LHC experiment cryogenics

Cooling methods of the large super-conducting magnets for LHC experiments

Goran Perinić, AT-ECR 30.05.2007

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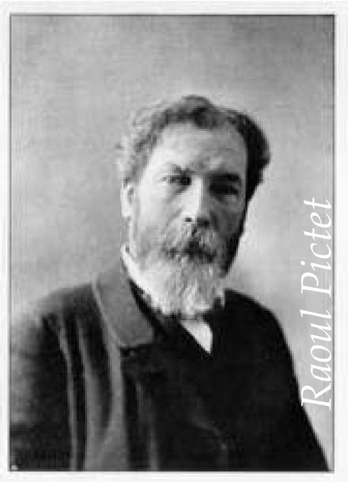
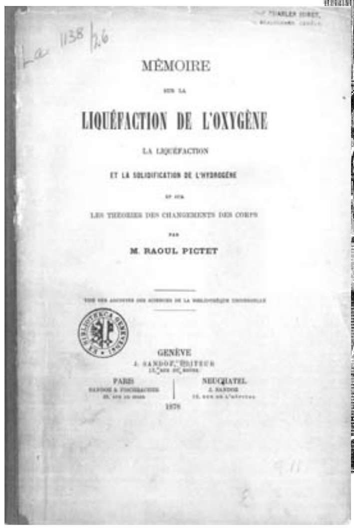
Geneva 1877



(1846-1929)

Pictet's apparatus for the liquefaction of oxygen
on the site of the
« Société genevoise de construction d'instruments de physique »



MÉMOIRE
SUR LA
LIQUÉFACTION DE L'OXYGÈNE
LA LIQUÉFACTION
ET LA SOLIDIFICATION DE L'HYDROGÈNE
ET SUR
LES THÉORIES DES CHANGEMENTS DES CORPS
PAR
M. RAOUL PICTET

GENÈVE
PARIS | NEUCHATEL
1878

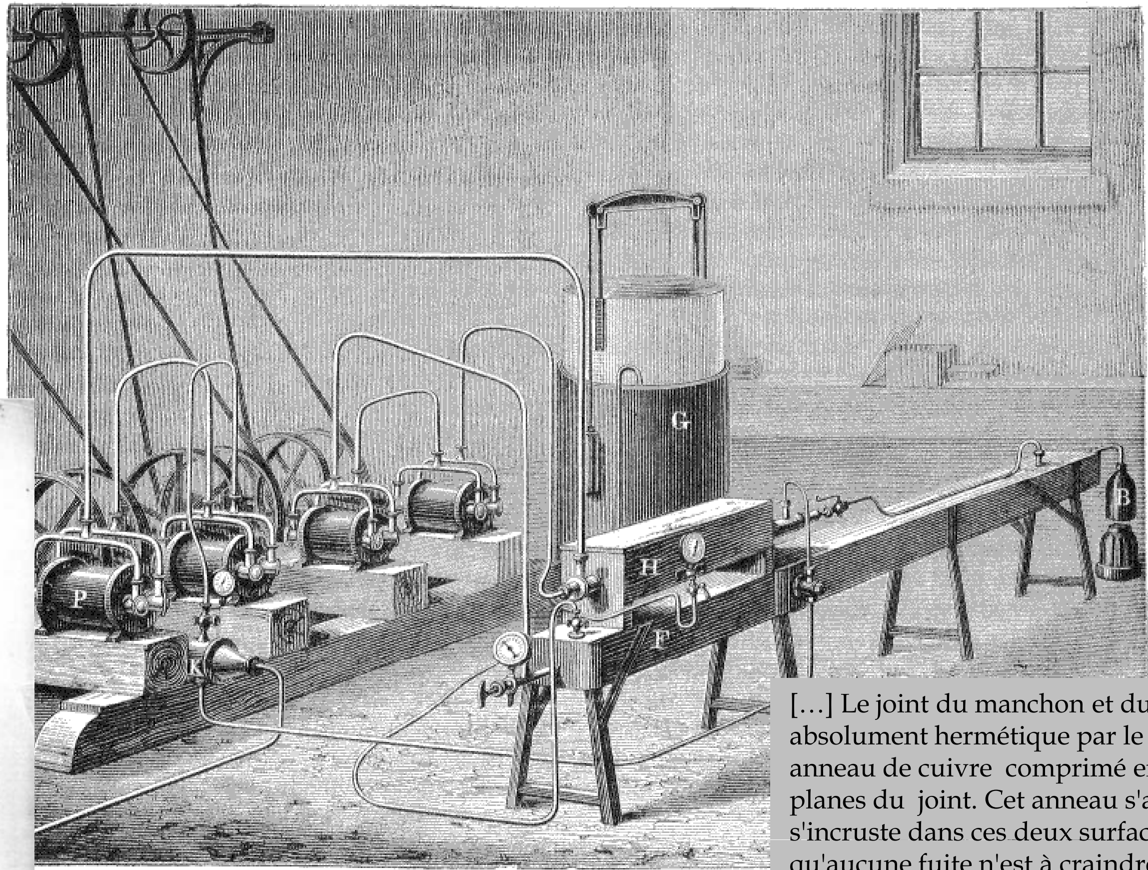
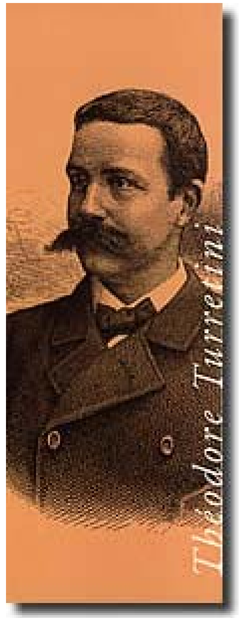


Fig. 1. — Grand appareil de M. Raoul Pictet pour la liquéfaction des gaz.

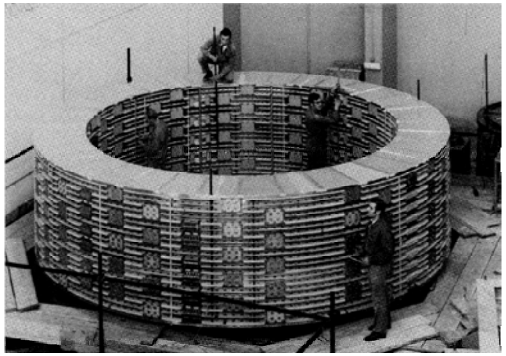


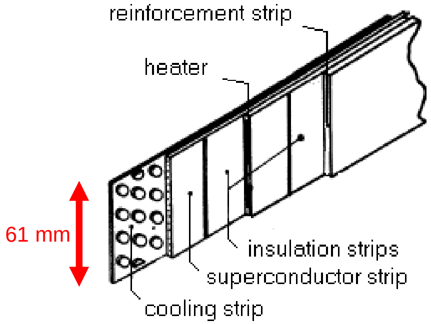
(1845-1916)

[…] Le joint du manchon et du manomètre est rendu absolument hermétique par le serrage à bloc d'un anneau de cuivre comprimé entre les deux surfaces planes du joint. Cet anneau s'aplatit légèrement et s'incruste dans ces deux surfaces d'une façon si intime qu'aucune fuite n'est à craindre. […]
extrait de R. Pictet: Mémoires sur la Liquéfaction de l'Oxygène (1878)

CERN – BEBC to LEP

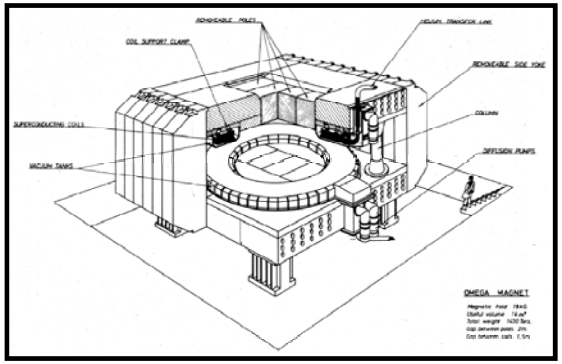
BEBC (1972)

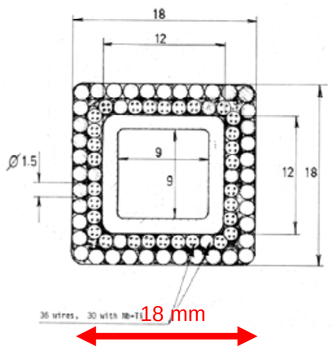




immersion

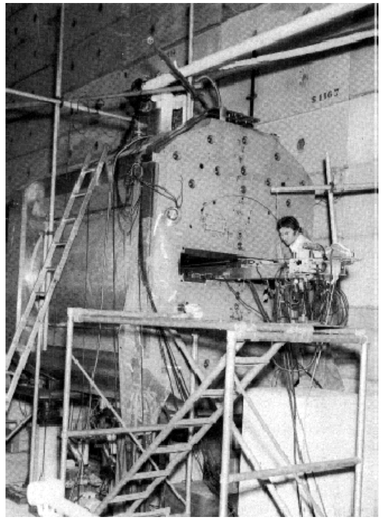
OMEGA (1973)

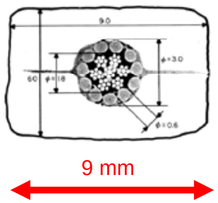




supercritical He
with re-cooling

ISR (1976)

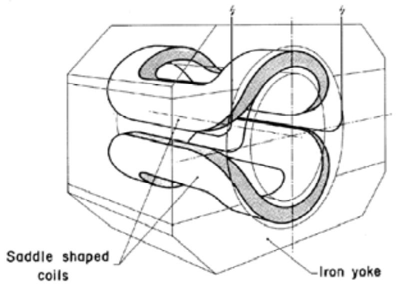




immersion

CERN – BEBC to LEP

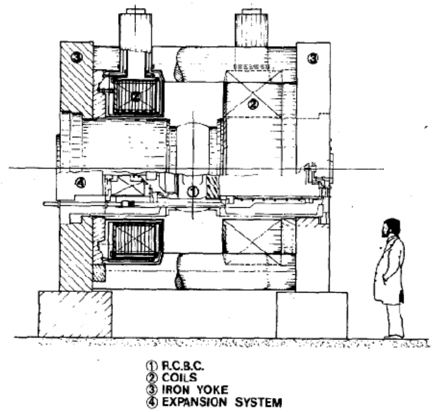
Dipole (1978)

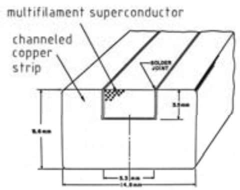


18 mm

forced 2-phase flow

M1-EHS (1980)

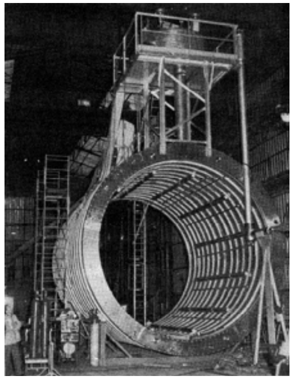


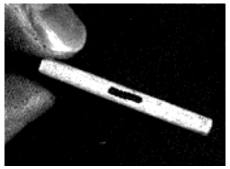


14.8 mm

immersion

ALEPH (1987)



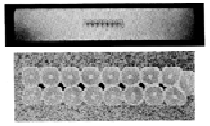


35 mm

thermosiphon

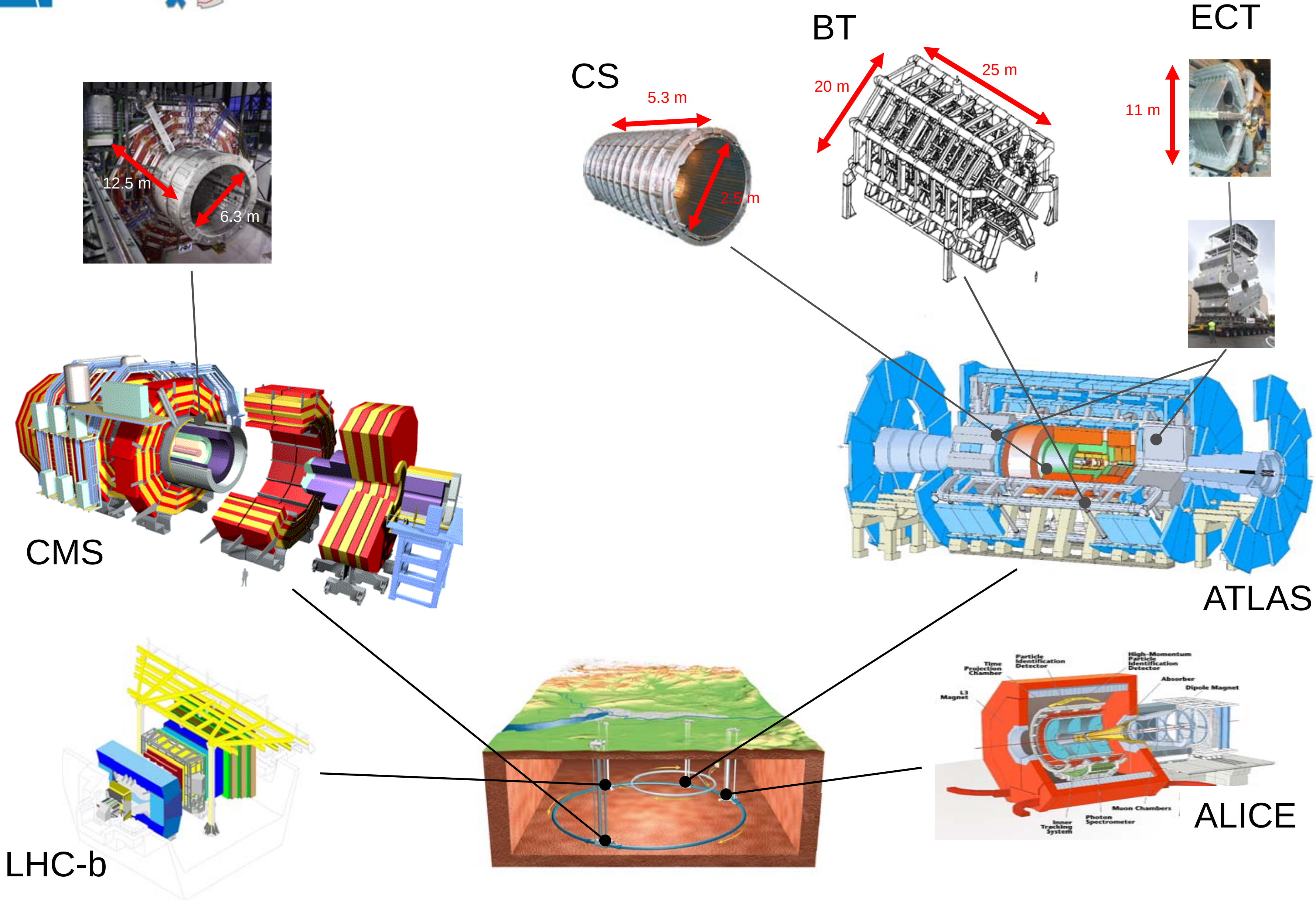
DELPHI (1988)

24 mm



forced 2-phase flow

CERN - LHC



CS
5.3 m
2.5 m
BT
20 m
25 m
ECT
11 m
12.5 m
6.3 m
CMS
ATLAS
LHC-b
ALICE
Time Projection Chamber
Particle Identification Detector
High-Momentum Particle Identification Detector
Absorber
Dipole Magnet
L3 Magnet
Muon Chambers
Photon Spectrometer
Inner Tracking System

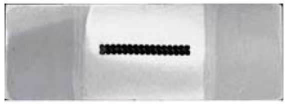
What is similar? I

- composite Al-stabilized conductors
- indirect cooling via the coil support
- operation temperature 4.5-4.8K
- cool-down with a maximum temperature gradient of 40K

CMS

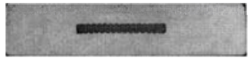
ATLAS

CS | BT | ECT

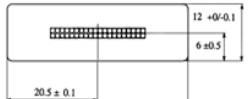


64 mm

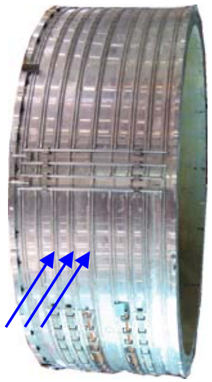
30 mm



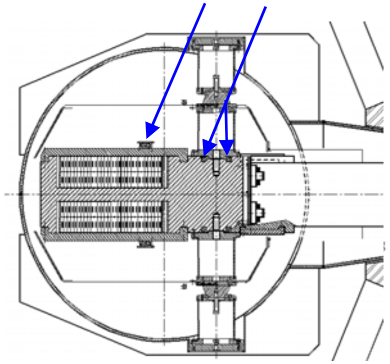
57 mm

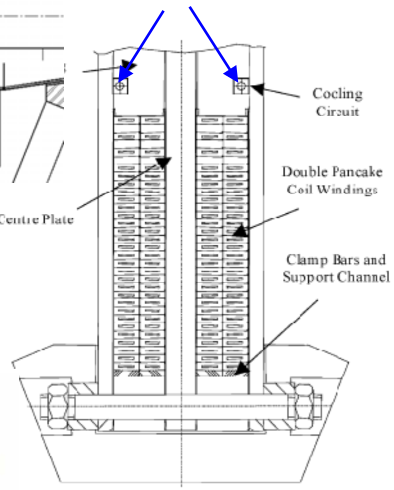


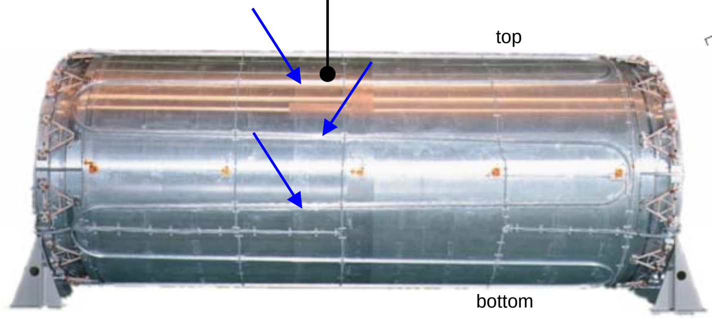
41 mm



view from top (CB-2 segment)

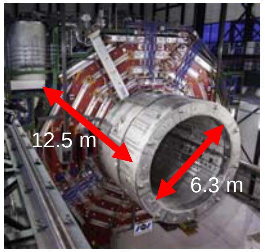
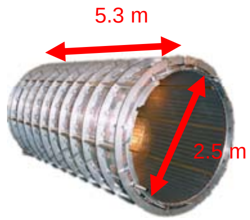
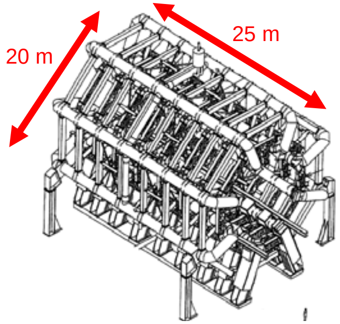
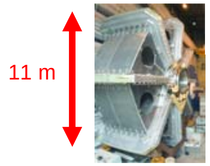






What is similar? II

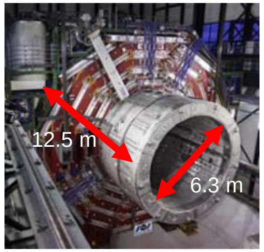
- **materials and bonding**

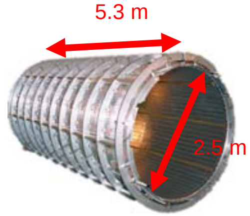
	CMS	ATLAS-CS	ATLAS-BT	ATLAS-ECT
				
Coil support	Al 5083 H321	Al 5083	Al 5083	Al 5083
Cooling channels	Al 6060 T5 welded on	Al 6063 welded on	Al 1070 glued on	Al 6061 T4 glued on
Shield	Al 3003 H22	Al	Al 3003 H22	Al 5083
Shield cooling channels	Al 6082 welded on	Al 6063 welded on	Al 1070 welded on	Al 1070 welded on

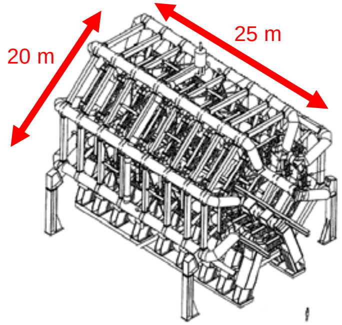
Where are the differences? I

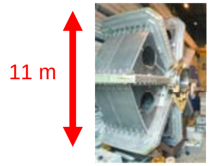
➢ **the helium circulation**

CMS	ATLAS-CS	ATLAS-BT	ATLAS-ECT









thermosiphon

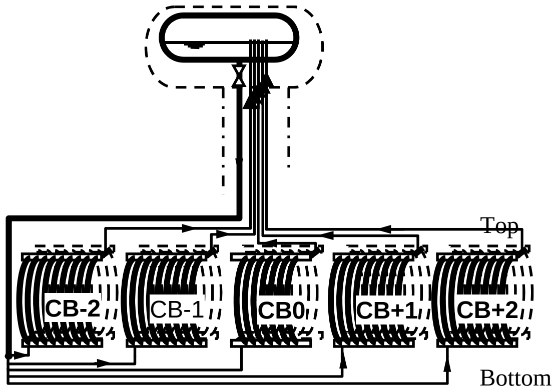
details in presentation by P. Bredy

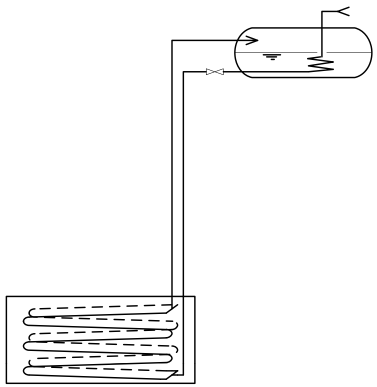
forced 2-phase flow + thermosiphon

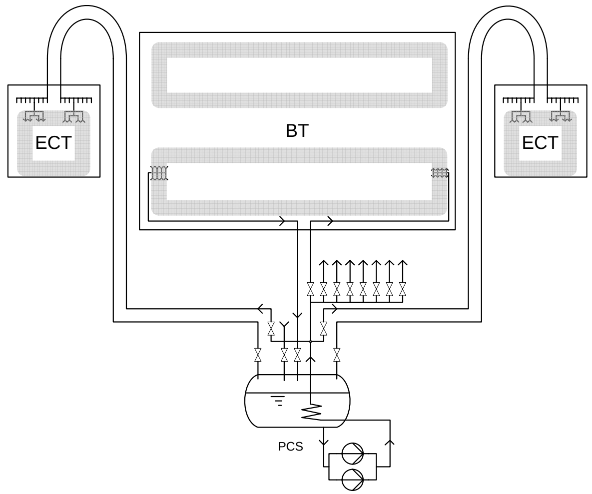
up to 7g/s driven by refrigerator

common forced 2-phase flow

BT 700 g/s + ECT 2 x 250 g/s driven by helium pump

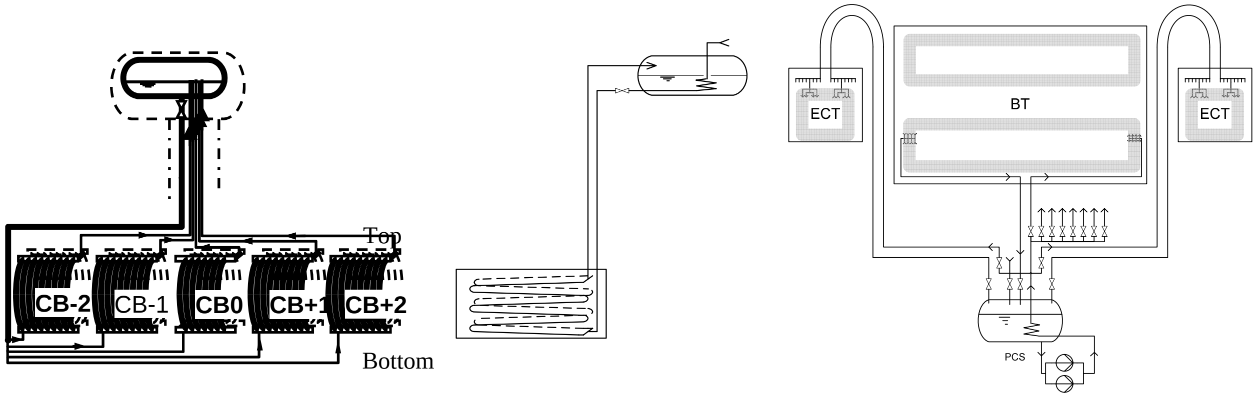






Where are the differences? II

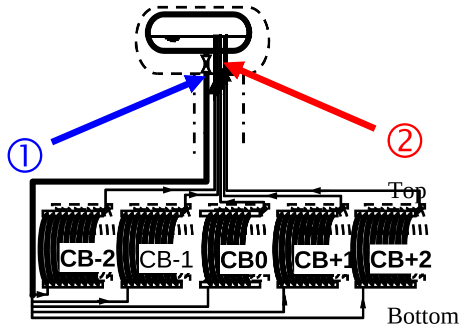
- **the helium circulation**

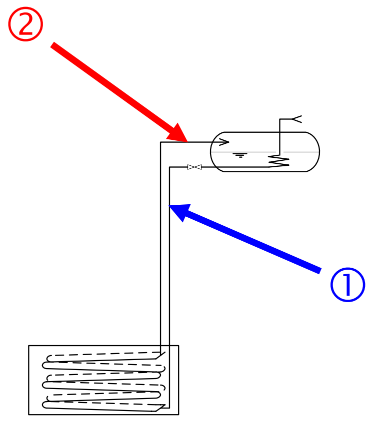


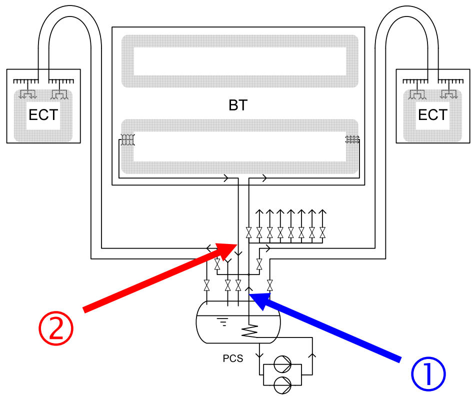
	CMS	ATLAS-CS	ATLAS-BT / ECT
static heat load	180 W	11 W	BT 8x 80 W+ ECT 2x 200W
max. height difference	12 m	13 m	20 m
cooling pipe dimensions	14 / 20 mm	18 / 24 mm	BT 14 / 20 mm ECT 15.7 /24 mm
phase separator vol.	800 l	280 l	4600 l
LHe inventory – phase sep.	150 l	180 l	2700 l
LHe inventory – cool. pipes	355 l	30 l	BT 800 l + ECT 500 l

Where are the differences? III

- the helium circulation



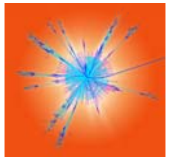




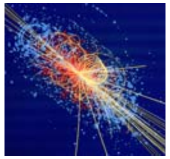
	CMS	ATLAS-CS	ATLAS-BT / ECT
① p_1; T_1; X_1	1,25 bar; 4,4 K (sat.) 0 %	1,35 bar; 4,5 K (2-ph.) 5 %	1,7 bar; 4,65 K (subc.) 0 %
mass flow	200-400 g/s	< 7 g/s	700 g/s + 500 g/s
② p_2; T_2; X_2	1,25 bar; 4,4 K (2-ph.) up to 10 %	1,3 bar; 4,5 K up to 33 %	1,67 bar; 4,8 K up to 8 %

- values variate in dependency of the heat load (static load, dynamic load)

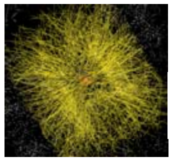
Conclusion



Four new superconducting magnets have been built for the LHC experiments thanks to an extensive collaboration in between CERN, external institutes and industrial suppliers. The new magnets surpass anything built before at CERN and elsewhere.



The magnet cooling methods have been chosen in dependency of the magnet design. They represent a consistent development of the technologies and experiences gained from previous projects at CERN.



The cooling systems have been designed and built for the long term operation.

Collaboration and Suppliers

- ATLAS collaboration
- CEA Saclay, Gif-sur-Yvette, France
- CERN, Geneva, Switzerland
- CMS collaboration
- INFN, Genova, Italy
- KEK, Tsukuba, Ibaraki, Japan
- INFN-LASA, Milan, Italy
- JINR Dubna
- NIKHEF, The Netherlands
- Rutherford Appleton Laboratory, Chilton, Didcot, UK

- probably incomplete

- Alstom Switzerland
- Ansaldo
- Austrian Aerospace
- Criotec Impianti
- EAS (VAC)
- Felguera CM
- Furukawa Co. Ltd.
- Hatehof
- Hitachi Co. Ltd.
- Nihon Sanso Co. Ltd.
- Outokumpu (EM)
- Schelde Exotech
- Taiyo Keisoku Co. Ltd.
- Technicatome
- Toshiba Co. Ltd.
- Yokogawa AIM Co. Ltd.
- Zanon Spa

- probably incomplete