WG7 SUMMARY: Cryogenics

by Nikolai Lobanov

8 “cool” talks: 7 in person and 1 remote

Talks covered many aspects of small/medium to large cryogenics plants, operation, upgrades and developments, purification systems, high filed superconducting magnets, cryomodule and superconducting technology for accelerators

CRYOGENICS WORKSHOPS

Workshop on Cryogenics Operations

The 8th International Workshop on Cryogenics Operations (Cryo-Ops 2018) is a conference that rotates every two years between Asia/Oceania, Europe, and the Americas. The Workshop provides a forum to present and discuss current technological advancements, operability and maintenance experience of large cryogenic systems. Cryo-Ops was held in IHEP, CAS, Beijing June 2018.

30th Space Cryogenics Workshop will be held on July 2023 in Kailua-Kona, Hawaii! All aspects of space cryogenics will be represented, with emphasis on those related to space exploration.

AND MORE

8th EUROPEAN SPACE CRYOGENICS WORKSHOP

5 - 7 JUNE 2023 AT ESA/ESTEC

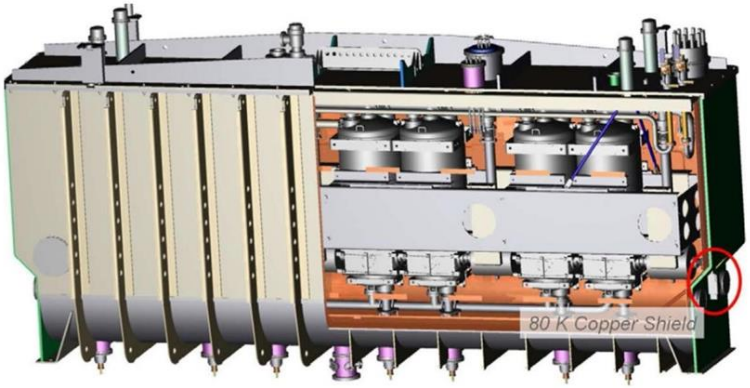
- Future needs in Space cryogenics.
- Active coolers (e.g. Stirlings, Pulse-Tubes, Turbo-Braytons, Joule-Thomson Coolers).
- Sub-Kelvin refrigeration systems (e.g. Dilution coolers, ADR, Sorption Pumped Coolers).
- Cryogenic testing facilities for space application T< 40K.
- Cryocoolers Integration Technologies (e.g. Thermal link assemblies, Energy Storage).
- Cryogenic for launchers, Storage and Zero Boil-Off.
- Space Cryogenic Instruments and Systems.
- Challenges in Cryogenic Systems (e.g. lifetime, margin philosophy, microvibrations).

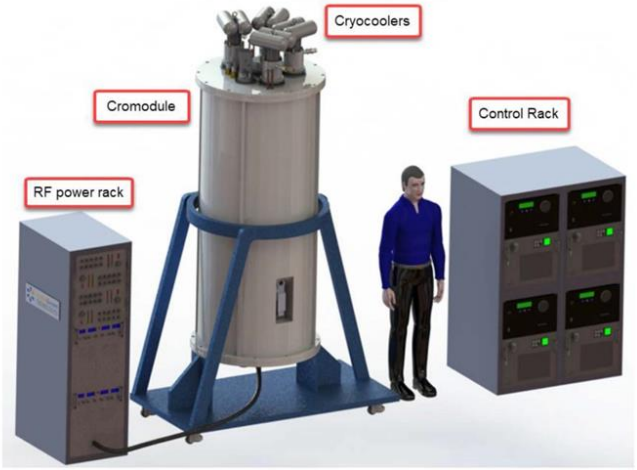
Stand-alone cryo-accelerator for HIAF ANU (N Lobanov)

14UD: ~ 3 M$/1 MV hardware cost;
~ 0.6 kW/1 MV power cost

Conventional linac:

~ 2 M$/1 MV hardware cost;
~ 3 kW/1 MV power cost





Stand alone linac:

~ 1 M$/1 MV hardware cost;
~ 3 kW/1 MV power cost

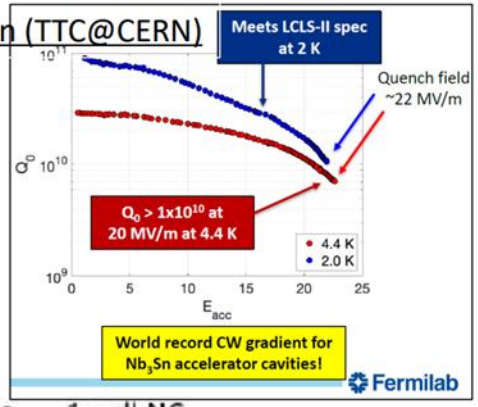
Kensei Umemori KEK iCASA WG3

Design of compact Nb3Sn accelerator for irradiation experiment

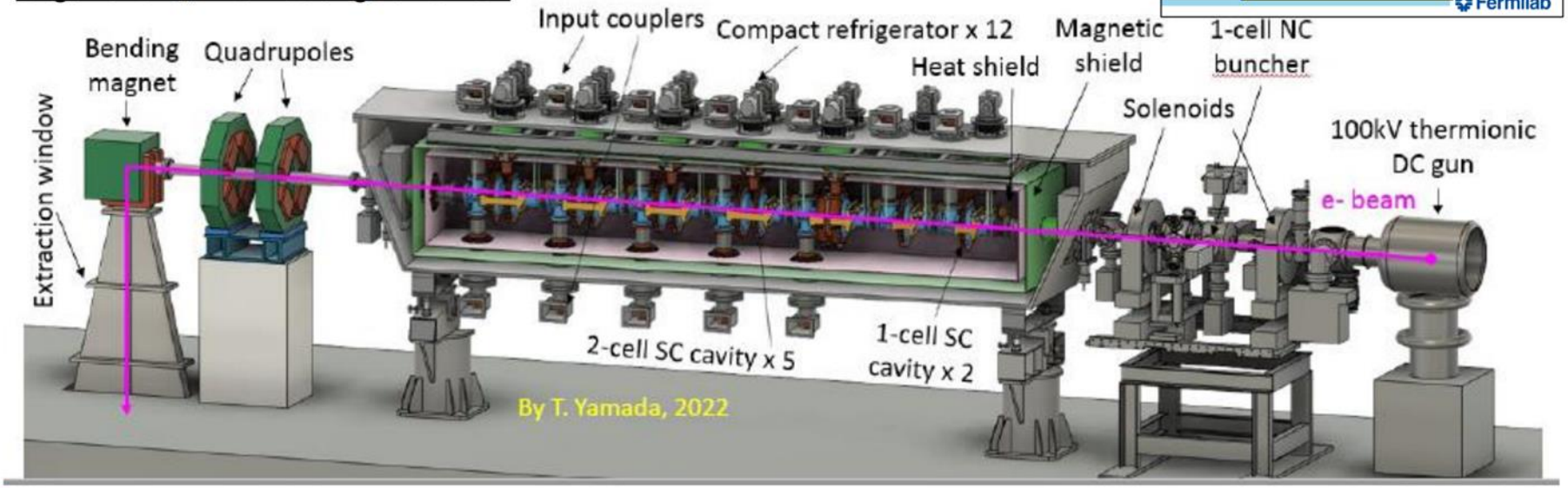
- Nb3Sn SRF cavity can achieve Q > 1e10 at 4K.
- Conduction cooling by cryo-cooler can be possible.

He free compact SRF accelerator

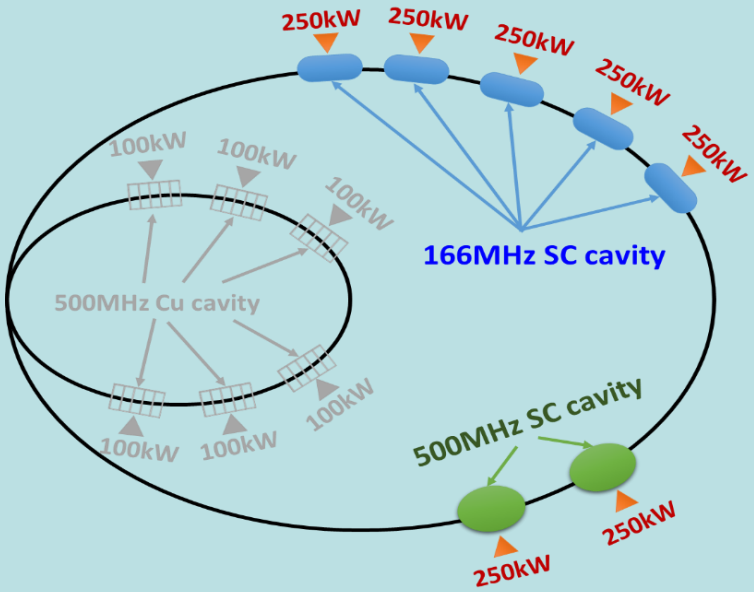
S. Posen (TTC@CERN)



Oliga Tanaka, TTC meeting at Aomori



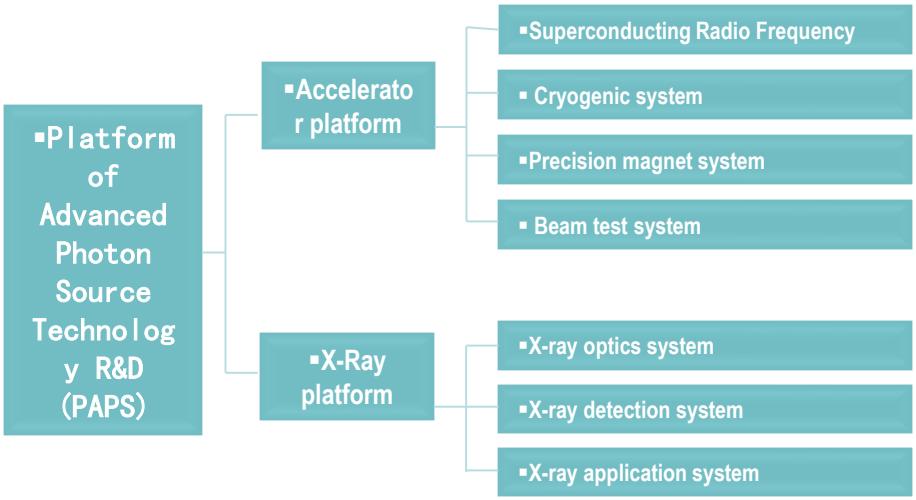
Rui GE CRYOGENIC SYSTEM FOR THE HIGH ENERGY PHOTON SOURCE AT IHEP



- **Helium cryogenic system**
  - Used to cool down five166.6MHz and two 499.8MHz superconducting cavities;
  - Cooling capacity ~2000 W@4.5K ;
- **LN_2 cryogenic system**
  - Used to cool down CPMU and Cryostal-Monochromator, cryogenic devices of Beam line station …;
  - Precooling of the refrigerator;
  - Shields of the superconducting cavities' cryostat
  - Cooling capacity ~46kW@80K.

1. Engineering Materials	60-170keV
2. Hard X-ray Multi-analytical Nanoprobe (HXMAN)	< 10nm; in situ nanoprobe; 200m long
3. Structural Dynamics Beamline (SDB)	Single shot for irreversible; 200m long
4. Hard X-ray Coherent Scattering	CDI, XPCS
5. Hard X-ray High Energy Resolution Spectroscopy	NRS, Raman and RIXS
6. High Pressure	Diffraction; 150nm, ultrahigh pressure
7. Hard X-Ray Imaging	Up to 300keV, 300mm beam size, 350m long
8. X-ray Absorption Spectroscopy	Sub-micron, quick XAFS
9. Low-Dimension Structure Probe (LODISP)	Surface and interface
10. Biological Macromolecule Micro-focus	1μm, serial crystallography
11. Pink SAXS	pink, least optics
12. High Res. Nanoscale Electronic Structure Spectroscopy	ARPES, 200-2000eV
13. Tender X-ray	Spectroscopy, BM beamline
14. Transmission X-ray Microscope	Nano imaging and spectroscopy
15. Test beamline	X-ray optics test

Liangrui Sun The Introduction of 2K Superfluid Helium Cryogenic Test System for PAPS IHEP China

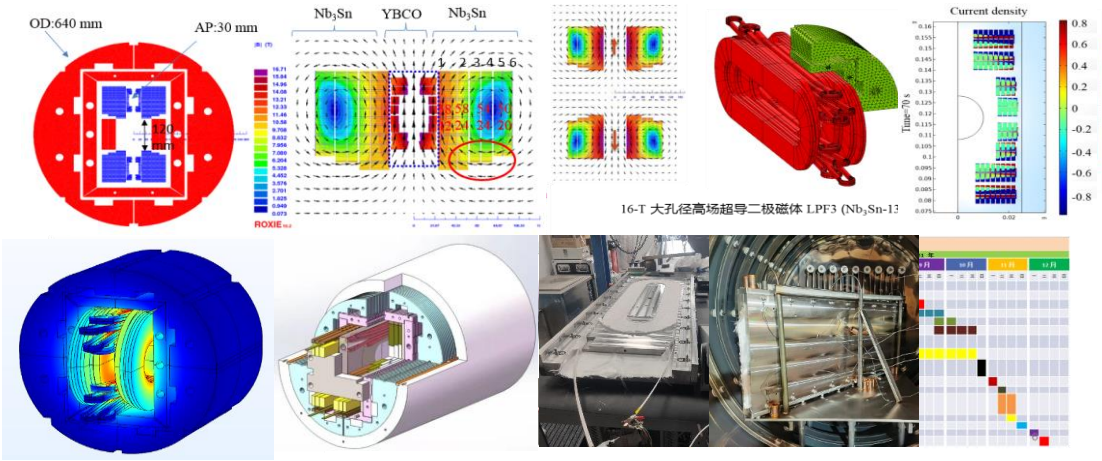


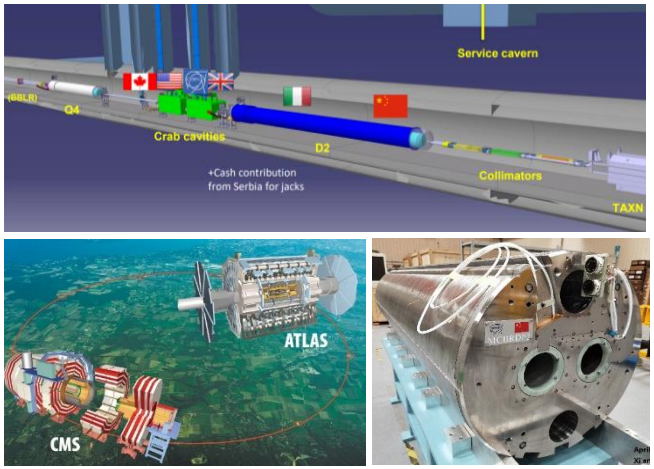
- **PAPS-Platform of Advanced Photon Source Technology R&D**
- **The acceptance test of helium refrigerator, helium recovery & purification system, and the capacity of 2K cryogenic system have been completed**
- **PAPS cryogenic system can serve as one of the superconducting cavity testing platform and superfluid helium performance research center**

Progress of the High Field Accelerator Magnets at IHEP-CAS

Qingjin Xu

- 12.47 T model dipole realized in mid 2021. 16 T under development.
- Stainless-steel stabilized IBS tape achieved the highest J_e in 2022! Significantly reduced the cost and raised the mechanical properties.
- China & CERN Collaboration on accelerator technology: development of HL-LHC CCT magnets going well.

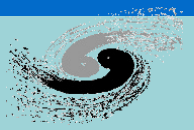




▪16 T Model Dipole under development:
Nb3Sn 12~13 T + HTS 3~4 T

▪Development of CCT Magnets for HL-LHC

R&D of the High Field Model Dipoles

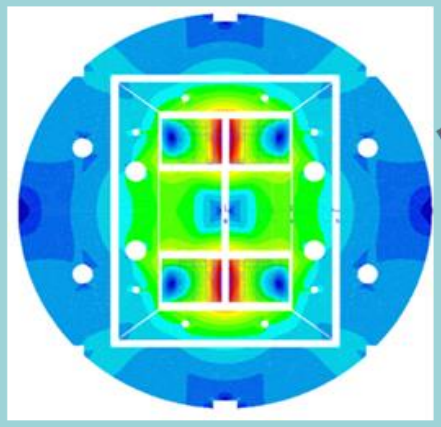


Field (T)

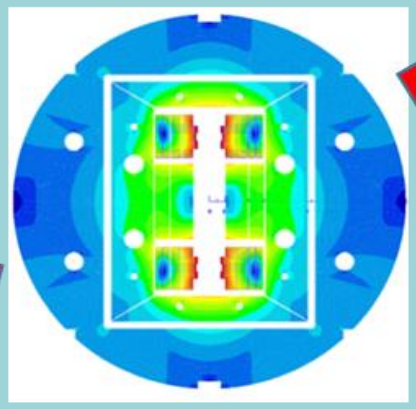
20

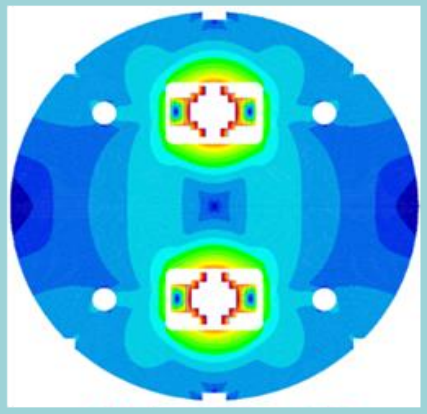
10

NbTi+Nb_3Sn
2*ϕ10 aperture
10T @ 4.2K

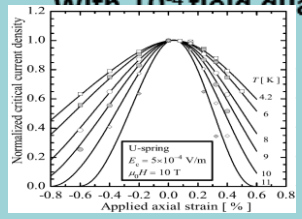


Nb_3Sn+HTS
2*ϕ30 aperture
15T @ 4.2K





Nb_3Sn+HTS or HTS
2*ϕ45 aperture
20T @ 4.2K
With 10^{-4} field quality



▪Challenges: Stress control, quench protection, field quality control,……

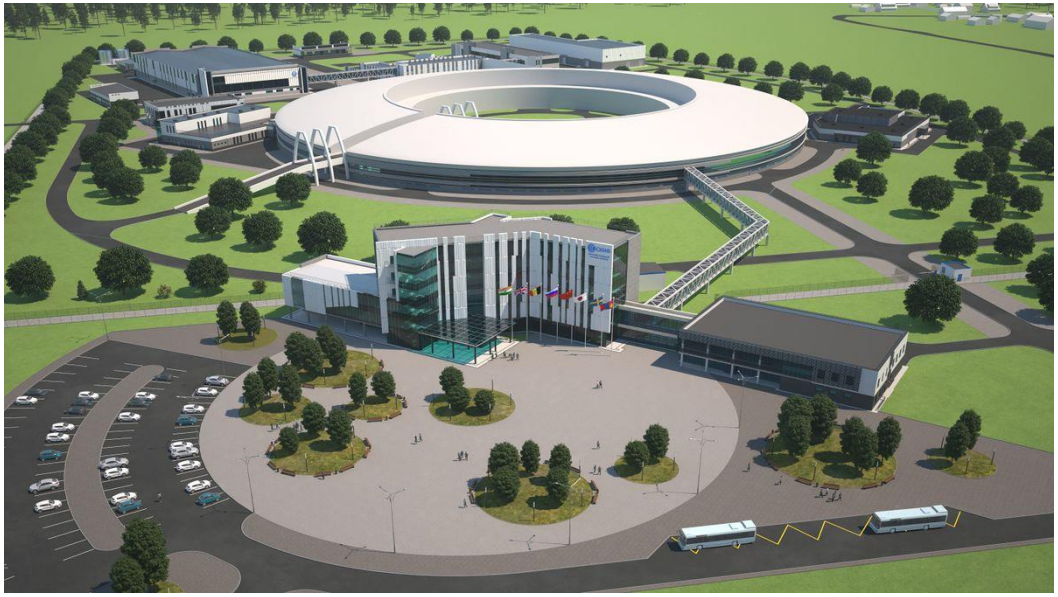
2018

2028

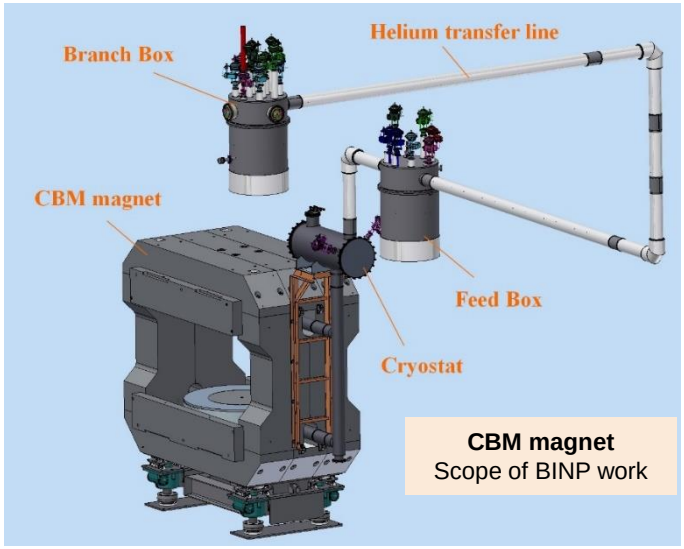
year

Overview of BINP works, Novosibirsk, Russia
Alexey Bragin

- **SKIF light source** is being built in Novosibirsk region
- This is the 4+ generation type light source.
- Energy 3 GeV, Accelerator length 476 m, Emittance 75 pm•rad
- The operation should start in December 2024
- It will be needed about 12 superconducting insertion devices.
- Four SC insertion devices will be manufactured in 2023.

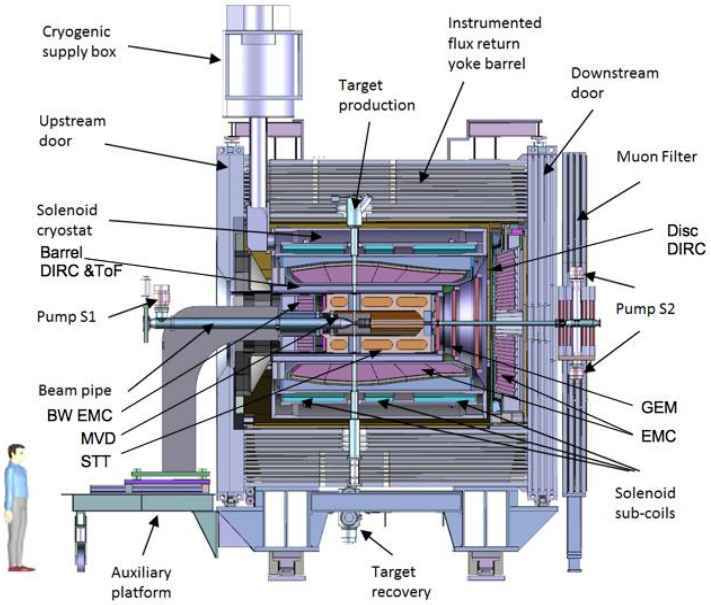


The type of insertion device and the station number	Magnetic field, T	Period, mm	Number of poles	Radiation horizontal angle, mrad	Radiation power, kW
Undulator, 1-1 station	1.25	15.6	128	± 0.32	7.66
Undulator, 1-2 station	1.25	15.6	128	± 0.32	7.66
Undulator, 1-4 station	1.6	18	111	± 0.46	11.75



CBM magnet
Scope of BINP work

- Superconducting magnets for CBM and PANDA detectors of FAIR facility are designed. The iron yokes are finished. The works are stopped.



PANDA solenoid

Prof. Liqiang Liu Research Advances in Key Technologies of Ultra-Large Cryo-plants at TIPC of CAS Technical Institute of Physics and Chemistry

Scale & Type of Cryo-plant (CP)

- **Scale Classification**

▪S-CL
▪ (Q_{eq}~W)

▪M-CP
▪ (Q_{eq}>100 W)

▪L-CP (Q_{eq}>1kW)

▪UL-CP (Q_{eq}>10kW)

- **Typical Type**
  - ➢ Ultra-Large 2K Cryo Refrigerator
  - ➢ Ultra-Large Hydrogen Liquefier
  - ➢ Ultra-Large Helium Liquefier

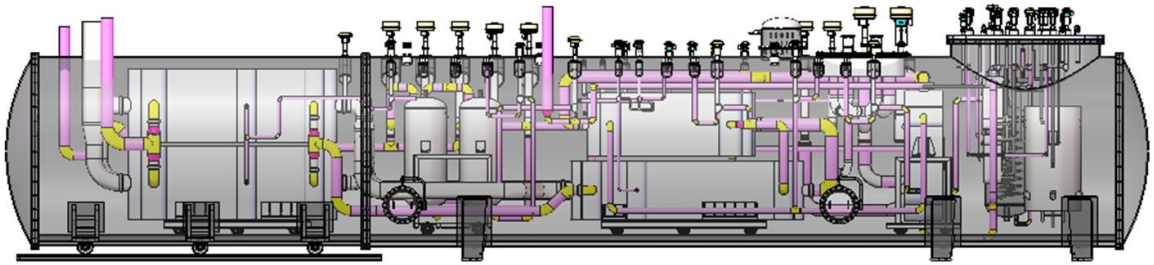
- Q_{eq}: Equivalent cooling capacity @ 4.5K

Prof. Liqiang Liu Research Advances in Key Technologies of Ultra-Large Cryo-plants at TIPC of CAS

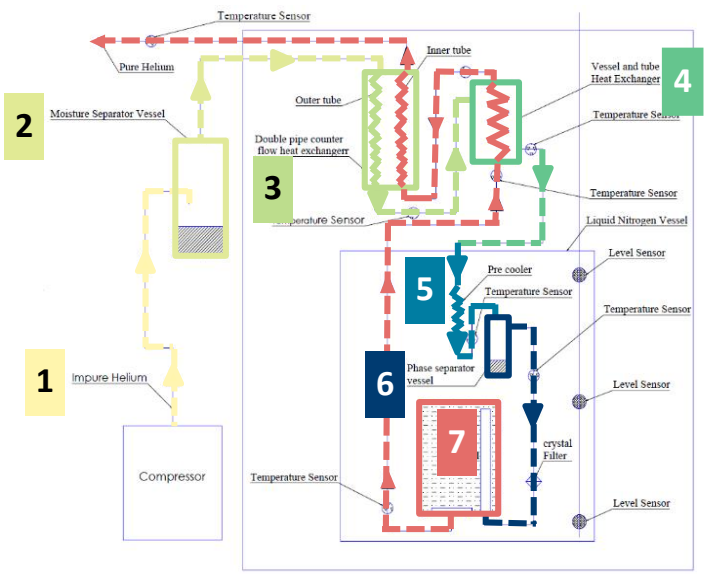
▪4. Conclusions and Prospects:

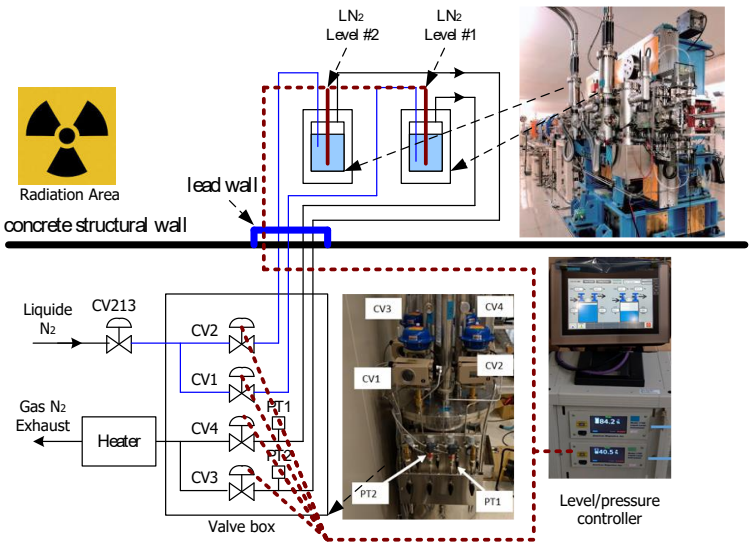
- **The core technologies of the series of 10kW CP represented by "HL-TE, LF-CC, Internal Purifier, and process design" have been conquered for the first time at TIPC of CAS and in China.**

- **With the support of relevant government departments and enterprises, the R&D of the complete systems of the 10kW CP are being in progress**
  - ✓ **3000 L/h Helium Liquefier → LS-Facilities, Helium resource extraction**
  - ✓ **5 t/d H_2 Liquefier × 2 → H_2 Energy Utilization**
  - ✓ **4 kW@2K Superfluid Helium Cryo-plant → LS Facilities**



Huang-Hsiu Tsai NSRRC Taiwan Purifier Module for LHe system and Liquid Nitrogen Cooling System for Cryogenic In-vacuum Undulator

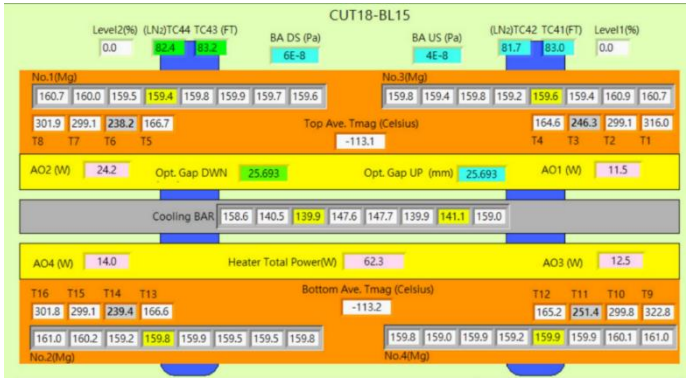




- **The cryogenic helium gas purifier has been designed and fabricated 85% completion.**

- **A Liquid Nitrogen Cooling System has been developed at NSRRC for the NdFeB-based cryogenic in-vacuum undulator with a period length of 18 mm and effective magnetic field of 1.18 Tesla.**

- **The cooling margin of the Liquid Nitrogen Cooling System is measured at around 220 W. The maximum beam-induced heat load that the storage ring effects the Permanent Magnet is around 85.5 W at beam current of 500 mA.**



Zong-Kai Liu Operation status and future plans of the SRF module at NSRRC

1. There are two light sources (TLS & TPS) in NSRRC. Both of them use 500 MHz SRF modules as their accelerating cavity. The MTBF of both RF systems are all > 500 hours in 2022.
2. Major trip types and improvements in recent years for the SRF modules:
   - ① For CESR type SRF module of 1.5 GeV ring-TLS: Unknown quench events and solved by partial warm up and lower operating RF voltage.
   - ② For KEKB type SRF module of 3.0 GeV ring-TPS:
     - One of the major trip is due to the multipacting in coaxial coupler, and solved by applying positive bias voltage.
     - Soft alarm system is developed to shorten the downtime and improve the reliability.
3. Future plans for TPS SRF activity:
   - ① Power combination (80 kw SSPA tower combined with 300 kW klystron) for each SRF module to support 500 mA operation with more beam line installed.
   - ② Install SC 3rd harmonic cavity to lengthen the electron bunch, therefore to reduce the heat load of IDs and increase the beam lifetime.

Conclusion:

-emerging new applications such as LH2 storage/liquefication

-cryo-cooler based compact installations

-pushing boundaries to 10 kW systems

-in-house developed purification systems

-next frontier 16 T magnets and high gradient srf cavities

-excellent career opportunities for next “cool” generation

Thank you!