

Hot and dense QCD in the LHC era and beyond: Recent highlights

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for the SA1_HQCD of the SA1: The Standard Model to the limits

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Santiago de Compostela

SA1_HQCD: Hot and dense QCD in the LHC era and beyond

QCD was proposed 50 years ago. Despite intense theoretical and experimental effort, its complete understanding is still lacking.

Non-perturbative domain

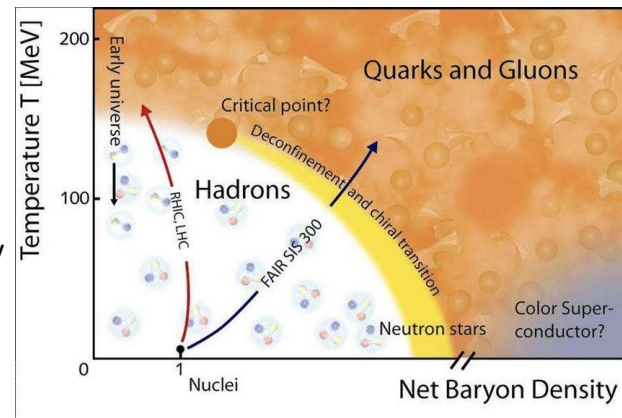
Confinement and chiral symmetry breaking turn quarks and gluons into the hadrons and nuclei we observe — evidence from lattice, but no qualitative/analytic understanding

Phases at high T and density

A rich phase structure (QGP, color superconductivity,...) is postulated from perturbative and non-perturbative methods, but remains unconfirmed theoretically and experimentally

Perturbative domain

Need to resum kinematically-enhanced higher-order diagrams; instabilities of the perturbative series; existing techniques reach their limits



Our goal: to improve our understanding of all these QCD problems by developing technical tools, particularly in the perturbative domain, by comparing with existing experimental data from the LHC and with astrophysical observations such as GW, and by proposing new observables for present and future accelerators (EIC, LHeC, FCC...).

RA1: Parton structure and saturation

RA2: Phenomenological models in the soft domain

RA3: Hard probes in heavy-ion collisions: jet quenching and quarkonium

RA4: Skyrme model applied to nuclear physics and astrophysics

Hot and dense QCD in the LHC era and beyond: Members

Permanent staff:

Christoph Adam, Néstor Armesto, Elena G. Ferreira, Carlos Merino, C.A. Salgado, Bin Wu (junior staff), Carlos Pajares (emeritus), Joaquín Sánchez-Guillén (emeritus)

Postdocs & Research staff:

Florian Cougoulic, Fabio Domínguez, Xiaojian Du, Xavier Feal, Óscar García Montero, Pablo Guerrero, Meijian Li, Raymond Lin Chen, Wenyang Qian, Daniel Pablos, Robin Törnkqvist,

PhD students:

Sergio Barrera Cabodevila ✓, Jorge Castelo ✓, André Cordeiro, Iván Cuntín Broullón, Víctor Díaz Díaz, Carlos Lamas Rodríguez, Alberte X. López Freire, Víctor López Pardo, Xoán Mayo López ✓, João Miguel Martins da Silva, Andrés Rodríguez Anadón, Adrián Romero González, Xiangpan Duan ✓

✓ *defended thesis in 2025*

Regular visitors & external collaborators:

Tolga Altinoluk, Carlota Andrés, Pedro Agostini, Liliana Apolinário, Miguel Escobedo, A. Kovner, J.-P. Lansberg, Carlos Naya, Jhony Eredi Ramírez Cancino, Andrzej Wereszczynski, + many more

Theses defended (2024–2026)

2024

Miguel Huidobro García

"Skyrme Neutron Stars"

dir. C. Adam

2025

Jorge Castelo Mourelle

"Universal relations for bosonic stars"

dir. C. Adam

2025

Sergio Barrera Cabodevila

"Thermalization in Hot QCD Plasmas"

dir. B. Wu, C.A. Salgado

2025

Xoán Mayo López

"Jet imaging of evolving anisotropic QCD matter"

dir. C.A. Salgado

2026

Xiangpan Duan

"Dynamical evolution of jets in vacuum and QCD medium"

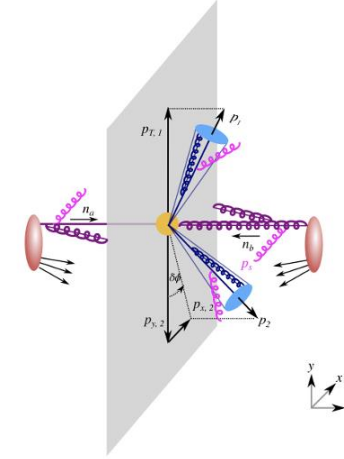
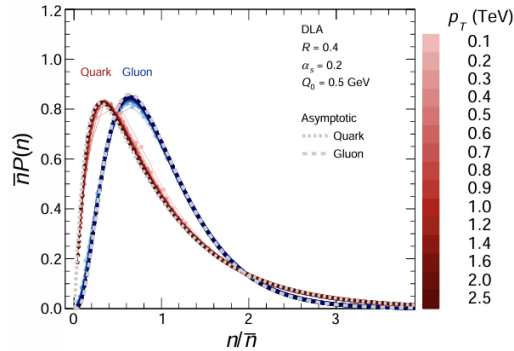
dir. G.-L. Ma, B. Wu, C.A. Salgado

RA1: Parton structure and saturation — collinear framework

Members: N. Armesto, E.G. Ferreiro, C. Pajares, C. Salgado, Bin Wu, Xiangpan Duan

Analysis of nuclear parton densities and new QCD dynamics in the collinear framework

Quark/gluon jet multiplicities, multi-jet production (qT slicing), future e-A colliders



nPDF fits & LHC data

Awaiting new LHC data; J/ψ UPC inclusion blocked by unresolved theoretical uncertainties.

Proposal for new fixed-target and e-N experiments at LHC submitted to ESPP 2026.

Koba-Nielsen-Olesen scaling in quark & gluon jets

X.-P. Duan, L. Chen, G.-L. Ma, C.A. Salgado, B. Wu
Phys.Rev.D 112 (2025) 094022 [2503.242]

KNO scaling & multiplicity distributions in QCD jets

X.-P. Duan, L. Chen, G.-L. Ma, C.A. Salgado, B. Wu
JHEP 02 (2026) 123 [2509.06158]

qT slicing with multiple jets

R.-J. Fu, R. Rahn, D.Y. Shao, W.J. Waalewijn, B. Wu
Phys.Rev.Lett. 135 (2025) 171903 [2412.05358]

Resummed azimuthal decorrelation & p_T imbalance of dijets

R.-J. Fu, R. Rahn, D.Y. Shao, W.J. Waalewijn, B. Wu
[2602.20249]

LHeC as bridge project for CERN

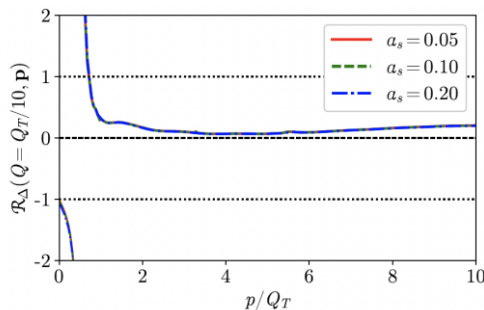
F. Ahmadova, K. André, N. Armesto et al. (42 authors) [2503.17727]
Physics with high-luminosity p-A at LHC: D. d'Enterria, ... E.G. Ferreiro et al., J.Phys.G 52 (2025) 090501

RA1: Parton structure and saturation — CGC & low-x

Members: N. Armesto, A. Kovner, V. López-Pardo, Meijian Li, A. Romero, T. Altinoluk, F. Domínguez, F. Cougoulic, P. Agostini, Ó. García Montero

Pursuing precision in CGC: low-x dynamics

Non-eikonal corrections, DGLAP in JIMWLK, energy-energy correlators at small x, 3D initial conditions



DGLAP resummation in JIMWLK Hamiltonian

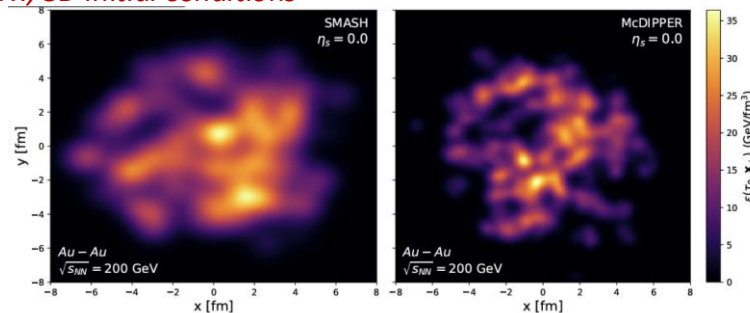
N. Armesto, A. Kovner, V. López-Pardo
JHEP 07 (2025) 207 [2501.1925]

Dijet in DIS at next-to-eikonal accuracy (CGC)

P. Agostini, T. Altinoluk, N. Armesto, G. Beuf, F. Cougoulic, S. Mulani
Phys.Rev.D 113 (2026) 054035 [2512.17848]

Non-eikonal corrections to dijet production in DIS

N. Armesto, F. Domínguez, A. Romero
[2603.26526] — ongoing: unified back-to-back limit with TMD



Energy-energy correlators at small x

Z. Kang, R. Kao, M. Li, J. Penttala
Phys.Rev.D 112 (2025) 076006 [2504.00069]
One-point energy correlator at small x [2603.023]

3D initial-state dynamics in heavy-ion collisions

L. Constantin, O. Garcia-Montero, N. Götz, H. Elfner
[2605.16914] — saturation vs. string-based descriptions

EIC / LHeC physics case & ESPP 2026

Néstor Armesto: invited talks at DIS2025, CEPC 2025, Open Symposium Venice, EPS-HEP 2025, Benasque QCD 2025, CEPC 2026, DIS2026
Contribution to Physics Briefing Book CERN Yellow Rep. 8 (2025)

RA1: Transport models for medium dynamics

Members: C.A. Salgado, Bin Wu, Xiaojian Du, Sergio Barrera Cabodevila, Robin Törnkvist

Developing Boltzmann to study the medium dynamics

Quark thermalization, bottom-up scenario, final-state interactions in small systems

Going against the flow: QCD degrees of freedom in hadronic collisions

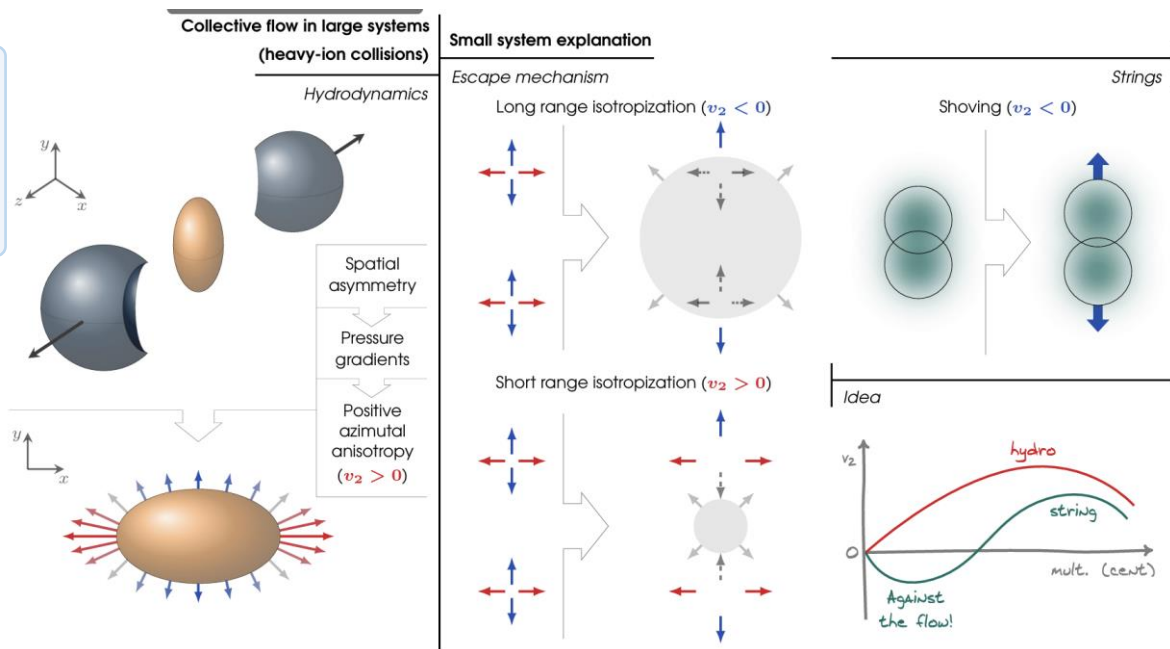
C. Bierlich, P. Christiansen, G. Gustafson, L. Lönnblad, R. Törnkvist, K. Zapp Phys.Lett.B 874 (2026) 140216 [2409.16093]
Negative elliptic flow in small systems from final-state interactions

Quark production in bottom-up thermalization

S. Barrera Cabodevila, X. Du, C.A. Salgado, B. Wu
Phys.Lett.B 871 (2025) 139987 [2503.24291]
+ PoS ICHEP2024 (2025) 628

Machine-learning approach to QCD kinetic theory

S. Barrera Cabodevila
Talk at Quark Matter 2025, Frankfurt — novel ML methods for Boltzmann equation

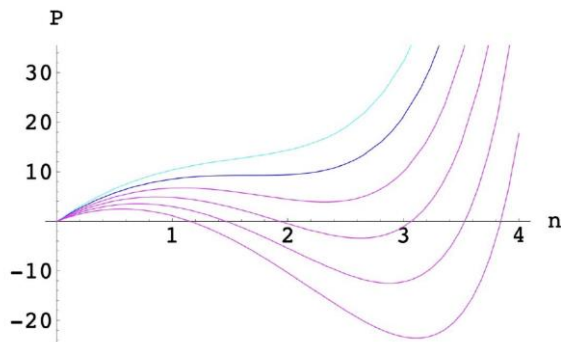


RA2: Phenomenological models in the soft domain

Members: Carlos Merino, Carlos Pajares, Jhony Eredi Ramírez Cancino

Multiparticle production and collective phenomena

Non-perturbative string and percolation models, from large to small systems



Critical Phenomena in Hadronic and DIS Processes

L.L. Jenkovszky, C. Merino

[2508.15409]

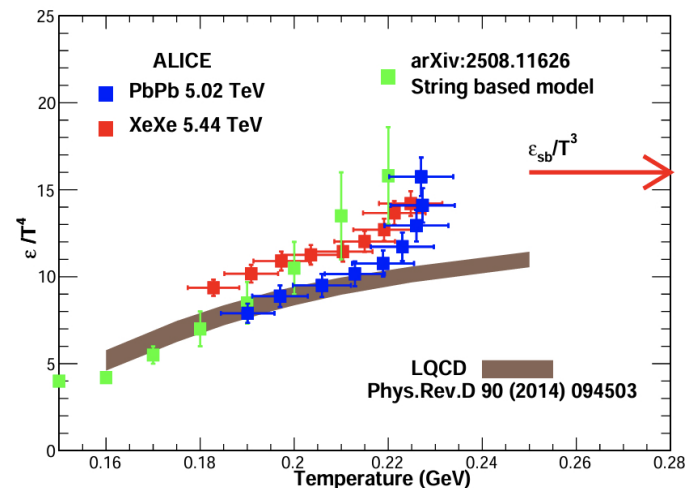
published as "Collective Phenomena in Large and Small Hadronic Systems",
Ukr.J.Phys. 71 (2026) 2, 113

Thermal-nonthermal transition of charged particle production in pp collisions

J. Alonso Tlali, D. Rosales Herrera, J.R. Alvarado García, A. Fernández Téllez,

C. Pajares, J.E. Ramírez

[2509.14175]



Percolation and de-confinement in relativistic heavy ion collisions

B.K. Srivastava, R.P. Scharenberg, C. Pajares

[2601.05139]

Thermal-nonthermal transitions in nuclear collisions

C. Pajares, Jhony Eredi Ramírez Cancino

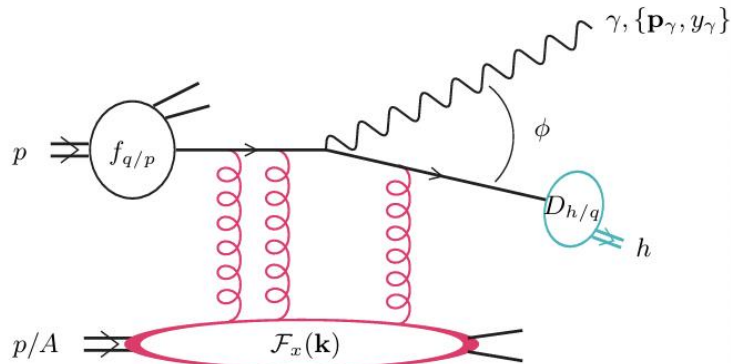
Formulation of liquid-to-gas type transitions and their effect on observables

RA3: Hard probes — Jet quenching

Members: N. Armesto, C.A. Salgado, Bin Wu, L. Apolinário, F. Domínguez, Meijian Li, W. Qian, C. Lamas, X. Mayo, J.M. Silva, X. Duan, P. Guerrero

A novel theoretical framework for studying jet quenching

*Glasma effects, factorization,
quantum simulation,
energy-energy correlators*



Glasma effects on jets (light-front Hamiltonian / tBLFQ)

M. Li, T. Lappi, X. Zhao, C.A. Salgado: Phys.Rev.D 112 (2025) 016009 [2504.07162]
D. Avramescu, C. Lamas, T. Lappi, M. Li, C.A. Salgado: EPJ Web Conf. 339 (2025) 02008; [2604.0852]; [2605.10413]

Energy-energy correlators in nuclear matter & small x

C. Andres, F. Dominguez, J. Holguin, C. Marquet, I. Moul: Phys.Rev.Lett. 136 (2026) 122301 [2411.15298]
J. Barata, Z. Kang, X. Mayo López, J. Penttala: Phys.Rev.Lett. 134 (2025) 25 [2411.11782]
Z. Kang, R. Kao, M. Li, J. Penttala: Phys.Rev.D 112 (2025) 076006

Factorization, parton showers & uncertainties in jet quenching

C. Andres, L. Apolinário, N. Armesto, A. Cordeiro, F. Dominguez, J.G. Milhano JHEP 08 (2025) 160 [2409.13536] + EPJ Web Conf. 364 (2026) 10010

Quantum simulation of QCD jets

W. Qian, M. Li, C.A. Salgado, M. Kreshchuk: Phys.Rev.D 111, 096001 (2025) [2411.09762]
J. Barata, M. Li, W. Qian, C.A. Salgado, J.M. Silva: multi-particle processes [2604.11616]
I. Cuntín, W. Qian, B. Wu: Quantum simulation thermal field theories, PoS ICHEP2024

Anisotropic medium: spin-polarized & azimuthal jet observables

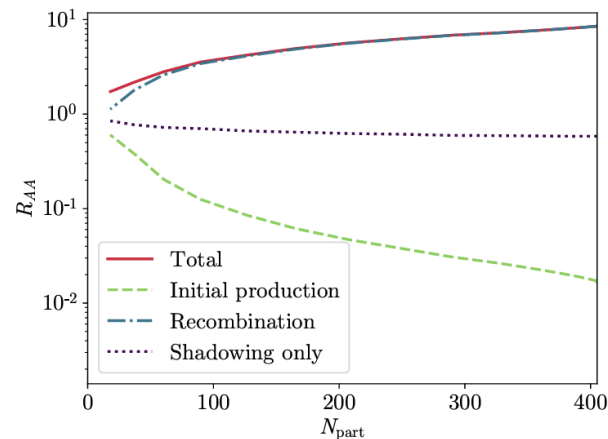
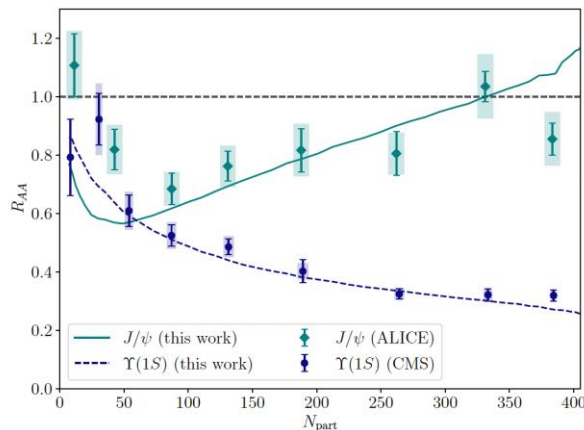
J. Barata, C. Salgado, J.M. Silva: JHEP 12 (2024) 023 [2407.04774]
C. Andres, F. Dominguez: Full energy fraction & angular dependence [2603.27846]
X.-P. Duan, L. Chen, G.-L. Ma, C.A. Salgado, B. Wu: jet quenching & color decoherence [2603.22014]

RA3: Hard probes — Quarkonia & open quantum systems

Members: N. Armesto, E.G. Ferreiro, M.A. Escobedo, V. López-Pardo, Meijian Li

Quarkonia and heavy-quark exotic states

Unified framework for quarkonium & exotics ($X(3872)$) using Lindblad equation



Potential approach to $X(3872)$ thermal behaviour

M.A. Escobedo, N. Armesto, E.G. Ferreiro, V. López-Pardo
EPJ Web Conf. 316 (2025) 04007 | PoS QNP2024 (2025) 112 | EPJ Web Conf. 339 (2025) 04011

Lindblad-driven recombination of $X(3872)$ tetraquark

M.A. Escobedo, N. Armesto, E.G. Ferreiro, V. López-Pardo
[2512.11539] — complete open quantum systems framework from potential models

Lindblad-driven quarkonium production in heavy-ion collisions

N. Armesto, M.A. Escobedo, E.G. Ferreiro, V. López-Pardo
[2605.19985] — description of LHC data + predictions for future runs

Relativistic dynamics of charmonia in strong magnetic fields

L. Wen, M. Li, Y. Zhou, Y. Li, J.P. Vary
Phys.Rev.D 112 (2025) 014019 [2504.03294]

Optimal temperature probes in heavy-ion collisions

V. López-Pardo, A. Rothkopf: J.Subatomic Part.Cosmol. 4 (2025) 100229
Optimal observables for (non-)equilibrium quantum metrology [2506.236]

Workshop: Exotic Quarkonia in Heavy-Ion Collisions

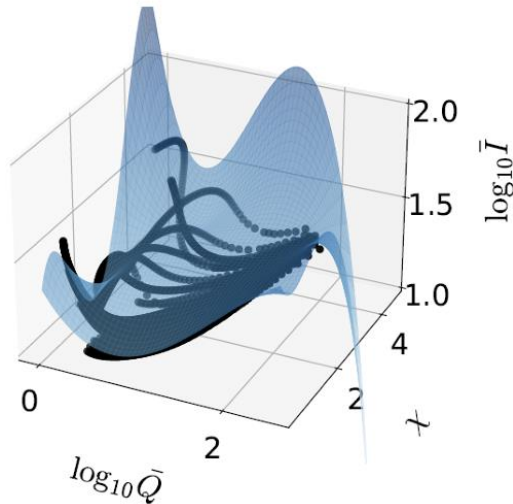
Organized by M.A. Escobedo, E.G. Ferreiro et al.
Mainz Institute for Theoretical Physics, Johannes Gutenberg University, February 2-6 2026

RA4: Skyrme model — baryonic matter & compact stars

Members: Christoph Adam, A. García Martín-Caro, A. Wereszczynski, J. Castelo Mourelle, A.X. López Freire, C. Naya, V. Díaz

Non-perturbative study of strongly interacting matter at high densities and in compact stars

Chiral Skyrme extension, electroweak form factors, rotating boson stars

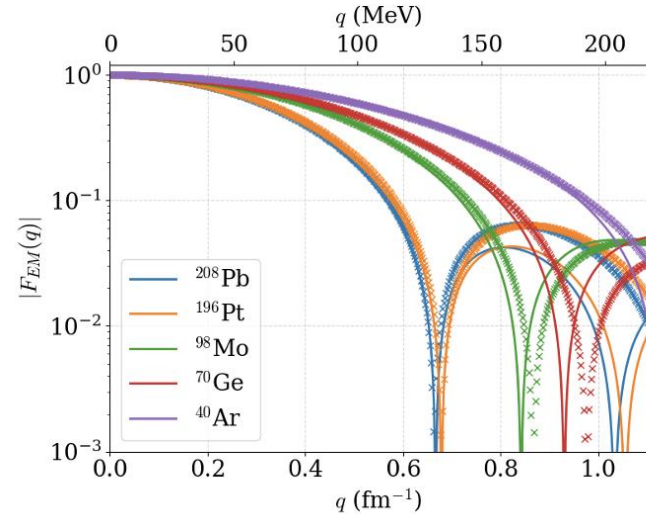


Spinning boson stars in nonlinear sigma models — universal relations

C. Adam, J. Castelo Mourelle, A. García Martín-Caro, A. Wereszczynski

Phys.Rev.D 112 (2025) 023004 [2502.20923]

Universal multipolar relations $\approx$ non-rotating boson stars $\approx$ Kerr black holes



Electroweak form factors of large nuclei as BPS skyrmions

X. López Freire, C. Adam, A. García Martín-Caro, D. González Díaz

[2510.25841]

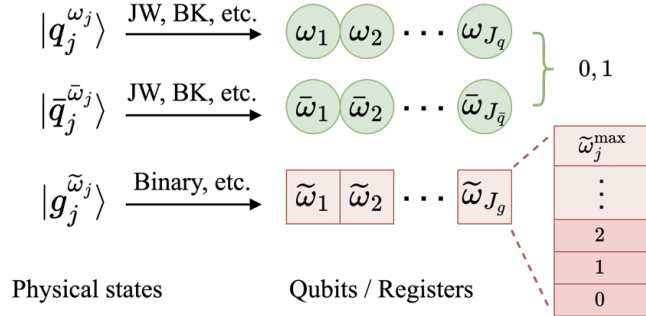
Chiral Skyrme extension; comparison with Ca48 and Pb208 experimental data

Cross-cutting: Quantum simulation & computation

Members: C.A. Salgado, Meijian Li, Wenyang Qian, Iván Cuntín, Bin Wu

Simulating physics with quantum computing

Rapidly growing activity across all research areas — jets, thermalization, DIS, hadronic scattering



Efficient quantum simulation of QCD jets on the light front

W. Qian, M. Li, C.A. Salgado, M. Kreshchuk
Phys.Rev.D 111, 096001 (2025) [2411.09762]

Quantum simulating multi-particle processes: dijets & color (de)coherence

J. Barata, M. Li, W. Qian, C.A. Salgado, J.M. Silva [2604.11616]

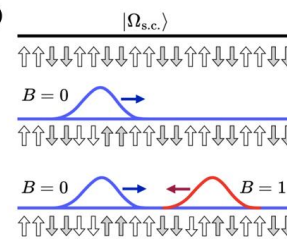
Quantum simulation of deep inelastic scattering (Schwinger model)

K. Ikeda, Z.B. Kang, D. Kharzeev, W. Qian [2512.18062]

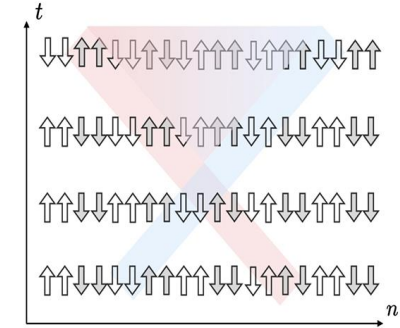
(a)

$n \equiv 1$	$\bar{r}$	$\downarrow$	v	$\uparrow$
$n \equiv 2$	$\bar{g}$	$\downarrow$	v	$\downarrow$
$n \equiv 3$	r	$\uparrow$	v	$\downarrow$
$n \equiv 0$	g	$\uparrow$	v	$\downarrow$

(b)



(c)



Hadronic scattering in SU(2) lattice gauge theory from tensor networks

J. Barata, J. Hormaza, Z.B. Kang, W. Qian [2511.00154]

Partonic distribution functions & amplitudes using tensor networks

Z.B. Kang, N. Moran, P. Nguyen, W. Qian
JHEP 09, 176 (2025) [2501.09738]

Quantum entanglement between partons (strongly coupled QFT)

W. Zhang, W. Qian, Y. Zhou, Y. Li, Q. Wang [2512.21228]
Real-time chiral dynamics at finite T: K. Ikeda et al., JHEP 10, 31 (2024)

>50

publications

4

theses
defended

>70

conference
contributions

4

workshops
organized

>4

Active projects (ERC, AEI,
STRONG, Xunta...)

Participation in
multiple boards & IACs

Nuclear Physics Board
European Physical
Society

Executive & Governing
Board STRONG2020 &
STRONG2030

Plenary ECFA European
Committee for Future
Accelerators

EIC board members
from European
institutions

LHeC/FCC-eh
Coordination

AEI - Agencia Estatal de
Investigación

EPJC & EPL Editors

Advanced Grants Panel
- SNSF Horizon Europe
Transition Measures

GSI Helmholtz Panel

Department of Energy
DOE – USA Panel

IACs: HP2025, DIS2025,
QM2025, Baryons2025