

MILLENNIUM INSTITUTE  
FOR SUBATOMIC PHYSICS  
AT HIGH-ENERGY FRONTIER  
**SAPHIR**  
Theory Group



TARAPACA



COQUIMBO



VALPARAÍSO

METROPOLITANA



PONTIFICIA  
UNIVERSIDAD  
CATOLICA  
DE CHILE



SAPHIR



# SAPHIR Theory Group

- Antonio Carcamo (UTFSM),
- Giovanna Cottin (UAI),
- Marco Aurelio Díaz (PUC),
- Juan Carlos Helo (ULS),
- Sergey Kovalenko (UNAB),
- Valey Lyubovitskij  
(UTFSM, U. Tuebingen)
- Farinaldo Queiros  
(Universidade Federal  
do Rio Grande do Norte),
- Tércio de Melo (UNAB),
- Jilberto Zamora-Saa (UNAB),
- Alfonso Zerwekh (UTFSM)

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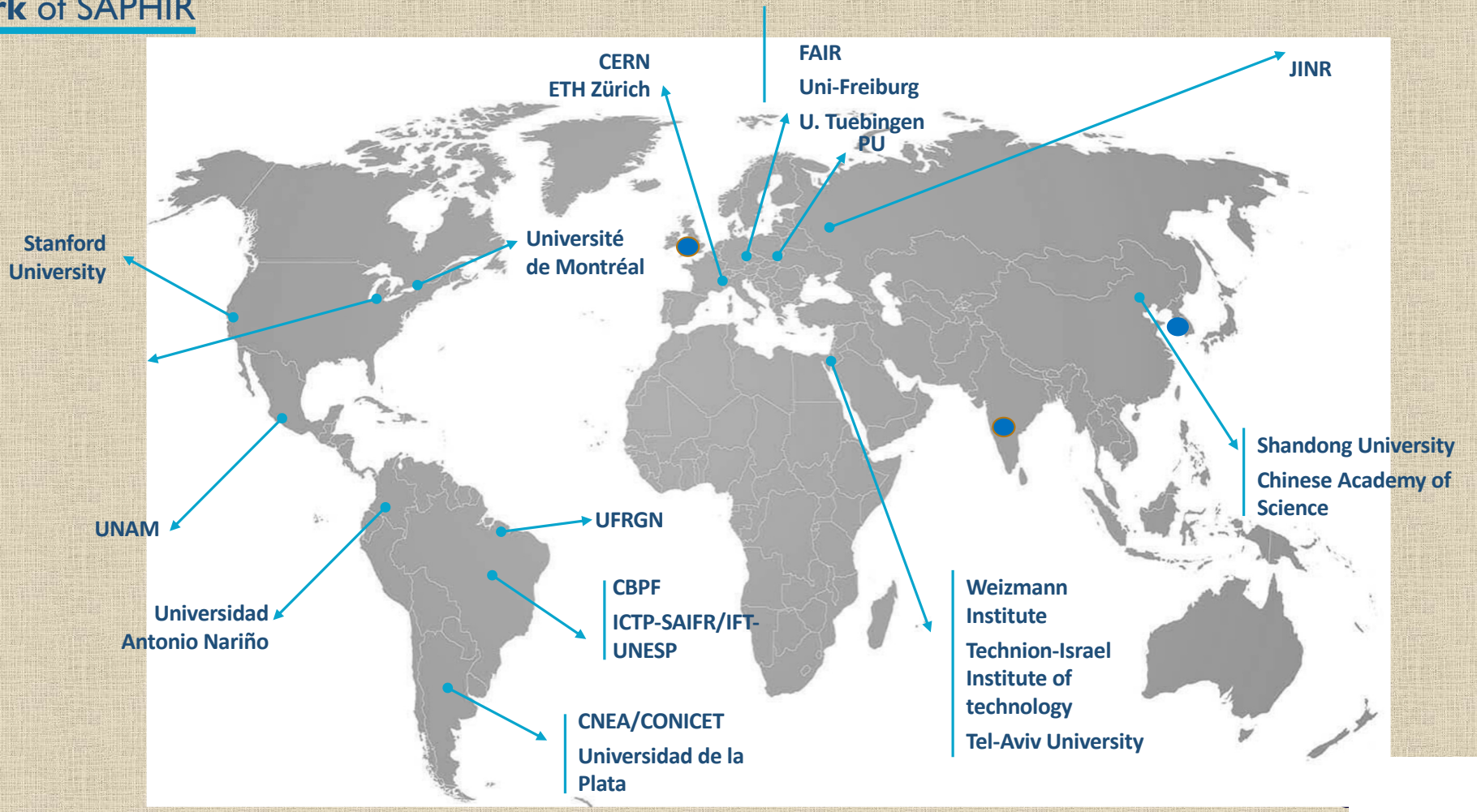


## National Collaborators

Claudio Dib (UTFSM),  
Ivan Schmidt (UTFSM),  
Cesar Bonilla (UCN), Carolina Arbelaez (UTFSM),  
Nicolas Neill (UTA), Marcela Gonzalez (UTFSM),  
Daniel Salinas (UTFSM), Bastian Dias (USACH),  
Markos Maniatis (U Bio-Bio)...

**Students:** Yocelyne Hidalgo and Nicolás Pérez, Juan Marchant, Sebastián Acevedo,  
Nicolas Vargas, Gonzalo Ortega, Sebastian Norero,...

# International Th network of SAPHIR



# International Collaborators

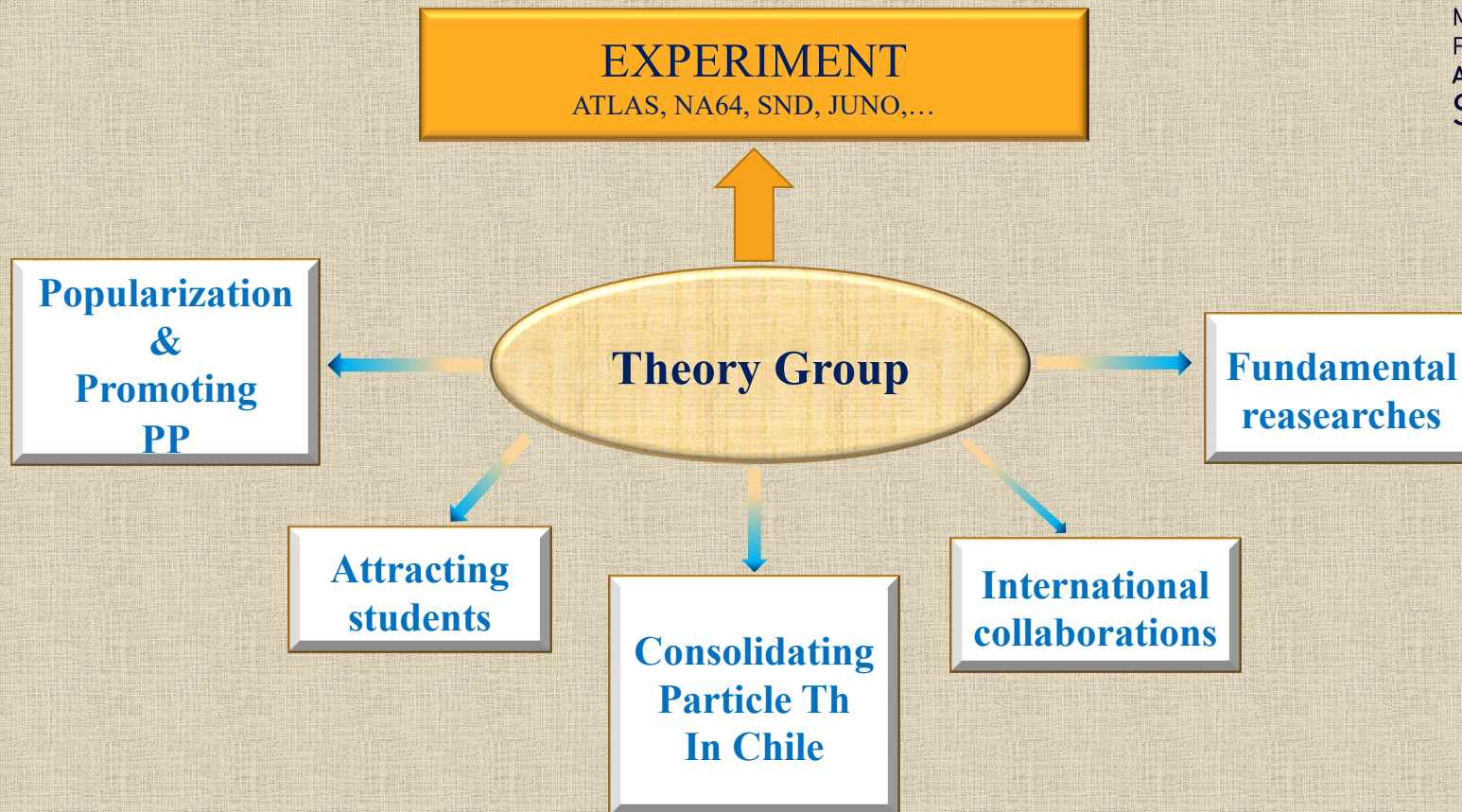
## International:

José Valle (IFIC), Carlos Vaquera (UG), Chandan Haiti (IFIC), Omar Medina (IFIC),  
Martin Hirsch (IFIC), Simon Wang (Taiwan), Abner Soffer (Israel),  
Fedor Simkovic (Bratislava U), Si Xie (Fermilab), Huong Ngoc Long (IOP, Vietnam),  
Do Thi Huong (IOP, Vietnam), Bu Hoa Vinh (IOP, Vietnam), Pham Ngoc Thu (IOP, Vietnam),  
Roman Paschenik (Lund), Huchan Lee (NCBJ), Alexander Belyaev (Southampton U.),  
Werner Vogelsang (Tübingen U., Germany), Fabian Wunder (Tübingen U., Germany),  
Alexey Zhevlakov (JINR, Russia), Yuri Anikin (Tomsk U., Russia), Stanley Brodsky (SLAC, USA),  
Yubing Dong (IHEP, China),.....



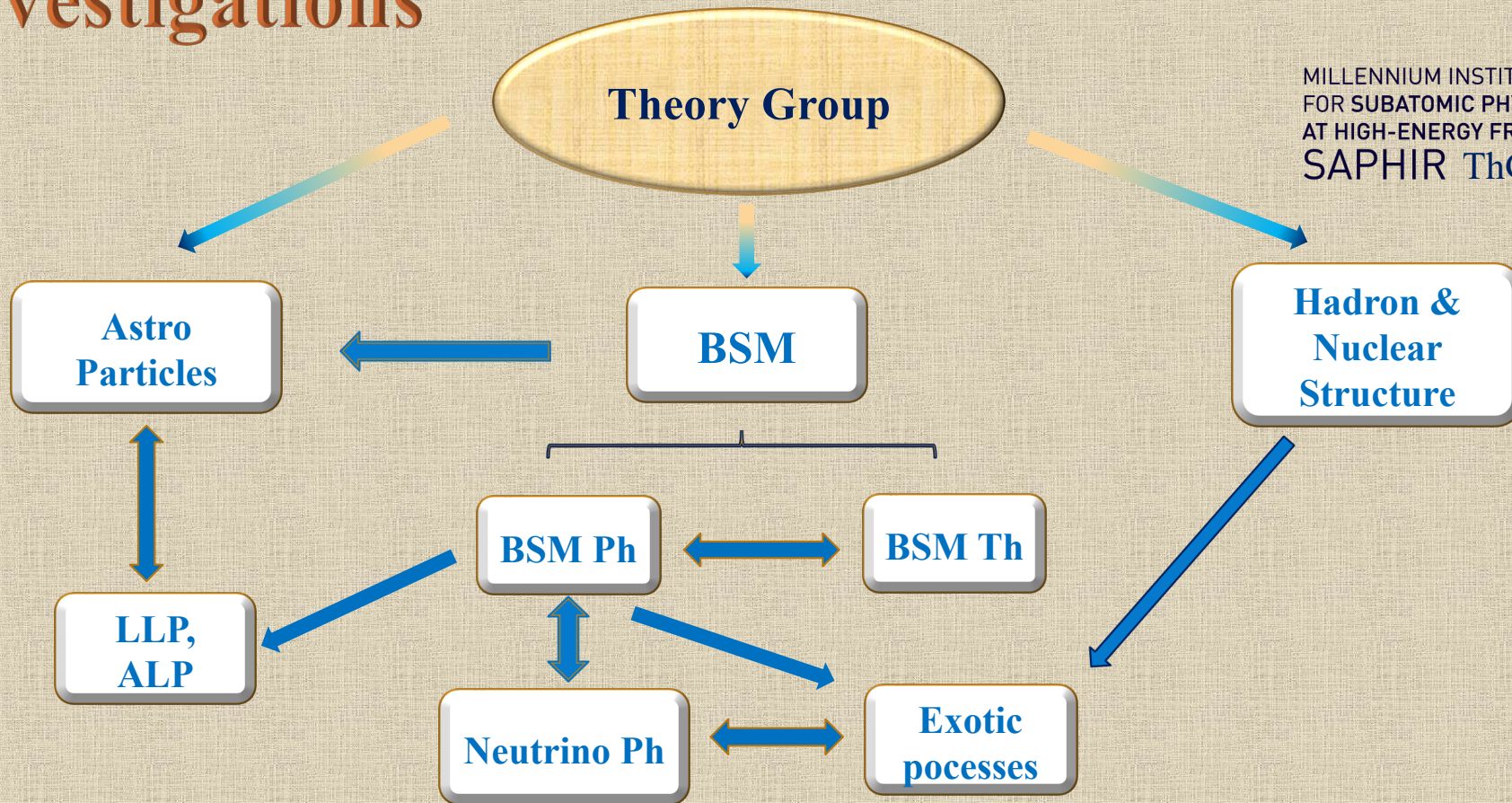
# Mission

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# Investigations

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What is the mechanism for neutrino masses and oscillations? What type of particle are (Majorana or Dirac) and what is their hierarchy (normal or inverted)? What is the nature and properties of DM? What are the properties of the Higgs boson? Are there other Higgs-like particles? Why have they not been observed in colliders? Are they long lived?..... ?

## BSM building and their phenomenological and cosmological implications

BSM = SM extensions with **enlarged gauge and global symmetries, extended field content** in order to address

- smallness of neutrino masses (low scale seesaw, radiative seesaw,...),
- fermion mass and mixing hierarchy,
- three fermion families,
- Gauge hierarchy,
- DM
- BAU
- ....

Phenomenological implications of the constructed models for collider physics, electroweak precision tests, rare processes etc.

[Antonio, Sergey, Marco Aurelio]



## BSM physics at colliders (LHC, Future colliders) and fixed target (NA64, Brazilian LE accelerator) experiments.

### New physics Discovery potential

Particular interest to **LLPs**. [Giovanna, Juan Carlos, Marco Aurelio]

- Inventing and analysing **models predicting LLPs** and connected with DM and neutrino masses. LLP (double charged, single charged and neutral) in Georgi-Machacek Model with a Type-II Seesaw Mechanism, RPV-SUSY. [Marco Aurelio]
- Identification their exotic **signatures at collider** for a given model and reinterpretation of experimental results to new theoretical frameworks.
- Light neutralino (=LLP) in B-meson decays. [Juan Carlos, Valery]
- Possible extensions of the **LLP** pheno at LHC towards **SND@LHC**, and setting discussion in the LHC-LLP WG. [Giovanna]

**Giovanna Cottin** is currently a theory co-convenor of the LHC-LLP Working Group at CERN (<https://lpsc.web.cern.ch/lhc-llp-wg>).

- Search for new heavy mediators connected to dark matter with ATLAS ( $Z'$ , )  
and prospects for FCC-hh (100 TeV)  
[Farinaldo, Sergey, Alfonso, Juan Carlos]
- Interplay between Flavor Physics and Collider.  
A proper choice of the parameterization of the quark mixing allows relaxing FCNC bounds, opening good prospects for the FCNC searches at colliders.  
[Farinaldo, Alfonso, Sergey, Tessio]

## NA64 &amp; other fixed target experiments:

- **Light species** connected to dark matter such as Dark Photon, light scalars, light  $Z'$ , and light neutral fermions.

- **New portals** connecting Standard Model (SM) and Dark Matter (DM) sectors.

[Farinaldo, Alfonso, Sergey Kuleshov  
Juan Carlos, Valery, Sergey Kovalenko, T  ssio]

BSM

## BSM physics at fixed target experiments

(Brazilian LE accelerator)

LLPs at low-energy accelerators with

$$e^+(3 \text{ GeV}) + e^- \rightarrow \gamma + LLP$$

A 3 GeV positron beam impinging on a diamond target.

The first proposed searches:

ALP and leptophilic light scalars, in the 1 MeV-50 MeV mass range, that couple to electrons.

According to preliminary estimations the proposed experiment is competitive with other experiments.

[Farinaldo Queiroz, Serguei Kuleshov]

BSM

Neutrino Ph

Astro  
Particles

- **RPV SUSY** (Bilinear, trilinear)  $\rightarrow$  neutrino mass and gravitino DM + positron flux from the space;

- LFV phenomenology lepton (non)-universality in **SUSY** models with neutrino mass and mixing. [Marco Aurelio]

- Neutrino mass models in EFT (1-loop openings of the WO, ...) [Juan Carlos, Sergey]

**The SM extension with a fundamental, adjoint and 5-plet massive vector field  $V$**  and a singlet neutral fermion  $N$  as a low energy limit of a non-minimal 331 model. [Alfonso, Jilberto]

- Contains *DM candidates*  $N$  or  $V^0$ , allows neutrino mass and rich pheno.

- *Photon Flux* from Sommerfeld Enhanced vector DM annihilation.

- *Vector boson mediated* 1-loop corrections to the **WWA** vertex.

Constrains on the model parameters from the LEP data and prospects for measurements at *future lepton colliders*.

- Vector Dark Matter with *fermionic portal* (mediated by neutral lepton): Leptonic Case and Neutrino Physics.



## Interplay between cosmology and Particle Physics

- Dark matter models beyond the **SM +  $\Lambda$  CDM** allowing relaxation of the existing tension between the local and CMB measurements of the Hubble rate constant.  
[Farinaldo, Alfonso, Sergey]

Exotic  
processes

## LNV & LFV processes

Neutrino Ph

$0\nu\beta\beta$ -decay, rare meson and baryon decays, ...: SMEFT and NME from new approaches (AdS/QCD)  
[Valery, Sergey]

- Heavy and light neutrino oscillations in **QFT** [Sergey]
- Heavy quasi-degenerate neutrino oscillations in particle decays as a source of CP-violation.  
[Jilberto]
- Prospects for discovering heavy **neutrino oscillations** in rare Bc meson decays at HL-LHCb  
via measurement of the *modulation of the decay rate* along the detector length  
[Jilberto]

## Hadronic & Nuclear Structure

### Hadron and Nuclei Structure in perturbative QCD, Holographic QCD [Valery]

- Hadronic and Nuclear ME for rare processes (LFV, LNV)
- PDFs, TMDs, GPDs, etc; proton heavy quark content.
- SM processes in fixed-target experiments: Drell-Yan, SIDIS (semi inclusive DIS), DIS, ...  
[Valery, Sergey Kuleshov]
- Multiquark exotic states at modern colliders (LHC, Belle, BES, JLab): search for hadronic molecules, tetraquarks and pentaquarks, dibaryons in order to constrain dynamics of quark forces, masses and partial decay widths of new particles
- Light pseudoscalars (pion, eta, and eta') in the meson-nucleus collisions.

# Group Development

- Establish well defined research lines so the SAPHIR-TH group can be internationally recognized for a specific expertise. Develop an "identity".
- Define our role in the experiments which SAPHIR participates in
- Apply for grants together (i.e. postdocs, fondecyt, international grants)
  - Recent success: Téo Melo (FONDECYT postdoc)
  - Alfonso, Juan Carlos, Valery, Sergey (FONDECYT regular)
- Organize small in-person meetings for SAPHIR-TH (perhaps once a year).
  - Already done in January 2022
- Improve the organization of SAPHIR-TH regular meetings.
  - Already implemented practice.
- More synergy between us and strengthening collaboration with Chilean colleagues
- Hosting international conferences

**Thanks !**