Report from IRFU

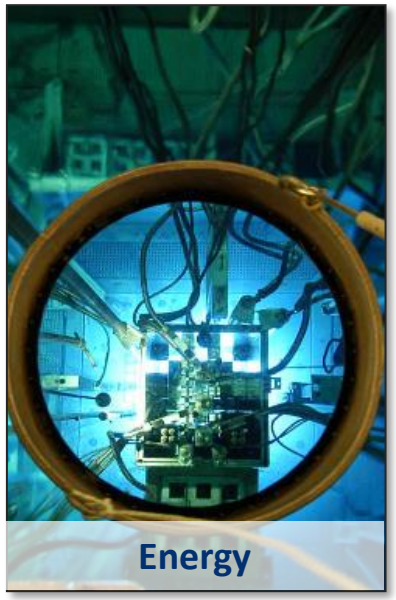
Institute for Research into the Fundamental laws of the Universe

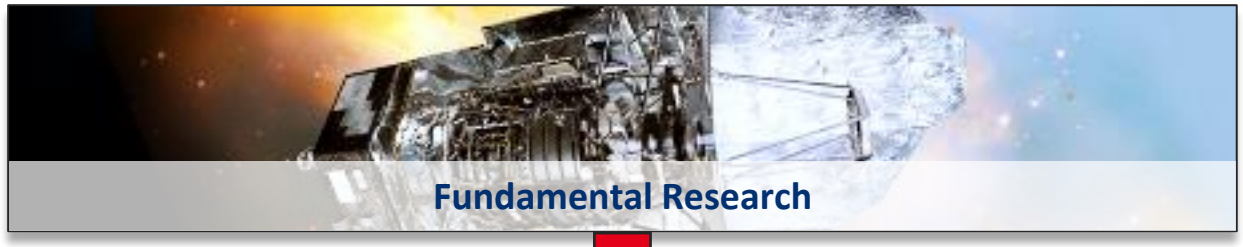
FJPPN & FKPPN workshop – May, 2025

Nathalie Besson

On behalf of IRFU director Franck Sabatié

CEA – The French Alternative Energies and Atomic Energy Commission





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

21000 employees

5.8 billion euros

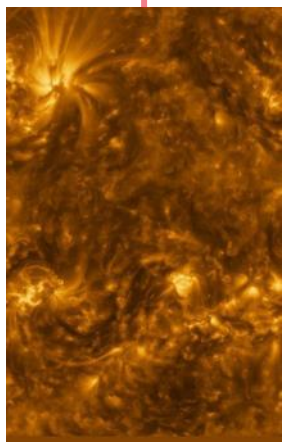
> 5000 publications

> 450 European projets

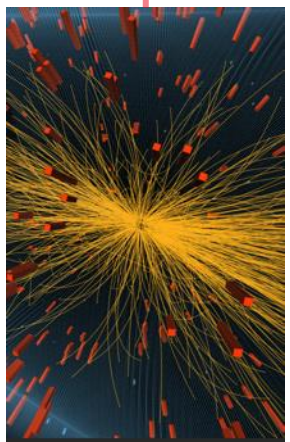
Staff on 2024, December

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

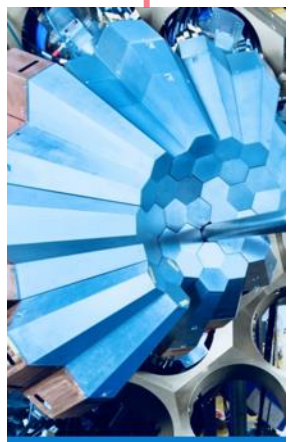
Management Office



DAP
Astrophysics



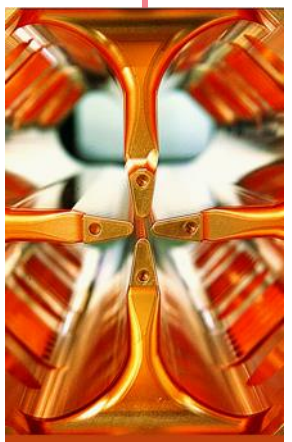
DPHP
Particle Physics



DPHN
Nuclear Physics

GANIL
Heavy Ion National Accelerator

DEDIP
Detectors
Electronics
Computing



DACM
Accelerators
Cryogenic
Magnets

DIS
System Engineering

- **679 permanents contracts**
- **398 fixed term contracts** (inc. 117 PhD students and 90 postdoctoral fellows)
- **20% women**

900/y

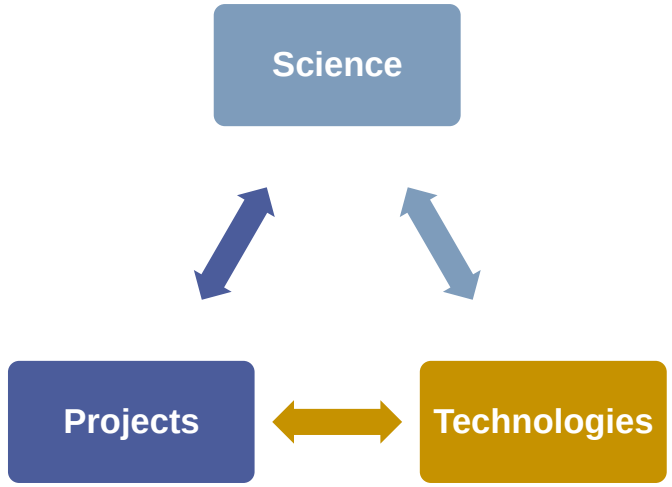
24 ERC
(8 ongoing)

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:

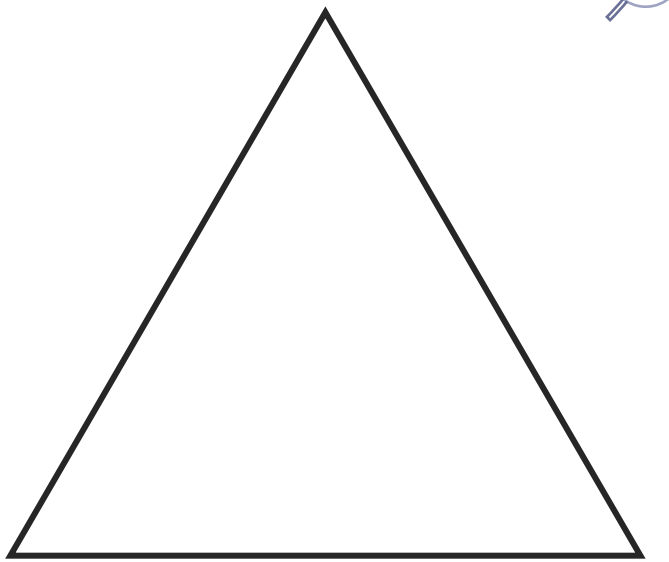
- **Ability to cover the entire research chain**
  - Theory, experiment proposal, simulation, design, construction, operation, data analysis, phenomenology and communication
- **Ability to manage large, innovative and complex projects**
  - Accelerators, magnets, detectors

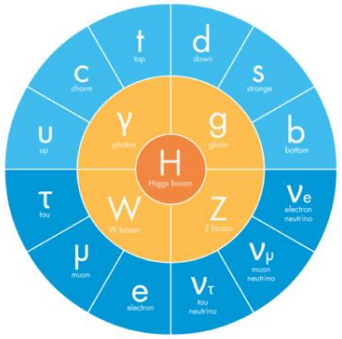


IRFU research themes

Structure of the Universe

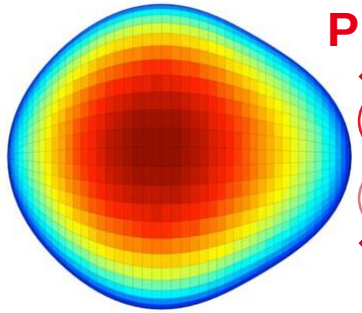
- Energy content of the Universe
- Formation and evolution of structures, galaxies, stars
- Stars and planetary systems
- Exploration of the transient Universe





Elementary constituents, Fundamentalsymmetries

- 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

IRFU research themes

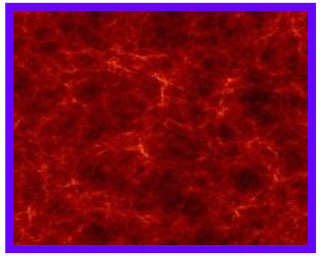
Structure of the Universe

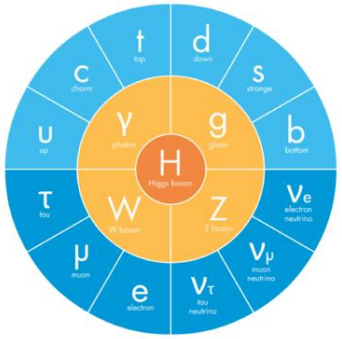
- Energy content of the Universe
- Formation and evolution of structures, galaxies, stars
- Stars and planetary systems
- Exploration of the transient Universe

Detection systems

Infrastructures & Platforms

Simulation and Big data analysis

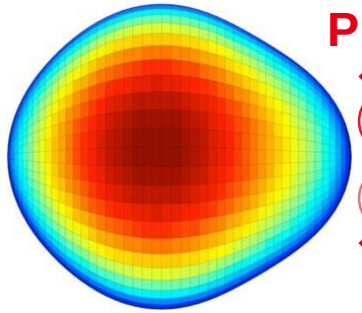




Elementary constituents, Fundamentalsymmetries

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

Accelerator systems and cryomagnetism

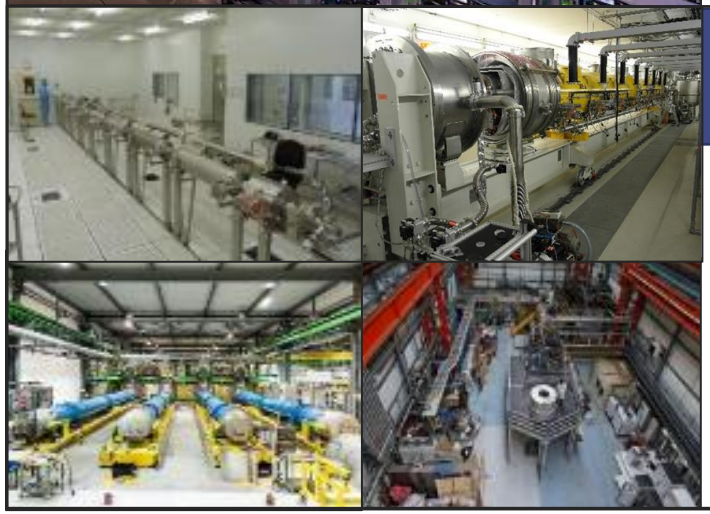


Property of Nuclear matter

- Nuclear structure and dynamics
- Dynamics of quarks and gluons

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

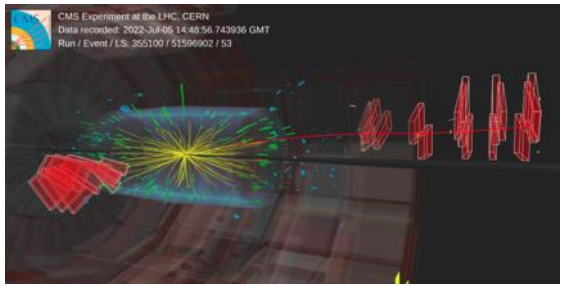
Cyclotrons: ion beams from ^{12}C to ^{238}U at different energies
SPIRAL2: high intensity beams including light ones (p and d)

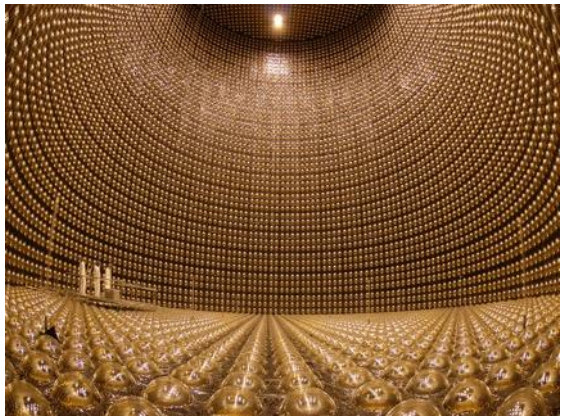
Elementary constituents
Fundamental symmetries

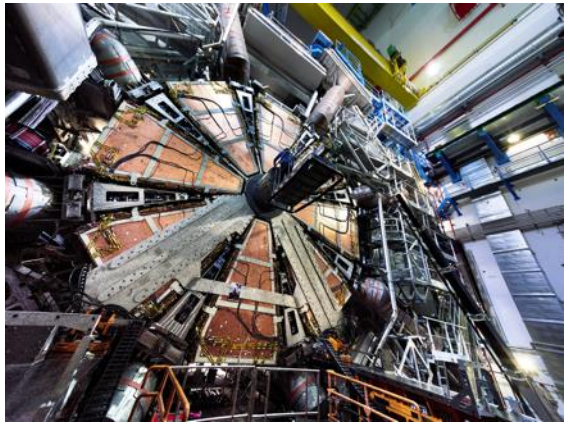
- Consistency tests of the Standard Model
- Structural tests of the Standard Model

- Search for deviations from the Standard Model by studying bosons and quarks
- Mass hierarchy, nature and properties of neutrinos

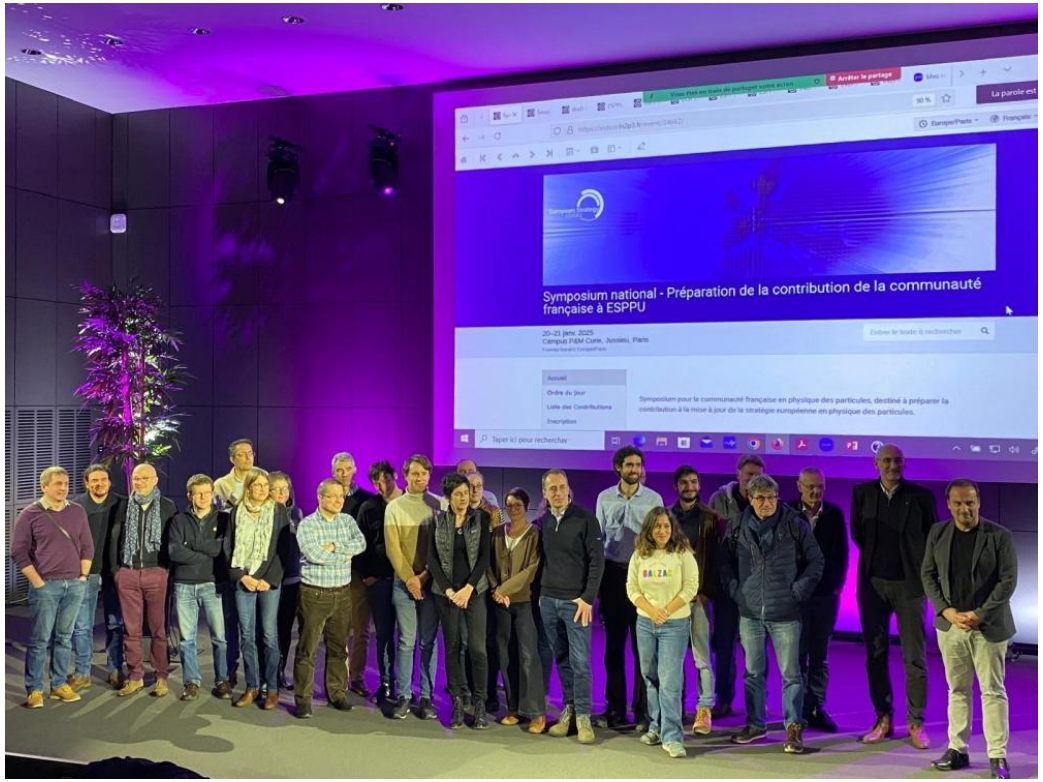
Current LHC Experiments
ATLAS & CMS Upgrades
T2K
HyperK
DUNE
NUCLEUS
CUPID - BINGO - TINY
GBAR







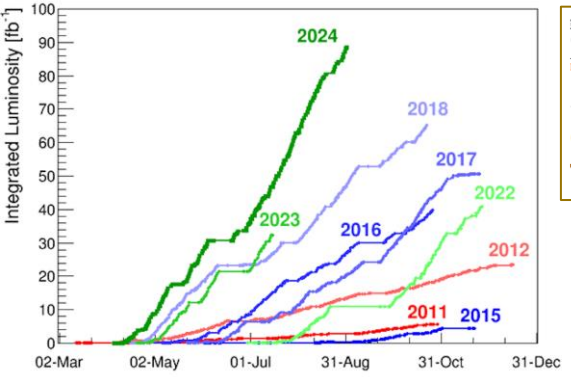
Highlight – ESPPU



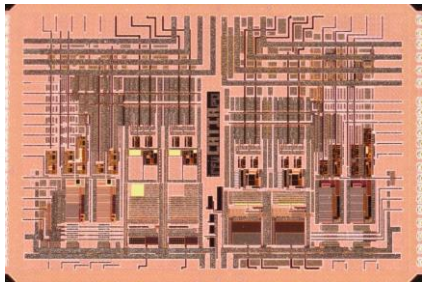
Over 280 members of the French physics community gathered to imagine the future of particle physics

- January 20 and 21, 2025 at Jussieu
- 5 working groups
  - Standard model and beyond
  - Flavor physics and fundamental interactions
  - Neutrinos
  - QCD and heavy-ion collisions
  - Future scenarios
- Cross-disciplinary topics: theory, instrumentation and R&D, young researchers, sustainable development, etc.

Highlight – LHC & GBAR




Physics Reports
Volume 1116, 22 April 2025, Pages 127-183
Climbing to the Top of the ATLAS 13 TeV data ☆

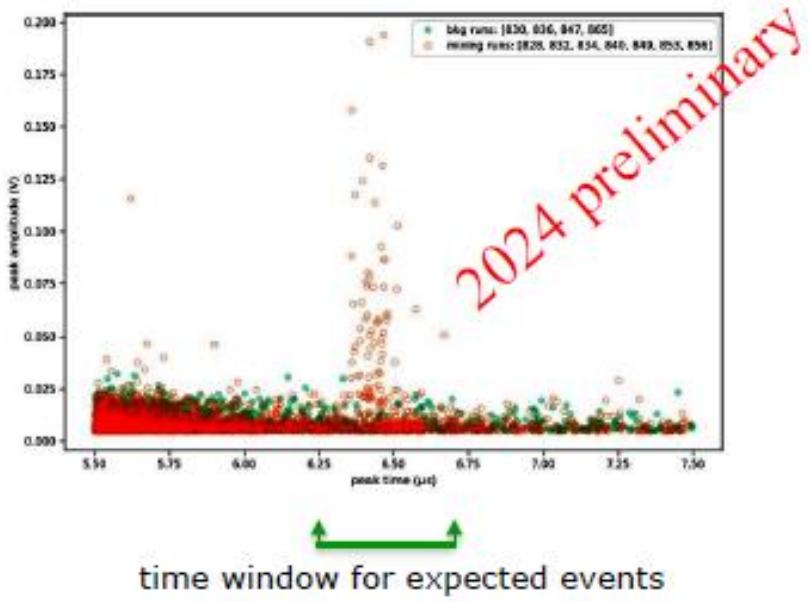


Run 3 at the record energy of 13.6 TeV & already high $\mathcal{L}$!

- Main focus on Higgs, EW and top physics
- Inc. phase 1 upgrade (ATLAS/NSW, ALICE/MFT+MUONS)
- Commissionning of LHC on-going, collisions for physics next week

Phase 2 upgrades in or entering production phase

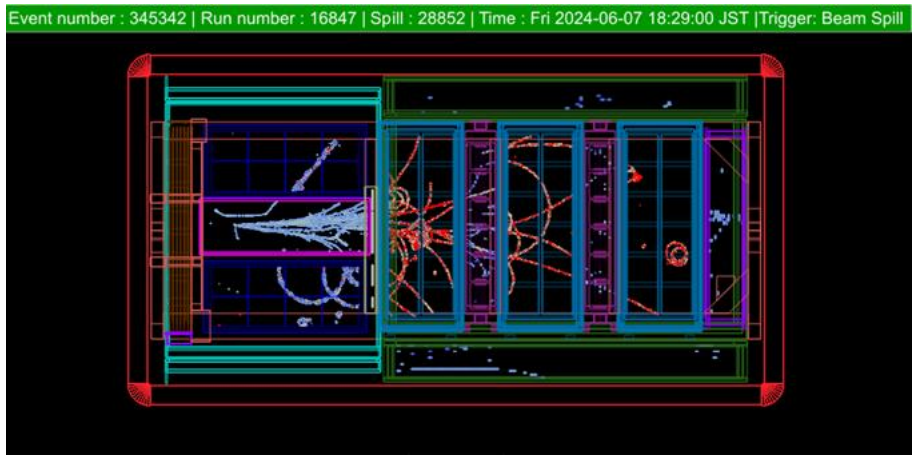
- ATLAS (Itk, LAr, HGTD, MUONS) & CMS (BCAL, HGCAL, MTD)

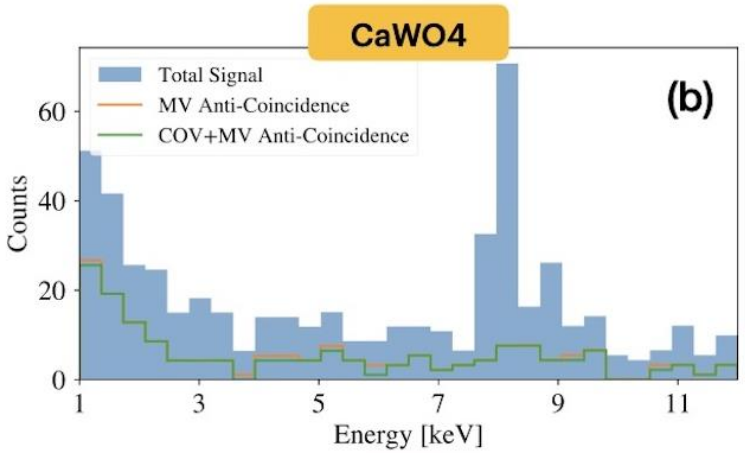


GBAR produces $\bar{H}$!

- Antiparticle trapping records:
  - 8 10^9 e^+ in 20 minutes
  - 6 10^6 $\bar{p}$ per extraction from ELENA
- Many efforts (traps, reaction cavity, fine adjustments) rewarded:
  - 2023: 0.003 $\bar{H}$ per extraction from ELENA
  - 2024: 0.1 $\bar{H}$ per ELENA extraction **x30 !**

Highlights – Neutrinos





Milestones in long baseline experiments

- T2K has a brand new **near detector ND2080** with HA-TPC installed and commissioned last year and taking data.
- **Congratulations to Shivam Joshi** for winning the 2025 TYL-FJPPL Young Investigator Award for his contributions to the High Angle Time Projection Chamber of the near detector upgrade of the T2K experiment within the NU_10 project.
- We are very proud to contribute to the **Hyper Kamiokande** international collaboration. The MoU is in the process of being finalized

NUCLEUS long background run @ Munich

- The experiment took 50 days of data to validate its background reduction strategy last fall
- In the process of moving to Chooz nuclear plant

Property of Nuclear matter

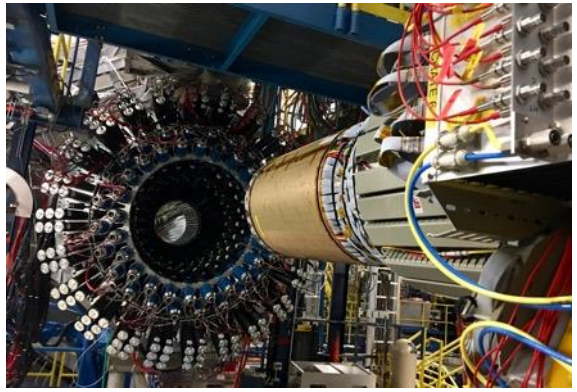
Nuclear structure and dynamics

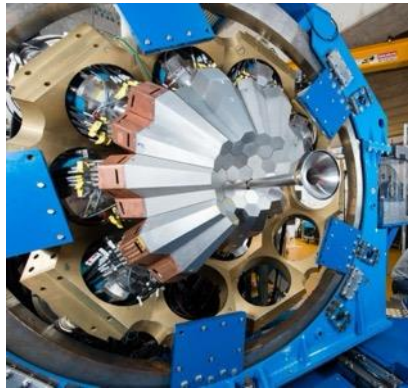
Binding limits of nuclei, nature of the nuclear interaction, influence of the nuclei structure on nuclear reactions

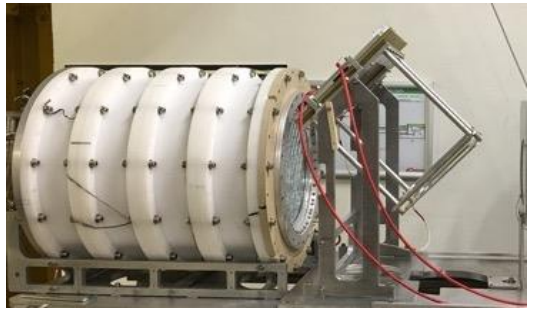
Dynamics of quarks and gluons

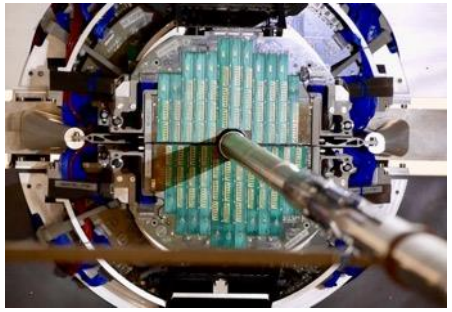
Quark and gluon plasma, 3D structure of the nucleon

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

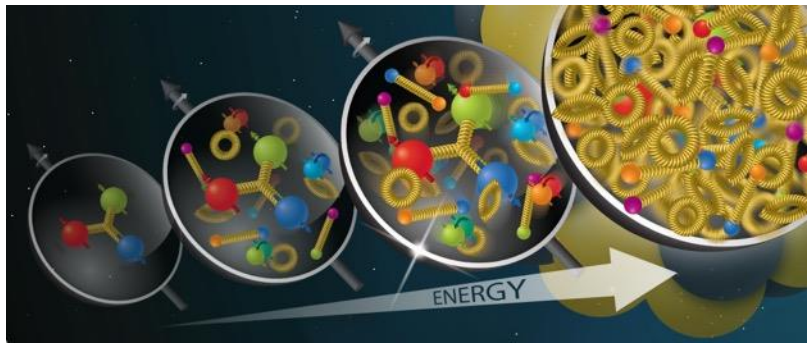


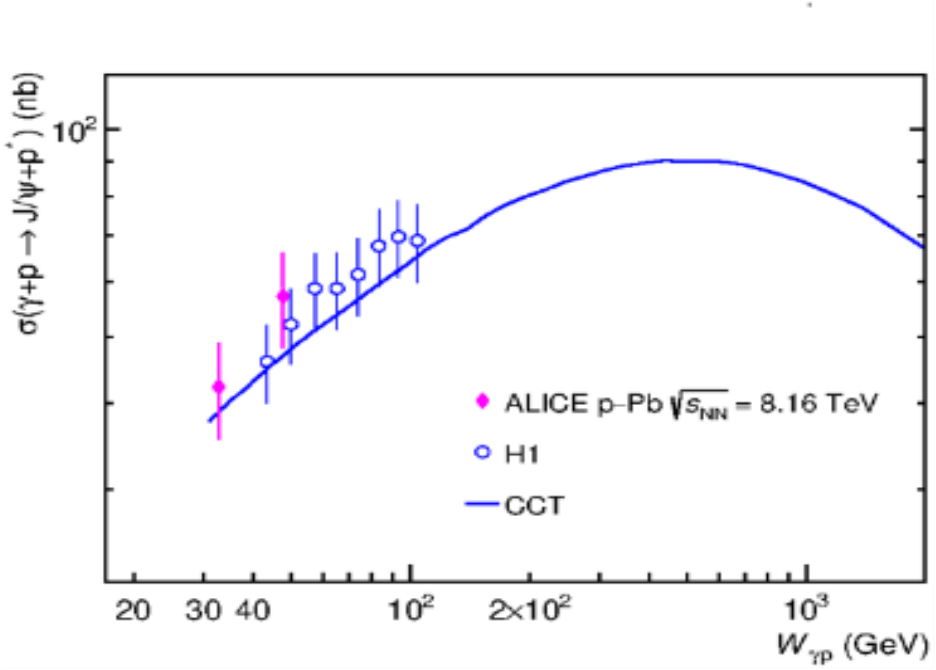






Highlight – ALICE

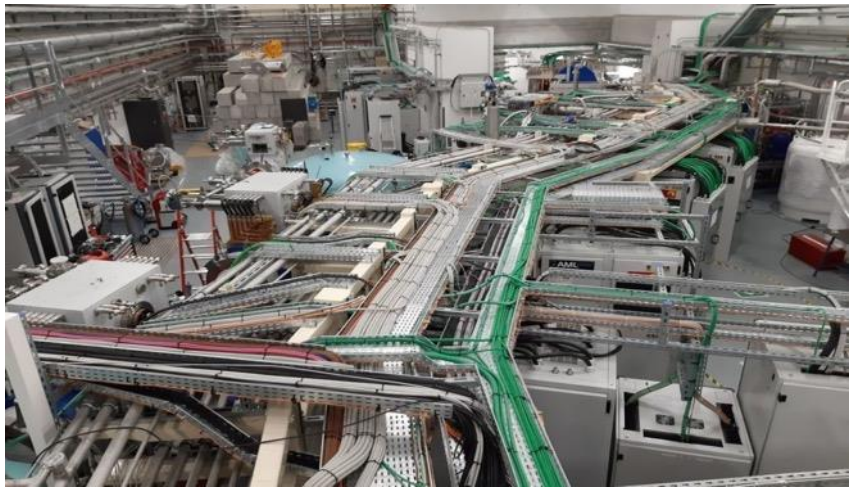




Strong interaction theory predicts gluon density saturation, which could constitute a new state of matter

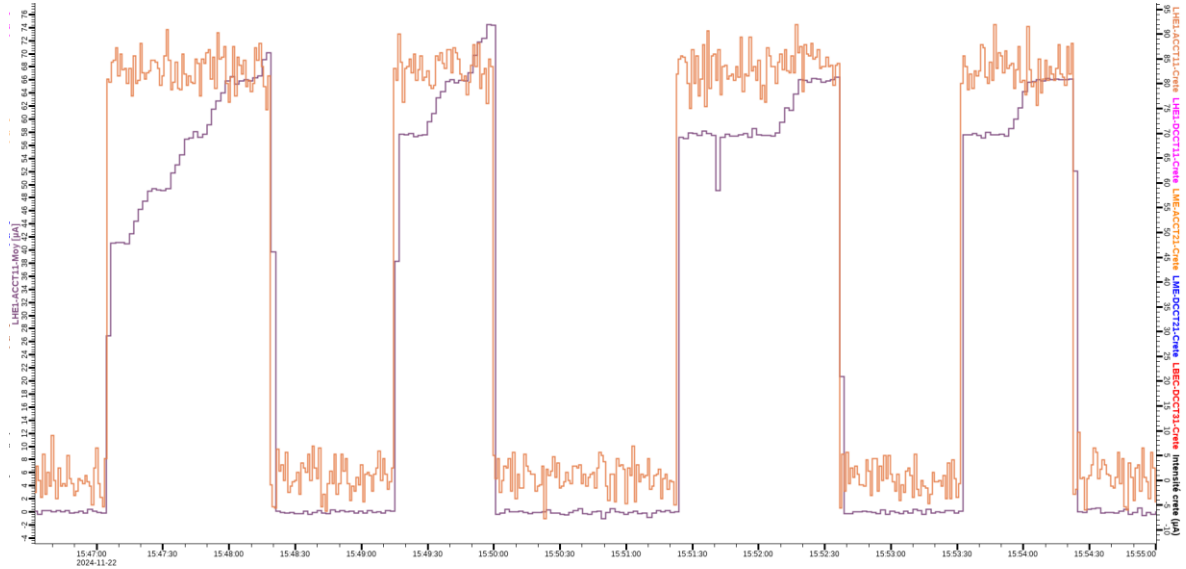
- Study of the photoproduction of J/ Ψ on ALICE (p-Pb), sensitive to fluctuating gluon density in the proton
- Results consistent with HERA data and theoretical model including saturation effects

Highlight – GANIL



Late in November, a high-intensity Argon40 beam with an energy of 5 MeV/A is sent to the S^3 spectrometer

- Successful commissionning of S^3
- Synchronization of target rotation with LINAC beam structure



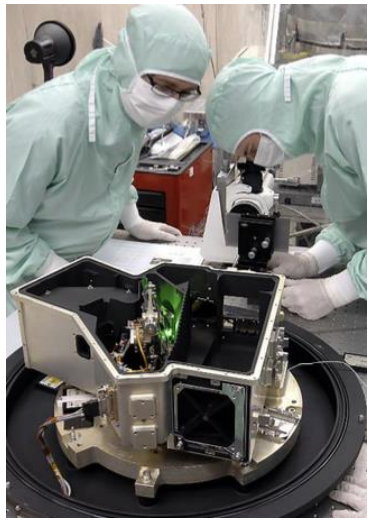
Beam intensity out of the LINAC (orange)
Beam intensity in S^3 (blue)

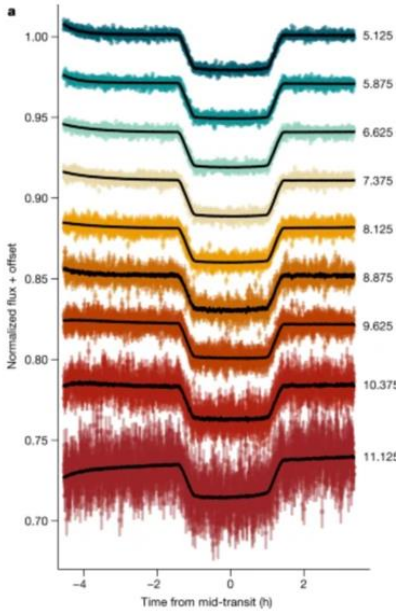
Structure of the Universe

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

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

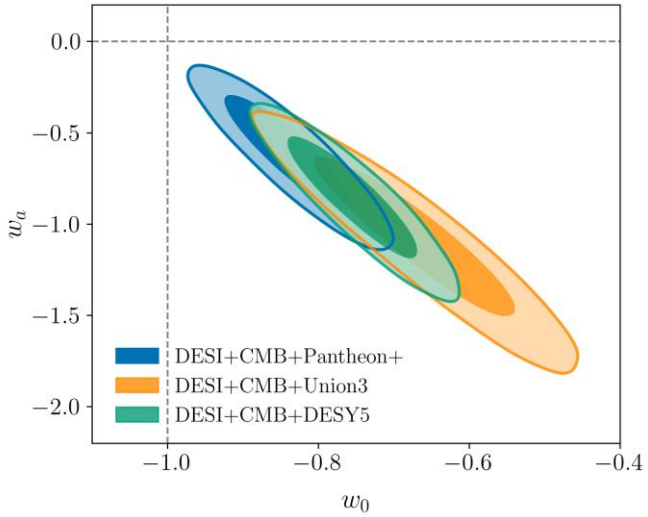
Highlight – JWST & DESI





MIRI detects and measures sulfur dioxide abundance on a hot Saturn (WASP-39b)

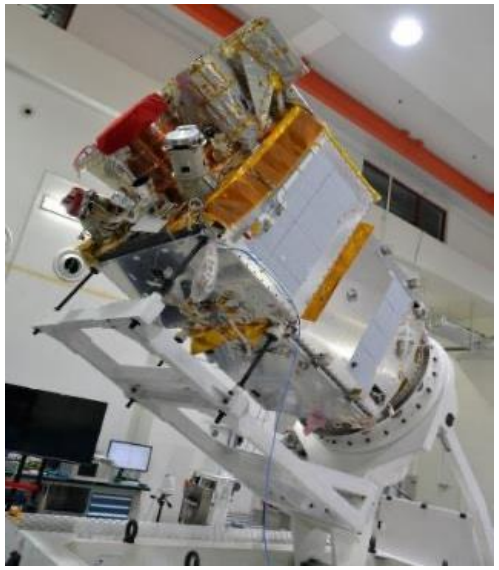
- Observed using the transit technique, the JWST detected for the first time the presence of SO_2 clouds in the atmosphere of a gaseous exoplanet
- A compound produced by photochemistry: a phenomenon never before observed in an exoplanet!
- MIRI (Mid-InfraRed Instrument) played a key role in seeing the two characteristic molecular lines, which made it possible to constrain the abundance of the exoplanet



A year after its first results and with twice as much data, **DESI published in March the results of the analysis of 3 years of data taking**

- **Confirmation of Einstein's theory of general relativity** on cosmological scales, already with exceptional precision
- **Confirmation also of the surprising result of year 1** the preference for dynamical dark energy!

Highlight – SVOM

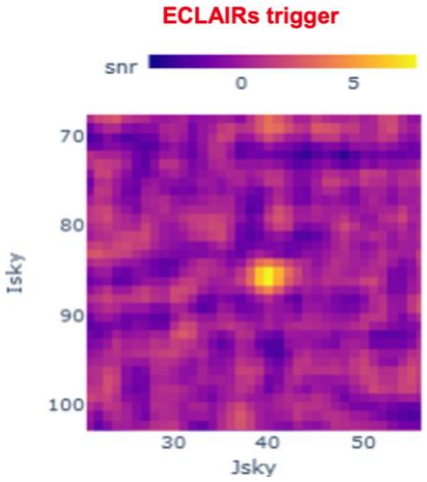


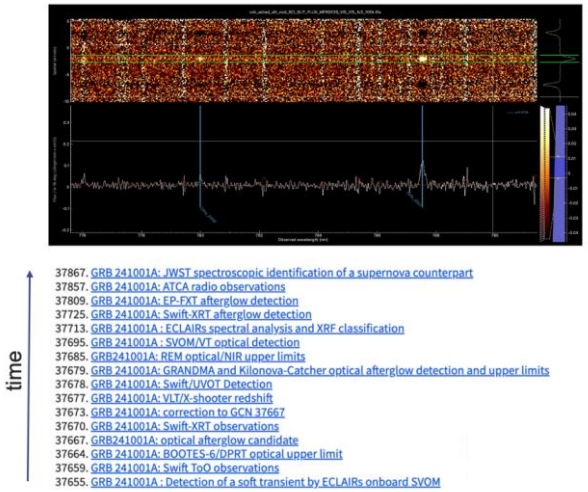
Franco-Chinese SVOM satellite was launched on June 22, 2024 from the Xichang launch base

- Satellite successfully placed in low orbit (650 km)
- Communication with the VHF network despite fears

Major participation by IRFU

- Two French instruments: ECLAIRs & MXT
- Ground segment development
- Development of the French scientific center at IRFU





Example of GRB detection by SVOM from a core-collapse supernova

- Extensive follow-up which validated SVOM alert concept

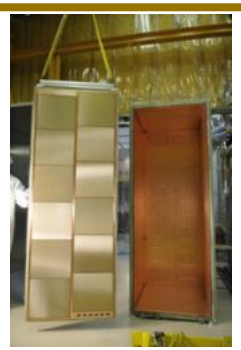
Detection systems, sample of projects

in operation

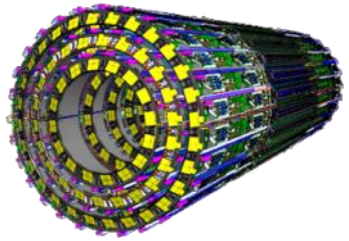
in development

Elementary constituents, Fundamental symmetries

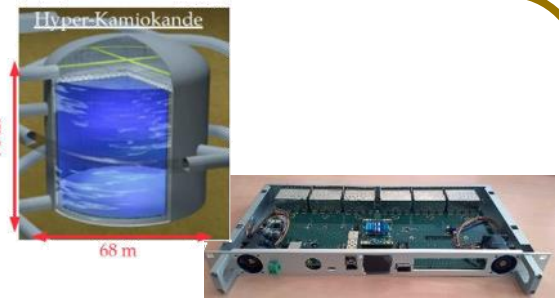
ATLAS New Small Wheels
400m^2 of Micromegas detectors



T2K Micromegas Time projection chambers system Tokai Lab (Japon)



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



HyperK Neutrinos Oscillations
High precision clock distribution system

Property of Nuclear matter

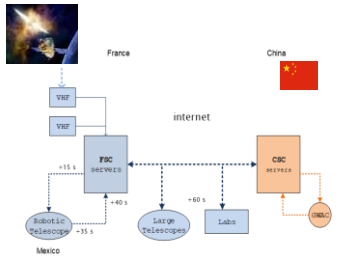
ALICE Muon Forward Tracker
based on MAPS technology

ALICE muon arm
Upgraded back-end electronics

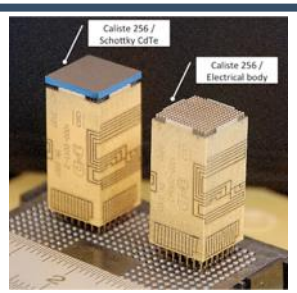
ESS Advanced beam diagnostics High Intensity profile monitors and low energy beam loss monitors

Sirius Silicon detectors used at GANIL/Spiral2-S3

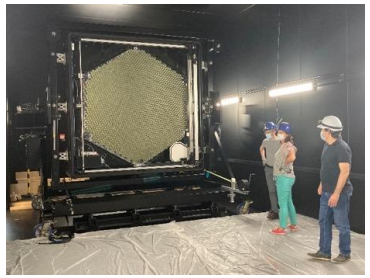
Structure of the Universe



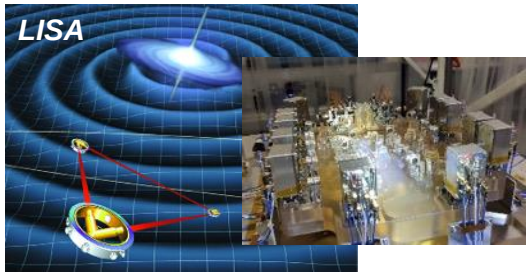
SVOM On-board computing
&Ground Segment



Solar Orbiter / Caliste: mini CdTe gamma camera



NectarCAM MDT telescopes of CTA
& Mirrors

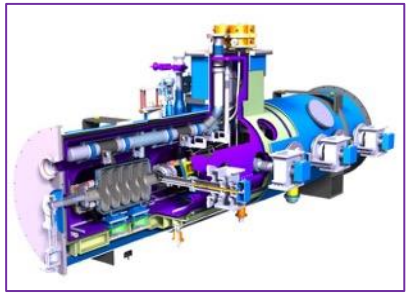


LISA ground support equipment
Data analysis based on IA technologies

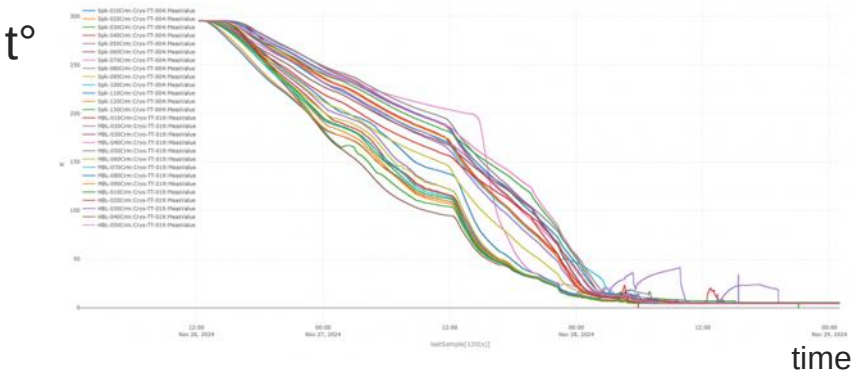
Accelerator systems and cryomagnetism

- **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 – Accelerator: ESS



180m of accelerator cooled down for the 1st time

After 5 years of assembly at Saclay, the cryomodules installed in the European Spallation Source (ESS) tunnel were cooled for the first time to 4K at the end of November.

- First assembled section of the linac, capable of accelerating protons up to 876 MeV, including 14 cryomodules integrated at Irfu
- These high-energy cryomodules are 6.6 meters long, weigh 5.5 tonnes each. They take 9 weeks to assemble at Saclay
- The first cool-down was smooth and remarkably stable, testifying to the high quality of the preparation of this complex equipment

Highlights – Accelerator: PIP-II

Manufacturing of the components of the L650 pre-production cryomodule

- All contracts have been placed
- Some components received at Saclay

Preparation of the assembly of the L650 pre-production cryomodule

- Manufacturing of the assembly tooling in progress
- Coupler installations (to validate the assembly process, the infrastructure and the operators)
  - 1st coupler installation OK @CEA
  - 2nd coupler installation OK @CEA using the collaborative robot

Preparation of the test infrastructure

- Cold box: commissioning on-going
- Cryogenic Distribution System: main transfer line delivered @CEA, installation in the next weeks
- Solid State Amplifiers: Site Acceptance Tests done


Vacuum tank


RF amplifier test bench


Prototype B61-EZ-002

Thank you for your attention