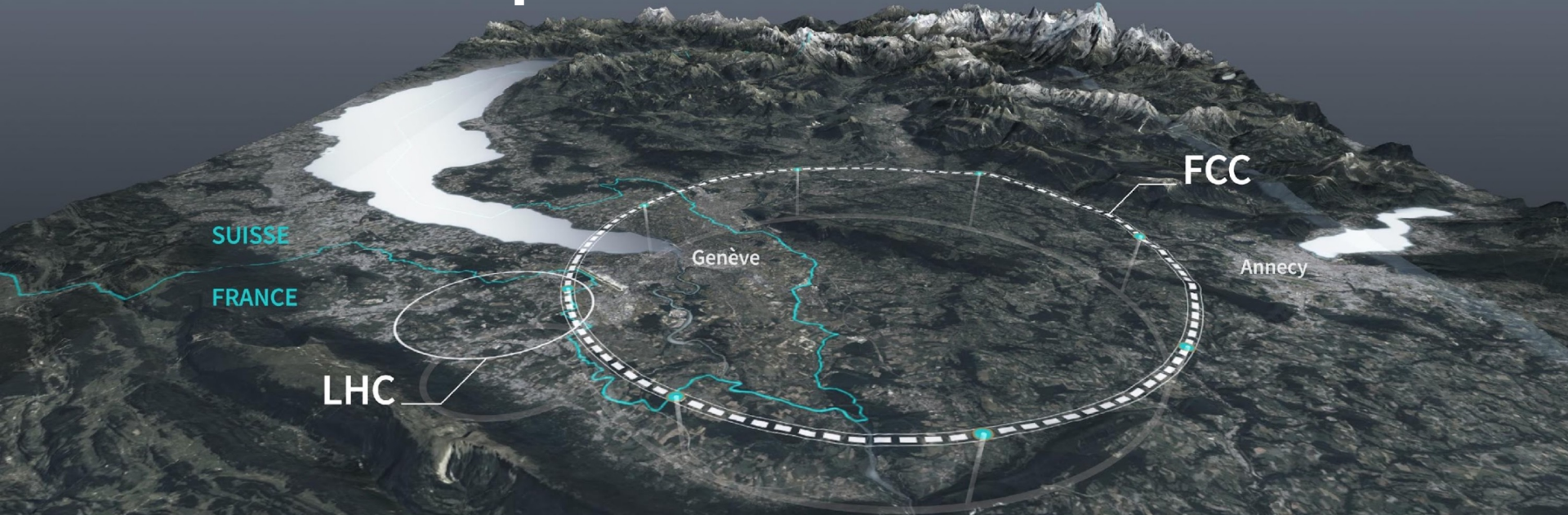


# FCC Group – Future Circular Collider



LIP Advisory Board Meeting  
27 April 2026  
Ricardo Gonalo – UC / LIP

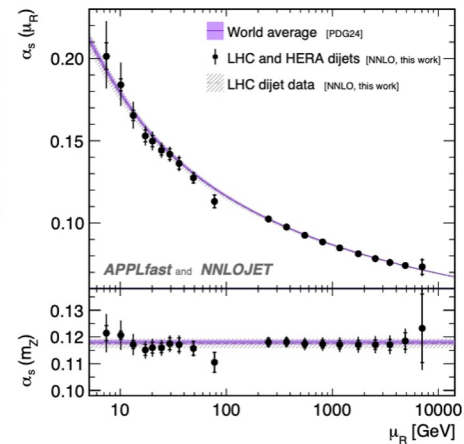
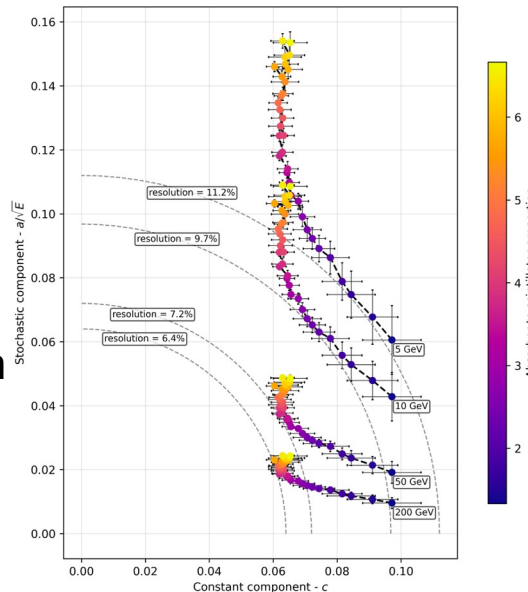
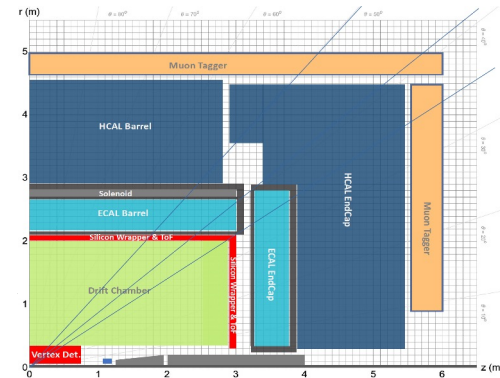


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# FCC Group – Activities

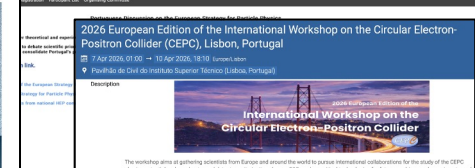
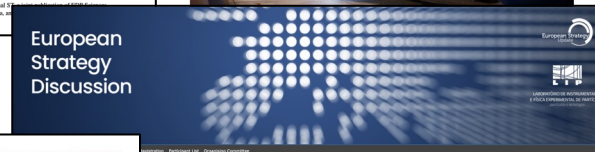
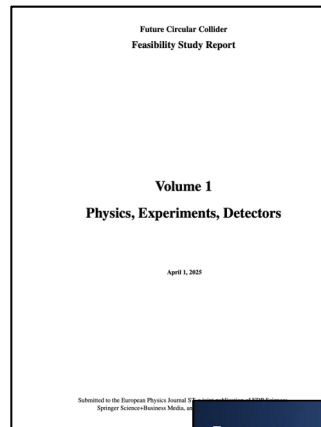
- Rad-hard scintillator development
  - Based on PEN and PET
- Allegro detector concept for FCC-ee
  - High Granularity HCAL / Iron Yoke:
    - Scintillator + Iron
    - SiPMs directly on Scintillator
  - Hadronic calorimeter simulation
  - Design optimisation - absorber / scintillation proportion
- Several physics feasibility studies on future accelerator scenarios:
  - FCC, muon collider, ILC, e-p ...





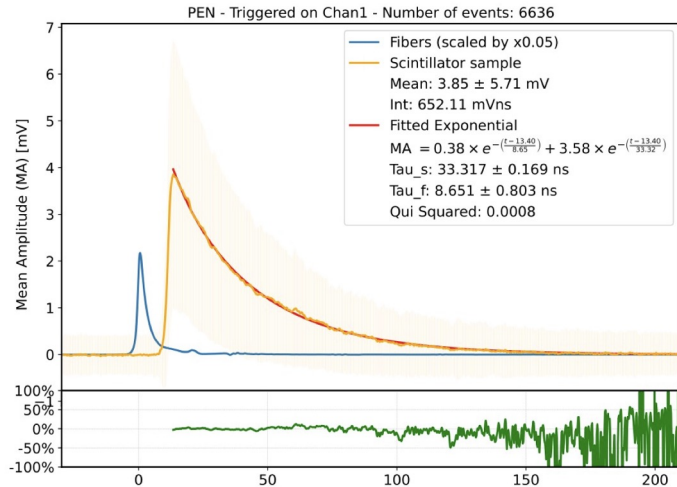
# The Past Year in the FCC Group

- FCC Feasibility Study – Final Report
  - LIP contributed to FCC feasibility study
  - <https://cds.cern.ch/record/2928193> 31 Mar 2025
  - Initial objective of the group achieved!
- Organized Portuguese input to update of European Strategy for Particle Physics
  - Well-attended session on 20 Jan 2025
- International CEPC Workshop in Lisbon 7 April 2026
  - Co-organized by group members
  - <https://indico.cern.ch/event/1598929/timetable/?view=standard>
- Participating in ECFA Detector R&D roadmap
  - DRD6: Calorimetry -

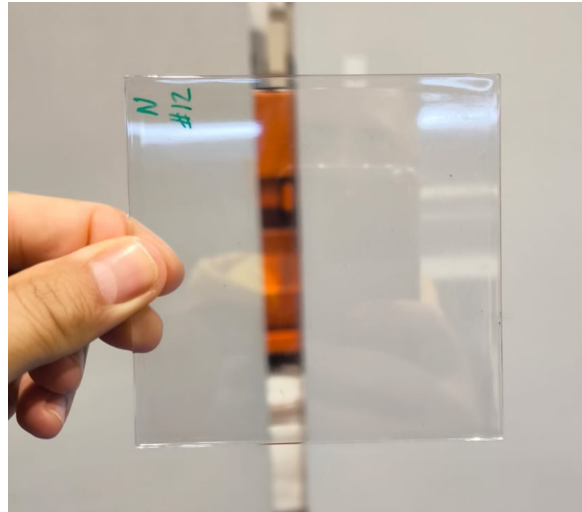


# Pastic scintillator materials R&D

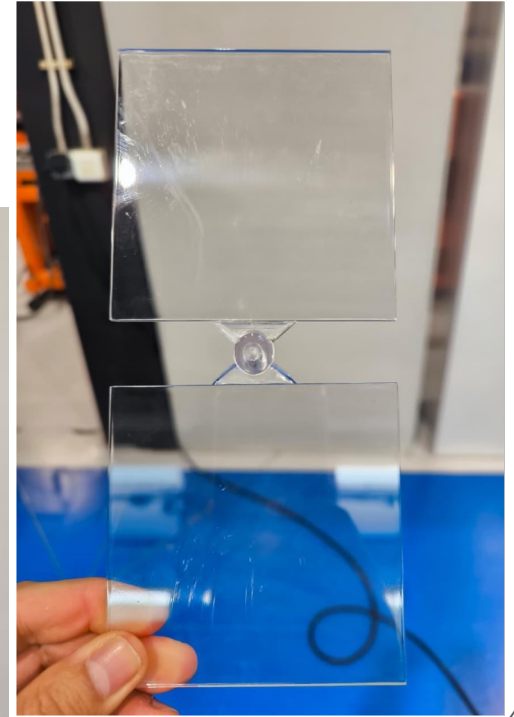
- Successful production of 100x100x3 mm<sup>3</sup> plates based on PET and PEN
- NEW: timing characterisation
- Collaboration with IPC/UMinho



PEN

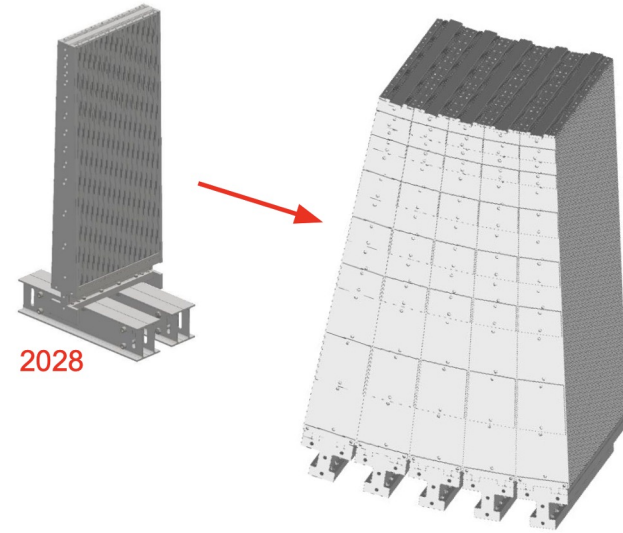
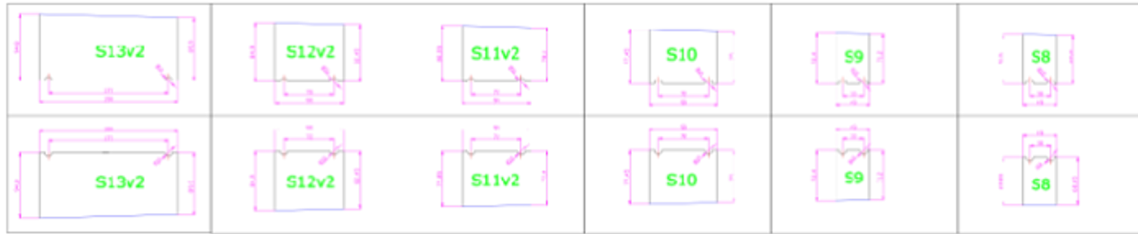


PET

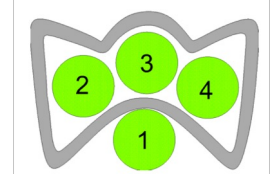


# Preparing for HCal/ALLEGRO prototype

- Leadership of tile-based HCal proposal for ALLEGRO/FCCee
- Current production compatible with prototype geometries



- Responsible for scintillator light readout with WLS fibres (profiles from TileCal production)



# CP-violation in HWW interactions at future colliders

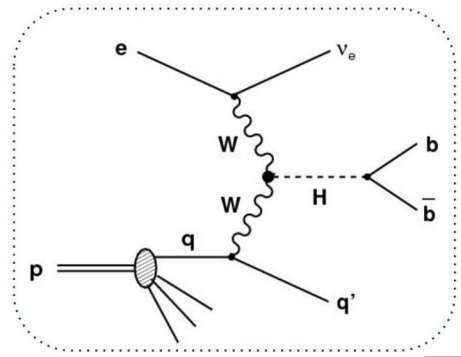
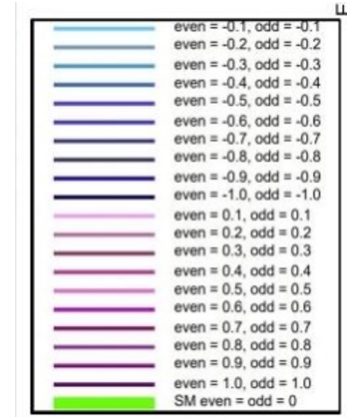
How well can different Future Collider options search/measure CP-violation effects in HWW interactions?

- Difficult measurement in  $e^+e^-$  collisions (FCC, ILC)
  - ▶ ZH production dominates
  - ▶ VBF sensitive variable: angle between the two neutrinos

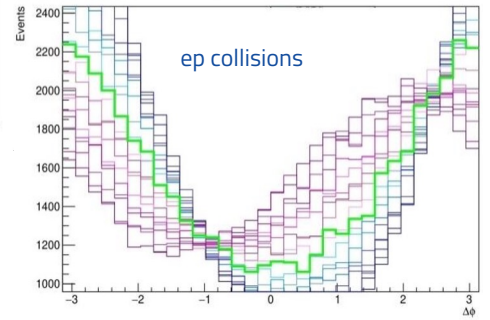
Easier in ep collisions (LHeC)

Initiated studies to compare sensitivity in different machines

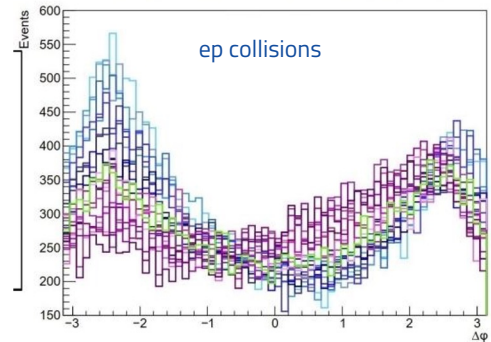
- Using MadGraph+Pythia+DELPHES
- Signal/background separation
- $e^+e^-$  collisions:
  - ▶ Studying ML (Neural Posterior Estimator) to combine all kinematic variables of the event
- ep collisions:
  - ▶ Signal/background separation
  - ▶ VBF jet tagger
  - ▶ Reconstruct angular observable ( $\Delta\phi_{\nu\text{-jet}}$ )



At parton level  
 $\Delta\phi$ : Neutrino-Quark



After event reconstruction  
 $\Delta\phi(\text{MET, VBF})$ , after Event Reconstruction (CHW)



Possible CP-even:  $c_{HW} h^\dagger h W_{\mu\nu}^I W^{I\mu\nu}$   
 CP-odd couplings:  $c_{HW} - h^\dagger h W_{\mu\nu}^I W^{I\mu\nu}$

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_{d>4} \sum_i \frac{c_i O_i^{(d)}}{\Lambda^{(d-4)}}$$

# FCC Group – Training and Outputs

## Ongoing theses:

- Radiation Damage of the TileCal Optics components at the High Luminosity LHC phase (R. Machado, PhD)
- Radiation Damage of Optical Components in Scintillator Detectors: from the ATLAS/LHC Tile Calorimeter to Future Experiments (B. Pereira, PhD)
- Future collider calorimeter optimisation with machine learning (B. Rodrigues, MSc)

## Concluded MSc theses:

- W reconstruction for TGC at the ILC (A.Silva, 2024)
- 3-jet cross section for  $\alpha_s$  measurement of  $\alpha_s$  (J.Reis, 2024)
- $e^+e^- \rightarrow e^+e^-H$  Higgs production (F.Casalinho, 2023)

## Conference proceedings and articles:

- Joao Pires, "Precision determination of  $\alpha_s$  from Dijet Cross Sections in the Multi-TeV Range", Proceedings of the 59th Rencontres de Moriond on QCD and High Energy Interactions (Moriond QCD 2025)
- Bruno Rodrigues, Inês Ochoa, Agostinho Gomes: "Design optimization of hadronic calorimeters for future colliders", PoS MODE2025 (2025) 015
- Christina Agapopoulou , I. Ochoa et al. (25 authors): "The critical importance of software for HEP", Eur. Phys. J. C 85 (2025) 1142

# The future...

- Lines of Work and Objectives for Next Year
  - Scintillator R&D: focus on the characterisation of scintillator plates, including in beam tests at CERN
  - Hadronic calorimeter simulation: study the performance for the FCC
  - Physics: finish comparison of sensitivity to BSM spin/CP HWW components in FCC, ILC and LHeC
  - Extend FCC-ee calorimeter simulation to machine learning workflow for automated optimization
- Looking forward to the final decision on the FCC in 2028

# Strengths, Weaknesses, Opportunities and Threats

- **Strengths:**
  - Experienced team from different LIP sites and universities – access to students
- **Weaknesses:**
  - Limited researcher time devoted to FCC – not the only interest of most people in the group
- **Opportunities:**
  - The current FCC Feasibility Study and the ECFA Detector Roadmap present opportunities for work leading to a long-term, unique facility
  - Good opportunity for student training
  - Technological studies have wide applicability
- This group provides interesting opportunities for undergraduate and master students to participate in the initial stages of the study, planning, and design of future world-level experimental facilities, where they may come to develop their careers in particle physics.
- **Threats:**
  - Shortness of dedicated research time

**Team:** Ricardo Gonalo, Agostinho Gomes, Filipe Veloso, Grigorios Chachamis, Guilherme Milhano, Inês Ochoa, Joo Nuno Pires, Liliana Apolinrio, Michele Gallinaro, Patricia Conde, Rute Pedro, Lus Gurrana; students: Beatriz Pinheiro Pereira, Rudnei Machado, Bruno Rodrigues, Carolina Miranda

# Bonus slides



**LIP**  
**LET'S INSPIRE PEOPLE**

# Status of the FCC Global Collaboration

Increasing international collaboration is a prerequisite for success:

→ links with science, research & development and **high-tech industry** will be essential to further advance and prepare the implementation of the FCC

→ Next step is preparation of a plan with national laboratories for in-kind contributions to the project

## 39 Participating Countries

Austria – Belgium – Brazil – Canada – Chile –  
Colombia – Czech Republic – Denmark – Estonia –  
Finland – France – Georgia – Germany – Greece –  
Hungary – India – Iran – Italy – Japan – Latvia –  
Lithuania – Malta – Mexico – Netherlands – Norway –  
Pakistan – Poland – Portugal – Republic of Korea –  
Romania – Serbia – Spain – Sweden – Switzerland –  
Thailand – Türkiye – Ukraine – United Kingdom –  
United States of America

180  
Institutes

39  
Countries  
+  
CERN

