DE LA RECHERCHE À L'INDUSTRIE

cea

SBT

UNIVERSITÉ GRENOBLE ALPES

Innovative He cycle

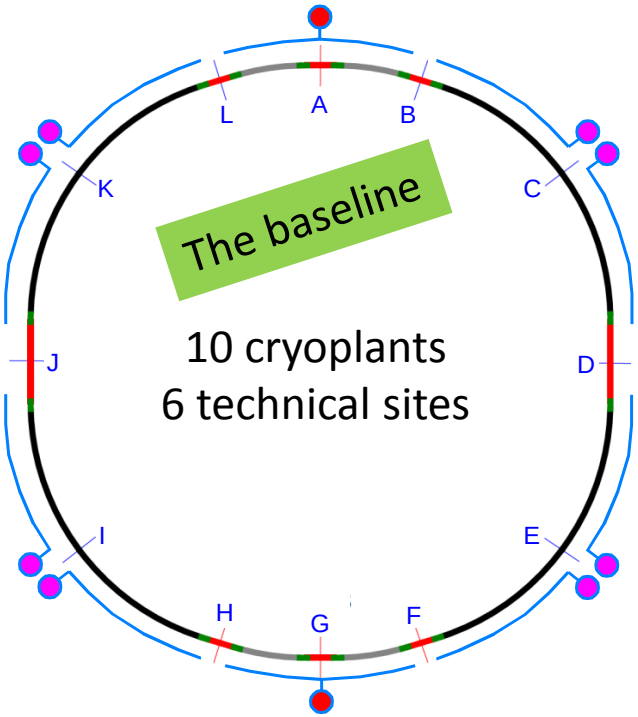
Francois Millet

FCC hh ee he

Contents

- FCC needs and constraints
- Experiences from existing large-scale He plants
- He plant study
  - Separated cooling loops
  - Overall architecture & operation modes
  - He plant options
- Energy recovery
- Conclusions

FCC needs and constraints – FCC_hh cryogenic capacity

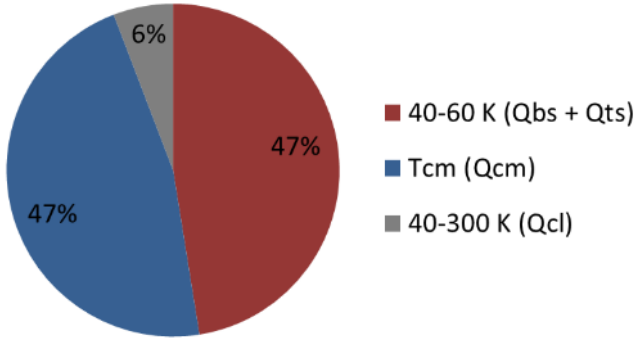


Main FCC_hh cryogenic users :

- Beam Screen and Thermal Shields
  40-60 K cooling
- Superconducting Magnet Cold Mass
  1.9 K cooling (tbc)
- HTS Current Leads
  40-300 K cooling

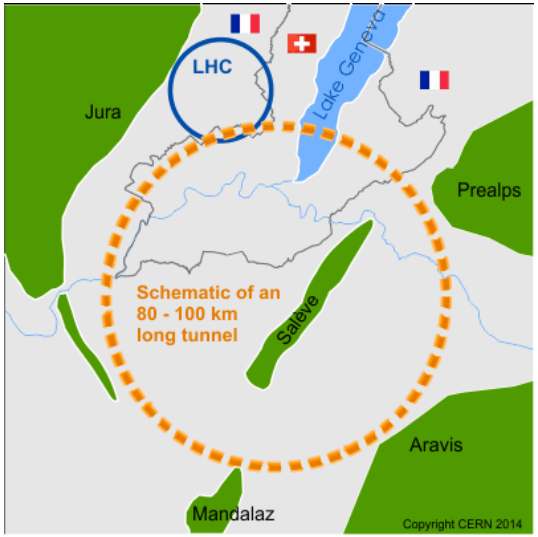
Cryoplant	40-60 K [kW]	Tcm [kW]	40-300 K [g/s]
	592	11	85
	616	12	85
TOTAL	**6110**	**118**	**850**

Without operational margin !

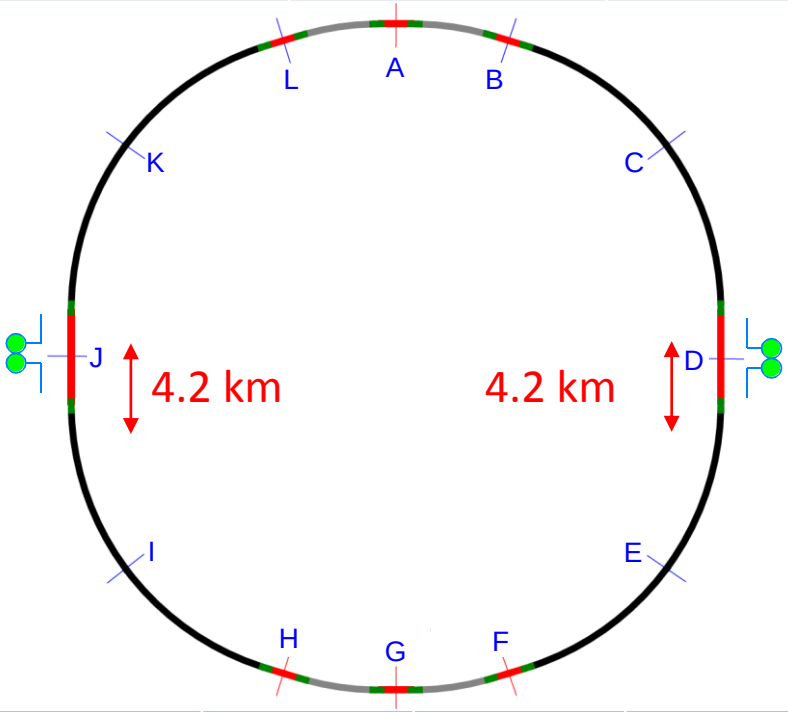


=> Total power consumption : 150 to 200 MW

FCC needs and constraints – FCC_ee layout and heat loads



Circumference [km]	Energy [GeV]	Q_0 [10e9]
100	175	3.1



- RF-cavity modules installed in the long straight sections (Points J and D)
- Bending field adapted to the beam energy loss (SR) along the 50 km half-turn.
- Operating temperature still to be optimized (**4 K, 2 K, 1.8 K, 1.6 K**)

Cryoplant	Q stat [kW]	Q dyn [kW]	Qtot [kW]
	8	37	46
Total FCC-ee	**31**	**154**	**185**

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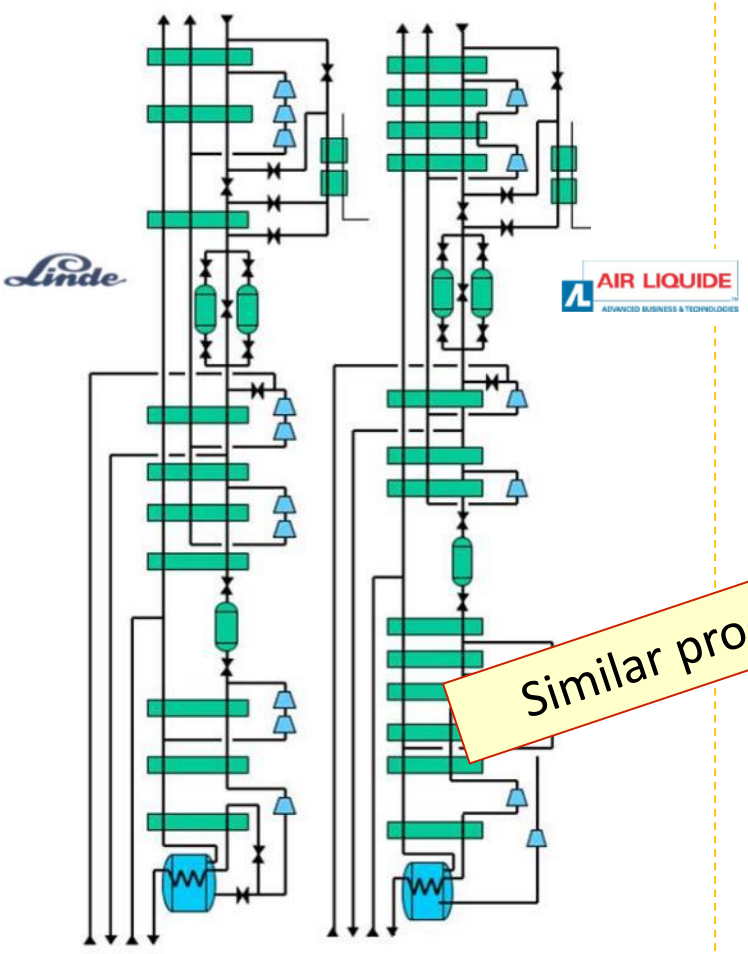
Existing large-scale He plants – 4.5 K design

LHC 4.5 K Refrigerators

8 modules of 18 kWeq @4.5K



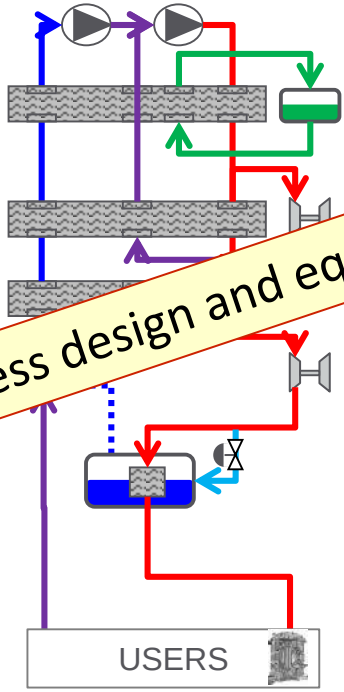
U.Wagner/ CERN

Under construction

ITER He Plant

3x25 kWeq @4.5K

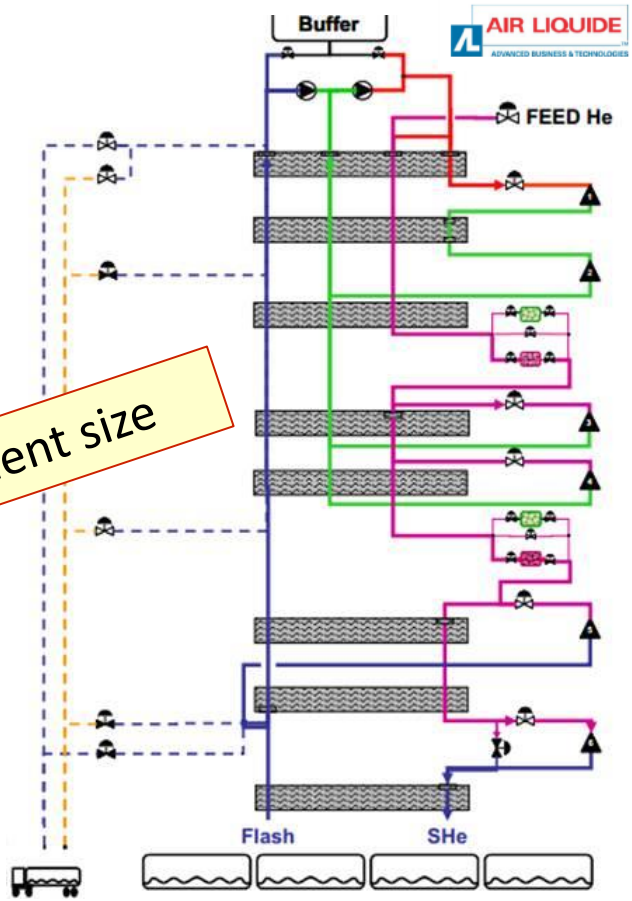
3 modules in //



Similar process design and equivalent size

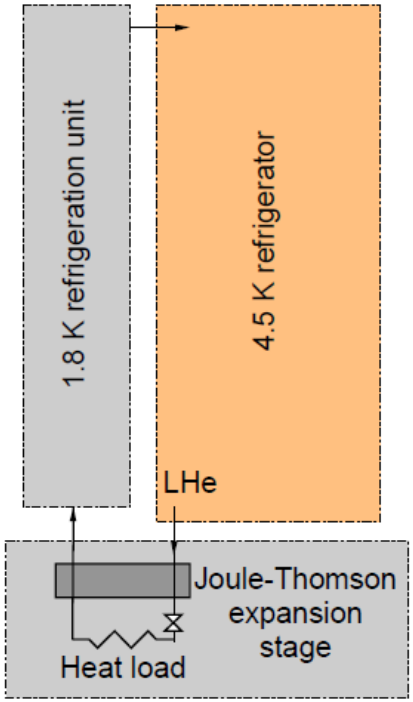
Qatar Helium Recovery Unit

20 tons/day - 24 kWeq @4.5K

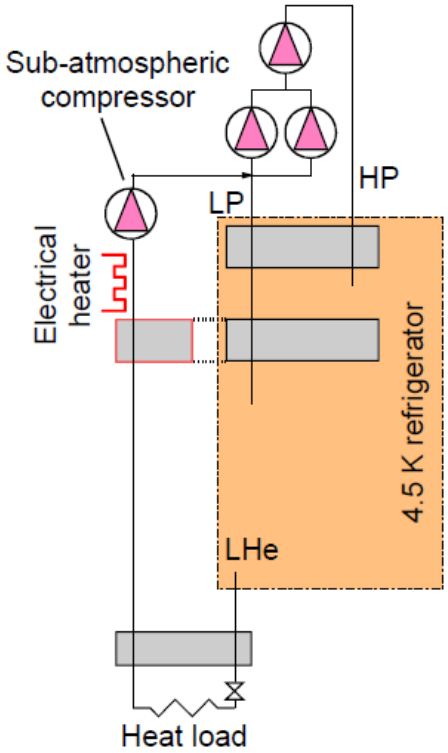


F.Andrieu / SLAT

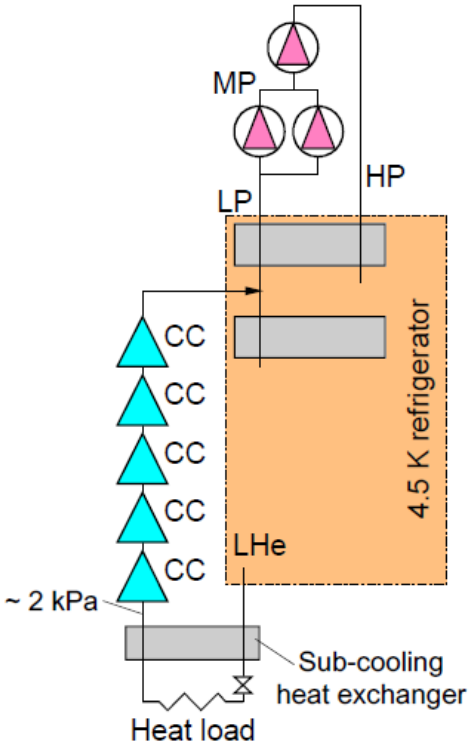
Existing large-scale He plants – 1.8 K design



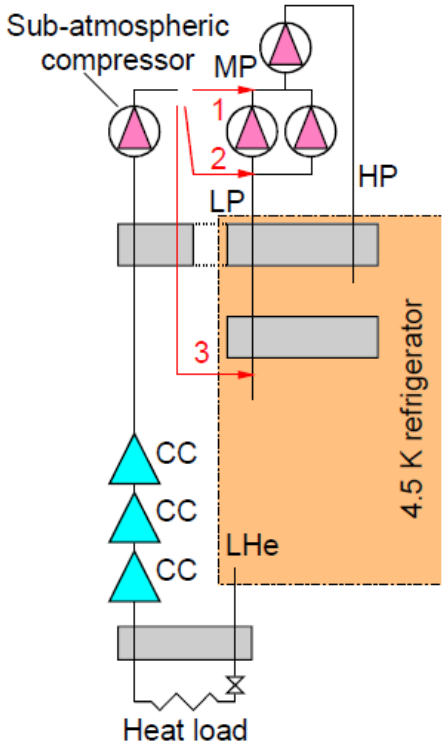
Generic scheme



"Warm" cycle
SCA (Stanford)
KIT test facility
CERN test test bench



"Integral cold" cycle
CEBAF – SNS
2 x 5.2kW@2K



"Mixed" cycle
Tore Supra
CEA test facility
LHC
8 x 2.4kW@1.8K

=> Integral cold and mixed compression preferred for large-scale 1,8 K He plant

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He plant study – FCC_hh cooling architecture

300-40 K cryoplant

- Beam screen (40-60 K)
- Thermal shield (40-60 K)
- Current leads (40-300 K)
- Precooling of Magnet cryoplant ?

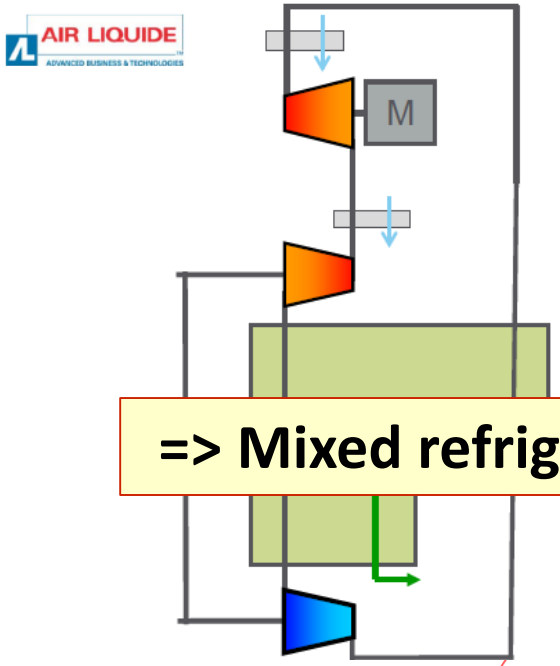
1.9 K cryoplant (4.5 K ?)

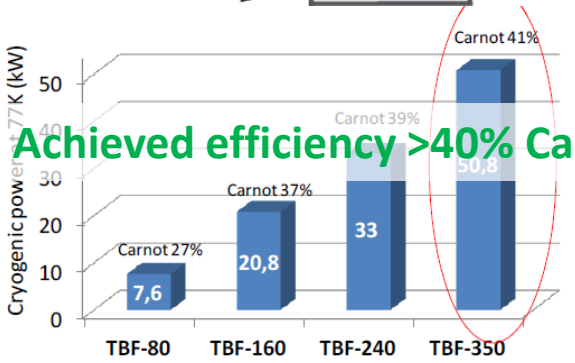
- SC magnet cold mass

=> Dedicated cryoplants to optimise overall efficiency

40-300 K cryoplant – Turbo-Brayton with mixed refrigerants

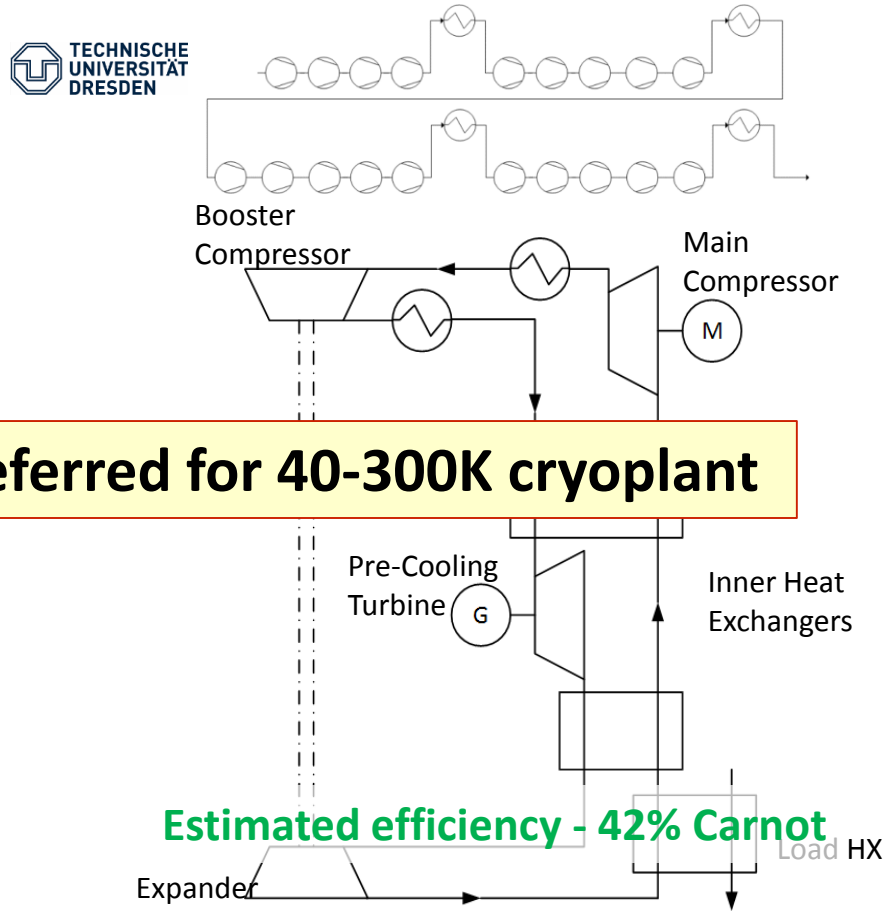
Air Liquide existing products
25 kW@50K





Achieved efficiency >40% Carnot

TU Dresden development
800 kW@40-60K



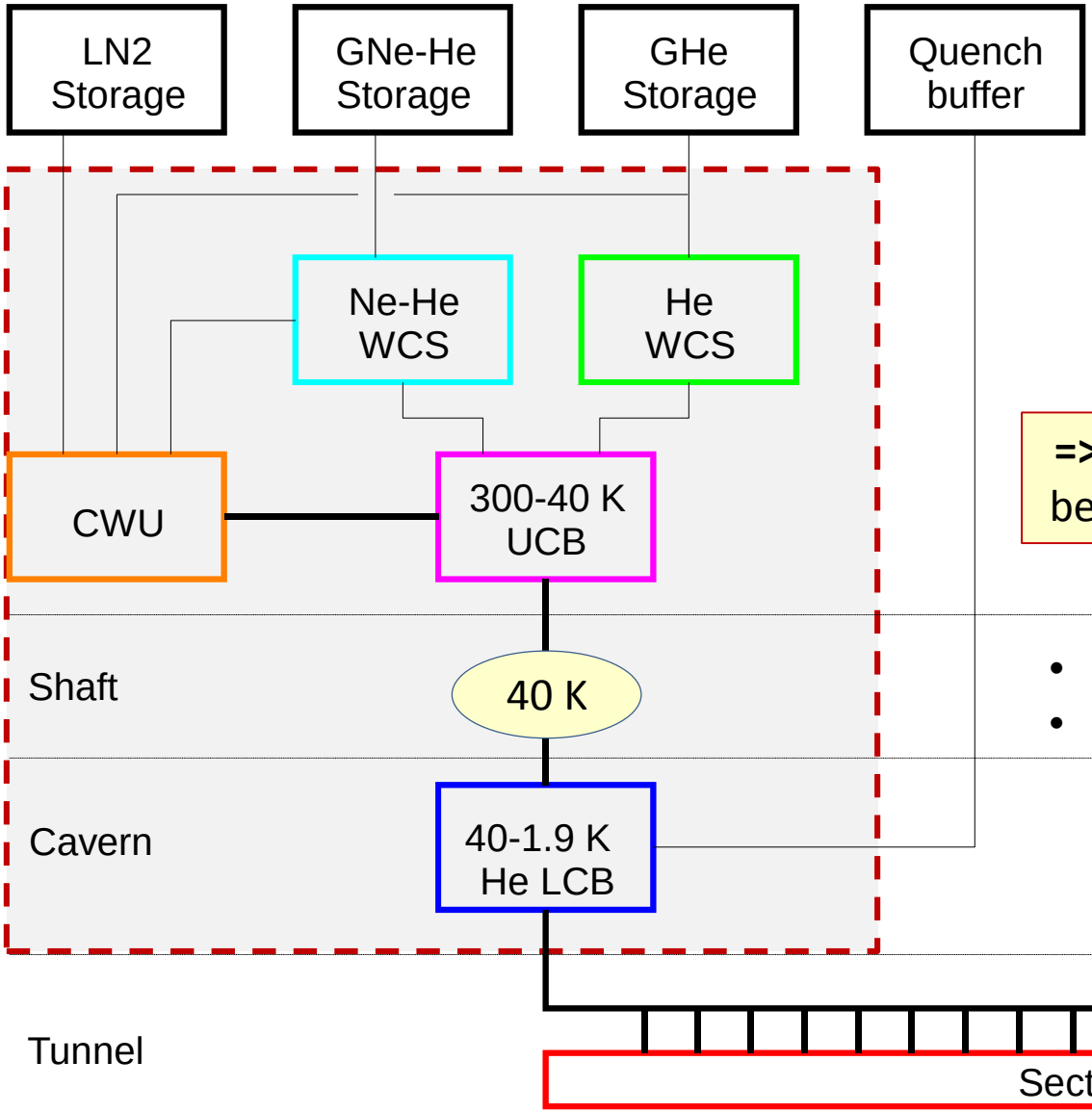
Estimated efficiency - 42% Carnot

=> Mixed refrigerants preferred for 40-300K cryoplant

See for details : presentation of S.Kloppel "Ne-He cycle refrigeration above 40 K"

Overall FCC cryogenic architecture

L.Tavian/ CERN



=> 40 K as **interface temperature** between **ground level** and **cavern**

- **To avoid Neon underground**
- **To minimize pressure losses**

See for details : presentation of L.Tavian "Cryogenics overview"

FCC_hh Operation Modes

L.Tavian/ CERN

Steady-state modes :

- Nominal mode : High energy / intensity
- Low mode : Low energy / intensity

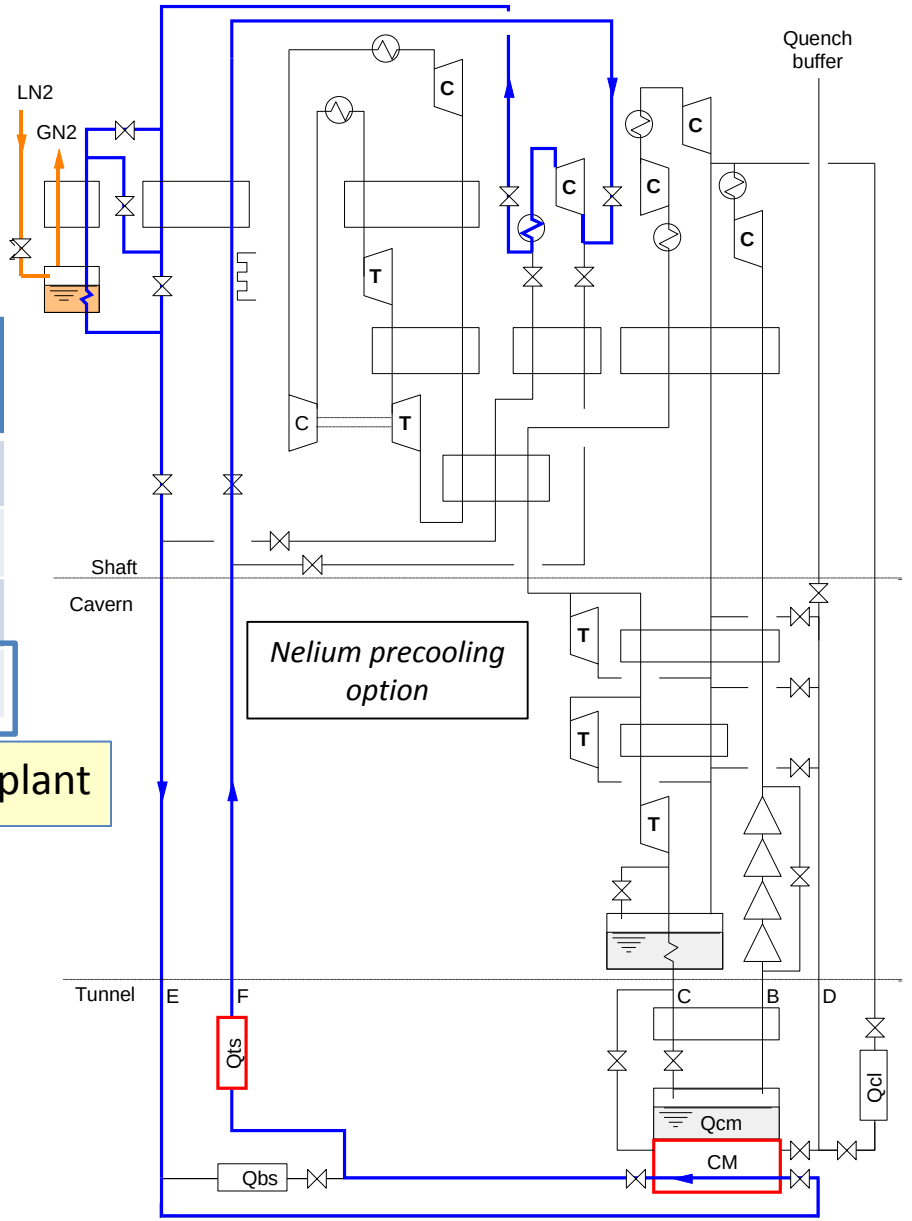
Baseline - 10 cryoplants		Nominal mode	Low mode
40-300 K	**Qcl** [g/s]	85	42
40-60 K	**Qts** [kW]	90	90
	Qbs [kW]	530	-
1.9 (4.5K)	**Qcm** [kW]	12	5.0

=> Turn-down capability ~2.5 for He plant

Transient modes :

- Cooldown
- Warmup

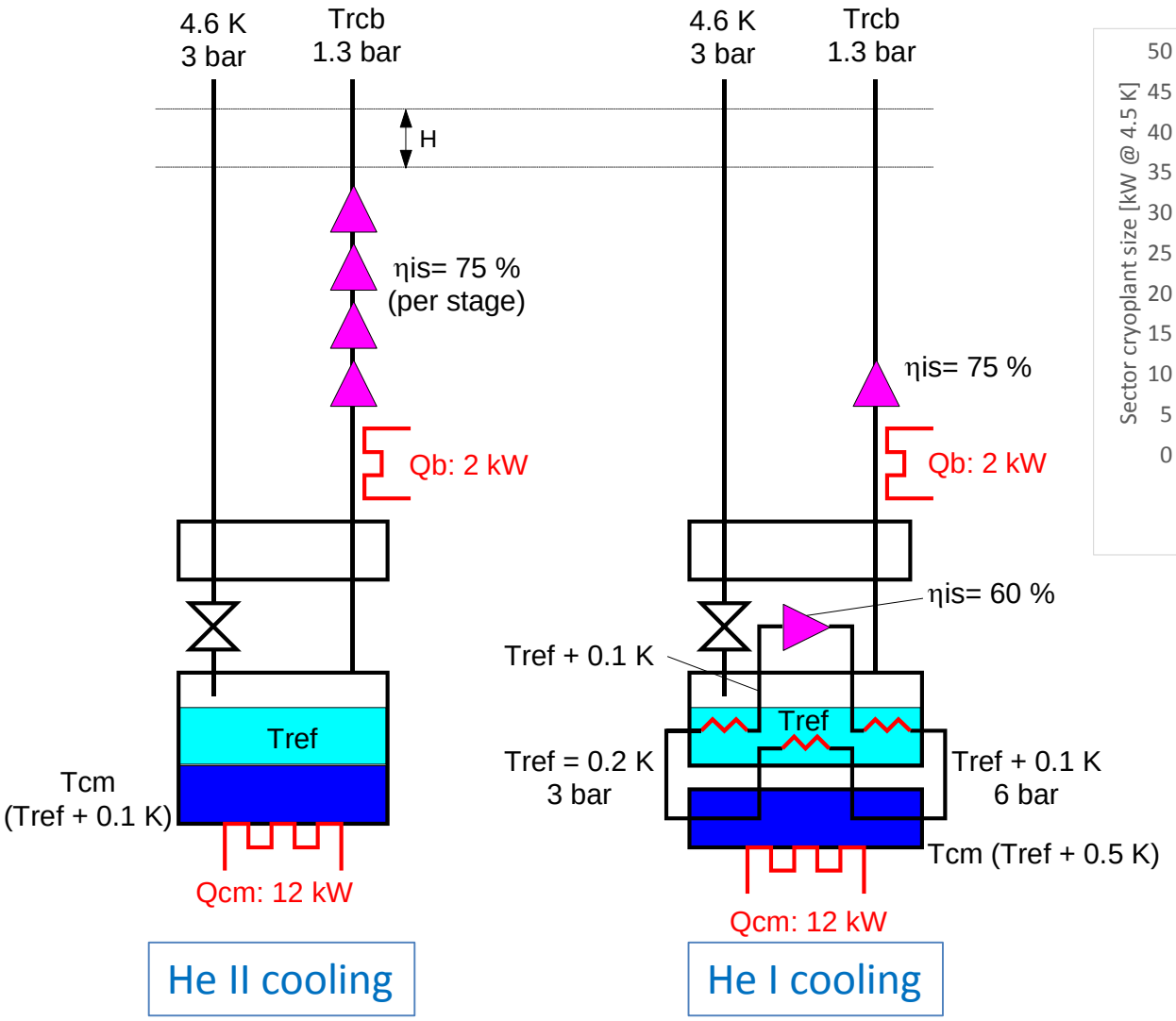
=> Dedicated CWU
(LN2 & electrical heater)

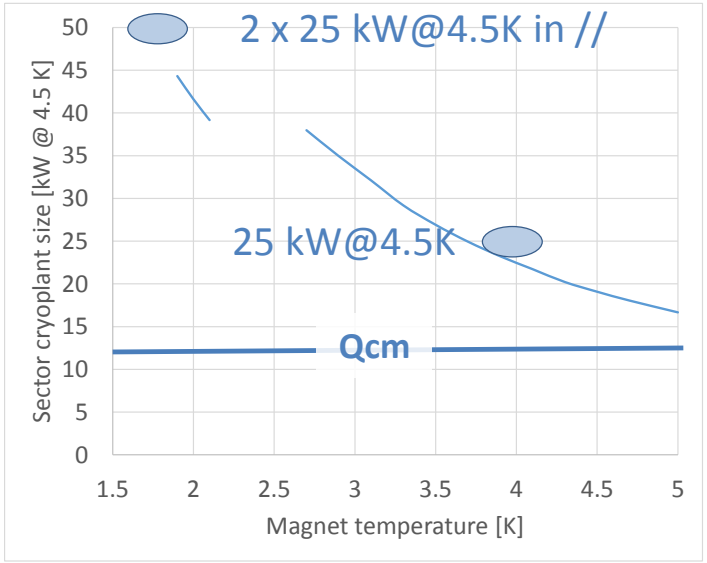


See for details : presentation of H.CORREIA RODRIGUES
"Cool-down and warm-up studies of a FCC sector"

Magnet cooling – Operating temperature options

L.Tavian/ CERN





=> large & efficient centrifugal compressors

=> 20 to 50 kW@4.5K He plant

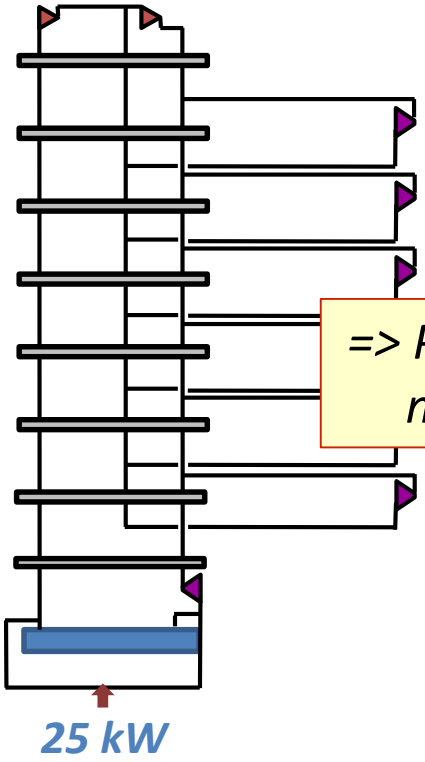
Magnet temperature under evaluation with FCC magnet team

See for details : presentation of L.Tavian "Cryogenics overview"

Magnet cryoplant - He process options

No pre-cooling & 7 expanders

Pelec. ~6.45 MW



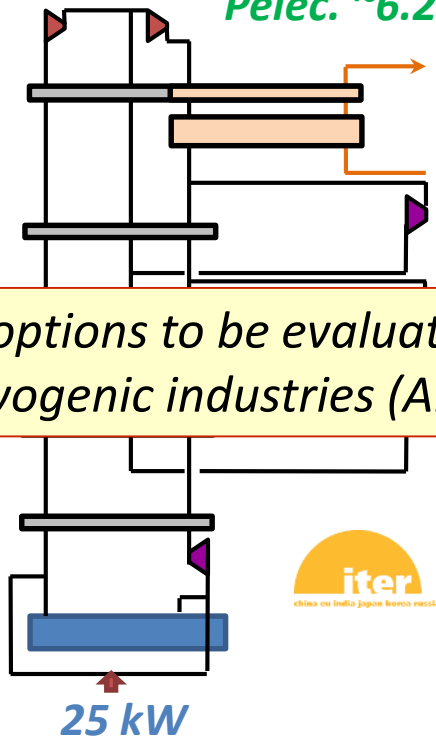
25 kW

- Autonomous
- Less efficient ?

LN2 pre-cooling & 4 expanders

Pelec. ~6.0 MW + LN2

Pelec. ~6.2 MW



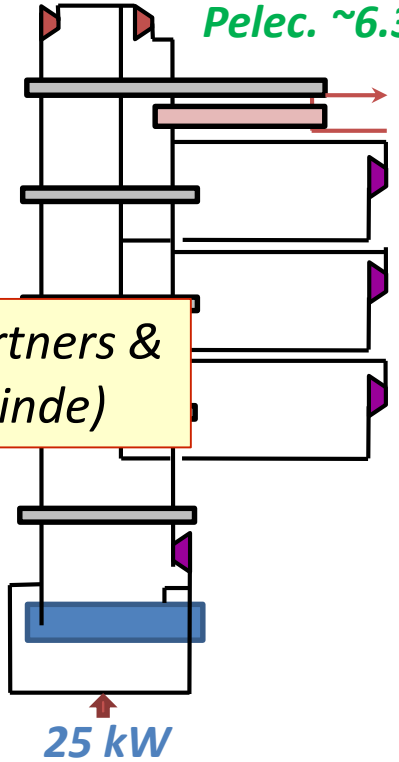
25 kW

- Dependent of LN2 supply
- Selected when LN2 plant present on site (ITER)

Nelium pre-cooling & 4 expanders

Pelec. ~6.0 MW + Nelium

Pelec. ~6.3 MW



25 kW

- Dependent of Ne-He plant

=> Process options to be evaluated with partners & major cryogenic industries (Air Liquide, Linde)

Standard efficiencies for comp. & expanders / η_{LN2} = 55% / $\eta_{e\text{-}He}$ = 42%

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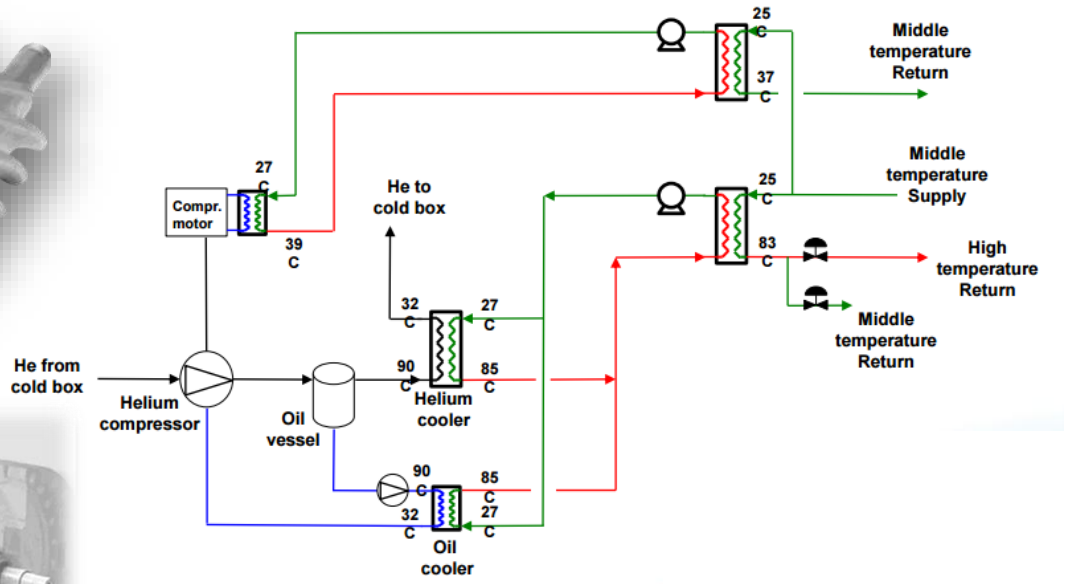
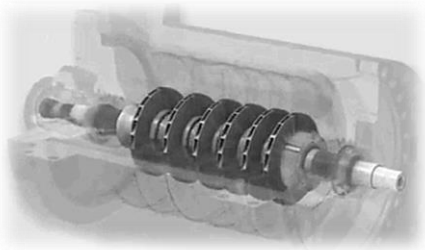
Energy recovery from FCC cryoplants

- **Warm compression generates huge gas heating (150 to 200 MW) and requires large water cooled heat exchangers and cooling towers**

  Gas heating will be function of gas nature and compressor technology

=> Heat Recovery System (in addition to HVAC system) to optimise global energy management on FCC site

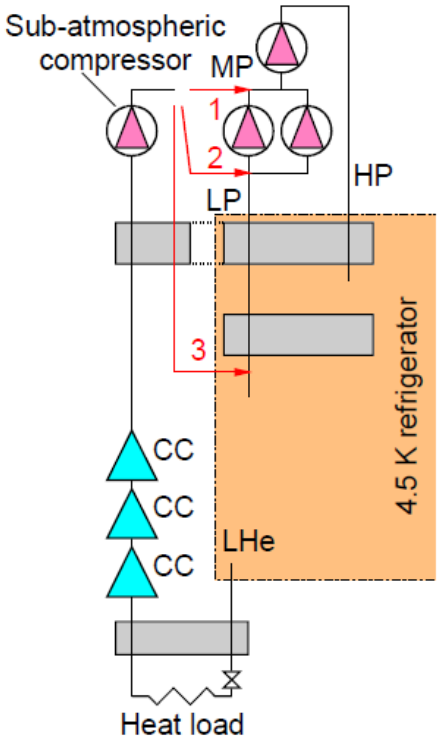




Office building heating

City heating

Conclusions



- **Review of different He cycle options** *(expanders vs precooling)*
- **Industry studies will be started in 2016 to confirm :**
  - He process cycle
  - Large & efficient centrifugal compressors
- Introduction of Heat Recovery System for FCC

Thank you for your attention