Toward a $K_L$ program at JLab

Simon Taylor / JLab
May 17, 2016

- Motivation for a $K_L$ beam
- Existing measurements
- Hall D beam line and GlueX apparatus
- Preliminary simulation results
Constituent Quark Model successful framework for mapping out 3-quark baryon states

But there are many predicted but missing states...

Hyperons (Λ's, Σ's, Ξ's, Ω's) are less well-understood than N^*'s, Δ's

What about hybrids (states with “valence glue”) and multi-quark(>3) states?
Lattice QCD results

Thick borders: hybrid states

$\Xi^*$ and $\Omega^*$ status

Situation for $\Omega$'s is worse: only one well-known state...

Black bars: quark model calculations

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Reactions of interest

Elastic and charge-exchange

Two-body with $S=-1$

- $K_L^0 p \rightarrow K_S^0 p$
- $K_L^0 p \rightarrow K^+ n$

Two-body with $S=-2$

- $K_L^0 p \rightarrow \pi^+ \Lambda$
- $K_L^0 p \rightarrow \pi^+ \Sigma^0$

Three-body with $S=-2$

- $K_L^0 p \rightarrow K^+ \Xi^0$
- $K_L^0 p \rightarrow K^+ \Xi^0^*$

Three-body with $S=-3$

- $K_L^0 p \rightarrow \pi^+ K^+ \Xi^-$
- $K_L^0 p \rightarrow \pi^+ K^+ \Xi^-^*$

- $K_L^0 p \rightarrow K^+ K^+ \Omega^-$
- $K_L^0 p \rightarrow K^+ K^+ \Omega^-^*$

Existing data with $K_L$ beam is sparse ... especially for polarization measurements.
Differential cross sections

\[ \frac{d\sigma}{d\Omega} = \chi^2(|f|^2 + |g|^2) \]

To extract resonance parameters, need coupled-channel Partial Wave Analysis...

\[ f(W, \theta) = \sum_{l=1}^{\infty} [(l+1)T_{l+} + lT_{l-}]P_l(\cos \theta) \]

\[ g(W, \theta) = \sum_{l=1}^{\infty} [T_{l+} - T_{l-}]P_l^1(\cos \theta) \]

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Polarization observables

\[ P \frac{d\sigma}{d\Omega} = 2\lambda^2 \text{Im}(fg^*) \]

\[ f(W, \theta) = \sum_{l=1}^{\infty} [(l+1)T_{l+} + lT_{l-}] P_l(\cos \theta) \]
\[ g(W, \theta) = \sum_{l=1}^{\infty} [T_{l+} - T_{l-}] P_l^1(\cos \theta) \]
Simulation with GlueX:
1 day at $10^4 K_L$/s

Jackson, Oh, Haberzettl, Nakayama
CEBAF and Hall D complex

Diamond Radiator
Tagger Magnet
Hodoscope
Electron beam / dump
μ-scope
γ-polarimeter

Solenoid-Based detector

New Hall-D
γ
D
CEBAF at 12 GeV

Counting House

PS Pair

Spectrometer

Photon Beam dump

Hall D

75 m
Photon beam source

**K_L** program requires high photon flux

- Using existing radiator/tagger configuration with thicker radiator not feasible
  - Dose rates and activation would be unacceptable
- Solution:
  - "Compact Gamma Source"

![Diagram showing electron beam and tungsten radiator](image)
Beam line into Hall D

- Sweeping magnet
- Be
- Pb
- Collimator area
- Hall D
- Liquid hydrogen target
- Spectrometer
- Collimators
- Wall
- L 40cm
- L 15cm
- 16...20m to target
**K\textsubscript{L} beam**

- \(\phi(1020)\) decays are a good source for \(K\textsubscript{L}\)'s
  - \(BR(\phi \rightarrow K\textsubscript{L}K\textsubscript{S}) = 34\%\)
  - Photoproduction cross section \(\sim 500\) nb @ 5 GeV

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\[\gamma \text{ beam} \rightarrow K\textsubscript{L} \rightarrow \phi\]

- 5 \(\mu\)A e\textsuperscript{-} beam, 5\% radiation length radiator \(\rightarrow \sim 7000\) \(K\textsubscript{L}\)/s on GlueX target

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Neutron background

Yields in Be

Rate Hz / 50 MeV

neutrons DINREG, with Pb shield
neutrons DINREG
Klongs
neutrons Pythia

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P (GeV/c)
Cryogenic target

Polarized target feasible: butanol (C$_4$H$_{10}$O) frozen spin

Existing LH2 target

Conceptual design for K$_L$ program

C. Keith
The GlueX detector

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Particle identification

Energy loss in drift chambers, time-of-flight to outer detectors

(simulated $K_L p \rightarrow pK_S$ events)
Example: $K_L p \rightarrow p K_S$

Using $K_L$ flight time

$K_S \rightarrow \pi^+ \pi^-$

(BR=69.2%)
Red points: $W$ derived from $K_L$ flight time
Blue points: invariant mass of final state particles
Projected statistical uncertainties

$K_L p \rightarrow p K_S$

Expected cross sections + uncertainties in 100 days

$K_L p \rightarrow \Lambda \pi^+$

Expected cross sections + uncertainties in 100 days

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KL2016 workshop proceedings:
https://arxiv.org/abs/1604.02141

Talks are online:
https://www.jlab.org/conferences/kl2016/program.html
Summary

- Constituent Quark Models and lattice calculations predict a large number of hyperon states yet to be seen experimentally.
  - $K_L$ beam can provide access to these states.

- An experimental program using $K_L$ beam is feasible in Hall-D using the GlueX detector.