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A Plan of the HWR Superconducting Linac Development at KOMAC

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On behalf of the KOMAC Accelerator team

29 Jan., 2018

KOMAC, KAERI

KAERI

KOMAC
Korea Multi-Purpose Accelerator Complex
양성자가속기연구센터

Outline

- Introduction to KOMAC facility
- Secondary Particle Beam Utilization Facility
- Previous Experiences on SRF at KOMAC
- Half Wave Resonator Design
- Design of Cryomodule
- Cryogenic System
- Summary

KOMAC – KOrea Multi-purpose Accelerator Complex

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◆ Located on Miraero (road to the future), Gyeongju (a historic city)

- ✓ Developed via Proton Engineering Frontier Project (2002.7~2012.12, 10.5 Year)
- ✓ Budget investigated: ~300M $US (Gov: 180M, Gyeongju: 110M, Industry: 10M)

Main Facility of KOMAC

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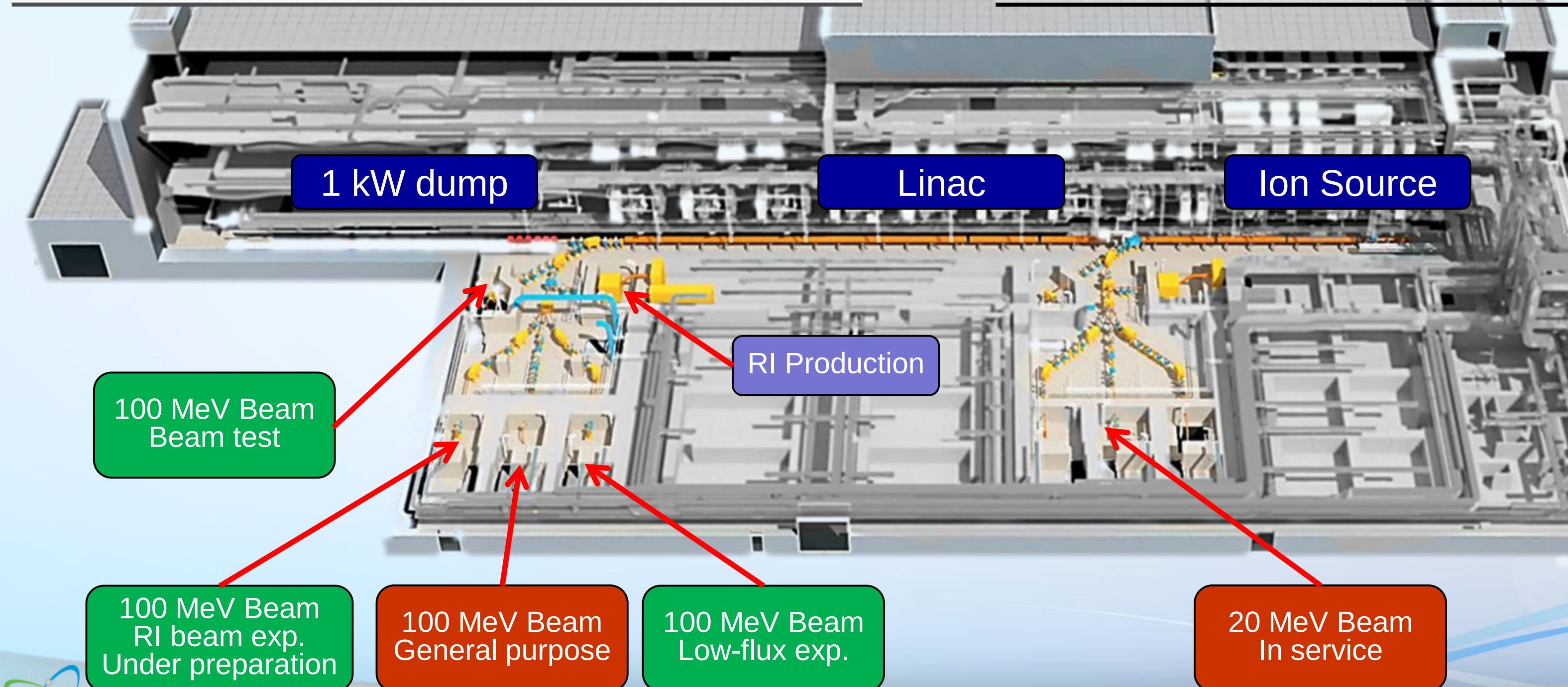
- Area: 180,000 m²
- Building: 27,322 m²
- Power : 154 kV, 20 MVA

Overview of 100 MeV Linac and Beam Lines

Features of KOMAC 100MeV linac

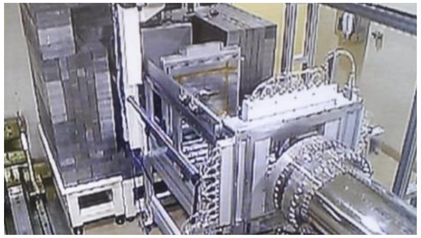
- 50-keV Injector (Ion source + LEBT)
- 3-MeV RFQ (4-vane type)
- 20 & 100-MeV DTL
- RF Frequency : 350 MHz
- Beam Extractions at 20 or 100 MeV
- 5 Beamlines for 20 MeV & 100 MeV

Output Energy (MeV)	20	100
Max. Peak Beam Current (mA)	1 ~ 20	1 ~ 20
Max. Beam Duty (%)	24	8
Avg. Beam Current (mA)	0.1 ~ 4.8	0.1 ~ 1.6
Pulse Length (ms)	0.1 ~ 2	0.1 ~ 1.33
Max. Repetition Rate (Hz)	120	60
Max. Avg. Beam Power (kW)	96	160



20 MeV BL (TR23)

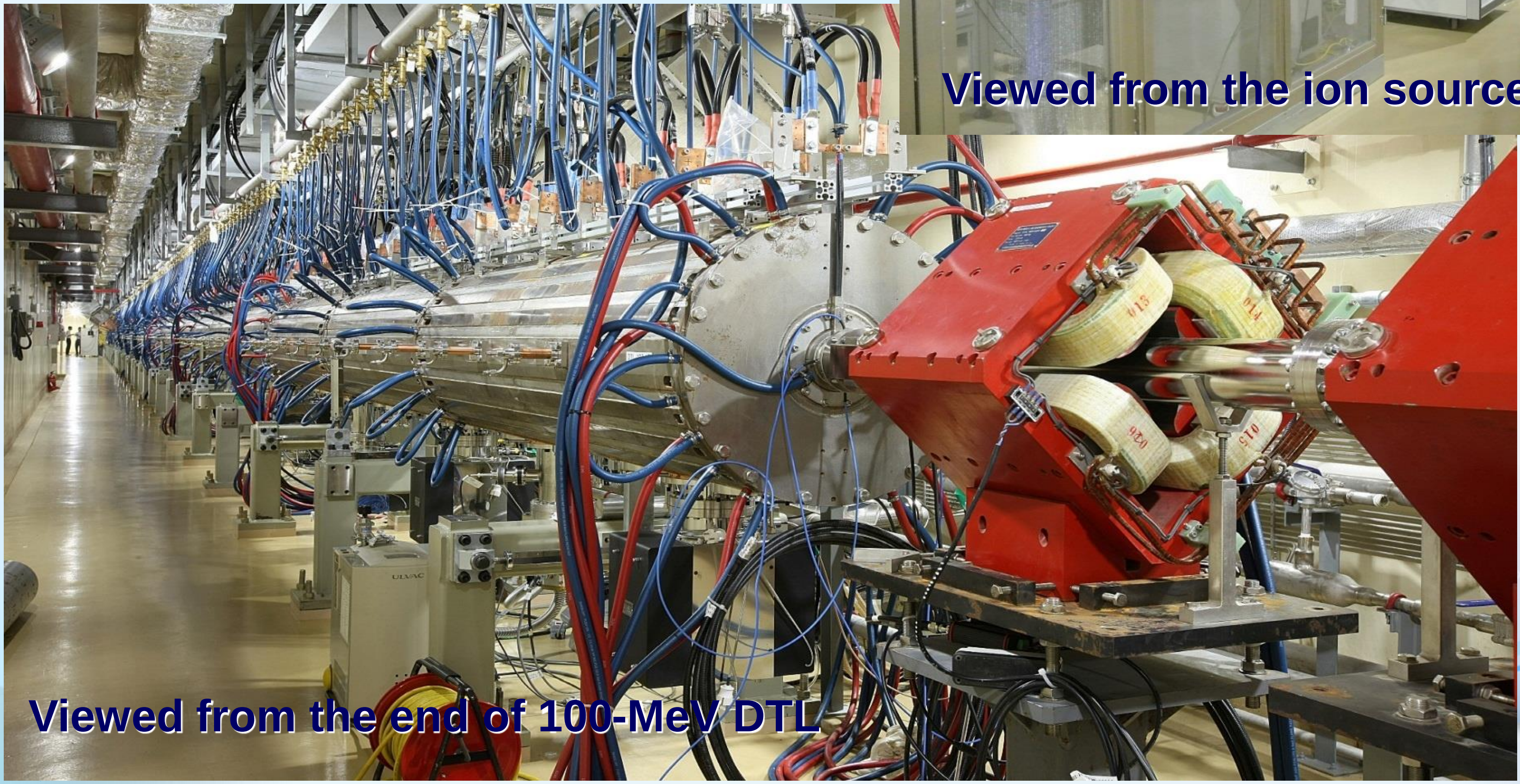
100 MeV BL (TR103)



100-MeV Linac

- Linac and beam lines : installed in 1st floor
- 100-MeV linac : 75 m
- HPRF and cooling system : installed in 2nd floor
- Modulator for klystron : installed in 3rd floor

Viewed from the ion source



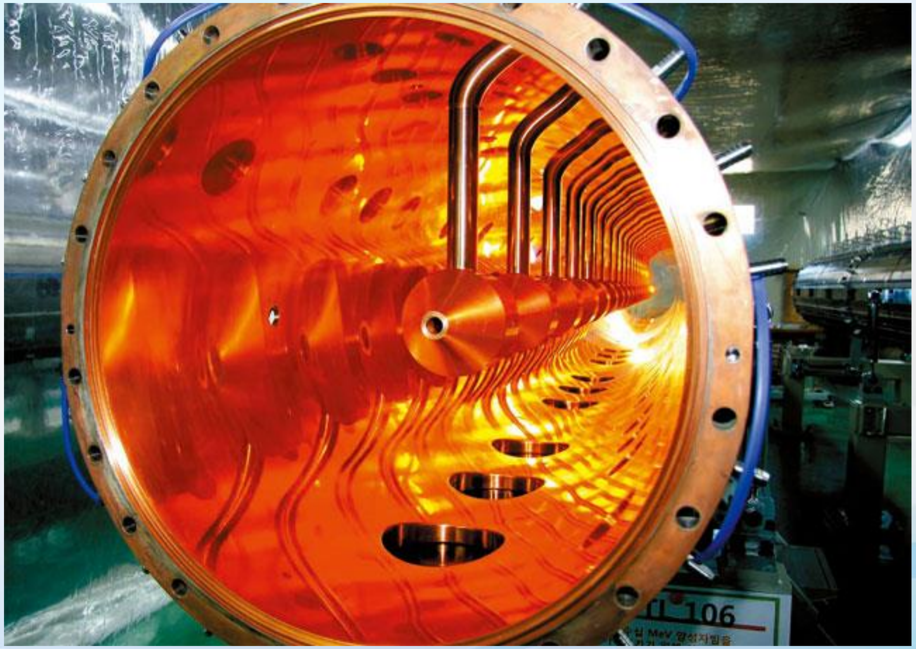
Viewed from the end of 100-MeV DTL

Accelerator Development at KOMAC

- Developed proton linac technologies over the past 15 years
  - Microwave ion source
  - RFQ
  - DTL
  - Elliptical SC cavity
  - LLRF and EPICS control system

- Built KOMAC 100-MeV proton linac of our own design with the technologies

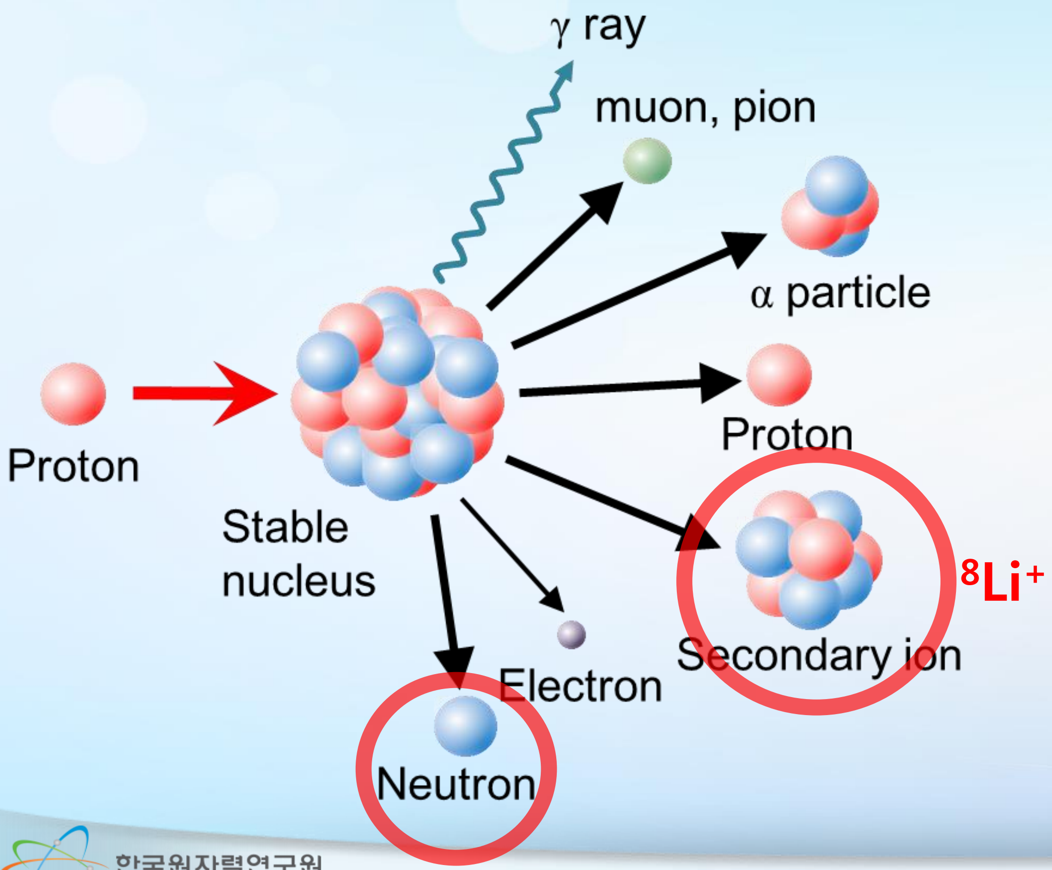
KOMAC DTL

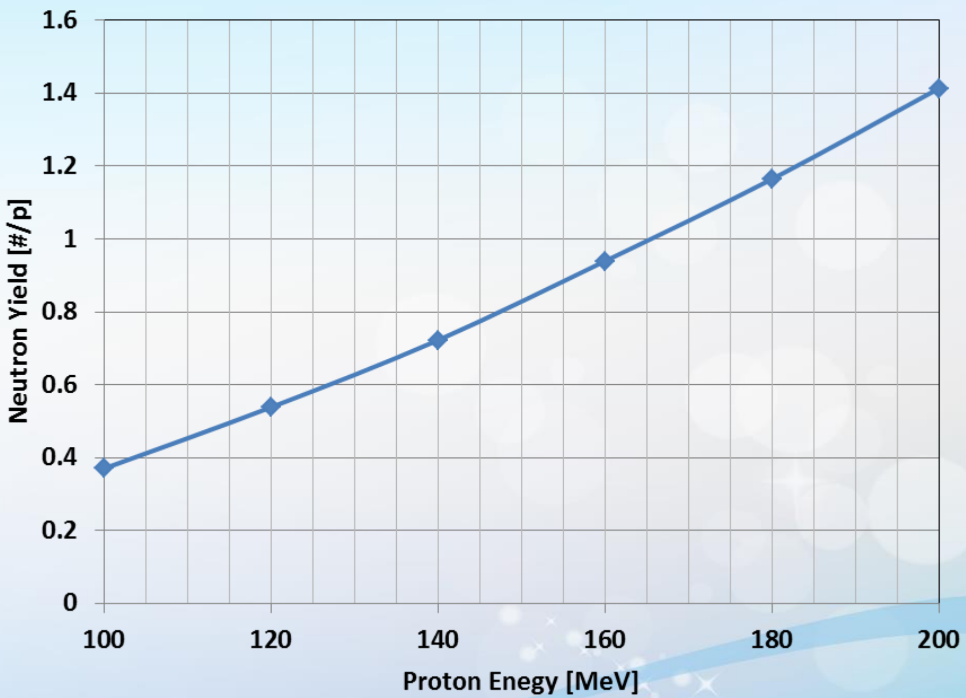


Secondary Particle

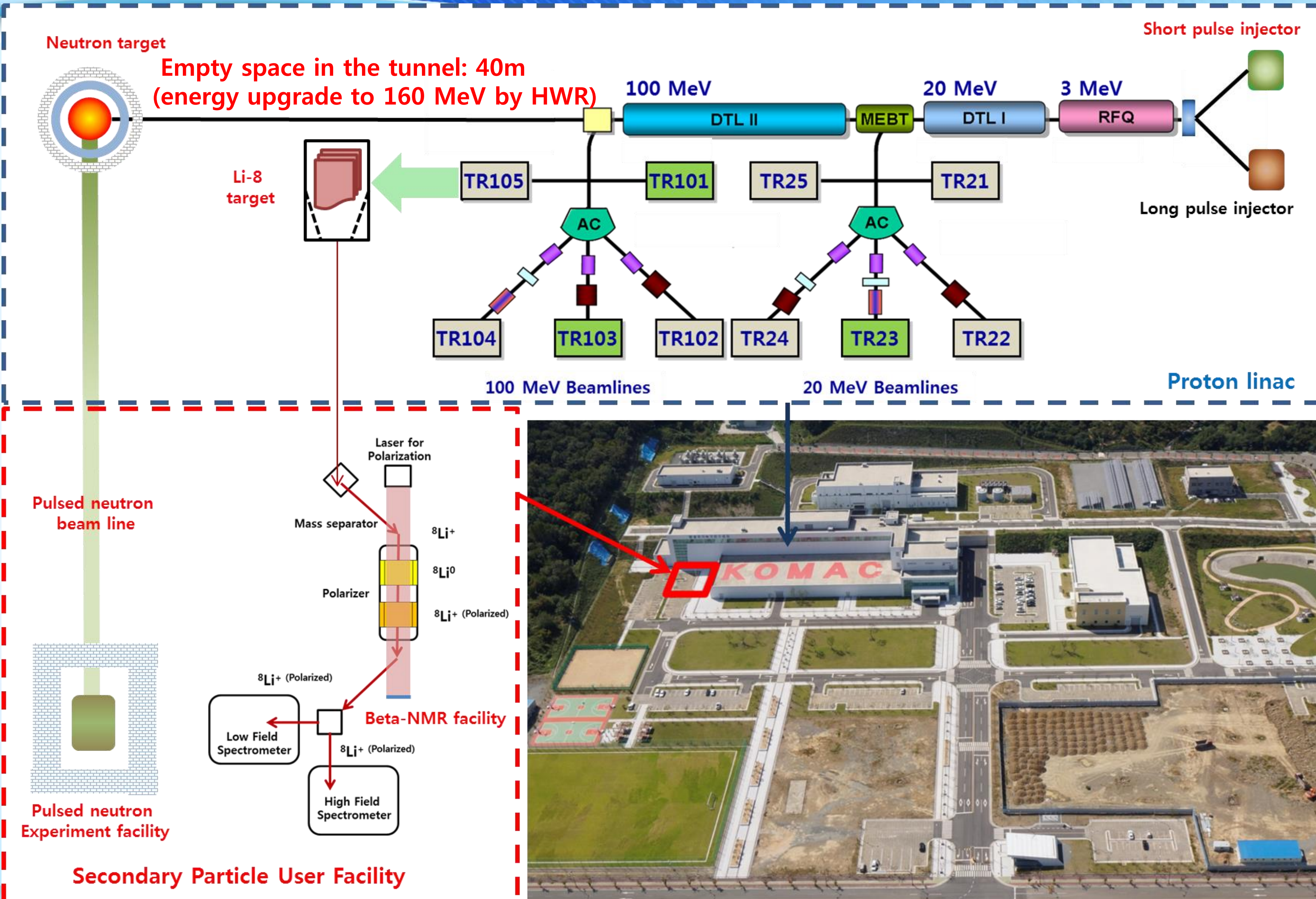
❖ KOMAC prepares programs to supply secondary particle to expand the utilization of 100 MeV proton linac.

- Neutron: Neutron imaging, Nuclear data, Detector, Semiconductor, space, etc.
- RI: Medical imaging(^{67}Cu, ^{82}Sr, ^{22}Na, etc.), β-NMR(^{8}Li, ^{11}Be, ^{31}Mg, etc.), etc.



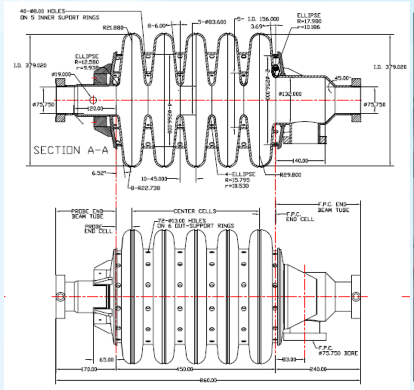


Planned Secondary Particle Facility



Previous Experience - Elliptical SC Cavity

- Prototyping the 700 MHz, 5-cell elliptical cavity with domestic company
- Design, fabrication and test experience on the elliptical cavity



Design

Forming

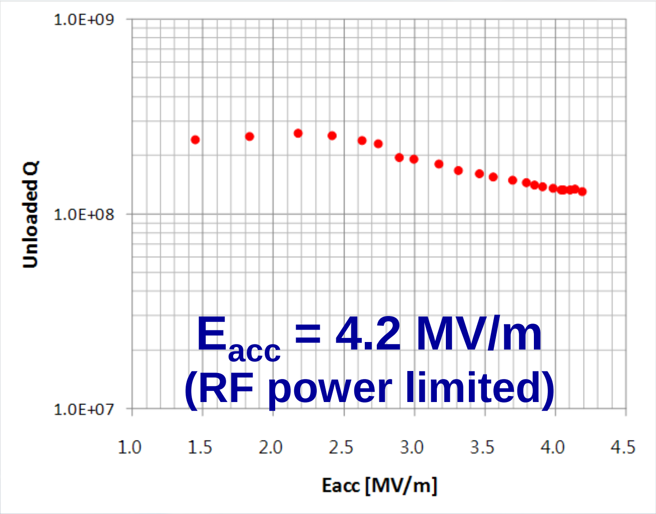
E-beam welding

Tuning

Cleaning

Test preparation

Test



Test result

HWR Parameter Sweep – TTF and Energy Gain

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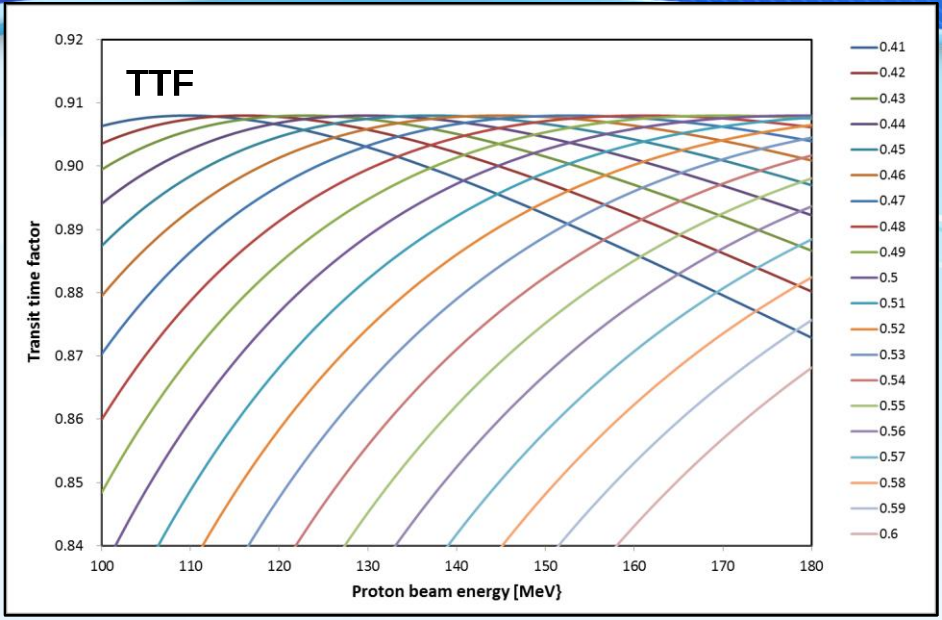

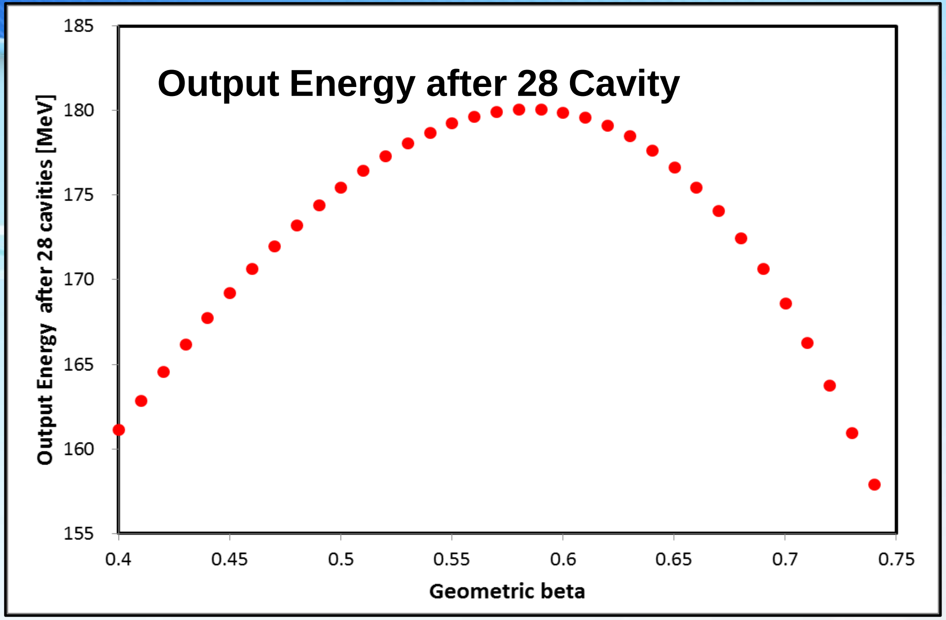

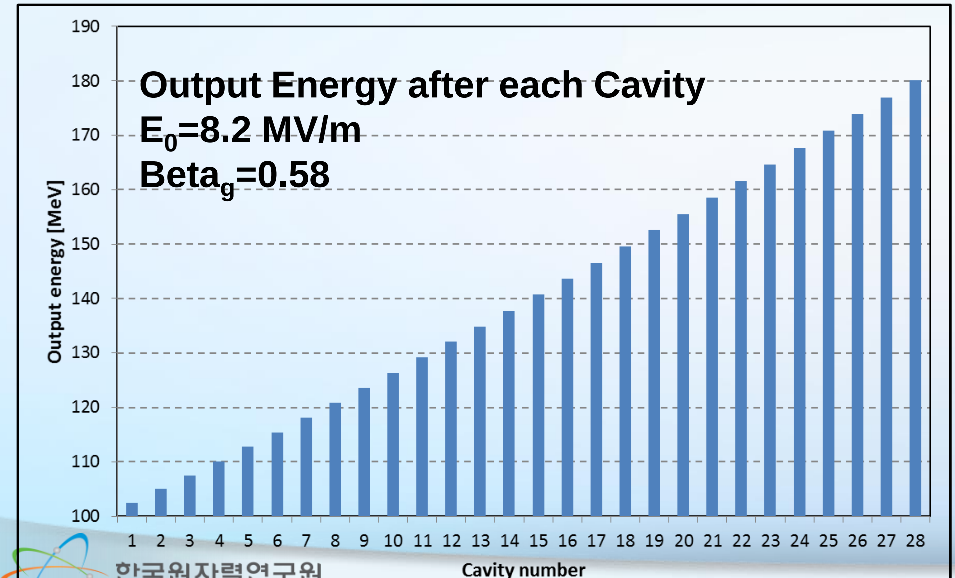

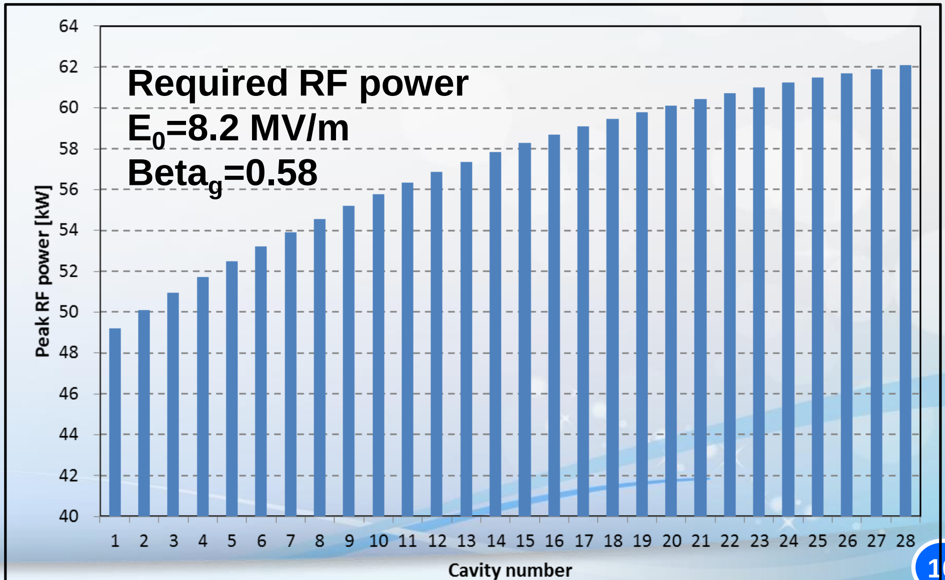

Baseline Design Concept

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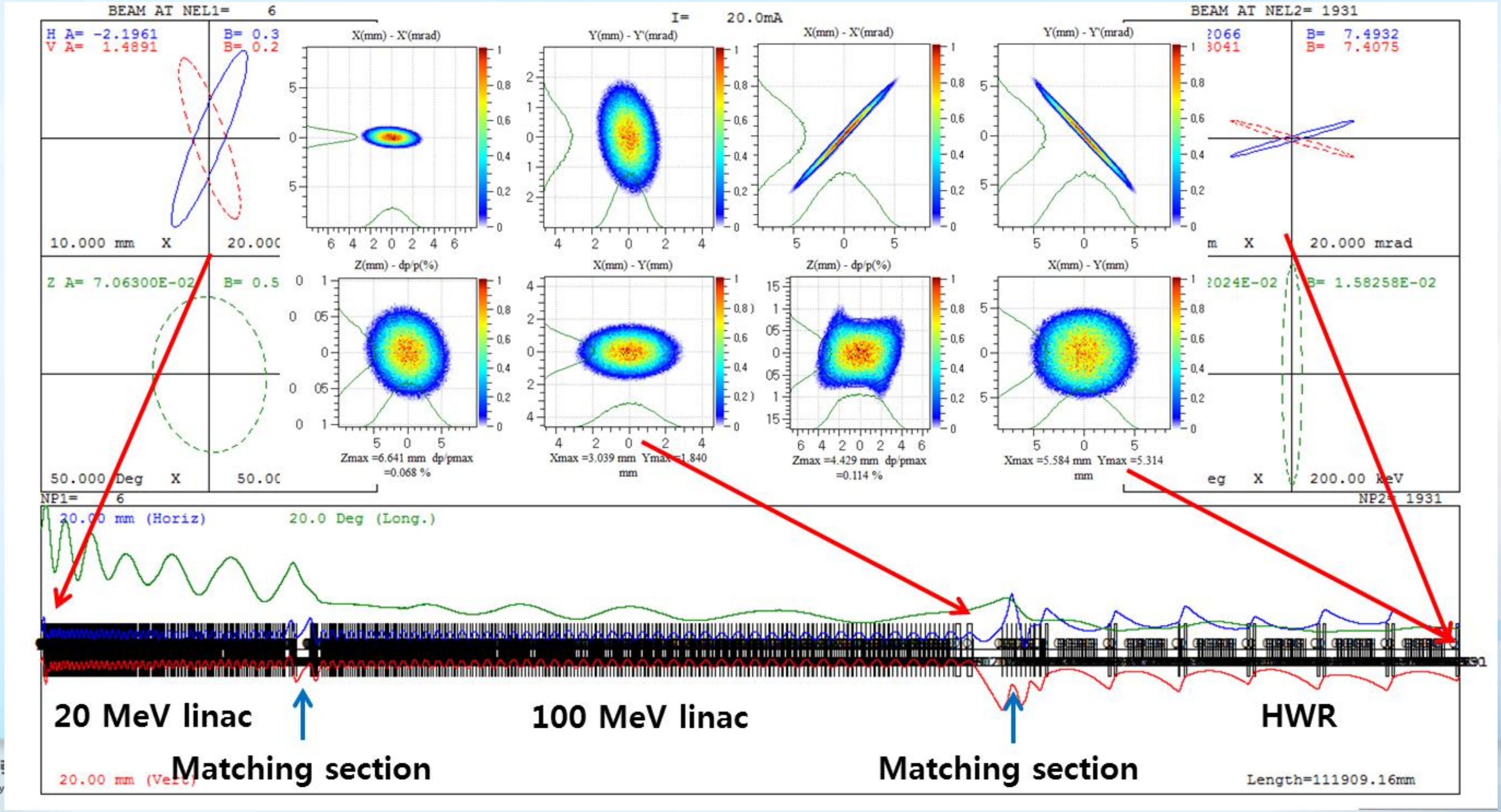
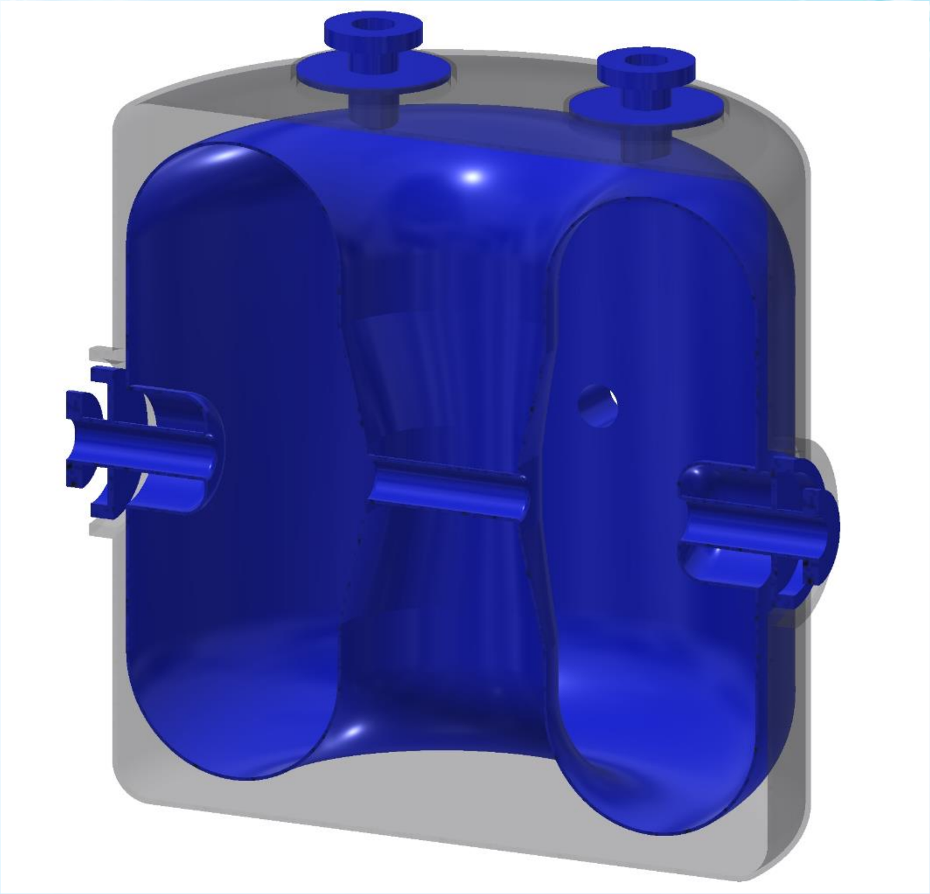
- 4 cavities / cryomodule
- External normal conducting quadrupole magnet for focusing
- Lattice: doublet
- Operation temperature: 2 K
- Cavity geometry: height~0.5 * λ, diameter~beta_g * λ, cylindrical cryomodule
- Use well proven technologies (tuner, coupler, cryomodule, etc.) except HWR cavity



HWR Design – Baseline Design Parameter

Design constraint: Epeak < 35 MV/m, Bpeak < 70 mT



Parameter	Unit	Value
Frequency	MHz	350
Optimum beta	-	0.65
Geometric beta	-	0.58
Stored energy	J	20.26
Vacc @optimum beta	MV	3.623
V0	MV	4.074
Eacc @optimum beta	MV/m	7.295
E0	MV/m	8.200
Ep	MV/m	34.370
Bp	mT	69.680
Ep/Eacc	-	4.71
Bp/Eacc	mT/(MV/m)	9.55
R/Q @optimum beta	ohm	294.9
G	ohm	128.4
Q_0 @Rs=20 nΩ	-	6.42E+09
Cavity loss @RS=20 nΩ	W	6.94
Aperture	mm	40
Leff	m	0.496799

HWR Design – Electric and Magnetic Field

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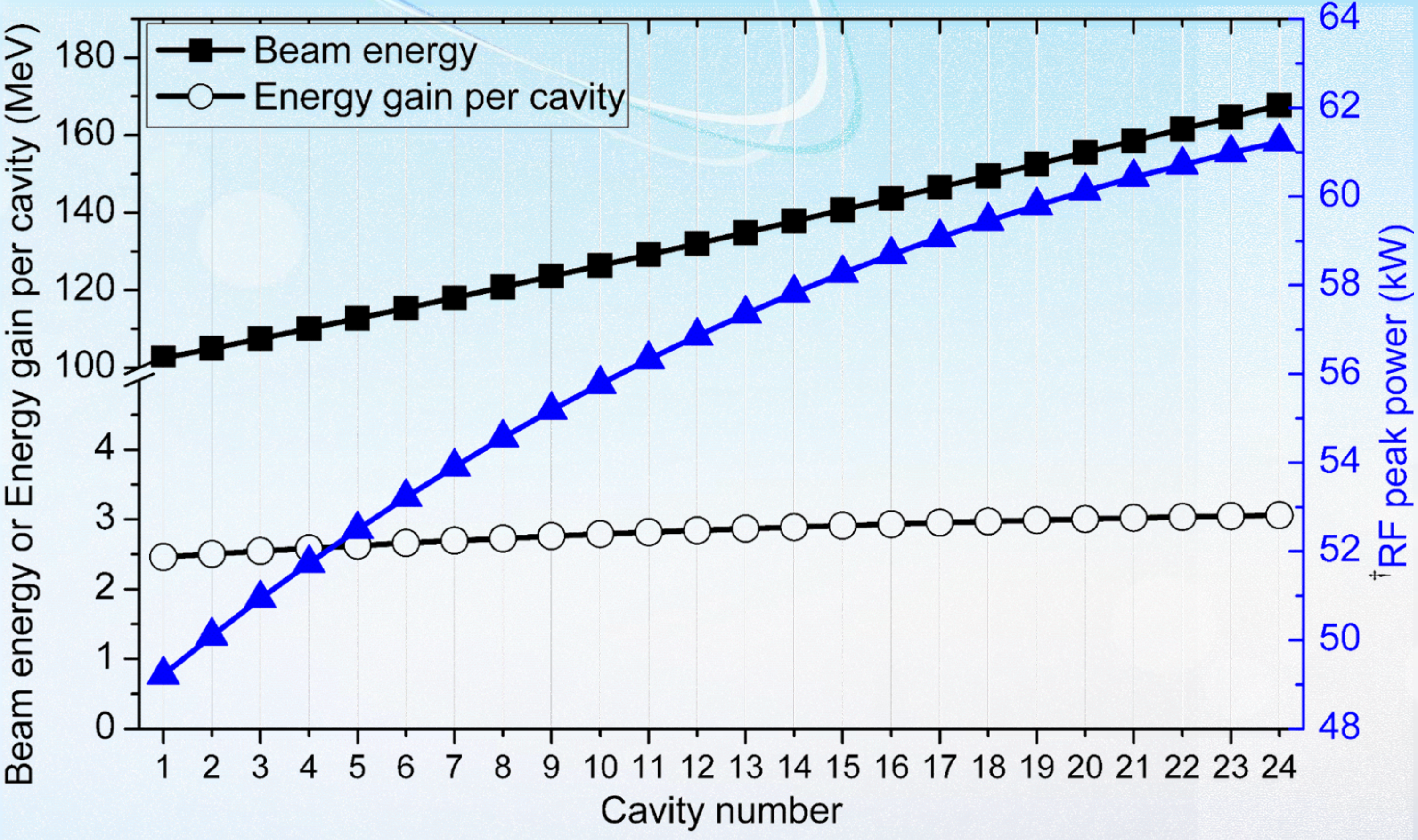

†$I_{beam,pk}$ = 20 mA

HWR Design – Electric and Magnetic Field

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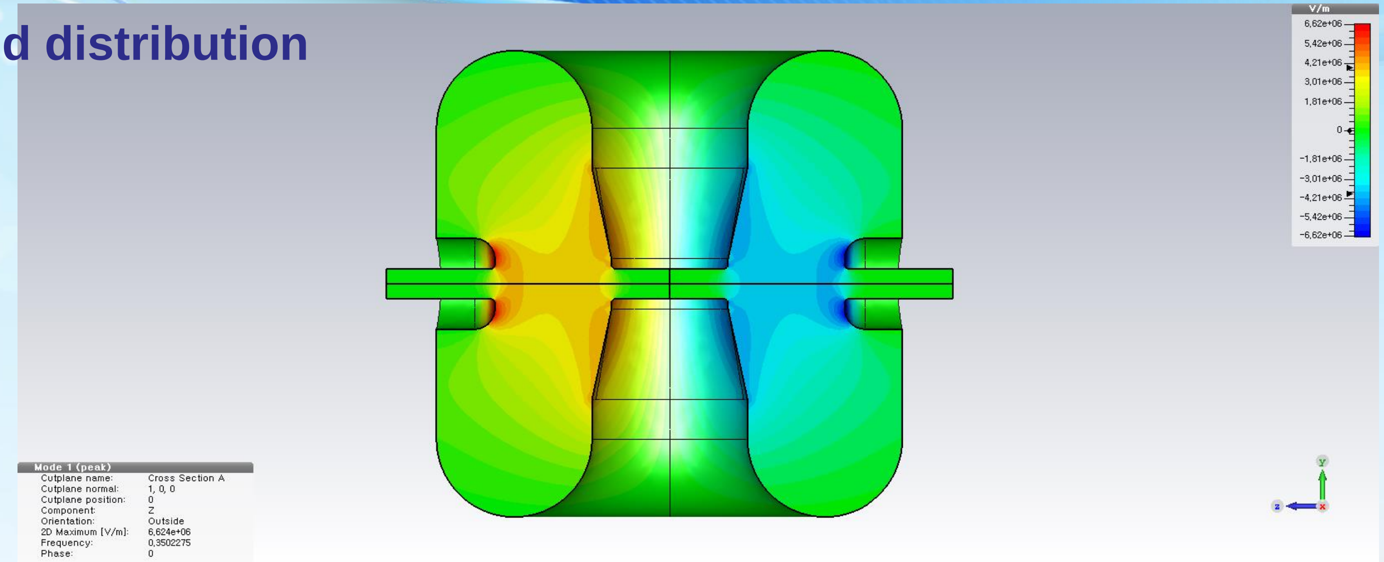
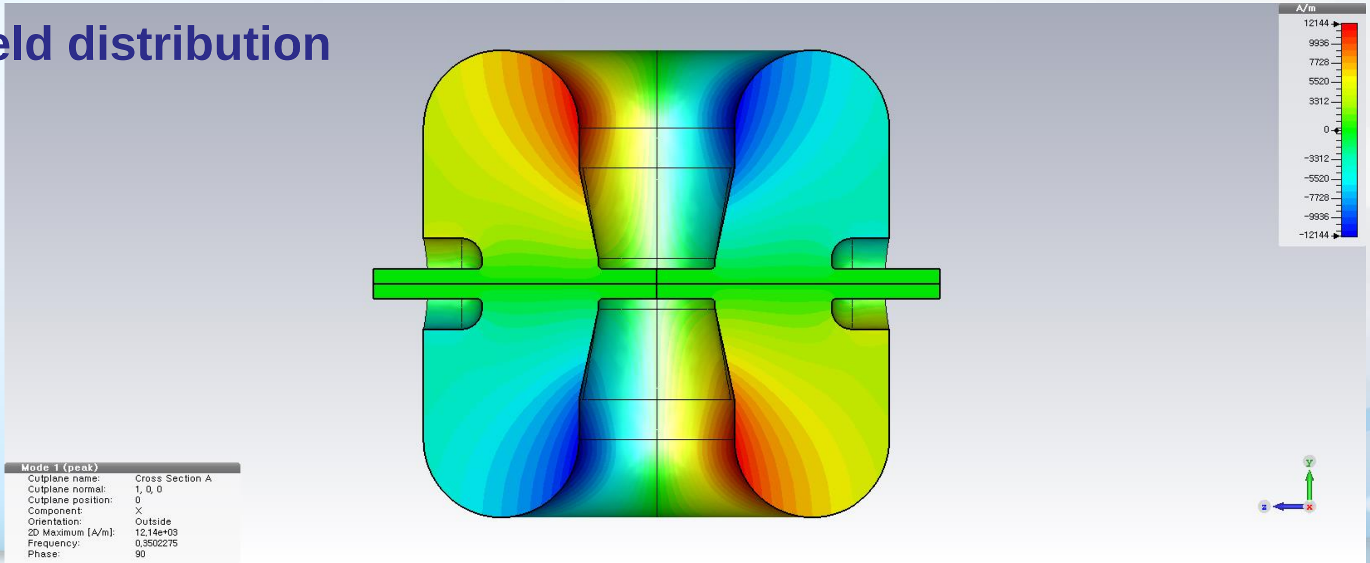
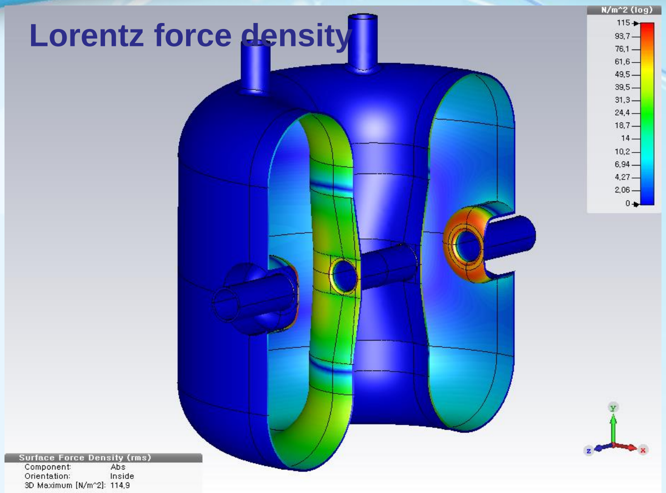
Electric field distribution

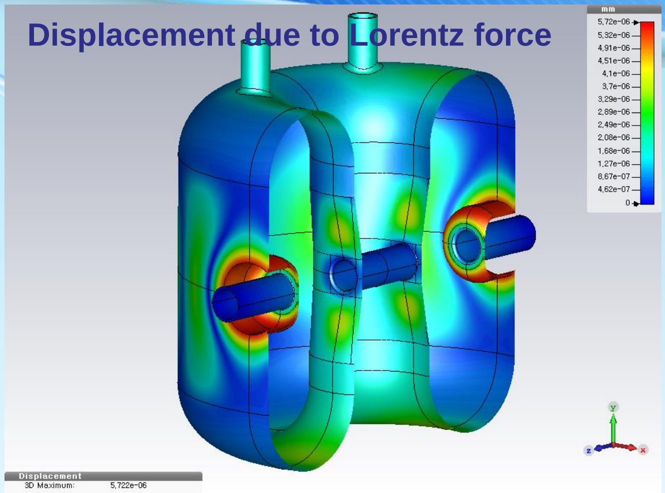


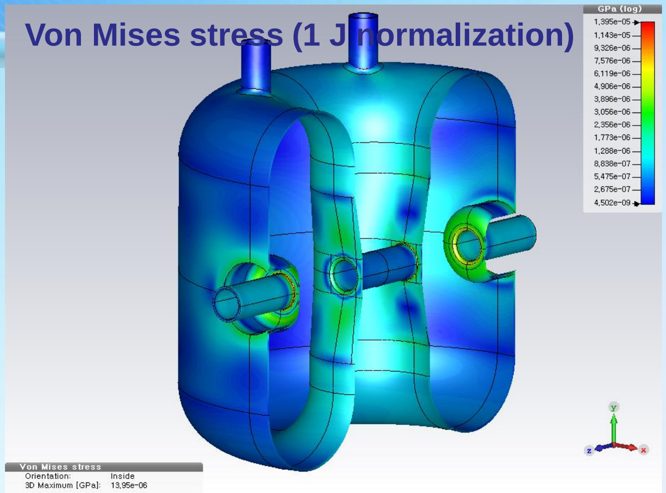
Magnetic field distribution

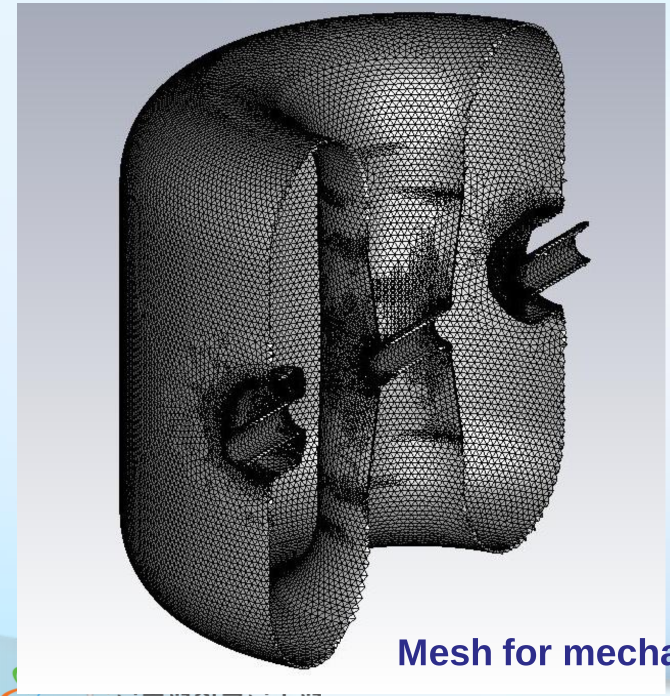


HWR Design – Mechanical Aspect





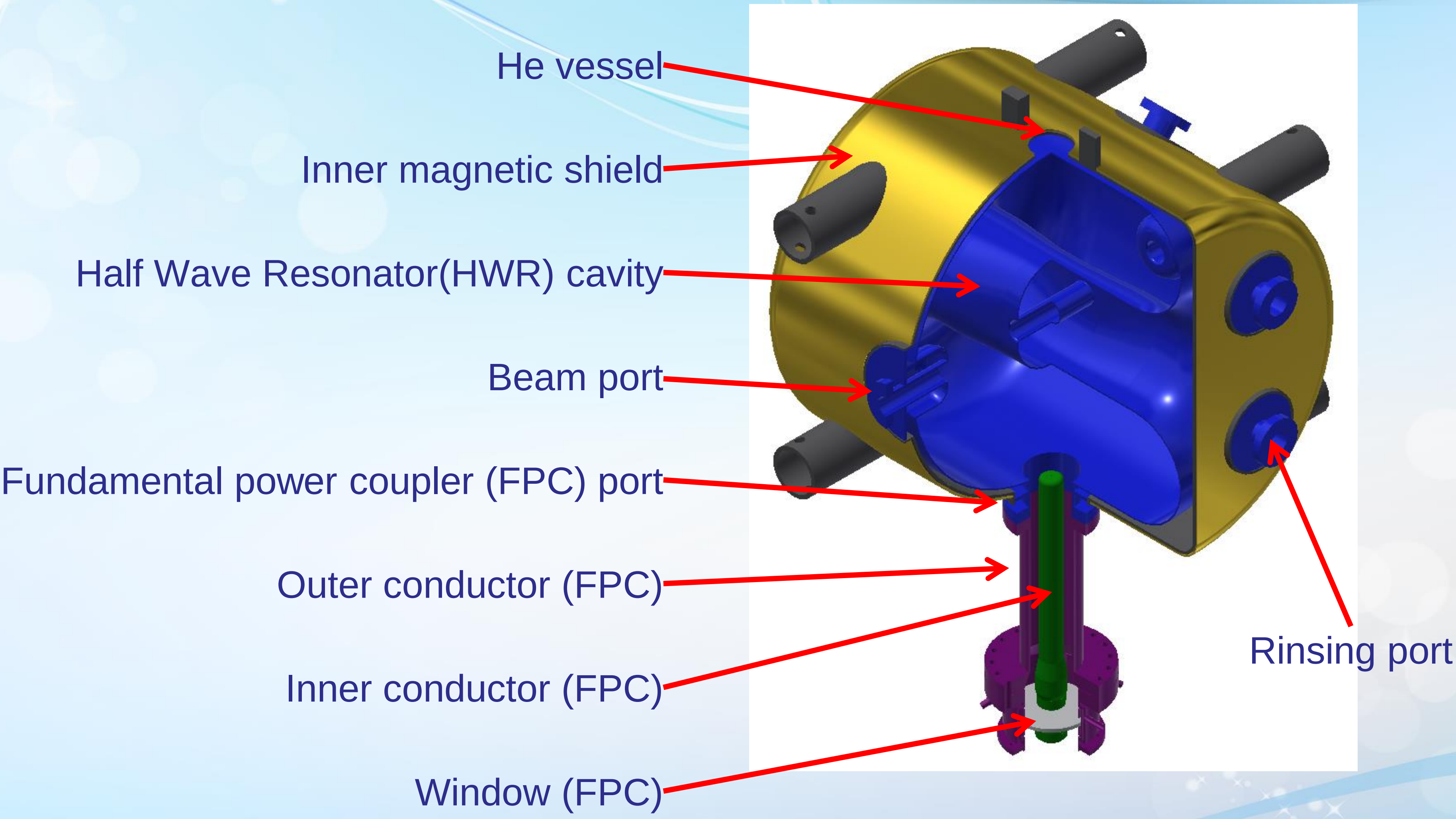




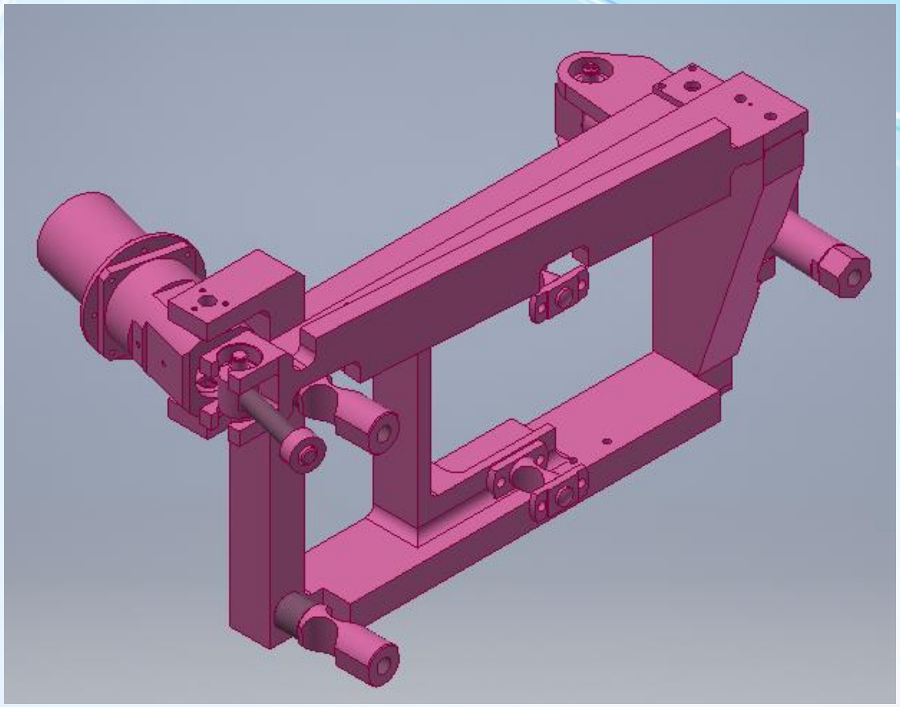
Wall thickness	2.5	3.0	3.5	4.0	[mm]
Lorentz Detuning	-2.2	-1.7	-1.4	-1.2	[Hz/(MV/m)^2]
He pressure sensitivity	5.1	5.0	3.3	3.0	Hz/torr
Tuning sensitivity	88.8	87.1	89.3	101.3	kHz/mm (±0.5 mm)

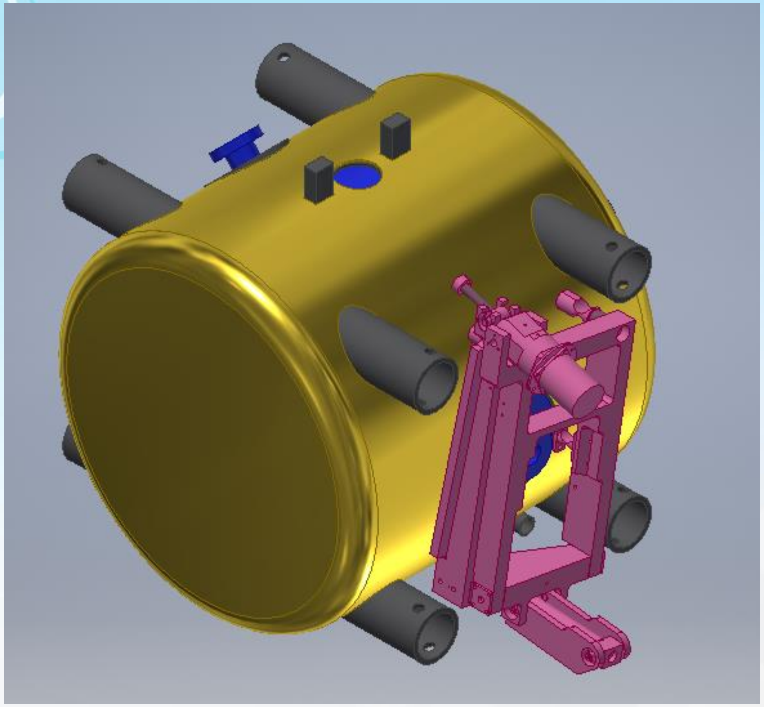
Mesh for mechanical Analysis

HWR Design – Helium Vessel Assembly



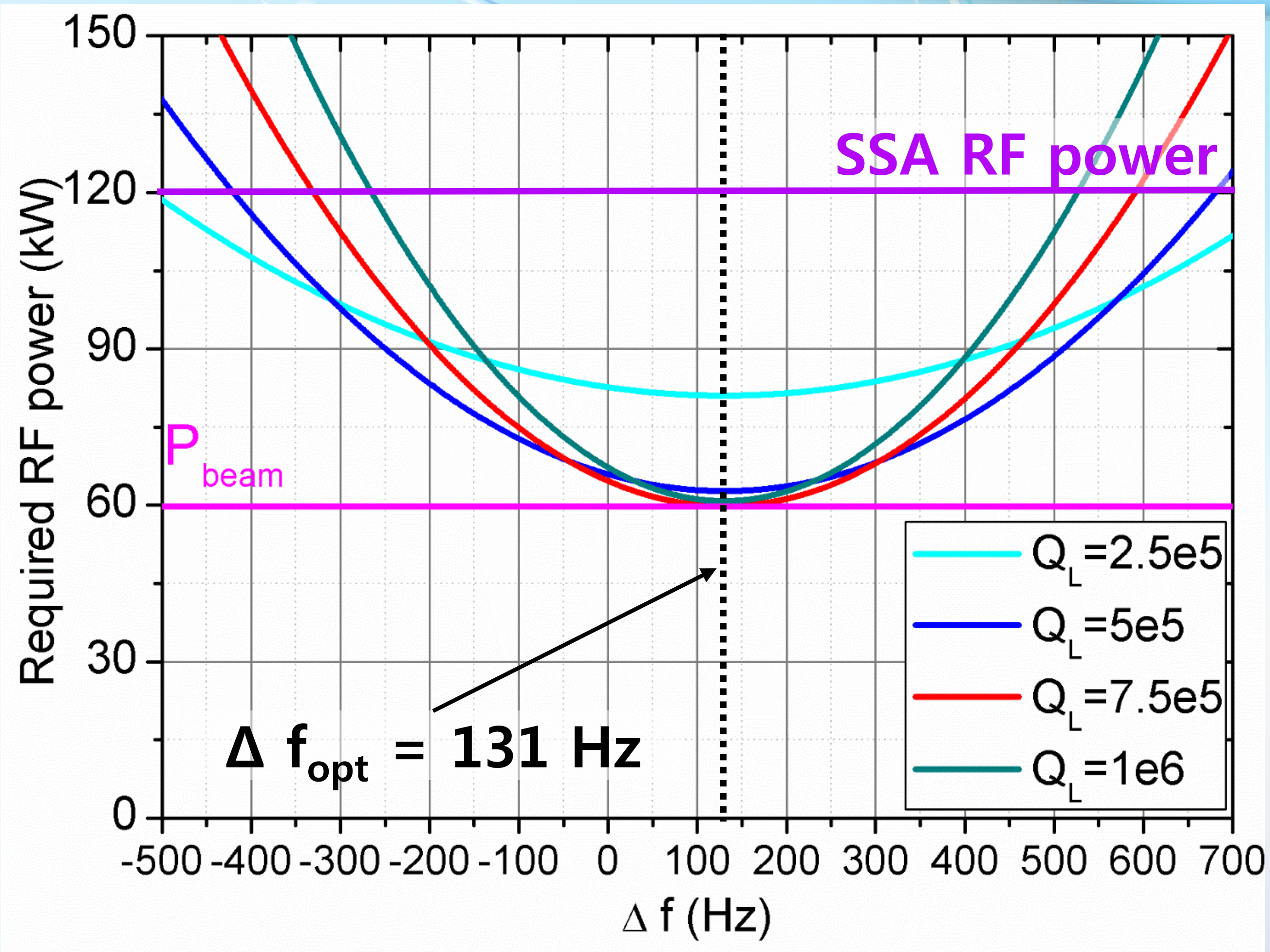
Cavity Tuner





- End lever Saclay-I type (well-proven in TTF, SNS)
- Piezo tuner for fast tuning may be omitted
- Detailed mechanical analysis will be performed

RF Power Coupler



- β = 0.51 (150 MeV)
- $I_{beam,pk}$ = 20 mA
- Q_b = 7.74E5

- **Max. detuning due to Lorentz force ~ 400 Hz**
- **Avoid fast tuner by large bandwidth of RF coupler and RF power margin**

RF Coupler External Q

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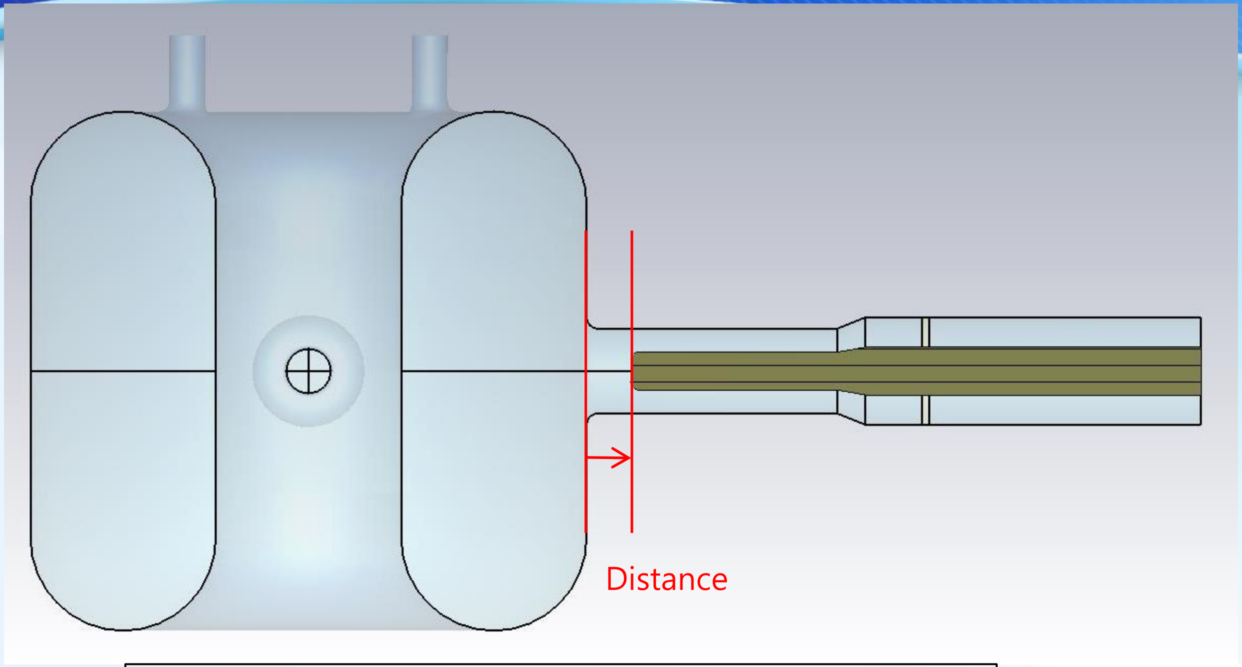
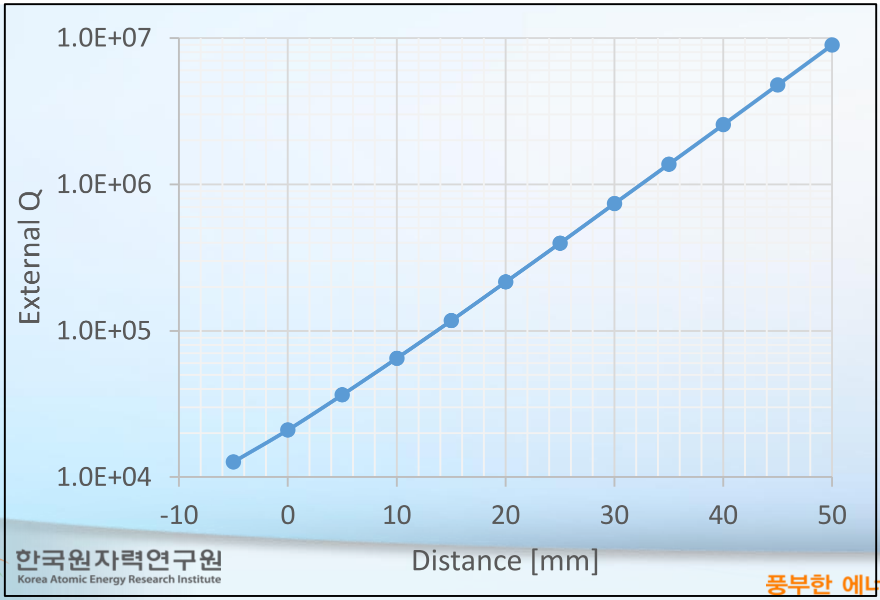
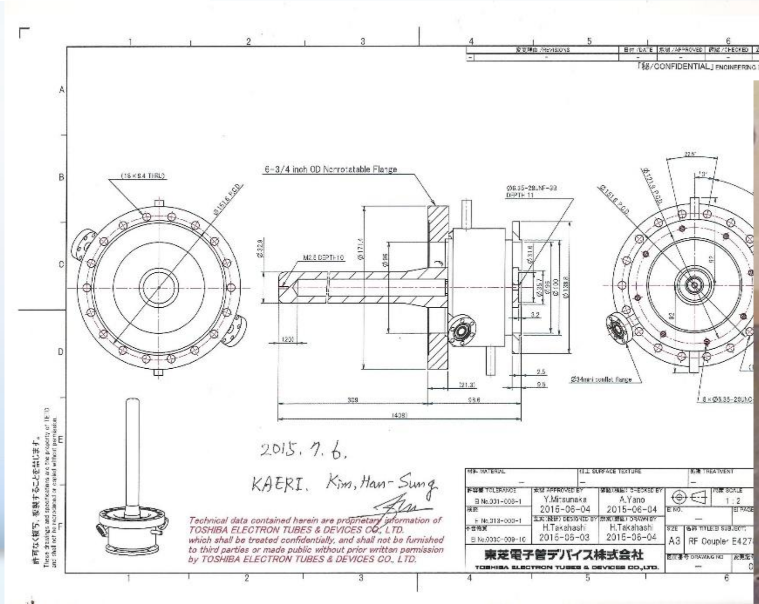


Distance [mm]	Qex
-5	1.27E+04
0	2.10E+04
5	3.65E+04
10	6.48E+04
15	1.17E+05
20	2.15E+05
25	3.96E+05
30	7.38E+05
35	1.37E+06
40	2.55E+06
45	4.77E+06
50	8.93E+06





High Power RF System

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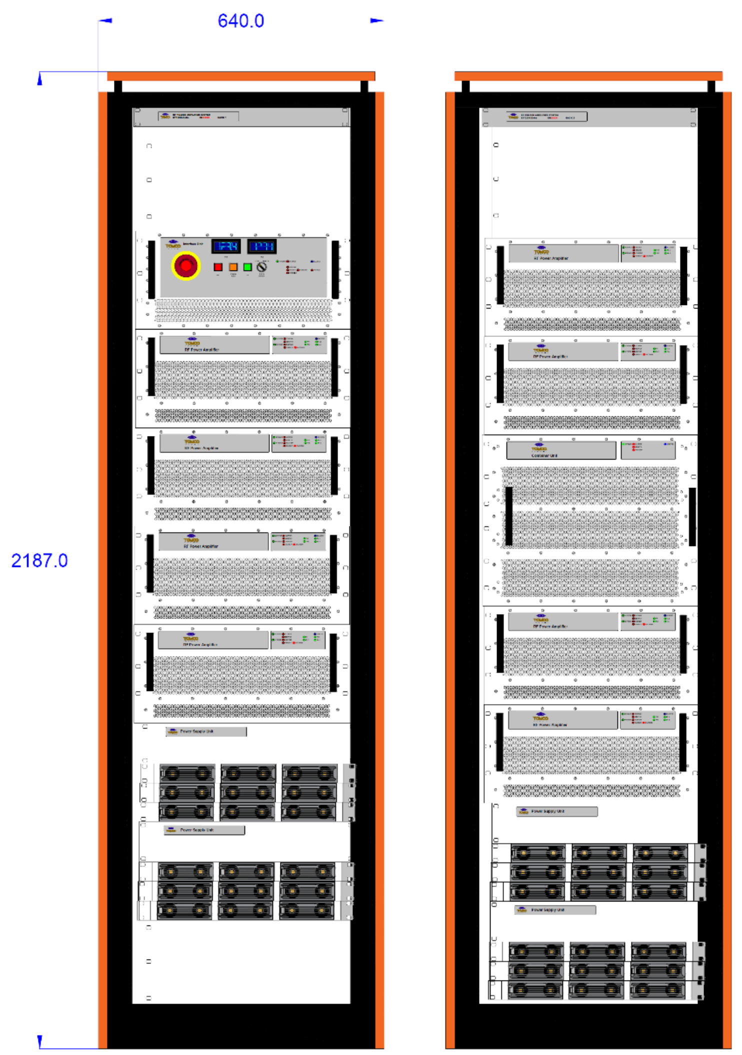
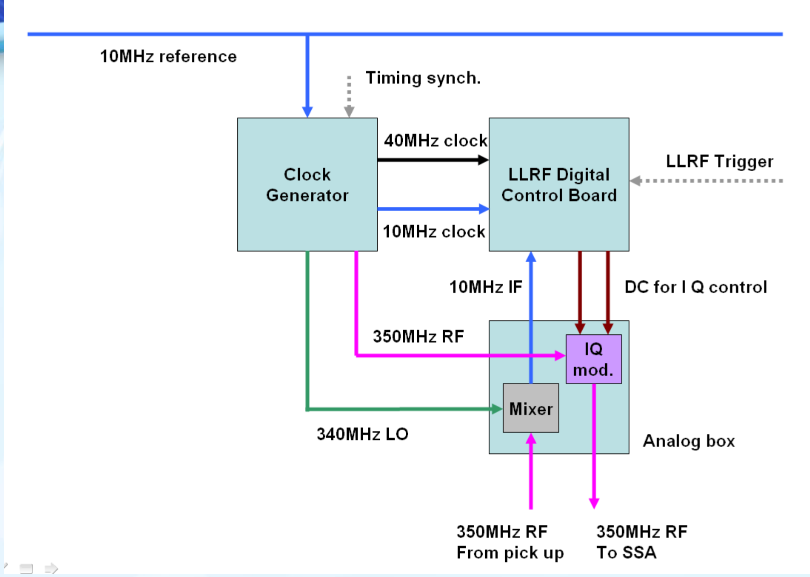


Rack 1: 4 x Amplifer Units, 1 x Interface Unit

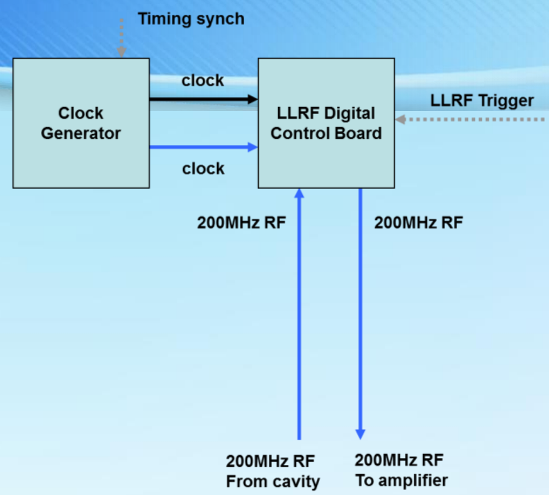
Rack 2: 4 x Amplifer Units, 2 x Power Supply Units, 1 x 8:1 Combiner Unit

Parameter	Specification
Frequency	350 MHz
1dB bandwidth	+/- 2 MHz
Rated power	120 kW
Max. pulse width	1.6 ms
Max. duty cycle	10 %
Harmonics	Less than -30 dB
Load VSWR	Handles 1.5 mismatch
RF input signal	10 dBm for full power
Connectors	3-1/8" flange
Cooling	Forced air
Protection	Over temperature Over drive Out-of-band input Excessive VSWR

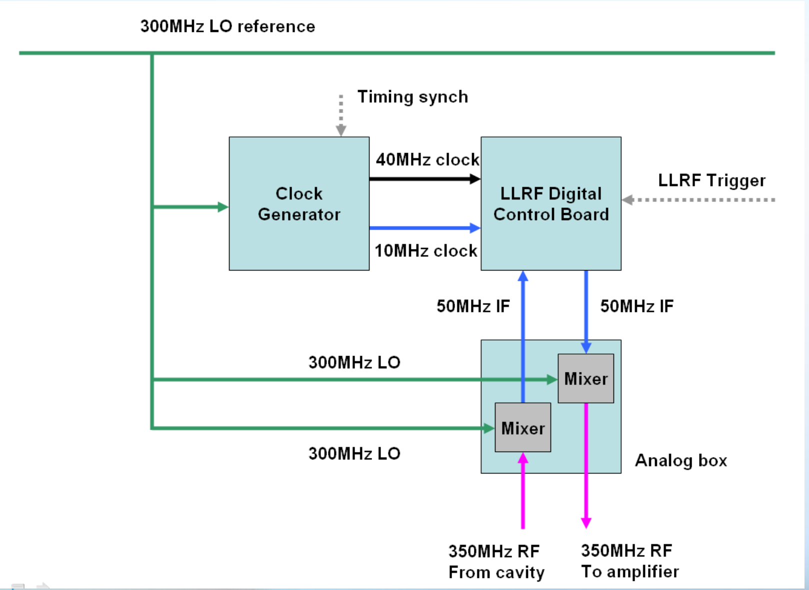
Low-Level RF System



1st generation digital LLRF for KOMAC 100MeV linac



Proposed digital LLRF for He RFQ



2nd generation digital LLRF for KOMAC 100MeV linac

- Direct RF sampling
  - Minimizing analog components (especially mixer)
  - Increasing error due to the jitter
  - Non-IQ sampling

Cryomodule Design

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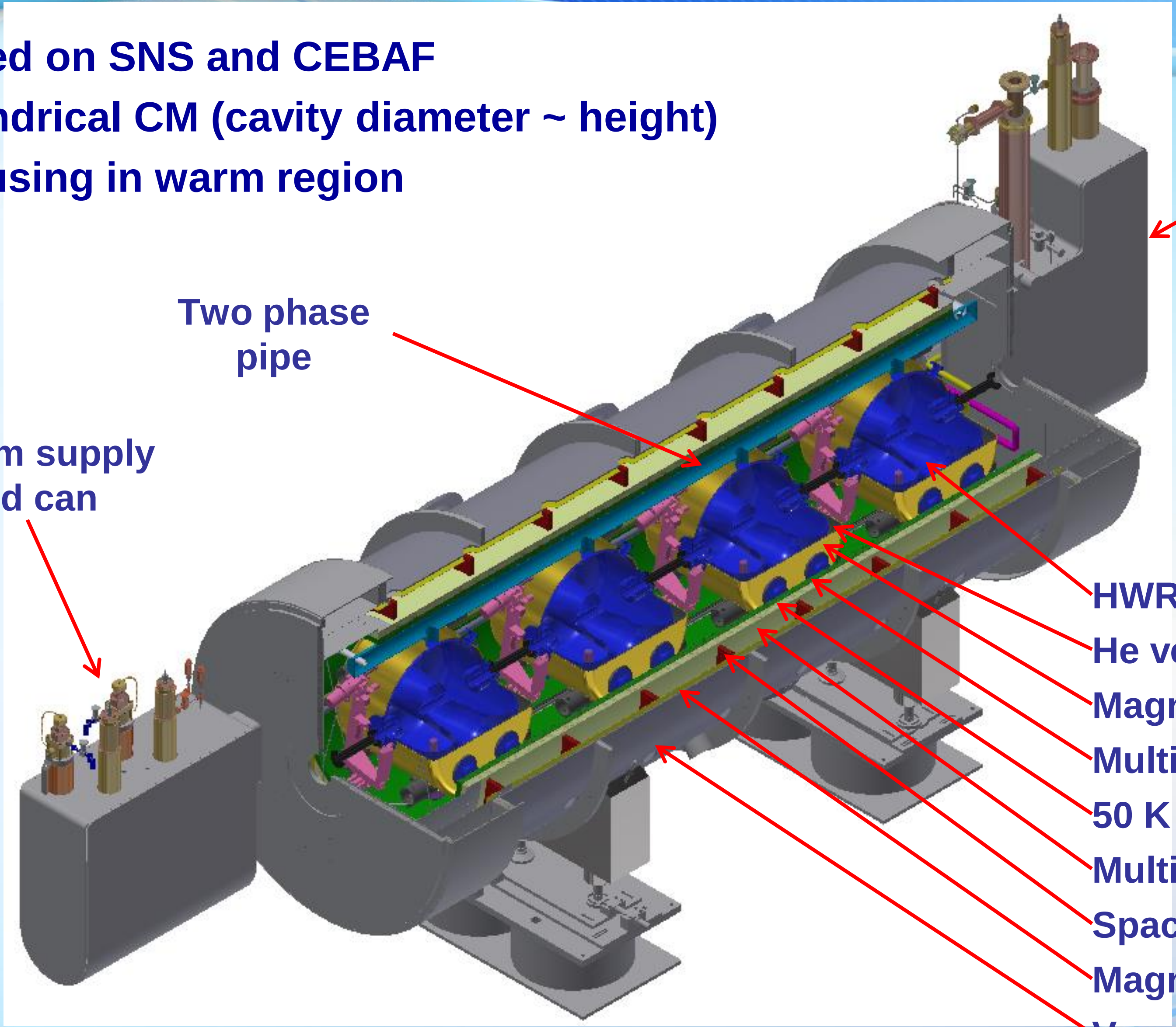
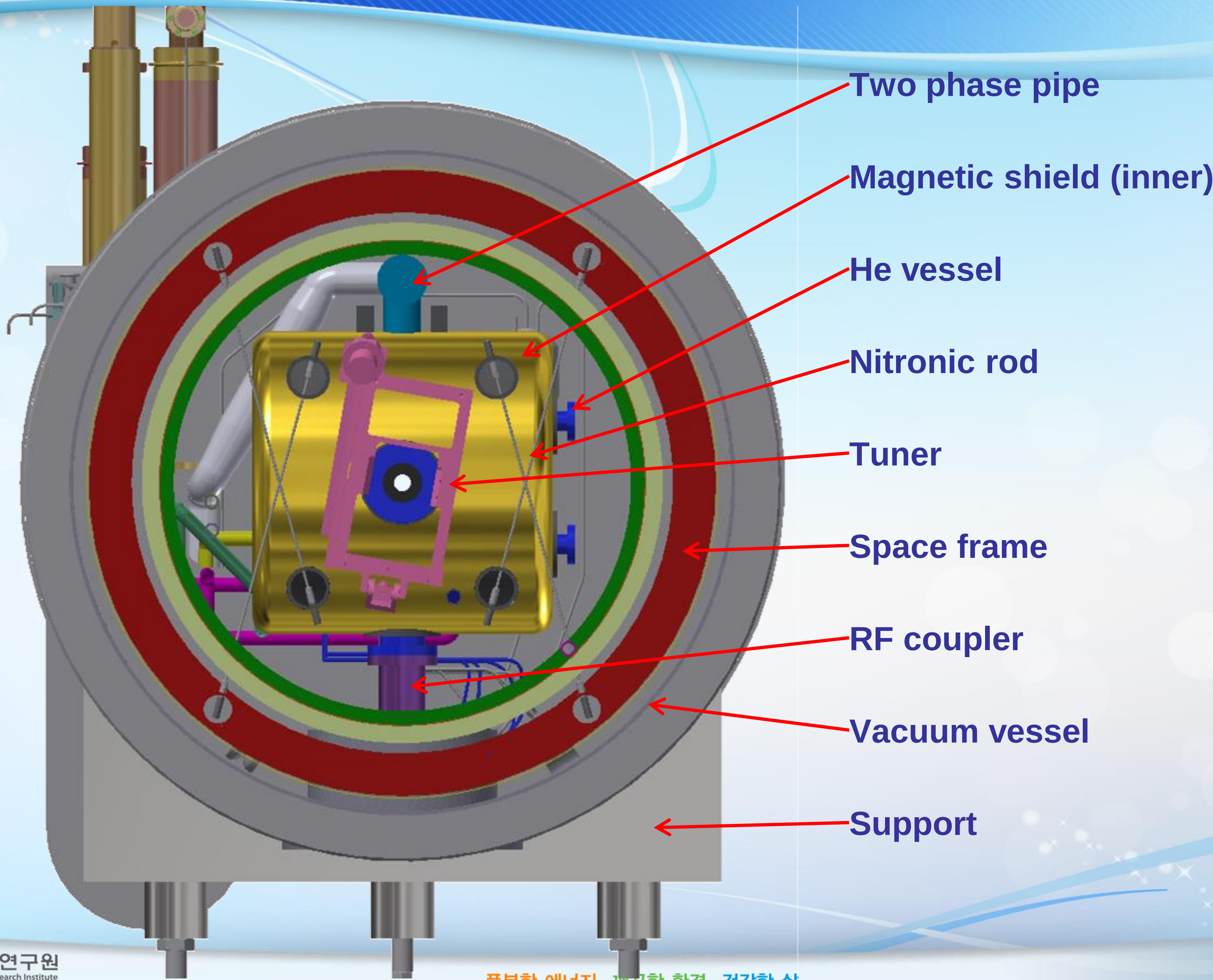
- Based on SNS and CEBAF
- Cylindrical CM (cavity diameter ~ height)
- Focusing in warm region



Inside Cryomodule



Heat Load Estimation

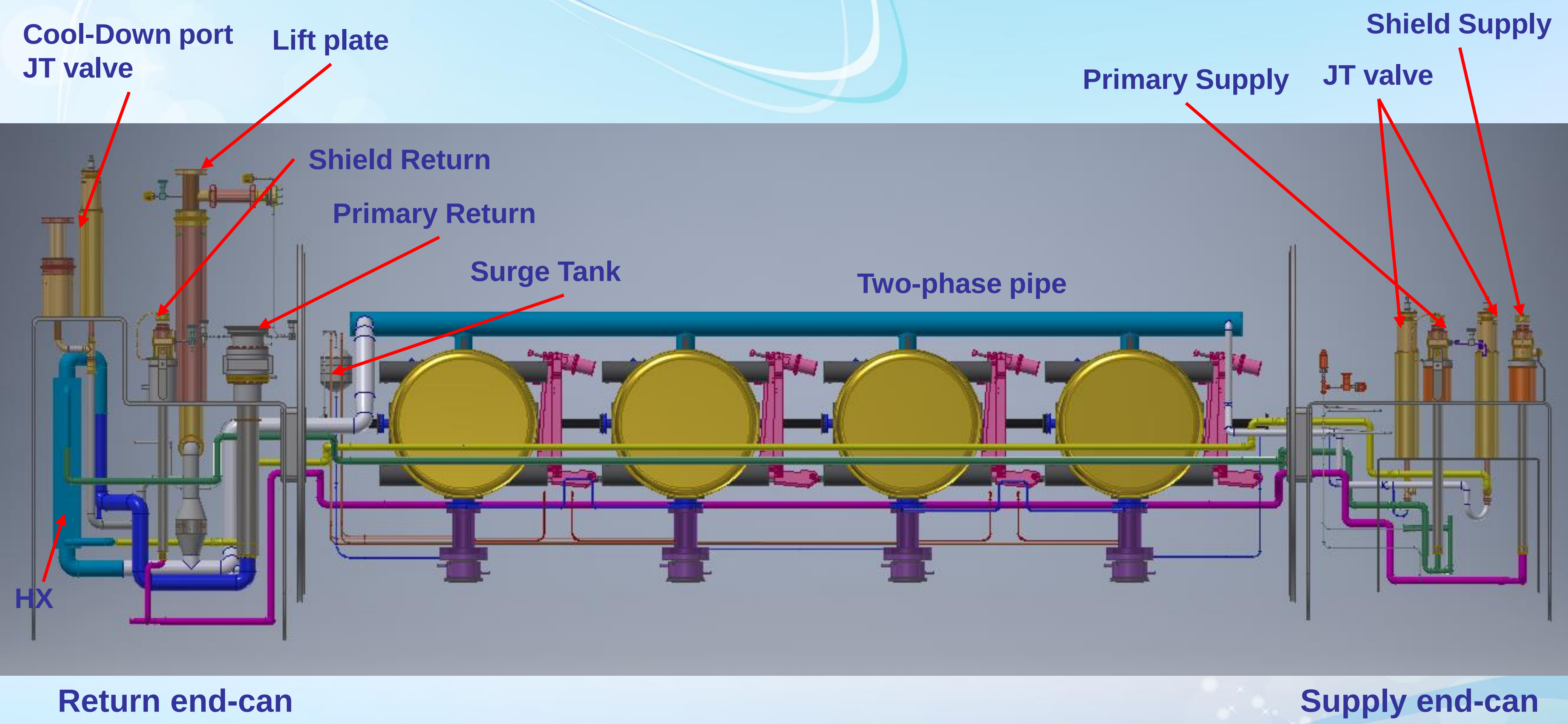
- Heat shield
  - 50 K heat shield
  - MLI inside and outside heat shield
- Heat load
  - Static: coupler, tuner, He vessel supports, beam tube, cables, valves, etc
  - Dynamic: cavity, coupler

	2 K	50K
Static	10.4W	125W
Dynamic	3.8W	-
U-tube and line*	10W	24W
Total	24,2W	149W

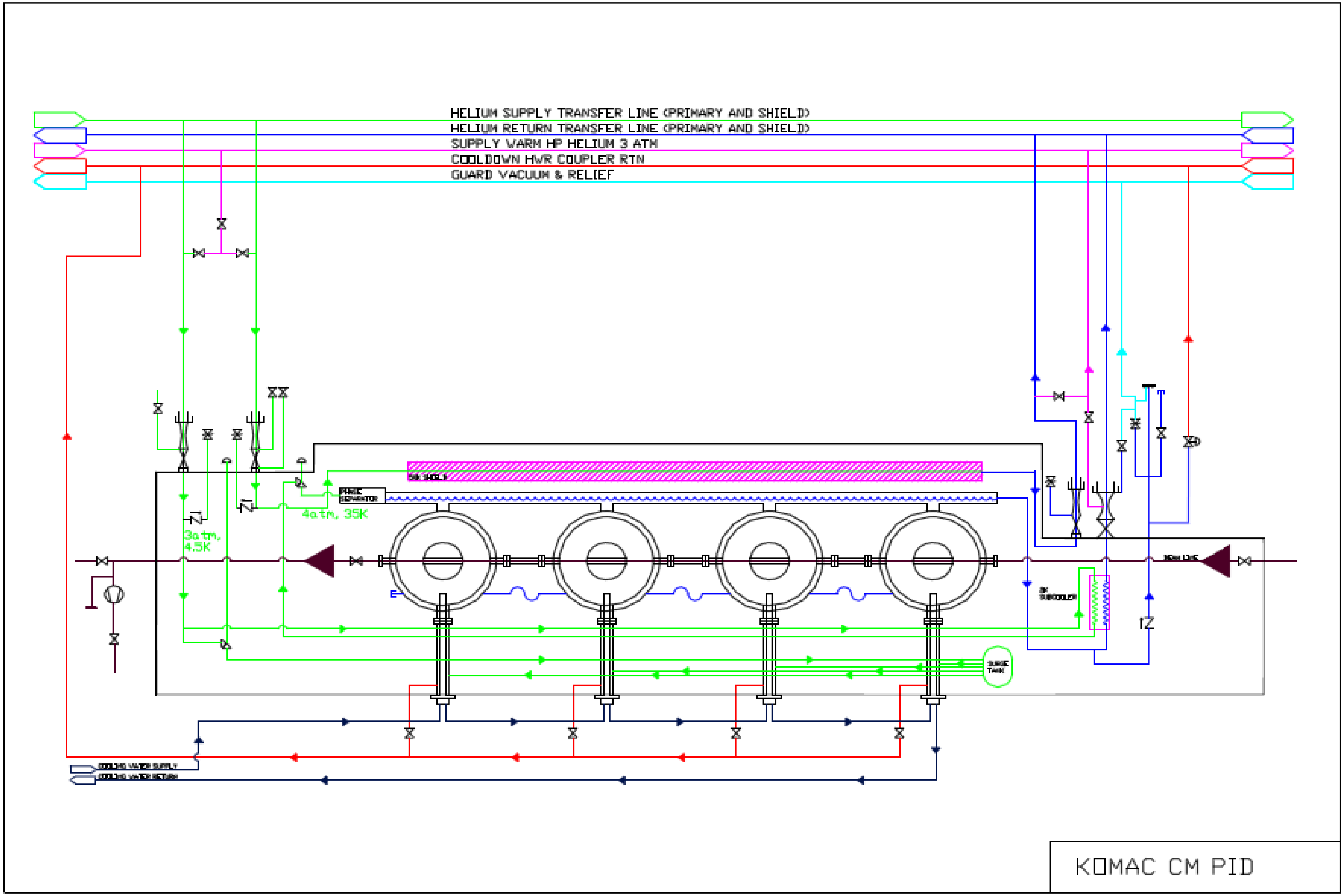
85W (4K equivalent) / cryomodule

* Ref. SNS cryomodule parameter

Cryogenics Piping in Cryomodule



Cryogenic Helium Flow



Cryogenic Plant

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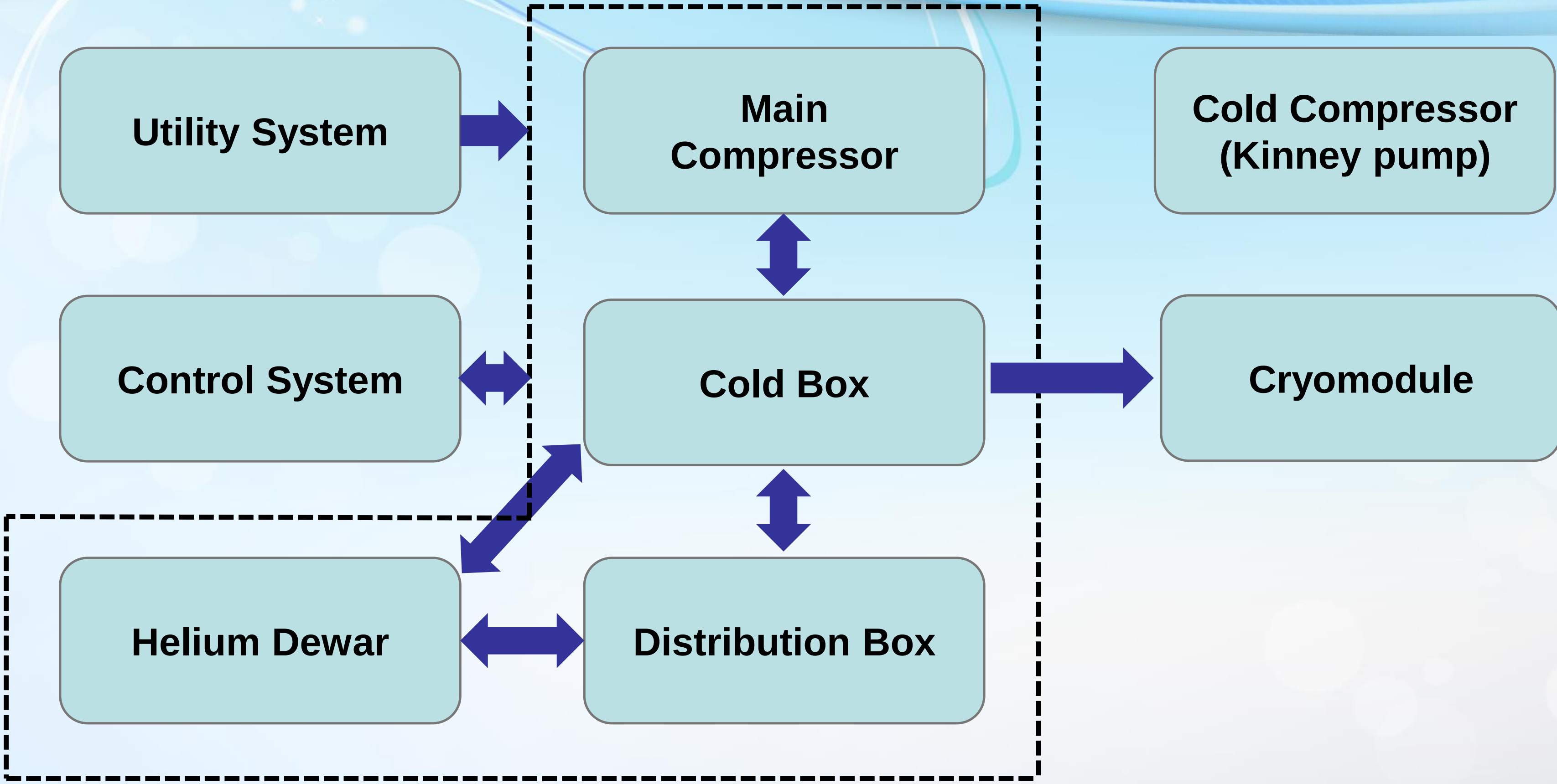

Operating mode	Refrigeration	Liquefaction	Note
Refrigeration mode	213 W @4.5K	NA	With LN2 precooling
Mixed mode	190 W @4.5 K	4 L/h @1.25 bara	With LN2 precooling
Liquefaction mode	NA	40 L/h @1.25 bara	With LN2 precooling

Summary

- Facility for Secondary Particle Beam is planned at KOMAC
  - Pulsed neutron for neutron-related science and technology
  - Li-8 beam for beta-NMR (advanced surface analysis)
  - Neutron yield can be increased more than factor of 2 with energy upgrade to 160 MeV
  - Space available in existing tunnel
- SCL based on Half-Wave Resonator
  - 350 MHz (same as normal conducting section)
  - Geometric beta: 0.58
  - Electromagnetic and Structural Mechanical Analysis
  - RF power coupler based on coaxial window with peak RF power of 120 kW
- Cryomodule and Cryogenics
  - Cylindrical cryomodule (well proven technology)
  - 4 cavities / cryomodule
  - Normal conducting quadrupole doublet focusing in warm section
  - Cryogenics (helium plant) are under study
  - Prototyping of cavity and CM from this year


Thank you
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