

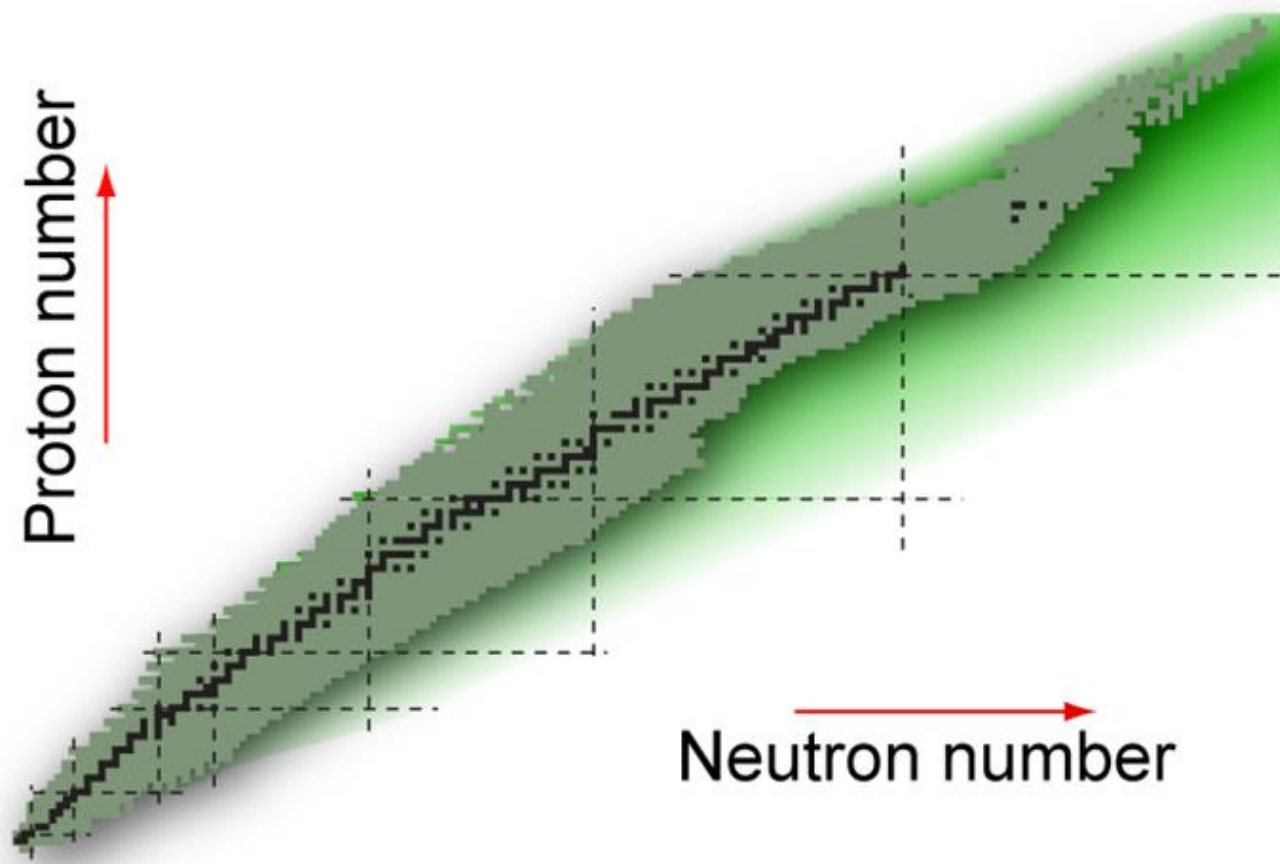
An aerial photograph of a modern, multi-story university building with large glass windows and brick accents. A large crowd of people is gathered on the sidewalk and lawn in front of the building. The scene is set on a street corner with a grassy area and trees. The text "Nuclear Shapes and Shells: Studying the decay of short-lived states" is overlaid in the center of the image.

Nuclear Shapes and Shells: Studying the decay of short-lived states

S.N. Liddick
Sept. 20, 2018

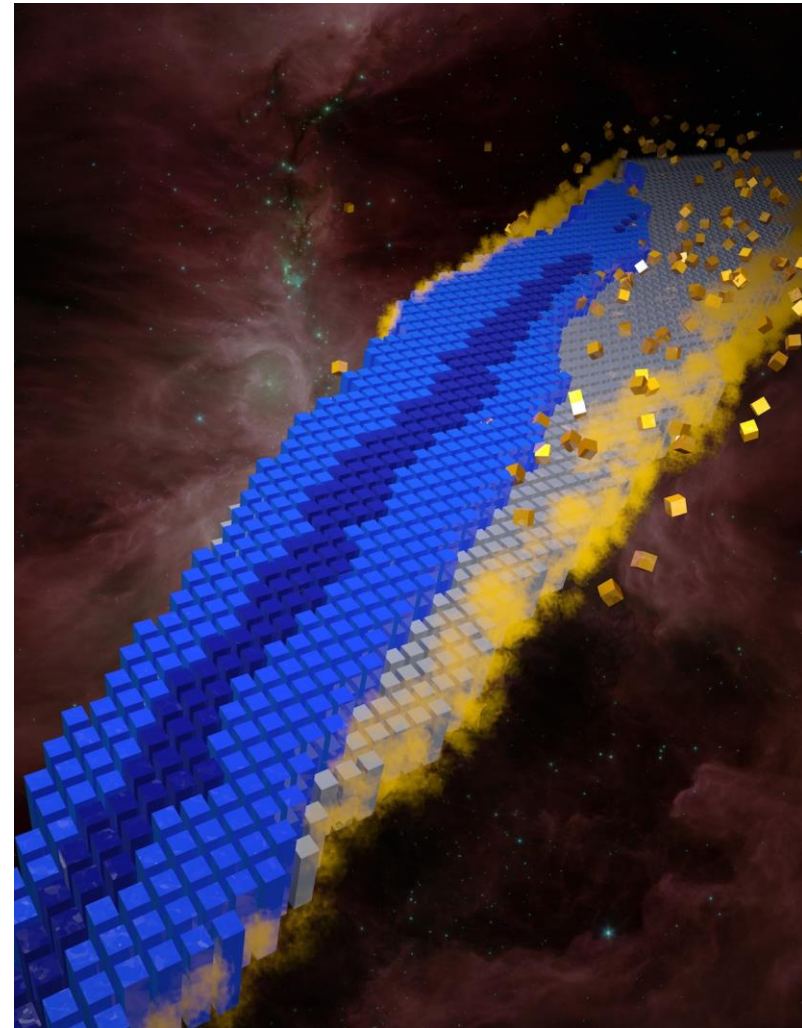
Periodic Table

1 H 1.0079																	2 He 4.0026																														
3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180																														
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	18 Ar 39.948																														
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.90																														
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29																														
55 Cs 132.91	56 Ba 137.33	57-71 La-Lu	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)																														
87 Fr (223)	88 Ra (226)	89-103 Ac-Lr	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Uun (281)	111 Uuu (272)	112 Uub (285)			114 Uuq (289)																																	
<table border="1"> <tbody> <tr> <td>57 La 138.91</td> <td>58 Ce 140.12</td> <td>59 Pr 140.91</td> <td>60 Nd 144.24</td> <td>61 Pm (145)</td> <td>62 Sm 150.36</td> <td>63 Eu 151.96</td> <td>64 Gd 157.25</td> <td>65 Tb 158.93</td> <td>66 Dy 162.50</td> <td>67 Ho 164.93</td> <td>68 Er 167.26</td> <td>69 Tm 168.93</td> <td>70 Yb 173.04</td> <td>71 Lu 174.97</td> </tr> <tr> <td>89 Ac (227)</td> <td>90 Th 232.04</td> <td>91 Pa 231.04</td> <td>92 U 238.03</td> <td>93 Np (237)</td> <td>94 Pu (244)</td> <td>95 Am (243)</td> <td>96 Cm (247)</td> <td>97 Bk (247)</td> <td>98 Cf (251)</td> <td>99 Es (252)</td> <td>100 Fm (257)</td> <td>101 Md (258)</td> <td>102 No (259)</td> <td>103 Lr (262)</td> </tr> </tbody> </table>																		57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97	89 Ac (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)
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Nuclear Science Challenges

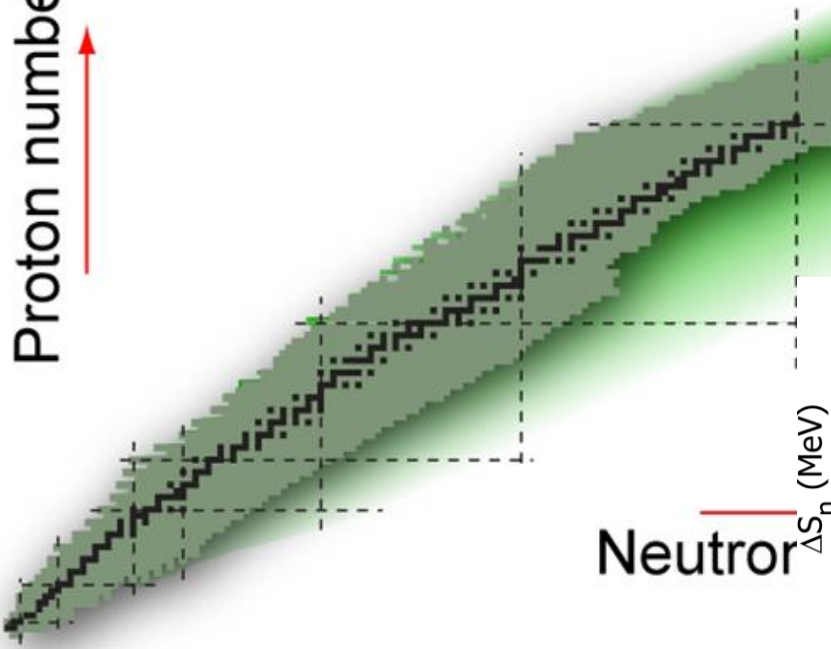
- Comprehensive and predictive model of atomic nuclei.
 - Evolving structure of atomic nuclei as a function of protons and neutrons from first principles.
- Understanding the origin of the elements.
 - Explosive nucleosynthesis
- Use of atomic nuclei to test fundamental symmetries.
- Search for new applications of isotopes and solutions to societal problems.



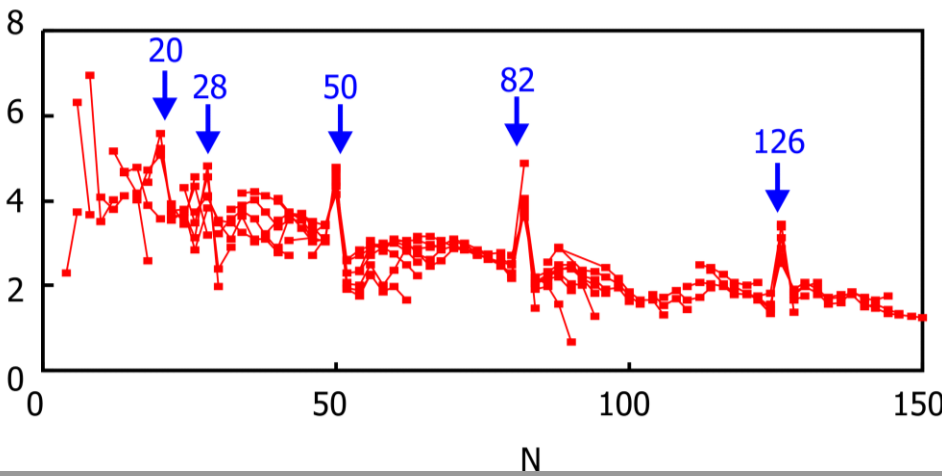
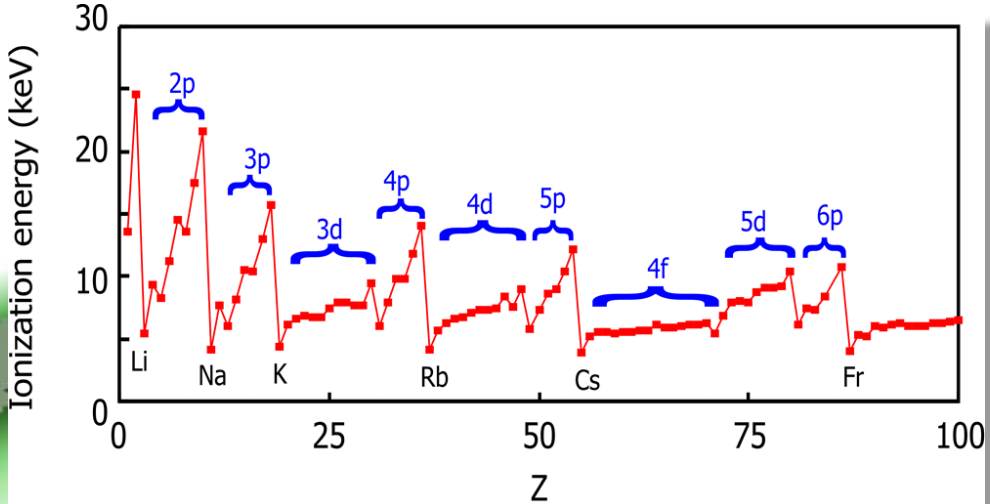
A. Sproles, Oak Ridge National Laboratory

Magic Numbers

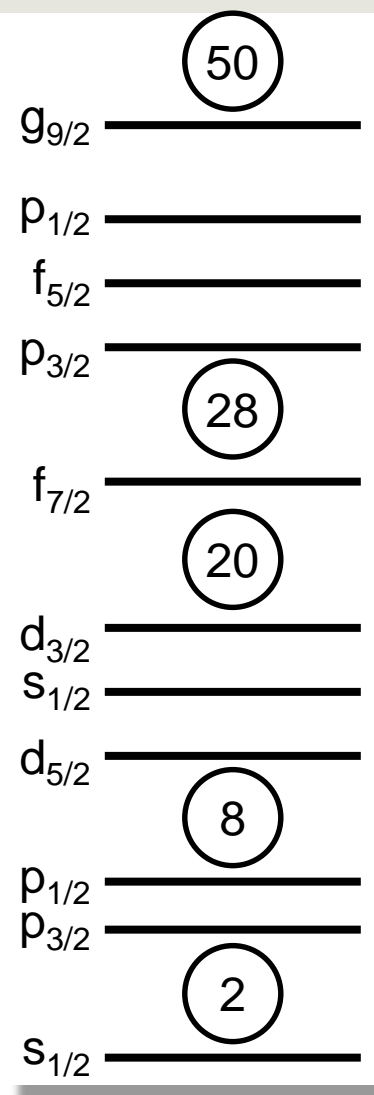
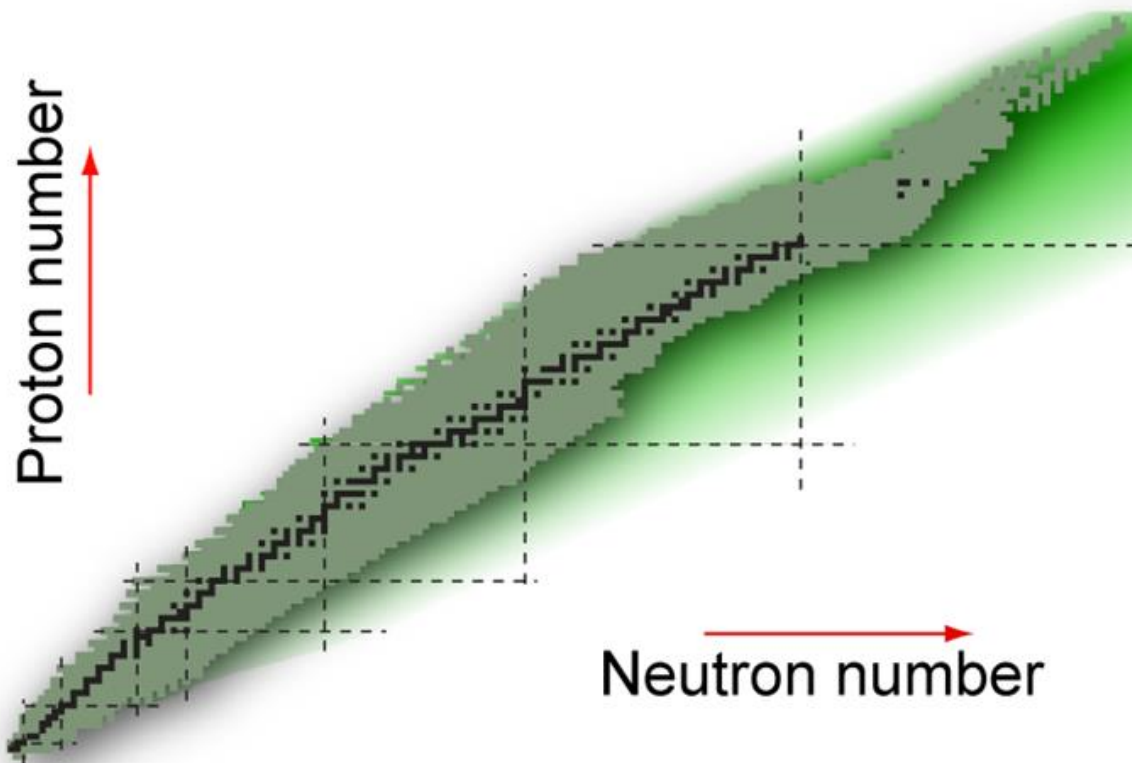
Proton number ↑



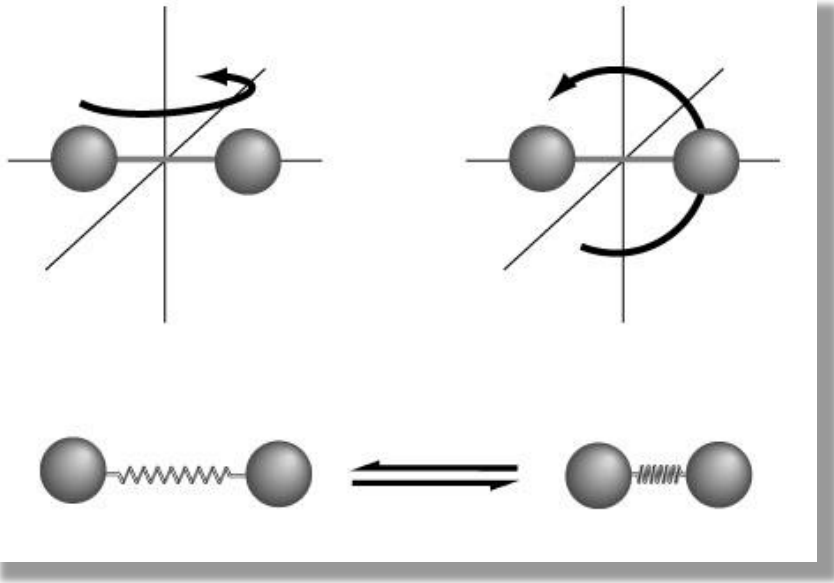
Neutron ΔS_n (MeV)



Shell Structure



Energy Scales

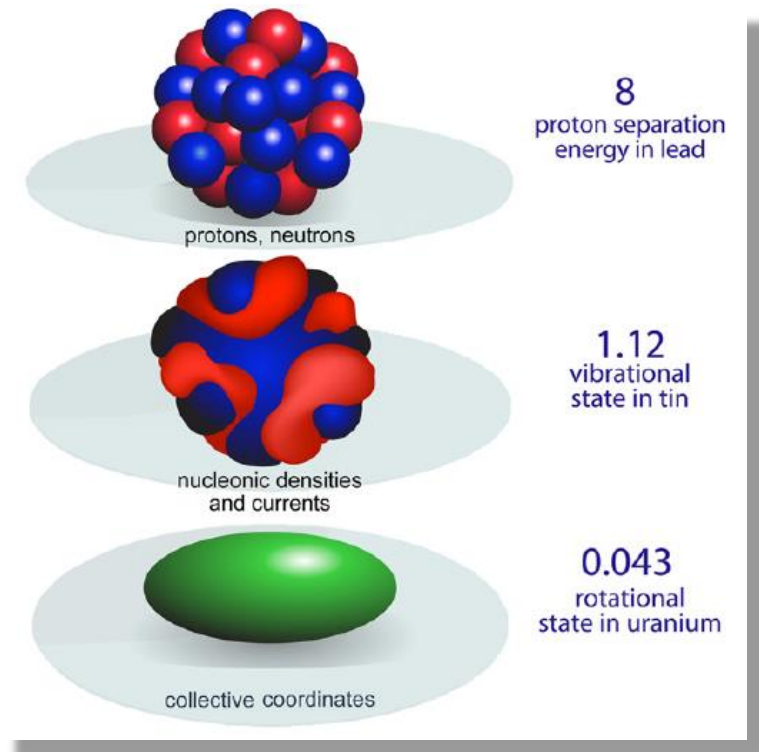


- Molecular excitations occur on very different energy scales:

$$E_{\text{elec}} \gg E_{\text{vib}} \gg E_{\text{rot}}$$

UV/VIS \gg IR \gg Microwave

eV \gg meV \gg ueV




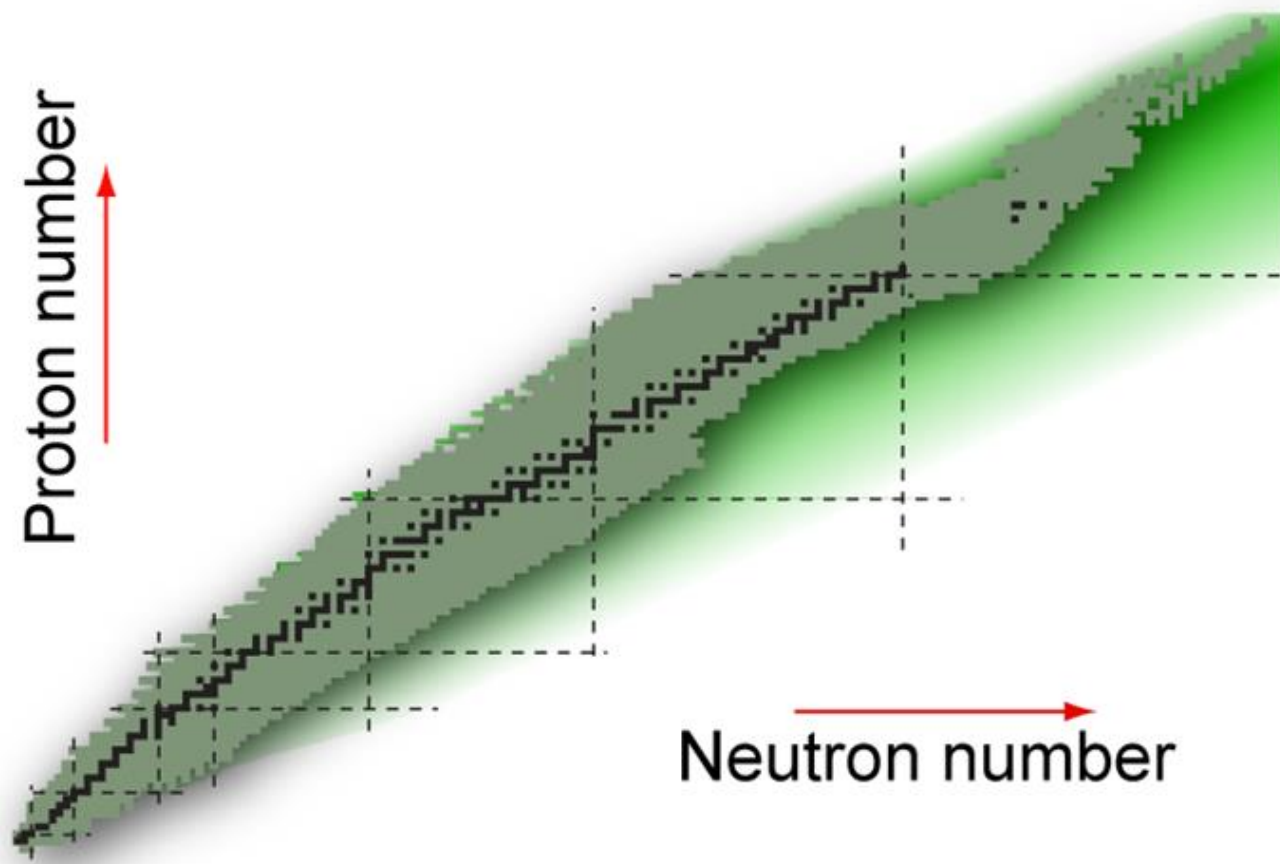
- Nuclear excitations occur on similar energy scales:

$$E_{\text{sp}} \sim E_{\text{vib}} \sim E_{\text{rot}}$$

MeV scales

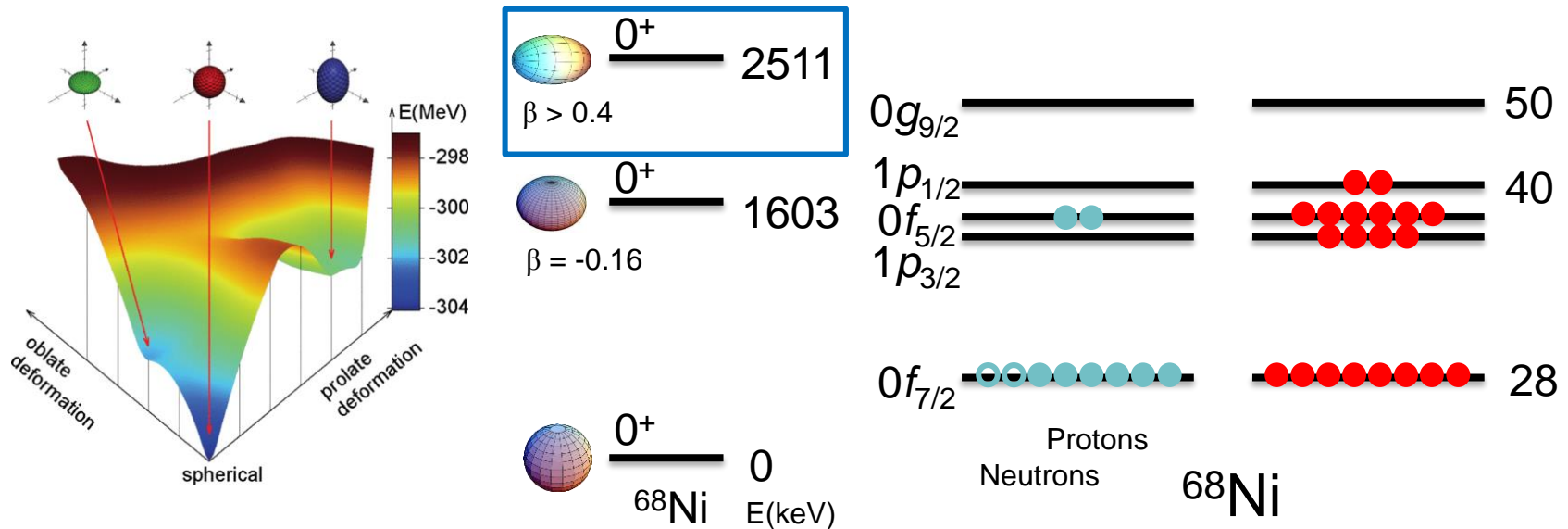
Observables and Problems

- Determine the properties of exotic nuclei.
 - Improve predictive power of theory.
- 
- Available information includes
 - Excitation energies,
 - half-lives,
 - decay modes,
 - moments,
 - production cross sections, ...
 - However, many desirable nuclei for study
 - Only live fractions of a second.
 - Are produced in limited quantities.



Shape Coexistence in ^{68}Ni

- Predictions and experimental indications for triple shape coexistence

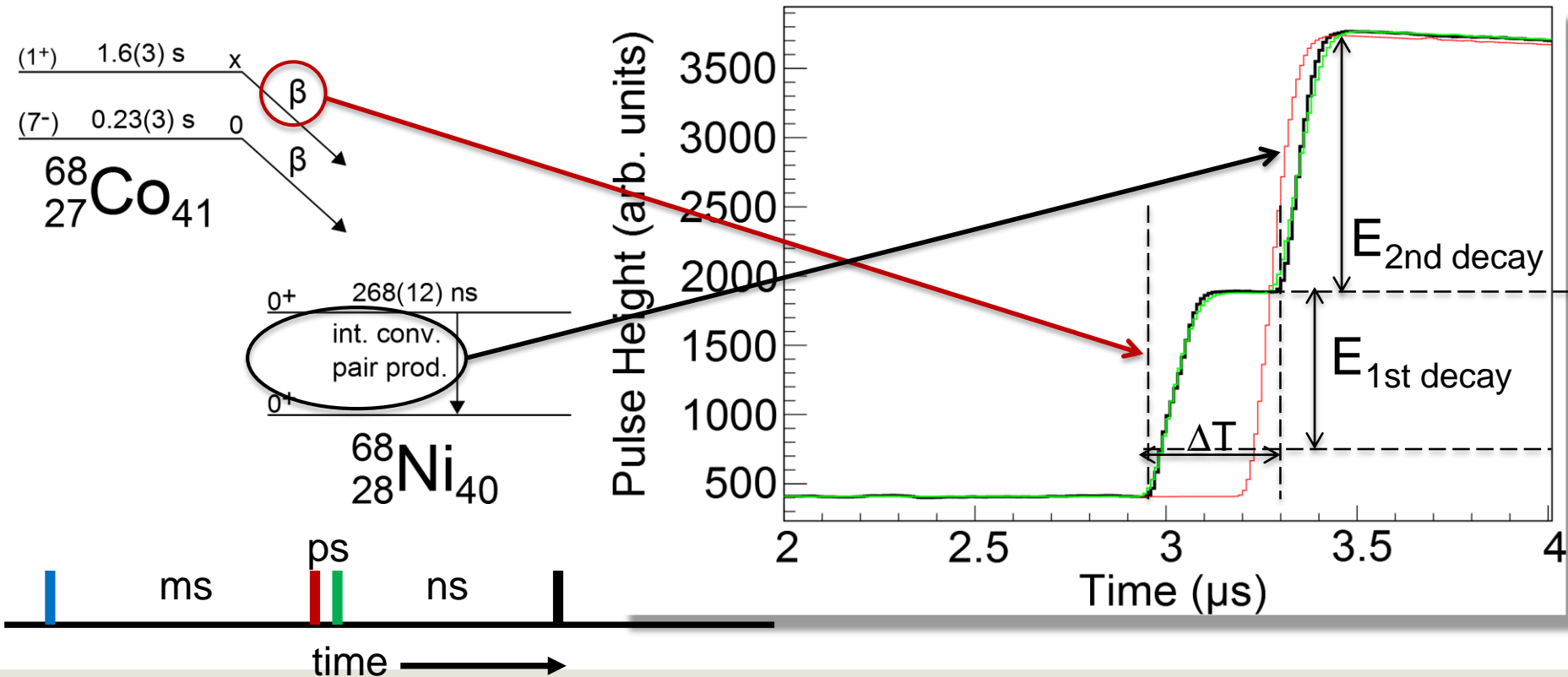


S. Suchyta *et al.*, Phys. Rev. C **89**, 021301(R) (2014).
031301 (2014).

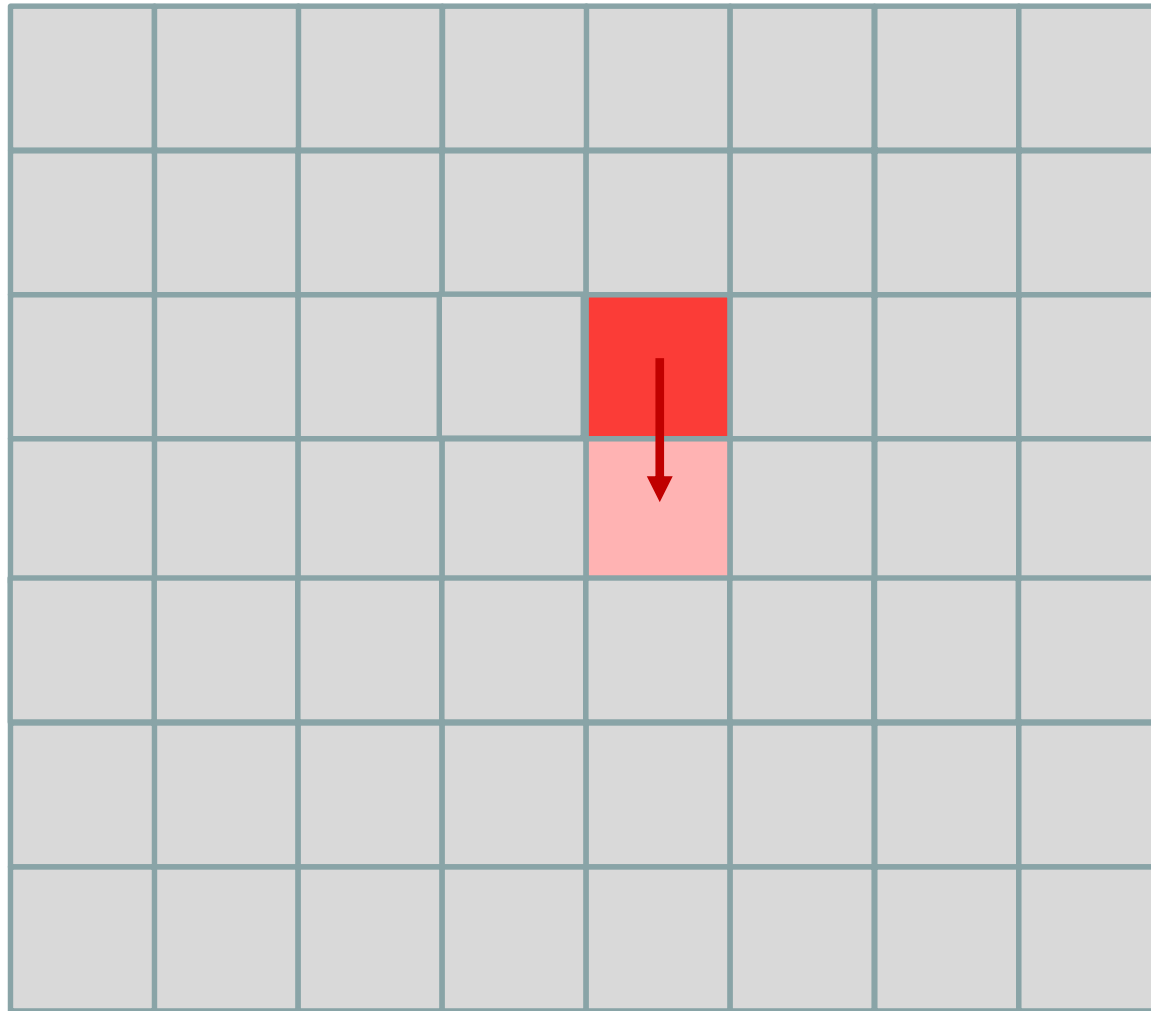
Y. Tsunoda *et al.*, Phys. Rev. C **89**,

Multiple Interaction Event

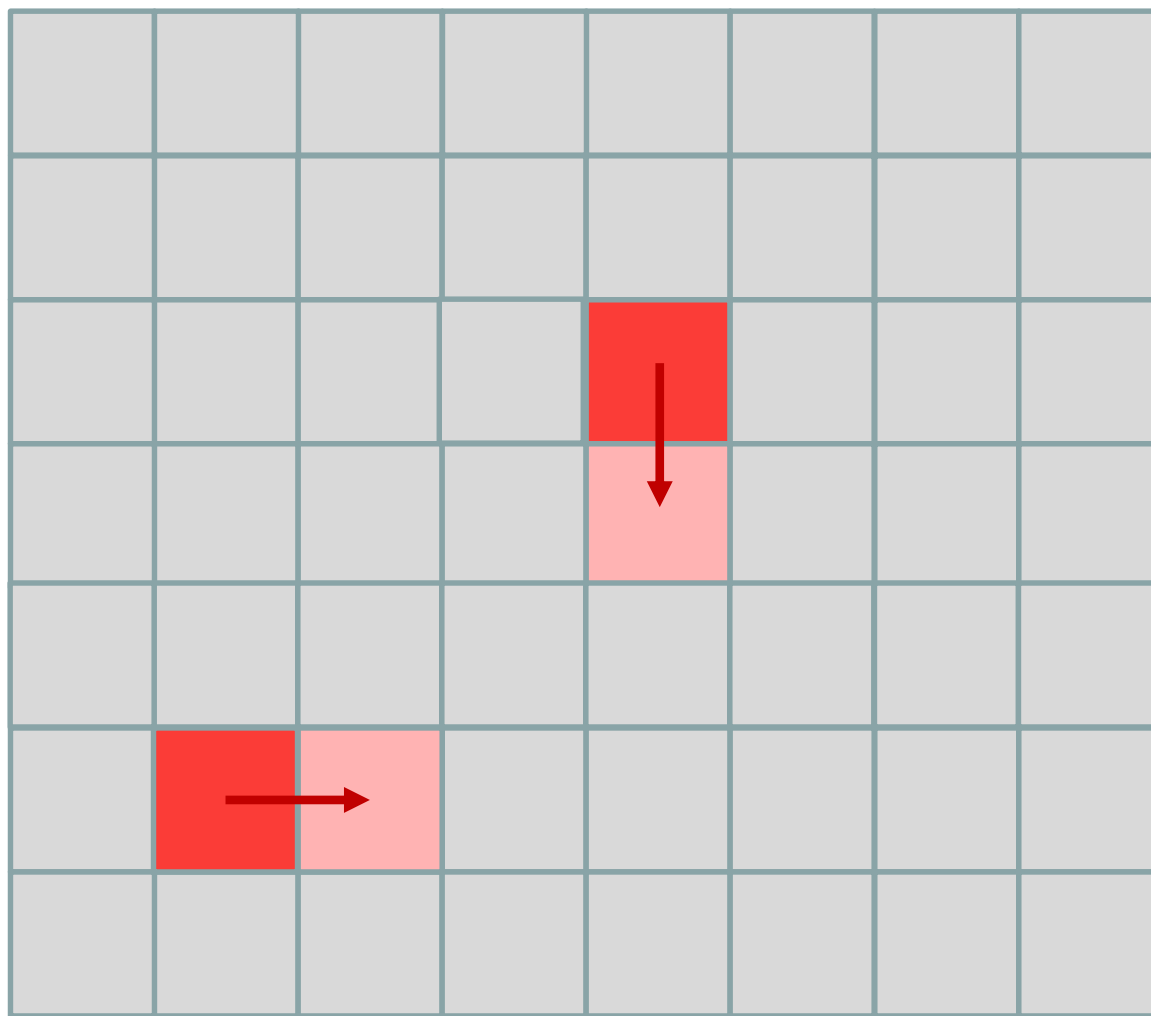
- Small fraction of signals show “stair-step” time profile.
- First rise from beta decay.
- Second decay from E0 transition.



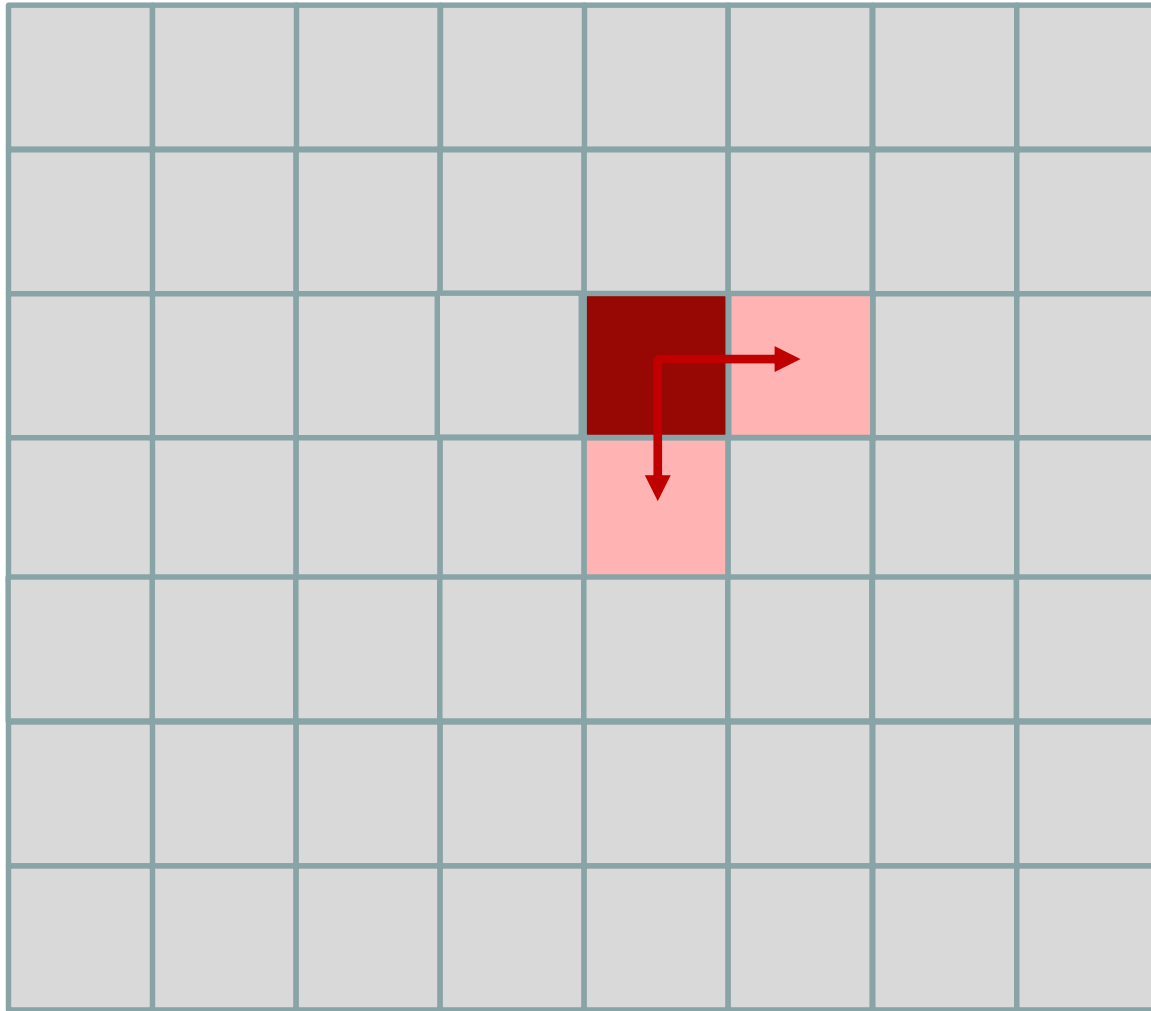
The problem: 1 electron



The problem: 2 electrons widely separated



The problem: 2 electrons close together



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