GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

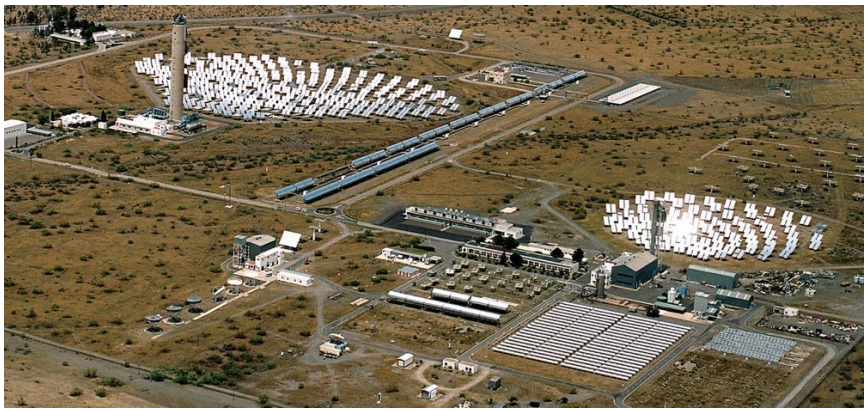
CIEMAT

Research Center for Energy, Environment and Technology

Plenary ECFA
L.N. Frascati
4-07-2024

N. Colino

CIEMAT Geographical distribution



PSA Almería: Solar Energy

CEDER Soria: Renewable Energy

CETA Trujillo

Computation

CIEDA Soria

Environment

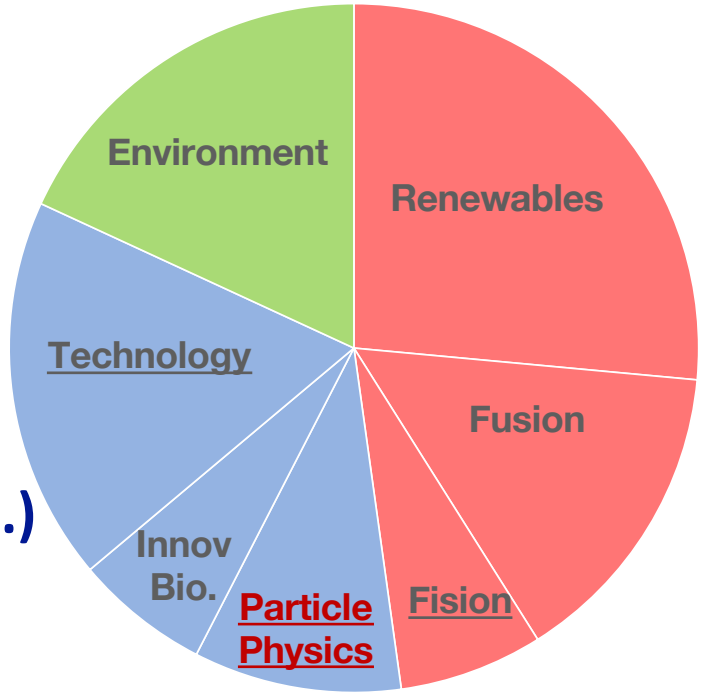
CISOT & PIC Barcelona

PIC (UAB)

CIEMAT Structure

About 1250 people (M/F: 42/58%)
R&D areas: 910 (40/60), 390 PhD. (44/56) + 271 Grad. (40/60)

Environment (170 p.)



Energy (450 p.)

Knowledge & Innovation (290 p.)

Ciemat

R&D areas at CIEMAT

Budget from National Budget	~120M€/year
External income	~25%

Knowledge & Innovation

- Technologies
  Accelerators, Materials for Energy
  Scientific computing
  Medical application of Ionizing Radiation
- Biomedical Innovation
- Particle Physics
- Energy: Nuclear Innovation

External income sources

Type of activity at CIEMAT

1. Mid to large size projects

Involving science, engineering and technology. Large multidisciplinary teams

Contribution to the Big Science, which involve complex instrumentation

2. Involved in scientific strategies at international level

Participant at flagship international projects

Member of the main alliances in the relevant areas

3. Collaboration and technology transfer to Industry

Neutron sources for fusion development

LIPAC

DONES

World record achieved in 2019:. 125 mA of D+ at 5 MeV

Developments on Magnet Technology

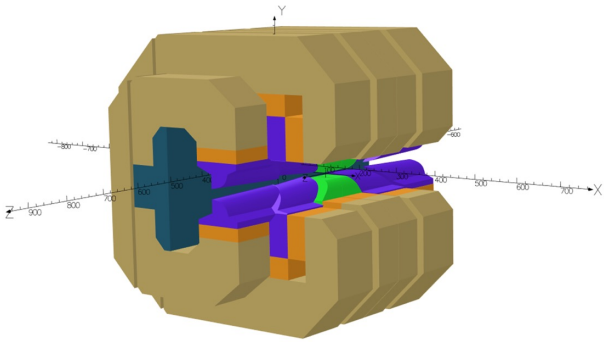
(a) Particle colliders (HFM)

- HL-LHC: 18 short and long nested superconducting (SC) orbit correctors
- FCC: 14 T dipole in common coil configuration
- CLIC: dipole with longitudinally variable field
- ILC: conduction cooled SC magnet package

Orbit corrector assembled with low-beta quadrupole for HL-LHC

(b) Science, medical, energy, transport

- I.FAST, HITRI+: SC magnets for hadrontherapy gantries
- I.FAST: dipole with longitudinally variable field for Elettra
- POSEIDON: SC magnetic energy storage for maritime transport
- AMIT: SC cyclotron magnet for radioisotope production

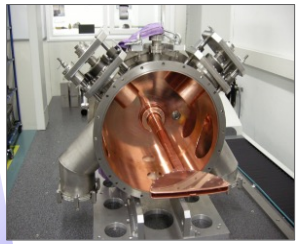


3D model of dipole with longitudinally variable field for Elettra

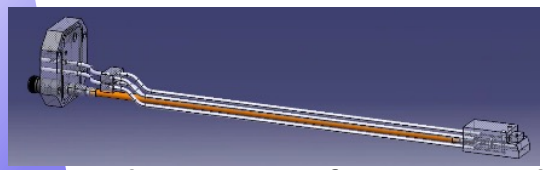
A program under preparation on HTS for Particle Physics and Fusion

CIEMAT. Accelerator Unit

Accelerators for nuclear imaging



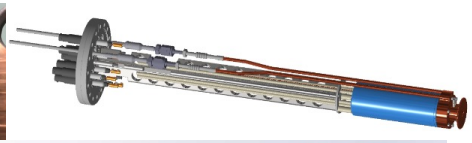
Cyclotron for PET production



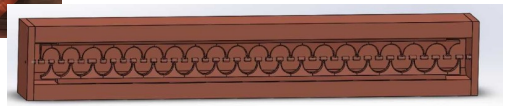
Patented RF ion source for compact cyclotrons

Hadrontherapy

- Electron gun development for C6+ EBIS source
- High Frequency RFQ
- IH cavities design

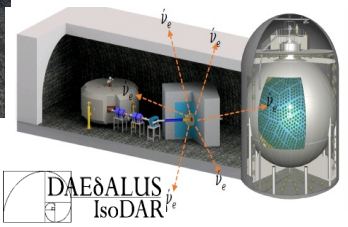


Egile



High Energy Physics

Cavities for CLIC



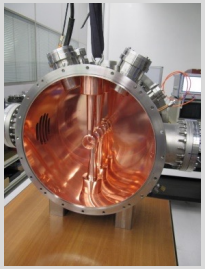
Beam Dynamics of IsoDAR Cyclotron

Accelerators for fusion roadmap (IFMIF)

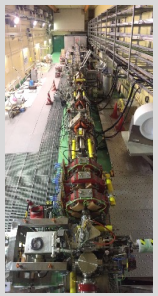
MEBT

Diagnostic Plate

LIPAC

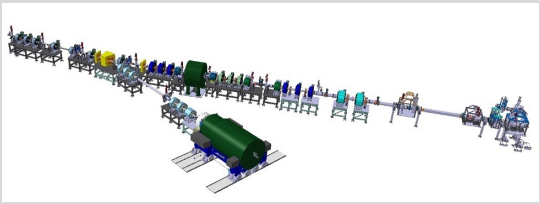


Buncher

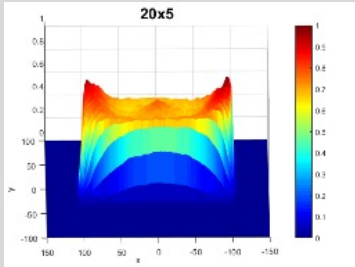


Commissioning

DONES



HEBT + BDTL



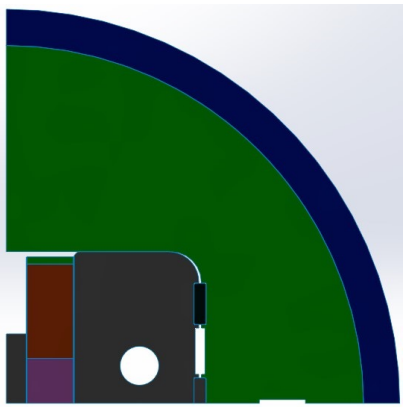
Target beam profile

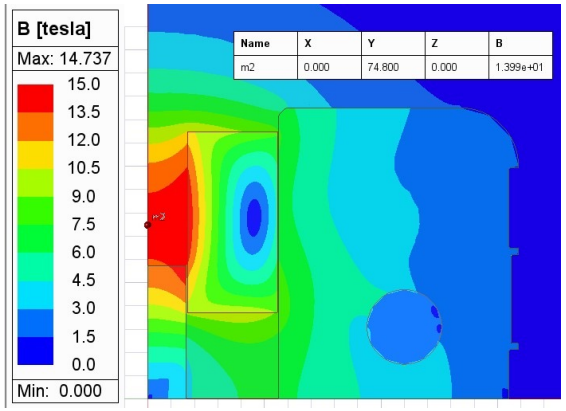
CIEMAT. Accelerator Unit : High field magnets for FCC

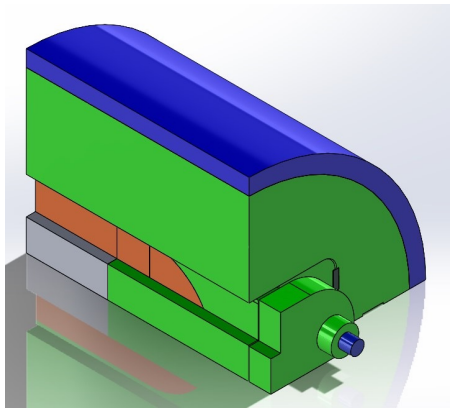
CIEMAT contribution consists of:

- Model magnet (ISAAC) using CERN existing coils in common coil configuration.
- Revisit the CIEMAT design of 16T common coil dipole magnet (EuroCirCol).
- Research on fabrication techniques: react-and-wind coils.
- Prototype of a high field magnet in common coil configuration.

These activities are performed in the new laboratory for magnet prototyping.







ISAAC: Investigating Superconducting Assembly to Address Common coil mechanics

Left: 2-D cross section

Center: 2-D magnetic field map

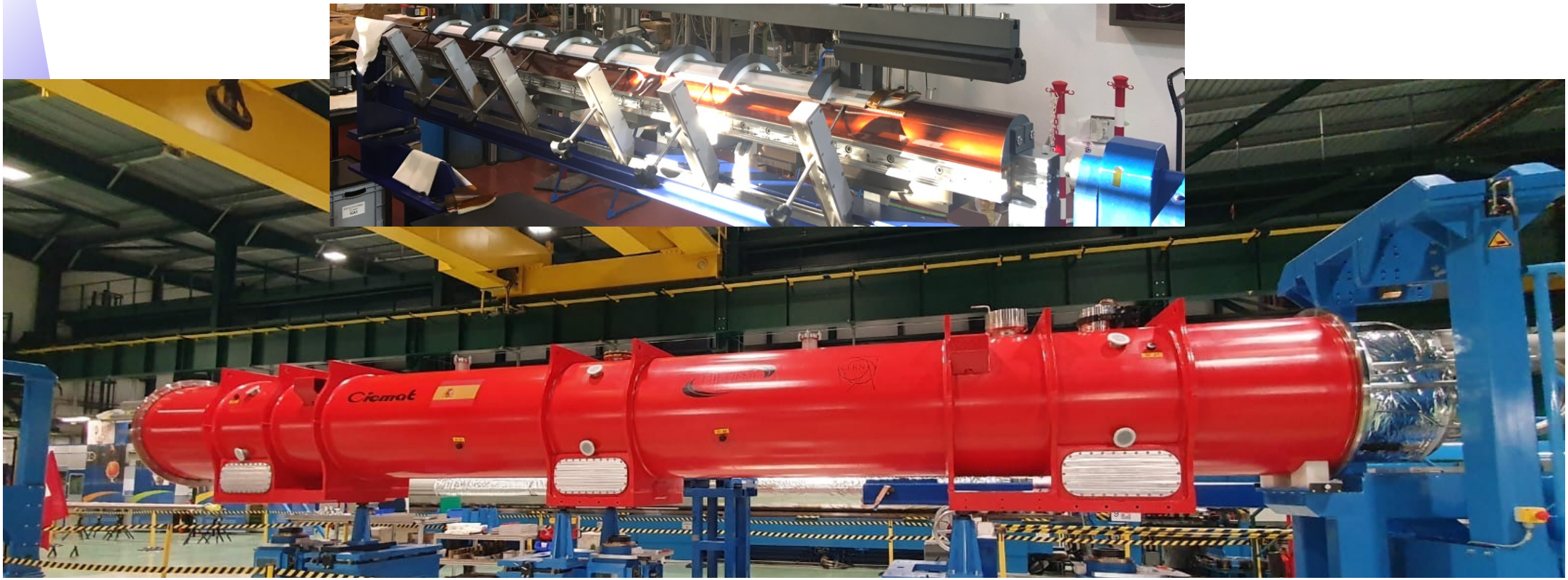
Right: 3-D model

CIEMAT. Accelerator Unit

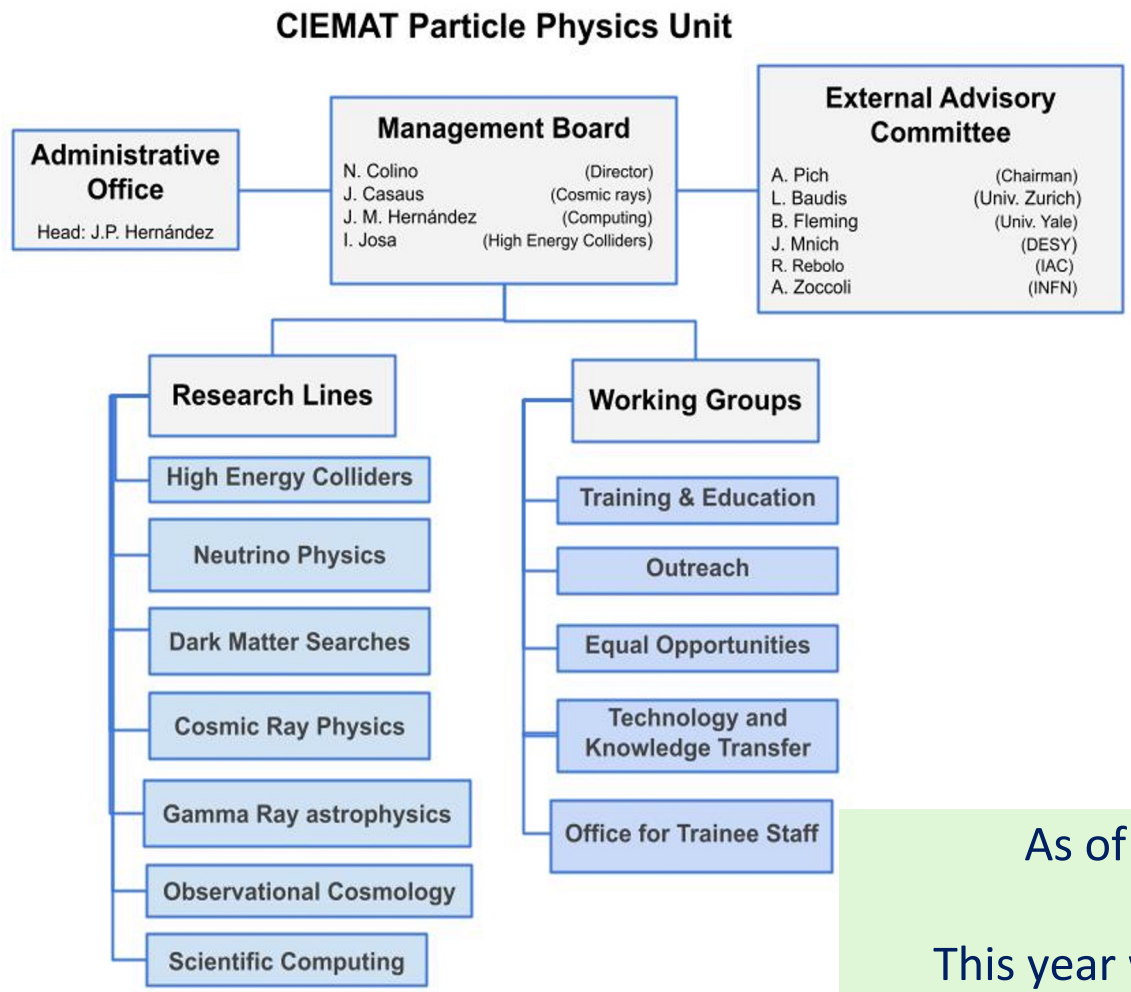
Collaboration and technology transfer to Industry

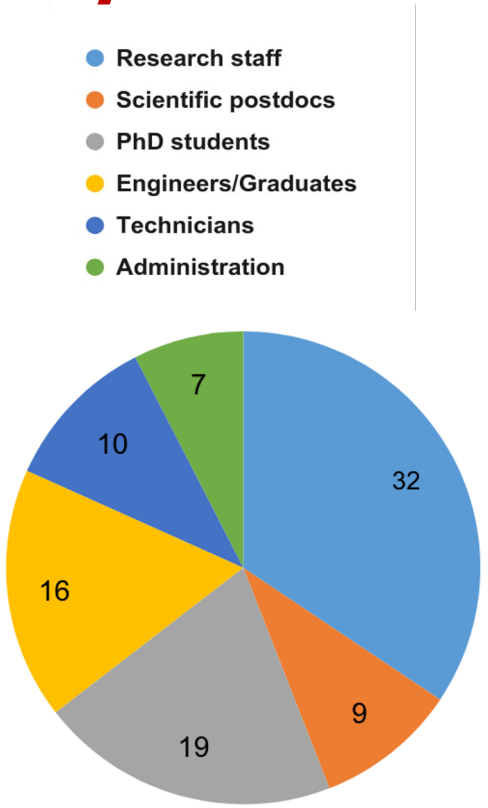
ANTECSA, ELYTT, Suprasys,
AVS, EGILE, Arquimea, ...

(HFM program with CDTI)



Structure of the CIEMAT Particle Physics Unit





As of 2023, comprises 93 members,
~50% PhD, 22% female.
This year we have having a big increase (~ 12%)

CIEMAT Particle Physics Research Lines

Our research program has 7 main lines:

High Energy Colliders: Probing the constituents of the matter
CMS@LHC: Test the SM to the higher precision and look for new Physics

Neutrino Physics: Unveiling the properties of neutrinos
Dchooz, DUNE, SBND, CLOUD: Determination of neutrino oscillation parameters

Direct Dark Matter Detection
ArDM, DEAP,DarkSide: look for hints of dark matter scattering.

Cosmic Rays Detection: Dark matter and antimatter
AMS@ISS, HERD@CSS: Understanding the origin and history of the cosmic rays and using them to study the physics beyond the standard model

Physics with very high energy gamma rays
MAGIC, CTA: unveiling the most energetic processes of the universe and the dark domain

Cosmology
DES, PAU, DESI, LSST-DESC, Euclid: Most competitive constraints to cosmological parameter of the universe through large scale galaxy surveys.

Advanced Computing Technology
WLCG: R+D+I in computing technologies and infrastructure for processing and analyzing huge volumes of scientific data: big science => big data => big computing

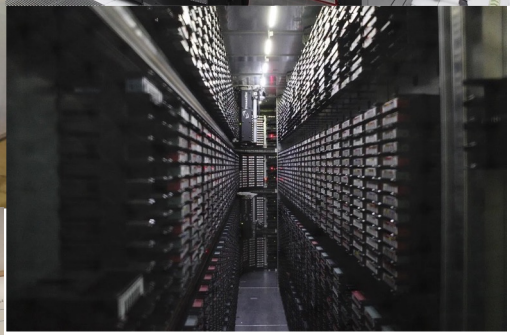
+ Emerging line in Gravitational waves (Adv. Virgo and ET)
+ Detector R&D, participation on DRD collaborations:1,2,6,7

CIEMAT and Particle Physics Unit facilities

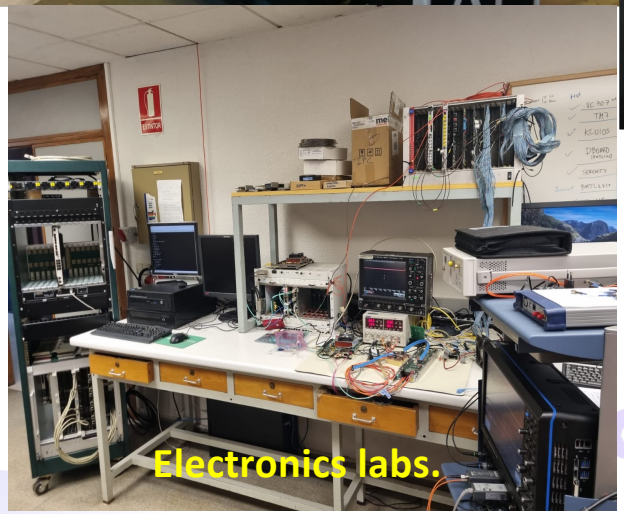

Clean room(B. 20)


Assembly Hall (B. 75)

Computing facilities




Mechanical workshops


Electronics labs.

Ciemat

CIEMAT CMS at LHC Run 3

CIEMAT involved in CMS since the Collaboration start.

Responsible in design, construction, operation and calibration of ¼ Muon Drift Tubes (DT) system, a tremendously robust system

L1 HLT Trigger Coordination 2022-2024

Continuous development of Trigger strategies in Run 3

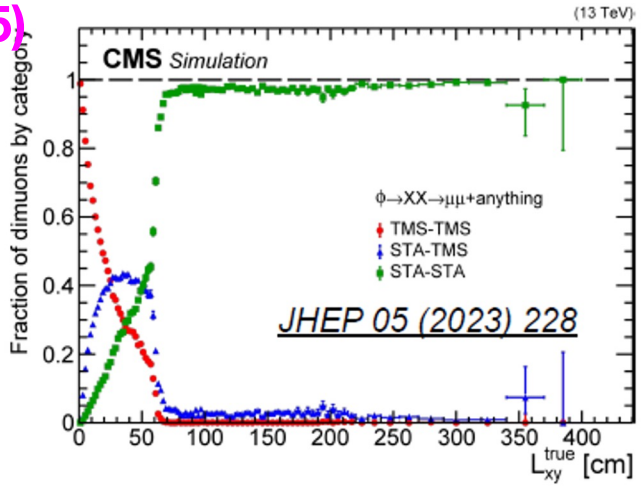
Detector Performance: very energetic muons, displaced muons, b-/c-tagging.

DT Project Manager (2019-2021)

L3 Muon Selection Convenorship (2023-2025)

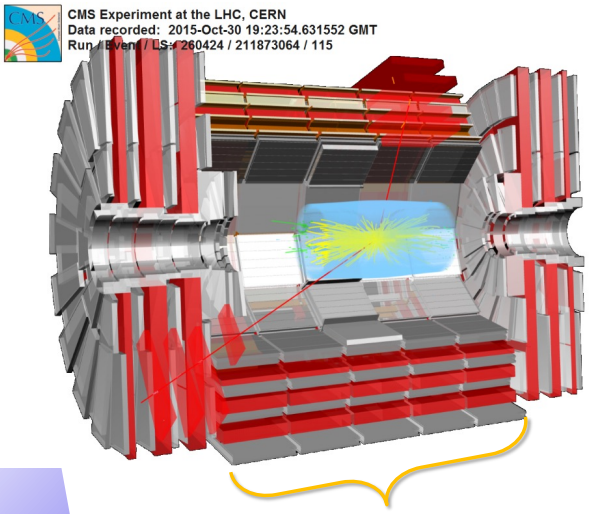
Well positioned to **maximize the physics output from Run 3 data**, keeping our **key role in CMS experiment** with **relevant positions** and **leading important physics analysis**

Improved signal efficiency with dedicated displaced muon triggers



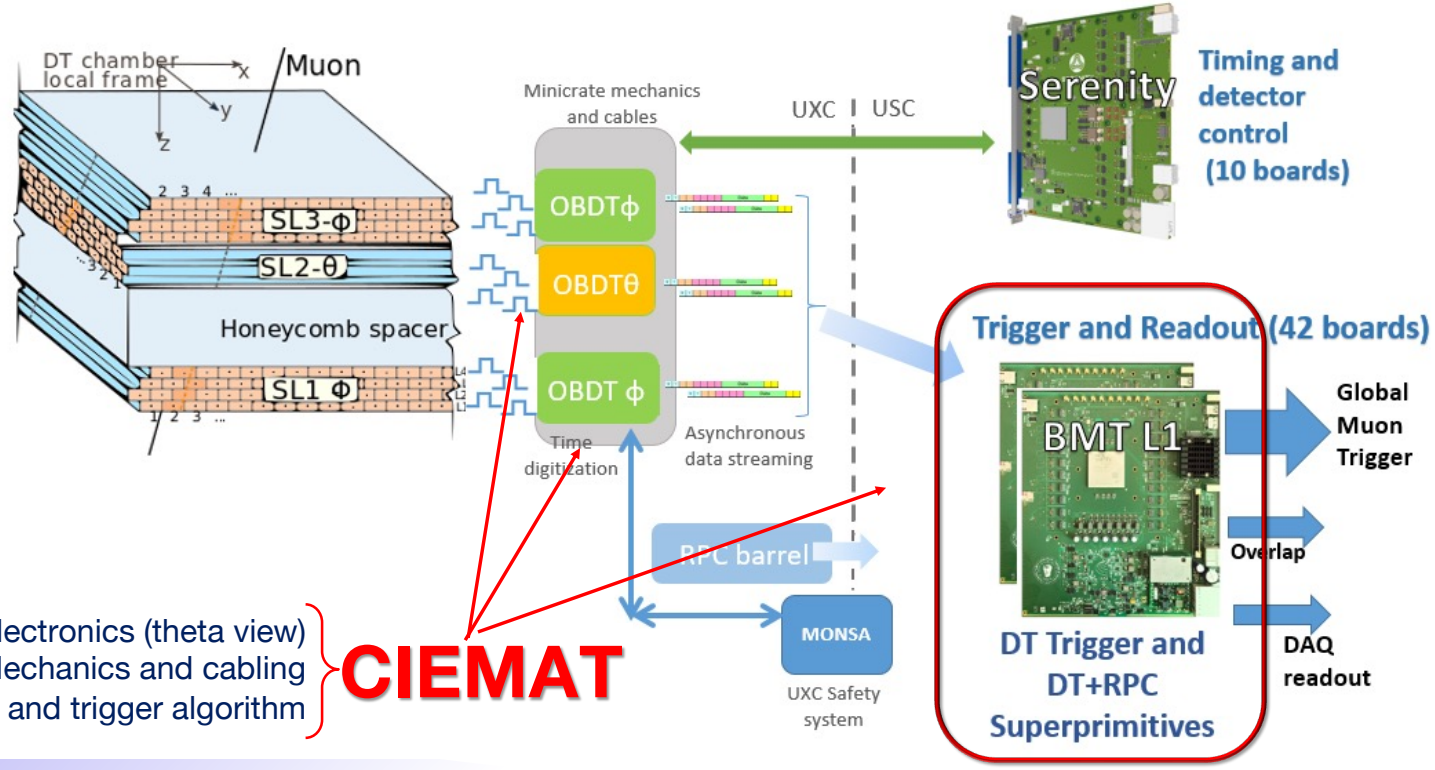
Plan de Recuperación, Transformación y Resiliencia
Funded by the European Union
NextGenerationEU

CMS Muon Drift Tube HL-LHC Upgrade



- Drift tube chambers longevity: several years of radiation campaigns at GIF++ (Gamma Irradiation Facility) to validate its performance under HL-LHC. Efficiency loss should be aceptable
- Electronics needs to be replaced to stand: L1A rate, occupancy, radiation
- Full architecture change to move to a full streaming of detector information

- 250 chambers to be refurbished with new electronics:
  - Time digitization of the 172200 channels
  - Chamber interfaces, pressure ADCs, alignment forks, RPC interfaces, etc
- 830 boards embeded in the 250 Minicrates structures
- Full refurbishment of backend electronics with improved performance



-Electronics (theta view)
-Mechanics and cabling
-Backend and trigger algorithm

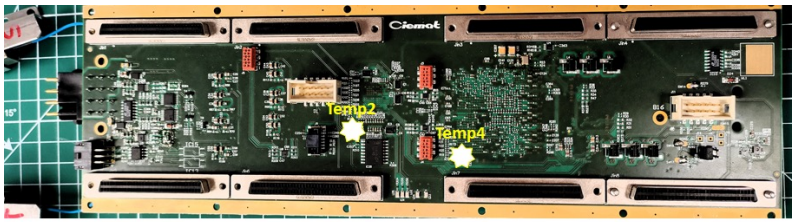
CIEMAT

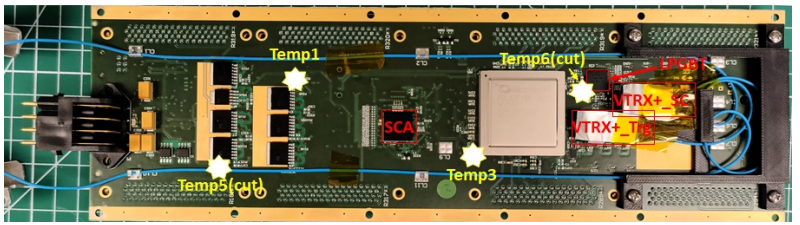
Plan de Recuperación, Transformación y Resiliencia
Funded by the European Union
NextGenerationEU

CMS Muon Phase 2: DT on detector electronics

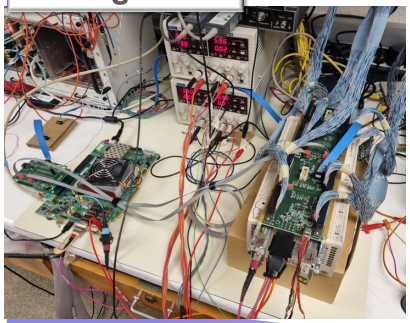
- **OBDT-theta board: designed and produced at CIEMAT**
- Time digitization on the FPGA (228 channels/board) at 0.7 ns. **Radiation tolerant FPGA Microsemi Polarfire**
- **High speed optical communication (10 Gbps/link),** total throughput available **80 Gbps/board**
- Makes use of CERN ASICs: lpGBT, SCA, VTRX
- Halogen free, radiation tested
- Automatic safety mechanisms embedded (temperature, current, voltage protections)

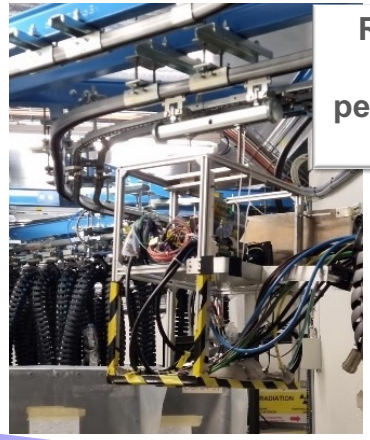
OBDT-theta board





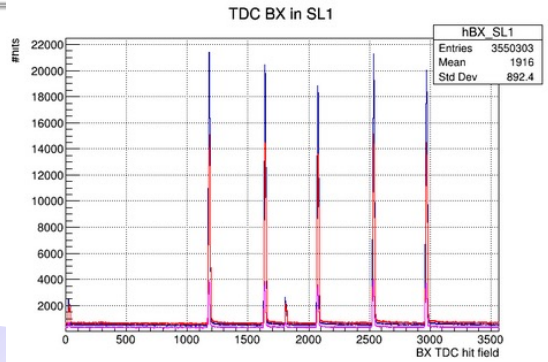
Tests stands being built



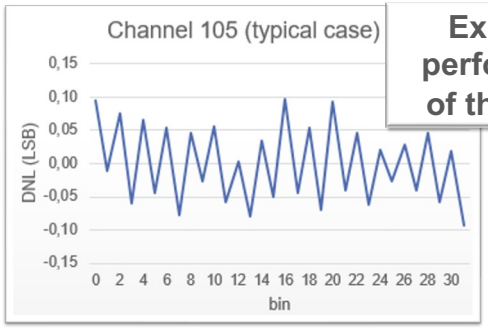


Radiation tests performed at CHARM

Board validated with collisions in CMS (Slice Test)



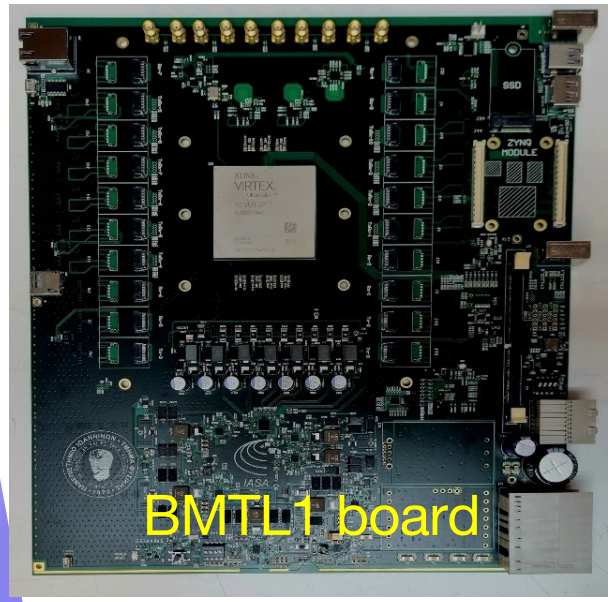
Excellent performance of the board



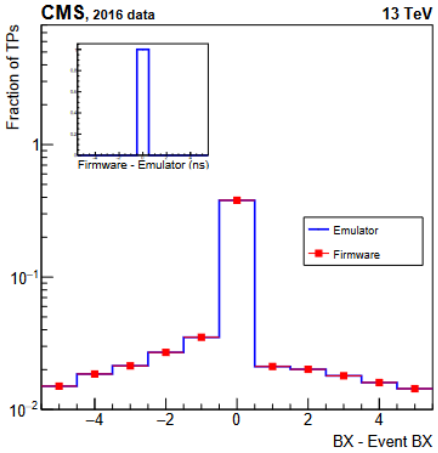
- Prototyping phase completed
- Pre-production validated
- Production ongoing

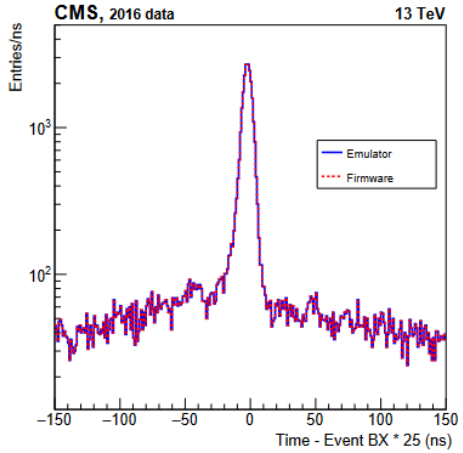
Plan de Recuperación, Transformación y Resiliencia
Funded by the European Union
NextGenerationEU

CMS Level 1 Trigger Phase 2 upgrade



Responsibles of the Muon Barrel Trigger primitives for HL-LHC





Muon trigger algorithm development

- **Analytical Method** (proposed by CIEMAT)
- **Exploits maximum achievable resolution**, closer to **offline performance capabilities**.
- In collaboration with UAM and Univ. Oviedo. Uni Ovi also participates in OMTF

Hardware backend

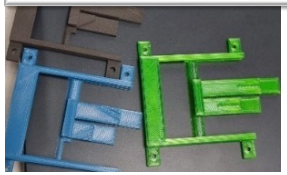
- 42 ATCA boards so called BMTL1
- AMD VU13P FPGA
- 3.8 Tpbs throughput
- Collaboration with Univ. Ioannina (PCB), CIEMAT (design of the firmware)
- Half of the production in spanish industries

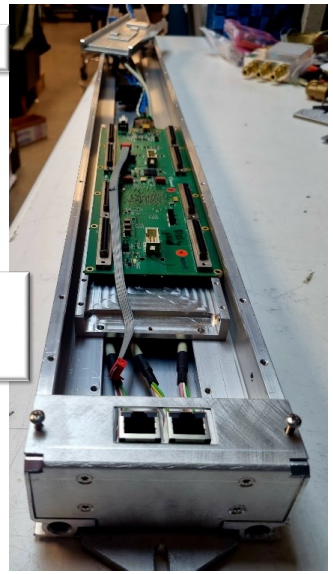
CMS Muon Phase 2: DT Minicrate mechanics

Mechanics fabrication
250 Minicrates (2 meters long)
+ 800 diffferent pieces

Cooling validation

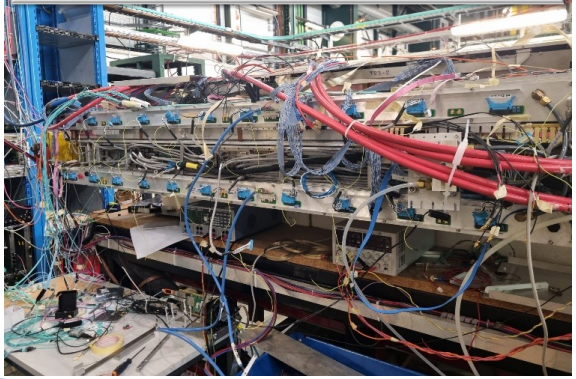
3D printing for fiber routing. Validation of plastics under radiation





Preparation of assembly hall at CIEMAT and at CERN

Cabling and integration tests



Installation exercises at CERN

Slice Test: two CMS sectors working in parallel with upgrade electronics

Plan de Recuperación, Transformación y Resiliencia
Funded by the European Union
NextGenerationEU

CMS Physics exploitation

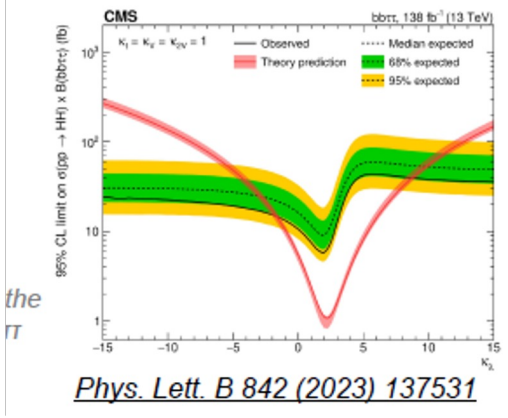
Higgs boson physics

Consolidated our participation in SM Higgs boson studies, BSM Higgs searches and HH production during Run 2 and currently in Run 3

H→ WW, LFV H→μτ, eτ, eμ, HH→bbττ

L3 H->WW Higgs PAG Convenorship (2020-2022)

L2 Higgs PAG Convenorship (2019-2021)



Phys. Lett. B 842 (2023) 137531

Improved search of HH→bbττ with sensitivity approaching SM value

Searches for new particles/interactions

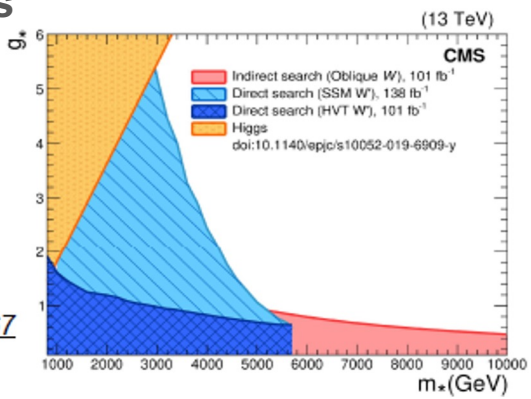
Reference group for searches with high pT leptons (muons) all along Run 2 and in Run3

L3 Non-Hadronic EXO PAG Convenorship (2018-2020)

Lepton + MET final state, Higgs Compositeness, Long-lived Particles

Exclusion regions (at 95% CL) in the *m*-g** plane using different inputs

JHEP 07 (2022) 067



Precision measurements of SM

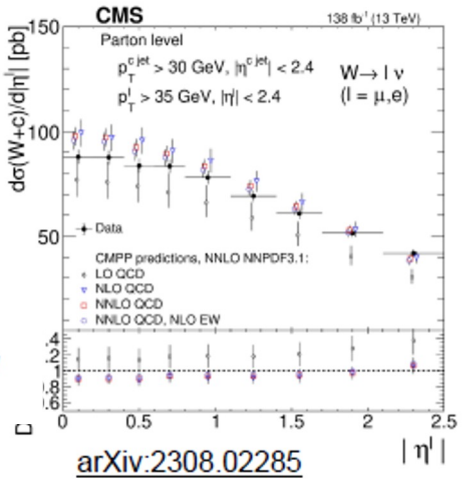
Deep expertise in studies of Vector boson + Heavy Flavour quarks

W+c, Z+c, WW?

L3 Vector+jets SMP PAG Convenorship (2019-2021, 2023-2025)

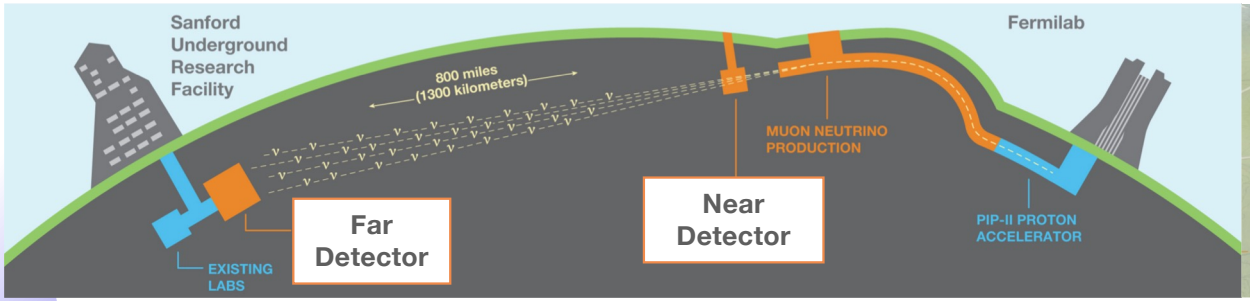
Various PhD Theses and MSc Theses with work in these areas

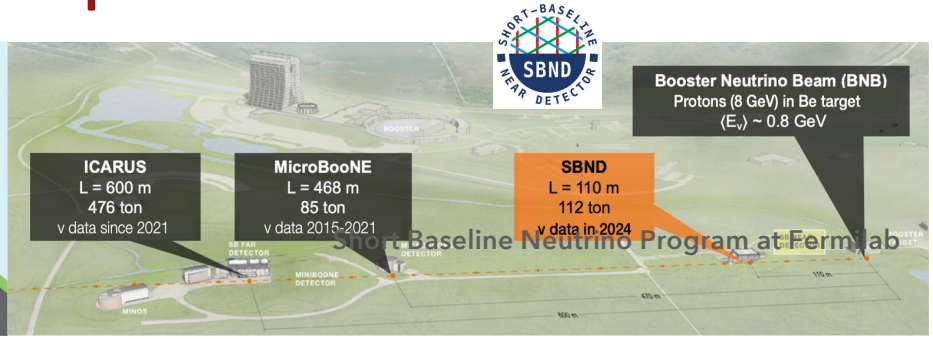
Comparison with state-of-the-art NNLO QCD predictions (+NLO EW corrections)



arXiv:2308.02285

The DUNE Neutrino Experiment





- Fundamental physics at flagship neutrino experiment for the next decades
  - Precise neutrino oscillation measurements:

    CP violation, **neutrino mass ordering**, **PMNS unitarity**
  - New measurements on **astrophysical neutrinos**

    core-collapse supernovae, sun
  - **Beyond Standard Model searches**

    (sterile neutrinos, proton decay, non-standard interactions, dark matter, …)

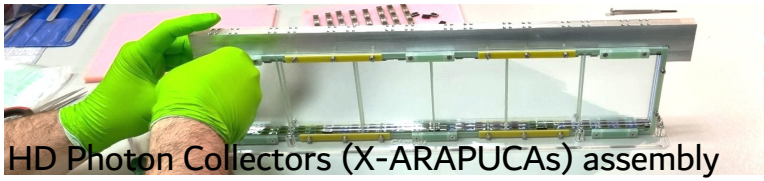
DUNE Phase I (start installation at SURF in 2026, physics 2029, neutrino beam 2031):
FD-VD (17 kton) & FD-HD (17 kton) + 1.2 MW beam + ND
LArTPC prorotypes being tested at the **CERN Neutrino Platform**

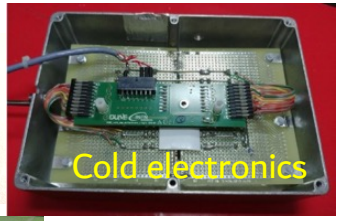
DUNE Phase II:
2 additional FD modules + beam upgrade (>2 MW) + MCND
Opportunities for R&D on LArTPCs to enhance the detector performance and extend physics reach being in explore in DRD2

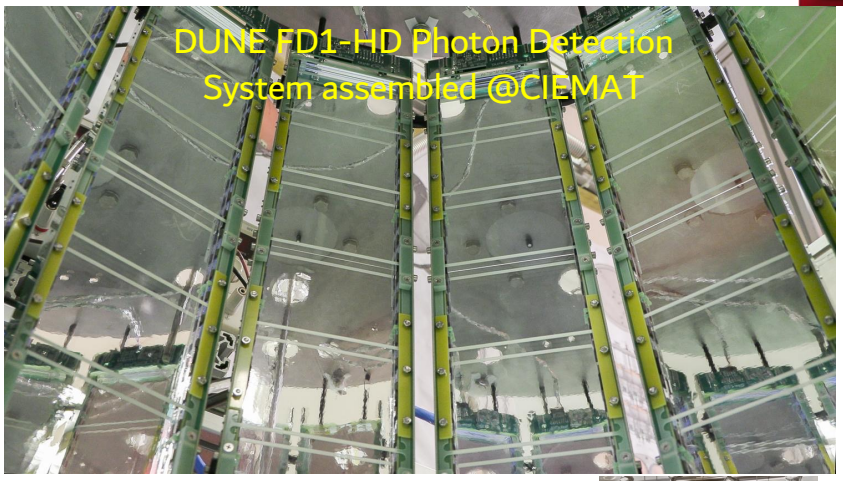
Ciemat

CIEMAT contribution to DUNE detectors


CIEMAT team installing PDS calibration system in ProtoDUNE-VD @CERN


HD Photon Collectors (X-ARAPUCAs) assembly


Cold electronics

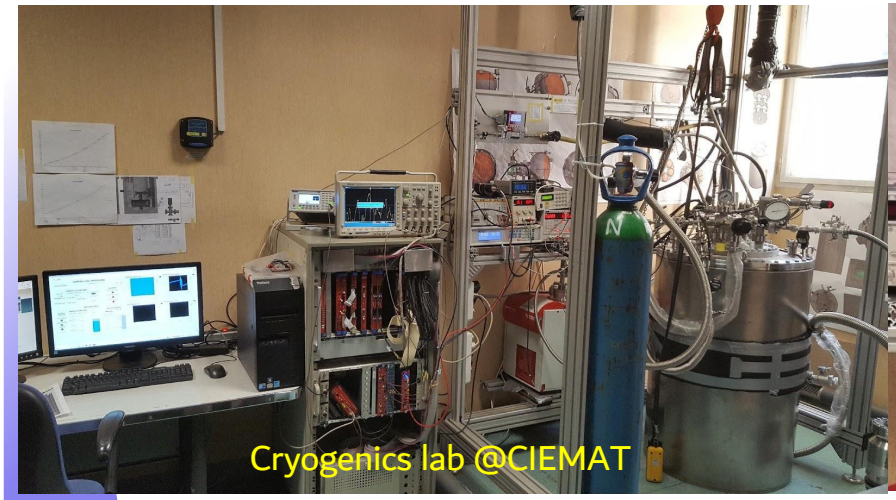

DUNE FD1-HD Photon Detection System assembled @CIEMAT

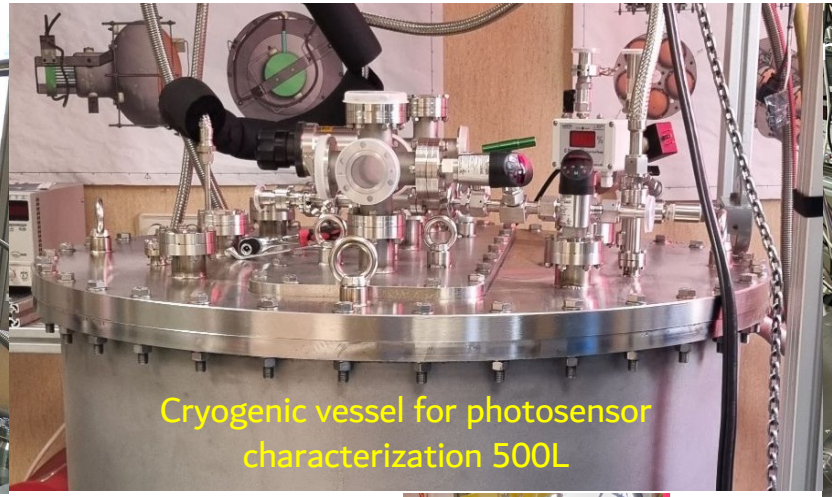

Cryo-testing and characterization of X-ARAPUCAs @CIEMAT

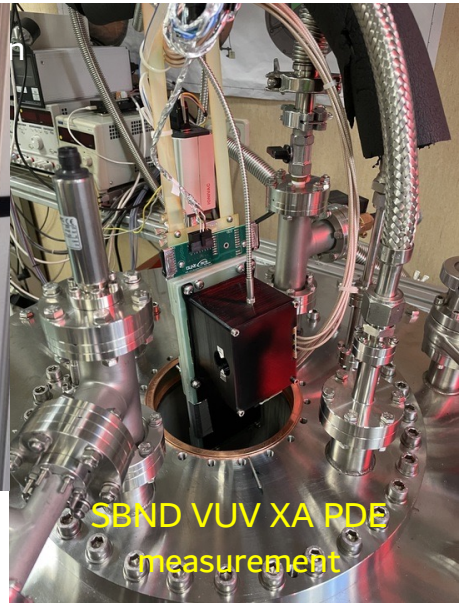

FD2-VD PDS assembly @CIEMAT

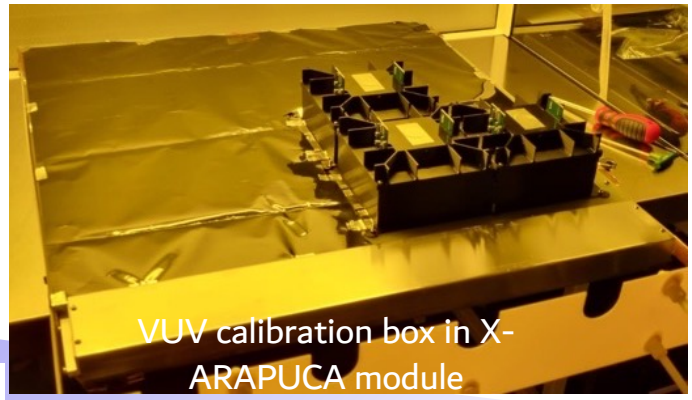

CIEMAT team installing PDS-VD in ProtoDUNE-VD @CERN

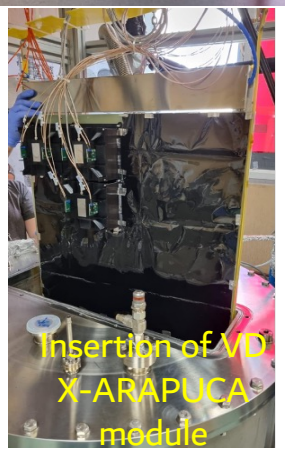
CIEMAT Cryogenic Photon Detection Facility


Cryogenics lab @CIEMAT


Cryogenic vessel for photosensor characterization 500L


SBND VUV XA PDE measurement

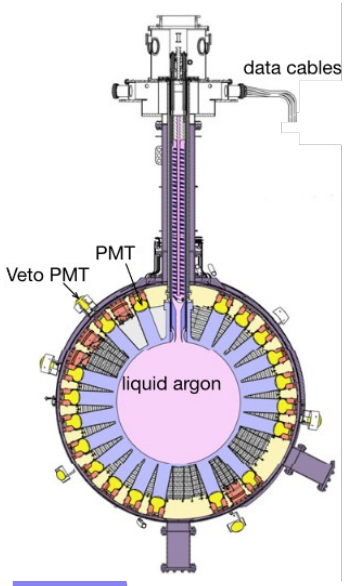

VUV calibration box in X-ARAPUCA module


Insertion of VD X-ARAPUCA module

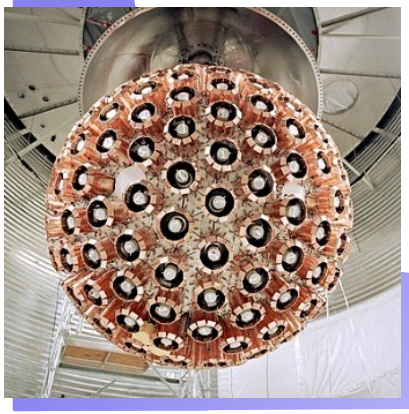
Plan de Recuperación, Transformación y Resiliencia
Funded by the European Union
NextGenerationEU

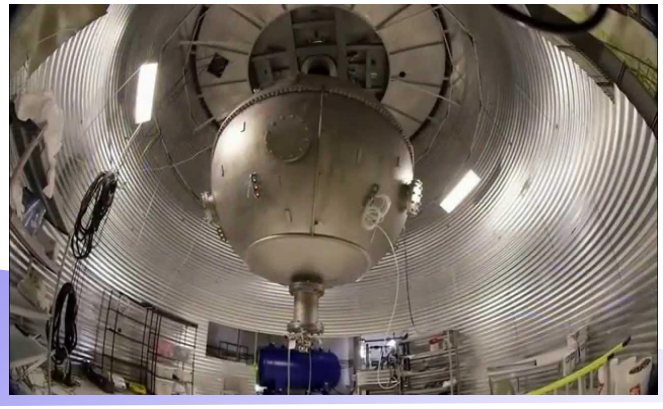
Direct detection of DM: GADMC

DEAP – 3600 @ SNOLAB



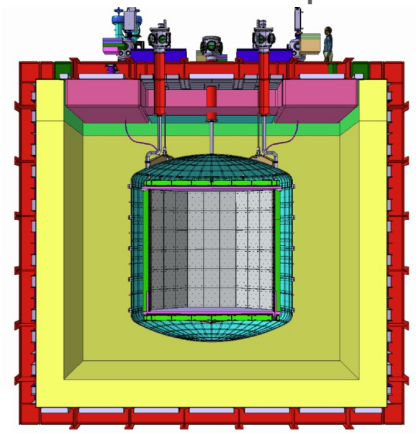
- 3600 kg LAr - Most massive detector of this type for DM
- In operation @ SNOLAB
- New DM run data to be published
- "*First Direct Detection Constraints on Planck-Scale Mass Dark Matter*" CIEMAT

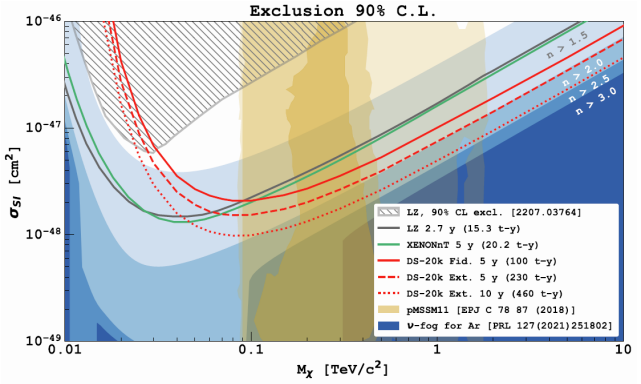


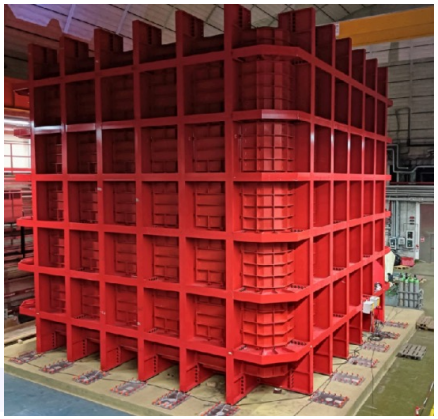


DarkSide-20k @ LNGS

- 50 t radiopure argon in (20 t fiducial)
- 650 t atmospheric argon in the muon veto







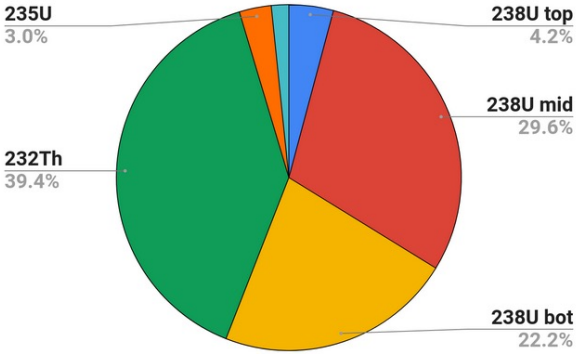
- Two radiopure cryogenic SiPM optical planes (21 m^2 in total)
- 200 t·y: **6.3×10^{-48}cm^2** (90% C.L., 1 TeV/c^2)
- < 0.1 bkg in 200×20 t·y exposure ~***Background free***

Most sensitive for high WIMP mass

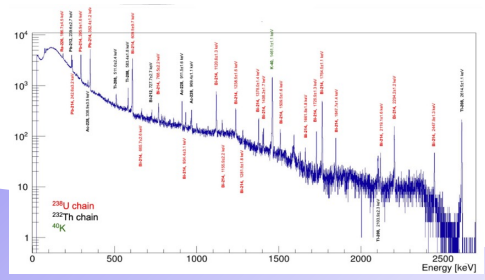
CIEMAT @ DarkSide-20k

Materials background and mitigation strategies

- Responsibility for the Materials assay campaign and bkg calculation:
  - ICPMS, Elemental analysis, HPGe@LSC
  - α,n calculation, Monte Carlo, analysis

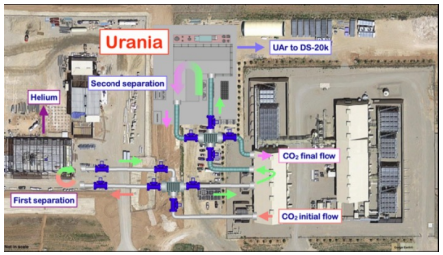


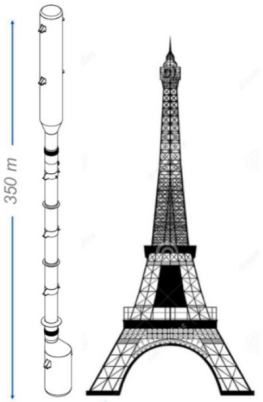
- LNGS environmental radioactivity measurement: Full characterization of γ , n, and radon in the lab, surface contam.



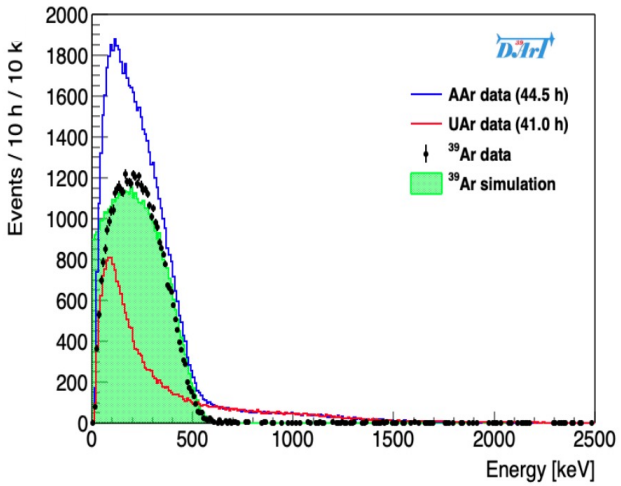
Research of radiopure UG argon

- URANIA project (USA): extraction of underground argon
- ARIA site (Italy): UAr chemical purification
- DArT at LSC (Spain): UAr radiopurity measurement

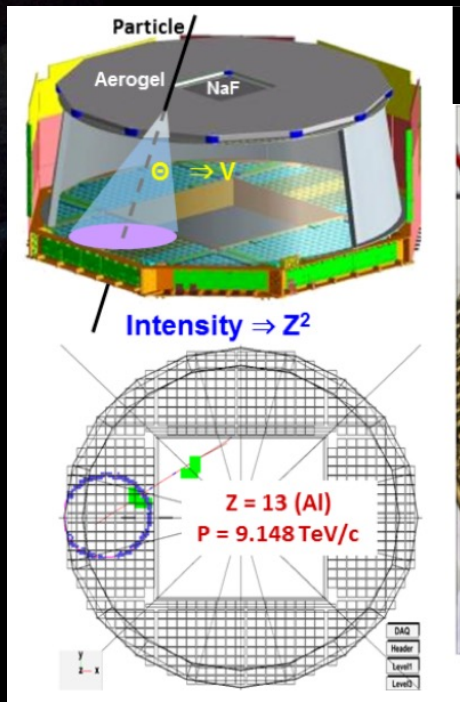


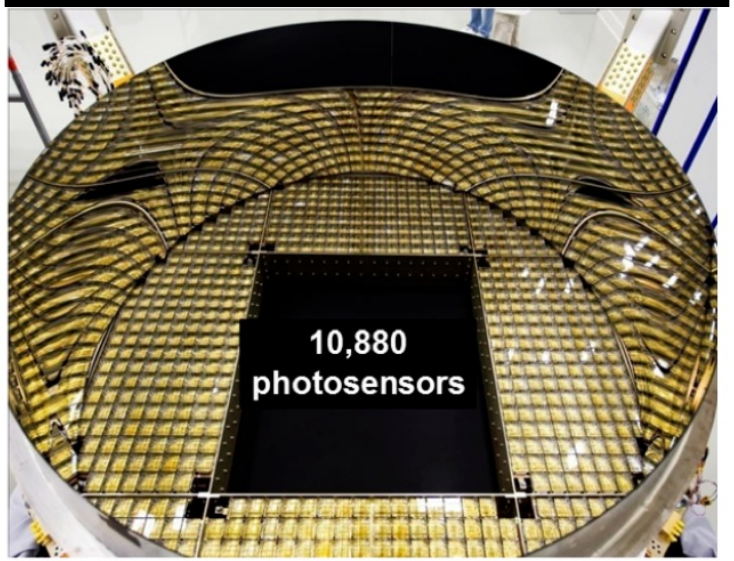


DArT@LSC:



- AMS is a TeV precision magnetic spectrometer installed on the International Space Station in May 2011
- To date, AMS has collected more than 230 billion cosmic ray events





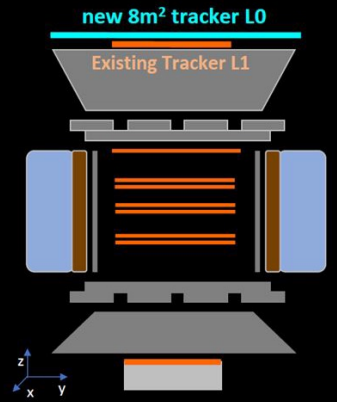
- CIEMAT made major contribution to the AMS-RICH detector and is responsible for its operation

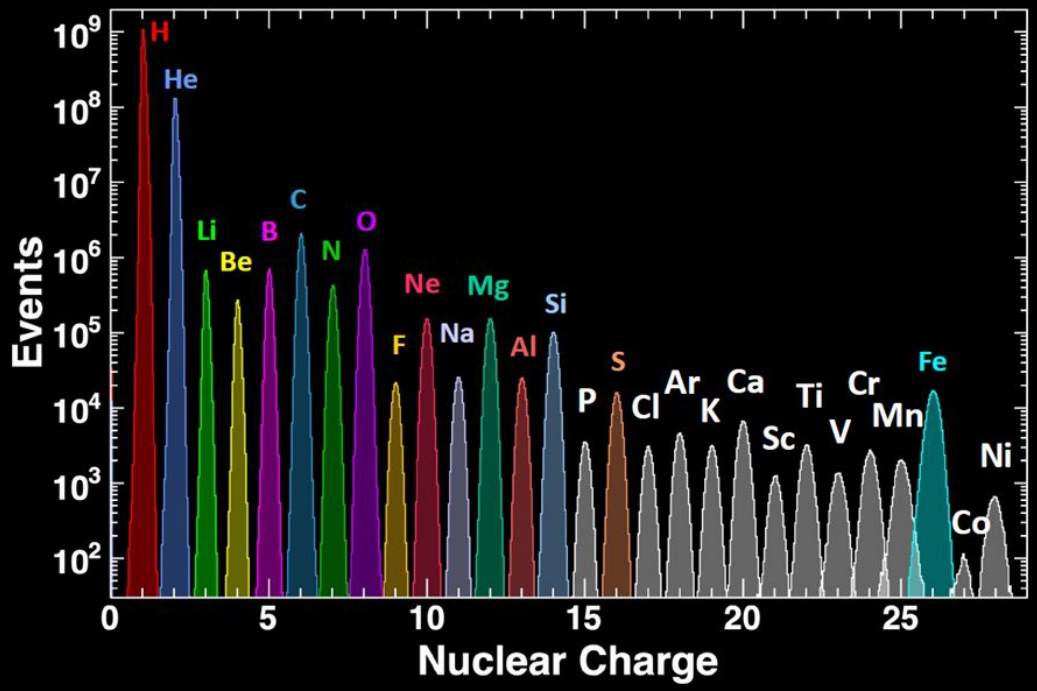
Plan de Recuperación, Transformación y Resiliencia
Funded by the European Union
NextGenerationEU

AMS will continue taking data during the ISS lifetime (2030+) with new tracker layer to increase acceptance to 300%

AMS 2011-2025
Continuous data taking

AMS 2025-2030
Acceptance increased to 300%

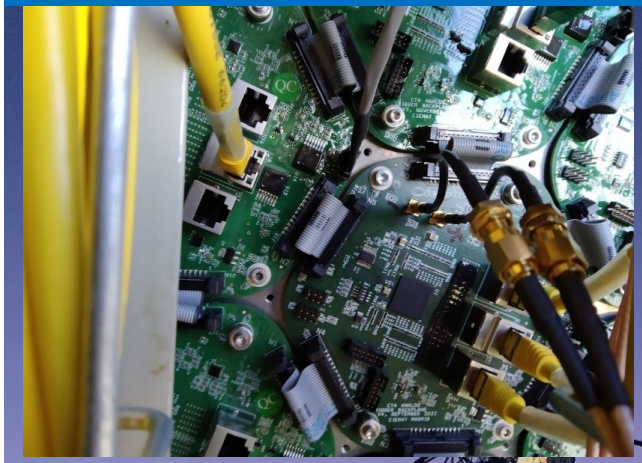




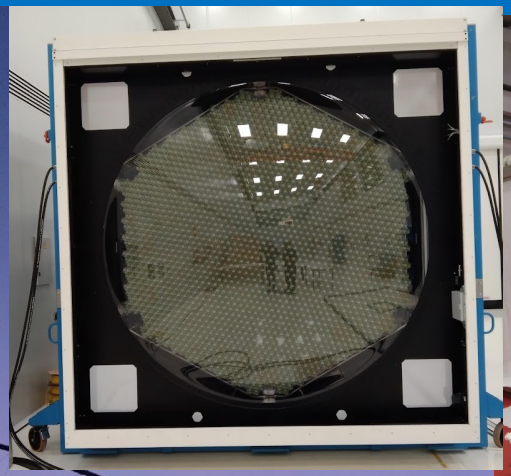
AMS will provide complete and accurate spectra for the 29 elements and provide the foundations for a comprehensive theory of cosmic rays

Plan de Recuperación, Transformación y Resiliencia
Funded by the European Union NextGenerationEU

INSTALLATION OF LST-1 INTENSITY INTERFEROMETER SYSTEM

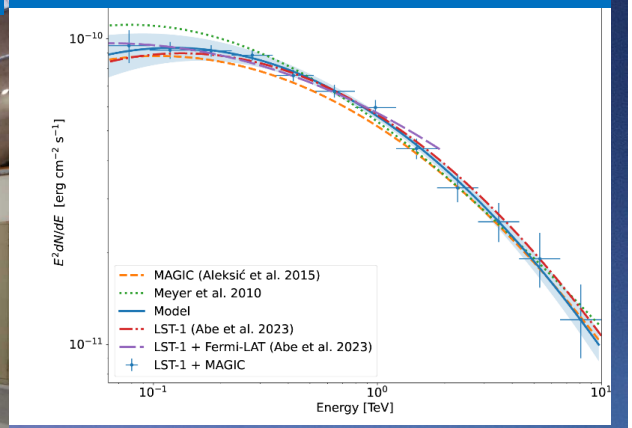


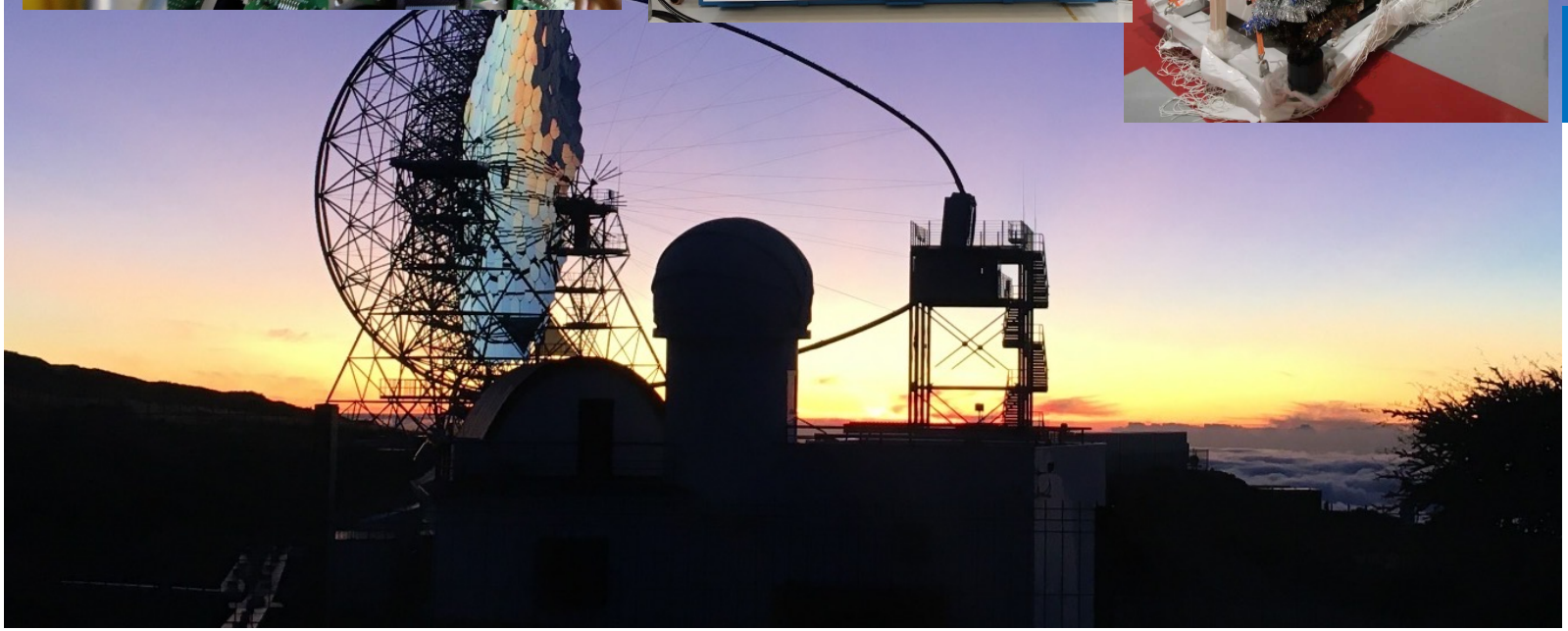
LST-2,3,4 CAMERAS VALIDATED IN LAB



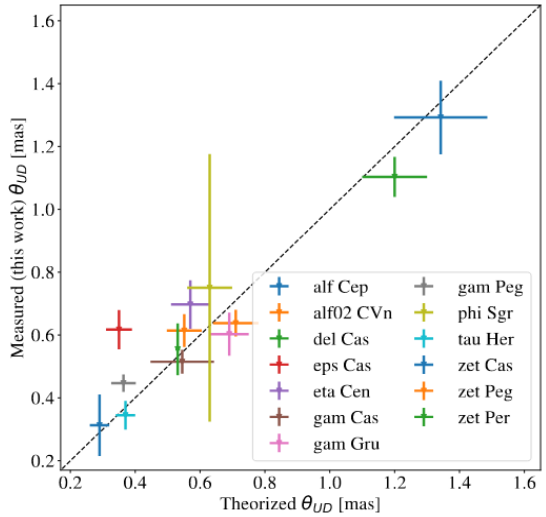
MST CAMERA MECH. DELIVERED

LST-1 PERFORMANCE ASSESED WITH CRAB DATA

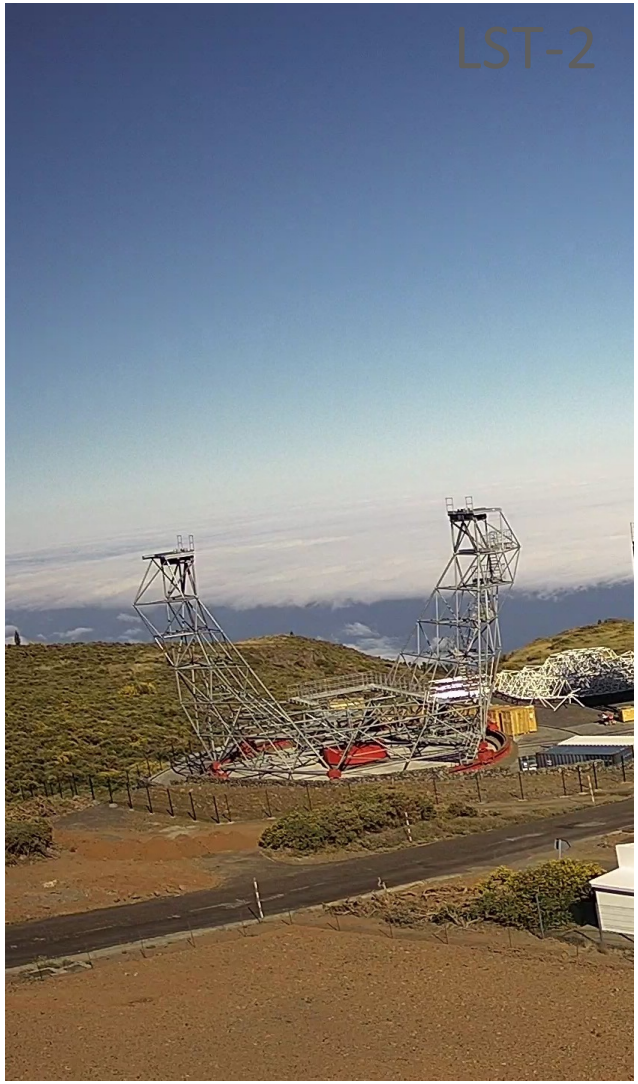




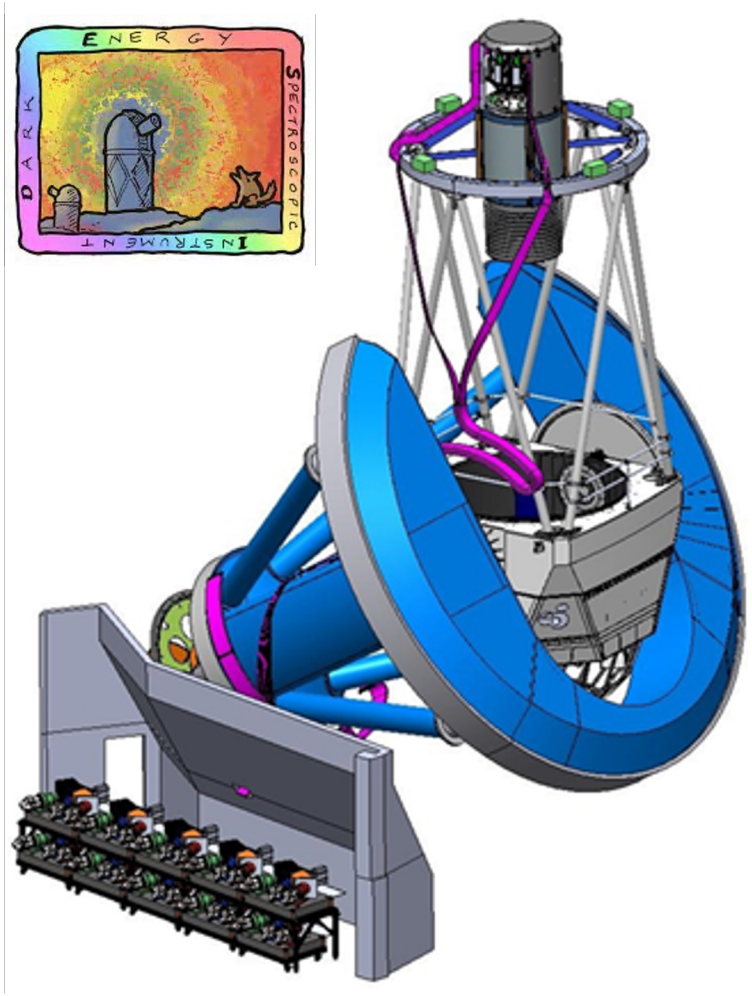
RESULTS ON MAGIC INTERFEROMETER CAMPAIGN

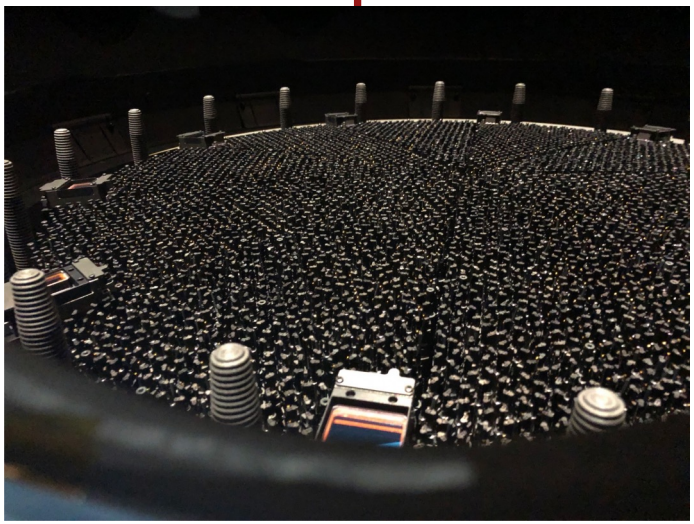


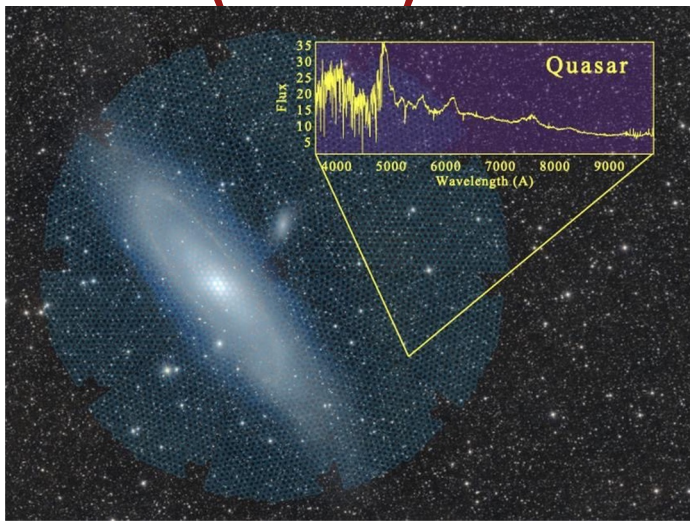
CONSTRUCTION OF LST-2, LST-3 AND LST-4 PROGRESSES AS EXPECTED



Dark Energy Spectroscopic Instrument (DESI)







The DESI collaboration has built and installed:

A new corrector for the Mayall telescope at Kitt Peak (8 sq-deg FOV)

A new top ring, barrel and hexapod

A focal plane with 5000 robots fiber positioner

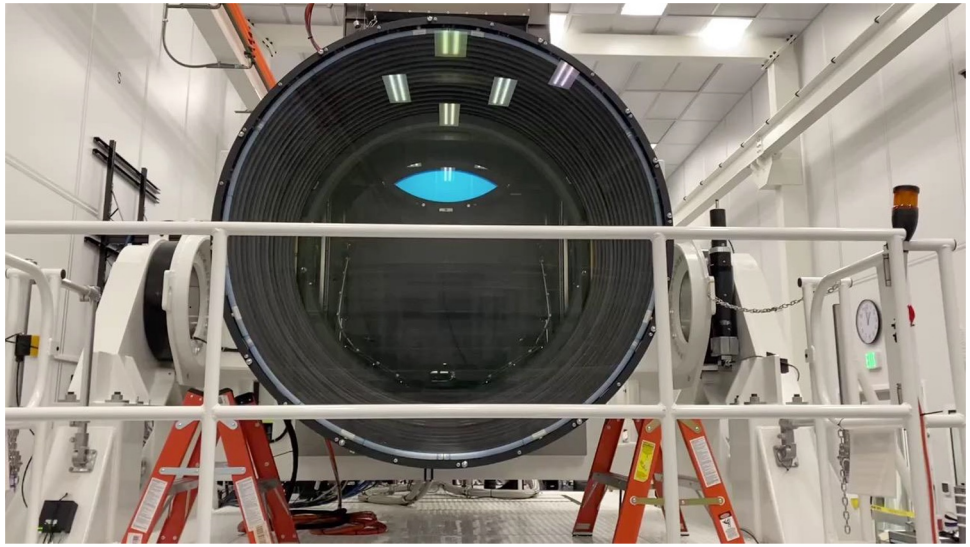
10 espectrographs, following the BOSS design

Instrument control and data proccess systems

Spain: Guiding and Focus System (IFAE, CIEMAT, ICE, UAM)

Data taking started on May 17th, 2021

Legacy Survey of Space and Time (LSST)

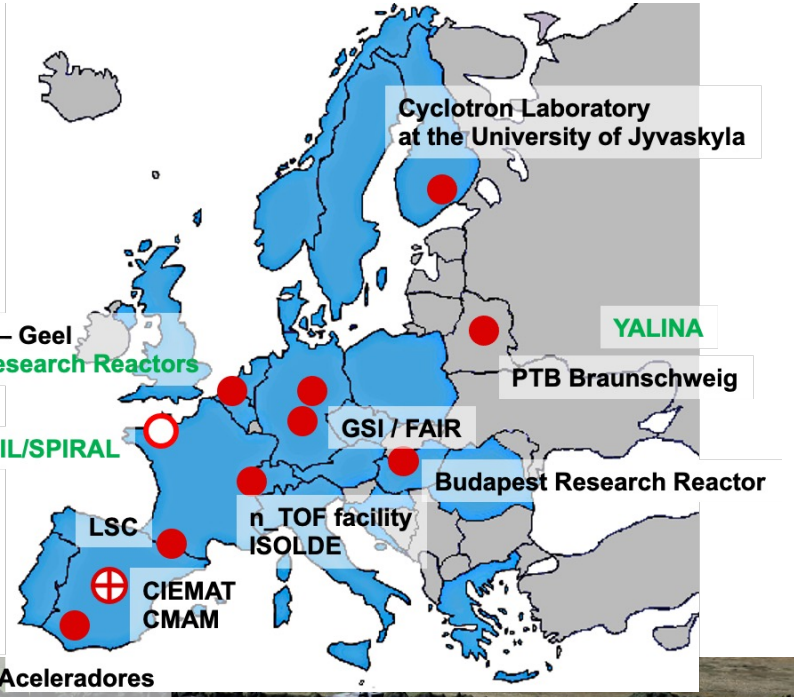


New Observatory (Vera Rubin) in Chile, New telescope and new camera
Currently in commissioning. First light in 2024 and survey start in 2025
CIEMAT: Commissioning, Photo-z, management

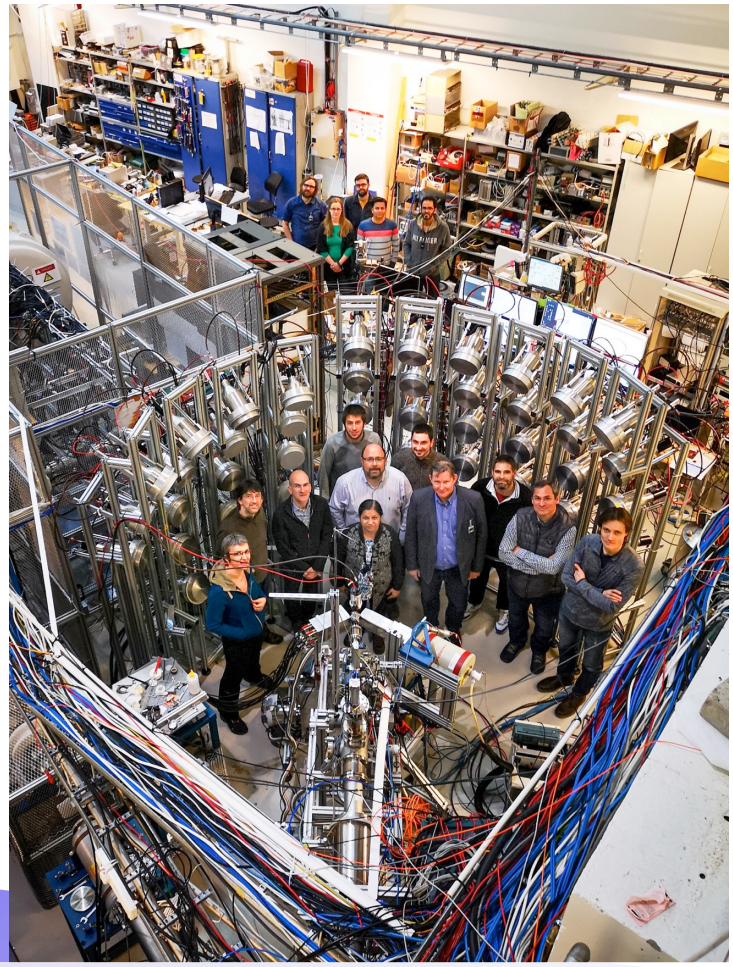
CIEMAT PP Computing infrastructure

- Data centers at PIC (Barcelona) and CIEMAT Madrid
  - 20k CPU cores,
  - 25 PB disk storage,
  - 50 PB tape archive,
  - 200 Gbps WAN network
- PIC is a node of the Spanish Supercomputing Network
- LHC experiments
  - Tier-1 center for ATLAS, CMS, LHCb
  - Tier-2 center for CMS
- Tier-0 center for MAGIC and PAUS
- Spanish data center for CTA and Euclid
- Infrastructure for DUNE, Virgo/Ligo
- Local analysis facility for all scientific projects

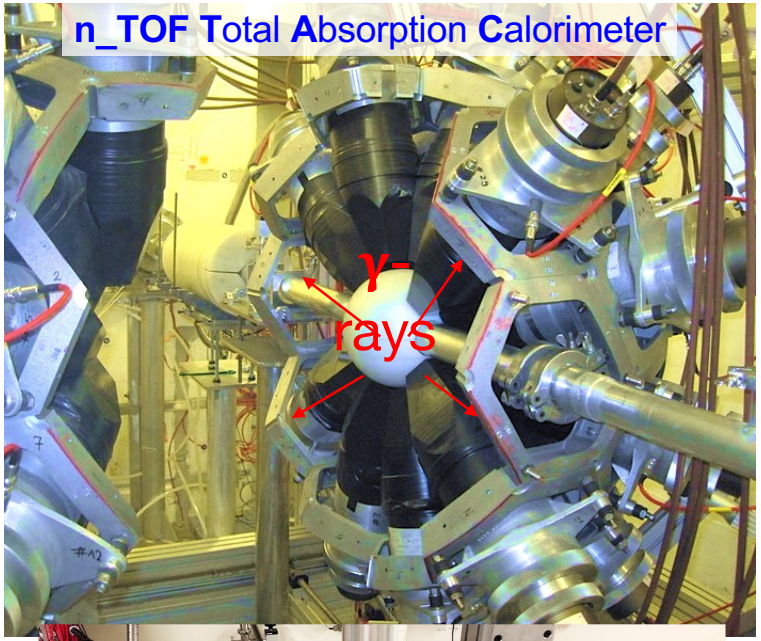
Experiments at CERN n_TOF y other facilities

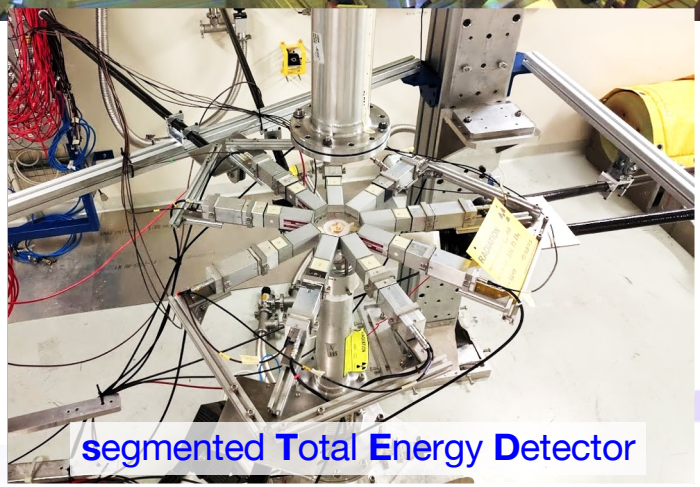


R&D on neutron γ-ray detectors



MOdular **N**eutron **S**pectrome**TER** MONSTER





segmented **T**otal **E**nergy **D**etector