White-paper on Nuclear Science in Brazil

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The Scientific Field of Nuclear Science:

- Hadron Physics - QCD and structure of hadrons and nuclei;
- QCD and phases of strongly interacting matter at extreme conditions
- Nuclear Structure and Reaction Dynamics
- Nuclear Astrophysics
- Fundamental Symmetries
- Applications and Societal Benefits

Ref: Long Range Plan NSAC 2015; Long Range Plan NuPECC 2017

Obs. Some subjects have overlap with Particles and Fields, Astroparticles, Astrophysics and Astronomy

Nuclear Science in Brazil today:

Since 2017 the majority of the Brazilian nuclear physics community is united in a large project called National Institute of Science and Technology-Nuclear Physics and Applications (INCT-FNA, a CNPq-FAPERJ funding program). Its objectives are:

- Consolidate a community of Nuclear Physics and Applications of Excellence
- Provide a scientific environment of international reference for the development of young scientists in the coming decades.
- Continue efforts to disseminate to society the knowledge and modern technologies of the area.

Current Nuclear Science Efforts and Facilities in Brazil

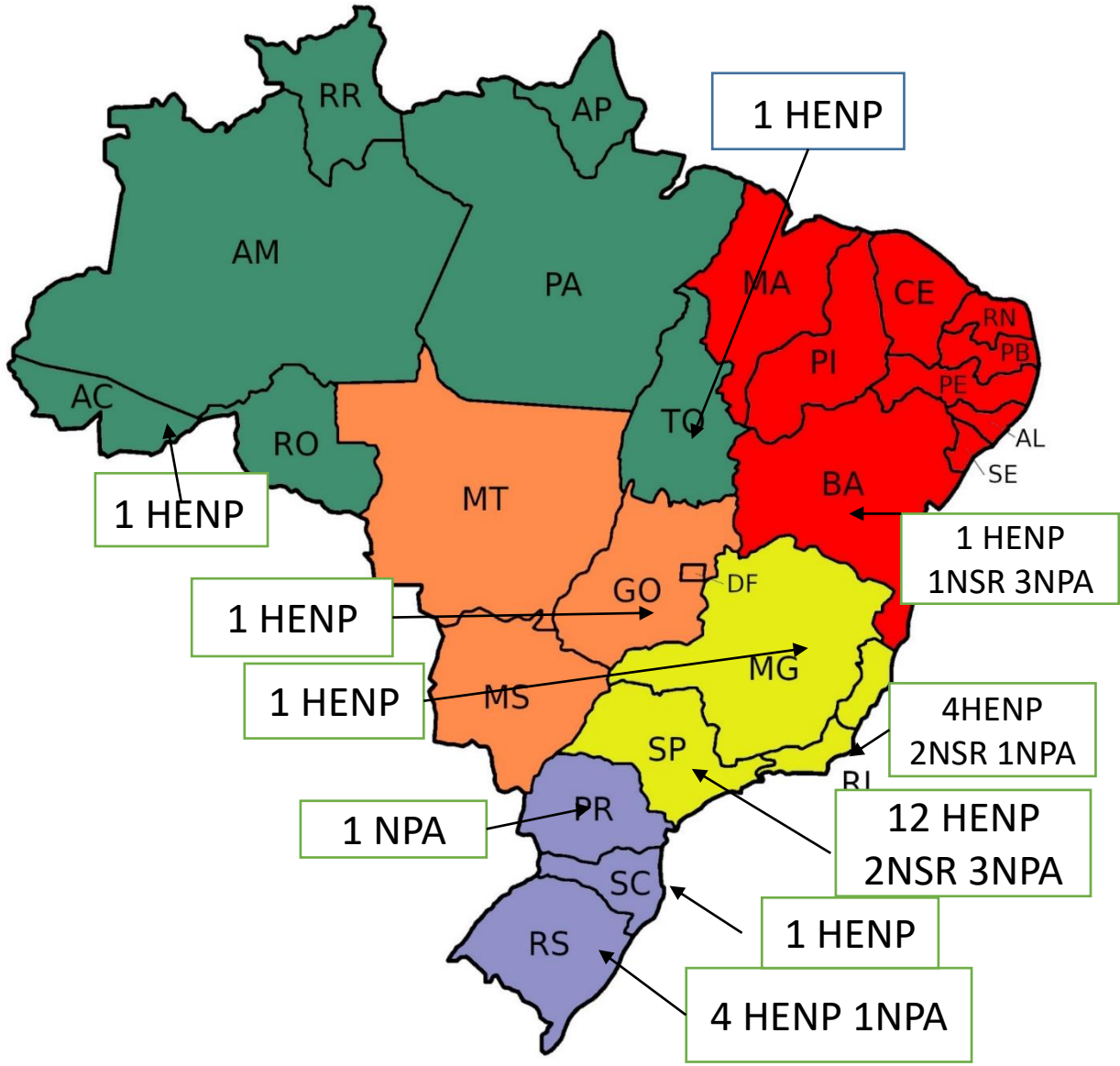
divided in 3 subfields:

HENP : High Energy Nuclear Physics
NSR : Nuclear Structure and Reactions
NPA : Nuclear Physics Applications

40 institutions in 10 states
172 researchers : 80 in HENP
45 in NSR
47 in NPA
~ 92 students and pos-docs

Groups in South-East region (25), South (7), North-East (5), North (2) and Central-West (1)

Obs: numbers are based mainly on INCT and are probably underestimated in HENP and NPA



High Energy Nuclear Physics in Brazil:

Theory:

- Hadron theory, effective models, QCD sum rules etc. (**17 researchers;** at IFUSP, IFSC, UNICAMP, Mackenzie, IFT-UNESP, UCS, ITA, UFSC, UERJ, UFG, UFRGS, UFPel, UFSM)
- Stars, EOS with quarks and hadrons, Magnetic field etc. (**14 researchers;** at ITA, USP, UFF, UFRJ, CEFET/RJ, CBPF, UERJ, UFSC, UFRGS, FURG)
- Heavy ions, hydrodynamics, Quark Gluon Plasma etc. (**18 researchers;** at IFUSP, IFT&SPRACE/UNESP, UFFS, UFABC, UNICAMP, EEL-USP, UNESP, UFRJ, UFF, UFSC, FURG, UFPel, UNIFAL)
- QCD phenomenology, low x and Color Glass Cond. etc. (**9 researchers;** at IFUSP, UNICAMP, UFRJ, UFSC, UFRGS, FURG, UFPel.)
- QCD theory, lattice, eq. Dyson-Schwinger etc. (**9 researchers;** at IFUSP, UERJ, UNICAMP, UFRJ, UFSC, UFRGS, FURG, UFPel.)

Experiment:

Heavy ions, hydrodynamics, Quark Gluon Plasma etc. (**8 researchers;** of IFUSP, UNICAMP, UFABC working at ALICE@CERN, **3 researchers** of IFT-SPRACE/ UNESP, S.Korea working at CMS@CERN) and **1 researcher** at STAR@RHIC and SPHENIX@RHIC)

High Energy Nuclear Physics in Brazil:

Future Perspectives :

- Stronger links between **theoretical and experimental** groups/ **theoretical communities**
- Access to **high performance computing** systems
- Attract **new students and post-docs**
- Expand and strengthen **national and international collaborations**
- Focus on the **upcoming experiments**
- Intermediate and long term **planning**
- **Geographical expansion**
- Increase the number of groups **doing lattice calculations**
- Increase the number of **experimentalists in general** and in JLAB , BESIII and future colliders
- More activity in **phenomenology**
- More activity in **EoS of nuclear matter**, phase transition at high baryonic chemical potential (NICA, GSI-FAIR)

Nuclear Structure and Reactions activity in Brazil:

Theory:

- Calculations of **direct reactions with breakup** of radioactive and stable weakly bound nuclei (**7 researchers** IFUSP, ITA, UFF, UFRJ)
- Description of light exotic nuclei using **few-body models** (**3 researchers** ITA, IFUSP, IFT)
- **Dirac-Hartree-Fock-Bogoliubov and Dirac-Brueckner** approximations for nuclear matter and finite nuclei (**1 researcher** ITA)
- Studies of stable and exotic nuclei, including **pairing effects** (**2 researchers** UFF)
- Effective theories for weakly bound nuclear systems (**3 researchers** ITA,IFUSP, IFT)

Experiments:

- Measurement of nuclear reactions with **radioactive/stable** beams (**25 r.** IFUSP, UFF)
- Measurement of nuclear reactions with **astrophysical interest** (**3r.** IFUSP)
- Measurement of isomeric states and half-lives using gamma spectroscopy(**1r.**)

NSR facility: Open Laboratory for Nuclear Physics (LAFN) University of São Paulo

- About **60-70 users**, staff members, pos-docs, graduate students and external users.
- **Project Advisory Committee (PAC)**
- Nuclear reactions with stable or **radioactive beams 5AMeV**
- **Radioactive Ion Beams in Brasil (RIBRAS)**
  2 superconducting solenoids
  Produces light, radioactive beams ^{6}He,^{7}Be,^{8}B,^{8}Li,^{10}Be etc

8MV Pelletron Tandem Accelerator

Several beamlines:

1.Radioactive Ion Beams in Brasil (RIBRAS)

2.Large multipurpose scattering chamber

Investment in new detectors/electronics:

-thin Single/Double Sided Strip Detectors (DSSD) of Si for charged particle detection

-Lyso crytstals for γ-detection with SiPM (arrays in scattering chamber)

-neutron wall (position/energy sensitive)

-Fully digital electronics, acquisition systems

Achievements of the Brazilian Nuclear Science community in 2017-2019

926 publications in peer-reviewed journals
96 masters theses and 56 PhD theses, 30 post-docs.
Large number of projects supported by funding agencies
Large number of international collaborations: > 30
Large number of participation in international conferences >100

Some highlights:

In High Energy Nuclear Physics :

- SAMPA chip developed at USP included in detection systems of Alice
- Study of hybrid stars (hadronic matter with quark core). EoS of both hadronic and quark matter compatible with the existence of a phase transition at low temperature and high baryonic chemical potential, as in the QCD phase diagram.

In Nuclear Structure/Reactions and Nuclear Astrophysics (NSR)

- The low energy, radioactive ion beams of RIBRAS/Pelletron with the digital upgrade financed by new thematical project of FAPESP will have an important role in the international scenario.

Findings:

- The nuclear science community has a **well qualified team of researchers**, englobing all activity in basic nuclear science
- **Collaboration** between theory groups is sound and increasing
- Collaboration between **experimental and theory groups** is very strong in NSR
- Practically no experimental activity in Hadron Physics in Brazil
- Serious **problems for science funding**, for fellowships students/pos-docs, travel expenses for collaboration

Recommendations:

- Expansion to other regions and states in Brazil
- Future plans for new experimental infrastructure for NSR
- Establish collaboration with Chilean experimental hadron physics group:http://www.cctval.cl/index.php/es/

Latin American Symposium on Nuclear Physics and Applications (LASNPA)

1995 Caracas, Venezuela
1997 Caracas, Venezuela
1999 San Andrés, Colombia
2001 Ciudad de México, México
2003 Santos, Brazil
2005 Iguazu, Argentina
2007 Cuzco, Peru
2009 Santiago, Chile
2011 Quito, Ecuador (IUPAP support cat. C)
2013 Montevideo, Uruguay
2015 Medellin, Colombia (IUPAP sup cat.B)
2017 Havana, Cuba (IUPAP support cat.B)
2020 San Jose, Costa Rica (IUPAP support cat.B)

Asociación Latino Americana de Física Nuclear y Aplicaciones (ALAFNA)

Founded in **2009 VIII LASNPA in Santiago** by researchers representing mainly the fields of **NSR and NPA** from several Latin American countries. ALAFNA is an **experts committee** and its main activity has been to organize LASNPA. It is **recognized by IUPAP** and **represents LA in WG9 of IUPAP**.
Its objectives are:
- To strengthen ties among the Latin American Communities doing nuclear research and applications to foster collaborations and promotion of activities,
- To educate the scientific community and the general public through the promotion of nuclear physics and the peaceful uses of nuclear technology,
- To do periodic overall assessments of nuclear science in Latin America in the context of world wide activities, and
- To discuss at a multi-national level future planning of nuclear science activities in Latin America.

New collaboration between ALAFNA and IAEA

THANK YOU