Measuring E3 matrix elements in pear-shaped nuclei: Miniball or ISS?

Peter Butler (U. Liverpool)

$$(d\sigma/d\Omega)_\ell^{\text{exp}} = \beta_\ell^2 (d\sigma/d\Omega)_\ell^{\text{DWBA}}$$

$$B(E\ell;0 \rightarrow \ell) = (3ZeR_\ell/4\pi)^2 \beta_\ell^2$$

H.I. Coulex	**(d,d')**
model independent	model dependence *(sys. error)*
purely EM	strong+Coulomb *(sys. error but higher σ)*
single channel	competing channels *(possible backgrd.)*
multi-step (H.I.)	~single-step *(simpler analysis)*
transitions	states *(simpler analysis, see g.s.)*
particle-gamma	particle *(no icc problems, higher ε)*
thick target	thin target *(σ x ε x t ~ Coulex p-γ)*
3-10 keV	20-50 keV

Motivation #1: Octupole enhanced atomic EDM moment

related to Q_3

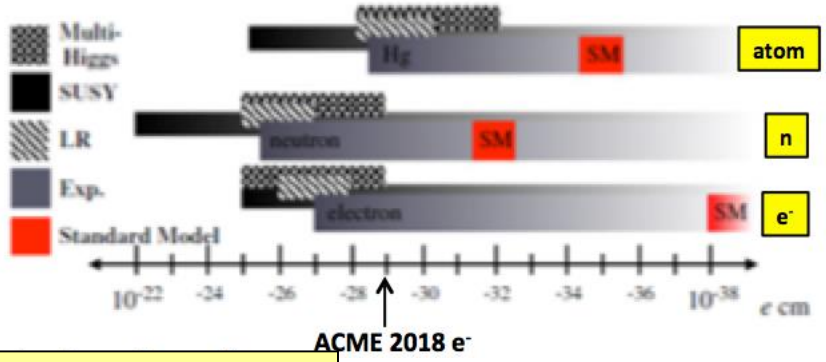
P,T-violating n-n interaction,etc

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

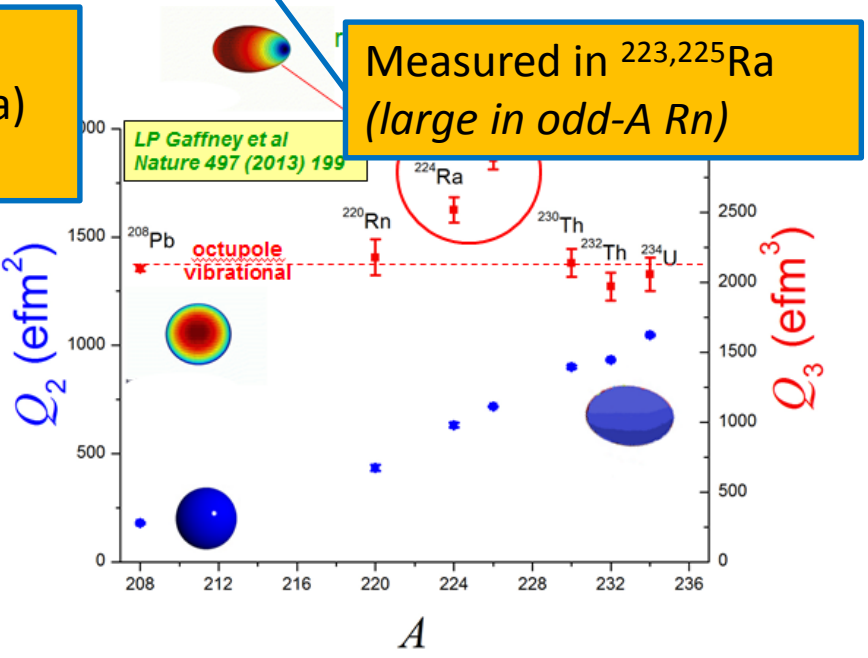
energy splitting of parity doublet

Measured in ^{220}Rn, ^{224,226}Ra, (^{222}Rn,^{222,228}Ra) *(but not odd-A nuclei)*

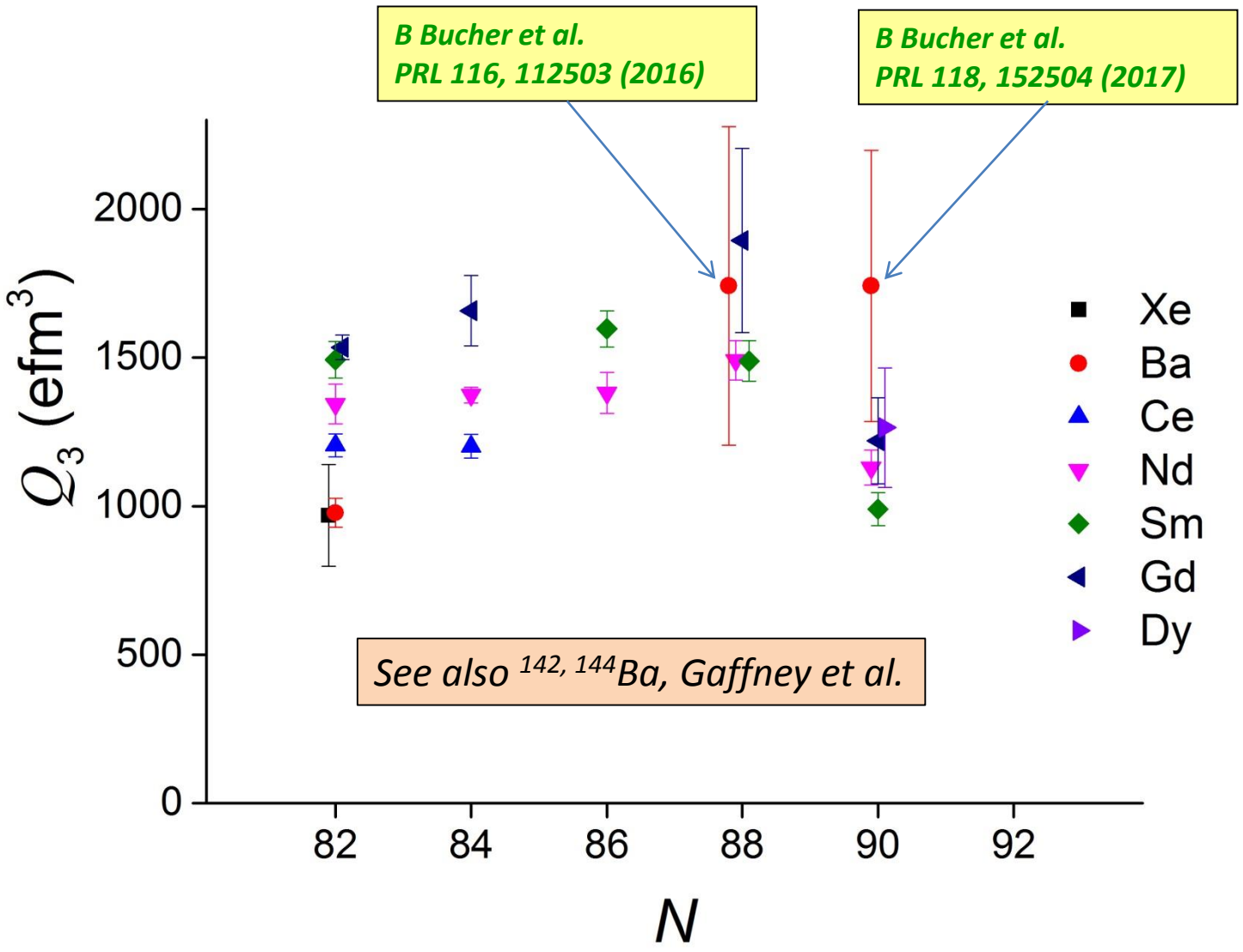
Measured in ^{223,225}Ra *(large in odd-A Rn)*



ER Tardiff et al
Hyp Int 225(2014) 197



Motivation #2: B(E3)s in ^{144,146}Ba



spectrograph data

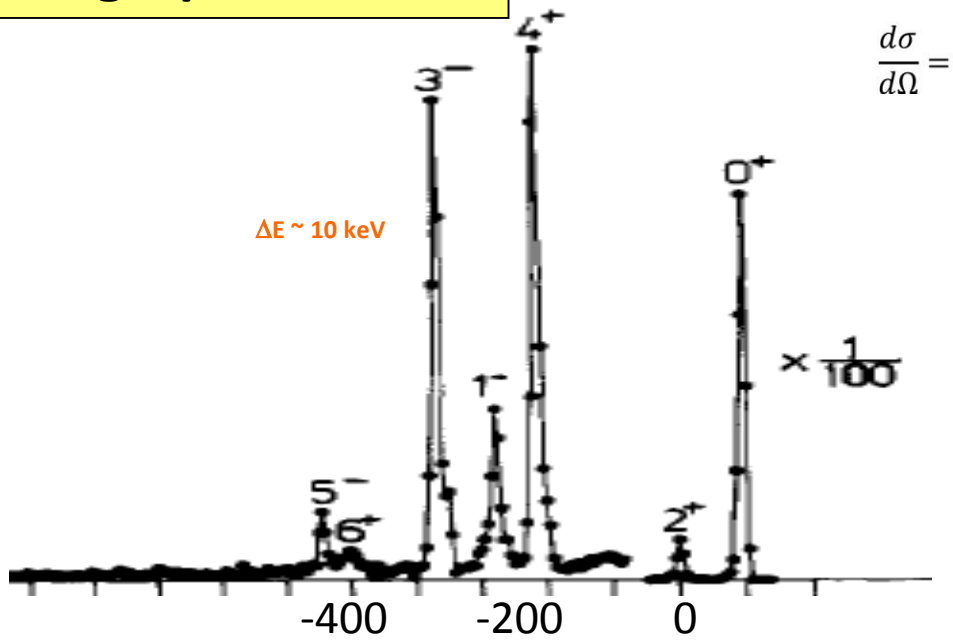
$$\frac{d\sigma}{d\Omega} = \beta_\ell^2 |< I_A \ell K 0 | I_B >|^2 \, \sigma_{\mathrm{DWUCK}}$$

^{226}Ra(d,d')

actual data

Thorsteinsen et al.

Phys. Scr. 42 (1990) 141

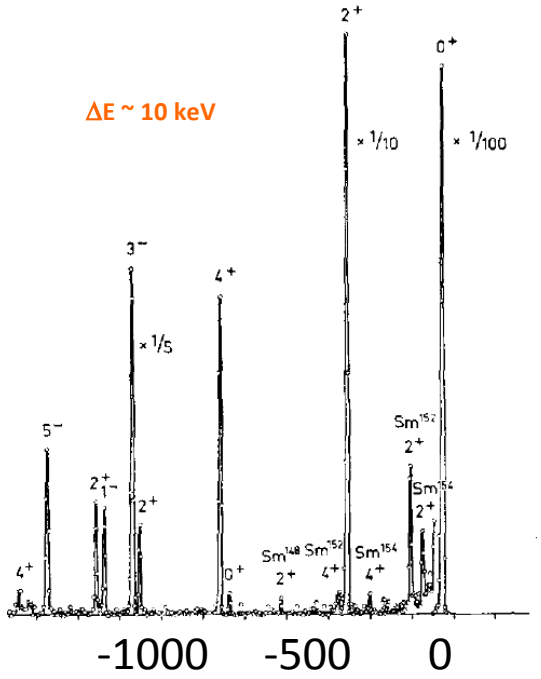


^{150}Sm(d,d')

actual data

Veje et al.

Nucl. Phys. A109 (1968) 489

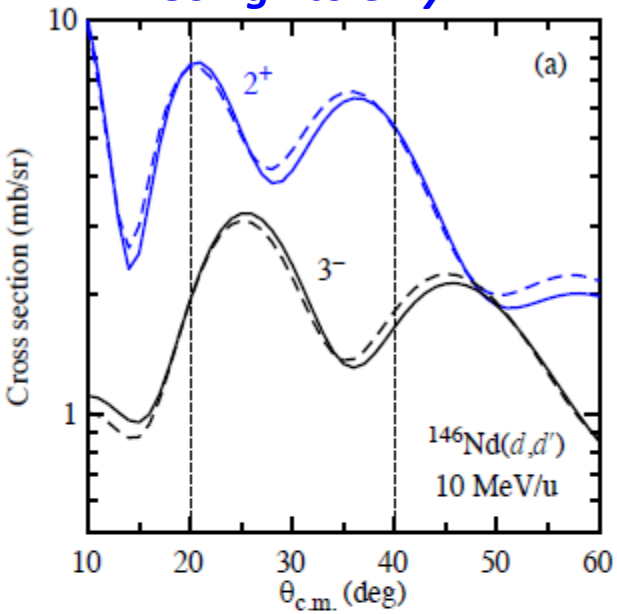


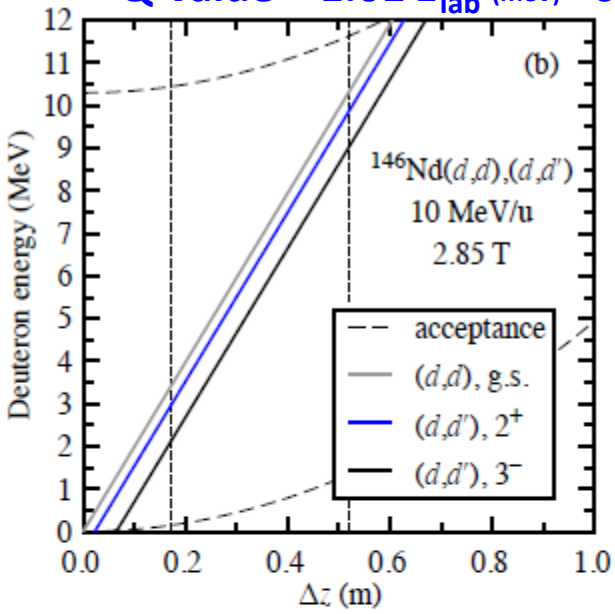
ISS Experimental details

(taken from Ben Kay et al., ATLAS #1619, scheduled September)

Using Ptolemy

Q-value = 1.01 E_{lab} (MeV) - 0.20Δz (cm)





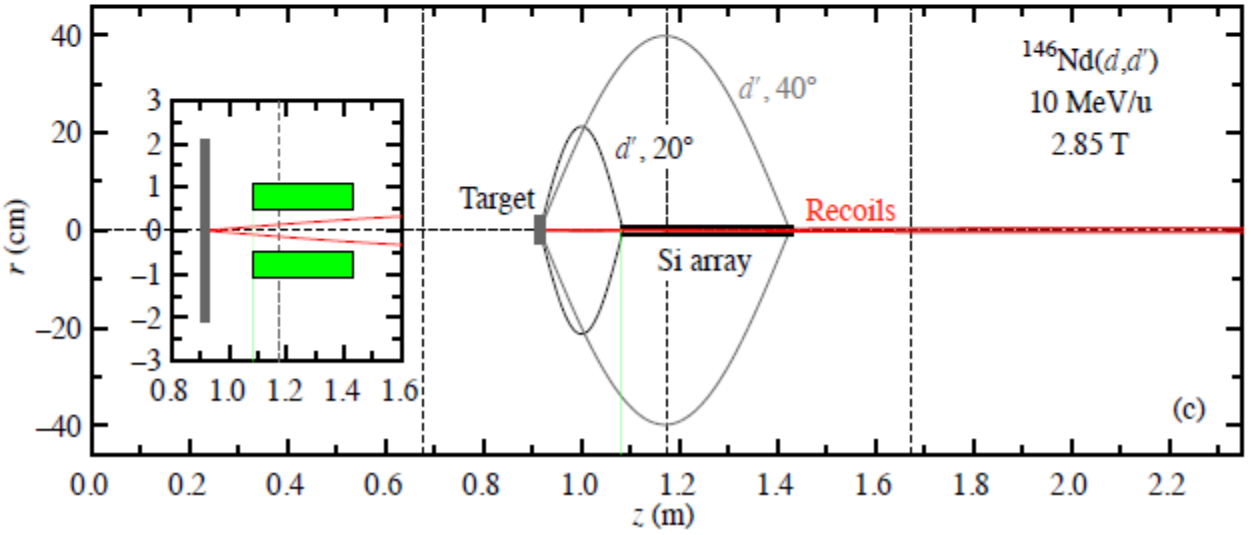
competing channels:

CN

(d,t)

(d,^{3}He)

(d,α)



5 days:

~10% error in B(E3)

(10^5 ions/s

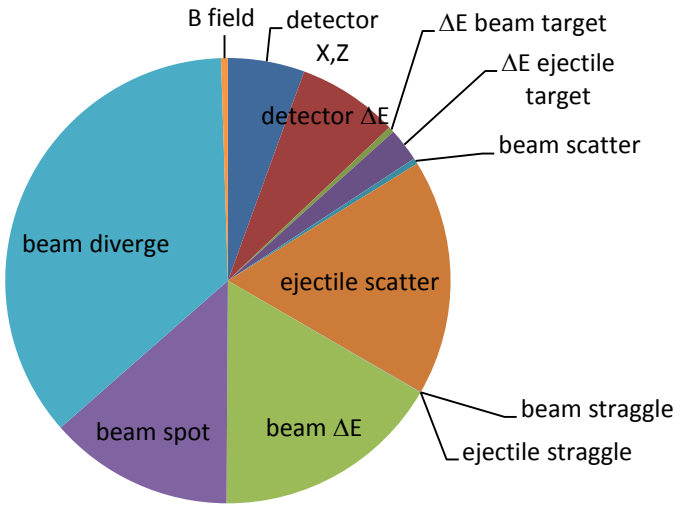
20 μg/cm^2)

Similar to Coulex IS553

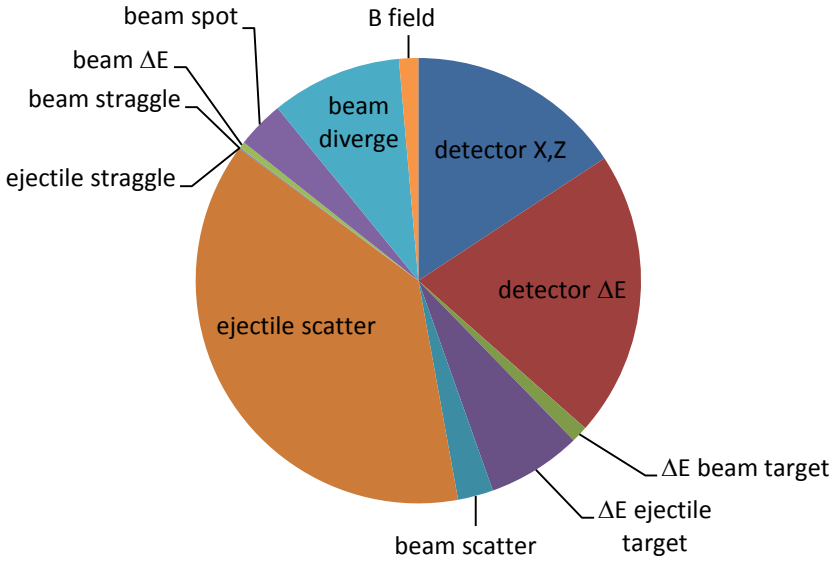
ISS Q-value resolution

d(^{24}Ne,p)^{25}Ne @ 10 MeV/u

With HIE-ISOLDE beam: ~40 keV



With manipulated beam*: ~25 keV

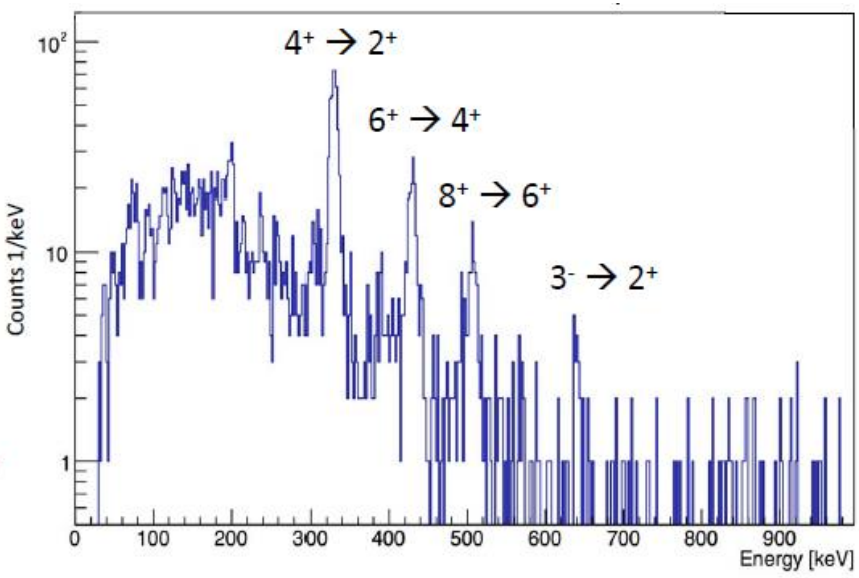


Similar results obtained by M Labiche

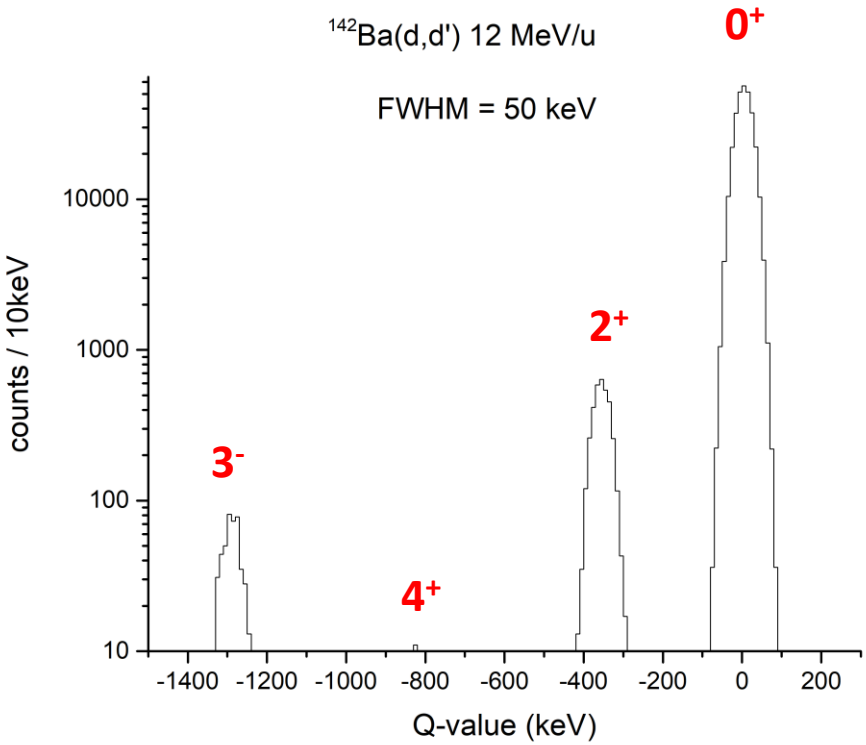
*manipulated beam:
FWHM ΔE/E reduced from 0.5% to 0.1% through de-bunching and phase rotation
Transverse emittance (normalised rms) reduced from 0.1 to 0.02 mm mrad through collimation

^{142}Ba MB v ISS

^{142}Ba + ^{208}Pb HIE-ISOLDE + Miniball 2018
actual data ***(Liam Gaffney)***



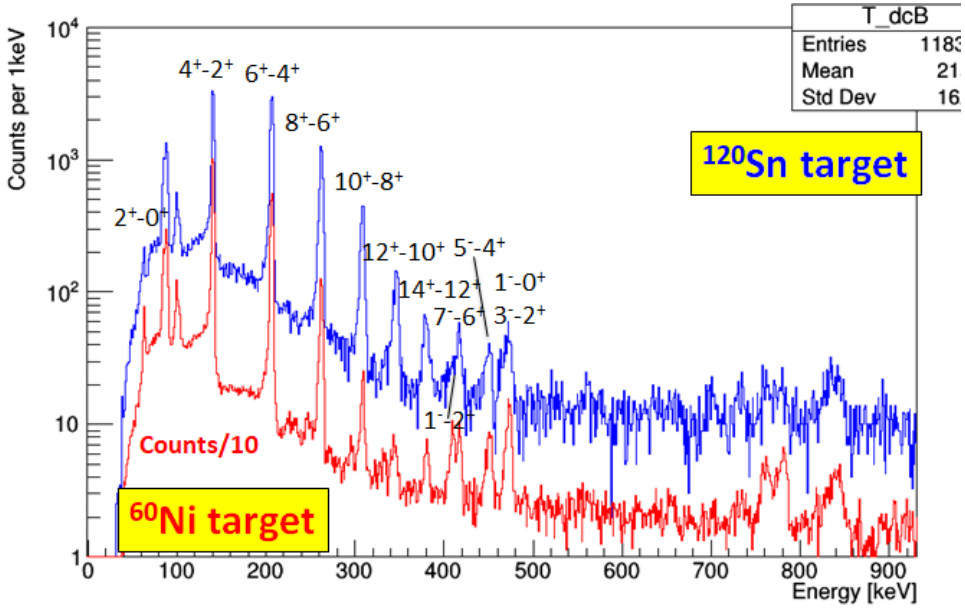
ISS simulated

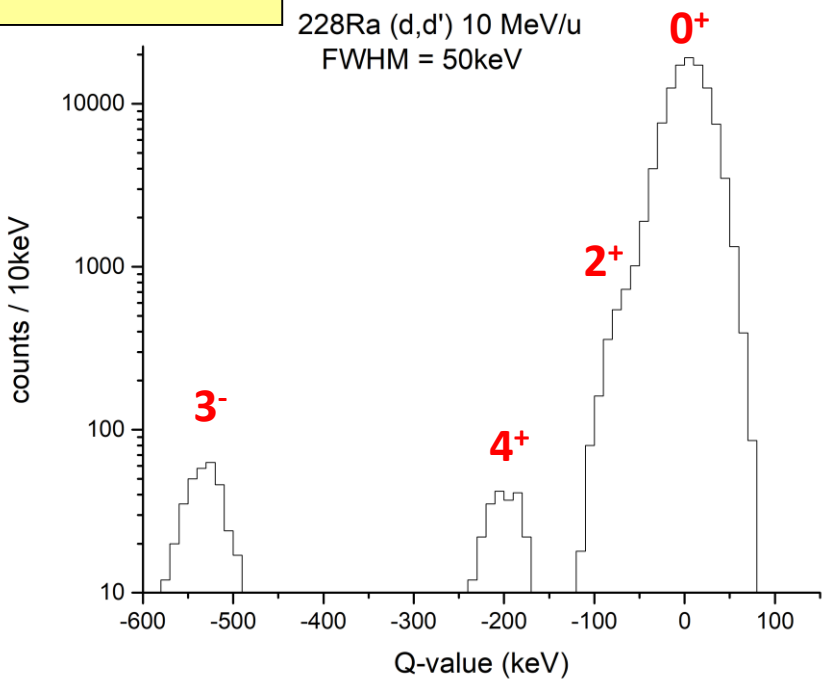


Even-even radium MB v ISS

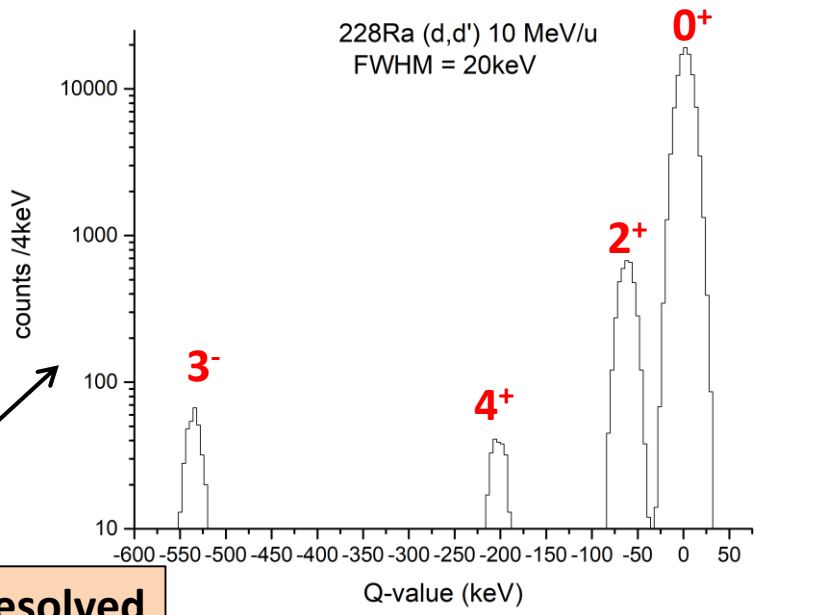
ISS simulated

^{228}Ra HIE-ISOLDE + Miniball 2018
actual data



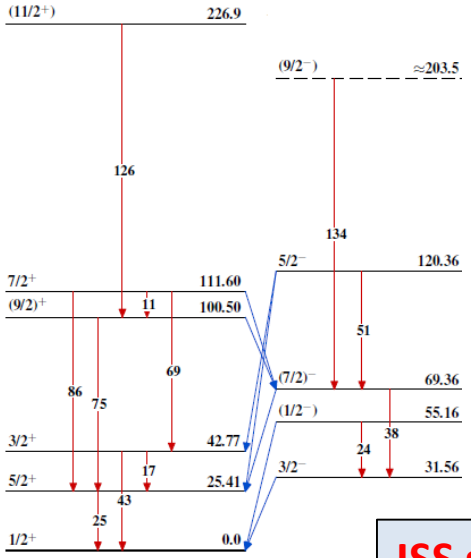


also measured
^{222,224,226}Rn and ^{222}Ra

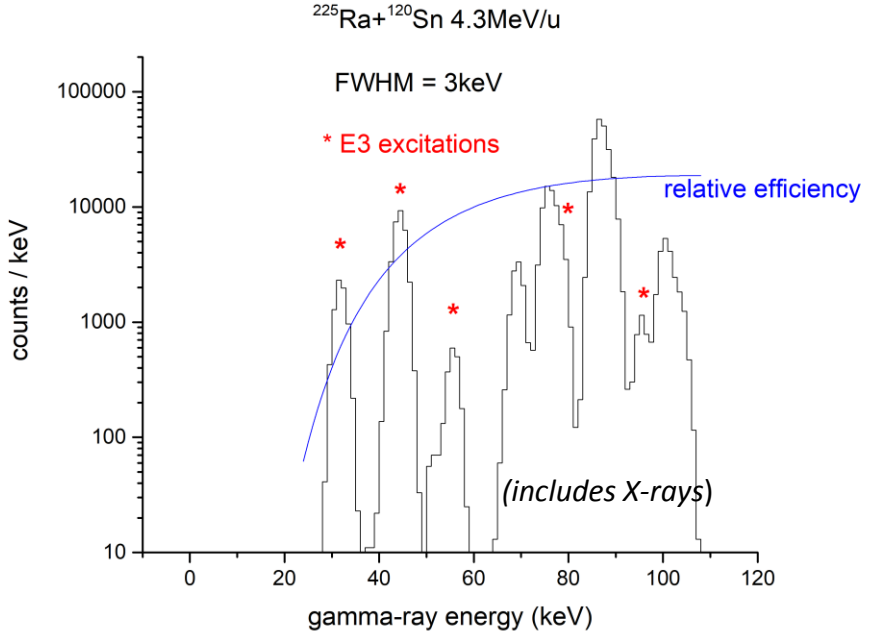


NB in ^{222}Ra 4^+ and 3^- states cannot be resolved

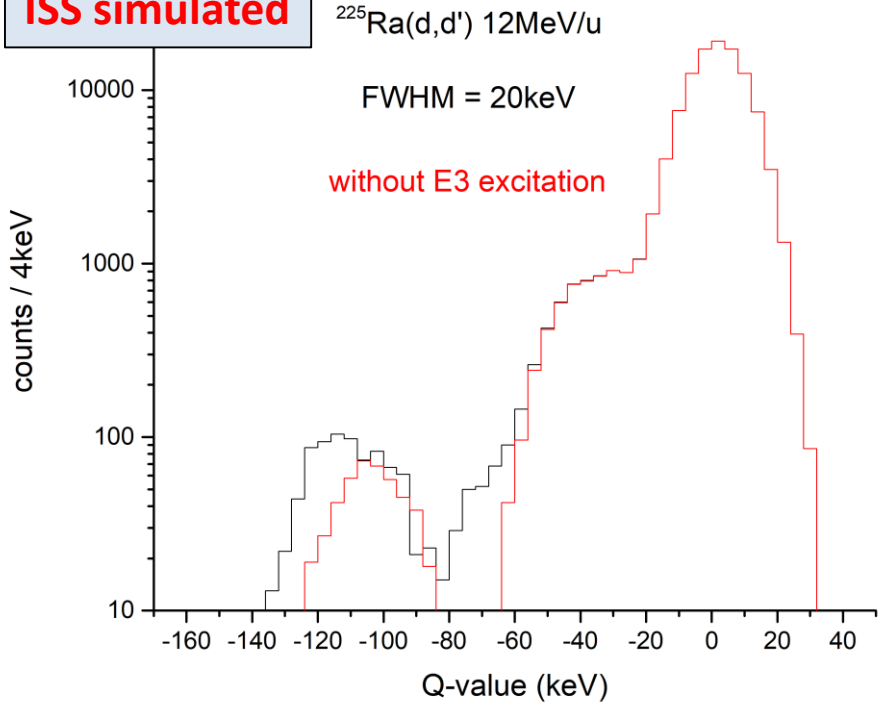
^{225}Ra Miniball v ISS



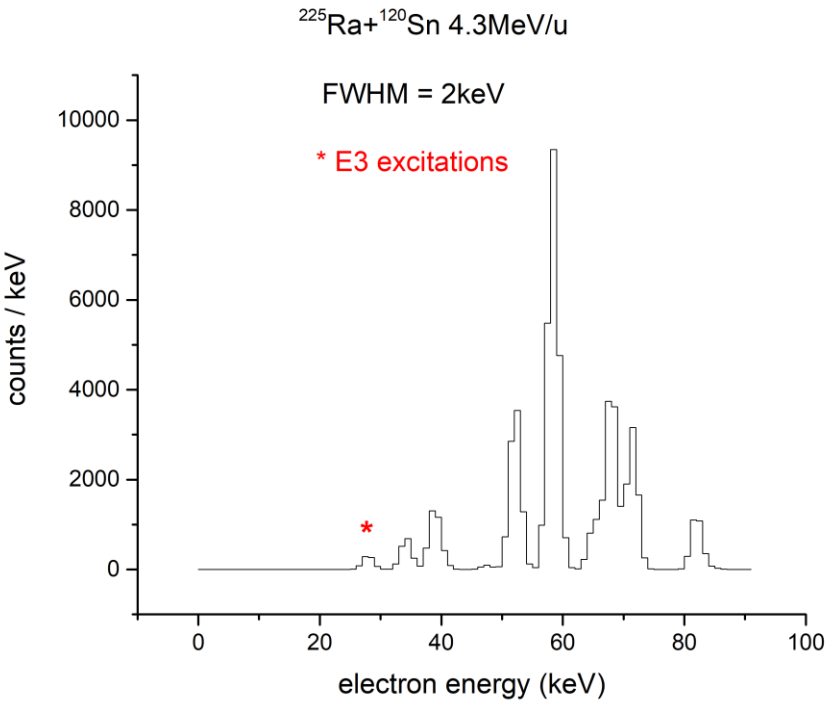
Miniball simulated

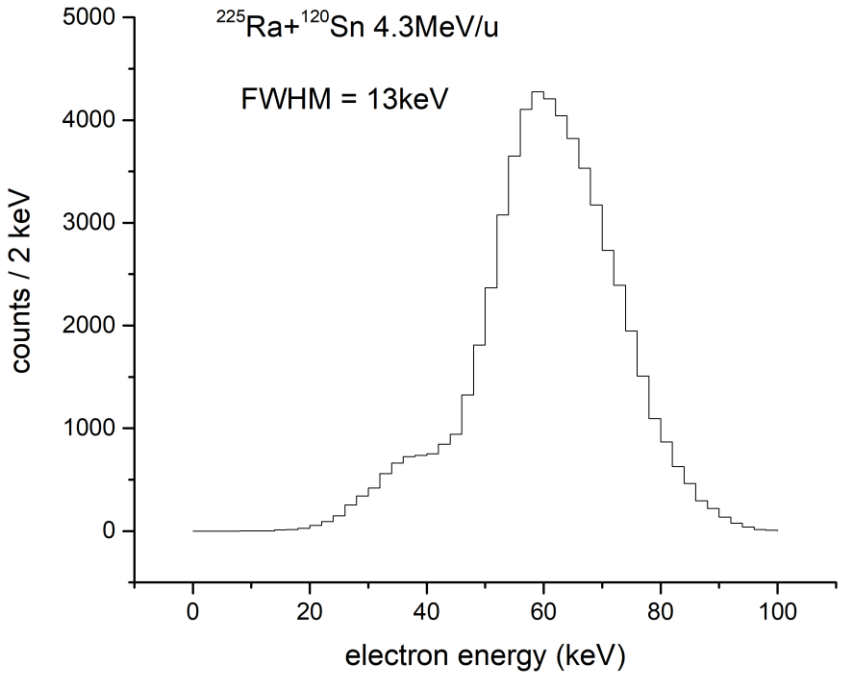


ISS simulated



^{225}Ra SPEDE


225Ra+120Sn 4.3MeV/u
FWHM = 2keV
* E3 excitations
counts / keV
electron energy (keV)
0
2000
4000
6000
8000
10000
0
20
40
60
80
100


225Ra+120Sn 4.3MeV/u
FWHM = 13keV
counts / 2 keV
electron energy (keV)
0
1000
2000
3000
4000
5000
0
20
40
60
80
100

Summary

The Jury is out!

However…

ISS issue: **timing reference**

Heavy ion recoil angle ^{142}Ba(d,d') ~ 0.8 deg
^{228}Ra(d,d') ~ 0.5 deg

rms beam divergence + multiple scattering ~ 0.015 deg (collimated)
~ 0.15 deg (direct beam)

Miniball issue: GOSIA analysis

THANKS: Ben – very useful discussions on (d,d')
Matthew Fraser (CERN) & Alberto - beam manipulation
Liam – help with GOSIA
Philippos & Danny Cox (Lund) – SPEDE response