

**P-347**

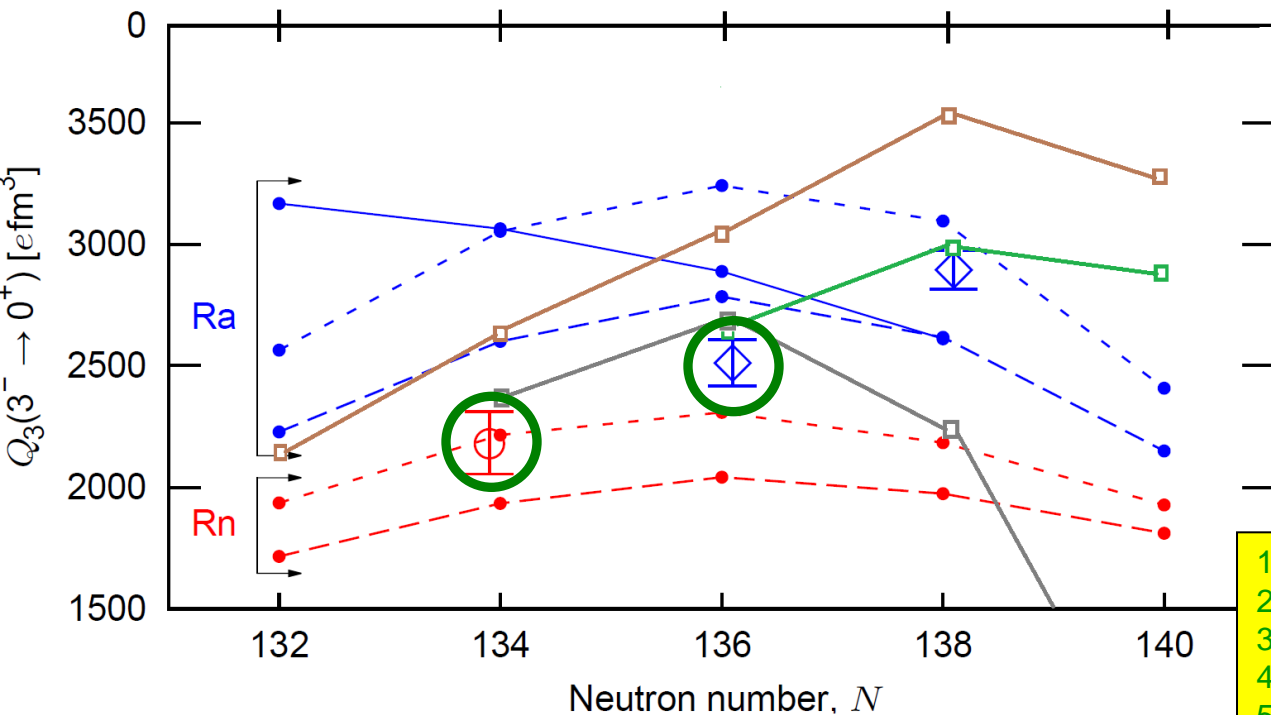
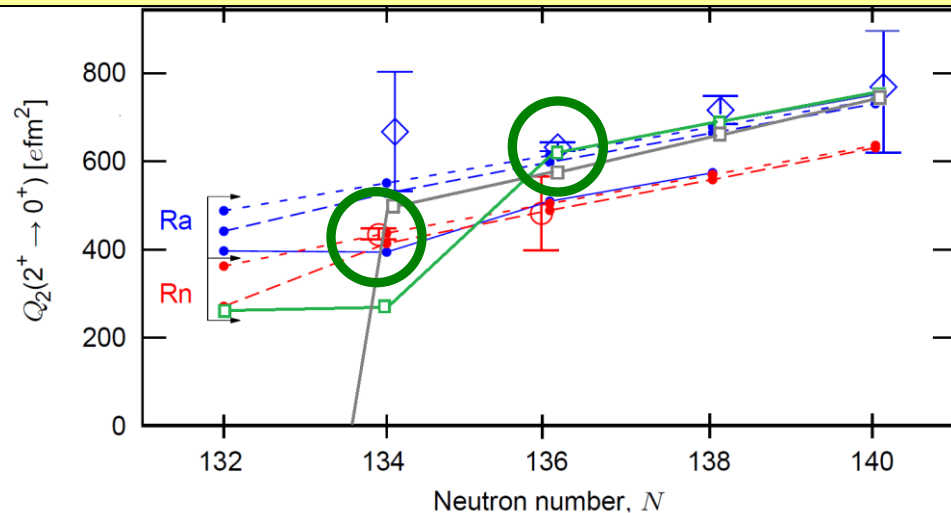
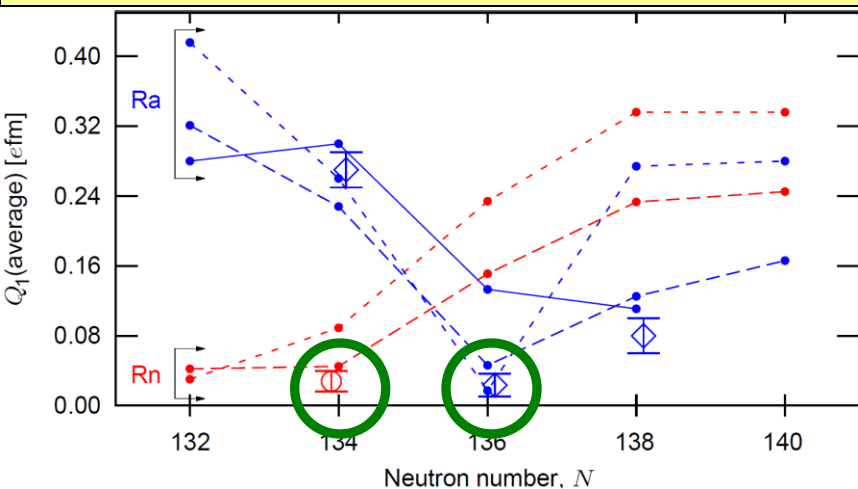
**Measurements of octupole collectivity in Rn  
and Ra nuclei using Coulomb excitation  
Addendum**

Peter Butler, David Joss and Marcus Scheck on behalf of

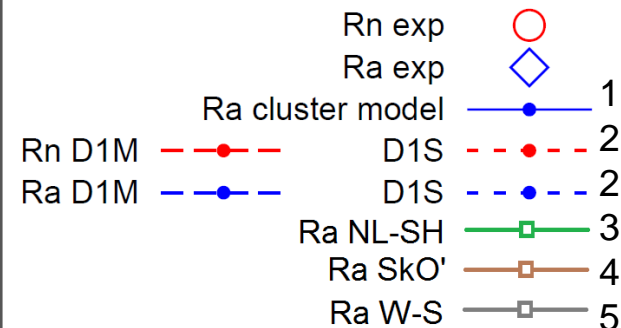
ISOLDE-Darmstadt-GANIL-*Groningen*\*-*Guelph*\*-Jyvaskyla-Koln-Livermore-  
Leuven-Liverpool-Lund-*Michigan*\*-C Michigan-Oslo-Rochester-Saclay-SAS-  
Warsaw-W Scotland-York collaboration

*\*EDM programmes at ANL and TRIUMF*

# $^{220}\text{Rn}$ , $^{224}\text{Ra}$ : comparison with theory



Our measurements 



1. Shneidman et al PRC 67 (2003) 014313
2. Robledo & Bertsch PRC 84 (2011) 054302
3. Rutz et al. NP A590 (1995) 680
4. Engel et al. PRC 68 (2003) 025501
5. Nazarewicz et al NP A429 (1984) 269

# Octupole enhanced atomic EDM moment

V Spevak, N Auerbach, and VV Flambaum  
PR C 56 (1997) 1357

related to  $Q_3$

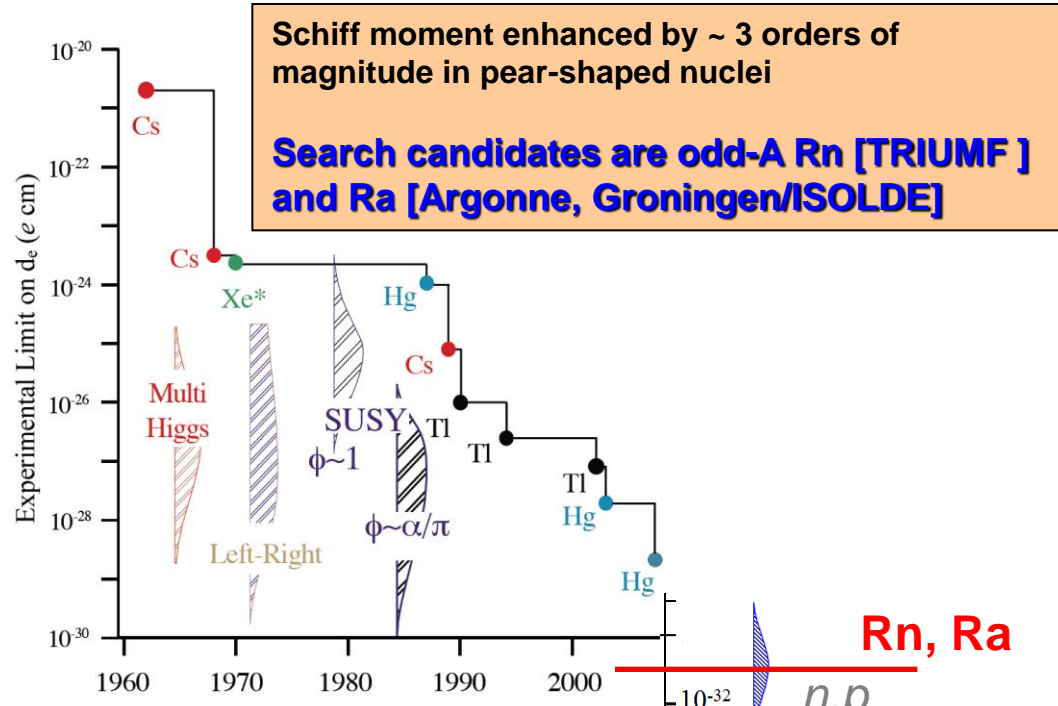
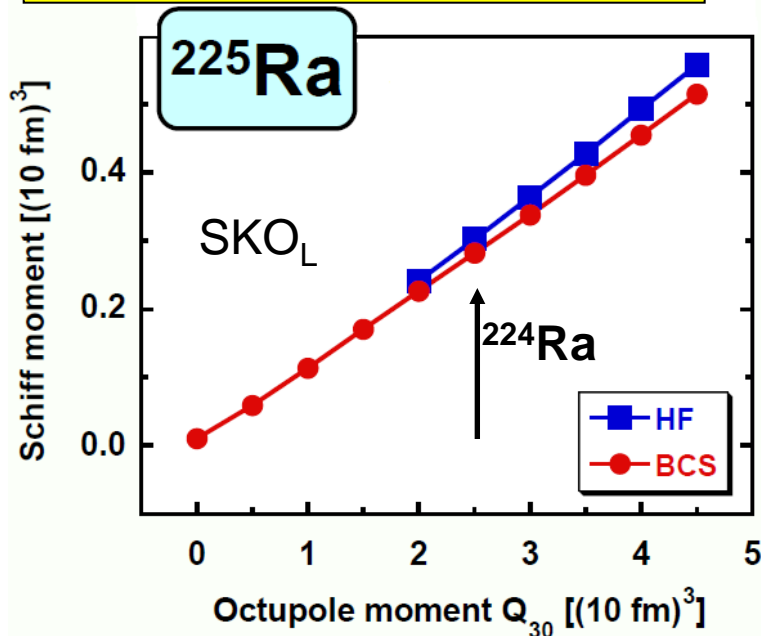
P,T-violating n-n interaction

Schiff moment:

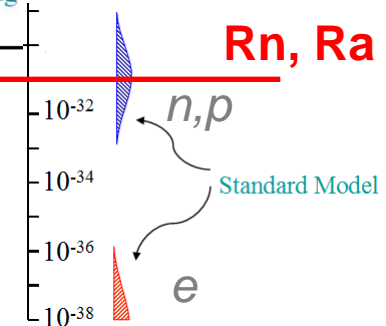
$$S = -2 \frac{J}{J+1} \frac{\langle \hat{S}_z \rangle \langle \hat{V}_{PT} \rangle}{\Delta E}$$

energy splitting of parity doublet

J Dobaczewski (Trento, 2010)



Measure:  $Q_3$  in even-A Rn, Ra  
 $\Delta E$  in odd-A Rn



# Signature of pear-shape: B(E3)

Le Monde.fr

Des noyaux atomiques en forme de poire détectés au CERN

Los Angeles Times | SCIENCE

Physicists get a good look at pear-shaped atomic nuclei

Neue Zürcher Zeitung

Kernphysik

Atomkerne können auch birnenförmig sein

BBC RADIO

4

$Q_2$  (efm<sup>2</sup>)

THE CHRISTIAN SCIENCE MONITOR

Why hasn't everything been annihilated yet? Pear-shaped atomic nuclei could hold answer.

2500

$Q_3$  (efm<sup>3</sup>)

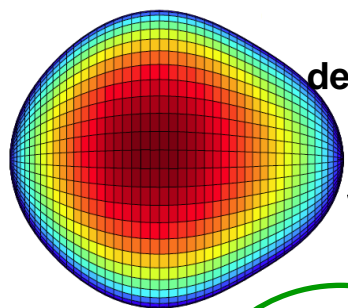
500

dS De Standaard

kernfysica Atoomkern neemt peervorm aan

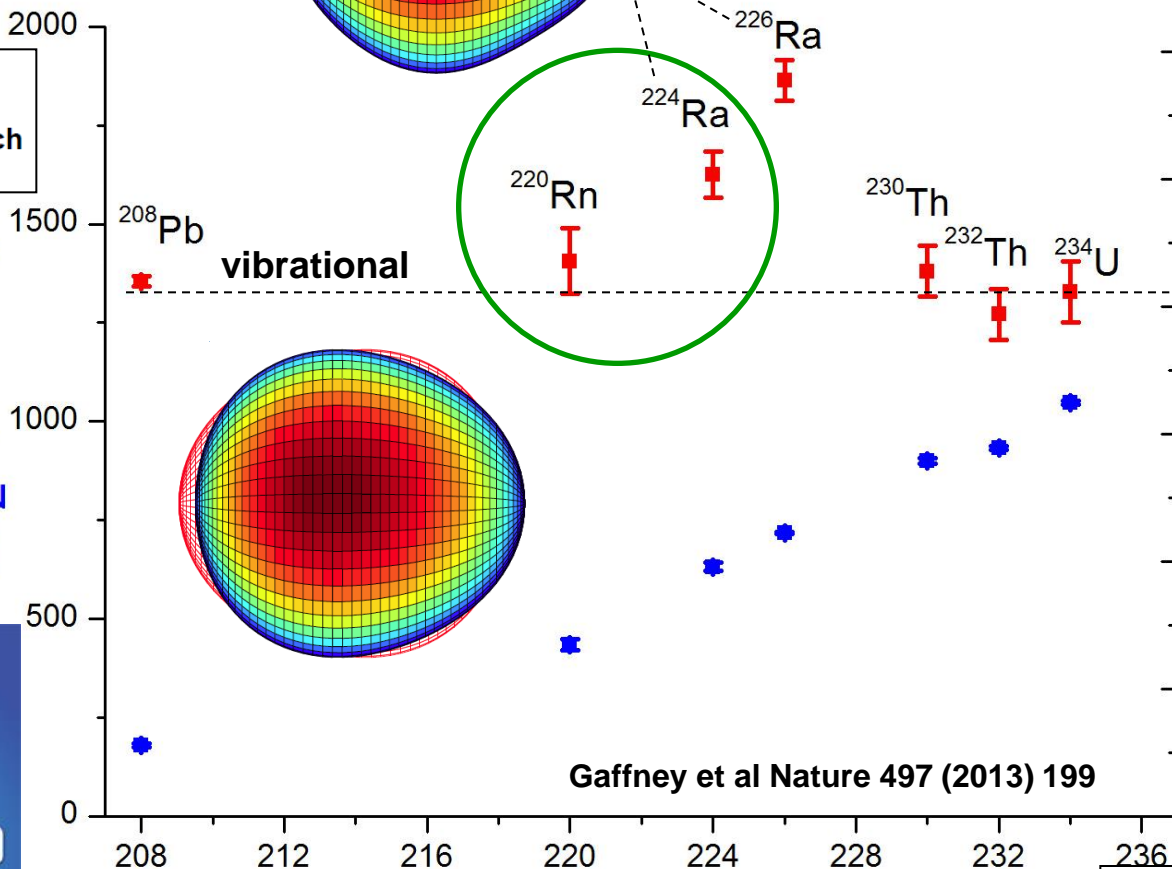
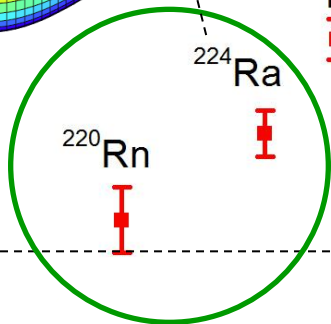
Telegraph.co.uk

Nuclear physics goes pear shaped: CERN scientists show some atomic nuclei are stubby and lopsided



rigid deformation

radioactive targets



Gaffney et al Nature 497 (2013) 199

SCIENTIFIC AMERICAN™

Pear-Shaped Nucleus Boosts Search for Alternatives to "Standard Model" Physics

The strange shape of radium 224 could lead to new physics

A

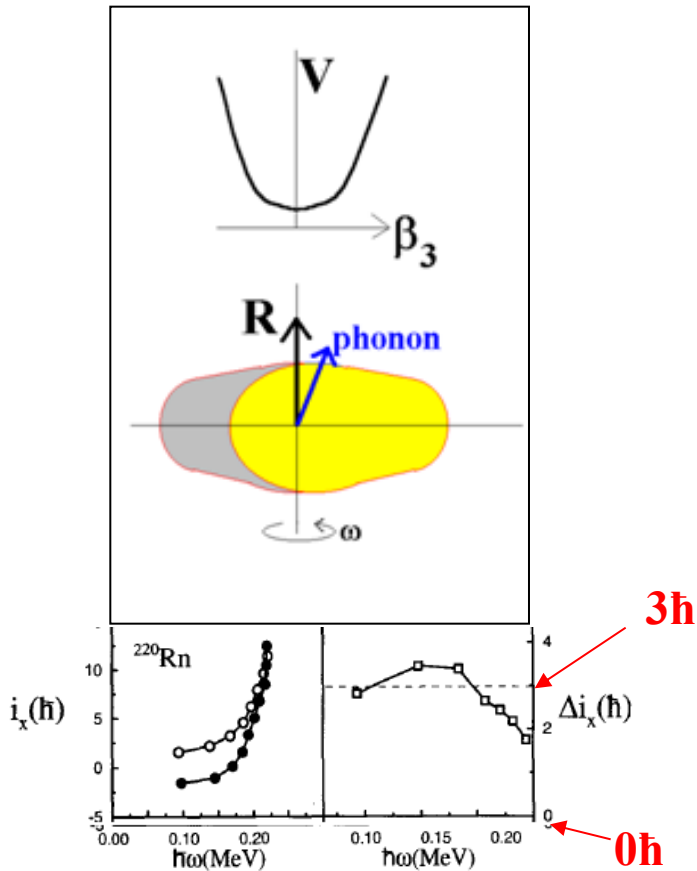
SPiegel ONLINE WISSENSCHAFT

Birnenförmige Atomkerne: Neue Spur im Antimaterie-Rätsel



# Signature of pear-shape: rotational alignment

## Octupole vibrational



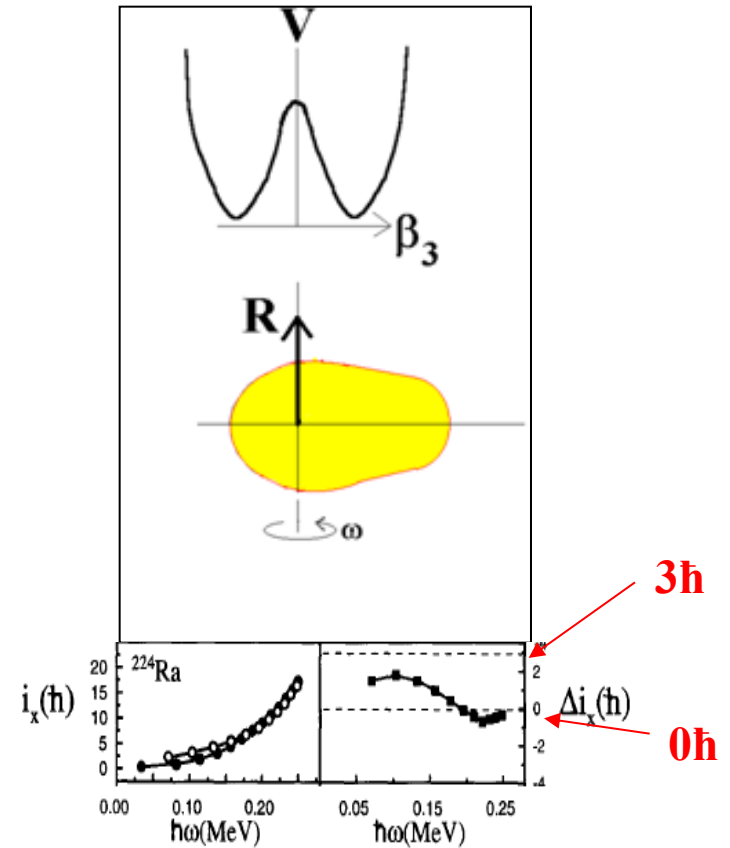
even-even



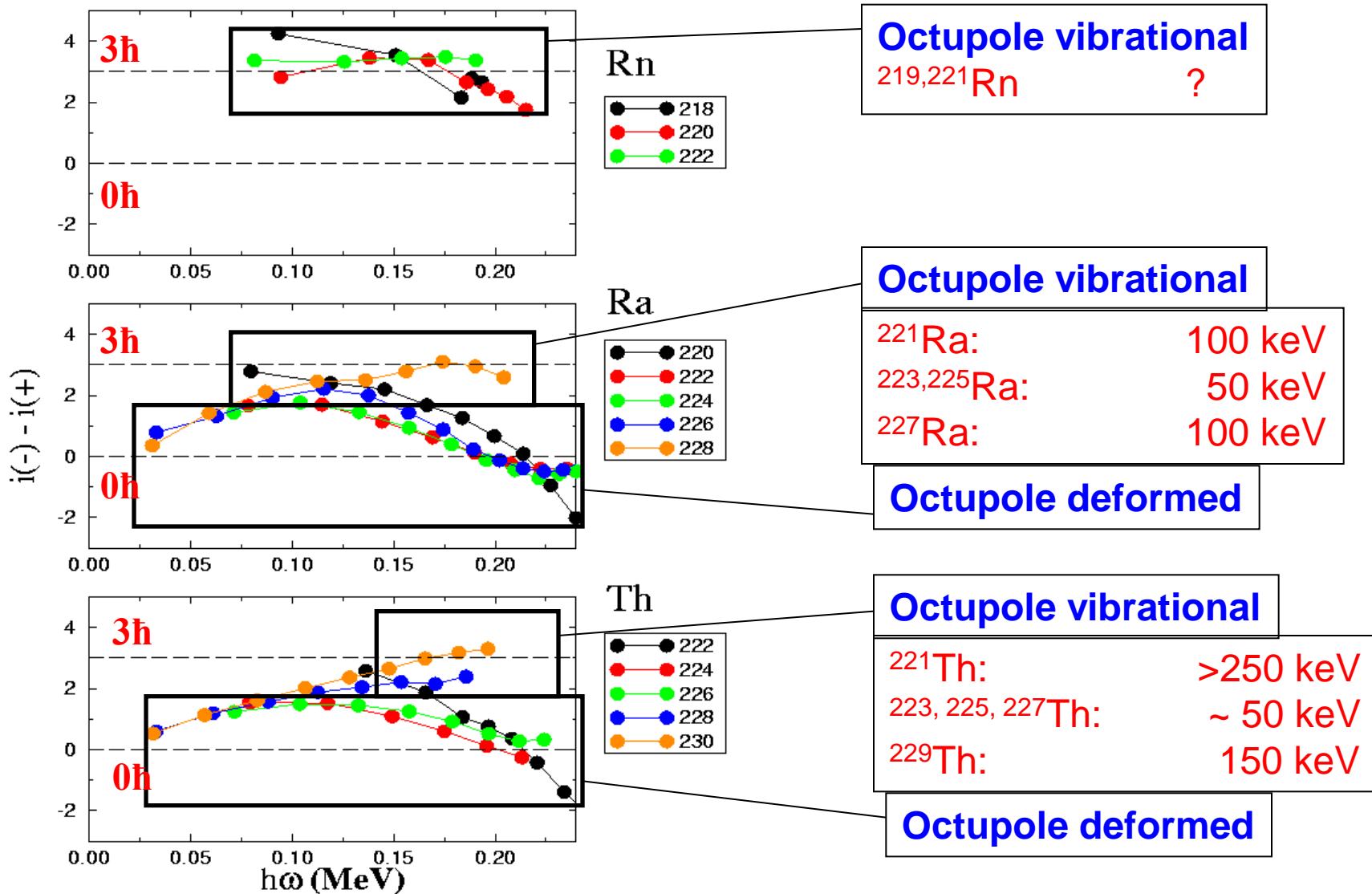
odd-A



## Octupole deformed



# Rotational properties for even-even nuclei



JFC Cocks et al PRL 78 (1997) 2920, NP A645 (1999) 61

# Plan of octupole Rn-Ra programme

## Published:

B(E3)s in  $^{220}\text{Rn}$ ,  $^{224}\text{Ra}$

## Approved:

B(E3)s in  $^{222}\text{Rn}$ ,  $^{222,226,228}\text{Ra}$

## Addendum, to measure:

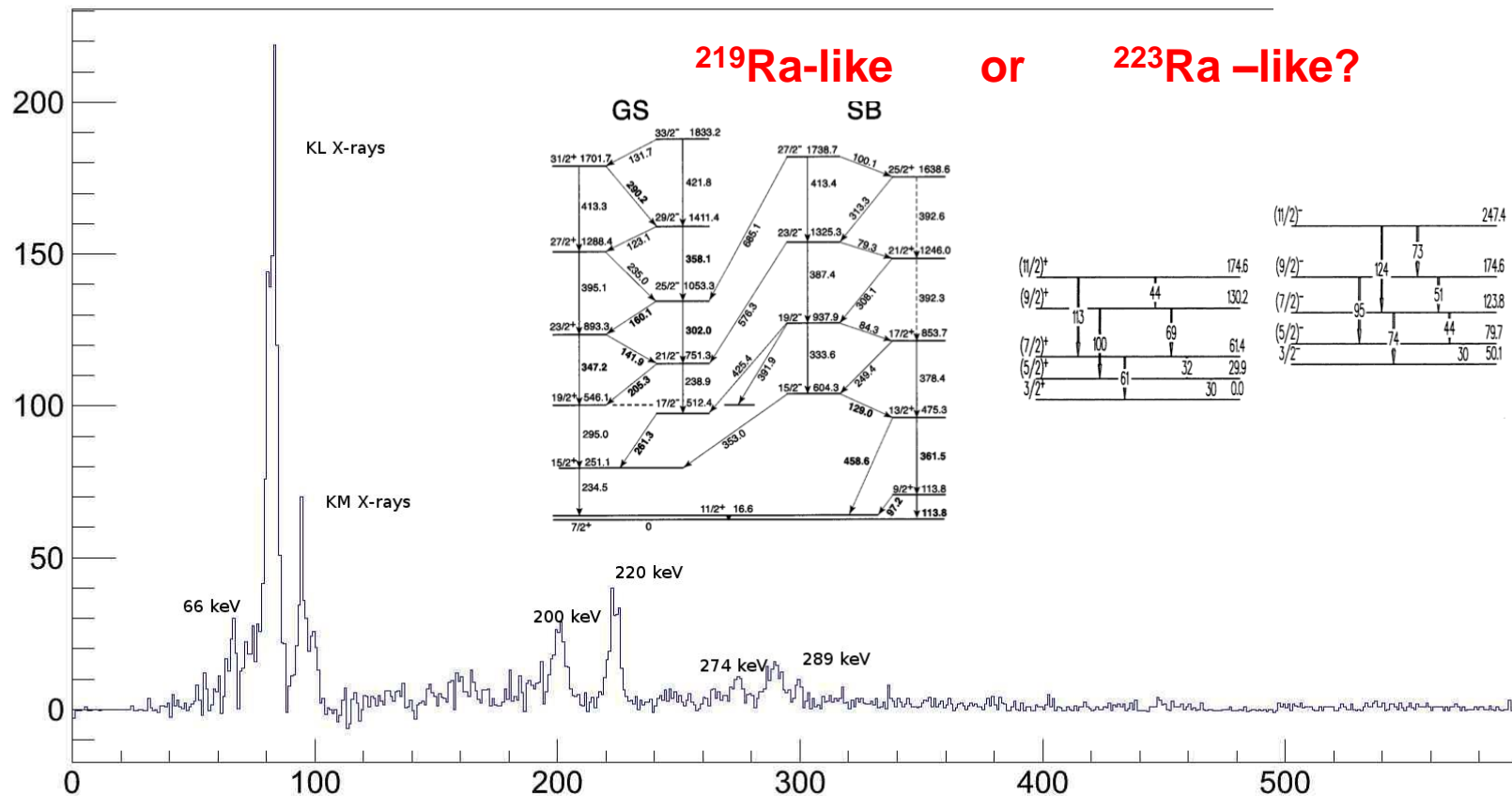
level schemes of unknown  $^{224,226}\text{Rn}$  – *infer behaviour of  $^{223,225}\text{Rn}$*

B(E3:  $0^+ - 3^-$ ) in  $^{224}\text{Rn}$  at 4 and 5 MeV/u

B(E3:  $0^+ - 3^-$ ) in  $^{226}\text{Rn}$  at 5 MeV/u

level scheme of  $^{221}\text{Rn}$  at 5 MeV/u – *probably vibrational*

# IS475: $^{221}\text{Rn}$ gamma-ray spectrum

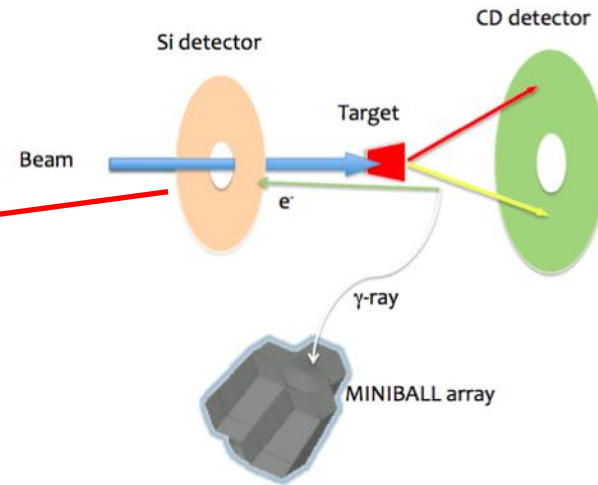
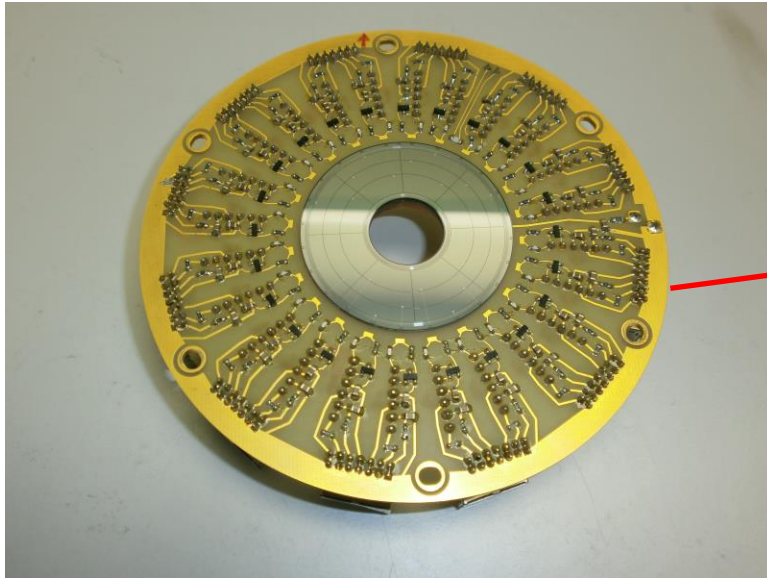


**Spectrum taken in 24h, with  $5 \cdot 10^3$  ions/s ( $\text{UC}_x$ ) at 2.8 MeV/u.  
Propose to re-measure with  $3 \cdot 10^5$  ions/s ( $\text{ThC}_x$ ) at 5 MeV/u**

**We propose to measure both  $\gamma$ -rays and internal conversion electrons.**



# SPEDE: conversion electron spectrometer



## Resources:

Mechanical design and manufacturing being made at JYFL.  
Liverpool has taken care of the front-end PCB design and manufacture.

## Timeline:

SPEDE will be commissioned at JYFL. 8 days allocated by PAC. We aim to have detector and PCB ready for testing in Spring 2014.

Manpower: J Pakarinen (Finnish Academy Fellow) +P Papadakis at Jyvaskyla PAB and G O'Neill (STFC project student) at Liverpool

## Beam time request

*1 shift set-up*

1 shift  $^{224}\text{Rn}$  4 MeV.A

*1 shift change over*

1 shift  $^{224}\text{Rn}$  5 MeV.A

*1 shift change over*

9 shifts  $^{226}\text{Rn}$  5 MeV.A

*1 shift change over*

3 shifts  $^{221}\text{Rn}$  5 MeV.A

18 shifts in total

Dedicated  $\text{ThC}_x$  target

# Importance of higher beam energies

