Baryon-Baryon Potentials with QCD-based Cores

QCDから導かれた短距離コアをもつバリオン間ポテンシャル模型

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バリオン間(BB)相互作用の研究

ハイパー核、ストレンジ核物理学の進歩によって進展
　ハイパー核、ダブルハイパー核の豊富な知識
　　YN,YY相互作用についての知識　　J-PARC
理論的研究
　OBEPなどの中間子交換モデル　　中、長距離パート
　クオークモデル＋中間子交換モデル　　短、中、長距離パート
　カイラル摂動論によるモデル
　QCDによる理論計算　　短距離パート

短距離パート（第3領域）の性質がQCDにもとづく理論計算で解明されつつある

＊従来の中間子交換モデルでは、短距離パートを現象論的に導入してきた。
＊クオークモデルによる計算

整合性はどうなっているか？
QCDによる短距離相互作用と中間子交換モデルは両立可能か？
もし可能であれば、どういう性質をあたえるか？（とくにYN、YY相互作用について）

by Shoji SHINMURA

ハドロン交換機構によるハドロン間ポテンシャル

共通の土台: Hadron Exchange Mechanism with
SU(3)symmetric Coupling Constants

		NN	YN,YY	πN,KN	$K^{bar}N$	$\pi\pi,\pi K,N^{bar}N$
Julich	OHEP, Form Factor, No Phenomenological Core	○	○	○	△	△
Nijmegen	OHEP, TMEP, Pomeron(Quark-Gluon Effects) Form factor	○	○	○		
fgA,fgB (2000)	OBEP with short-range cutoff Phenomenological Core	○	○			
GSOBEP (2005)	OHEP+Source Function No Phenomenological Core	○	○	○	△ (2010)	

fgA,fgB（PTP Vol.104, 995,2000）:

Scalar meson masses are different between the models
SRC + OBEP with cutoff(at r=0.4fm)

$$V = V_{core}(r) + [1-\exp(-(r/r_c)^2]^4 V_{OBEP} \quad r_c=0.4\text{fm}$$

$$V_{core}(r)= V_c \exp(-(r/r_g)^2) \quad r_g=0.5(0.49147)\text{ fm for fgA(fgB)}$$

List of the values of V_c

fgA	{27}	{10*}	{10}	{8a}	{8s}	{1}
Even	2768	2277	40	1162	3579	173
Odd	28	178	267	2219	1072	-

fgB	{27}	{10*}	{10}	{8a}	{8s}	{1}
Even	2822	2473	75	41	256	230
Odd	5	3112	96	3962	3603	-

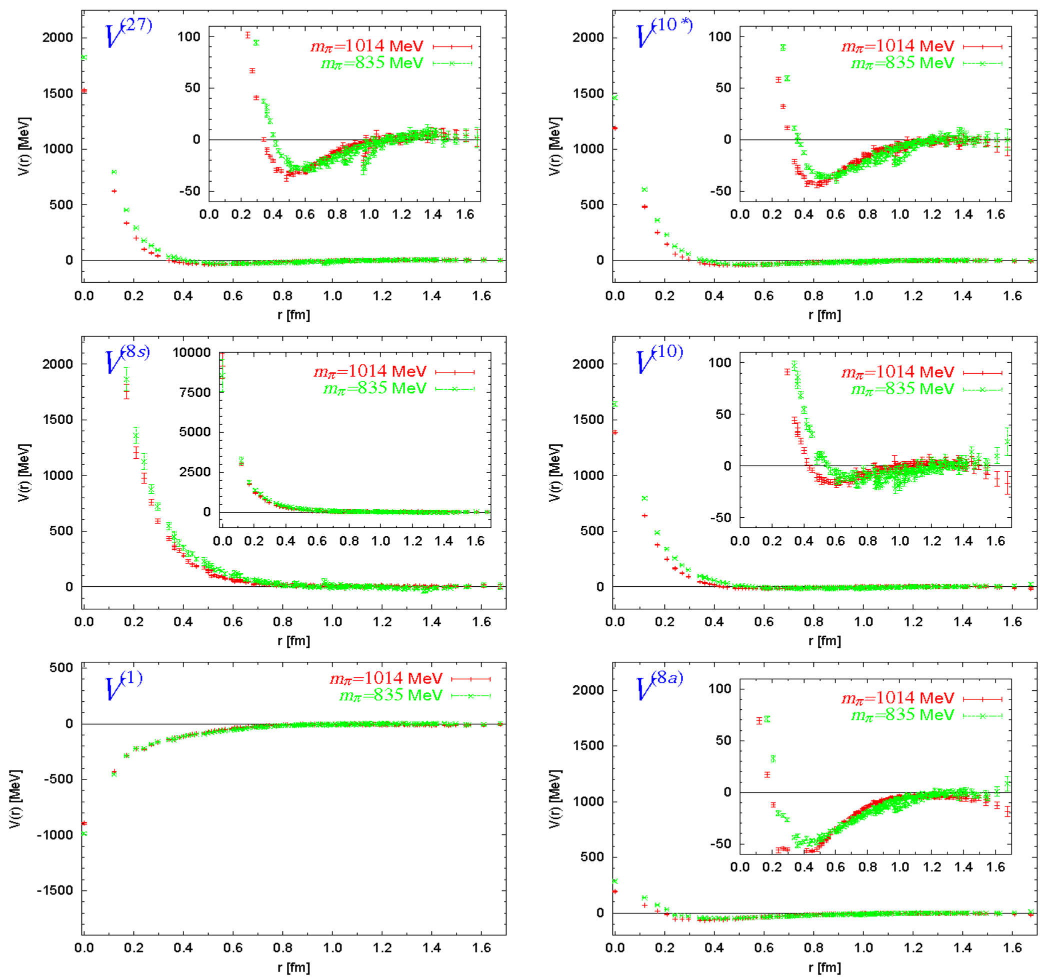

Fig. 2. The six independent BB potentials for S-wave in the flavor SU(3) limit, extracted from the lattice QCD simulation at $m_\pi = 1014$ MeV (red bars) and $m_\pi = 835$ MeV (green crosses).

T. Inoue et al.
(HAL QCD collaboration)
arXiv:1007.3559[hep-lat]

Flavor SU(3) Limit
Even(1S0,3S1) states

pion mass = 1014 MeV red
pion mass = 835 MeV green

Relative Strengths:

	{27}	{10*}	{10}	{8a}	{8s}	{1}
LQCD	1	0.8	1.1	0.2	4.1	-0.6
fgA	1	0.8	0.01	0.4	1.3	0.06
fgB	1	0.9	0.03	0.08	0.09	0.01
	---NN---		--------YN---------			--YY--

NNはたいへんよい一致！
定性的にはfgAが相性がよい

fgAの「改良版」

Relative Strengths of Short Range Cores:

	{27}	{10*}	{10}	{8a}	{8s}	{1}	
LQCD	1	0.8	1.1	0.2	4.1	-0.6	
fgA	1	0.8	0.01	0.4	1.3	0.06	
fgA'	1	0.8	1.1	0.2	3.0	-0.6	Only c.c. are opitimized
fgA''	1	0.8	1.1	0.2	3.0	-0.6	Fully optimized
	-------NN-------		--------------YN--------------			-----YY----	

Coupling Constants:

	g(1)	g(8)	α	θ
scalar mesons	5.37138	0.76202	3.21258	-5.61
ps-mesons	0.14853	0.26600	0.49061	-23.92
vector mesons ge	3.44302	0.68648	1.00000	36.44
gm	4.72583	6.12176	0.43590	36.44

Blue numbers are fixed

Optimized parameters
11=10+1(Vc({27})) in fgA'
16=10+1(Vc({27}))+5(Vc(Odd)) in fgA''

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{10},{8s}{1}に大きな変化:

NN : 影響なし

ΛN : 影響小さい
1S0:{8s}のみで統計的重みは小さい(10%)

ΣN : 影響大きい
I=3/2 3S1 {10}100%
I=1/2 1S0{8s} 90%

ΛΛ、ΞN : 影響大きい
I=0 1S0 {1}{8s}:
I=1 1S0{8s}:
I=1 3S1{10}:

現象論的な知識＝拘束条件の量と質に符合！！

by Shoji SHINMURA

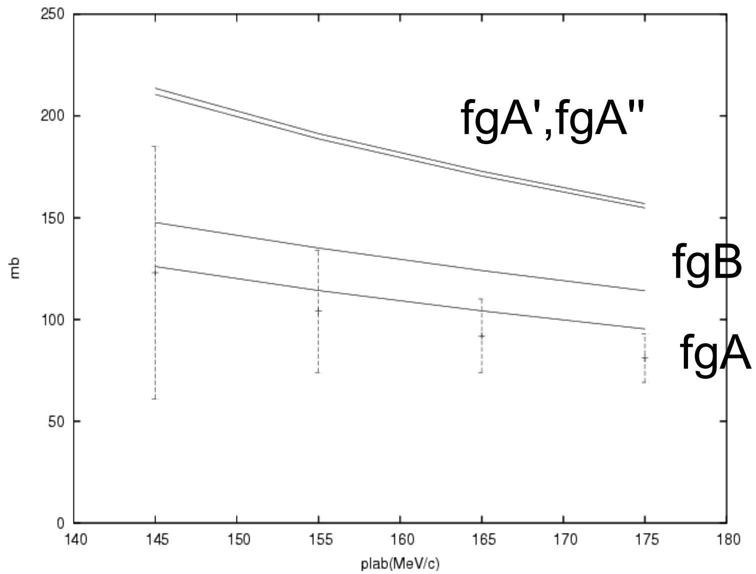
Coupling Constants:

fgA	g(1)	g(8)	α	θ
scalar mesons	5.37138	0.76202	3.21258	-5.61
ps-mesons	0.14853	0.26600	0.49061	-23.92
vector mesons ge	3.44302	0.68648	1.00000	36.44
gm	4.72583	6.12176	0.43590	36.44

Blue numbers are fixed

fgA'	g(1)	g(8)	α	θ
scalar mesons	5.41223	1.14430	2.12067	-6.39
ps-mesons	0.13503	0.26600	0.49061	-23.92
vector mesons ge	3.40179	0.68655	1.00000	36.44
gm	5.45281	6.02445	0.35211	36.44

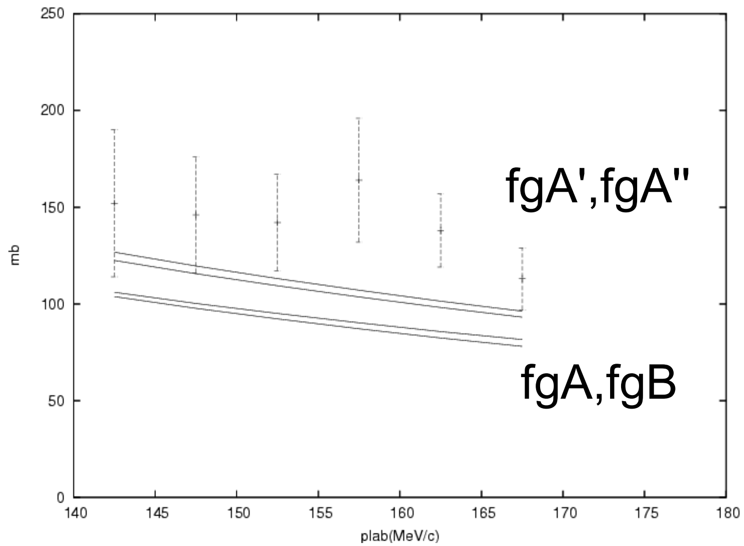
fgA''	g(1)	g(8)	α	θ
scalar mesons	5.35849	1.12632	2.08724	-4.93
ps-mesons	0.13990	0.26600	0.49061	-23.92
vector mesons ge	3.49537	0.70097	1.00000	36.44
gm	5.41256	6.17634	0.34902	36.44



Σ^+p-Σ^+p Elastic Cross sections

fgA,fgB : good
fgA', fgA" : overestimation

3S1 {10} 100% 0.01 → 1.1



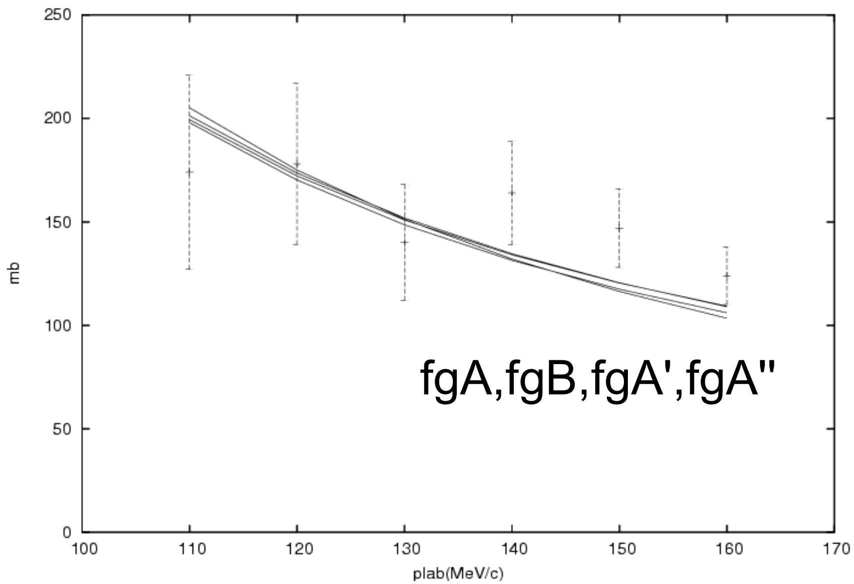
Σ^-p-Σ^-p Elastic Cross sections

fgA,fgB : underestimation
fgA',fgA" : improved

1S0 {8s} 60% 1.3 → 3.0

Σ^-p-Λn Reaction Cross sections

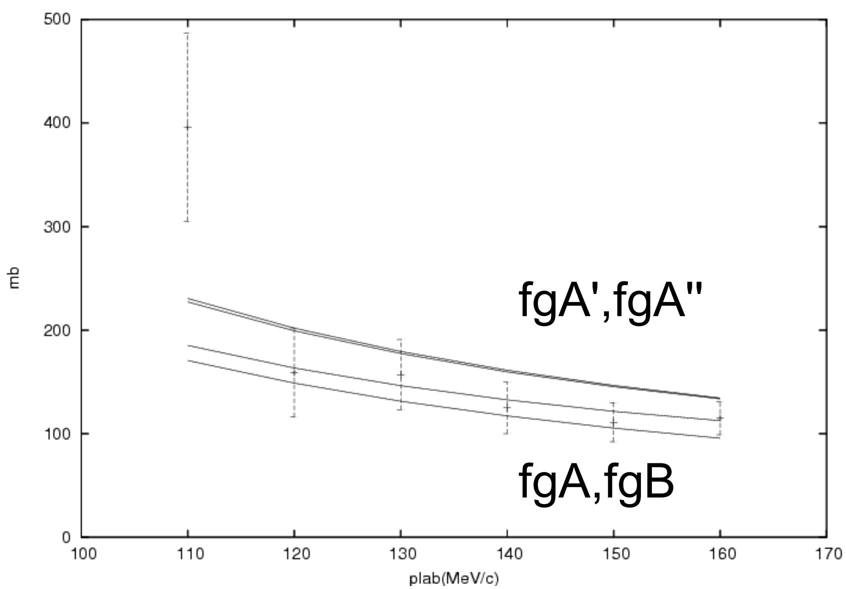
fgA,fgB,fgA'.fgA'' : good



Σ^-p-Σ^0n Reaction Cross sections

fgA'.fgA'' : overestimation ?

fgA.fgB : good ?



$\Sigma^{-}p$ Inelastic Capture Ratio:

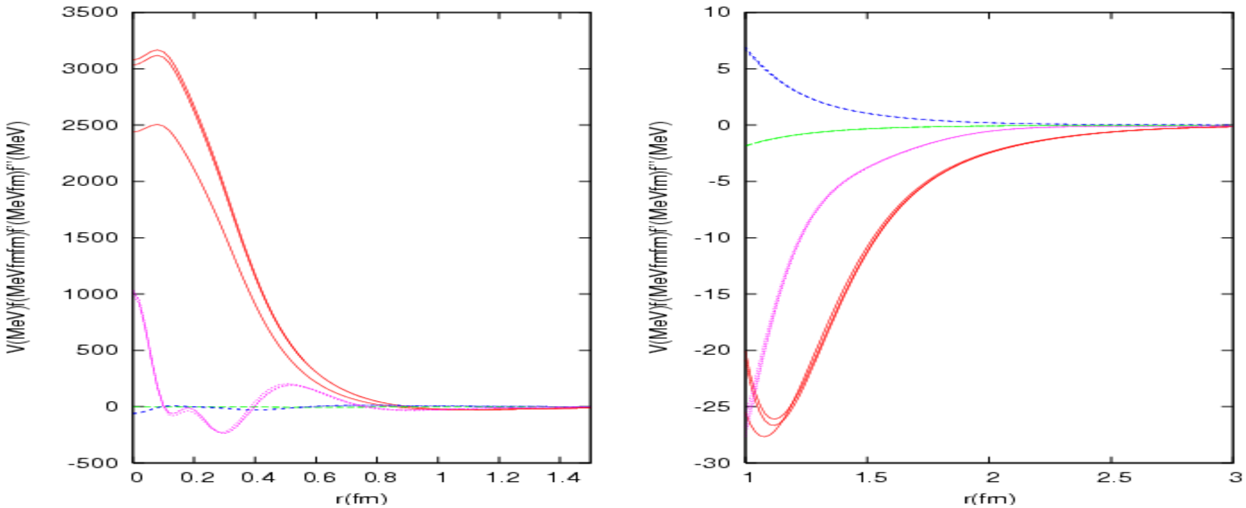
$$r = \sigma(\Sigma^{-}p \rightarrow \Sigma^{0}n)/[\sigma(\Sigma^{-}p \rightarrow \Sigma^{0}n) + \sigma(\Sigma^{-}p \rightarrow \Lambda n)]$$

$$r_{av} = (1/4)r(\text{singlet}) + (3/4)r(\text{triplet})$$

	r_{av}
Exp	0.33±0.05
	0.474±0.016
	0.465±0.011
Calc	
fgA	0.467
fgA'	0.516
fgA''	0.511

fgA' and fgA'' cannot reproduce experimental data !

by Shoji SHINMURA



ΛΛ–ΛΛ(1S0)

weak attraction

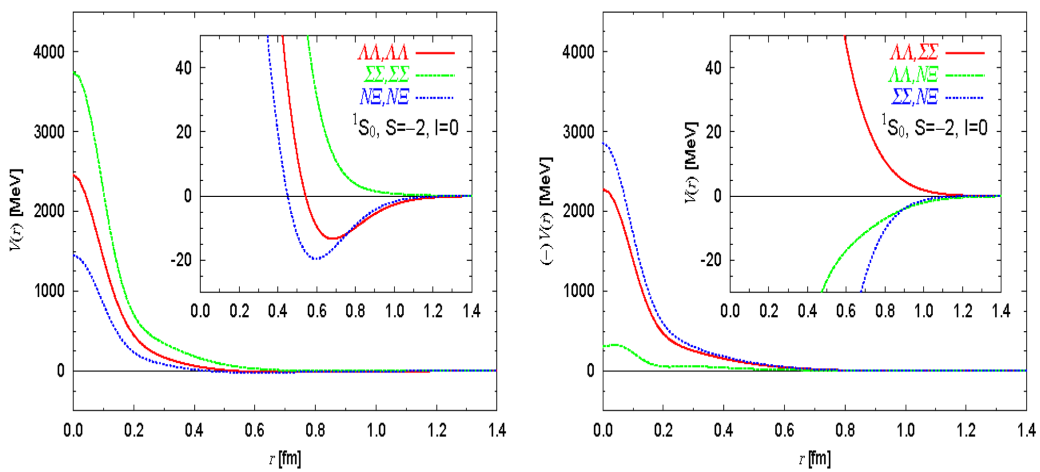
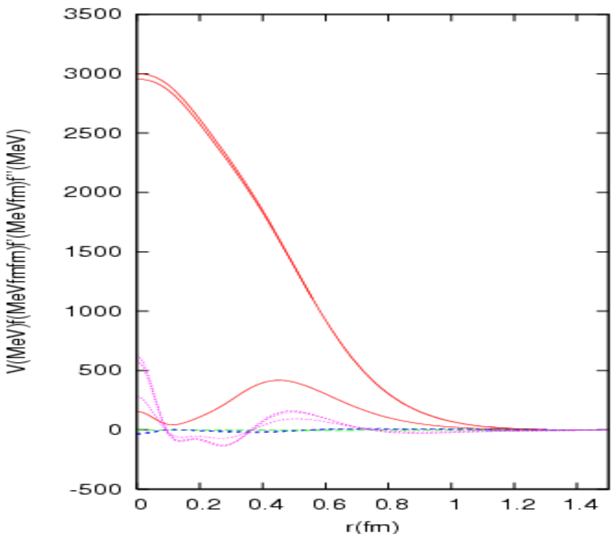


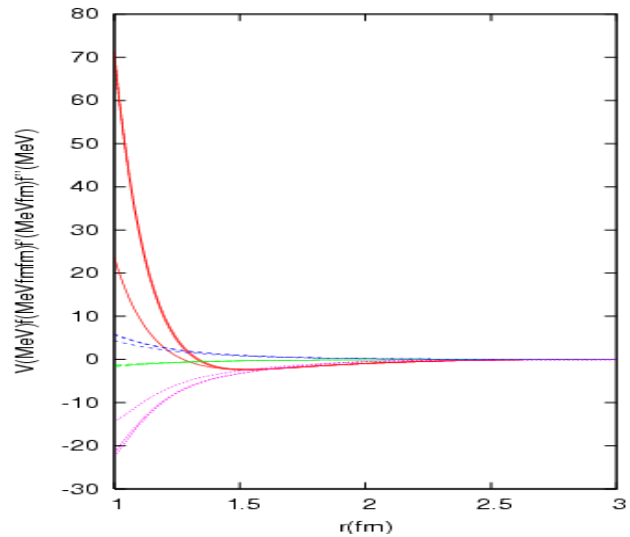
Fig. 3. BB potentials in baryon basis for S=−2, I=0, $^1S_0$ sector. Three diagonal(off-diagonal) potentials are shown in left(right) panel. Phase of off-diagonal ones in the right panel are arranged in zoom-out plot. Their true signs are shown in the insertion.

HAL-QCD calc.
by T, Inoue et al.

weak attraction

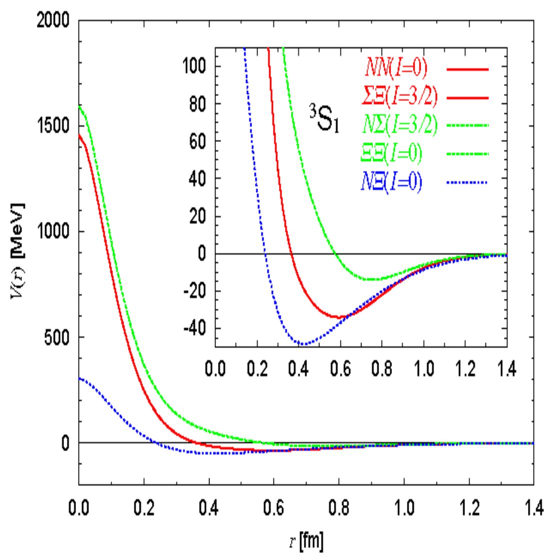
by Shoji SHINMURA





Σ⁺p(3S1)

Strong repulsion

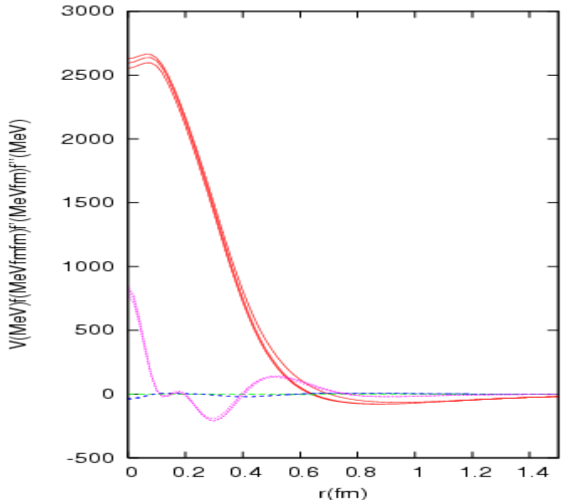


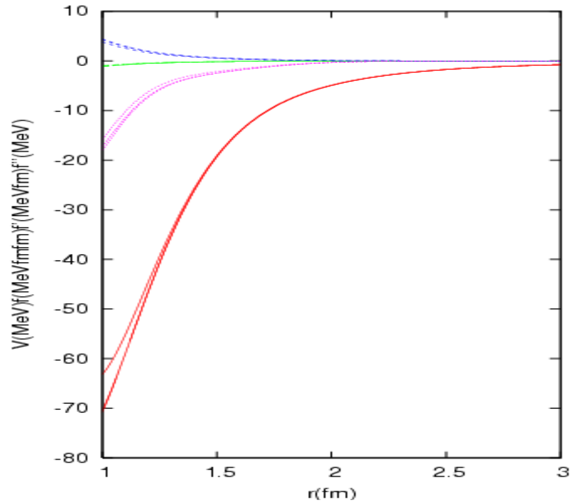
HAL-QCD calc.
by T, Inoue et al.

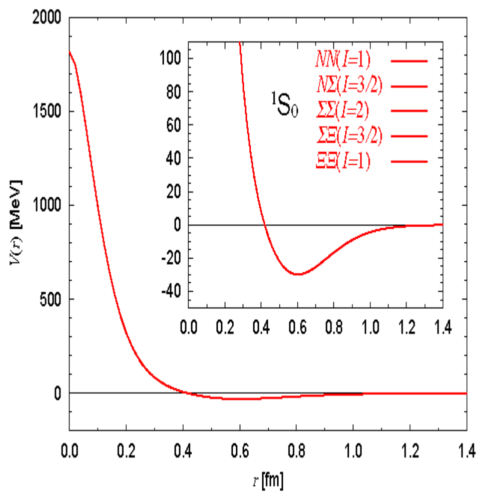
weak attraction

$\Sigma^{+}p(1S0)$

attraction

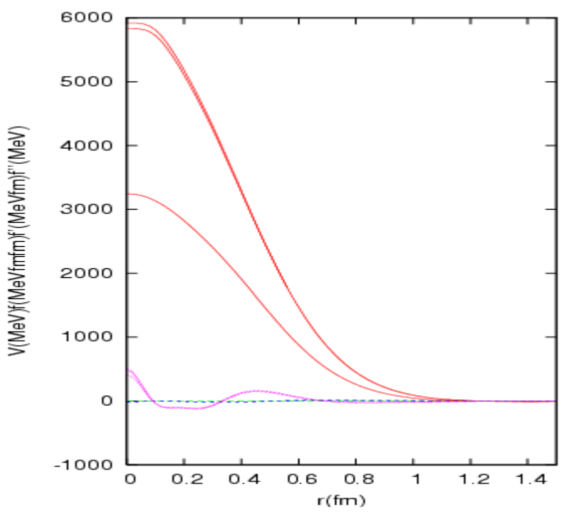


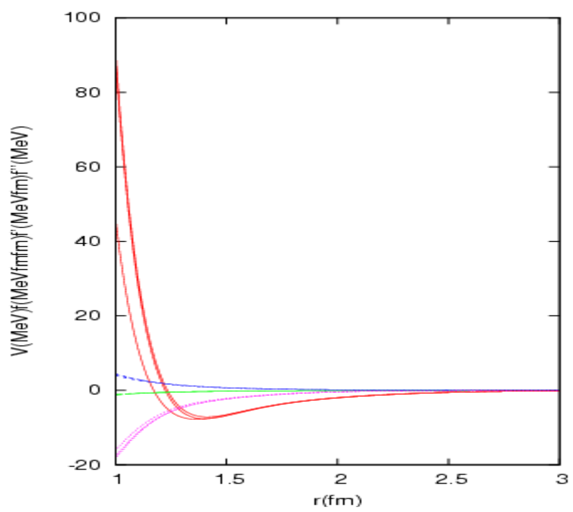




HAL-QCD calc.
by T, Inoue et al.

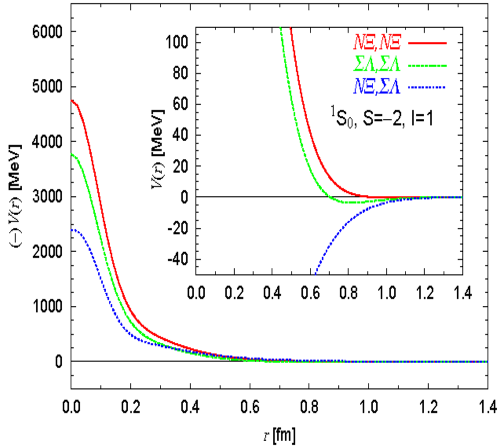
attraction





Ξ⁻n(1S0)

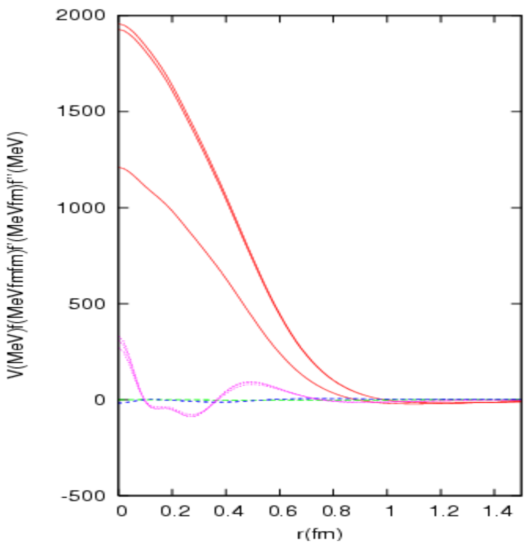
strong repulsion

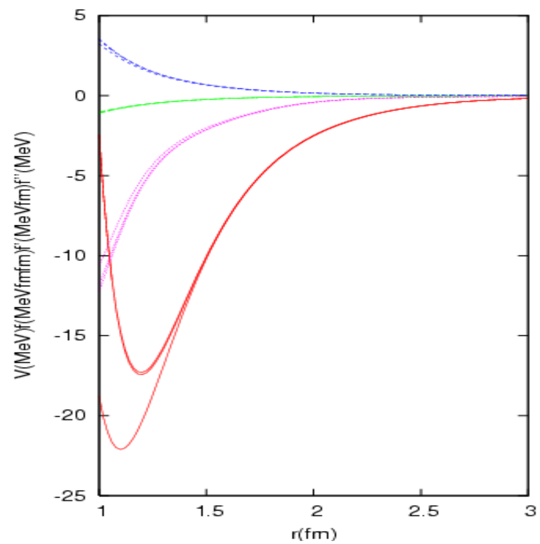


HAL-QCD calc.
by T, Inoue et al.

strong repulsion

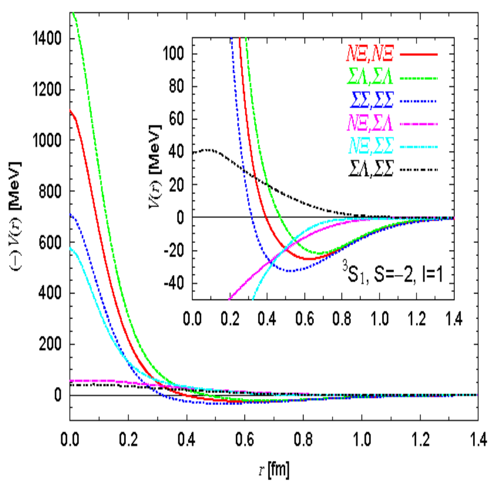
by Shoji SHINMURA





Ξ⁻n(3S1)

weak attraction



HAL-QCD calc.
by T, Inoue et al.

weak attraction

まとめ

○OBEP with cutoff＋現象論的短距離力という枠組みは、実験データが整備される条件の下で、QCDと整合性をもつように思える。

NN data → Vc({27}) : Vc({10*})= 1 : 0.8

YN, YY data → Vc({10}), Vc({8a}),Vc({8s}), Vc({1}) ???

QCD {27}:{10*}:{10}:{8a}:{8s}:{1}=1 : 0.8 : 1.1 : 0.2 : 4.0 : -0.6

○QCDの短距離コア＋OBEPというモデルは構築可能であると思われる
YN、YY相互作用の予言を行うことも可能

○Hadron間相互作用への拡張
NN,YN,YY, πN,KN,K^{bar}N, $\pi\pi$, N^{bar}N,πK