Commisioning of KIRAMS-30 Cyclotron for Nuclear Science Research

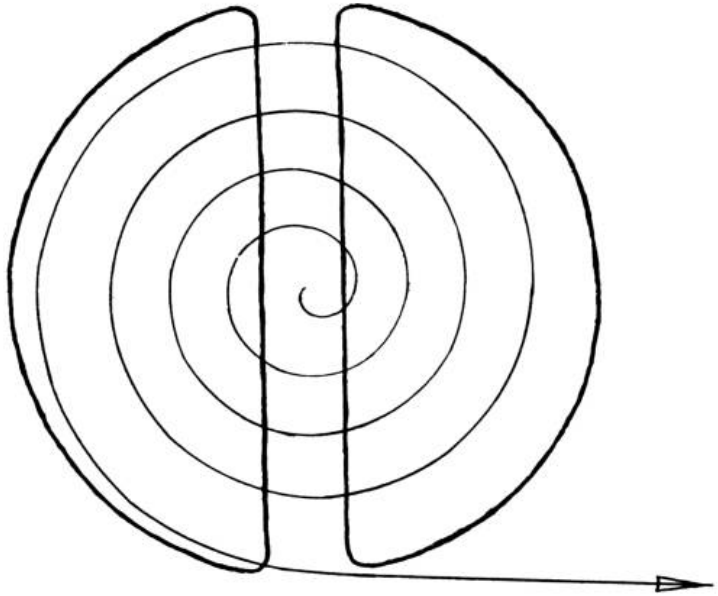
Jong-Seo CHAI

Radiation Medical Science Research Center

Korea Institute of Radiological and Medical Science

(KIRAMS)

Introduction

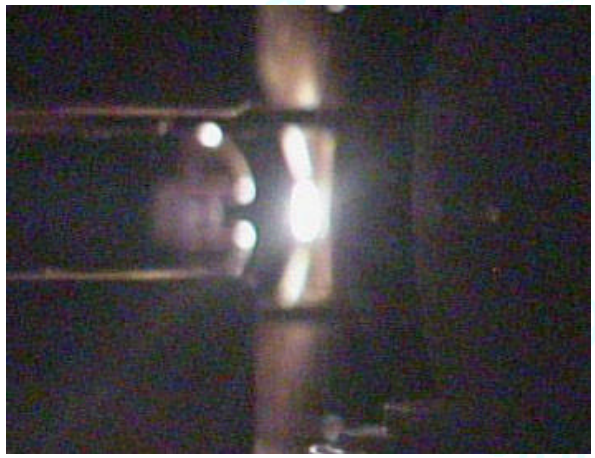


. . . the inventor

XBD9705-02291.TIF

2000. 10 First Development of 1 MeV Cyclotron

Energy: 1 MeV
Particle:proton
Beam Current: 100 nA

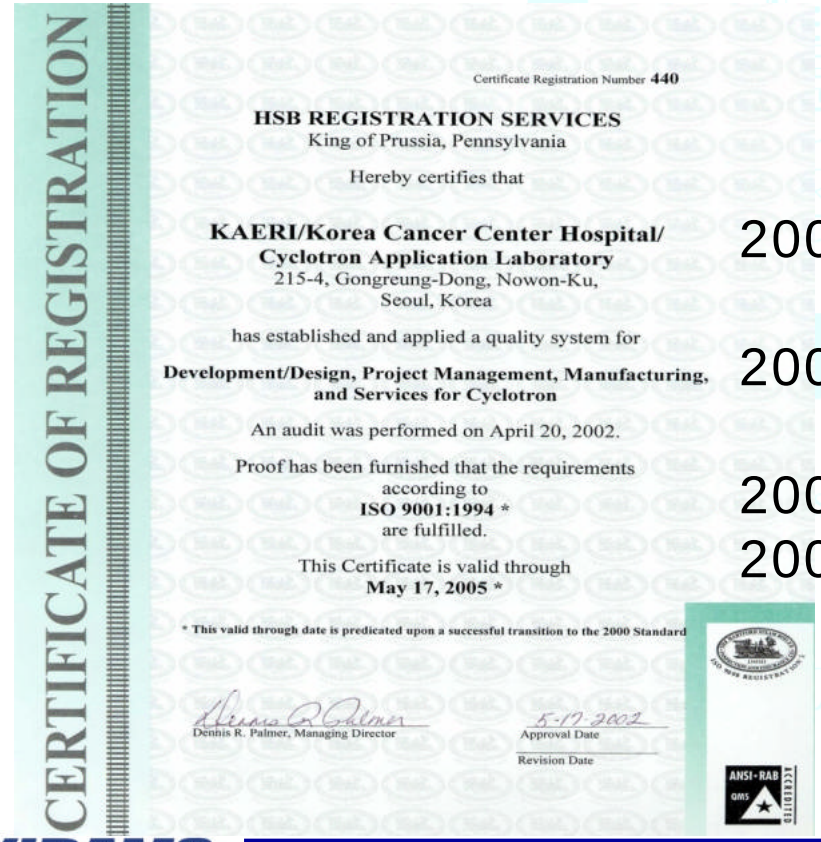


2002. 2. Development of 13 MeV Cyclotron for the Medical use

Beam Energy : 13 MeV

Particles :Proton, Deuteron

Beam Current : 10 ㎂



CERTIFICATE OF REGISTRATION

Certificate Registration Number 440

HSB REGISTRATION SERVICES
King of Prussia, Pennsylvania

Hereby certifies that

KAERI/Korea Cancer Center Hospital/
Cyclotron Application Laboratory
215-4, Gongreung-Dong, Nowon-Ku,
Seoul, Korea

has established and applied a quality system for

Development/Design, Project Management, Manufacturing, and Services for Cyclotron

An audit was performed on April 20, 2002.

Proof has been furnished that the requirements according to
ISO 9001:1994 *
are fulfilled.

This Certificate is valid through
May 17, 2005 *

* This valid through date is predicated upon a successful transition to the 2000 Standard

Dennis R. Palmer, Managing Director

5-17-2002
Approval Date

Revision Date

ANSI-RAB QMS ACCREDITED

2002. 4. ISO 9001 Certification of Registration

2002. 10. IAEA Efficiency Test (IAEA-ROK/4/030-08-01)

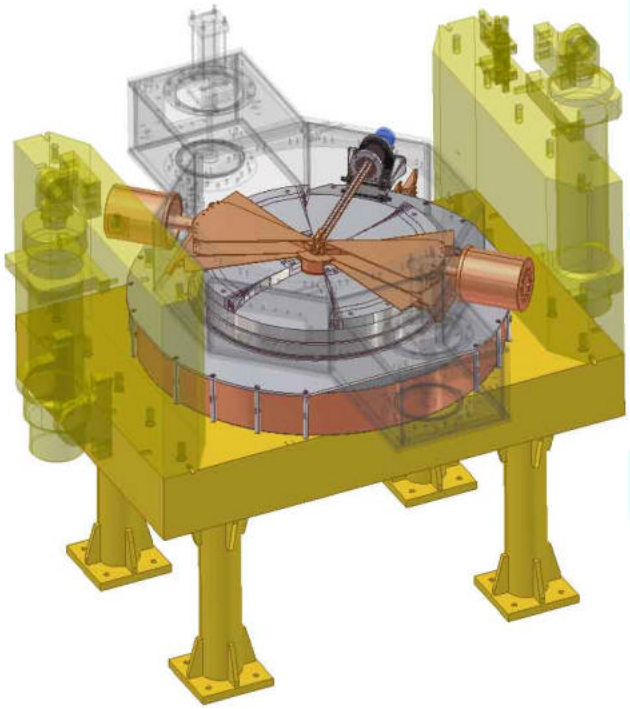
2003. 6 Start “Regional Cyclotron” Project

2004. 9 Development of Double-grid $[^{18}O]$ water target

KIRAMS-13 Specification

Characteristic Beams	Ions	proton, deuteron
	Energy / Current	13 MeV / 70 ,A (proton)
Magnet	Type	H
	Number of sectors	4
	Pole diameter	0.96 m
	Hill / Valley gap	4 cm / 12 cm
	ν_r / ν_z	1.022 / 0.25~0.3
	B_{max}(hill) / B_{max}(valley)	1.99 T / 0.9 T
	Coil current	148 A
	Power	12 kW
RF	Frequency	77.3 MHz
	Harmonic number	4
	Number of dees	2
	dee angular width	39 deg
	dee voltage	40 kV
Extraction	Charge Exchange Carbon Foil	
Ion Source	Internal Cold Cathode PIG	

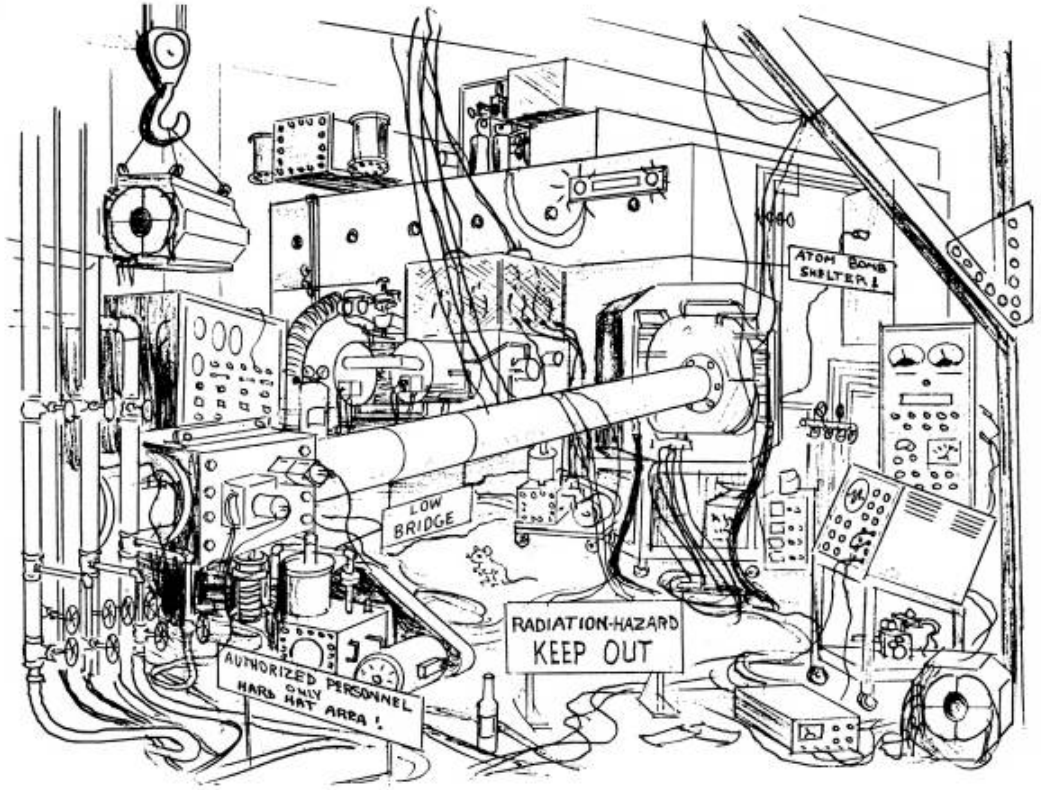
KIRAMS-13 Cyclotron



KIRAMS-13 installed in Kyungpook National University Hospital

Regional Cyclotron Center in KOREA

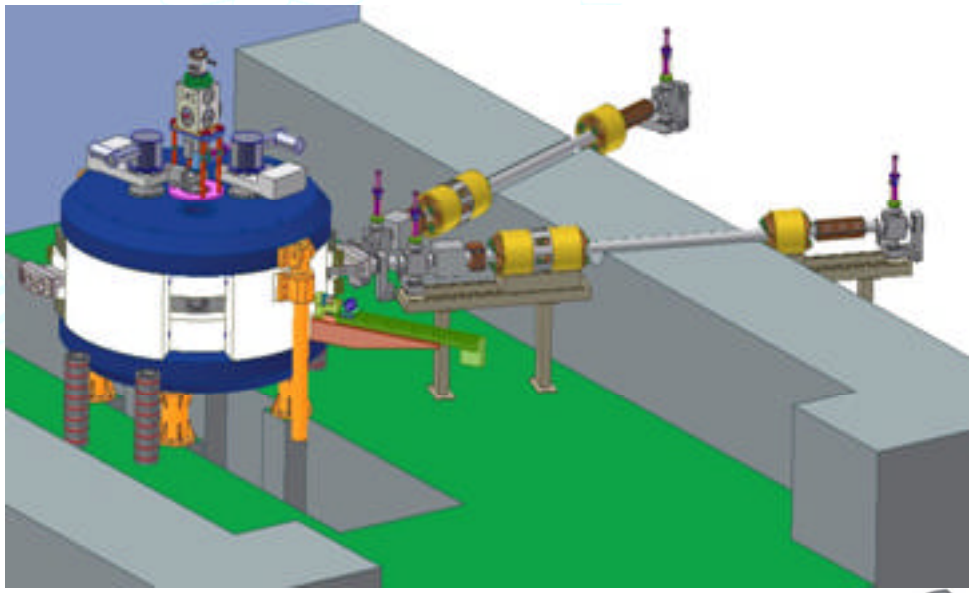
What we have developed in KIRAMS-30



. . . the visitor

General Specifications

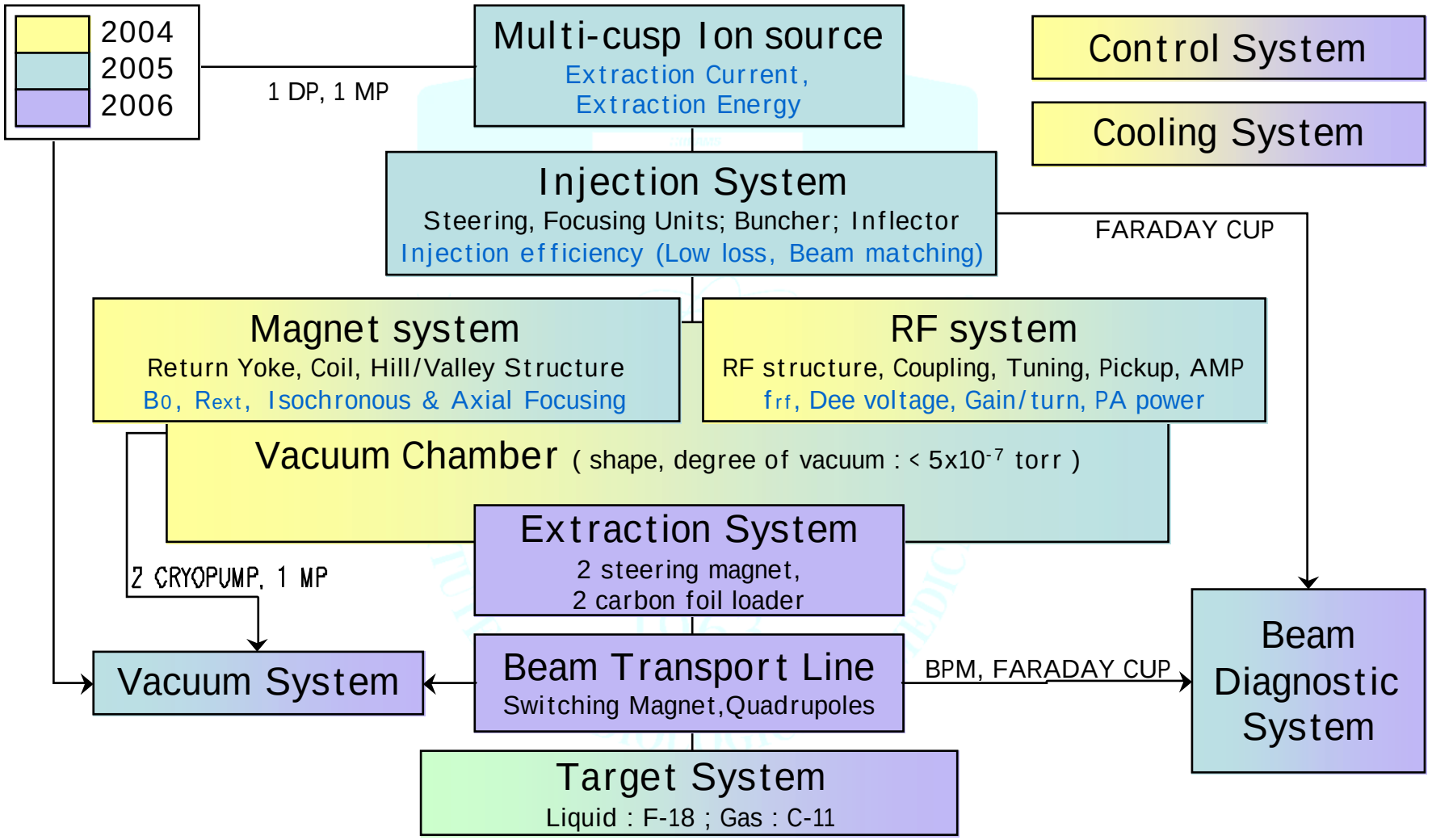
	General Specifications
Type of Accelerated Ions	Negative Hydrogen
Extraction method	Stripper carbon foil
Beam Energy(proton)	15 ~ 30 MeV
Beam Current(proton)	Max 500 uA
No. of Beam lines	4
Dual beam	available



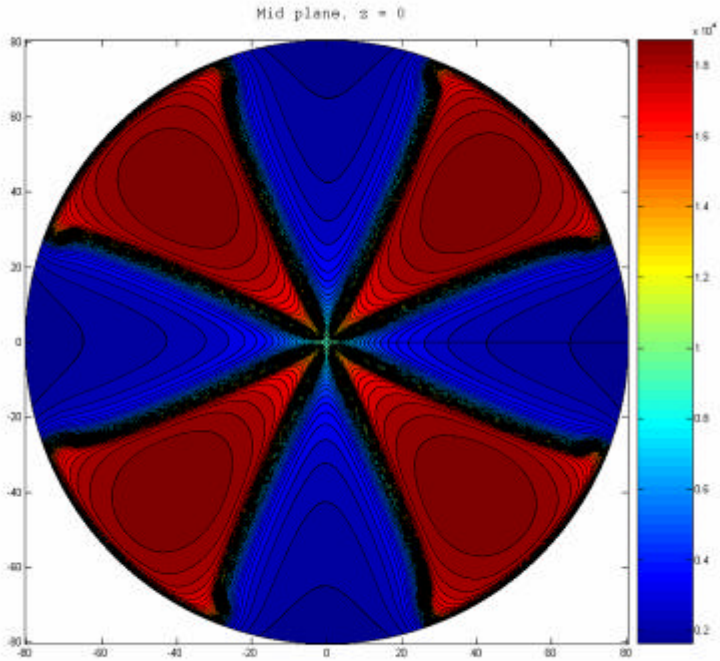
Detail Specifications

Ion Source	Ion Source	Multicusp type
	Max. Extracted Beam Current	10mA
	Type of Extracted Ions	Negative Hydrogen
Injection system		SQQ, Spiral Inflector
Extracted beam	Extraction Method	Stripper Carbon Foil
	Type of extracted ions	proton
	Extraction Beam Current	Max. 500 uA
	Extraction Beam Energy	15MeV-30MeV
	No. of Beam lines	4
	Beam irradiation	Dual available
RF system	RF frequency	63.95MHz
	Harmonic number	4
	Amp power	50kW
Magnet system	Center field	10.50 kG
	radial/vertical tunes	1.1/0.7

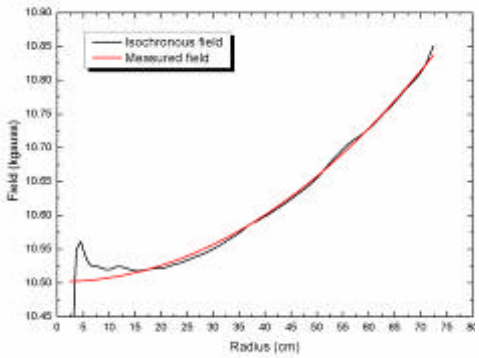
TIME BLOCK DIAGRAM OF KIRAMS-30



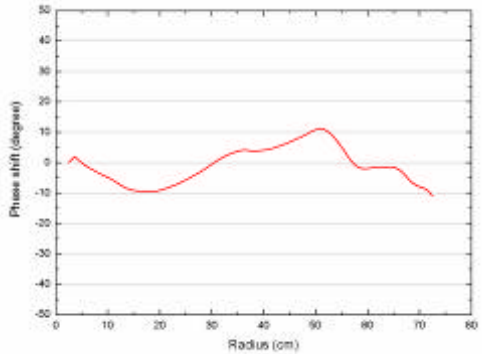
Magnetic Field Characteristics



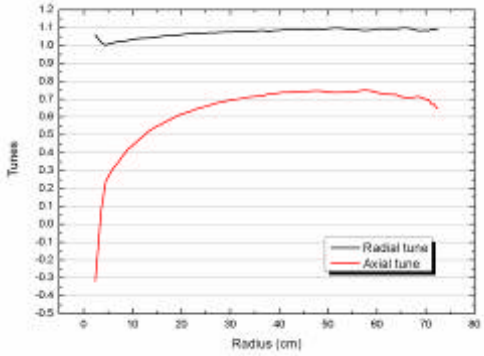
Magnetic Field Distribution



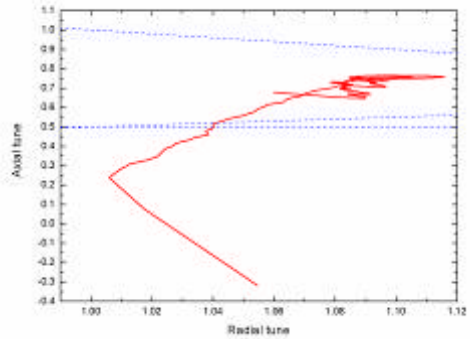
Average Field



Phase Accumulation Error



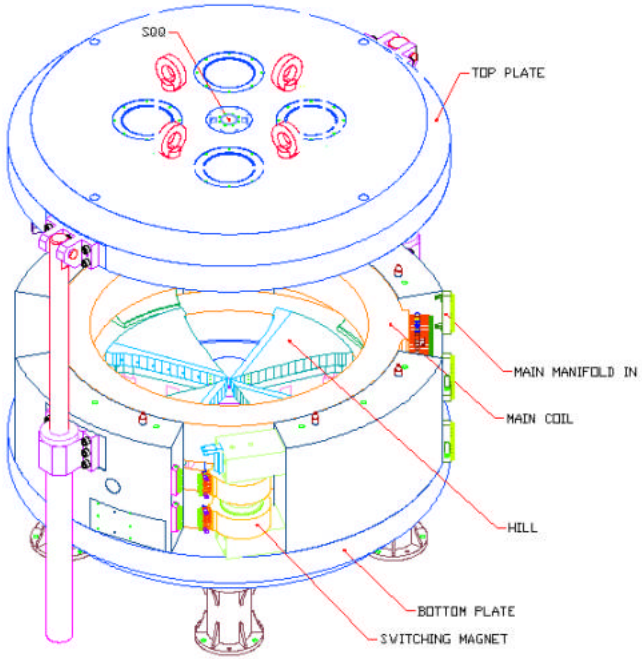
Horizontal and Axial Focusing

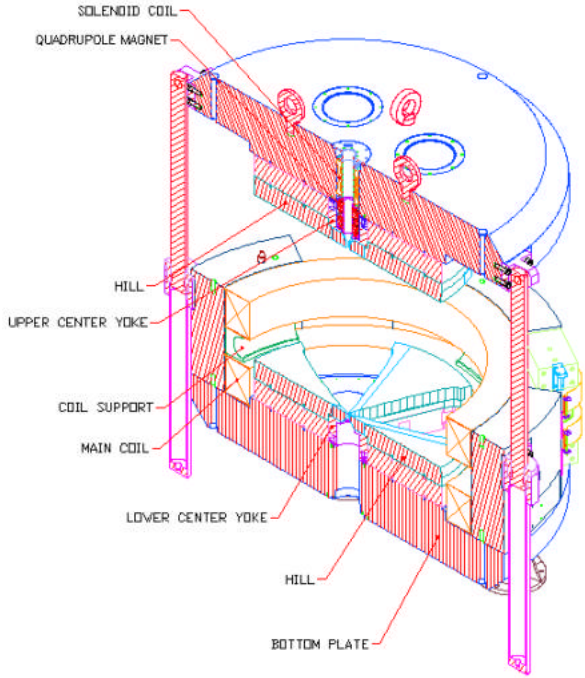


Beam Path diagram

Magnet

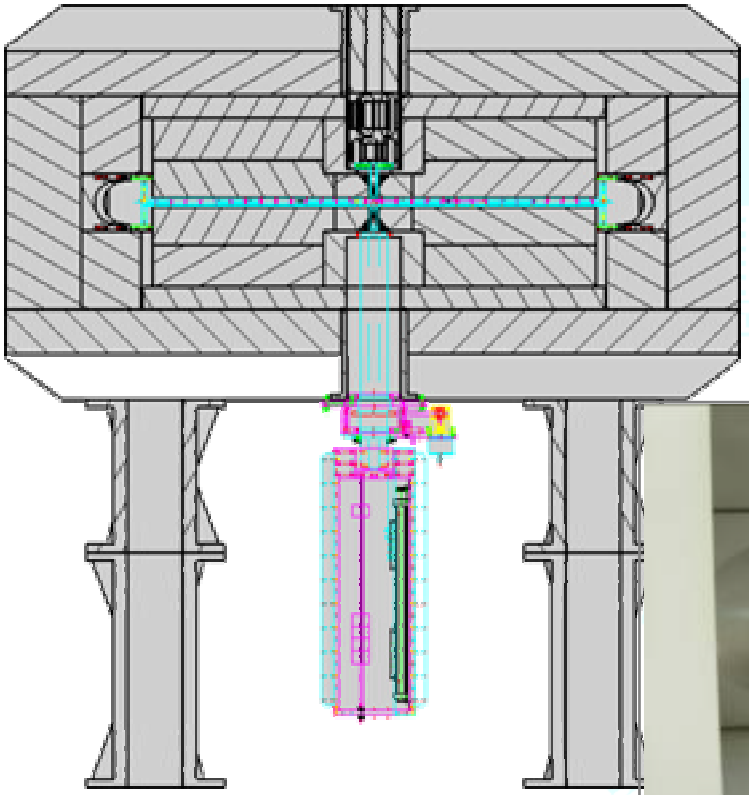
Central field	1.05 T
Extraction radius	0.736 m
Pole radius	0.81 m
Hill, Valley gap	0.03, 0.62 m
Tune (ν_r, ν_z)	1.05-1.1, 0.75
Hill angle	48 °
Operating current	130.5 A
Coil turns	22 x 16 x 2
Coil power	11.27 kW
Dimension	H 1.44 m, • 2.7m
Weight	50 ton

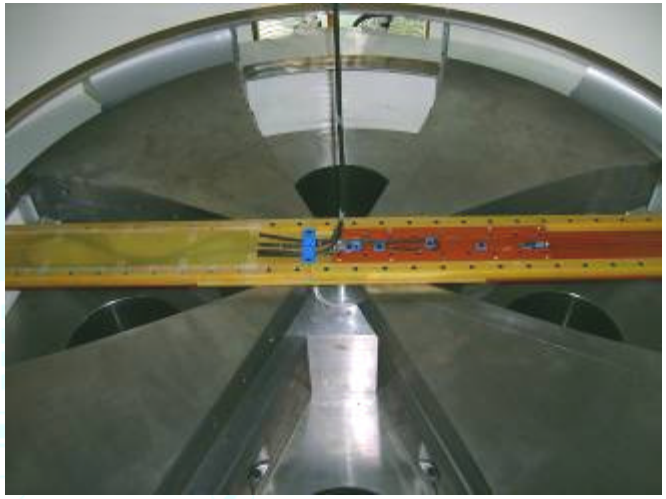


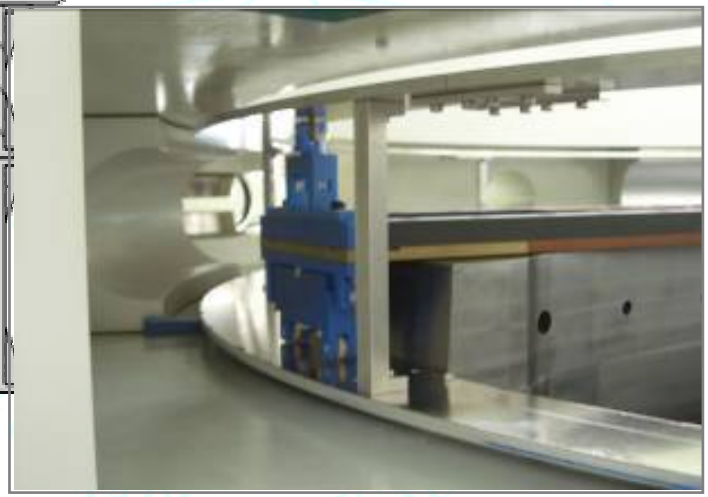


Magnet

Magnetic Field Measurement

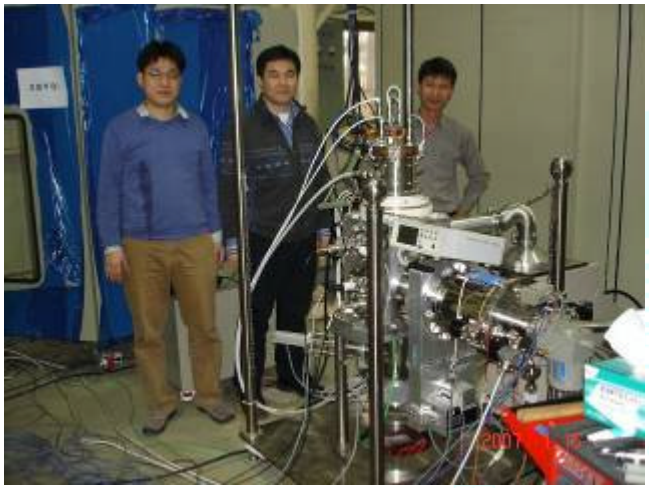


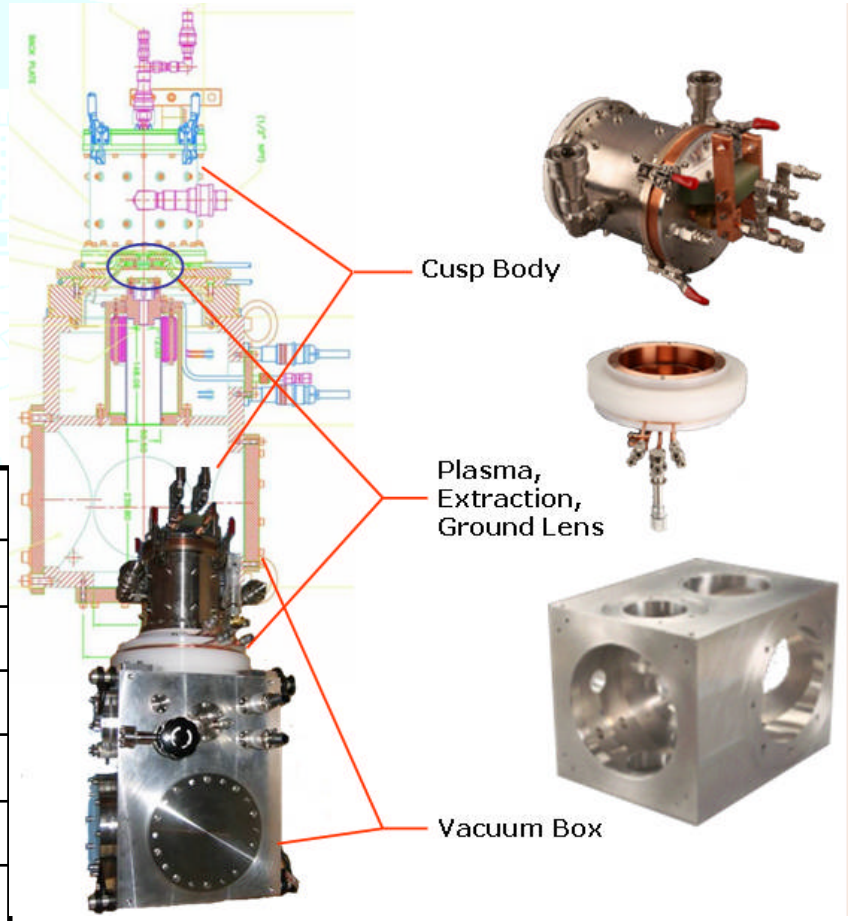




Ion source

- negative hydrogen ion extraction
- max. 30 keV extraction energy
- max. 10 mA beam current
- normalized beam emittance ~0.8 mm mrad



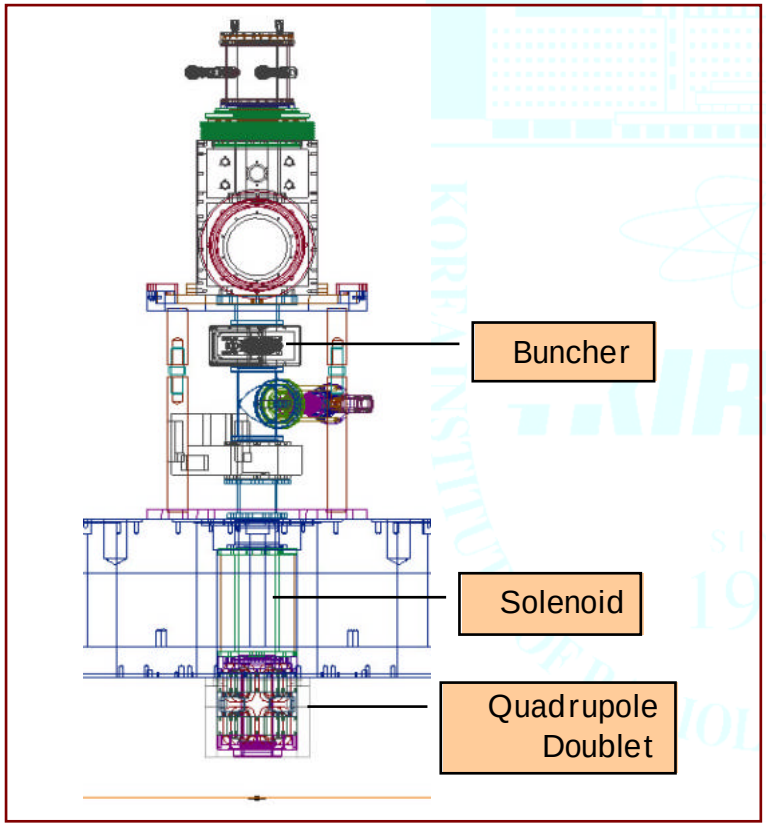


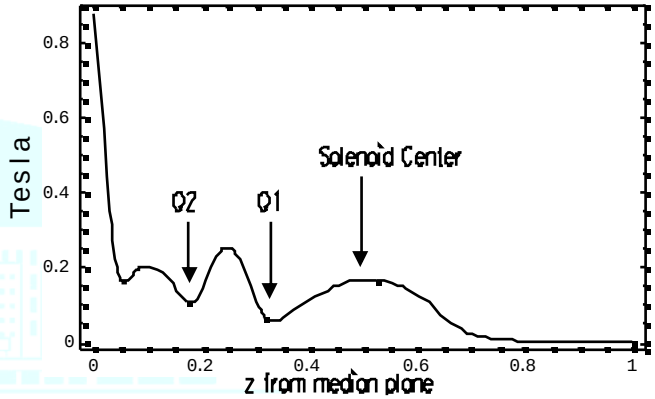
Measured Beam current & parameter values

. . (H–)	1mA	2mA	5mA	10mA
Arc(V/A)	100/2	100/3	100/8	100/20.5
Plasma(V/A)	1.7/1.2	2.0/1.8	3.1/4.8	3.6/11.1
Extractor(kV/mA)	1.1/5	1.3/10	2.5/19	3.3/45
Filament(V/A)	3/170	3/170	3/180	3/170
Hydrogen(sccm)	3.5	4	8.5	14
Bias(V/mA)	25/2.5	25/5.0	25/12.5	25/21.3

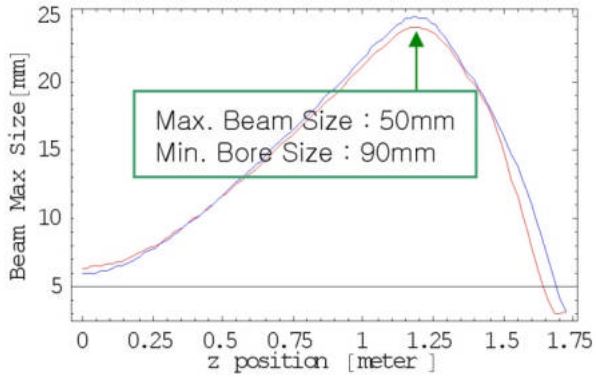
Injection

- (Buncher + Solenoid + Q doublet) with the magnetic field in the yoke hole.
- Adjust beam size and divergence at the entrance of the inflector



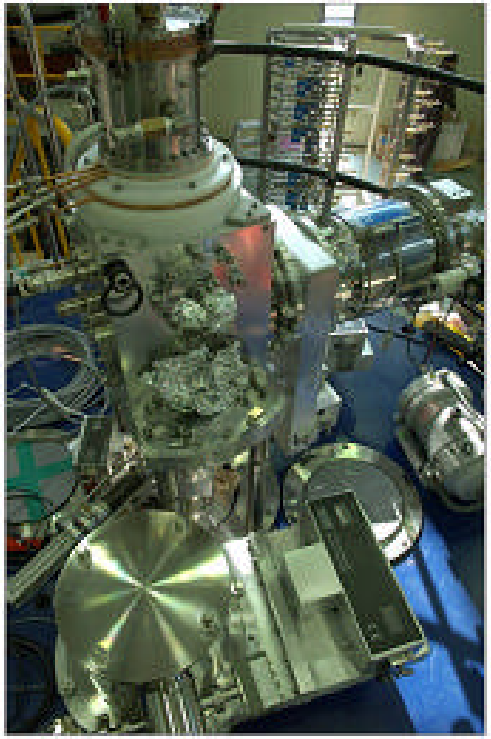


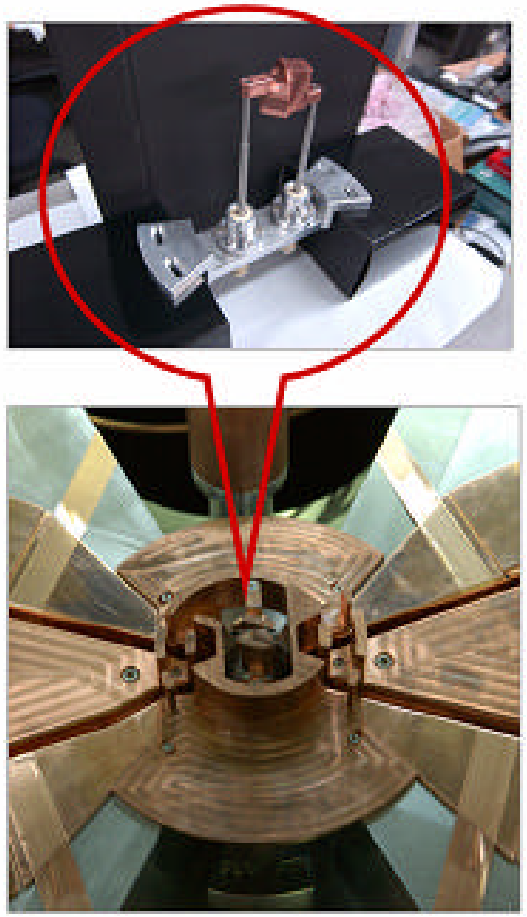
Axial Magnetic Field (Bz)



Beam Max. Size (mm)

The results of 10 mA Beam simulation with space charge effect and 90% space charge neutralization.



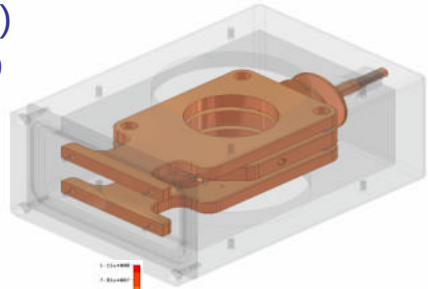


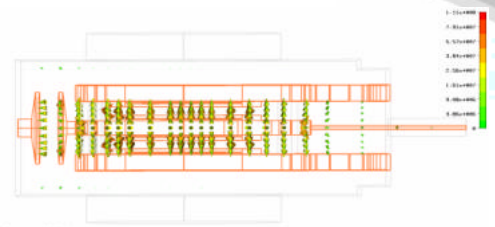
Multicusp Ion source S-QQ Inflector

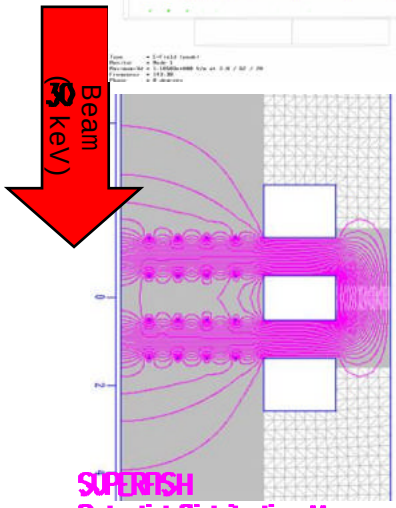
Buncher

Initial Beam Energy	30keV
Buncher Frequency	63.95 MHz
Buncher Voltage	200V
Amp Power	250W
Bunching gap width	8.7mm
Gap distance	18.7mm (half lambda mode)
Buncher aperture size	60mm

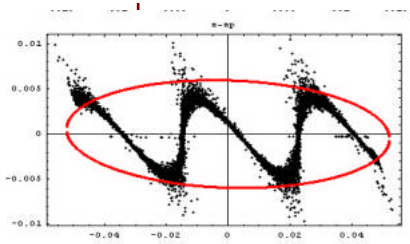
Micro Wave Studio (MWS)
Potential Distribution Map

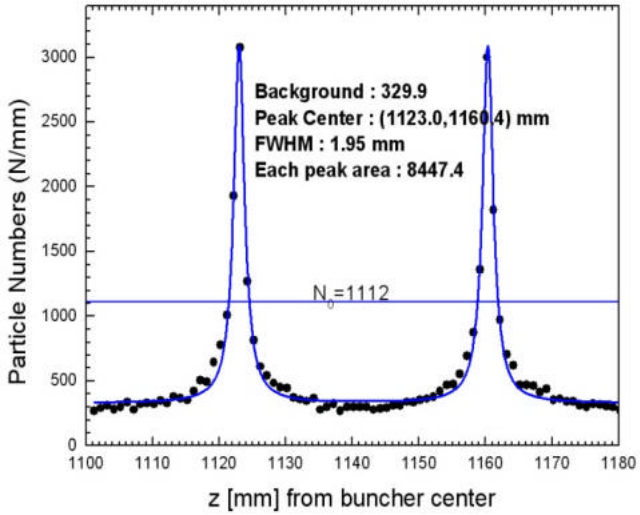




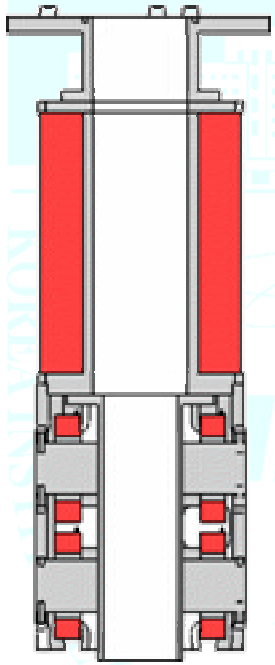


Bunched beam status
Bunch Width : 3.9mm
RF Phase width : 37.5 deg
Bunch Factor : 3.34





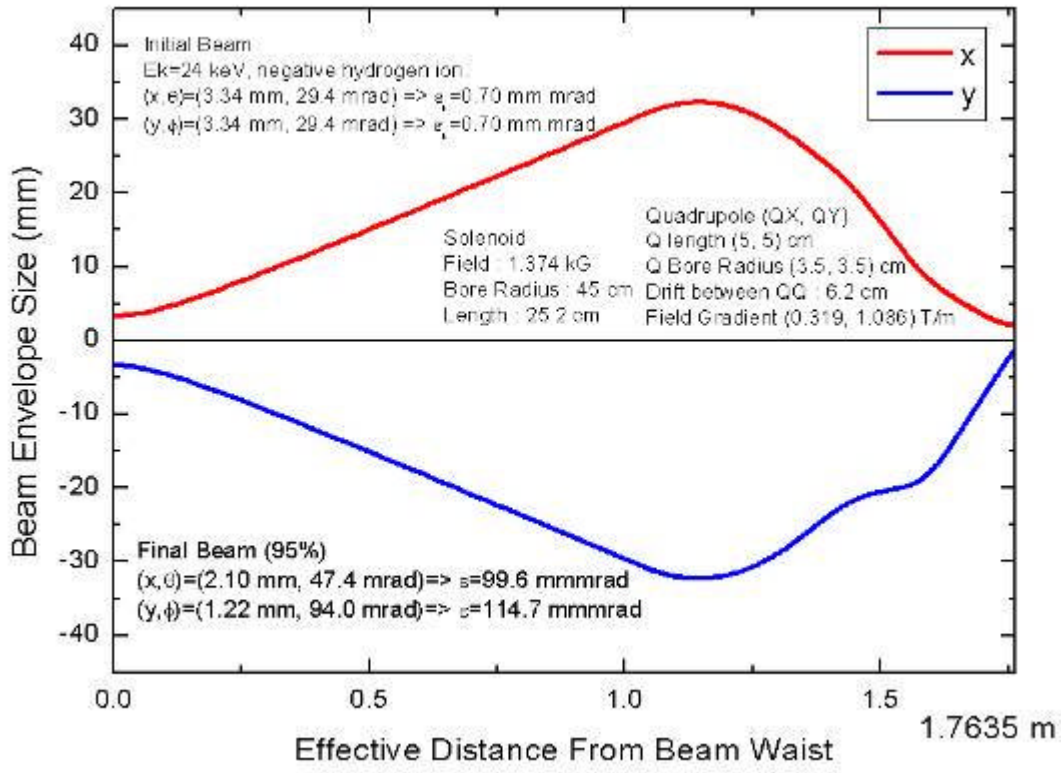
Beam Focusing Units



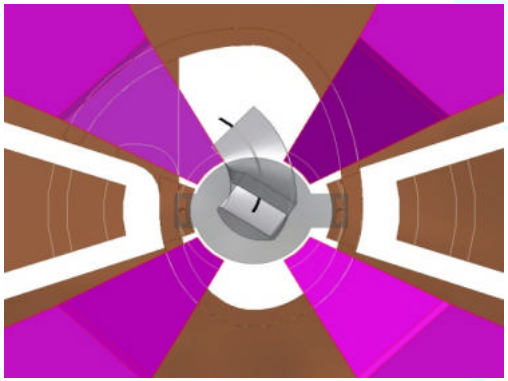
elements	specifications	size
Extraction Beam	30 keV	8mm x 8mm 100 mm mrad
Ion Source	10 mA	
Solenoid	1.8 kG	Length 25 cm Bore Diameter : 9 cm
Qx	60 G	Length 5 cm Bore Diameter : 8 cm
Qy	90 G	Length 5 cm Bore Diameter : 8 cm

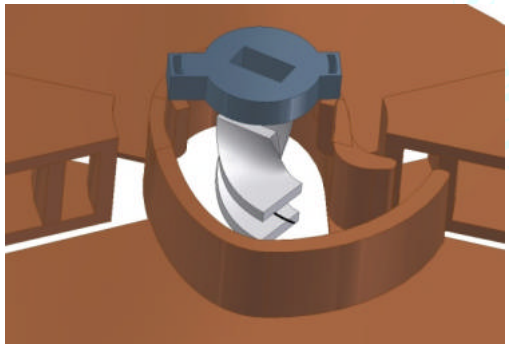
SQQ

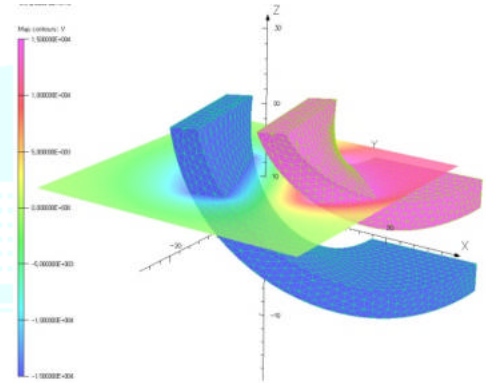
Injection H- Beam energy : 24 keV
Injection System – Solenoid+Q-doublet

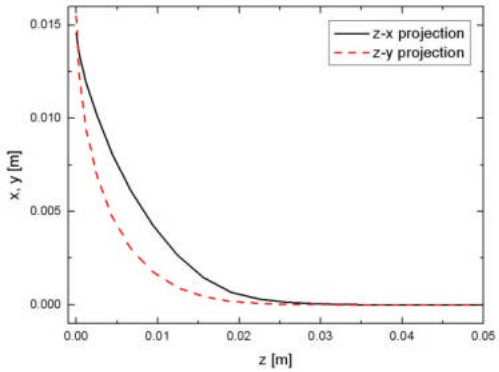


Central Region





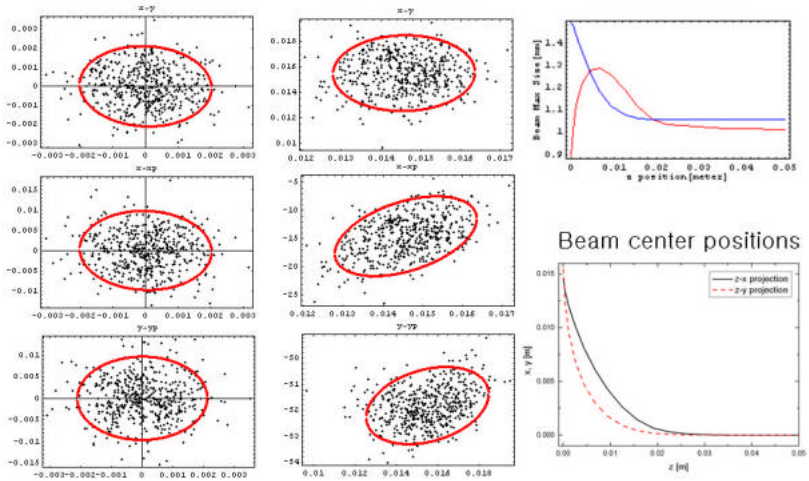




Entrance of Inflector

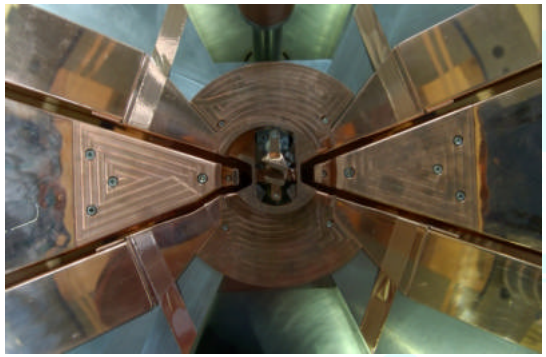
Exit of Inflector

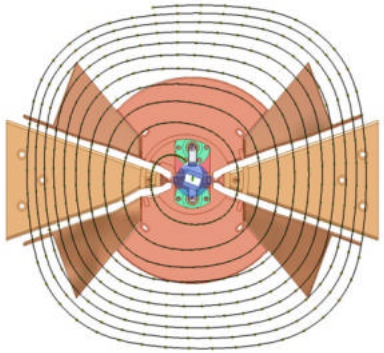
rms beam size

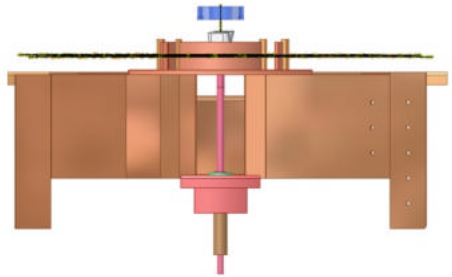


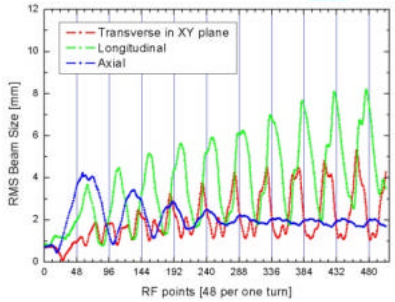
Beam center positions

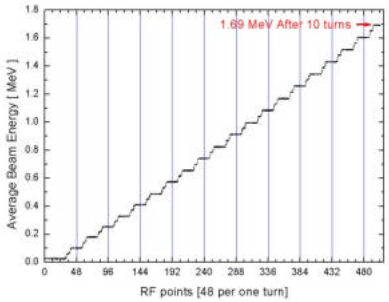
Cetral Region

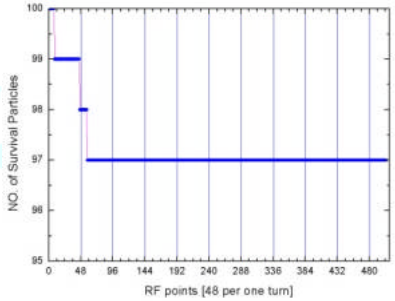




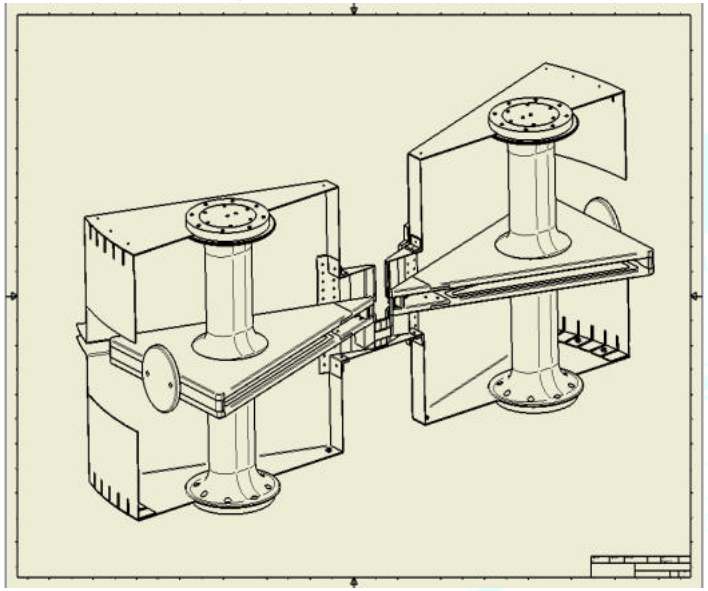




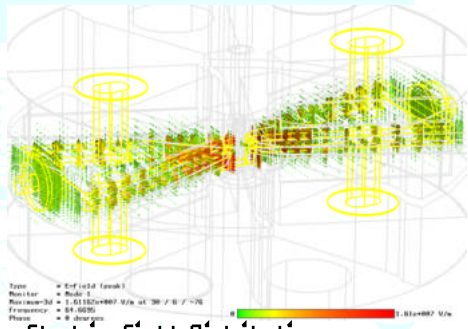




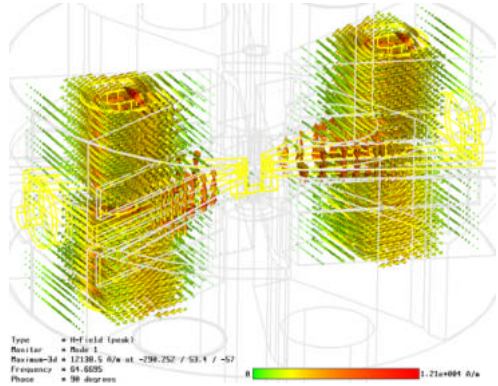
RF system



Micro Wave Studio (MWS) Simulation

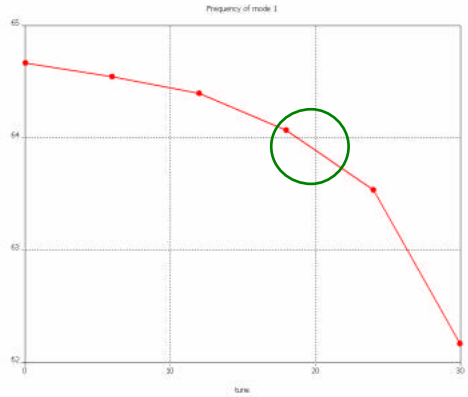


Electric Field Distribution



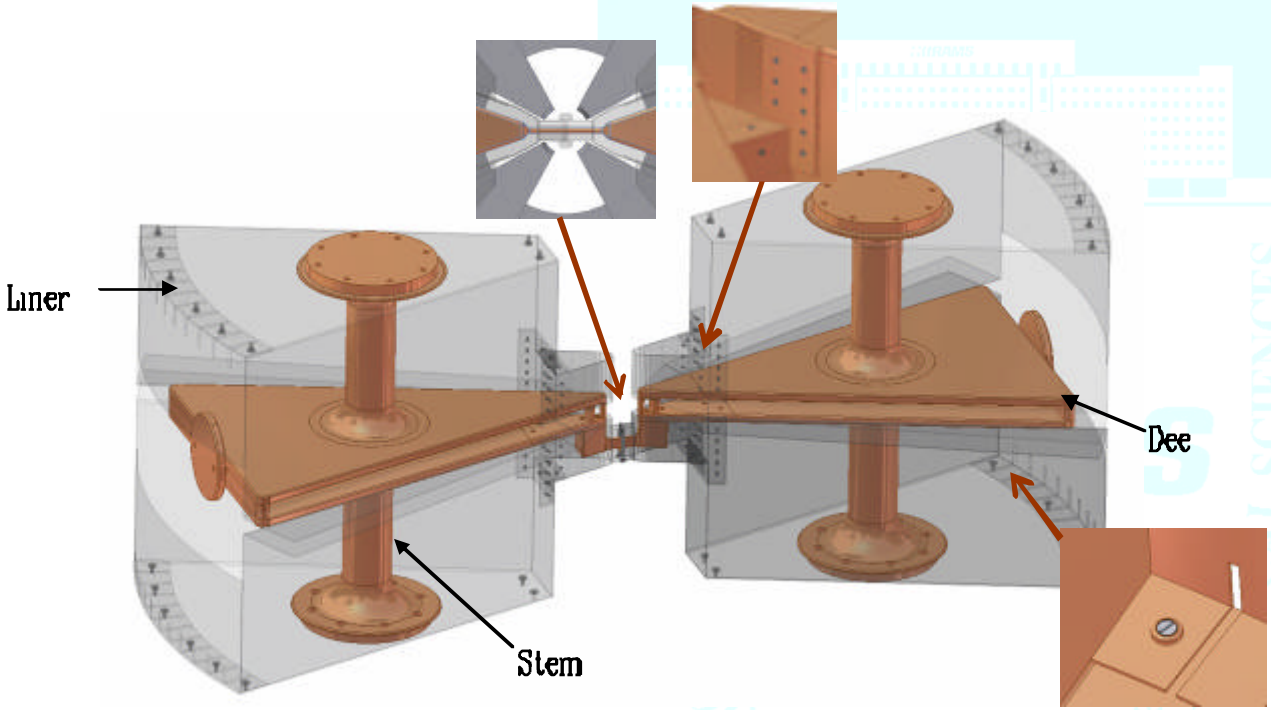
Magnetic Field Distribution

Resonant Freq. Variation with Tuner Position



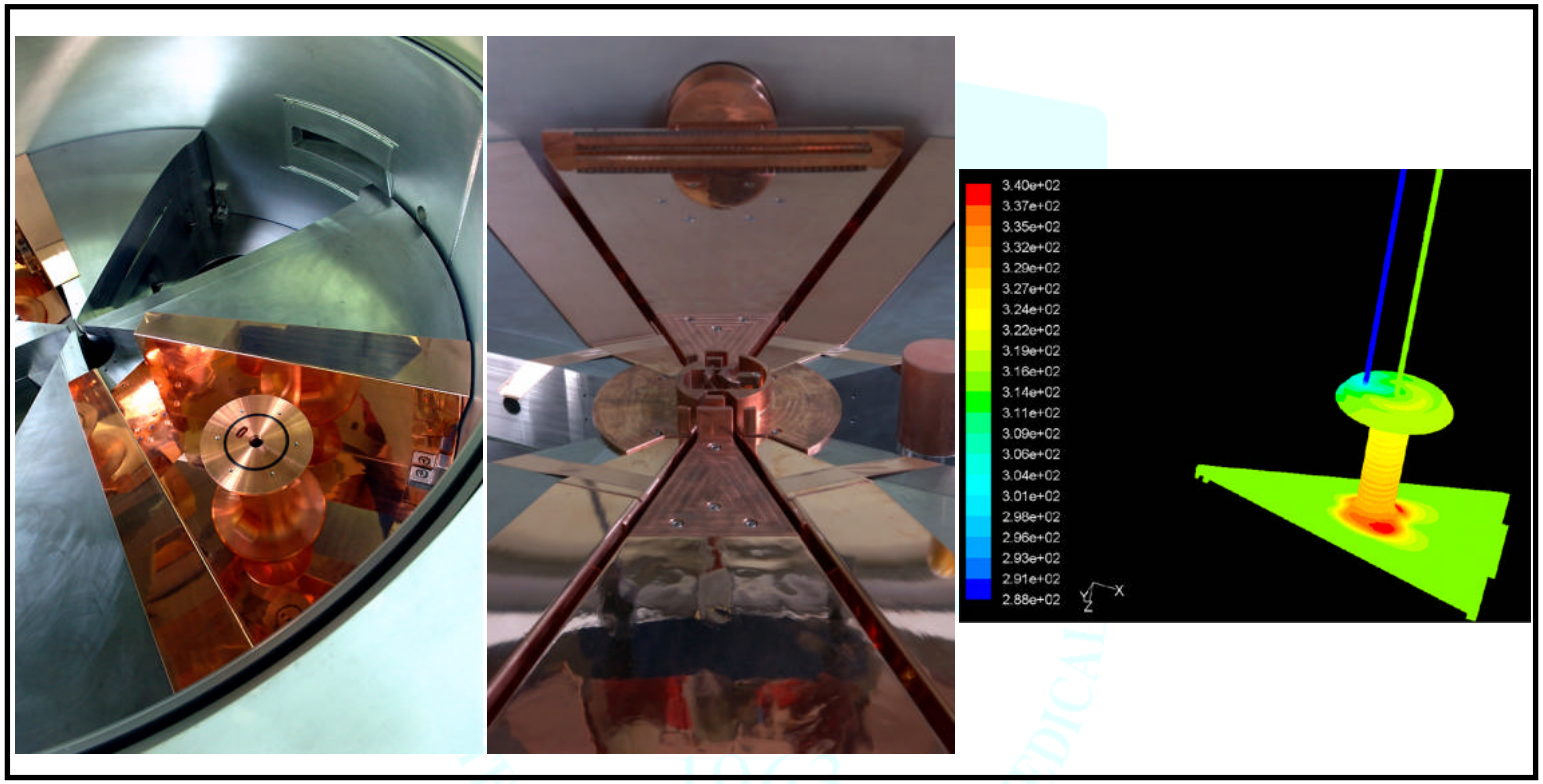
Parameters	Values
Resonant Frequency	63.96 MHz
Harmonic Number	4th
Dee Voltage	(nominal) 55kV
Resonant Mode	,/2 mode
Matching Impedance	50 ,
Material	OFHC copper
Number of Dee	2

RF system



RF Frequency	63.96 MHz
Harmonic number	4
Type of Cavity	DualCavity vertically
Number of Cavities	4
Number of Dees	2
Dee Angle	~39°
Coupling type	Capacitive
Cooling Method	Water Cooling
RF Amp Power	50kW

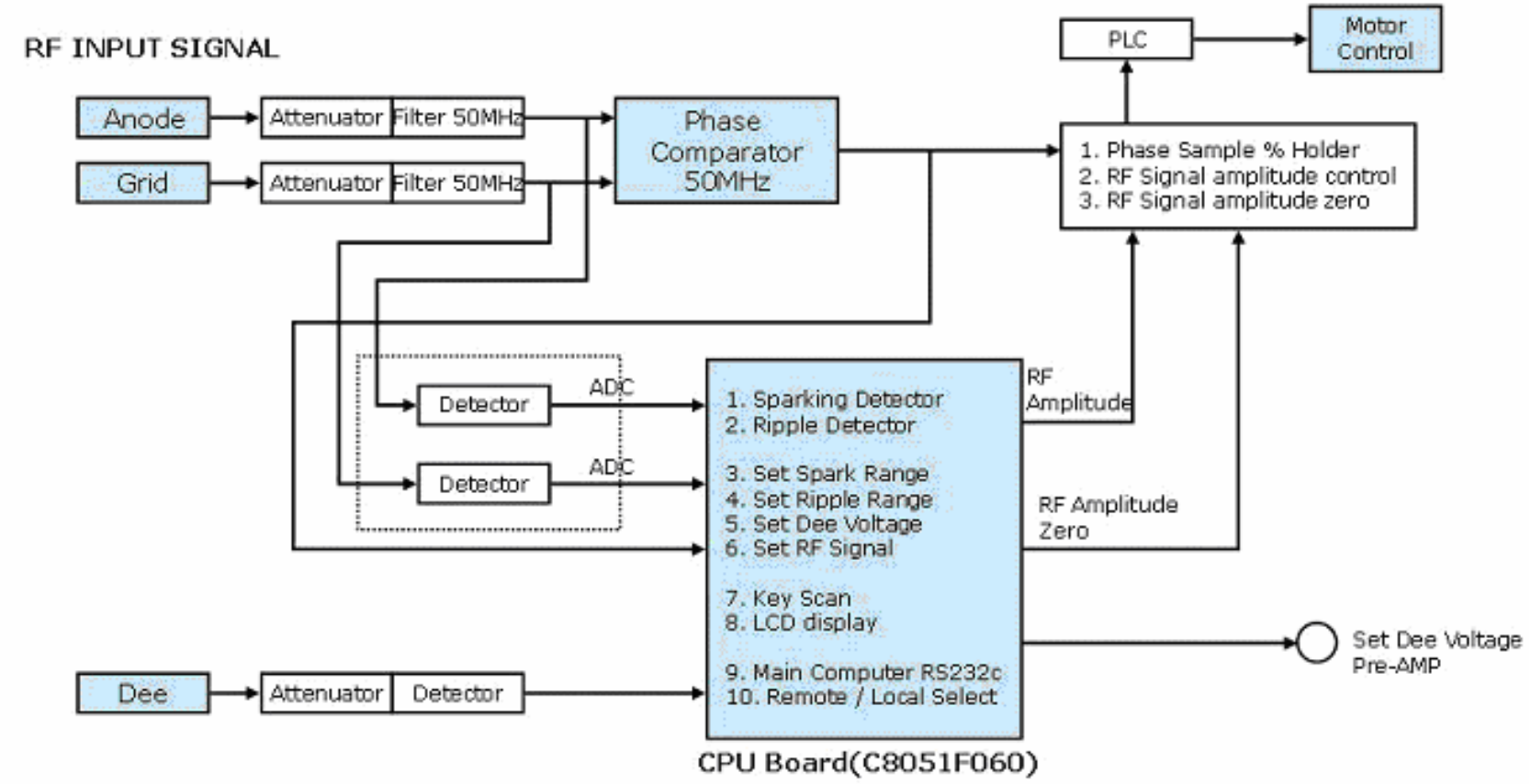
RF system



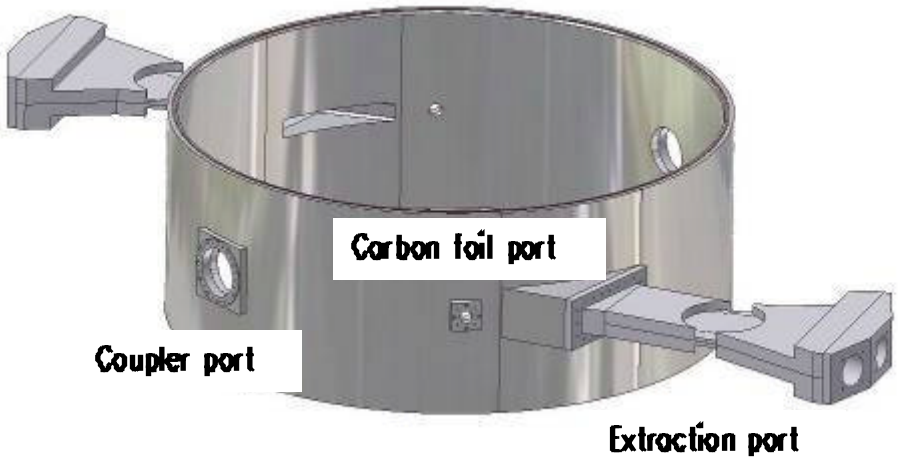
-RF stem, Capacitive coupling & capacitive fine tuner

-63.96 MHz RF resonance Frequency Q=7525

RF autotuning system: 63.96 MHz

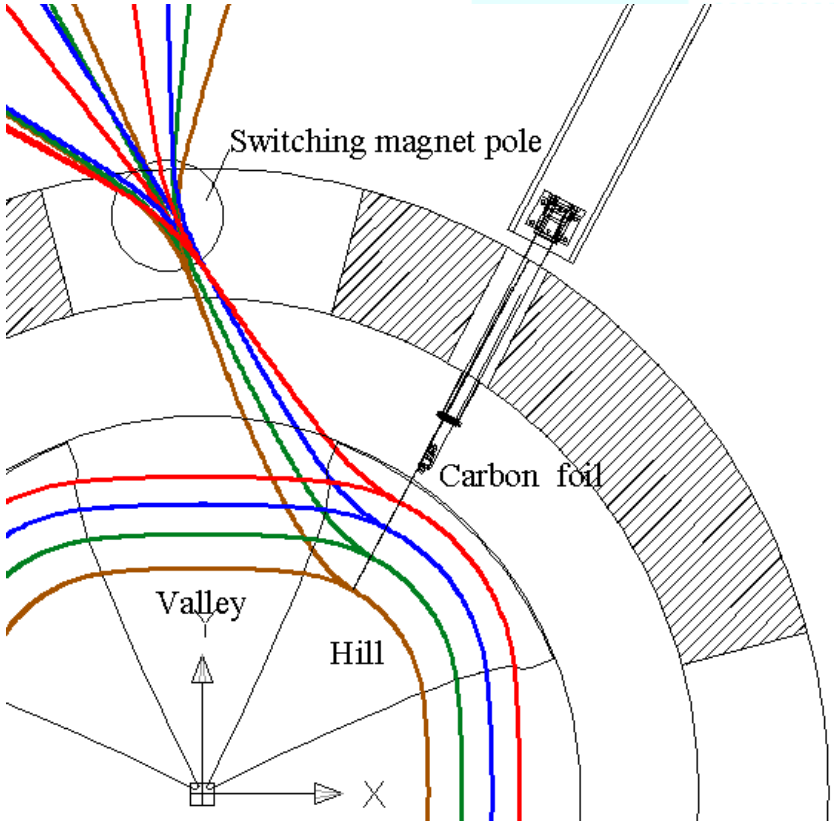


Vacuum Chamber

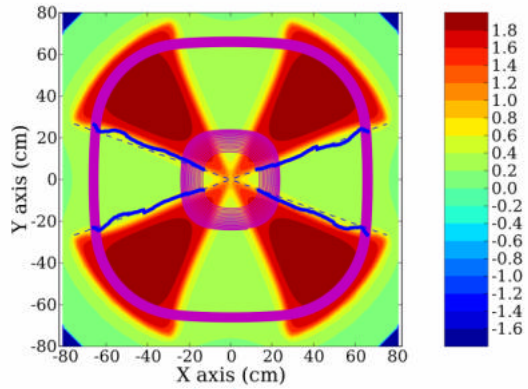


Extraction

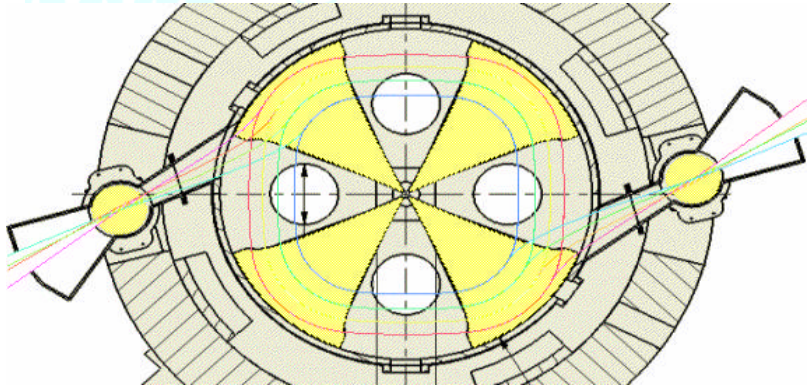
15~30 MeV Proton Extraction



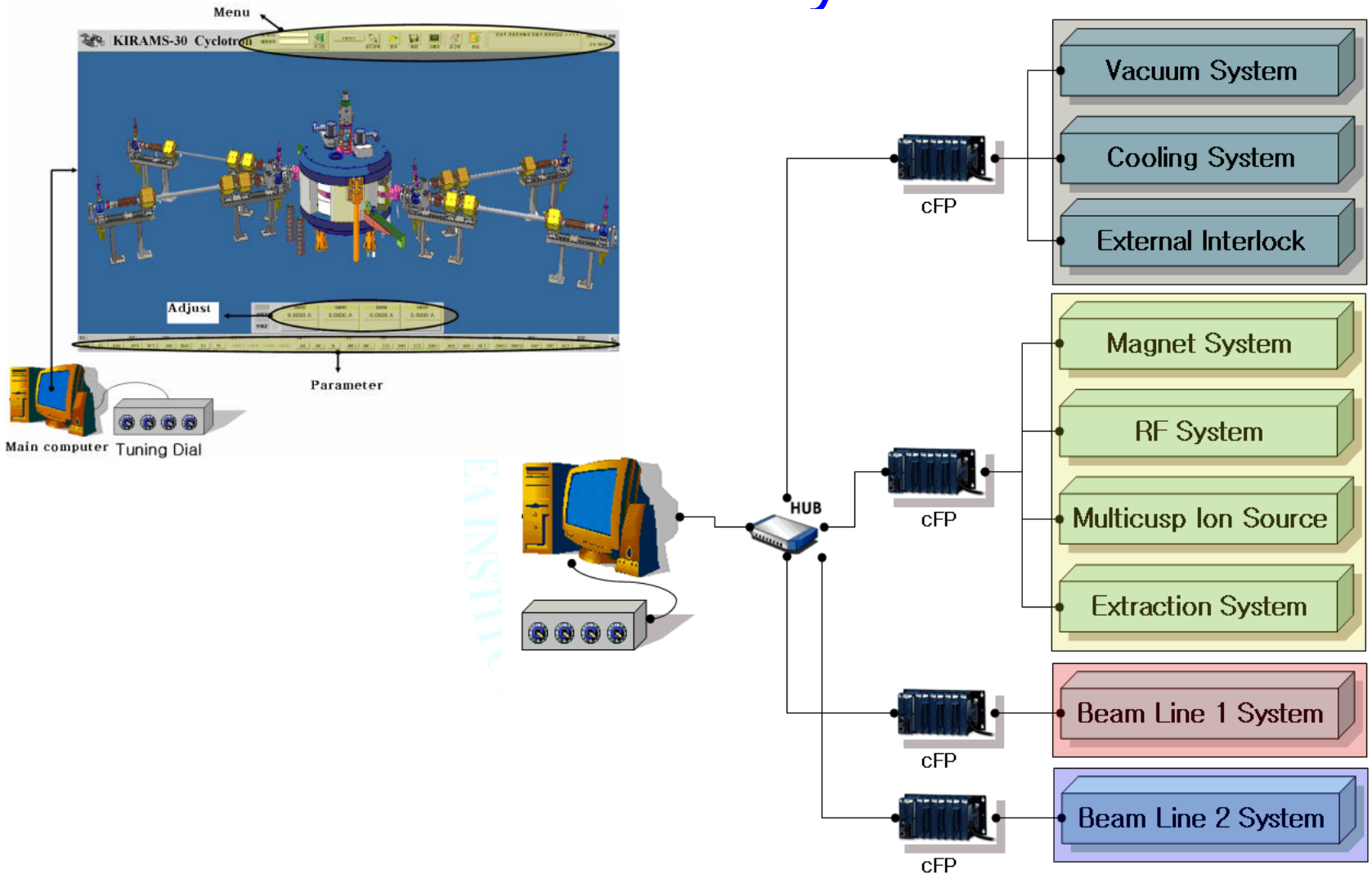
1MeV to 30 MeV Acceleration
Beam Trajectory Calculation



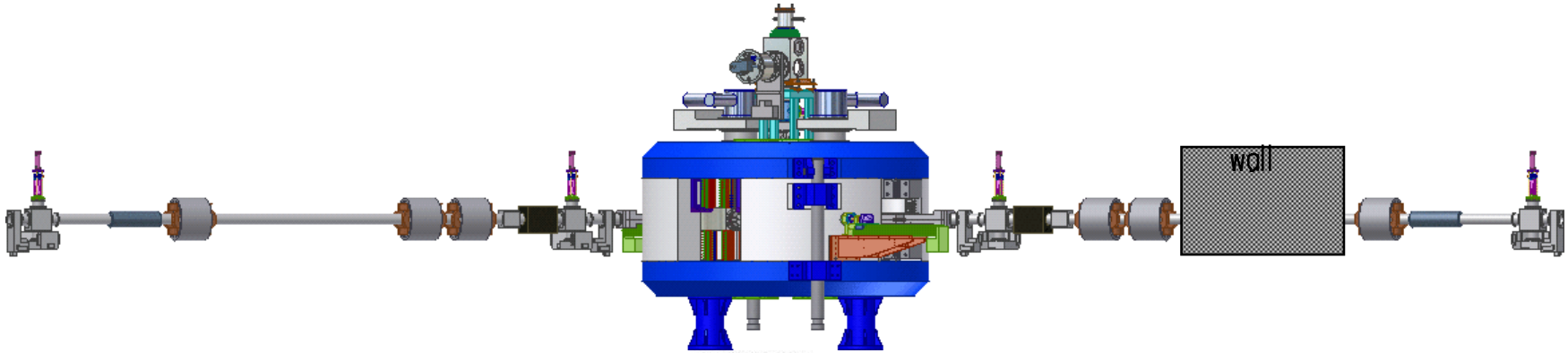
Dual Beam Extraction is available

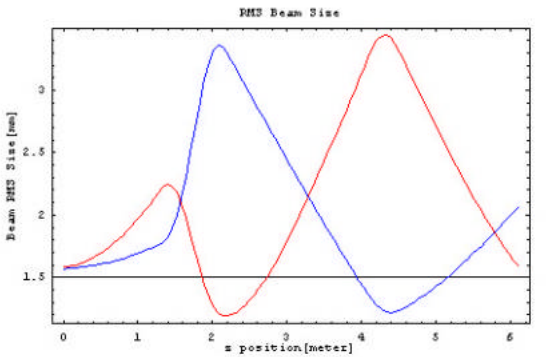


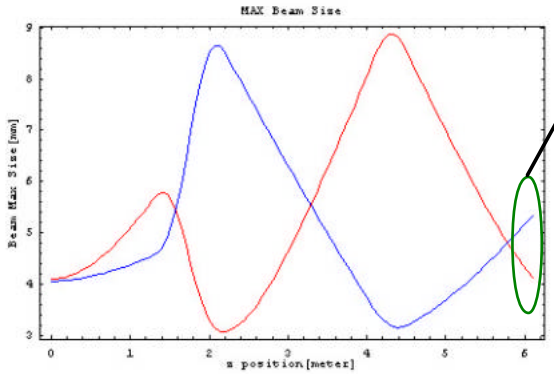
Control System

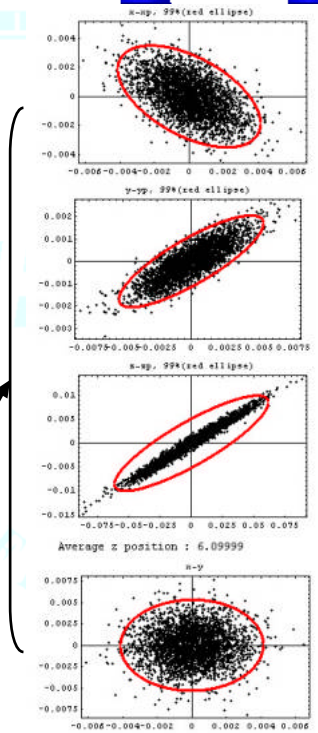


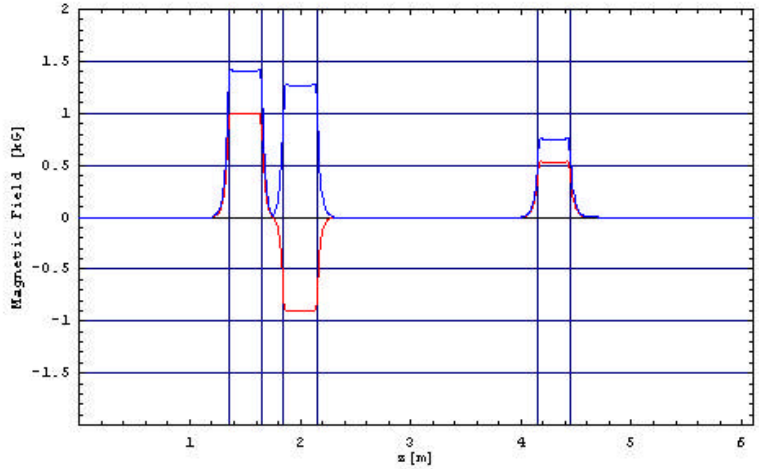
Beam Transport Line





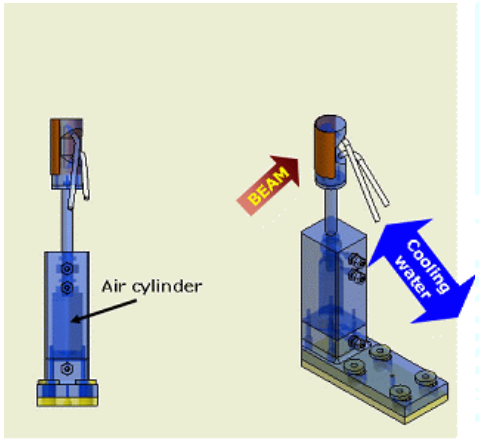




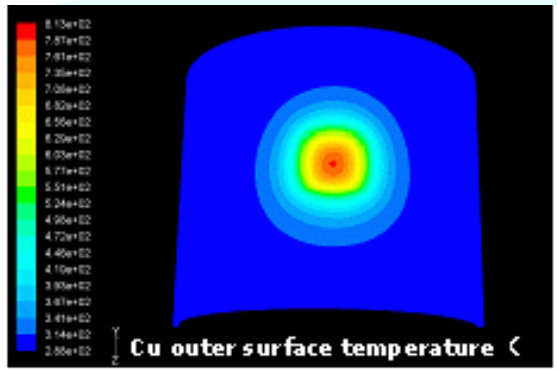


Magnetic Field Variation
through the BTL with the Q-triplet

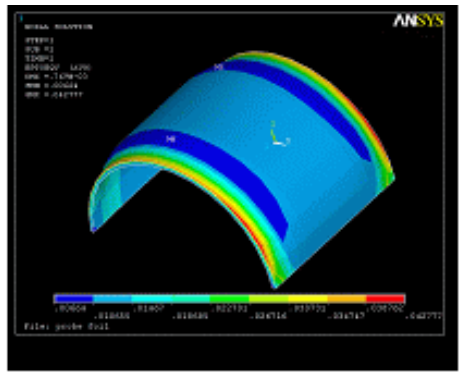
Beam Measurement system



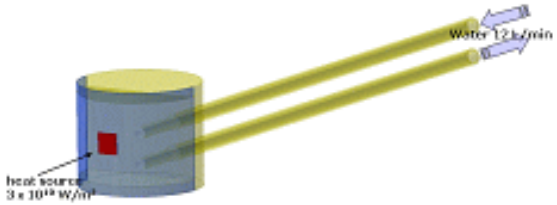
Pop-up Probe



Generated heat source = 3×10^{10} W/m²
Flow rate = 12 L/min
k-ε turbulence flow model



Von Mises total strain contour result at 800K



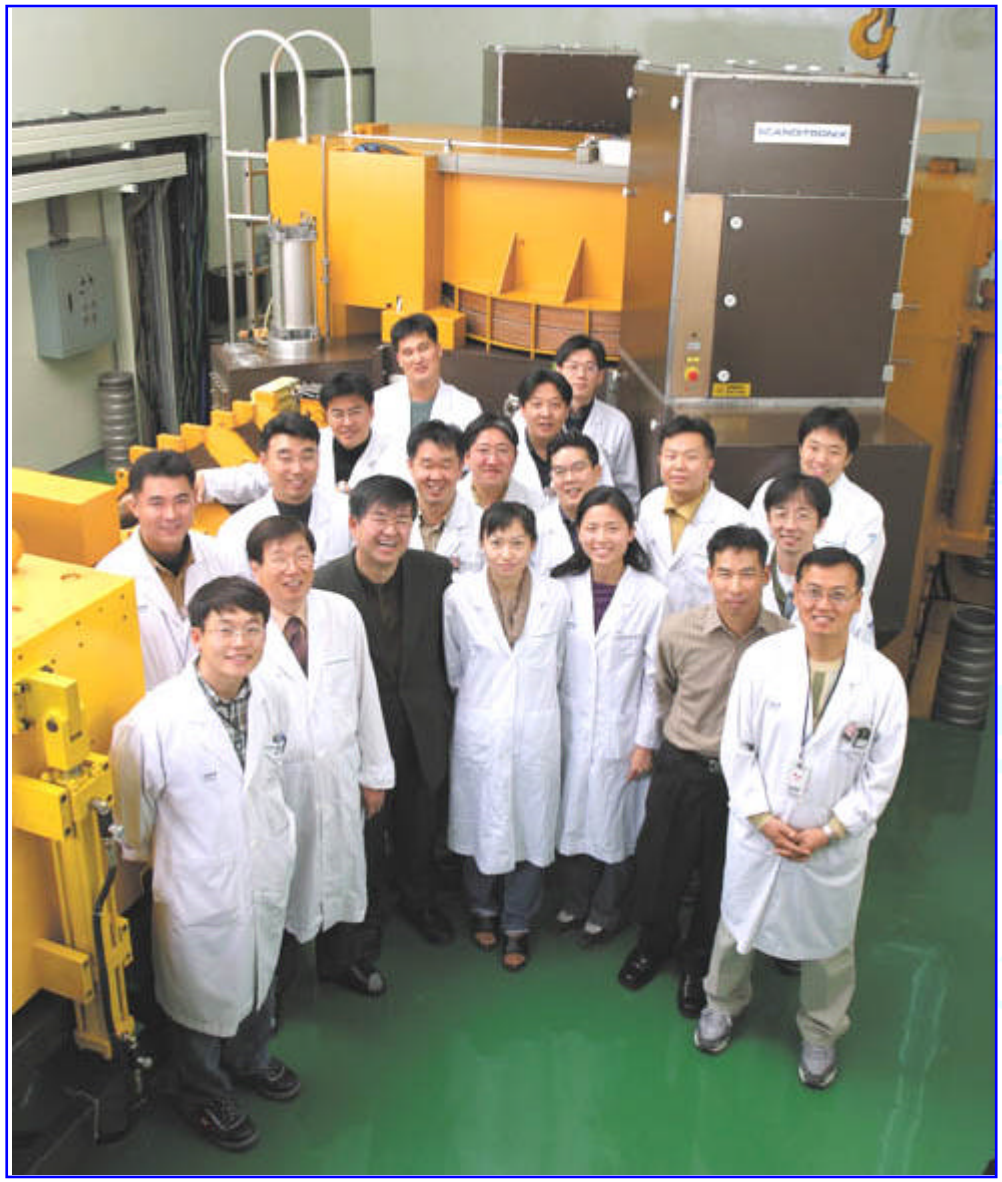
Cu, t:1mm, 800K

Commissioning Schedule

2006. 5 - 2007. 3	Installation
2007. 3 - 2007. 5	Beam commissioning
2007. 6	The First Beam : 30 mA @ 1.5 MeV
2007. 8	Beams 70 mA @ 1.5 MeV
2007. 12	Expected Beam Intensity 300 mA @ 1.5 MeV
2008. 8	Expected Beam Intensity 500 mA @ 1.5 MeV
2008. 9 - 2008. 10	Disassembly KIRAMS-30
2008. 11 - 2009. 3	New Insallation
2009. 3 - 2009. 5	Beam Commissioning 100 mA @ 30 MeV
2009. 8	Beams 100 mA @ 30 MeV
2009. 11	Maximum Beams 500 mA @ 30 MeV Realization

Conclusion

•KIRAMS-30 cyclotron has been developed for nuclear technology development and research.
•Design feature of KIRAMS-30 has optimization, low power consumptions, and cost effectiveness realization.
• After movement at regular building we get 30MeV energy and 500mA maximum currents.



Thank you
for your attention