(SOME) OPEN PROBLEMS IN THEORETICAL PARTICLE PHYSICS

MSc Theses / research opportunities

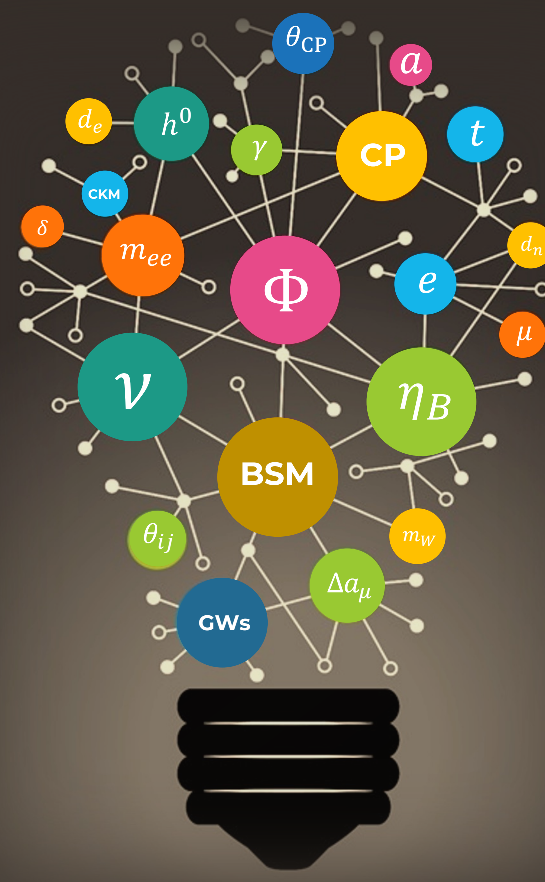
FILIPE R. JOAQUIM

Centro de Física Teórica de Partículas (CFTP)

Departamento de Física IST

filipe.joaquim@tecnico.ulisboa.pt

Ext. 3704

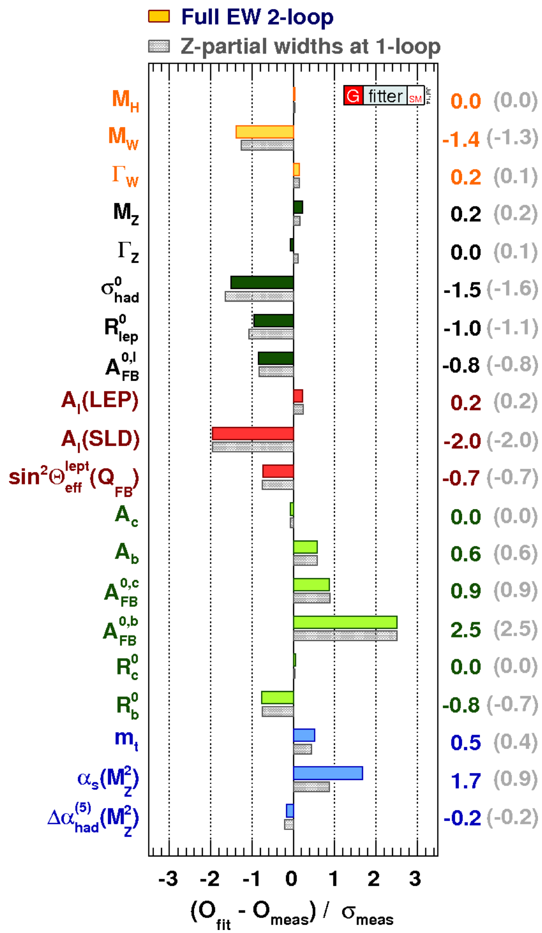


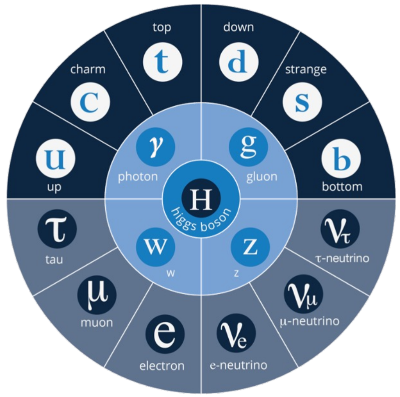
9th Mini-School on Particle and Astroparticle Physics

Inatel – Oeiras (5,6 fevereiro 2024)

THE (ALMOST) PERFECT THEORY

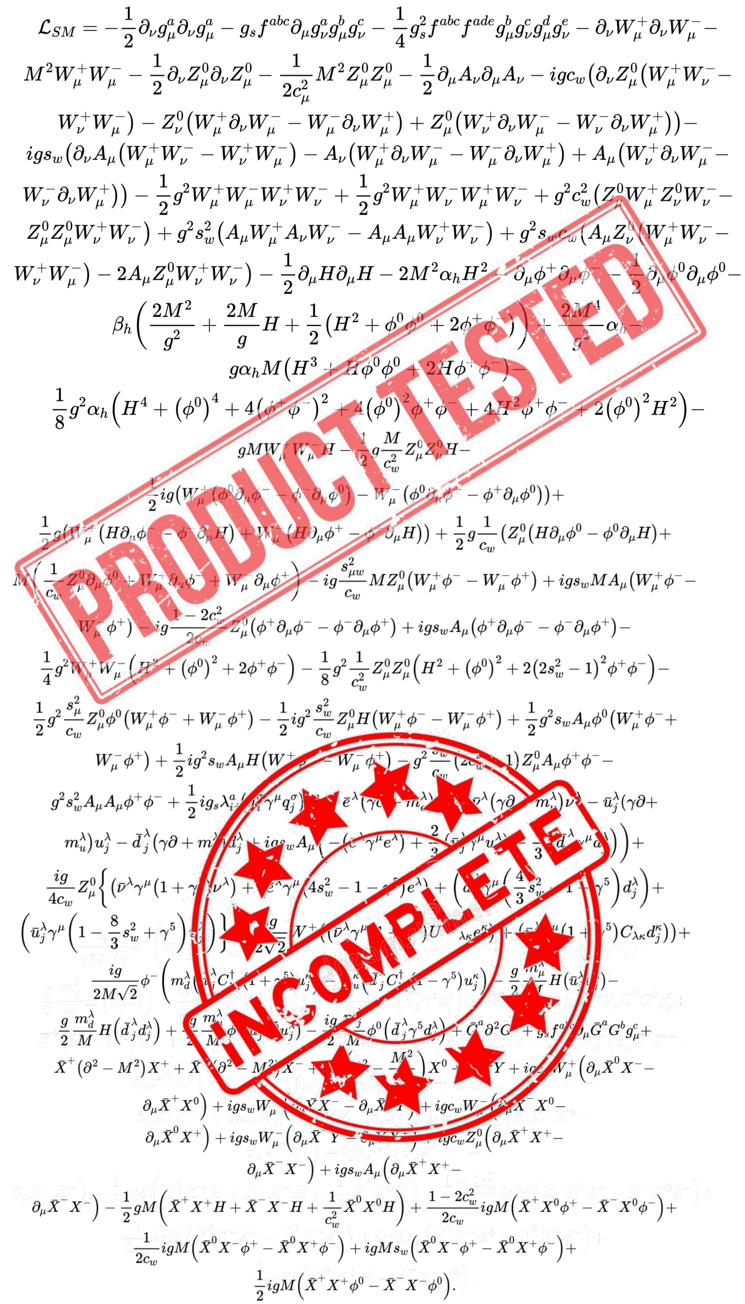
As you may have realised by now, the **Standard Model (SM)** is a very successful theory.





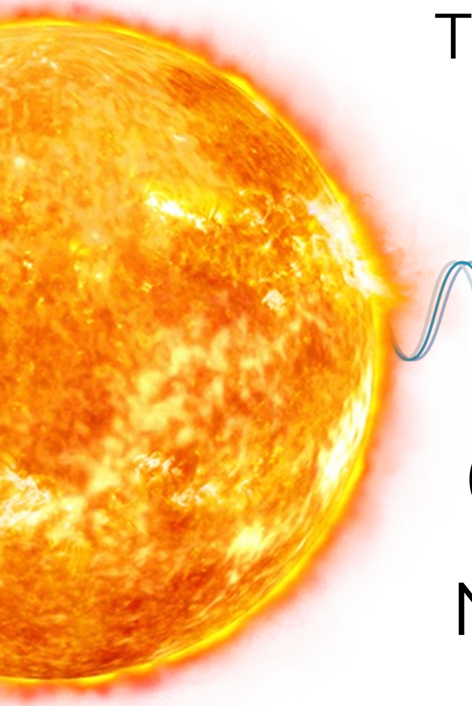
But...It is not perfect!

In fact it's incomplete...

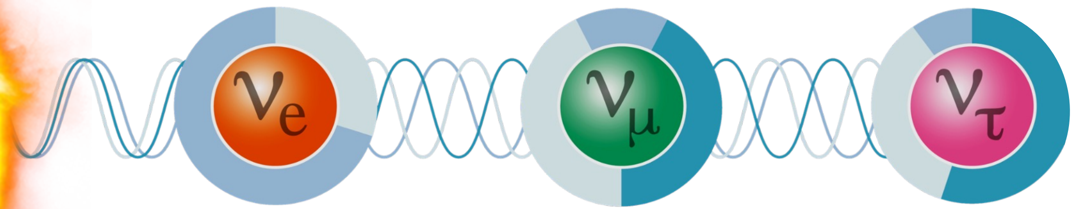


NEUTRINOS

The Chameleons of space



The **solar neutrino flux** detected on earth is smaller than expected



Neutrinos OSCILATE!!

(You have seen how this works with Valentina and Ivo)

Neutrinos are **strictly massless** in the SM

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \mathcal{L}_{d>4} \ , \ \mathcal{L}_{d>4} = \sum_{k=5} \frac{\mathcal{O}_k}{\Lambda^{k-4}}$$

Dark Matter

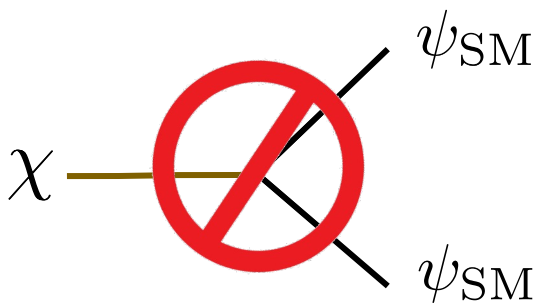
What is it?

Is there any **neutral stable** particle which can account for enough **Dark Matter** in the SM?

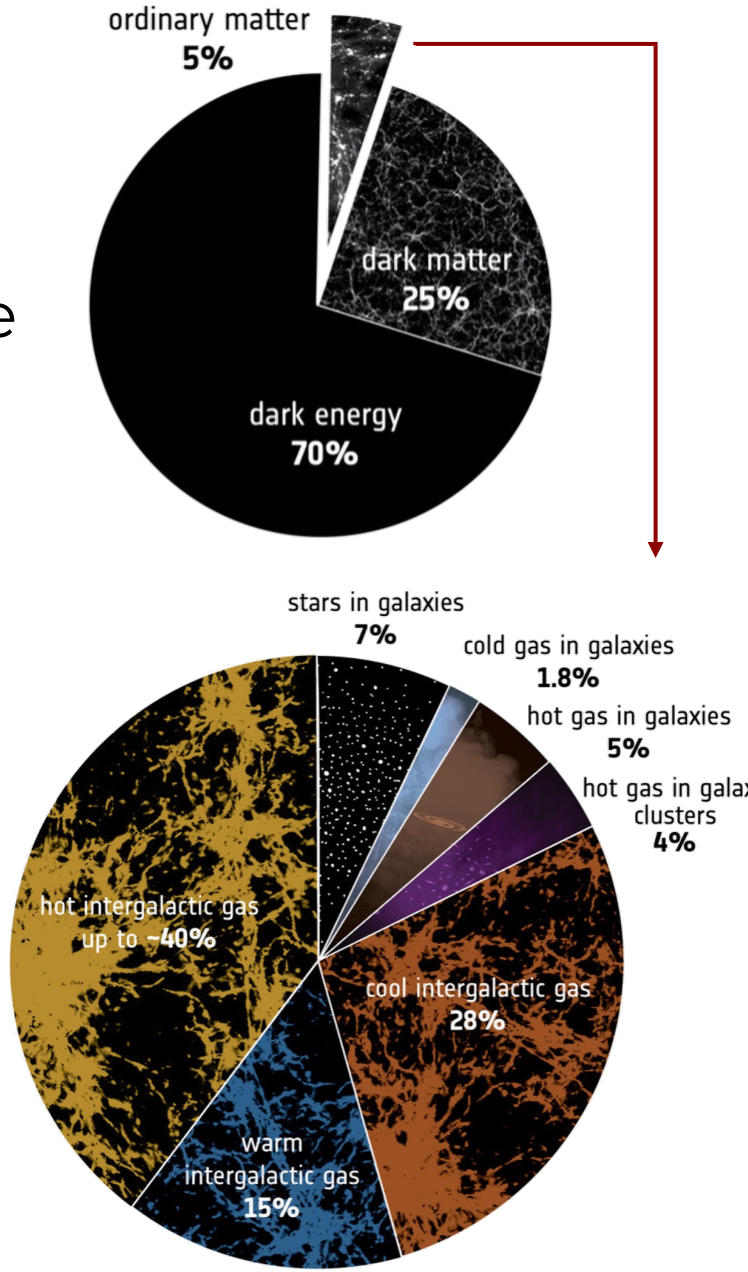
No!

Usually we stabilize dark matter using discrete symmetries, e.g. Z_2

$$\chi \to -\chi \ , \ \psi_{\rm SM} \to \psi_{\rm SM}$$



The particle is **stable**



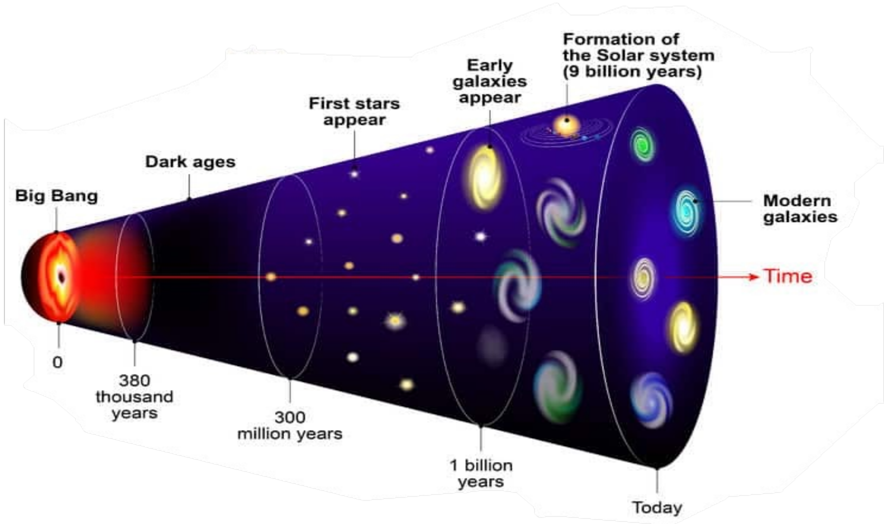
Baryon asymmetry of the Universe

or... why are we here?

The most natural thing is that after the **BIG-BANG** the Universe would have the same amount of

MATTER & **ANTIMATTER**

MATTER	**ANTIMATTER**
10 000 000 001	10 000 000 000



ANTIMATTER was theoretically predicted

$$(i\partial_\mu \gamma^\mu - m)\psi = 0$$

Dirac, 1928

The SM cannot explain this number!

BSM in the three frontiers of Particle Physics

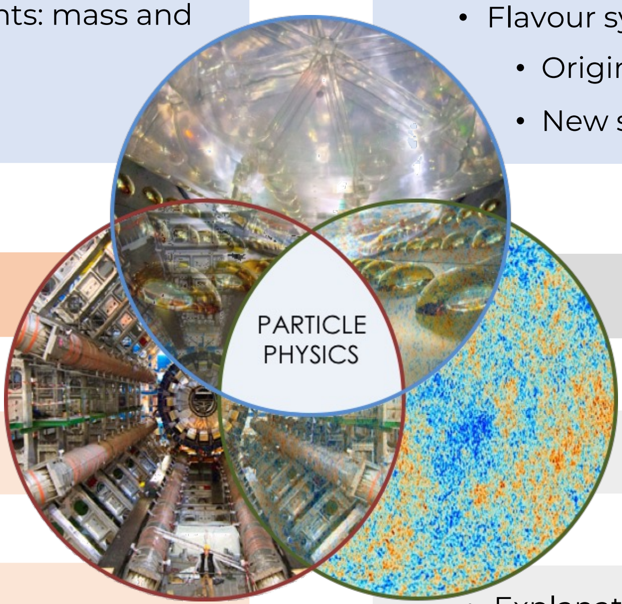
INTENSITY FRONTIER

Experiment

- Neutrinoless double beta decay searches
- Neutrino oscillation experiments: mass and mixing data
- LFV searches

Theory

- Are neutrinos Dirac or Majorana particles ?
- Flavour symmetries (discrete/continuous)
  - Origin of leptonic CP violation
  - New sources of flavour



ENERGY FRONTIER

Experiment

Large Hadron Collider (LHC)

Theory

- Models with new particles: fermions or scalars (neutrino mass messengers, multi-Higgs,...)
- New interactions:
  extended gauge group – symmetries

COSMIC FRONTIER

Experiment

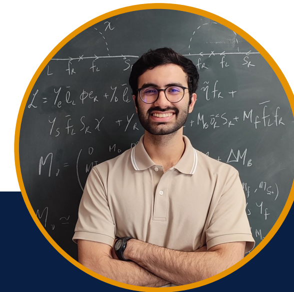
Cosmological observations

Theory

- Explanation for the matter-antimatter asymmetry of the Universe (Leptogenesis)
- New leptonic CP-violating effects
- Models with viable dark matter candidates
- GWs

SOME OF MY CURRENT COLLABORATORS

Who happen to be students doing their **PhD or MSc** under my supervision, also in co-supervision with other (inter)national.



ADITYA BATRA

PhD Student @ CFTP (2023-2027)

Centro de Física Teórica de Partículas (CFTP)

FCT PhD Grant: UI/BD/154391/2023
aditya.batra@tecnico.ulisboa.pt

PhD Programme: Neutrinos: a window to the Universe

Supervisors:
Filipe Joaquim (CFTP/IST)
Rahul Srivastava (IISER Bhopal)
José W. F. Valle (IFIC, Valencia)

HENRIQUE CÂMARA

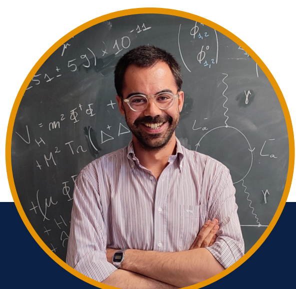
PhD Student @ CFTP (2021-2025)

Centro de Física Teórica de Partículas (CFTP)

FCT PhD Grant: 2021.06340.BD
henrique.b.camara@tecnico.ulisboa.pt

PhD Programme: Beyond the SM – Interplay between particle and astroparticle physics

Supervisors:
Filipe Joaquim (CFTP/IST)
Ricardo Felipe (CFTP, ISEL)



BERNARDO GONÇALVES

PhD Student @ CFTP (2019-2024)

Centro de Física Teórica de Partículas (CFTP, IST)

Centro de Física Teórica e Computacional (CFTC, FCUL)

FCT PhD Grant: SFRH/BD/139165/2018
bernardo.lopes.goncalves@tecnico.ulisboa.pt

PhD Programme: Multi-Higgs Physics

Supervisors:
Filipe Joaquim (CFTP/IST)
Pedro Ferreira (CFTC/UL, ISEL)

JOSÉ ROCHA

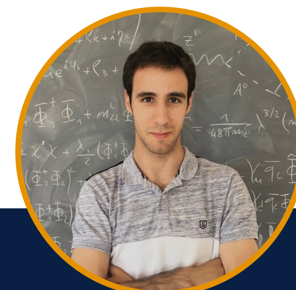
MSc Student @ CFTP (2022-2024)

Centro de Física Teórica de Partículas (CFTP)

FCT MSc Grant: BL229 2023
jose.r.rocha@tecnico.ulisboa.pt

Msc Programme: Flavour symmetries and the strong CP problem

Supervisors:
Filipe Joaquim (CFTP, IST)
Henrique Câmara (CFTP, IST)



JOÃO SEABRA

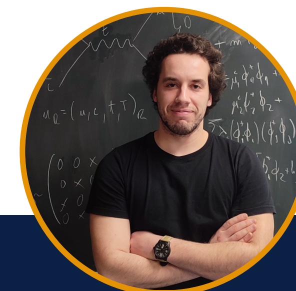
PhD Student @ CFTP (2019-2024)

Centro de Física Teórica de Partículas (CFTP)

FCT PhD Grant: SFRH/BD/143891/2019
joao.f.seabra@tecnico.ulisboa.pt

PhD Programme: New Physics signals at the Large Hadron Collider

Supervisors:
Filipe Joaquim (CFTP/IST)
Juan A. Aguilar Saavedra (IFT, Madrid)



RICARDO AMADEU

MSc Student @ CFTP (2022-2024)

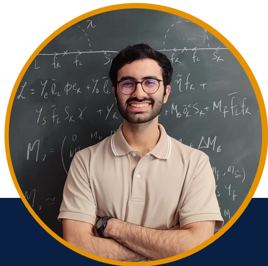
Centro de Física Teórica de Partículas (CFTP)

ricardo.amadeu@tecnico.ulisboa.pt

Msc Programme: Phenomenology of SM extensions with vectorlike quarks

Supervisors:
Filipe Joaquim (CFTP, IST)
Henrique Câmara (CFTP, IST)

A couple of RECENT HIGHLIGHTS



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PhD Student @ CFTP (2021-2025)

Centro de Física Teórica de Partículas (CFTP)

FCT PhD Grant: 2021.06340.BD
henrique.b.camara@tecnico.ulisboa.pt

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Supervisors:
Filipe Joaquim (CFTP/IST)
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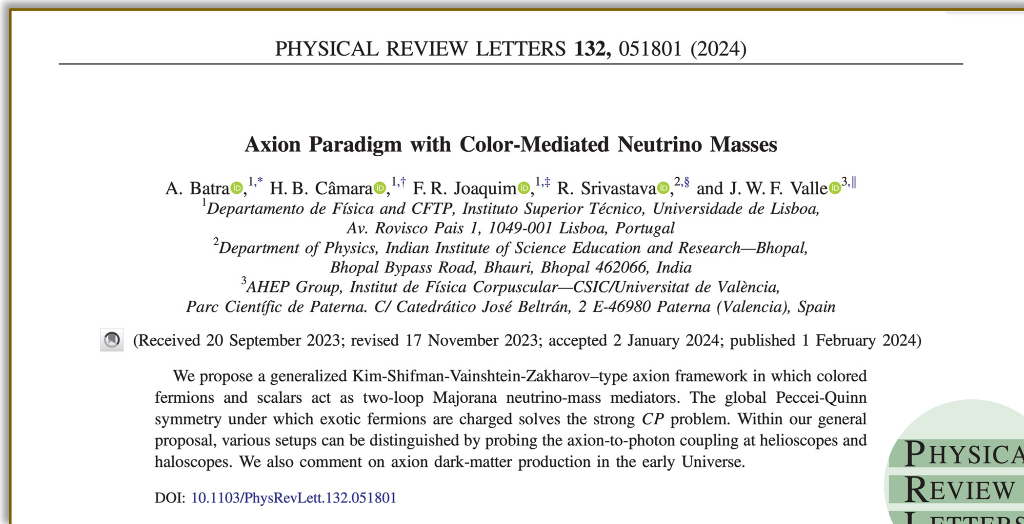


PHYSICAL REVIEW LETTERS **132,** 051801 (2024)

Axion Paradigm with Color-Mediated Neutrino Masses

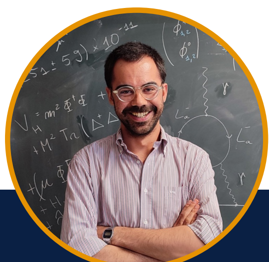
A. Batra,[1,*] H. B. Câmara,[1,†] F. R. Joaquim,[1,‡] R. Srivastava,[2,§] and J. W. F. Valle[3,‖]
[1]*Departamento de Física and CFTP, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais 1, 1049-001 Lisboa, Portugal*
[2]*Department of Physics, Indian Institute of Science Education and Research—Bhopal, Bhopal Bypass Road, Bhauri, Bhopal 462066, India*
[3]*AHEP Group, Institut de Física Corpuscular—CSIC/Universitat de València, Parc Científic de Paterna. C/ Catedrático José Beltrán, 2 E-46980 Paterna (Valencia), Spain*

(Received 20 September 2023; revised 17 November 2023; accepted 2 January 2024; published 1 February 2024)

We propose a generalized Kim-Shifman-Vainshtein-Zakharov–type axion framework in which colored fermions and scalars act as two-loop Majorana neutrino-mass mediators. The global Peccei-Quinn symmetry under which exotic fermions are charged solves the strong *CP* problem. Within our general proposal, various setups can be distinguished by probing the axion-to-photon coupling at helioscopes and haloscopes. We also comment on axion dark-matter production in the early Universe.

DOI: 10.1103/PhysRevLett.132.051801

PHYSICAL REVIEW LETTERS



BERNARDO GONÇALVES

PhD Student @ CFTP (2019-2024)

Centro de Física Teórica de Partículas (CFTP, IST)
Centro de Física Teórica e Computacional (CFTC, FCUL)

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PhD Programme: Multi-Higgs Physics

Supervisors:
Filipe Joaquim (CFTP/IST)
Pedro Ferreira (CFTC/UL, ISEL)

Bernardo won a **Fulbright scholarship** to work in the United States for six months (Oct 22-Mar 23) with **Marc Sher** @ the High-Energy Theory Group of the Department of Physics (William and Mary)

FULBRIGHT Portugal

fct Fundação para a Ciência e a Tecnologia

WILLIAM & MARY CHARTERED 1693

RESEARCH OPPORTUNITIES

SO … WHAT CAN YOU DO?

Come and talk to us we will find a topic for you to work on

Office 4-8.3
(4th floor IST Department of Physics)

Some examples of theses and papers published during MEFT

SCAN ME!