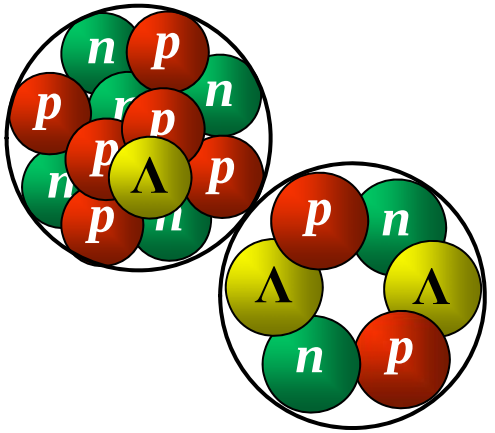
Hypernuclei: latest results from LNF and future programs at J-PARC



Italia del futuro

Istituto Italiano di Cultura di Tokyo
17 aprile – 17 maggio, 2013

イタリア文化会館
2013年4月17日～5月17日

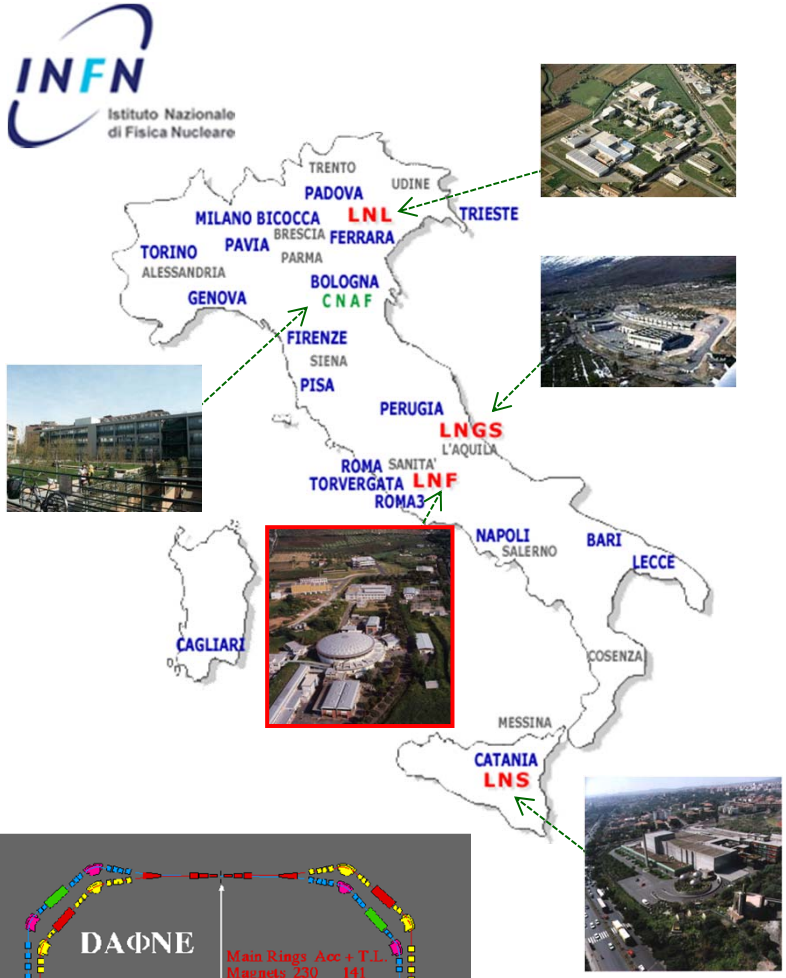
Alessandro Feliciello

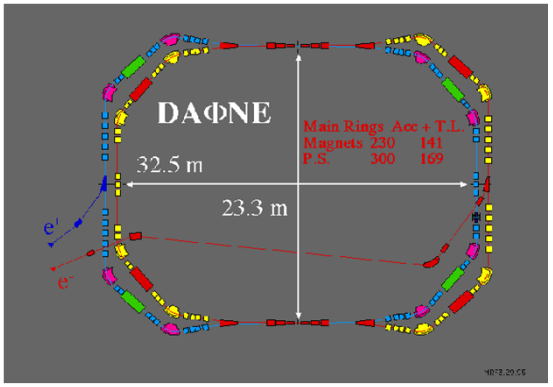
I.N.F.N. - Sezione di Torino

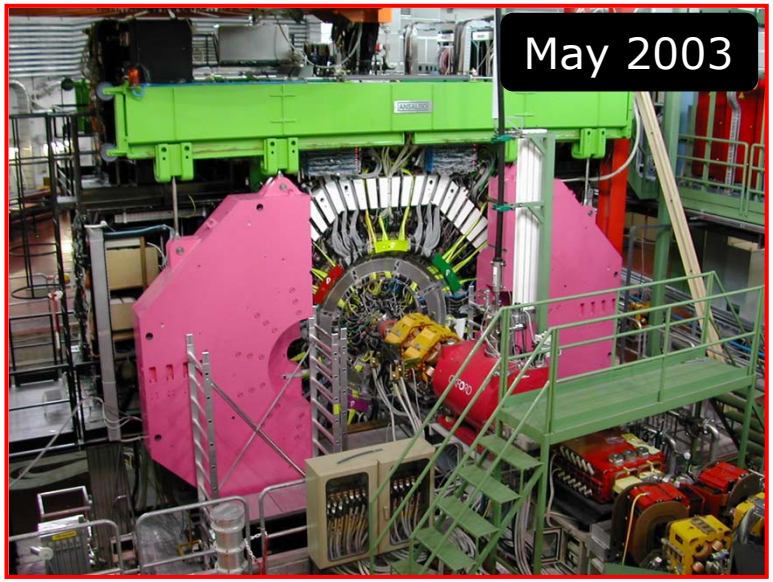
Outline

- The FINUDA experiment at DAΦNE
- hypernuclear physics results:
  - ${}^{6}H_{\Lambda}$ neutron-rich hypernucleus
  - 2 $\mathcal{N}$ induced hypernucleus weak decay
- Looking to the future:
  - the INFN ULYSSES initiative @ J-PARC

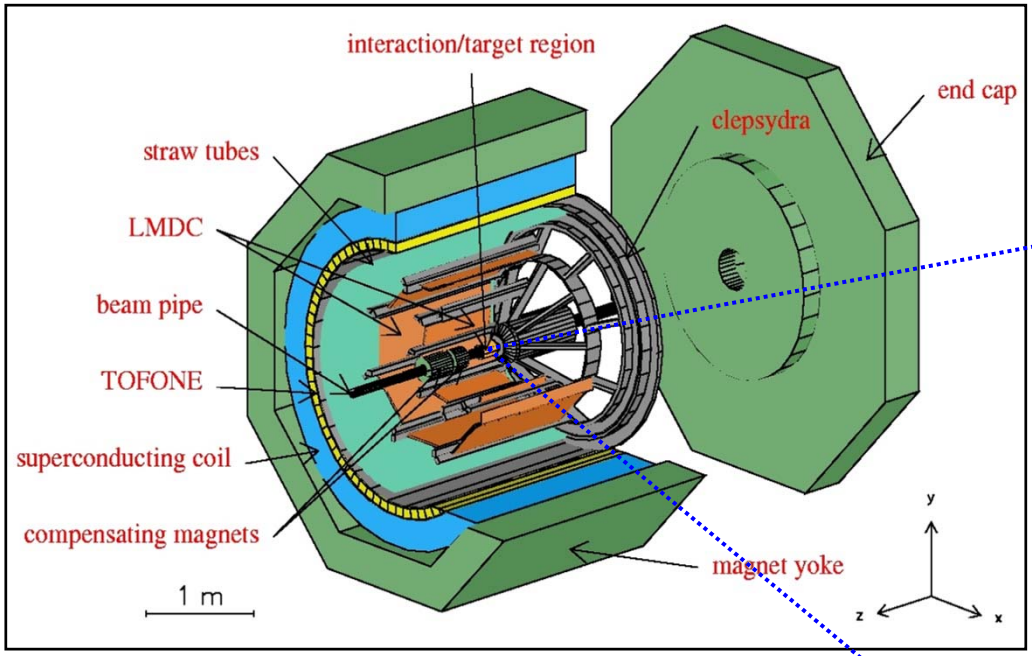
FINUDA @ DAΦNE





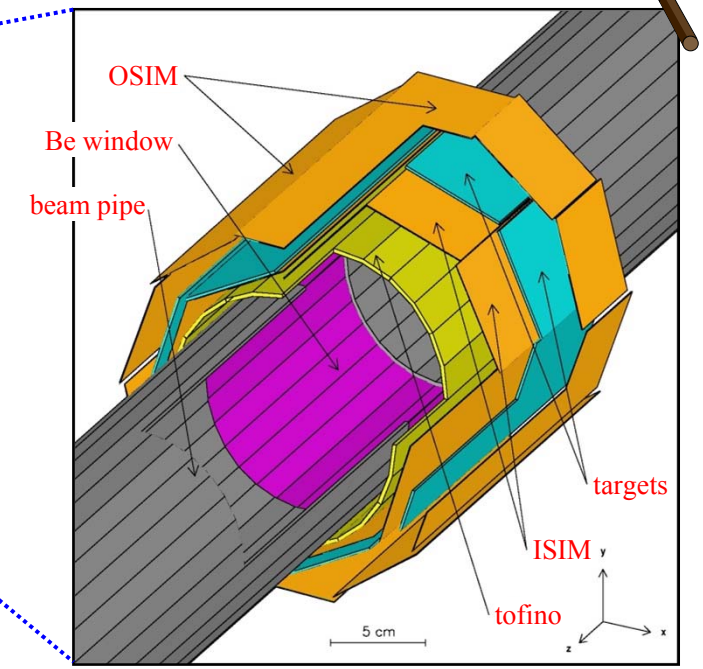


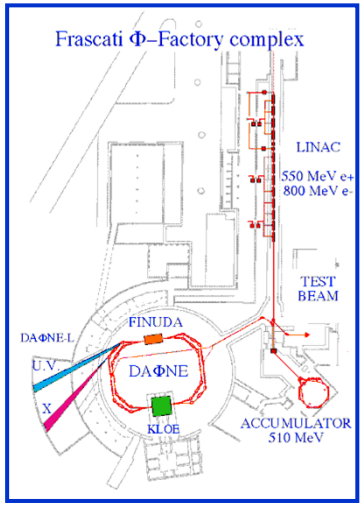
FINUDA @ DAΦNE



$$e^- + e^+ \rightarrow \phi \rightarrow K^- K^+$$

$$K^-_{stop} + {}^{A}Z \rightarrow {}^{A}_{\Lambda}Z + \pi^-$$





energy	510 MeV
luminosity	5 10^{32} cm^{-2} s^{-1}
σ_x (rms)	2.11 mm
σ_y (rms)	0.021 mm
σ_z (rms)	35 mm
bunch length	30 mm
crossing angle	12.5 mrad
frequency (max)	368.25 MHz
bunch/ring	up to 120
part./bunch	8.9 10^{10}
current/ring	5.2 A (max)

$$ {}^{A}_{\Lambda}Z \rightarrow \begin{cases} {}^{A}(Z+1) + \pi^- \\ {}^{(A-2)}(Z-1) + p + n \\ {}^{(A-3)}(Z-1) + p + n + n \end{cases}$$

FINUDA key features

- very thin nuclear targets (0.1 ÷ 0.3 g/cm^2)
  - → high resolution spectroscopy
- coincidence measurement with large acceptance
  - → decay mode study
- event by event K^+ tagging
  - → continuous energy and rate calibration
- irradiation of different targets in the same run
  - → systematic error reduction

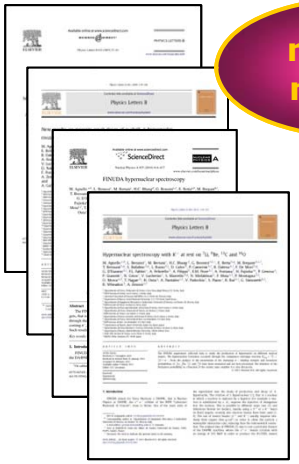
The FINUDA Collaboration

- I.N.F.N. Bari and Bari University
- Brescia University
- KEK
- I.N.F.N. / L.N.F. Frascati
- I.N.F.N. Pavia and Pavia University
- RIKEN
- Seoul National University
- Teheran Shahid Beheshty University
- I.N.F.N. Torino and Torino University
- Torino Polytechnic
- I.N.F.N. Trieste and Trieste University
- TRIUMF

Physics output (S = -1)

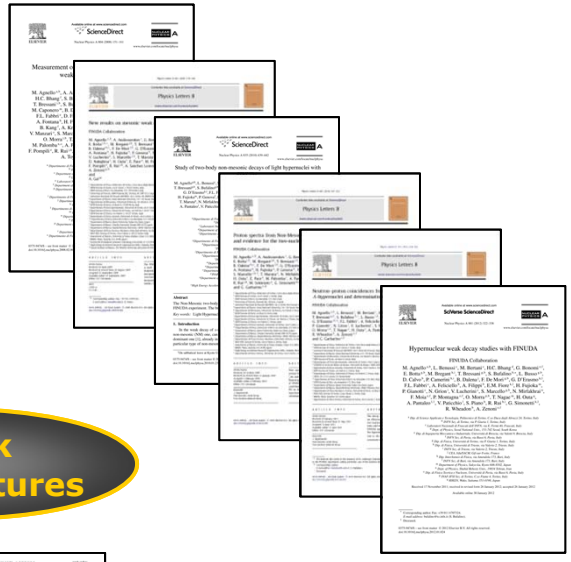
M. Agnello *et al.*, *PLB* 640 (2006) 145
M. Agnello *et al.*, *PRL* 108 (2012) 042501
M. Agnello *et al.*, *NPA* 881 (2012) 269
M. Agnello *et al.*, *PRC* 86 (2012) 057301

nuclear models

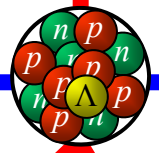


neutron-rich Λ-hypernuclei

4B weak interaction



spectroscopy



(weak) decay

M. Agnello *et al.*, *PLB* 622 (2005) 35
M. Agnello *et al.*, *PLB* 681 (2009) 139
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M. Agnello *et al.*, *PLB* 685 (2010) 247
M. Agnello *et al.*, *PLB* 701 (2011) 556
M. Agnello *et al.*, *NPA* 881 (2012) 322

The new NRH search strategy

$\mathscr{L}_{int} \approx 1156\ pb^{-1}$

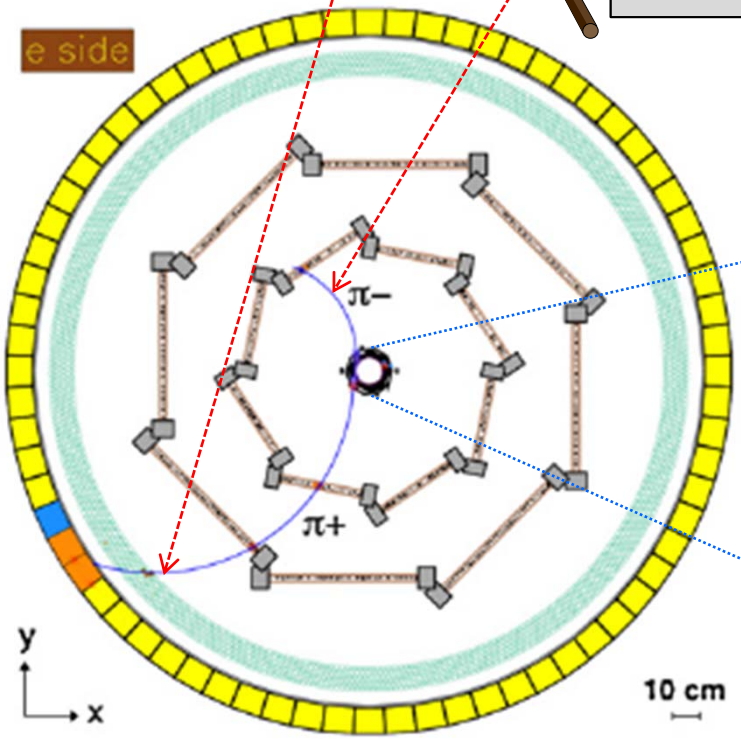
coincidence measurements

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

double C-EX
p ~ 252 MeV/c

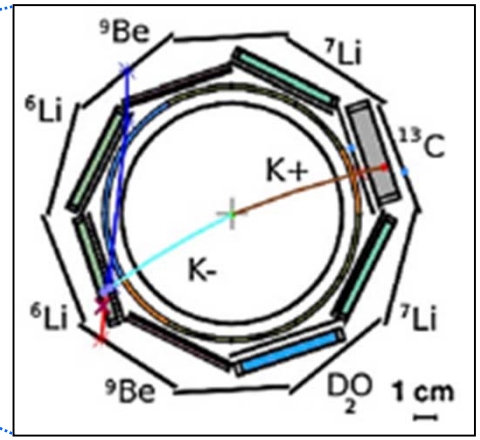
$${}^6_\Lambda H \rightarrow {}^6He + \pi^-$$

n.m. decay
p ~ 134 MeV/c



apparatus capabilities:

- selective trigger
  (based on fast scintillator detectors)
- precise K^- vertex identification < 1 mm^3
  (PID + spatial resolution + K^- tagging)
- π, K, p, d, … separation (OSIM & LMDC dE/dx)
- high momentum resolution
  6‰ FWHM π^- @ 270 MeV/c
  6% FWHM π^- @ 110 MeV/c
  (tracker performance + He bag + thin target)



Analysis technique

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

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

$(\tau({}^6He) \approx 801 \text{ ms})$

if ${}^6H_\Lambda$ is a stable system ⇒ 2 independent two-body reactions:

decay at rest

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

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

atomic mass tables

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

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

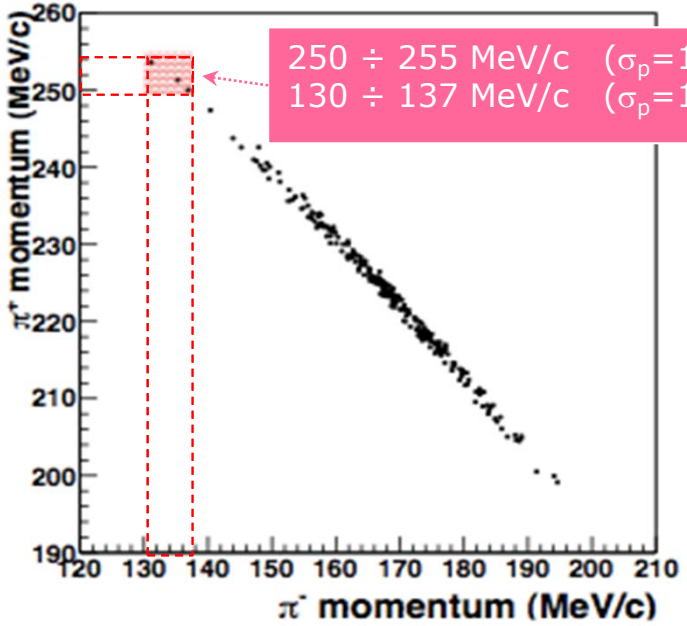
$$M({}^6_\Lambda H) = M({}^5H) + M(\Lambda) - B(\Lambda)$$

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

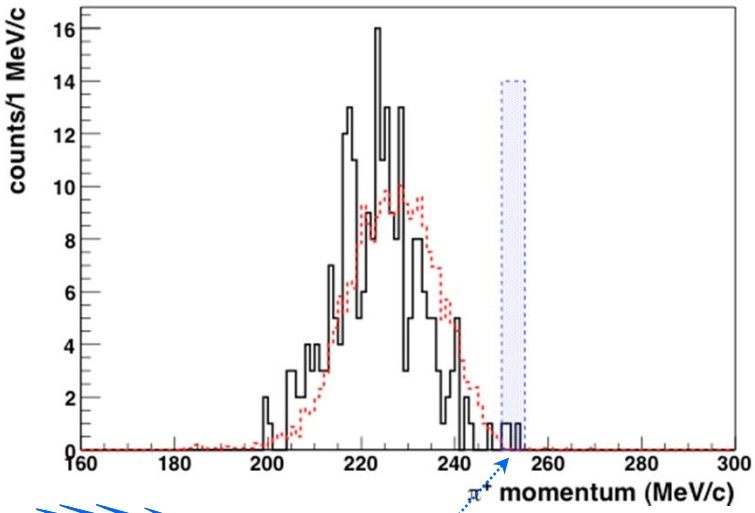
$$= 203.0 \pm 1.3 \text{ MeV} \qquad (203.5 \div 203.3 \text{ MeV with } B_\Lambda = 0 \div 6 \text{ MeV})$$

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

Data selection

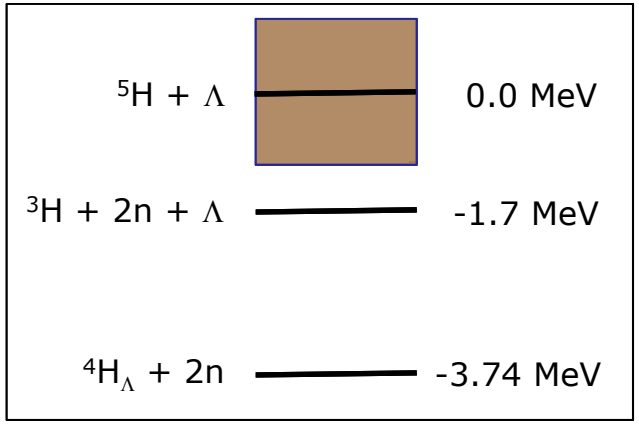


250 ÷ 255 MeV/c (σ_p=1.1 MeV/c)
130 ÷ 137 MeV/c (σ_p=1.2 MeV/c)



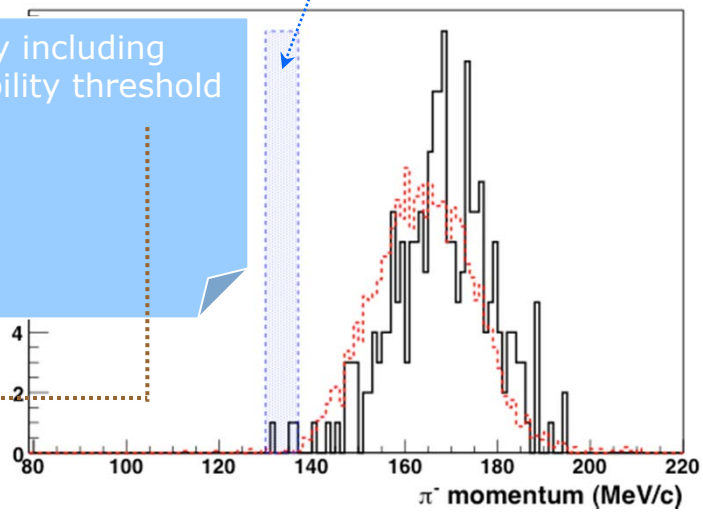
3 candidate events

(out of 27 10^6 stopped K^- events)



selection range fixed by including
^{6}H$_Λ$ lowest particle stability threshold
$p_{π+}$ = 251.9 MeV/c
$p_{π-}$ = 135.6 MeV/c

$B_Λ$ = 1.5 ÷ 6 MeV



Production rate

background sources

- accidentals: π^+ (250 ÷ 255 MeV/c) and π^- (130 ÷ 137 MeV/c) — 0.27 ± 0.27 ev. BGD2
- $K^-_{stop} + {}^6Li \rightarrow \Sigma^+ + \pi^- + {}^4He + n$ — end point ~190 MeV/c
  ↳ $n + \pi^+$ — end point ~282 MeV/c — 0.16 ± 0.07 ev. BGD1
- $K^-_{stop} + {}^6Li \rightarrow {}^4_\Lambda H + n + n + \pi^+$ — end point ~252 MeV/c
  ↳ $^4He + \pi^-$ — p(π^-) = 133 MeV/c — negligible

production rate

- total background on ^{6}Li: BGD1 + BGD2 = 0.43 ± 0.28 ev.
- Poisson statistics: 3 events DO NOT belong to pure background @ C.L. = 99%

$$R * BR(\pi^-) = (3 - \mathrm{BGD1} - \mathrm{BGD2}) / [\varepsilon(\pi^-)\varepsilon(\pi^+)(n.\ K^-_{stop} \text{ on } {}^6Li)]$$

$BR(\pi^-)\,{}^4_\Lambda H = 0.49$

$$R * BR(\pi^-) = (2.9 \pm 2.0)\ 10^{-6} / K^-_{stop}$$

H. Tamura *et al.*, *PRC* 40 (1989) R479

$$R = (5.9 \pm 4.0)\ 10^{-6} / K^-_{stop} \quad \Leftrightarrow \quad (2.5 \pm 0.5^{+0.4}_{-0.1}) \cdot 10^{-5} / K^-_{stop}$$

FINUDA Coll. and A. Gal, *PRL* 108 (2012) 042501

M. Agnello *et al.*, *PLB* 640 (2006) 145

Kinematics and binding energy

T_{tot} (MeV)	$p_{\pi}+$ (MeV/c)	$p_{\pi}-$ (MeV/c)	$M(^{6}_{\Lambda}H)$ prod. (MeV)	$M(^{6}_{\Lambda}H)$ decay (MeV)	$M(^{6}_{\Lambda}H)$ mean (MeV)	$\Delta M(^{6}_{\Lambda}H)$ (MeV)
202.6 ± 1.3	251.3 ± 1.1	135.1 ± 1.2	5802.33 ± 0.96	5801.41 ± 0.84	5801.87 ± 0.96	0.92 ± 1.28
202.7 ± 1.3	250.1 ± 1.1	136.9 ± 1.2	5803.45 ± 0.96	5802.73 ± 0.84	5803.09 ± 0.96	0.72 ± 1.28
202.1 ± 1.3	253.8 ± 1.1	131.2 ± 1.2	5799.97 ± 0.96	5798.66 ± 0.84	5799.32 ± 0.96	1.31 ± 1.28

$(N+Y)/Z(^{6}_{\Lambda}H) = 5 >> N/Z(^{8}He) = 3$

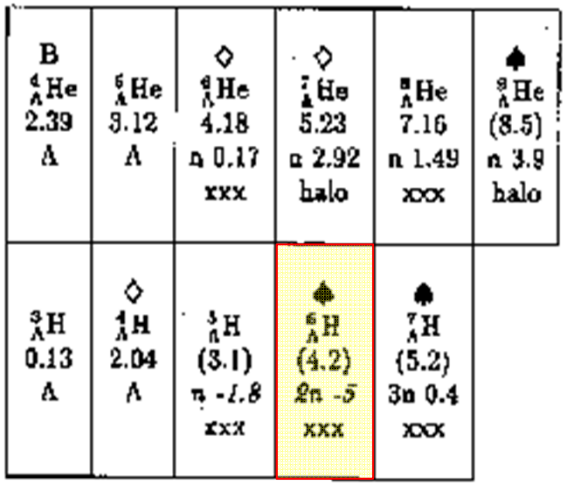
formation mass values systematically higher than the ones from decay

(0.98 ± 0.74) MeV

excited states production

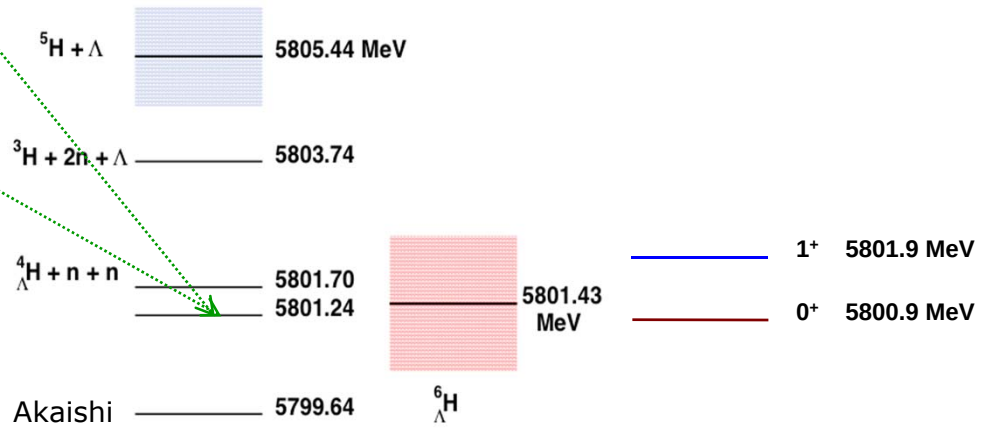
theoretical predictions

- B_{Λ} = 4.2 MeV — R.H. Dalitz and R. Levi Setti, *NC* 30 (1963) 489
- B_{Λ} = 4.2 MeV — L. Majling, *NPA* 585 (1995) 211c



nrh prod. rate: ~10^{-2} hyp. prod. rate in (K^{-}_{stop}, π^{-})

$\bar{M}$ = (5801.4 ± 1.1) MeV



B_{Λ} = (4.0 ± 1.1) MeV (^{5}H + Λ)

~~B_{Λ} = 5.8 MeV (^{5}H + Λ)~~
~~ΛNN force ≡ 1.4 MeV~~

FINUDA Coll. and A. Gal, *PRL* 108 (2012) 042501
FINUDA Coll. and A. Gal., *NPA* 881 (2012) 269

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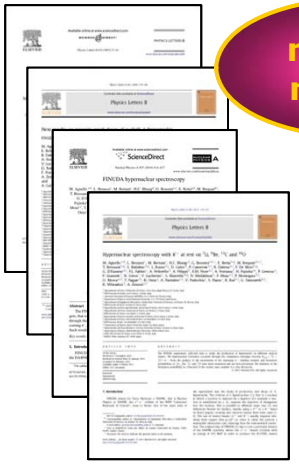

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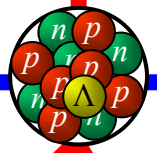
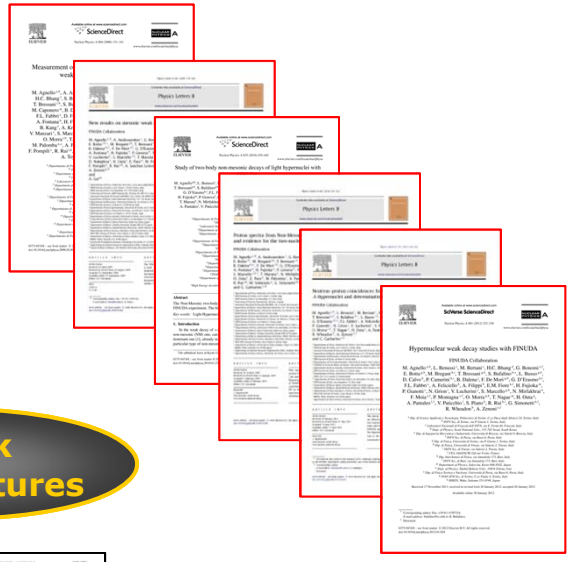


(weak) decay



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M. Agnello *et al.*, *PLB* 685 (2010) 247
M. Agnello *et al.*, *PLB* 701 (2011) 556
M. Agnello *et al.*, *NPA* 881 (2012) 322

$2\mathcal{N}$ induced weak decay

- relevance first pointed out by: W.M. Alberico *et al.*, *PLB* 256 (1991) 134
- key role in data interpretation ⟹ many theoretical predictions

E. Bauer
G. Garbarino
A. Parreño
A. Ramos

- importance of the effect: ~20-25% of the total NMWD width
- several experimental evidences, but indirect

Ref.	Γ_2/Γ_Λ	Γ_2/Γ_{NM}	Notes
BNL-E788 [47]		$\leqslant 0.24$	${}^{4}_{\Lambda}$He, n and p spectra
KEK-E508 [48]	0.27 ± 0.13	0.29 ± 0.13	${}^{12}_{\Lambda}$C, nn and np spectra
FINUDA [8]		0.24 ± 0.10	$A = 5$–16, p spectra
FINUDA [9]		$0.21 \pm 0.07_{\text{stat}}\,{}^{+0.03}_{-0.02}\,\text{sys}$	$A = 5$–16, np spectra

consistent within large errors

E. Botta, T. Bressani, G. Garbarino, *EPJA* 48 (2012) 21

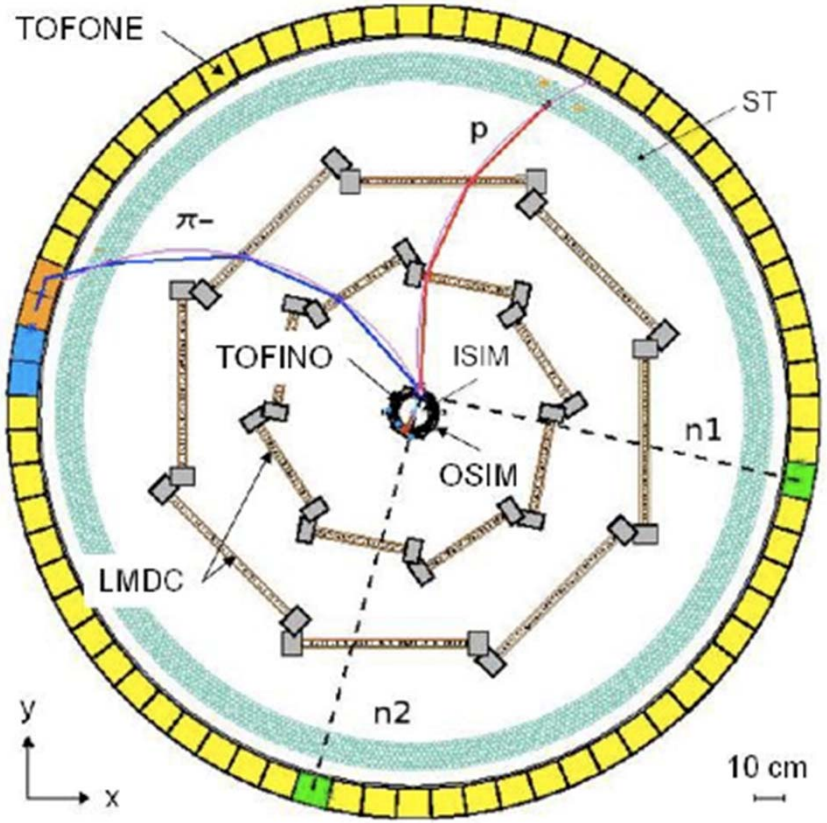
☛ "smoking gun" evidence missing!

- experimental hardness: 3 nucleons emitted from Λ-hypernucleus g.s.
  4-fold coincidence measurement (π^-, p, n, n)

$2\mathcal{N}$ induced decay exp. evidence

triple coincidence: $(n + n + p)$ events

exclusive $\Lambda np \rightarrow nnp$ decay event: $^{7}_{\Lambda}Li \rightarrow {}^{4}He + p + n + n$



p_{π^-}	=	276.9 ± 1.2 MeV/c
p_{miss}	=	217 ± 44 MeV/c
E_{tot}	=	178 ± 23 MeV
MM	=	3710 ± 23 MeV/c^2
E(n1)	=	110 ± 23 MeV
E(n2)	=	16.9 ± 1.7 MeV
E(p)	=	51.11 ± 0.85 MeV
ϑ(n1 n2)	=	94.8° ± 3.8°
ϑ(n1 p)	=	102.2° ± 3.4°
ϑ(n2 p)	=	154° ± 19°

no n-n or p/n scattering

$^{7}_{\Lambda}$Li	MM (MeV/c^2)
^{4}He	3727.4
^{3}He + n	3748.0
^{3}H + p	3747.2

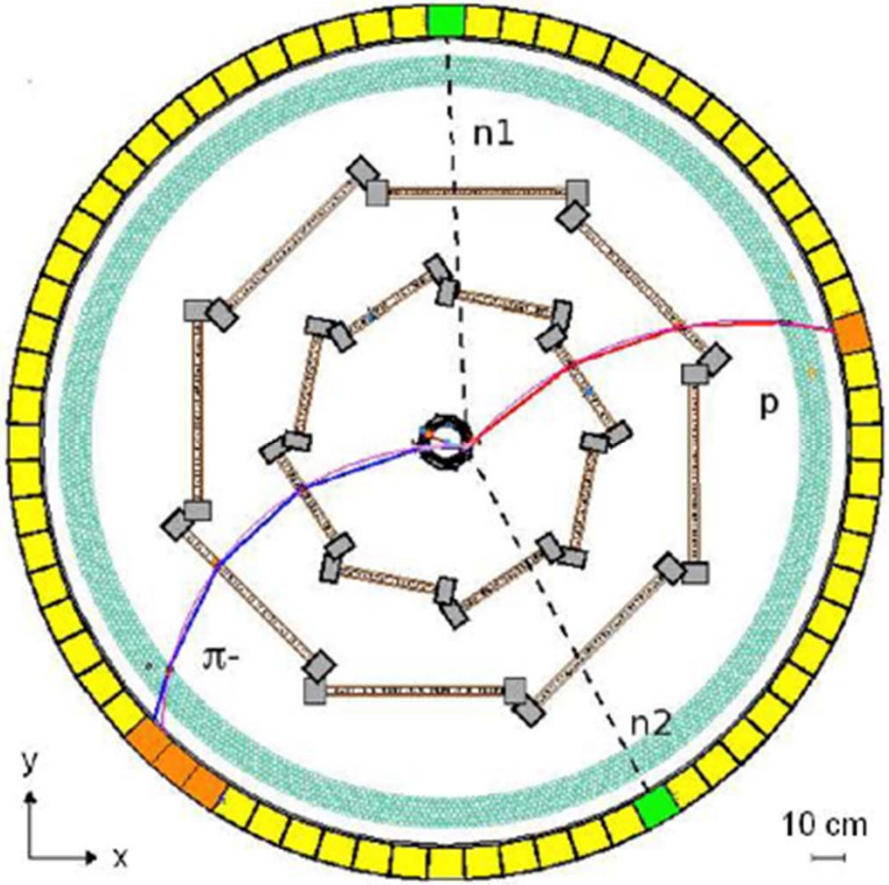
first, direct experimental evidence

M. Agnello *et al.*, *NPA* 881 (2012) 322

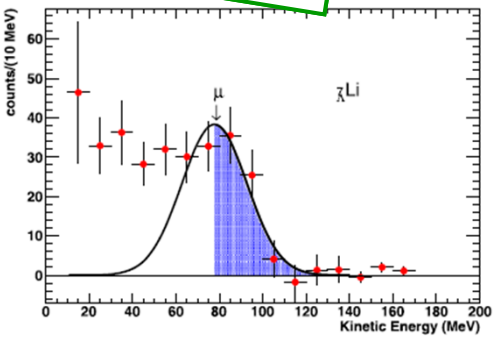
2$\mathcal{N}$ induced decay exp. evidence

triple coincidence: $(n + n + p)$ events

exclusive $\Lambda np \rightarrow nnp$ decay event: $^{7}_{\Lambda}Li \rightarrow {}^{4}He + p + n + n$



cut on E_p released



p_{π^-}	=	276.5 ± 1.2 MeV/c
P_{miss}	=	447 ± 18 MeV/c
E_{tot}	=	147.1 ± 4.2 MeV
MM	=	3720.3 ± 4.7 MeV/c^2
E(n1)	=	21 ± 2.0 MeV
E(n2)	=	35.3 ± 3.6 MeV
E(p)	=	90.83 ± 0.50 MeV
ϑ(n1 n2)	=	126.5° ± 5.4°
ϑ(n1 p)	=	53.5° ± 4.3°
ϑ(n2 p)	=	124.6° ± 3.9°

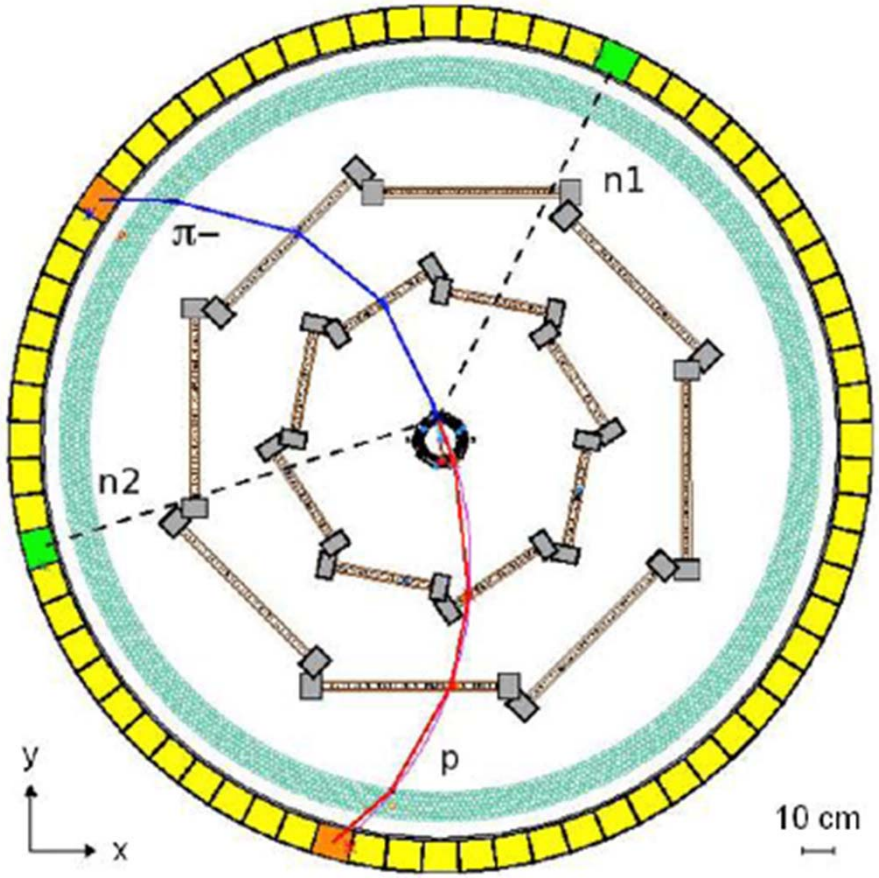
no n-n or p/n scattering

2$\mathcal{N}$ induced decay exp. evidence

triple coincidence: $(n + n + p)$ events

exclusive $\Lambda np \rightarrow nnp$ decay event: $^{9}_{\Lambda}Be \rightarrow {}^{3}He + {}^{3}H + p + n + n$

cut on E_p released



p_{π^-}	=	286.7 ± 1.2 MeV/c
P_{miss}	=	253 ± 18 MeV/c
E_{tot}	=	123.5 ± 4.9 MeV
MM	=	5617.3 ± 5.0 MeV/c^2
E(n1)	=	20.2 ± 2.5 MeV
E(n2)	=	31.5 ± 4.2 MeV
E(p)	=	71.77 ± 0.80 MeV
ϑ(n1 n2)	=	133.6 °± 7.5°
ϑ(n1 p)	=	128.5°± 5.5°
ϑ(n2 p)	=	95.4°± 3.6°

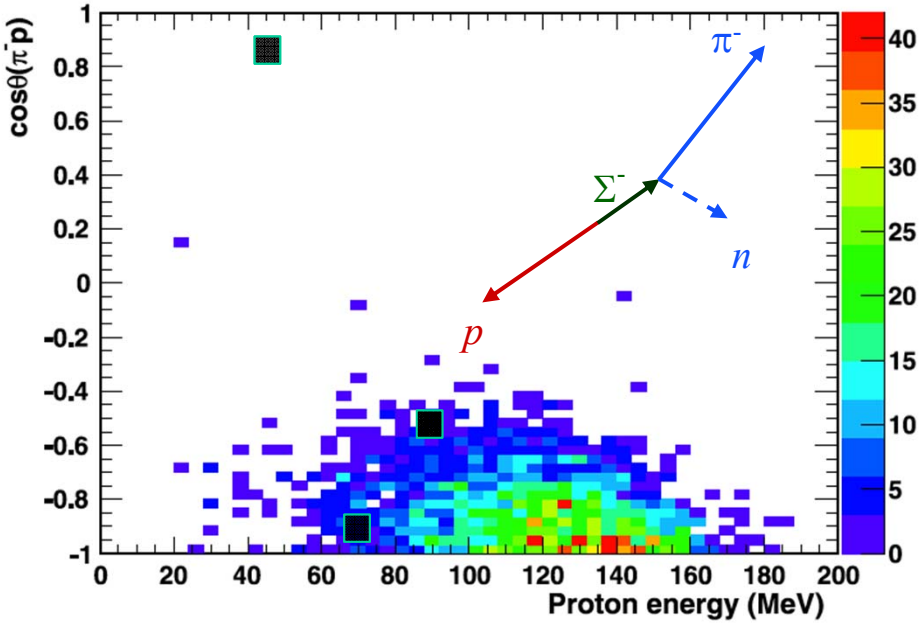
no n-n or p/n scattering

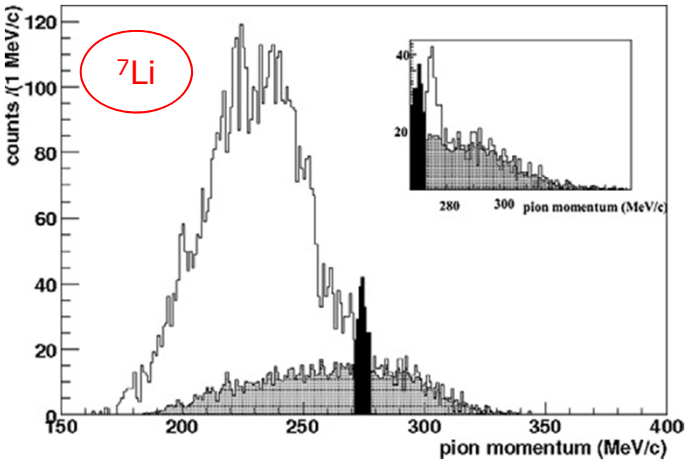
$^{9}_{\Lambda}$Be	MM (MeV/c^2)
^{6}Li	5601.5
^{5}Li + n	5607.2
^{4}He + d	5603.0
^{3}He + ^{3}H	5617.3

Background evaluation

$$K^- + (np) \rightarrow \Sigma^- + p$$

$$\Sigma^- \rightarrow \pi^- + n$$



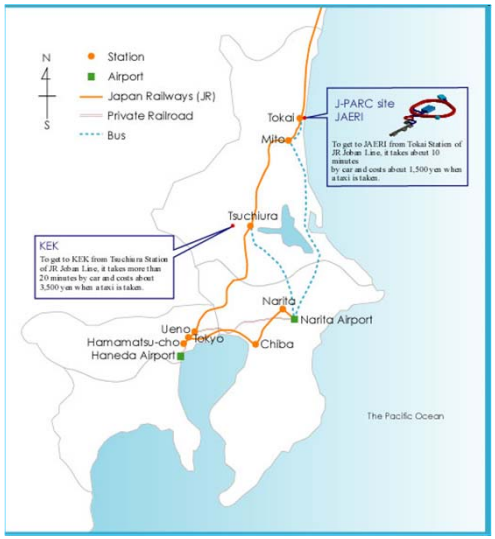


Target	$\vartheta(\pi^- p)$	E_p (MeV)
^{7}Li	33.4 ° ± 3.7°	51.11 ± 0.85
^{7}Li	121.7 ° ± 3.2°	90.83 ± 0.50
^{9}Be	159.3 ° ± 5.9°	71.77 ± 0.80

- significant back-to-back correlation → this feature rules out completely the first event on ^{7}Li
- the correlation between $\cos\vartheta(\pi^- p)$ and E_p was studied for the simulated background: major contribution from this source when π and p are emitted nearly back-to-back and $E_p \geq 100$ MeV
- evaluation of the number of simulated events surviving to a 3σ cut on $\cos\vartheta(\pi^- p)$ and E_p on ^{7}Li and ^{9}Be: $\sim 10^{-3}$ events were found for both targets

the 2 $\Lambda np \rightarrow nnp$ real events DO NOT belong to background to a confidence level ≥ 99%.

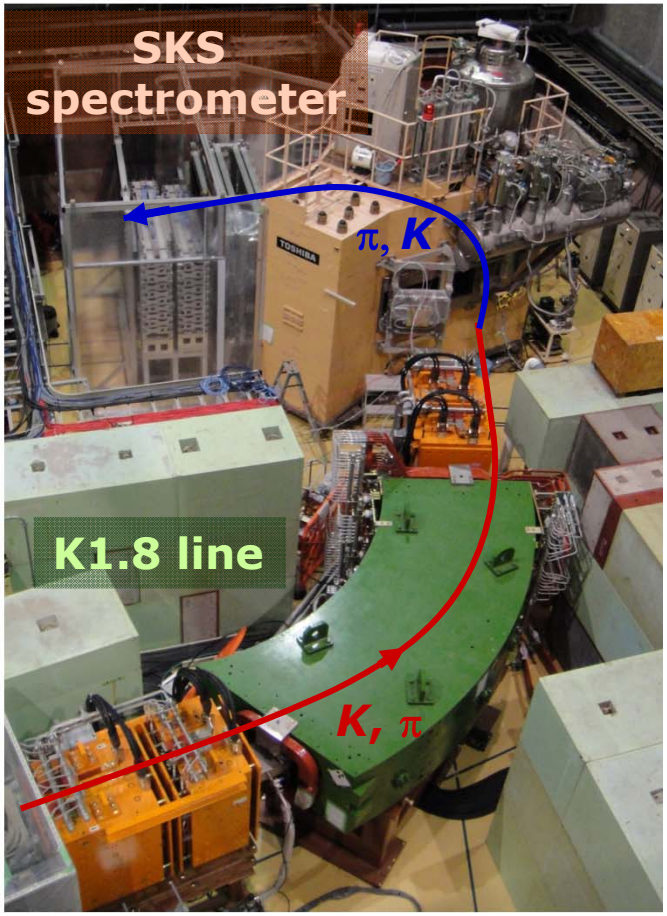
SKS @ J-PARC


N
S
Station
Airport
Japan Railways (JR)
Private Railroad
Bus
Tokai
Mito
J-PARC site
JAERI
Tsuchiura
KEK
Narita
Narita Airport
Ueno
Tokyo
Hamamatsu-cho
Haneda Airport
Chiba
The Pacific Ocean


50GeV Synchrotron


Linac
Neutrino Facility
beam extraction to
Hadron Hall
3GeV
Synchrotron
500m
Materials and Life
Science Facility


Nuclear and Particle Experimental Facility
(Hadron Hall)
2008.12.20


SKS
spectrometer
π, K
K1.8 line
K, π

J-PARC scientific program

---- J-PARC PAC Approval summary after the 15th meeting ---

Proposals

	(Co-)Spokespersons	Affiliation	Title of the experiment	Approval status (PAC recommendation)	Slow line priority		Beamline	from 2012
					Day1?	Day1 Priority		Leading Referees
E03	K.Tanida	SNU	Measurement of X rays from Σ⁻ Atom	Stage 2			K1.8	Weise,Kishimoto,Nagae,Shimizu
P04	J.C.Peng; S.Sawada	U of Illinois at Urbana-Champaign; KEK	Measurement of High-Mass Dimuon Production at the 50-GeV Proton Synchrotron	Deferred			Primary	Nagae, Gross-Pendekamp, Imai, Dote
E05	T.Nagae	Kyoto U	Spectroscopic Study of Σ-Hypernucleus, ^{12}Be, via the ^{12}C(K⁻, K⁺) Reaction	Stage 2	Day1	1	K1.8	Weise, Shimizu, Sakurai
E06	J.Imazato	KEK	Measurement of T-violating Transverse Muon Polarization in K⁺ -> π⁰ μ⁺ ν Decays	Stage 1			K1.1BR	Browder, Blucher, Kleinknecht, Isidori
E07	K.Imai, K.Nakazawa, H.Tamura	JAEA, Gifu U, Tohoku U	Systematic Study of Double Strangeness System with an Emulsion-counter Hybrid Method	Stage 2			K1.8	Weise, Shimizu, Kishimoto
E08	A.Krutenkova	ITEP	Pion double charge exchange on oxygen at J-PARC	Stage 1				..., Nagae, Ik
E10	A. Sakaguchi, T. Fukuda	Osaka U, Osaka EC U	Production of Neutron-Rich Lambda-Hypernuclei with the Double Charge-Exchange Reaction (Revised from Initial P10)	Stage 2				
E11	T. Kobayashi	KEK	Tokai-to-Kamioka (T2K) Long Baseline Neutrino Oscillation Experimental Proposal	Stage 2				
E13	H.Tamura	Tohoku U	Gamma-ray spectroscopy of light hypernuclei	Stage 2	Day1			
E14	T.Yamanaka	Osaka U	Proposal for K_L -> π⁰ ν ν-bar Experiment at J-PARC	Stage 2				
E15	M.Iwasaki, T.Nagae	RIKEN, Kyoto U	A Search for deeply-bound kaonic nuclear states by in-flight 3He(K⁻, n) reaction	Stage 2	Day1			
E16	S.Yokkaichi	RIKEN	Electron pair spectrometer at the J-PARC 50-GeV PS to explore the chiral symmetry in QCD	Stage 1				
E17	R.Hayano, H.Outa	U Tokyo, RIKEN	Precision spectroscopy of Kaonic ^{3}He 3d->2p X-rays	Stage 2	Day1		K1.8BR	Imai, ...
E18	H.Bhang, H.Outa, H.Park	SNU, RIKEN, KRISS	Coincidence Measurement of the Weak Decay of ^{12}C and the three-body weak interaction process	Stage 2			K1.8	Weise, Kishimoto, ...
E19	M.Naruki	KEK	High-resolution Search for θ⁺ Pentaquark In π⁻p -> K⁻X Reactions	Stage 2	Day1		K1.8	Sakurai, Dote, K...
E21	Y.Kuno	Osaka U	An Experimental Search for $\mu^- - e$ Conversion at a Sensitivity of 10^{-16} with a Slow-Extracted Bunched Beam	Stage 1			New beamline	Louis, Weise, Inoue, Kleinknecht, Bow Isidori
E22	S. Ajimura, A.Sakaguchi	Osaka U	Exclusive Study on the Lambda-N Weak Interaction in A=4 Lambda-Hypernuclei (Revised from Initial P10)	Stage 1			K1.8	Weise, Imai, Kishimoto
T25	S.Mihara	KEK	Extinction Measurement of J-PARC Proton Beam at K1.8BR	Test Experiment	will be coordinated by JPNC		K1.8BR	-
E26	K.Ozawa	KEK	... modification in the in-medium ω->π⁰γ decay.	Stage 1			K1.8	Dote, Sakurai, Nagae
E27	T.Nagae	Kyoto U	Search for a nuclear Kbar bound state K⁻pp in the d(π⁺,K⁺) reaction	Stage 2			K1.8	Weise, Shimizu, Sakurai
E29	H.Ohnishi	RIKEN	Search for φ-meson nuclear bound states in the pbar + ^{A}Z -> φ + $^{(A-1)}$(Z-1) reaction	Stage 1			K1.1	Dote, Shimizu, Nagae, Gross-Perdekamp
E31	H.Noumi	Osaka U	Spectroscopic study of hyperon resonances below KN threshold via the (K⁻,n) reaction on Deuteron	Stage 1			K1.8BR	Weise,Shimizu,Imai,Kishimoto
T32	A. Rubbia	ETH, Zurich	Towards a Long Baseline Neutrino and Nucleon Decay Experiment with a next-generation 100 kton Liquid Argon TPC detector at Okinoshima and an intensity upgraded J-PARC Neutrino beam	Test Experiment	schedule and beam time will be coordinated by JPNC		K1.1BR	Blucher, Inoue, Louis,Kleinknecht
P33	H. M. Shimizu	Nagoya U	Measurement of Neutron Electric Dipole Moment	Deferred			Linac	Blucher, Louis, Gross-Perdeckamp, Kleinknecht, Imai, Isidori

~30% of the initiatives is dedicated to strangeness nuclear physics

- 22 experiments
- 7 proposals
- 4 tests

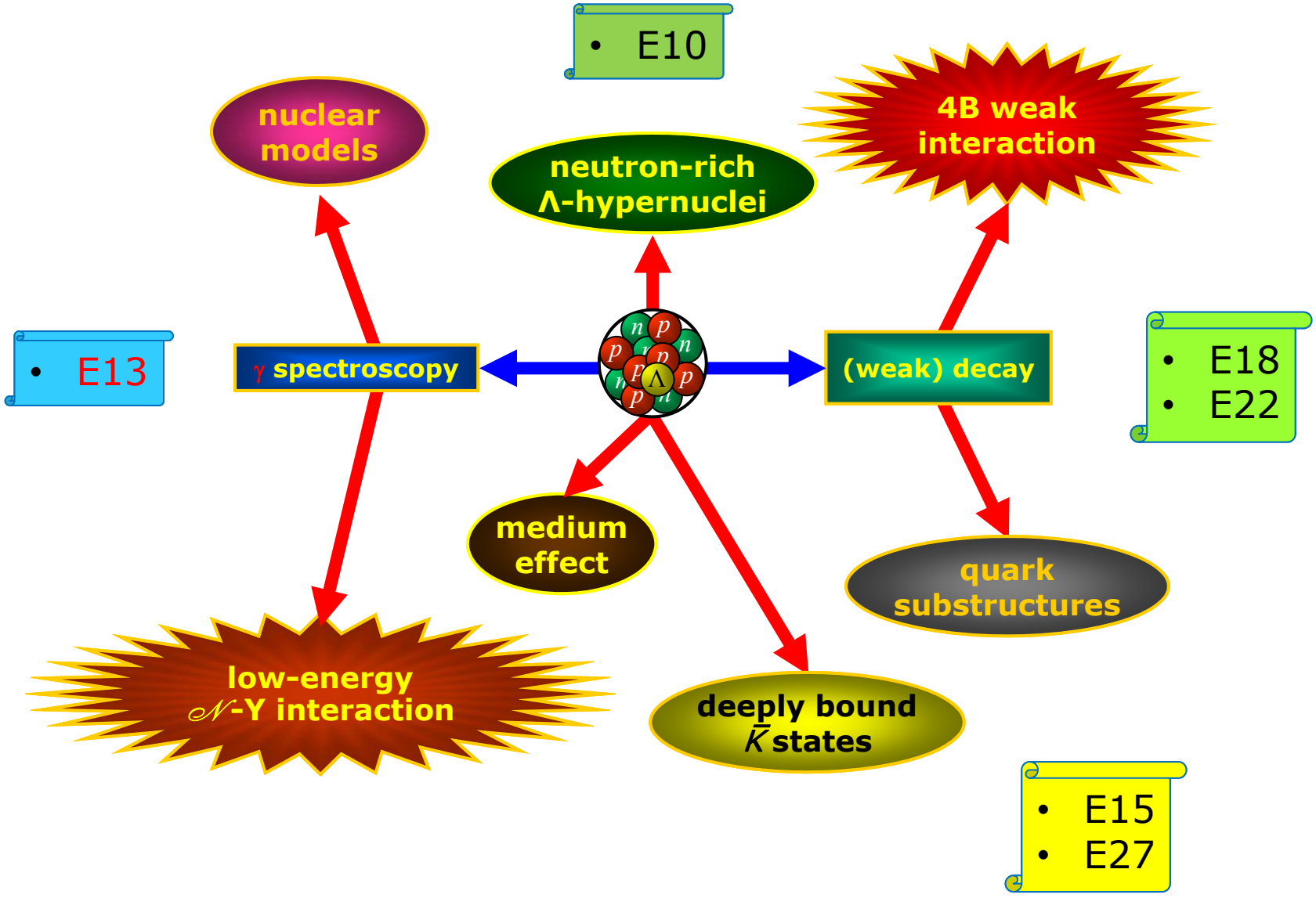
---- J-PARC PAC Approval summary after the 15th meeting ---

Proposals

E34	N. Saito, M. Iwasaki	KEK, RIKEN	An Experimental Proposal on a New Measurement of the Muon Anomalous Magnetic Moment g-2 and Electric Dipole Moment at J-PARC	Stage 1			MLF	Louis,Browder,Inoue, Gross-Perdeckamp, Isidori
P36	M. Kohl, S.Shimizu	Hampton U, Osaka U	Measurement of Γ(K+ -> e+ ν)/Γ(K+ -> μ+ ν) and Search for heavy sterile neutrinos using the TREK detector system	Stage 1			K1.1BR	Browder, Blucher, Kleinknecht, Louis, Isidori
E40	K.Miwa	Tohoku U	Measurement of the cross sections of Σp scatterings	Stage 1			K1.8	Gross-Perdekamp, Dote, Nagae,Imai
P41	M.Aoki	Osaka U	An Experimental Search for $\mu^- - e$ Conversion in Nuclear Field at a Sensitivity of 10^{-14} with Pulsed Proton Beam from RCS	Deferred			MLF	Louis, Weise, Inoue, Kleinknecht, Bowder, Isidori
P42	J.K. Ahn	Pusan National U	Search for H-Dibaryon with a Large Acceptance Hyperon Spectrometer	Stage 1			K1.8	Kishimoto, Dote, Nagae,Sakurai
T43	K.Aoki	RIKEN	Test of Hadron Blind Detector and GEM Tracker for the J-PARC E16 Experiment	Test Experiment			K1.1BR	
T44	T.Koike	Tohoku U	Study of in-beam performance of Hyperball-J Ge detector units with the current beam structures at the K1.1BR beam line	Test Experiment	schedule and beam time will be coordinated by JPNC		K1.1BR	Discussion in the sub-committee
P45	K.H. Hicks, H. Sako	Ohio U, JAEA	3-Body Hadronic Reactions for New Aspects of Baryon Spectroscopy	Deferred			K1.8	Shimizu, Dote, Nagae
P46	K. Ozawa	KEK	EDIT2013 beam test program	(no discussion)			K1.1BR	Discussion in the sub-committee

Report in PAC15
Decision in PAC15

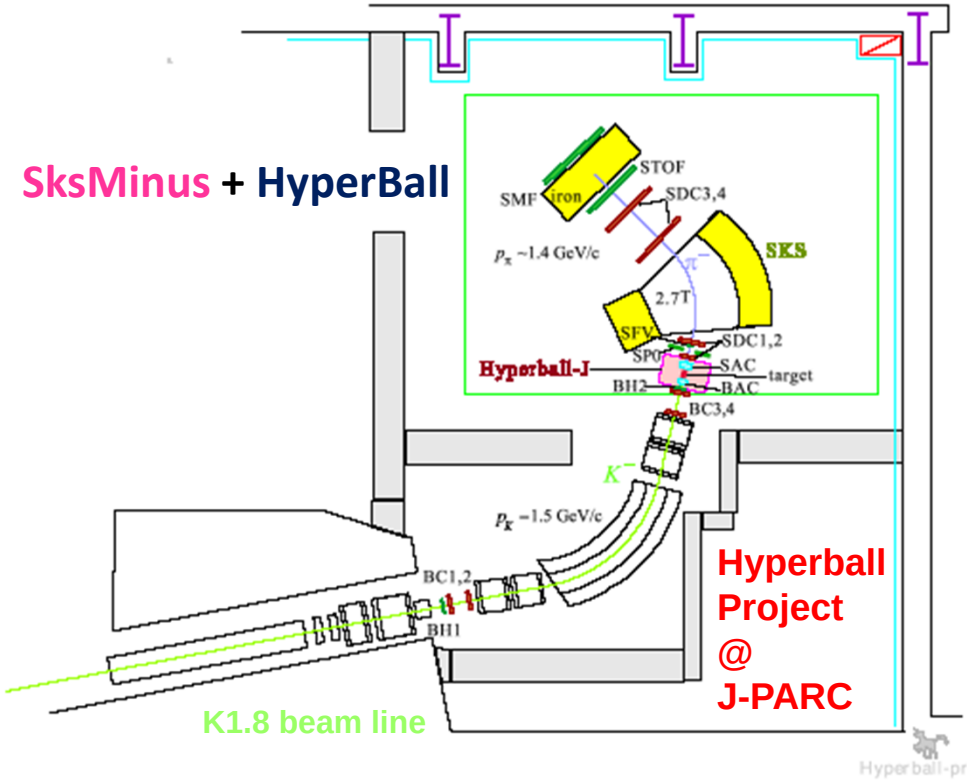
Physics output (S = -1)

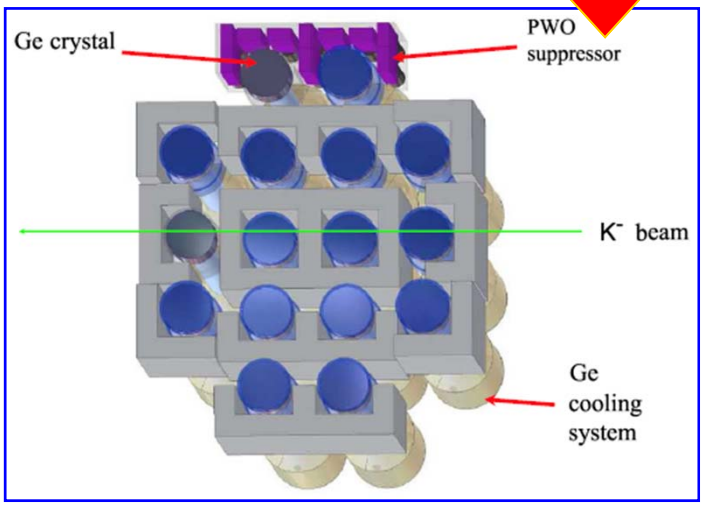


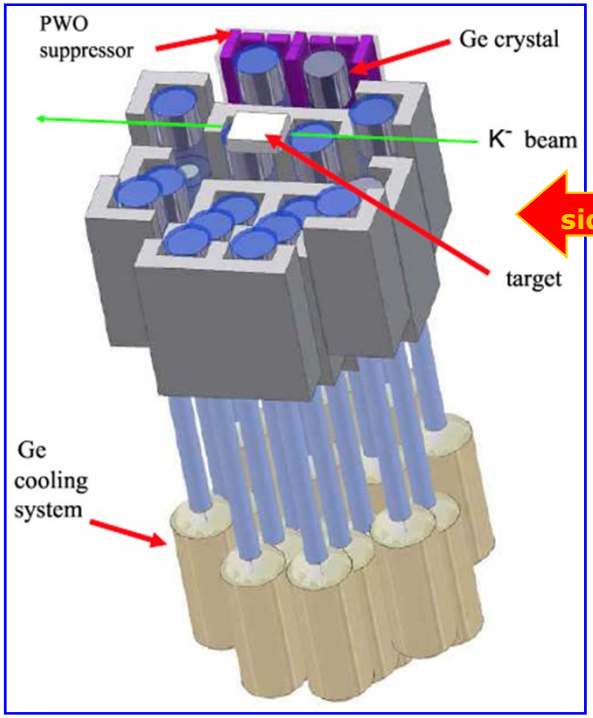
E13 experiment layout

γ-ray spectroscopy of hypernuclei

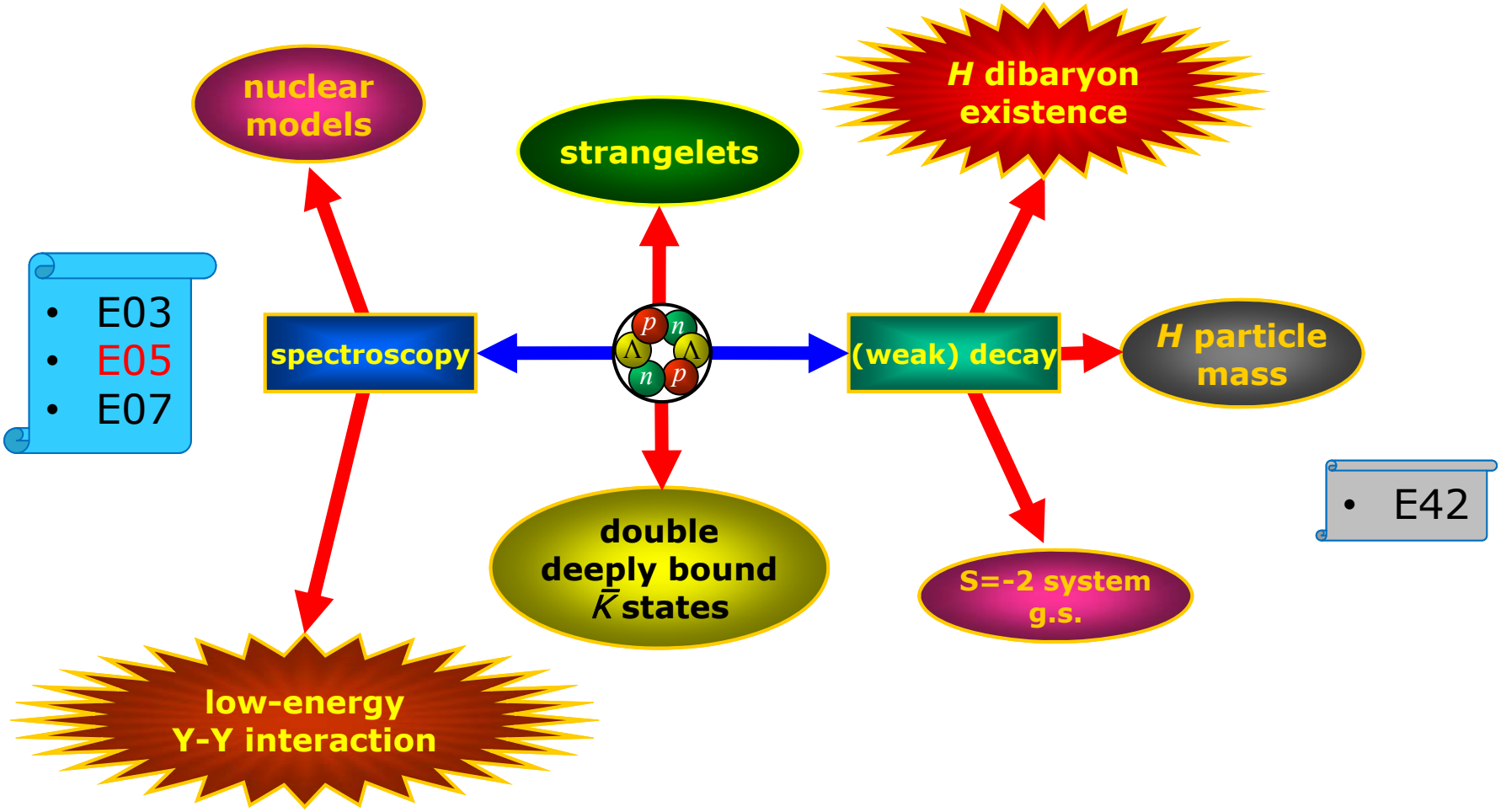
- further study of ΛN interaction: $^{4}He_{\Lambda}$, $^{10}B_{\Lambda}$, $^{11}B_{\Lambda}$, $^{19}F_{\Lambda}$
  - ΛN-ΣN coupling and 3-body force
  - charge symmetry breaking (Λn ≠ Λp?)
  - radial dependence (interaction range)
- g_{Λ} in a nucleus from spin-flip B(M1): $^{7}Li_{\Lambda}$





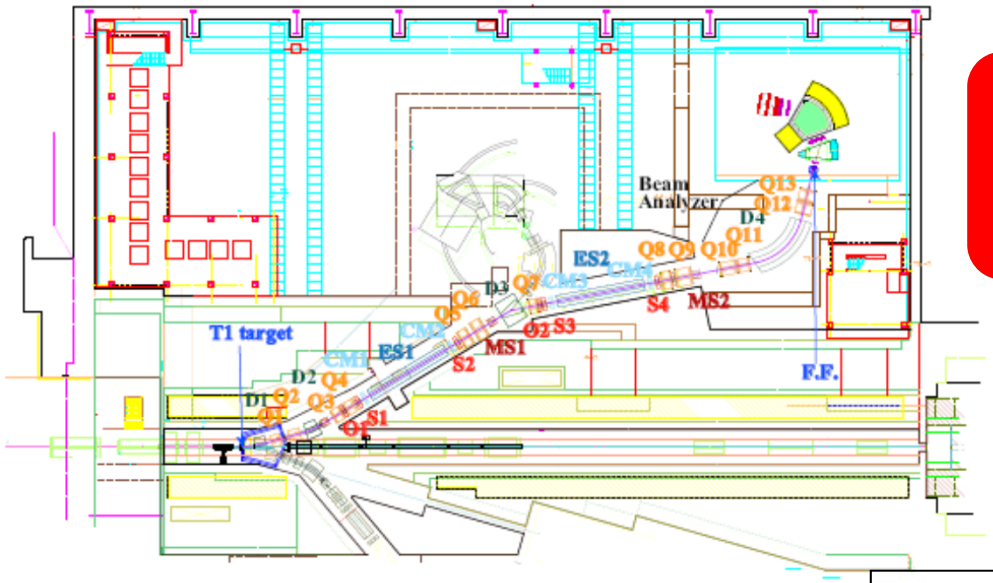


Physics output (S = -2)



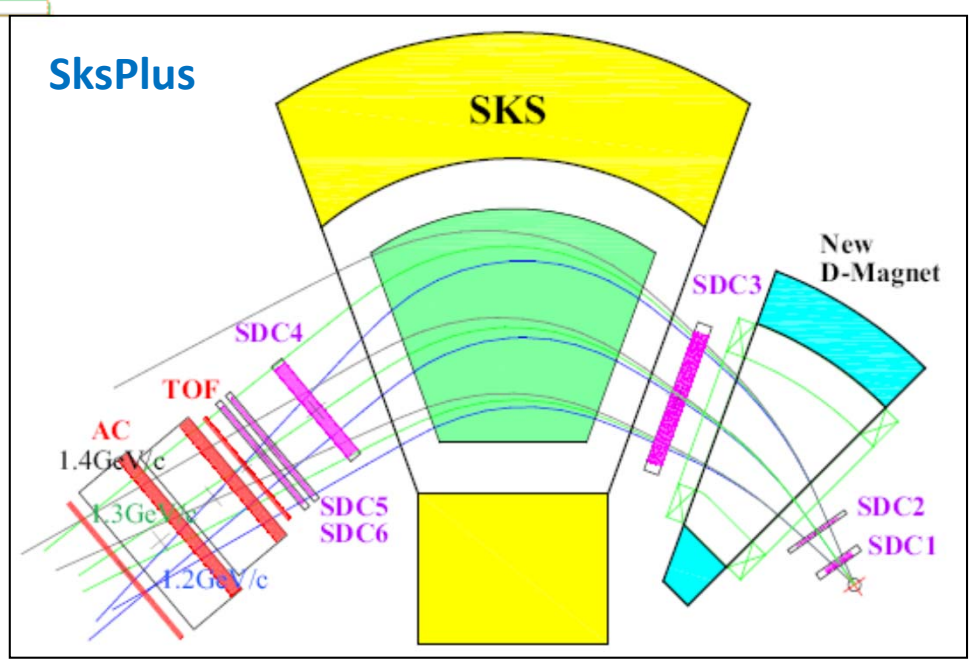
E05 experiment layout

AXiS with SKS+



Spectroscopic study of Ξ-hypernucleus, $^{12}Be_{\Xi}$, via the $^{12}C(K^-,K^+)$ reaction

- first spectroscopic study of S = -2 systems in (K^-,K^+) reaction
- ΞN interaction
  - ? attractive or repulsive
  - ? depth of Ξ-nuclear potential
  - ? isospin dependence
  - ? ΞN-ΛΛ *coupling force*



Summary

- Last but not least results from FINUDA:
  - first experimental evidence for the heavy hyperhydrogen $^{6}H_{\Lambda}$
  - first direct observation of $2\,\mathcal{N}$ induced hypernucleus weak decay

- FINUDA could be considered an ideal bridge between the KEK and the J-PARC eras:

we are now looking forward for new and exciting world class results

Thank you!

どうも　ありがとう