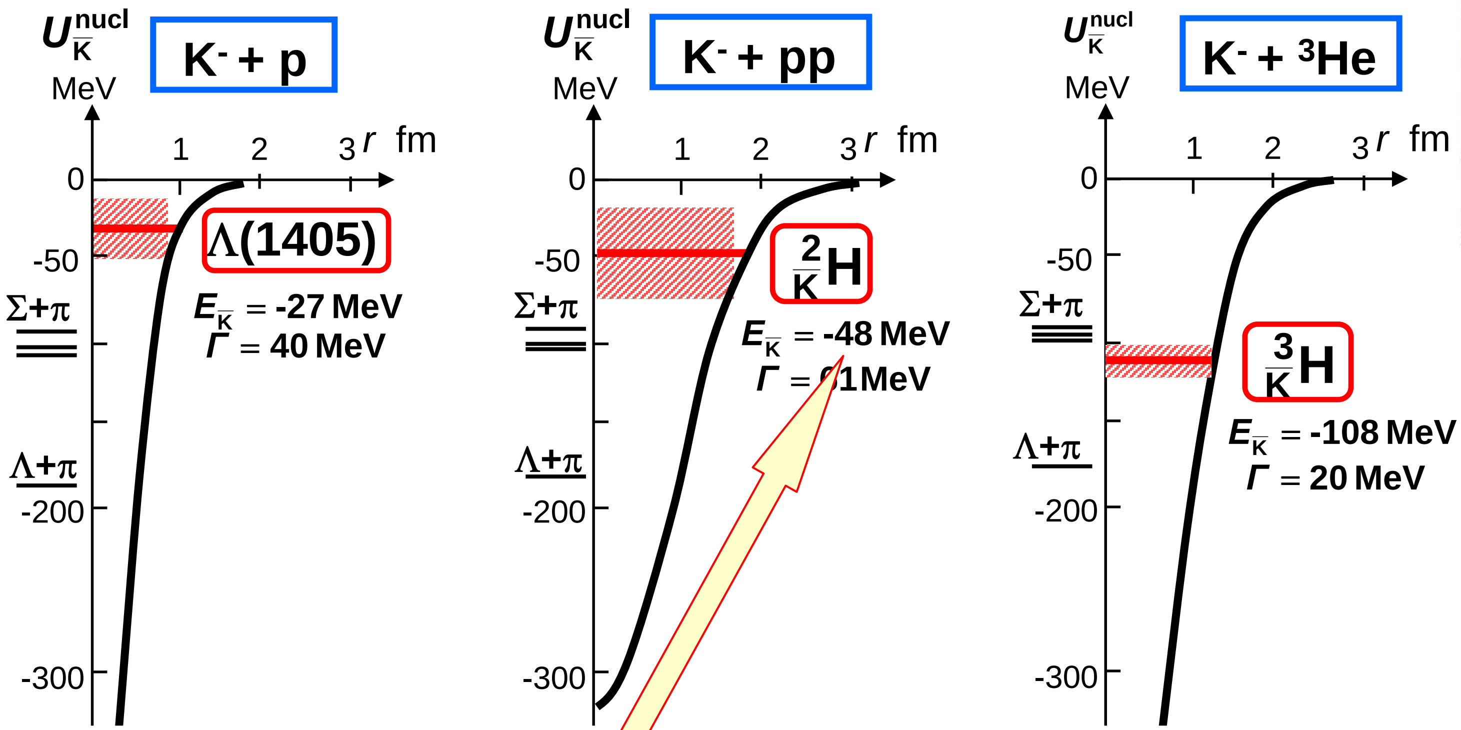
HYP2015, Sendai
September 7, 2015

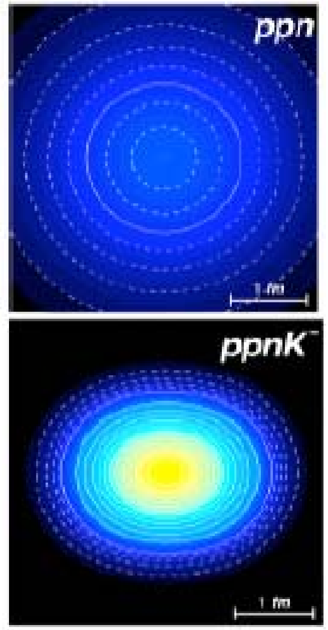
Possible Existence of Λ* Strangelets

——— toward Λ*=$(K^{-}p)^{I=0}$ condensed matter ———

Yoshinori **AKAISHI** & **T**oshimitsu **YAMAZAKI**

"Λ(1405) Ansatz"





Shrinkage!

N.V. Shevchenko, A. Gal & J. Mares, Phys. Rev. Lett. 98 (2007) 082301
E = **-55~-70** MeV, *Γ* = **90~110** MeV
Y. Ikeda & T. Sato, Phys. Rev. C 76 (2007) 035203
E = **-80** MeV, *Γ* = **73** MeV
A. Dote, T. Hyodo & W. Weise, Phys. Rev. C 79 (2009) 014003
E = **-20**+-3 MeV, *Γ* = **40~70** MeV

Y. Akaishi & T. Yamazaki, Phys. Rev. C 65 (2002) 044005
T. Yamazaki & Y. Akaishi, Phys. Lett. B 535 (2002) 70

K^-p

Which is the $\Lambda(1405)$ mass,

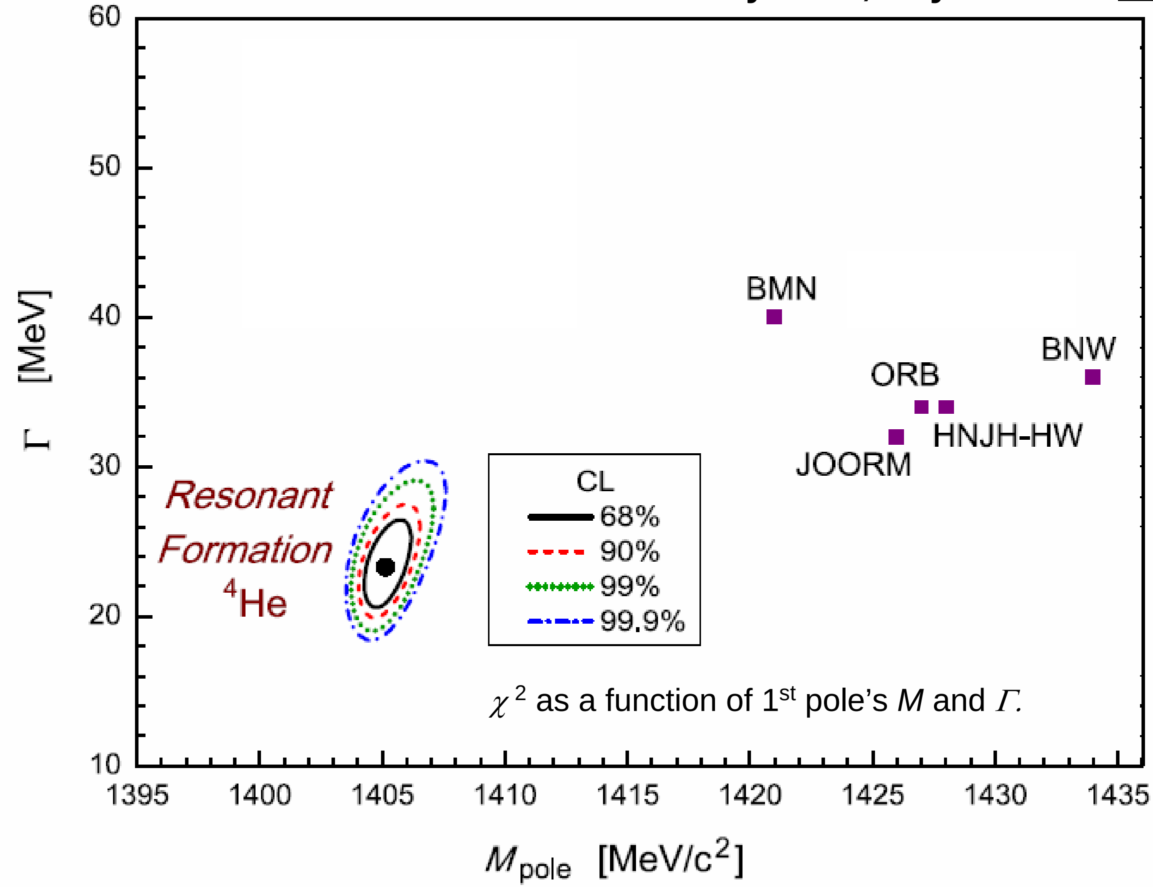
1405 or 1420 MeV/c^2**?**

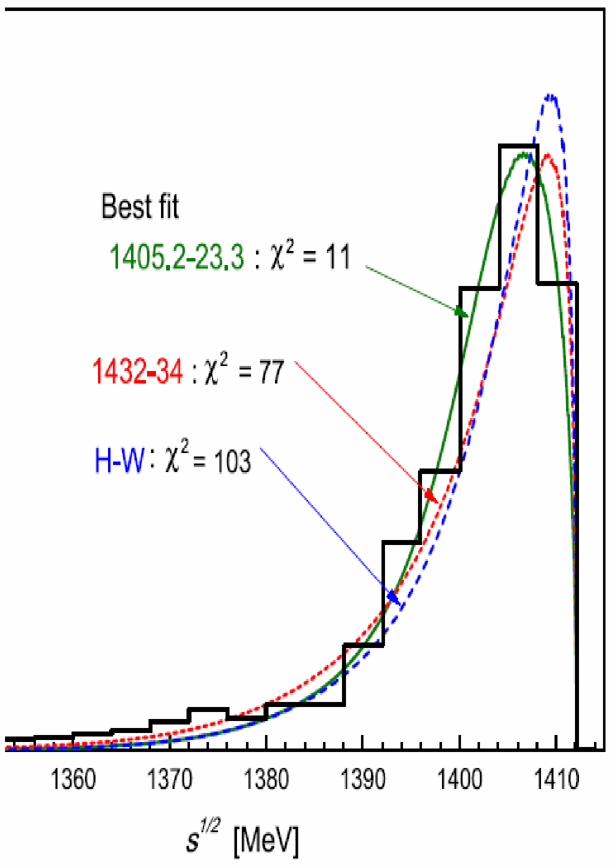
$\Sigma\pi$ invariant mass from stopped K$^-$ on ^{4}He

J. Esmaili, Y. Akaishi & T. Yamazaki, Phys. Lett. B686 (2010) 23

$$M = 1405.5^{+1.4}_{-1.0}\ \mathrm{MeV}/c^2 \quad \text{and} \quad \Gamma = 23.6^{+4}_{-3}\ \mathrm{MeV}$$

Data : B. Riley et al., Phys. Rev. D 11 (1975) 3065

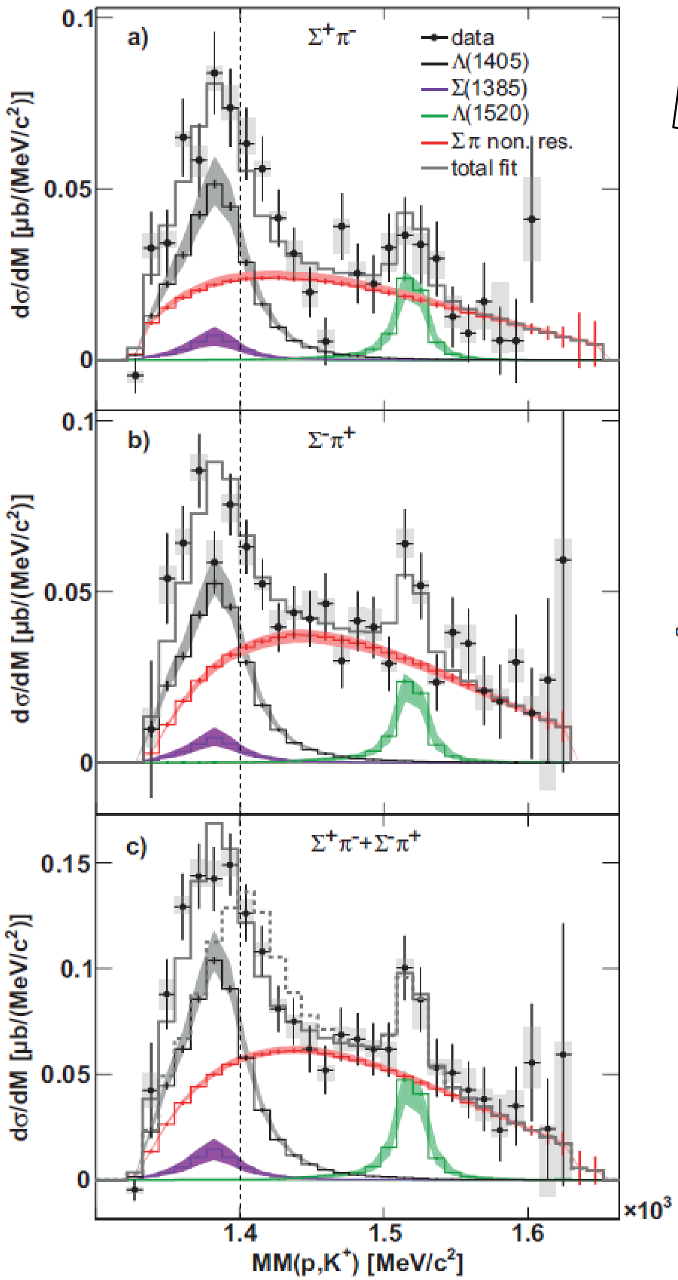


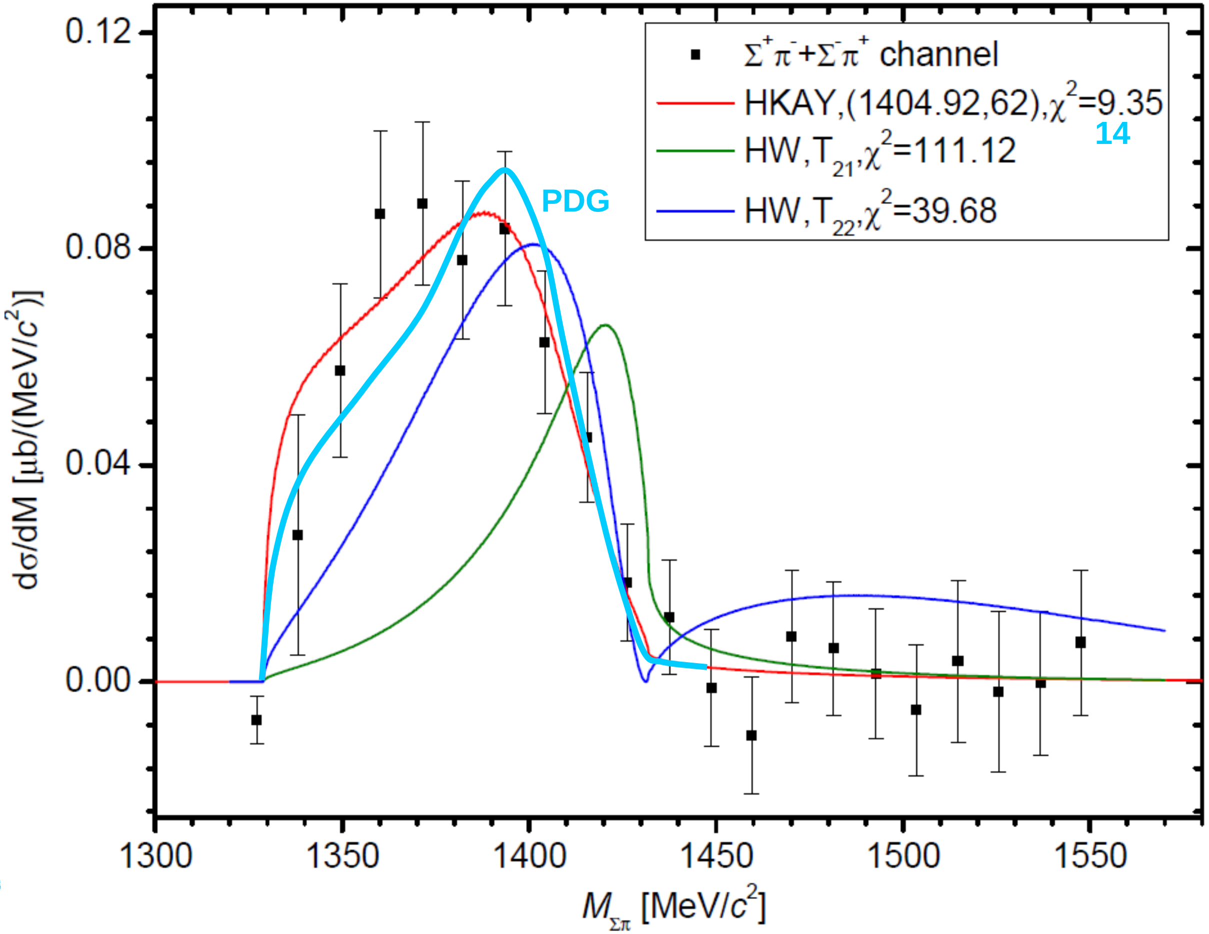


Λ(1405) from HADES

G. Agakishiev et al., Phys. Rev. C 87 (2013) 025201

M. Hassanvand et al., Phys. Rev. C 87 (2013) 055202





$\Lambda(1405)\ 1/2^-$

$I(J^P) = 0(\frac{1}{2}^-)$ Status: ∗∗∗∗

2015

$\Lambda(1405)$ MASS

PRODUCTION EXPERIMENTS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
$1405.1^{+1.3}_{-1.0}$ OUR AVERAGE					
$1405\ ^{+11}_{-9}$		HASSANVAND	13	SPEC	$pp \to p\Lambda(1405)K^+$
$1405\ ^{+1.4}_{-1.0}$		ESMAILI	10	RVUE	$^4\text{He}\,K^- \to \Sigma^\pm\pi^\mp X$ at rest
1406.5 ± 4.0		[1] DALITZ	91		M-matrix fit
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1391 ± 1	700	[1] HEMINGWAY	85	HBC	K^-p 4.2 GeV/c
~ 1405	400	[2] THOMAS	73	HBC	π^-p 1.69 GeV/c
1405	120	BARBARO-...	68B	DBC	K^-d 2.1–2.7 GeV/c
1400 ± 5	67	BIRMINGHAM	66	HBC	K^-p 3.5 GeV/c
1382 ± 8		ENGLER	65	HDBC	π^-p, π^+d 1.68 GeV/c
1400 ± 24		MUSGRAVE	65	HBC	$\overline{p}p$ 3–4 GeV/c
1410		ALEXANDER	62	HBC	π^-p 2.1 GeV/c
1405		ALSTON	62	HBC	K^-p 1.2–0.5 GeV/c
1405		ALSTON	61B	HBC	K^-p 1.15 GeV/c

$\Lambda(1405)$ WIDTH

PRODUCTION EXPERIMENTS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
50.5 ± 2.0 OUR AVERAGE					
62 ± 10		HASSANVAND	13	SPEC	$pp \to p\Lambda(1405)K^+$
50 ± 2		[1] DALITZ	91		M-matrix fit

• • • We do not use the following data for averages, fits, limits, etc. • • •

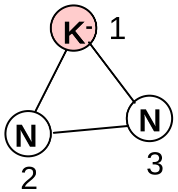
K^-pp

Variational wave function of K$^-$pp

ATMS

Amalgamation of **T**wo-body correlations into **M**ultiple **S**cattering process

$$\Psi = \left[\left\{f^{I=0}(r_{12})\hat{P}_{12}^{I=0} + f^{I=1}(r_{12})\hat{P}_{12}^{I=1}\right\} f_{\mathrm{NN}}(r_{23}) f(r_{31}) + f(r_{12}) f_{\mathrm{NN}}(r_{23}) \left\{f^{I=0}(r_{31})\hat{P}_{31}^{I=0} + f^{I=1}(r_{31})\hat{P}_{31}^{I=1}\right\}\right] \left|T = 1/2\right\rangle$$



$$\hat{P}_{12}^{I=0} = \frac{1 - \vec{\tau}_{\mathrm{K}}\vec{\tau}_{\mathrm{N}}}{4}, \quad \hat{P}_{12}^{I=1} = \frac{3 + \vec{\tau}_{\mathrm{K}}\vec{\tau}_{\mathrm{N}}}{4}$$

$$\left|T = 1/2\right\rangle = \sqrt{\frac{3}{4}} \left[\left(\overline{K}_1 N_2\right)^{0,0} p_3\right] + \sqrt{\frac{1}{4}} \left[-\sqrt{\frac{1}{3}} \left(\overline{K}_1 N_2\right)^{1,0} p_3 + \sqrt{\frac{2}{3}} \left(\overline{K}_1 N_2\right)^{1,1} n_3\right]$$

$\Lambda^* p$

Euler-Lagrange equation

$$\delta_f \left\{\left\langle \Psi \middle| H \middle| \Psi \right\rangle - \lambda \left\langle \Psi \middle| \Psi \right\rangle\right\} = 0$$

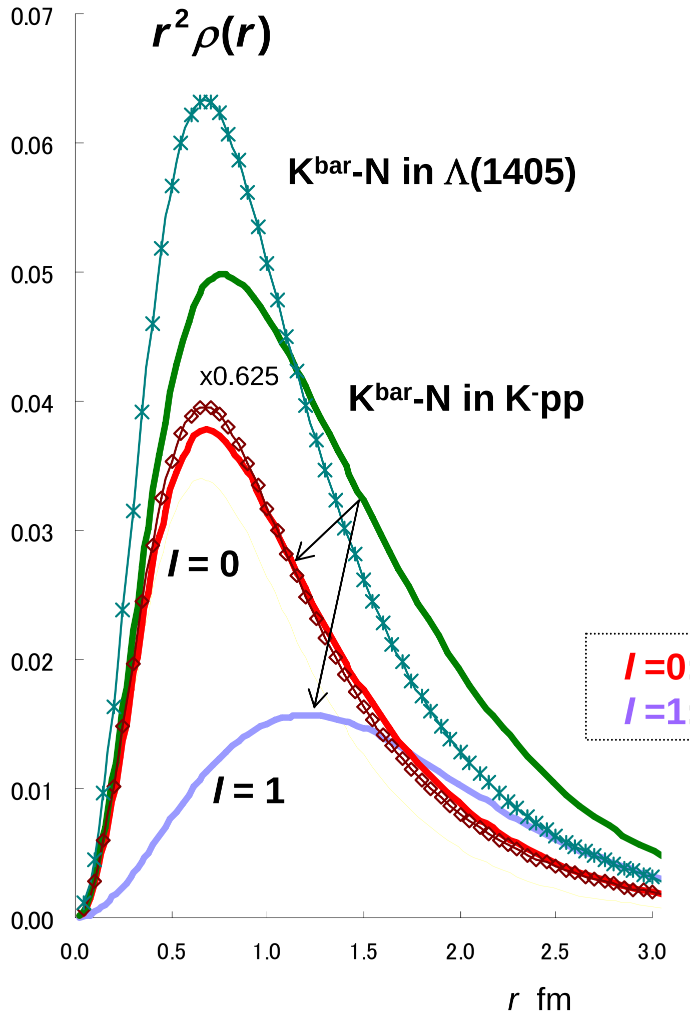
$$v_{\overline{\mathrm{K}}\mathrm{N}}^{T=0}(r) = \{-595 - i83\}_{\mathrm{MeV}} \exp\left\{-(r/0.66_{\mathrm{fm}})^2\right\}$$

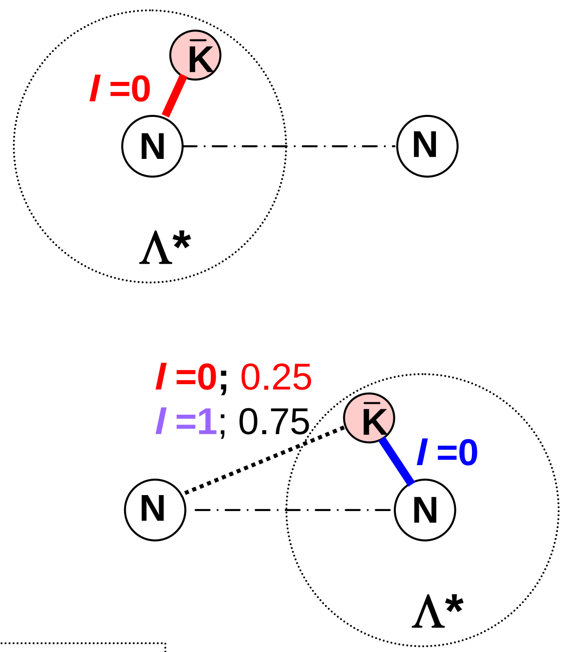
$$v_{\overline{\mathrm{K}}\mathrm{N}}^{T=1}(r) = \{-175 - i105\}_{\mathrm{MeV}} \exp\left\{-(r/0.66_{\mathrm{fm}})^2\right\}$$

$$v_{\mathrm{NN}}(r) = 2000_{\mathrm{MeV}} \exp\left\{-(r/0.447_{\mathrm{fm}})^2\right\} - 270_{\mathrm{MeV}} \exp\left\{-(r/0.942_{\mathrm{fm}})^2\right\} - 5_{\mathrm{MeV}} \exp\left\{-(r/2.5_{\mathrm{fm}})^2\right\}$$

Density distributions of K^{bar}-N

T. Yamazaki and Y. Akaishi, Phys. Rev. C 76 (2007) 045201

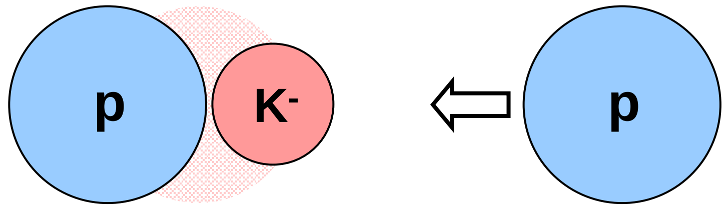


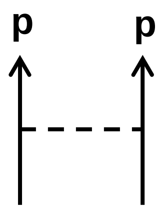


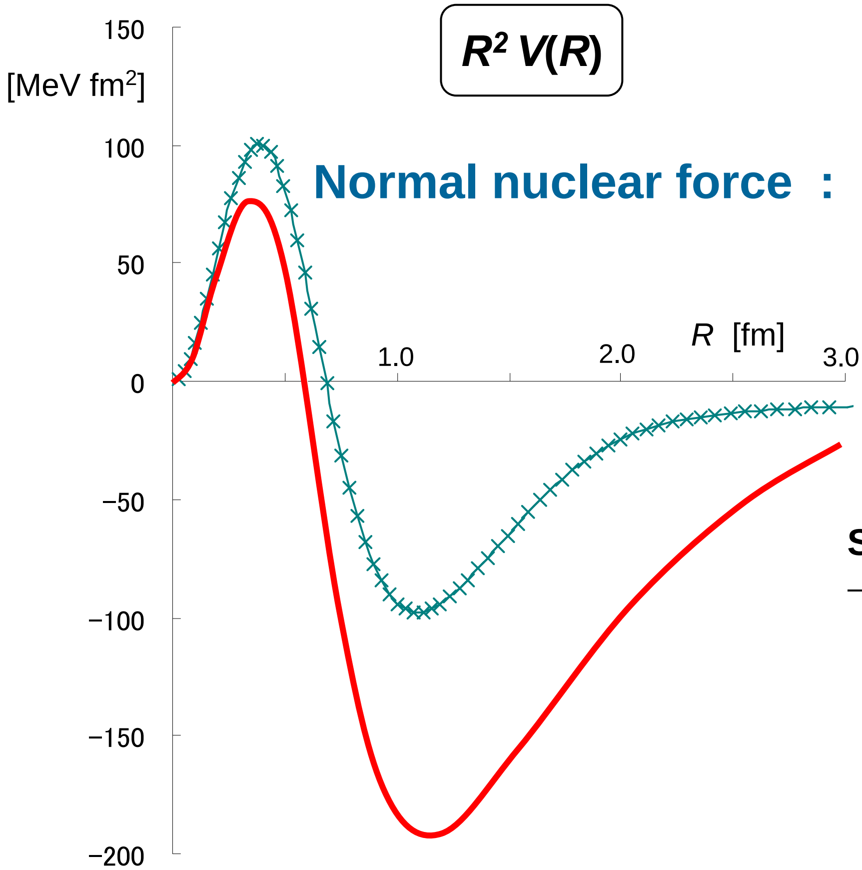
I =0: 0.5x(1+0.25)=**0.625**
I =1: 0.5x0.75= **0.375**

Dynamically favored

Adiabatic p-p potential in $K^{-}pp$







Normal nuclear force : virtual meson exchange

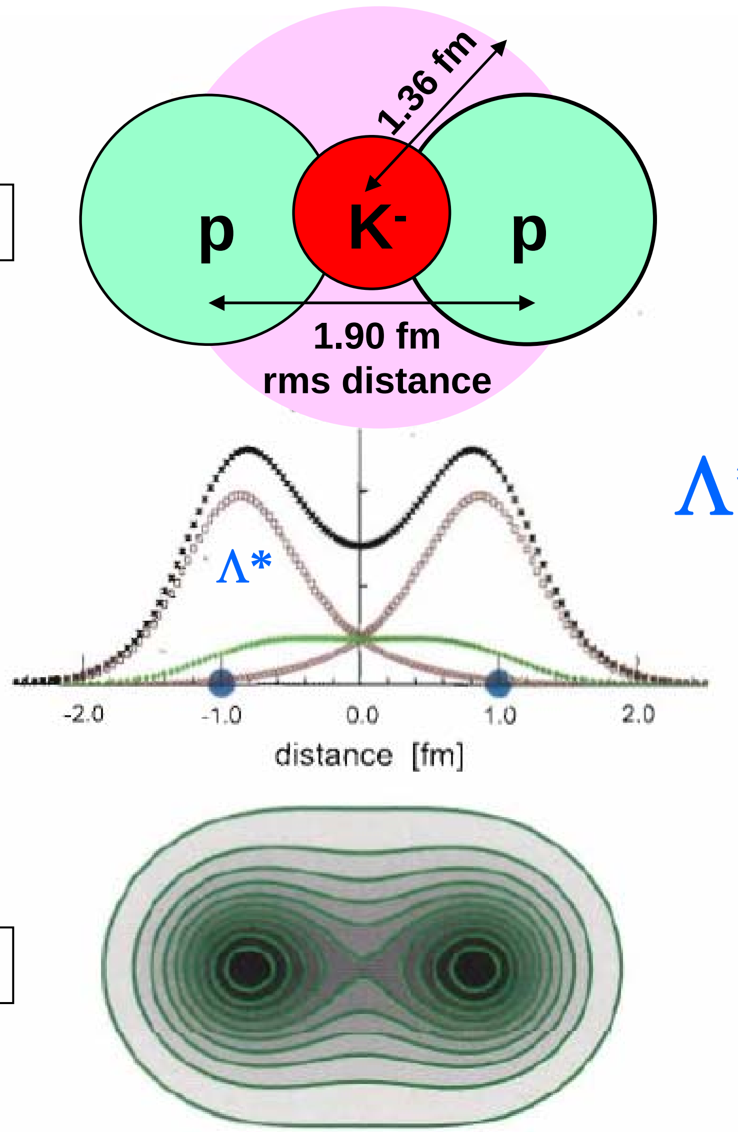
Super strong / Normal ~ 4.1
– volume integral ratio –

Super-strong nuclear force : real K^{bar} migration

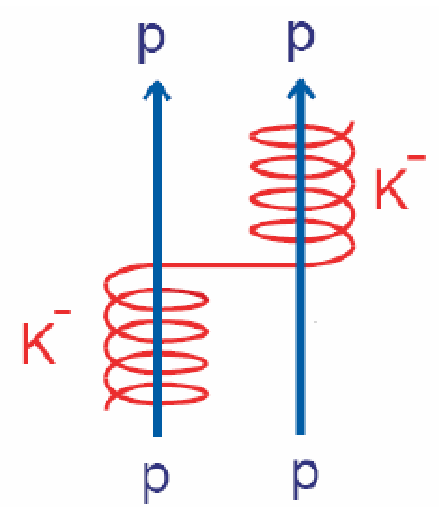
K^-pp quasi-bound state

2002

2007



Λ*-p structure

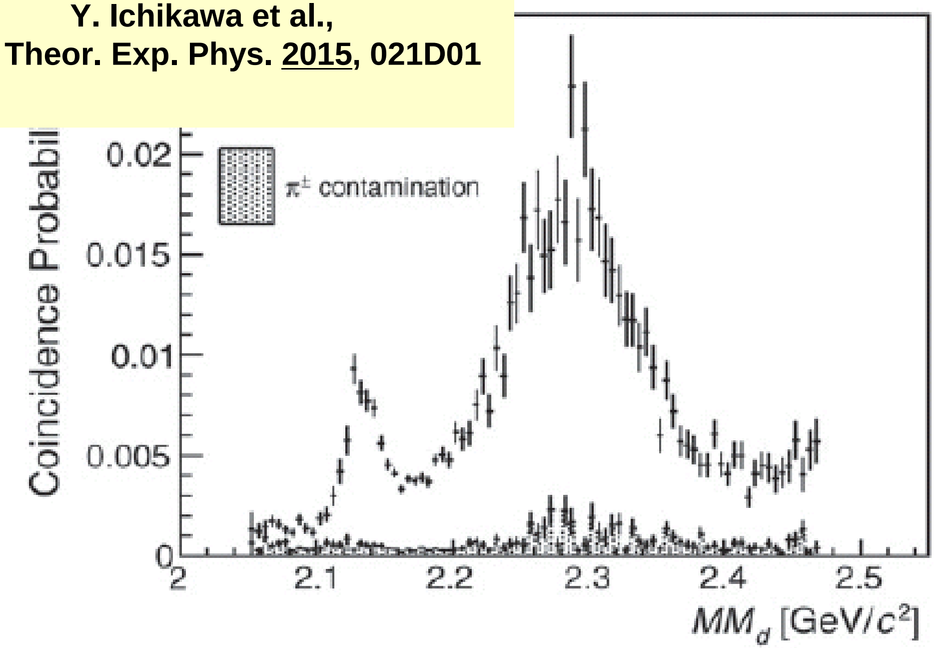


SSNF due to **real K^{bar} migration**

T. Yamazaki and Y. Akaishi, Phys. Rev. C 76 (2007) 045201

E27@J-PARC

Y. Ichikawa et al.,
Prog. Theor. Exp. Phys. 2015, 021D01



Λ^*_{1405}

Attractive interaction is enhanced;

$s \rightarrow f\, s_0, \quad s_0 = -1.37$

f	*V*	*T*	*BE*
1.00	−182.9	156.2	26.6
1.05	−219.2	182.7	36.4
1.10	−256.1	208.6	47.5
1.15	−293.6	233.9	59.7

Theor.

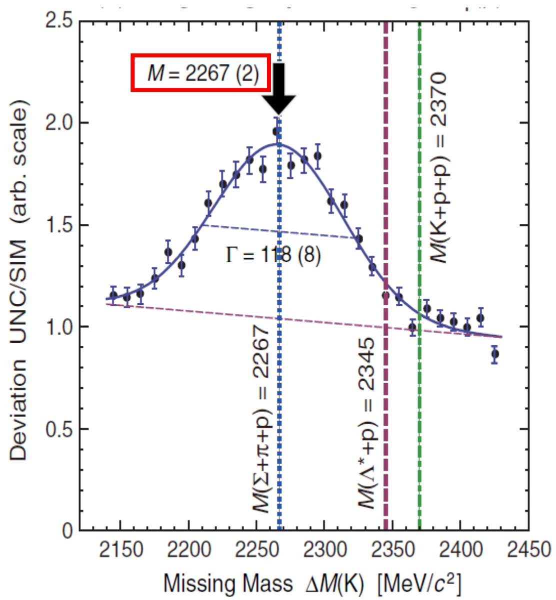
Yamazaki-Akaishi

$E_{\bar{K}}$ = -48 MeV
Γ = 61 MeV

17% enhanced
K^bar N interaction

S. Maeda et al.,
Proc. Jpn. Acad. B 89 (2013) 418

$E_{\bar{K}}$ = -103 MeV
Γ = 118 MeV



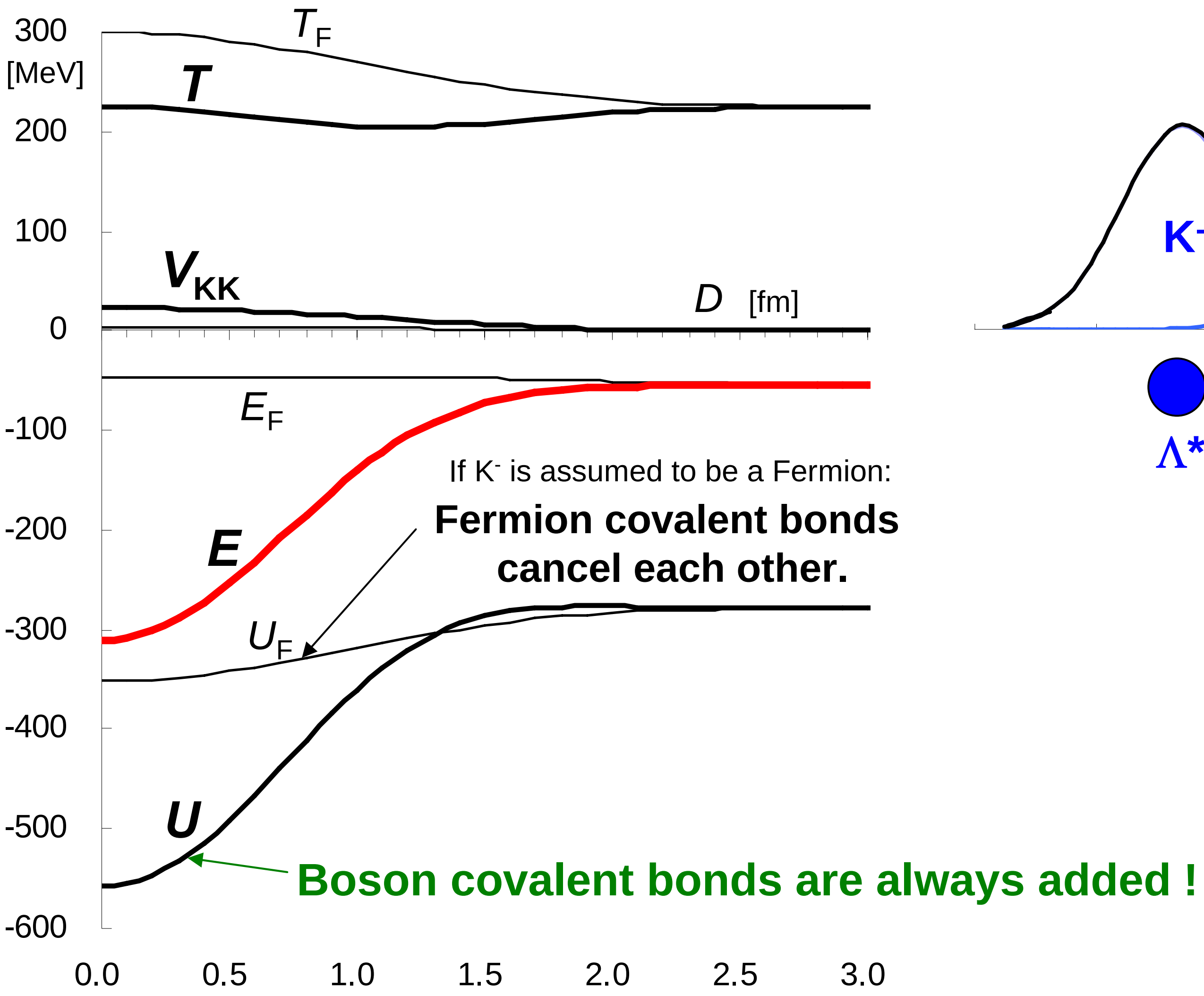
DISTO

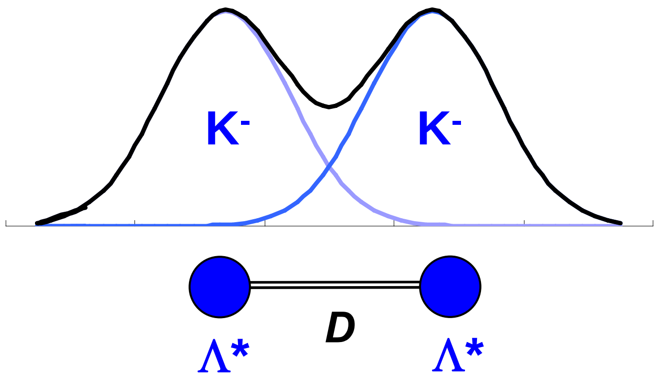
T. Yamazaki et al.,
Phys. Rev. Lett. 104 (2010) 132502

K^-K^-pp & strangelets

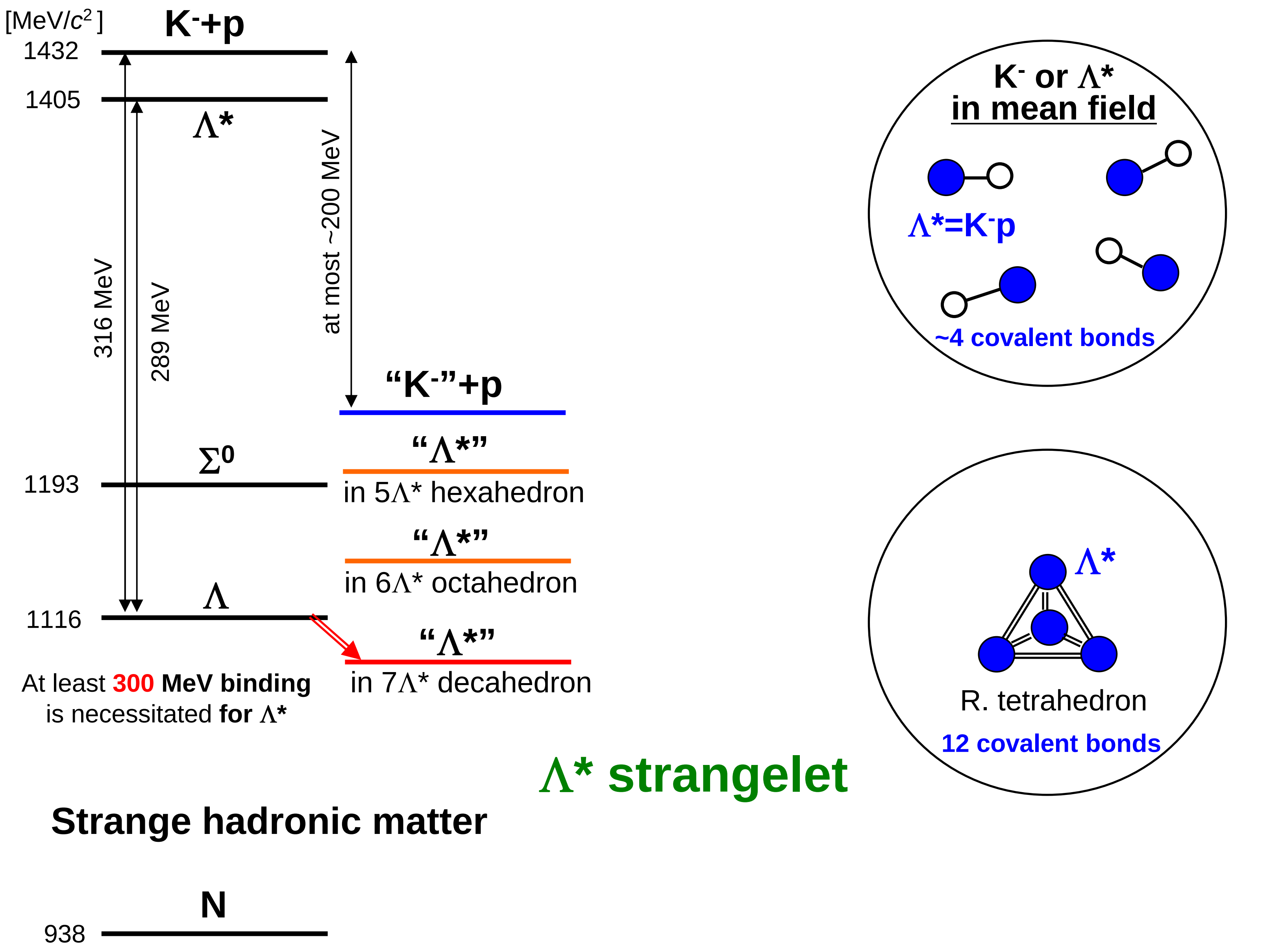
$\Lambda^*\Lambda^*$ model for K^-K^-pp

$$\Phi(\vec{r}_1,\vec{r}_2)=N\{\phi_a(\vec{r}_1)\phi_b(\vec{r}_2)\pm\phi_b(\vec{r}_1)\phi_a(\vec{r}_2)\}$$





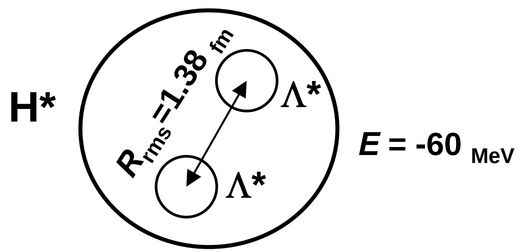
Possible existence of "few-body Λ* strangelet"

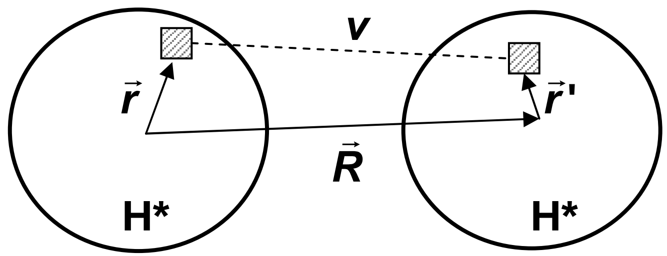


H*-H* double folding potential

Λ*-Λ* potential

$$v(r_{rel}) = 751_{MeV}\exp\left\{-\left(\frac{r_{rel}}{0.6_{fm}}\right)^2\right\} - 416_{MeV}\exp\left\{-\left(\frac{r_{rel}}{1.2_{fm}}\right)^2\right\}$$





$$U(\vec{R}) = \int d\vec{r}'\,d\vec{r}\ \rho_B(\vec{r}')\,v(\vec{R}+\vec{r}'-\vec{r})\,\rho_A(\vec{r})$$

H*-H* double folding potential

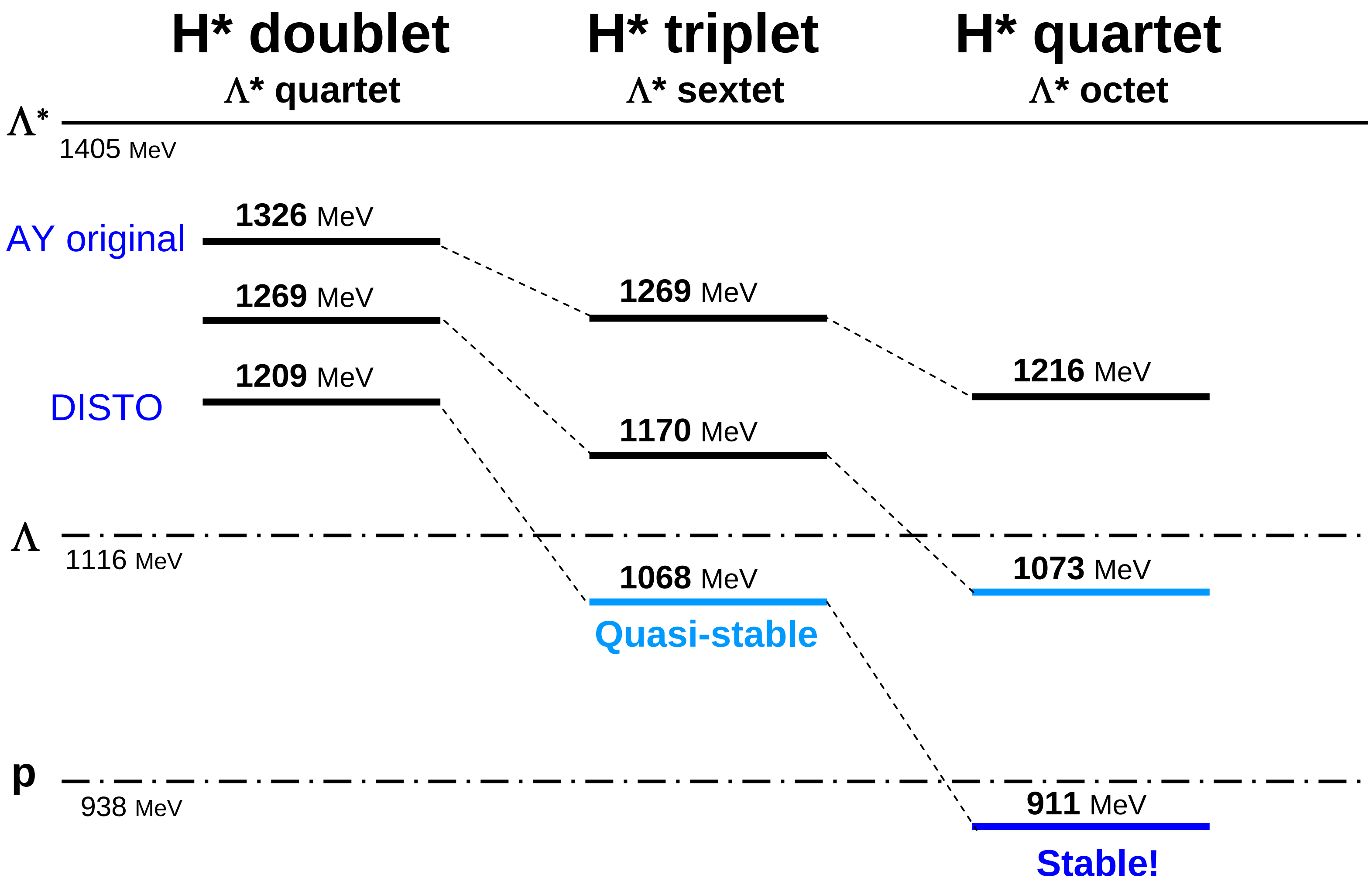
$$U(R) = 662_{MeV}\exp\left\{-\left(\frac{R}{0.99_{fm}}\right)^2\right\} - 967_{MeV}\exp\left\{-\left(\frac{R}{1.44_{fm}}\right)^2\right\}$$

Pauli forbidden state

$$\varphi_{0s}(R) = \left(\frac{A}{\pi}\right)^{3/4}\exp\left\{-\frac{1}{2}AR^2\right\},\quad A = \frac{3}{2\,R_{rms}} = 0.79\ _{fm^{-2}}$$

Λ* effective mass in H* strangelet

H* = Λ*Λ* = K^-K^-pp

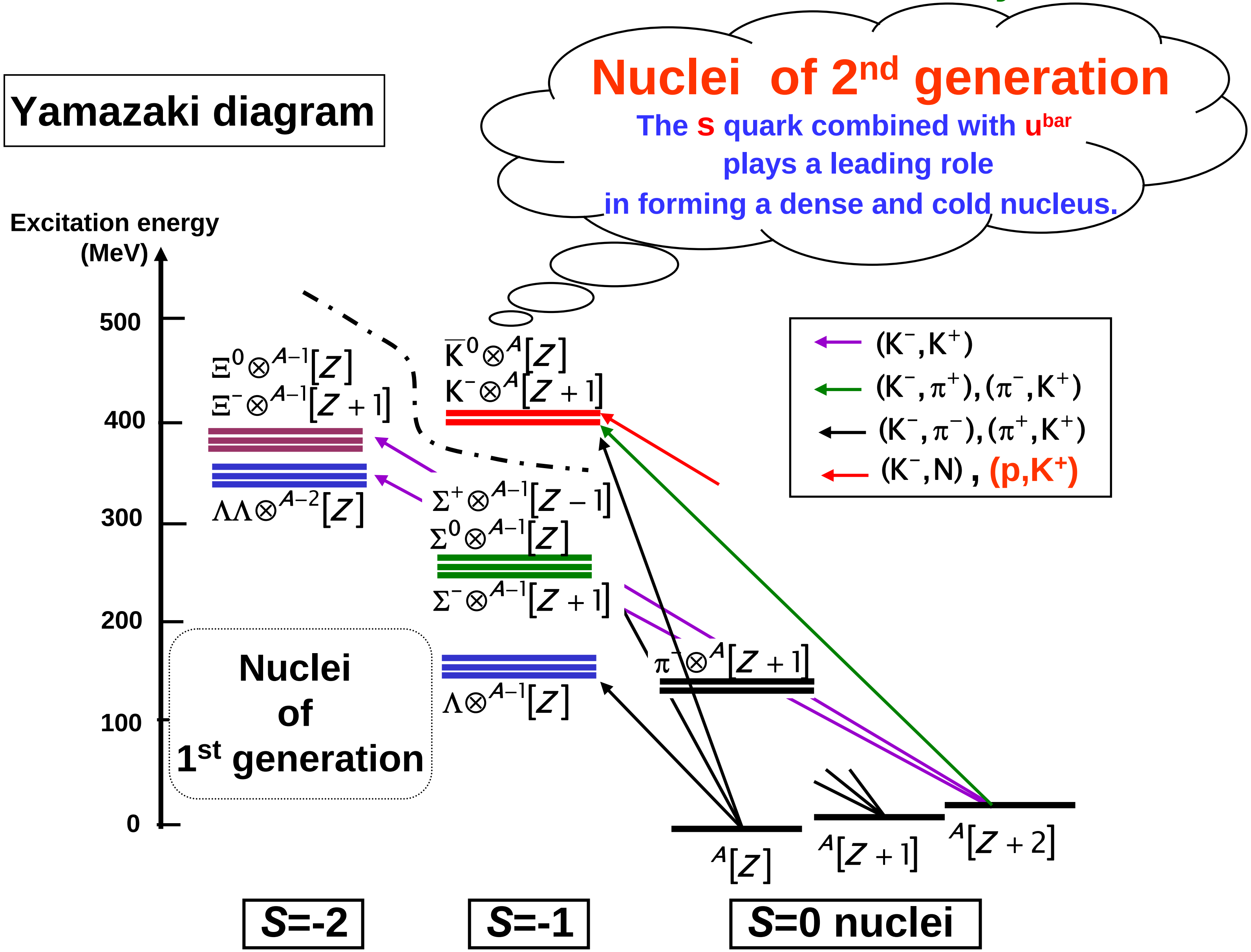


ATMS calculation

jade/HsHs.f jade/ATMS3Hs2.f jade/ATMS4Hs2.f

A new paradigm of nuclear physics

"Swan Nuclear Physics"

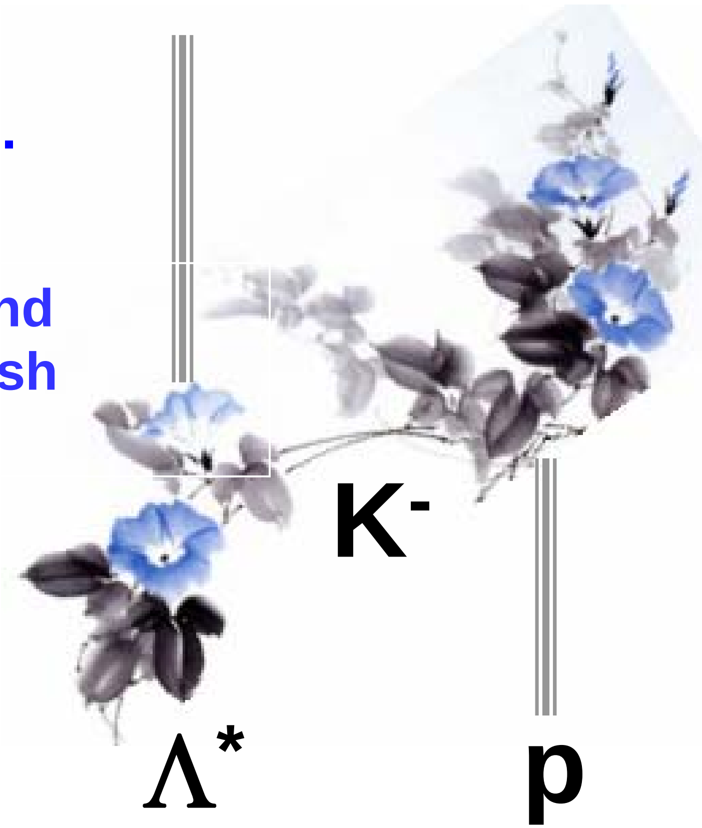


Remarks

The Λ*=Λ(1405) plays an essential role in forming "K^{bar} Nuclear Clusters" (KNC).

Experimental information on Λ*p=K^-pp and Λ*Λ*=K^-K^-pp is vitally important to establish the "super-strong nuclear force" (SSNF).

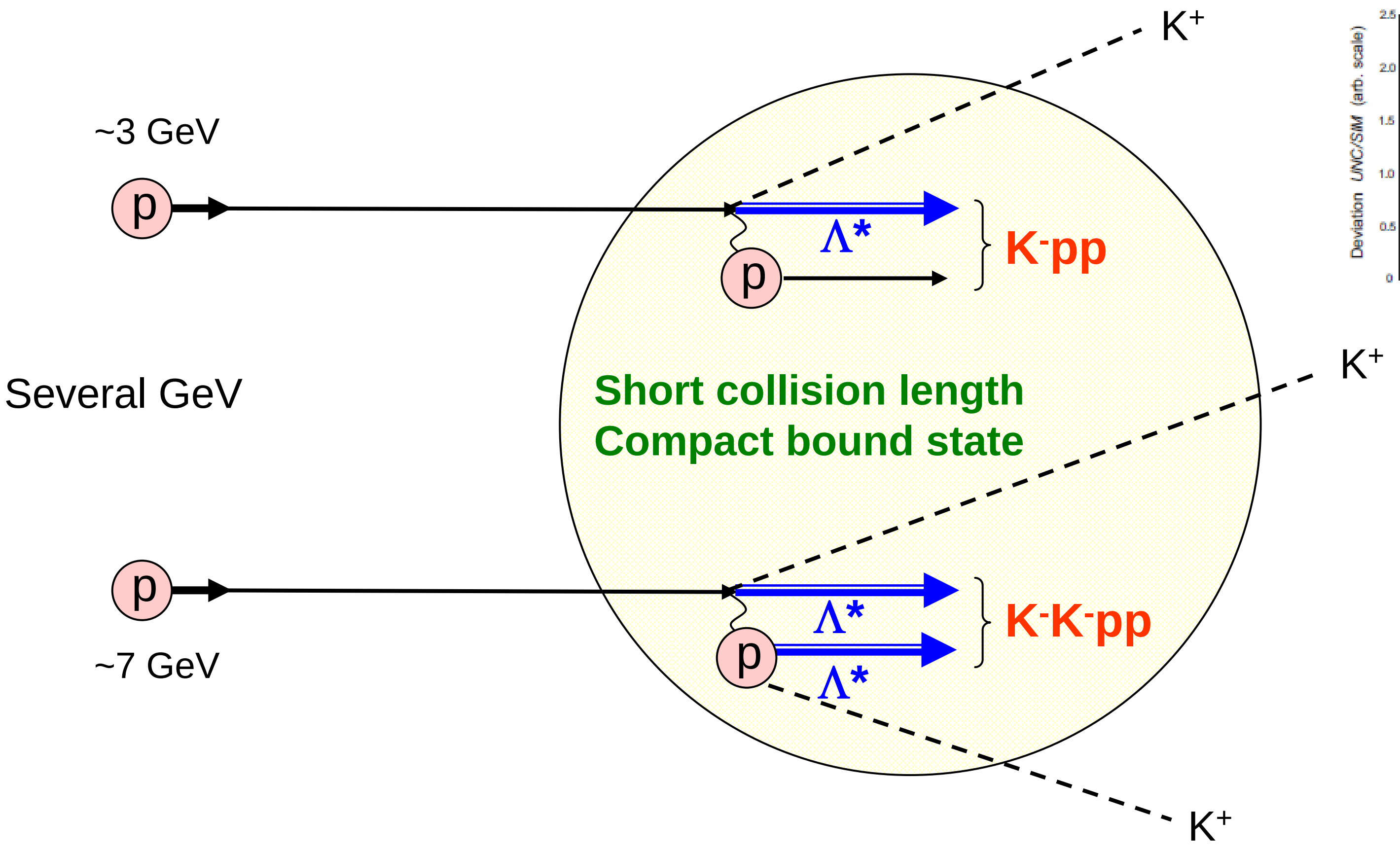
SSNF due to boson (K^{bar}) covalency predicts the possible existence of "finite Λ* strangelets", which could be stable against some strong decays.

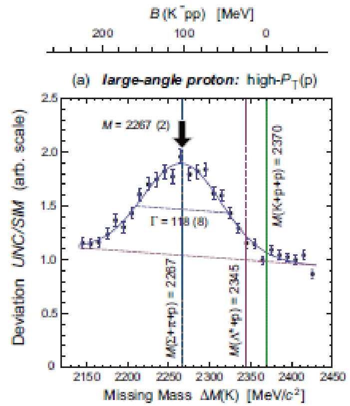


The late Prof. Nishijima

Gateway to "Swan Nuclear Physics"

T. Yamazaki, Y. Akaishi & M. Hassanvand, Proc. Jpn. Acad. B 87 (2011) 362





DISTO

Thank you very much!