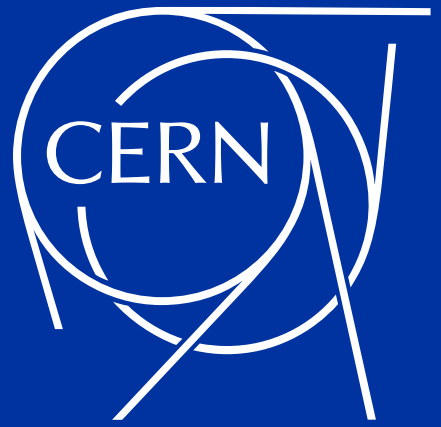


Cryogenics at CERN

Johan Bremer, Cryogenics Group, Technology Department

April 17 2024, iFAST Big Science Workshop

Agenda

Brief Introduction to CERN & Cryogenics

The Accelerators & Detectors Complex

The Cryogenics Group at CERN

Present & future cryogenic refrigeration capacity

Use of Cryogenics; Cryogenic Plants

Management of Cryogen at CERN

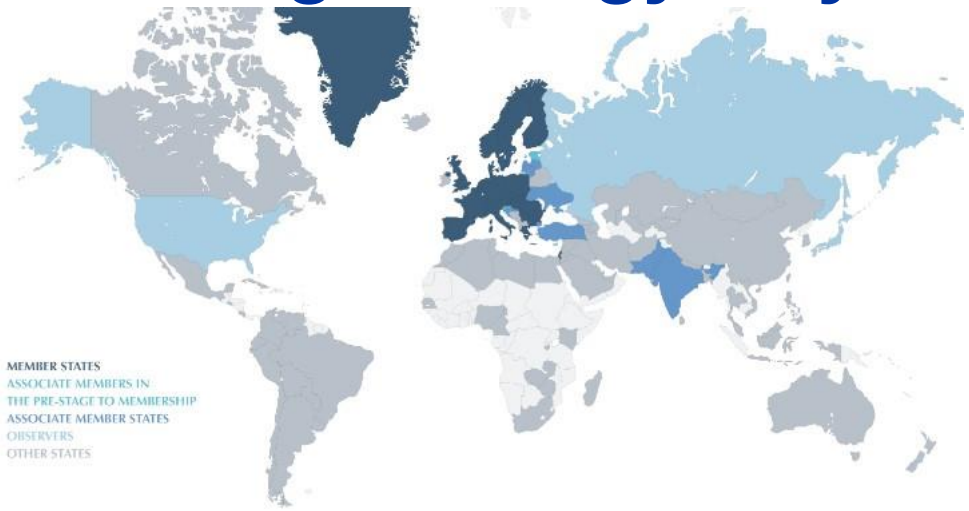
Forthcoming Estimated Procurements for Cryogenic Systems (over 2024-2027)

Summary

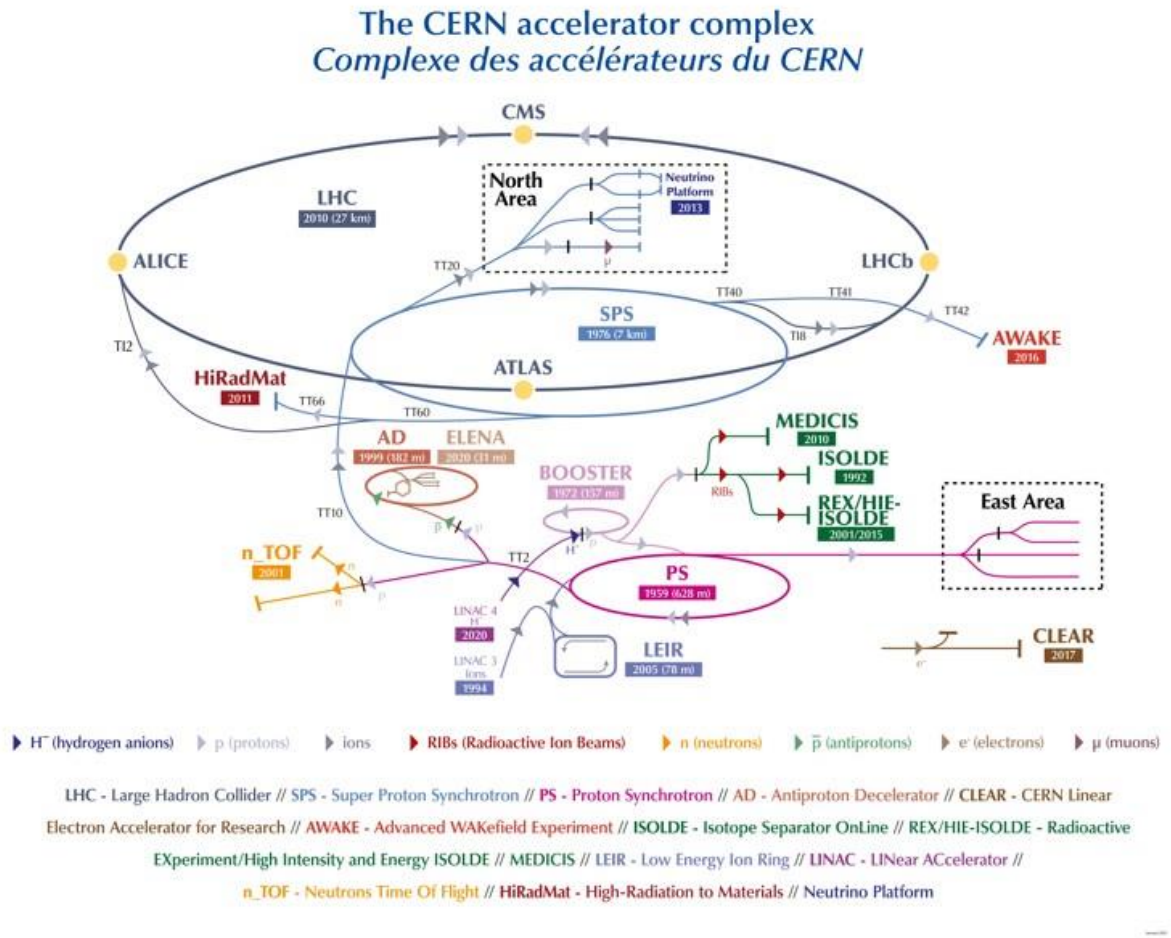
CERN, European Organization for Nuclear Research, an Intergovernmental Organization for the High Energy Physics

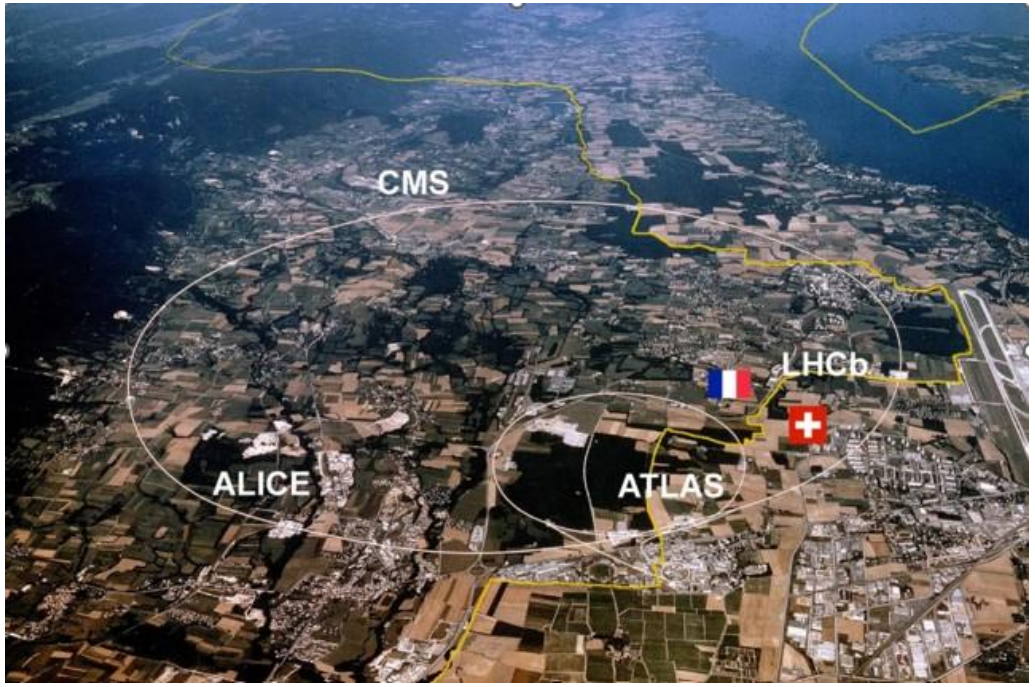
CERN's mission:

- **Perform world-class research in fundamental physics.**
- **Provide a unique range of particle accelerator facilities that enables research at the forefront of human knowledge, in an environmentally responsible and sustainable way.**
- **Unite people from all over the world to push the frontiers of science and technology, for the benefit of all.**
- **Train new generations of physicists, engineers and technicians, and engage all citizens in research and in the value of science.**



The Accelerators at CERN





Main Accelerators & Detectors technologies

Electrical fields to accelerate beams: superconducting radiofrequency cavities

Magnetic fields to steer, kick & focus beams for accelerators, particles tracking and identification for detectors: superconducting magnets

Vacuum nearly absolute (10^{-13} atm) in accelerators beam pipes to avoid beam interaction with existing matter

Cryogenics to cool down magnets & cavities at 4.5 K or 1.8 K (and less for specific applications) generating and maintaining superconductivity (quasi absence of electrical resistivity), and for detector purposes

Powering energy for all

Cryogenics @ CERN: definition

The branch of physics dealing with the production and effects of very low temperatures (below 120 K).

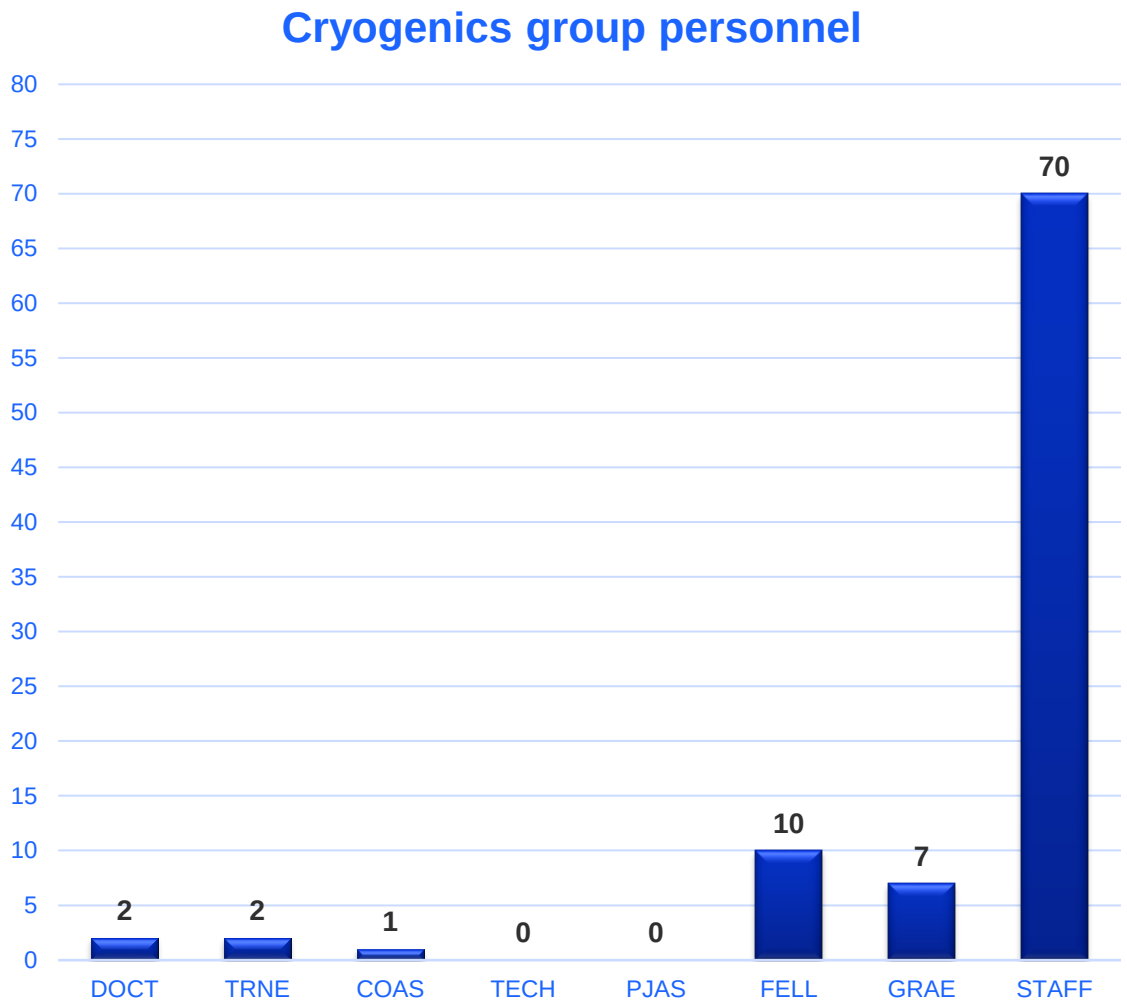
The liquefied gasses in this temperature range:

Krypton (119.8 K), Methane (111.6 K), Oxygen (90.2 K), Argon (87.3 K), Nitrogen (77.4 K), Neon (27.1 K), Hydrogen (20.3 K), Helium (4.2 K)

Cryogenics Group @ CERN: mandate

- All scientific and technological disciplines dealing with cryogenic temperatures; production and effects of very low temperatures
- Design, construction, commissioning, operation & maintenance and upgrade of the cryogenic systems for CERN accelerators complex, detectors, cryogenic laboratory, test facilities and infrastructures
- Low-temperature R&D and tests program at the Cryogenic Laboratory
- Supply of bulk cryogenic fluids CERN-wide (helium, nitrogen, argon, krypton)
- World-wide consultancy and support in cryogenic design and cryogenic instrumentation

The Cryogenics group



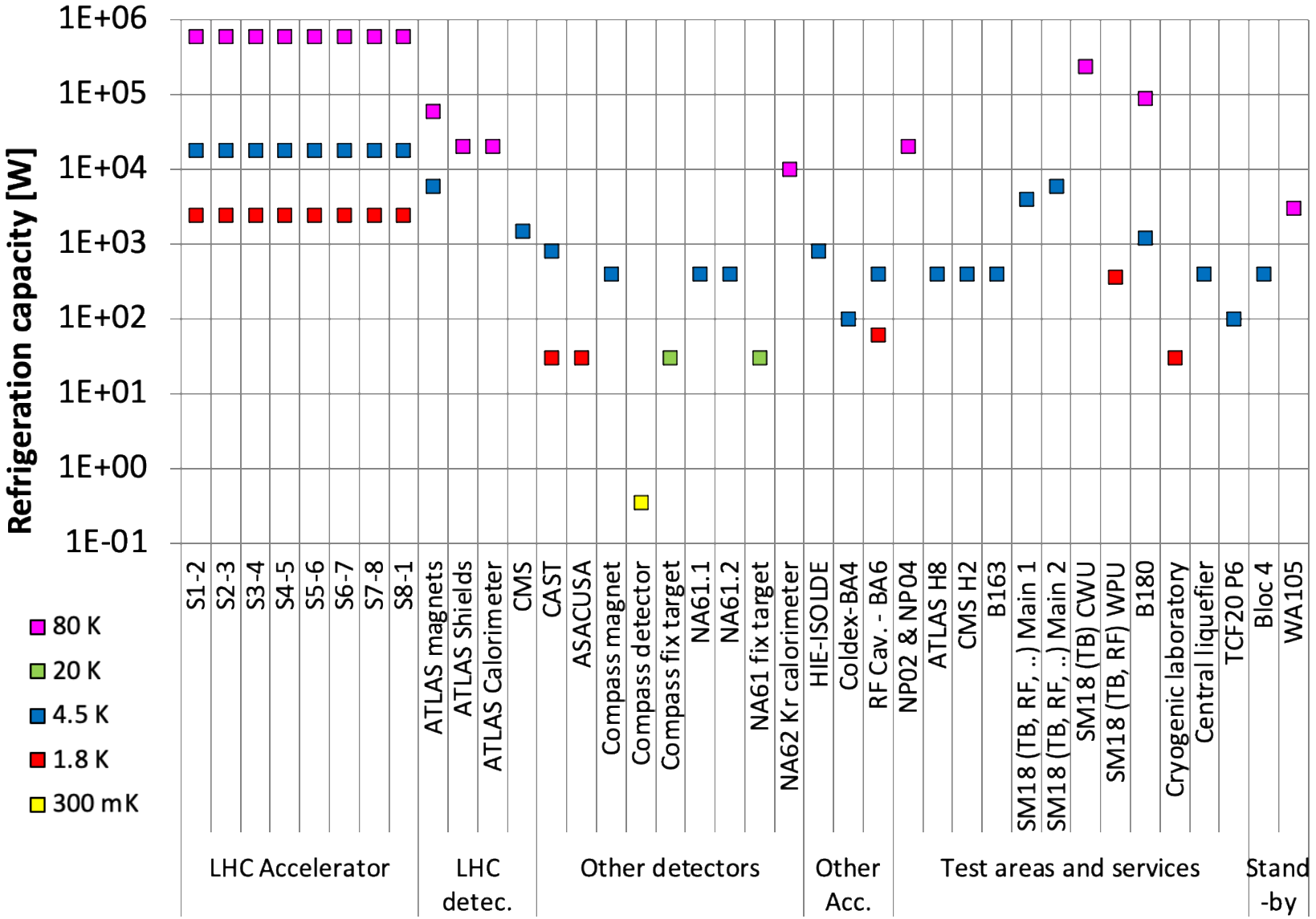
Sections
- Cryogenic Laboratory (R&D)
- Mechanical Engineering
- Process Controls, Instrumentation & Electrical Engineering
- Maintenance Management & Logistics
- Operation

Professional class:
- 59% Technical work,
- 41% Scientific & Engineering work

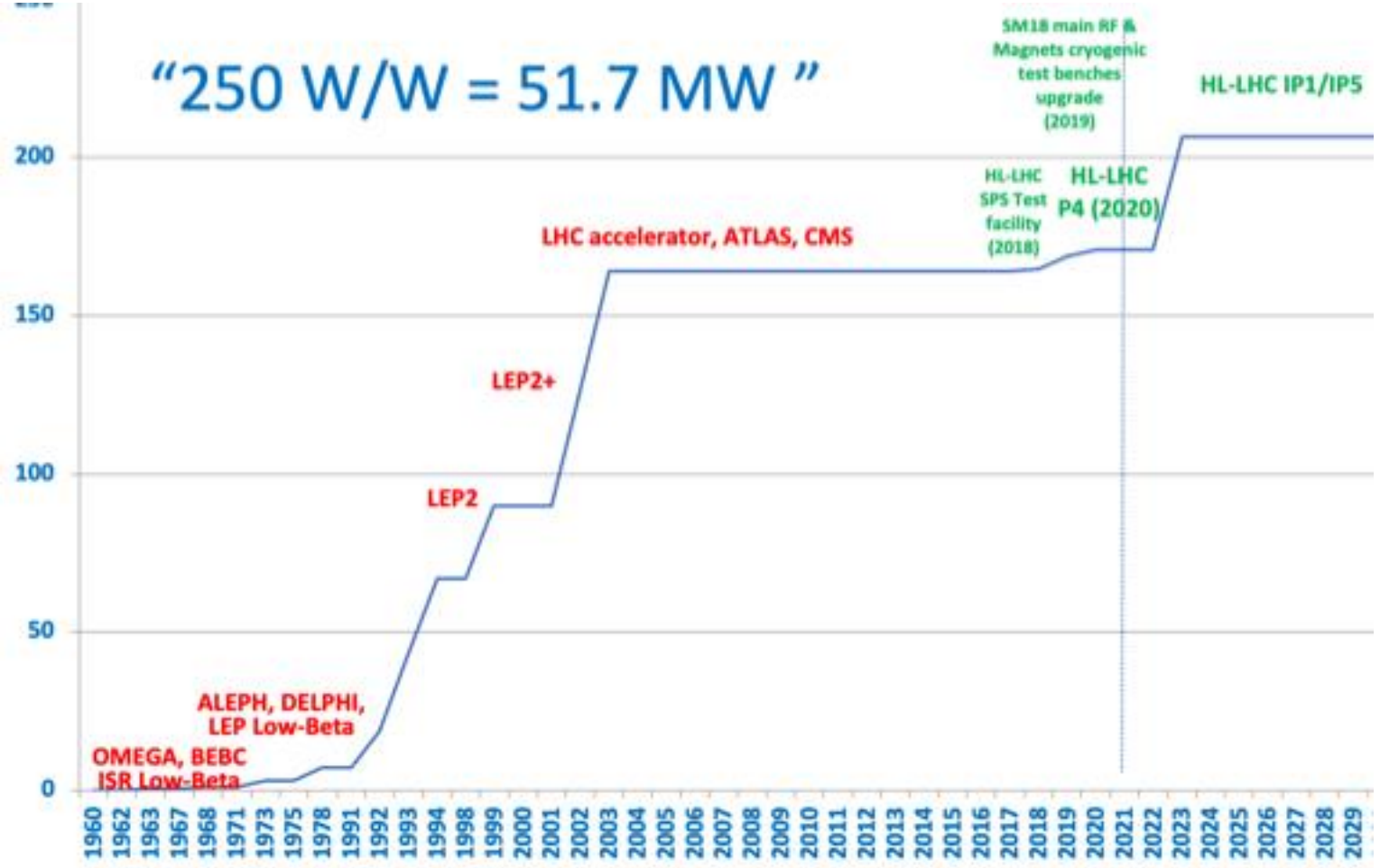
Industrial support resources (service contracts)

- General mechanical, electrical, instrumentation support: 18 FTE
- Maintenance & Operation (M&O) dedicated service contract: 47 FTE

Cryogenics @ CERN: large T spectrum



Cryogenics @ CERN: large power (refrigeration & energy)



Cryogen (helium, nitrogen, argon, krypton)

Helium inventory at CERN**: 170 t (today)**

- LHC (accelerator & detectors) helium full inventory: **136 t**
- Strategic permanent storage **: 20 t**

Nitrogen liquid for LHC (accelerator & detectors) full cool down: **11’500 t**
(equivalent to 500 **ISO-**transportable containers delivered), normal consumption CERN wide about **6’000 t/year**.

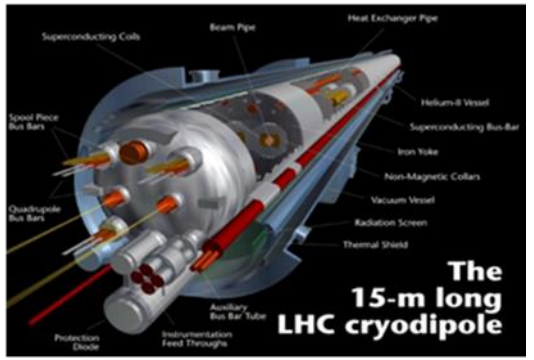
Argon liquid for Neutrino platform and ATLAS calorimeter: up to **1’800 t**

Krypton liquid for NA62 calorimeter: **24 t** (detector cryostat 30 years in continuous operation)

Use of Helium Cryogenics (1/2)

LHC accelerator

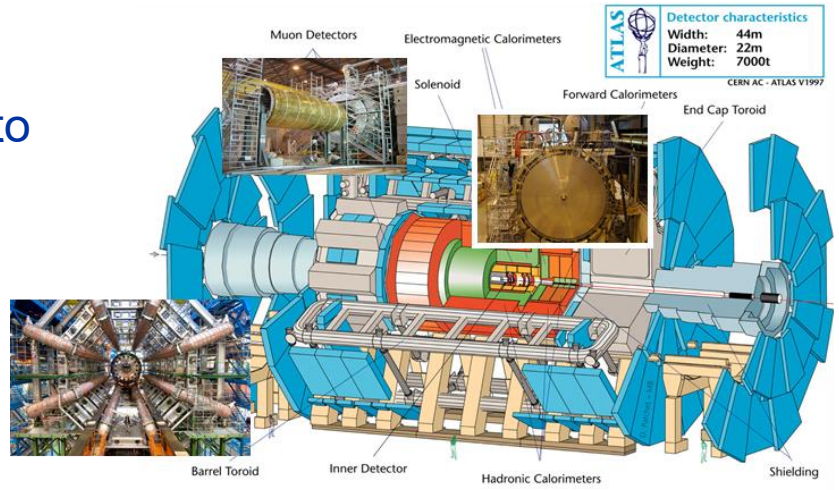
Cooling at 1.9 K of the superconducting magnets (36’000 t of cold mass) distributed over the 26.7 km underground accelerator

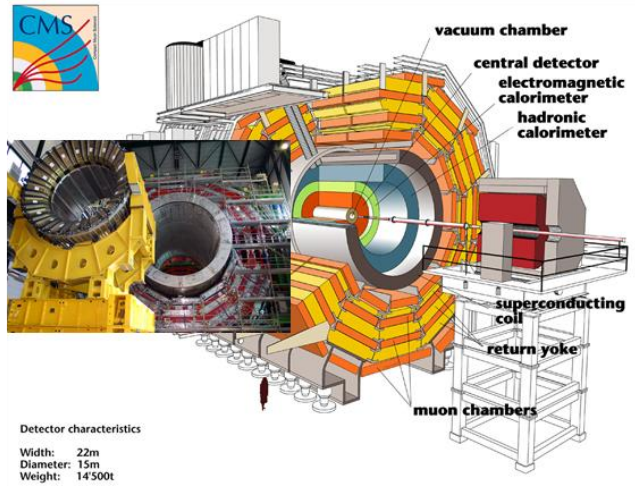


LHC physics detectors

ATLAS, cooling at 4.5 K of the superconducting magnetic system (1’275 t of cold mass) and at 80 K to cool 90 m3 of liquid argon

CMS, cooling at 4.5 K of the superconducting solenoid (225 t of cold mass)





Use of Helium Cryogenics (2/2)

CERN wide helium refrigeration systems for:

Test benches for accelerator magnets, cables and wires, RF cavities

Detectors' components tests (magnets and sub-detectors)

Large magnetic spectrometers for fixed target physics experiments

Cryogenic laboratory test bench facilities

In situ helium liquefaction for users without dedicated cryogenic plant

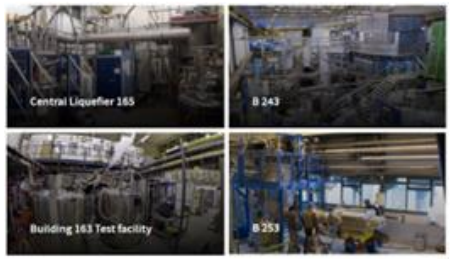
SM18 test Facility

West Area test Facility

HIE Isolde Cryo Modules

SPS BA4 COLDEX

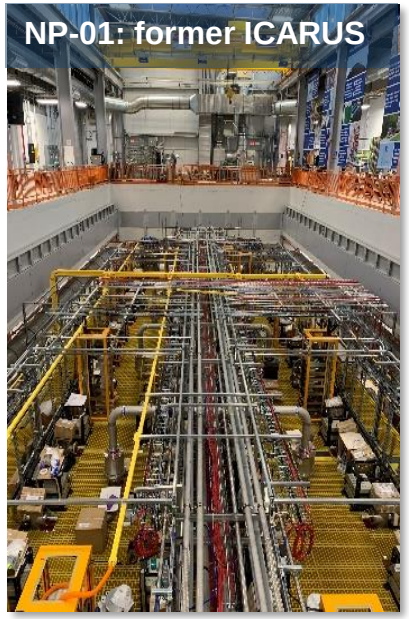
SPS BA6 Crab Cavities

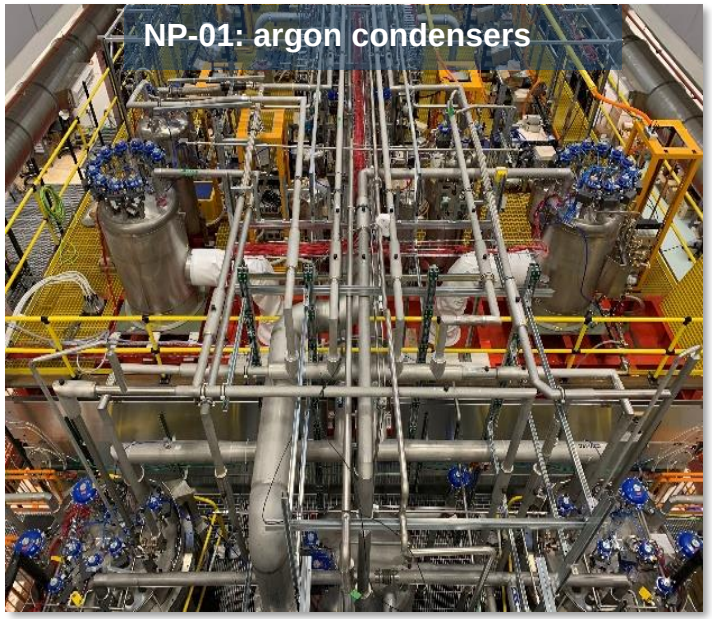


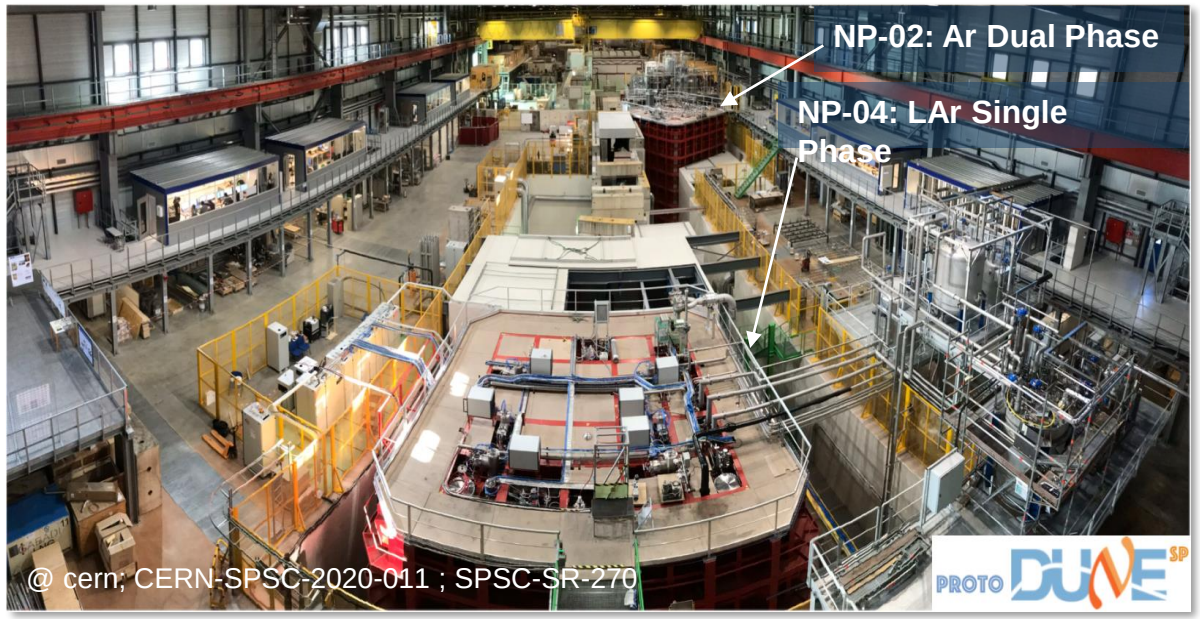
Central Liquefier

North Area

Neutrino platform facilities (CERN & US); Liquid Argon







At CERN:

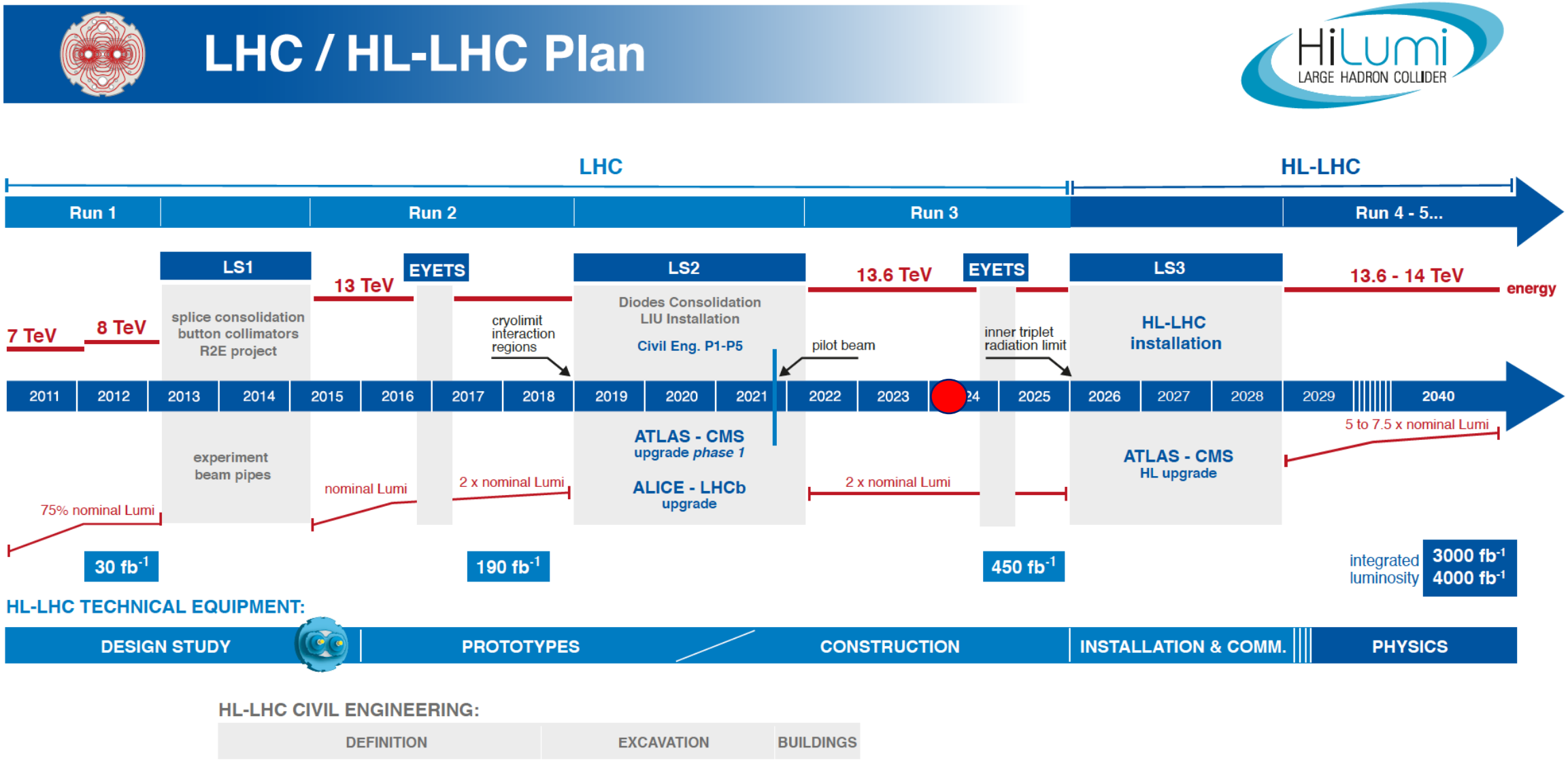
- NP02/NP04 : liquid argon single/double phase prototype neutrino detector installed and operated; liquid argon volume 550 m^3/600 m^3 respectively

At Fermilab, US (proximity cryogenics from CERN):

- NP01: former ICARUS detector (600 m^3 of liquid argon) installed as far detector: in operation
- NP03: near detector (300 m^3 of liquid argon) ; in operation

Now start working on the LBNF/DUNE proximity cryogenics in US: re-condensing and purification of GAr, purification and recirculation of LAr. Cryostats (inner dimensions, liquid and gas): 65m x 15m x 15m placed at 1500 meter below ground level.

LHC & HL-LHC timeline updated



CERN's Forthcoming Estimated Procurements for Cryogenic Systems

CERN public scale
<200 kCHF
>200 kCHF , < 750 kCHF
>750kCHF, <5 MCHF
>5 MCHF, <10 MCHF
>10 MCHF
MS: Market survey
IT: Invitation to Tender

System	CERN public scale	2024	2025	2026	2027
LBNF argon condenser system to be delivered in US	>750kCHF, <5 MCHF	MS, IT			
Major overhauling helium compressors at manufacturer's premises	>750kCHF, <5 MCHF		IT		
Major overhauling helium cold compressors at manufacturer's premises	>200 kCHF , < 750 kCHF			IT	
Major overhauling 3.3 kV electrical motors for helium compressors	>200 kCHF , < 750 kCHF		MS, IT		
Supply of High Grade Helium & Management of Part of the LHC Helium Inventory	> 10 MCHF		MS, IT		
Supply of liquid nitrogen vessels	>200 kCHF , < 750 kCHF	IT			
Supply of electrical controls cabinets	>200 kCHF , < 750 kCHF	MS, IT			
Onsite re-work of existing cryogenic distribution multi-header line	>750 kCHF, <5 MCHF	MS, IT			
Cryogenic instrumentation (PT, LD, Actuators)	>750 kCHF, <5 MCHF	MS, IT			
Cryogenic instrumentation (Rad Tol Electronics, 1500 cards, 50 crates)	>750 kCHF, <5 MCHF	MS, IT			

Summary

Cryogenics at CERN: since 1960's for cooling components on accelerators, physics detectors & test facilities

Very large spectrum of cryogenic engineering & working conditions (applications and refrigeration capacity @ T K)

Implementation & successful operation of "state of the art" industrial cryogenic equipment at the edge of the present technology: The LHC cryogenic system (26.7 km, cooling @1.8 K, 80 ton of He II)

Availability to users**:**

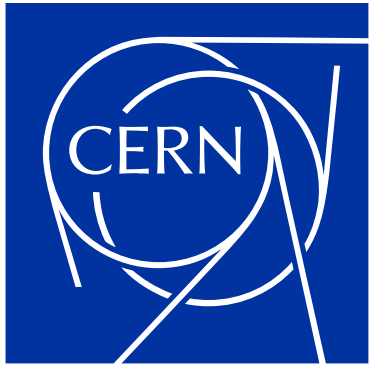
- Before the LHC era: nearly 590'000 running hours have been cumulated over 15 years with a mean availability rate of 99%
- The present LHC mean availability is situated around 98%; impressive progress despite the incomparable complexity with the previous era

Procurement and management of large cryogen inventory (helium, argon and nitrogen)

Specification, procurement, installation, commissioning, operation & maintenance of new cryogenic plants

Consultancy & R&D in low temperature domains


ICEC/ICMC
29th International Cryogenic Engineering Conference
International Cryogenic Material Conference 2024
July 22-26, 2024, Geneva, Switzerland



home.cern