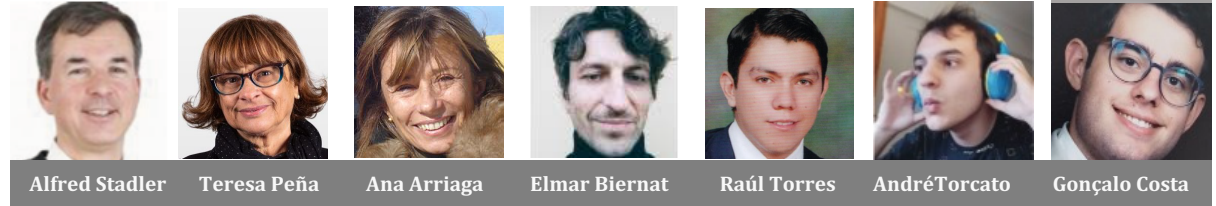


NPStrong at a glance



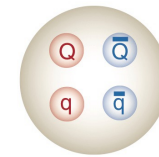
Group Composition

- 4 faculty members (IST + FCUL + UE)
- 2 PhD students (late stages) + 1 International co-supervision U. Graz
- 2 Master students (1 ongoing, 1 finished degree) + 1 to join
- 4 undergraduate trainees

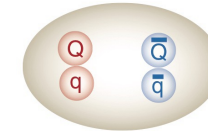
We connect hadron structure, multiquarks, and nuclei.

Core Topics

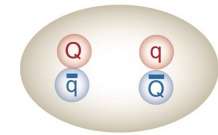
- Heavy Baryons.
- Pentaquarks/multiquark clustering.
- Meson spectra.
- Effective nuclear interaction.



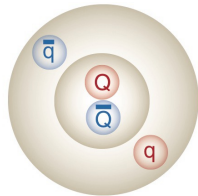
compact tetraquark



diquark-antidiquark

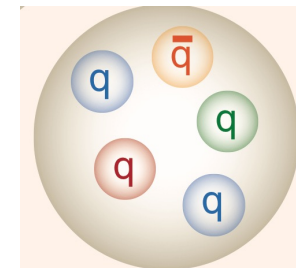


meson molecule



'hadro-quarkonium'

Tetraquarks



Pentaquarks



NPStrong What do we do?

Methods

Continuum non-perturbative functional QCD (as DSE–BSE or CST),
complementary to lattice QCD,
to generate bound states and correlations.

Outputs

Observables: Spectra, Form Factors, PDFs/TMDs;
weights of cluster components.

Impact

Complementary cross-checks to lattice;
constraints from/for experiment;
bridge to nuclear applications.

NPStrong

Strengths

Unique national expertise in non-perturbative continuum QCD functional methods.

Complementary theoretical methods to test model independence.

International recognition and collaborations.

Opportunities

Synergies between Nuclear & Particle & Astroparticle Physics.

Natural unit synergies with NUC-RIA, PHENO groups.

Weaknesses

Heavy teaching and administrative load.

Reduced dimension is a continuity risk.

Threats

No PhD grant pipeline program, at the nuclear–particle interface.

Limited/uncertain funding makes increasingly difficult to plan activities and retain talent.

Shift in public policy that prioritizes immediate productive innovation over research.

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Full Length Article

Electric and magnetic timelike form factors of hyperons at large transfer momentum

G. Ramalho ^{a,*}, M. T. Peña ^{b,c}, K. Tsushima ^d, Myung-Ki Cheoun ^a

•Our asymptotic-regime prediction for hyperon timelike form factors agrees with recent measurements at small momentum transfer.

•Message:
Asymptotic behavior sets in early i.e. already in the small momentum transfer region.

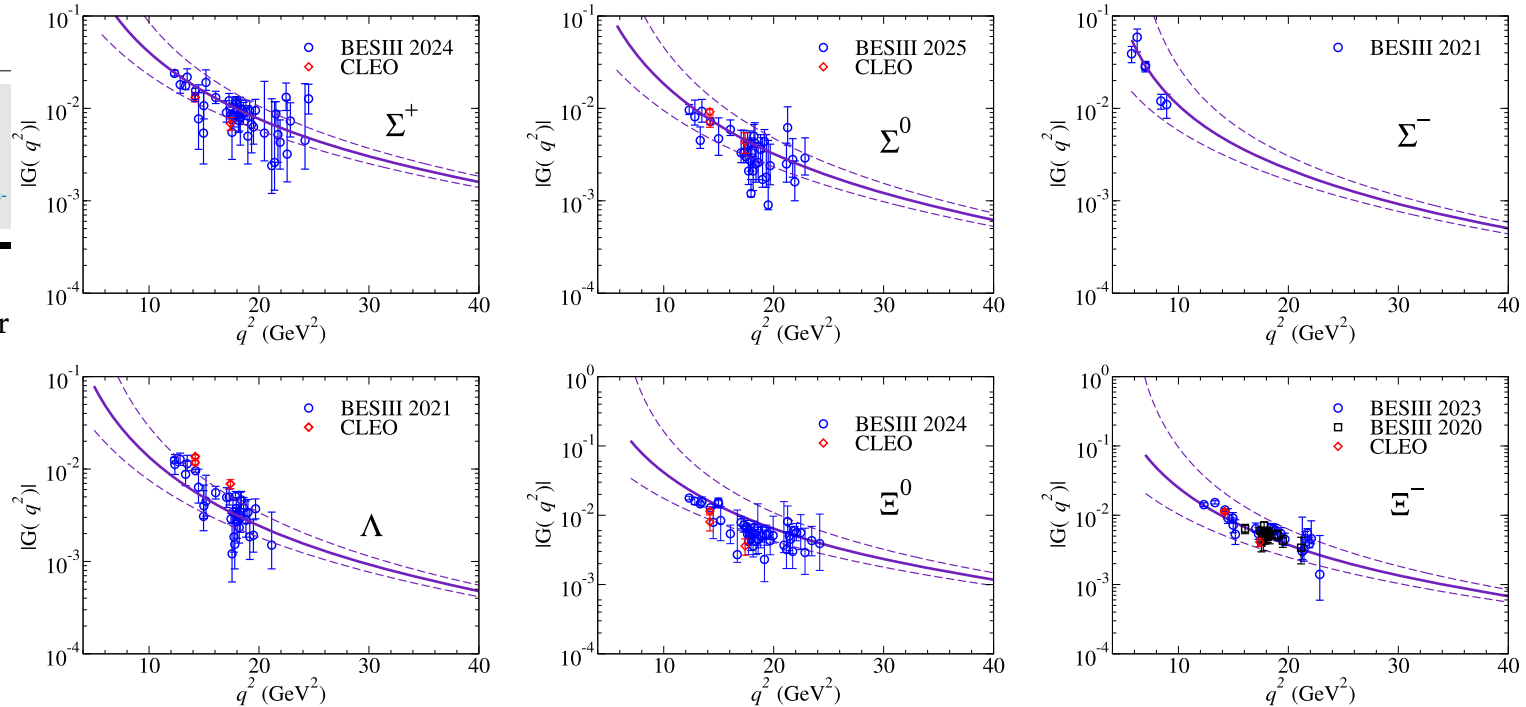
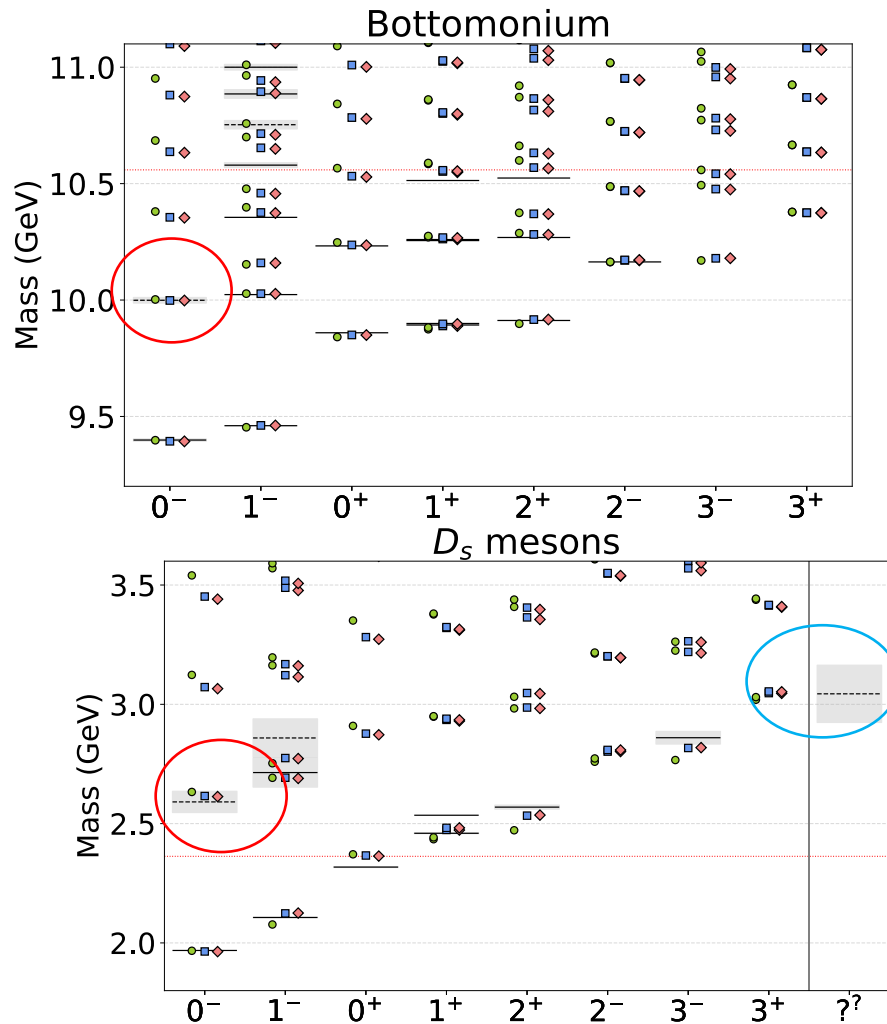


Fig. 1. Effective form factors $|G(q^2)|$ of the hyperons for $q^2 > 10 \text{ GeV}^2$ (solid line) [2]. The dashed lines represent the limits of deviations from the asymptotic relations. The data are from CLEO [5] and BESIII [8,9]. For Σ^- we include also BESIII data below $q^2 = 10 \text{ GeV}^2$.

Electric and Magnetic hyperon form factors of hyperons
Our prediction confirmed by new data in the **10-20 GeV** region.



- Covariant description of heavy and heavy-light mesons in CST extended for arbitrary spin (previously only $J=0$ and 1).
- Numerical calculations for all known heavy and heavy-light mesons (i.e., up to $J=3$) with spectrum is very well described with (7) universal parameters.

What is it good for?

- Prediction of not yet observed states;
- **Confirmation of unconfirmed states;**
- **Helps determining unknown quantum numbers of seen states;**
- Calculated wave functions then enter into structure calculations.

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Where are we going? **Preparing the Future.**

QCD-Matters with PHENO

Submission of Project

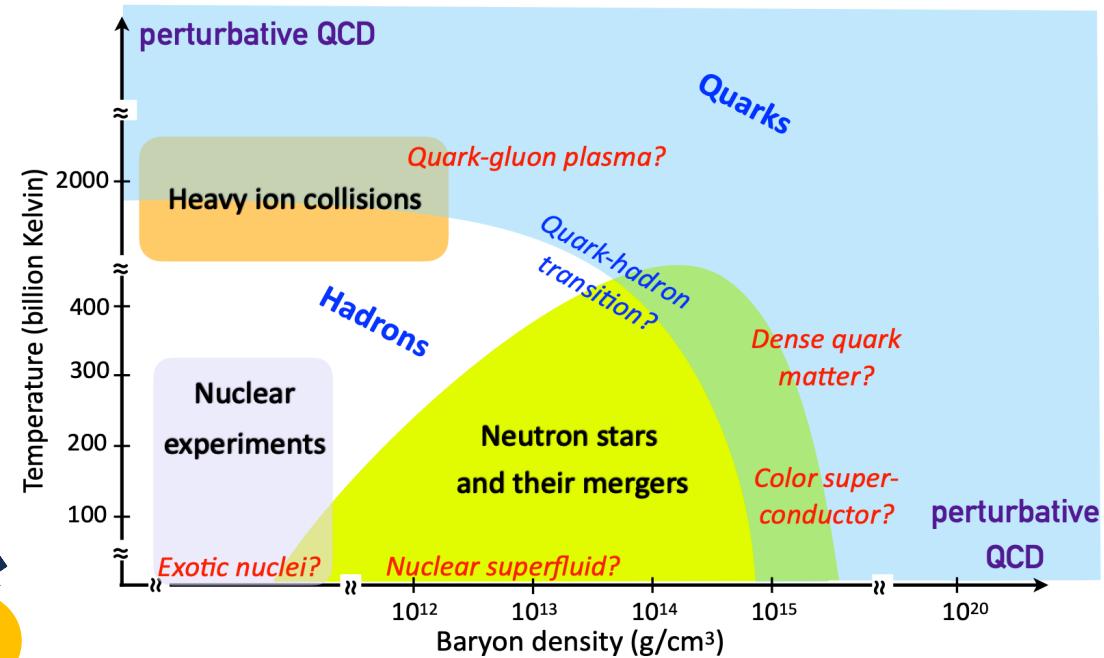
To investigate strongly interacting matter across different regimes of QCD, from high-temperature quark–gluon plasma to neutron stars.

Pillar A Heavy-ion collisions and jets as probes of QCD matter.

Pillar B Lattice QCD calculations of quark propagator and three-gluon vertex, at finite temperature.

Pillar C Hadronic correlations at finite temperature and density from DSE-BSE. **NEW horizons for NPSTRONG!**

Pillar D QCD phase diagram, composition of neutron stars



Laboratory in the Universe

❖ Student **André Torcato** & Faculty Members **Alfred Stadler** & **Elmar Biernat** active in **LIP Outreach Activities**.

❖ MTP

- member of **International Light Cone Adv. Committee** & **International Conferences Adv. Committees**
- Portuguese representative at **NuPECC**.
- Co-authored **white paper** “Hadron Physics Opportunities at FAIR”

Hadron Physics at GSI and FAIR: Prospects for the Next Decade

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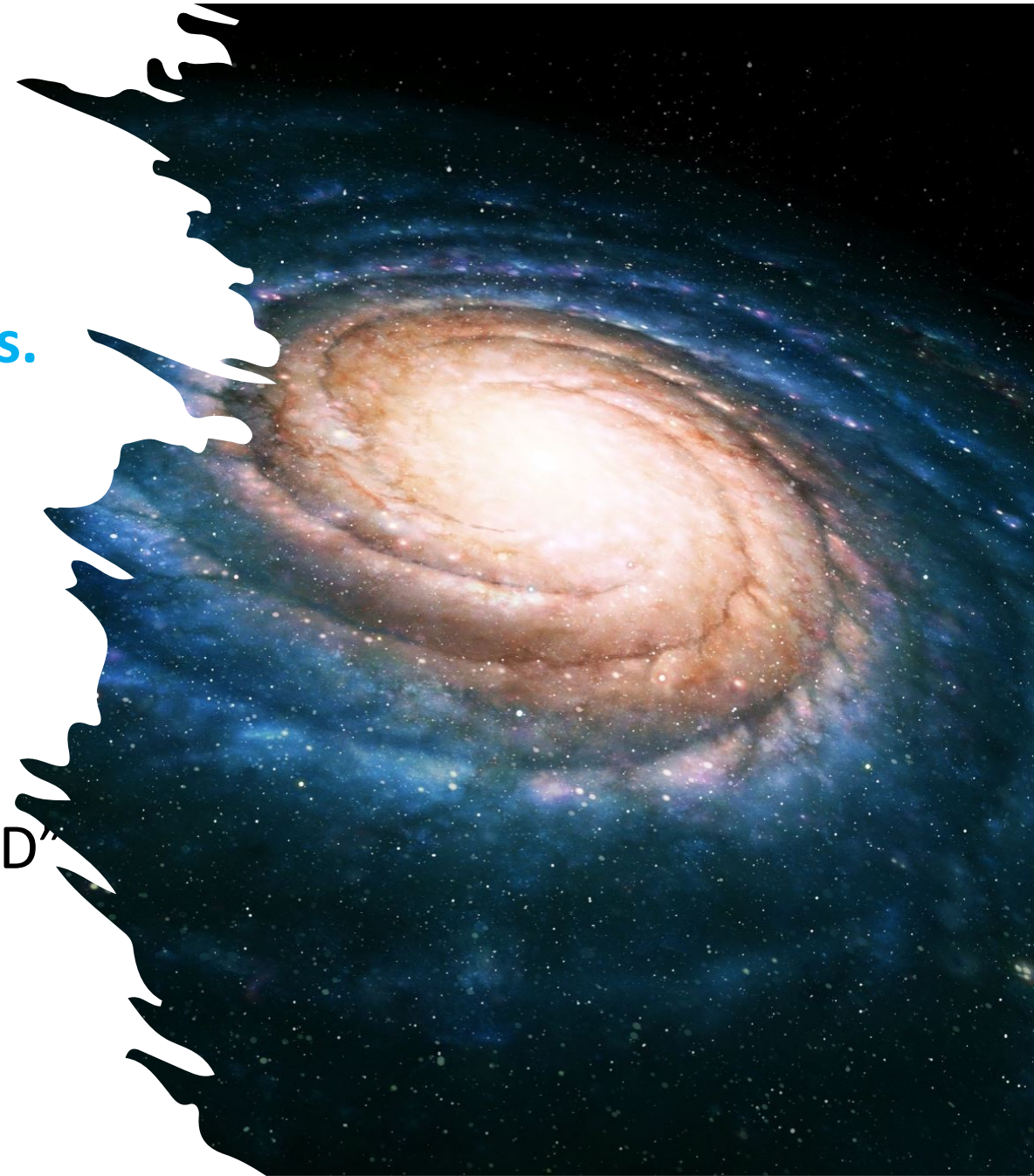
Strongly endorsed by JSC (Joint Scientific Council)

Backup Slides

QCD is paramount in the connection of
Particle, Astro, Hadron and Nuclear Physics.

It has the double role of
source and **sink** of knowledge:

“Research **streams flow into and out** of QCD”



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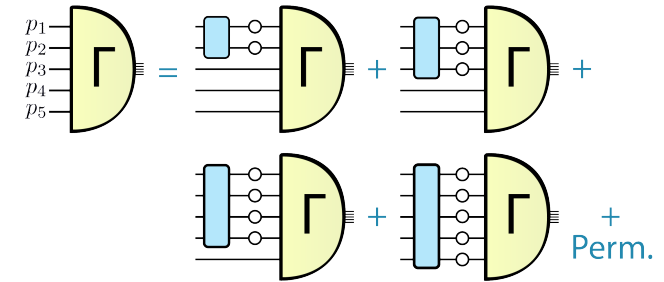
Research Highlights

Pentaquarks: Calculation of 5-body ground and excited states & consistent 2-, 3-, and 4-body equations.

n	\mathcal{S}_0	P^2	η_i	$p_1^2 \dots p_n^2$	\mathcal{M}	Total	Indep.
2	1	1	1	—	—	3	3
3	1	1	2	2	—	6	6
4	1	1	3	3	2	10	10
5	1	1	4	4	5	15	14
6	1	1	5	5	9	21	18
n	1	1	$n-1$	$n-1$	$n(n-3)/2$	$n(n+1)/2$	$4n-6$

TABLE I. S_n multiplet counting for an n -body system [43], see text for the discussion.

two-body system forms two singlets (q2 and P2) and an antisinglet (q·P).
 three-body systems give two singlets (S0 and P2) and two doublets.
 four- body system form two singlets (S0 and P2), a doublet and two triplets .



Lorentz invariants can be arranged into multiplets of the permutation group S_5 , namely two singlets, two quartets and a quintet

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Research Highlights

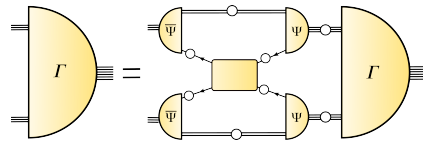
Λ

Baryons: Calculations of structure of singly-charmed baryons Λ_c and Σ_c ,

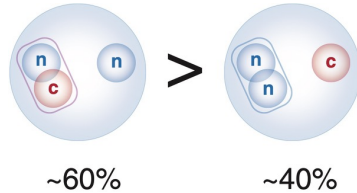
In progress:

full spectrum of charm and bottom sectors.

Deuteron: as a Hexaquark system



- $m_D = 1.868$ GeV, less than 1% below Exp. value
- no excited states
- cancellation of quark and diquark exchanges confirms effective baryon- meson degrees of freedom as the appropriate in low-energy physics



Pentaquarks: Calculation of 5-body ground and excited states & consistent 2-, 3-, and 4- body states.

