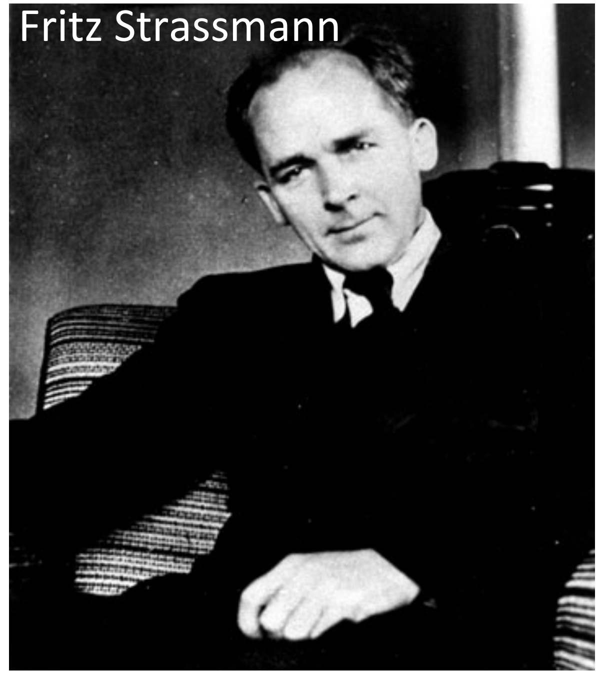
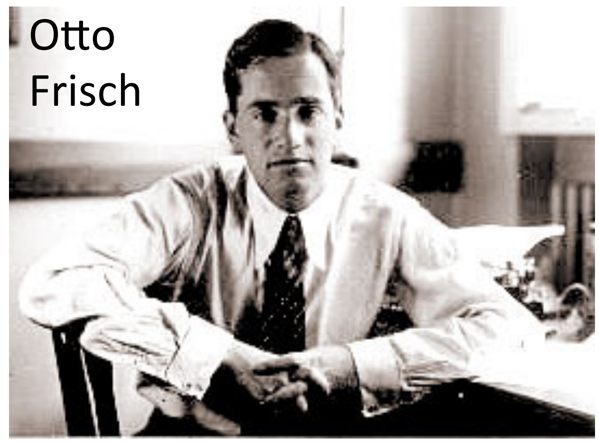
Lecture 4
Nuclear Fission

Discovery of Nuclear Fission – December 1938





Hahn and Strassmann

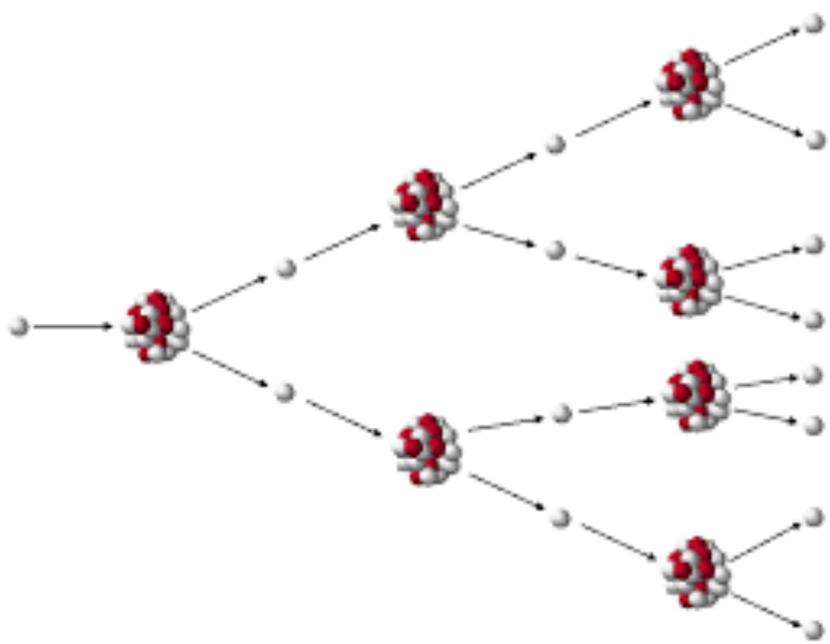
December 1938

$$_{92}U + n \longrightarrow {}_{56}Ba + {}_{36}Kr$$

F. P. $Z = 30 - 62$

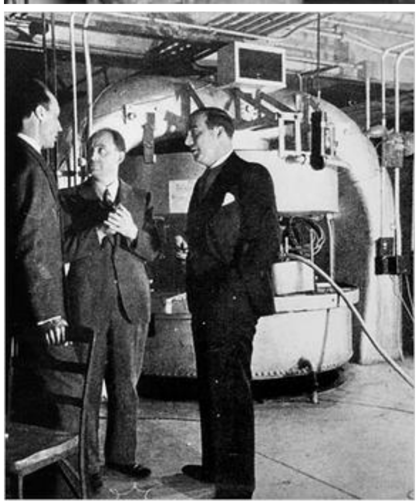
Some important historical details

Szilard's conception of a chain reaction, 1930's
(interestingly *before* the discovery of fission)



Some more important historical details

Alfred Nier and John R. Dunning demonstrate that it is the *minority* component of uranium that is fissionable by slow neutrons, in 1940 (i.e. the 0.72% ^{235}U rather than ^{238}U)

Nier & Dunning

Nier's mass spectrometer

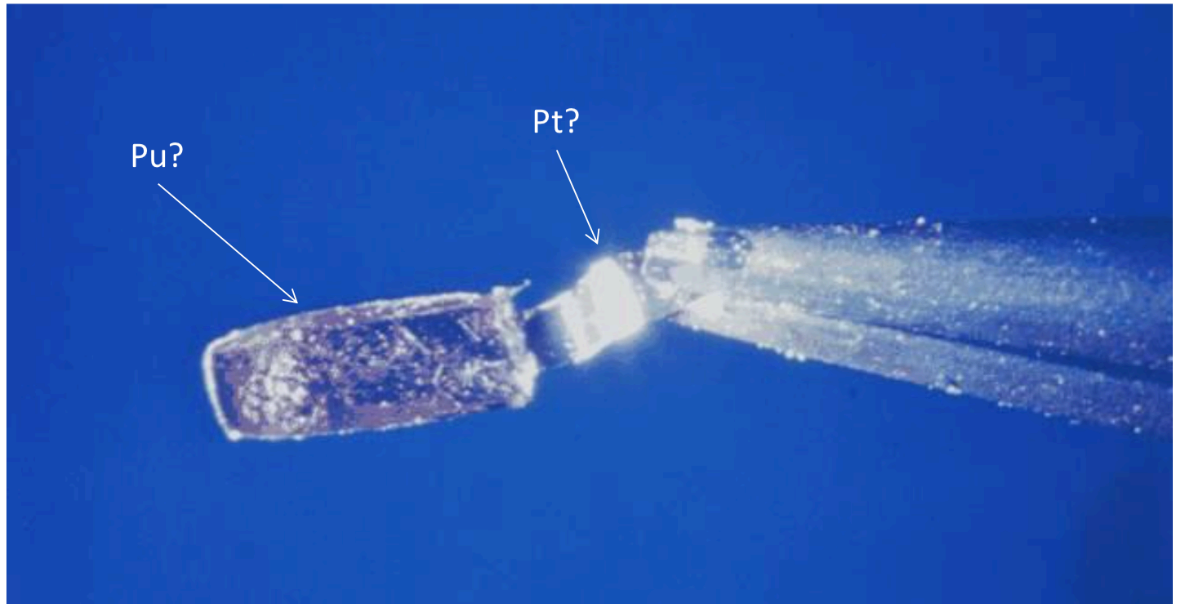
Mass spec ion source

Foil catcher

Some exciting local history

Glenn Seaborg produces & isolates first ^{239}Pu December 14, 1940

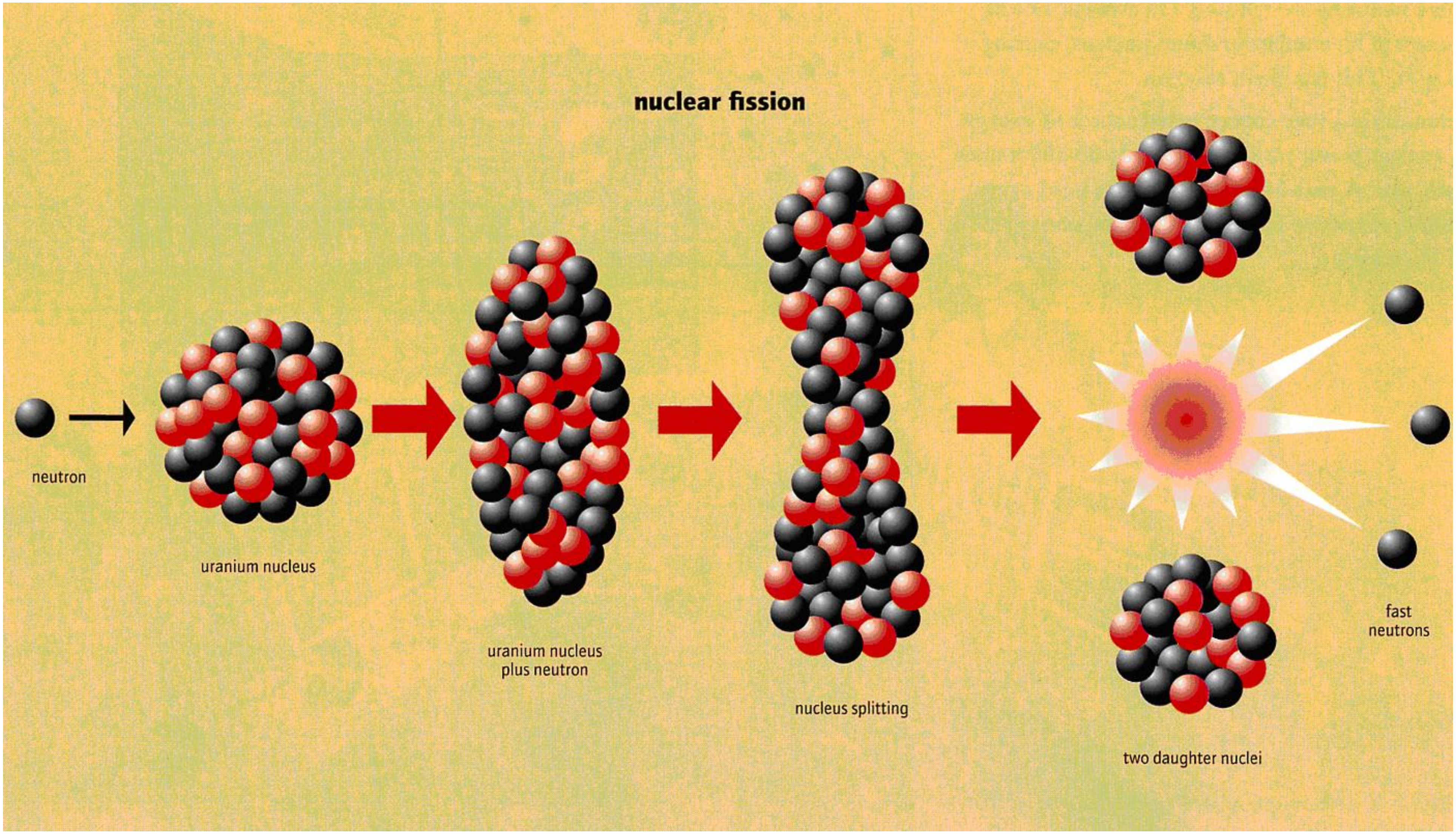
Macroscopic quantity precipitated out at Univ. Chicago Met Lab, September 1942



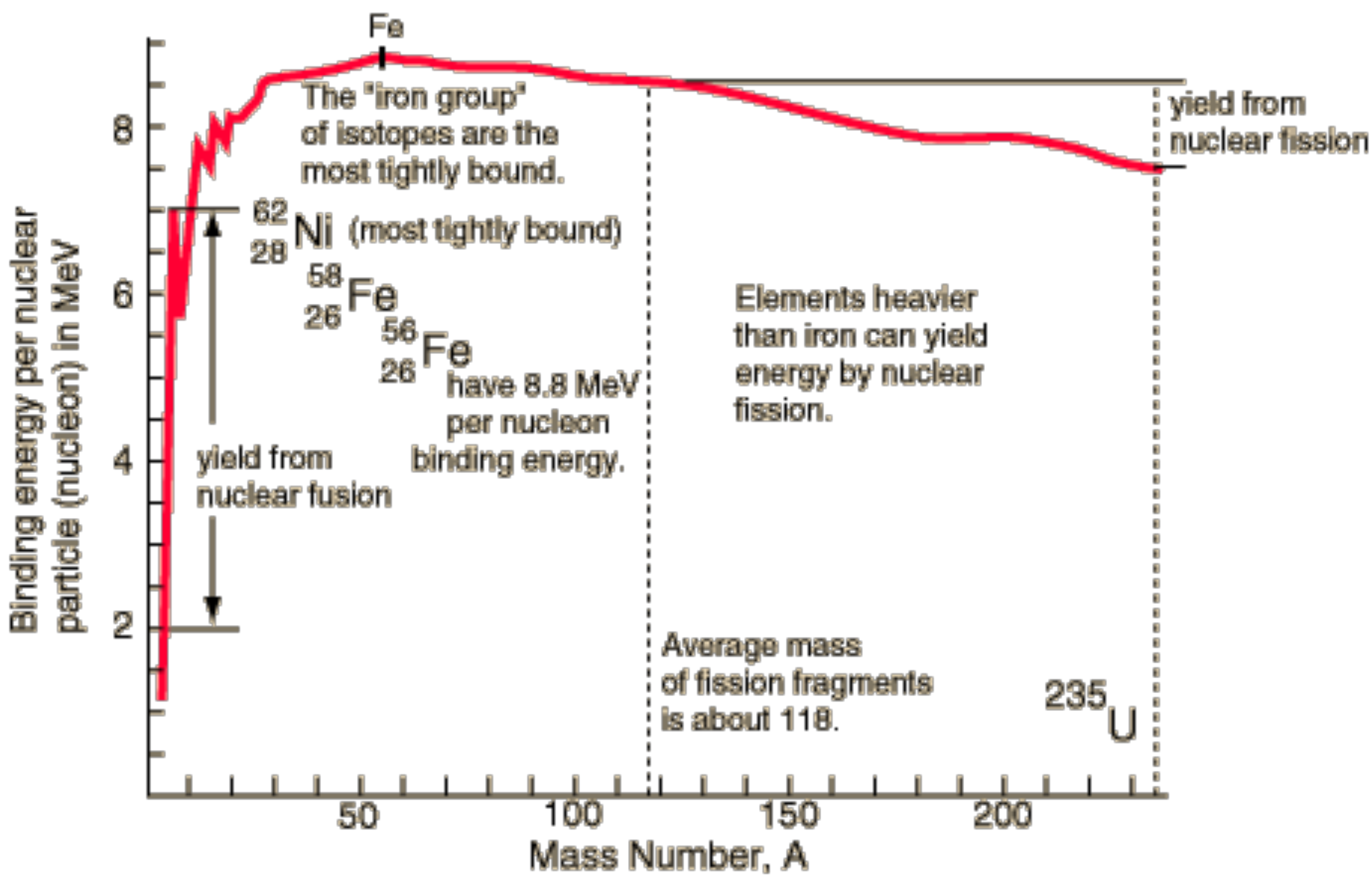
The first sample of ^{239}Pu containing 2.7-micrograms of oxide was weighed on September 10, 1942, at the University of Chicago's Metallurgical Laboratory. It is shown here as a deposit on a platinum foil held by forceps.

In Summer 2014, EH&S informed us that they thought they had it in a cigar box, and asked it we wanted it! Prof. Rick Norman, and two students confirmed it by gamma spectroscopy

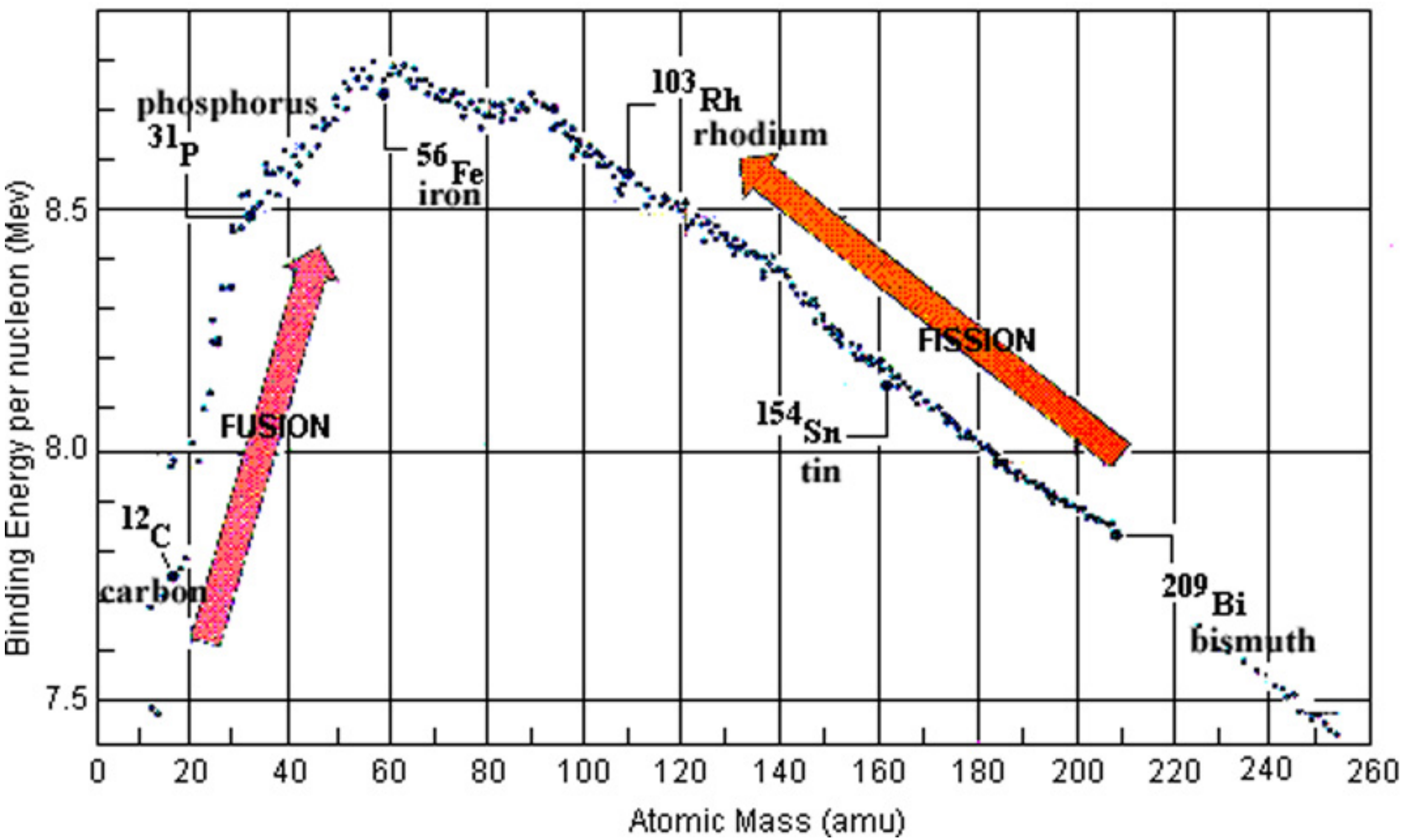
Fission - the basic picture



The curve of binding energy



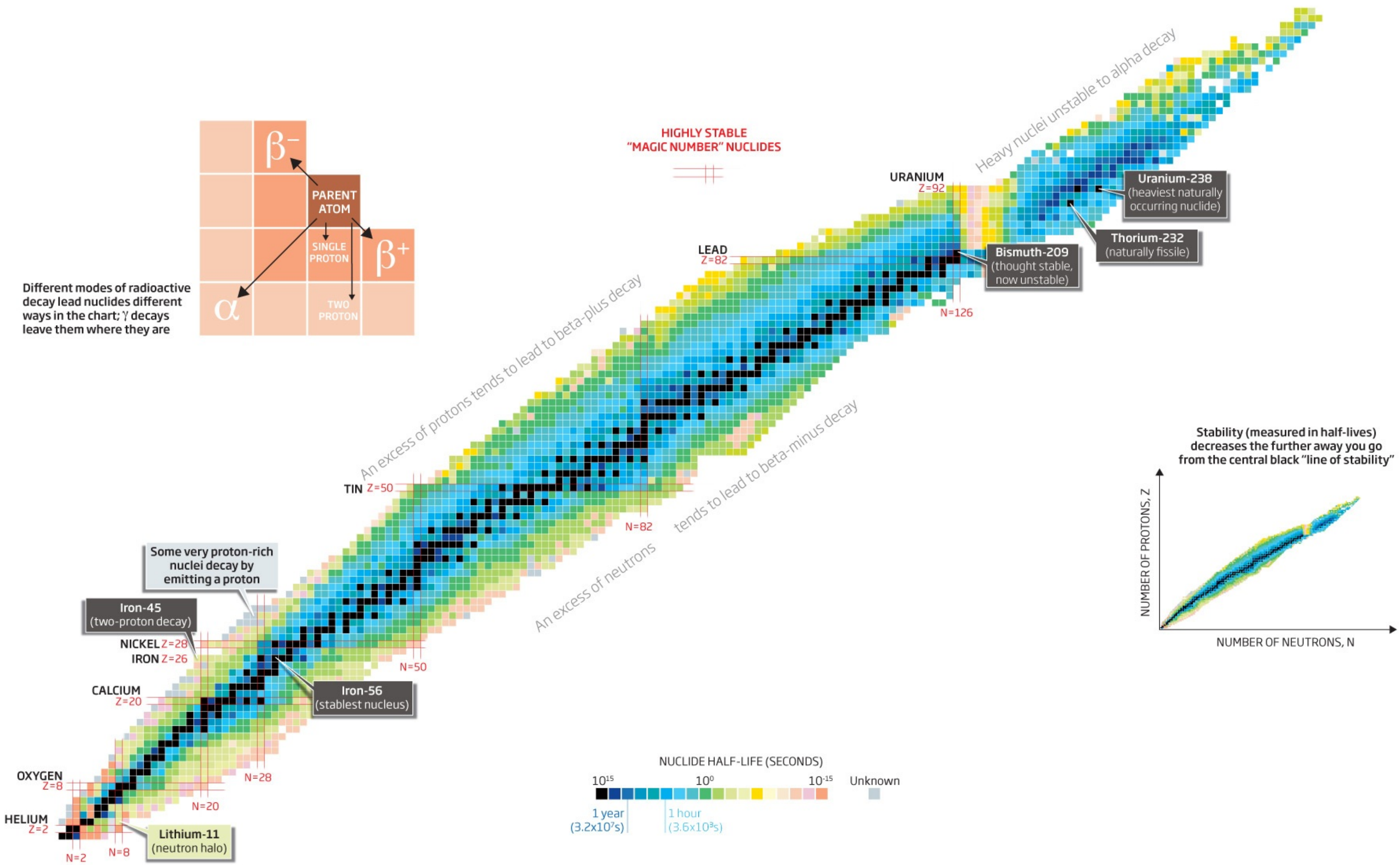
Expanding the scale around B.E. = 8 MeV



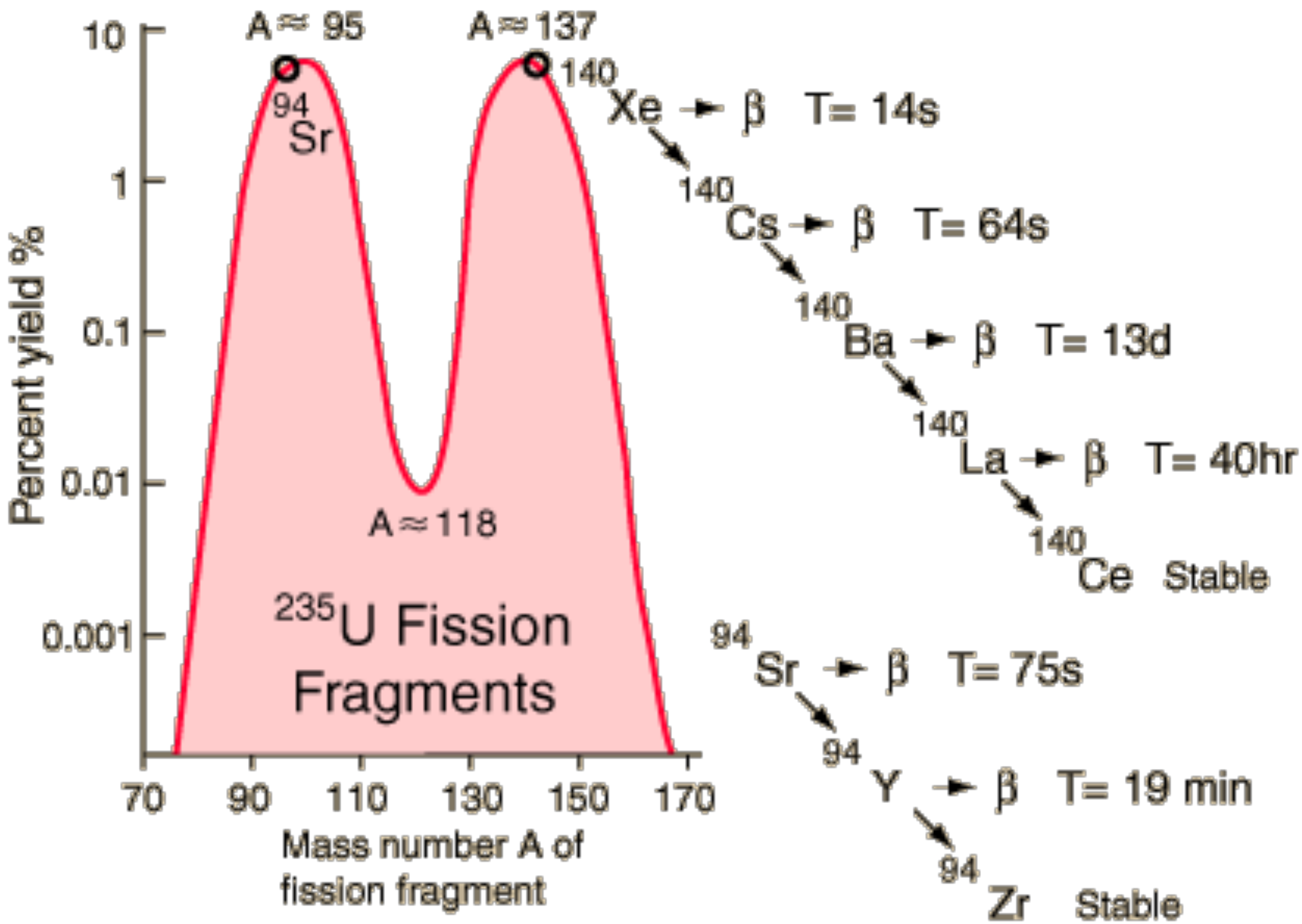
How is the energy released partitioned?

Energy from Fission of ^{235}U	MeV
Fission fragment kinetic energy	166
Neutrons (~2.5 total)	5
Prompt gamma rays	7
Fission product gamma rays	7
Beta particles	5
Neutrinos (not useful energy)	10
TOTAL	**200**

Look closely – where will the fission fragments land?



Statistically, fission is asymmetric
What happens to the fragments after



What are the two isotopes from which one can most readily make either a nuclear reactor or a weapon?

- **^{235}U**
  - Minority component of natural U (0.7%)
  - Four separation methods: electromagnetic, gaseous diffusion, centrifuge, laser isotope
- **^{239}Pu**
  - Produced as a by-product in ^{235}U reactors
  - Then can be easily chemically separated
  - $^{238}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \longrightarrow ^{239}_{92}\mathrm{U} \xrightarrow[23.5\ \mathrm{min}]{\beta^-} ^{239}_{93}\mathrm{Np} \xrightarrow[2.3565\ \mathrm{d}]{\beta^-} ^{239}_{94}\mathrm{Pu}$

Both fission upon capture of *slow* neutrons (thermal)

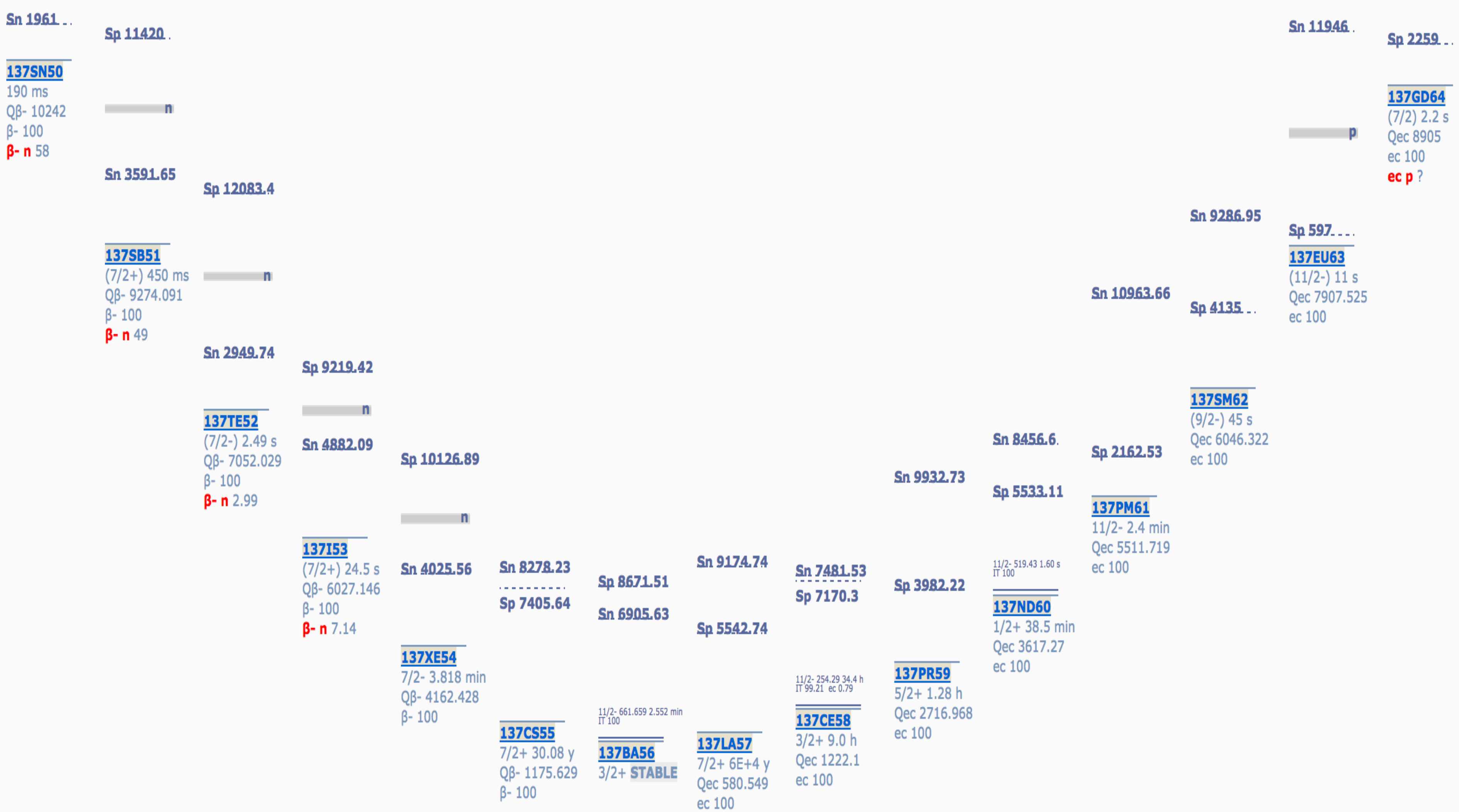
Fission products

- Fission produces a vast number of different isotopes, of widely varying half-lives & activities
- It's not the very short lived, or the very long lived that are problematic, but the ones in between
  - Shows up as radiation and heat
- A few which are responsible for much of the radioactivity in spent fuel: ^{137}Cs (30.17 a, 1.176 MeV), ^{129}I , ^{90}Sr (28.79 a, 0.546 MeV) ...

A = 137 (IAEA database) & ^{137} Cs

IAEA – Nuclear Data Section

https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html



Fission on YouTube

- https://www.youtube.com/watch?v=RgZDXxux9s4#t=514.182951

- https://www.youtube.com/watch?v=mBdVK4cqiFs