



入射器更新の概要と現状 I

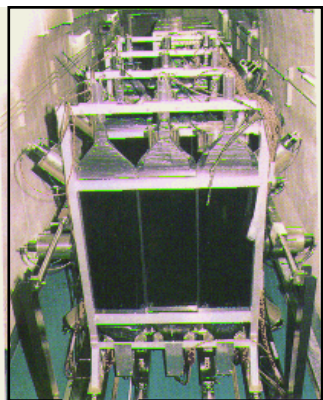
RCNP研究会:

**RCNP入射サイクロトロン更新で
展開される新しい研究**

平成19年2月19日
畑中吉治

Cyclotron Facility of Research Center for Nuclear Physics (RCNP)

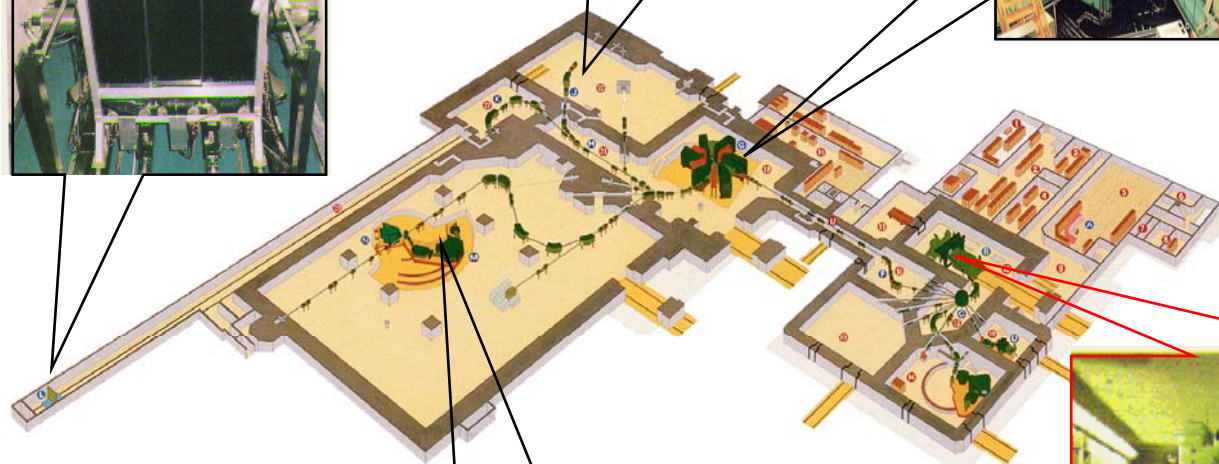
Neutron TOF Course



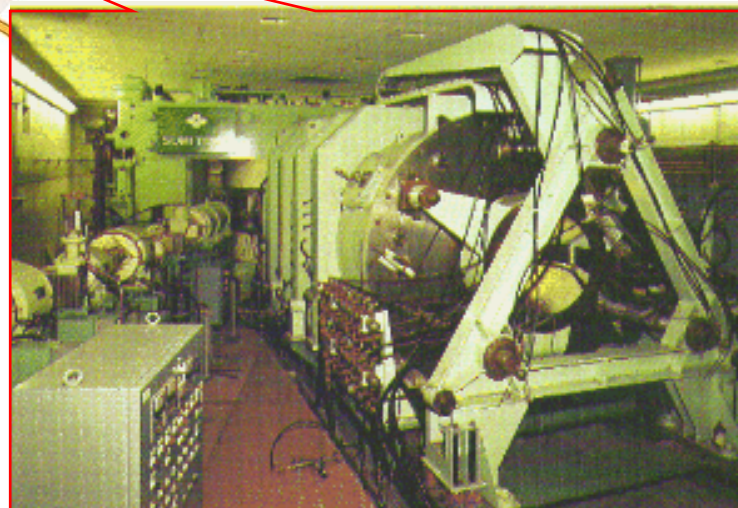
East experimental hall



Ring Cyclotron



AVF Cyclotron



Focal Plane Polarimeter

West experimental hall

AVF 更新計画

- ・ビーム輝度の向上

ビーム軌道(再)解析

主加速電源の性能向上(RCA4648 ⇒ RS2042SK)

FT 加速の導入(Slotted Dee 電極) → 福田(20日)

- ・重イオンビーム増強

18GHz 超伝導 ECR イオン源

分析・バイパスビームライン

核化学ビームコース整備

- ・機器の更新

トリムコイル・磁気チャネル電源

制御系

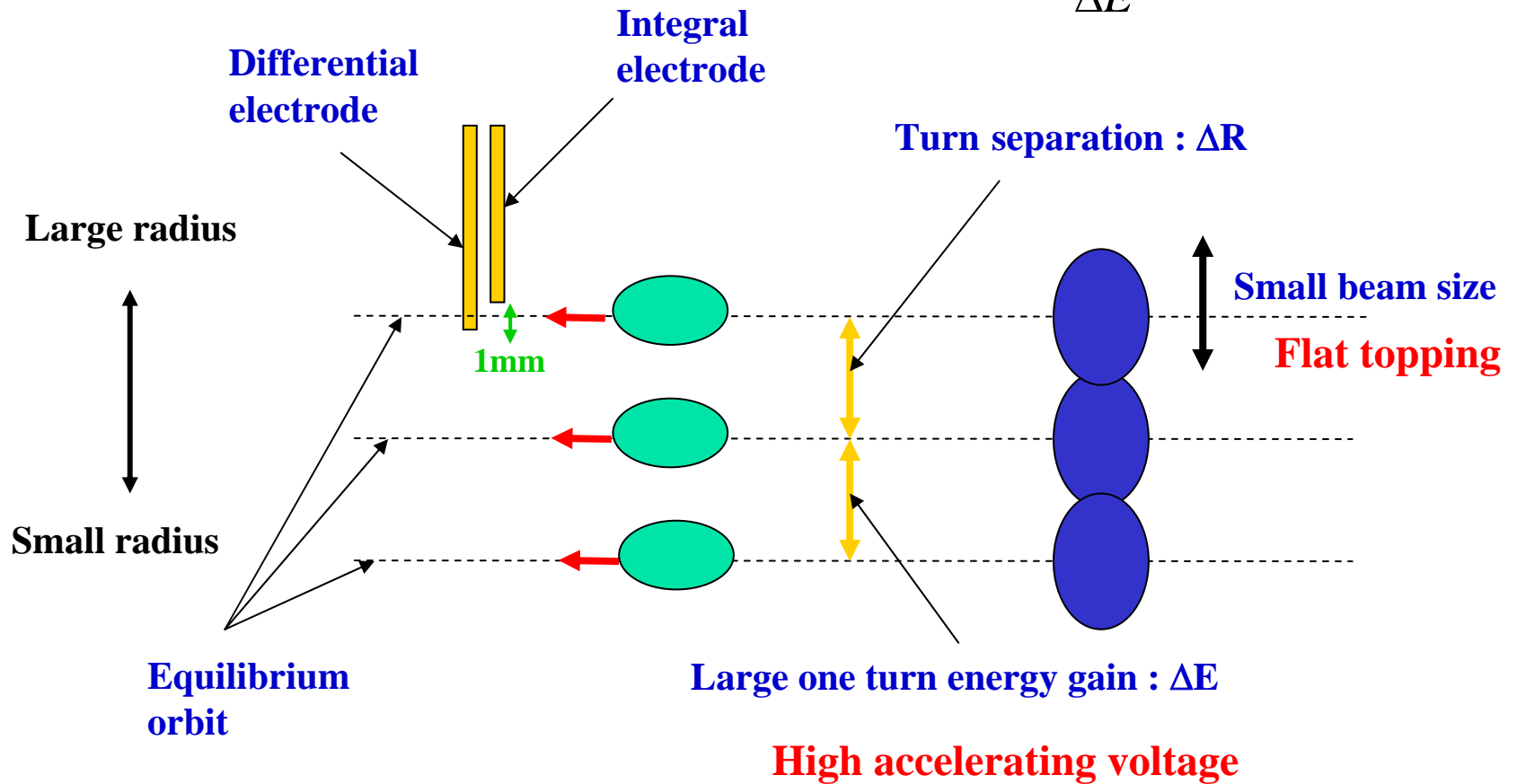


軌道解析と電磁石電源の更新

Measurement of the beam profile by the radial probe

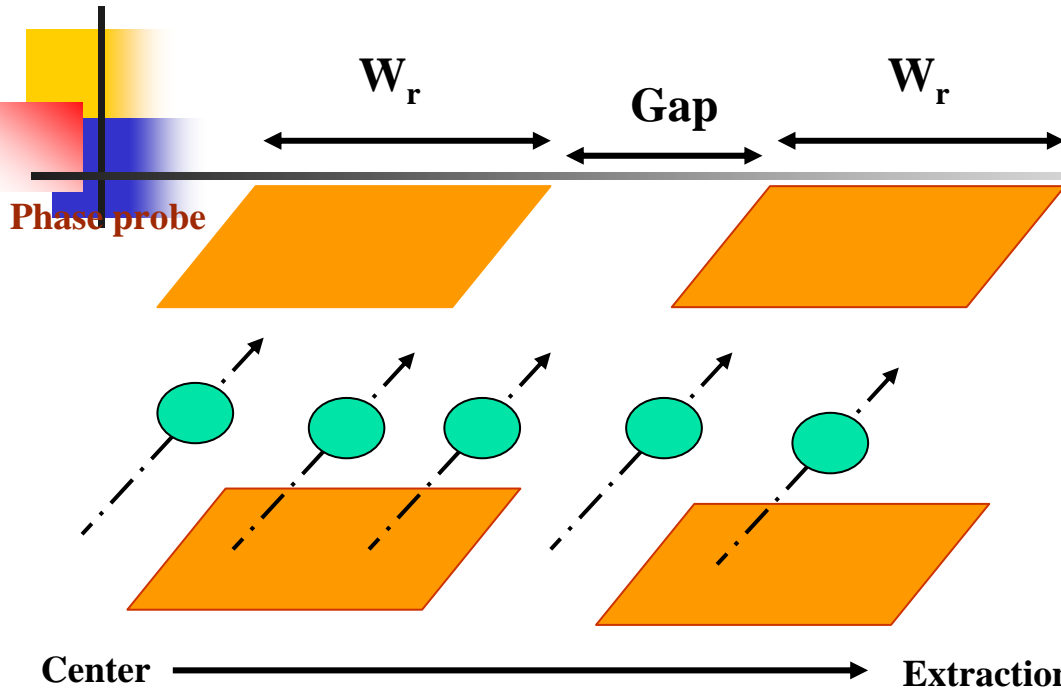
$$\Delta R = R_{ext} \cdot \frac{\Delta E}{2E_{ext}} = \frac{1}{2} \frac{R_{ext}}{N}$$

$$N = \frac{E_{ext}}{\Delta E}$$



Isochronous field

Phase excursion



$$\Delta\phi = (360^\circ) \times h \int_0^N \frac{\Delta B}{B} dn$$

for example,

$$\Delta B/B = 50(\text{G}) / 12000(\text{G}) = 4 \times 10^{-3}$$

$$N = 10 \text{ (turn)}$$

$$\Delta\phi = 15 \text{ (deg.)}$$

$$\cos(\Delta\phi) = 0.966$$

$$\Delta E = V_{\text{dee}} \times N' = 50 \text{ (kV)} \times 10 \text{ (turn)}$$

$$\delta(\Delta E) = 17 \text{ (keV)}$$

$W_r = 53 \text{ (42) mm} : \sim 20 \text{ turns}$

$\text{Gap} = 47 \text{ (18) mm} : 10 \sim 20 \text{ turns}$

Averaged phase of multi-turn is measured.

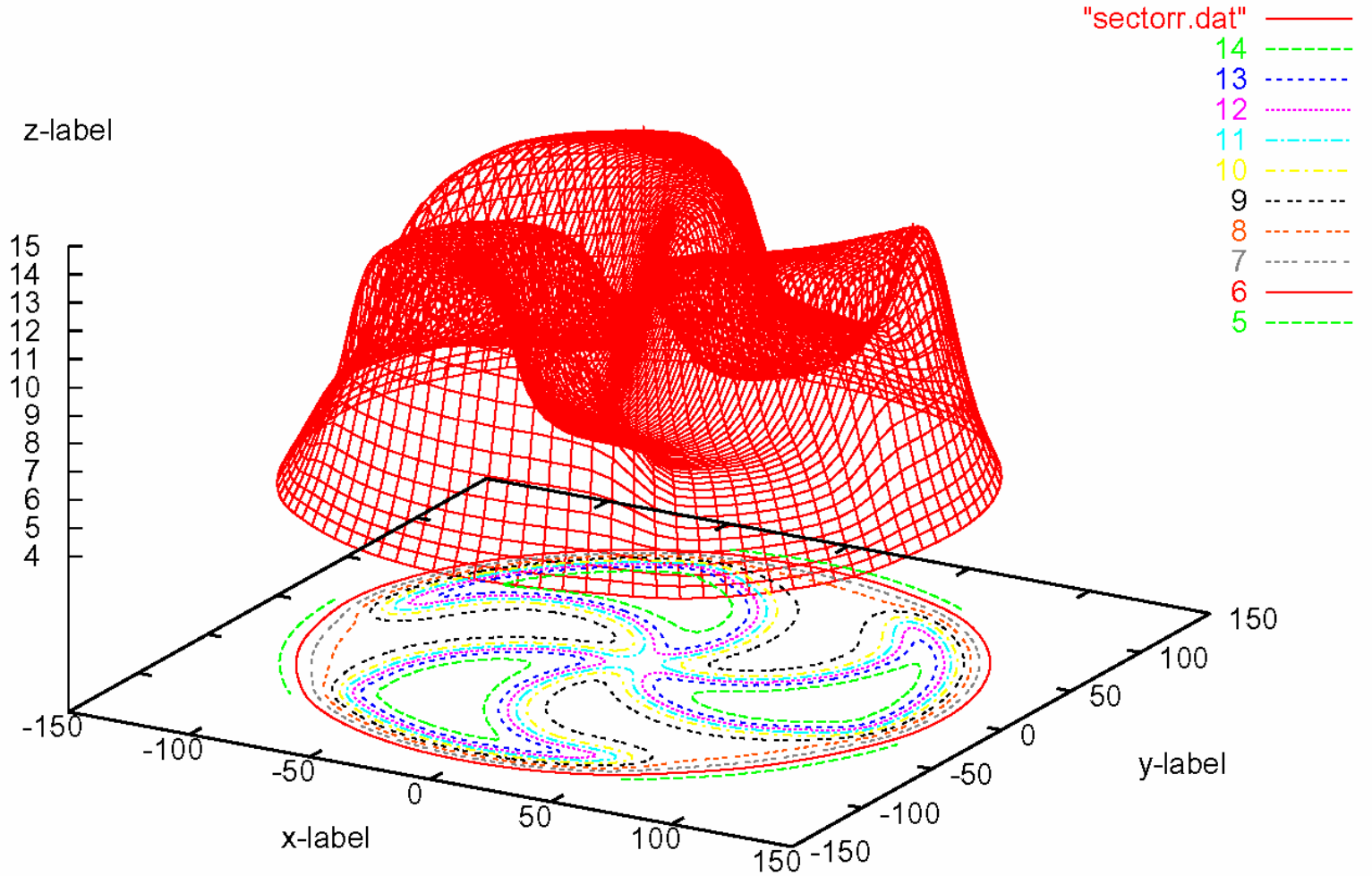
No measurements at several radii.



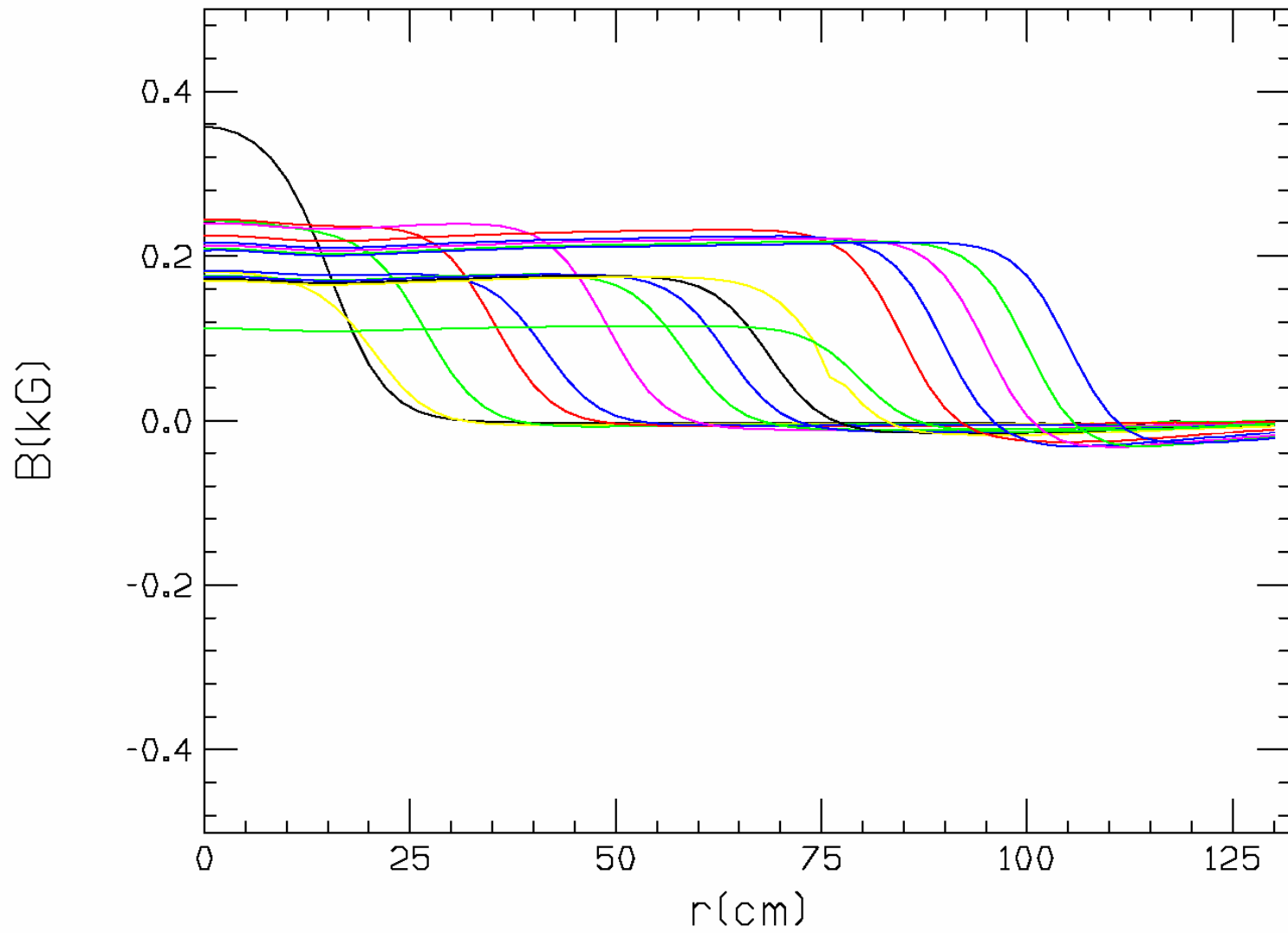
Local distribution of the magnetic field is important.

It should be as smooth as possible.

RCNP AVF cyclotron (p-65 MeV)



RCNP AVF cyclotron



Initial setting currents to trim coils.

1. Equilibrium closed orbits at several radii
2. Isochronous condition ($\Delta\phi < 30$ deg.)

(by K. Hosono)

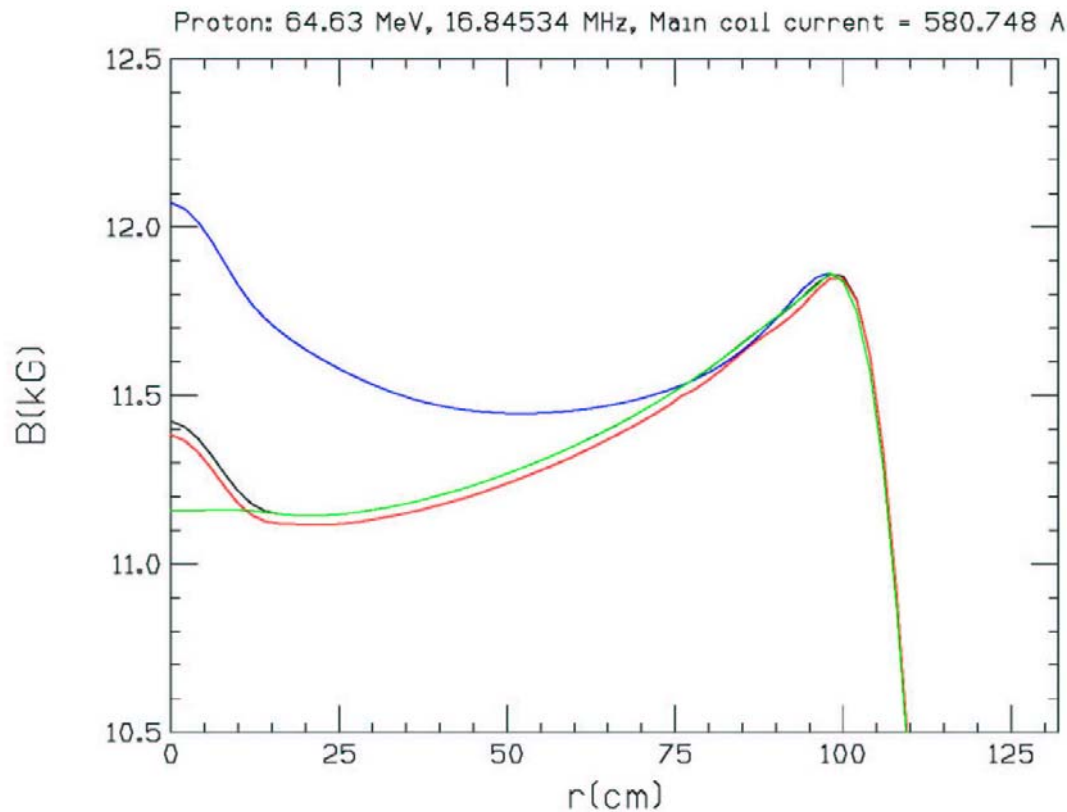


Solution of the eq. of motion by RKG integration method.

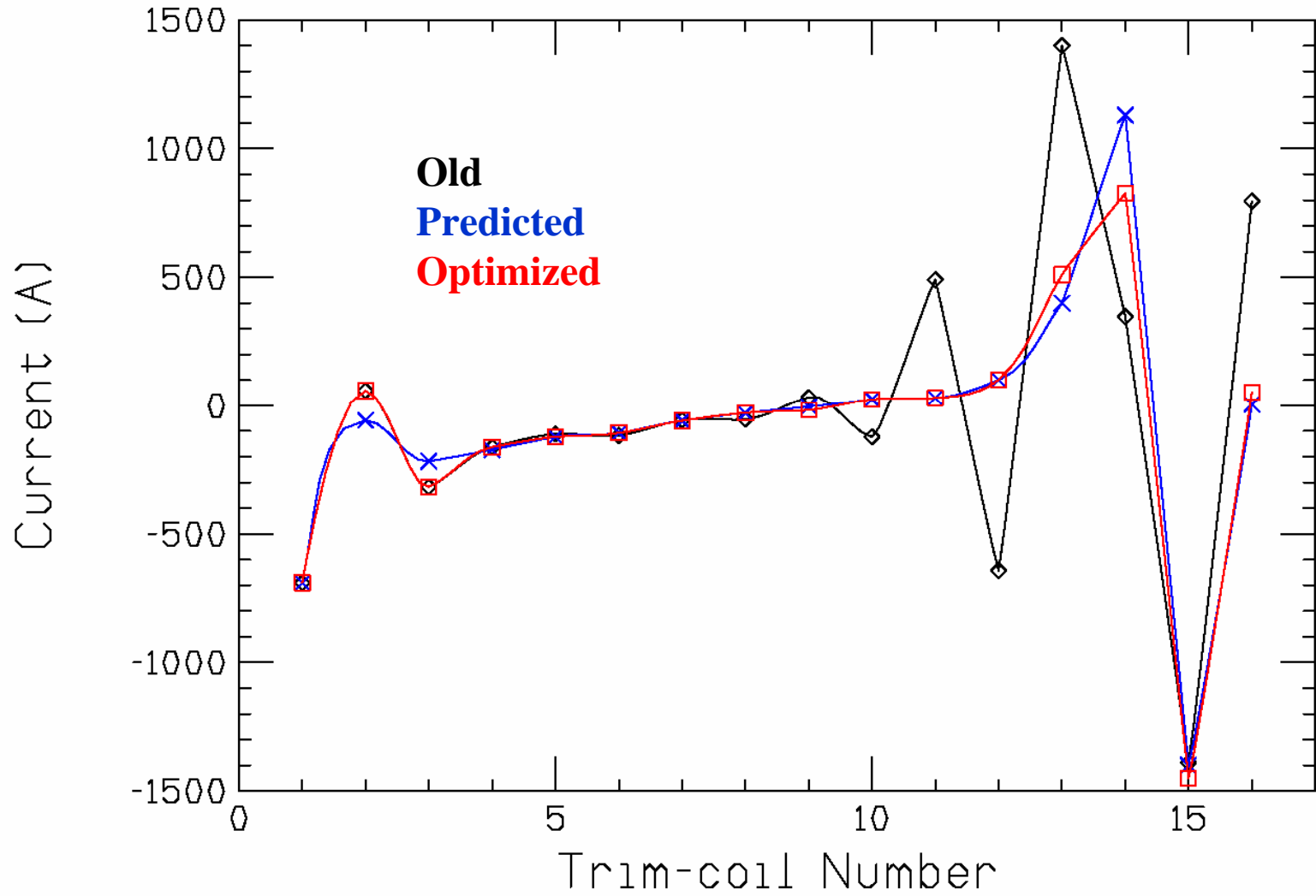
from the entrance of the inflector to the extraction radius of the cyclotron.

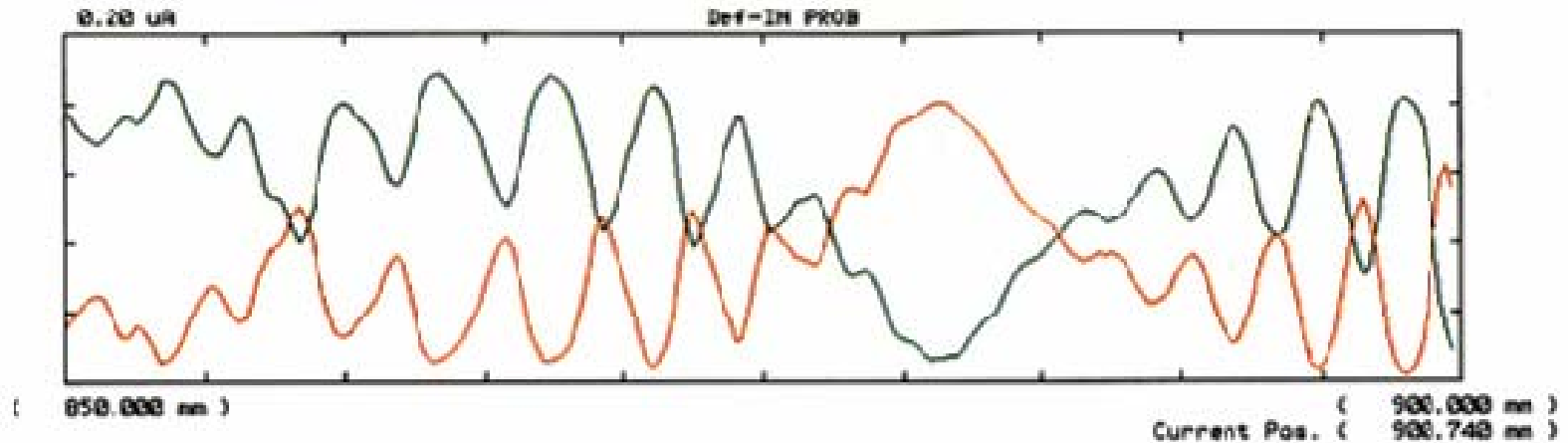
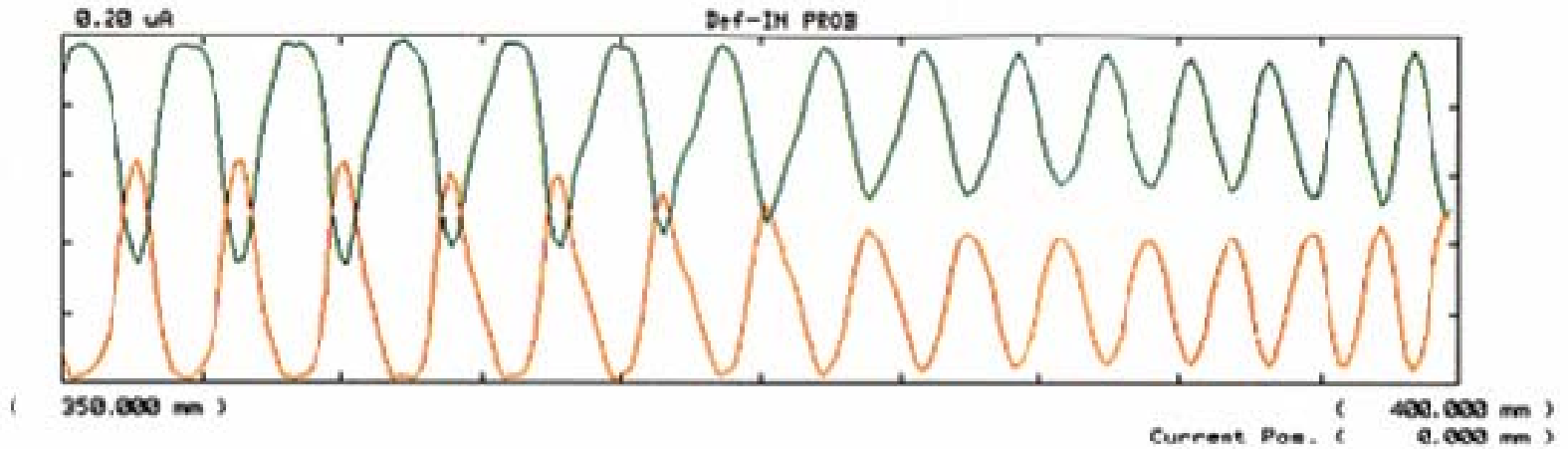
1 – 2 min. (CPU time)

30 – 60 μ s (beam)



Trim-coil currents: 3He 88 MeV (420 MeV) 11.650 MHz, Vdee = 38 kV





New initial parameter. After adjusting currents of a few trim-coils at the extraction region.

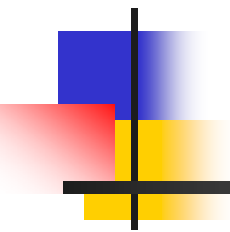
トリムコイル・磁気チャネル電源



AVF 本体室地下

Table 2: Specification of the power supplies for trim coils, dipole and quadrupole magnets

Coil or magnet	Max. current (A)	Max. voltage (V)	Polarity	Stability (/8h)	Ripple
Trim #1	1000	12	no	0.64×10^{-5}	0.29×10^{-7}
Trim #2	500	6	yes	0.78×10^{-5}	0.10×10^{-6}
Trim #3	500	6	yes	0.70×10^{-5}	0.15×10^{-5}
Trim #4	300	5	yes	0.88×10^{-5}	0.81×10^{-5}
Trim #5	300	5	yes	0.78×10^{-5}	1.53×10^{-5}
Trim #6	300	5	yes	0.80×10^{-5}	0.31×10^{-5}
Trim #7	300	5	yes	0.63×10^{-5}	0.51×10^{-5}
Trim #8	300	5	yes	1.00×10^{-5}	0.54×10^{-5}
Trim #9	300	5	yes	0.88×10^{-5}	1.04×10^{-5}
Trim #10	300	5	yes	0.80×10^{-5}	0.28×10^{-5}
Trim #11	300	5	yes	0.48×10^{-5}	0.34×10^{-5}
Trim #12	500	6	yes	0.89×10^{-5}	0.10×10^{-6}
Trim #16	300	5	no	0.48×10^{-5}	0.34×10^{-5}
Mag. channel	1000	6	no	0.79×10^{-5}	0.20×10^{-5}
Dipole A1	450	70	no	0.42×10^{-5}	0.30×10^{-6}
Dipole A2	450	70	no	0.83×10^{-5}	0.13×10^{-6}
Dipole A3	450	45	no	0.69×10^{-5}	0.42×10^{-6}
Quad. magnet	75	45	no	0.40×10^{-4}	0.60×10^{-5}
Quad. magnet	35	40	no	0.30×10^{-4}	0.80×10^{-5}



加速系



AVF 高周波系の仕様

Accelerationg frequency	6-18 MHz
Max. accelerating voltage	100 kV peak
Max. accelerating RF power	400 kW
Flat-top harmonic number	5, 7, 9
Max. flat-top voltage	5 kV peak
Max. Q-value of flat-top RF power	15 kW
Max. flat-top resonator voltage	80 kV peak
Max. flat-top resonator current dnsity	50 A/cm



終段増幅器



中間段増幅器

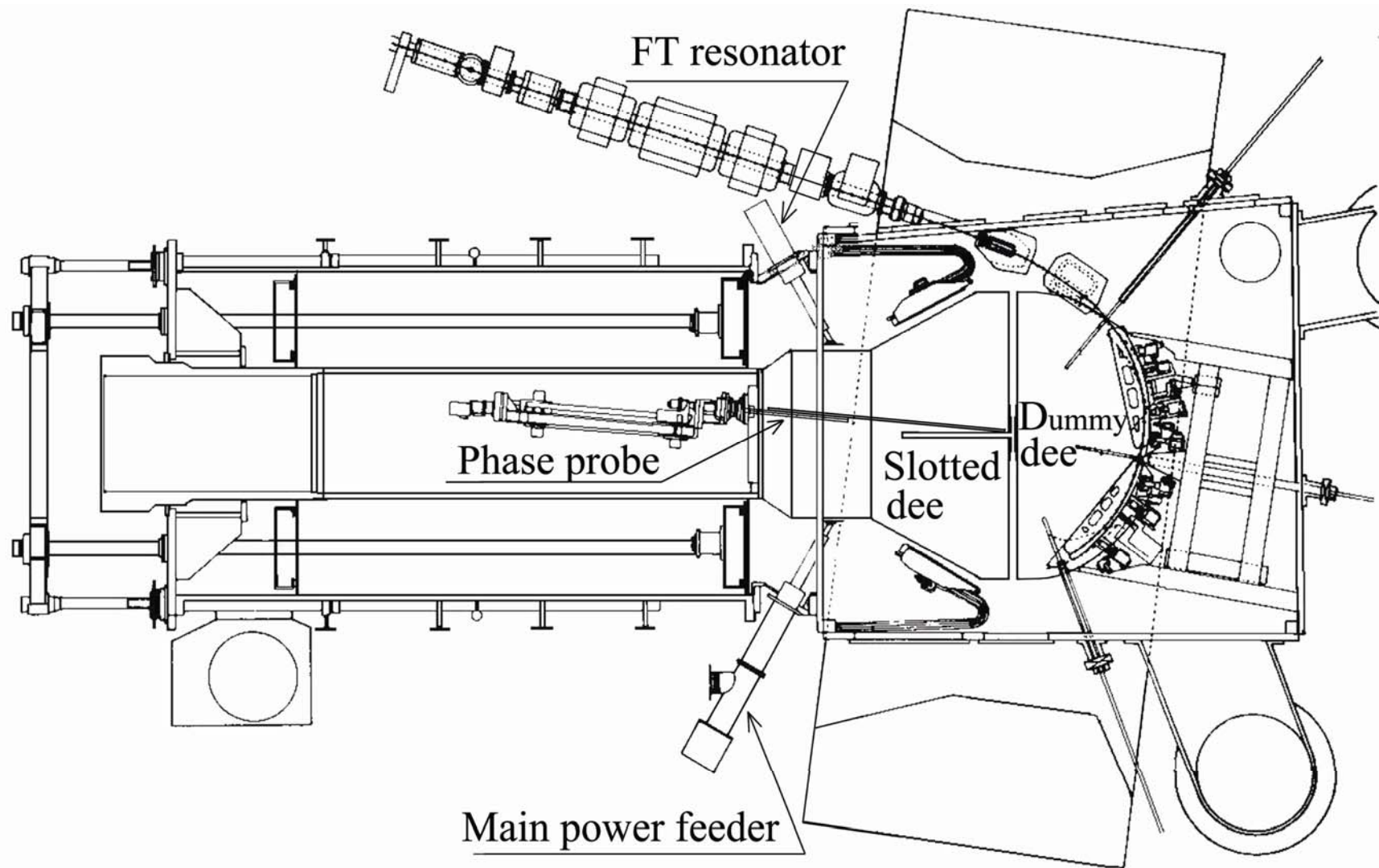
RS2042SK

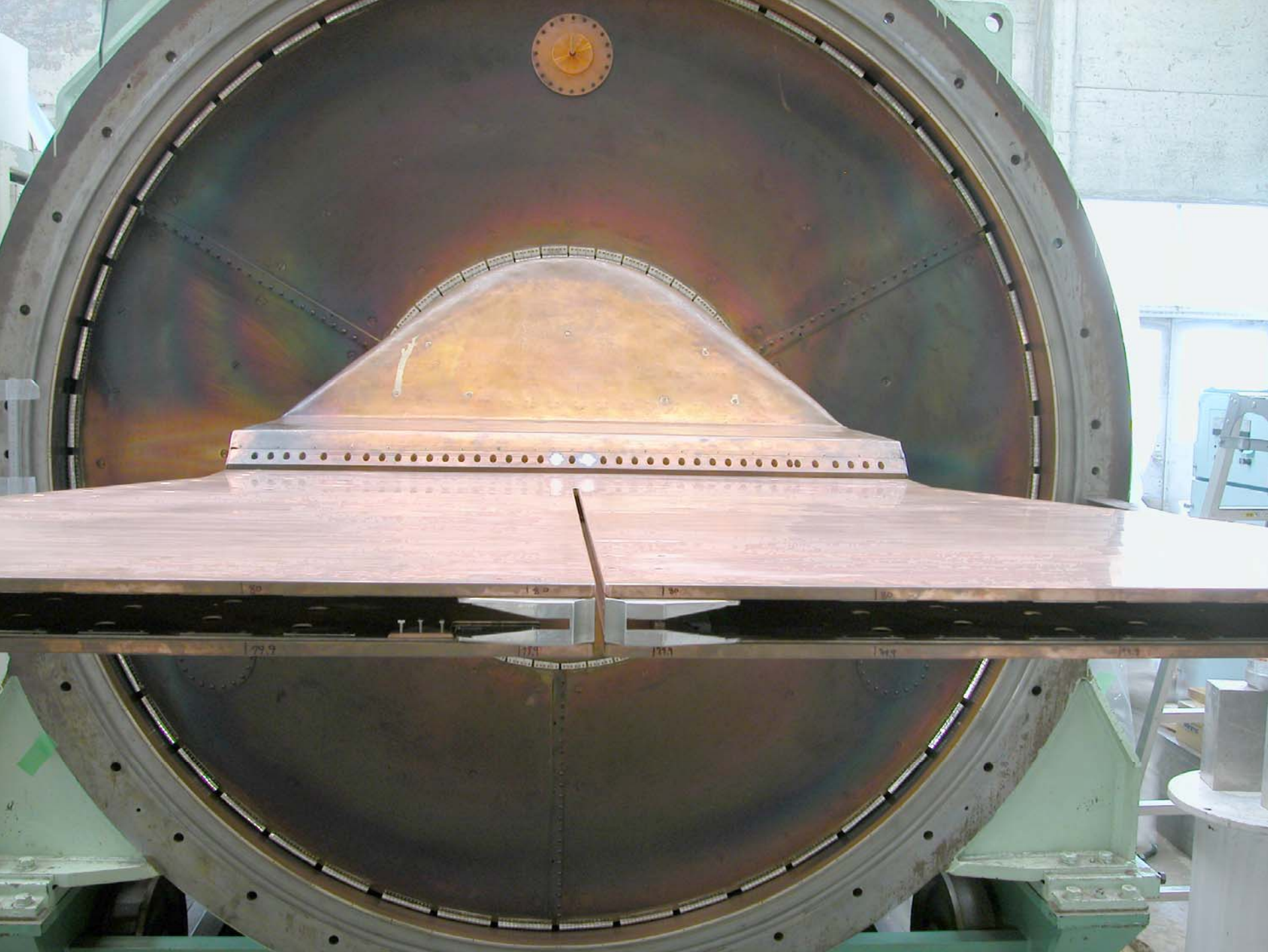
DANGER
HIGH VOLTAGE



電力フィーダー

AVF共振器

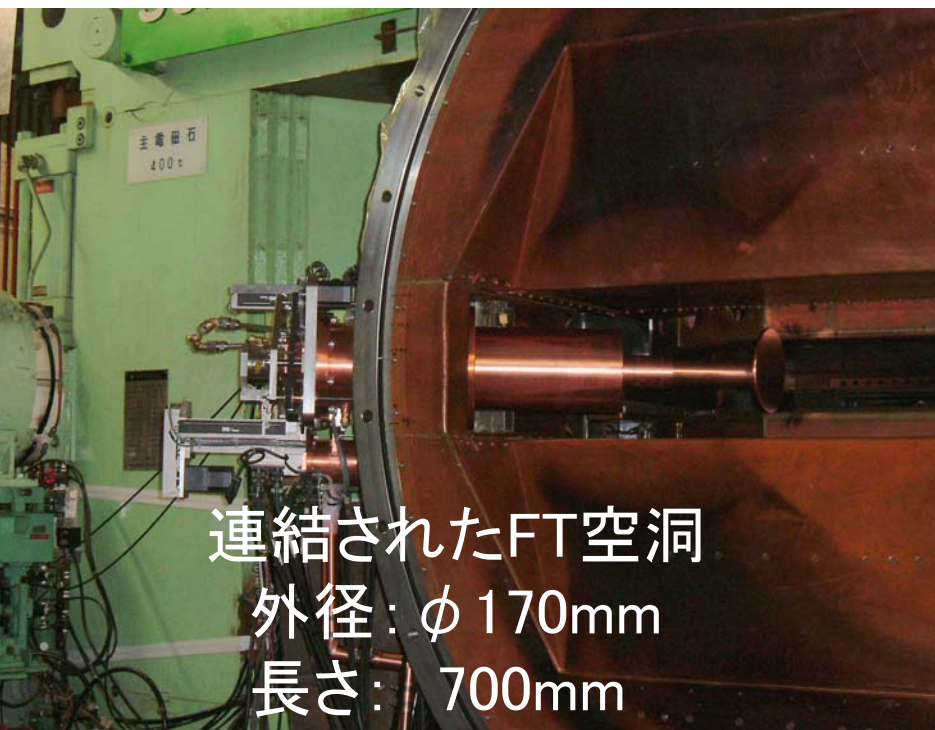




FT 空洞



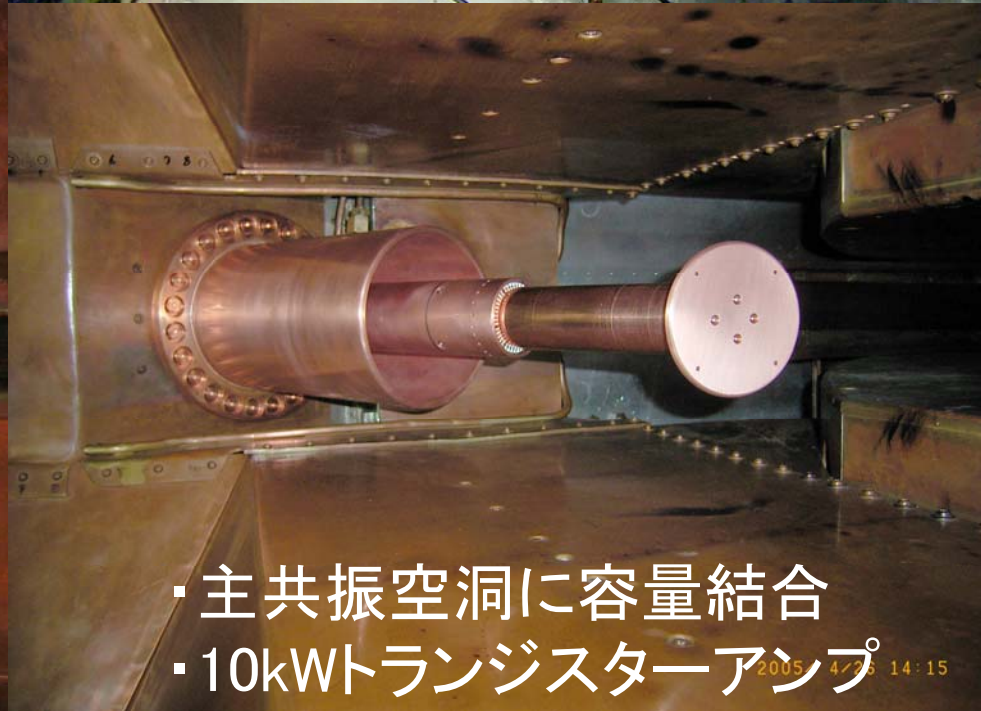
FT 空洞



連結されたFT空洞

外径： $\phi 170\text{mm}$

長さ：700mm



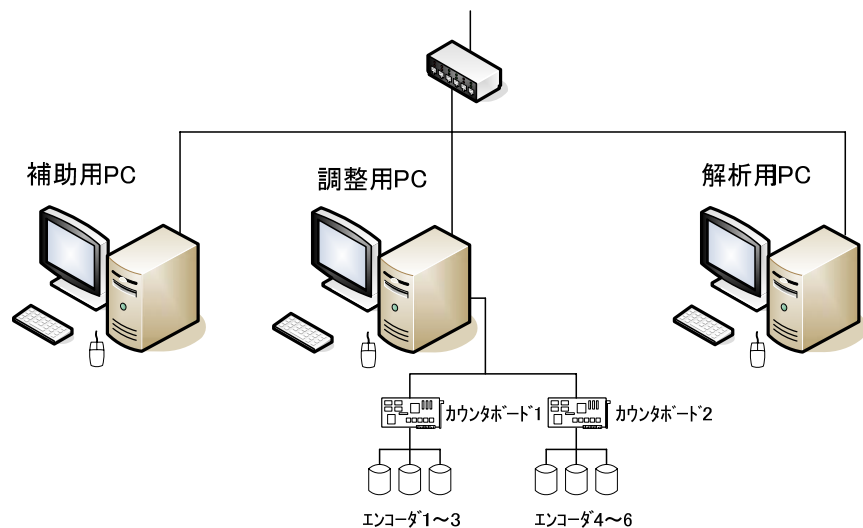
・主共振空洞に容量結合

・10kWトランジスターアンプ

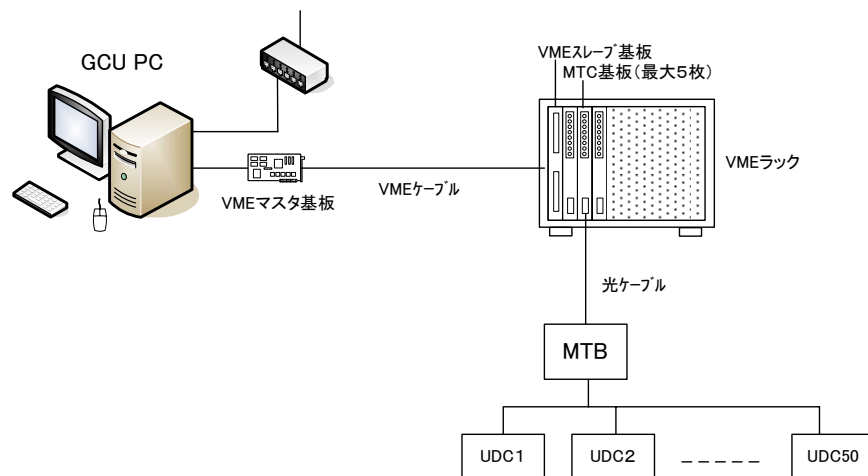


制御系

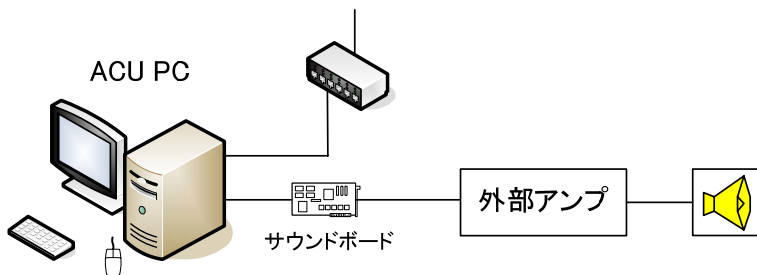
SCU 3 系統



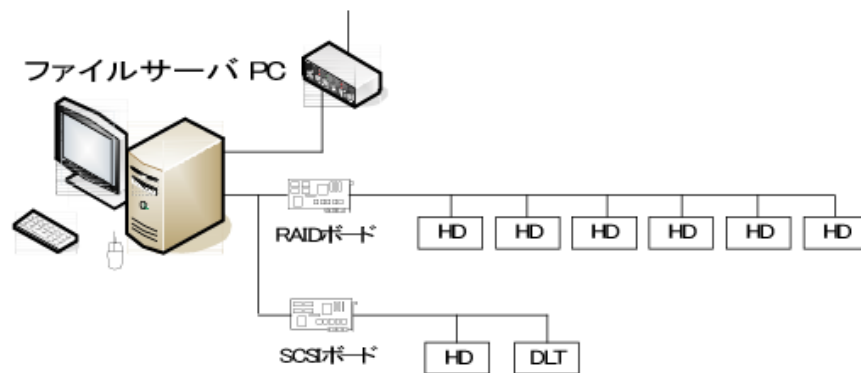
GCU 6+1 系統



ACU



File server



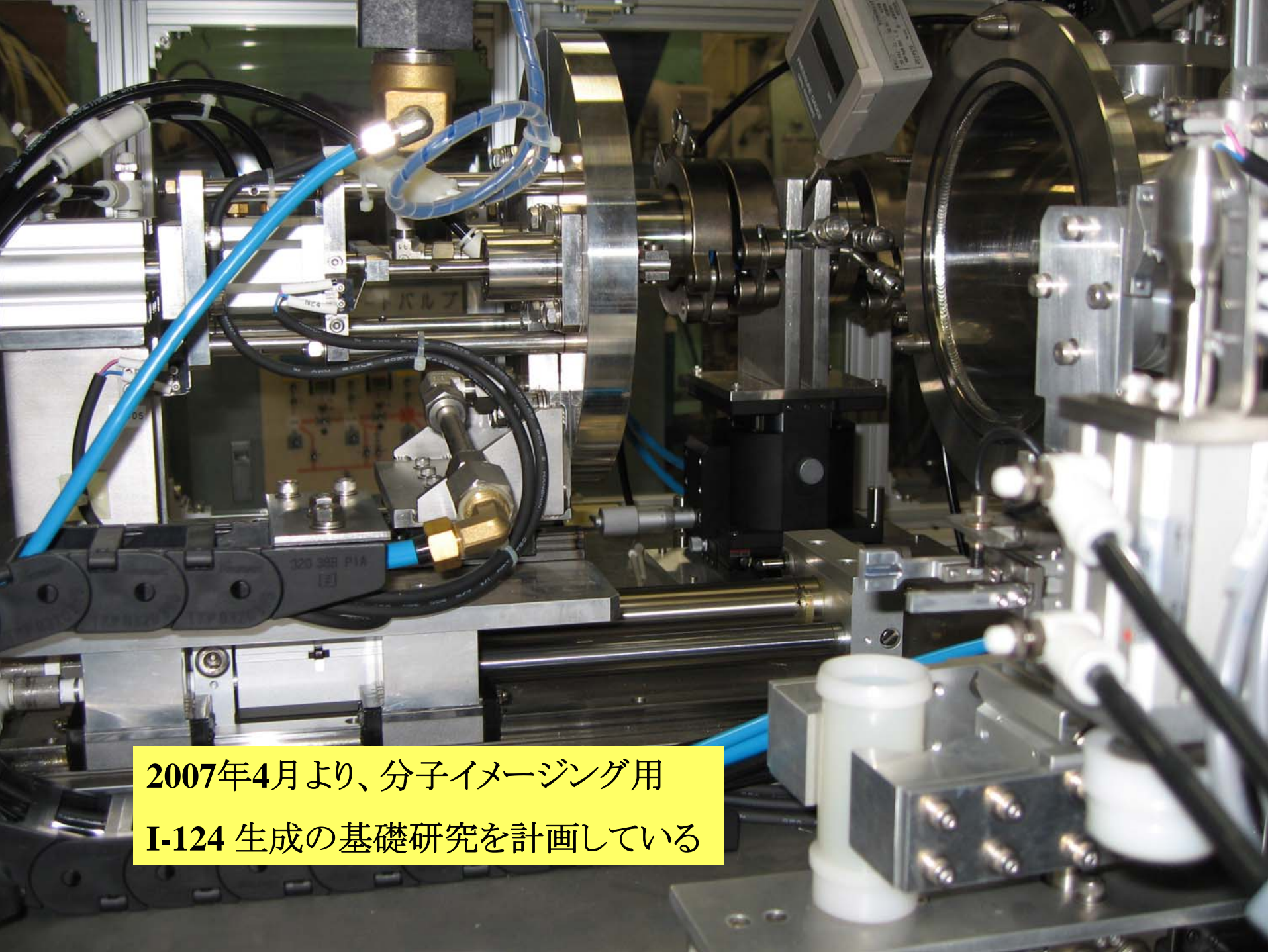


10
Sun Mon Tue Wed Thu Fri Sat
2 3 4 5 6 7 8
9 10 11 12 13 14 15
16 17 18 19 20 21 22
23 24 25 26 27 28 29

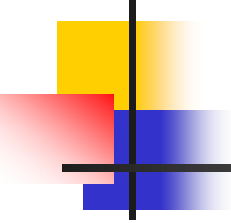


核化学(Kコース)





2007年4月より、分子イメージング用
I-124 生成の基礎研究を計画している



分析・バイパスビームライン

- AVF ビームの診断

二重収束

運動量ディスパージョン **12.6 m**

(時間幅)

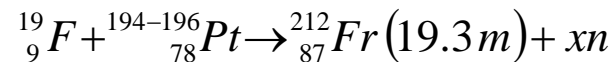
- AVF ビームの直接利用

p: 10-400 MeV

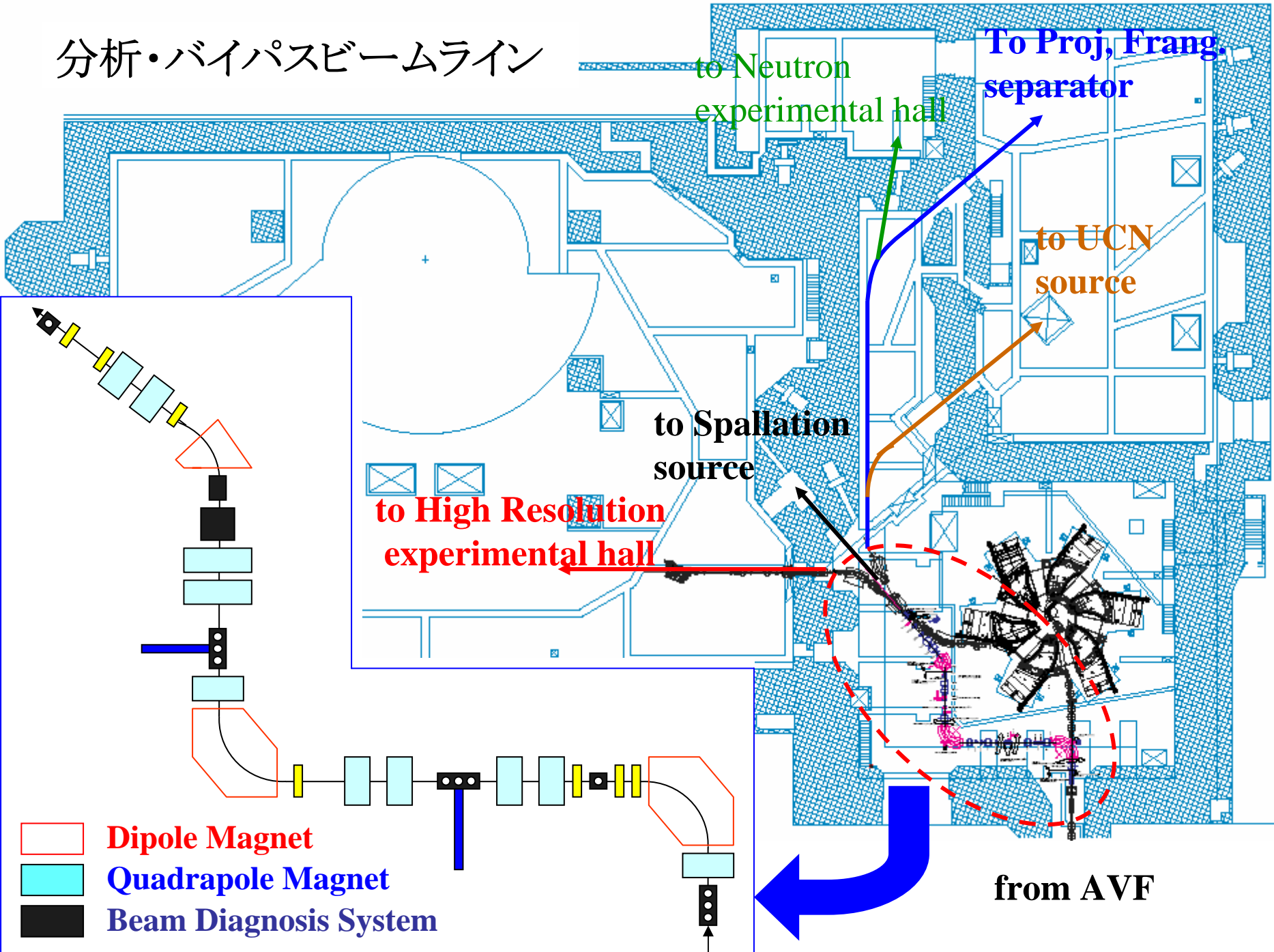
$^{40}\text{Ar}^{8+}$: 5MeV/u

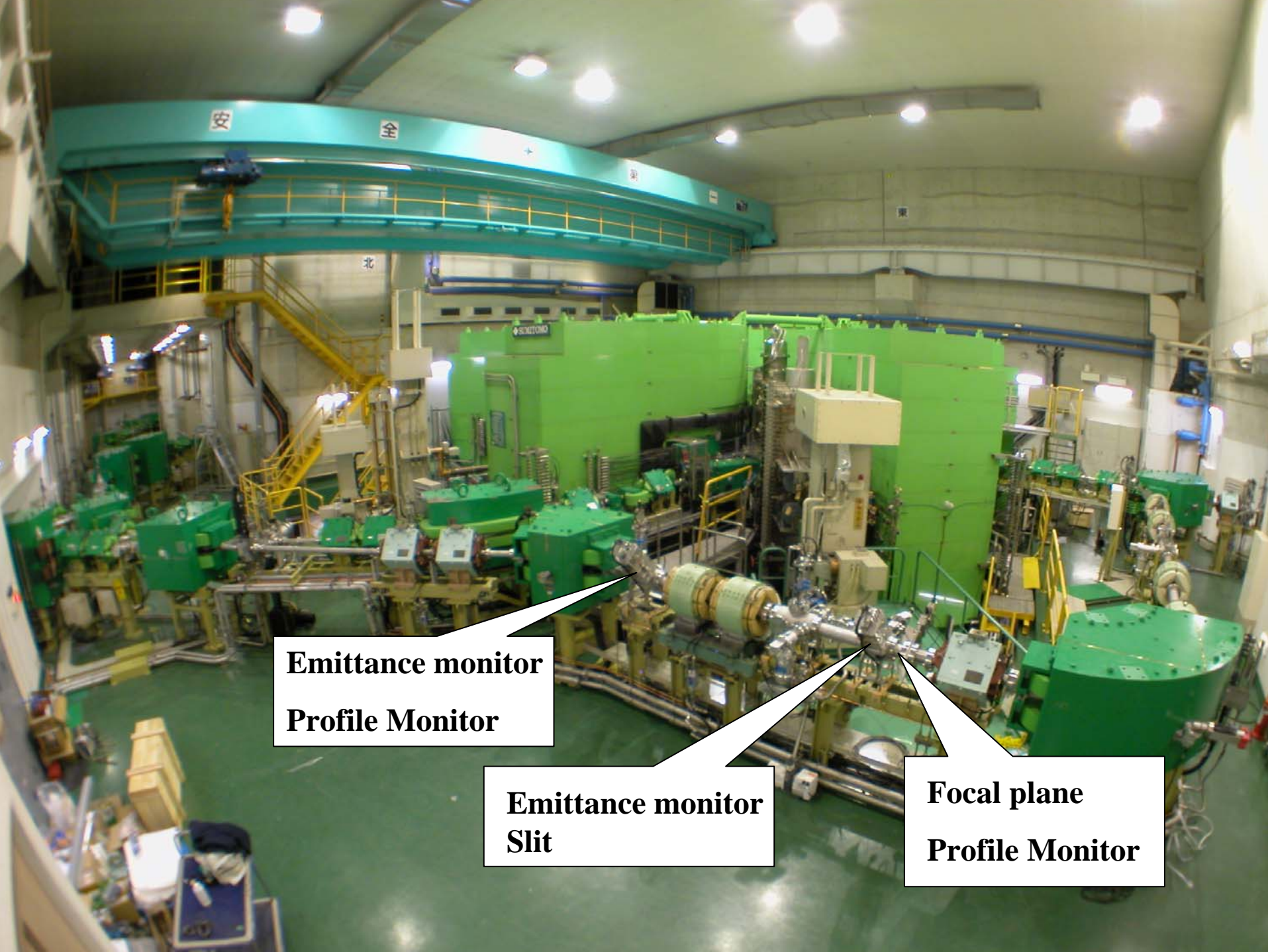
$^{86}\text{Ar}^{23+}$: 8.5MeV/u

$^{19}\text{F}^{4+}$: 100MeV, 500nA



分析・バイパスビームライン





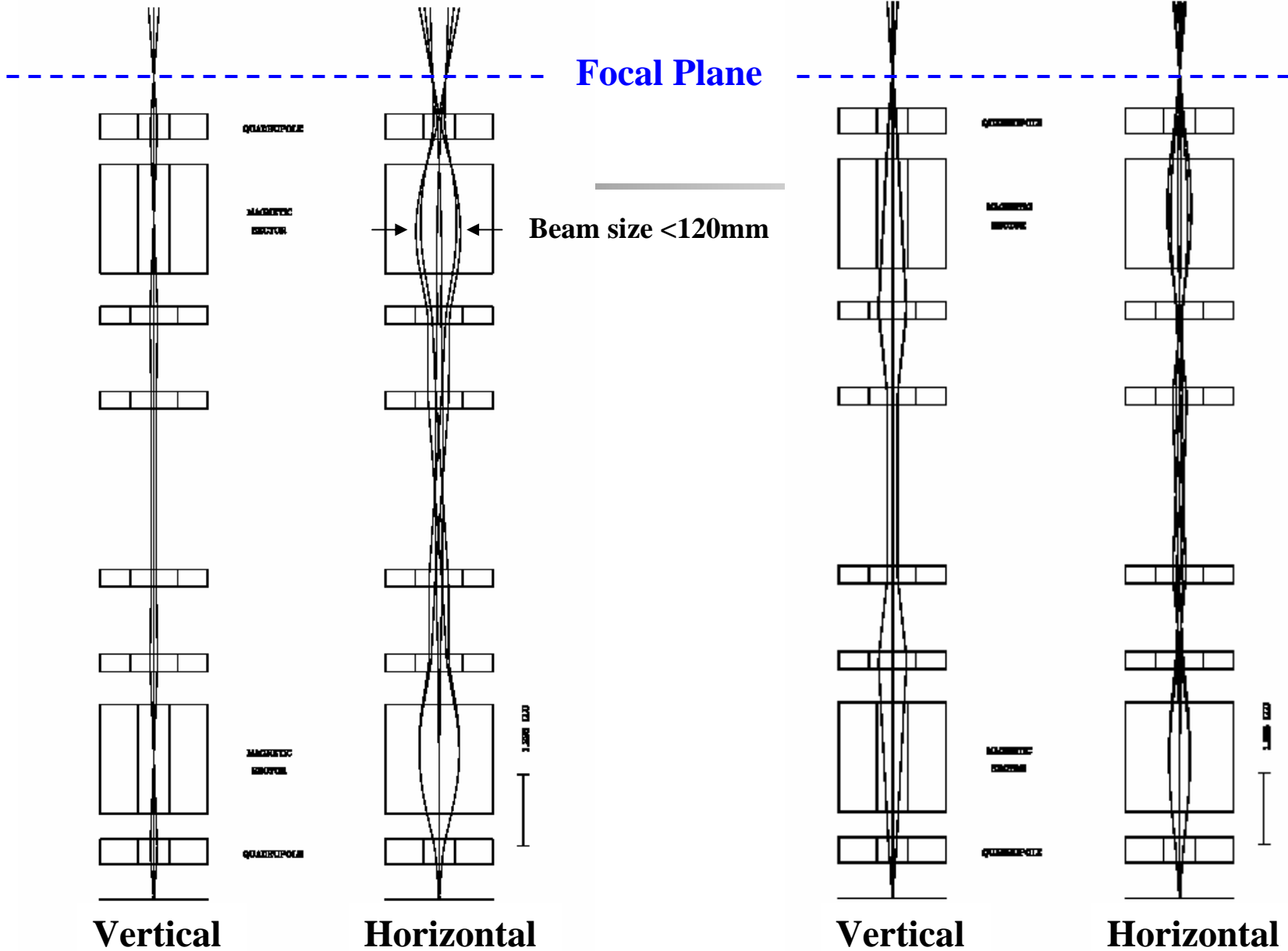
Emittance monitor
Profile Monitor

Emittance monitor
Slit

Focal plane
Profile Monitor

Dispersive Transport

Achromatic Transport



ビームエミッタンス測定

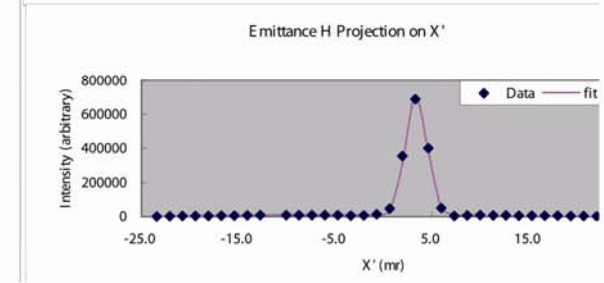
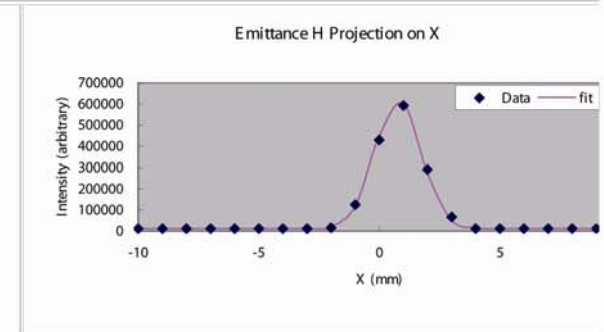
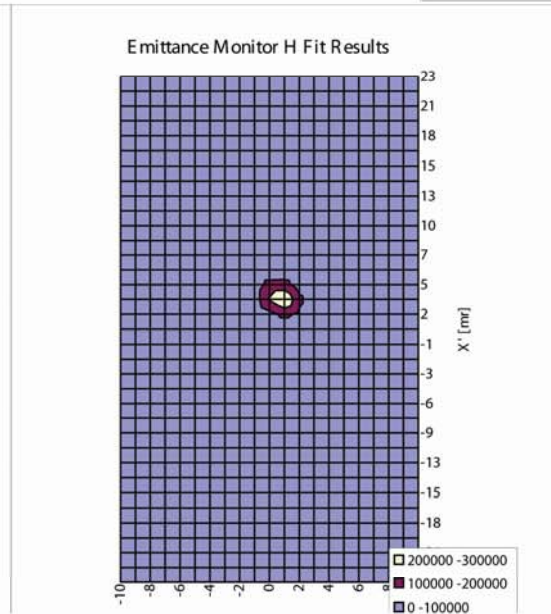
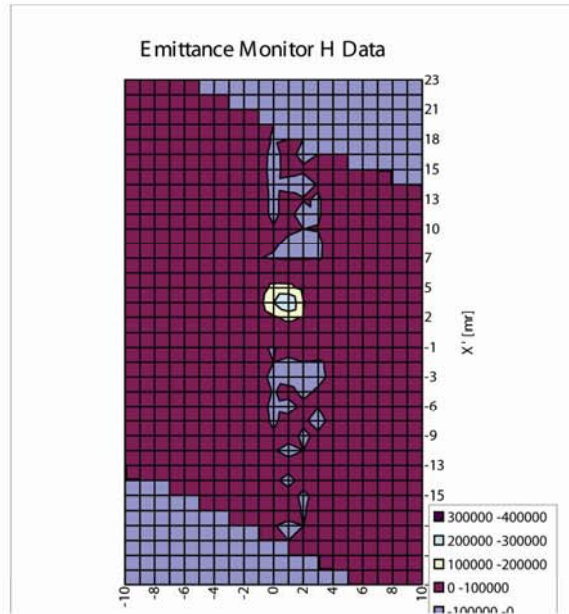
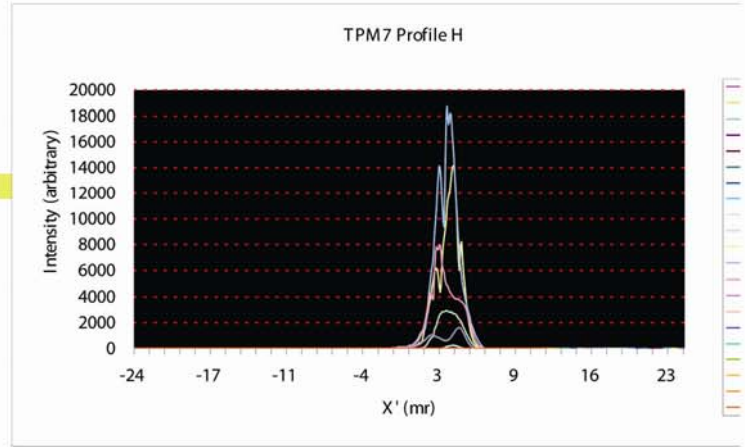
鳥丙作	朮	蟹	萱	蕁	薙	・刈
・厄葺瀧	2007	1	24	16	53	52

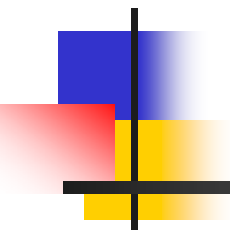
	紋鮫秣単	・ 糎厄単	
height	16290.12	1727.18	
X_0	0.77	0.71	mm
X_sigma	0.95	2.56	mm
X'_0	3.38	3.01	mr
X'_sigma	1.02	4.21	mr
correlation (rho)	-0.25	-0.32	
constant	24.27		

1-rho^2 0.94
 r.m.s. deviation 213.52

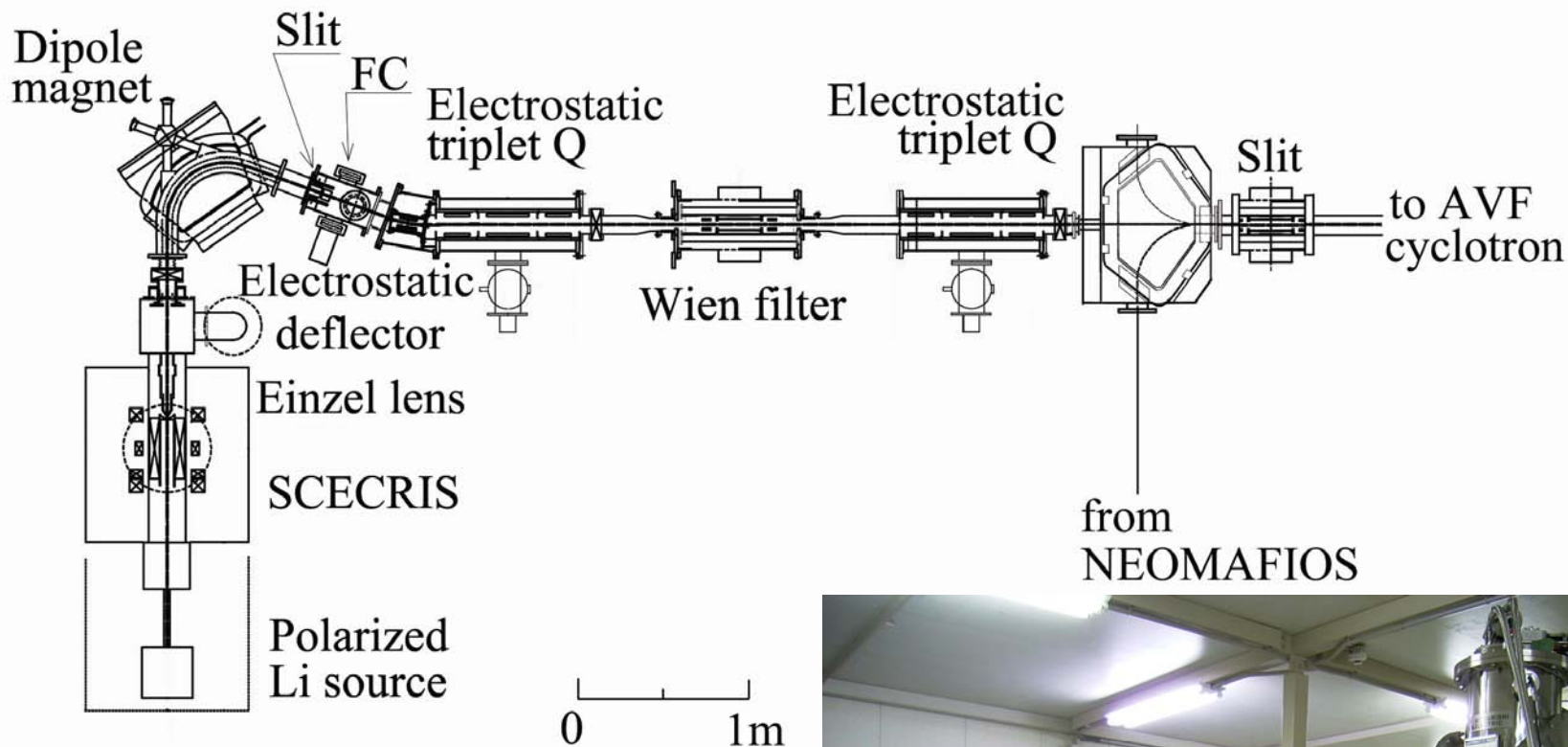
emittance (sigma)	0.94	・ mm mr
Emittance (50%)	1.30	・ mm mr
Emittance (90%)	4.33	・ mm mr

紋瘡蝶標:
 emh_070124165352.csv





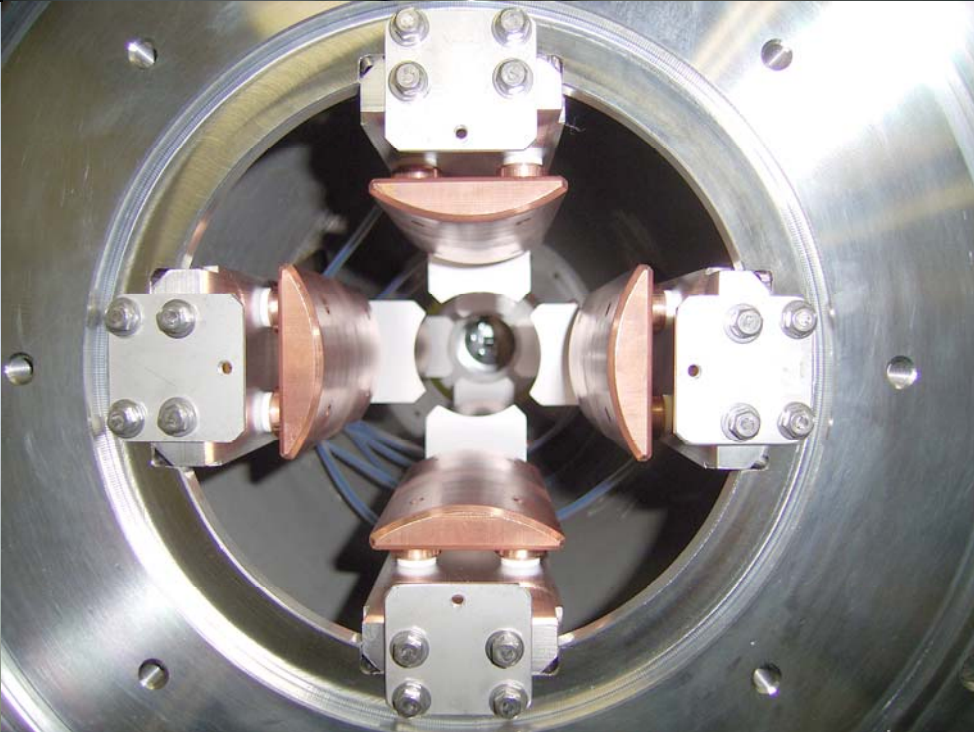
イオン源



- 六極電磁石内径を90mm、プラズマ
チャンバー内径を80mmに拡大

18GHz 超伝導 ECR イオン源







18GHz ECRIS 開発

^{15}N 6+: 15 μA

Without charge stripping, **64MeV/u** from Ring cyclotron

With charge stripping, **80MeV/u** from Ring cyclotron

^{40}Ar 8+: 10 μA

5MeV/u from AVF cyclotron

12+: 2 μA

Without charge stripping, **36MeV/u** from Ring cyclotron

With charge stripping, **42MeV/u** from Ring cyclotron

13+: 700pA

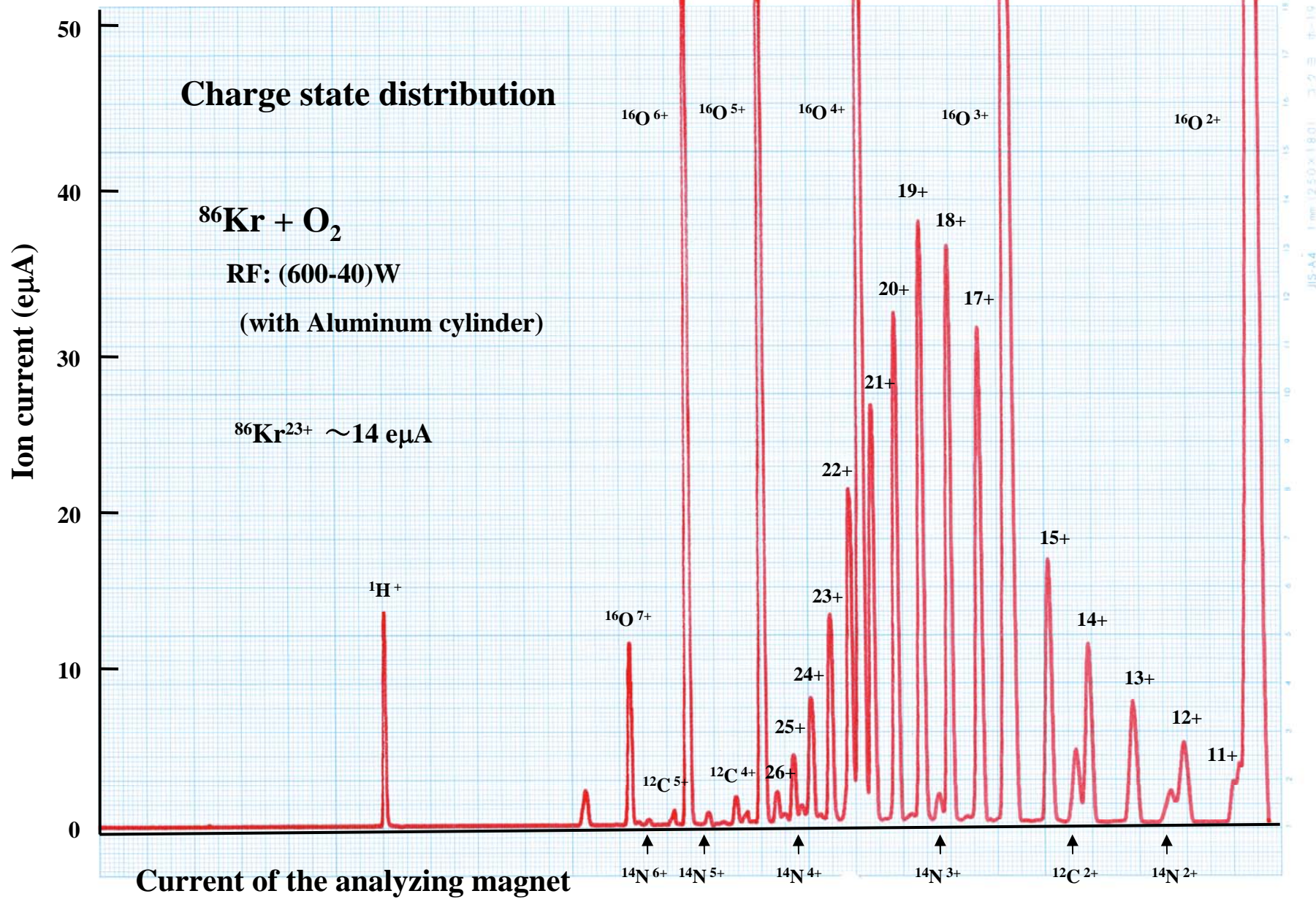
Without charge stripping, **42MeV/u** from Ring cyclotron

^{84}Kr 22+: 200pA

7.5MeV/u from AVF cyclotron

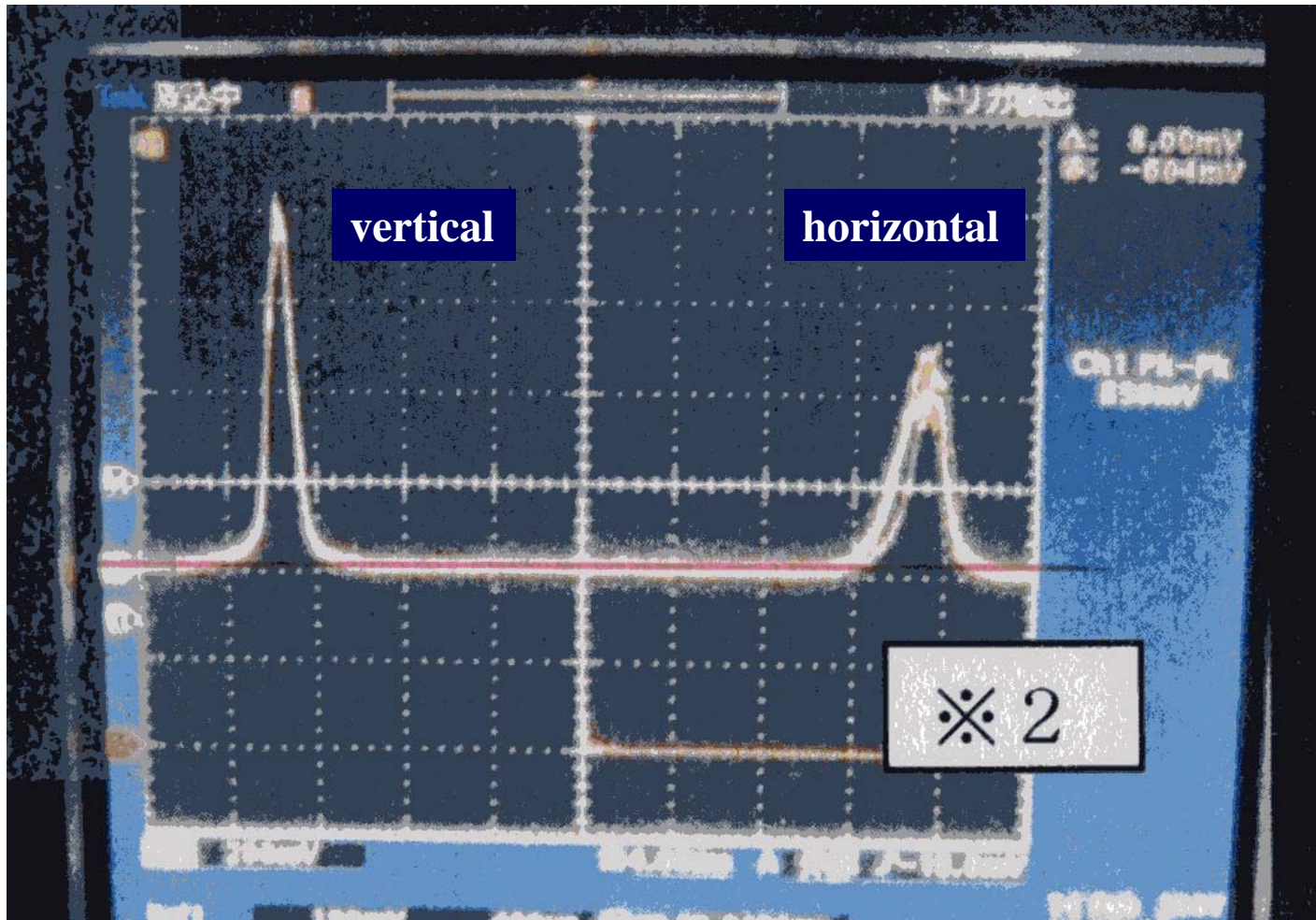
^{86}Kr 23+: 600pA

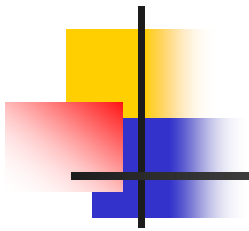
8.5MeV/u from AVF cyclotron



Beam profile at the Wien filter position

(middle of two electrostatic quadrupole lenses)



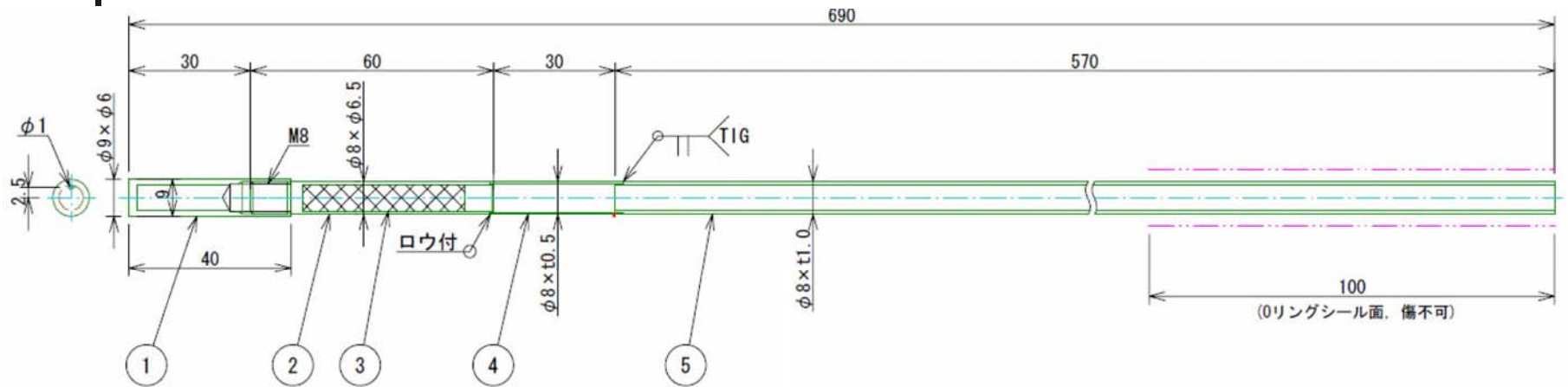


今後の開発課題

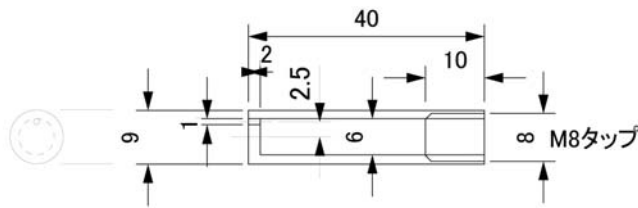
- ミラーコイル磁場
- ×ライナー(アルミニウム)
- バイアスプローブ
- ガスミキシング
- 金属イオン
- 輸送・入射・加速テスト

1月以降を予定

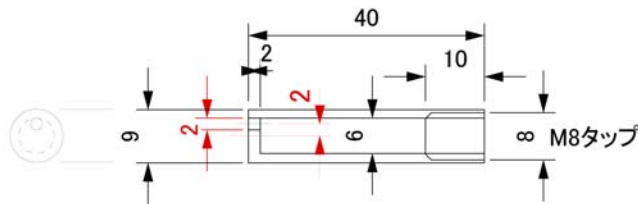
Li マイクロオーブン開発



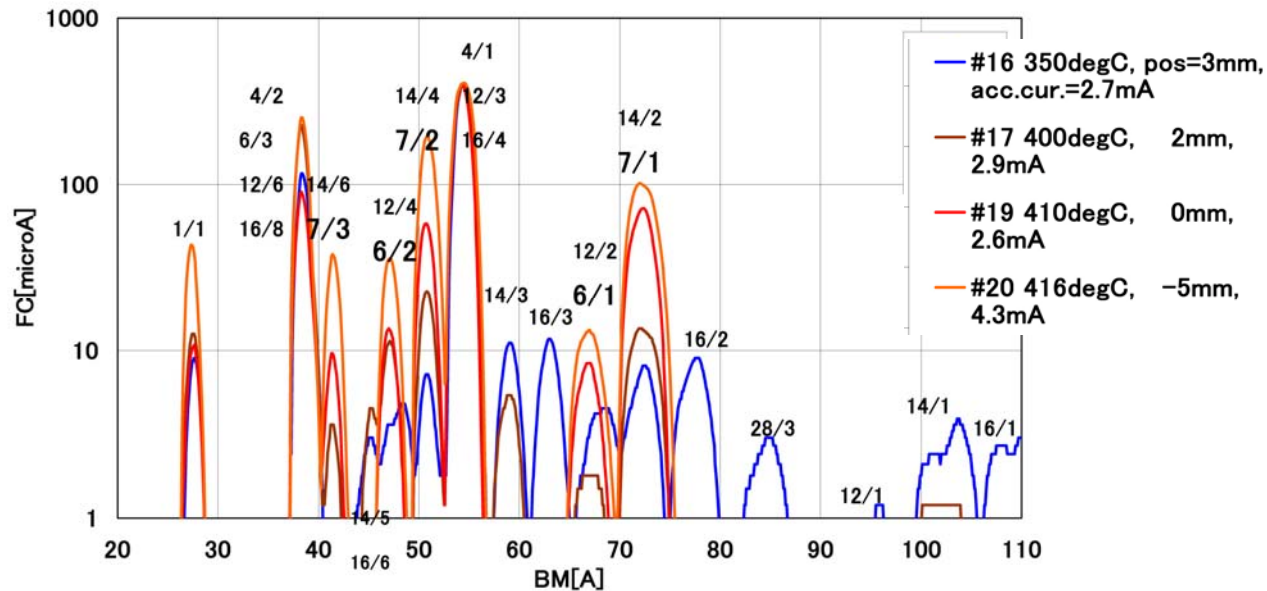
⑩1 銅 × 2個



⑩2 銅 × 2個



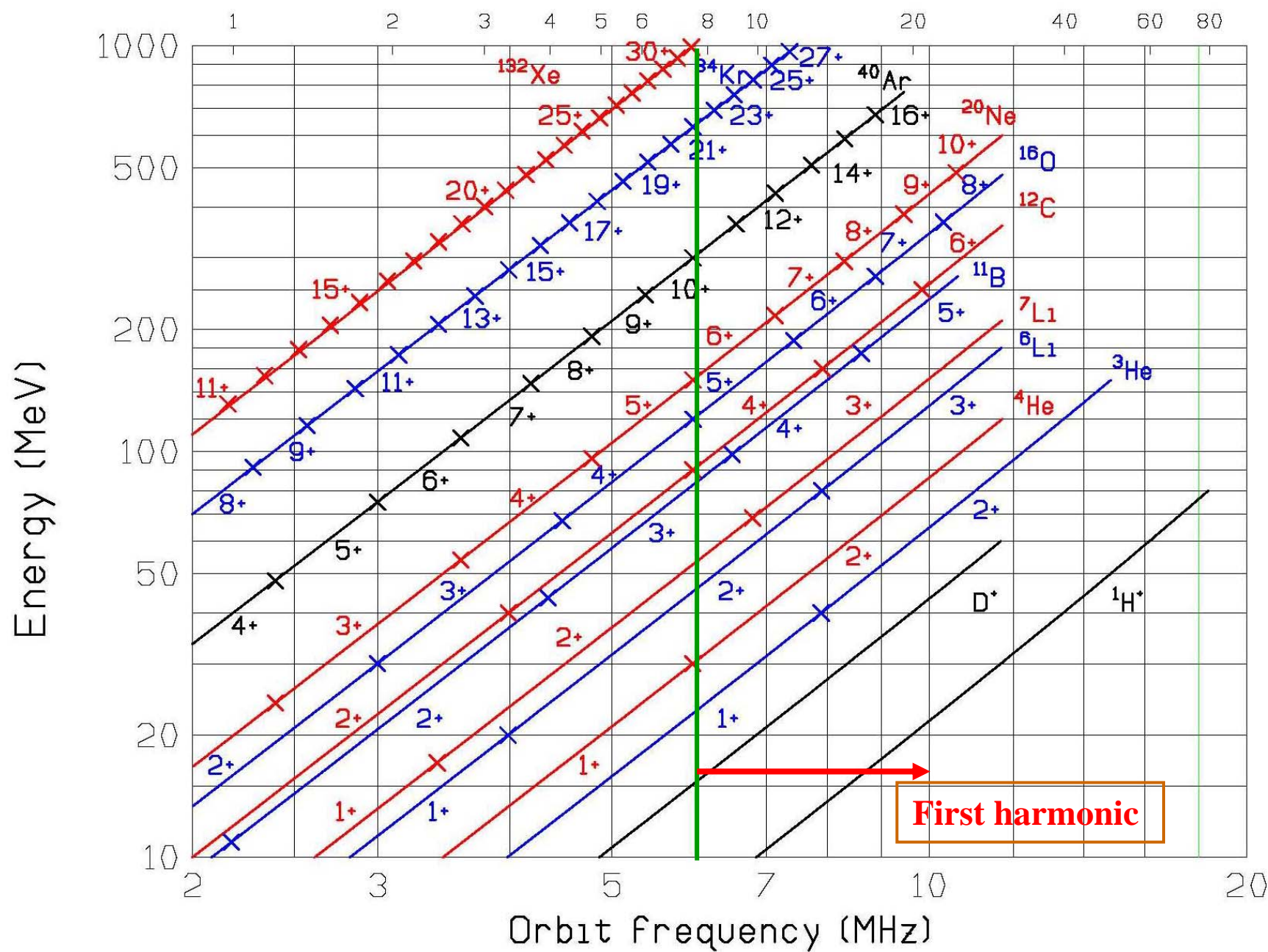
${}^7\text{Li}^{3+}$: 40 μA at 416 deg.

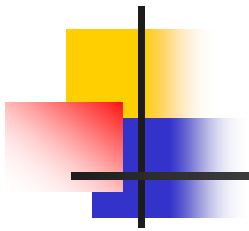


今後の開発課題:

- Li 蒸気量増 → プラズマ増 → オープン温度増 → Li 増 (又はガス放出増) で暴走
- 500°C 仕様のオープン
 ロウ付け ⇒ EMW
 熱電対内臓カートリッジヒータ
- オープン形状の最適化

Energy at R = 100 cm (MeV/nucleon)





共同研究者

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富永健一、森信俊平、佐藤健次、二宮史郎、酒見泰寛、
後藤英樹、稲田洋司、魚梁博之、大江洋一、増田欽哉、
佐田野圭吾、羽田知史、力石 将樹、齋藤典亨、
矢富一慎、樋掛正明、大成善之助
密本俊典(住重)、川口武男(KTサイエンス)