Introduction
to Tohoku University and Nuclear Physics

Kouichi Hagino
Tohoku University, Sendai, Japan

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こんにちは！

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TOHOKU
UNIVERSITY

1. Introduction of myself
2. Introduction of this lecture series
3. Introduction of Tohoku University and Sendai
4. Brief introduction to nuclear physics

Introduction of myself

- Name: Kouichi Hagino　萩野浩一　はぎのこういち　ハギノコウイチ
- Date of Birth: February 24, 1971 (46 years old)
- Career:

Tohoku University (B.Sc.)	March, 1993
Tohoku University (M.Sc.)	March, 1995
Tohoku University (D.Sc.)	March, 1998
University of Washington (post-doc)	1998-2000
Kyoto University (Assistant Prof.)	2000-2004
Tohoku University (Associate Prof.)	2004-

- Research fields: nuclear theory
  - low-energy heavy-ion reactions
  - structure of exotic nuclei
  - structure of hypernuclei

Introduction of this lecture series

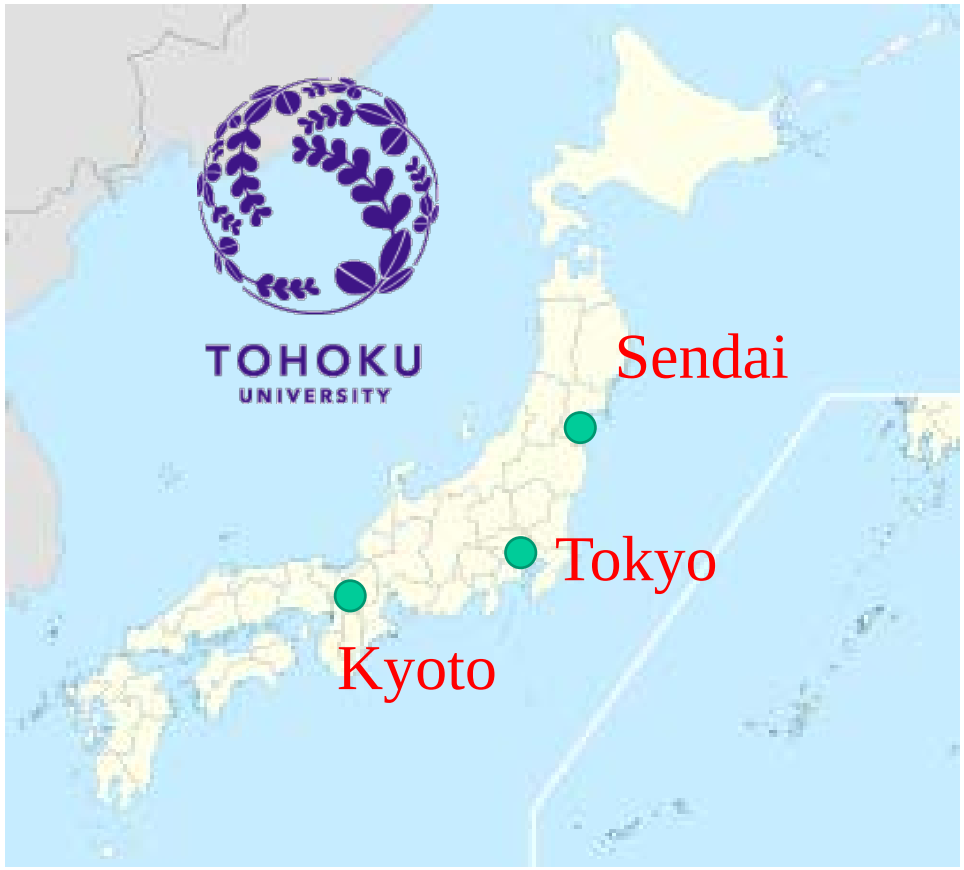
Dec. 6 (today): introductory talk (1 hour)
Dec. 7 (tomorrow):

9:30 am – 11:00 am	nuclear physics about elements and superheavy elements
13:00 pm – 14:30 pm	quantum mechanics about many-body systems and magic numbers

Dec. 9 (Saturday):

8:30 am – 10:00 am	lecture on heavy-ion fusion reactions (for graduate students)

Introduction of Tohoku University and Sendai



Sendai:

- ✓ the largest town in the Tohoku region
- ✓ population: about 1 million

city of trees

Introduction of Tohoku University and Sendai

Matsushima (one of the “3 most beautiful places” in Japan)

Sendai castle

nice sea-foods

Introduction of Tohoku University and Sendai

March 11, 2011 a huge earthquake

Sendai airport

after 1 month

after 1 month

Introduction of Tohoku University and Sendai

Tohoku University

TOHOKU
UNIVERSITY

- Established in 1907 (110 years ago)
- the third oldest university in Japan
- the first university in Japan which accepted female students (in 1913)

First Women Students in 1913 Tohoku University

Introduction of Tohoku University and Sendai

Nuclear theory group in Tohoku University

Associate professors

Shoichi Sasaki (hadron physics), Kouichi Hagino

Assistant professors

Masahiro Maruyama, Akira Ono, Yusuke Tanimura

Students

3 in Ph.D. course, 4 in master course

Introduction of Tohoku University and Sendai

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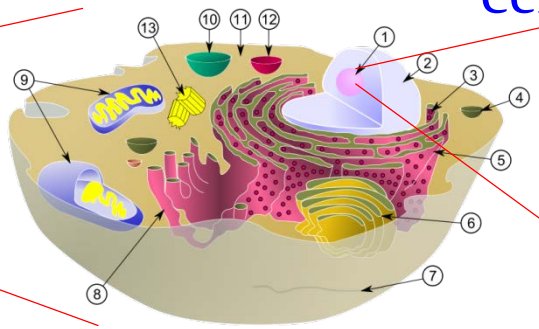
Dr. Nyein Wink Lwin
(2002-2007)

Dr. Myaing Thi Win
(2006-2011)

Introduction: atoms and atomic nuclei

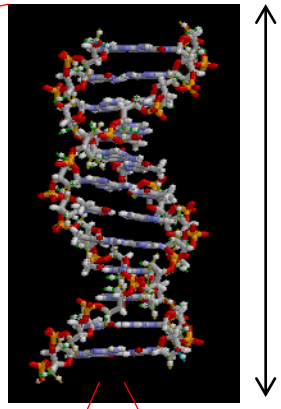
~ 50 cm

cells



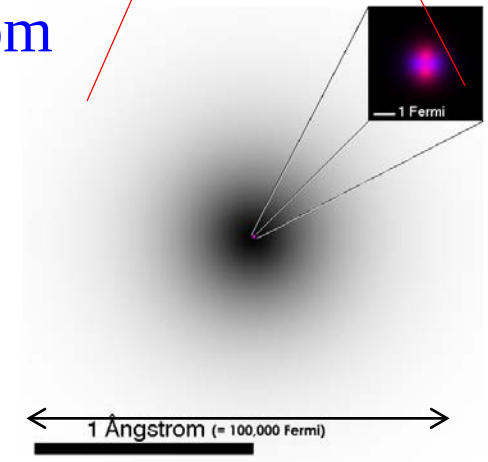
~ μm = 10^{-6} m

DNA



~ 10^{-8} m

atom



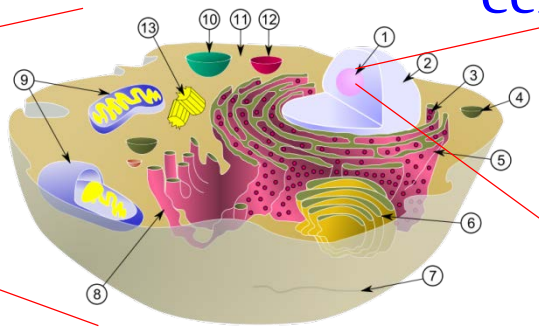
~ 10^{-10} m

Everything is made of atoms.

Introduction: atoms and atomic nuclei

~ 50 cm

cells



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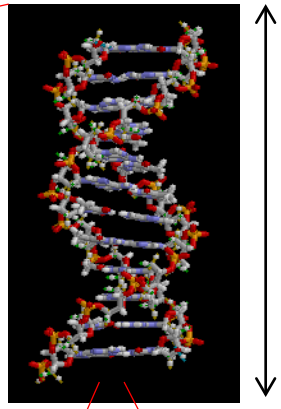
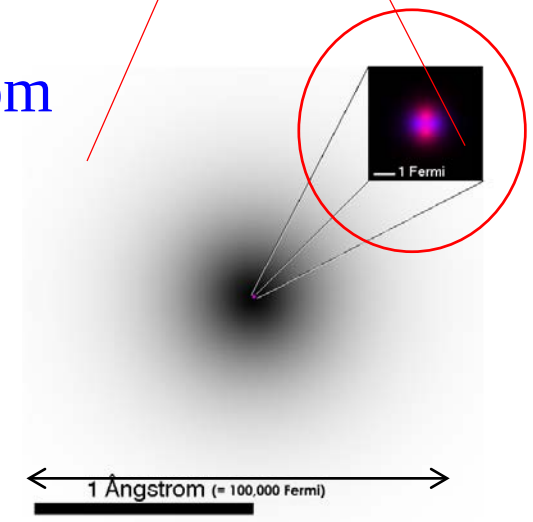


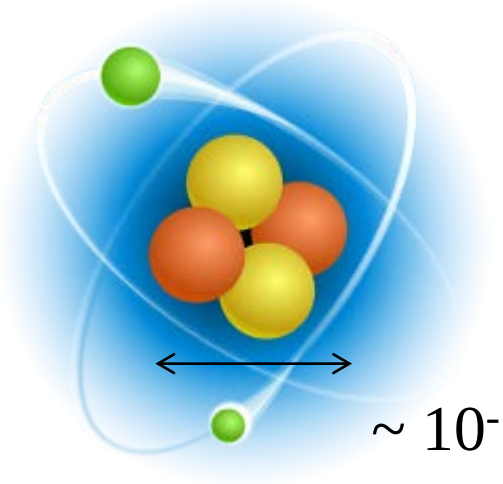
~ 10^{-8} m

atom

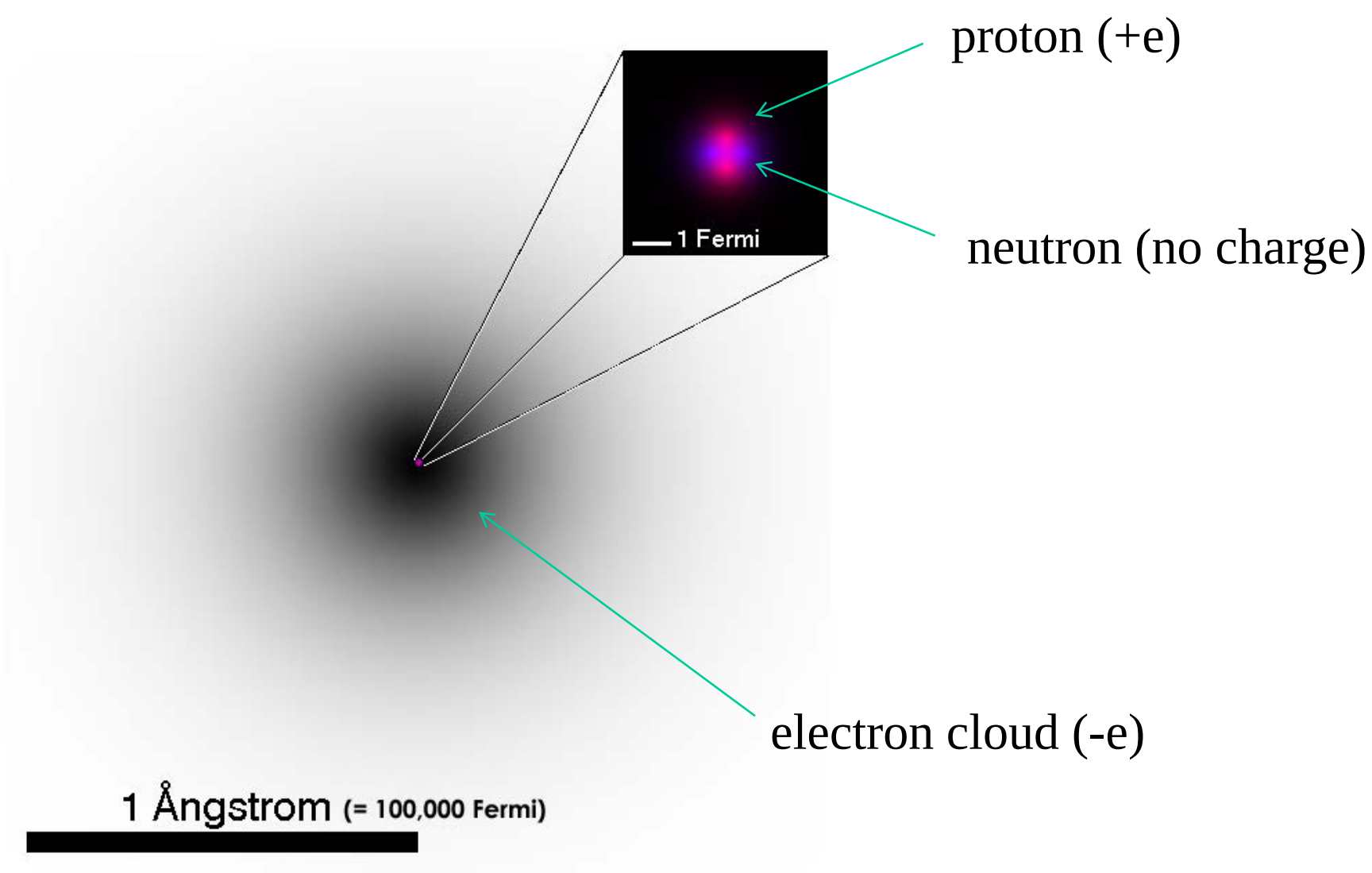


~ 10^{-10} m

atomic nucleus



~ 10^{-15} m

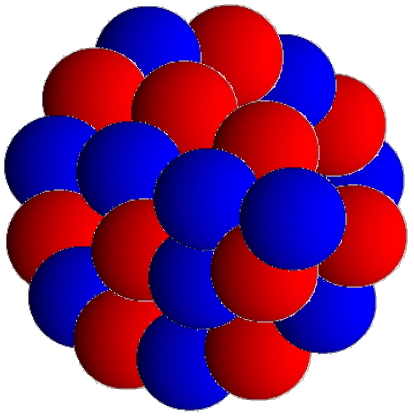


- Neutral atoms: # of protons = # of electrons
- Chemical properties of atoms ⟶ # of electrons
- $M_p \sim M_n \sim 2000\, M_e$ ⟶ the mass of atom ~ the mass of nucleus

(Low-energy) Nuclear Physics:

to understand rich nature of atomic nuclei starting from nucleon-nucleon interactions

- size, mass, density, shape
- excitations
- decays
- nuclear reactions



two kinds of particle: protons and neutrons

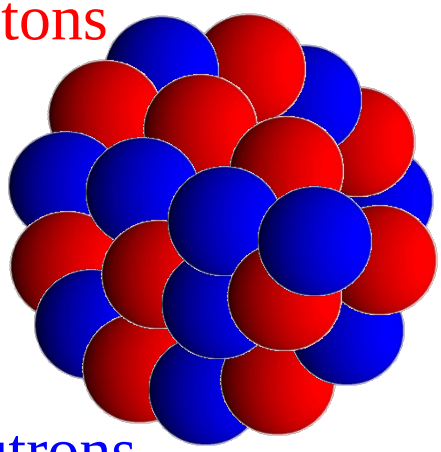
Basic ingredients:

	charge	mass (MeV)	spin,parity
Proton	+e	938.256	$\frac{1}{2}^+$
Neutron	0	939.550	$\frac{1}{2}^+$

(note) $n \rightarrow p + e^- + \bar{\nu}$ (10.4 min)

protons and neutrons: Fermions → Pauli principle

protons

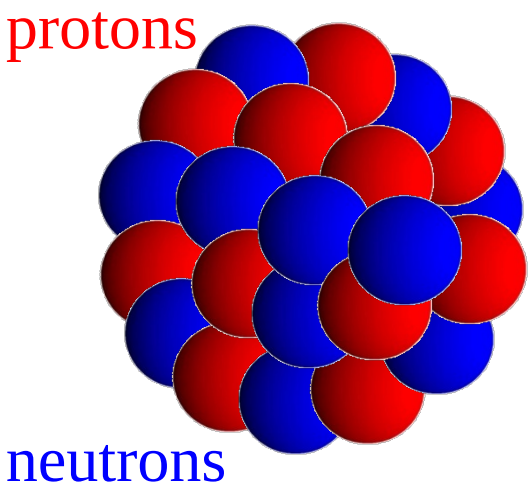


neutrons

- Nucleons are not stopping inside a nucleus.
  (they move relatively freely)

- Yet, they are not completely independent.
  a nucleus keeps its shape
  due to the interactions among nucleons

a self-bound system



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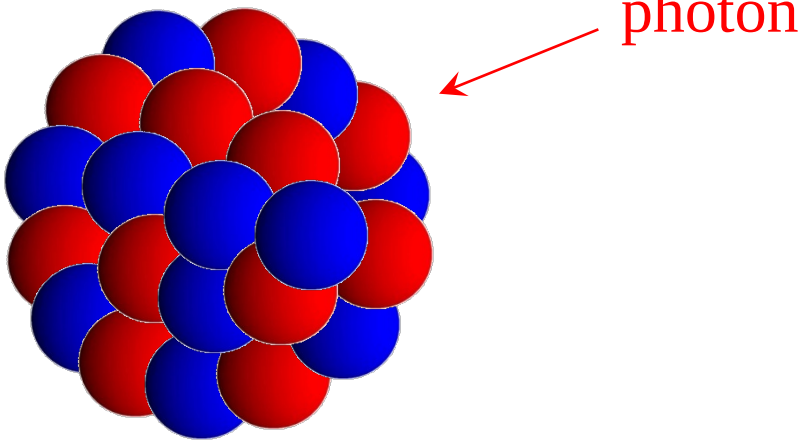
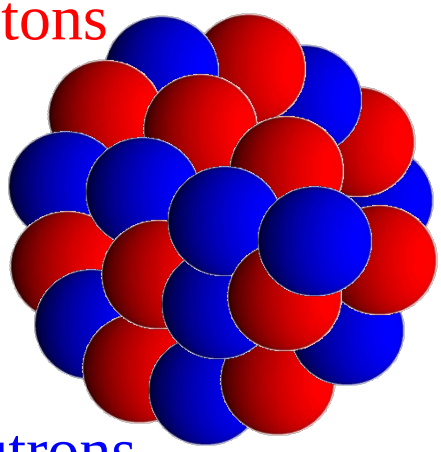
What happens if a photon is absorbed into a nucleus?
- one nucleon simply starts moving faster?





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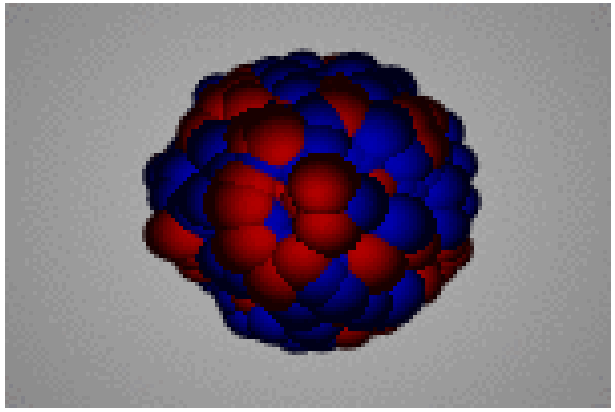
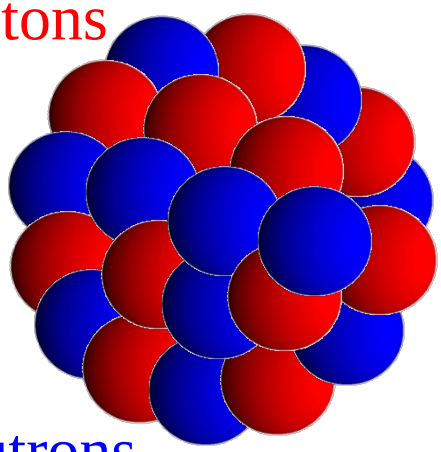


Very coherent
motion can happen
due to the correlation

Collective motions



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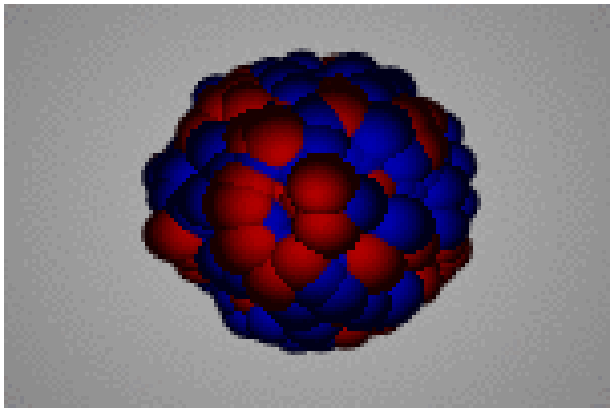

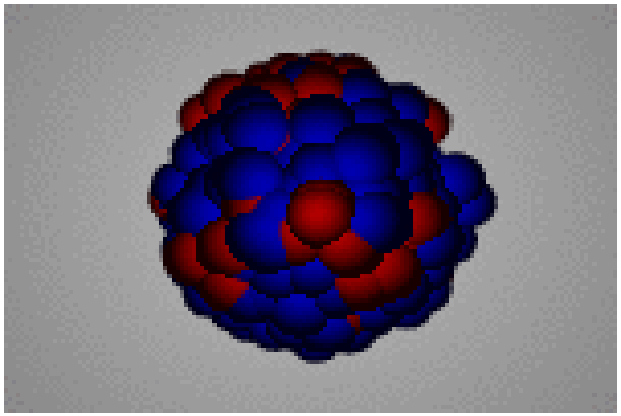

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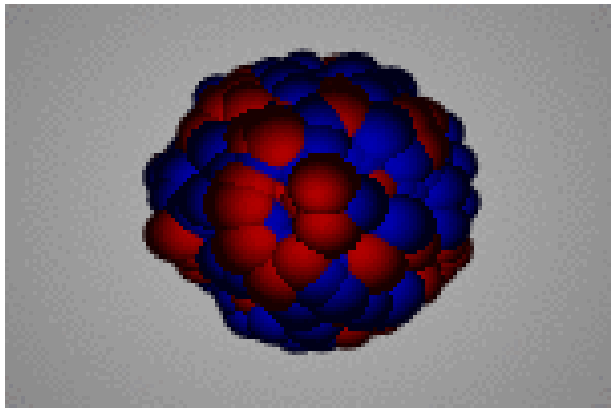
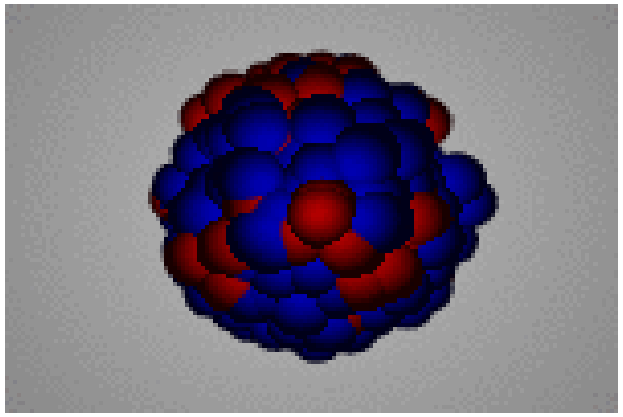

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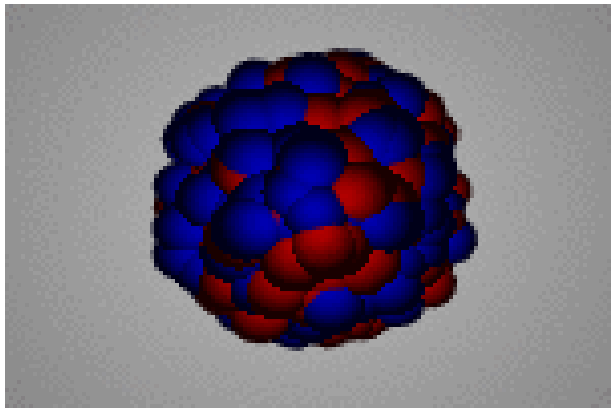
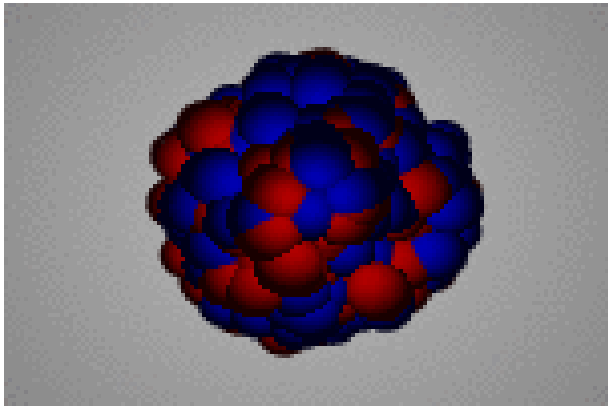
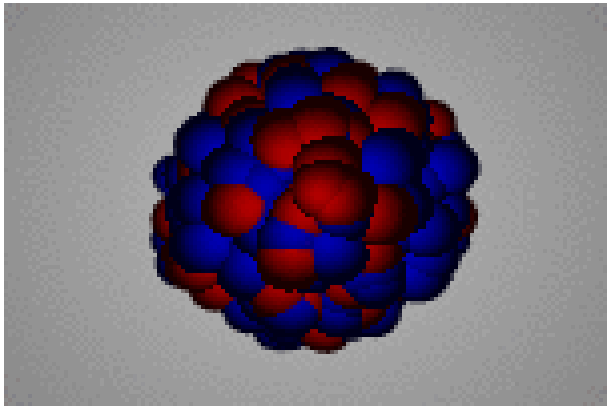
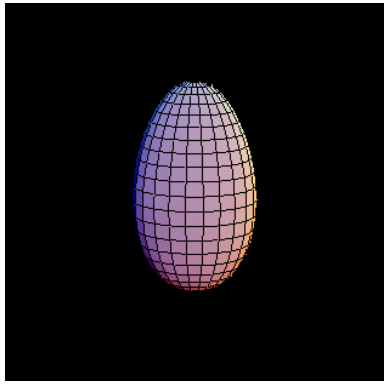
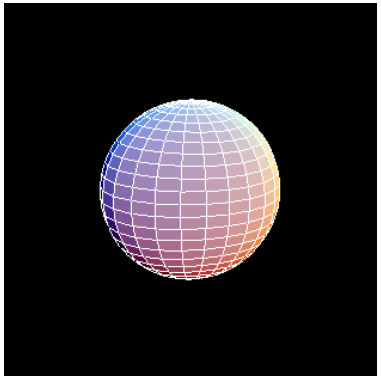
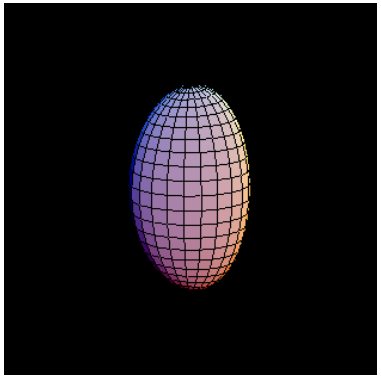
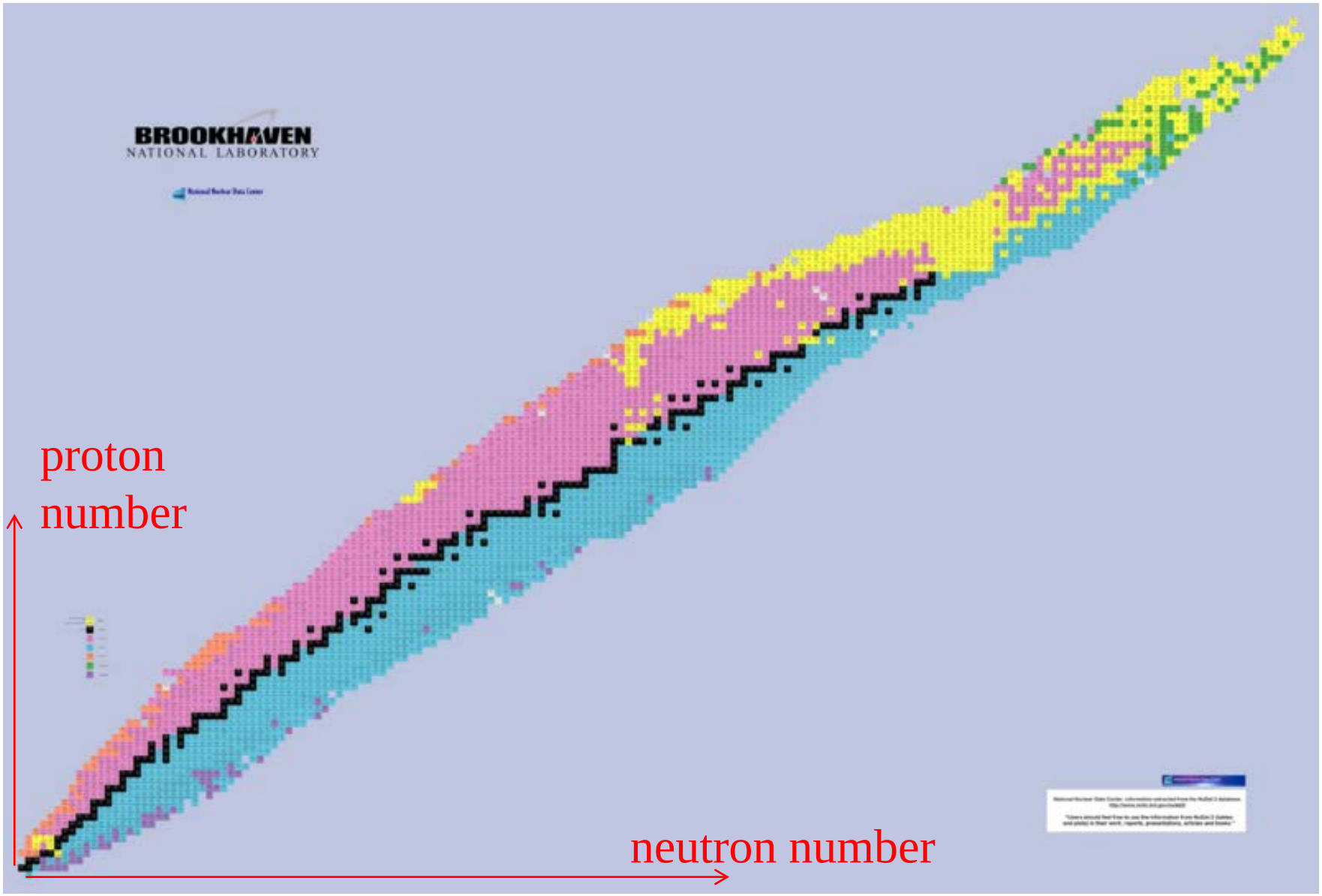



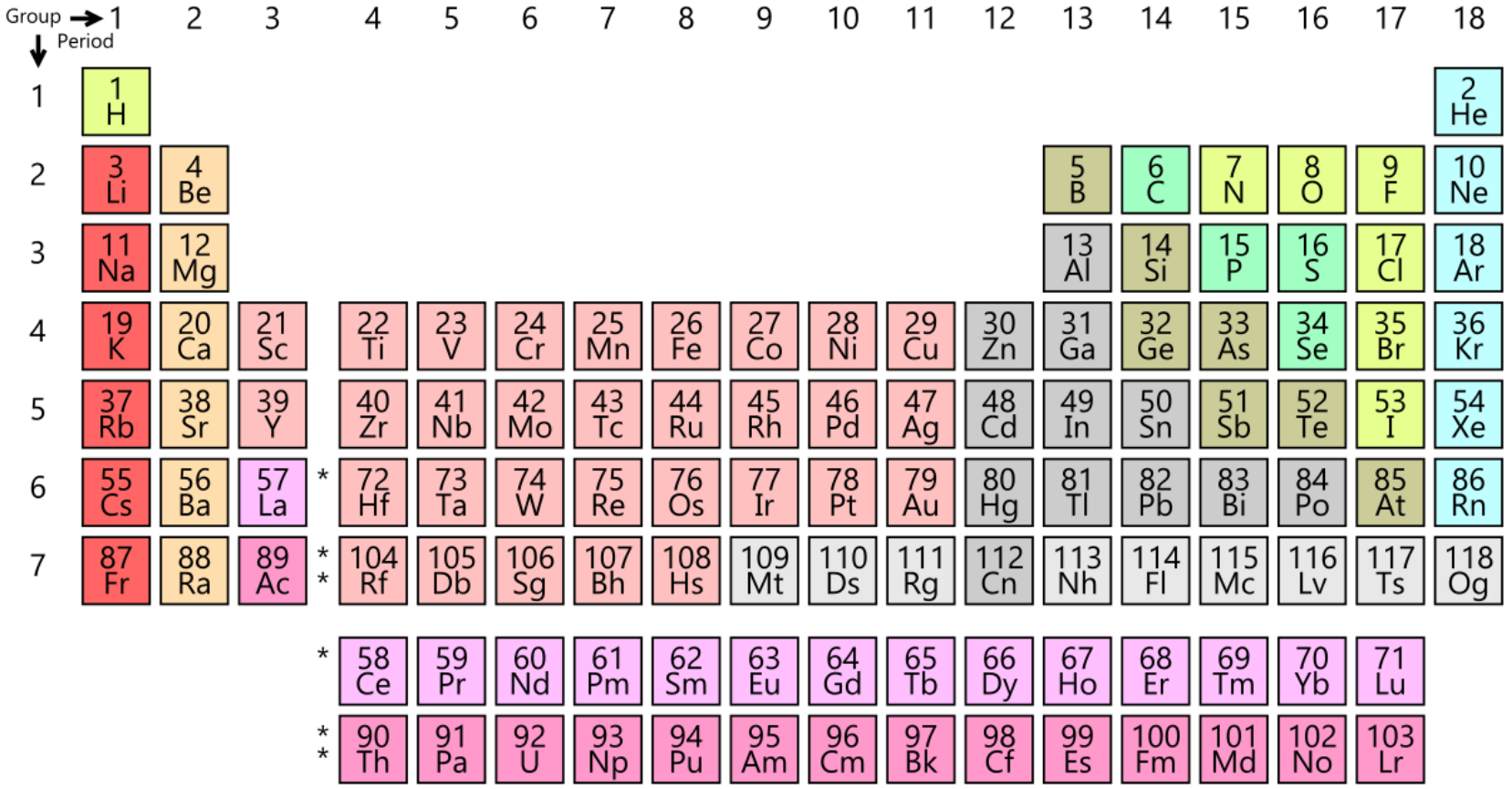
a variety of motions
→ very rich!

Nuclear Chart: 2D map of atomic nuclei

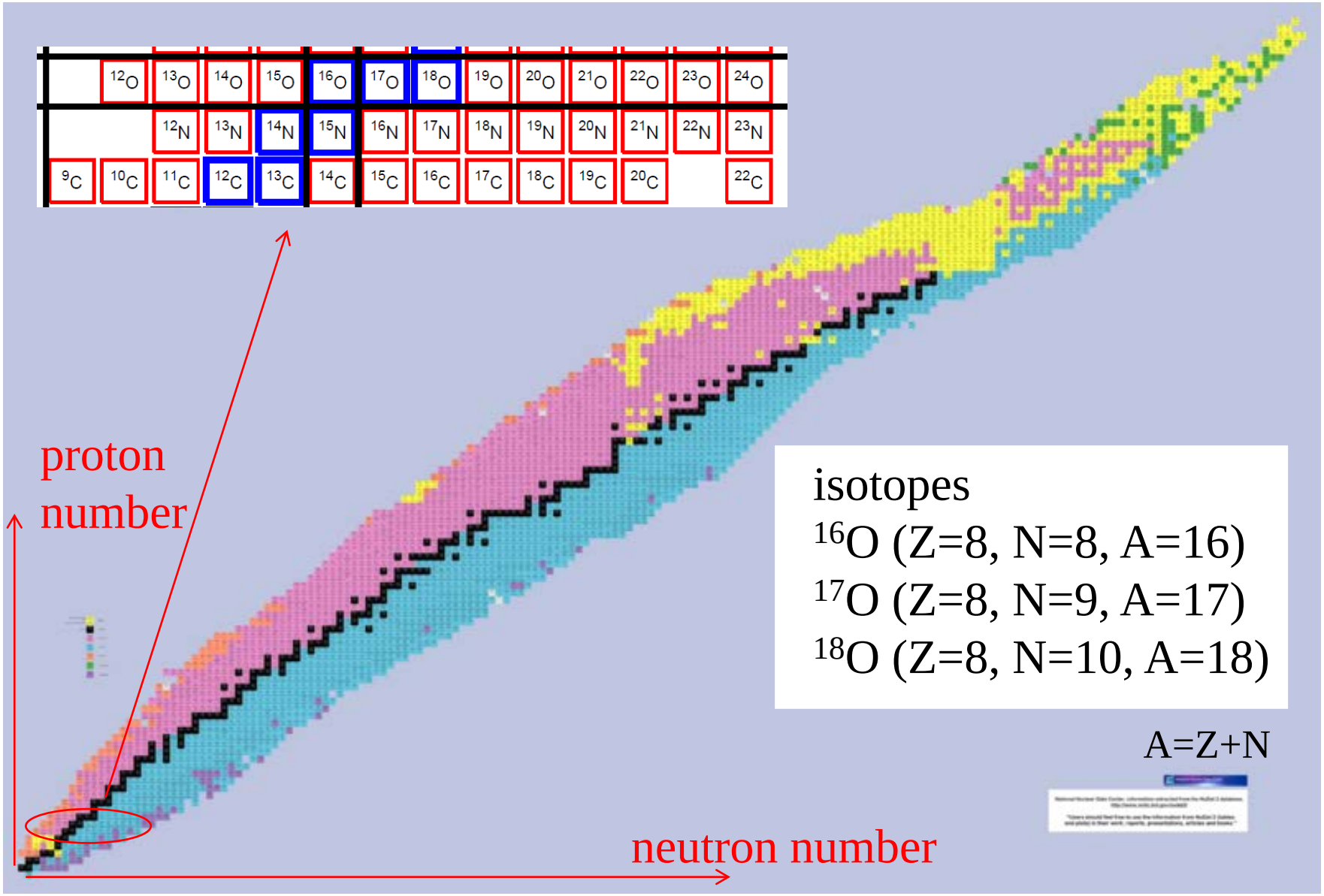


Periodic table of elements

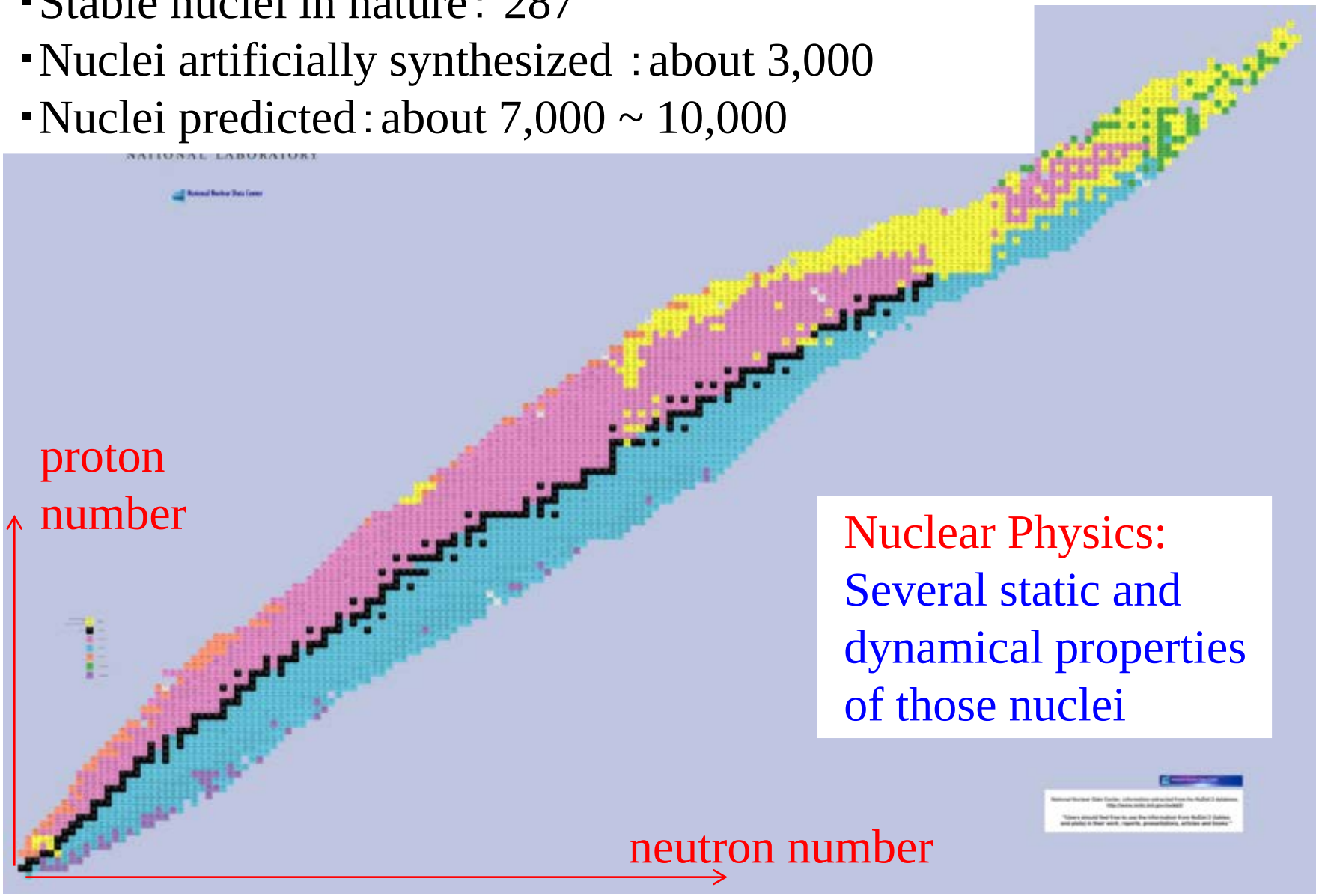


protons only; no information on neutrons!

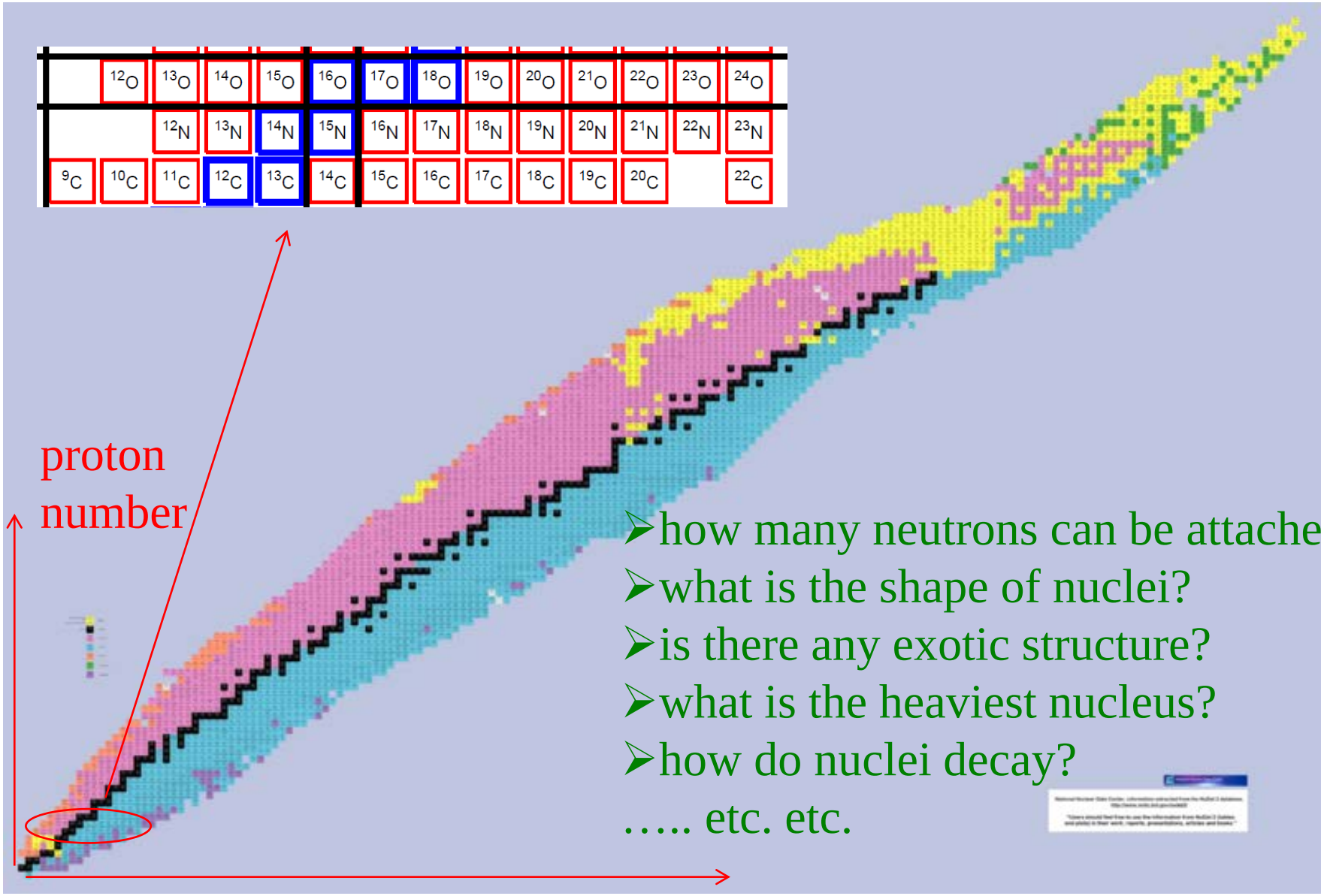
Nuclear Chart: 2D map of atomic nuclei



- Stable nuclei in nature : 287
- Nuclei artificially synthesized : about 3,000
- Nuclei predicted : about 7,000 ~ 10,000



Nuclear Chart: 2D map of atomic nuclei

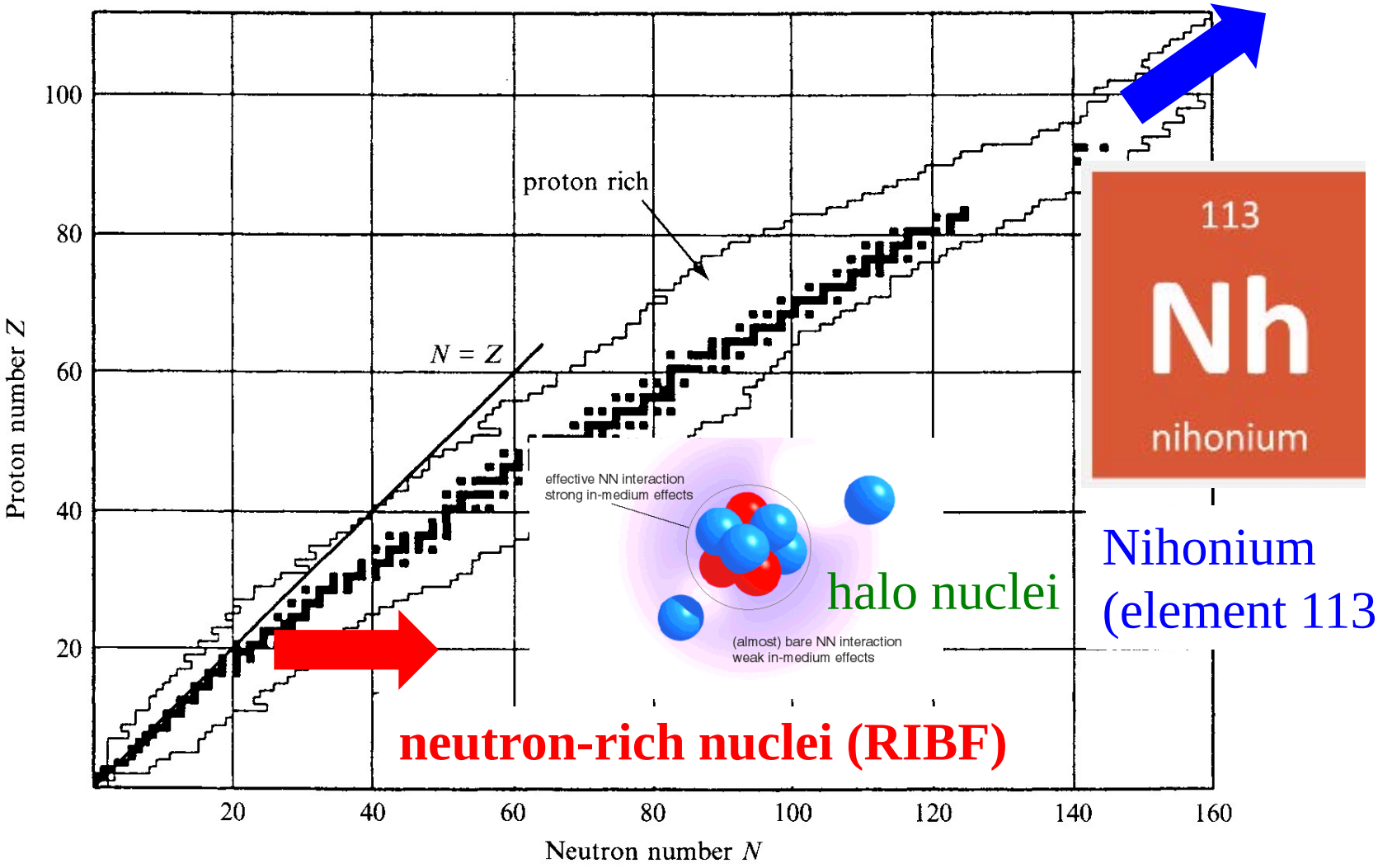


- how many neutrons can be attached?
- what is the shape of nuclei?
- is there any exotic structure?
- what is the heaviest nucleus?
- how do nuclei decay?

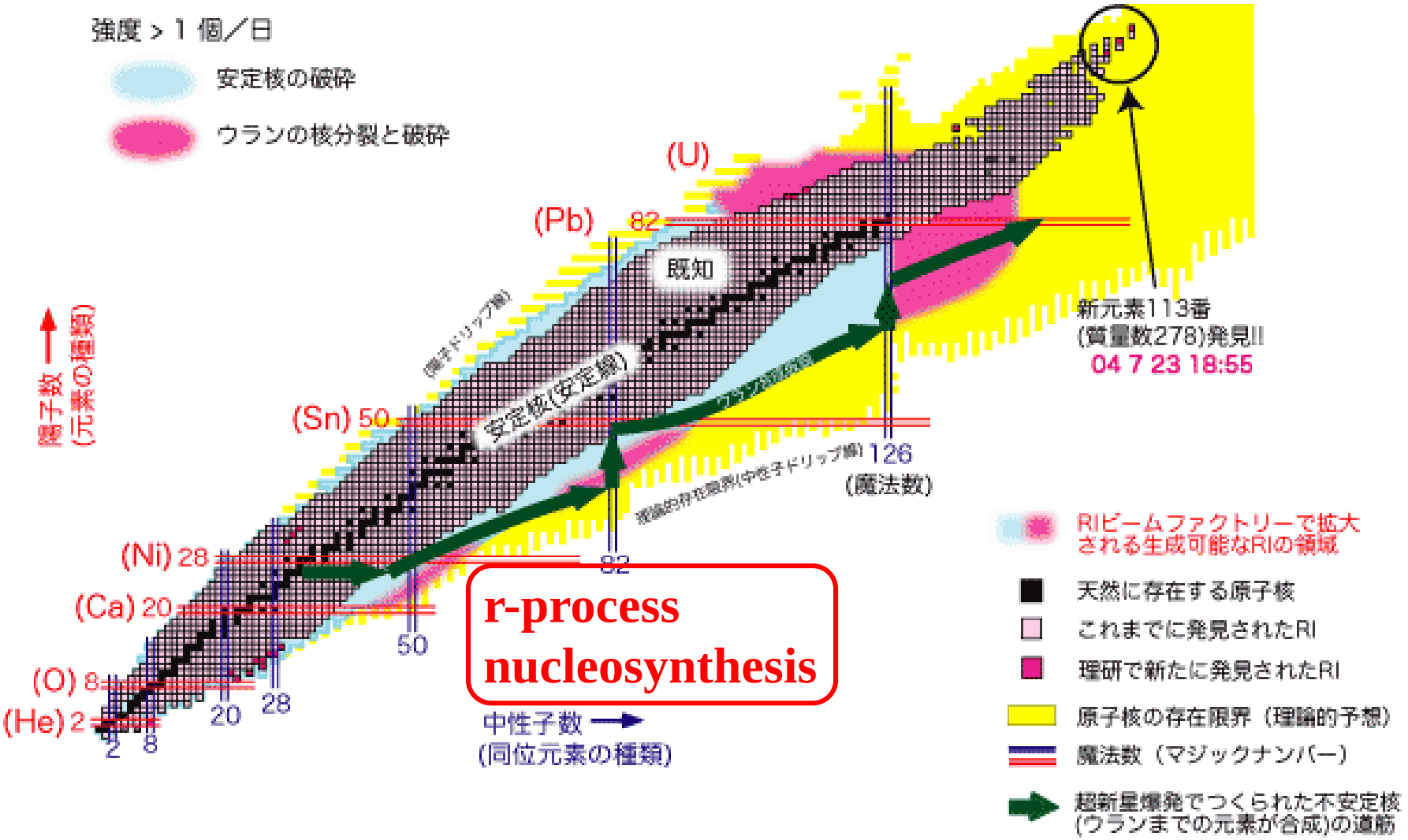
….. etc. etc.

Extension of nuclear chart: frontier of nuclear physics

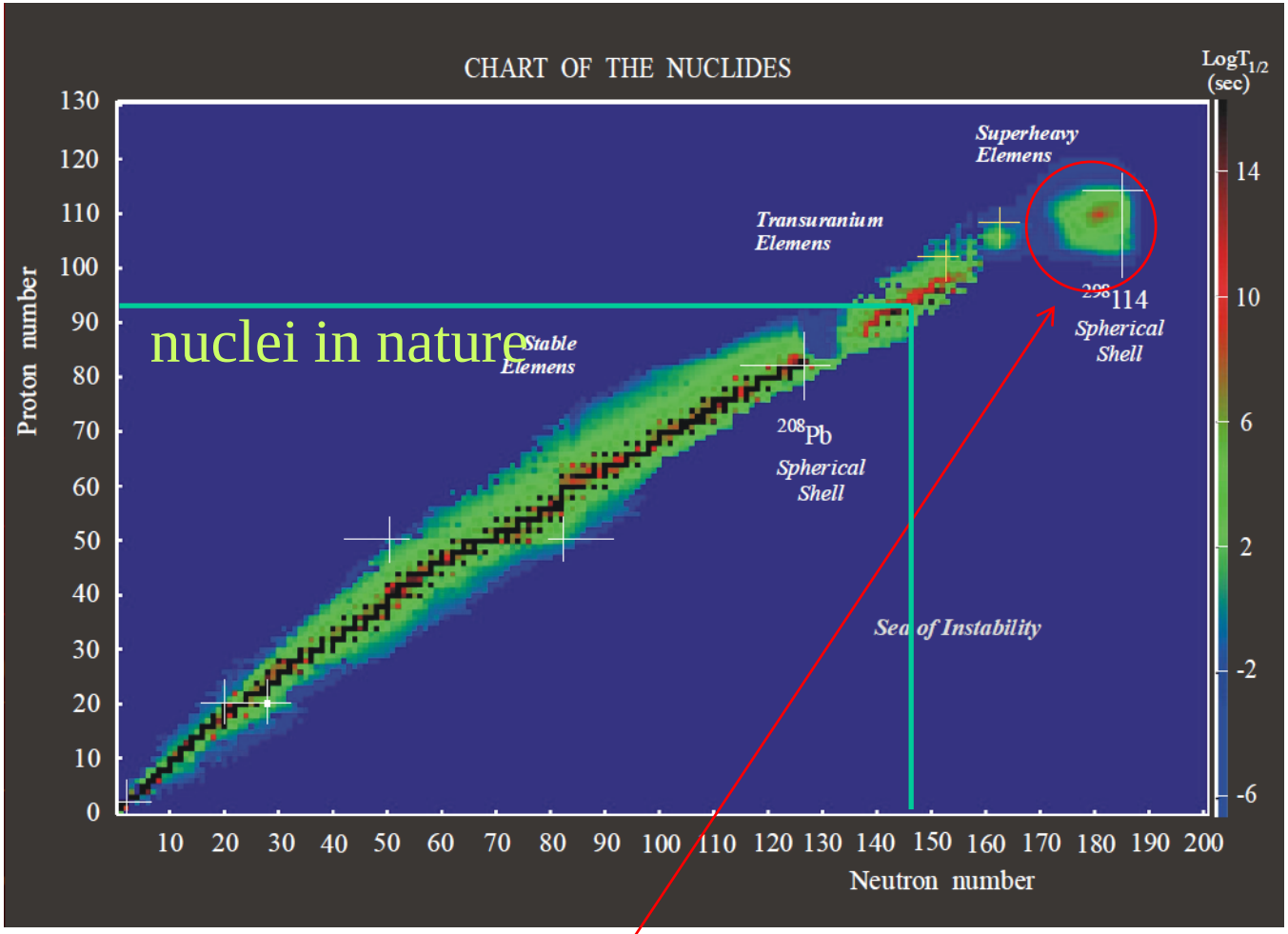
superheavy elements



Neutron-rich nuclei (RIBF at RIKEN)



Prediction of island of stability: an important motivation of SHE study



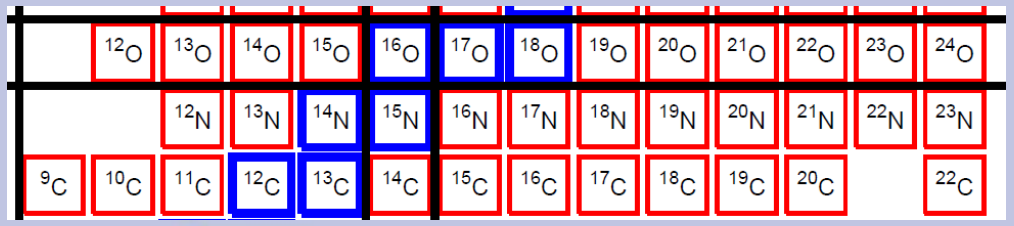
island of stability around Z=114, N=184

Yuri Oganessian

W.D. Myers and W.J. Swiatecki (1966), A. Sobiczewski et al. (1966)

… more tomorrow

Nuclear Chart: 2D map of atomic nuclei



proton number

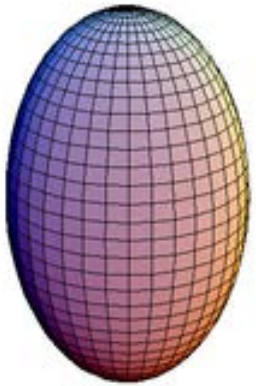
neutron number

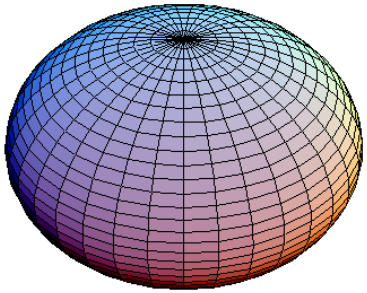
- how many neutrons can be attached?
- what is the shape of nuclei?
- is there any exotic structure?
- what is the heaviest nucleus?
- how do nuclei decay?

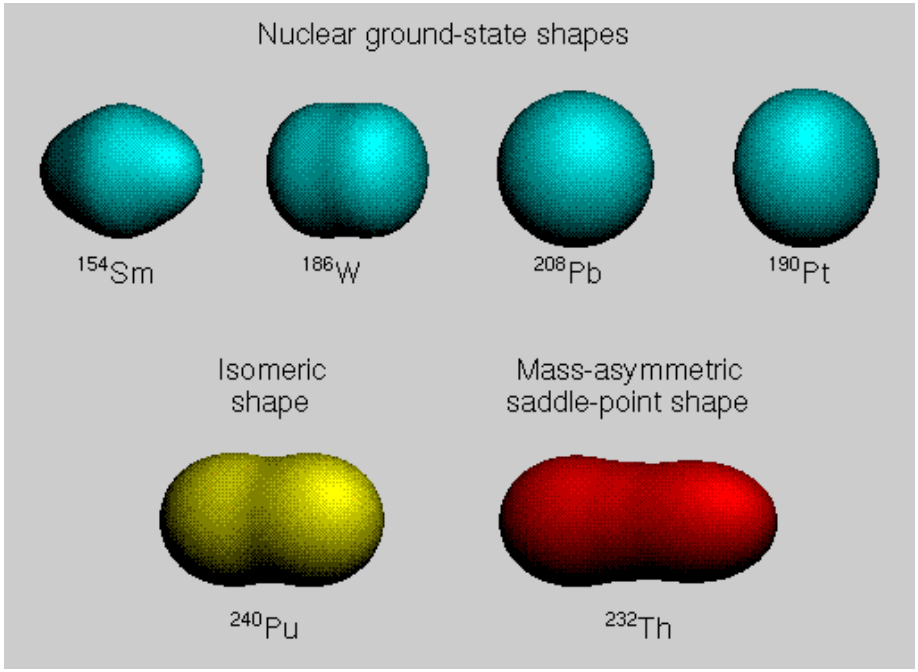
….. etc. etc.

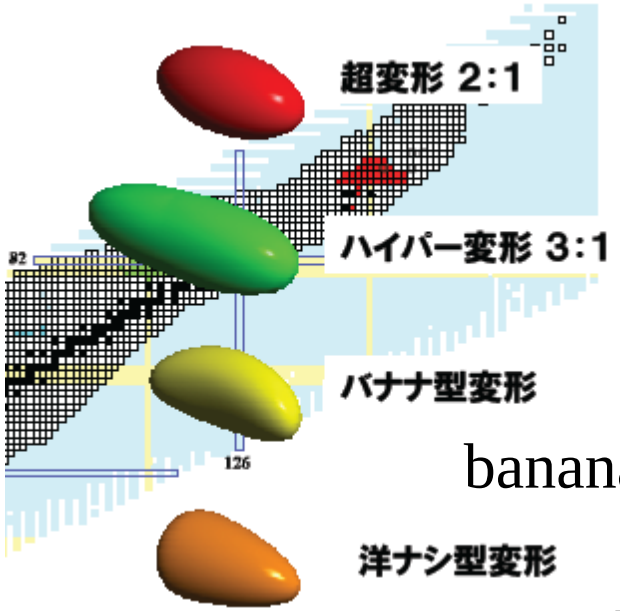
a nucleus is not always spherical

Quantum shape dynamics









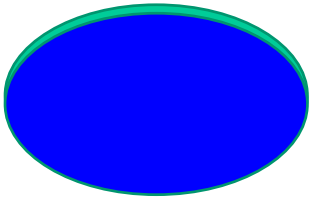
banana shape

pear shape

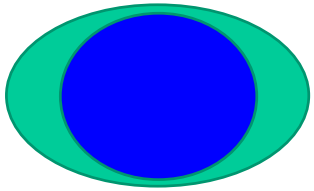
Some nuclei are deformed in the ground state!

what are combinations of (Z,N) which yield a deformation?

Different deformation between protons and neutrons

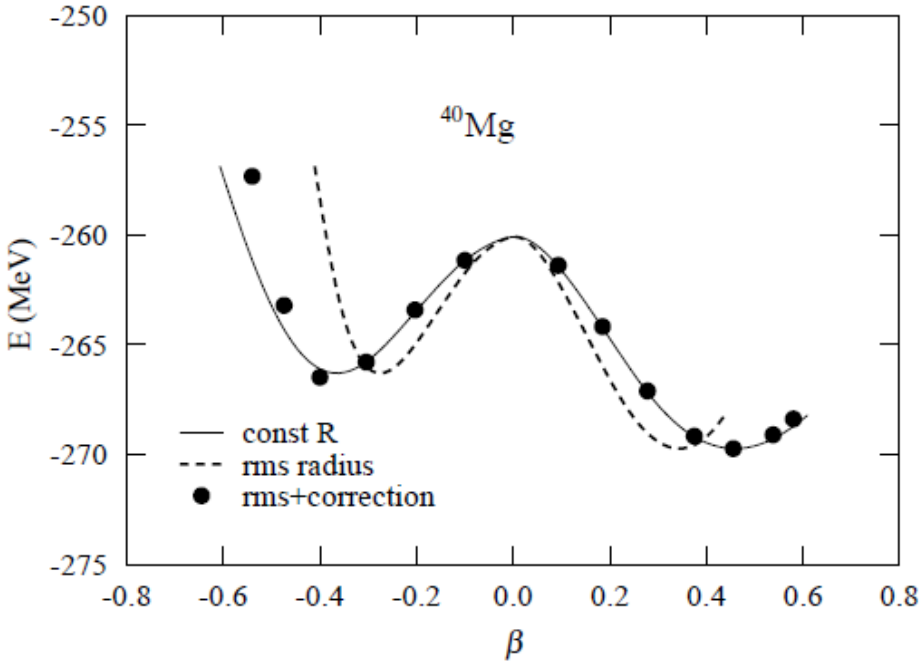


stable nuclei: $\beta_n \sim \beta_p$

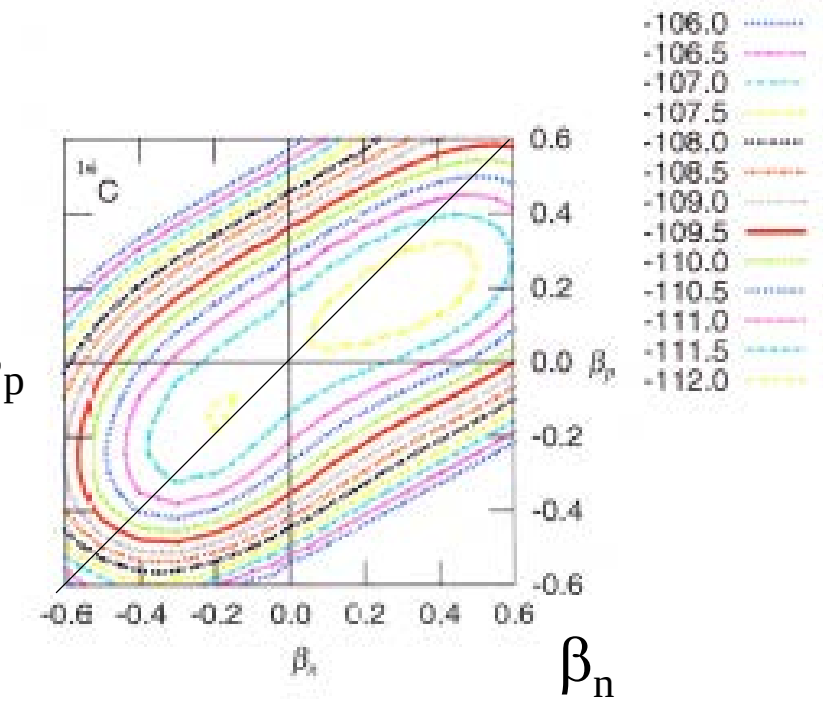


exotic nuclei: $\beta_n > \beta_p$

Dr. Nyein Wink Lwin



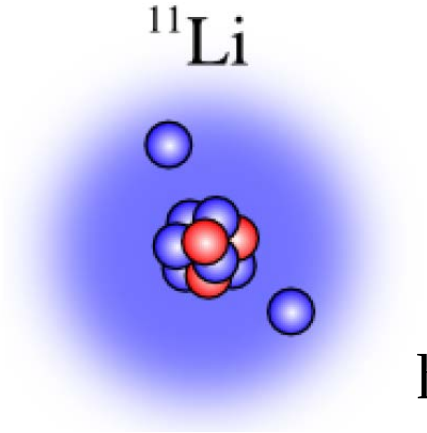
β_p



β_n

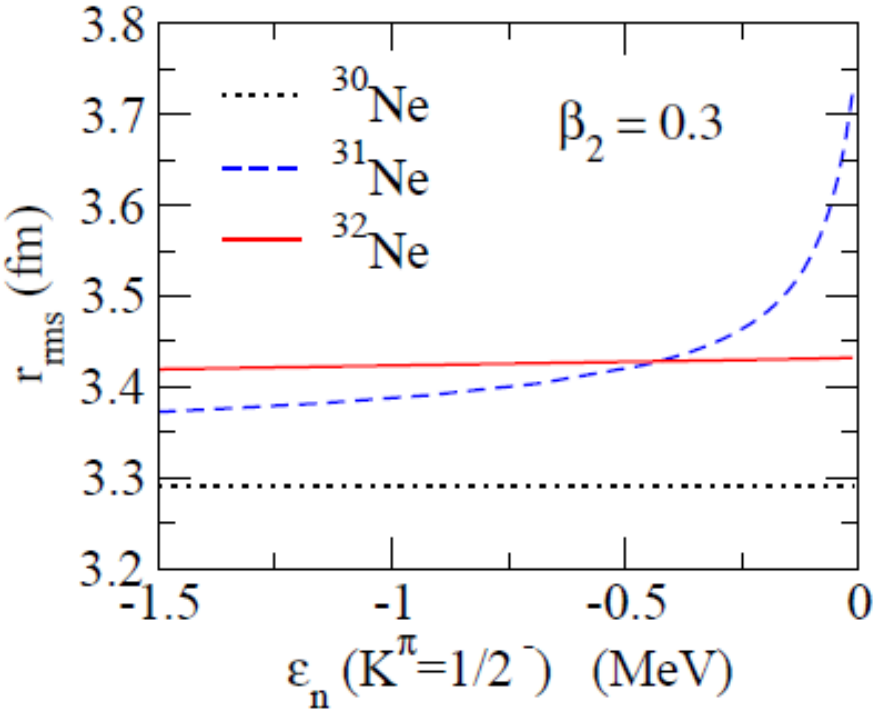
K.Hagino, N.W. Lwin, and M. Yamagami, PRC74 (‘06) 017310

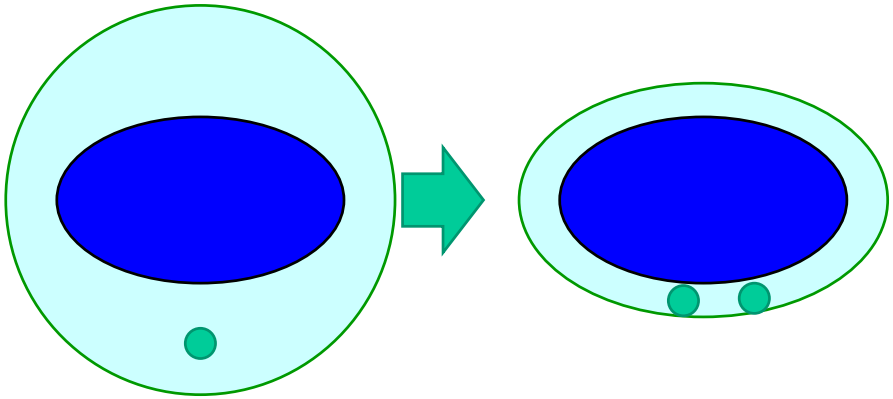
Deformed halo nucleus



halo structure

Dr. Yasuko Urata
(2008-2017)



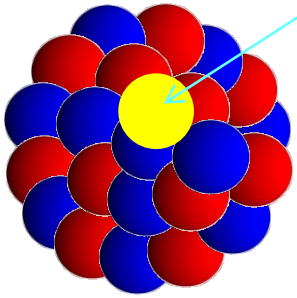


deformed core
+ n

deformed core
+ n+n

Y. Urata, K. Hagino, and H. Sagawa, arXiv:1710.07884

Λ hypernuclei



Λparticle: the lightest hyperon with strangeness (no charge, no isospin)

proton

neutron

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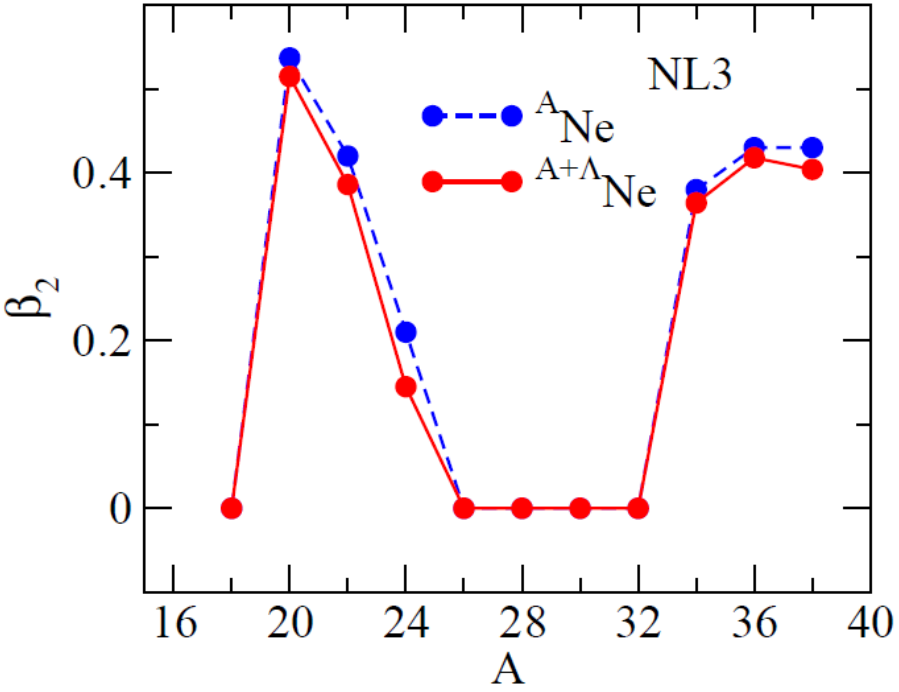
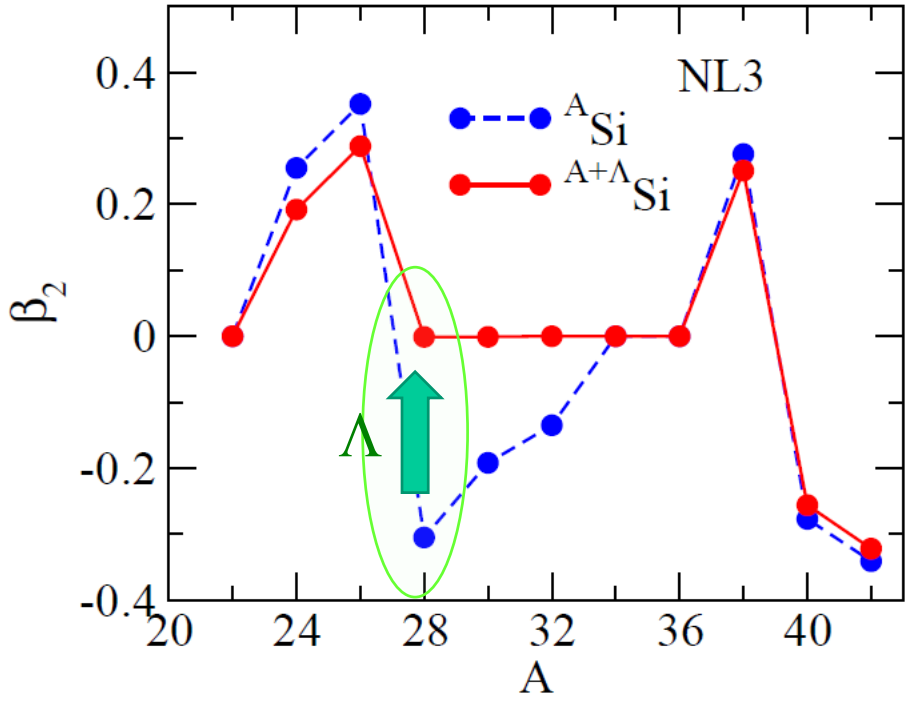
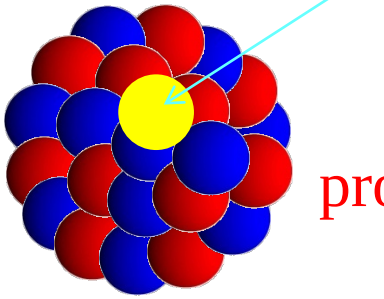
Ne isotopes



Si isotopes



Λ hypernuclei



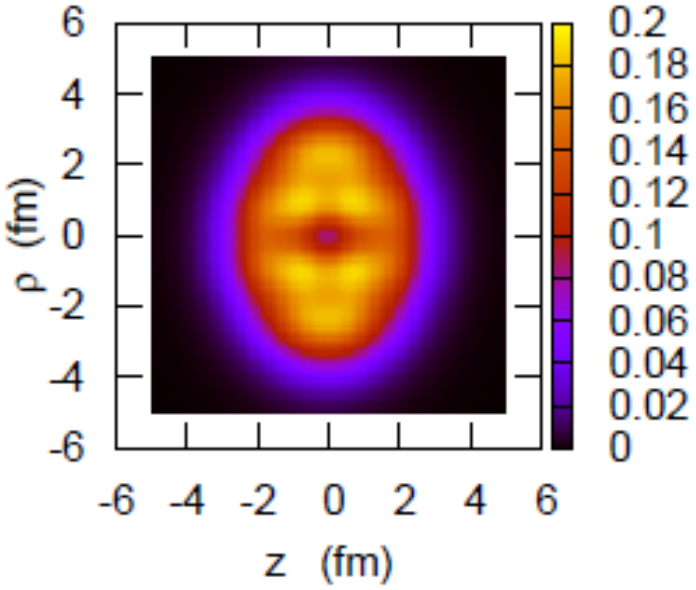
Λparticle: the lightest hyperon
with strangeness
(no charge, no isospin)

proton

neutron

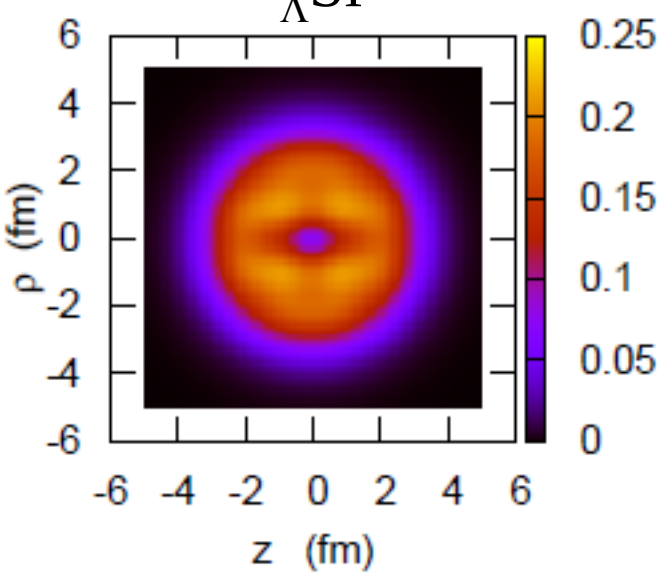
Dr. Myaing Thi Win

^{28}Si



Λ

$^{29}_{\Lambda}$Si



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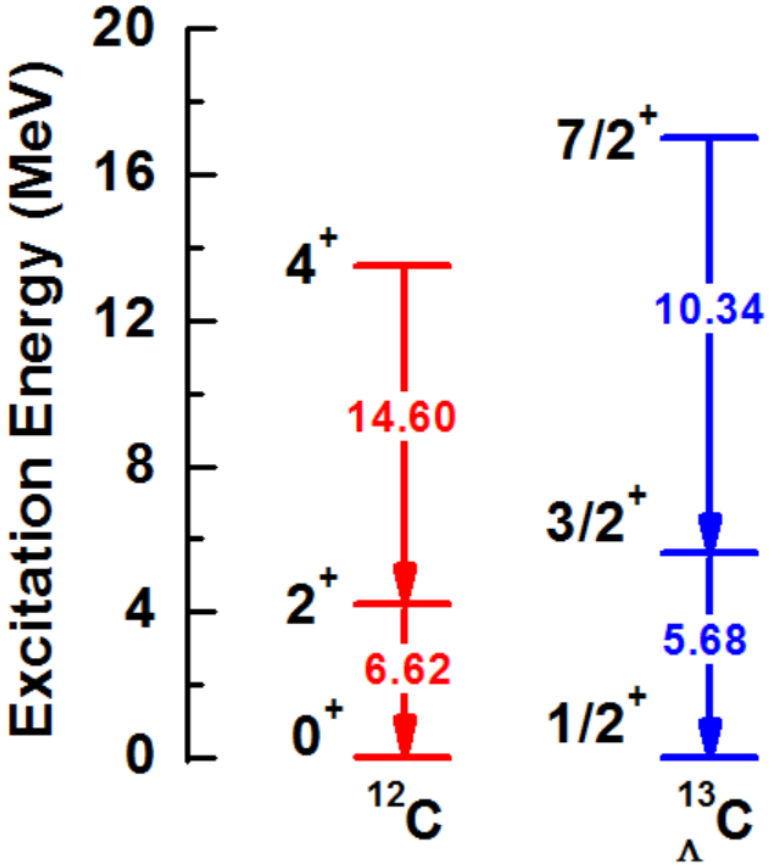
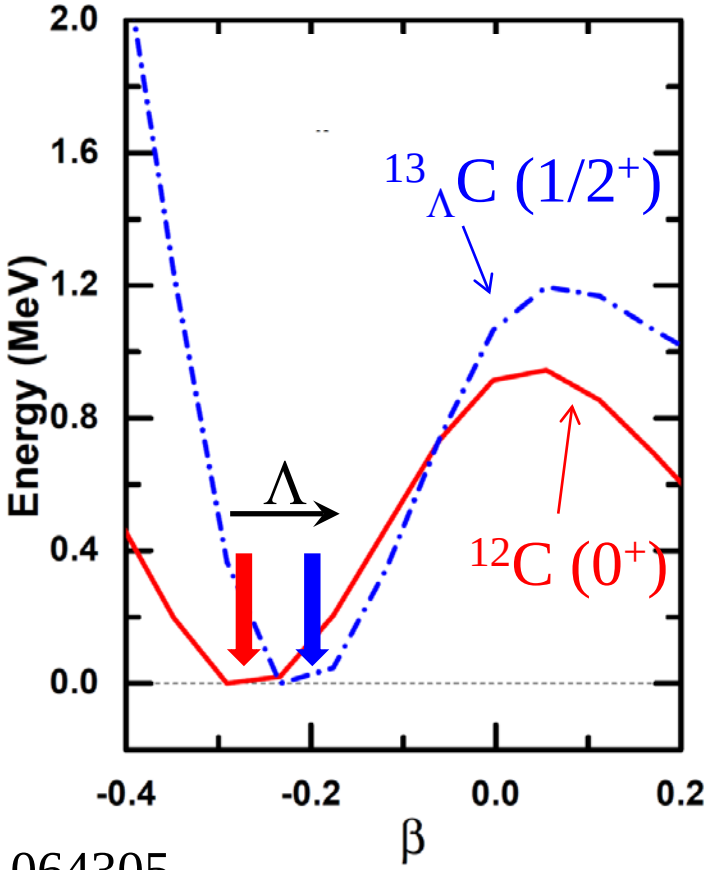
"beyond the mean-field approximation"

Dr. Mei Hua
(2013-2016)





H. Mei, K.Hagino, J.M. Yao, T. Motoba, PRC91('15) 064305