CRYOGENICS OPERATIONS 2008

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Design choices of the cryogenic system for the long-term operation of ATLAS and CMS detector magnets

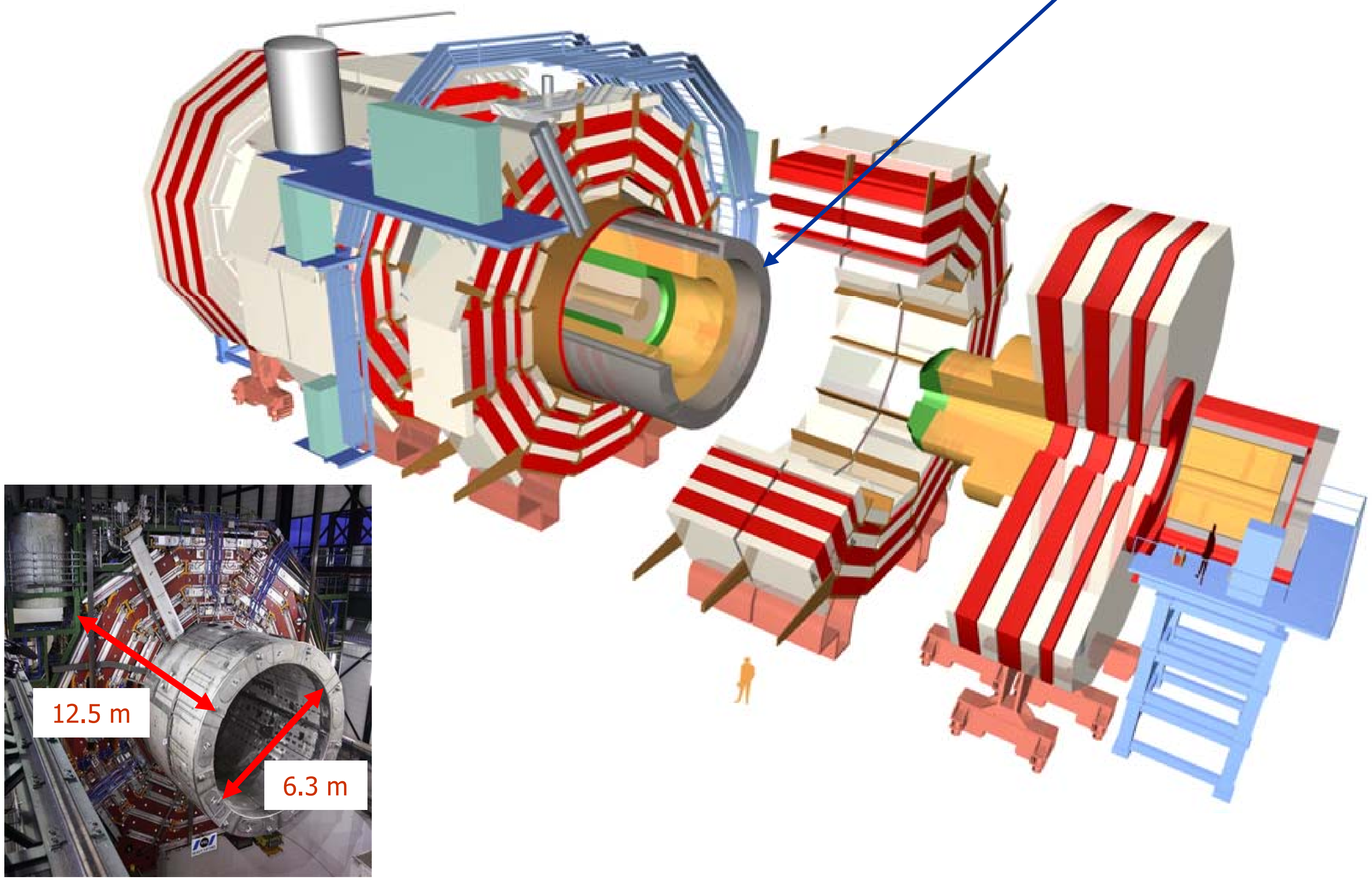
N. Delruelle

Outline

- Introduction
- Type of He circulation driving force
- Why using large buffer Dewars
- Advantages of a separate He fridge for ATLAS shielding
- Design of the new ATLAS compressor station
- Conclusions

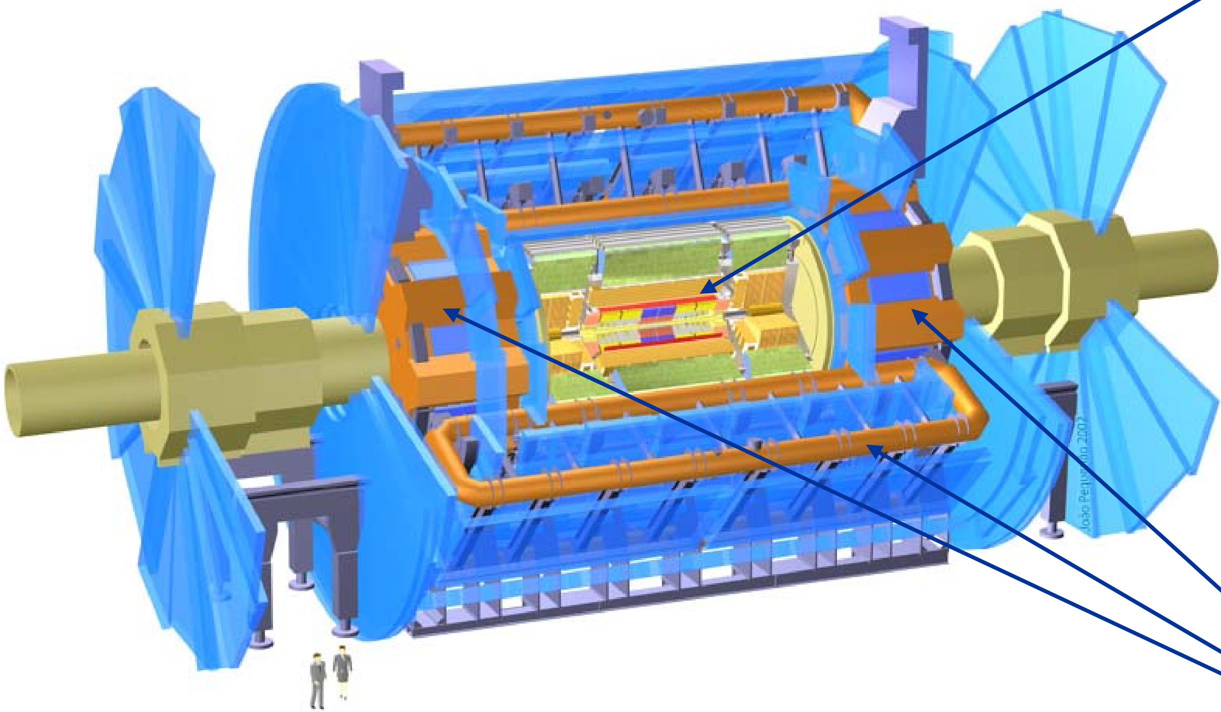
Introduction (1)

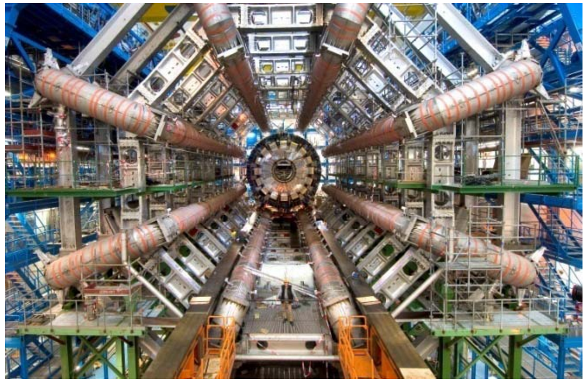
- **CMS magnet system = 1 S.C. solenoid**



Introduction (2)

- **ATLAS magnet system = 1 S.C. solenoid…**



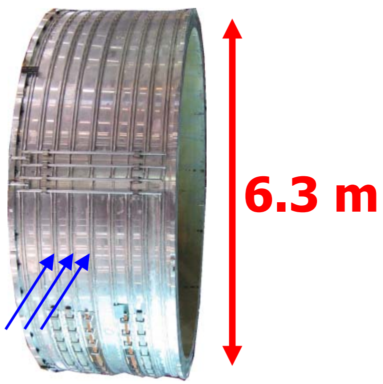


… + 3 S.C. toroids

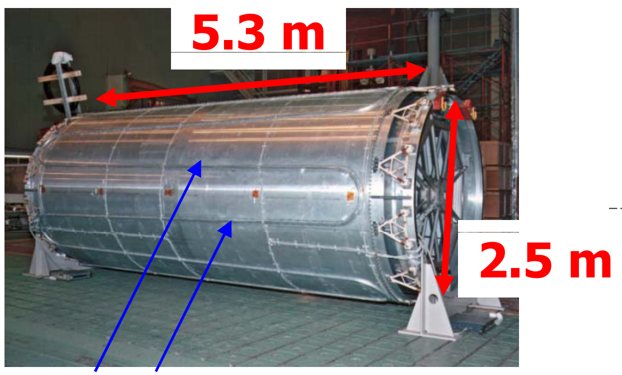
Introduction (3)

- **All CMS and ATLAS coils are cooled via an "<u>indirect" cooling method</u>, i.e. cooling pipes welded onto the coil structure**
  ➔ no need of complex and bulky He vessels.

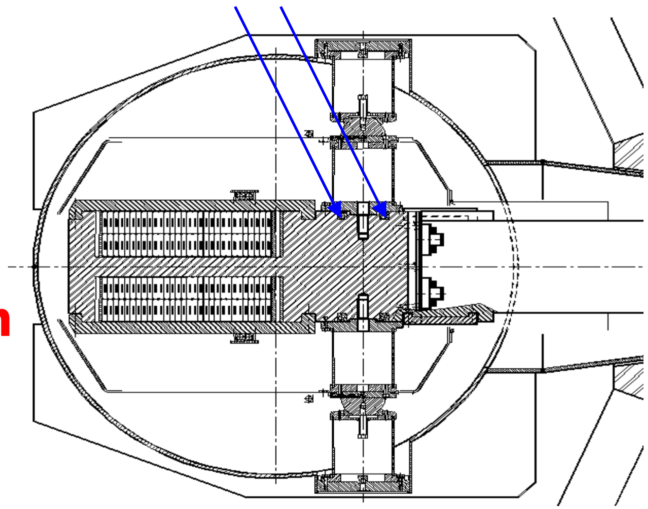
1/5 CMS solenoid



ATLAS solenoid



ATLAS barrel



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Type of He circulation force (1)

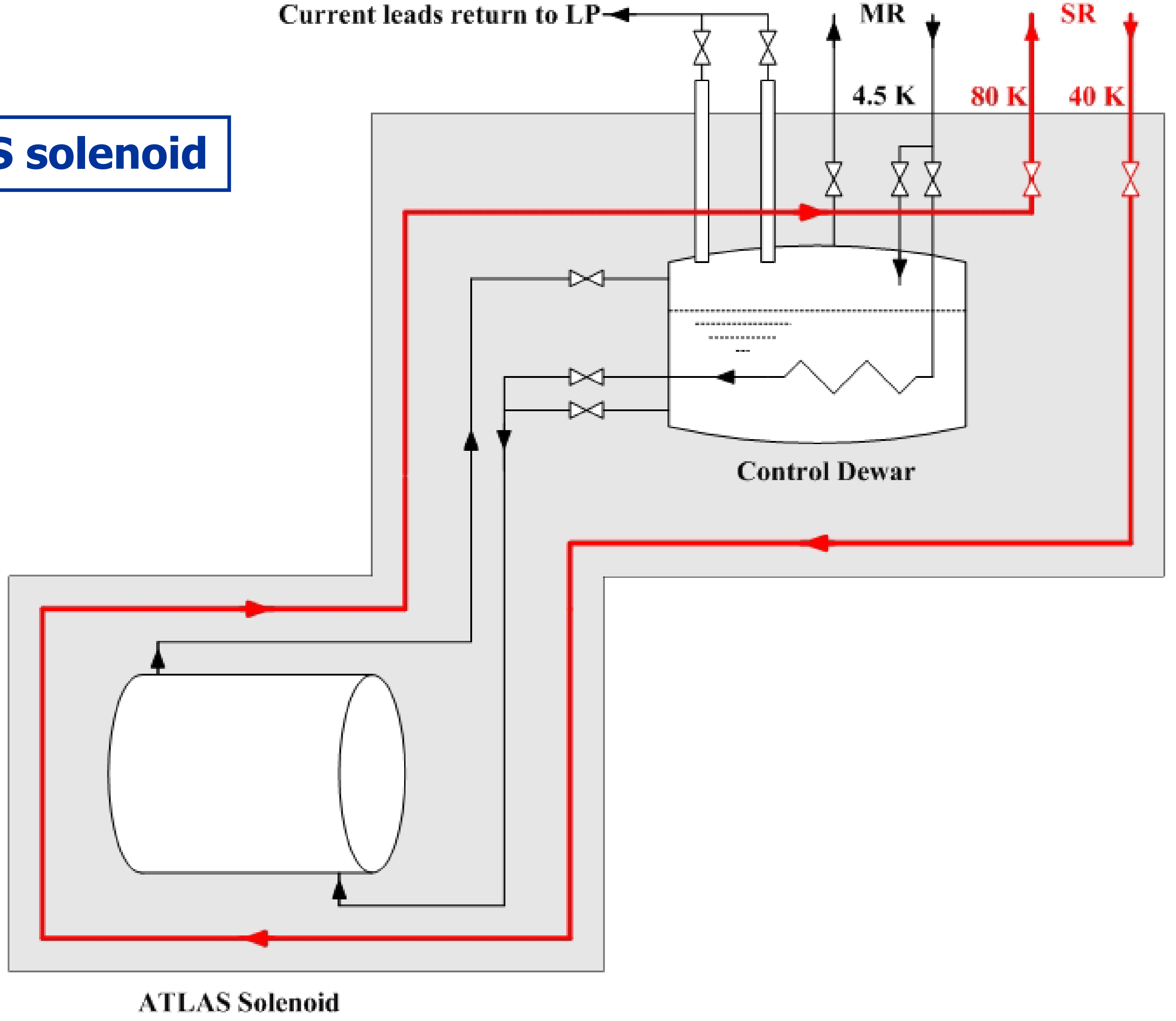
- **"As simple & reliable as possible" !**
- **CMS and ATLAS solenoids have simple cylindrical piping distribution**

  ➔ Thermo-siphon cooling is possible.

- **Advantage:**
  high mass-flow rate obtained only with natural hydrostatic ΔP (driving force)
  ⇔ no external driving system (like pump) subject to failure.

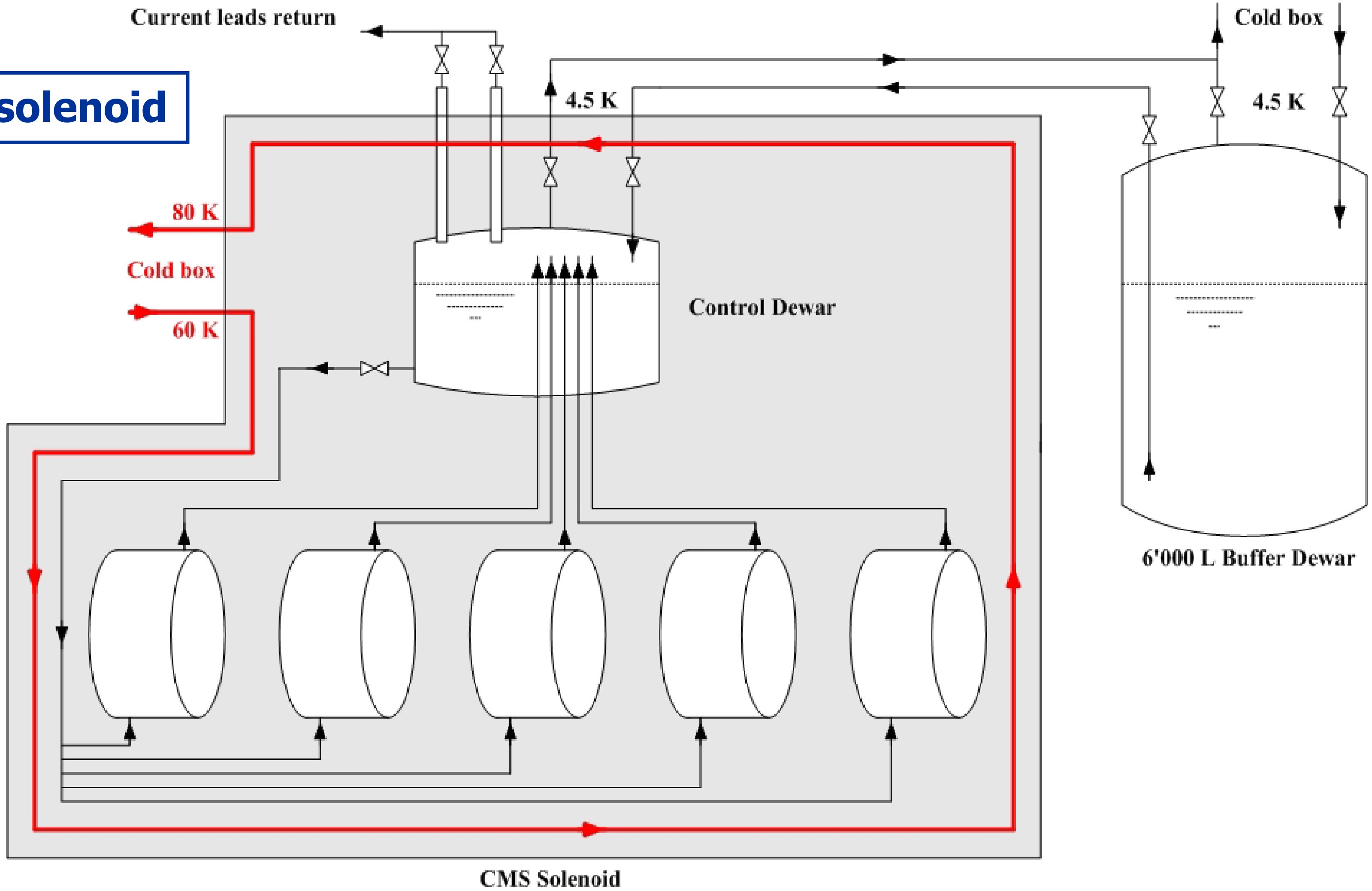
Type of He circulation force (2)

ATLAS solenoid



Type of He circulation force (3)

CMS solenoid



Type of He circulation force (4)

- **Each ATLAS toroid consists of 8 individual coils symmetrically placed around the beam axis**

➔ Complex geometry & piping distribution

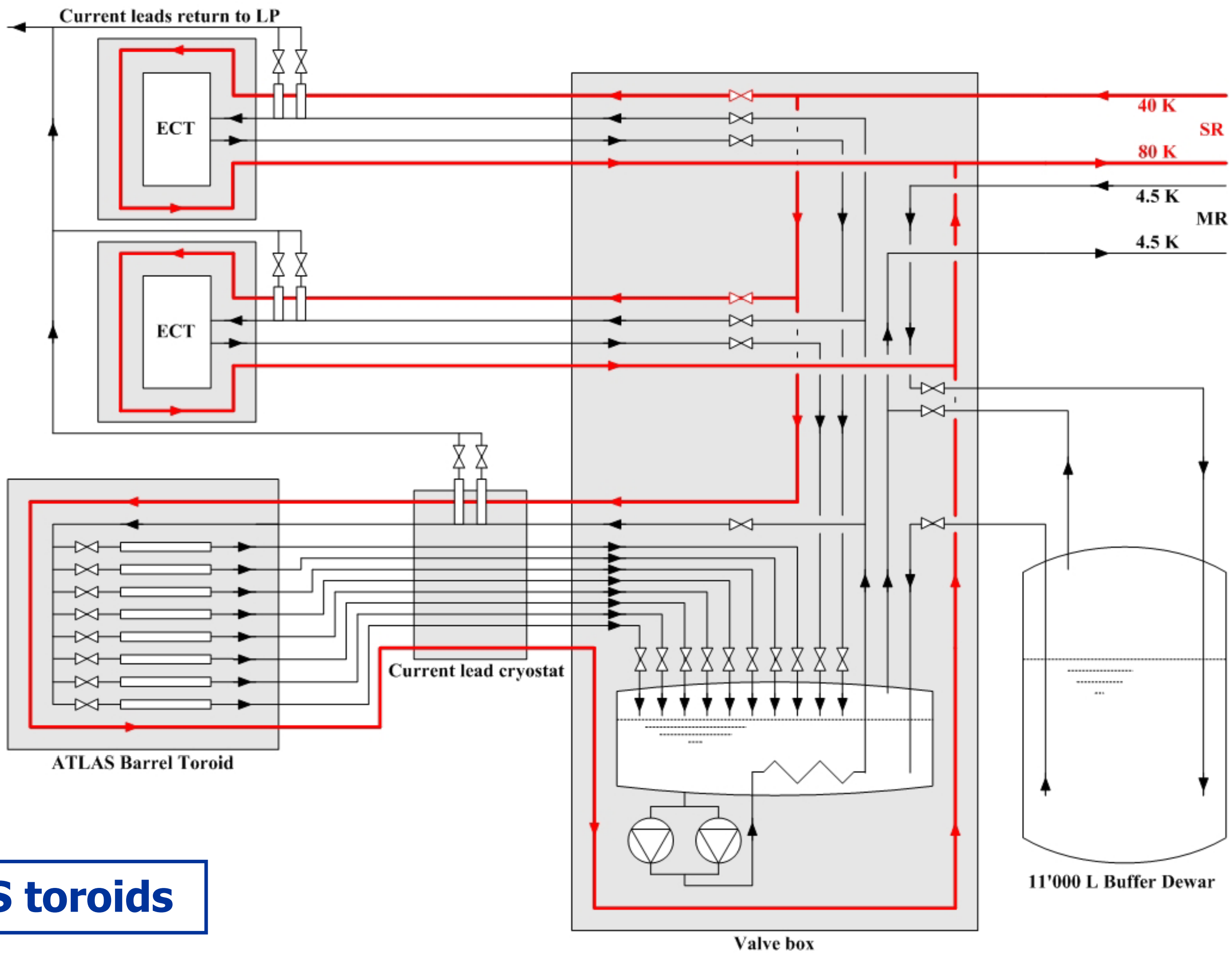
➔ Thermo-siphon not possible

➔ Use of <u>liquid He pump mandatory</u> to get:

» mass flow rate/area > 4 $g.s^{-1}.cm^{-2}$

» vapour mass fraction at coils outlet < 10%

Type of He circulation force (5)



ATLAS toroids

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Why using large buffer Dewars

- CMS and ATLAS magnets have "sufficient" buffer-volume with LHe to always ensure a "slow dump" of magnets, even in case the fridge stops (power failure, etc.).

- CMS slow dump ≤ 5 hours
  heat load @4.5 K = 800 W → 40 g/s during 5 hours = 5'760 L → 6'000 L.

- ATLAS slow dump ≤ 2.5 hours
  head load @4.5 K = 2'400 W → 120 g/s during 2.5 hours = 8'640 L → 11'000 L.

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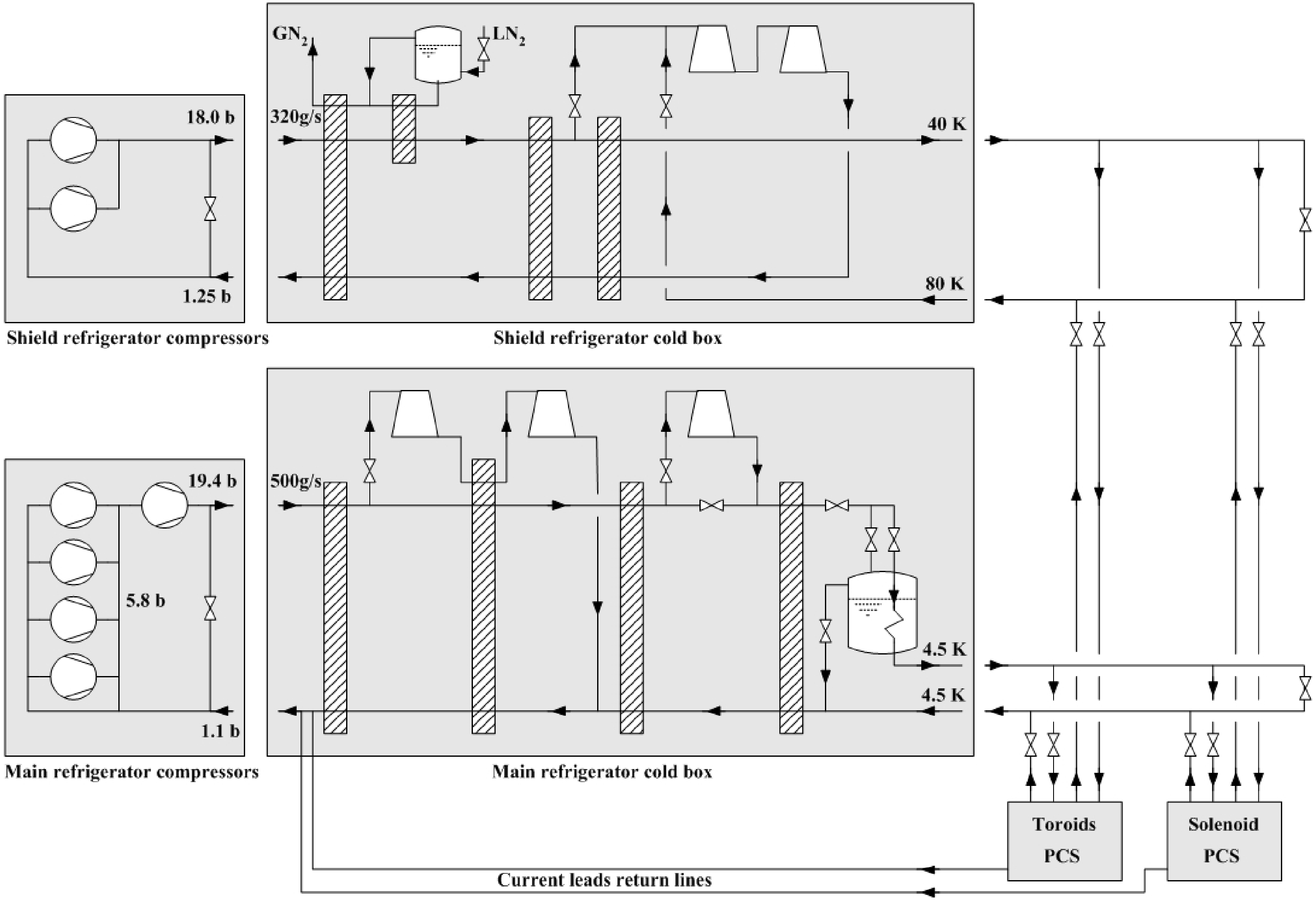
Separate fridge for ATLAS shielding (1)



Separate fridge for ATLAS shielding (2)

- **ATLAS magnets have 2 separate cryoplants**
  - » 1 for the shields cooling between 40 K and 80 K
  - » 1 for the cooling at 4.5 K (and the quench recovery)
- **Advantages:**
  - » Shield refrigerator has only 2 compressors + 2 turbines:
    ➔ annual maintenance time reduced to 3 weeks
    ➔ drift (warm-up) of cold mass temperatures limited in time to 3 weeks and then stabilized at T ≤ 80 K.
  - » Shield refrigerat. needs only 1 compressor + 2 turbines in steady state:
    ➔ In case of services failure (electricity, water, etc.), the simple shield refrigerator is rapidly restarted. More time is needed for main fridge (LHe @4.5 K)!

Separate fridge for ATLAS shielding (3)

- **Drawback**:
  - » Global efficiency of 2 separated refrigerators is less than the efficiency of one “big” fridge:
    ➔ we consume more electricity.

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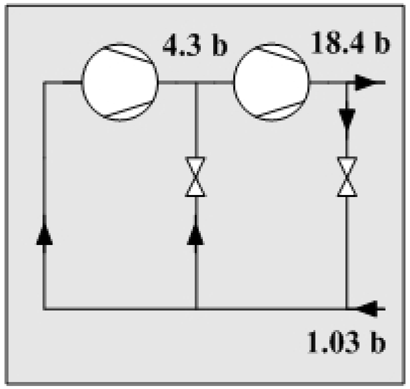
Design of ATLAS compressor station

Compressor station classical layout

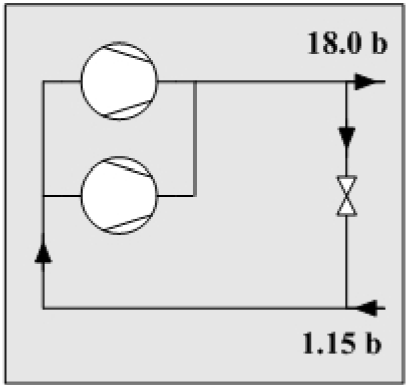


2 compressors in series

Pressure ratio ≈ 5

Isoth. efficiency ≈ 0.45

ATLAS shield compressor station layout



Shield refrigerator compressors

1 compressor is needed (second is redundant)

Pressure ratio ≈ 18

Isoth. efficiency ≈ 0.39
←→ more electricity

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Conclusions

- **Design choices for ATLAS & CMS cryogenics based on "as simple & reliable as possible":**
  - » IF magnet geometry allows it THEN use thermo-siphon (passive) cooling ELSE use centrifugal pump (active);
  - » Use of large buffer Dewar to always ensure magnets slow dump, even when fridges are stopped;
  - » Use of separate and simple fridge for magnets shields, which minimize magnets warm-up in shut-down period;
  - » For small compressor station, prefer single compressor with pressure ratio ≈ 18 and reduced η_{isoth} but fully redundant than more optimized configuration without redundancy;
- **But only the next 15 years of operation will confirm these choices…hopefully !**