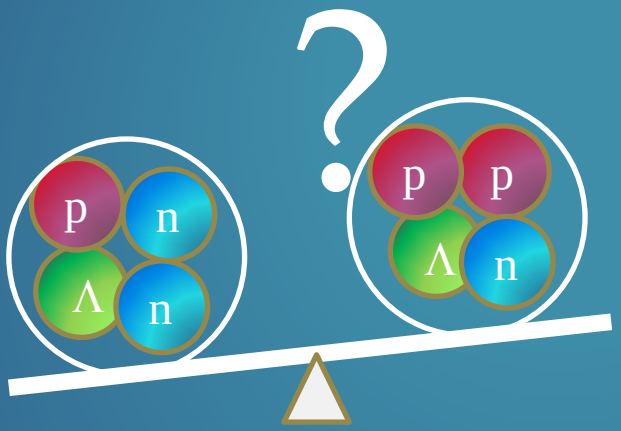
Spectroscopy of Lambda Hypernuclei



Satoshi N. Nakamura
Tohoku University

12 March 2017

SNP 2017 @ Osaka E-C Univ.

Congratu
on your re
Fukuda

I defensed my thesis in 1995 . O

23rd INS International Symposium
Nuclear and Particle Physics with Meson Beams in the 1 Ge V/c Region

Tokyo
March 15-18, 1995

What we were discussing in 1995.

(π^+,K^+)

Stopped K^-

Σ hyper

Polarized hyper*nucl.* and weak decay

Lifetime of Λ hyper

H dibaryon

S=-2

Σ^+p scat.

KbarN int

What we are discussing in 2017.

CSB, 3BRF for hyperron puzzle

$(e, e' K^+)$

Lattice QCD

n-rich HY with DCX

S=-2

Lifetime of ${}^{3}_{\Lambda}\mathrm{H}$

KbarN int

Meson in nucleus

Charmonic hadrons

Hyperon puzzle

Strangeness with HI beam

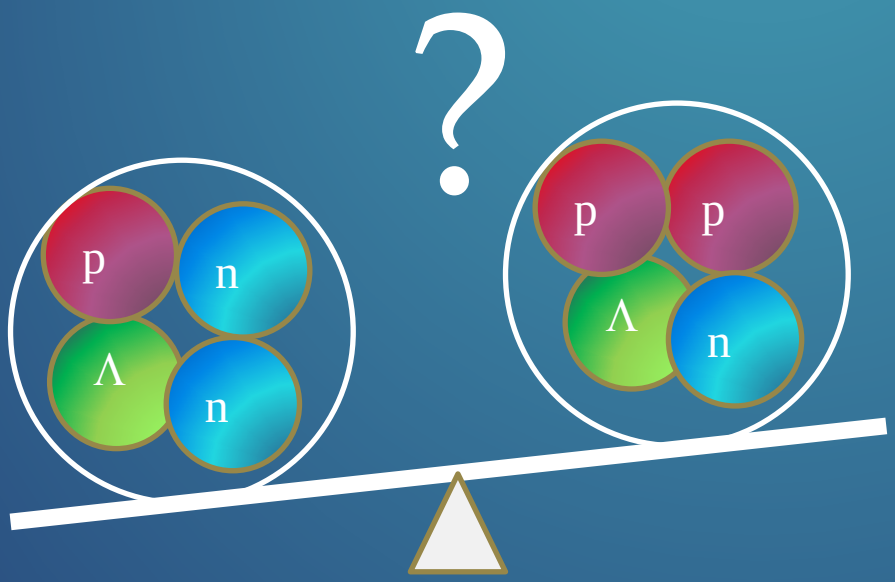
egistration		
. Fukuda	Osaka E-C. Univ.	Opening address
. Fukuda		
.N. Nakamura	Tohoku Univ.	Spectroscopy of Lambda Hypernuclei
. Isaka	RCNP	Hypernuclear structure with antisymmetrized molecular dyna
. Funaki	Beihang Univ.	Clusters in 12C and 13_LC
. Umeya	NIT	P-shell hypernuclear structure and its production rates base
unch		
. Ren	Nanjing Univ.	
. Nemura	Tsukuba Univ.	Lambda-N and Sigma-N interactions from 2+1 lattice QCD
. Harada	Osaka E-C. Univ.	Production of hypernuclei
. Honda	Osaka Univ.	Recent progress of search for H6-Lambda via the 6Li(pi-, K
. Fujioka	Kyoto Univ.	A plan to search for a tetraneutron state in the 4He(pi-,pi+)
. Tokiyasu	Tohoku Univ.	Hypernuclear spectroscopy via the real photo-induced reacti
reak		
. Noumi	RCNP/KEK	
. Nagae	Kyoto Univ.	Spectroscopy of S=-2 systems with (K-, K+) reaction
. Motoba	Osaka E-C. Univ.	Production and structure of Ξ-hypernuclei
. Sasaki	YITP	QCD simulations on the S = -2 baryon-baryon interaction
-S.Geng	Beihang Univ.	A relativistic formulation of baryon-baryon interactions in ch
. Ekawa	Kyoto Univ.	Experimental study of double hypernuclei with a hybrid emuls
	Ekimae campus	
. Hiyama	RIKEN	
. Zhao	IHEP	Understanding the shortened lifetime of Hypertriton
. Nagao	Tohoku Univ.	Design of an experiment for hypernuclear lifetime measureme
reak		
. Harada	Osaka E-C. Univ.	
. Sakuma	RIKEN	Experimental studies on the Kbar

T. Sekihara	JAEA	On the structure observed in the in-flight 3He (K-, Lambda p) n reaction at J-PARC
Renli Xu	Nanjing Univ.	Dynamics of kaonic nuclei in an improved quark mass density-dependent model
K. Inoue	RCNP	Analysis status of the d(K-,n)pi+ Sigma-+ and d(K-,p) pi-Sigma 0 at J-PARC K1.8BR beam line
Lunch		
Q. Zhao	IHEP	
H. Ohnishi	RIKEN	Phi meson in nucleus at J-PARC
Y. Yamaguchi	RIKEN	Quark mass dependence of H-dibaryon in Lambda-Lambda scattering
X-H. Zhong	Hunan Univ.	KN scattering and hyperon resonance
Break		
T. Nagae	Kyoto Univ.	
H. Noumi	RCNP	Baryon Spectroscopy with Heavy Flavors at J-PARC
Y. Ikeda	RCNP	Charm hadron interactions from lattice QCD
S. Yasui	TIT	Kondo effect for charm hadrons in nuclear matter
T. Miyamoto	YITP	Lambda_c N interaction from lattice QCD and Lambda_c nuclei
T. Hyodo	YITP	Universal physics of two neutrons with one flavored meson
Workshop dinner		
	Ekimae campus	
H. Tamura	Tohoku Univ.	
A. Ohnishi	YITP	Recent developments in strangeness nuclear physics and the hyperon puzzle
R. Xu	Peking Univ.	Strangeness in Compact Stars
H. Togashi	RIKEN	Hyperon stars at zero temperature with the variational method
Break		
Y. Ma	CAS	
J. Hu	Nankai Univ.	The strangeness quark mean field theory
C-J. Xia	CAS	Quark matter in compact stars: implication from recent observations
Y. Yamamoto	RIKEN	B-B interaction and neutron star EOS
Lunch		
X-R. Zhou	East China Normal Univ.	
Y. Ma	CAS	Strangeness production in RHIC beam energy scan
P. K. Saha	JAEA	Strangeness int... beam acceleration ...
K. Tanida	JAEA	...stable new Lambda* resonance with J^P=3/2+ in ... Lambda_c decay and K-p -> Lambda eta
E. Hiyama	RIKEN	Closing

Recent

Mysteries in Hypernuclear Physics

Large CSB for A=4 hypernuclei



Hyperon Puzzle

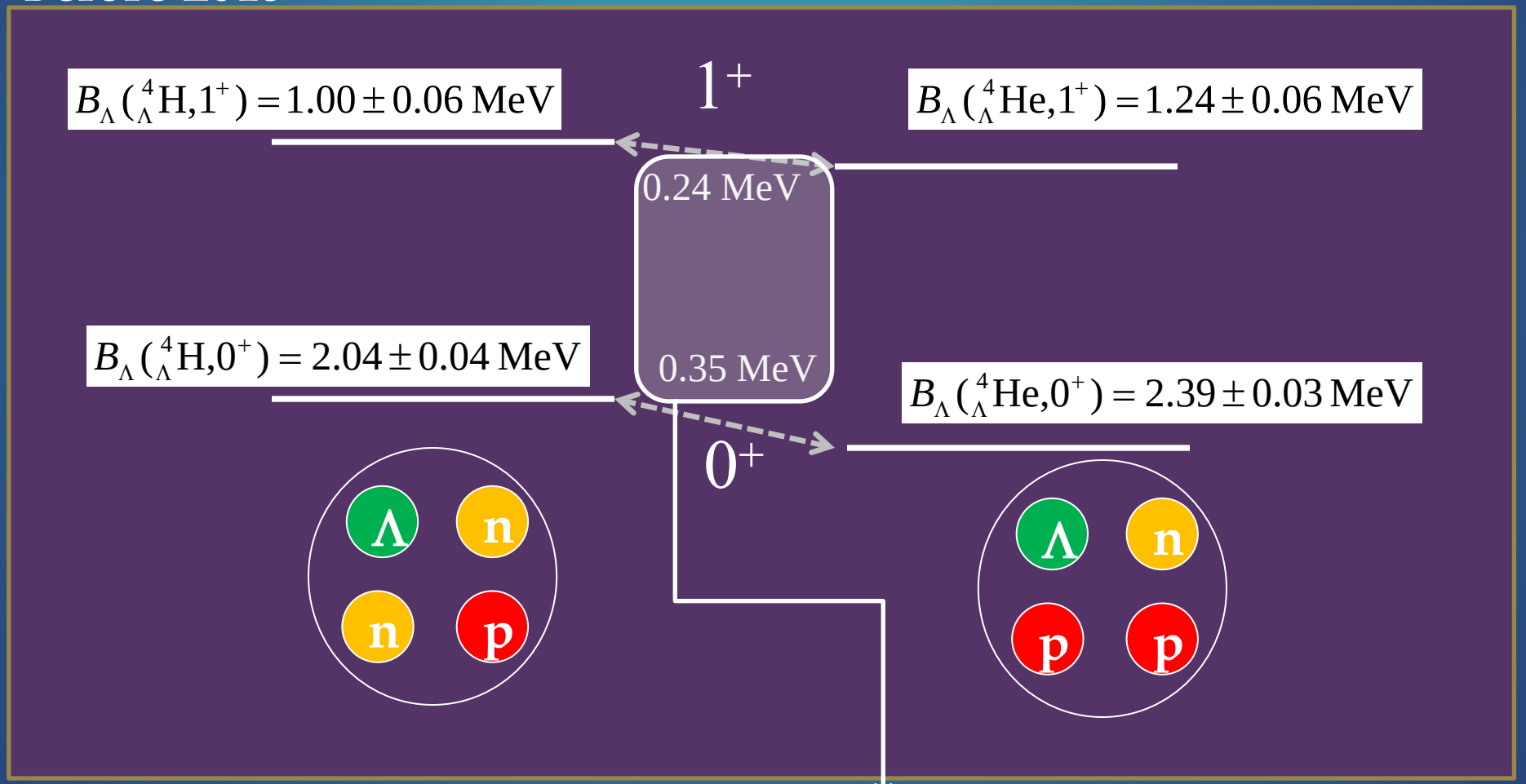
Two solar mass neutron stars

Charge Symmetry Breaking of the ΛN interaction

A=4 system
CSB ΛN potential

Data from
Emulsion
NaI γ-ray

Before 2015



Coulomb effect is very small.

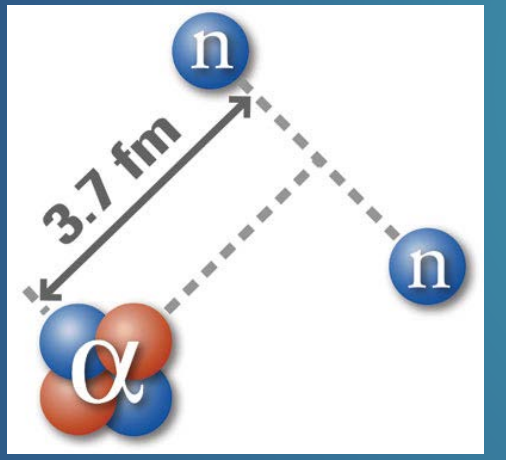
$-\Delta B_c = 0.050 \pm 0.02$ MeV ,

$-\Delta B_c^* = 0.025 \pm 0.015$ MeV

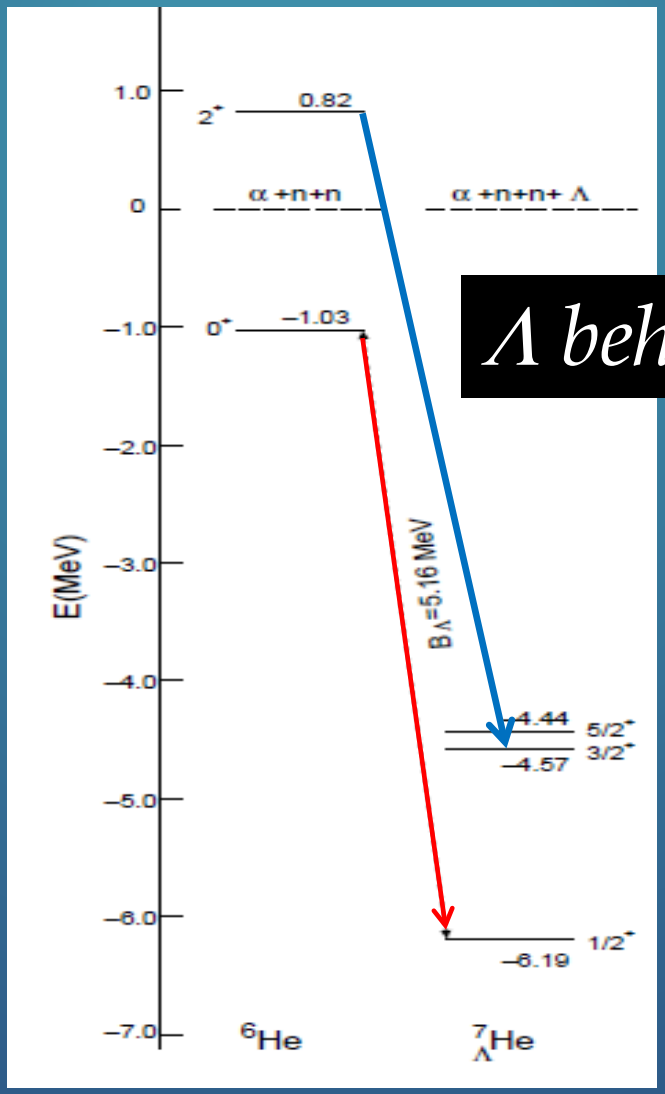
Charge Symmetry Breaking

cf) B(^{3}H)-B(^{3}He)-ΔB_c ~ 70 keV

${}^{7}_{\Lambda}\mathrm{He} = {}^{6}\mathrm{He} + \Lambda$



^{6}He : 2n halo

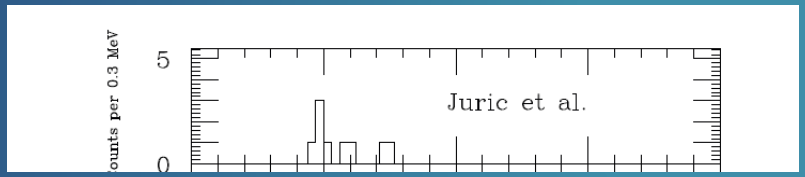


Λ behaves like glue

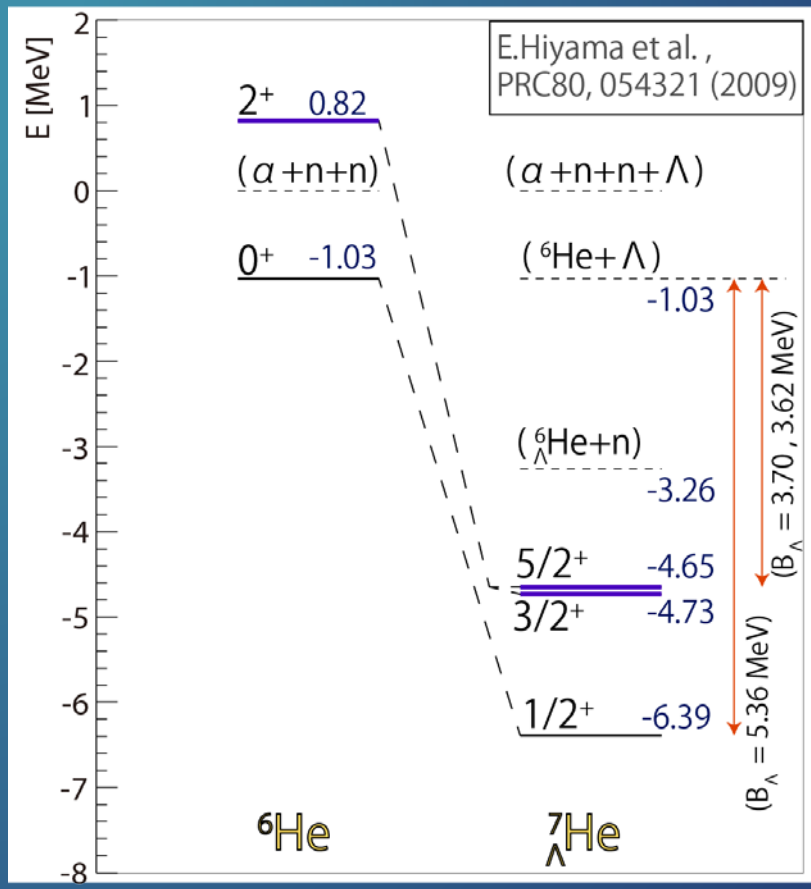
E.Hiyama et al. PRC 80, 054321 (2009)

$^{7}_{\Lambda}$He spectrum

Juric et al., Nucl. Phys. A484 (1988) 520



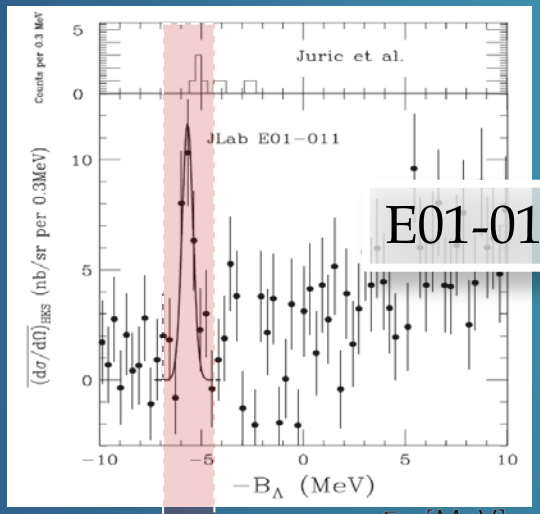
No B_{Λ} was obtained.

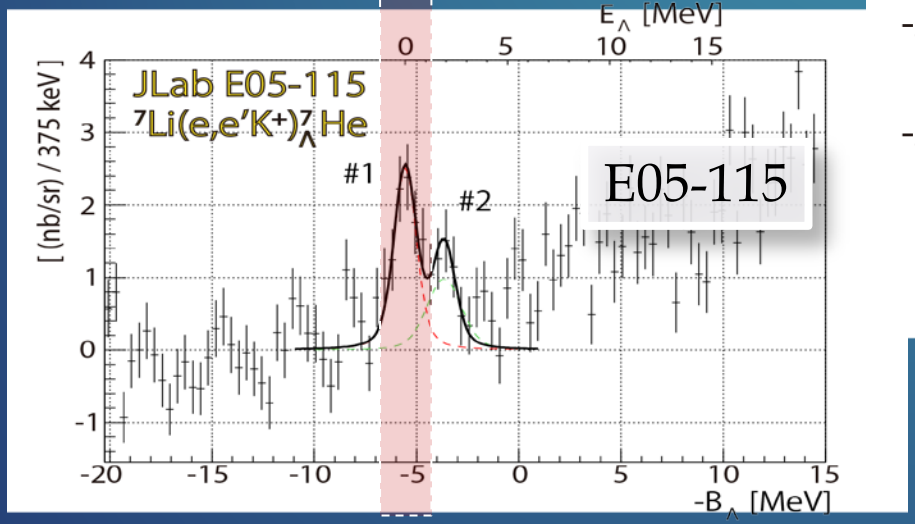


CSB interaction test for A=7

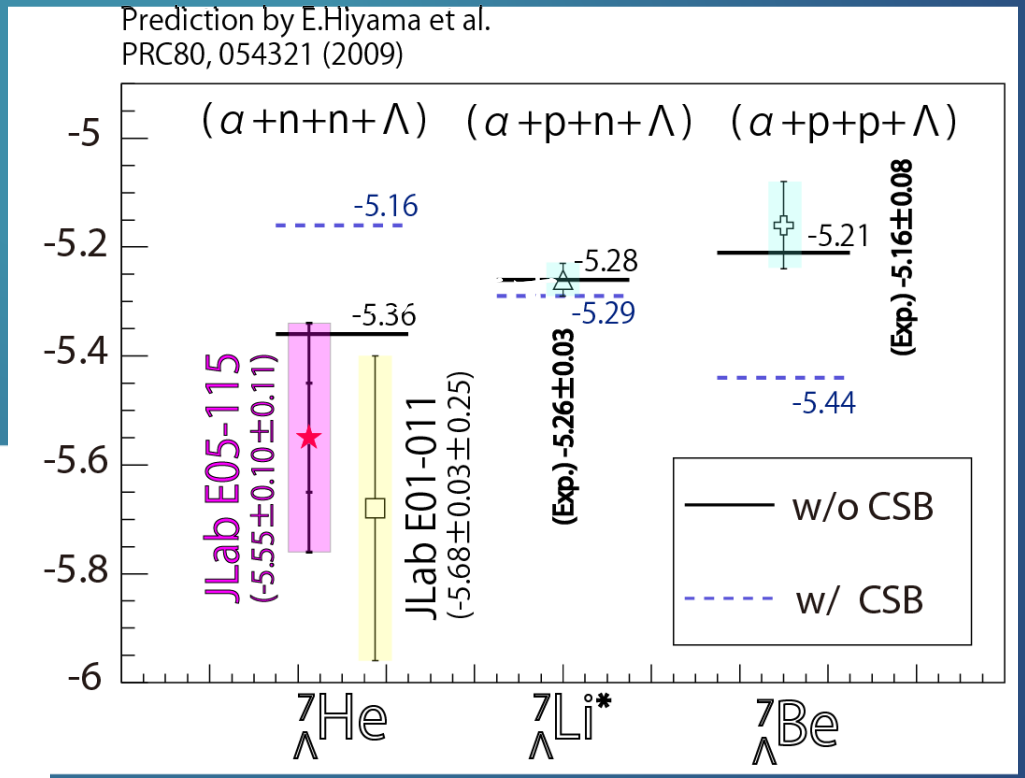
$^{7}\mathrm{Li}(e,e'K^{+})^{7}_{\Lambda}\mathrm{He}$

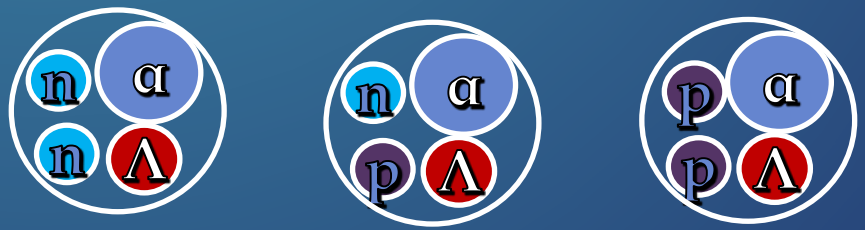
SNN et al., PRL 110, 012502 (2013)





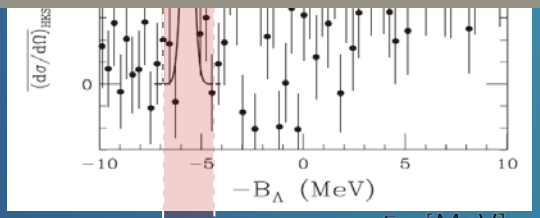
T.Gogami et al., PRC 94 (2016) 021302(R)

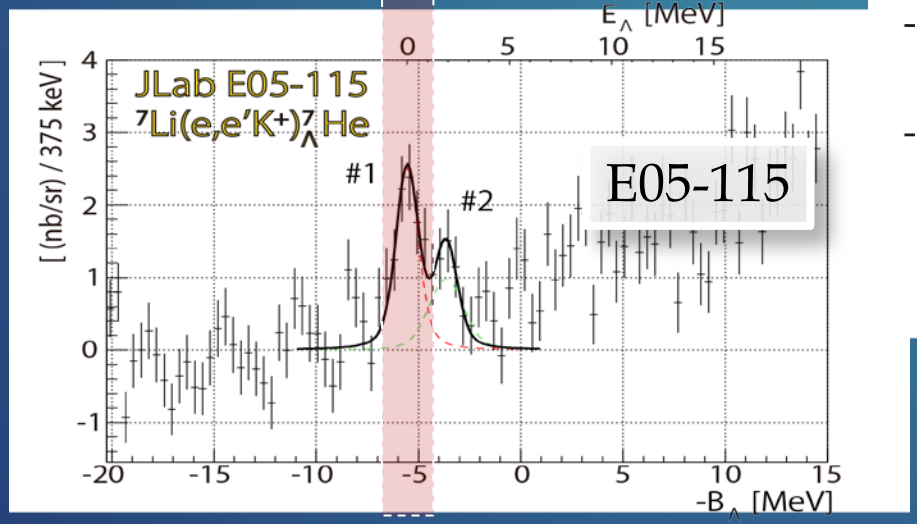




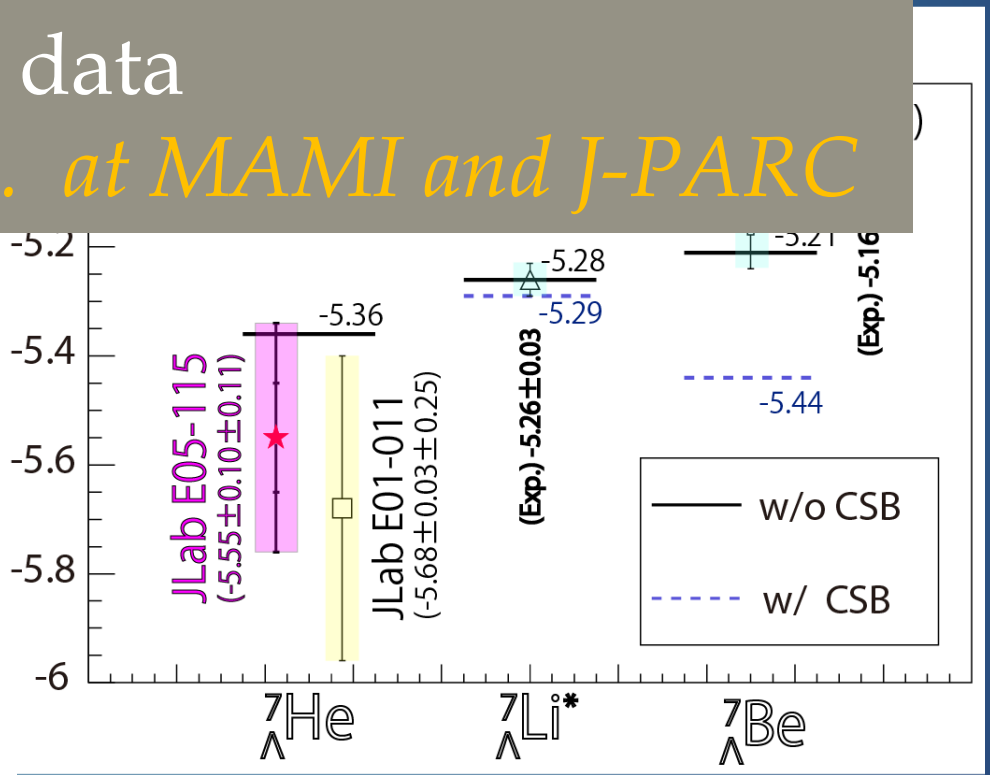
CSB interaction test in A=7

CSB potential is not necessary for A=7
Assumed CSB potential is too naïve or problem for A=4 data
→*New exps. at MAMI and J-PARC*





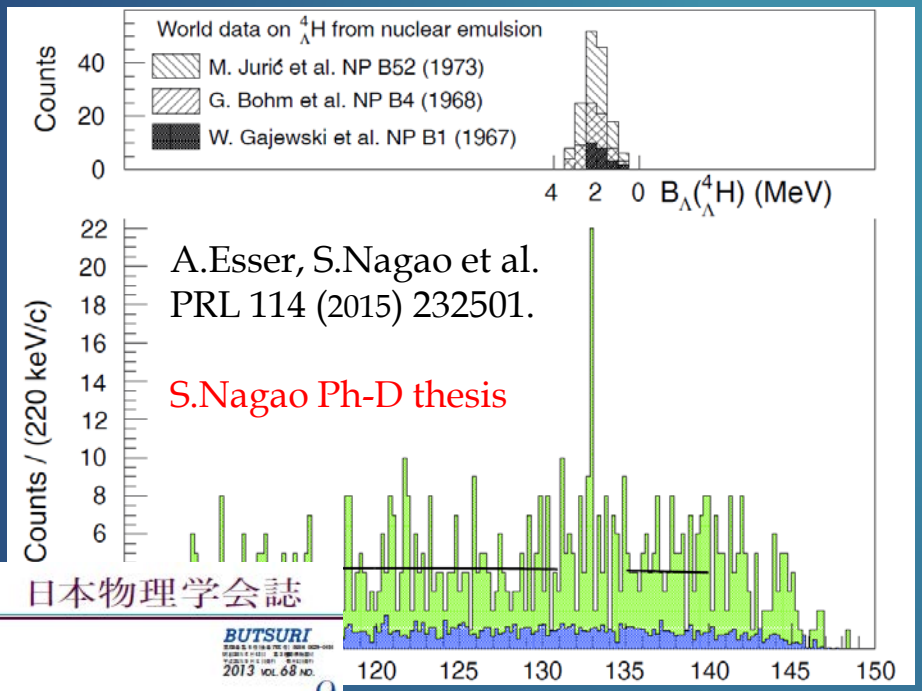
T.Gogami et al., PRC 94 (2016) 021302(R)



New Experiments at Mainz and J-PARC

$^{4}_{\Lambda}$H

$^{4}_{\Lambda}$He

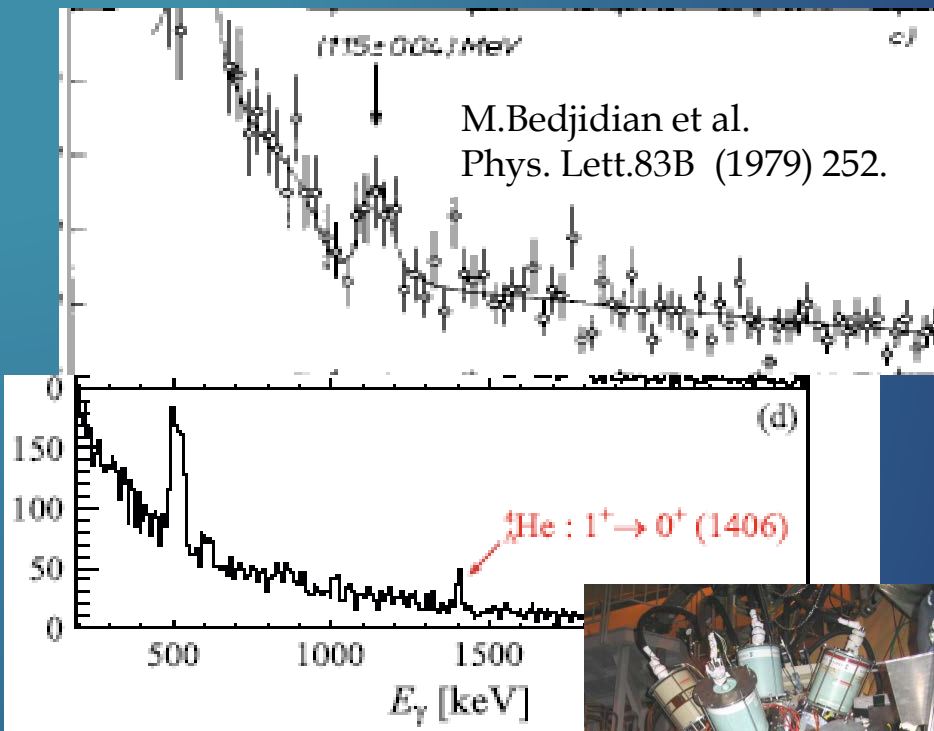


A.Esser, S.Nagao et al.
PRL 114 (2015) 232501.

S.Nagao Ph-D thesis

日本物理学会誌

BUTSURI 2013 VOL.68 NO.9



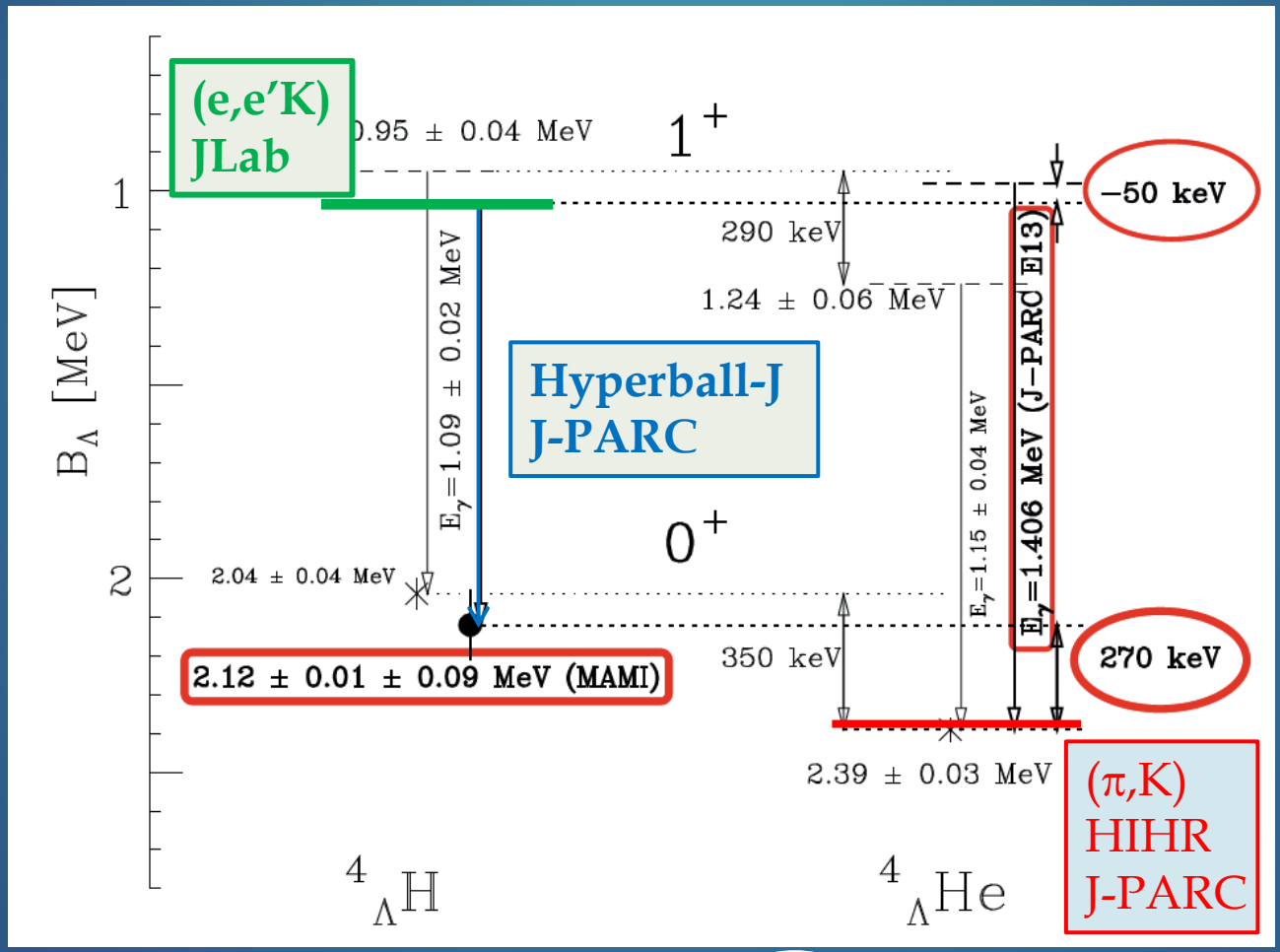
T.O.Yamamoto et al.
PRL 115 (2015) 222501.

T.O.Yamamoto Ph-D thesis

New Decay π spectroscopy @ MAMI

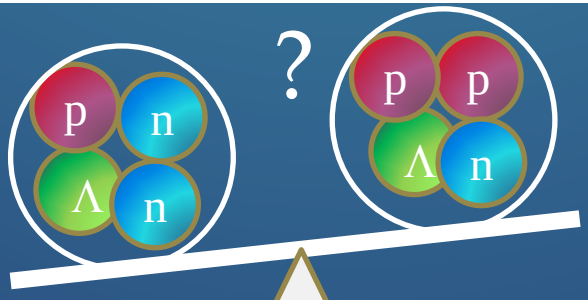
Hyperball Experiment @ J-PARC

CSB for A=4 hypernuclei : Current Status



Small CSB

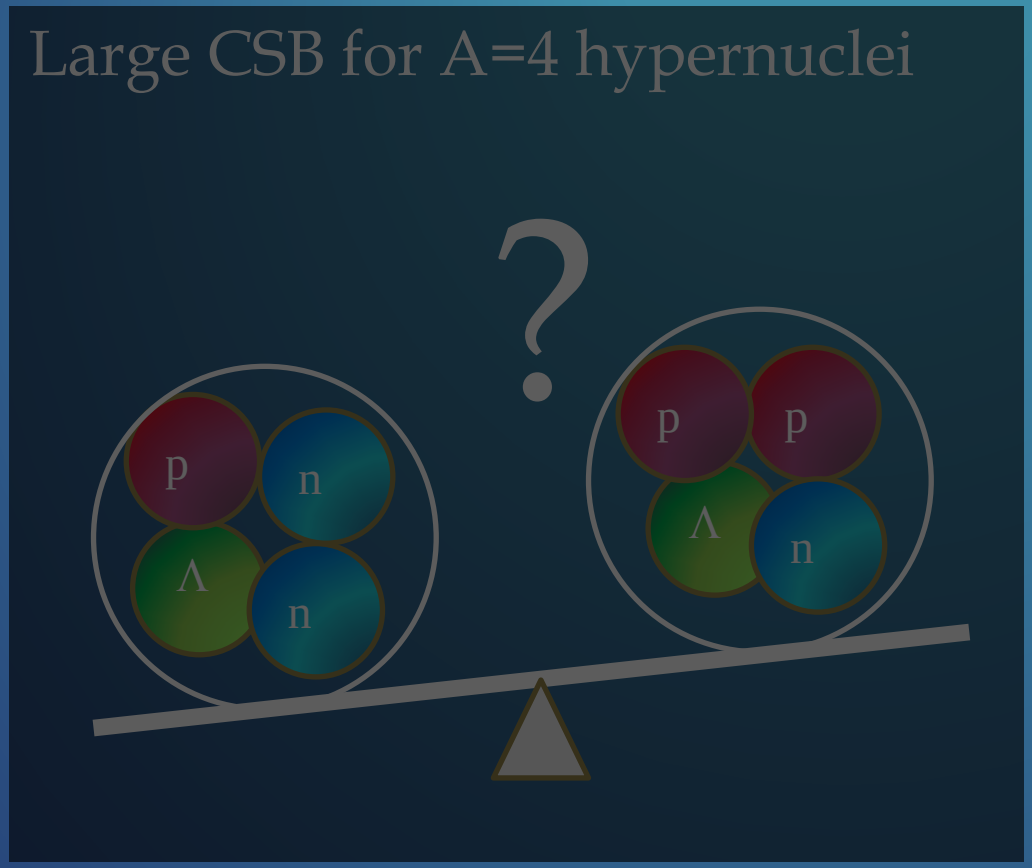
Large CSB



ΛN-ΣN coupling is a key

Recent

Mysteries in Hypernuclear Physics



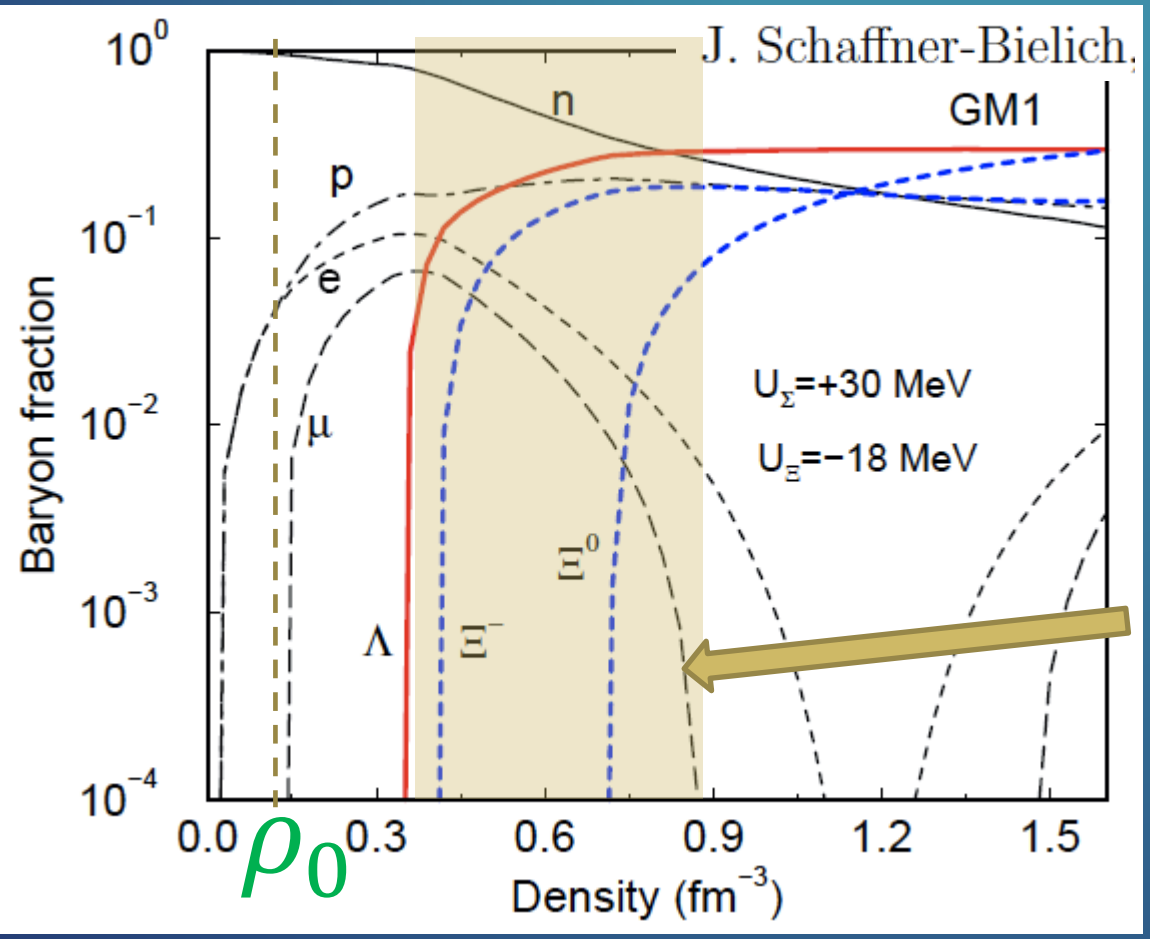
Hyperon Puzzle

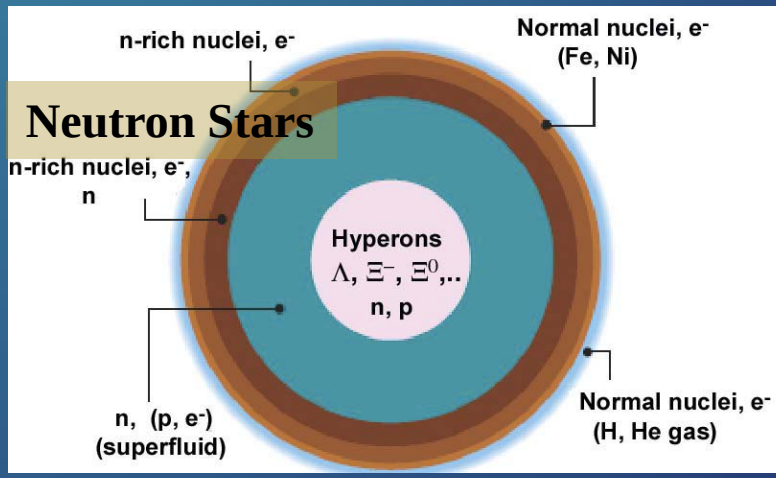
Two solar mass neutron stars

Neutron star and Strange hadronic matter

Sym. Nucl. Matter : Limit for size (due to Coulomb force)

Asym. Nucl. Matter : Neutron Stars, Strange Hadronic Matter

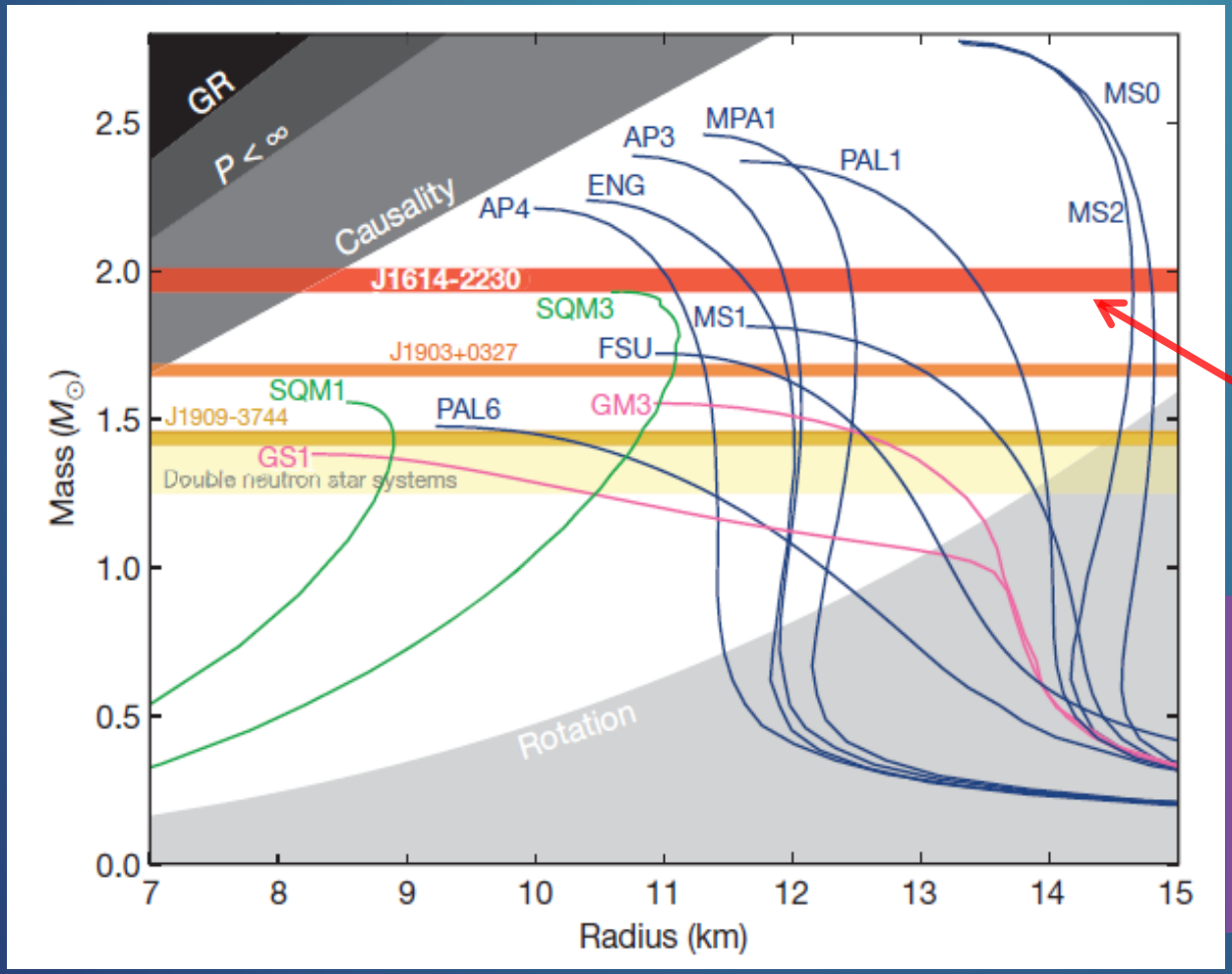




Hyperon Puzzle

Based on our knowledge on Baryonic Force:

Hyperon should appear at high density ($\rho=2\sim3\rho_0$)



Too Soft EOS

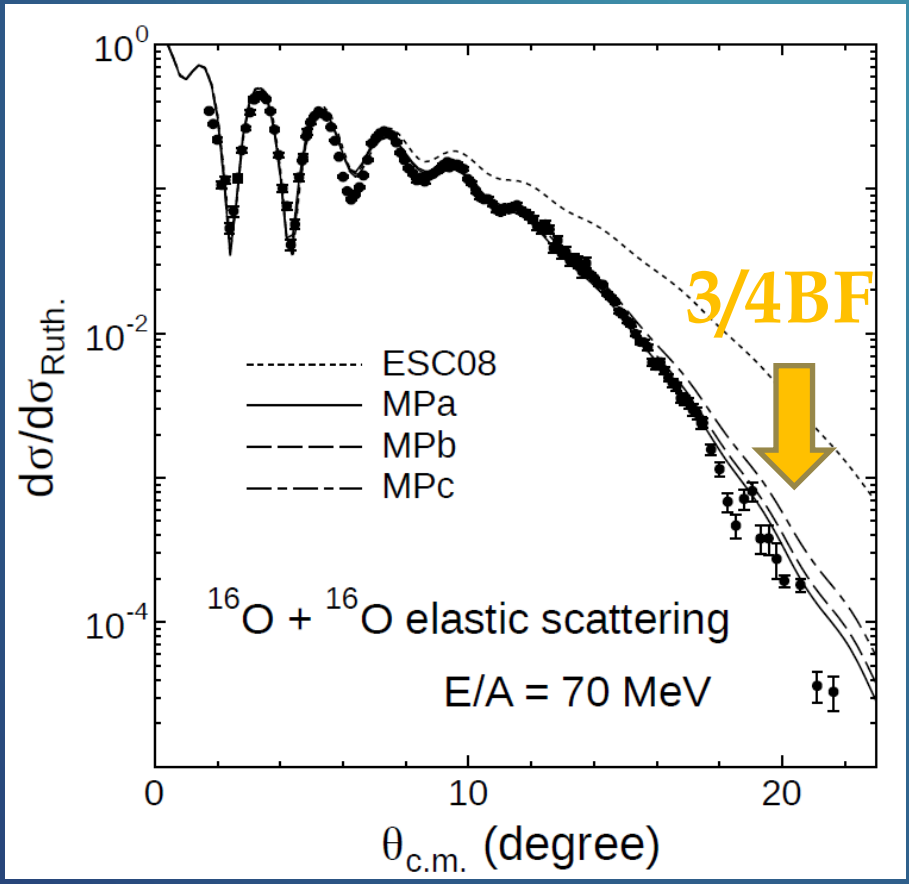
Contradict to observation

2 M_{solar} Neutron Stars

Hyperon Puzzle :
One of most important issues to be solved in nuclear physics

EOS of nuclear matter

Microscopic nuclear force model @ $\rho_0 \rightarrow 2\,\rho_0$



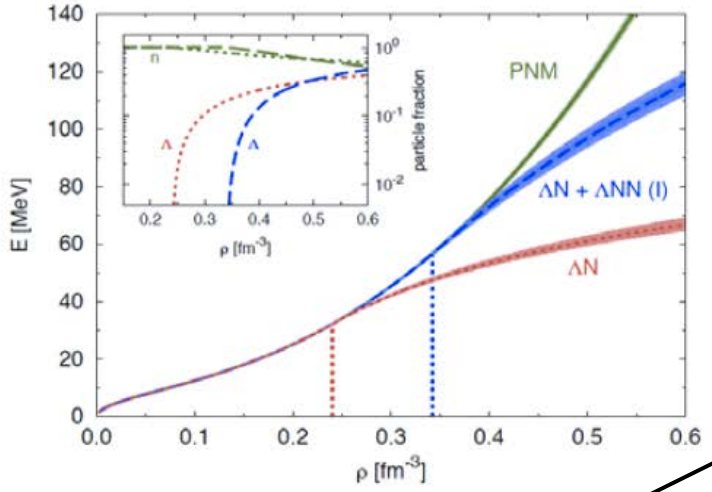
Higher density

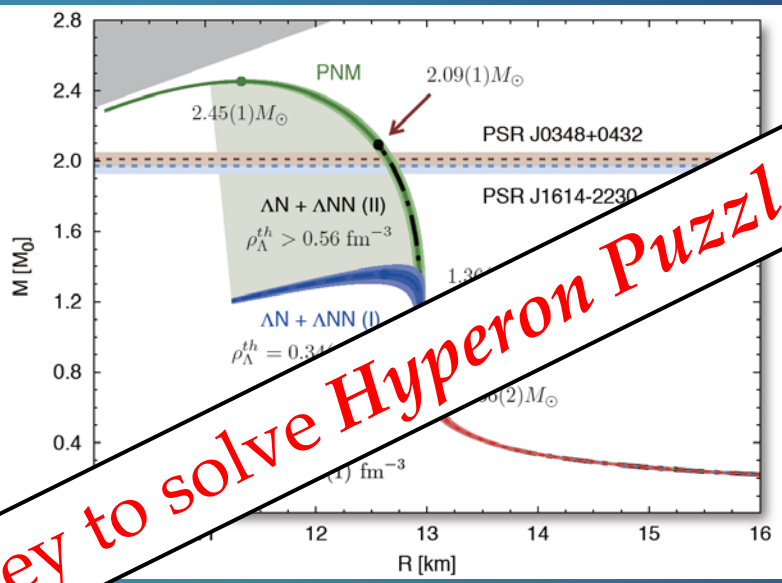
3B/4BF play key roles

Promising scenario to solve Hyp. Puzzle
Repulsive 3B/4B force in YN sector

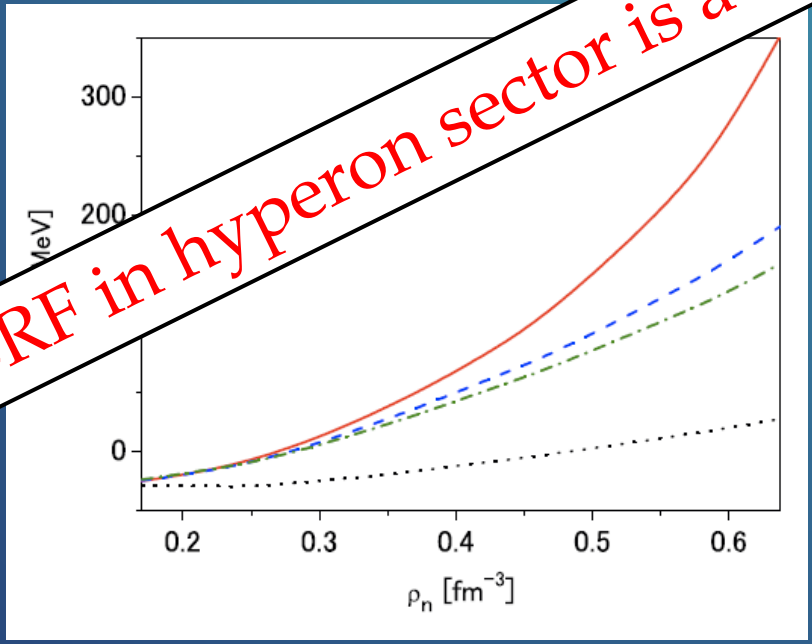
Furumoto, Sakuragi, Yamamoto, PRC 79 (2009) 0011601(R)

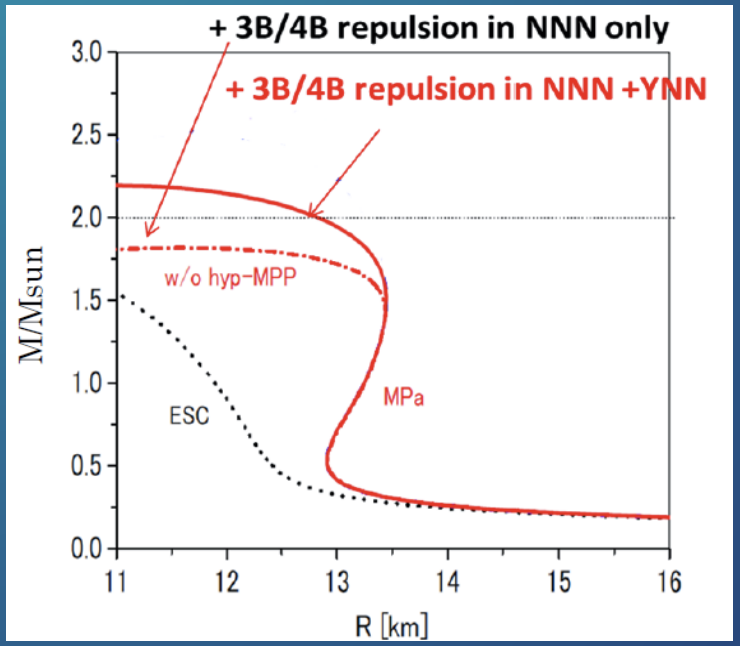
AFDMC by Lonardoni et al. PRL114 (2015) 092301, updated (2016)





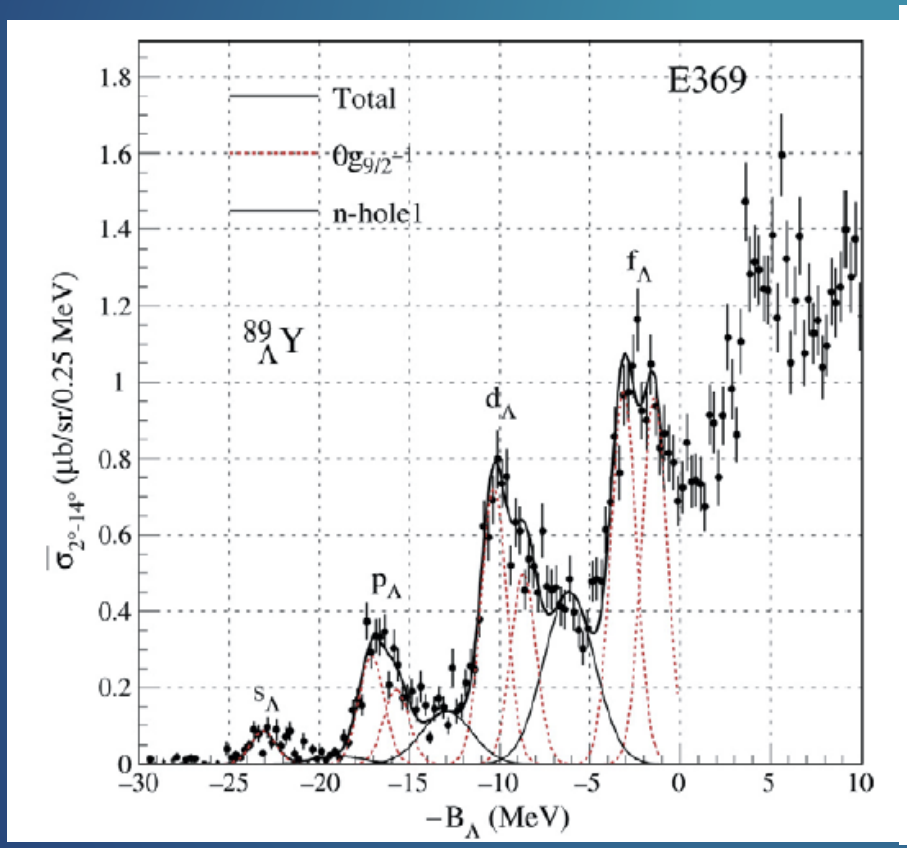
3BRF in hyperon sector is a key to solve Hyperon Puzzle!





ESC08c + 3B/4B RF : G-Matrix Calc. by Yamamoto et al., PRC 90 (2014) 045805.

Mid-heavy data from (π,K) exp.



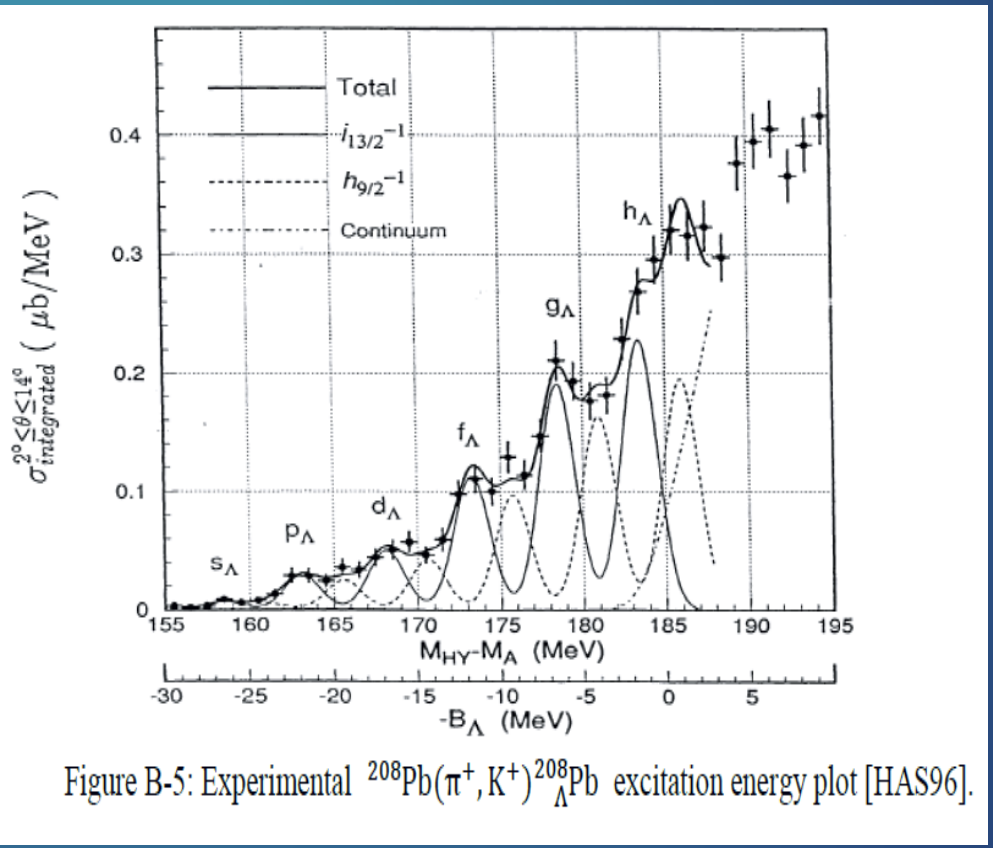
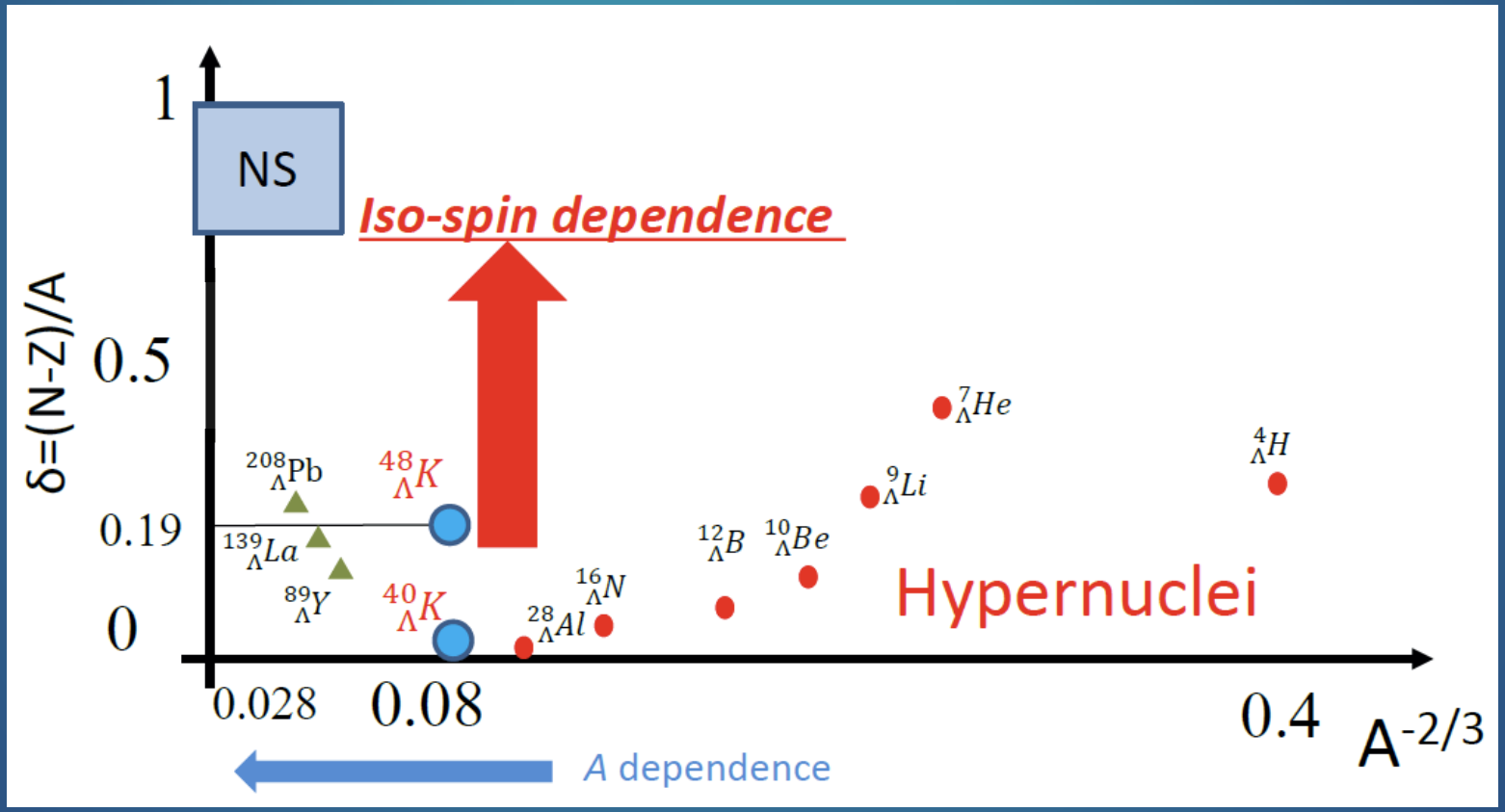


Figure B-5: Experimental ^{208}Pb$(\pi^+,K^+)^{208}_{\Lambda}$Pb excitation energy plot [HAS96].

From hypernuclei to neutron star

$^{40,48}\mathrm{Ca}(e,e'K^+)^{40,48}_{\Lambda}\mathrm{K}$ ^{48}Ca and ^{40}Ca targets

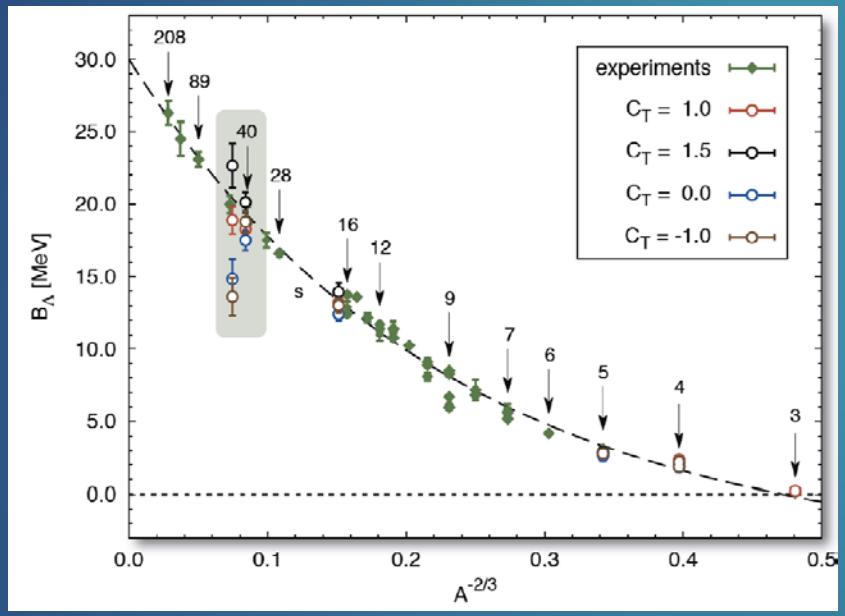


Key issues : *A* Dependence of 3BRF

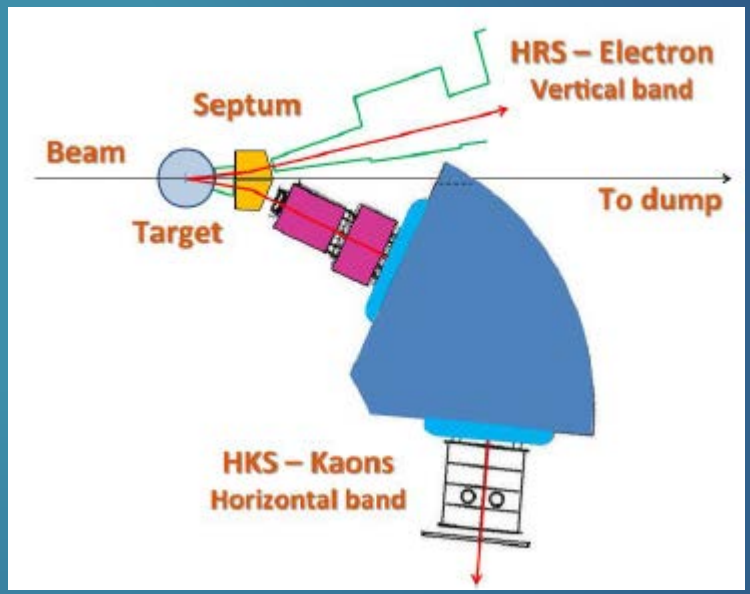
Iso-spin Dependence

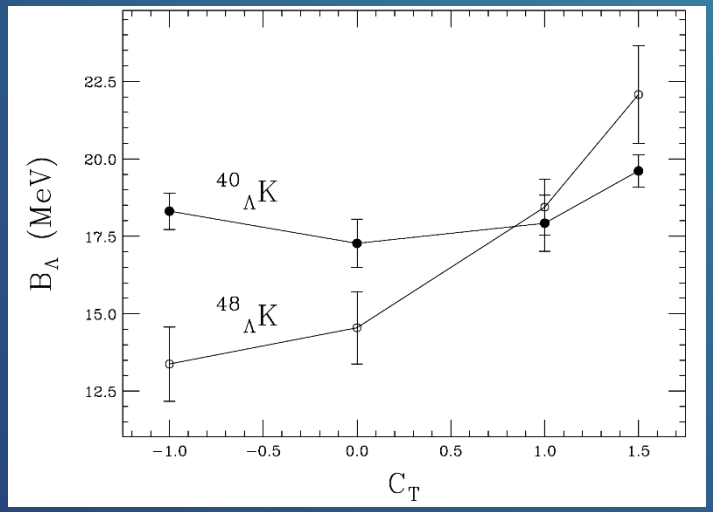
So far, NO experimental inputs for iso-spin dependence in mid-heavy HY

Phenomenological 3BRF+AFDMC



JLab Hall-A





^{40}Ca(e ,e′K$^+$)$^{40}_{\Lambda}$K and , ^{48}Ca(e, e′K$^+$)$^{48}_{\Lambda}$K

New experiment was approved as E12-15-008.

New Septa magnet + HKS + HRS

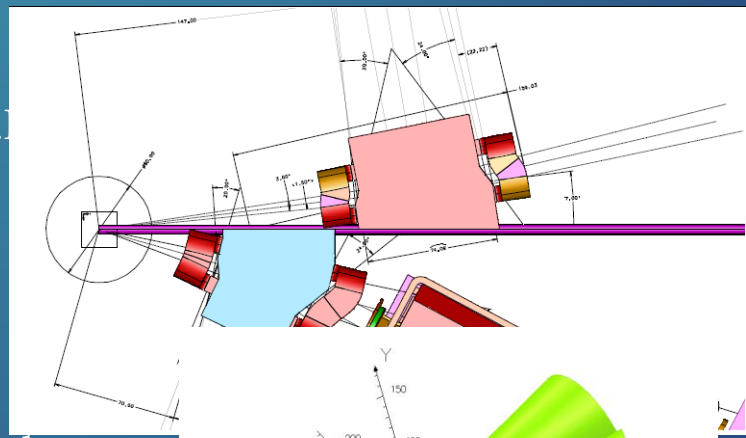
JLab Hypernuclear WS May 27-29, 2014
2nd JLab Hypernuclear WS 14, 15 March 2016

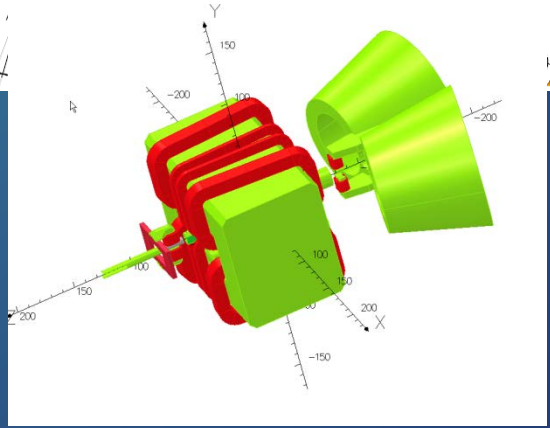
JLab Hypernuclear Collaboration Meeting 23, 24 March, 2017

- 10:00 Opening : Nue Nakamura
  10:15 Hall Status : Steve Wood
  10:30 Status of Septum magnet design : Nakamura, Aida
  11:00 HKS platform design and Hall-A floor plan : Robin Wines, Alan Gavalya
  Discussion about Mechanical items
  Sieve Slit, Collimator, Interface between Septa and HKS/HRS
  11:45 Magnets PS requirements, Hall-A Power, Water : Jack Segal, Nakamura

  12:15-14:00 Lunch Break

  14:00 Target (Ca40, 48) : Nakamura based on report by D.
  14:30 Hall-A DAQ : Alexandre Camsonne
  15:00 HKS Detectors
  HDC : Tang
  HTF : Gogami
  AC : Reinhold
  WC : Gogami
  HRS Detectors : TBA
  17:00 Discussion (necessary resources) & Summary of 1st day



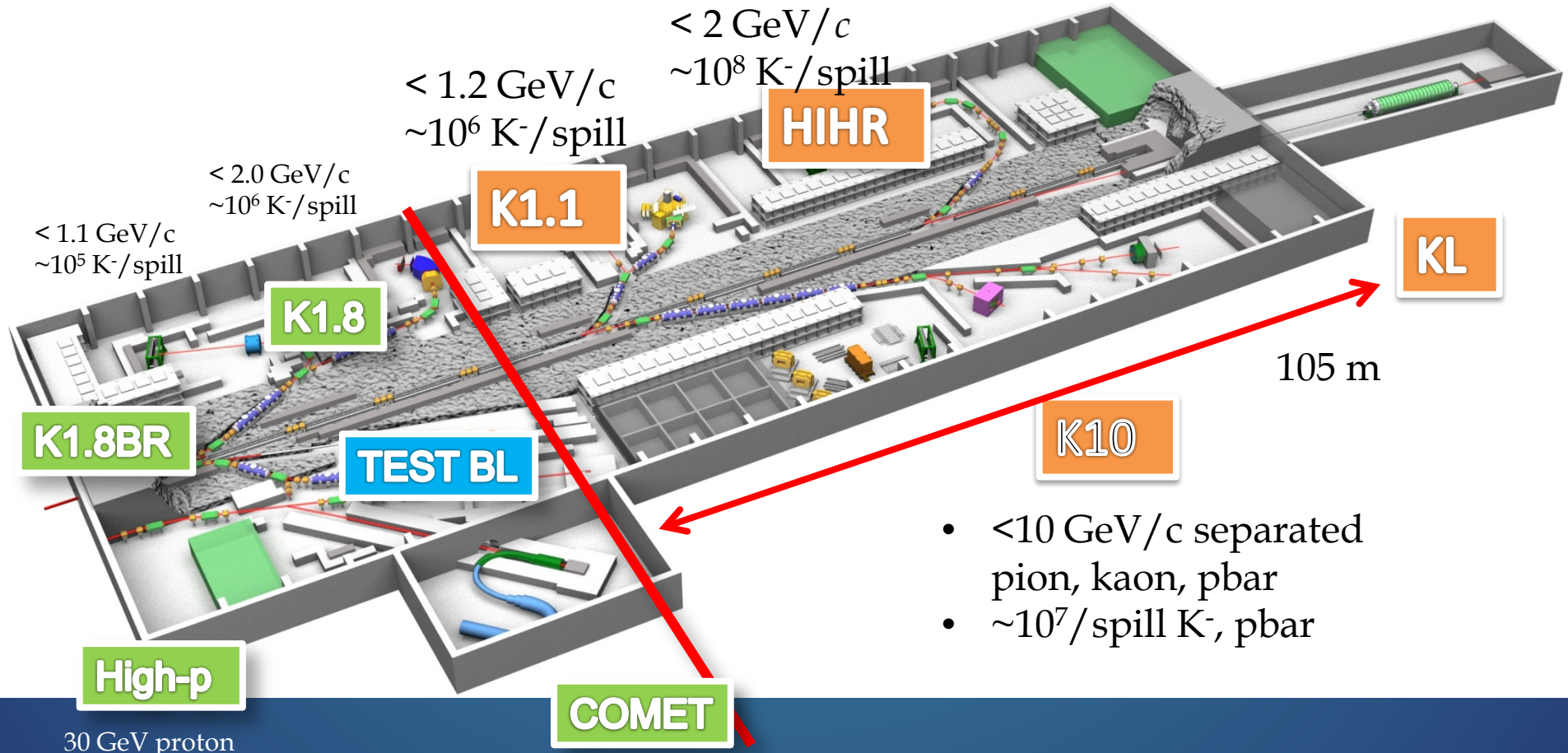


New Project@J-PARC

Hadron Experimental hall Extension

Selected as one of 4 high-priority projects
at KEK Program Implementation Plan Committee
(May 2016)

WP DL and supporter sign-up from:
https://**kds.kek.jp/indico/event/23853/**



- <10 GeV/c separated pion, kaon, pbar
- ~10^7/spill K^-, pbar

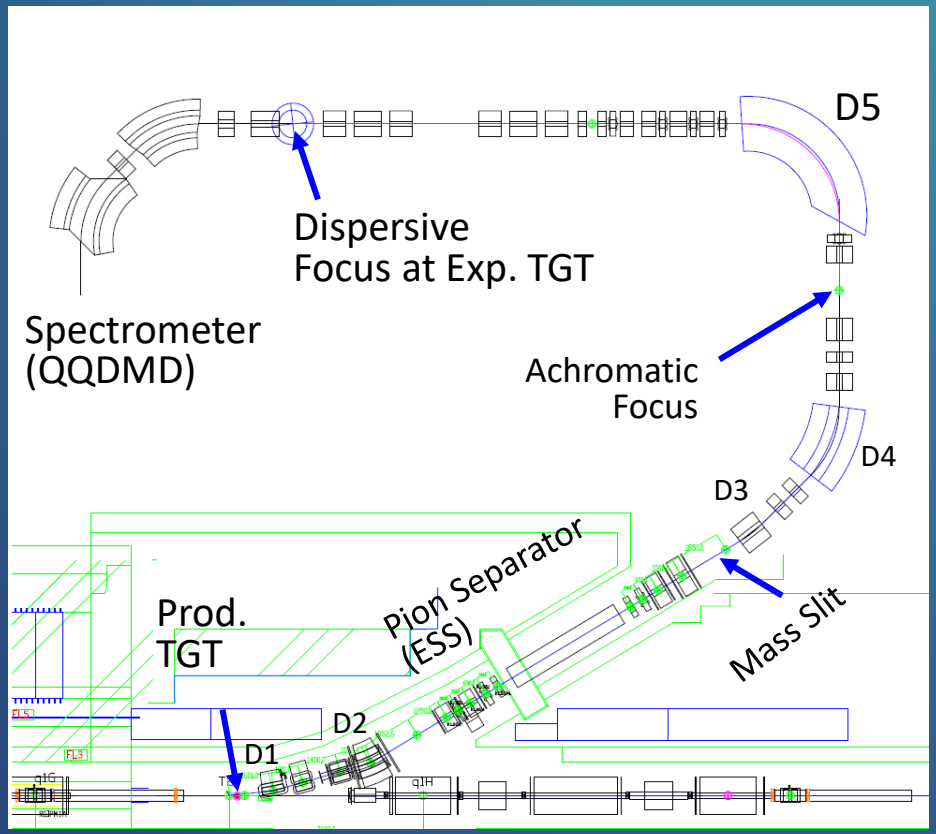
30 GeV proton
<31 GeV/c unseparated 2ndary beams
(mostly pions), ~10^7/spill

Muon

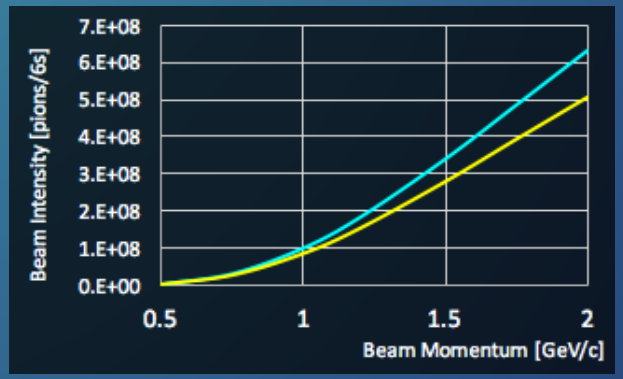
Future Plan at J-PARC : HIHR

Present beam lines:
~10^6 pions/pulse, $\Delta p/p \sim 1/1000$

- High-Intensity High-Resolution Beam line
  for High Precision (π, K^+) Spectroscopy with ΔE=0.1 MeV
  - Dispersion matching + no beam tracking



Intensity: ~ 1.8×10^8 pion/pulse
(1.2 GeV/c, 58 m, 1.4msr*%,
100kW, 6s spill, Pt 60mm)
$\Delta p/p \sim 1/10000$



Complementary Program
to the JLab program

Summary

CSB of Λ hypernuclei

Determination of $B_\Lambda(^7_\Lambda He_{gs})$ triggered intensive study for A=4 iso-doublet hypernuclei ($^4_\Lambda H$ and $^4_\Lambda He$)

⇨ Mainz : Decay π spectroscopy
J-PARC E13 : γ–ray spectroscopy

Indicates that 0^+ large CSB, 1^+ small CSB

ΛNN 3BRF to solve the hyperon puzzle

New experiment for ($^{40}_\Lambda K$ and $^{48}_\Lambda K$) is under preparation to clarify the isospin dependence of 3BRF which is necessary to solve the hyperon puzzle.

⇨ Future HIHR at J-PARC Extended Hadron Hall