Latin American Strategy Forum for Research Infrastructures for High Energy, Cosmology, Astroparticle Physics LASF4RI for HECAP

Latin American Strategy for HECAP

Proposal endorsed by the High Level Strategy Group

Strategy Document Committee

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1. Executive Summary

An important effort is currently being forged in Latin America to map a landscape of initiatives in High Energy, Cosmology and Astroparticle Physics (HECAP) towards the development of strategic research infrastructures for the region. The process derived from the October 2018 Iberoamerican Science and Technology Ministerial meeting and its corresponding declaration[1]. This declaration was then ratified at the end of 2018 by the Heads of State[2]. The declaration gave the mandate to create a Strategic Forum for Research Infrastructures, both to provide an incentive for participation in existing facilities as well as to encourage the development of new projects and initiatives. It is important to note that in the area of HECAP Spain and Portugal take part in the European processes for the development of the corresponding strategy. Thus, a necessary first step was to pursue the HECAP strategy at the Latin American level that would then interface with those of Spain and Portugal. Additionally, the LASF4RI-HECAP initiative is aligned with current national efforts aiming at including HECAP in the roadmap of Science and Technology (S&T) programs.

High energy, cosmology and astroparticle physics research focuses on new phenomena arising from the smallest to the largest scales in the Universe. Inspired by the fundamental unknowns in cosmology, astroparticle and particle physics, Latin American scientists have come together to jointly build the landscape of current efforts and to layout the trajectory in Latin America for future developments of experimental research in these fields. Both regional projects and the participation in key global projects are prioritized. Thus, this document presents the main experimental activities and thrusts in high energy physics, cosmology and astroparticle physics for the short and mid term, at the same time identifying where they should be focused for long term future.

The LASF4RI-HECAP process comes about for the first time in Latin America in a similar time frame to analogous reiterative processes occurring in the US and Canada, while Europe has recently completed an update to its own process for particle physics. The main goals and milestones of the Latin American process are described in the next section. Nevertheless, the fundamental objective is to strengthen regional cooperation, that accompanied with proper funding, with allow for more impactful contributions and benefits for the region from the development of research infrastructures and the participation in global projects.

The principal outcome of this process are **ten** recommendations that aim to foster the development, and define the roadmap, for experimental HECAP projects and facilities in the region, for a sustained and active participation and leadership in global flagship projects, for efforts to maintain continuous capacity building in advanced training, technological developments and computing, as well as for societal engagement. Figure 1.1 summarizes both the landscape and the roadmap, exemplifying the growing community that is engaged and that could continue to

[1] https://www.segib.org/wp-content/uploads/Declaracion-III-Reunion-de-Ministros-y-Altas-Autoridades-en-Ciencia-Tecnologia-e-Innovacion_ES.pdf

[2] https://www.segib.org/wp-content/uploads/III-PROGRAMA-DE-ACCION.pdf

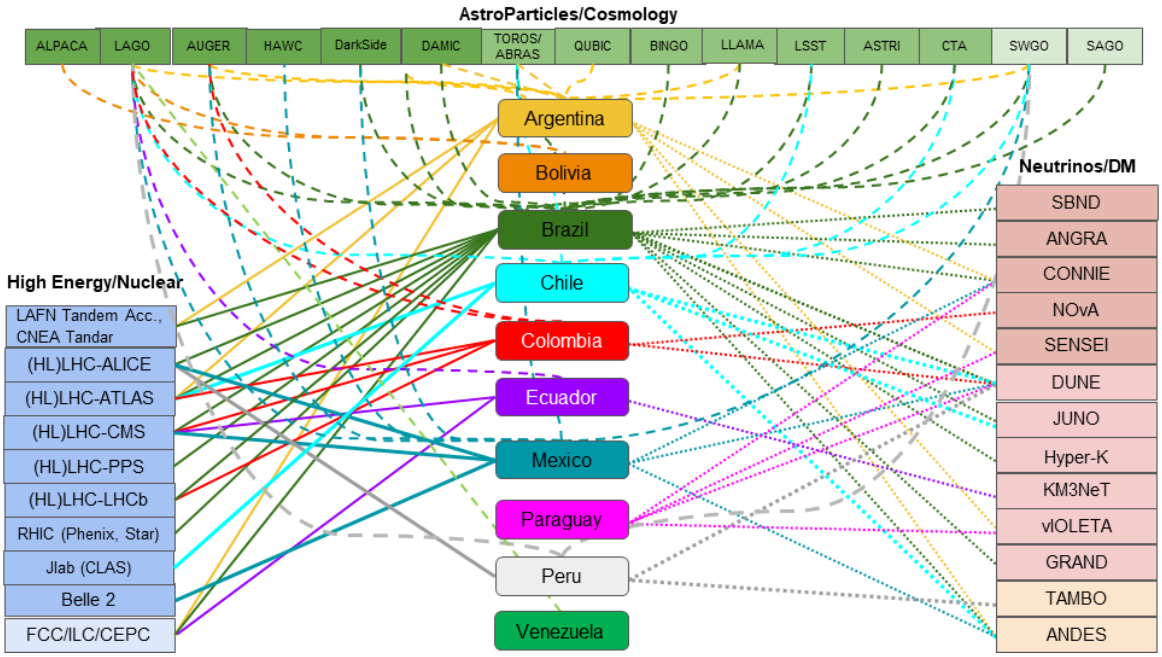

Figure 1.1: Landscape and roadmap of experiments of Latin American countries participating in LASF4RI for HECAP. The color coding in the experiments are for experiments already taking data (darker colors) to experiments/facilities being planned (lighter colors). The different lines (solid for High Energy/Nuclear, dotted for Neutrinos/DM and dashed for AstroParticle/Cosmology) are just intended for better visualization.

thrive with sustained resources[3]. The long term future projects under consideration are identified by the lighter colors.

In this document, a scientific roadmap of research infrastructures for HECAP is presented for each of the following areas: astrophysics, multi-messenger astronomy and astroparticles, cosmology, dark matter, collider and neutrinos. The software and computing requirements and strategy are also discussed. At the same time explicit social and economic benefits are detailed that justify the corresponding recommendations. Outreach and citizen science[4] initiatives are presented to fully complement the picture of a strategic development of HECAP, relevant for scientific discoveries and societal impact. Recognizing that the final stages of this process has occurred against the backdrop of the global pandemic, some highlights of the activities performed by HECAP scientists to support the national responses to the COVID-19 pandemic are also presented.

The Latin American HECAP Physics Briefing Book is a supporting document which delves into the contributions received from the scientific community during the LASF4RI-HECAP process. It is intended to be useful reference for the community. Additional benefits of this strategic process is the development of national roadmaps via in-depth discussions of the communities at the national level, and to promote the knowledge, visibility and diffusion of regional expertise

[3]Latin American scientists have participated in many other experiments in the last decade, not included here are those that have finalized their operational data taking activities such as Minerνa, DES, etc.

[4]Citizen Science allows members of the public to participate and contribute to research, e.g. following a guided process of data collection and analysis, public participants can help accelerate research and in the process learn valuable research skills and abilities.

raising awareness internationally of this coordinated regional strategy.

To finalize, this effort has led to the conclusion that a coordinating body for HECAP at the Latin American level is needed and is an important next step that the scientific community should develop.

2. Introduction

Latin American experimental and theoretical groups in high energy, cosmology and astroparticle physics have come together for the first time to pursue the development of a strategy for the field through the establishment of the Latin American Strategy Forum for Research Infrastructures (LASF4RI)[1] for HECAP. This effort has been an enriching process that has allowed the identification of a baseline and landscape of ongoing experimental activities situated either in the region or at existing facilities worldwide. In addition, current times serve as a reminder of the absolute need to strengthen cooperation and integration in the region with adequate backing of resources to be able to contribute and impact more, for the benefit of the region, and its contributions and relevance in global projects.
It is widely accepted that the development of significant research infrastructures can:

a) provide major advances in the construction of hubs of knowledge

b) foster international scientific collaborations and science diplomacy

c) build science capability and science leadership

d) enhance technology advances and technology transfer to industry

e) deliver stronger and broader opportunities for Science, Technology, Engineering, and Mathematics (STEM) education

f) create new pathways to the forefront of global science and research

g) communicate the benefits of science to communities through outreach programs

The main goals of this strategy process have been:

- To chart the landscape of existing infrastructure and expertise already developed in the region.
- To set-up the Latin American scientific roadmap based on actual participation in regional and global experiments and the inherent need for long term planning and funding implementing an open call for input from the scientific communities.
- To enable a more effective development of Latin American research groups, facilitating multilateral participation in regional and global research infrastructures, increasing their impact.

[1] `lasf4ri.org`

- To devise specific recommendations to allow for a more strategic approach to the development of and participation in leading experiments in HECAP with the goal of increasing the impact and benefits associated with this participation.
- To inform the Ministerial meetings of the development, implementation and impact of the LA strategy for HECAP.

As a result of this planning process it can be stated that Latin American research in HECAP currently manifests both a privileged position and clear progress in key competencies to play leading roles in regional projects and in major projects around the world.

The successful regional deployment of large international projects have demonstrated the capacity to design, construct and operate these research infrastructures. It is important to note that the Latin American region presents comparative geographical advantages for projects, particularly in the areas of astroparticles, astronomy and cosmology. There are a plethora of competitive projects approved or developed in the region that could benefit from a more significant number of participants from other Latin American countries. Details can be found in the Latin American HECAP Physics Briefing Book.

Over the last decades technological expertise has been acquired and developed by several groups in the Latin American region that have allowed them to make more significant hardware, computing and software contributions to major experiments. At the same time, specific detector technologies and data acquisition and processing capacities are now part of new detector proposals for experiments in the region and abroad. This effort should be sustained by both allowing a continuous enriched collaboration with major global facilities to enhance Latin American group capabilities in detector technologies and by funding the regional projects that utilize this expertise.

The benefits of inspiring young people into STEM fields and developing advanced training opportunities is of paramount importance. An increase in the number of Latin American groups participating actively in astro and cosmology experiments in regional facilities should also be supported to further capacity building of young talent in STEM, with special attention on avoiding the "brain draining effect" in the region. Similarly, maintaining close involvement and advanced training opportunities in major global facilities has allowed for the aforementioned technological expertise to flourish and the establishment of a critical mass of researchers in Latin America.

The next section describes the main recommendations for planning a strategy and defining a roadmap for research infrastructures in HECAP. It includes ongoing, short term (under upgrade or construction), mid term (under construction or approved projects), long term (future facilities) experiments, all dates indicated refer to start of operations.

Timeline of the process

The process that has been followed is summarized below in the timeline that contains the main milestones achieved[2].

[2]In the final months of the process interest arose from groups in Guatemala, Costa Rica and Honduras, and a small Mexican group focused on accelerator physics.

TIMELINE

- November 2016 ICTP-SAIFR 5^{th} anniversary (brainstorming).
- November 2016 SILAFAE in Guatemala (discussions with HEP community).
- 2017-2018 Two-page briefs of 18 experiments (initial landscape analysis).
- October 2018 Ministerial Science and Technology meeting Guatemala (mandate declaration).
- December 2018 SILAFAE in Peru (Town hall meeting to discuss mandate and next steps).
- January-March 2019 National Meetings and conformation of Preparatory Group delegates from 10 LA countries.
- April-May 2019 LASF4RI Workshop at ICTP-SAIFR, under the auspices of FAPESP, with representatives of Funding Agencies and agreement to add representatives from Asia-Japan, Europe-CERN and USA to the Preparatory Group.
- May 1 2019 First meeting of the Preparatory Group to outline the next steps.
- May-June 2019 Definition of the composition of the High-level Strategy Group.
- December 2019 Deadline for community white papers with 40 submissions.
- January 2020 Kick-off meeting of the High-Level Strategy Group.
- July 2020 Open Virtual Symposium of LASF4RI for HECAP, delayed from March due to pandemic.
- August 31 2020: Deadline for chapter contributions to the LA HECAP Physics Briefing Book.
- September 30 2020: First version of the Strategy Document prepared by the Strategy Document Committee.
- October 20 2020: Meeting of the High-Level Strategy Group to discuss Strategy Document.

3. Recommendations

A key element for a synchronized local and international strategy is to make research infrastructures multi-disciplinary and multi-purpose, ensuring a positive impact on society and the surrounding communities. The research infrastructures with Latin American participation detailed in this document offer excellent conditions within this scope. This section presents the final recommendations resulting from this strategic process.

Recommendation 1

Support the development and operation of current- and next-generation projects in astronomy, cosmology and astroparticle physics located in Latin America, enhancing leadership roles in these strategic regional projects that drive capacity building and technological development.

In the past decades, Latin America has been involved in the design, deployment and operation of top-ranked observatories is astrophysics. Motivated by strong scientific drivers that have contributed to revolutionary breakthroughs in our understanding of the Universe, the on-going and planned international research infrastructures have benefited from the excellent geographical location and atmospheric conditions in the region. These comparative advantages, alongside the support and enthusiasm of the local scientific communities, have been decisive when choosing the site of their location. The sustained annual increase in scientists and engineers participating in these endeavors is, probably, the clearest evidence of their impact in the region. Nevertheless, it is desirable to further push this development with an increased participation of Latin American scientists. To keep the advantageous trend of enhancing the scientific community, it is compulsory for Latin American countries to assure the continuity of both human resources and funding. As is widely accepted the benefits to society, particularly of, the larger projects far exceeds the investments.

The international experiments focused on astroparticles, cutting edge multi-messenger astronomy and observational cosmology hosted in LA-countries are[1]:

- Ongoing experiments: AUGER, LAGO, TOROS
- Short term (< 3 years): ABRAS, AUGERPrime, BINGO, QUBIC, LLAMA, LSST
- Mid term (3-10 years): CTA/Astri, SWGO
- Long term (> 10 years): GRAND200K, SAGO

[1]The details of each experiment can be found in the Latin American HECAP Physics Briefing Book and references therein.

According to the start of their operations or their future projections, all these projects cover, at least, a decade-long timescale that conforms to the main goals of global strategic plans in astrophysics and paint a bright and promising outlook for the future of our region.

Recommendation 2

Pursue the establishment of the flagship international laboratory, ANDES, that will enable the region as a global center for underground physics and other sciences.

A particular opportunity is presented with the ANDES lab proposal to focus on underground physics and related science experiments which could become the flagship international laboratory for the region. ANDES represents an attractive multi-purpose local large-scale infrastructure included in the Latin America roadmap. The detection and understanding of the nature of neutrinos, the search for dark matter, geology and plate tectonics science, radiation harm and biology studies, as well as nuclear astrophysics and low radioactivity measurements are among the multi-disciplinary research that can be pursued with this first-class deep underground laboratory. Thanks to its unique location, ANDES offers a unique opportunity to do frontier science in our region. There is no doubt that, to sustain such an international effort, a coordinated and strategic contribution from Latin American countries is required.

Recommendation 3

Support the existing efforts in international projects in which Latin American groups are actively participating, and in some cases leading initiatives, as a strategy to position Latin America to key leadership roles in future international flagship projects in collider and neutrino physics.

There are two main domains in which there is multiple involvement of Latin American groups in major international experiments. These are in collider physics at the Large Hadron Collider (LHC) at CERN, and neutrino physics at the upcoming DUNE experiment at Fermilab. While at the LHC the Latin American involvement is spread throughout the four major experiments, at DUNE there has been a more coordinated effort to contribute jointly to a main subsystem of the far detector, the photon detection system.

Colliders

Participation in the HL-LHC experiments (ATLAS, CMS, LHCb and ALICE) will cover the immediate and mid-term future priorities for pursuing the science drivers of electroweak, quantum chromodynamics (QCD), flavour and beyond the Standard Model physics accessible at the high energy frontier. Inline with the current level of expertise and focus Latin American groups have expressed interest in also being actively involved in the discussions and planning for future colliders. Given the discovery of the Higgs boson, the highest priority is an electron positron collider that will serve as a Higgs factory. A clear planning in order to focus efforts for future collider experiments that will enhance participation and impact has been expressed by groups in Brazil. *The recommendation at the Latin American level is among these same lines*. The energy

frontier facility for strong interactions is on an even longer timescale with a high energy (100 TeV) hadron collider.

- Ongoing experiments: LHC
- Mid term (3-10 years): HL-LHC
- Long term (> 10 years): FCC/ILC/CEPC

Neutrinos

There are seven countries actively engaged in neutrino projects in the Latin American region: Argentina, Brazil, Chile, Colombia, Ecuador, Peru and Paraguay. Unlike the collider case, most Latin American groups have come together to contribute to the DUNE experiment in a more cohesive manner focused on the photon detection system (PDS). The physics program at DUNE is not limited to precision neutrino oscillation measurements, it encompasses beyond the Standard Model physics related to: sterile neutrinos, dark matter, non standard neutrino interactions, supernovae neutrino physics, baryon number violation, neutrino trident production, among others. This broad physics program places strong requirements on the PDS sensitivity and capabilities. The exciting collaborative Latin American effort should be a top priority for the region. Furthermore, specific programs in Europe with CERN and other large-scale multidisciplinary research infrastructures as KM3NeT, set a promising versatile future for Latin America in neutrino physics. The timeline of neutrino experiments with Latin America participation is:

- Ongoing experiments: NOνA, νANGRA, CONNIE, SBND, KM3NeT (Phase-I).
- Short term (< 3 years): νIOLETA, JUNO.
- Mid term (3-10 years): DUNE, Hyper-K, KM3NeT (Phase-II).
- Long term (> 10 years): TAMBO, GRAND 200K

Recommendation 4

Support small scale, high impact dedicated experiments across HECAP.

There are important smaller scale experiments across HECAP that are targeting specific scientific objectives, with typically shorter time scales, while at the same time providing important contributions to the strategy presented in Recommendations 6 and 7, described below. The design, construction and commissioning of (sub)detector prototypes whose performance is tested in these scenarios to further improve R&D efforts is crucial whilst simultaneously providing important measurements. Notwithstanding scientific excellence and advancement are the criteria to fund these initiatives. Current examples of this type of experiments in LA include: ν-ANGRA, νIOLETA, SENSEI, CONNIE, LAGO.

Recommendation 5

Strengthen the collaboration among different theoretical groups in the region working in HECAP and their interactions with the experimental efforts.

Experiments are driven by scientific questions that can be posed by theoretical models proposed to describe the Universe. Latin America already has a strong theoretical community working in HECAP topics. The interaction among theorists and experimentalists is of fundamental importance. The Simposio Latino Americano de Física de Altas Energias (SILAFAE), a biennial meeting of the HECAP community that started in 1996, is the natural forum for this interaction and, in addition to other smaller workshops in the region, should be supported.

Recommendation 6

Support and develop advanced training programs that harness regional capacities and expertise across all Latin American countries active in HECAP.

Advanced training is critical to infuse all of the above efforts. Several important initiatives that have been developed in past years have shown the usefulness and benefits of advanced training programs. Inter-regional networks can be enhanced and supplemented by strong links to key facilities around the world. Such international efforts towards the construction of large research facilities play a crucial role both fostering local scientific communities and boosting the capacity building and technological development of our societies.
Keeping in mind the Open Access and multidisciplinary nature of the mentioned research endeavours, the capacity building programs must have a cross-experience component. This means, to deploy programs that teach and retain knowledge transfer in technologies and expertise relevant to multiple experiments and facilities, that can even be used in other areas inside and outside academia or basic research. In the long run, those initiatives would help to keep a critical mass of highly trained human talent, and also the possibility of the creation of industries around those expertise and capabilities.

Recommendation 7

Foster R&D capabilities in key technologies across HECAP, enabling connections with industry, and with possible broader societal impact.

This is the second important dimension for capacity building together with advanced training. Strong and continuous R&D efforts in instrumentation, hardware, software and computing are crucial to provide successful participation and contributions to major experimental endeavors. Innovative technology developments allow for the novel design of experiments to pursue the outstanding scientific drivers.
Particular relevance must be given to those endeavours that pursue R&D in areas that are common to several experiments, like software and computing techniques and protocols. Also to incentivize and boost those initiatives that look to enhance the connectivity between existing and future infrastructure in the Latin American countries, and not only those between efforts of single countries with external partners in North America, Europe and Asia.

Recommendation 8

Enhance the high performance computing infrastructure and internet connectivity in the region.

The development of a robust, high-performance scientific computing (HPSC) infrastructure, as well as the improvement of internet connectivity in the region, is fundamental to all experimental efforts. A huge amount of data will be generated by experiments such as CTA, LSST and many others that need to be processed in the region and also sent to other continents; in addition to the data that is already arriving at facilities in the region from other large multinational experiments, like those at LHC, for example.
A Latin American Science Cluster, similar to the European ESCAPE project, that includes HECAP should be a priority. Besides the fact that an interconnected infrastructure will help to take better advantage of current human and technical resources, having a common HPSC infrastructure also allows for the training and capacity building in the area of software development, computer-integration and data analysis. Past and current efforts like multiple Software and Computing (S&C) in collaboration with multinational partners like CERN, ICTP, Fermilab, the HSF (HEP Software Foundation), among others, are already facilitating the practical expertise on how to successfully execute those programs and learn from worldwide experiences and experts.

Recommendation 9

Develop formal and stable mechanisms for coordination and funding among research councils and funding agencies at the regional level to support HECAP initiatives.

Coordinating support at the funding agency level for Latin American groups in HECAP research will allow for developing synergies, increasing both scientific impact and local benefits. The rich description of projects in HECAP with their corresponding timelines presented in the above recommendations clearly states the case for the need of continuous funding. It is of utmost importance to guarantee that resources are available to contribute to hardware, software and computing requirements for the various experiments and the successful completion of these projects, fulfilling collaboration commitments, to ensure their expected scientific outcomes and societal impact.

Recommendation 10

Encourage the dissemination of knowledge, outreach and the active involvement of the general population in scientific research, boosting Societal Engagement.

The involvement of society is relevant for a long term strategy. Societal engagement can encourage people to embrace such scientific projects, help to promote youth interests in scientific subjects and contribute to an increase in the number of those that pursue studies in STEM areas. Citizen science projects and traditional outreach programs must be supported and developed. It also allows the possibility to create a positive culture around the facilities and experiments, crucial for their long-term survival.

4. Roadmap

4.1 Research infrastructures

4.1.1 Astronomy, Astrophysics and Astroparticles

The Earth is being continuously bombed by sub-atomic particles with macroscopic energies reaching values above 10^{20} eV, orders of magnitude beyond those reachable by the most powerful terrestrial accelerators. The mere existence of such particles face us with several compelling questions about the extreme, non-thermal, Universe that surrounds us and the laws that rule its evolution. The quest of satisfactory answers is nowadays pushed to the limit by the combined observations of cosmic rays, gamma-rays, cosmic neutrinos and gravitational waves. The *multi-messenger* approach calls for scenarios which involve both the domain of elementary particles, the micro-Cosmos, and the realm of the huge Celestial objects, the macro-Cosmos.

The most immediate questions that the astroparticle field is currently addressing are:

- What is the nature of the extraordinary energetic particles? Are they ordinary particles, accelerated in extreme astrophysical environments, or are they annihilation or decay products of super-heavy dark matter or other exotic objects?
- In such extreme physical processes, is Lorentz invariance still valid? Are the particles interacting according to the Standard Model or is there new physics involved? What is the cross section of protons at $\sqrt{s} > 10^5$ GeV?
- Are their sources related to those of high-energy neutrinos, gamma rays, and/or gravitational waves, such as the recently observed mergers of compact objects?

The Latin American scientific community has the unique opportunity to host several large intercontinental projects covering astronomy, astroparticle and astrophysics fields. The main and still open questions on Ultra-High Energy Cosmic Rays, High-Energy Gamma-Rays, High-Energy Neutrinos, Cosmology, Gravitational Waves and Radio Astronomy, are or will be covered by ongoing projects like the Pierre Auger Observatory (PAO), the Laser Interferometer Gravitational-Wave Observatory (LIGO) and the Transient Optical Robotic Observatory of the South (TOROS) or the experiments under construction as Cherenkov Telescope Array (CTA), the Large Latin American Millimeter Array (LLAMA) or the Southern Wide-FoV Gamma-Ray Observatory (SWGO). All these multi-national efforts are located in our region, with scientists and engineers of the local Latin American communities playing leadership roles. But not only the present and short-term future are bright in this area of research, long-term projects like the Giant Radio Array for Neutrino Detection (GRAND) will benefit from the crystal-clear skies, the large flat areas and the low anthropogenic noise of our region. Also to note are the existing efforts that address space weather topics mainly via the Latin American Giant Observatory

(LAGO), and other initiatives given that the center of the South Atlantic magnetic anomaly is located in Paraguay[1].

In short, Latin America has a strong commitment in astroparticle physics, a field that has increased substantially its community in the past decades mainly based on the large projects that have selected our region as sites for building scientific infrastructures. The contribution of local communities within such endeavours, has also shown their capacity to conceive, design and execute large observatories that have favored the progress of the region in research, technology, innovation and education.

4.1.2 Cosmology

Standing at the interface between theoretical physics, particle physics, and astrophysics, and having exhilarating deep connections with fundamental physics, cosmology provides a suitable arena for community-wide synergies and global endeavors.

The main questions the community is aiming to address are:

- What are the nature, properties and origin of the dark components (i.e., Dark Matter and Dark Energy)?
- What is the origin of matter-antimatter asymmetry?
- What are the nature and the properties of neutrinos?
- What are the nature and properties of Black Holes? Do primordial Black Holes exist? Are they (part of) the Dark Matter?
- What is the origin and nature of the primordial perturbations? Are there primordial gravitational waves?
- Are the standard assumptions wrong? Is General Relativity the applicable theory of gravity? Is Lorentz symmetry violated?

The current Latin America community working on cosmology is rather sparse. There are individual groups scattered about the region, with diverse and complementary expertises, that are now pursuing or considering joint ventures. Acknowledged beneficial approaches for boosting Latin America global impact are to promote the integration of the Latin America community working in Astrophysics and Cosmology, to increase the participation of the Latin America community in the experiments installed in the region and the amount of qualified human resources with the required expertise. The development of frontier experiments in the region, local facilities and resources, their synergies, capacity building and collaborative work are key elements in this roadmap.

The ongoing and short term landscape of projects involve the Brazilian-led BINGO experiment, and the global international projects: QUBIC/LLAMA, TOROS/ABRAS, and Rubin Observatory's LSST. These projects imply the development of new facilities and resources. Future

[1] Another new project is the Next Generation Very Large Array (ngVLA) constituted by 256 antennas of 18-m each distributed across a region 300 lm wide. It will have one order of magnitude better angular resolution and sensitivity than the VLA. The ngVLA will be distributed in the south of the USA and the north of Mexico.

projects can take advantage of these developments. The sites are located in Argentina, Brazil and Chile. The Alto Chorrillos site (with QUBIC and LLAMA experiments) and Macon Ridge (with TOROS and ABRAS), both are in the northwest corner of Argentina, in the Atacama Plateau shared with Chile. BINGO is being built in Paraíba, the Northestern Brazil. While the LSST telescope will observe from a developed site in Chile, the project involves the implementation of an independent Data Access Center (iDAC) in Brazil. These projects represent an opportunity to participate actively in the data analysis and simulations as well as to contribute in electronics and software design. Their potential impact on Latin America community concern technological developments and high level human resources training in engineering, cosmology and gravitation. The possibility of SAGO in the long term future will depend on the capabilities the pertinent community (already working on LIGO) can gather in experimental activities, data analysis and technology for 3G gravitational wave detectors.

4.1.3 Dark Matter

The compelling evidence for Dark Matter (DM) is based on gravitational signatures. Understanding its nature has called for a particle physics interpretation of dark matter. Such a particle physics interpretation requires physics beyond the Standard Model (SM). In turn, this particle physics interpretation of DM has led to many dedicated searches for new physics at direct detection, indirect detection and collider experiments, and beyond. Despite decades of experimental scrutiny, the nature of DM remains a mystery. Even the most fundamental properties such as its mass and interaction strength with Standard Model particles are still unknown.

A new era of DM exploration is starting, and the Latin American community may have an opportunity to uniquely contribute to this endeavour. Experimental searches range from standard WIMP scenarios to light DM candidates calling for extended dark sectors, to axions and axion-like particles as well as sterile neutrinos. In the coming decade an amazing new set of experiments will probe DM and the Latin American community is playing a leading role in it, that can be further enhanced by coordinated activities.

Among direct detection experiments, DarkSide with Latin American involvement in it, plays a crucial role in the search for standard WIMP DM. New technologies, such as Skipper-CCDs, at SENSEI and future related experiments, present a unique opportunity to highlight contributions to low energy DM searches that can cover extreme WIMP-like scenarios and the light dark matter region in the sub-GeV mass range. A remarkable effort in this direction is the creation of the LAMBDA laboratory in Argentina, which will strengthen the technology lead in the region, and the development and future applications of front-line technologies for particle detectors for DM and neutrinos.

In the future, Latin America has a unique opportunity to host the ANDES lab facility, that may provide an optimal environment to host a diverse type of DM and neutrino experiments at an international level.

If DM has a particle physics interpretation, it is natural to think that an extended Dark matter sector is around the corner. Related research infrastructures in Latin America are the nuclear reactors in Argentina and in Brazil, where signatures for particular candidates that may be associated with an extended dark sector will be searched for. Neutrino experiments, such as CONNIE (in Angra II nuclear power plant in Brazil) and νIOLETA (in Atucha II Nuclear Power Plant in Argentina) open the window for tantalizing dark sector explorations.

It is worth highlighting that for indirect detection DM exploration, a dedicated community involvement in CTA and SWGO, including synergies with Baryon Acoustic Oscillation experiments like LSST and BINGO, could have a very significant impact.

Also important to highlight is that Latin America has a long history and a very strong involvement in collider strategies and searches at the LHC. Those efforts have already capitalized, e.g. by Latin American contributions to DM searches at CMS, but there is significant opportunity to extend the Latin America involvement in DM and dark sector searches at the upcoming Run 3 and at the future high luminosity LHC, and younger generations of students and postdocs can profit very much from that.

Finally we highlight that the theory community in Latin America has been a driving force moving forward with new ideas, new experimental searches and building capabilities among the young researchers in the region. Similarly to the collider and neutrino arena, theorists are now playing a unique role in new search strategies and educating new generations of experimental physicists in the DM world.

4.1.4 Colliders

Colliders are essential to expand our knowledge of the most fundamental components of our universe by exploring physics at the energy frontier. The main physics drivers are:

a) precision tests of the Standard Model;

b) studies of the Higgs properties and mechanism of electroweak symmetry breaking;

c) study properties of the quark-gluon plasma;

d) better understanding of the proton structure through improved parton distribution functions;

e) explore new sources of CP violation that could explain the matter-antimatter asymmetry in the universe;

f) search for dark matter candidates;

g) test models for the origin of neutrino masses;

h) search for new physics beyond the Standard Model;

The LHC at CERN is currently the only facility in the world exploring the energy frontier. Groups in Latin America are already active in the LHC main experiments: ATLAS, CMS, LHCb and ALICE. There are also participation in the heavy ion experiments SPhenix and Star at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory as well as in nuclear physics at the CLAS experiment at Jefferson Lab. The only high energy electron-positron collider currently active is Japan's SuperKEKB and Mexico participates in its Belle II detector. The nuclear physics facilities in Argentina (CNEA) and in Brazil (LAFN) should also be highlighted.

The participation of LA groups in different HEP experiments can be seen in Figure 1.1. It is estimated that there are on the order of 500 people involved in these experiments. The contribution of Latin American groups to these state-of-the-art experiments led to the development of different capabilities in the region. Among these capabilities the following are highlighted:

- design of a chip called SAMPA in Brazil for readout of ALICE detectors to be installed for Run 3;
- design and test of Global Trigger and Rear Transition Modules for ATLAS in Argentina;
- construction of parts of the muon detector for the ATLAS upgrade in Chile.
- electronics for the Large Angle Beamsstrahlung Monitor for Belle II developed in Mexico;
- Brazilian contribution to the design of the CMS-TOTEM Precision Proton Spectrometer;
- testing of Low Gain Avalanche Detectors for ATLAS in Brazil;
- expertise and leading roles in several experimental analysis in all collaborations;
- several computer clusters dedicated to these experiments are installed in the region;
- expertise in theoretical calculations in most aspects of Standard Model and Beyond Standard Model processes;
- contribution to capacity building through education programs described in Section 5.1.

The roadmap for this area is clear. The LHC program extends up to 2035 with a High Luminosity Upgrade. This major upgrade involves new paradigms and capabilities in detector technology, such as adding precision timing capabilities, where exciting opportunities exist to join projects relying on cutting-edge technologies. Support should be given to the groups that are already heavily involved with the LHC program and encourage coordination among them to reach a larger impact.

Synergies among different groups have been identified in the Physics Briefing Book, such as muon chamber construction (RPC, GEM) and electronics design (SAMPA chip, readout circuits). Interaction and coordination among groups should be encouraged.

Looking further ahead in the Energy Frontier, some groups in the region demonstrated interest in the participation in future colliders, such as FCC (with its three options: *ee*,*eh* and *hh*), ILC and CEPC. These groups should be encouraged to coordinate their efforts and to participate actively in the Working Groups for these future accelerators in order to increase their visibility and become engaged.

4.1.5 Neutrinos

Neutrino physics currently constitutes one of the general areas of interest with intersection between high energy physics, cosmology and astroparticle physics. As such, there is a diverse spectrum of facilities around the world including small, medium and large-scale collaborations/laboratories, where new information regarding both known, and very importantly, unknown properties of these particles are being sought out.

Scientists from many countries of Latin America participate in one or several of these efforts. In fact, some enterprises belonging to the small and medium-scale collaborations/laboratories are physically present in the continent (supported by funding from several participating countries). This full-fledged participation by Latin American scientists has led to a very robust body of know-how in the area and the existence of a high-quality scientific community associated to this

type of endeavors. Of particular importance is the creation and development of a very strong tradition in the area of photonics, something that lies at the core of most neutrino experiments. Due in part to this situation, namely the existing experienced human talent, and the fact that the facilities commonly associated to this type of science tend to touch several disciplines, the project associated to ANDES constitutes the large scale "flagship" project that incorporates a broad set of interests and that aims at producing relevant first-rate science. By "large scale" we explicitly mean a facility/project that in order to exist necessarily, due to its size and perspective, requires the funding participation of several countries. The ANDES project in fact also constitutes a natural contribution to the worldwide efforts represented by the current worldwide flagship projects associated to neutrino physics, namely DUNE at Fermilab in the USA, KM3NeT in the Mediterranean in Europe (multi-disciplinary and multi-purpose), Hyper-K in Japan, and JUNO in China. Latin American scientists participate in these large-scale collaborations, DUNE being the most representative due to the fact that there is a very strong and direct participation involving many Latin American countries.
The future ANDES laboratory will be open to multi-disciplinary and multi-purpose science. In addition to neutrino/dark matter experiments it also opens the possibility of novel geo-sciences and biology experiments. Thus, a synergy among different fields and interests - surpassing those of HECAP - is natural in this setting.

Neutrinos are the key in our understanding of matter structure and the subatomic world. The main open questions nowadays regarding neutrinos may be addressed following two approaches: study of neutrino properties and the role of neutrino as a probe. The neutrino puzzle is open, with unknown parameters being insistently pursued:

- precision measurements, mass hierarchy and leptonic CP-violation phase,
- absolute masses and nature,
- sources (terrestrial and extra-terrestrial),
- signatures of new neutrino states, physics beyond the Standard Model (BSM) and non-standard interactions (NSI).

In addition to studying fundamental properties of neutrinos there are clear potential applications of neutrino related-technology to homeland security, large-scale geological survey and non-conventional communications. Neutrino Science and Technology (S&T) are not exclusive concerns of the international scientific community. It is of interest in Latin America to couple to efforts for future research infrastructures via upgrades and scaling of already existing facilities or to support new ones. Most of the above open questions are being addressed with the leverage of worldwide collaborations like the ones listed previously. The most explored technologies in neutrino detection can be summarized as:

- scintillation (noble elements gas, liquid, solid or dual phase) and hydrid detectors (e.g., scintillation + cherenkov),
- water cherenkov detectors (liquid, solid/ice),
- radio cherenkov detectors (ice, atmosphere) and pressure-waves acoustic detectors (water, ice),

- pixelated detectors (semiconductors).

Underground/ice/water observatories offer excellent conditions for multi-disciplinary research in Earth and Life Sciences, as well as in subatomic science as searches for rare events, exotic physics, and tests of fundamental physics. They also offer low background conditions for atmospheric, reactor, solar (space-based accelerators in general), and earth-based accelerator neutrino experiments. Additionally, nuclear astrophysics processes, where neutrinos act as a probe are also favored. The proposed experiment TAMBO, to study tau neutrino from astrophysical sources located in the Andean mountains of Peru, is a novel option for a large scale experiment located in Latin American in the era of multi-messenger astronomy.

4.1.6 Roadmap summary

Table 4.1 presents concisely the experimental projects roadmap considering the detailed descriptions presented in this section and recommendations of the previous section.

Table 4.1: Roadmap of current and future experiment across HECAP with LA participation. Options of future colliders are included but the recommendation is to focus efforts on only one initiative.

Field	**Project**	**Scientific Driver**	**Status**	**Start of Operations**
Astro	Auger	UHECR	Ongoing	NA
Astro	AugerPrime	UHECR	Upgrade	2022
Astro	LAGO	γ rays	Ongoing	NA
Astro	LLAMA	CMB+Radio	Under construction	2020
Astro	CTA	γ rays	Under construction	2025
Astro	SWGO	γ rays	Collaboration Agreement	2026
Astro/Neutrinos	GRAND 200K-LA sub-array	Neutrino astronomy/UHECR	Future experiment	>2030
Cosmo	TOROS	EM follow up GW	Under construction	2020
Cosmo	ABRAS	EM follow up GW	Under construction	2021
Cosmo	BINGO	BAO in radio	Under construction	2022
Cosmo	QUBIC	CMB polarization	Under construction	2021
Cosmo	LSST	Dark Matter/Dark Energy	Under construction	2022
Cosmo	SAGO	Next generation GW	Future experiment	2040
Colliders	LHC (all experiments)	EW/Higgs/BSM/Flavour/CP/QCD	Upgrade for Run 3	NA
Colliders	HL-LHC (all experiments)	EW/Higgs/BSM/Flavour/CP/QCD	Approved	2027
Colliders	FCC/ILC/CEPC	Higgs/BSM	Future collider	>2035
Neutrinos	NoνA	ν oscillation prop.	Ongoing	NA
Neutrinos	SBND	Precision ν-Ar interactions	Ongoing	NA
Neutrinos	νANGRA	Nuclear safeguards	Ongoing	NA
Neutrinos	CONNIE	CEνNS	Ongoing	NA
Neutrinos	KM3NET (Phase-I)	neutrino astronomy	Ongoing	NA
Neutrinos	νIOLETA	CEνNS, NMM, Light Vector Mediators	Under construction	2021
Neutrinos	JUNO	Precision oscillation, mass hierarchy, BSM	Under construction	2022
Neutrinos	Hyper-K	CP violation, solar neutrinos, mass hierarchy, BSM	Under construction	2025
Neutrinos	DUNE	ν properties, Leptonic CP, BSM	Under construction	2026
Neutrinos	TAMBO	ν_τ astronomy	Future experiment	>2030
Neutrinos/DM	ANDES	Low mass DM/ $\nu 0\beta\beta$	Future facility	>2030

As can be seen in the table there are seven ongoing experiments, two upgrades, ten experiments under construction of which only two are not located in the Latin American region. In addition, only four future experiments/facilities are identified: SWGO, SAGO, TAMBO and ANDES. SWGO already has an established collaboration agreement and should start operations in 2026. The other three initiatives have longer timescales however work needs to be done now for these projects to become a reality. The start of operations column is reflected in Figure 1.1 of the executive summary by the color coding.

4.2 Software and Computing

The landscape of Software and Computing in particle and astroparticle physics as well as in cosmology, is shifting rapidly. Current and new experimental projects need to consider not only detectors and R&D costs but also computing innovations, challenges and costs. Chips architectures and associated software and networking are under constant review for proper adaptation and optimizations. Taking into account all these factors, there are common challenges and aims for different experiments and facilities. As such, computing can be and has been developed to take into account more than one experiment, use or scientific discipline [2]. Regarding that evolution, several elements stand out: the hardware architectures and dispositions, the complexity and sizes of the datasets and the distributed nature of the researchers, engineers and students.

Long-term computing projects are moving more and more towards open source and open data models, and hybrid combinations of public and private (academic + volunteer + commercial) resources are being explored. No less relevant, data management and preservation need substantial redefinition for future experiments, while keeping in mind budget limitations.
A successful approach is the integration of already existing infrastructures to develop and consolidate linked macro-structures that perform as a single entity. Initiatives like the Worldwide LHC Computing Grid demonstrate how a very heterogeneous set of computer centres, universities and dedicated High-Performance Computing (HPC) facilities can join resources (including human expertise) to consolidate a global network. Since 2008 a group in Latin America made an effort to integrate to the WLCG grid system. With the support from CERN, a Resource Operator Center for the Latin American (ROC-LA) was started to coordinate grid activities. Due to formalities it was signed with CLAF that became the responsible unit for ROC-LA until today. ROC-LA currently works successfully, with more grid sites added, from Chile and São Paulo. The annual production is greater than 2 millions jobs/year. The main Virtual Organization (VO) supported in this period were: ALICE, ATLAS biomed, CMS and LHCb. Currently, the CBPF site is preparing to run jobs from DUNE.

On the software side, constant changes and larger collaborations have emerged inside the global scientific community. The software sophistication needed by large experiments forces the development of a more global approach.
Constant and long-lasting communication between research teams in the region such that common grounds can be identified and resources exploited in the most optimal way, while keeping close contact with the appropriate enterprises, protocols and industrial standards should be encouraged. Figure 4.1 gives an idea or such cross-common services.

[2] Some recent developments in the region include SCALAC that groups high performance computing initiatives for several Latin American countries https://scalac.redclara.net/index.php/es/somos/organizacion. Another initiative in Chile, that could be extended to Latin America is the so-called Data Observatory, similar to ESCAPE, https://www.dataobservatory.net/

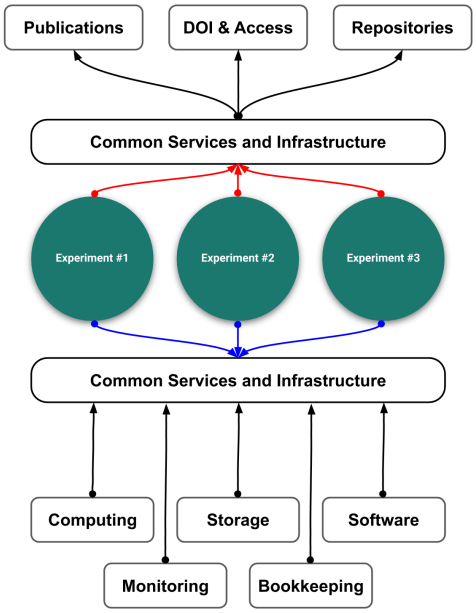

Figure 4.1: A simplified view of multiple experiments and the ways they can access services and tools through common Service Provider Platforms in the areas of S&C.

The use of cross-common resources and protocols also allow doing more, and many of these resources are already in place. Figure 4.2 exemplifies some of them. Open Access (Data, Software, Hardware) define current and future scientific endeavours. This environment is beneficial for long terms projects that researchers can profit from and contribute to as well. In addition, because they are used in the industry, a high quality of the activities is ensured and allows researchers to have the know-how that can be relevant in their professional future inside and outside academia.

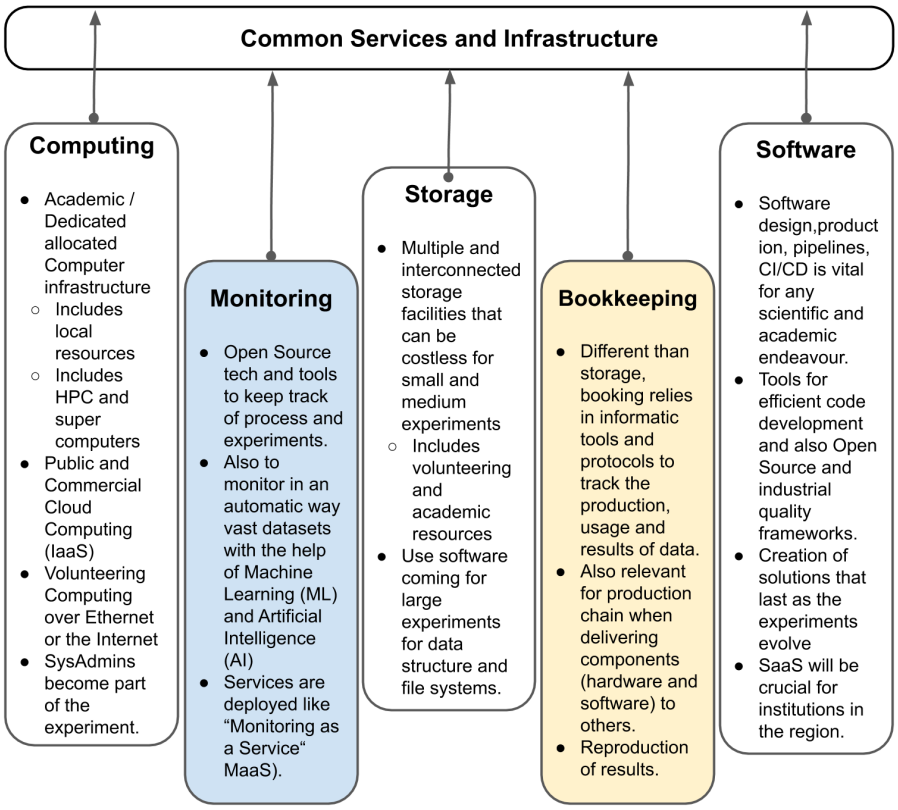

Figure 4.2: A non-exhaustive set of components and resources to exemplify standard services that tend to be generic among different experiments and R&D activities.

The submitted white papers show already multiples international collaborations in the development of computing networks and sophisticated software. They also show the need to encourage communication between Latin American countries to strengthen existing efforts and new projects. Smaller groups and institutions can join multinational experiments if they can partner with another group in the region that already has such a collaboration, reducing the initial friction that some find when trying to join large experiments. Finally, all these efforts need to be wrapped in a constant and coordinated flow of high-level training. As is mentioned in the next section, training is critical to reach those goals of long-term scientific production and qualified human capital that later on can integrate into other scientific and economic activities in the region.

5. Social and Economic Impact

Research in HECAP can have many important social benefits for Latin American countries. This section focuses on the positive social impact that results from these research activities. The case is put forward of the clear additional benefits to the physics quest. In first place let us note that a thriving research dynamics will inspire the younger generations to pursue careers in STEM related fields, something that needs to continue to be fostered in Latin American countries. Secondly, providing advanced training to educate young people at the same level as their peers globally is critical to guarantee effective participation, integration and leadership in world scientific communities. In third place the relevance of mastering enabling technologies which in turn will allow to develop industrial connections in the region is stressed. The role of communicating broadly to our communities on the advancements and challenges of the scientific endeavor can only be beneficial to our societies.

5.1 Advanced Training for Highly Qualified Human Resources

Historically, opportunities for advanced training in particle physics in the region that were established via agreements and collaborations with Fermilab and CERN were critical to spark the development of this field in Latin America. To this day the CERN Latin American School on High Energy Physics (CLASHEP), which rotates among different countries in the region continues to be a great resource of advanced training. The EU-funded programs of HELEN and Eplanet, under the direction of Luciano Maiani, were an important milestone that cemented cooperation of the Latin American groups in particle physics with European counterparts and in particular the inclusion of Latin American groups in LHC experiments with the corresponding development of advanced training via mid and long term stays at CERN by early career researchers. Latin American collaborators on LHC (CMS in particular) can take advantage of the Guests & Visitors program at the LHC Physics Center (LPC) at Fermilab, supported by DOE, with funding for visits to work on CMS projects and physics analyses with Fermilab and university physicists at the LPC. Similar opportunities at the Neutrino Physics Center at Fermilab can be used with respect to work on DUNE and other neutrino projects at Fermilab.

A variety of regional efforts have been developed including CEVALE2VE, LA-CoNGA and PPG-Cosmo. An important part of future efforts is the continuation of educational activities to form a new generation of particle physicists, such as MasterClasses e.g. in the context of International Particle Physics Outreach Group (IPPOG) and the LA-CoNGA courses. The Institutes in the region can continue to play a major role. In fact, ICTP-SAIFR has already organized several Schools in Particle Physics mostly for participants from the region, as well as the ICTP Physics Without Frontier (PWF) program activities.

The proposal of the Latin American PhD program in Astrophysics, Cosmology and Gravitation or a similar one, which emphasizes the need of increasing Latin American participation in facil-

ities installed in the region, together with workshops, schools and mobility programs, can have an important impact at strengthen collaborative work and knowledge and technology transfer.

Current efforts should be enhanced and expanded to allow for greater inclusion of participating institutes and countries that still need significant capacity building of young talent. A recent development is the new CERN-CLAF agreement to enable stays of students and early career researchers at CERN. However, obtaining funding to support these stays on the scale that the size and need of the HEP community remains a challenge. It is crucial to ensure the preparation of the next generation of scientists and technology experts to take the lead of future initiatives.

It is relevant also to mention that many capacity building programs rely on web-based and online resources and courses, particularly those related to fundamental physics, computing handling and software development. Remote learning platforms have the tremendous potential of complementing, enhancing and eventually integrating into formal education degrees. Through these, the community can not only teach each other but also develop solid networks of researchers and -even more important- students that later on will be responsible for these scientific projects.

The improvement and stable funding of the connectivity infrastructure plays, once again, a key role in this present process and in the long run. Also, good connectivity and internet access tackles the known problem in the inequality of access to education, making world-class material and instructions accessible to a broader young population pursuing those academic programs. Such improvements in the communication in the region also improve outreach, as part of this holistic educational view.

5.2 Enabling Technologies and Industrial Connections

A wide variety of HECAP technologies have important applications across diverse economic and industrial domains including: health (medical imaging and radiation treatments), nuclear monitoring as safeguards, geophysics, data science applications, high performance computing, industrial-kind software development, among others. A critical conclusion is that it is distinctly advantageous to develop and provide access to shared infrastructures and tools.

The main mechanism for direct economic impact of HECAP scientific activity is through industrial connections. It is a clear and concrete benefit to the economic and social development of a country. Recognizing that hosting large international projects can increase the links between research and industry and can enhance local science and technological capabilities is paramount. Specific examples of established industrial connections from current and future HECAP activity include:

- In the case of BINGO the instrument is being constructed by Brazilian companies.
- Advanced computational methods including machine learning and fast image processing arise from several experimental collaborations including LSST. See below for an example of the application of these tools in the response to the COVID-19 pandemic.
- Optics and laser technologies required for SAGO can provide future synergies with industry.
- Readout electronics, FGPA boards for fast triggering, and chip design are important contributions from Latin American groups for experiments such as ALICE, ATLAS, DUNE, QUBIC, LLAMA, LHCb, AUGER.

- sPMTs and SiPMs are used across a variety of experiments.
- Charged Coupled Devices (CCDs) and Skipper-CCDs are detector technologies that have been mastered regionally, and electronic readout systems have been developed. They will be used in experiments such as: CONNIE, TOROS, SENSEI, DAMIC-M, νIOLETA.
- Hardware for computer processing power, networks, storage elements are critical requirements for many experiments and a successful approach can be the integration into existing infrastructures to consolidate linked macro-structures.
- The ATLAS-Brazil cluster has been at the forefront of the development of large Collaboration Management Tools. It is worth noting that these activities have spurred the creation of several start ups in Brazil.
- Creation of the LAMBDA laboratory in Argentina for the development and applications of low detection threshold particle detectors.

5.3 Citizen Science and Outreach

Citizen science, defined as research conducted by amateur scientists, including people of all ages and social backgrounds, has proved in multiple occasions to be a vehicle for the dissemination of knowledge and methods that enhance the common ground of the collective awareness of the value of science. It also improves educational programs at different levels with extra-curricular activities that involves students in a practical and collaborative environments. There are some clearly identified initiatives in citizen science such as RACIMO, in Colombia, that monitors air quality in different regions. It has a strong educational component that targets mainly elementary students, participating in all of the developing process with the help of young university students and researchers. Other goals of the project are the development of communication skills and a solid social engagement with their communities.

It is inevitable to see the connection between training and education programs with the development of citizen science projects. Most of the citizen science projects start inside an academic or research institution as experiments to apply knowledge and expertise coming from a particular field, like HECAP, to a completely different context or problem. Later on, these projects are extended to society. Such interconnections help to understand the value of the investment and support for internet connectivity, of training and outreach programs, and visibility of these institutions.

Another set of successful citizen science can be evidenced in other parts of the world related to volunteer computing. Volunteer computing refers to the activities where users join a project, with their computer at home, to help to solve a problem that requires a substantial amount of computer power (like LHC@home or Folding@home). Such type of projects are gaining more and more popularity due to their relatively easy access and the social engagement that involve. Due to current exceptional circumstances, worldwide, particular attention to ideas in this direction (especially those developed in local languages) can be encouraged to support them, in sync with the remote learning approaches and distributed knowledge transfer in the Latin American region.

Outreach programs have been a constant part of the scientific enterprise in HECAP throughout the region providing especially younger generations with exposure to the main scientific open questions and the theoretical and experimental approaches that try solve them. It is a firm commitment of HECAP scientists to continue this endeavor for the benefit of our national communities.

5.4 Response to COVID-19

In different Latin American countries HECAP scientists have been instrumental to national efforts in response to COVID-19. The goal of this section is not to present an exhaustive list of activities. A few specific contributions are highlighted to illustrate the relevance of HECAP scientists and their varied expertise to address this social crisis.

Argentina

The HECAP community has been involved in providing tools and data analysis to governments for public policies. In Argentina, scientists from ICAS (UNSAM) and Instituto Balseiro (CAB) have contributed with theoretical models, simulations and on-stream data analysis with Machine Learning techniques to mitigate the COVID-19 pandemic. Many of these works have been through official collaborative agreements with the Argentine Government, Buenos Aires Province and the main telephone company Telefonica.

The Argentine National Administration and most of the provinces have been using, since early April, as one of their main monitoring tools a mobility index developed in collaboration with the telephone company Telefonica. Currently they are also using many derivative indices and alarms elaborated through Machine Learning techniques which could detect anomalies and focus public policies in specific regions.

Additionally, a tight collaboration with the Health Care Administration of the Province of Buenos Aires has allowed to implement different LHC and HEP techniques in an Early Outbreak Alarm that works by analyzing on-stream phone calls to a COVID-line. The key is to realize that the phone calls consist of a background proportional to the district population and a signal proportional to the number of first-day-symptomatic infected in the given district. By using previous weeks' data to learn of these proportions and features, a system was developed that can provide an early alarm of outbreaks, a few days before the laboratory results are ready[1]. This alarm has been crucial from April to mid June to detect and control many outbreaks.

This processed information[2], have been crucial to detect and decide a strict isolation of Villa Azul, with high impact in the news. This and other similar cases have been important for mitigating the virus spread and assisting in the so-called flattening of the curve. Since June the alarm is working as an early visualization of the overall situation and is one of the main monitoring tools for the Buenos Aires Province Health Care System.

The performance of this Early Outbreak Alarm has encouraged the Latin America Development Bank (CAF) to work in collaboration with HEP scientists in order to develop an advanced and improved version of the alarm to be scaled and used in other Latin America cities[3]. In

[1] More related details in Ref.[https://doi.org/10.1101/2020.07.26.20162008], full work is in preparation.

[2] Results communicated in Ref. [https://arxiv.org/abs/2008.12636]

[3] (https://www.caf.com/es/actualidad/noticias/2020/07/veeduria-distrital-de-bogota-gana-el-llamado-a-instituciones-publicas-de-caf/)

particular, the next version is likely to use not only the previous signal/background and Machine Learning techniques, but also LHC jet clustering-like techniques to identify and measure in advance possible COVID-19 outbreaks. Moreover, the tool is planned to be used for other collective phenomena, such as dengue outbreaks and catastrophes.

It is worth mentioning that in most of the activities described above the HECAP techniques and tools have been decisive to provide compelling results for public policies. In particular techniques in modeling, simulations, and error-bar computations have been central in all projects. Scientists involved in the mentioned programs are Ezequiel Alvarez (ICAS), Leandro Da Rold (IB), Daniel De Florian (ICAS), Federico Lamagna (IB) and Manuel Szewc (ICAS).

Brazil and Chile

In both Brazil (@UFRJ) and Chile (@ UTFSM) HECAP scientists have been involved in the design and construction of mechanic ventilators for COVID-19 patients.

Paraguay

In response to COVID-19, in Paraguay, the CONACYT (the National Council of Science and Technology) made a call to the scientific community to present ideas and plans to act against pandemic related issues. As part of that challenge, the FIUNA (Engineering Faculty of National University of Asuncion) developed a prototype of an automatic "Ambu-Bag" that can be used for mechanical ventilation. Several engineering groups in collaboration with industry presented their prototypes with different features, including some intensive Care Units. Rigorous testing of the ventilators by clinical experts has to be done to ensure they meet the standards for patient safety and effectiveness of treatment, which is of vital importance for any ventilator design. For this purpose FIUNA proposed the construction of a laboratory to perform tests in order to verify the safety, effectiveness and the Electromagnetic Compability (EMC) of the equipment built according to international standards. We are at the stage of building this new laboratory to work with Health authorities to authorize the use of the equipment locally designed and built.

Peru

Involvement of a Peruvian High-Energy group in the fight against the pandemic has been on two fronts:

1. Together with a varied group of scientists, two members of the PUCP High-Energy Physics group (J.L. Bazo and A. M. Gago) have worked on a project (awarded by the Peruvian national funding agency - Concytec) with the goal of developing a tool for analyzing data coming from non-hospitalized, hospitalized, and recovered patients with COVID-19. This tool will be fed with data obtained from an App and that will be filled by the patient (non-hospitalized and recovered cases) and the health personnel (hospitalized case). The aforementioned information will be stored in a especially designed database for this purpose. The analysis tools and the data will be available for health authorities, for evidence-based decision making, and also for researchers and doctors in the front-line.

2. Since April 2020, the leader of the PUCP High-Energy Physics group, Alberto Gago has participated as a member of a working group appointed by the Peruvian Ministry of Health. The duties of this working group has been to make recommendations in innovation and technology, from diverse fronts, with the aim of getting a better response and containing the pandemic.

Appendices

A. High Level Strategy Group

Chair: Luciano Maiani
Co-chair: Fernando Quevedo

Country/Regional Scientific Representatives

Argentina: Maria Teresa Dova
Brasil: Joao dos Anjos
Chile: Claudio Dib
Ecuador: Bruce Hoeneisen
Mexico: Jacobo Konigsberg
Venezuela: Jose Ocariz
Europe/CERN: Peter Jenni
Asia: Hesheng Chen
US: Francis Halzen and Gabriela Gonzalez
ICFA/Fermilab: Pushpa Bhat
Asia Pacific: Geoffrey Taylor

Institute Directors

Nathan Berkovits, ICTP South American Institute for Fundamental Research (ICTP-SAIFR, São Paulo)
Daniel de Florian, International Center for Advanced Studies (ICAS, Buenos Aires)
Álvaro Ferraz, International Institute of Physics (IIP, Natal)
Antonio José Roque, Sirius, Laboratório Nacional de Luz Sincroton (LNLS, Campinas)
Ignacio Bediaga, Centro Latino Americano de Física (CLAF, Rio de Janeiro)
Luis Felipe Rodriguez, Meso American Institute of Science (MAIS, Chiapas)

B. Glossary of Experiments

ABRAS: Argentina-Brasil Astronomical Center
ALICE: A Large Ion Collider Experiment
ALPACA: Andes Large-area PArticle detector for Cosmic-ray physics and Astronomy
ANDES: Agua Negra Deep Experiment Site
ANGRA: Angra Dos Reis Nuclear complex
ASTRI: Astrofisica a Specchi con Tecnologia Replicante Italiana
ATLAS: A Toroidal LHC ApparatuS
AUGER: Pierre Auger Observatory
BELLE 2: B detector at KEK
BINGO: BAO from Integrated Neutral Gas Observations
CEPC: Circular Electron-Positron Collider
CLAS: CEBAF Large Acceptance Spectrometer
CMS: Compact Muon Solenoid
CNEA TANDAR: Acelerador TANDAR, Comisión Nacional de Energía Atómica
CONNIE: Coherent Neutrino Nucleus Interaction Experiment
CTA: Cherenkov Telescope Array
DAMIC-M: Dark Matter in CCDs at Modane
DARKSIDE: Two phase TPC for Dark Matter Direct Detection
DUNE: Deep Underground Neutrino Experiment
FCC: Future Circular Collider
GRAND: Giant Radio Array for Neutrino Detection
HAWC: High Altitude Water Cherenkov Gamma-ray Observatory
HL-LHC: High Luminosity Large Hadron Collider
Hyper-K: Hyper Kamiokande
ILC: International Linear Collider
JUNO: Jiangmen Underground Neutrino Observatory
KM3NeT: Cubic Kilometre Neutrino Telescope
LAGO: Latin American Giant Observatory
LAFN Tandem: Tandem Accelerator at Laboratório Aberto de Física Nuclear
LHCb:Large Hadron Collider beauty
LLAMA: Large Latin American Millimetre Array
LSST: Legacy Survey of Space and Time
NoνA: NuMI Off-axis ν_e Appearance
PHENIX:Pioneering High-Energy Nuclear Interaction eXperiment
PPS: Precision Proton Spectrometer
QUBIC: Q&U Bolometric Interferometer for Cosmology
RACIMO: Red Ambiental CIudadana de MOnitoreo
RHIC: Relativistic Heavy Ion Collider
SAGO:South American Gravitational-Wave Observatory

SBND: Short Baseline Neutrino Detector
SENSEI: Sub-Electron-Noise Skipper Experimental Instrument
STAR:Solenoidal Tracker at RHIC
SWGO:Southern Wide-field-of-view Gamma-ray Observatory
TAMBO:Tau Air Shower Mountain-Based Observatory
TOROS: The Transient Optical Robotic Observatory of the South
νIOLETA:Neutrino Interaction Observation with a Low Energy Threshold Array