

Study of the (K^+, K^0) reaction on medium-light nuclei close to threshold



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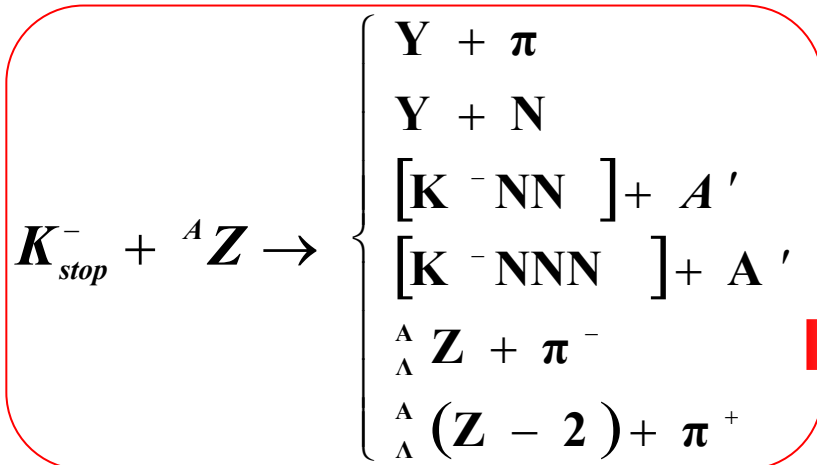
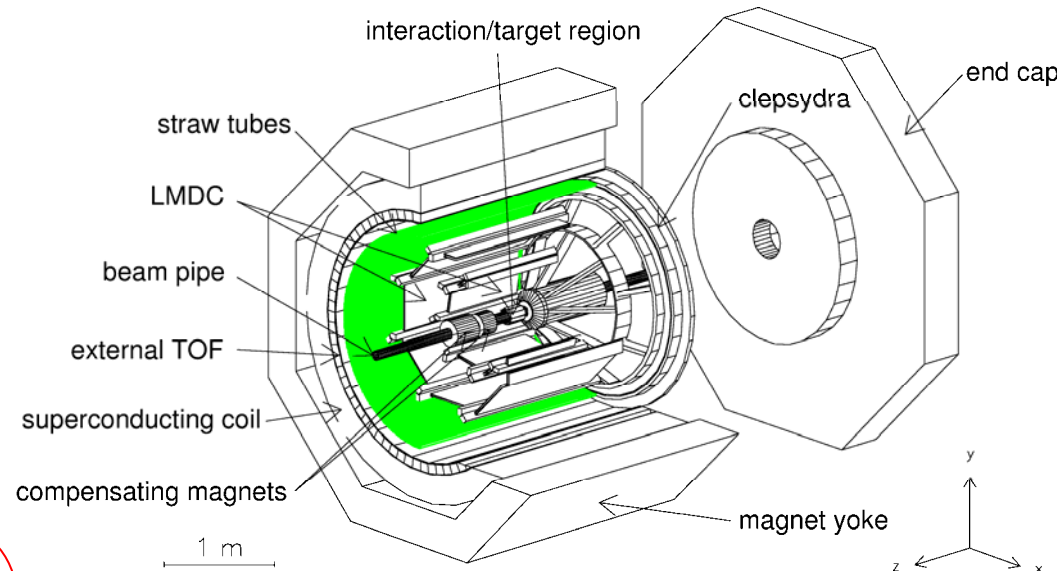
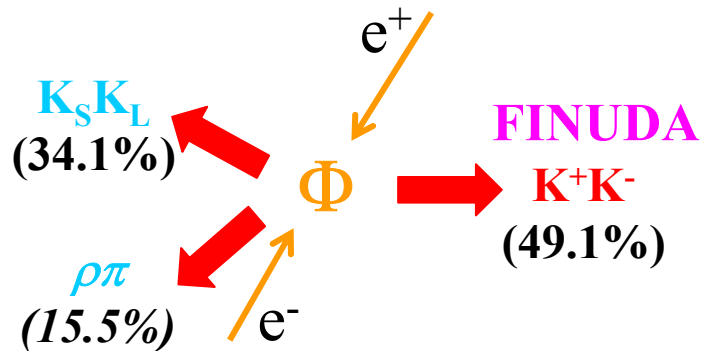


Outline

- Introduction to FINUDA experiment
 - the apparatus
 - the physics items
- (K^+, K^0) charge exchange reactions
 - Results of first FINUDA run
 - Preliminary estimations for new data

FINUDA (Fisica NUcleare a DAΦNE)

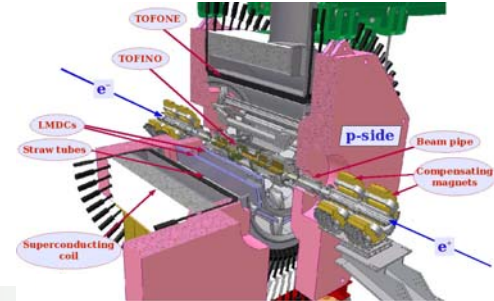
Beam Energy **510 MeV**



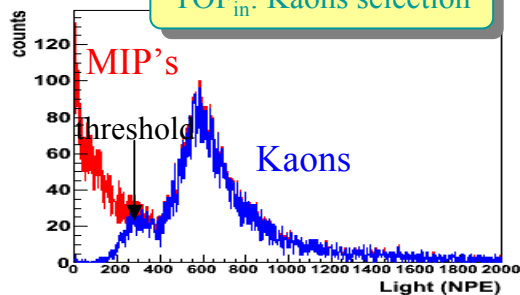
Cylindrical geometry

Strange hadronic systems decay
by multi-tracking analysis

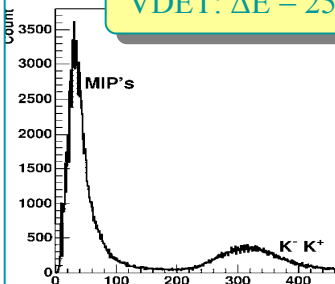
Detector performance



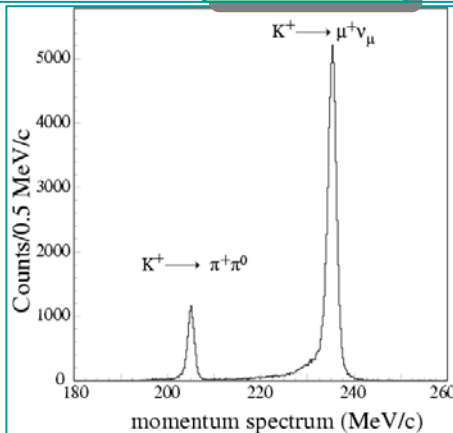
TOF_{in}: Kaons selection



VDET: $\Delta E = 25\%$ FWHM (K)

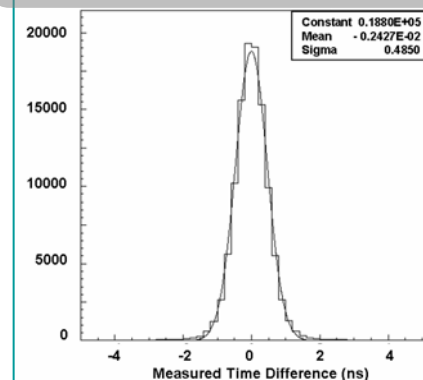


$\Delta p/p \sim 0.5\%$

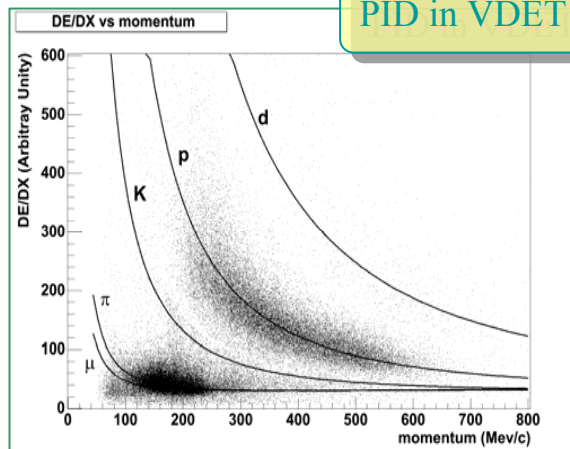


- ✦ *Selective trigger* based on fast scintillation detectors (TOFINO, TOFONE)
- ✦ *K⁻ vertex identification* (ISIM P.ID. + x, y, z resolution + K⁺ tagging)
- ✦ *p, K, p, d, ... P.ID.* (OSIM dE/dx)
- ✦ *High momentum resolution* (tracker resolution + He bag + thin targets)
- ✦ *Neutron detection* (TOFONE)
- ✦ *Time-Of-Flight* (TOFONE-TOFINO)

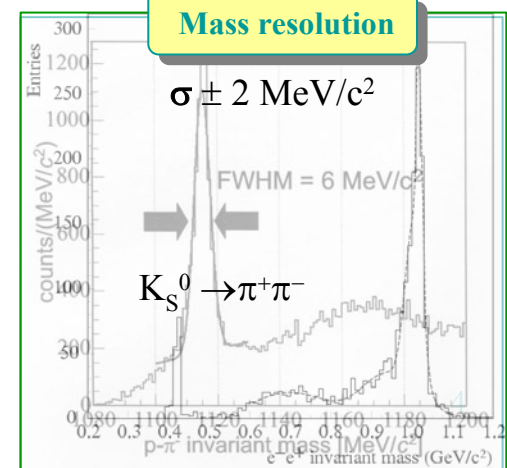
TOF_{out}: $\sigma_t \cong 450$ ps
Neutron efficiency $\sim 10\%$;
 $\Delta E \sim 8$ MeV



PID in VDET



Mass resolution



FINUDA topics

■ Hypernuclear physics

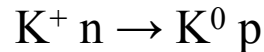
- Spectroscopy of ${}^7_{\Lambda}\text{Li}$, ${}^{12}_{\Lambda}\text{C}$, ${}^{13}_{\Lambda}\text{C}$, ${}^{16}_{\Lambda}\text{O}$... with $(\text{K}^-_{\text{stop}}, \pi^-)$ reaction
- Non Mesonic Weak Decay of (Talk by S. Bufalino)
 ${}^5_{\Lambda}\text{He}$, ${}^7_{\Lambda}\text{Li}$, ${}^{12}_{\Lambda}\text{C}$, ${}^{13}_{\Lambda}\text{C}$, ${}^{16}_{\Lambda}\text{O}$
- Search for Neutron Rich Λ Hypernuclei
 ${}^6_{\Lambda}\text{H}$, ${}^7_{\Lambda}\text{H}$, ${}^9_{\Lambda}\text{He}$, ${}^{12}_{\Lambda}\text{Be}$, ${}^{13}_{\Lambda}\text{Be}$, ${}^{16}_{\Lambda}\text{C}$

■ Hadron physics with strangeness

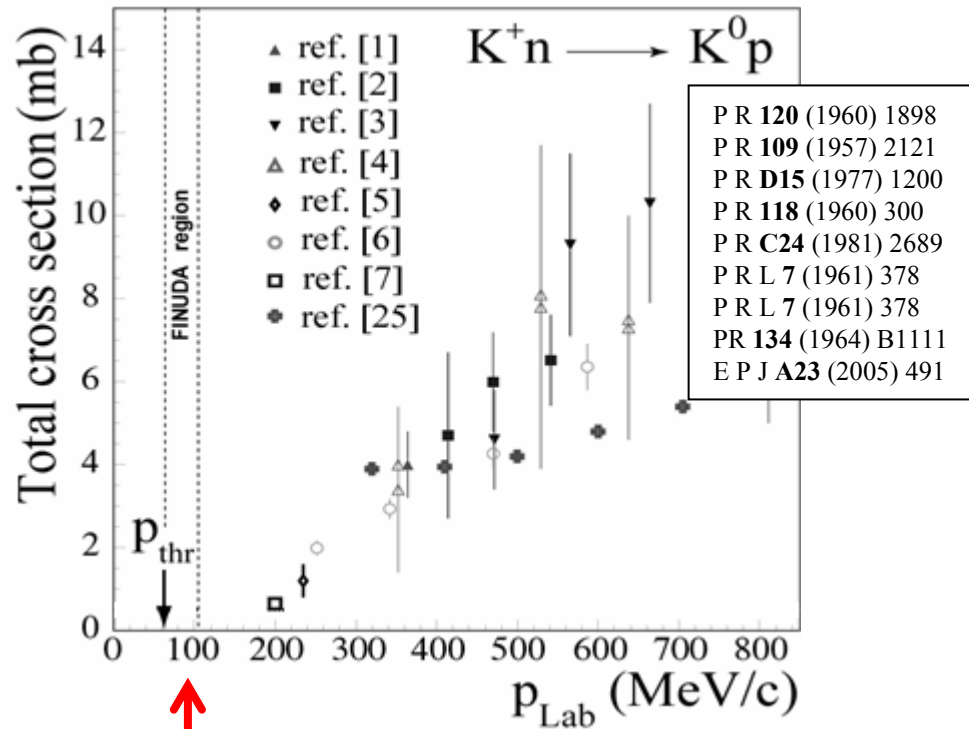
- K^- -nuclear systems ($\text{K}^- \text{pp}$, $\text{K}^- \text{ppn}$) (Plenary talk by S. Piano)
- **(K^+, K^0) charge exchange reaction on medium-light nuclei close to threshold**

K⁺ charge exchange reaction

- K⁺ N scattering data are lacking and very old in the low kaon momentum region for elastic, inelastic and charge exchange channel:



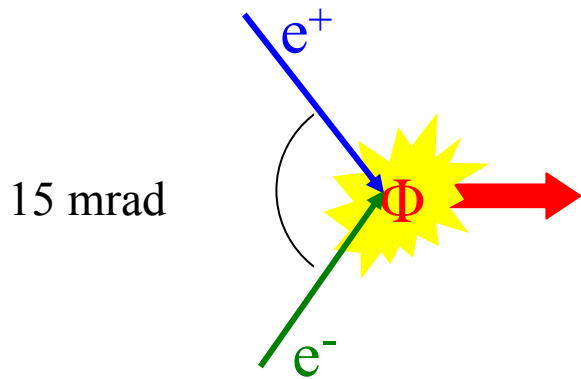
- In the eighties, the relatively “weak” K⁺ interaction with nuclei at intermediate energies was used to probe the possible presence of strange quark content in nucleons.
- Provide experimental information on the scattering amplitude 1/2 (f₁-f₀)



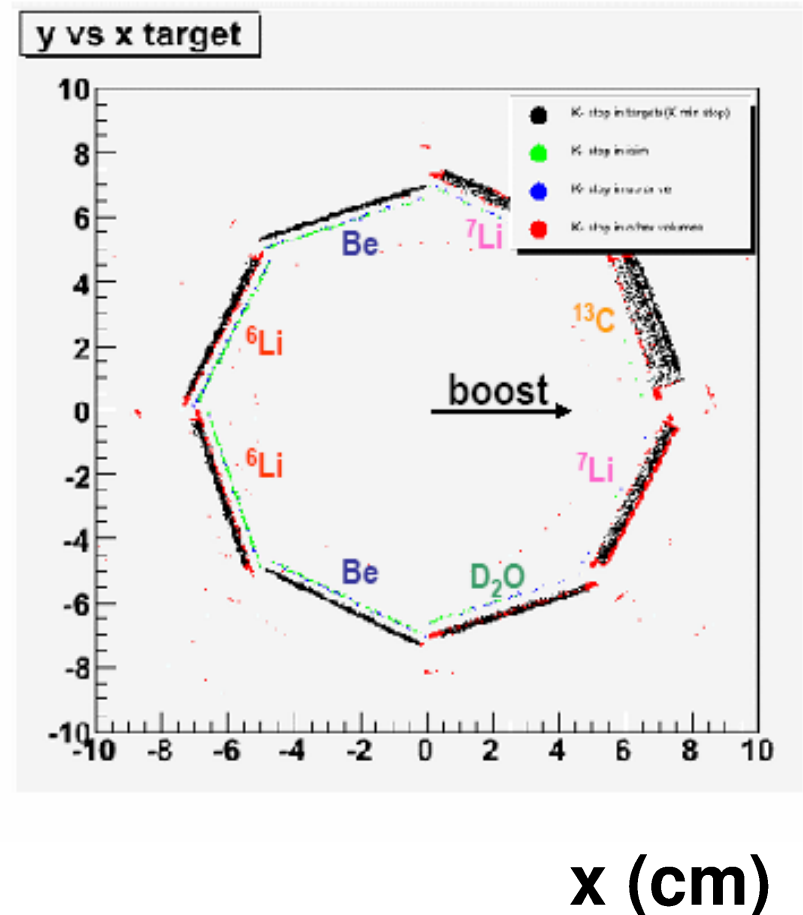
Φ boost

The nominal momentum of K^\pm is 127 MeV/c for a Φ produced at rest.

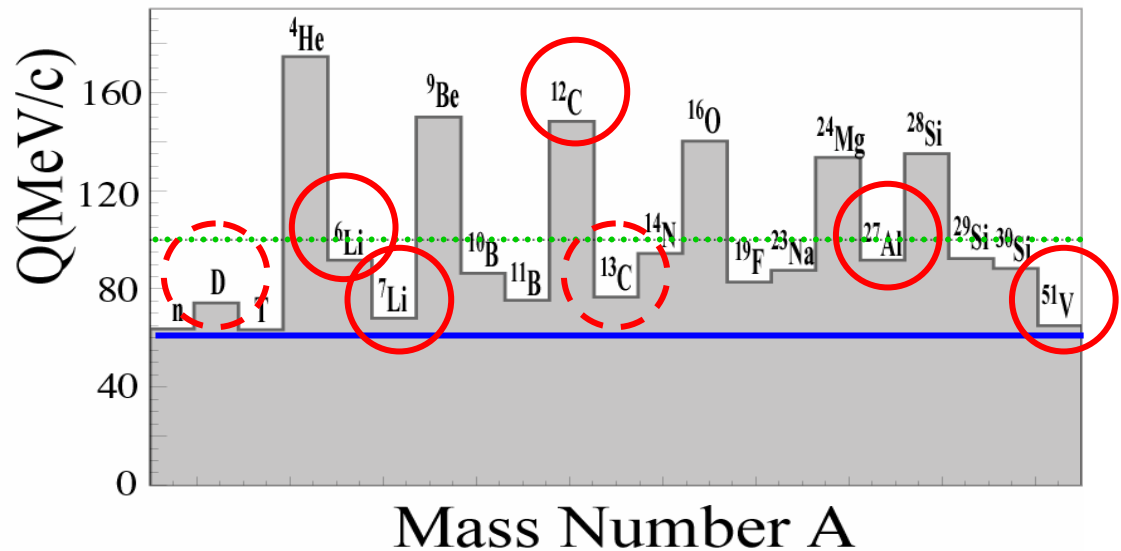
+ Outward boost ≈ 13 MeV/c in the radial plane



second FINUDA run 2006/2007



K⁺ charge exchange reaction in FINUDA



On nuclei, **three effects** are expected.

- 1) a **damping** of the reaction due to the Pauli principle, that could even result in a cross section lower than the elementary one;
- 2) a **threshold bigger** than that on a free neutron and varying from nucleus to nucleus;
- 3) a role of the **Coulomb barrier** increasing with Z.

FINUDA sensitivity to $(K^+K_S^0)$

The expected counts are related to the **cross section** σ of the reaction, the **integrated luminosity** $\int L$ and the **detection efficiency** ε by:

$$\int N_{\text{ev}} = \sigma_{K_S^0} \cdot \varepsilon \cdot \int L$$

Effective **integrated luminosity** for each target \rightarrow

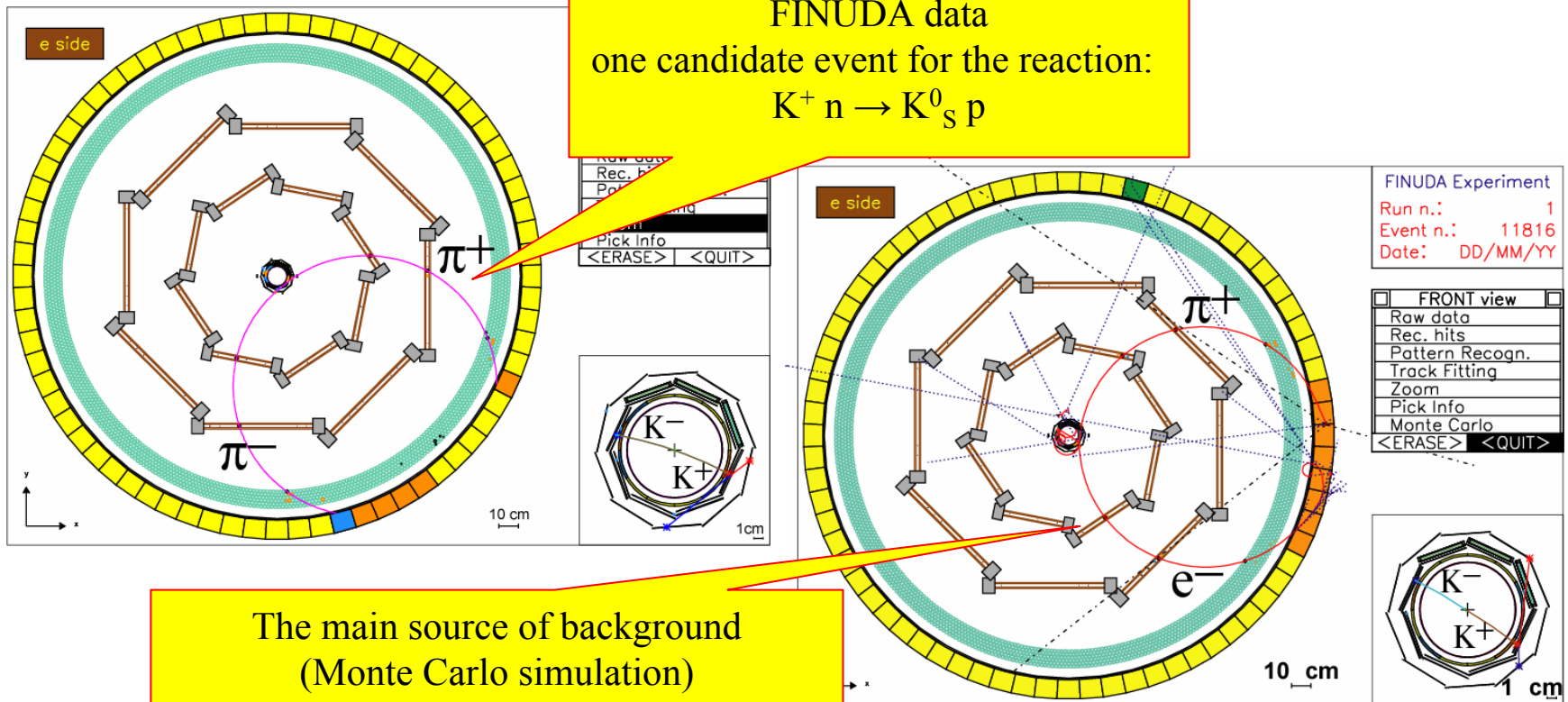
The **detection efficiency** ε for $K_S^0 \rightarrow \pi^+\pi^- \cong \mathbf{0.12}$

First FINUDA run sensitivity ≈ 1 mb per event on the ${}^7\text{Li}$ target

Nuclear target		Integrated Luminosity (run 2003-2004)
${}^{12}\text{C}$		Below Threshold
${}^6\text{Li}$		Below Threshold
${}^6\text{Li}$		1.47×10^{24}
${}^7\text{Li}$		8.71×10^{27}
${}^{12}\text{C}$		Below Threshold
${}^{27}\text{Al}$		8.35×10^{25}
${}^{51}\text{V}$		3.97×10^{26}
${}^{12}\text{C}$		Below Threshold

Electromagnetic background

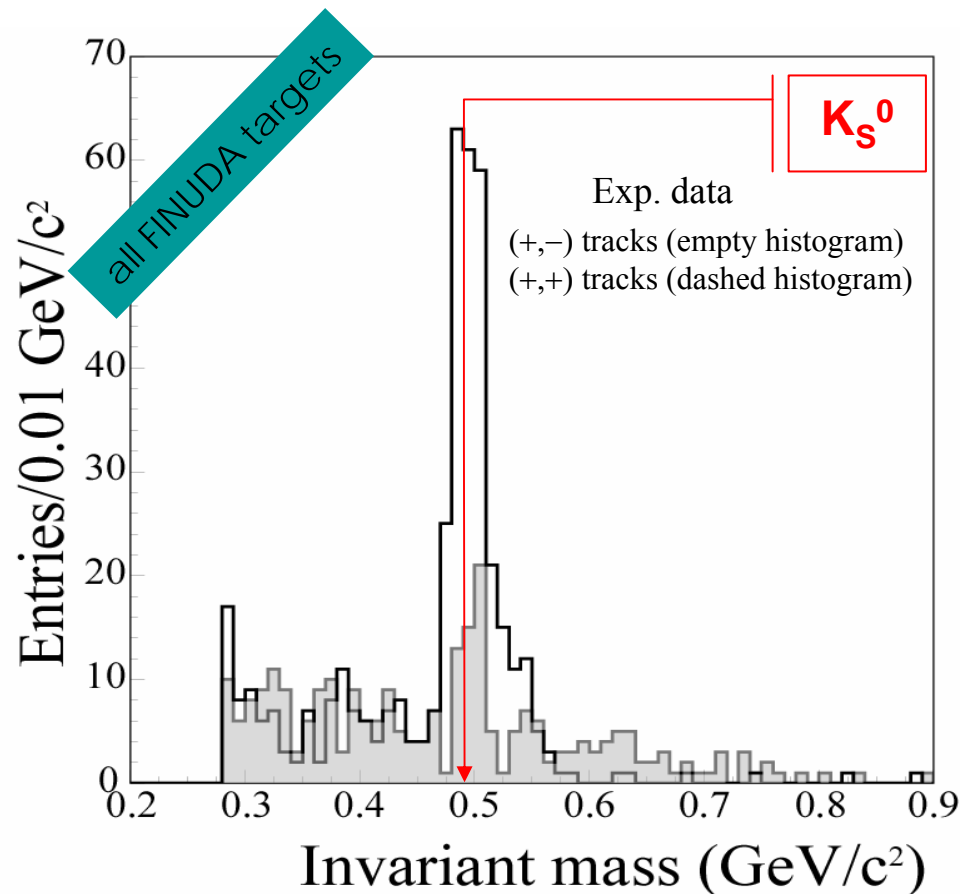
The presence of the reactions: $K^+_{\text{stop}} \rightarrow \pi^+\pi^0$, $\pi^0 \rightarrow \gamma\gamma$, $\gamma+A \rightarrow A'e^+e^-$ can generate **spurious peaks** close to the mass of K^0_S .



Electromagnetic background (2)

The presence of the reactions
 $K^+_{\text{stop}} \rightarrow \pi^+\pi^0$, $\pi^0 \rightarrow \gamma\gamma$,
 $\gamma + A \rightarrow A'e^+e^-$ has been proven
with data by looking at π^+e^+ pair

π^+e^+ distribution is depleted by
lower acceptance

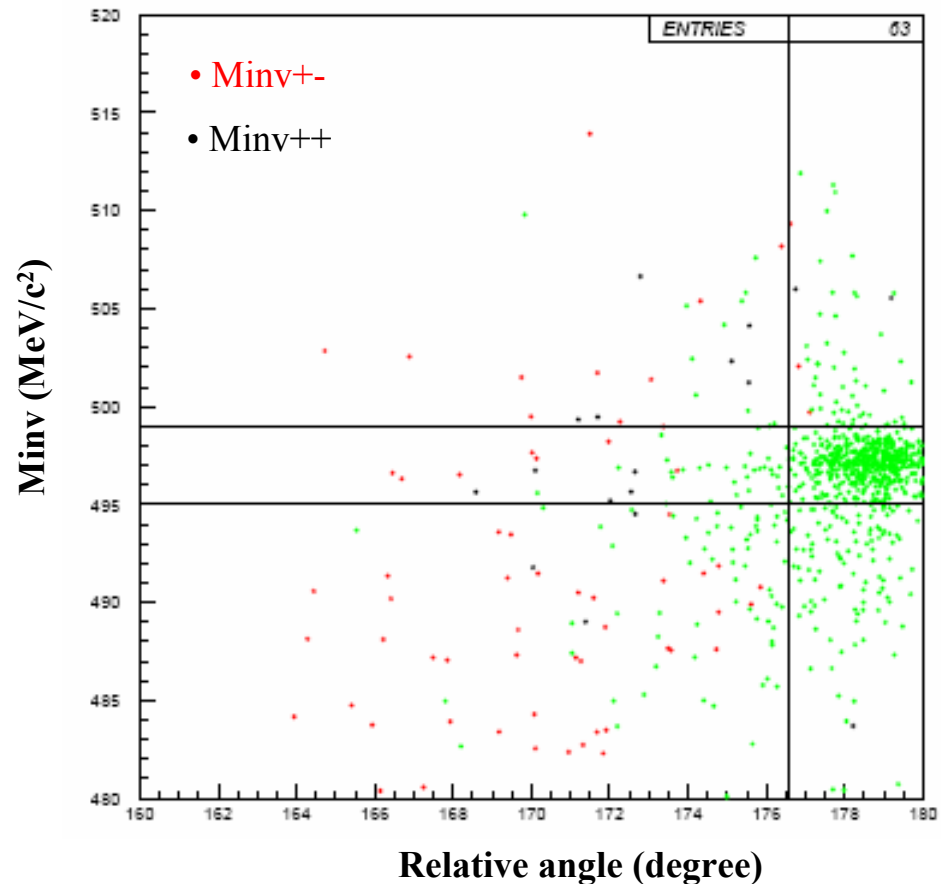


Signal region vs background

Monte Carlo studies of invariant mass $\pi^+ e^-$ and $\pi^+ e^+$ vs their relative angle from the reactions:

$$K^+_{\text{stop}} \rightarrow \pi^+ \pi^0, \pi^0 \rightarrow \gamma\gamma, \\ \gamma + A \rightarrow A' e^+ e^-$$

Finuda K_S^0 resolution $\pm 2 \text{ MeV}/c^2$ and imposing $\pi^+ \pi^-$ from a K_S^0 almost at rest gives a **signal region** of **494-502 MeV/c^2** and **176°-180°** background free at 95% C.L.

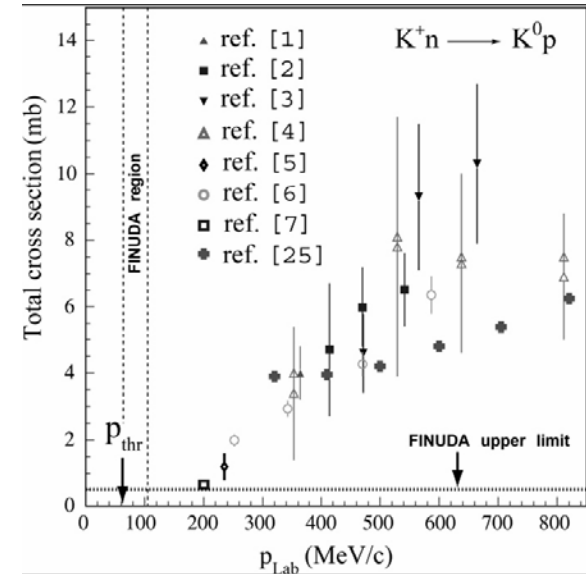
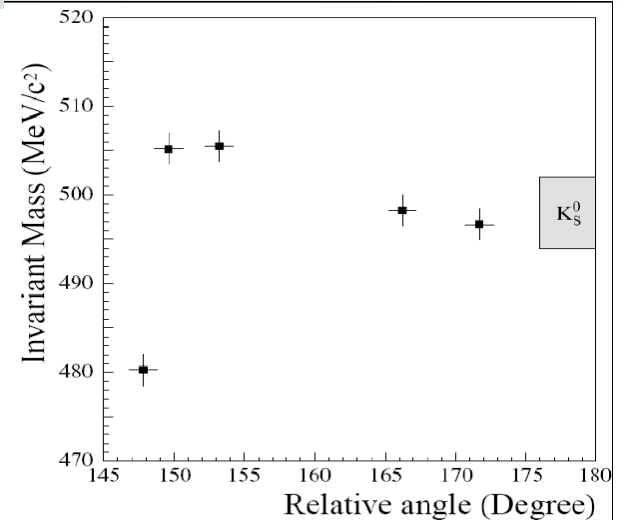


Results of 2003/2004 run

$${}^7\text{Li}(\text{K}^+, \text{K}_s^0){}^7\text{Be}$$

- ❑ no candidate events have been found in the signal region
- ❑ @ $P_{\text{Lab}} \approx 90 \text{ MeV/c}$
 $\sigma < 1 \text{ mb}$ at 68% C.L.
 $\sigma < 2 \text{ mb}$ at 95% C.L.
- ❑ σ for the elementary process is in agreement with extrapolation of data at higher momentum, assuming σ proportional to the number of nucleons

FINUDA PLB 649 (2007) 25-30



2006/2007 run

Run 2003/2004: $\int L \sim 220 \text{ pb}^{-1}$



Run 2006/2007: $\int L \sim 964 \text{ pb}^{-1}$

- **4 targets** (2 of ^7Li , 1 of D_2O , 1 of ^{13}C)
 - $\text{K}^+ + ^7\text{Li} \rightarrow \text{K}^0 + ^7\text{Be}$
 - $\text{K}^+ + ^{13}\text{C} \rightarrow \text{K}^0 + ^{13}\text{N}$
 - $\text{K}^+ + \text{d} \rightarrow \text{K}^0 + \text{p} + \text{p}$

Can be studied with:

- Refined MC simulation of $(\text{K}^+\text{K}_\text{s}^0)$ reaction
- K_s^0 secondary vertex reconstruction
- Prompt events from TOF to reject delayed π from K^+ decay
- Internal μ -strip signal to tag background

Nuclear target		Integrated Luminosity (run 2006-2007)	Sensitivity Events/ 1 mb
^6Li		Below Threshold	
^9Be		Below Threshold	
^7Li		1.13617×10^{29}	~ 13.6
^{13}C		1.42054×10^{29}	~ 17.0
^7Li		1.66538×10^{29}	~ 12.0
D		2.81157×10^{28}	~ 5.0
^9Be		Below Threshold	
^6Li		Below Threshold	

Summary and future plans

- Events due to the charge exchange reaction induced by slow K^+ have been searched for the **first time** in the **near threshold** region
- **Cross section** for ${}^7\text{Li}(K^+, K_s^0){}^7\text{Be}$ reaction **< 1-2 mb**
- In the second FINUDA run, we are able to study this reaction with **tenfold more statistics** and we have access also to other nuclei: ${}^2\text{H}$ and ${}^{13}\text{C}$ in the momentum region from their thresholds to $\approx 100 \text{ MeV}/c$.