The K_{Long} Facility in Hall D at Jefferson Lab

Exotic Hadron Spectroscopy

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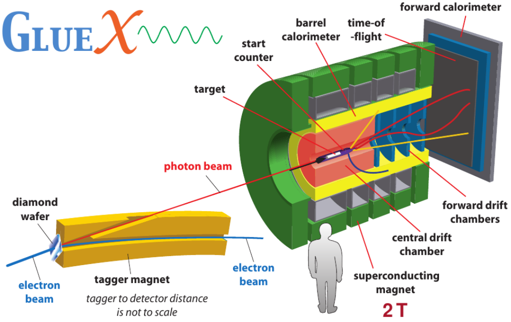
CEBAF

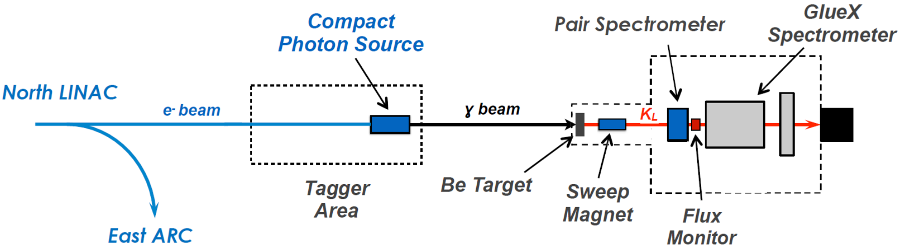
- **C**ontinuous **E**lectron **B**eam **A**ccelerator **F**acility
- Superconducting RF accelerator
- Anti-parallel double linac, 7/8 of a mile in circumference
- Electron beam energies up to 12 GeV
- Diverse experimental program in four halls
- High-current Electron beams in Halls A and C
- Large acceptance detectors in Halls B and D
- Secondary beams available (real photons) and proposed (K_{Long})

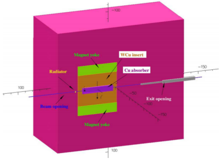
Hall D

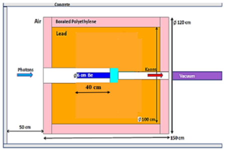


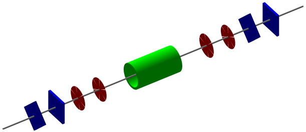
- 12 GeV electron beam produces real photon beams up to 9 GeV via Bremsstrahlung
- Charged and neutral particle detection in a hermetic solenoid-based detector
- Uniform acceptance
- GlueX is a meson spectrosopy experiment, but hall and equipment used for other experiments

K_{Long} Facility in Hall D



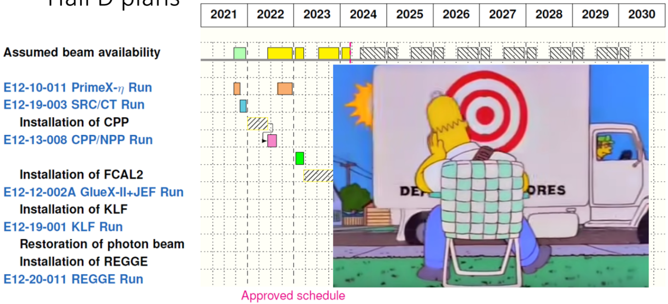


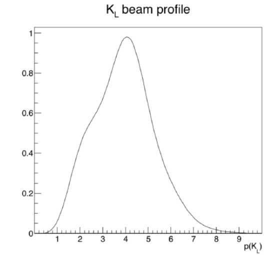


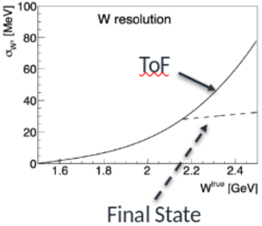


Planning and Schedule

Hall D plans



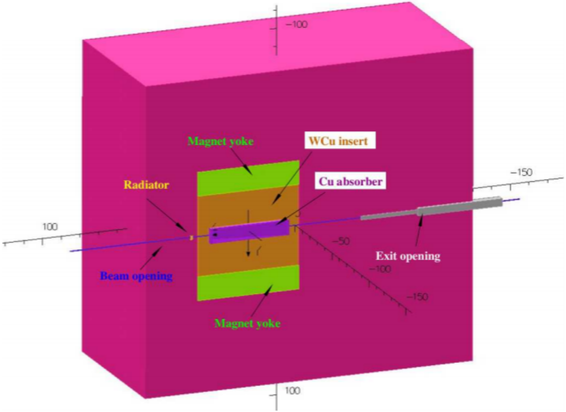




- Intense kaon beam on target
- Proton and neutron targets (100 days approved)
- Low background
- Exclusive final states

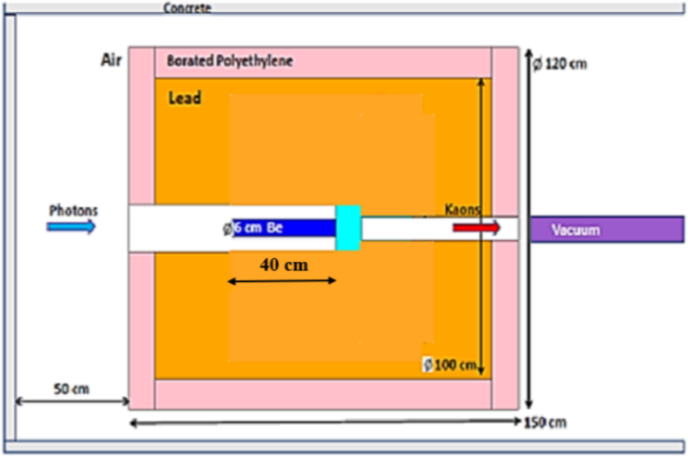
Compact Photon Source

- Tertiary K_{Long} beam, first produce photons from CEBAF electrons

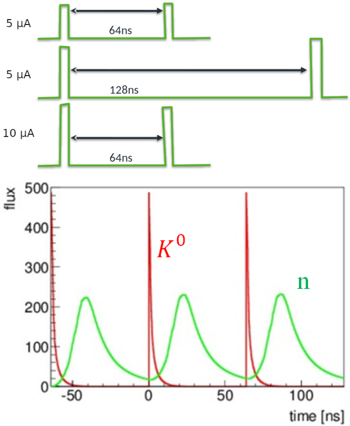


K_{Long} Production

- Photons from CPS impinge on a Be target, producing K_{Long} beam



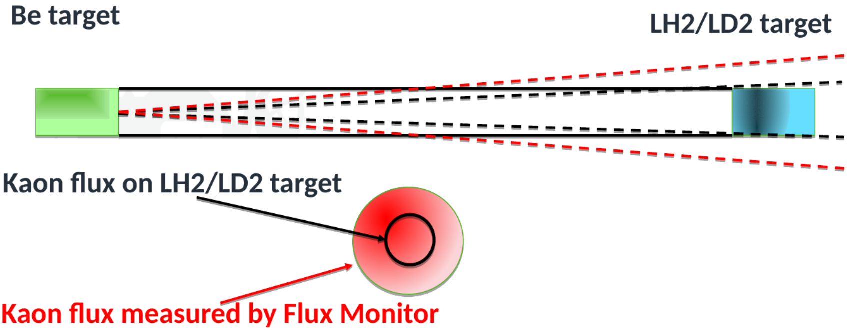
Time Structure of K_L Beam



- CEBAF beam typically has a 2 ns beam bucket structure
- However, high beam current required for K_{Long} production (5-10 nA)
- Use higher harmonics of CEBAF, with more current per bunch
- One effect of this is to separate neutron background in K_L beam

Measuring K_{Long} Flux

- Flux of diverging K_{Long} beam can be measured by careful choice of flux monitor location
- Flux at target can be inferred from measuring K_{Long} decays (if no information lost in beampipe)

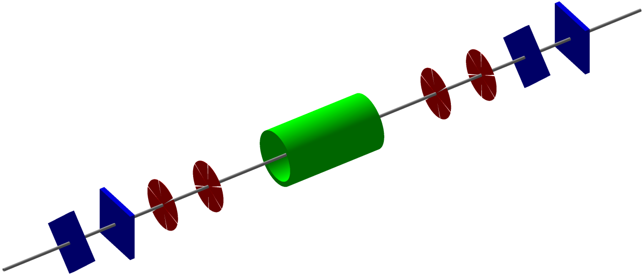


K_L Decays

Decay	BR (%)
$K_L \rightarrow \pi^{\pm} e^{\mp} \nu_e$	40.55
$K_L \rightarrow \pi^{\pm} \mu^{\mp} \nu_{\mu}$	27.04
$K_L \rightarrow \pi^{+} \pi^{-} \pi^{0}$	12.54
$K_L \rightarrow \pi^{0} \pi^{0} \pi^{0}$	19.52

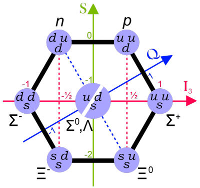
- Roughly 21% of Kaons decay in flight
- Any decay with charged particles can be used

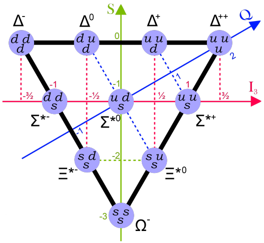
K_{Long} Flux Monitor



- Flux Monitor development led by York
- Straw tube trackers and TOF components under evaluation
- Concept allows for solenoid magnet to enhance capabilities

Hyperons



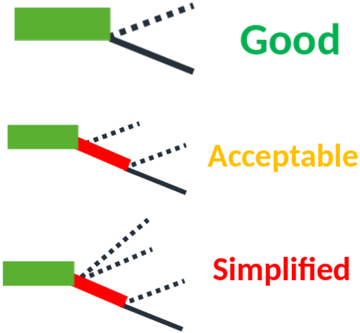


	Predicted (Lattice)	"Observed" (PDG)
N^*	62	21
Δ^*	38	12
Λ^*	71	14
Σ^*	66	9
Ξ^*	73	6
Ω^*	36	2

R.G. Edwards et al. Phys Rev D87 (2013) 054506

Hyperons

Kaon beam brings one unit of strangeness

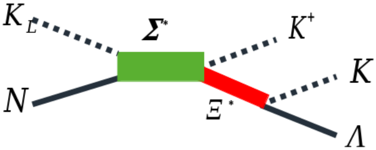


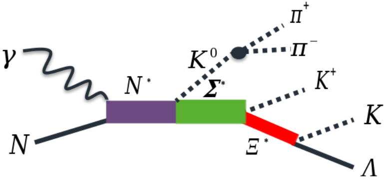
No associated kaons for Λ^*,Σ^* production

1 associated kaon for Ξ^*

2 associated kaons for Ω^*

Strange Beams





Sigma Factory

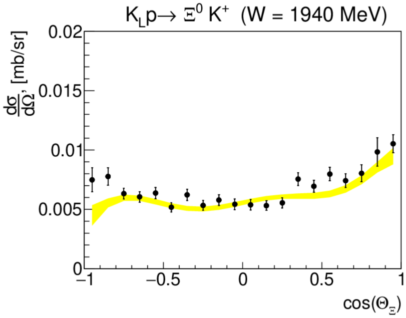
$$K_L p \to \Sigma^* \to K_S p$$
$$K_L p \to \Sigma^* \to \pi^+ \Lambda$$
$$K_L p \to \Sigma^* \to K^+ \Xi^0$$
$$K_L p \to \Sigma^* \to \pi^0 \Sigma^+$$
$$K_L p \to \Sigma^* \to \eta \Sigma^+$$
$$K_L p \to \Sigma^* \to \omega \Sigma^+$$
$$K_L p \to \Sigma^* \to \eta' \Sigma^+$$

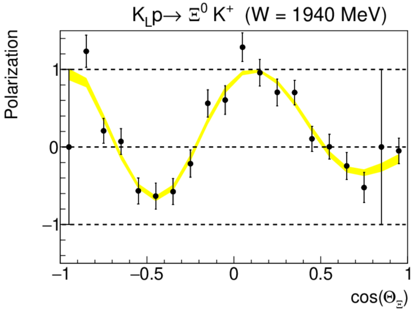
- 2 body final state
- Pure Σ^* channels
- Self-polarising observables

$K_L p \to K^+ n$ Non-resonant background

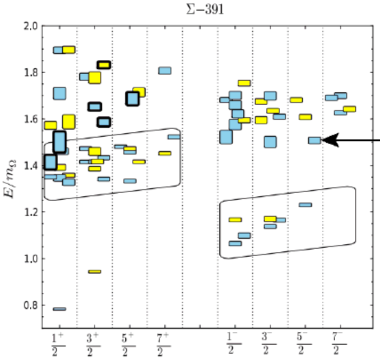
Expected Results

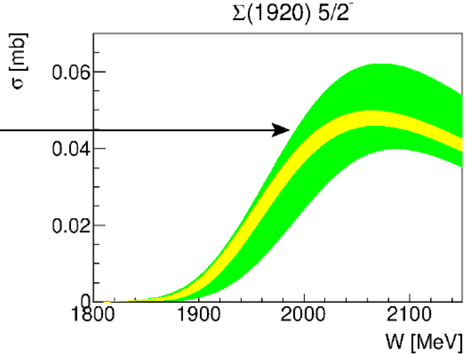
$$K_L p \to K^+ \Xi^0$$





Expected Results

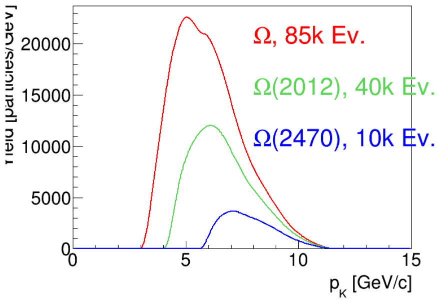


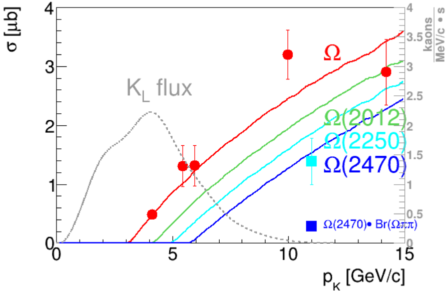


Green = 20 days running Yellow = 100 days running

Omega States

Expected Yields and Cross Sections for Ω^* states





Sectors

Strangeness can bridge the light and heavy quark sectors

- Many thresholds
- Cusps
- Molecules
- Dynamic Resonances

Light Sector

Pros

- High Statistics
- Easy to produce

Cons

- Too broad
- Too many interferences

Strange Sector

Pros

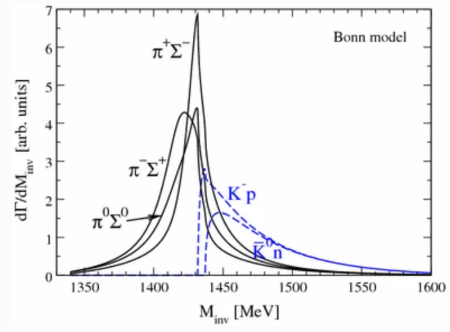
- High Statistics
- Easy to produce with K_L
- Width just right
- Good spacing

Heavy Sector

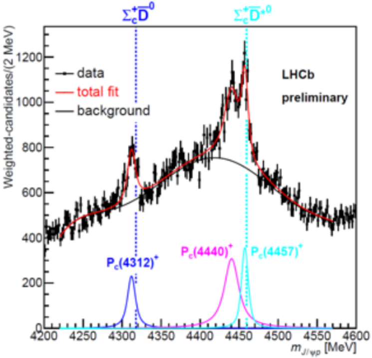
Cons

- Low Statistics
- Hard to produce
- Too narrow

Sectors

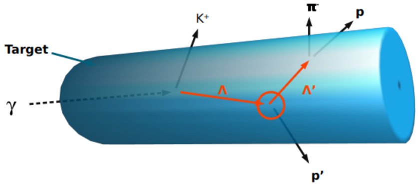


$\Lambda(1405)$ - $\pi\Sigma/\bar{K}N$ molecule



P(4450) - $D^*\bar{\Sigma}_C$ molecule

Hyperon-nucleon Scattering



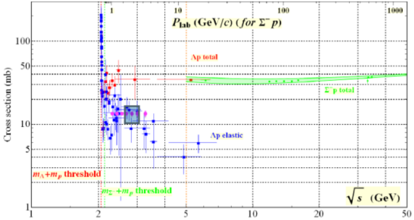
Cross Sections

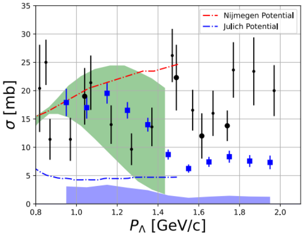
- Λp
- $\Sigma^- p$
- $\Sigma^+ p$
- Λd

Polarisation Observables

- Λn
- $\Sigma^- p$
- Λd
- Λp

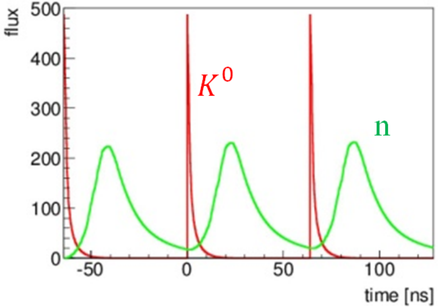
Phys. Rev. Lett 127 272303 (2021)

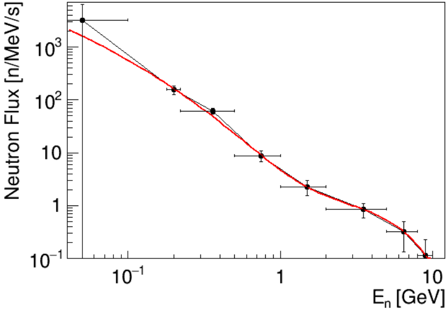




Neutron Beams

Recall the K_{Long} beam has neutron background



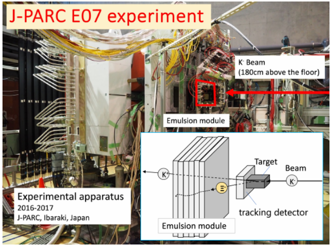


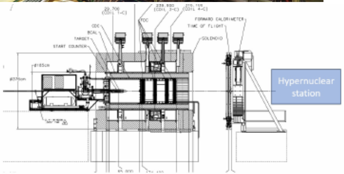
- Could use low energy neutrons for studies of nuclear structure

Hypernuclei

K_{Long} beam can be used to produce hypernuclei

- Nuclear emulsion technology enables high-resolution tracking
- Used at J-PARC with K^- beam
- Hypertriton binding energy measurement
- Similar setup being proposed for inclusion in KLF program





Conclusions and Outlook

- Development of a K_{Long} beam facility is well underway at Jefferson Lab
- This will enable JLab to greatly expand its physics program, leveraging strangeness to new extremes
- University of York has a leading role;
  - Design of the Kaon Flux Monitor
  - Simulation studies of several reactions
  - New ideas to expand the scope of the project

Future Developments

- JLab are actively investigating a 22 GeV upgrade to CEBAF, running KLF at these energies could push into Ω production studies
- Upgrades to flux monitor capabilities (solenoid magnet, bespoke trackers, optimisations of existing design) would improve expected uncertainties, and provide additional physics capabilities, e.g. search for rare kaon decays
- Leveraging existing strangeness datasets, e.g. the very strange experiment at CLAS12 (A. Acar, this morning), will help direct future analyses