Cryogenic activities at IHEP

Shaopeng Li

On behalf of IHEP cryogenic team

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

The 18th International Workshop on Cryogenic Operation, Beijing, June 4-7, 2018

Outline

- Brief introduction of cryogenic activities at IHEP
- In operation
  - BEPCII cryogenic system
  - ADS Injector I cryogenic system
  - CSNS cryogenic system
- Under construction
  - PAPS cryogenic system
  - HEPS cryogenic system
- Under planning
  - CEPC cryogenic system
- Summary

Brief introduction of cryogenic activities at IHEP

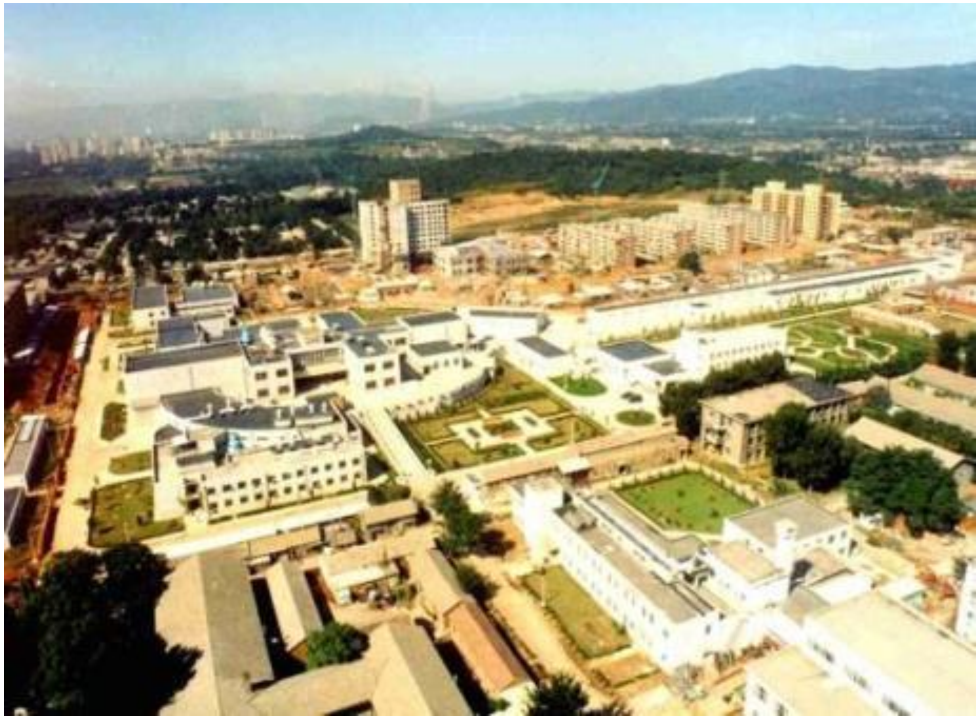
- **BEPCII cryogenic system is the first cryogenic system in IHEP, which was built from 2004 to 2007. So far, the superconducting cavity and superconducting magnet have been operating steadily for 10 years.**
- **ADS injector I 2K cryogenic system was completed in 2015, providing 4K/2K vertical test of dozens of superconducting cavities and the operation of two cryomodules with beam.**
- **CSNS cryogenic system is a 20K supercritical hydrogen system, which was completed and put into operation in 2017**

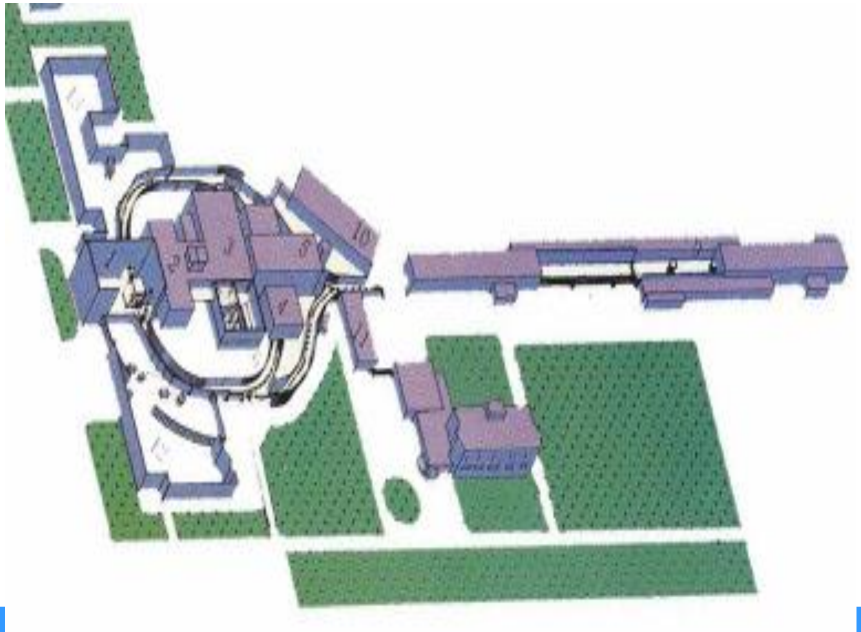
Brief introduction of cryogenic activities at IHEP

- **PAPS cryogenic system is also a 2K cryogenic system, providing the R&D of various superconducting cavities. The system will be completed in 2020.**
- **HEPS project will adopt five 166.6MHz single cell SC cavities and two 499.8MHz third harmonic SC cavities. The project will start at the end of 2018 and is scheduled to be completed in 2025.**
- **CEPC cryogenic system is currently in the stage of conceptual design and the R&D of key equipment. It is expected the construction from 2022**

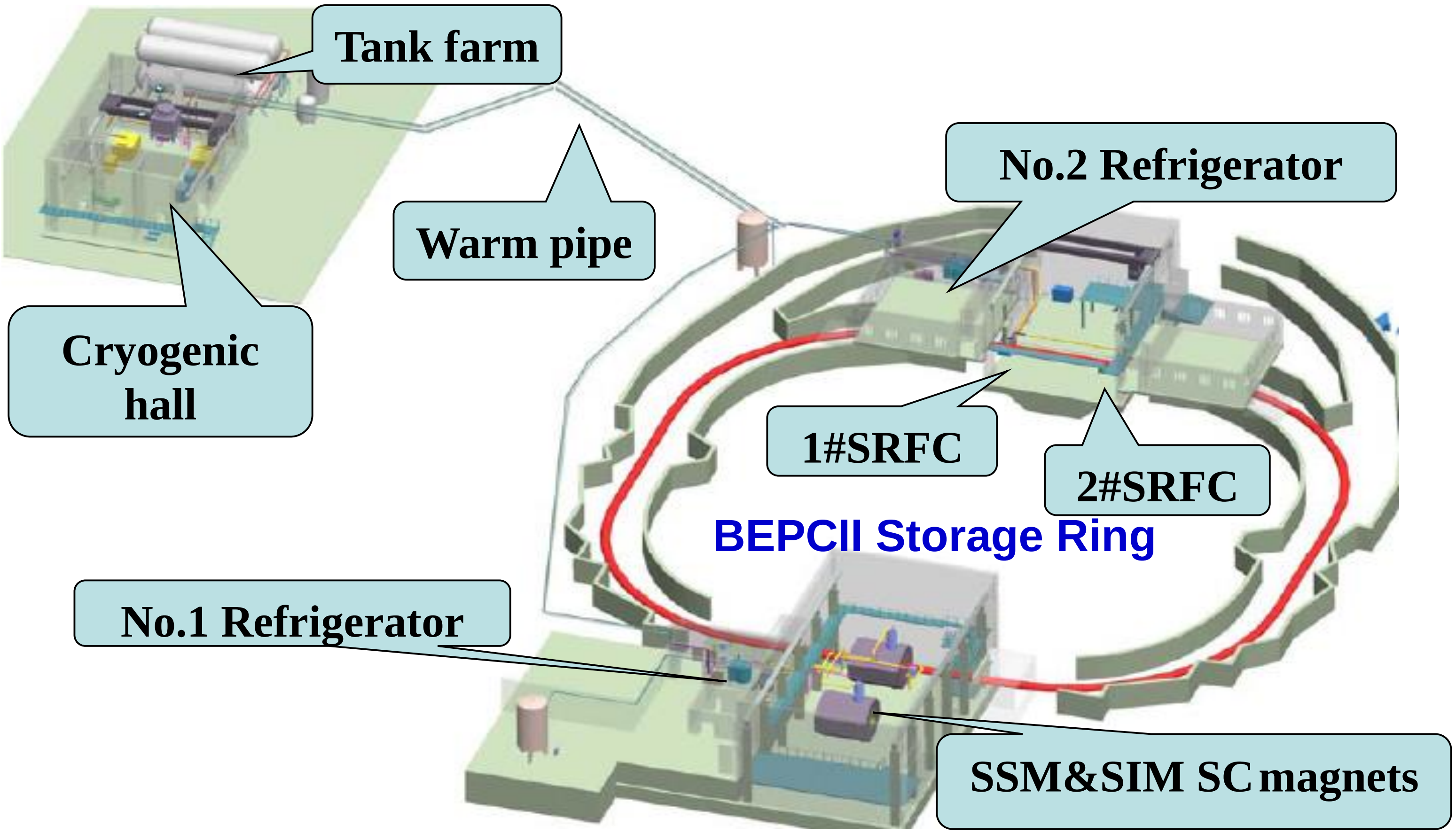
BEPC & BEPCII

- Beijing Electron Positron Collider :
  - Constructed: 1984-1988
  - BESI: run from 1989-1998
  - BESII: run from 1999-2004
- Upgraded (BEPCII):
  - 2004-2008
  - BESIII: run from 2008





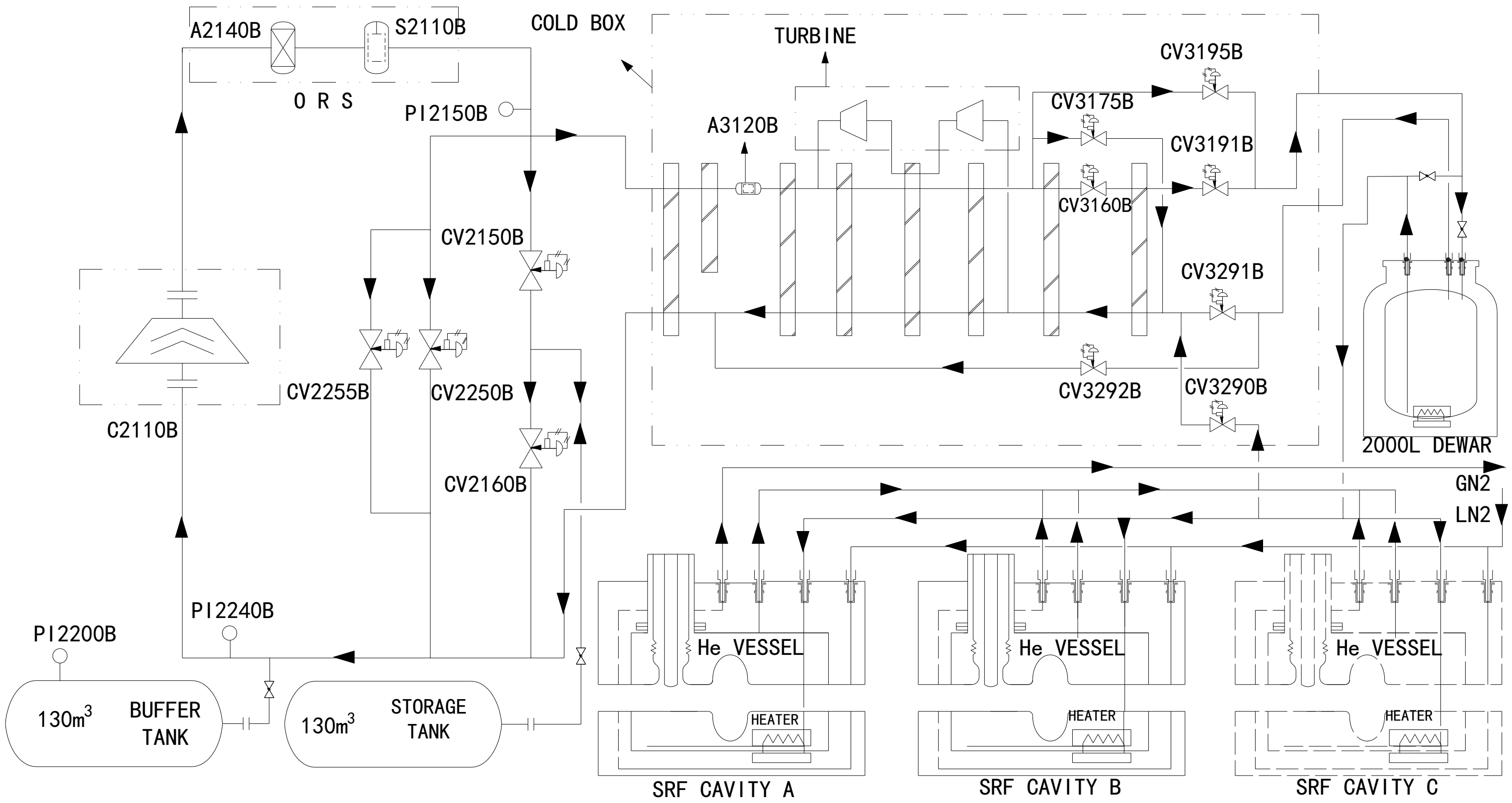
Layout of BEPCII cryogenic system



Heat Loads of SC Cavity cryogenic system

SRF static heat load（W）		2×30
Dynamic heat loads	RF loss（W）	2×84
	coupler（W）	2×12
Common parts	Distribution valve box（W）	20
	Cryogenic transfer lines（W）	24
	Helium dewar and heaters（W）	30
Margin 20%　（W）		65.2
Total（W）		391.2W

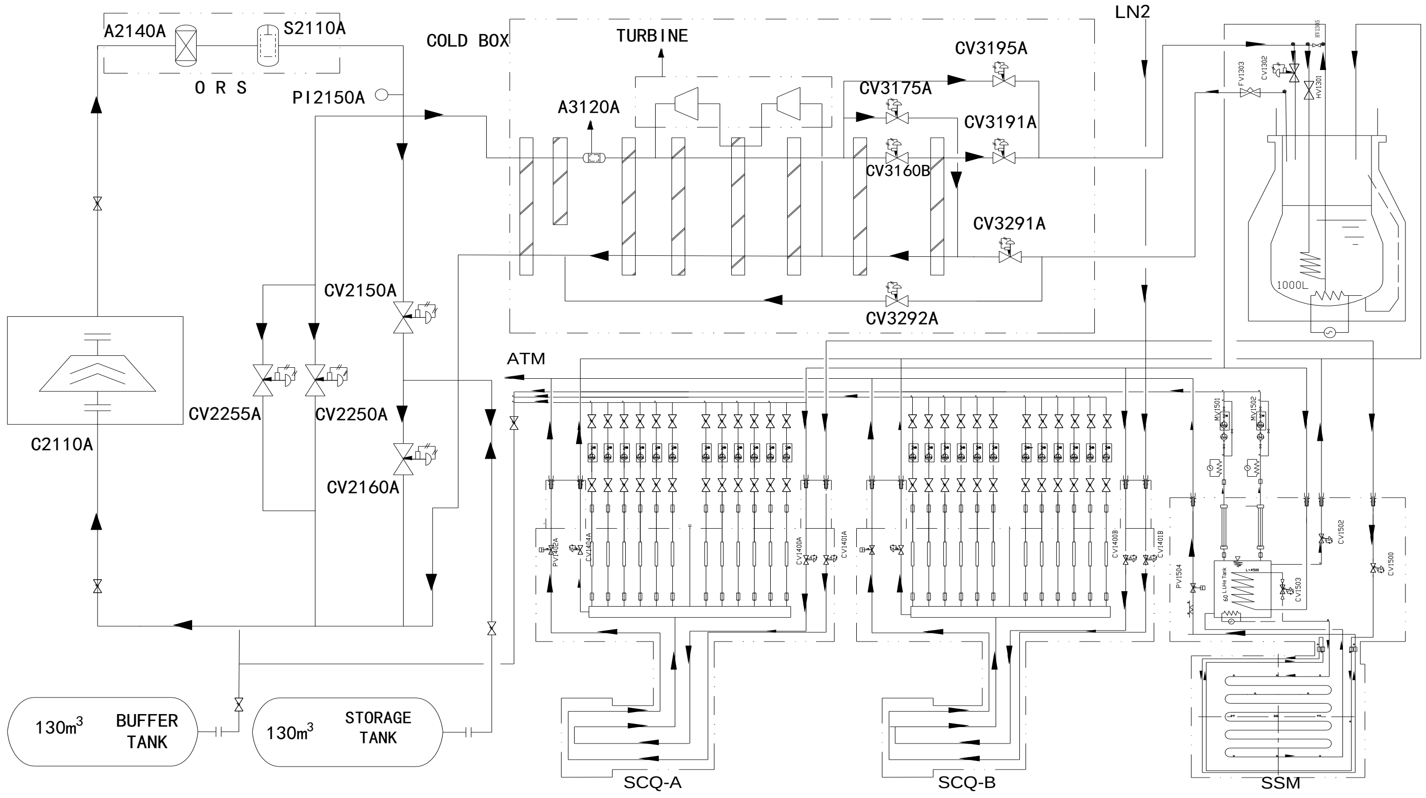
Flowchart of SC cavity cryogenic system



Heat loads of SC magnet cryogenic system

Cryogenic devices	SCQ×2	SSM
Cryostats for magnets	15×2	25
Current leads	0.3g/s×2	0.4g/s
Eddy current loss		15
Valve boxes for magnets	9×2	15
Cryogenic transfer lines	35	23
1000L Dewar& Valve Box	30	
Subcooled heat exchanger	20	
Subtotal	211+1g/s	
Margin	30%	
Total	274.3 W+1.3 g/s	

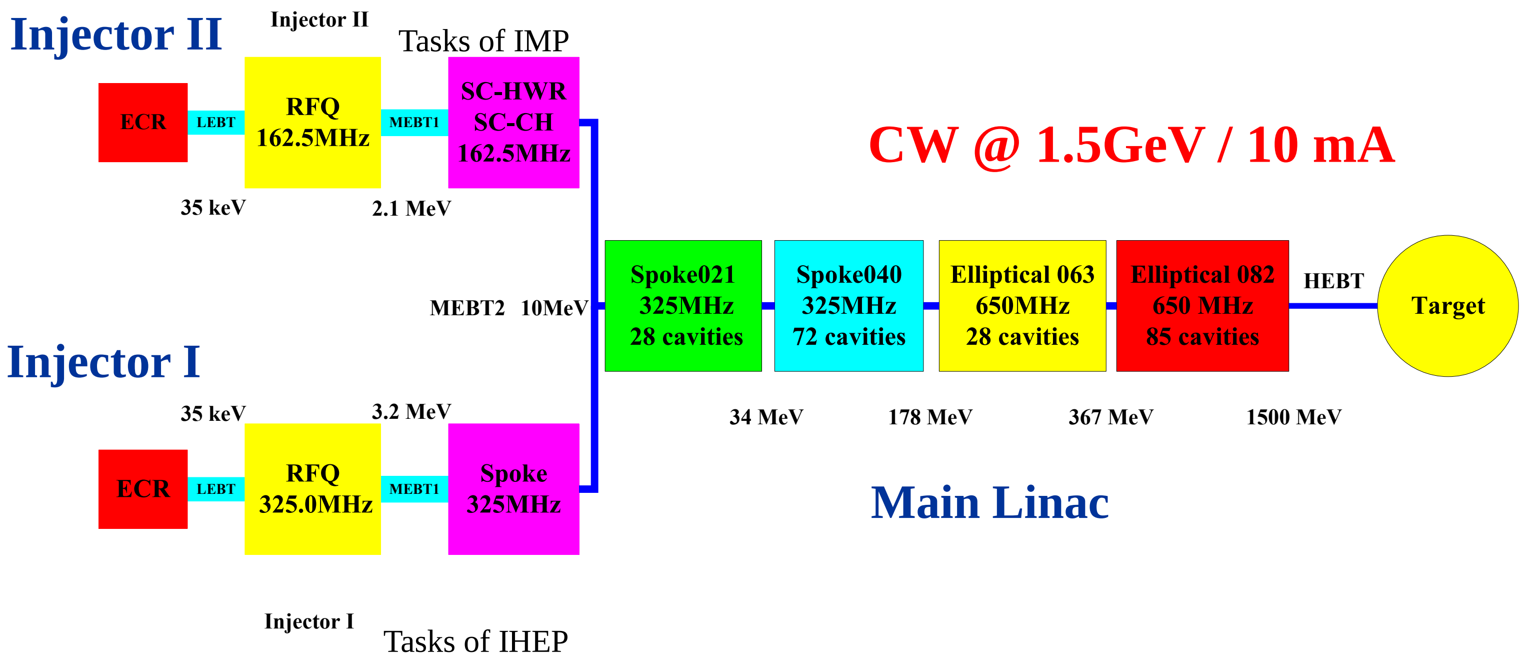
Flowchart of SC magnet cryogenic system



Milestone of BEPCII cryogenic system

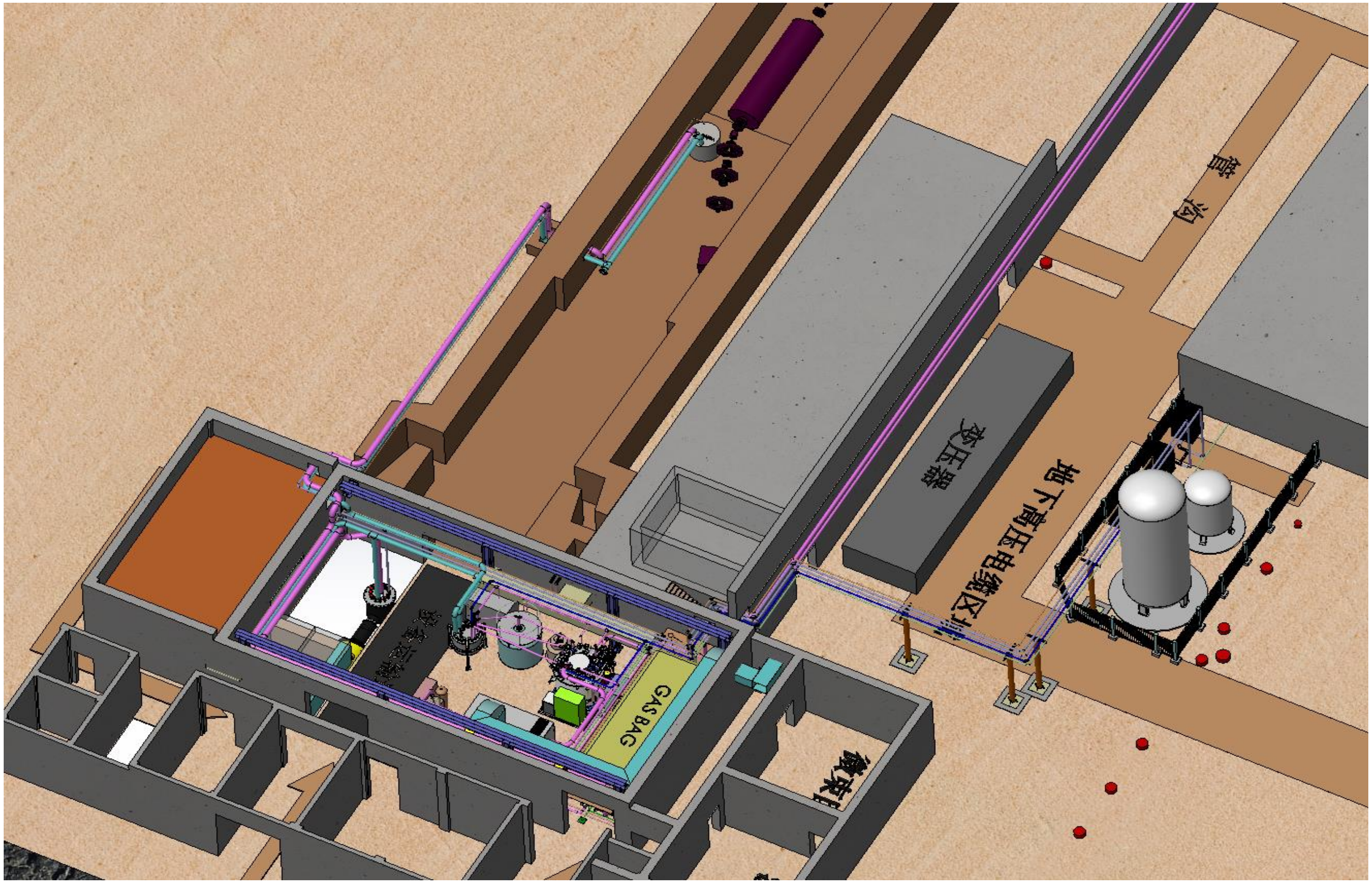
- **Nov. 2001 to May 2002** — **Conceptual design**
- **Feb. 2003 to Feb. 2005** — **Engineering Design**
- **Feb. 2003 to May 2005** — **Standard equipment procurement**
- **Nov. 2004 to Aug. 2006** — **Non-standard equipment manufacture and installation**
- **May 2005 to Sept. 2005** — **Acceptance tests for two 500W@4.5K**
- **refrigerators**
- **May 2006 to Aug. 2006** — **Commissioning and Cryogenic test for SRFC cryogenic system**
- **Nov. 2006 to now** — **SRFC cryogenic system operation**
- **Sept. 2006 to Dec. 2006** — **Modification for 1000L Dewar & Valve Box**
- **Sept. 2006 to Apr. 2007** — **Modification for SCQA/B valve boxes and**
- **current leads**
- **May 2007 to Jun. 2007** — **SCQA/B & SSM cryogenic system**
- **commissioning**
- **Jun. 2007 to now** — **SCQA/B & SSM cryogenic system operation**

ADS Injector I Project



- Chinese ADS proton linear has two 0~10MeV injectors and one 10~1500MeV superconducting linac.
- Injector I and Injector II were constructed by Institute of High Energy Physics (IHEP) and Institute of Modern Physics (IMP) respectively.

Layout of IHEP-ADS cryogenic system(Building1#）



Heat loads of ADS injector I cryogenic system

IHEP-ADS equipments:

- 3000L dewar
- 4.2K Distribution valve box
- 2K coldbox
- 4K，2K cryogenic transferline
- Operation Cryomodule (OCM)
- Horizontal Cryomodule (HCM)
- Vertical test dewar（DW）

IHEP-ADS equipments	80K热负荷 (W)	4K热负荷 (W)	2K热负荷 (W)
4.2K Distribution valve box		26	
4K cryogenic transferline		30	
2K Coldbox		17	5
2K cryogenic transferline		5	2
Operation Cryomodule (OCM)	2×267	2×57.5	2×21
	534	193	49
Total (redundancy 50% ）	801	289.5	73.5
equivalent to 4K		657	

Main parameters of refrigerator

Performance	Guaranteed Values	Expected Values
1. Refrigeration With LN2	**> 1000W@4,5K P_{dewar} = 1,3bar abs +/- 2 mbar**	> 1050W@4,5K LN2 consumption =30 L/h
2. Liquefaction With LN2	**>284L/h**	> 290L LN2 consumption =130 L/h
3. Refrigeration & Liquefaction With LN2	>350W@4.5K&200L/h	>370W@4.5K&210L/h
4. Refrigeration Without LN2	> 720W@4,5K Pdewar = 1,3bar,abs +/- 2 mbar	> 750W@4,5K
5. Liquefaction Without LN2	>90L/h	> 95L/h
6. Refrigeration & Liquefaction Without LN2	>250W@4.5K&70L/h	>275W@4.5K&70L/h

Milestone of ADS injectoer I cryogenic system

- Project application from 2010
- Preliminary design in 2011
- Construction from 2012
- Refrigerator commissioning in 2014
- Commissioning of whole cryogenic system in 2015

China spallation neutron source (CSNS) Project

- CSNS construction site locates at Dongguan, Guangdong province.
- It is about 85 km from Guangzhou and about 125 km from Hong Kong.

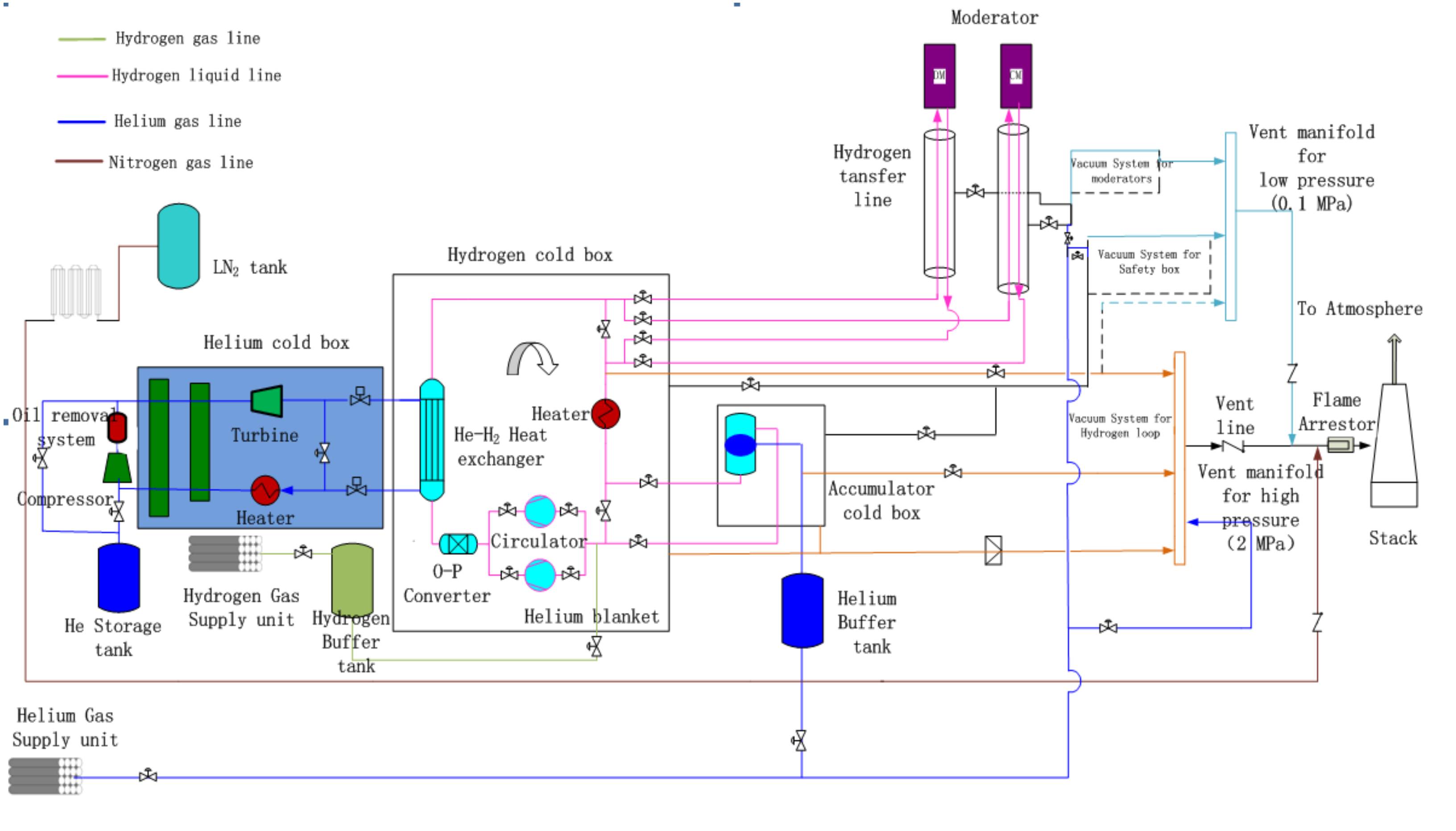
CSNS cryogenic system

Cryogenic system of China spallation neutron source (CSNS) provides 20K supercritical hydrogen for neutron moderators, and it is consist of helium refrigerator and hydrogen circulation system. The total hydrogen volume in hydrogen circulation is about 140 liters.

Design parameters of CSNS cryogenic system

<table>
<tr><td rowspan="5">Helium refrigerator</td><td>Flow rate</td><td><110g/s</td><td rowspan="5">Hydrogen circulation system</td><td>Circulation temp.</td><td>18-21.8K</td></tr>
<tr><td>Inlet temp.</td><td>>13.5K</td><td>Circulation pressure</td><td>1.5±0.1MPa</td></tr>
<tr><td>Outlet temp.</td><td><20.8K</td><td>Design pressure</td><td>2.5MPa</td></tr>
<tr><td>Discharge pressure</td><td><1.5MPa</td><td>Static heat load</td><td>800W</td></tr>
<tr><td>Cooling power</td><td>2200W@20K</td><td>Dynamic heat load</td><td>700W</td></tr>
</table>

Flow chart of CSNS cryogenic system



Milestone of CSNS cryogenic system

- October 20th, 2011, start construction of CSNS.
- December 5th, 2012, sign contract for helium refrigerator.
- November 18th, 2015, performance test of hydrogen cold box with 80K helium gas.
- August 5th, 2016, tested refrigeration power is 2300W@20K, reached the acceptance target.
- January 8th, 2017, start commissioning of CSNS cryogenic system.
- April 12th, 2017, successful cooling down with 20 K helium gas.
- May 5th, 2017, successful cooling down with 20 K hydrogen gas.
- June 21st, 2017, joint commissioning with moderators.
- December 11th, 2017, cryogenic system start operation till now.
- February 14th, 2018, national test of cryogenic system

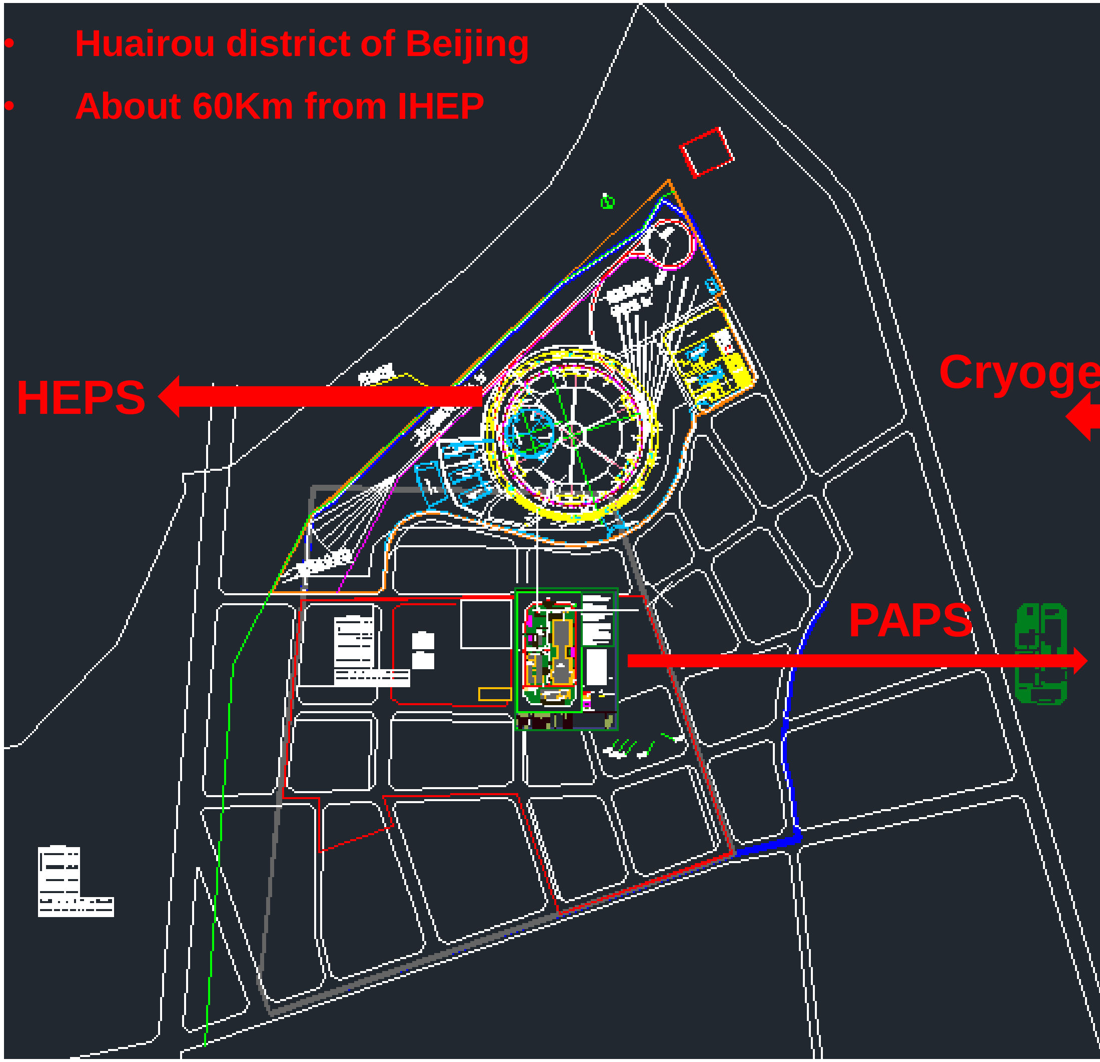
PAPS and HEPS Projects

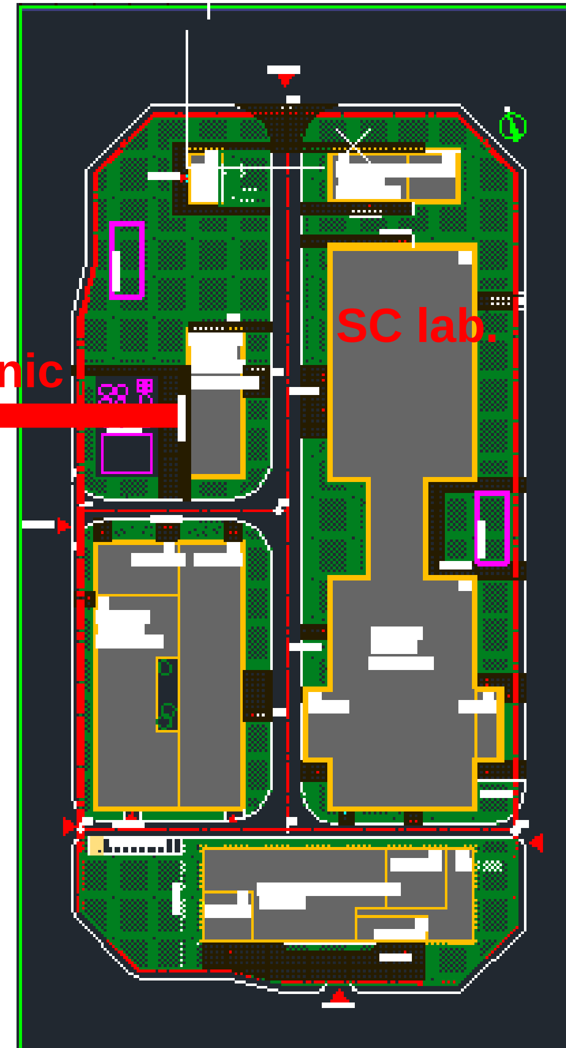
- Platform of Advanced Photon Source Technology R&D (PAPS) was officially launched in Feb. 2017.
- The goal of the PAPS project is to provide a good foundation and condition for R&D, engineering testing and verification for the high energy photon source (HEPS) project to be completed on schedule and 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 kick off of HEPS project is scheduled in November, 2018.

HEPS-High Energy Photon Source

It will be constructed from Dec 2018 to Jun 2025

Construction site



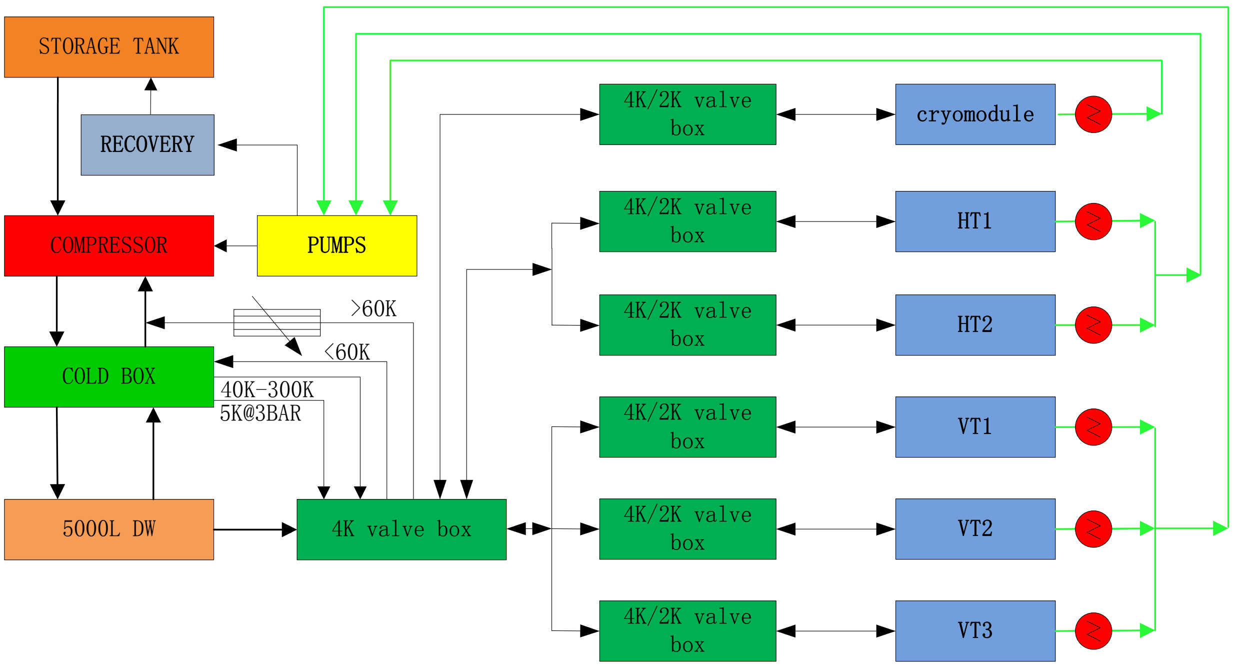


Construction goals of PAPS cryogenic system

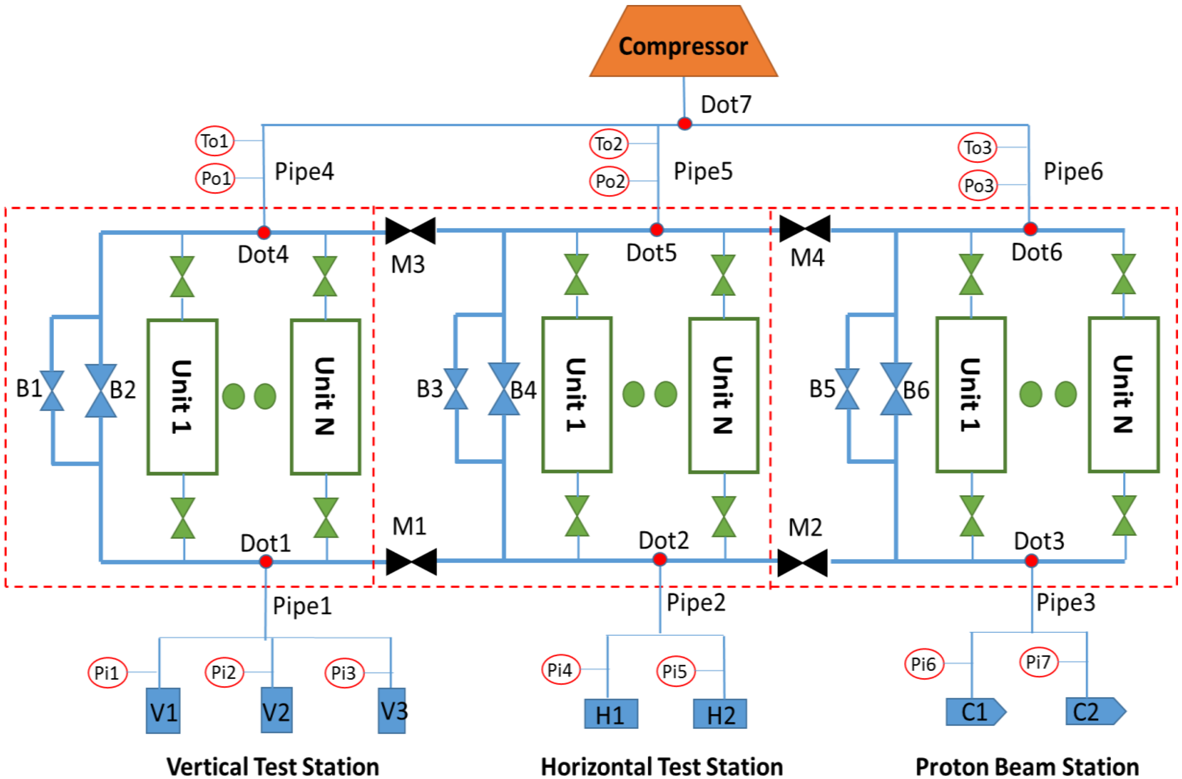
- Construct a 2.5KW@4.5K or 300W@2K cryogenic system with three vertical test stand, two horizontal test stand and a beam test stand of superconducting cavity.
- Construct a impure helium recovery and purification system with the capacity of 210m3/h helium recovery and 100m3/h helium purification
- Support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



2K pumping system



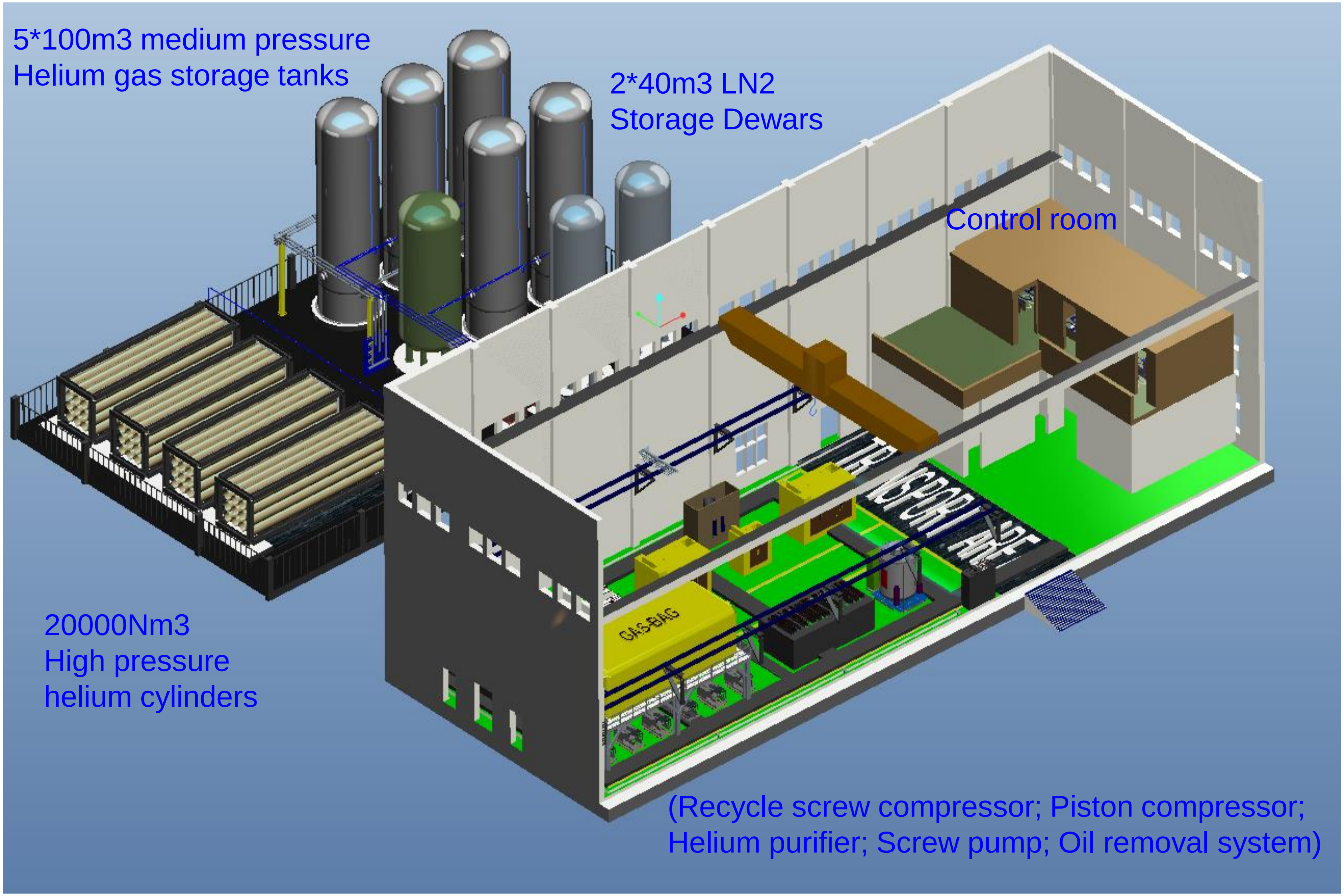
Function diagram

Main parameters

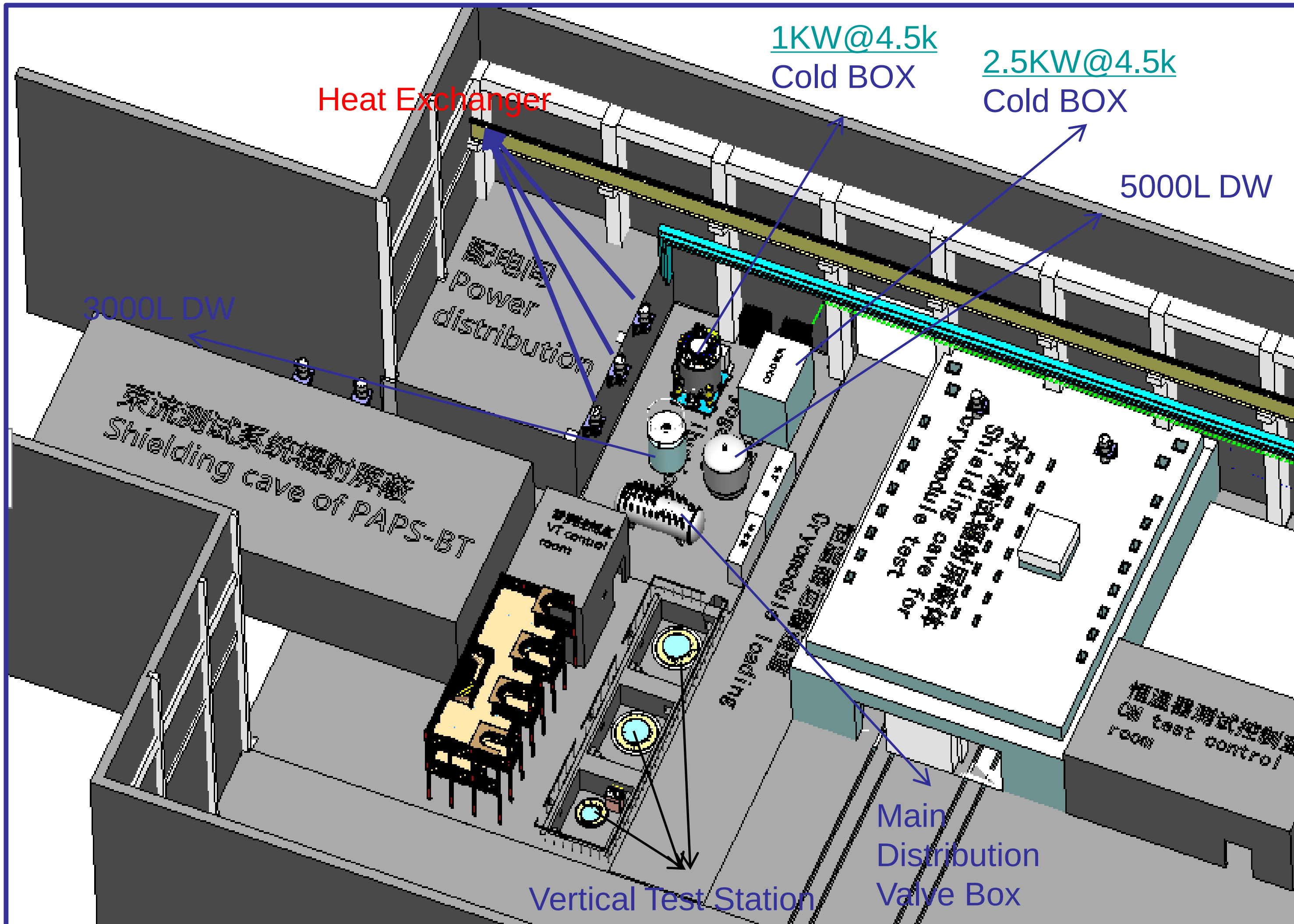
Helium tank pressure	3129 Pa
Pressure stability	+/-10 Pa
Max mass flow	26.7 g/s
Total pumps system capacity	19200 m^3/h （300K,30mbar）
Pumps station inlet temperature	300K
Pumps station outlet pressure	1.2 Bar
Noise level	<80 dB@1m
Leakage rate	1E-6 Pa·m^3/s
Vibration size	<5mm/s

- 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



PAPS 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

Main components of HEPS cryogenic system

- **4.5K helium cryogenic system**

➢ **used to cool down five166.6MHz and two 499.8MHz superconducting cavities, two another 499.8MHz will be added in the next phase;**

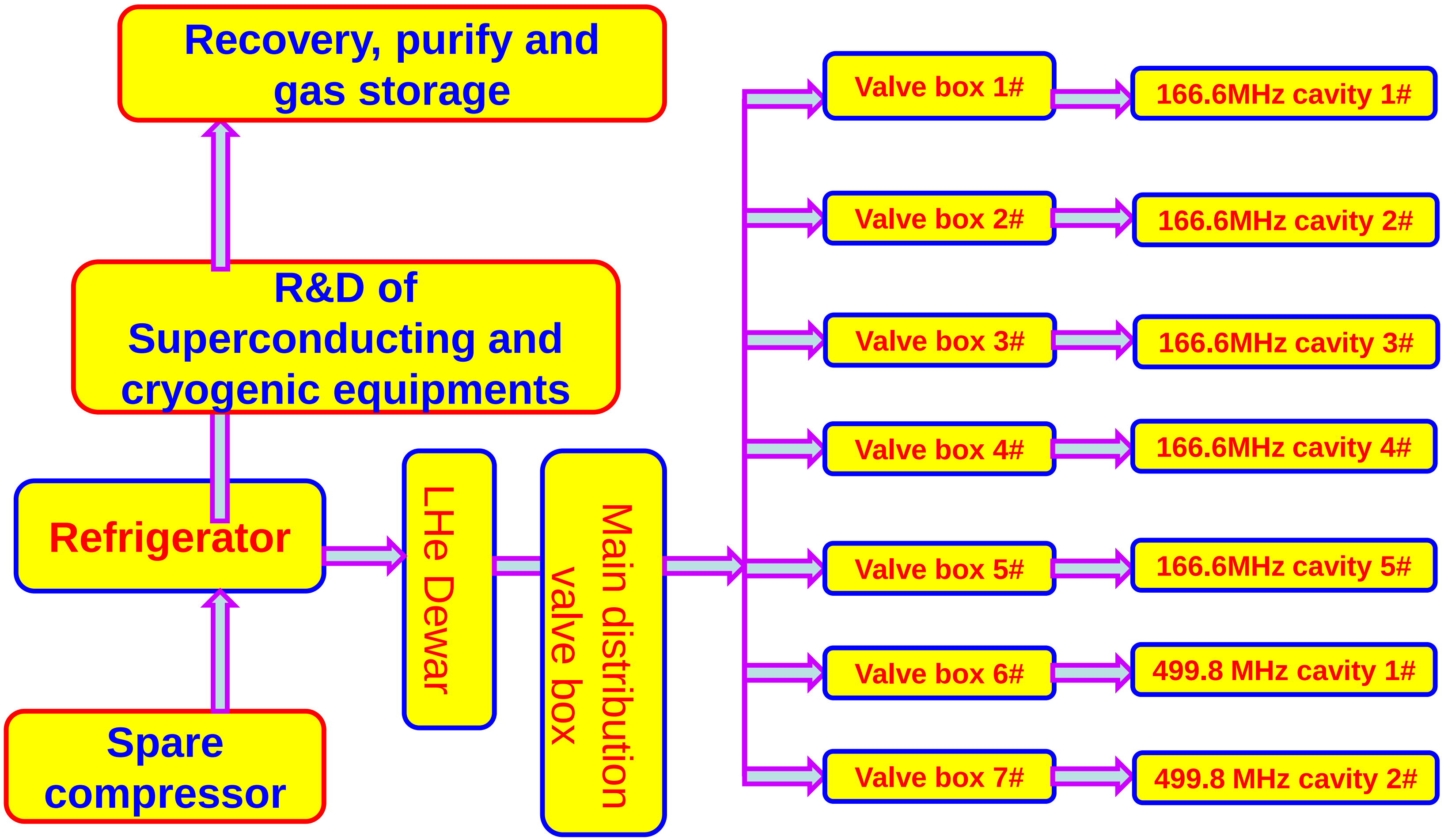
➢ **Cooling capacity 2 KW@4.5K；**

➢ **auxiliary system, impure helium gas recovery and purify**

- **LN2 cryogenic system**

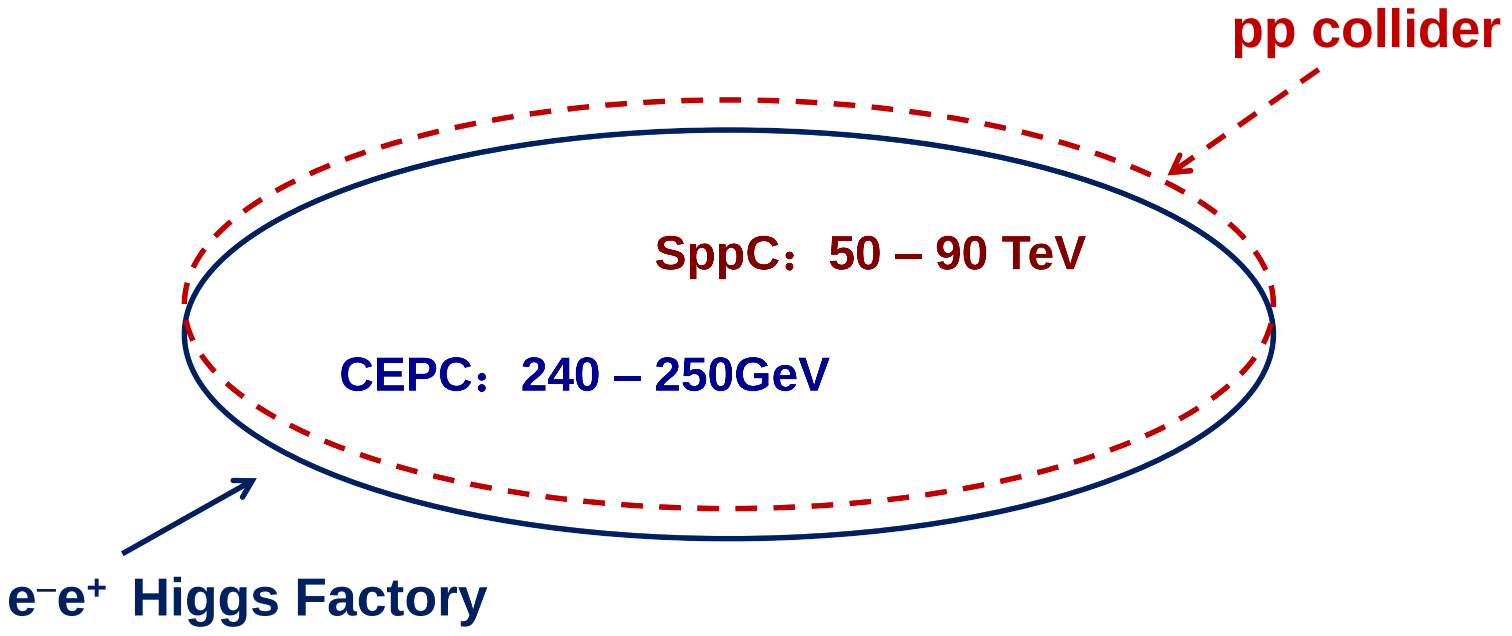
➢ **Used to cool down several tens cryogenic devices, CPMU and monochromator.**

Block diagram of HEPS cryogenic system



CEPC-SppC

- A circular e+/e- collider as Higgs Factory has been studying at IHEP. The machine can be converted into a proton-proton collider for tens TeV high-energy frontier.



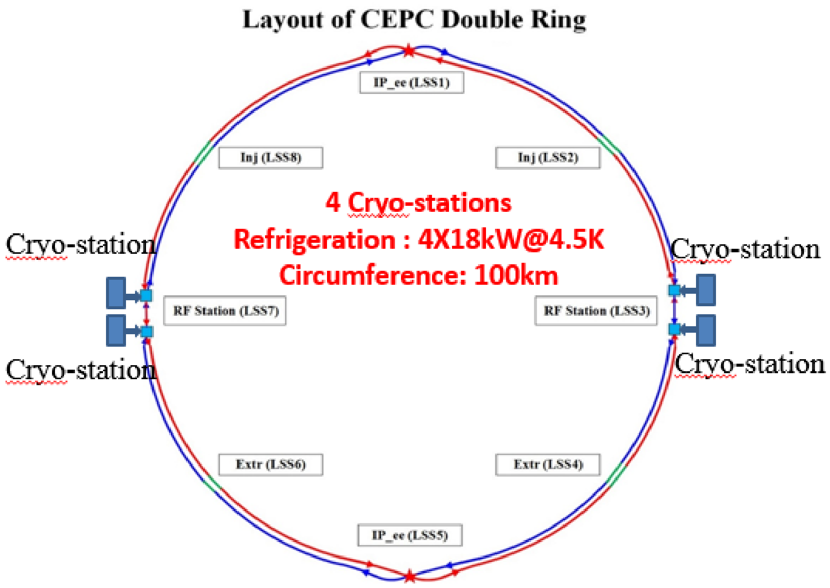
Layout of CEPC cryogenic system

Booster ring:

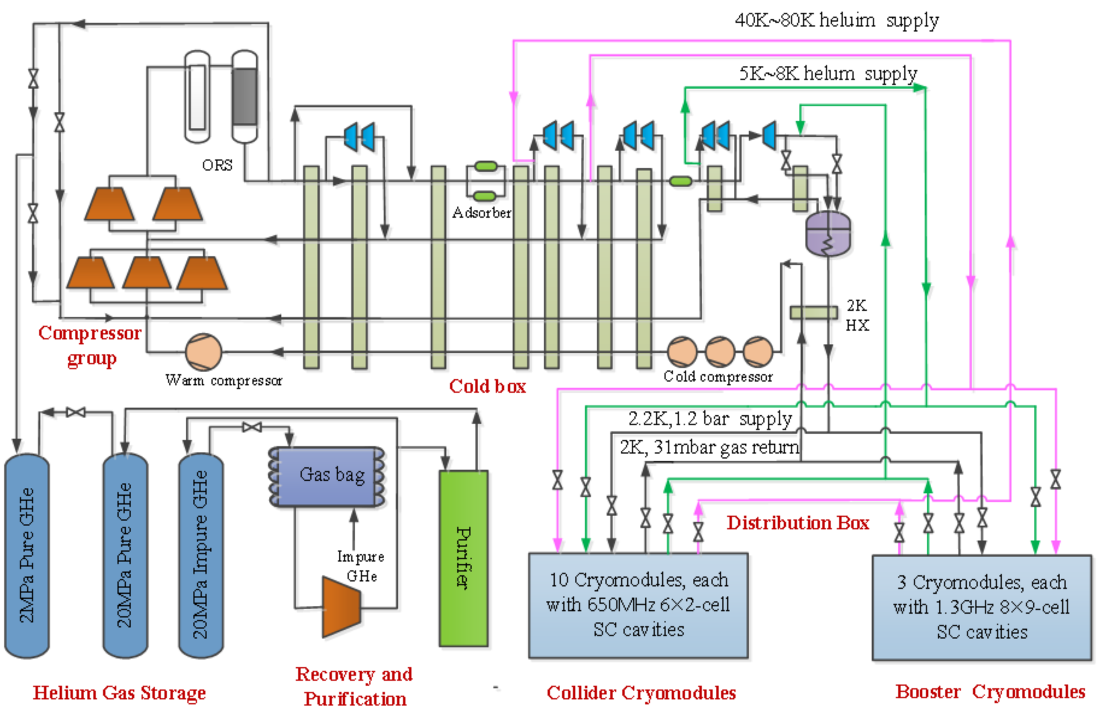
- 1.3 GHz 9-cell cavities, 96 cavities
- 12 cryomodules
- 3 cryomodules/each station
- Temperature: 2K/31mbar

Collider ring:

- 650MHz 2-cell cavities, 240 cavities
- 40 cryomodules
- 10 cryomodules/each station
- Temperature: 2K/31mbar



Flowchart of cryogenic system for one Cryo-station



- Each Cryo-station mainly includes Compressor, Cold box, helium gas storage tanks, cryomudules and purification system.
- The cryomodules have two shields, a 40K~80K shield and a 5K~8K shield.
- A 2.2K, 1.2bar helium is supplied for the cryomodules and the 2K, 31mbar helium gas return to the cold box with the cold compressors.

Heat load of cryogenic system

Higgs Mode	Unit	Collider			Booster		
		40-80K	5-8K	2K	40-80K	5-8K	2K
Static heat load per cryomodule	W	300	60	12	140	20	3
Cavity dynamic heat load per cryomodule	W	300	60	153.59	140	10	13.98
Input coupler dynamic heat load per cryomodule	W	20	12	2	40	3	0.4
HOM dynamic heat load per cryomodule	W	60	40	6	2	1	1
Module dynamic heat load	W	380	112	161.59	182	14	15.38
Connection boxes	W	50	10	10	50	10	10
Cryomodule number		40			12		
Total heat load	kW	29.20	7.28	7.34	4.46	0.53	0.34
Total mass flow	g/s	139.93	227.15	346.58	21.39	16.47	16.07
Overall net cryogenic capacity multiplier		1.54	1.54	1.54	1.54	1.54	1.54
4.5K equiv. heat load with multiplier	kW	3.38	10.14	36.18	0.52	0.74	1.68
Total 4.5K equiv. heat load with multiplier	kW	49.70			2.93		
Total 4.5K equiv. heat load of booster and collider	kW	52.63					

CEPC Time Schedule

CEPC

2015 | 2020 | 2025 | 2030 | 2035

Pre-studies
(2013-2015)

R&D
Engineering Design
(2016-2022)

Construction
(2022-2028)

Data taking
(2028-2038)

1st Milestone: Pre-CDR (by the end of 2014) ;**2nd Milestone:** R&D funding from MOST (in Mid 2016); **3rd Milestone:** CEPC CDR Status Report (by the end of 2016); **4th Milestone:** CEPC CDR Report (by the end of 2017);**5th Milestone:** CEPC TDR Report and Proto R&D (by the end of 2020);**6th Milestone:** CEPC construction start (2022);

SPPC

2020 | 2030 | 2040

R&D and CDR
(2014-2030)

Engineering Design
(2030-2035)

Construction
(2038-2045)

Data taking
(2045-2060)

Summary

- Since 2002, from the design of BEPCII cryogenic system, IHEP has accumulated 15 years of experience in the design, construction and operation of the cryogenic system.
- A professional team of cryogenic engineering has been built, which supports the construction and development of large science engineering project at IHEP.

Thank you for your attentions!