Spectroscopy of ^{63,65,67}Mn: Strong Coupling in the Island of Inversion with N~40 & Implication in Urca Cooling in the Accreted Neutron Star Crust

Zhong Liu

Institute of Modern Physics, CAS

The International Symposium on Simplicity, Symmetry and Beauty of Atomic Nuclei
In honor of Professor Arima's 88th birthday

Prof. Arima is much appreciated as
an outstanding scientist,
bringing simplicity, symmetry and beauty to nuclear structure;
a beloved colleague,
promoting scientific cooperation between China and Japan;
an excellent educator,
making our life more enjoyable by poetry, broad and profound knowledge on history, liberal art …

Content

(1) In-beam γ spectroscopy of ^{63,65,67}Mn:
Strong Coupling in the Island of Inversion with N~40

(2) Alpha-decay of short-lived actinides with N~130:
Crossing the boundary between spherical and deformed nuclei
(octupole + quadrupole)

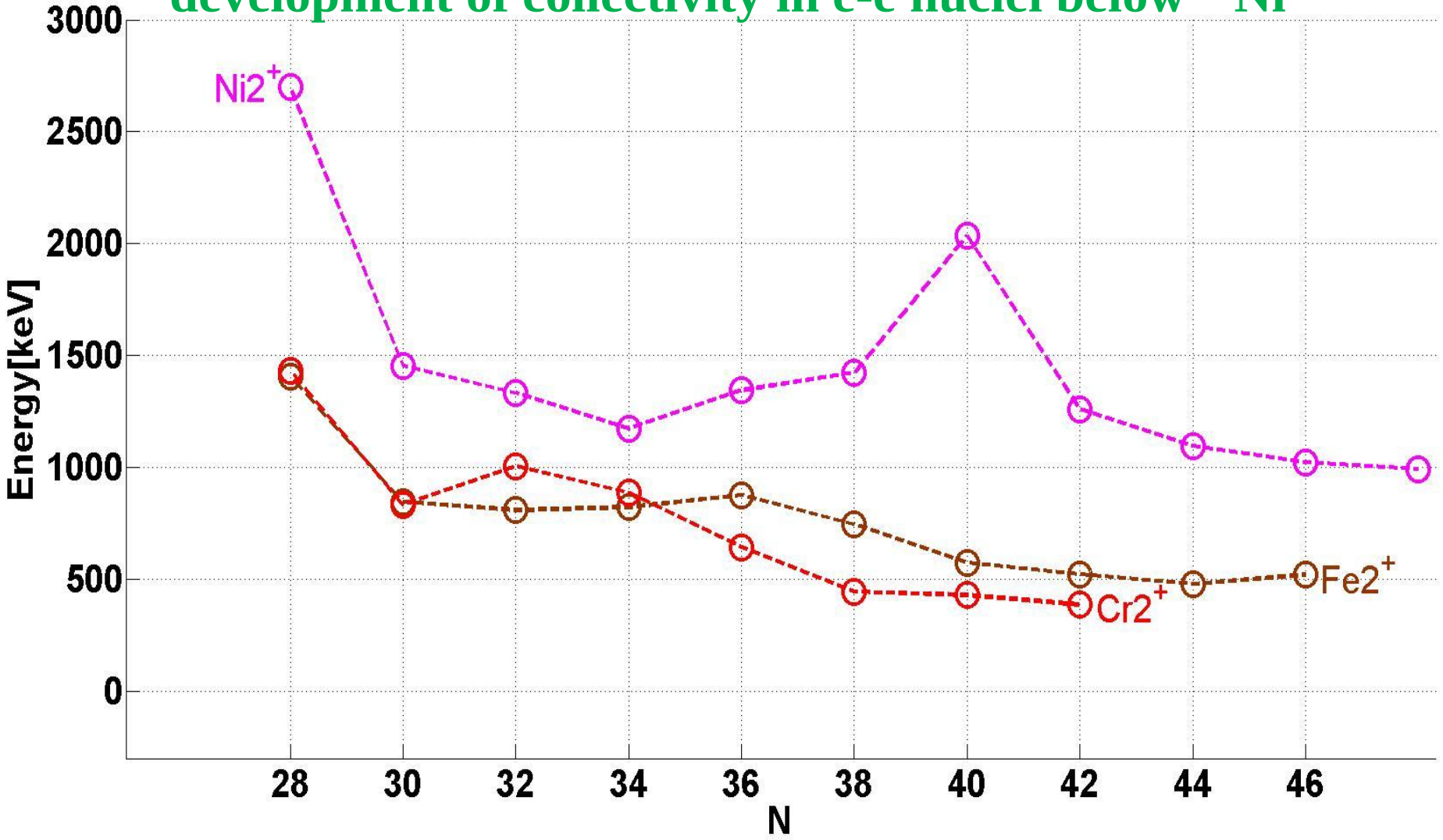
odd-mass nuclei

Spectroscopy of ^{63,65,67}Mn

harmonic shell closure at N=40

doubly magic appearance in ^{68}Ni

development of collectivity in e-e nuclei below ^{68}Ni



Levels in odd-A nuclei sensitive to

deformation of the core and

the configuration of the unpaired nucleon

provide more detailed insight into the structure evolution

But data are scarce due to experimental challenges

* Higher level density

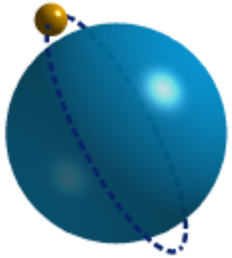
* More complicated level structures

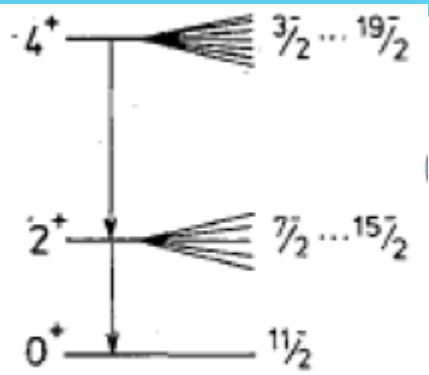
* Especially in deformed odd-A nuclei

Situation even more challenging in deformed odd-odd nuclei

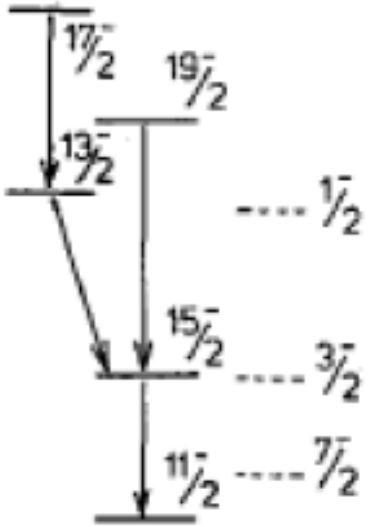
Three coupling schemes in odd-A nucleus

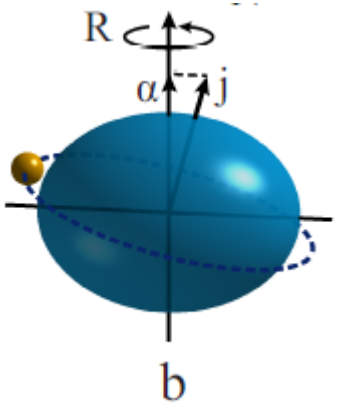
Weak coupling: $\beta_2 \sim 0$



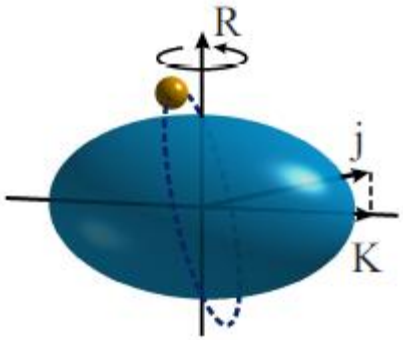


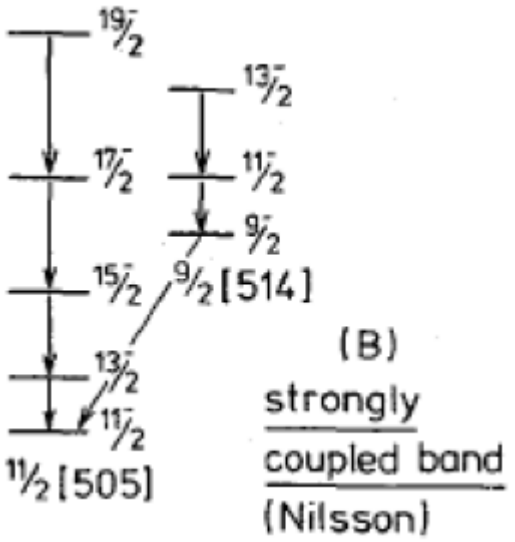
Decoupling: moderate β_2 strong Coriolis interaction





Strong coupling: large β_2 weak Coriolis interaction high-K, ΔI=1 band





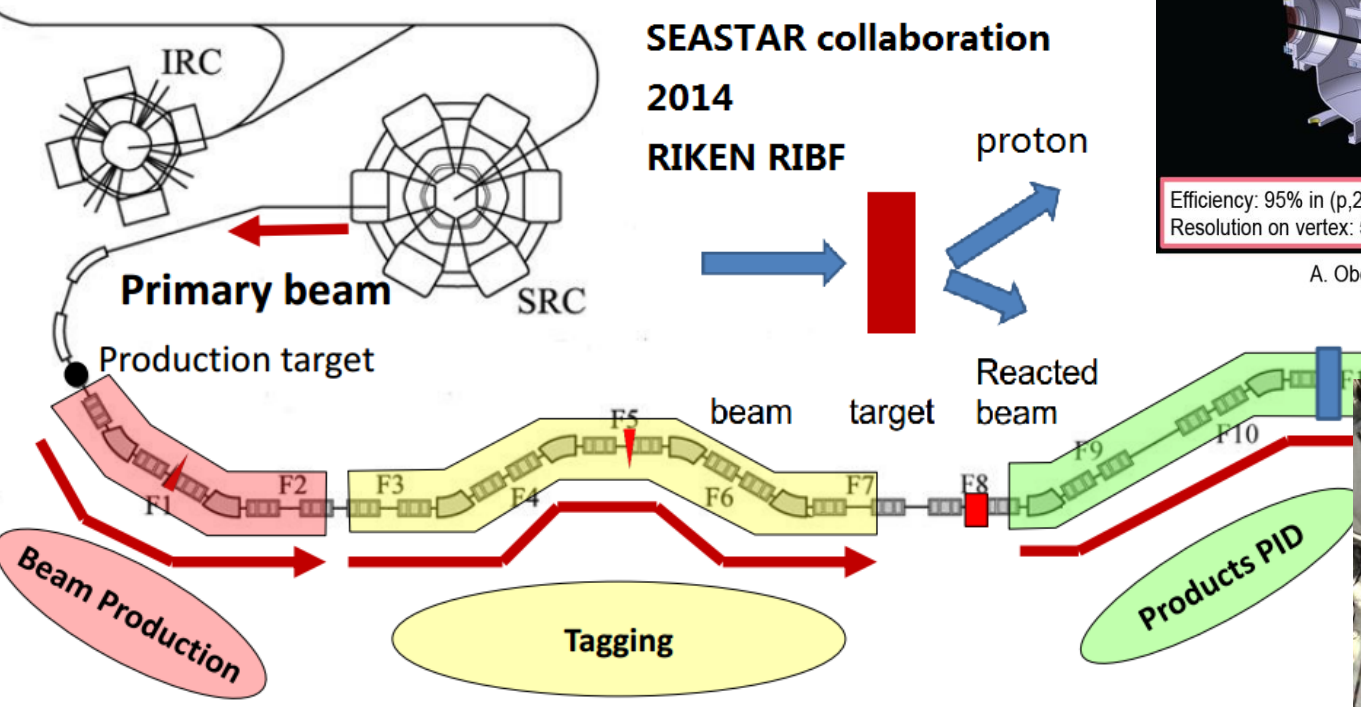
Experimental Setup

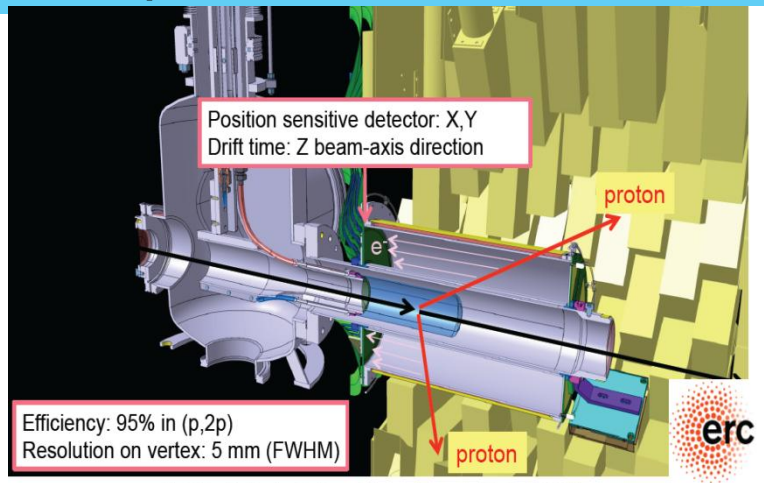
(1) BigRIPS: RI beam production and purification: *Bρ*-ΔE- *Bρ*

(2) Particle identification: *Bρ*, TOF, ΔE

(3) target and detector systems: MINOS +DALI2

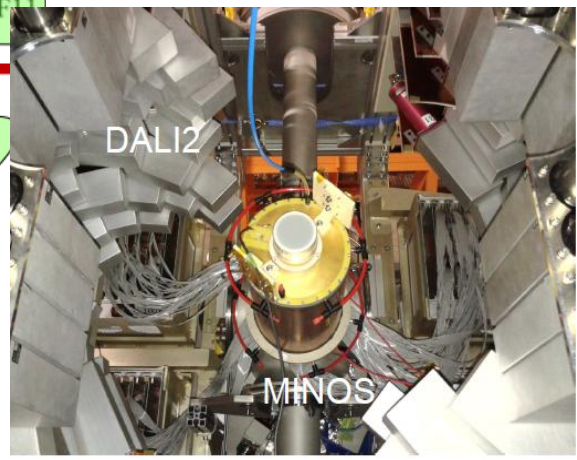
(4) ZDS: reaction residue identification: *Bρ*, TOF, ΔE





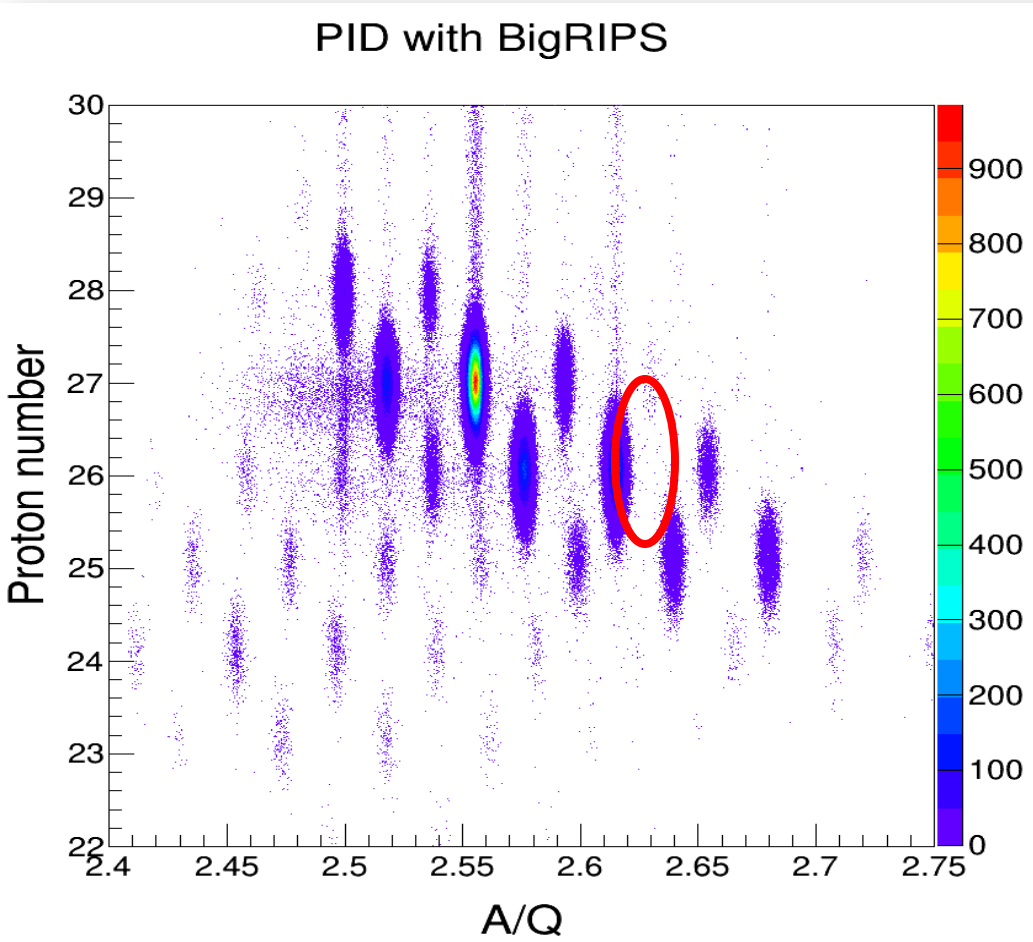
A. Obertelli *et al.*, Eur. Phys. Jour. A **50**, 8 (2014)

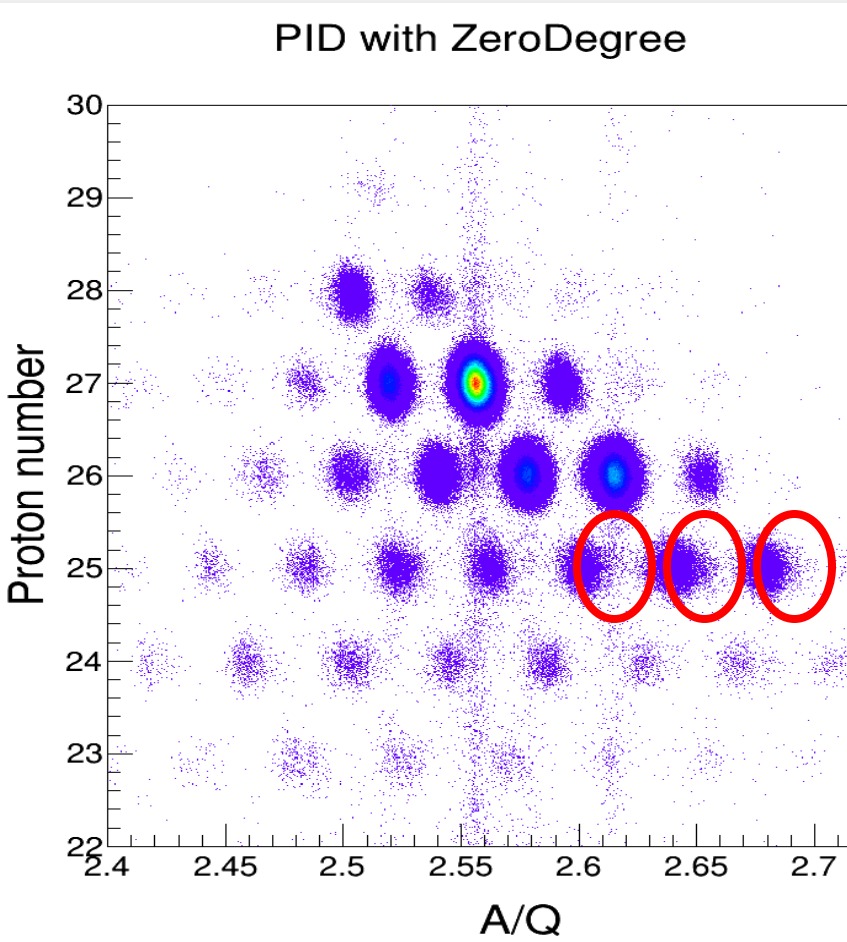
http://minos.cea.fr



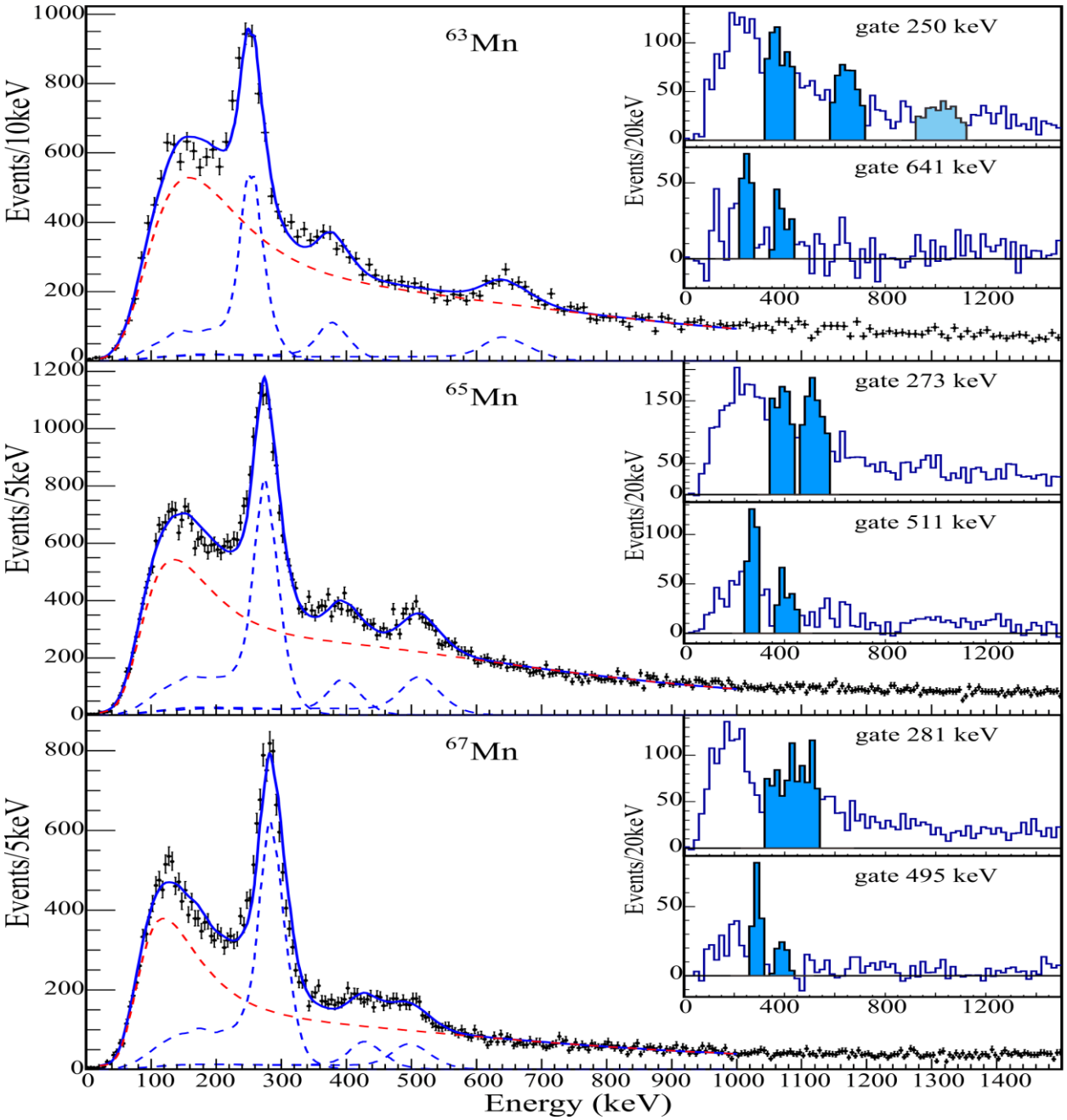
^{68}Fe(p,2pxn)^{63,65,67}Mn : x = 4, 2 and 0

PID before and after the Liquid H_2 target





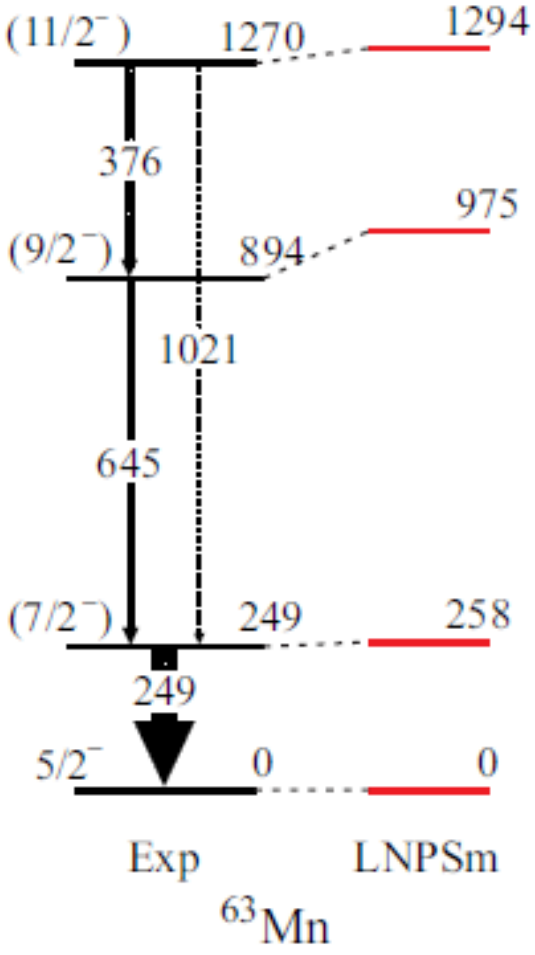
γ transitions identified in ^{63,65,67}Mn

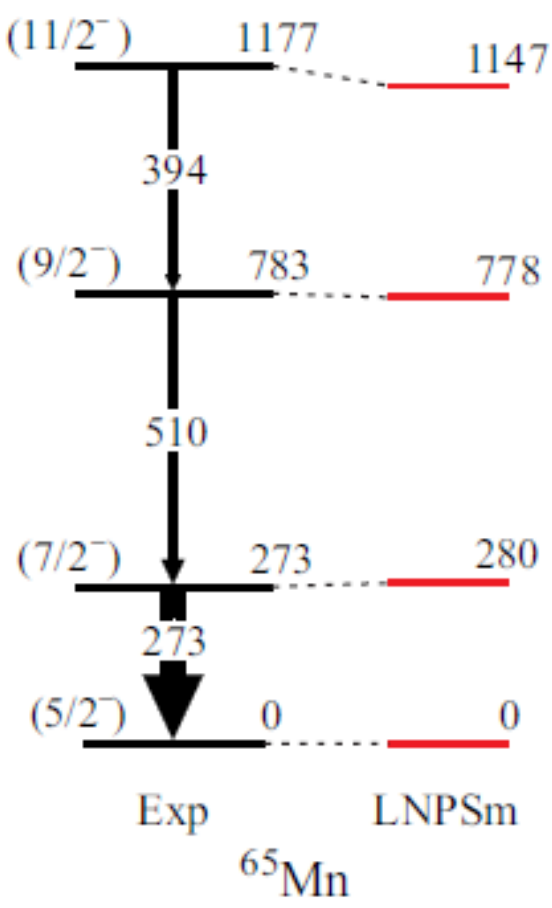


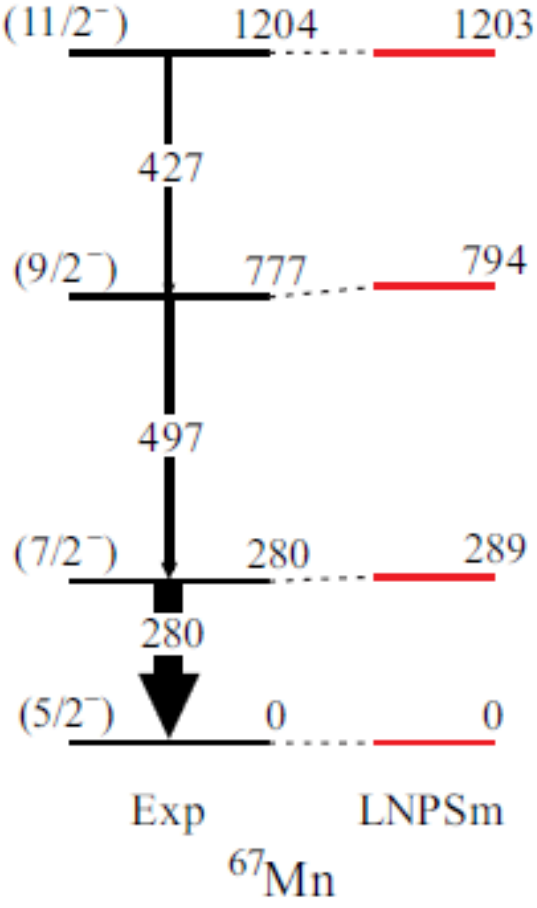
level schemes in ^{63,65,67}Mn

J^{π} based on systematics and SM calculations

decay pattern：ΔI=1 transitions dominate





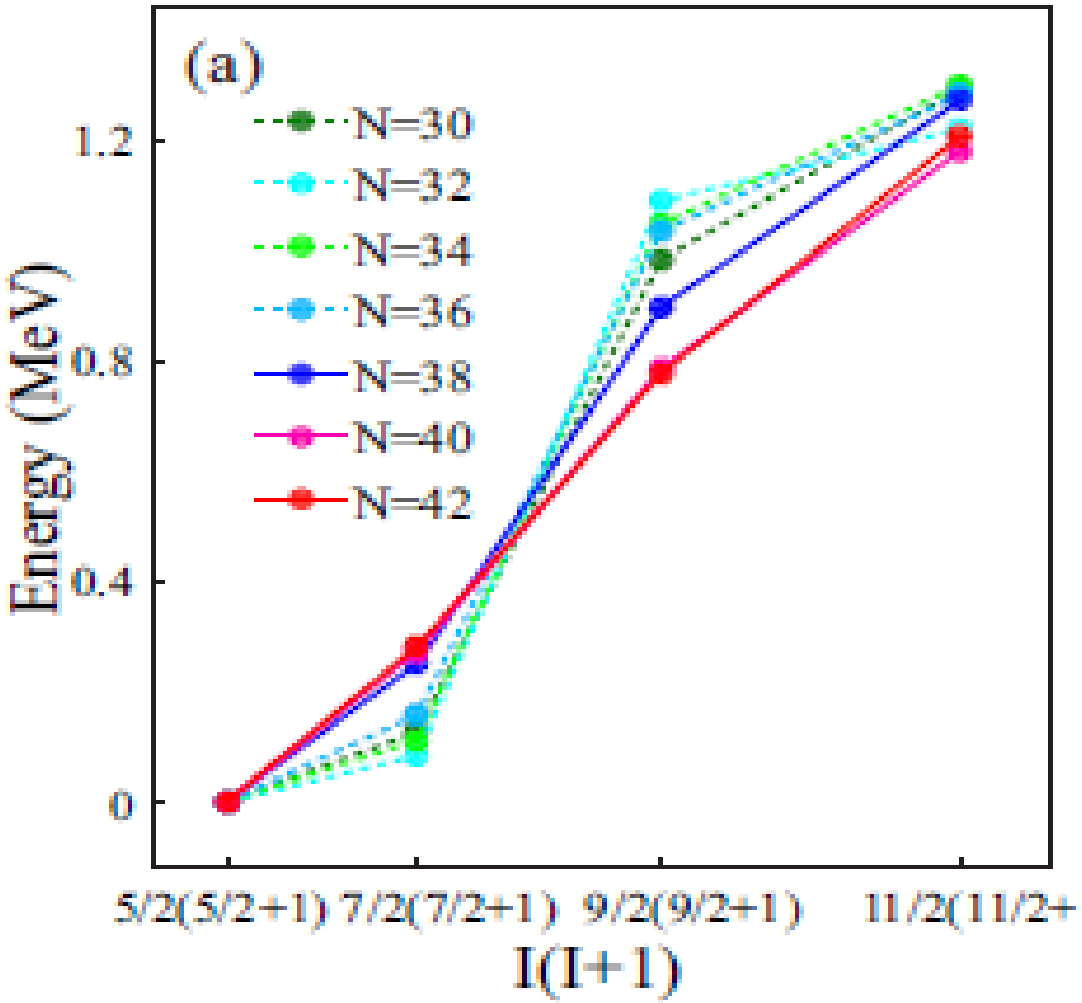


Shell model calculations (LNPSm) reproduced data very well

dominance of 4p-4h neutron configuration

^{65,67}Mn: strongly coupled bands with K = 5/2

^{63}Mn: transitional feature between decoupling and strong coupling



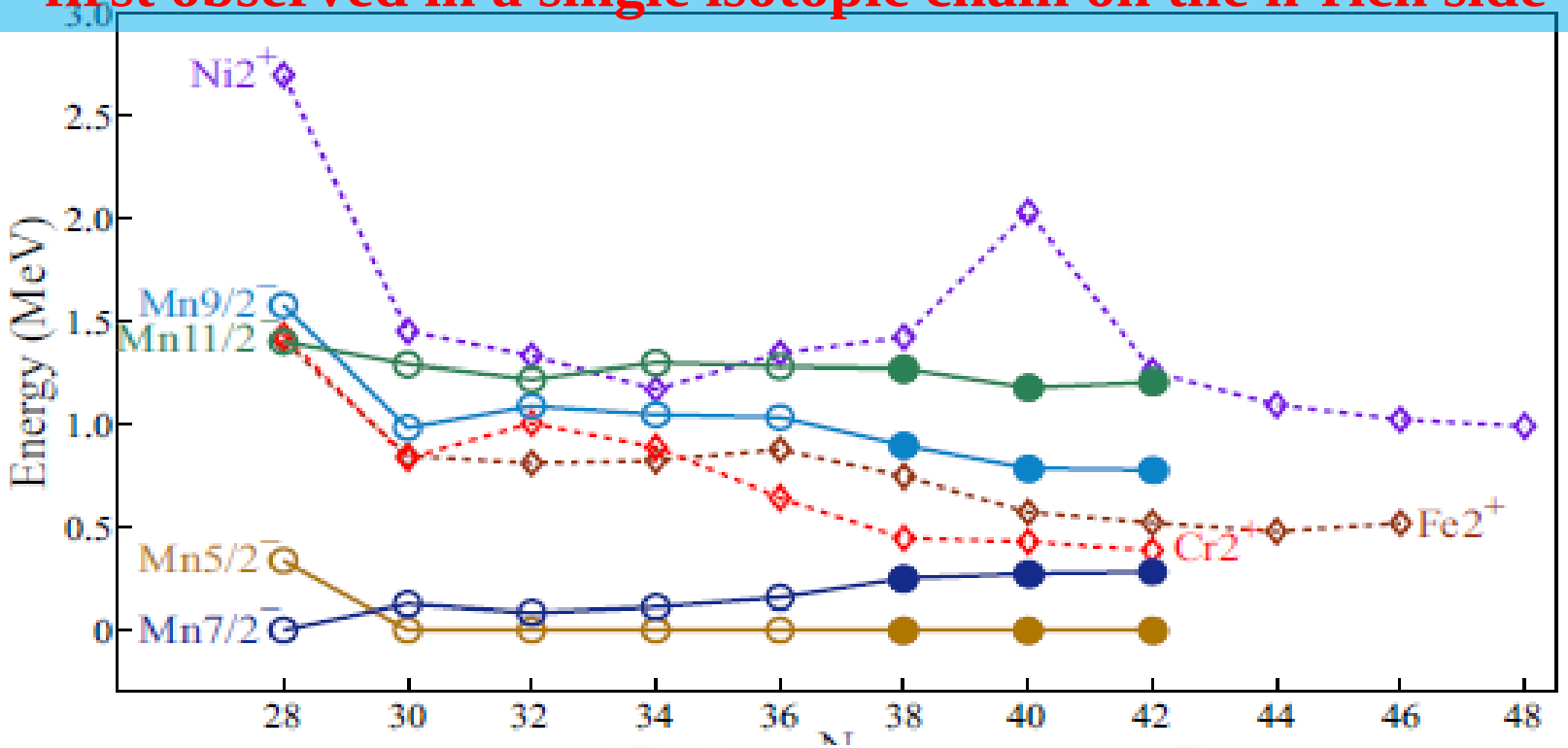
The signature staggering can be attributed to the softness in the PES suggested in the MCSM and constrained HFB plus local q.p. RPA

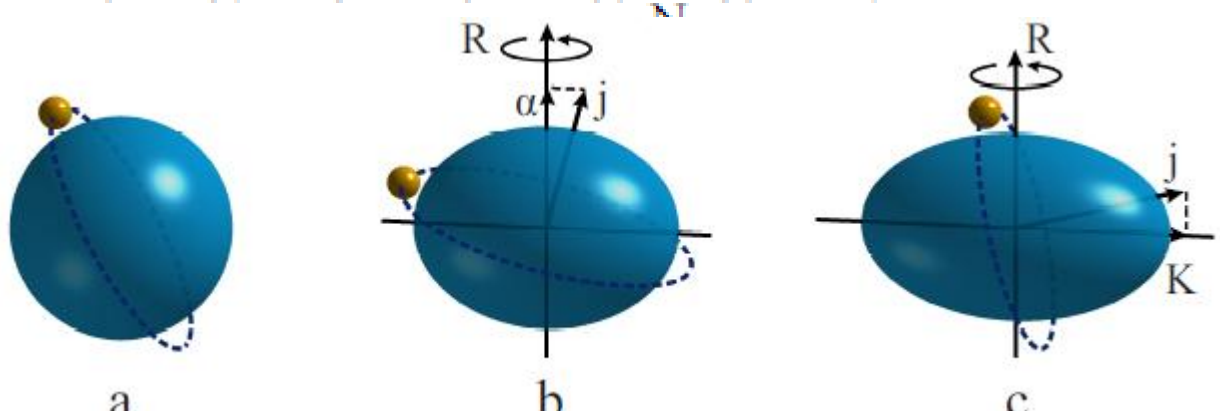
A textbook example of structure evolution observed in odd-A Mn

weak coupling → decoupling → strong coupling

X.Y. Liu et al., Physics Letters B 784 (2018) 392–396

first observed in a single isotopic chain on the n-rich side





Physics Letters B 784 (2018) 392–396

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Physics Letters B

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Spectroscopy of $^{65,67}_{25}$Mn: Strong coupling in the $N = 40$ "island of inversion"

X.Y. Liu [a,b], Z. Liu [a,*], B. Ding [a,*], P. Doornenbal [c], A. Obertelli [c,d,e], S.M. Lenzi [f],

Many thanks to

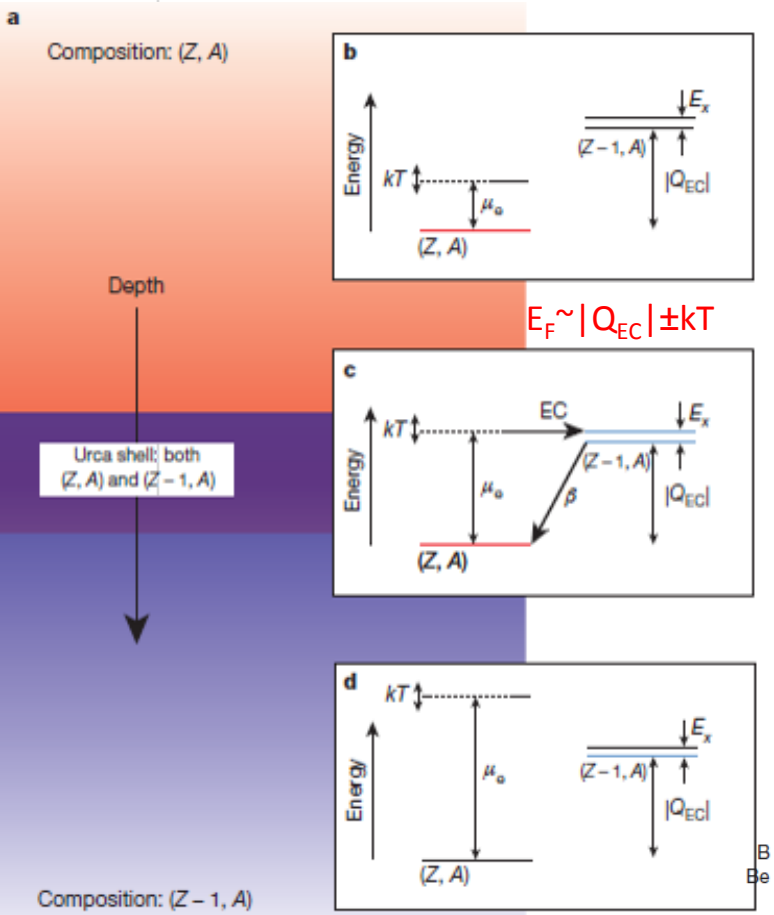
SEASTAR collaboration
Data analysis: X.Y. Liu, B. Ding
SM calculations: S. Lenzi

Discussions with **J. Meng, Y. Sun, F.R. Xu and H. Jin**

Urca cooling process in accreting neutron star crust

H. Schatz et al. *Nature 505*, 62(2014)

Surface burning ashes, sinking to the NS crust can undergo EC/β⁻-decay cycling, leading to strong ν-cooling: Urca process

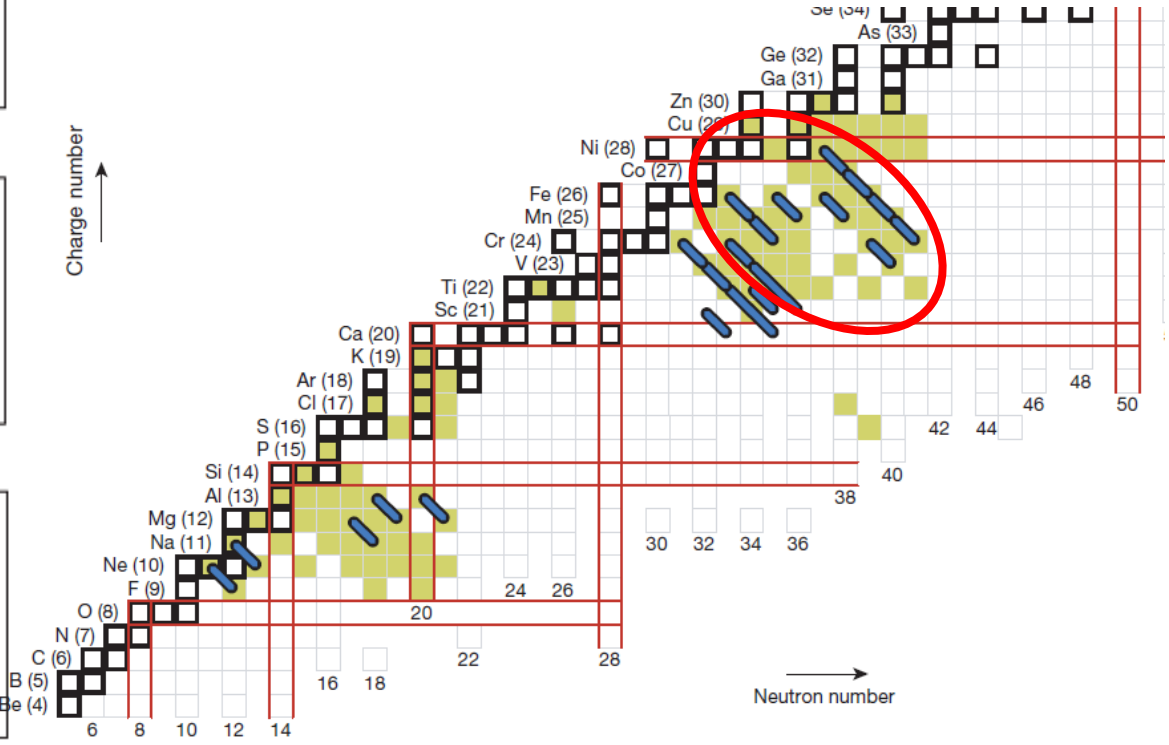


$E_F \sim |Q_{EC}| \pm kT$

Urca cooling pairs predicted in n-rich deformed regions

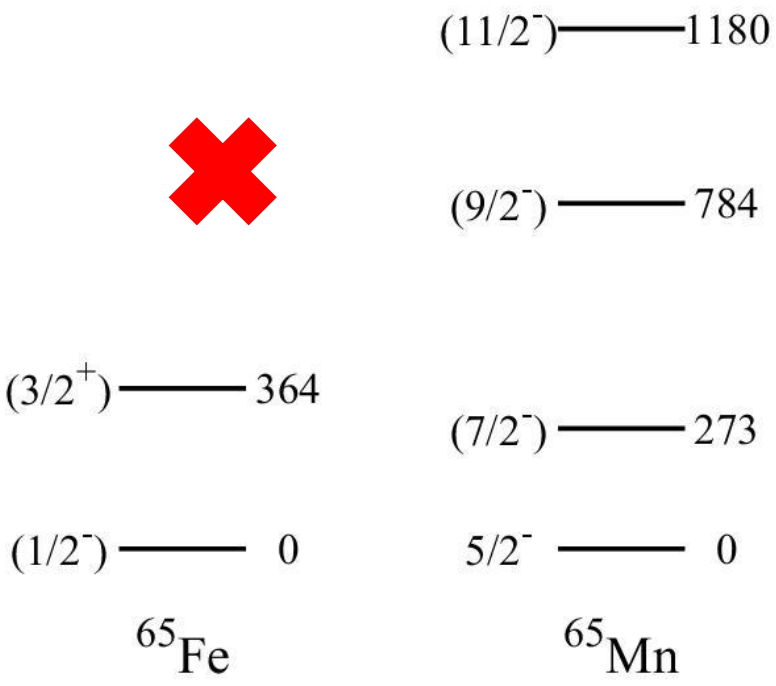
N~40 region is one of such regions

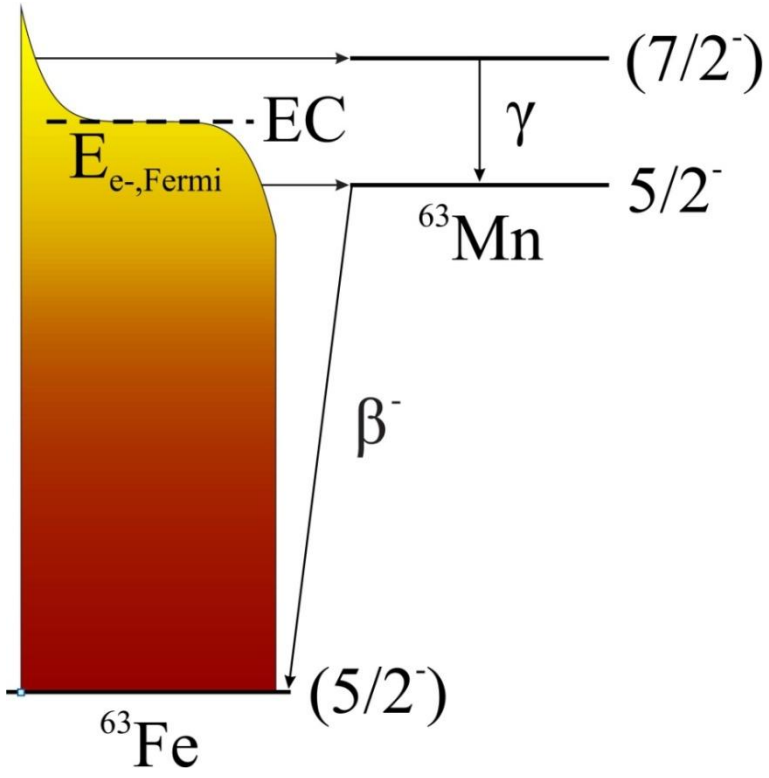
^{65}Fe-^{65}Mn: Urca cooling pair



Our results rule out ^{65}Fe-^{65}Mn as Urca cooling pair as J^{π} not match

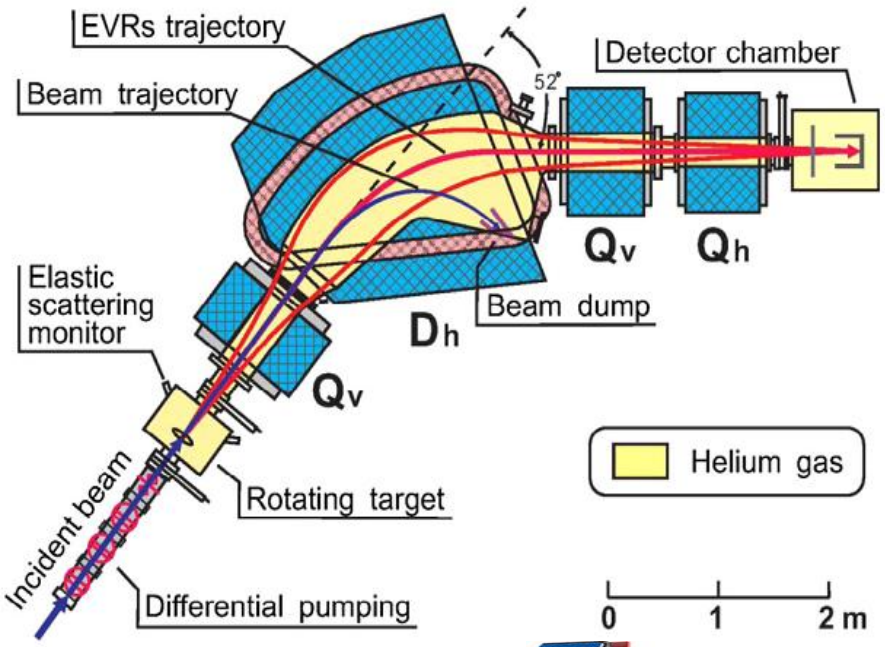
Instead ^{63}Fe-^{63}Mn is Urca cooling pair

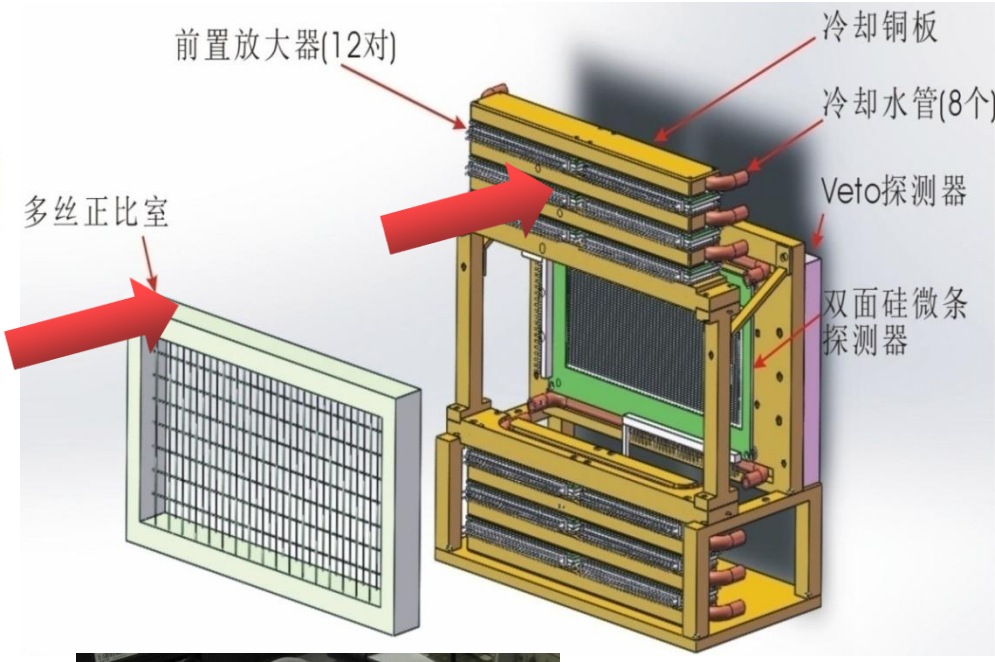




Alpha decay spectroscopy at SHANS

--digital pulse processing 技术

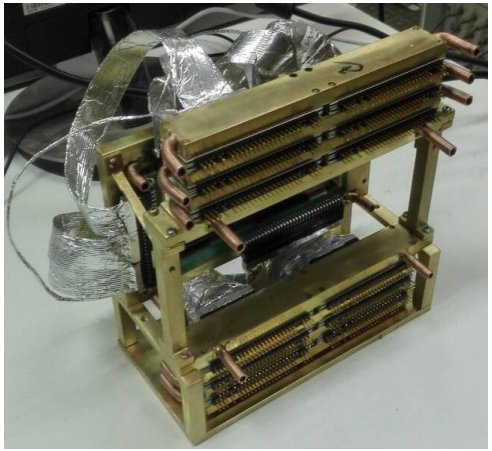




V1724

Sampling rate: 100 MHz

1500-μs waveform



48×128 DSSD

Strip width: 1mm

Si veto

Summary of the results

New short-lived isotope ^{223}Np and the absence of the Z = 92 subshell closure near N = 126
Phys. Lett. B 771 (2017) 303

new isotope ^{224}Np （accepted in PRC）

Alpha-decay chain of the short-lived isotope ^{220}Pa established using a digital pulse processing technique
Phys. Rev. C 96 (2017) 014324

new g.s. data and fine structure in ^{223}U （to be submitted）

						130	131			
						223Np 9.477 2.15μs	224Np 9.147 38 μs	8.630	8.000	7.651
						221U 9.71 66 μs	222U 9.310 4.7 μs	223U 8.993 57 μs		
91	167ms	3.6 ms	113 μs	60 ns	0Pa 9.520 0.90μs	221Pa 9.080 5.9 μs	222Pa 8.330 2.9 ms	223Pa 8.178 5.10 ms	224Pa 7.488 0,79 s	225Pa 7.25 1.8 ms
90	215Th 7.522 1.2 s	216Th 7.923 26 ms	217Th 9.250 252 μs	218Th 9.666 109 ns	219Th 9.340 1.05 μs	220Th 8.790 9.7 μs	221Th 8.146 1.68 ms	222Th 7.982 2.8 ms		
89	214Ac 7.215 8.2 s	215Ac 7.604 0.17 s	216Ac 9.072 0.44 ms	217Ac 9.650 69 ns	218Ac 9.205 1.08 μs	219Ac 8.664 11.8 μs	220Ac 7.86 26.4 ms			
88	213Ra 6.732 2.7min	214Ra 7.137 2.435 s	215Ra 8.699 1.55 ms	216Ra 9.349 0.18 μs	217Ra 8.99 1.6 μs	218Ra 8.39 25.6 μs	219Ra 7.678 10 ms			

Thank you for your attention

Happy Rice-age Birthday to Arima Sensei !

Health, happiness and longevity to you !