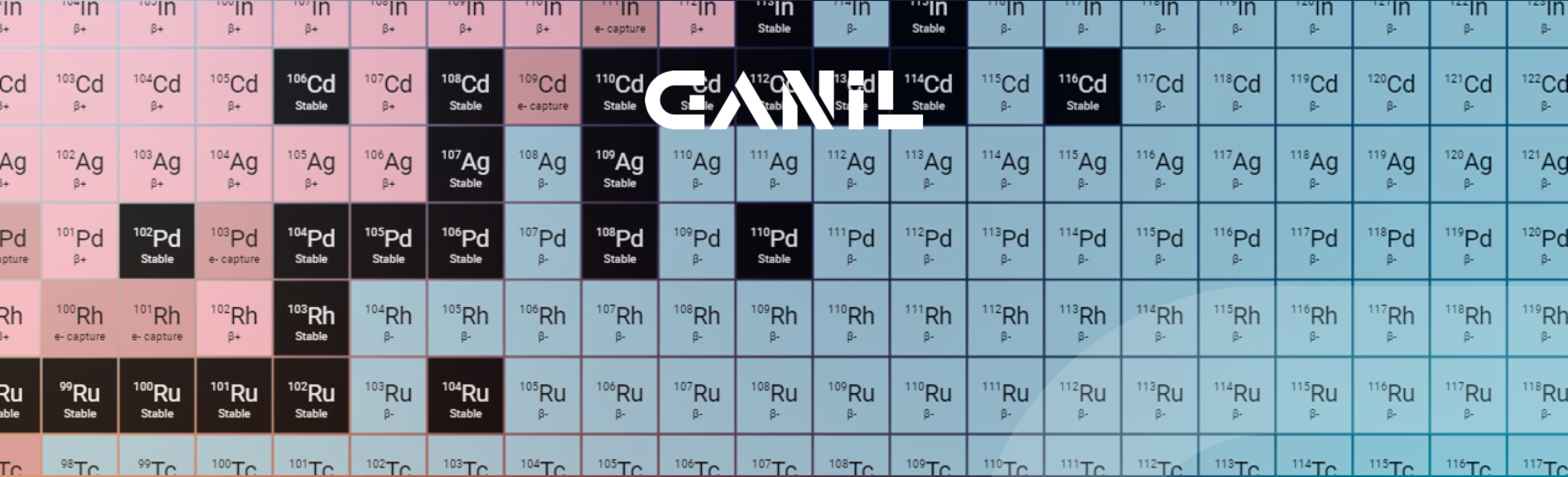
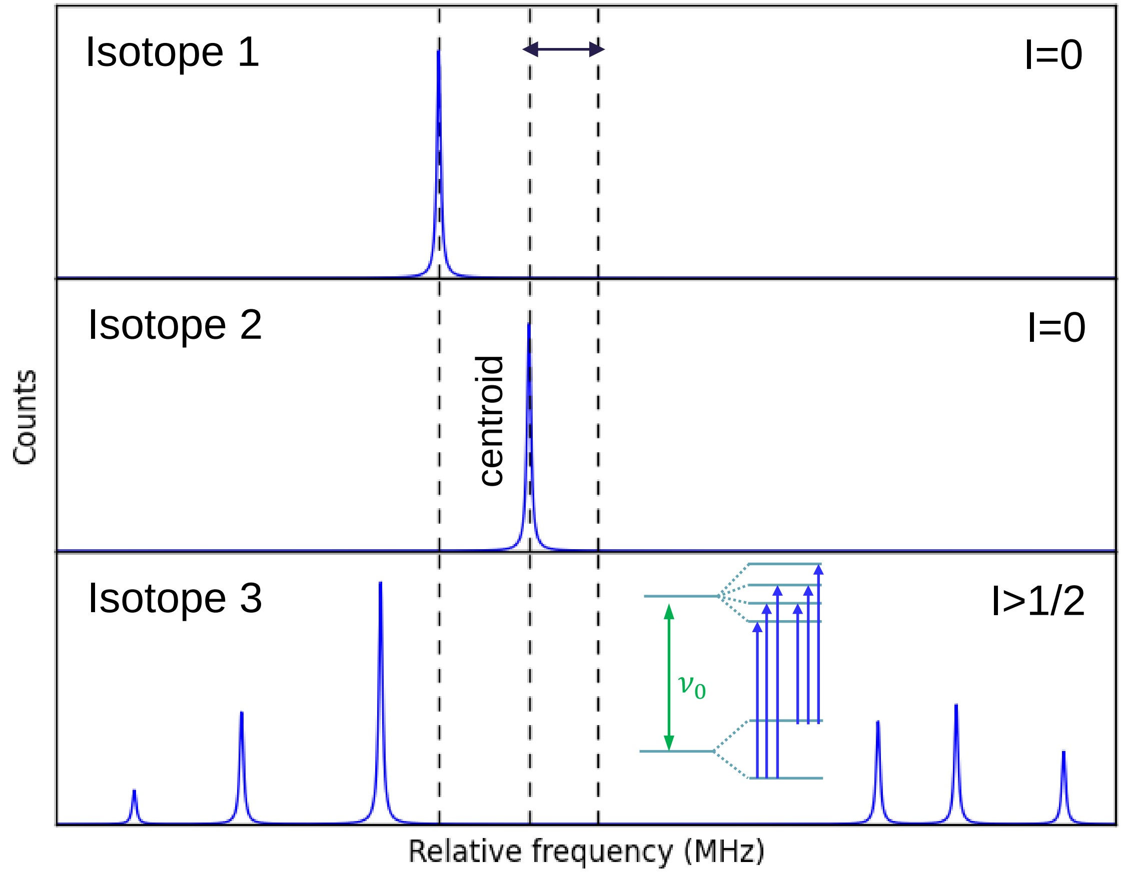


Nuclear structure of Pd isotopes via optical spectroscopy

Sarina Geldhof

Atomic spectra



$$\nu_F = \nu_0 + A f(I,J,F) + B g(I,J,F)$$

Nuclear configuration/ shell model states

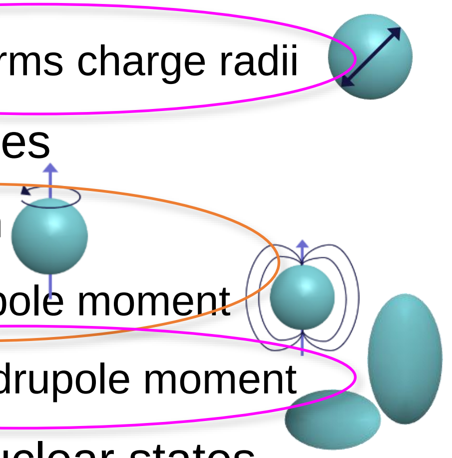
Isotope shifts

- Changes in rms charge radii

Hyperfine structures

- Nuclear spin
- Magnetic dipole moment
- Electric quadrupole moment

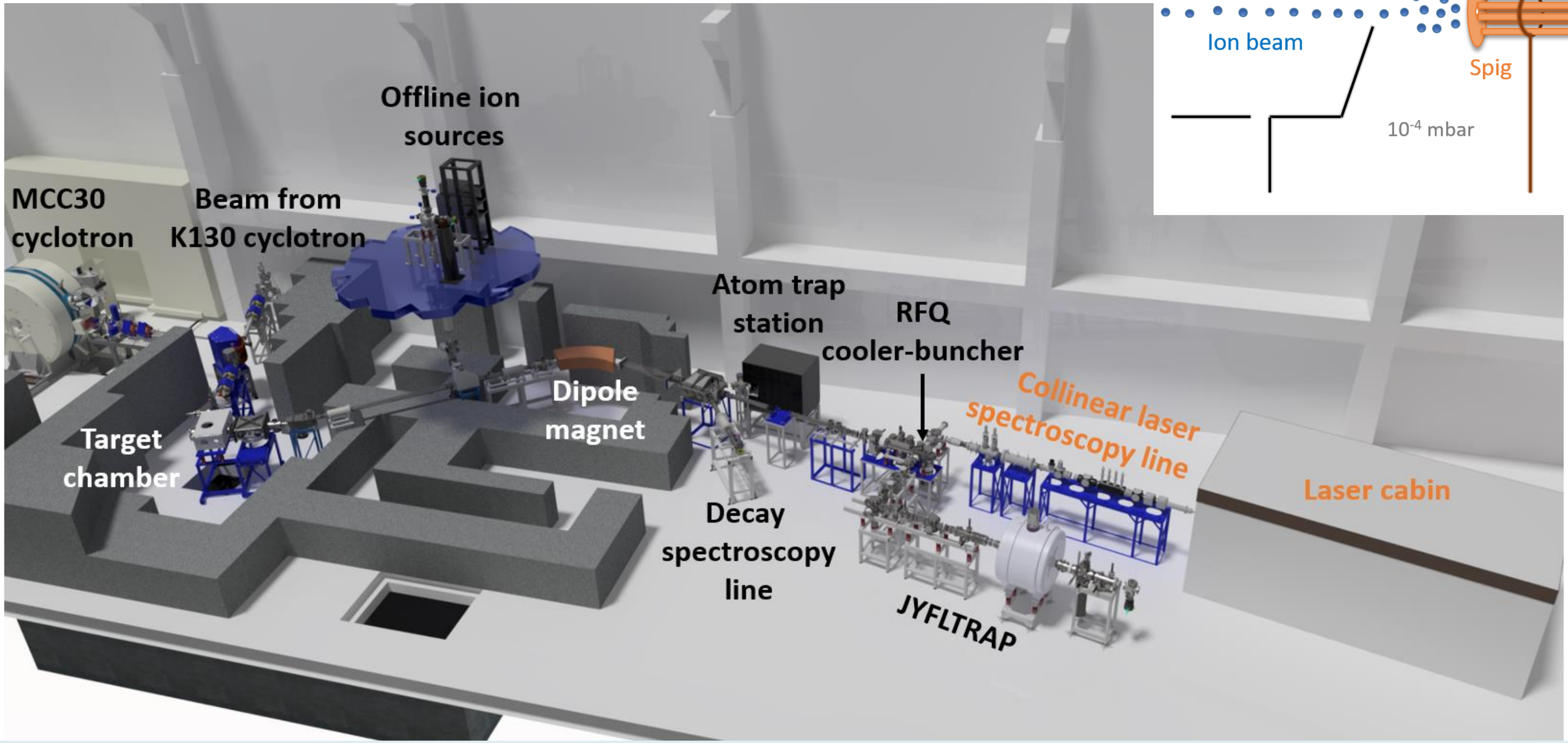
Identification of nuclear states

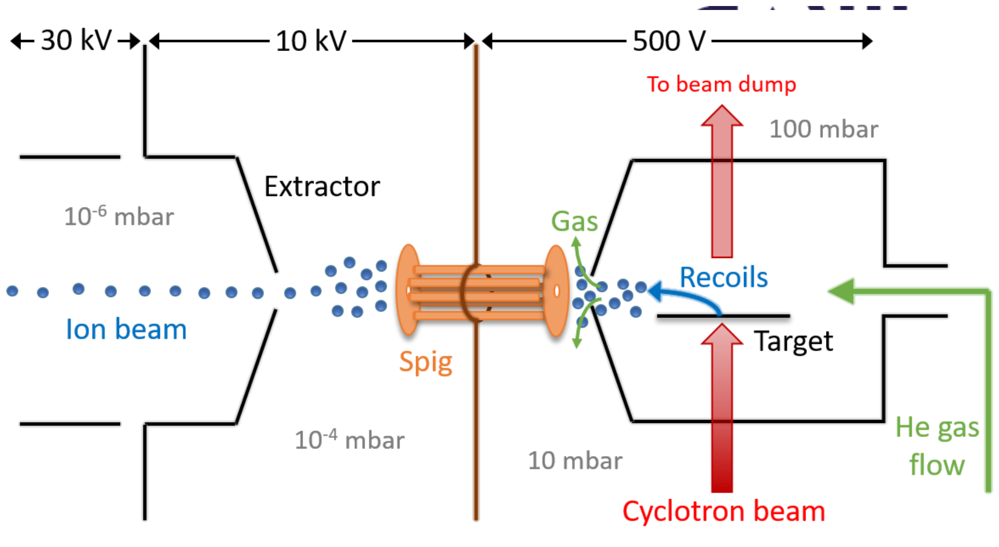


Static and dynamic deformation

$$A = \mu \frac{B_e}{|IJ|} \qquad B = eQ_s \left\langle \frac{\partial^2 V}{\partial z^2} \right\rangle$$

The IGISOL facility



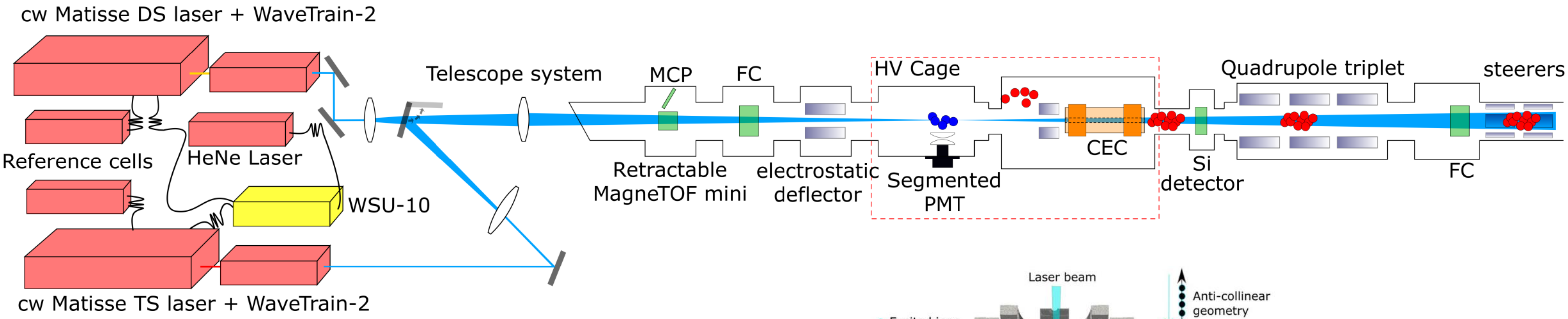


- Cyclotron beam hits thin target
- Recoils stopped in He buffer gas
- Supersonic jet guides into an ion guide
- Fast and chemically insensitive → universal

The IGISOL facility

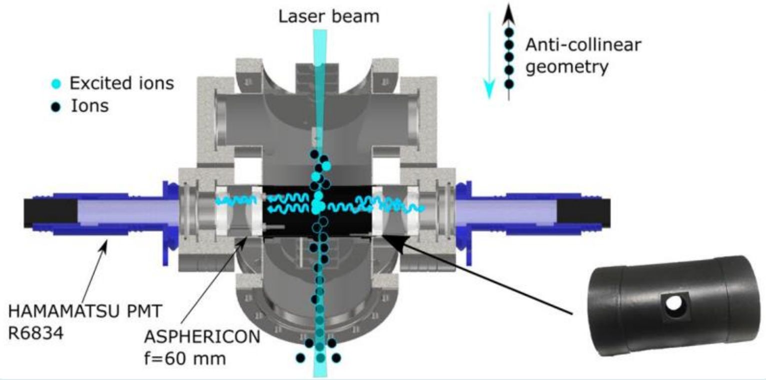
Additions to the collinear laser spectroscopy beamline beforehand:

- Charge-exchange cell*
- New laser system



Upgrades since: new light collection-region and shorter bunches

See talk A. Raggio



* Courtesy of W. Nörtershäuser, TU Darmstadt

A. Koszorús et al., Sci Rep 13, 4783 (2023)

Motivation

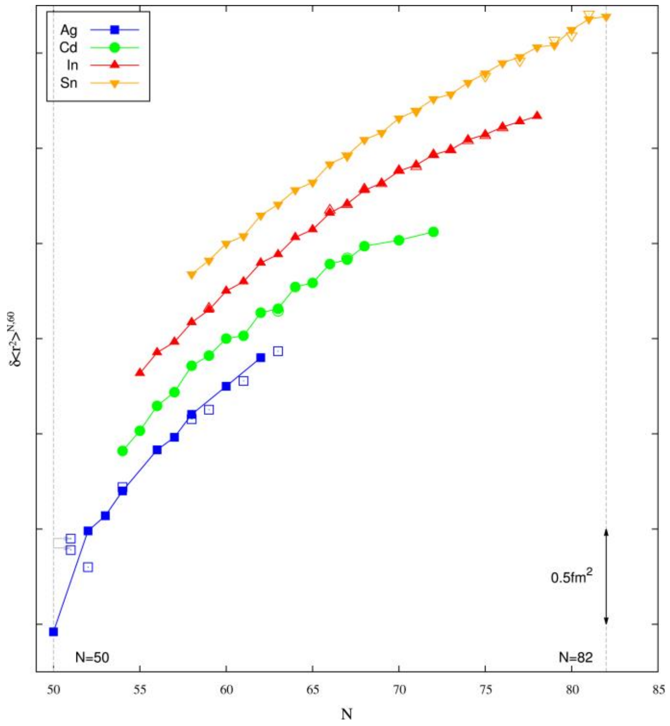
Gap in optical spectroscopy data: up to recently Tc, Ru, Rh, Pd isotopes ‘missing’

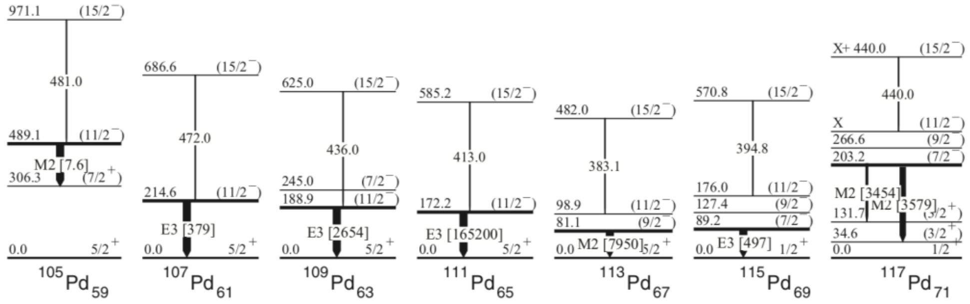
- Refractory elements & complex atomic structure

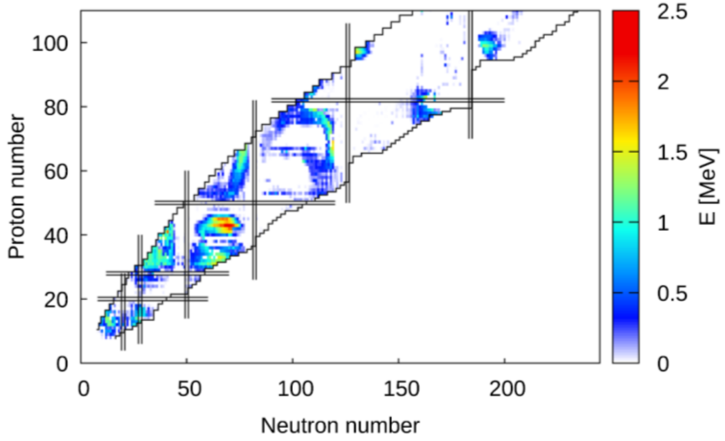
Measurements of charge radii powerful for testing nuclear Density Functional Theory (DFT) and ab-initio approaches

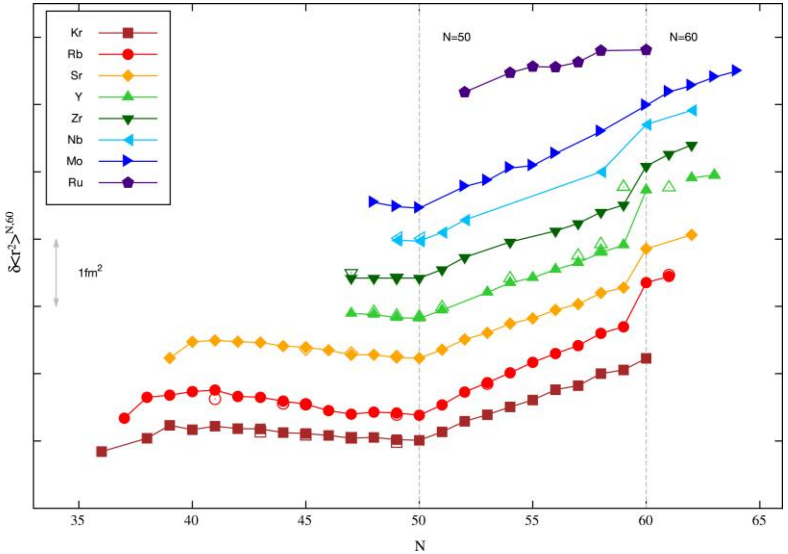
Ground state & isomer properties needed to clarify various phenomena in region and underpin decay spectroscopy studies

- Rapid changes in deformation, shape coexistence,…
- Firm spin assignments missing
- Triaxiality







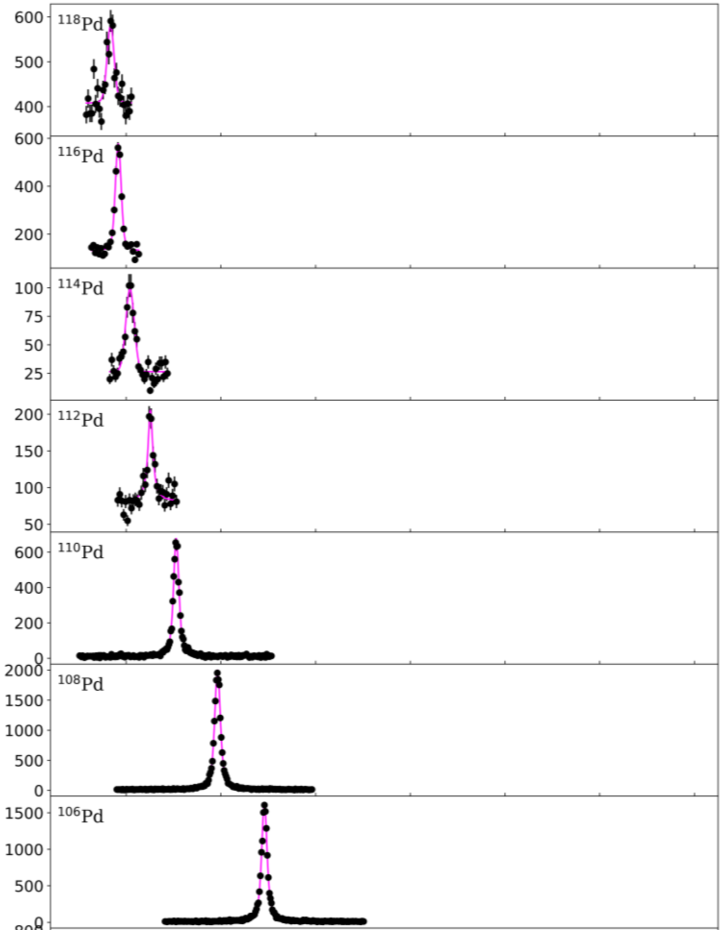


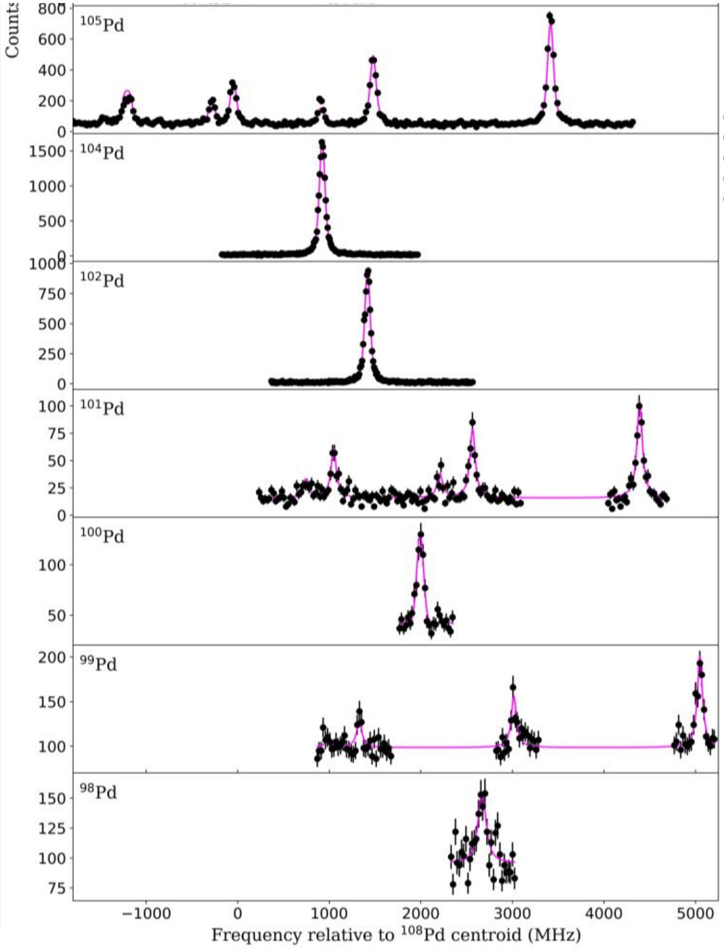
J. Kurpeta et al., Phys. Rev. C 98, 024318 (2018)

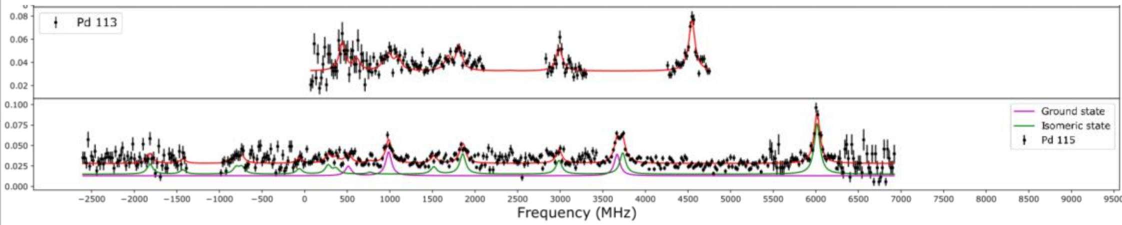
G. Scamps et al., Eur. Phys. J. A 57, (2021)

P. Campbell, I. D. Moore and M. R. Pearson, Progress in Particle Physics 86, 127 (2016)

Results



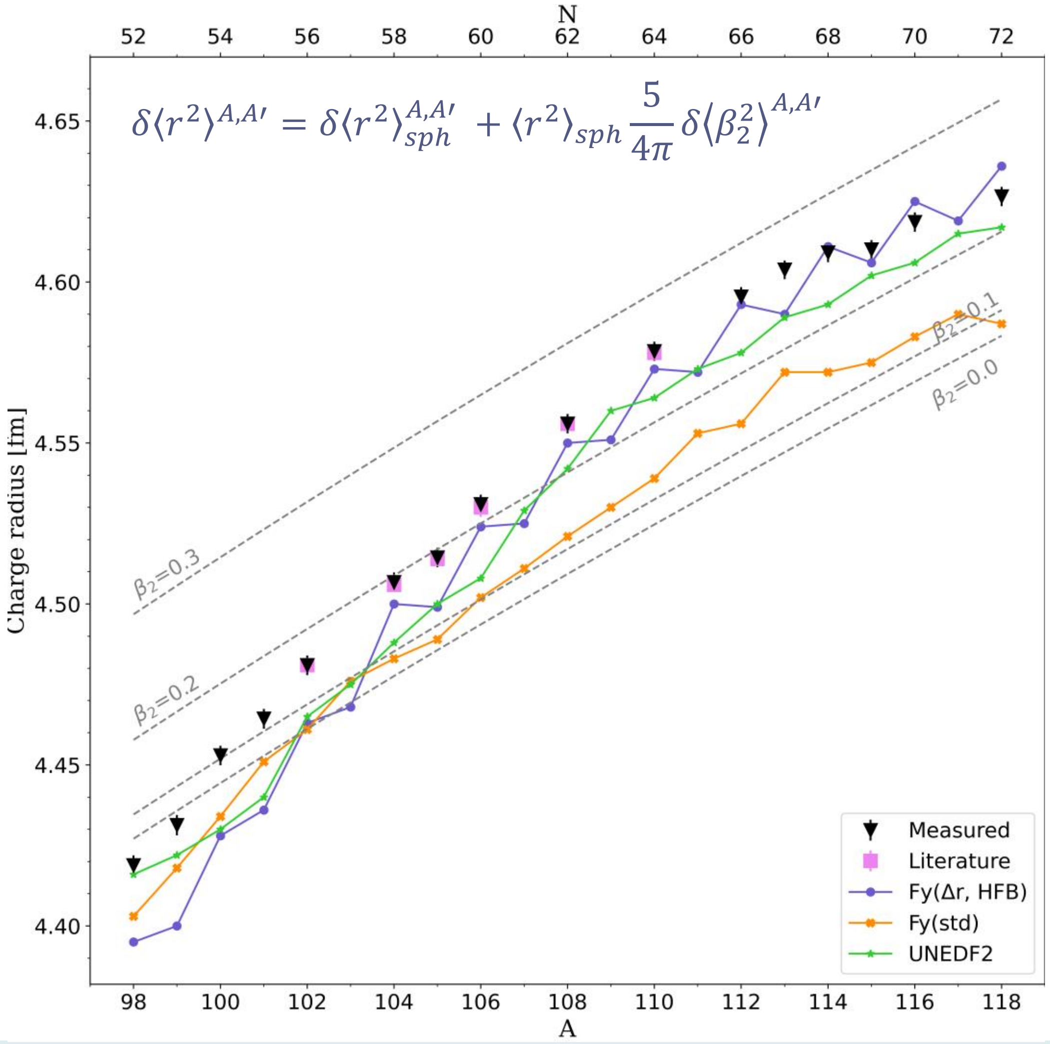




Isotopes in the range A = 98-118

- 98-101: fusion-evaporation reactions
- 102-110: stable, spark source
- 112-118: fission on Th target

Charge radii



$$\delta\nu^{A,A'} = F\,\delta\langle r^2\rangle^{A,A'} + M\,\frac{(A-A')}{AA'}$$

F = −2.9 GHz/fm^2 , M = 845 GHz amu

Parabolic curvature towards higher N, centred around N = 66, where largest degree of collectivity and deformation is expected

No sign of sudden change(s) in deformation

Comparison to nuclear DFT calculations

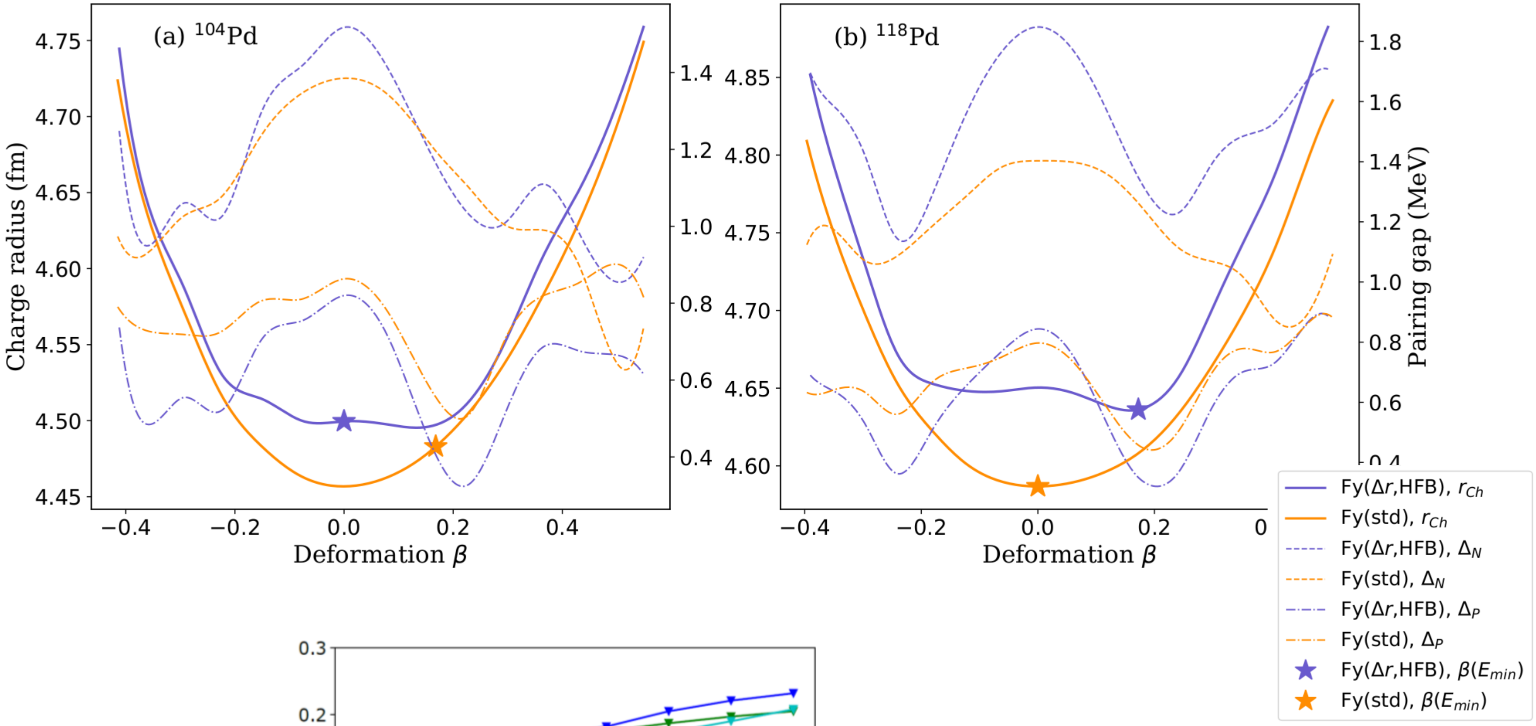
- UNEDF2
- Two forms of Fayans EDF which feature particular pairing functional

S. Geldhof et al., Phys. Rev. Lett 128, 152501 (2022)

S. Geldhof et al., Hyperfine Interact 241, 41 (2020)

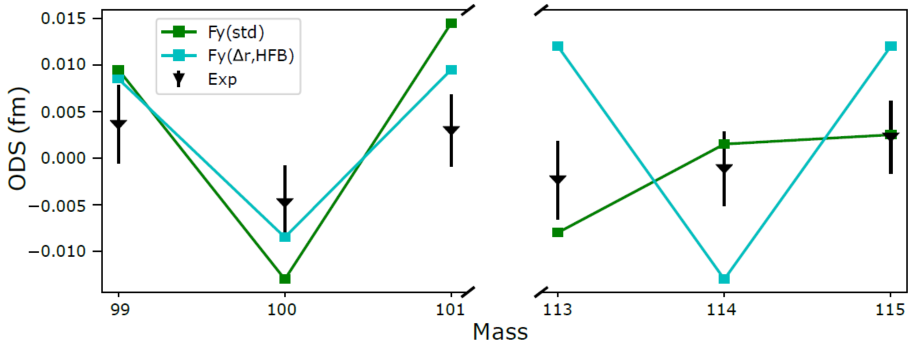
Charge radii: influence of pairing

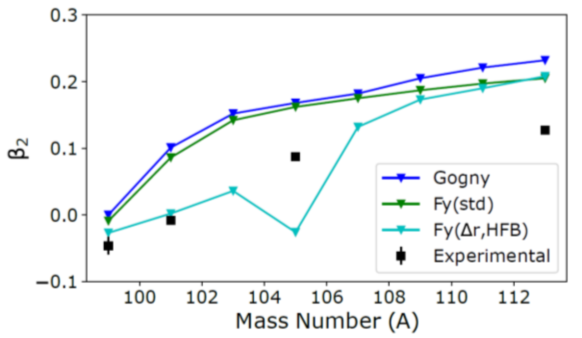
$$\delta\langle r^2\rangle^{A,A'} = \delta\langle r^2\rangle_0^{A,A'} + \langle r^2\rangle_0 \frac{5}{4\pi}\delta\langle\beta_2^2\rangle^{A,A'}$$



Strong pairing correlations in Fy(Δr,HFB) modify nuclear mean-field more at surface → larger charge radius and enhanced OES

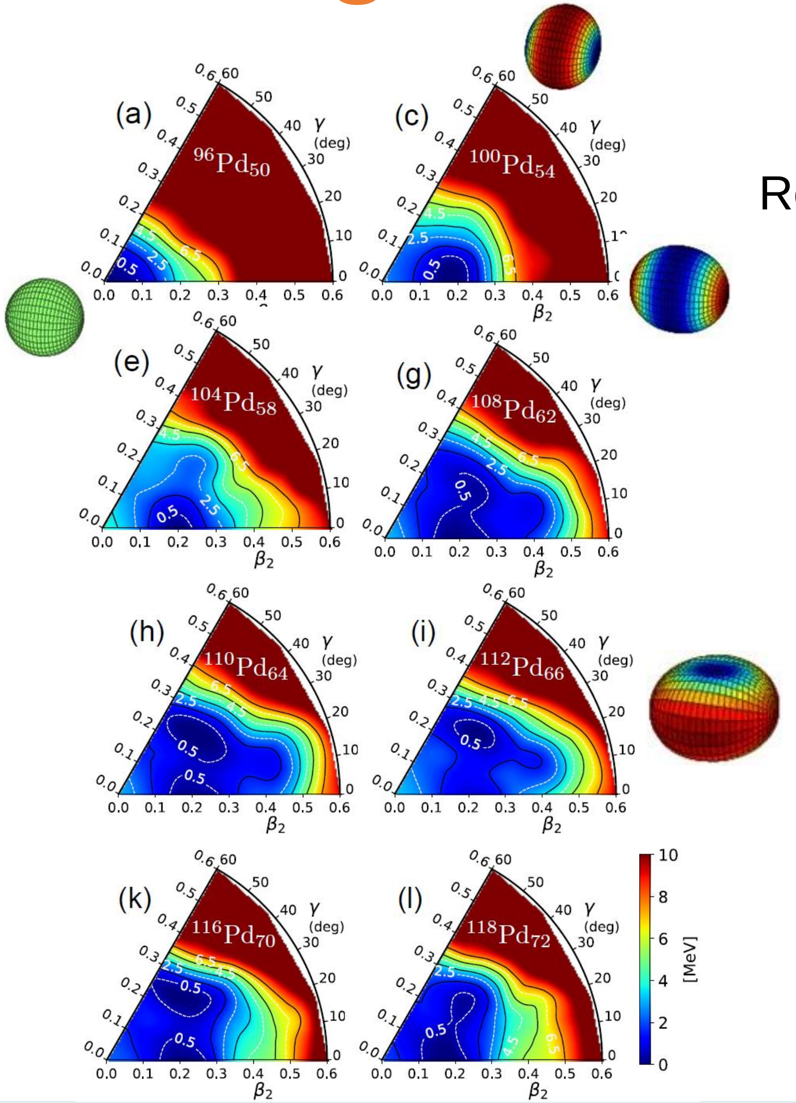
$$\Delta_R^{(3)} = \frac{1}{2}(R_{A+1} + R_{A-1} - 2R_A)$$



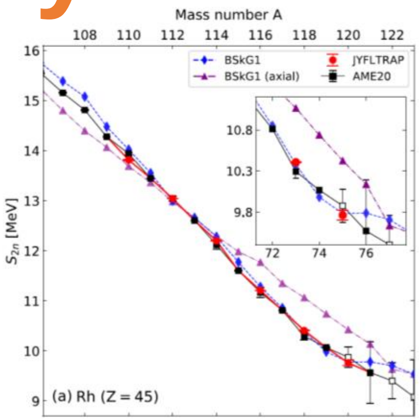


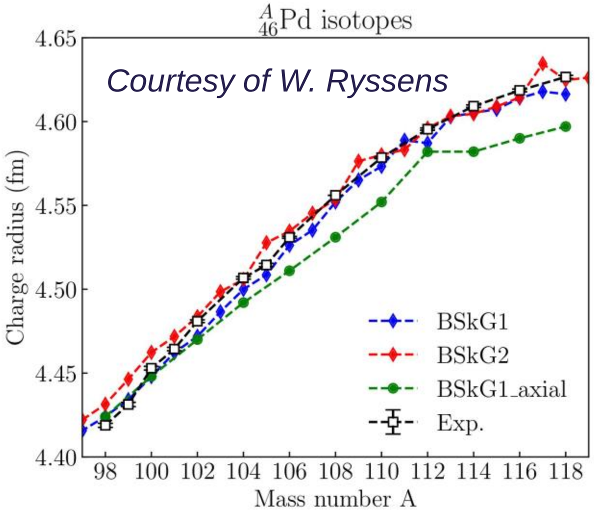
β_2 extracted from electric quadrupole moments naively compared to calculations

Charge radii: triaxiality?



Region 'forecast' to be triaxial



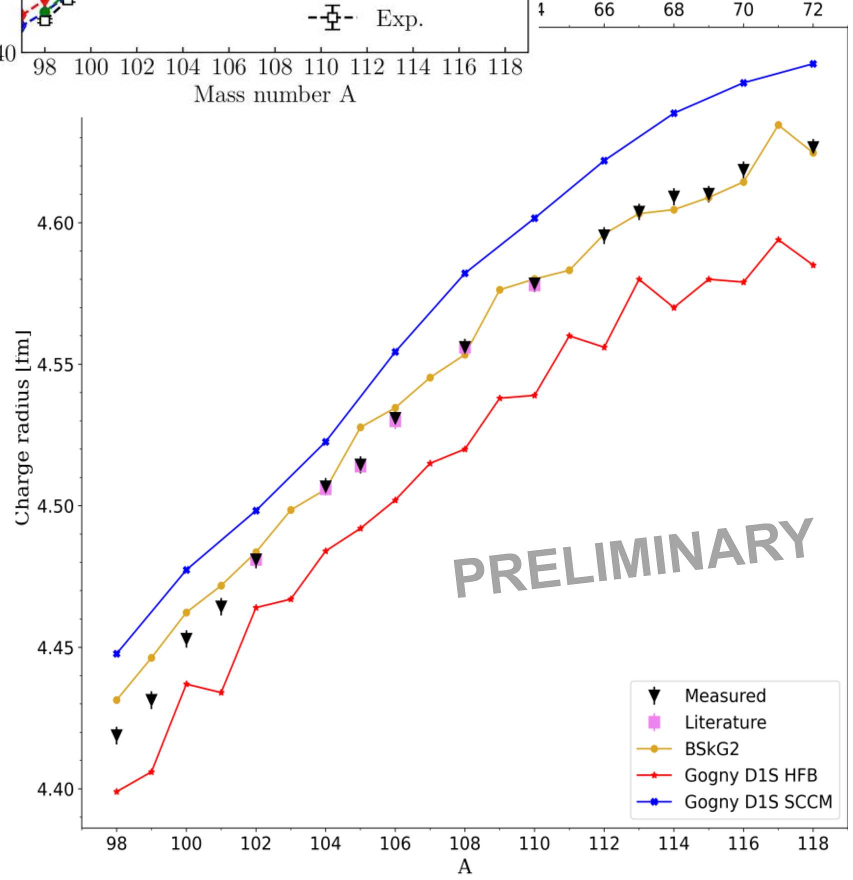


Further theoretical calculations:

- Gogny D1S EDF within HFB and Symmetry Conserving Configuration Mixing
- BSkG2 EDF

Breaking of axial symmetry → better overall agreement with experiment

- But: none of these EDFs capture OES
- Exact effect on charge radii hard to disentangle



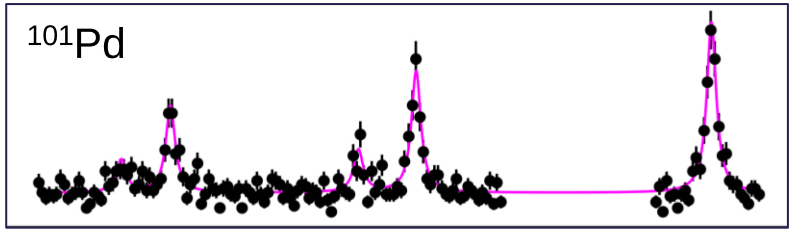
A. Ortiz-Cortes et al., to be submitted

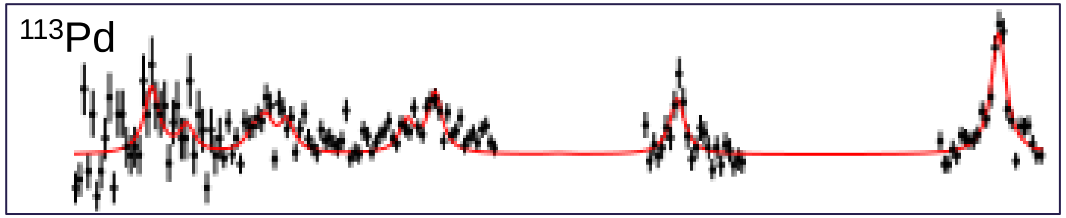
M. Hukkanen et al., Phys. Rev. C 107 (2023)

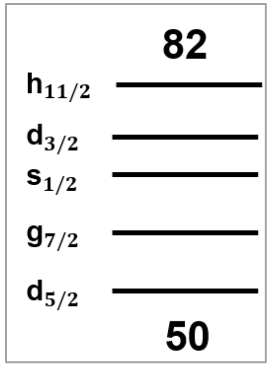
***D1S**: L. M. Robledo and T. R. Rodriguez*
***BSkG2**: W. Ryssens et al., Eur. Phys. J. A 58:246 (2022)*

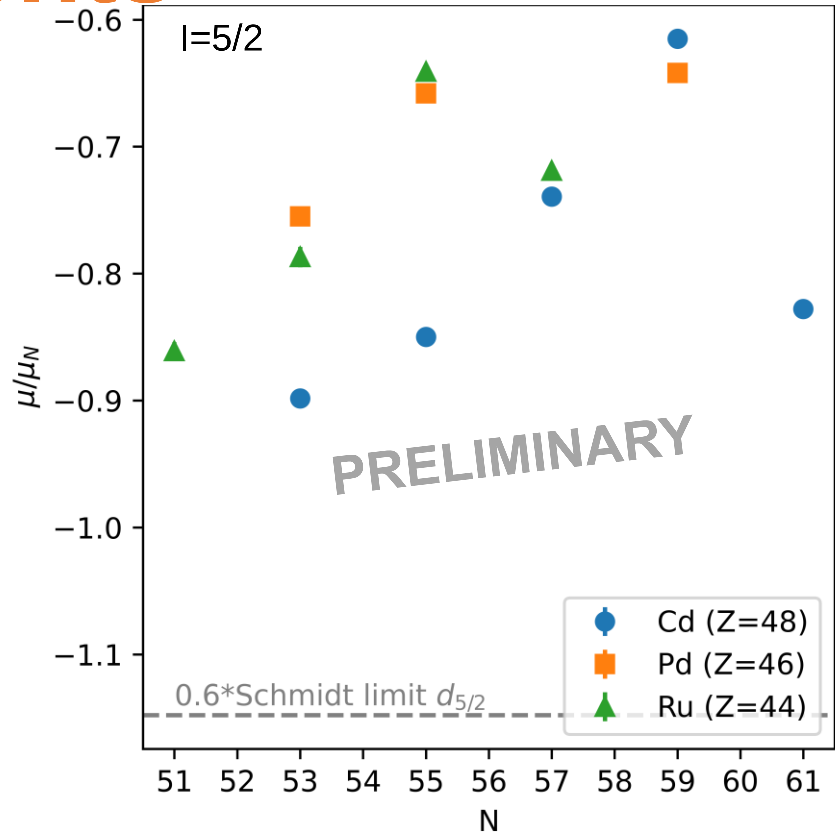
Spins & magnetic dipole moments

Spin 5/2 confirmed for ^{99,101,113}Pd

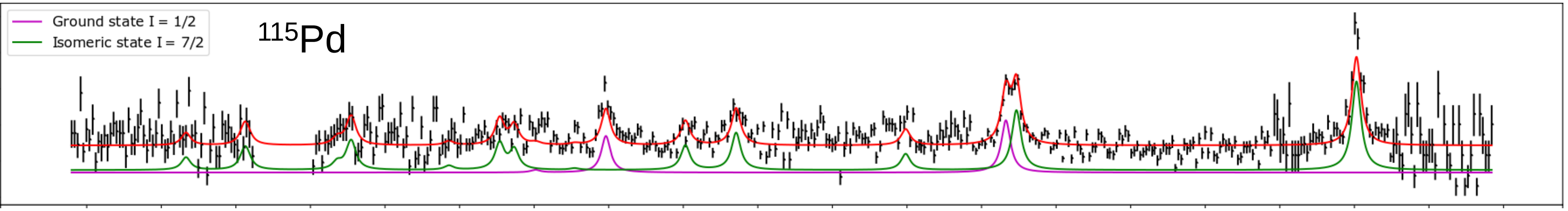








Spins 1/2 and 7/2 assigned to ^{115}Pd ground state and isomer respectively



Trend going up from N=50, away from $d_{5/2}$ Schmidt limit

In Cd: simultaneous filling of $g_{7/2}$ (and $d_{3/2}$ / $s_{1/2}$) with positive magnetic dipole moments

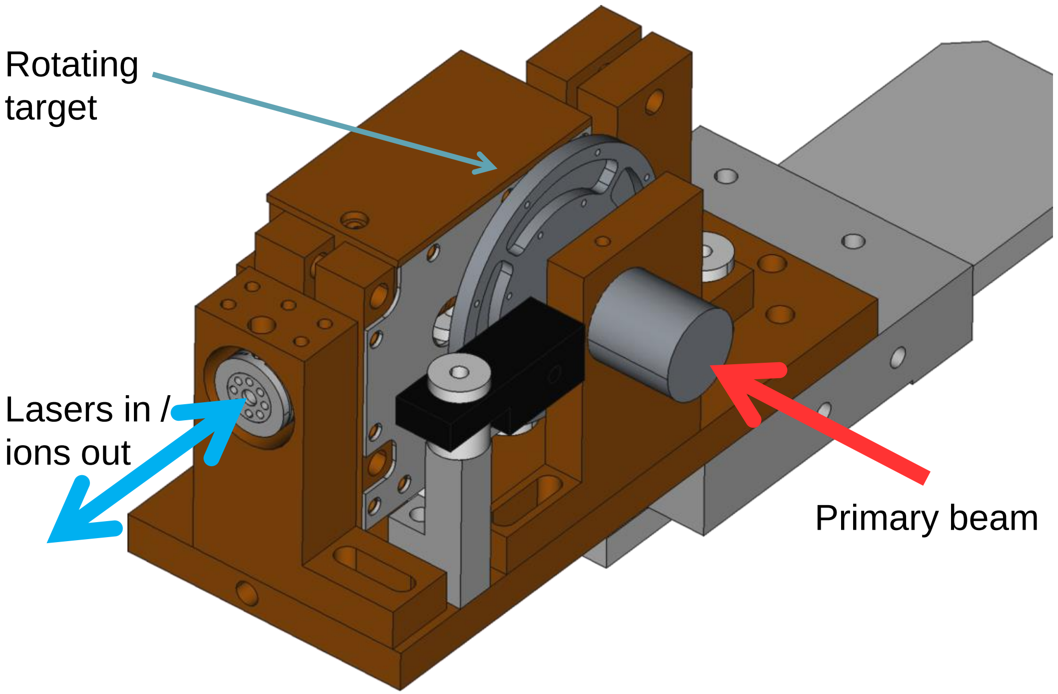
A. Ortiz-Cortes et al., to be submitted

Perspectives

Push towards n-deficient isotopes using hot-cavity ion source

- Successful production and mass measurements recently
- In-source laser spectroscopy difficult, use RAPTOR?

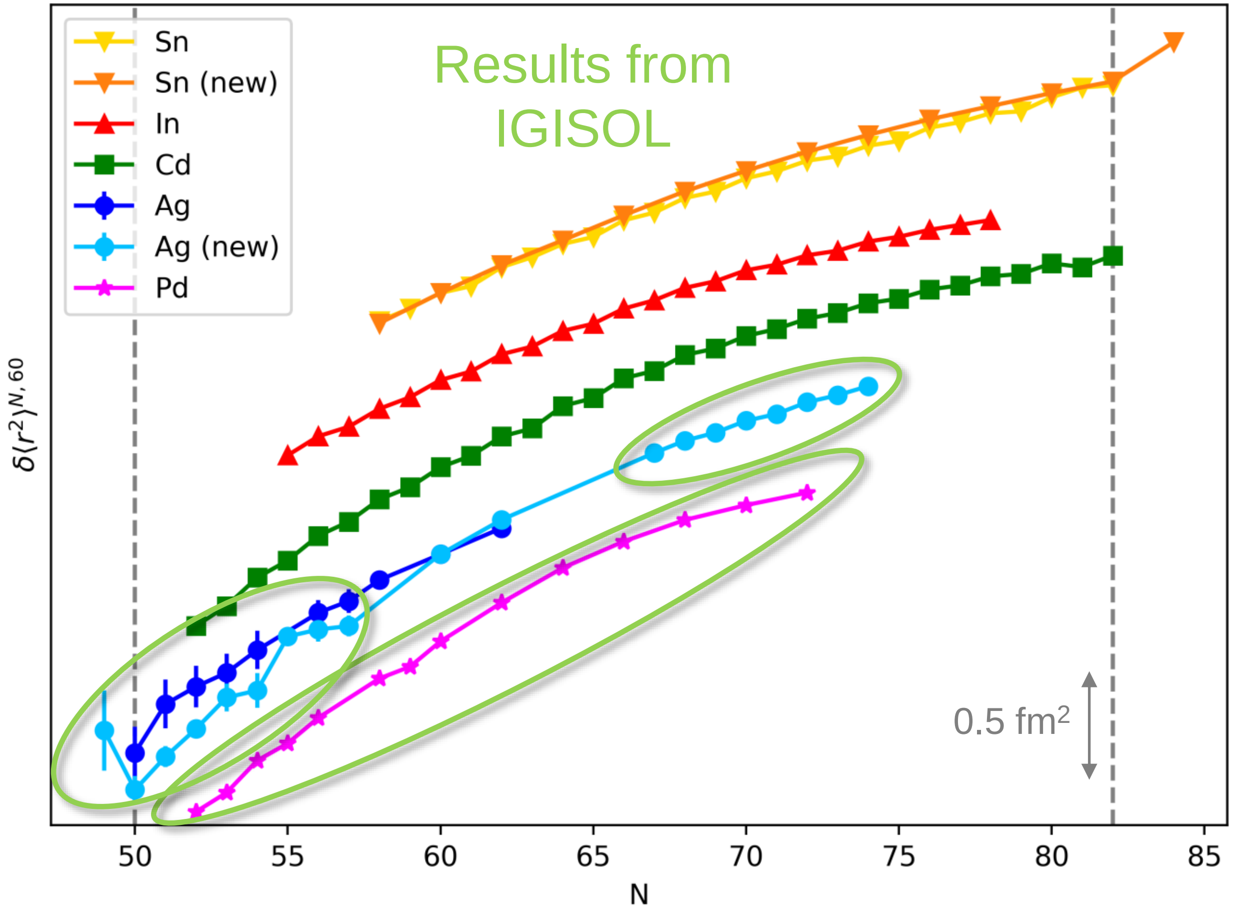
See poster S. Kujanpää



See poster
S. Chinthakayala
(and talk V. Virtanen)

Based on M. Reponen et al., Rev. Sci. Instrum. 86 (2015)

Conclusion



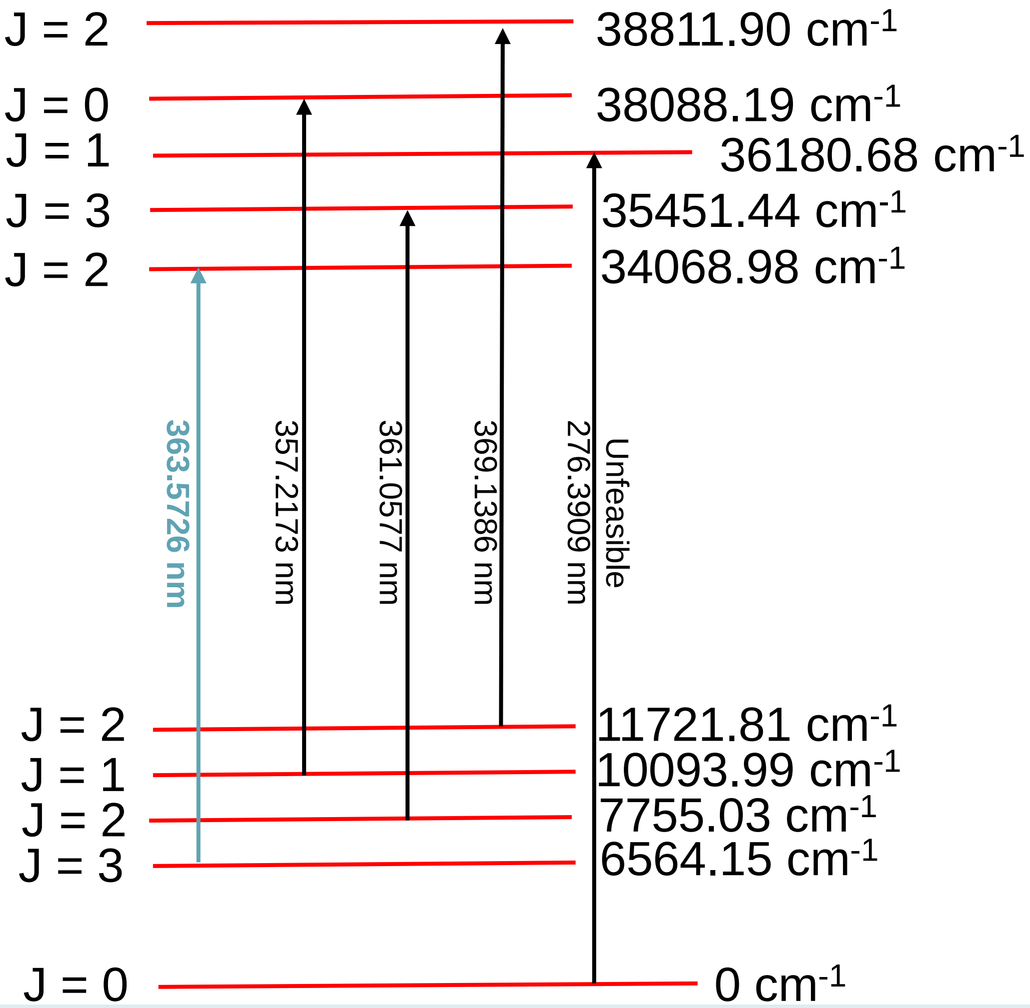
- First laser spectroscopy of unstable Pd, first application of Fayans EDF to well-deformed nuclei
- Fy(Δr, HFB) performs well, but overestimates OES
- Allowing for triaxial shapes improves calculated charge radii, but difficult to pinpoint effect
- Odd-A spins established
- N=Z ‘reached’, to be studied

***Sn, In, Ag**: I. Angeli & K.P. Marinova, At. Data Nucl. Data Tables 99, 69 (2013)*
***Sn**: C. Gorges et al., Phys. Rev. Lett. 122, 192502 (2019)*
***Ag**: M. Reponen et al., Nat. Commun. 12, 4596 (2021)*
***Cd**: M. Hammen et al., Phys. Rev. Lett. 121, 102501 (2018)*

Thank you for your attention!

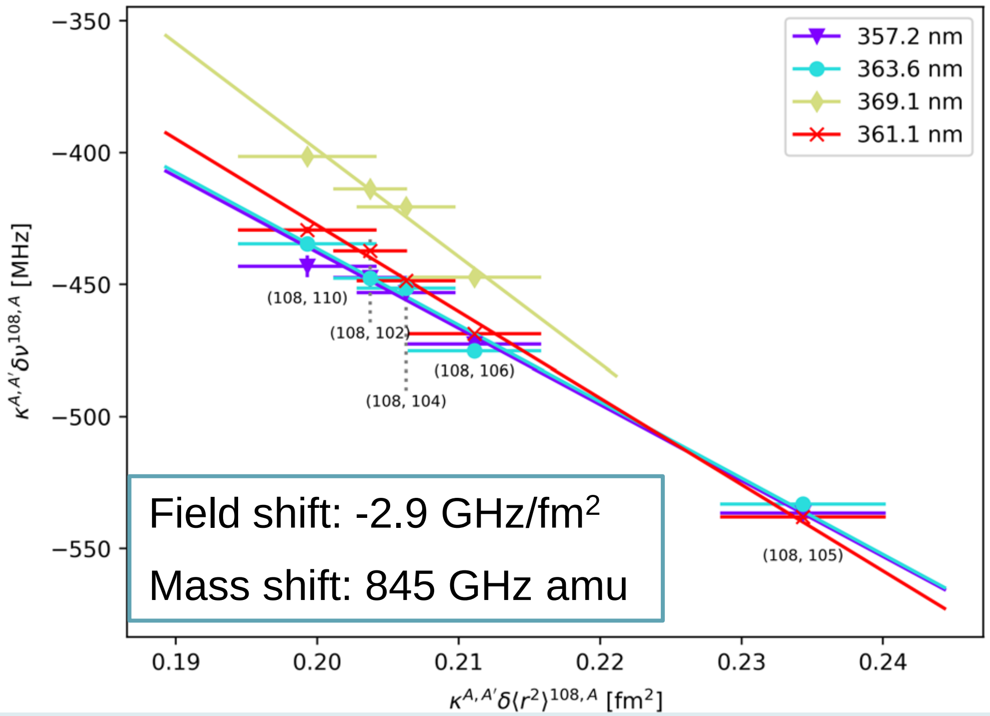
A. Ortiz-Cortes, O. Beliuskina, L. Caceres, P. Campbell, L. Cañete, B. Cheal, K. Chrysalidis, C.S. Devlin, R.P. de Groote, T. Eronen,
Z. Ge, W. Gins, M. Kortelainen, A. Koszorus, S. Kujanpää, D. Nesterenko, F. Nowacki, I. Pohjalainen, I.D. Moore, A. Raggio,
M. Reponen, L.M. Robledo, T.R. Rodríguez, J. Romero, A. de Roubin, H. Salvajols, F. Sommer

Preparation



6 tested transitions from ground and different metastable states populated in charge exchange

King plot technique for calibration of atomic factors



 S. Geldhof et al., Hyperfine Interact 241, 41 (2020)