Experiments using a recoil-producing nuclear separator

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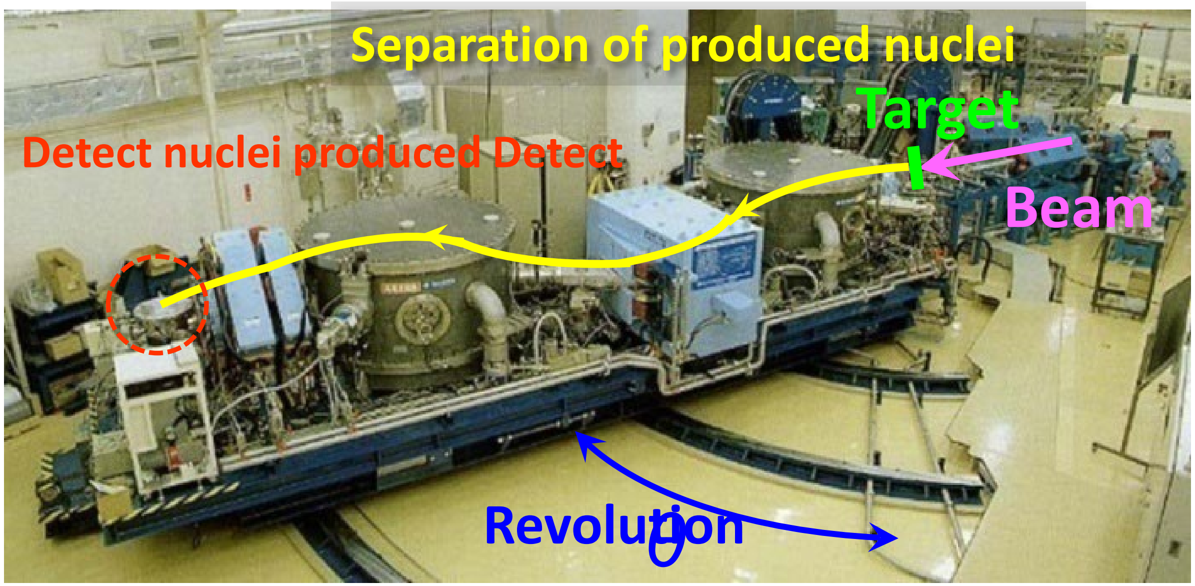
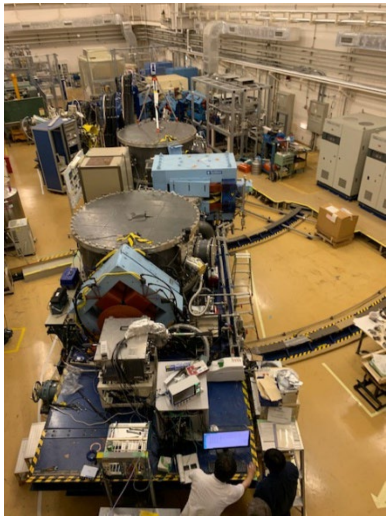
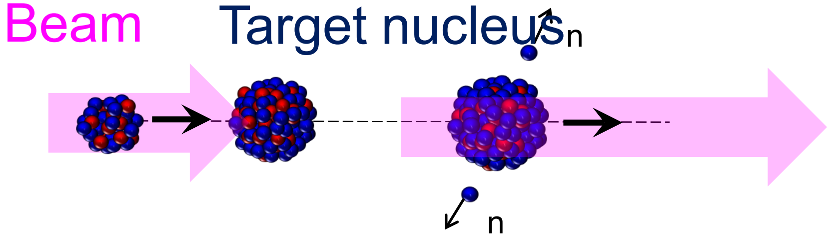
Recoil-producing nuclear separator
(JAEA Recoil Mass Separator)

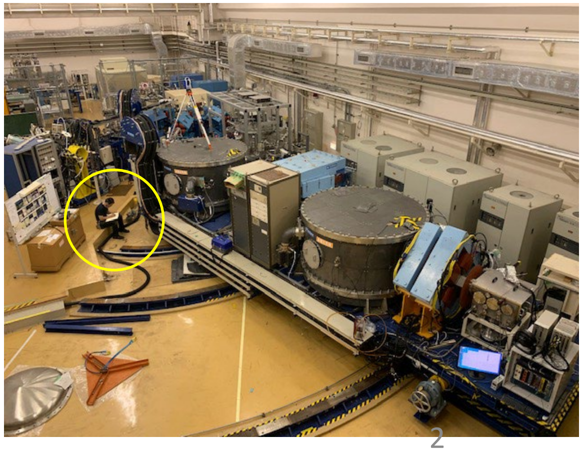


θ = 0°





θ = 40°



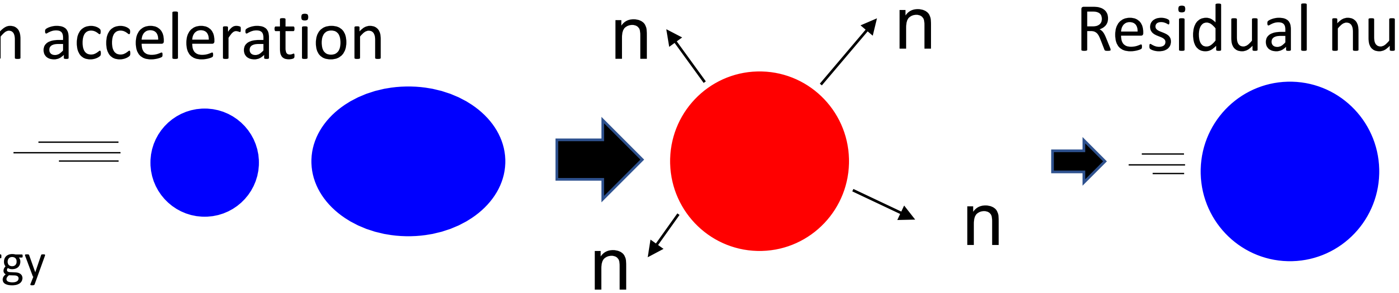
The nuclei produced in the fusion reaction recoil and fly out in the same direction as the beam (set RMS in the zero-degree direction).

Reactions learned in practice

Compound nucleus

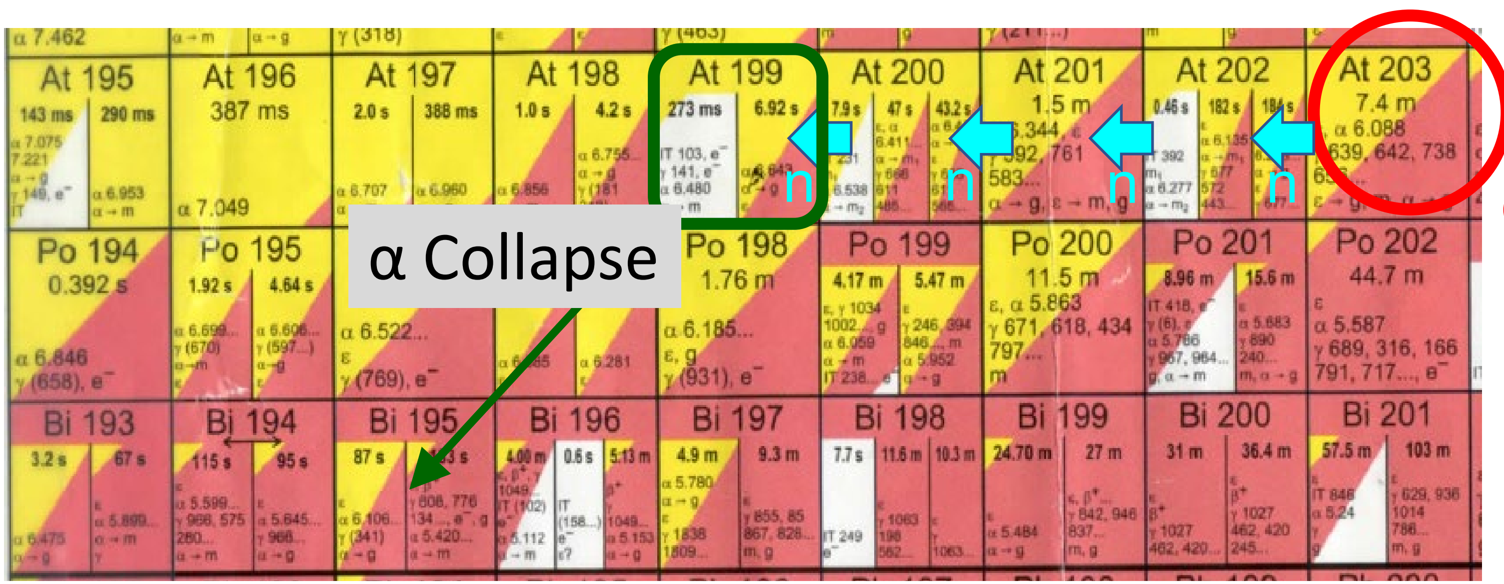
Tandem acceleration

Residual nucleus



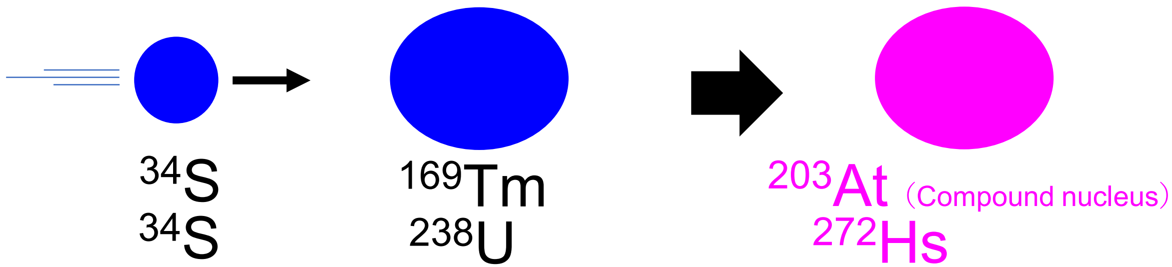
【Beam energy 160MeV】

$^{34}_{16}S + ^{169}_{69}Tm = ^{203}_{85}At$ $\quad$ ^{199}At

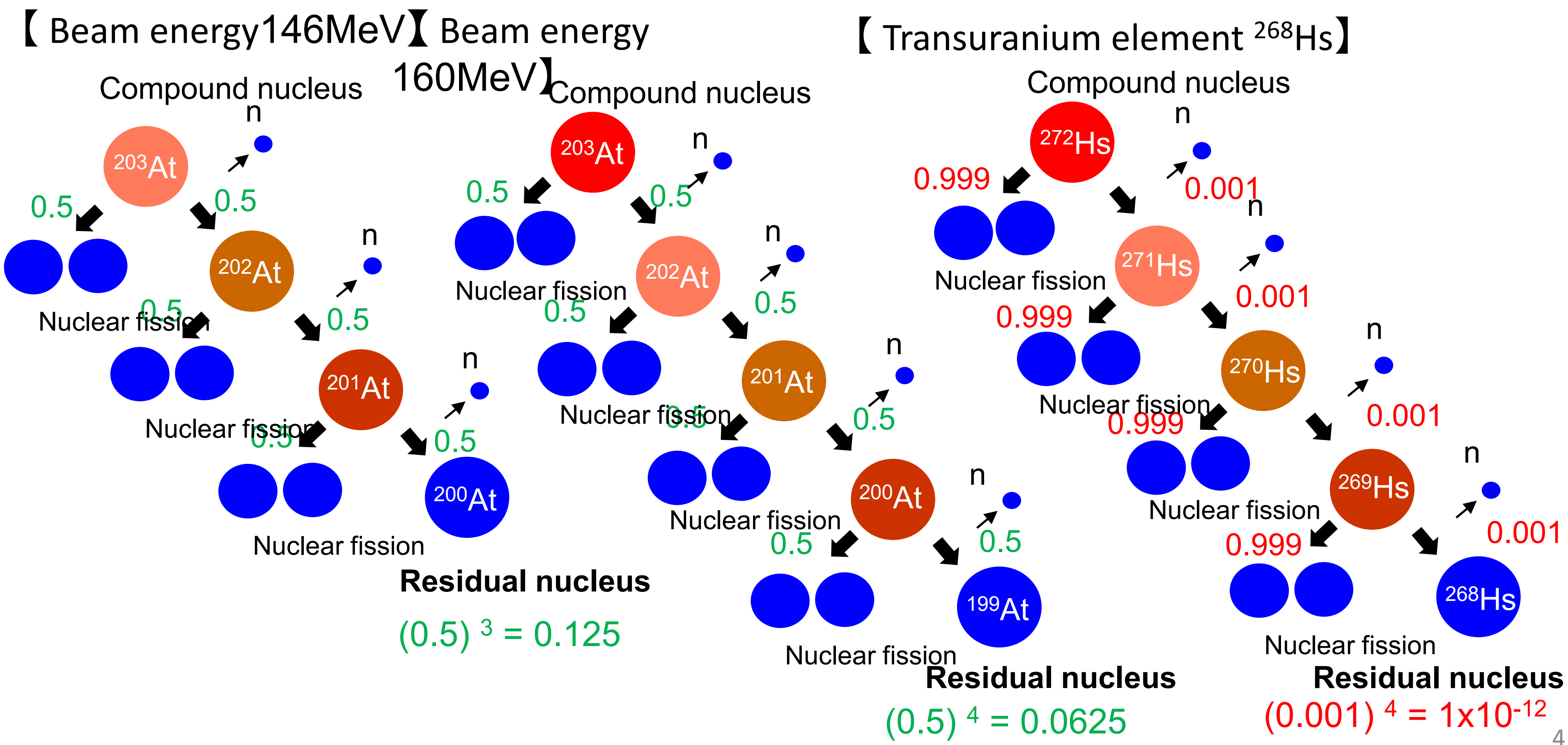


Compound nucleus

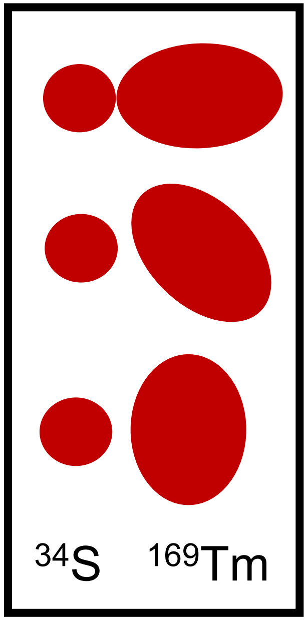
Beam energy and evaporated residual nuclei produced



The excitation energy increases in proportion to the kinetic energy of ^{34}S.

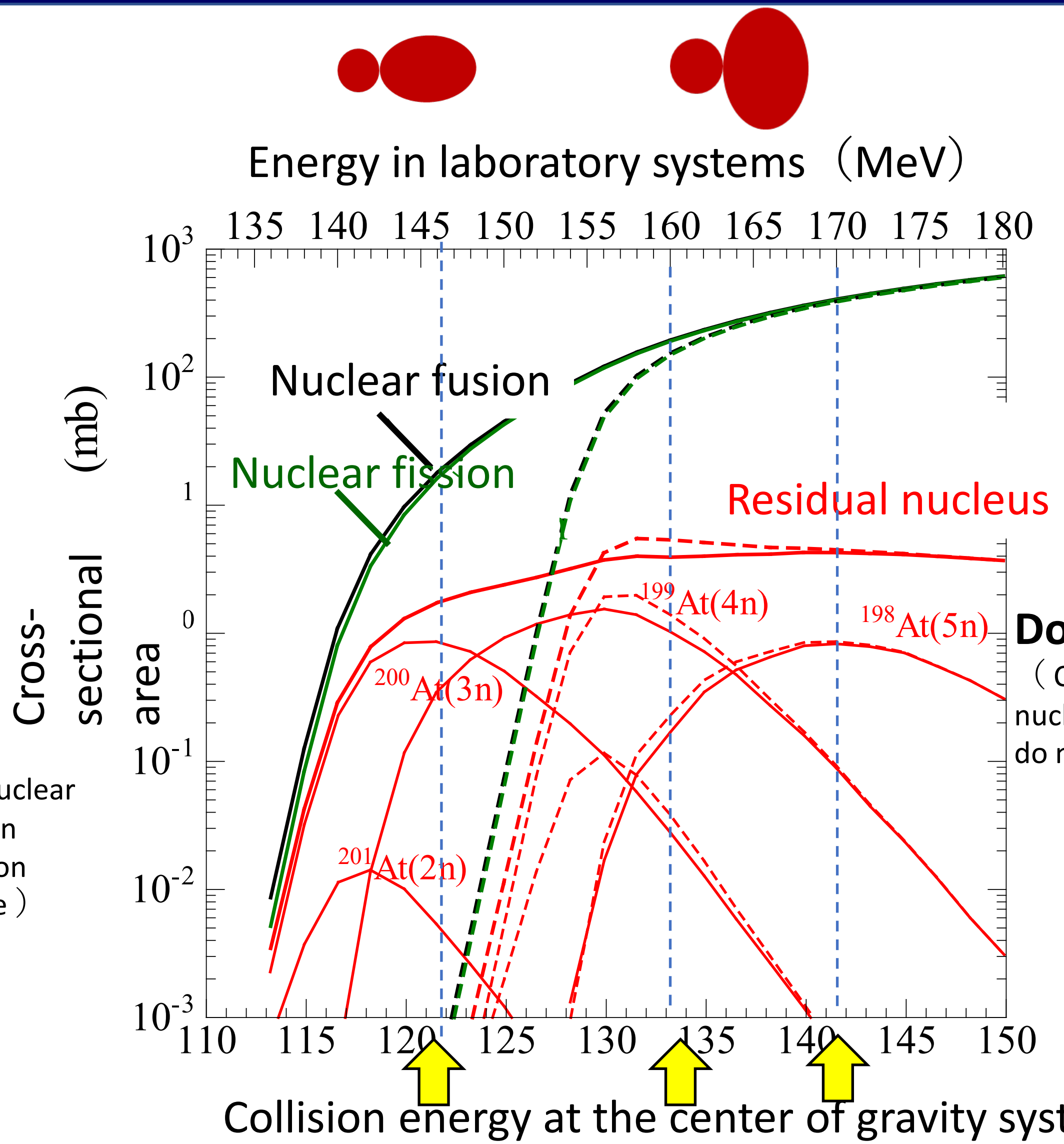


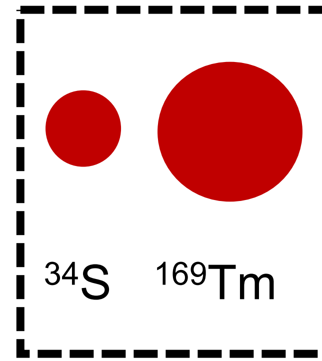
Generation cross section of astatine evaporation residual nuclei



Solid line

（Calculations incorporating nuclear deformation The calculation incorporates the deformation of the nucleus, correct image）





Dotted line

（Calculations that do not incorporate nuclear deformation Calculations that do not incorporate）

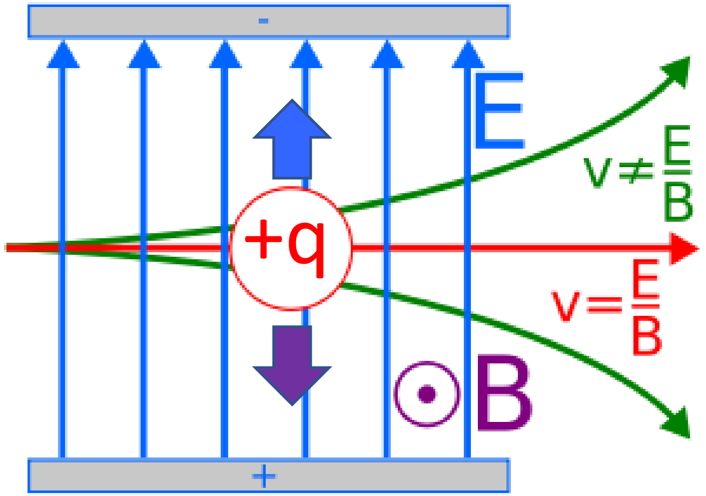
Velocity Filter (Velocity Selector)

Force applied by an electric field

$\vec{F}_E = q\vec{E}$

Force applied by magnetic field

$\vec{F}_B = q\vec{v} \times \vec{B}$



Apply a magnetic field so that it intersects the electric field, also make the forces work in opposite directions.

$$F_E = q\,E$$
$$F_B = q\,v\,B$$

Both forces are balanced to move straight ahead. $(F_E = F_B)$

$$\frac{E}{B} = v$$

Through an evaporation residue (residue) or through a beam (beam), respectively.

$$\frac{E_{residue}}{B_{residue}} = v_{residue} \qquad \frac{E_{beam}}{B_{beam}} = v_{beam}$$

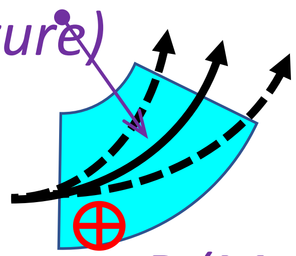
$v_{residue}$ (^{199}At) = 0.50 cm/ns

v_{beam} (^{34}S) = 3.01 cm/ns

$v_{residue} \neq v_{beam}$ So the two can be separated.

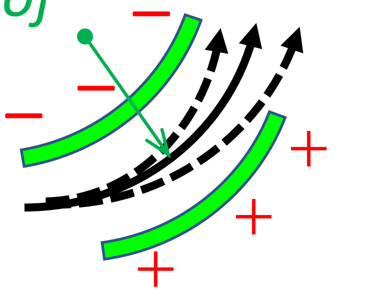
Ion's resistance to bending in magnetic field *B* and electric field *E*（*B*ρ and *E*ρ）

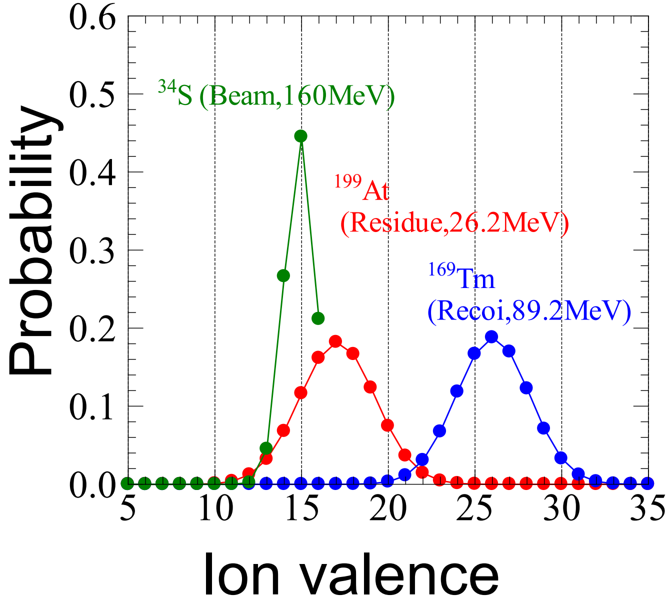
*B*ρ and *E*ρ are ion (mass number A, kinetic energy ε, charge + q) specific values, the resistance to bending in magnetic and electric fields, respectively.



$$B\rho \propto \frac{\sqrt{A\cdot\varepsilon}}{q}$$

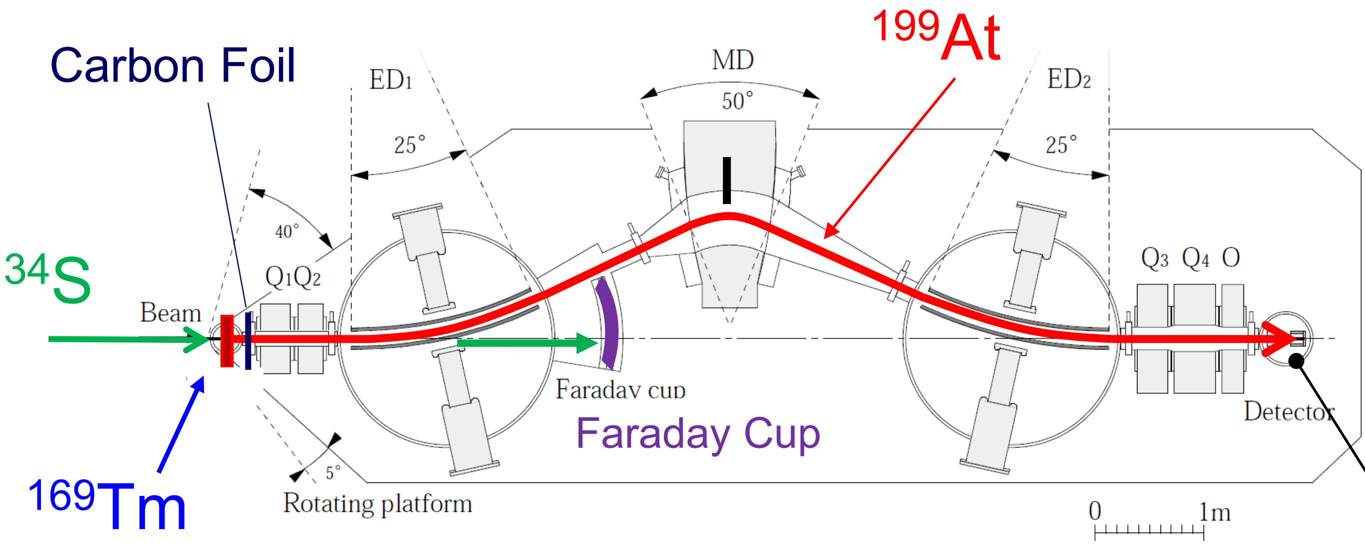
$$E\rho \propto \frac{2\varepsilon}{q}$$

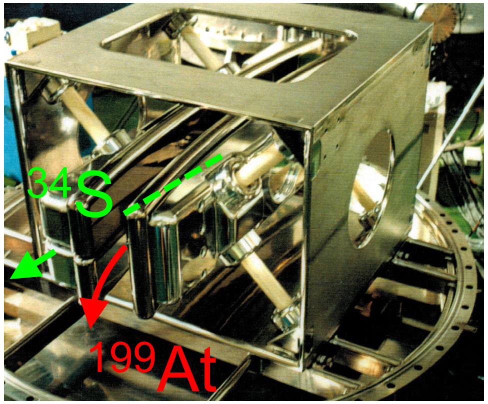




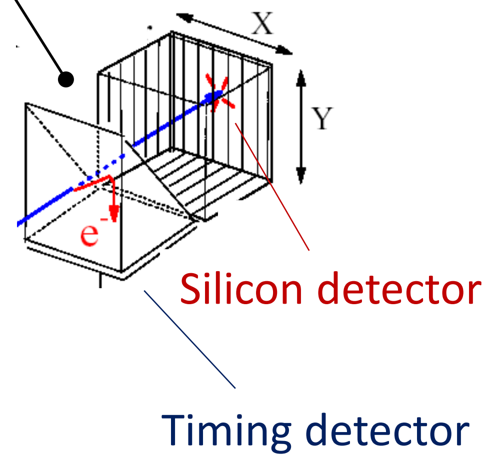
	Bρ (Tm)	Eρ (MV)	Eρ/Bρ（Any）
S-34 (15$^+$, 160MeV)	0.7088	21.33	30.09
At-199 (17$^+$, 26.2MeV)	0.6110	3.08	5.04
Tm-169 (26$^+$, 89.2MeV)	0.6800	6.86	10.09

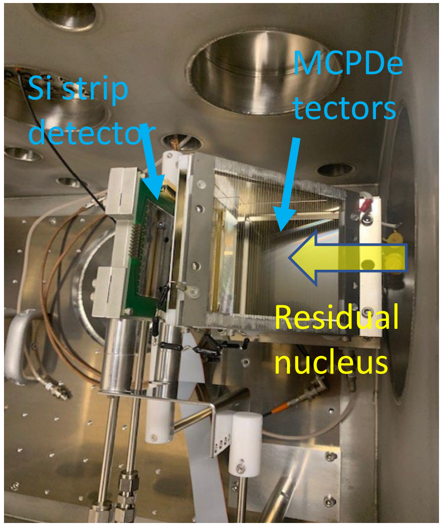
Recoil-producing nuclear separator （JAEA－RMS）





$Q_{1,2}$ Electric field Magnetic field Electric field $Q_{3,4}$

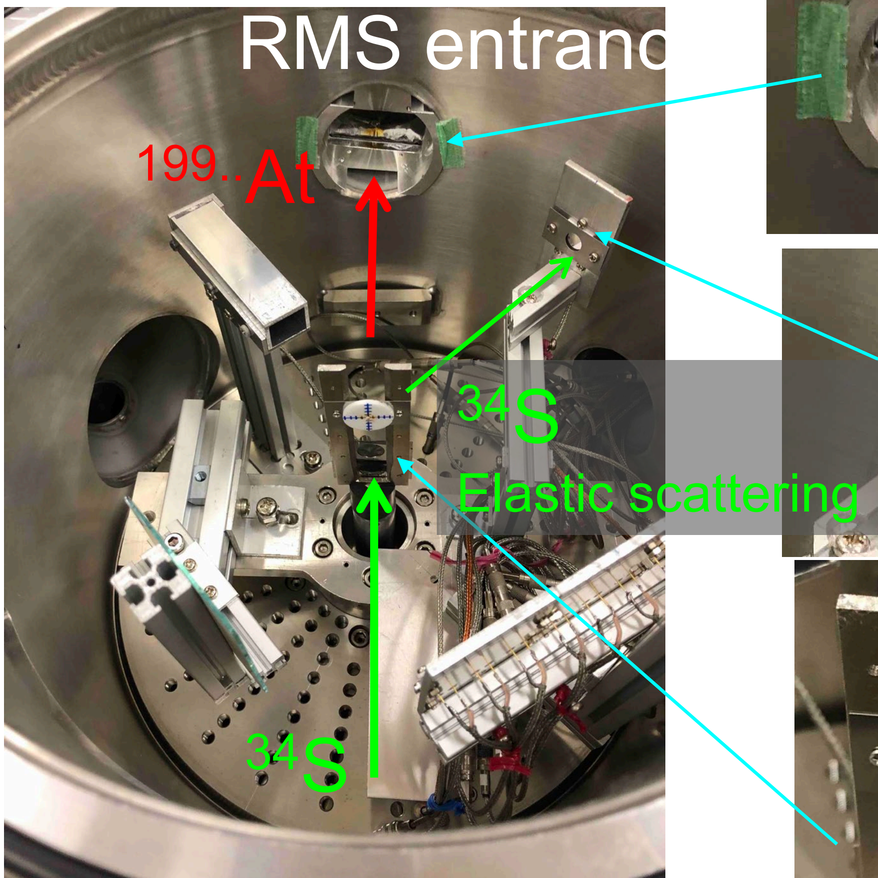


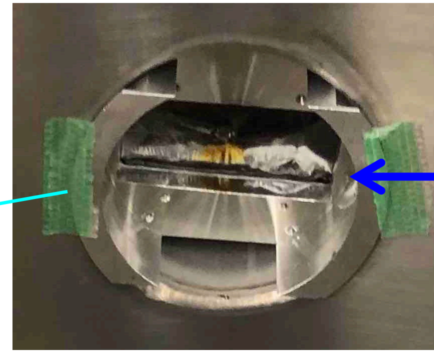


Acceptance of kinetic energy
＝±１２％ of set value

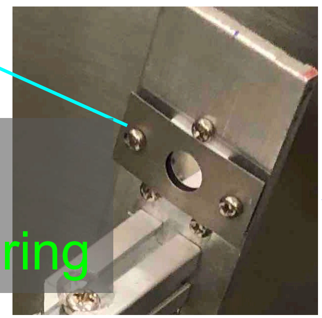
Acceptance of mass number
＝±４％ of set value

Target scattering tank（e.g. ^{169}Tm thin film target）

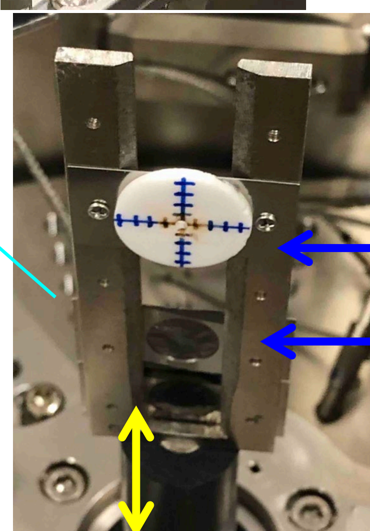




Charge reset
Foil (film of carbon)
Equilibrate charge distribution



Measure Elastic Scattering
Silicon detector
Evaporation residual nucleus cross section Necessary to determine



Make the beam glow

^{169}Tm thin film target

Setting up the electric and magnetic fields for RMS

Determine the mass number A, kinetic energy E, and charge +q of the evaporating residual nucleus

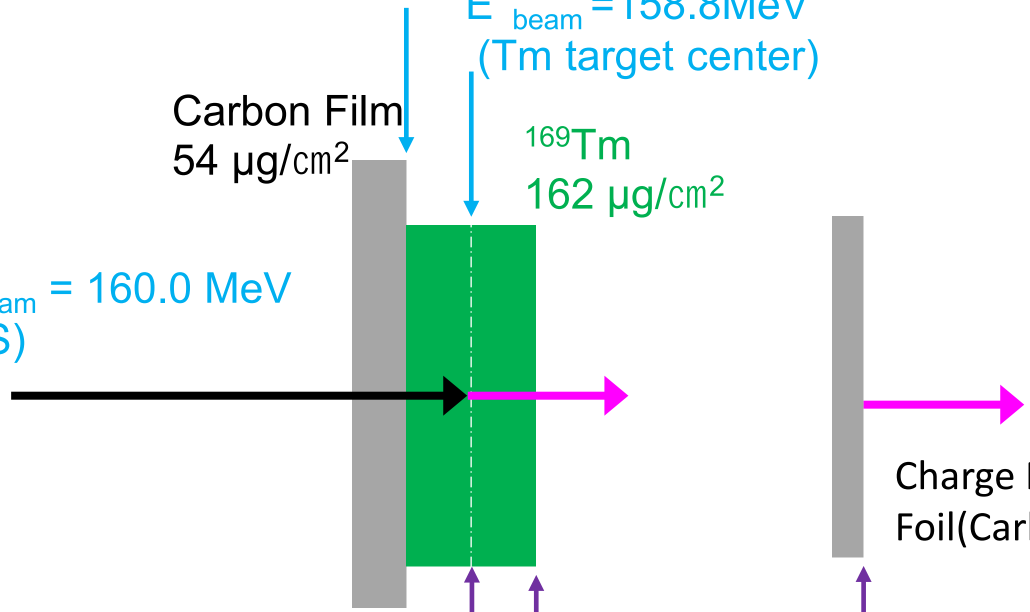
E'_{beam} = 159.3 MeV
(After passing through carbon thin film)

E''_{beam} =158.8MeV
(Tm target center)

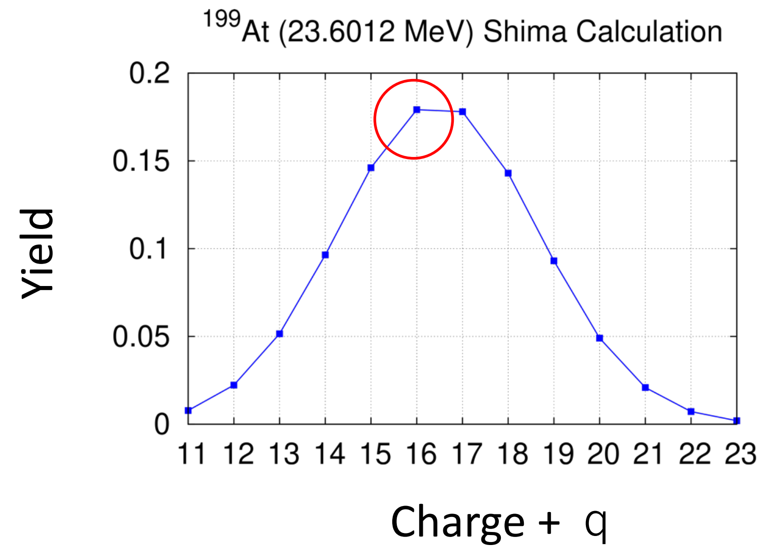
Carbon Film
54 μg/cm²

^{169}Tm
162 μg/cm²

E_{beam} = 160.0 MeV
(^{34}S)



Charge Reset Foil(Carbon film)



$^{199}_{85}At^{16+}$

$E_{residue}$ = 26.2 MeV
4n neutrons evaporated
Energy of evaporation of 4n neutrons ^{199}At
（Tm target center)

Composite nucleus kinetic energy $\times \frac{199}{203}$

$E''_{residue}$ = 23.6 MeV
Energy after passing through carbon film

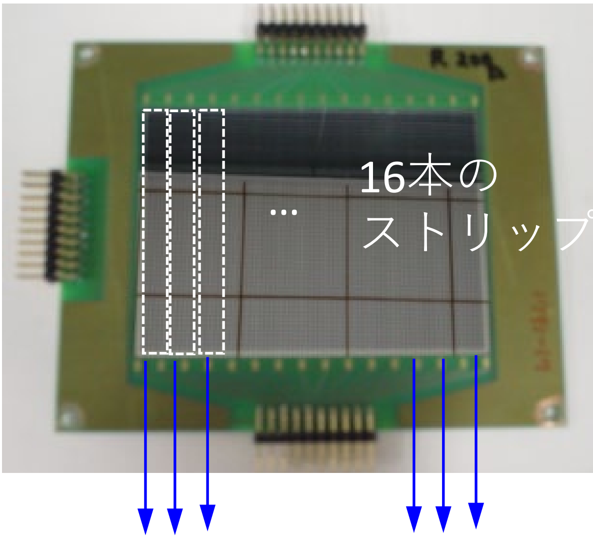
$E'_{residue}$ = 25.5 MeV
Energy after passing through half the thickness of the Tm target

$$B\rho \propto \frac{\sqrt{A \cdot E}}{q}$$

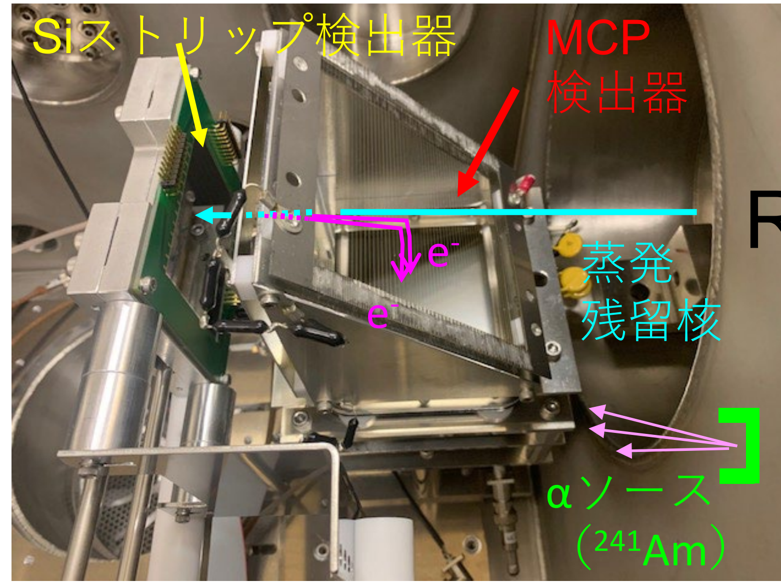
$$E\rho \propto \frac{2E}{q}$$

α崩壊を観測する検出器

シリコン（Si）ストリップ検出器



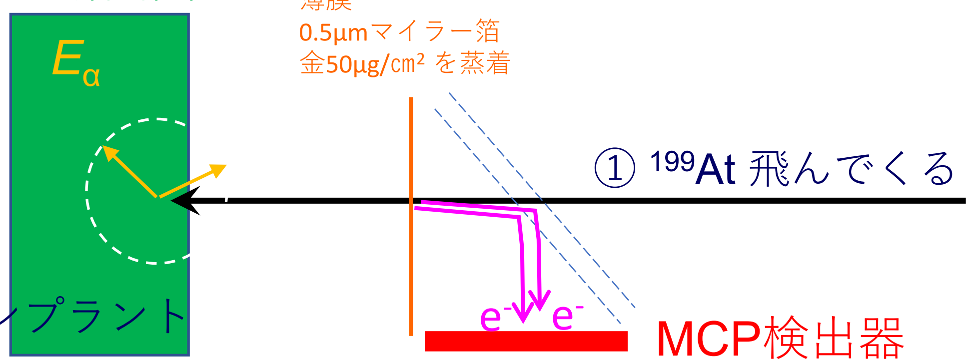
16本のストリップから
それぞれ信号を出す。



RMS

Si断面図

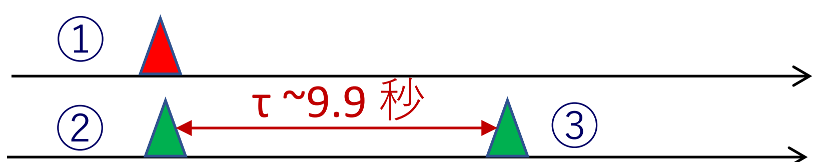
薄膜
0.5μmマイラー箔
金50μg/㎠ を蒸着



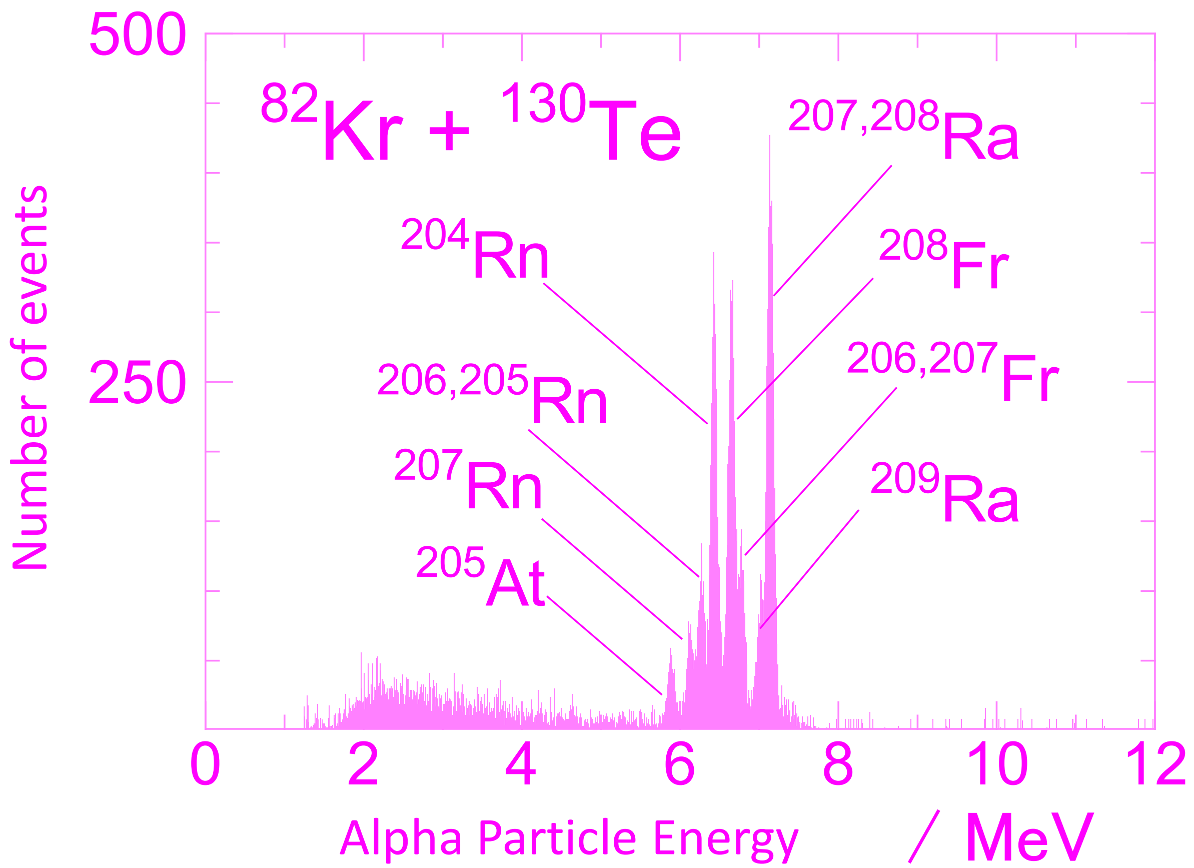
③ α崩壊の観測
（寿命τののち）
~60％が全エネルギー
吸収

MCP検出器

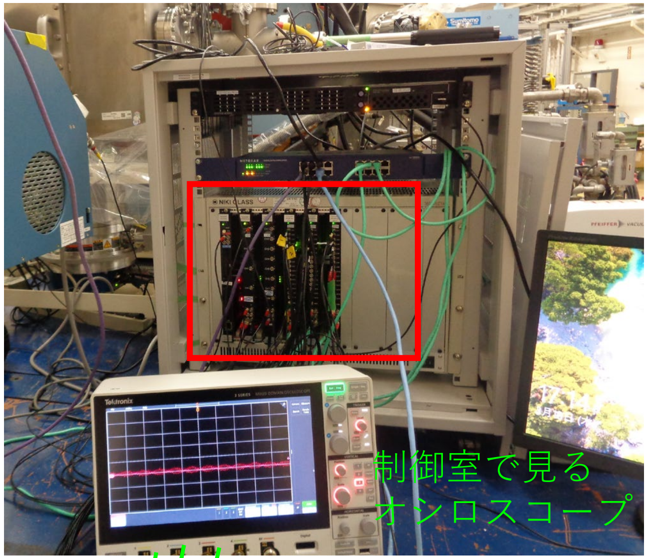
Siストリップ検出器

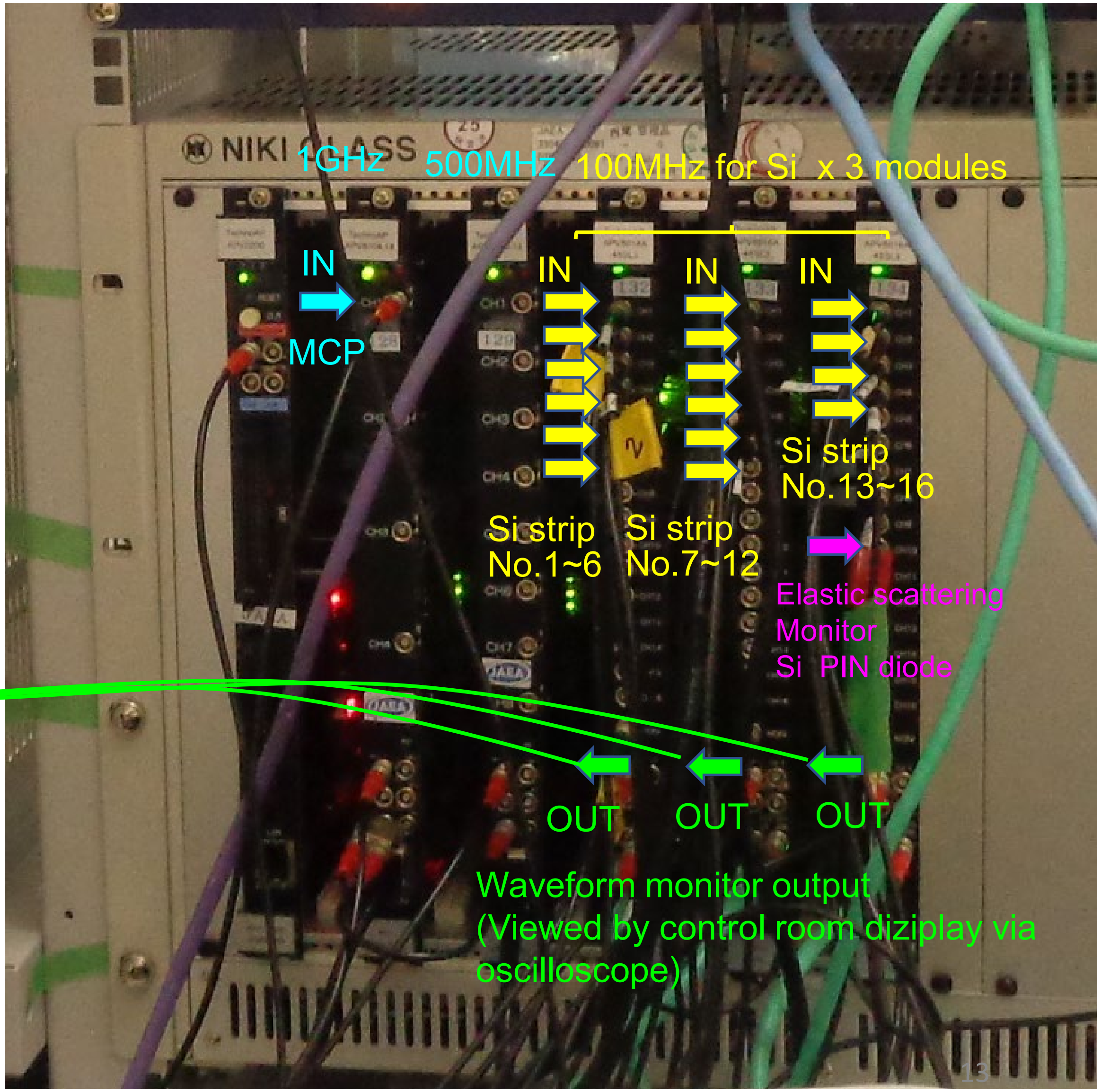


Energy spectrum of alpha ray (example of measurement)



Digital data processing





Evaporation process may emit protons.