Toward a K_L program at JLab

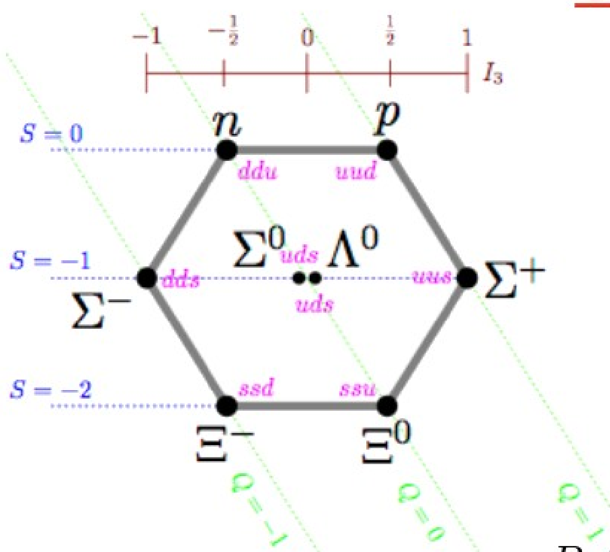
Simon Taylor / JLab

May 17, 2016

- Motivation for a K_L beam
- Existing measurements
- Hall D beam line and GlueX apparatus
- Preliminary simulation results

Motivation

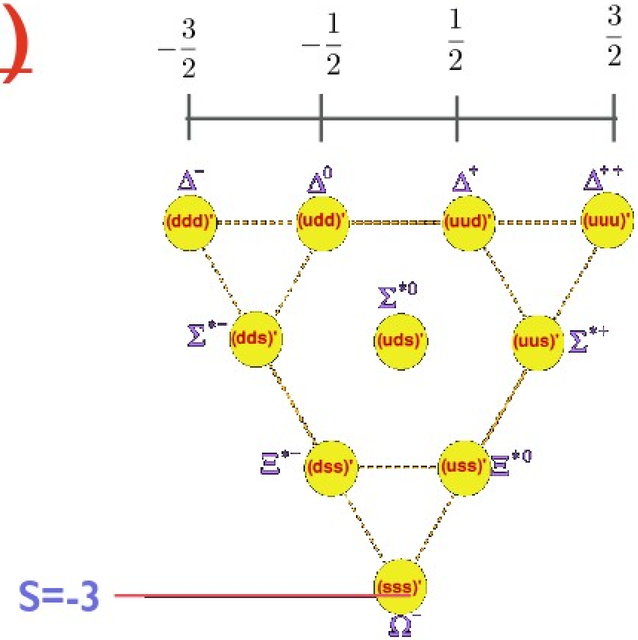
Octet



SU(3)

$$Q = I_3 + \frac{B+S}{2}$$

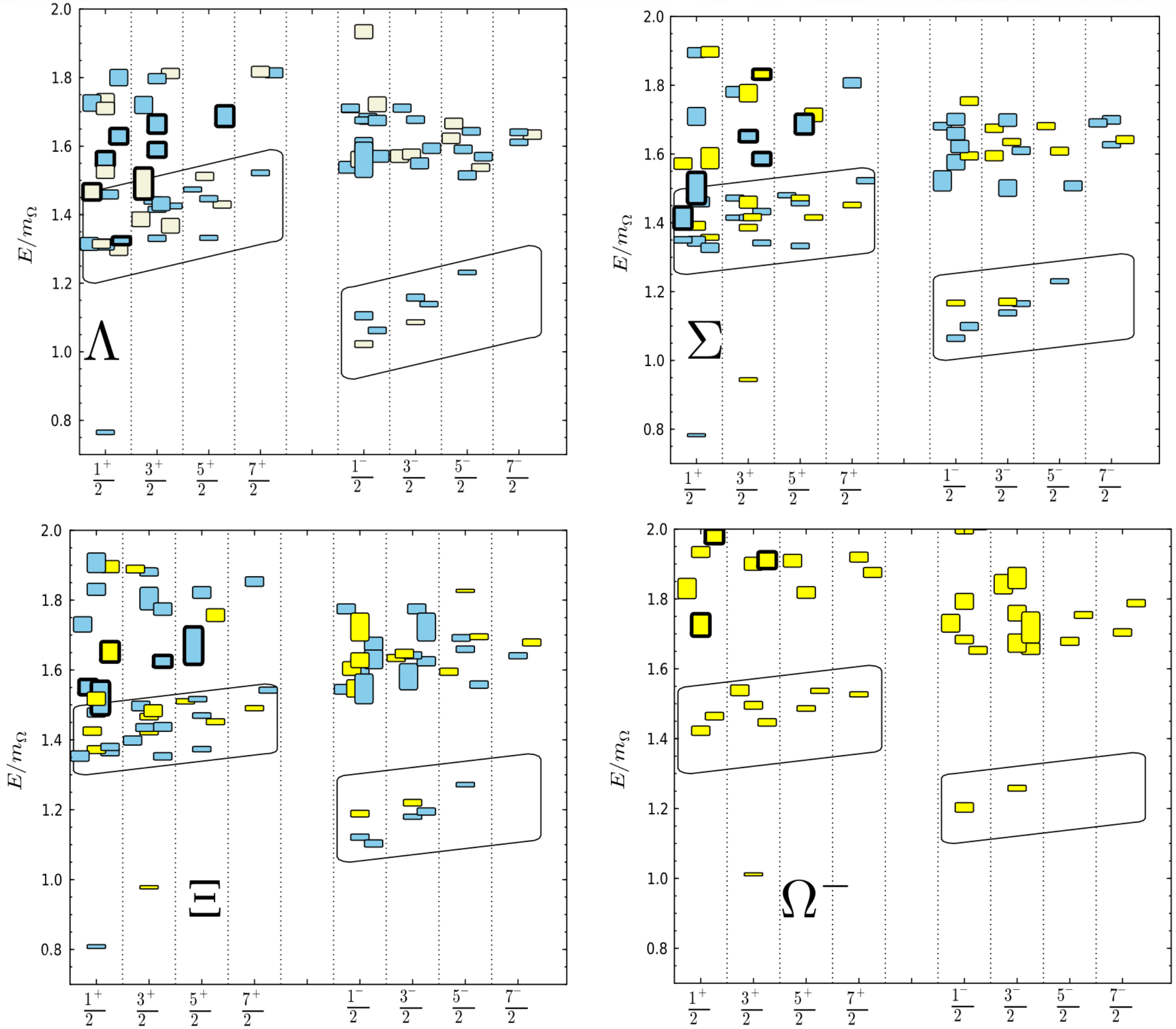
Decuplet



- 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

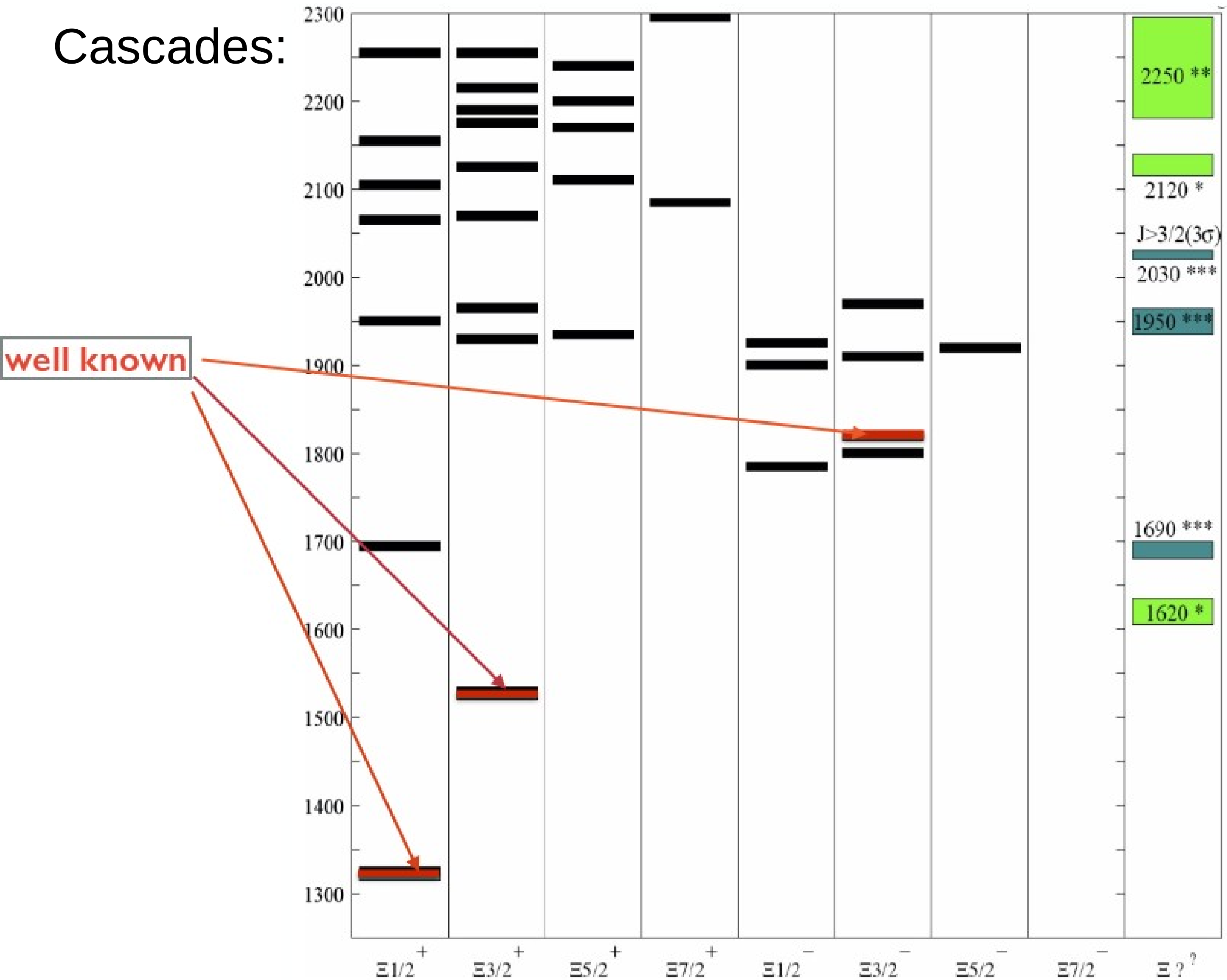
Thick borders: hybrid states



Edwards, Mathur, Richards and Wallace, Phys. Rev. D 87, 054506 (2013)

Ξ^* and Ω^* status

Cascades:



- Situation for Ω's is worse: only one well-known state...

Black bars: quark model calculations

Reactions of interest

Elastic and charge-exchange

$$K_L^0 p \to K_S^0 p$$
$$K_L^0 p \to K^+ n$$

Two-body with S=-1

$$K_L^0 p \to \pi^+ \Lambda$$
$$K_L^0 p \to \pi^+ \Sigma^0$$

Two-body with S=-2

$$K_L^0 p \to K^+ \Xi^0$$
$$K_L^0 p \to K^+ \Xi^{0*}$$

Three-body with S=-2

$$K_L^0 p \to \pi^+ K^+ \Xi^-$$
$$K_L^0 p \to \pi^+ K^+ \Xi^{-*}$$

Three-body with S=-3

$$K_L^0 p \to K^+ K^+ \Omega^-$$
$$K_L^0 p \to K^+ K^+ \Omega^{-*}$$

- *Existing data with K_L beam is sparse ... especially for polarization measurements*

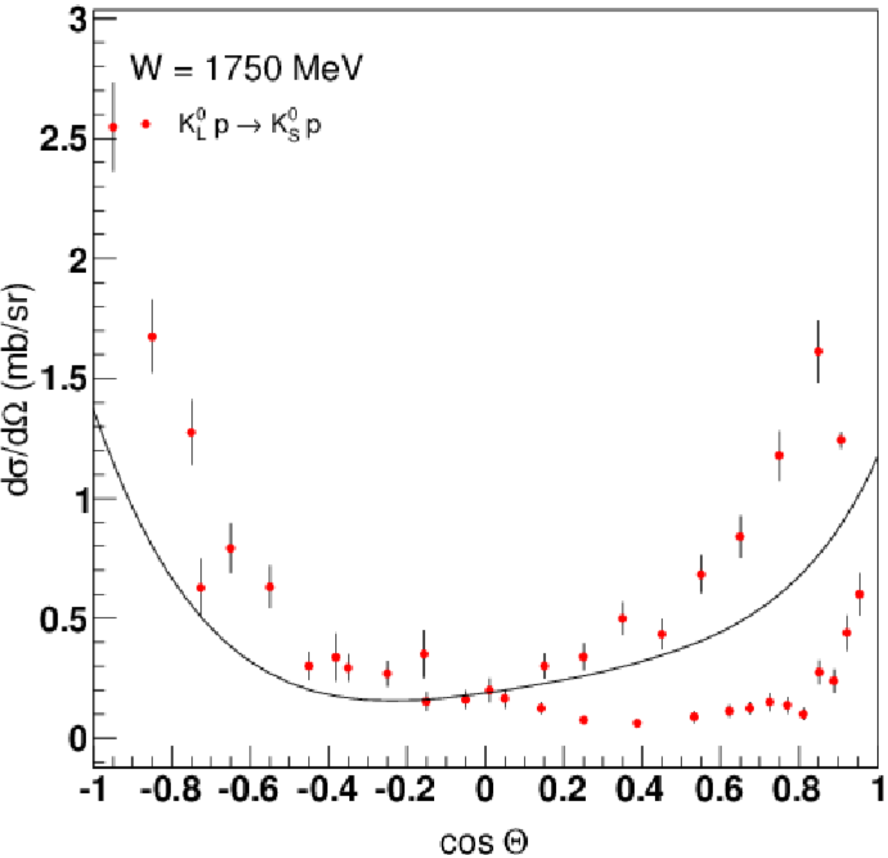
Differential cross sections

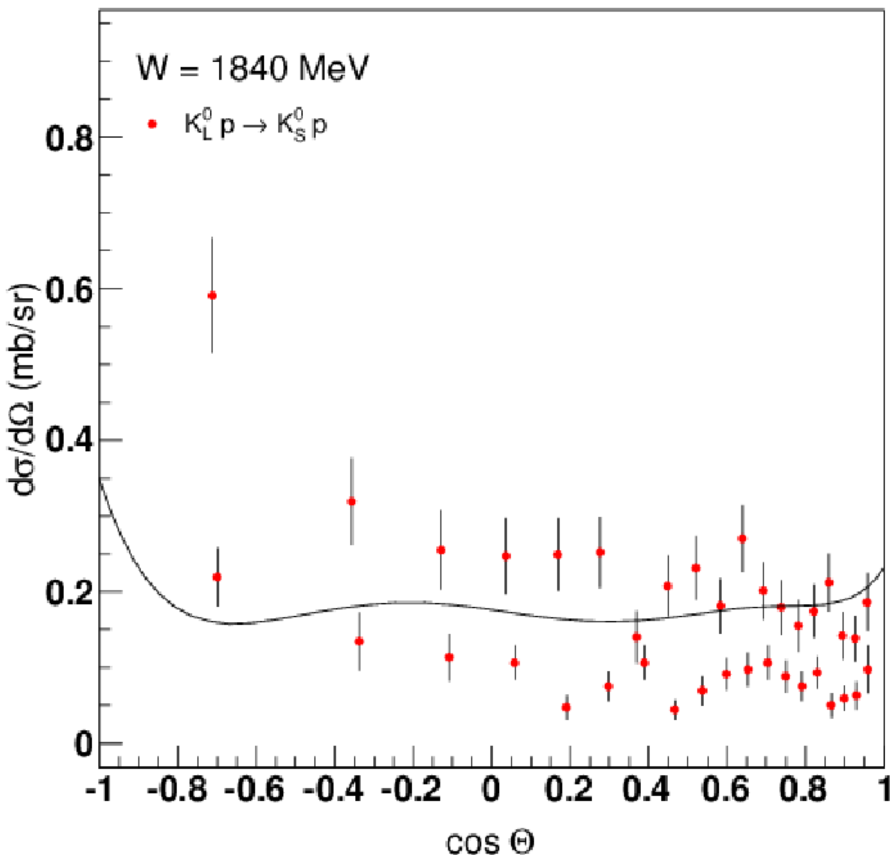
$$\frac{d\sigma}{d\Omega} = \lambda\!\!\!^{-2}(|f|^2 + |g|^2)$$

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

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

D.M.Manley





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

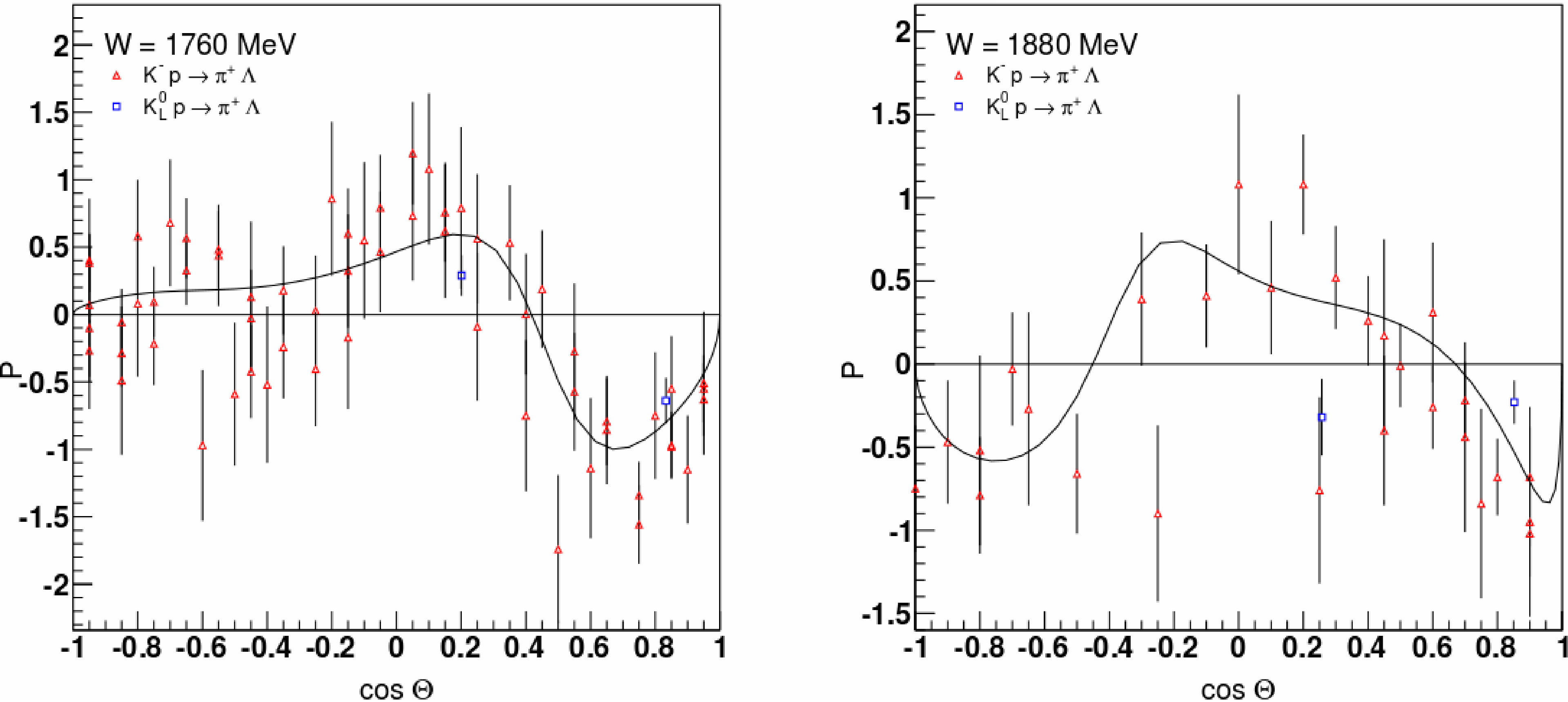
Polarization observables

$$P\frac{d\sigma}{d\Omega} = 2\lambda\!\!\!^{-2}\,\mathrm{Im}(fg^*)$$

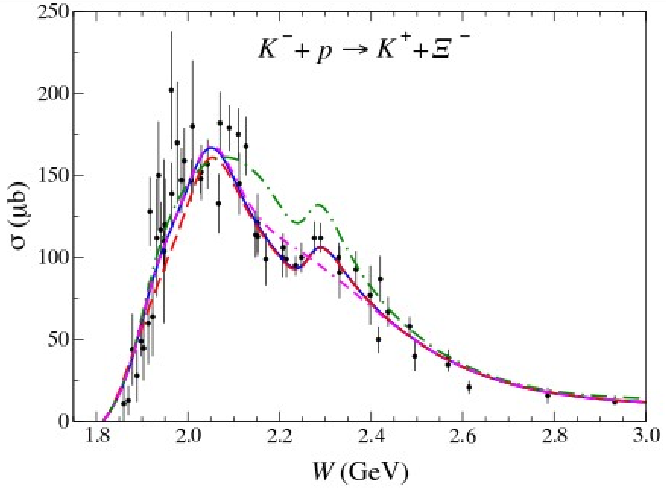
$$f(W,\theta) = \sum^{\infty}[(l+1)T_{l+} + lT_{l-}]P_l(\cos\theta)$$

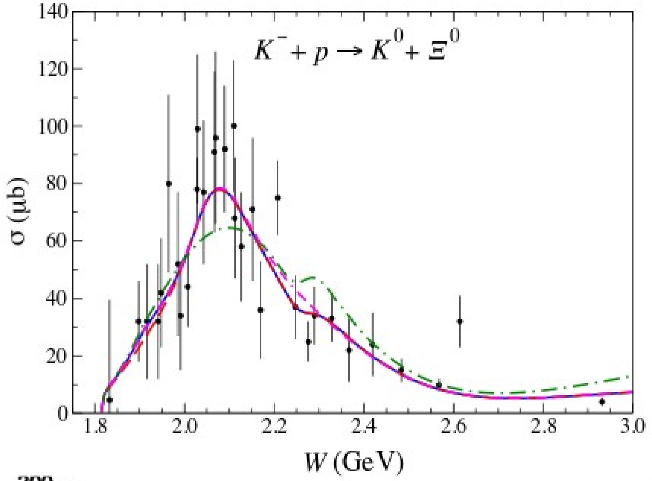
$$g(W,\theta) = \sum_{l=1}^{\infty}[T_{l+} - T_{l-}]P_l^1(\cos\theta)$$

D.M.Manley



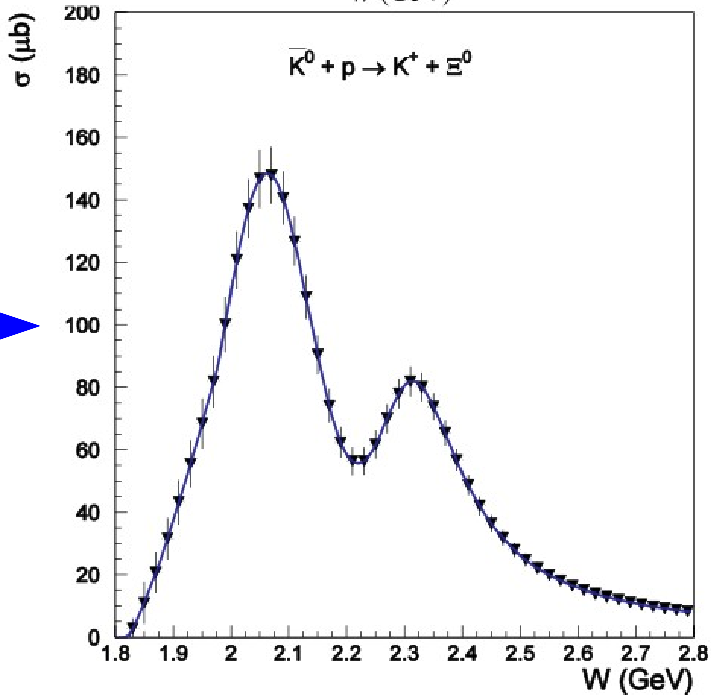
Ξ physics



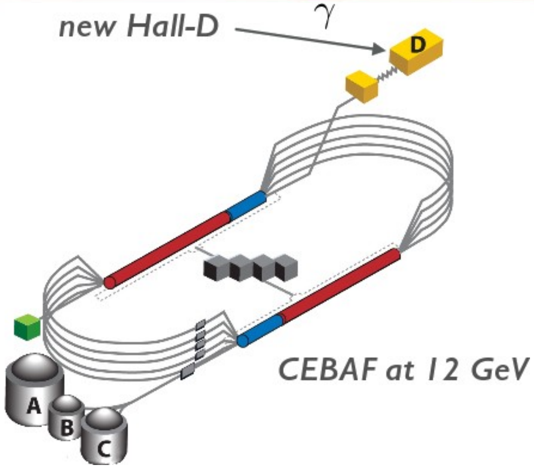


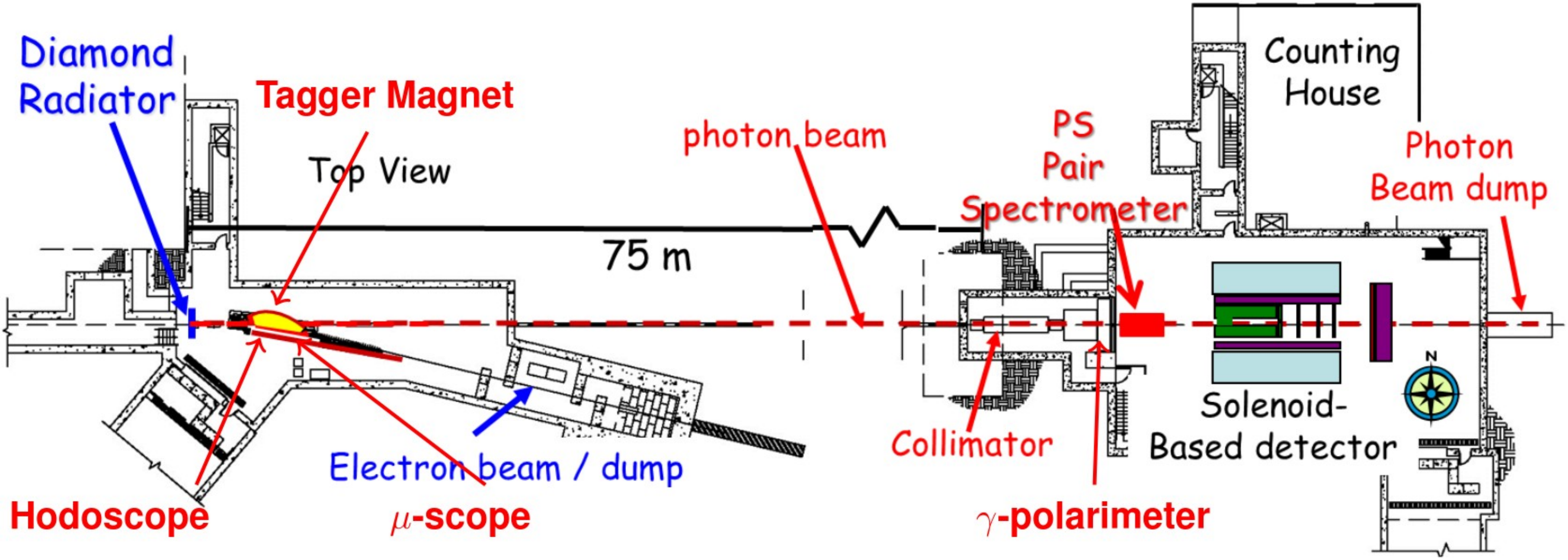
Jackson, Oh, Haberzettl, Nakayama
Phys. Rev. C 91, 065208 (2015)

Simulation with GlueX:
1 day at 10^4 K_L/s

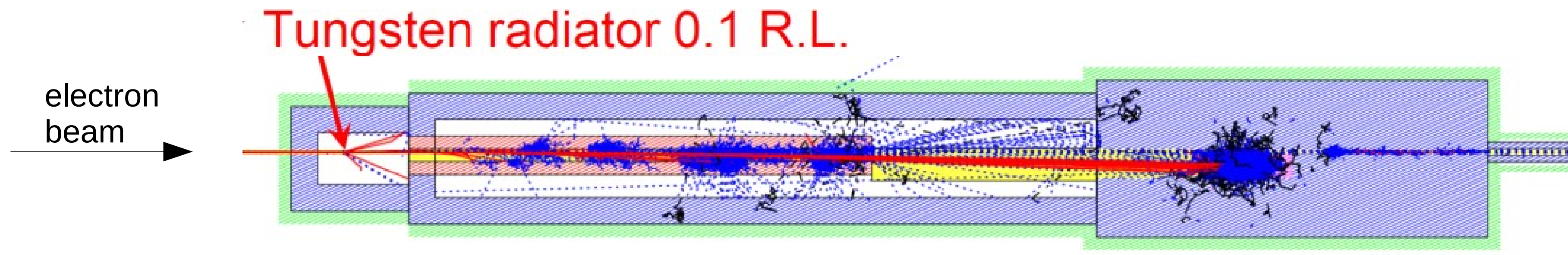


CEBAF and Hall D complex

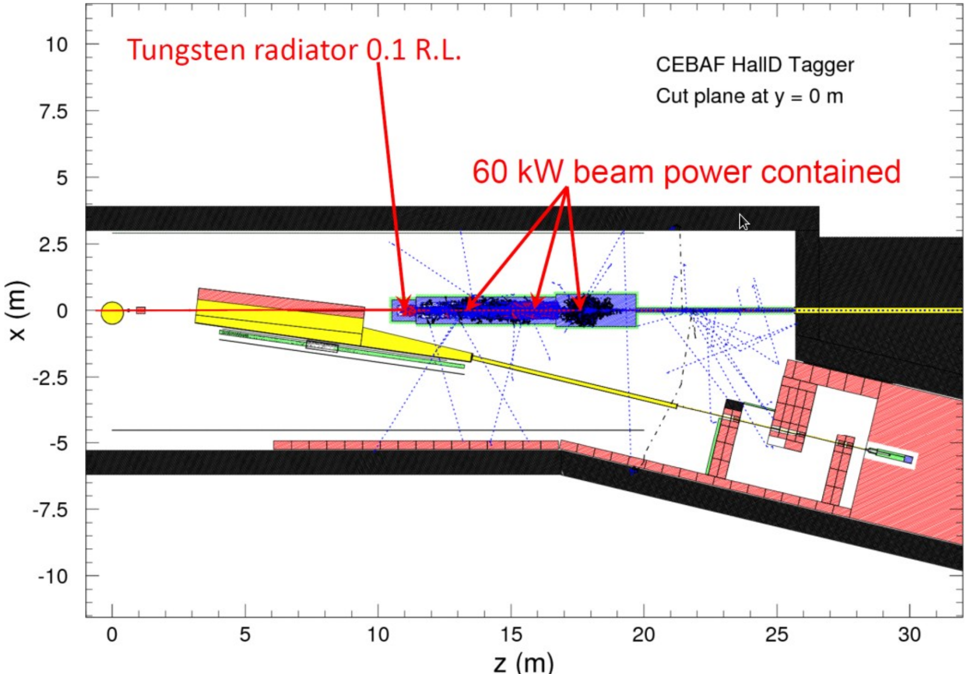




Photon beam source

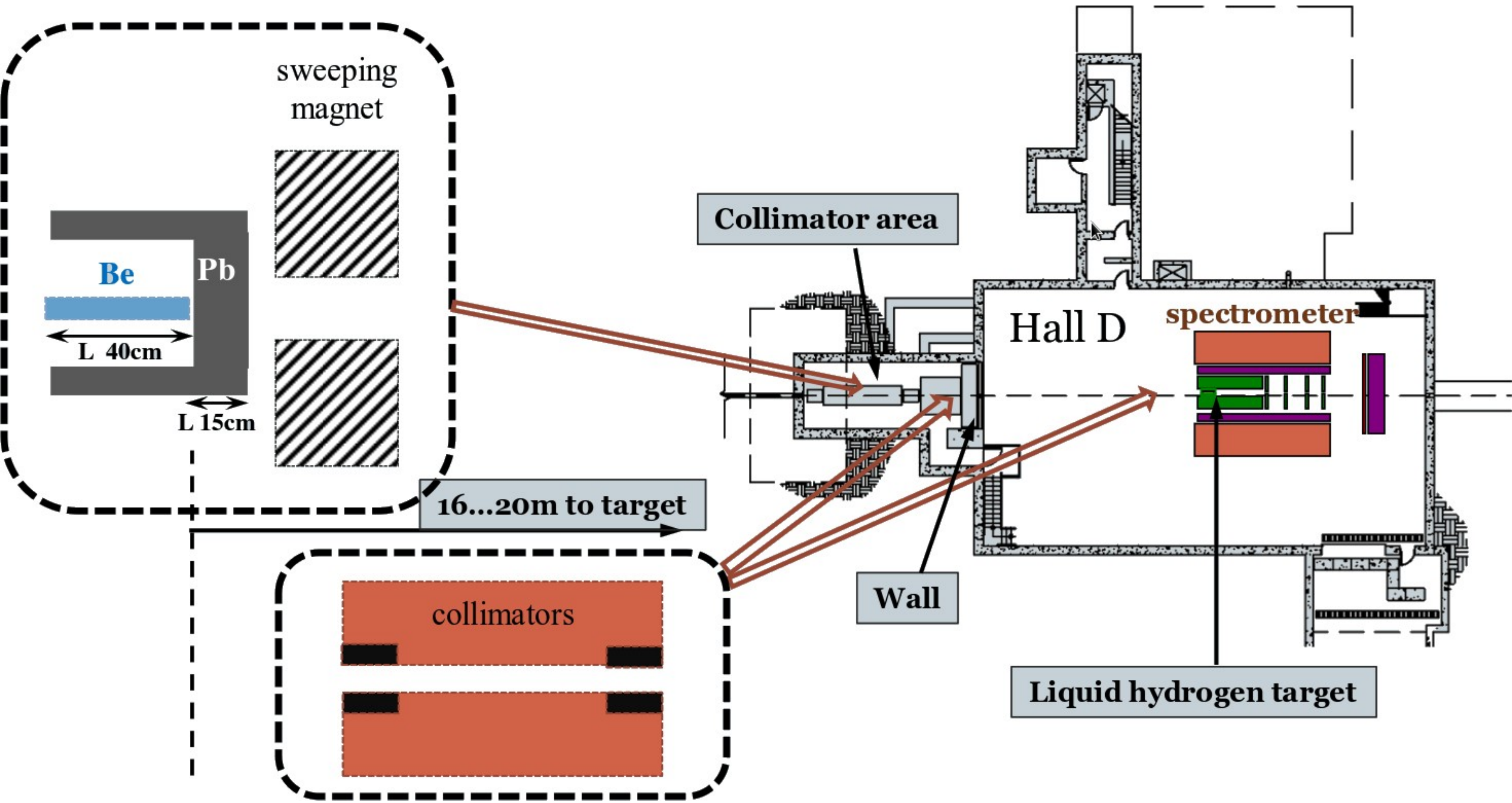


- K_L program requires high photon flux
  - Using existing radiator/tagger configuration with thicker radiator not feasible
    - Dose rates and activation would be unacceptable
  - Solution:
    "Compact Gamma Source"



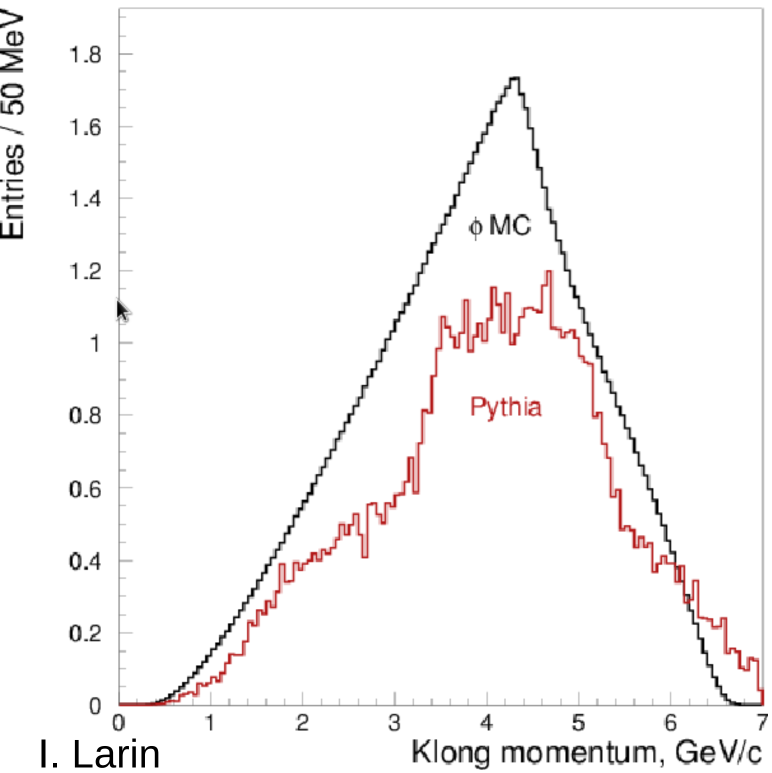
P. Degtiarenko

Beam line into Hall D

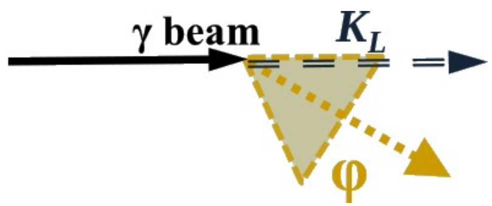


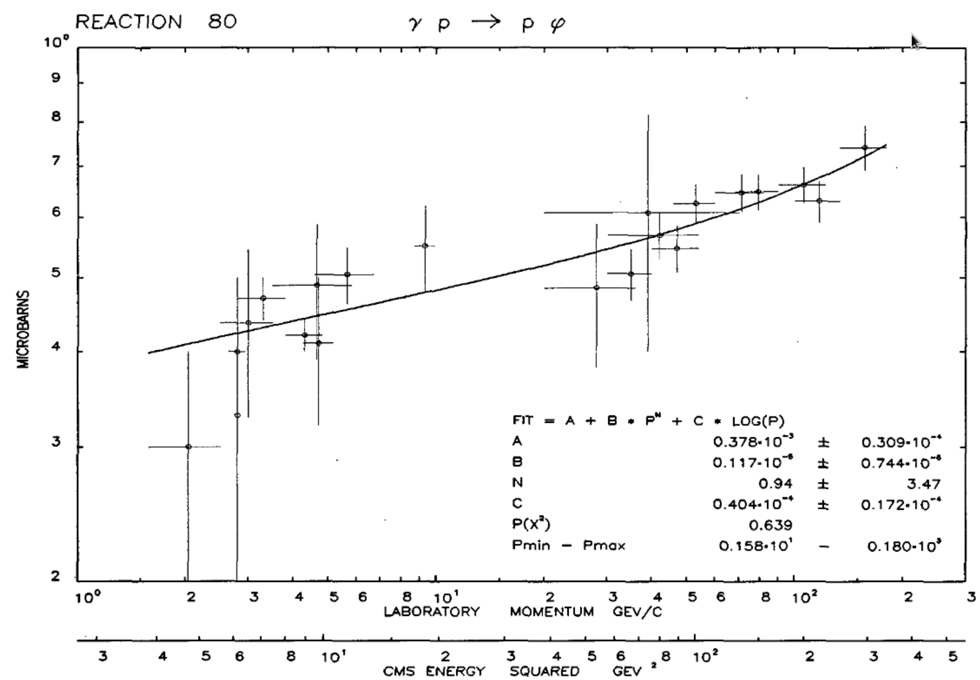
K_L beam

- $\phi(1020)$ decays are good source for K_L's
  - $BR(\phi \to K_L K_S) = 34\%$
  - Photoproduction cross section ~500 nb @ 5 GeV



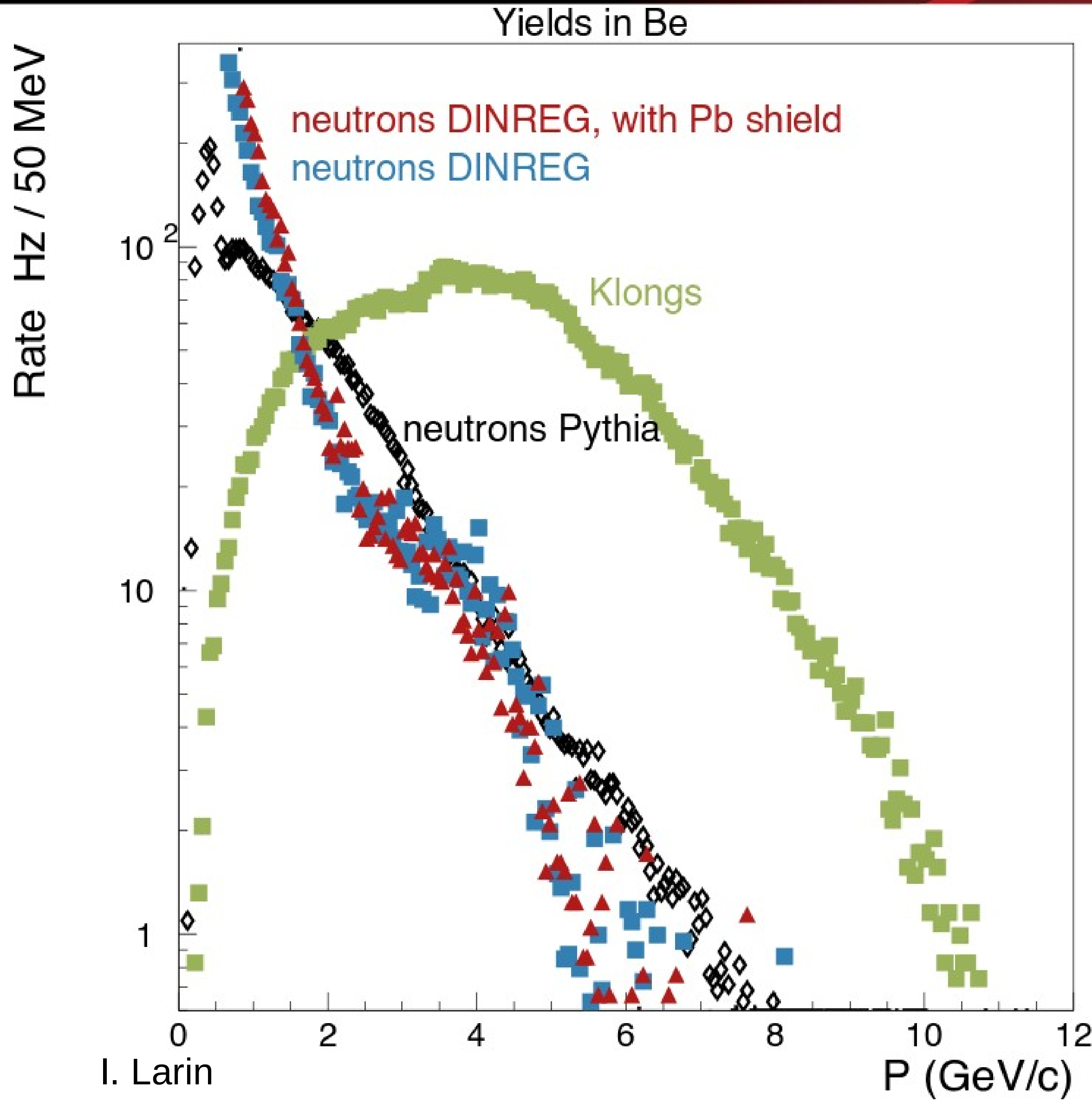
I. Larin





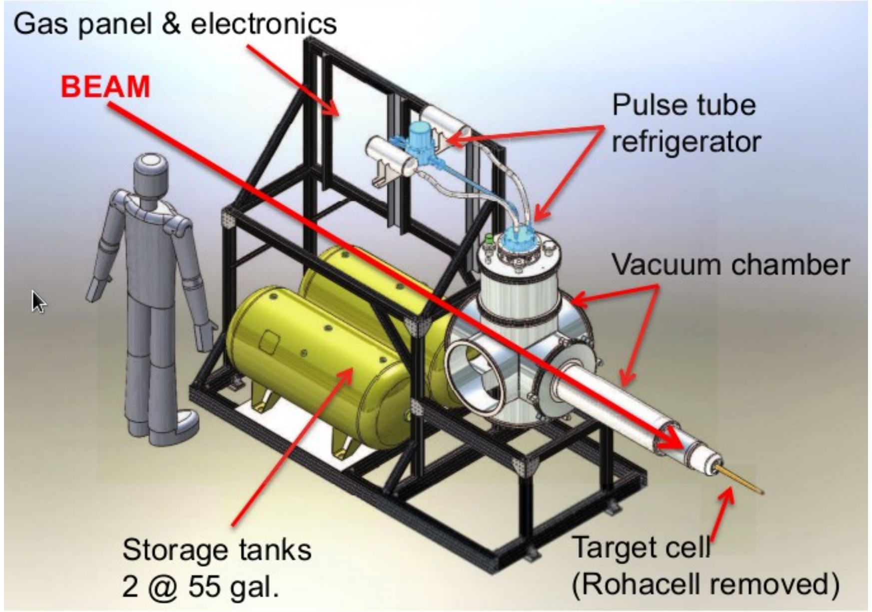
- 5 μA e^- beam, 5% radiation length radiator → ~7000 K_L/s on GlueX target

Neutron background

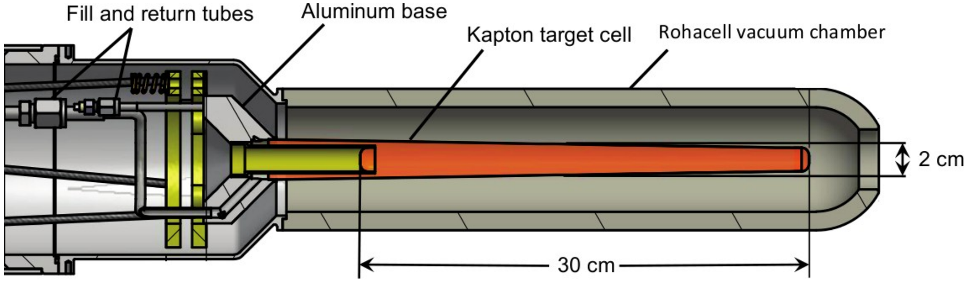


I. Larin

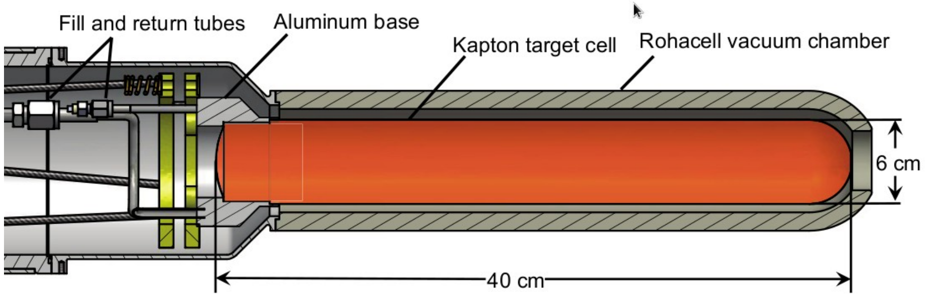
Cryogenic target



Existing LH2 target



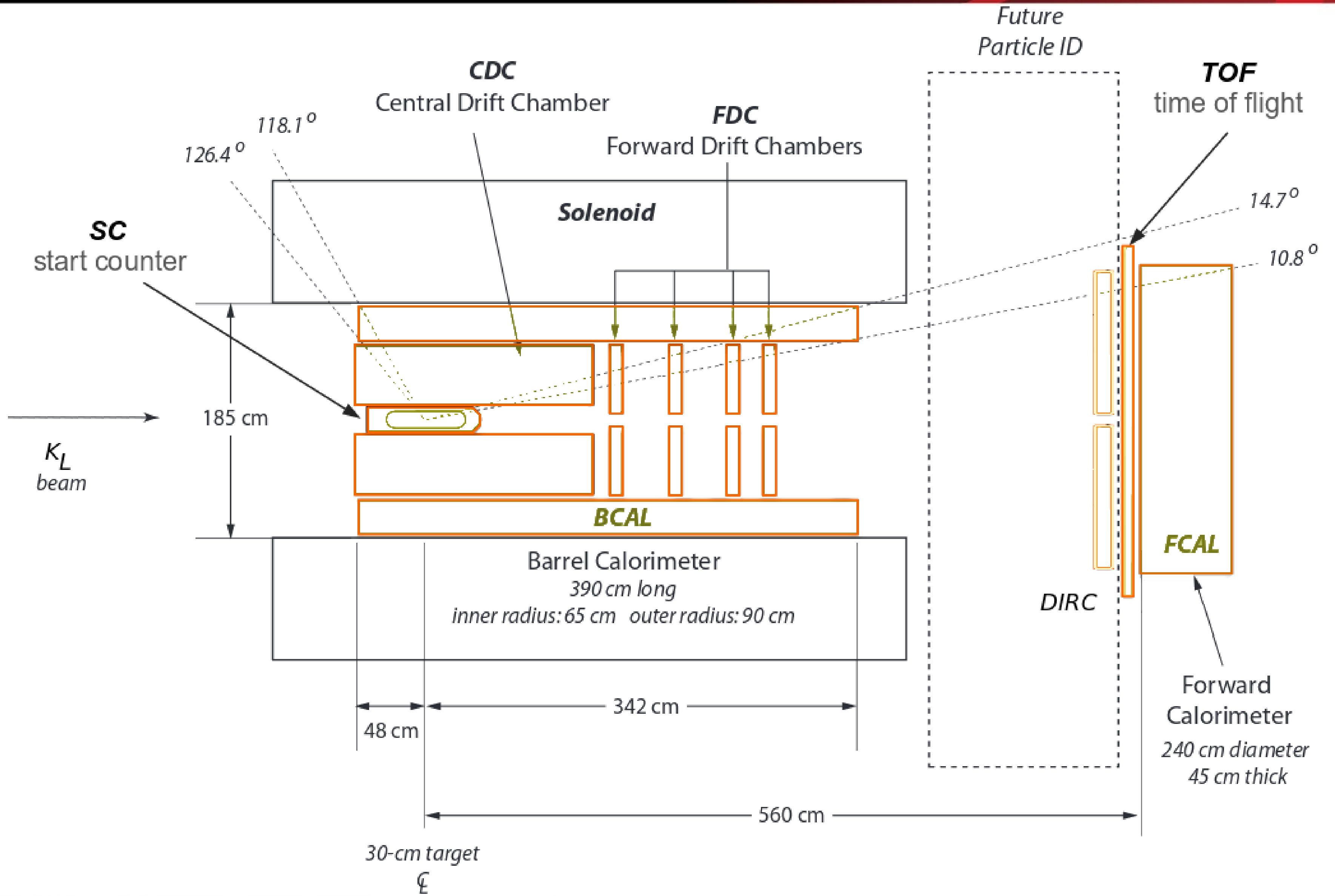
Conceptual design for K_L program



C. Keith

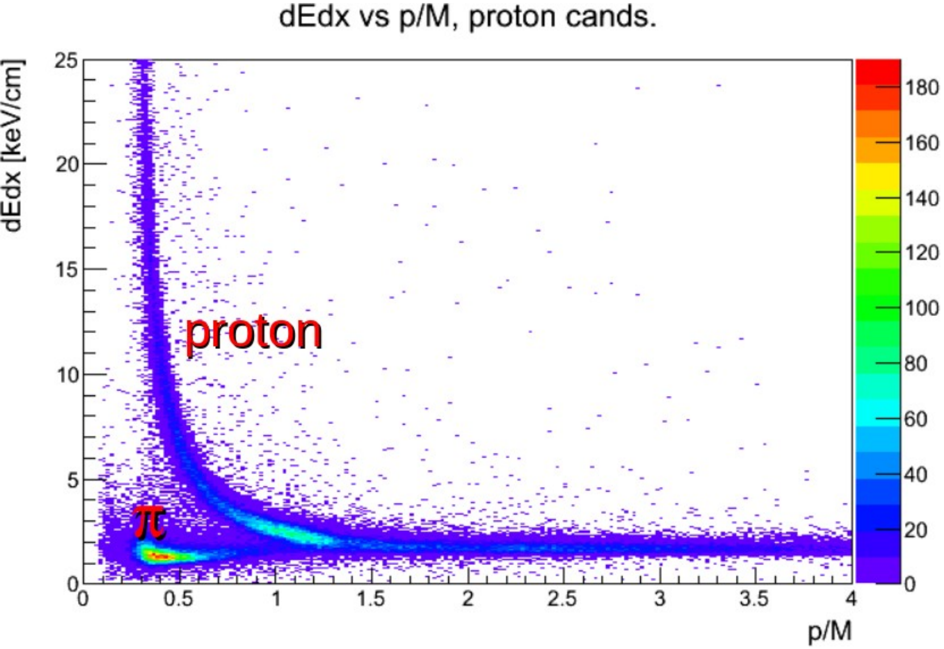
- Polarized target feasible: butanol ($C_4H_{10}O$) frozen spin

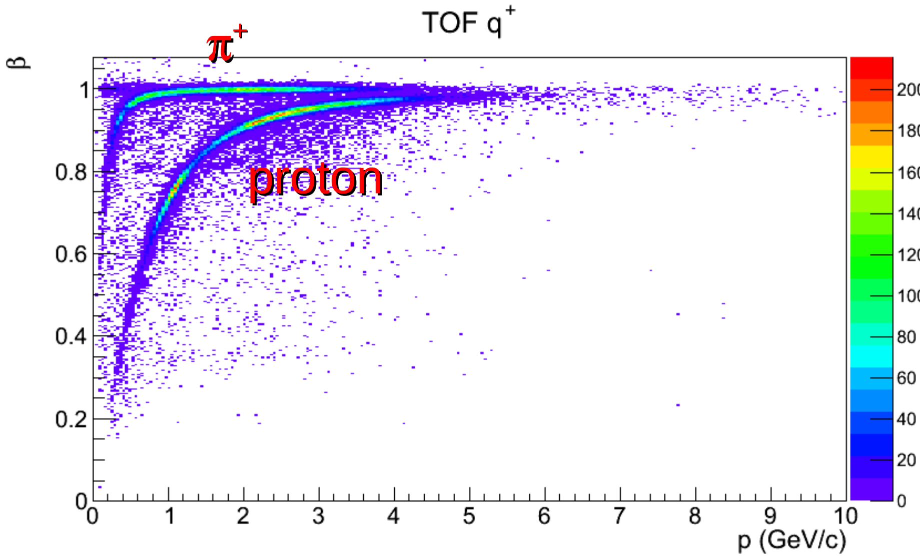
The GlueX detector



Particle identification

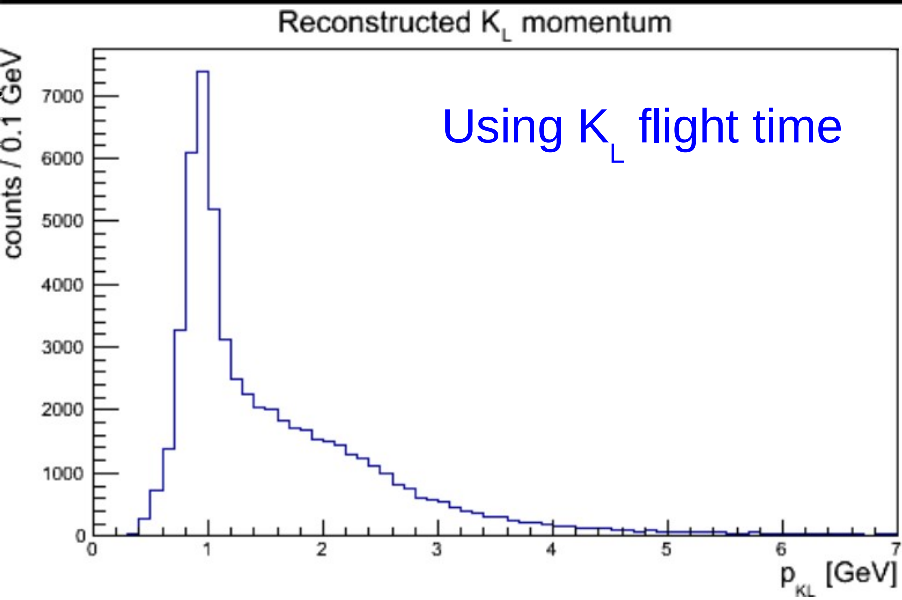
- Energy loss in drift chambers, time-of-flight to outer detectors

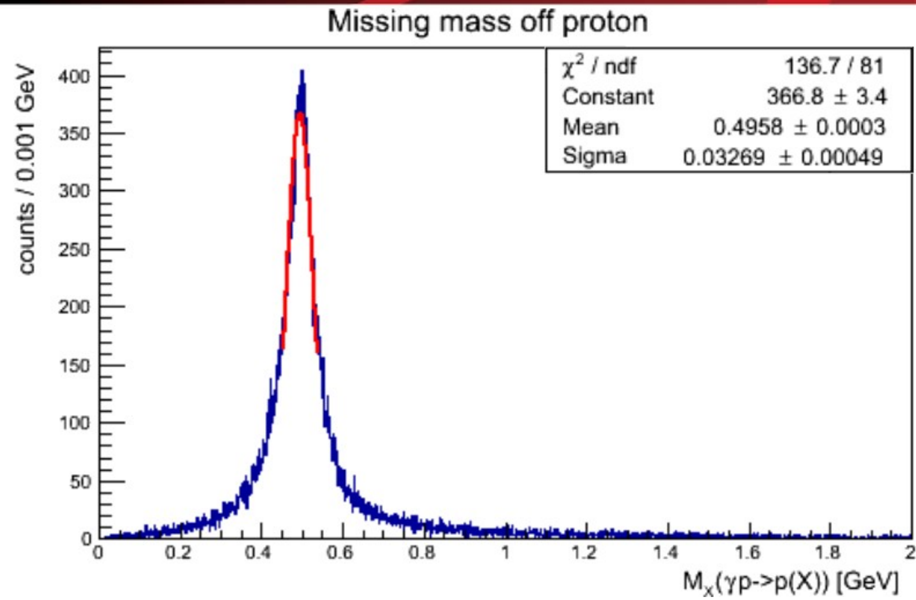


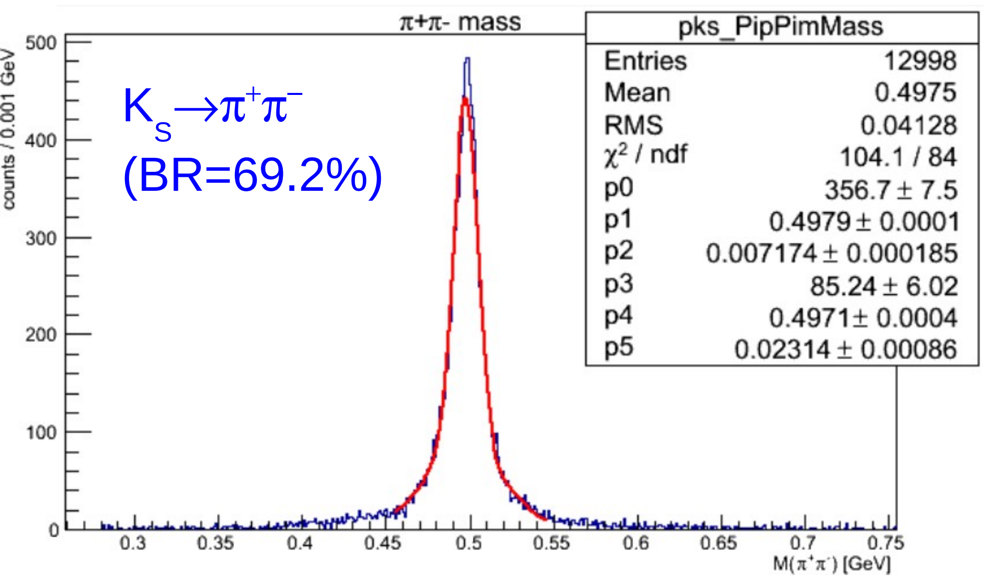


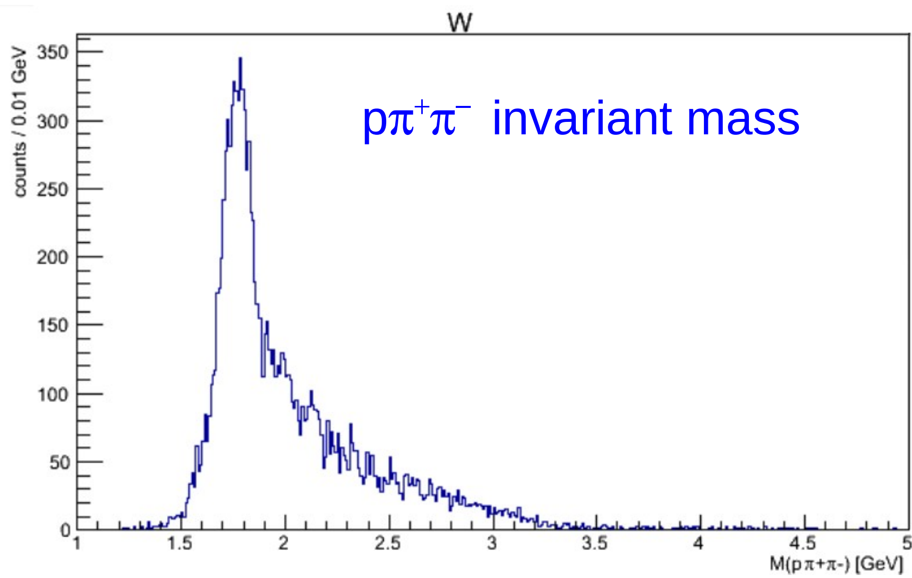
(simulated $K_L p \to p K_S$ events)

Example: $K_L p \to p K_S$

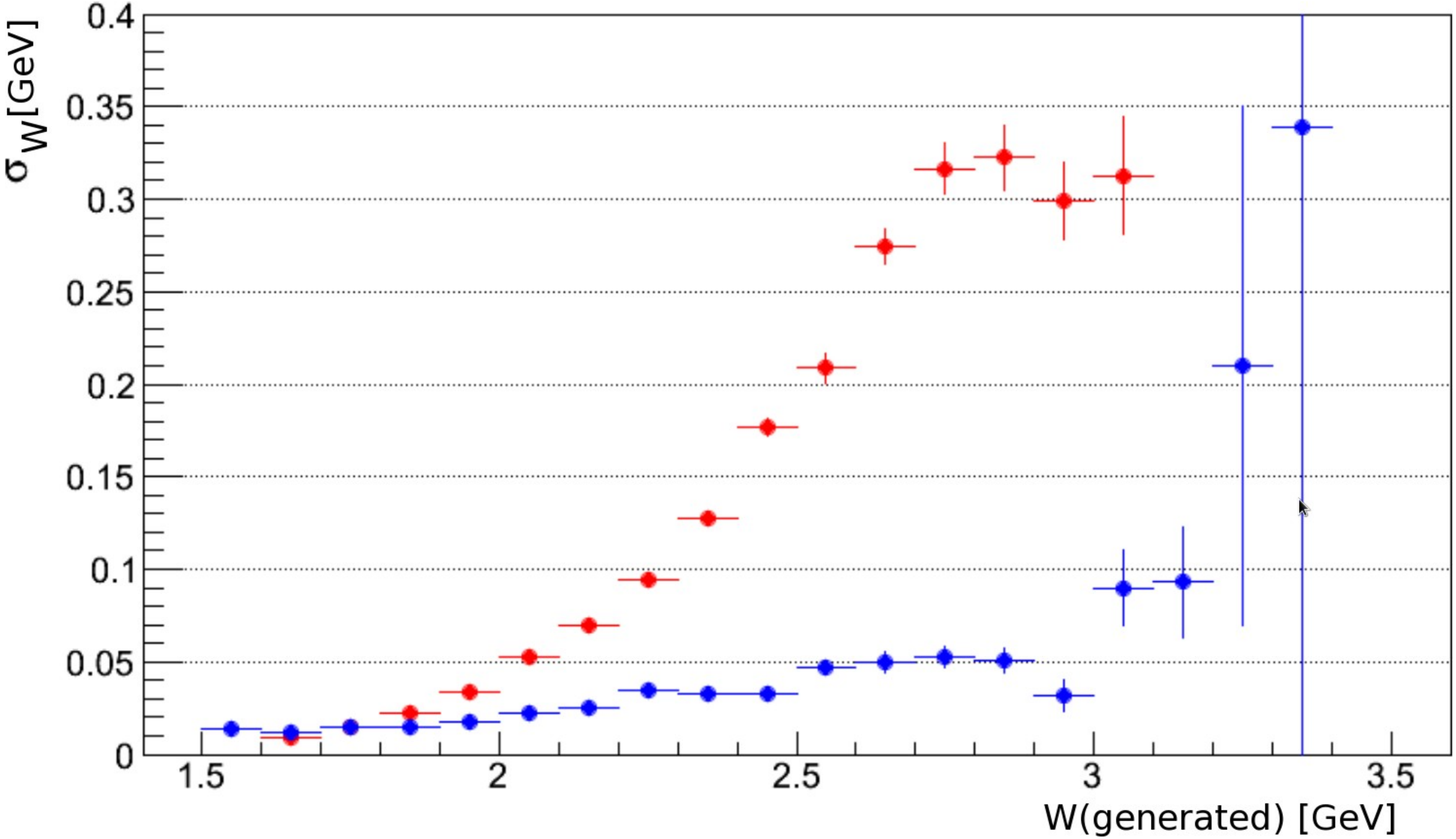








W resolution

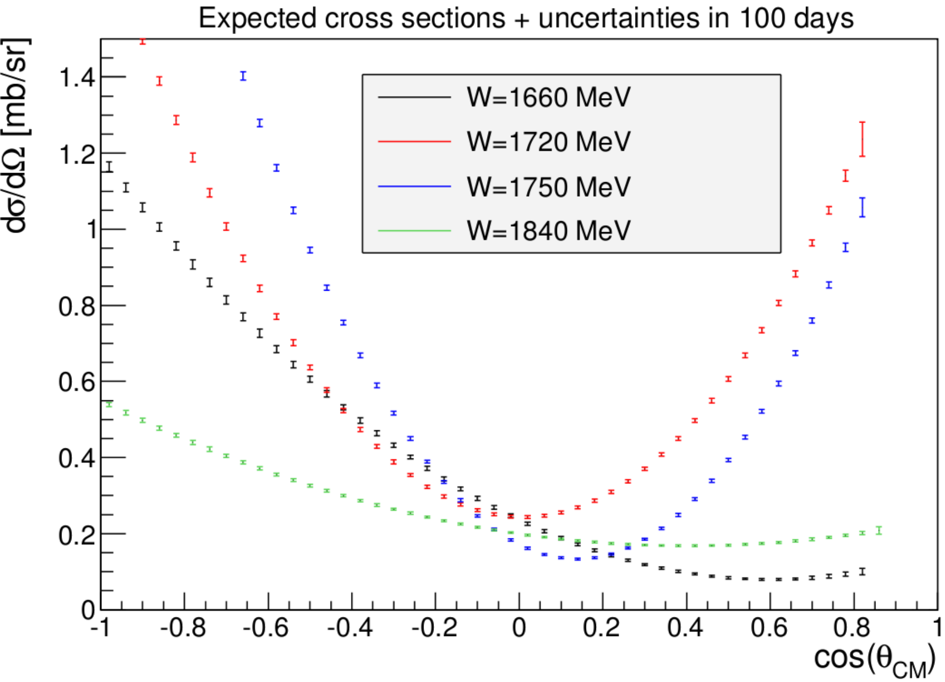


Red points: W derived from K_L flight time

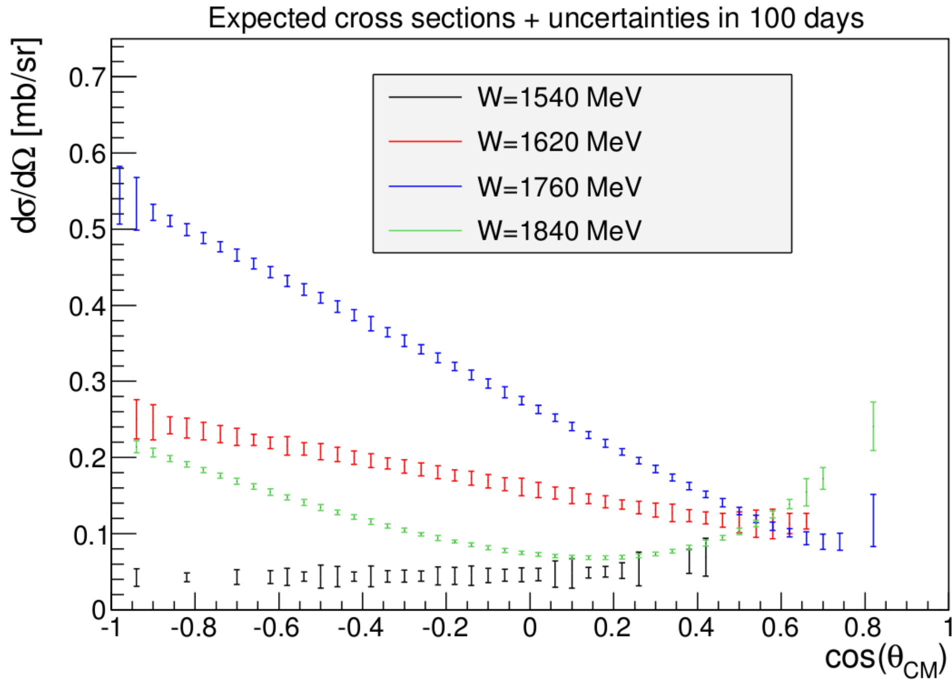
Blue points: invariant mass of final state particles

Projected statistical uncertainties

$K_L p \rightarrow p K_S$



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



More information

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