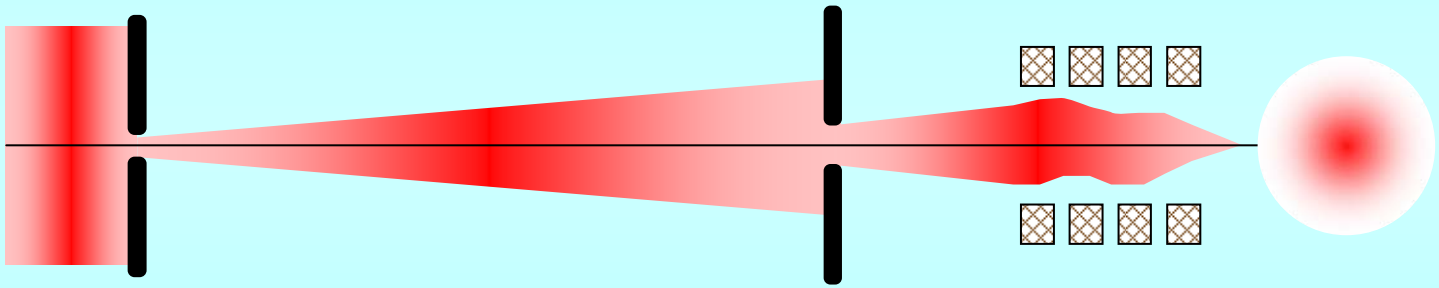
Use of Microbeam at JAEA Takasaki



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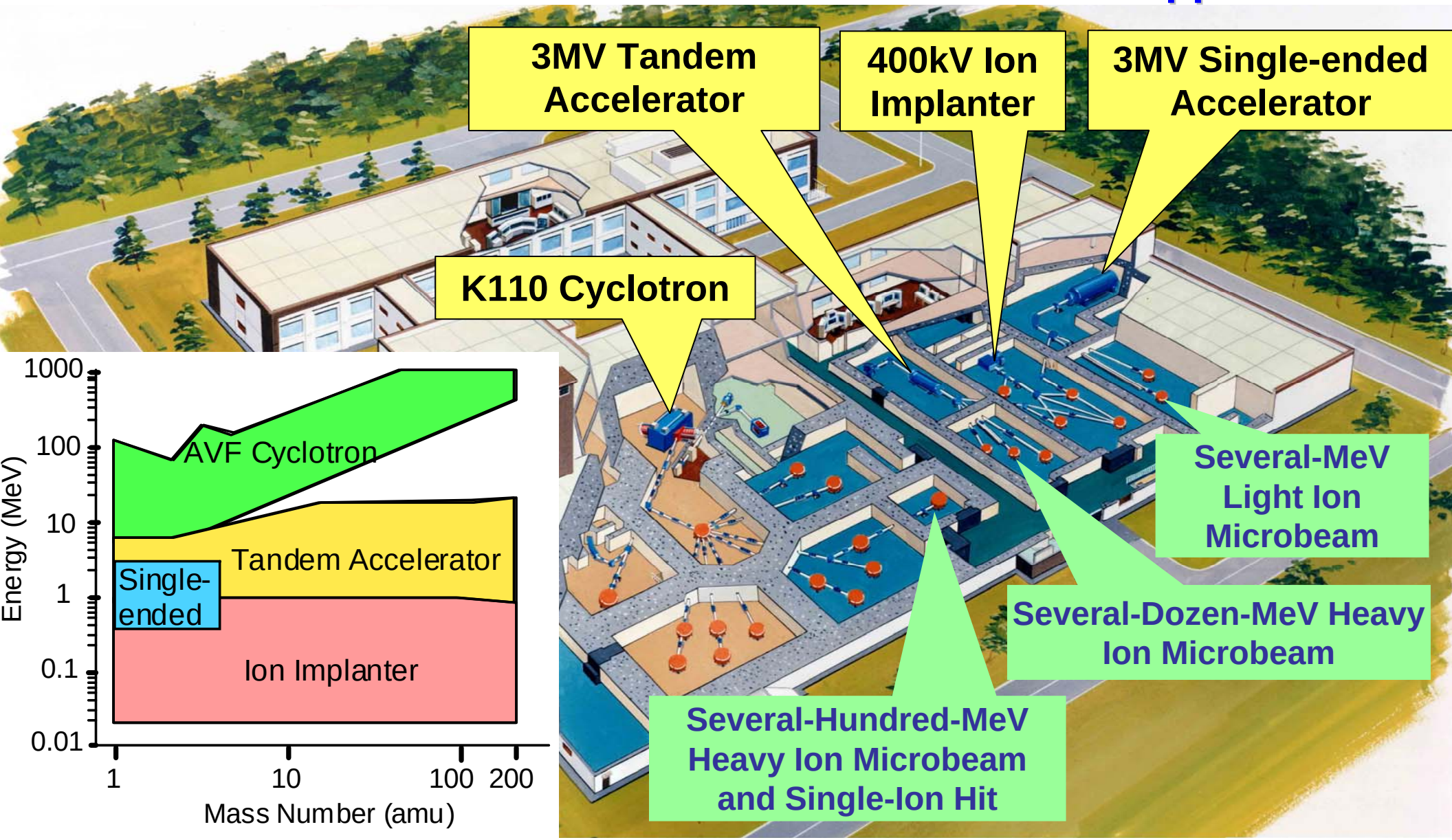
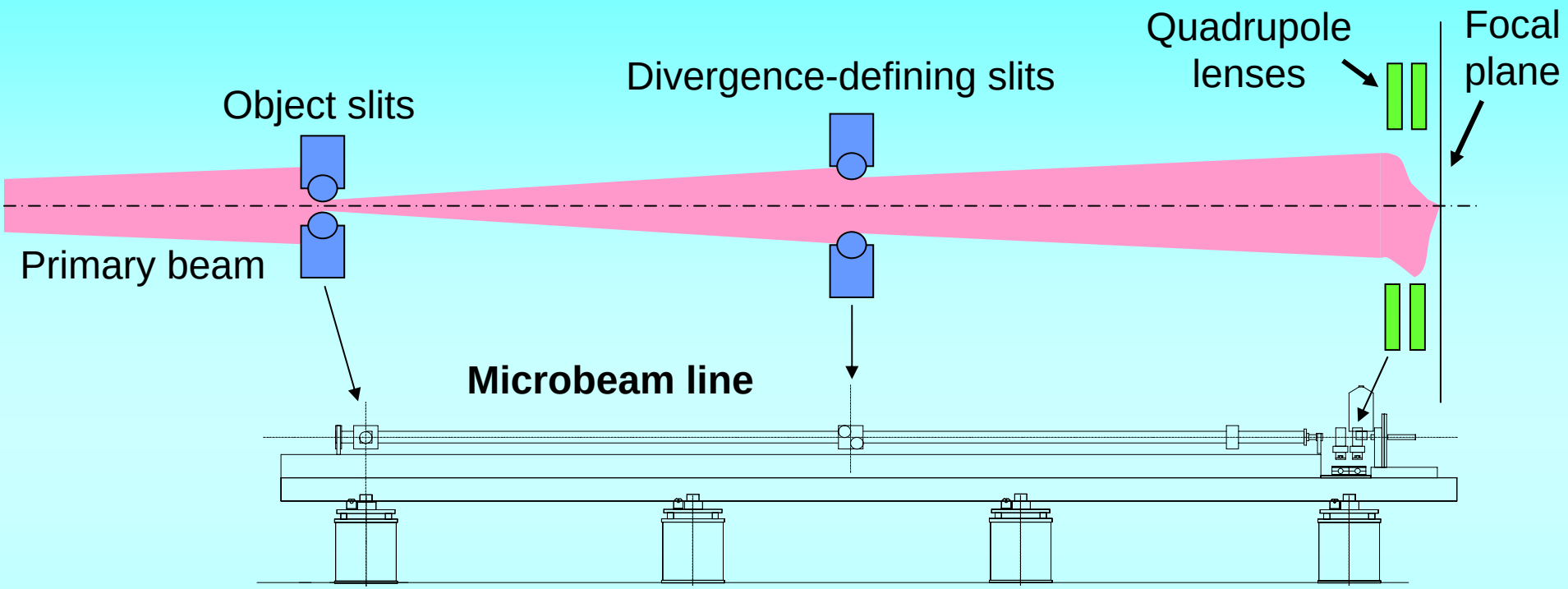
1. Microbeam Production Systems at TIARA Facility

Takasaki Ion accelerators for Advanced Radiation Application



Production of Microbeam

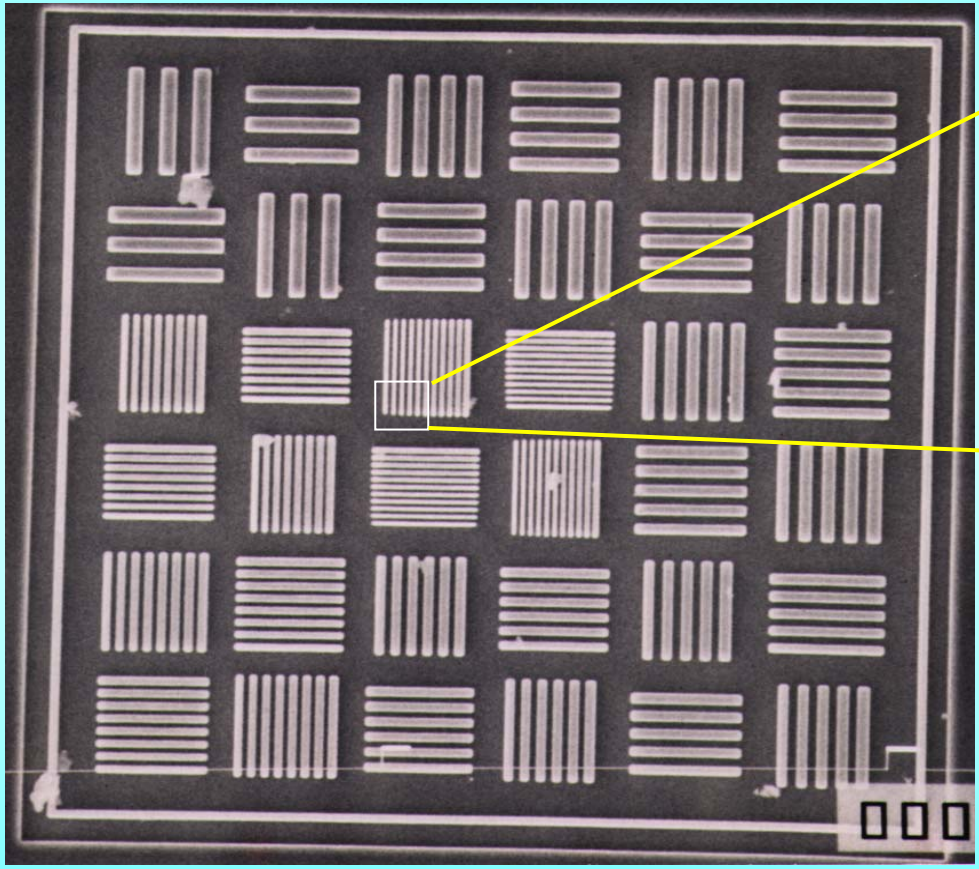


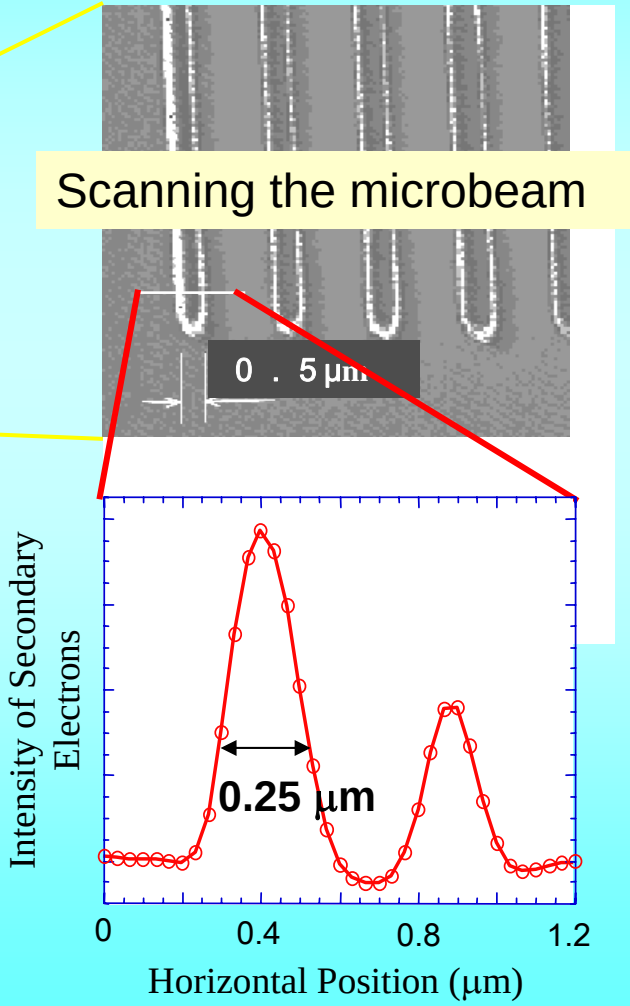
Heavy Ion Microbeam Line

Light Ion Microbeam Line

Spot Size of Light Ion Microbeam

Secondary electron mapping
to measure the beam spot size



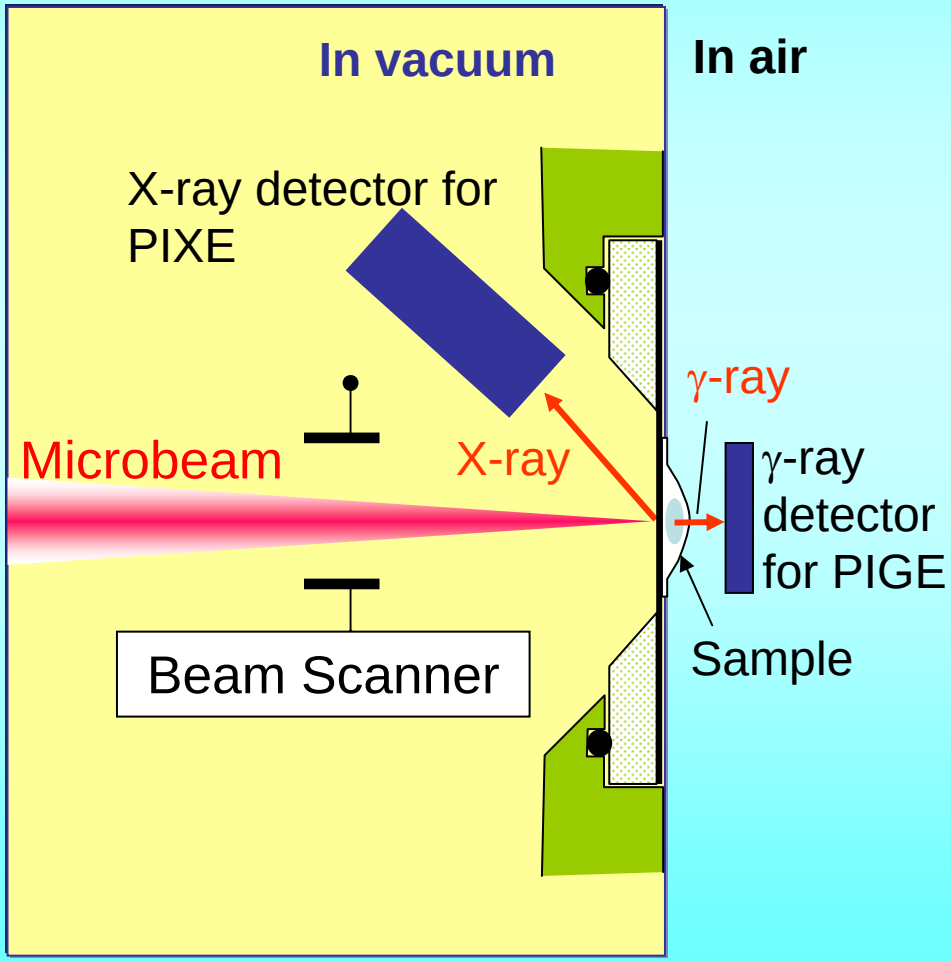


SEM(Scanning Electron Microscope) image of a silicon relief pattern

2. Applications of the Microbeams

In-air Micro-PIXE Analysis Using 2 MeV Proton Microbeam

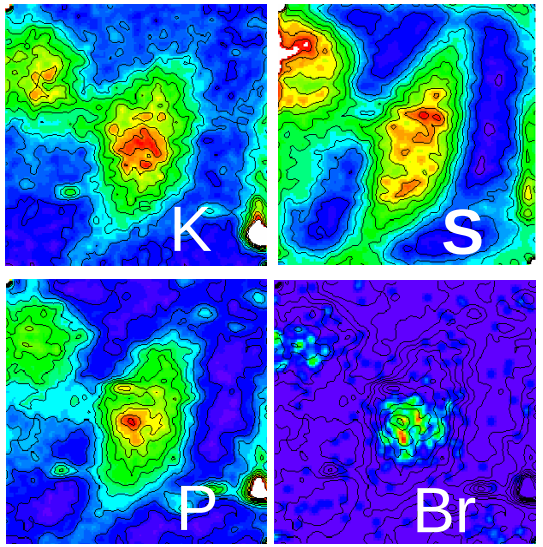
Measurement System



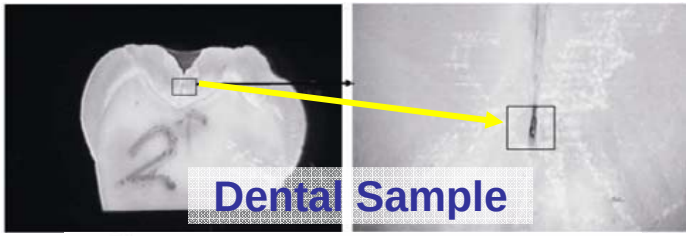
Cell

2 dimensional distribution of elements in cattle blood vessel cell

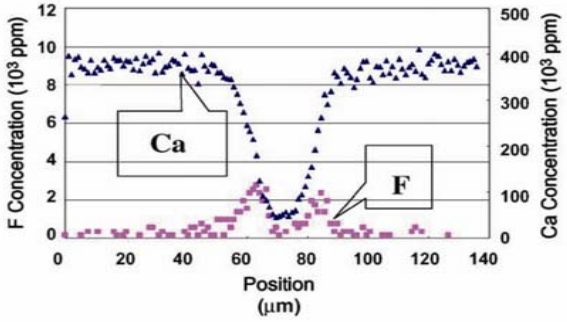
20μm x 20μm



Tooth

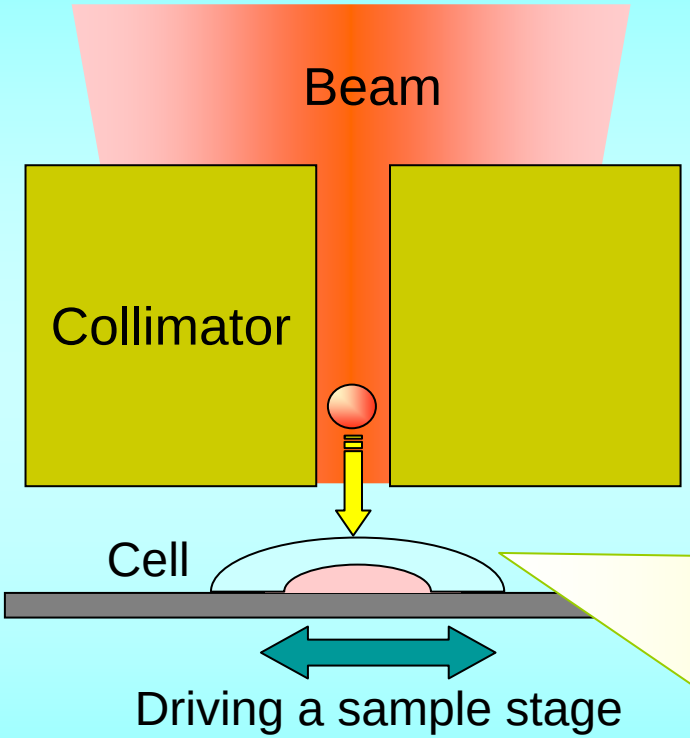


Distribution of fluorine and calcium in tooth



Application of several-hundred-MeV heavy ion Microbeam

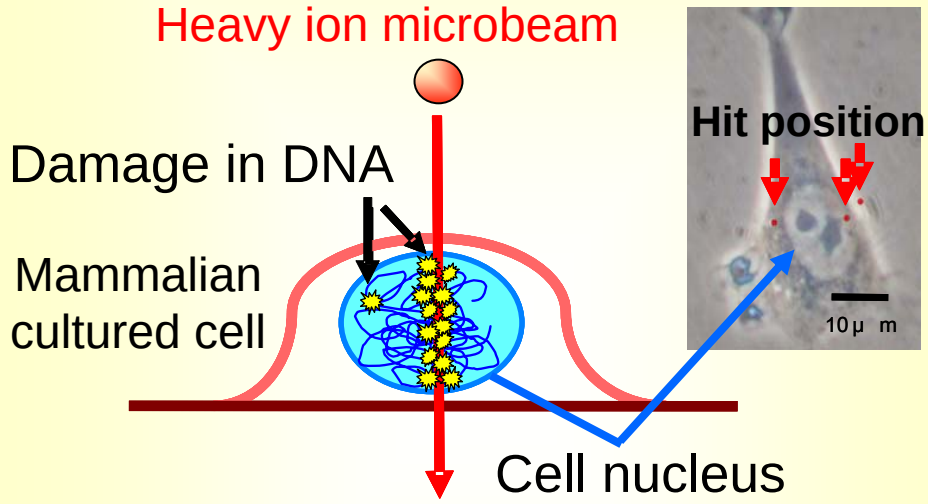
Collimation of Beam



Beam spot size : **5 ~ 10 μm**

Single-ion hit rate : **several hits/min**

Elucidation of Cellular Radiation Response



- Investigation of cell-to-cell communications such as “bystander effects”
- Analysis of cellular spatial sensitivity, interaction of damages, dynamics of cellular repair and intra-cellular process like apoptosis

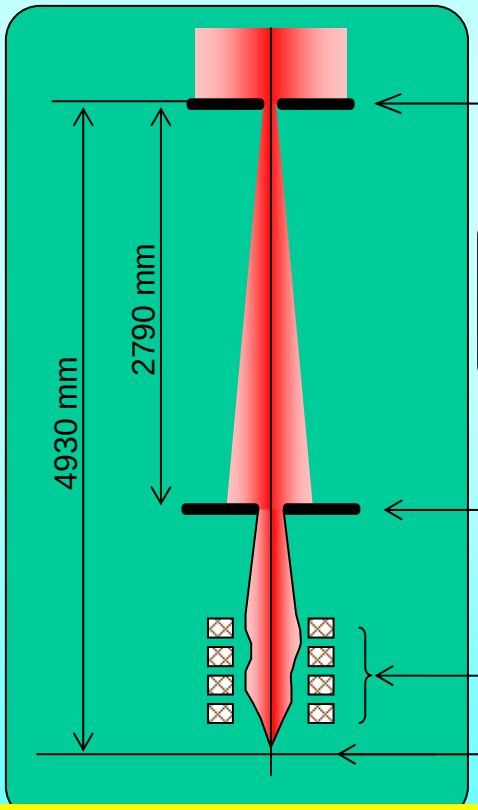
3. Development of a New High-Energy Heavy Ion Microbeam System

Several-hundred-MeV heavy ion beam

(ΔE/E < 0.02%)

1st Floor

Basement Floor



Ion Beam Optics

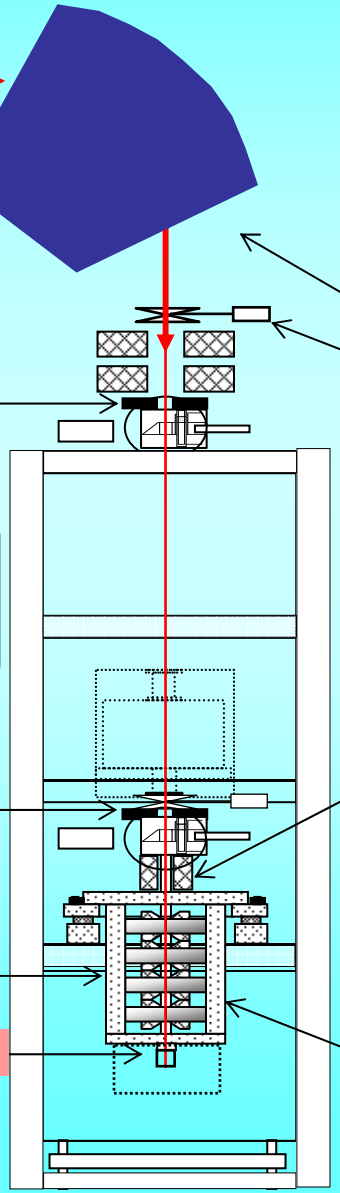
Micro Slits

Focusing type

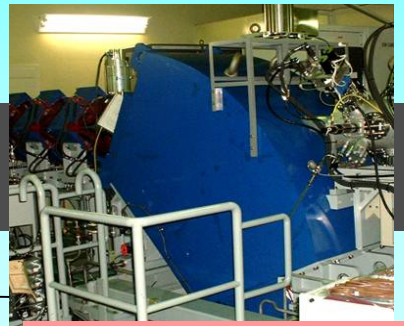
Divergence Defining Slits

Quadruplet

End-station

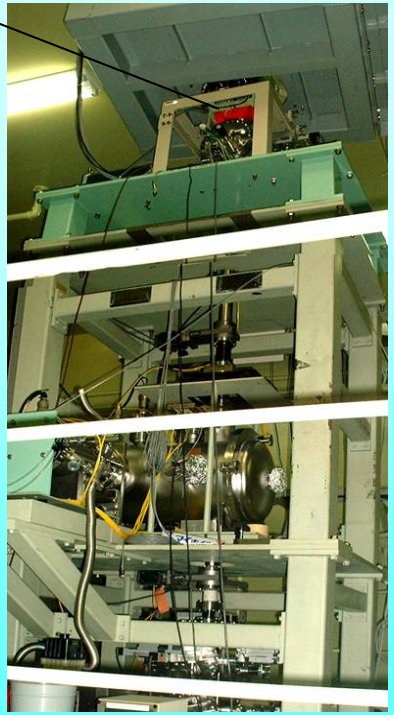


Beam Shifter



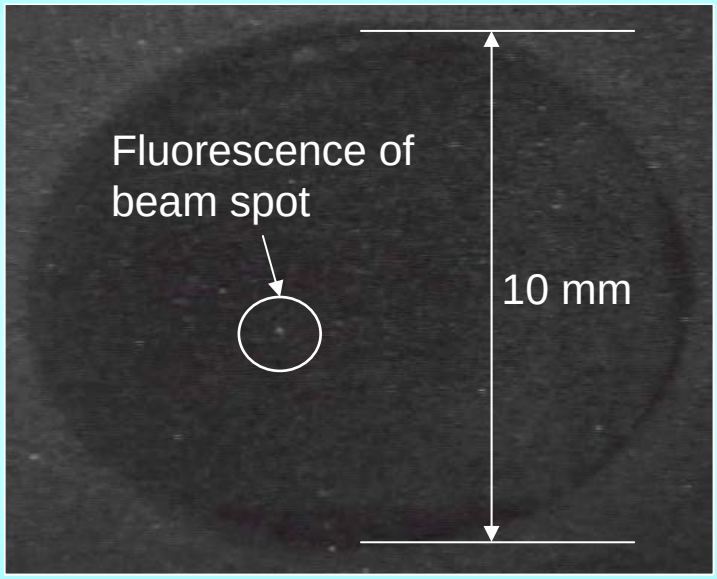
Deflection Magnet

Beam Scanner



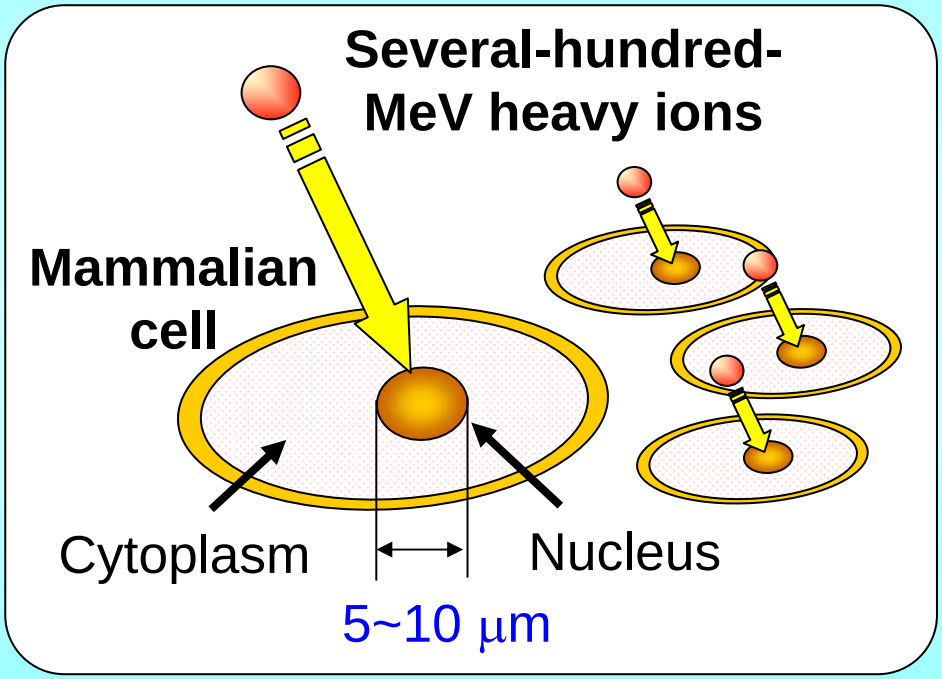
Preliminary Result

Observation of beam spot on a plastic scintillator



applied to

High speed single-ion hit with targeting accuracy less than 1μm



Beam spot size

about 0.7 μm in diameter (achieved)

Single-ion hit rate

more than 600 hits / min (under development)

4. Generation of High Quality Beams by Upgrading Cyclotrons

Upgrade of AVF Cyclotron

-Flattop Acceleration System

Energy Spread $\Delta E/E = 0.01 \sim 0.05$ %

-Temperature Control System

Magnetic Field Stability : $\Delta B/B < 0.001$%

TIARA Cyclotron Facility

Microbeam Applications

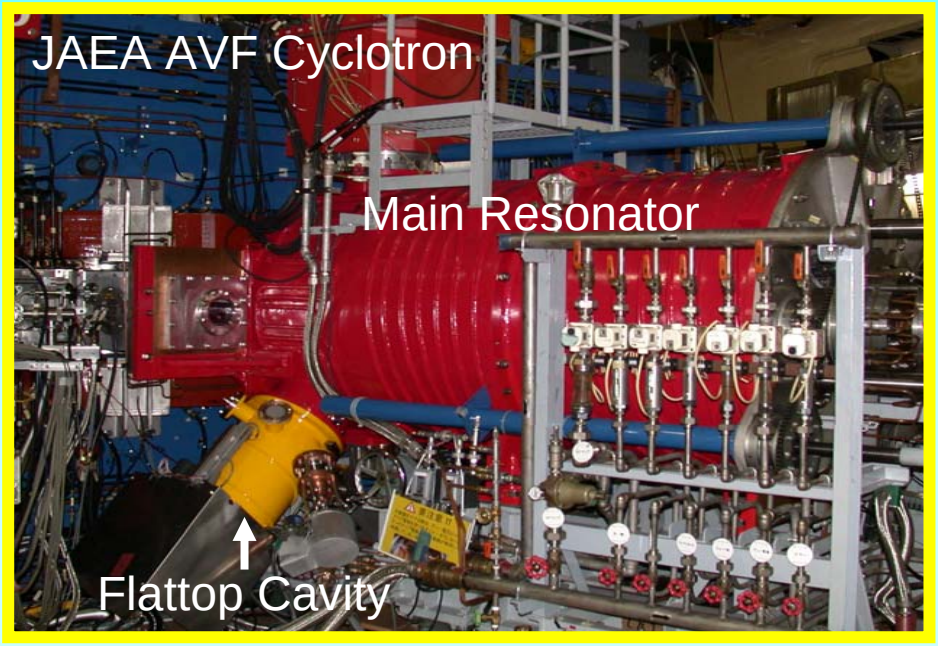
Materials, Medical, Biological Sciences

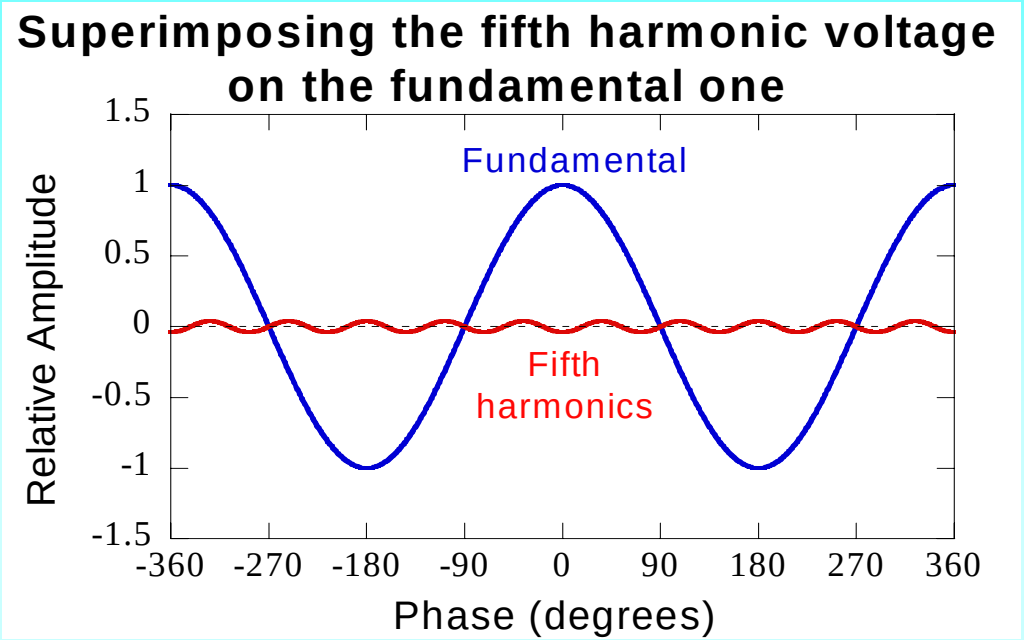
RCNP Cyclotron Facility

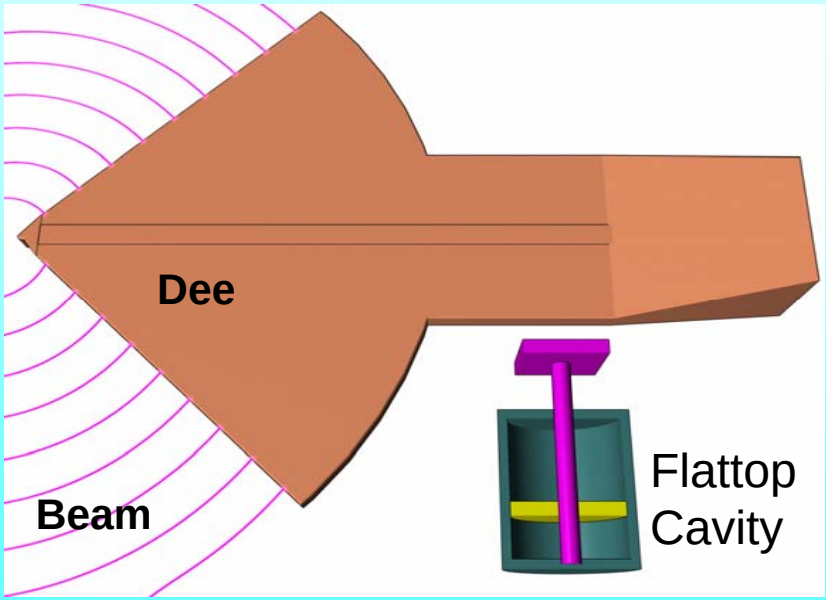
Ultrahigh Resolution Experiment

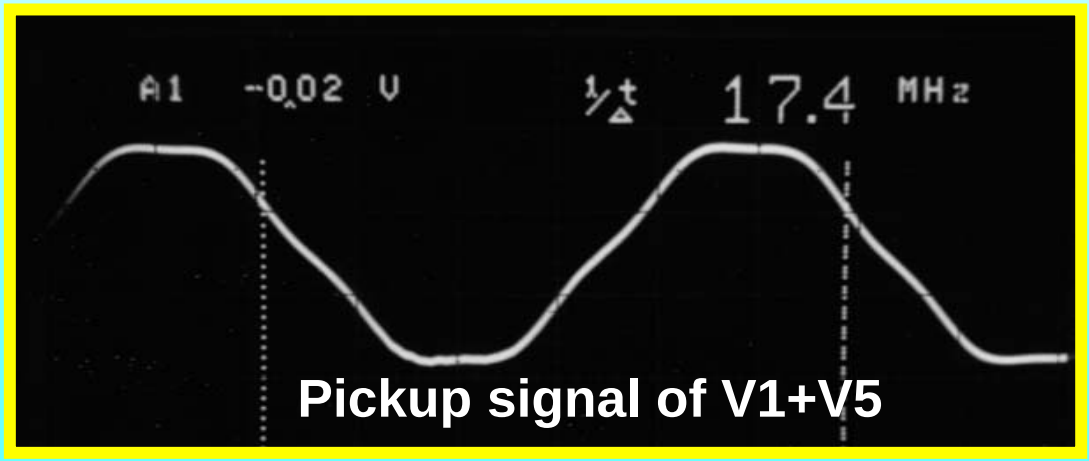
Nuclear Physics

Development of Flattop Acceleration System





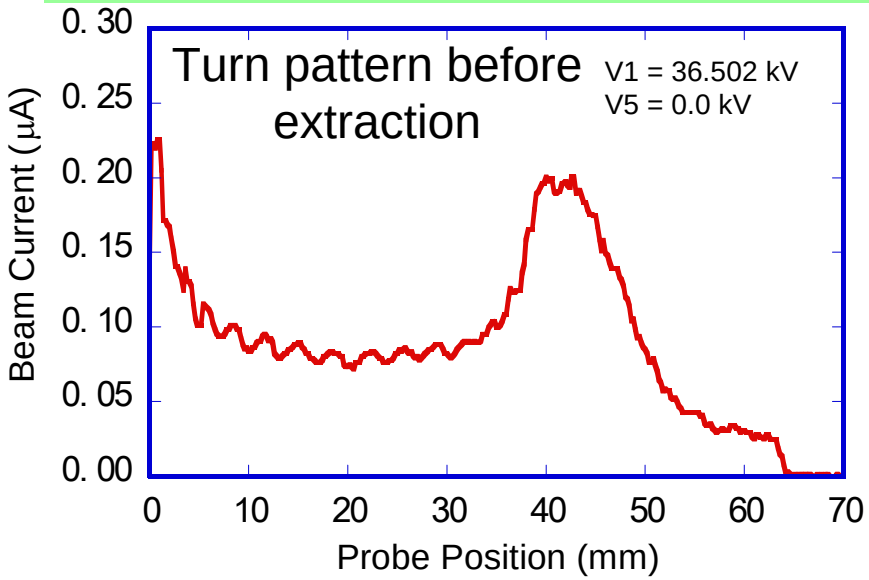




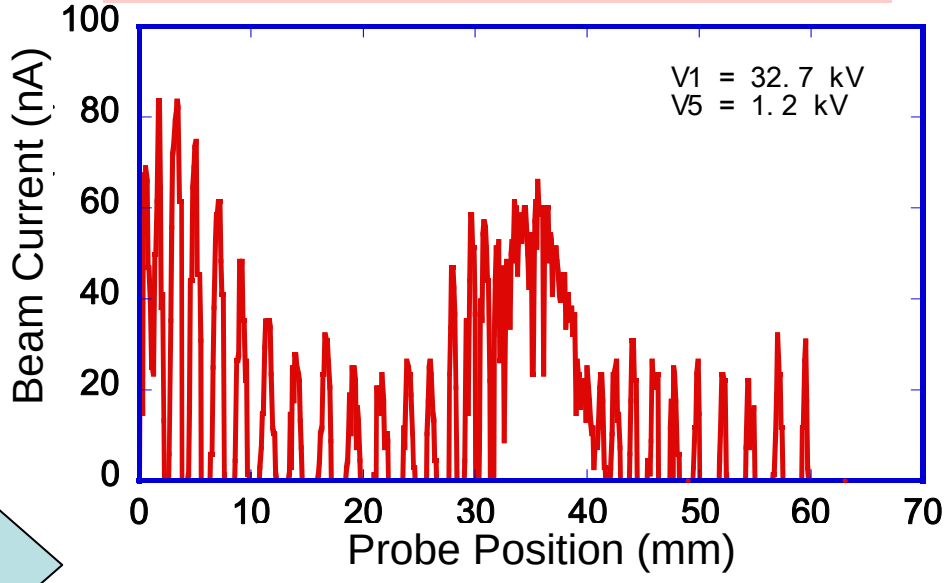
Single Turn Extraction

260 MeV $^{20}Ne^{7+}$
@ JAEA AVF Cyclotron

Ordinary Acceleration

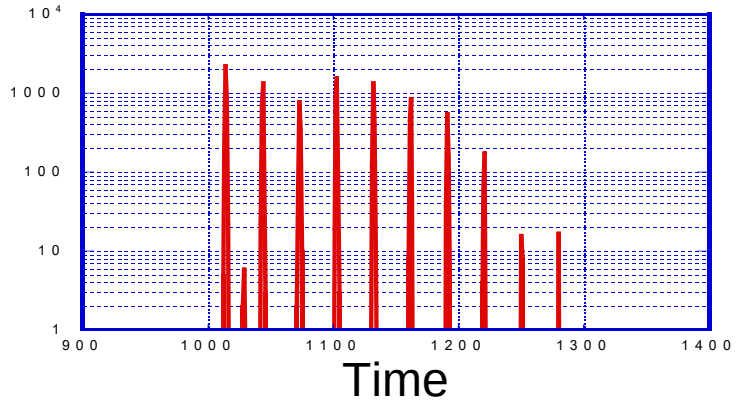


Flattop Acceleration

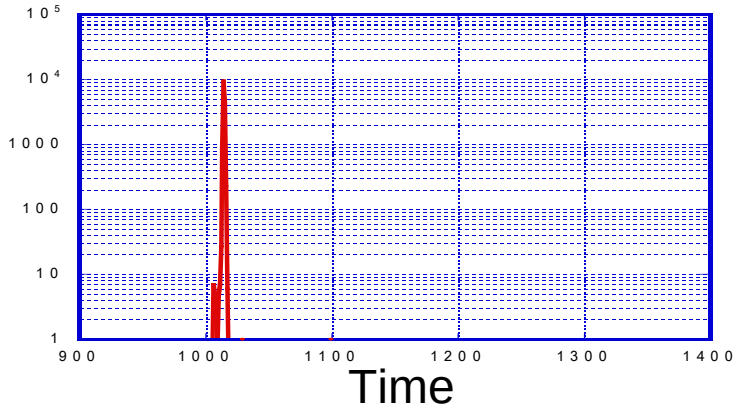


Multiturn extraction

Beam bunch for single-pulse injection



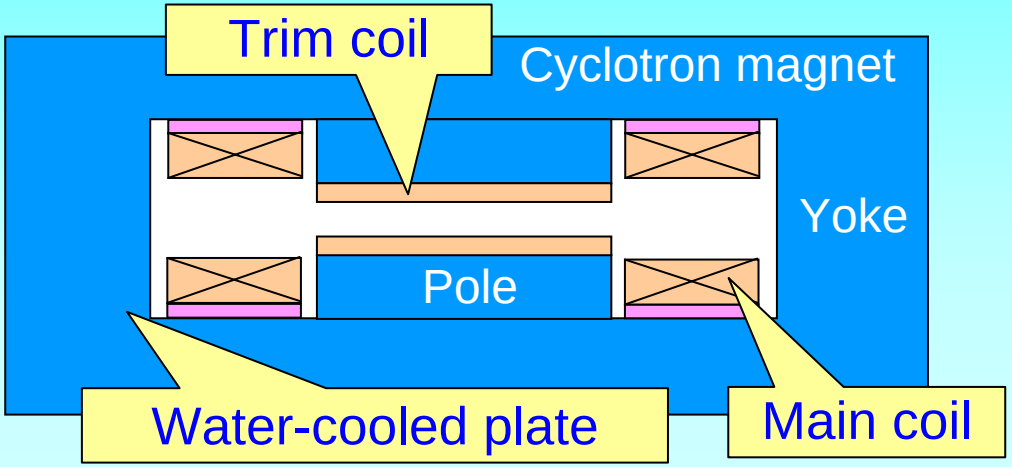
Single turn extraction



Stabilization of Cyclotron Magnet Field by Controlling Cooling Water Temperature

Temperature increase caused by heat from coils : Δt_{yoke} ~5 ^{o}C

Magnetic field stability : $\Delta B/B \sim 3\times10^{-4}$



Improved

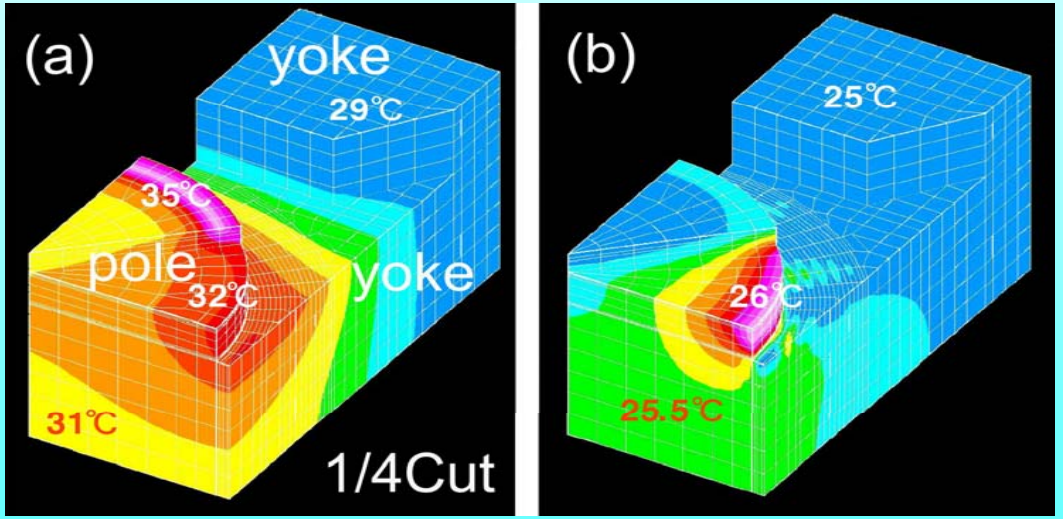
- Insertion of water cooled plate for heat shielding

  $\Delta t_{yoke} \sim 0.1$ ^{o}C
- Stabilization of cooling water temperature for coils

  $\Delta t_{coolant} \sim 0.5$ ^{o}C

$\Delta B/B \sim 1\times10^{-5}$

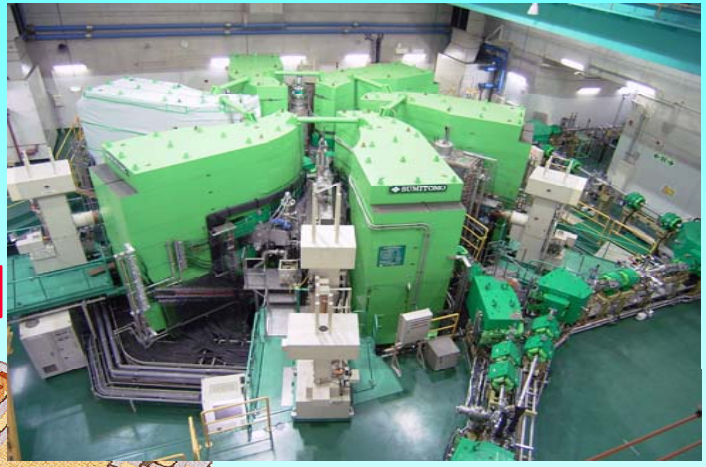
Calculated temperature distribution
(a) without plate (b) with plate



High Quality Beam at RCNP Cyclotron Facility

Energy Resolution
ΔE/E ~ 0.005%

Ring Cyclotron
K=400 MeV
ΔE/E ~ 0.01%
Since 1992



Stability of Magnetic Field
ΔB/B < 0.001%

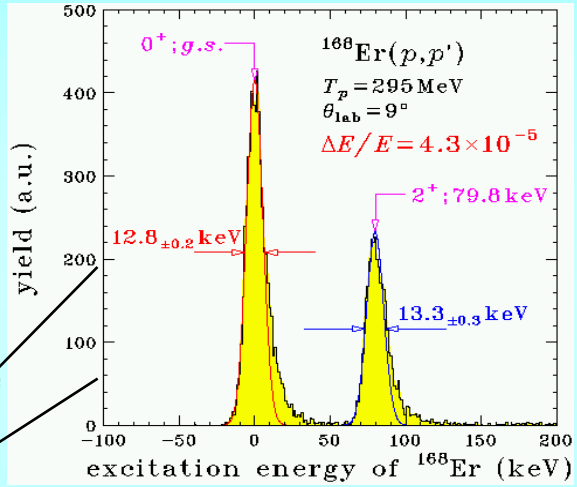
AVF Cyclotron
K=140 MeV
ΔE/E < 0.1%
Since 1973

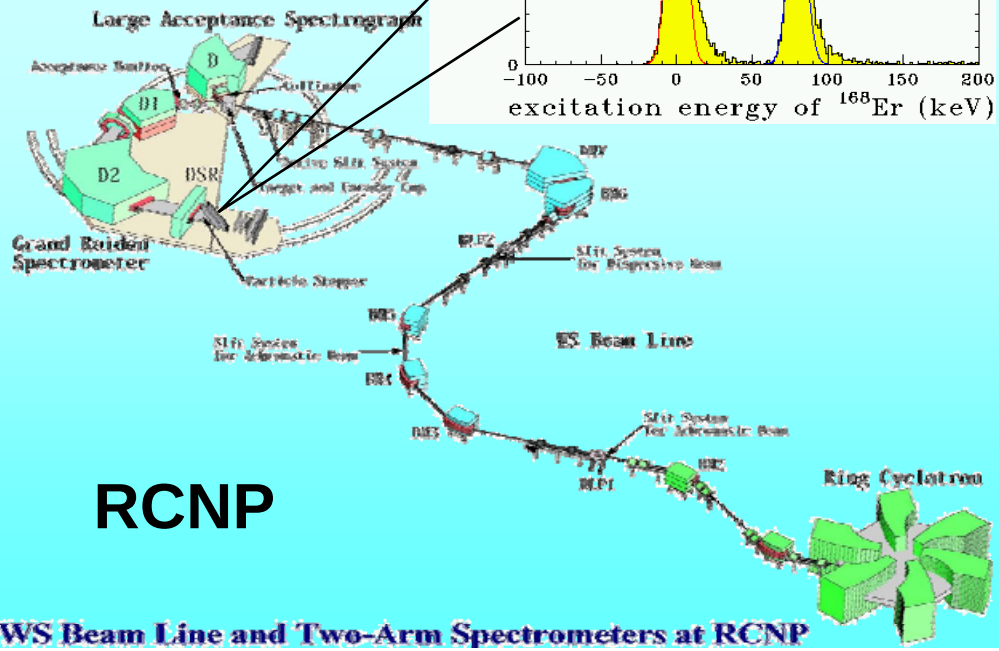
Ultrahigh Energy Resolution Experiment Using the High Quality Beam

Lateral and Angular dispersion matching between WS-beam line and Grand RAIDEN

Ultrahigh resolution of ΔE = 12.8 keV

World record !!

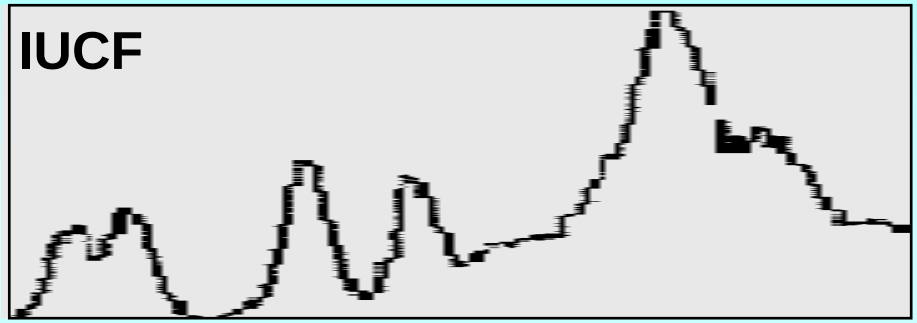




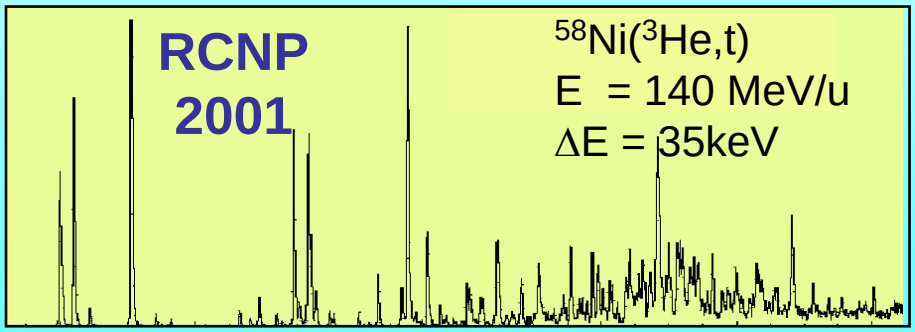
WS Beam Line and Two-Arm Spectrometers at RCNP

Comparison of resolutions

Ordinary resolution (p,n) measurement

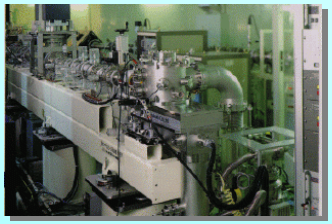


Ultrahigh resolution (^{3}He,t) measurement



5. Summary

Microbeams available at TIARA, JAEA Takasaki

Microbeam	Accelerator	ΔE/E	Ion	Spot size	Applications
Light ion 	3MV Single-ended	10^{-5}	2~3 MeV H, He	0.25 μm	- Micro-PIXE analysis - PBW (Proton Beam Writing)
Heavy ion 	3MV Tandem	10^{-4}	H ~ Au	<1 μm	- Analysis of single event phenomena in semiconductor devices
High-Energy Heavy-ion 	K110 AVF Cyclotron	$>10^{-3}$ (original)	H ~ Xe	5 ~ 10 μm (Collimation)	- Elucidation of Irradiation effects to living cells
		10^{-4} (new)	260 MeV Ne	< 1 μm (Focussing)	