Accelerators, instrumentation and computing

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Thanks for all the contributions!

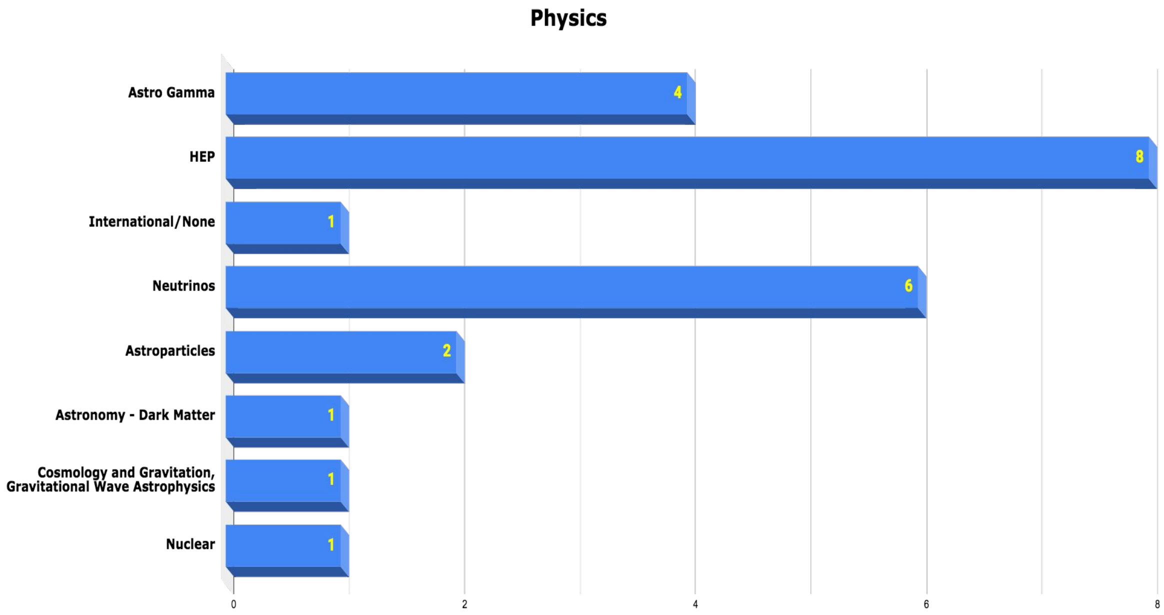
- Total number of contributions
  - **Accelerators and detectors:** 4 contributions
  - **Instrumentation and computing:** 24 white papers

- Incredible diversity of activities ongoing in the region
- Great to get the overview of the experience, skills and potential available
- Overview obtained from the white papers and some presentations from the first workshop.

We will have the opportunity to discuss specificities during the individual presentations that were not included in the whitepapers!

Thanks for all the contributions!

- Main topics/areas in the region:
  - **Colliders experiments** (ALICE, ATLAS, CMS, LHCb)
  - **Neutrinos**: reactor and accelerator based (NoVA, DUNE, SBND, Connie, JUNO)
  - **Nuclear physics**
  - **Cosmo, astrophysics and astroparticle physics** (ASTRI mini-array precursor for CTA, CTA itself, SWGO, Pierre Auger, LAGO)



  - **Gravitational waves** (SAGO, VIRGO, LIGO)
  - **Capacity building** (all of the above, LA-CoNGA)

List of White Papers and References

1) Colombian Network on High Energy Physics - Input on Experimental HEP
2) Argentina Experimental HEP Input
3) Brazilian Participation in the Next-Generation Collider Experiments (Young Scientists)
4) White Paper on Nuclear Science in Brazil. Contribution to the Latin American Strategy Forum for Research Infrastructure
5) The ASTRI MINI-ARRAY: a Precursor for the Cherenkov Telescope Array (CTA)
6) The Cherenkov Telescope Array (CTA)
7) DUNE in the context of LASF4RI. The Colombian Case
8) LA-CoNGA Physics perspectives for the Latin America Strategy Forum for Research Infrastructure
9) Coherent Neutrino-Nucleus Scattering Experiment (CONNIE)
10) The Study of the Quark-Gluon Plasma with the ALICE-LHC Experiment
11) Letter of Intent of the Paraguayan Group
12) Latin American Contribution to JUNO
13) Brazilian Community Report on Neutrino Physics
14) Brazilian Report on Safeguards Application of Reactor Neutrinos
15) Short baseline neutrino experiment in nuclear reactors in Argentina
16) The South American Gravitational wave Observatory (SAGO) White Paper
17) Participants from Brazil in the Pierre Auger Collaboration
18) Physics exploration with the LHCb experiment. LHCb Group in Brazil
19) The ATLAS/Brazil Cluster: Current Status and Perspectives from the ATLAS Upgrade Programme
20) CMS Group - Universidade do Estado do Rio de Janeiro (UERJ)
21) A proposal for Transversal Computer-related Strategies & Services for Scientific and Training efforts
22) Developing the first astronomical and quantum imaging instrument using the Smart Skipper-CCD technique
23) Southern Wide-field-of-view Gamma-ray Observatory (SWGO)
24) The Cherenkov Telescopes Array: fundamental physics and instrumentation.

Our objectives with this discussion

- Bring together this network to discuss current and future scientific and technological development in the region

- Discuss how to consolidate the research in High Energy, Nuclear, Cosmology and Astroparticle Physics by extending the technical competences Latin-American researchers and discuss strategies taking into account:
  - the Latin-American reality, the international landscape, synergies with neighboring fields, environmental and social impact

- Strengthen the existing partnerships (or promote the creation of new ones) among institutions for research and development of software, computing and instrumentation

- Valorise the industrial, social and environmental impact of our activities

The main scientific drivers

Accelerators and detectors:

- How to achieve proper complementarity for the high-intensity frontier vs. the high-energy frontier?
- What are the options and challenges for accelerator technology?

Instrumentation:

- What areas of instrumentation R&D are ongoing and how do they meet the needs of future experimental programs? And possibilities of collaborations to boost the efforts?

Computing:

- How should computing evolve to support future scientific programs and their specific needs?
- What R&D activities are ongoing? and how to boost them in order to enable this computing evolution? While ensuring computation and science reproducibility as well as open access principles.

Also, important drivers in our region (1/2)

- Equally important and partially covered in some contributions:
  - How to preserve knowledge, technical expertise and train the future generation of experts in detector R&D?
    - Capacity building, training, recognition
    - Capacity keeping in academia: It is essential to make the research environment in particle physics as attractive as possible
  - Funding stability
  - Strengthen the collaboration between institutions in ongoing and future projects
  - Environmental and society impact: Links with industry (instrumentation, AI) & knowledge transfer, outreach & communication, environmental impact of our activities

Also, important drivers in our region (2/2)

- It is essential to have a coherent plan and approach in the region, in particular for future collaborations and training.
  - Funding stability and industry links might be more country-dependent
- e-infrastructure and internet performance varies a lot in the region
- TechEd and digital education status in the region needs development as shown during the last months → important for the capacity building and training of new generations
- Keep in mind that those are global scientific fields, so, look for synergies and/or sync with other relevant initiatives is important, like Snowmass + European Strategy
- **Planning for next years could not ignore the new normality during and after pandemia**

The main scientific drivers: accelerators (1/2)

In the region:

- For groups involved in collider experiments, focus on successful completion of HL-LHC upgrade remains a priority. Institutions already participating in LHC experiments in Colombia, Brazil and Argentina expressed interest in continuing their involvement in HL-LHC. Several instrumentation activities ongoing, key projects in the regions!
  - Minor involvement at the accelerators technology development sector.
  - But Colombian, Brazilian and Argentinian institutions keep an eye on the new developments and global physics interests discussion (to be discussed in other physics-related sessions)
- Colombia, Paraguay and Peru and Brazil, participate in accelerator-based neutrino experiments but focus on the detector instrumentation.

The main scientific drivers: accelerators (2/2)

In the region:

- There are two particle accelerators dedicated to basic nuclear physics in South America: One at the LAFN at the Institute of Physics of the University of Sao Paulo **[4]** equipped with a Tandem Accelerator which produces stable beams of energies around 5 MeVA maximum. Another called Tandar, at CNEA in Buenos Aires, Argentina.
  - Some of the scientific subjects could be in close relationship with the subjects of the HEP community
- Let’s not forget the Sirius Synchrotron Light Source (presented in 1st workshop, no white paper)
- In general a topic not presented in white papers
- Vacancy in the region.

The main scientific drivers: instrumentation (1/2)

Our global picture challenges:

- Future experiments require very challenging detector technologies, depending on the application:
  - Much improved spatial resolutions (few um per hit, low mass)
  - Much improved time resolutions (down to 10 ps per hit)
  - High performance photo-detectors
  - Very high tolerance to radiation
  - Very large area coverage at low costs
  - Very high number of channels
  - Very high readout speed
  - Enhance the performance for reconstruction and triggering
  - Low threshold acquisition systems with low readout noise

↓

The main scientific drivers: instrumentation (2/2)

- Future experiments require very challenging detector technologies, depending on the application:
  - Increase Exposure
  - Single photon-electron resolution
  - Third Generation (3G) of Interferometric Gravitational-wave Detectors
  - Advanced detector simulation tools are also essential

Our drivers

- What areas of instrumentation R&D are ongoing and how do they meet the needs of future experimental programs? possibilities of collaborations to boost the efforts?

Instrumentation

We identified common developments on the following subjects

- FPGA Boards and Read Out systems
- Small Photomultipliers (SPMTs)
- Silicon Photomultipliers (SiPMs)
- Charge-Coupled Devices (CCDs and Skipper CCDs)
- Resistive Plate Chambers (RPC)
- ARAPUCA Light Trap (Argon R&D Advanced Program at UNICAMP)
- Water Cherenkov Detectors (WCD)
- Laser Interferometer

FPGA Boards

Argentina

- **ATLAS:** Proposal **[2]** for an electronic laboratory to design and test FPGA Boards and the corresponding firmware for the Level Zero Trigger of ATLAS experiment for the HL-LHC (2026).
- **Skippers CCDs:** Institutions in collaboration with Fermilab, working on the design of a readout FPGA board **[9,15, 22]**.
- **LTA**: Low Threshold Acquisition system have just been developed for the Dark Matter experiments (the first controller specially designed to operate Skipper CCDs) that uses an FPGA to make the signal controlling **[22].**

Brazil

- **CMS L1 trigger**: A team is developing with Fermilab an L1 level trigger for the CMS front muon system, based on deep neural networks implemented in FPGA **[20]**.
- **ATLAS- Calorimetry:** There is a Cluster of institutions involved in both electronic instrumentation and algorithm development **[19].** The activities aim at developing the new back-end electronics (FPGA-based) and new energy estimation algorithms based on deconvolution strategies.
- **ν-Angra:** For a fast trigger decision, the selection algorithm was developed to be implemented in a dedicated FPGA. For remote configuration and upgrade of its firmware, a Raspberry PI card with Ethernet connection has been integrated to the FPGA circuit **[14]**.

Readout Systems (1/2)

Brazil

- **ALICE:** For the Run-3 upgrade, groups have provided major contribution through the full development of a new front-end readout chip for two ALICE detectors, the Time Projection Chamber (TPC) and the Muon Chamber (MCH), and the construction of the mechanical support of the new Muon Forward Tracker (MFT) **[10].**
- **ALICE Upgrade for LHC Run-4:** The FoCal is a high-granularity calorimeter localized in the very high rapidity region (forward) of the experiment adding new capabilities. The aimed contribution in this project is the R&D and construction of the FoCal Silicon Pad layers readout system. Given the large experience of the group with the development of the SAMPA chip, which will instrument the ALICE TPC and MCH detectors beyond Run-3, it is natural to expect that a significant contribution to this part of the project can be achieved **[10].**

Argentina

- **Skpier CCDS:** Develop faster readout strategies for low-noise Skipper CCDs **[9,15, 22]**

Readout Systems (2/2)

Colombia (Peru and Paraguay)

- **DUNE:** Two institutions are working directly in the design of the digitalization boards **[1]**.
  To read the SiPMs signals, digitalization at room temperature will be performed by electronics boards currently under designing by Colombian engineers in collaboration with Fermilab.
  The boards are known as DAPHNE (Detector Electronic for Acquiring Photons from Neutrinos) and will be in charge of the digitalization, initial processing and communication.
  As a result of this work at the beginning of the year 2020, the production of a small number of prototypes board is planned. The prototypes will be tested at different facilities around the world with the close collaboration between Colombian, Peruvian and Paraguayan engineers **[7].**

CCDs (Charge-Coupled Devices)

Argentina, Brazil, Mexico and Paraguay in collaboration with Fermilab

- **CONNIE:** The experiment installed in Brazil, has a total accumulated exposure of data considered in the most recent analysis corresponds to 8 good-performance CCDs (47.6 g active mass) and 3.7 kg-days: 2.1 kg-days taken with the reactor on and 1.6 kg-days with the reactor off **[9]**. There is a proposal to upgrade the experiment with Skipper CCDs, a new technology that will allow to achieve lower detection thresholds and greatly increase its Sensitivity **[9].**

- **Nuclear reactor in Argentina:** There is a wider effort in Latin America to build the next big reactor neutrino experiment using Skipper CCDs **[15]**. One strong contender for the experiment site is the Atucha reactor in Argentina , which may allow one to place the detector at a minimal distance of 12 m from the reactor core, inside its dome, thus increasing the neutrino flux and also profiting from the concrete shielding from the dome to decrease the cosmic muon background **[9].**

- **New Astronomical Instrument:** Develop Smart Skipper-CCD camera to install the camera in new instruments. This proposal seeks to develop technology and scientific forecasts for next-generation cosmic surveys probing the ‘dark sector’. Specific aims are **[22]**: (1) to develop faster readout strategies for low-noise Skipper CCDs, (2) characterize the optical performance of these detectors for use in quantum imaging applications and cosmic surveys, (3) to demonstrate the first implementation of Skipper CCDs on a prototype astronomical instrument, and (4) to assess the sensitivity of future cosmic surveys to fundamental properties of dark matter.

SiPM (Silicon Photomultiplier)

Paraguay

- **DUNE:** Efforts to help to the ARAPUCA detector system in two items **[11]**:
  - Cold electronics for the amplification of the SiPM
  - In the communication of the DAPHNE module (in charge of the digitization of the signals) with the DAQ system.
- For SBND we help in the integration of the ARAPUCA signals with the DAQ.
- The ARAPUCA concept has been proposed for increasing the effective collection area of SiPMs through the shifting and trapping of scintillation light in noble liquids (Brazil Neutrinos).

Colombia

- Institutions are working in the design of the readout system for DUNE experiment **[7].**

Brazil

- **ASTRI MINI-ARRAY (Precursor of CTA):** ASTRI telescopes are characterized by an optical system based on a dual-mirror Schwarzschild-Couder design and a camera at the focal plane composed of silicon photomultiplier sensors managed by a fast read-out electronics specifically designed.
  Brazilian engineers have been involved in the development of the prototype as well as with the construction of the ASTRI camera, and they must continue their activities in Italy, in order to participate of the final testing of the telescope with the camera and acquire the entire knowhow for future manufacturing in Brazil of other SST telescopes for the CTA-South Array **[5, 6, 24]**.

SPMT (Small-area PMT)

Brazil and Chile

- **JUNO:** A set of 25000 photomultipliers, designed to have a better single photon-electron resolution in order to work in "photon-counting mode".
  The Latin American activities within the JUNO collaboration are focused on the SPMT system, with both hardware and software contributions. In particular the Chile Team work is devoted to the high-voltage splitter (HVS) **[12]** and the underwater box (UWB). On the simulation side the Brazilian groups are involved in developing the code for the SPMT electronic simulation **[12]**.

Brazil

- **AugerPrime:** The addition of a fourth, small-area PMT (SPMT) in each WCD will drastically reduce the number of events with saturated signals **[17]**. This effort involves the acquisition of the PMTs, HV, cables and further components, characterizing them and assembling them inside the WCD at the Auger site in Argentina. The team will share this responsibility working in close collaboration with the group of the Osservatorio Astrofisico di Torino (INAF) and INFN, Sezione di Torino, in Turin, Italy.

ARAPUCA

Brazil in collaboration with Colombia, Peru and Paraguay

- **DUNE:** The far detector of the experiment will be constituted by a liquid argon time projection chamber with an active mass of 40 kton. Dimmer light coming from the most faraway region of the TPC needs to be collected, for that reason a large photon collection is required at the far end with the use of a new technology developed in Brazil **[13, 7]**.

- **ARAPUCA concept:** It is a light trap, which will allow to increase significantly the light detection efficiency of the detector with respect to the previous design based on scintillating/guiding bars **[13]**.

- **X-ARAPUCA:** currently represents the baseline choice for the photon detection system of the DUNE experiment. The X-ARAPUCA is a development of the traditional ARAPUCA. This concept was conceived to reduce losses on the internal surfaces of the ARAPUCA by diminishing the average number of reflections before detection **[13]**.

WCD (Water Cherenkov Detectors) (1/2)

Large International Collaboration in LA

- **LAGO:** Many countries are working on the development, construction and operation of Water Cherenkov detectors for different site, as well as the development of a new electronic readout, a DAQ custom system, and also the modelling and simulation of the signal **[1]**.

- **Pierre Auger Observatory:** The array consist of 1600 WCD spread over 3000 km2 **[1, 17]**. Cherenkov light from the passage of ultra-relativistic charged particles is collected by three 9” photomultiplier tubes (PMTs) pointing into the water.

https://www.symmetrymagazine.org/article

WCD (Water Cherenkov Detectors) (2/2)

Large International Collaboration in LA

- **SWGO**: Development of the Southern Wide-field-of-view Gamma-ray Observatory (SWGO), a next-generation instrument with sensitivity to the very-high-energy band to be constructed in the Southern Hemisphere **[23]**. Will provide a unique view on gamma-ray and cosmic-ray emission from tens of GeV to hundreds of TeV. The facility will improve upon the success of the HAWC Gamma-ray Observatory in Mexico that is surveying the Northern gamma-ray sky.

Brazil

- **ν-Angra:** The Neutrinos Angra Experiment is a water-based Cherenkov detector located in the Angra dos Reis nuclear power plant **[14]**. In addition to the detector itself, a complete data acquisition system has been designed and integrated for the experiment in order to perform tasks, such as: biasing of the PMTs (High Voltage power supply), amplification of PMT output signals (Front- End electronics), sampling and digitization of the signals (NDAQ electronics), online events selection (Trigger system) and local data storage (commercial Network Attached Storage). FPGAs will control the data flow and perform the fast trigger decision.

RPC (Resistive Plate Chambers)

Brazil

- **Auger Upgrade:** Brasil intend to continue to deploy, test and operate at the Auger site the RPC assembled in Brazil in collaboration with scientists from institutions in Portugal **[17]**.
- **CMS:** The muon Upgrade project consists of installation of a new Link System for the RPC system and new chambers in the high eta regions **[20]**. This project will be finished with the installation of the new RPC chambers and electronics during the Yearly Technical Stops at the end of 2022 and 2023. Working in the standard maintenance of the detector, during LS2 and also have participated in software activities as: online software upgrade and maintenance, update of the readout software for Run-3, and the data certification using Machine Learning (ML) techniques to evaluate performance using autoencoder. The group will share the responsibility to develop: 1) The online software to control and monitor the Front End boards and the new Link System; 2) A new Data Quality Monitoring for the online monitoring of the detector performance; The plan is to build in Rio a laboratory fully equipped with all electronics and set-up needed to develop and validate the new software.

Colombia

- **CMS:** Some groups has been involved in the operation and upgrades of the RPCs and Gas electron multiplier detectors used for muon identification and triggering of the CMS experiment, some of the engineers have been stationed for about two years at CERN, others at FERMILAB **[1]**.

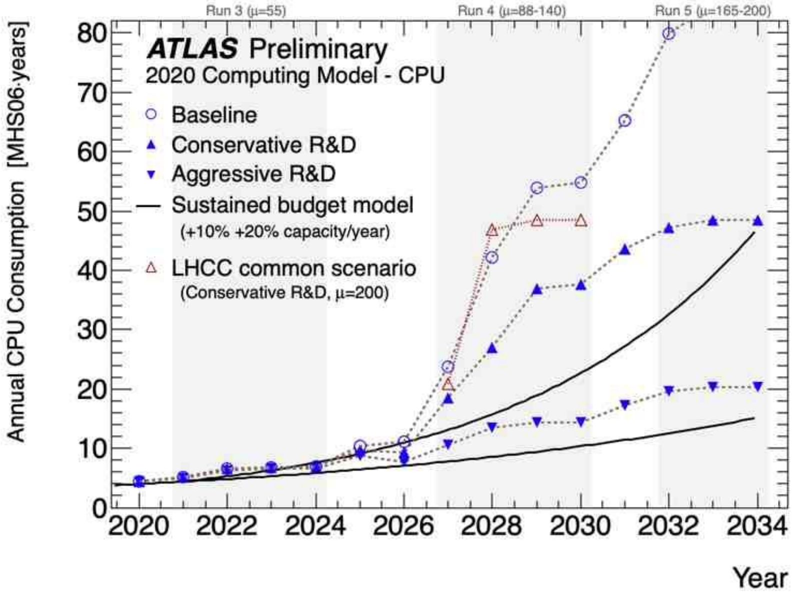
Laser Interferometer

SAGO (The South American Gravitational wave Observatory): After 2030, it is likely that two other observatories will step in: Einstein Telescope (ET) and Cosmic Explorer. They will be the first ones of the so called third generation (3G). They will need a third partner for triangulation of arrival times in order to determine more precisely the source position in the sky.
So, there will be an opportunity for a South American Gravitational wave Observatory, if the Latin American community reach by that time a critical mass of experimentalists already educated in the 3G technology. The main goal is the construction and the subsequent operation of a 3G laser interferometer for gravitational wave observation in South America **[16]**.

There are only two groups in Latin America involved in the LIGO Scientific Collaboration (LSC) and one in Virgo. All three groups are in Brazil. And there are only a few Latin Americans involved in laser interferometer projects.
Therefore, the challenges to overcome in order to propose a project for the construction and development of a gravitational wave observatory in South America are enormous.

The main scientific drivers: computing and software infrastructure

- HEP computing is evolving
  - The landscape has shifted significantly in the last decade (heterogeneity, accelerators, ...)
  - “Bad software is extremely expensive!”
  - synergies and collaborations across HEP (mention Latam workshop for example!)
- New projects need to consider not only detectors/R&D costs but also computing costs
- Data management plans are crucial
- Long-life computing projects are moving more and more towards open source/data models
  - Also in hybrid combinations of public and private (volunteer+commercial) resources

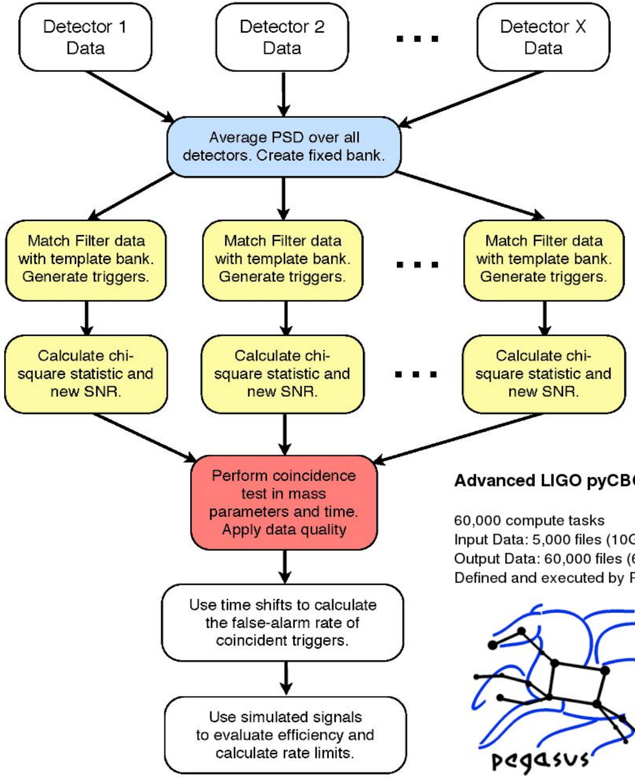


Projected CPU requirements of ATLAS between 2020 and 2034 based on 2020 assessment.
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ComputingandSoftwarePublicResults

The main scientific drivers: computing and software infrastructure

Questions to answer:

- How should Scientific Computing evolve in order to support future scientific programs and their specific needs?
- What R&D activities must be supported, and how, in order to enable this computing evolution?
- A lot of efforts in different communities to harmonise resources and techniques:
    - The way that computing resources are used, and
    - The techniques and protocols that software development and studies reproducibility is done



Advanced LIGO pyCBC Workflow

60,000 compute tasks
Input Data: 5,000 files (10GB total)
Output Data: 60,000 files (60GB total)
Defined and executed by Pegasus WMS

https://pegasus.isi.edu/2016/02/11/pegasus-powers-ligo-gravitational-waves-detection-analysis/

Computing and Data Management

Brazil

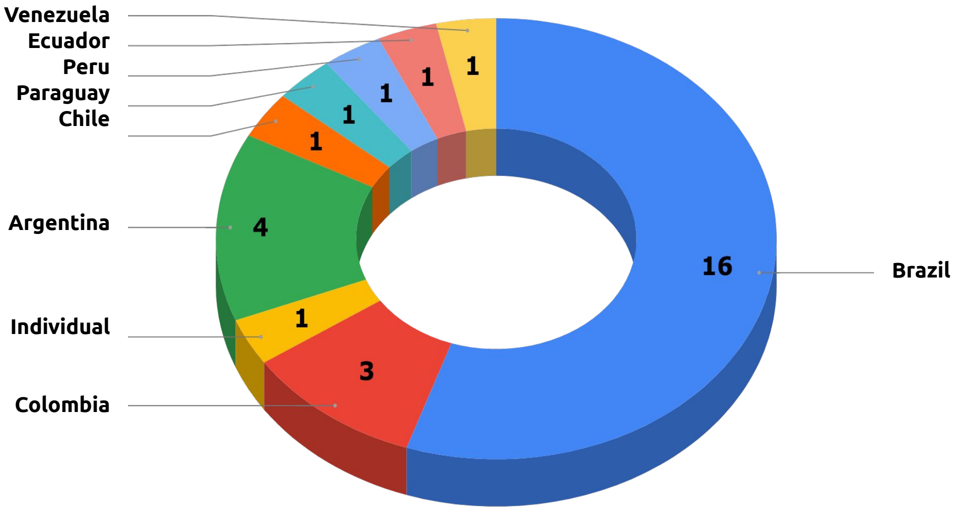
- **CONNIE:** data is currently stored, processed and analysed at the CHE cluster at CBPF, which is the only machine allowed by Eletronuclear to connect directly to the laboratory hosting CONNIE at Angra 2. The cluster has a professional storage system with currently 100TB dedicated to CONNIE and 280 cores available for CONNIE processing **[9]**.

- **ALICE:** groups have been providing its fair share contribution to the experiment since 2007 through the SAMPA cluster (acronym from the Portuguese, Sistema de Analise e Multi-Processamento Avancado), hosted in the Physics Institute of Universidade de São Paulo.

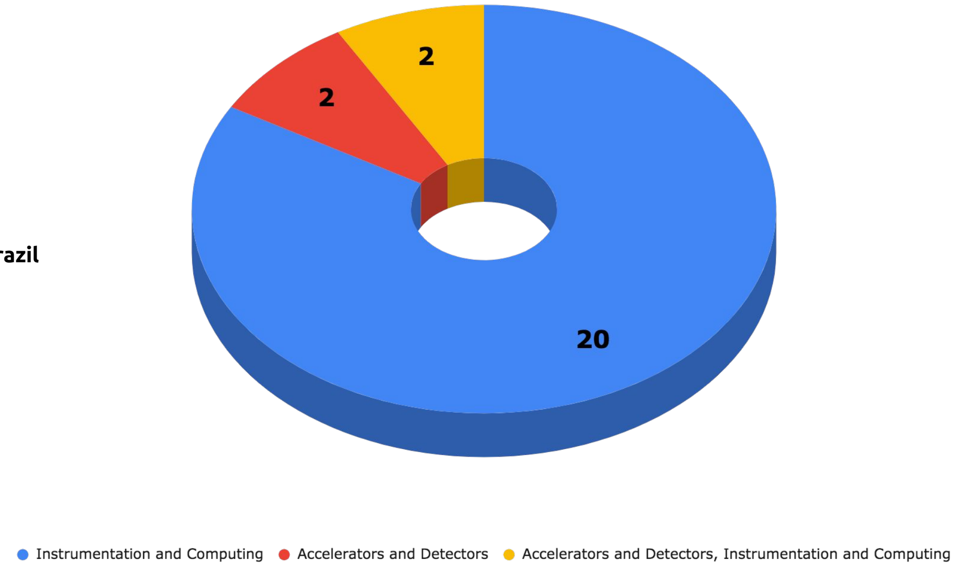
  Currently, the cluster has 2408 CPU cores, totalising 18.7 kHS06 of processing power and 0.85 PB of storage. However, it is important to highlight that part of this processing capability, around 6 kHS06, is used by local users, outside the GRID **[10]**.

Overview of Countries and Categories

LA countries involved



Category of the White Paper

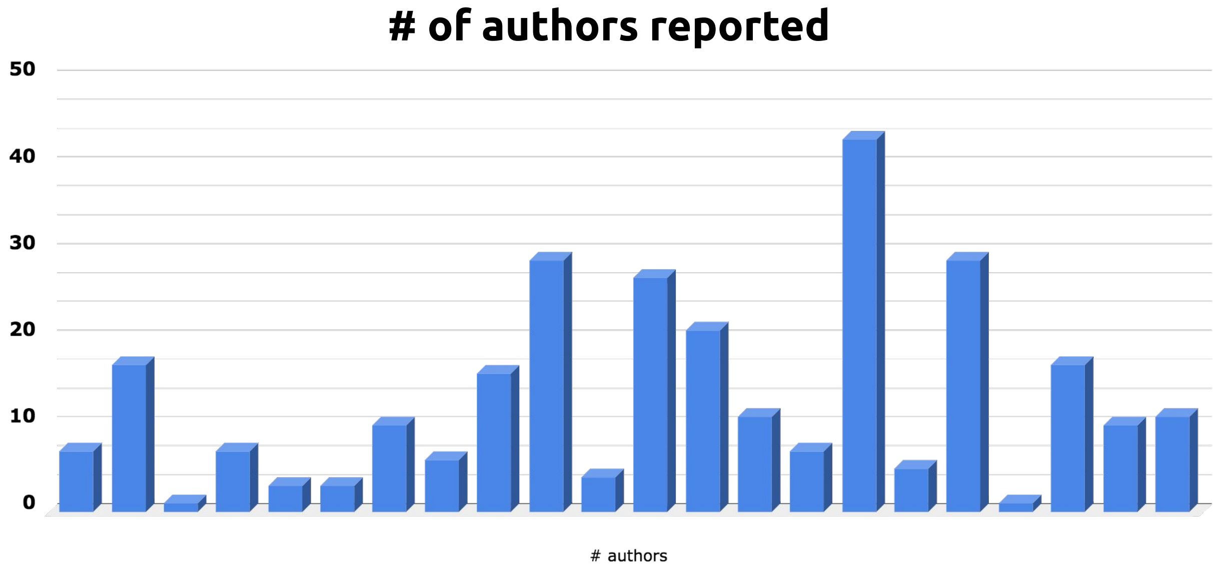


A simple view of the proposal by country/contributor and the main categories they selected

Overview of the Authors

Using the list of authors/co-authors/interested people in the WP, we can see that numbers does not diverge so much between the proposals

- Of course, we understand that in some cases thee WP represents much larger collaborations
- But, this histogram wants to give a view of the people directly involved in the WP production

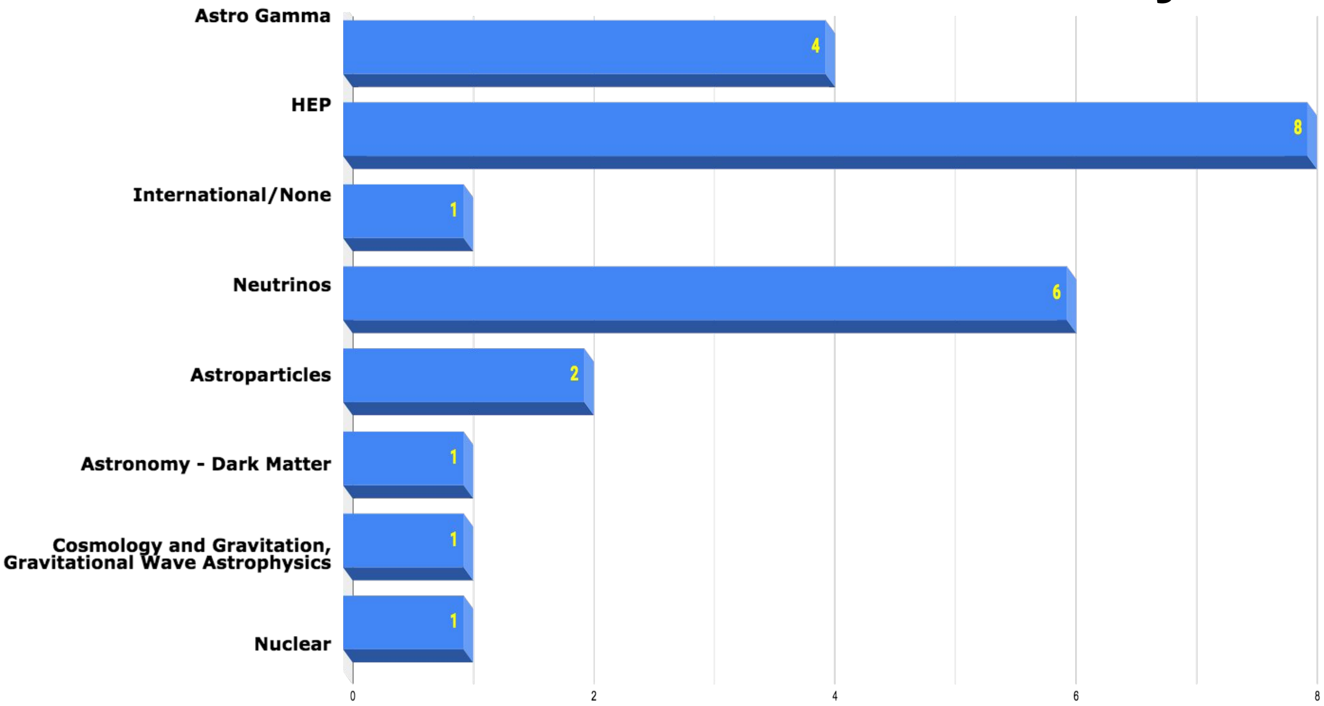


Those numbers can help already to identify useful resources (e.g. computing, consultancy,...) for relative compact groups. Also, shows something obvious but relevant: the interest in the region. **Almost 300 people give direct input to the WPs.**

Overview of the Physics

The proposal cover a large amount of physics programs Collider fundamental physics (SM and BSM), Dark Matter searches, neutrinos physics (on multiples experimental setups), nuclear physics, astro-particles and relevant cosmic-rays experiences, Gravitational Wave and Multi-messenger astronomy + related and traversal computing and software developments

Physics



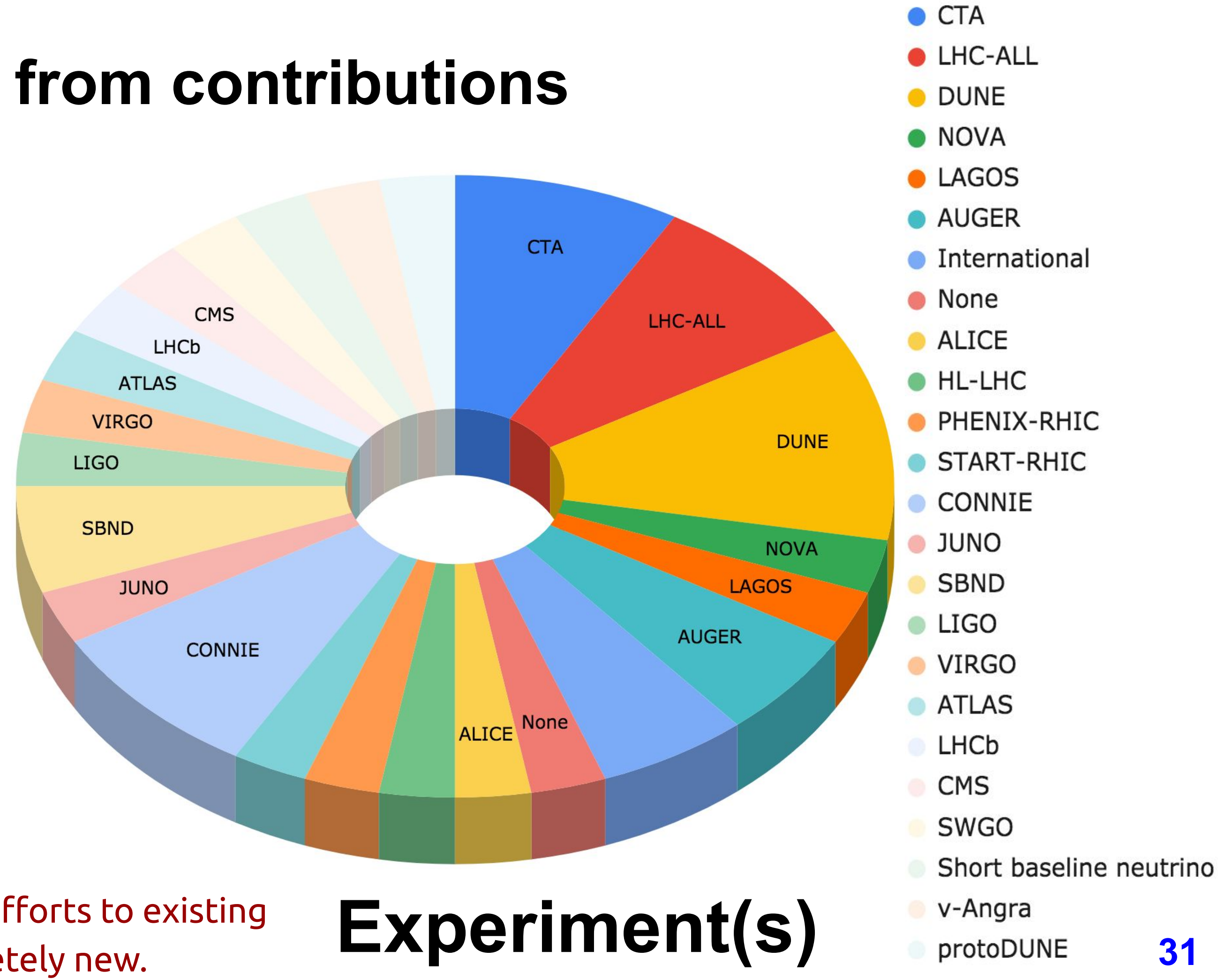
Can appreciate a broad physics program and a pragmatic approach of making specific skills and experiences available to large-scale projects

Regional picture from contributions

A qualitative view of the experiments

A group effort to find common keywords within the WP, from different perspective.

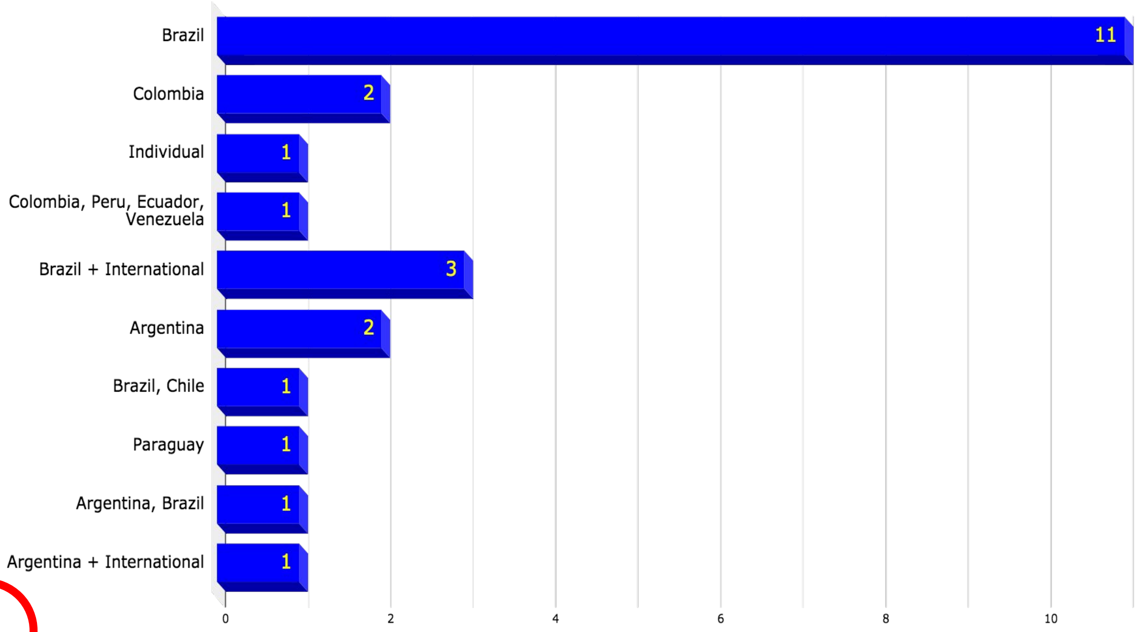
The proposals refer to International (LHC x4 larger experiments, CTA, DUNE, FCC,...) and also regional (American Gravitational wave Observatory, LAGOS, computing and scientific + professional training...)



Even when the majority refers to efforts to existing projects, some of them are completely new.

Overview of the Proposals*

- The plot reflects the number of proposal submitted by country, where also we can appreciated collaborations between countries in the region
- The correspond to large and/or targeted collaborations
- International (CTA, DUNE, FCC) & regional (American Gravitational wave Observatory, ANDES)



ANDES A regional major project in planning phase. A multidisciplinary experiments planned → broad instrumentation program
No white paper but stay tuned for its presentation tomorrow (Tuesday)
http://andeslab.org/index.php

*Proposals in terms of research project of presented WP. Not included the fact that many countries collaborate already in Pierre Auger, LAGO, SWGO, CTA, CONNIE, ATLAS, etc.

Synergies with neighboring fields

- Computer science: collaboration in the use of cloud computing, big data and storage external services was also mentioned. Usage and development of ML/AI
- Sharing of “generic” resources and trainings, like computing, software development and management, consultancy with external parties, like companies
- The UniANDES group in Colombia mentions its participation in interdisciplinary applications of semiconductor and gaseous radiation detectors
- Geophysics (e.g. muon tomography with MuTE/UIS)
- Citizen science (RACIMO for environmental monitoring)
- Paraguay started working with space weather (due to its location at the center of the South Atlantic Magnetic Anomaly)
- Others like medical physics, biology, facilities, etc...
- Argentina and its series of dedicated reactors and the collaboration between them due to a single overseeing agency, like another example.

Moving towards WP presentations and open discussion

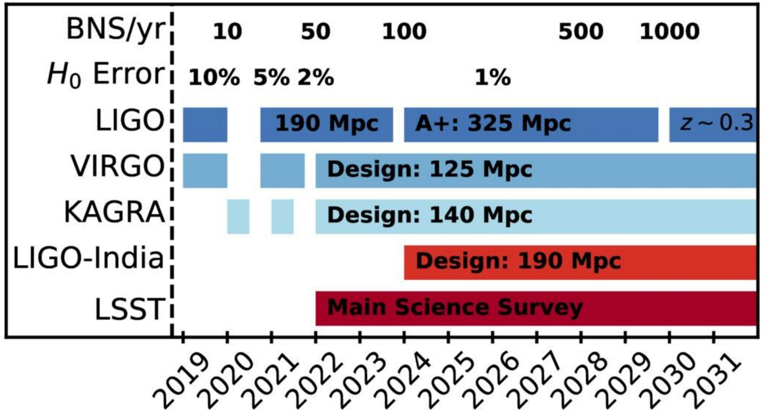
- To Speakers and attendees, please keep in mind the following points to help us drive the discussion afterwards:

    - What are your scientific drivers? Relation with global scientific drivers?
    - Timescales and personpower available
    - Challenges and needs
    - Possibility of collaboration in the region and/or international ongoing collaboration?
    - Possibility of knowledge and technology transfer? Or other link with society (e.g. citizen science, education, outreach)
    - Environmental impact?

Looking forward to the individual presentations and the following discussions!

Backup

Overview of the Experiments



https://arxiv.org/abs/1904.02718