Nuclear Structure Studies with a RTC

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The use of a compound nucleus separator (such as the Berkeley Gas-filled Separator) with a Recoil Transfer Chamber (RTC) for gas-jet transport of the separated heavy element products to a low-background location for γ- and α-particle spectroscopy presents new capabilities for studies of the nuclear structure of heavy element isotopes.

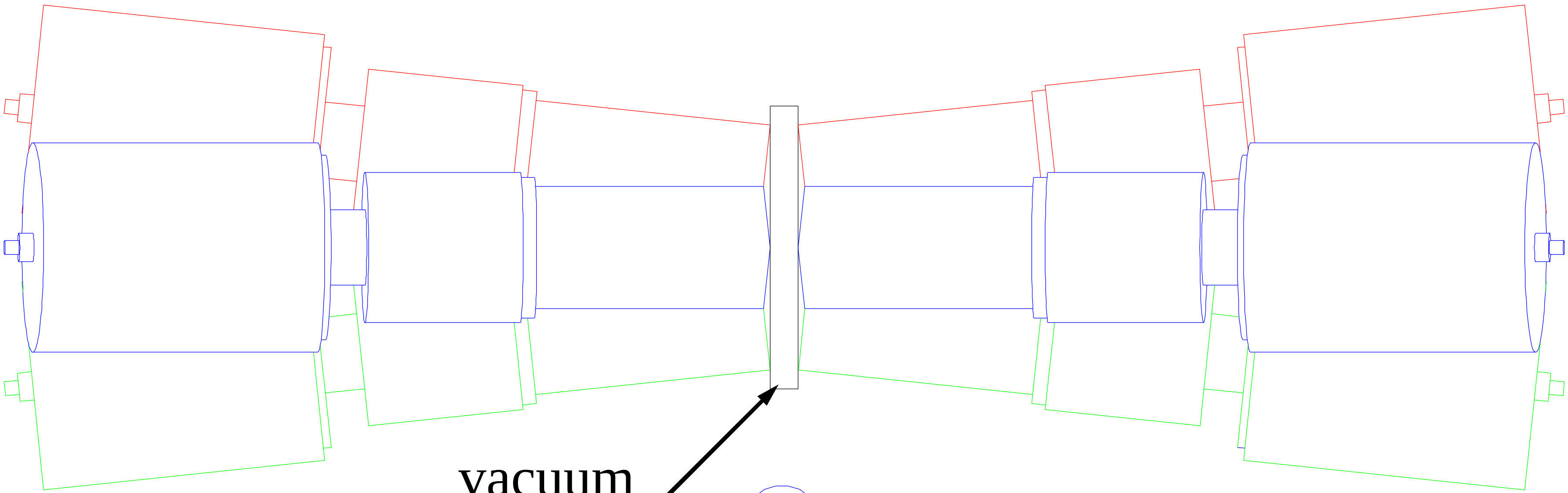
1) Detection system schematic

2) Nuclear structure experiments

Recoil Transfer Chamber v.3

Smaller volume (344 cm^3) . . . transport time < 10s, faster with inserts
Thinner MYLAR (1.5 μm) . . . actinide targets with A > 20 projectiles

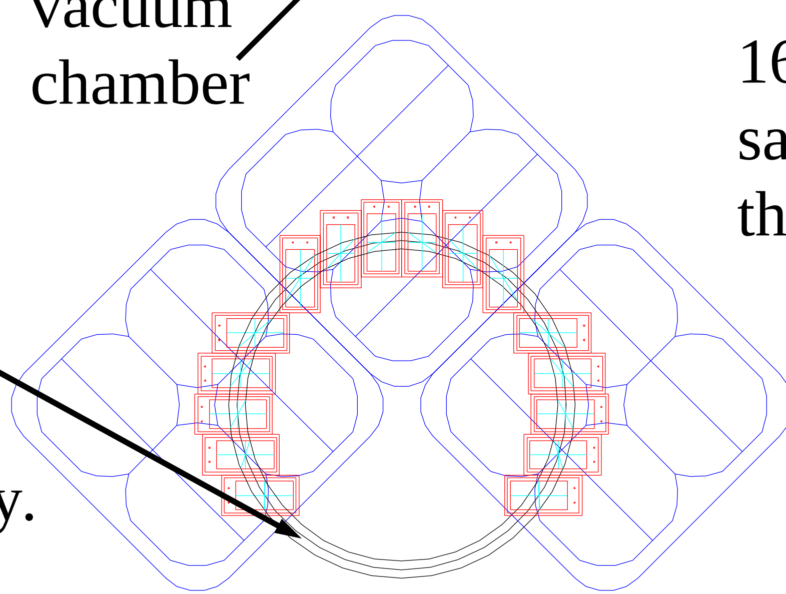
pin-diode and clover detector arrangement: high efficiency for γ and α detection



vacuum chamber

6 Clover detectors can be used at the 88-Inch Cyclotron.

16 pairs of pin diodes sandwich wheel with thin MYLAR foils



Gas-jet enters here. Wheel rotates step-wise or continuously.

Collection radius can vary to prevent mass buildup

An Example of Physics Possible with Separation followed by transport to a shielded detector station

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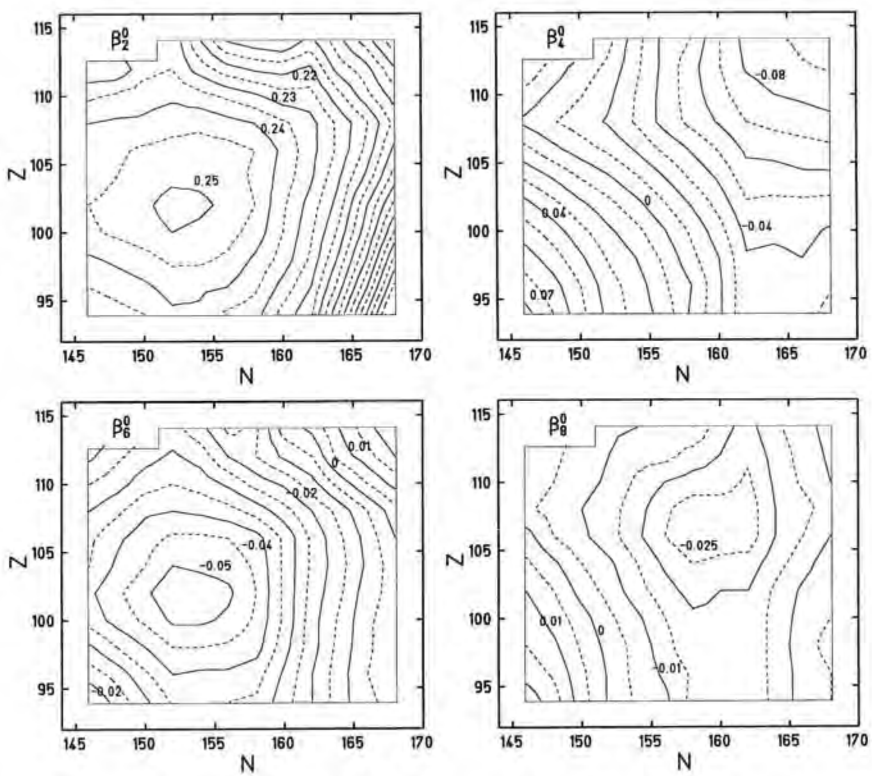
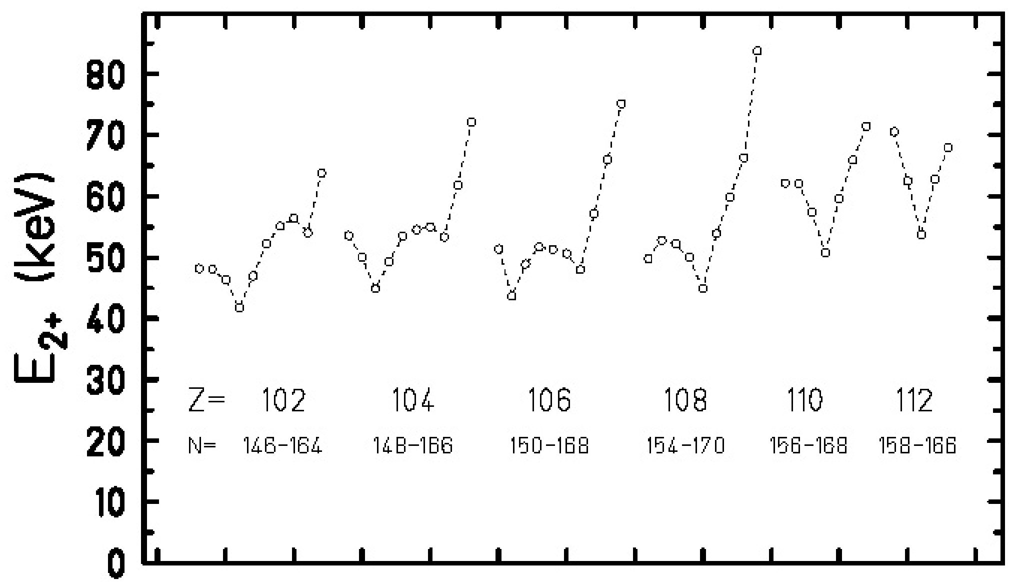
Prediction of Heavy Element Shapes According to Muntian and Sobiczewski

Acta Phys. Pol. B 32 (2001) 629

β_2 deformations near N=152, Z=102
β_8 deformations near N=162, Z=108

Predicted E_{2+} energies show minima at N=152 and N=162 (positions of maximum deformation) and a trend toward sphericity above N=162.





How can we measure E_{2+}?

α spectroscopy with sufficient resolution to see rotational spectra is difficult

Low-lying rotational transitions are strongly converted

Conversion electron spectra with RITU-SACRED are hard to interpret

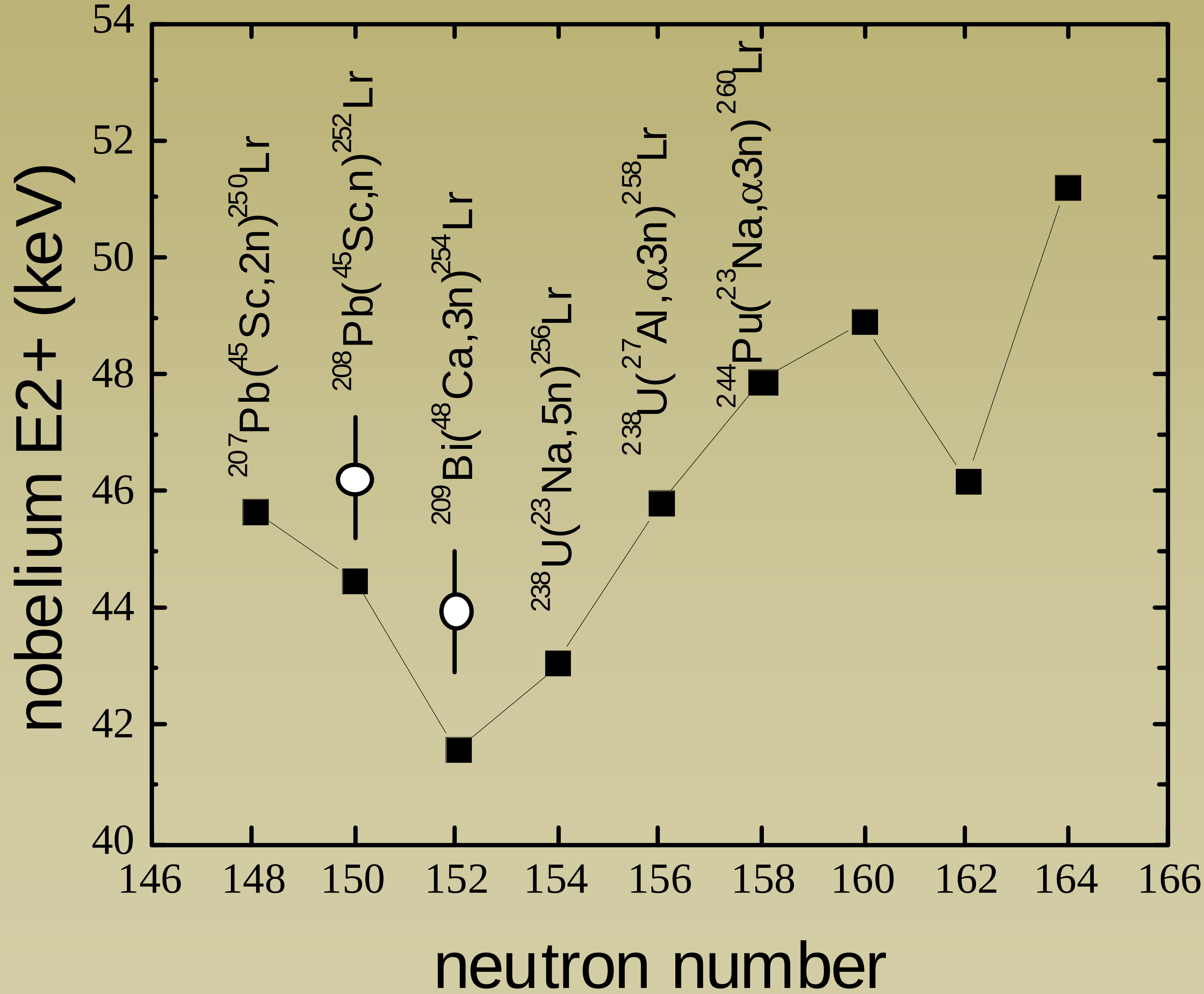
RDT with FMA-Gammasphere and RITU-Jurosphere populates higher-spin yrast states . . . extrapolation to E_{2+} necessary (±1 keV error bars on points on next slide)

Electron capture from odd-odd precursors will polulate states above the pairing gap. These states will decay to multiple members of the Ground State rotational band. Energy differences give spacing of the low-lying members of the GS rotational band

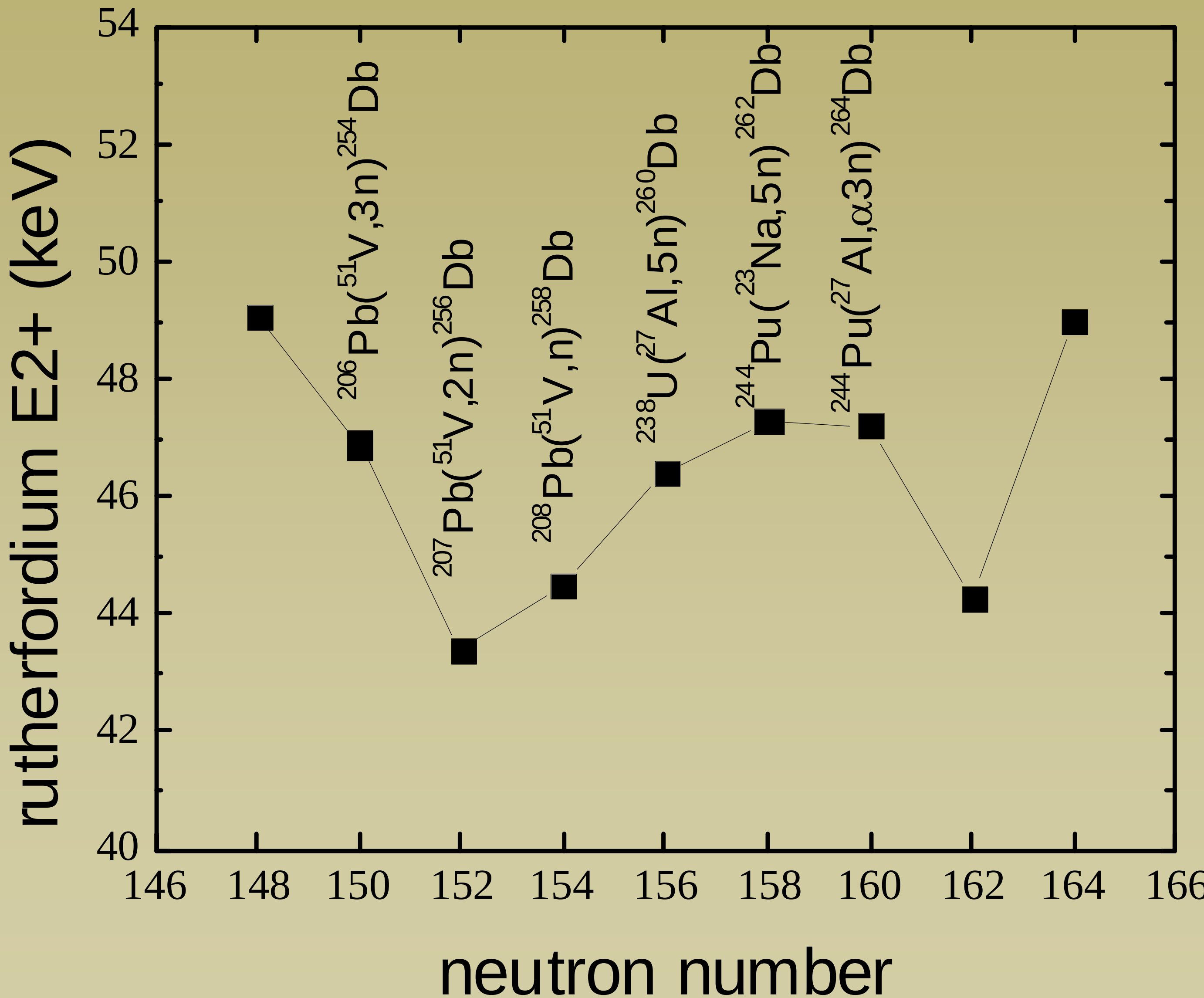
New method for merasuring E_{2+} in heavy element isotopes

1) Produce odd-odd precursors and separate with the BGS
2) Transport to shielded γ-detector array (clover detectors in cave 2)
3) Measure K x-ray - γ-ray coincidences

Reactions to produce odd-odd Lr electron-capture precursors decaying to even-even No isotopes



Reactions to produce odd-odd Db electron-capture precursors decaying to even-even Rf isotopes



Identification of Heavy Element SF Activities

The use of several segmented clover γ-ray detectors in a close geometry may allow identification of the Z (and ~A) of spontaneous fission activities by identification of the prompt γ-rays from the deexcitation of the fission fragments.

Symmetric fission produces relatively few fission products

Ge solid angle is up to 50% of 4π

Segmented clover granularity is sufficient for SF γ-ray multiplicity of 8-10

^{244}Pu(^{22}Ne,4n)^{262}Rf (2.1-sec SF decay)
^{238}U(^{48}Ca,3n)^{283}112 (4-sec α to 180ms SF decay) (α - X-ray coincidences)
^{244}Pu(^{48}Ca,3n)^{289}114 (2.7-sec α to 34-sec α to 9.6 sec SF decay)
SF decays at the ends of the E115 decay chains

Radioactive Beam Experiments With a Recoil Separator

Here's how:

1) Form a radioactive beam at the BGS target position

2) Use the BGS to get rid of the primary beam and

3) Focus the secondary beam on a secondary target at the BGS focal plane

4) Let secondary reaction products recoil out of the secondary target, and pass into the Recoil Transfer Chamber (RTC)

5) Use gas-jet to transport the secondary reaction products to a low-background counting facility (particle detectors and clover detectors)

6) Measure the decay of the secondary reaction products

Radioactive Beam Example: ^{6}He

UND did $^{7}Li(^{9}Be,^{6}He)^{10}B$, separated ^{6}He with TWINSOL to measure γ-rays in ^{66}Zn via $^{63}Cu(^{6}He,p2n)^{66}Zn$ S.M. Vincent et al. NIM A 491 (2002) 426

A BGS-RTC example to illustrate production rates . . .

Primary Reaction (at BGS target) $^{7}Li(^{9}Be,^{6}He)^{10}B$
Secondary Reaction (at BGS "detector") $^{18}O(^{6}He,pn)^{22}F$

Why?:
Study states populated by β decay of 4.2-sec ^{22}F (Q_{β}=10.8 MeV)
^{22}Ne at 10.8 MeV E* is unbound wrt/ n and α
measure cross sections with this neutron-halo nucleus.

Production Rates:
^{6}He intensity at BGS "detector" position 2.5×10^{6} s-1
^{22}F production rate = 0.12 s^{-1} gives 9700 atoms/day

Radioactive Beam Example: ^{6}He

Transport:
Let the ^{22}F recoil out of the target,
through a 3.6 μm MYLAR foil,
and stop in 1-atm gas in the RTC,
gas-jet transport to low-background rotating wheel detector system
Transport efficiency ~ 50% resulting in 5000 ^{22}F decays/day

Detection:
Clover γ efficiency = 10% -> 500 counts/day
Particle efficiency = 50% -> exotic decay modes with branches >0.1%

Conclusion: We should think about Nuclear Physics experiments possible with systems such as BGS-RTC or TASCA