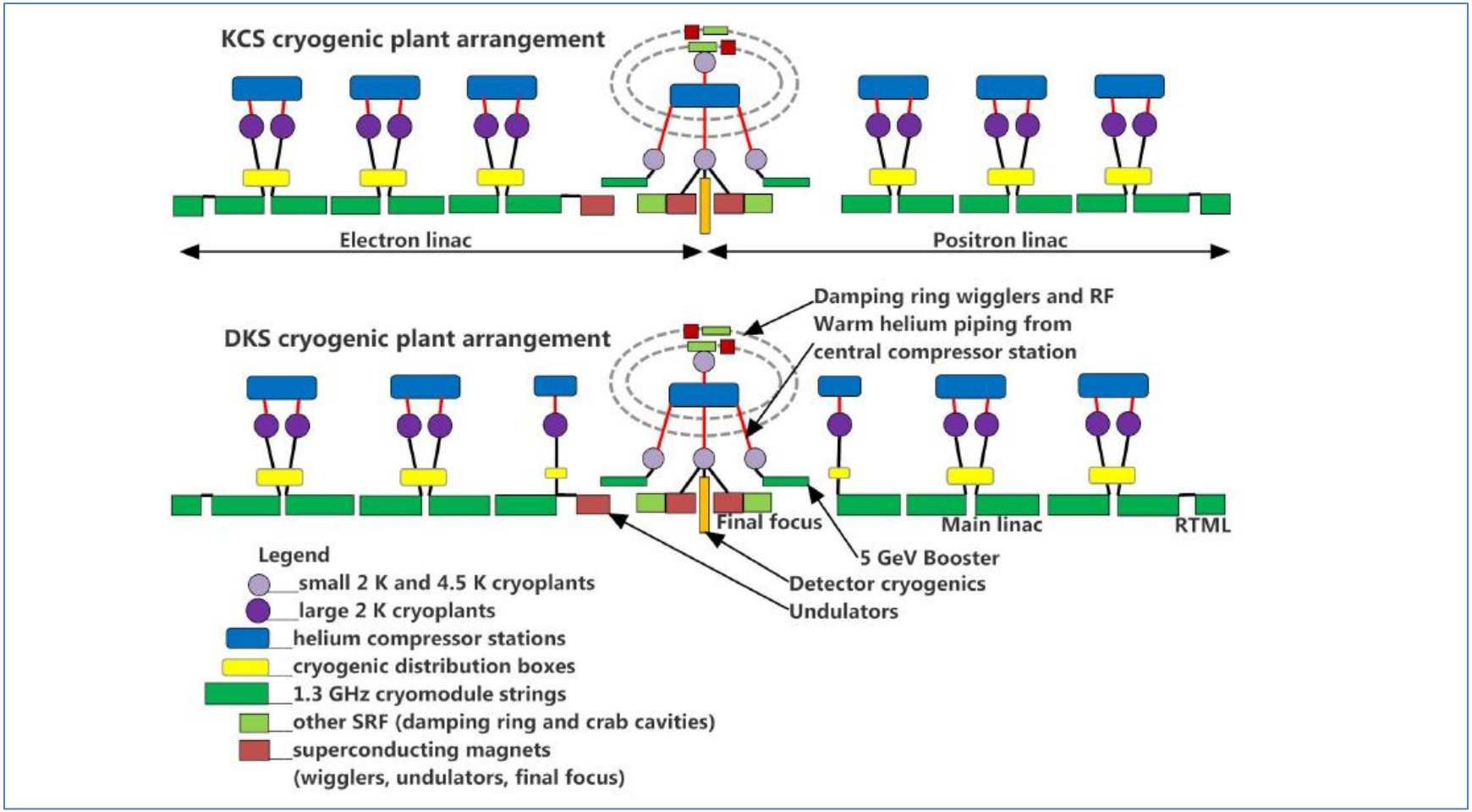
2 K cryogenic plant turn-down

Two slides from a talk by Laurent Tavian (CERN)
Presented at Fermilab (27 Sep 2012)

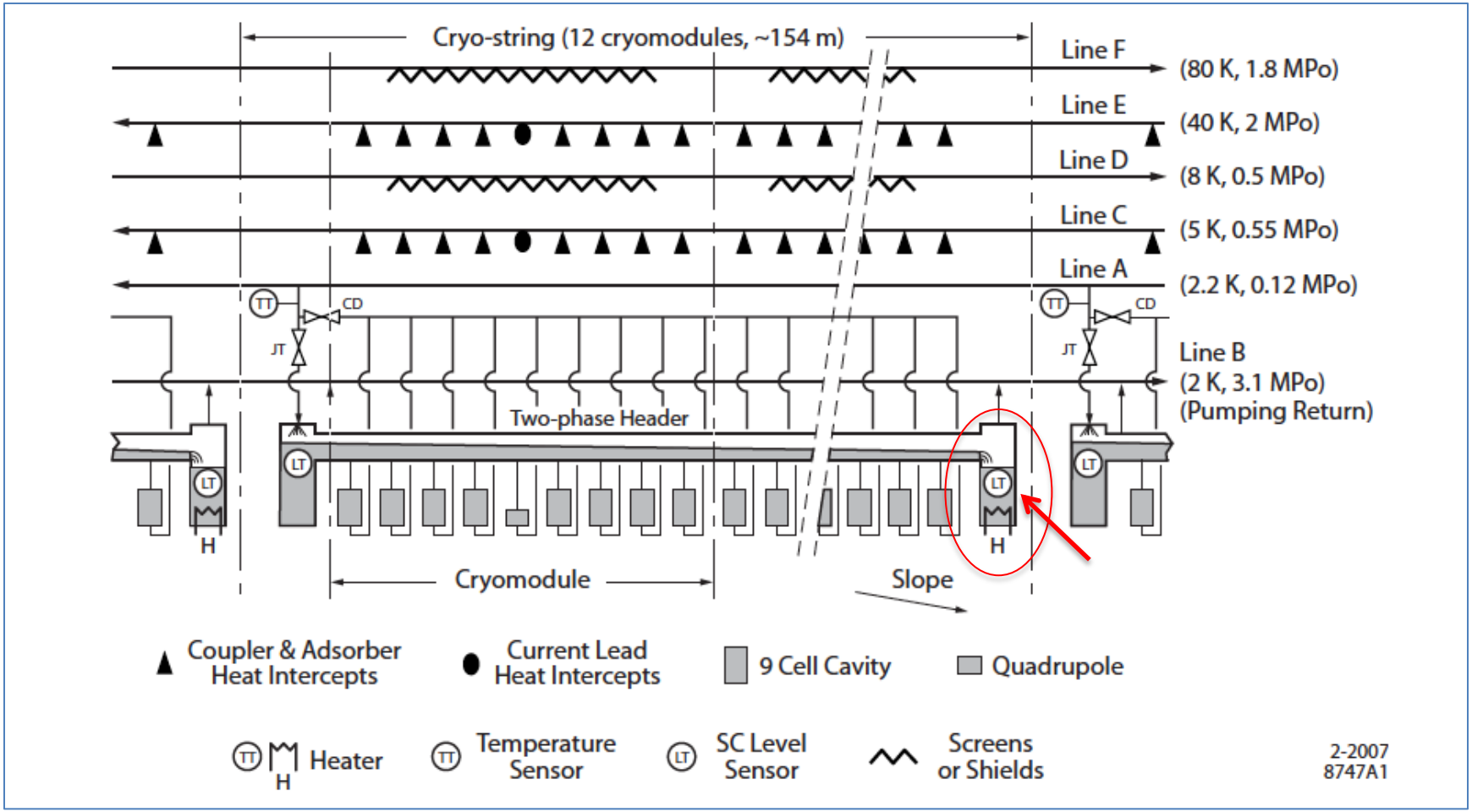
With introduction from Tom Peterson (Fermilab)

To be presented at LCWS-12, Oct. 23, 2012, by Akira Yamaoto (KEK)
(with some additional slides)

ILC Cryogenics Configuration



Cooling Scheme of a Cryo-String



ILC ML Thermal Load

	40-80 K	5-8 K	2 K
Predicted module static heat load (W/mod)	59.19	10.56	1.70
Predicted module dynamic heat load (W/mod)	94.30	4.37	9.66
Modules per cryo unit	192	192	192
Non-module heat load per cryo unit (kW)	1.0	0.2	0.2
Total predicted heat per cryo unit (kW)	30.47	3.07	2.38
Efficiency (fraction Carnot)	0.28	0.24	0.22
Efficiency (Watts/Watt)	16.45	197.94	702.98
Uncertainty & overcapacity factor (Fo)	1.54	1.54	1.54
Heat Load per Cryo Unit including Fo (kW)	46.92	4.72	3.67
Installed power (kW)	771.7	934.9	2577.6
Installed 4.5 K equivalent (kW)	3.5	4.3	11.8
Percent of total power at each level	18.0	21.8	60.2
Total operating power for one cryo unit based on predicted heat (MW)			3.34
Total installed power for one cryo unit (MW)			4.33
Total installed 4.5 K equivalent power for one cryo unit (kW)			19.57

Cryogenics Plant Power Consumption

Area	# of Plants	Installed Plant Size (each) (MW)	Total Installed Power (MW)	Operating Power (each) (MW)	Total Operating Power (MW)
Main Linac + RTML	10	4.35	43.52	3.39	33.91
Sources	2	0.59	1.18	0.46	0.92
Damping Rings	2	1.26	2.52	0.88	1.76
BDS	1	0.41	0.41	0.33	0.33
Total			47.63		36.92

How much fraction need to be adjusted ?

Comments from Tom Peterson about cryogenic capacity and efficiency

- Cryogenic plant efficiency is optimal when the plant capacity is matched to the load.

- Due to various factors such as uncertainties in final as-installed heat loads, overcapacity required for control, and variability or absence of large dynamic heating, ILC may experience varying levels of mismatch between cryogenic plant capacity and loads.

- This mismatch results not only in inefficiency but control difficulties for the 2 Kelvin system due to the dynamic nature of the cold compressors.

Matching load to capacity

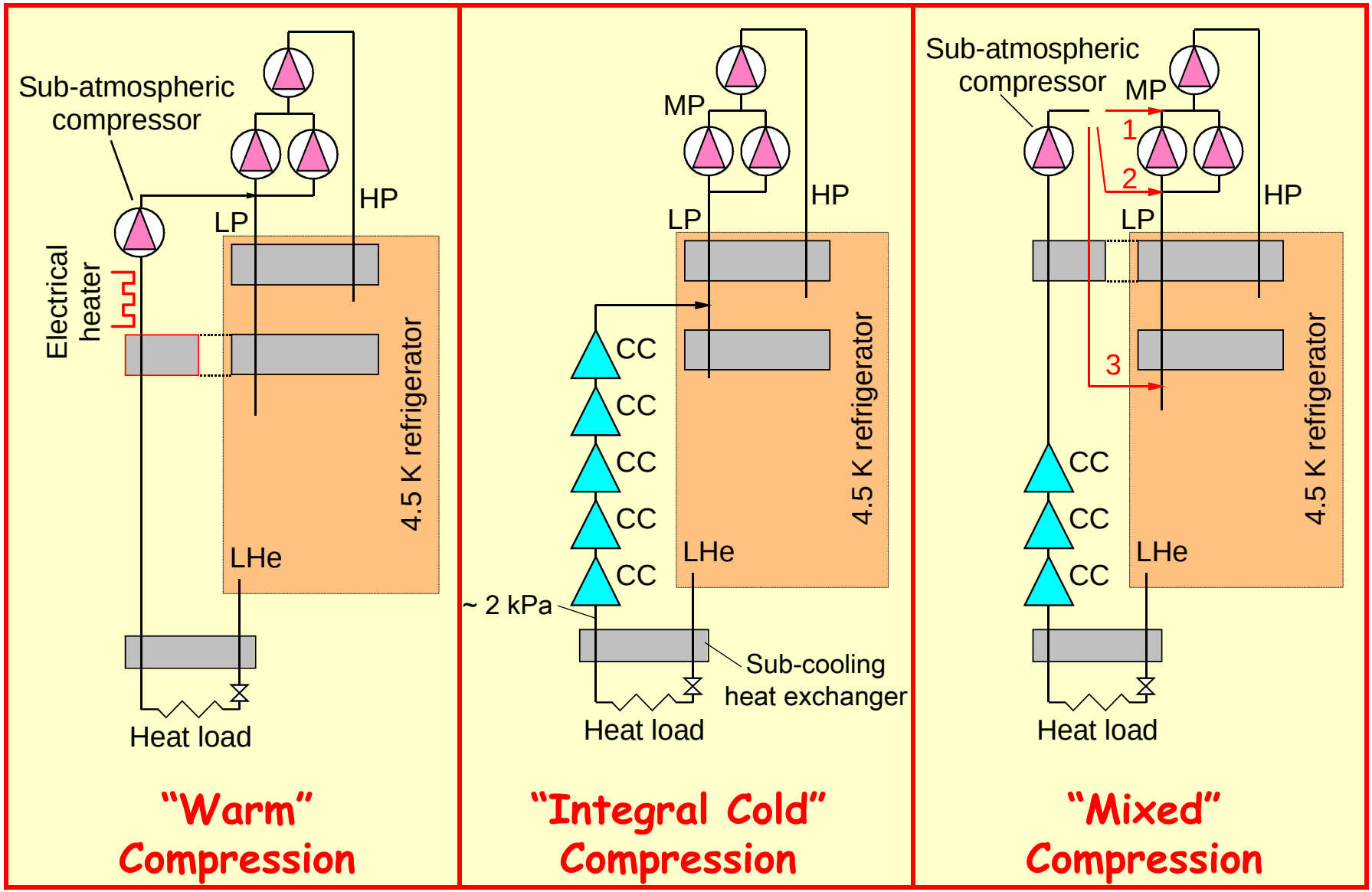
- Two mechanisms (among other features in the cryogenic plant) would provide matching of cryogenic capacity to the load in an ILC

- 1. Electric heaters in cryomodules will be required to compensate dynamic loads from variations in RF power.
  - These will also operate continuously at some low level for control

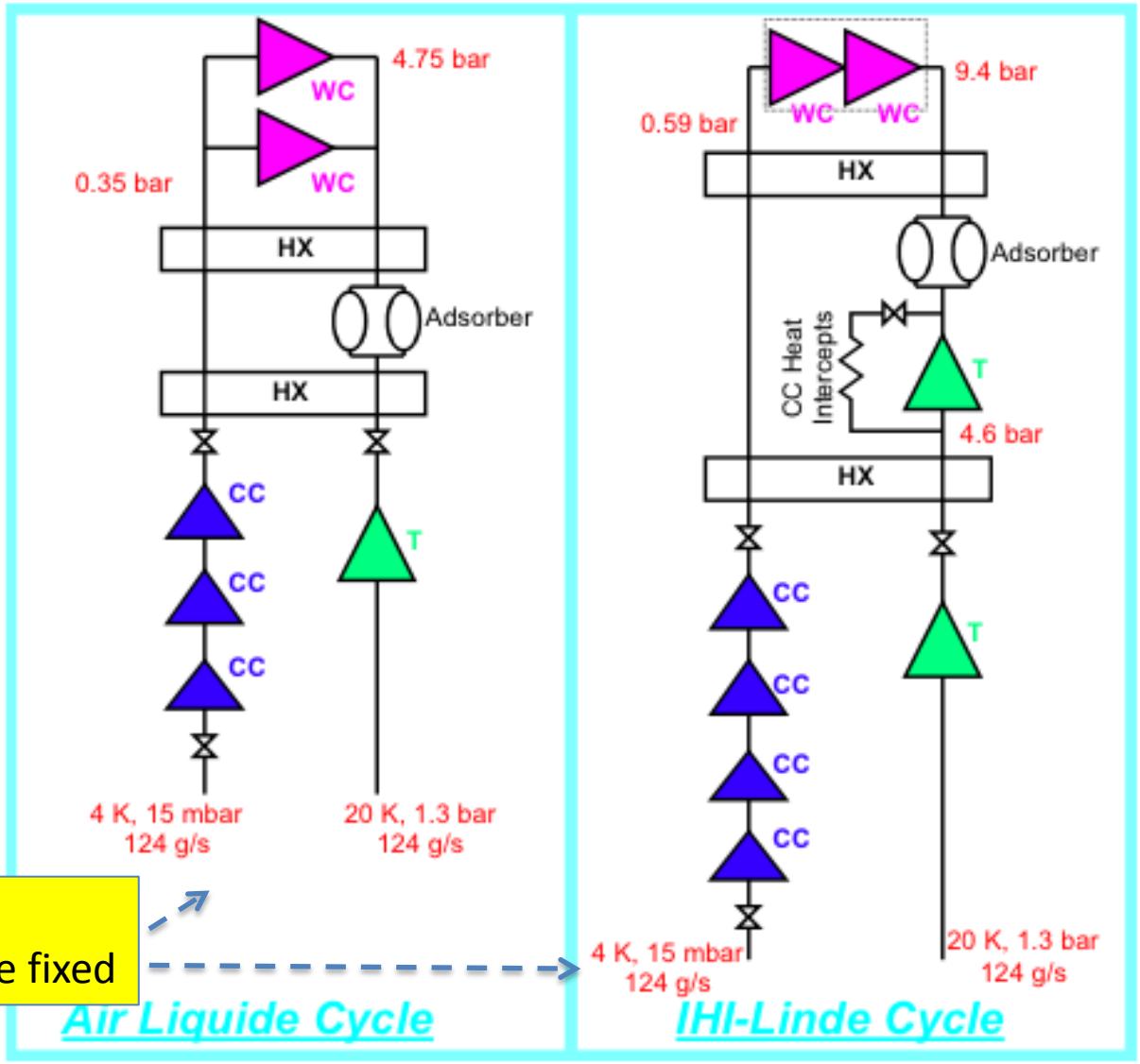
- 2. Slow changes in required capacity can be accommodated by the cryogenic plant at the 2 Kelvin level using a mixed compression cycle as described by Laurent Tavian in the following slides.

Cycles for refrigeration below 2 K

P. Lebrun



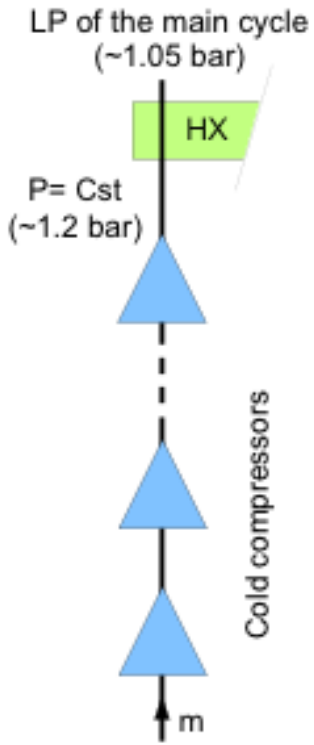
Simplified flow-schemes of the 1.8-K refrigeration units of LHC



Condition need to be fixed

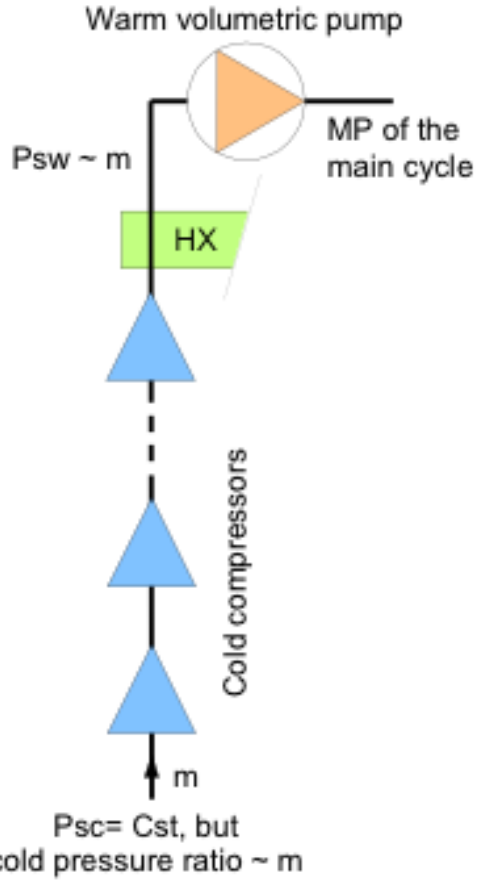
Mixed compression cycle !

Integral-cold vs mixed compression cycle



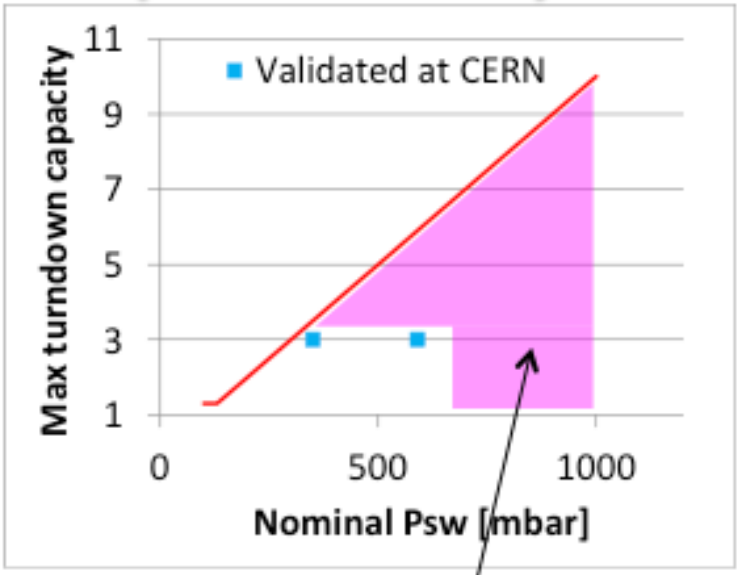
Integral-cold

Limited turndown capacity : ~1.3 (electrical heating required)

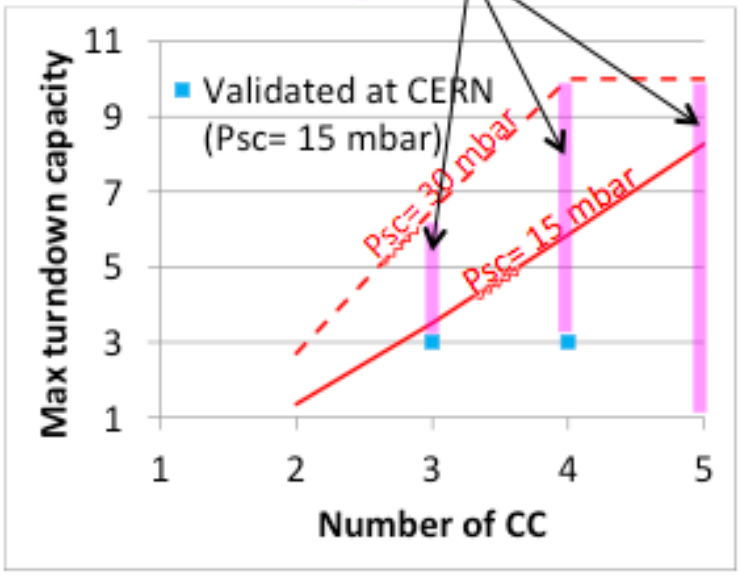


Mixed

Turndown capacity: theoretically up to 10 depending on CC number and the nominal warm suction pressure Psw



Terra Incognita



Summary

- Cryogenics power can be adjusted by using two approaches
  - Heater power adjustment for quick feedback and actions, as the most reliable and safest operation.
  - Cold and warm compressor power adjustment for slow and long-term response to mazimize power-saving and overall efficiency.