Theoretical Particle Physics in Portugal

M. N. Rebelo & F. R. Joaquim (CFTP/IST, U. Lisboa)

RECFA visit to Portugal

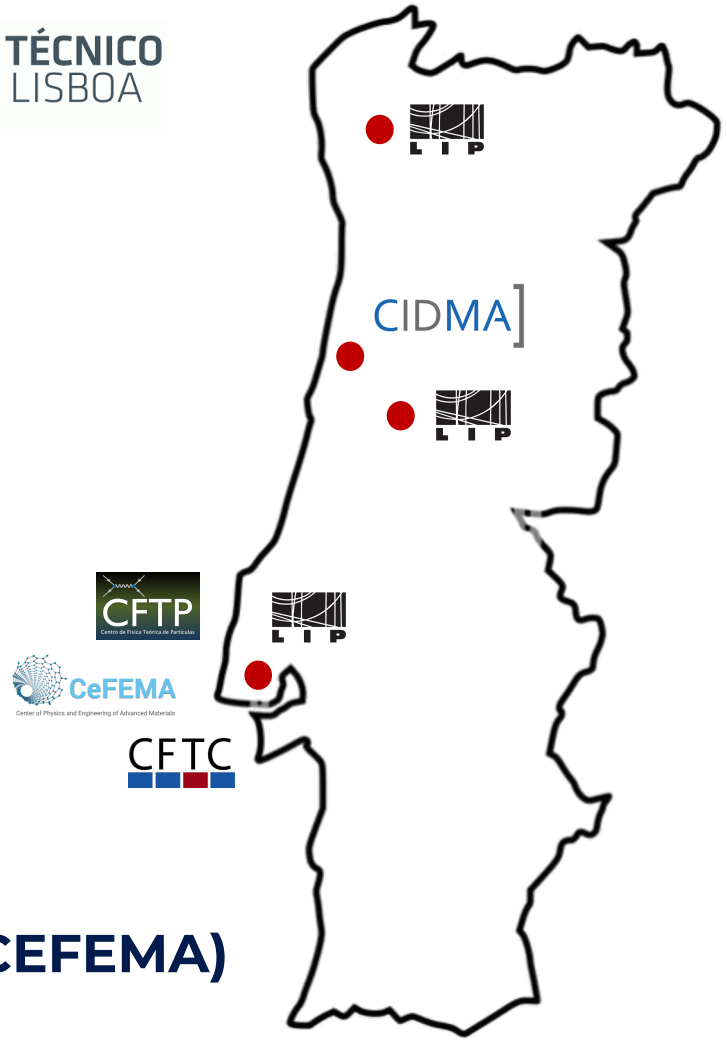
Biblioteca Nacional de Portugal
Lisboa, 16 September 2023

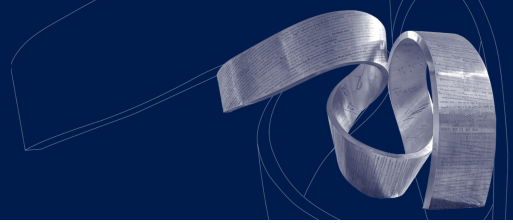
RECFA visit to Portugal

Theoretical Particle Physics in Portugal

On behalf of:

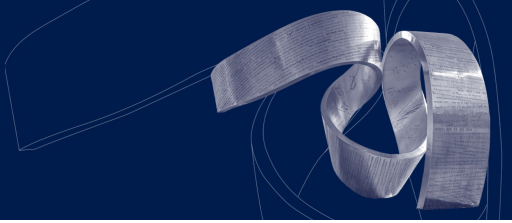
- Centro de Fisica Teórica de Partículas (CFTP)
- LIP Pheno Group (LIP Lisboa, Coimbra e Braga)
- Centro de Física Teórica e Computacional (CFTC)
- Centro de Investigação e Desenvolvimento em Matemática e Aplicações (CIDMA)
- CEntro de Física e Engenharia de Materiais Avançados (CEFEMA)





COMPOSITION OF CFTP

- **Twelve permanent members** (eleven working in theoretical particle physics). One female (President of CFTP in the last four years);
- **One Assistant Researcher** (male) with an Individual FCT contract (6 years);
- **Two postdoctoral fellows** (male);
- About **ten PhD students** (male). Recently a female PhD student has finished her PhD;
- About **eight MSc students** (one female).



COMPOSITION OF LIP PHENO GROUP (Lisboa, Coimbra & Braga)

- **5 senior members** (1 female)

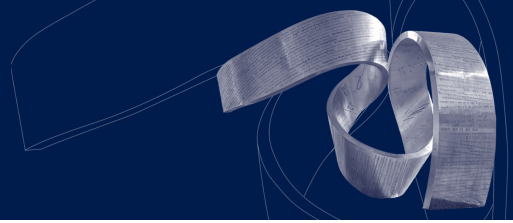
  - 2 with tenured positions
  - 3 with individual FCT 6-year contracts as “Investigador Auxiliar”

- **3 postdocs** (including one individual Junior Researcher FCT 6-year contract)

- **6 on-going PhD students**;

- **8 on-going MSc students** (2 female)

Theoretical Particle Physics in Portugal
People



CFTC U LISBOA | UNIVERSIDADE DE LISBOA

- **2 senior members** (Pedro Ferreira and Rui Santos)

- **Several PhD and MSc students** also in co-supervision with CFTP, LIP Pheno group members and other international researchers;

CIDMA] universidade de aveiro

António Morais who collaborates with **two researchers** at the Universidade de Aveiro where there are at the moment **three PhD students.**

CeFEMA Center of Physics and Engineering of Advanced Materials

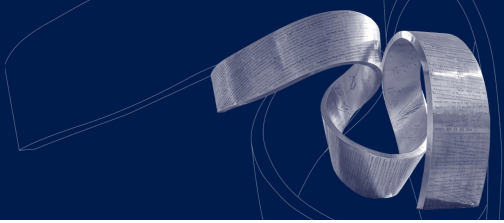
TÉCNICO LISBOA **George Rupp** is a senior researcher at CEFEMA.

Theoretical Particle Physics in Portugal
Main topics of research

- **CFTP:** Higgs Physics, Flavour Physics, Neutrino Physics, Collider Physics, interface with Cosmology and Astroparticle Physics. Around **30 papers/year** in different national and international collaborations
- Worldwide collaborations and several participations in international Working Groups, e.g. @ CERN
- **Pedro Ferreira and Rui Santos** have common interests in these research areas.

RECFA visit to Portugal

Theoretical Particle Physics in Portugal
Main topics of research



Addressing the CKM unitarity problem with a vector-like up quark

JHEP

G.C. Branco, J.T. Penedo, Pedro M.F. Pereira, M.N. Rebelo and J.I. Silva-Marcos

Centro de Física Teórica de Partículas, CFTP, Departamento de Física, Instituto Superior Técnico, Universidade de Lisboa, Avenida Rovisco Pais nr. 1, 1049-001 Lisboa, Portugal

E-mail: gbranco@tecnico.ulisboa.pt, joao.t.n.penedo@tecnico.ulisboa.pt, pedromanuelpereira@tecnico.ulisboa.pt, rebelo@tecnico.ulisboa.pt, juca@cftp.tecnico.ulisboa.pt

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Type-I seesaw with eV-scale neutrinos

G.C. Branco,[a,b] J.T. Penedo,[a] Pedro M.F. Pereira,[a] M.N. Rebelo[a,b,1] and J.I. Silva-Marcos[a]

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The C2HDM revisited

Duarte Fontes,[a] Margarete Mühlleitner,[b] Jorge C. Romão,[a] Rui Santos,[c,d,e] João P. Silva[a] and Jonas Wittbrodt[b,f]

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Multi-Higgs doublet models: physical parametrization, sum rules and unitarity bounds

Miguel P. Bento,[a] Howard E. Haber,[b] J.C. Romão[a] and João P. Silva[a]

PHYSICAL REVIEW D **104,** 053008 (2021)

$(g-2)_\mu$ in the 2HDM and slightly beyond: An updated view

P. M. Ferreira,[1,2] B. L. Gonçalves,[3,2] F. R. Joaquim,[3] and Marc Sher[4]

[1]*Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa, 1959-007 Lisboa, Portugal*
[2]*Centro de Física Teórica e Computacional, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, Edifício C8, 1749-016 Lisboa, Portugal*
[3]*Departamento de Física and CFTP, Instituto Superior Técnico, Universidade de Lisboa, 1049-001 Lisboa, Portugal*
[4]*High Energy Theory Group, William & Mary, Williamsburg, Virginia 23187, USA*

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Generalised CP symmetry in modular-invariant models of flavour

P.P. Novichkov,[a] J.T. Penedo,[b] S.T. Petcov[a,c,1] and A.V. Titov[d]

Mass Unspecific Supervised Tagging (MUST) for boosted jets

JHEP

J.A. Aguilar-Saavedra,[a] F.R. Joaquim[b] and J.F. Seabra[b]

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[b]*Departamento de Física and CFTP, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal*

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PHYSICAL REVIEW D **101,** 055033 (2020)

Multiple modular symmetries as the origin of flavor

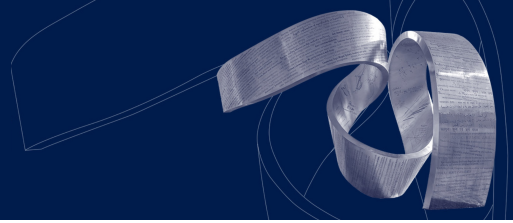
Ivo de Medeiros Varzielas,[1,*] Stephen F. King,[2,†] and Ye-Ling Zhou[2,‡]

[1]*CFTP, Departamento de Física, Instituto Superior Técnico, Universidade de Lisboa, Avenida Rovisco Pais 1, 1049 Lisboa, Portugal*
[2]*School of Physics and Astronomy, University of Southampton, SO17 1BJ Southampton, United Kingdom*

CFTP Centro de Física Teórica de Partículas

HIGHLIGHTS

Theoretical Particle Physics in Portugal
Main topics of research



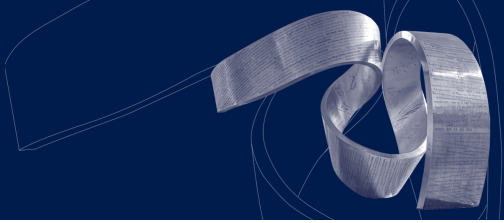
The **LIP Pheno Group** develops its main activities in the following topics of research:

- **Precision QCD** focusing on higher accuracy jet cross-section;
- **Forward Physics** with main activity in non-linear QCD (BFKL);
- **Heavy ions** with emphasis in jet quenching;
- **Beyond SM physics** (multi-Higgs, effective field theories)

- **Regular collaborations** with Santiago de Compostela, Madrid, Barcelona and Granada Universities, CERN and MIT.
- Since the creation of the group six years ago (2018) about **60 peer-reviewed papers** have been published.

RECFA visit to Portugal

Theoretical Particle Physics in Portugal
Main topics of research



Eur. Phys. J. C (2021) 81:250
https://doi.org/10.1140/epjc/s10052-021-08996-y

THE EUROPEAN PHYSICAL JOURNAL C

Review

May the four be with you: novel IR-subtraction methods to tackle NNLO calculations

W. J. Torres Bobadilla[1,2,a], G. F. R. Sborlini[3], P. Banerjee[4], S. Catani[5], A. L. Cherchiglia[6], L. Cieri[5], P. K. Dhani[5,7], F. Driencourt-Mangin[2], T. Engel[4,8], G. Ferrera[9], C. Gnendiger[4], R. J. Hernández-Pinto[10], B. Hiller[11], G. Pelliccioli[12], J. Pires[13], R. Pittau[14], M. Rocco[15], G. Rodrigo[2], M. Sampaio[6], A. Signer[4,8], C. Signorile-Signorile[16,17], D. Stöckinger[18], F. Tramontano[19], Y. Ulrich[4,8,20]

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PUBLISHED: July 17, 2020

Medium-induced gluon radiation with full resummation of multiple scatterings for realistic parton-medium interactions

Carlota Andres,[a] Liliana Apolinário[b,c] and Fabio Dominguez[d]

PHYSICAL REVIEW D **107,** 035004 (2023)

Exploring parameter spaces with artificial intelligence and machine learning black-box optimization algorithms

Fernando Abreu de Souza,[*] Miguel Crispim Romão,[†] Nuno Filipe Castro,[‡] and Mehraveh Nikjoo[§]
LIP—Laboratório de Instrumentação e Física Experimental de Partículas, Escola de Ciências, Departamento de Física, Universidade do Minho, 4701-057 Braga, Portugal

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Institut für Theoretische Physik und Astrophysik, Uni Würzburg Campus Hubland Nord, Emil-Hilb-Weg 22, D-97074 Würzburg, Germany

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IOP Publishing

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J. Phys. G: Nucl. Part. Phys. **47** (2020) 065102 (29pp) https://doi.org/10.1088/1361-6471/ab7cbc

Novel tools and observables for jet physics in heavy-ion collisions

Harry Arthur Andrews[1], Liliana Apolinario[2,3], Redmer Alexander Bertens[4], Christian Bierlich[5,6], Matteo Cacciari[7,8], Yi Chen[9], Yang-Ting Chien[10], Leticia Cunqueiro Mendez[4,11], Michal Deak[12], David d'Enterria[9], Fabio Dominguez[13], Philip Coleman Harris[14], Krzysztof Kutak[12], Yen-Jie Lee[14], Yacine Mehtar-Tani[15,16], James Mulligan[17], Matthew Nguyen[18], Chang Ning-Bo[19], Dennis Perepelitsa[20], Gavin Salam[21,26], Martin Spousta[22], José Guilherme Milhano[2,3,21], Konrad Tywoniuk[21,27], Marco Van Leeuwen[23], Marta Verweij[24,25], Victor Vila[13], Urs A Wiedemann[21] and Korinna C Zapp[2,21]

JHEP

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ACCEPTED: December 18, 2019
PUBLISHED: January 8, 2020

Modification of jet substructure in heavy ion collisions as a probe of the resolution length of quark-gluon plasma

J. Casalderrey-Solana,[a] G. Milhano,[b,c] D. Pablos[d,e,f] and K. Rajagopal[g]

Eur. Phys. J. C (2021) 81:561
https://doi.org/10.1140/epjc/s10052-021-09346-8

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Theoretical Physics

Time reclustering for jet quenching studies

Liliana Apolinário[1,2,a], André Cordeiro[2,b], Korinna Zapp[3,c]

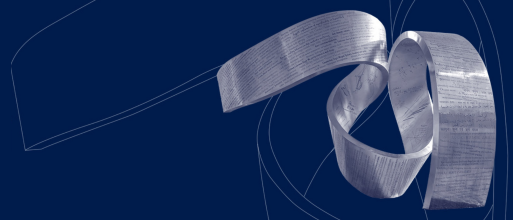
[1] LIP, Av. Prof. Gama Pinto, 2, 1649-003 Lisbon, Portugal
[2] Instituto Superior Técnico (IST), Universidade de Lisboa, Av. Rovisco Pais 1, 1049-001 Lisbon, Portugal
[3] Department of Astronomy and Theoretical Physics, Lund University, Sölvegatan 14A, 223 62 Lund, Sweden

LIP

LIP Pheno Group

HIGHLIGHTS

Theoretical Particle Physics in Portugal
Main topics of research



CIDMA] universidade de aveiro

António Morais has been working on:

- **Stochastic Gravitational Wave Background** from 1st order phase transitions in BSM theories;
- **BSM** collider phenomenology;
- **Ultra-light bosons**;
- **GUT phenomenology**

(**25 papers** published in the last 7 years)

CeFEMA Center of Physics and Engineering of Advanced Materials

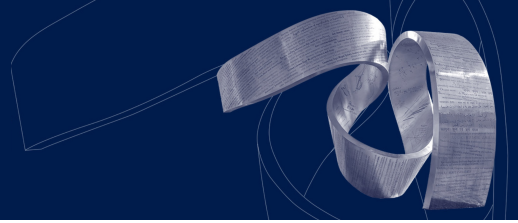
IST TÉCNICO LISBOA

George Rupp has many publications with the late Eef van Beveren on **Unquenched Meson Spectroscopy**. Also interested in **hypothetical scalar bosons** motivated by experiment.

Theoretical Particle Physics in Portugal
Main topics of research

All these research topics are fully in line with the

European Strategy for Particle Physics



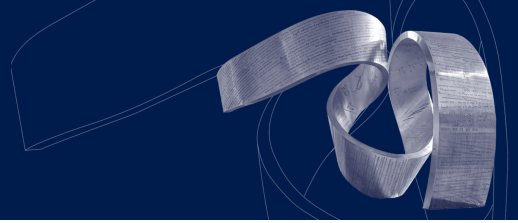
fct Fundação para a Ciência e a Tecnologia

CERN

CERN/FCT FUNDING

Extremely important to fund the **Experimental and Theoretical Particle Physics** research in CERN-related research topics.
Crucial to attract young researchers to the field (MSc, PhD students)

- **CERN/FIS-PAR/0002/2017:** Multi-Higgs Phenomenology at the LHC and Beyond
  PI: Pedro Ferreira; 30k euros; Fciências.ID
- **CERN/FIS-PAR/0004/2017:** Particle Physics in the LHC era
  PI: G. C. Branco; co-PI: M. N. Rebelo; 50k euros; IST-ID
- **CERN/FIS-PAR/0022/2017:** Probing Quark Gluon Plasma with jets
  PI: Guilherme Milhano; 30k euros; LIP
- **CERN/FIS-PAR/0034/2017:** Phenomenological studies at the LHC
  PI: Antonio Onofre; 10k euros; LIP

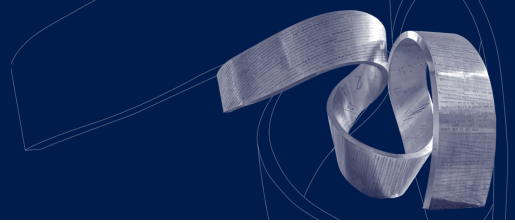


fct Fundação para a Ciência e a Tecnologia

CERN

CERN/FCT FUNDING

- **CERN/FIS-PAR/0004/2019:** Neutrino Physics: From Accelerators to Cosmos
  PI: Filipe Joaquim; co-PI: Ricardo Felipe; 35k euros; IST-ID
- **CERN/FIS-PAR/0008/2019:** Particle Physics in the LHC Era
  PI: G. C. Branco; co-PI: M. N. Rebelo; 80k euros; IST-ID
- **CERN/FIS-PAR/0014/2019:** Standard Model Extensions at the LHC
  PI: Rui Santos; 40k euros; Fciências.ID
- **CERN/FIS-PAR/0024/2019:** Bridging Theory and Experiment: Collider Phenomenology
  PI: José Guilherme Milhano; 90k euros; LIP
- **CERN/FIS-PAR/0027/2019 (15% HEP component):** Ultralight DM particles, black hole shadows and gravitational waves; PI: Carlos Herdeiro; 70k euros; U. Aveiro
- **CERN/FIS-PAR/0029/2019:** Multi-Higgs Phenomenology
  PI: António Onofre ; 45k euros; LIP

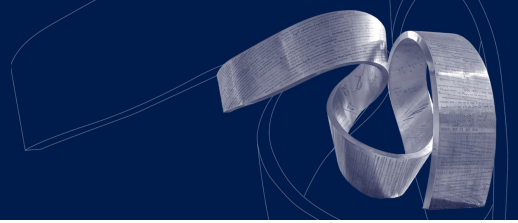


fct Fundação para a Ciência e a Tecnologia

CERN

CERN/FCT FUNDING

- **CERN/FIS-PAR/0002/2021:** Particle Physics in the LHC era and beyond
  PI: M. N. Rebelo; co-PI: G. C. Branco; 60k euros; IST-ID
- **CERN/FIS-PAR/0019/2021:** Neutrino Phenomenology: From oscillations to Gravitacional Waves
  PI: Filipe Joaquim; co-PI: R. Gonzalez-Felipe; 20k euros; IST-ID
- **CERN/FIS-PAR/0021/2021:** PI: António Morais; co-PI: Filipe Freitas 15k euros; U. Aveiro
- **CERN/FIS-PAR/0024/2021 (15% HEP component):** PI: C. Herdeiro; co-PI: N. S. Gual; 20k euros; U. Aveiro
- **CERN/FIS-PAR/0025/2021:** Multi-Higgs Phenomenology at the LHC and Beyond
  PI: Pedro Ferreira; co-PI: Rui Santos 30k euros; Fciências.ID
- **CERN/FIS-PAR/0032/2021:** The Strong force and multiparticle dynamics at hadron colliders
  PI: José Guilherme Milhano; co-PI: Liliana Apolinário 80k euro; LIP
- **CERN/FIS-PAR/0029/2019:** Multi-Higgs Phenomenology
  PI: António Onofre ; 45k euros; LIP



fct Fundação para a Ciência e a Tecnologia

PTDC Projects (call for projects on **all domains of science**)

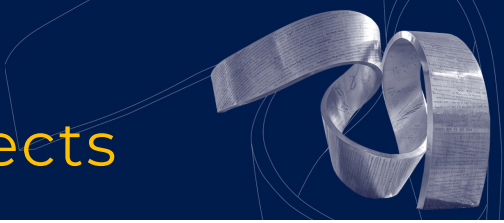
These projects last for **three years** rather than two, which is the case of CERN projects, and are expected to **support researchers** via work contracts or fellowships.

There is also the possibility of applying for 2-year **Exploratory Projects** (max funding 50k)

- **PTDC/FIS-PAR/29436/2017:** PI: M. N. Rebelo, Funding: 234k euros
- **PTDC/FIS-PAR/31000/2017:** PI: António Morais, Funding 250k euros
- **The LIP Pheno Group** has two PTDC Projects adding 100k euros of funding

Often the teams of CERN and PTDC projects include in their teams researchers from different (national and/or international) institutions

Theoretical Particle Physics in Portugal
European Funding and other International Projects



- **The LIP Pheno Group** received one **ERC** (400k euros) and 125k euros from **STRONG2020**

European Research Council
Established by the European Commission

STRONG-2020

- **Rui Santos** was the PI of the Portuguese node of Polish Project **Harmonia** with a total of 224k euros for several countries; and of the contract **RISE** (funding: 328.5k euros for several countries)

Marie Skłodowska-Curie Actions

- **Filipe Joaquim** belongs to the MC (representing Portugal) of a COST Action (CA18108). Another COST Action (CA15108) was active until recently, represented by **M. N. Rebelo** (Vice-chair). Three members of the LIP Pheno group where/are members of the Management Committee of three COST actions.

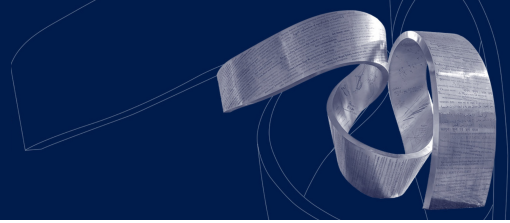
cost
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

- **Rui Santos** has been the Portuguese PI of two FCT Bilateral Actions

CNRST

DAAD
Deutscher Akademischer Austauschdienst
German Academic Exchange Service

Theoretical Particle Physics in Portugal
Regular FCT funding



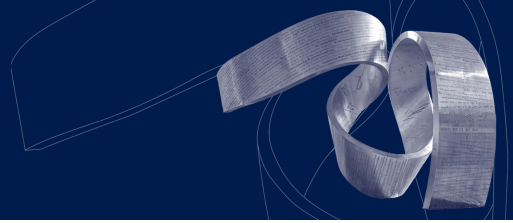
CFTP is a research unit of FCT (777) and therefore receives **"Financiamento Plurianual"**

IN THE LAST FOUR YEARS:

- **"Financiamento Base"** (175k euros) – mainly used for a few initial training fellowships, management expenses of the Centre, equipment, scientific journal subscription fees, consultants and a few Missions.
- **"Financiamento Programático"** (270k euros) – mainly for one postdoctoral fellowship and a researcher contract
- **Four PhD fellowships** (allowed us to attract excellent international students)

FUNDING FROM FCT/CERN PROJECTS IS CRUCIAL!

Theoretical Particle Physics in Portugal
Other activities

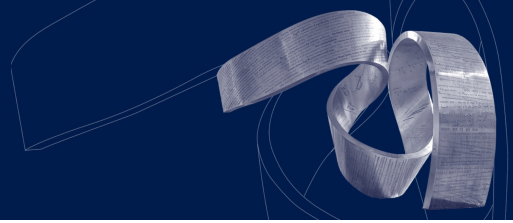


The theoretical particle physics community has also been **actively involved** in:

- **Organization of scientific events** (conferences, workshops, schools, colloquia, seminars, etc), also in joint collaboration with LIP;
- **Participation in international working groups;**
- **Transfer of knowledge** through teaching, supervision of MSc and PhD students, also in joint supervision with experimentalists;
- **Edition and authorship of academic manuals, technical and outreach books,** also in collaboration with colleagues from LIP;
- **Editorial activities** in specialised journals;
- **Professional training activities** e.g. CERN School for Teachers in Portuguese.
- **Outreach activities** e.g. visits to schools, participation in student events, media, etc.

and others ...

Theoretical Particle Physics in Portugal
Some of the difficulties



- **Impossibility to hire the best young researchers;**
- **Lack of coordination with international deadlines for job offers;**
- **Instability of FCT funding;**
- **Need for more funding for smaller projects** – better distribution of resources;
- **Evaluation panels should include members with the required expertise to evaluate ALL projects and grant proposals** – this has not been the case for the area of theoretical particle physics.