



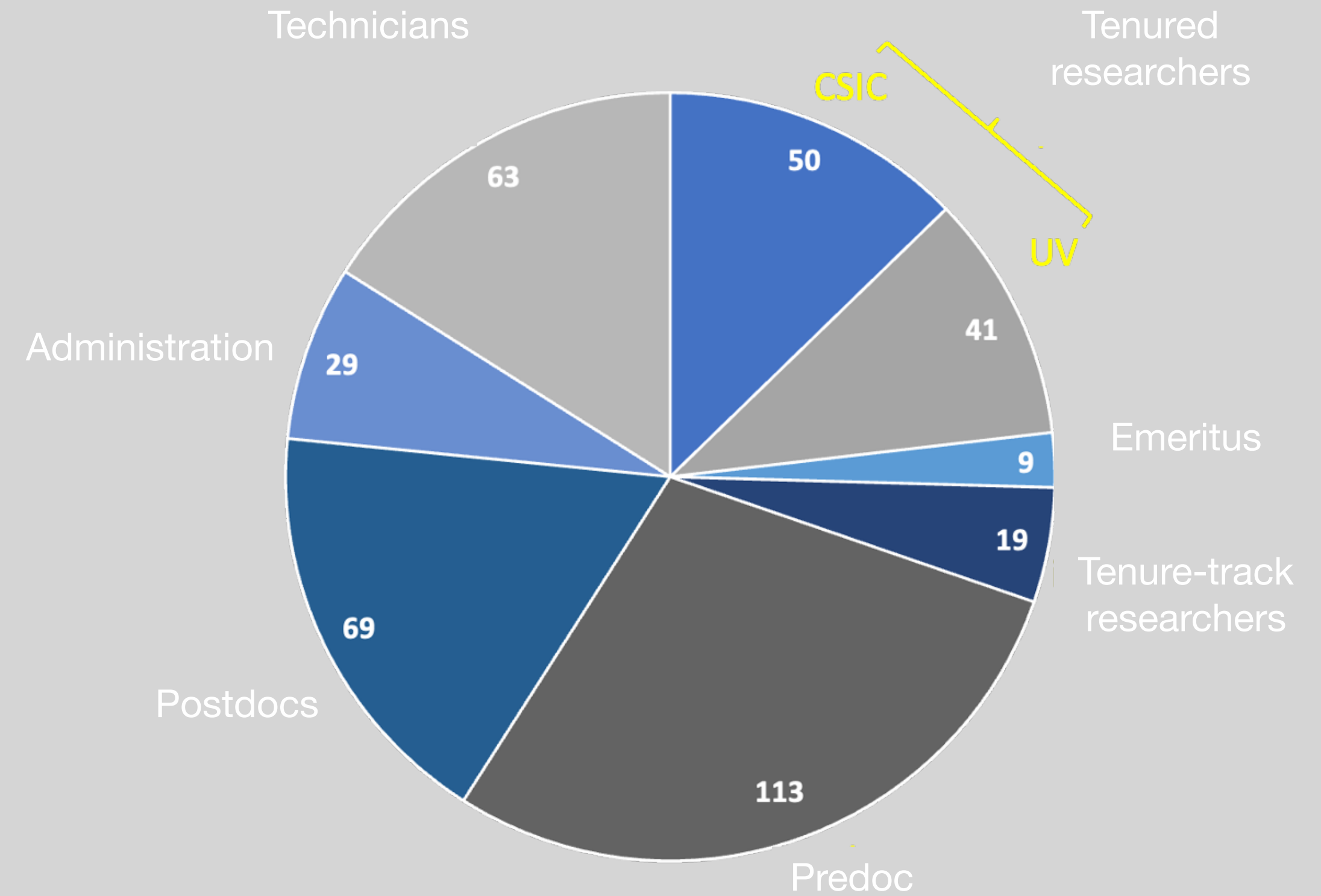
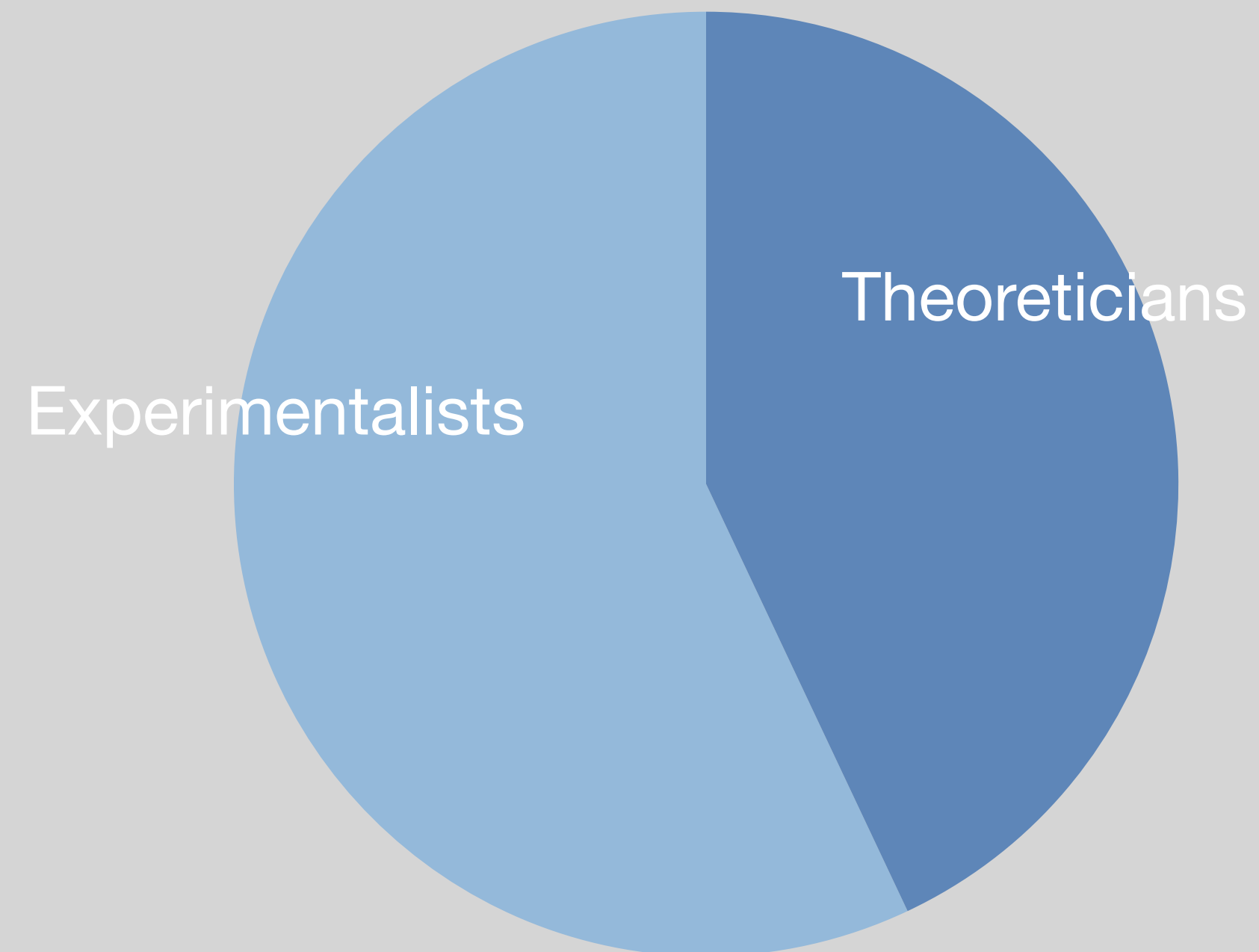
VNIVERSITAT
DE VALÈNCIA



L. Fiorini, R. Gozzini, A. Irlés, J. López-Pavón, C. Mariñas, J. Martín-Albo, V. Mitsou, L. Molina-Bueno, A. Oyanguren, E. Torró

The Institute

393 members



Support units:

- Electronic and microelectronic laboratories
- Mechanical workshop
- Computing infrastructure



The Institute

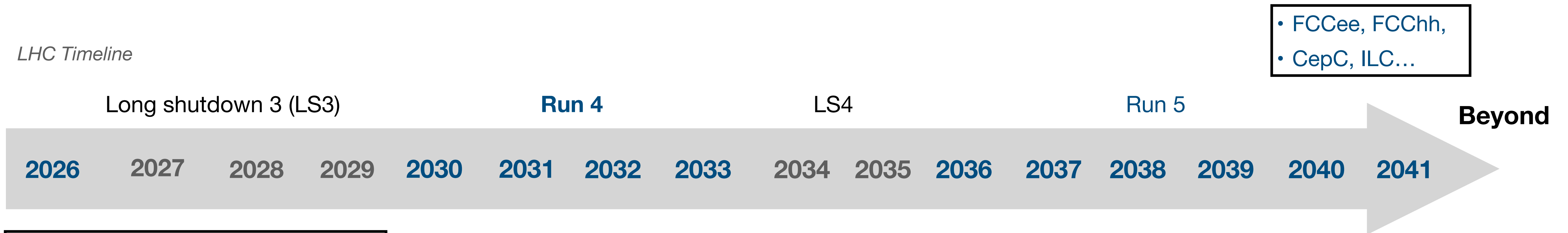


FIPs/LLPs @IFIC

[More details about the experimental context and timeline in C. Antel, *et al.* Eur. Phys. J. C 83 (2023) no.12, 1122]

- Broad community at IFIC involved in many projects from the theory and experimental perspectives.
- Participation in several FIPs/LLP searches at existing and future facilities at the intensity, cosmic and energy frontiers.

LHC Timeline



- **NA64**, NA62, FASER, DarkQuest, PADME, LUXE, MiliQan...
- SBND, Microboone, T2K, ICARUS, **COHERENT**, **DUNE/ProtoDUNE...**
- **Belle II**, **ATLAS**, CMS, **LHCb**, **MOEDAL...**

- **NA64**, **LUXE**, DarkQuest, DarkSHINE, LDMX, BDX, M3,...
- **DUNE**, HyperK, **COHERENT**, ProtoDUNE@SPS,...
- **Belle II**, **HL-LHC**,...

- SHIP, Forward Physics Facility (FASER2, FORMOSA, FLARE,...), **MATHUSLA**, Codex-B, Anubis,...
- HyperK, **DUNE**, ...
- **Belle II**, **HL-LHC**,...

Colliders

Fixed target

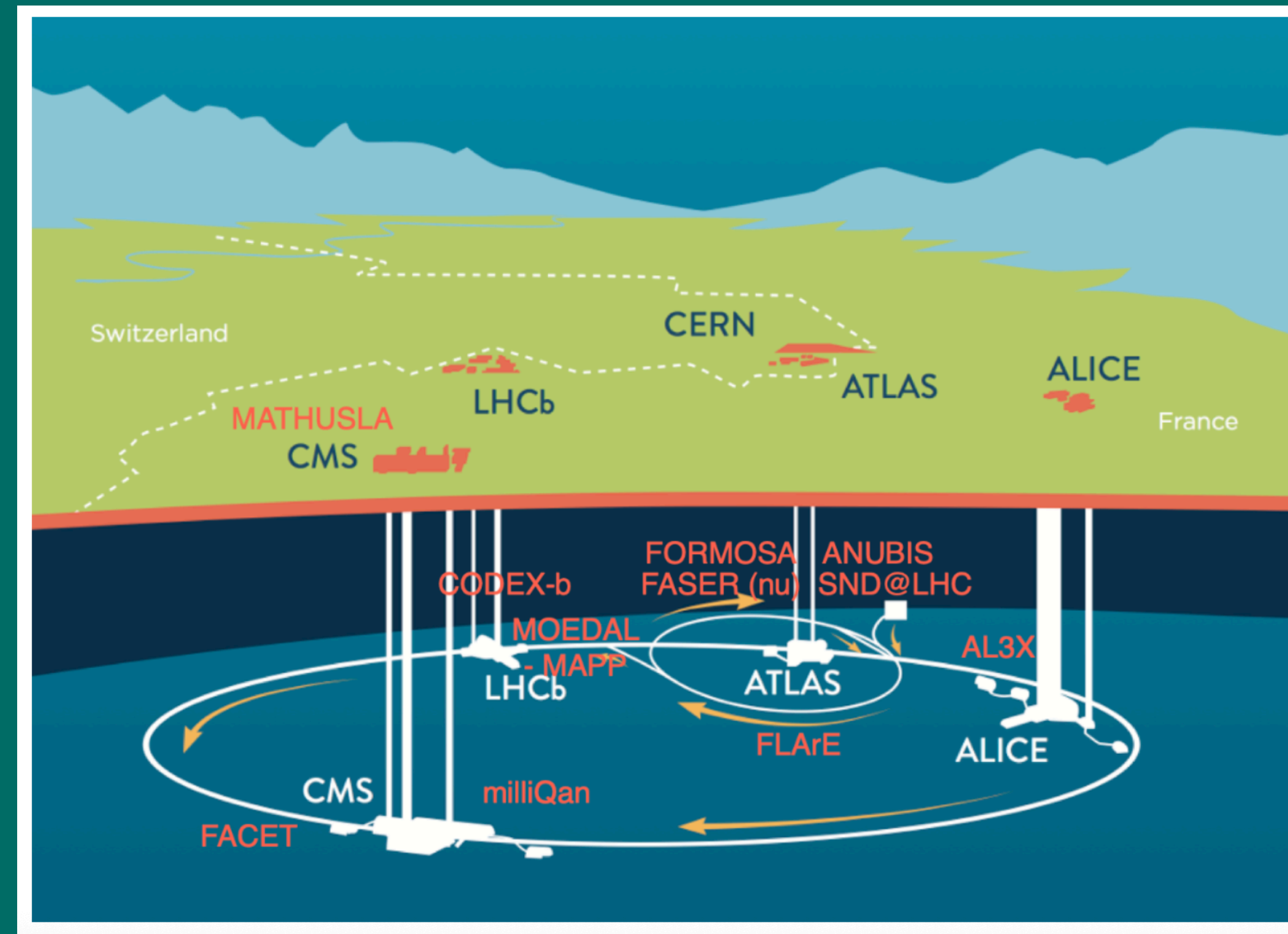
Neutrino experiments

*in bold IFIC participation

• And many more...

• Complementary to cosmic frontier and DM direct detection: **(Baby) IaXo**, CADEX, ..., LZ, PANDAX, XenonNT, ..., **Km3net**, Icecube, ...

LLPs @colliders



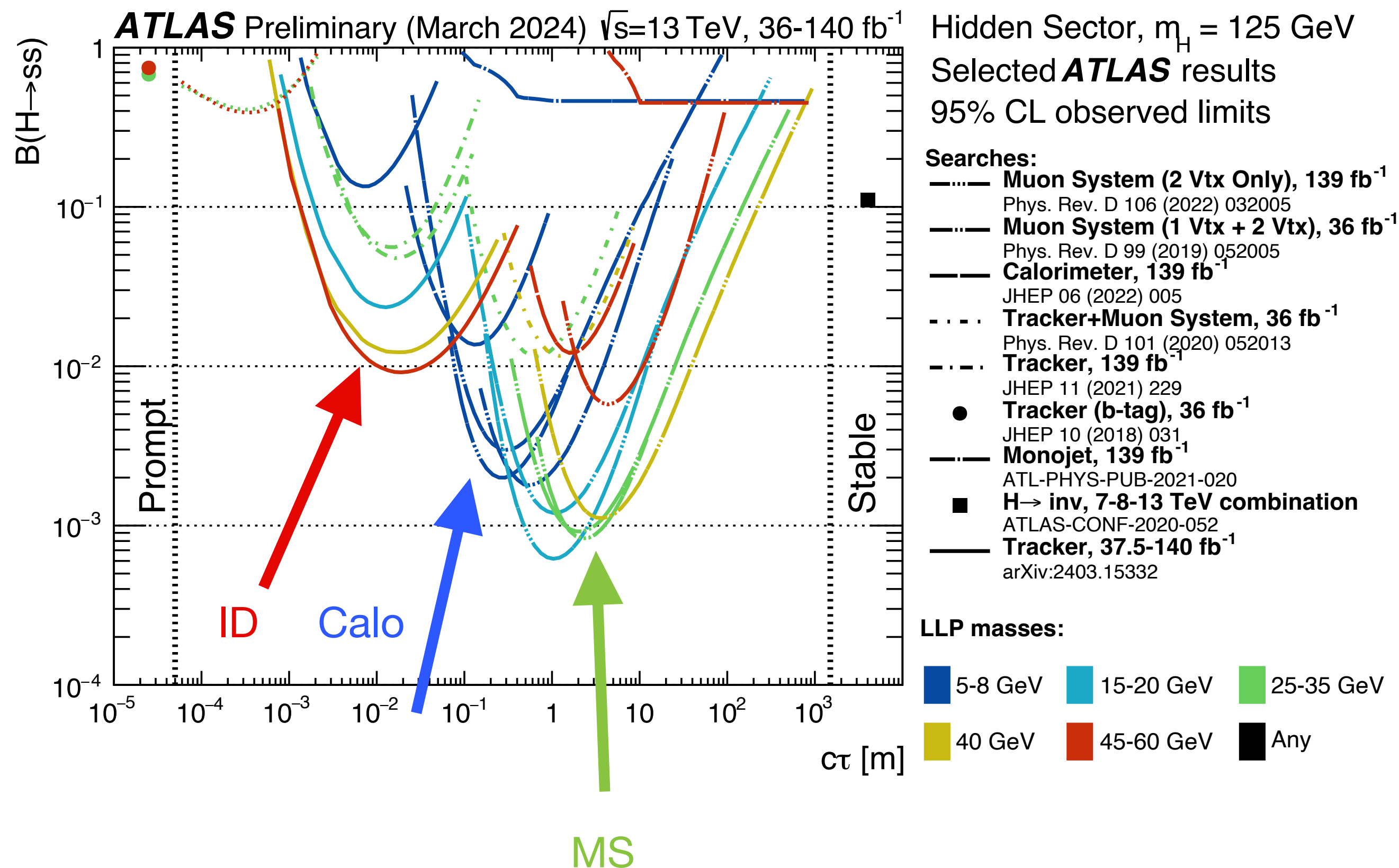
From: <https://ep-news.web.cern.ch/content/llp11-eleventh-workshop-long-lived-particle-community>

- **Searches for hadronically decaying LLPs with extensive lifetime range coverage**

- Leading searches for displaced jets in the ATLAS calorimeters (Calo) since 2015
- Great involvement in searches for displaced jets in the ATLAS Inner Detector (ID) and Muon System (MS)

- PhD thesis (2024): "SEARCHING FOR NEUTRAL LONG-LIVED PARTICLES WITH HADRONIC DECAYS IN THE ATLAS EXPERIMENT AND IDENTIFICATION OF NON-COLLISION BACKGROUNDS", V. Sanchez Sebastián

Trigger and software tools
Analysis



- Triggers and data reduction formats for LLPs
- Pioneers in the use of Machine Learning (ML) for displaced objects identification
- Reinterpretation
- Benchmark models:
 - Dark sectors
 - Long-lived ALPs (for the first time in ATLAS)
 - HNLs
 - Baryogenesis
 - R-parity violating SUSY

Present experiments

*V. Mitsou, R. Ruiz de Austri,
V. Vento, O. Vives*



AITANA

- Phenomenology, e.g. dark monopoles with suppressed decays to photons [2507.06697](#) [hep-ph]
- ML techniques on tracking
[EPJC 85 \(2025\) 460](#)
- Collaborations on LLPs with IHEP Beijing (Ostrovsky), Bonn (Dreiner)

Software tools
Analysis

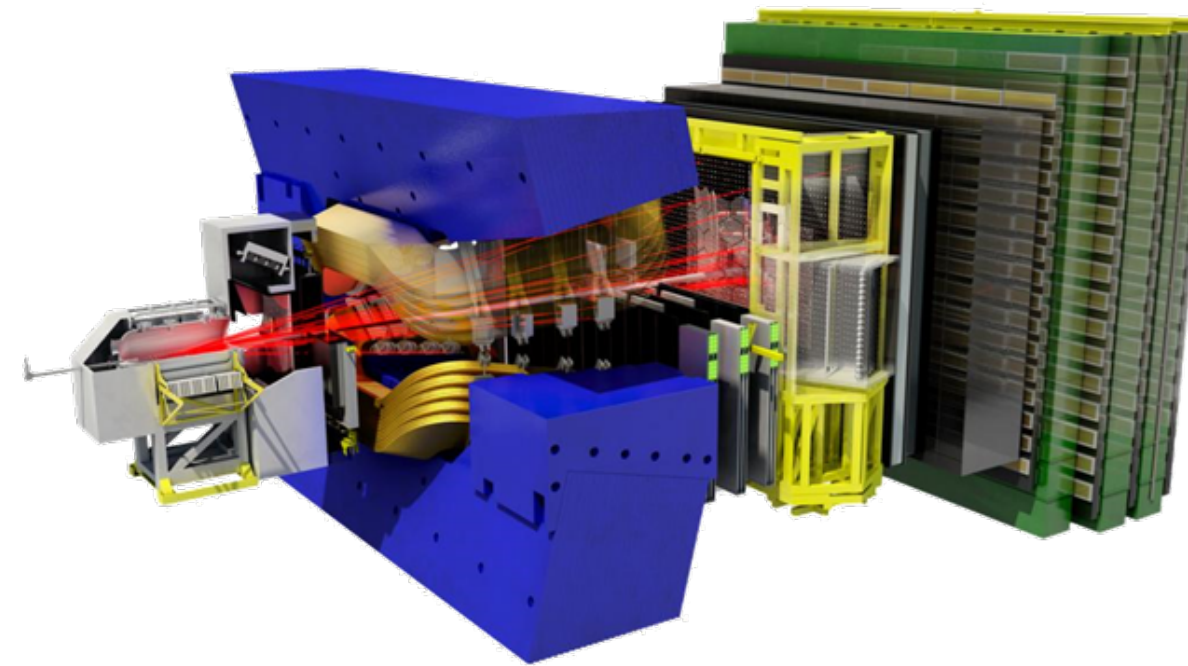
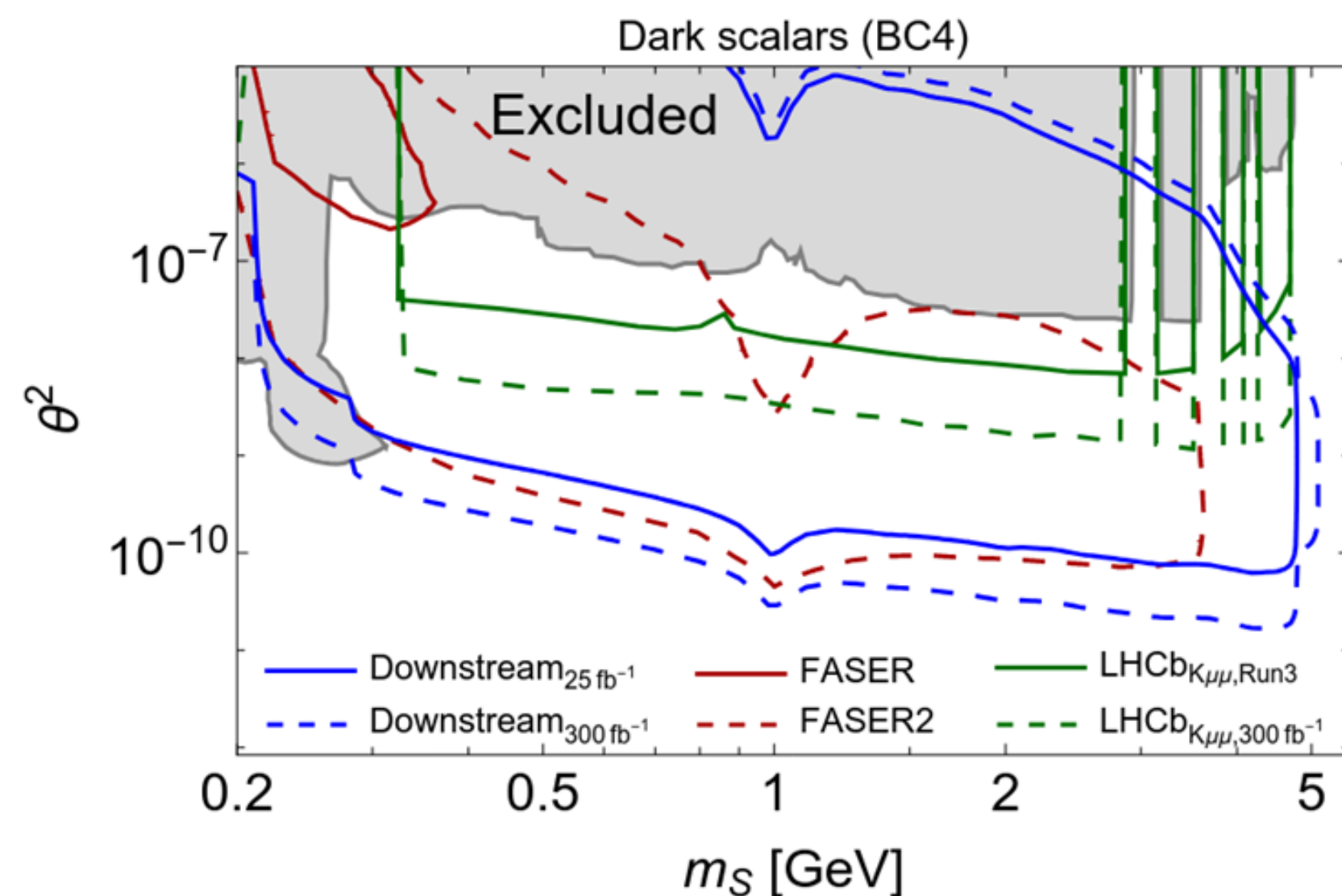
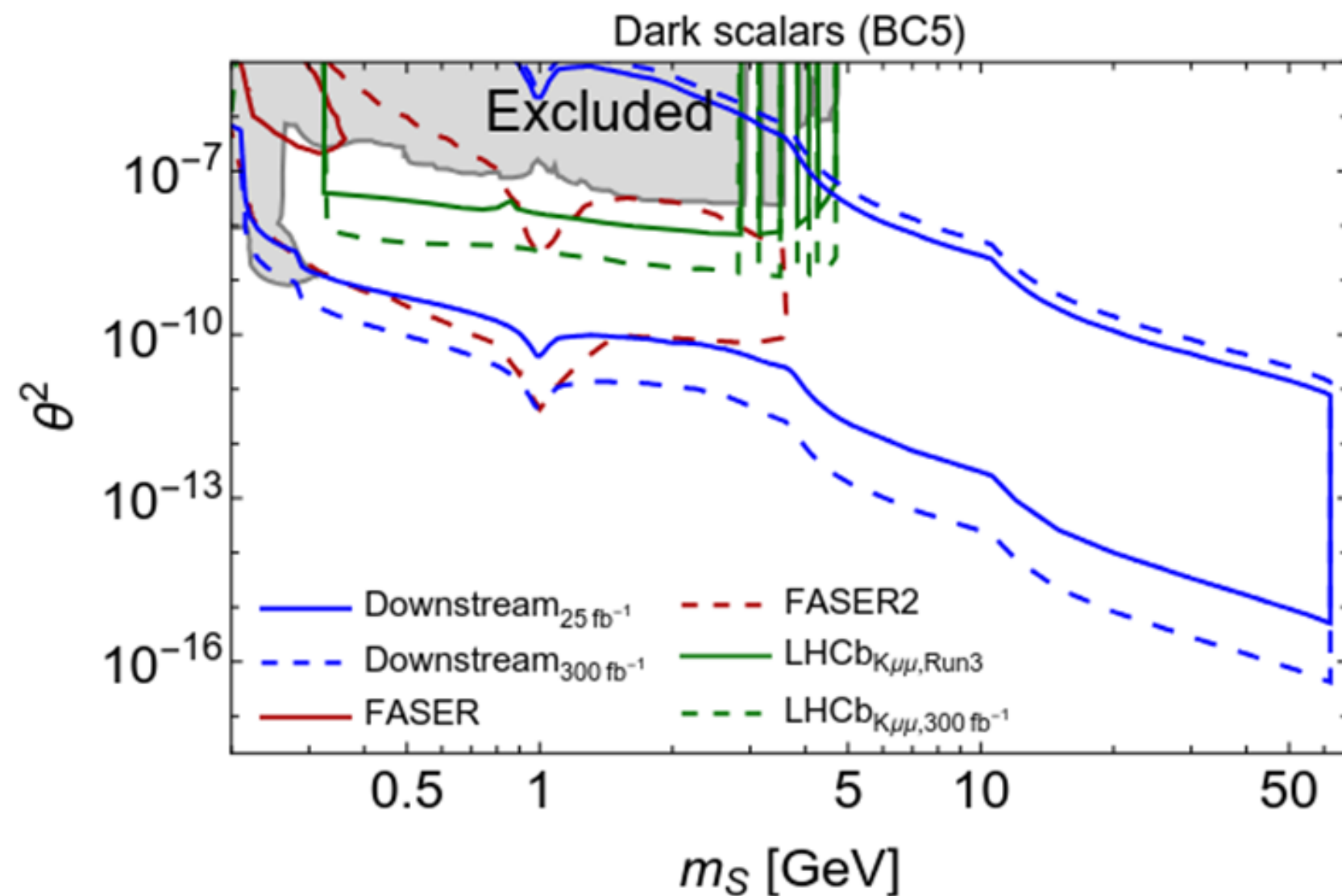
- BSM LLPs phenomenology & LHC experimental data analysis
 - LL SUSY particles
 - Dark Sectors
 - ALPs
 - Magnetic monopoles / multiply charged particles
 - Lepton flavour violation
- Machine learning in raw data
- UFO models in MadGraph

Present experiments

A. Oyanguren, J. Zhuo



Development of software-based triggers to enhance the sensitivity to LLPs (up to two orders of magnitude)



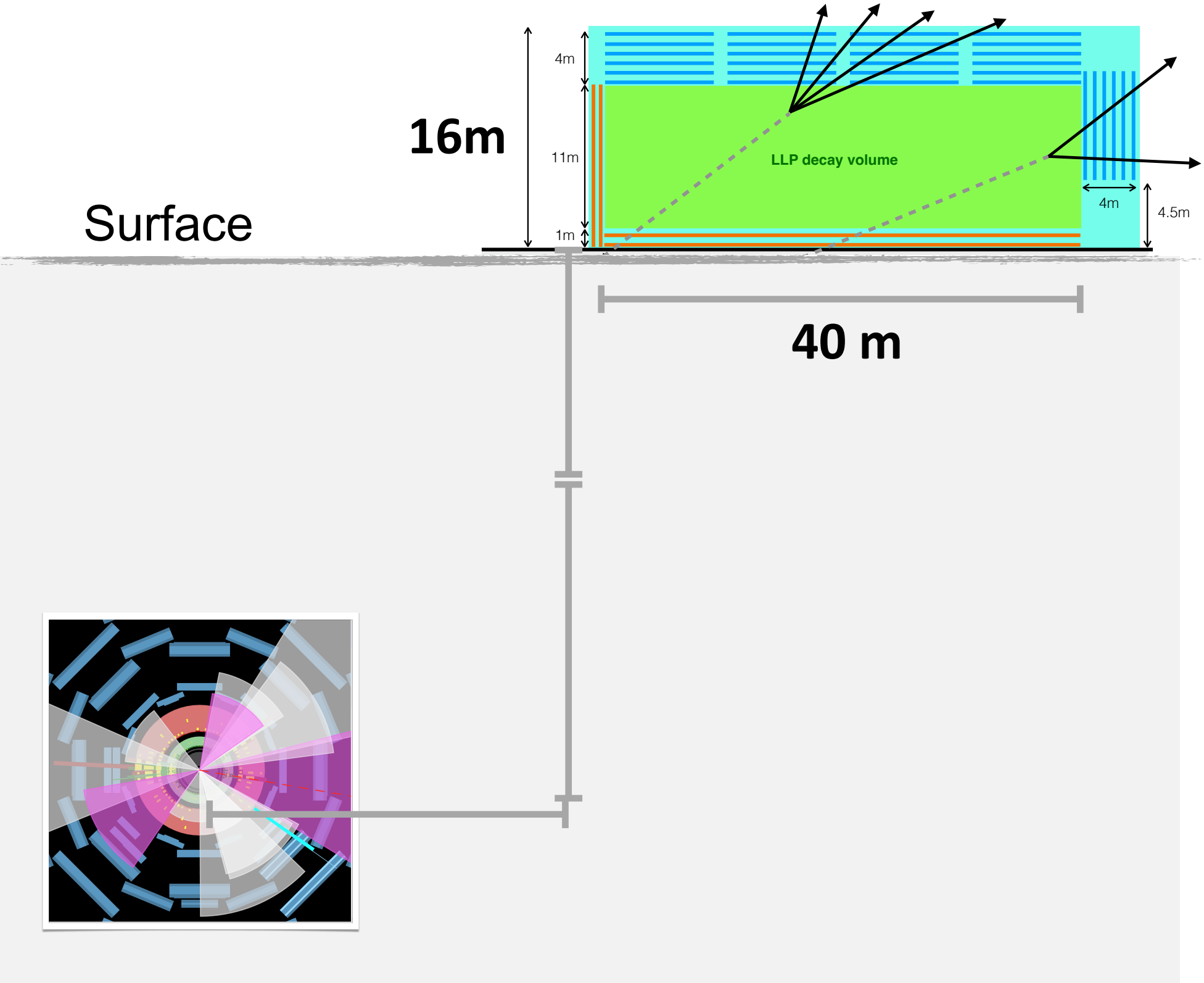
Trigger and software tools
Analysis

- Heterogeneous computing architectures (GPUs, FPGAs)
- Advanced computing techniques.
- Tracking reconstruction in real time.
- Developments of new triggers (Downstream tracks and BuSca algorithm, investigating the application on fixed target at NA64 with L. Molina-Bueno).
- Physics analysis (rare decays)
- Detector optimisation (MODE collaboration)

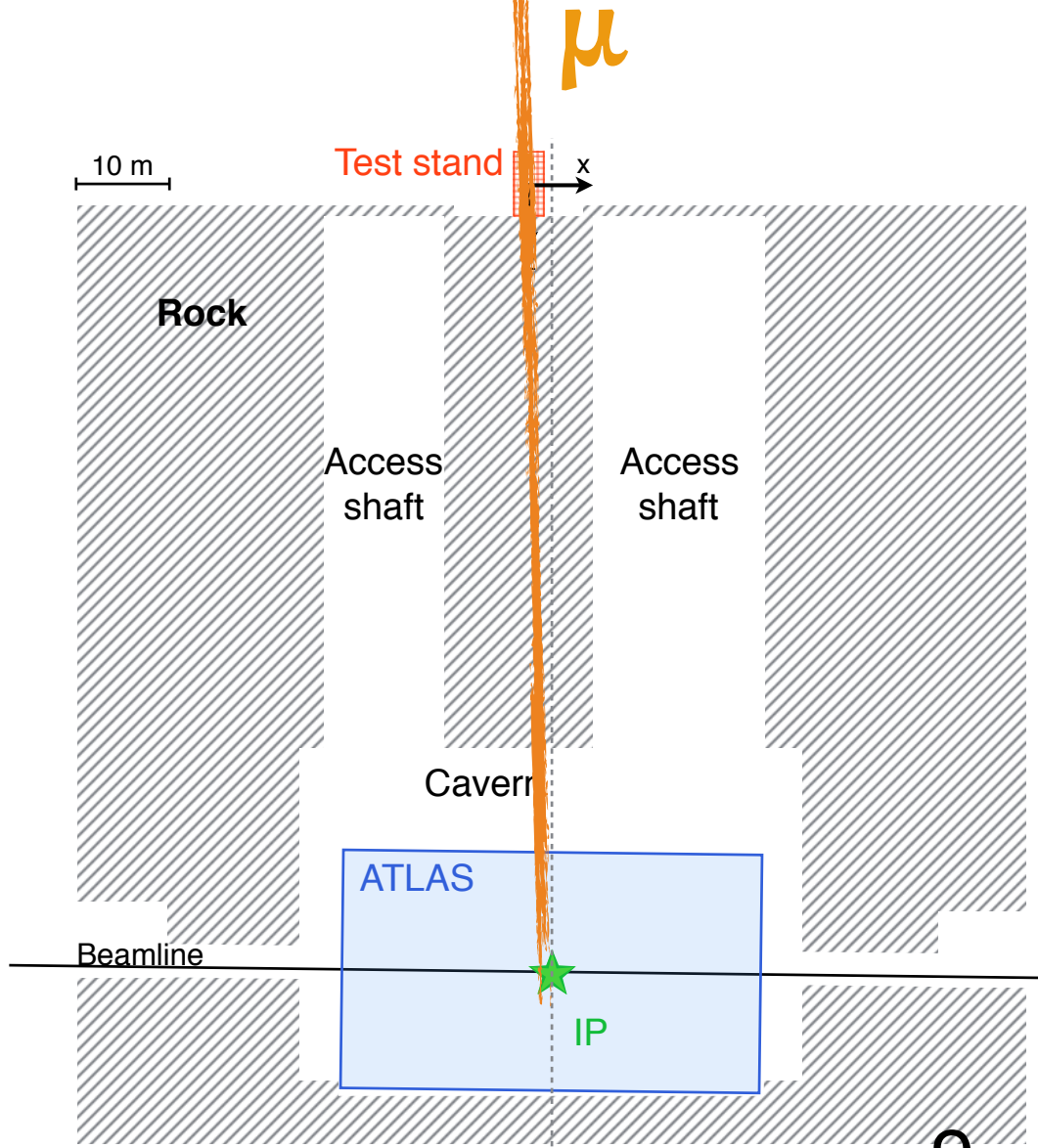
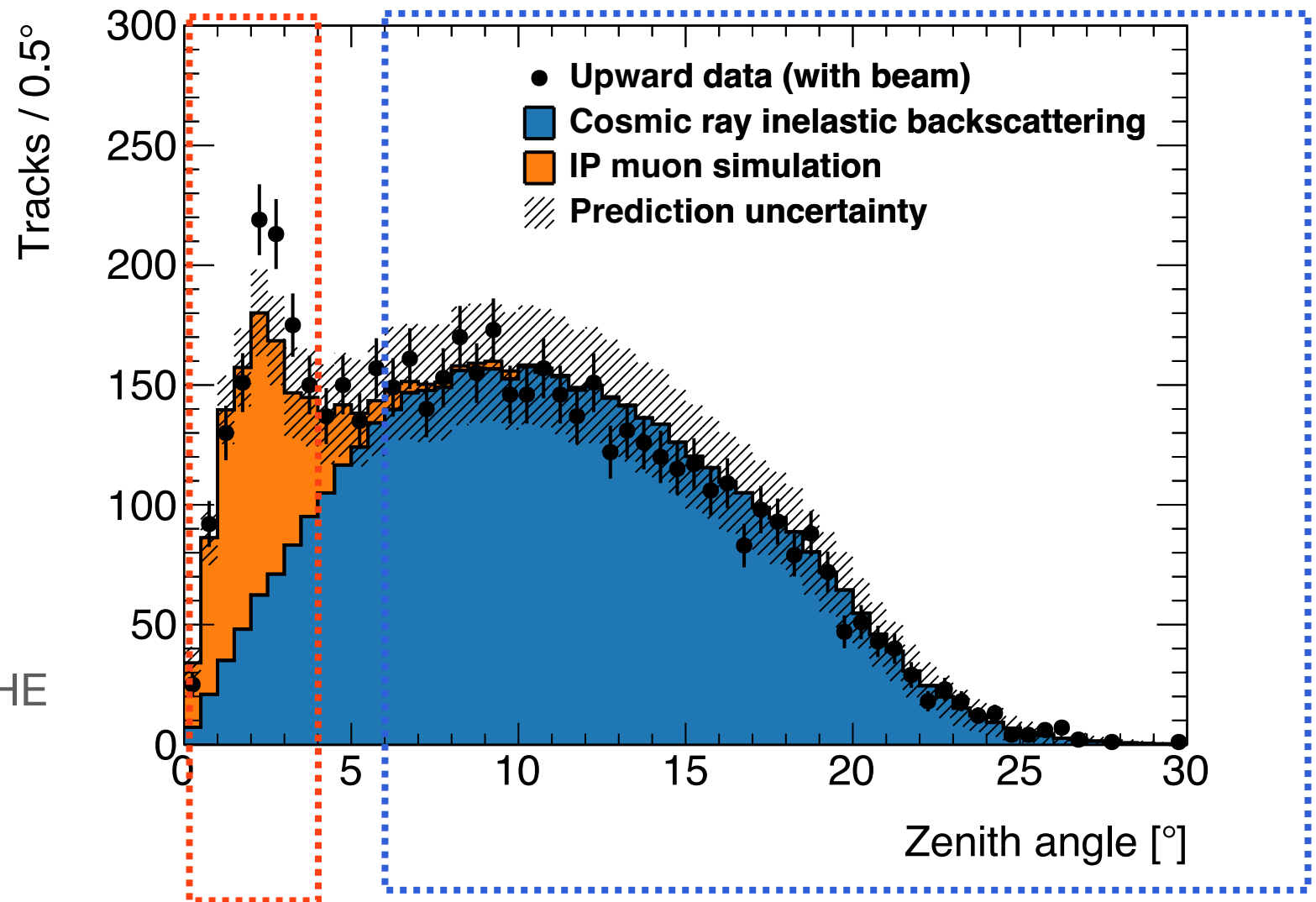
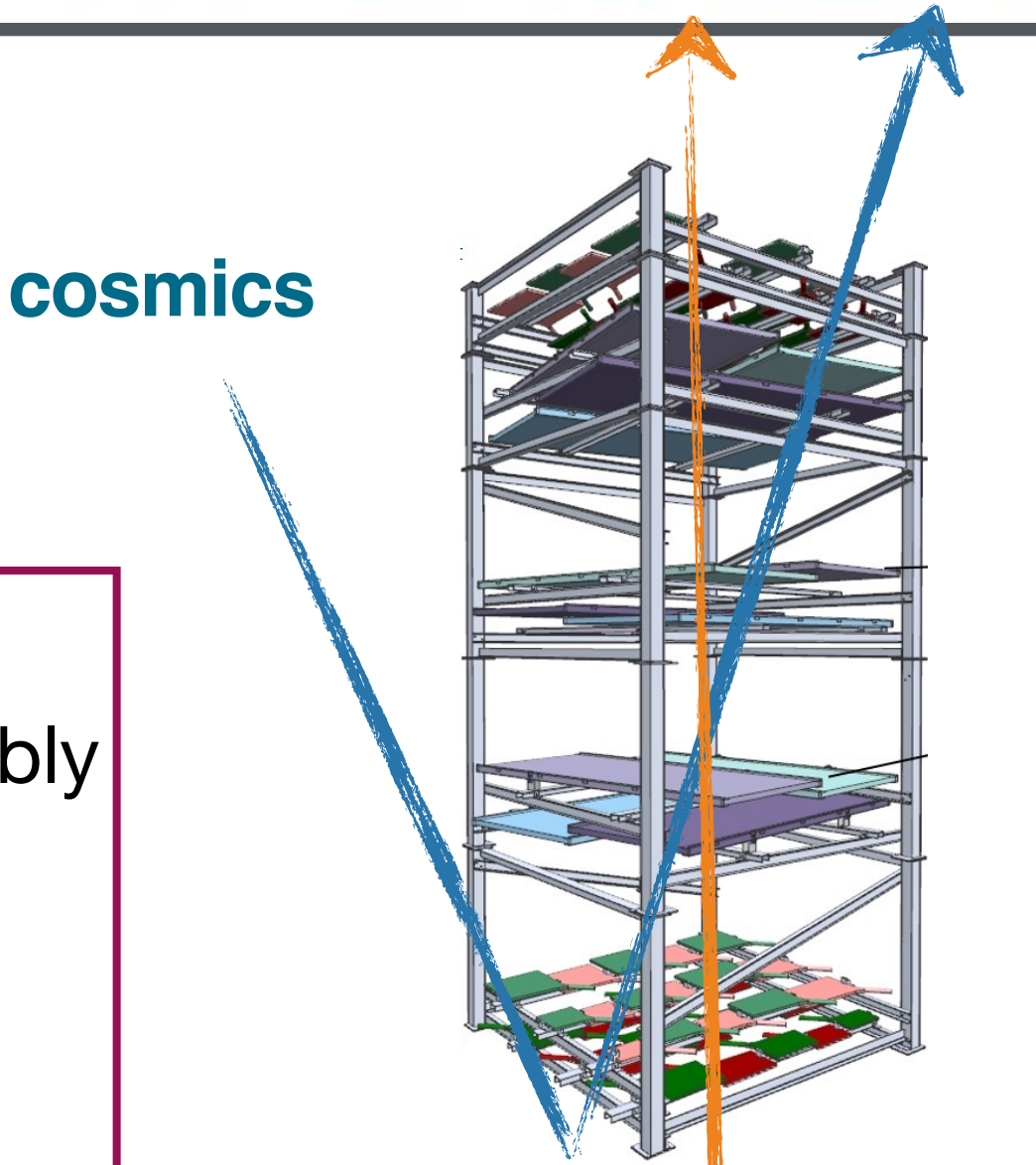
Future experiments

- Acceptance and background studies

Detector characterisation and optimisation



- MATHUSLA Test Stand
 - Detector characterisation and assembly
 - TDAQ
 - Track reconstruction
 - Data analysis

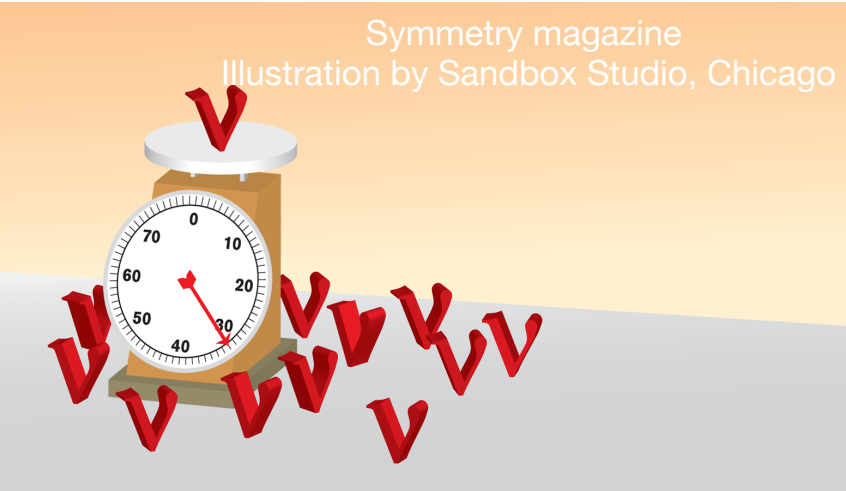


• PhD thesis (2025): SEARCH FOR NEUTRAL LONG-LIVED PARTICLES PRODUCED AT THE LHC DECAYING IN THE ATLAS CALORIMETERS IN ASSOCIATION WITH A Z BOSON FROM PROTON-PROTON COLLISIONS USING RUN 2 DATA AND THE MATHUSLA EXPERIMENT

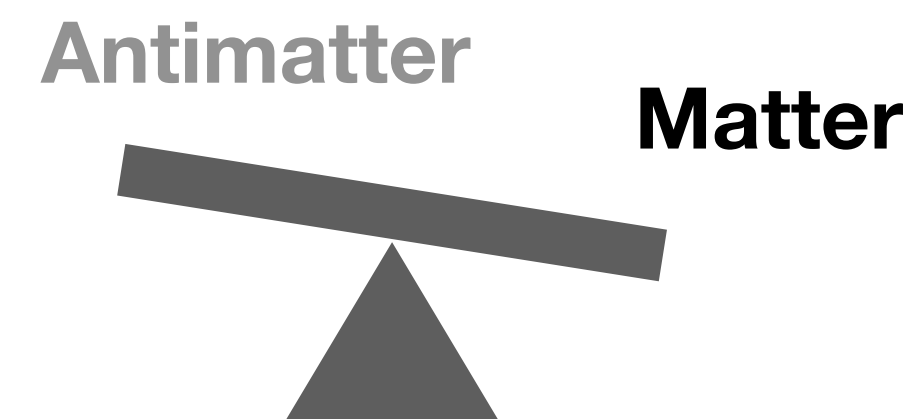
Heavy neutral leptons

Neutrino masses

- Mechanisms to generate it
- Why are so small?



Matter-antimatter asymmetry

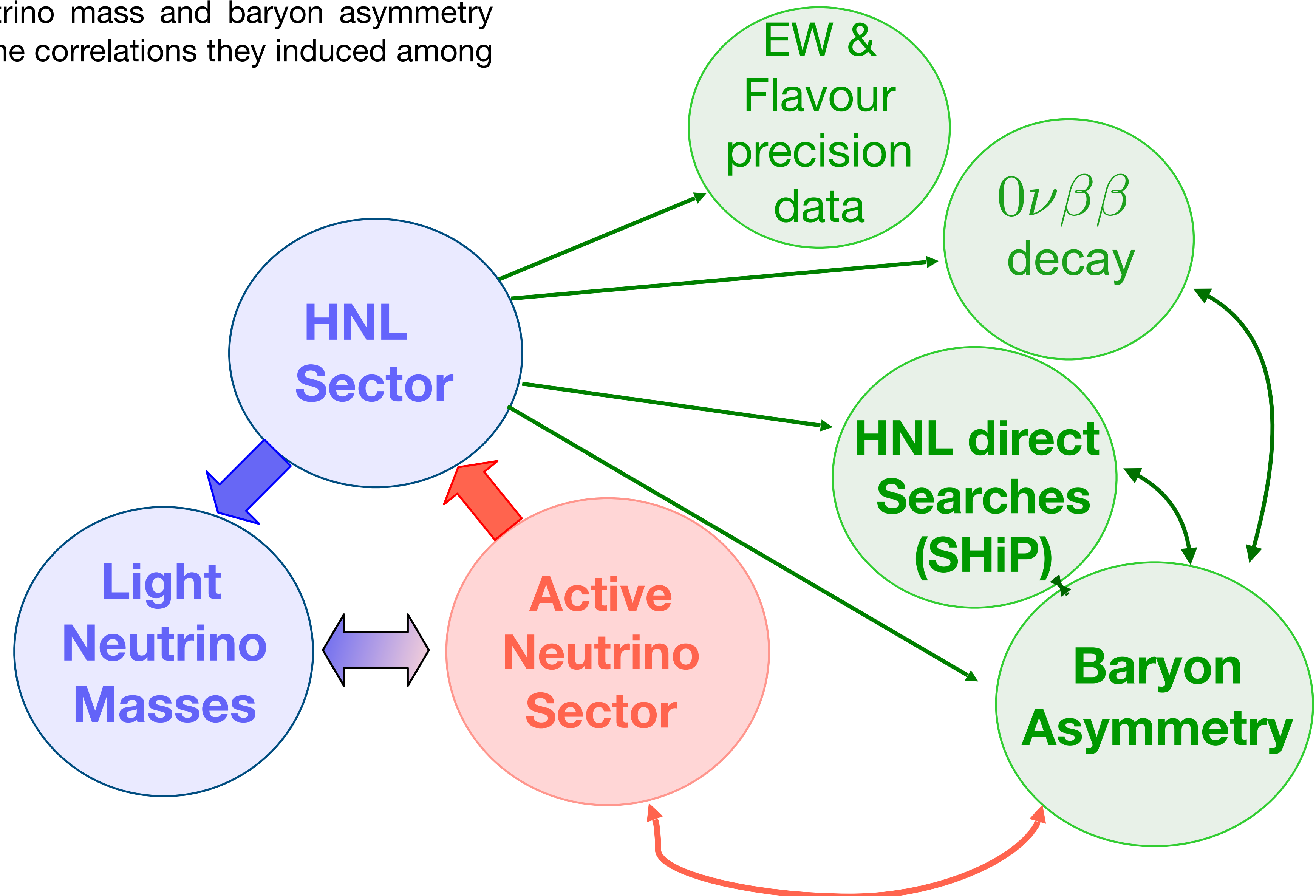


Theoretical interests

P. Hernández, J. López-Pavón,
N. Rius



- **Primary goal:** to test neutrino mass and baryon asymmetry mechanisms by analyzing the correlations they induced among different observables.

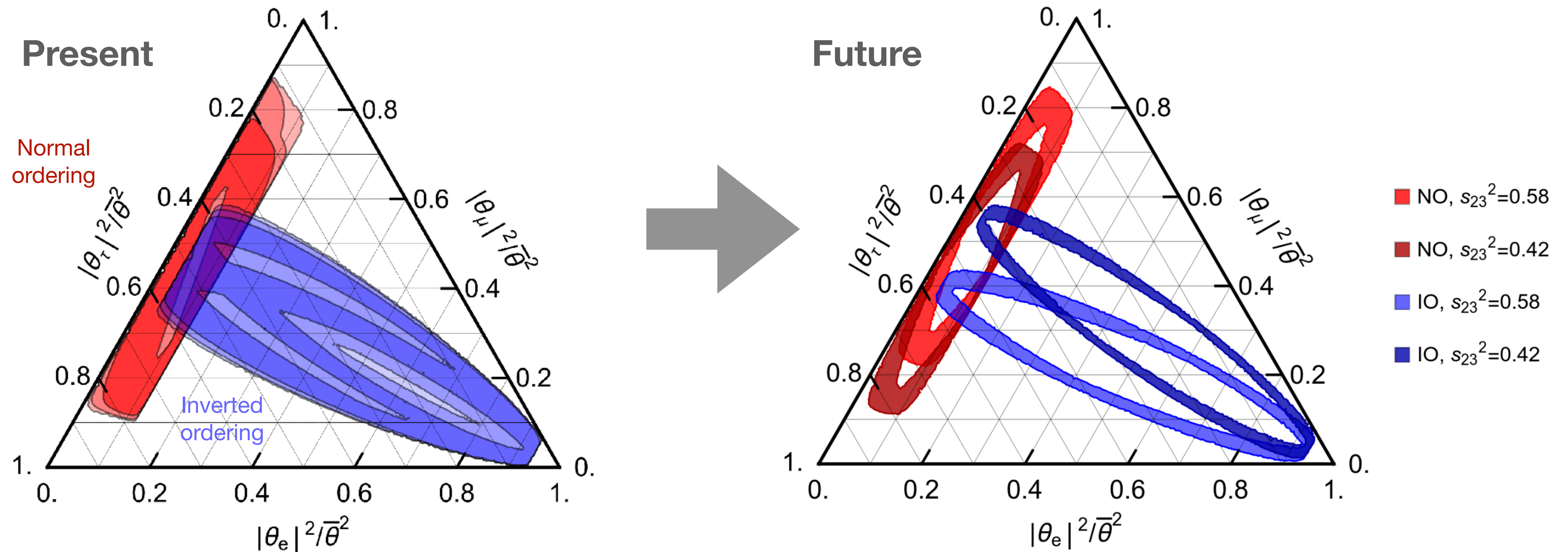


Theoretical interests

P. Hernández, J. López-Pavón,
N. Rius



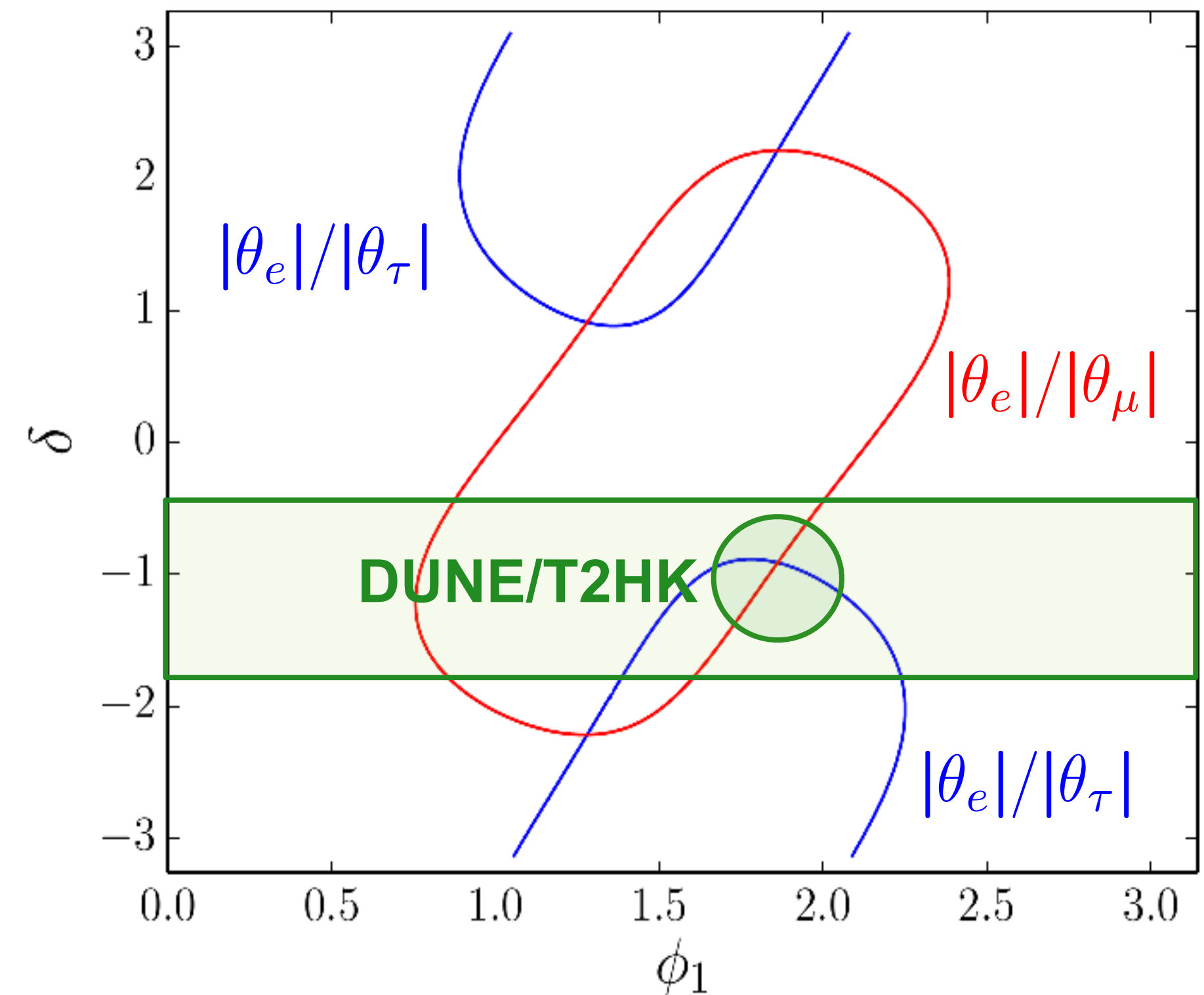
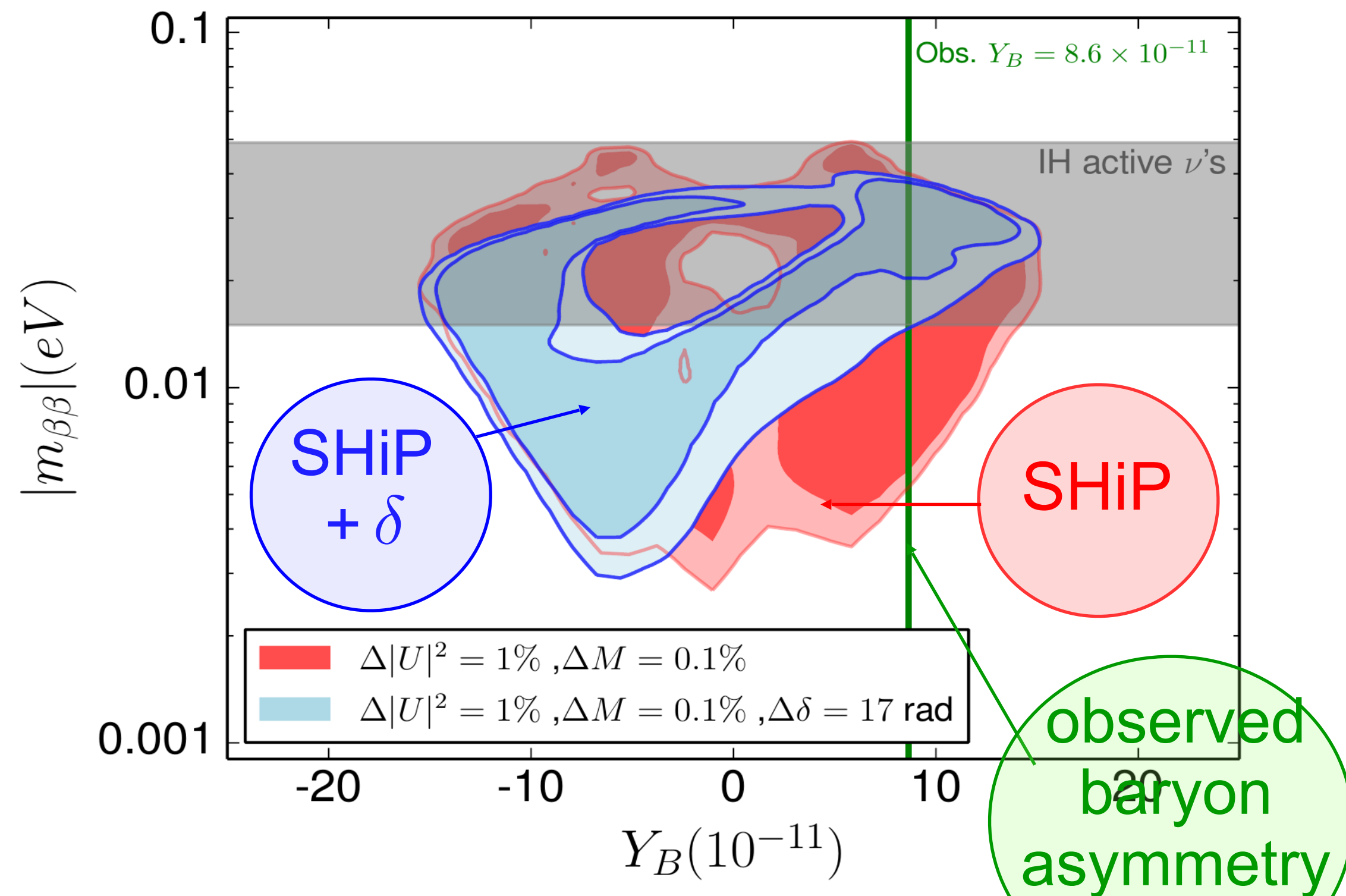
- Neutrino **mass mechanism** in minimal low scale seesaw model predict **flavour structure of HNL mixing pattern**.
- *Strong complementarity between HNL direct searches and neutrino oscillation measurements.*



Abdullahi et al 2203.08039; Drewes, Klaric, Lopez-Pavon 2207.02742; Caputo, Hernandez, Lopez-Pavon, Salvado 1704.08721

Measurement of HNL mass and mixing can:

- Combined with neutrinoless double beta decay rate and CP violation in neutrino oscillations can suffice to **pin down matter-antimatter asymmetry from lab measurements.**
- Allows an **indirect determination of CP phases** of the PMNS matrix (even Majorana phases!) in minimal seesaw models.



Hernandez, Lopez-Pavon, Rius, Sandner 2305.14427

Hernandez, Lopez-Pavon, Rius, Sandner 2207.01651

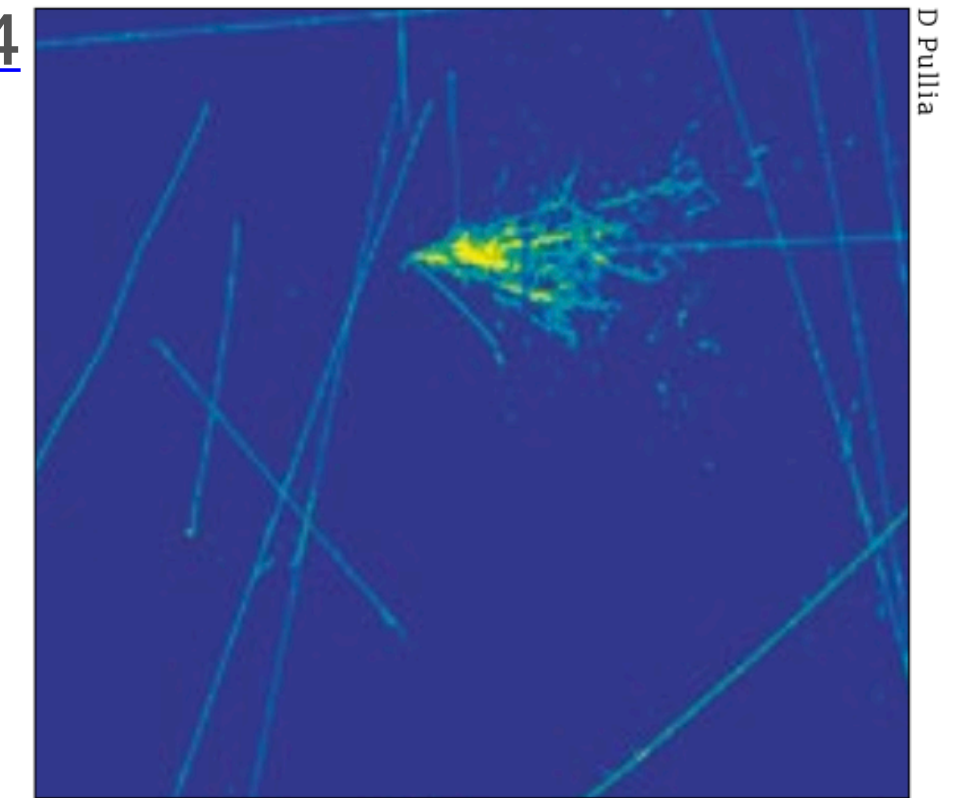
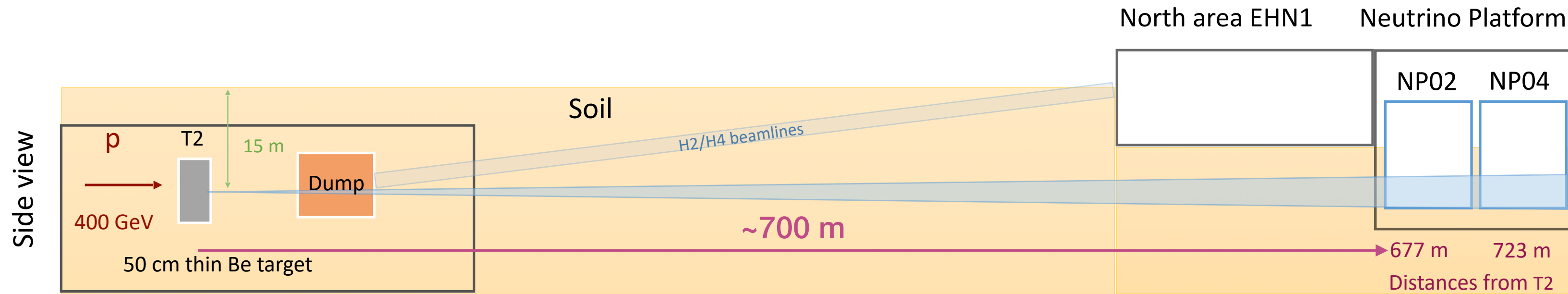
Hernandez, Kekic, Lopez-Pavon, Racker, Salvado 1606.06719

Caputo, Hernandez, Kekic, Lopez-Pavon, Salvado 1611.05000

Hernandez, Kekic, Lopez-Pavon, Racker, Salvado 1606.06719

Potential proof of principle for searches using LArTPCs

P. Coloma, J. López-Pavón, L. Molina-Bueno and S. Urrea, JHEP 01 (2024), 134 doi:10.1007/JHEP01(2024)134

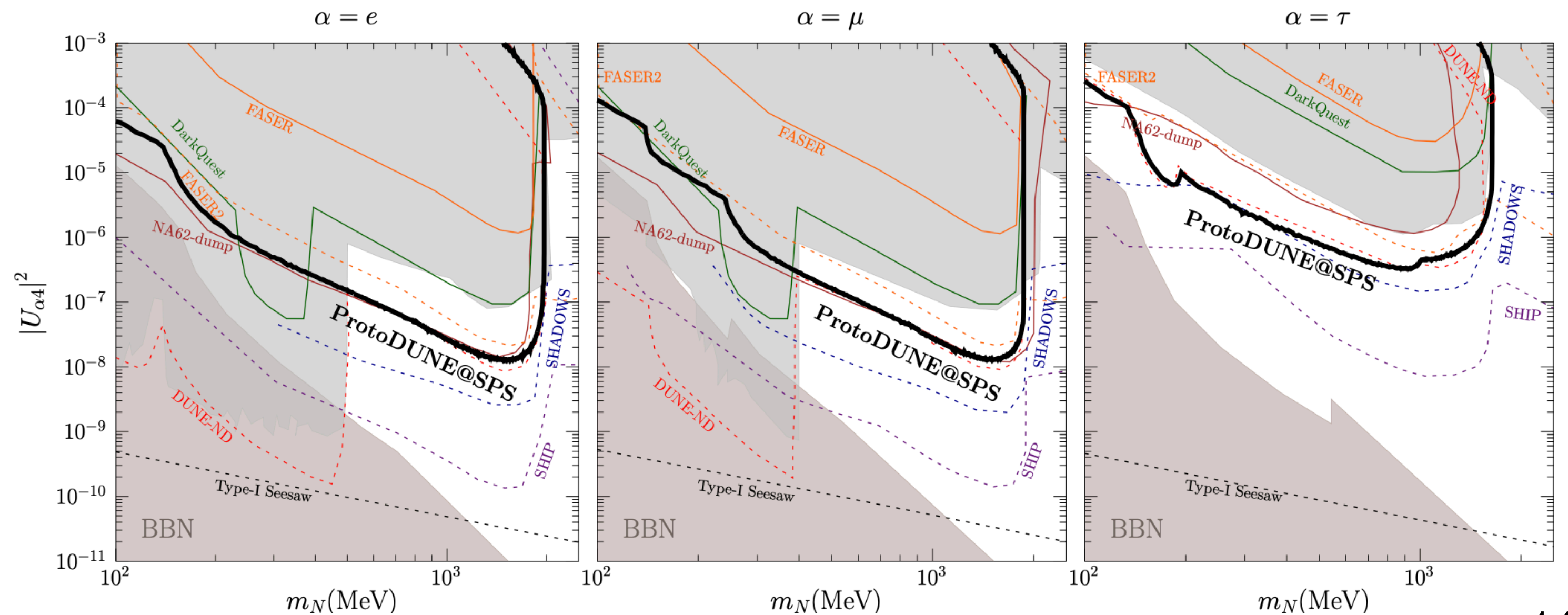
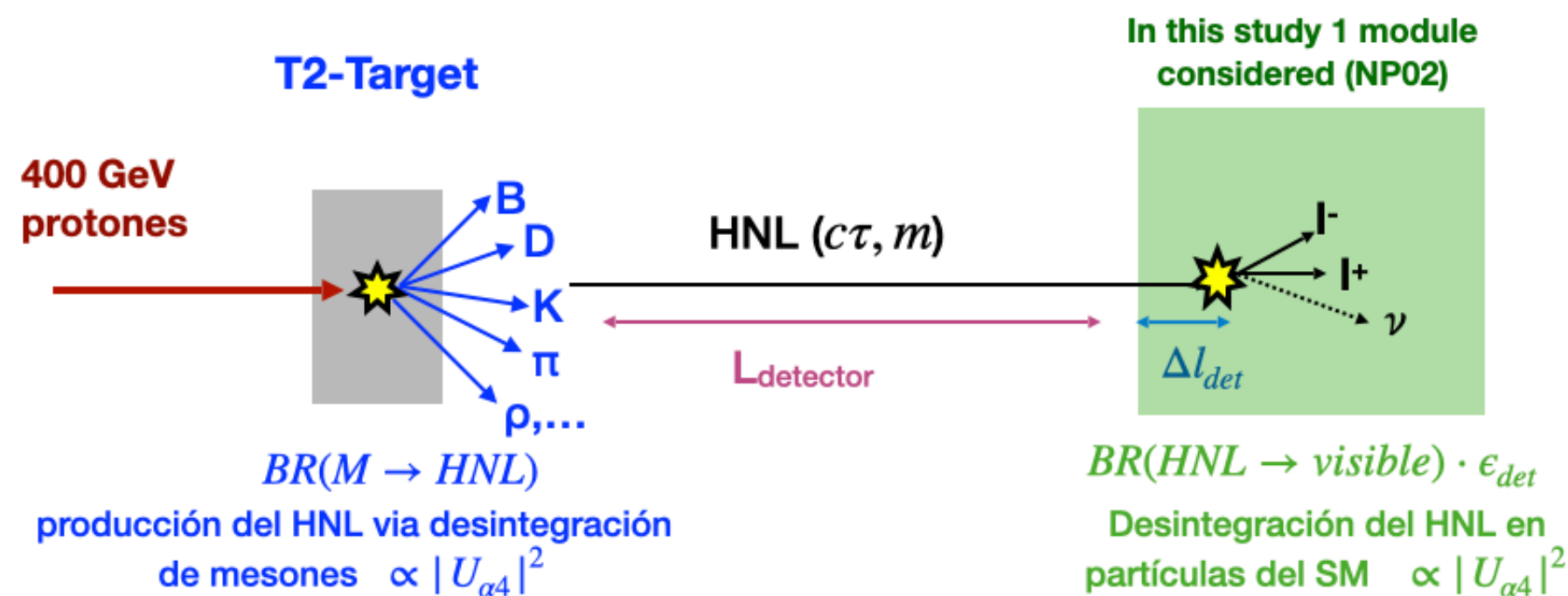


A muon-neutrino interaction candidate.

Working group created in December 2023 to demonstrate the proof-of-principle within DUNE collaboration (P. Coloma et al. + H. Amar (PhD), J. Martin-Albo)

Benchmark HNL
Escenario minimal: solo un neutrino pesado (HNL, N) se mezcla con un neutrino estándar

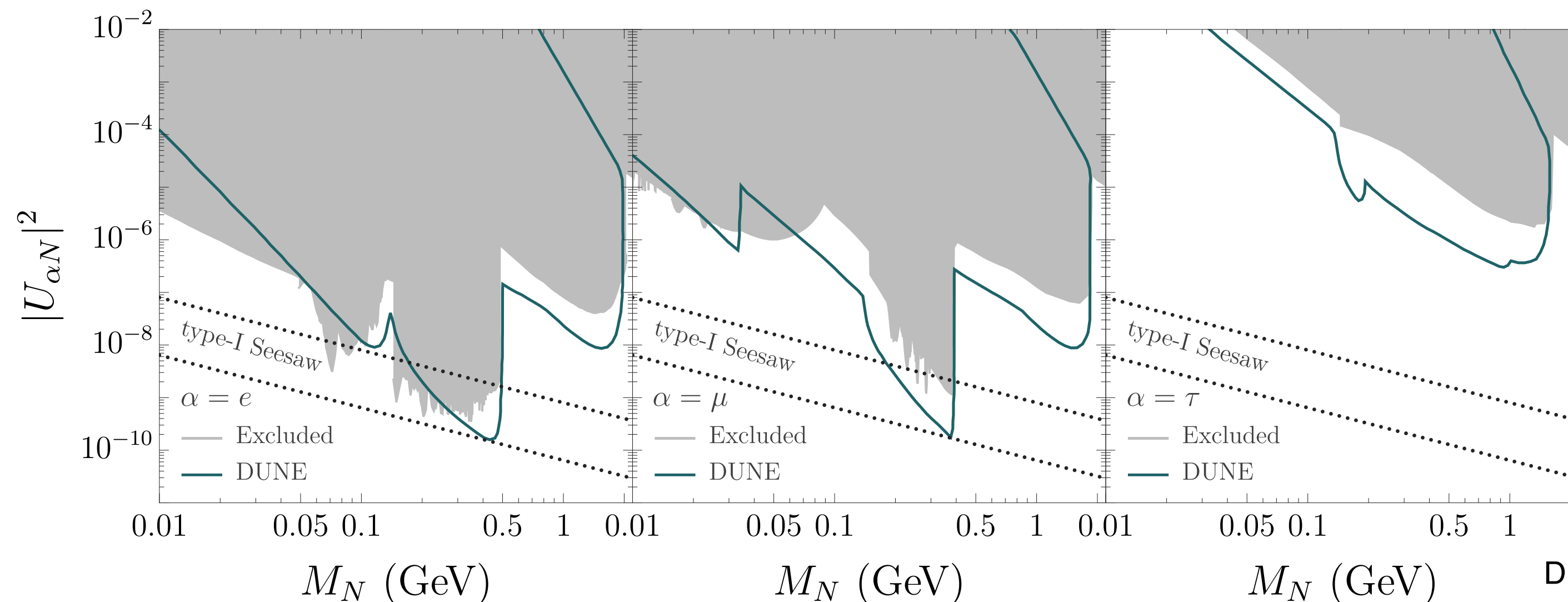
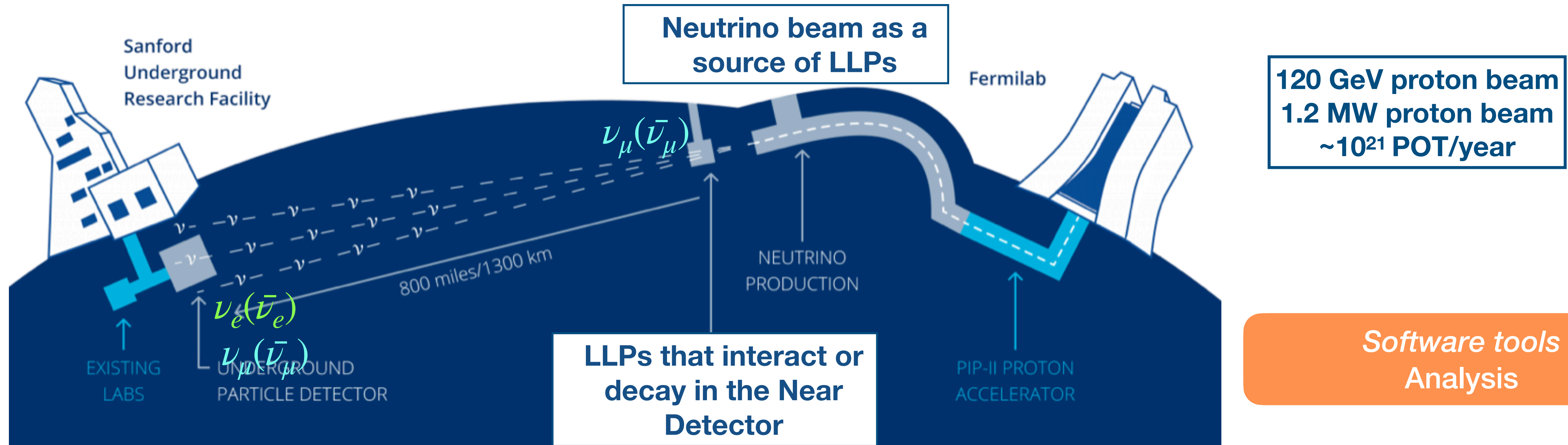
$$\mathcal{L} \supset -\frac{m_W}{v} \bar{N} U_{\alpha 4}^* \gamma^\mu l_{L\alpha} W_\mu^+ - \frac{m_Z}{\sqrt{2}v} \bar{N} U_{\alpha 4}^* \gamma^\mu \nu_{L\alpha} Z_\mu$$



Decays considered: $N \rightarrow \nu e e, \nu \mu \mu, \nu e \mu, e \pi, \mu \pi, \nu \pi^0$

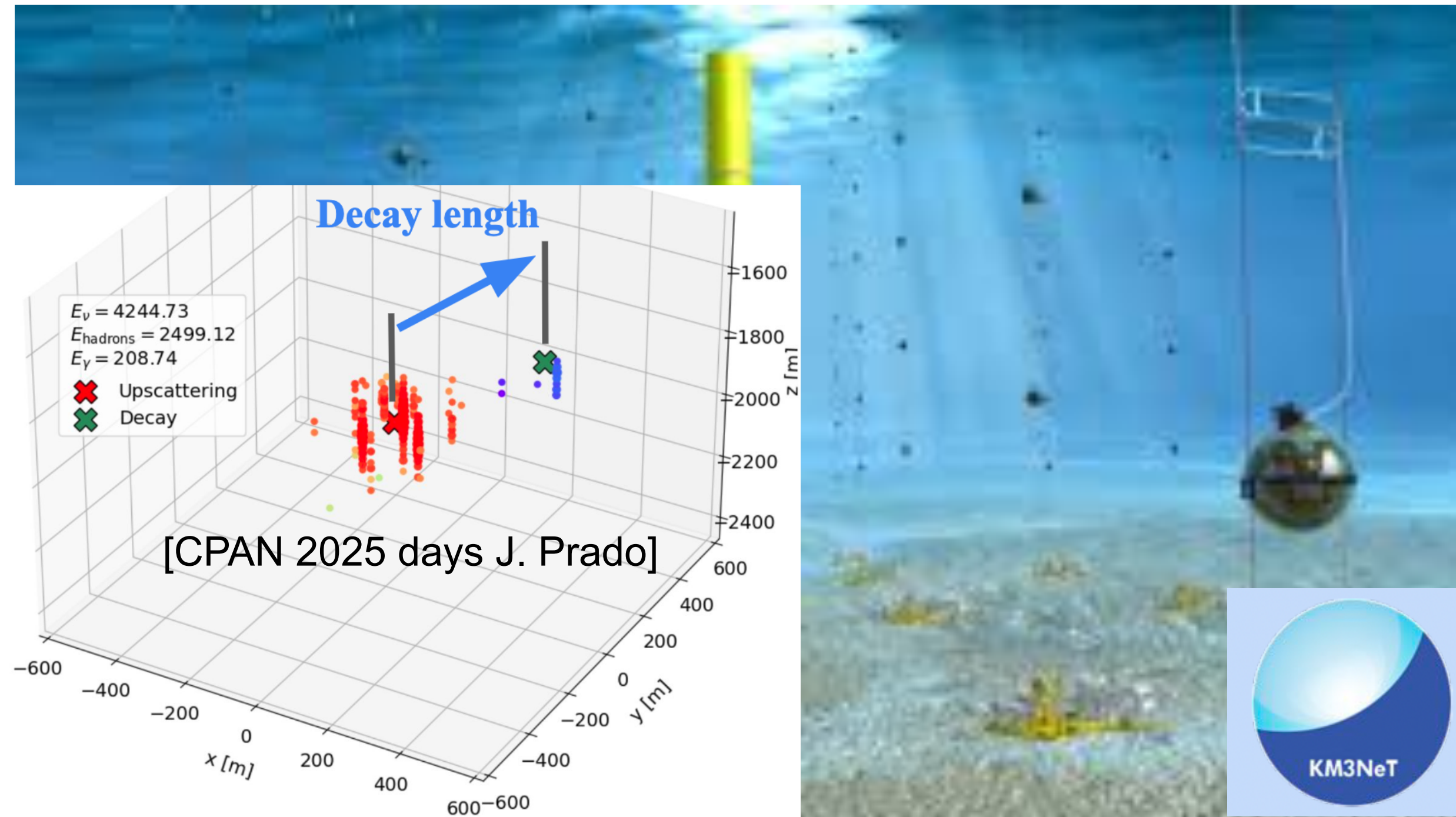
Complementary with HNL/LLP searches @DUNE

J. Martin-Albo



- **Leadership** in BSM physics in **DUNE**
- Focus: **long-lived particles** (LLPs) at the **Near Detector** (ND)
- Additional BSM physics program: non-standard oscillations, rare neutrino interactions (e.g., tridents), nucleon decay...

Complementarity with searches at the cosmic frontier



A. García Soto, R. Gozzini, J. Hernández,
J. Prado (PhD), S. Madarapu (PhD)

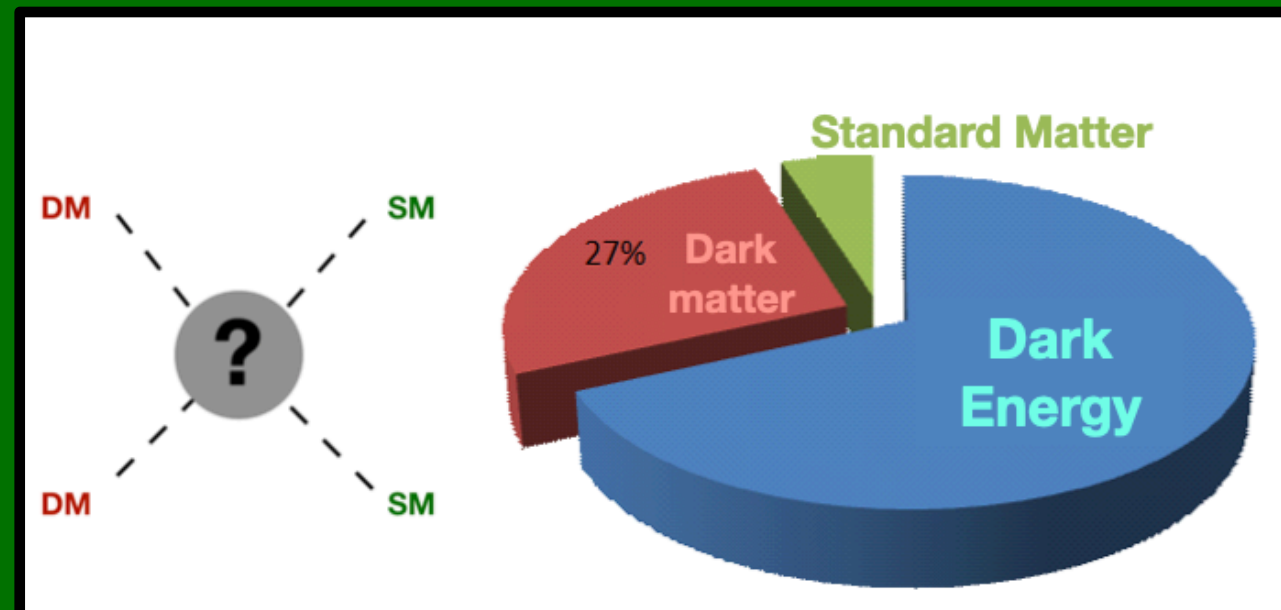
Software tools
Analysis

- Development of new analysis tools
- Application of ML techniques

• Search for HNL via double-cascade signatures at low energies

- Adaptation of SIREN lepton injection [[arXiv: 2406.01745](https://arxiv.org/abs/2406.01745)] to the case of neutrino telescopes to generate signal; currently generation in *dipole moment* scenario, alternative to mixing.
- Reconstruction based onBDT and GNN (GraphNet) aiming at both classification of double-cascade events and regression of distance and energy distribution in each vertex.

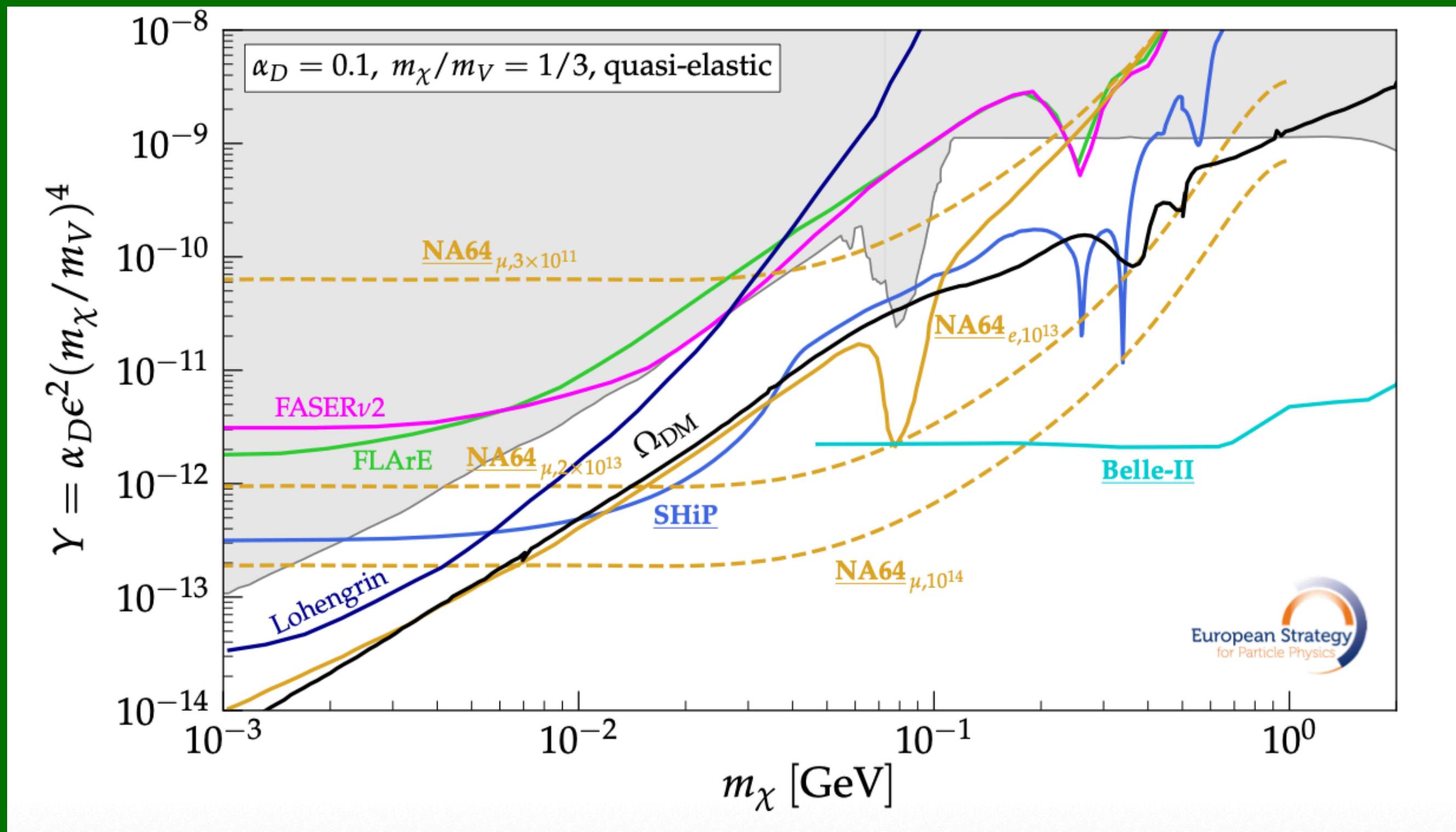
Dark Matter composition



Standard Model

Dark Photon

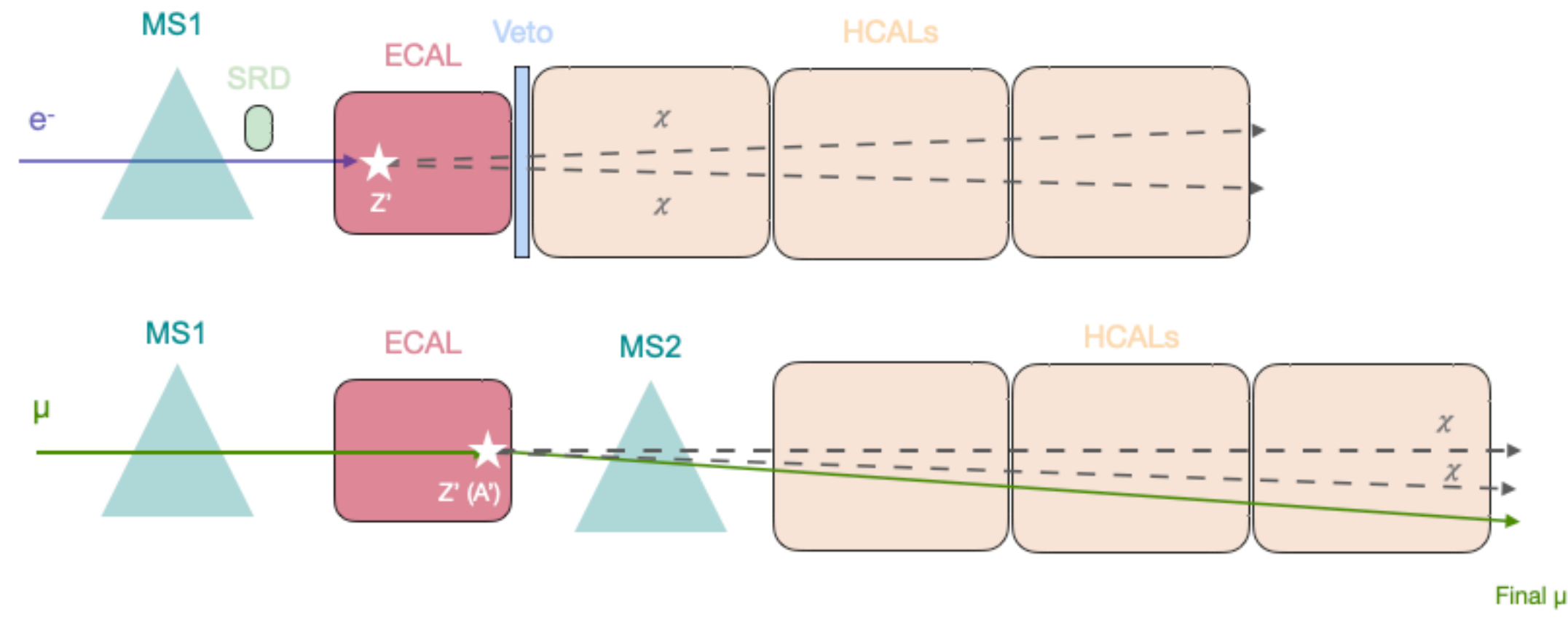
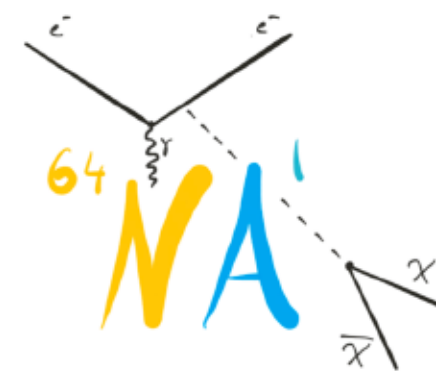
Dark sector
 $A' \rightarrow \chi\chi$



LDM searches at fixed-target experiments

L. Molina-Bueno, K. Salamatin
M. Tuzi (PhD), P. Such Borràs (Master/PhD)

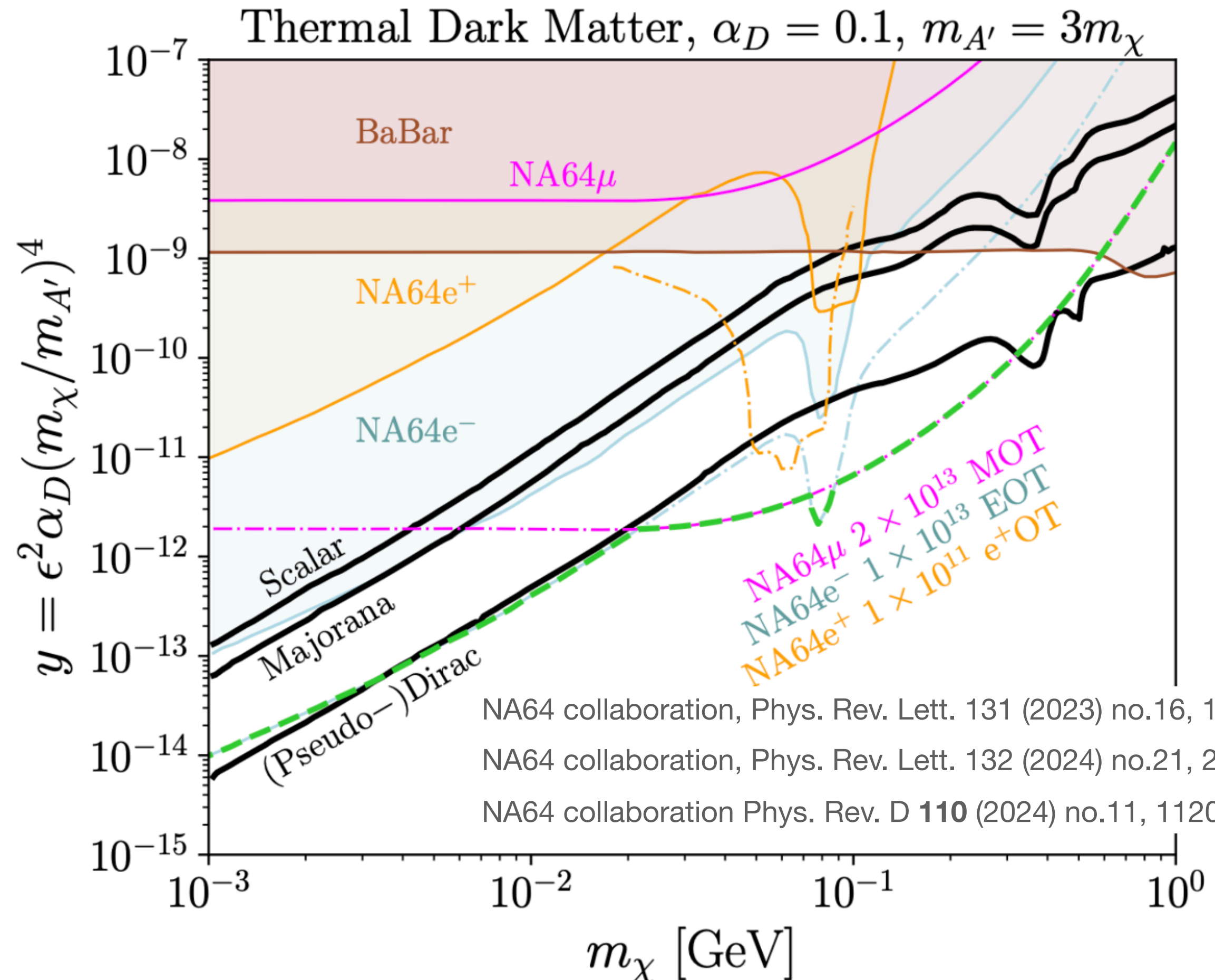
Complementary beams
NA64e⁻ **NA64e⁺** **NA64μ**



Simulation, trigger and software tools, analysis

Preparation, commissioning and data taking campaigns

- Monte Carlo simulations for detector and trigger optimisation
- Exploration of new signatures
- Tracking
- Analysis and sensitivity studies



Synergies/possible interests

- Many groups involved in FIPs/LLPs searches.
- Complementarity with other experiments.
- Theoretical interests to exploit the physics case, in particular in the context of HNL.
- Experience in **analysis and software development**:
 - Monte Carlo simulations:
 - Detector optimisation
 - Exploration of new signatures
 - Trigger
 - Tracking
 - Application of ML tools
 - Electric/magnetic millicharged particles @ SHiP ?

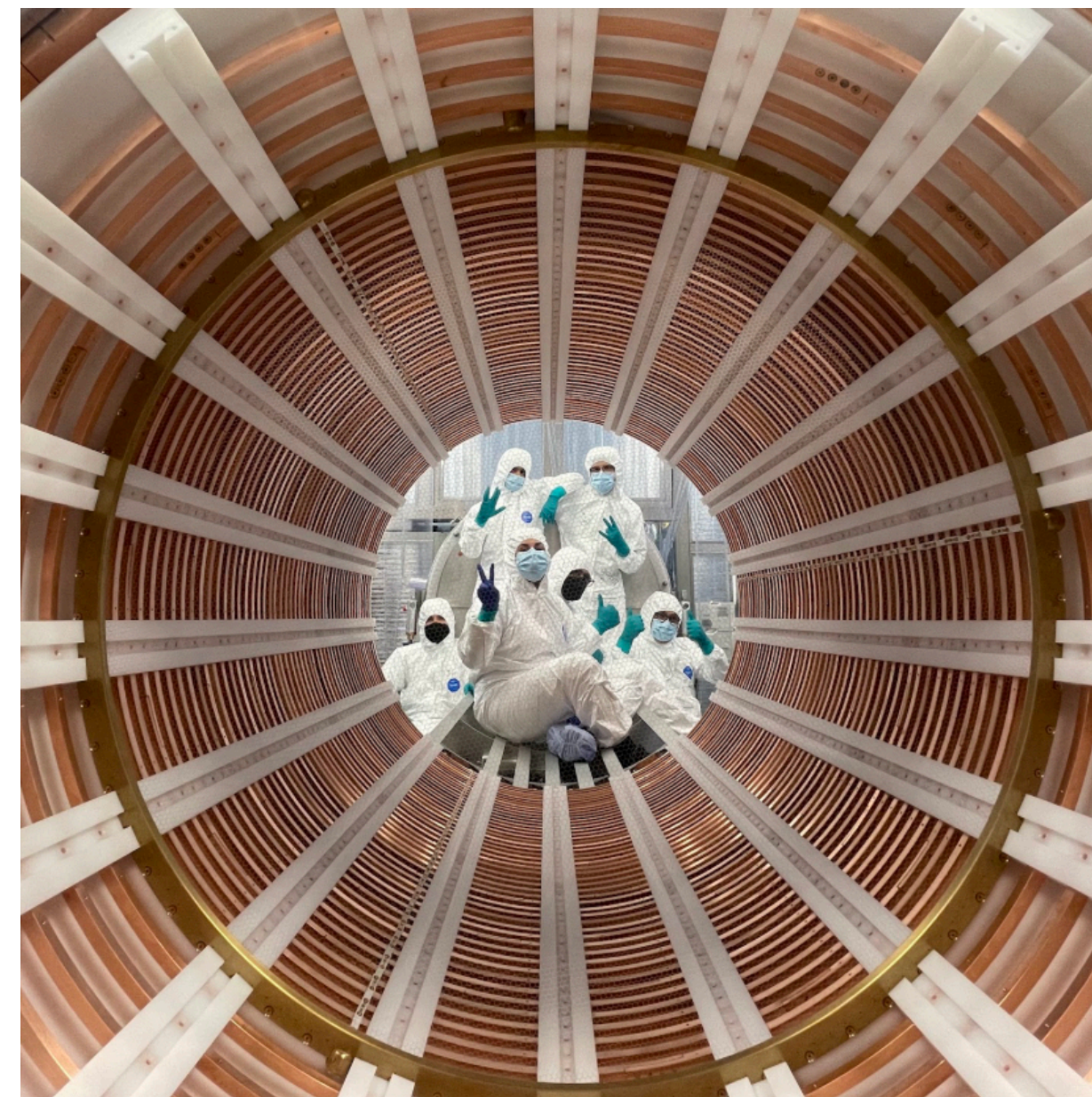
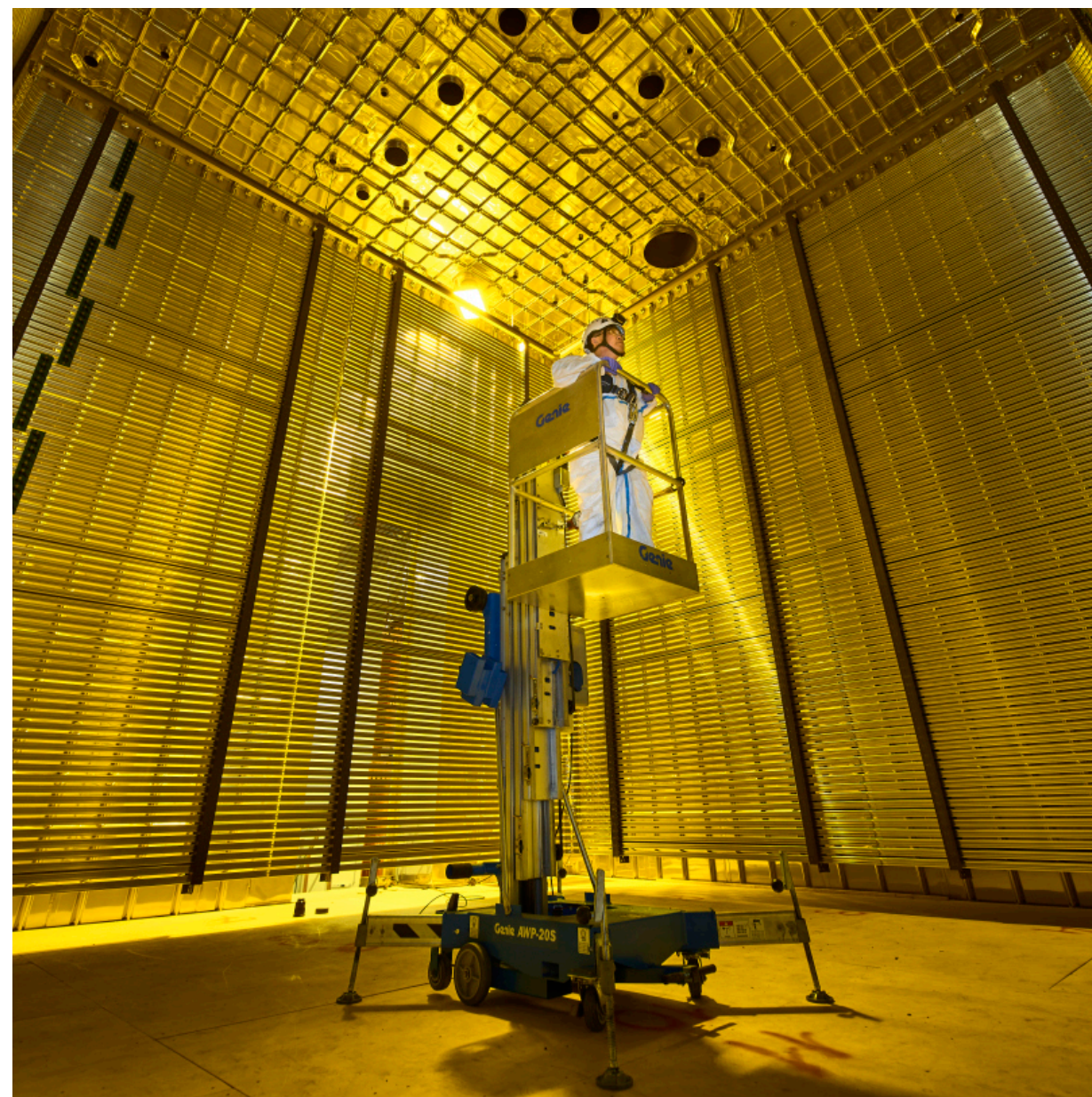
R&D/Instrumentation

Noble element detectors (DUNE, NEXT, COLINA):

- VUV photon detection and light collection
- Cryogenic instrumentation
- High-pressure systems
- Charge amplification structures
- Readout electronics

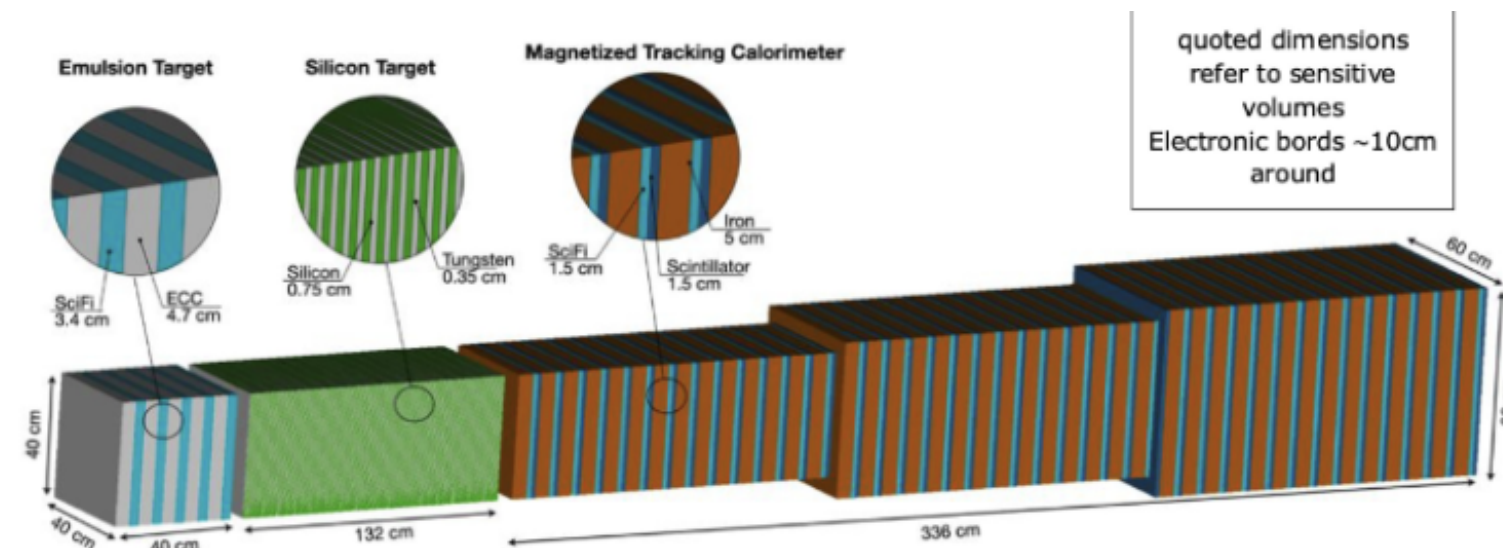
CERN DRDs participation:

- DRD1 (gaseous detectors): electronic integration into DAQ for fixed-target experiments, TPCs for neutrino physics
- DRD2 (liquid detectors): light collection and detection.





- Key installation for DRD Calo WP1 devoted to characterisation and hybridisation of silicon sensors for high granularity calorimetry.
- Sensor assembly and characterisation for SiW-ECAL & HighCompactCalo for DRD Calo.
- **LUXE/SHiP/.. stepping stones before Higgs Factory**
 - Strong collaboration @IJCLab, proposing to use DRD calo SiWECAL for SND detector/
 - Contributions to R&D, prototype production and testbed operation/analysis.



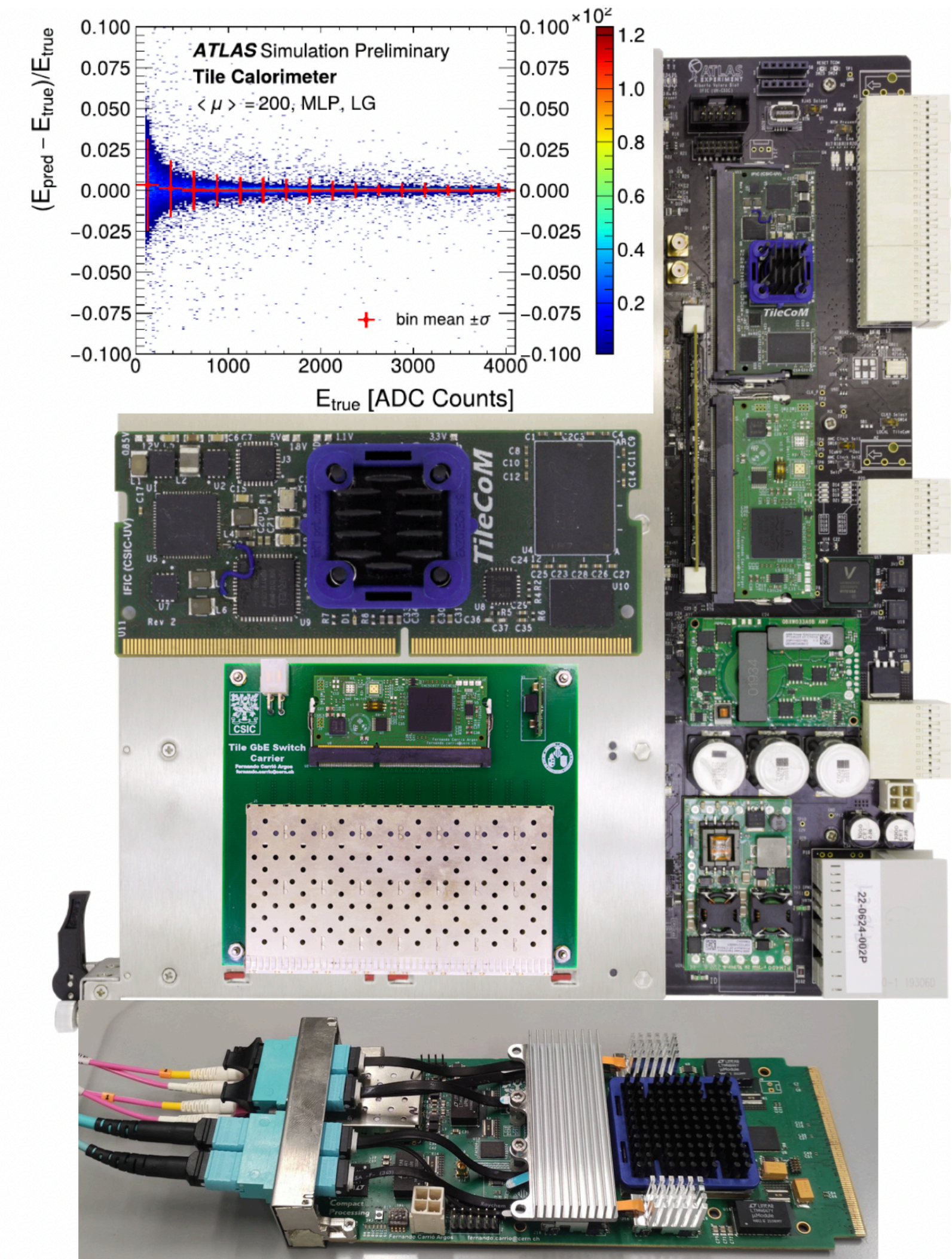
R&D in calorimeters

F. Carrió, L. Fiorini, A. Valero,
X. Poveda, A. Ruiz

- Design and production of high-throughput read-out electronics.
- Firmware development and software for fixed-latency FPGA
- SoC design and operations
- Real time signal reconstruction for calorimeters

Achievements:

- ATLAS Tile Calorimeter Read-out Devices (2006-2026)
- ATLAS TileCal PreProcessor (TilePPr) for HL-LHC
 - ATCA Based Board with Xilinx KU-115 FPGA
 - Interface between the “on-detector electronics” and the trigger & data acquisition system, 40 Tb/s throughput



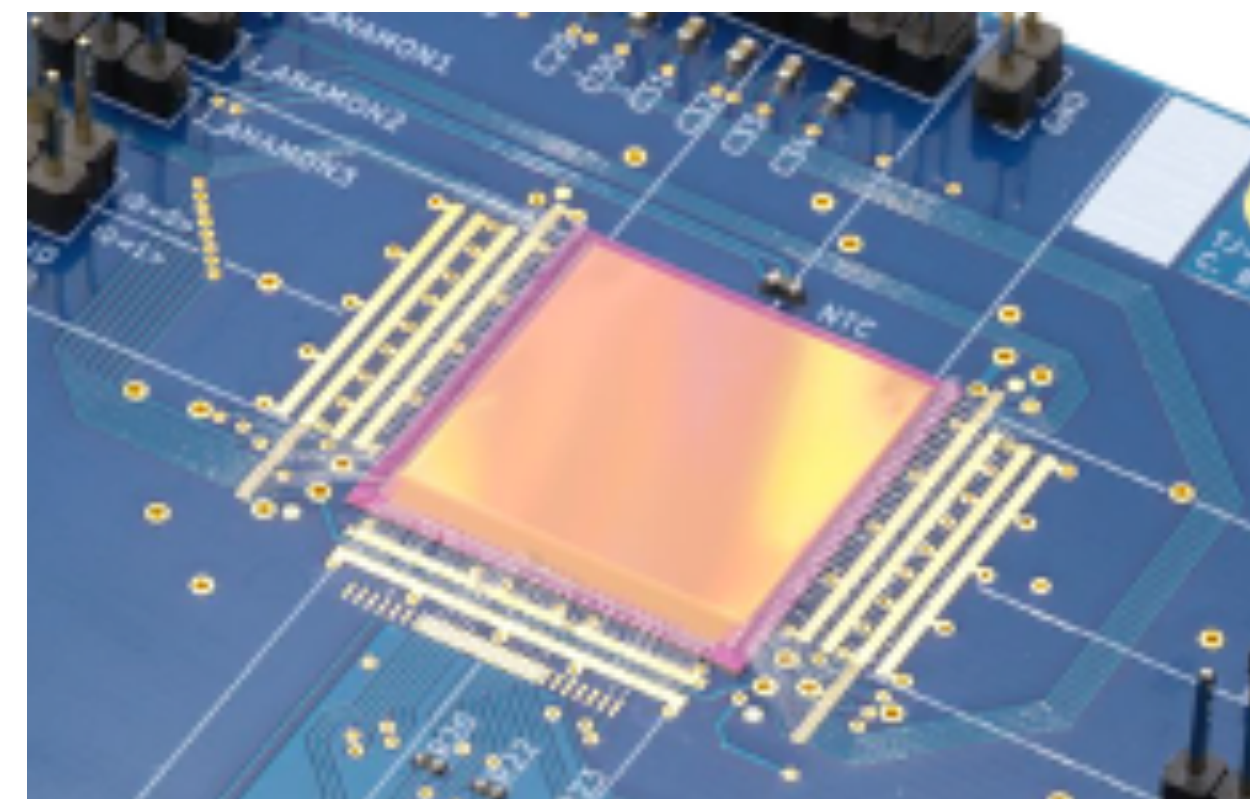
R&D in solid-state detectors

C. Castro, D. Galacho, J. Iddon, C. Lacasta, C. Mariñas, S. Marti, L. Molina-Bueno, K. Salamatin, S. Vico

Main development lines towards potential upgrades of *ATLAS*, *Belle II*, *NA64* and future collider experiments:

- **Monolithic silicon technologies**
 - OBELIX (Tower 180 nm): Spatial resolution, triggering and radiation hardness
 - MANTA (TPSCo 65 nm): Versatile pixel grouping, power consumption
 - MONSTERA (LFoundry 150 nm): Monolithic CMOS strips
- **Characterization techniques and infrastructure**
 - TPA-TCT, IR microscopy, large tracking demonstrator systems
- **Interconnections and postprocessing:**
 - Redistribution layers, optical connections, etching, dicing, ...

DRD3



Synergies/possible interests

We are participating into several R&D activities within the DRD programs that could have synergies:

- R&D in noble gases Time Projection Chambers
 - Light detection and collection
- Tracking
 - Solid-state and gaseous detectors: *Time Projection Chambers, DMAPS pixels*
- TDAQ
 - Optical links, high performant FPGAs
- Calorimeters
 - *High granular ECAL calorimeters*