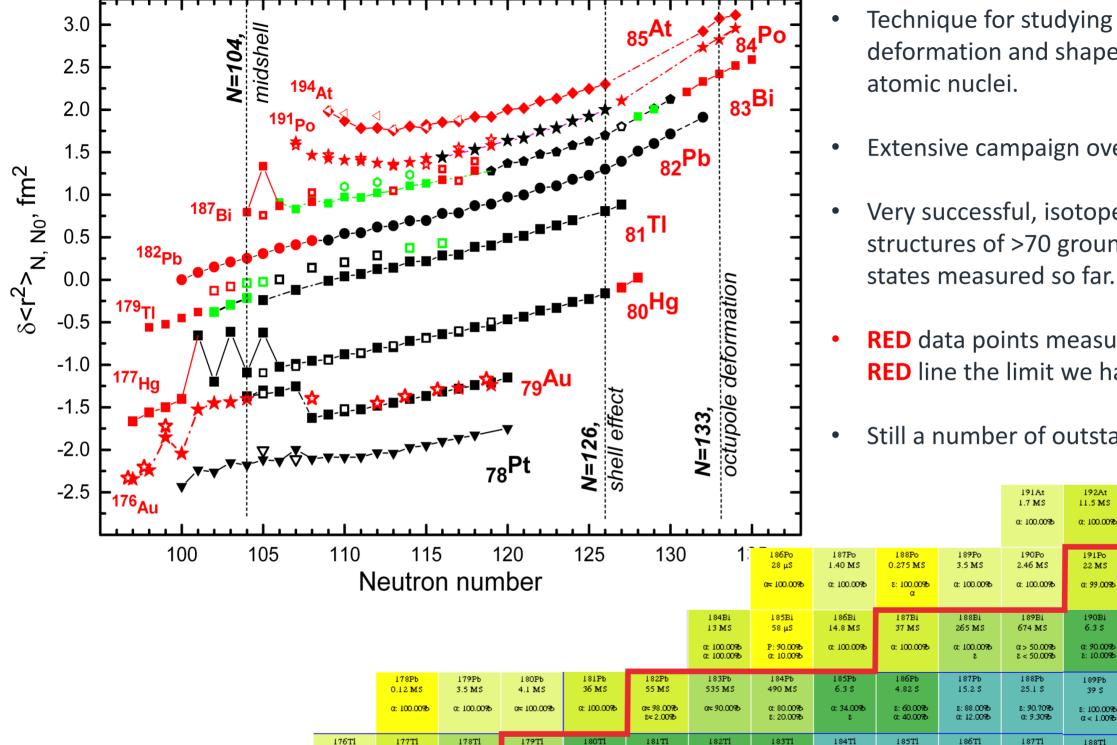
# Benefits of 2-GeV protons @ ISOLDE for insource laser spectroscopy and betadelayed fission in the lead region.

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

#### In-source laser spec. in the Pb region



α: 100.00%

α: 100.00%

171Au 17 μS

α: 100.00%

26.3 MS

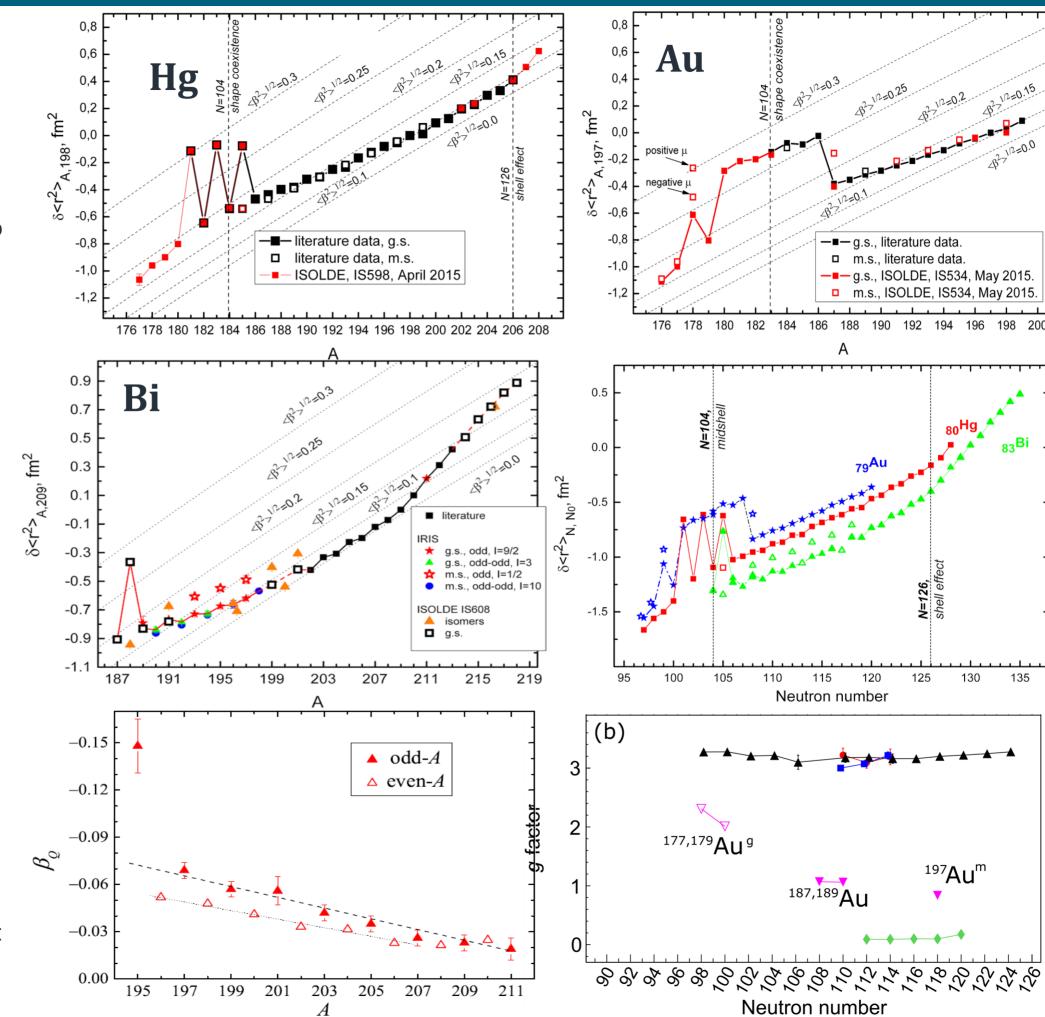
- Technique for studying evolution of deformation and shape coexistence in
- Extensive campaign over the past 10 years.
- Very successful, isotope shift and hyperfine structures of >70 ground and isomeric
- **RED** data points measured at ISOLDE **RED** line the limit we have reached.
- Still a number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

				<b>&gt;</b>			<u>-</u>				191At 1.7 MS 0: 100.00%	192At 11.5 MS α: 100.00%	193At 28 MS 0: 100.00%	194At 310 MS α	195At 290 MS 0: 100.00%	196At 0.388 S c≈ 95.10% ε: @ 4.90%
110	115	5 1	20	125	130	1	186Ро 28 µS	187Po 1.40 MS	188Po 0.275 MS	189Po 3.5 MS	190Po 2.46 MS	191Po 22 MS	192Po 32.2 MS	193Po 245 MS	194Po 0.392 S	195Po 4.64 S
Neutron number							a≈ 100.00%	a: 100.00%	s: 100.00% a	a: 100.00%	a: 100.00%	a: 99.00%	0≂ 99,50% 8≂ 0,50%	as 100.00%	a: 100.00% 8	a: 94.00% 8: 4.00%
						184Bi 13 <b>M</b> S	185Bi 58 μS	186Bi 14.8 <b>M</b> S	187Bi 37 MS	188Bi 265 MS	189Bi 674 MS	190Bi 6.3 S	191Bi 12.4 S	192Bi 34.6 S	193Bi 63.6 S	194Bi 95 S
						a: 100.00% a: 100.00%	P: 90.00% a: 10.00%	a: 100.00%	a: 100.00%	a: 100.00% E	a> 50.00% 8 < 50.00%	a: 90,00% a: 10,00%	0: 51.00% 8: 49.00%	8: 88,00% 0: 12,00%	8: 96,50% 0: 3,50%	8: 99.54% 0: 0.46%
	178Pb 0.12 MS	179Pb 3.5 MS	180Pb 4.1 <b>M</b> S	181Pb 36 MS	182Pb 55 MS	183Pb 535 <b>M</b> S	184Pb 490 MS	185Рb 6.3 S	18бРь 4.82 S	187РЬ 15.2 S	188Рь 25.1 S	189Pb 39 S	190Pb 71 S	191Pb 1.33 M	192Pb 3.5 M	193Pb 5.8 M
	a: 100.00%	a: 100.00%	o≂ 100.00%	a: 100.00%	o≂ 98,00% 8≂ 2,00%	a≂ 90.00%	a: 80.00% 8: 20.00%	a: 34,00% E	ଃ: 60.00% α: 40.00%	8: 88,00% 0: 12,00%	8: 90.70% 0: 9.30%	8: 100.00% 0 < 1.00%	8: 99.60% 0: 0.40%	8: 99.99% 0: 0.01%	8: 99.99% 0: 5.9E-3%	8
176Tl 5.2 MS	177Tl 18 MS	178Tl 254 MS	179Tl 0.23 S	180Tl 1.09 S	181 <b>Tl</b> 3.2 S	182Tl 3.1 S	183Tl 6.9 S	184Tl 10.1 S	185Tl 19.5 S	186Tl 27.5 S	187Tl ≃51 S	188Tl 71 S	189Tl 2.3 M	190Tl 2.6 <b>M</b>	191Tl 5.22 <b>M</b>	192Tl 9.6 <b>M</b>
P: 100,00%	a: 73.00% P: 27.00%	o≂ 53.00% 5≂ 47.00%	a < 100.00% E	8: 94,00% 0: 6,00%	as 10.00% E	8: 97.50% 0 < 5.00%	ε> 0.00% α	8: 97.90% 0: 2.10%	8	a: 100.00% o≈ 6.0E-3%	8: 100.00% 0≈ 0.03%	s: 100.00%	s: 100.00%	s: 100.00%	s: 100.00%	s: 100.00%
175Hg 10.6 <b>M</b> S	176Hg 20.3 <b>M</b> S	177Hg 118 MS	178Hg 266.5 <b>M</b> S	179Hg 1.05 S	180Hg 2.59 S	181Hg 3.6 S	182Hg 10.83 S	183Hg 9.4 S	184Hg 30.87 S	185Hg 49.1 S	186Hg 1.38 M	187Hg 1.9 <b>M</b>	188Hg 3.25 <b>M</b>	189Hg 7.6 M	190Hg 20.0 <b>M</b>	191Hg 49 M
a: 100.00%	a: 94.00%	a: 100.00%	a≈ 70.00% a≈ 30.00%	a: 55,00% a: 45,00%	8: 52,00% 0: 48,00%	8: 73.00% 0: 27.00%	8: 86,20% 0: 13,80%	8: 88,30% 0: 11,70%	8: 98.89% 0: 1.11%	8: 94.00% 0: 6.00%	8: 99.98% 0: 0.02%	8: 100.00% α < 3.7E-4%	8: 100.00% 0: 3.7E-5%	s: 100.00% α < 3.0E-5%	s: 100.00% α < 3.4E-7%	8: 100.00% 0: 5.0E-6%
174Au 139 MS	175Au 156 MS	176Au 1.05 S	177Au 1.53 S	178Au 2.6 S	179Au 7.1 S	180Au 8.4 S	181Au 13.7 S	182Au 15.5 S	183Au 42.8 S	184Au 20.6 S	185Au 4.25 <b>M</b>	186Au 10.7 <b>M</b>	187Au 8.4 M	188Au 8.84 M	189Au 28.7 M	190Au 42.8 M
a > 0.00%	α ε	α	s: 60.00% ග: 40.00%	as 60.00% ca 40.00%	8: 78.00% 0: 22.00%	ε < 98.20% α > 1.80%	8: 97.30% 0: 2.70%	ε: 99,87% α: 0.13%	8: 99,45% 0: 0.55%	8: 100.00% 03: 0.02%	ε: 99.74% α: 0.26%	8: 100.00% 0: 8.0E-4%	8: 100.00% 0: 3.0E-3%	s: 100.00%	8: 100.00% 0 < 3.0E-5%	a: 100.00% a < 1.0E-69

# Specific cases

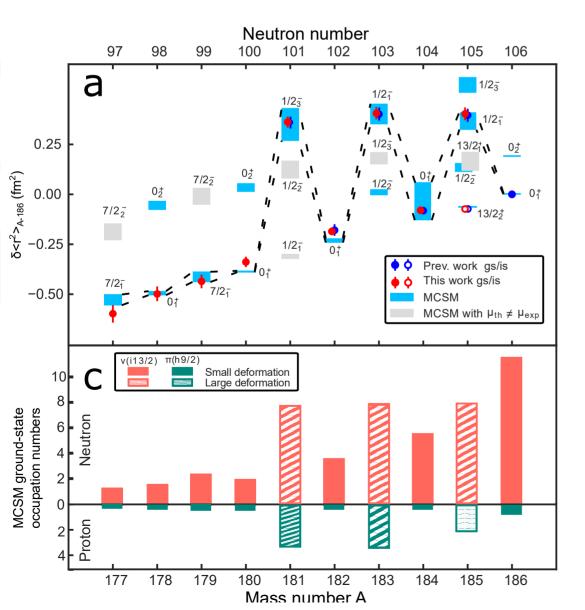
- Measurement of <sup>186</sup>Bi
  is necessary in order to
  understand if isolated
  case, or staggering as
  in the mercury chain.
- In all cases there is a smooth trend as well as dramatic behaviour

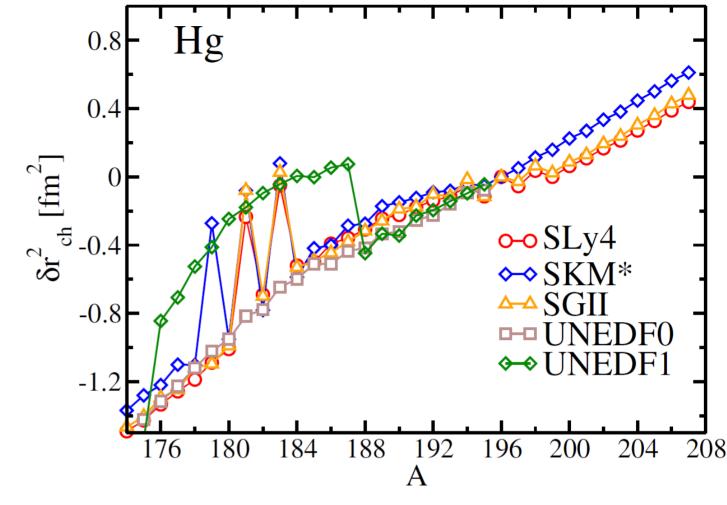
   does how far does this continue, when does it end?
- In golds either side of deformed region, see mixed I=1/2 states, possibly linked to triaxiality?
- In astatine a large jump in deformation (based on Q mom.) is seen, does this continue in the lightest isotopes?

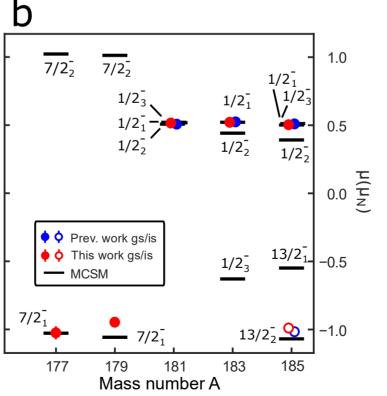


## Interest/impact for theoreticians

- Attempts to describe mercury results using two theoretical approached:
  - (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...



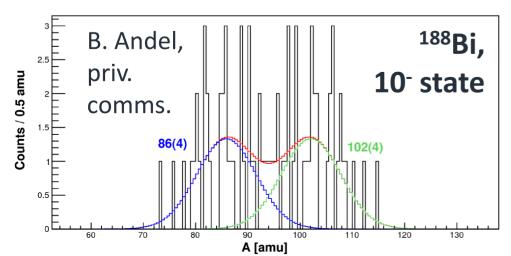


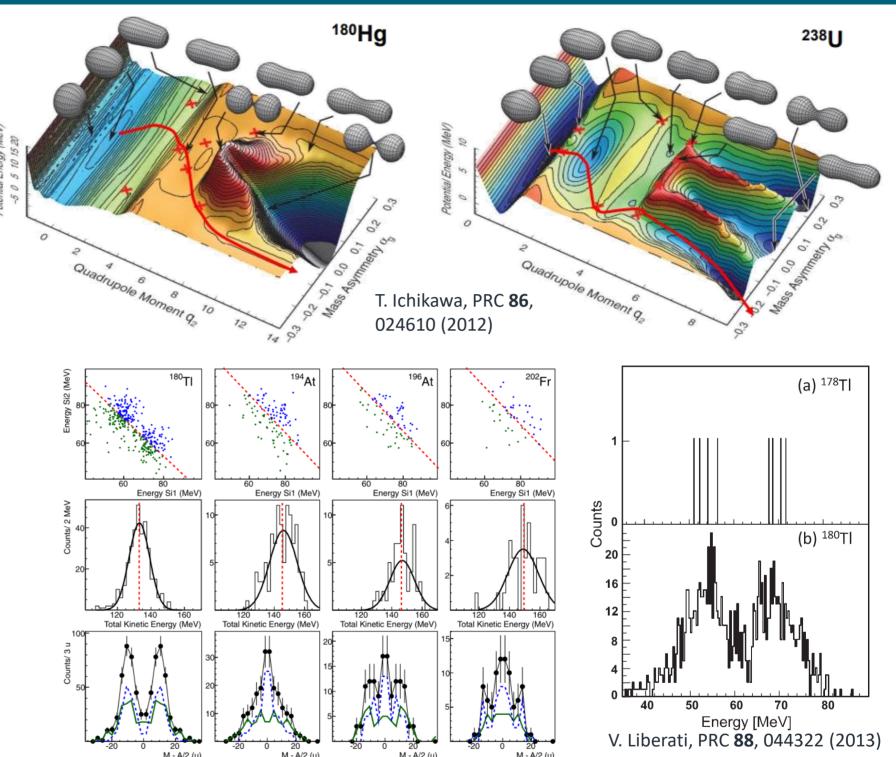


- MCSM can reproduce experiment, however, surprising results! Number of protons & neutrons occupying intruder states much greater than expected!
- The staggering in Hg is a subtle interplay between:
  - (i) shape coexistence
  - (ii) pairing strength
  - (iii) deformed shell structure

### 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!





 New and exciting frontier – isomerically selective bDF studies now possible at ISOLDE.

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

 Need more yields! RILIS in narrowband mode significantly reduces the ion production rate!

