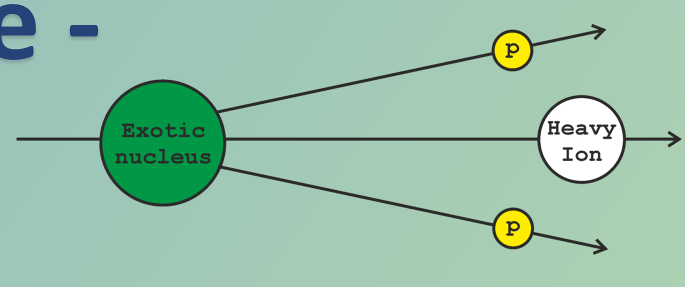
Towards the limits of existence of nuclear structure - excursion beyond the proton dripline



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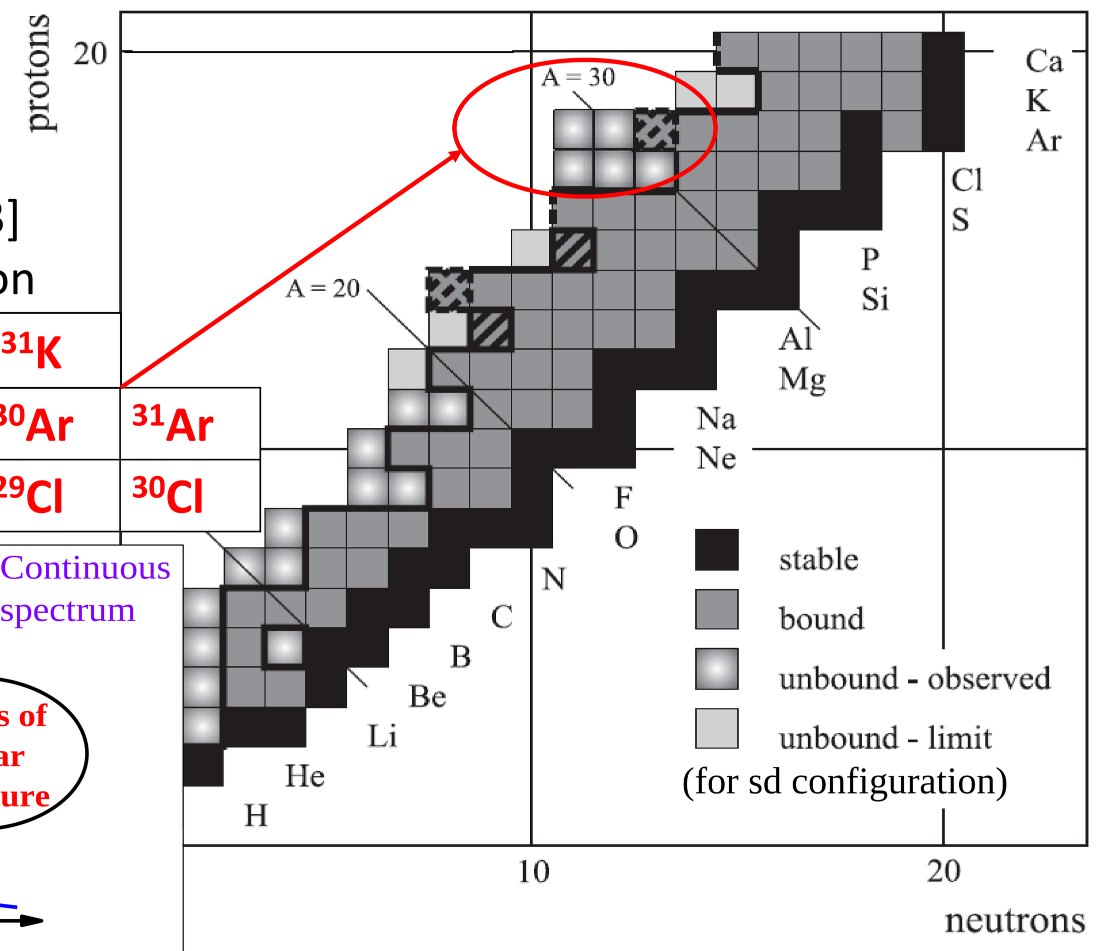
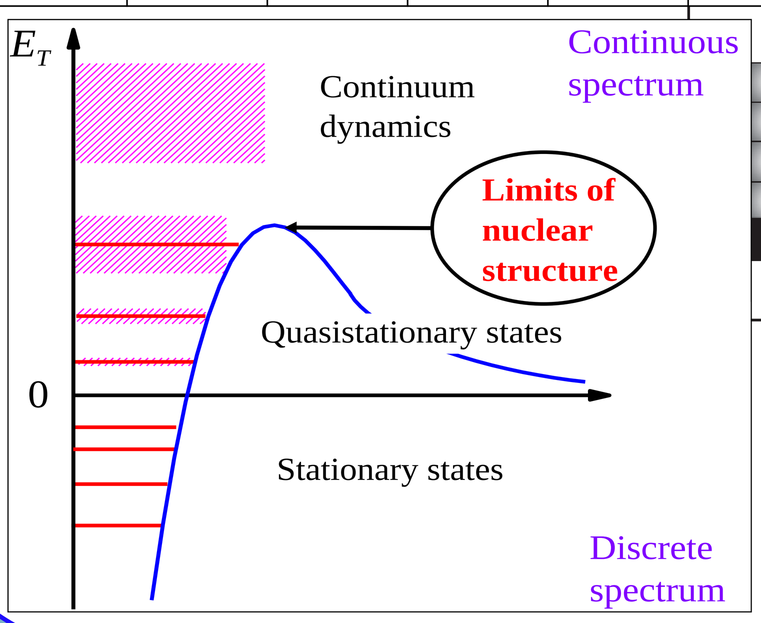
How far beyond the dripline nuclear structure exists? In order to answer this, we performed the systematic studies of proton separation energies for **Argon** and **Chlorine isotopic chains** and took a look at **the most remote from stability isotope ^{31}K**. These proton-unbound isotopes have been studied by measuring trajectories of their decay-in-flight products by using **a tracking technique with microstrip detectors.** The proton (1*p*), two-proton (2*p*) or three-proton (3p) emission processes have been detected in the measured angular correlations "heavy ion" (HI) + number of emitted protons.

Motivation

- 2p-radioactivity [1]
- First observation ^{45}Fe [2,3]
- Isotopes far beyond proton dripline

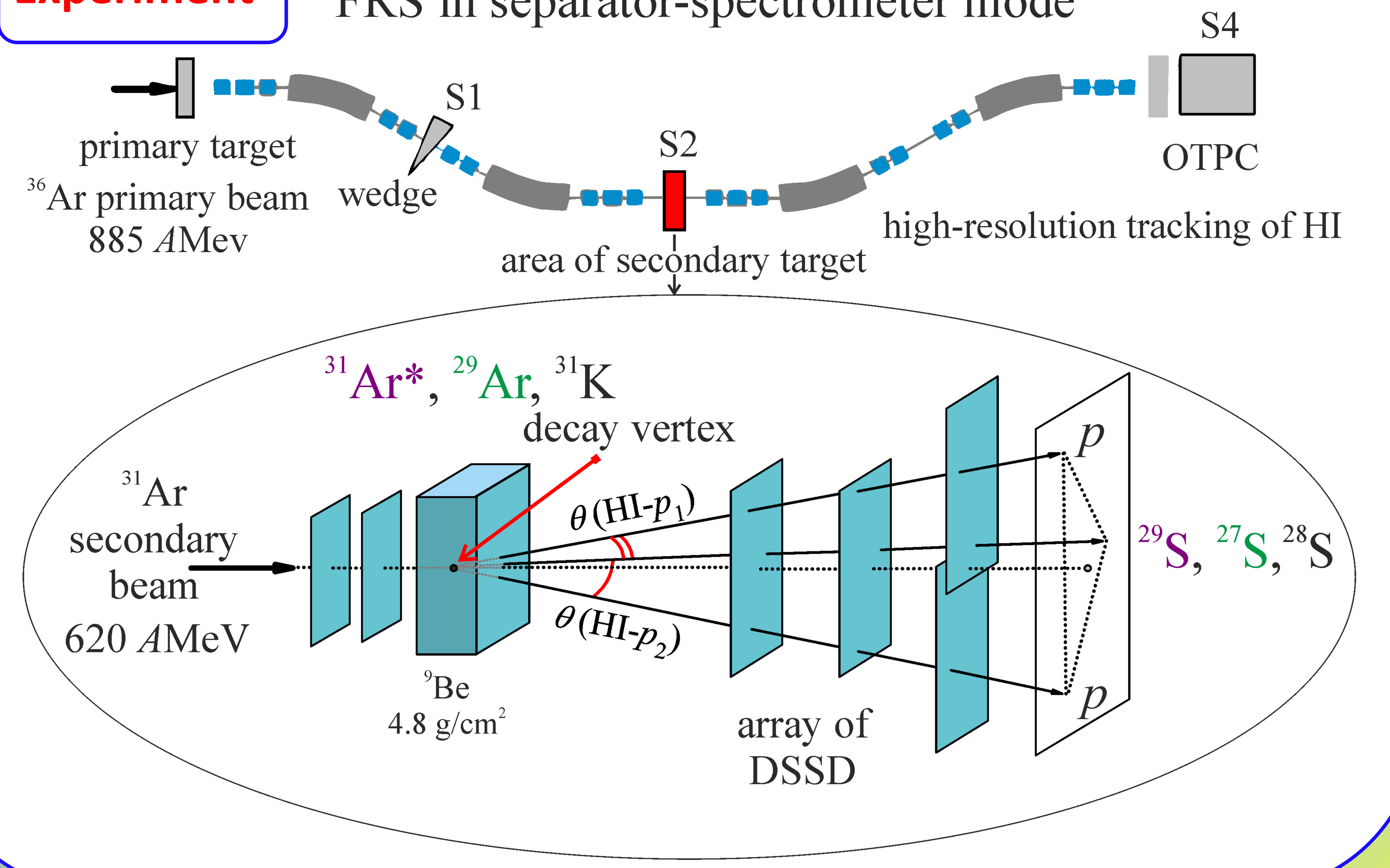
				^{31}K	
^{26}Ar	^{27}Ar	^{28}Ar	^{29}Ar	^{30}Ar	^{31}Ar
^{25}Cl	^{26}Cl	^{27}Cl	^{28}Cl	^{29}Cl	^{30}Cl





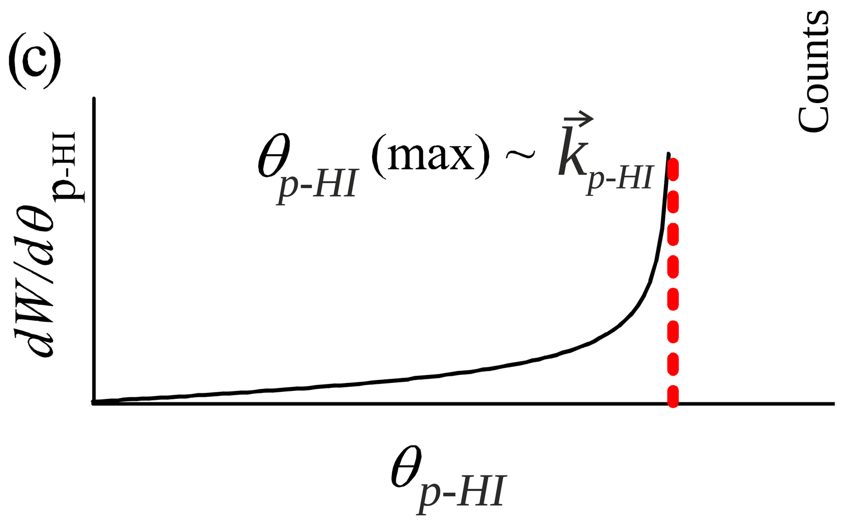
- Nuclear astrophysics: (2p,γ) capture
- The effects of small binding

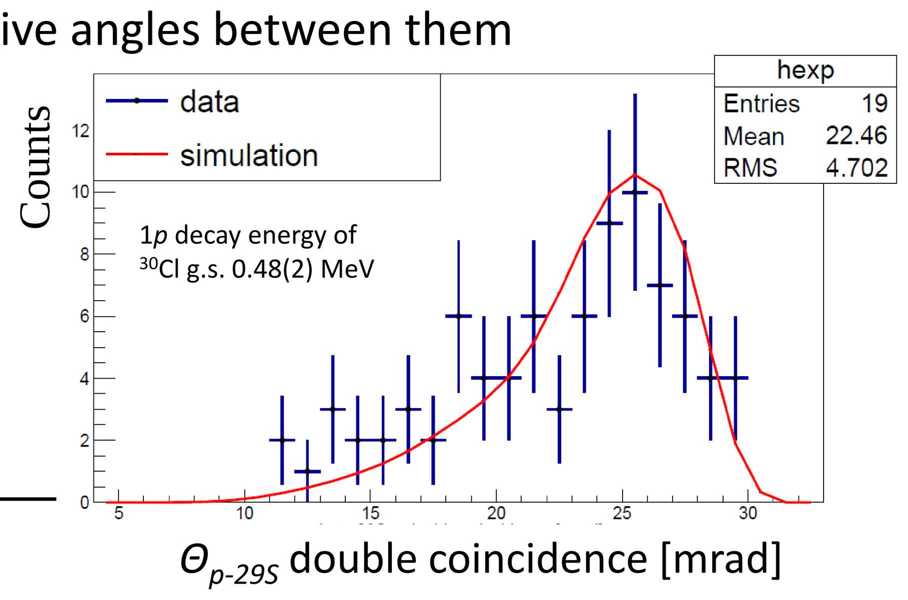
Experiment



How nuclear structure information is derived

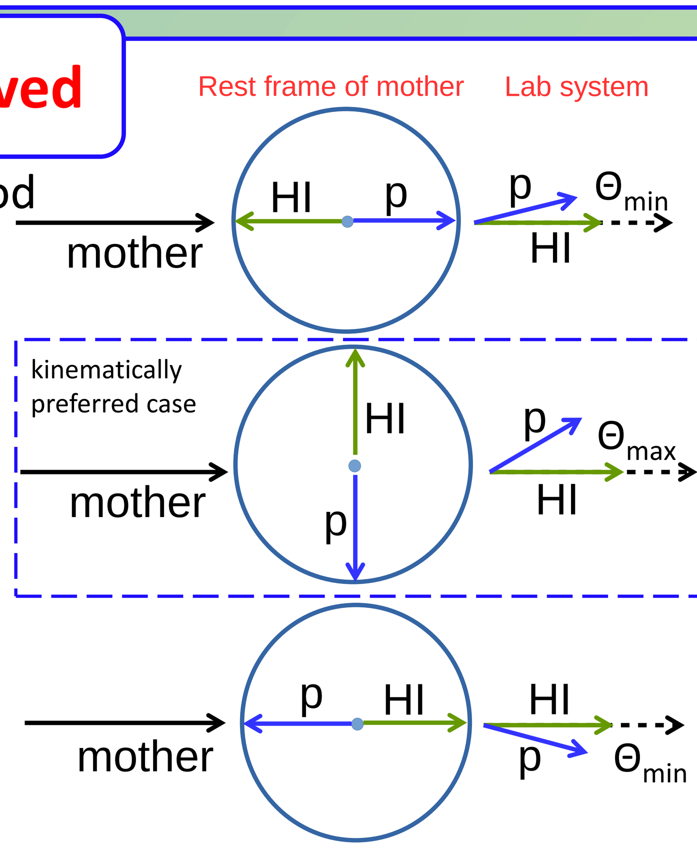
- Conventional method (well-established procedure [4-8]): tracking all decay products and obtaining relative angles between them

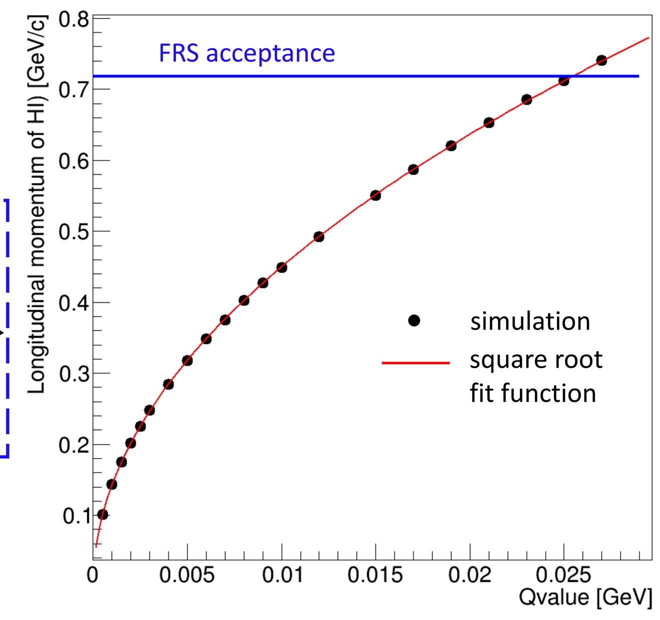




- Alternative method (under investigation): Impact of $p_{||}$(HI)

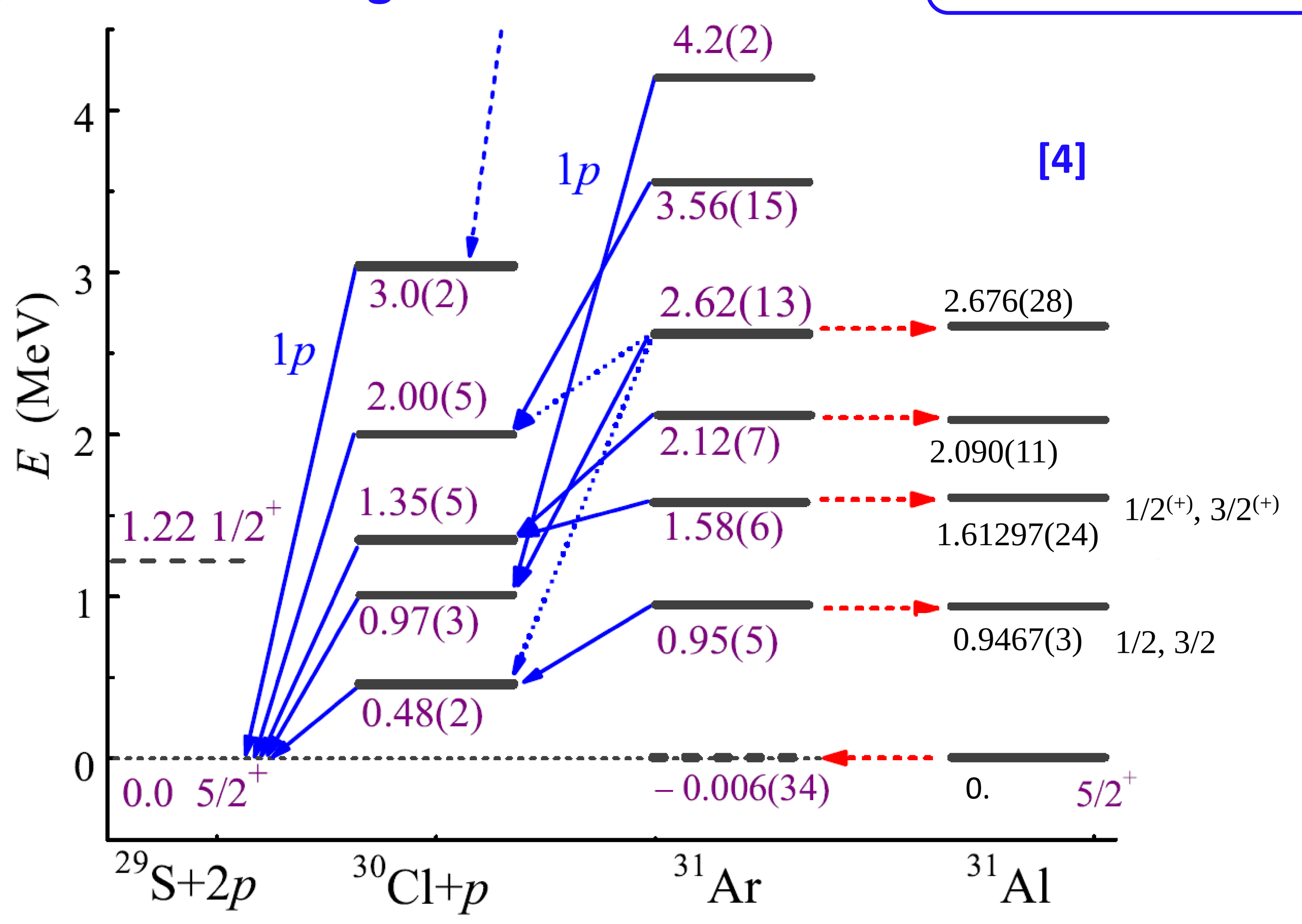
FRS in high-resolution mode: p/Δp = 16500





Spectroscopy of new isotopes

Argon and Chlorine

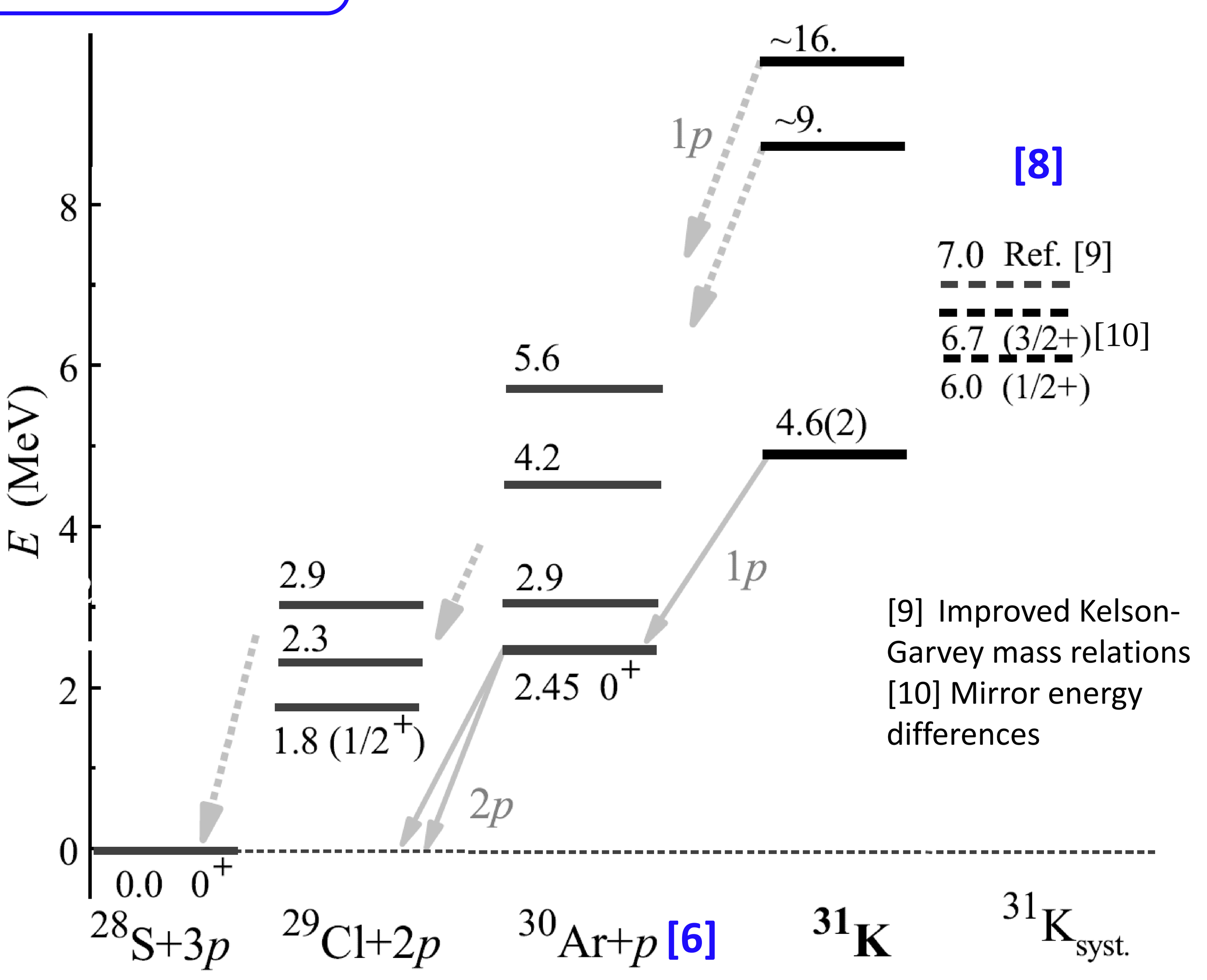


A	$S_p(^A$Cl) (MeV)		$S_{2p}(^A$Ar) (MeV)	
	Theory	Expt., [Ref]	Theory	Expt., [Ref]
31			– 0.08(15)	0.006(34), [1]
30	– 0.311(1)	– 0.48(2), [1]	– 2.43(17)	-2.45^{+5}_{-10}, [3]
29	– 1.75(1)	– 1.8(1), [2]	– 2.93(25)	– 5.50(18),[a] [1]
28	– 1.83(2)	– 1.60(8), [1]	– 6.90(35)	
27	– 4.14(7)		– 8.90(40)	
26	– 4.66(9)		– 11.3(8)	
26			– 11.7(3)[b]	
25	– 6.15(15)			

[a]Not clear whether this is a ground state or an excited state.
[b]This theoretical result is obtained with the three-body model (see Fig. 6).

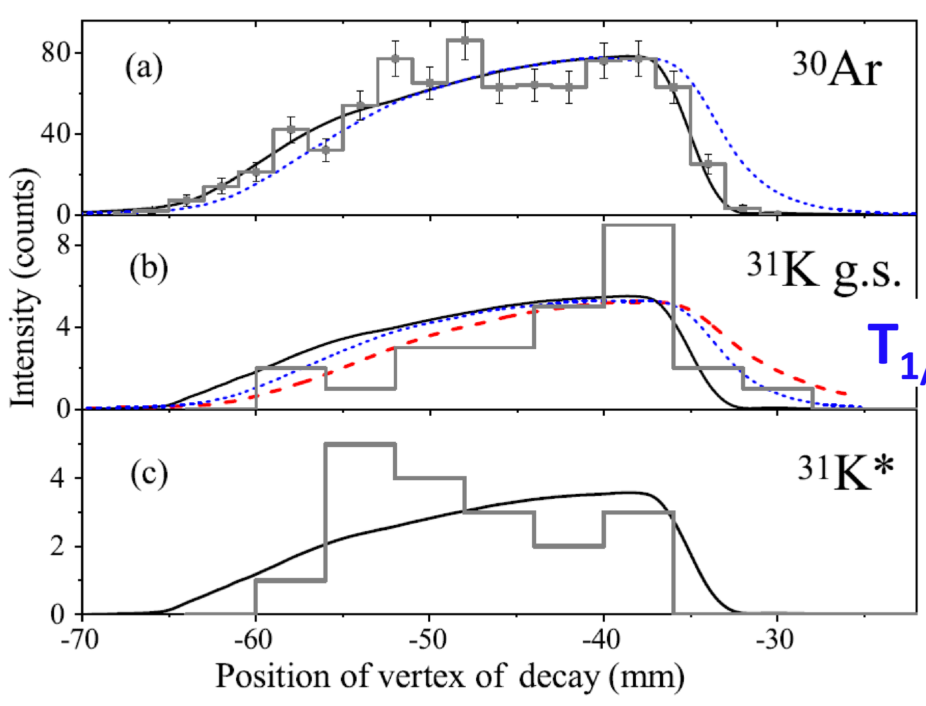
[5]

Potassium-31



[9] Improved Kelson-Garvey mass relations
[10] Mirror energy differences

Half-life of ^{31}K by tracking



$T_{1/2}(^{31}K) < 10$ ps

Summary

- **Previously-unknown isotopes ^{28,30}Cl** and **^{29}Ar**
- **Excited states in ^{28,30}Cl**
- **Excitation spectrum of ^{31}Ar, isospin symmetry** with **^{31}Al**
- **Limits of nuclear structure existence: ^{26}Ar** and **^{25}Cl**
- **$S_{2p}(^{31}Ar) = 6(34)$ kev**!
- Discovery and first spectroscopy of **three-proton emitter ^{31}K**

Outlook

- Large rms radius of ^{31}Ar?
- 2p-radioactivity of ^{31}Ar
- Charge-exchange reactions with ^{48}Ni, ^{67}Kr
- Test of nuclear mass models in a transition region to chaotic nuclear matter

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References:

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