ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Probing light dark particles with rare meson decays

SUPERVISOR(S): Sergi Gonzalez-Solis

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UNIVERSITY/RESEARCH CENTER: University of Barcelona and Institute of Cosmos Sciences

ABSTRACT

The sensitivity of the rare decays $\eta/\eta' \to \pi^0\gamma\gamma$ to signatures of Beyond the Standard particles in the MeV-GeV mass range will be analyzed in this work. By adding new fundamental scalar (S) and vector (V) bosons through the decay channels $\eta/\eta' \to \pi^0 S \to \pi^0\gamma\gamma$ and $\eta/\eta' \to V\gamma \to \pi^0\gamma\gamma$, respectively, to the Standard Model contributions from vector, tensor and scalar meson exchanges, and employing experimental data for the associated branching ratios, this project will set constraints on the new particle fundamental properties -mass and coupling to the Standard Model particles. The results will be relevant for the dark-sector particles search programs at existing and forthcoming light-meson factories, such as BESIII (China) and Jefferson Lab Eta Factory (USA) experiments.

The work will require state-of-the-art reading, as well as analytical and computational skills. It will be developed at the University of Barcelona, but remote supervision is possible.

References:

[1] L. Gan, B. Kubis, E. Passemar and S. Tulin, ``*Precision tests of fundamental physics with η and η' mesons*," Phys. Rept. **945** (2022), 1-105, doi:10.1016/j.physrep.2021.11.001, [arXiv:2007.00664 [hep-ph]].

[2] R. Escribano, S. Gonzalez-Solis, R. Jora and E. Royo,``*Theoretical analysis of the doubly radiative decays $\eta/\eta' \to \pi^0\gamma\gamma$ and $\eta' \to \eta^0\gamma\gamma$*", Phys. Rev. D **102** (2020) no.3, 034026, doi:10.1103/PhysRevD.102.034026, [arXiv:1812.08454 [hep-ph]].

[3] R. Escribano, S. Gonzalez-Solis and E. Royo, ``Sensitivity of the *$\eta/\eta' \to \pi^0\gamma\gamma$ and $\eta' \to \eta^0\gamma\gamma$* decays to a sub-GeV leptophobic $U(1)_B$ boson," Phys. Rev. D **106** (2022) no.11, 114007, doi:10.1103/PhysRevD.106.114007, [arXiv:2207.14263 [hep-ph]].

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Understanding the $\rho\pi$ puzzle in the vector charmonium decays $J/\psi\to\pi^0\pi^+\pi^-$ and $\psi(2S)\to\pi^0\pi^+\pi^-$

SUPERVISOR(S): Sergi Gonzalez-Solis

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UNIVERSITY/RESEARCH CENTER: University of Barcelona and Institute of Cosmos Sciences

ABSTRACT

The different experimental picture between the J/ψ and $\psi(2S)$ vector charmonium decays into three pions is known as the "$\rho\pi$ puzzle" and still remains largely unresolved -while the $\rho\pi$ intermediate state $J/\psi\to\rho\pi\to\pi\pi\pi$ vastly dominates the decay of the J/ψ, the $\rho\pi$ contribution is subleading in the $\psi(2S)$ one and almost all events are found in the center of the Dalitz plot. New high-statistics data on charmonium decays from the BESIII experiment (China) will soon be available which could be used to greatly improve the theoretical uncertainties. In this project, a theoretical framework based on the analytical properties of the decay amplitude supplemented with meson resonance exchange ideas will be developed to describe these decays with the accuracy matching the experimental precision. This will improve the understanding of charmonium decays and help clarify the $\rho\pi$ puzzle.

The work will require state-of-the-art reading, as well as analytical and computational skills. It will be developed at the University of Barcelona, but remote supervision is possible.

References:

[1] JPAC Collaboration, ``*Novel approaches in hadron spectroscopy*," Prog. Part. Nucl. Phys. **127** (2022) 103981, https://doi.org/10.1016/j.ppnp.2022.103981, [arXiv: 2112.13436 [hep-ph]].

[2] JPAC Collaboration,``*Khuri-Treiman analysis of $J/\psi\to\pi\pi\pi$*", Phys. Rev. D **108** (2023) no.1, 014035, https://doi.org/10.1103/PhysRevD.108.014035, [arXiv: 2304.09736 [hep-ph]].

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Causal transport coefficients of heavy particles

SUPERVISOR(S): Juan Torres-Rincon (University of Barcelona)
Vincenzo Greco (University of Catania)

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UNIVERSITY/RESEARCH CENTER: University of Barcelona

ABSTRACT
(just few lines 5-10 explaining briefly the idea of the proposed work and the place where it will be developed).

The dynamics of heavy-flavor particles in a thermal medium can be described by the Langevin equation, which incorporated several transport coefficients as parameters. To be respectful with the special relativity principles, a recent study has considered a causal version of the Langevin equation which requires an additional coefficient, the memory time [1]. In this project, the nature of the memory time will be studied from microscopic interactions of heavy particles. By applying the theory of hydrodynamic fluctuations, this parameter will be extracted for realistic systems performing numerical simulations.

The work will be mainly developed at the University of Barcelona supervised by Juan Torres-Rincon and concluded at University of Catania guided by Prof. Vincenzo Greco.

[1] M.Ruggieri et al. Phys.Rev.D 106 (2022) 3, 034032

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Tensor Mesons Photoproduction

SUPERVISOR(S): Vincent Mathieu (Universitat de Barcelona)

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UNIVERSITY/RESEARCH CENTER: Universitat de Barcelona, departament de física cuántica

ABSTRACT

In this thesis, you will develop a powerful technique to analyze baryon resonances produced in photoproduction through the angular decomposition of their decay product. You will generalize the formalism developed in Ref~[1] to the baryon system.
The project can be carried in Barcelona and/or remotely with weekly Zoom meetings with the supervisor.
Do not hesitate to contact the supervisor for more details, without any commitment.

[1] V.~Mathieu \textit{et al.} [JPAC],
``Moments of angular distribution and beam asymmetries in $\eta\pi^0$ photoproduction at GlueX,"
Phys. Rev. D \textbf{100} (2019) no.5, 054017
doi:10.1103/PhysRevD.100.054017
[arXiv:1906.04841 [hep-ph]].

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Tensor Mesons Photoproduction

SUPERVISOR(S): Vincent Mathieu (Universitat de Barcelona)

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UNIVERSITY/RESEARCH CENTER: Universitat de Barcelona, departament de física cuántica

ABSTRACT

In this thesis, you'll develop a model describing the photoproduction of tensor mesons based on the model from Ref. [1] and the data from Refs. [2-4]. You will learn some standard techniques and theories used in particle physics such as the helicity formalism, the decomposition into partial waves, the S-matrix (or scattering) theory and Regge theory.
The project can be carried in Barcelona and/or remotely with weekly Zoom meetings with the supervisor.
Do not hesitate to contact the supervisor for more details, without any commitment.

[1] V.~Mathieu \textit{et al.} [JPAC],
``Exclusive tensor meson photoproduction,"
Phys. Rev. D \textbf{102} (2020) no.1, 014003
doi:10.1103/PhysRevD.102.014003
[arXiv:2005.01617 [hep-ph]].

[2] M.~Carver \textit{et al.} [CLAS],
``Photoproduction of the $f_2(1270)$ meson using the CLAS detector,"
Phys. Rev. Lett. \textbf{126} (2021) no.8, 082002
doi:10.1103/PhysRevLett.126.082002
[arXiv:2010.16006 [nucl-ex]].

[3] A.~Celentano \textit{et al.} [CLAS],
``First measurement of direct photoproduction of the $a_2(1320)^0$ meson on the proton,"
Phys. Rev. C \textbf{102} (2020) no.3, 032201
doi:10.1103/PhysRevC.102.032201
[arXiv:2004.05359 [nucl-ex]].

[4] The GlueX Collaboration, to appear soon.

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Strange Cascade with a Polarized Target

SUPERVISOR: Vincent Mathieu

SUPERVISOR contact- email: vmathieu@ub.edu

UNIVERSITY/RESEARCH CENTER: Universitat de Barcelona, departament de física cuántica.

ABSTRACT

In this thesis, you will develop a model for a strange cascade, that is, a reaction in which several baryons containing strange quarks are produced. The GlueX collaboration (Hall D at the Thomas Jefferson Lab) is exploring the possibilities of setting up a polarized proton target [1]. A polarized target could potentially help in the determination of the quantum numbers of the produced strange baryon. To investigate this possibility, you will develop models for various spin-parity baryons and test their differences in the polarized target observables.
The project can be carried in Barcelona and/or remotely with weekly Zoom meetings with the supervisor.
Do not hesitate to contact the supervisor for more details, without any commitment.

[1] F.~Afzal, M.~M.~Dalton, A.~Deur, P.~Hurck, C.~D.~Keith, V.~Mathieu, S.~Sirca and Z.~Yu, ``White Paper on Polarized Target Studies with Real Photons in Hall D,"
[arXiv:2407.06429 [nucl-ex]].

ERASMUS MUNDUS MASTER IN NUCLEAR PHYSICS
Academic Year 2024/2025

MASTER THESIS PROPOSAL

TITLE: Baryon Form Factors from HADES

SUPERVISOR(S): Vincent Mathieu (Universitat de Barcelona)

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UNIVERSITY/RESEARCH CENTER: Universitat de Barcelona, departament de física cuántica

ABSTRACT

In this thesis, you will make predictions for the forthcoming measurements of baryon form factors by the HADES collaboration [1].

The project can be carried in Barcelona and/or remotely with weekly Zoom meetings with the supervisor.
Do not hesitate to contact the supervisor for more details, without any commitment.

[1] R.~Abou Yassine \textit{et al.} [HADES],
``First measurement of massive virtual photon emission from N* baryon resonances,"
[arXiv:2205.15914 [nucl-ex]].