Hyperon-Hyperon Interactions & Exotic Di-Hyperons Workshop

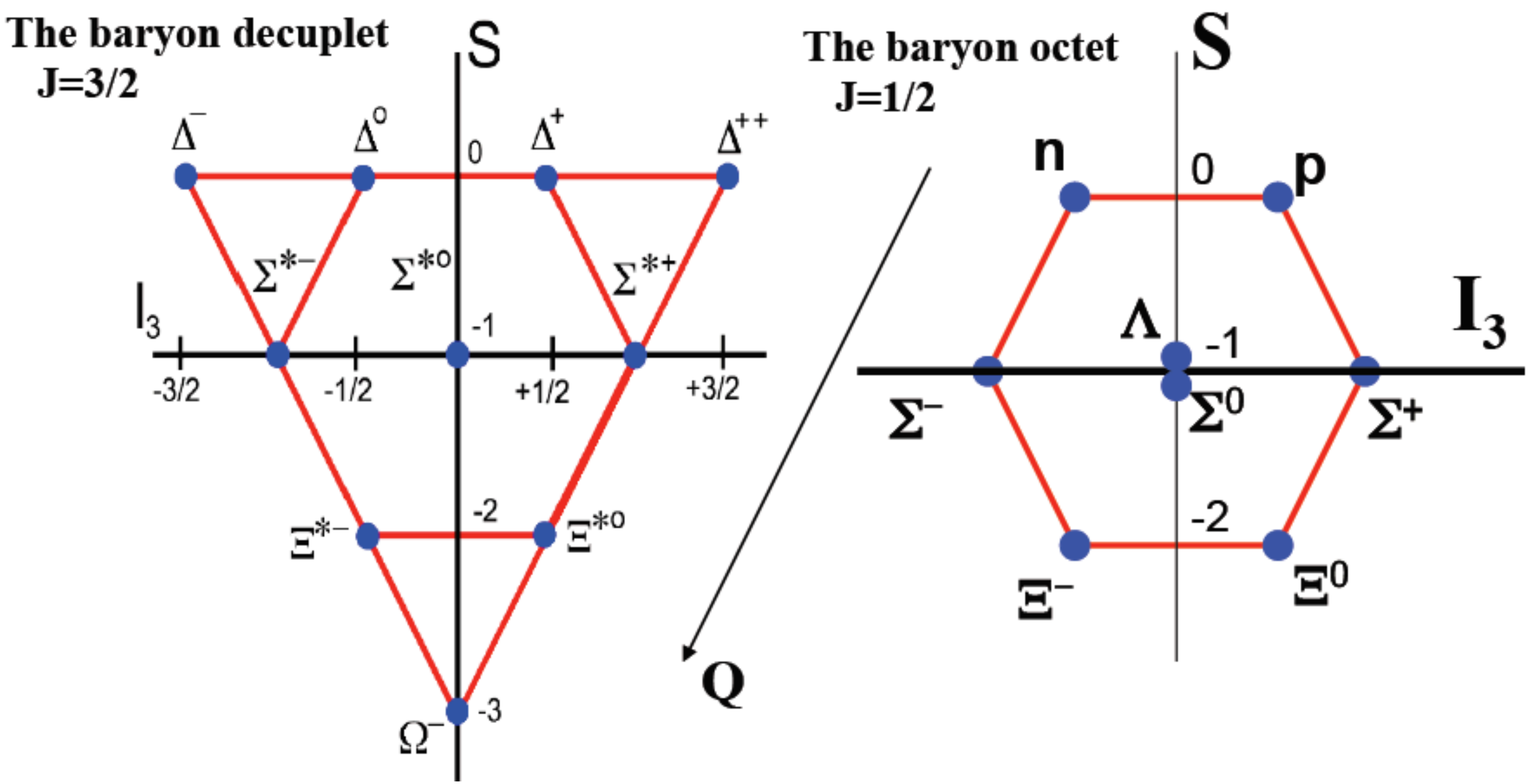
Summary Lecture

Berndt Müller

RBRC ***HHI Workshop***

29 Feb - 2 March 2012

The ground state baryons



Why Nuclear Collisions?

- Nuclear collisions at RHIC and LHC equilibrate s-quarks thermally and chemically.
  - All possible hadronic states made of (u, d, s) quarks should be produced “copiously”.
  - Production of hadrons from deconfined (QGP) phase should facilitate production of non-molecular multi-quark states, if they exist.
  - Study of two-particle interactions should be possible, because hadron pairs of all kinds are produced copiously within a small volume.
  - Large and growing datasets exist.
  - Powerful detectors with excellent particle-ID are available.

Part 1

Theorists' dreams

Theorists’ dreams I

The Historic

Production of the *H* dibaryon in relativistic heavy-ion collisions

C. B. Dover, P. Koch,* and M. May
Brookhaven National Laboratory, Upton, New York 11973
(Received 8 March 1989)

We discuss mechanisms for the production of exotic hadrons in heavy-ion collisions at high energy, focusing on the doubly strange H dibaryon. In a hadron gas phase, we estimate the H formation rate, per central Si+Au collision, to be of order 0.01 for temperatures $T = 120-140$ MeV, based on a conventional coalescence model. If the quark-gluon plasma phase is excited, we expect an enhancement relative to the rate for a hadron gas. We explore various schemes for detecting the H in the high multiplicity background characteristic of heavy-ion collisions. The proposed detection techniques include the measurement of weak decays such as $H \rightarrow \Sigma^- p$, the search for nuclear fragments with anomalous charge/mass ratio, and diffractive dissociation processes such as $Hp \rightarrow \Xi^- pp$.

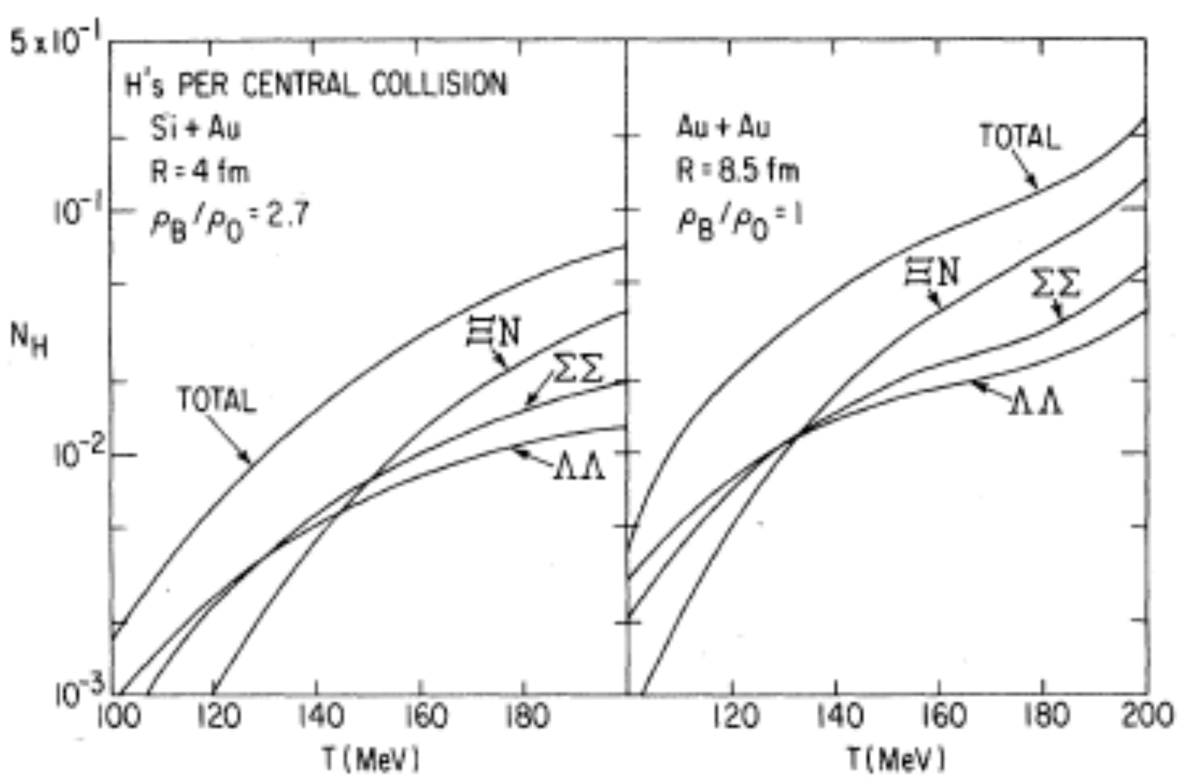


FIG. 4. The total number of H's per central collision and the individual baryon-baryon fusion contributions are shown as a function of temperature for Si+Au collisions (left-hand side) and Au+Au collisions (right-hand side).

Brief Interlude

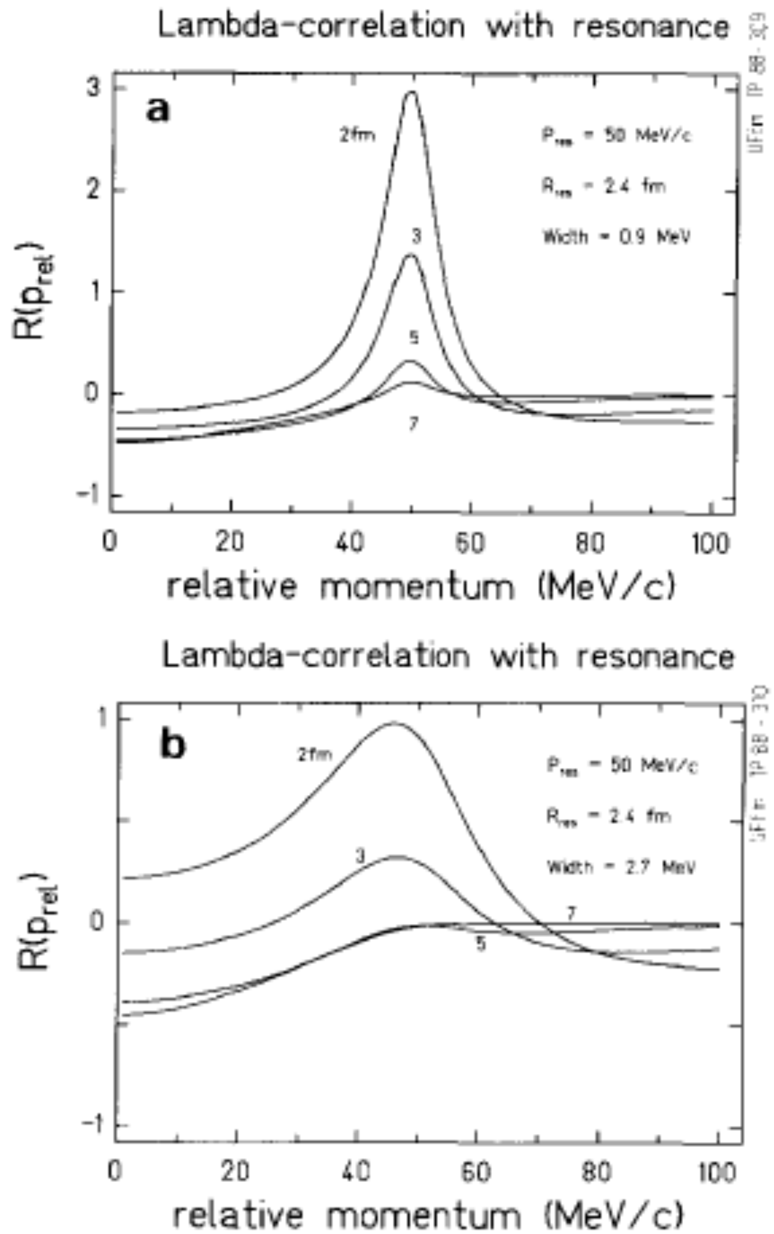
Why the "H" is really the "Eτα"

The η meson is a S=0, I=0 hadron with B=0

The H di-baryon is a S=0, I=0 hadron with B=2

But even Bob Jaffe gave up on fighting for the "correct" pronunciation.
Besides, who cares if the particle does not exist.....

Theorists’ dreams II



PAIR CORRELATIONS OF NEUTRAL STRANGE PARTICLES EMITTED IN RELATIVISTIC HEAVY ION COLLISIONS

Carsten GREINER [1]
Nuclear Science Division, Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA

and

Berndt MÜLLER
Institut für Theoretische Physik, J.W. Goethe-Universität, Postfach 111932, D-6000 Frankfurt am Main

Received 19 September 1988; revised manuscript received 28 December 1988

Our article is organized in the following way: In the next section we present a brief derivation of the two-particle correlation function (HBT-effect), where we also consider the effect of a possible Λ–Λ resonance. We then present model calculations for various correlation functions and discuss the possible influence of the dibaryonic H-particle on the Λ–Λ correlation.

Note: Assumed QGP source radius (2.4 fm) is too small → resonance effect is overestimated.

Theorists’ dreams III

The Bold

VOLUME 58, NUMBER 18 PHYSICAL REVIEW LETTERS 4 MAY 1987

Separation of Strangeness from Antistrangeness in the Phase Transition from Quark to Hadron Matter: Possible Formation of Strange Quark Matter in Heavy-Ion Collisions

Carsten Greiner, Peter Koch, and Horst Stöcker
Institut für Theoretische Physik, Johann Wolfgang Goethe Universität, D-6000 Frankfurt am Main, West Germany
(Received 10 November 1986; revised manuscript received 25 March 1987)

We present a mechanism for the separation of strangeness from antistrangeness in the deconfinement transition. For a net strangeness of zero in the total system, the population of s quarks is greatly enriched in the quark-gluon plasma, while the $\bar{s}$ quarks drift into the hadronic phase. This separation could result in "strangelet" formation, i.e., metastable blobs of strange-quark matter, which could serve as a unique signature for quark-gluon plasma formation in heavy-ion collisions.

The Smart

NT@UW-06-16

Detecting Strangeness −4 Dibaryon States

Gerald A. Miller
University of Washington Seattle, WA 98195-1560

Recent experiments at Jefferson Laboratory and potential new facilities at the Japan Proton Accelerator Research Complex (J-PARC) make it evident that the discovery of a ${}^1S_0$ di-cascade bound state of two Ξ particles is feasible. We state the simple arguments, based on $SU(3)$ flavor symmetry, for the existence of this bound state, review the previous predictions and comment on the experimental conditions necessary for detection.

Theorists’ dreams IV

Soft-core baryon-baryon potentials for the complete baryon octet

V. G. J. Stoks
Physics Division, Argonne National Laboratory, Argonne, Illinois 60439
and Centre for the Subatomic Structure of Matter, University of Adelaide, Adelaide, SA 5005, Australia

Th. A. Rijken
Institute for Theoretical Physics, University of Nijmegen, Nijmegen, The Netherlands
(Received 13 January 1999)

The Professional

The NN, ΣN, $\Sigma\Sigma$, $\Xi\Sigma$, and $\Xi\Xi$ $^1S_0$ interactions all belong to the same {27} irrep. For these interactions this is also the only irrep. The $NN(^1S_0)$ interaction has a quasi-bound state, and so we also expect (quasi) bound states in the other channels. This is indeed what we find. The effective

less repulsion than the $\Xi\Sigma$ interaction. The attractive tails of the NN and ΣN interactions are almost identical, and so it is not surprising that we also find a quasibound state in Σ^+p and Σ^-n; note that the scattering lengths are rather similar to those of pp and nn.

The tail of the $\Sigma\Sigma$ interaction is almost twice as strong—strong enough to support a bound state. The presence of bound states could already be inferred from the relatively large positive scattering lengths for these systems; see Table X. The binding energies in $\Sigma^+\Sigma^+$ range from –1.53 MeV for NSC97a to –3.07 MeV for NSC97f, while in $\Sigma^-\Sigma^-$ they range from –1.59 MeV for NSC97a to –3.17 MeV for NSC97f.

The attraction in $\Xi\Sigma$ is even stronger and extends to smaller inter-baryon distances. The binding energies in $\Xi^0\Sigma^+$ range from –3.02 MeV for NSC97a to –16.5 MeV for NSC97f. The presence of the Coulomb interaction in $\Xi^-\Sigma^-$ causes a shift of roughly 1 MeV, resulting in binding energies of –2.30 MeV for NSC97a to –15.6 MeV for NSC97f.

Finally, the attraction in $\Xi\Xi$ is also strong enough to support a bound state. The $\Xi^0\Xi^0$ and $\Xi^-\Xi^0$ give almost identical results ranging from –0.10 MeV for NSC97a to –15.8 MeV for NSC97f. Again, the presence of the Coulomb interaction in $\Xi^-\Xi^-$ causes a shift of about 1 MeV, and so the NSC97a model no longer supports a bound state in this channel.

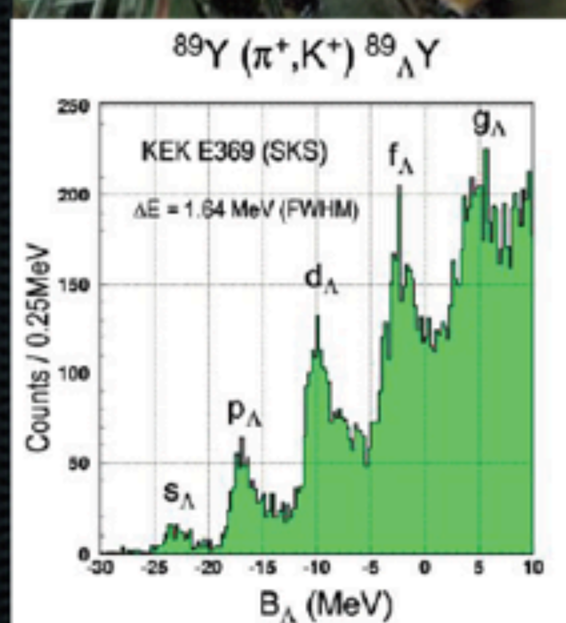
What we know

Λ Hypernuclei

T. Nagae

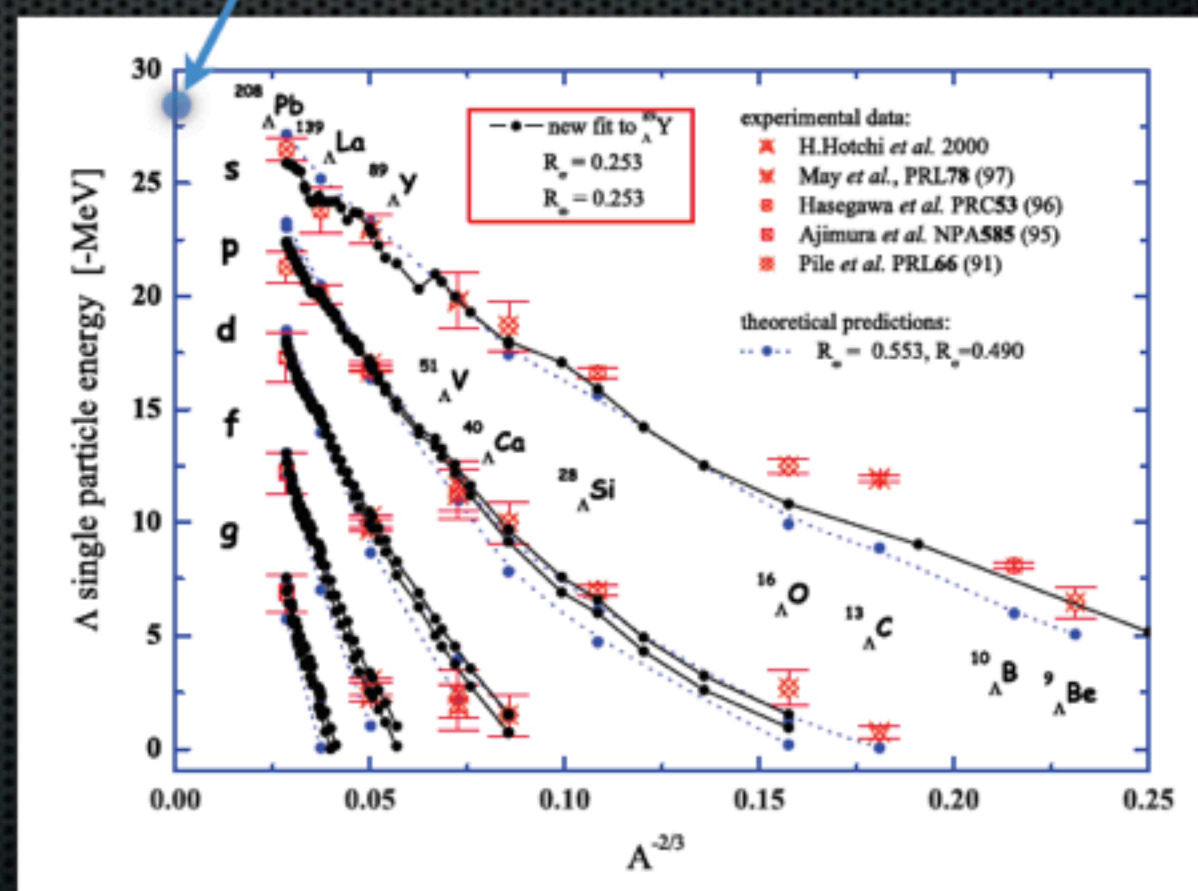
J. Millener

Success of (π^+,K^+) Spectroscopy



H.Hotchi et al., PRC 64, 044302(2001)

- Λ single-particle energy
  → U_Λ=28 MeV



ΛN Effective Interaction

$$V_{\Lambda N}^{eff} = V_0(r) + V_\sigma(r)\vec{s_\Lambda}\vec{s_N} + V_\Lambda(r)\vec{\ell}_{\Lambda N}\vec{s_\Lambda} + V_N(r)\vec{\ell}_{\Lambda N}\vec{s_N} + V_T(r)S_{12}$$

Δ $\quad S_\Lambda$ $\quad S_N$ $\quad T$

Parameters in MeV

	Δ	S_Λ	S_N	T
$A = 7-\ ?$	0.430	−0.015	−0.390	0.030
$A = 11 - 16$	0.330	−0.015	−0.350	0.024

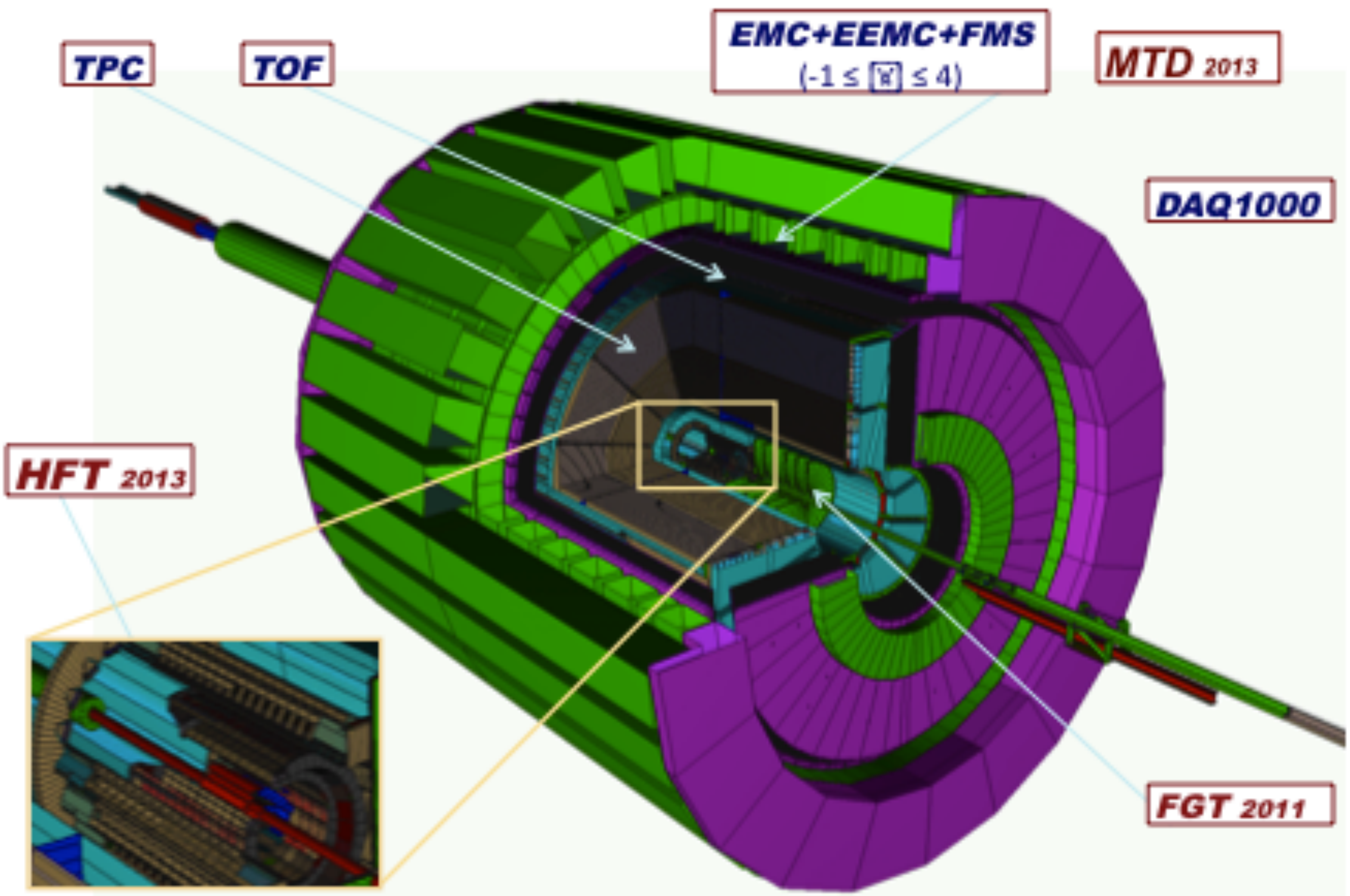
Very small LS

by D.J. Millener

STAR

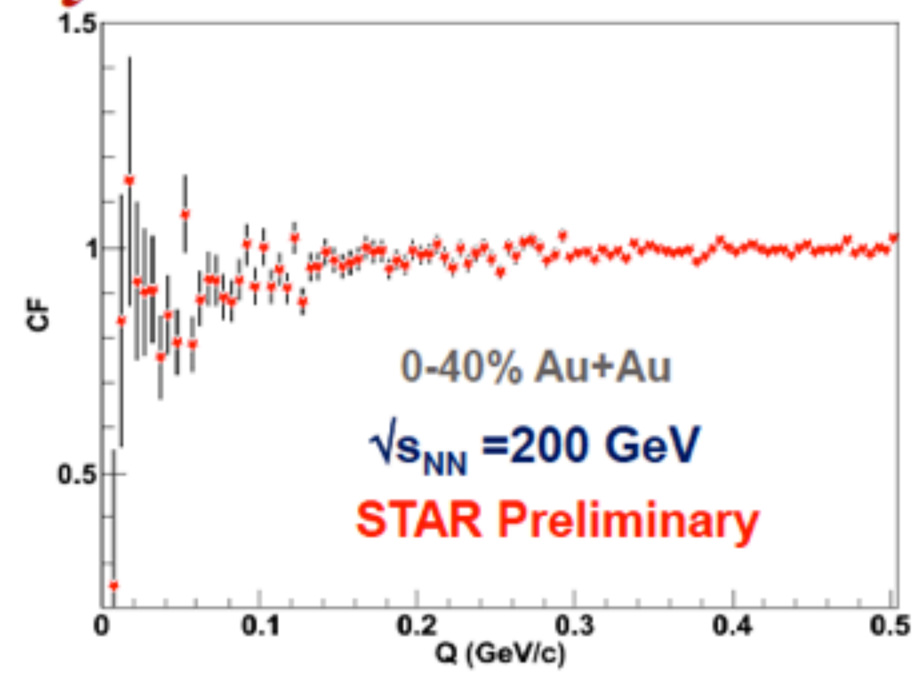
N. Shah

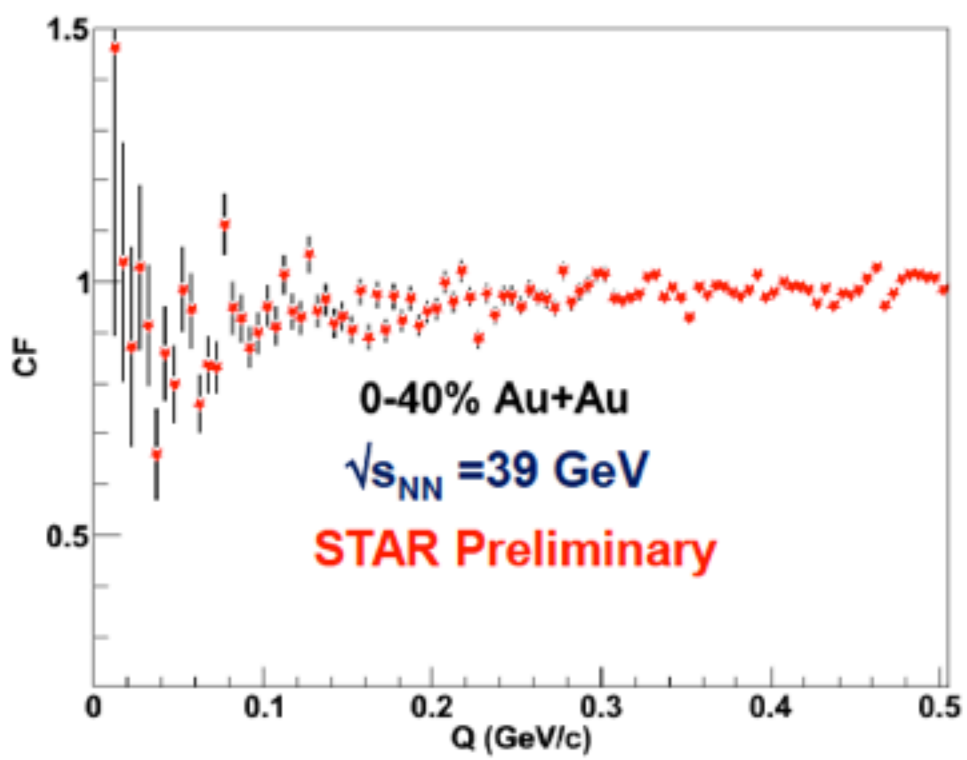
STAR Detector

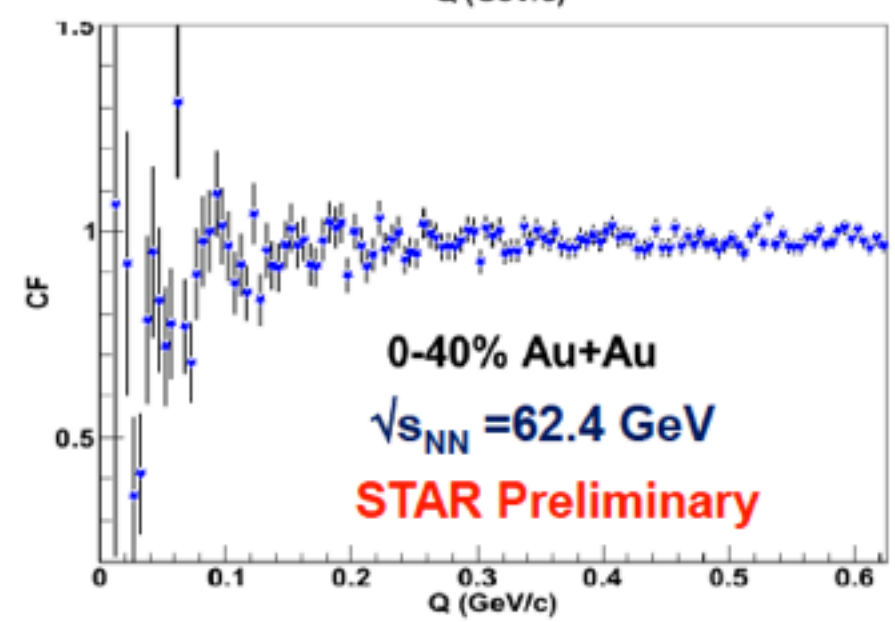


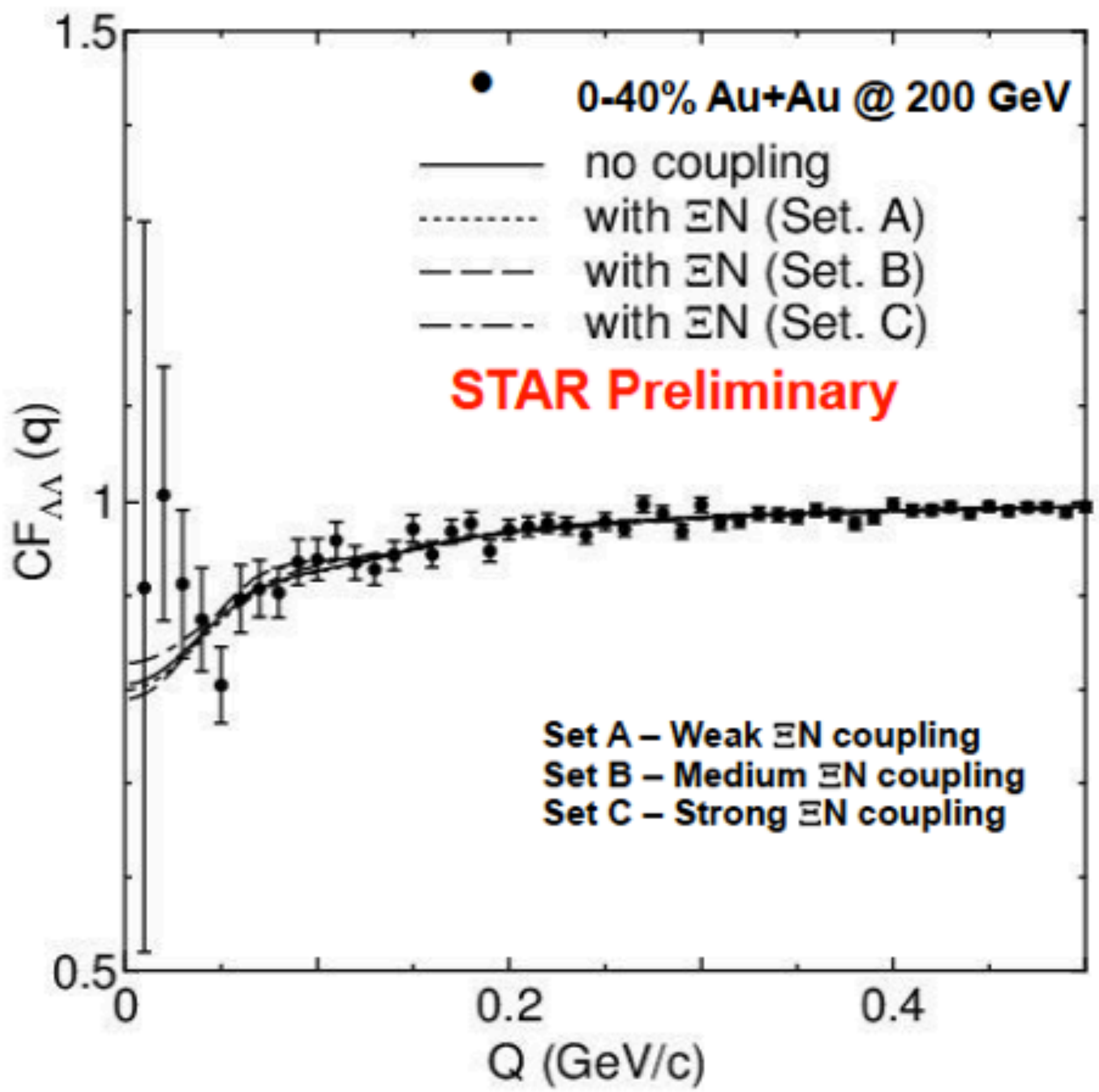
ΛΛ analysis

- Purity corrected correlation functions for 0-40 % Au+Au collisions at $\sqrt{s_{NN}}$ = 39, 62.4 and 200 GeV
- Statistical error only









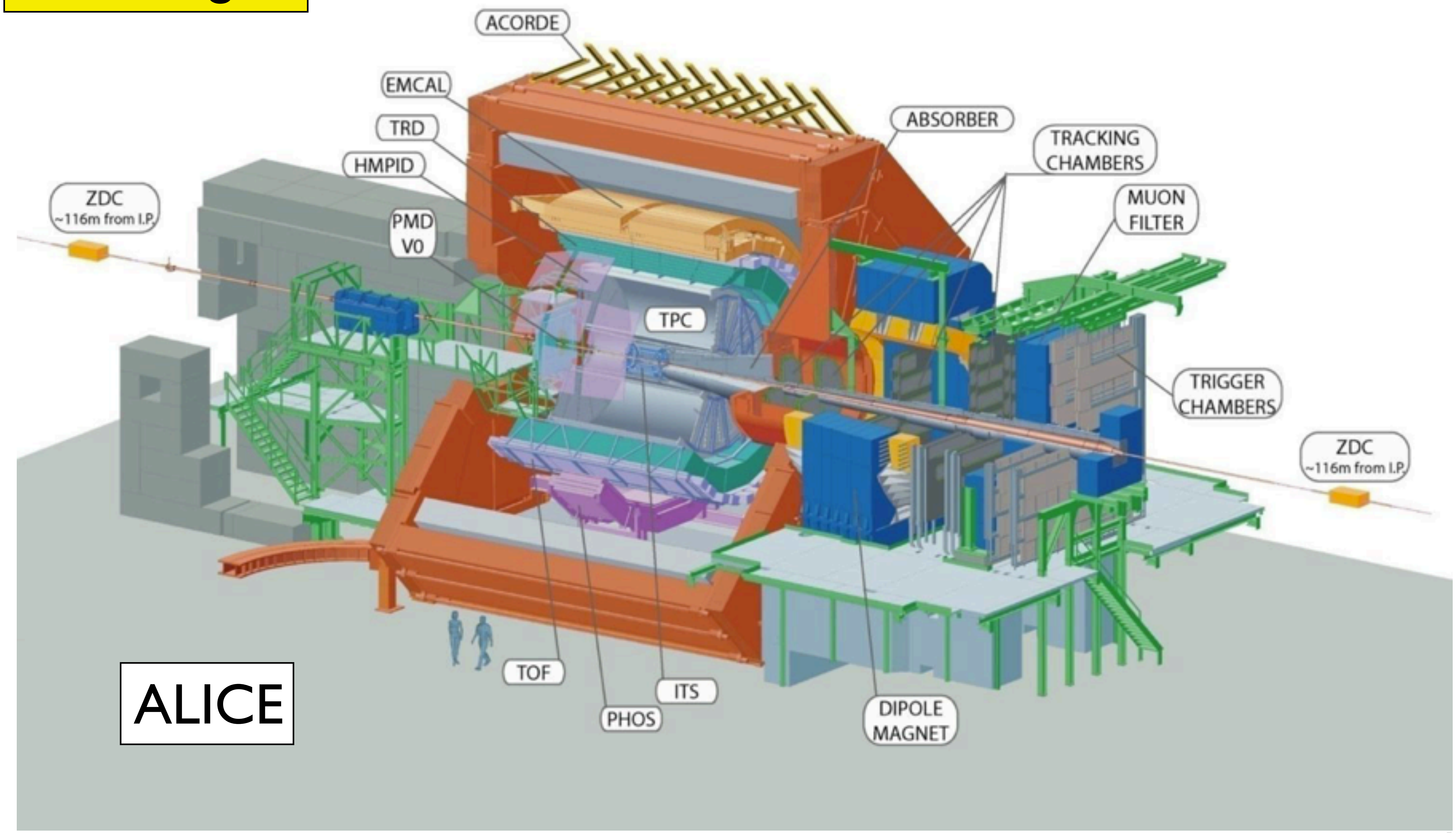
➢ The scattering length (a_0) and the effective range (r_{eff}) with no, weak, medium, and strong coupling to Ξ-N :

	a_0 (fm)	r_{eff} (fm)
No coupling	-2.42	-6.36
weak (Set.A)	-2.47	-6.65
medium (Set.B)	-2.98	-13.53
strong (Set.C)	-2.27	-2.61

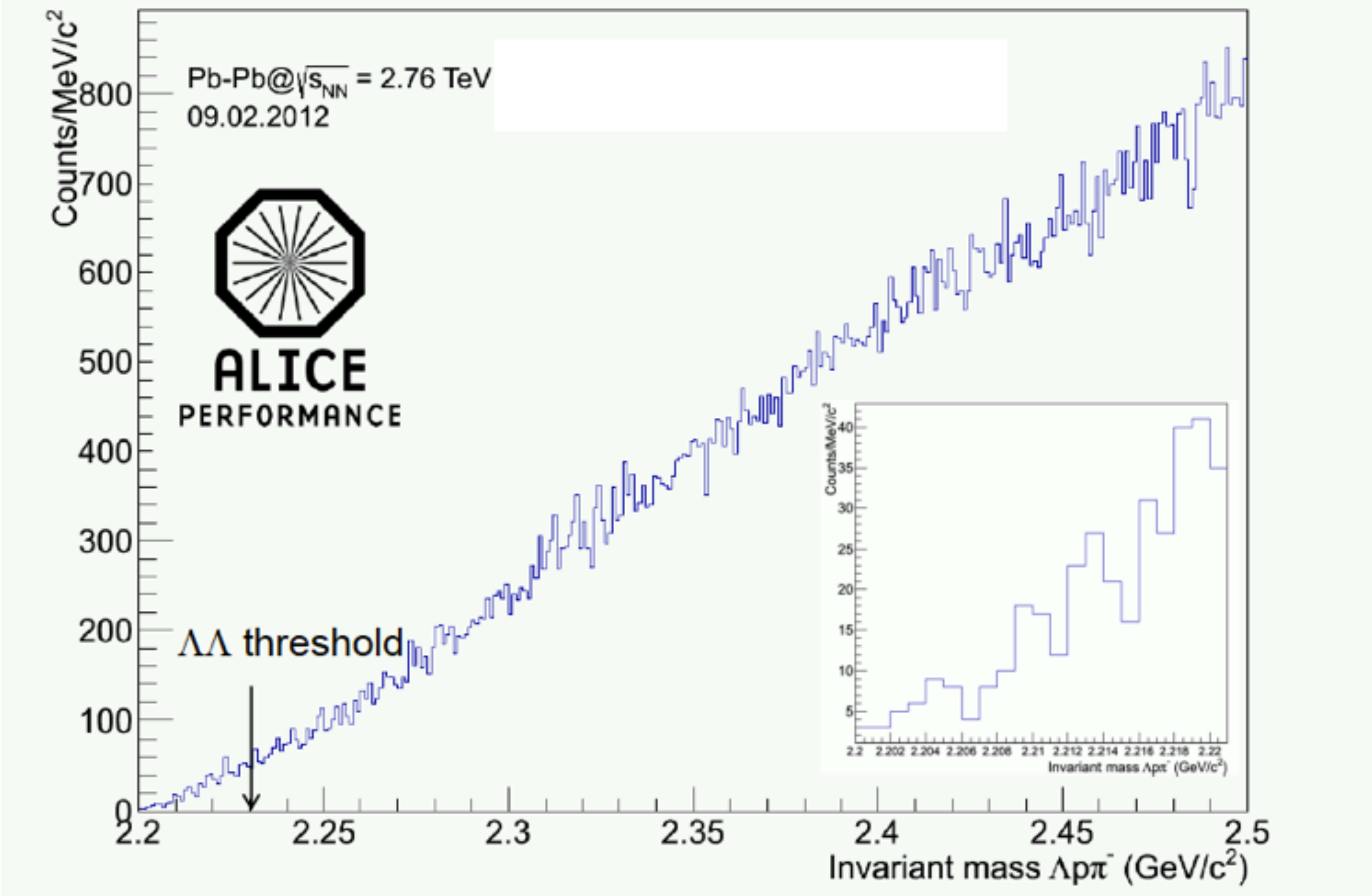
➢ Current fit gives indication towards non-existence of strong bound state of ΛΛ

ALICE

B. Dönigus



H-Dibaryon



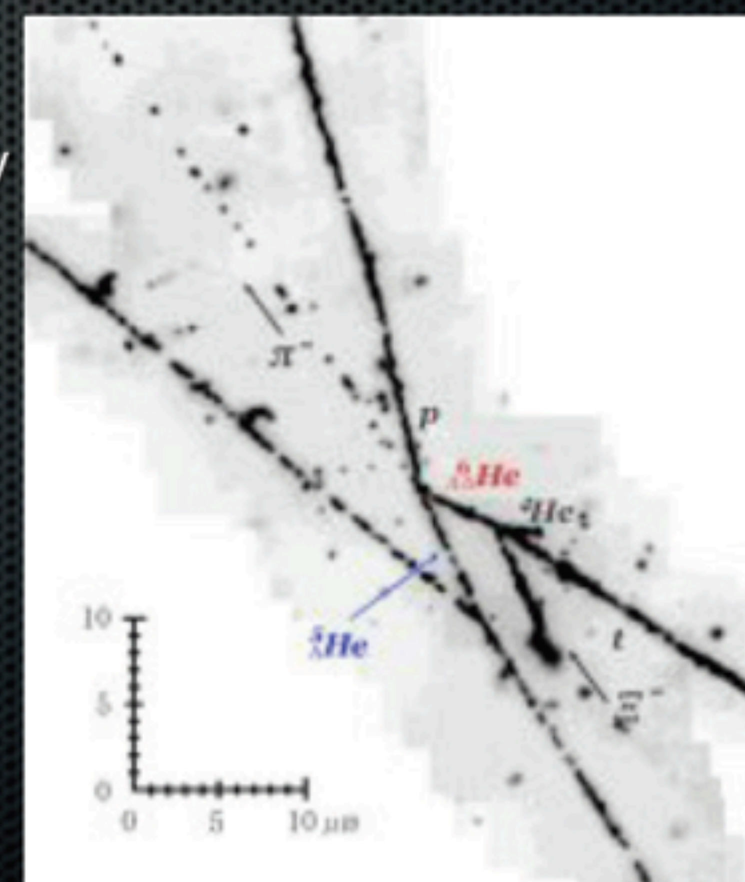
Using the data from 2010, no signal is observed in Λpπ/ΛΛ

Double-Λ Hypernuclei

- “Nagara” event; $_{\Lambda\Lambda}{}^{6}He$
  - Uniquely identified
  - $\Delta B_{\Lambda\Lambda}$=1.01±0.02+0.18/-0.11 MeV

    0.67±0.17 MeV (updated by Nakazawa@Hyp-X)
  - smaller than before (~4 MeV)

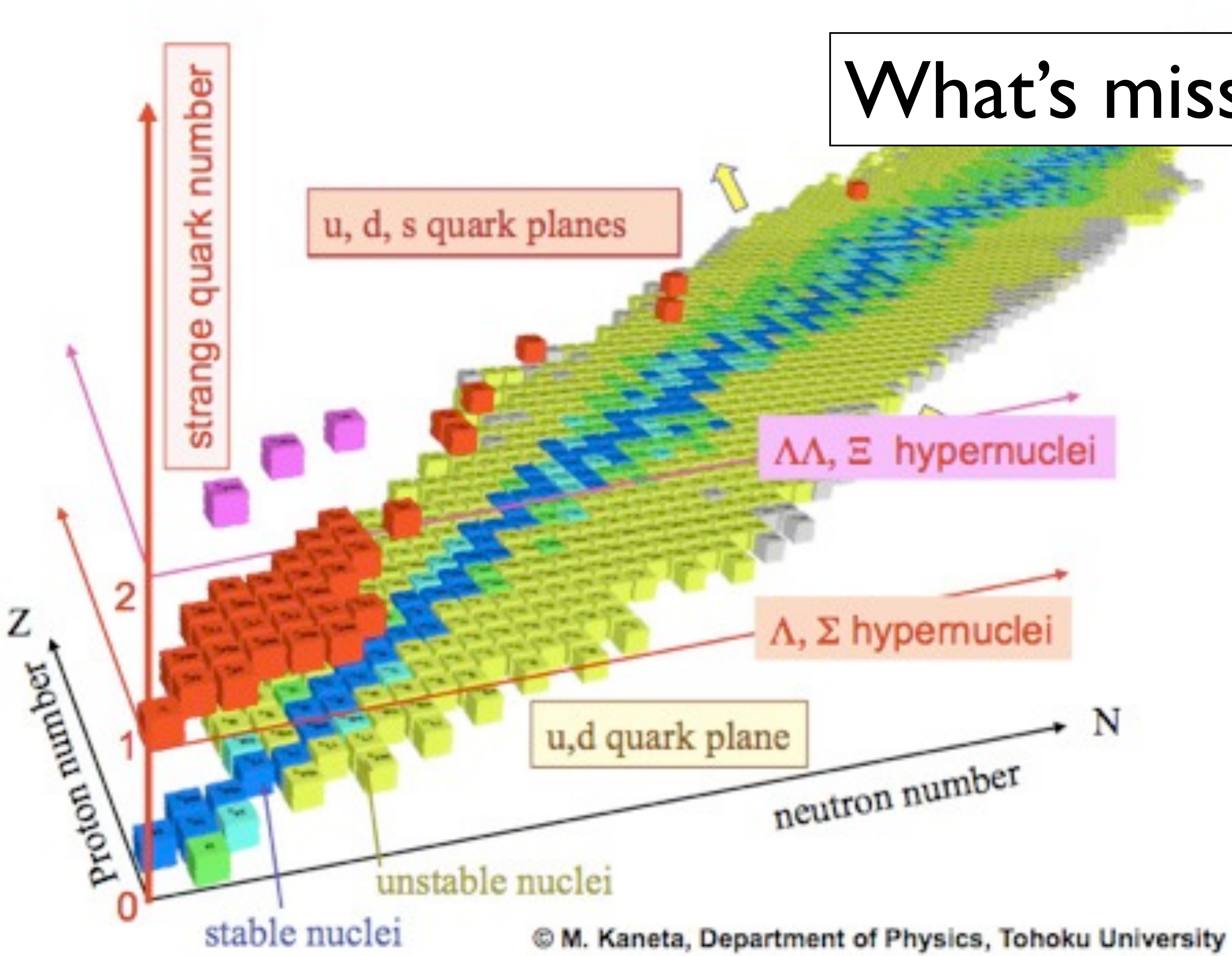
KEK E373



H. Takahashi et al., PRL87, (2001) 212502.

The 3-D nuclear isotope chart

What's missing?

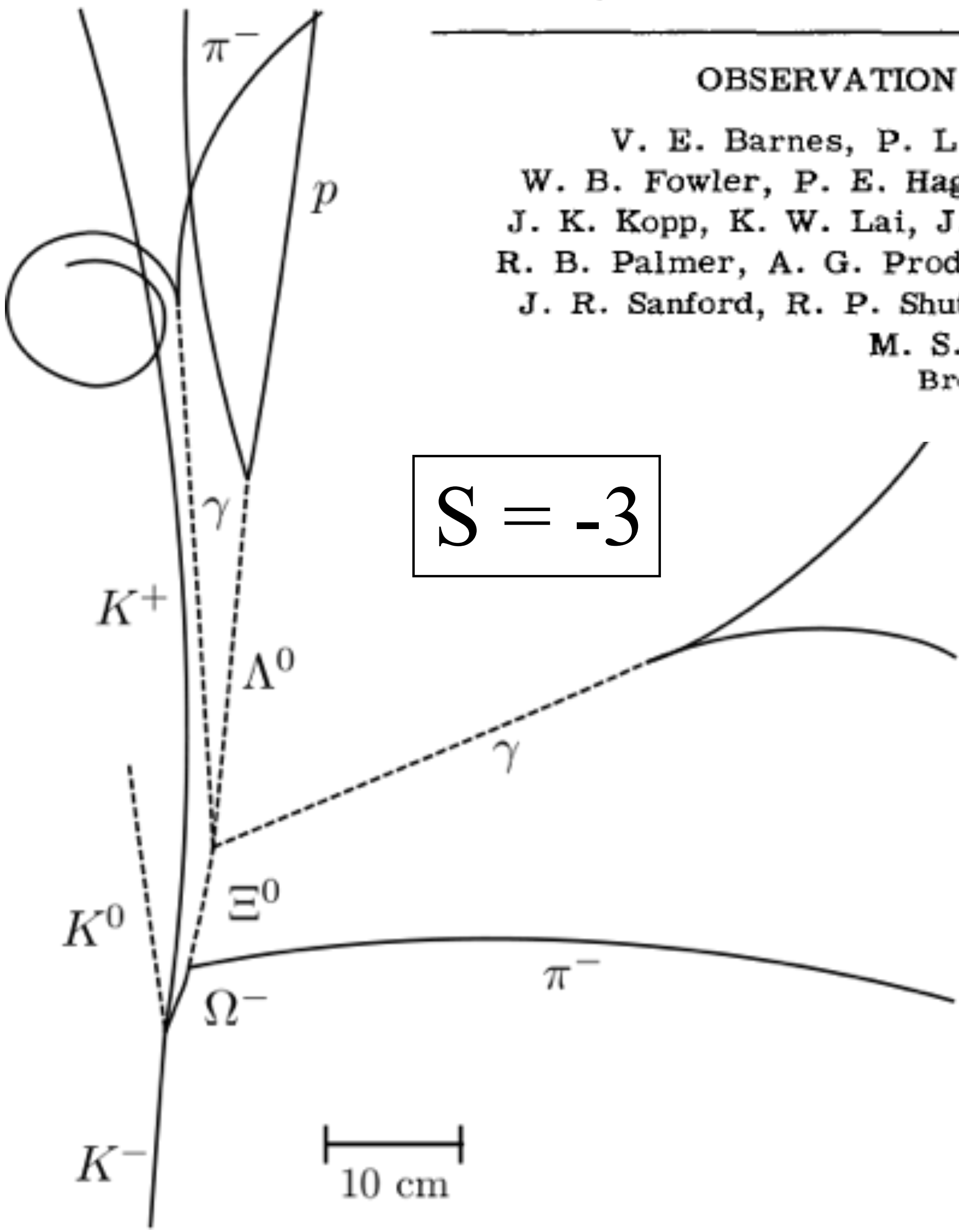


A record for all eternity?

VOLUME 12, NUMBER 8 PHYSICAL REVIEW LETTERS 24 FEBRUARY 1964

OBSERVATION OF A HYPERON WITH STRANGENESS MINUS THREE*

V. E. Barnes, P. L. Connolly, D. J. Crennell, B. B. Culwick, W. C. Delaney, W. B. Fowler, P. E. Hagerty,† E. L. Hart, N. Horwitz,† P. V. C. Hough, J. E. Jensen, J. K. Kopp, K. W. Lai, J. Leitner,† J. L. Lloyd, G. W. London,‡ T. W. Morris, Y. Oren, R. B. Palmer, A. G. Prodell, D. Radojičić, D. C. Rahm, C. R. Richardson, N. P. Samios, J. R. Sanford, R. P. Shutt, J. R. Smith, D. L. Stonehill, R. C. Strand, A. M. Thorndike, M. S. Webster, W. J. Willis, and S. S. Yamamoto
Brookhaven National Laboratory, Upton, New York
(Received 11 February 1964)

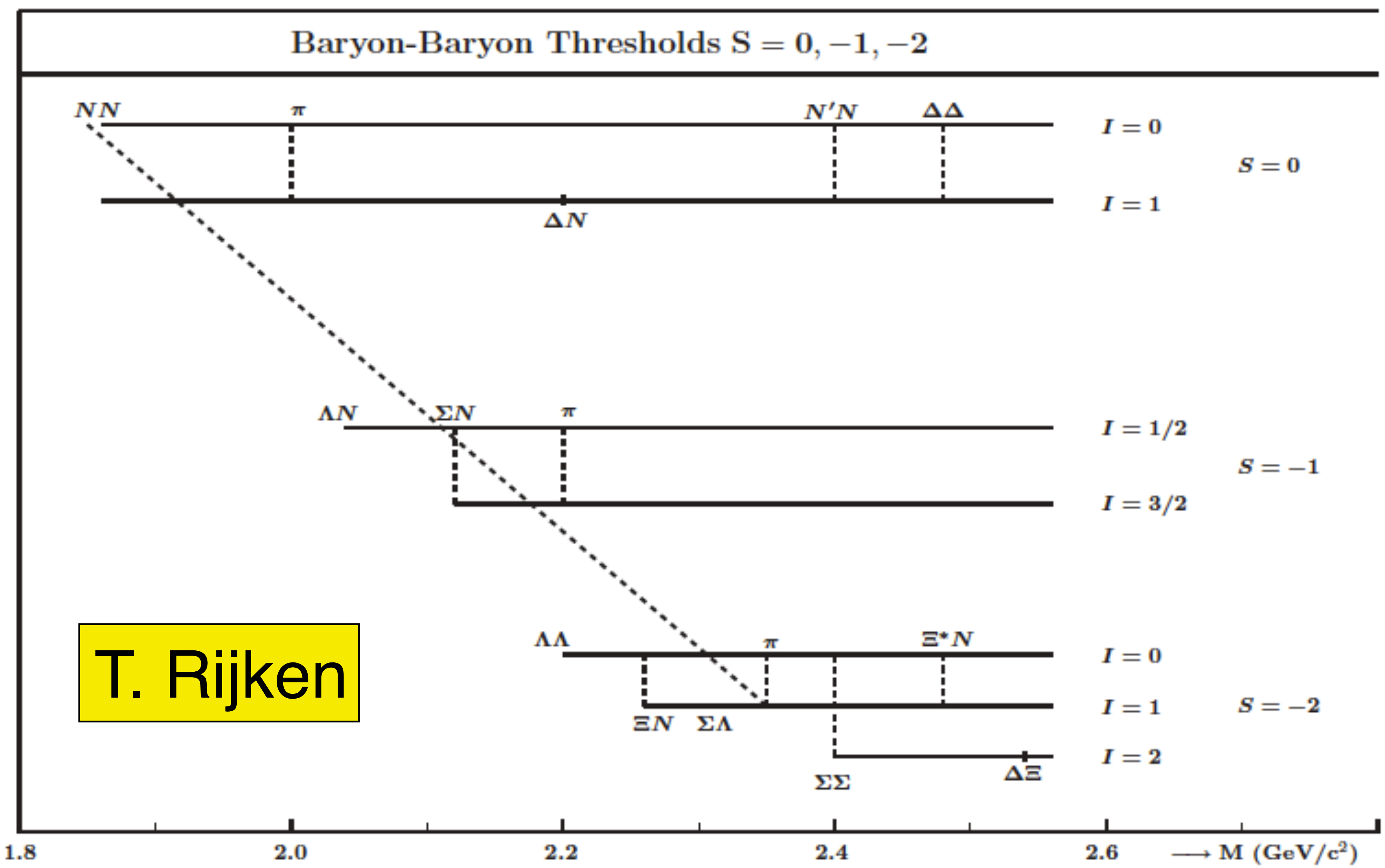


Almost 40 years of experimental efforts have not resulted in the discovery of a state with |S| > 3.

Is this like the 4-minute mile, or has Nature set up unsurmountable obstacles?

Theorists hard at work

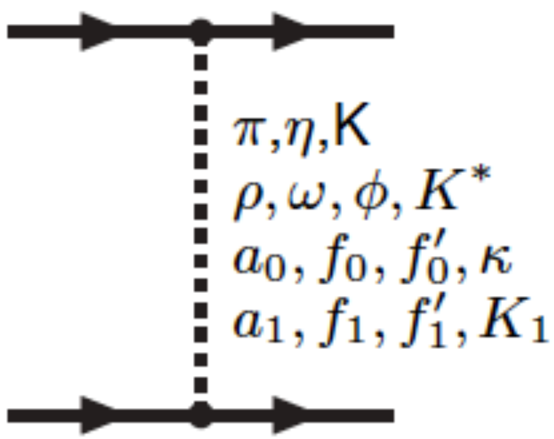
BB channels (S = 0,-1,-2)



Nijmegen ESC model I

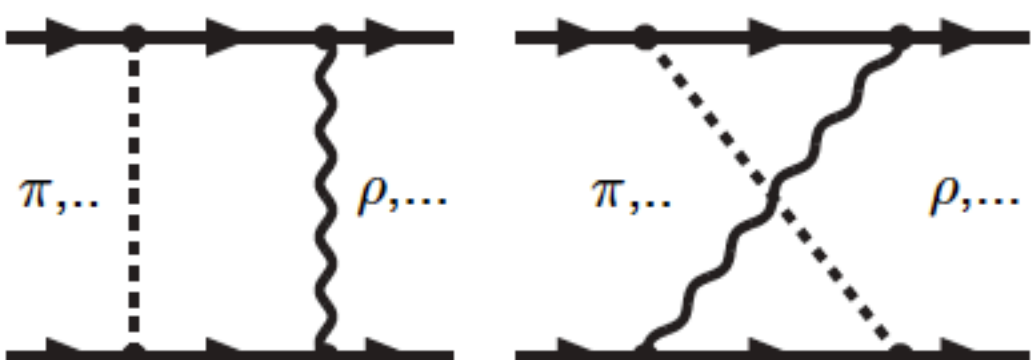
BB-interactions in the ESC-model:

One-Boson-Exchanges:



pseudo-scalar	π	K	η	η'
vector	ρ	K^*	ϕ	ω
axial-vector	a_1	K_1	f_1'	f_1
scalar	δ	κ	S^*	ϵ
diffractive	A_2	K^{**}	f	P

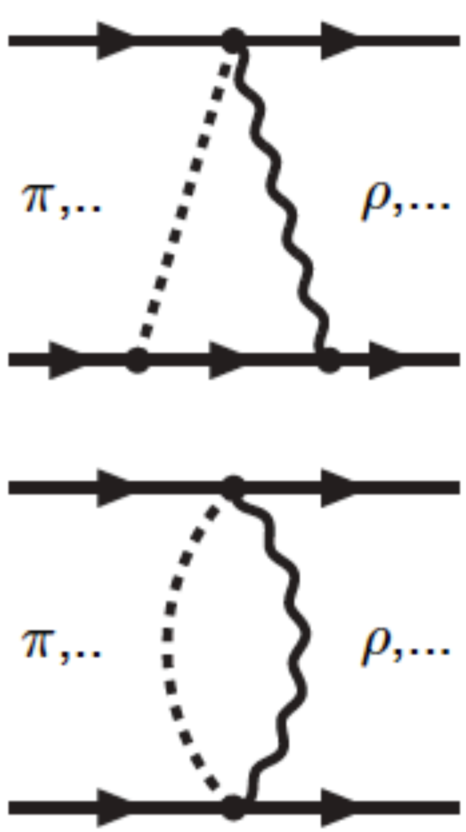
Two-Meson-Exchanges:



$$\begin{pmatrix} \pi \\ K \\ \eta \\ \eta' \end{pmatrix} \otimes \left\{ \begin{array}{cccc} \pi & K & \eta & \eta' \\ \rho & K^* & \phi & \omega \\ a_1 & K_1 & f_1 & f_1' \\ \delta & \kappa & S^* & \epsilon \\ A_2 & K^{**} & f & P \end{array} \right.$$

BB-interactions in the ESC-model (cont.):

Meson-Pair-Exchanges:



$PP\hat{S}_{\{1\}}$: $\pi\pi,\ K\bar{K},\ \eta\eta$

$PP\hat{S}_{\{8\}_s}$: $\pi\eta,\ K\bar{K},\ \pi\pi,\ \eta\eta$

$PP\hat{V}_{\{8\}_a}$: $\pi\pi,\ K\bar{K},\ \pi K,\ \eta K$

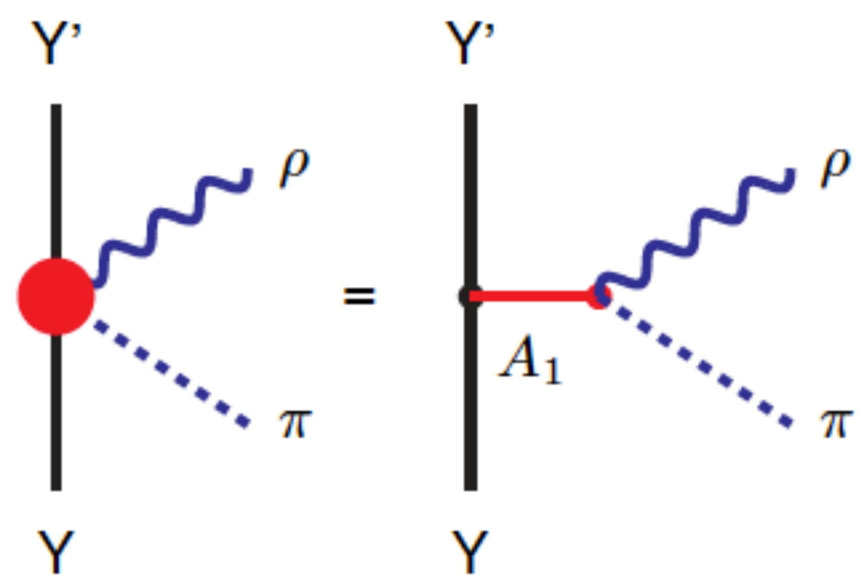
$PV\hat{A}_{\{8\}_a}$: $\pi\rho,\ KK^*,\ K\rho,\ \ldots$

$PS\hat{A}_{\{8\}}$: $\pi\sigma,\ K\sigma,\ \eta\sigma$

Hyperon sector

SU(3)-Extension ESC to Hyperon-Nucleon

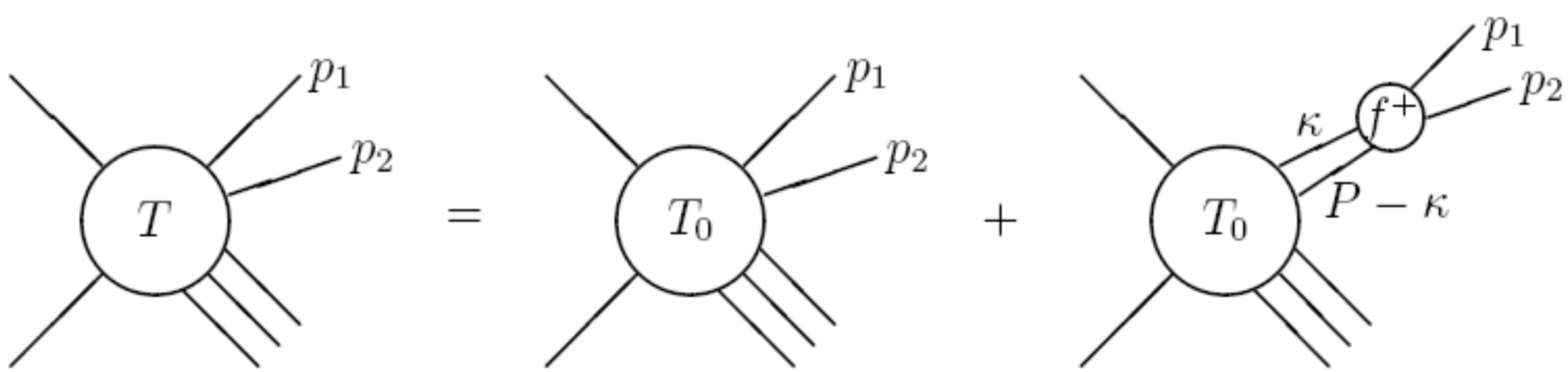
- MPE: Boson-dominance model:



4. NO S=-1 Bound-States, NO $\Lambda\Lambda$-Bound-State,
5. Prediction: $D_{\Xi N} = \Xi N(I = 1, {}^3S_1)$ B.S.!, $D_{\Xi\Xi} = \Xi\Xi(I = 1, {}^1S_0)$ B.S. ??!

2-particle correlations

R. Lednicky



Source is revealed through quantum statistics and final-state interactions.

Usual (Gaussian) source functions imply many approximations;
pair purity is also an important issue.

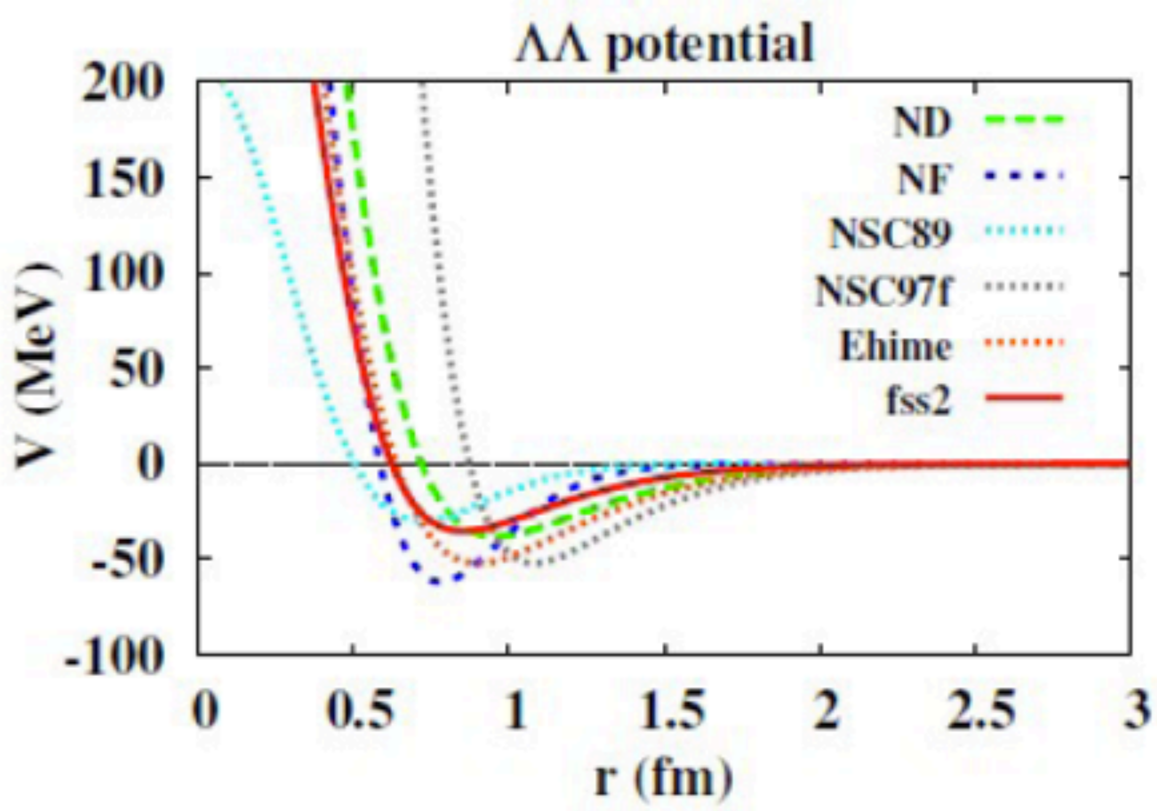
For *BB* correlations, low-energy expansion (a, r_0) of full S-matrix required.

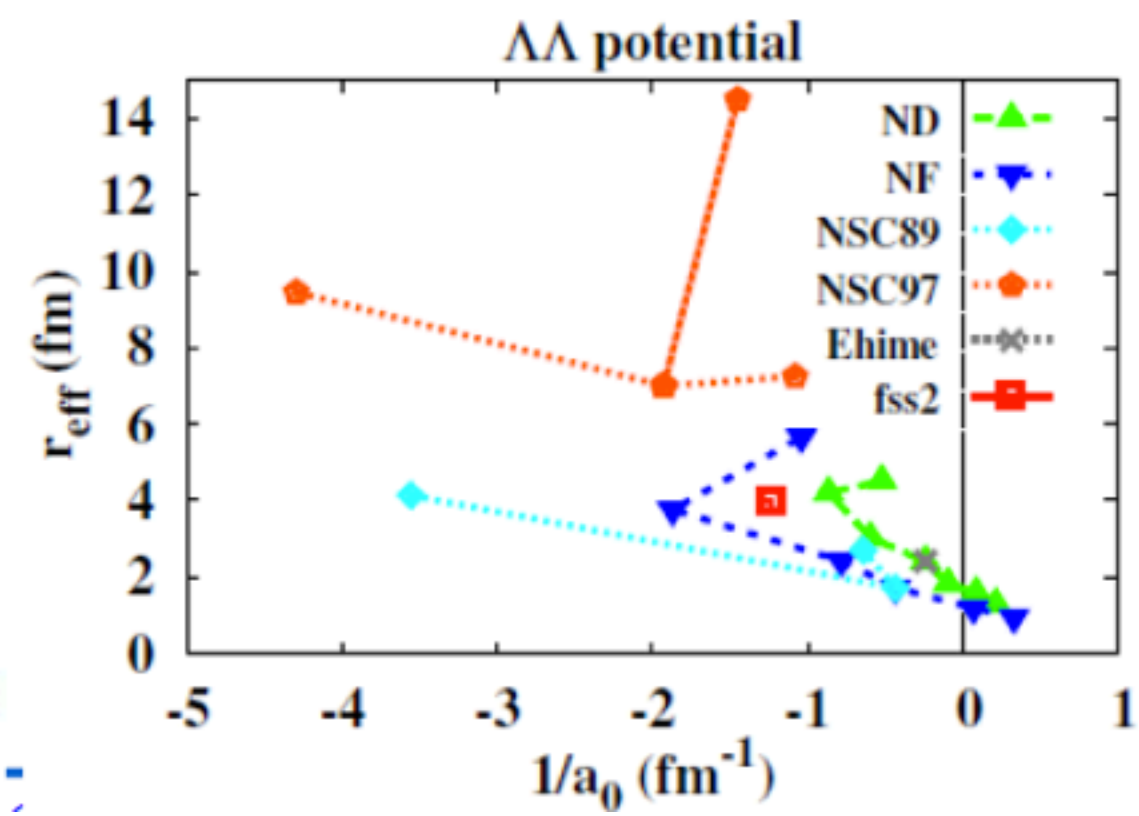
ΛΛ interaction

- **Type of ΛΛ interactoin**
  - **Meson exchange models: Nijmegen model D, F, Soft Core (89, 97)**
    Nagels, Rijken, de Swart ('77, '79), Maessen, Rijken, de Swart ('89), Rijken, Stoks, Yamamoto ('99)
  - **Quark cluster model interaction: fss2**
    Fujiwara, Fujita, Kohno, Nakamoto, Suzuki ('00)
  - **Phenomenological model: Ehime**

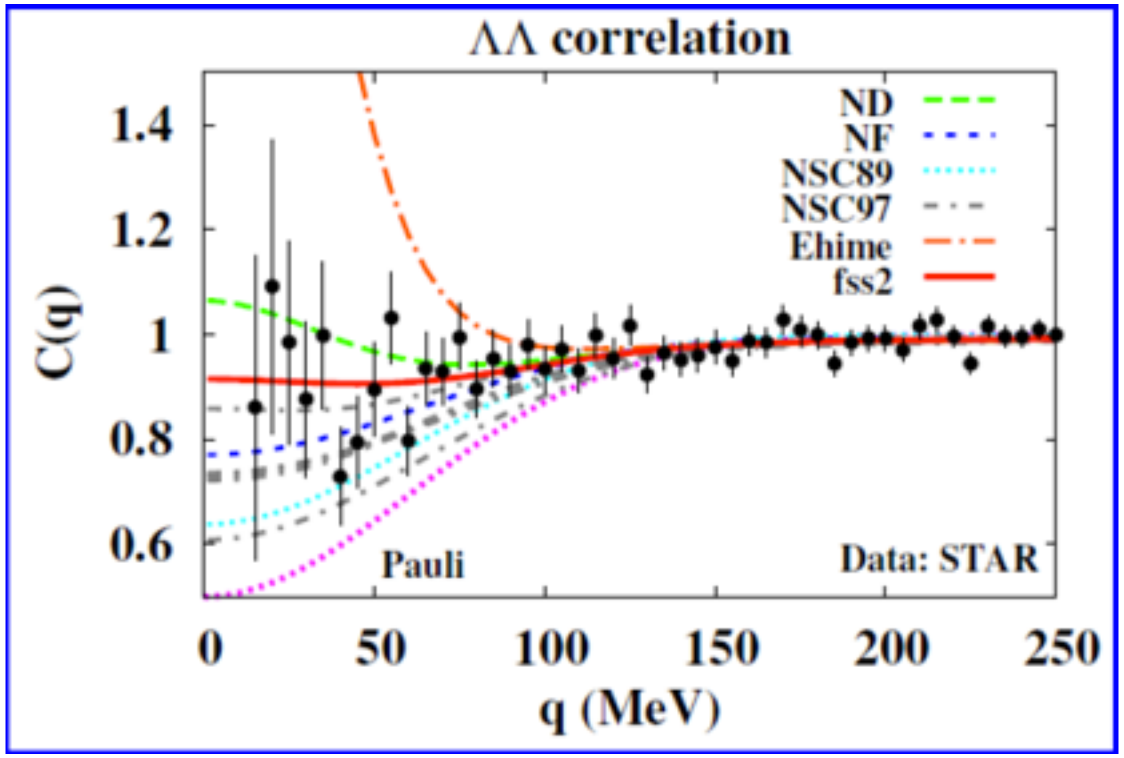
A. Ohnishi

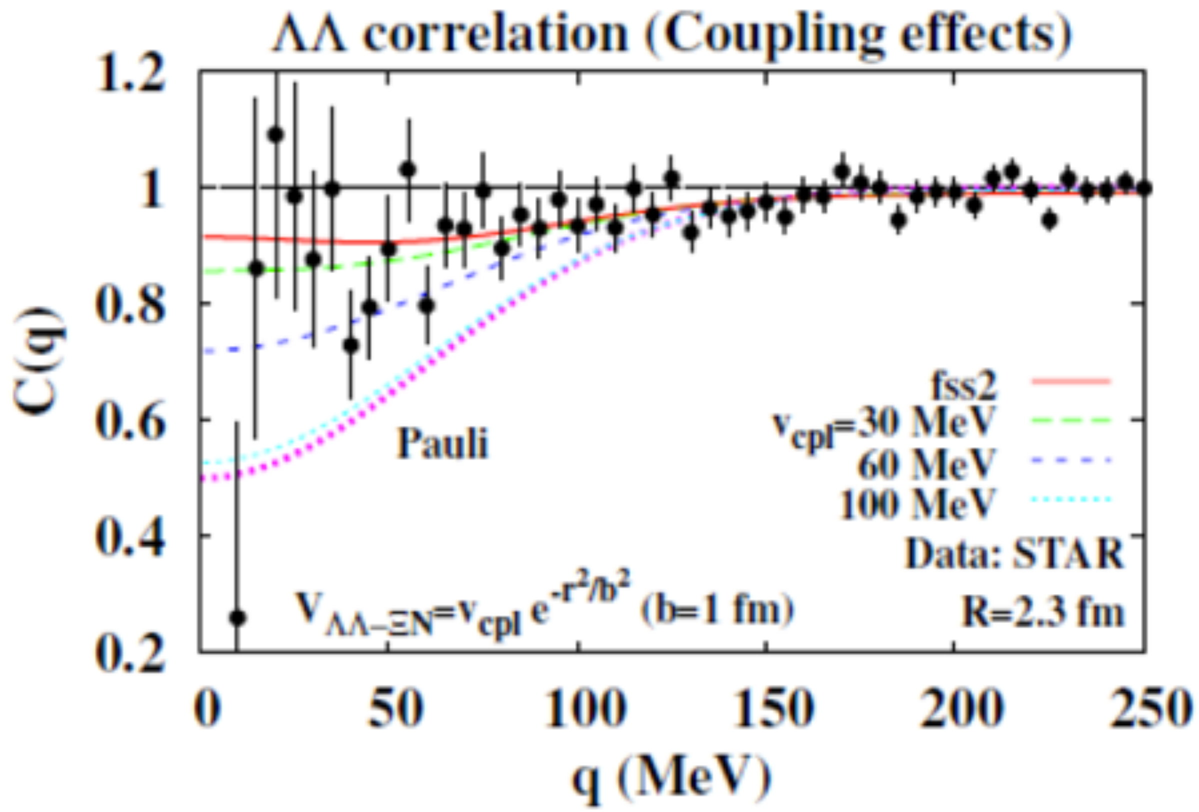
- **Two (or three) range gaussian fit results are used in the analysis.**

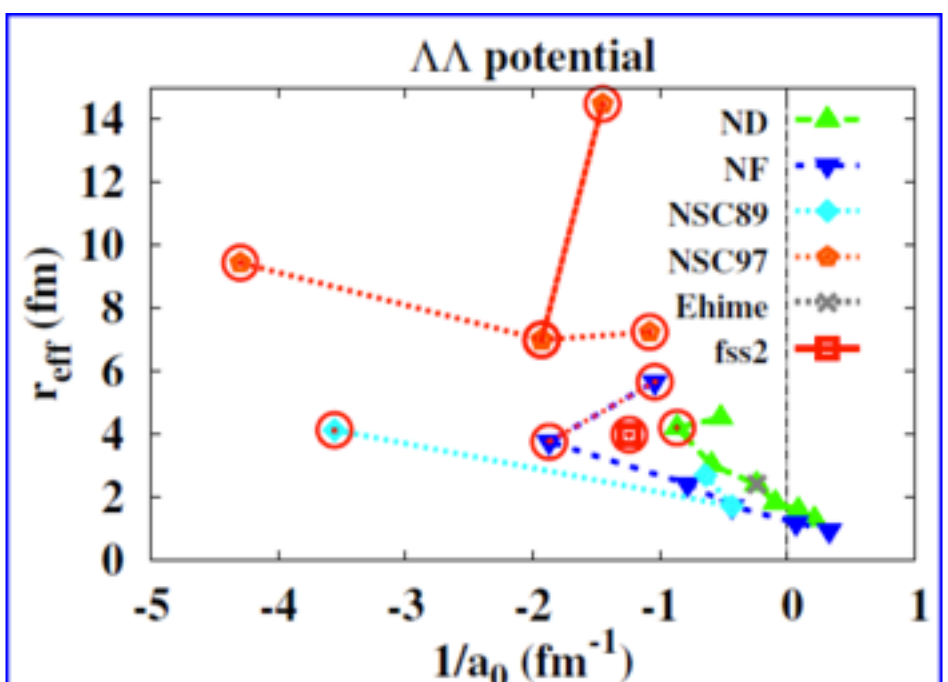




Model predictions







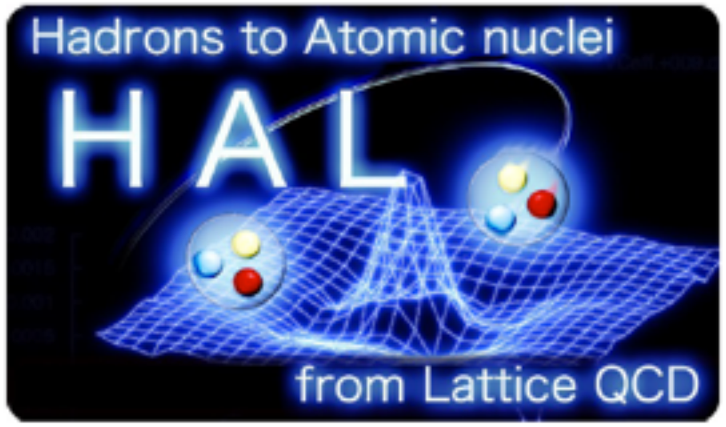
Preferred results:

$1/a < -1\ fm^{-1}$

$r_{eff} > 3$ fm.

Potential from NBS wave function

Nambu-Bethe-Salpeter w.f.



T. Inoue

- NBS wave function

(the same: $B_i(\vec{x}+\vec{r},t)\, B_j(\vec{x},t)$; $|B=2, \text{a-plet}\rangle$: QCD generated state)

$$\psi^{(a)}(\vec{r},t) \overset{\text{def}}{=} \sum_{\vec{x}} \langle 0 | B_i(\vec{x}+\vec{r},t)\, B_j(\vec{x},t) | B=2, \text{a-plet}\rangle$$

$$\propto \sum_{\vec{x}} G^{(a)}(\vec{x}+\vec{r},\vec{x},t)$$

4-point function

$$G^{(a)}(\vec{x},\vec{y},t-t_0) = \langle 0 | \underbrace{B_i(\vec{x},t)\, B_j(\vec{y},t)}_{\text{sink}}\ \underbrace{\overline{BB}^{(a)}(t_0)}_{\text{source}} | 0 \rangle$$

- Point type octet baryon field operator at sink

$$p_\alpha(\underline{x}) = \epsilon_{c_1 c_2 c_3} (C\gamma_5)_{\beta_1\beta_2} \delta_{\beta_3\alpha}\, u(\xi_1) d(\xi_2) u(\xi_3) \quad \text{with} \quad \xi_i = \{c_i, \beta_i, \underline{x}\}$$

$$\Lambda_\alpha(x) = -\epsilon_{c_1 c_2 c_3} (C\gamma_5)_{\beta_1\beta_2} \delta_{\beta_3\alpha} \sqrt{\frac{1}{6}} \left[d(\xi_1)s(\xi_2)u(\xi_3) + s(\xi_1)u(\xi_2)d(\xi_3) - 2u(\xi_1)d(\xi_2)s(\xi_3) \right]$$

- Quark wall type BB source in the flavor irreducible rep.

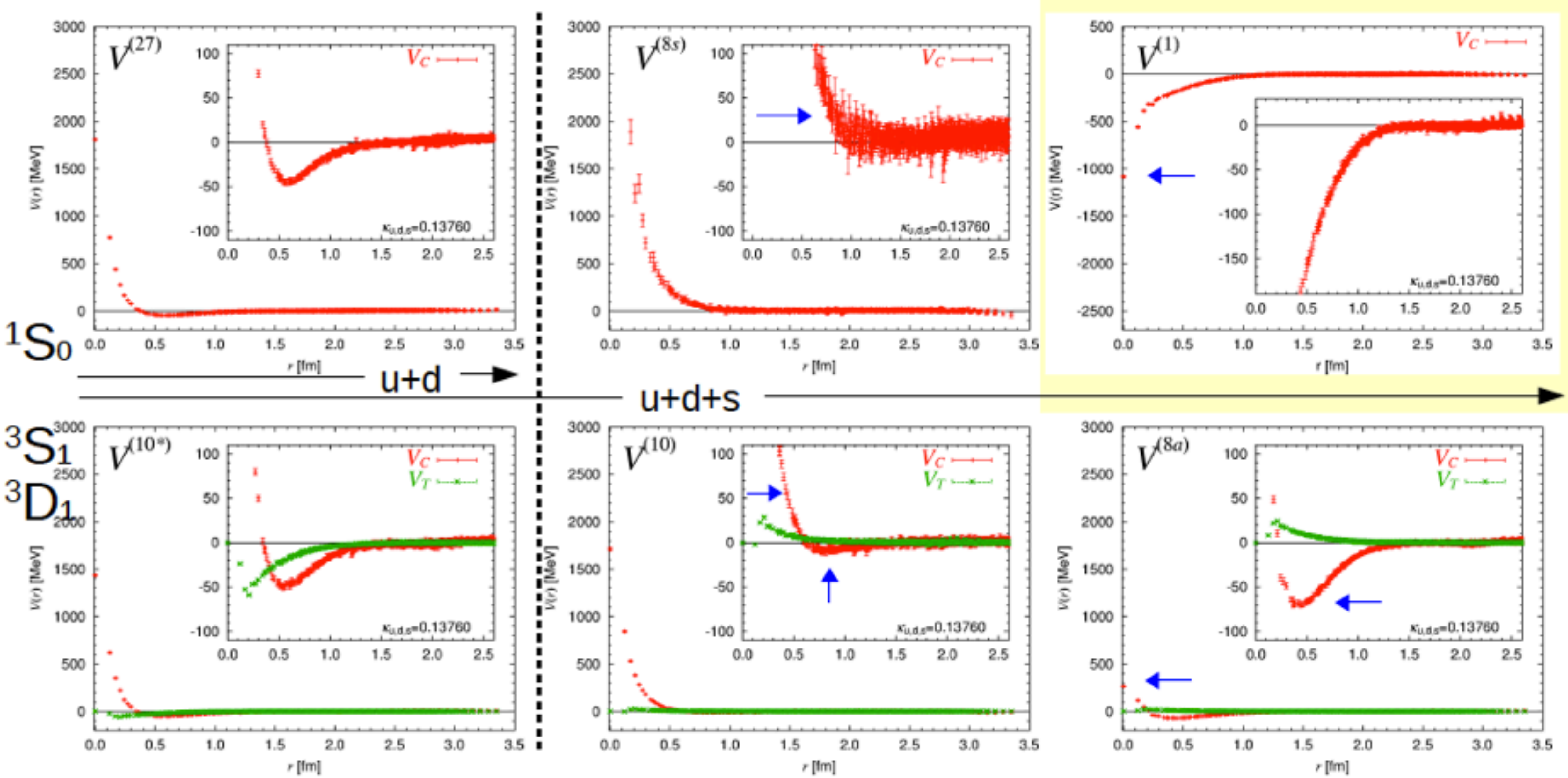
e.g for flavor-singlet $\overline{BB}^{(1)} = -\sqrt{\frac{1}{8}}\, \overline{\Lambda}\,\overline{\Lambda} + \sqrt{\frac{3}{8}}\, \overline{\Sigma}\,\overline{\Sigma} + \sqrt{\frac{4}{8}}\, \overline{N}\,\overline{\Xi}$

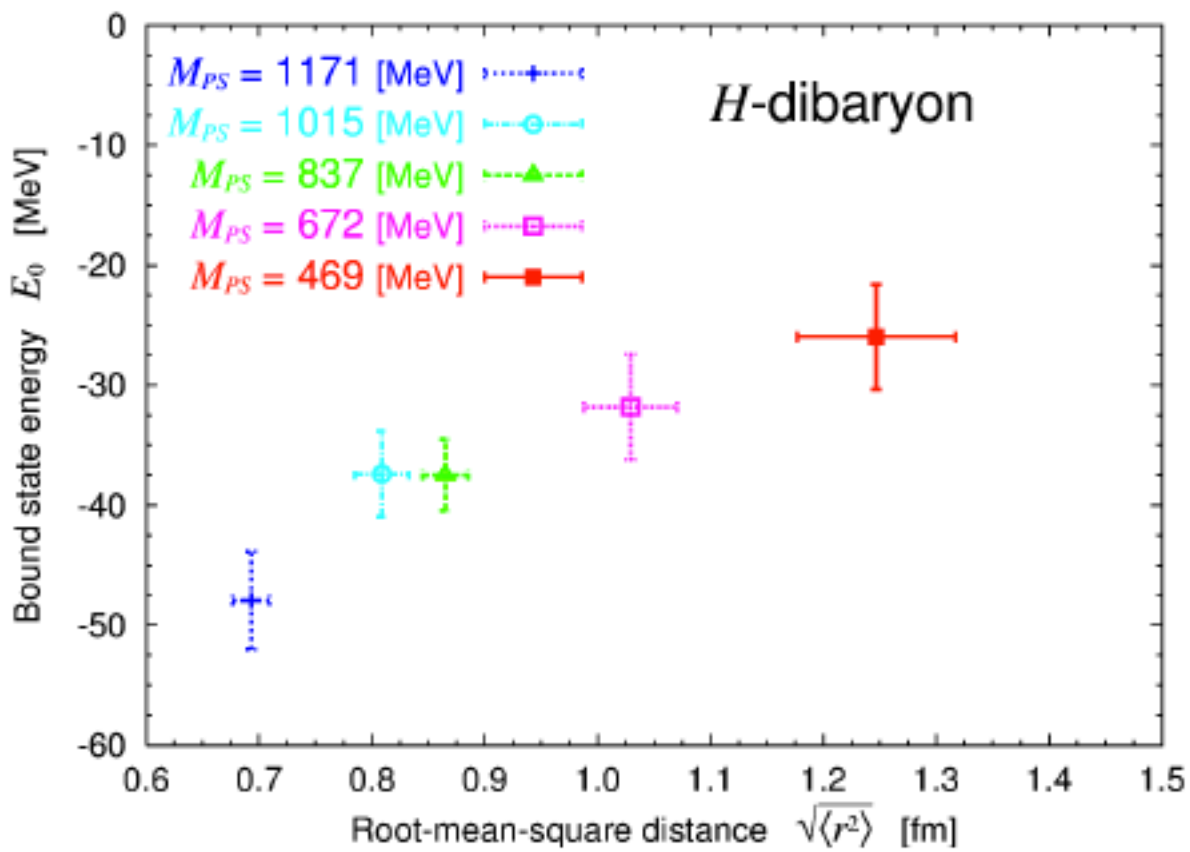
12

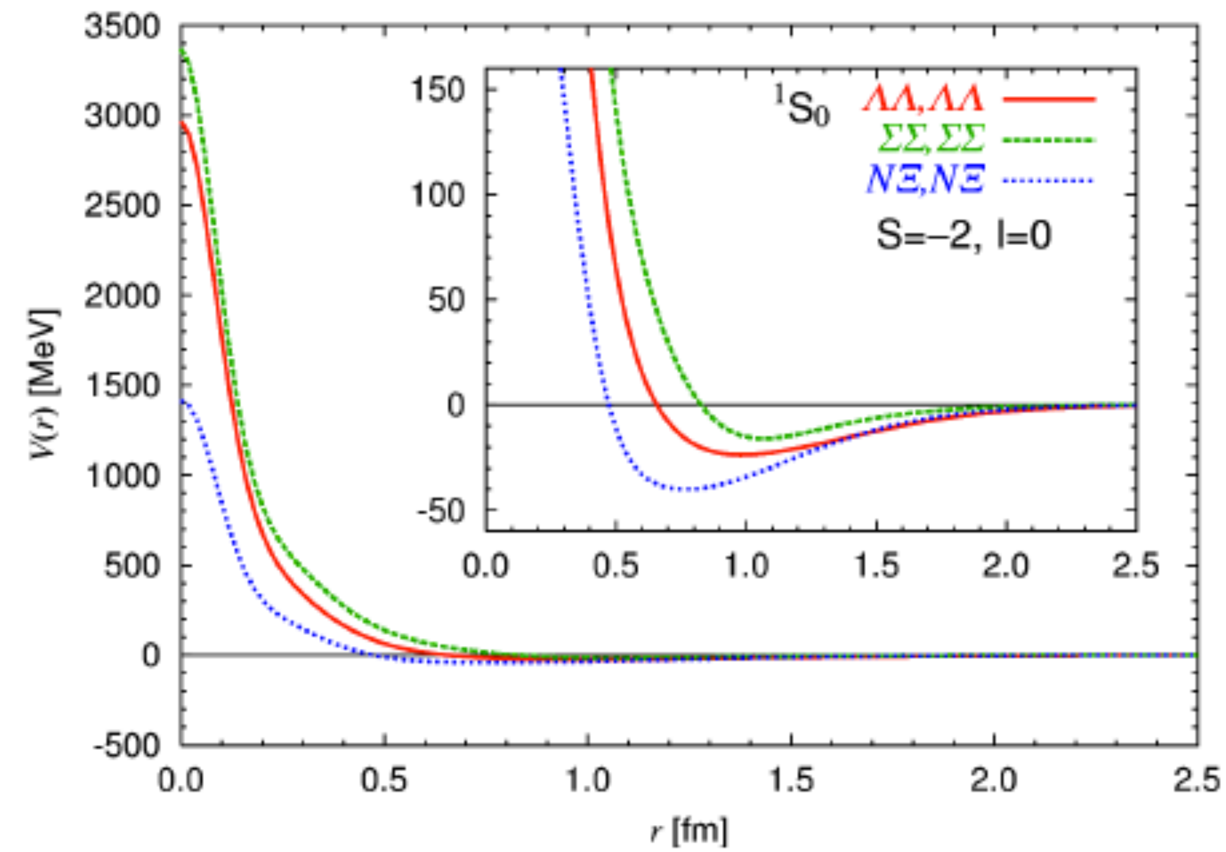
BB interaction from LGT

$$\psi(\vec{r},t) = \phi_{Gr}(\vec{r})e^{-E_{Gr}t} + \phi_{1st}(\vec{r})e^{-E_{1st}t}$$

$$V(\vec{r}) = \frac{1}{2\mu}\frac{\nabla^2\psi(\vec{r},t)}{\psi(\vec{r},t)} - \frac{\frac{\partial}{\partial t}\psi(\vec{r},t)}{\psi(\vec{r},t)} - 2M_B$$



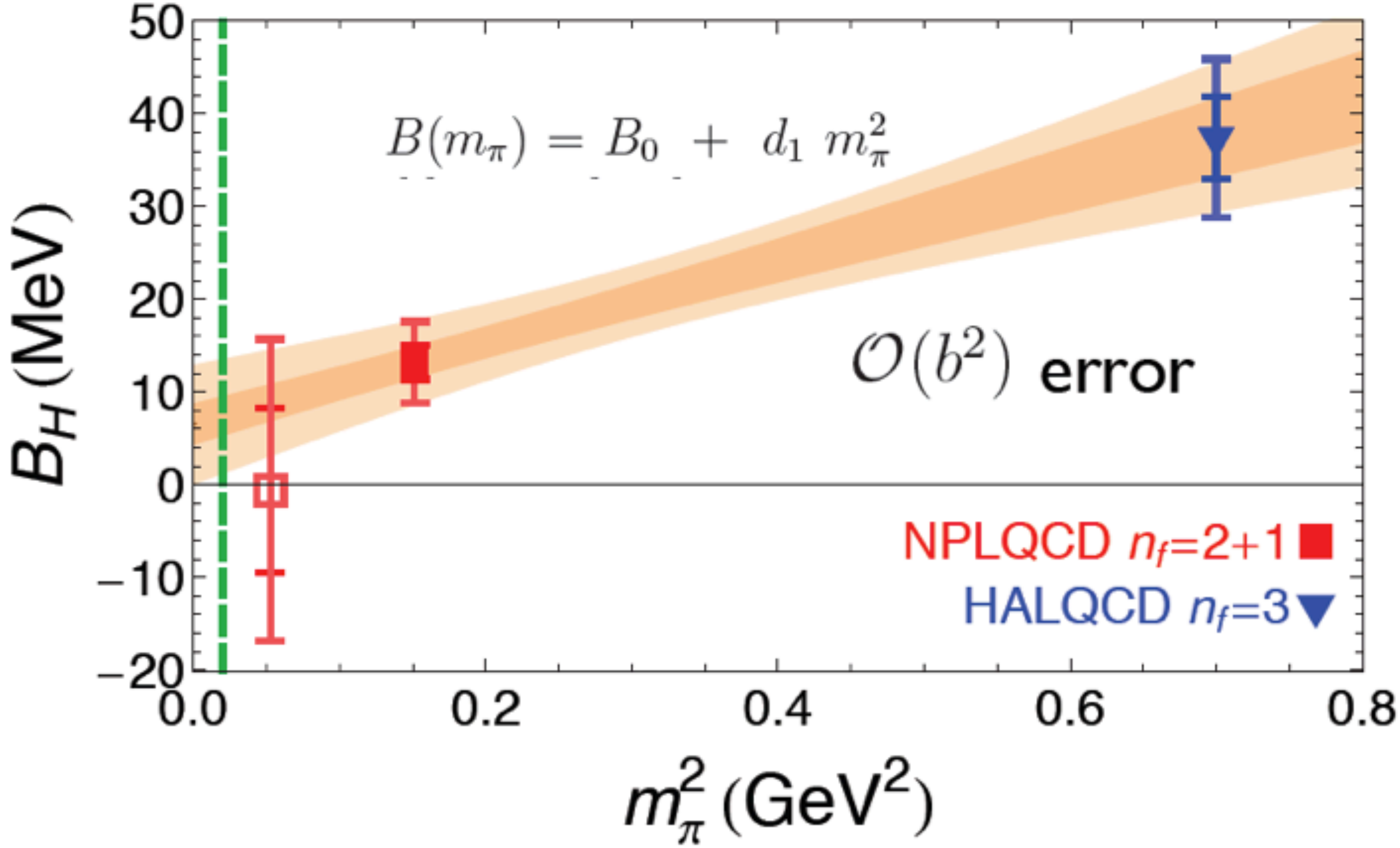




HHI in S=−2, I=0 sector

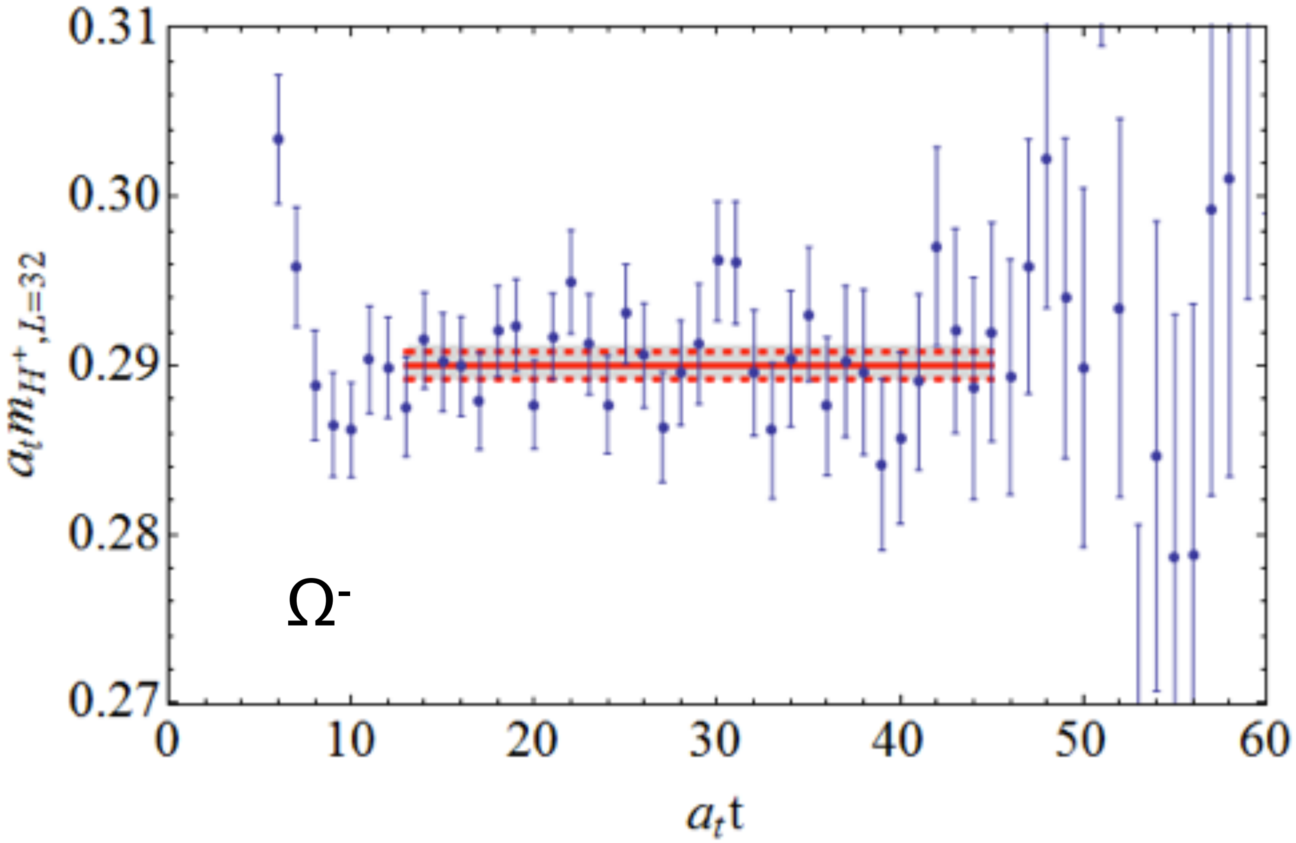
Attempt to estimate $SU(3)_F$ breaking effects using LGT potentials puts *H* bound by 3 MeV below the NΞ threshold.

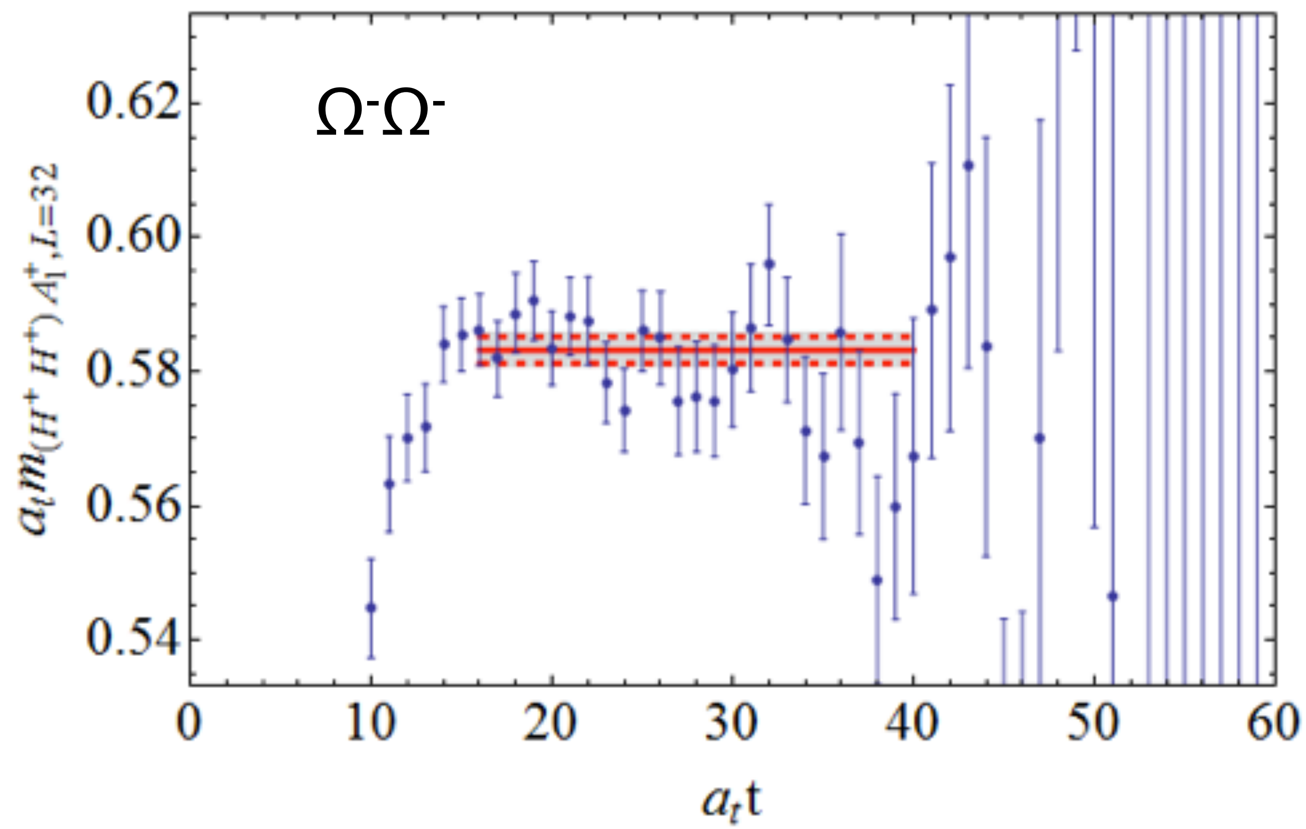
H Di-baryon in LGT

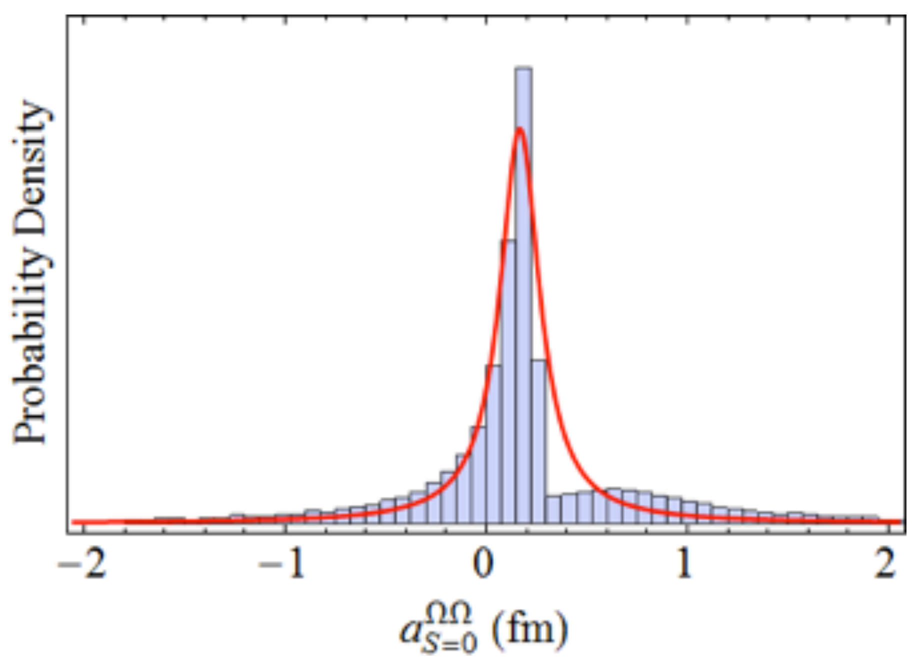


$$B_H^{\text{quadratic}} = 7.4 \pm 2.1 \pm 5.8\ \text{MeV}$$

ΩΩ scattering on the lattice







J. Wasem

$$a_{S=0}^{\Omega\Omega} = 0.16 \pm 0.22 \text{ fm}$$

m_π~390 MeV

Exotic hadron yields are not small !

C.M. Ko

Exotic hadron yields at RHIC and LHC

TABLE V. Exotic hadron yields in central Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV at RHIC and in central Pb + Pb collisions at $\sqrt{s_{NN}} = 5.5$ TeV at LHC from the quark coalescence ($2q/3q/6q$ and $4q/5q/8q$) and the hadron coalescence (Mol.), as well as from the statistical model (Stat.)

	RHIC				LHC			
	$2q/3q/6q$	$4q/5q/8q$	Mol.	Stat.	$2q/3q/6q$	$4q/5q/8q$	Mol.	Stat.
Mesons								
$f_0(980)$	3.8, 0.73($s\bar{s}$)	0.10	13	5.6	10, 2.0 ($s\bar{s}$)	0.28	36	15
$a_0(980)$	11	0.31	40	17	31	0.83	1.1×10^2	46
$K(1460)$	—	0.59	3.6	1.3	—	1.6	9.3	3.2
$D_s(2317)$	1.3×10^{-2}	2.1×10^{-3}	1.6×10^{-2}	5.6×10^{-2}	8.7×10^{-2}	1.4×10^{-2}	0.10	0.35
T_{cc}^{1} [a]	—	4.0×10^{-5}	2.4×10^{-5}	4.3×10^{-4}	—	6.6×10^{-4}	4.1×10^{-4}	7.1×10^{-3}
$X(3872)$	1.0×10^{-4}	4.0×10^{-5}	7.8×10^{-4}	2.9×10^{-4}	1.7×10^{-3}	6.6×10^{-4}	1.3×10^{-2}	4.7×10^{-3}
$Z^+(4430)$ [b]	—	1.3×10^{-5}	2.0×10^{-5}	1.4×10^{-5}	—	2.1×10^{-4}	3.4×10^{-4}	2.4×10^{-4}
T_{cb}^{0} [a]	—	6.1×10^{-8}	1.8×10^{-7}	6.9×10^{-7}	—	6.1×10^{-6}	1.9×10^{-5}	6.8×10^{-5}
Baryons								
$\Lambda(1405)$	0.81	0.11	1.8–8.3	1.7	2.2	0.29	4.7–21	4.2
Θ^+ [b]	—	2.9×10^{-2}	—	1.0	—	7.8×10^{-2}	—	2.3
$\bar{K}KN$ [a]	—	1.9×10^{-2}	1.7	0.28	—	5.2×10^{-2}	4.2	0.67
$\bar{D}N$ [a]	—	2.9×10^{-3}	4.6×10^{-2}	1.0×10^{-2}	—	2.0×10^{-2}	0.28	6.1×10^{-2}
$\bar{D}^*N$ [a]	—	7.1×10^{-4}	4.5×10^{-2}	1.0×10^{-2}	—	4.7×10^{-3}	0.27	6.2×10^{-2}
Θ_{cs} [a]	—	5.9×10^{-4}	—	7.2×10^{-3}	—	3.9×10^{-3}	—	4.5×10^{-2}
BN [a]	—	1.9×10^{-5}	8.0×10^{-5}	3.9×10^{-5}	—	7.7×10^{-4}	2.8×10^{-3}	1.4×10^{-3}
B^*N [a]	—	5.3×10^{-6}	1.2×10^{-4}	6.6×10^{-5}	—	2.1×10^{-4}	4.4×10^{-3}	2.4×10^{-3}
Dibaryons								
H [a]	3.0×10^{-3}	—	1.6×10^{-2}	1.3×10^{-2}	8.2×10^{-3}	—	3.8×10^{-2}	3.2×10^{-2}
$\bar{K}NN$ [b]	5.0×10^{-3}	5.1×10^{-4}	0.011–0.24	1.6×10^{-2}	1.3×10^{-2}	1.4×10^{-3}	0.026 – 0.54	3.7×10^{-2}
$\Omega\Omega$ [a]	3.2×10^{-5}	—	1.5×10^{-5}	6.4×10^{-5}	8.6×10^{-5}	—	4.4×10^{-5}	1.9×10^{-4}
H_c^{++} [a]	3.0×10^{-4}	—	3.3×10^{-4}	7.5×10^{-4}	2.0×10^{-3}	—	1.9×10^{-3}	4.2×10^{-3}
$\bar{D}NN$ [a]	—	2.9×10^{-5}	1.8×10^{-3}	7.9×10^{-5}	—	2.0×10^{-4}	9.8×10^{-3}	4.2×10^{-4}
BNN [a]	—	2.3×10^{-7}	1.2×10^{-6}	2.4×10^{-7}	—	9.2×10^{-6}	3.7×10^{-5}	7.6×10^{-6}

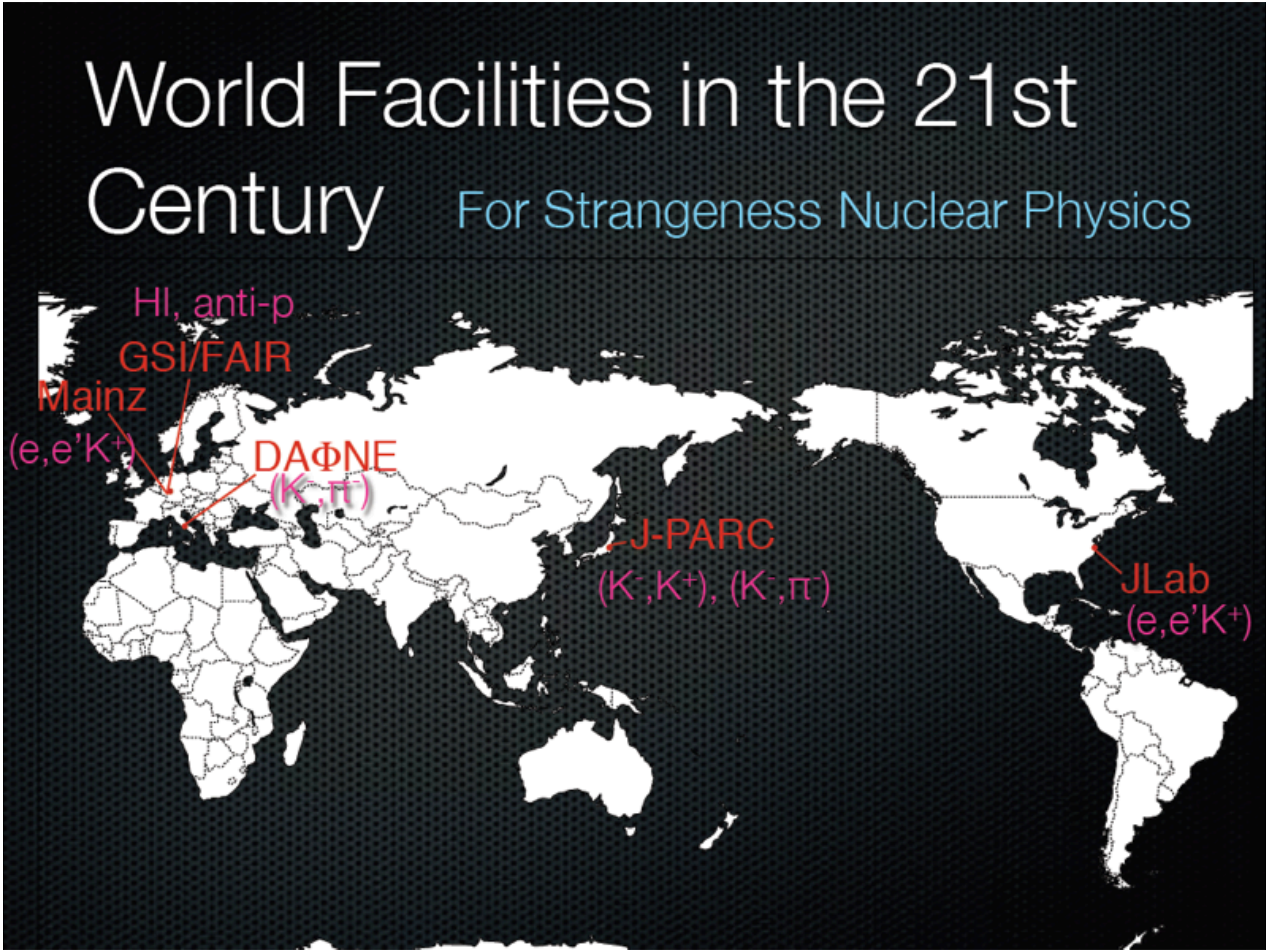
[a] Particles that are newly predicted by theoretical model.
[b] Particles that are not yet established.

- Most yields are sufficient large ($>10^{-5}$)

17

Why we may soon know more

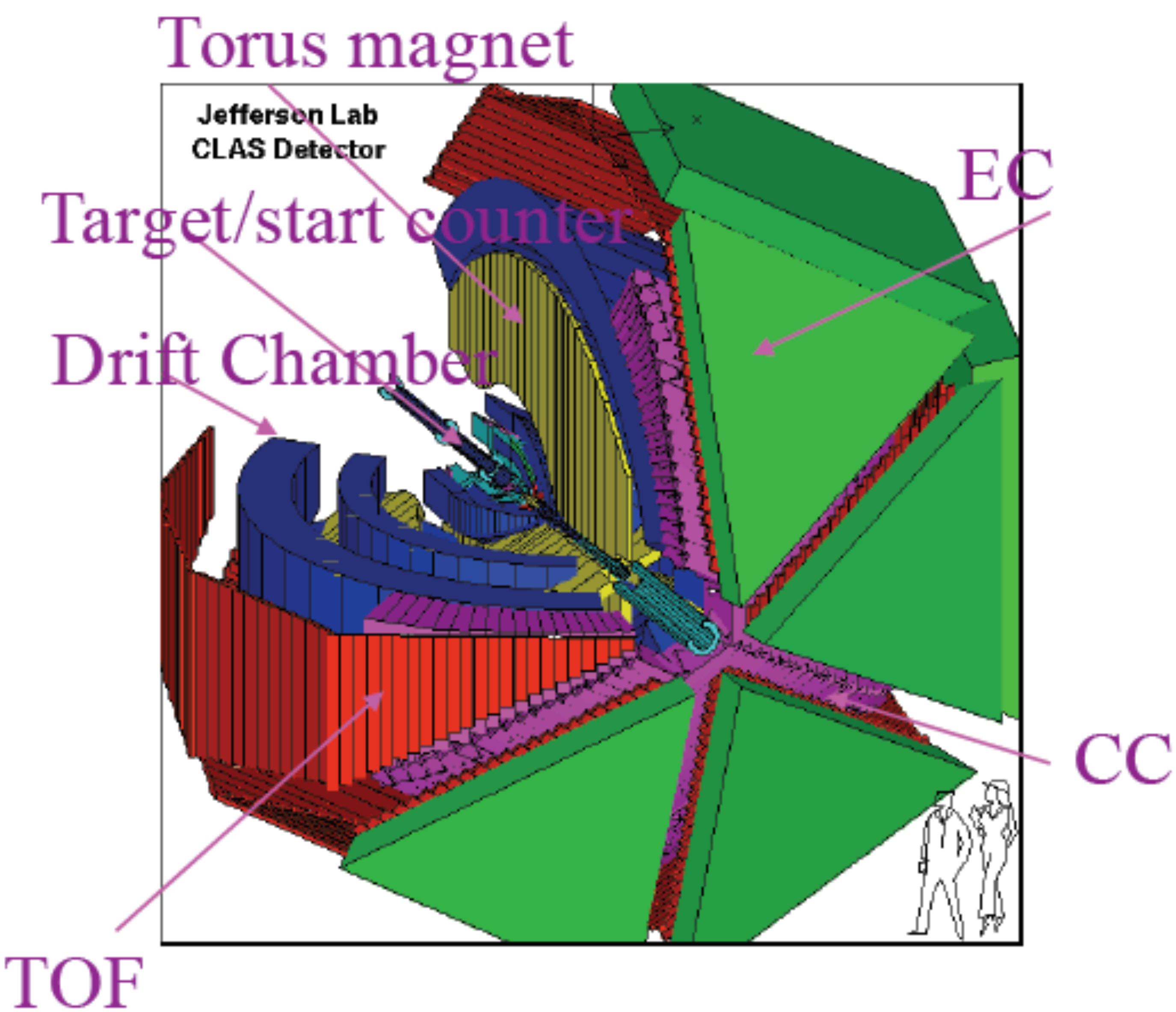
The onslaught



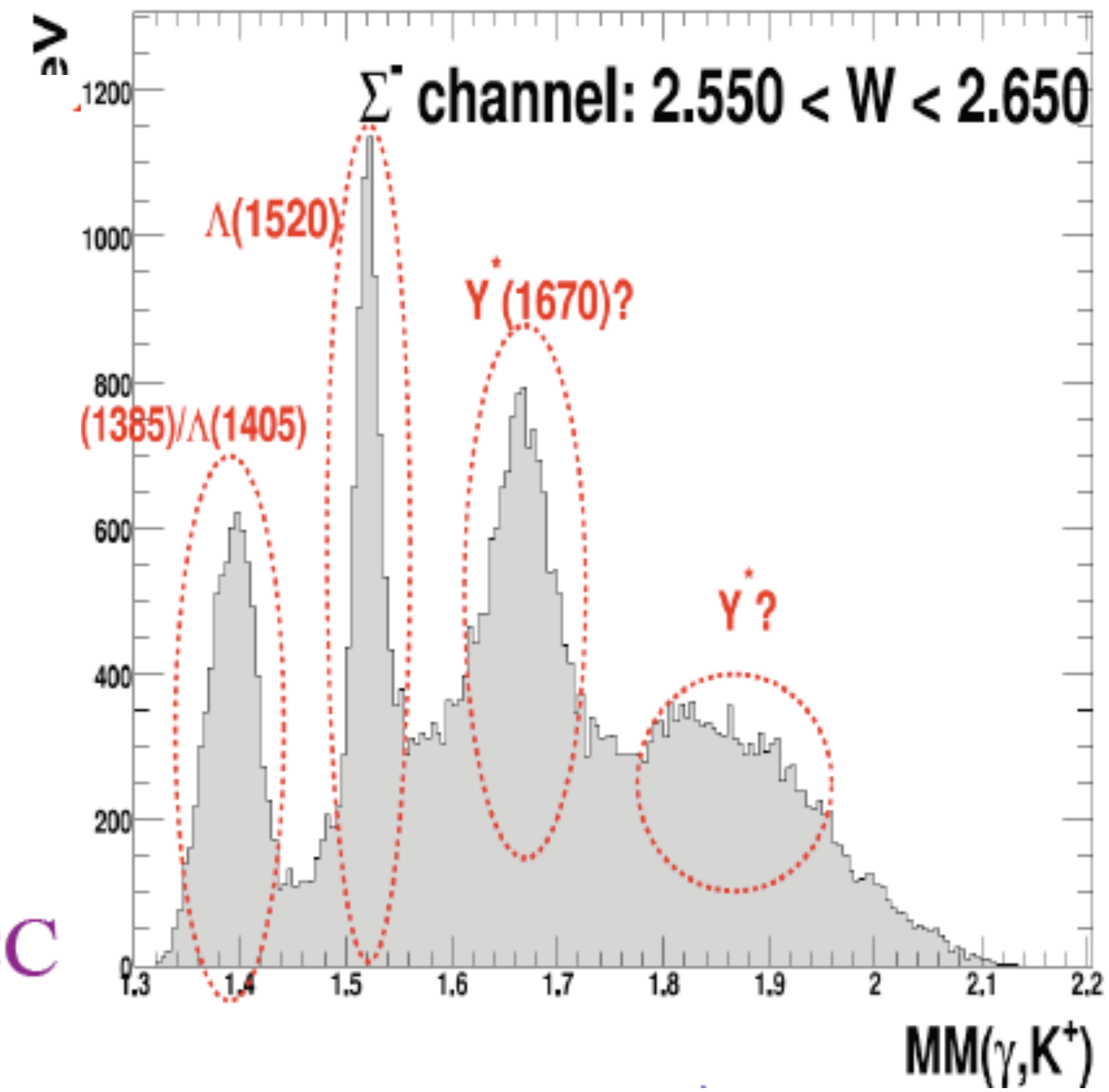
CLAS

L. Guo

CLAS

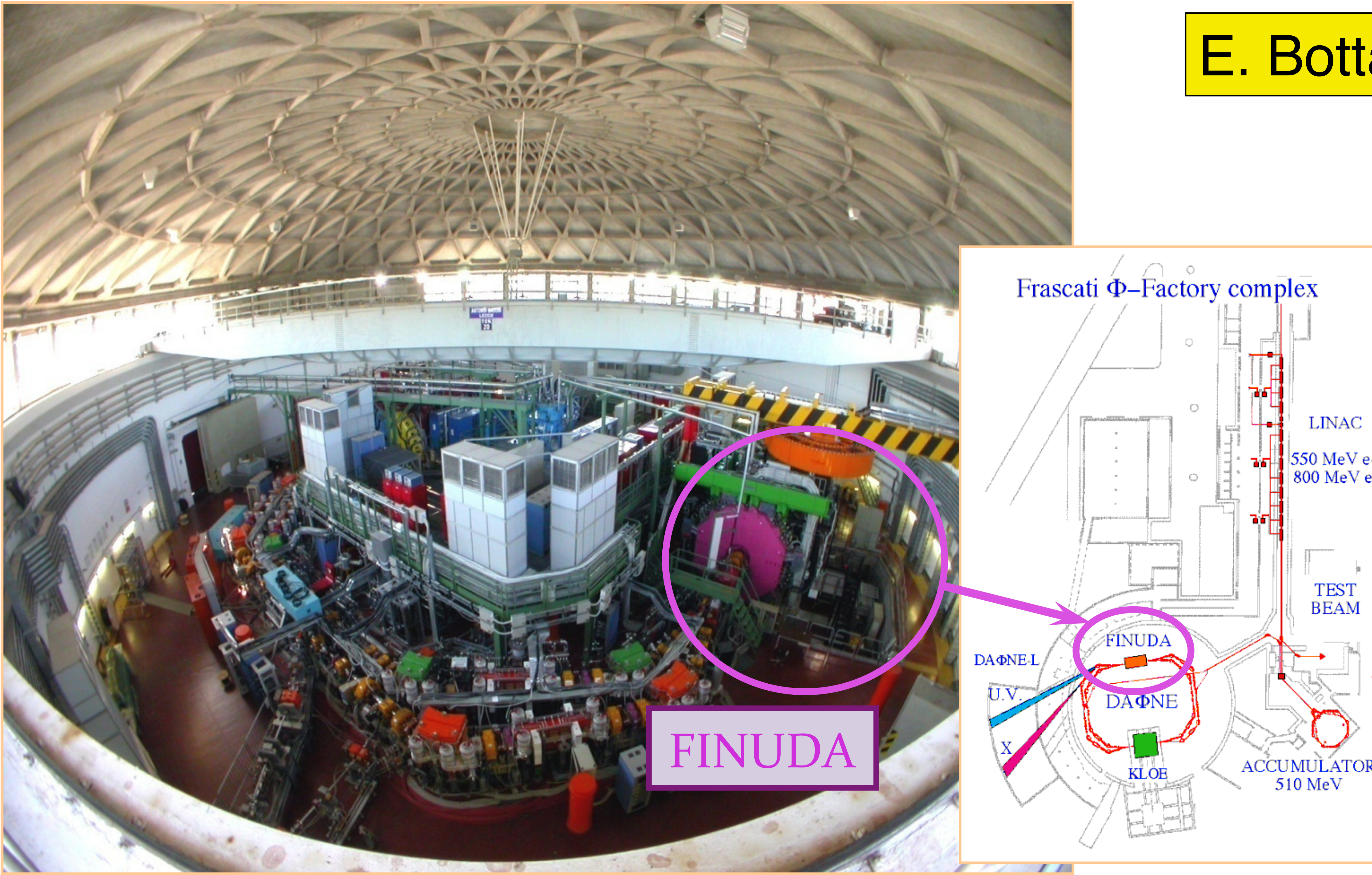


A small sample of CLAS hyperon data



FINUDA

E. Botta



Hyper-heavy hydrogen

$^{6}_{\Lambda}H$ search with FINUDA

$K^-_{stop} + {}^6Li \rightarrow {}^6_{\Lambda}H + \pi^+$

${}^6_{\Lambda}H \rightarrow {}^6He + \pi^-$

independent reactions: decay at rest

$$M(K^-) + 3\,M(n) + 3M(p) - B(^6Li) = M(^6_{\Lambda}H) + T(^6_{\Lambda}H) + M(\pi^+) + T(\pi^+)$$

$$M(^6_{\Lambda}H) = 4\,M(n) + 2M(p) - B(^6He) + T(^6He) + M(\pi^-) + T(\pi^-)$$

$\sqrt{M^2(^6He) + p^2(\pi^-)} - M(^6He)$

$\sqrt{M^2(^6_{\Lambda}H) + p^2(\pi^+)} - M(^6_{\Lambda}H)$

$M(^6_{\Lambda}H) = M(^5H) + M(\Lambda) - B(\Lambda)$

$$T(\pi^+) + T(\pi^-) = M(K^-) + M(p) - M(n) - B(^6Li) + B(^6He) - T(^6He) - T(^6_{\Lambda}H) - M(\pi^+) - M(\pi^-)$$

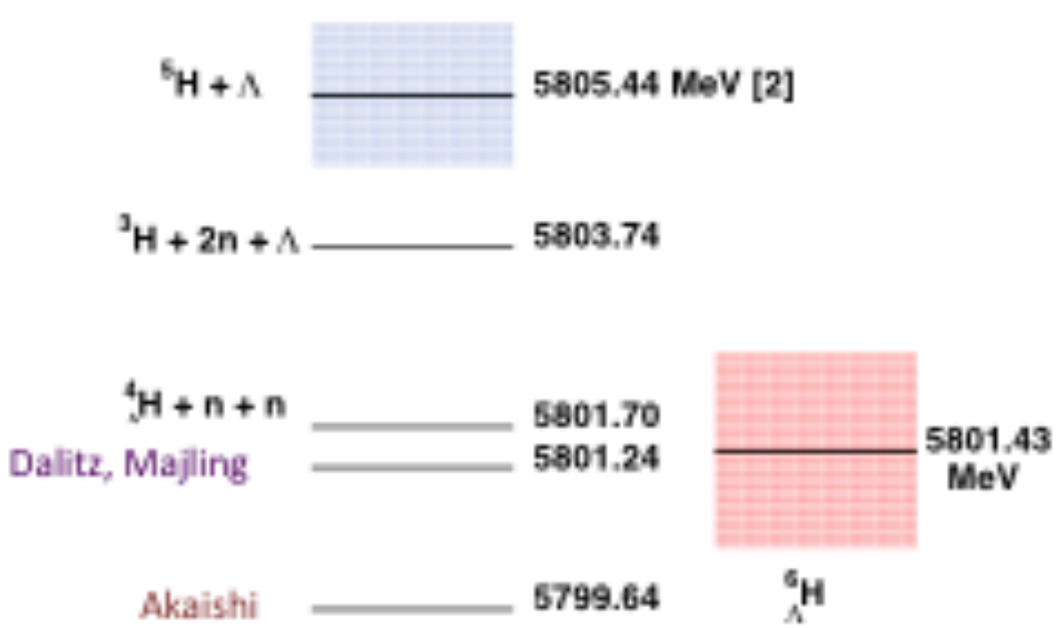
= **203.0 ± 1.3 MeV** (203.5÷203.2 MeV with B_{Λ}= 0÷6 MeV)

cut on $T(\pi^+) + T(\pi^-)$: 202÷204 MeV

25

kinematics

T_{tot} (MeV)	$p(\pi^+)$ (MeV/c)	$p(\pi^-)$ (MeV/c)	$M(^6_\Lambda H)$ formation (MeV/c^2)	$M(^6_\Lambda H)$ decay (MeV/c^2)
202.5±1.3	251.3±1.1	135.1±1.2	5802.33±0.96	5801.41±0.84
202.7±1.3	250.0±1.1	136.9±1.2	5803.45±0.96	5802.73±0.84
202.1±1.3	253.8±1.1	131.2±1.2	5799.97±0.96	5798.66±0.84



mean value = 5801.4±1.1

B_Λ = 4.0±1.1 MeV (^{5}He + Λ)

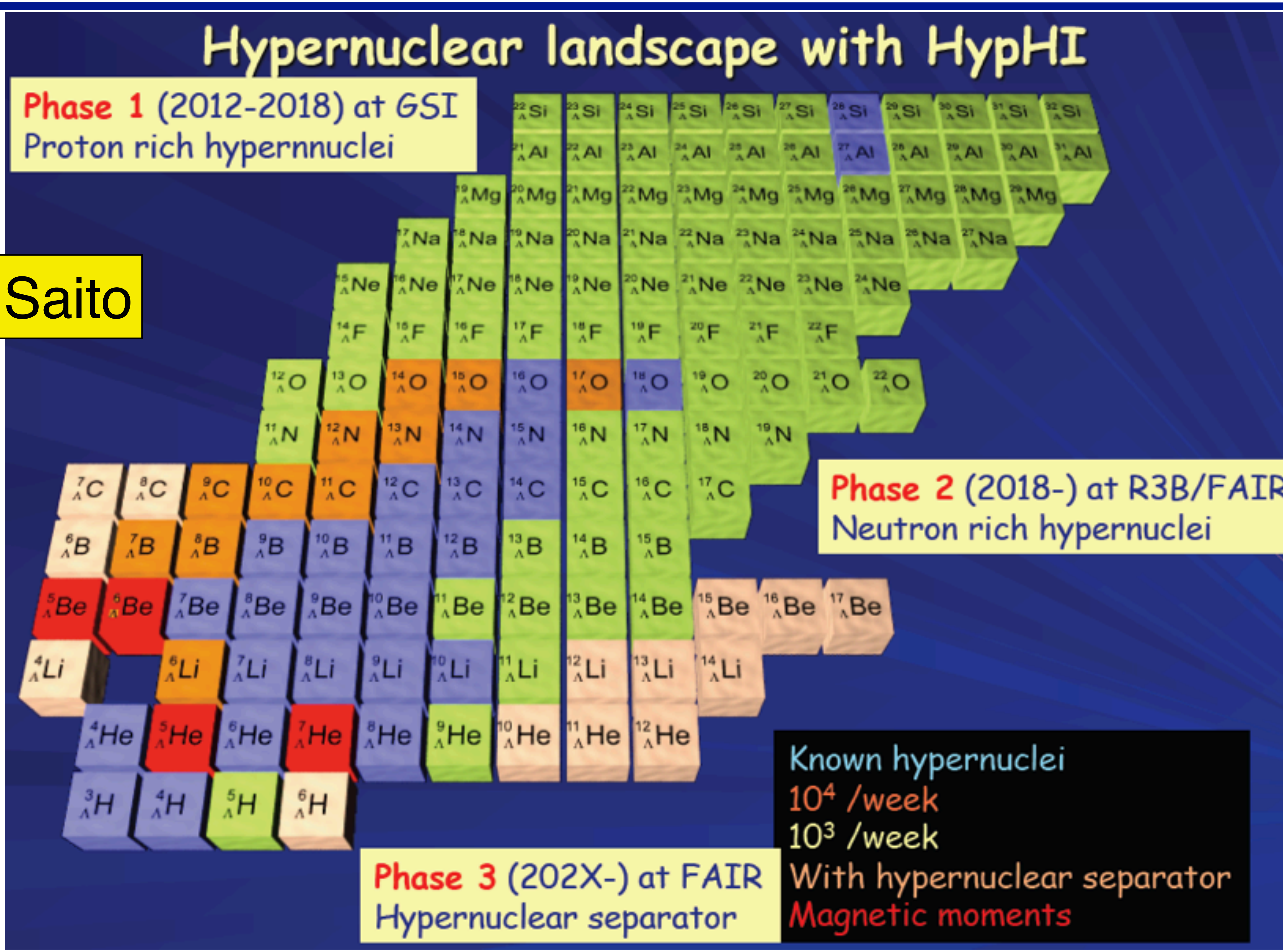
B_Λ = 5.8 MeV (^{5}He + Λ)
LNN force: 1.4 MeV

formation – decay = 0.98±0.74 MeV
excitation spectrum of $^6_\Lambda$H

M. Agnello et al., PRL 108 (2012) 042501

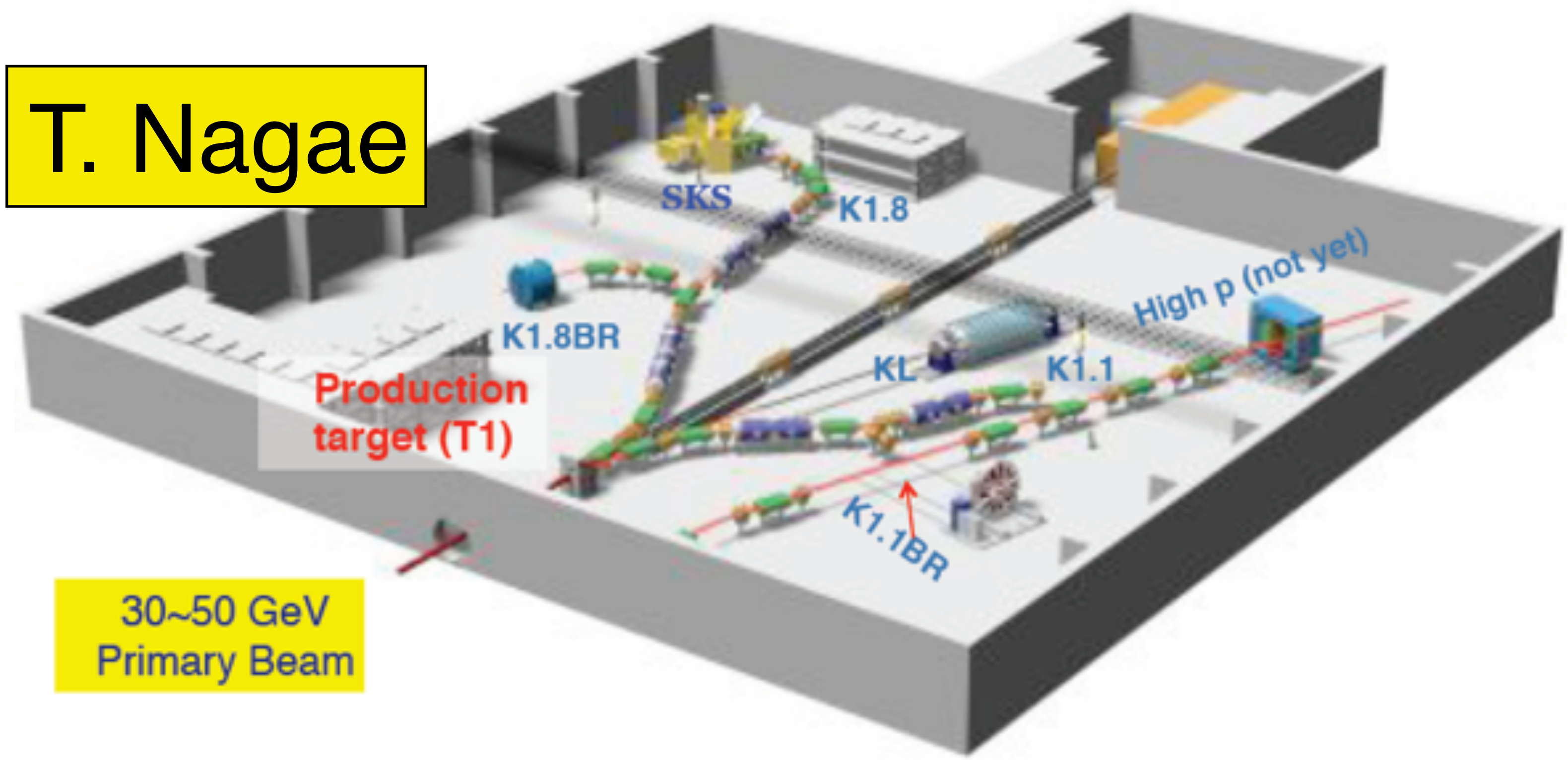
HypHI @ GSI/FAIR

T. Saito

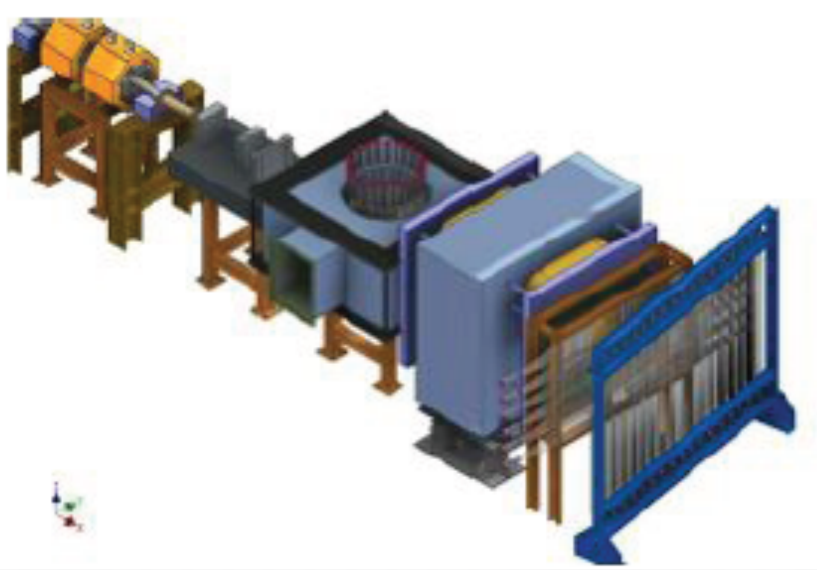


J-PARC

T. Nagae



$^{12}{}_{\Xi}$Be, via the ^{12}C(K$^-$,K$^+$) Reaction



H search at J-PARC

(K$^-$,K$^+$) reaction

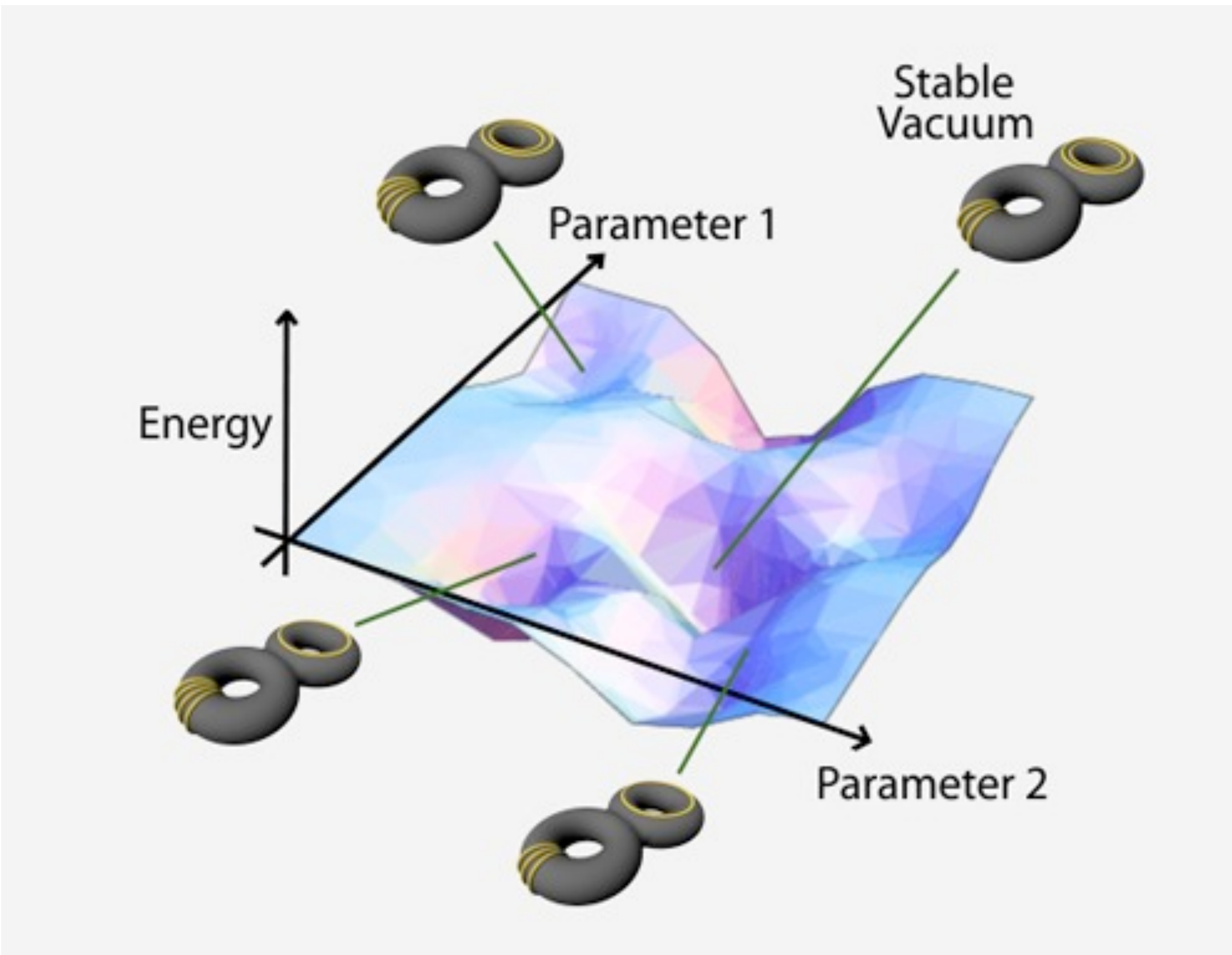
The Question

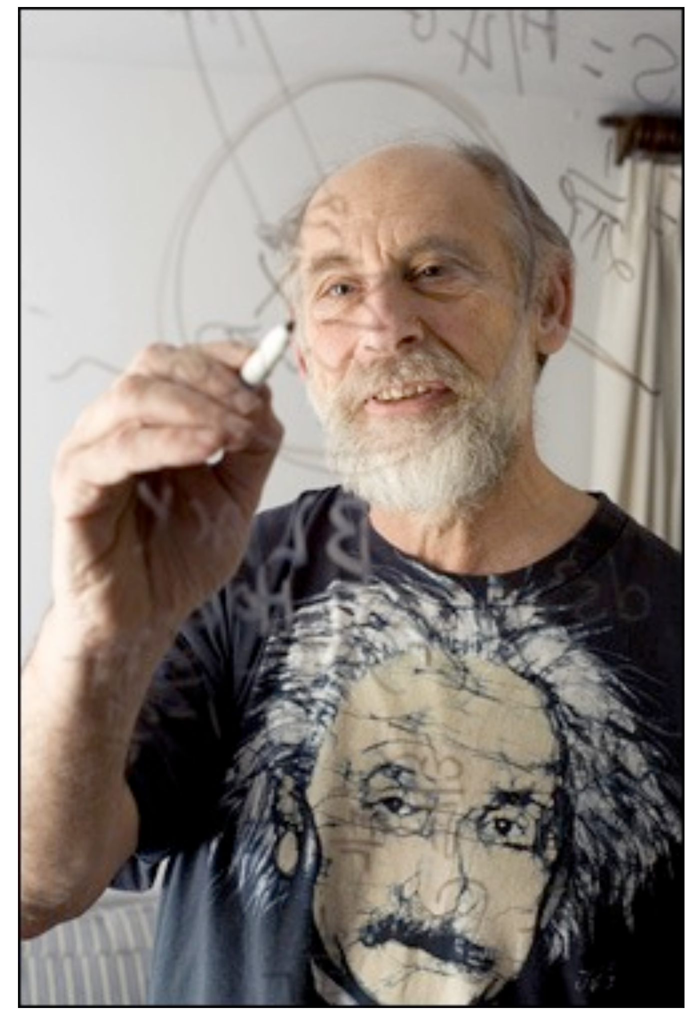
Nu Xu: Is it enough to measure $\Lambda\Lambda$ correlations, or do we need to also measure $\Xi\Xi$ correlations?

My response: The $\Lambda\Lambda$ system has different quantum numbers than the *NN* system, and it is the pathway to the *H* di-baryon, if it exists. It's important.
The $\Xi\Xi$ is just a copy of the *NN* system with different quark masses. It's relatively boring.

This was one of the stupidest answers I have given!

The string landscape





The anthropic principle

P(our existence) =
P(our existence | fundamental parameters)
× P(fundamental parameters)

Fundamental parameters:
coupling constants
quark and lepton masses
mixing angles
VEV’s

Dependence on quark masses is least well known.

Are quark masses constant?

Variation of Fundamental Couplings and Nuclear Forces

Silas R. Beane, Martin J. Savage

(Submitted on 12 Jun 2002 (v1), last revised 16 Jul 2002 (this version, v2))

The dependence of the nuclear force on standard model parameters plays an important role in bounding time and space variations of fundamental couplings over cosmological time scales. We discuss the quark-mass dependence of deuteron and di-neutron binding in a systematic chiral expansion. The leading quark-mass dependence of the nuclear force arises from one-pion exchange and from local quark-mass dependent four-nucleon operators with coefficients that are presently unknown. By varying these coefficients while leaving nuclear observables at the physical values of the quark masses invariant, we find scenarios where two-nucleon physics depends both weakly and strongly on the quark masses. While the determination of these coefficients is an exciting future opportunity for lattice QCD, we conclude that, at present, bounds on time and space variations of fundamental parameters from the two-nucleon sector are much weaker than previously claimed. This brings into question the reliability of coupling-constant bounds derived from more complex nuclei and nuclear processes.

Comments:16 pages LaTeX, 4 eps figs, 12 ps figs
Subjects: **High Energy Physics - Phenomenology (hep-ph)**; Astrophysics (astro-ph); High Energy Physics - Lattice (hep-lat); High Energy Physics - Theory (hep-th); Nuclear Theory (nucl-th)
Journal reference: Nucl.Phys. A713 (2003) 148-164
DOI: 10.1016/S0375-9474(02)01268-X
Report number: NT@UW-02-015
Cite as: arXiv:hep-ph/0206113v2

Mass dependence of the cosmos

Nuclear Astrophysics of Worlds in the String Landscape

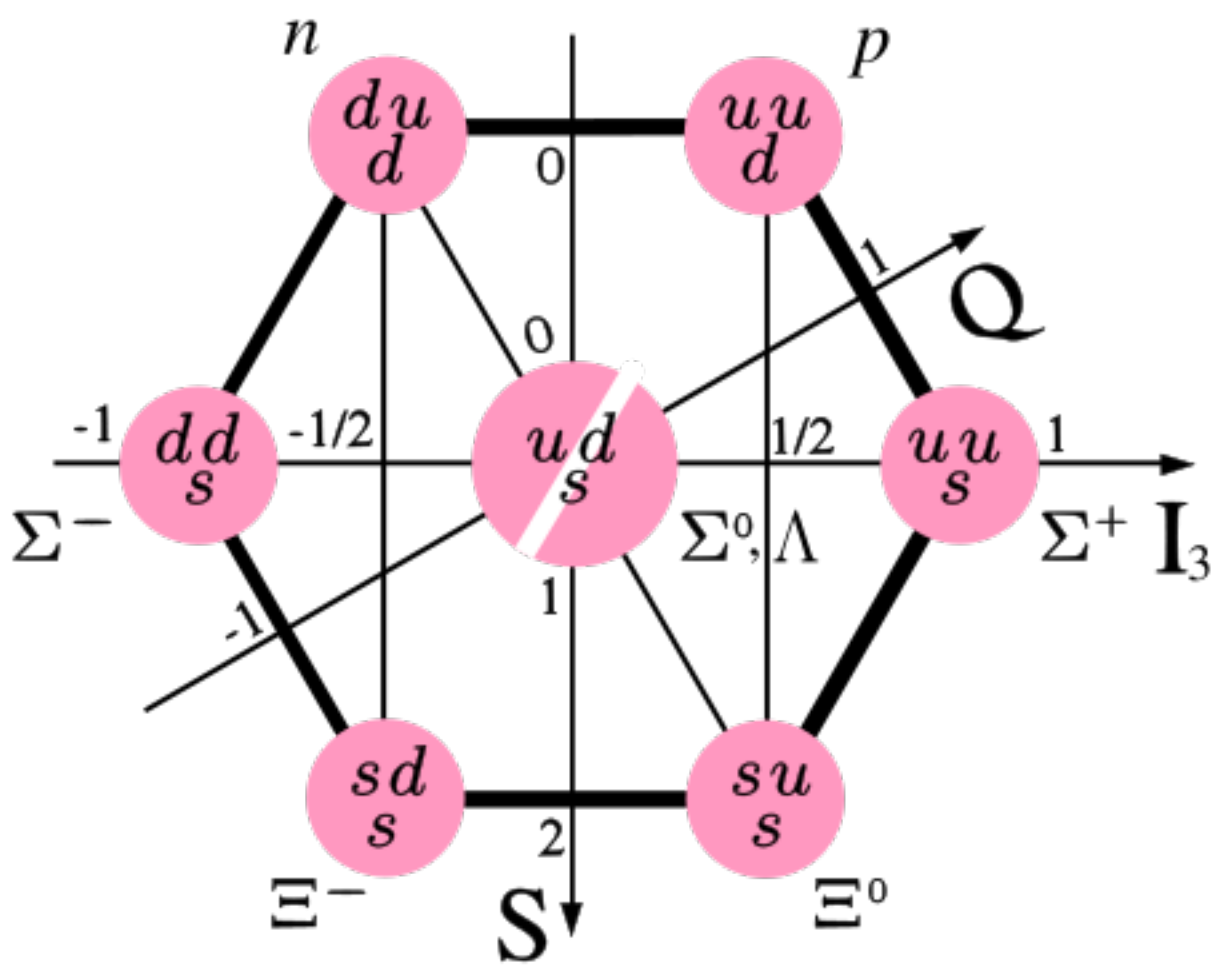
Craig J. Hogan

(Submitted on 6 Feb 2006 (v1), last revised 7 Dec 2006 (this version, v4))

Motivated by landscape models in string theory, cosmic nuclear evolution is analyzed allowing the Standard Model Higgs expectation value w to take values different from that in our world (w=1), while holding the Yukawa couplings fixed. Thresholds are estimated, and astrophysical consequences are described, for several sensitive dependences of nuclear behavior on w. The dependence of the neutron-proton mass difference on w is estimated based on recent calculations of strong isospin symmetry breaking, and is used to derive the threshold of neutron-stable worlds, w ~ 0.6+/- 0.2. The effect of a stable neutron on nuclear evolution in the Big Bang and stars is shown to lead to radical differences from our world, such as a predominance of heavy r-process and s-process nuclei and a lack of normal galaxies, stars and planets. Rough estimates are reviewed of w thresholds for deuteron stability and the pp and pep reactions dominant in many stars. A simple model of nuclear resonances is used to estimate the w dependence of overall carbon and oxygen production during normal stellar nucleosynthesis; carbon production is estimated to change by a fraction ~15(1-w). Radical changes in astrophysical behavior seem to require changes in w of more than a few percent, even for the most sensitive phenomena.

Comments: 11 pages, Latex, to appear in Phys. Rev. D
Subjects: **Astrophysics (astro-ph)**; High Energy Physics - Phenomenology (hep-ph)
Journal reference: Phys.Rev. D74 (2006) 123514
DOI: 10.1103/PhysRevD.74.123514
Cite as: arXiv:astro-ph/0602104v4

How ΞΞ would help



NN: (ud)u ↔ (ud)d

ΞΞ: (ss)u ↔ (ss)d

We cannot change the u/d quark masses, but we can replace u/d by s !

Exploring the ΞΞ interaction is as close as we will ever get to verifying theoretical predictions for the quark mass dependence of nuclear forces.

The Future

The quest continues....

"You'll have to take over Weinbart's entropy experiment — he died."

The Future

The quest continues….

"You'll have to take over Weinbart's
for the *H* di-baryon — he graduated."

The Future

The quest continues....

"You'll have to take over Weinbart's for the *H* di-baryon — he graduated."

The END

The Future

The quest continues....

"You'll have to take over Weinbart's search for the *H* di-baryon — he graduated."

The END