The FINUDA Collaboration

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Hypernuclear physics at DAΦNE

DAΦNE a high luminosity Φ factory

$\mathcal{L}$~0.5 10^{33}cm^{-2}s^{-1} 2 500 Φ s^{-1}

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

$K_S K_L$
(34%)

FI.NU.DA
Hypernuclear
physics

Φ

K^+K^-
(49%)

$\rho\pi$
(13%)

DEAR
K^-N scattering

Source of monochromatic, collinear, background free, tagged neutral and charged kaons

FI.NU.DA.
FIsica NUcleare a DAΦne

- A fixed target experiment carried out at a collider

Main physics idea

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

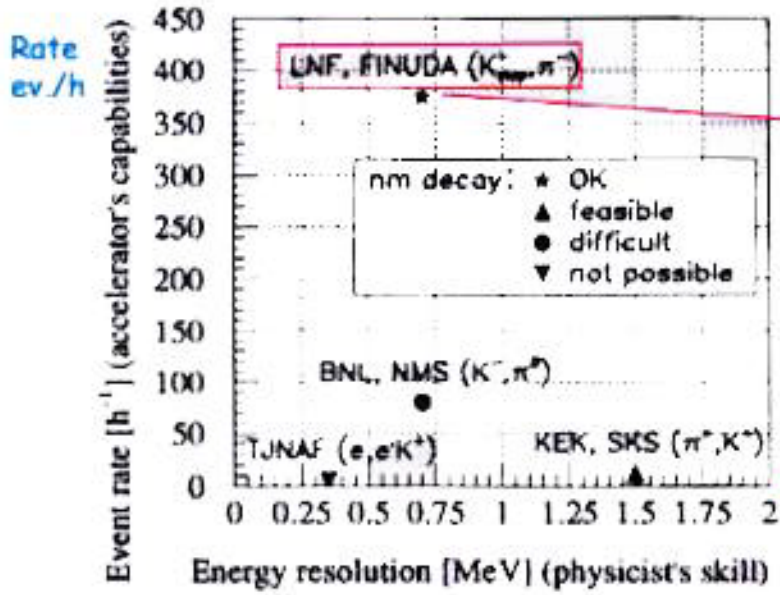
High resolution spectroscopy

low energy (16 MeV) monochromatic tagged background free

Mesonic and Non-mesonic decay

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

	DAΦNE K^- beam	K^- extracted beams
Target thickness	Very thin (0.2 g/cm^2)	Thick (some g/cm^2)
Resolution on hypernuclear levels	~700 KeV	~1-2 MeV
Acceptance	Large (Collider exp.)	Small (Fixed target)
Rates (event/hour) (10^{-3} capture rate)	400 ($\mathcal{L}$=5 10^{32} cm^{-2}s^{-1})	~10



Non-mesonic decay can be studied

Milestones of the hypernuclear physics program of FINUDA

- Measurement of the ${}^{12}_{\Lambda}C$ excitation spectrum with resolution < 1 MeV
  - Detection of states produced at capture rate 10^{-4}
  - Measurement of the lifetime $\tau = \hbar / \Gamma_{tot}$
  - Measurement of mesonic and non-mesonic decays

- High statistics study of the production, decay and lifetime of p-shell hypernuclei : ${}^{7}_{\Lambda}Li$, ${}^{9}_{\Lambda}Be$, ${}^{10}_{\Lambda}B$

- High statistics study of ${}^{5}_{\Lambda}He$ formation and decays using a ${}^{6}Li$ target.

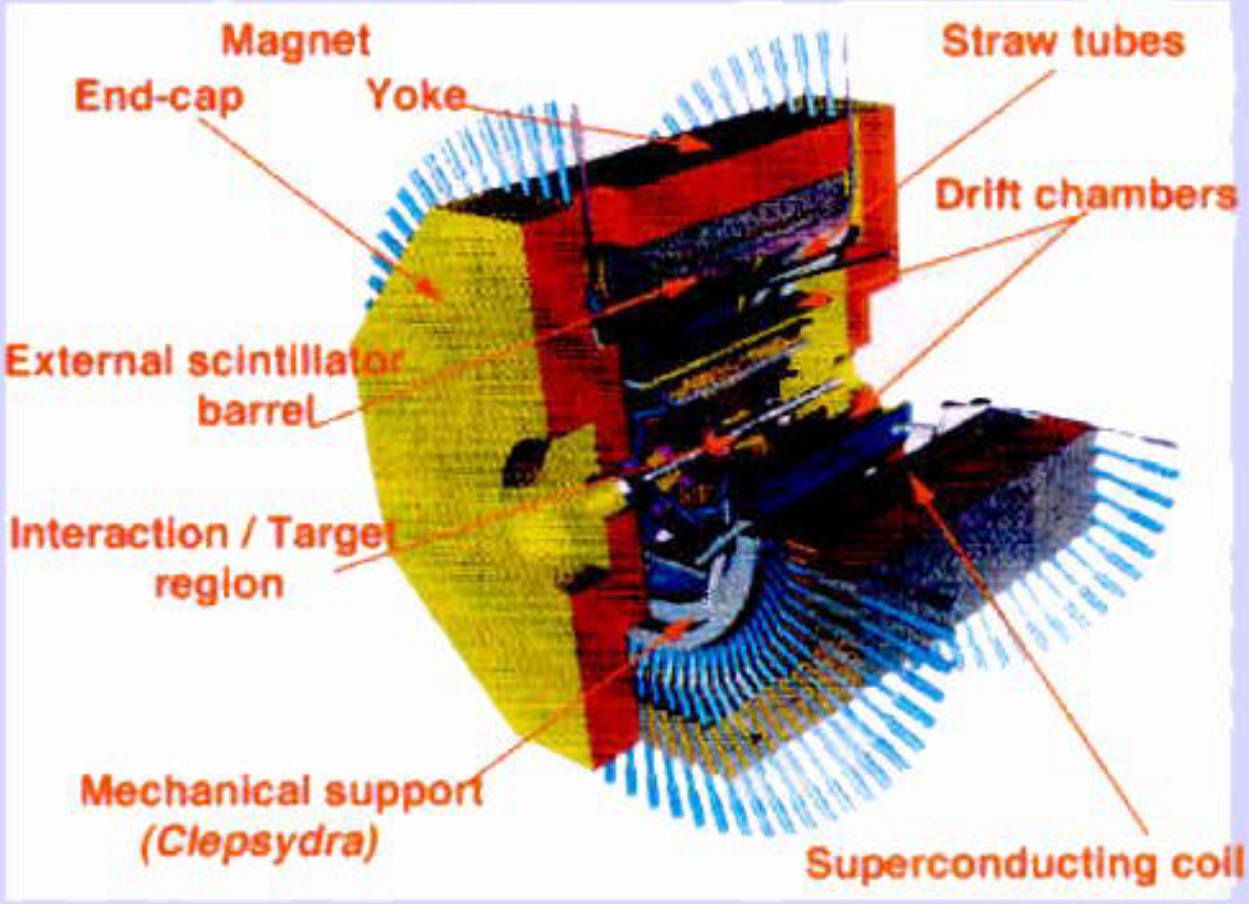
- With the same ${}^{6}Li$ target study of ${}^{6}_{\Lambda}He$ non-mesonic decay to (n,n) with an exclusive measurement.

- High statistics survey of the production of hypernuclei of higher mass : ${}^{27}_{\Lambda}Al$, ${}^{28}_{\Lambda}Si$, ${}^{51}_{\Lambda}V$, ${}^{89}_{\Lambda}Y$, ${}^{133}_{\Lambda}Cs$, ${}^{165}_{\Lambda}Ho$, ${}^{209}_{\Lambda}Bi$

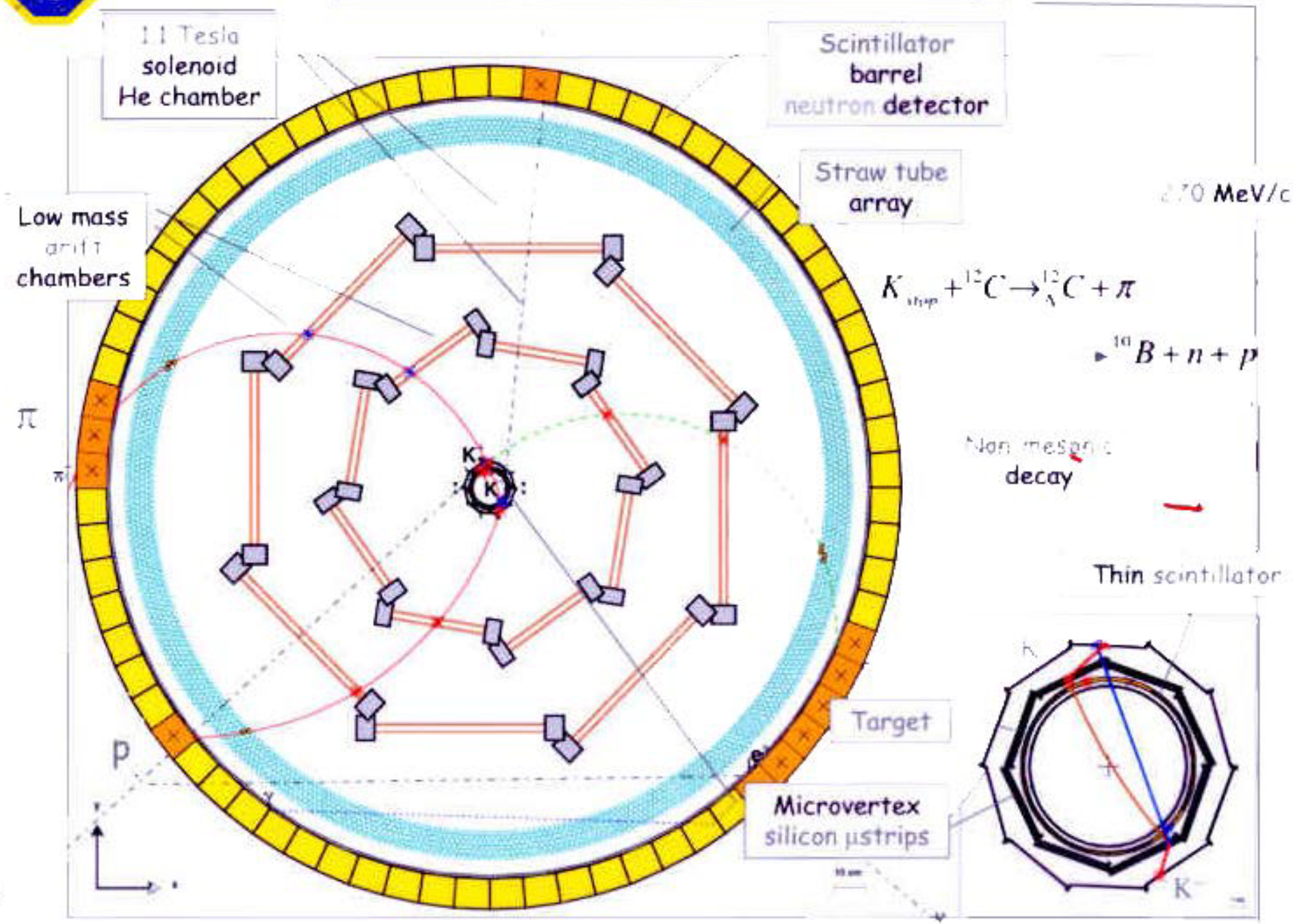
REMARKS

- Different targets can be used in the same run period
- Products of non-mesonic decay (n,p) and (n,n) are seen in coincidence

FINUDA experimental set-up



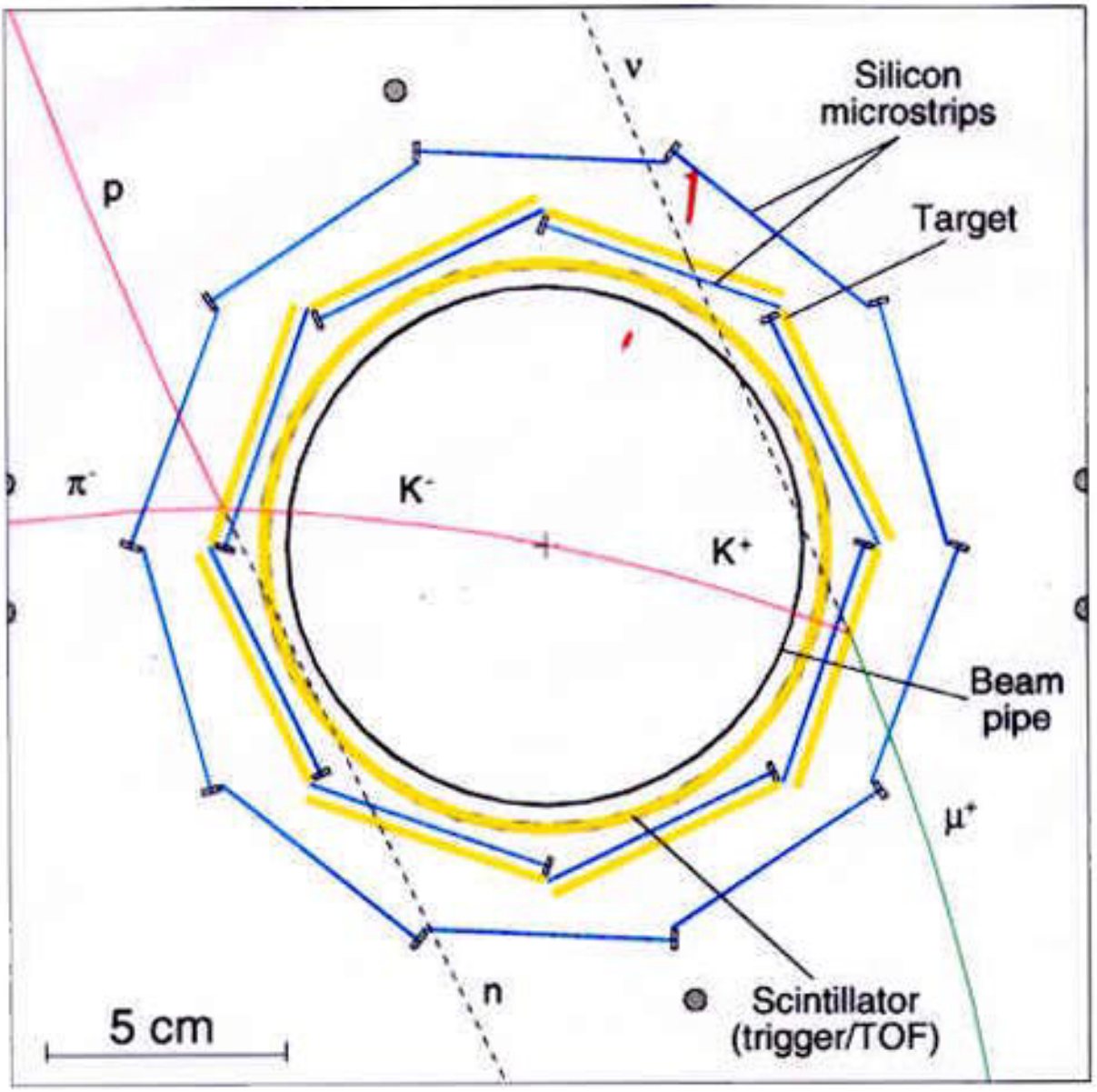
Typical (p-n) non-mesonic decay event



$K^-_{stop} + {}^{12}C \rightarrow {}^{12}_{\Lambda}C + \pi$

$\blacktriangleright {}^{11}B + n + p$

Non mesonic
decay

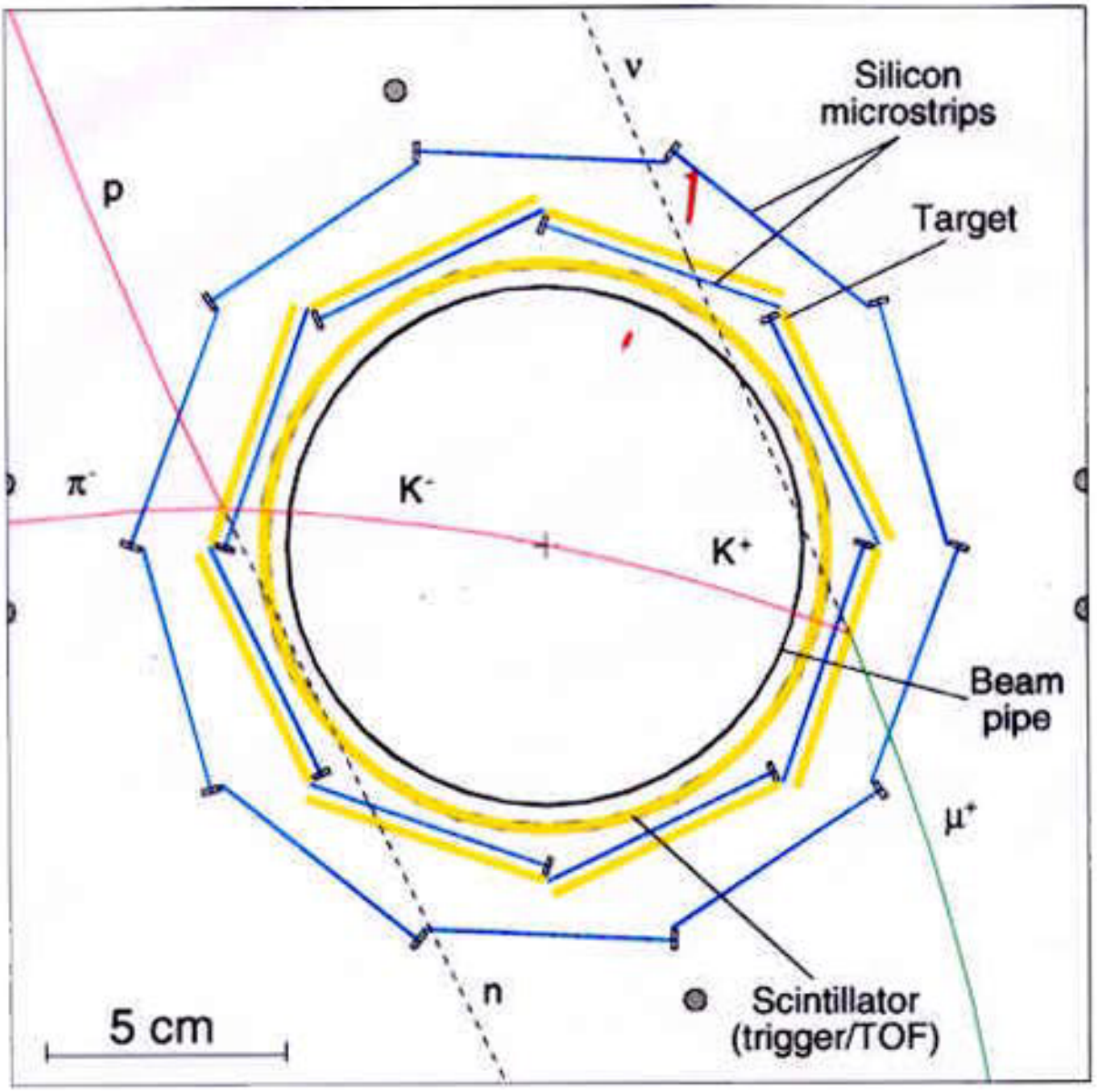


Vertex detector requirements:

- detect K^+ K^- pairs
- define interaction vertex inside target
- provide first position measurement on outgoing tracks
- discriminate in mass and position between π, p, and K

Position resolution undemanding (~ 30 μm)

But need large dynamic range (1 -> 20 MIP)



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Hypernuclear decay

Mesonic decay (like **free** Λ) $\quad \Gamma_m = \Gamma_{\pi^0} + \Gamma_{\pi^-}$

Partial rate	transition
Γ_{π^0}	$\Lambda \to n + \pi^0$
Γ_{π^-}	$\Lambda \to p + \pi^-$

Suppressed by Pauli blocking in medium-heavy hypernuclei

Non-mesonic decay (only in **hypernuclei**) $\quad \Gamma_{nm} = \Gamma_n + \Gamma_p$

Partial rate	transition
Γ_n	$\Lambda + n \to n + n$
Γ_p	$\Lambda + p \to n + p$

Dominant in medium-heavy hypernuclei

Hypernucleus **lifetime**

$$\tau = \hbar / \Gamma_{tot}; \quad \Gamma_{tot} = \Gamma_n + \Gamma_p + \Gamma_{\pi^-} + \Gamma_{\pi^0} = \Gamma_m + \Gamma_{nm}$$

- Some hypernuclear decay **observables**

		$^{12}_{\Lambda}C$
$\Gamma_{tot}/\Gamma_\Lambda$	total decay rate (lifetime) (strength of the interaction)	1.25 ± 0.18 [4]
Γ_p/Γ_Λ	proton induced decay rate	$0.31 \pm 0.07^{+0.11}_{-0.04}$ [2]
Γ_n/Γ_Λ	neutron induced decay rate	
$\Gamma_{nm}/\Gamma_\Lambda$	total non-mesonic decay rate	1.14 ± 0.20 [1] $0.89 \pm 0.15 \pm 0.03$ [2]
$\Gamma_{\pi^-}/\Gamma_\Lambda$	mesonic (π^-) decay rate (pion nucleus distortion)	$0.14 \pm 0.07 \pm 0.03$ [2] $0.052^{+0.063}_{-0.035}$ [1]
Γ_n/Γ_p	n/p induced decay rate (isospin structure of interaction)	$1.33^{+1.12}_{-0.81}$ [1] $1.87 \pm 0.59^{+0.32}_{-1.00}$ [1] 0.70 ± 0.3 [3] 0.52 ± 0.16 [3]

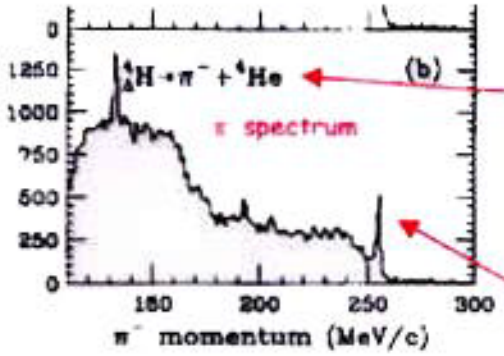
Few measurements with **large errors**

(1) J.J. Szymanski et al. Phys. Rev. C43, (1991) 849
(2) H. Noumi et al., Phys. Rev. C52 (1995) 2936
(3) A. Montwill et al., Nucl. Phys. A234 (1974) 413
(4) R. Grace et al., Phys. Rev. Lett. 55(1985) 1055

Hypernucleus mesonic decay

- Kinematic features of mesonic decays (suppressed in medium-heavy hypernuclei)

Two body decay



$$K^-_{stop} + {}^4He \rightarrow {}^4_\Lambda H + \pi^0$$

$$\downarrow$$

$${}^4He + \pi^- (133\,MeV/c)$$

hyp. decay π^- monochromatic

$$K^-_{stop} + {}^4He \rightarrow {}^4_\Lambda He + \pi^-$$

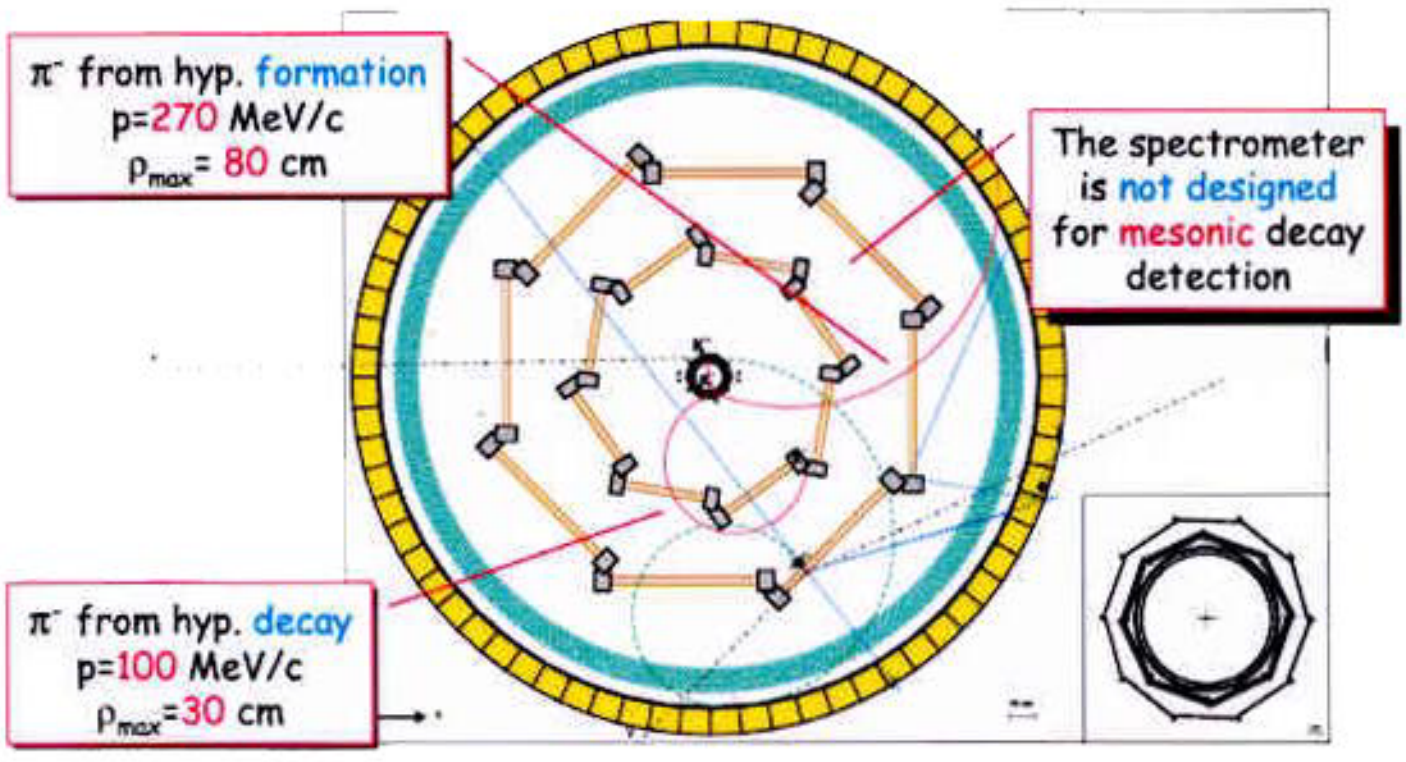
hyp. formation π^- monochromatic

Three body decay

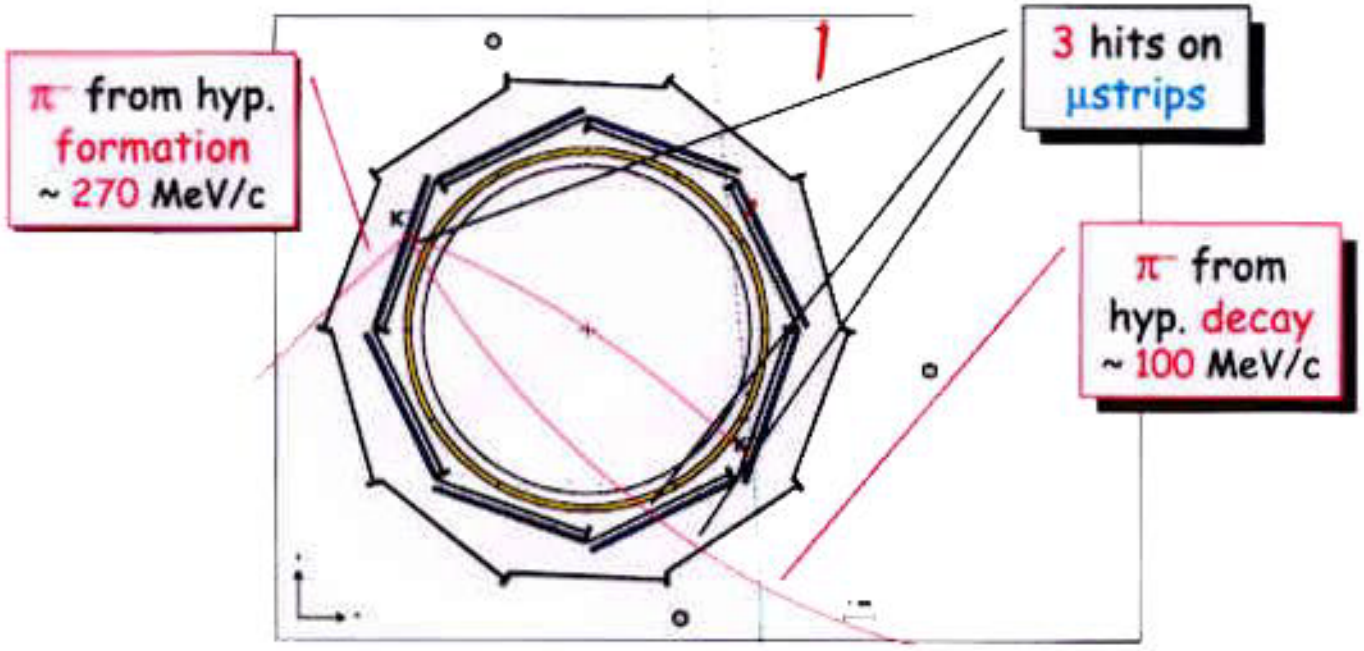
$${}^5_\Lambda He \rightarrow {}^4He + p + \pi^-$$

decay spectrum of π^- is centred at 100 MeV/c

- Low momentum pions are out of the acceptance of the FINUDA spectrometer

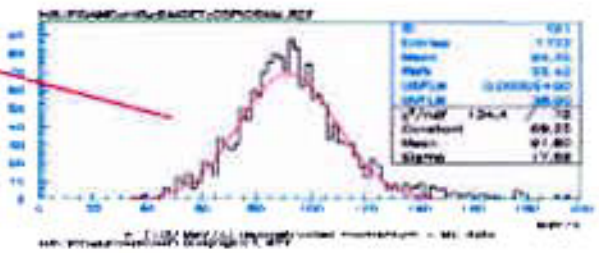


- Nevertheless FINUDA can detect and measure π^- from mesonic decay by means of the two μstrip internal arrays

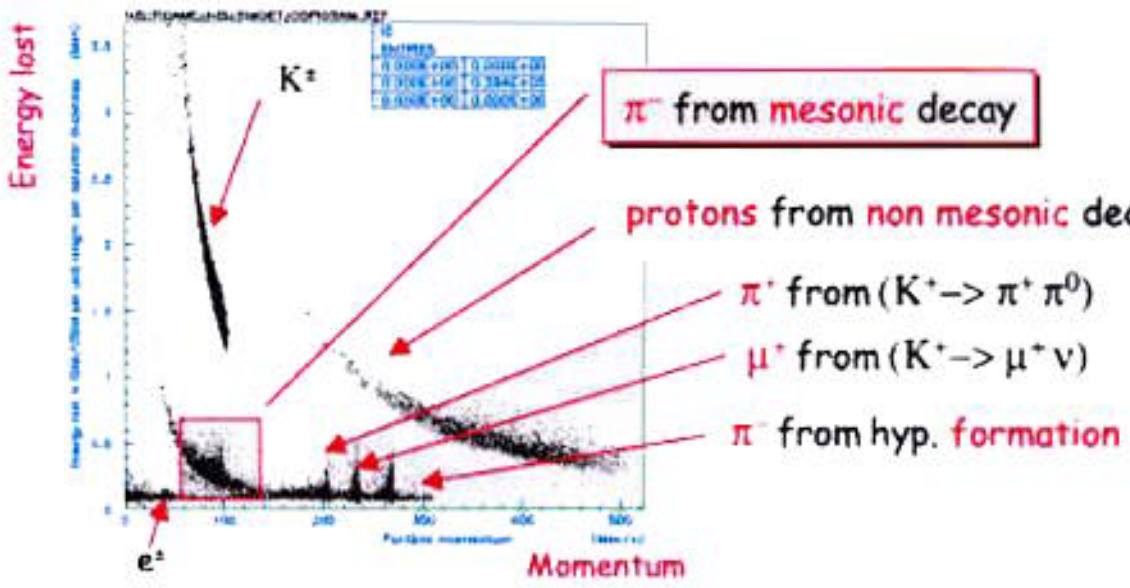


- The momentum resolution is poor due to multiple scattering

Δp/p(fwhm) ~ 40%



- However, identification is good thanks to dE/dx in the μstrips



- Acceptance is 20% (3 hits in ISIM & OSIM)