Production of neutron-rich Hypernuclei at DaΦne2

Status

and

Perspectives

Vincenzo Paticchio (I.N.F.N. Bari) – Finuda collaboration

Physics motivations

- Search for the existence of neutron-rich hypernuclei

Physics motivations

- Search for the existence of neutron-rich hypernuclei

Theoreticians:

L.Majiling,Nucl.Phys.A 585(1995),211c

T.U. Tretyakova and D.E.Lanskoy, Eur.Phys.J. A5(1999) 391; Nucl.Phys.A 691(2001),51c

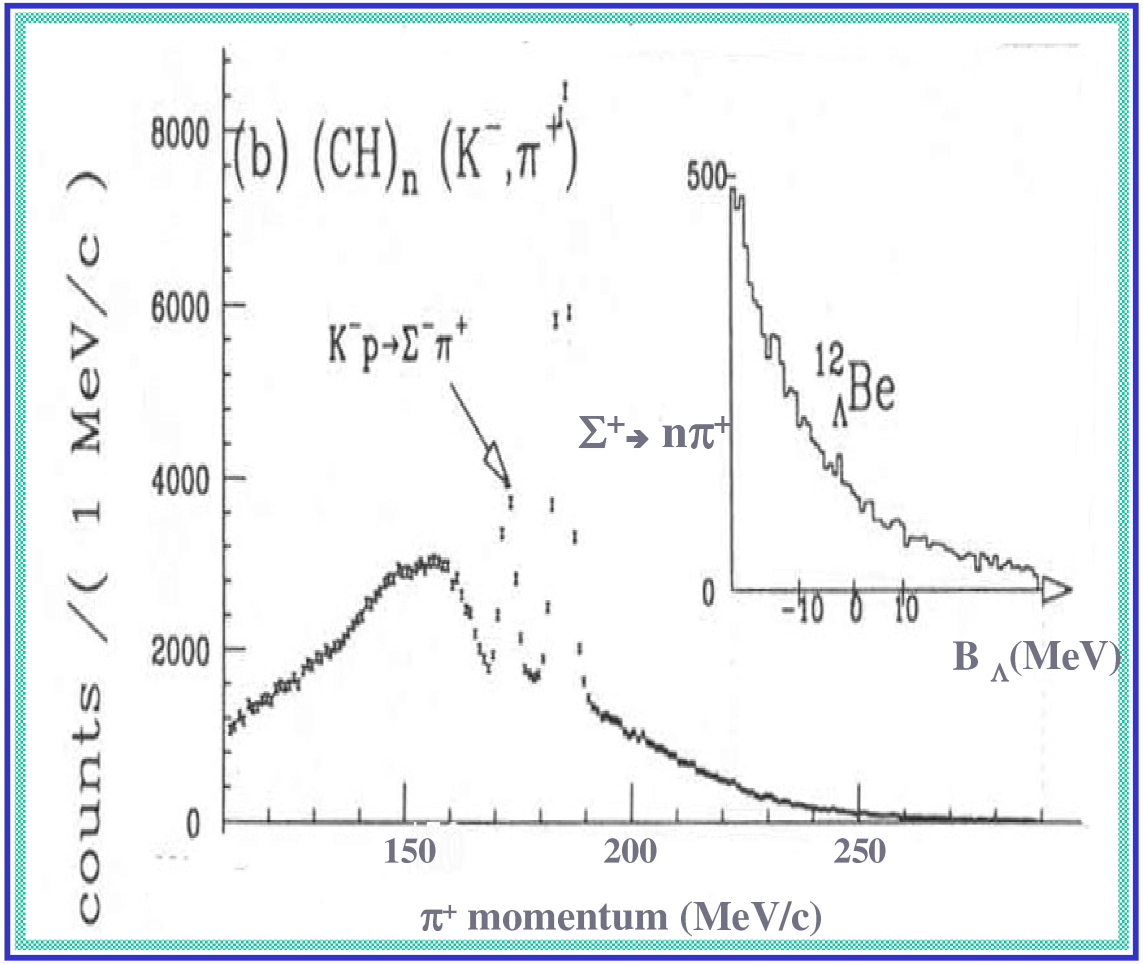
Y.Akaishi et al., Phys.Rev.Lett. 84(2000) 14

Experimentalists:

K.Kubota et al.,Phys.Rev.C53,(1996)2075 *

P.K. Saha,T.Fukuda and H.Noumi, LoI at the 50 GeV Proton Synchrotron; KEK-PS-E521

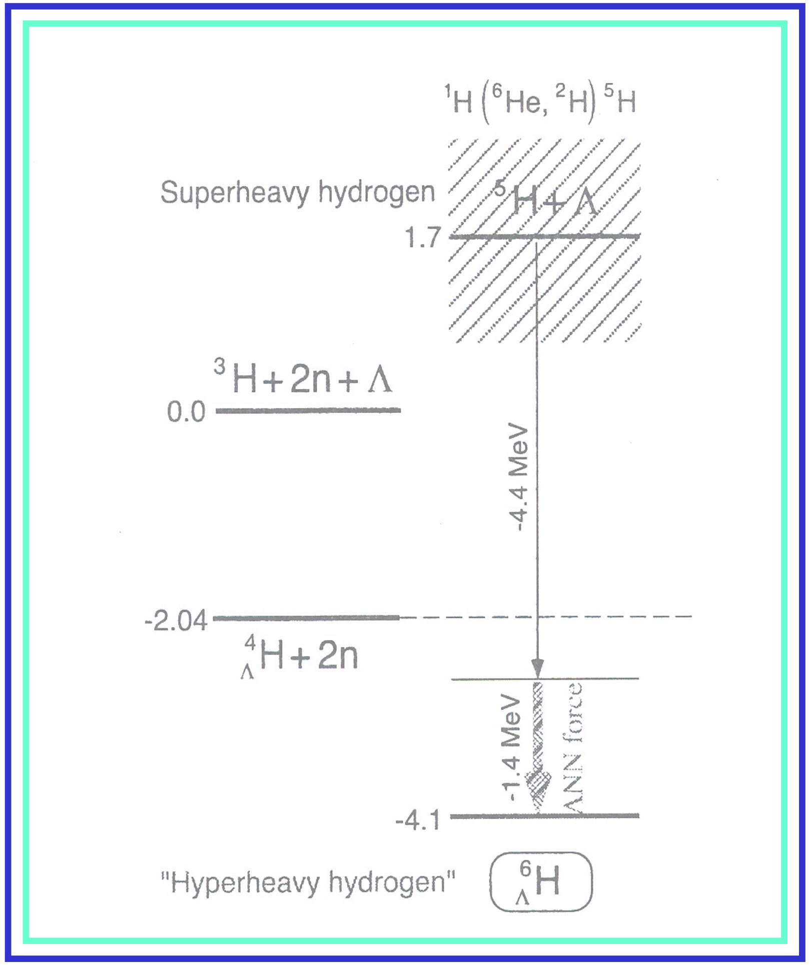
Physics motivations



Physics motivations

- Search for the existence of neutron-rich hypernuclei
- Exotic nuclear matter, with extreme N/Z ratio (${}^{7}_{\Lambda}H$, ${}^{6}_{\Lambda}H$, ${}^{12}_{\Lambda}Be$) *

Physics motivations



Y.Akaishi et al. Frascati Physics series,Vol. XVI

Physics motivations

- Search for the existence of neutron-rich hypernuclei
- Exotic nuclear matter, with extreme N/Z ratio ($^{7}_{\Lambda}H$, $^{6}_{\Lambda}H$, $^{12}_{\Lambda}Be$)
- Study of larger radial mass distributions than in ordinary nuclei with the glue-like role of the Λ *

Physics motivations

- T. Bressani:

  Hypernuclei: Perspectives of hypernuclear physics in this decade

  in "Proceedings of the International School of Physics *Enrico Fermi*", Course CLIII - 2003, p. 323-344

  IOS Press Amsterdam

Physics motivations

- Search for the existence of neutron-rich hypernuclei
- Exotic nuclear matter, with extreme N/Z ratio ($^{7}_{\Lambda}H$, $^{6}_{\Lambda}H$, $^{12}_{\Lambda}Be$)
- Study of larger radial mass distributions than in ordinary nuclei with the glue-like role of the Λ
- Study of the effect of Λ hyperon on neutron-halo

The three-body model of ${}^{6}_{\Lambda}$He

^{5}He ***unbound***

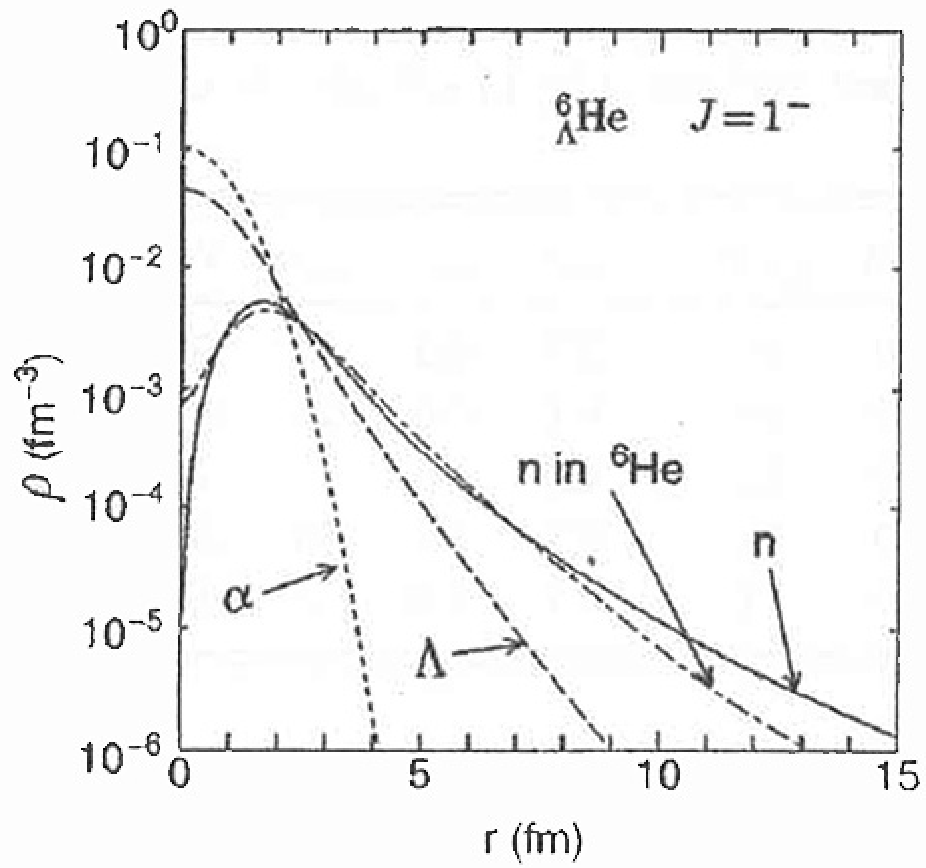
(0.89 MeV above α+n)

${}^{6}_{\Lambda}$He ***bound***

(0.17 MeV below ${}^{5}_{\Lambda}$He+n)

Three-body model:

α(core) + Λ (skin) + n (halo)



From E.Hiyama et al., *PRC 53 (1996), 2075*

Physics motivations

- Search for the existence of neutron-rich hypernuclei
- Exotic nuclear matter, with extreme N/Z ratio ($^{7}_{\Lambda}H$, $^{6}_{\Lambda}H$, $^{12}_{\Lambda}Be$)
- Study of mass distributions more extended than ordinary nucleus
- Study of the effect of Λ hyperon on neutron-halo
- Interest of astrophysics to explain various phenomena of high density matter in neutron-star

Physics motivations

Interest of astrophysics to explain various phenomena of high density matter in neutron-star:

- **S.Balberg and A.Gal, Nucl.Phys.A625(1997)435**
- **M.Prakash and J.M.Lattimer, Nucl.Phys.A639(1998)433c**
- **Y.Yamamoto,S.Nishizaki and T.Taktsuka, Nucl.Phys.A691(2001)432c**

Production mechanisms of neutron-rich hypernuclei

- The two main processes leading to the production of neutron-rich hypernuclei are the following ones:

1) The double charge exchange mechanism

$$\mathbf{K^-_{stop} + p \rightarrow \Lambda + \pi^0} \qquad \mathbf{\pi^0 + p \rightarrow \pi^+ + n}$$

$$p_{\Lambda} = 250 \text{ MeV/c} \; ; \quad p_{n} = 4 \div 400 \text{ MeV/c}$$

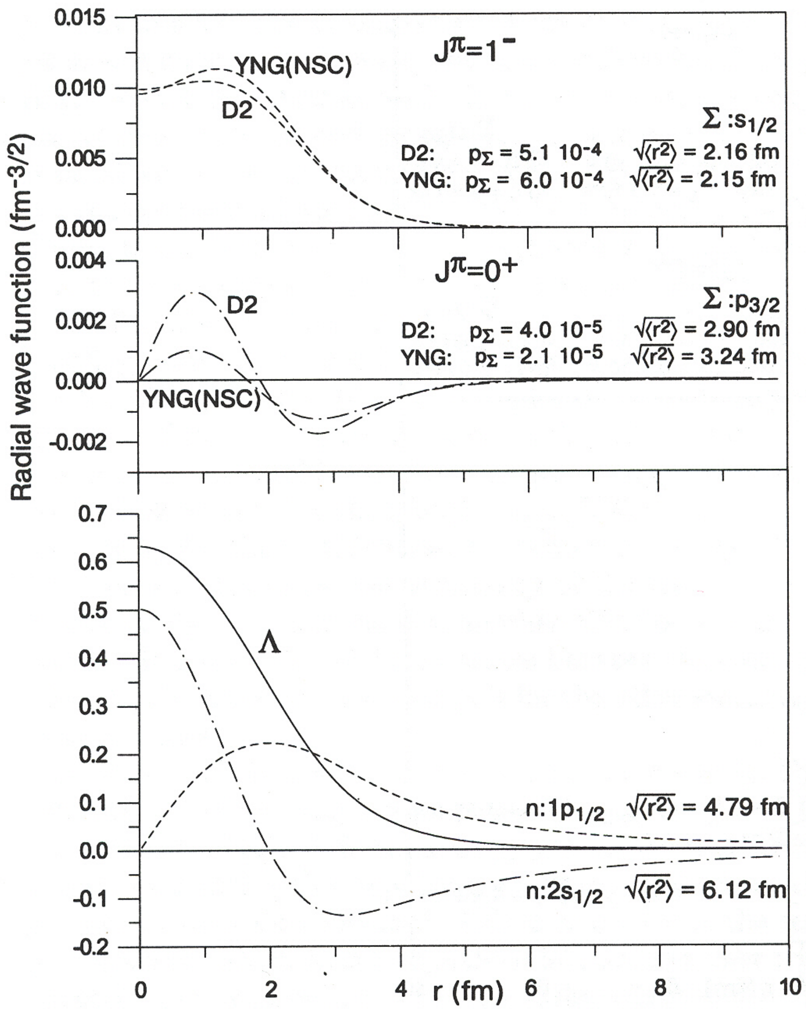
Production mechanisms of neutron-rich hypernuclei

2) via the Σ^- production:

$$\mathbf{K^-_{stop} + p \rightarrow \pi^+ + \Sigma^-} \qquad \mathbf{\Sigma^- + p \rightarrow \Lambda + n}$$

$$p_\Lambda = 290 \text{ MeV/c} \; ; \quad p_n = 220 \div 380 \text{ MeV/c}$$

Production mechanisms of neutron-rich hypernuclei



$^{12}C\ (K^-_{stop},\pi^+)\ ^{12}_{\Lambda}Be$

J^π	(1)	P_{HYP}	(2)
1^-	1.8×10^{-5}		1.2×10^{-6}
0^+	6.0×10^{-6}		1.6×10^{-7}

T.U.Tretyakova and D.E.Lanskoy Nucl.Phys.A 691(2001),51c

FINUDA : Expected counting rates

$$R_{HYP} = N_{\Phi} \bullet BR(K^+K^-) \bullet \varepsilon_{Riv} \bullet P_{HYP}$$

R_{HYP} : expected hypernucleus counting rate

$N_{\Phi} = \mathcal{L} \bullet \sigma_{\Phi} \bullet \Delta t$ where $\sigma_{\Phi} \approx 5\mu b$

$BR(K^+K^-) = 49\%$

$\varepsilon_{Riv} = \varepsilon_{Trg} \bullet \varepsilon_{Rec} \bullet \varepsilon(\pi^{\pm})$

- ε_{Trg} : trigger efficiency (high res: 0.130; low res.: 0.255)
- ε_{Rec} : reconstruction efficiency (0.95)
- $\varepsilon(\pi^-) = 1$; $\varepsilon(\pi^+) = 0.67$

P_{HYP} : production rate

$^{12}_{\Lambda}$Be FINUDA Expected Counting Rates

$$R_{HYP} = N_{\Phi} \bullet BR(K^+K^-) \bullet \varepsilon_{Riv} \bullet P_{HYP}$$

$$R_{HYP} = 8.9 \times 10^{7} \bullet 0.082 \bullet 1.8 \times 10^{-5}$$

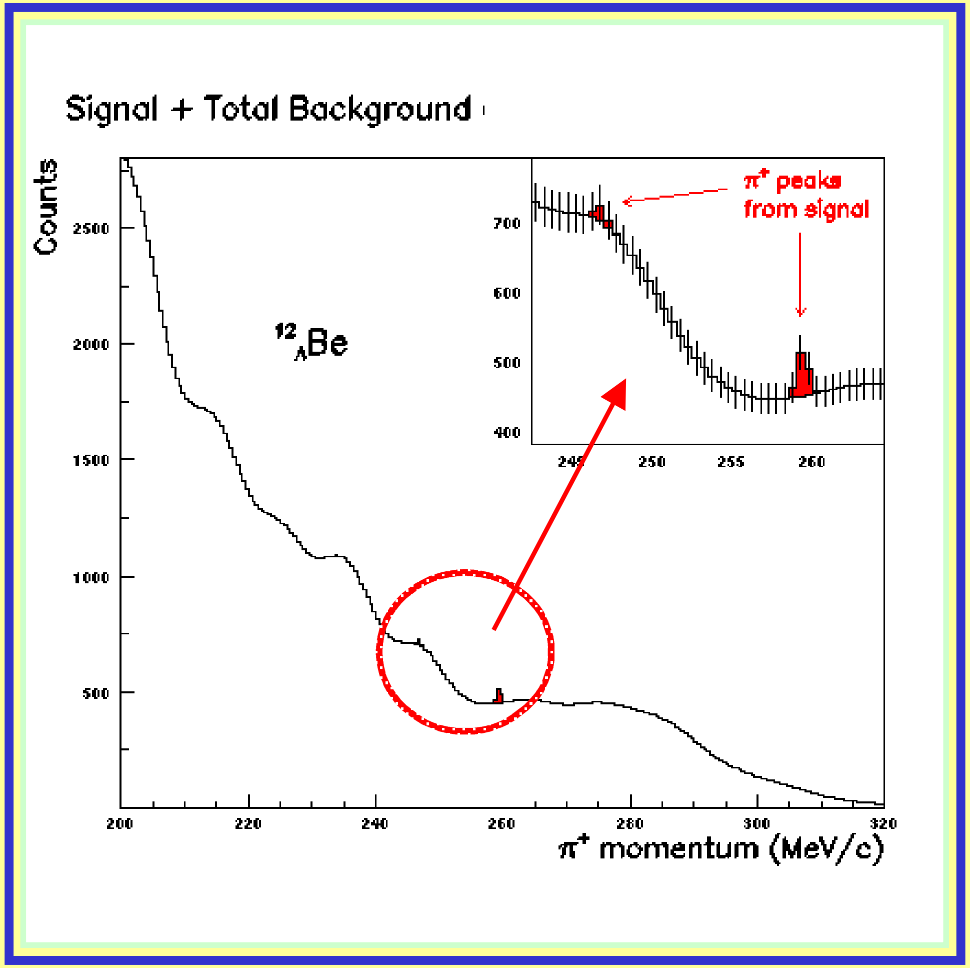
$\mathcal{L} = 10^{34}\ cm^{-2}\ s^{-1}$

1 hour

$R_{HYP} = 131$ counts/h

FINUDA Monte Carlo

$^{12}_{\Lambda}$Be: Simulated π^+ Spectra



Peaks identification

($S>2\sigma_B$ at $L=10^{34}$ cm^{-2}s^{-1})

J^π	S/B	Time
1^-	0.05	37’
0^+	0.01	8h 14’

Expected counting rates very exotic nuclei ${}^{6}_{\Lambda}H$ ${}^{7}_{\Lambda}H$

- B_{Λ} in ${}^{6}_{\Lambda}H$
  - Y.Akaishi et al., Phys.Rev.Lett. 84(2000) 14
- B_{Λ} in ${}^{7}_{\Lambda}H$
  - L. Majling, Few Body System Suppl. 5 (1992) 348

pictorial argument

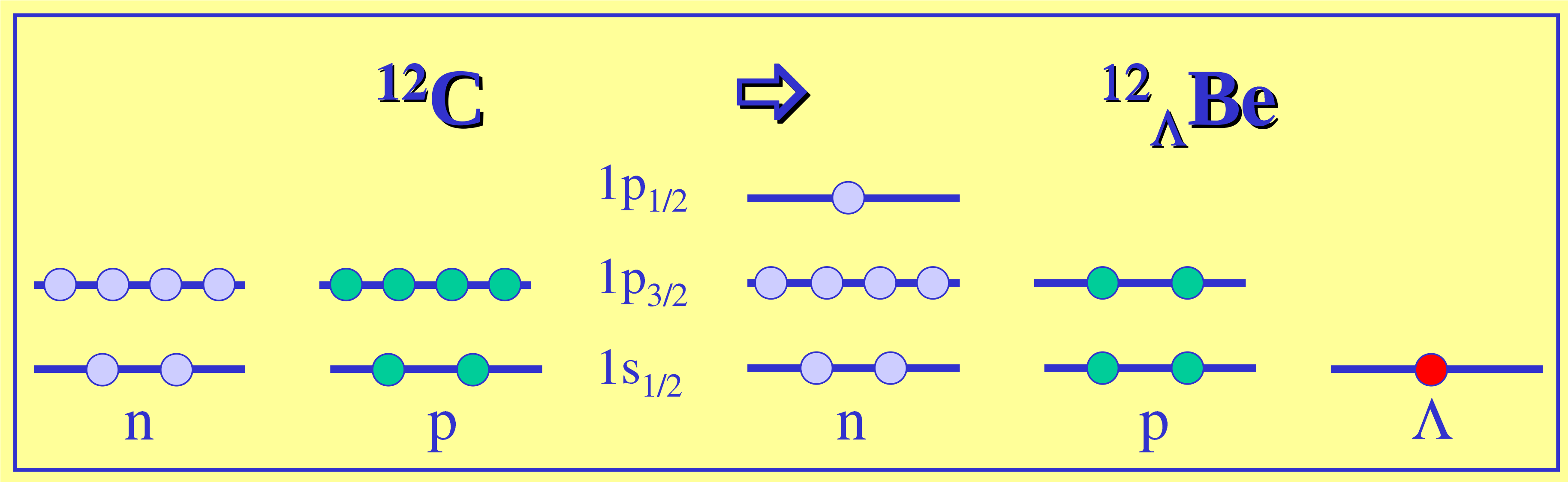
theoretical calculation

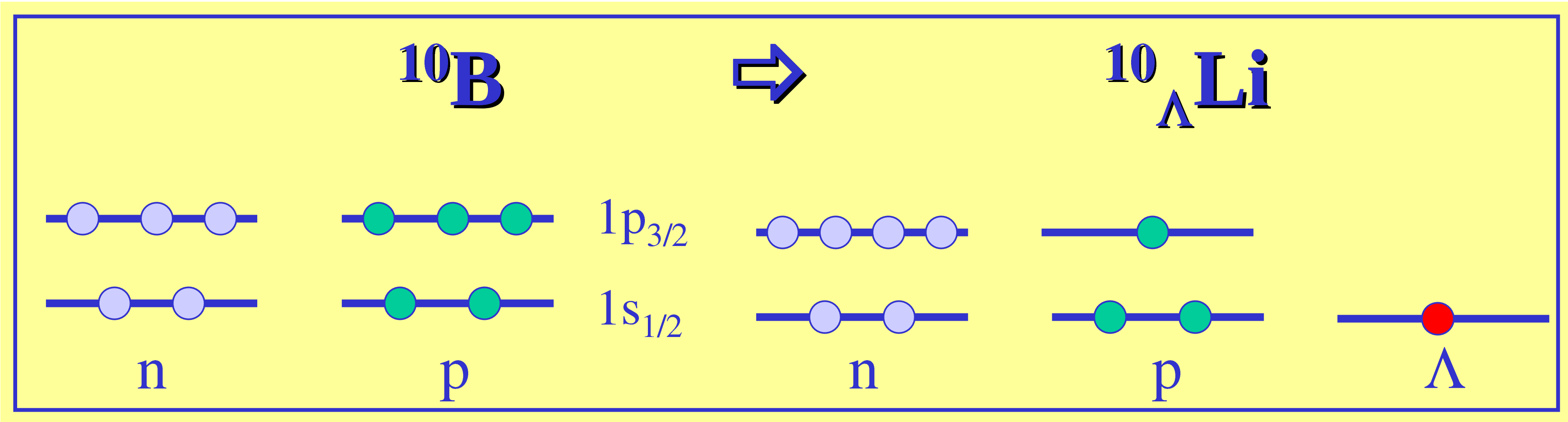
P.K. Saha et al LOI at the 50-GeV PS

${}^{A}{}_{Z}(Z\text{-}2)$	J^{π}	*p*	*n*	Λ	$d\sigma/d\Omega$
${}^{12}{}_{\Lambda}Be$	1^-	$p_{3/2}$	$p_{1/2}$	$s_{1/2}$	6.5
${}^{10}{}_{\Lambda}Li$	2^-	$p_{3/2}$	$p_{3/2}$	$s_{1/2}$	66.8

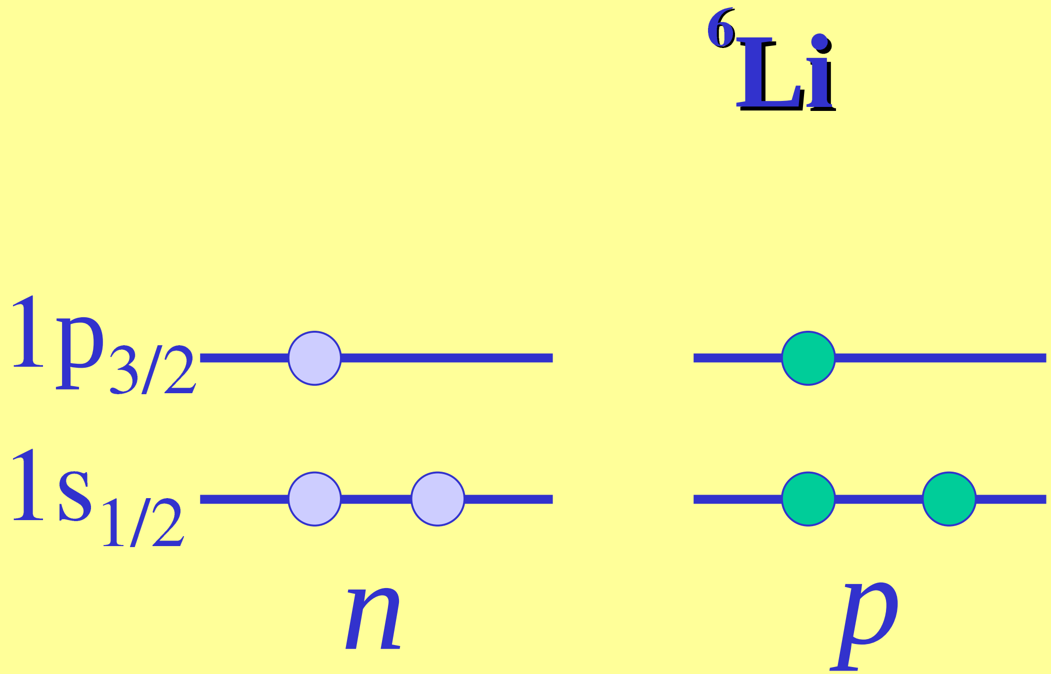
different $d\sigma/d\Omega$ values depends on the proton and neutron distributions in the targets

pictorial argument
the naive explanatìon



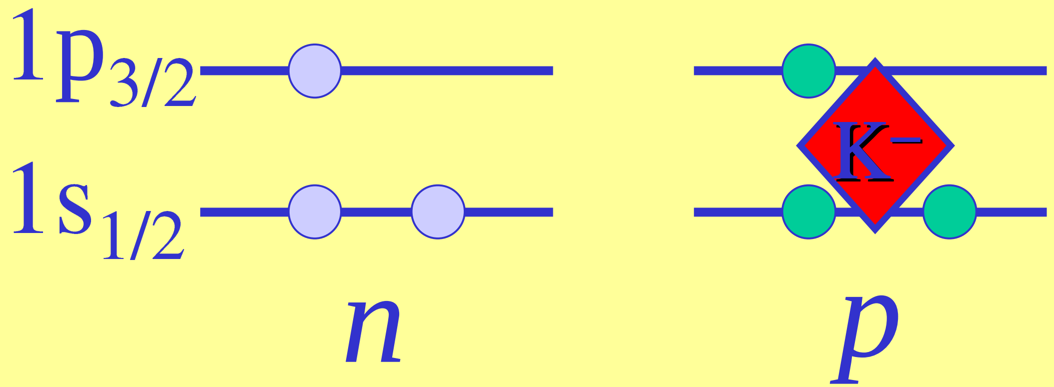


$^{6}_{\Lambda}H$ production: the naive explanatìon



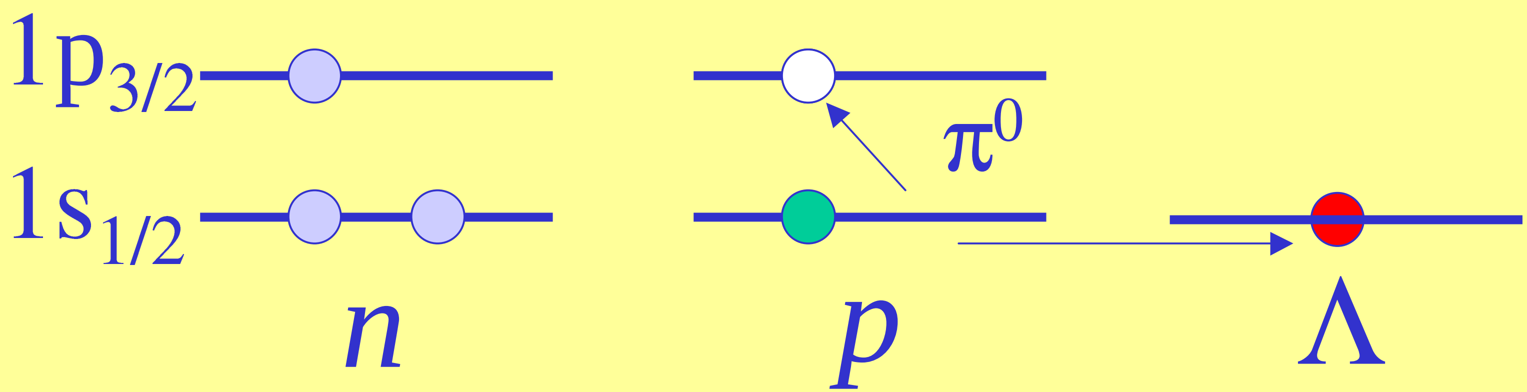
$^{6}_{\Lambda}H$ production: the naive explanatìon

$^{6}Li\,(K^{-}, \pi^{+})\,^{6}_{\Lambda}H$



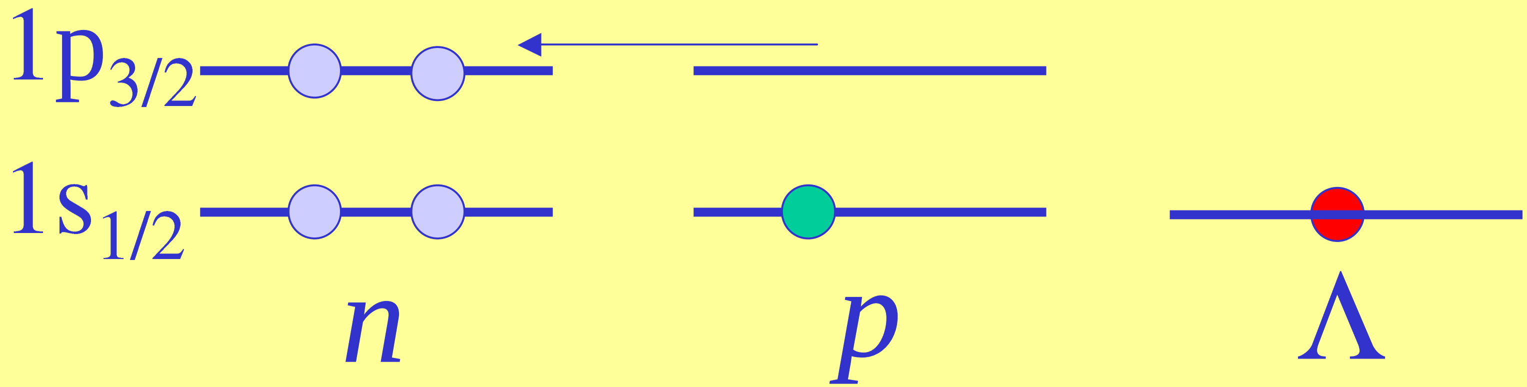
${}^{6}_{\Lambda}H$ production: the naive explanatìon

$K^- ({}^{6}Li, {}^{6}_{\Lambda}H) \pi^+$



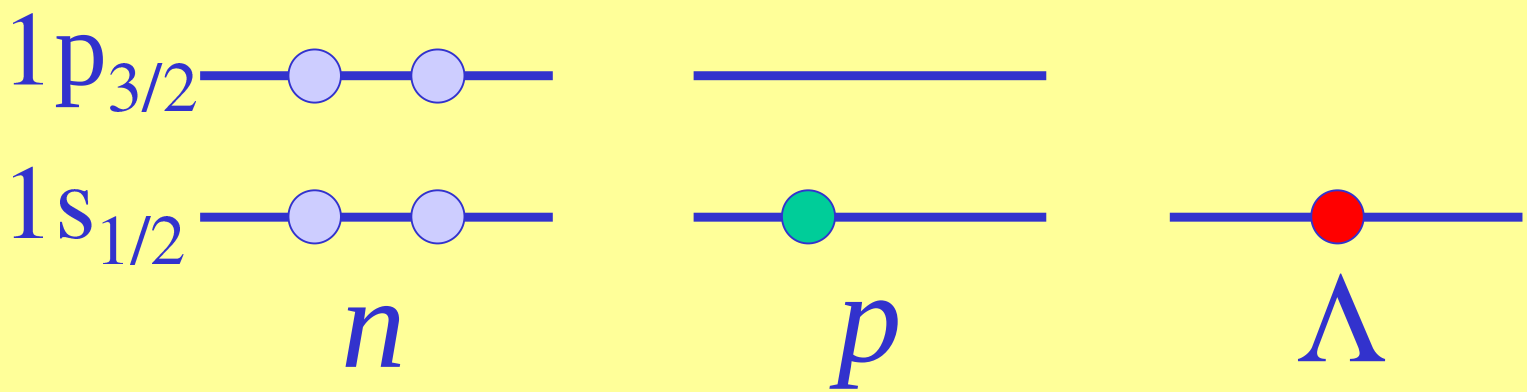
${}^{6}_{\Lambda}H$ production:
the naive explanatìon

$K^{-}\,({}^{6}Li\,,\,{}^{6}_{\Lambda}H)\,\pi^{+}$



$^{6}_{\Lambda}$H production: the naive explanatìon

$^{6}_{\Lambda}$**H**



the proton to neutron conversion doesn't require angular momentum transfer

Transition is favoured

${}^{6}_{\Lambda}H$
FINUDA Expected Counting Rates

$$R_{HYP} = N_{\Phi} \bullet BR(K^{+}K^{-}) \bullet \varepsilon_{Riv} \bullet P_{HYP}$$

$$R_{HYP} = 8.9 \times 10^{7} \bullet 0.082 \bullet 1. \times 10^{-4}$$

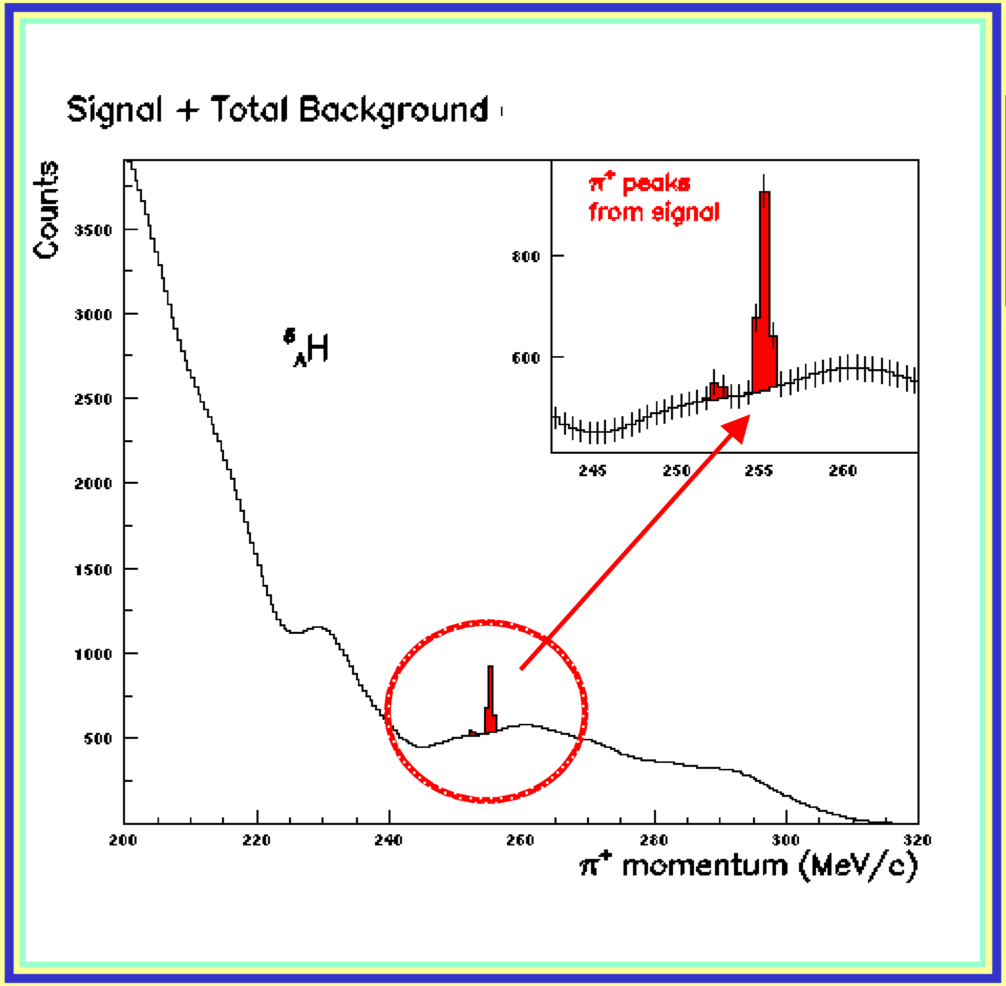
$\mathcal{L} = 10^{34}\, cm^{-2}\, s^{-1}$

1 hour

$R_{HYP} = 728$ counts/h

FINUDA Monte Carlo

Simulated π^+ Spectra $^6_\Lambda H$

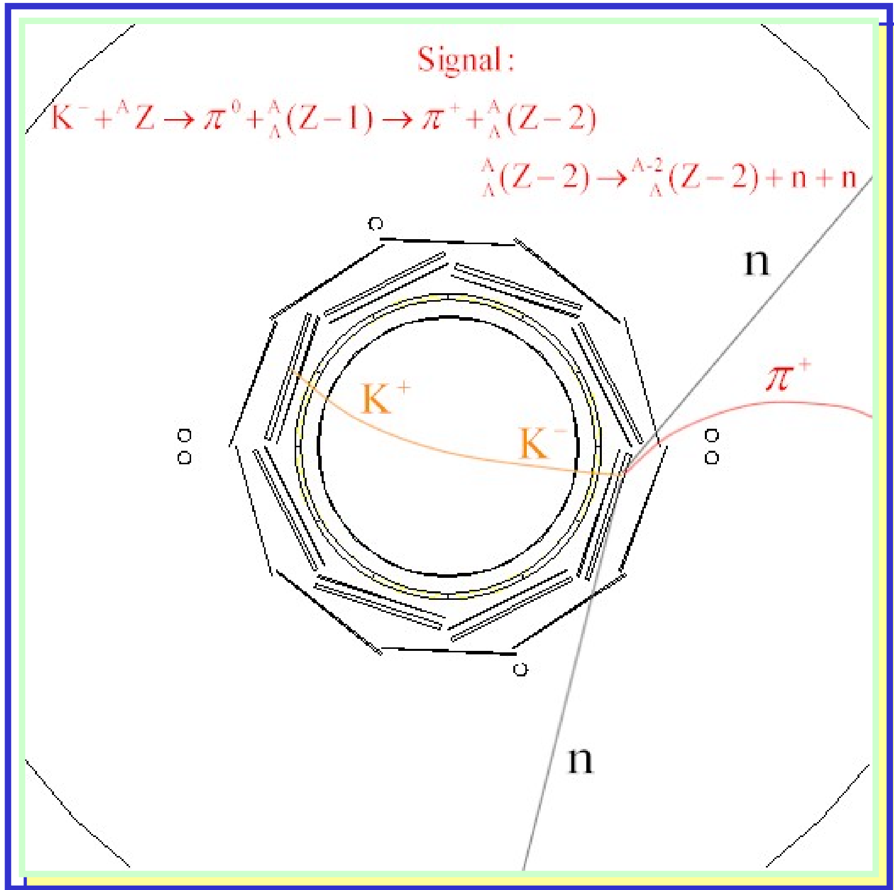


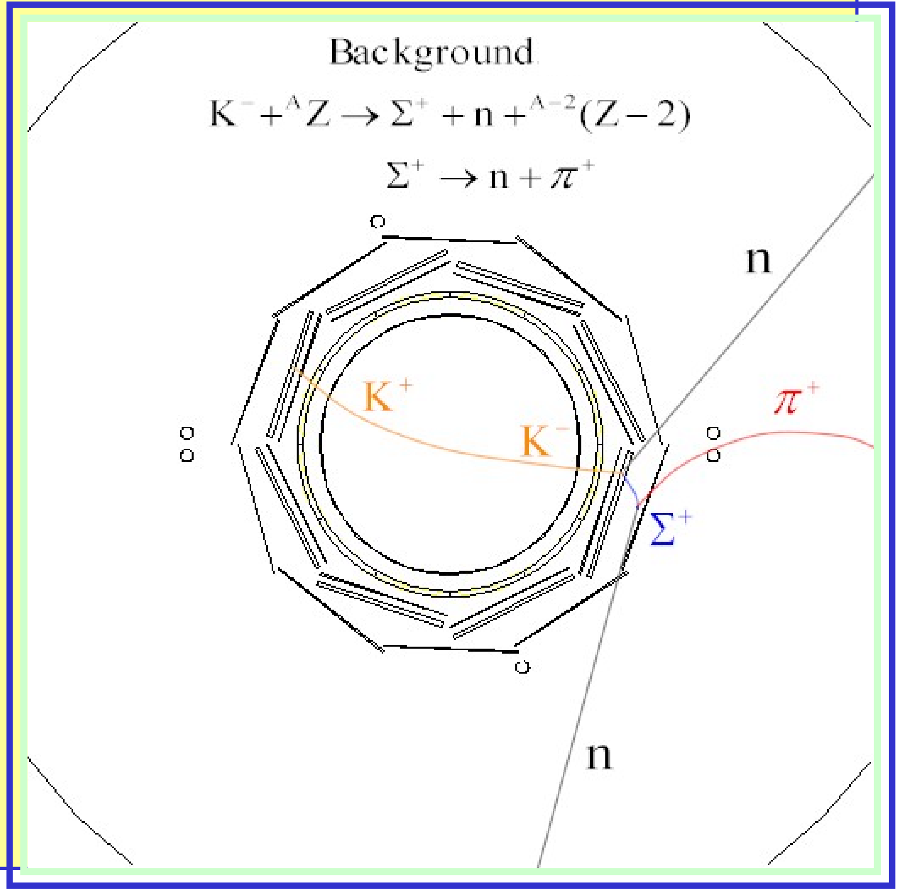
Peaks identification

($S>2\sigma_B$ at $L=10^{34}$ $cm^{-2}s^{-1}$)

J^π	S/B	Time
0^+	0.24	90’’
1^+	0.02	165’

Signal & Background topologies in FINUDA





Conclusions

The FINUDA spectrometer

+

DaΦne2 ($\mathcal{L} = 10^{34}\ cm^{-2}\ s^{-1}$)

=

High quality neutron-rich hypernuclei identification