) and higher momentum region (>500 MeV/c) were challenged by several experiments in the past years. A complete review on n-bar physics can be found in [18]. The annihilation cross section from n-bar-proton and antiproton-neutron in the momentum range from 50 MeV/c up to 700 MeV/c were investigated by several experiments and collaborations [19 - 23] and their comparison shows a good agreement in the same momentum range (even if the relative uncertainties are high, due to the small collected statistics) as expected by isospin symmetry. Concerning the comparison of proton-antiproton and anti-neutron-proton cross sections, their ratio is close to one in the low momentum range between (300-500) MeV/c, while it becomes larger with, however, huge fluctuations both for lower and higher momenta. The measurements of n-bar nucleon annihilation cross sections is consistent with a scaling law of A^(2/3), where A is the mass number of the material, and a n-bar momentum dependence proportional to 1/p. The neutron-n-bar annihilation can lead to the production of between two and six intermediate particles. Using isospin symmetry relations the corresponding probability [24] for n-bar-neutron annihilation into neutral final states is close to 5%.

We plan to develop the project along two main directions:
1) n-bar identification via electromagnetic signatures based on an independent study of a clusterization algorithm

2) n-bar energy measurement via the combination of time-of-flight and calorimeter deposit information, using the Belle II and BESIII data as benchmark.

To develop these research lines we have defined five different working packages (WPs), each of which may be divided into several sub-tasks necessary to achieve the final goal. The methodologies, objectives and expected deliverables for each WP are summarized below.

WP1 is focused on the study of the electromagnetic response. The features of all the observables needed to identify and reconstruct the energy and momentum distributions from the shower induced by n-bar's could be optimized based on Machine Learning technique. The results will be then compared with experimental data from BESIII and Belle II. When the clusterization algorithm is ready, it could be expanded including the information from other detectors, as investigated in WP2 and WP3. The WP1 will be coordinated by the Torino Unit (UNITO): the expertise on n-bar physics from S. Marcello (expert of n-bar physics at PS178 and PS201 at LEAR - CERN and at FENICE - ADONE, member of the team for the construction of a neutron tagging detector based on plastic scintillators, expert of Antinucleon-Nucleon and Nuclei Interaction Dynamics at LEAR) and S. Spataro (software expert for tracking and particle identification for several collaborations, expert of multivariate analysis and machine learning techniques), along with the involvement in both Belle II and BESIII Collaborations make the UNITO unit the ideal candidate to coordinate this WP.

WP2 and WP3 share common activities but are based on two different experimental setups and software frameworks. Starting from simulated and real data from Belle II and BESIII, the backsplash and n-bar annihilation in Belle II TOP (WP2) and BESIII TOF (WP3) will be studied in detail. In addition, the possibility to include, respectively, the KLM and MUC detectors should be investigated to improve the quality of the time information. The WP2 will be coordinated by the INFN unit which could profit from the great

experience of A. Filippi on n-bar physics (main author of the n-bar review "Antineutron physics" [18] and author of all the meson spectroscopy papers on anti-neutron induced reactions as well as of the studies of annihilation dynamics of antineutron-protons reactions, with the data collected by the PS201 experiment at CERN) and the expertise of U. Tamponi (member of Belle II collaboration and expert of particle identification and TOP detector operations, as well as expert of analysis techniques for quarkonia and di-baryon studies at Belle II). The WP3 will be coordinated by the Ferrara unit (UNIFE) thanks to the expertises achieved by I. Garzia (member of BESIII collaboration with wide experience on particle identification and tracking software, expert of physics analysis in BESIII and BaBar collaborations).

WP4: this WP requires the synergy of all the three units. The clusterization algorithm together with all the studies and results pursued in WP2 and WP3 will be merged in a general-purpose technique aimed to identify and measure the energy of n-bar in modern spectrometers. First, this technique will be validated using ad-hoc benchmark channels identified in the Belle II and BESIII experiments. This WP will be supervised by the INFN unit which will profit from the knowledge of Belle II group experts on developing NN-based clustering algorithms. Its main task is the coordination of all the efforts and skills (including also the experience of F. De Mori, expert analyst and member of BESIII collaboration) for the finalization of this WP.

WP5: dissemination of the results to dedicated conferences and outreach events, such as the International Conference on Computing in High-Energy and Nuclear Physics (CHEP), the International Workshop on Advanced Computing and Analysis Techniques in Physics Research (ACAT), the International Workshop on Ring Imaging Cherenkov Detectors (RICH), and "Notte dei Ricercatori'' at Torino and Ferrara towns. The deliverables will be distributed to the HEP community for validation and test by other experiments, reaching a large and qualified audience. These reasons make both CHEP and ACAT the best choices. The coordination of this WP will be covered by the UNIFE unit taking advantage of the experiences achieved in outreach event organization and dissemination.
A detailed description of each working package is given in section B.3
Several physics channels have been identified to test the n-bar identification procedure and the energy reconstruction technique, as well as to check all the intermediate stages from the different WPs.

Thanks to the 10 billion J/psi events collected by the BESIII experiments, a high purity n-bar sample could be selected searching for the e+e- → J/psi → proton n-bar pi- decay channel, whose branching fraction is (2.12 $\pm$ 0.09) *10^(-3) [12, 24]. This means that approximately we can count on a sample of about 2*10^7 n-bar's.
The typical n-bar momentum range for this decay goes up to 1.2 GeV/c, with n-bar's emitted in the full 4pi solid angle, and the n-bar's kinematics can be determined with very high precision from the reconstruction of the four-momenta of proton and pion together with the constraint on the initial four-momentum of the J/psi, with a very low background level.
In the BESIII experiment the n-bar candidate is usually reconstructed by looking at the invariant mass of the system recoiling against the reconstructed charged tracks (proton and pion in this case) [24 - 26] . This means that the momentum may be calculated, as well as its direction with a precision, respectively, of few MeV and few mrad. The results from the missing mass approach can therefore be compared with those from the new developed technique.
In addition, there are a lot of different ongoing BESIII analysis on J/psi → hyperon anti-hyperon decays in which the n-bar is reconstructed by looking at the missing mass distributions of the system recoiling against the reconstructed charged tracks. A tool for n-bar energy reconstruction could provide not only a complementary analysis technique, but it could also allow more complex final states to be investigated.
As for the BESIII case, Belle II experiment offers an unique n-bar's data set useful for testing the developed technique. Anti-neutron can be tagged by charmed baryon decays: lambda_c → n-bar K^0_S pi (with a branching fraction of 1.82%) and lambda→n-bar pi0 (with a branching fraction of about 39%). In addition, using initial-state-radiation (ISR) J/psi events (about 40 events/fb-1 with tagged ISR photon) the technique could also be tested in the J/psi → proton n-bar pi- decay channel, allowing a direct comparison of the proposed methods using the same analysis channel from two different experimental setups and different center of mass energies.

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3. Project development, with identification of the role of each research unit, with regards to related modalities of integration and collaboration

The project is scheduled to complete in two years. As mentioned in section B.2 we foresee five working packages, namely:
WP1: Calorimetric signature
WP2: Time-of flight signature in cherenkov detectors
WP3: Time-of-flight signature in scintillators
WP4: Development of the global reconstruction algorithm
WP5: Dissemination
The project will articulate over two phases: the first one encompasses the activities of WP1, WP2 and WP3. Its goal is to provide the foundations on detector response which will be used as input to the second phase. The core of phase 2 will be WP4, which is intended to gather all the information from the preliminary studies and deliver the tools to identify the n-bar and measure its energy. All the available workforce already committed to WP1-3 will contribute to WP4. WP5 will start close to the end of phase 2, when preliminary results will be available for presentation at conferences and outreach activities. A detailed description of the human resources needed for each WP will be described later in this section.

We list in the following the sub-structure of each working package. As several people will be working together on the same WP, some

tasks can be completed in parallel.

WP1 timeline:
1.1: implementation of GEANT4 calorimeter model.
1.2: study of the n-bar, photons and hadrons shower features and identification of the variables needed for n-bar discrimation.
1.3: comparison of the simulation with real data from BESIII and Belle II using dedicated control channels with n-bar's and anti-protons from anti-Lambda decays.

WP2 timeline:
2.1: Study of the timing signature of n-bar annihilation and backsplash events in the TOP active volume and identification of the relevant variables for its measurement.
2.2: Development of a reconstruction algorithm to measure the timing of the interactions studied in 2.1.
2.3: Study the timing signature of n-bar interactions in the innermost layers of the muon identification system. This step is expected to be quicker as the default muon system reconstruction is already designed to identify n-bar interactions.
2.4: comparison of the simulation results with real data from Belle II using control channels with n-bar’s and anti-protons from anti-Lambda decays.

WP3 timeline:
3.1: Study the timing signature of n-bar annihilation and backsplash events in the BESIII ToF volume and identify the relevant variables for its measurement.
3.2: Development of a reconstruction algorithm to measure the timing of the interactions studied in 2.1.
3.3: Study the timing signature of n-bar interactions in the innermost layers of the BESIII muon identification system.
3.4: comparison of the simulation results with real data from BESIII using control channels with n-bar’s and anti-protons from anti-Lambda and J/psi decays.

WP4 timeline:
4.1: Determination of the NN design for the identification of the n-bar interaction and training on MC simulation.
4.2: Determination of the NN design for the measurement of the energy on the n-bar and training on a MC simulation.
4.3: Application of the method to a simplified detector geometry modeled with GEANT4 to prepare general usage publication.
4.4: Application on the existing dataset by BESIII and Belle II.

WP5 timeline:
5.1: Preparation of a stand at the event “Notte dei Ricercatori - Torino" with virtual reality display of n-bar interactions in the Belle II detector. The exact exhibition period will depend on the starting date of the project.
5.2: Preparation of a stand at the event “Notte dei Ricercatori - Ferrara" to illustrate the use of neural networks to identify elusive particles. The exact exhibition period will depend on the starting date of the project.
5.3: Preparation of talks to be presented at the CHEP, ACAT and RICH conferences, depending on the starting date of the project.
5.4: Submission of a publication about the method to an appropriate international, peer-reviewed journal.

We also suggest internal milestones for each WP in six-months time-lapses to monitor the progress.

WP1 milestones:
6th month: Complete characterization of the shower shapes relevant for the n-bar identification, with basic comparison with the available data.
12th month: Final list of variables to be used for discrimination training both on real and simulated data
WP2 milestones:
6th month: Complete the algorithm to measure the timing of n-bar interactions and backsplash events in the TOP counter.
12th month: Comparison of simulation and data and finalization of the list list of timing variables to be used for Belle II
WP3 milestones:
6th month: Complete the algorithm to measure the timing of n-bar interactions and backsplash events in the BES III ToF counter.
12th month: Comparison of simulation and data and finalization of the list list of timing variables to be used for BES II
WP4 milestones:
18th month: Method proof-of-principle on a simulated simplified detector model.
24th month: Results of the application of the method to real detector conditions.
WP5 milestones:
24th month: Presentation of the results at least two international conferences and one outreach event. Submission of a publication to an international, peer-reviewed journal.

Each WP will be coordinated by one of the research units based on the available expertise.
The UniTo unit will coordinate the activities of WP1, as it features most of the expertise on clustering and calorimetry (S. Marcello, S. Spataro), and provides personnel already involved in both Belle II and BESIII projects (S. Spataro, S. Marcello), as well as expertise on

BESIII analysis framework (F. De Mori). UniFe (I. Garzia) provides expertise in both the BESIII detector and software, and in organizing outreach events. For these reasons it will coordinate both WP3 and WP5, whose activities won't be overlapping in time. The INFN unit provides deep knowledge of the Belle II reconstruction software and TOP detector operations (U. Tamponi), expertise in anti-neutron physics (A. Filippi) and connections with the Belle II KIT group that is developing a NN-based clustering for merged photon clusters. It will coordinate the activities of WP2 and WP4.

We plan to open three positions for a postdoctoral researcher, one per unit, each one for the full duration of the project. Each of these term researchers will first work on one of the Phase 1 WPs, and then contribute to WP4 and WP5. UniTo will require a position with good expertise in clustering, machine learning and knowledge of the Belle II experiment to lead the WP1 activities and contribute to WP4. INFN will require a position with good expertise in machine learning and knowledge of the Belle II experiment to lead WP2 and WP4 activities. UniFe will require a position with good expertise in machine learning and knowledge of the BESIII experiment to lead WP3 and contribute to WP4 activities. All personnel are expected to contribute to WP5.

Coordination among the research units is not foreseen to present criticalities. The Unit coordinators already collaborate within their experiments. UniTo and INFN also share the same building. We plan to hold regular, weekly remote meetings and organize an in-person workshop once or twice per year, according to the progress speed and the needs.

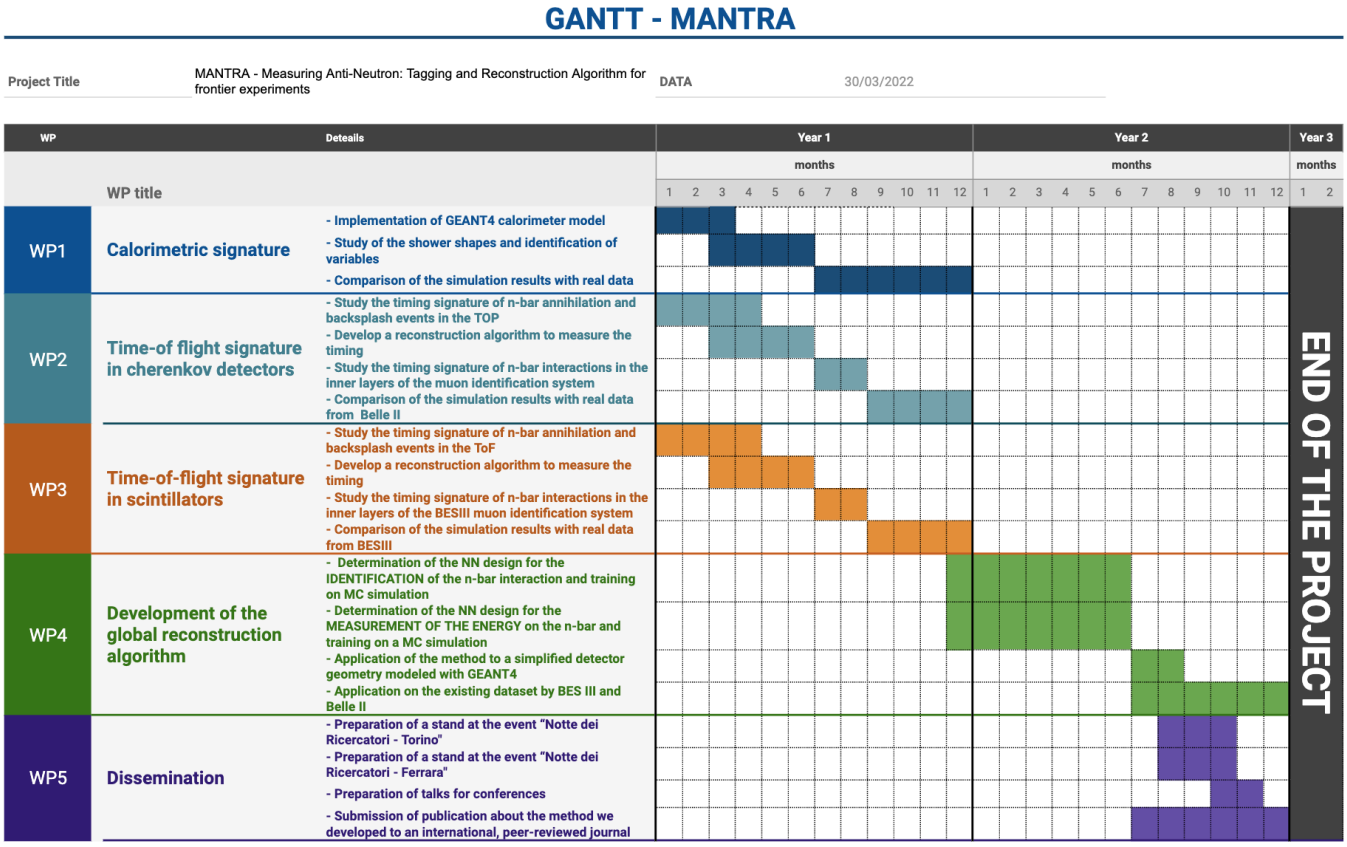

Figure 1. Timeline of the project since its beginning, per each working package.

4. Possible application potentialities and scientific and/or technological and/or social and/or economic impact

MANTRA is a fundamental research project. By its nature it is not expected to produce an immediate economic or industrial impact. It will however have significant effects on the long term, both inside and outside the high energy physics community.
The main application of the project is the possibility to use the developed method for n-bar identification and energy reconstruction in all particle detectors in which an electromagnetic calorimeter either with good enough time resolution, and detectors for the measurement of the time-of-flight are available (for instance: old Babar and Belle experiments, and new apparata at future tau-charm factories, or the upgraded CMS with the new MIP timing detector). From past and present experiments a huge amount of data is already available. This means that, if the project is financed and the final goal reached, an enormous data set is already available without additional cost and investments in new experiments. We believe the latter is an additional asset of the project: the optimization of all the already available resources , the minimization of the cost and the negligible environmental impact, make this project an exciting challenge.
These large datasets will provide measurements with important consequences for astrophysics. As mentioned above, there is no

measurement of the neutron-hyperon interaction potential yet, which directly enters the equation of state of neutron stars. The completion of MANTRA will make such a measurement immediately feasible .

The studies needed for the development of MANTRA will also be useful outside of the High Energy Physics community. The current understanding of the anti-nucleon interaction is a limiting factor for the interpretation of some measured rare anti-nuclei fluxes in the primary cosmic rays, particularly anti-deuterons. Other collaborations have started to measure the anti-nuclei absorption on materials [27], and the validation performed on the Belle II and BESIII dataset will promptly contribute to this global effort.

The impact of our project outside of the particle physics community will come in the form of highly-trained, young researchers and professionals. The use of machine learning is now ubiquitous in industry and business. Professionals highly trained in their use are more and more requested, and such training can be provided by the academy. The budget requested for the development of the project is mainly used for personnel.To this purpose, we will take particular care to build their skills in the usage of the modern, python-based analysis tools that are becoming standard in the industry. Being part of large, international collaborations and being soon appointed to coordination roles within MANTRA, they will acquire the typical soft skills required for team working. Their abilities, both hard and soft, will be immediately spendable both inside and outside the academic world at the end of the project.
We also expect to supervise and train several undergraduate students, providing them with the same tools and skills during the two years of the project.

5. Financial aspects: costs and funding for each research unit

nº		Total cost (euro)	Co-funding (item A.1) (euro)	MUR funding (other items) (euro)
1.	GARZIA Isabella	64.300	0	64.300
2.	TAMPONI Umberto	122.910	27.752	95.158
3.	SPATARO Stefano Giovanni	133.494	43.246	90.248
	Total	**320.704**	**70.998**	**249.706**

6. Bibliography

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B.2

1. Scientific Curriculum of the Principal Investigator

PERSONAL DATA
Place and date of birth: Casarano (LE), September 21th, 1984
Work address: Dipartimento di Fisica e Scienze della Terra, University of Ferrara, via G. Saragat 1, 44122 Ferrara (Italy)
Telephone: +39 3204029917, +39 0532 974430

EDUCATION
2008 Master's Degree in Physics, University of Ferrara, Title of thesis "Study of charmonium chi_cj states in proton-anti-proton annihilation for the PANDA experiment at FAIR" (final mark: 110/110 cum laude)
2012 Ph.D in Particle Physics, Ferrara University, Title of thesis "Measurement of Collins asymmetries in inclusive production of pion pairs"

CAREER
Feb 2012-July 2012: fellowship at SLAC National Accelerator Center, Menlo Park, CA (USA)
Aug. 2012- Dec. 2016: Post-Doctoral Researcher, INFN-Ferrara
Jan. 2017 - Nov. 2019: Tenure track Associate Professor (RTDa) Physics Department, Ferrara University
2009 – now: Associate Researcher, Istituto Nazionale di Fisica Nucleare (INFN), Italy
Dec. 2019 – now: Tenure track Associate Professor (RTDb), Physics Depatment, Ferrara University

RESEARCH
2006 SLAC National Accelerator Center, summer student program and bachelor thesis on Limited Streamer Tubes for the BaBar experiment
2009-now: member of BaBar Collaboration
2007-2016: member of PANDA Collaboration
2013 – now: member of BESIII Collaboration
2015 – now: member of RD51 Collaboration
2020-now: member of the FCC-ee Collaboration

RESEARCH RESPONSIBILITIES
2013-2018: Data quality group expert for the Instrumented Flux Return for the BaBar Collaboration
Dec 2015 - now: coordinator of the "Inclusive Hadronic Particle Spectra" analysis working group for BaBar Collaboration
Dec 2016 - 2022: software coordinator of the "CGEM-IT project" for the BESIII Collaboration
Oct 2019 - Feb 2022: local responsible of the outreach project "Pint of Science-Ferrara"
Oct 2019 - now: Ferrara local coordinator for STRONG-2020 project
Sep 2021 – now: coordinator of the "Light Hadron Group" for the BESIII Collaboration
Jan 2022 – now: coordinator of "Comitato Italiano di Fisica" for the BESIII-IT Collaboration

OTHER RESPONSIBILITIES AND ACTIVITIES
- PANDA Coll: responsible of the implementation of the Forward Target Spectrometer (FTS); Study of the detector performances as a function of different FTS geometric configurations;
- BaBar and BESIII Collaborations: responsible of the analyses on polarized fragmentation functions (Collins functions) in e+e- annihilation (PRD90,052003(2014), PRD92,111101(R)(2015), PRL116, 042001 (2016)) for pion pairs, kaon pairs, and pion-kaon pairs;
- BESIII Coll.: responsible of the analysis jpsi --> omega eta' pipi for the search of the X(1835) state in the eta'pipi invariant mass distribution (PRD99,071101(2019)); responsible of an ongoing analysis on the search for Lepton Number Universality Violation in the Psi(2S)-->tau+tau- decay using BESIII data;
- 2015-2019: as member of the H2020-MSCA-RISE-2014 Project "BESIIICGEM - An innovative Cylindrical Gas Electron Multiplier Inner Tracker for the BESIII Spectrometer", I was responsible of the implementation and performance studies for the new CGEM-IT, as well as on the geometry implementation of the CGEM-IT in the official software of the BESIII Collaboration. The GEANT4 description of the three layers of the CGEM-IT was fully implemented and I

performed detailed studies on the impact of the material budget on the electromagnetic calorimeter of BESIII; Implementation and performances studies of the Hough transform algorithm for the tracking using the CGEM-IT and the Multilayer Drift Chamber detectors of the BESIII experiment;
- From 2021 - now: study of the muon detector geometry for FCC-ee. A first standalone GEANT4 parametric implementation was performed; It is ongoing the implementation of the muon detector geometry in the official FCC-ee software framework;
- Scientific secretaries for the International Conference of High Energy Physics - ICHEP2022 – Bologna, 6-13 July 2022;
- Conveners of the session “Equality, Diversity and Inclusion” - ICHEP2022 – Bologna, 6-13 July 2022;

PEER-REVIEWING
I have been a referee for the Physics Review D Journals and Modern Physics Letters A;
I’m in the review committee of several analysis for both BaBar and BESIII Collaborations.
Guest Editor for the open access journal Universe, special issue (ISSN 2218-1997)

ACADEMIC ACTIVITIES
2009: teaching support of the Course “General Physics” for “LT-Scienze della Terra”
2009-2011: teaching support of the Course “Mathematics” for LT in Physics
2009-2011: teaching support of the Course “Mathematics” for LT in Physics
2011 – 2014: teaching support of the Course “Laboratory of physics with statistical and informatics elements” for the LT in Physics – Ferrara University
2014 – 2015: laboratory assistant of the Course “Digital Electronics” and “Laboratory of physics with statistical and informatics elements” for the LT in Physics – Ferrara University
2016 – 2017: teaching support of the Course “Digital Electronics” and “Laboratory of physics with statistical and informatics elements” for the LT in Physics – Ferrara University
2017 – 2020: Professors of the Course “General Physics” for the LT in Mathematics – Ferrara University
2018 – 2021: Professors of the Course “Physics” for the LT in Physics – Ferrara University
2018 – now: Professors of the Course “Mathematics Methods for Economist” for the LT in Economia – Ferrara University
2020 – now: Lectures of the Course “General Physics - Thermodynamics” for the LT in Mathematics – Ferrara University
2021 – 2022: Lectures of the Course “Physics” for the LM in CTF – Ferrara University
2020 – 2022: Lectures of the Course “Physics” for the LM in Farmacia – Ferrara University
2021 – now: Professors of the Course “Physics” for the LT in Mathematics – Ferrara University

ACADEMIC RESPONSIBILITIES
2020-now: Member of the PhD Academic Board in Physics - Ferrara University
2022-now: Member of the “Consiglio di parità ” – Ferrara University
SUPERVISING ACTIVITIES
Supervisor of several Bachelor, Master thesis and "Borse di studio post laurea" at Ferrara University

OUTREACH
- From 2012 to 2016 I have performed several outreach activities in Elementary Schools introducing children to physics phenomena and laboratories activities;
- 2019: lecture on “Particle physics” under the “Corsi di Eccellenza” program at the Ferrara University for high school students
- April-May 2019: I have been one of the organizers of a series of scientific seminars organized through the “Comune di Bondeno”;
- In May 2018 I had a public seminar on particle physics under the international project “Pint of Science”,
- From 2019 to now: organization commettee of Pint of Science - Ferrara;
- From 2020 to now: I am one of the organizer of “Stage-Estivi” at the Ferrara University;
- From 2020 to now: involved in the organization of “Porte Aperte al Polo” in which the door of our laboratories are open for a full week to school and publics for guided tours.
- Participation to the INFN project “What Next: il future raccontato dai giovani” and coordinator of the thematic area “Data analysis and Computing” (2020 – now)
- Dec. 2021: organization of the seminar "Women in Science and Engineering: Issue, theories and new findings" done by Silvia Sara Canetto, PhD Full Professor - Colorado State University;
- Participation in the 2021 Editions of the “European Researchers' Night”.

INVETED SEMINARS
SLAC National Accelerator Center - July 2012: seminar on “Polarized fragmentation functions at BaBar – The Collins effect”
University of Adelaide – June 2012: “Fragmentation functions in e+e- annihilation – Collins asymmetry at BaBar”

AWARDS
Best PhD thesis in Physics of the 24th cycle – University of Ferrara
Menzione Speciale – SIF 2017, 103th Italian Conference in Trento for the communication “Recent results from the BESIII experiment”

WORKSHOP AND INTERNATIONAL CONFERENCES
Speaker/invited speaker to about 30 international conferences and workshops
Speaker/invited speaker to about 10 national conferences and workshops

BIBLIOMETRIC PARAMETERS (Source: Scopus – 16/03/2022):
- co-author of more than 500 papers in international journals with referees;
- author of the review “Transverse-momentum-dependent fragmentation functions in e+e- annihilation” published on Eur. Phys. J. A 52, 152 (2016). https://doi.org/10.1140/epja/i2016-16152-8
- more then 13.000 citations
- H-index: 56

2. Scientific Curriculum of the associated investigators

1. TAMPONI Umberto

Name: Umberto
Surname: Tamponi
Address : Via Pietro Giuria 1 Torino, 10125, Italy
Phone: (+39) 339 7874846
Homepage: www.to.infn.it/~tamponi

Research interest

Di-baryons and QCD exotics: Production of hyperons and QCD
loosely bound states, particularly in e^+e^- collisions.

Correlation functions and baryon-baryon interactions: two- and
three- body correlations in in e^+e^- collisions.

Heavy quarkonium physics: Bottomonium spectroscopy, rare decays and search
for new physics in leptonic decays.

Fast timing detectors: Development of detectors for time-of-flight and
Cherenkov-based applications.

Employment history

2017--present: Ricercatore (staff) at Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Torino.

2016--2017: Postdoctoral Fellow, University of Torino.
2013--2016: PhD student, University of Torino.
2011--2012: Collaborator, Department of physics, University of Torino.

Publication summary

Inspire-hep database:
Papers: 388 published, 458 citable
h-index: 113 (published papers only), 115 (citable papers)
Citations/paper: 102.5 (published papers only), 117.7 (citable papers)

ISI-Web of science database:
Papers: 385
h-index: 78
Citations/paper: 54.9

Grants and projects

2019--2021 Principal investigator of ComPID - A compact imaging device for particle identification.
Grant: INFN Grant nr. 19593 ("Attribuzione n. 73 Grant per attività formazione").
Budget: 20000 Euro.

Coordination roles

2021--present: Data Production coordinator, Belle II collaboration.
2016--present: Co-convener of the bottomonium working group, Belle II collaboration.

2020--2021: Deputy Data Production coordinator, Belle II collaboration.
2019--2021: Principal investigator of the ComPID project.
2018--2020: Belle II Calibration manager, Belle II collaboration.
2016--2019: TOP counter calibration manager, Belle II collaboration.
2016: TOP counter commissioning coordinator, Belle II collaboration.
2012: Responsible of the ϕ-symmetry calibration, CMS collaboration.

Visiting and adjuncts research positions

2020--present: Adjunct assistant professor at University of Mississippi, Oxford, MS (USA).
2018: Foreign visiting researcher at Kobayashi-Maskawa Institute, Nagoya, Japan.

Education

2016: Dr. of Physics and Astrophysics (PhD), University of Torino.

Thesis: Study of eta meson transitions from Upsilon(4S and Upsilon(5S) with the Belle experiment.

2011: Master of Physics of the fundamental interactions, University of Torino (110/110 cum laude).
Thesis: Search for eta transitions between bottomonium states at Belle

2009: Bachelor of Physics, University of Torino (103/110).
Thesis: Montecarlo studies of the $B^{\pm} \to l^{\pm}\nu$ decay with the SuperB experiment setup.

Teaching

2018-2020: Cherenkov detectors for particle and astroparticle physics, Doctoral school of natural science, University of Torino (teacher)

2014: Electromagnetism, BSc in physics, University of Torino (Teaching assistant).
2013: Introduction to general physics, BSc in agricultural sciences, University of Torino (Teacher)
2010--2011: Laboratory of mechanics and thermodynamics, BSc in physics, University of Torino (Teaching assistant)

Languages

Italian: Mothertongue
English: Fluent
French: Basic speaking, good reading

Invited seminars

Bottomonium at the Super-B factories: QCD and new physics,
University of Bonn, Bonn, June 6 2019.

New physics and other exotica in bottomonium annihilation
HEPHY, Vienna, January 15 2019.

Bottomonia: exploring low energy QCD with heavy quarks,
Kobayashi-Maskawa institute, Nagoya, November 26 2018.

Experimental quarkonia: an overview,
TD Lee Institute, Shanghai, October 31 2018.

Conventional quarkonia: few experimental ideas,
Galileo Galilei institute for theoretical physics, Firenze, March 13 2018.

New perspectives on the study of bottomonium physics in Belle II,
University of Torino, July 14 2015.

Hyperon production in Y(nS) annihilations at Belle,
University of Torino, February 16 2015.

Experimental techniques for quarkonium physics at the Belle experiment,

HASPECT week, Genova, Italy, May 21 2014.

Research resumee

The research activity is focused on the experimental investigation of non-perturbative quantum-chromodynamics in the bottomonium and hyperon sector, and on the construction of Cherenkov detectors for particle identification.

2011-present: Nuclei and Hyperons production at e^+e^- colliders
Study of the production of hyperons in $\Upsilon(nS) \to ggg$ annihilation at the Belle experiment, with a focus on the measurement of hyperon-hyperon correlation functions.
Study of the anti-deuteron production from $\Upsilon(nS)$ both at the Belle and Belle II experiments. Currently working on the reconstruction of anti-deuteron with the Belle II experiment, and on the study of the production of bound states in $\Upsilon(nS)$ annihilations.

2011-present: Heavy quarkonium physics at e^+e^- colliders.
Study of the single-meson transitions among bottomonium states as a probe of the heavy quark spin symmetry and the role of light degrees of freedom in the heavy quarkonium. Focus on the η meson transition, with the first observation of $\Upsilon(4S) \to \eta h_b(1P)$ and subsequent high precision measurement of the $\eta_b(1S)$ and $h_b(1P)$ resonance parameters.
Since 2018, search for new physics signatures in bottomonium decays. Study of the lepton universality using the $\Upsilon(nS) \to \tau^+\tau^-, \mu^+\mu^-$ processes and search for the rare decays $\chi_{b0}(nP) \to l^+l^-$ and $\Upsilon(1S) \to invisible$.
Appointed co-convener of the bottomonium working group of the Belle II collaboration in 2016. Currently working on the analysis of the data taken by the Belle and Belle II experiments.

2013-present: Construction of the TOP sub-detector for the Belle II experiment.
Worked on the construction and commissioning of the TOP time-of-propagation detector, a novel type of Cherenkov counter for particle identification based on total internal reflection.
Took part in the design, prototyping and construction of a laser-based time calibration system, including the simulation of the light propagation inside single-mode and multi-mode optical fibers, the optimization of the coupling efficiency between the different optical fibers.
Assumed the role of run coordinator for the full detector commissioning during and after the installation of the TOP detector.
Appointed calibration coordinator of the TOP calibration during the first phase of the experiment in 2016, and working on calibration and performance optimization since then.

2019-present: Development of novel PID detectors.
Simulation and design of light Cherenkov and time-of-flight detectors for the anti-nuclei identification in the primary cosmic rays. Principal investigator of ComPID project for the design of novel particle identification detector. Currently designing a time-of-flight counter for the Belle II upgrade.

Selected Talks

30th International Symposium on Lepton Photon Interactions at High Energies
(Lepton-Photon 2021),
Hadron physics - experimental review: spectroscopy and exotics (plenary).

16th International Workshop on Meson Physics (Meson2021),
Quarkonium at Belle II (plenary).

Light Cone 2019 - QCD on the light cone: from hadrons to heavy ions (LC 2019),
Exotic and Conventional Quarkonium Physics Prospects at Belle II (plenary).

54th Rencontres de Moriond, QCD session (MoriondQCD 2019),
Status and first results of the Belle II experiment (plenary).

104th Congresso SIF, Rende (SIF 2018)
Status and first results of the Belle II experiment (invited).

The 10th International Workshop on Ring Imaging Cherenkov Detectors (RICH 2018)
The TOP counter of Belle II: status and first results} (plenary)}.

XXVI International Workshop on Deep-Inelastic Scattering and Related Topics (DIS 2018),
Exotic and conventional bottomonium studies at Belle II.

XVII International Conference on Hadron Spectroscopy (Hadron 2017),
Plans for exotic bottomonium-like states at Belle II.

XXV International Workshop on Deep-Inelastic Scattering and Related Topics (DIS 2017),
Exotic quarkonium-like states and spectroscopy at Belle.

Non-Perturbative QCD workshop (NPQCD 2017),
Mesons and tetraquarks (invited, plenary).

XVI International Conference on Hadron Spectroscopy (Hadron 2015),
Bottomonium physics above the $B\bar{B}$ threshold with the Belle experiment.

X Quarkonium Working Group (\textbf{QWG2014}),
Bottomonium(-like) Spectroscopy and transitions at Belle (plenary).

XI Quark Confinement and the Hadron Spectrum (QCHS 2014),
Recent results on Bottomonium(like) at Belle.

XXII International Workshop on Deep-Inelastic Scattering and Related Topics (DIS2014),
Spin effects in bottomonium.

IX Quarkonium Working Group (QWG2013}),
Bottomonium decays at Belle} (plenary).

Rencontres de Moriond - QCD (Moriond-QCD 2013),
Baryons in B decays and e^+e^- collisions (plenary).

XX International Workshop on Deep-Inelastic Scattering and Related Topics (DIS2012),
Bottomonium(-like) states at Belle.

International Europhysics Conference on High Energy Physics (EPS-HEP2011),

Study of rare $\Upsilon(2S)$ transitions to charmonia and lower bottomonia with the Belle detector.

2. SPATARO Stefano Giovanni

ORCID: http://orcid.org/0000-0001-9601-405X

Bibliometric Parameters (28/03/2022)
- Web Of Science
Publications: 476
Citations: 9452
h-index: 47
- Scopus
Publications: 535
Citations: 11178
h-index: 52

Education
2002 Master Degree in Physics -cum laude – Università di Catania
2006 PhD in Physics cum laude - Università di Catania

Career
2006 Post-Doc - II Physichalisches Institut – Universität Gießen (DE)
2008 Researcher at the Physics Department, Universitá di Torino - 02/A1, FIS/01
2016 Associate Professor at the Physics Department, Universitá di Torino - 02/A1, FIS/01

Research
HADES (2000 – 2017)
The High Acceptance Di-Electron Spectrometer, installed at the GSI Laboratory (DE), is an experiment to study the production of hadrons in nuclear collisions at 1-2A GeV.
I have characterized the TOF detector, developing software algorithms for time calibration, alignment and particle identification. I have analyzed C+C@1-2A GeV data, verifying the dilepton invariant mass distribution and the hadron production.
I was involved in the simulation and data analysis of p+p @ 2.2 GeV reactions; i.e. the study of a first level trigger, the development of algorithms to reconstruct the start time of the reaction and to identify particles, the characterization of the tracking algorithms, the reconstruction of pp->ppeta and pp->pppi0 channels for the measurement of cross section, electromagnetic form factors and helicity angles.
I dealt with data analysis of p+p @ 3.5 GeV collisions, including the study of the direct decays rho/omega->e+e- and the hyperon production. I have also monitored and evaluated the performances of the 2nd level trigger during my staying at Giessen University. More recently I worked for the development and maintenance of the online monitoring software for the beam time, and for the calibration of the diamond START detector.

PANDA (from 2006)
The PANDA spectrometer will be built at the facility FAIR and will study antiproton collisions (from 1 GeVc up to 15 GeV/c) against protons or heavy nuclei.
I was higly involved in software developments for the simulation and data analysis:
• I was responsible of the event generators and of the geometry of passive structures;
• I was responsible of the software for the electromagnetic calorimeter (EMC); I have implemented the geometry, parts of the reconstruction code and particle identification algorithms;
• I was responsible of the muon tracker software package; I implemented the geometry, the tracking code and the muon identification algorithm; I was editor of the TDR of the Muon Detector;
• I worked for the particle tracking, maintaining the pattern recognition and fit code, and coordinating the software and computing activities for the realization of the Central Tracker Technical Design Report;
• I was responsible of the software for particle identification, developing algorithms based on Bayesian approach and on Multivariate Analysis;
• I have done studies on physics benchmark channels, analyzing charmonium decay chains and Drell-Yan processes.
• I have worked for the realization of a Technical Design Report of the FAIR computing, evaluating computing requirements for PANDA and investigating possible computing models.
I had the following responsibility duties:

• 2008-2016: coordinator of the particle identification software;
• 2009-2016, 2022-now: member of the Computing Committee;
• 2010-2012: deputy Computing Coordinator;
• 2011-2016: PandaGrid exploitation manager.
• 2012-2016: Computing Coordinator, member of the Executive Board, the Technical Board, the Physics Board, the Finance Board;
• 2013-now: member of the Collaboration Board, from 2016 as local responsible of Torino University;
• 2014-2016: member of the Common task Drafting Committee
* 2021-now: member of the Publication Committee

BES3 (from 2008)
The BES3 experiment is installed in Beijing (RPC), studying e+e- collisions in the energy sqrt(s) = 2–4.9 GeV with high luminosity.
I have followed data analyses focused on proton and neutron electromagnetic form factors, by the study of the ppbar and nnbar channels. I have followed the analysis for the proposals of the charmonium resonances scan, to measure the phase angle between the strong and the electromagnetic interactions, and I am currently following the analyses of such data. I have followed analyses on the hyperon production for the measurements of cross sections, branching ratios and polarization.
I have contributed in the composition of the Conceptual Design Report of the CGEM-IT detector, for the software part, and I am following the software activities correlated to digitization, reconstruction, global tracking, analysis of benchmark channels and analysis of the cosmics data from the test setup currently placed in Beijing.
I have the following responsibility duties:
Since 2018 I am co-convener of the CGEM Software working group.
Since 2021 I am member of the Publication Committee
I am internal referee for spectroscopy papers, local coordinator of the “Collaboration Wide Review” of the Torino group.

BELLE-II (from 2016)
The BELLE-II spectrometer studies e+e- collisions in the bottomonium energy range in Tsukuba (JP).
I am mainly involved in software and analysis activities.
I have been member of the Skim group as Bottomonium liaison, responsible for the algorithms to select events containing bottomonium states; I developed skims for the exclusive selection of Y(1S), Y(2S) and eta_b states, and for the inclusive selection of eta_b and h_b.
I am member of the tracking software group, focusing on the development and characterisation of the track fitting package, based on Kalman Filter and Deterministic Annealing Filter. I have characterised the track fitting performance under different mass hypotheses, in terms of resolution, CPU time and required disk space, compared to the original single pion hypothesis, to decided finally the usage of three hypotheses in the standard fitting (pi, K, p) of the global reconstruction. I have studied the electron reconstruction and the effects of bremsstrahlung on energy loss, as well as the shell and density corrections in the evaluation of the collisional energy loss (de/dx) for charged particles.
I am member of the Bottomonium working group, and I follow analyses aimed to the search of exotic states and their decays, with a focus on energies higher than Y(4S), as well as bottomonium decays at lower energies.

Others
I supervised more than 20 (BSc and MSc) thesis, 5 PhD thesis and 4 Post-Doc.
I have been local organizer of the “QWG 2019 – The 13th International Workshop on Heavy Quarkonium”, 137 registered participants.

Conferences
2005 Bormio – “XLIII International Winter Meeting on Nuclear Physic” - Talk “pp collisions at 2.2GeV with HADES”
2006 - Krakow (PL) - “9th International Workshop on Meson Production, Properties and Interaction (MESON2006)” - Talk “eta meson reconstruction in pp reactions at 2.2GeV with HADES”
2007 - Gießen (DE) - “DPG (Deutsche Physikalisches Gesellschaft) Tagung 2007” – Talk “Simulation and event reconstruction inside the PandaRoot framework”
2007 – Victoria (CA) - “International Conference on Computing in High Energy and Nuclear Physics (CHEP2007)” - Talk “Simulation and Event Reconstruction inside the PandaRoot Framework”
2007 – Frascati - “XII International Conference on Hadron Spectroscopy (HADRON’07)” - Talk “Dielectron Spectroscopy at 1-2 AGeV with HADES”

2008 - Darmstadt (DE) - “DPG (Deutsche Physikalisches Gesellschaft) Tagung 2008” - Talk “Exclusive Reconstruction in pp Reactions at 3.5 GeV with HADES”
2009 - Bochum (DE) - “European Nuclear Physics Conference 2009 / DPG (Deutsche Physikalisches Gesellschaft) Tagung 2009” - Talk “The PandaRoot framework for simulation and analysis”
2010 - Taipei (TW) - “International Conference on Computing in High Energy and Nuclear Physics (CHEP2010)” - Talk “The PandaRoot Framework for Simulation, Reconstruction and Analysis”
2011 - Como - “13th ICATPP Conference on Astroparticle, Particle, Space Physics and Detectors for Physics Applications” - Invited Talk “Reconstruction of pbarp events in PANDA”
2011 - Frascati - ”STORI'11 - The 8th International Conference on Nuclear Physics at Storage Rings” - Invited Talk “Recent BESIII Results”
2012 - NYC (USA) “International Conference on Computing in High Energy and Nuclear Physics (CHEP2012)” - Talk “Event Reconstruction in the PandaRoot framework”
2012 - Rauischholzhausen (DE) - “HGS-HIRe Lecture Week on Hadron Physics” – Invited seminars (8 hours + student assistance) “Physics at PANDA”
2013 - Amsterdam (NL) - “International Conference on Computing in High Energy and Nuclear Physics (CHEP2013)” - Invited Key note “Designing the Computing for the Future Experiments”
2014 - Frankfurt (DE) - “Fifth International Workshop for Future Challenges in Tracking and Trigger Concepts” - Invited Talk “Computing and Reconstruction in PANDA”
2014 - Catania - “Workshop della Commissione Calcolo e Reti dell’INFN” - Invited Talk “Computing model di Panda: stato e prospettive”
2015 - Paphops (CY) - “Electromagnetic Interactions with Nucleons and Nuclei (EINN2015)” – Invited Talk “Spectroscopy in the charm range: from BESIII to PANDA”
2016 - San Francisco (USA) - “International Conference on Computing in High Energy and Nuclear Physics (CHEP2016)” - Poster “Customization of the general fitting tool genfit2 in PandaRoot”
2018 - Bormio – “LVI International Winter Meeting on Nuclear Physic” – Invited Lecture “Hadron Physics: selected topics”
2018 - Sofia (BG) - “International Conference on Computing in High Energy and Nuclear Physics (CHEP2018)” - Talk “Track Fitting for the BELLE II Experiment”
2018 - Bogotà (CO) - “XXXVIII international symposium on Physics in Collision (PIC2018)” - Invited talk “Spectroscopy of exotic states”
2019 - Quy Nhon (VN) - “15th Rencontres du Vietnam: Perspectives in Hadron Physics” - Invited talk “Quarkonium Physics Prospects at Belle II”
2020 - Bormio – “LVIII International Winter Meeting on Nuclear Physic” – Invited Talk “Exotic Results from BESIII”

3. Main Principal Investigator's scientific publications (Max. 20)

1. Ablikim M., Achasov M. N., Adlarson P., Ahmed S., Albrecht M., Aliberti R., Amoroso A., An Q., Anita, Bai X. H., Bai Y., Bakina O., Baldini Ferroli R., Balossino I., Ban Y., Begzsuren K., Berger N., Bertani M., Bettoni D., Bianchi F.,...(2021). Observation of a Near-Threshold Structure in the K+ Recoil-Mass Spectra in e+e- →k+ (Ds- D∗0+ Ds∗- D0). PHYSICAL REVIEW LETTERS, vol. 126, p. 102001, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.126.102001 - **Articolo in rivista**

2. Ablikim, M., Achasov, M. N., Adlarson, P., Ahmed, S., Albrecht, M., Aliberti, R., Amoroso, A., An, Q., Lavania, Anita, Bai, X. H.,...(2021). Oscillating features in the electromagnetic structure of the neutron. NATURE PHYSICS, vol. 17, p. 1200-1204, ISSN: 1745-2473, doi: 10.1038/s41567-021-01345-6 - **Articolo in rivista**

3. Ablikim M., Achasov M. N., Adlarson P., Ahmed S., Albrecht M., Alekseev M., Amoroso A., An F. F., An Q., Anita, Bai Y., Bakina O., Ferroli R. B., Balossino I., Ban Y., Begzsuren K., Bennett J. V., Berger N., Bertani M., Bettoni D.,...(2020). Measurement of Proton Electromagnetic Form Factors in e+e-→p $\bar{p}$ in the Energy Region 2.00-3.08 GeV. PHYSICAL REVIEW LETTERS, vol. 124, p. 042001, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.124.042001 - **Articolo in rivista**

4. Ablikim M., Achasov M. N., Adlarson P., Ahmed S., Albrecht M., Alekseev M., Amoroso A., An F. F., An Q., Bai Y., Bakina O., Ferroli R. B., Balossino I., Ban Y., Begzsuren K., Bennett J. V., Berger N., Bertani M., Bettoni D., Bianchi F.,...(2020). Measurement of the Cross Section for e+e- → Ξ- $\bar{\Xi}$ + and Observation of an Excited Ξ

Baryon. PHYSICAL REVIEW LETTERS, vol. 124, p. 032002, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.124.032002 - **Articolo in rivista**

5. Ablikim M., Achasov M. N., Adlarson P., Ahmed S., Albrecht M., Alekseev M., Amoroso A., An F. F., An Q., Bai Y., Bakina O., Ferroli R. B., Ban Y., Begzsuren K., Bennett J. V., Berger N., Bertani M., Bettoni D., Bianchi F., Biernat J.,...(3872) →ωJ /ψ. PHYSICAL REVIEW LETTERS, vol. 122, p. 232002-1-232002-8, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.122.232002 - **Articolo in rivista**

6. Ablikim, M., Achasov, M. N., Ahmed, S., Albrecht, M., Alekseev, M., Amoroso, A., An, F. F., An, Q., Bai, J. Z., Bai, Y.,...(2018). Precision Measurement of the e+e- → Λc+ Λ c- Cross Section Near Threshold. PHYSICAL REVIEW LETTERS, vol. 120, p. 132001-1-132001-8, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.120.132001 - **Articolo in rivista**

7. Ablikim, M, Achasov, M. N., Ai, X. C., Albayrak, O., Albrecht, M., Ambrose, D. J., Amoroso, A., An, F. F., An, Q., Bai, J. Z.,...(3900). PHYSICAL REVIEW LETTERS, vol. 119, p. 072001-1-072001-7, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.119.072001 - **Articolo in rivista**

8. Ablikim, M., Achasov, M. N., Ahmed, S., Ai, X. C., Albayrak, O., Albrecht, M., Ambrose, D. J., Amoroso, A., An, F. F., An, Q.,...(2017). Evidence of Two Resonant Structures in e+e- →π+π-hc. PHYSICAL REVIEW LETTERS, vol. 118, p. 092002-1-092002-8, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.118.092002 - **Articolo in rivista**

9. Ablikim, M., Achasov, M. N., Ahmed, S., Ai, X. C., Albayrak, O., Albrecht, M., Ambrose, D. J., Amoroso, A., An, F. F., An, Q.,...(2016). Observation of an Anomalous Line Shape of the eta 'pi(+)pi(-) Mass Spectrum near the p(p)over-bar Mass Threshold in J/psi -> gamma eta 'pi(+)pi(-). PHYSICAL REVIEW LETTERS, vol. 117, p. 042002-1-042002-7, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.117.042002 - **Articolo in rivista**

10. Ablikim, M., Achasov, M. N., Ai, X. C., Albayrak, O., Albrecht, M., Ambrose, D. J., Amoroso, A., An, F. F., An, Q., Bai, J. Z.,...(2016). Measurement of Azimuthal Asymmetries in Inclusive Charged Dipion Production in e+e- Annihilations at root s =3.65 GeV. PHYSICAL REVIEW LETTERS, vol. 116, p. 042001-1-042001-7, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.116.042001 - **Articolo in rivista**

11. Ablikim, M., Achasov, M. N., Ai, X. C., Albayrak, O., Albrecht, M., Ambrose, D. J., Amoroso, A., An, F. F., An, Q., Bai, J. Z.,...(2016). Measurements of Absolute Hadronic Branching Fractions of the Λc+ Baryon. PHYSICAL REVIEW LETTERS, vol. 116, p. 052001-1-052001-7, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.116.052001 - **Articolo in rivista**

12. Garzia, Isabella, Giordano, Francesca (2016). Transverse-momentum-dependent fragmentation functions in e+e-annihilation. THE EUROPEAN PHYSICAL JOURNAL. A, HADRONS AND NUCLEI, vol. 52, p. 152, ISSN: 1434-6001, doi: 10.1140/epja/i2016-16152-8 - **Articolo in rivista**

13. Ablikim M., Achasov M. N., Ai X. C., Albayrak O., Albrecht M., Ambrose D. J., Amoroso A., An F. F., An Q., Bai J. Z., Baldini Ferroli R., Ban Y., Bennett D. W., Bennett J. V., Bertani M., Bettoni D., Bian J. M., Bianchi F., Boger E., Boyko I.,...(3900)(0) in e(+)e(-) -> pi(0)pi(0) J/Psi. PHYSICAL REVIEW LETTERS, vol. 115, p. 112003-1-112003-7, ISSN: 1079-7114, doi: 10.1103/PhysRevLett.115.112003 - **Articolo in rivista**

14. Ablikim, M., Achasov, M. N., Ai, X. C., Albayrak, O., Albrecht, M., Ambrose, D. J., Amoroso, A., An, F. F., An, Q., Bai, J. Z.,...(2015). Study of e+e- -->omega chi_cJ at center of mass energies from 4.21 to 4.42 GeV. PHYSICAL REVIEW LETTERS, vol. 114, p. 092003-1-092003-7, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.114.092003 - **Articolo in rivista**

15. Ablikim, M., Achasov, M. N., Ai, X. C., Albayrak, O., Albrecht, M., Ambrose, D. J., Amoroso, A., An, F. F., An, Q., Bai, J. Z.,...(2015). Observation of a Neutral Structure near the D D ¯ ∗ Mass Threshold in e+e- → (D D ¯ ∗)0π0 at s =4.226 and 4.257 GeV. PHYSICAL REVIEW LETTERS, vol. 115, p. 222002-1-222002-7, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.115.222002 - **Articolo in rivista**

16. Ablikim, M., Achasov, M. N., Ai, X. C., Albayrak, O., Albrecht, M., Ambrose, D. J., Amoroso, A., An, F. F., An, Q., Bai, J. Z.,...(3885)(-/+) in e(+)e(-) -> pi(+/-) (D(D)over-bar*)(-/+) with double D tag. PHYSICAL REVIEW D, PARTICLES, FIELDS, GRAVITATION, AND COSMOLOGY, vol. 92, p. 092006-1-092006-15, ISSN: 1550-7998, doi: 10.1103/PhysRevD.92.092006 - **Articolo in rivista**

17. Ablikim, M., Achasov, M. N., Ai, X. C., Albayrak, O., Albrecht, M., Ambrose, D. J., Amoroso, A., An, F. F., An,

Q., Bai, J. Z....(4020)0. PHYSICAL REVIEW LETTERS, vol. 113, p. 212002, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.113.212002 - **Articolo in rivista**

18. J. .P. Lees, V. Poireau, V. Tisserand, E. Grauges, A. Palano, G. Eigen, B. Stugu, D. .N. Brown, L. .T. Kerth, Y.u. .G. Kolomensky, M. .J. Lee, G. Lynch, H. Koch, T. Schroeder, C. Hearty, T. .S. Mattison, J. .A. McKenna, R. .Y. So, A. Khan, V. .E. Blinov...(2014). Antideuteron production in ϒ(nS) decays and in e+e−→qqbar at √s≈10.58 GeV. PHYSICAL REVIEW D, PARTICLES, FIELDS, GRAVITATION, AND COSMOLOGY, vol. 89, p. 111102-1-111102-8, ISSN: 1550-7998, doi: 10.1103/PhysRevD.89.111102 - **Articolo in rivista**

19. J. P. Lees, V. Poireau, V. Tisserand, E. Grauges, A. Palano, G. Eigen, B. Stugu, D. N. Brown, L. T. Kerth, Y.u. G. Kolomensky, M. J. Lee, G. Lynch, H. Koch, T. Schroeder, C. Hearty, T. S. Mattison, J. A. McKenna, R. Y. So, A. Khan, V. E. Blinov...(2013). Search for CP Violation in B^{0}- B[over ¯]^{0} Mixing Using Partial Reconstruction of B^{0}→D^{*-}Xℓ^{+}ν_{ℓ} and a Kaon Tag. PHYSICAL REVIEW LETTERS, vol. 111, p. 1-7, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.111.101802 - **Articolo in rivista**

20. J. P. Lees, V. Poireau, V. Tisserand, J. Garra Tico, E. Grauges, A. Palano, G. Eigen, B. Stugu, D. N. Brown, L. T. Kerth, Y.u. G. Kolomensky, G. Lynch, H. Koch, T. Schroeder, D. J. Asgeirsson, C. Hearty, T. S. Mattison, J. A. McKenna, R. Y. So, A. Khan...(2013). Branching fraction measurement of B^{+}→ωℓ^{+}ν decays. PHYSICAL REVIEW D, PARTICLES, FIELDS, GRAVITATION, AND COSMOLOGY, vol. 87, p. 032004, ISSN: 1550-7998, doi: 10.1103/PhysRevD.87.032004 - **Articolo in rivista**

4. Main scientific publications of the associated investigators (Max. 20, for each research unit)

1. **TAMPONI Umberto**

1. Jia S, Shen CP, Adachi I, Aihara H, Al Said S, Asner DM, Atmacan H, Aushev T, Ayad R, Babu V, Behera P, Belous K, Bennett J, Bessner M, Bhardwaj V, Bhuyan B, Bilka T, Bobrov A, Bodrov D, Bonvicini G...(2022). Search for a Light Higgs Boson in Single-Photon Decays of Upsilon(1S) Using (SIC)(2S) -> pi(+) pi(-) Upsilon(1S) Tagging Method. PHYSICAL REVIEW LETTERS, vol. 128, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.128.081804 - **Articolo in rivista**
2. Abudinen F, Adachi I, Aihara H, Akopov N, Aloisio A, Ameli F, Ky NA, Asner DM, Aushev T, Aushev V, Babu V, Baehr S, Bahinipati S, Bambade P, Banerjee S, Bansal S, Baudot J, Becker J, Behera PK, Bennett JV...(2020). Search for Axionlike Particles Produced in e(+)e(-) Collisions at Belle II. PHYSICAL REVIEW LETTERS, vol. 125, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.125.161806 - **Articolo in rivista**
3. Guan Y, Vossen A, Adachi I, Adamczyk K, Ahn JK, Aihara H, Al Said S, Asner DM, Atmacan H, Aulchenko V, Aushev T, Ayad R, Babu V, Badhrees I, Bakich AM, Bansal V, Behera P, Beleno C, Berger M, Bhardwaj V...(2019). Observation of Transverse Lambda/(Lambda)over-bar Hyperon Polarization in e(+)e(-) Annihilation at Belle. PHYSICAL REVIEW LETTERS, vol. 122, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.122.042001 - **Articolo in rivista**
4. Mizuk R, Bondar A, Adachi I, Aihara H, Asner DM, Aulchenko V, Aushev T, Ayad R, Badhrees I, Bahinipati S, Bakich AM, Behera P, Beleno C, Berger M, Bhardwaj V, Bilka T, Biswal J, Bozek A, Bracko M, Browder TE...(2019)220 - **Articolo in rivista**
5. Guido E, Mussa R, Tamponi U, Aihara H, Said S, Asner DM, Atmacan H, Aulchenko V, Aushev T, Ayad R, Babu V, Badhrees I, Bakich AM, Bansal V, Behera P, Berger M, Bhardwaj V, Biswal J, Bondar A, Bonvicini G...(2018). Observation of Upsilon(4S) -> eta 'Upsilon(1S). PHYSICAL REVIEW LETTERS, vol. 121, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.121.062001 - **Articolo in rivista**
6. Tamponi U, Guido E, Mussa R, Adachi I, Aihara H, Al Said S, Asner DM, Atmacan H, Aulchenko V, Aushev T, Ayad R, Babu V, Badhrees I, Bakich AM, Bansal V, Barberio E, Behera P, Berger M, Bhardwaj V, Bhuyan B...(2018). Inclusive study of bottomonium production in association with an eta meson in e(+)e(-) annihilations near Upsilon(5S). THE EUROPEAN PHYSICAL JOURNAL. C, PARTICLES AND FIELDS, vol. 78, ISSN: 1434-6044, doi: 10.1140/epjc/s10052-018-6086-4 - **Articolo in rivista**
7. Yelton J, Adachi I, Ahn JK, Aihara H, Al Said S, Asner DM, Atmacan H, Aushev T, Ayad R, Babu V, Badhrees I, Bahinipati S, Bakich AM, Bansal V, Beleno C, Berger M, Bhardwaj V, Bhuyan B, Bilka T, Biswal J...(2018). Observation of an Excited Omega(-) Baryon. PHYSICAL REVIEW LETTERS, vol. 121, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.121.052003 - **Articolo in rivista**
8. Yelton J, Adachi I, Aihara H, Al Said S, Asner DM, Aulchenko V, Aushev T, Ayad R, Aziz T, Babu V, Bakich AM, Bansal V, Barberio E, Behera P, Berger M, Bhardwaj V, Bhuyan B, Biswal J, Bobrov A, Bozek A...(2018). Observation of excited Omega(c) charmed baryons in e(+)e(-) collisions. PHYSICAL REVIEW D, vol. 97, ISSN: 2470-0010, doi: 10.1103/PhysRevD.97.051102 - **Articolo in rivista**
9. Guido E, Mussa R, Tamponi U, Adachi I, Aihara H, Al Said S, Asner DM, Aulchenko V, Aushev T, Ayad R, Badhrees I,

Bakich AM, Bansal V, Behera P, Bhardwaj V, Bhuyan B, Biswal J, Bobrov A, Bondar A, Bozek A...(2017). Study of eta and dipion transitions in Upsilon(4S) decays to lower bottomonia. PHYSICAL REVIEW D, vol. 96, ISSN: 2470-0010, doi: 10.1103/PhysRevD.96.052005 - **Articolo in rivista**

10. Garmash A, Abdesselam A, Adachi I, Aihara H, Asner DM, Aushev T, Ayad R, Aziz T, Babu V, Badhrees I, Bakich AM, Behera P, Bhardwaj V, Bhuyan B, Bobrov A, Bondar A, Bonvicini G, Bozek A, Bracko M, Browder TE...(2016). Observation of Z(b)(10610) and Z(b)(10650) Decaying to B Mesons. PHYSICAL REVIEW LETTERS, vol. 116, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.116.212001 - **Articolo in rivista**
11. Garmash A, Bondar A, Kuzmin A, Abdesselam A, Adachi I, Aihara H, Al Said S, Asner DM, Aulchenko V, Aushev T, Ayad R, Bakich AM, Bala A, Bhardwaj V, Bobrov A, Bonvicini G, Bozek A, Bracko M, Browder TE, Cervenkov D... (2016). Amplitude analysis of e(+)e(-) -> Upsilon(nS)pi(+)pi(-) at root s=10.866 GeV. PHYSICAL REVIEW D, vol. 91, ISSN: 2470-0010, doi: 10.1103/PhysRevD.91.072003 - **Articolo in rivista**
12. Mizuk R, Bondar A, Adachi I, Aihara H, Asner DM, Atmacan H, Aulchenko V, Aushev T, Ayad R, Badhrees I, Bakich AM, Barberio E, Behera P, Bhardwaj V, Bhuyan B, Biswal J, Bobrov A, Bonvicini G, Bozek A, Bracko M...(2016). Energy Scan of the e(+)e(-) -> h(b)(nP)pi(+)pi(-) (n=1, 2) Cross Sections and Evidence for Upsilon(11020) Decays into Charged Bottomoniumlike States. PHYSICAL REVIEW LETTERS, vol. 117, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.117.142001 - **Articolo in rivista**
13. Aad G, Abbott B, Abdallah J, Abdinov O, Aben R, Abolins M, AbouZeid OS, Abramowicz H, Abreu H, Abreu R, Abulaiti Y, Acharya BS, Adamczyk L, Adams DL, Adelman J, Adomeit S, Adye T, Affolder AA, Agatonovic-Jovin T, Aguilar-Saavedra JA...(2015). Combined Measurement of the Higgs Boson Mass in pp Collisions at root s=7 and 8 TeV with the ATLAS and CMS Experiments. PHYSICAL REVIEW LETTERS, vol. 114, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.114.191803 - **Articolo in rivista**
14. Tamponi U, Mussa R, Abdesselam A, Aihara H, Arinstein K, Asner DM, Atmacan H, Aushev T, Ayad R, Badhrees I, Bakich AM, Barberio E, Bhardwaj V, Bhuyan B, Biswal J, Bondar A, Bonvicini G, Bozek A, Bracko M, Browder TE... (2015). First Observation of the Hadronic Transition Upsilon(4S) -> eta h(b)(1P) and New Measurement of the h(b)(1P) and eta(b)(1S) Parameters. PHYSICAL REVIEW LETTERS, vol. 115, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.115.142001 - **Articolo in rivista**
15. Chilikin K, Mizuk R, Adachi I, Aihara H, Al Said S, Arinstein K, Asner DM, Aulchenko V, Aushev T, Ayad R, Aziz T, Bakich AM, Bansal V, Bondar A, Bonvicini G, Bozek A, Bracko M, Browder TE, Cervenkov D, Chekelian V...(2014). Observation of a new charged charmoniumlike state in B-0 -> J/psi K- pi(+) decays. PHYSICAL REVIEW D, PARTICLES, FIELDS, GRAVITATION, AND COSMOLOGY, vol. 90, ISSN: 1550-7998, doi: 10.1103/PhysRevD.90.112009 - **Articolo in rivista**
16. Kato Y, Iijima T, Adachi I, Aihara H, Asner DM, Aushev T, Bakich AM, Bala A, Ban Y, Bhardwaj V, Bhuyan B, Bobrov A, Bonvicini G, Bozek A, Bracko M, Browder TE, Cervenkov D, Chekelian V, Chen A, Cheon BG...(2014). Search for doubly charmed baryons and study of charmed strange baryons at Belle. PHYSICAL REVIEW D, PARTICLES, FIELDS, GRAVITATION, AND COSMOLOGY, vol. 89, ISSN: 1550-7998, doi: 10.1103/PhysRevD.89.052003 - **Articolo in rivista**
17. Chilikin K, Mizuk R, Adachi I, Aihara H, Arinstein K, Asner DM, Aulchenko V, Aushev T, Aziz T, Bakich AM, Bala A, Bhardwaj V, Bhuyan B, Bondar A, Bonvicini G, Bozek A, Bracko M, Brodzicka J, Browder TE, Chekelian V...(4430)(+). PHYSICAL REVIEW D, PARTICLES, FIELDS, GRAVITATION, AND COSMOLOGY, vol. 88, ISSN: 1550-7998, doi: 10.1103/PhysRevD.88.074026 - **Articolo in rivista**
18. Kim BH, Olsen SL, Adachi I, Aihara H, Asner DM, Aulchenko V, Bay A, Belous K, Bhuyan B, Bonvicini G, Bozek A, Bracko M, Browder TE, Chekelian V, Chen A, Cheon BG, Chilikin K, Chistov R, Cho IS, Cho K...(2013). Search for an H-Dibaryon with a Mass near 2m(Delta) in Y(1S) and Y(2S) Decays. PHYSICAL REVIEW LETTERS, vol. 110, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.110.222002 - **Articolo in rivista**
19. Liu ZQ, Shen CP, Yuan CZ, Adachi I, Aihara H, Asner DM, Aulchenko V, Aushev T, Aziz T, Bakich AM, Bala A, Belous K, Bhardwaj V, Bhuyan B, Bischofberger M, Bondar A, Bonvicini G, Bozek A, Bracko M, Brodzicka J...(2013). Study of e(+)e(-) -> pi(+)pi(-) J/psi and Observation of a Charged Charmoniumlike State at Belle. PHYSICAL REVIEW LETTERS, vol. 110, ISSN: 0031-9007, doi: 10.1103/PhysRevLett.110.252002 - **Articolo in rivista**
20. Tamponi U, Mussa R, Adachi I, Aihara H, Asner DM, Aulchenko V, Aushev T, Bakich AM, Barrett M, Bhuyan B, Bondar A, Bozek A, Bracko M, Browder TE, Chen A, Chen P, Cheon BG, Chilikin K, Cho IS, Cho K...(2013). Study of the hadronic transitions Y(2S) -> (eta, pi(0))Y(1S) at Belle. PHYSICAL REVIEW D, PARTICLES, FIELDS, GRAVITATION, AND COSMOLOGY, vol. 87, ISSN: 1550-7998, doi: 10.1103/PhysRevD.87.011104 - **Articolo in rivista**

2. SPATARO Stefano Giovanni

1. Ablikim M., Achasov M. N., Adlarson P., Ahmed S., Albrecht M., Aliberti R., Amoroso A., An M. R., An Q., Bai X. H., Bai Y., Bakina O., Baldini Ferroli R., Balossino I., Ban Y., Begzsuren K., Berger N., Bertani M., Bettoni D., Bianchi F.... (2021). Measurement of proton electromagnetic form factors in the time-like region using initial state radiation at BESIII. PHYSICS LETTERS. SECTION B, vol. 817, p. 136328-1-136328-10, ISSN: 0370-2693, doi: 10.1016/j.physletb.2021.136328 - **Articolo in rivista**
2. Ablikim M., Achasov M. N., Adlarson P., Ahmed S., Albrecht M., Aliberti R., Amoroso A., An Q., Lavania A., Bai X. H., Bai Y., Bakina O., Ferroli R. B., Balossino I., Ban Y., Begzsuren K., Berger N., Bertani M., Bettoni D., Bianchi F.... (2021). Oscillating features in the electromagnetic structure of the neutron. NATURE PHYSICS, vol. 17, p. 1200-1204, ISSN: 1745-2473, doi: 10.1038/s41567-021-01345-6 - **Articolo in rivista**

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5. Main staff involved (max 10 professors/researchers for each research unit, in addition to the PI or associated investigator), highlighting the time commitment expected

List of the Research Units

Unit 1 - GARZIA Isabella

Personnel of the research unit

nº	Surname Name	Qualification	University/ Research Institution	e-mail address	Months/person expected
1.	GARZIA Isabella	Ricercatore a t.d. - t.pieno (art. 24 c.3-b L. 240/10)	Università degli Studi di FERRARA	garzia@fe.infn.it	5,0

Possible sub-unit

Surname	Name	Qualification	e-mail address	Months/person expected

Unit 2 - TAMPONI Umberto

Personnel of the research unit

nº	Surname Name	Qualification	University/ Research Institution	e-mail address	Months/person expected
1.	TAMPONI Umberto	Ricercatore	Istituto Nazionale di Fisica Nucleare	tamponi@to.infn.it	5,0
2.	FILIPPI	Primo	Istituto Nazionale di Fisica	alessandra.filippi@to.infn.it	1,0

	Alessandra	ricercatore	Nucleare		

Unit 3 - SPATARO Stefano Giovanni

Personnel of the research unit

nº	Surname Name	Qualification	University/ Research Institution	e-mail address	Months/person expected
1.	SPATARO Stefano Giovanni	Professore Associato (L. 240/10)	Università degli Studi di TORINO	spataro@to.infn.it	5,0
2.	MARCELLO Simonetta	Professore Ordinario	Università degli Studi di TORINO	simonetta.marcello@unito.it	1,0
3.	DE MORI Francesca	Professore Associato (L. 240/10)	Università degli Studi di TORINO	demori@to.infn.it	1,0

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6. Information on the new contracts for personnel to be specifically recruited

nº	Associated or principal investigator	Number of expected RTD contracts	Number of research grants expected	Number of PhD scholarships expected	Overall expected time commitment (months)
1.	GARZIA Isabella	0	1	0	18
2.	TAMPONI Umberto	0	1	0	18
3.	SPATARO Stefano Giovanni	0	1	0	18
	Total	**0**	**3**	**0**	**54**

7. PI "Do No Significant Harm (DNSH)" declaration, in compliance with article n. 17, EU Regulation 852/2020. (upload PDF)

Upload:

MUR also has the right to the dissemination of the main economic and scientific data related to the funded projects.”.

Date 31/03/2022 ore 13:10