The ESS Cryogenics System

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Outline

- Introduction to ESS
- Applications of Cryogenics at ESS
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  - Target Moderator Cryoplant
  - Test and Instruments Cryoplant
- He Recovery and Storage
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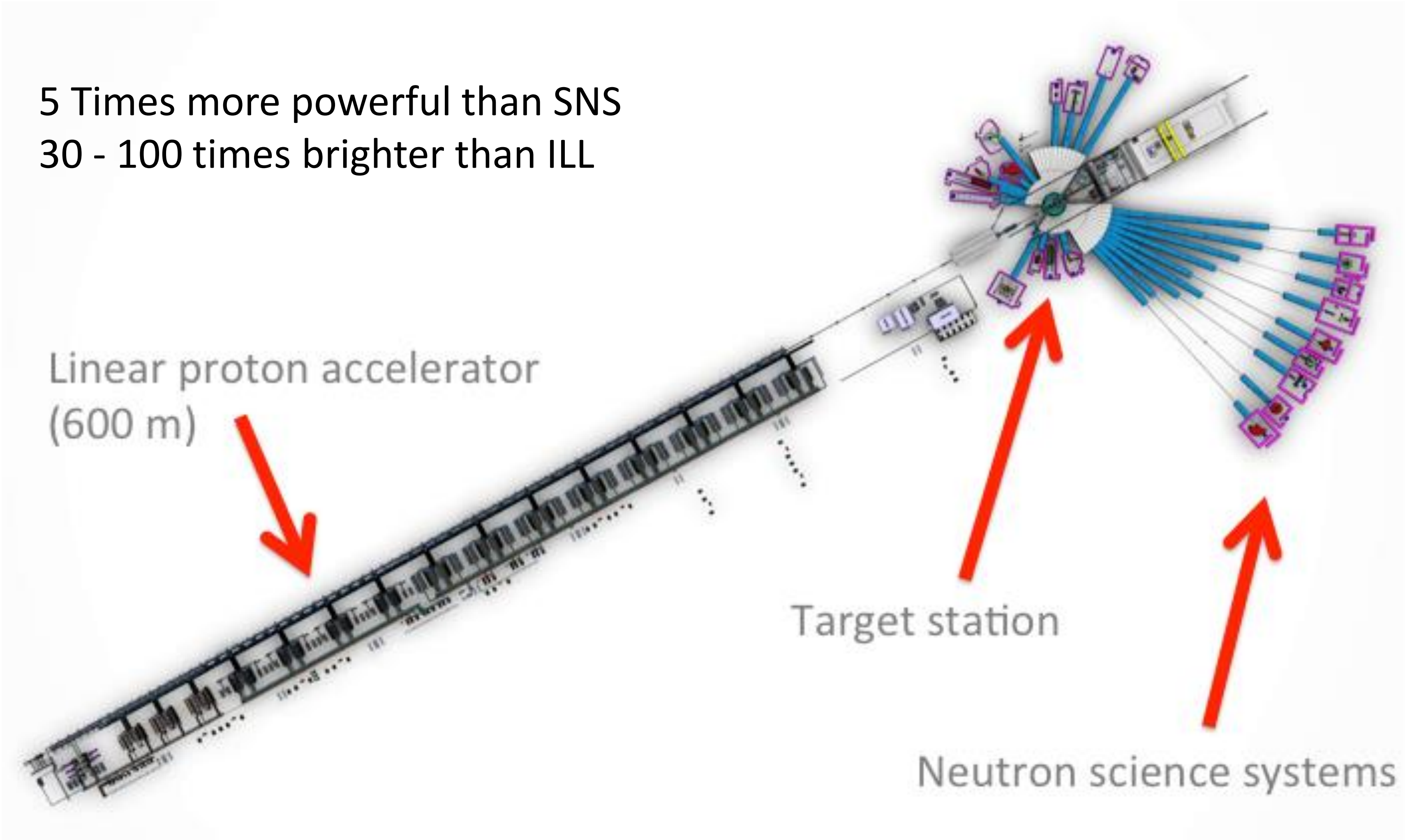
Introduction to ESS

The goal of ESS is to provide a spallation based neutron source significantly more powerful than existing sources: 30 - 100 times brighter than ILL and 5 times more powerful than SNS

This facility will enable neutron based research in a wide range of fields including: materials science, condensed matter and biomedical studies

ESS Overview

5 Times more powerful than SNS
30 - 100 times brighter than ILL



The view of the Southwest in 2025

- MAX IV – a national research facility, under construction, opens up in 2016
- Science City – a new part of town
- ESS – an international research facility

Applications of Cryogenics at ESS

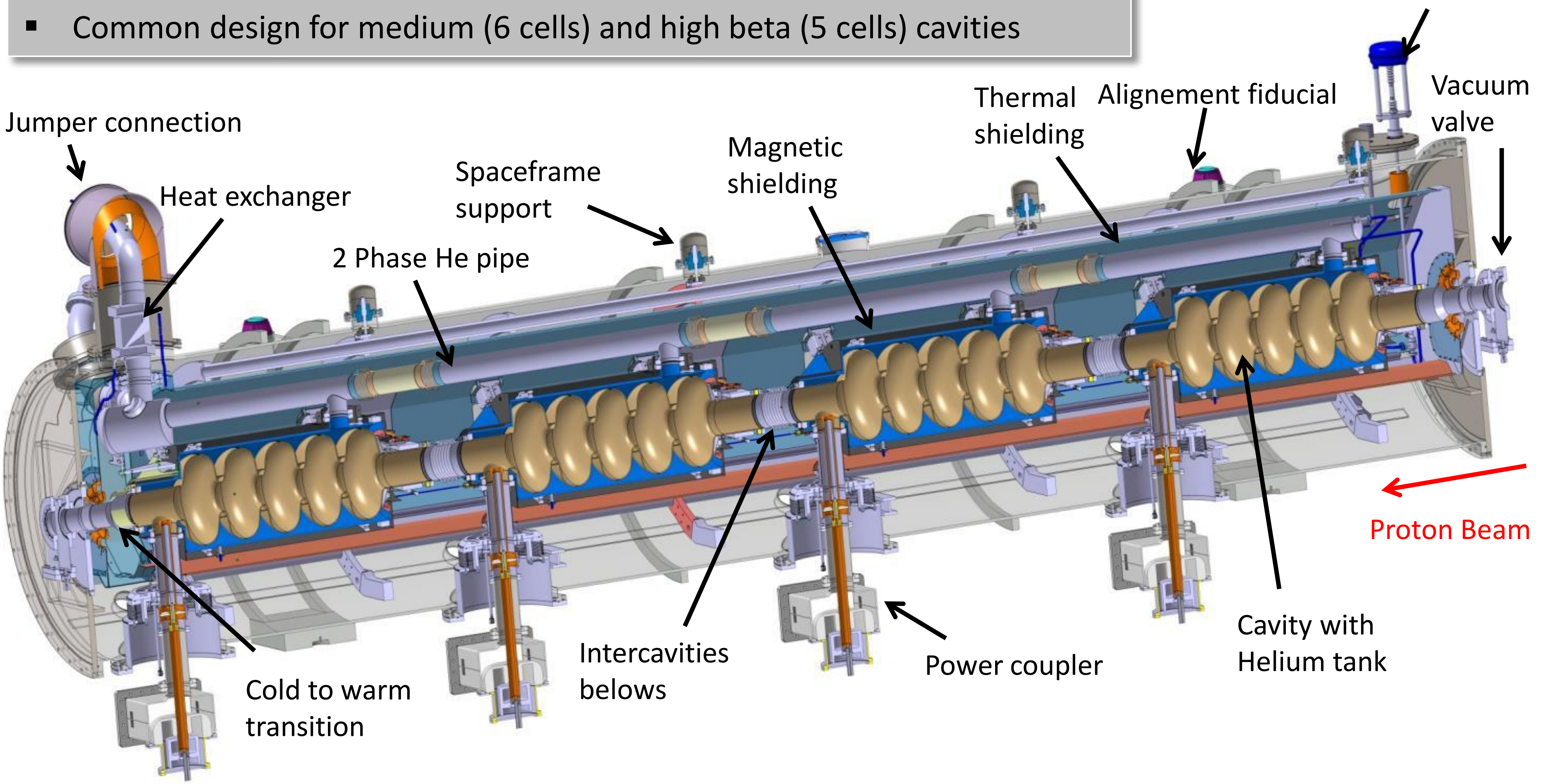
- Cooling for the cryomodules (2 K, 4.5 – 300 K and 40 K)
- Cooling for the Target supercritical H_2 Moderator (16.5 K)
- Liquid Helium and Liquid Nitrogen for the Neutron Instruments
- Cooling for the cryomodule test stand (2 K, 4.5 – 300 K and 40 K)
- This is accomplished via 3 separate cryoplants

Accelerator Cryogenics

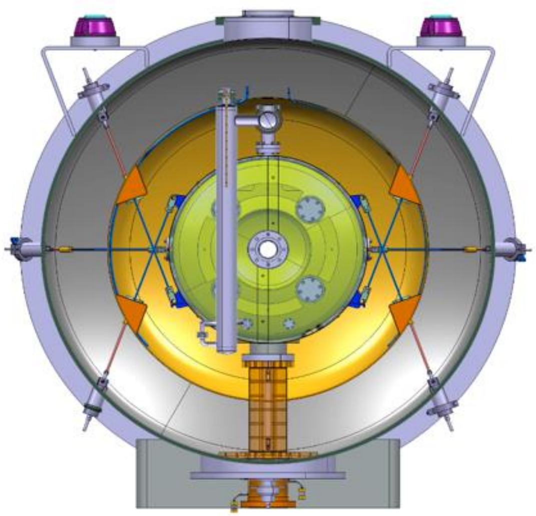
- Bulk of acceleration is carried out via 3 classes of SRF cavities: Spoke, Medium (β = 0.67) Beta Elliptical and High (β = 0.86) Beta Elliptical
- No superconducting magnets in the accelerator. There are some in the instruments
- Cavities operate at 2 K with a 40 – 50 K thermal shield
- Inner power coupler cooling from 4.2 K to 300 K
- Accelerator lattice permits an 14 additional cryomodules to compensate for lower than expected cryomodule gradients (Stage 2)

Elliptical Cavities & Cryomodule

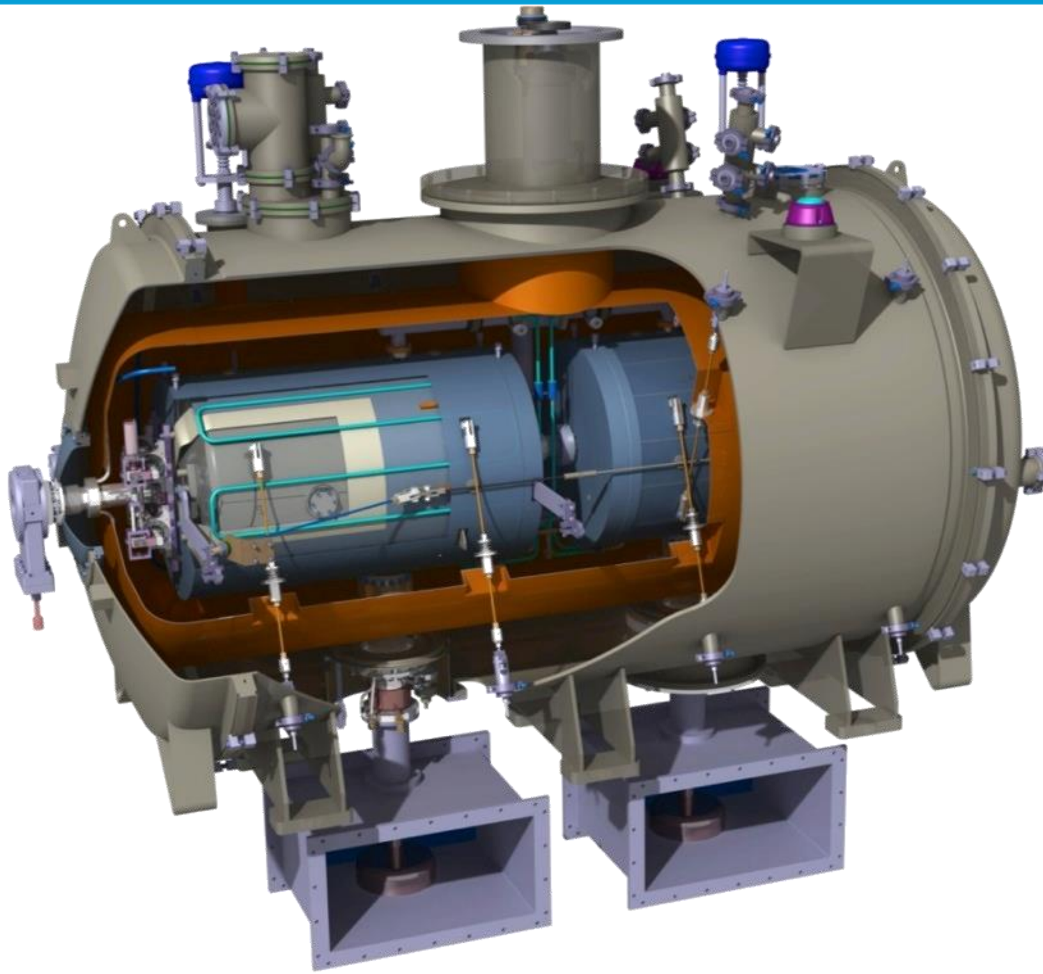
- Similar to CEBAF/SNS cryomodule concept with 4 cavities per cryomodule
- Common design for medium (6 cells) and high beta (5 cells) cavities

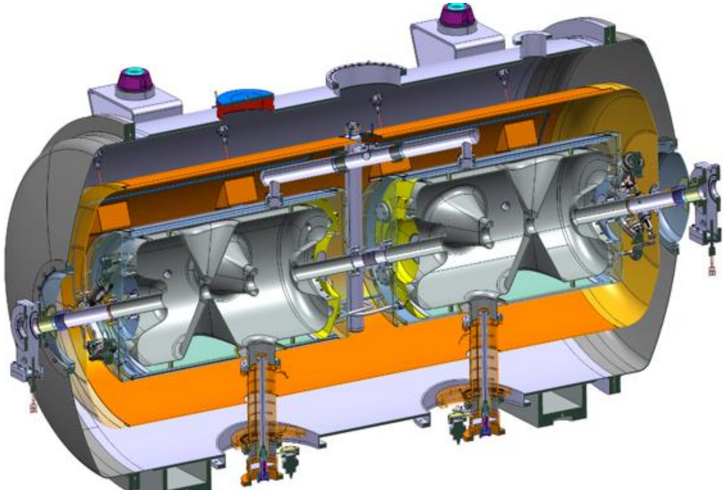


Spoke cavity string and cryomodule package



Diameter
1350 mm





2900 mm

ESS Accelerator Cryoplant (ACCP)

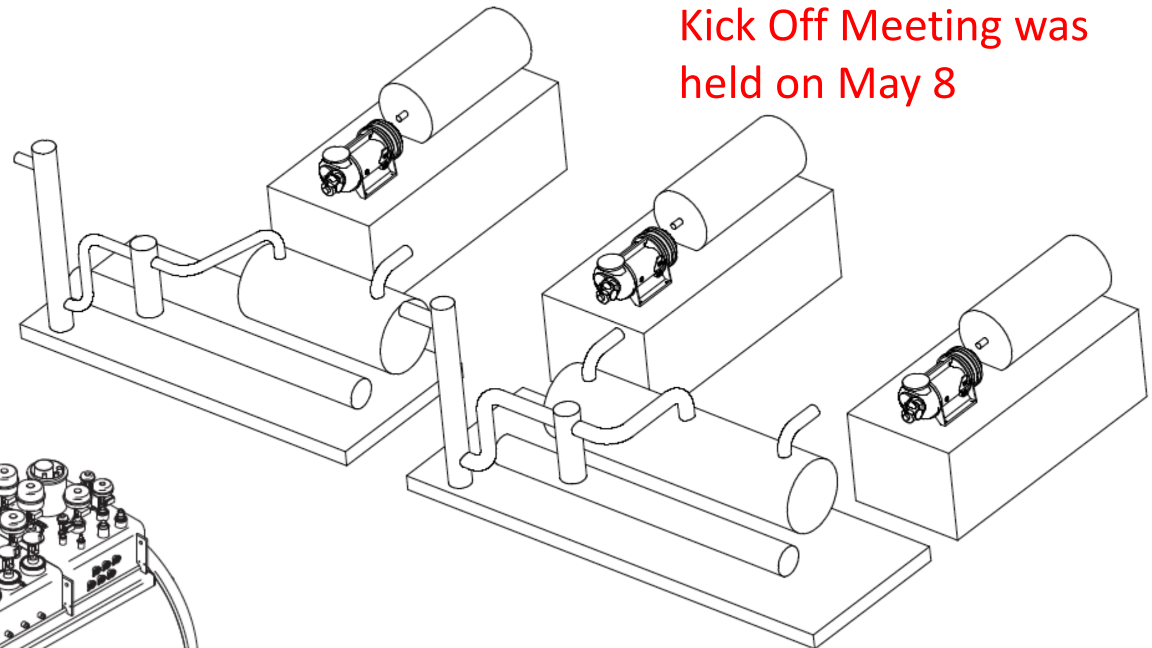
- Provides cryogenic cooling to Cryomodules
  - 13 Spoke and 30 Elliptical (Stage 1)
  - Sized to allow an additional 14 Elliptical Cryomodules for design contingency (Stage 2)
- Allows for number of operating modes
- Connected to the cryomodules via a cryogenic distribution system
- High availability and turn down capability are important features
- Compressor heat is absorbed by Lund District Heating System (unique ESS feature)

Accelerator Cryoplant (ACCP) Capacities

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	1852	627	2478		6.8	8551
	Turndown	845	627	1472		6.8	8551
	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
	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					

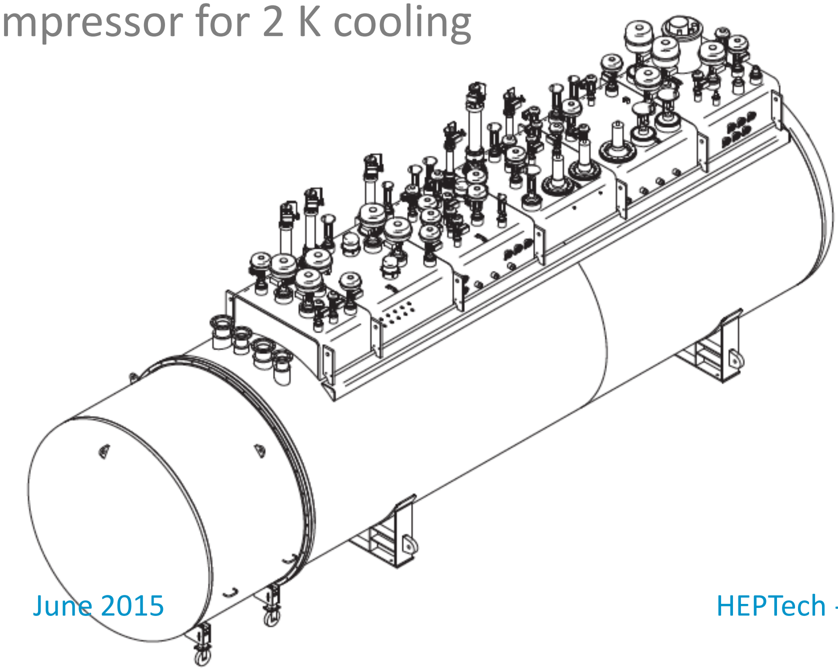
ACCP – Contract Award to Linde Kryotechnik AG in December 2014

Compressor System:
Three identical machines for SP→MP, LP→MP and MP→HP compression, hot standby compressor is under discussion



Kick Off Meeting was held on May 8

System uses 3 cold compressors + 1 warm sub-atmospheric compressor for 2 K cooling



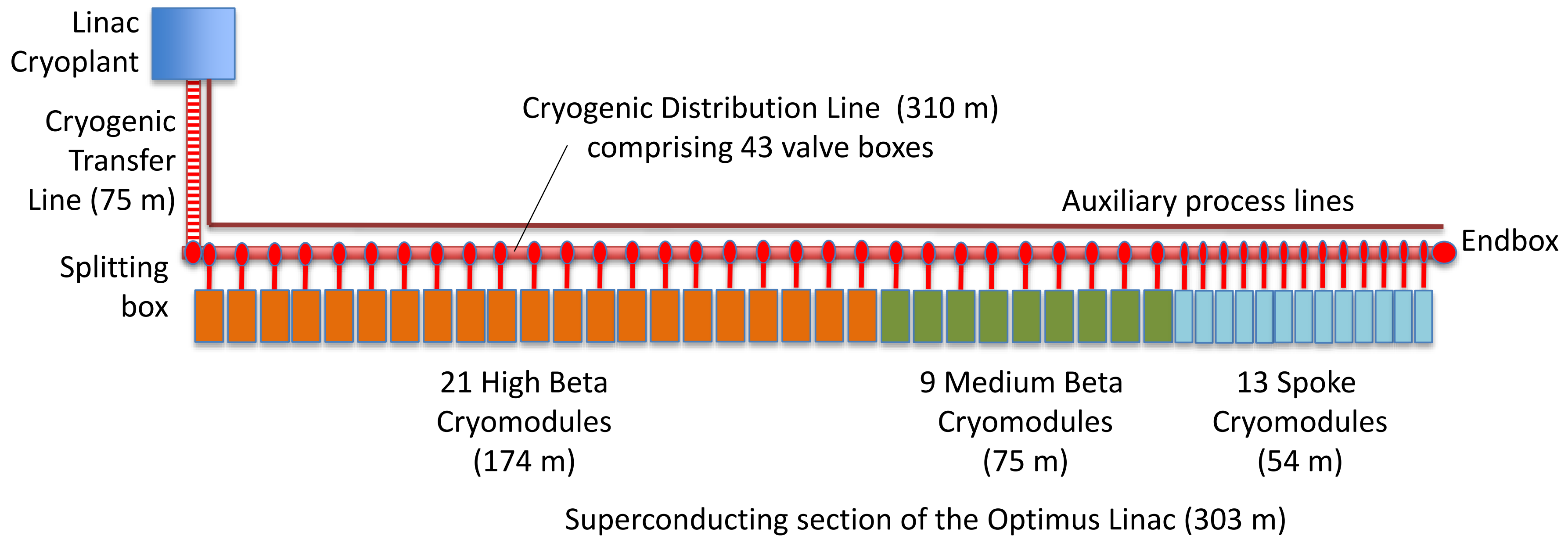
One Coldbox comprising 6 expansion turbines, 3 cold compressors, in-built acceptance test equipment

Cryogenic Distribution System

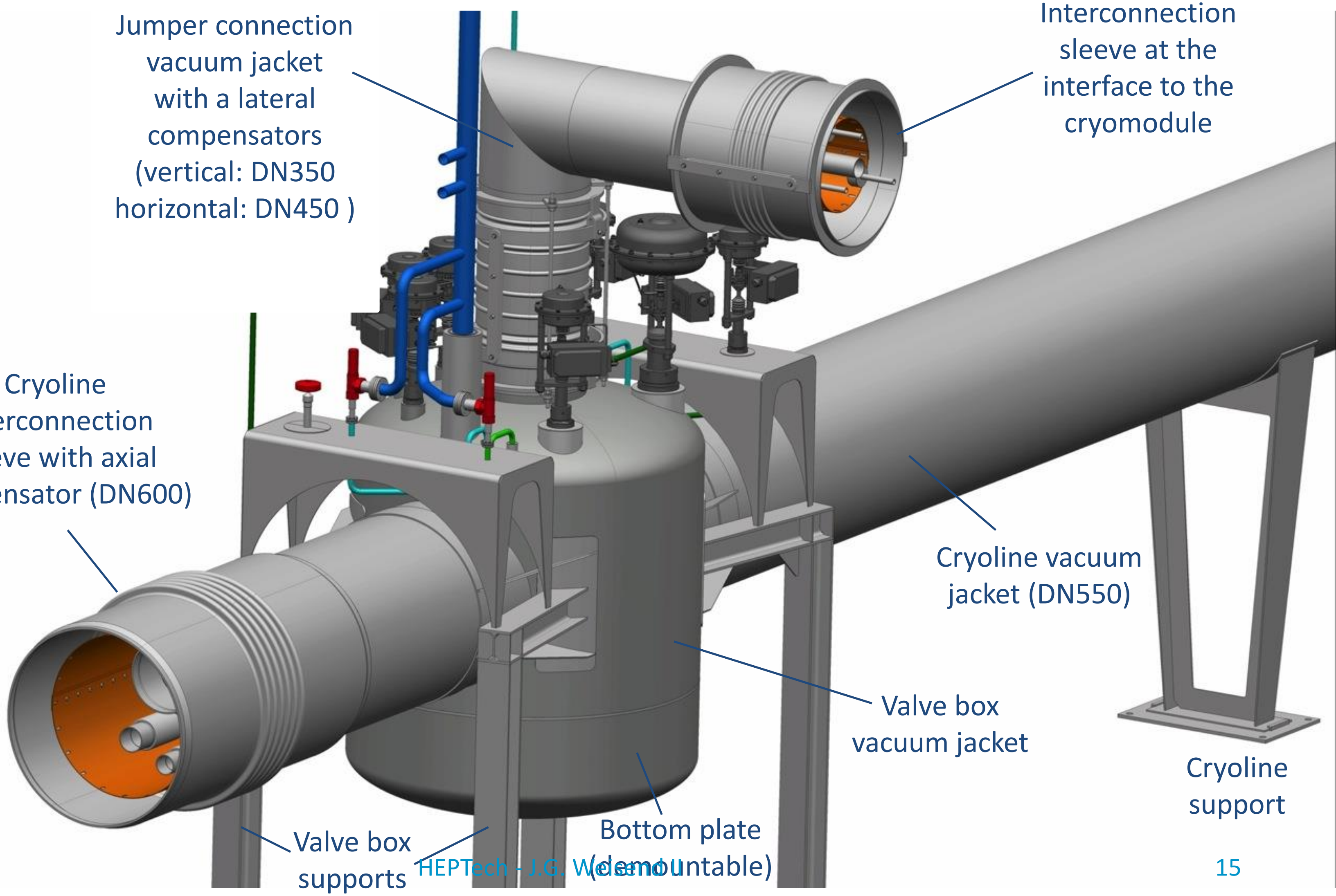
- Allows warm up and cool down of one or more cryomodules w/o affecting remaining cryomodules
- Connection between distribution line & cryomodule is done via fixed connections
- Separate isolation vacuums in the distribution lines and cryomodules
- Operating modes defined
- Conceptual design complete
- Provided as an In Kind Contribution by IPN Orsay (France) and WrUT (Poland)
- Cryogenic Distribution System must be complete and installed by December of 2017

Linac CDS – function and layouts

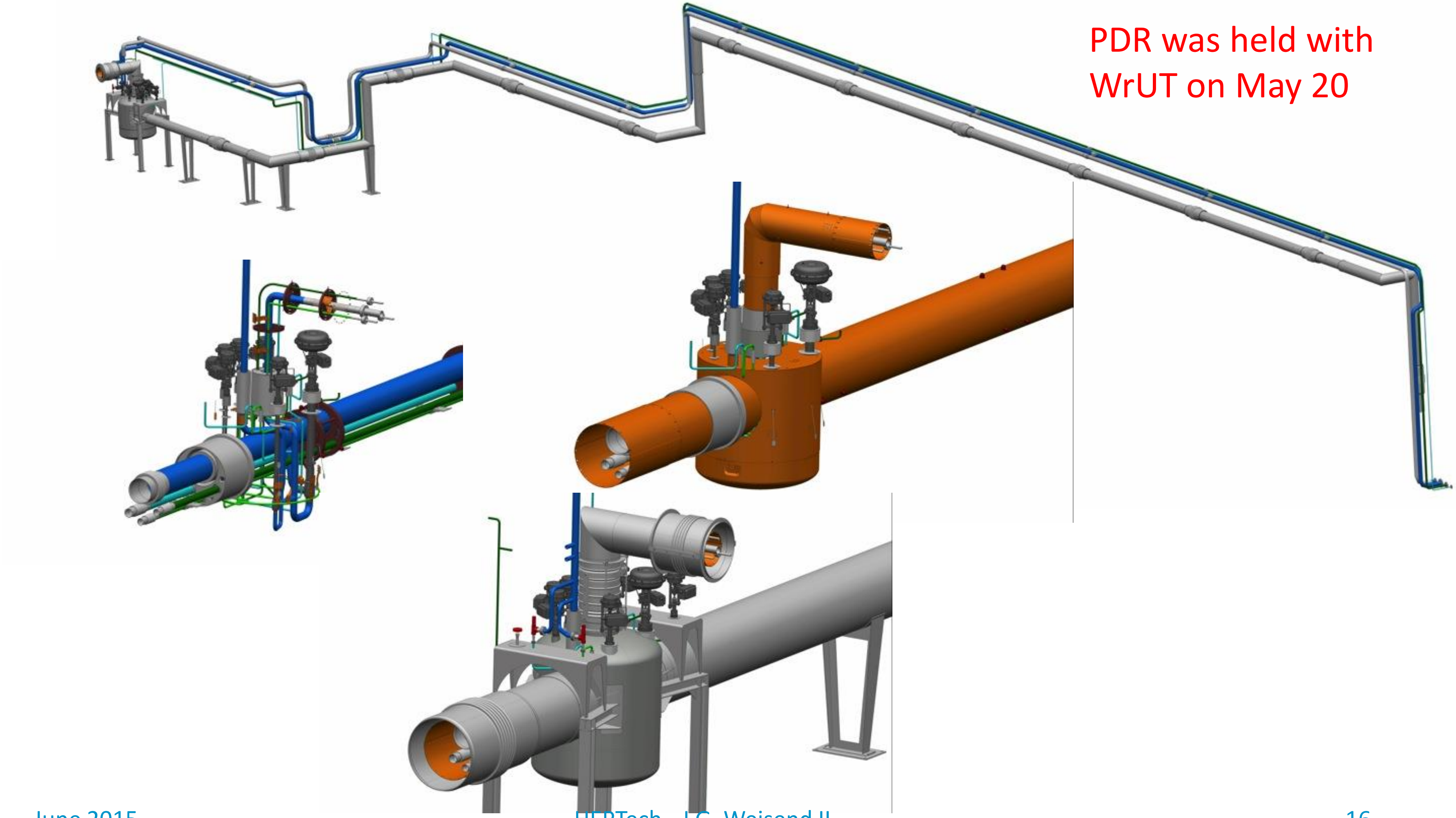
Cryogenic System of the Optimus Linac



Valve box – vacuum jacket

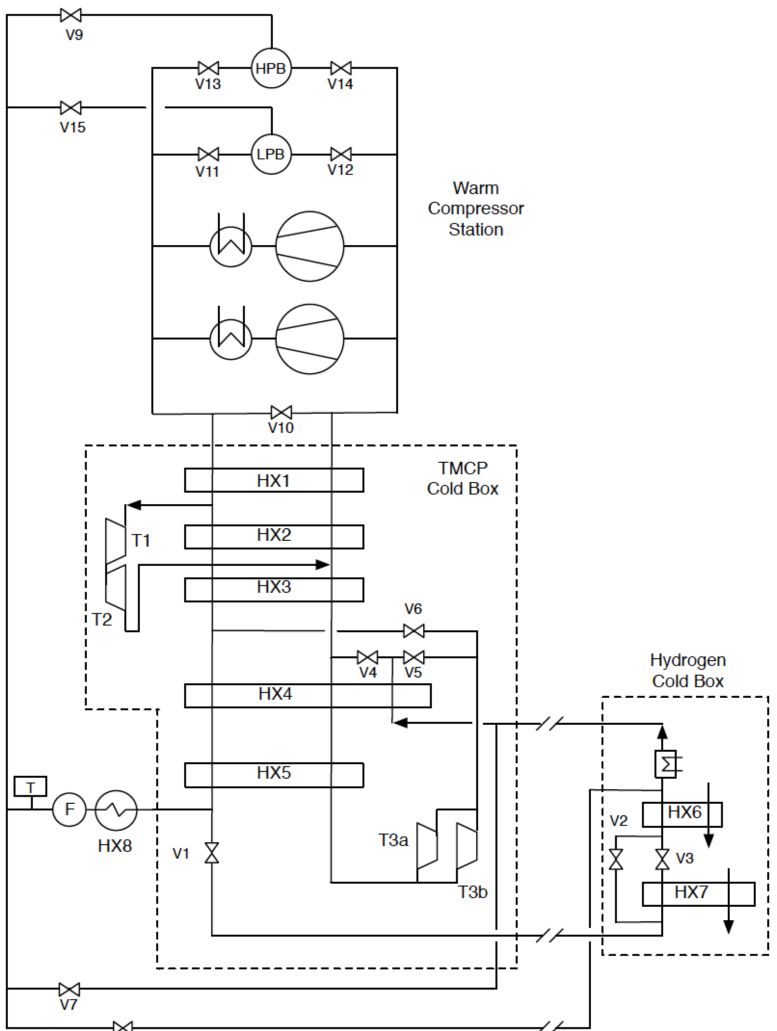


CDS – In kind Agreements with IPNO and WrUT



PDR was held with WrUT on May 20

Target Moderator Cryoplant – Substantial Load Increase



Heat Load at 15 K increased from 20 kW to 35 kW due to moderator re-design (higher brightness, more neutrons)

Impact on space requirements, utilities, interference with other cryoplants and budget (minimal impact on schedule) – technical solutions are currently worked out

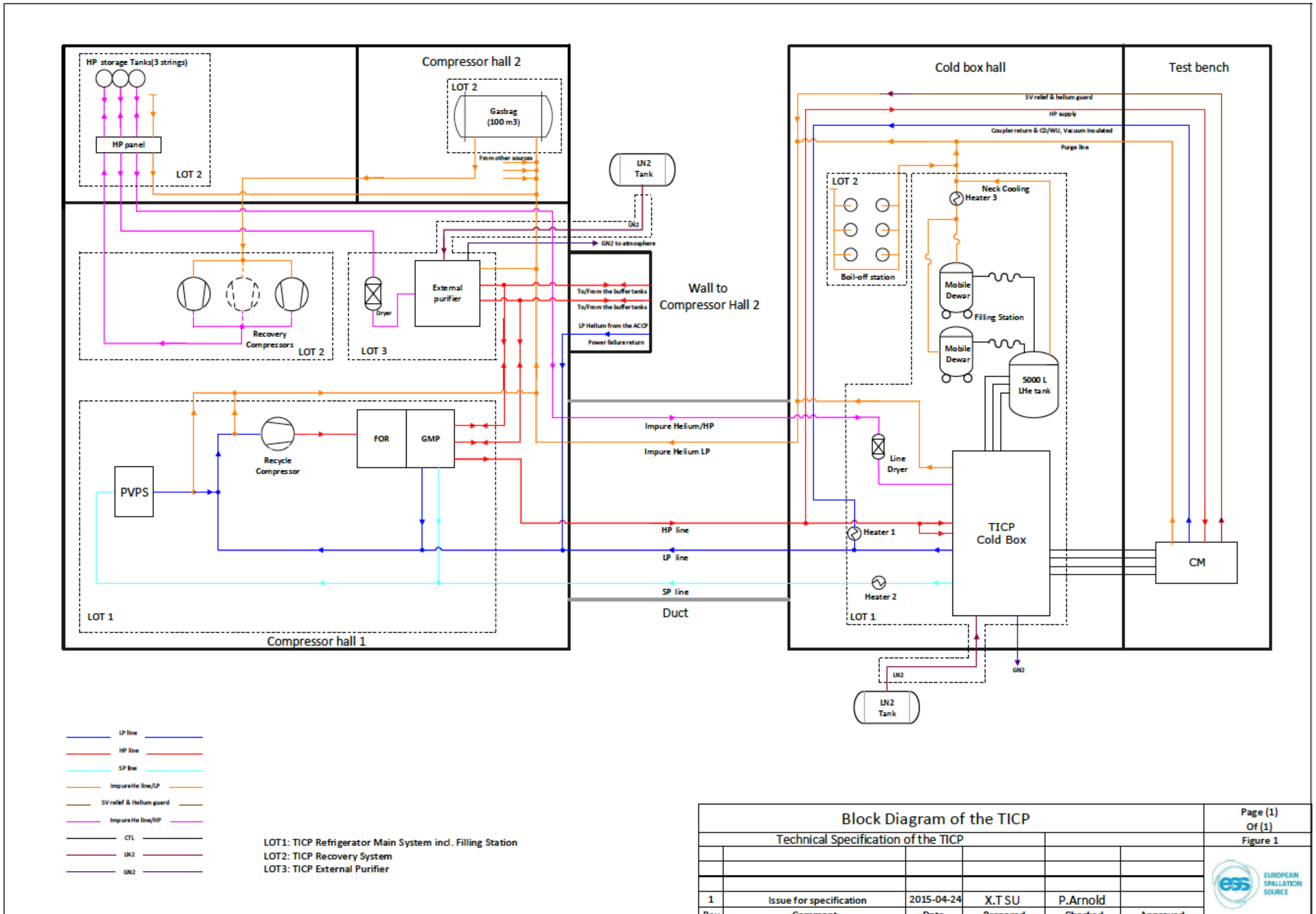
Tight collaboration with TU-Dresden, Hans Quack and FZ Jülich

Plant will likely be ordered in Q1 2016

Test & Instruments Cryoplant (TICP)

- Provides cooling for Cryomodule Test Stand
- During Science Operations, also provides LHe for sample environments and Science Instruments
- TICP provides for CM testing: 76 W at 2 K, 422 W at 40 K and 0.2 g/s of liquid helium
- Sub-atmospheric operation via warm vacuum pumps
- During Science Operations, the TICP shall provide more than 7500 liters of LHe per month
- A recovery system is being built to recover all He gas from instrument halls and return it for purification and liquefaction.
- We expect to order this plant in Q4 2015

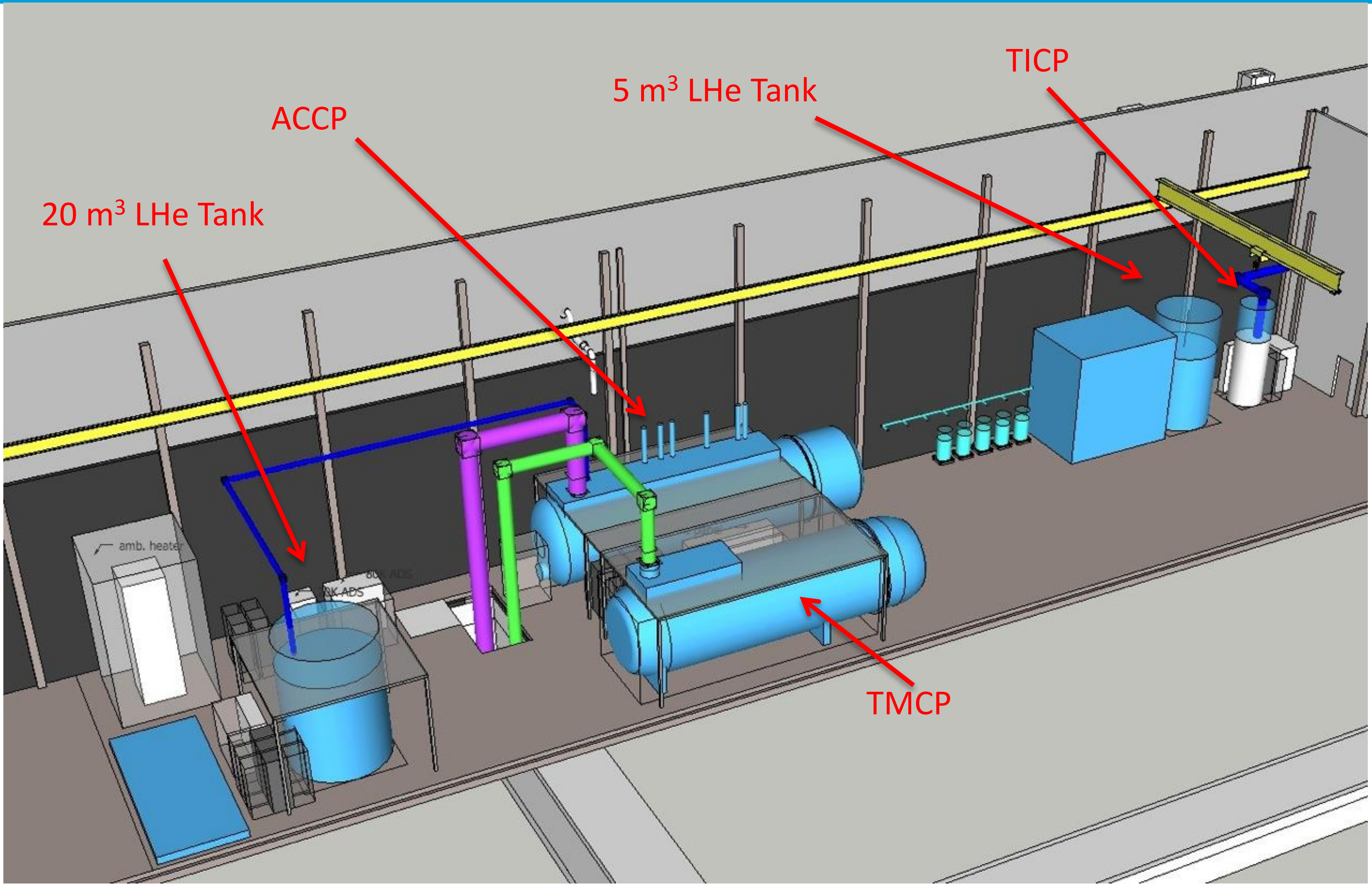
Test & Instruments Cryoplant (TICP)



Helium Recovery and Storage

- The ESS goal is to recovery, purify and reuse as much He as possible
- ACCP and TICP cryoplants will share a common gas system while TMCP has separate storage that can be cross connected
- The system will include a separate cryogenic purifier
- Systems will be provided by IKC or separate contracts
- Expected He Storage Capacities:
  - LHe
    - 20 m^3 (Includes storage for second fill of linac)
    - 5 m^3 (Backup for Instruments He)
  - GHe (20 Bar)
    - 1000 m^3 - sufficient to hold all the linac inventory
  - GHe (200 Bar)
    - 12 m^3 - Instrument He storage

Plant arrangement in the Cold Box Building



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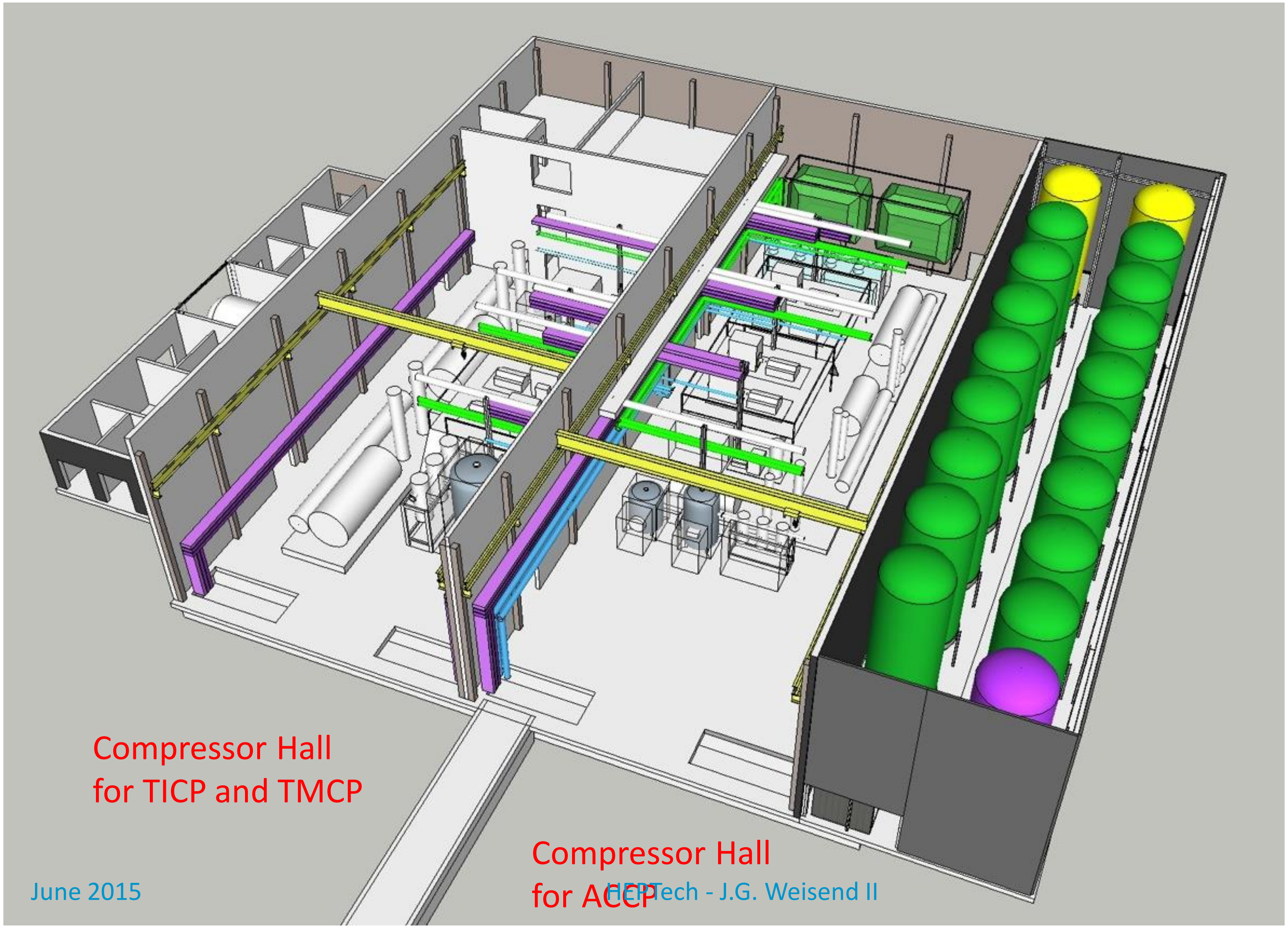
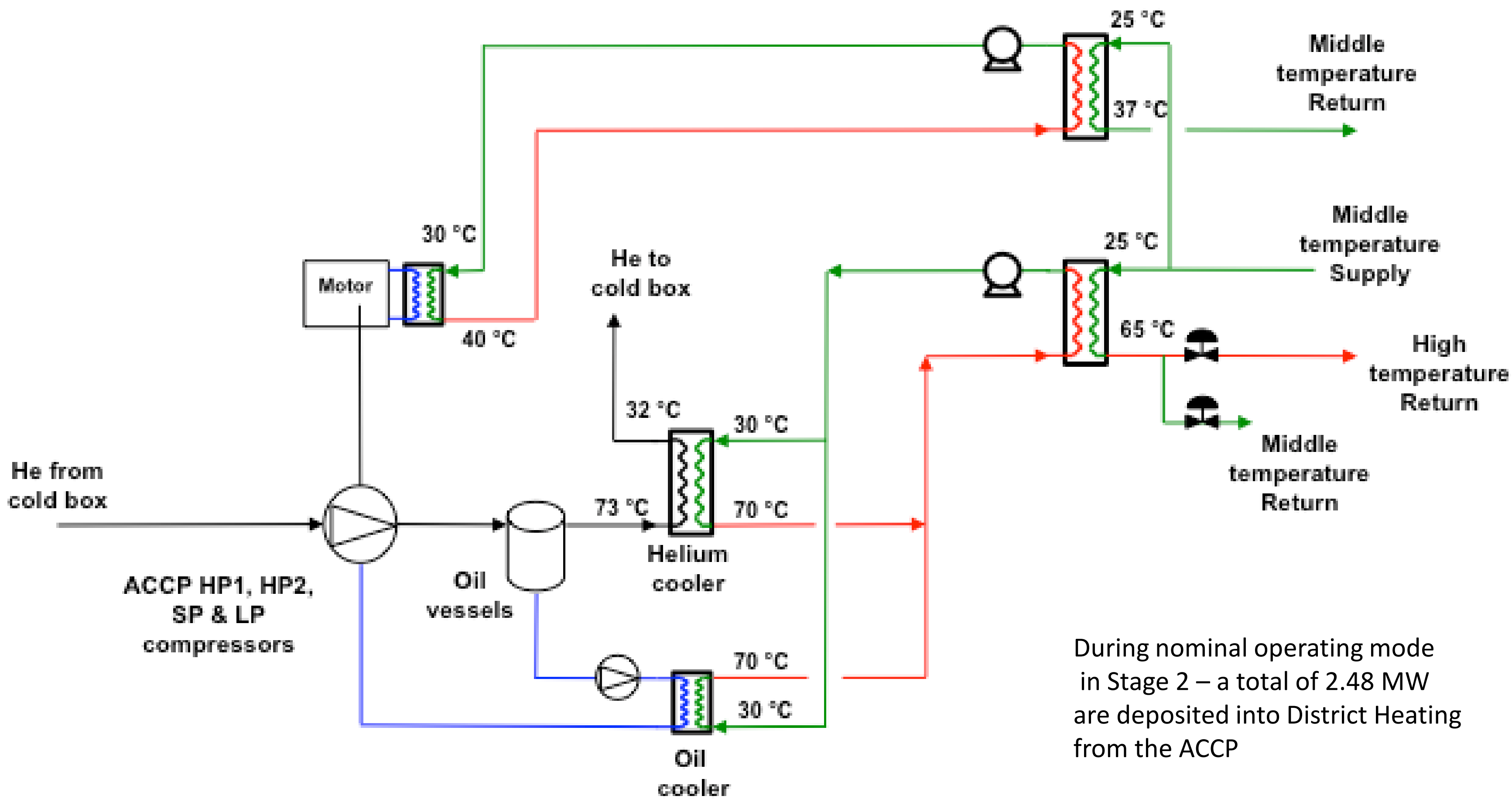
Plant arrangement in the Compressor Building

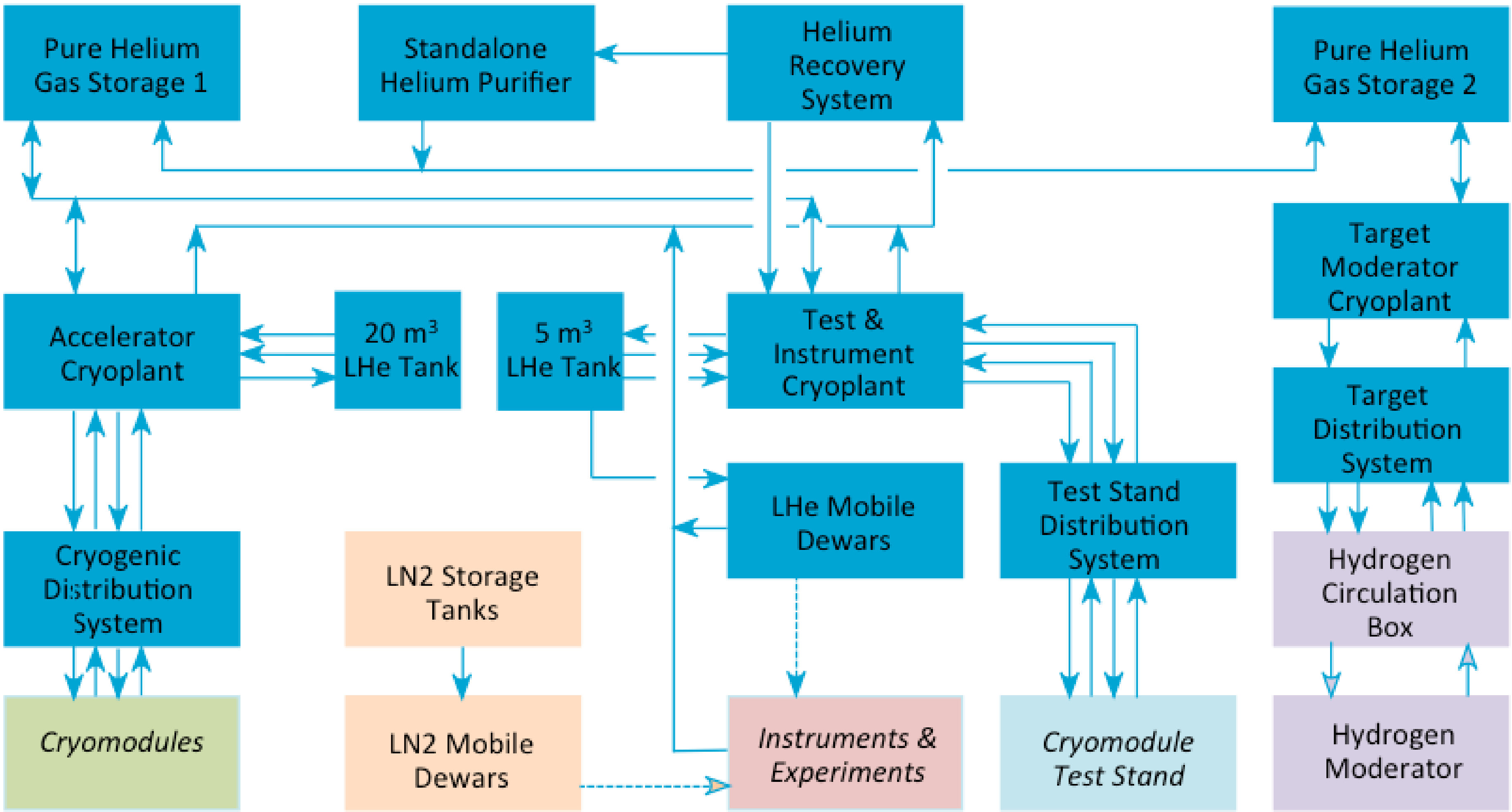


Energy Recovery from ACCP Compressors

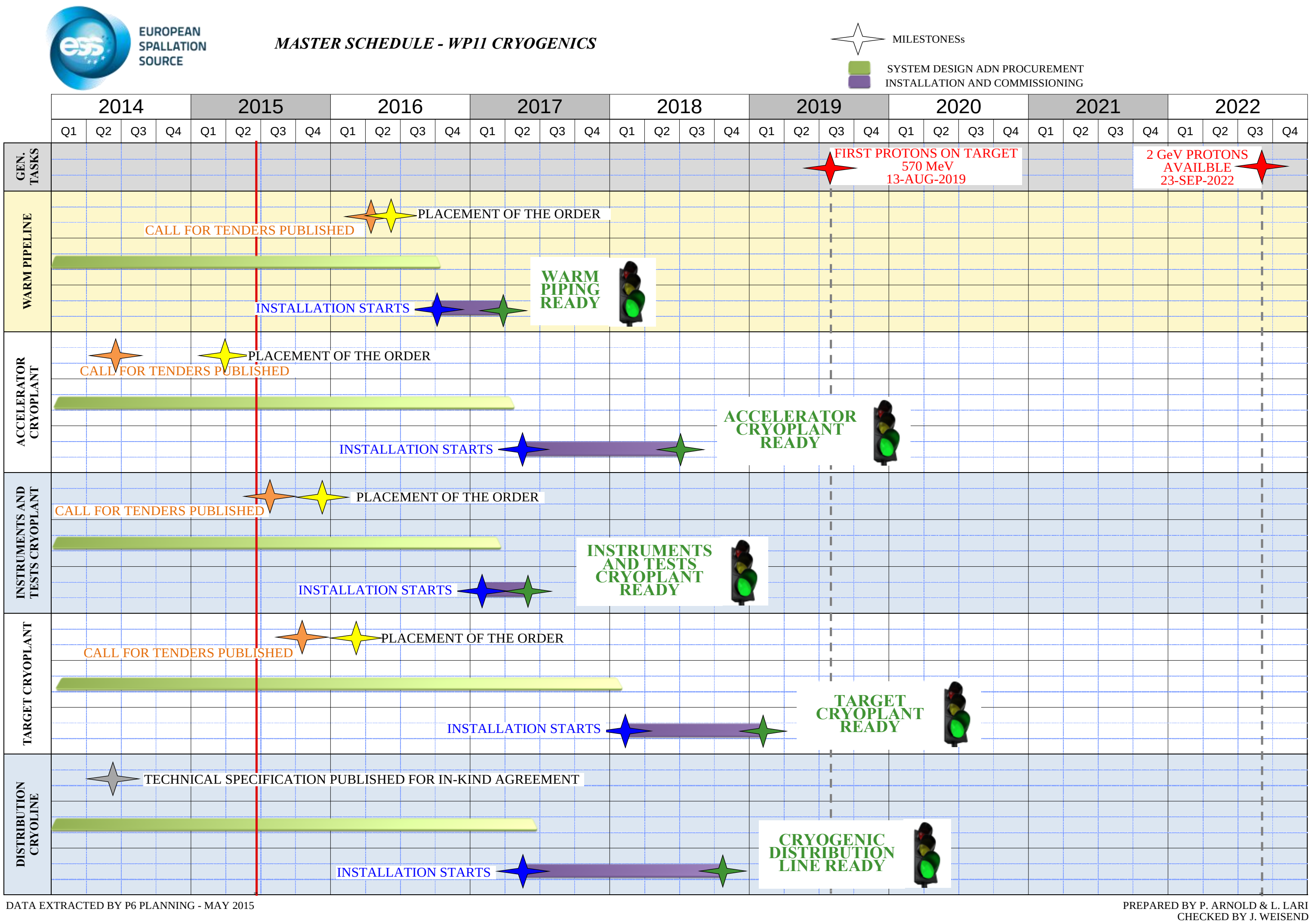


During nominal operating mode in Stage 2 – a total of 2.48 MW are deposited into District Heating from the ACCP

ESS Cryogenic System



WP11 Master Schedule



Summary

- Cryogenics will play a major role in ESS and affects the accelerator, target and instruments projects
- Work is well underway
    - A very skilled team has been assembled
    - Conceptual designs and technical specifications are complete or under preparation
    - Required buildings and utilities have been defined and are under detailed design
    - Accelerator Cryoplant order has been placed (Kick off meeting was held on May 8)
    - PDR for the WrUT portion of the CDS was held on May 2015
    - Additional cryoplant orders will be placed in late 2015 and early 2016