FROM RESEARCH TO INDUSTRY

POTENTIAL IN-KIND CONTRIBUTION TO PIP-II CONSTRUCTION

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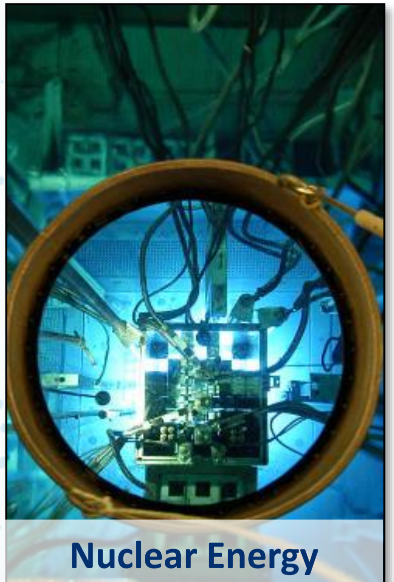
on behalf of
CEA, DRF/Irfu

December 12, 2017

www.cea.fr

CEA MISSIONS

The French Alternative Energies and Atomic Energy Commission (CEA)



FUNDAMENTAL RESEARCH

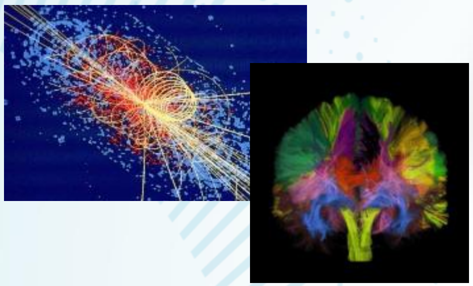
16 000 Technicians, engineers, researchers and staff

4 400 Million euros budget

10 Research centers in France

FUNDAMENTAL RESEARCH ACTIVITIES

PUSHING THE LIMITS OF TECHNOLOGY … TO ACHIEVE CUTTING EDGE SCIENCE



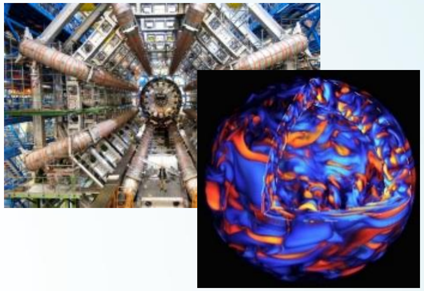
From basic research to applications

- Physics
  (Nuclear physics, high energy physics, astrophysics, fusion, quantum engineering)
- Material sciences, chemistry
- Biology and biotechnologies, health
- Climate & environmental studies

KNOWLEDGE

CEA Fundamental Research Division

KNOW-HOW

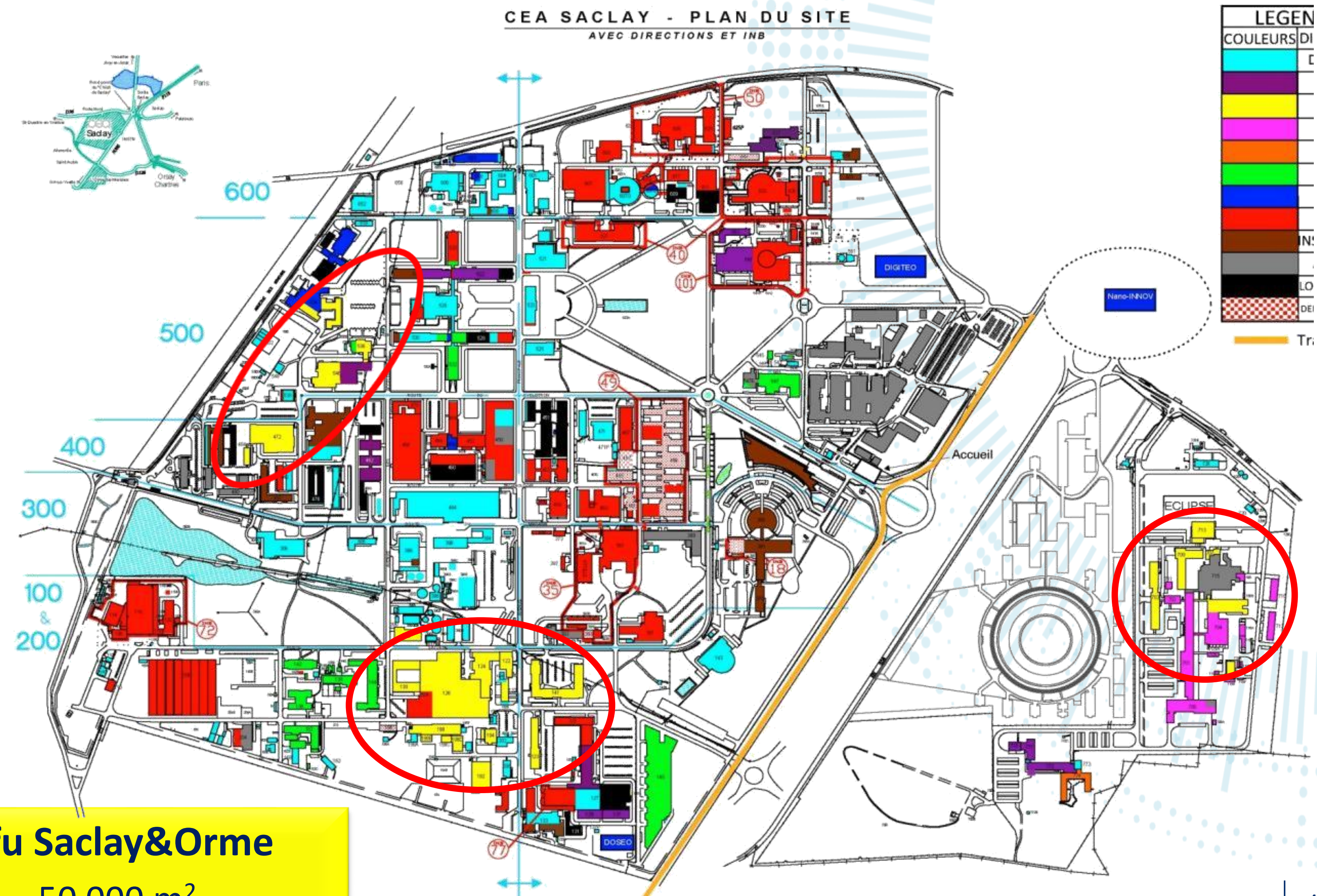


Infrastructures and instrumentation

- Cryotechnologies, accelerators, magnets, lasers, detectors
- Radioisotopic tagging, radiochemistry
- Genomics, proteomics, radiobiology, bio-imaging
- High performance computing
- Micro and Nanotechnologies, material processes

DE LA RECHERCHE À L'INDUSTRIE

CEA SACLAY RESEARCH CENTER

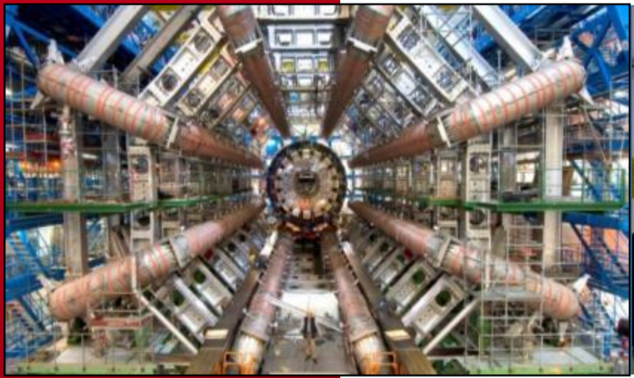


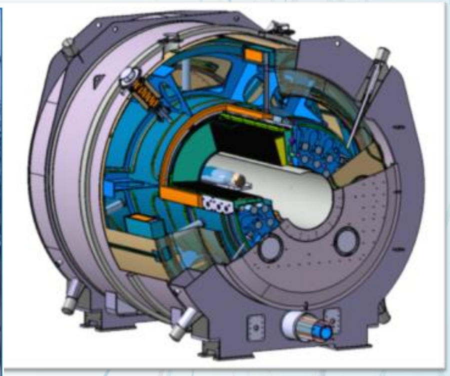
Irfu Saclay&Orme

50 000 m^2

DE LA RECHERCHE À L'INDUSTRIE

Irfu : overview





Anne-Isabelle Etienvre
Head of Institute

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IRFU:OVERVIEW

CEA
Alternative Energies & Atomic Energy Commission

Basic Research

- 17 ERC
- 975 publications
- 65 active patents

~ 950 FTE

Institut de recherche sur les lois fondamentales de l'univers

- **GANIL** – 115 FTE
- **DAp** Astrophysics – 180 FTE
- **DACM** Accelerators, Supra. Magnets – 165 FTE
- **DPhN** Nuclear Physics – 75 FTE
- **DEDIP** Detectors, Electronics, Computing – 140 FTE
- **DPhP** Particle Physics – 100 FTE
- **DIS** Engineering – 130 FTE

GENERAL STRATEGY

- **Basic Research in Physics in link with large scale facilities**
  Researches into the fundamental laws of the Universe
  - Co-Leader in France with CNRS (INSU & IN2P3), Universities
  - Goals: 4 key questions and associated technology

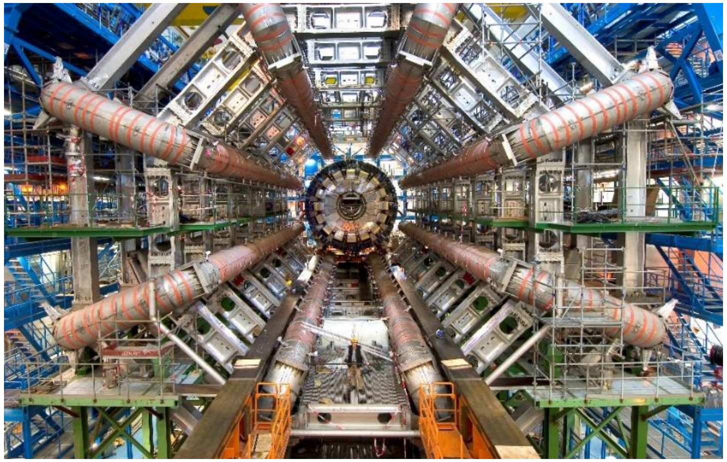
    What are the ultimate constituents of matter?
    What is the energy content of the Universe?
    How is the Universe structured?
    What are nuclear matter self-organisation processes?

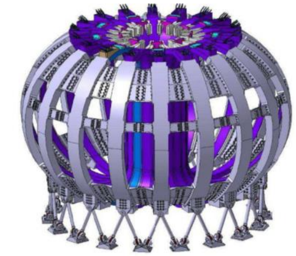
- **Broader approach, large scale facilities and Cryotechnologies**
  - Goals: 2 specific technological topics

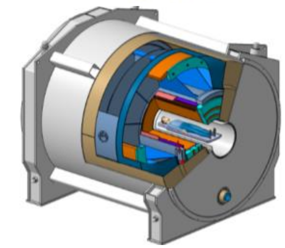
    Superconducting Magnets
    Particle Accelerators

STRONG INTERNATIONAL COLLABORATIONS

DEPARTMENT FOR ACCELERATORS, CRYOGENICS AND MAGNETISM (IRFU/DACM, ~165 FTE)

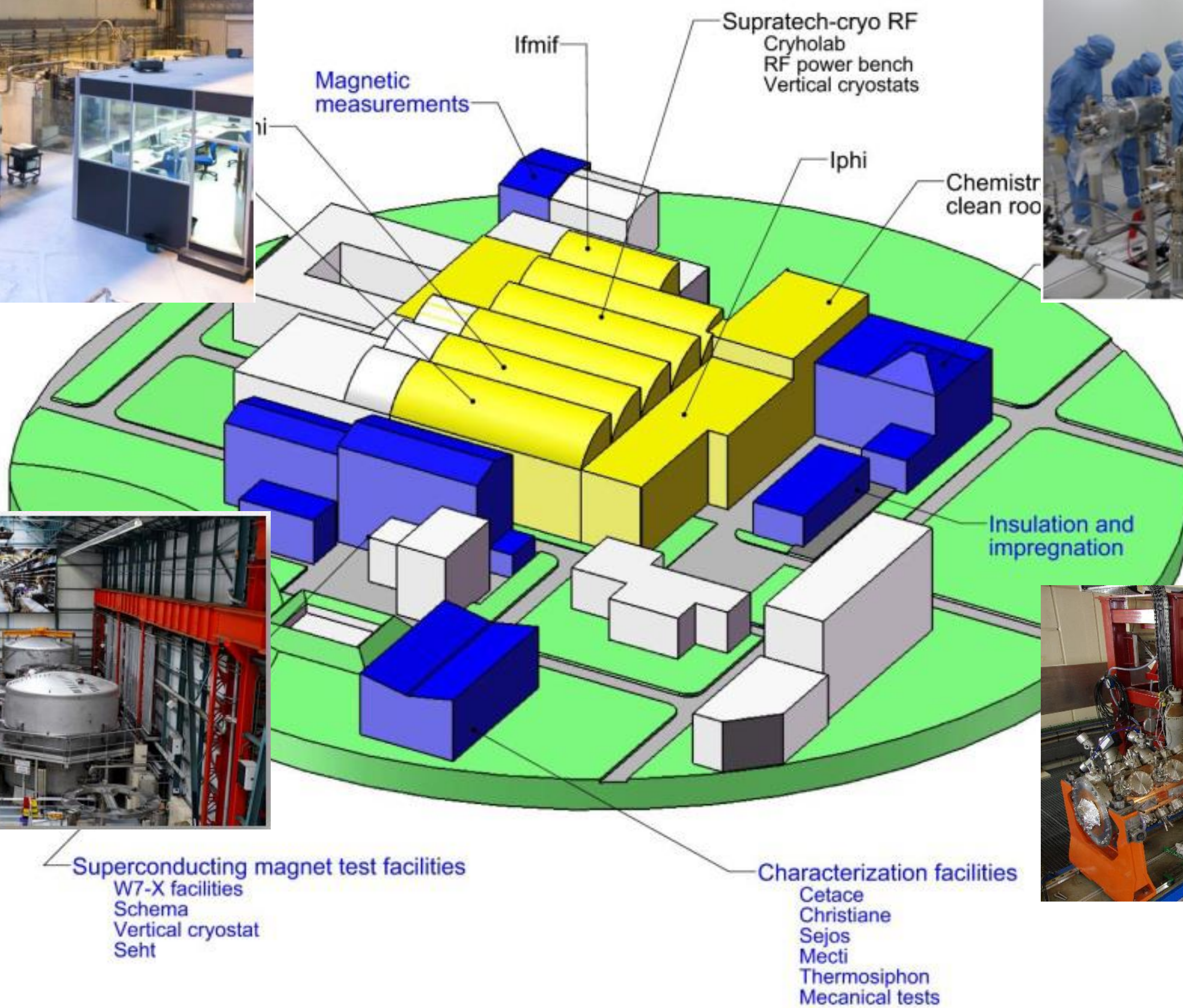






- Irfu/DACM is developing and realizing particle accelerators, cryogenic systems and superconducting magnets for the scientific programs of Irfu, and more widely of CEA.
- Iru/DACM develops R&D activities to support these programs.
- Irfu/DACM is also involved in large scale projects in Europe and Japan
- These projects are managed within the Irfu project organisation
- These projects rely on the skills of the Systems Engineering Department
- In December 2016, 81 engineers and 44 technicians, CEA staff, belonged to the Irfu/DACM Department.

DACM TECHNOLOGICAL INFRASTRUCTURES (25 000 M²)

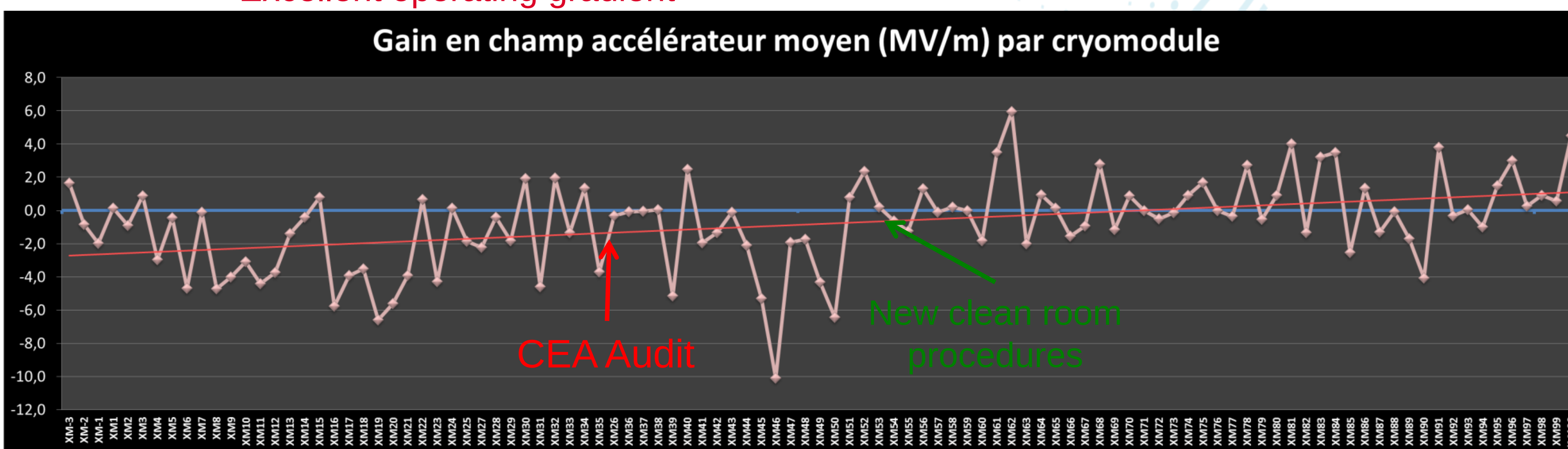


EU-XFEL : ACHIEVEMENT OF THE 100 CRYOMODULES INTEGRATION

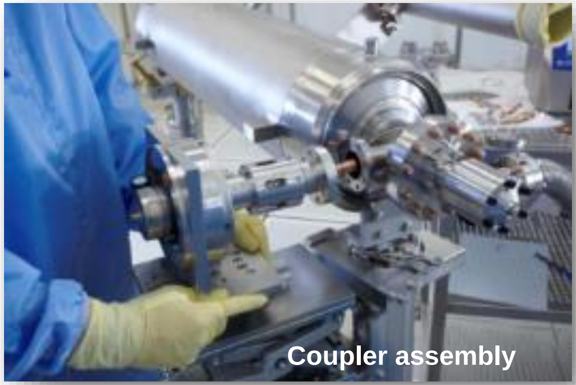
First series cryomodule assembly started on September 3, 2013

Last of 100 series cryomodule left Saclay on July 24, 2016

Excellent operating gradient



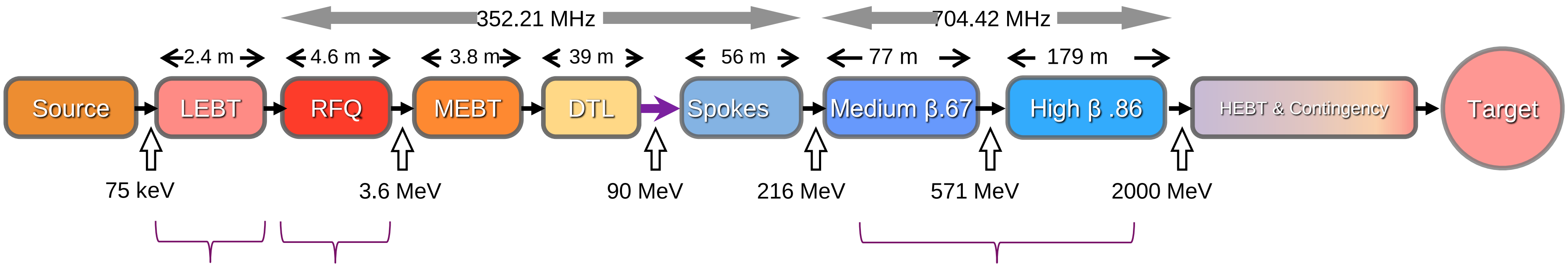
EU-XFEL ASSEMBLY: FROM CAVITIES TO CRYOMODULES



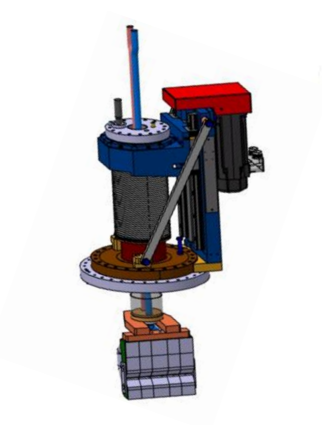
THE ESS PROJECT @ LUND, SWEDEN
EUROPEAN SPALLATION SOURCE

Protons
2 GeV
60 mA peak
2.86 ms / 14 Hz
W target, 5 MW
10^{18} n/s

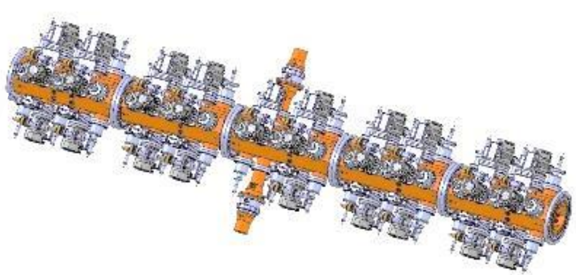
- CEA/Irfu is responsible for the design, construction, commissioning of several accelerator components within the French In-Kind contribution.



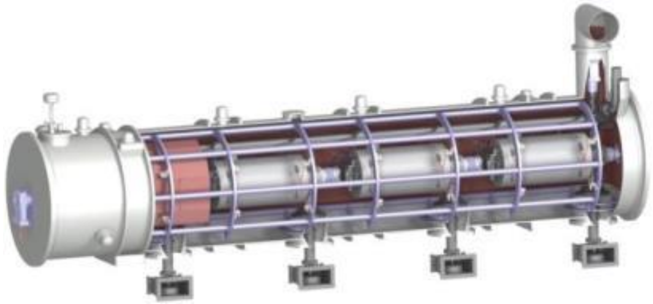
Beam diagnostics



RFQ 352 MHz



Elliptical cavities cryomodules 704 MHz



TA AIK 5.3 ELLIPTICAL CRYOMODULES ENGINEERING, ASSEMBLY AND TEST" & "TECHNICAL ASSIS-TANCE IN CAVITY DESIGN, MANUFACTURING AND TESTS, CEA

EUROPEAN SPALLATION SOURCE

Delivery:

- 30 Cryomodules (9 medium-beta and 21 high-beta) are required to accelerate protons from an energy of 216 MeV up to an energy of 2 GeV.
- The medium-beta and the high-beta Cryomodules have the same general design with different cavities and only minor differences in the components.
- The cryostat design has been taken over by IN2P3/IPNO.

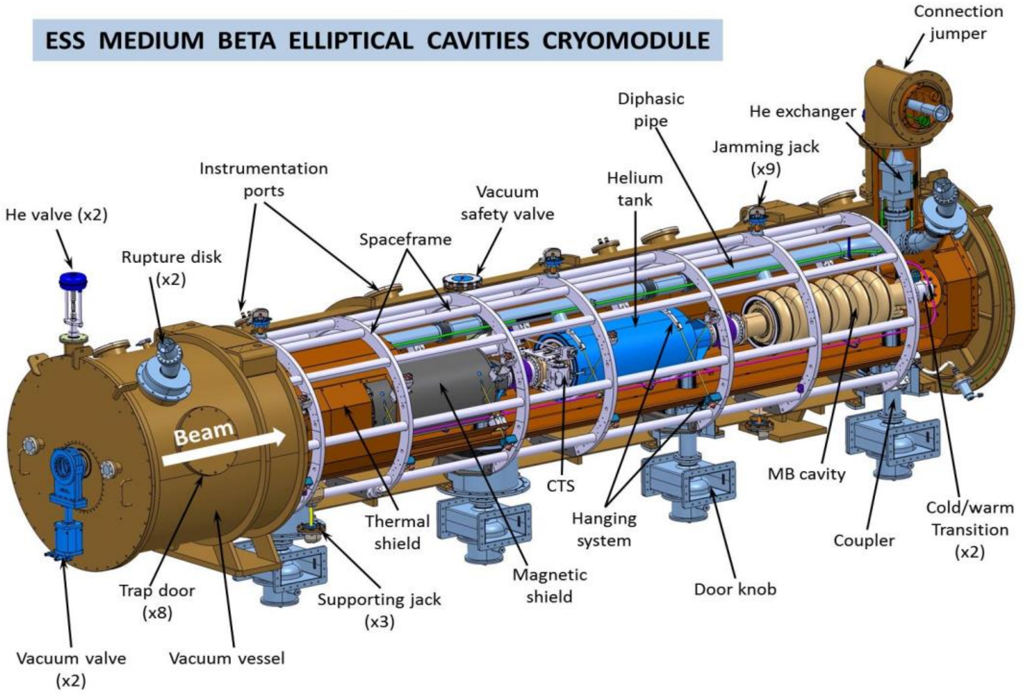


Figure 1: View of one Medium elliptical cavities cryomodule (Courtesy of IPNO)

TA AIK 5.3 ELLIPTICAL CRYOMODULES ENGINEERING, ASSEMBLY AND TEST" & "TECHNICAL ASSIS-TANCE IN CAVITY DESIGN, MANUFACTURING AND TESTS, CEA

Key Activities

1. **The component assembly and associated tooling design necessary for the assembly and tests.**
2. **The acceptance operations of the Cryomodules components and cavities before assembly.**
3. **The assembly of 9 medium-beta Cryomodules and 21 high-beta Cryomodules.**
4. **The development of the Cryomodule verification plan**
5. **Provide assistance to ESS (and partners) regarding cavity manufacturing.**
6. **The 3 first Cryomodules of each type (3 Medium-beta and 3 High-beta) will be tested at Saclay in the test stand allowing RF power tests at 2 K. A total of 6 RF power tests will be performed.**

ESS MODULE PROTOTYPING AT CEA

ASSEMBLAGE DU TRAIN DE CAVITÉS EN SALLE BLANCHE ISO 4

Jan. 2017

Mars 2017

ASSEMBLAGE HORS SALLE BLANCHE

Avril 2017

Mai 2017

CEA: INTEREST IN PIP-II CONSTRUCTION

- The Eu-XFEL cryomodule assembly at Saclay ended in July 2016.
- The end of the ESS 704 MHz cryomodule assembly is scheduled in 2022.
- CEA has the technical infrastructure and capability, and will have a unique experience to take over the production of the 11 PIP-II LB650 cryomodules.
- This venture has been discussed at the technical level between CEA and FNAL since the 'DOE Project Independent Review' in June 2015.
- This venture aligns with the participation of Irfu in the DUNE collaboration.
- Technically, this venture could encompass anything in-between
  a) an 'ESS-like' contribution including: design and procurement of all 11 module components (e.g. RF couplers, tuners, cryostats, magnetic shielding, etc.) excepted cavities; assembly of 11 strings and modules; up to 11 RF modules tests; QA-QC off all the above.
  b) an 'Eu-XFEL' contribution consisting of assembly 11 string and module assembly; a limited number of procurements (e.g. magnetic shielding, superinsulation, etc.); QA-QC of the above.
- Discussion at the Agency level has started and it needs to be continued at the Ministry level, to investigate the funding mechanism.

SCRF Accelerators / Europe [29=5+11+4+9] >200 cryomodules

Name	Particles	# cavities		Type	Material	Gradient	Mode	T	Status	Location
HERA	electrons, positrons	16	500 MHz	β=1 elliptical 4-cell	Nb	4.0 MV/m	CW	4.2 K	de-commissioned	DESY
LEP200	electrons, positrons	16 272	352 MHz	β=1 elliptical 4-cell	Nb Nb/Cu	5 MV/m 7 MV/m	CW	4.5 K	de-commissioned	CERN
LISA	electrons	4	500 MHz	β=1 elliptical 4-cell	Nb	6 MV/m	pulsed	4.2 K	de-commissioned	LN Frascati
MACSE	electrons	5	1.5 GHz	β=1 elliptical 5-cell	Nb	10 MV/m	CW	1.8 K	de-commissioned	CEA-Saclay
Tandem PA	ions	16 34	81 MHz 135 MHz	β=0.085 helix λ/2 β=0.085 helix λ	Nb	2.2 MV/m	CW	4.2 K	de-commissioned	CEA-Saclay
ALICE	electrons	2 2	1.3 GHz	β=1 elliptical 9-cell β=1 elliptical 9-cell	Nb	3-5 MV/m 13.5 MV/m	pulsed	2 K	operation	Daresbury
ALPI	ions	2 12 50 58	80 MHz 80 MHz 160 MHz 160 MHz	β=0.0255 RFQ β=0.055 QW β=0.13 QW β=0.13 QW	Nb Nb Pb/Cu Nb/Cu	2-3 MV/m 4 MV/m 2.7 MV/m 4.8 MV/m	CW	4.5 K	operation de-commissioned	LN Legnaro
DIAMOND	electrons	2	500 MHz	β=1 elliptical 1-cell	Nb	6.5 MV/m	CW	4.5 K	operation	Oxford
ELBE	electrons	1 4	1.3 GHz	β=1 elliptical 3½-cell β=1 elliptical 9-cell	Nb	8 MV/m 9 MV/m	CW	2 K	operation	HZDR
ELETTRA	electrons	1	1.5 GHz	β=1 elliptical 2-cell	Nb	5 MV/m	CW	4.5 K	operation	Trieste
FLASH	electrons	56 4	1.3 GHz 3.9 GHz	β=1 elliptical 9-cell	Nb	20-30 MV/m 14.5 MV/m	pulsed	2 K	operation	DESY
ISOLDE	ions	12 20	101 MHz	β=0.063 QW β=0.103 QW	Nb/Cu	6 MV/m	CW	4.5 K	operation	CERN
LHC	protons, ions	16	400 MHz	β=1 elliptical 1-cell	Nb/Cu	6 MV/m	CW	4.5 K	operation	CERN
S-DALINAC	electrons	1 1 10	3 GHz	β=0.85 elliptical 2-cell β=1 elliptical 5-cell β=1 elliptical 20-cell	Nb	5 MV/m 5 MV/m 5 MV/m	CW	2 K	operation	Darmstadt
SLS	electrons	1	1.5 GHz	β=1 elliptical 2-cell	Nb	5 MV/m	CW	4.5 K	operation	PSI
SOLEIL	electrons	4	352 MHz	β=1 elliptical 1-cell	Nb/Cu	6 MV/m	CW	4.2 K	operation	SOLEIL
B*ERL* inPro	electrons	1 3 3	1.3 GHz	β=1 elliptical 1½-cell β=1 elliptical 2-cell β=1 elliptical 7-cell	Nb	20 MV/m 18 MV/m	CW	2 K	construction	HZB
E-XFEL	electrons	808 8	1.3 GHz 3.9 GHz	β=1 elliptical 9-cell	Nb	24 MV/m 15 MV/m	pulsed	2 K	construction	Hamburg
IFMIF-EVEDA	D+	8	175 MHz	β=0.094 HW	Nb	4.5 MV/m	CW	4.5 K	construction	Rokkasho
SPIRAL2	D+, ions A/Q = 3	12 14	88 MHz	β=0.07 QW β=0.12 QW	Nb	6.5 MV/m 6.5 MV/m	CW	4.2 K	construction	GANIL
ESS	protons	28 64 112	352 MHz 704 MHz 704 MHz	β=0.5 double spoke β=0.7 elliptical 5-cell β=0.9 elliptical 5-cell	Nb	8 MV/m 15.5 MV/m 18.2 MV/m	pulsed	4.5 K	design	Lund