CGS15 August 25th 2014

"No-spin" states and low-lying structures in ^{130}Xe and ^{136}Xe

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Motivation

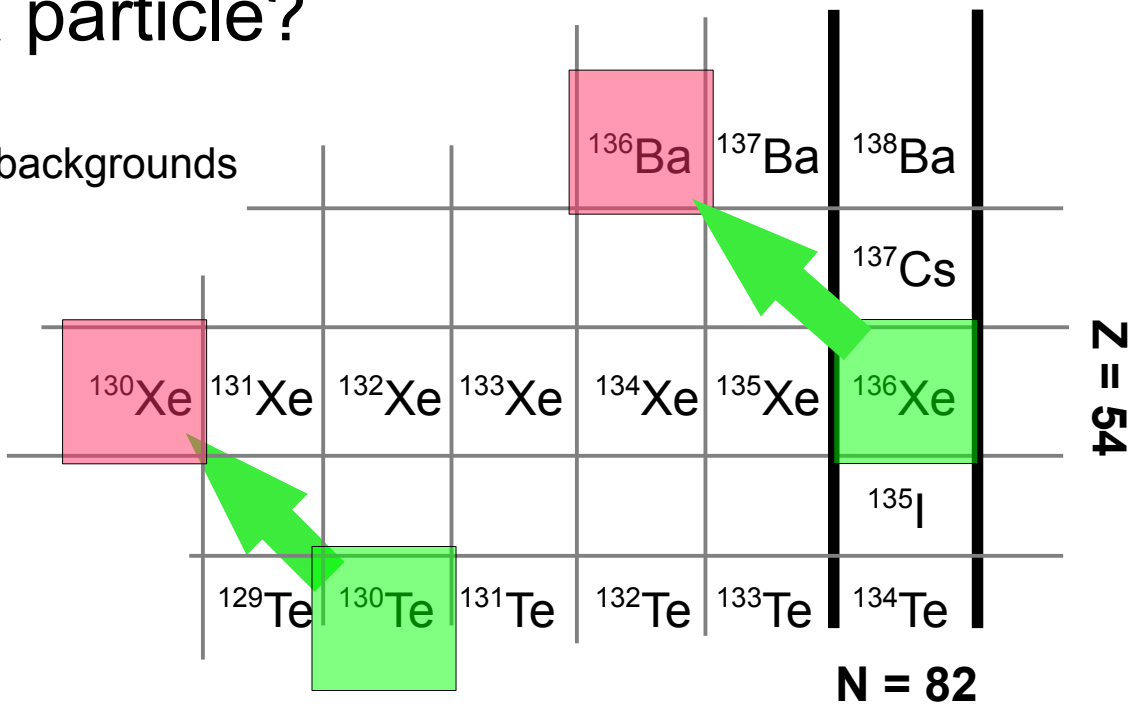
Xenon – Why do I care?

Neutrinoless double beta decay.

Is the neutrino a Majorana particle?

Structure for NME's
Cross sections for potential search backgrounds

$$2n \rightarrow 2p + 2e^- + 2\bar{\nu}_e$$



Also structure:

Several recent studies which I'll discuss

Shape change spherical to γ-soft
Mixed symmetry states
Octupole collectivity

Motivation

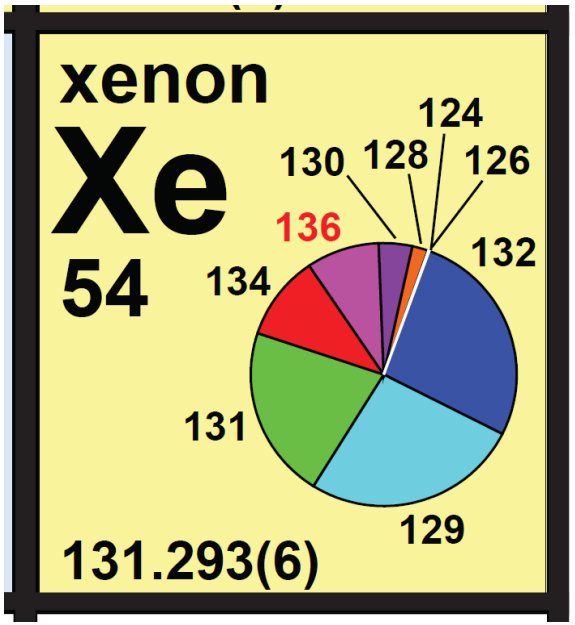
Xenon – Why do I care?

Xenon is a Noble gas.

Solid XeF_2 targets.

9 stable isotopes remain relatively unstudied

Significant current interest



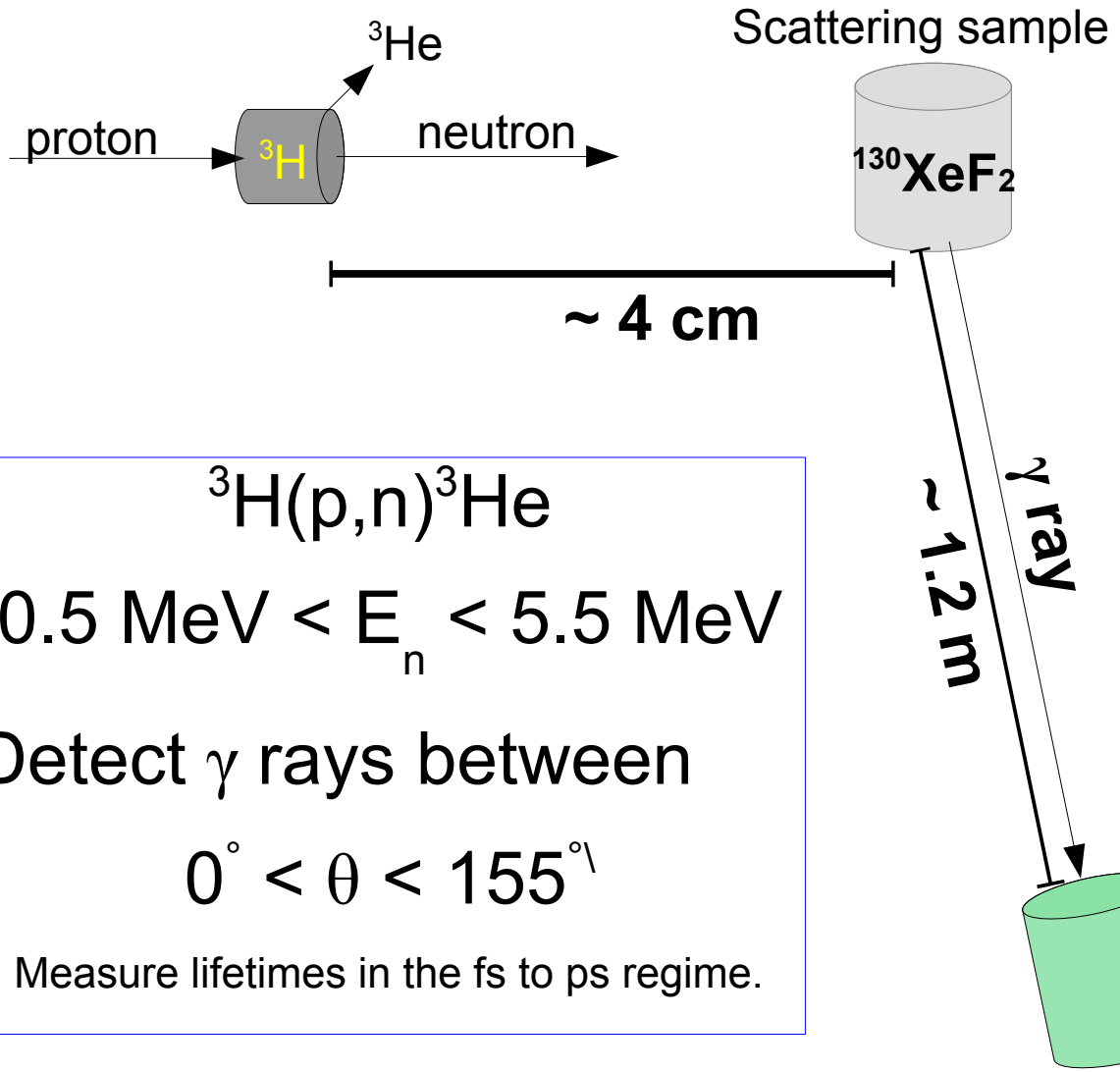
Sir William Ramsay and Lord Rayleigh
1904 Nobel prize winners.

http://www.ciaaw.org/pubs/Periodic_Table_Isotopes.pdf

Experiment

7 MV Van de Graaff Accelerator at University of Kentucky

I've been beaten to the punch a little here...



$^3H(p,n)^3He$

$0.5\ MeV < E_n < 5.5\ MeV$

Detect γ rays between

$0^\circ < \theta < 155^\circ$

Measure lifetimes in the fs to ps regime.

Germanium detector
(complete with LOTS of shielding)

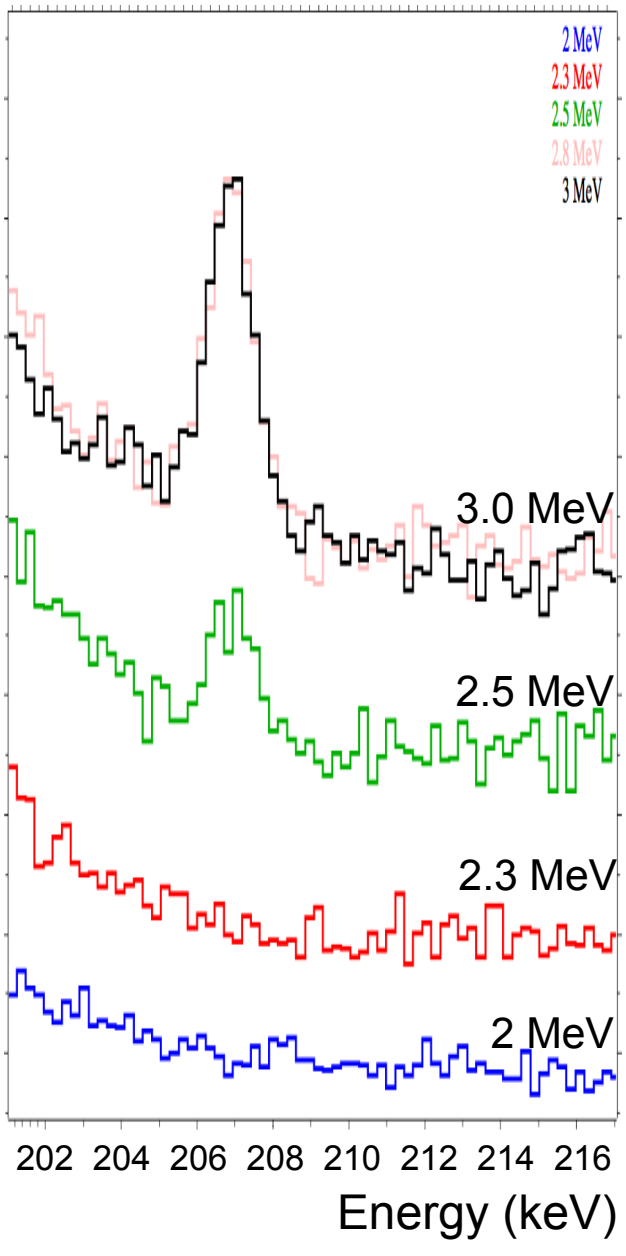
Vary the neutron energy –

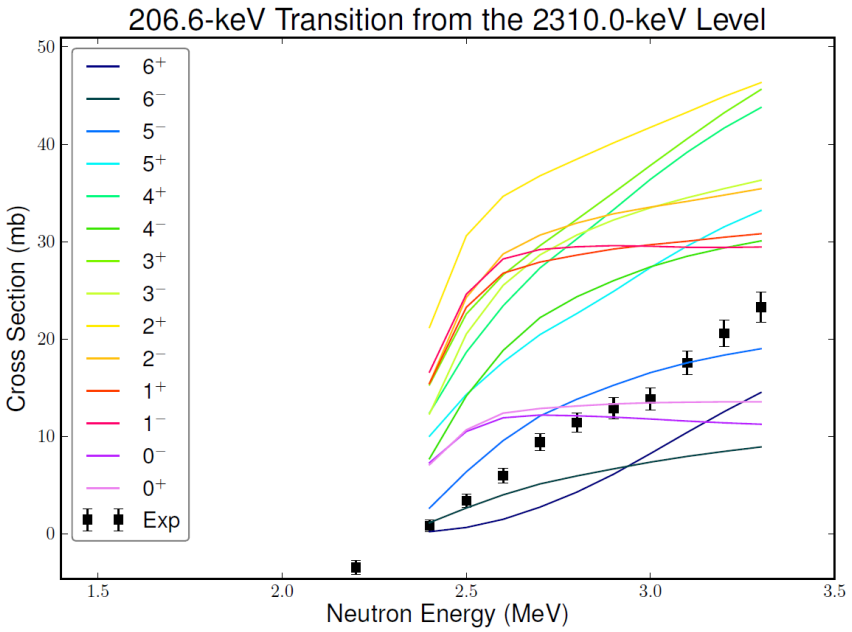
Excitation function: Yields γ-ray thresholds *and* level J^{π}

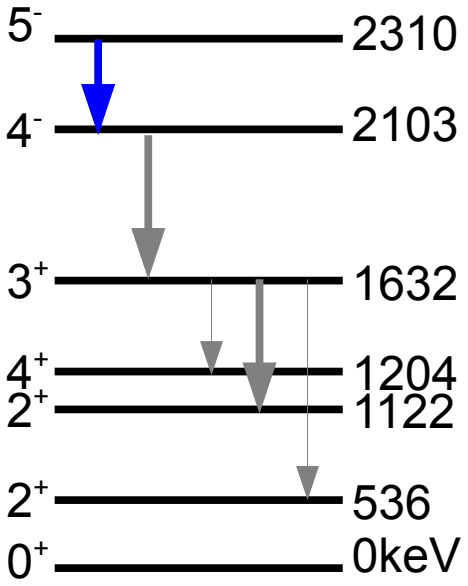
Transitions "appear" as we increase E_n above the level energy.

- Confirm the level scheme
- Place new levels
- Measure J^{π}

Example: Gate on 206 keV transition from the 2310 keV level.







^{130}Xe

What do we populate?

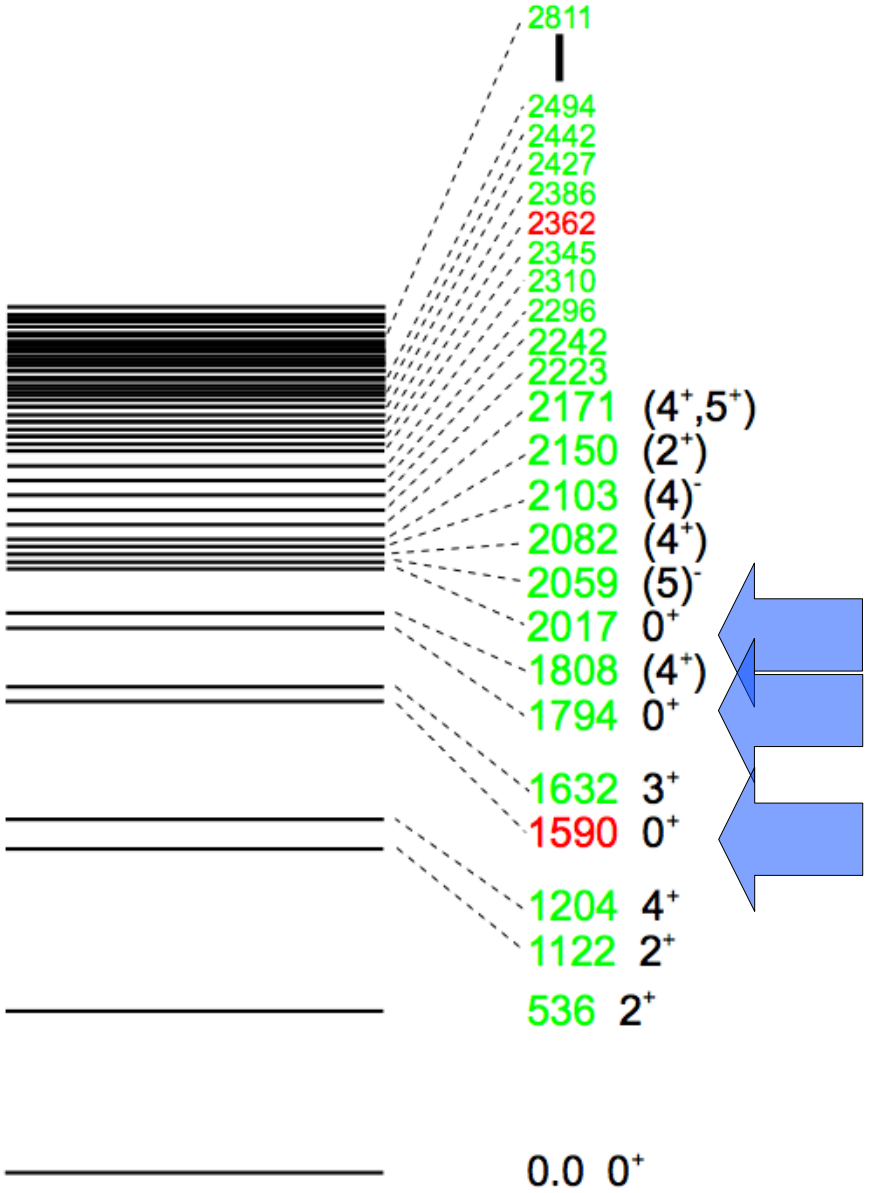
Excitation function data between 1.8 and 3.3 MeV

Angular distributions at 2.5 and 3.2 MeV

Populate almost all known levels below 3 MeV (of spin < ~ 6)

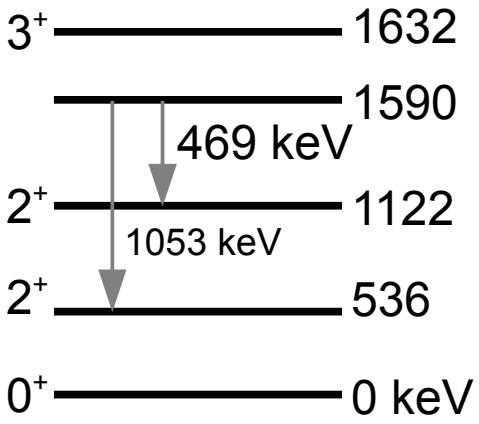
I'll focus on three 0^+'s (1590, 1794 and 2017 keV)

Several other recent works. There is confusion here.



0^+ candidate #1 at 1590 keV.

Coquard *et al.* $^{12}C(^{130}Xe,^{130}Xe^*)^{12}C$ Coulex at Gammasphere.

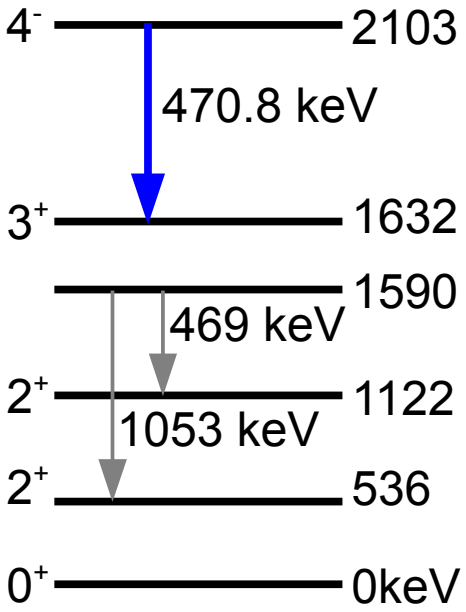


- Coquard *et al.* list one 0^+ level at 1590 keV.
- Observed previously once.
  (Thermal neutron capture – Hamada *et al.* J. Phys. G: Nucl. Phys. **14** (1988) p.1237)
- The footnotes are interesting:
  e) J^π assumed.
  f) only observed in coincidences.
  g) not observed

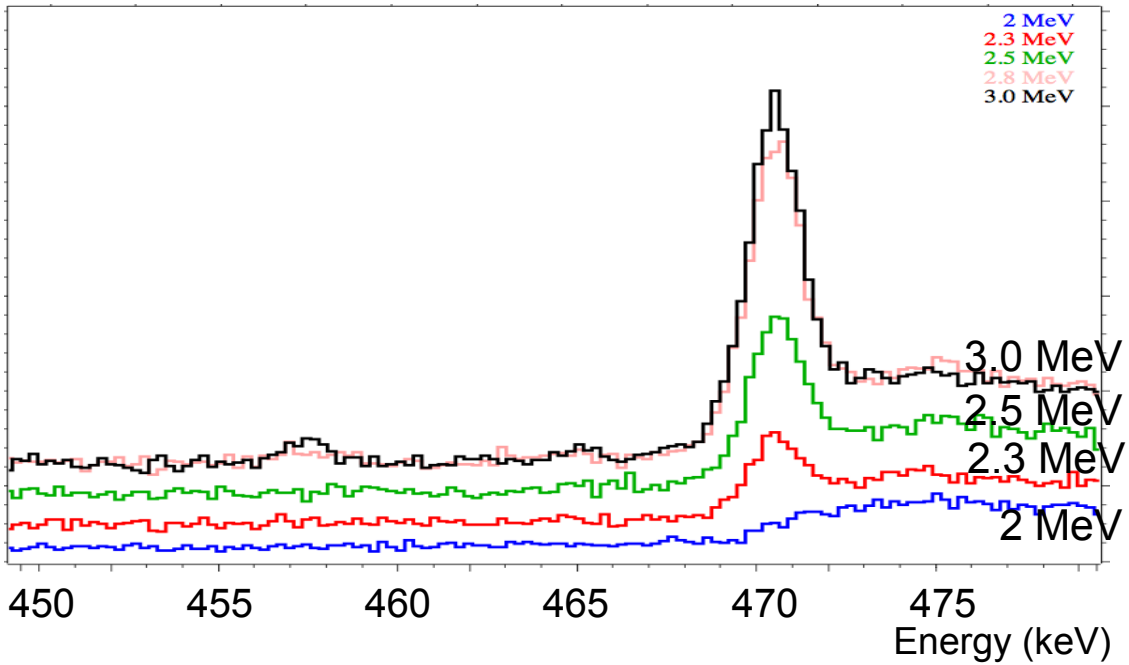
E_{level} (keV)	J^π	E_γ (keV)	I_γ	J^π_{final}	δ[a]	σ	$B(E2)$[b] W.u.
536	2_1^+	536	10^6	0_1^+		+	33.2(26)[c]
1122	2_2^+	586	3973(28)	2_1^+	+3.75(12)	−	44.3(81)
		1122	681(6)	0_1^+		+	0.28(5)
1204	4_1^+	82[d]		2_2^+		−	
		668	4835(34)	2_1^+		+	46.4(46)
1590	0_2^+[e]	469[f]	18.6(24)	2_2^+		−	256(118)
		1053[g]	15(15)	2_1^+		+	3.6(38)

L. Coquard *et al.* PRC **82**, 024317 (2010)

0^+_1 at 1590 keV.



Not a sniff of 469 OR 1053 in our data.



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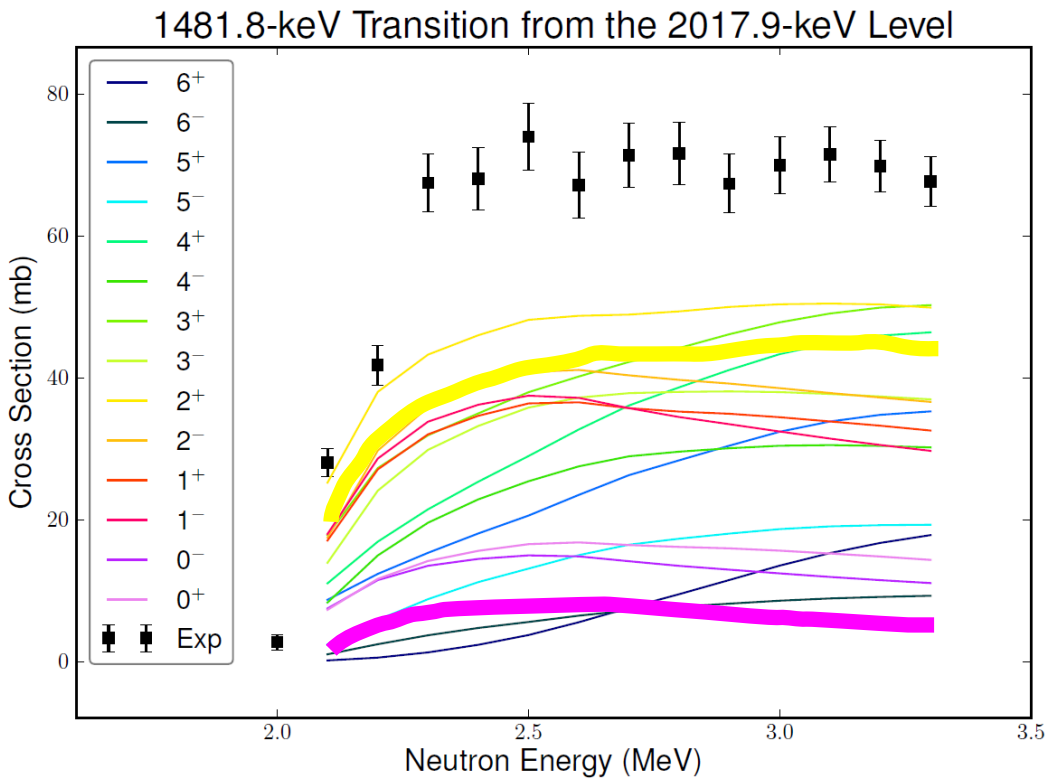
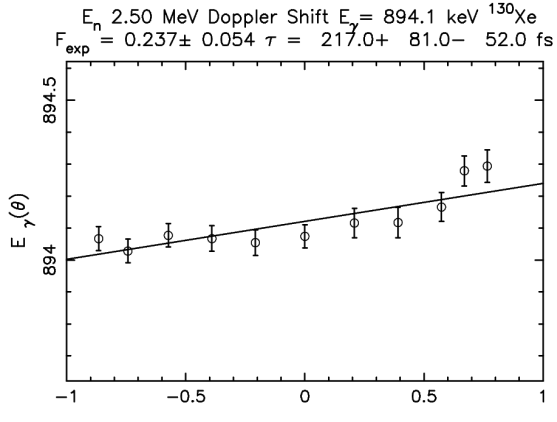
L. Coquard *et al.* PRC **82**, 024317 (2010)

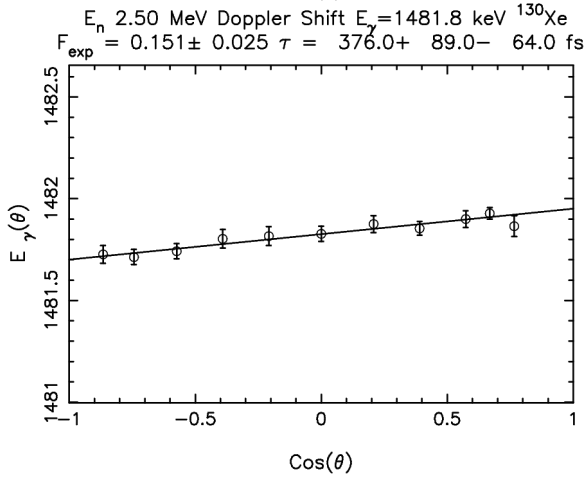
0^+ candidate #2

Level at 2017 keV

There is a well established level at this energy from numerous studies. (w/ two transitions)







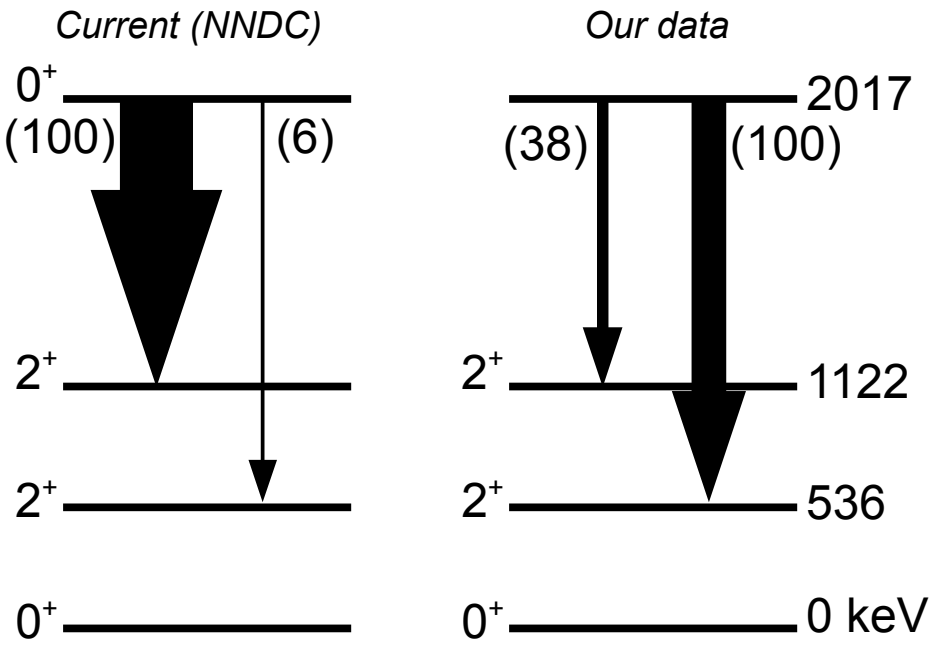
We see both transitions. The excitation functions look similar.

But do not agree with any singles calculation.

The level lifetime determined from these two gamma rays don't agree.

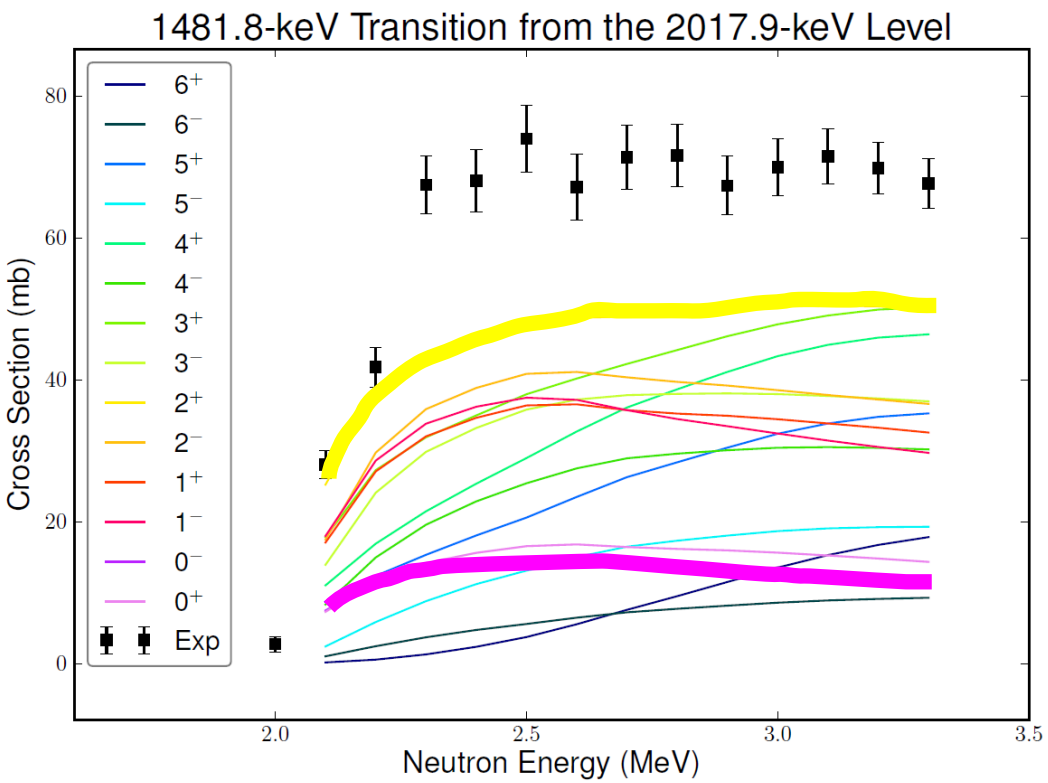
0^+ candidate #2

there has been previous questions about the relative intensities



I can't see a g.s. Transition.
But I can confirm new intensities for the decays we observe.

(these agree with the study of Coquard who claim this is a 2^+)



The excitation is quite well fit by the addition of the 0^+ and 2^+ calculations.

It appears there could be a 0^+ -- 2^+ level doublet here. Hard to disentangle with my gamma-ray singles data...

That brings us to the third candidate.

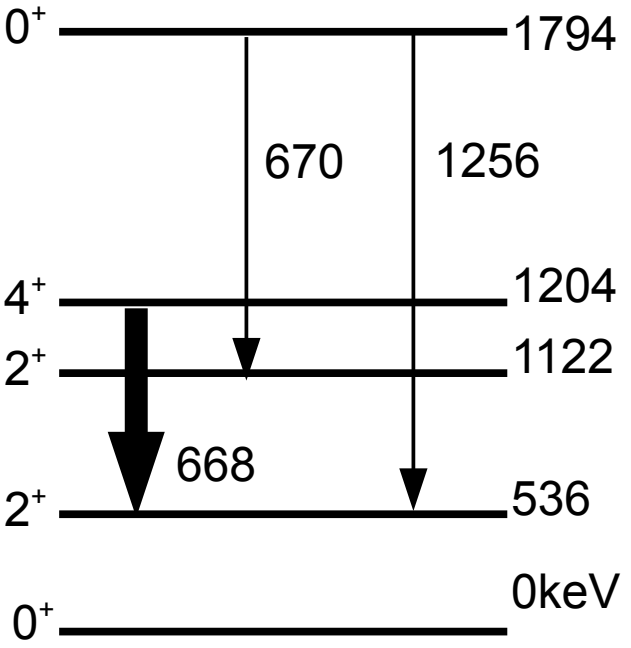
With regret my only comment ...

… is that I can't really comment.

Level at 1794 keV.

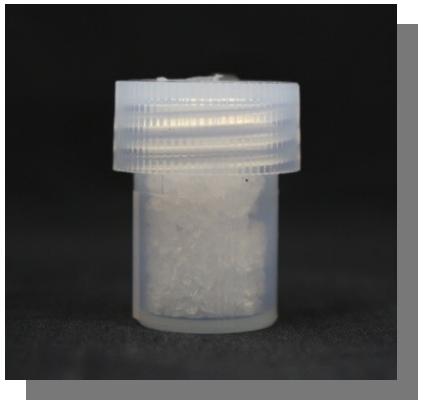
- 671 keV is a shoulder on $4^+ \rightarrow 2^+$.
  Extending my excitation function measurement below 1.8 MeV may help.

- 1257keV is awkward.
  Hidden beneath a fluorine line in my spectrum. I can learn some information from data taken at forward angles.

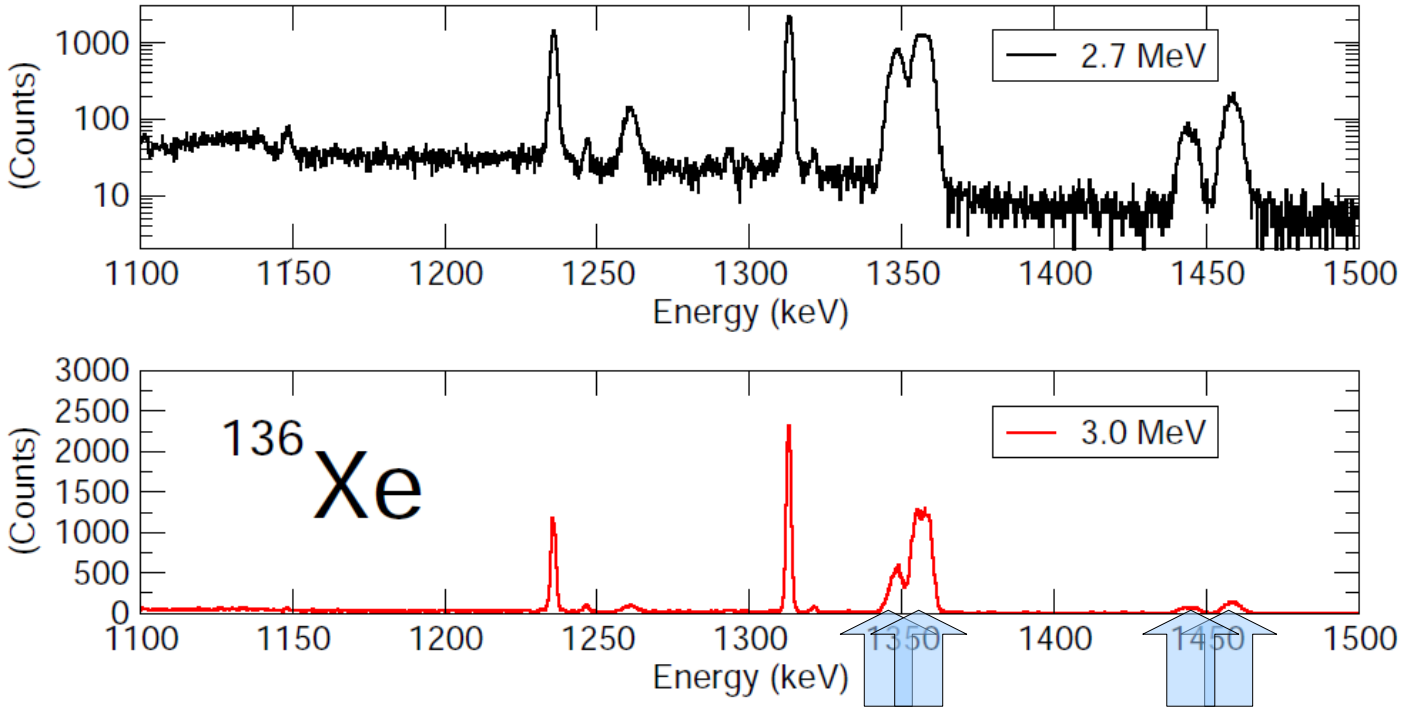


Scars on the landscape –

The fluorine in the target can cause issues...



XeF2 in Teflon® vial



1348, 1357, 1444, 1458

We see the lowest lying ~10 fluorine lines. Some of which have large doppler shifts.

We're starting to play with subtracting the fluorine away and using gamma-gamma.

Several works over the last few years.

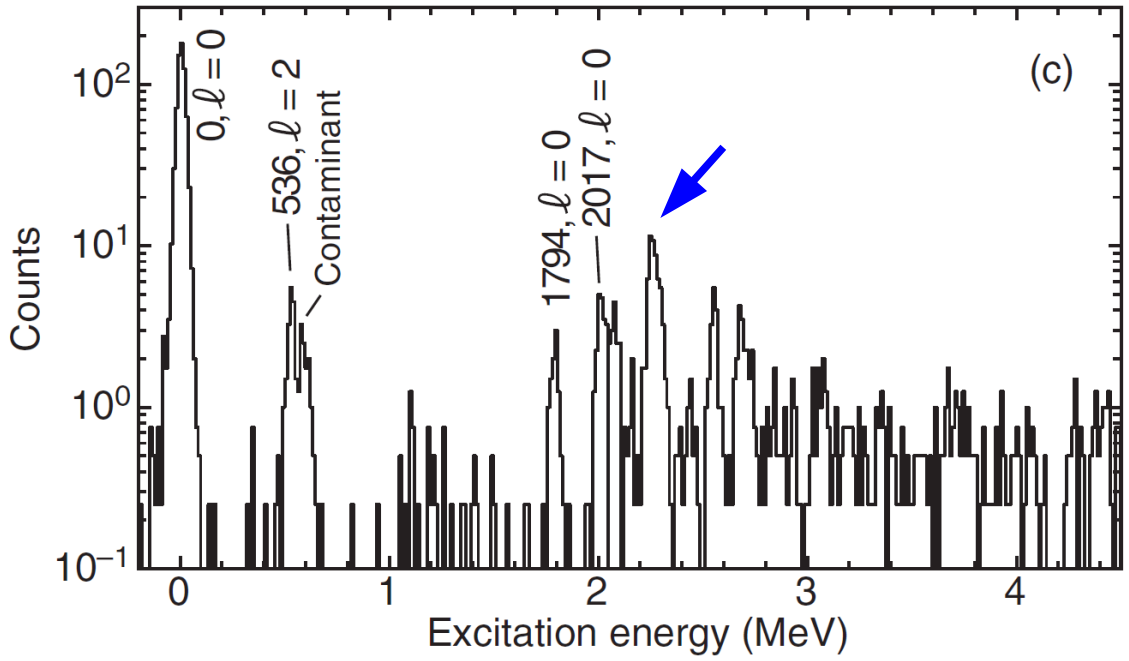
Kay *et al.* (p,t)

Kay and collaborators have carried out some really nice studies of the Xe's and Te's by transfer reactions.

Interested in possible pairing excitations and effects on QRPA nuclear matrix element calculations for 0νββ searches.

2017 keV level is listed in NNDC as 0^+.

Transfer to excited 0^+ levels is small.



B. Kay *et al.* PRC **87**, 011302(R) (2013)

Two new 0+ candidates at 2.2MeV

1590 keV level:
Appears not to exist.

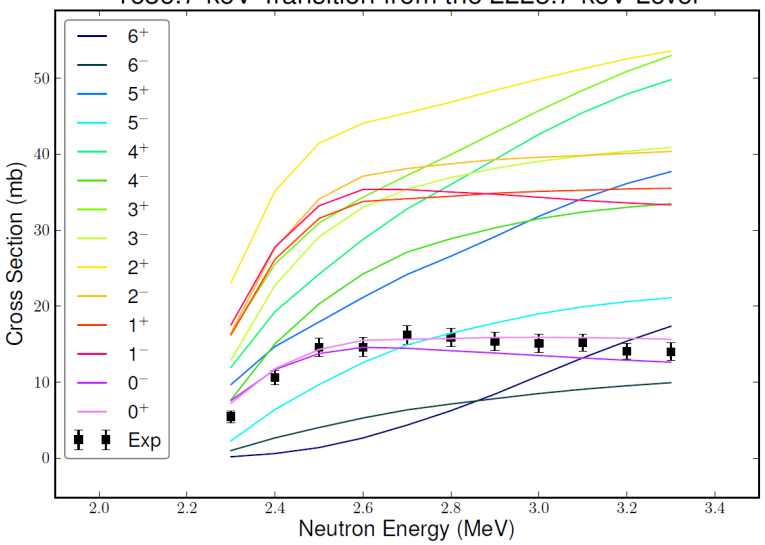
1794 keV level:.
I need to do some more work.

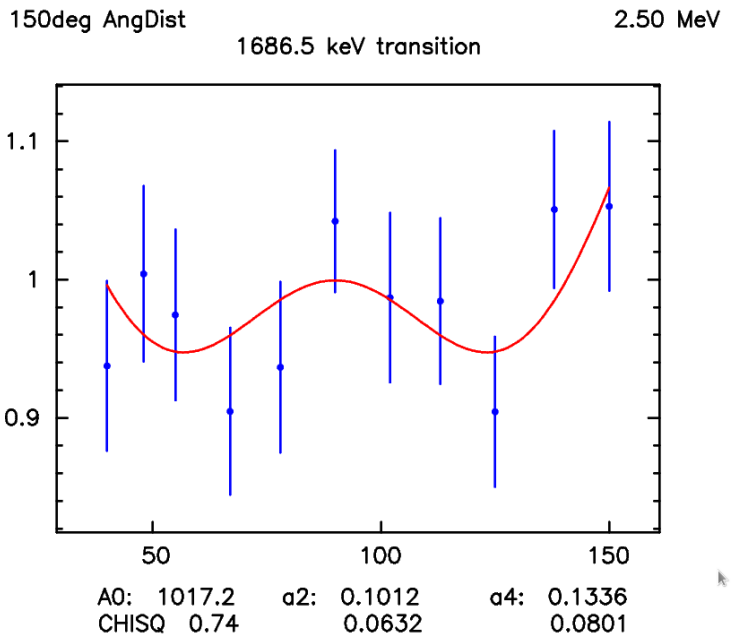
2017 keV level:
Also complicated!

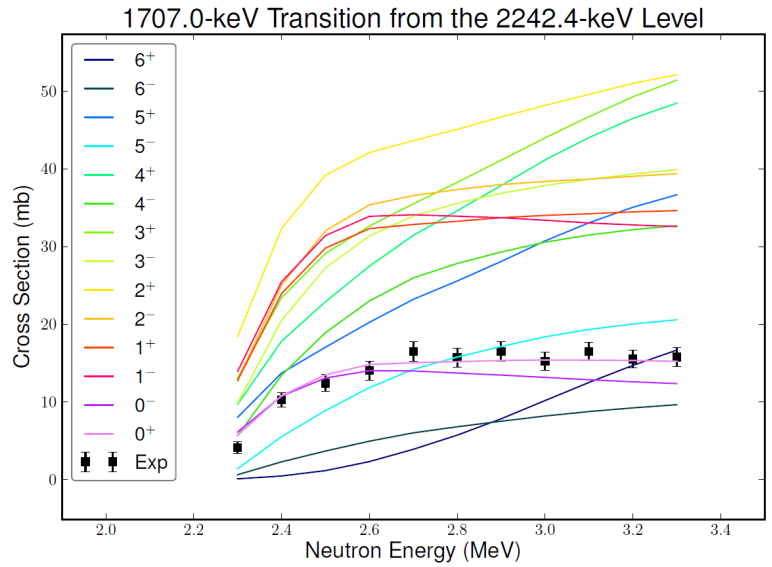
Two new 0^+ candidates:

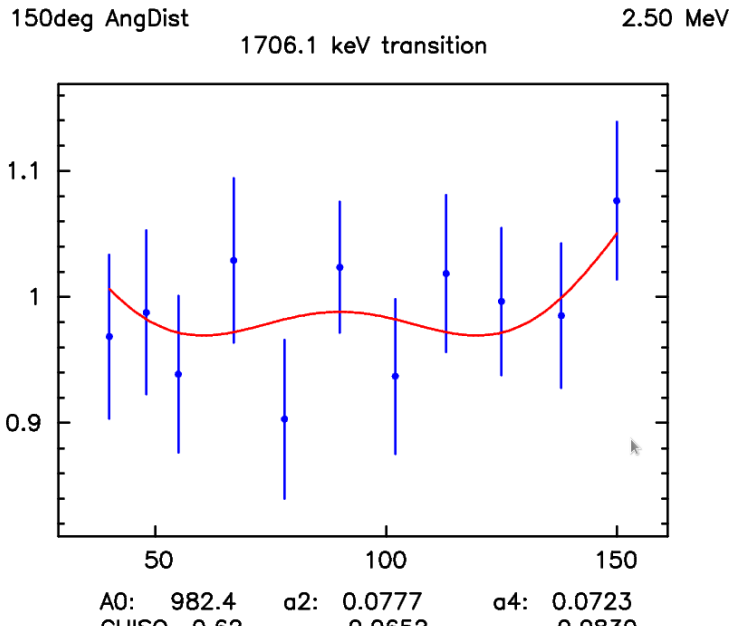
- Excitation functions look good.
- The angular distribution is relatively flat.
- I measure lifetimes and B(E2)'s for these guys.

Still work to do!





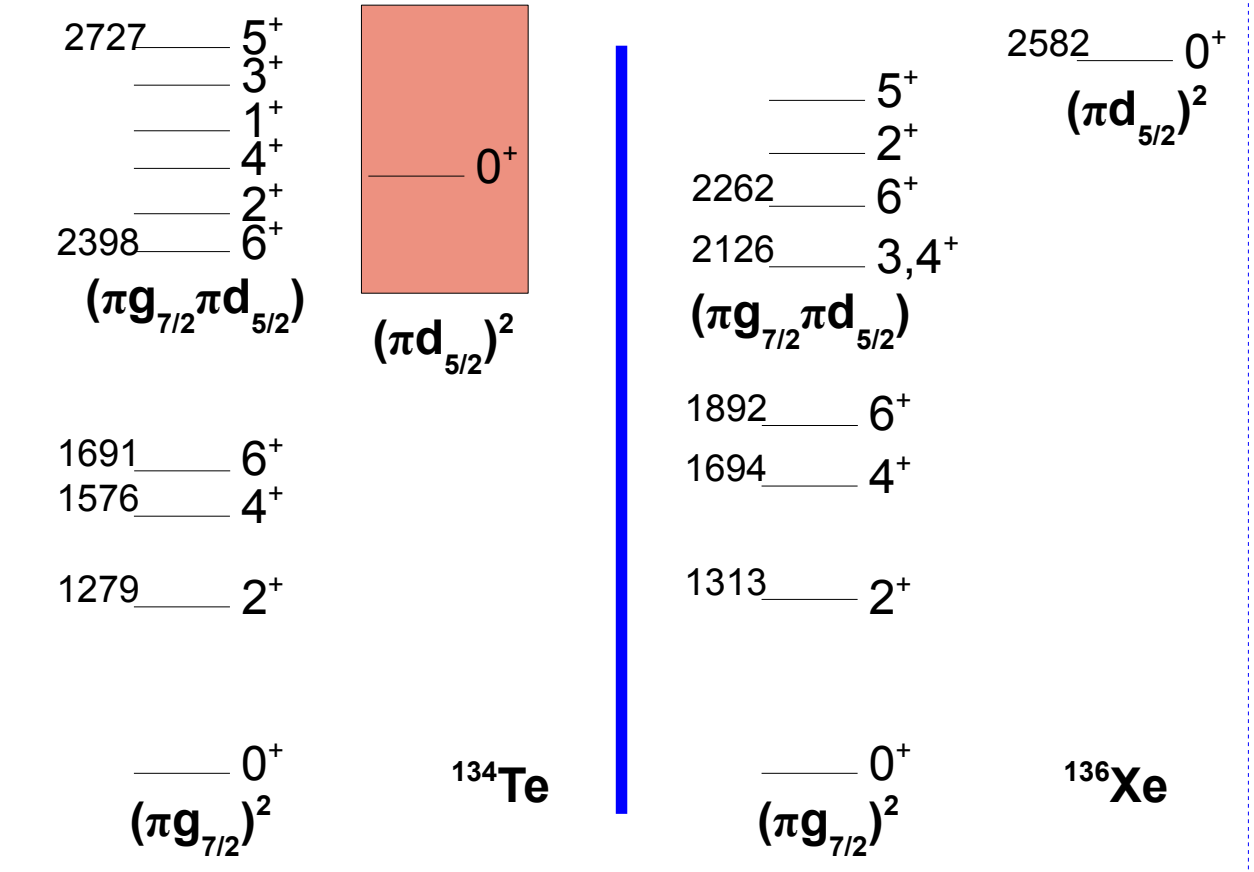


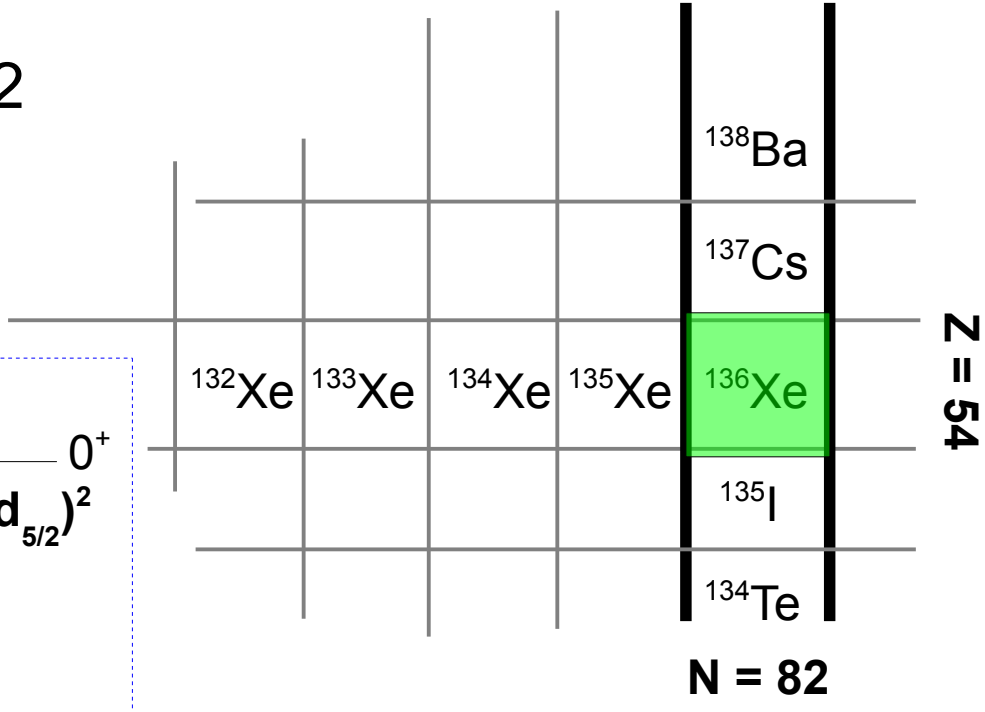


Now we'll turn attention to ^{136}Xe

6 additional neutrons. We're at N = 82

Seniority scheme picture.

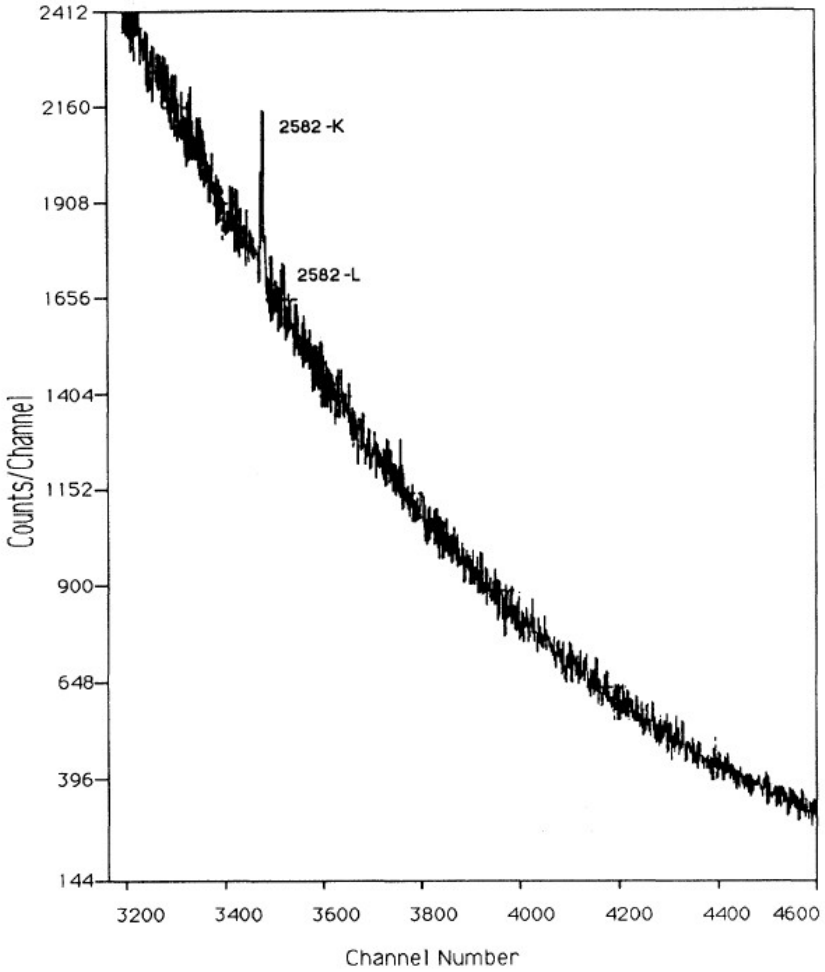




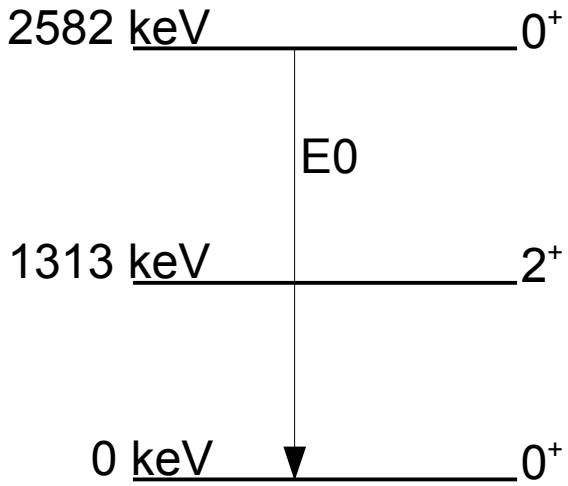
For ^{132,134}Xe see E.Peters tomorrow afternoon.

Only one 0^+ is expected

and there is one in the literature...



Established by conversion e^- spectroscopy



VOLUME 43, NUMBER 4 APRIL 1991

$E0$ transitions and O^+ levels in ^{136}Xe

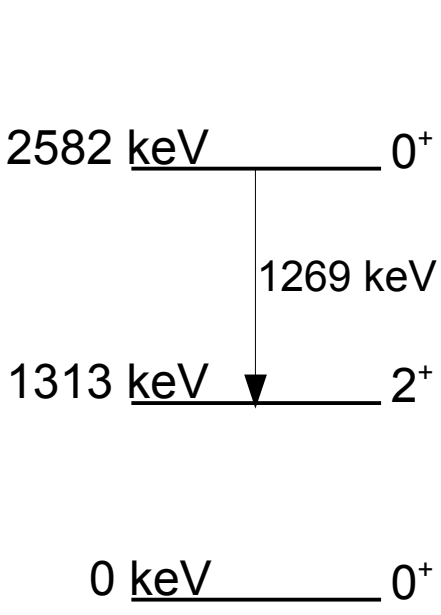
P. F. Mantica, Jr., B. E. Zimmerman, and W. B. Walters
Department of Chemistry and Biochemistry, University of Maryland, College Park, Maryland 20742

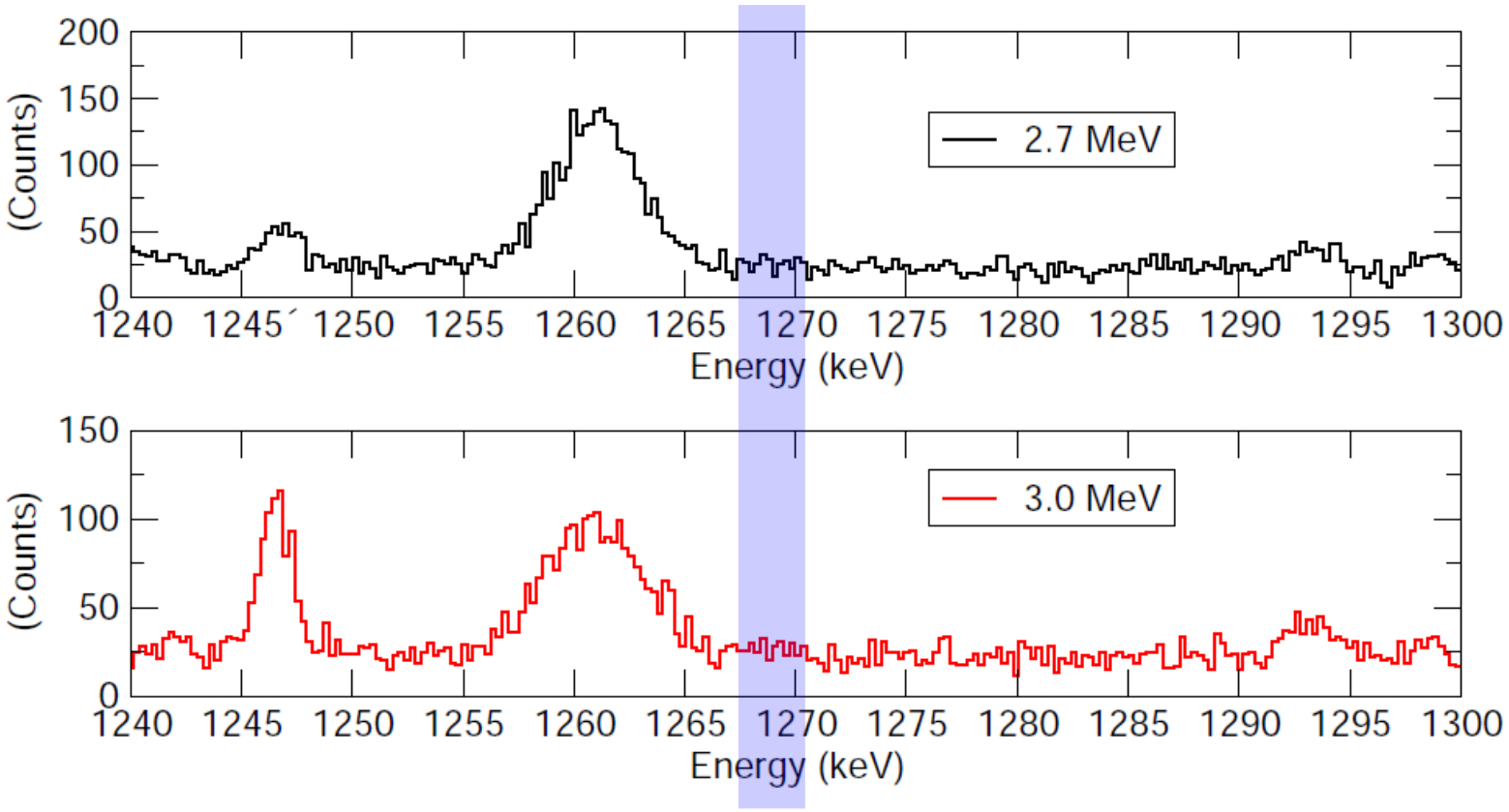
K. Heyde
Institute for Nuclear Physics and Institute for Theoretical Physics, Proeftuinstraat 86, B-9000 Gent, Belgium
(Received 18 June 1990)

But I see no hint of other expected transitions to lower lying states...

Erroneously assigned?

I don't know, they clearly had a large signal there.



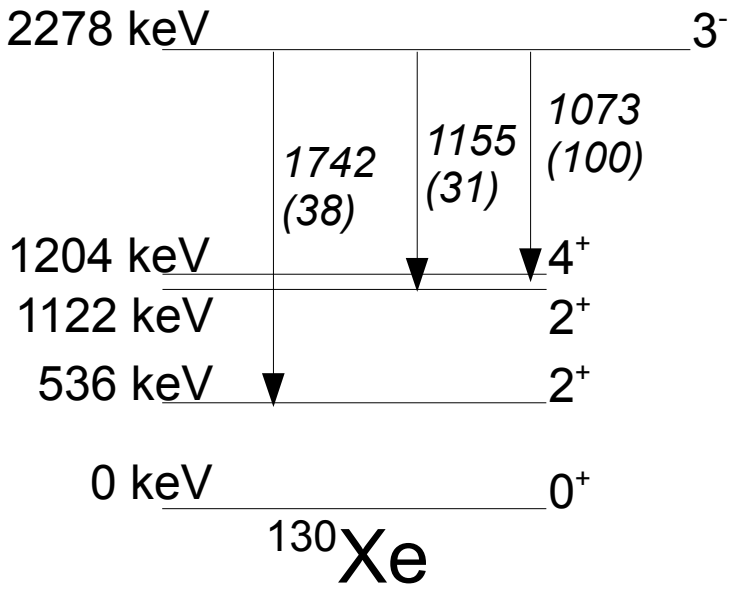


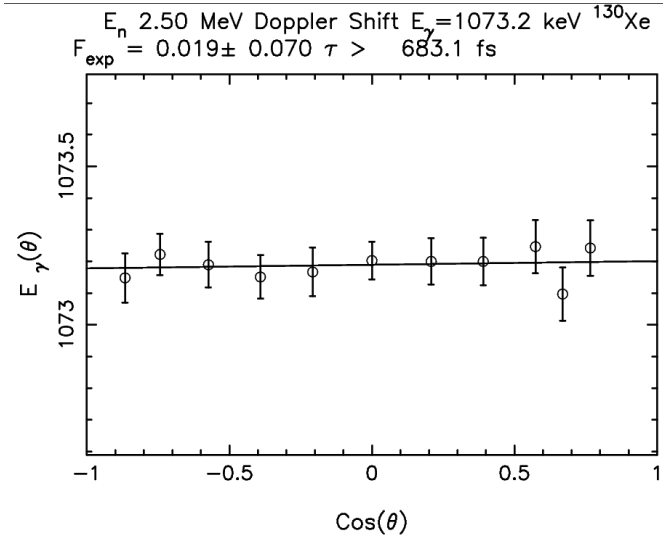
Octupole 3^- states in the xenons

^{130}Xe

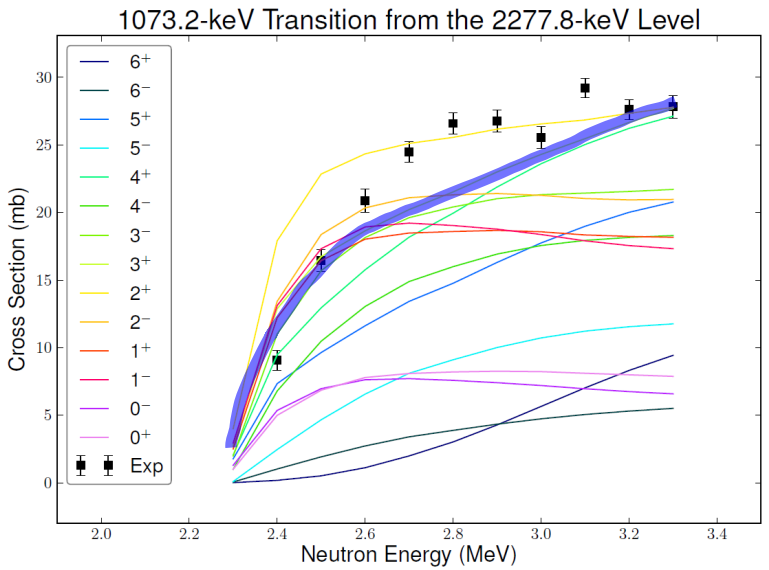
Mueller *et al.* recently assigned a 3^- candidate in ^{130}Xe at 2278 keV.

Coquard *et al.* Observed an additional transition.





The lifetime is too long for us to measure. (but is consistent for all 3 gamma rays)



Excitation function is in agreement with calculations for a 3^- state.

W.F. Mueller *et al.* PRC **73**, 014316 (2006)

L. Coquard *et al.* PRC **82**, 024317 (2010)

Octupole 3^- systematics

Mueller *et al.* suggest an equation that predicts E_{3-}

New assignment in ^{134}Xe at 2653 keV from the University of Kentucky (E. Peters Ph.D. Thesis)

PHYSICAL REVIEW C **73**, 014316 (2006)

Variation with mass of $B(E3; 0_1^+ \rightarrow 3_1^-)$ transition rates in $A = 124-134$ even-mass xenon nuclei

W. F. Mueller,[1,*] M. P. Carpenter,[2] J. A. Church,[1,3,†] D. C. Dinca,[1,3,‡] A. Gade,[1] T. Glasmacher,[1,3] D. T. Henderson,[2] Z. Hu,[1,§] R. V. F. Janssens,[2] A. F. Lisetskiy,[1,‖] C. J. Lister,[2] E. F. Moore,[2] T. O. Pennington,[2] B. C. Perry,[1,3] I. Wiedenhöver,[4] K. L. Yurkewicz,[1,3,¶] V. G. Zelevinsky,[1,3] and H. Zwahlen[1,3]

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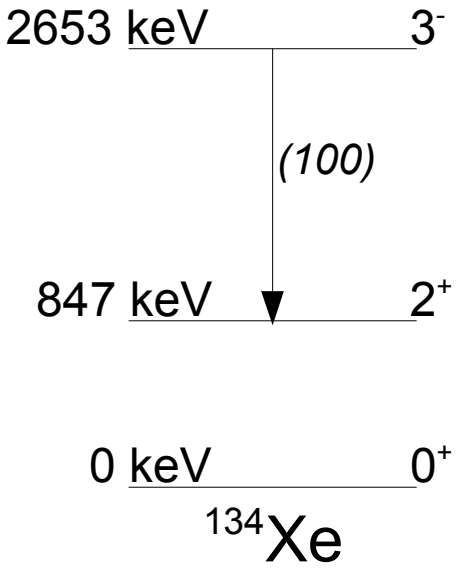
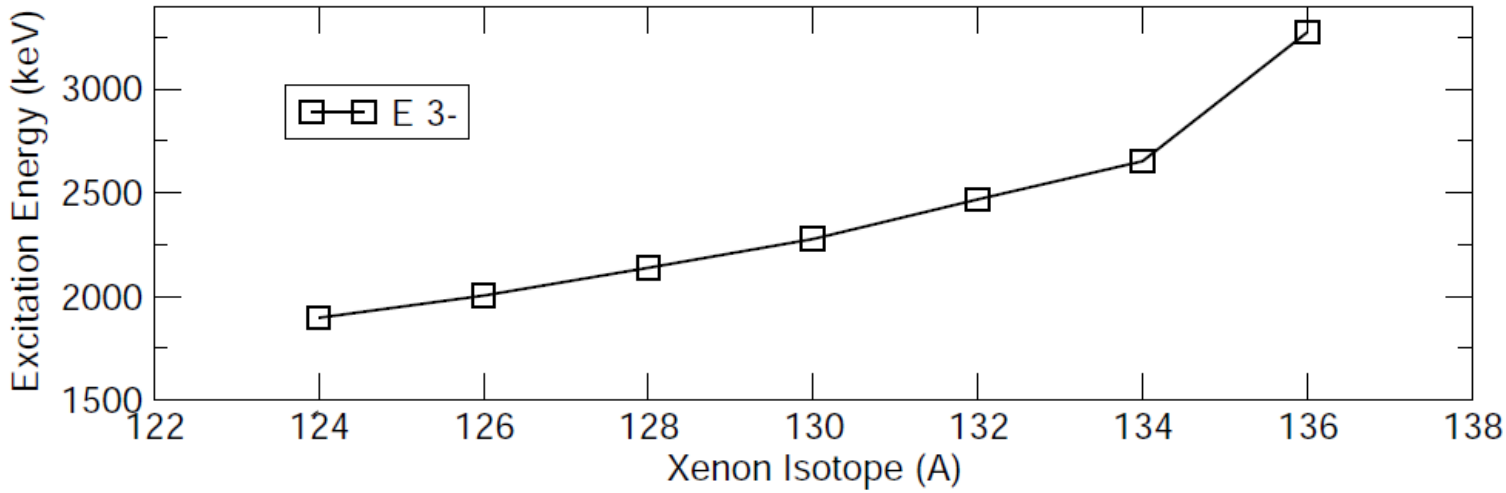
(Received 18 April 2005; published 27 January 2006)





Summary and looking forward.

- We've discussed some confusion concerning 0^+ assignments in ^{130}Xe.
- ^{136}Xe seems to be much better understood
- Octupole 3^-'s in these nuclei.
- Going forward ...

Thanks for listening!

T.J. Ross[1], E.E. Peters[1], A. Chakraborty[1],
B.P. Crider[1], A. Kumar[1], S. Liu[1],
M.T. McEllistrem[1], F.M. Prados-Estévez[1],
J.R. Vanhoy[2] and S.W. Yates[1]

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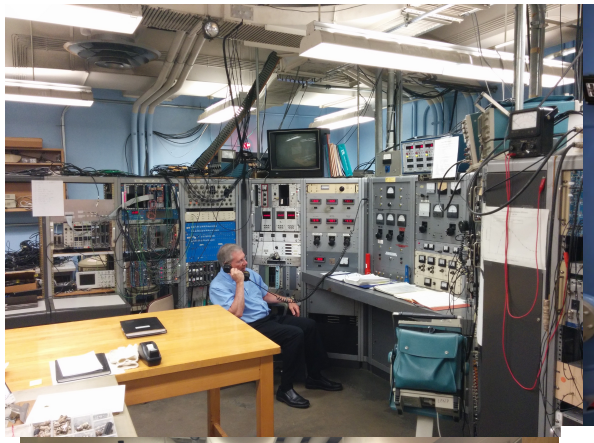

University of Kentucky

50 years

UK

1964-2014

Accelerator Laboratory