QCD in Chile

Will Brooks
for the Chilean QCD Team

CCTVal
CENTRO CIENTÍFICO TECNOLÓGICO DE VALPARAÍSO

EX UMBRA IN SOLEM
UNIVERSIDAD TECNICA FEDERICO SANTA MARIA

MILLENNIUM INSTITUTE FOR SUBATOMIC PHYSICS AT HIGH-ENERGY FRONTIER
SAPHIR

Where is Chile?

Eight institutions with known QCD-relevant activity

The currently known Chilean QCD community

- UTFSM: Experimental: WB, Hayk Hakobyan, Taisiya Mineeva, Jorge Lopez (Heidelberg U.), Ahmed El Alaoui, Christian Romero, Sebastián Tapia (Iowa State U.), Miguel Arratia (U. California Riverside). Theoretical: Ivan Schmidt, Boris Kopeliovich, Marat Siddikov, Irina Potashnikova, Benjamín Guiot, Claudio Dib, Eugene Levin, Carlos Contreras, Gorazd Cvetic, Valery Lyubovitsky (also experiment), Informatics: Claudio Torres.
- Universidad de La Serena: Experimental: Orlando Soto, Pablo Ulloa. Theoretical: Juan Carlos Helo
- Pontificia Universidad Católica de Chile: Theoretical: Marcelo Loewe, Marco Aurelio Díaz, Experimental: Francisca Garay.
- Universidad de Andrés Bello: Experimental: Sergey Kuleshov, Theoretical/computational: Sergey Kovalenko, Yuri Ivanov
- Universidad de Tarapacá: Experimental/Theoretical Sonia Kabana, Nicolás Neill
- Universidad de Chile: Hugo Arrellano (Theoretical, but also with experimental student PhD projects in cooperation with CCHEN)
- Comisión Chilena de Energía Nuclear (CCHEN): Francisco Molina, Marcelo Zambra (Experimental nuclear astrophysics, Monte Carlo modeling)
- Universidad de Valparaíso: Informatics: Raquel Pezoa

Universidad de Valparaíso
Informatics: people and interests

- **Raquel Pezoa**

Machine Learning
High Energy Physics Data Analysis
Biomedical Image Processing
Computer Vision

raquel.pezoa@uv.cl

Comisión Chilena de Energía Nuclear (CCHEN): people and interests

fmolina@cchen.cl
mzambra@cchen.cl

- **Francisco Molina, Marcelo Zambra**

Experimental Nuclear Astrophysics. Recent paper titles:

1.- Calculation of kinetic parameters β_{eff} and Λ with modified open source Monte Carlo code OpenMC(TD)

2.- β decay of the very neutron-deficient 60Ge and 62Ge nuclei

3.- Studying the exotic decay 70Kr

4.- Two-proton radioactivity: The interesting case of 67Kr and further studies

Sharing of student training with Prof. Hugo Arrellano at the U. of Chile: Pablo Aguilera, former PhD student of U.Chile, did his PhD and MSc thesis at CCHEN, in an international collaboration with the Instituto de Física Corpuscular de Valencia. PhD Student Mr. Jaime Romero B. His thesis is entitled: "Time-dependence Monte Carlo in fissile systems with beta-delayed neutron precursors".

Universidad de Chile Theory/ Experiment: people and interests

arellano@dfi.uchile.cl

- **Hugo Arellano**

Collision theory, nuclear matter and hadronic systems.

Example paper titles:

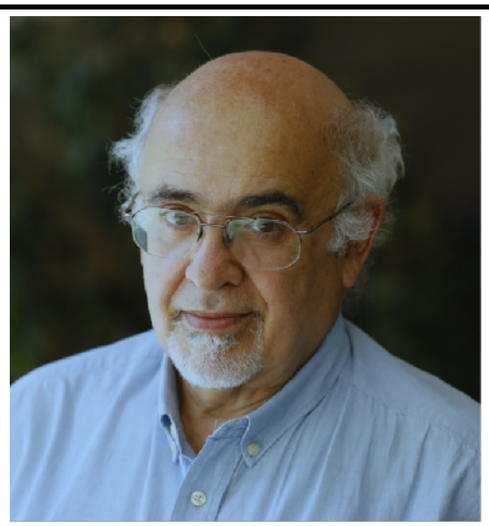
Reaction cross sections for proton scattering from stable and unstable nuclei based on a microscopic approach.

Microscopic positive-energy potential based on the Gogny interaction.

Recent PhD student experimental thesis (Pablo Aguilera) in collaboration with CCHEN & IFC Valencia:

Study of Gamow-Teller Transitions of $T_z = -2$ ^{64}Se and $T_z = -1$ ^{66}Se

Pontificia Universidad Católica de Chile: Theory: people and interests



- **Marcelo Loewe**

mloewelo@yahoo.com

I am interested in the phase diagram of QCD, in the presence of external fields, and its implications in relativistic heavy ion collisions and compact stars.

QCD phase diagram in a magnetized medium from the chiral symmetry perspective: The linear sigma model with quarks and the Nambu--Jona-Lasinio model effective descriptions.
Chemical sensing with graphene: A quantum field theory perspective.
Magnetic field dependence of nucleon parameters from QCD sum rules

Universidad de Tarapaca Theory & Experiment: people and interests

- **Sonia Kabana** Sonja.Kabana@cern.ch

- TH Theory of **multiquarks** (I am searching for collaborators)

- TH I am interested in theory of **flow** analysis in **heavy ions**.

- EXP AND TH Search for **Dark Matter** candidates via new methods in A+A, p+A, and p+p collisions - see our recent paper: "Thermal production of sexaquarks in heavy-ion collisions" Published in: Int. J. Mod. Phys. A 36 (2021) 25, 2141005 • e-Print: 2111.03770 [hep-ph]

and **Dark Photon** etc. in A+A, p+A, See our paper: "New physics searches with heavy-ion collisions at the CERN Large Hadron Collider Published in: J.Phys.G 47 (2020) 6, 060501 • e-Print: 1812.07688

-EXP **Strangeness , heavy flavor, quarkonia** in A+A, p+A, and p+p collisions at RHIC and LHC

- EXP **Flow** (v1,v2,v3..) in A+A, p+A, and p+p collisions at RHIC and LHC. We now work on **flow** of **Strangeness** in STAR

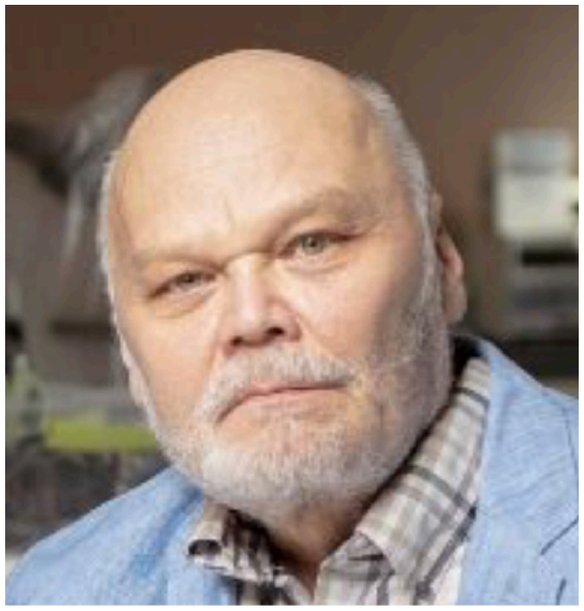
- TH **Thermal model** analysis in heavy ion collisions and p+A, p+p for QGP physics

"Second virial coefficients of light nuclear clusters and their chemical freeze-out in nuclear collisions" Published in: Eur.Phys.J.A 56 (2020) 11, 293 • e-Print: 2005.01555 [nucl-th]

- EXP Search for new **exotic hadrons** (**multiquarks**) in A+A, p+A, and p+p collisions and that can be a line of research in EIC too.

- **Nicolás Neill:** BSM Physics in processes involving hadrons.

Universidad de Andres Bello Theory/ computation/Experiment: people and interests



- **Sergey Kuleshov** Serguei.Koulechov@cern.ch

Particle Detector fabrication technologies, calorimetry, tracking devices, multi-technology spectrometer systems, data acquisition systems. Member of ATLAS Collaboration, deputy spokesperson of the NA61 experiment that searches for visible and invisible decays of dark photons, muon g-2 and a new leptonic dark boson, invisible decays of K_L and K_S, and the Bell-Steinberger relation, invisible decays of $\pi 0, \eta, \eta'$, and searches for Mirror Dark Matter.

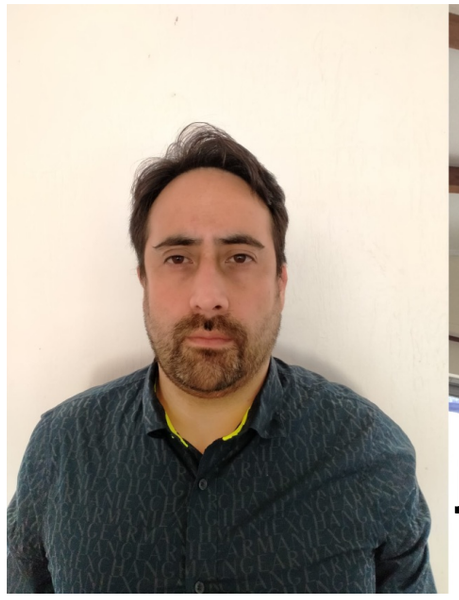
- **Yuri Ivanov** yury.ivanov@unab.cl

Particle physics theory, computing cluster design and operation, Worldwide LHC Computing Grid, distributed computing. See presentation: https://indico.cern.ch/event/982791/contributions/4138982/attachments/2160851/3645845/Cluster-10%2B.pdf and writeup: http://ceur-ws.org/Vol-1787/34-39-paper-5.pdf.

- **Sergey Kovalenko** sergey.kovalenko@unab.cl

My interests in QCD are due to its significant corrections to the low-energy electroweak observables, mainly lepton number and flavor violating meson and nuclear decays, ultraviolet and infrared limits of the QCD coupling constant needed for the determination of the GUT scale and proper scale for low-energy observables.

Universidad de La Serena Theory/ Experiment: people and interests



- **Orlando Soto** oj.5070@gmail.com

Experimental determination of hadronization mechanisms in DIS leading to eta meson production

- **Juan Carlos Helo** jchelo@userena.cl

Theory: Physics Beyond the Standard Model

- **Pablo Ulloa** pablo.ulloa@cern.ch

Pablo is interested in technical details of experimental physics, mainly in construction of particle detectors based on scintillation and Silicon Photomultipliers.

He participated in the ATLAS and NA64 experiments, and recently he is getting involved in SWGO and SND collaborations.

Currently he is a professor at the Universidad de La Serena, from where he hopes to contribute by training of students, construction of a laboratory, and research in experimental physics.

UTFSM Theory: people and interests

- **Ivan Schmidt, Page 1** ivan.schmidt@usm.cl

Deep inelastic lepton scattering on nuclei at small Bjorken variable x_{Bj}. In this regime the lepton-nuclear cross section involves the interference between the standard lepton-quark scattering amplitude for the deep inelastic scattering (DIS) process on a single nucleon and a **two-step process where diffractive scattering on a first nucleon combines with the amplitude for DIS on a second nucleon**. A main observable consequence is the impossibility of extracting momentum and spin sum rules from nuclear structure functions.

Decomposition of the gluon correlator at leading twist, using as a basis four tensors (one antisymmetric and three symmetric). These tensors are expressed through generators of the U(2) group acting in the two-dimensional plane of the transverse momentum of a gluon. One of the new results is that **all gluon TMDs stand as tensor structures**, proportional to one of the basis set.

The quark and gluon parton distributions intrinsic to hadron structure will be misidentified, unless one **excludes the diffractive DIS events**; for example, the correct determination of the PDFs for proton derived from the DIS data $\gamma_* p \to X$ requires the explicit subtraction of the leading-twist DDIS contribution $\gamma_* p \to p' X$ from the full DIS cross section.

UTFSM Theory: people and interests

- **Ivan Schmidt, Page 2** ivan.schmidt@usm.cl

Study of the **electroproduction of open heavy flavor D- and B-mesons** in the kinematics of future ep colliders, such as the Electron Ion Collider (EIC), the Large Hadron electron Collider (LHeC) and the Future Circular Collider (FCC-he).

Production of strangeness in proton-proton collisions in the kinematics of large transverse momenta p_T of the produced hadrons, using the **color dipole framework.**

Gluon parton densities [parton distribution functions (**PDFs**), transverse momentum distributions (**TMDs**), generalized parton distributions (**GPDs**)] and form factors in **soft-wall AdS/QCD**.

Electroexcitation of nucleon **resonances** with **higher spins**, in a **soft-wall AdS/QCD** model, comparing the results with existing data from the CLAS Collaboration at JLab, from MAMI, and other experiments.

Single diffractive production of **open heavy flavor mesons** and **non-prompt charmonia** in pp collisions, using the **color dipole approach**.

QCD color-singlet configuration in nuclei, formed by combining six scalar [ud] diquarks in a strongly bound SU(3)C channel. The resulting **hexadiquark state is a charge-2, spin-0, baryon number-4, isospin-0, color-singlet state** which should be present in nuclei.

UTFSM Theory: people and interests

- **Boris Kopeliovich**
- **Irina Potashnikova**

bzk@mpi-hd.mpg.de irina.potashnikova@usm.cl

Dipole description of inclusive production of **heavy flavors**.
Perturbative fragmentation of **heavy quarks**
Heavy flavored hadrons and jets from pp to AA collisions
High-pT hadrons and jets in **pA** and **AA** collisions
Vacuum and medium induced energy loss
Breakdown of QCD factorization in hard diffraction
Absorptive corrections in single diffraction
Leading neutrons in pp and pA collisions
Single-spin asymmetry of neutrons from polarised pp and pA collisions
CNI single-spin asymmetry and measurement of the spin-flip component of the Pomeron
Large multiplicity pp, pA and AA collisions

UTFSM Theory: people and interests

- **Marat Siddikov**

As of now I am working on **phenomenological studies** of Quantum Chromodynamics in **lepton-hadron** and **hadron-hadron collisions**. My research interests encompass (but are not limited to) different hadronic processes which will be studied at the forthcoming Large Hadron Collider **(LHC)**, the Electron Ion Collider **(EIC)**, as well as other possible future accelerating facilities. The main competitive advantage of the forthcoming accelerating facilities over their predecessors is a very high luminosity. This fact enables analysis of many **rare channels** which might provide important information about the **internal structure of the hadrons** and the **dynamics of the collision** process. Currently I am working on detailed analysis of the **double- and multiple meson production in high energy electron, proton and heavy ion collisions**, as well as possible information about different **parton distributions** which might be extracted from these channels.

UTFSM Theory: people and interests

benjamin.guiot@usm.cl

- **Benjamín Guiot**

Quark-gluon plasma, TMD factorization, high-energy factorization and small-x physics, heavy-flavor production, hadronization and jets.

To be more specific, recently I have mainly worked on

1)Heavy-flavor production with the high-energy factorization (or kt-factorization).
2) SIDIS at moderate energies and TMD factorization (I am also interested in the fracture functions but did not have time to study this in more detail).

UTFSM Theory: people and interests

claudio.dib@usm.cl

- **Claudio Dib**

My main interest in QCD is in its effects in **electroweak hadron decays**. **QCD corrections, hadron form factors, chiral perturbation theory**.

- **Eugene “Genya” Levin**

eugeny.levin@usm.cl

My main interests:

1. Entropy and multiplicity distribution in hard processes in the framework of quantum information approach (EE and so on);

2. Gribov-Zwanziger confinement and unsolved problems in the Color Glass Condensate: large *b* behavior and t and s channel unitarity;

3. Attempt to describe soft interactions in CGC approach.

UTFSM Theory: people and interests

- **Gorazd Cvetic** gorazd.cvetic@gmail.com

QCD areas that I am interested in:

1.) **Landau singularities** vs **holomorphic behavior** of the QCD running coupling and of space-like QCD quantities, their role in the **renormalon** effects and in the **Operator Product Expansions**.

2.) The **renormalon** structure of **QCD sum rules** and their role in the determination of the QCD coupling constant.

Using improved Operator Product Expansion in Finite Energy Sum Rules with ALEPH τ decay data, and determination of pQCD coupling

CP violation in the rare Higgs decays via exchange of on-shell almost degenerate Majorana neutrinos, $H \to \nu_k N_j \to \nu_k \ell^- U \bar{D}$ and $H \to \nu_k N_j \to \nu_k \ell^+ \bar{U} D$

Determination of perturbative QCD coupling from ALEPH τ decay data using pinched Borel-Laplace and Finite Energy Sum Rules

Lattice-motivated QCD coupling and hadronic contribution to muon *g*–2

pQCD running couplings finite and monotonic in the infrared: when do they reflect the holomorphic properties of spacelike observables?

Infrared-suppressed QCD coupling and the hadronic contribution to muon g-2

Exploring CP-violation, via heavy neutrino oscillations, in rare B meson decays at Belle II

Probing new physics scenarios of muon *g*–2 via J/ψ decay at BESIII

Evaluation of neutrinoless double beta decay: QCD running to sub-GeV scales

Renormalon-based resummation for QCD observables

UTFSM Theory+Experiment: people and interests

- **Valery Lyubovitskij** valeri.lyubovitskij@uni-tuebingen.de

Main research topics:

(1) **Hadrons and Exotic States in QCD and Effective Field Theories** (theory and experiment [GlueX/JLab Collaboration, COMPASS/CERN Collaboration])

(2) New Physics Beyond Standard Model and **Light Dark Matter** (theory and experiment [NA64/CERN Collaboration])

III. Keywords: QCD processes at fixed-target regime, Hadron Structure in QCD, AdS/QCD and Light-Front QCD, Dark Matter, New Hidden Particles (Axions, Dark Photon, Vector Bosons), Lepton Flavor and Lepton Number Violation, CP-Violation

Novel Corrections to the Momentum Sum Rule for Nuclear Structure Functions

Analysis of the nonleptonic two-body decays of the Λ hyperon

Radiative transitions of charmonium states in the covariant confined quark model

New findings in gluon TMD physics

The Diffractive Contribution to Deep Inelastic Lepton-Proton Scattering: Implications for QCD Momentum Sum Rules and Parton Distributions

Form-factor-independent test of lepton universality in semileptonic heavy meson and baryon decays

New ideas for handling of loop and angular integrals in D-dimensions in QCD

Gluon parton densities in soft-wall AdS/QCD

UTFSM Informatics (computing): people and interests

- **Claudio Torres** ctorres@inf.utfsm.cl

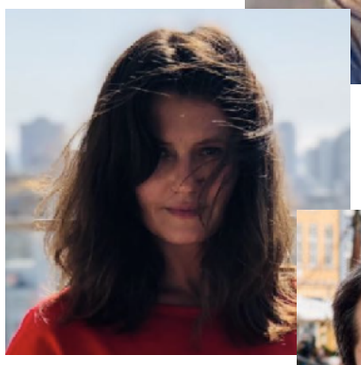
Areas of interest: **scientific computing**, high-performance computing, numerical analysis, numerical linear algebra, preconditioners of systems of linear equations, analysis and computation of vortex methods, fluid dynamics, particle methods, dynamical systems, **Machine Learning**, and growth of grains in polycrystals .

UTFSM Experimental: people and interests

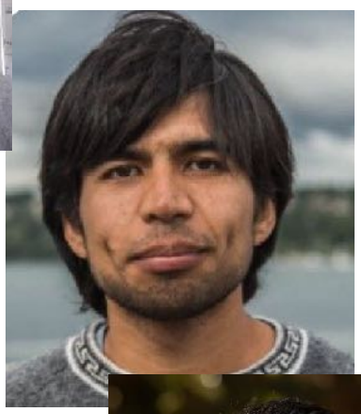
- **Hayk Hakobyan**
- **Taisiya Mineeva**
- **Jorge Lopez (Heidelberg U.)**
- **Ahmed El Alaoui**
- **Christian Romero**
- **Sebastián Tapia (Iowa State U.)**
- **Miguel Arratia (U. California Riverside)**
- **Will Brooks**
- Very active collaboration with: **Lamiaa Elfassi** (Mississippi State U.), **Raphaël Dupré** (Saclay), **Michael Wood** (Canisius College) and others.

npwg_cp@jlab.org

This whole group collaborates together on study of color propagation and hadron formation using Semi-Inclusive Deep Inelastic Scattering off nuclear targets, leading to identified final state hadrons. The data are from the CLAS Collaboration in the past and also in the future, and similar studies are planned for the EIC.






also, Polarized EMC effect (W.B.), DVCS (A.A.), dihadron production (M.A.), ATLAS Heavy Ions (S.T., W.B.), Color Transparency (L.E.), CONDOR Collaboration (M.A.).