Week 9, Lecture 2 – Reactions in the Lab

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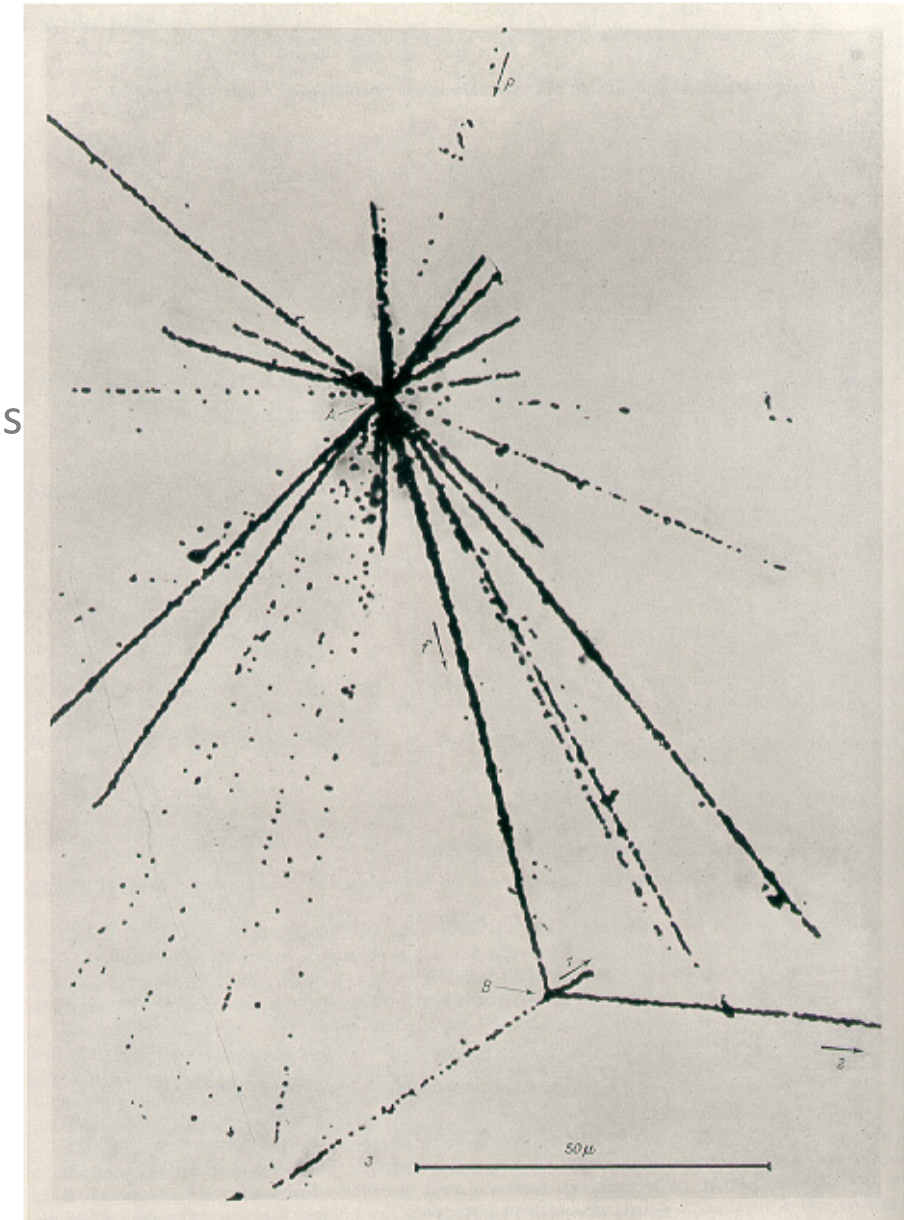
Nuclear Reactions

-- Nuclear Reactions overview
--- neutron induced reactions
--- charged particle induced reactions
-- Cross Section, Target attenuation
-- Energetics, Q-values, thresholds
-- Conservation of Momentum, Center of Mas
-- Reactions between complex nuclei
--- Low energy reactions, fusion
--- “High” energy reactions, fragmentation



Whence High Energy?

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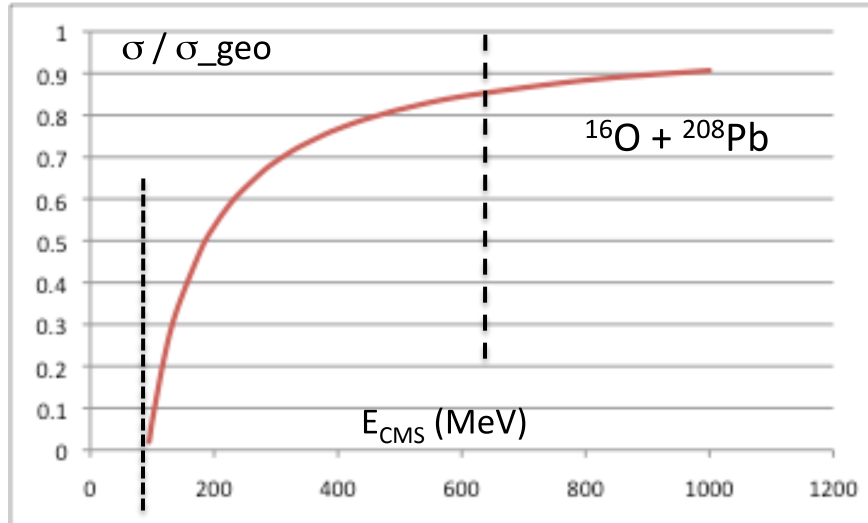
Last time: A qualitative dividing line between "low" and "high" energy reactions might be when the projectile moves past (or perhaps through) the target so fast that the nucleons inside don't have time to react.

$E/A_{beam} \sim 30 + V_{Coul} \sim 36$ MeV/A

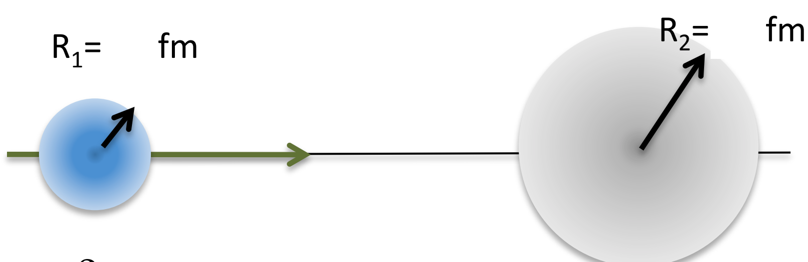


$^{16}O + ^{208}Pb \sim$ MeV (CMS) $V_{coul}=$ MeV (CMS)

MeV (LAB) $E^* =$ MeV

$\lambda_{deB} =$ fm $\Delta\tau > h/(2\pi\, E^*)$

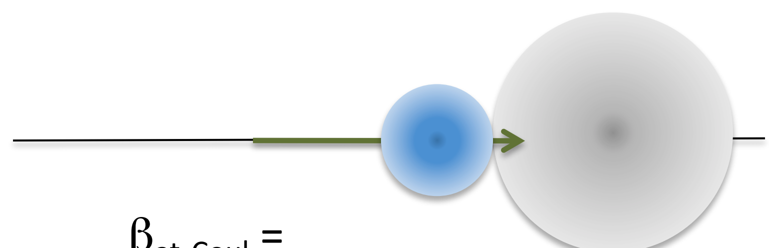
$L_{max}=$ h-bar > s



$\beta_{far} =$

$v_{far} =$ cm/ns

$\Delta t_{far} = 2\, R_2/v_{far} =$ s



$\beta_{at\ Coul} =$

$v_{at\ Coul} =$ cm/ns

$\Delta t_{at\ Coul} = 2\, R_2/v_{Coul} =$ s

Particle Trajectories

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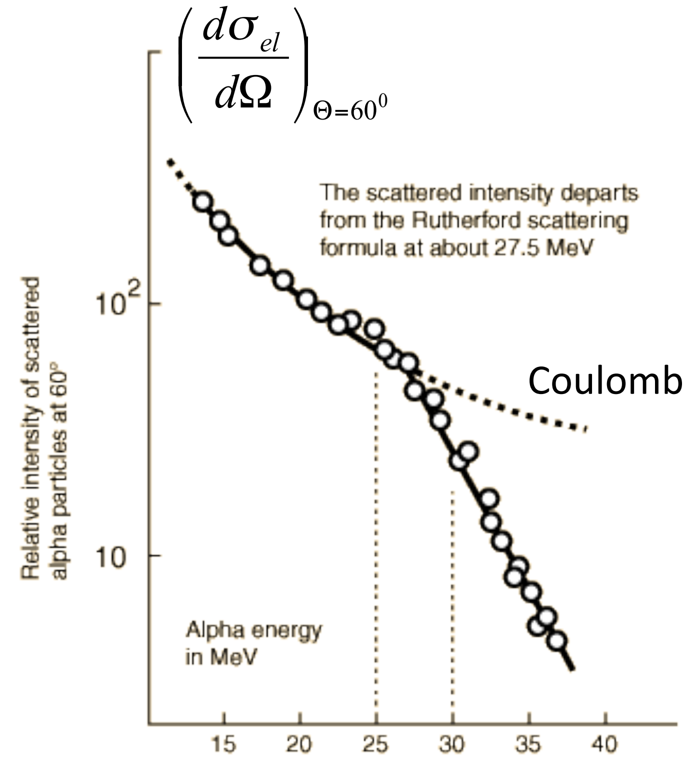
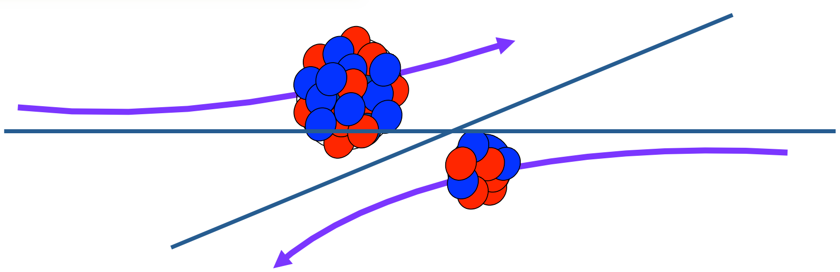
Rutherford Scattering Formula

$$\frac{d\sigma}{d\cos\theta} = \frac{\pi}{2} z^2 Z^2 \left(\frac{1}{137}\right)^2 \left(\frac{\hbar c}{KE}\right)^2 \frac{1}{(1-\cos\theta)^2}$$

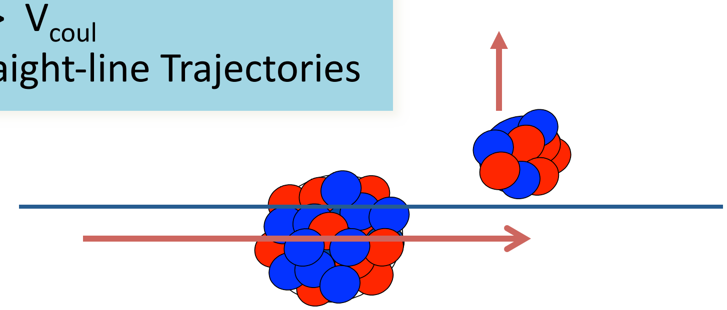
e.g., ^{4}He + Pb, Eisberg and Porter, Rev. Mod. Phys. **33**(1961)190



KE ~ V_{coul}
Coulomb Trajectories



KE >> V_{coul}
~ Straight-line Trajectories



Fragmentation

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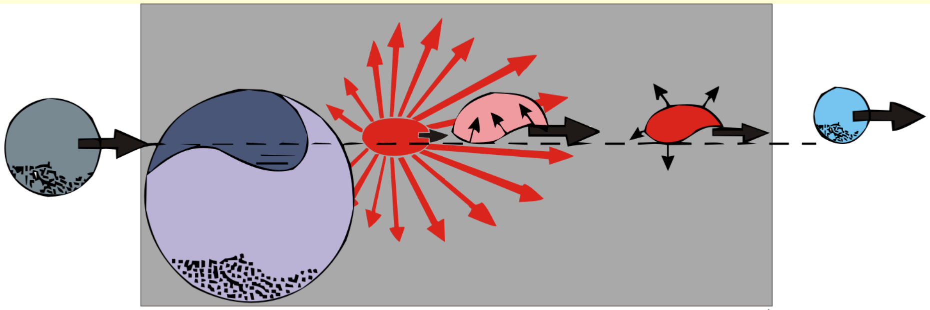
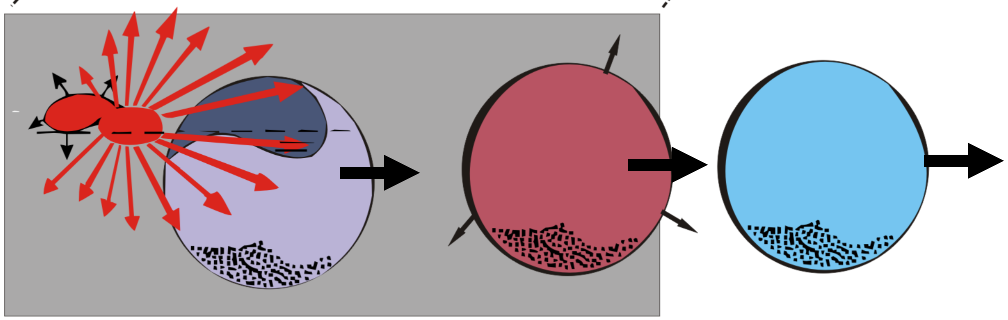
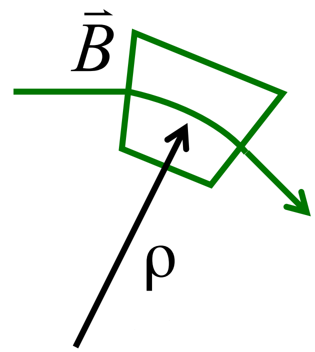
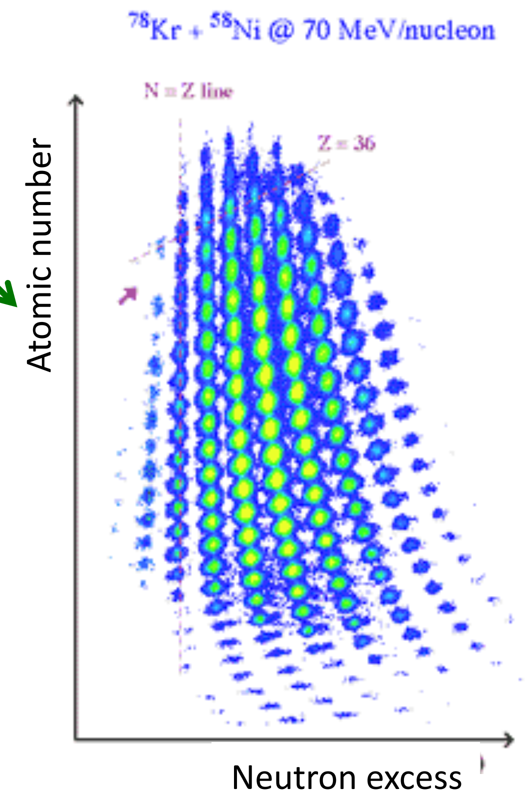


Late 1970's: $A_{proj} < A_{target}$:
[Macroscopic pictures]
"Participants" & "Spectators"

Fig. 10-32 in the text







Nowadays: $A_{proj} > A_{target}$
"Projectile Fragmentation"

Aside: doubly magic nuclei

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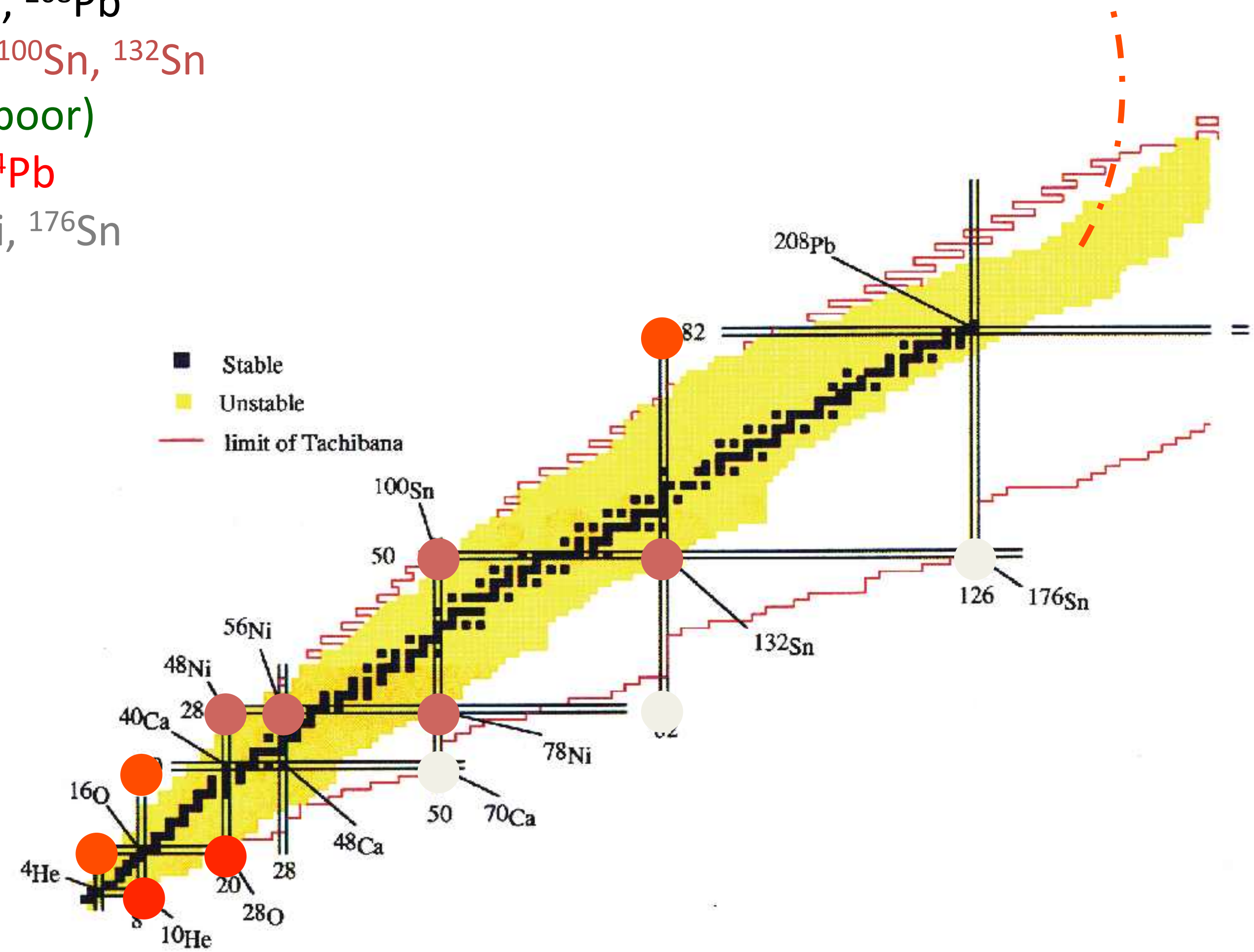
Benchmarks for Nuclear Structure

Stable: ^{4}He, ^{16}O, ^{40,48}Ca, ^{208}Pb
Found: ^{48}Ni, ^{56}Ni, ^{78}Ni, ^{100}Sn, ^{132}Sn
Hopeless: ^{10}O, ^{28}Ca (n-poor)
Unbound: ^{10}He, ^{28}O, ^{164}Pb
Unlikely: ^{36}O, ^{70}Ca, ^{110}Ni, ^{176}Sn

(opinion)



Overview of Fragment Separation at NSCL

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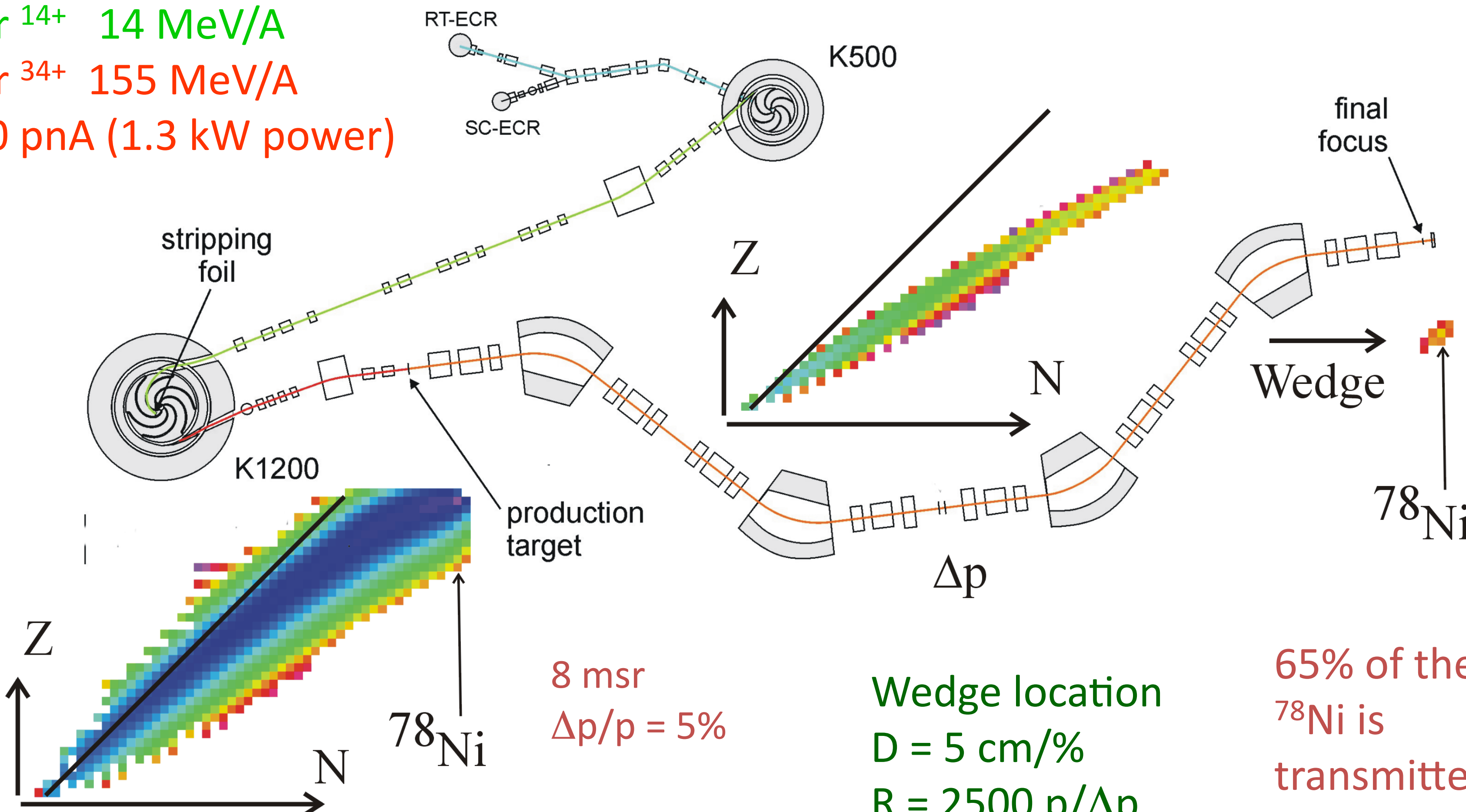
Example: $^{86}Kr \rightarrow ^{78}Ni$, NSCL at full beam power

$^{86}Kr^{14+}$ 8 pμA ECR

$^{86}Kr^{14+}$ 14 MeV/A

$^{86}Kr^{34+}$ 155 MeV/A

100 pnA (1.3 kW power)



8 msr

Δp/p = 5%

Wedge location

D = 5 cm/%

R = 2500 p/Δp

65% of the ^{78}Ni is transmitted