laboratoire commun CEA/DRF CNRS/IN2P3

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

Collinear laser spectroscopy of Pd isotopes at Jyväskylä

Alejandro Ortiz Cortés

Supervisors: Lucia Caceres

Iain Moore

Outline

1. Motivation
   - Neutron rich (first experiment)
   - Neutron deficient (second experiment)

2. Experimental setup

3. Results
   - Mean square charge radiii
   - Dipole magnetic moments
   - Quadrupole electric moments
   - Theoretical calculations

Outline

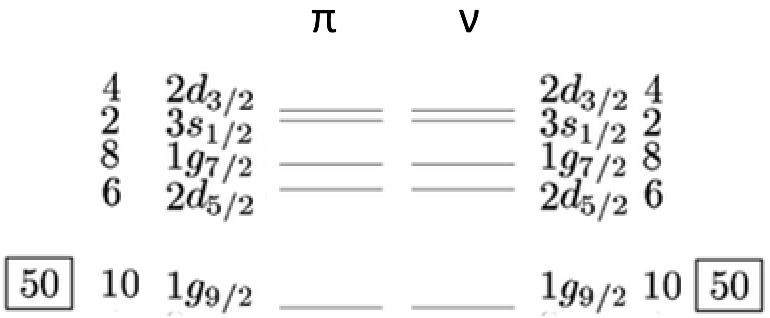
1. ***<u>Motivation</u>***
   - ***Neutron rich (first experiment)***
   - ***Neutron deficient (second experiment)***

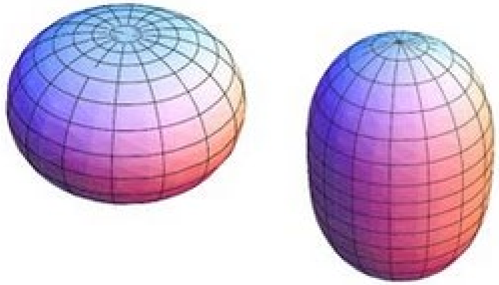
2. Experimental setup

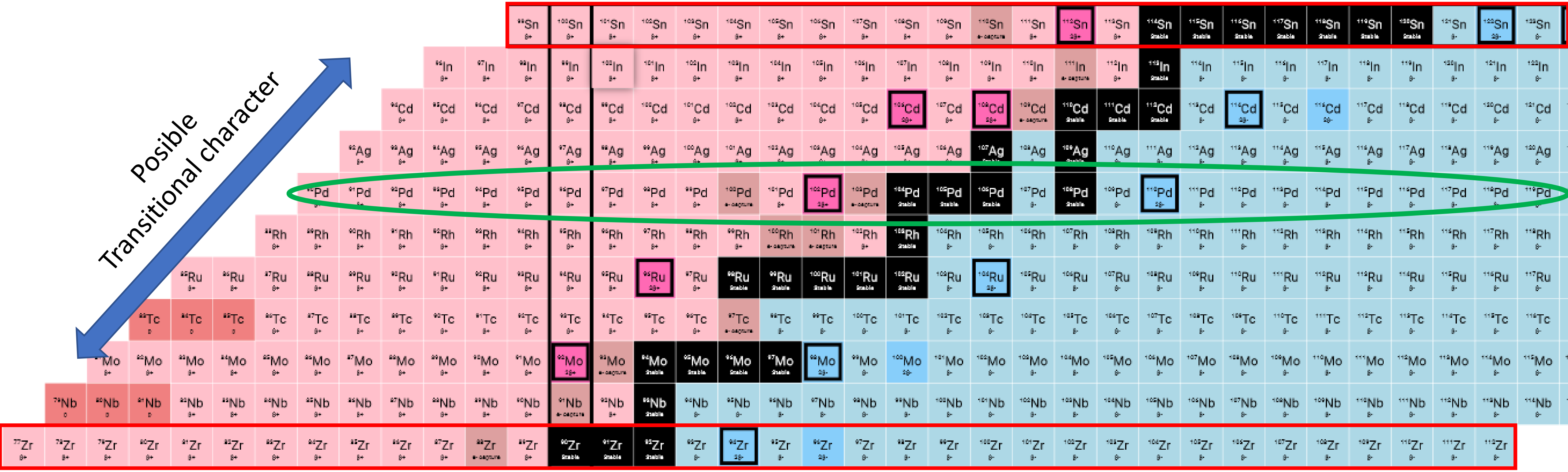
3. Results
   - Mean square charge radiii
   - Dipole magnetic moments
   - Quadrupole electric moments
   - Theoretical calculations

1. Motivation

Single particle VS Collectivity

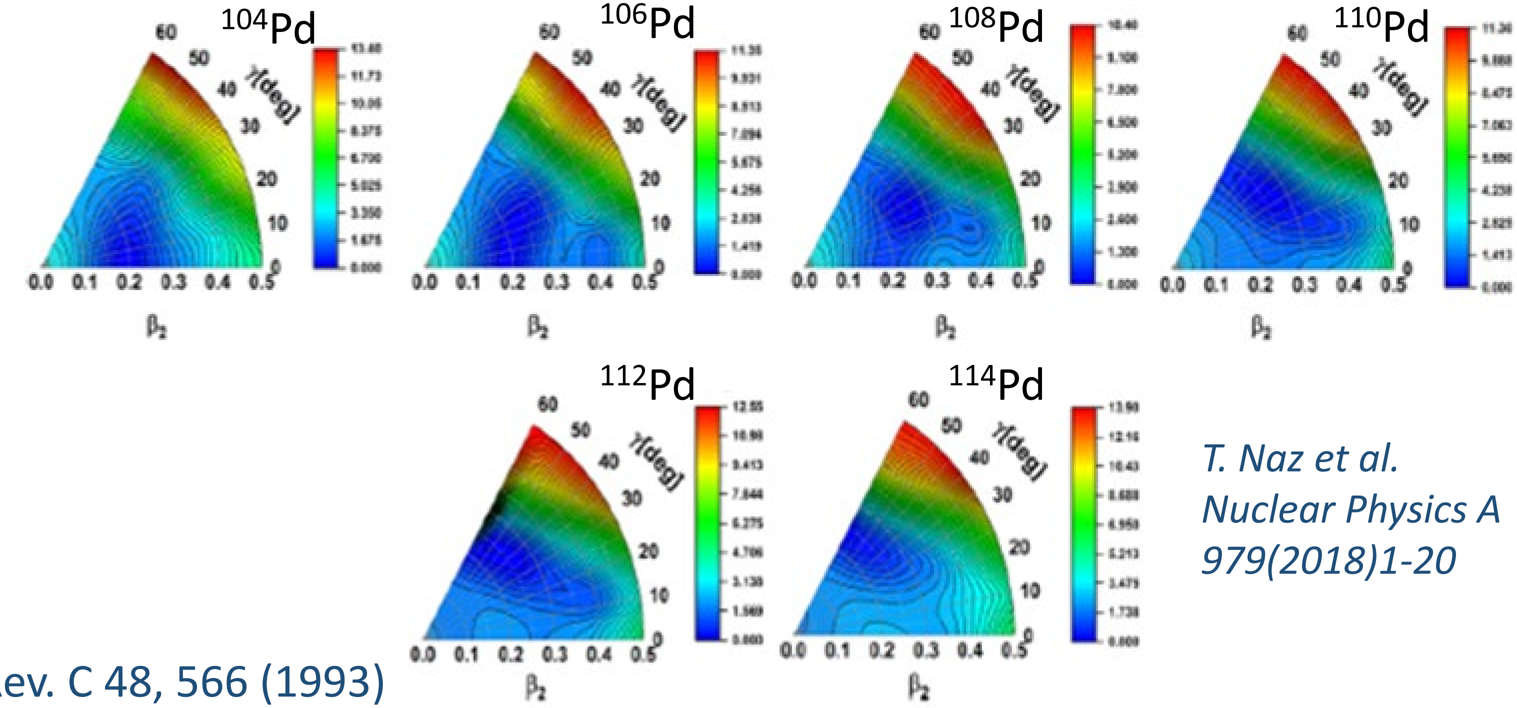




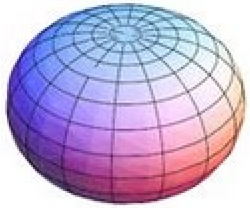


1. *Motivation*

Neutron rich



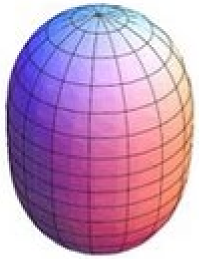
T. Naz et al.
Nuclear Physics A
979(2018)1-20



oblate

^{112,114,116}Pd

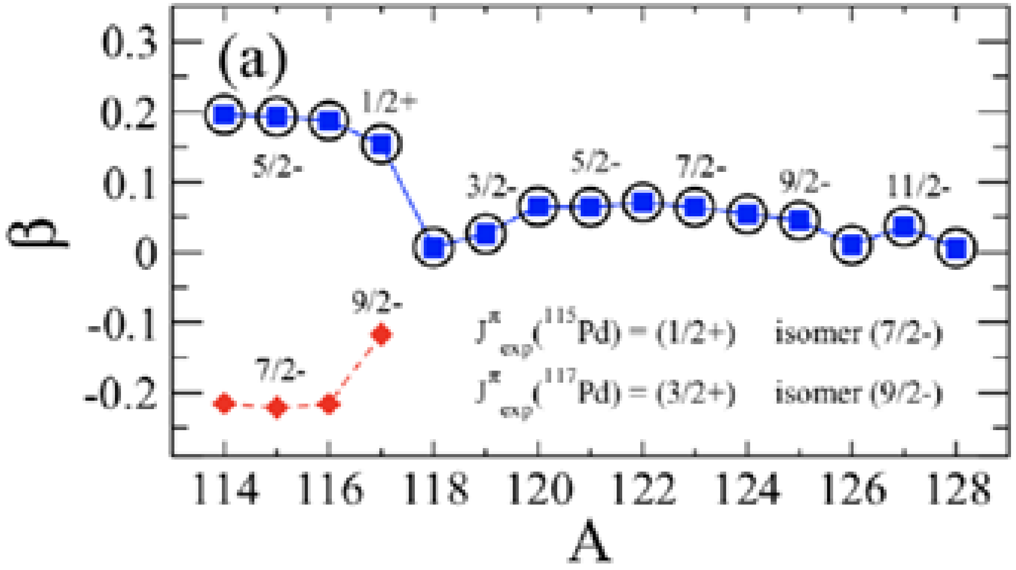
R. Aryaienejad et al., Phys. Rev. C 48, 566 (1993)



prolate

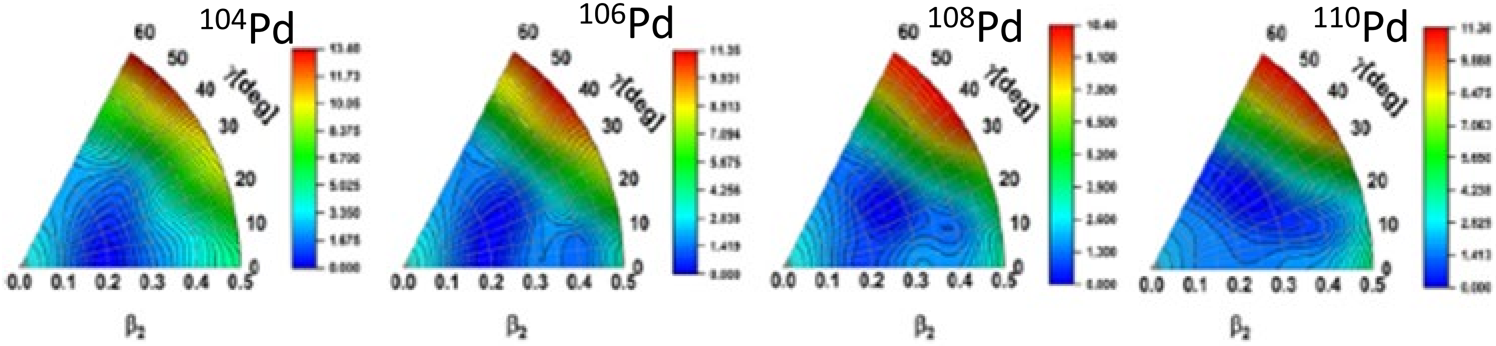
$^{109-123}$Pd

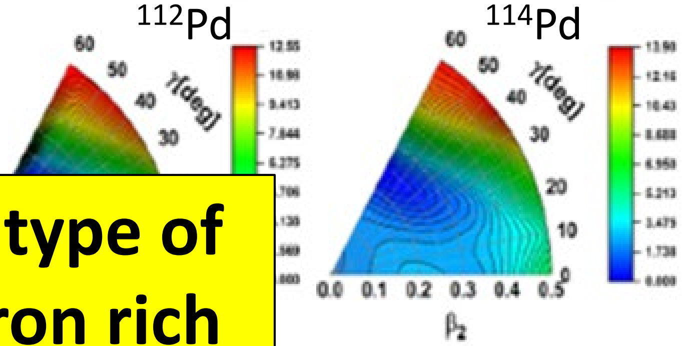
M. Houry et al., Eur. Phys. J. A 6, 43 (1999).



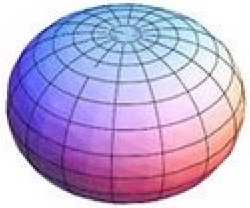
P. Sarriguren. Phys. Rev. C 91, 044304 (2015)

1. Motivation
Neutron rich





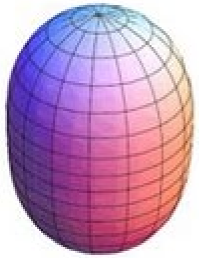
T. Naz et al. Nuclear Physics A 979(2018)1-20



oblate

R. Aryaienejad

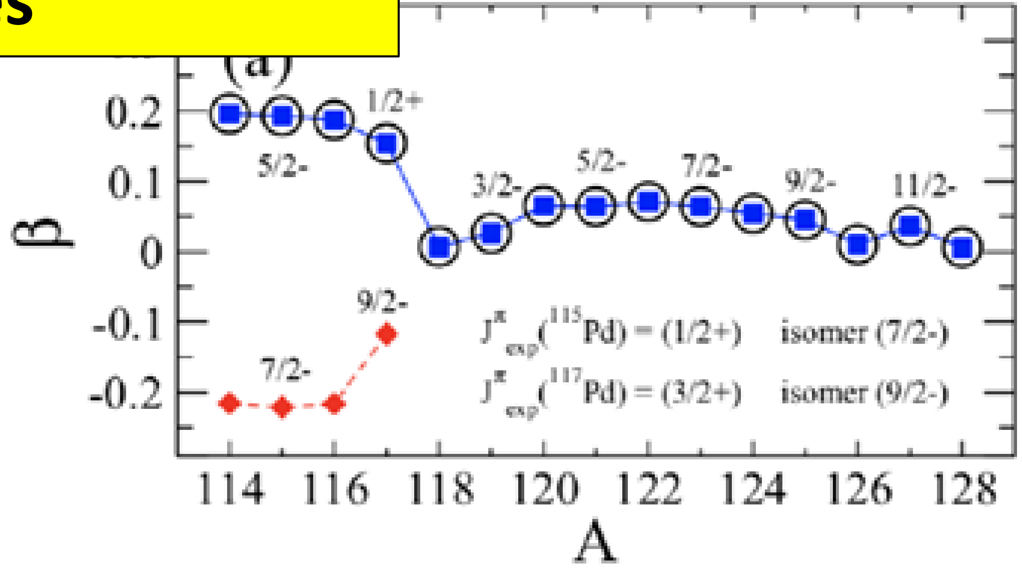
Disagreement on the type of deformation on neutron rich isotopes



prolate

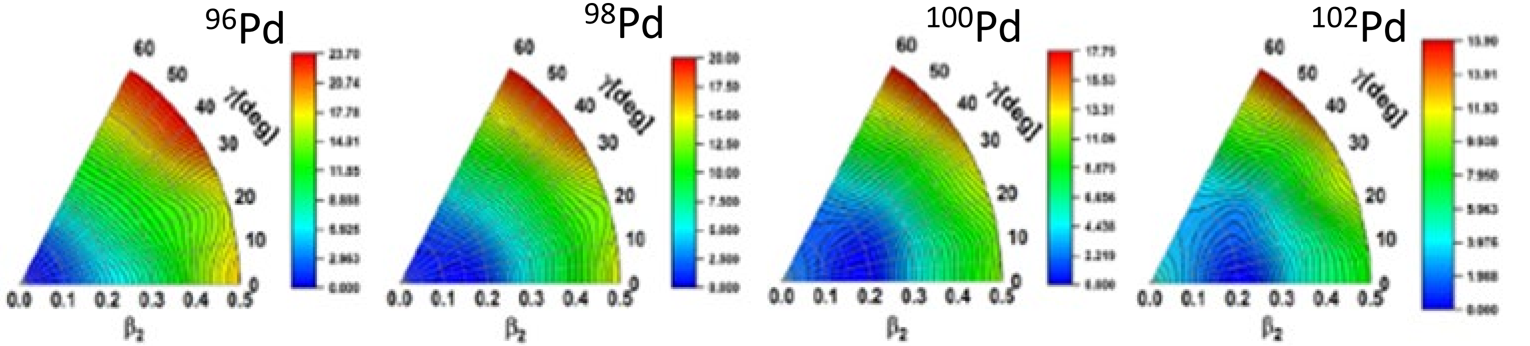
$^{109-123}$Pd

M. Houry et al., Eur. Phys. J. A 6, 43 (1999).



P. Sarriguren. Phys. Rev. C 91, 044304 (2015)

1. Motivation
Neutron deficient



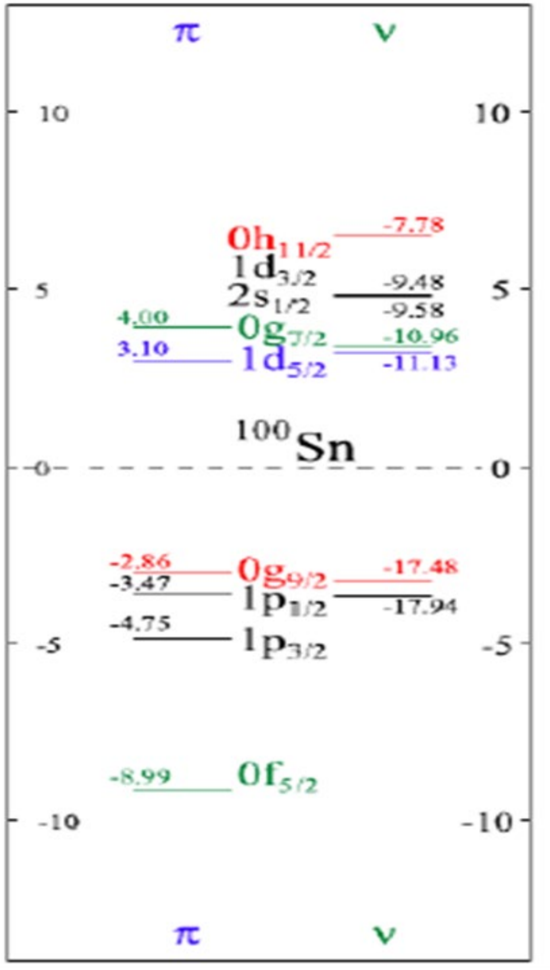
T. Naz et al. Nuclear Physics A 979(2018)1-20

Large Scale Shell Model (LSSM) calculations have computational limitations due to the large model space. The phenomenological correction gives very good results.

Energy Density Functionals (EDF) has been tested by **nuclear charge radii**

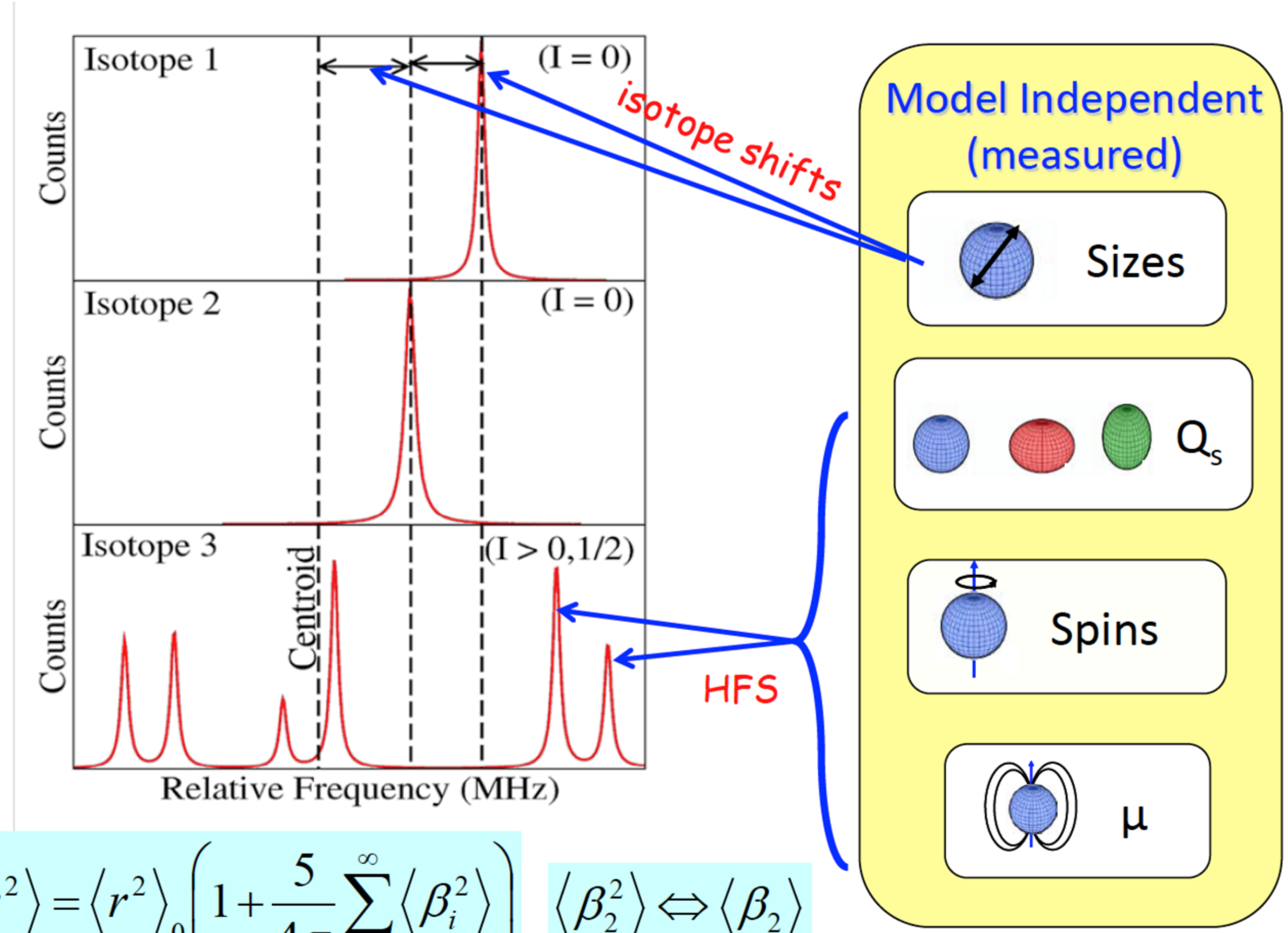
Ab-initio requires a consistent description of electro-weak currents. **Magnetic moments** are sensitive observables.

Beyond-mean field calculations define the intrinsic wave functions (HFB) along the quadrupole deformations. **Quadrupole moments** are sensitive observables.



H. Grawe and M. Lewitowicz, Nucl. Phys., vol. A 693, pp. 116-132, 2001

1. Measure of nuclear observables



$$A = \frac{\mu B_0}{\hbar^2 I J}$$

$$B = eQ_s \langle \frac{\partial^2 V_e}{\partial z^2} \rangle$$

$$Q_s = \frac{3\Omega^2 I(I+1)}{(I+1)(2I+3)} Q_0$$

$$Q_0 = \frac{3}{\sqrt{5\pi}} Z \langle r_{sph}^2 \rangle \langle \beta_2 \rangle (1 + 0.36 \langle \beta_2 \rangle)$$

$$\langle r^2 \rangle = \langle r^2 \rangle_0 \left(1 + \frac{5}{4\pi} \sum_{i=2}^{\infty} \langle \beta_i^2 \rangle \right)$$

$$\langle \beta_2^2 \rangle \Leftrightarrow \langle \beta_2 \rangle$$

Courtesy I. Moore

Outline

1. Motivation
   - Neutron rich (first experiment)
   - Neutron deficient (second experiment)

2. ***<u>Experimental setup</u>***

3. Results
   - Mean square charge radiii
   - Dipole magnetic moments
   - Quadrupole electric moments
   - Theoretical calculations

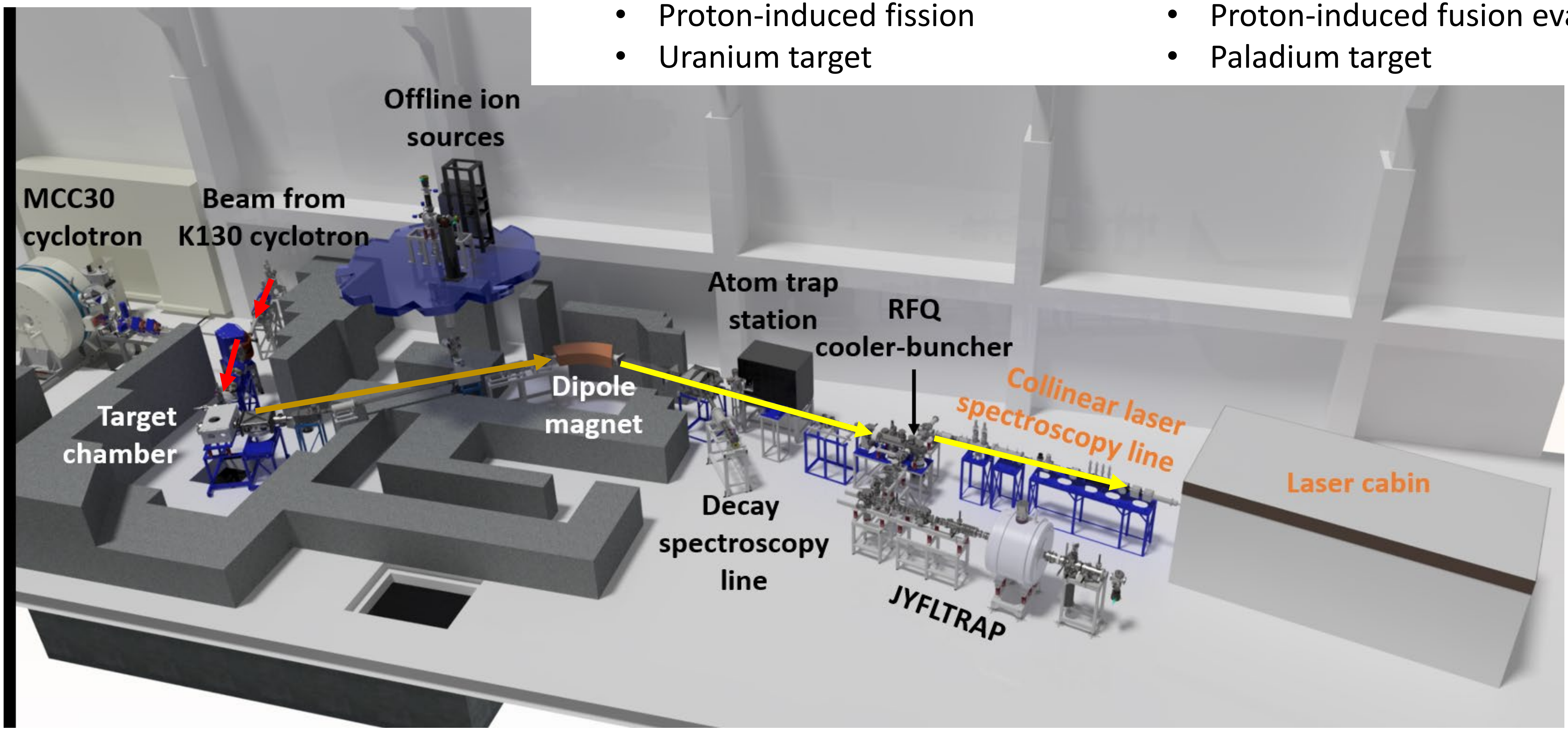
2. IGISOL collinear laser spectroscopy line

Neutron rich:

- Proton-induced fission
- Uranium target

Neutron deficient:

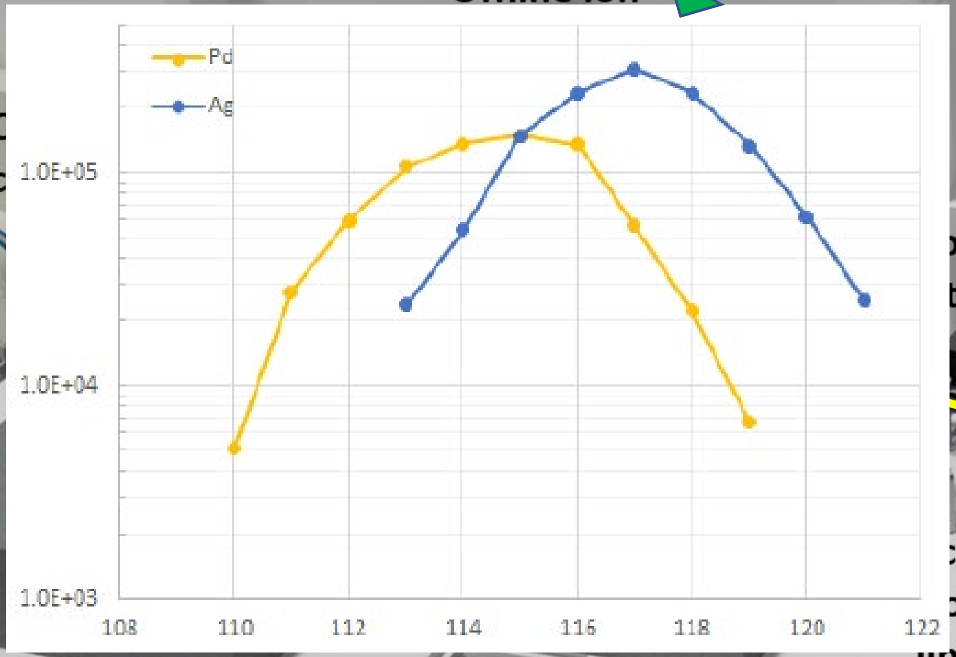
- Proton-induced fusion evaporation
- Paladium target

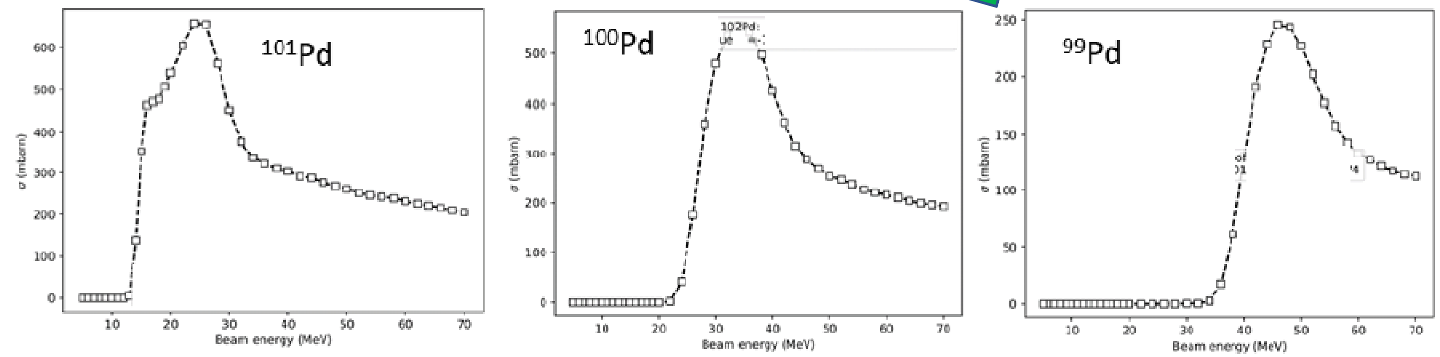


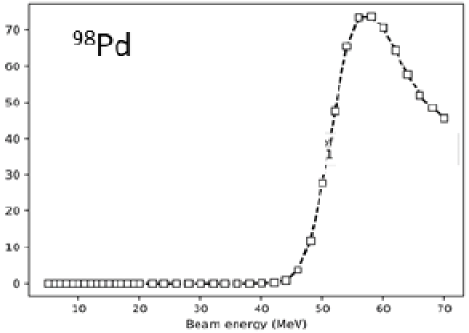
2. *IGISOL collinear laser spectroscopy line*

Neutron rich:
- Proton-induced fission
- Uranium target

Neutron deficient:
- Proton-induced fusion evaporation
- Paladium target

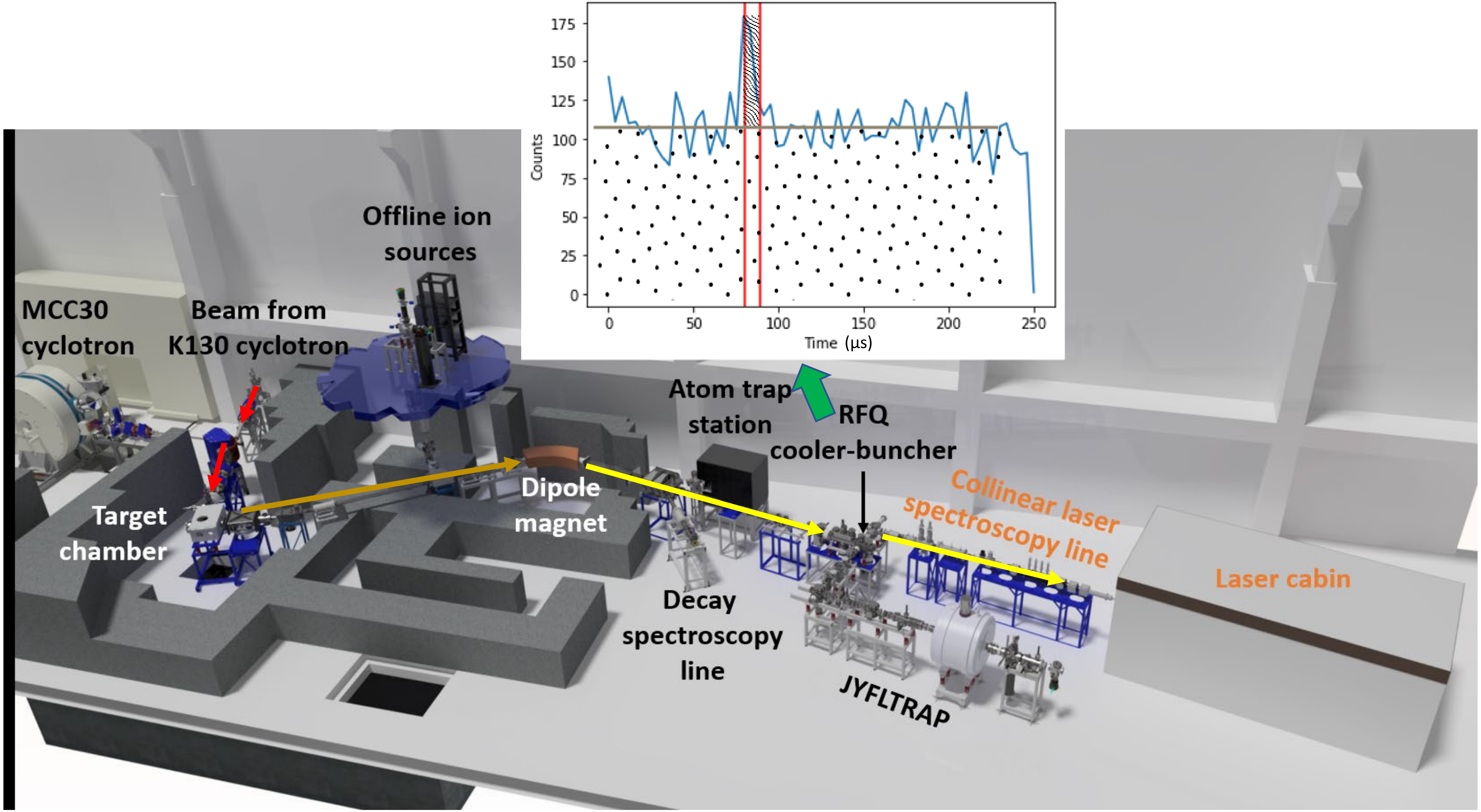




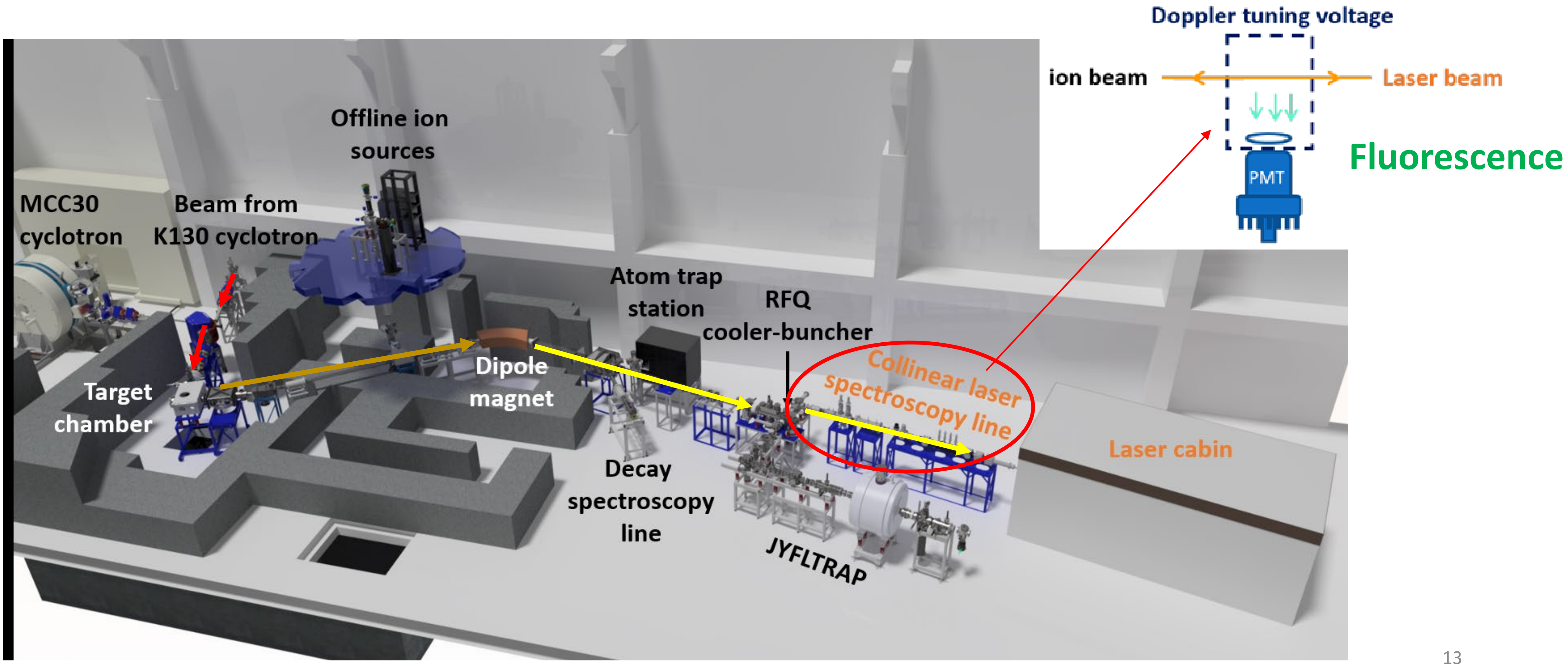


A	E[MeV]	Yield [1/s]
101	25	60000
100	35	55000
99	45	25000
98	60	7000

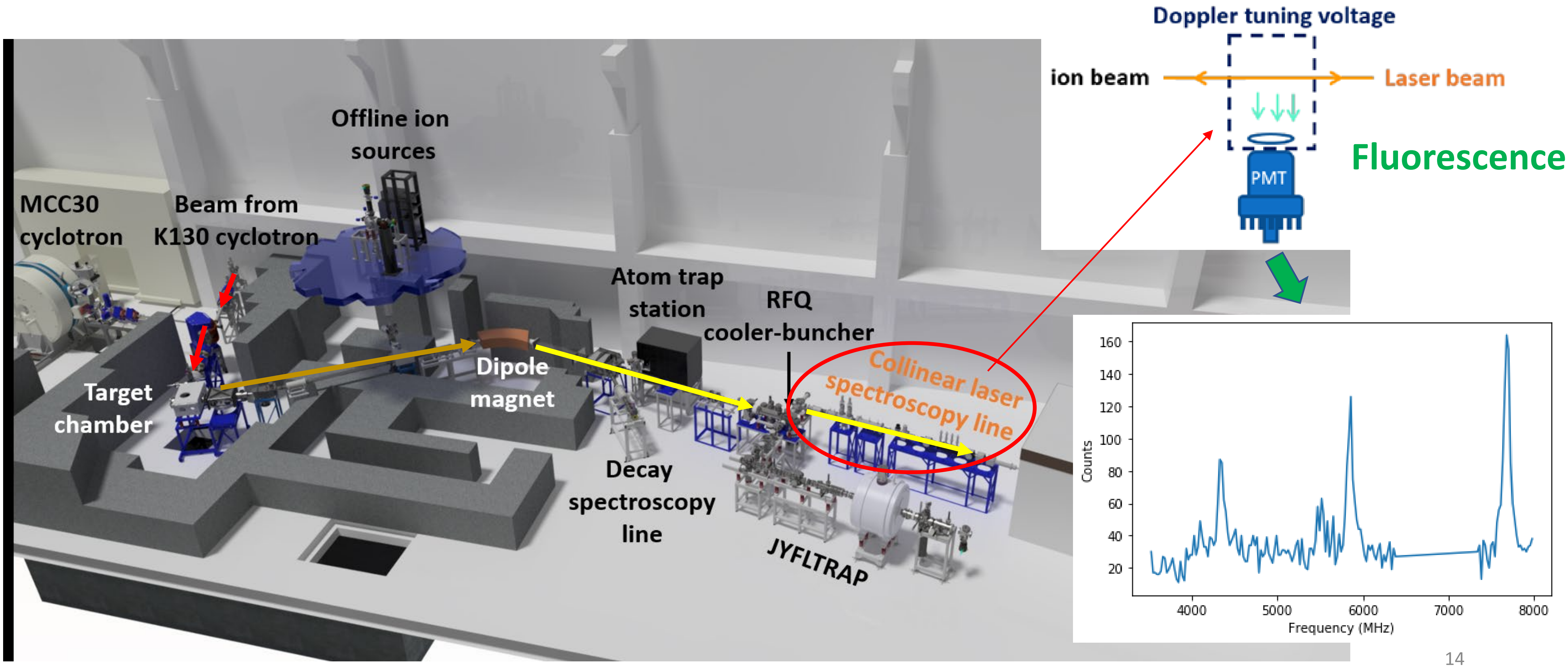
2. IGISOL collinear laser spectroscopy line



2. IGISOL collinear laser spectroscopy line



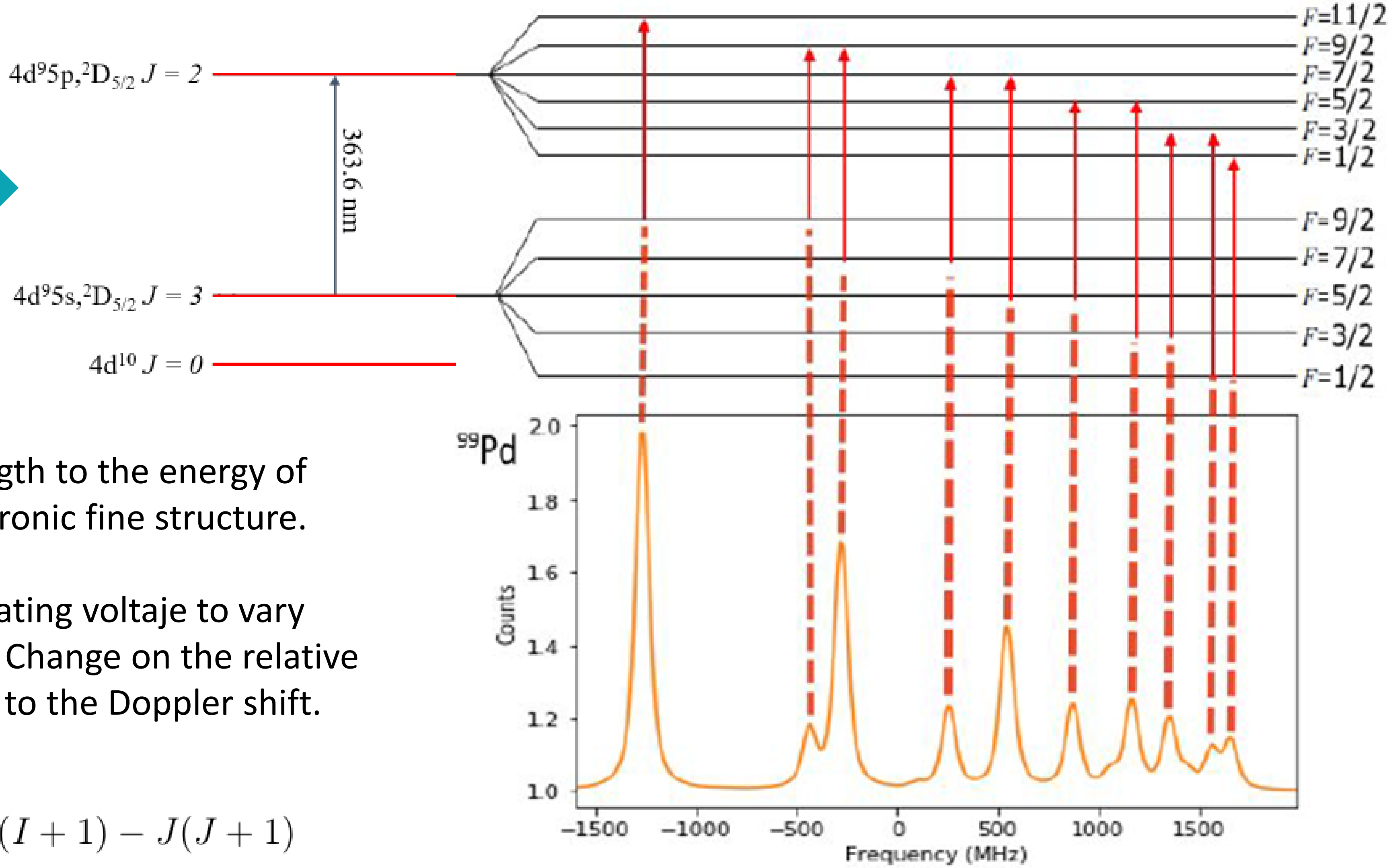
2. IGISOL collinear laser spectroscopy line



2. Laser spectroscopy

$$\frac{\Delta E}{\hbar} = \frac{K}{2}A + \frac{3K(K+1) - 4I(I+1)J(J+1)}{8I(2I-1)J(2J-1)}B$$

Laser Beam



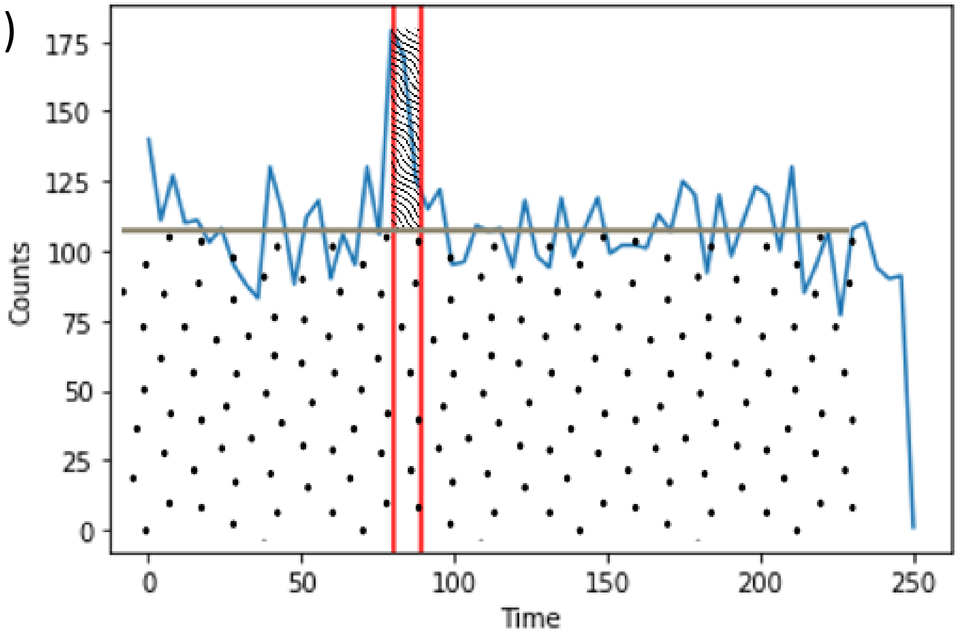
- Set the laser wavelength to the energy of transition in the electronic fine structure.
- Scan with the accelerating voltaje to vary the kinetic energy → Change on the relative laser wavelength due to the Doppler shift.

$$K = F(F+1) - I(I+1) - J(J+1)$$

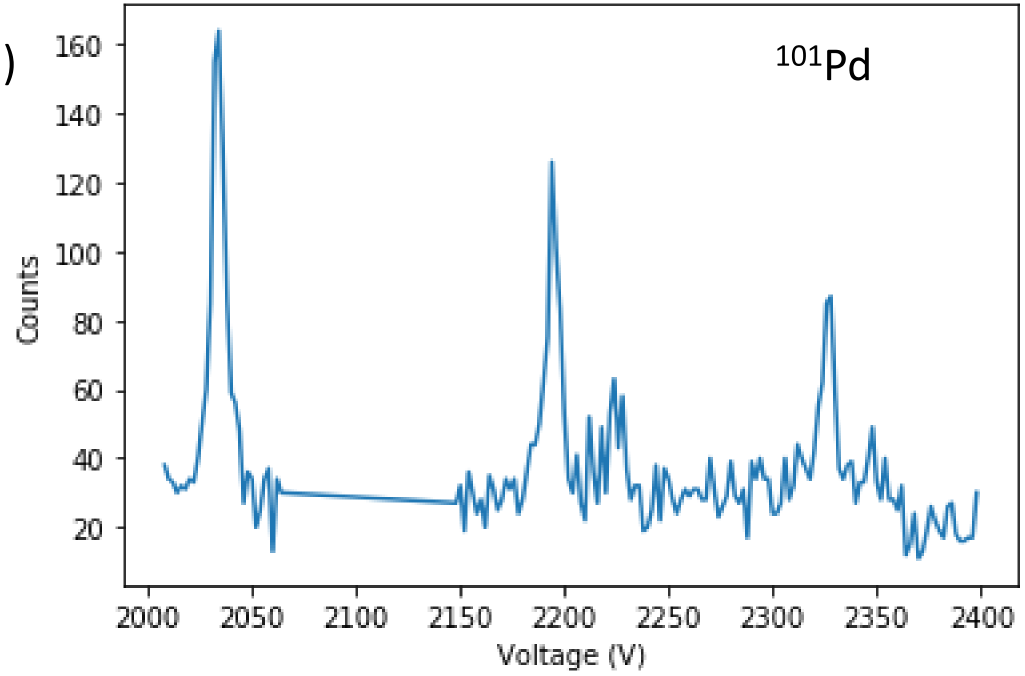
Simulation

2. Analysis

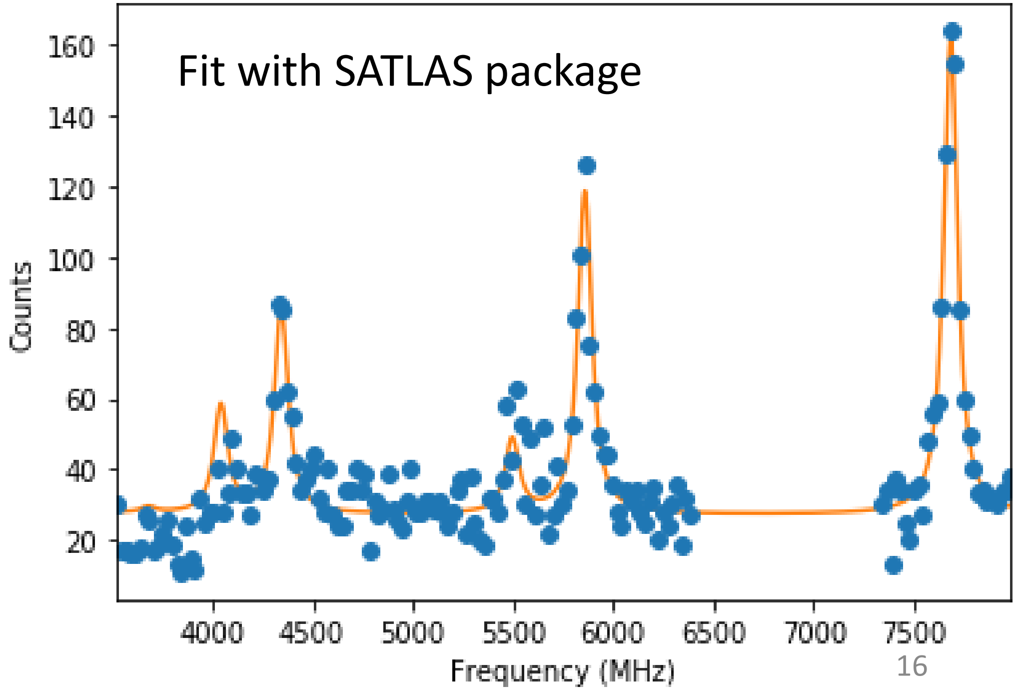
1)



2)



3)



Neutron rich experiment

- Even isotopes $^{112-118}$Pd
- Odd isotopes ^{113}Pd and ^{115}Pd
- Reference isotope ^{108}Pd

Neutron deficient experiment

- All isotopes $^{98-101}$Pd
- No able to measure ^{103}Pd
- Reference isotope ^{102}Pd

Isotope	Measure time (hours)
98	13
99	27.5
100	3.5
101	9
102 reference	11.5

Outline

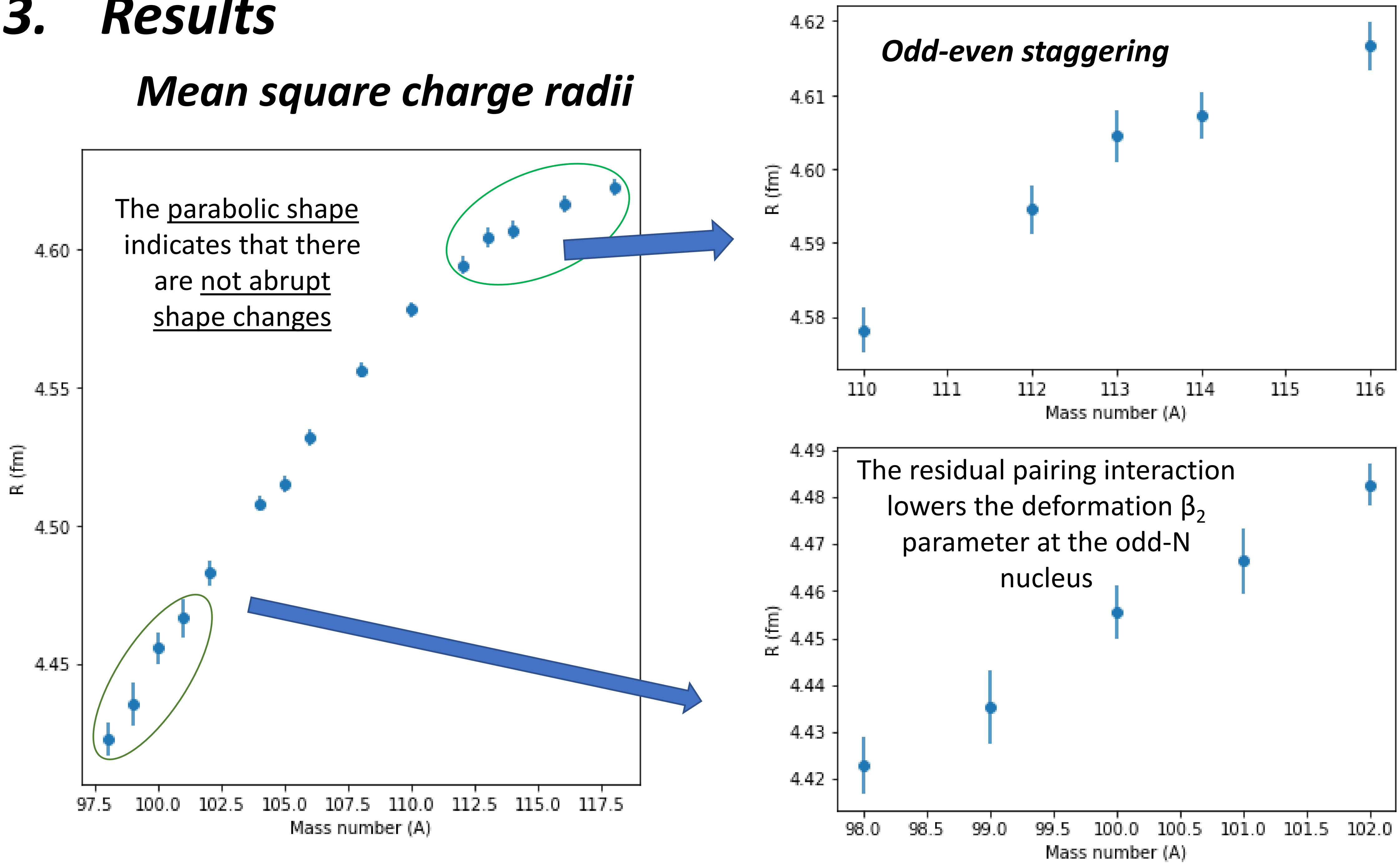
1. Motivation
    - Neutron rich (first experiment)
    - Neutron deficient (second experiment)

2. Experimental setup

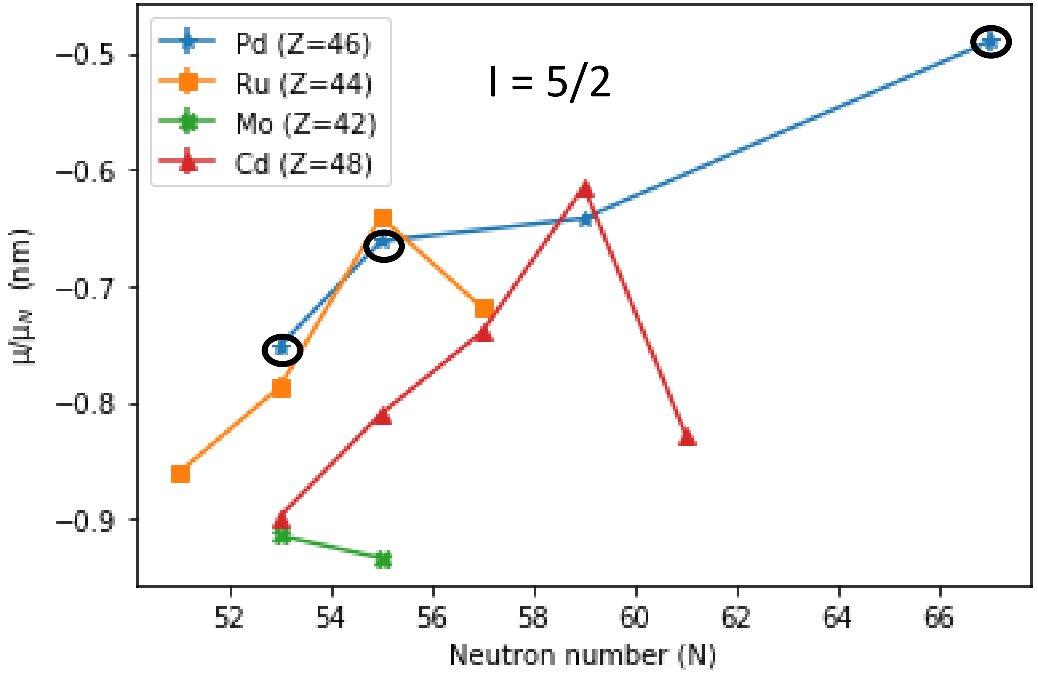
3. ***<u>Results</u>***
    - ***<u>Mean square charge radiii</u>***
    - ***<u>Dipole magnetic moments</u>***
    - ***<u>Quadrupole electric moments</u>***
    - ***<u>Theoretical calculations</u>***

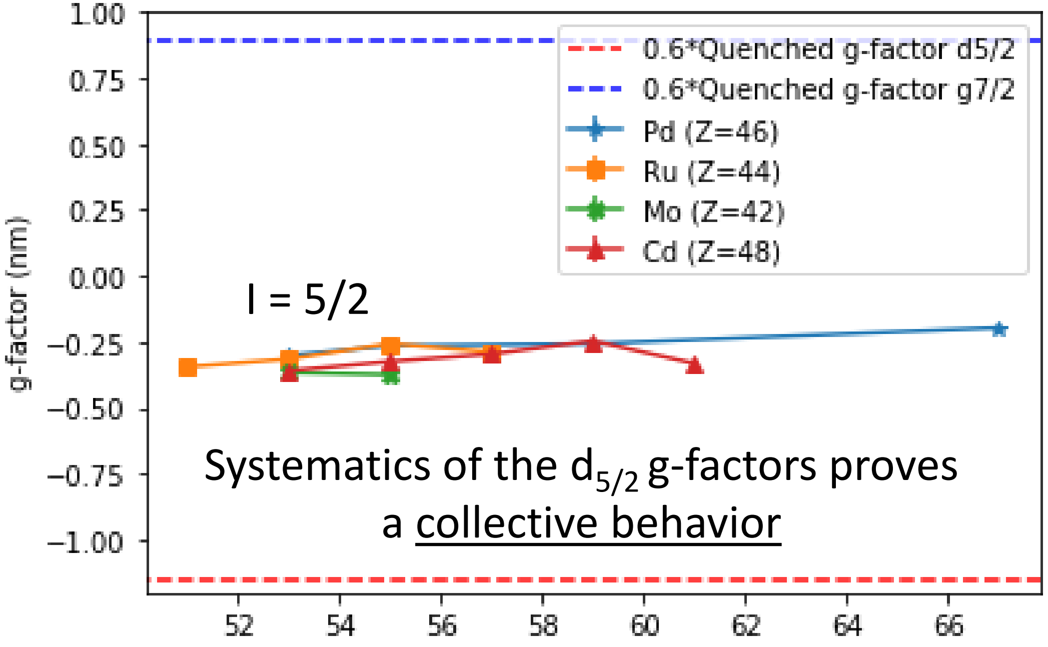
3. Results

Mean square charge radii

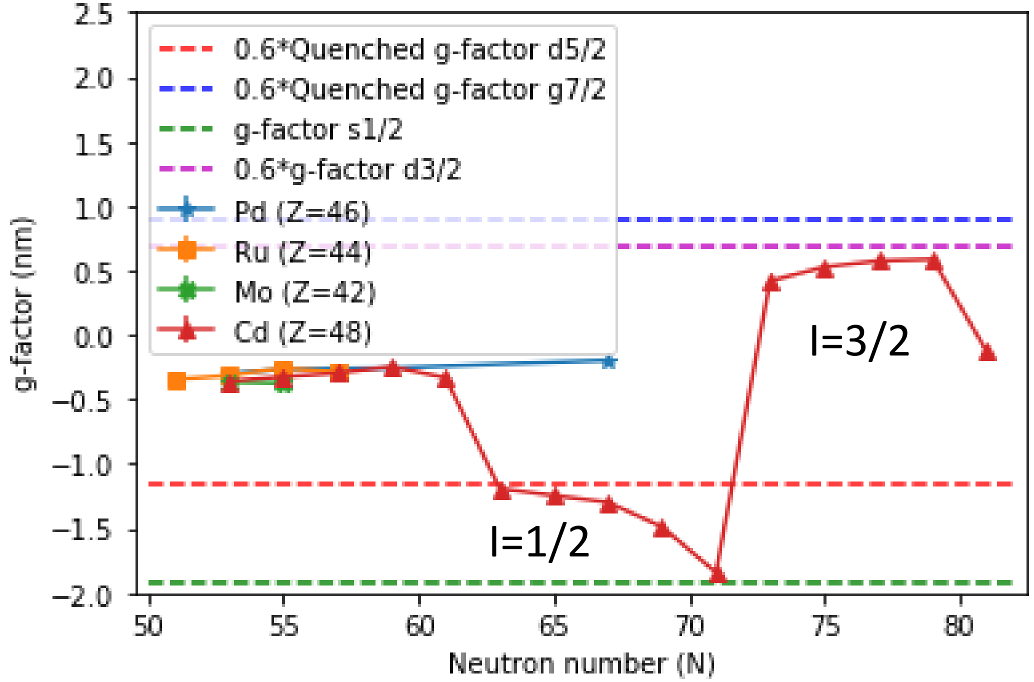


3. Results
Magnetic moments





Systematics of the $d_{5/2}$ g-factors proves a <u>collective behavior</u>

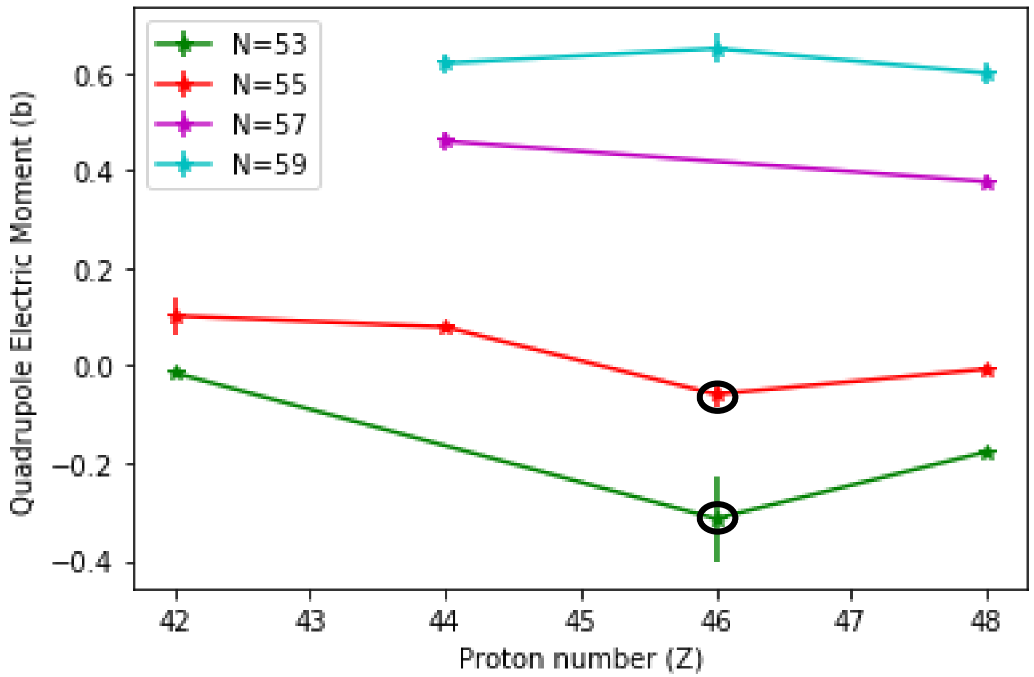


Atomic Data and Nuclear Data Tables 109–110 (2016) 1–204 /
D. T. YORDANOV et al. PHYSICAL REVIEW C98, 011303(R) (2018)

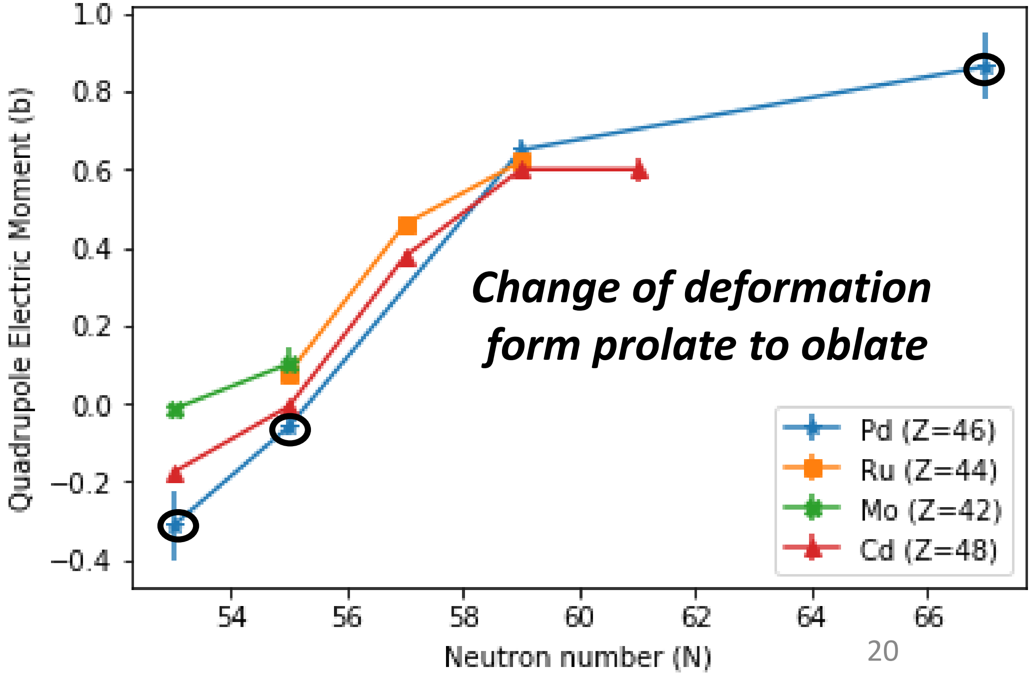
3. Results

Quadrupole electric moment

- The flat shape of the isotonic lines suggest that there is no significant effect on the deformation with increasing Z
- Palladium (Z=46) is the element who seems to have the most deformation in the region

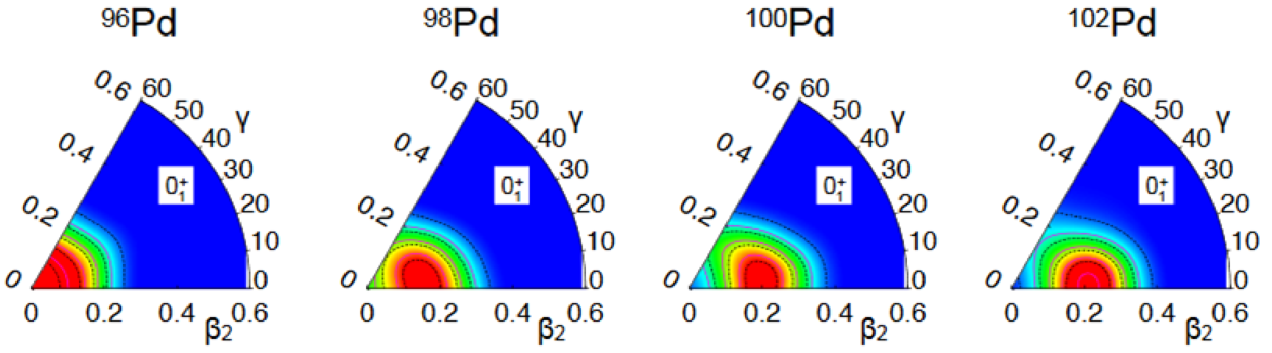


- Systematics of the región show a linear trend, probably due to the addition of neutron pairs to the $d_{5/2}$ shell plus an odd neutron
- The small increase between the ^{105}Pd and the ^{113}Pd could be due to that the neutron ocupation of the $d_{5/2}$ Shell is already at maximum as could happend for ^{109}Cd[]



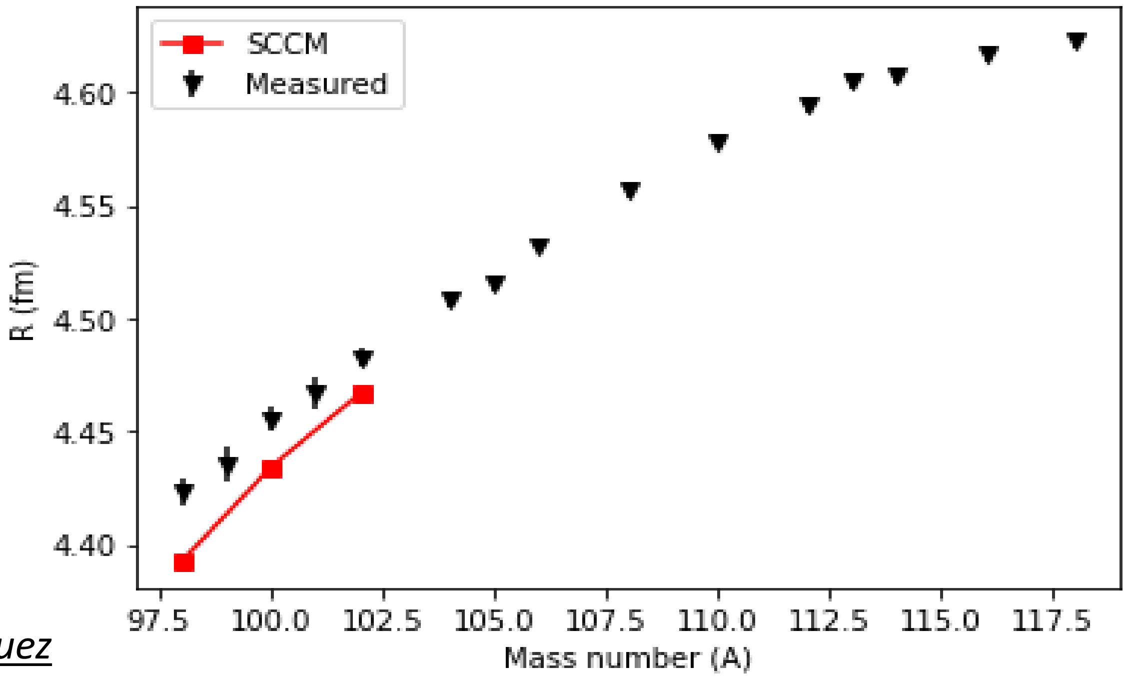
Atomic Data and Nuclear Data Tables 109–110 (2016) 1–204 /
[]D. T. YORDANOV et al. PHYSICAL REVIEW C98, 011303(R) (2018)

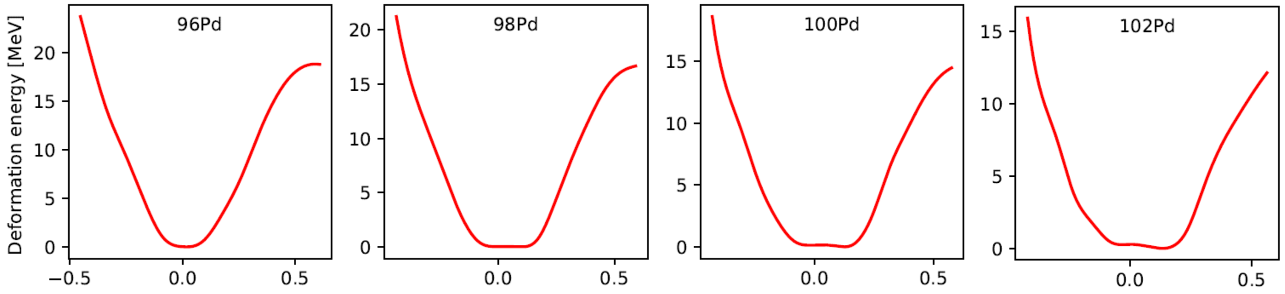
3. *Preliminary theoretical calculations*



Symmetry conserving configuration mixing (SCCM)

Tomas R. Rodriguez

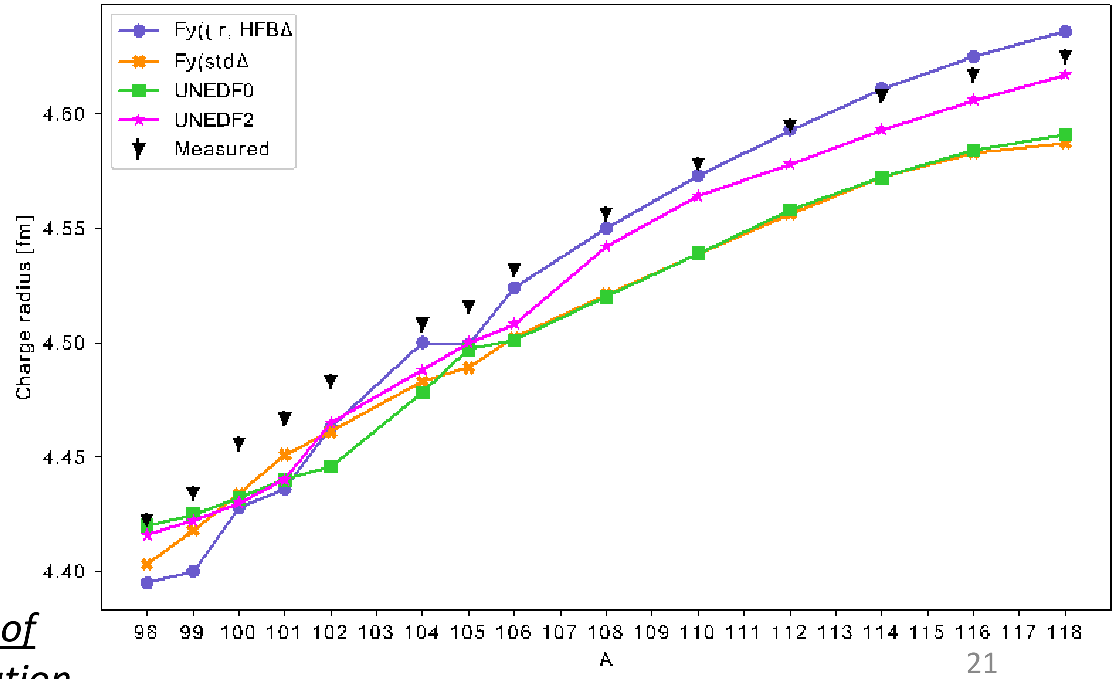




Fayans Energy Density Functionals

M. Kortelainen

Waiting for F. Nowacki calculations
Large Scale Shell Model



S.Geldhof
In preparation

3. Outlook and conclusions

Conclusions

- Prolate deformation on neutron rich nuclei
- Theoretical calculations do not reproduce oblate deformation in neutron deficient isotopes

Perspectives

- Colinear laser spectroscopy on ^{103}Pd
- Hot cavity laser spectroscopy on more neutron deficient isotopes, crossing N=50

THANKS FOR YOUR ATTENTION