Introduction of PAPS cryogenic system

Shaopeng Li

On behalf of PAPS cryogenic team

Institute of High Energy Physics (IHEP), CAS, CHINA

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Outline

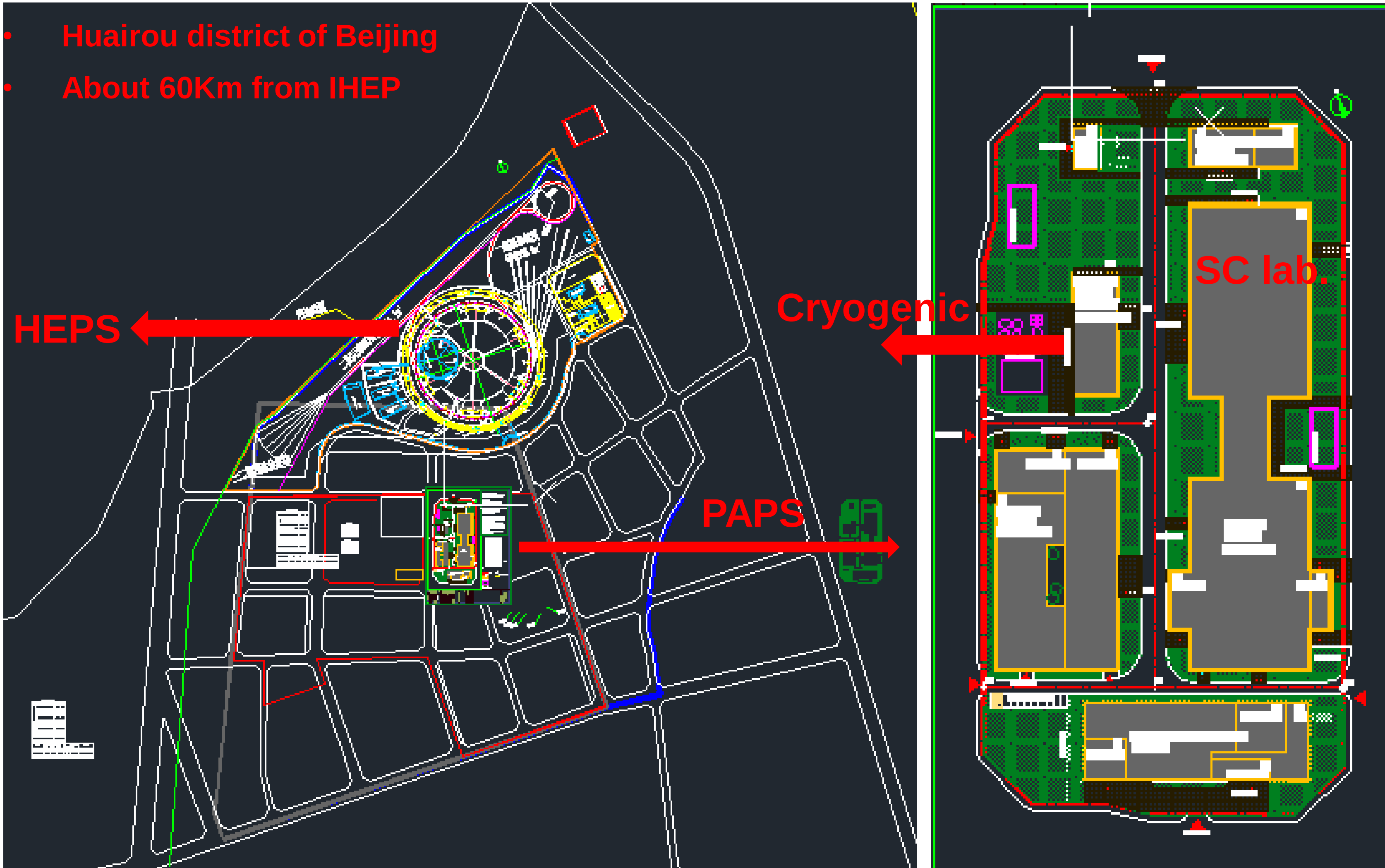
- PAPS and HEPS projects
- Introduction of PAPS cryogenic system
  - Flow chart/Flow calculation
  - Plant performance and requirements
  - 2K pumping system/Recovery and purification system
  - Design of key equipment
- Summary

PAPS and HEPS Projects

- Platform of Advanced Photon Source Technology R&D (PAPS) was officially launched in Feb. 2017. The total project investment is 0.5 billion RMB.
- The goal of the PAPS project is to provide a good foundation and condition for R&D, engineering testing and verification for the high energy phone source (HEPS) project to be completed on schedule and to achieve the expected design target.
- The other goal of the PAPS project is able to produce and test 200 SC cavities and 20 EXFEL-like cryomodules every year.
- The energy of the HEPS storage ring is 6 GV, the emittance is less than 0.06 nm ·Rad, and the capacity of the high performance beam-line station is not less than 90.
- Total HEPS project investment is 5 billion. The kick off of project is scheduled in November, 2018.

Construction site

- Huairou district of Beijing
- About 60Km from IHEP

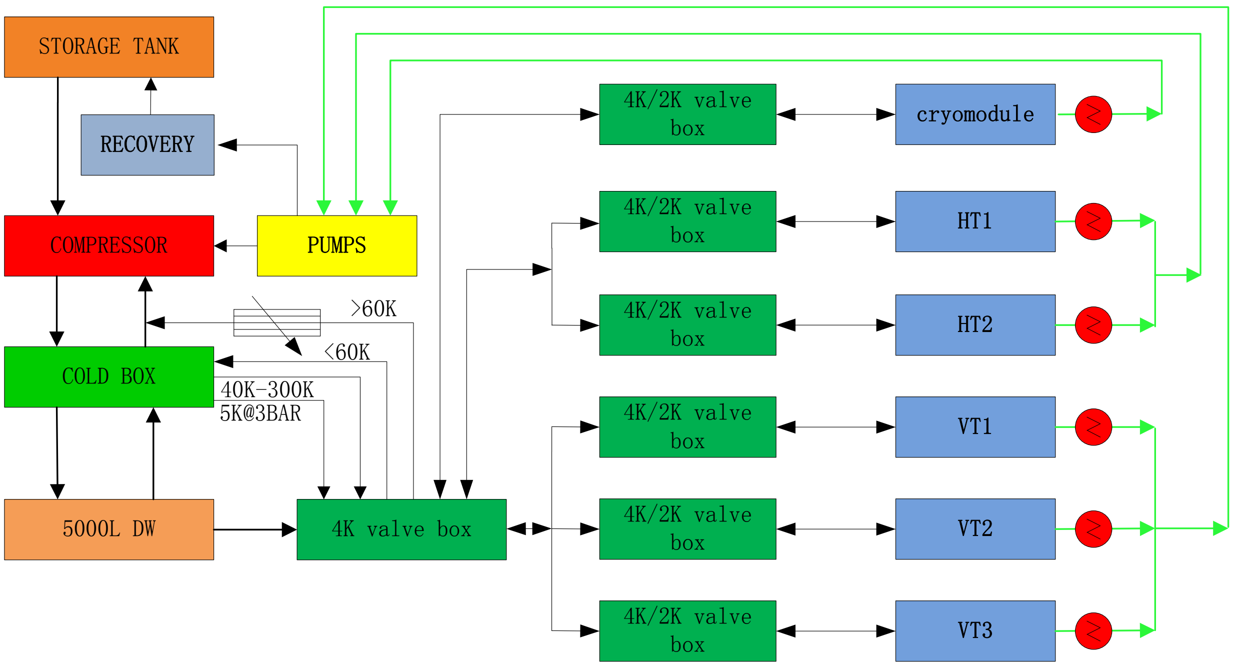


Construction goals of PAPS cryogenic system

- **Construct a 2.5KW@4.5K or 300W@2K superfluid helium cryogenic system with three vertical test stand, two horizontal test stand and a beam test stand of superconducting cavity.**
- **Construct a impure helium recovery and purification system with the capacity of 210m3/h helium recovery and 100m3/h helium purification**
- **Support the performance test of various type of superconducting cavity.**

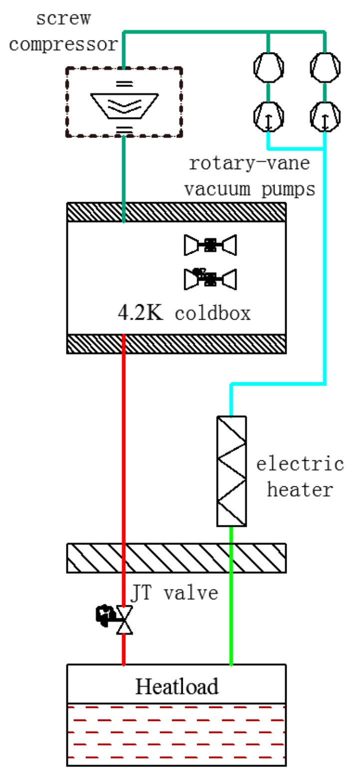
Flow chart of PAPS cryogenic system

- **Key equipment :**
  - Refrigerator/liquefier
  - Helium Storage
  - Transfer and distribution
  - 2K pump system
  - 2K JT heat exchanger
  - Vertical test dewar
  - Cryomodules
  - LN2 system
  - Recovery and purifaction system

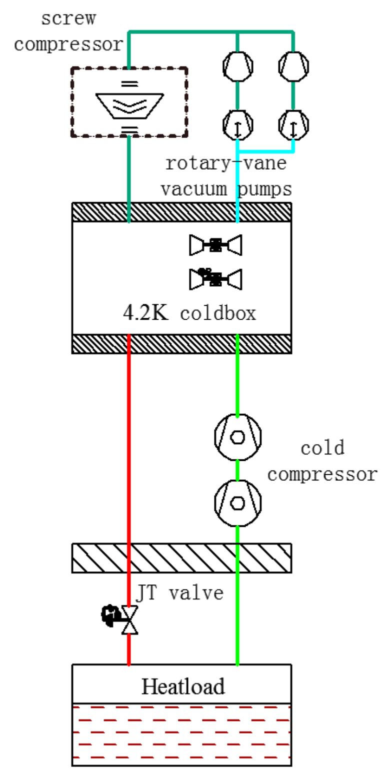


Scheme of production 2K helium

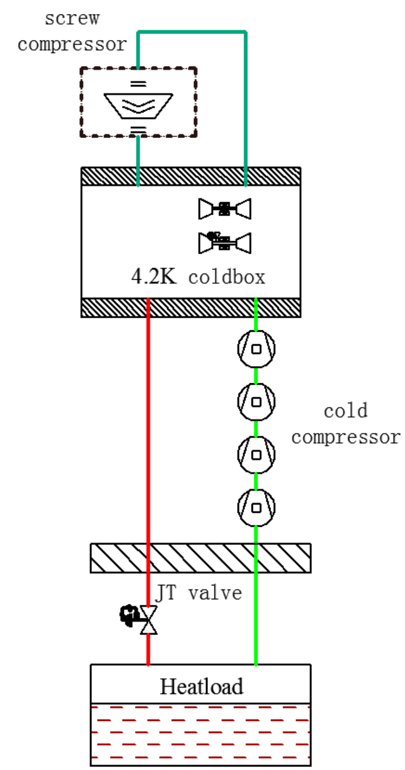
- Reduce the saturated liquid helium pressure to 31 mbar or 16 mabar to produce 2K or 1.8 K superfluid helium
- The reflux cold helium subcool the saturated liquid helium through a 2K JT heat exchanger, and then the subcooled helium throttle to 2K liquid helium.



Warm pump

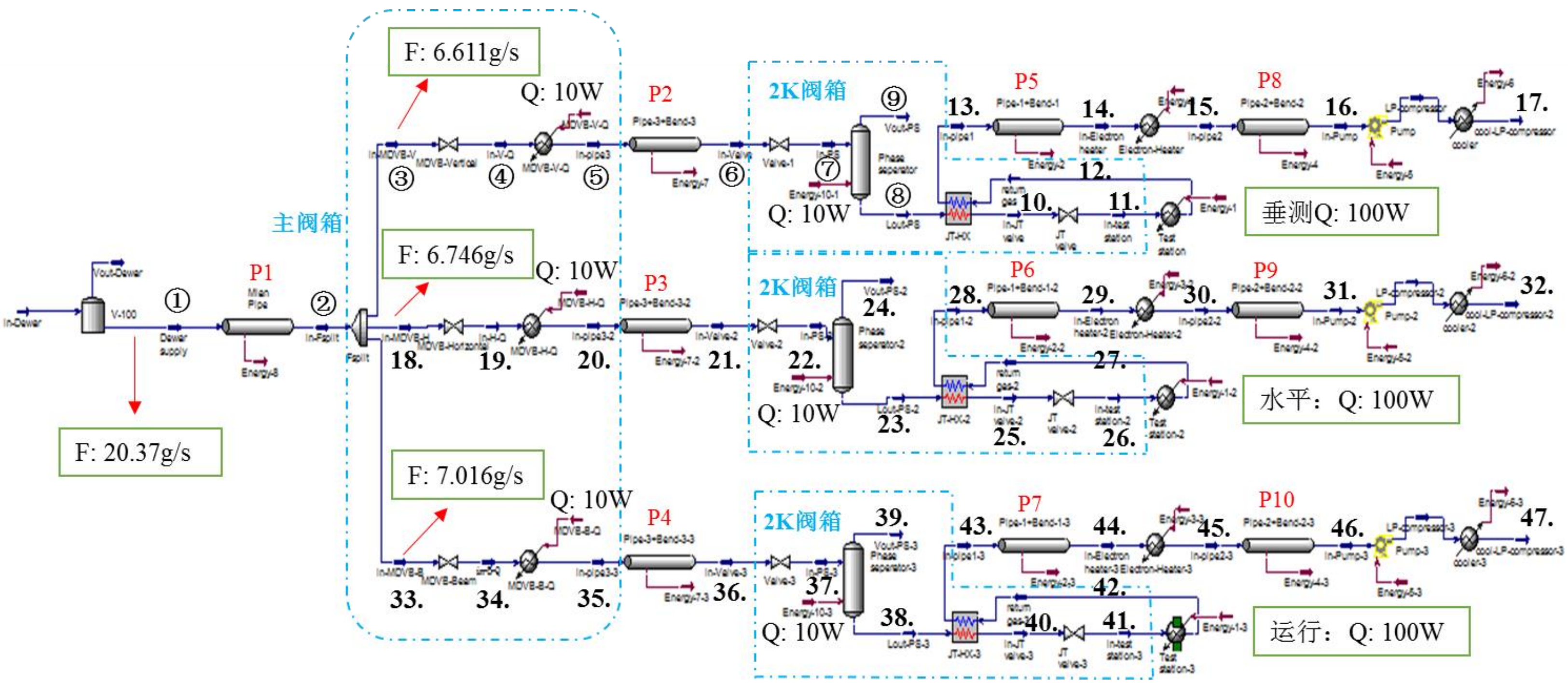


Warm pump and cold compressor



Cold compressor

Flow calculation



Vertical test station

Horizontal test station

Beam test station

Process flow diagram of cryoplant

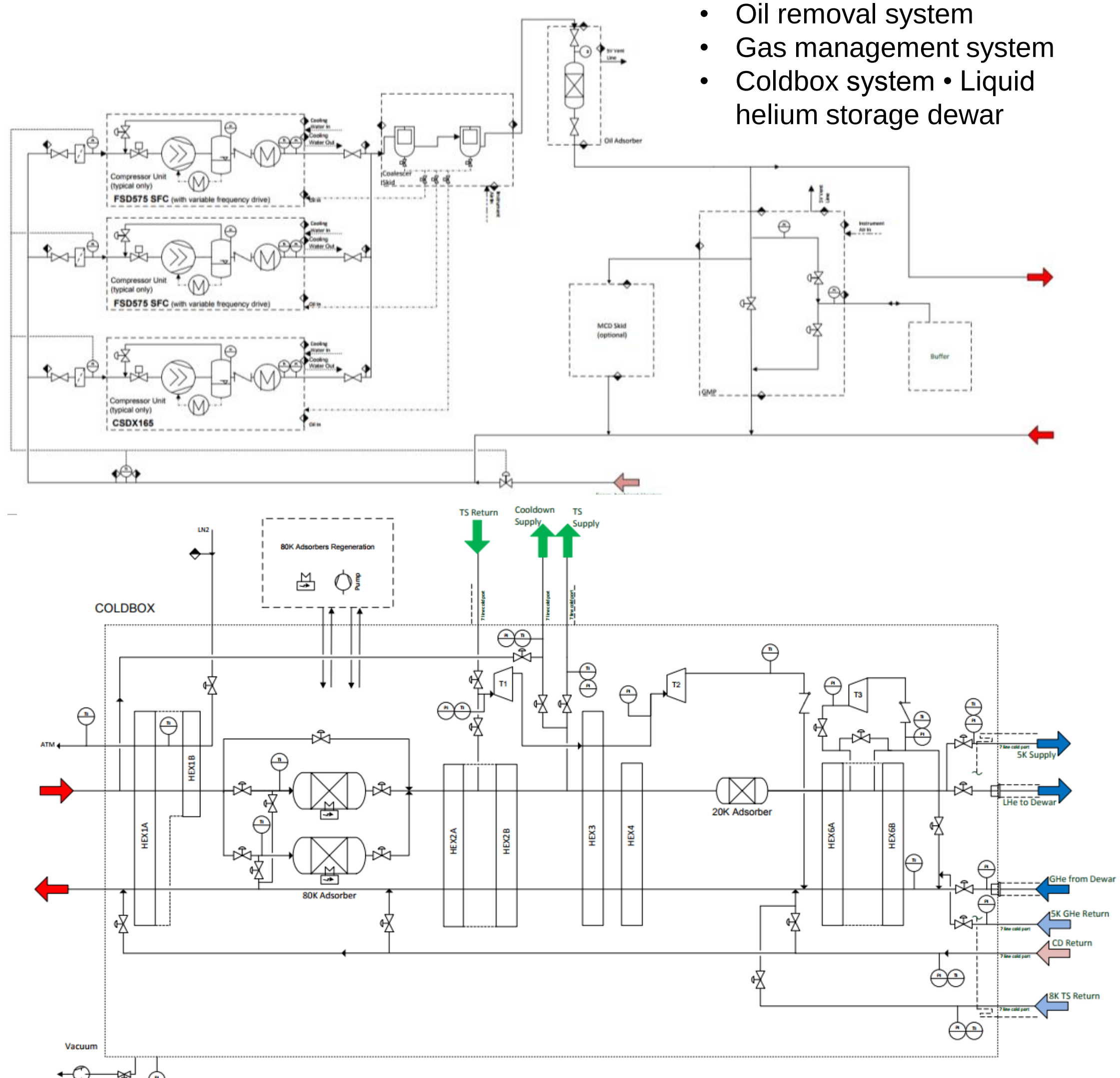
- Helium compression system
- Oil removal system
- Gas management system
- Coldbox system • Liquid helium storage dewar

BEIJING-IHEP-16: LR700

- 2x FSD575 SFC each with up to 105.7 g/s at 15bara
- 1x CSD165 with 30.3 g/s at 15bara
- Total available massflow rate is: 241.7 g/s at 15bara

- Ports for cold helium shall be provided as follows
  - LHe/GHe to dewar
  - 5K cold GHe return
  - 5K shield SHe supply
  - 8K shield GHe return
  - 40K shield SHe supply
  - 80K shield SHe return
  - cool-down GHe supply 300K to 40K
  - cool-down GHe return with valves at 3 different temperature levels

- Expected shield loads are
  - 5K shield: 500 W
  - 40K shield: 1000 W



Plant Performance

BEIJING-IHEP-16: LR700

Performance	Guaranteed Values	Expected Values
Refrigeration capacity with LN2	≥ 2500W@4.5K	≥ 2625W@4.5K
Liquefaction rate with LN2	≥ 800L/h	≥ 840L/h
Refrigeration & Liquefaction With LN2	≥ 500W@4.5K&650L/h	≥ 525W@4.5K&684L/h
Refrigeration Without LN2		≥ 2310W@4.5K
Liquefaction Without LN2		≥ 256L/h
Refrigeration & Liquefaction Without LN2		≥ 905W@4.5K&290L/h

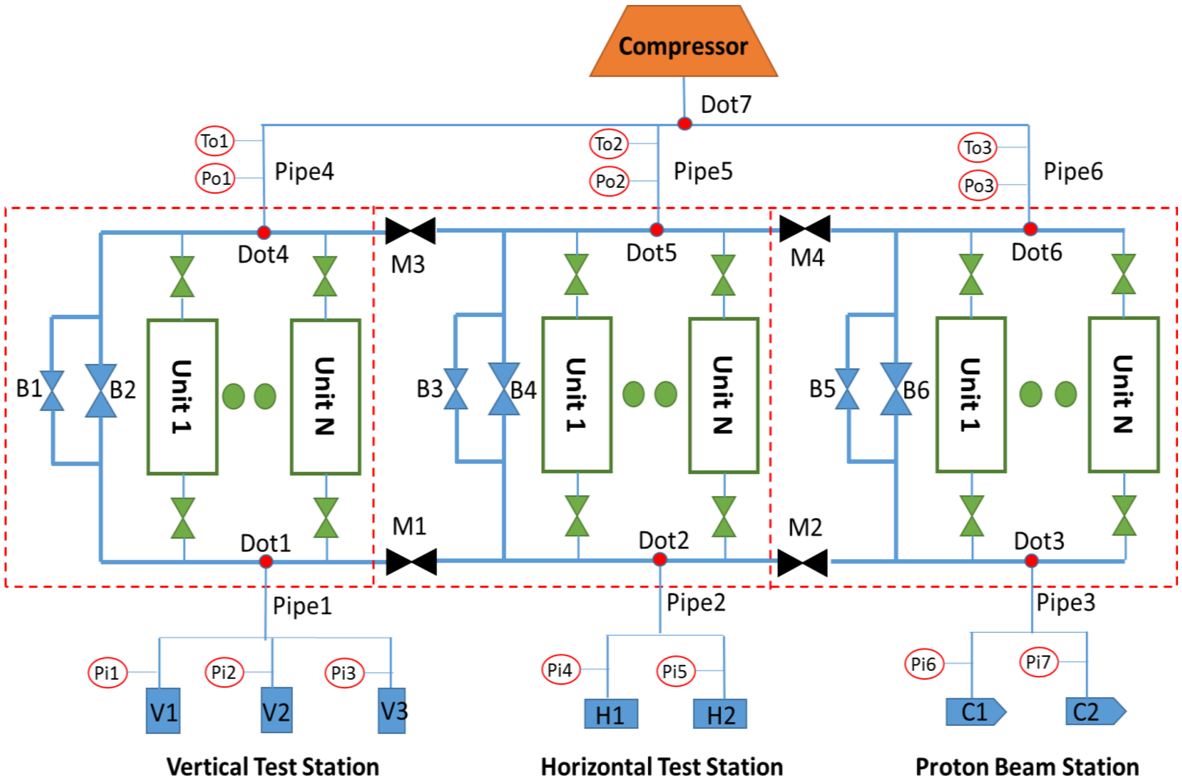
2K pumping system

- The vertical test station (three Dewars), the horizontal test station (two cryostats), and the proton beam station (two cryostats). The heat load of each station at 2 K is 100W and the lowest temperature needed will be below 1.4 K.
- Vacuum pumps work together with electric heater.
- The maximum pumping speed of each station is not less than 6400 m^3/h, when helium pressure is 30 mbar and temperature 300 K. The lowest pressure limit of each vacuum pumps set is less than 2.5mbar.
- The refrigeration capacity at 2K is about 120W. And the rest capacity at 1.4K is 10W.

Capacity at different temperatures

Temperature （K）	Saturation pressure （Pa）	Refrigeration capacity （W）	Mass flow （g/s）	Volume flow （m^3/s）	Remarks
2	3129	120	8.89	6400	Continuous liquid helium injection
1.8	1638	63	4.63	6400	Continuous liquid helium injection
1.6	746	28	2.14	6400	Continuous liquid helium injection
1.4	282	10	0.8	6400	Continuous liquid helium injection

2K pumping system



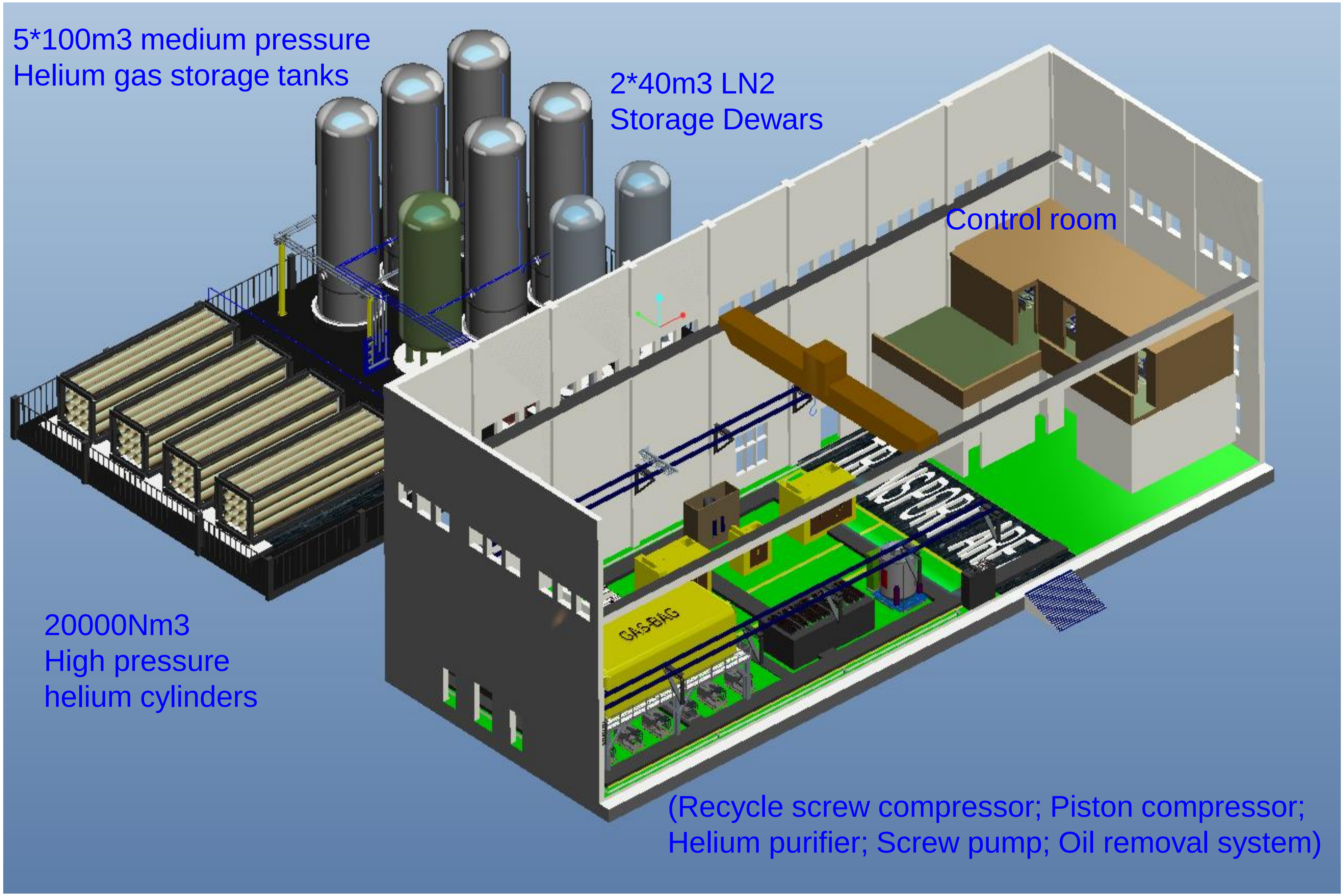
Function diagram

Main parameters

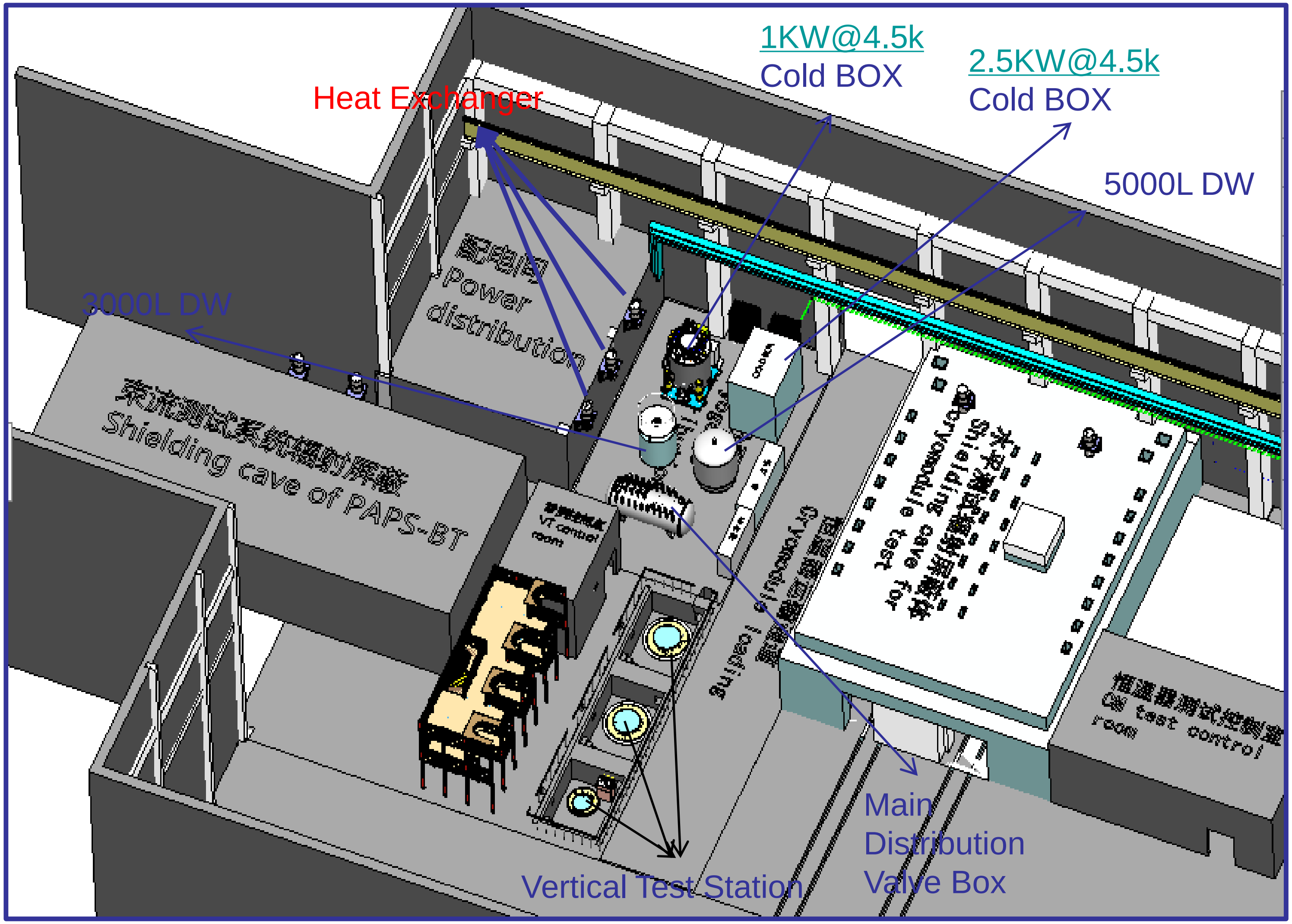
Helium tank pressure	3129 Pa
Pressure stability	+/-10 Pa
Max mass flow	26.7 g/s
Total pumps system capacity	19200 m^3/h （300K,30mbar）
Pumps station inlet temperature	300K
Pumps station outlet pressure	1.2 Bar
Noise level	<80 dB@1m
Leakage rate	1E-6 Pa·m^3/s
Vibration size	<5mm/s

- Separate control systems will be set up for each station. The control system is divided into manual and automatic modes, including two parts: local and remote.
- When the pressure of station reach to 31mbar, the pressure fluctuation will be controlled within ± 10Pa .

Layout of PAPS Cryogenic hall



Layout of PAPS SC test stands



Design of 2K J-T heat exchanger

Fluid	Liquid helium	Gas helium
Inlet temperature（K）	4.45	2
Inlet pressure（Pa）	1.25E+05	3100
Outlet temperature（K）	2.2	3.36

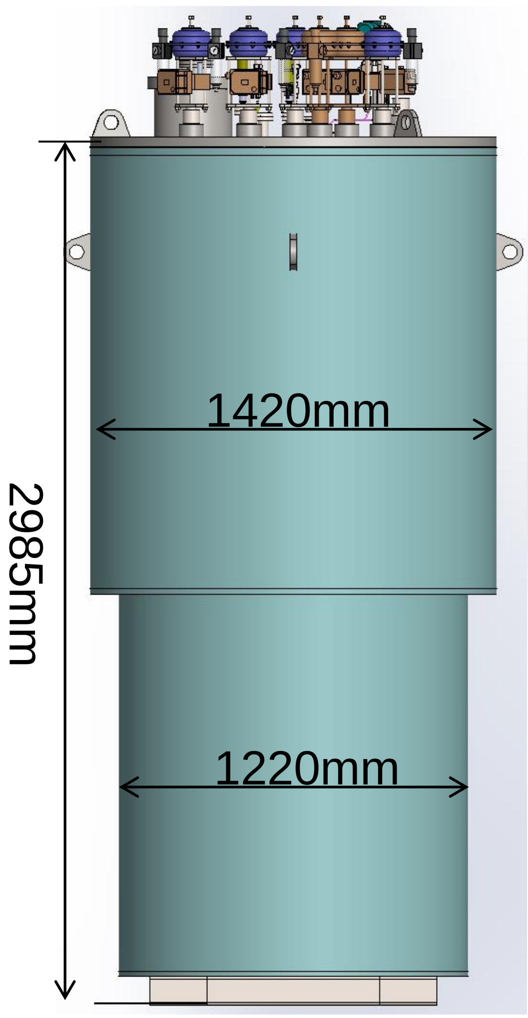
Table 1 The designed working condition

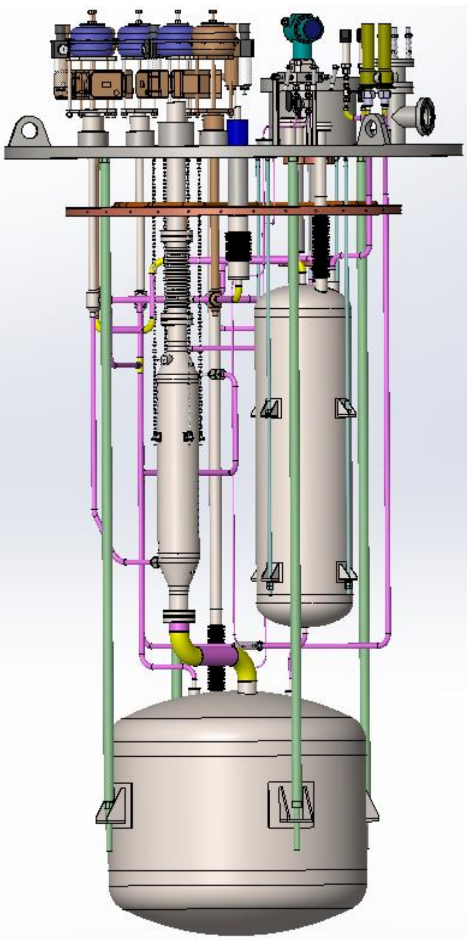
Mass flow rate	m=2g/s	m=5g/s	m=10g/s
Axial length of coil finned tube (m)	0.52	0.603	0.691
Axial length of heat exchanger (m)	0.72	0.803	0.891
Pressure drop for the shell side (Pa)	6.1	30.6	70.2
Pressure drop for the tube side (Pa)	36.2	242	388.9
Heat exchanger efficiency	91.8%	91.8%	91.8%

Table 2 The design results of J-T heat exchanger for m=2g/s，m=5g/s and m=10g/s

Fig.1 J-T heat exchanger

Test platform for 2K heat exchanger



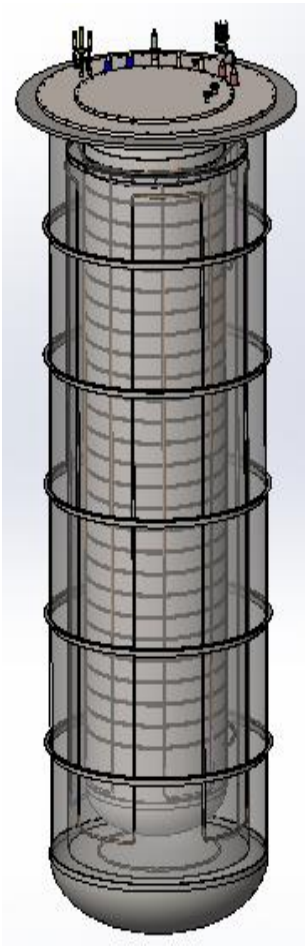


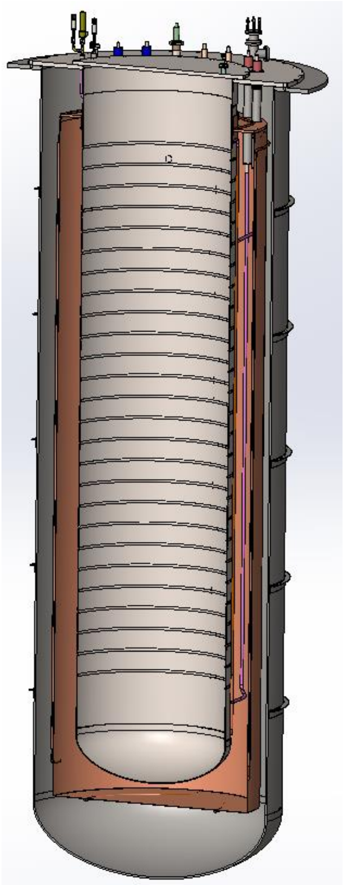
	volume（L）	height（m）	diameter (m)
Liquid helium tank	200	0.398	0.800
Heat exchanger		0.500	0.200
Phase separator	60	0.624	0.35

Mechanical structure design:

- In order to changing heat exchangers easily, the way of “take off” is accepted. In other words, the upper vessel and upper cold shield can be take off by crane. and then the heat exchanger can be shown and changed.
- We select VCR connector for the pipeline of liquid nitrogen and indium wire seal for the pipeline at the temperature of 2 K.

Design cryostat for vertical test stand





Main technical parameters：

- Working temperature：2K；
- Working pressure：

  -0.1MPa to 0.35MPa（inner vessel）

  -0.1MPa (outer vessel)
- Dimension：

Φ1250（inner diameter）×5360mm(height)

Φ1976（outer diameter）×5925mm(height)

Total height：6325mm

- Main components:

  Inner vessel

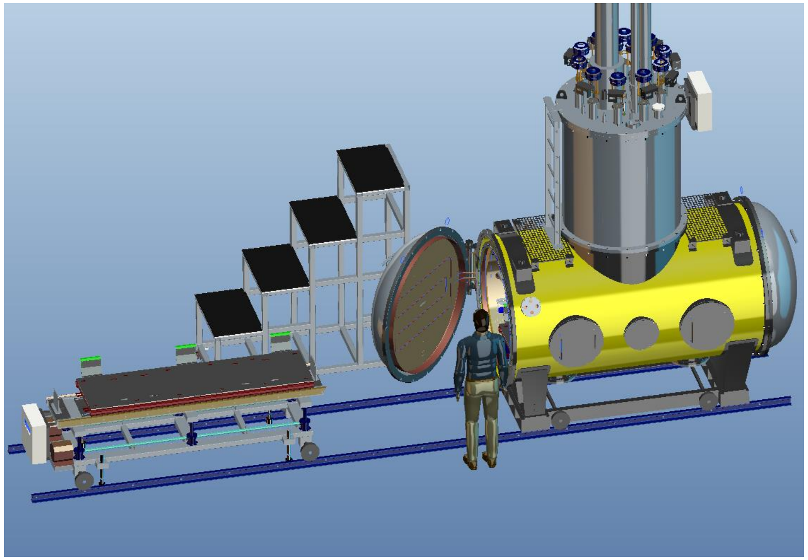
  80K shield

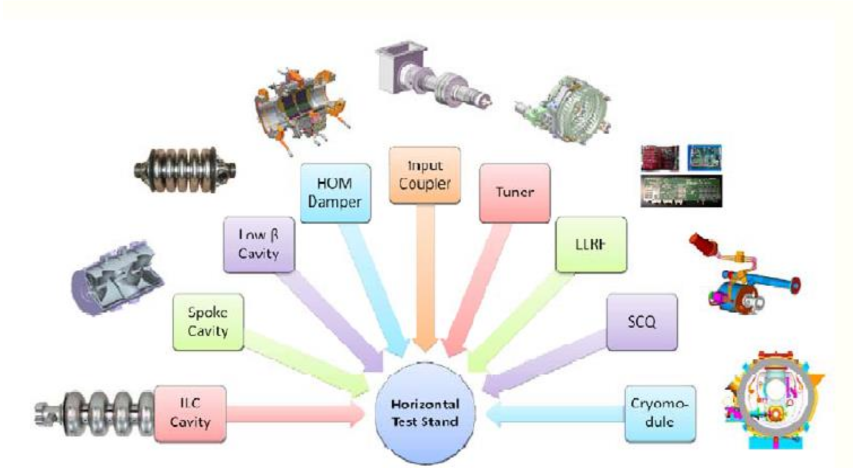
  Vacuum jacket

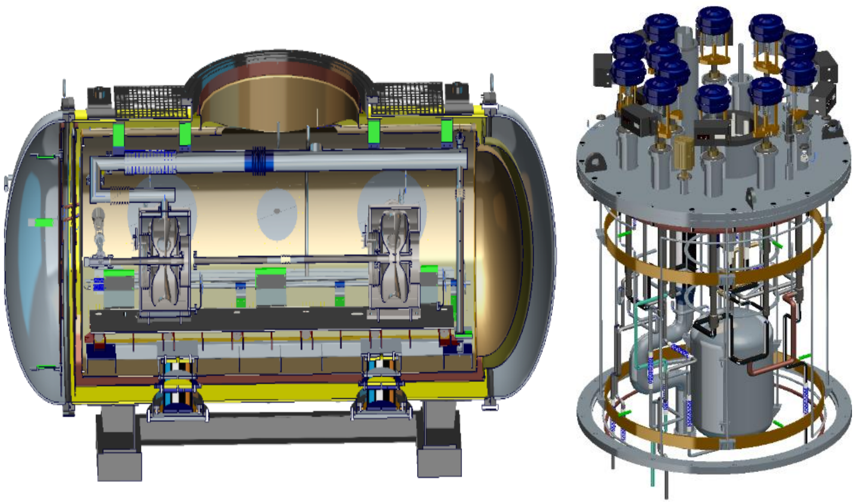
  Two layer magnetic shield

- Materials：inner vessel and cryogenic pipeline:SUS316L，outer vessel:SUS304.

PAPS Horizontal Test Cryomodule

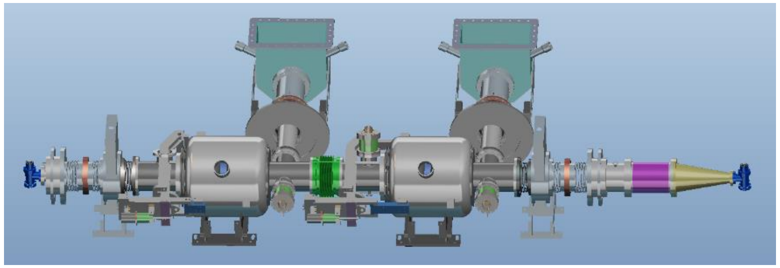


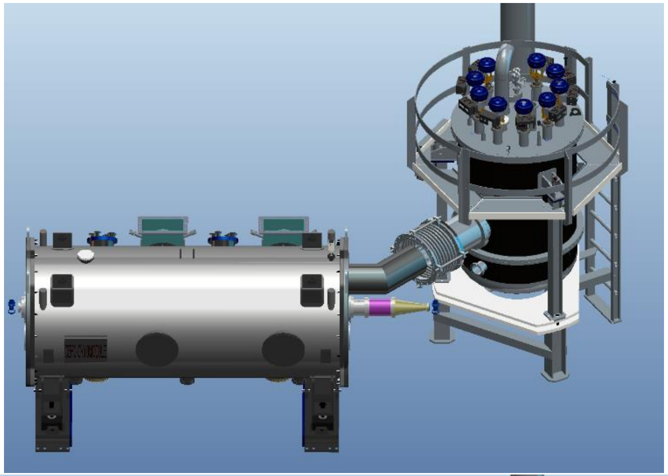


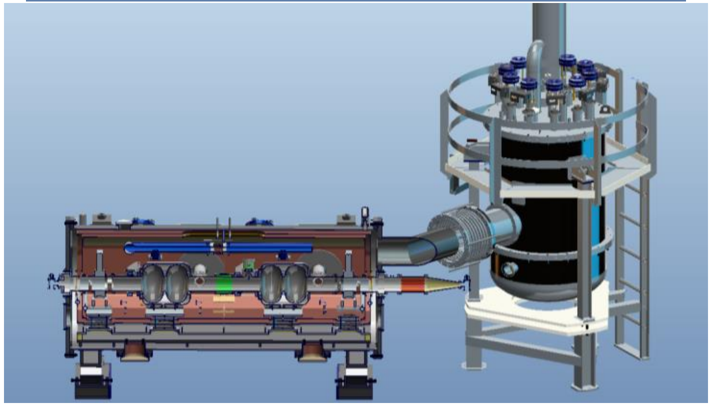


- Length: 3800
- Height: 3200
- Diameter:1400
- Fast cooling down test
- Test two cavities at a time
- Test cavity performance at 2K
- Test and check key equipment of SC cavity such as tuner, power coupler,HOM coupler etc.

650MHz cryomodule for beam test



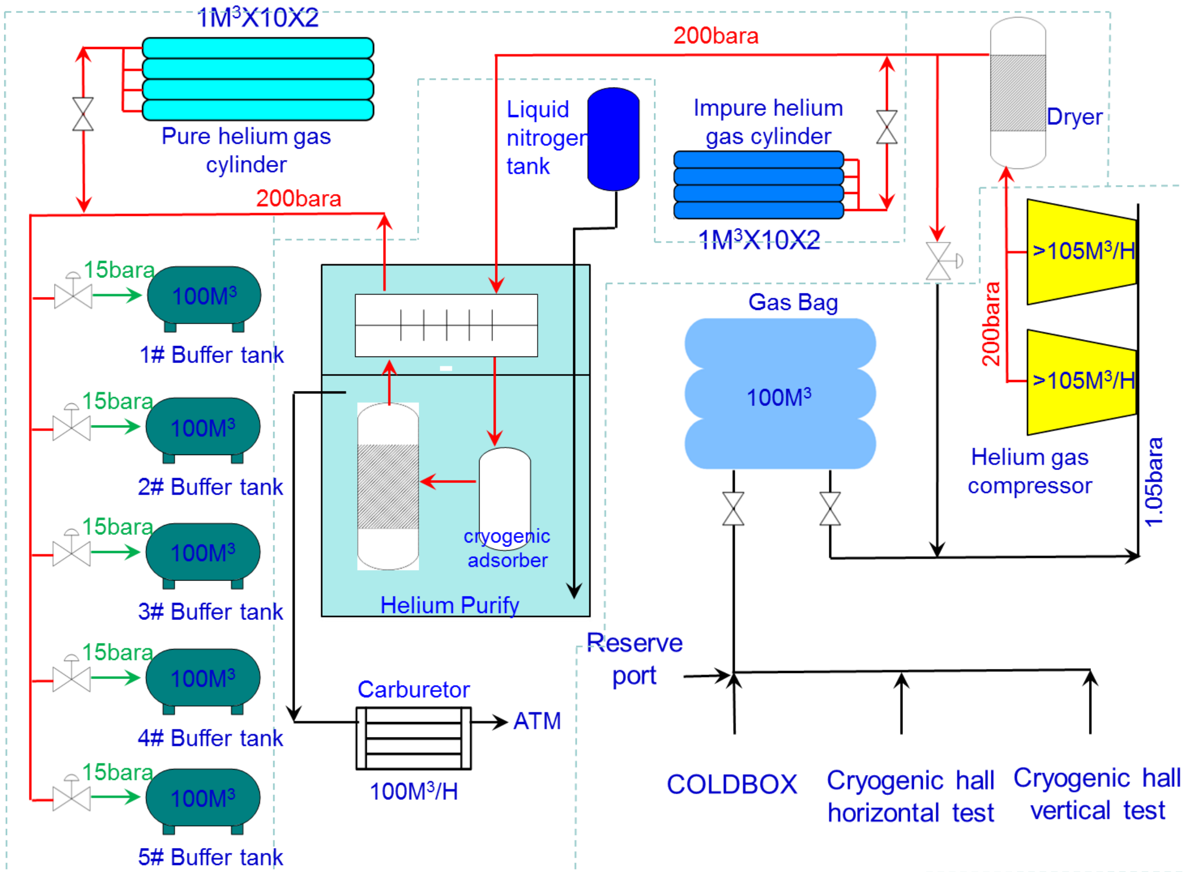




- Design for Beam test
- Two 2-cell 650 MHz superconducting cavities;
- Two high power couplers
- Two mechanical tuners
- Two HOM absorbers
- Fast cool-down is introduced

- Vacuum vessel
  - –Outer diameter:1324mm
  - – Length:3000mm
- Support post
  - –Supporting the all cold mass in the vacuum vessel
  - –Supporting Cavities：Diameter is 180mm
  - –Supporting RF-Gate Valve：Diameter is 150mm
  - –Number:2+2=4
  - –Material：FRP(G-10)
- Thermal shield
  - –Aluminum plate
  - – Two layer: 40K-70K , 5K-10K
- Strongback
  - –Stainless steel
  - –Room temperature

The helium recovery and purification system



Main parameters

Storage capacity	≤20000NM3
Working pressure	≤200bara
Recovery efficiency	≤99.5%
Purification ability	≥105NM3/H
Recovery ability	≥210NM3/H
Gas helium purity	≥99.9995%
Operation	Automatic

- Working modes include recovery, purification and regeneration;
- All the processes can work manually and automatically.
- The regeneration of absorption cylinders is completed by heating and evacuation.

Time schedule

- Feb. 2017 Project start
- Aug. 2017 Preliminary design
- Oct. 2018 Civil work
- Aug. 2017 Contract of cryoplant
- Jul. 2019 Pipe work
- Jul. 2019 Commissioning of recovery and purification system
- Aug. 2019 Commissioning of cryoplant
- Sept. 2019 Commissioning with Vertical/Horizontal/Beam test stand
- Dec. 2019 Cryogenic system operation
- Jun. 2020 Project finish

Summary

- Completed the preliminary design of PAPS cryogenic system
- Organized the review of technical scheme of PAPS cryoplant
- Signed the contract of cryoplant
- Completed the preliminary layout of cryogenic system
- Completed the biddings for middle/high pressure storage tanks, LN2 storage tank, high pressure compressor, helium purifier and 2K pump system
- Completed the design of vertical test cryostat, horizontal test cryomodule and test platform of J-T HEX
- The design of beam test cryomodule, main distribution valve box and cryogenic transfer-line are in progress.

Welcome to workshop on Cryogenics Operations!

Thank you for your attentions!