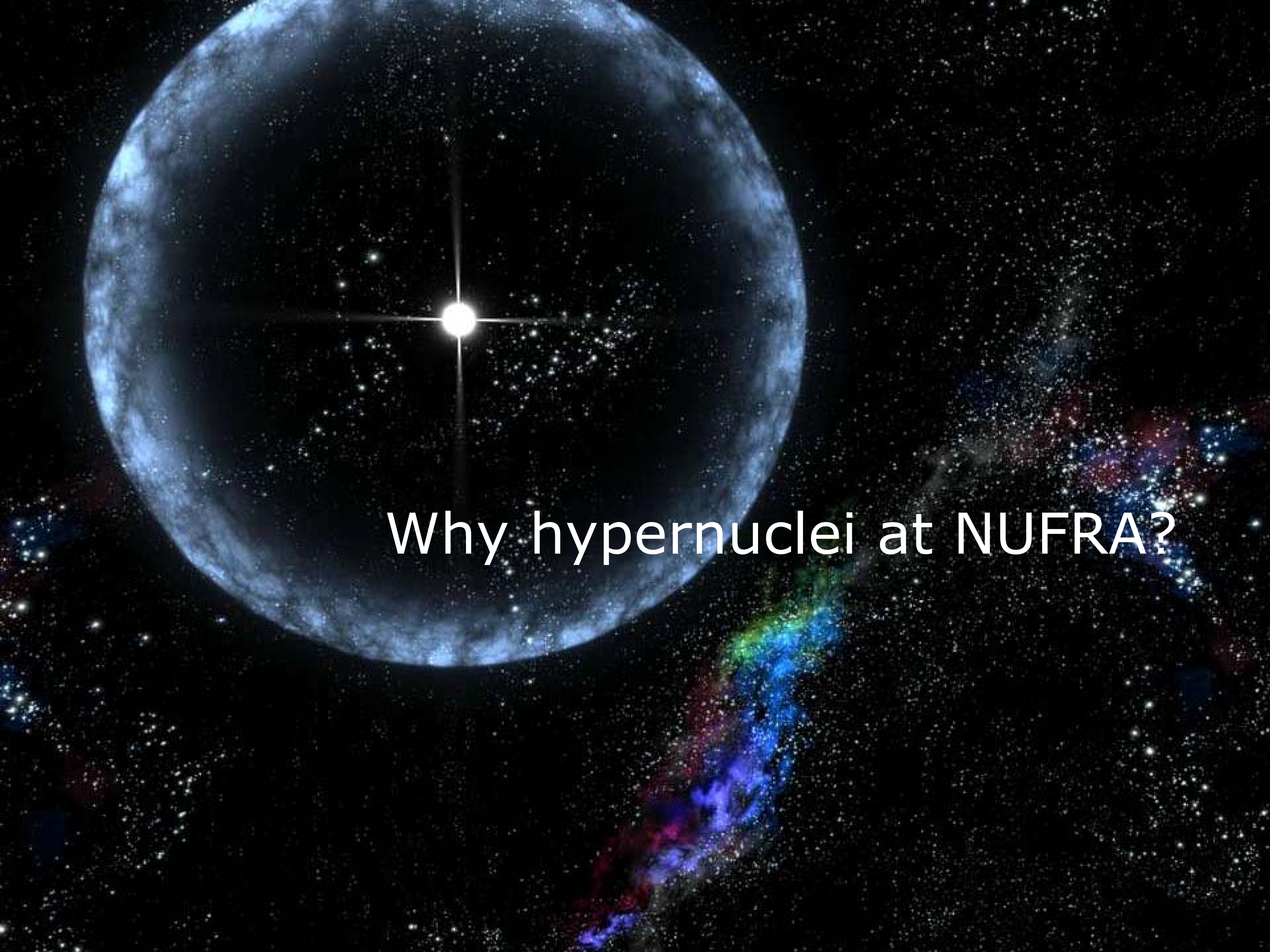
Roadmap for Hypernuclear Physics

Josef Pochodzalla

- Why hypernuclei at NUFRA?
- Why do we need so many different experimental facilities?
- Double hypernuclei

Why hypernuclei at NUFRA?



Hypernuclear physics is in a strange position. It is neither fish nor fowl. High-energy physicists do not look to it for valuable advances in their understanding of the interactions of fundamental particles. Nuclear physicists also see the field as something apart. Its main relevance for the fundamentals is the information it can provide on N–Λ and Λ–Λ interactions.

J. D. Jackson

Lawrence Radiation Laboratory,
Berkeley, California

QCD ↔ Nuclei

Science, Vol. 159, p. 1346

5 decades of hyperons in neutron stars

NEUTRON STAR MODELS

A. G. W. Cameron
Atomic Energy of Canada Limited, Chalk River, Ontario, Canada
Received June 17, 1959

Another reason why the writer has not taken into account complications inherent in using a relativistic equation of state is that no such things as pure neutron stars can be expected to exist. The neutrons must always be contaminated with some protons and sometimes with other kinds of nucleons (hyperons or heavy mesons).

- Alastair G.W. Cameron, Astrophysical Journal, vol. 130, p.884 (1959)

Hyperons in neutron stars (2008)

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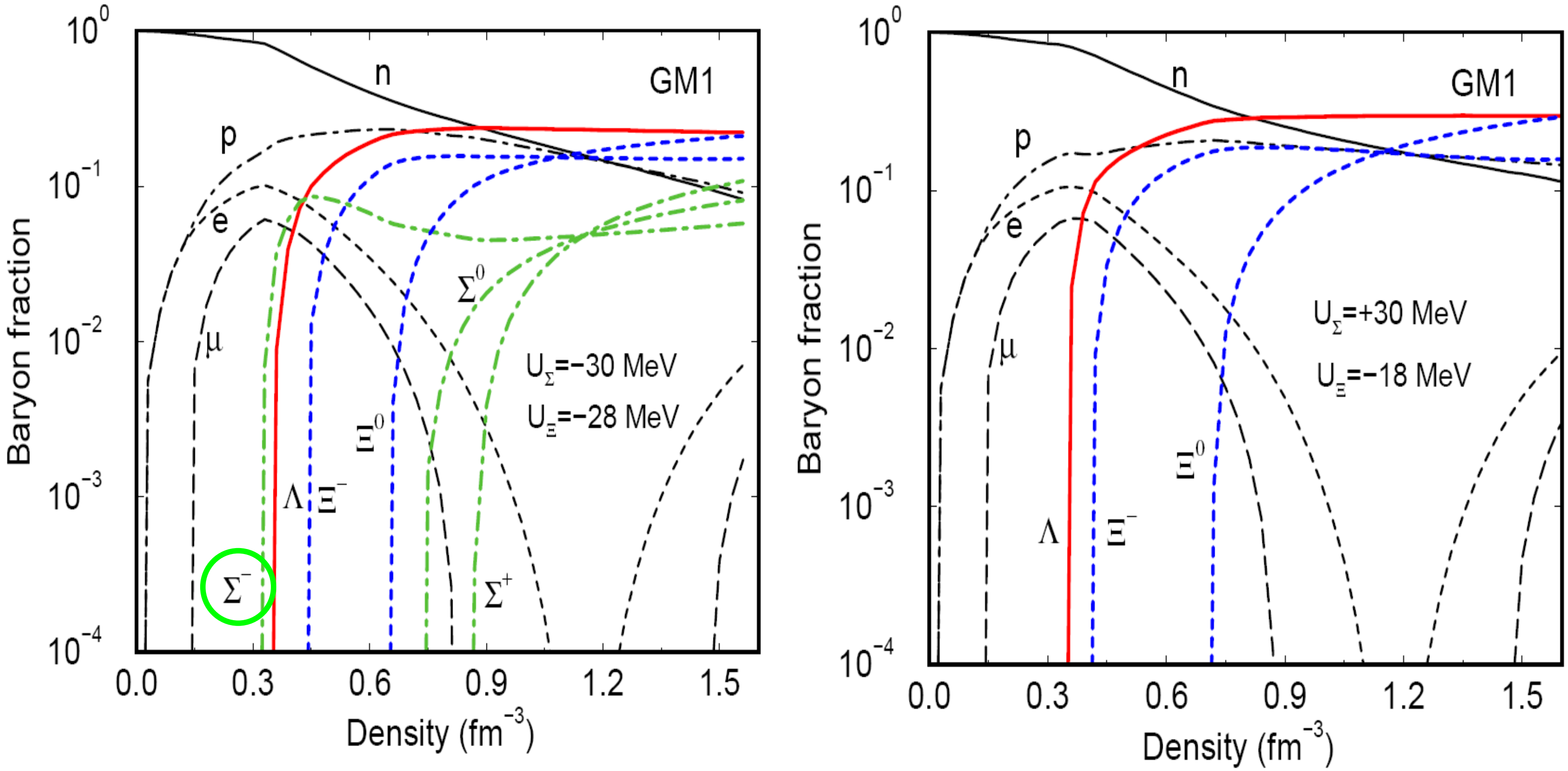
- Haris Djapo, Bern-Jochen Schäfer and Jochen Wambach
  arXiv:0811.2939v1 [nucl-th] 18 Nov 2008

In conclusion, irrespective of the YN interactions, incompressibility and symmetry parameter used, hyperons will appear in dense nuclear matter at densities around $\sim 2\rho_0$. This immediately leads to a softening of the EoS which in turn results in a smaller maximum mass of a neutron star.

With the prediction of a low onset of hyperon appearance it becomes practically impossible to ignore strangeness when considering neutron stars. Even though the prediction for the maximum masses of neutron stars are too low, the appearance of hyperons in neutron stars is necessary and any approach to dense matter must address this issue.

Baryon stars

- Input: Baryons in chemical Equilibrium, conservation laws, interaction

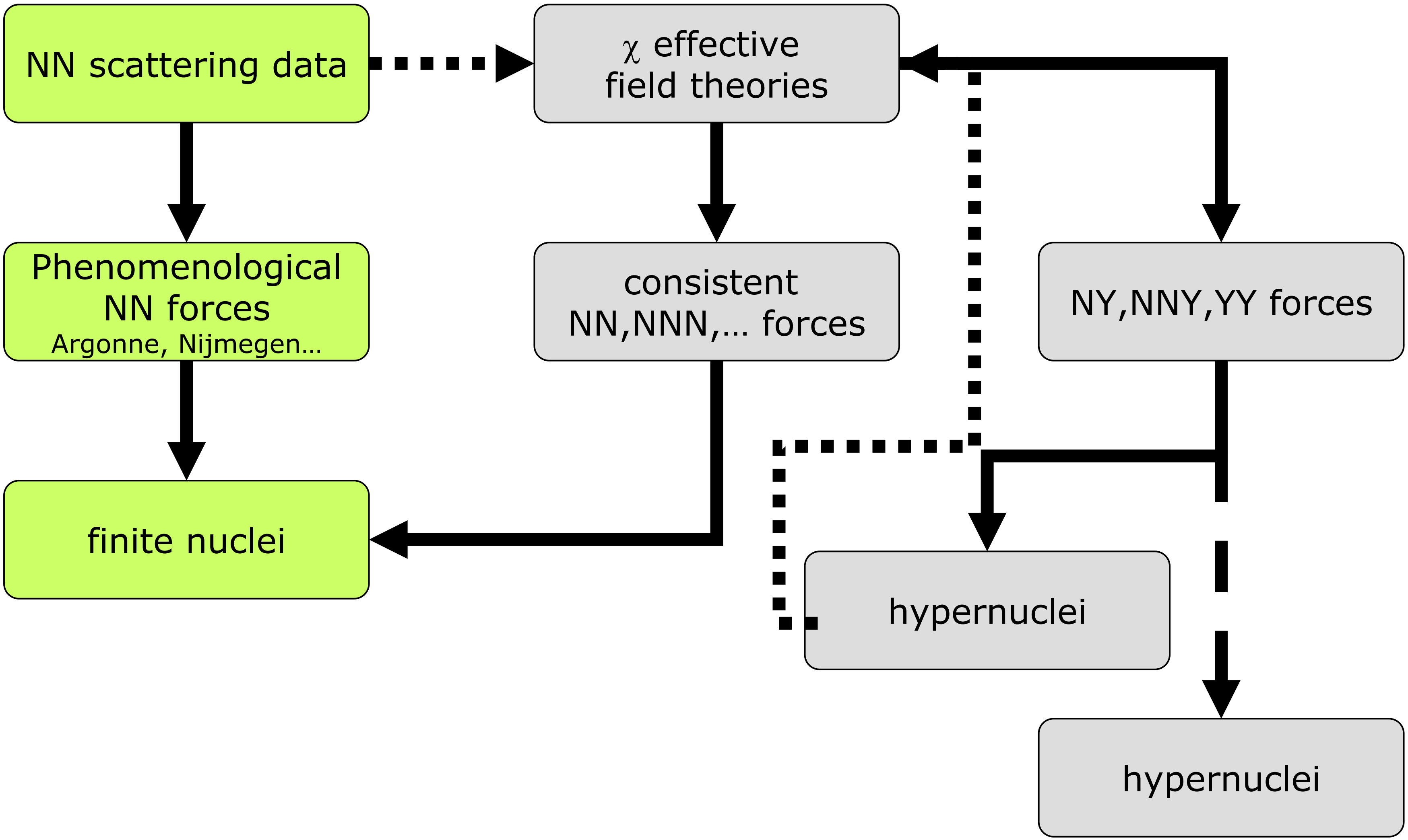


N. K. Glendenning, Phys. Rev. C **64**, 025801 (2001)

  - beyond $2\rho_0$ hyperons may play a significant role in neutron stars
  - in the core hyperons may even be more abundant than neutrons

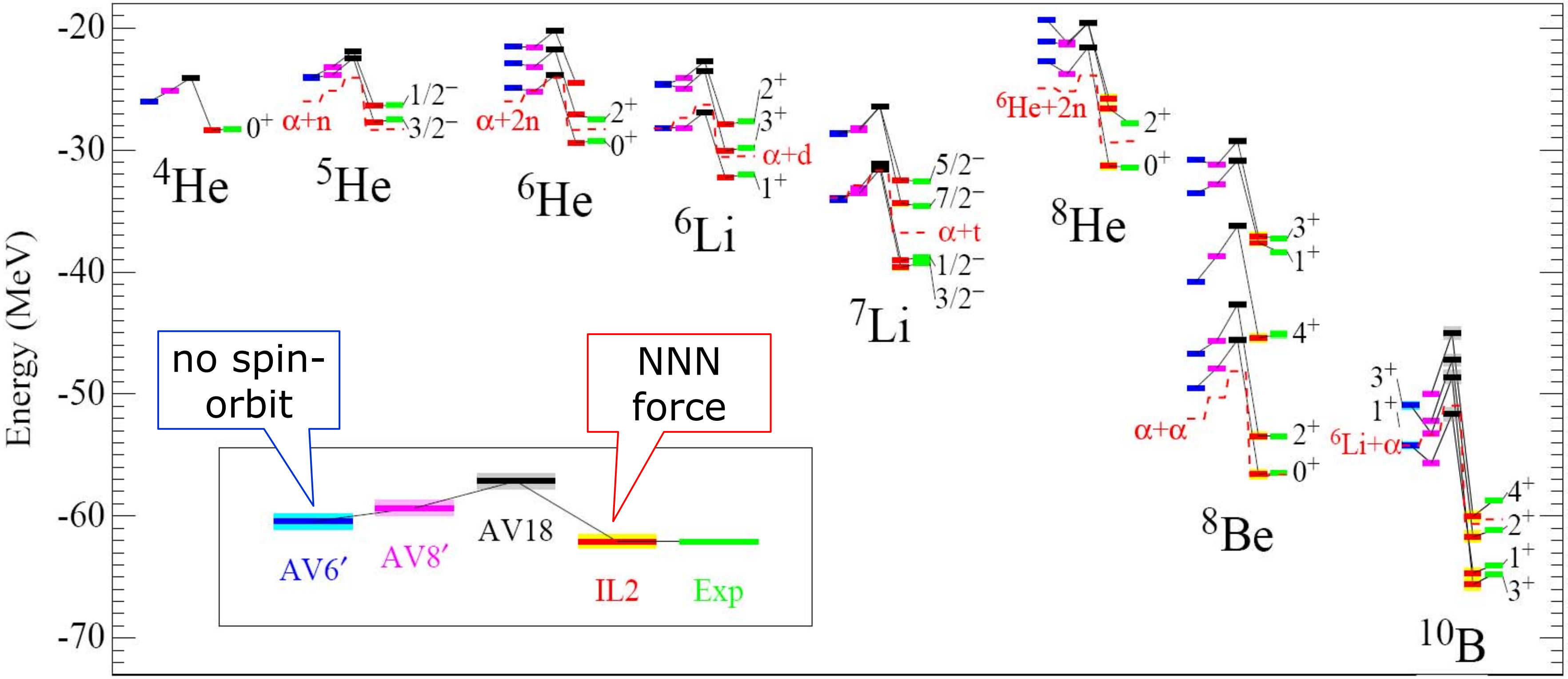
- needed: full BB interaction at high density= at small distances

Strategy


NN scattering data
χ effective
field theories
Phenomenological
NN forces
Argonne, Nijmegen...
consistent
NN,NNN,... forces
NY,NNY,YY forces
finite nuclei
hypernuclei
hypernuclei

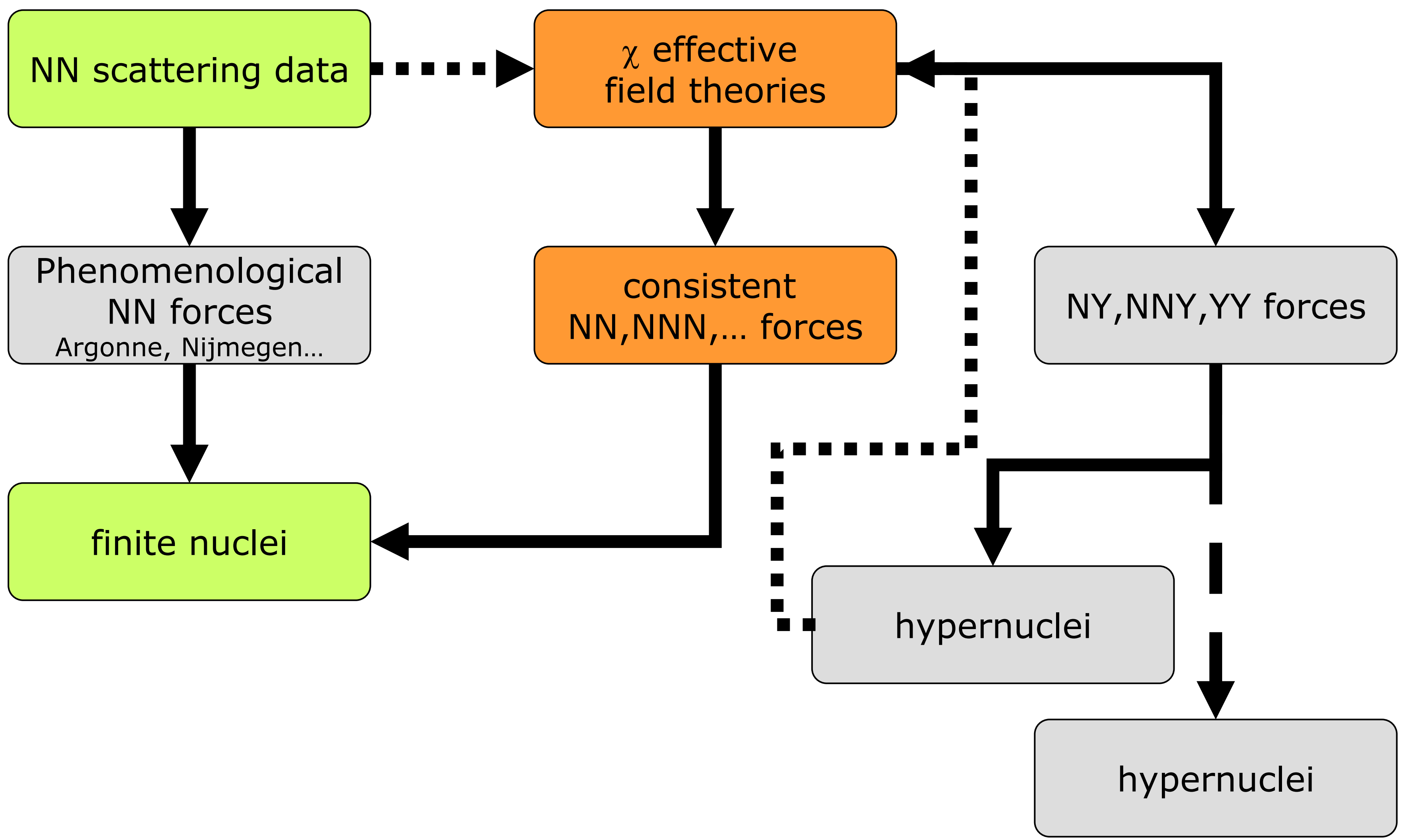
Microscopic View of Nuclear Structure

- Steven Stephen C. Pieper *et al.*, 2002
- potentials with increasing complexity



- spin-isospin and tensor forces present in long-range one-pion-exchange are essential
- multi-nucleon forces are vital
- sub-MeV precission (~3 parameters only)

Strategy


NN scattering data
χ effective
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Argonne, Nijmegen...
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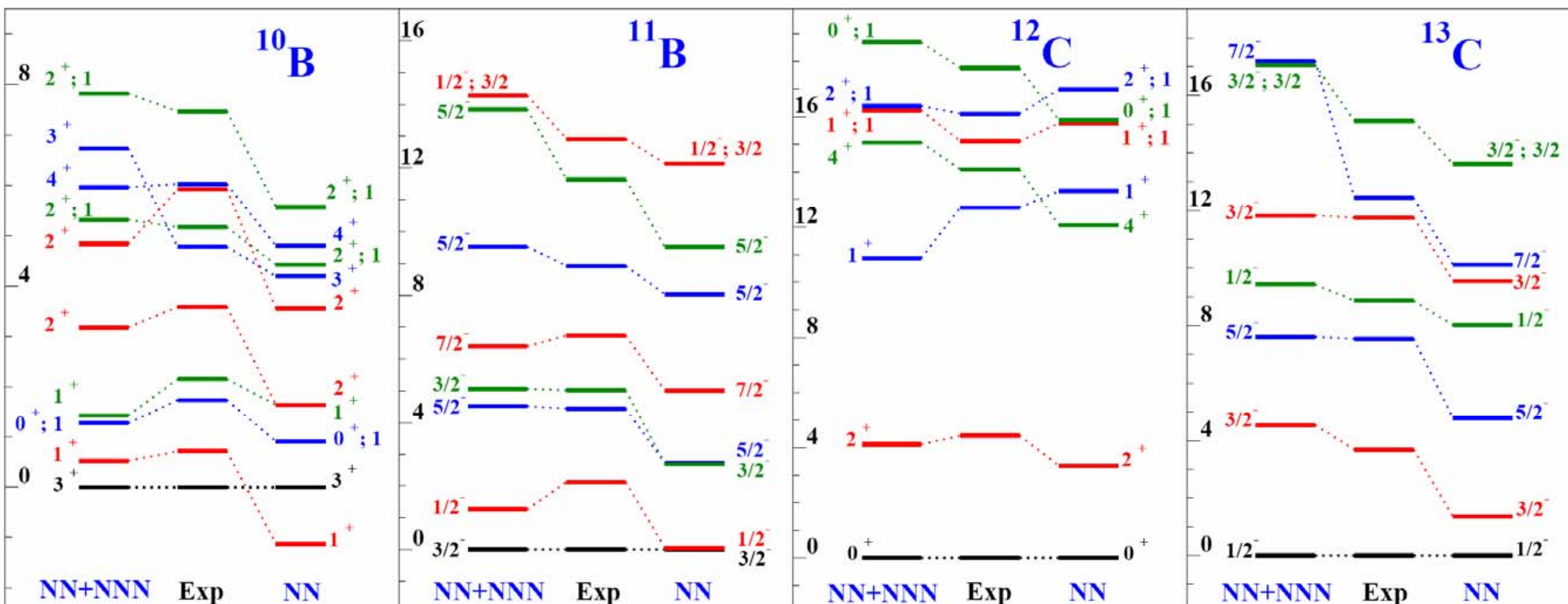
NY,NNY,YY forces
finite nuclei
hypernuclei
hypernuclei

χEFT - Results

Table 3 Binding energies E and expectation values of the NN ($\langle V_{NN} \rangle$) and $3N$ ($\langle V_{3NF} \rangle$) interactions for ^{4}He. All energies and the cut-offs are given in MeV. The experimental binding energy is −28.30 MeV

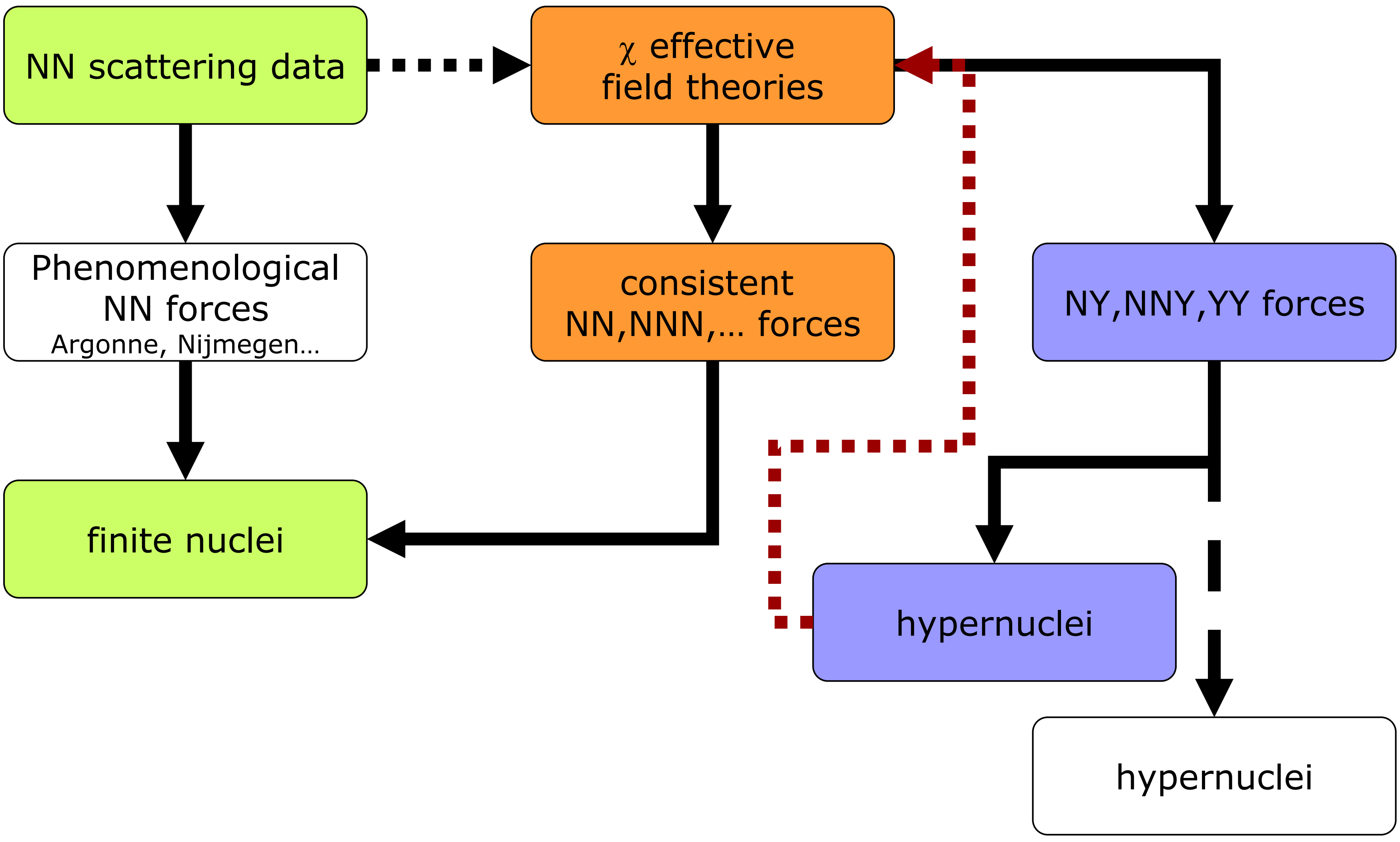
Interaction	$\Lambda/\tilde{\Lambda}$	E	$\langle V_{NN} \rangle$	$\langle V_{3NF} \rangle$	$\langle V_{NN} \rangle / \langle V_{3NF} \rangle$
Q^3	450 / 700	−27.65	−84.56	−1.11	1.3%
Q^3	600 / 700	−28.57	−93.73	−6.83	7.3%
Q^4-3NF-A	500 / DR	−28.27	−99.45	−4.06	4.1%
Q^4-3NF-B	500 / DR	−28.24	−98.92	−7.10	7.2%

A. Nogga



Navratil *et al.*

Strategy


NN scattering data
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finite nuclei
hypernuclei
hypernuclei

χEFT - Hypernuclei

- A. Nogga

Table 4 Λ separation energies of the 0^+ ($E_{sep}(0^+)$) and 1^+ ($E_{sep}(1^+)$) states and their difference ΔE_{sep} for ${}^4_\Lambda$H and the difference of the separation energies for the mirror hypernuclei ${}^4_\Lambda$He and ${}^4_\Lambda$H (CSB-0^+ and CSB-1^+). Results for the chiral *YN* interaction for various cut-offs Λ are compared to results for two phenomenological models [17, 18] and the experimental values

Λ [MeV]	500	550	650	700	Jülich 05	Nijm SC97f	Expt.
$E_{sep}(0^+)$ [MeV]	2.88	2.60	2.41	2.41	1.87	1.60	2.04
$E_{sep}(1^+)$ [MeV]	2.08	1.67	1.31	1.07	2.34	0.54	1.00
ΔE_{sep} [MeV]	0.80	0.93	1.10	1.34	−0.48	0.99	1.04
CSB-0^+ [MeV]	0.01	0.02	0.02	0.03	−0.01	0.12	0.35
CSB-1^+ [MeV]	−0.01	−0.01	−0.01	−0.01	–	−0.01	0.24

${}^4_\Lambda H$

Why do we need so many different facilities ?

International Hypernuclear Network

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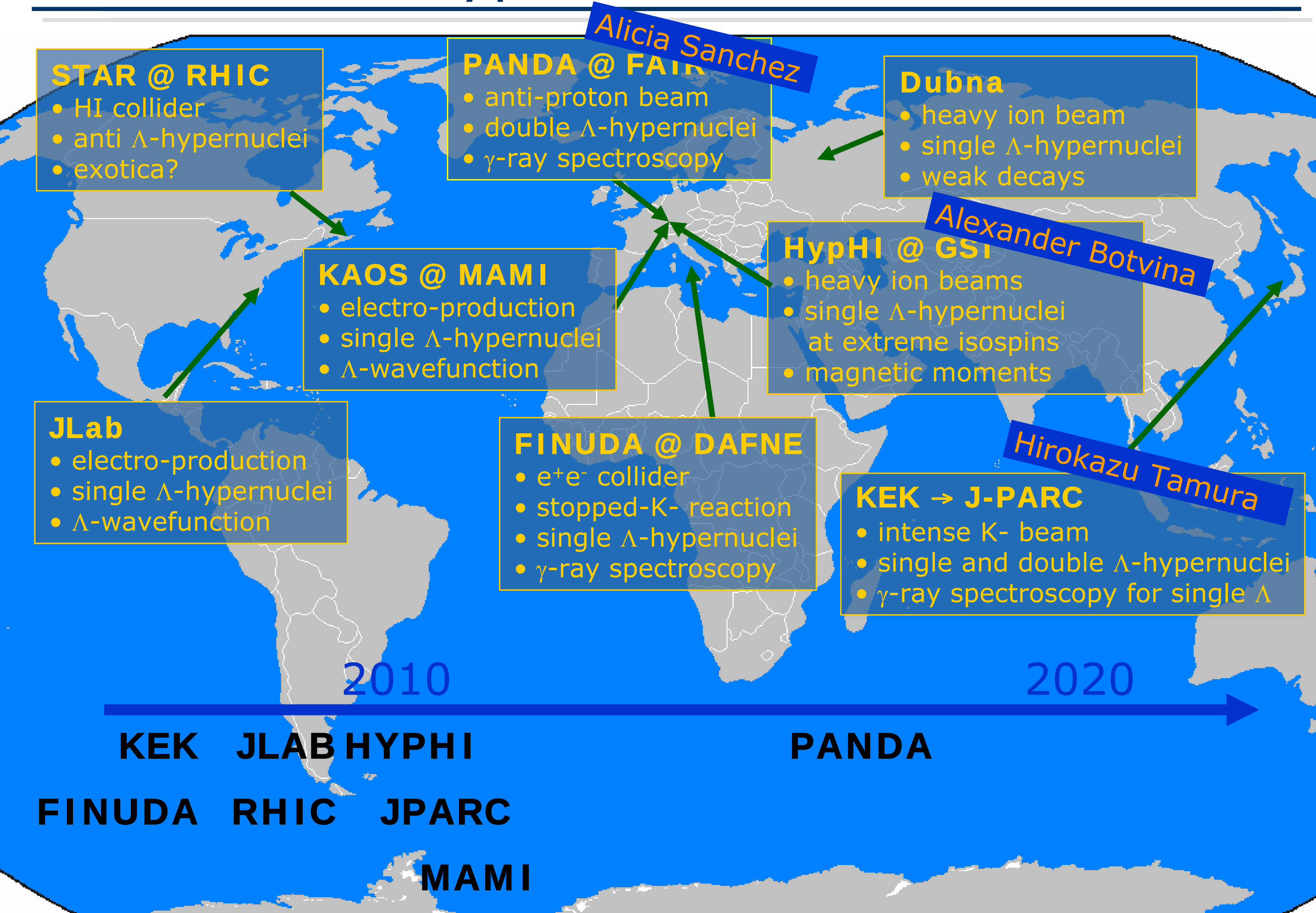
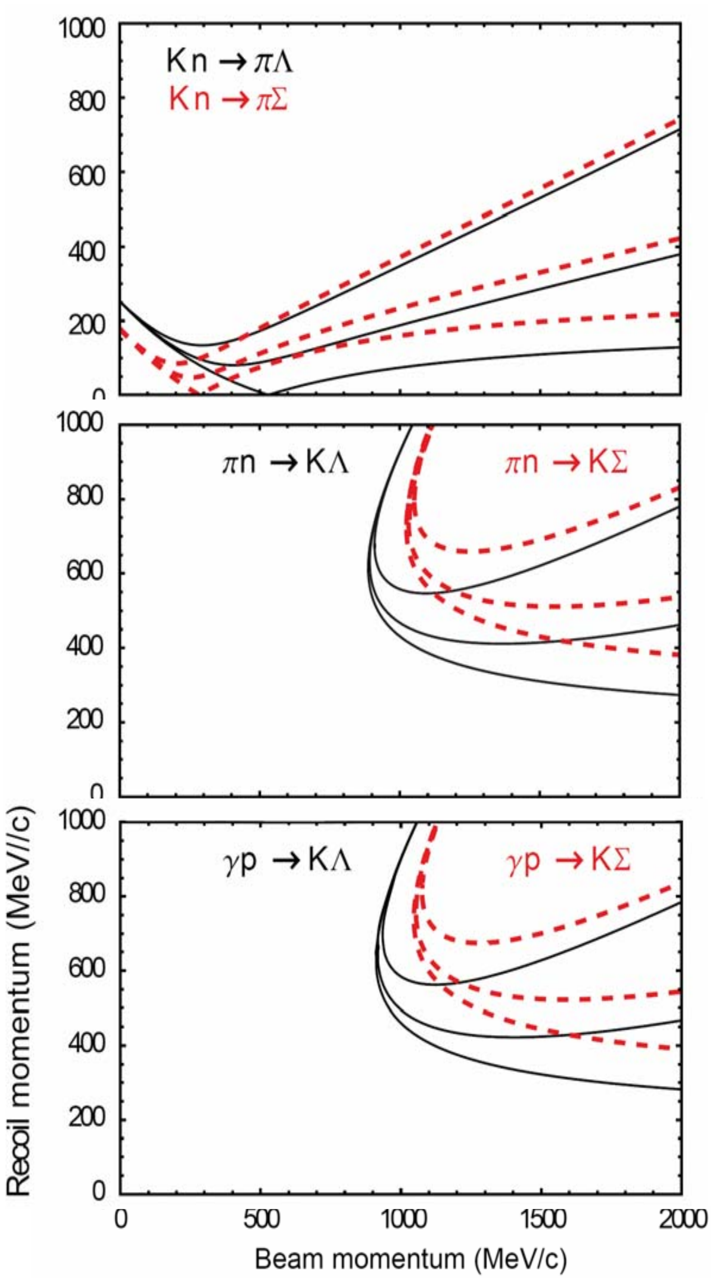
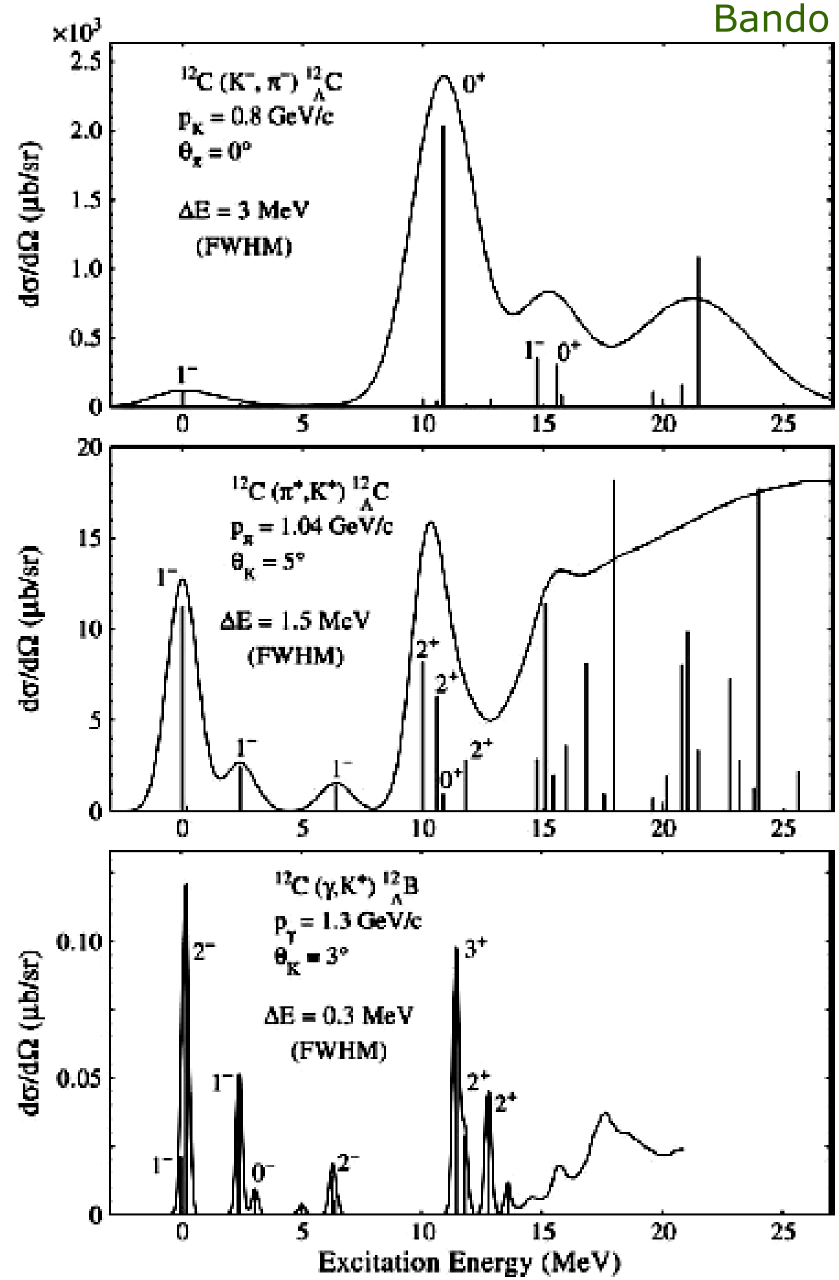


Missing mass experiments $a+b \rightarrow M+{}_{Y}Z$



Bando



Single Hypernuclei - Two-body Reactions

Proton Number \ Neutron Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
18													$^{32}_{\Lambda}$Ar	$^{33}_{\Lambda}$Ar	$^{34}_{\Lambda}$Ar	$^{35}_{\Lambda}$Ar	$^{36}_{\Lambda}$Ar	$^{37}_{\Lambda}$Ar	$^{38}_{\Lambda}$Ar	$^{39}_{\Lambda}$Ar	$^{40}_{\Lambda}$Ar	$^{41}_{\Lambda}$Ar	$^{42}_{\Lambda}$Ar	$^{43}_{\Lambda}$Ar	$^{44}_{\Lambda}$Ar	$^{45}_{\Lambda}$Ar	$^{46}_{\Lambda}$Ar	$^{47}_{\Lambda}$Ar	$^{48}_{\Lambda}$Ar	$^{49}_{\Lambda}$Ar
17														$^{32}_{\Lambda}$Cl	$^{33}_{\Lambda}$Cl	$^{34}_{\Lambda}$Cl	$^{35}_{\Lambda}$Cl	$^{36}_{\Lambda}$Cl	$^{37}_{\Lambda}$Cl	$^{38}_{\Lambda}$Cl	$^{39}_{\Lambda}$Cl	$^{40}_{\Lambda}$Cl	$^{41}_{\Lambda}$Cl	$^{42}_{\Lambda}$Cl	$^{43}_{\Lambda}$Cl	$^{44}_{\Lambda}$Cl	$^{45}_{\Lambda}$Cl	$^{46}_{\Lambda}$Cl	$^{47}_{\Lambda}$Cl	$^{48}_{\Lambda}$Cl
16											$^{28}_{\Lambda}$S	$^{29}_{\Lambda}$S	$^{30}_{\Lambda}$S	$^{31}_{\Lambda}$S	$^{32}_{\Lambda}$S	$^{33}_{\Lambda}$S	$^{34}_{\Lambda}$S	$^{35}_{\Lambda}$S	$^{36}_{\Lambda}$S	$^{37}_{\Lambda}$S	$^{38}_{\Lambda}$S	$^{39}_{\Lambda}$S	$^{40}_{\Lambda}$S	$^{41}_{\Lambda}$S	$^{42}_{\Lambda}$S	$^{43}_{\Lambda}$S	$^{44}_{\Lambda}$S	$^{45}_{\Lambda}$S	$^{46}_{\Lambda}$S	$^{47}_{\Lambda}$S
15												$^{28}_{\Lambda}$P	$^{29}_{\Lambda}$P	$^{30}_{\Lambda}$P	$^{31}_{\Lambda}$P	$^{32}_{\Lambda}$P	$^{33}_{\Lambda}$P	$^{34}_{\Lambda}$P	$^{35}_{\Lambda}$P	$^{36}_{\Lambda}$P	$^{37}_{\Lambda}$P	$^{38}_{\Lambda}$P	$^{39}_{\Lambda}$P	$^{40}_{\Lambda}$P	$^{41}_{\Lambda}$P	$^{42}_{\Lambda}$P	$^{43}_{\Lambda}$P	$^{44}_{\Lambda}$P	$^{45}_{\Lambda}$P	$^{46}_{\Lambda}$P
14									$^{24}_{\Lambda}$Si	$^{25}_{\Lambda}$Si	$^{26}_{\Lambda}$Si	$^{27}_{\Lambda}$Si	$^{28}_{\Lambda}$Si	$^{29}_{\Lambda}$Si	$^{30}_{\Lambda}$Si	$^{31}_{\Lambda}$Si	$^{32}_{\Lambda}$Si	$^{33}_{\Lambda}$Si	$^{34}_{\Lambda}$Si	$^{35}_{\Lambda}$Si	$^{36}_{\Lambda}$Si	$^{37}_{\Lambda}$Si	$^{38}_{\Lambda}$Si	$^{39}_{\Lambda}$Si	$^{40}_{\Lambda}$Si	$^{41}_{\Lambda}$Si	$^{42}_{\Lambda}$Si	$^{43}_{\Lambda}$Si	$^{44}_{\Lambda}$Si	$^{45}_{\Lambda}$Si
13										$^{24}_{\Lambda}$Al	$^{25}_{\Lambda}$Al	$^{26}_{\Lambda}$Al	$^{27}_{\Lambda}$Al	$^{28}_{\Lambda}$Al	$^{29}_{\Lambda}$Al	$^{30}_{\Lambda}$Al	$^{31}_{\Lambda}$Al	$^{32}_{\Lambda}$Al	$^{33}_{\Lambda}$Al	$^{34}_{\Lambda}$Al	$^{35}_{\Lambda}$Al	$^{36}_{\Lambda}$Al	$^{37}_{\Lambda}$Al	$^{38}_{\Lambda}$Al	$^{39}_{\Lambda}$Al	$^{40}_{\Lambda}$Al	$^{41}_{\Lambda}$Al	$^{42}_{\Lambda}$Al	$^{43}_{\Lambda}$Al	$^{44}_{\Lambda}$Al
12							$^{20}_{\Lambda}$Mg	$^{21}_{\Lambda}$Mg	$^{22}_{\Lambda}$Mg	$^{23}_{\Lambda}$Mg	$^{24}_{\Lambda}$Mg	$^{25}_{\Lambda}$Mg	$^{26}_{\Lambda}$Mg	$^{27}_{\Lambda}$Mg	$^{28}_{\Lambda}$Mg	$^{29}_{\Lambda}$Mg	$^{30}_{\Lambda}$Mg	$^{31}_{\Lambda}$Mg	$^{32}_{\Lambda}$Mg	$^{33}_{\Lambda}$Mg	$^{34}_{\Lambda}$Mg	$^{35}_{\Lambda}$Mg	$^{36}_{\Lambda}$Mg	$^{37}_{\Lambda}$Mg	$^{38}_{\Lambda}$Mg	$^{39}_{\Lambda}$Mg	$^{40}_{\Lambda}$Mg	$^{41}_{\Lambda}$Mg		
11								$^{20}_{\Lambda}$Na	$^{21}_{\Lambda}$Na	$^{22}_{\Lambda}$Na	$^{23}_{\Lambda}$Na	$^{24}_{\Lambda}$Na	$^{25}_{\Lambda}$Na	$^{26}_{\Lambda}$Na	$^{27}_{\Lambda}$Na	$^{28}_{\Lambda}$Na	$^{29}_{\Lambda}$Na	$^{30}_{\Lambda}$Na	$^{31}_{\Lambda}$Na	$^{32}_{\Lambda}$Na	$^{33}_{\Lambda}$Na	$^{34}_{\Lambda}$Na	$^{35}_{\Lambda}$Na	$^{36}_{\Lambda}$Na	$^{37}_{\Lambda}$Na	$^{38}_{\Lambda}$Na				
10						$^{17}_{\Lambda}$Ne	$^{18}_{\Lambda}$Ne	$^{19}_{\Lambda}$Ne	$^{20}_{\Lambda}$Ne	$^{21}_{\Lambda}$Ne	$^{22}_{\Lambda}$Ne	$^{23}_{\Lambda}$Ne	$^{24}_{\Lambda}$Ne	$^{25}_{\Lambda}$Ne	$^{26}_{\Lambda}$Ne	$^{27}_{\Lambda}$Ne	$^{28}_{\Lambda}$Ne	$^{29}_{\Lambda}$Ne	$^{30}_{\Lambda}$Ne	$^{31}_{\Lambda}$Ne	$^{32}_{\Lambda}$Ne	$^{33}_{\Lambda}$Ne	$^{34}_{\Lambda}$Ne	$^{35}_{\Lambda}$Ne						
9						$^{16}_{\Lambda}$F	$^{17}_{\Lambda}$F	$^{18}_{\Lambda}$F	$^{19}_{\Lambda}$F	$^{20}_{\Lambda}$F	$^{21}_{\Lambda}$F	$^{22}_{\Lambda}$F	$^{23}_{\Lambda}$F	$^{24}_{\Lambda}$F	$^{25}_{\Lambda}$F	$^{26}_{\Lambda}$F	$^{27}_{\Lambda}$F	$^{28}_{\Lambda}$F	$^{29}_{\Lambda}$F	$^{30}_{\Lambda}$F	$^{31}_{\Lambda}$F	$^{32}_{\Lambda}$F								
8				$^{13}_{\Lambda}$O	$^{14}_{\Lambda}$O	$^{15}_{\Lambda}$O	$^{16}_{\Lambda}$O	$^{17}_{\Lambda}$O	$^{18}_{\Lambda}$O	$^{19}_{\Lambda}$O	$^{20}_{\Lambda}$O	$^{21}_{\Lambda}$O	$^{22}_{\Lambda}$O	$^{23}_{\Lambda}$O	$^{24}_{\Lambda}$O	$^{25}_{\Lambda}$O	$^{26}_{\Lambda}$O	$^{27}_{\Lambda}$O												
7				$^{12}_{\Lambda}$N	$^{13}_{\Lambda}$N	$^{14}_{\Lambda}$N	$^{15}_{\Lambda}$N	$^{16}_{\Lambda}$N	$^{17}_{\Lambda}$N	$^{18}_{\Lambda}$N	$^{19}_{\Lambda}$N	$^{20}_{\Lambda}$N	$^{21}_{\Lambda}$N	$^{22}_{\Lambda}$N	$^{23}_{\Lambda}$N	$^{24}_{\Lambda}$N														
6			$^{10}_{\Lambda}$C	$^{11}_{\Lambda}$C	$^{12}_{\Lambda}$C	$^{13}_{\Lambda}$C	$^{14}_{\Lambda}$C	$^{15}_{\Lambda}$C	$^{16}_{\Lambda}$C	$^{17}_{\Lambda}$C	$^{18}_{\Lambda}$C	$^{19}_{\Lambda}$C	$^{20}_{\Lambda}$C	$^{21}_{\Lambda}$C																
5			$^{9}_{\Lambda}$B	$^{10}_{\Lambda}$B	$^{11}_{\Lambda}$B	$^{12}_{\Lambda}$B	$^{13}_{\Lambda}$B	$^{14}_{\Lambda}$B	$^{15}_{\Lambda}$B	$^{16}_{\Lambda}$B	$^{17}_{\Lambda}$B	$^{18}_{\Lambda}$B																		
4		$^{7}_{\Lambda}$Be	$^{8}_{\Lambda}$Be	$^{9}_{\Lambda}$Be	$^{10}_{\Lambda}$Be	$^{11}_{\Lambda}$Be	$^{12}_{\Lambda}$Be	$^{13}_{\Lambda}$Be	$^{14}_{\Lambda}$Be	$^{15}_{\Lambda}$Be																				
3		$^{6}_{\Lambda}$Li	$^{7}_{\Lambda}$Li	$^{8}_{\Lambda}$Li	$^{9}_{\Lambda}$Li	$^{10}_{\Lambda}$Li	$^{11}_{\Lambda}$Li	$^{12}_{\Lambda}$Li																						
2	$^{4}_{\Lambda}$He	$^{5}_{\Lambda}$He	$^{6}_{\Lambda}$He	$^{7}_{\Lambda}$He	$^{8}_{\Lambda}$He	$^{9}_{\Lambda}$He																								
1	$^{3}_{\Lambda}$H	$^{4}_{\Lambda}$H																												

$n \to \Lambda$: (K^-,π^-), (K^-_{stop},π^-), (π^+,K^+)

$p \to \Lambda$: $(e,e'K^+)$, (K^-_{stop},π^0)

$pp \to n\Lambda$: (π^-,K^+)

The present nuclear chart

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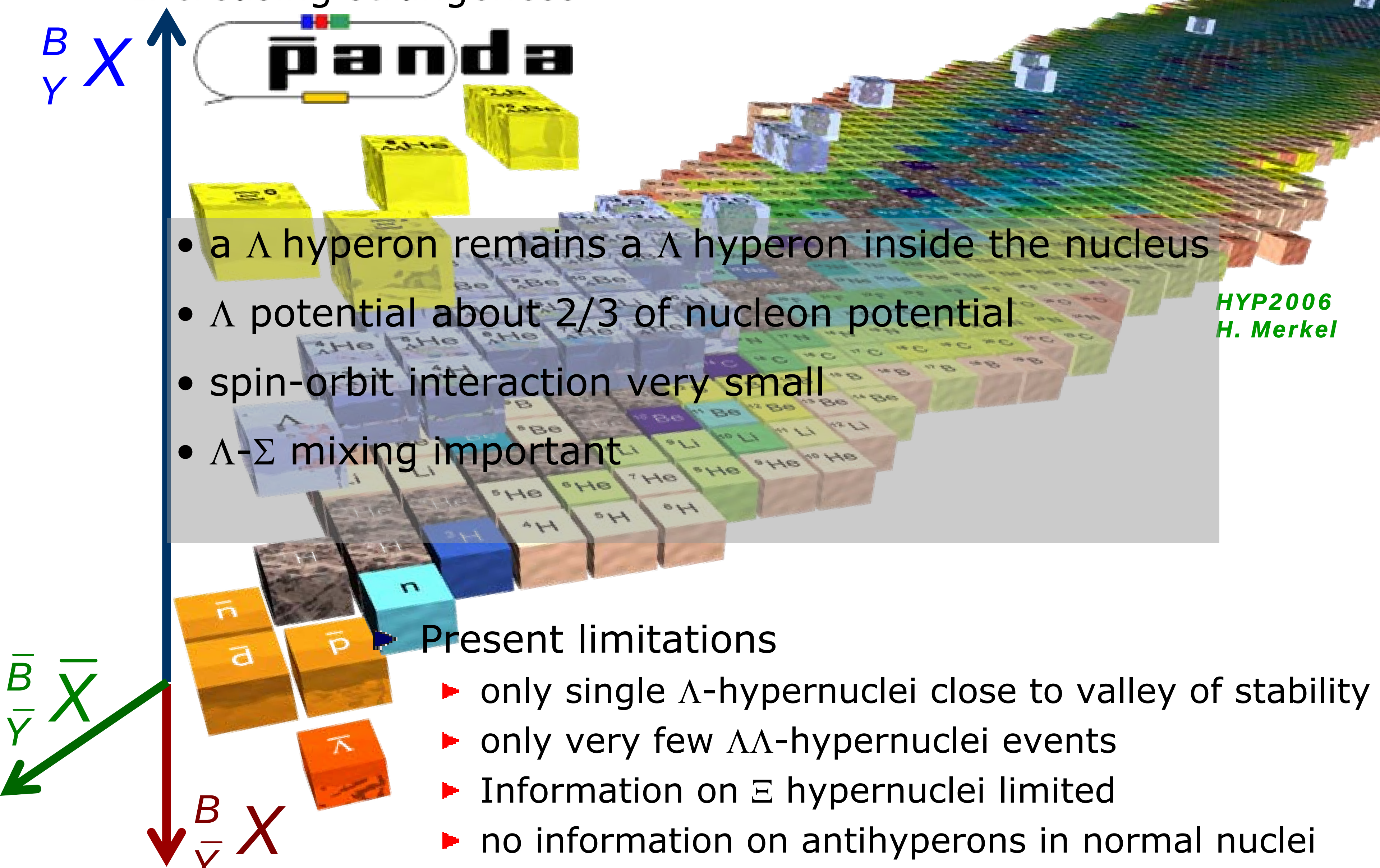
Increasing strangeness



- a Λ hyperon remains a Λ hyperon inside the nucleus
- Λ potential about 2/3 of nucleon potential
- spin-orbit interaction very small
- Λ-Σ mixing important

- Present limitations
  - only single Λ-hypernuclei close to valley of stability
  - only very few ΛΛ-hypernuclei events
  - Information on Ξ hypernuclei limited
  - no information on antihyperons in normal nuclei

International Hypernuclear Network

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RHIC
- HI colli
- anti Λ-
- exotica

JLab
- electro-
- single
- Λ-wave

Dubna
- heavy ion beam
- single Λ-hypernuclei
- weak decays

HypHI @ GSI
- heavy ion beams
- single Λ-hypernuclei at extreme isospins
- magnetic moments

E
n
ei

KEK → J-PARC
- intense K- beam
- single and double Λ-hypernuclei
- γ-ray spectroscopy for single Λ

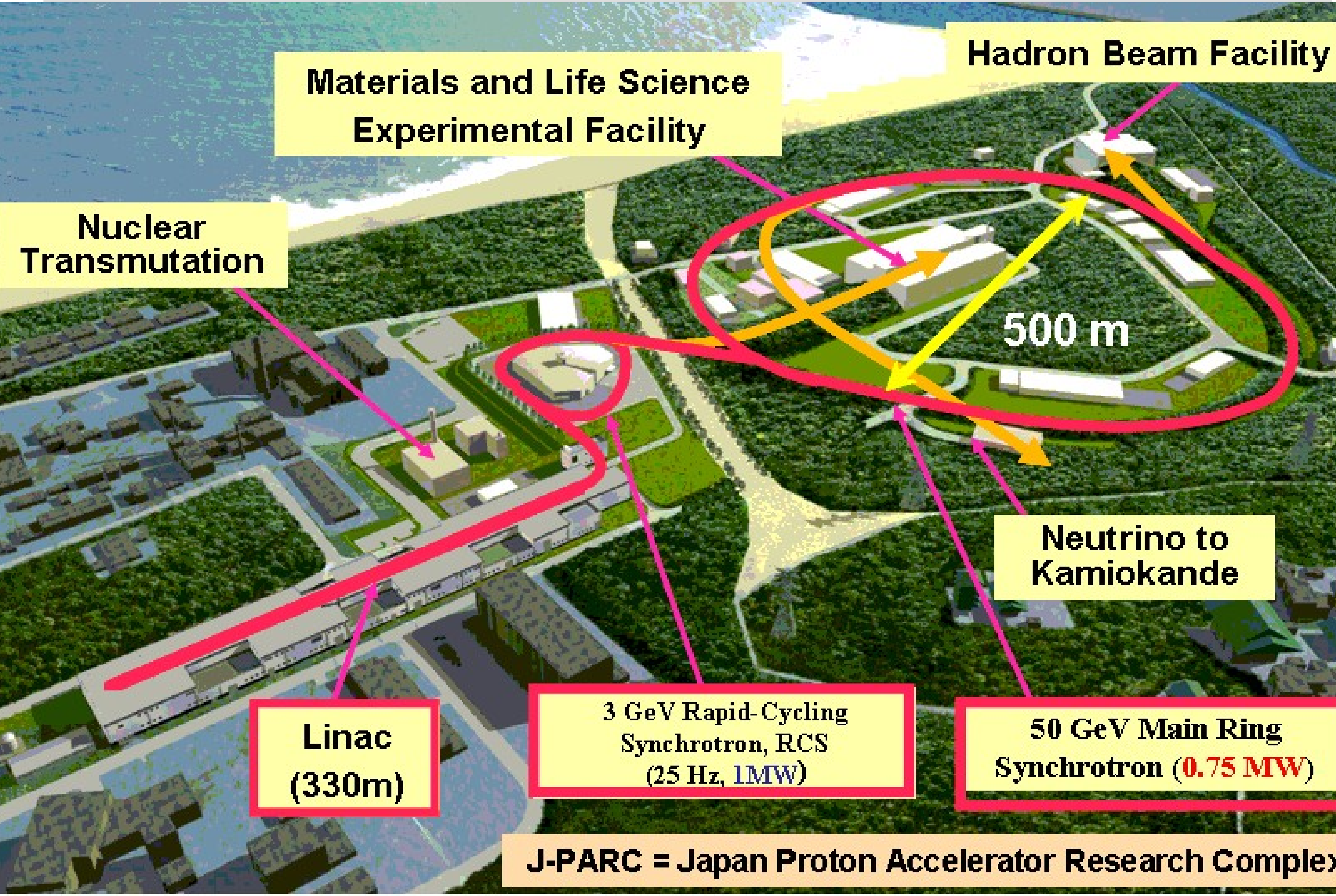
2020

KE

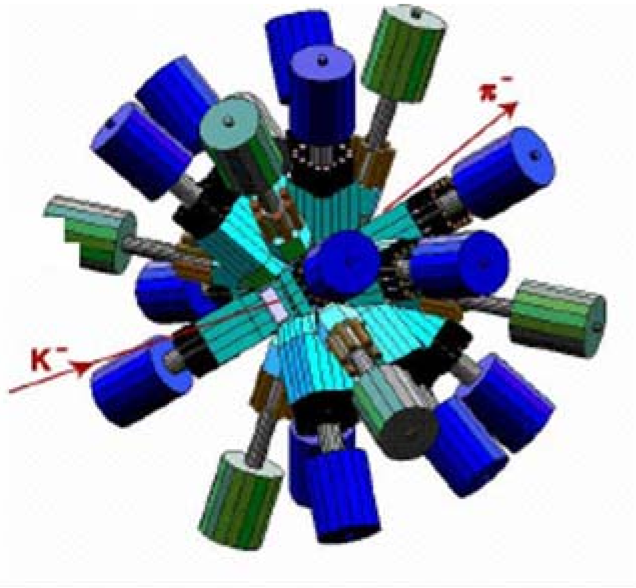
FINUD

PANDA

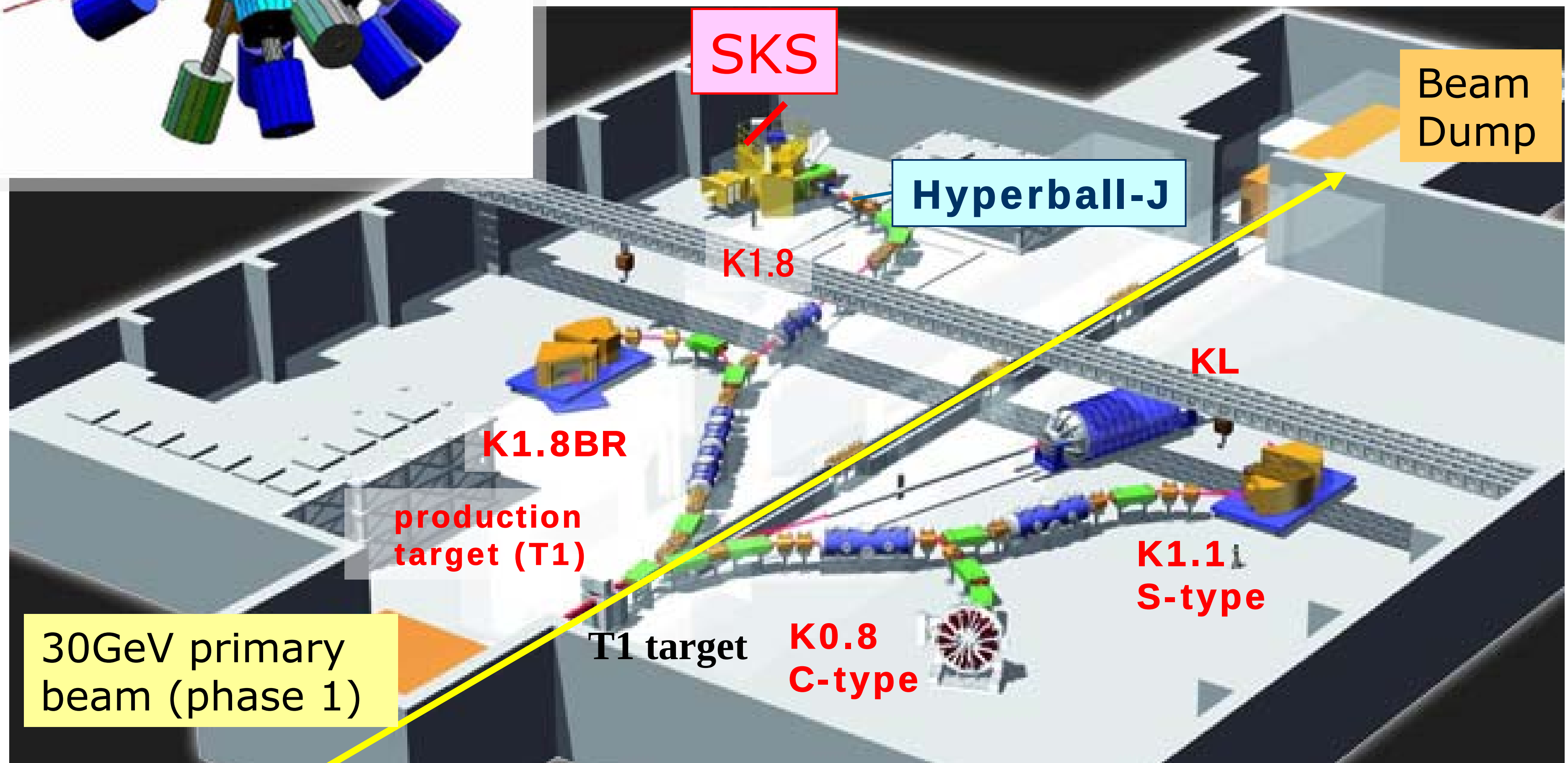
MAMI


Hadron Beam Facility
Materials and Life Science
Experimental Facility
Nuclear
Transmutation
500 m
Neutrino to
Kamiokande
Linac
(330m)
3 GeV Rapid-Cycling
Synchrotron, RCS
(25 Hz, 1MW)
50 GeV Main Ring
Synchrotron (0.75 MW)
J-PARC = Japan Proton Accelerator Research Complex

J-PARC beyond 2009



- Several intense K- beam lines
- γ-ray spectroscopy for single Λ
- Complete study of light (A<30) hypernuclei
- Study of medium and heavy hypernuclei
- n-richer/p-richer mirror hypernuclei
- Double strangeness



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RHIC
- HI collider
- anti Λ-hypernuclei
- exotica?

PANDA @ FAIR
- anti-proton beam
- double Λ-hypernu
- γ-ray spectroscopy

KAOS @ MAMI
- electro-production
- single Λ-hypernuclei
- Λ-wavefunction

JLab
- electro-production
- single Λ-hypernuclei
- Λ-wavefunction

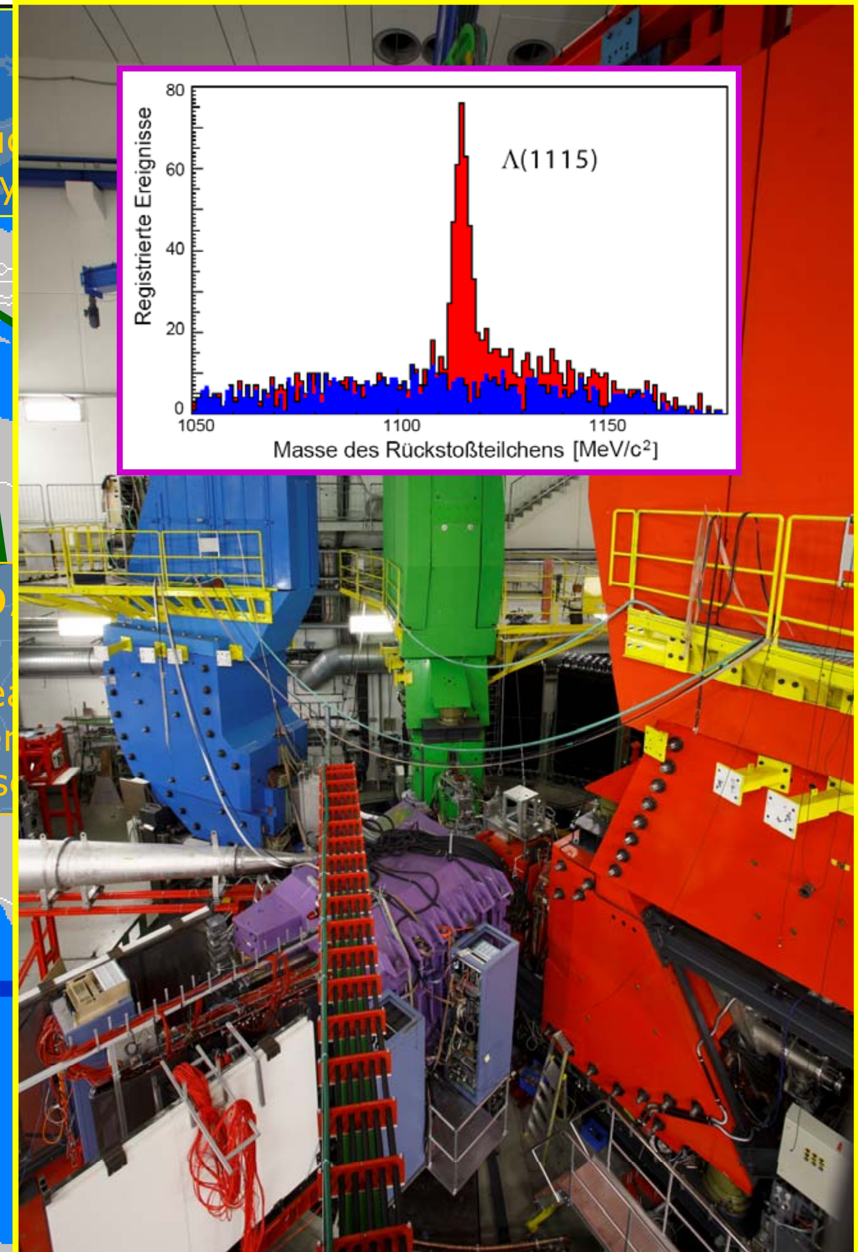
FINUDA @ D
- e^+e^- collider
- stopped-K- rea
- single Λ-hyper
- γ-ray spectros

2010

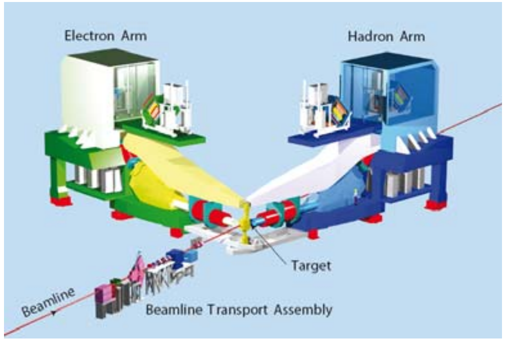
KEK **JLAB** **HYPHI**

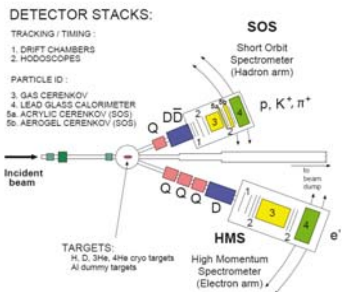
FINUDA **RHIC** **JPARC**

MAMI

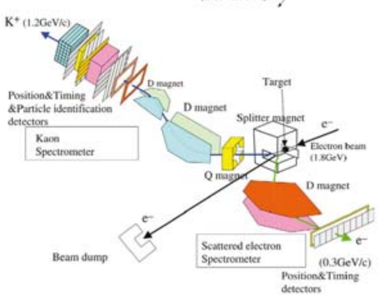


J-Lab Experiments

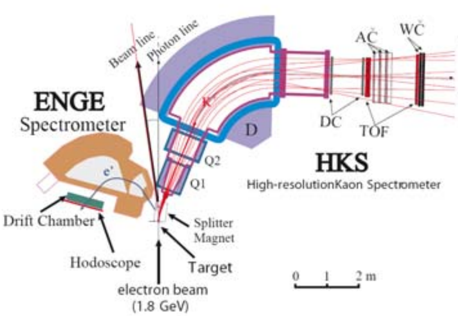




Setup E91-016
$^3_\Lambda H$, $^4_\Lambda H$

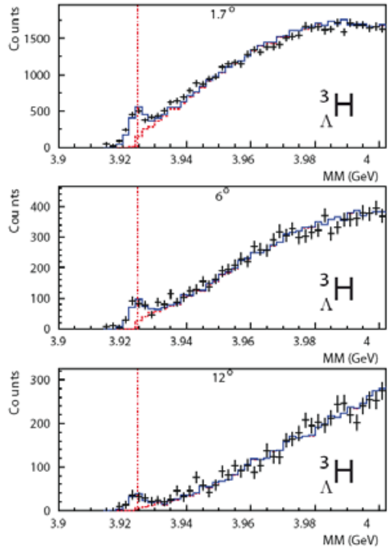


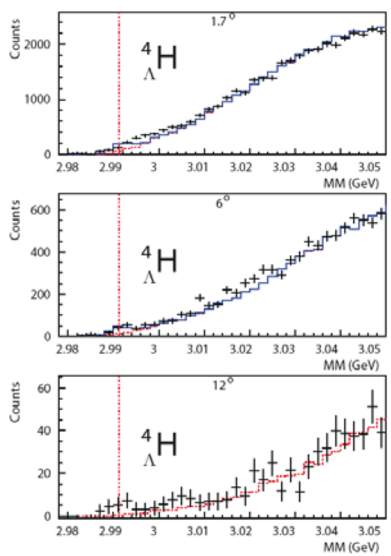
Setup E89-009
$^7_\Lambda He$, $^{12}_\Lambda B$



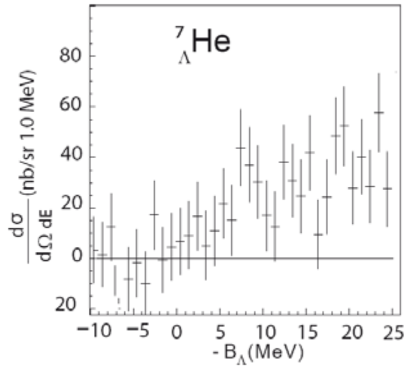
Setup E01-011
$^{28}_\Lambda Al$

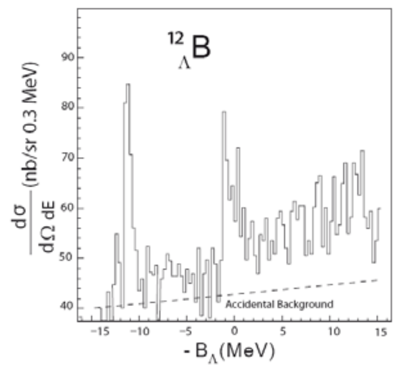
Hall C

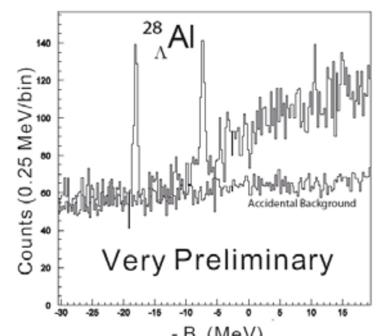




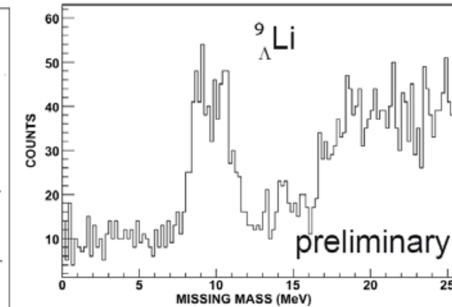
Hall C

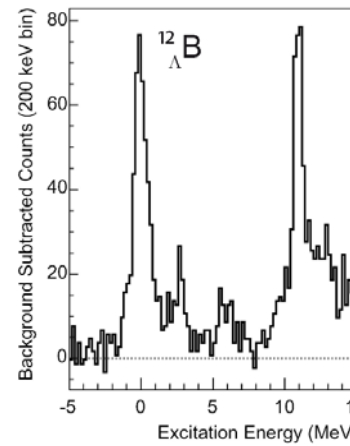


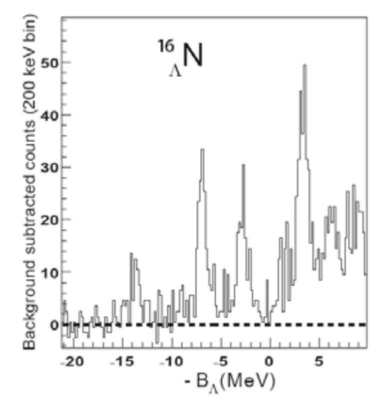




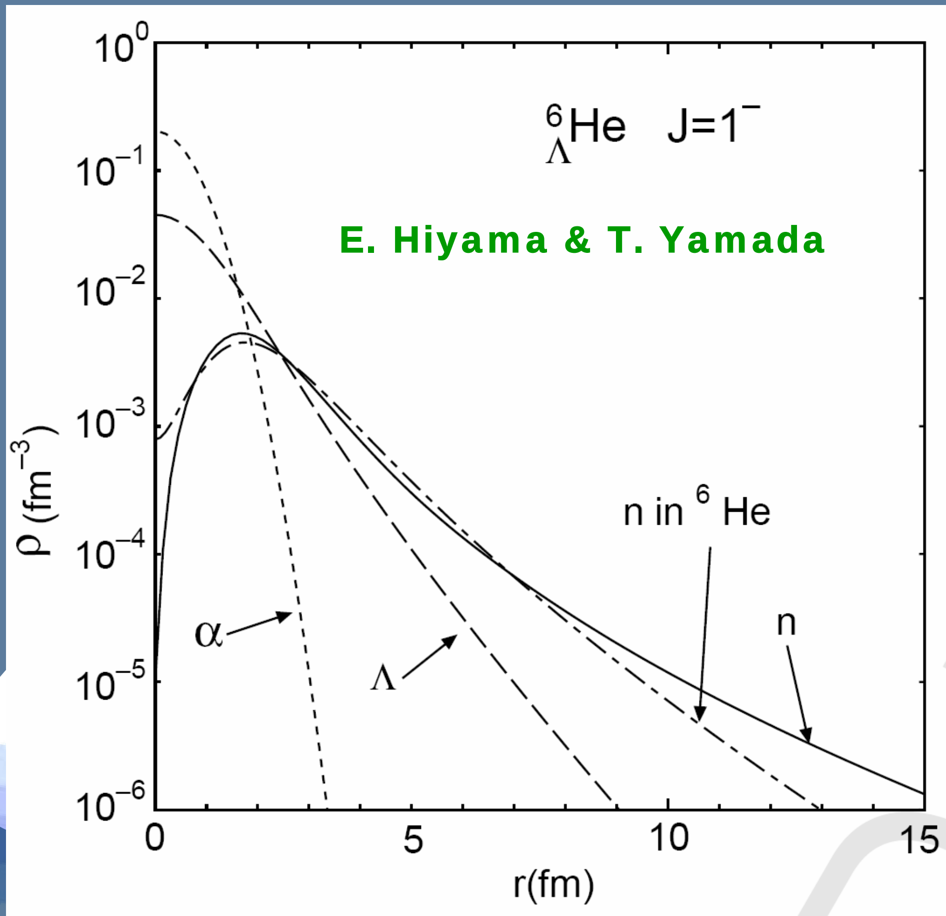
Hall A



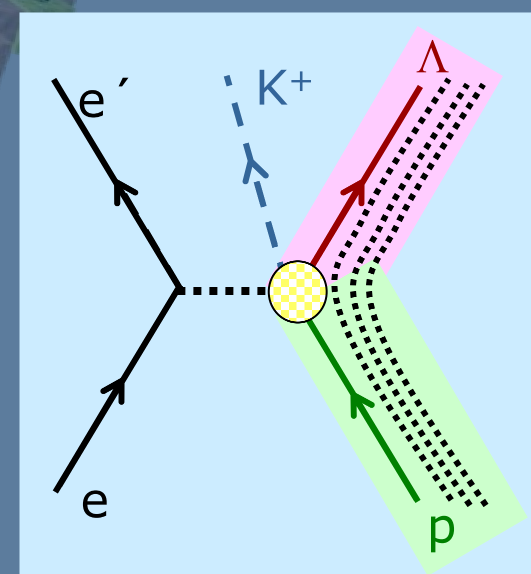




KAOS @ MAMI



- neutron rich hypernuclei
- wave function of Λ
- large momentum transfer components
- particle unstable states



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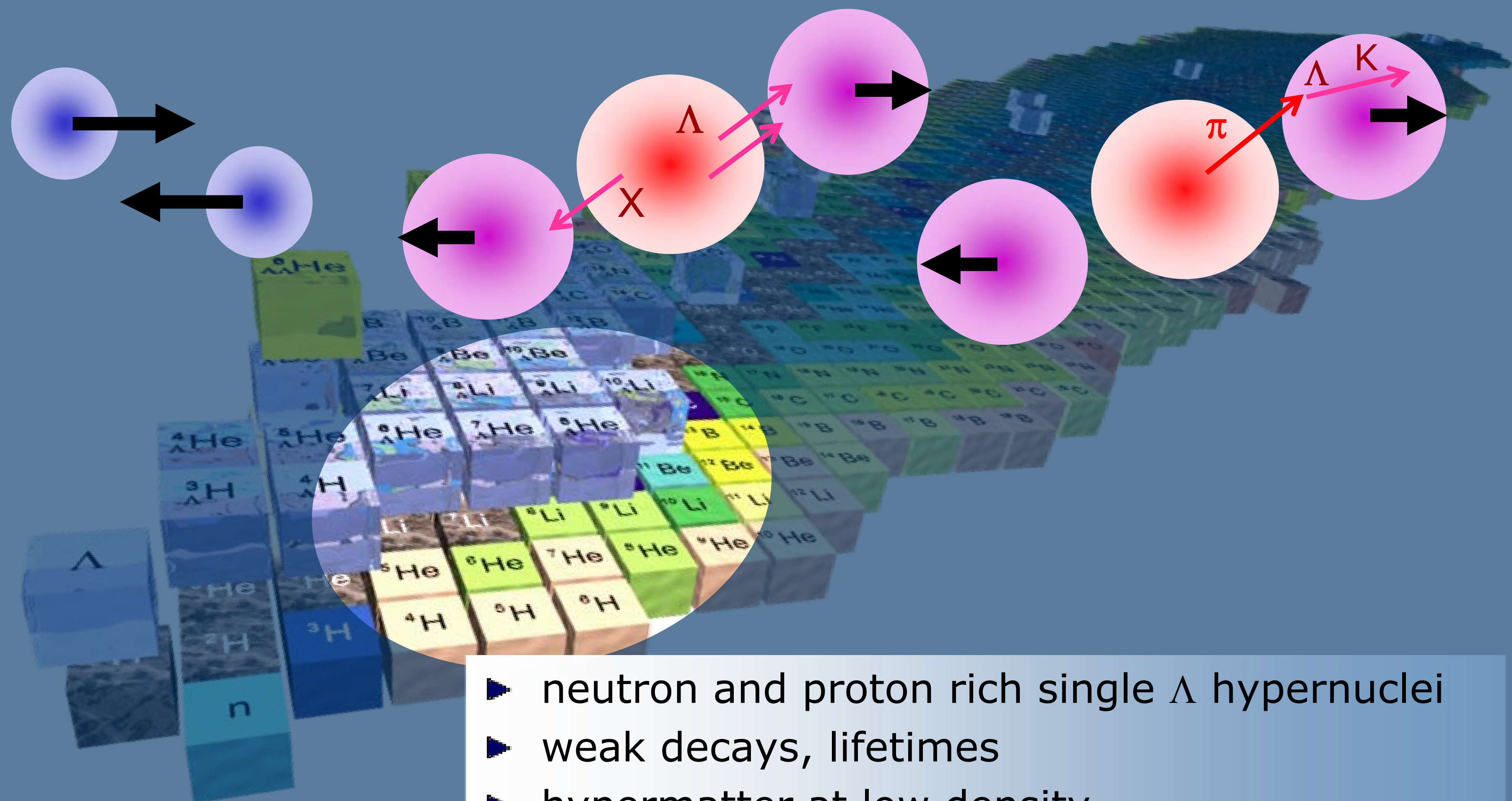
2010

KEK **JLAB** **HYPHI**

FINUDA **RHIC** **JPARC**

MAMI

HYPHI @ GSI/FAIR



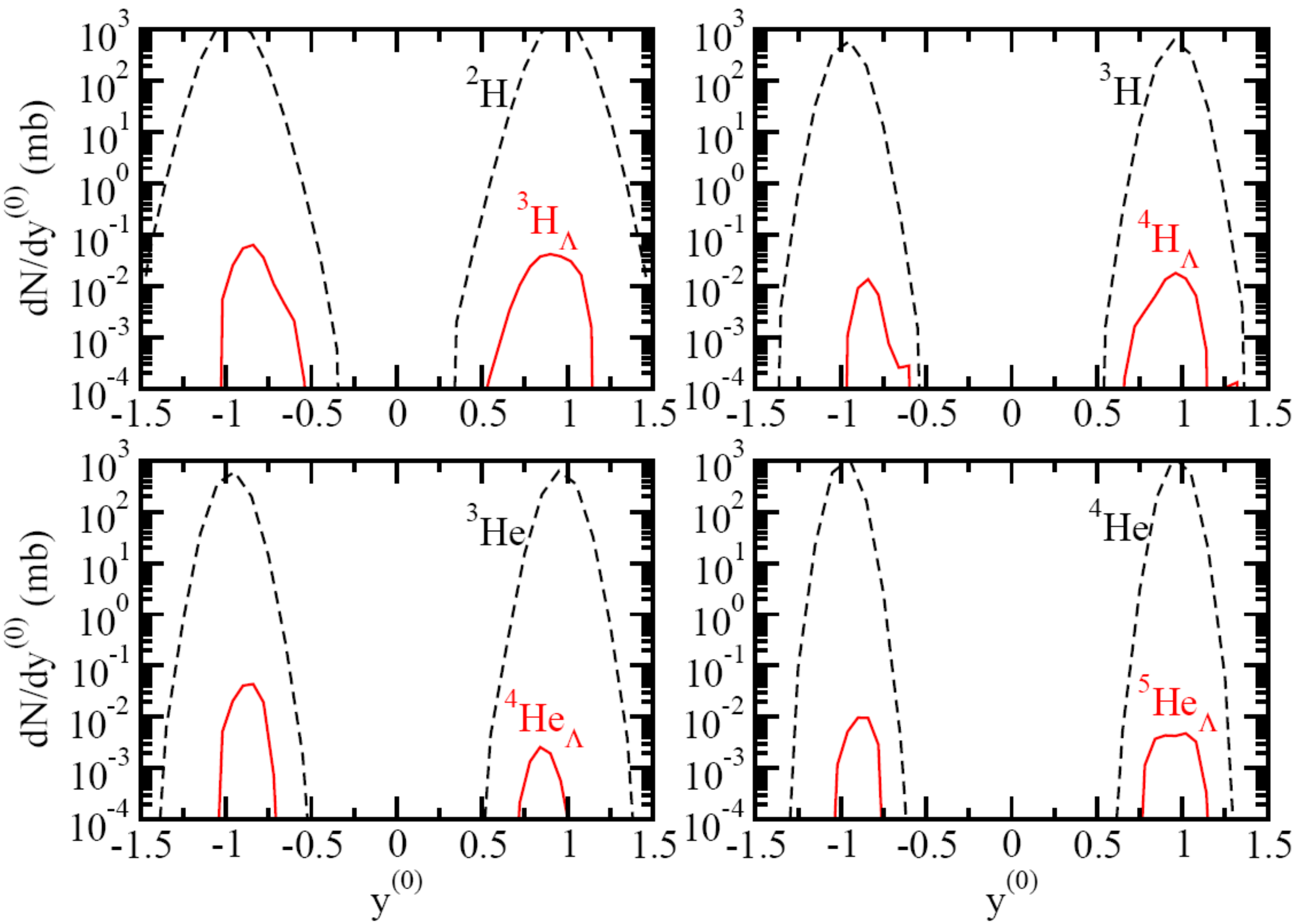
- neutron and proton rich single Λ hypernuclei
- weak decays, lifetimes
- hypermatter at low density
- magnetic moment of Λ inside nucleus

Take Saito (GSI,Mainz)

$^{12}C+^{12}C$ @ 2AGeV

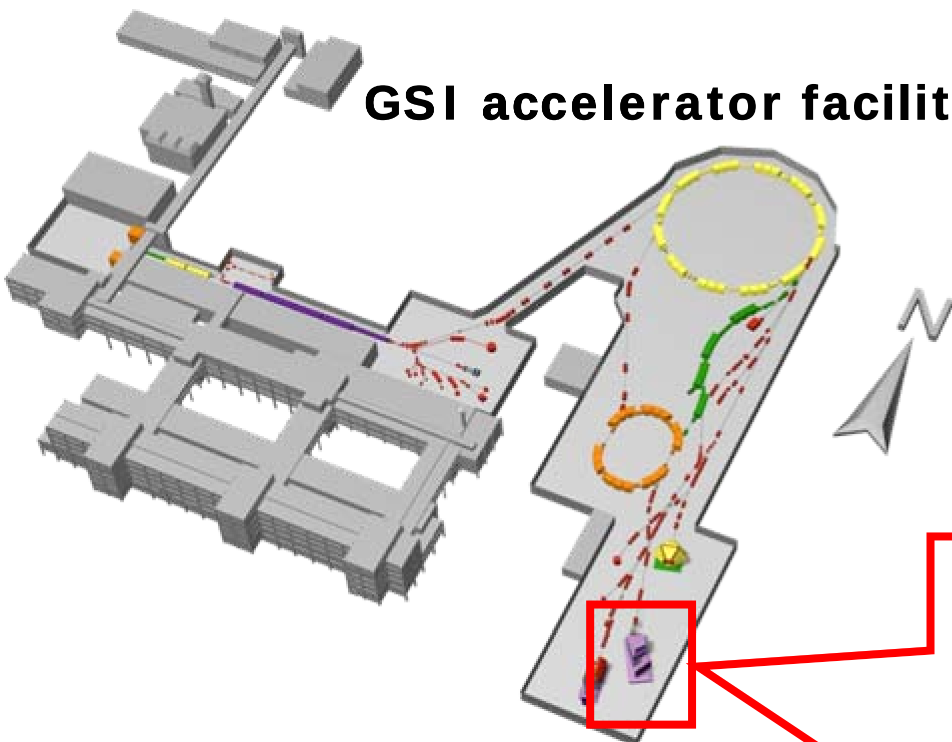
- **Gaitanos, Lenske, Mosel**

	$^{4}_{\Lambda}H$	$^{4}_{\Lambda}He$	$^{5}_{\Lambda}He$
total yield (μb)	2.2	4	1.4
pionic contribution (μb)	0.3	0.2	0.03

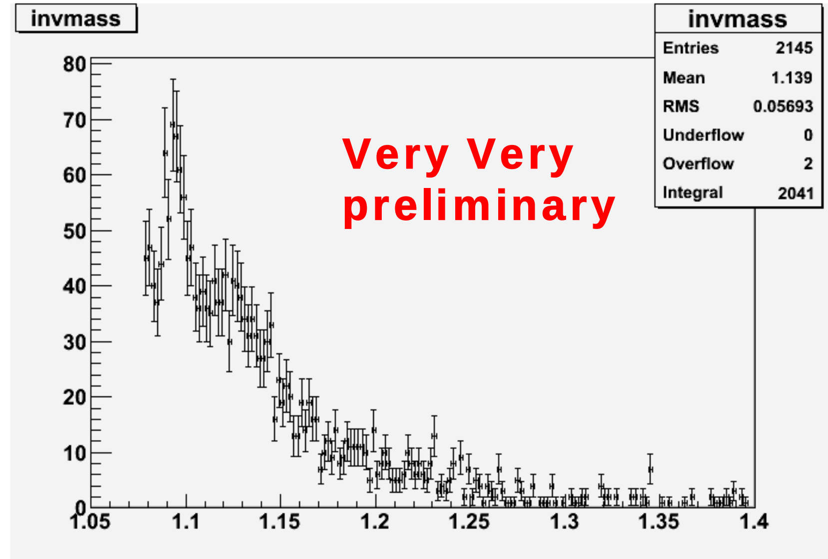


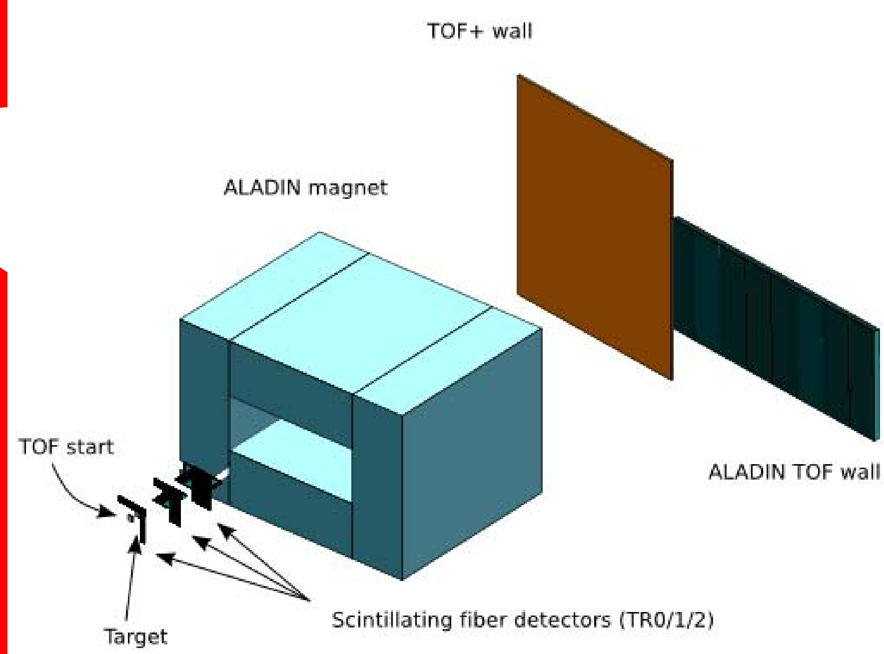
Phase 0 experiment at GSI, in 2009 T.Saito

GSI accelerator facility



Cave C





International Hypernuclear Network

STAR @ RHIC
- HI collider
- anti Λ-hypernuclei
- exotica?

PANDA @ FAIR
- anti-proton beam
- double Λ-hypernuclei
- γ-ray spectroscopy

Dubna
- heavy ion beam
- single Λ-hypernuclei
- weak decays

KAOS @
- electro-p
- single Λ-
- Λ-wavef

JLab
- electro-production
- single Λ-hypernuclei
- Λ-wavefunction

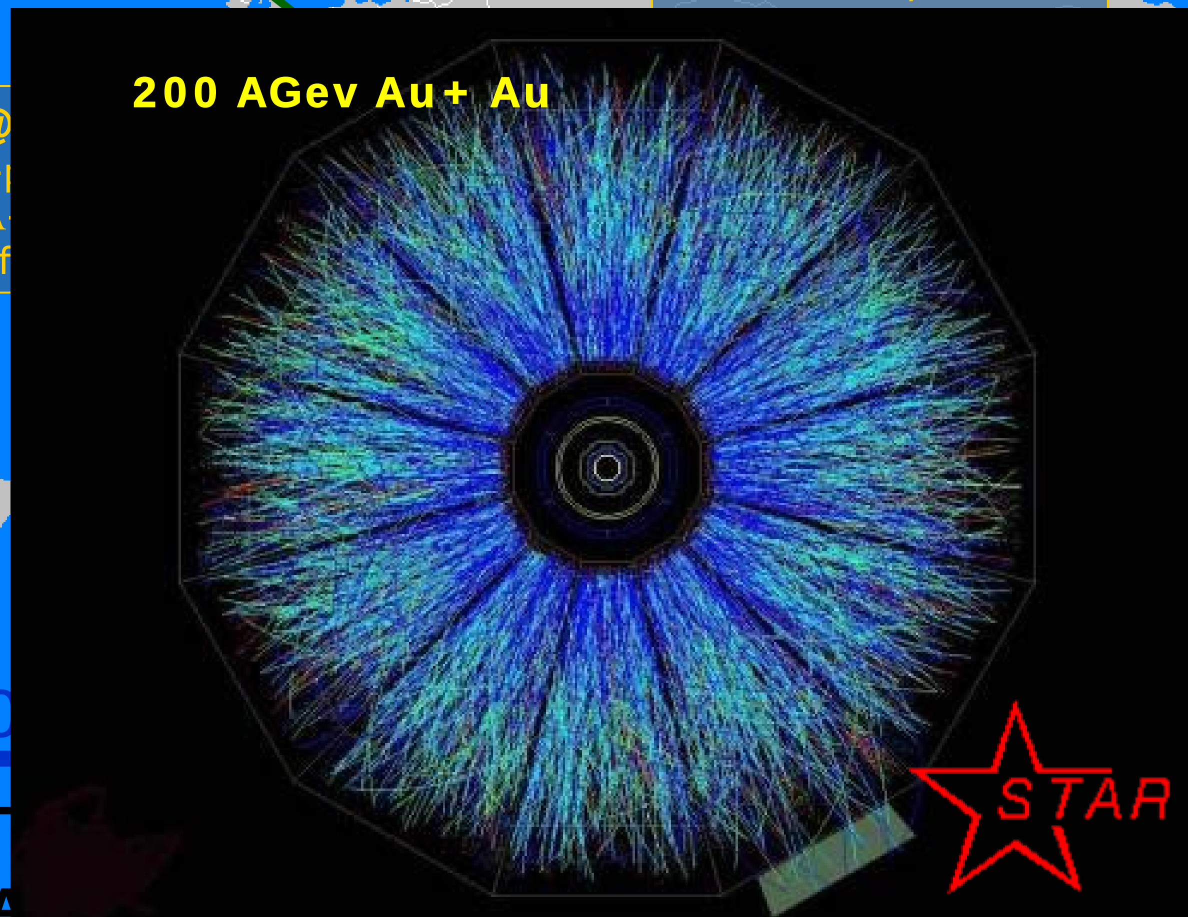
lei
Λ

2010

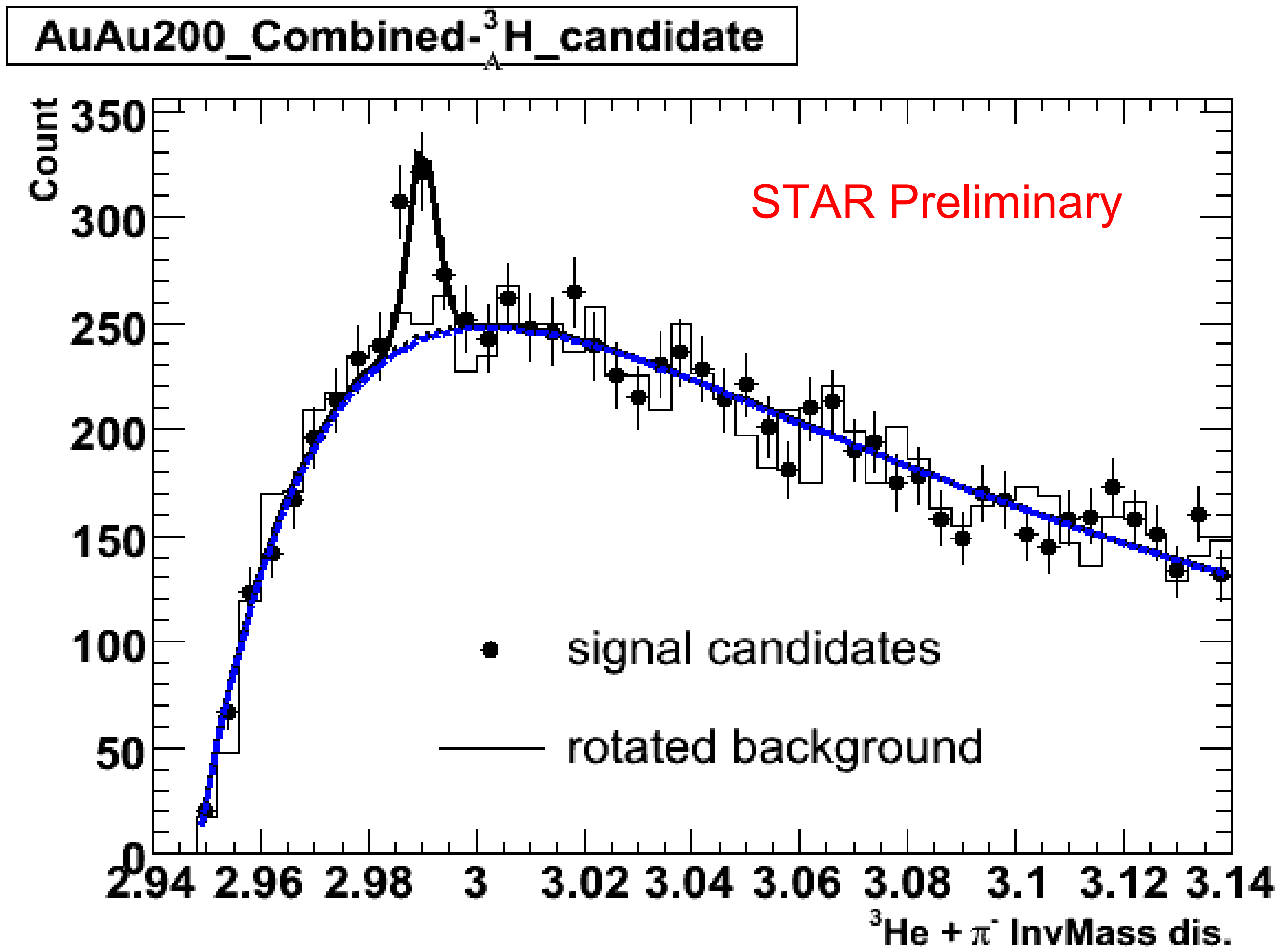
KEK JLAB HYPH

FINUDA RHIC JPA

MAMI

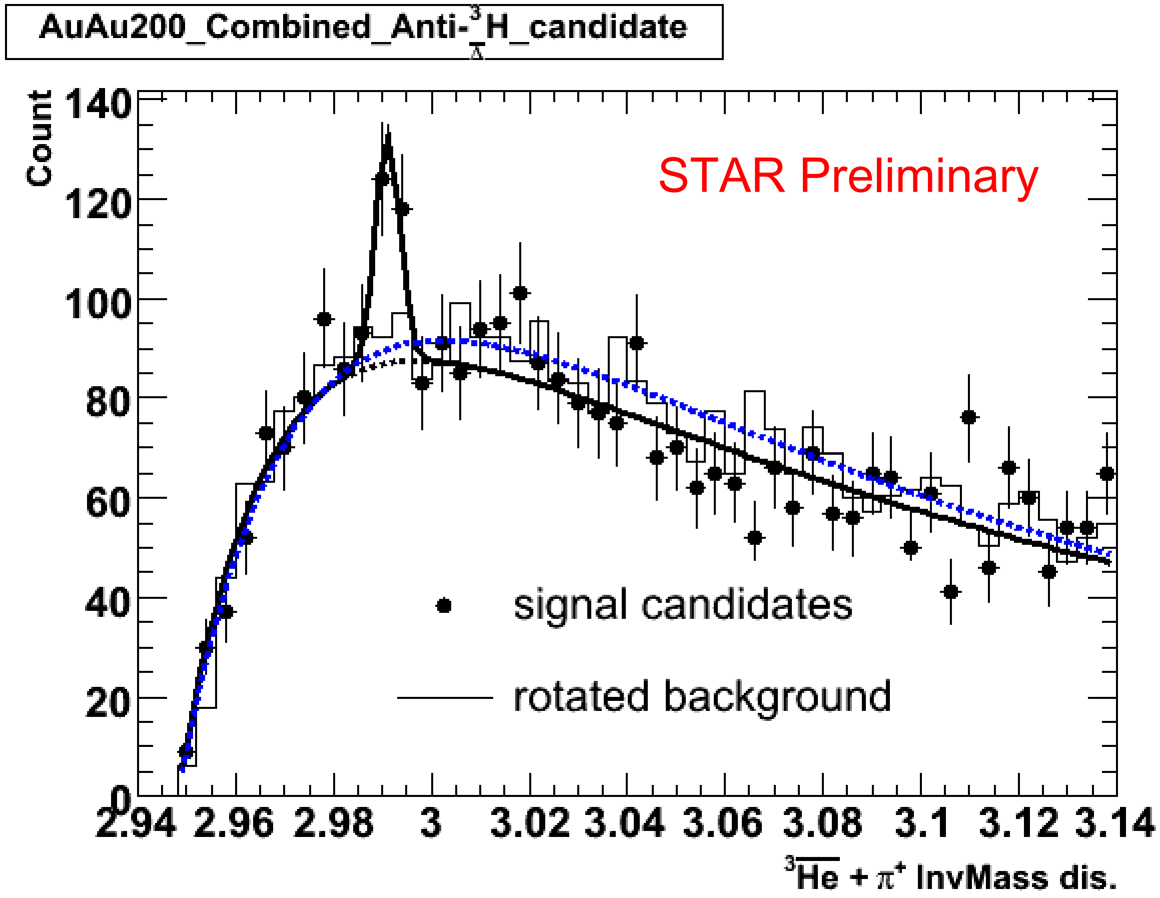


$^{3}_{\Lambda}H$ at STAR



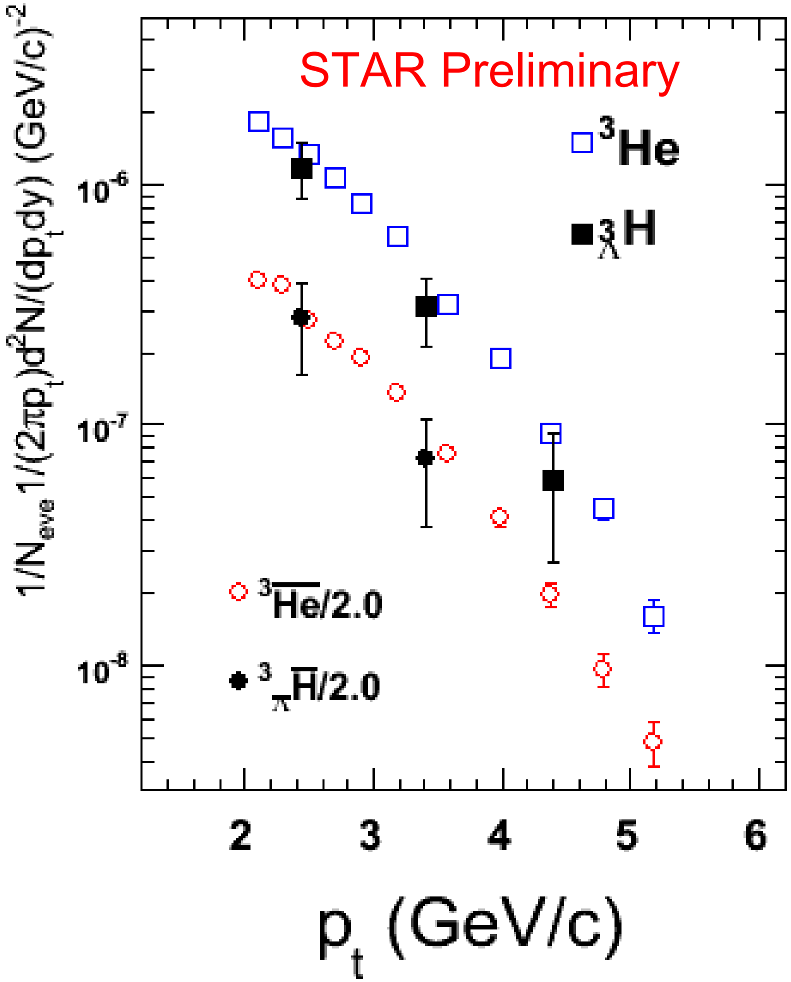
- background shape determined from rotated background analysis
- Signal observed from the data (bin-by-bin counting): 177 $\pm$ 30
- Mass: 2.990 $\pm$ 0.001 GeV; Width (fixed): 0.0025 GeV.

The first antihypernucleus: ${}^{3}_{\bar{\Lambda}}\bar{H}$ @ STAR



- Signal observed from the data (bin-by-bin counting): 68 ± 18
- Mass: 2.991 ± 0.001 GeV; Width (fixed): 0.0025 GeV

Yield ratios

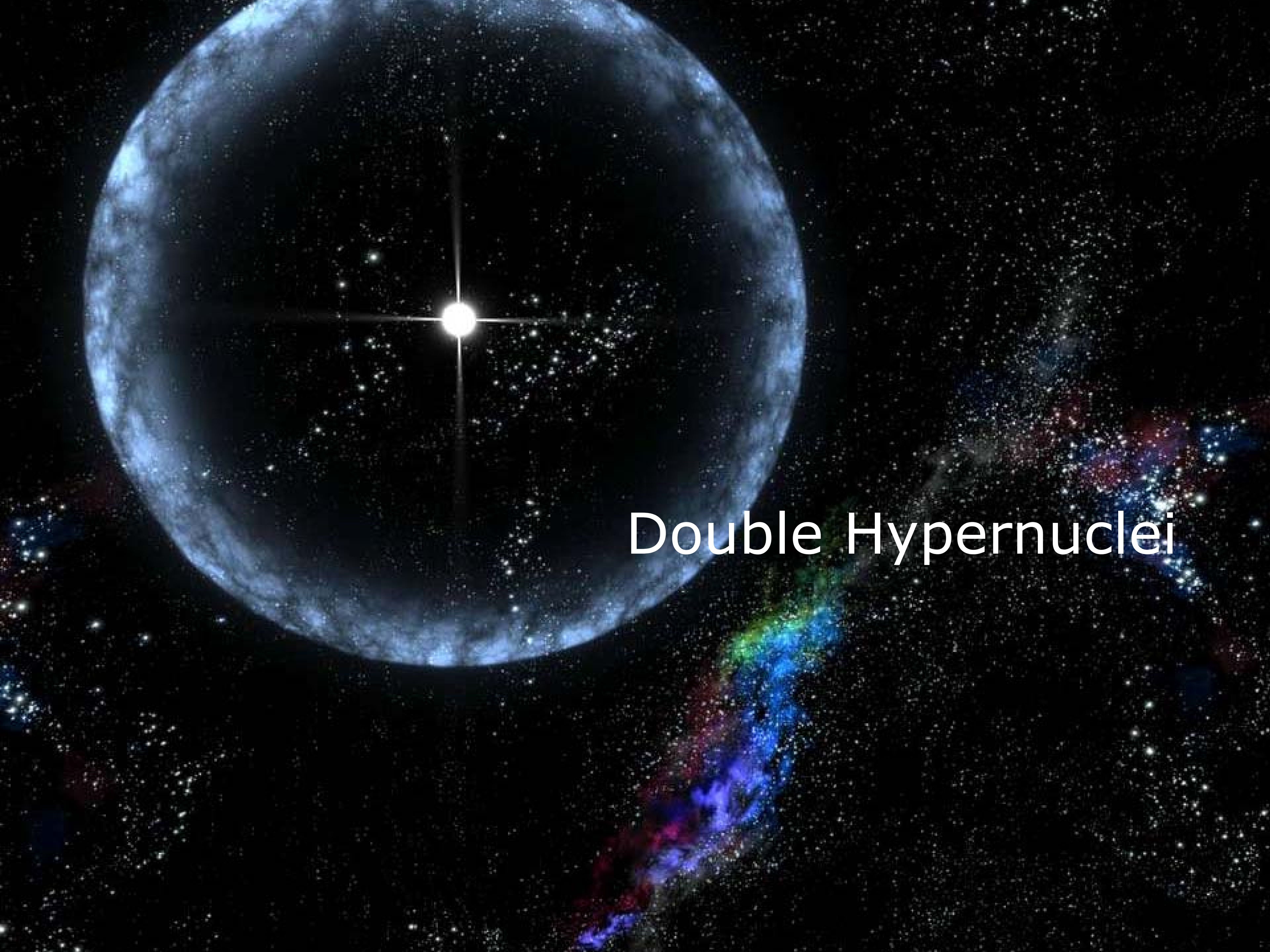


$${}^{3}_{\bar{\Lambda}}\overline{H} / {}^{3}_{\Lambda}H \propto (\bar{p}/p)(\bar{n}/n)(\bar{\Lambda}/\Lambda) \qquad = 0.49 \pm 0.18$$

$${}^{3}\overline{He} / {}^{3}He \propto (\bar{p}/p)^{2}(\bar{n}/n) \qquad = 0.44 \pm 0.02$$

$${}^{3}_{\bar{\Lambda}}\overline{H} / {}^{3}\overline{He} \propto (\bar{\Lambda}/\bar{p}) \qquad = 0.89 \pm 0.28$$

$${}^{3}_{\Lambda}H / {}^{3}He \propto (\Lambda/p) \qquad = 0.82 \pm 0.16$$

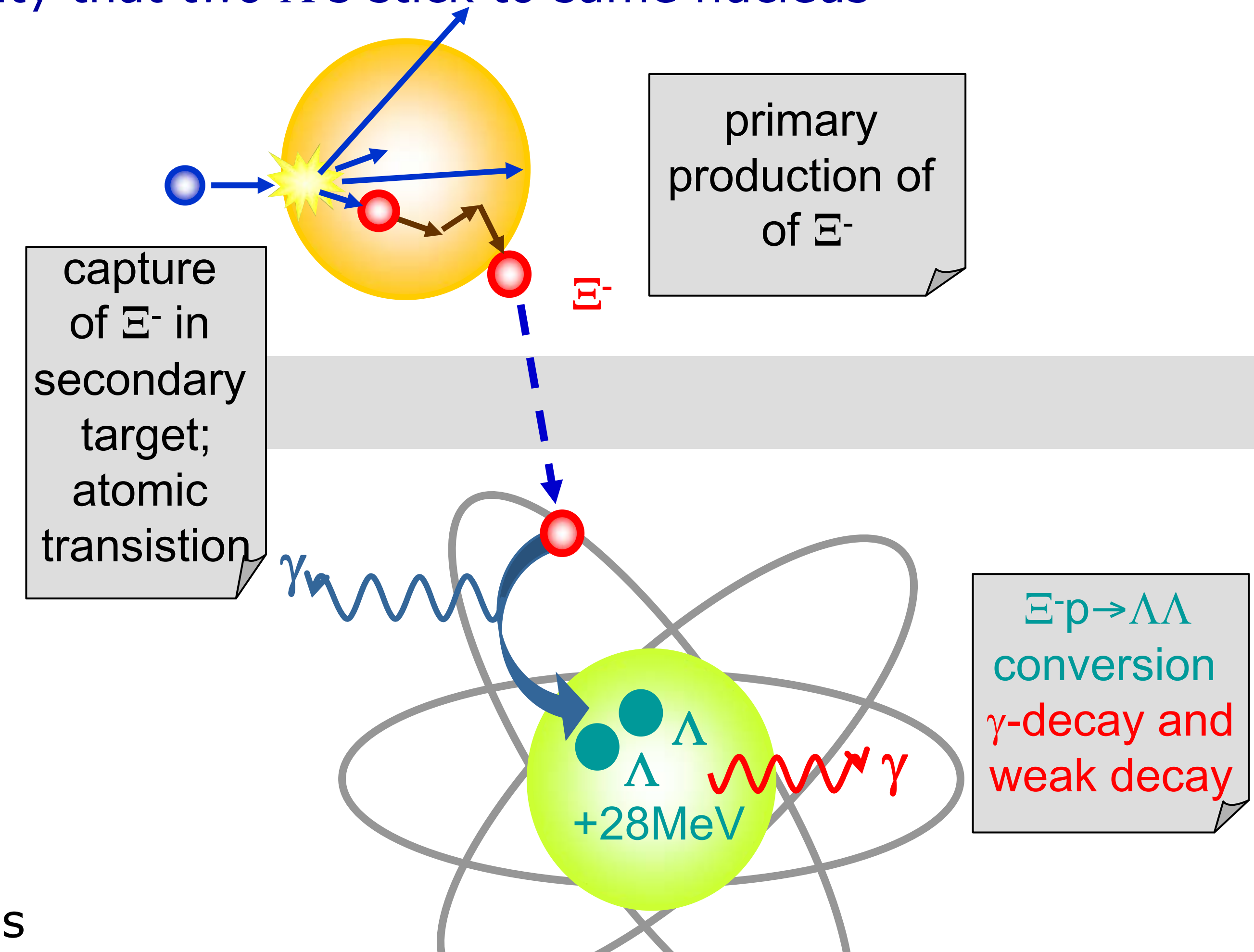


Double Hypernuclei

Production of ΛΛ Hypernuclei

- simultaneous implantation of two Λ's impossible
- Ξ^- conversion in 2Λ: $\Xi^- + p \rightarrow \Lambda + \Lambda$ + 28MeV

  ⇒large probability that two Λ's stick to same nucleus

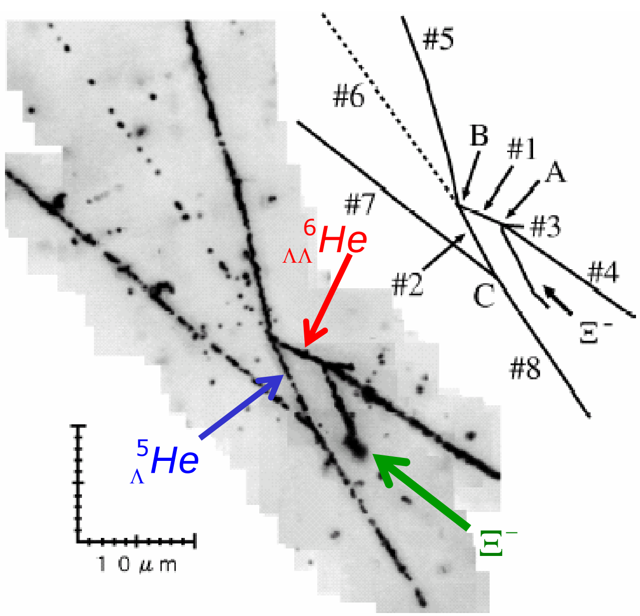


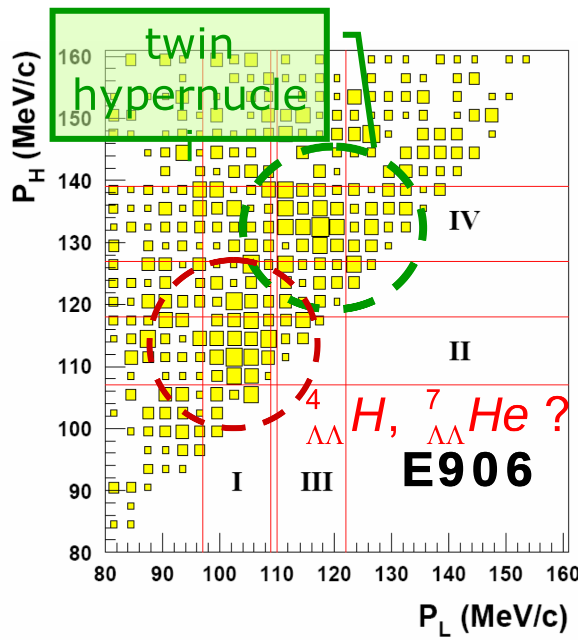
- two-step process

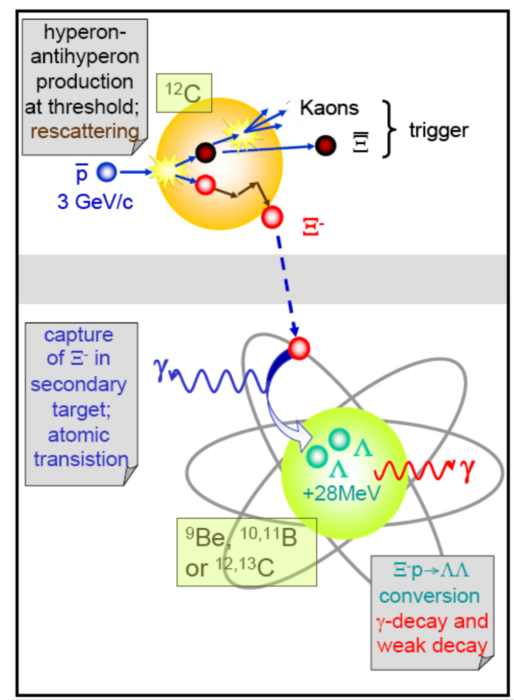
  ⇒ spectroscopic studies only via the decay products

Decay Products of ΛΛ Hypernuclei

- nuclear fragments ⇒ emulsion — hadron+nucleus
  - detection of charged products only
  - limited to light nuclei
- weak decay products ⇒ BNL-AGS E906 — $^{9}Be(K^{-},K^{+})X$
  - resolution limited
  - no information on excited states
  - interpretion not unique because π momenta are similar
- γ- spectroscopy ⇒ PANDA — $\bar{p}$+A
  - no excited states observed yet, but theoretically predicted
  - How to identify the nucleus



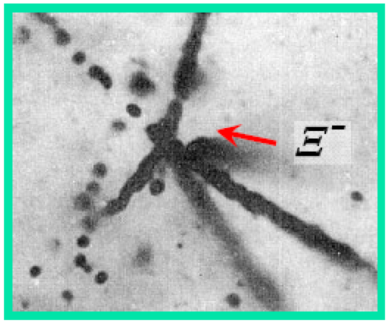




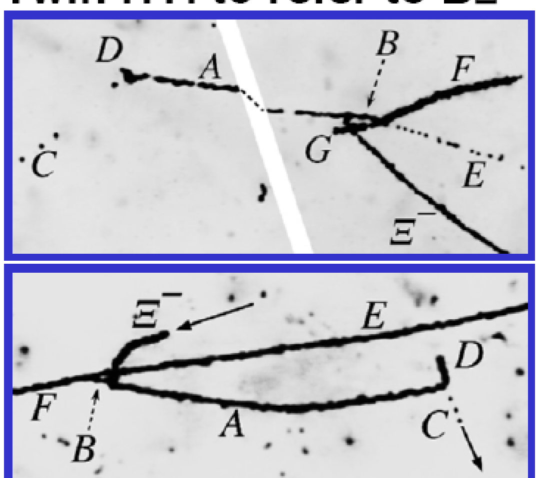
Today's Menu (events to be discussed)

KEK-E176

in ~80 Ξ⁻ stops



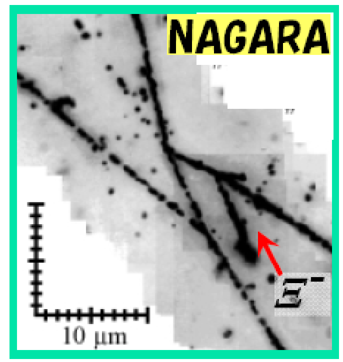
Twin HY. to refer to BΞ⁻

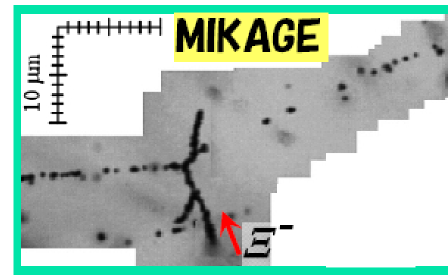


S.Aoki et al., NP. A828 (2009) 191-232

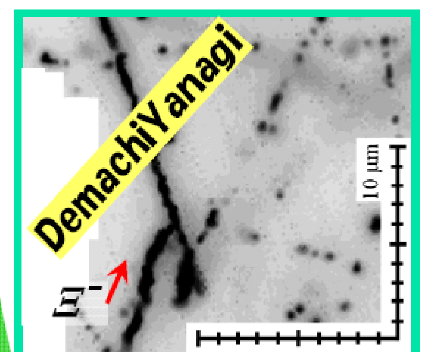
KEK-E373

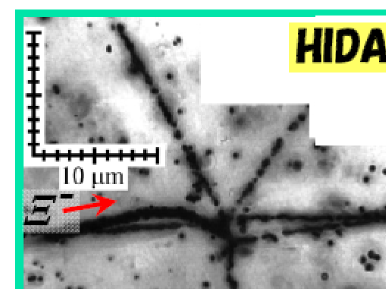
~2x10⁴ Ξ⁻ tracks (followed) → ~10³ Ξ⁻ stops





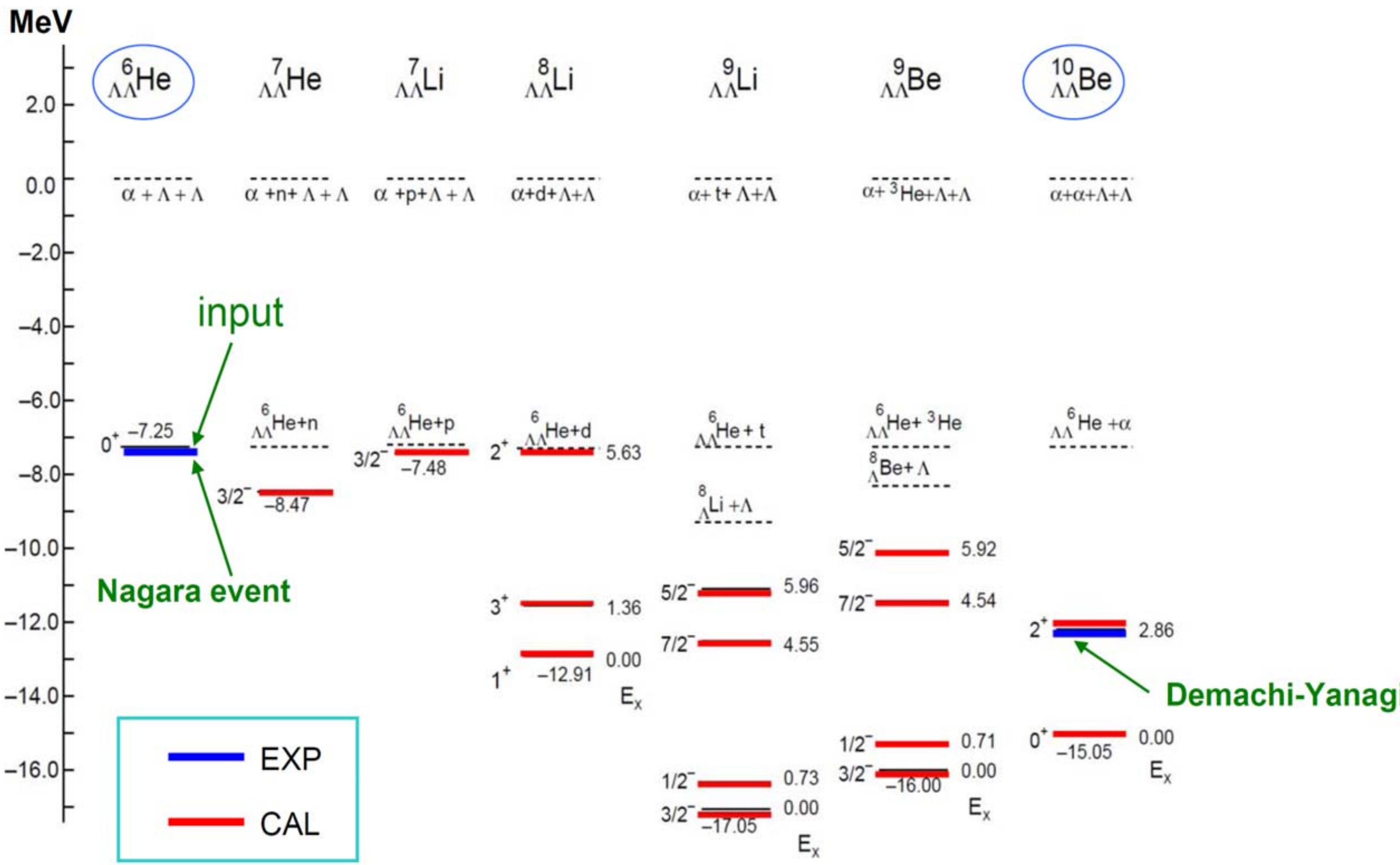
preliminary





Spectroscopy of ΛΛ-hypernuclei

E. Hiyama, M. Kamimura, T.Motoba, T. Yamada and Y. Yamamoto
Phys. Rev. 66 (2002), 024007



- many excited, particle stable states in double hypernuclei predicted
- level structure reflects levels of core nucleus

Is there a show stopper?

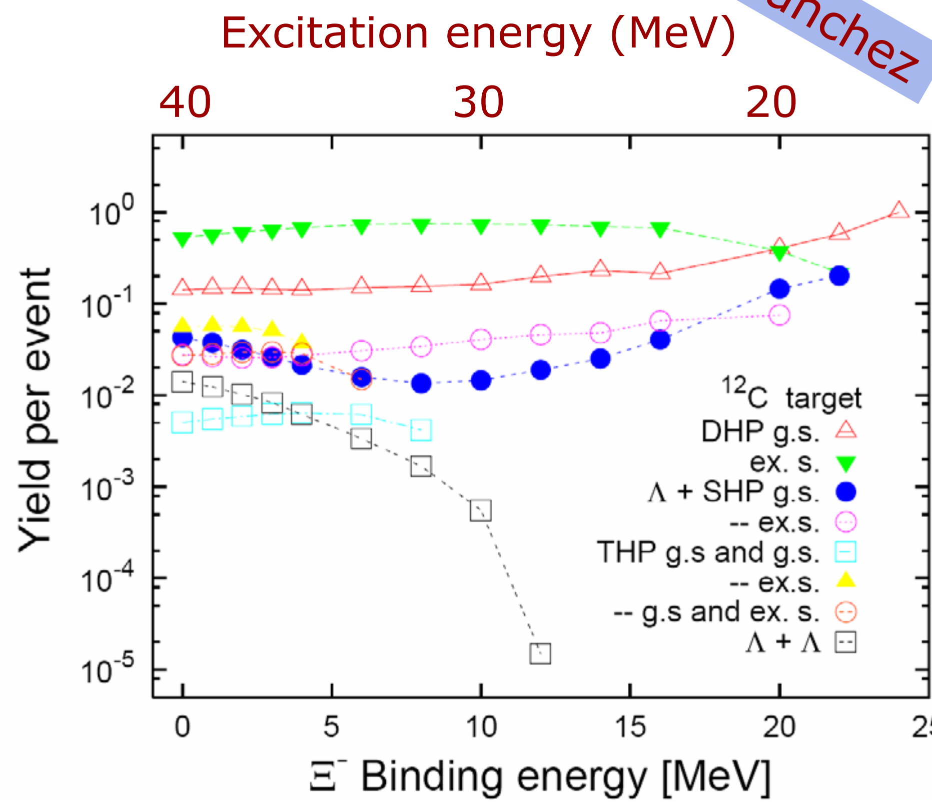
- Given that a Ξ^- is indeed captured and converted into 2 Λ hyperons and thus forms an excited $\Lambda\Lambda$-nucleus
  - What is the chance that individual excited, particle stable states of double hypernuclei are produced?
  - Can we develop a strategy to identify and assign possible γ-transitions?

$\Rightarrow$ **Alicia Sanchez Lorent**

Excitation Function for ${}^{13}_{\Lambda\Lambda}B^*$ decays

Alicia Sanchez

- DHP ▼△: double hypernuclei
  - dominates
  - Somewhat larger than in other calculations, but compatible with scarce data
- SHP ●○ : single hypernuclei
  - below B_Ξ=-12MeV only ${}^{12}_{\Lambda}B$ states
- THP □▲○: twin hypernuclei
  - ~10%
- Please note: relevant range probably $B_\Xi \approx 0 \ldots 5$MeV



Summary

- Hypernuclear physics is a multicultural activity – it links QCD and nuclei
- Hypernuclei are a key to neutron stars
- Hypernuclear physics needs a variety of experimental probes
- γ-spectroscopy of double hypernuclei seems possible at PANDA


THANK YOU