ESS Accelerator Cryoplant Process Design

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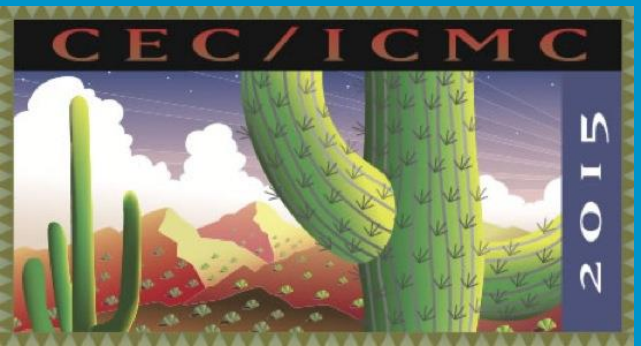


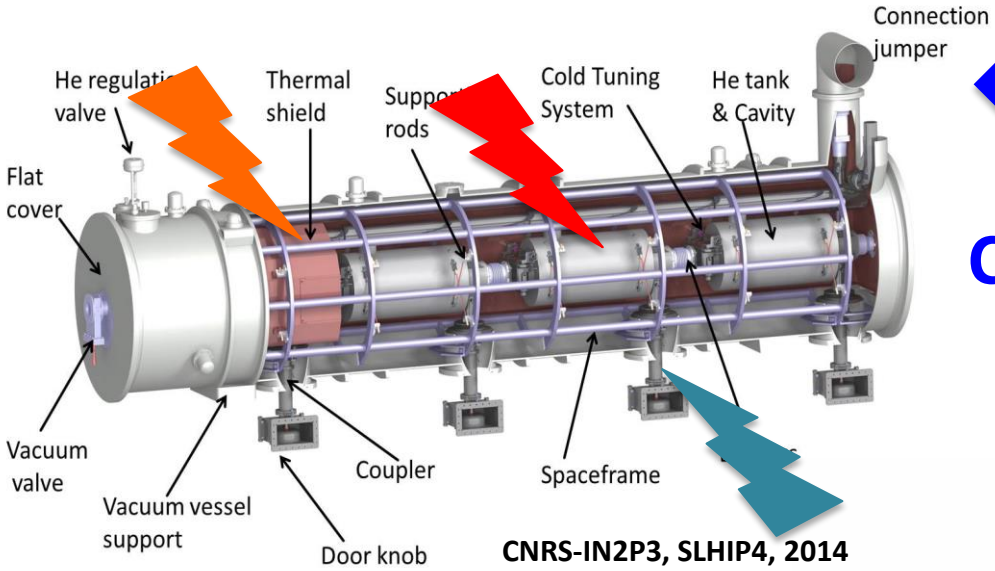
Outline

- Status
- Clients
- Performance
- Process design
- Exergy analysis
- Next step

Status

- Two industry studies in Nov 2013
- Call for tender in June 2014
- Contract awarded to LKT in DEC 2014
- Contract signed in March 2015
- Kick-off meeting in May 2015
- Currently under preliminary design stage

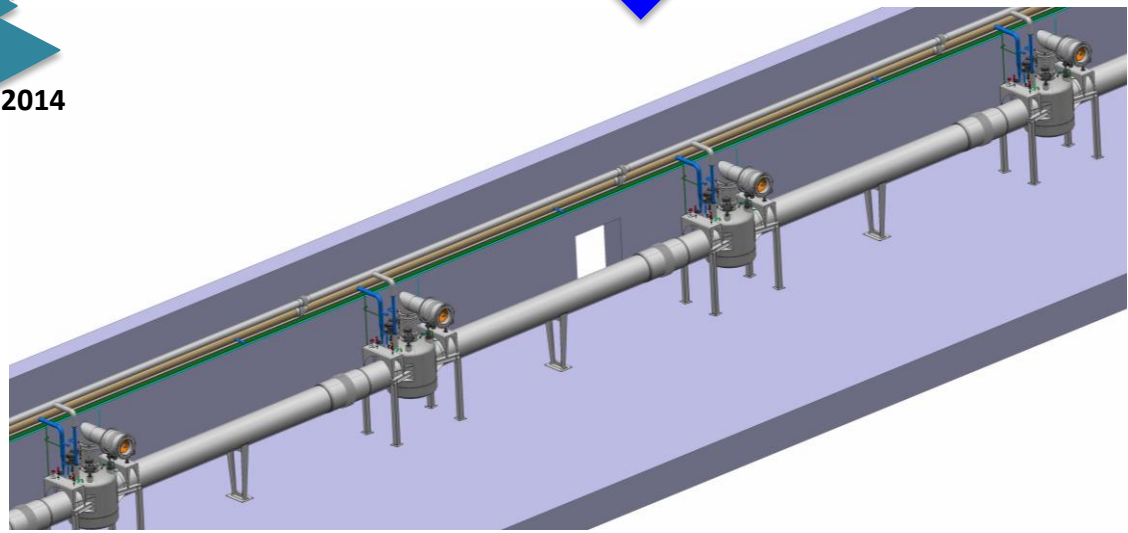
Clients



CNRS-IN2P3, SLHIP4, 2014

43 (+14) Cryomodules

Cryogenic distribution system



Temperature levels

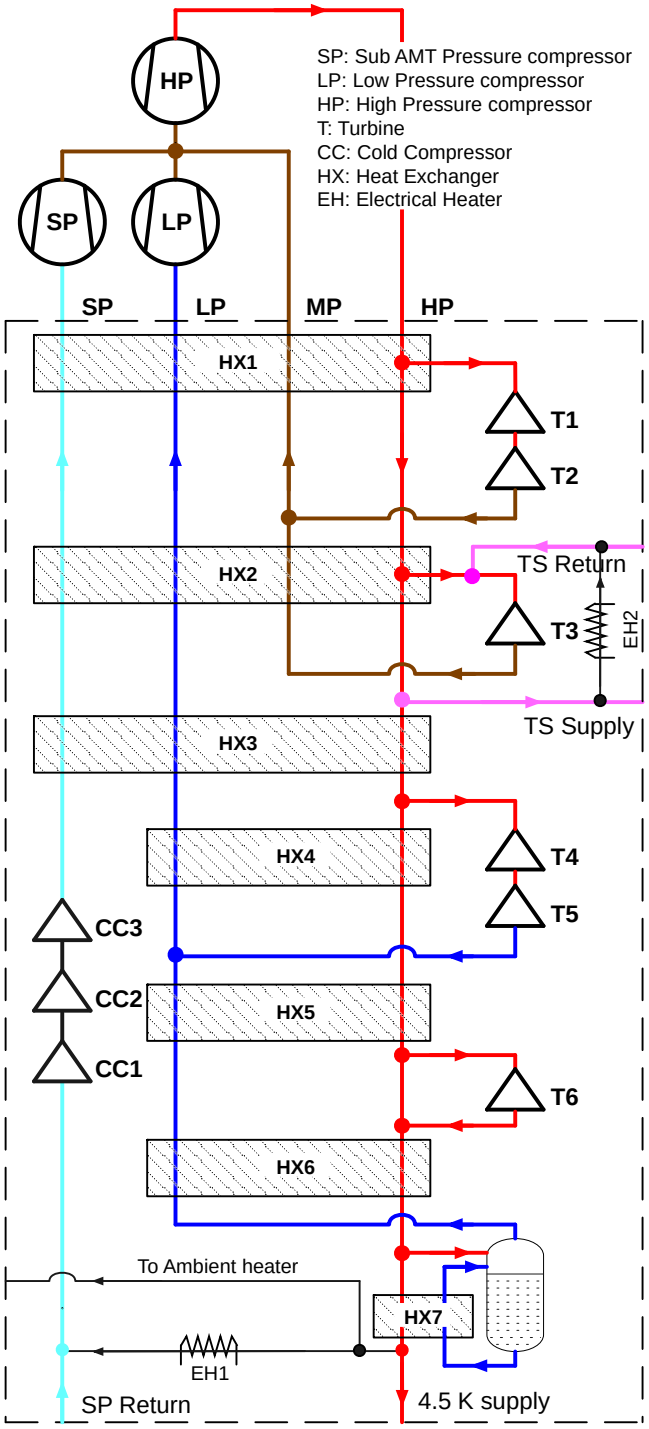
- **Cavities: 2 K**
- **Shield: 40-50 K**
- **Couplers : 4.5 - 300 K**

Performance

Operation modes		2 K Load, W			4.5 K Load		40-50 K, W
		Isothermal	Non-isothermal	Total	4.5 K, W Total	Liquefaction, g/s	Total
Stage 1 2019-2023	Nominal	1860	627	2478		6.8	8551
	Turndown	845	627	1472		6.8	8551
	4.5 K Standby	-	-	-	1472	6.8	8551
	TS Standby	-	-	-	-	-	8551
	Maximal Liquefaction	Loads in standby mode plus maximum liquefaction rate at rising level into the storage tank					
Stage 2 2023-…	Nominal	2226	824	3050		9.0	11380
	Turndown	1166	824	1990		9.0	11380
	4.5 K Standby	-	-	-	1990	9.0	11380
	TS Standby	-	-	-	-	-	11380
	Maximal Liquefaction	Loads in standby mode plus maximum liquefaction rate at rising level into the storage tank					

Process design

- Three warm compressors, six turbines, three cold compressors and several bunches of heat exchangers
- Mixed compression cycle at 2 K
- Capacity control
  - Floating pressure cycle for HP compressor
  - VFD for SP, LP compressors and CCs
  - Exchange of CCs and turbine flow parts
- All built-in acceptance test equipment



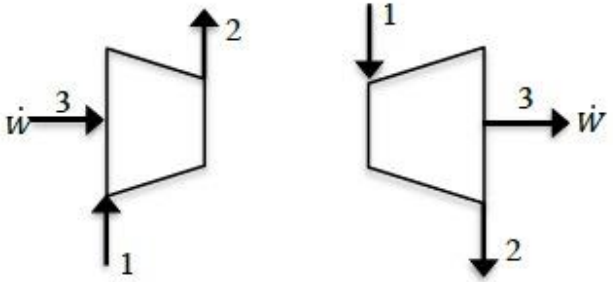
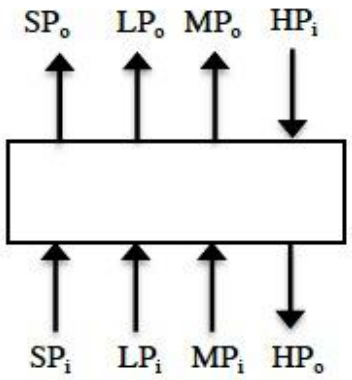
Exergy analysis (1)

A state parameter

$$\dot{X}_{S,1} = \dot{W}_{max} = m[h_1 - h_0 - T_0(s_1 - s_0)]$$

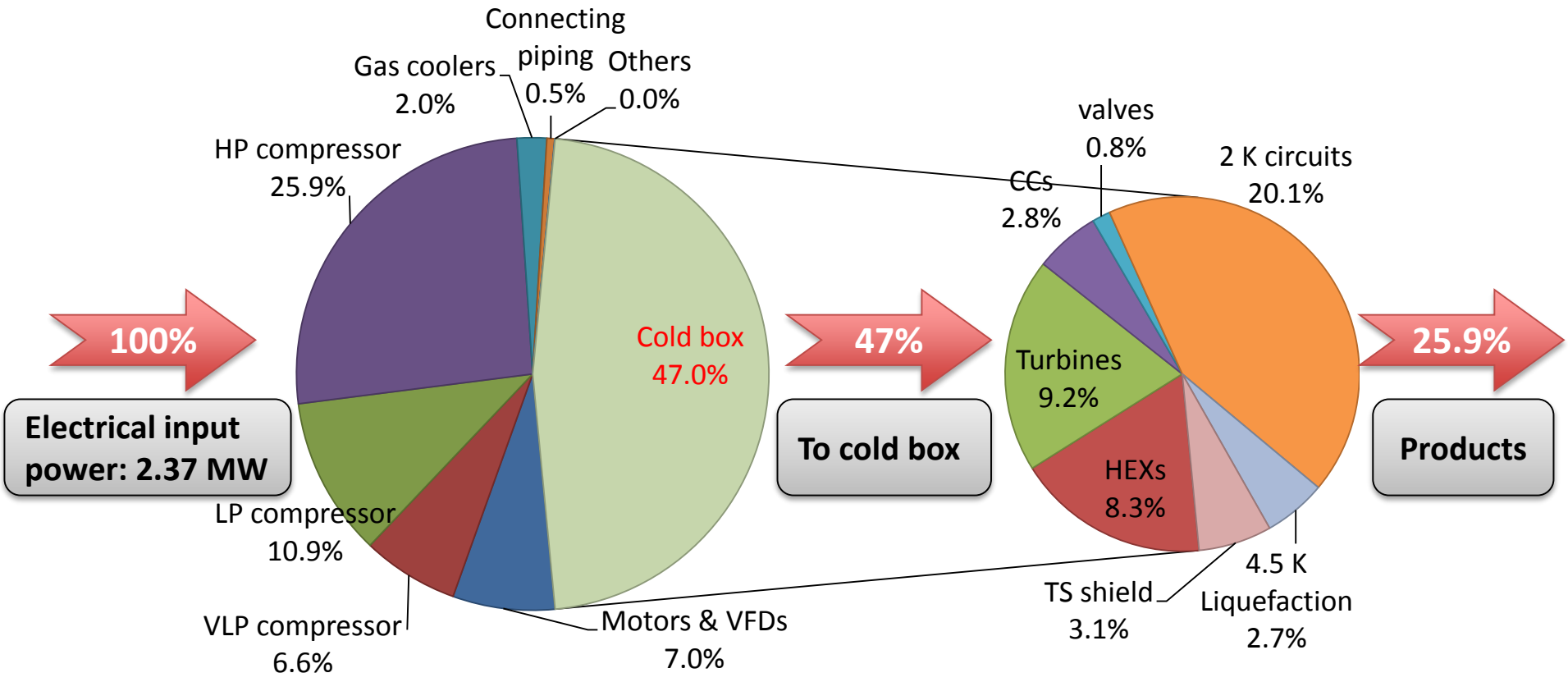
Exergy balance at steady state

$$\dot{X}_{in} = \dot{X}_{out} + \dot{X}_{des}$$

Components	Warm/Cold compressor	Turbines	Heat exchanger
Schematic			
Rate of exergy destruction	$\dot{X}_{des} = \dot{W} + \dot{X}_1 - \dot{X}_2$	$\dot{X}_{des} = \dot{X}_1 - \dot{X}_2 - \dot{W}$ $\dot{W} = \dot{m} \cdot (h_1 - h_2)$	$\dot{X}_{des} = \dot{X}_{HP_i} + \dot{X}_{MP_i} + \dot{X}_{LP_i} + \dot{X}_{SP_i} - \dot{X}_{HP_o} - \dot{X}_{MP_o} - \dot{X}_{LP_o} - \dot{X}_{SP_o}$

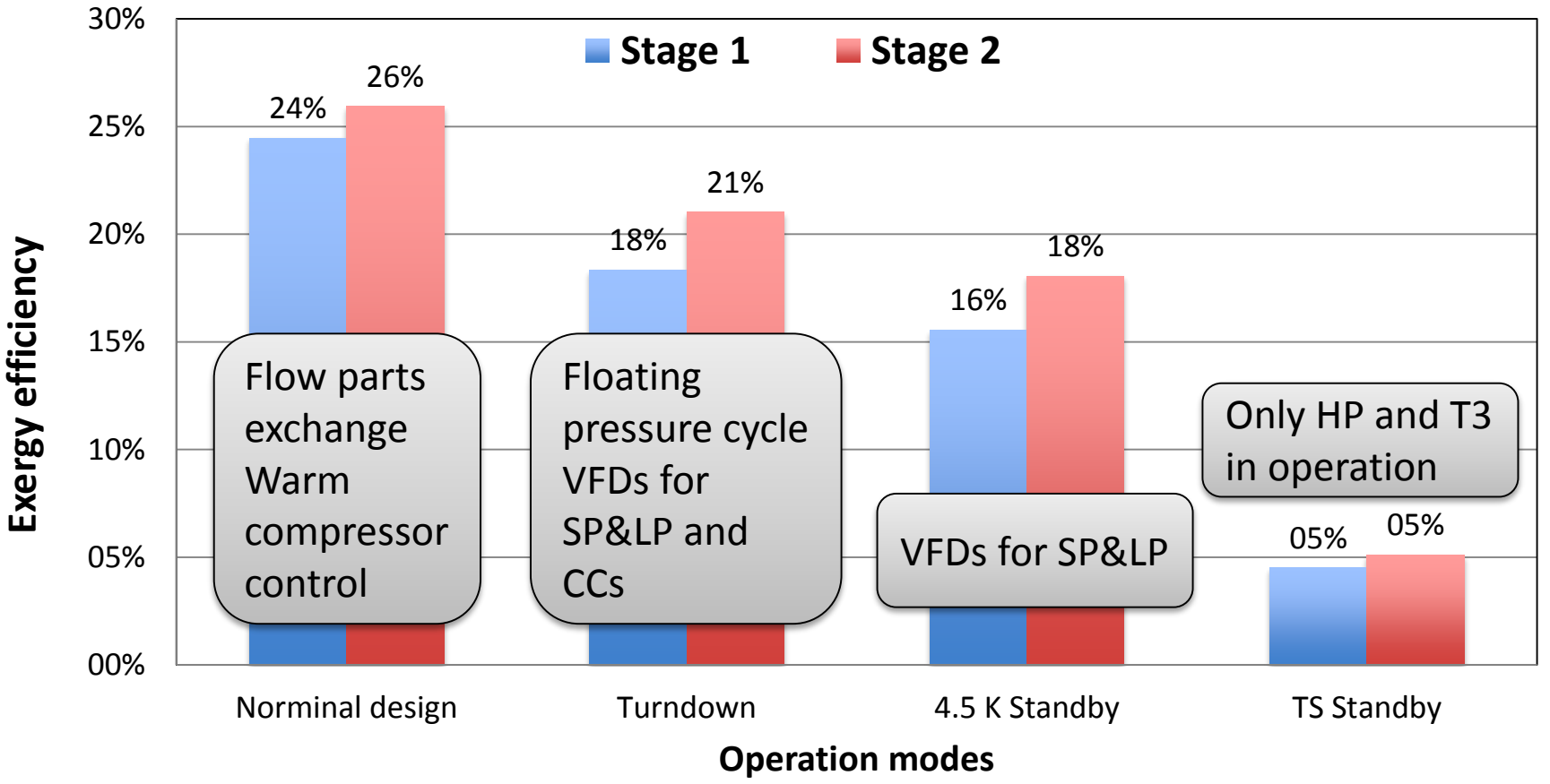
Exergy analysis (2)

Exergy destruction at stage 2 nominal design case



Exergy analysis (3)

Exergy efficiencies at various operation modes of both stages



Next step

- Preliminary design review in SEP 2015
- Key components ordered in this year
- Site acceptance test finished in July 2018

End

EUROPEAN SPALLATION SOURCE

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