Symposium for the inauguration of the LHC cryogenics
31 May to 01 June 2007

Cryogenics for ATLAS and CMS Experimets

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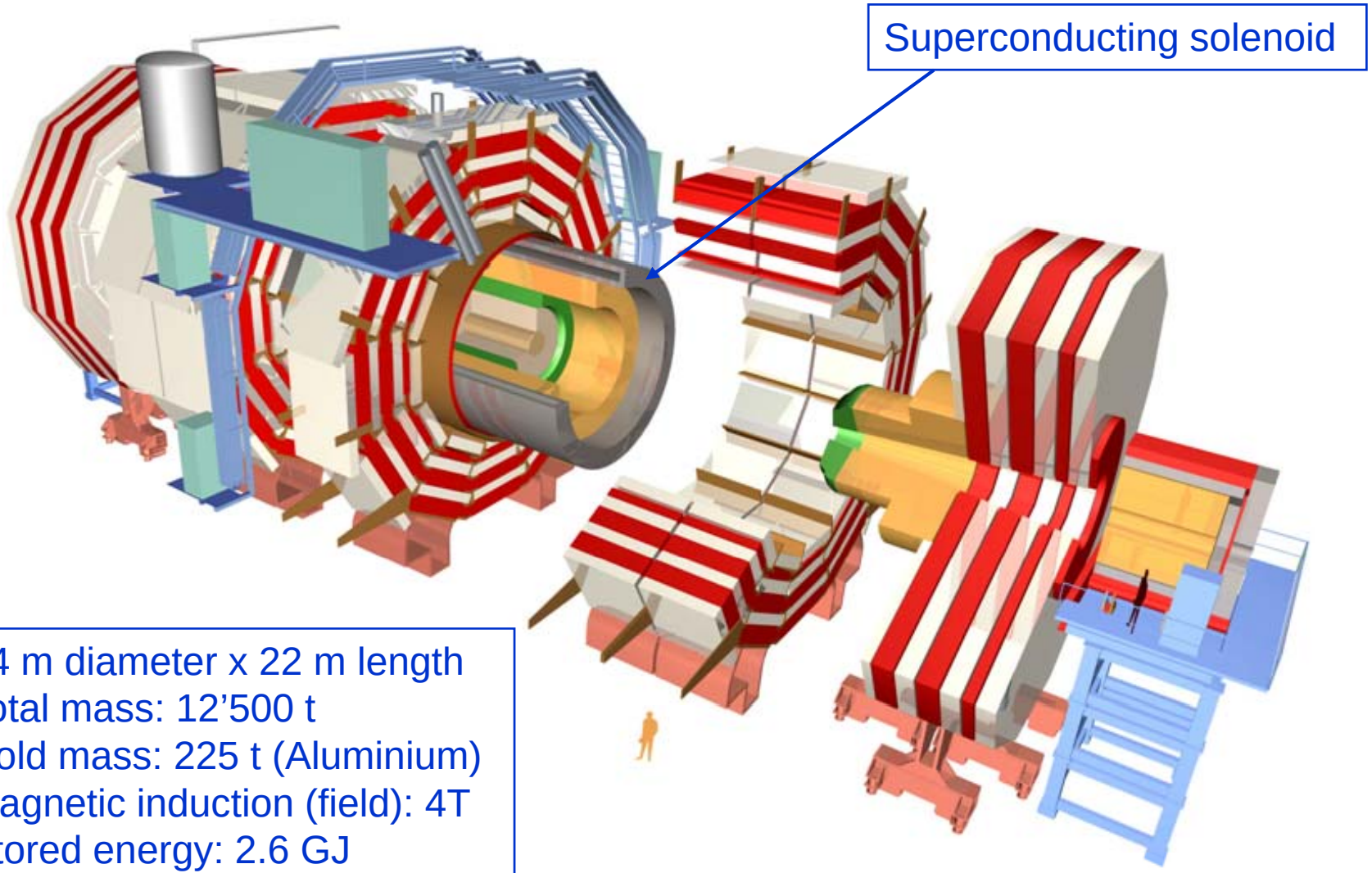
Outline

- Introduction
- Basic choices prior tendering
- Helium refrigerators
- Proximity cryogenics
- Conclusions

Introduction (1)

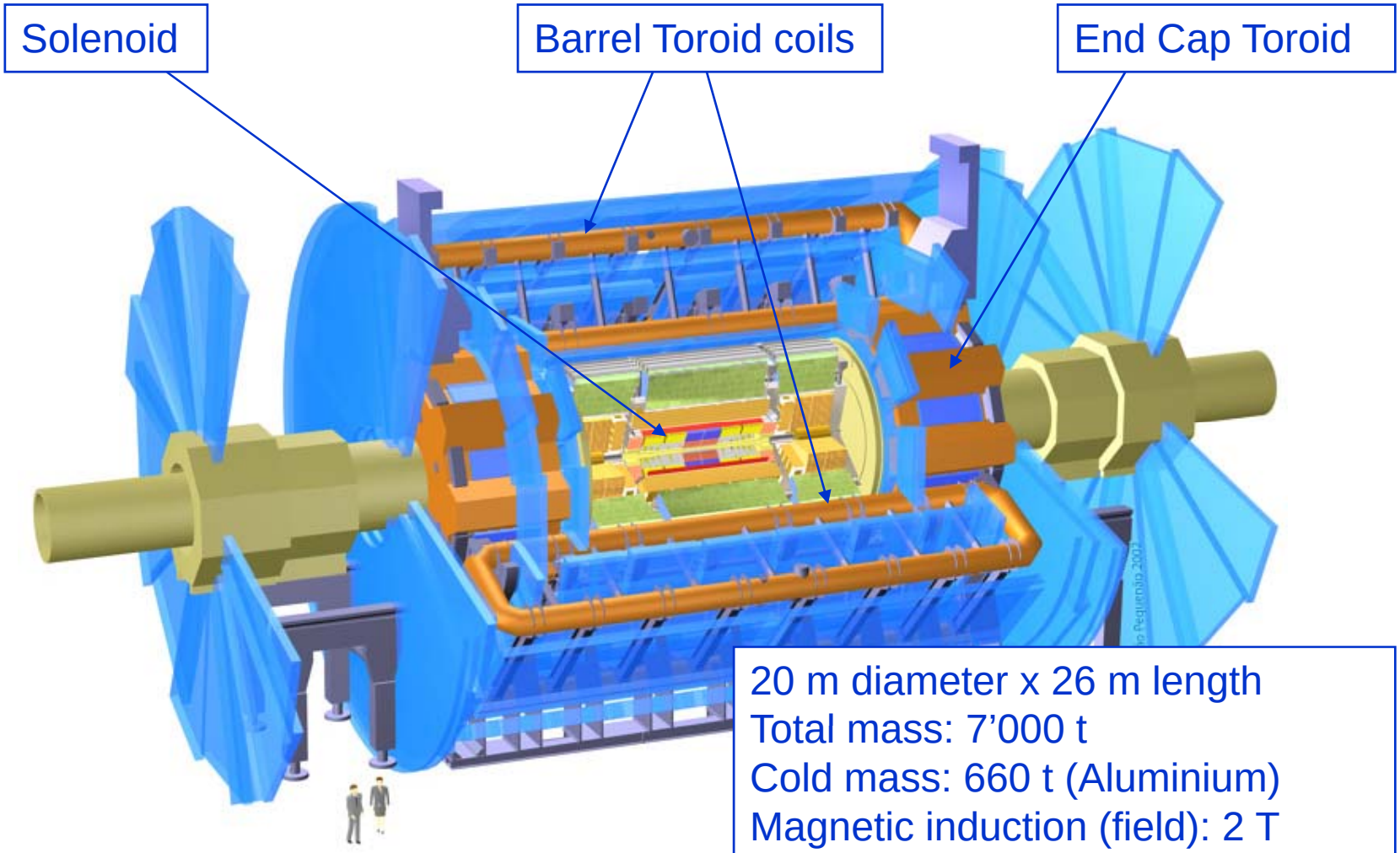
- CMS
  - Magnet system = 1 supercond. solenoid
    => magnetic field for inner tracker
    and muon chambers.
- ATLAS
  - Magnet system =
    1 supercond. solenoid => longitudinal field for inner tracker
    +
    3 toroid magnets => tangential field for muon spectrometers

Introduction (2)



14 m diameter x 22 m length
Total mass: 12’500 t
Cold mass: 225 t (Aluminium)
Magnetic induction (field): 4T
Stored energy: 2.6 GJ

Introduction (3)



20 m diameter x 26 m length
Total mass: 7'000 t
Cold mass: 660 t (Aluminium)
Magnetic induction (field): 2 T
Stored energy: 1.6 GJ

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Basic choices prior tendering (1)

- Common philosophy for CMS–ATLAS
  - Magnet system sub-divided into 3 parts:
    - Internal cryo = cooling circuits for coils and magnet thermal shields
    - Proximity cryo = auxiliary equipment for the magnet operation (phase separator, current leads, helium pump and distribution valves)
    - External cryo = production and control of the helium cooling power (refrigerators and transfer lines)

Basic choices prior tendering (2)

- Use of LN_2 precooler for 300K-100K cool-down, then expansion turbines for steady-state.

  Why ?

  To avoid over-dimensioning of refrigerators for only 2-3 weeks of cool-down per year.

- Thermal shields cooled with He turbines.
- "Sufficient" buffer volume with LHe to always ensure a "slow dump" of magnet

  (5 hours for CMS, 2 hours for ATLAS), even in case of refrigerator stop (power failure, etc.)

Basic choices prior tendering (3)

➢ Common components for CMS-ATLAS

- Use of screw- (and not piston-) compressors for the refrigerators.

  Why ?
  - Smaller, less noisy, over lubricated, lower operating temperature (=>no oil-change), lower vibration level => lower maintenance costs.
  - Higher pressure ratios per unit.

- Use of gas-bearing expansion turbines (and not oil-lubricated).

  Why ?
  - Maintenance-free with MTBF ~ 40'000 hours.
  - No pollution of the expanded fluid.

Basic choices prior tendering (4)

Specific features of CMS magnet

Requirements	Solenoid
Isothermal load at 4.5K	800 W
Non-isothermal load 60K-80K	4'500 W
Liquefaction load	4 g/s
Cool-down time for 300K -> 100K	2 weeks

- Simple cylindrical piping distribution for solenoid => Thermosiphon cooling is possible.

Basic choices prior tendering (5)

➢ Specific features of ATLAS magnets

Requirements	Solenoid	Barrel	End Caps	Prox.+ Ext. cryogenics
Isothermal load at 4.5K	80 W	660 W	360 W	1'300 W
Non-isothermal load 40K-80K	500 W	6'600 W	4'500 W	1'900 W
Liquefaction load	0.8 g/s	3.4 g/s	6.8 g/s	--
Cool-down time for 300K -> 100K	3 weeks			

Basic choices prior tendering (6)

- Re-use of existing 6 kW@4.5K fridge
  - But insufficient for:
    - reasonable cool-down time of magnets;
    - thermal shields loads between 40K-80K.

  => second refrigerator needed and used for:
    - cool-down from 300K to 100K (boosted with LN_2);
    - shields operation.
- Complex piping distribution for 3 toroids => use of one <u>centrifugal pump</u>

  providing 1'200 g/s (~10 L/s) of saturated He.

  - Two-phase stability if:
    - mass flow rate/area > 4 $g.s^{-1}.cm^{-2}$
    - vapour mass fraction at coils outlet < 10%.

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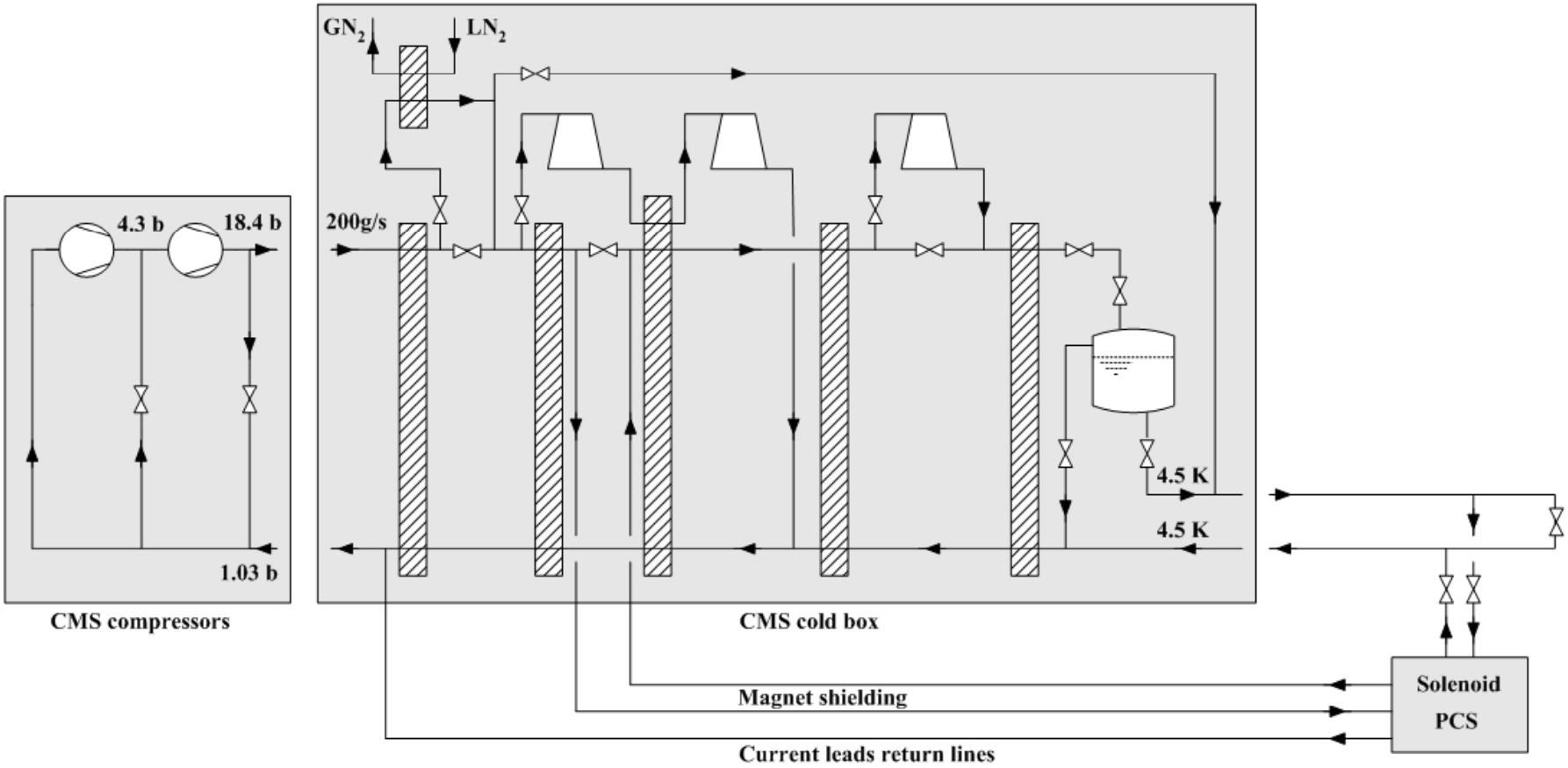
Helium refrigerators (1)

➢ CMS refrigerator

- Duties:
  - Cool-down from 300K -> 100K of solenoid (225 t).
    30 kW power required for 2 weeks per year
    => boosting by a LN_2 precooler;
  - Cool-down from 100K -> 4.5K only with expansion turbines in an other 2 weeks;
  - Steady-state operation @ 4.5K.
    4'500 W between 60K and 80K for shielding
    800 W refrigeration power @ 4.5K
    4 g/s (~115 L/h) of liquefaction.

Helium refrigerators (2)



Helium refrigerators (3)

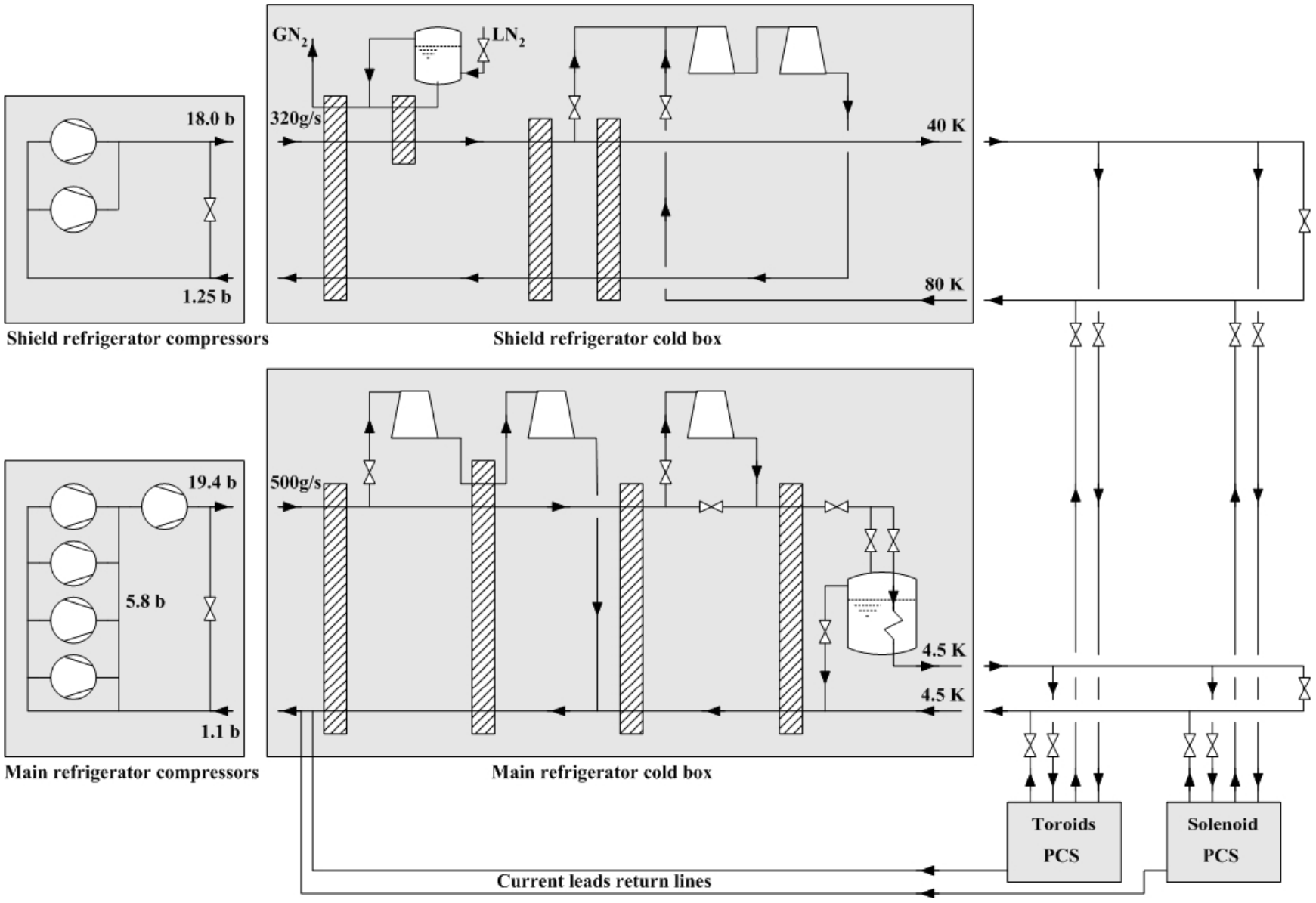
ATLAS Shield Refrigerator

- Duties:
  - Cool-down from 300K -> 100K of all magnets (660 t).
    60 kW power required for 3 weeks per year
    => boosting by a LN_2 precooler;
  - Keep thermal shields between 40K and 80K during steady-state operation.
    20 kW power only with expansion turbines.

Helium refrigerators (4)

- ATLAS Main Refrigerator
  - Duties:
    - Cool-down from 100K -> 4.5K of all magnets (660 t).
    - Steady-state operation @ 4.5K. Equivalent power of 6 kW @ 4.5K, from which 11 g/s (~317 L/h) of liquefaction are withdrawn for current leads cooling.

Helium refrigerators (5)



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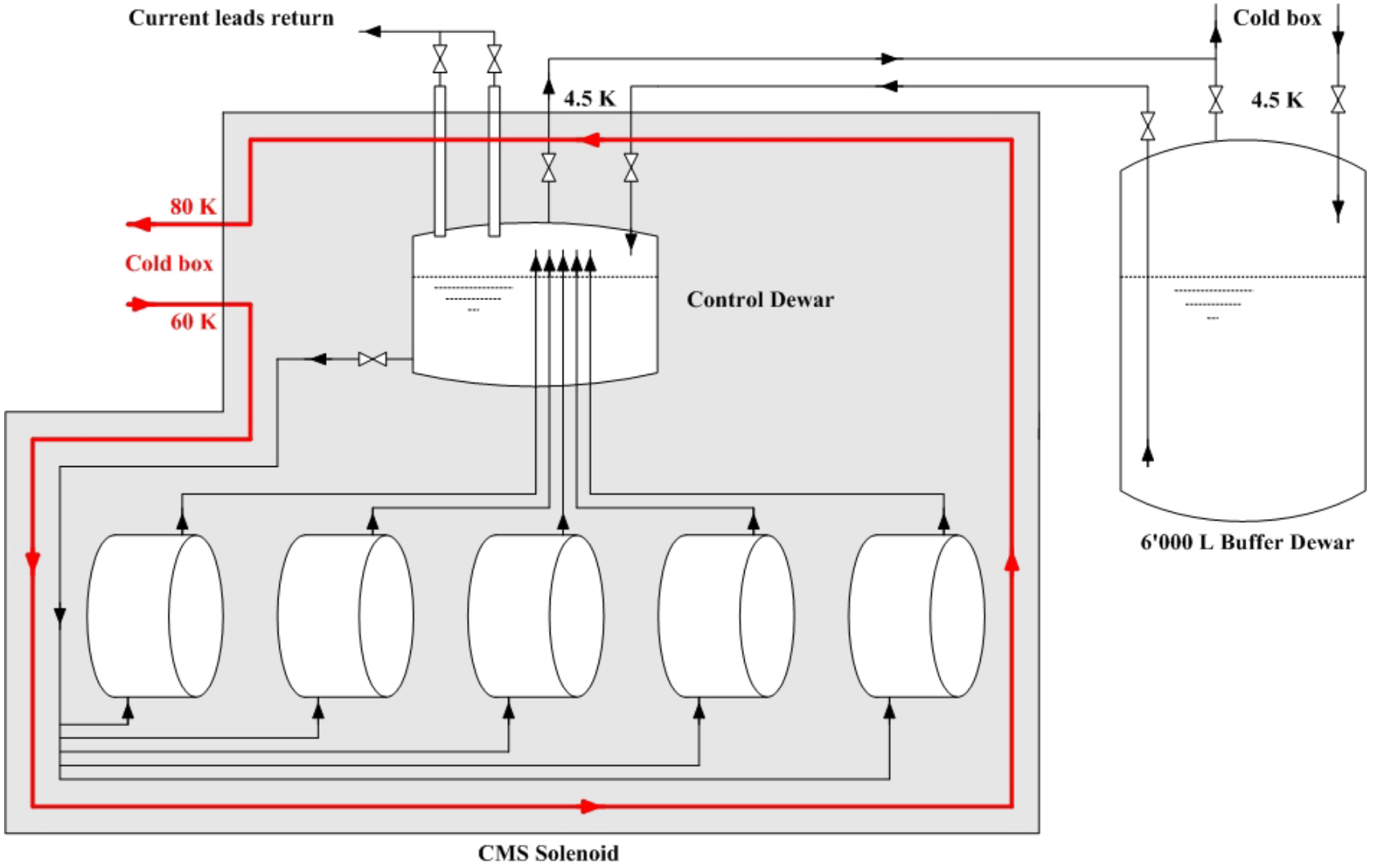
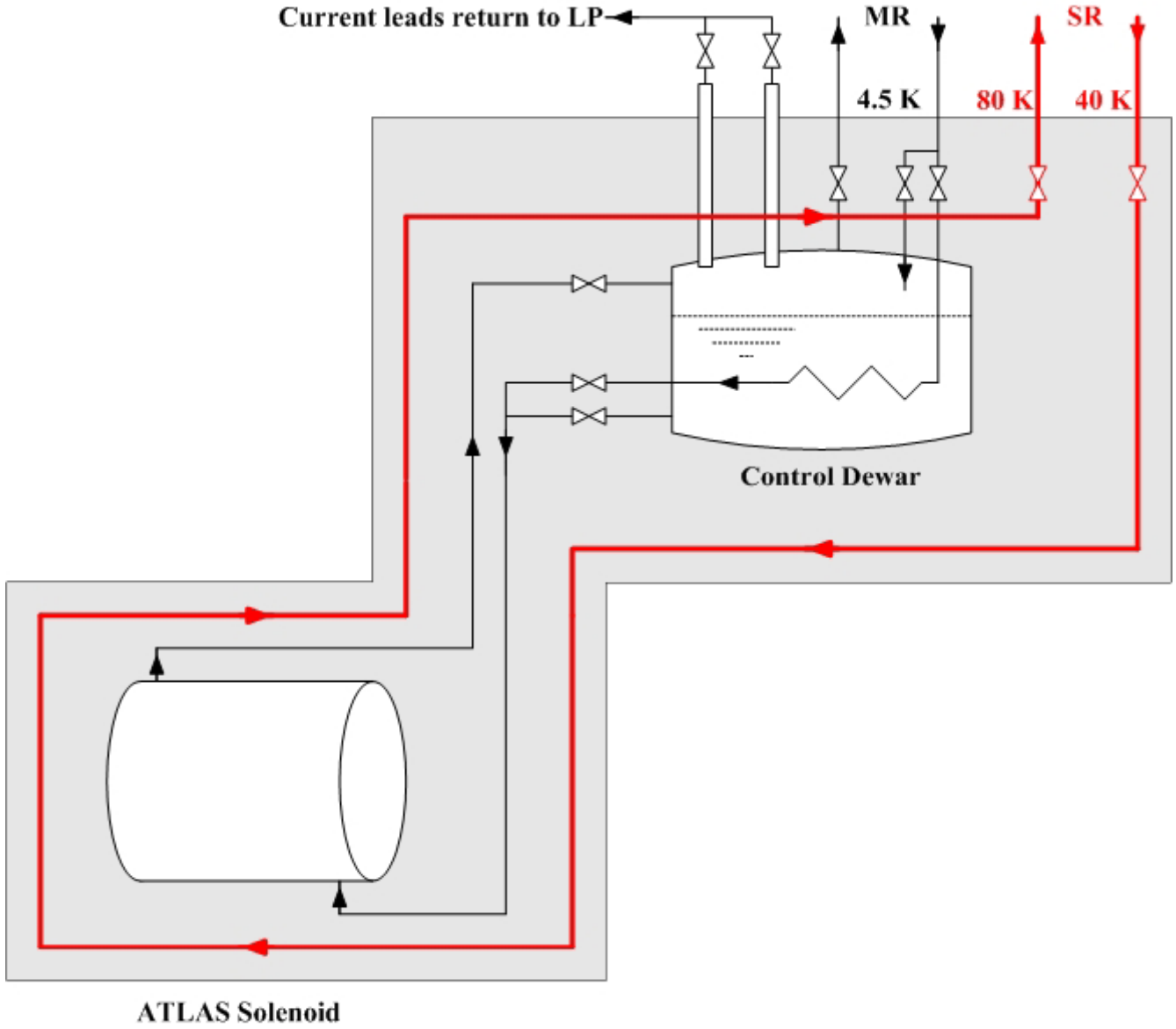
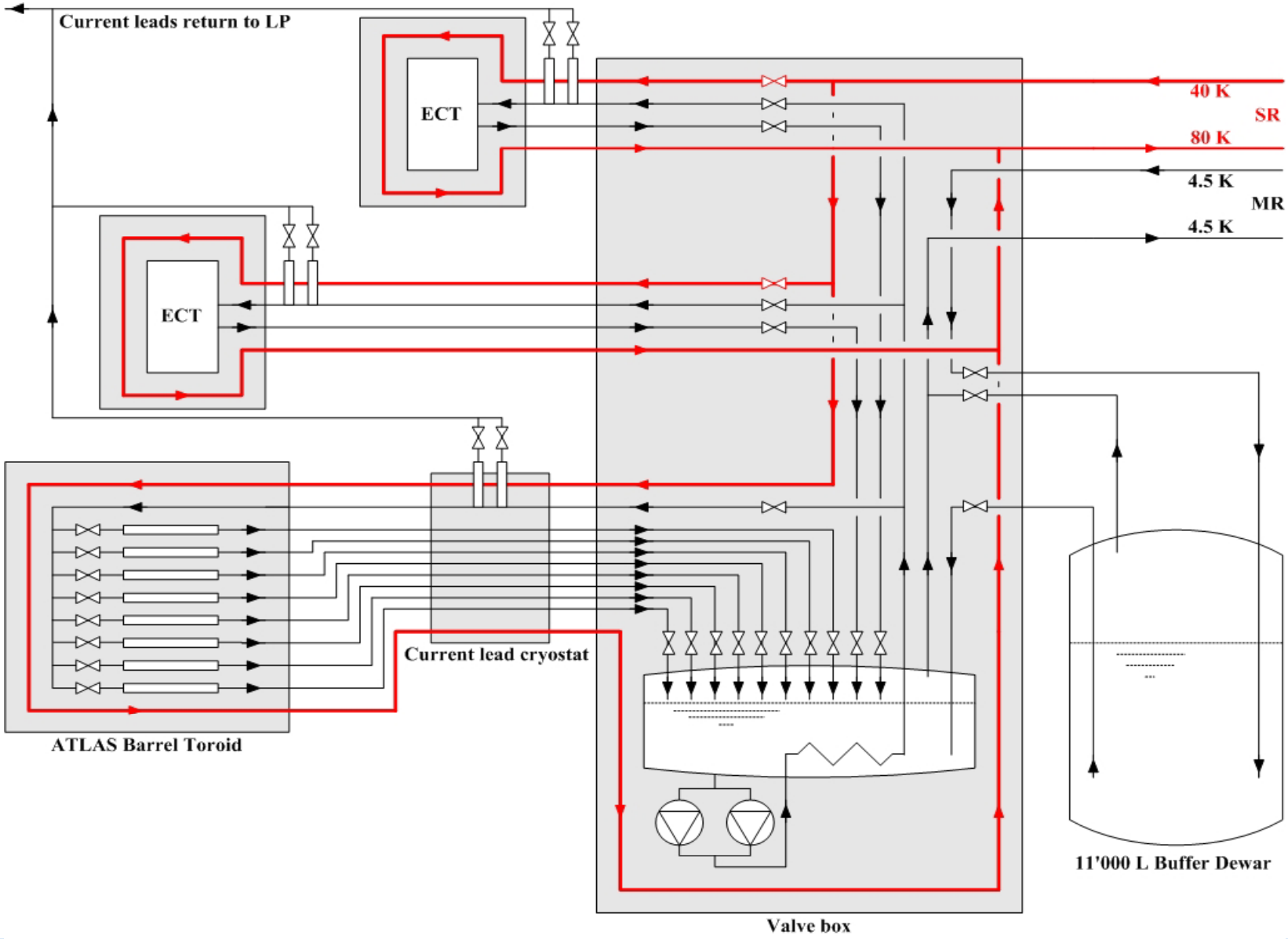
Proximity cryogenics (1)



Proximity cryogenics (2)



Proximity cryogenics (3)



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Conclusions

- To ease the sub-contracting of the CMS and ATLAS cryoplants, we have divided their magnet system into 3 parts: internal, proximity and external cryog.;
- Use of LN_2 during 2-3 wks/year of cool-down to avoid fridge over-dimensioning;
- Large LHe buffer volumes to always ensure a "slow dump" of all magnets;
- The 3 Helium refrigerators for CMS and ATLAS fulfill both detectors requirement and are ready for LHC operation.