

Science @



Summary of research lines

Luis Alvarez Ruso

# Prelude

- Big research center:
  - Total staff: **355**
  - **76% researchers** (experiment & theory)
    - 56 postdocs
    - 99 PhD students
  - **Annual Report 2023**  
<https://ibox.ific.uv.es/nextcloud/index.php/s/3RTGXbCEHPZsbgn>

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- Broad range of scientific interests...
- ... and activities:
  - Colloquia
  - Seminars
  - Scientific meetings
  - (PhD) Courses
- Visitors

## FEATURED EVENTS

## Forthcoming Colloquia

The neutron decay anomaly and dark neutron decay  
 Prof. Benjamin Grinstein  
 Thursday, 5 December, 2024 - 12:30 | Salón de Actos | 🇪🇸

## Forthcoming Seminars

IFIC seminar: Top Secret(s): Probing the Standard Model with rare processes involving top quarks  
 Dr. Josh McFayden  
 Tuesday, 26 November, 2024 - 12:00 | Paterna. Seminario | 🇪🇸

IFIC Seminar: Detecting relic neutrinos and measuring the neutrino mass with Ptolemy  
 Prof. Nicolás De Groot  
 Wednesday, 27 November, 2024 - 12:00 | Paterna. Seminario | 🇪🇸

Topical seminar: Using Machine Learning Techniques to Increase Model Agnosticism in Statistical Analyses  
 Dr. Bernat Capdevila  
 Thursday, 28 November, 2024 - 11:30 | Paterna. Seminario | 🇪🇸

## Thesis Defense

Electron efficiency measurements and search for Higgs boson production in association with top quarks with the ATLAS experiment  
 Lorenzo Varriale  
 Wednesday, 27 November, 2024 - 10:30 | Salón de Actos - Edificio Cabecera | 🇪🇸

Novel radio frequency accelerating cavity developments for compact linear accelerators in hadrontherapy treatment  
 Pablo Martínez Reviriego  
 Friday, 29 November, 2024 - 11:00 | Paterna. Seminario | 🇪🇸

## Forthcoming Events

IFIC Newcomers Fest 2024  
 Monday, 25 November, 2024 - 09:00 | 🇪🇸

Jornadas científicas IFIC: Origin of mass. L1 Higgs Force  
 Luca Fiorini, Arcadi Santamaría, Salvador Martí García, Germán Rodrigo  
 Monday, 2 December, 2024 - 09:30 | Paterna. Seminario | 🇪🇸

Atmospheric Neutrinos: Experiments and Phenomenology  
 Dr. Alfonso Andres García Soto, Mariam Tórtola  
 Wednesday, 4 December, 2024 - 09:00 | 🇪🇸

## NEWS



El IFIC se reúne de nuevo con su Comité Científico Asesor Internacional

Este comité está compuesto por científicos internacionales de reconocido prestigio con el fin de evaluar la actividad científica y la gestión del centro.

Fri, 25/10/2024



Los investigadores del IFIC Gonzalo Olmo y Santiago G. de la Hoz, nuevos directores de departamento en la Facultat de Física

Gonzalo Olmo Alba dirigirá el departamento de Física Teórica y Santiago González de la Hoz, el de de Física Atómica, Molecular y Nuclear.

Wed, 23/10/2024



Francis Halzen repasará la primera década de astronomía con neutrinos de alta energía en el próximo coloquio del IFIC

Halzen es el investigador principal del observatorio IceCube, instalado en el hielo del polo sur.

Mon, 21/10/2024



Recrean en el CERN una reacción nuclear clave para conocer la evolución química de nuestra galaxia y del sistema solar

Investigadores del IFIC logran medir en el laboratorio la formación de un elemento clave en la evolución de la composición química de los elementos pesados

Mon, 21/10/2024

1 2 ... siguiente última

## VISITANTES

Fri, 08/11/2024 Dr. Rishav Roshan visits IFIC from November 11th to 15th, 2024  
 Tue, 15/10/2024 Dr. Wolfram Ratzinger visits IFIC from October 13th to 17th, 2024  
 Mon, 07/10/2024 Dr. Alejandro Saez visits IFIC from October 7th to November 6th, 2024  
 Mon, 30/09/2024 Prof. David Lin visits IFIC from October 21th to 29th, 2024

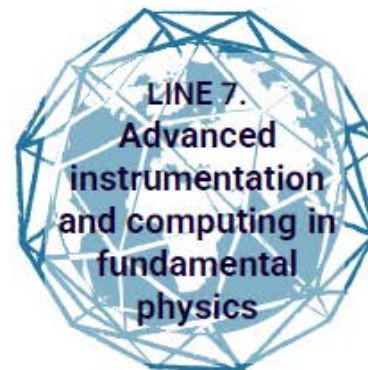
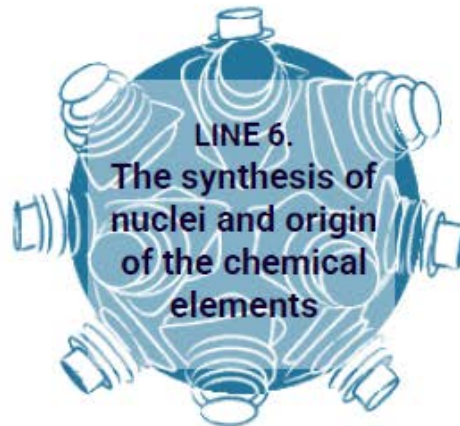
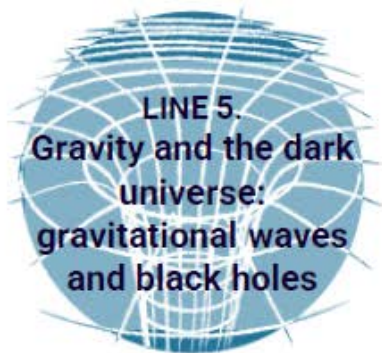
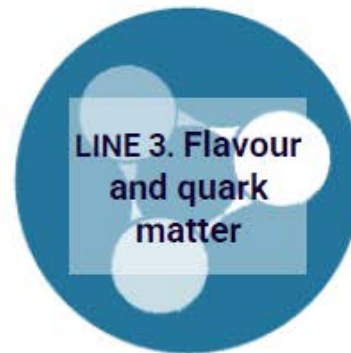
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- **Opportunities for collaboration**

# Research Lines



# L1. The Higgs Force

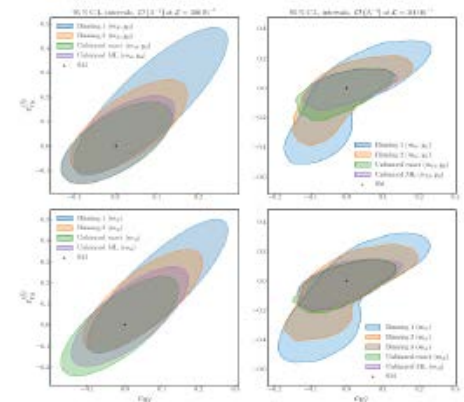
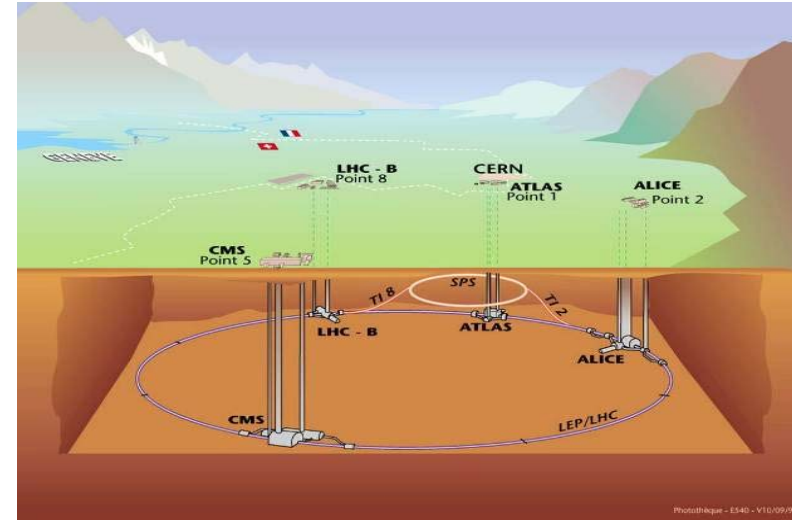
## ■ Experiment:

### ■ ATLAS @ LHC, CERN

- Detector operation and calibration
- Software & computing
- Precision measurements:
  - Higgs properties and interactions
  - Top quark production
- BSM searches and constrains:
  - LFV
  - $W', Z'$

## ■ Theory:

- Higher orders in perturbative QFT (EW & QCD)
- EFT for BSM & Pheno
  - Machine learning
  - Quantum computing



The 95% CL regions in the  $(ctG, ct_u)$  plane obtained for the parton-level top quark pair production process described in Sect. 4.2 of the paper. We present results based on EFT calculations at the linear level (left) and also including quadratic contributions (right panels).

# L2. Neutrinos and lepton flavor

## ■ Experiment:

- NEXT @ LSC: NEXT-100 construction and data taking

- Search for  $\beta\beta_{0\nu}$  decay

- T2K measurements

- $\nu$  fluxes, cross sec., osc. param.

- DUNE & ProtoDUNE @ CERN

- Design and construction

- Analysis strategies: proton decay

- ANTARES & KM3Net-ORCA

- Monte-Carlo & algorithm development

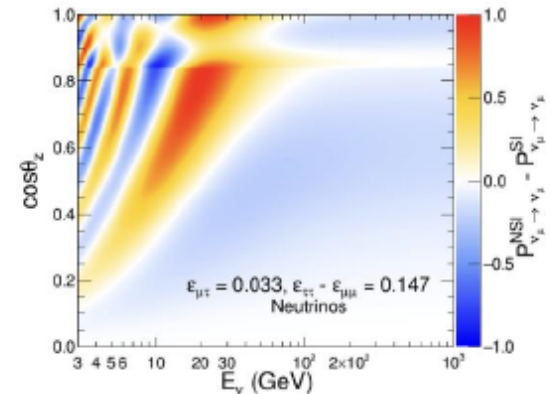
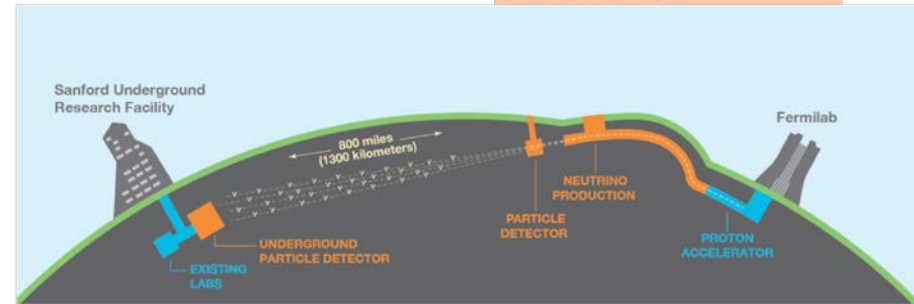
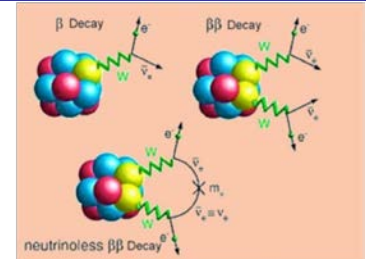
- Atmospheric  $\nu$ : oscillations, NSI,  $\nu$  decay

## ■ Theory:

- Global analyses of  $\nu$  oscillations

- $\nu$  mass models,  $\nu$  in cosmology

- $\nu$  interactions with matter, including CE $\nu$ NS, NSI



Example of the modifications induced by non-standard neutrino interactions on the disappearance probabilities of muon neutrinos, as a function of the true neutrino energy and cosine of the zenith angle, that can be studied with data from ANTARES.

# L3. Flavor and quark matter

## ■ Experiment:

### ■ LHCb, ATLAS @ CERN, Belle-II @ KEK

#### ■ b- and c-baryon (rare) decays

#### ■ Asymmetries, polarization observables

#### ■ Sensitive to non-perturbative QCD and new physics

#### ■ FCNC, flavor anomalies

#### ■ Searches: baryon EDM, HNL, Hexaquarks

## ■ Theory:

### ■ New physics in hadron and $\tau$ decays

### ■ EFT in hadron physics:

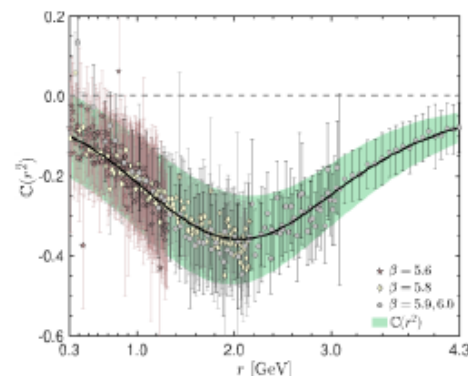
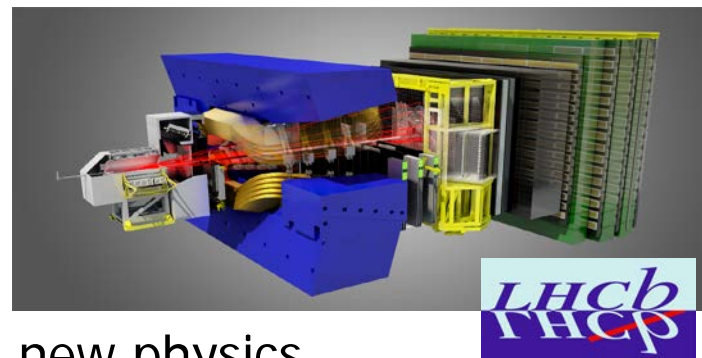
#### ■ Exotic states, hadronic molecules

#### ■ Baryon properties and interactions with ChPT

### ■ Lattice QCD

### ■ Synergy between LQCD and continuum methods:

#### ■ Dyson-Schwinger eqs., hadrons @ finite volume, quark mass dep.



The activation of the Schwinger mechanism hinges on the formation of composite massless poles, which modify the analytic structure of the fundamental vertices of the theory and induce smoking gun displacements in the corresponding Ward identities. This displacement, denoted by  $C(r^2)$ , is obtained using central fits for the lattice data (black solid curve). The green band expresses the uncertainty in this result. The dashed gray line represents the null result, i.e., no Schwinger mechanism.

# L4. Astroparticles, DM and cosmology

## ■ Experiment:

■ ATLAS, LHCb, MATHUSLA, MAPP-MoEDAL, NA64 @ CERN

## ■ Searches:

- CP-violation, SUSY, long-lived particles
- light DM, magnetic monopoles

## ■ ANTARES & KM3Net-ARCA

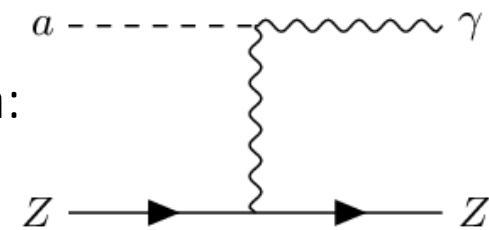
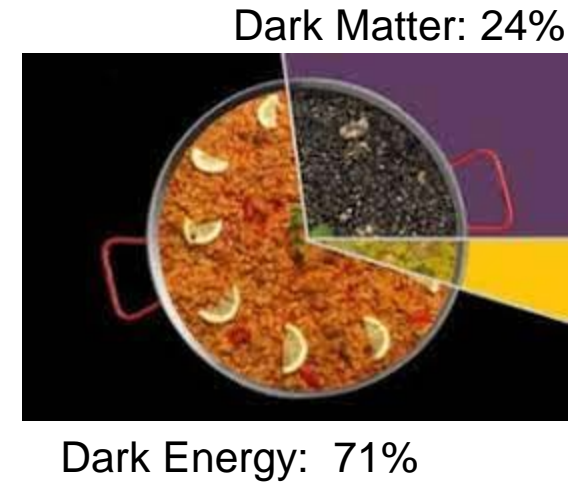
- Cosmic neutrino detection, multi-messenger astronomy
- Neutrinos from DM

## ■ RAD.ES, babyIAXO, CADEX

- Axion searches using inverse Primakoff mechanism:

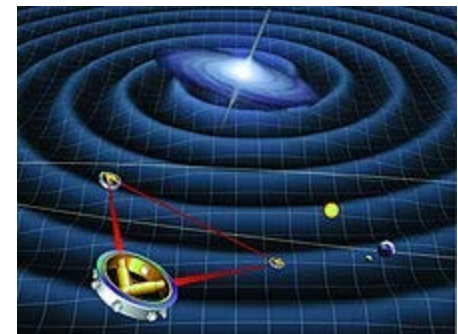
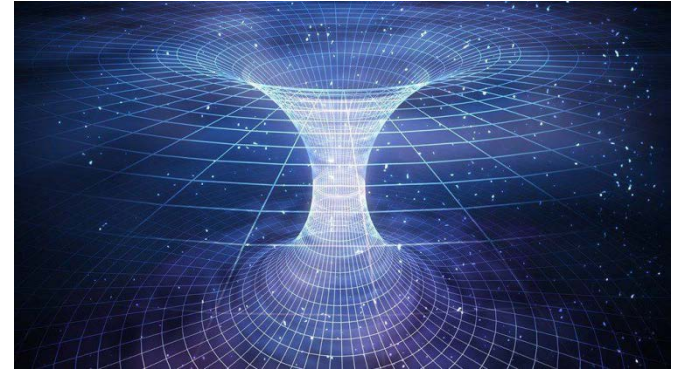
## ■ Theory:

- Dark matter models and pheno.
- Production of long-lived particles
- Leptogenesis



# L5. Gravity and the dark universe: gravitational waves and black holes

- **Theory:**
- Primordial black holes
- Modified gravity
- Quantum effects in gravity
- Gravitational waves as probes of this physics
- QFT in curved spacetime
- Participation in exp. projects:
  - Laser Interferometer Space Antenna (LISA):
  - Einstein Telescope
  - SKA radio telescope



# L6. The synthesis of nuclei and origin of the heavy chemical elements

## ■ Experiment:

■ ISOLDE, n\_TOF @ CERN, AGATA @ LNL, FAIR @ GSI, HENSA @ LSC, RIKEN, GANIL, IGISOL

■ Gamma and neutron spectroscopy

■ Nuclear structure, astrophysics & applications:

■ Exotic nuclei at driplines

■  $\beta$  decays,  $\bar{\nu}$  reactor fluxes

■ Stellar nucleosynthesis

■ Ambient neutron rates

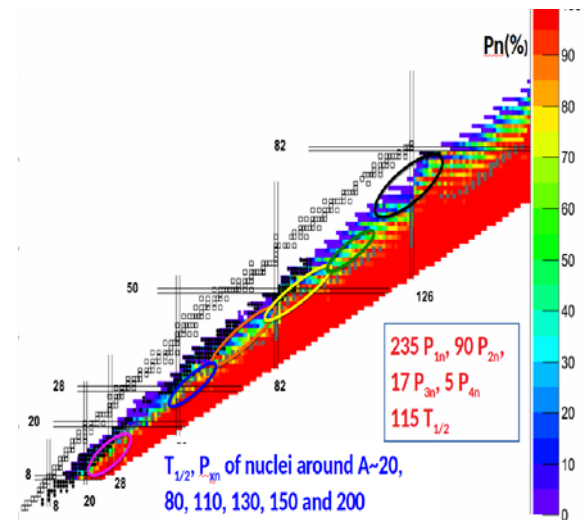
■  $(\alpha, n)$  reactions

■ Development of instrumentation

## ■ Theory:

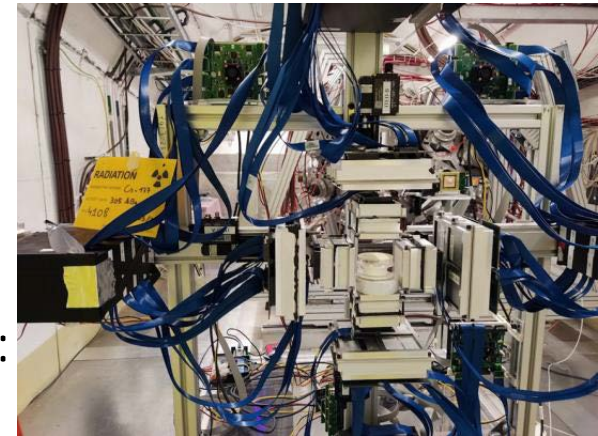
■ Precision & BSM physics with  $\beta$  decays

■ CKM unitarity tests



# L7. Advanced instrumentation and computing in fundamental physics

- Instrumentation development for different experiments:
  - TileCal, ITk for **ATLAS**
  - ECAL for **LHCb**
  - CMOS pixel sensors for **Belle II**
  - Detector R&D for future colliders
  - New electronics for **AGATA**
  - Active detectors and novel materials for **n\_TOF**:
    - **NEXT-100** detector
    - Cryogenics and photon detection system for **DUNE**
- Computing:
  - ATLAS-GRID
  - ARTEMISA infrastructure for ML and AI
  - GLUON HPC system

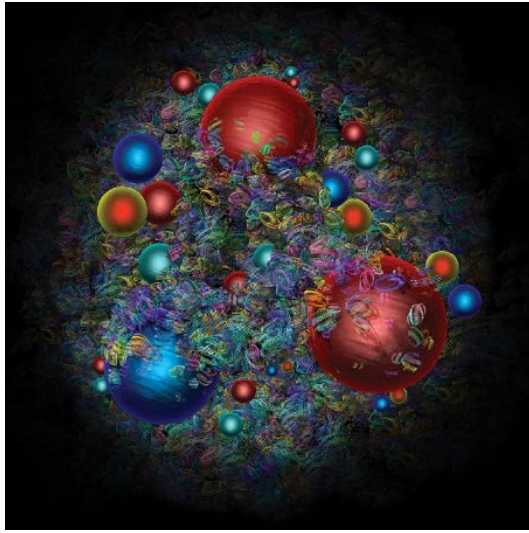


# L8. Advanced instrumentation and computing for societal challenges

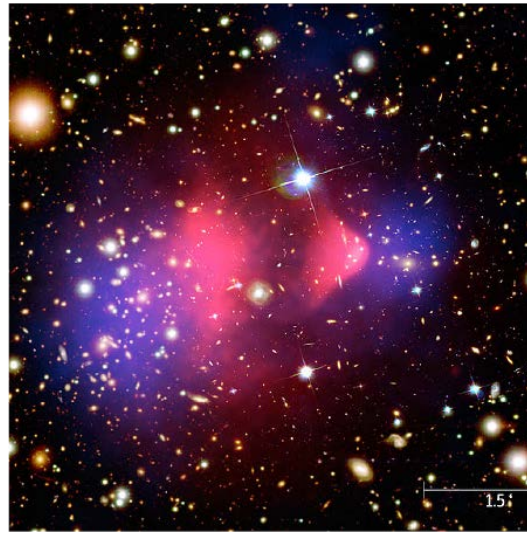
- Medical applications:
  - Positron Emission Tomography (PET), Liquid Xenon PET (**PETALO**)
  - Hadron therapy: monitoring and C6+ injector
  - Molecular & ultrasound imaging for guiding cancer biopsies in real-time (**MAGAS**)
  - Gamma & neutron imaging
  - AI applied to medical image reconstruction:
    - Simulations for risk reduction in brachytherapy
- (Real time) radioactivity monitoring:
  - In water (**TRITIUM**)
  - Gamma imaging for nuclear waste classification (**GUALI**):
  - Radiotracers for the study of marine ecosystems (**REMO**)
- **Space Weather**: AI-based early warning system for solar storms



# Summary



**Origin of mass:**  
understanding the  
fundamental laws of  
physics



**Origin of matter:**  
understanding the  
Universe



**Advanced  
instrumentation  
and computing:**  
from fundamental  
physics to society

# Summary

- **Theoretical research** includes: particle physics phenomenology in the Standard Model and beyond (including collider, flavor, Higgs and neutrino physics), astroparticle physics, cosmology, gravitation and black holes, QCD and strong interactions, hadron and nuclear physics.

# Summary

## ■ Experiments:



Enjoy!