Spectroscopy of the low lying states of the neutron rich Iodine nucleus (^{134}I)

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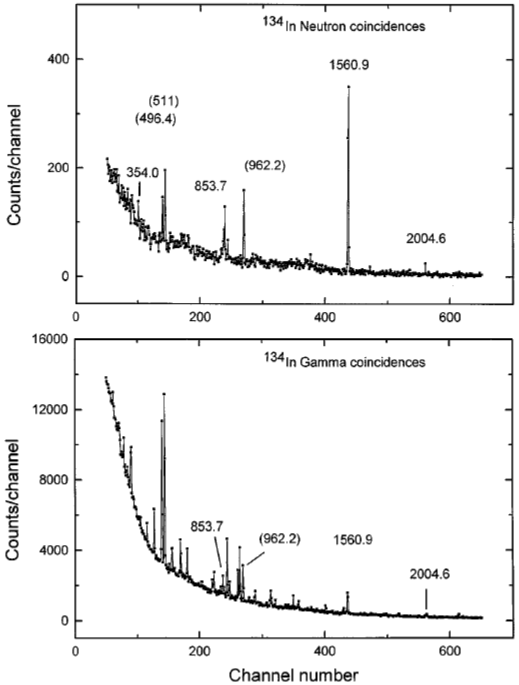
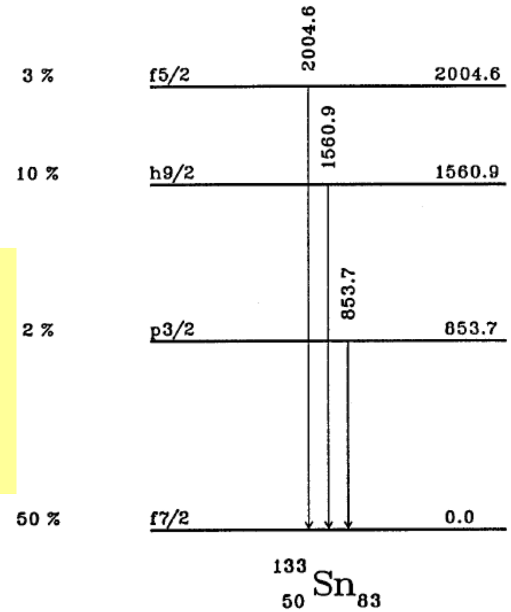
Physics Motivation

Doubly magic $^{132}_{50}Sn_{82}$

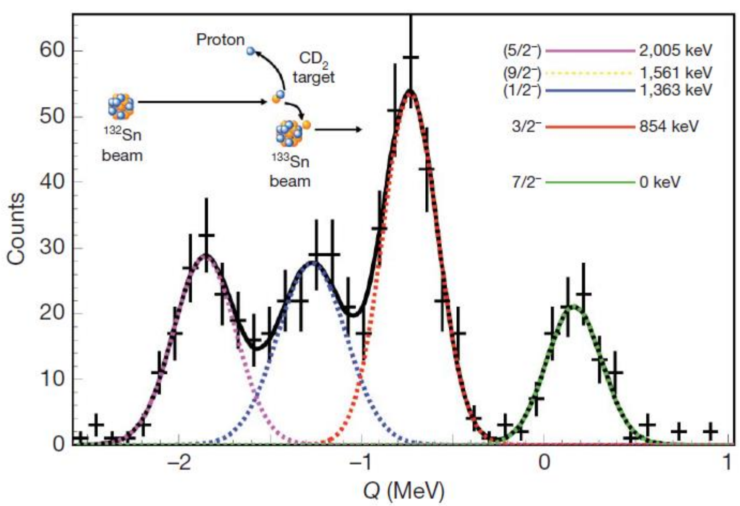


P. Hoff et al. Phys. Rev. Lett. **77**, 1020 (1996).

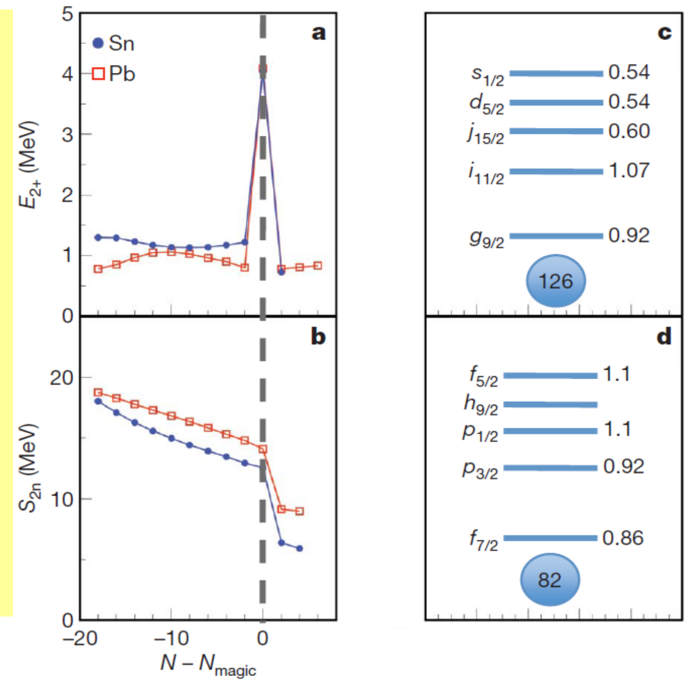
- ✓ Low lying states of ^{133}Sn was measured from βn decay of ^{134}In and β decay of ^{133}In
- ✓ γ–γ , n-γ coincidence study and half life measurement was performed



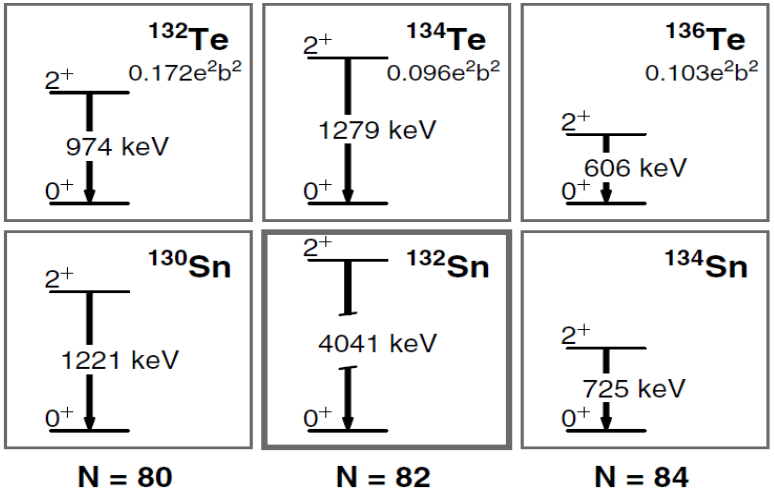
K. L. Jones et al., nature **465**, 454 (2010).



- ✓ Low S_{2n} beyond N = 82 and high E(2$^+$) at N = 82
- ✓ (d,p) reaction preferably populates low l (p, f) orbitals (confirmed comparing expt. with DWBA calculations) – shows the single particle excitation of ^{133}Sn nucleus



Even-Even nuclei around ^{132}Sn



D. C. Radford, Phys. Rev. Lett., **88**, 222501 (2002).

Odd-Odd nuclei around ^{132}Sn

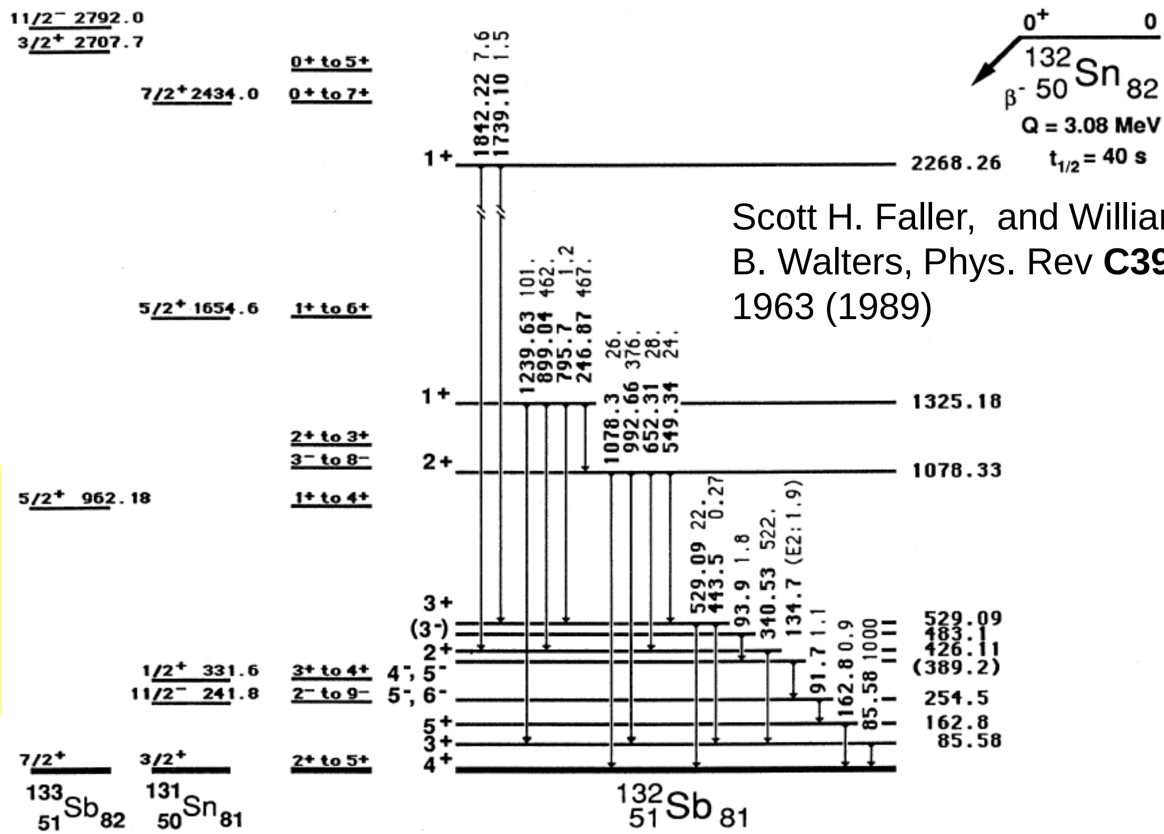
- ✓ Excitation energy
- ✓ Transition probability
- ✓ Single particle configuration
- ✓ Study of residual p-n interaction

Z =51 Sb nuclei are mostly studied from decay OR fission

Present case : odd -odd Iodine(Z =53) nuclei

Study of low lying structure from the γ-spectroscopic measurements

Measurement of lifetime and transition moments give the direct evidence for the structure of the excited states.



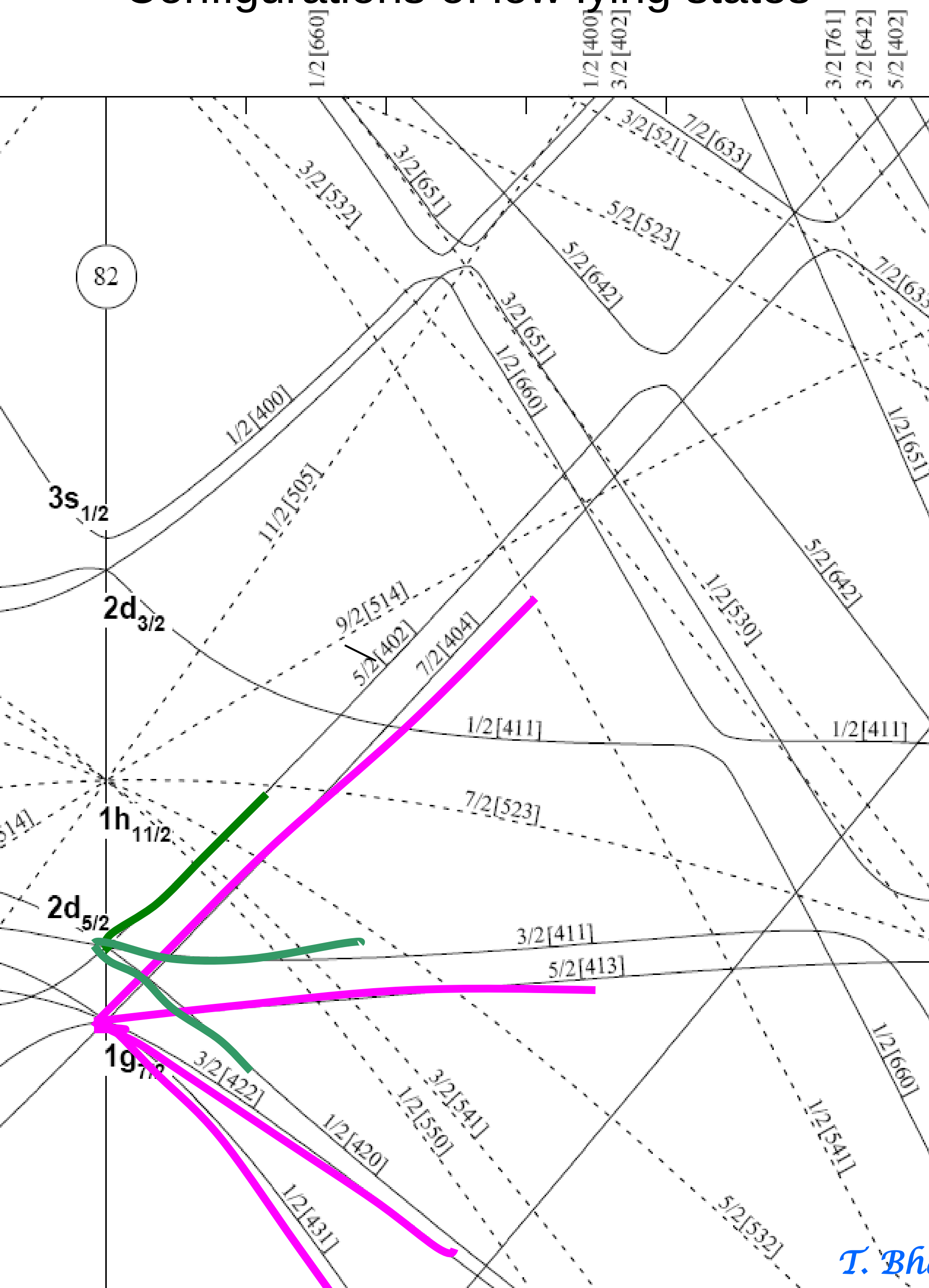
Scott H. Faller, and Willia
B. Walters, Phys. Rev **C39**
1963 (1989)

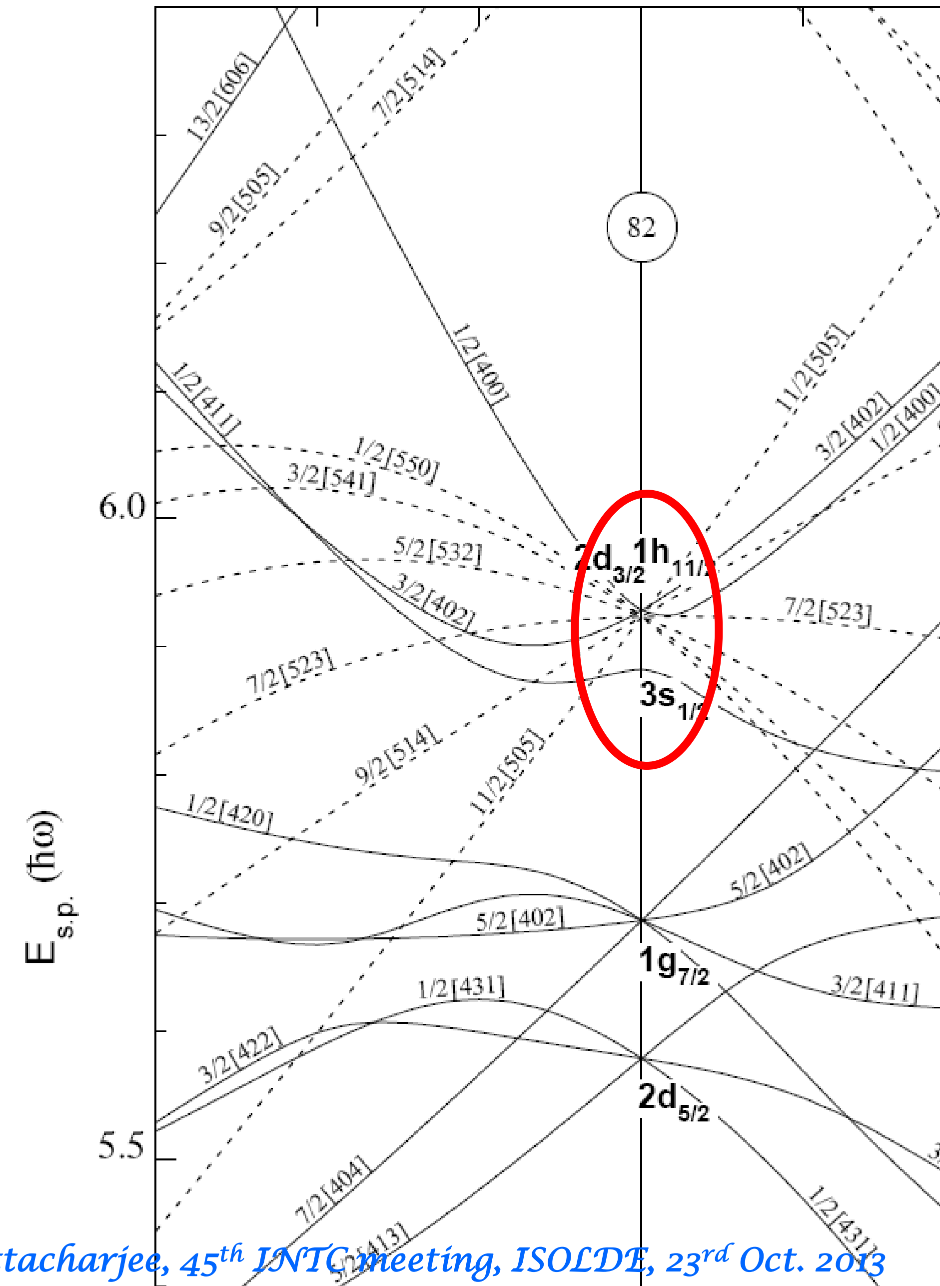
T. Bhattacharjee, 45th INTC meeting, ISOLDE, 23rd Oct. 2013

Systematic study of odd-odd Iodine nuclei

Configurations of low lying states

$\pi g_{7/2}\nu s_{1/2}$, $\pi g_{7/2}\nu d_{3/2}$, $\pi d_{5/2}\nu s_{1/2}$, $\pi d_{5/2}\nu d_{3/2}$, $\pi g_{7/2}\nu h_{11/2}$, $\pi d_{5/2}\nu h_{11/2}$

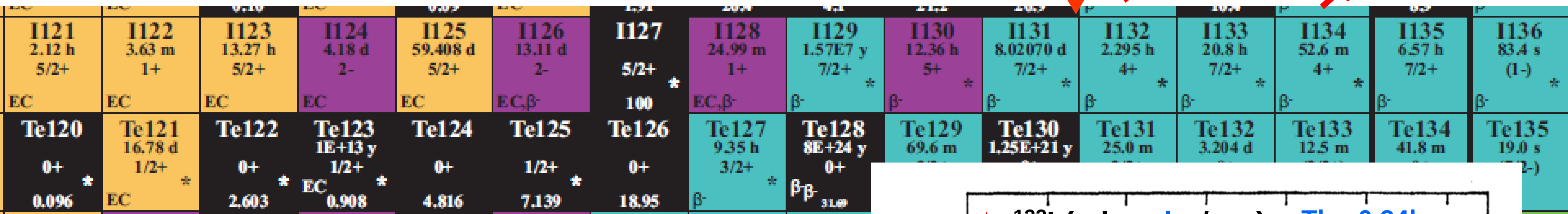




Odd-Odd Iodine @ VECC from In-beam PAD

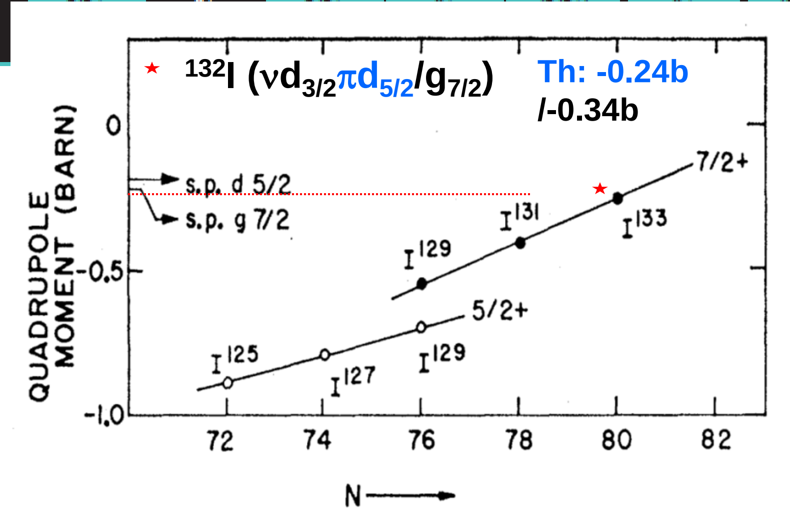
T. Bhattacharjee, abstract book of "National workshop on experimental proposal and possibilities for the Nuclear st with INGA at VECC", held on May 22-33, 2012, page-14.

Not possible from decay, planned with in-beam TDPAD at VEC



53	I	117	0	2.22 m	$(5/2)^+$	3.1 2	
53	I	118	0	13.7 m	2^-	2.0 2	
53	I	118	0+x	8.5 m	(7^-)	4.2 2	
53	I	119	0	19.1 m	$5/2^+$	(+)2.9 1	
53	I	119	306.9	34.6 ns	$9/2^+$	+5.40 14	
53	I	120	0	81.0 m	2^-	1.23 3	
53	I	120	0+x	53 m	4 to 8	4.2 2	
53	I	121	0	2.12 h	$5/2^+$	2.3 1	
53	I	121	2353.1	80 ns	(21/2)	+12.6 11	
53	I	122	0	3.63 m	1^+	0.94 3	
53	I	123	0	13.27 h	$5/2^+$	2.818 7	
53	I	123	2659.9	27.2 ns	$(21/2^+)$	+10.9 9	
53	I	124	0	4.18 d	2^-	1.14 8	
53	I	125	0	59.408 d	$5/2^+$	2.821 5	-0.889
53	I	125	188.414	0.34 ns	$3/2^+$	+1.06 7	
53	I	126	0	13.11 d	2	1.436 5	
53	I	126	110.85	55 ns		-2.235 18	
53	I	127	0	stable	$5/2^+$	+2.81327 9	-0.79
53	I	127	57.606	1.95 ns	$7/2^+$	+2.54 5	-0.71
53	I	127	202.860	0.39 ns	$3/2^+$	+0.97 7	
53	I	128	137.849	0.845 µs	4^-	-0.720 28	
53	I	129	0	1.57×10^7 y	$7/2^+$	+2.6210 3	-0.553
53	I	129	27.78	16.8 ns	$5/2^+$	+2.8045 26	-0.685
53	I	131	0	8.02070 d	$7/2^+$	+2.742 1	-0.40 1 ★
53	I	131	149.715	0.95 ns	$5/2^+$	+2.8 5	
53	I	131	1797.073	5.9 ns	$9/2^-, 11/2^-, 13/2^-$		0.75
53	I	132	0	2.295 h	4^+	3.088 7	0.09 1
53	I	132	49.720	7.14 ns	3^+	+2.24 30	0.23 7
53	I	132	277.86	1.42 ns	1^+	+1.88 11	(-)0.170 6
53	I	133	0	20.8 h	$7/2^+$	+2.856 5	-0.27 1 ★

Q ↓

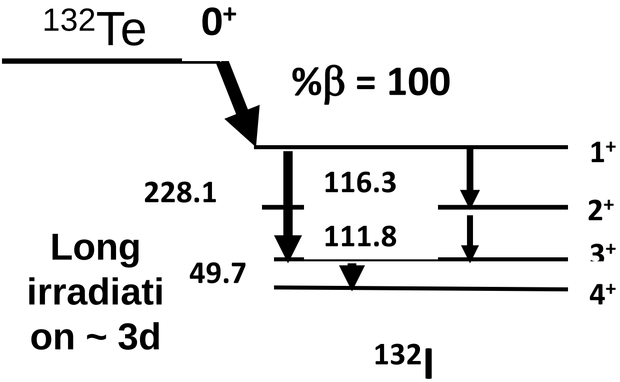


D. W. HAFEMEISTER, G. DzPASQUALI AND H. DZWAARD, Phys. Rev, **135**, B1089(1964)

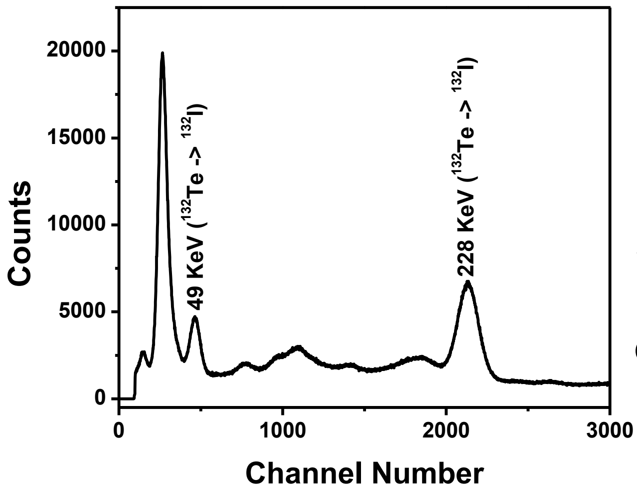
- **Q increases as the no of ν hole compared to N = 82 increases**
- **Extrapolated value for $\pi d_{5/2}$ at shell closure is much larger compared to that of $\pi d_{7/2}$ - coupling of all odd protons contribute**

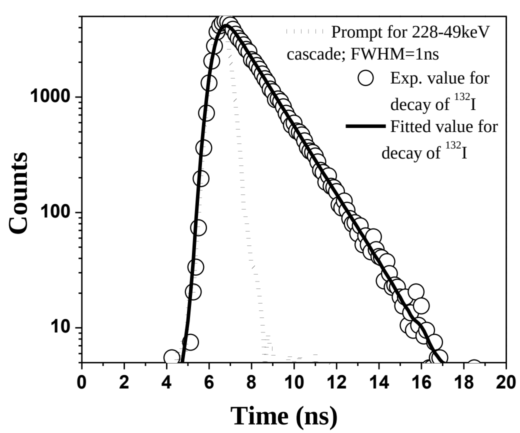
T. Bhattacharjee, 45th INTC meeting, ISOLDE, 23rd Oct. 2013

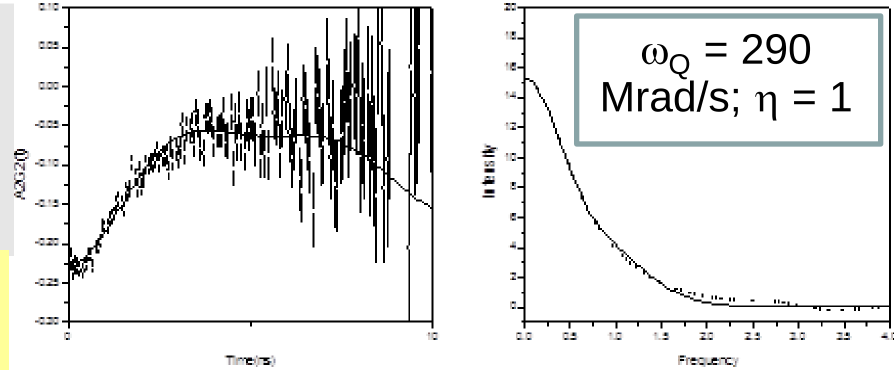
Study of Odd-Odd Iodine nuclei @ VECC, Kolkata



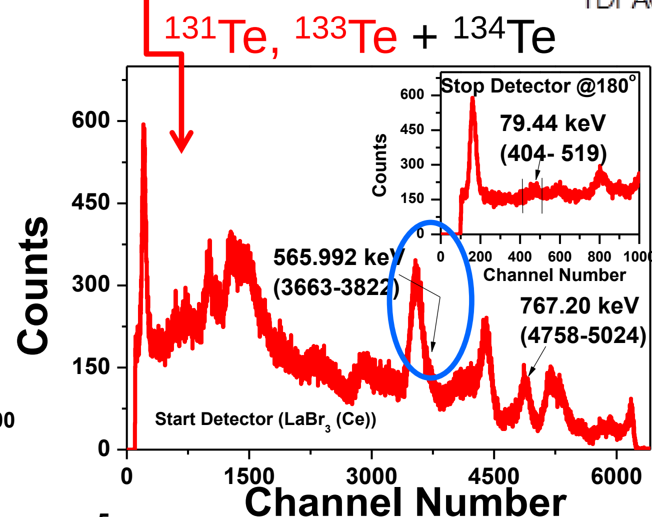
Short irradiation ~ 1hr

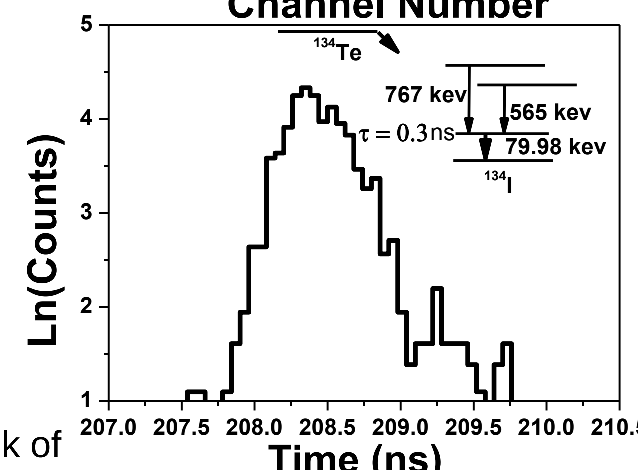






TDPAC study 49 keV state of ^{132}I in Te metal





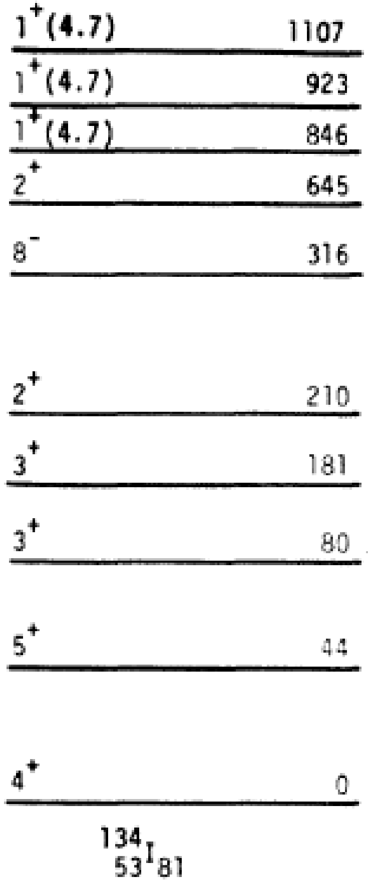
- ✓ Fission (^{238}U +α) + chemical separation
- ✓ Study of ^{132}I is possible by fission due to long half life of ^{132}Te(~ 3 days)
- ✓ Short half life (~40min) of ^{134}Te and the neighboring isotopic contamination poses the difficulty –
- ✓ **Chemical separation is not effective**

Clean activity of ^{134}Te is possible only at ISOLDE

S. Bhattacharya et al., **NS-016**, book of abstract-02, INPC2013: 2-7 June 2013,

T. Bhattacharjee, 45th INTC meeting, ISOLDE, 23rd Oct. 2013

Existing knowledge on ^{134}I



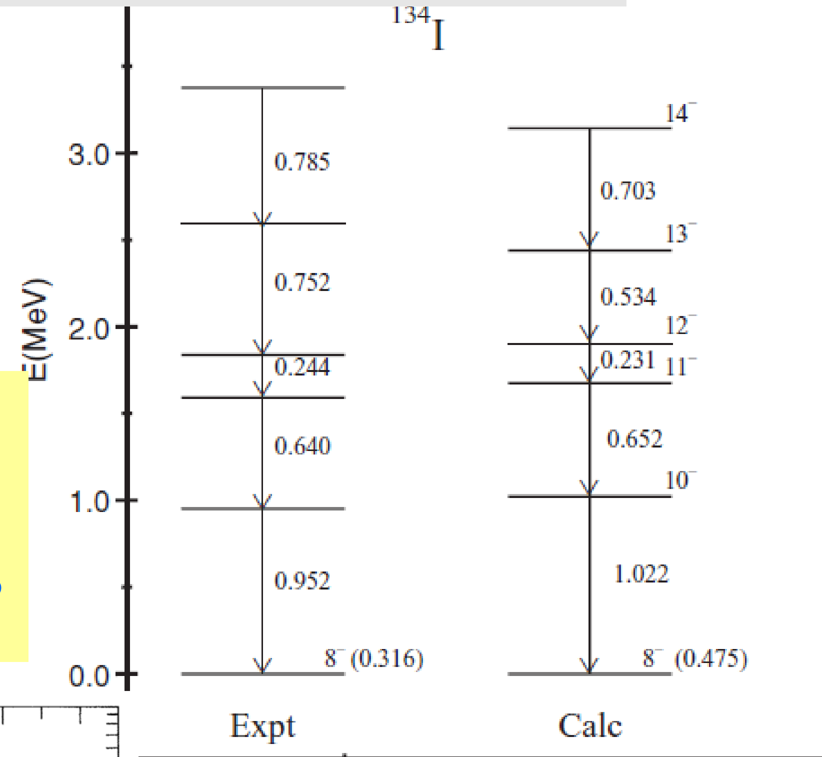
< 150 ps.

< 100 ps,

1.62 ns

Measurement low lying states used Ge(Li) detectors

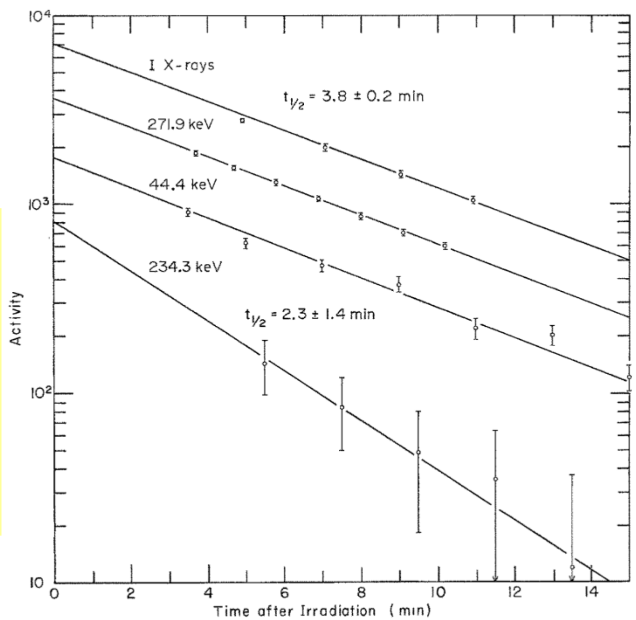
Lifetime measurement from electron gamma coincidence
V. Berg and A. Hoglund, Nuclear Physics **Al75,** 495 (1971).



Expt: S. H. Liu et al., Phys. Rev. **C79**, 067303 (2009).
Shell Model: L. Coraggio et al., Phys. Rev. **C80**, 061303(R) (2009).

A three proton particle and one neutron hole structure has been proposed for these low lying states with a large configuration mixing

R. A. Meyer et al., Phys. Rev. **C13**, 1617(1976).



One 3.8 min, 8- isomer has been identified in the nucleus from the decay measurements

[9] C.D. Coryell et al., Nuclear Physics **Al79** 689 (1972).

Experimental Plan

- Production of ^{134}I from the β- decay of ^{134}Te – ISOLDE

- γ–γ coincidence and decay measurement for studying the low lying states in terms of energy and coincidence – Two HPGe detectors and coincidence electronics with DAQ

- Lifetime measurement by slope technique for the 79 keV state.
- Measurement of quadrupole moment for the 79 keV state

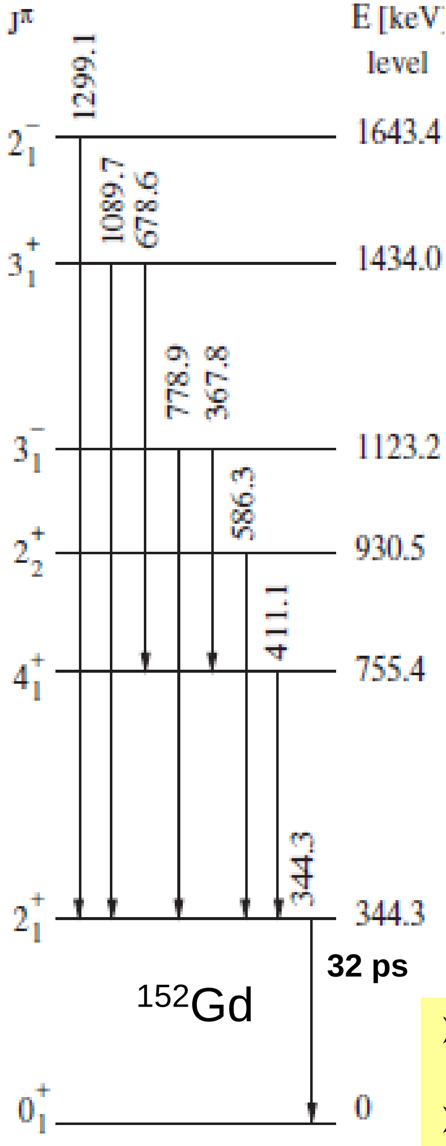
} PAC Facility

- Lifetime measurement by Mirror Symmetric Centroid Difference technique for the other low lying states – Two $LaBr_3$ detectors & Electronics and CAMAC data acquisition

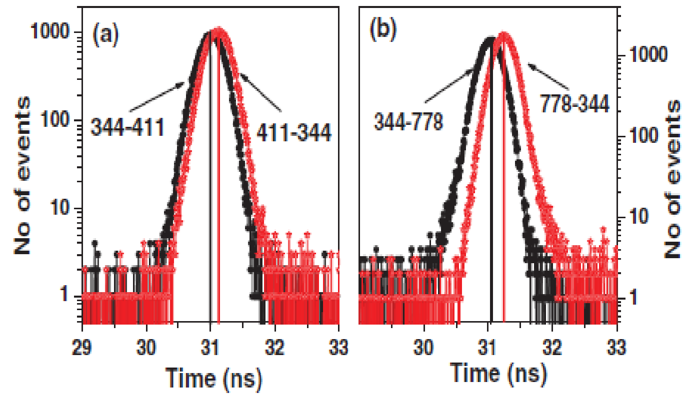
- Te activity will be gathered on an Al foil which will be dissolved in acid for the measurement of γ–γ coincidence and lifetimes.

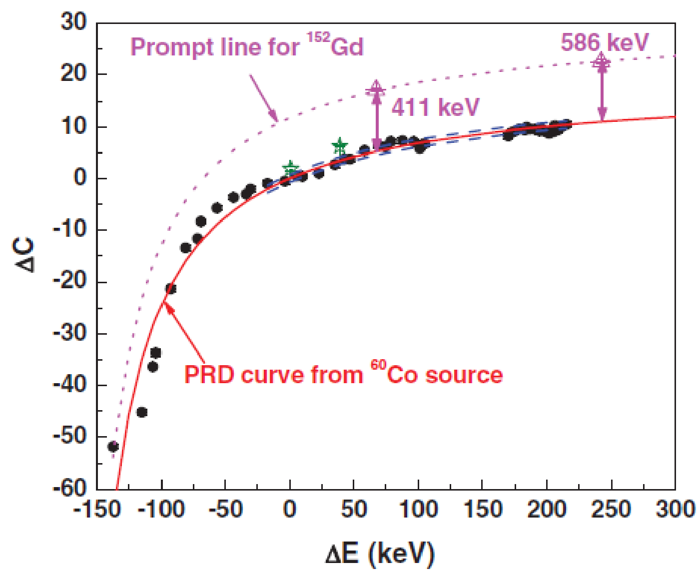
- The activity will be collected in Te metal for the quadrupole moment measurement

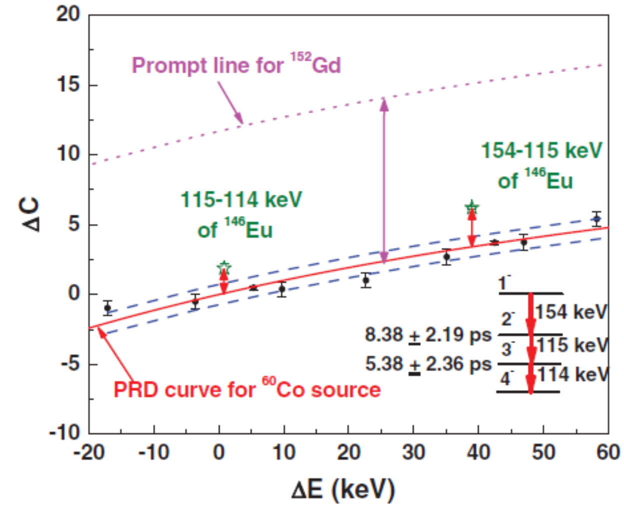
Mirror Symmetric Centroid Difference Technique



J.M. Regis et al., Nucl. Instr. & Meth. Phys. Res., **A622** 83 (2010).







^{146}Eu: < 200 ps
(from e – γ coincidence)
Arrived at ~ 8 ps

T. Bhattacharjee et al., Phys. Rev. **C88**, 014313 (2013).

Require ^{60}Co and ^{152}Eu source with activity ~ 10^4 Bq

- Centroid of the TAC spectrum varies with lifetime and increases with the energy of the decay γ –ray
- Centroid changes when the gating energy changes in the ‘START’ and ‘STOP’ detector
- Difference in Centroid increases as a function of energy difference – makes the calibration independent of γ-energy – involves twice the level lifetime

Experimental Plan

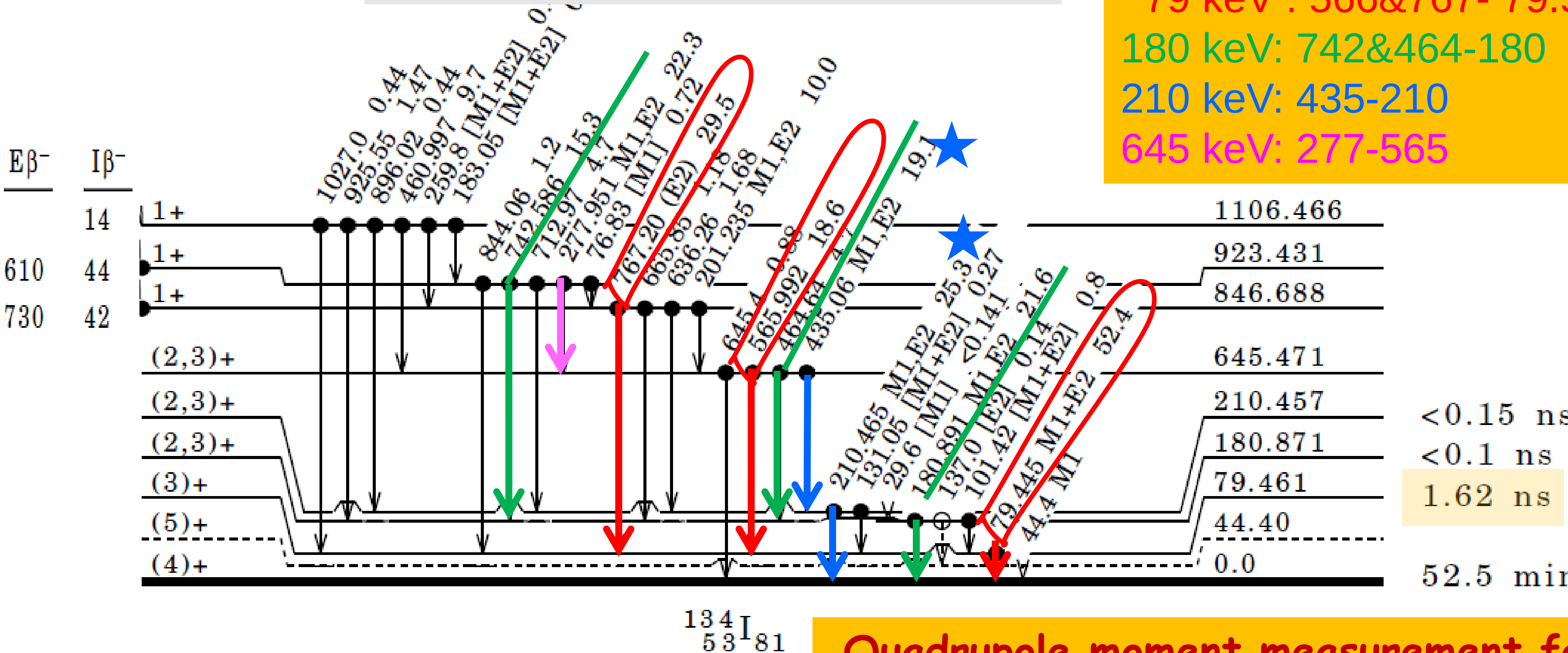
Cascades: (START- STOP)

79 keV : 566&767- 79.5

180 keV: 742&464-180

210 keV: 435-210

645 keV: 277-565



Quadrupole moment measurement for the 79 keV, 1.62 ns state

Implantation of Te activity in the Te matrix:

$$Q = \frac{\omega_Q . 4I(2I-1)\hbar}{eV_{zz}}$$

- Direct Implantation: Needs online heating arrangement
- Chemical doping : ^{132}Te is precipitated alongwith inactive Te as Te metal which has HCP lattice

Has been done in the measurement of ^{132}I by Ooms et al., Nucl. Phys. **A321** 180 (1979) - needs to sacrifice two half lives of ^{134}Te activity and Furnace facility.

Experimental Requirement

~ 30 Collections with ^{134}Te beam of activity ~10^{10} ions/sec

1 Collection = ~30 minutes ; ≥ ~3 hrs gap between each collection

– Beam on Target (~15hrs; 2 shifts)

Contamination:
Isobaric Contamination will not be a problem as the isobaric neighbors have very short half lives (~ secs).

Only isobaric activity of ^{134}I will be there anyway as a part of the measurement.

Facility:

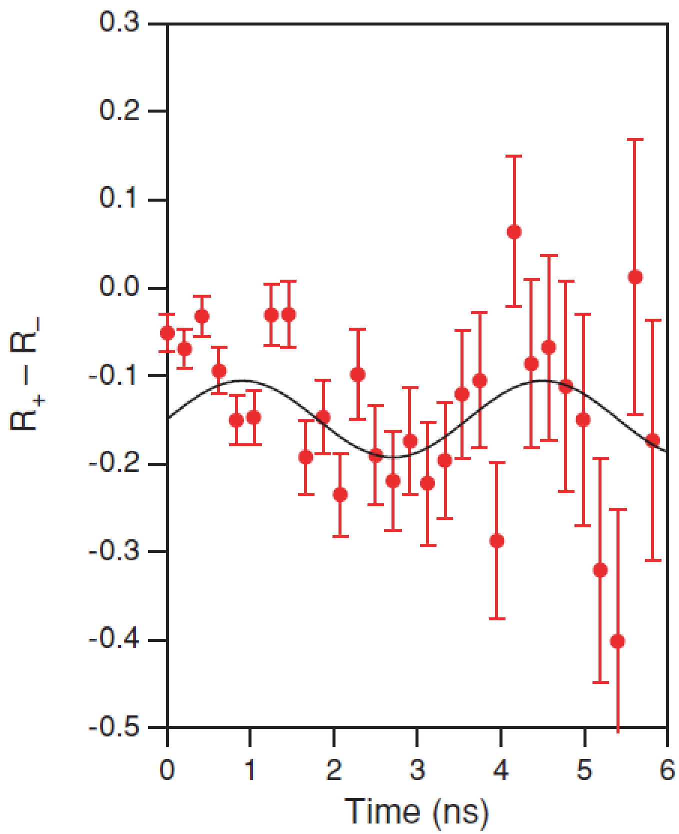
1. Two HPGe detector with coincidence electronics and DAQ

2. DIGIPAC system for the measurement of lifetime and q-pole moment of 79 keV state of ^{134}I

3. Two $LaBr_3$(Ce), coincidence electronics, CAMAC ADC, Controller, Computer with scientific Linux, DAQ software etc. for the lifetime measurement with MSCD technique
(items with blue will be carried by VECC)

4. ^{60}Co and ^{152}Eu source with activity ~ 10^4Bq

FUTURE PLAN



^{132}I

PHYSICAL REVIEW C **80**, 034304 (2009)

Done at ISOLDE implanting ^{132}Te in Ni foil

TO BE DONE

^{134}I

Magnetic moment measurement for the 79 keV, 1.62 ns state – implanting in Ni foil