CRYOGENICS OPERATIONS 2008

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CERN, Geneva, Switzerland

The world of cryogenics at CERN

L. Tavian, D. Delikaris

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- **Cryogenics at CERN**
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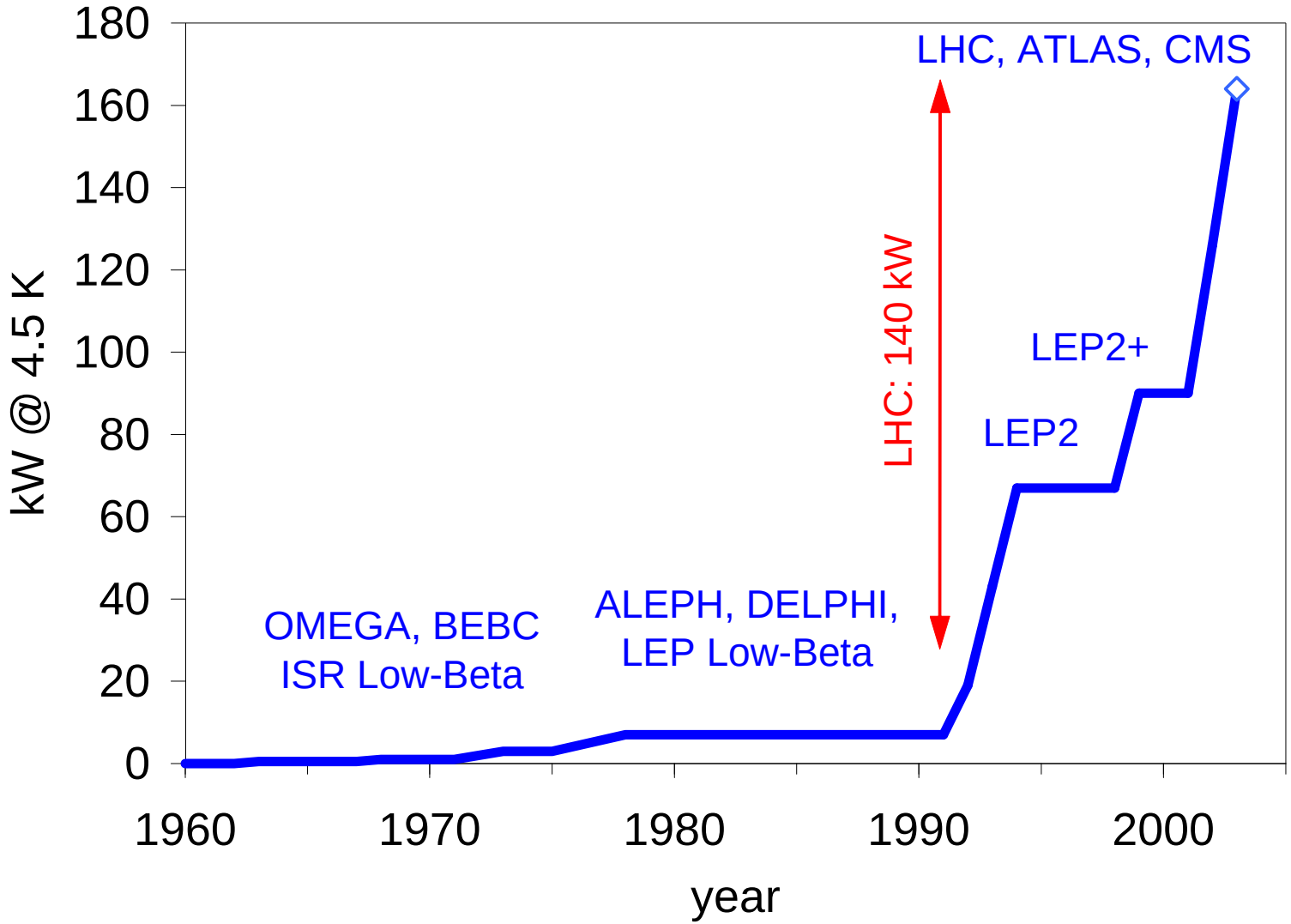
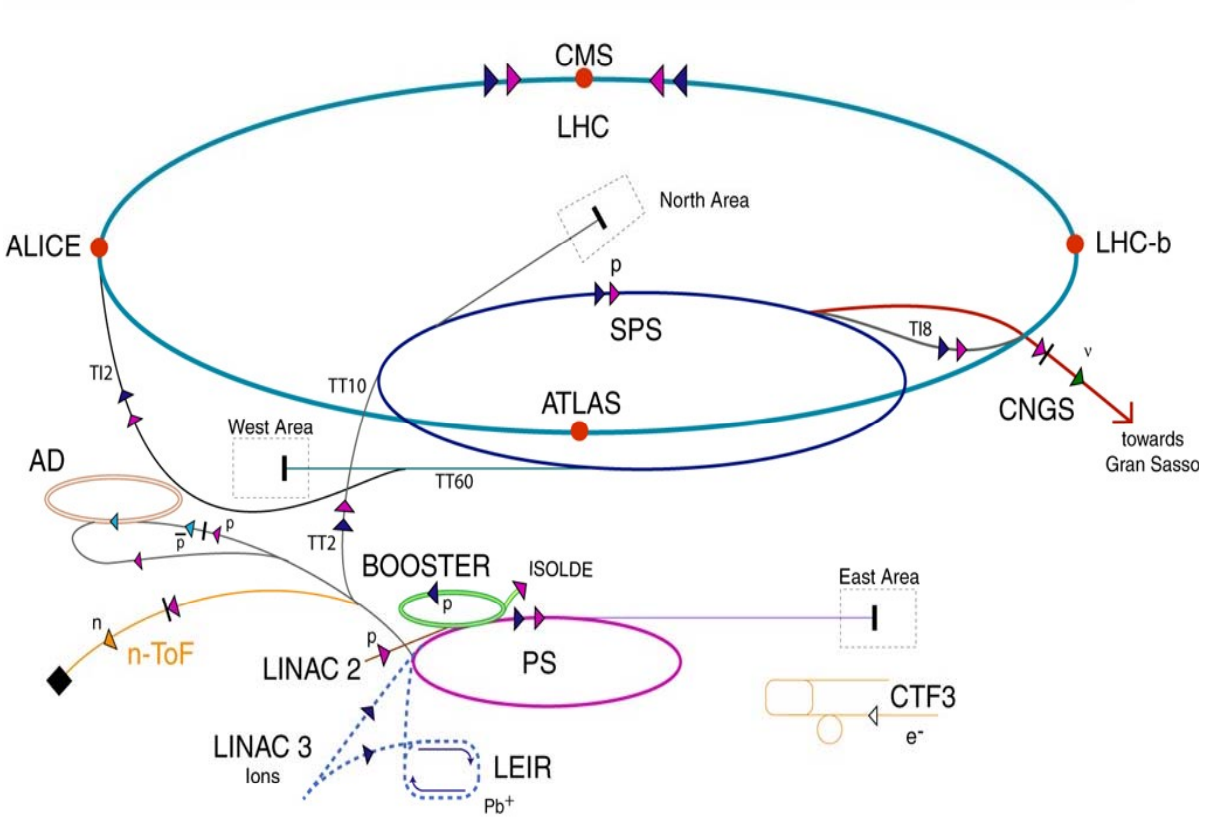
Cryogenic history

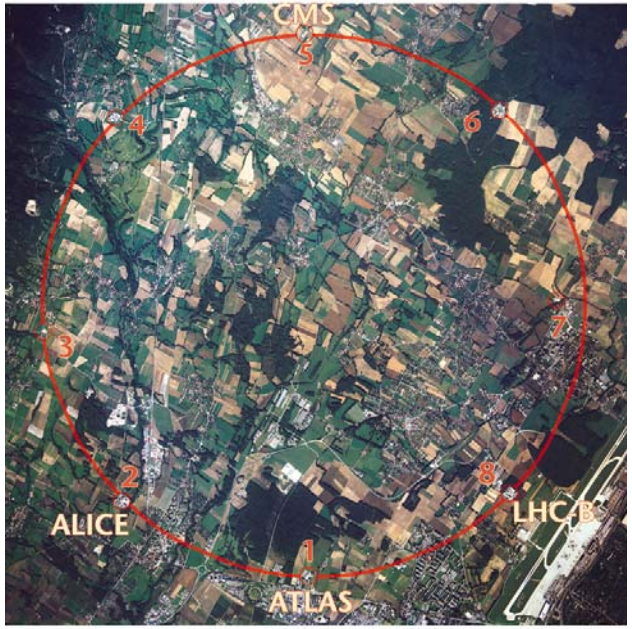


CERN accelerator complex



LHC

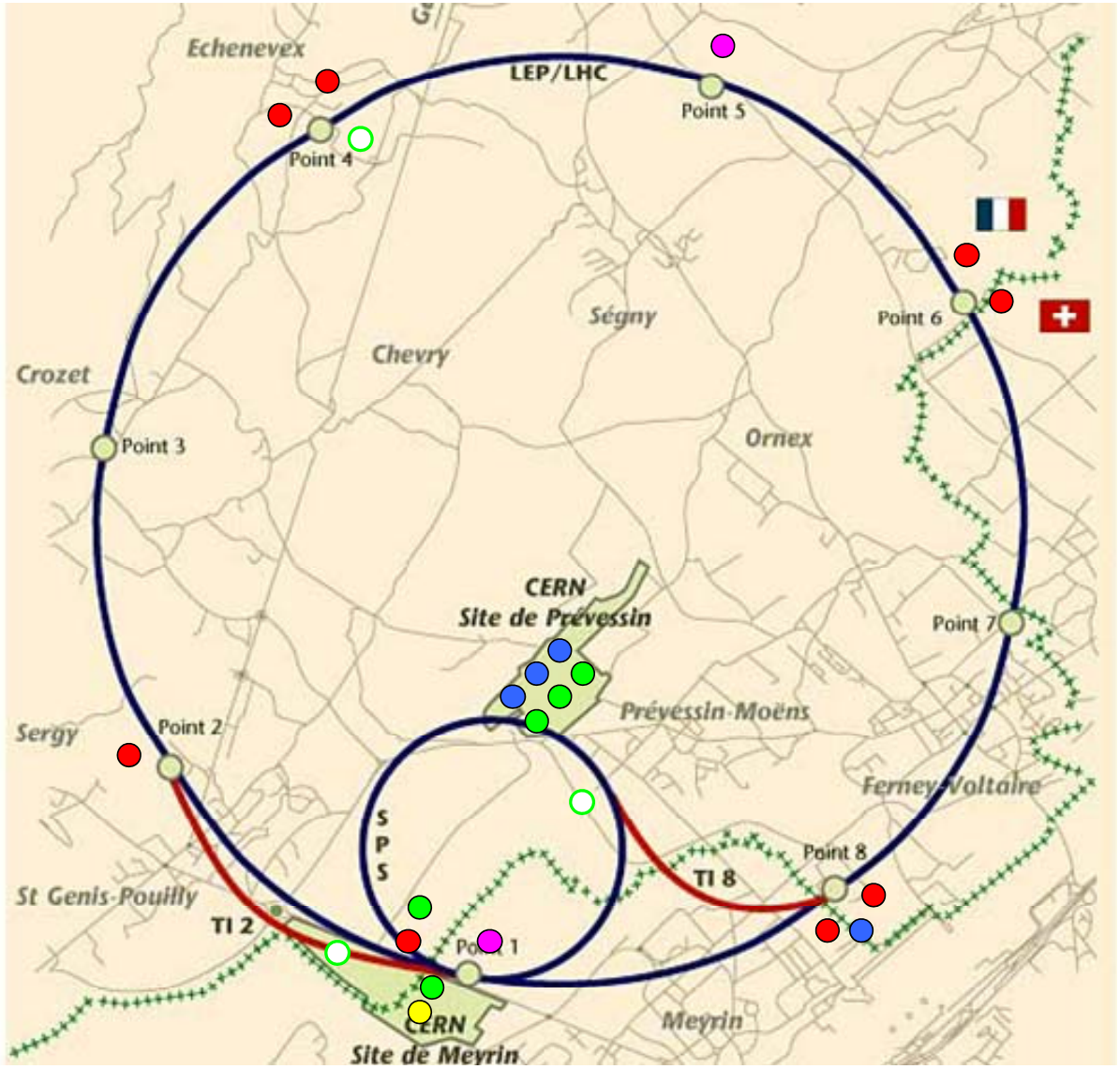
THE LARGE HADRON COLLIDER



LE GRAND COLLISIONNEUR DE HADRONS

CERN AC - F116

Footprint of cryogenic plant



- LHC accelerator
- LHC detectors
- Other detectors
- Test areas
- Central services
- Standby

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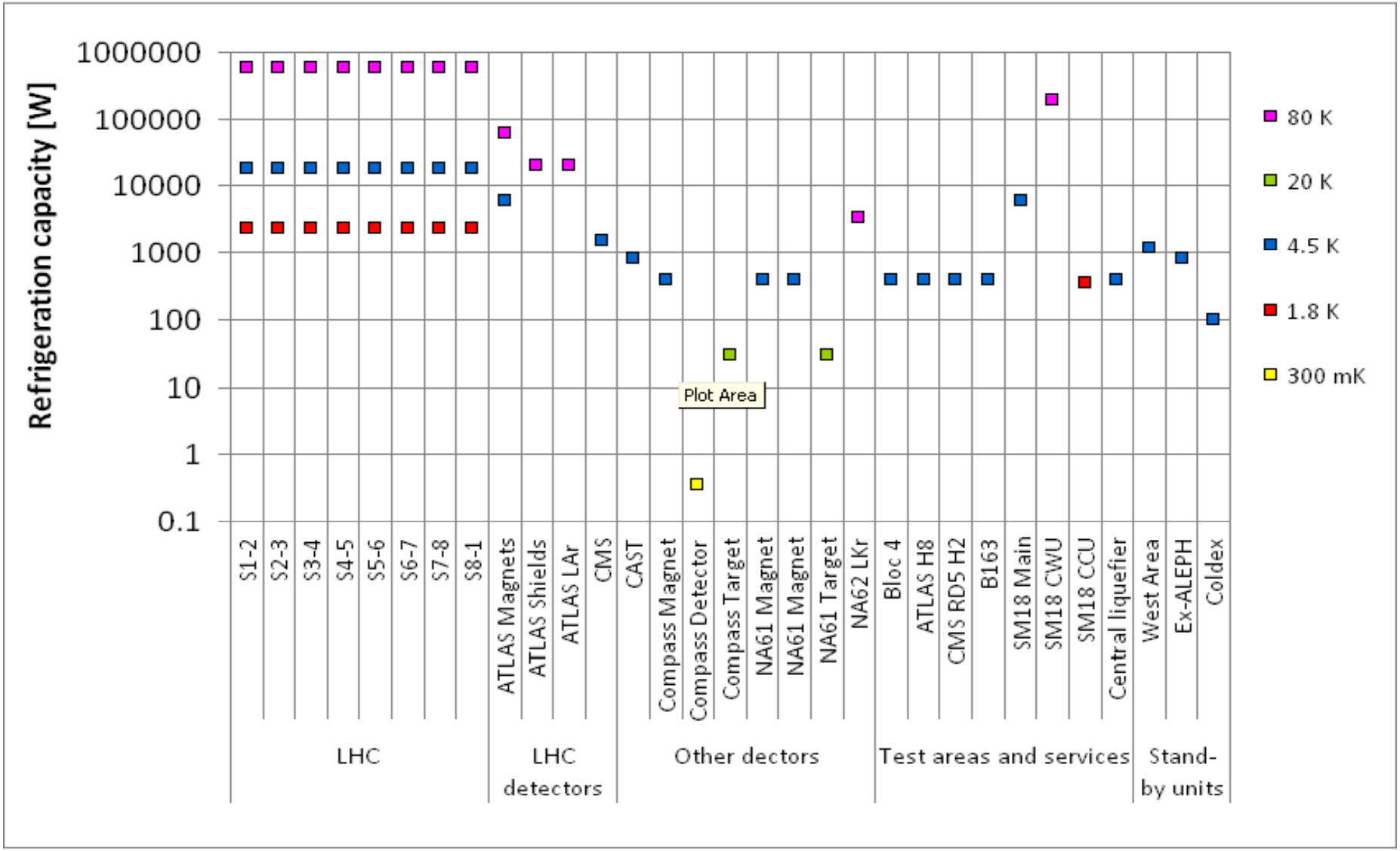
Refrigeration capacity @ CERN

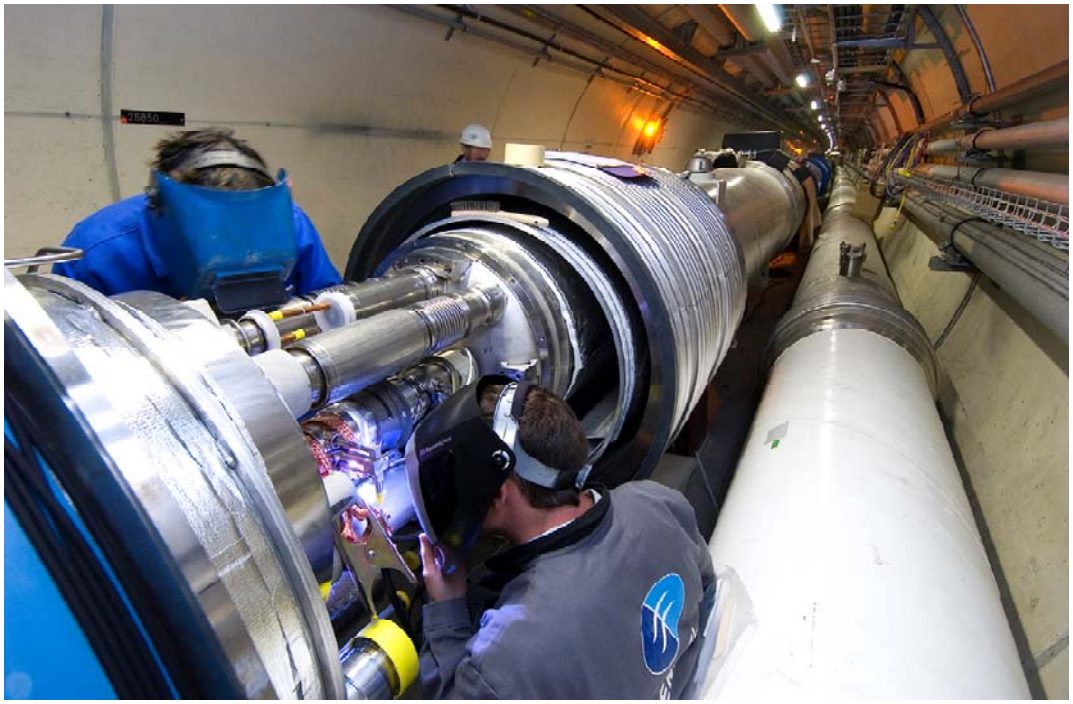


Overall refrigeration capacity

T level	Overall installed capacity	# of plants
80 K	5 MW	9
4.5 K	164 kW	23
20 K	60 W	2
1.8 K	19.6 kW	9
300 mK	350 mW	1

Plants & ancillary equipment to be operated continuously with respect to CERN's scientific program

LHC accelerator in the tunnel



36’000 ton of cold mass (superconducting magnets) distributed over 26.7 km of the underground accelerator to be cooled at 1.9 K

LHC Accelerator Cryogenics

18 kW @ 4.5 K units

Typical
Helium Compressors station
&
Cold Boxes

LHC Accelerator Cryogenics

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2.4 kW @ 1.9 K units

IHI- Linde

Air Liquide

Warm Compressors & Cold Boxes

LHC Accelerator Cryogenics

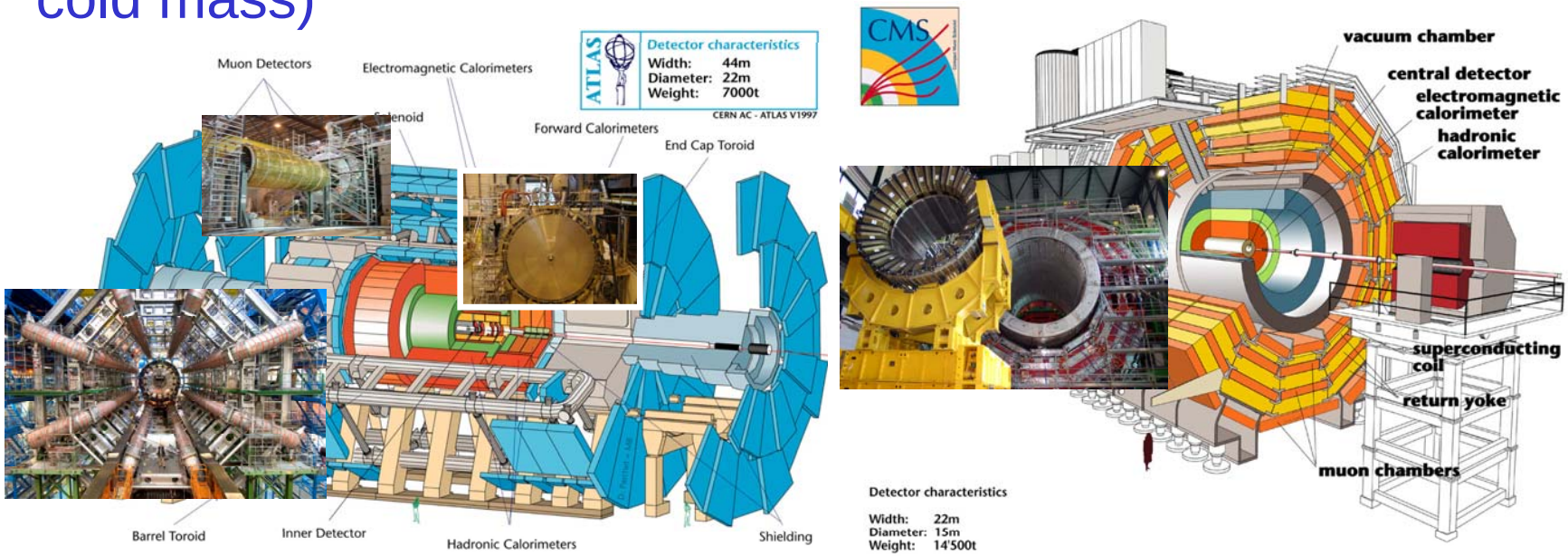
IHI-Linde

Air Liquide

LHC Cold Compressors (speed range 100 – 800 Hz)

ATLAS & CMS LHC Detectors

ATLAS, cooling at 4.5 K of a toroid superconducting magnetic system and central solenoid (1’275 t of cold mass)
ATLAS, liquid argon (83’000 liters) calorimeter system (660 t cold mass)
CMS, cooling at 4.5 K of a superconducting solenoid (225 t of cold mass)



ATLAS Detector Cryogenics (LHC)

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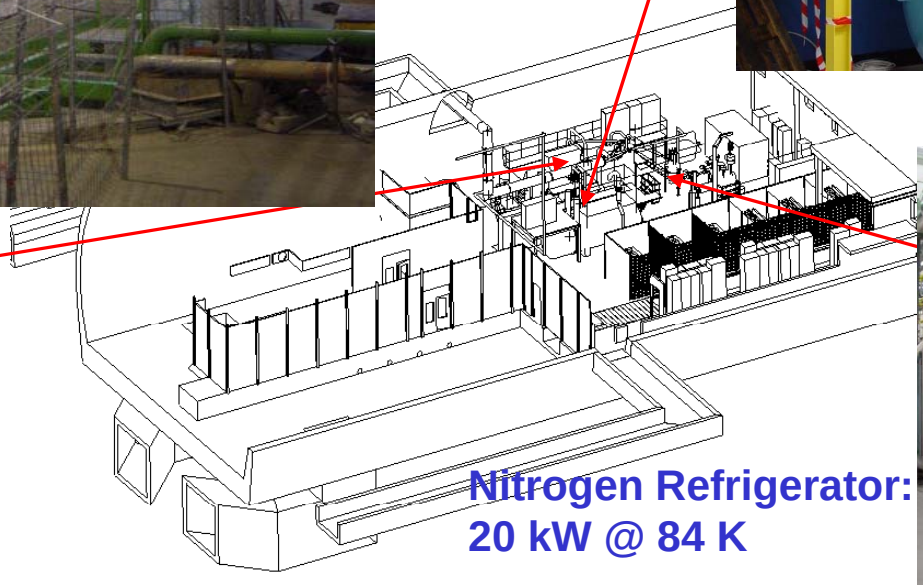
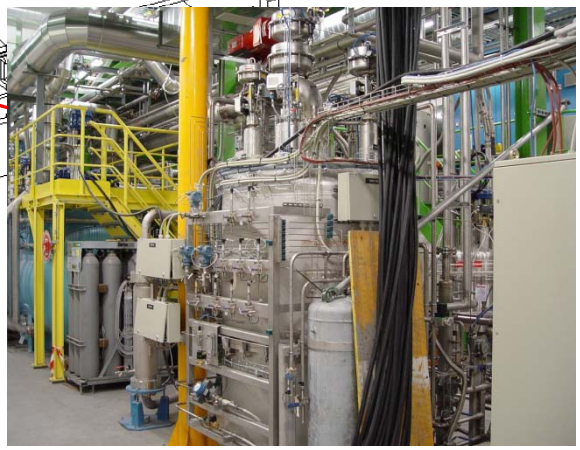
He Shield Refrigerator:
- 20 kW 40 - 80 K
- 60 kW 300 - 100 K



He Main Refrigerator: 6 kW @ 4.5 K



Nitrogen Refrigerator: 20 kW @ 84 K

CMS Detector Cryogenics (LHC)

1.5 kW @ 4.5 K unit

NA58 Compass Detector (SPS)

The Compass magnet & dilution Refrigerator

(400 W @ 4.5 K & 350 mW @ 300 mK)

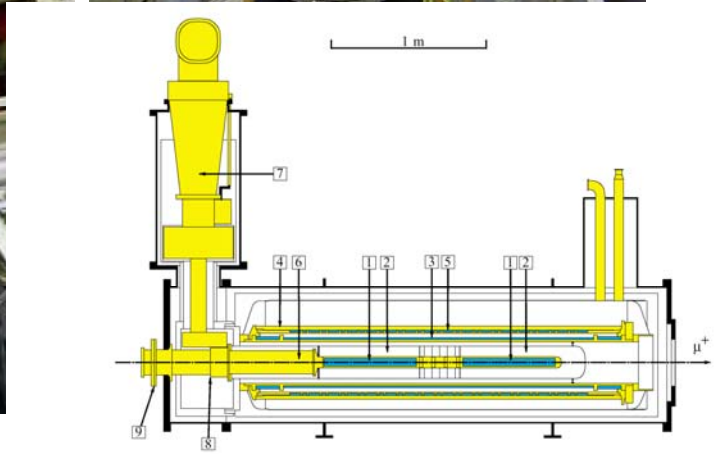
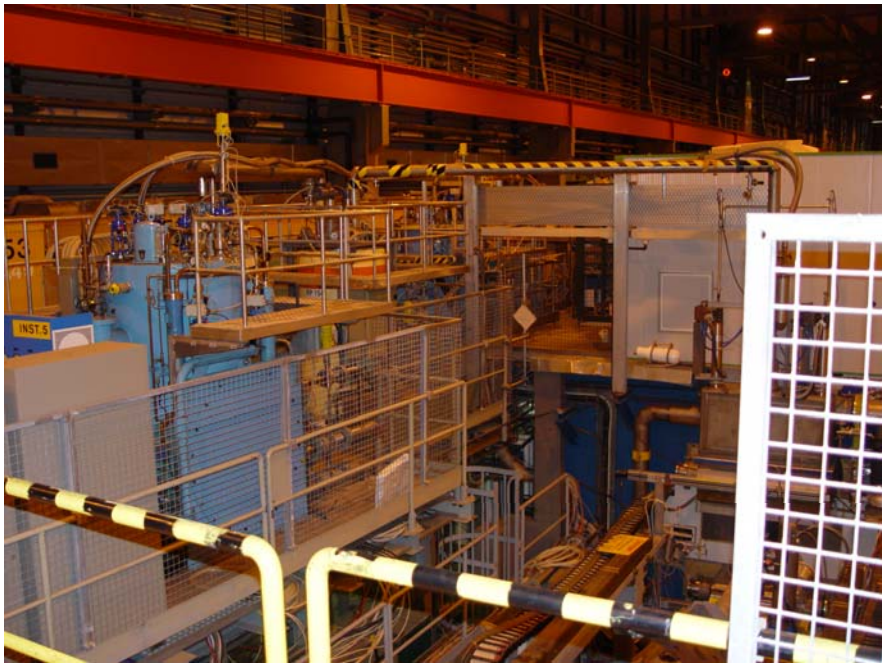


Fig. 5: The SMC target cryostat with the target holder as used in 1993 (from Ref. [3]). (1) target cells, (2) microwave cavity, (3) solenoid coil, (4) dipole coil, (5) correction coils, (6) dilution refrigerators, (7) precooler of ^{3}He, (8) indium seal, and (9) external seal.

NA61, NA62 Detectors (SPS)



NA61: 2 x 400 W @ 4.5 K
(2 magnets)

NA62: Liquid Krypton calorimeter(10’000 liters)

CAST Detector

CERN **A**xion **S**olar **T**elescope

800 W @ 4.5 K

Test Facilities for ATLAS & CMS (SPS)

CMS RD5 H2,
400 W @ 4.5 K

ATLAS H8, 400 W @ 4.5 K

Test facilities & general services

Cryogenic test benches for wires, cables and…

400 W @ 4.5 K

400 W @ 4.5 K …auxiliary superconducting magnets

SM18 Test benches (LHC magnets)

12 cryogenic test benches for the LHC magnets nominally tested before underground installation (several years of intensive, 24h/24, 7d/7 cryogenic operation)

Test facilities & general services

Central liquid helium production in situ and distribution by means of mobile containers (from 100 to 2000 liters) of up to 250'000 liters peryear

400 W @ 4.5 K

(R&D programs, accelerators & physics detectors without dedicated cryogenic plant)

Test facilities & general services
Cryogenic Laboratory (Cryolab)

- CERN wide support for testing and validating technical solution.
- Operation and development of special laboratory measuring equipment for CERN users.
- Consultancy for scientific, technical study and development for cryogenics.

Cryogen storage and distribution

Cryogen management (helium, nitrogen): Inventory

- LHC (accelerator & detectors) helium full inventory:

  136 t, completed by July 08

(LHC accelerator storage capacity: 75 t in situ, 55 t of "virtual storage" in collaboration with industrial suppliers)

- Present total helium inventory at CERN: **150 t**

- LHC (accelerator & detectors) liquid nitrogen needs for a full cool down: **11'500 t**, completed by end of June 08
- (LHC accelerator full cool down: **10'000 ton in 33 continuous days**; equivalent to 500 standard transportable containers delivered by industrial suppliers)

Cryogen storage and distribution

Storage infrastructure (in brackets: capacity dedicated to LHC)

Gas & liquid helium storage capacity at CERN

Gas tank capacity [m³]	**250 (at 2.1 MPa)**	**80 (at 1.5 & 2.1 MPa)**
Number of units at CERN	**58 (58)**	**65 (40)**



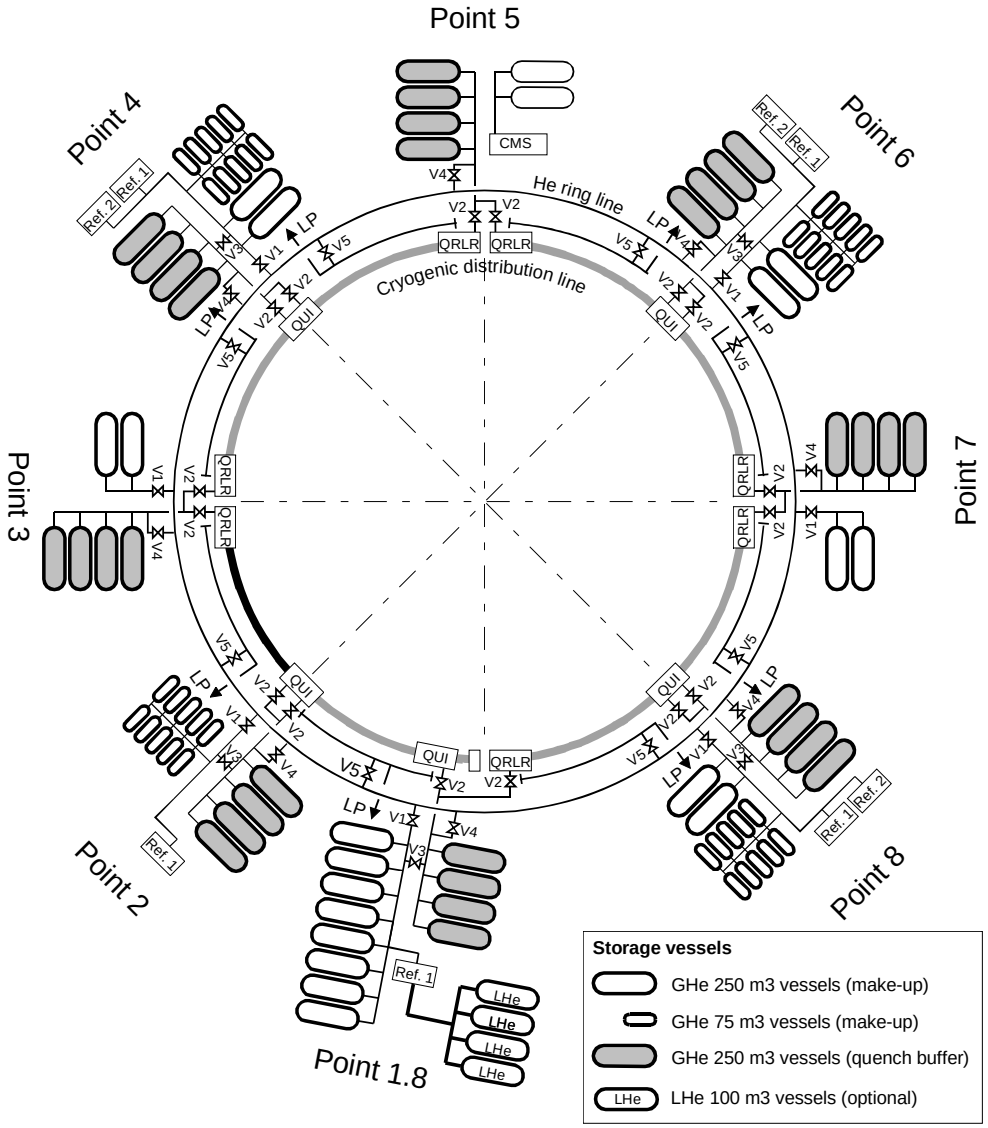
Liquid tank capacity [liter]	**120'000 (fixed)**	**25'000 (fixed)**	**11'000 (mobile)**	**6'000 (fixed)**
Number of units	**2 (2)**	**1**	**2**	**1**


Liquid nitrogen storage capacity at CERN

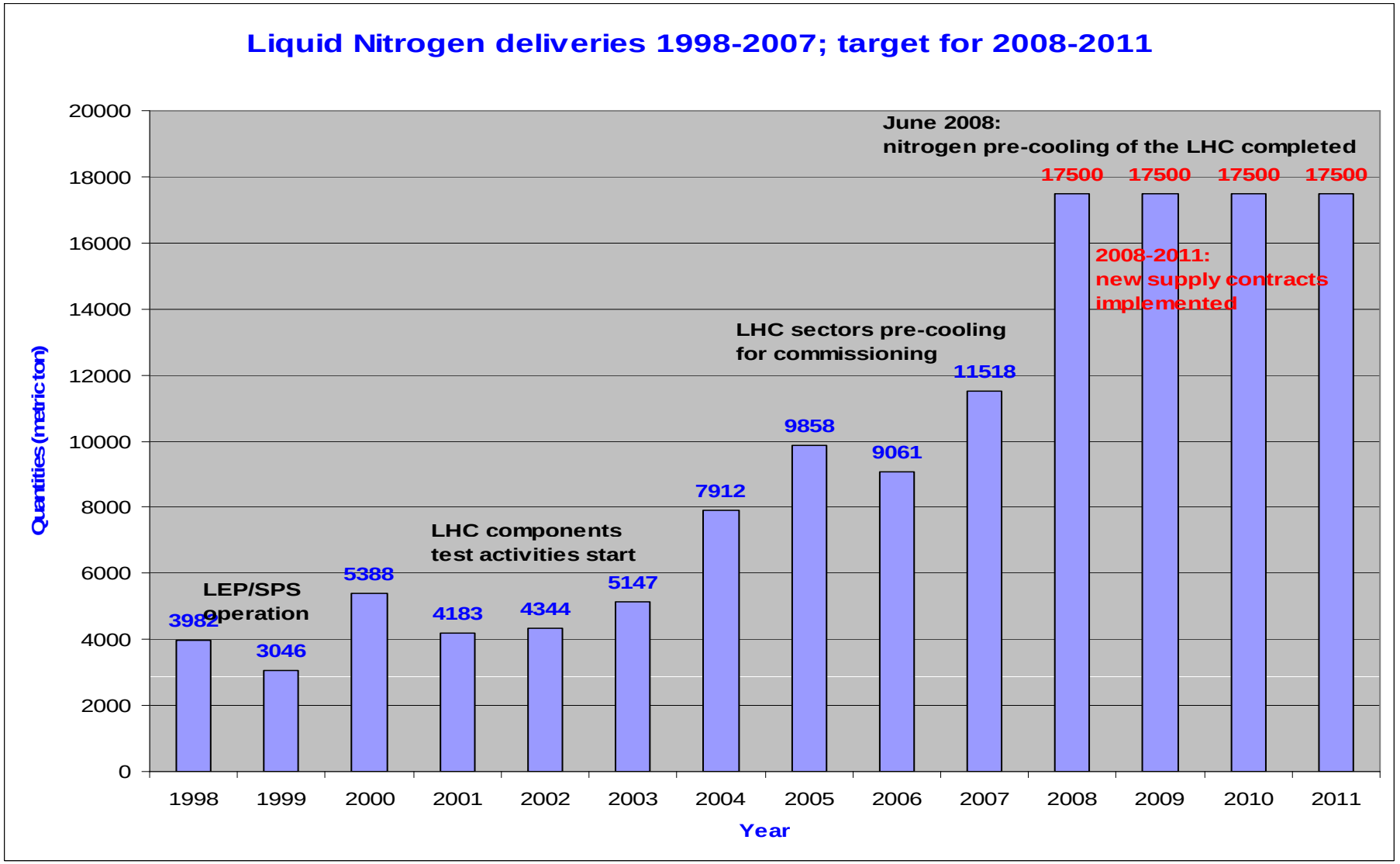
Container capacity [liter]	**50'000**	**40'000**	**27'000**	**20'000**	**15'000**	**10'000**	**6'000**
Number of units	**14 (13)**	**2**	**1**	**2**	**2**	**1**	**7**

Cryogen storage and distribution

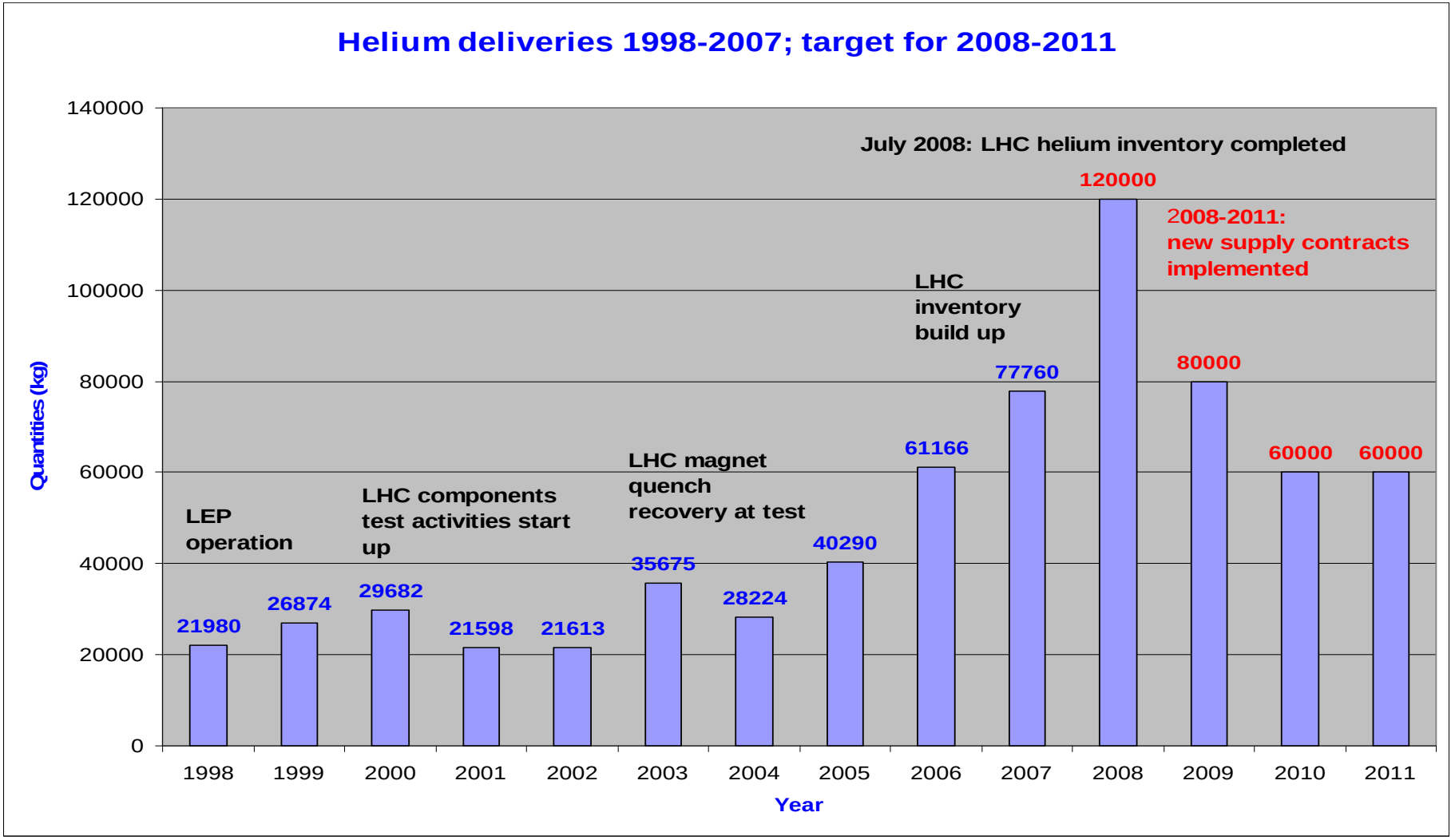
LHC helium storage
&
distribution



Cryogen storage and distribution



Cryogen storage and distribution



Cryogenics operation methodology

Operation & Maintenance (O&M) of the cryogenic plants & ancillary equipments at CERN:

- … - 1995 Under CERN's direct responsibility
- 1995 - 2009 Strategic decision to outsource the O&M in the frame of a full task delegation contract by establishing partnership with specialized industrial services provider including performance evaluation with contractual indicators (bonus, penalties application)
- Presently, 63 collaborators (42 operators, 17 for technical support & maintenance, 4 for the management team)

Conclusions

- Cryogenics at CERN: a long history, since 1960's for physics and related R&D programs
- Very large spectrum of applications and range of working conditions for the refrigeration plants (capacity, temperature, geographical location)
- Use of "state of the art" industrial cryogenic equipment at the edge of the present technology (examples: 1.9 K cold compressors refrigeration units; 1200 g/s liquid helium circulators)
- Very important cryogen inventory
- Cryogenic operation reliability & availability to the users:

  over the last 15 years, nearly 590'000 running hours have been cumulated with a mean non availability rate of < 1% depending on the application