RF System for heavy ion cyclotrons at RIKEN RIB-Factory

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Contents

- RIKEN RIB Factory from the rf point of view
- Requirement
- Key issues of RF System
- Present Performance

RIKEN RIB-Factory

- **Mission**

  expand the availavility of heavier RIB

- **Primary Beam from accelerators**

  wide mass range deuteron ～uranium

  variable energy 150 ～440 MeV/u

  high power <1 particle μA

- **Energy booster** (LINAC/AVF, RRC=>new facility)

  three cyclotrons : SRC, IRC, FRC

  velocity gain 2.25

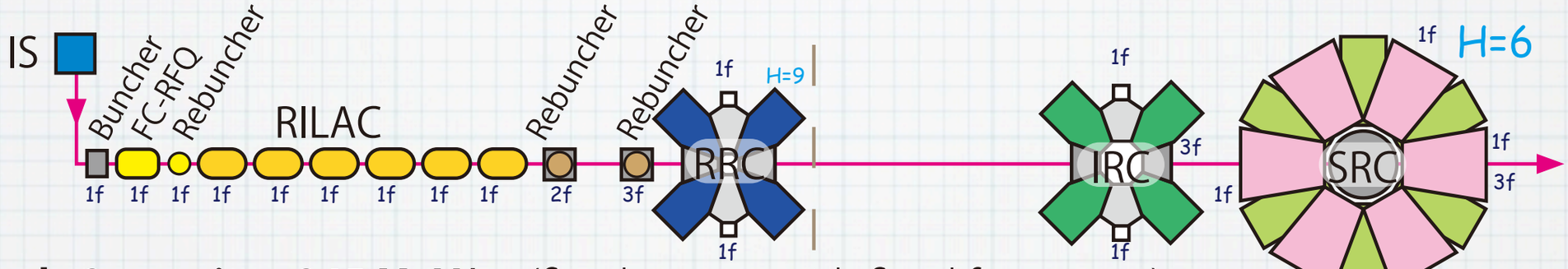
  charge conversion by stripper foils

- **Superconducting Ring Cyclotron**

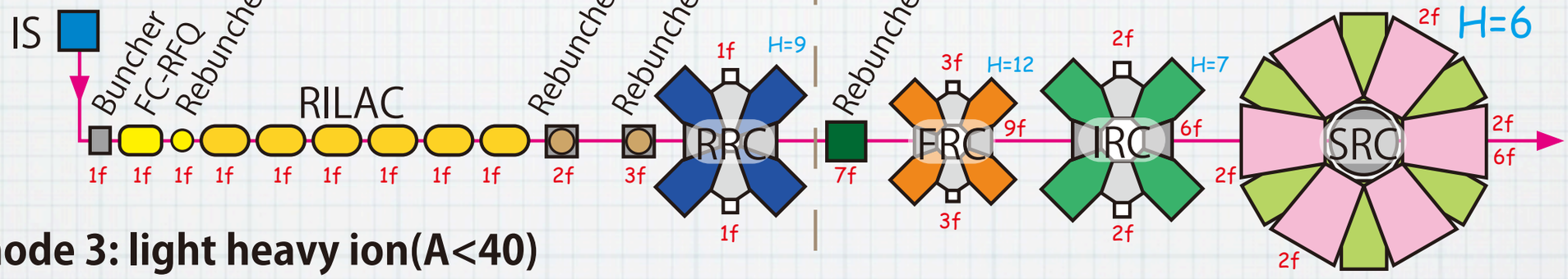
  K-value 2.6 GeV (Bmax = 4.2 T)

Schematic Layout of Accelerator Complex(3 modes)

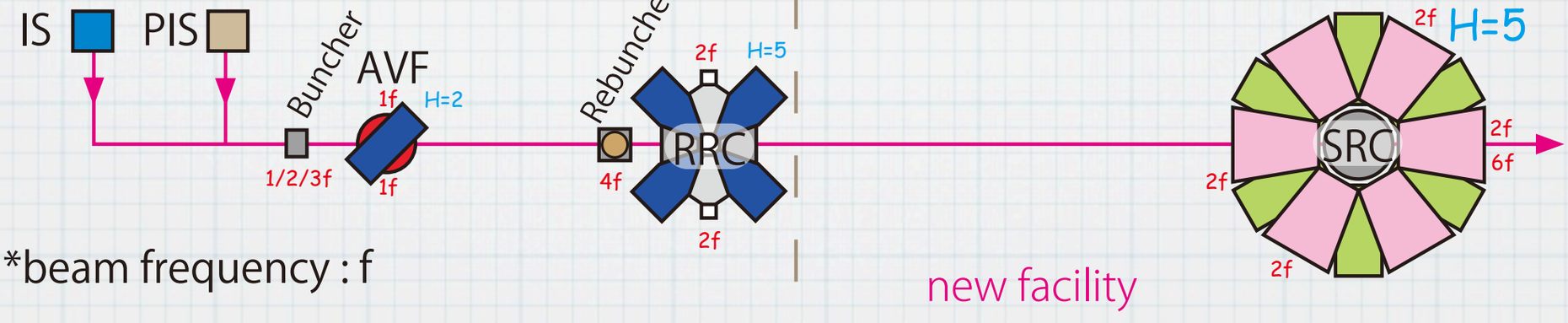
mode 1: very heavy ion(A>40) (variable energy with variable frequency)



mode 2: uranium 345 MeV/u (fixed energy with fixed frequency)



mode 3: light heavy ion(A<40)



*beam frequency : f

new facility

11 rf for new cyclotrons / 25 rf in the mode 2→Requirement??

What is required for rf of the SRC?

- Frequency tunable [cavity, amplifier]

RRC over octave: 18～42 MHz

- Single-turn extraction for high power beam

2 MV/turn(w/ 4 acceleration cavities) : $^{238}U^{79+}$ 3.5 mm@extraction

- Charge stripping by foil

Large acceptance by Flattopping : $\varphi < \pm 16^{o}$

- Large Turn # ～350 [low levels]

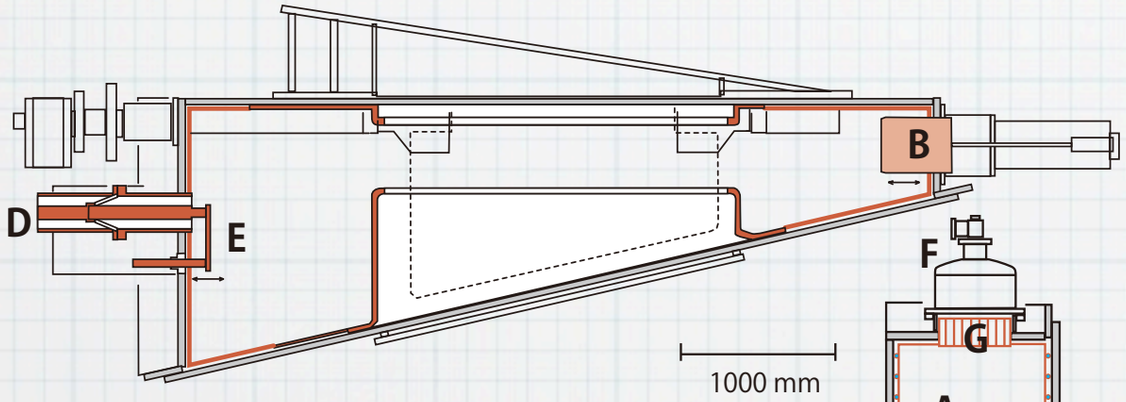
Stability: $|\Delta V/V| < 0.03\ \%$, $|\Delta \alpha| < 0.03^{o}$

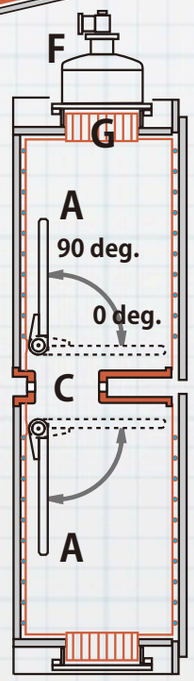
- Cascades of accelerators [new monitor]

Reliability : How rf works?

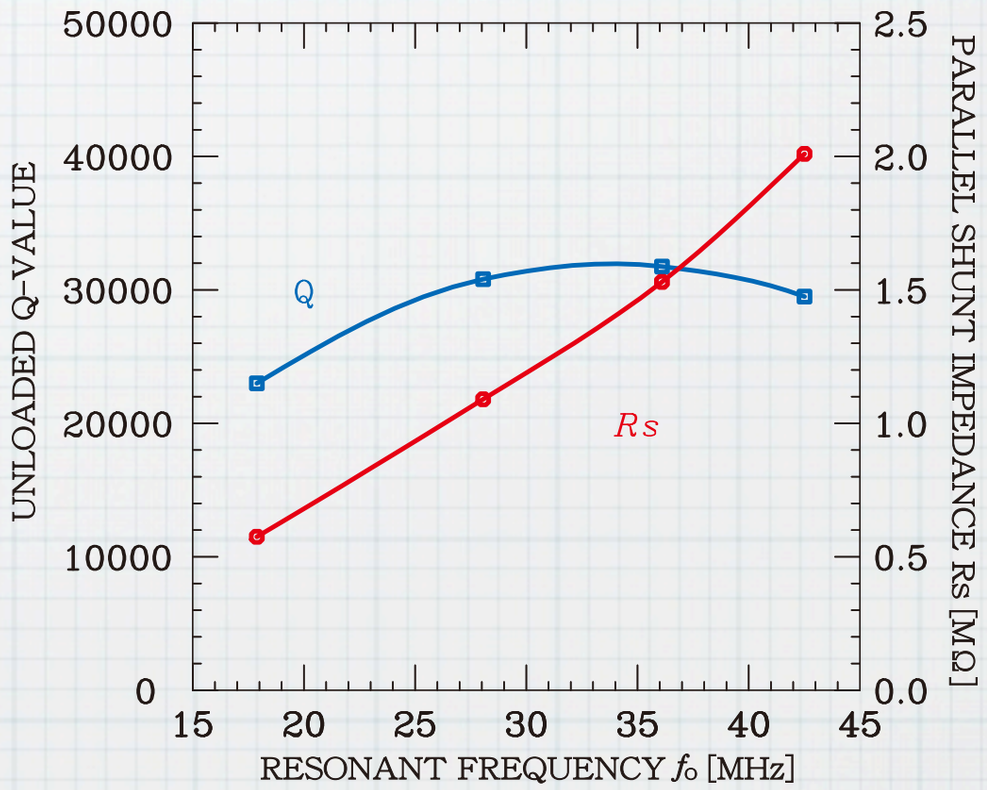
Cavities

- Room Tmeperature/Single Gap
- Capacitive Tuner 18～42 MHz
- Qo = 20000～30000, Rs　1.5 MΩ@36.5 MHz
- 1e-6 Pa by three 10,000 l/s cryogenic-pumps
- Individual amplifier





A. Tuners : 18～42 MHz
B. Trimmers : Δf/f ～ 0.65 %
C. Acceleration Gap : 400 mm
: 650 kV@36.5 MHz (150kW)
D. Power Transmission Line: WX-152D 50 Ω
E. Inductive Coupler : stroke 130 mm
F. Cryogenic-pump(3/cavity) : 5e-6 Pa
G. RF Shield



Amplifiers

- Tetrode based(grounded-grid)

  ACC:RS2042SK / FT:RS2058CJ

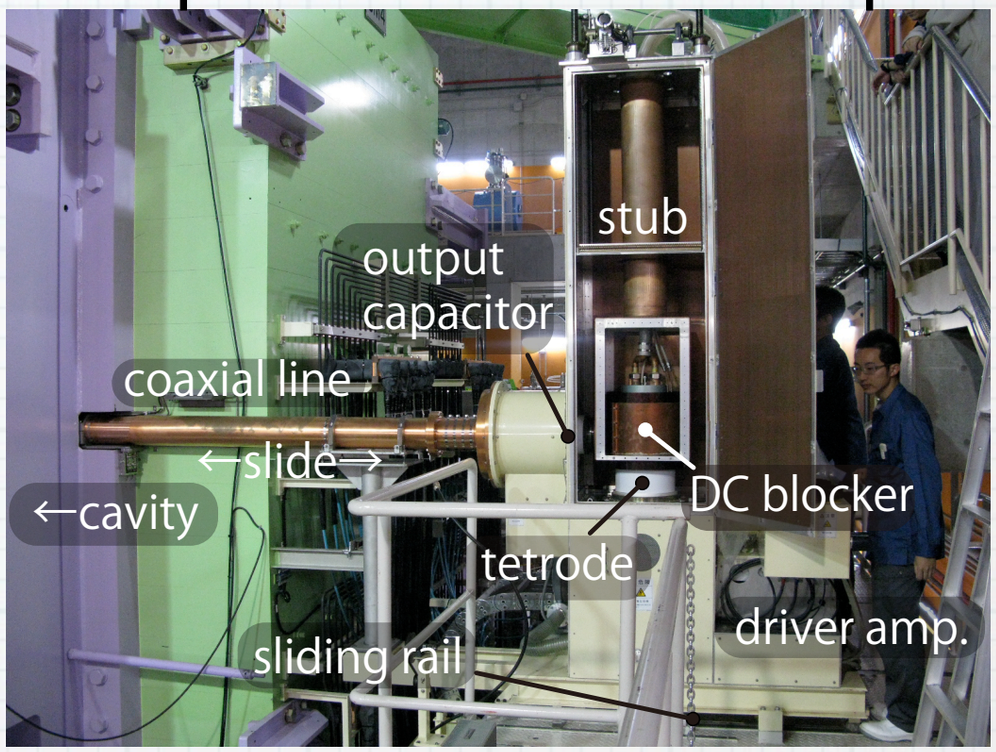
- Power Output　150 kW/60kW
- Frequency tunable
- Stray field of the sector magnet

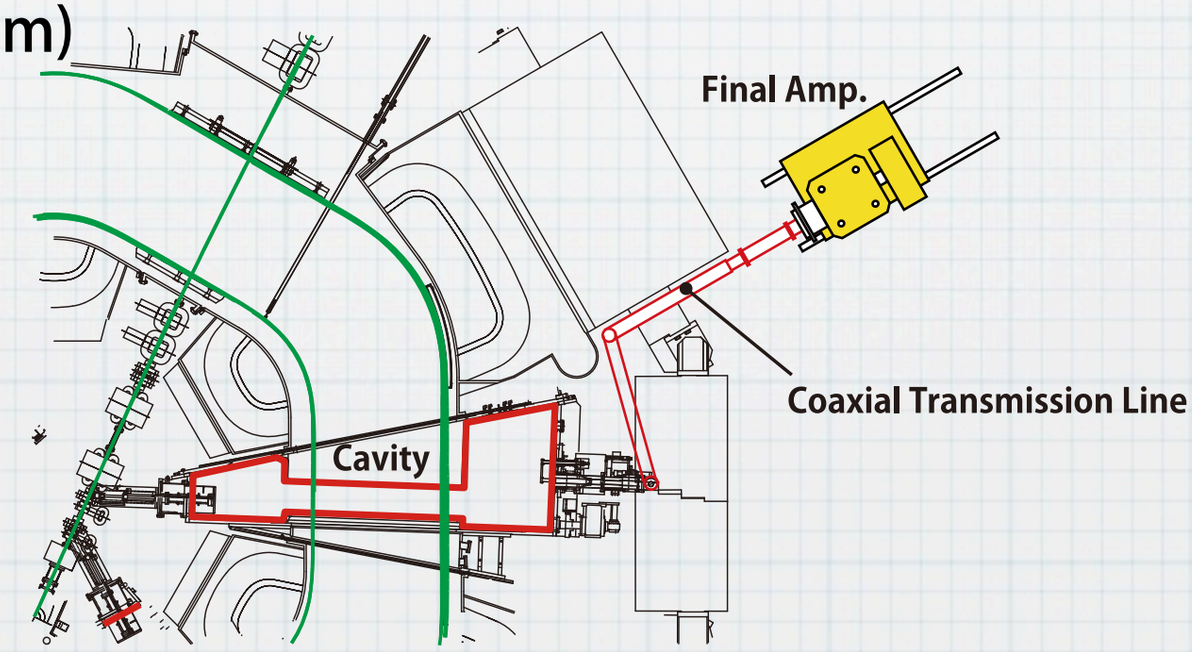
  ～100 G
- Parasitic modes

  + HOMs of Coaxial Line(15 m)

  Trombone (Δ L =1m)

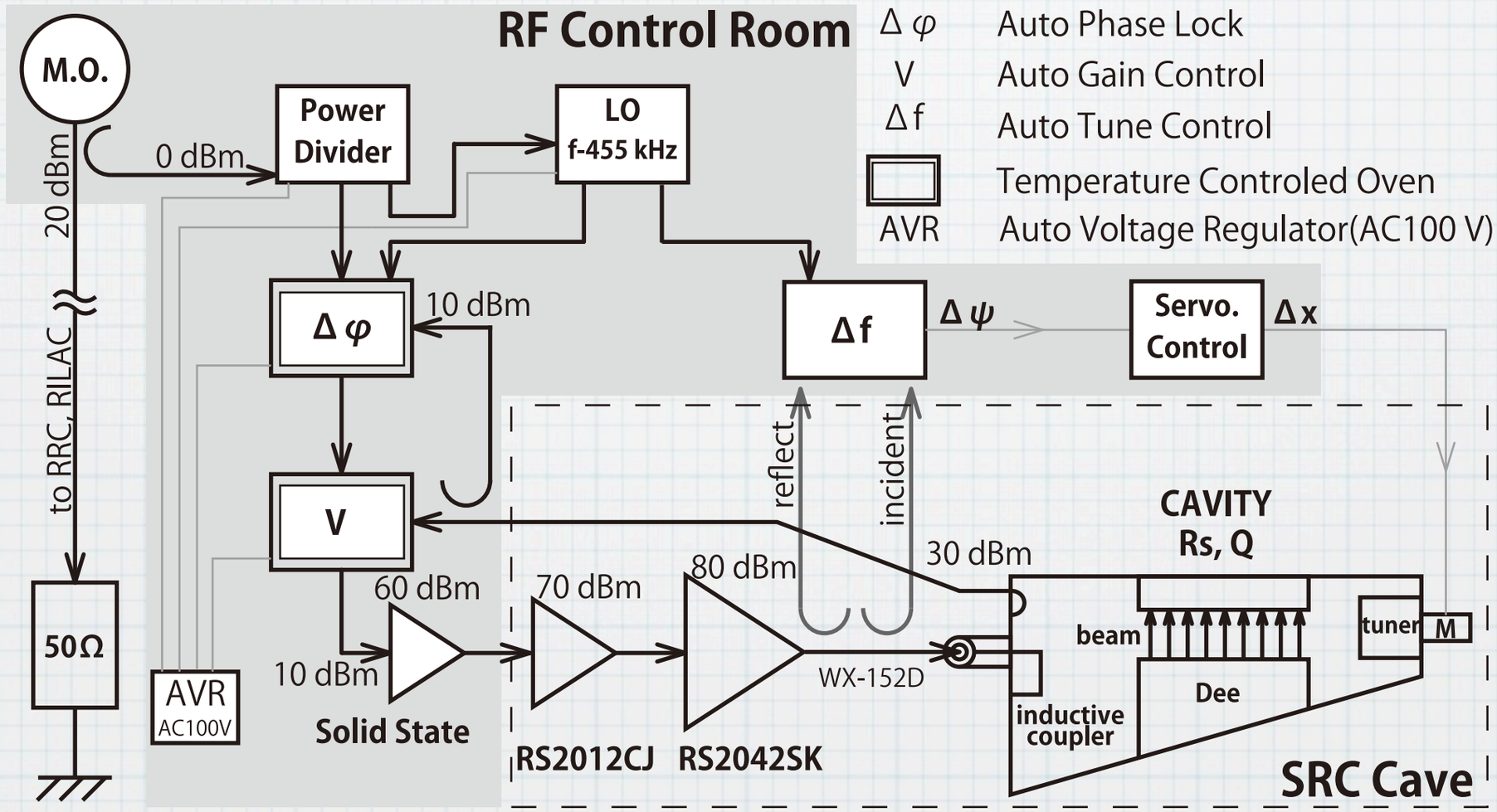
photo of 150 kW final amp





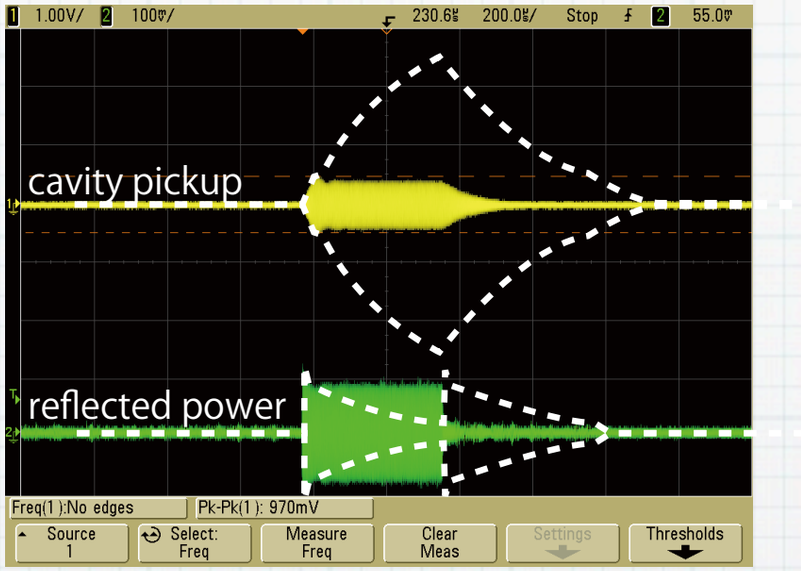
RF Control

- One master oscillator for all cavities
- Analogue feed back
- Temperature controled oven (0.03°C at ΔTroom 1°C)

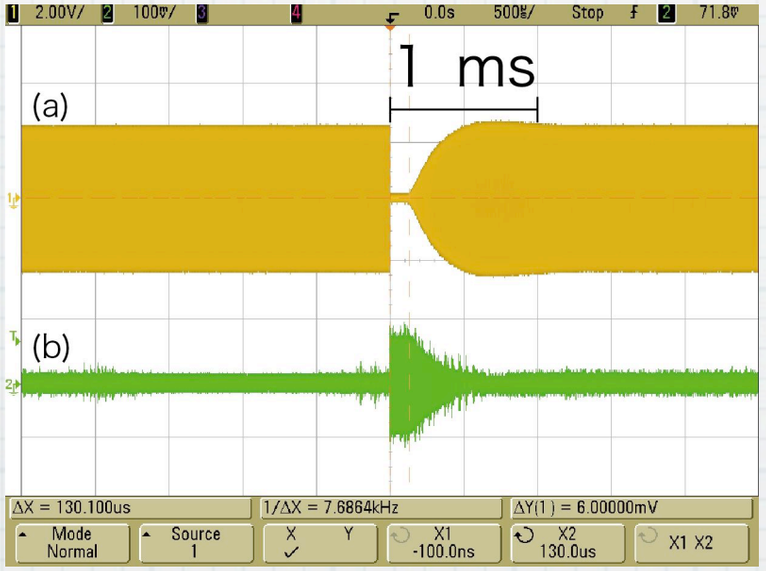


Fast Recoery

- Pulse mode via Multipactor



- Pulse/CW mode for Recovery within 1 ms



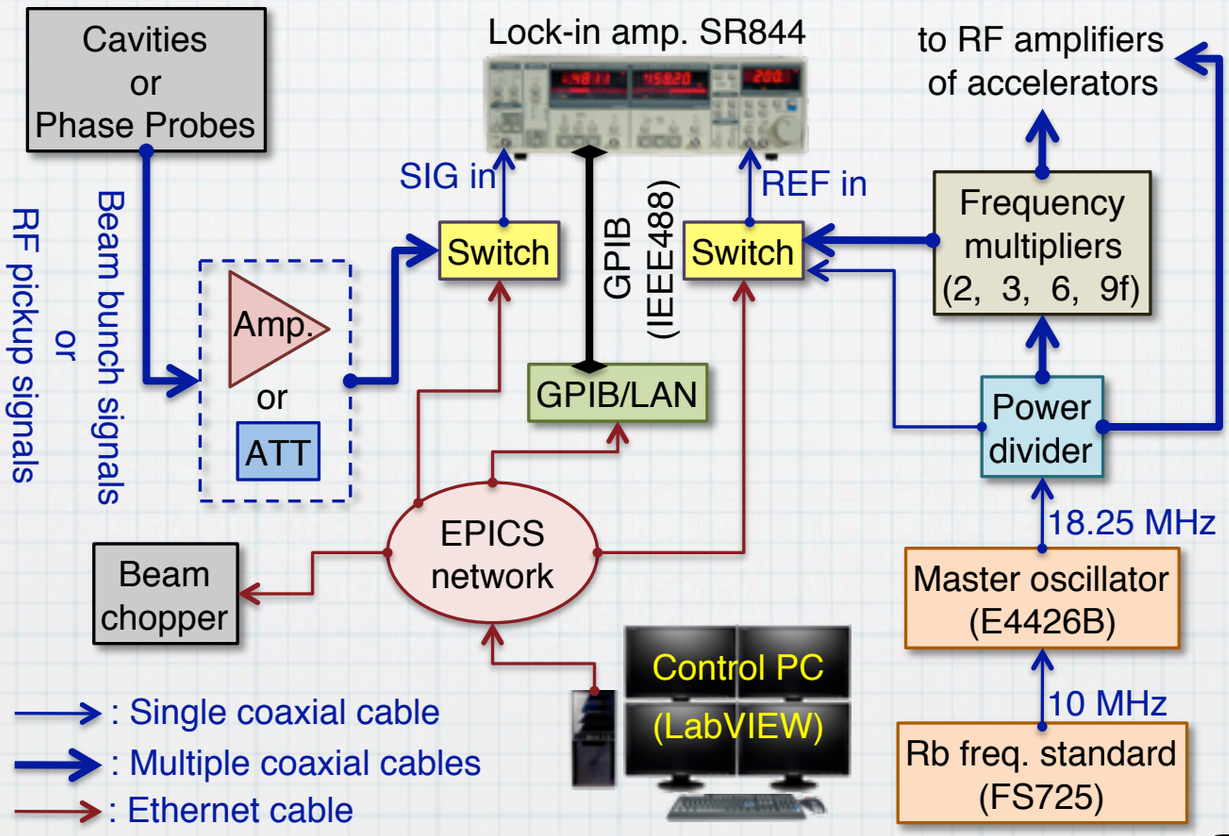
- Searching by moving trimmer until recovery

Monitoring System

- RF Lock-In-Amp. (Stanford Reserach Systems) replacing HP8508A

  wide bandwidth : 25 kHz - 200 MHz

- Feasibility : OK
- Estimated errors: amplitude : 10^{-4}, phase : $<0.03^{o}$
- Labview control



R.Koyama M.Fujimaki

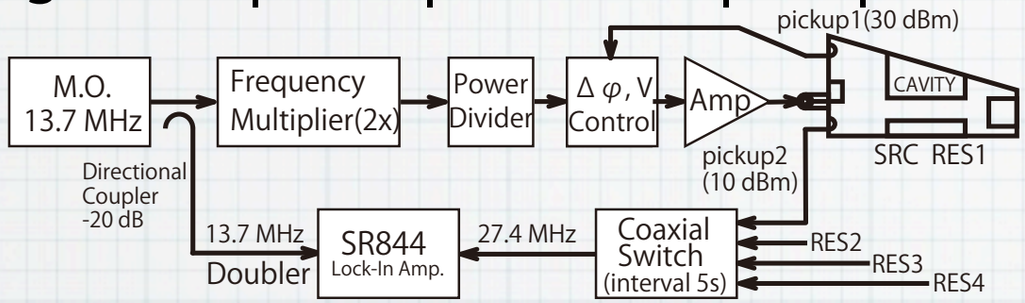
What were we prepared to do?

- Cavities and Amplifies
  - High Performance Room Temperature Cavity
  - Amplifier with trombone
- Low Levels
  - Feed Back System
  - Fast Recovery
- Monitoring System
  - Precise Measurement by rf Lock-In-Amplifier

Reliability and Stability??

Stability

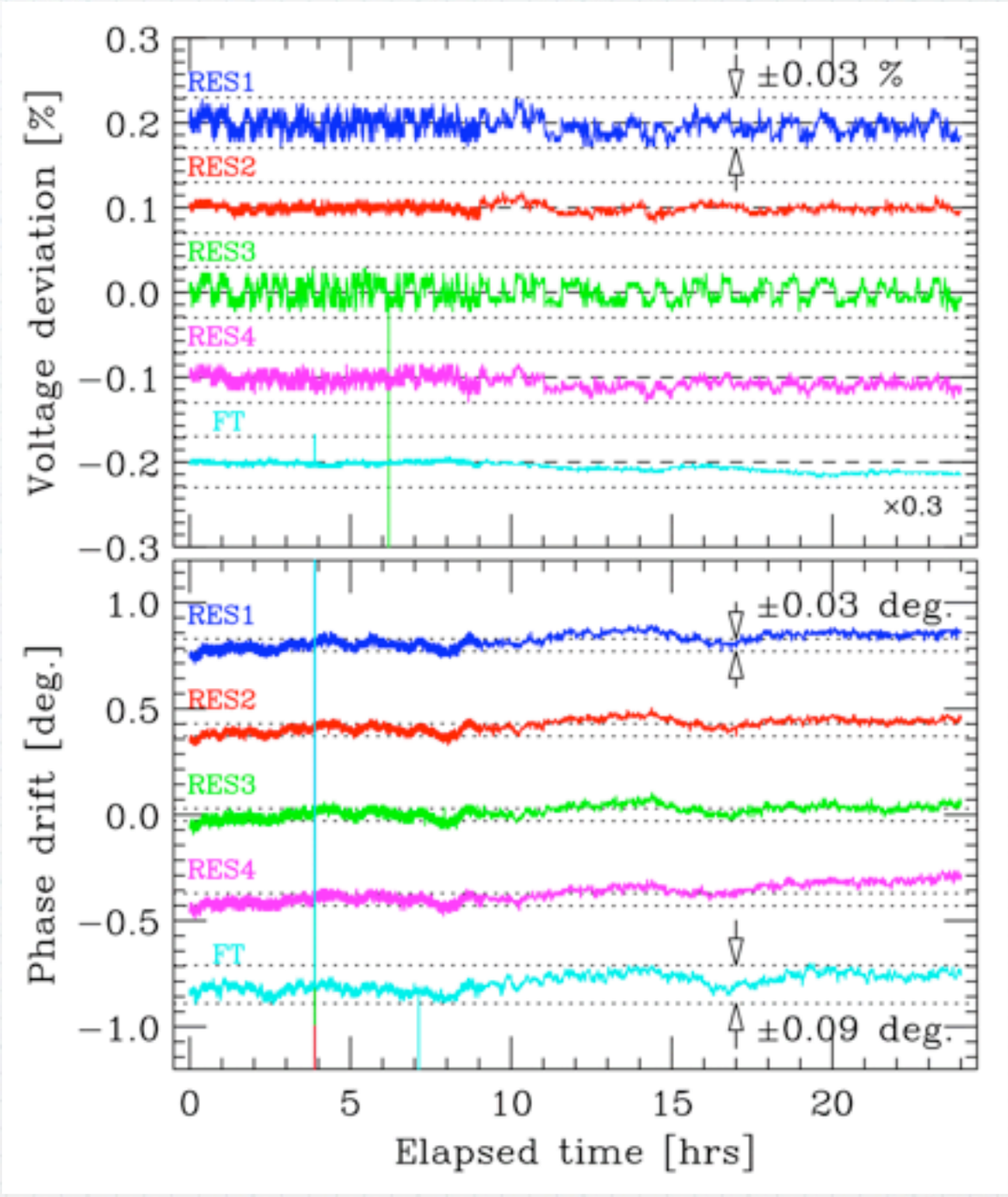
- Fast comp. : -70 dBc @300 Hz side band
- Long term : $|\Delta V/V| < 0.03$ %, $|\Delta \alpha| < 0.03^{o}$



- Automatic recovery works

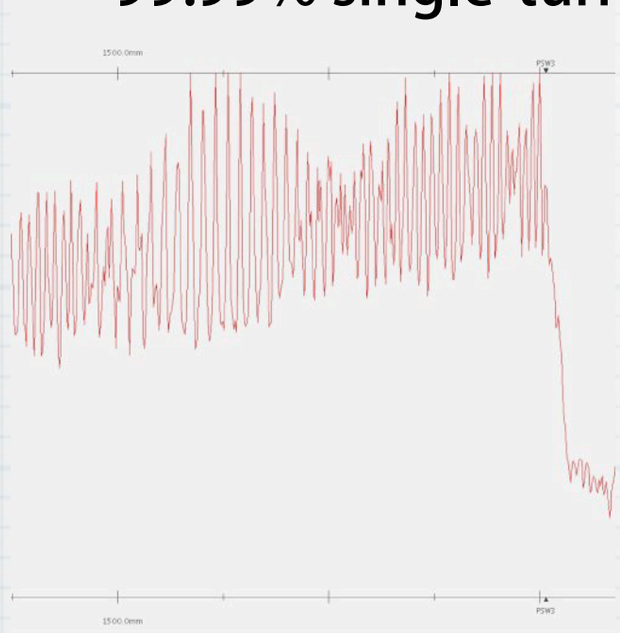
day	#1	#2	#3	#4	FT	all
5th	0	0	1	0	2	3
6th	0	0	0	1	0	1
7th	0	0	0	1(1)	1	2
8th	1	2(1)	2	1	3	9
9th	3(1)	3	1	2	1	10
10th	0	2	1	5(1)	1	9
11th	2	8(1)	1	4	2	17
total	6	15	6	14	10	51(5)

* () recovered manually.

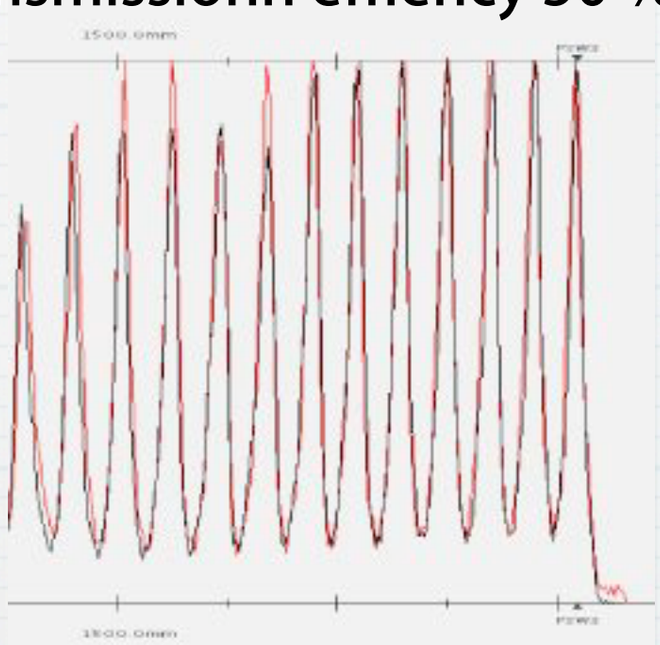


Single Turn Extraction in the mode 3

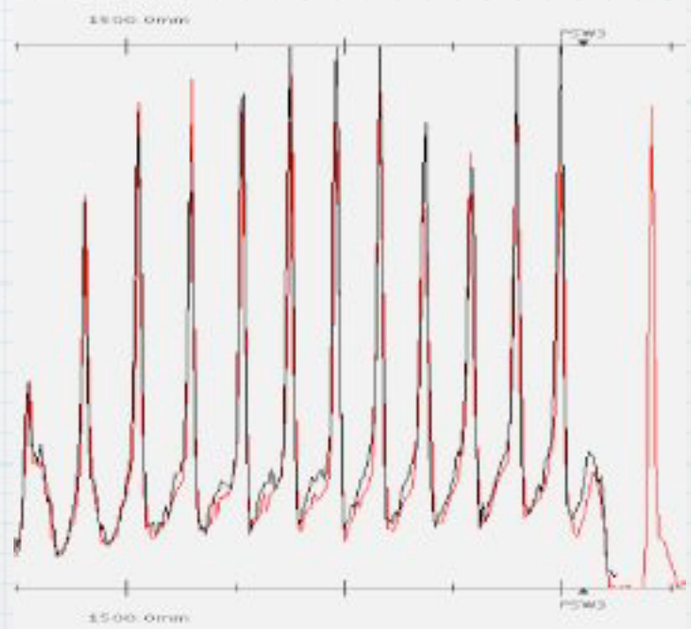
- Turn off the flattopping cavity
- Tune the phase of the acceleration cavity w/ well-centering
- make off-centering
- Tune the flattopping cavity to make the profile as sharp as possible
- 99.99% single-turn (Transmissionn effiency 50 %)



well-centered
EIC 70 kV



off-centering
EIC 48 kV



flattop on
single turn extraction!

What we achieved?

- Performance of the cavity

600 kV/cavity @36.5 MHz (mode1,2)

450 kV/cavity @27.4 MHz (mode 3)

- Stability

$|\Delta V/V| < 0.03\ \%, |\Delta \alpha| < 0.03^{o}$

Automatic Recovery

- Beams provided for experiments

mode 1: ^{48}Ca 345 MeV/u 170 pnA, mode 2: ^{238}U 345 MeV/u 0.4pnA,

mode3: ^{14}N, pol-d 250 MeV/u

- Single-Turn Extraction

99.99 %

Summary

- 11 cavities have been built for new cyclotrons

  Flattopping acceleration is essential.

- RF monitors with Lock-In-Amp.

  Sixteen SR844 measure 25 cavities and 10 beam phase.

- Performance of the rf system

  2MV/turn @36.5 MHz

  $|\Delta V/V| < 0.03\ \%, |\Delta \alpha| < 0.03^{o}$

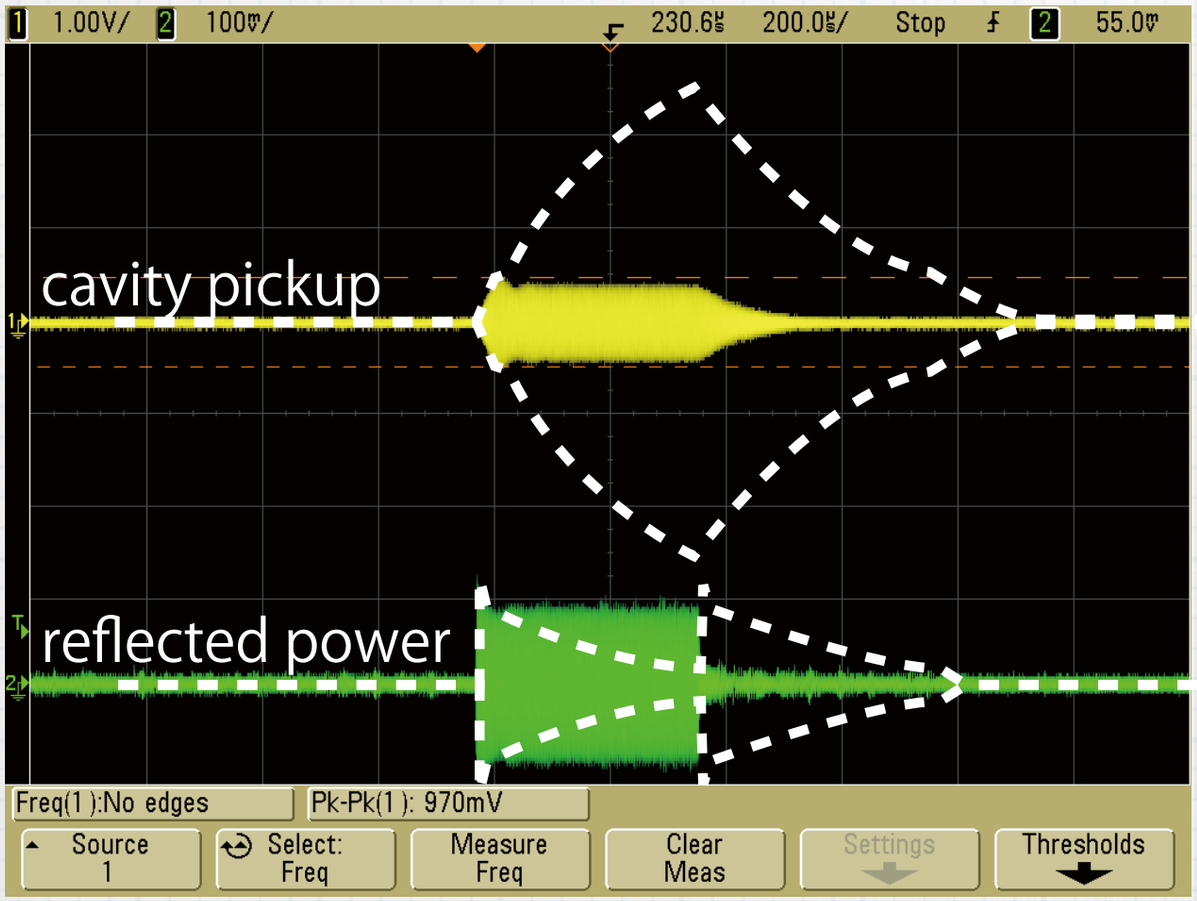
- Stability and Relaiablity

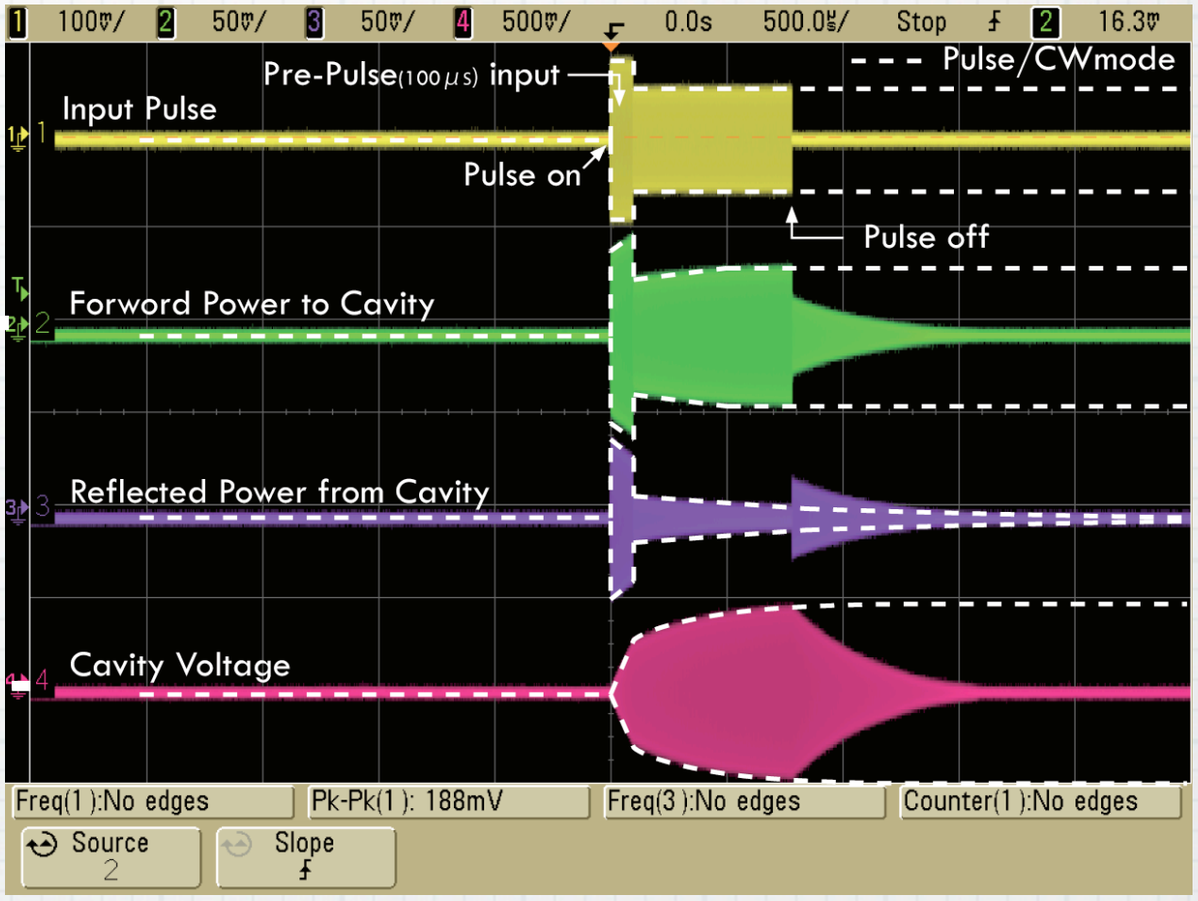
  Single-Turn Extraction

Thank you.

Multipactor

- Pulse Excitation

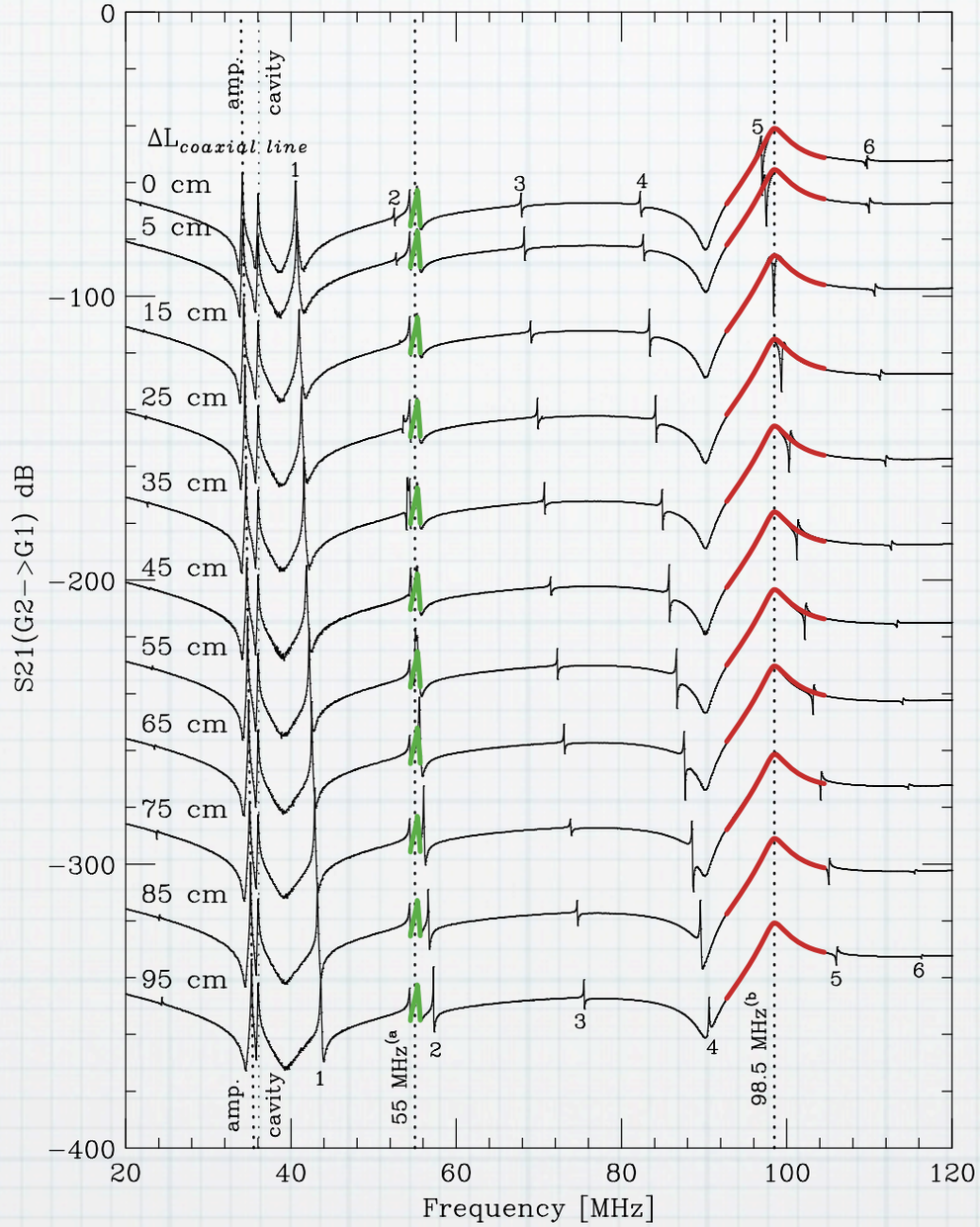




- Strong stray field of SRC

  Conditioning with cw rf power is very effective.

Parasitic modes of Amplifier



Superconducting Ring Cyclotron

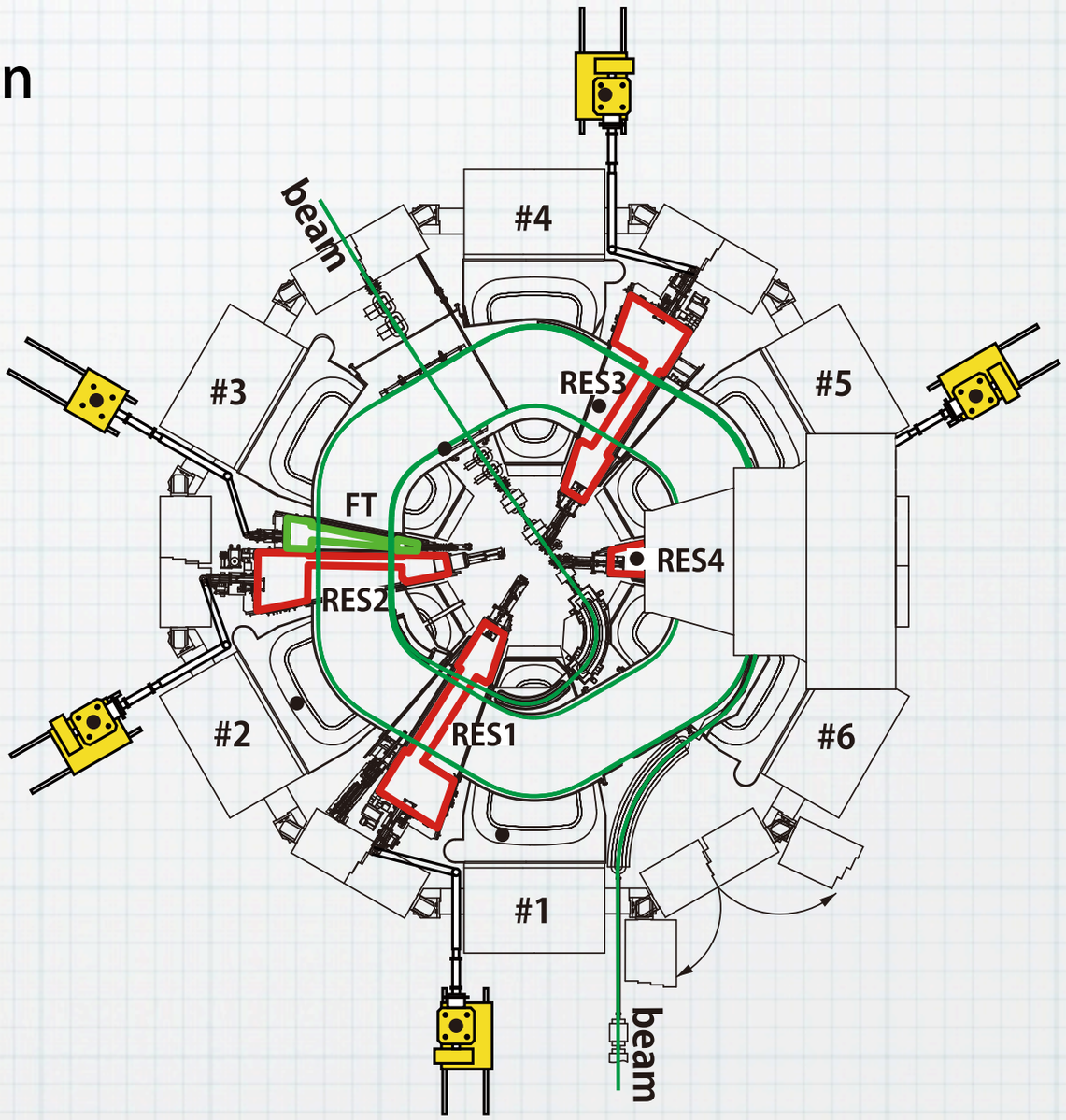
- 6 sector isochronous ring cyclotron
- K=2.6 GeV
- 4 acceleration cavities + FT
- Vg = 2 MV/turn @ 36.5 MHz
- Turn # 350
- accelerated beam

^{238}U/345 MeV/u 0.4 pnA

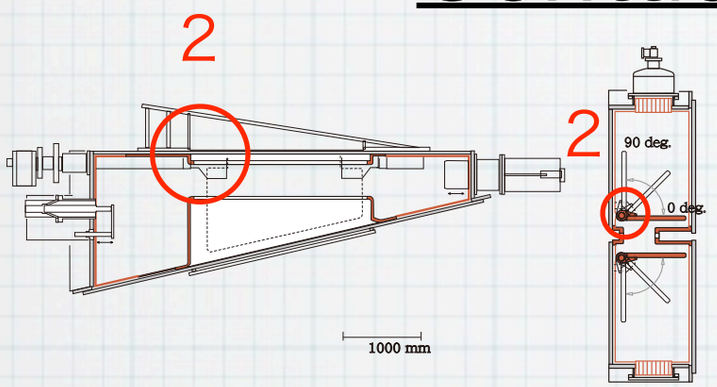
^{48}Ca/345 MeV/u 170 pnA

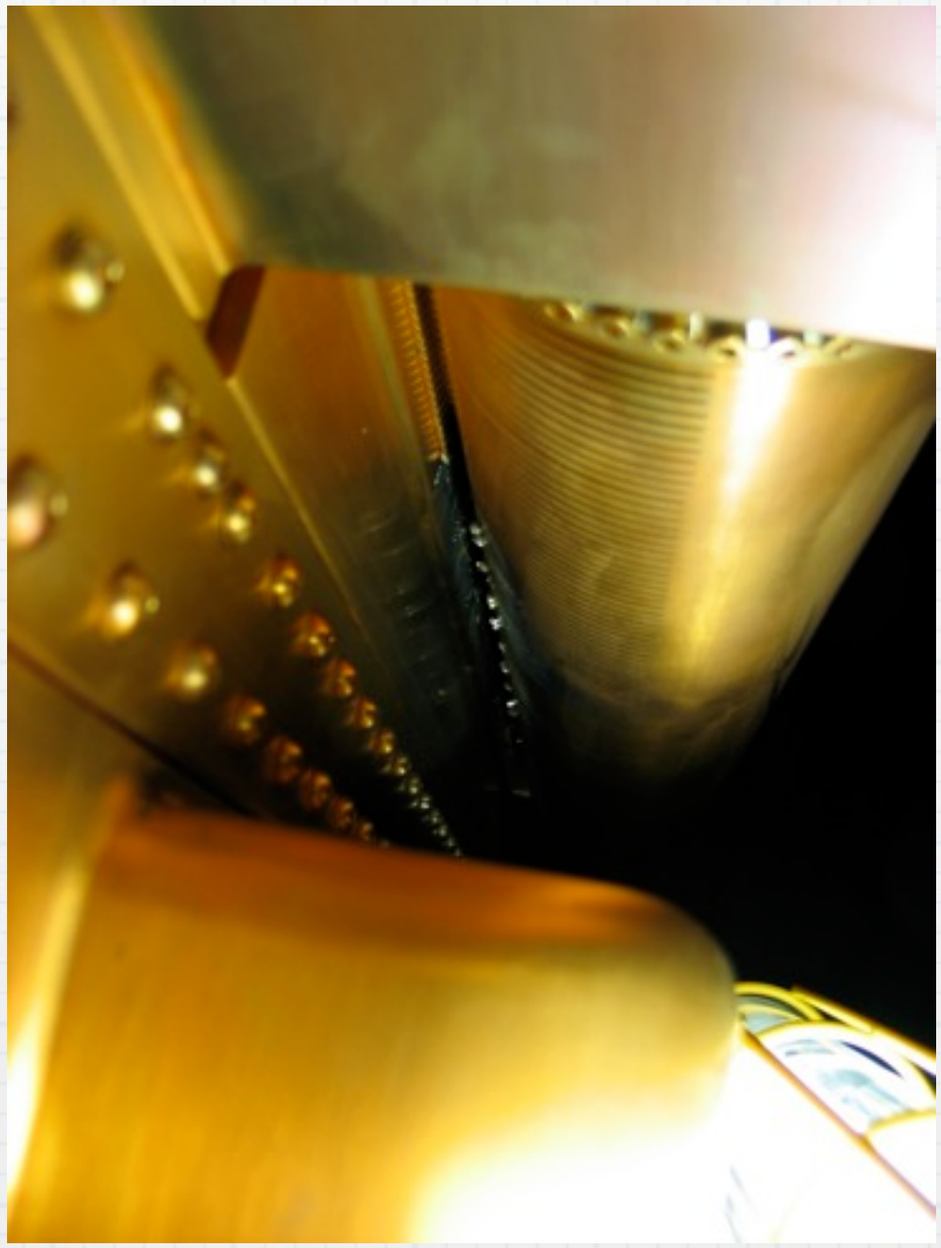
^{7}N/250 MeV/u

pol-d/250 MeV/u



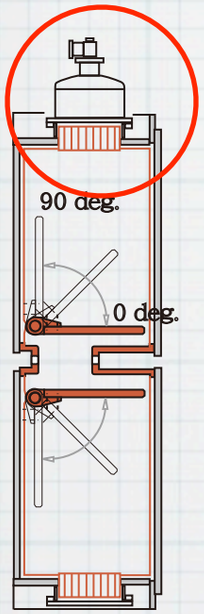
Contact Fingers and Copper film

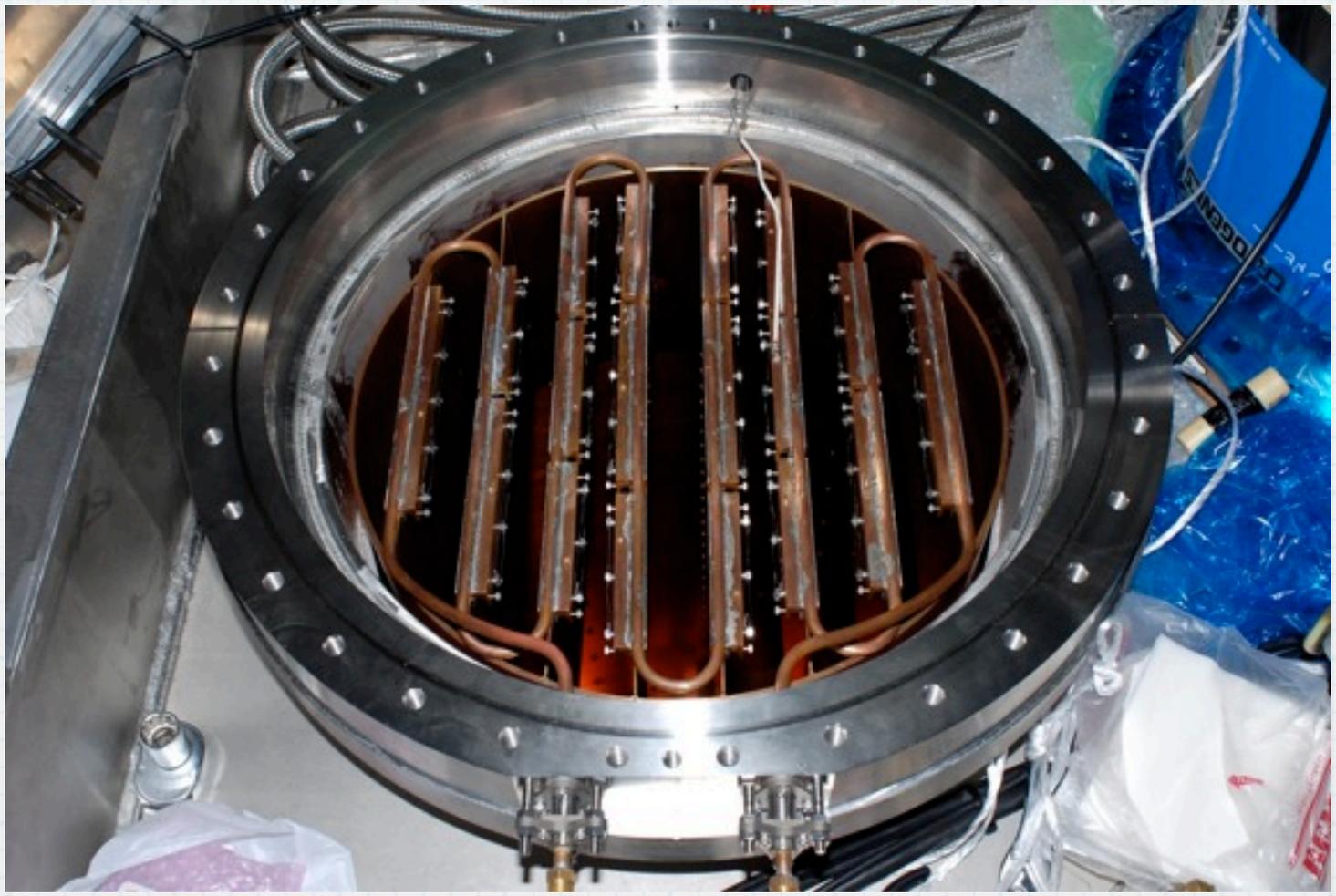




Jan 9, 2009

RF Shield for Cryogenic Pump



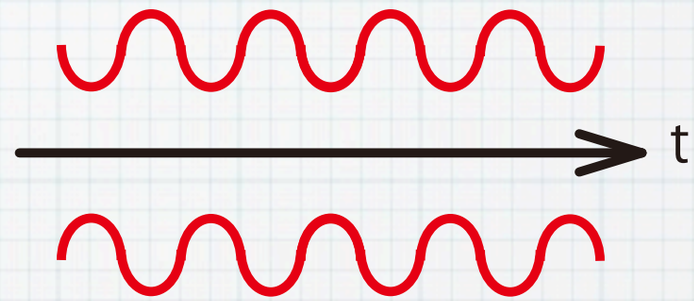


Yokouchi/Nishida

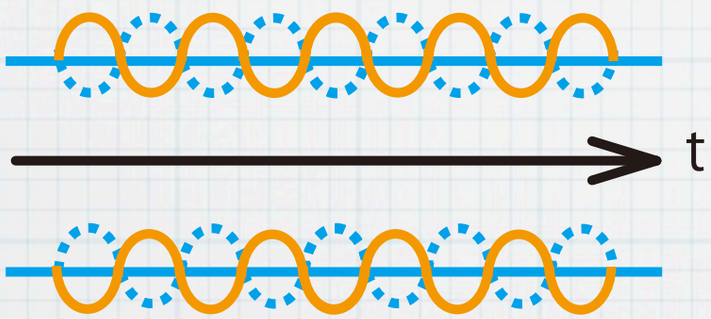
Feedback

Low Level OUT

Cavity Pickup



Low Level OUT (AGCON)



Cavity Pickup

50 Hz, 100 Hz, 300 Hz

*note a few kHz => L.L.

MHz-GHz => Amp.