Report from IRFU

Institute for Research into the Fundamental laws of the Universe

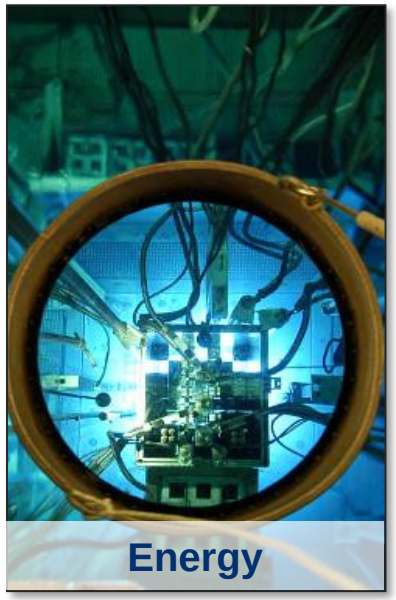
114th Plenary ECFA Meeting – Frascati

Nathalie Besson

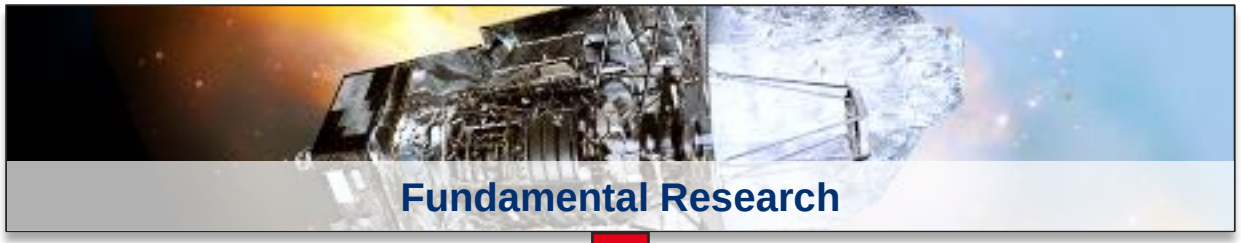
On behalf of IRFU director Franck Sabatié

CEA – The French Alternative Energies and Atomic Energy Commission


Defense


Energy


Technology


Fundamental Research

cea irfu — Institute for Research into the Fundamental Laws of the Universe

21000 employees

5.8 billion euros

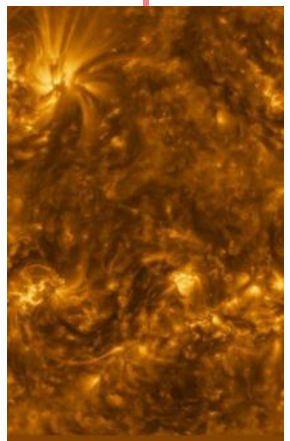
> 5000 publications

> 450 European projets

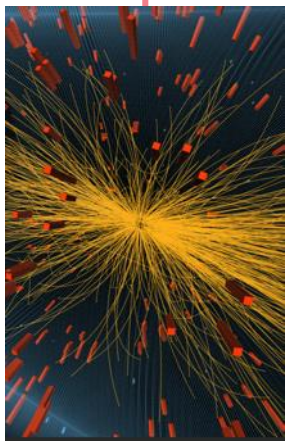
IRFU

cea irfu — Institute for Research into the Fundamental laws of the Universe

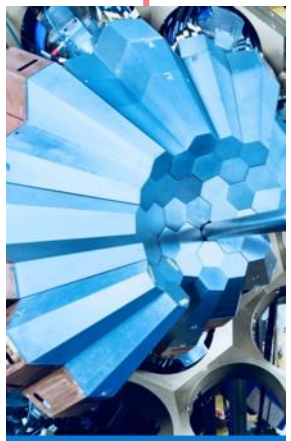
Management Office



DAP
Astrophysics



DPHP
Particle Physics



DPHN
Nuclear Physics

GANIL
Heavy Ion National Accelerator

DEDIP
Detectors
Electronics
Computing

DACM
Accelerators
Cryogenic
Magnets

DIS
System Engineering

1050

900/y

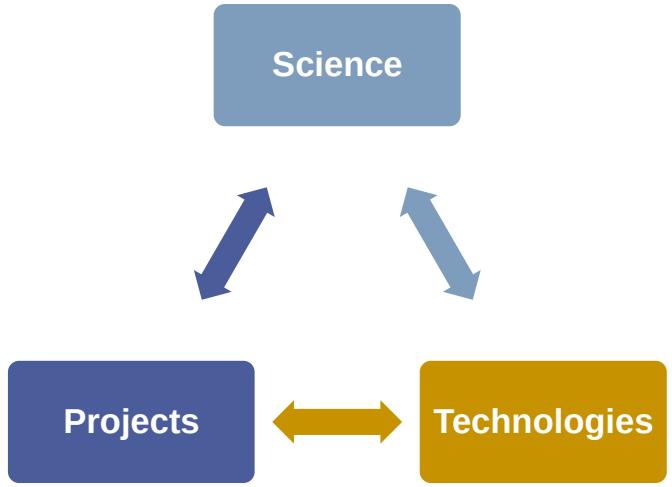
24 ERC
(8 ongoing)

Missions of IRFU

- **Carry out technological and fundamental research** within the framework of CEA's missions, in order to explore the fundamental laws of the Universe, from the smallest scales (elementary constituents, nuclear matter) to the largest (energy content and structure of the Universe)
- **Apply our technological innovations** to major national or international projects: MRI or fusion magnets, accelerators and neutron sources, medical imaging, etc.

With two specificities due to IRFU's size and the strong integration of its departments:

- **Ability to cover the entire research chain**
  - Theory, experiment proposal, simulation, design, construction, operation, data analysis, phenomenology and communication
- **Ability to manage large, innovative and complex projects**
  - Accelerators, magnets, detectors



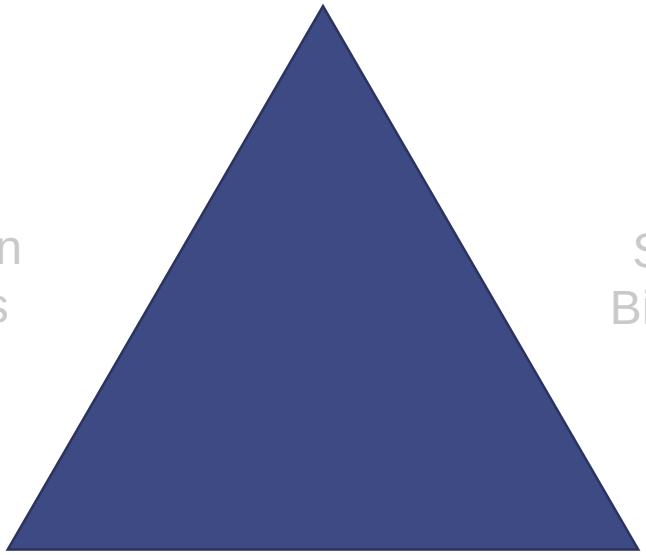
Science

Structure of the Universe

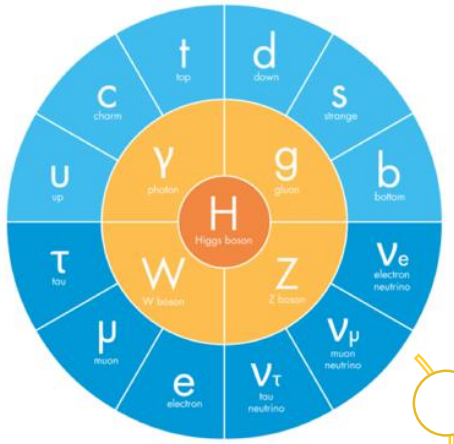
- Energy content of the Universe
- Formation and evolution of structures, galaxies, stars
- Stars and planetary systems
- Exploration of the transient Universe

Detection systems

Simulation and Big data analysis



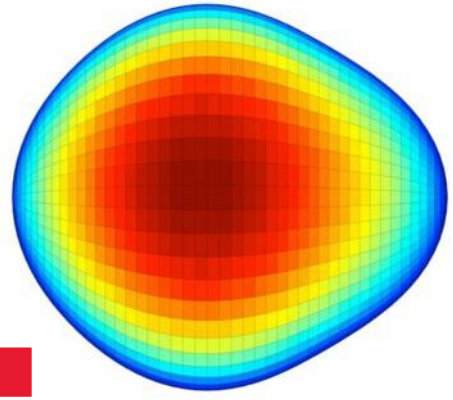
Accelerator systems and cryomagnetism



Elementary constituents, Fundamental symmetries

- Consistency tests of the standard model
- Structural tests of the standard model

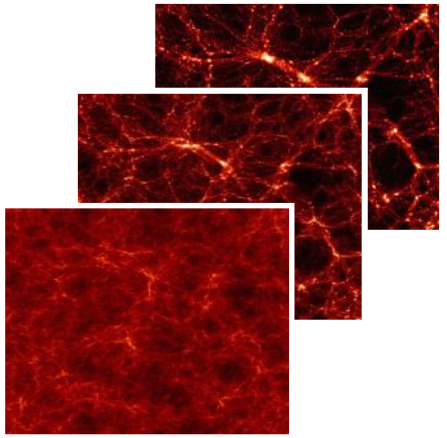
Property of Nuclear matter



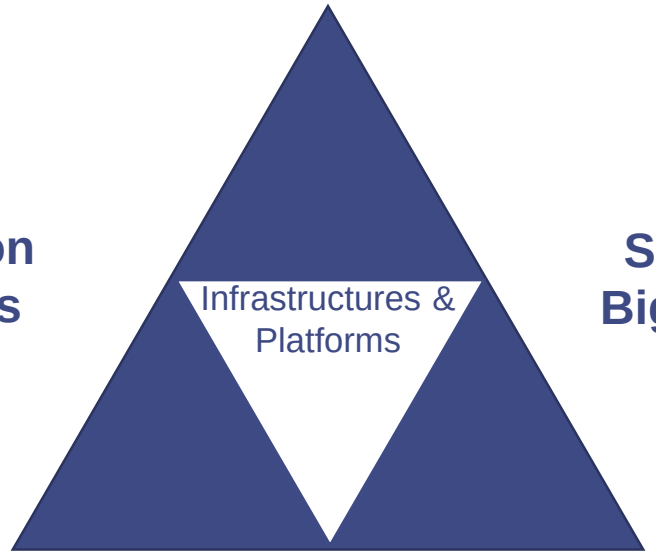
- Nuclear structure and dynamics
- Dynamics of quarks and gluons

Technologies

Structure of the Universe



Detection systems



Simulation and Big data analysis

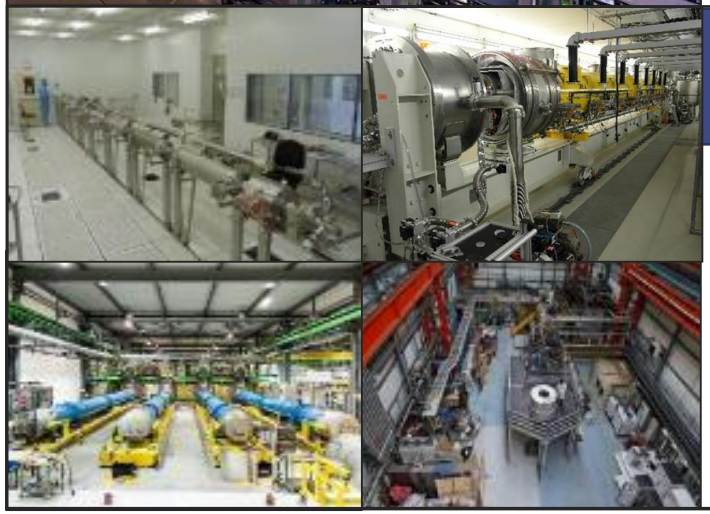
Elementary constituents, Fundamental symmetries

Property of Nuclear matter

Accelerator systems and cryomagnetism

Platforms

COMPUTING	SPACE
3 HPC clusters 13000 cores, 2500 Mh HS06/y **LHC Grid** (tier 2) 9000 cores, 500 Mh HS06/y	**Clean rooms** iso5-8 Instrumentation **Integration** and test halls



MAGNETS ACCELERATORS	DETECTORS
Synergium 25000 m^2 Clean rooms iso4-5 Integration halls and test cryostats	**Clean rooms** incl. Ciclad iso7 130m^2 and iso5 50m^2 **Integration** and test halls

Cyclotrons: ion beams from ^{12}C to ^{238}U at different energies
SPIRAL2: high intensity beams including light ones (p and d)

Elementary constituents, Fundamental symmetries

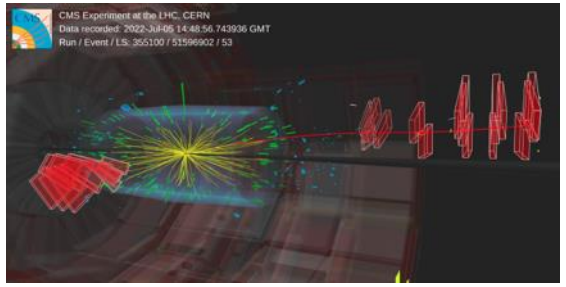
Consistency tests of the Standard Model

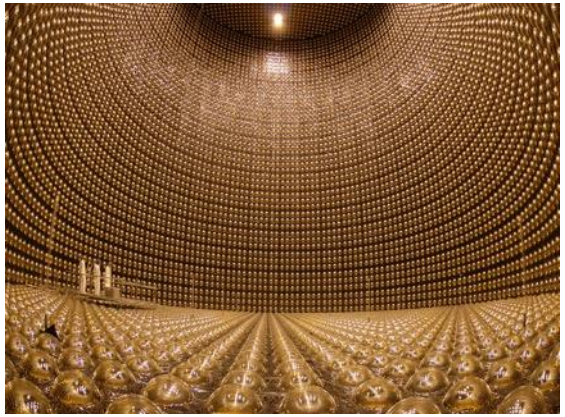
Search for deviations from the Standard Model by studying bosons and quarks

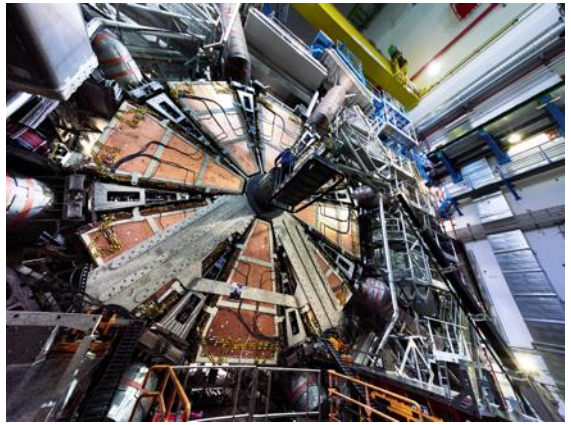
Structural tests of the Standard Model

Mass hierarchy, nature and properties of neutrinos

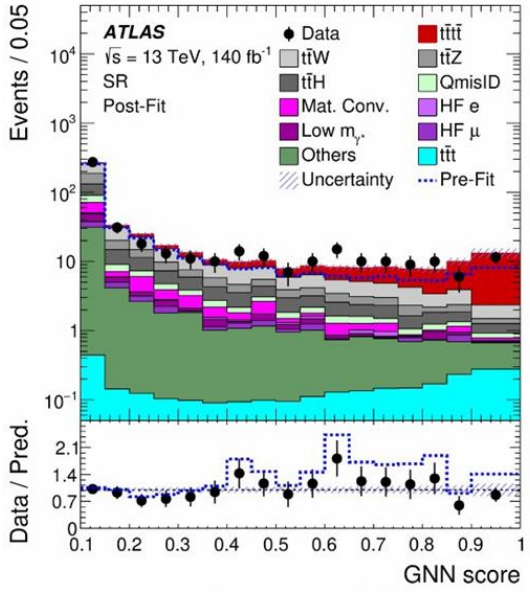
Current LHC Experiments
ATLAS & CMS Upgrades
T2K
HyperK
DUNE
NUCLEUS
KATRIN
CUPID
GBAR







Highlight - LHC Run 3 and Phase 2 upgrades

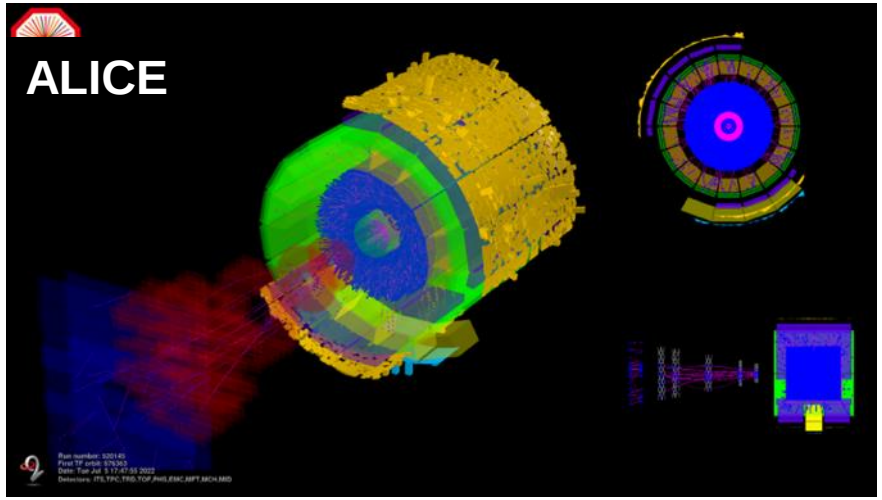


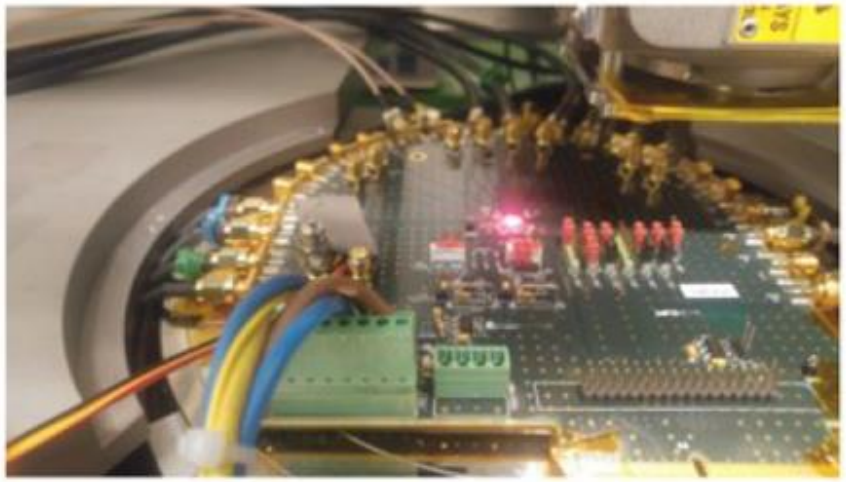
Run 3 at the record energy of 13.6 TeV

- Inc. phase 1 upgrade (ATLAS/NSW, ALICE/MFT+MUONS)
- Main focus on Higgs, EW and top physics

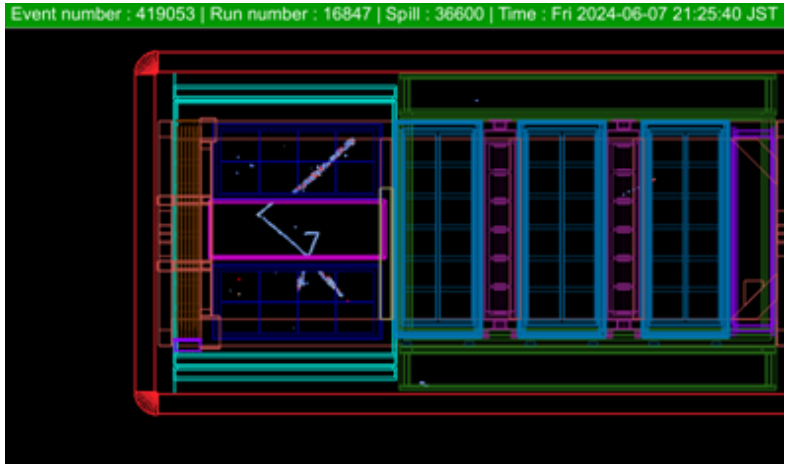
Phase 2 upgrades in production phase

- ATLAS (Itk, LAr, HGTD, MUONS) & CMS (BCAL, HGCAL, MTD)





Highlight – T2K and KATRIN



Commissionning of JPARC & T2K ND280 upgrades

- **JPARC**: beam power @ 800 kW
- New ND280 is taking data with new target and new high angle TPCs

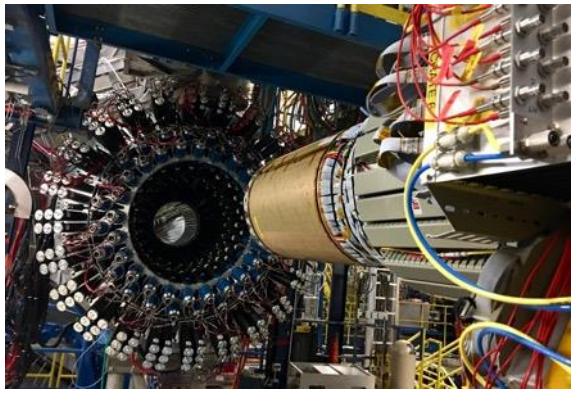
KATRIN unveils its last results @ NEUTRINO2024

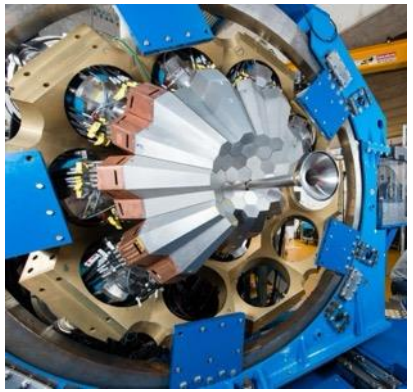
- Analysis of 259 jours of data (x6 wrt previous results)
- New upper limit: $m_\nu < 0.45$ eV at 90% CL

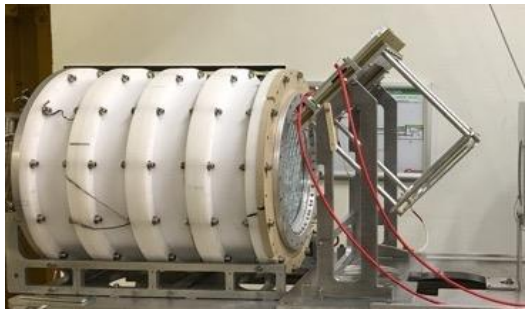
Property of Nuclear matter

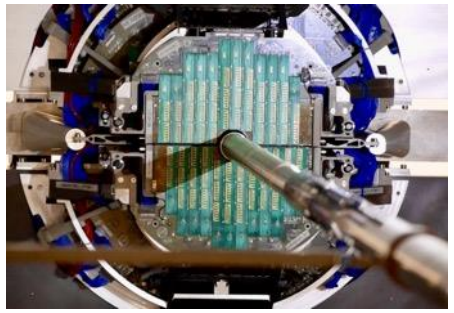
- **Nuclear structure and dynamics** — Binding limits of nuclei, nature of the nuclear interaction, influence of the nuclei structure on nuclear reactions
- **Dynamics of quarks and gluons** — Quark and gluon plasma, 3D structure of the nucleon

GANIL
Spiral2 (NFS, S3, DESIR)
AGATA
FAIR
n_TOF
Nuclear Theory
ALICE
LHCb upgrade
sPHENIX
Jefferson Lab
EIC
Hadronic Theory









Highlight - GANIL

SPIRAL1 and 2 new beams

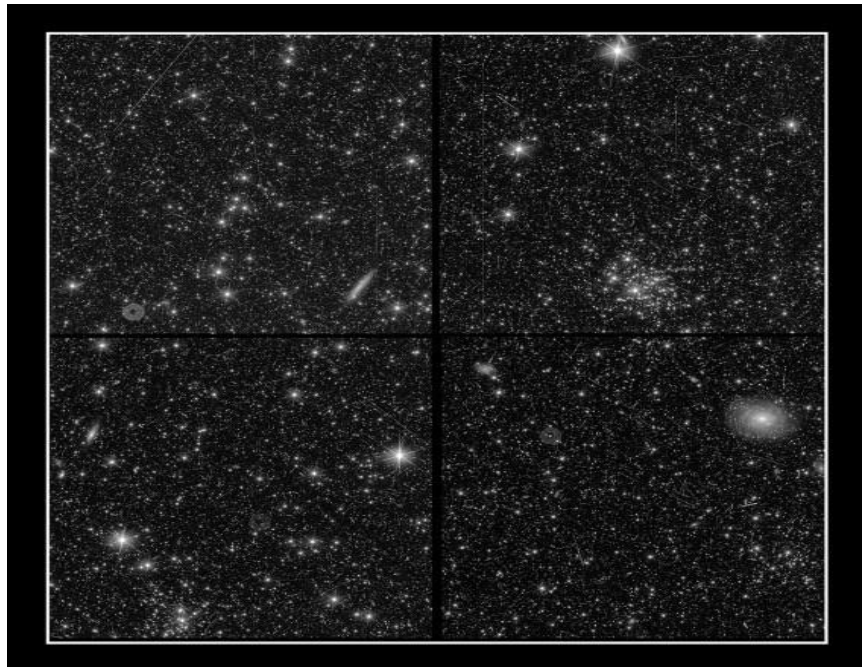
- After protons in 2019 and deutons in 2021, GANIL's linear accelerator is taking its first steps in accelerating heavy ions produced in the source
- 2022: Oxygen-18, a pilot beam for tuning many ions in the Linac, accelerated at 7 MeV/u
- 2024: first Lithium-8 beam cooled down to ~1 MeV/u produced

Structure of the Universe

Energy content of the Universe	Constraints on dark energy and dark matter
Formation and evolution of structures, galaxies, stars	Structure of the universe from the cosmic microwave background to the stars and the galaxies
Stars and planetary systems	Characterization of exoplanets and their host stars, study of the star-planet interaction
Exploration of the transient Universe	Multi-messenger observations (photons, GW) of transient phenomena in the Universe

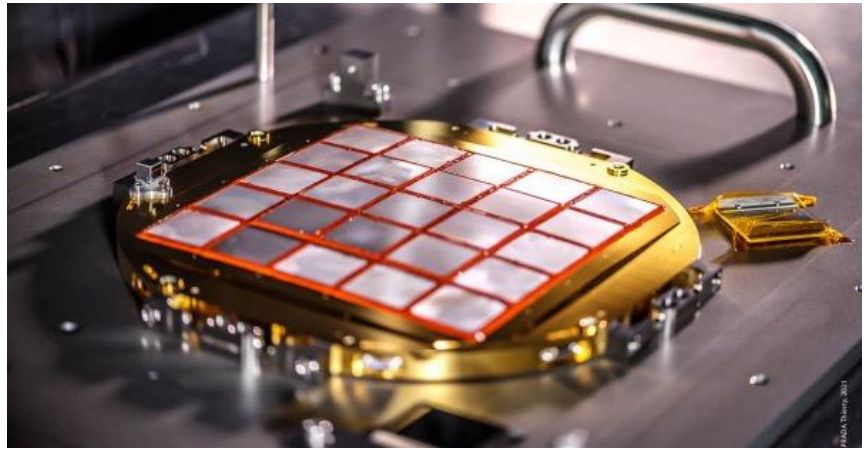
LISA	ARIEL
HESS	PLATO
DESI	SVOM
EUCLID	CTA
LITEBIRD	THESEUS
James Webb	SKA
ATHENA	

Highlight – EUCLID and SVOM



EUCLID

- Successful launch on 2023, July, 1
- EUCLID released last November 5 images from ERO
- First set of publications last January



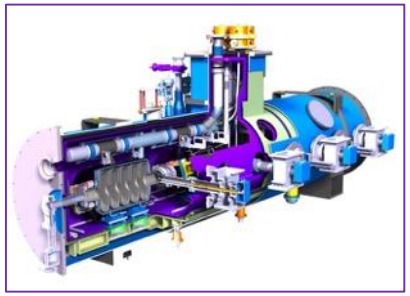
SVOM

- Successful launch on June, 22
- Instruments are alive and data flows to the VHF network

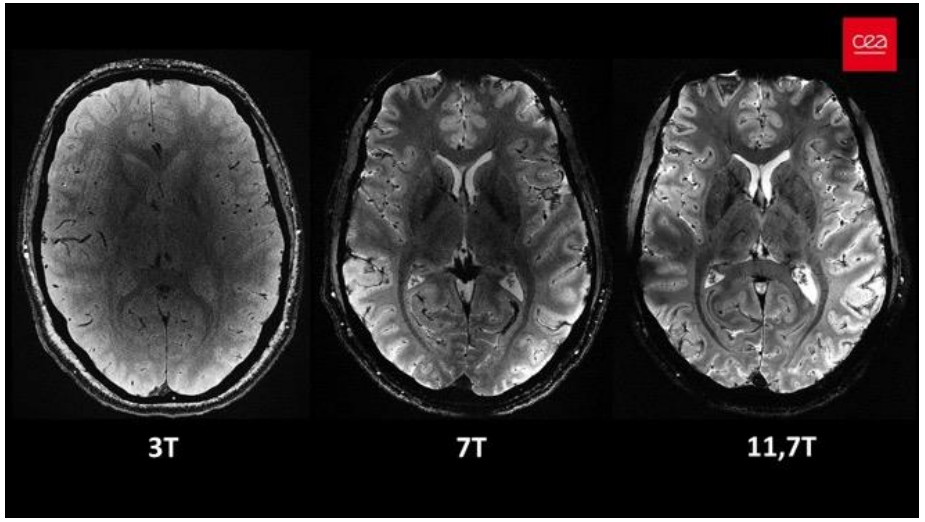
Accelerator systems and cryomagnetism

- **High-intensity/energy accelerators** — Developments of RF sources and injectors, studies on future colliders
- **Superconducting RF systems** — Cryomodules and superconducting cavities, studies on higher efficiency or gradients, and new cooling technologies
- **High-field superconducting magnets** — Simulation, design, manufacturing and operation of high-field / large / "special" / high homogeneity magnets

IFMIF	ISEULT (MRI)
TITAN / ICONE	CERN HL-LHC
NEWGAIN	CERN HFM
SARAF	EIC magnets
ESS	MADMAX
PIP-II	SUPRAFUSION (HTc)



Highlight – Magnets: ISEULT and HFM



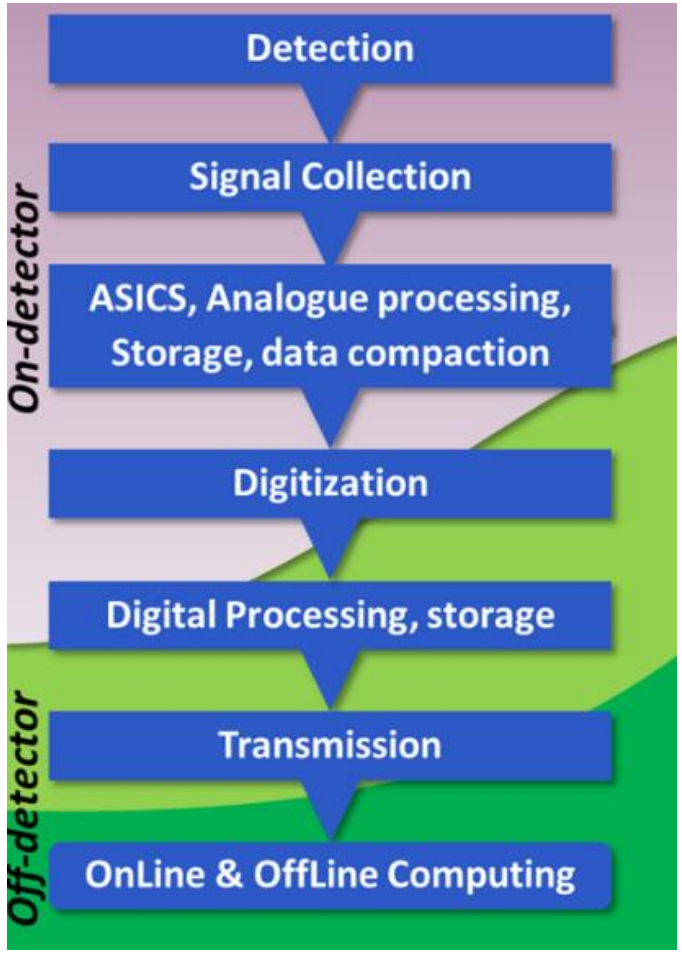
11.7 T Iseult MRI

- Commissioning of the 11.7 T Iseult MRI
- The first images on humans were released in April, culmination of nearly 20 years of research and development by the CEA

High Field Magnets

- In 2023 signature of two 5-years collaboration agreements between CEA-IRFU and CERN
  - Toward 16T magnets with Nb3Sn
  - Toward 20T magnets with HTS

Detection systems and Computing



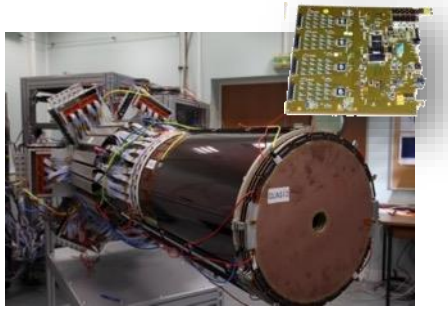
Strategy
- Full detector chain capability, from sensor to software
- Full TRL chain, including knowledge-transfer to industry
- From lab R&D to M&O in large international collaborations

R&T	Development	AIVT	Experiments
Microelectronics	Electronics & RT computing	Integration on PCBs	Installation Commissioning
New Detectors	Detector development	Detector construction & Integration	Operation
Signal Treatment	Software archi & developmt	Software integration	Maintenance

Physics departments | System engineering

Sample of projects in operation

detection
electronics
computing



CLAS12 (hadronic hysics) @ Jefferson Lab (USA):
Micromegas Tracker 30000 channels

T2K Micromegas Time projection
chambers system Tokai Lab (Japon)

DESI (Dark Energy survey)
10 spectrometers installed at Mayal (USA)

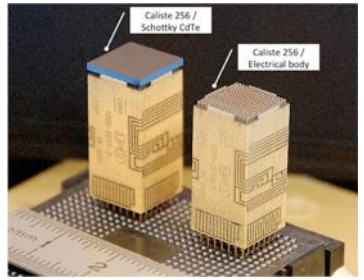
ATLAS Calorimeter
72 Digital Trigger
boards (200Gb/s /board)

CERN
LHC phase 1 Upgrades

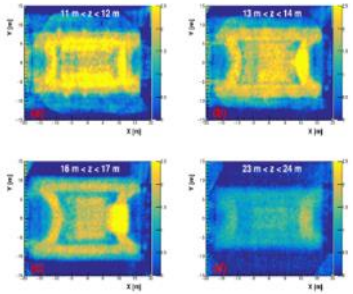
ATLAS New Small Wheels
400m² of Micromegas
detectors

ALICE Muon Forward Tracker
based on MAPS technology

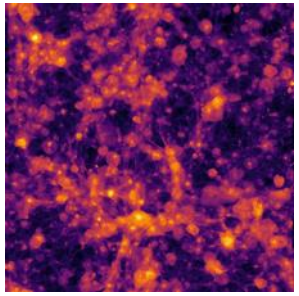
ALICE muon arm
Upgraded back-end electronics



Solar Orbiter / Caliste: mini
CdTe gamma camera

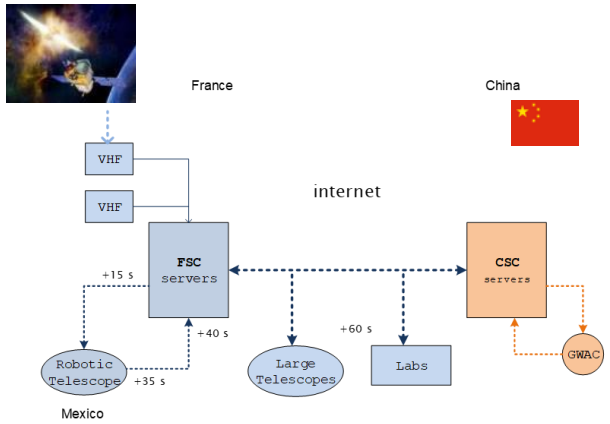


Muon imaging (here tomography
of an historical reactor)

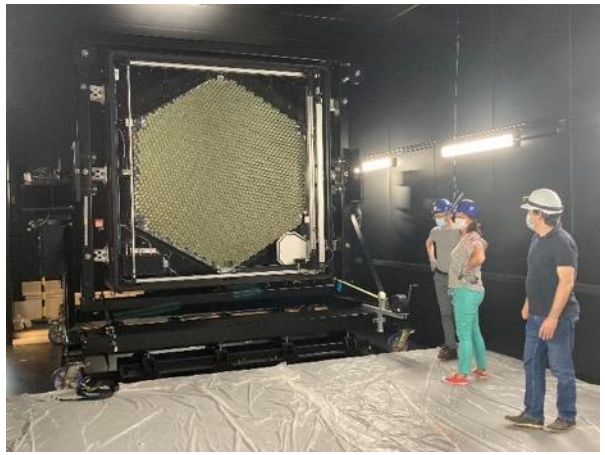


Extreme Horizon : 50Mhours
computation on TGCC/Joliot Curie

Sample of projects in development



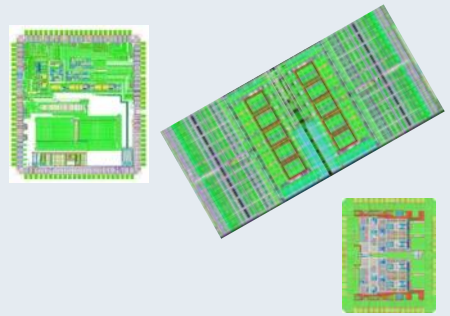
SVOM satellite for gamma ray burst detection (launch 2024)
FE electronics
On-board computing
Ground Segment (detection & world broadcast of alerts)



NectarCAM for the medium size telescopes of CTA (2024-2028)
Digitizers chips, software
Integration and qualification of 9 camera
Mirrors

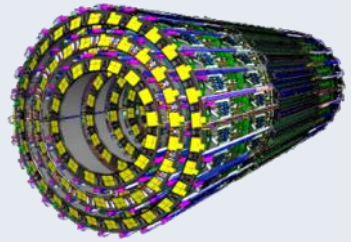
ESS Advanced beam diagnostics (2023)
High Intensity profile monitors and low energy beam loss monitors

Sirius Silicon detectors used at GANIL/Spiral2-S3

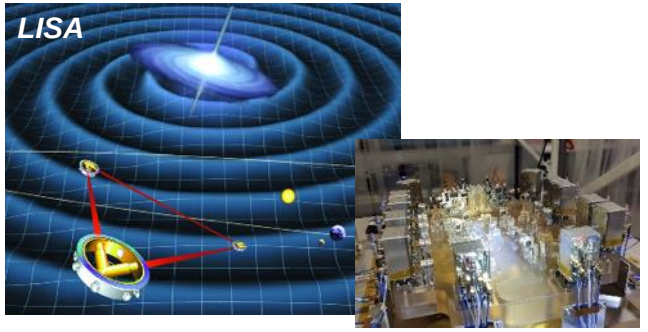


LHC phase 2 Upgrades

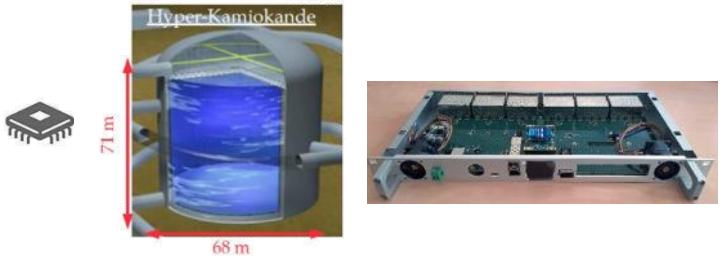
CMS chips for the calorimeters + clock distribution.
Extreme radiation hardness.10ps timing precision



ATLAS Itk Module assembly and testing.
1/4 of the silicon internal Tracker



LISA gravitational wave interferometer in space (launch 2032)
Contribution to the LISA optical bench (ground equipment): ultra-stable mechanical structures
Data analysis based on IA technologies



HyperK Neutrinos Oscillations (Japan, 2025)
High precision clock distribution system

DRDs @ IRFU

Involvement mainly in 4 DRDs

DRD1 Gazeous detectors – WP 1, 4, 7, 8, 9

- Maxim TITOV co-spokesperson
- TPC expertize (NA61/ ND280 Upgrade++/ DUNE ND) & R&D for the ILC

DRD3 Solid state detectors – WP1

- R&D for radhard and low power readout
- CACTUS/miniCACTUS (MAPS with high timing resolution < 50ps)

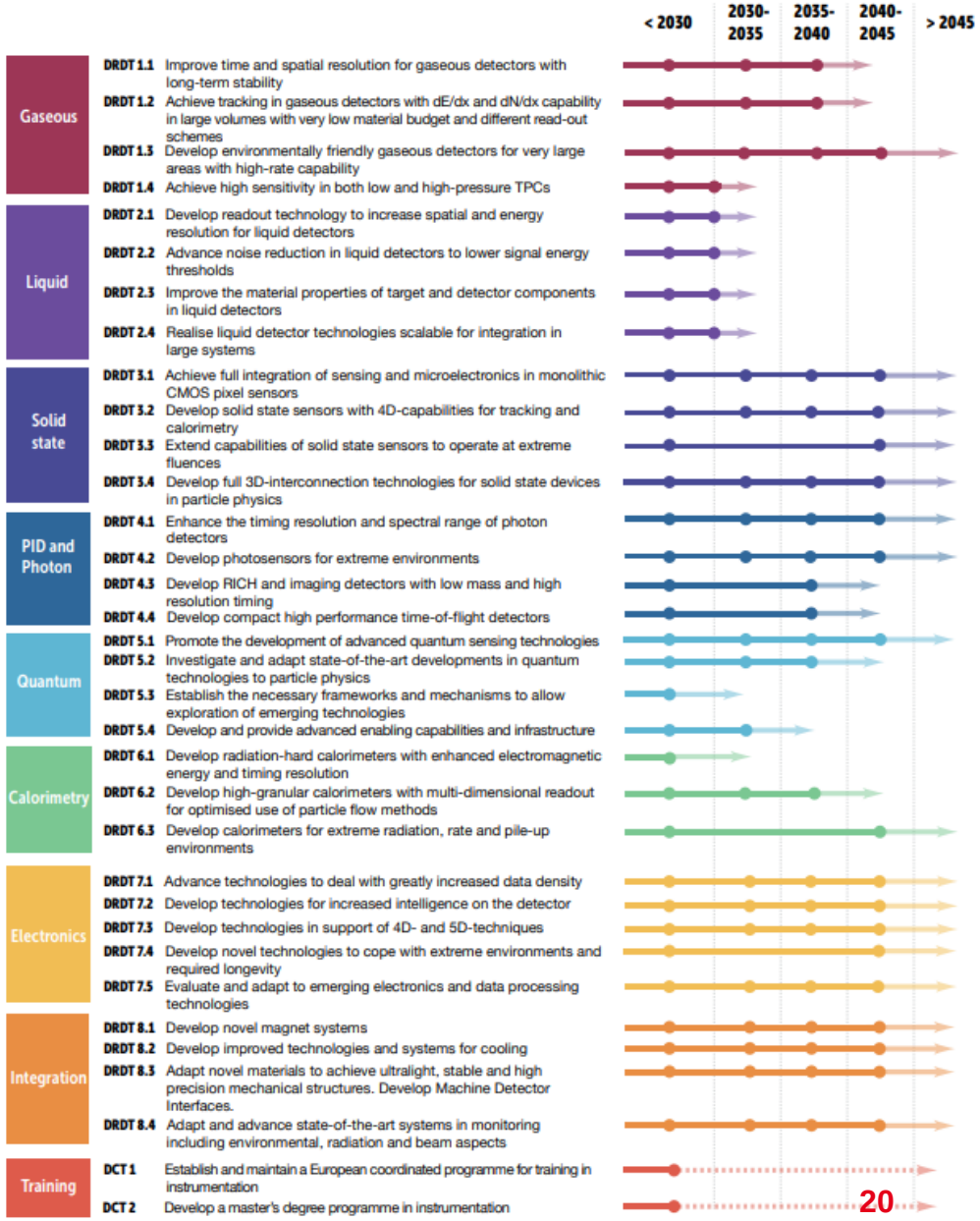
DRD6 Calorimetry – WP3

- Optical calorimeters, 5D Calorimetry and high temporal resolution (ClearMind)
- Scintillating bolometers for $0\nu2\beta$ (BINGO, TINY, CUPID)

DRD7 Electronics – WP3

- High performance TDC and ADC
- Continuation of efforts on HGCROC for CMS phase 2 AND EIC/AC-LGADs (10ps and below low power TDCs)

Participation to DRD4 on photodetectors, building on ClearMind experiment



European Strategy in Particle Physics Update

- Full commitment
- Specific animation within IRFU
- Organization of French community contribution together with CNRS/IN2P3

Thank you for your attention