Workshop on Hyperon Physics,

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夸克平均场对超核以及超子物质的研究

Jinniu Hu

School of physics, Nankai University

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Outline

1 Introduction

2 The quark mean field model

3 The strangeness with QMF model

4 The summary and perspective

Strangeness nuclear physics

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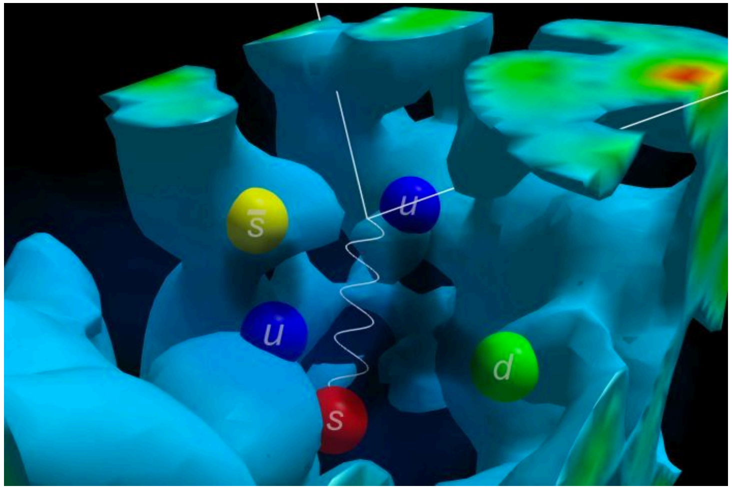
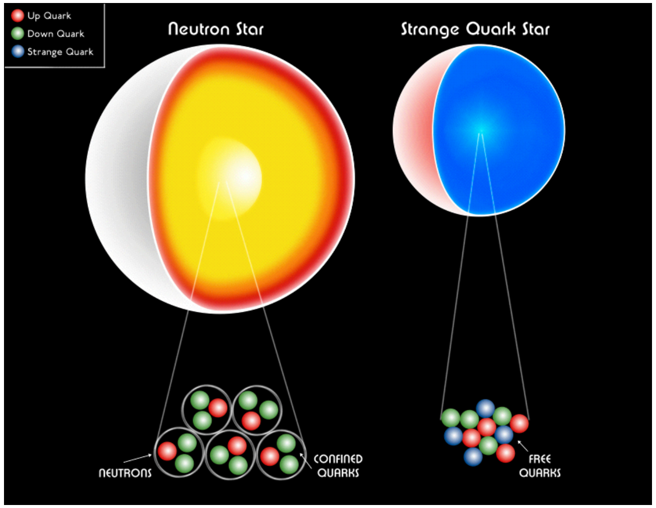
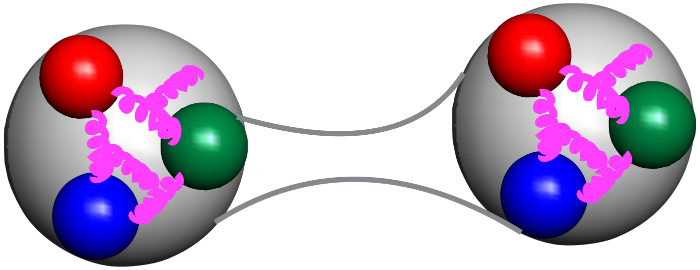
Hadrons



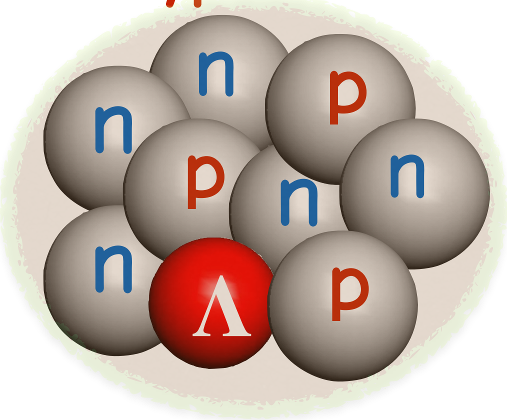
Compact star



Baryon-Baryon force



Hypernuclei



A. Gal, E. V. Hungerford, and D. J. Millener, Rev. Mod. Phys. 88(2016)035004

Baryon-Baryon scattering data

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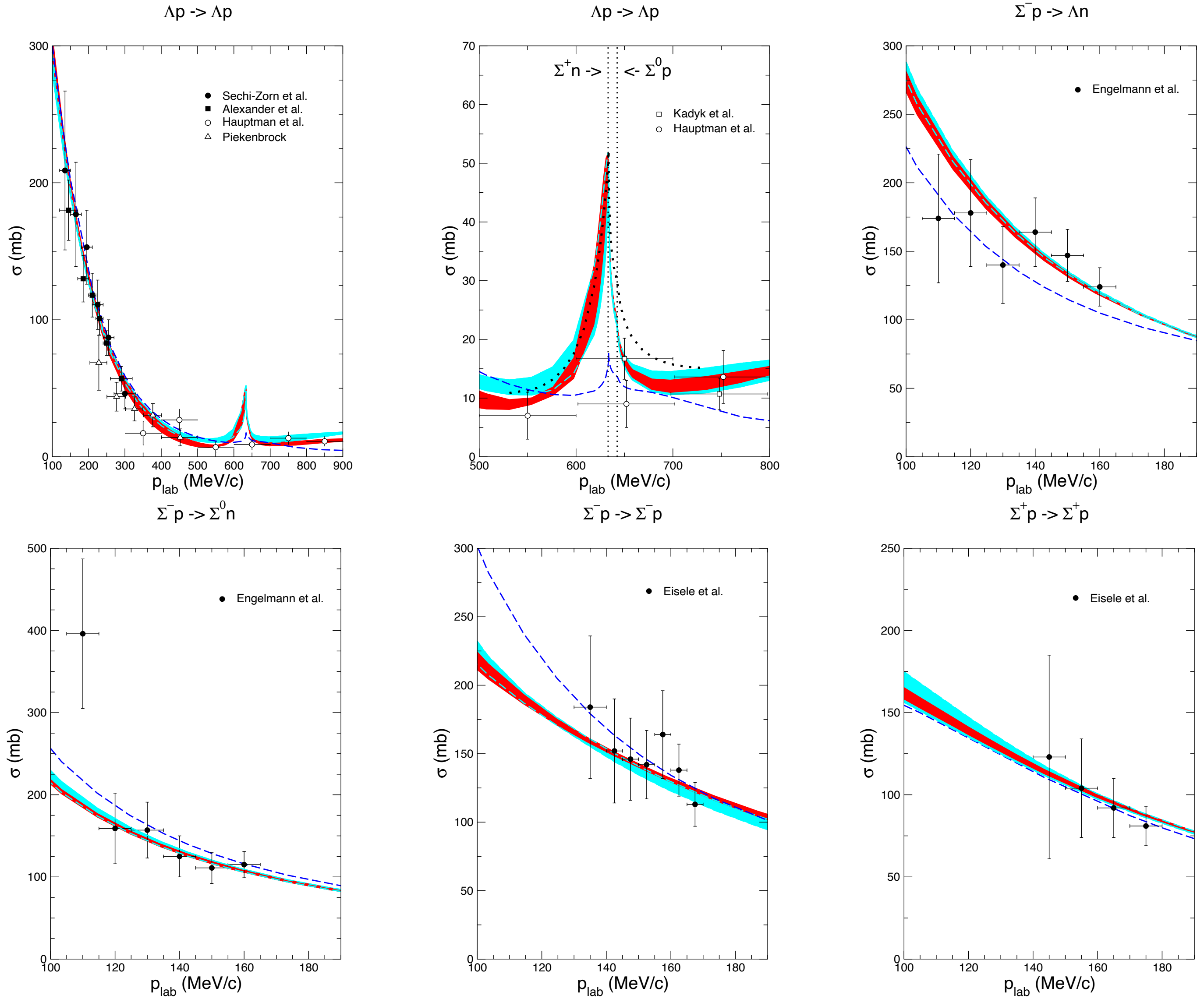

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Baryon-Baryon Interaction

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- Juelich Meson exchange exchange potential (Jul94,05)

  J. Haidenbauer, Ulf-G. Meissner, Phys.Rev. C72, 044005 (2005)

- Nijmegen potentials: OBE and ESC (ESC06, ESC12, ESC16)

  Th. A. Rijken and Y. Yamamoto, Phys. Rev. C 73, 044008 (2006)

- Quark-Cluster models

  Y. Fujiwara, Y. Suzuki, and C. Nakamoto, Prog. Part. Nucl Phys. 58, 439 (2007)

- Chiral effective potential (NLO13, NLO19)

  J. Haidenbauer, Ulf-G. Meissner, and A. Nogga, Eur. Phys J. A56, 91 (2020)

- Covariant Chiral effective potential

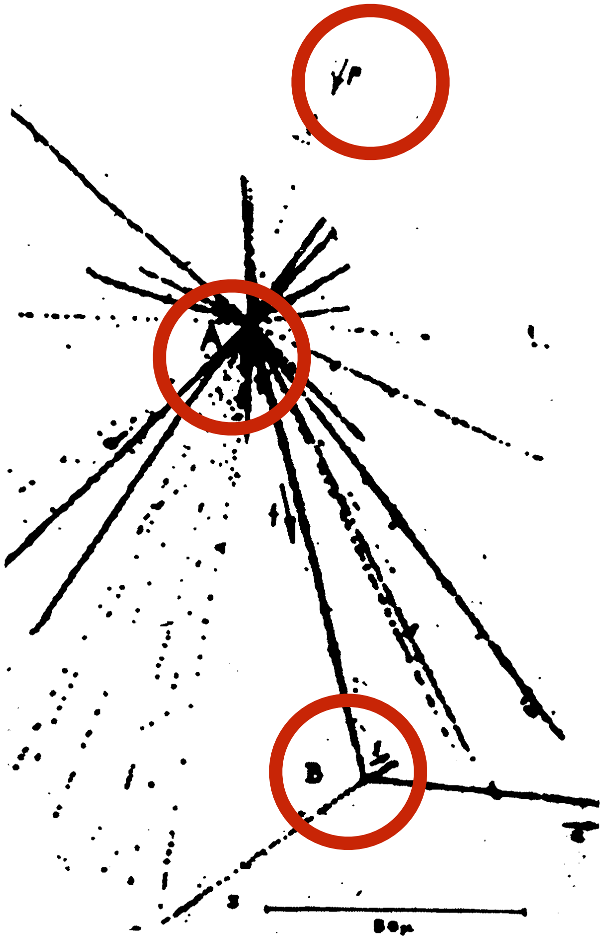
  J. Song, Z. Liu, K. Li, and L. Geng, Phys. Rev. C 105, 035203 (2022)

- Lattice QCD potential

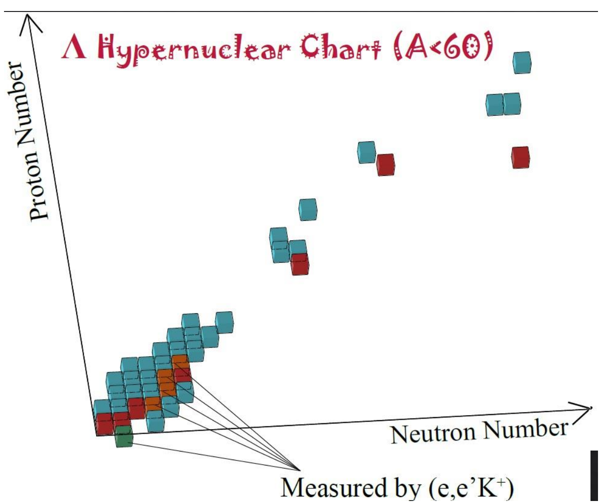
  H. Nemura, arXiv: 1810.04046

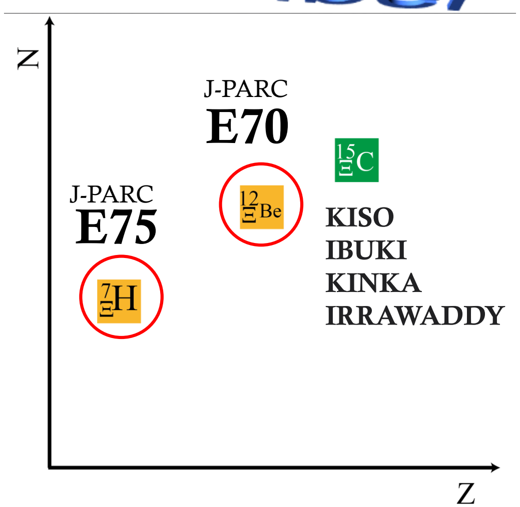
Discovery of first Λ-hypernuclei

Danysz and Pniewski discovered the first hypernucleus in Warsaw in September 1952. The hypernucleus was created when a high-energy proton interacted with a nucleus in the emulsions they were using as a detector, producing a hyperfragment.



Hypernuclei chart





Λ Hypernulcei

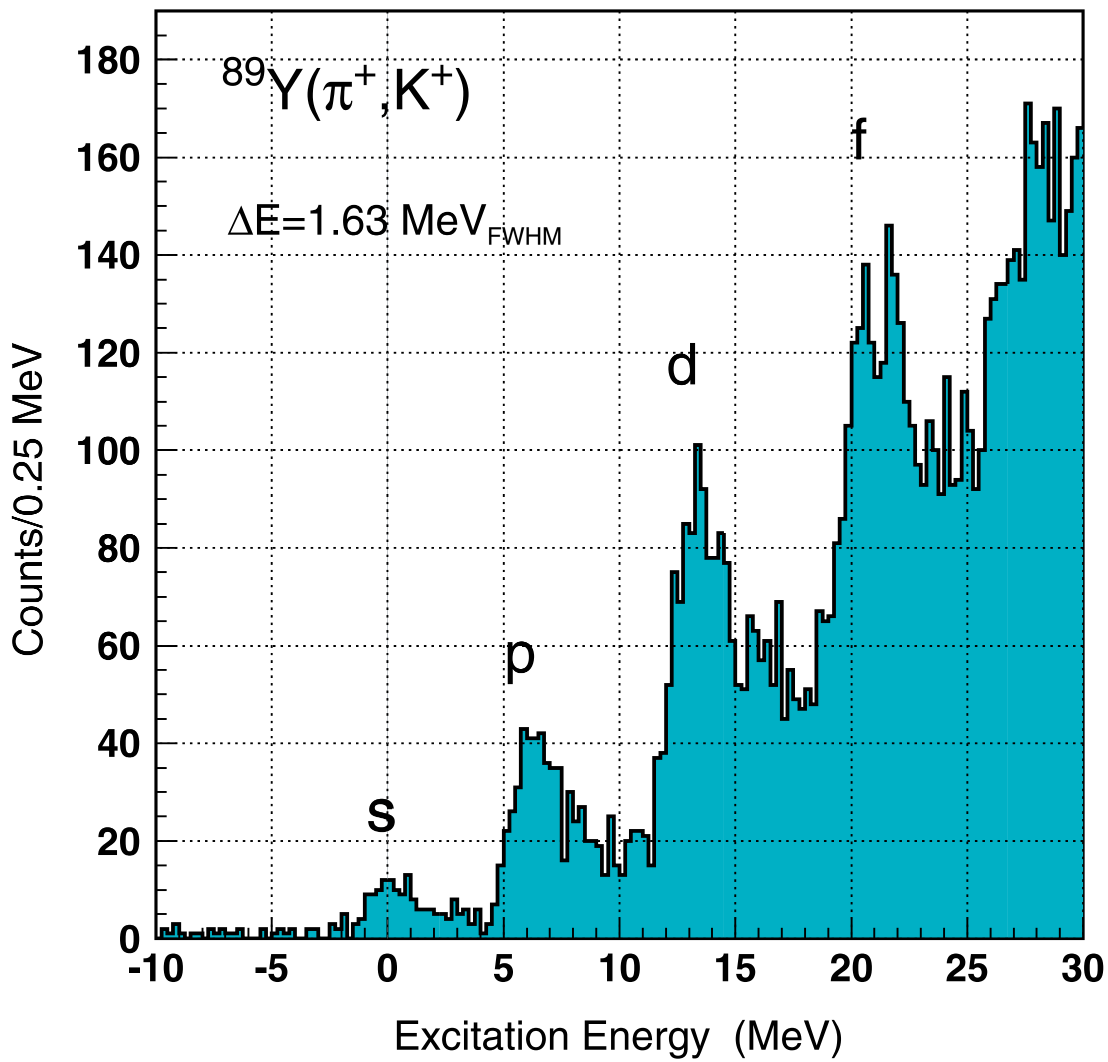
Hypernucleus	Number of events	$B_\Lambda \pm \Delta B_\Lambda$ (MeV)
$^{3}_{\Lambda}$H	204	0.13 ± 0.05
$^{4}_{\Lambda}$H	155	2.04 ± 0.04
$^{4}_{\Lambda}$He	279	2.39 ± 0.03
$^{5}_{\Lambda}$He	1784	3.12 ± 0.02
$^{6}_{\Lambda}$He	31	4.18 ± 0.10
$^{7}_{\Lambda}$He	16	Not averaged
$^{7}_{\Lambda}$Li	226	5.58 ± 0.03
$^{7}_{\Lambda}$Be	35	5.16 ± 0.08
$^{8}_{\Lambda}$He	6	7.16 ± 0.70
$^{8}_{\Lambda}$Li	787	6.80 ± 0.03
$^{8}_{\Lambda}$Be	68	6.84 ± 0.05
$^{9}_{\Lambda}$Li	8	8.50 ± 0.12
$^{9}_{\Lambda}$Be	222	6.71 ± 0.04
$^{9}_{\Lambda}$B	4	8.29 ± 0.18
$^{10}_{\Lambda}$Be	3	9.11 ± 0.22
$^{10}_{\Lambda}$B	10	8.89 ± 0.12
$^{11}_{\Lambda}$B	73	10.24 ± 0.05
$^{12}_{\Lambda}$B	87	11.37 ± 0.06
$^{12}_{\Lambda}$C	6	10.76 ± 0.19
$^{13}_{\Lambda}$C	6	11.69 ± 0.12
$^{14}_{\Lambda}$C	3	12.17 ± 0.33

Hypernucleus	s_Λ	p_Λ	d_Λ	f_Λ	g_Λ
			(π^+, K^+)		
$^{208}_{\Lambda}$Pb	26.9(8)	22.5(6)	17.4(7)	12.3(6)	7.2(6)
$^{139}_{\Lambda}$La	25.1(12)	21.0(6)	14.9(6)	8.6(6)	2.1(6)
$^{89}_{\Lambda}$Y	23.6(5)	17.7(6)	10.9(6)	3.7(6)	−3.8(10)
$^{51}_{\Lambda}$V	21.5(6)	13.4(6)	5.1(6)		
$^{28}_{\Lambda}$Si	17.2(2)	7.6(2)	−1.0(5)		
$^{16}_{\Lambda}$O	13.0(2)	2.5(2)			
$^{13}_{\Lambda}$C	12.0(2)	1.1(2)			
$^{12}_{\Lambda}$C	11.36(20)	0.36(20)			
$^{10}_{\Lambda}$B	8.7(3)				
			$(e, e'K^+)$		
$^{52}_{\Lambda}$V	21.8(3)				
$^{16}_{\Lambda}$N	13.76(16)	2.84(18)			
$^{12}_{\Lambda}$B	11.52(2)	0.54(4)			
$^{10}_{\Lambda}$Be	8.55(13)				
$^{7}_{\Lambda}$He	5.55(15)				
			Emulsion		
$^{13}_{\Lambda}$C	11.69(12)	0.8(3)			
$^{12}_{\Lambda}$B	11.37(6)				
$^{12}_{\Lambda}$C		0.14(5)			
$^{8}_{\Lambda}$Li	6.80(3)				
$^{7}_{\Lambda}$Be	5.16(8)				
			(K^-, π^-)		
$^{40}_{\Lambda}$Ca		11.0(5)	1.0(5)		
$^{32}_{\Lambda}$S	17.5(5)	8.2(5)	−1.0(5)		

A. Gal, E. V. Hungerford, and D. J. Millener, Rev. Mod. Phys. 88(2016)035004

Single Λ potential

A. Gal, E. V. Hungerford, and D. J. Millener, Rev. Mod. Phys. 88(2016)035004



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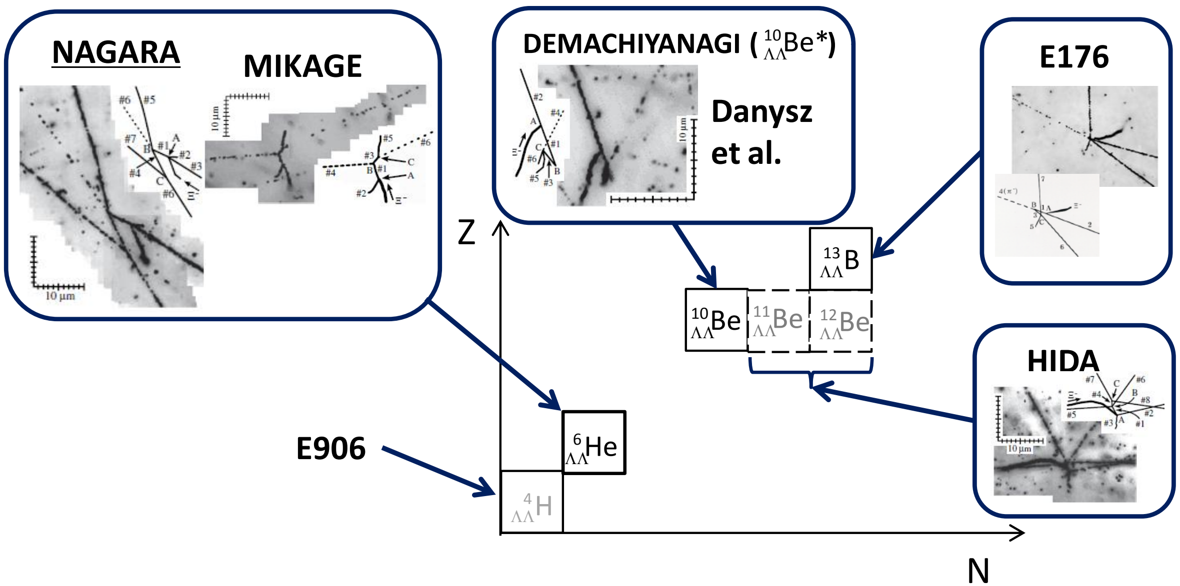
ΛΛ-Hypernuclear Chart

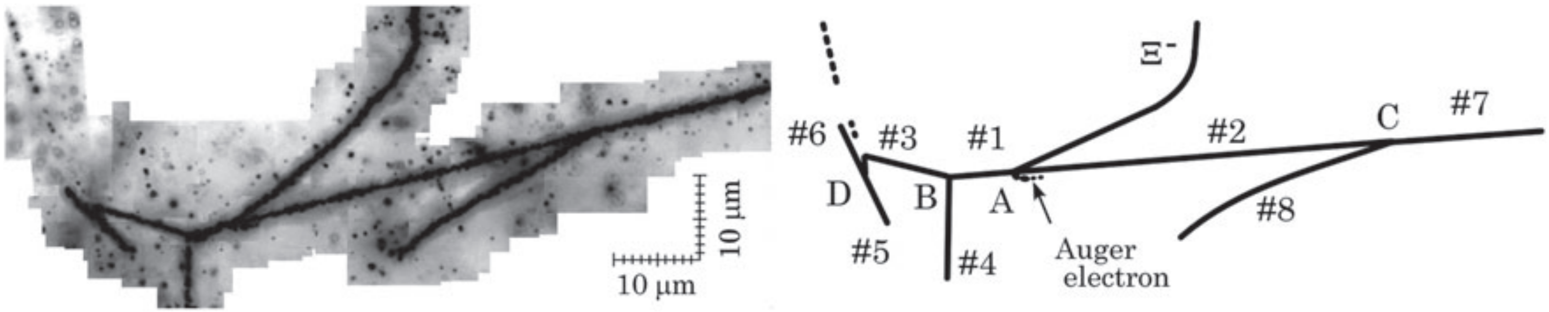


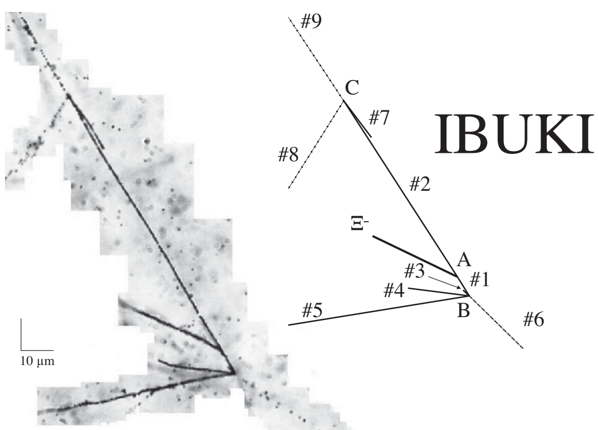
Event	$^{A}_{\Lambda\Lambda}Z$	$\bar{B}_{\Lambda}(^{A-1}_{\Lambda}Z)$	$B^{\rm exp}_{\Lambda\Lambda}$	$B^{\rm CM}_{\Lambda\Lambda}$	$B^{\rm SM}_{\Lambda\Lambda}$
E373-Nagara	$^{6}_{\Lambda\Lambda}$He	3.12 ± 0.02	6.91 ± 0.16	6.91 ± 0.16	6.91 ± 0.16
E373-DemYan	$^{10}_{\Lambda\Lambda}$Be	6.71 ± 0.04	14.94 ± 0.13	14.74 ± 0.16	14.97 ± 0.22[a]
E176-G2	$^{11}_{\Lambda\Lambda}$Be	8.86 ± 0.11	17.53 ± 0.71	18.23 ± 0.16	18.40 ± 0.28
E373-Hida	$^{11}_{\Lambda\Lambda}$Be	8.86 ± 0.11	20.83 ± 1.27	18.23 ± 0.16	18.40 ± 0.28
E373-Hida	$^{12}_{\Lambda\Lambda}$Be	10.02 ± 0.05	22.48 ± 1.21	⋯	20.72 ± 0.20
E176-E2	$^{12}_{\Lambda\Lambda}$B	10.09 ± 0.05	20.02 ± 0.78	⋯	20.85 ± 0.20
E176-E4	$^{13}_{\Lambda\Lambda}$B	11.27 ± 0.06	23.4 ± 0.7	⋯	23.21 ± 0.21

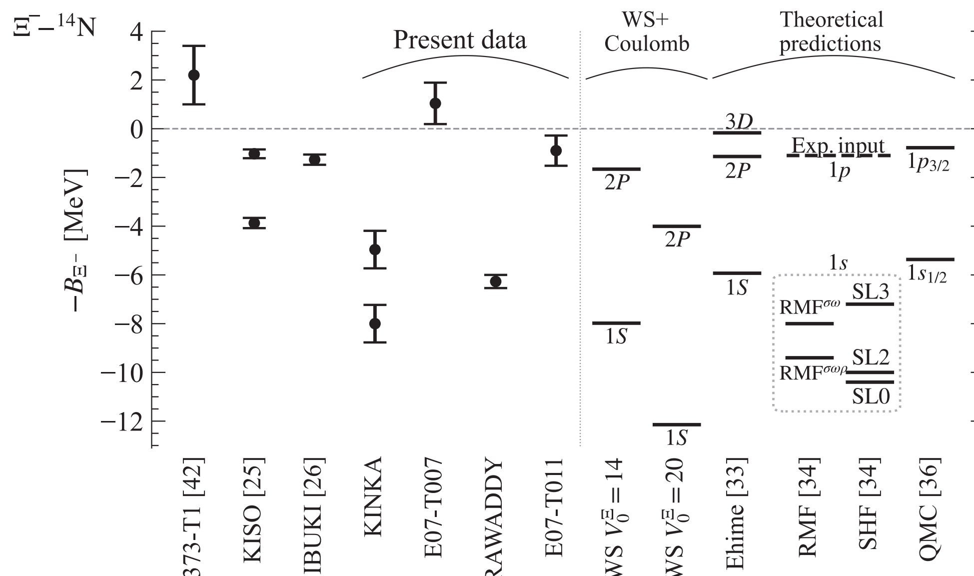
A. Gal, E. V. Hungerford, and D. J. Millener, Rev. Mod. Phys. 88(2016)035004

Ξ^- Hypernulcei

KISO







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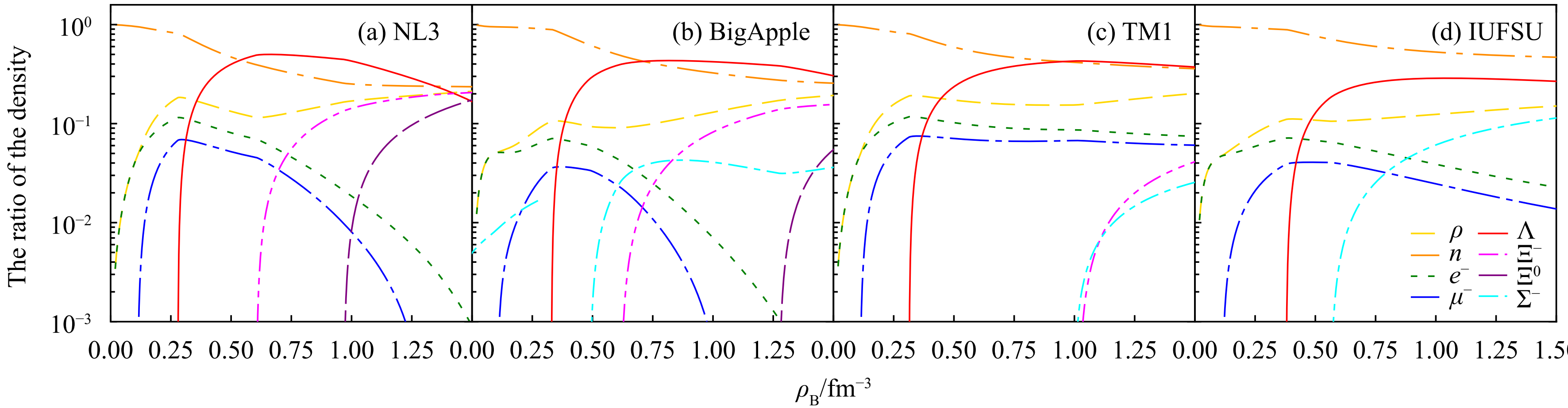
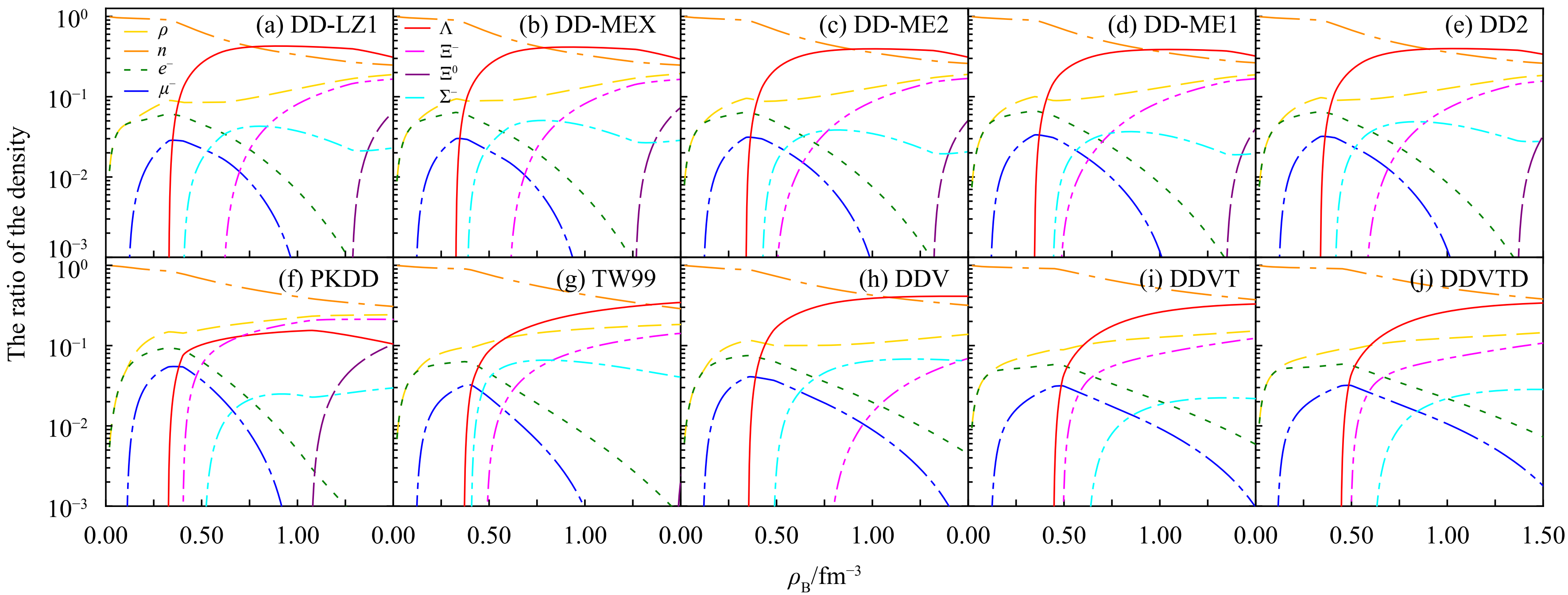
Hyperon in neutron star





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Hyperon in neutron star

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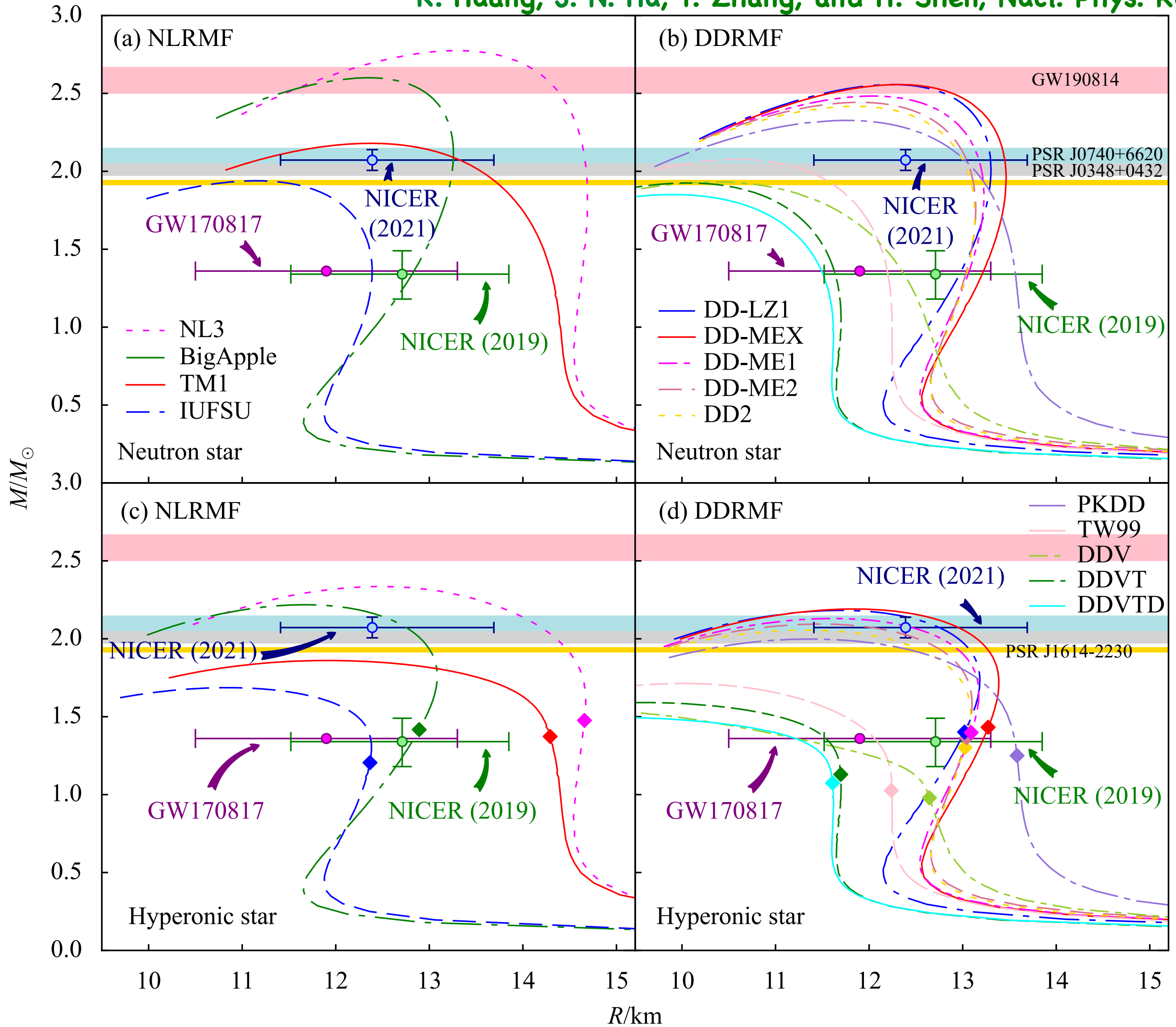

Hyperon-nucleon femtoscopy

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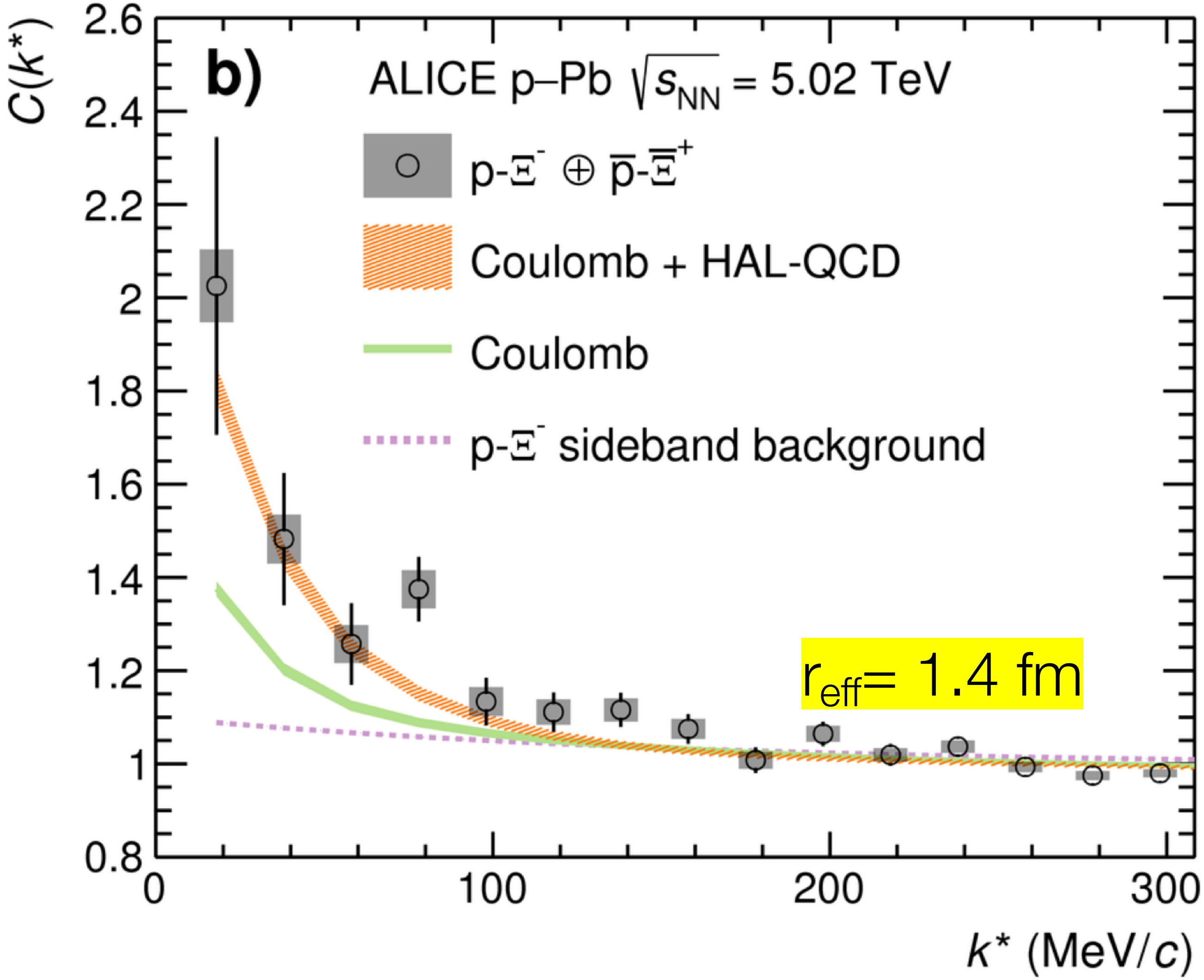

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Y. Zhang, H. Sagawa, and E. Hiyama Phys. Rev. C 103(2021)034321

√ Covariant density functional theory

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R. L. Xu, C. Wu, and Z. Z. Ren, J. Phys. G 39(2012)085107
T. T. Sun, et al., Phys. Rev. C 94(2016)064319
S. Y. Ding, Z. Qian, B. Y. Sun, and W. H. Long, Phys. Rev.C 106(2022)054311
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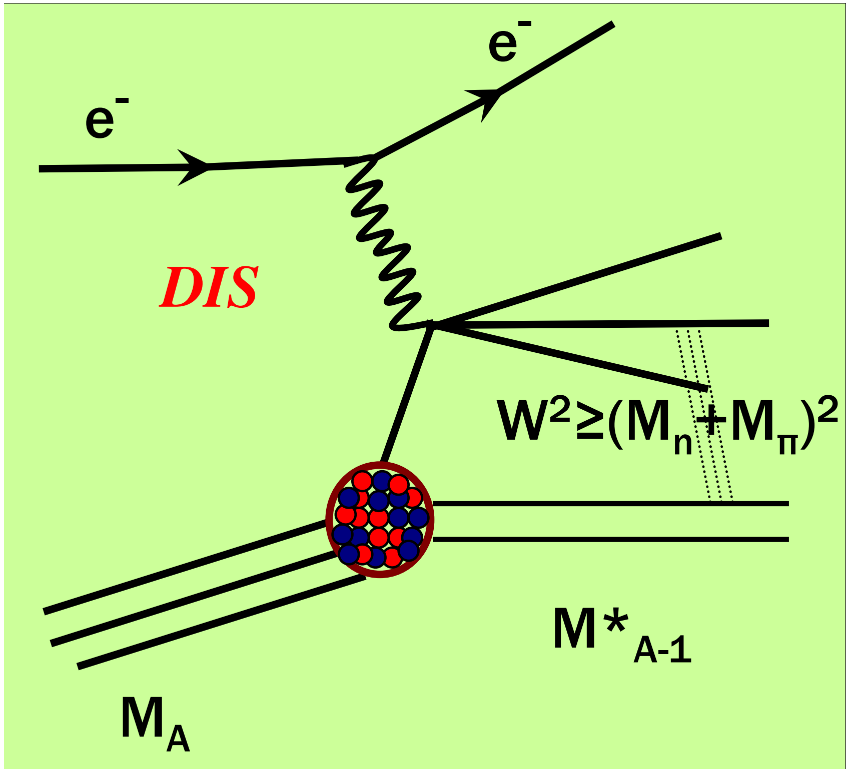
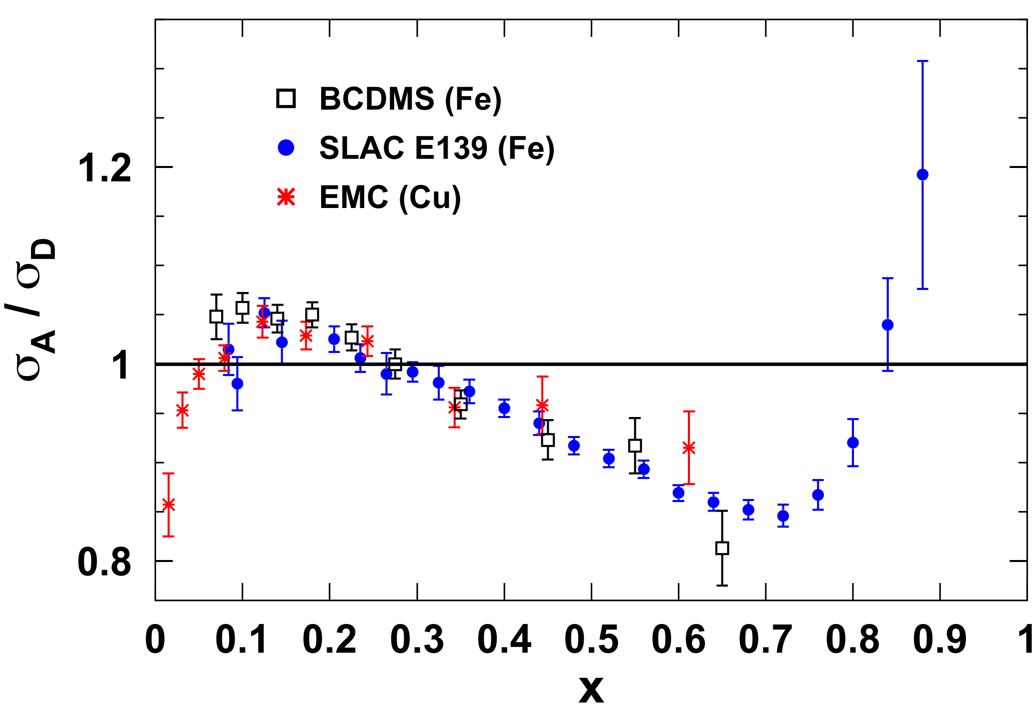
Europe muon collaboration effect 南開大學

I. C. Cloet, et al. J. Phys. G 46(2018)093001





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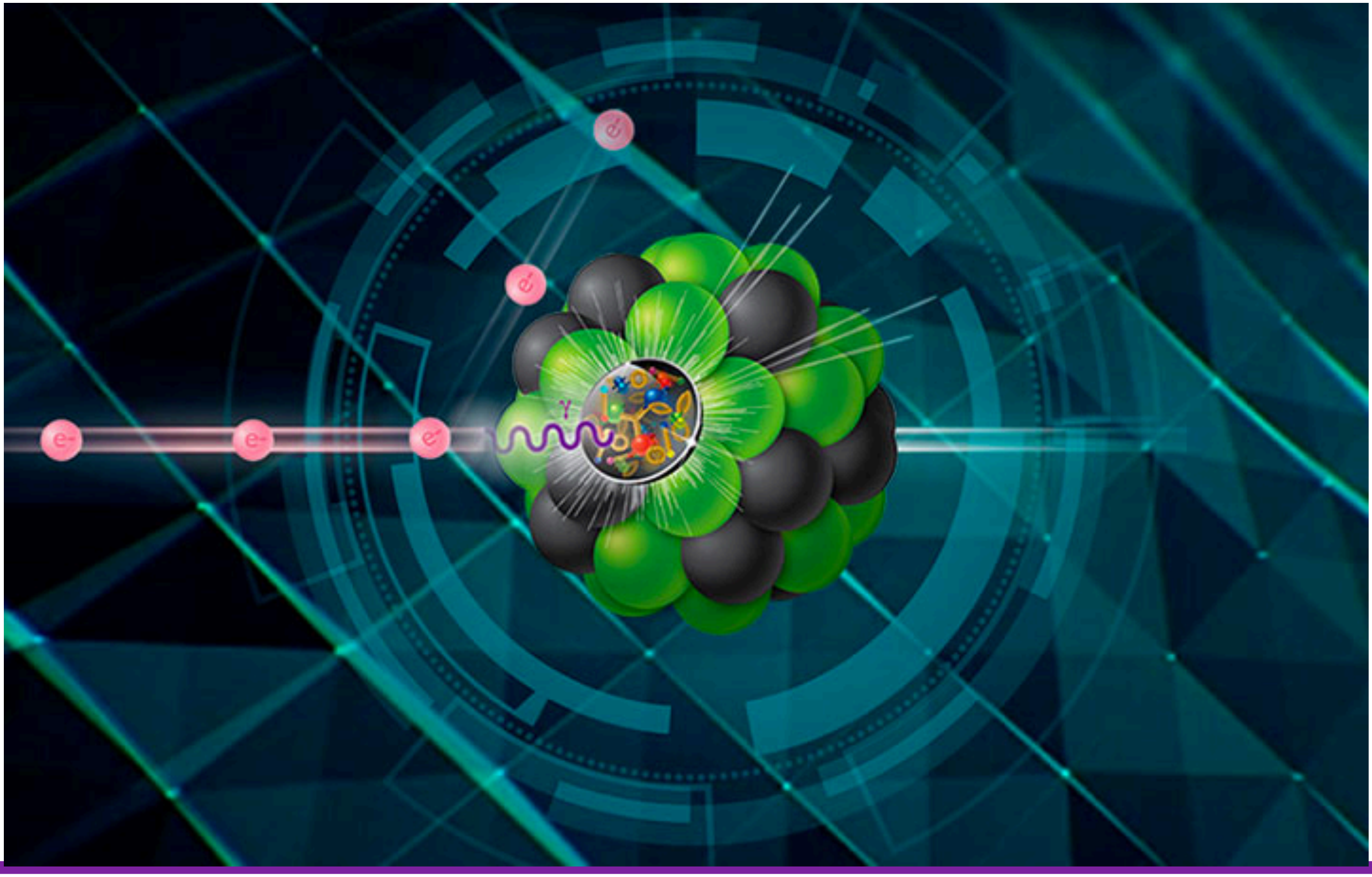
U.S. Department of Energy Selects Brookhaven National Laboratory to Host Major New Nuclear Physics Facility



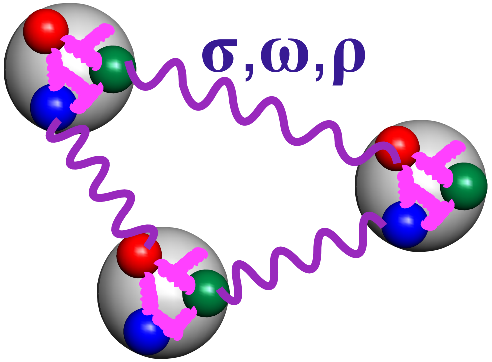
Relativistic many-body theories from quark level

- ✓ baryons are not point particles!
- ✓ baryon properties change in medium!
- ✓ quark-gluon plasma!

....

Hadron model ⟷ **many-body method**

Self-consistently



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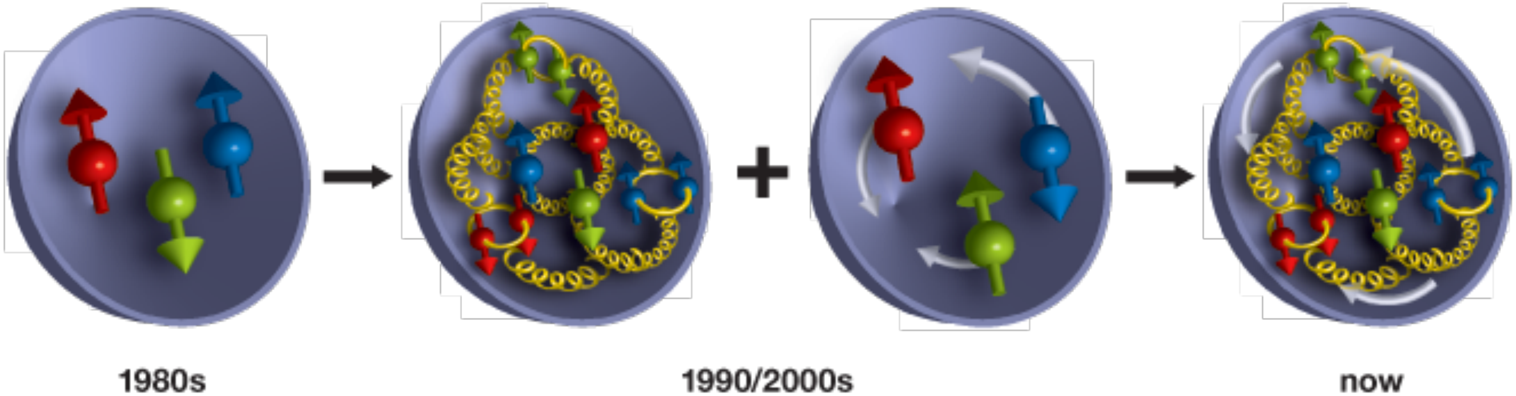

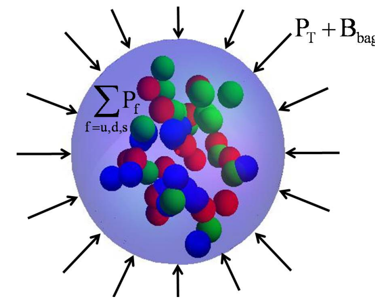

- ✓ Quark meson coupling (QMC) model
  K. Tsushima, et al. Nucl. Phys. A 630(1998)691
- ✓ Friedberg-Lee model
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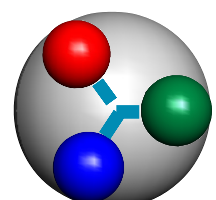
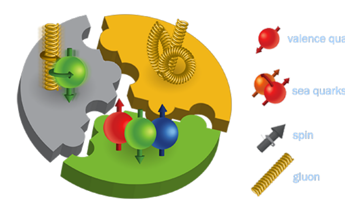
  ……





- ✓ Quark mean field (QMF) model
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Outline

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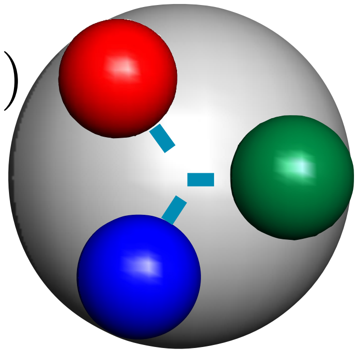
X. Xing, J.H., and H. Shen, Phys. Rev. C 94 (2016) 044308

- **Constituent quark in Dirac equation**

$$[-i\alpha\cdot\nabla+\beta m_i^*+\beta U(r)]q_i(r)=\varepsilon_i^* q_i(r)$$



where, the effective quark mass is

$$m_i^*=m_i+g_\sigma^i\sigma$$

and effective single particle energy is

$$\varepsilon_i^*=\varepsilon_i-g_\omega^i-g_\rho^i\rho\tau_3$$

- **Confinement potential**

$$U(r)=\frac{1}{2}(1+\gamma^0)(ar^2+V_0)$$

- **Center-of-mass corrections**

$$\langle B|\sum_{i=1}^{3}\gamma^0(i)\{\frac{1}{3}\gamma(i)\cdot\sum_{j=1}^{3}\vec{p}_j+\frac{1}{2}(1+\gamma^0(i))[U(r_i)-U(\rho_i)]\}|B\rangle$$

- **Pionic self-energy correction**

$$\delta M_B^\pi = -\sum_k \sum_{B'} \frac{V_j^{\dagger BB'} V_j^{BB'}}{w_k}$$

- **Gluon correction**

Color-electric $$(\Delta E_B)_g^E = \frac{1}{8\pi} \sum_{i,j} \sum_{a=1}^{8} \int \frac{d^3 r_i d^3 r_j}{|\vec{r}_i - \vec{r}_j|} \langle B | J_i^{0a}(\vec{r}_i) J_j^{0a}(\vec{r}_j) | B \rangle$$

Color-magnetic $$(\Delta E_B)_g^M = -\frac{1}{8\pi} \sum_{i,j} \sum_{a=1}^{8} \int \frac{d^3 r_i d^3 r_j}{|\vec{r}_i - \vec{r}_j|} \langle B | \vec{J}_i^a(\vec{r}_i) \cdot \vec{J}_j^a(\vec{r}_j) | B \rangle$$

Quark color current density $$J_i^{\mu a}(x) = g_c \bar{\psi}_q(x) \gamma^\mu \lambda_i^a \psi_q(x)$$

- **Baryon mass**

$$M_B^* = E_B^{*0} - \epsilon_{\text{c.m.}} + \delta M_B^\pi + (\Delta E_B)_g^E + (\Delta E_B)_g^M$$

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- **Strangeness QMF Lagrangian**

$$
\begin{aligned}
\mathcal{L}_{\mathrm{QMF}} &= \bar{\psi}\left[i\gamma_\mu\partial^\mu - M_N^* - g_\omega\omega\gamma^0 - g_\rho\rho\tau_3\gamma^0 - e\frac{(1-\tau_3)}{2}A\gamma^0\right]\psi \\
&+\bar{\psi}_H\left[i\gamma_\mu\partial^\mu - M_H^* - g_\omega^H\omega\gamma^0 + \frac{f_\omega^H}{2M_H}\sigma^{0i}\partial_i\omega\right]\psi_H \\
&-\frac{1}{2}(\bigtriangledown\sigma)^2 - \frac{1}{2}m_\sigma^2\sigma^2 - \frac{1}{3}g_2\sigma^3 - \frac{1}{4}g_3\sigma^4 \\
&+\frac{1}{2}(\bigtriangledown\omega)^2 + \frac{1}{2}m_\omega^2\omega^2 + \frac{1}{4}c_3\omega^4 \\
&+\frac{1}{2}(\bigtriangledown\rho)^2 + \frac{1}{2}m_\rho^2\rho^2 + \frac{1}{2}(\bigtriangledown A)^2,
\end{aligned}
$$

- **Dirac equations for baryons**

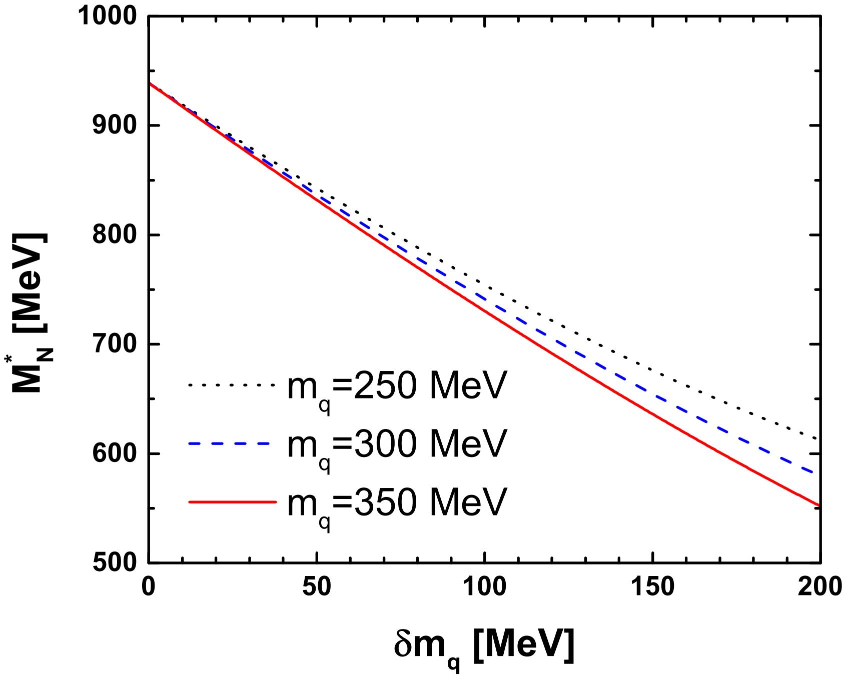
$$
\left[i\gamma_\mu\partial^\mu - M_N^* - g_\omega\omega\gamma^0 - g_\rho\rho\tau_3\gamma^0 - e\frac{(1-\tau_3)}{2}A\gamma^0\right]\psi = 0,
$$

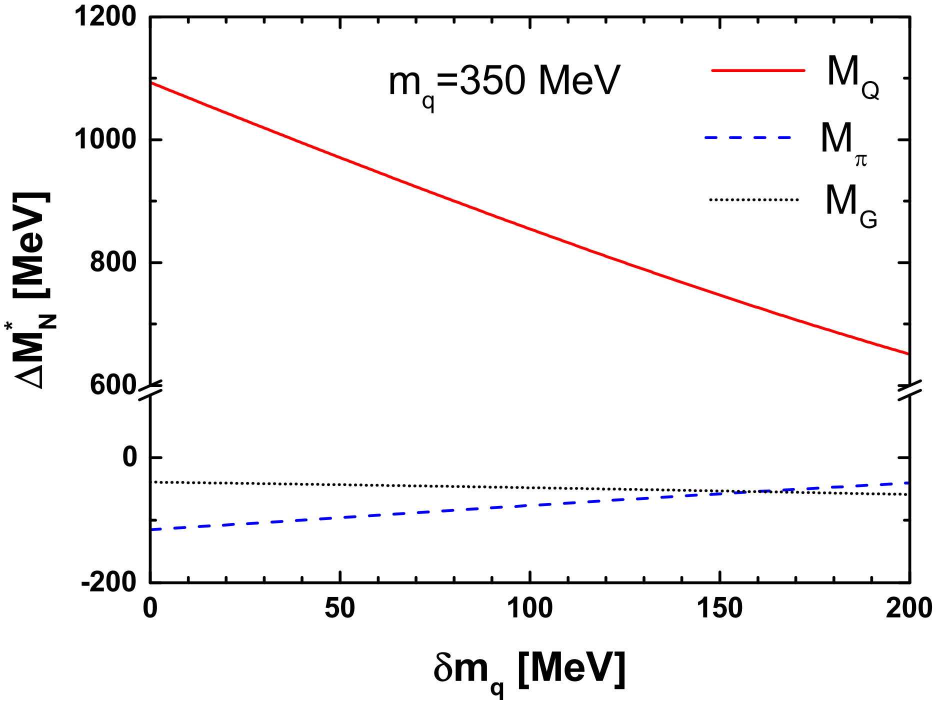
$$
\left[i\gamma_\mu\partial^\mu - M_H^* - g_\omega^H\omega\gamma^0 + \frac{f_\omega^H}{2M_H}\sigma^{0i}\partial_i\omega\right]\psi_H = 0.
$$

- **Equations of motion for mesons**

$$
\begin{aligned}
&\Delta\sigma - m_\sigma^2\sigma - g_2\sigma^2 - g_3\sigma^3 = \frac{\partial M_N^*}{\partial\sigma}\langle\bar{\psi}\psi\rangle + \frac{\partial M_H^*}{\partial\sigma}\langle\bar{\psi}_H\psi_H\rangle, \\
&\Delta\omega - m_\omega^2\omega - c_3\omega^3 = -g_\omega\langle\bar{\psi}\gamma^0\psi\rangle - g_\omega^H\langle\bar{\psi}_H\gamma^0\psi_H\rangle + \frac{f_\omega^H}{2M_H}\partial_i\langle\bar{\psi}_H\sigma^{0i}\psi_H\rangle, \\
&\Delta\rho - m_\rho^2\rho = -g_\rho\langle\bar{\psi}\tau_3\gamma^0\psi\rangle, \\
&\Delta A = -e\langle\bar{\psi}\frac{(1-\tau_3)}{2}\gamma^0\psi\rangle.
\end{aligned}
$$

The effective nucleon mass





m_q (MeV)	g_σ^q	g_ω	g_ρ	g_2 (fm^{-1})	g_3	c_3	a (fm^{-3})	V_0 (MeV)
250	5.15871	11.54726	3.79601	−3.52737	−78.52006	305.00240	0.57945	−24.28660
300	5.09346	12.30084	4.04190	−3.42813	−57.68387	249.05654	0.53430	−62.25719
350	5.01631	12.83898	4.10772	−3.29969	−39.87981	221.68240	0.49560	−102.04158

$$U(r) = \frac{1}{2}(1+\gamma^0)(ar^2 + V_0)$$

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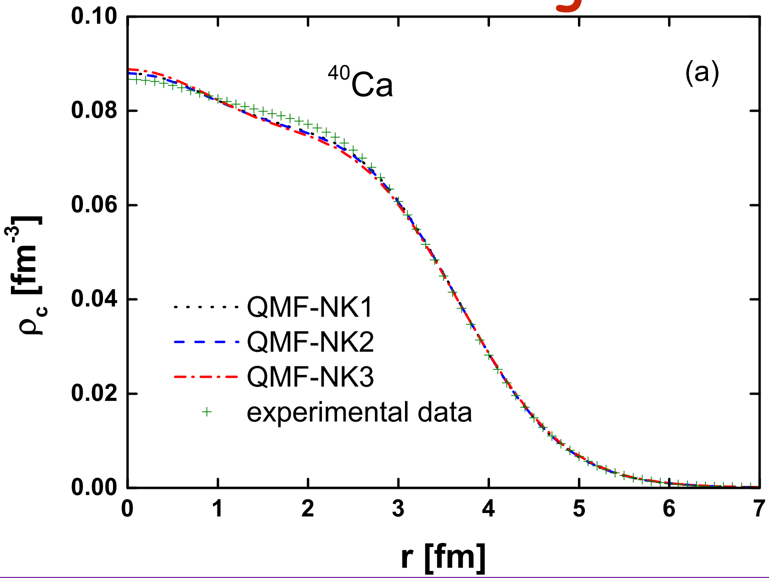
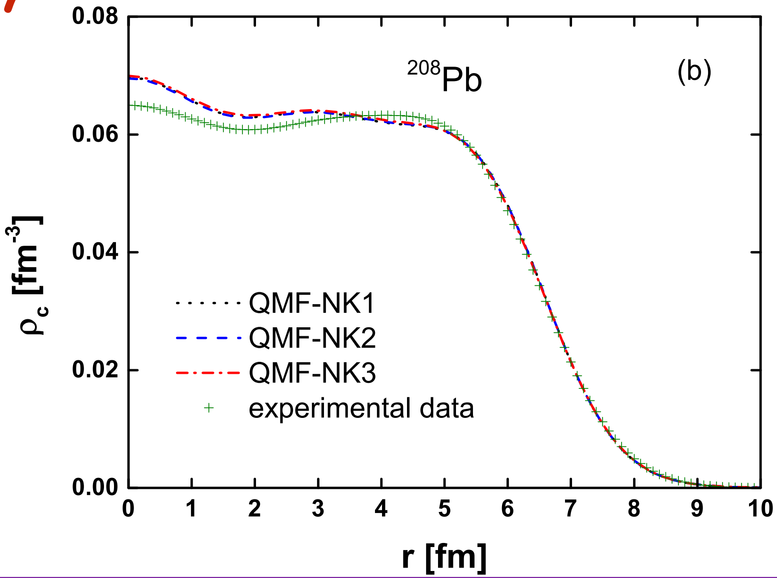
Binding energy and charge radii

Model	E/A (MeV)				R_c(fm)			
	^{40}Ca	^{48}Ca	^{90}Zr	^{208}Pb	^{40}Ca	^{48}Ca	^{90}Zr	^{208}Pb
QMF-NK1	8.62	8.61	8.65	7.92	3.43	3.47	4.26	5.49
QMF-NK2	8.61	8.61	8.67	7.91	3.44	3.47	4.26	5.50
QMF-NK3	8.59	8.63	8.68	7.90	3.44	3.46	4.26	5.50
QMF[18]	8.35	8.43	8.54	7.73	3.44	3.46	4.27	5.53
Expt.	8.55	8.67	8.71	7.87	3.45	3.45	4.26	5.50

Without pion and gluon corrections

Charge density distribution

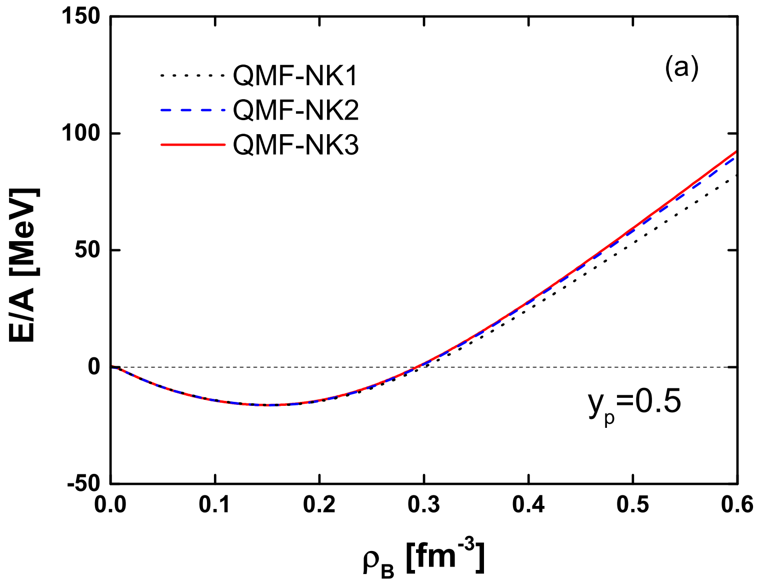




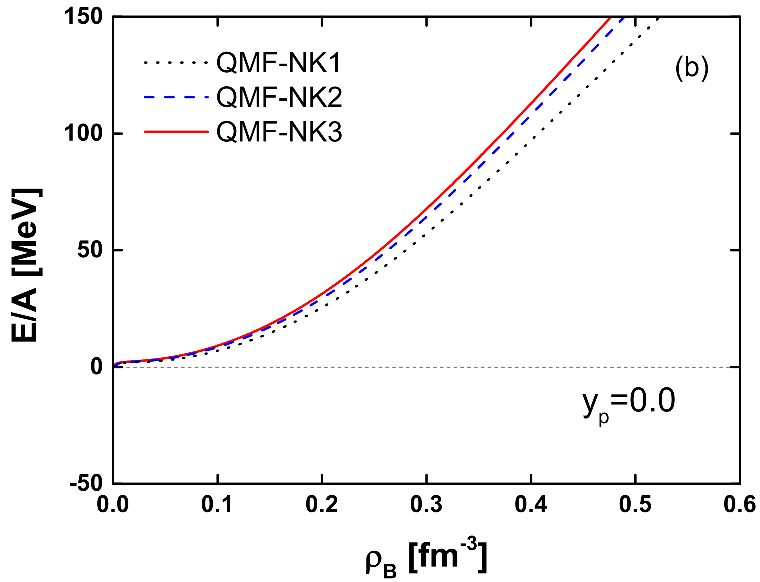
Nuclear saturation properties

Model	ρ_0 (fm^{-3})	E/A (MeV)	K_0 (MeV)	J (MeV)	M_N^*/M_N	L^0 (MeV)	K_{sym}^0 (MeV)	K_{asy} (MeV)	Q_0 (MeV)	K_τ (MeV)
QMF-NK1	0.154	-16.3	323	30.6	0.70	84.8	-28.8	-537.6	495.4	-667.7
QMF-NK2	0.152	-16.3	328	32.9	0.66	93.7	-23.5	-585.7	221.0	-648.8
QMF-NK3	0.150	-16.3	322	33.6	0.64	97.3	-12.0	-595.8	263.0	-675.3

symmetric nuclear matter



pure neutron matter



Outline

1 Introduction

2 The quark mean field model

3 The strangeness with QMF model

4 The summary and perspective

SQMF parameters

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The strength of quark confinement potential

	m_u (MeV)	V_u (MeV)	a_u (fm^{-3})	m_s (MeV)	V_s (MeV)	a_s (fm^{-3})
set A	250	−24.286601	0.579450	330	101.78180	0.097317
set B	300	−62.257187	0.534296	380	54.548210	0.087243
set C	350	−102.041575	0.495596	430	6.802695	0.079534

The coupling constants between meson and baryons

Model	m_u (MeV)	g_σ^u	g_ω	g_ω^Λ	g_ω^Ξ	g_ρ	g_2 (fm^{-1})	g_3	c_3
QMF-NK1S	250	5.15871	11.54726	$0.8258g_\omega$	$0.4965g_\omega$	3.79601	−3.52737	−78.52006	305.00240
QMF-NK2S	300	5.09346	12.30084	$0.8134g_\omega$	$0.4800g_\omega$	4.04190	−3.42813	−57.68387	249.05654
QMF-NK3S	350	5.01631	12.83898	$0.8040g_\omega$	$0.4681g_\omega$	4.10772	−3.29969	−39.87981	221.68240

$$U_\Lambda^{(N)} = -30 \ \ \mathrm{MeV}$$

$$U_\Xi^{(N)} = -12 \ \ \mathrm{MeV}$$

The effective masses of baryons

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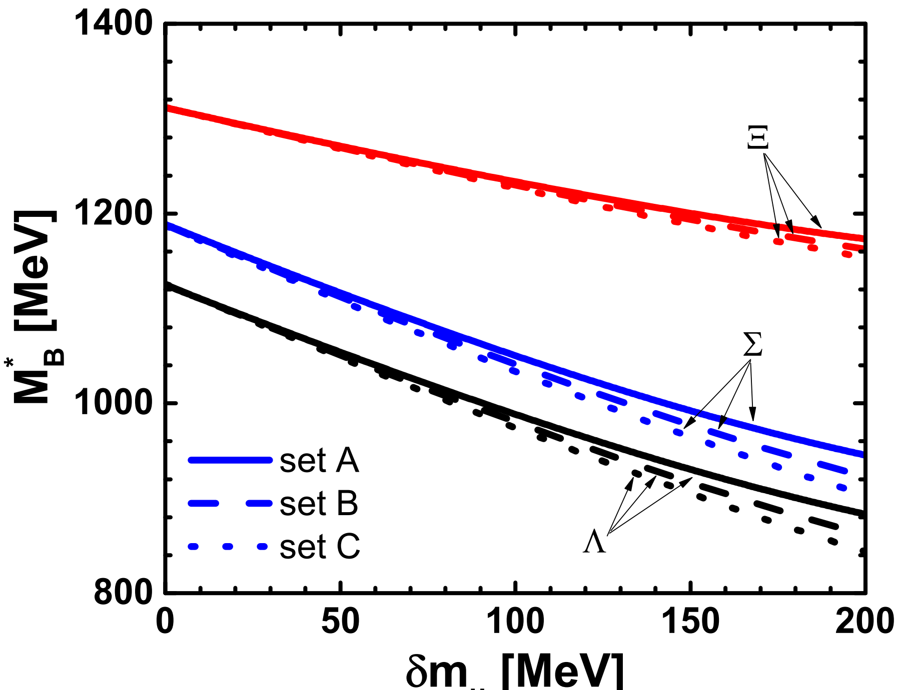
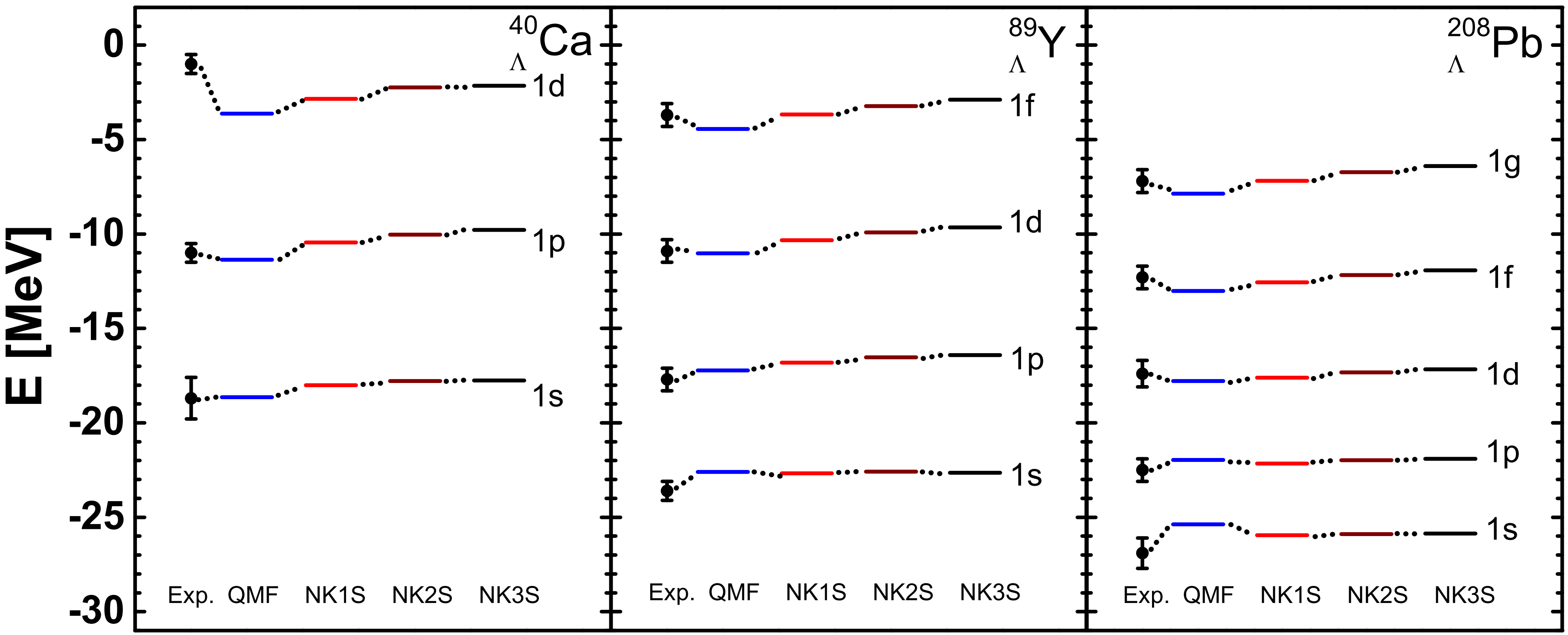
	Baryon	E_B^0	$\epsilon_{\text{c.m.}}$	δM_B^π	$(\Delta E_B)_g$	$M_B^{\text{Theor.}}$	$M_B^{\text{Expt.}}$
	Λ	1446.340	231.975	−65.172	−24.390	1124.803	1115.683 ± 0.006
set A	Σ^0	1446.340	231.975	−36.207	10.515	1188.673	1192.642 ± 0.024
	Ξ^0	1504.254	175.047	−16.293	−1.289	1311.625	1314.86 ± 0.20
	Λ	1433.489	220.692	−69.277	−18.313	1125.207	1115.683 ± 0.006
set B	Σ^0	1433.489	220.692	−38.487	13.753	1188.063	1192.642 ± 0.024
	Ξ^0	1491.611	165.564	−17.319	2.979	1311.707	1314.86 ± 0.20
	Λ	1421.908	210.233	−72.829	−13.170	1125.676	1115.683 ± 0.006
set C	Σ^0	1421.908	210.233	−40.461	16.203	1187.417	1192.642 ± 0.024
	Ξ^0	1480.703	157.102	−18.207	6.377	1311.771	1314.86 ± 0.20



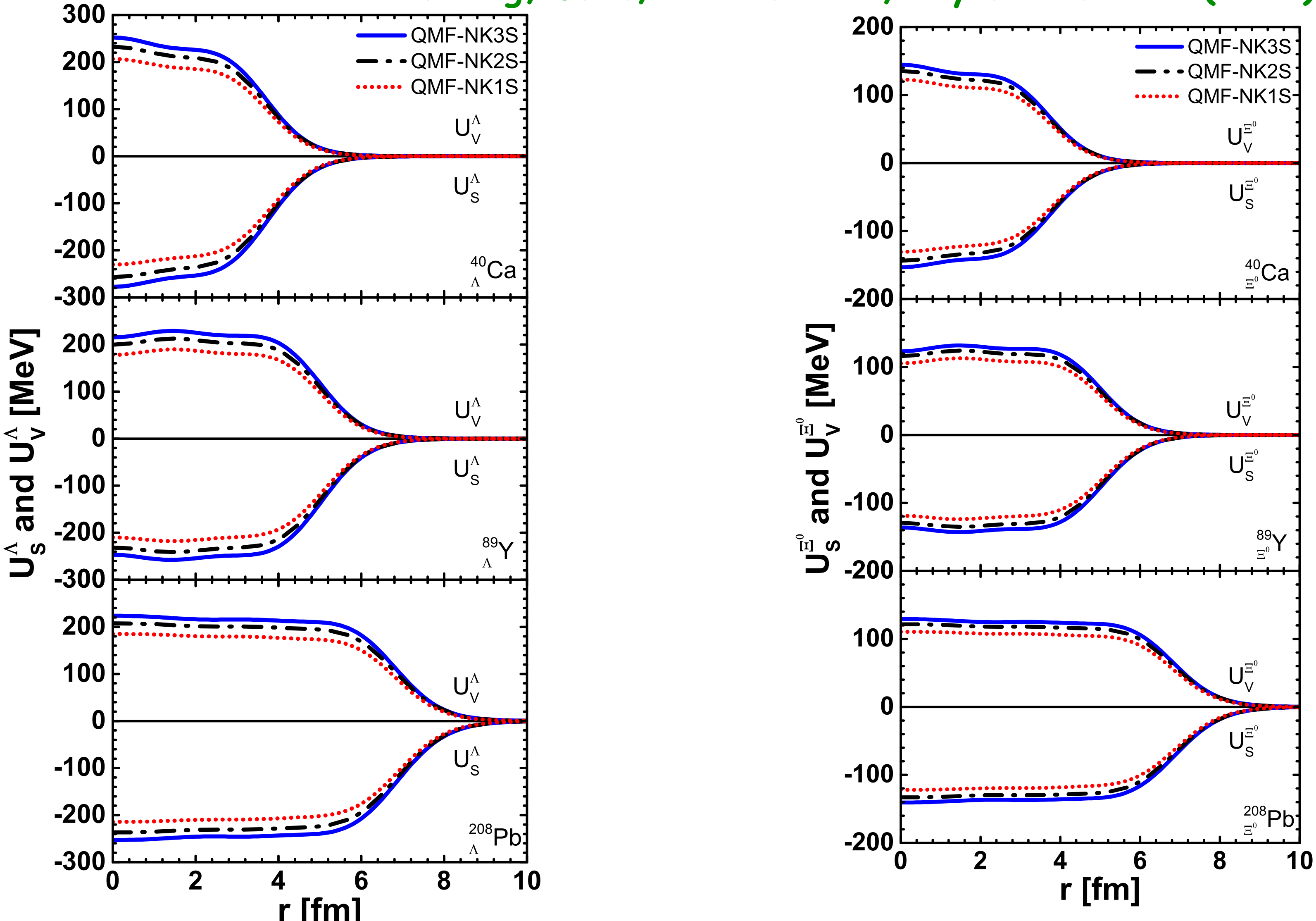
X. Xing, J.H., and H. Shen, Phys. Rev. C 95 (2017) 054310

The energy level of Λ hypernuclei



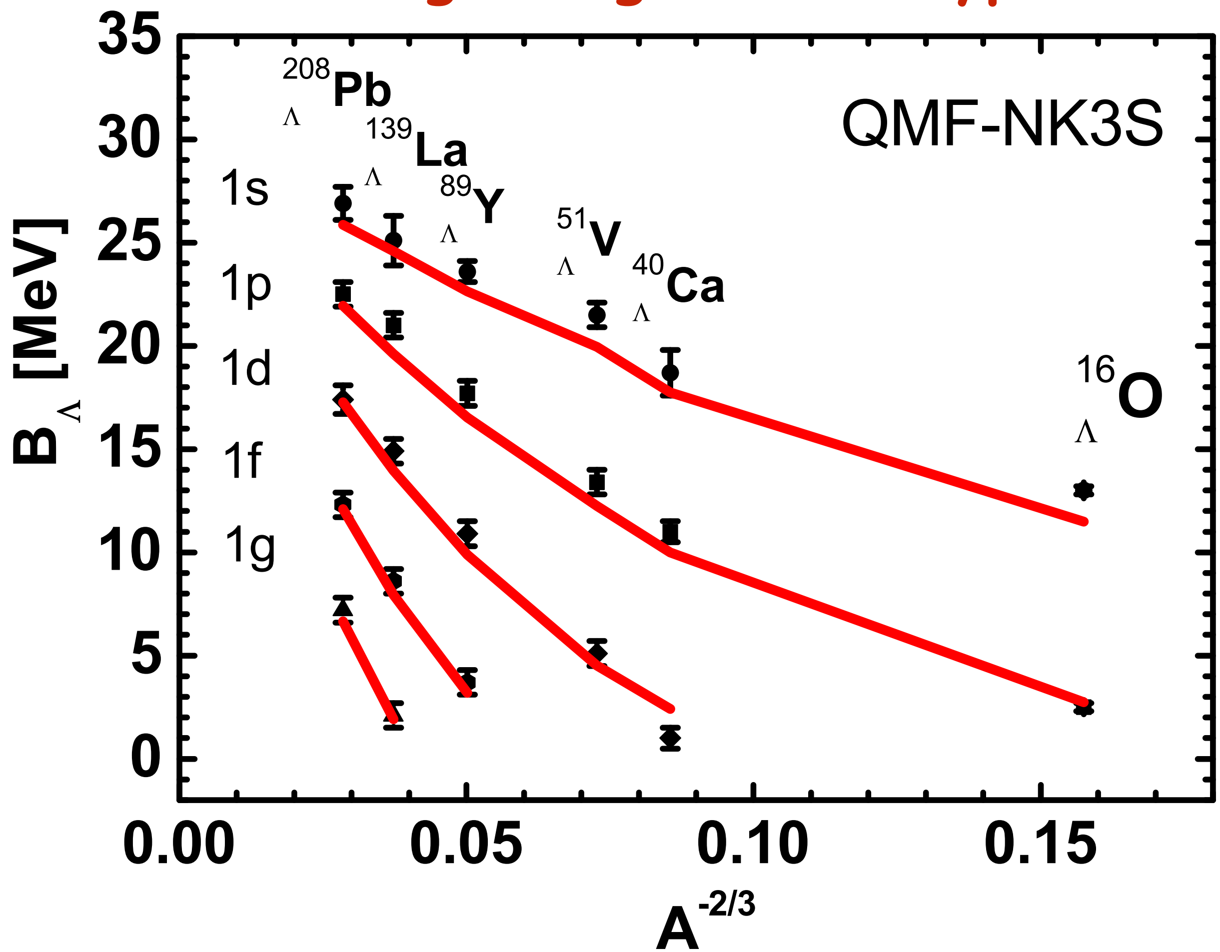
The potentials of hypernuclei

X. Xing, J.H., and H. Shen, Phys. Rev. C 95 (2017) 054310



X. Xing, J.H., and H. Shen, Phys. Rev. C 95 (2017) 054310

The binding energies of Λ hypernuclei



Exp. Data:A. Gal, E. V. Hungerford and D. J. Millener, Rev. Mod. Phys. 88(2016)035004

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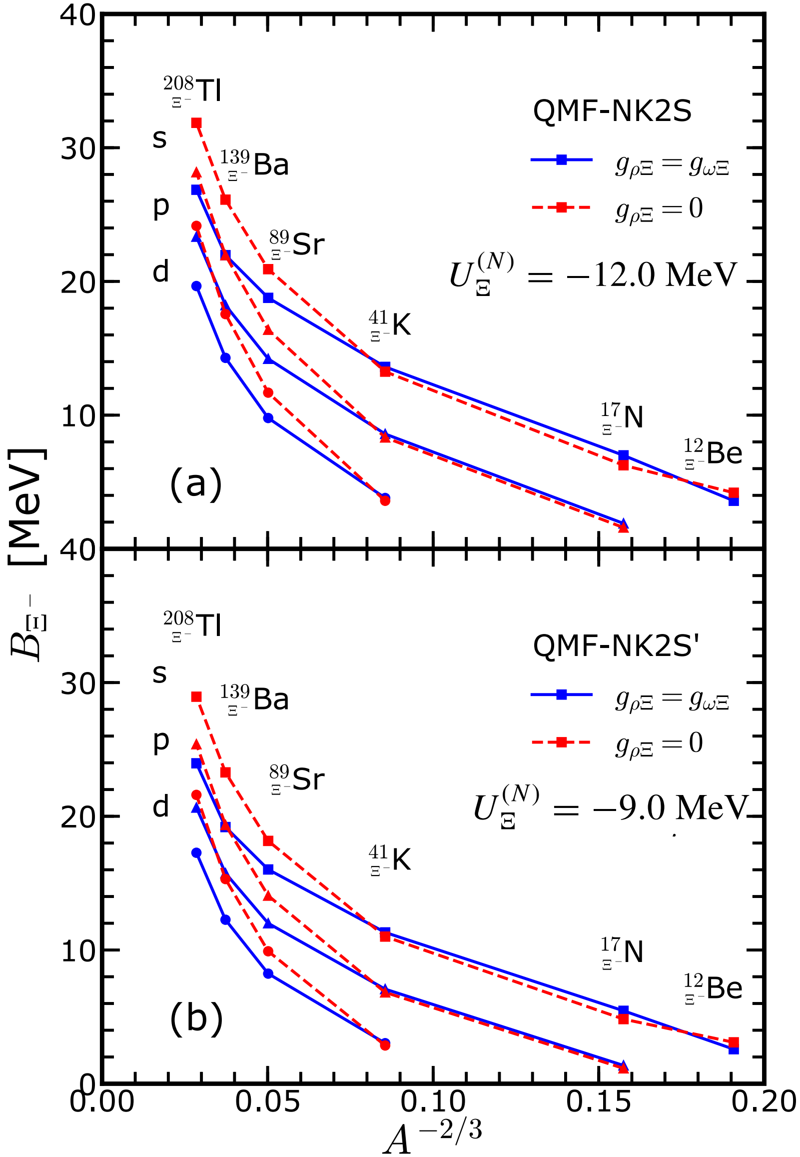
The KISO event (Ξ^-+^{14}N) of Ξ^- hypernuclei

K. Nakazawa et al., Prog. Theor. Exp. Phys. 2015, 033D02 (2015)

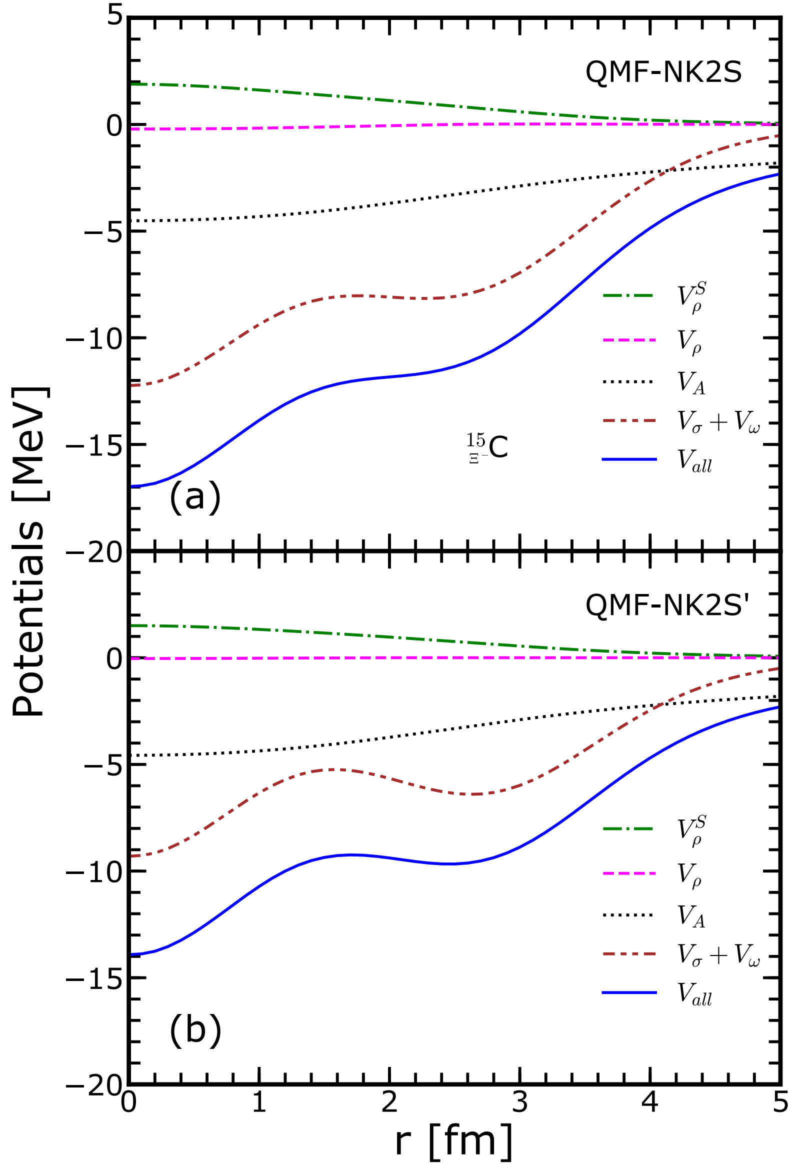
	$^{15}_{\Xi^-}$C(1s)	$^{15}_{\Xi^-}$C(1p)	$^{12}_{\Xi^-}$Be(1s)
QMF-NK1S($g_{\rho\Xi} = g_{\rho N}$)	5.82	1.21	3.78
QMF-NK2S($g_{\rho\Xi} = g_{\rho N}$)	5.69	1.14	3.59
QMF-NK3S($g_{\rho\Xi} = g_{\rho N}$)	5.61	1.08	3.49
QMF-NK1S($g_{\rho\Xi} = 0$)	5.80	1.21	4.35
QMF-NK2S($g_{\rho\Xi} = 0$)	5.65	1.14	4.20
QMF-NK3S($g_{\rho\Xi} = 0$)	5.58	1.08	4.11
Expt. or empirical data	4.38 ± 0.25	1.11 ± 0.25	$3.0 - 5.5$

T.T.Sun, E.Hiyama, H.Sagawa, H.J.Schulze, J. Meng, Phys. Rev. C 94, 064319 (2016)
J. Margueron, E. Khan, F. Gulminelli, Phys. Rev. C 96, 054317 (2017).

The IBUKI event (2021): 1.27 ± 0.21

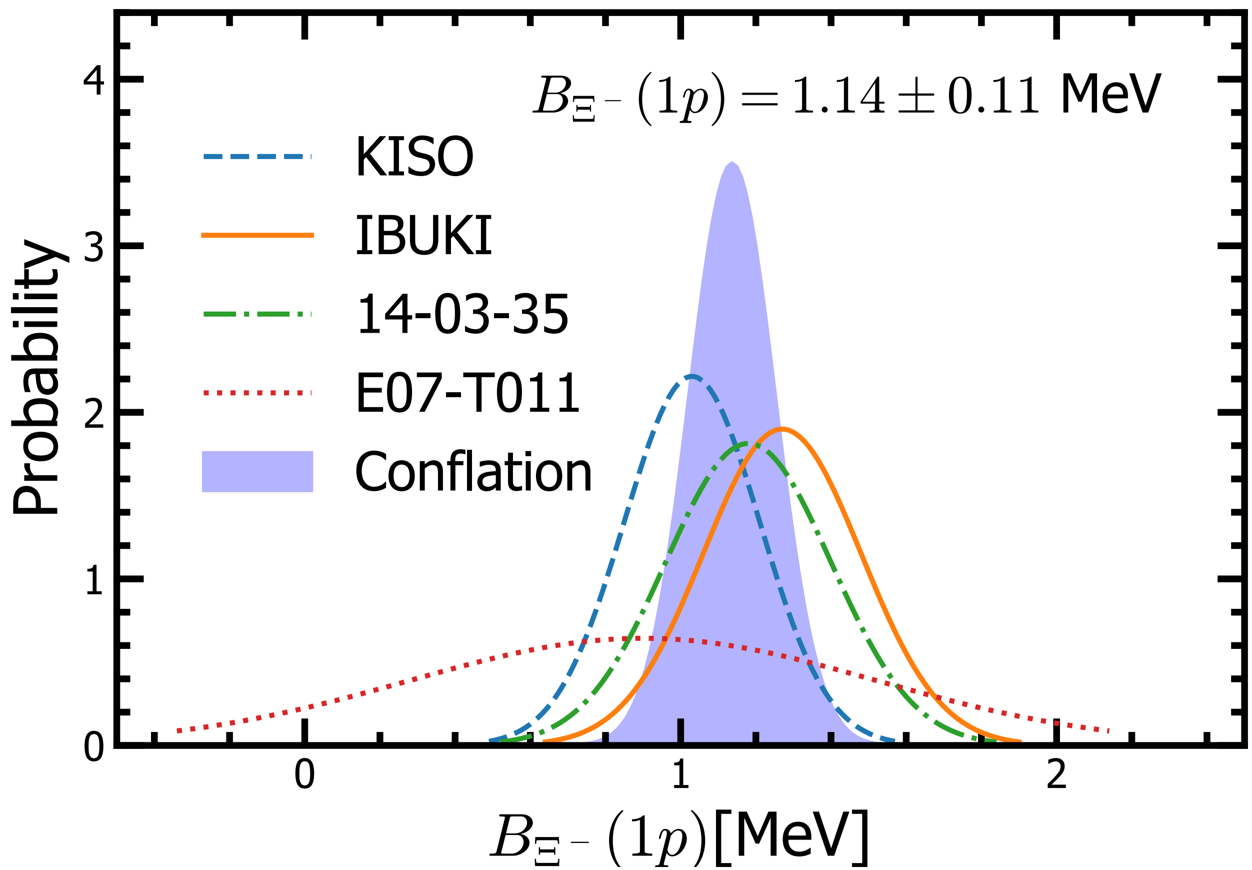


$^{208}_{\Xi^-}$Tl
$^{139}_{\Xi^-}$Ba
$^{89}_{\Xi^-}$Sr
$^{41}_{\Xi^-}$K
$^{17}_{\Xi^-}$N
$^{12}_{\Xi^-}$Be
s
p
d
QMF-NK2S
$g_{\rho\Xi} = g_{\omega\Xi}$
$g_{\rho\Xi} = 0$
$U_\Xi^{(N)} = -12.0$ MeV
(a)
QMF-NK2S'
$U_\Xi^{(N)} = -9.0$ MeV
(b)
B_{Ξ^-} [MeV]
$A^{-2/3}$



QMF-NK2S
QMF-NK2S'
V_ρ^S
V_ρ
V_A
$V_\sigma + V_\omega$
V_{all}
$^{15}_{\Xi^-}$C
(a)
(b)
Potentials [MeV]
r [fm]

The conflation values of 1p Ξ^- hyperon in Ξ^-+^{14}N system

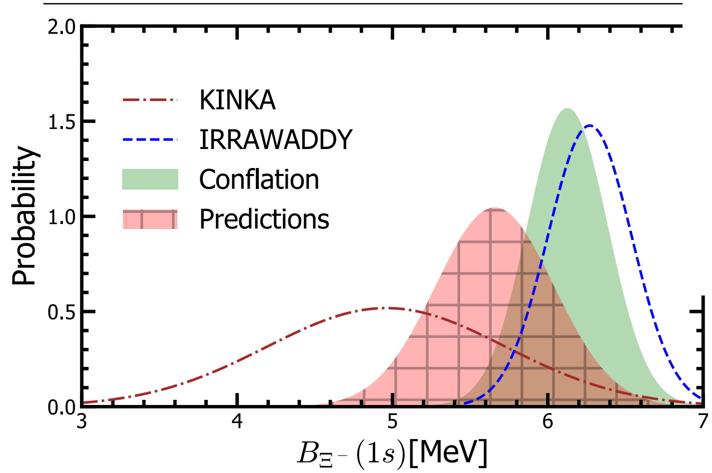


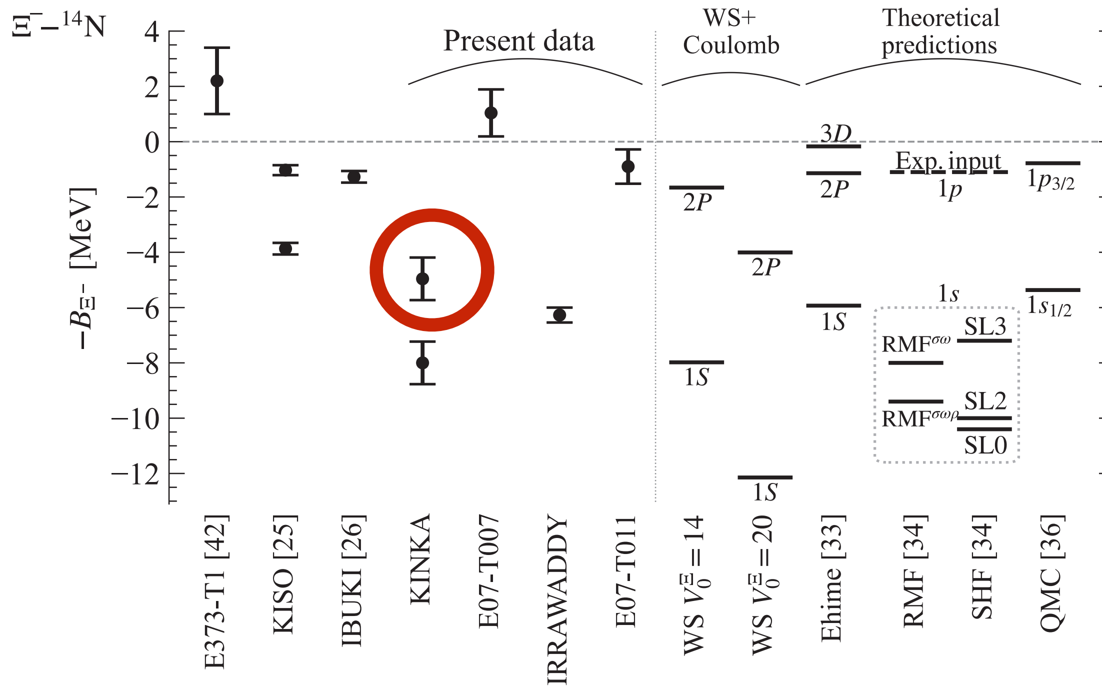
J. H, Y. Zhang, and H. Shen, J. Phys. G 49 (2022)025104

The present Ξ- hypernuclei data

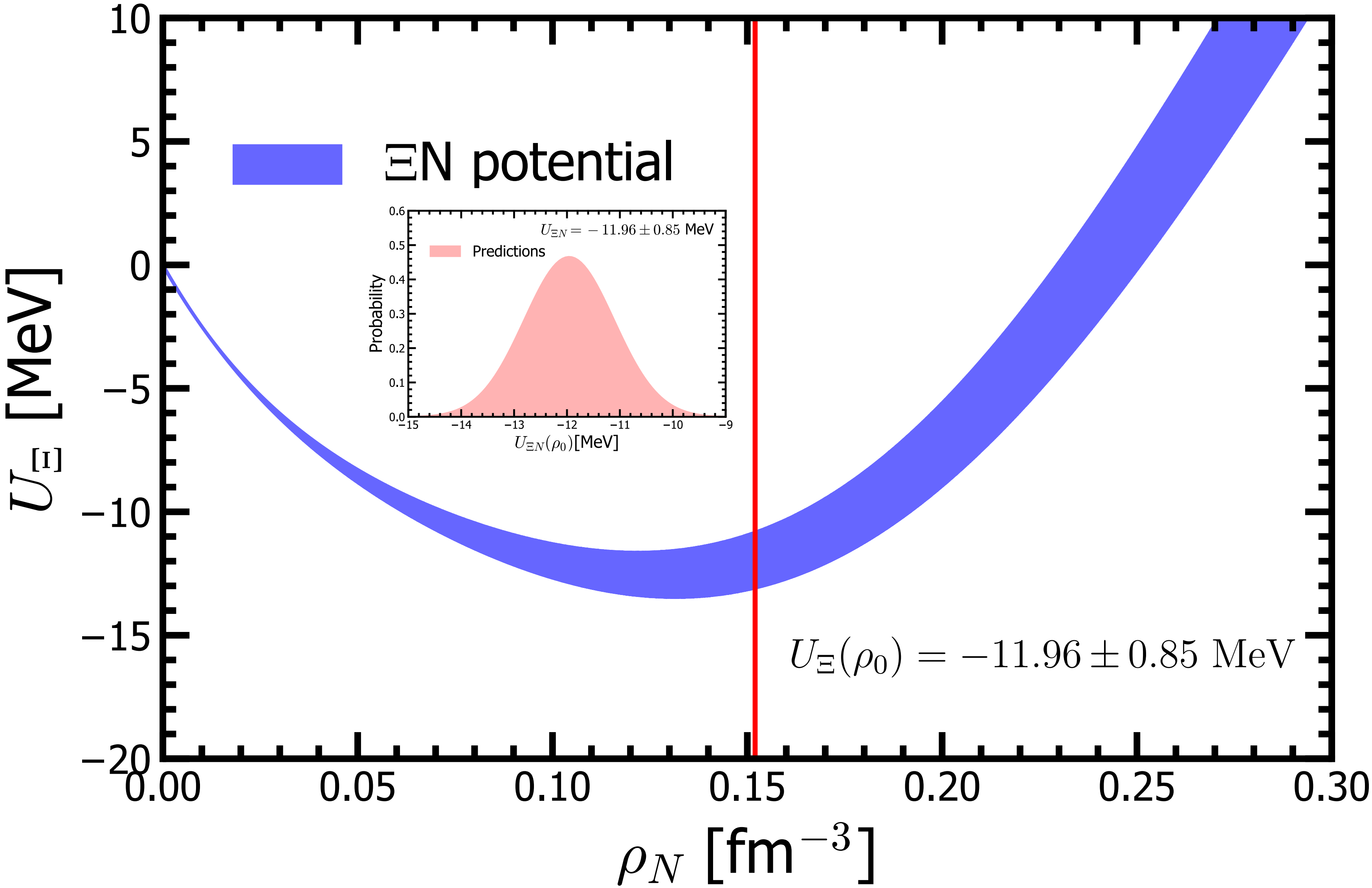
J. H, Y. Zhang, and H. Shen, J. Phys. G 49 (2022)025104

Sets	$g_{\omega\Xi}/g_{\omega N}$	$B_{\Xi^-}(1p)$	$B_{\Xi^-}(1s)$
QMF-NK1X1	0.5024	−1.03	−5.19
QMF-NK1X2	0.4954	−1.25	−5.91
QMF-NK2X1	0.4832	−1.03	−5.27
QMF-NK2X2	0.4771	−1.25	−6.01
QMF-NK3X1	0.4694	−1.03	−5.41
QMF-NK3X2	0.4638	−1.25	−6.11





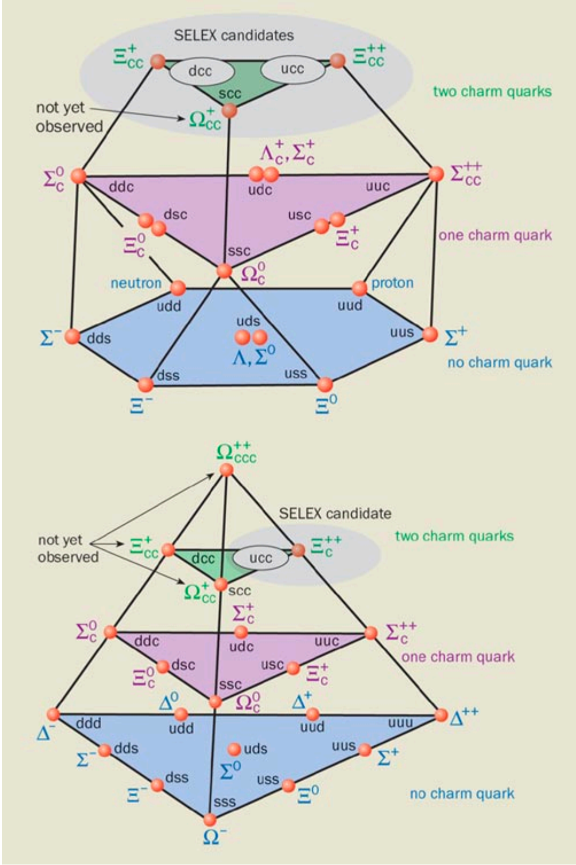
The KINKA event should be 1s state!

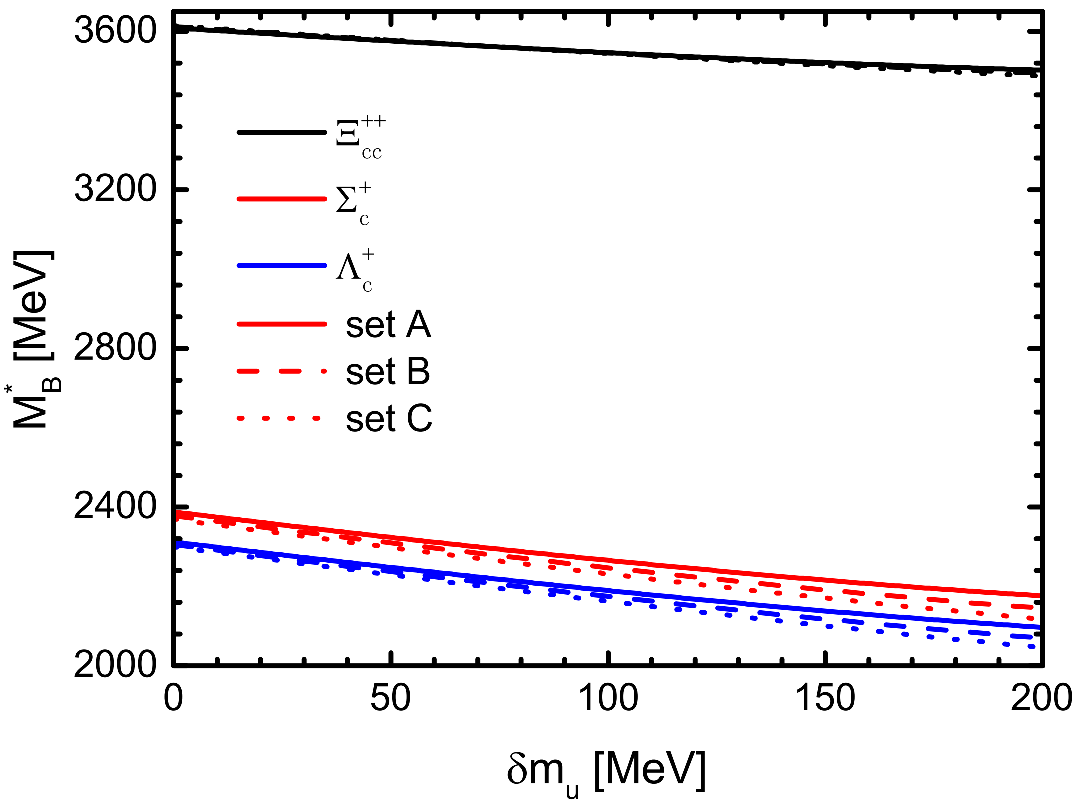


J. H, Y. Zhang, and H. Shen, J. Phys. G 49 (2022)025104

The charmed baryons

	m_u (MeV)	V_u (MeV)	a_u (fm^{-3})	m_c (MeV)	V_c (MeV)	a_c (fm^{-3})
Set A	250	−24.286601	0.579450	1300	284.58724	0.118172
Set B	300	−62.257187	0.534296	1350	239.53994	0.117312
Set C	350	−102.041575	0.495596	1400	193.67265	0.116036



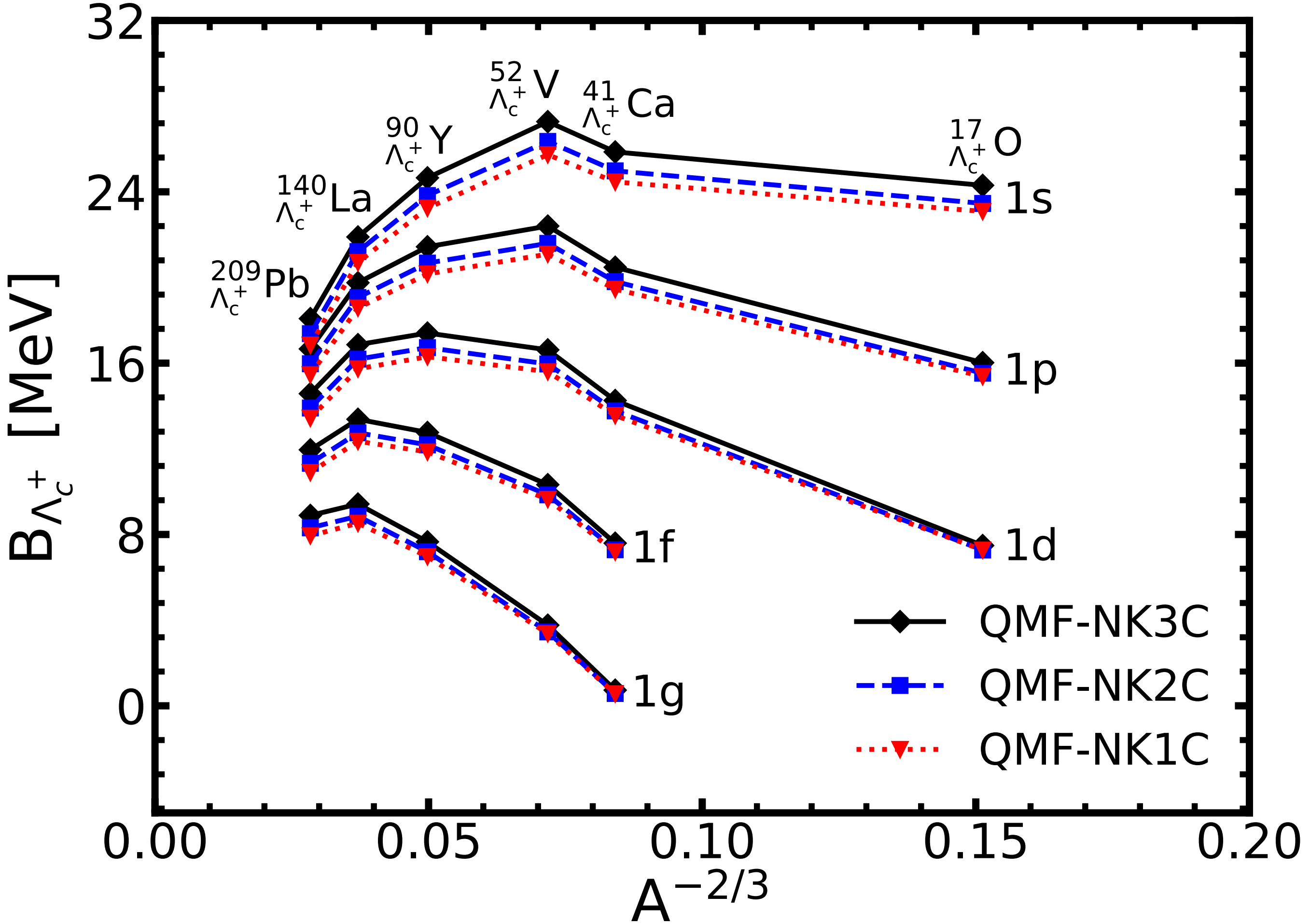


L. Wu, J.H., and H. Shen, Phys. Rev. C 101 (2020) 024303

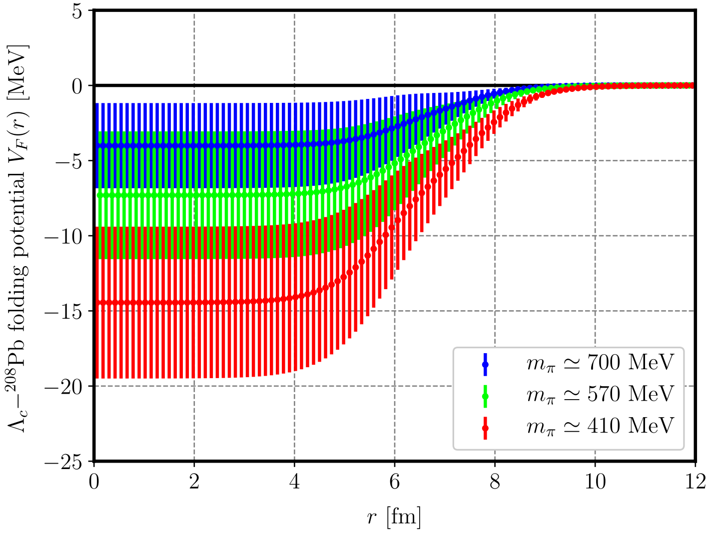
The charmed hypernuclei

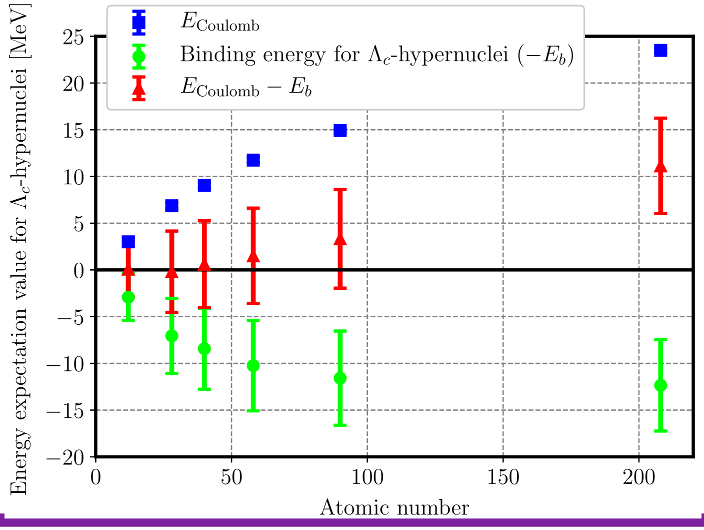
L. Wu, J.H., and H. Shen, Phys. Rev. C 101 (2020) 024303

$$g_{\omega\Lambda_c^+} = 2/3 g_{\omega N}$$

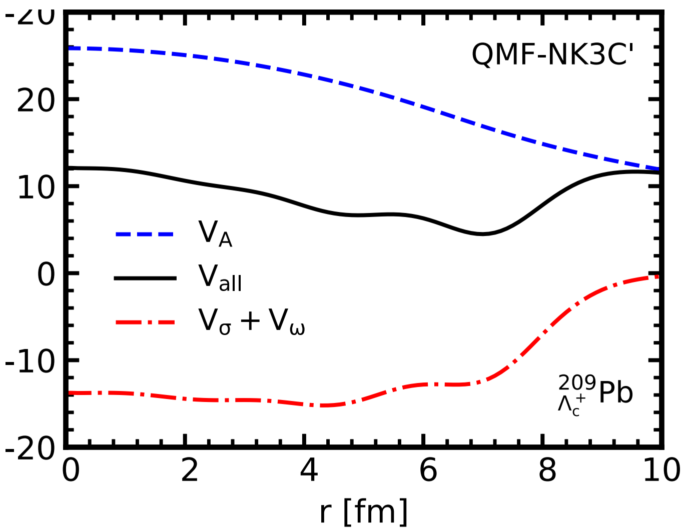


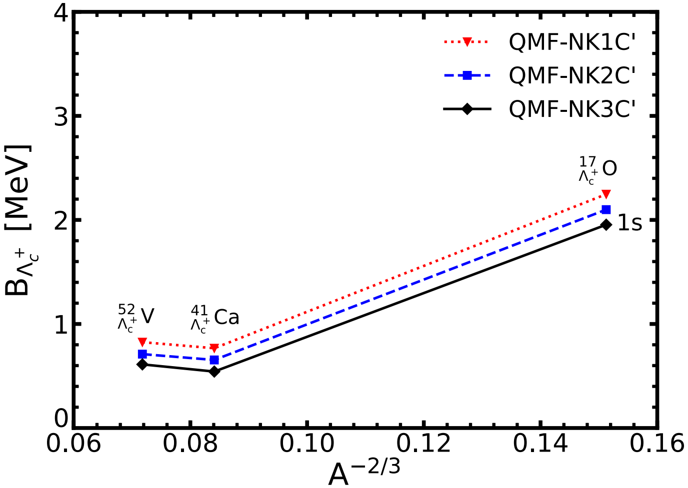
HAL QCD results





QMF results





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Binding energies and radius of charmed hypernuclei

L. Wu, J.H., and H. Shen, Phys. Rev. C 101 (2020) 024303

	QMF-NK3C					QMF-NK3C′				
	$-E/A$	r_{ch}	r_p	r_n	$r_{\Lambda_c^+}$	$-E/A$	r_{ch}	r_p	r_n	$r_{\Lambda_c^+}$
^{16}O	8.1377	2.7225	2.6042	2.5763		8.1377	2.7225	2.6042	2.5763	
$^{17}_{\Lambda_c^+}$O	9.1039	2.7298	2.6118	2.5797	1.8199	7.7937	2.7418	2.6244	2.5936	3.1746
^{40}Ca	8.5916	3.4562	3.3638	3.3141		8.5916	3.4562	3.3638	3.3141	
$^{41}_{\Lambda_c^+}$Ca	9.0333	3.4630	3.3708	3.3174	2.2599	8.4159	3.4692	3.3771	3.3252	3.8017
^{51}V	8.6403	3.6050	3.5200	3.6127		8.6403	3.6050	3.5200	3.6127	
$^{52}_{\Lambda_c^+}$V	9.0162	3.6086	3.5237	3.6123	2.3773	8.5047	3.6190	3.5343	3.6246	3.7366
^{89}Y	8.6990	4.2435	4.1724	4.2923		8.6990	4.2435	4.1724	4.2923	
$^{90}_{\Lambda_c^+}$Y	8.8925	4.2466	4.1755	4.2921	2.9105					
^{139}La	8.4276	4.8556	4.7954	4.9826		8.4276	4.8556	4.7954	4.9826	
$^{140}_{\Lambda_c^+}$La	8.5388	4.8565	4.7964	4.9812	3.5325					
^{208}Pb	7.8992	5.5037	5.4517	5.6898		7.8992	5.5037	5.4517	5.6898	
$^{209}_{\Lambda_c^+}$Pb	7.9623	5.5052	5.4532	5.6892	4.2618					

The Λ_c hyperon is inside of the nuclei with quark counting

The Λ_c hyperon is outside of the nuclei with lattice

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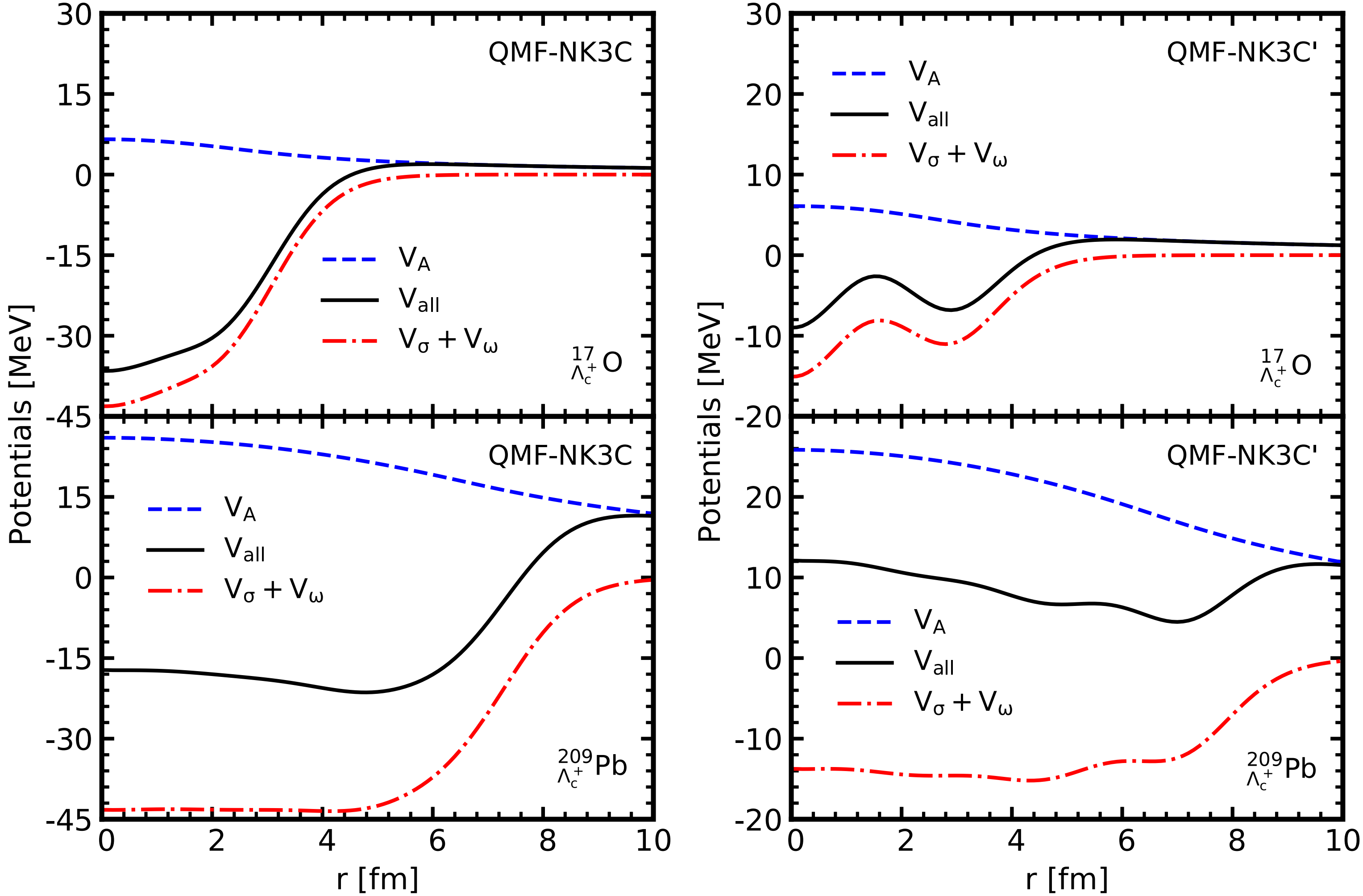
The potentials of charmed hyper nuclei

L. Wu, J.H., and H. Shen, Phys. Rev. C 101 (2020) 024303



The present Ξ- hypernuclei data

Experiment	Event	Daughters	B_{Ξ^-} [MeV]		
E373	T1 [39]	${}^{5}_{\Lambda}$He+${}^{5}_{\Lambda}$He+^{4}He+n	-2.2 ± 1.2		
E373	T2 KISO [24]	${}^{10}_{\Lambda}$Be + ${}^{5}_{\Lambda}$He	3.87 ± 0.21	or	1.03 ± 0.18
E07	T006 IBUKI [25]	${}^{10}_{\Lambda}$Be + ${}^{5}_{\Lambda}$He	1.27 ± 0.21		
E373	T3 KINKA	${}^{9}_{\Lambda}$Be+${}^{5}_{\Lambda}$He+n	8.00 ± 0.77	or	4.96 ± 0.77
E07	T007	${}^{9}_{\Lambda}$Be+${}^{5}_{\Lambda}$He+n	-1.04 ± 0.85		
E07	T010 IRRAWADDY	${}^{5}_{\Lambda}$He+${}^{5}_{\Lambda}$He+^{4}He+n	6.27 ± 0.27		
E07	T011	${}^{5}_{\Lambda}$He+${}^{5}_{\Lambda}$He+^{4}He+n	0.90 ± 0.62		

The conflation method

$$f(x) = \frac{1}{\sigma_i\sqrt{2\pi}} \exp\left[-\frac{(x-m_i)^2}{2\sigma_i^2}\right]$$

$$m_t = \sum_i^n m_i \sigma_i^{-2} \left(\sum_i^n \sigma_i^{-2}\right)^{-1},$$

$$\sigma_t = \left(\sum_i^n \sigma_i^{-2}\right)^{-1/2}.$$

m is the mean value

σ is the standard deviation

The strangeness in neutron star

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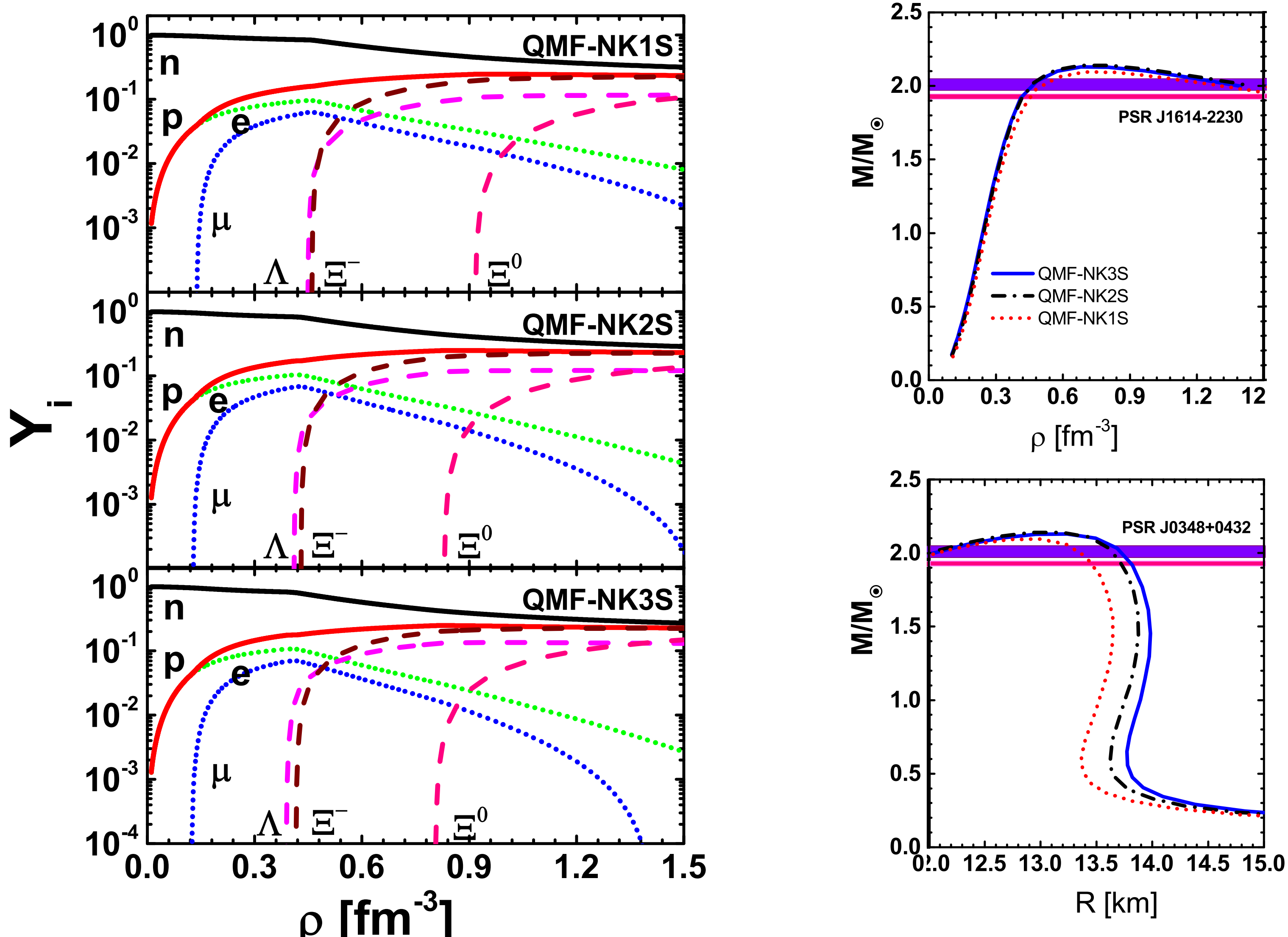

X. Xing, J.H., and H. Shen, Phys. Rev. C 95 (2017) 054310

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Summary and perspective

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The effects of chiral dynamics and gluons are introduced into the QMF model.

The improved QMF model was applied to the finite nuclei, Λ, Ξ^0, Ξ^-, Λ_c hypernuclei and neutron star, which can describe the many-body strangest system very well.

The EMC effect will be studied within QMF model.