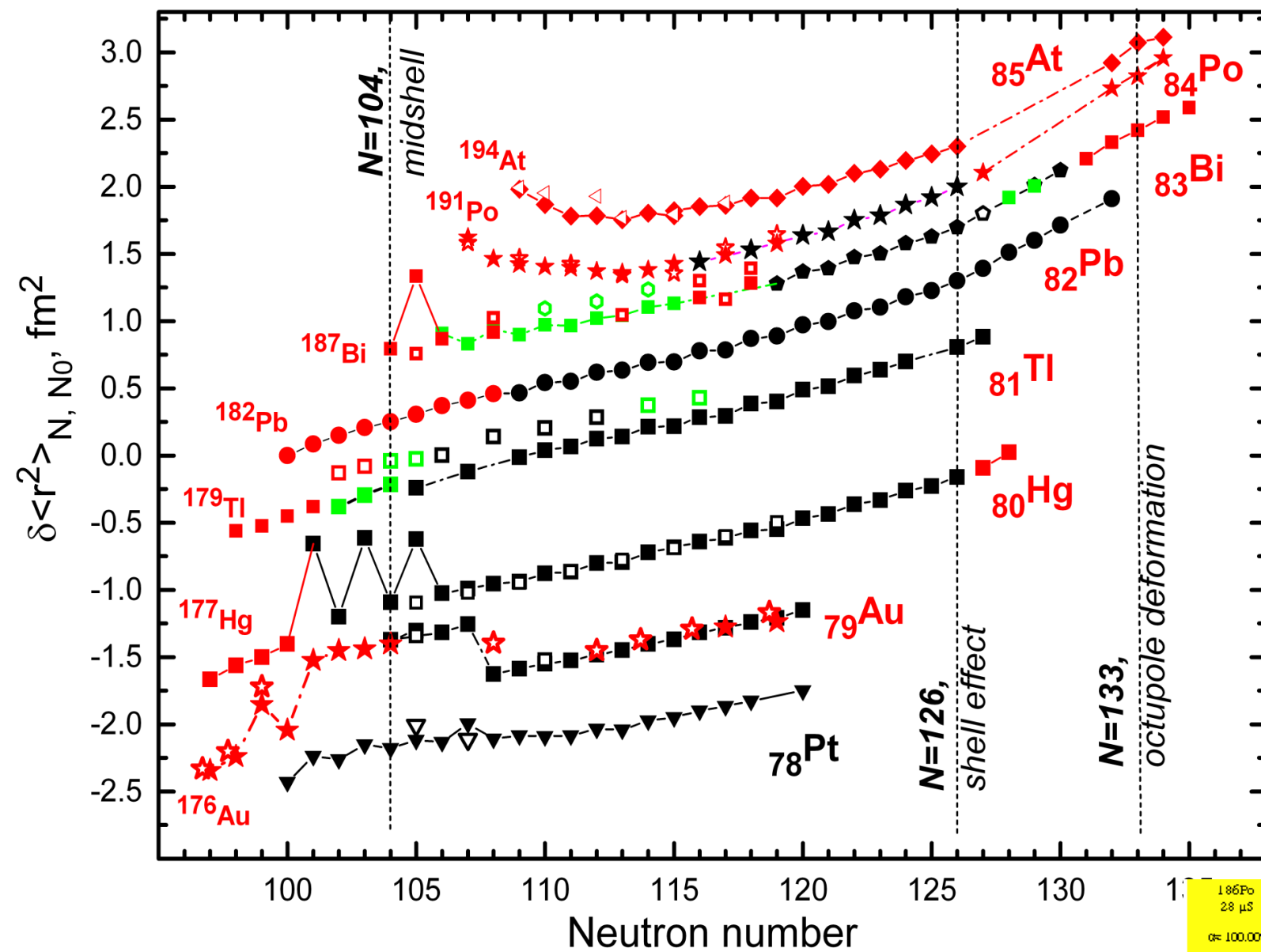


Benefits of 2-GeV protons @ ISOLDE for in-source laser spectroscopy and beta-delayed fission in the lead region.

James Cubiss

On behalf of the Windmill-RILIS-ISOLTRAP-IDS collaboration.

In-source laser spec. in the Pb region

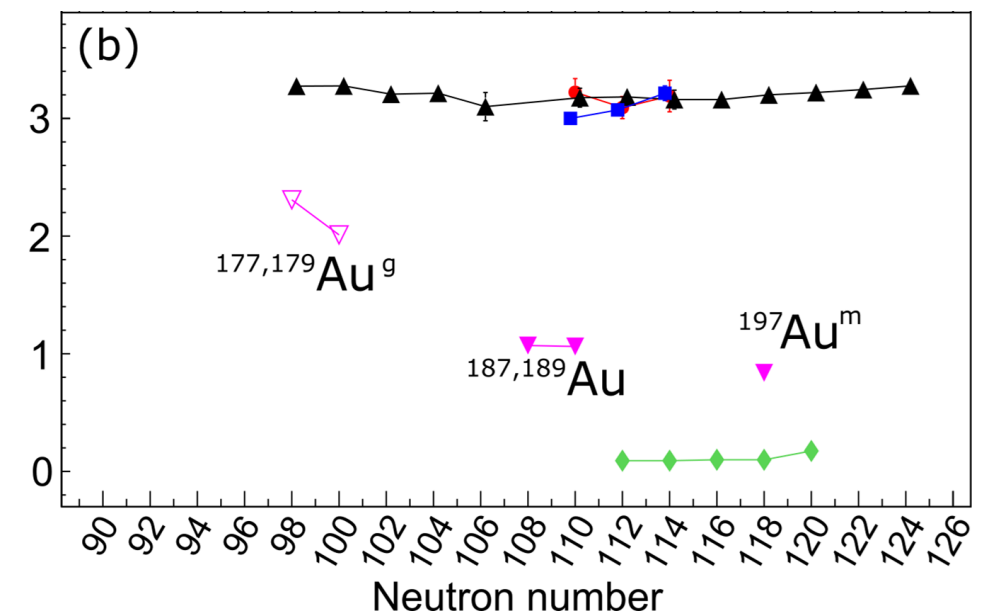
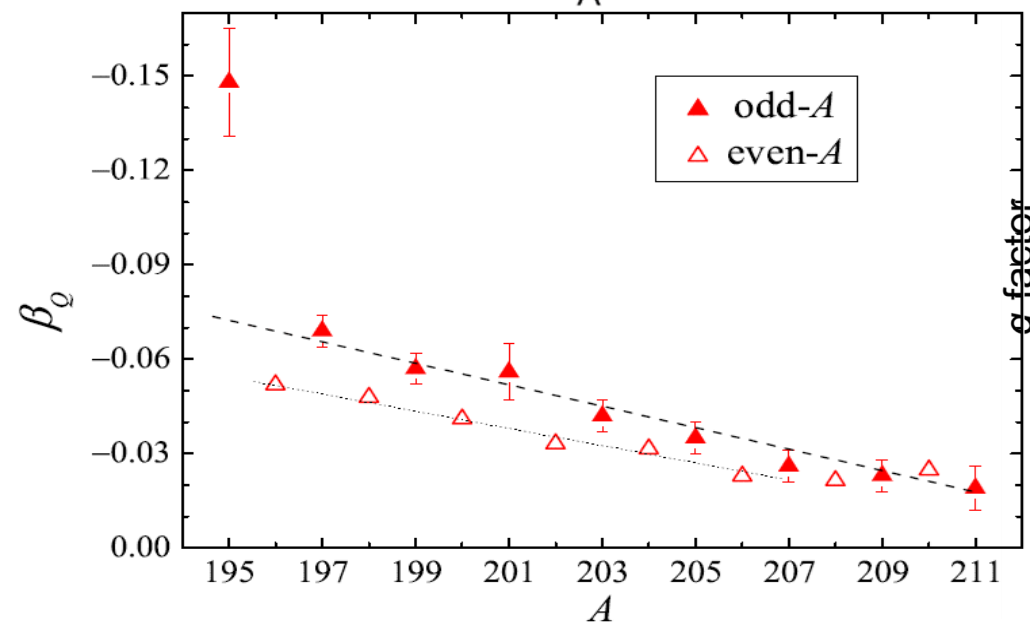
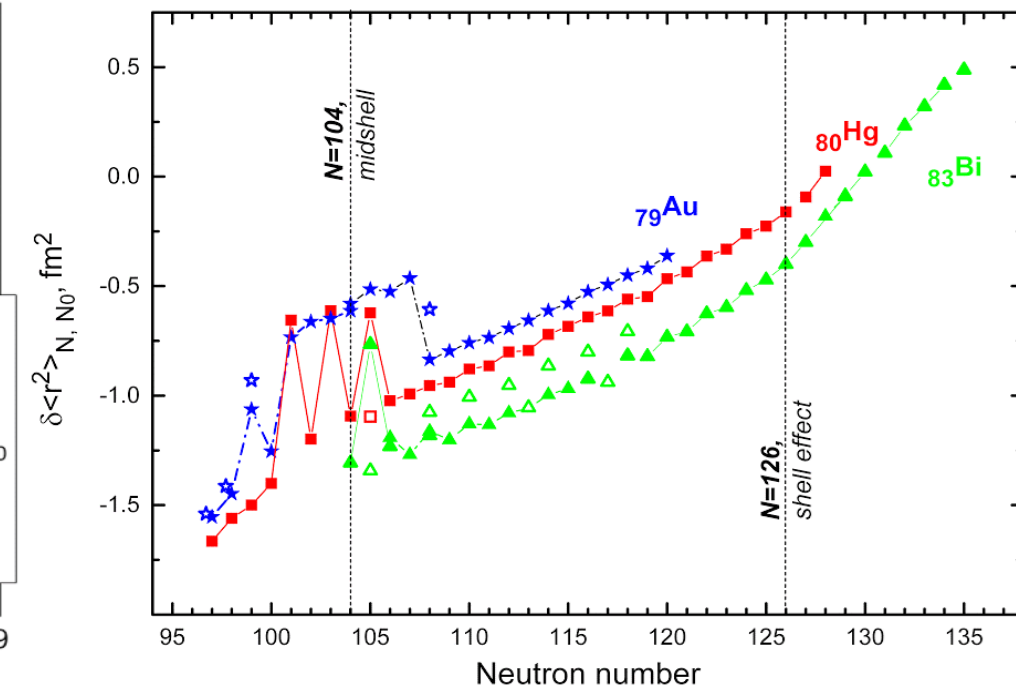
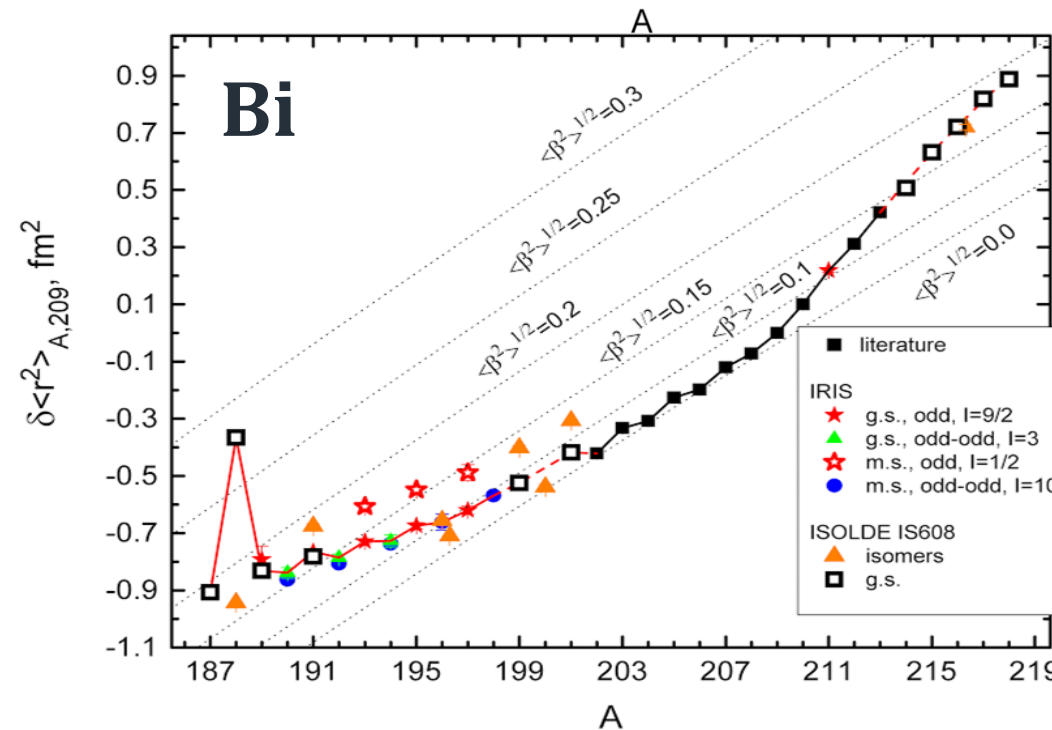
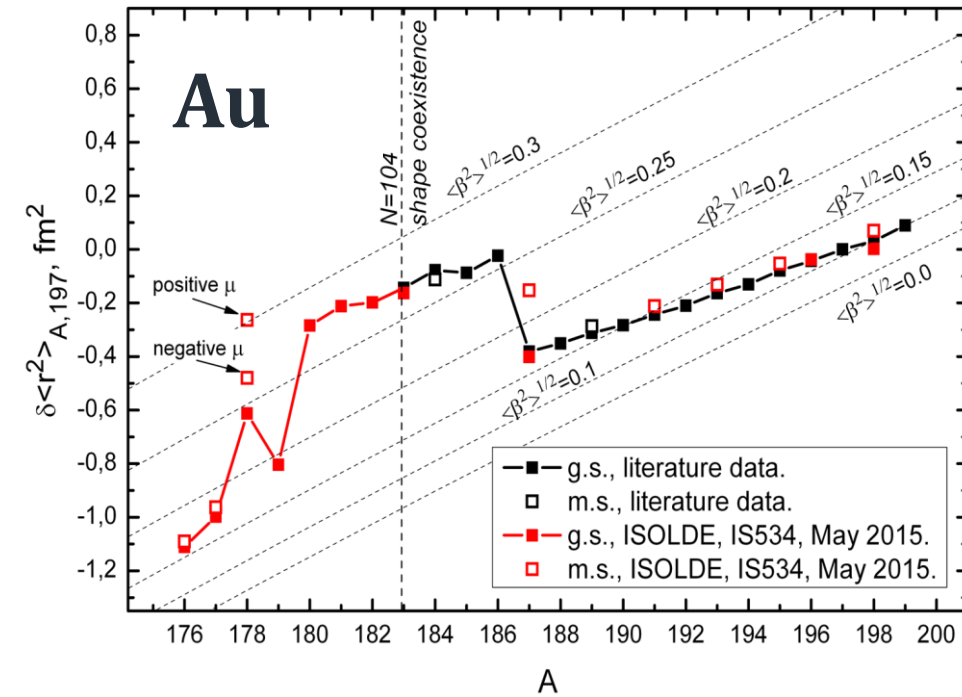
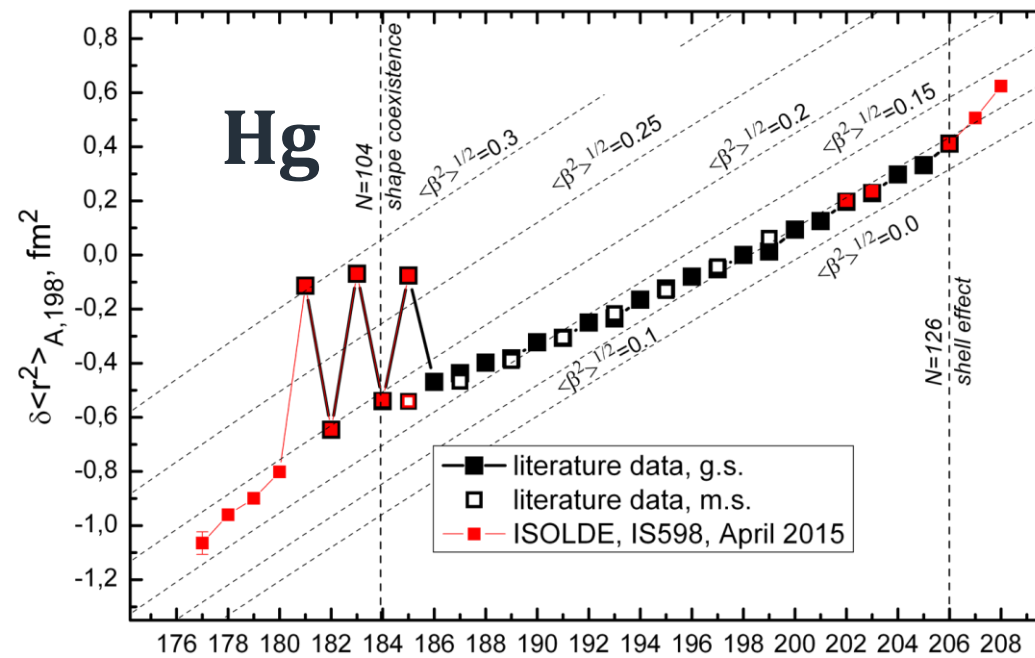


- Technique for studying evolution of deformation and shape coexistence in atomic nuclei.
- Extensive campaign over the past 10 years.
- Very successful, isotope shift and hyperfine structures of >70 ground and isomeric states measured so far.
- **RED** data points measured at ISOLDE
RED line the limit we have reached.
- Still a number of outstanding questions.

[illegible]

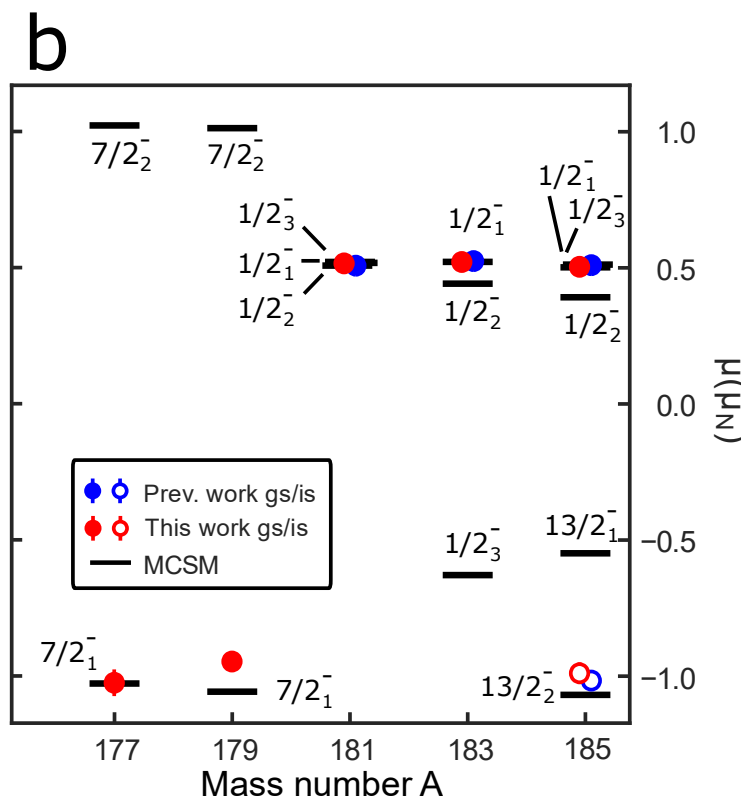
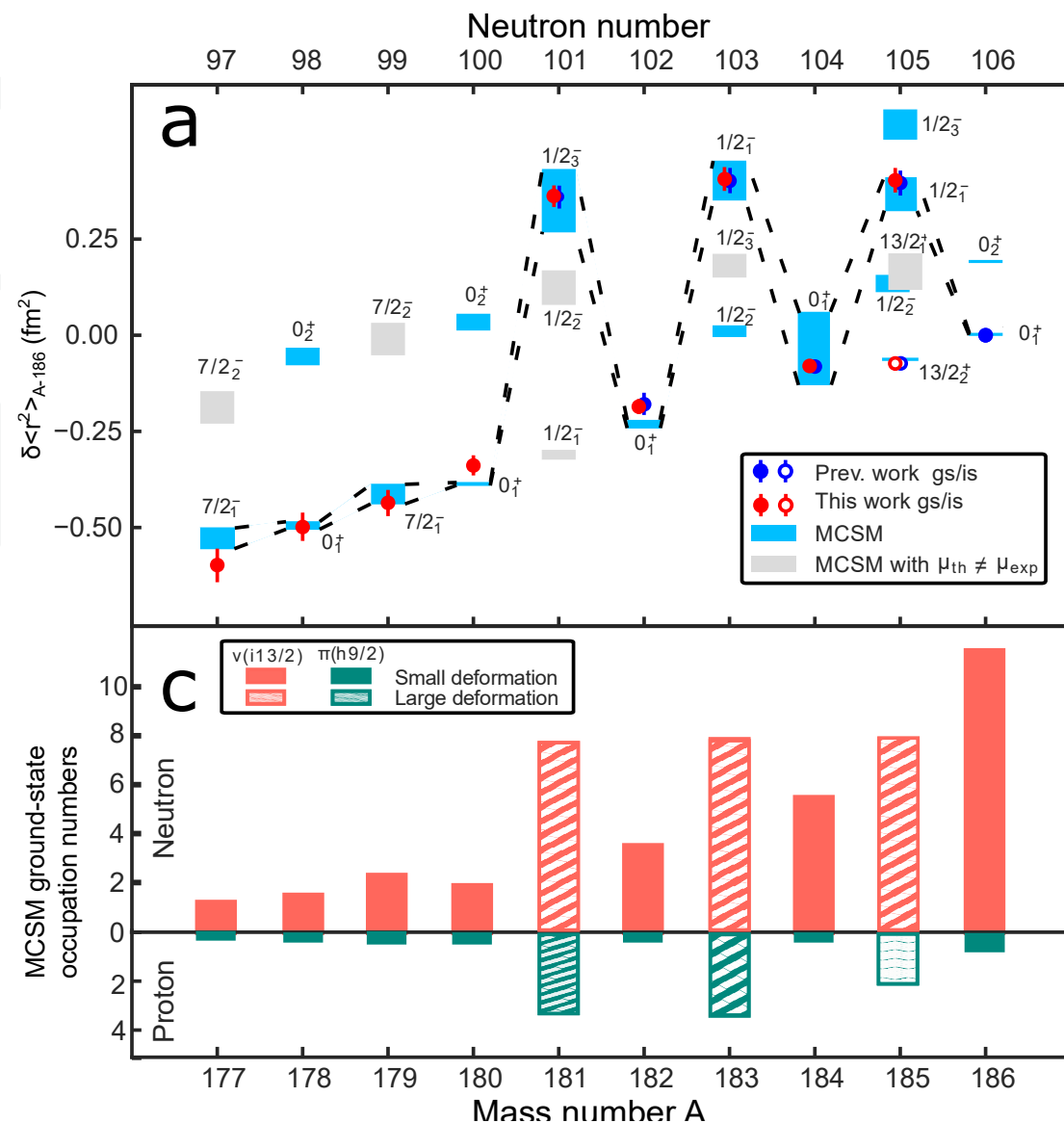
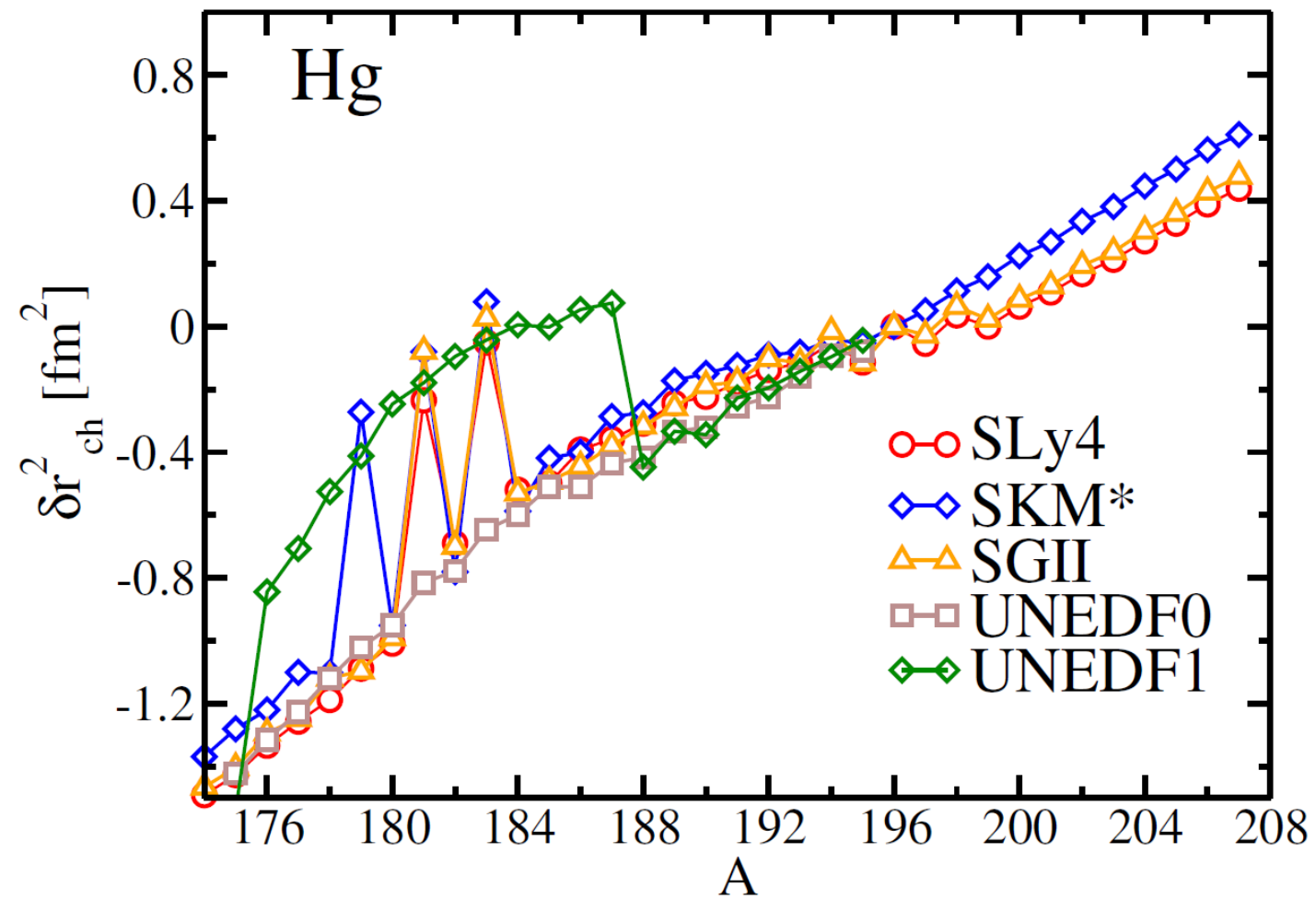
Specific cases

- Measurement of ^{186}Bi is necessary in order to understand if isolated case, or staggering as in the mercury chain.
- In all cases there is a smooth trend as well as dramatic behaviour – does how far does this continue, when does it end?
- In golds either side of deformed region, see mixed $I=1/2$ states, possibly linked to triaxiality?
- In astatine a large jump in deformation (based on Q mom.) is seen, does this continue in the lightest isotopes?



Interest/impact for theoreticians

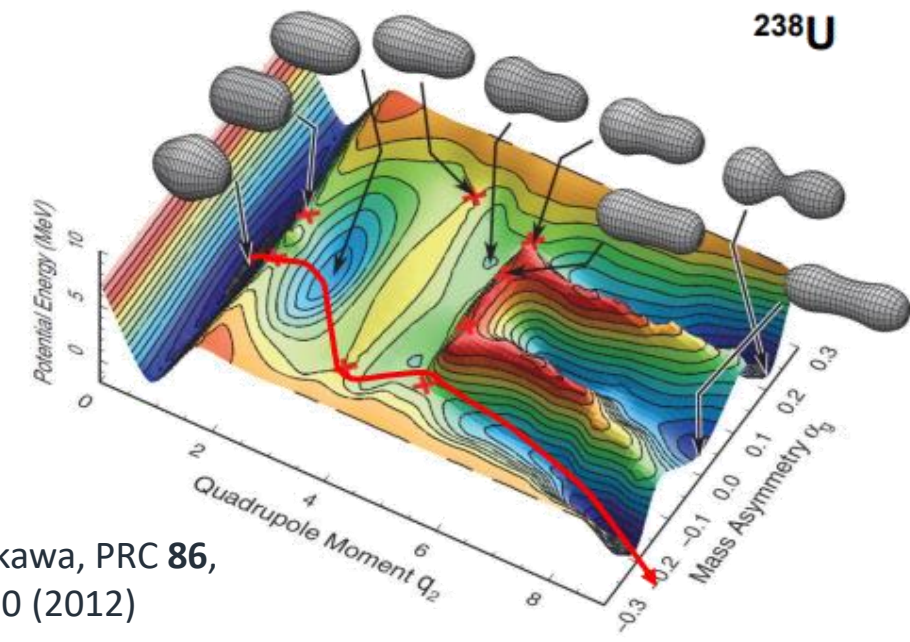
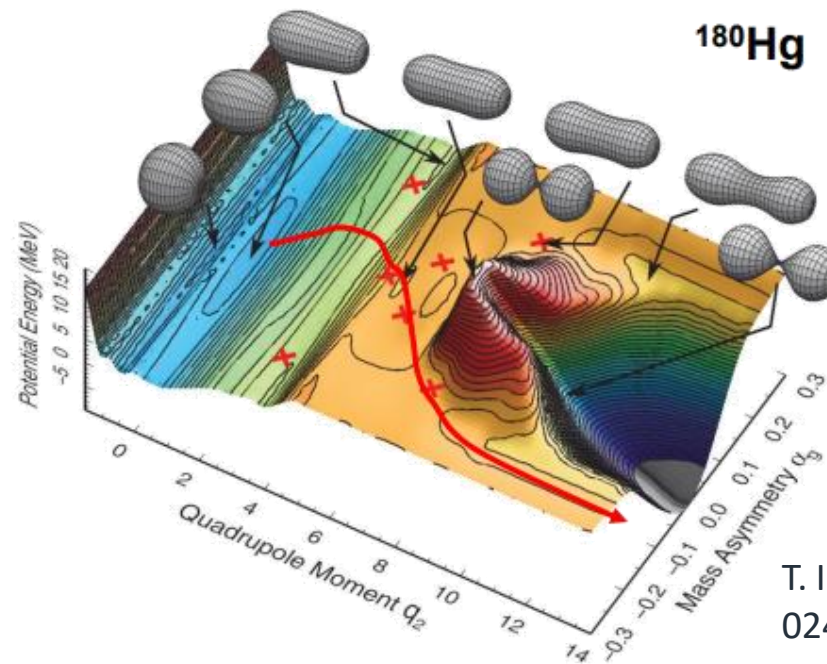
- **Attempts to describe mercury results using two theoretical approaches:**
 - (a) Density Functional theory (DFT)
 - (b) Monte-Carlo shell model (MCSM)
- The presently available functionals **do not allow** for reuniting these three aspects consistently, the essential features of the **effect can be reproduced...**



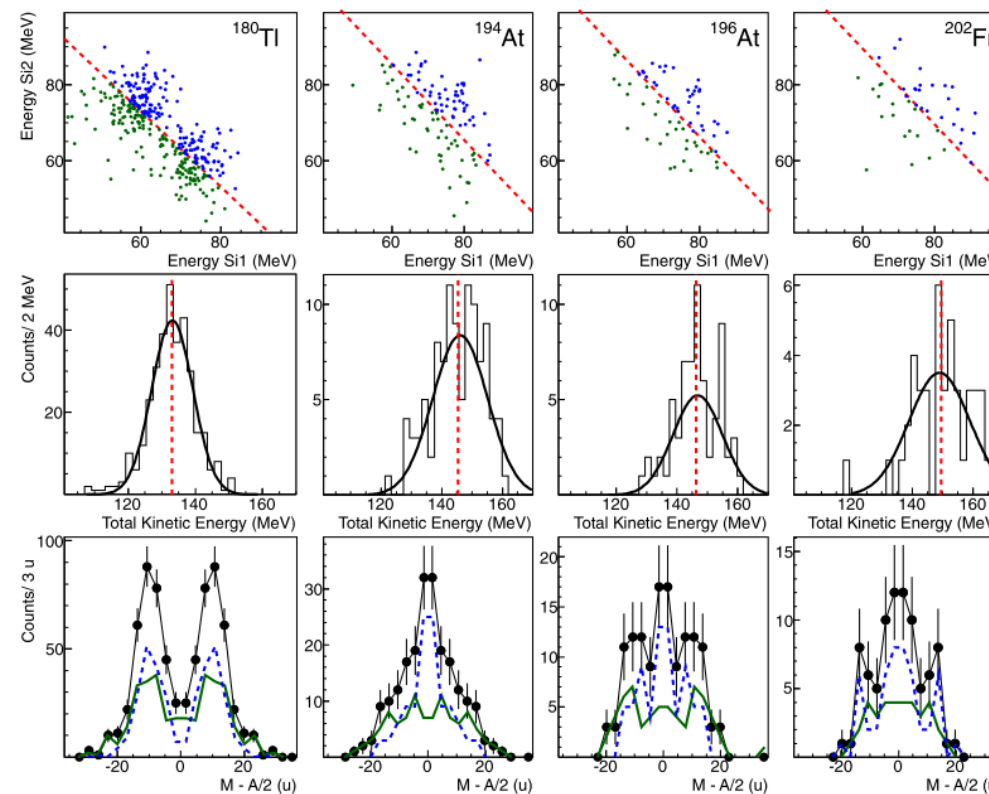
- MCSM can reproduce experiment, however, surprising results! Number of protons & neutrons occupying intruder states much greater than expected!
- **The staggering in Hg is a subtle interplay between:**
 - (i) shape coexistence
 - (ii) pairing strength
 - (iii) deformed shell structure

Beta-delayed fission

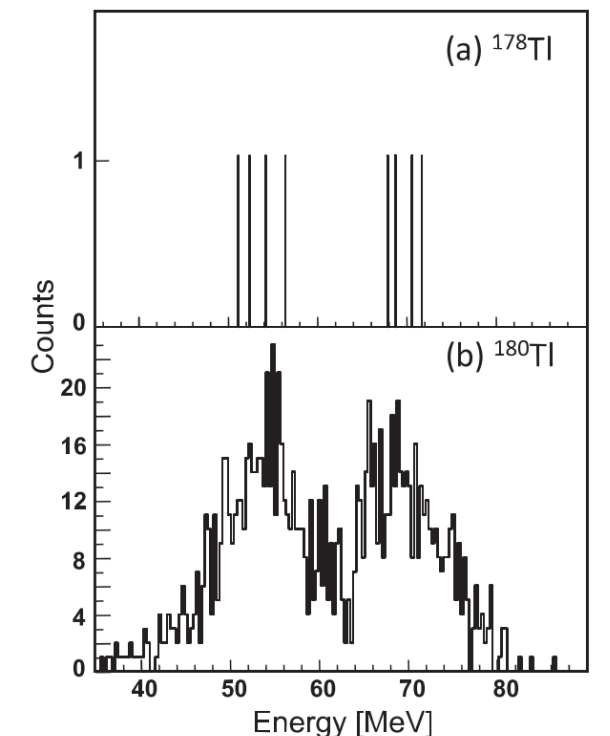
- Also considerable interest from theoretical community since discovery
- Important for understanding of termination points in r-process, and fission recycling in stars.
- A number of studies performed at ISOLDE on both n- and p-rich sides of chart.
- In a number of cases, only low statistics were achieved.
- For n-rich cases we need not only upgrade, but use of Th targets and LIST to help deal with contaminants!



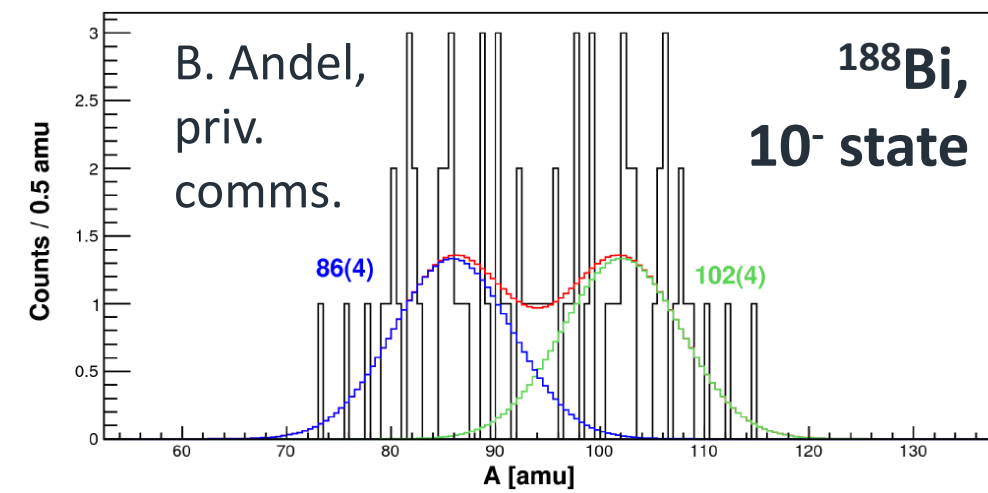
T. Ichikawa, PRC **86**, 024610 (2012)



L. Ghys, PRC **90**, 041301(R) (2014)



V. Liberati, PRC **88**, 044322 (2013)



- New and exciting frontier** – isomerically selective bDF studies now possible at ISOLDE.
- Need more yields! RILIS in narrowband mode significantly reduces the ion production rate!

Future possibilities

- ABRABLA and FLUKA calculations predict **1.5-4 times the production yields** in the p-rich isotopes of interest.
- Limiting factor not only production, but half-lives of isotopes.
- Therefore upgrade to intensity, and target design is also crucial for accessing most exotic cases.

- **BLUE** line represents where we would push for new laser spec. measurements.

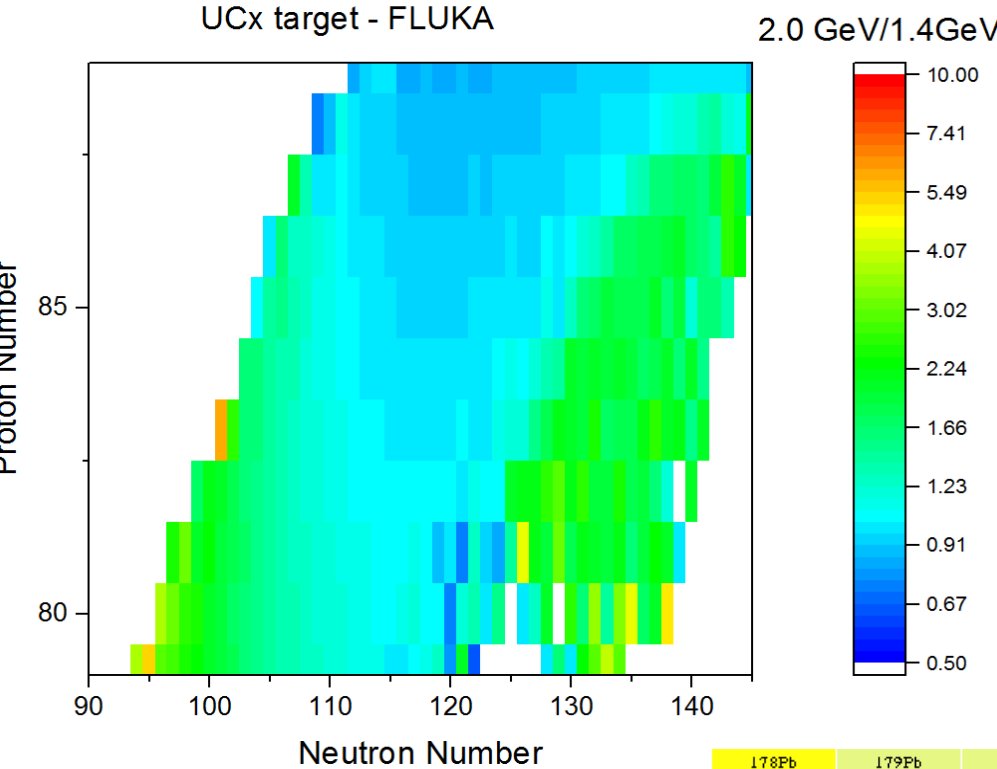
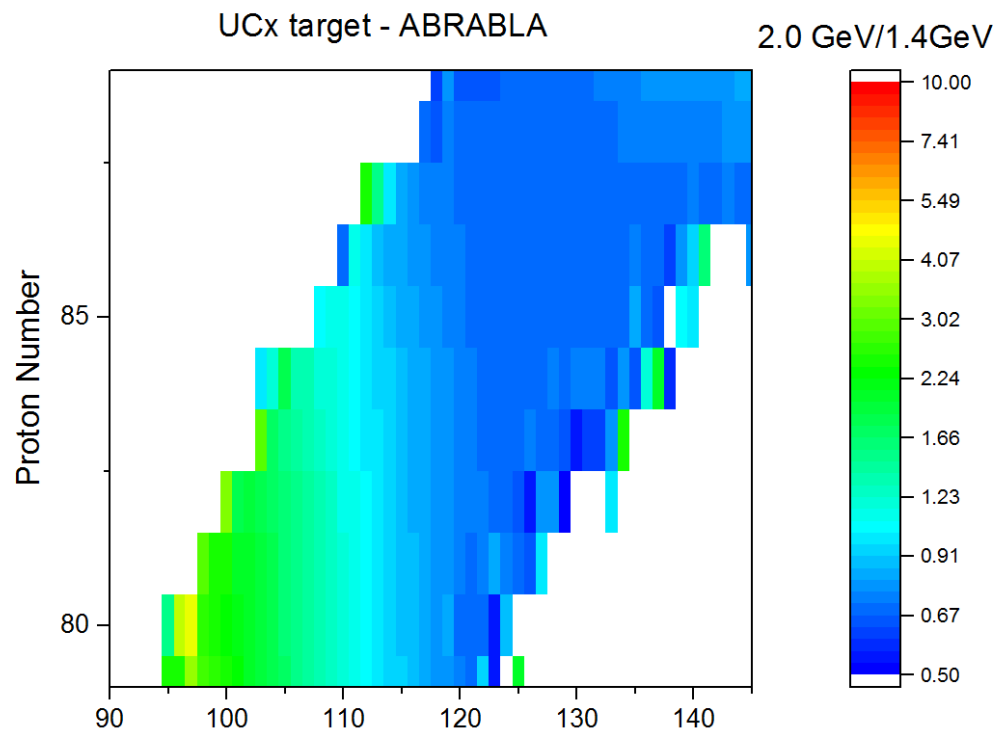
- **Stars and dumbbells** are for important laser spec. and bDF cases.

BLUE achievable with upgrade

GREEN isomeric bdf study possible with upgrade

ORANGE possible $T_{1/2}$ issue, may be possible

RED probably $T_{1/2}$ prohibited



Calculations courtesy of
J.P. Ramos – GUI May 2018

