Strong-interaction widths of kaonic helium isotopes

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PLB681(09)310 PLB697(11)199 arXiv:1205.0640v1 [nucl-ex]

21. May. 2012, LEANNIS meeting, Prague

Introduction
-- History --



Kaonic atom data (Z≥3)



Possible shift of Kaonic helium (Z=2)





SIDDHARTA Experiment

Experimental results before SIDDHARTA

z	Α	Target	Last	Level shift		
			orbit	Old experiments	New experiments	
1	1	¹ H	1 s	Attractive Davies (79), Izycki (80), Bird (83)	<mark>Repulsive</mark> KpX(97), DEAR (05)	
1	2	² D	1 s	No data	No data	
2	3	³ He	2р	No data	No data	
2	4	⁴He	2р	Large Wiegand (71), Batty (79), Baird (83)	<mark>Small</mark> KEK E570 (07)	

Recently performed experimental results: different from old data

SIDDHARTA experiment: All light targets (from hydrogen to helium-4) Confirmation of "New experimental results" and improvement of precession First data of kaonic deuterium and kaonic helium-3

Data taking periods of SIDDHARTA in 2009



Target	Reference		
He4 with 55Fe	PLB681(2009)310		
He4	PLB697(2011)199 arXiv:1205.0640v1 [nucl-ex]		
He3			
Н	PLB704(2011) 113		



Kaonic He-4 X-rays at SIDDHARTA



10 bar at NTP

First measurement with gas target

precise calibration: 4.5 keV & 5.9 keV X-rays as in-beam calibration lines



Summary of KHe-4 shifts (up to 2007)



Data taking periods of SIDDHARTA in 2009



Data taking periods of SIDDHARTA in 2009



Removed ⁵⁵Fe source in other data







X-ray peak fit

Line		Intensity ratio	Energy (eV)	width
		ratio		(eV)
Ti K	α_{11}	1	4510.918	1.37
	α_{12}	0.21666	4509.954	2.22
	α_{13}	0.13151	4507.763	3.75
	α_{15}	0.03738	4514.002	1.70
	α_{21}	0.60614	4504.910	1.88
	α_{22}	0.03424	4503.088	4.49
Cu K	α_{11}	1	8047.837	2.285
	α_{12}	0.138	8045.367	3.358
	α_{21}	0.407	8027.993	2.666
	α_{22}	0.181	8026.504	3.571
Au L	α_1	1	9713.44	7.57
	α_2	0.1134	9628.05	7.61

Natural line widths taken into account

X-ray peaks are fitted with Voigt function

$$V = V(\sigma, \Gamma) = G(\sigma) \otimes L(\Gamma)$$

 $G = G(\sigma)$: Detector response $V = L(\Gamma)$: Broadening of lines

Kaonic Helium-3 energy spectrum

arXiv:1010.4631v1 [nucl-ex], PLB697(2011)199

PLB697(2011)199

Comparison of results

	Shift [eV]	Reference
KEK E570	+2±2±2	PLB653(2007)387
SIDDHARTA (He4 with 55Fe)	+0±6±2	PLB681(2009)310
SIDDHARTA (He4)	$+5\pm3\pm4$	arXiv:1010.4631,
SIDDHARTA (He3)	-2±2±4	PLB697(2011)199

Comparison of results

	Shift [eV]	Reference
KEK E570	+2±2±2	PLB653(2007)387
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SIDDHARTA (He4)	$+5\pm3\pm4$	arXiv:1010.4631,
SIDDHARTA (He3)	-2±2±4	PLB697(2011)199

Comparison of results

Kaonic 4He 2p level shift

	Target	Shift [eV]
KEK E570	Liquid	+2±2±2 eV
SIDDHARTA (w/ 55Fe)	Gas	+0±6±2 eV
SIDDHARTA (New)	Gas	+5±3±4 eV

Kaonic 3He 2p level shift

	Target	Shift [eV]
SIDDHARTA	Gas	-2±2±4 eV
J-PARC E17	Liquid	??±?±? eV

shift
$$\Delta E_{2p} = E_{exp} - E_{e.m.}$$
 $\Delta E_{2p} > 0$ ("attractive" *shift*),
 $\Delta E_{2p} < 0$ ("repulsive" *shift*),

2p level widths

Nuclear Physics A392 (1983) 297-310

The shift measurements are seen to be in good agreement. The situation for the width values is much less satisfactory and the error bars of the two measured values do not overlap. The error on the quoted average has been taken from the external variance of the measured values."

Future directions in kaonic atom physics

E. Friedman

Predictions for the 2p level in kaonic He isotopes (in eV).

		³ He		$^{4}\mathrm{He}$	
added phen.	1385 res.	shift	width	\mathbf{shift}	width
no	no	0.2	1.9	0.4	2.1
no	yes	-0.1	1.9	-0.1	2.3
yes	no	0.3	2.1	-0.2	1.6
yes	yes	0.0	1.9	-0.3	1.9

EXA2011, Vienna, September 2011

2p level of K-4He by Akaishi

Exa05 Proc. by Akaishi

2p level shift of ³He-K⁻

Exa05 talk by Akaishi

x-ray yields per stopped K^- (%)
Uncertainty of detector resolution





Systematic error in the width determination



(Syst.): from uncertainty of sigma and R



Results of KHe3 and KHe4



Outlook

Discussion



Check of the sensitivity



Proposed method to determine width







X-ray transmission vs Width



Summary

- K-3He and K-4He X-rays were measured in SIDDHATRA
- Shift and width are found to be at most a few eV both in K-3He and K-4He
- The "kaonic helium puzzle" was solved both in shift and width
- The widths are much smaller than the detector resolution
- To improve the accuracy of the width measurement, the filter technique can be applied.
- The width information is very useful for the estimation of the Ka yields of kaonic helium, which can be measured in a future experiment, like upgraded SIDDHARTA-2 or J-PARC

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The (slightly) modified E17 goals







Photon cross section in helium





Comparison of X-ray detectors





T.Ishiwatari, Hyp. Int. 194(09)165

experiment		КрХ	DEAR	E570
Detector		Si(Li)	CCD	SDD
Area	[mm2]	200	724	100
Thickness	[mm]	5	0.03	0.26
∆ E (FWHM)	[eV]	410	170	185
∆ t (FWHM)	[ns]	290	\times -	430













"kaon-coincidence" with K-d data

Kapton window (C22H10N2O5)



Fit of kaonic (C/O/AI) atom X-ray lines with known energy



confirmation of the accuracy of energy determination & peak shift



Comparison of results



Comparison of results



Comparison of results

PLB697(2011)199












2p level shift of ³He-K⁻





