Summary of WG7:
Cryogenics, Cryomodule and Superconducting Technology for Accelerator

30 Jan. 2018
DCC, Daejeon, South Korea

Hyeok-Jung Kwon
On behalf of WG7 contributors

WG7 Program

WG7: Cryogenics, Cryomodule and Superconducting Technology for Accelerator. Room 107			
January 29			
Time	Title	Speaker	Affiliation
Session 1 Chair: Hirotaka Nakai (KEK)			
13:30-13:50	Status of Vertical Test Facility for HWR and QWR at RISP	JuWan Kim	RISP
13:50-14:10	Progress of CEPC cryogenic system	Jianqing Zhang	IHEP
14:10-14:30	A plan of the HWR superconducting linac development at KOMAC	Han-Sung Kim	KOMAC
14:30-14:50			
14:50-15:10			
15:10~15:40	**Coffee break**		
Session 2 Chair: H. J. Kwon (KAERI)			
15:40-16:00	Report on the Asian School on Superconductivity and Cryogenics for Accelerators (ASSCA2017)	Hirotaka Nakai	KEK
16:00-16:20	Cryogenic system of the SuperKEKB IR final focusing SC magnets	Zhanguo Zong	KEK
16:20-16:40	Introduction of PAPS cryogenic system	Shaopeng Li	IHEP
16:40-17:00	Current status of cryomodule development for SCL3 of RAON	Minki Lee	RISP
January 30			
Session 3 Chair: Shaopeng Li (IHEP)			
9:00-9:20	Conceptual design of CEPC superconducting RF system	Jiyuan Zhai	IHEP
9:20-9:40	Progress of Linear IFMIF Prototype Accelerator (LIPAc) in collaboratio with EU	Keishi Sakamoto	QST Rokkasho
9:40-10:00	Current status and challenges of cryogenic systems for RAON accelerator	Tae Kyung Ki	RISP
10:0~10:30	**Coffee break**		

- **Number of presentation - 10**
- **Facility - IHEP: 3, KEK: 2, KOMAC: 1, QST Rokkasho: 1, RISP: 3**
- **Topics - Cryogenic system: 5, Cyromodule, cavity: 4, SC and CR activity: 1**

The status of Vertical Test Facility for HWR and QWR at RISP

Juwan Kim

Accelerating System team,
Rare Isotope Science Project (RISP)

RAON Rare isotope Accelerator complex for ON-line experiments

Status of Vertical Test Facility for HWR and QWR at RISP

- **Vertical tests of 3ea. QWR prototype cavities, 3ea. HWR prototype cavities have been performed**
- **New cryostat for vertical test will be installed this month**
- **SRF test facility at RAON site (Sindong) will be constructed in 2019**

Progress of CEPC Cryogenic System

Jianqin Zhang, Shaopeng Li
Accelerator center, IHEP
AFAD2018

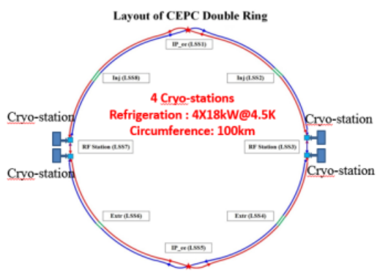
2018.01.29

Progress of CEPC Cryogenics System

Introduction

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

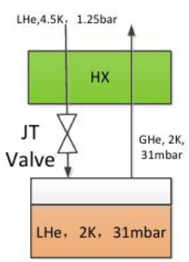
Collider ring:
- 650MHz 2-cell cavities, 336 cavities
- 56 cryomodules
- 14 cryomodules/each station
- Temperature: 2K/31mbar



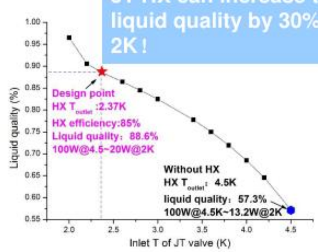
- **Cryogenic system design has been completed**
  - Heat load (4K eq.): 58.58kW
  - Total required power: 12.82 MW
  - 4 cryostations
  - 18kW, 4.5 K refrigerator / cryostation

- **R& D program for cryogenic components is in progress**

R&D 2K JT heat exchanger



Key points:
- efficiency ≥85%
- Pressure drop ≤100Pa
- Low heat loss

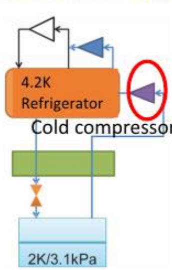


✓The 2K JT heat exchangers(HXs) were designed, the flow is 2g/s , 5g/s and 10g/s.
✓2K JT HX test stand will be built in **PAPS** in 2018.
✓The 2K JT HX with high efficiency will be used in the CEPC cryogenic system.

R&D Cold compressor

- Cold compressor is the key equipment for large 2K cryogenic system (mass flow> 10g/s).
- Only a few core manufacturers abroad have the design and manufacturing capacity.

The research of cold compressor is ongoing and supported by Key independent deployment project of Particle Accelerator Physics and Technology Key Laboratory .



Technical parameters:
- adiabatic efficiency: ≥60%
- Compression ratio: ≥2
- Leakage rate: 10-9 Pa•m3/s
- A high-speed motor output power: ≥1 kW
- High speed motor speed: ≥36krpm

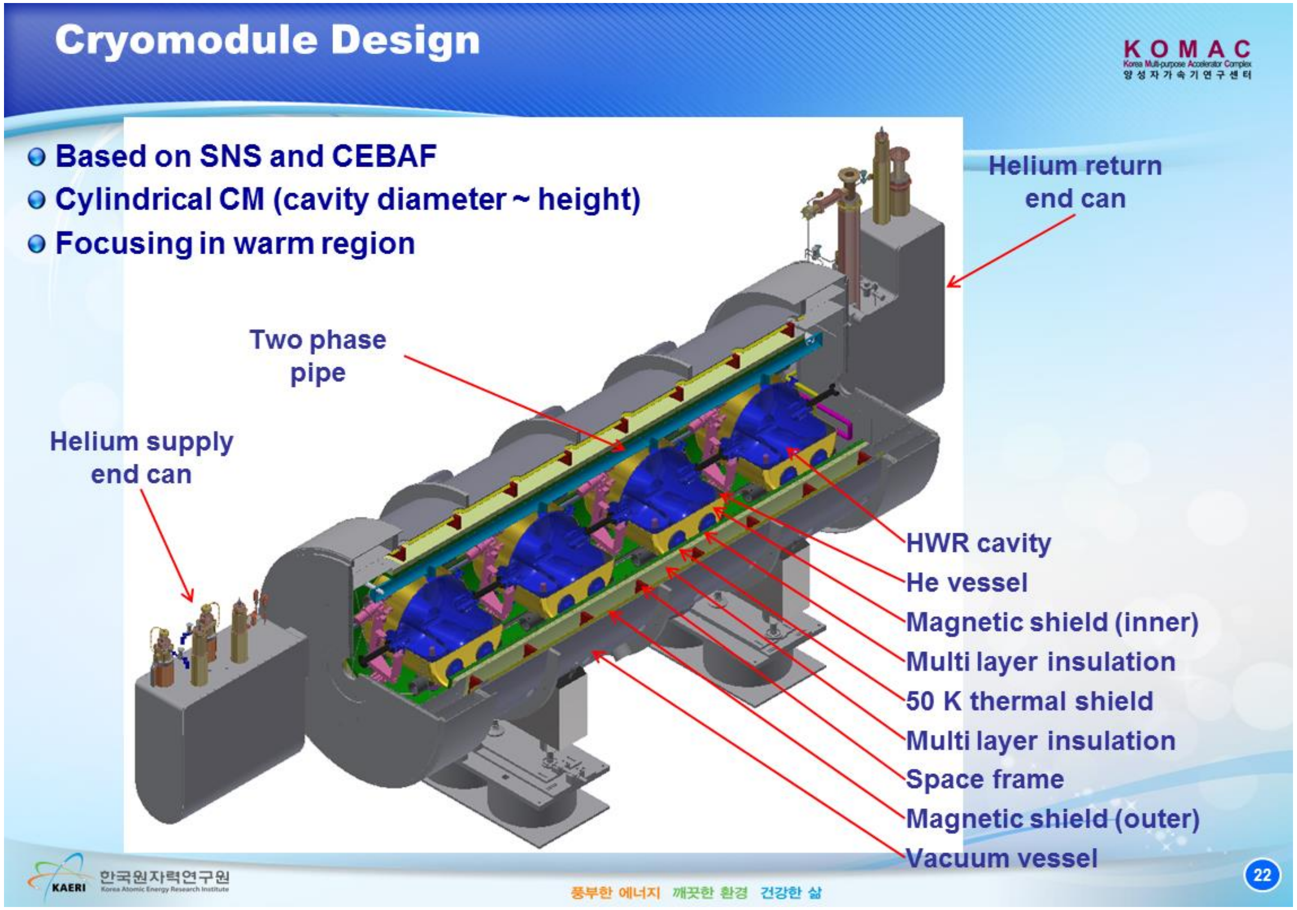
A Plan of the HWR Superconducting Linac Development at KOMAC

Han-Sung Kim
On behalf of the KOMAC Accelerator team

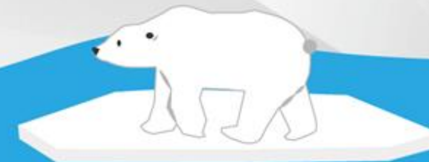
29 Jan., 2018
KOMAC, KAERI

KAERI
KOMAC
Korea Multi-Purpose Accelerator Complex
양성자가속기연구센터

A Plan of the HWR Superconducting Linac Development at KOMAC



- Conceptual design of superconducting HWR which will be used to increase the proton energy from 100 MeV to 160 MeV within existing tunnel has been completed
- Focus on the cavity, well proven technology will be used for other parts
- Prototyping of the CM and cavity starts in 2018



Report on the Asian School on Superconductivity and Cryogenics for Accelerators (ASSCA2017)

H. Nakai, Y. Hayashi, E. Kako, Y. Makida, T. Shidara, J. Urakawa (KEK) and T. S. Datta (IUAC)

Report on the Asian School on Superconductivity and Cryogenics for Accelerators (ASSCA2017)

- **December 10~17, 2017 at KEK**
- **Number of lectures: 18 (intro. 2, theoretical/engineering 10, special topic 6)**
- **Hand on training: 3 topics - superconducting cavity, magnet and cryogenics**
- **42 attendees and 15 lecturers from 9 countries**
- **The ASSCA2017 was successfully accomplished**

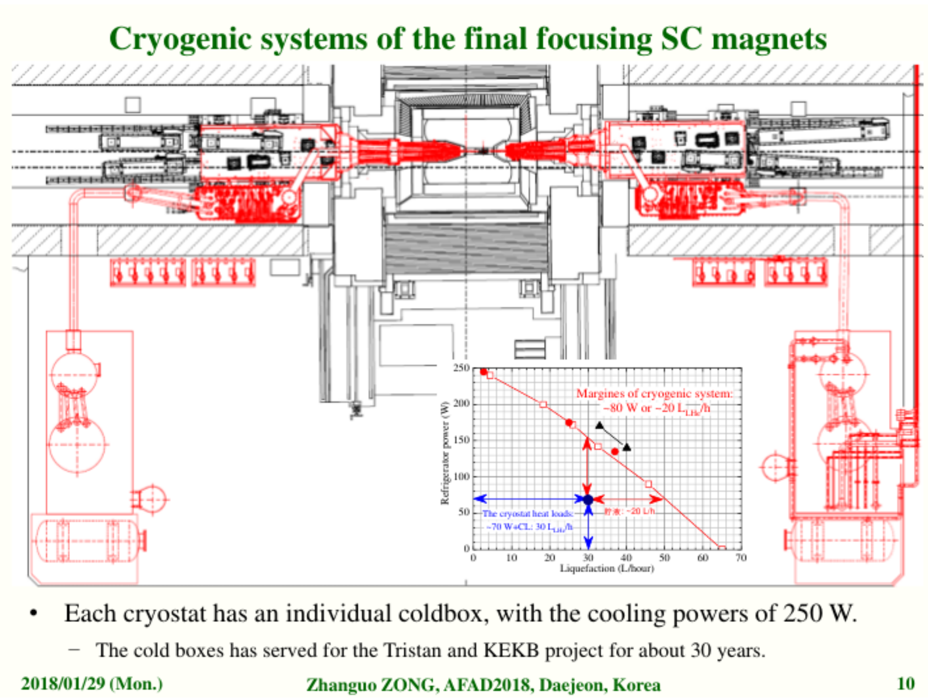
Cryogenic system of the SuperKEKB final focusing SC magnets

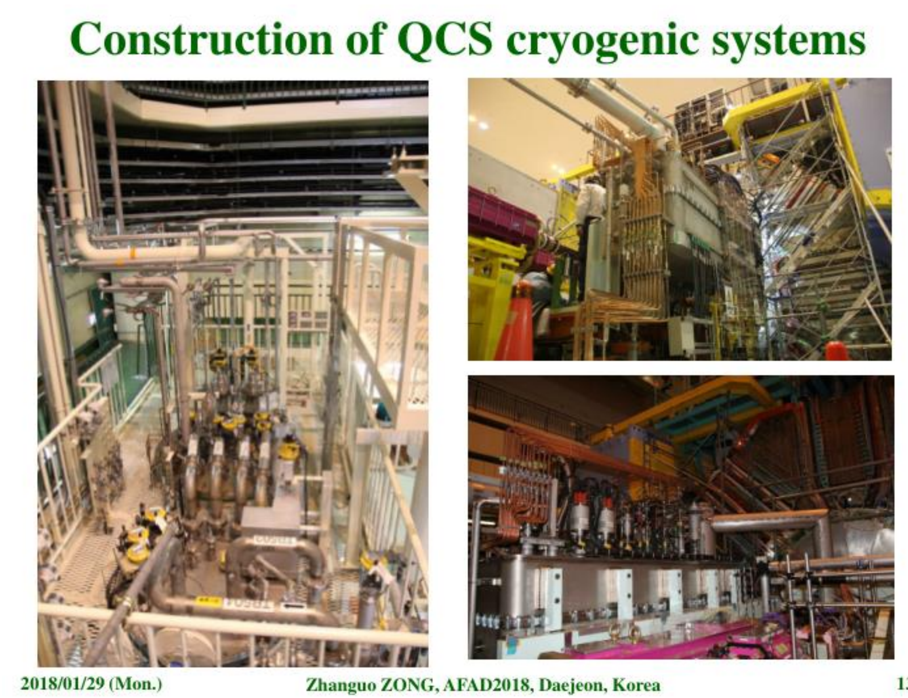
Zhanguo Zong, **Norihito Ohuchi, Yasushi Arimoto, Xudong Wang, Kiyosumi Tsuchiya, Masanori Kawai, Yoshinari Kondo, Hiroshi Yamaoka, Kanae Aoki, and Ryuichi Ueki**

SC magnet Group, Accelerator Laboratory,
High Energy Accelerator Research Organization (KEK)
Email: zhanguo.zong@kek.jp

The 9th Asian Forum for Accelerators and Detectors (AFAD2018),
from January 28 to 31, 2018 in the DCC (Daejeon Convention Center), Korea.

Cryogenic System of the SuperKEKB IR Final Focusing SC Magnets





- **Construction of new final focusing SC magnets (55ea.) and their cryogenic system has been completed**
- **Performance test of the SC magnets and cryogenics system was done in 2017 (Cool down, interlock, excitation, heat load, field measurement)**
- **SuperKEKB and Belle II are prepared for the phase II commissioning using new final focusing SC magnet in March 2018**

Introduction of PAPS cryogenic system

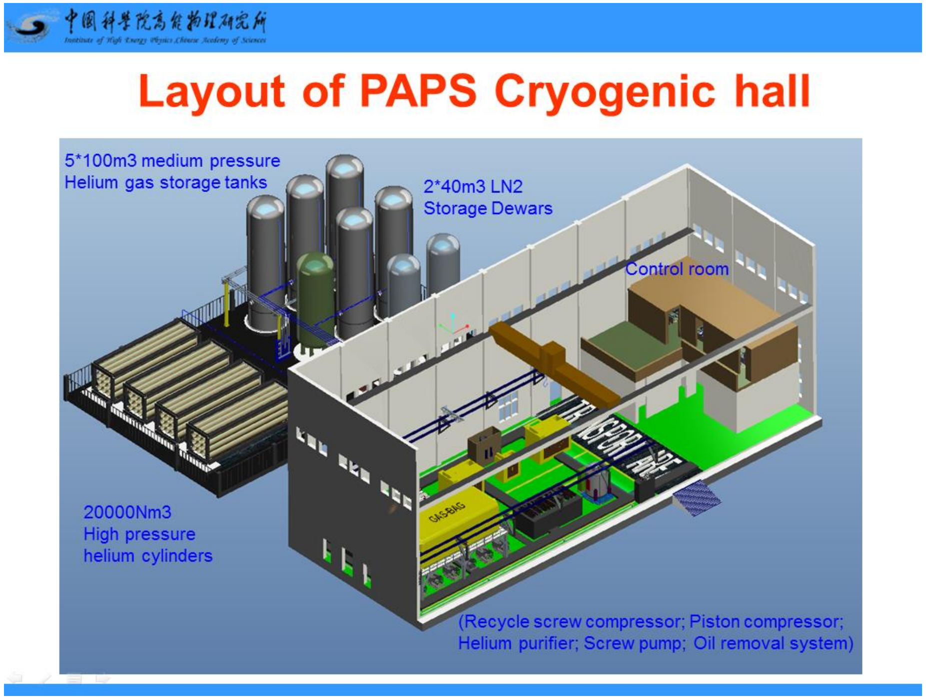
Shaopeng Li

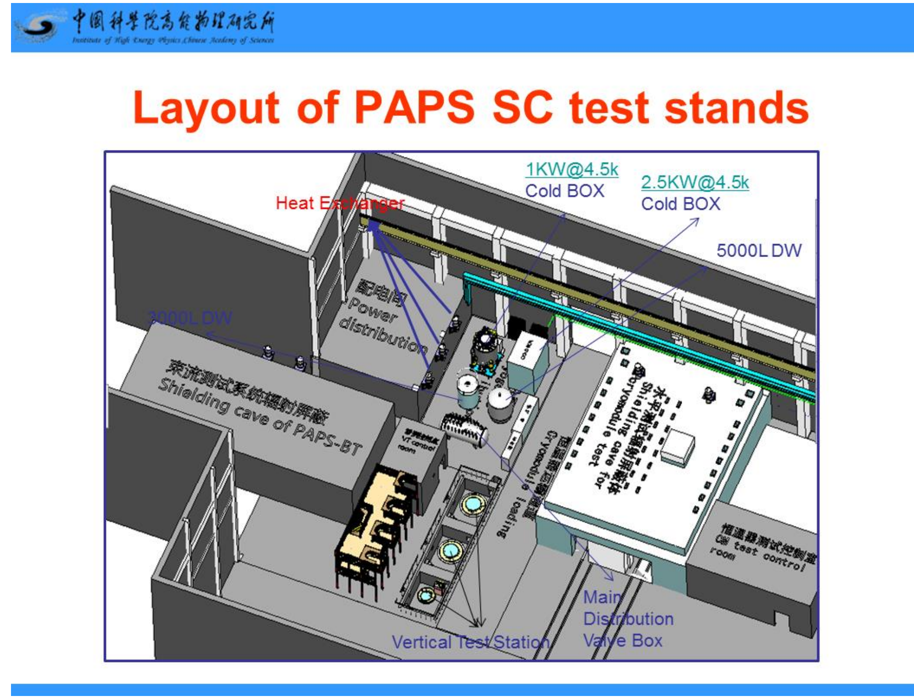
On behalf of PAPS cryogenic team

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

AFAD2018, Feb.29, 2018

Introduction of PAPS Cryogenic System





- Platform of Advanced Photon Source Technology R&D project
- Period & budget: Feb. 2017~Jun 2020, 0.5 billion RMB
- To supply R&D and engineering test platform for the SRF based large faciliti es such as CEPC and HEPS
- Cryogenic system with 2.5KW@4.5K or 300W@2K
- Test stand – 3 vertical test, 2 horizontal test, 1 beam test
- Test platform for R&D - JT HEX
- Design of almost parts is completed

CEPC Superconducting RF System

Jiyuan Zhai

On behalf of CEPC SRF team

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

Asian Forum for Accelerators and Detectors (AFAD) 2018

28-31 January 2018, Daejeon, Korea

Conceptual Design of CEPC Superconducting RF System

CEPC Collider Ring SRF Parameters

Collider parameters: 20180109	H	W	Z
SR power / beam [MW]	30	30	5.7
RF voltage [GV]	2.14	0.47	0.054
Beam current / beam [mA]	17.4	87.7	160
Bunch charge [nC]	24	8.6	6.4
Bunch length [mm]	3.26	3.43	6
Cavity number (650 MHz 2-cell)	336	216	48
Gradient [MV/m]	14	9.5	4.9
Input power / cavity [kW]	179	278	239
Klystron power [kW] (2 cavities / klystron)	800	800	800
HOM power / cavity [kW]	0.48	0.33	0.11
Optimal Q_L	1E6	3.2E5	1E5
Optimal detuning [kHz]	0.22	1.0	3.7
Q_0 @ 2 K at operating gradient (long term)	1E10	1E10	1E10
Total cavity wall loss @ 2 K [kW]	6.6	1.9	0.1
RF length [m]	896	576	128

Optimized for the Higgs mode of 30 MW SR power per beam, with enough operating margin and flexibility.

Cavity number determined by coupler power capacity, less is better for W and to reduce the detuning. 2-cell is a balan of gradient, beam loading and HOM power and damping.

Input coupler power limit 300 (500) kW, variable, low heat load, be short to reduce cryomodule diameter.

HOM power per cavity in the level of LEP2/LHC, but much wider freq.

Cavity acceptance Q_0 > 4E10 (N-doping), module horizontal test > 2E10 (clean assembly and magnetic hygiene

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CEPC Booster SRF Parameters

10 GeV injection	H	W	Z
Extraction beam energy [GeV]	120	80	45.5
Bunch charge [nC]	0.62	0.17	0.078
Beam current [mA]	0.53	0.53	0.51
Extraction RF voltage [GV]	1.83	0.7	0.36
Extraction bunch length [mm]	2.9	2.0	1.1
Cavity number in use (1.3 GHz TESLA 9-cell)	96	64	32
Gradient [MV/m]	18.4	10.5	10.8
Q_L (over-coupled)	1E7	1E7	1E7
Cavity bandwidth [Hz]	130	130	130
Beam peak power / cavity [kW]	8.8	2.6	0.5
Input peak power per cavity [kW] (with detuning)	14.1	4.4	3.4
Input average power per cavity [kW] (with detuning)	1	0.4	0.3
SSA peak power [kW] (one cavity per SSA)	25	25	25
HOM average power per cavity [W]	0.4	0.15	0.10
Q_0 @ 2 K at operating gradient (long term)	1E10	1E10	1E10
Total average cavity wall loss @ 4.5 K eq. [kW]	0.8	0.3	0.1

- **Design requirements are specified and parameters are set**
- **Challenges – high Q0 cavity, very high power variable couplers, high HOM coupler in a multi-cavity cryomodule, fast SRF voltage ramp with narrow BW in storage ring**
- **SRF key components design and R&D launched with the support of PAPS SRF facility**
- **SRF technology Industrialization & CEPC Industrial Promotion Consortiu m in 2017**

WG7 AFAD2018

Present status of Cryomodule and Cryoplant for LIPAc

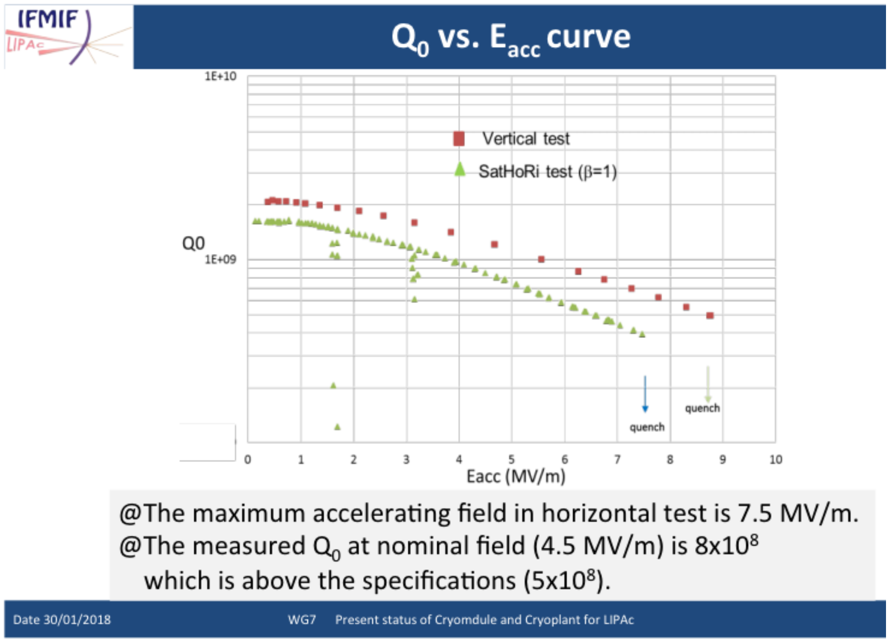
K.Sakamoto[1), G.Phillips[2)], S.Chel[3)], N.Basin[3)], A.Kasugai[1)], B.Renard[3)], S.Maebara[1)], T.Ebisawa[1)]

[1)] National Institutes for Quantum and Radiological Science and Technology (QST), Rokkasho Fusion Institute, 2-166 Oaza-Obuchi-Aza-Omotedate, Kamikita-gun, Rokkasho-mura, Aomori 039-3212, Japan

[2)] F4E, Fusion for Energy, BFD Department, Garching, Germany

[3)] CEA/Saclay, France

Progress of Cryomodule and Cryoplant for IFMIF Prototype Accelerator



- **HWR cavity test – nominal field of 4.5 MV/m and the Eacc + 20% field were successfully carried out and the measured Q0 at nominal field was $8X10^8$ (target Q0 : $5X10^8$)**
- **Tuner test**
- **Solenoid & steerer – First test results in Feb. 2018**
- **Assembling starts 2nd semester in 2018 at Rokkasho site**
- **Cryoplant has been installed at Rokkasho site**

Current status and challenges of cryogenic systems for RAON accelerator

Taekyung KI

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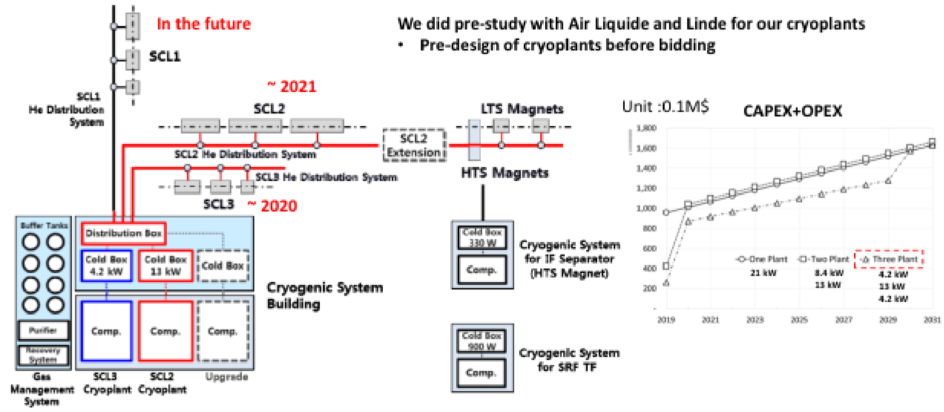
Current Status and Challenges of Cryogenic Systems for RAON Accelerator

Challenges

- Various operations of beam lines (combination of SCL lines)
  - Operation strategy for SCLs : how many cryoplants we need ?
    - Installation and operation : first -SCL3, second -SCL2, third - SCL1; **Long operation (30 years)**
    - Beam acceleration : SCL3-SCL2, SCL1-SCL2, SCL3, SCL1; **A distribution box is necessary**.
  - Cool-down and warm-up : how ?, How long time ?
    - **Fast cool-down** required (especially QWR : 150 K – 50 K within 2 hours; Q disease) and slow cool-down required (LTS magnets)
    - **Individual** cool-down and warm-up
    - Strategies are necessary for cool-down and warm-up **(thermal stress VS requirement)**.
- Stability
  - **Pressure stability**
    - ±1 mbar @ 4.5 K, ± 0.3 mbar @ 2 K due to performances of cavities
  - Safety @ various conditions
    - Quenches (LTS magnets) and leaks of insulation vacuum

Cryogenic system – Three cryoplants

- Three cryoplants with Helium Distribution System



- **Requirement and challenges are identified**
- **Cryogenic system design was introduced**
- **Three cryoplants are going to operate step by step along with the accelerator commissioning plan**
- **Cool down method and pressure stabilization method were proposed**

Thank you