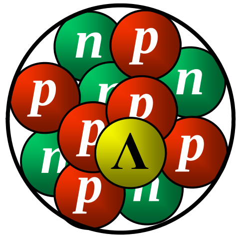
Latest results from FINUDA



Alessandro Feliciello

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

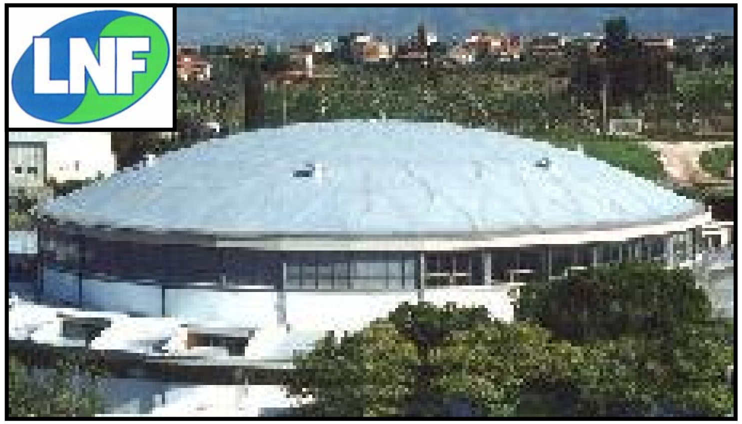
Outline

- introduction
- the experimental setup
  - the DAΦNE machine
  - the FINUDA experiment
- hypernuclear physics results:
  - search for neutron-rich hypernuclei
  - 2 $\mathcal{N}$ induced hypernucleus weak decay

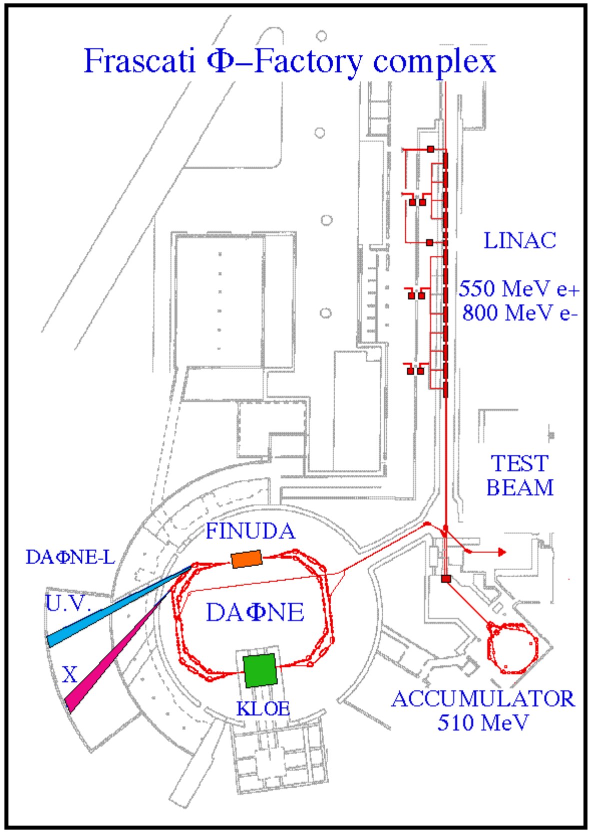
The DAΦNE machine

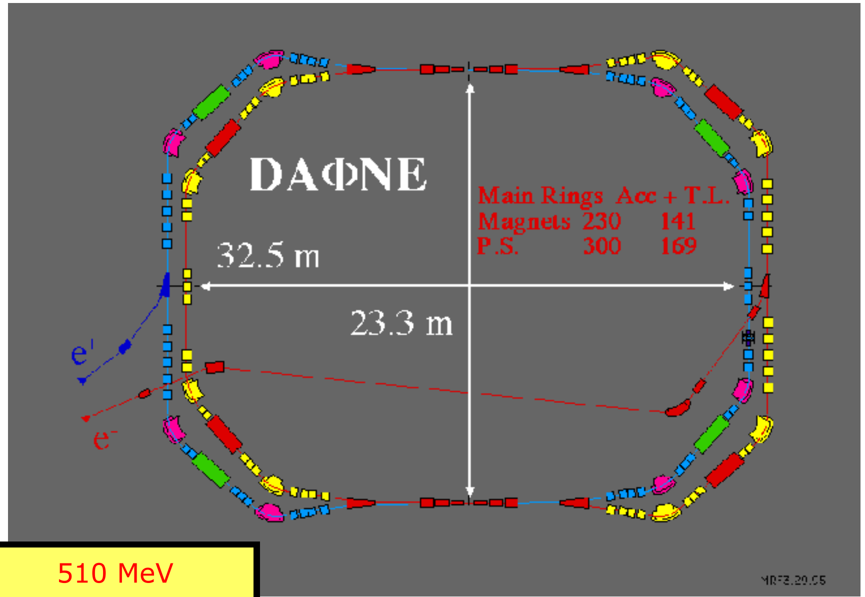
The DAΦNE Φ-factory

INFN
Istituto Nazionale di Fisica Nucleare

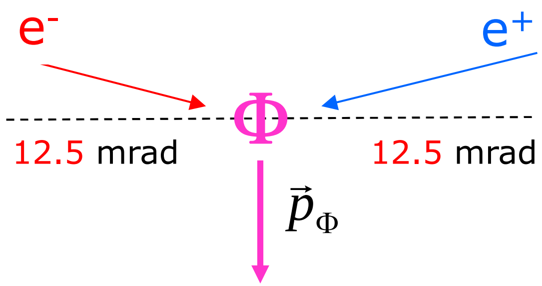


The DAΦNE e^+e^- collider





energy	510 MeV
luminosity	$\leq 5 \times 10^{32}$ 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)



What one can do with a Φ-factory?

source of (nearly) monochromatic, collinear, background free, tagged neutral and charged kaons

KLOE
CP, CPT violation
chiral dynamics
and more...

FINUDA
hypernuclear physics

$K_S K_L$
(34%)

$\rho\pi$
(13%)

$K^+ K^-$
(49%)

DEAR/SIDDHARTA
exotic atoms

Double
Annular
Φ-factory for
Nice
Experiments

The FINUDA way

$e^- + e^+ \rightarrow \phi$ σ = 3.26 μb $\mathscr{L} \approx 1 \times 10^{32}$ cm^{-2}s^{-1} ≈ 300 Hz

$K^- + K^+$ $T_{K^-} \approx 16.1$ MeV ≈ 150 Hz

a real unconventional experimental approach

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

$$\frac{\Delta T_\pi}{T_\pi} = \frac{\sqrt{p_\pi^2+m_\pi^2}+m_\pi}{\sqrt{p_\pi^2+m_\pi^2}} \cdot \frac{\Delta p_\pi}{p_\pi} \equiv f(p_\pi)\frac{\Delta p_\pi}{p_\pi}$$

coincidence measurement

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

The FINUDA apparatus

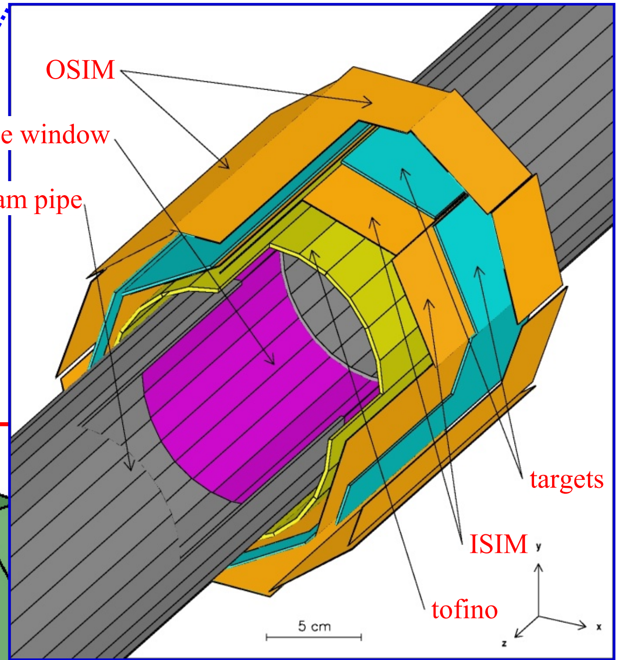
… nothing by chance

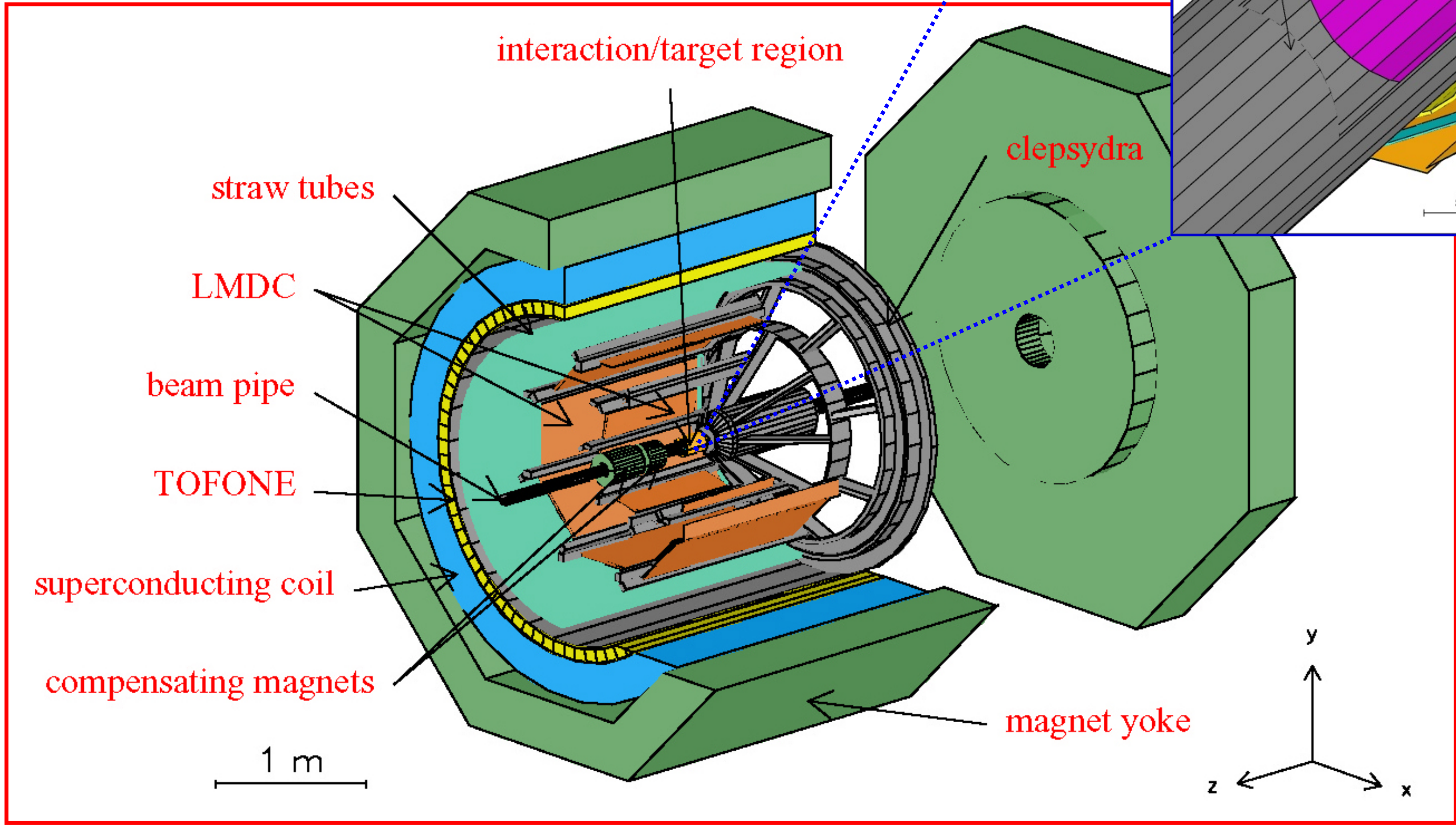
The FINUDA apparatus

- high resolution
- high acceptance

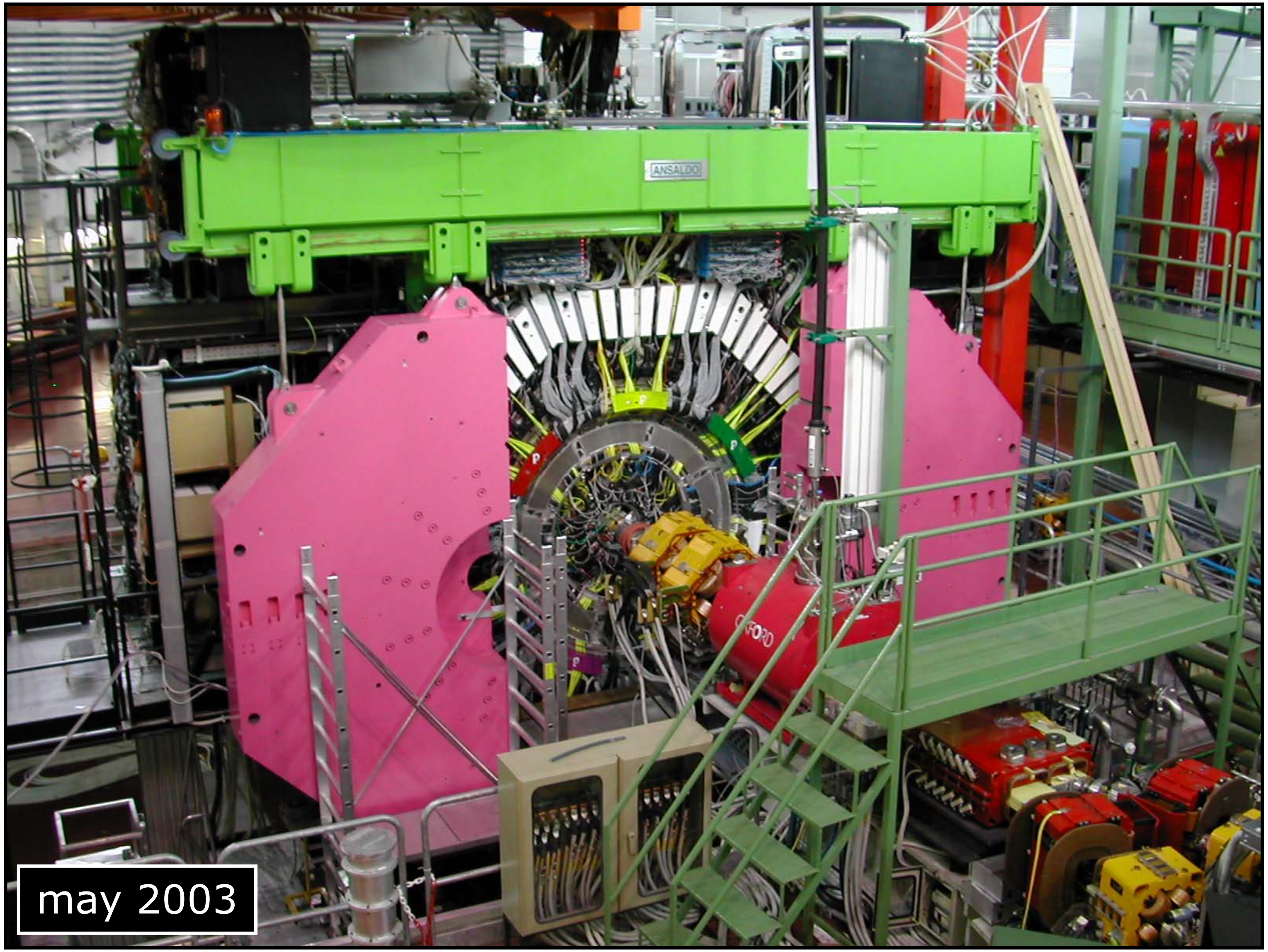
} magnetic spectrometer

- realistic (feasible)
- reasonable cost





Concept becomes reality

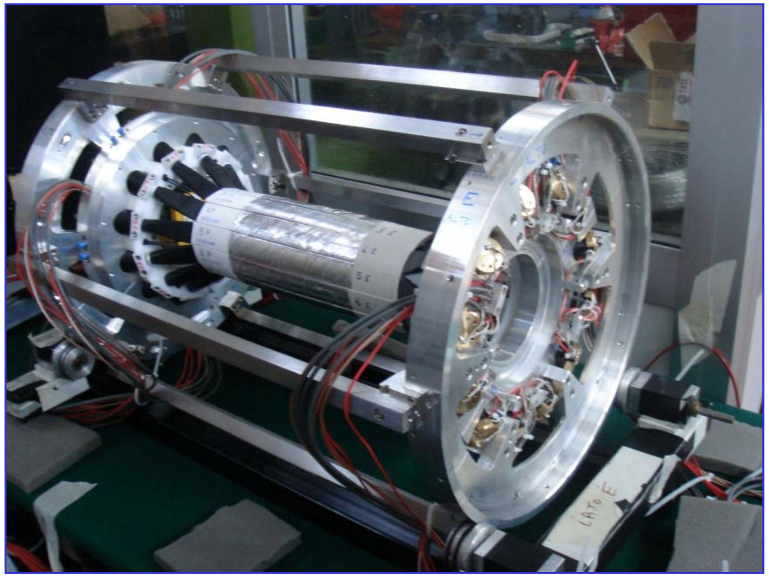


may 2003

FINUDA key features

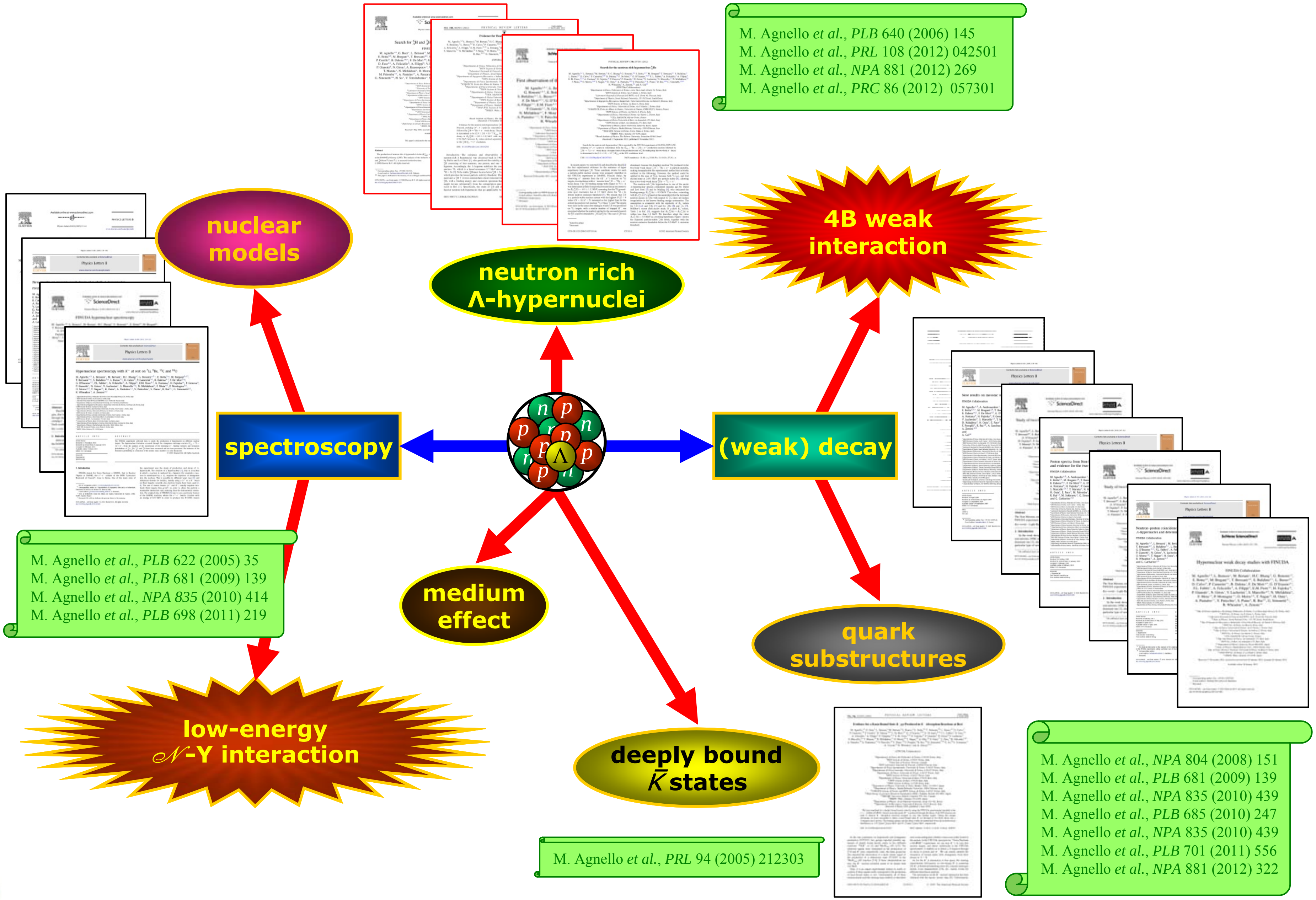
- very thin nuclear targets ($0.1 \div 0.3$ g/cm^2)
  - → high resolution spectroscopy
- coincidence measurement with large acceptance
  - → decay mode study
- event by event K^+ tagging
  - → continuous energy and rate calibration
- irradiation of different targets in the same run
  - → systematic error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

A paradigmatic example of collaboration



Search for neutron-rich hypernuclei

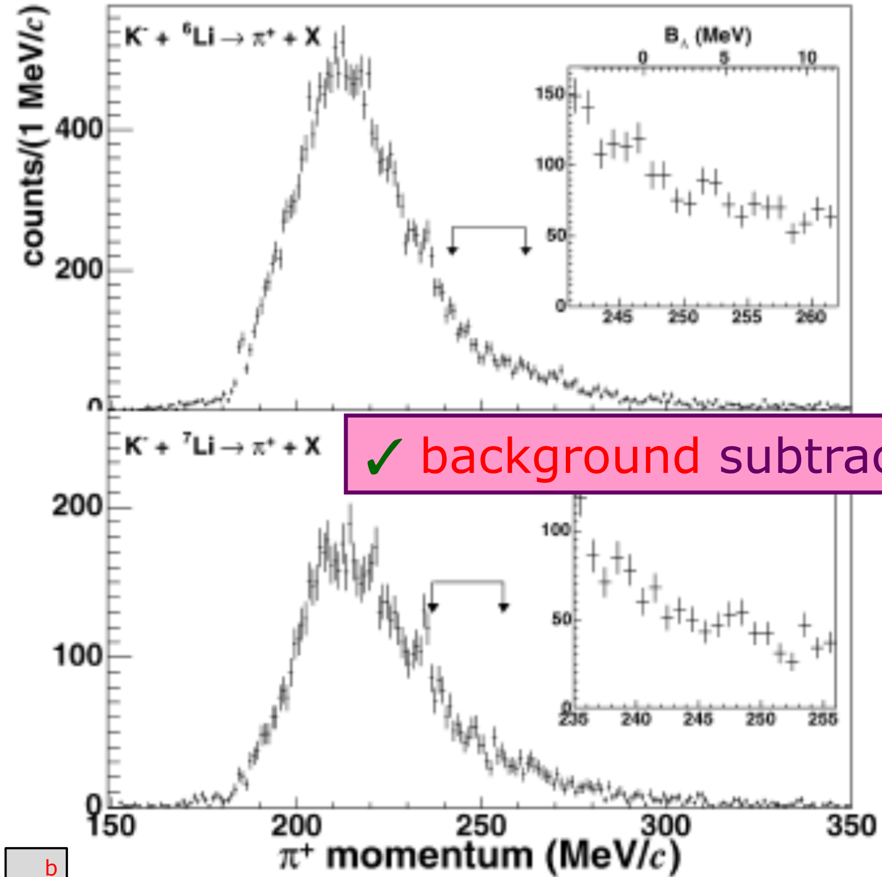
Physics output (S = -1)



The background issue

2003/2004 data

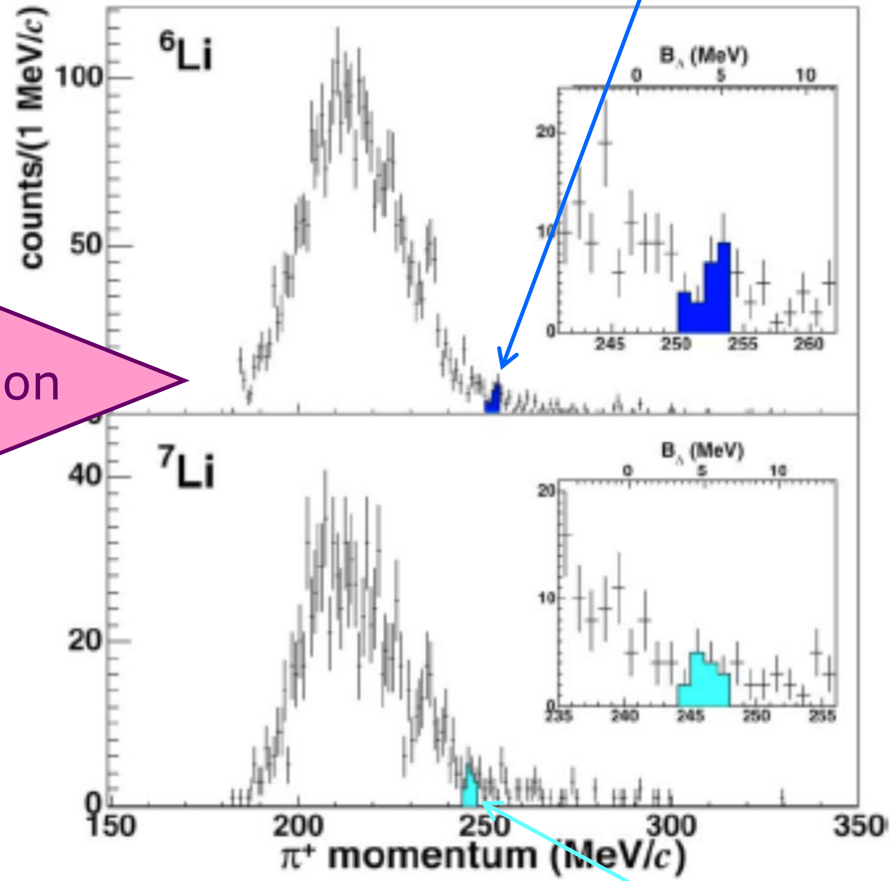
$$K^{-}_{stop} + {}^{A}Z \rightarrow {}^{A}_{\Lambda}(Z-2) + \pi^{+}$$



✓ background subtraction

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

$${}^{6}_{\Lambda}H({}^{6}Li): u.l. = (2.5 \pm 1.4)\cdot 10^{-5} / K^{-}_{stop}\ @\ 90\%\ c.l.$$



$$K^{-}_{stop} + {}^{7}Li \rightarrow {}^{7}_{\Lambda}H + \pi^{+}$$

main background

$$K^{-} + p \rightarrow \Sigma^{+} + \pi^{-}$$
$$\hookrightarrow n + \pi^{+} \quad (\sim 130 < p_{\pi^{+}} < \sim 250\ \mathrm{MeV}/c)$$
$$K^{-} + pp \rightarrow \Sigma^{+} + n$$
$$\hookrightarrow n + \pi^{+} \quad (\sim 100 < p_{\pi^{+}} < \sim 320\ \mathrm{MeV}/c)$$

$\mathscr{L}_{int} \approx 220\ pb^{-1}$

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

The status of the art

$$K^-_{stop} + {}^AZ \rightarrow {}^A_\Lambda(Z-2) + \pi^+$$

- $K^- + p \rightarrow \pi^0 + \Lambda$, $\pi^0 + p \rightarrow \pi^+ + n$: 2-step (S-EX + C-EX)
- $K^- + p \rightarrow \bar{K}^0 + n$, $\bar{K}^0 + p \rightarrow \Lambda + \pi^+$: 2-step (C-EX + S-EX)
- $K^- + p \rightarrow \pi^+ + \Sigma^-$, $\Sigma^- + p \rightarrow \Lambda + n$: 1-step (S-EX)

experimental results

KEK

- ${}^9_\Lambda He({}^9Be): u.l. = 2.3 \cdot 10^{-4} / K^-_{stop}$
- ${}^{12}_\Lambda Be({}^{12}C): u.l. = 6.1 \cdot 10^{-5} / K^-_{stop}$
- ${}^{16}_\Lambda C({}^{16}O): u.l. = 6.2 \cdot 10^{-5} / K^-_{stop}$

K. Kubota *et al.*, *NPA* 602 (1996) 327

INFN-LNF

- ${}^6_\Lambda H({}^6Li): u.l. = (2.5 \pm 1.4) \cdot 10^{-5} / K^-_{stop}$
- ${}^7_\Lambda H({}^7Li): u.l. = (4.5 \pm 1.4) \cdot 10^{-5} / K^-_{stop}$
- ${}^{12}_\Lambda Be({}^{12}C): u.l. = (2.0 \pm 0.4) \cdot 10^{-5} / K^-_{stop}$

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

theoretical predictions

$10^{-6} \div 10^{-7} / K^-_{stop}$

T.Y. Tretyakova *et al.*, *NPA* 691 (2001) 51c

$$\pi^- + {}^AZ \rightarrow {}^A_\Lambda(Z-2) + K^+$$

- $\pi^- + p \rightarrow \pi^0 + n$, $\pi^0 + p \rightarrow K^+ + \Lambda$: 2-step (C-EX + AP)
- $\pi^- + p \rightarrow K^0 + \Lambda$, $K^0 + p \rightarrow K^+ + n$: 2-step (AP + C-EX)
- $\pi^- + p \rightarrow K^+ + \Sigma^-$, $\Sigma^- + p \rightarrow \Lambda + n$: 1-step (AP)

experimental results

KEK

${}^{10}_\Lambda Li({}^{10}B): d\sigma / d\Omega = 11.3 \pm 1.9 \;\; nb/sr$

P.K. Saha *et al.*, *PRL* 94 (2005) 052502

theoretical predictions

T.Y. Tretyakova *et al.*, *PAT* 66 (2003) 1681

The new NRH search strategy

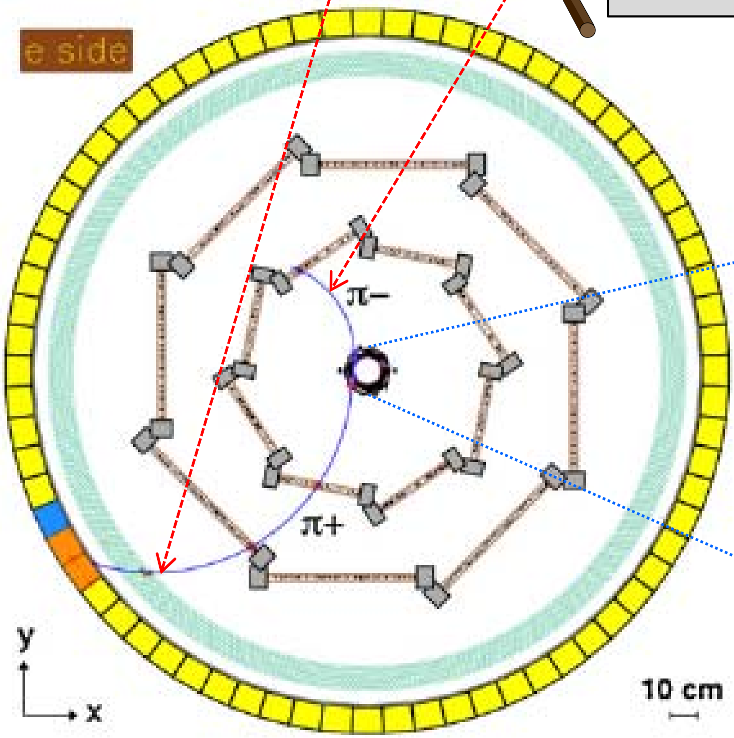
$\Delta\mathcal{L}_{int} \approx 960\ pb^{-1}$ → coincidence measurements

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

double C-EX
p ~ 252 MeV/c

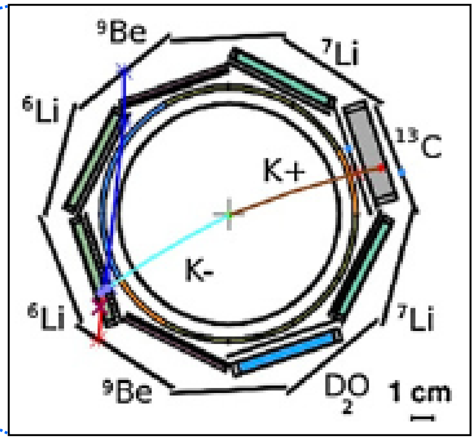
$${}^6_\Lambda H \to {}^6He + \pi^-$$

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)



2006/2007
data

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

$$\begin{cases} M(K^-) + 3M(p) + 3M(n) - B({}^6\text{Li}) = M({}^6_\Lambda\text{H}) + T({}^6_\Lambda\text{H}) + M(\pi^+) + T(\pi^+) \\ M({}^6_\Lambda\text{H}) = 2M(p) + 4M(n) - B({}^6\text{He}) + T({}^6\text{He}) + M(\pi^-) + T(\pi^-) \end{cases}$$

atomic mass tables

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

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

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

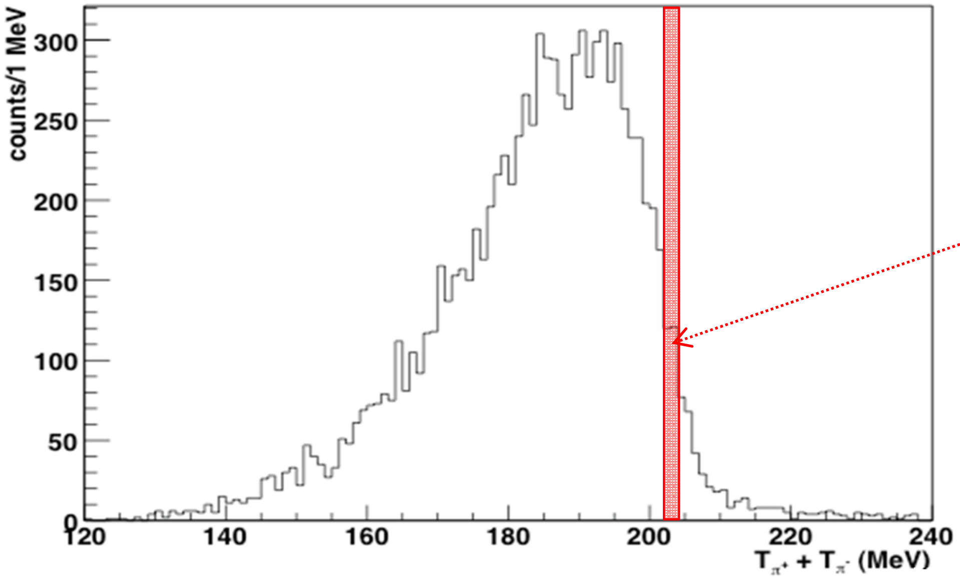
$$T(\pi^+) + T(\pi^-) = M(K^-) + M(p) - M(n) - 2M(\pi) - B({}^6\text{Li}) + B({}^6\text{He}) - T({}^6\text{He}) - T({}^6_\Lambda\text{H})$$

$$= 203.0 \pm 1.3\ \text{MeV}$$

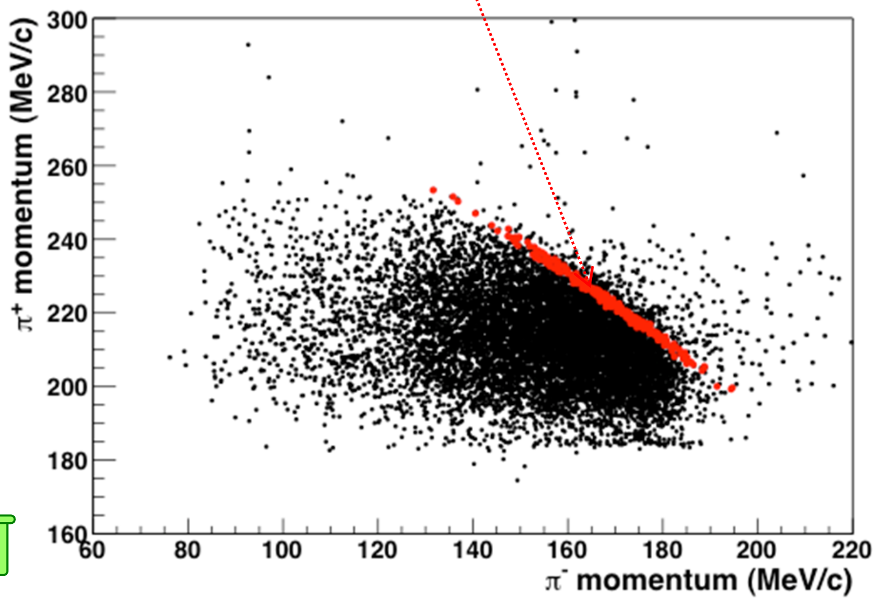
$$(203.5 \div 203.3\ \text{MeV with } B_\Lambda = 0 \div 6\ \text{MeV})$$

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

Data selection



$T(\pi^+) + T(\pi^-)$: 202 ÷ 204 MeV



absolute energy scale:

- μ^+ (235.6 MeV/c) from $K_{\mu 2}$
  Δ_p < 0.12 MeV/c
- π^-(132.8 MeV/c) from $^4H_\Lambda$
  Δ_p < 0.2 MeV/c

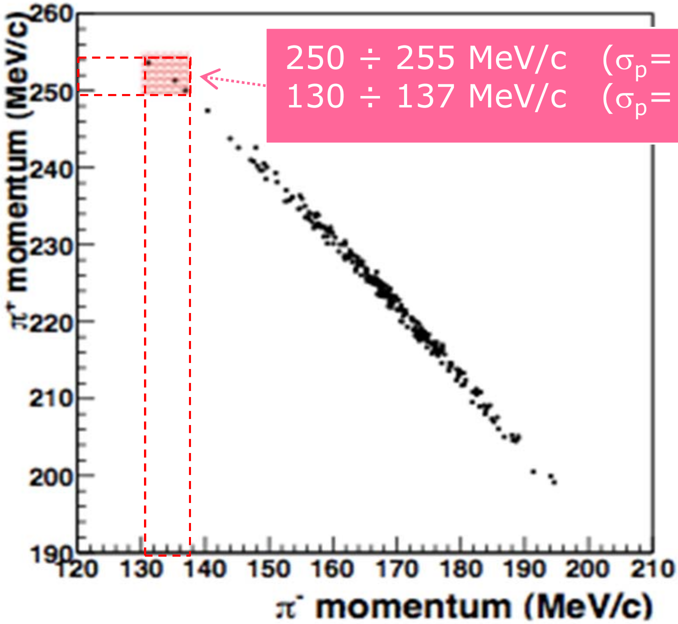
systematic errors

σT_{sys} = 0.17 MeV

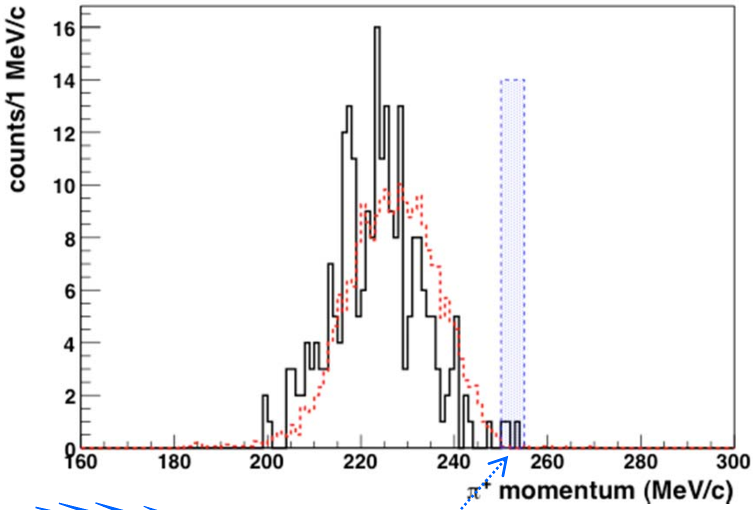
- $\sigma T(\pi^+)$ = 0.96 MeV, $\sigma T(\pi^-)$ = 0.84 MeV
- σT_{exp} = 1.3 MeV
- σT = 1.3 MeV

FINUDA Coll. And A. Gal, *NPA* 881 (2012) 269

Data selection

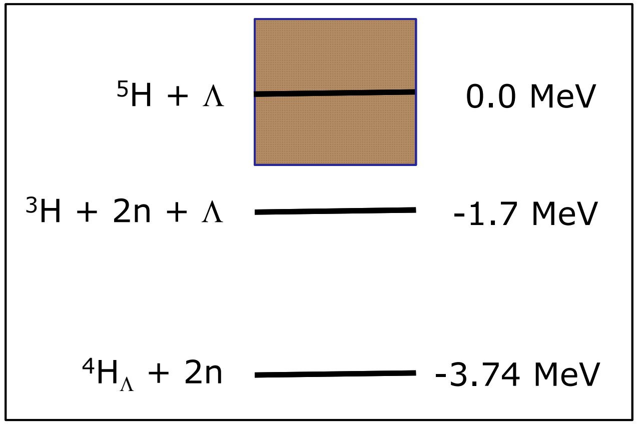


250 ÷ 255 MeV/c (σ_p=1.1 MeV/c)
130 ÷ 137 MeV/c (σ_p=1.2 MeV/c)



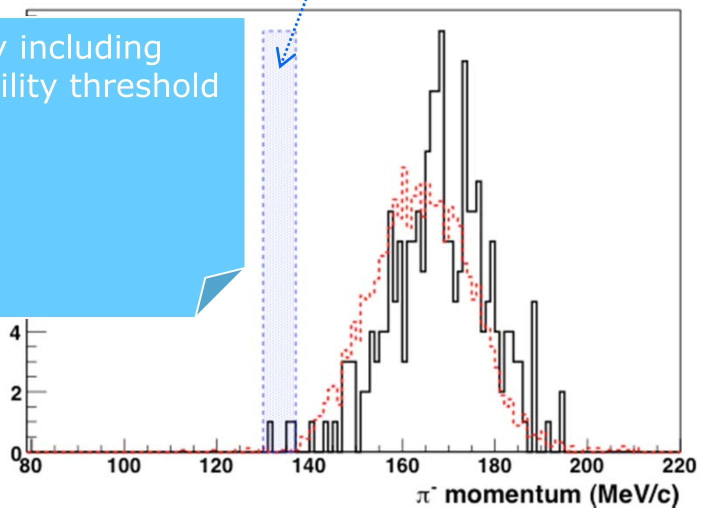
3 candidate events

(out of 2.7 10^7 stopped K^- event)

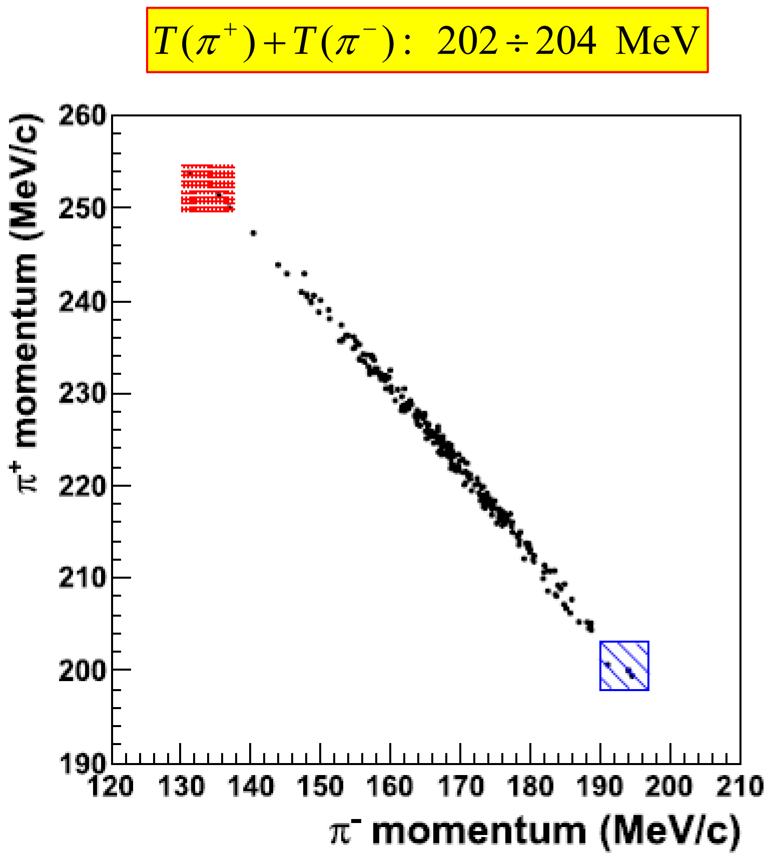


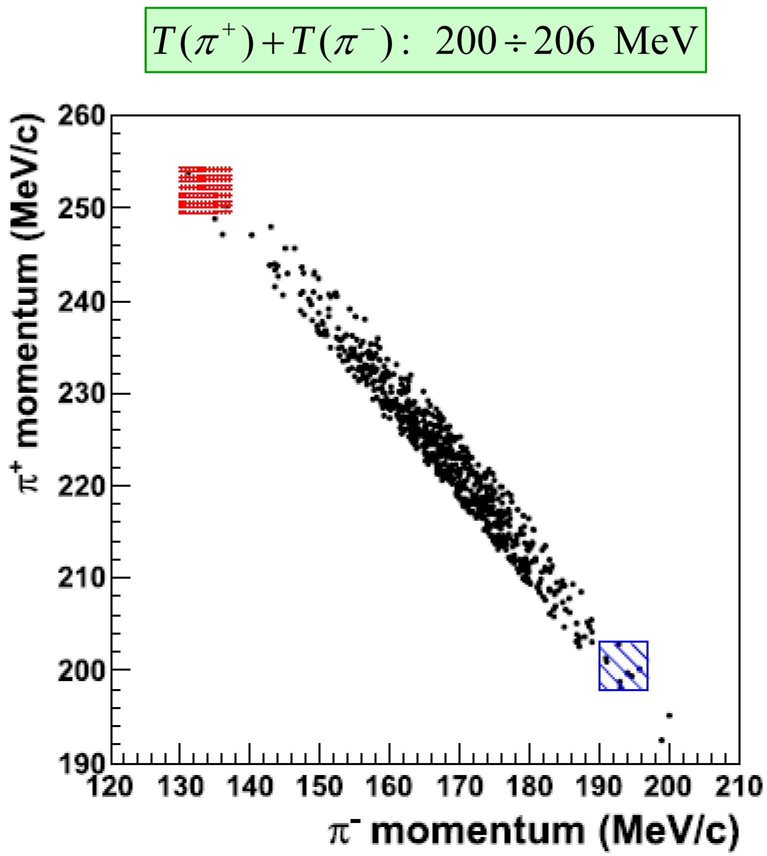
selection range fixed by including
^{6}H$_\Lambda$ lowest particle stability threshold
$p_{\pi+}$ = 251.9 MeV/c
$p_{\pi-}$ = 135.6 MeV/c

B_Λ = 1.5 ÷ 6 MeV



$T(\pi^+) + T(\pi^-)$ cut: systematics





$^{6}H_{\Lambda}$ 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

$$R = (5.9 \pm 4.0)\ 10^{-6} / K^-_{stop}$$

$$(2.5 \pm 0.5^{+0.4}_{-0.1}) \cdot 10^{-5} / K^-_{stop}$$

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_{π^+} (MeV/c)	p_{π^-} (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

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

formation mass values systematically higher than the ones from decay

(0.98 ± 0.74) MeV

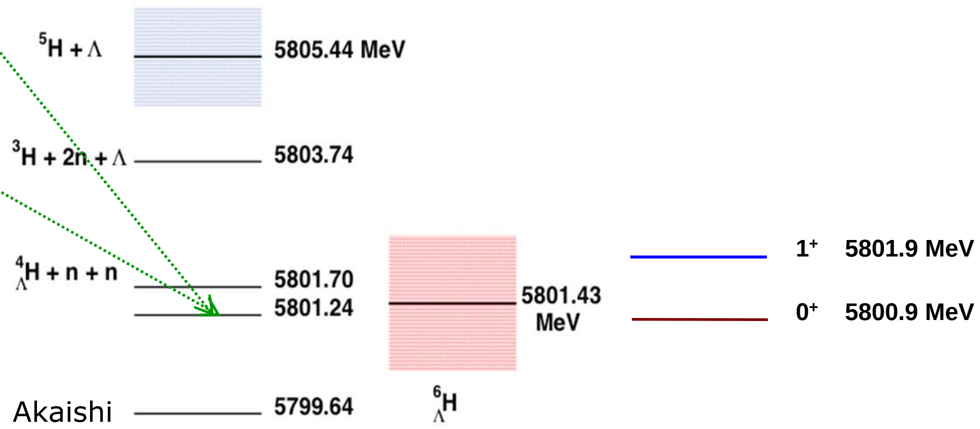
excited states production

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

B					
${}^4_\Lambda$He 2.39 Λ	${}^5_\Lambda$He 3.12 Λ	${}^6_\Lambda$He 4.18 n 0.17 xxx	${}^7_\Lambda$He 5.23 n 2.92 halo	${}^8_\Lambda$He 7.16 n 1.49 xxx	${}^9_\Lambda$He (8.5) n 3.9 halo
${}^3_\Lambda$H 0.13 Λ	${}^4_\Lambda$H 2.04 Λ	${}^5_\Lambda$H (3.1) n -1.8 xxx	${}^6_\Lambda$H (4.2) 2n -5 xxx	${}^7_\Lambda$H (5.2) 3n 0.4 xxx	

$\bar{M}$ = (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

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

Analysis technique

double C-EX
p ~ 257 MeV/c

n.m. decay
p ~ 117 MeV/c

$$K^-_{stop} + {}^9Be \rightarrow {}^9_\Lambda He + \pi^+$$

$$^9_\Lambda He \rightarrow {}^9Li + \pi^-$$

$(\tau({}^6Li) \approx 178 \text{ ms})$

if $^9He_\Lambda$ is a stable system ⇒ 2 independent two-body reactions:

decay at rest

$$\begin{cases} M(K^-) + 4M(p) + 5M(n) - B({}^9\mathrm{Be}) = M({}^9_\Lambda\mathrm{He}) + T({}^9_\Lambda\mathrm{He}) + M(\pi^+) + T(\pi^+) \\ M({}^9_\Lambda\mathrm{He}) = 3M(p) + 6M(n) - B({}^9\mathrm{Li}) + T({}^9\mathrm{Li}) + M(\pi^-) + T(\pi^-) \end{cases}$$

atomic mass tables

$$\sqrt{M^2({}^9Li) + p^2(\pi^-)} - M({}^9Li)$$

$$\sqrt{M^2({}^9_\Lambda He) + p^2(\pi^+)} - M({}^9_\Lambda He)$$

$$M({}^9_\Lambda He) = M({}^8He) + M(\Lambda) - B(\Lambda)$$

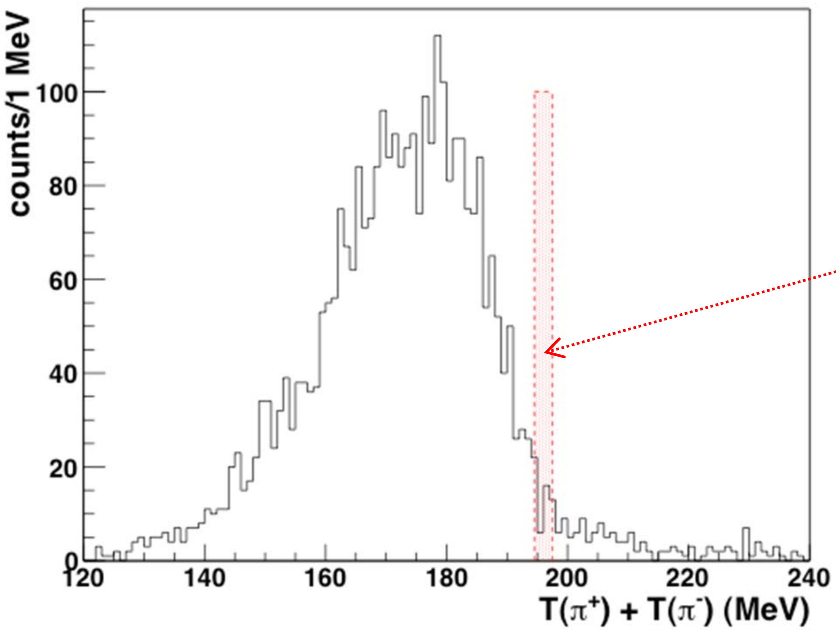
$$T(\pi^+) + T(\pi^-) = M(K^-) + M(p) - M(n) - 2M(\pi) - B({}^9\mathrm{Be}) + B({}^9\mathrm{Li}) - T({}^9\mathrm{Li}) - T({}^9_\Lambda\mathrm{He})$$

$$= 195.8 \pm 1.3 \text{ MeV}$$

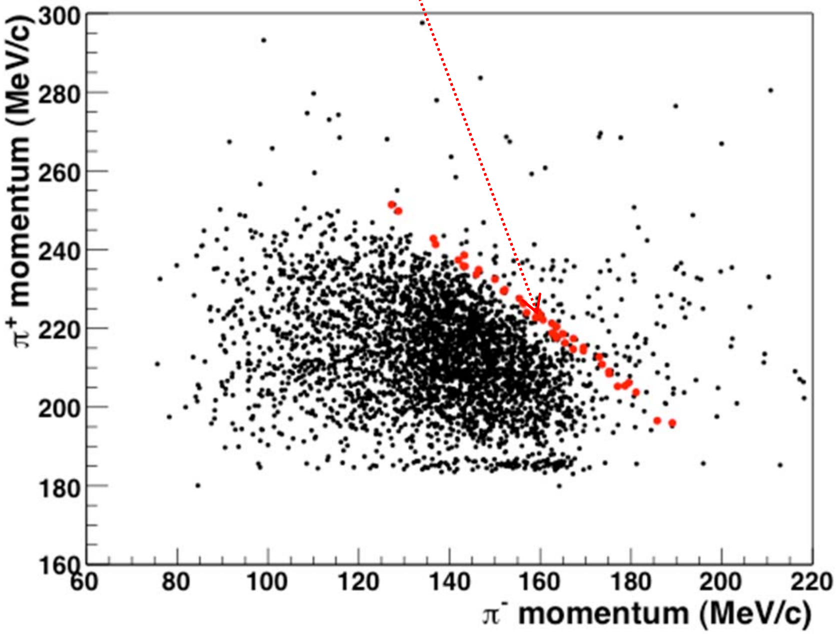
$(195.8 \div 195.7 \text{ MeV with } B_\Lambda = 0 \div 10 \text{ MeV})$

cut on $T(\pi^+) + T(\pi^-)$: $194.5 \div 197.5$ MeV

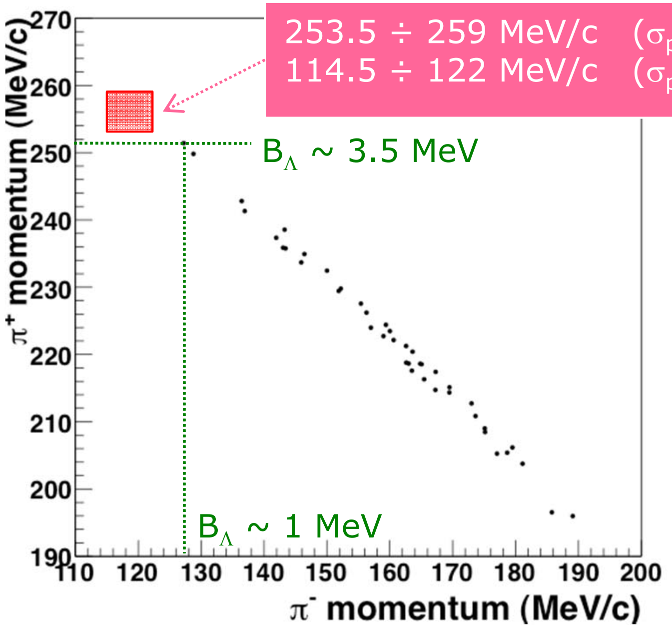
Data selection

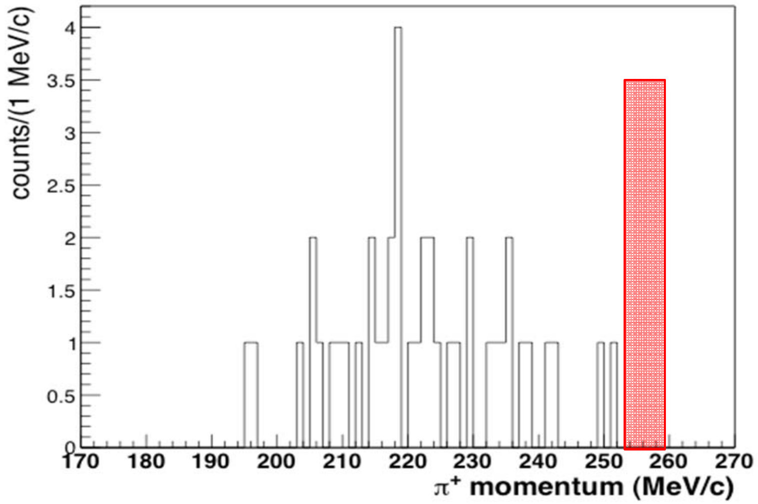


$T(\pi^+) + T(\pi^-)$: 194.5 ÷ 197.5 MeV

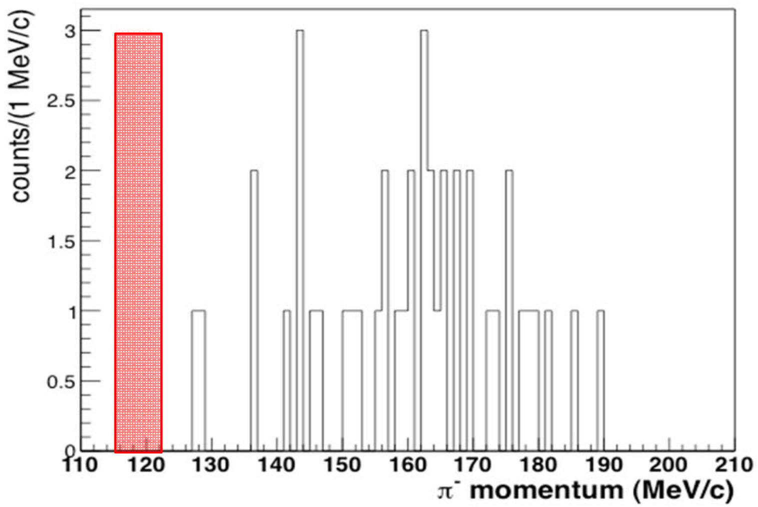


Data selection





B_Λ = 5 ÷ 10 MeV



$^9He_\Lambda$ production rate

- 0 observed events → upper limit evaluation
- ε(π⁻), ε(π⁺)
- n. stopped K^- on ^{9}Be = 2.5 × 10⁷ ev.

$$R * BR(\pi^-) < (2.3 \pm 1.9) \times 10^{-6} / (n.\ K^-_{stop}\ \text{on}\ ^9Be)\ (90\%\ \text{C.L.})$$

$$BR(\pi^-) = 0.323 \pm 0.062^{+0.025}_{-0.020}$$

$$\Gamma(^9_\Lambda He_{g.s.} \rightarrow {}^9Li_{g.s.} + \pi^-) = 0.261\ \Gamma_\Lambda$$

$^5_\Lambda He + 4$ spectator *neutrons*

M. Agnello *et al.*, *PLB* 681 (2009) 139

A. Gal, *NPA* 828 (2009) 72

$$R = 1.3 \cdot 10^{-5} / K^-_{stop}\ \ (90\%\ C.L.)$$

$$R = 1.6 \cdot 10^{-5} / K^-_{stop}\ \ (90\%\ C.L.)$$

M. Agnello *et al.*, *PRC* 86 (2012) 057301

KEK

$$2.3 \cdot 10^{-4} / K^-_{stop}$$

K. Kubota *et al.*, *NPA* 602 (1996) 327

2-nucleon induced weak decay

Physics output (S = -1)

spectroscopy

nuclear models

low-energy $\mathcal{N}$-Y interaction

M. Agnello *et al.*, *PLB* 622 (2005) 35
M. Agnello *et al.*, *PLB* 681 (2009) 139
M. Agnello *et al.*, *NPA 835* (2010) 414
M. Agnello *et al.*, *PLB* 698 (2011) 219

neutron rich Λ-hypernuclei

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

medium effect

deeply bound $\bar{K}$ states

M. Agnello *et al.*, *PRL* 94 (2005) 212303

(weak) decay

4B weak interaction

quark substructures

M. Agnello *et al.*, *NPA* 804 (2008) 151
M. Agnello *et al.*, *PLB* 681 (2009) 139
M. Agnello *et al.*, *NPA* 835 (2010) 439
M. Agnello *et al.*, *PLB* 685 (2010) 247
M. Agnello *et al.*, *NPA* 835 (2010) 439
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]		$0.21 \pm 0.07_{\mathrm{stat}}\,{}^{+0.03\,\mathrm{sys}}_{-0.02\,\mathrm{sys}}$	$A = 5$–16, np spectra

consistent within large errors

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

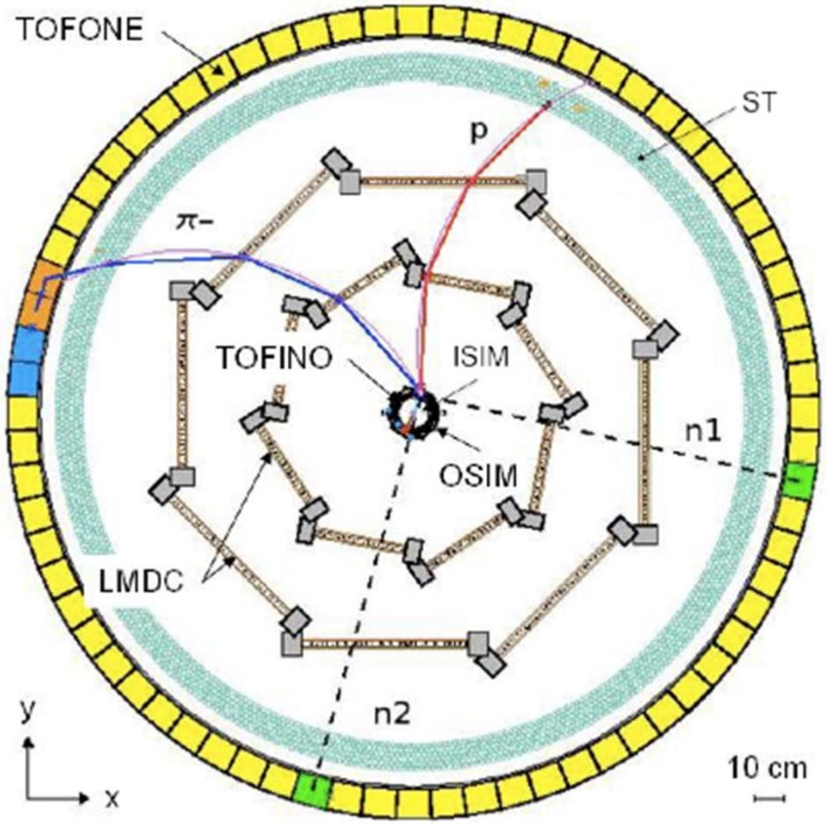
☛ "smoking gun" evidence missing!

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



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

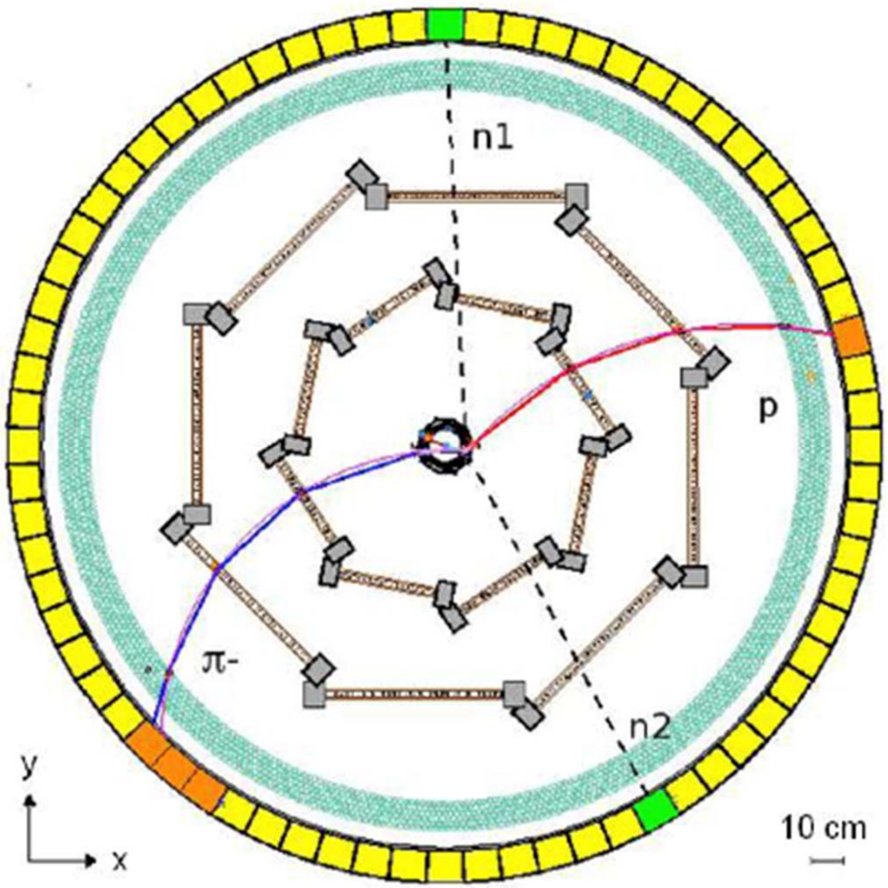
first, direct experimental evidence

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

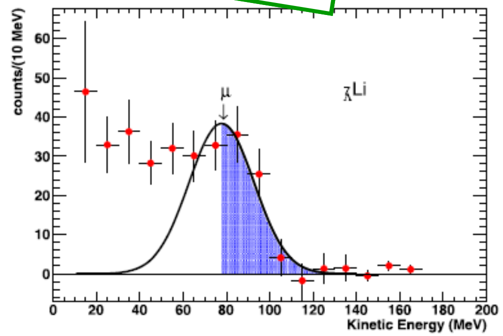
2$\mathscr{N}$ induced decay exp. evidence

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



$p_{\pi-}$ = 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°

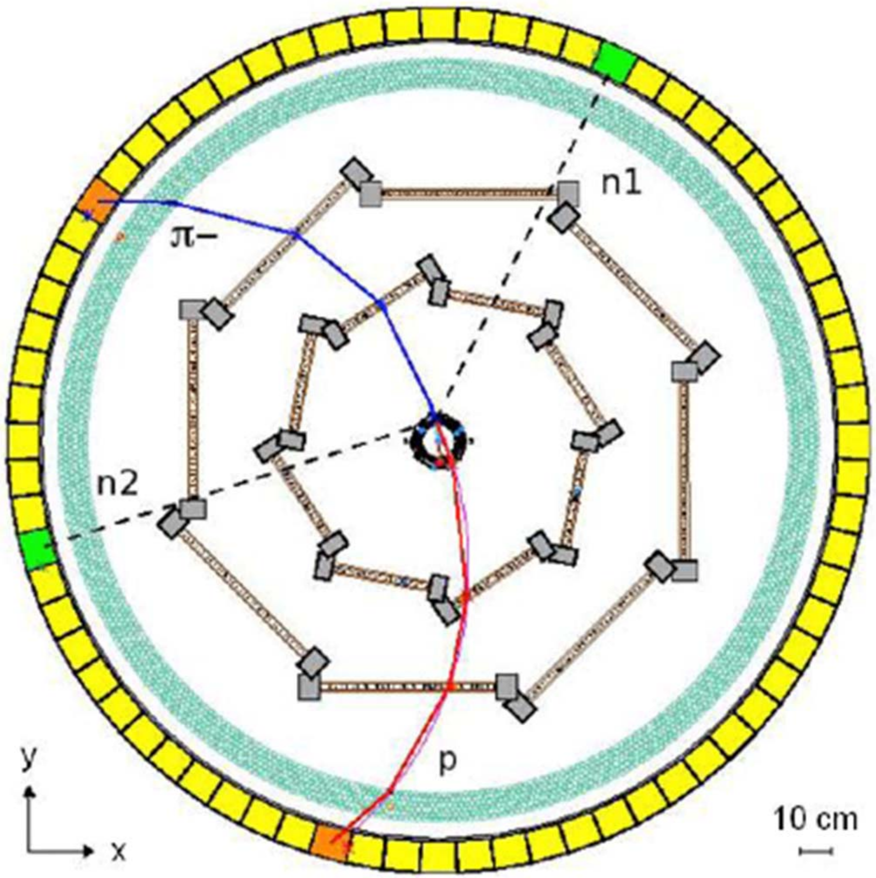
no n-n or p/n scattering

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



$p_{\pi-}$ = 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°

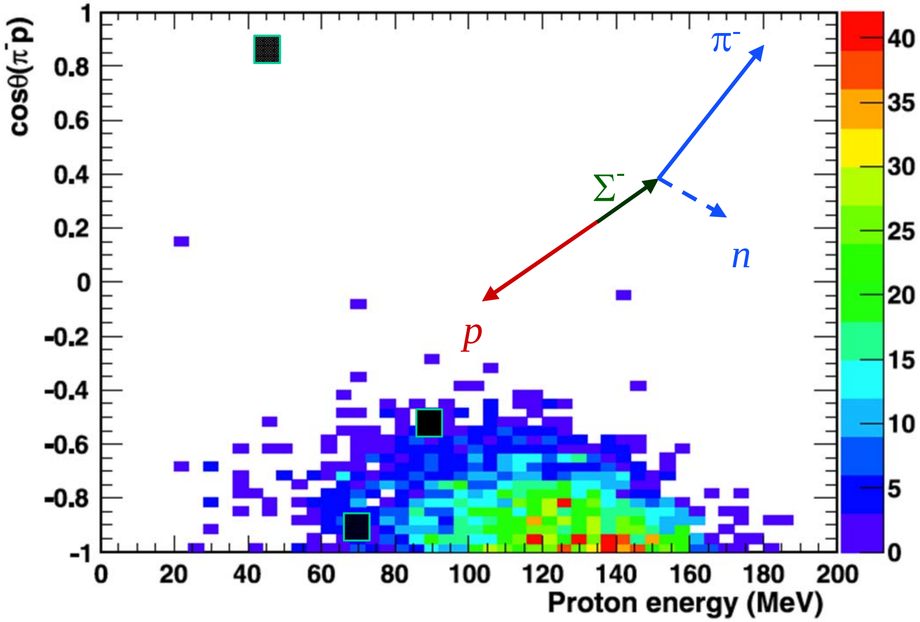
no n-n or p/n scattering

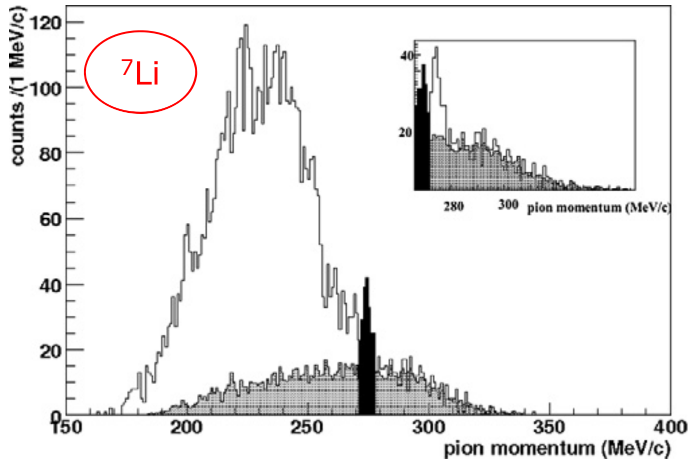
$^{9}_{\Lambda}$Be	MM (MeV/c^2)
^{6}Li	5601.5
^{5}Li + n	5607.2
^{4}He + d	5603.0
^{3}He + ^{3}H	5617.3

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%.

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