Simulation and Reconstruction Studies of $K_L p \to \Xi^0 K^+$

KLF Collaboration Meeting

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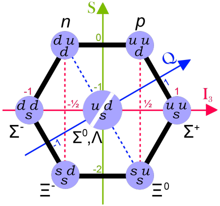
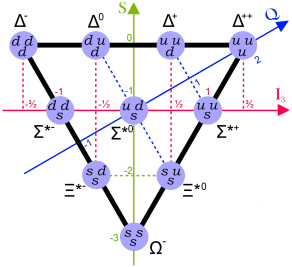
Motivation - Finding Resonances

Many more states predicted than observed





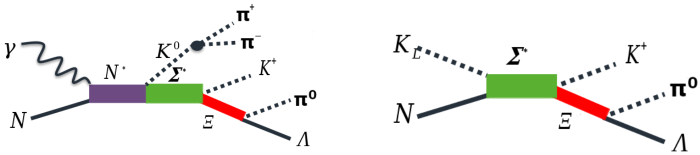
	Predicted	Observed
N^*	62	21
Δ^*	38	12
Λ^*	71	14
Σ^*	66	9
Ξ^*	73	6
Ω^*	36	2

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

This difference is even more pronounced in the Hyperons, where there is limited data

Motivation - Why KLF?

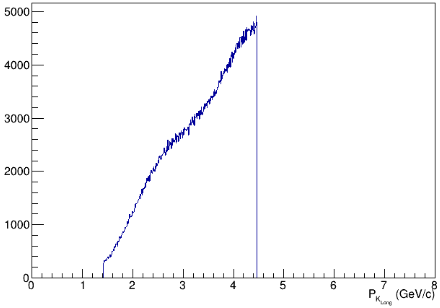
- KLF is expected to bring precision data to address burning questions in strangeness spectroscopy
- Unlike photo- or electroproduction, K_{Long} beam brings a unit of strangeness
- Especially useful for producing $S = 2$ particles, such as Ξ



- In this work, looking at $K_{Long} p \to K^+ \Xi^0$
- Ξ^0 decay to $\Lambda\pi^0$m with Λ further decaying to $p\pi^-$ (63.9% BR)
- Final state of $K^+ p\pi^- \gamma\gamma$

Generator Information

- KLGenerator_hddm_V3[1]
- Covers a comprehensive range of K_{Long} reaction channels on both proton and neutron
- Tunable K_{Long} beam parameters
- Can also generate γp and np events, use custom beam profiles and apply cross sections



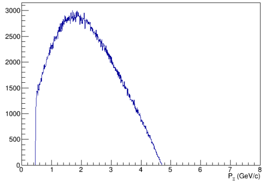
Focus here on a 4M event $K_L p \to K^+ \Xi^0$ phase space sample, generated with a K_{Long} beam between 1 and 4 GeV

[1] https://github.com/sdobbs/KLGenerator_hddm_V3 (forked from https://github.com/nickzachariou/KLGenerator_hddm_V3)

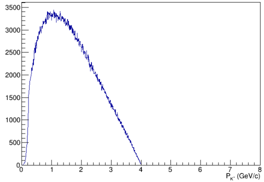
Reconstruction

- Particle decays and propagation handled by Hall D reconstruction software
- This includes smearing to appoximate detector effects, etc.
- Plots shown in the rest of this talk correspond to a *ReactionFilter* using a vertex constrained kinematic fit, with no mass constraint on the reconstructed Ξ^0

Generated Ξ momentum



Generated K^+momentum



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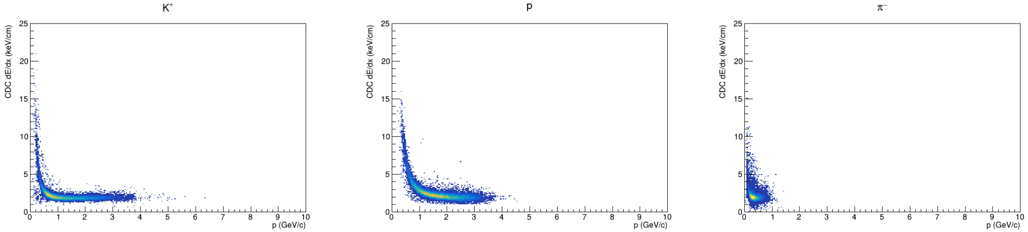
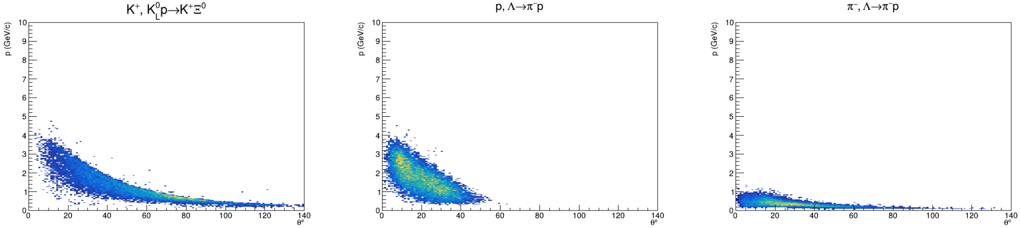
ReactionFilter Outputs

- dE/dX vs momentum of charged particles
- K^+ (left), proton (middle), π^- (right)



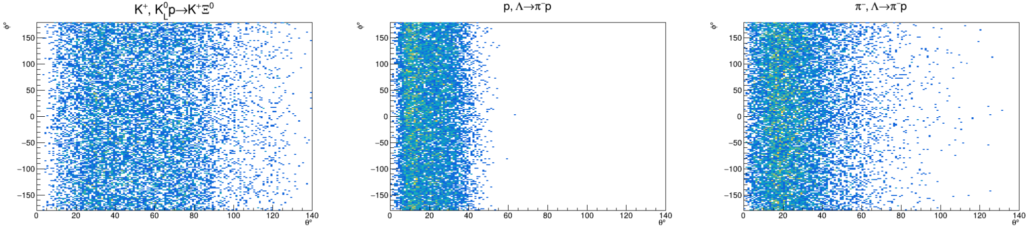
ReactionFilter Outputs

- Reconstructed particle distributions, θ vs momentum for K^+ (left), proton (middle), π^- (right)



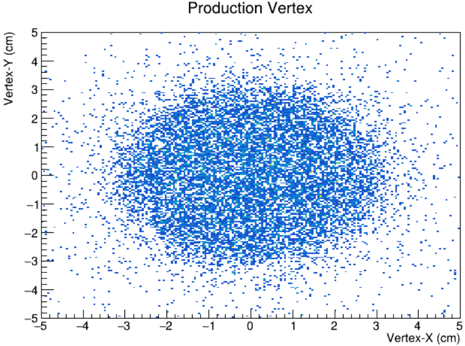
ReactionFilter Outputs

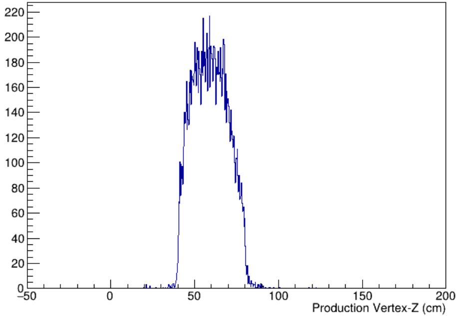
- Reconstructed particle distributions, θ vs ϕ for K^+ (left), proton (middle), π^- (right)



Vertex Reconstruction

Reconstructed X-Y and Z vertex distributions, from the final state K^+





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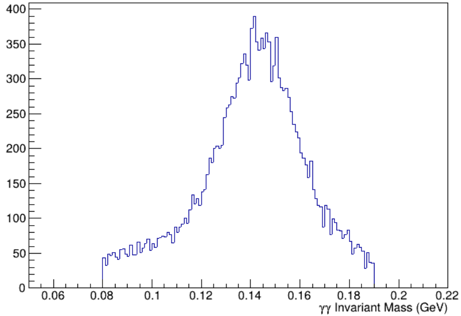
Event Selection

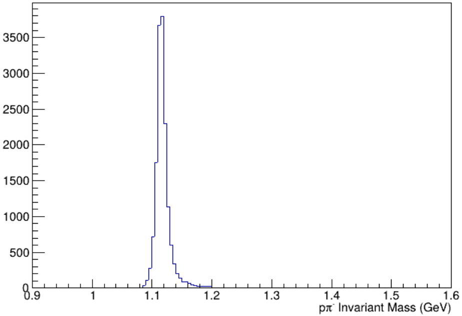
Apply some event selection cuts (exclusive topology)

- Missing mass cut, $-0.03 < M_X < 0.02$
- Reconstructed pion mass cut, $0.10 < M_{\gamma\gamma} < 0.17$
- Reconstructed Λ mass cut, $1.10 < M_{p\pi^-} < 1.15$

Reaction Reconstruction

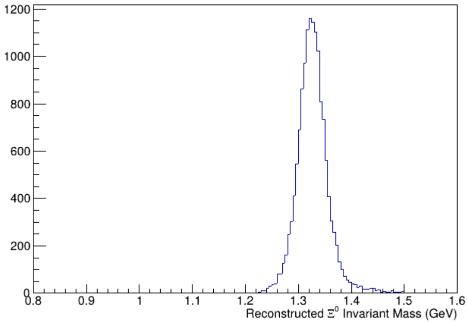
Left: π^0 reconstruction from two photon invariant mass
Right: Λ^0 reconstruction from proton π^- invariant mass





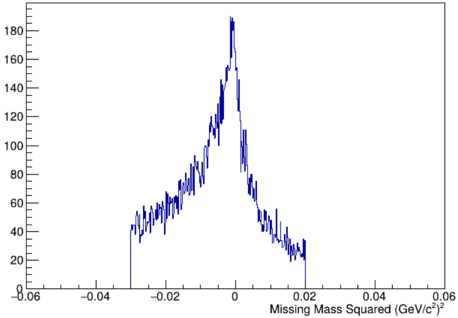
Ξ^0 Reconstruction

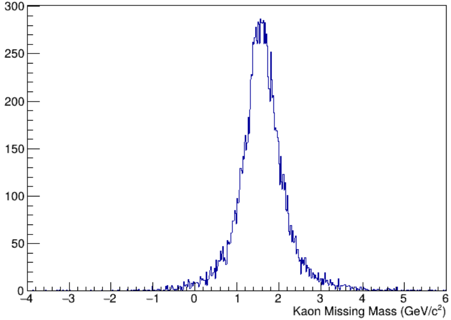
Ξ^0 reconstructed from proton, π^- and π^0



Missing Masses

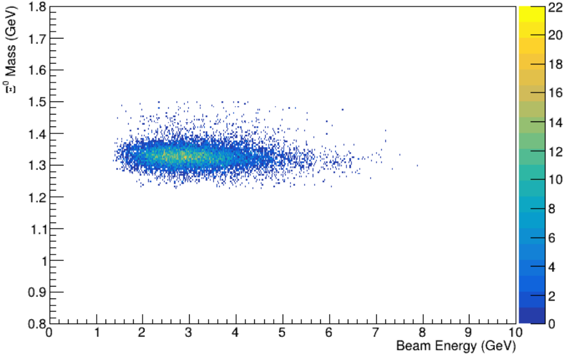
Left: Missing mass squared of all final state particles
Right: Missing mass of final state K^+





Ξ^0 Reconstruction

Ξ^0 reconstruction, after all cuts, shown against reconstructed beam energy



Physics Observables

Basic Cross Section Formula

$$\sigma = \frac{Y_{\Xi^0}}{A.\rho_T.l} \quad (1)$$

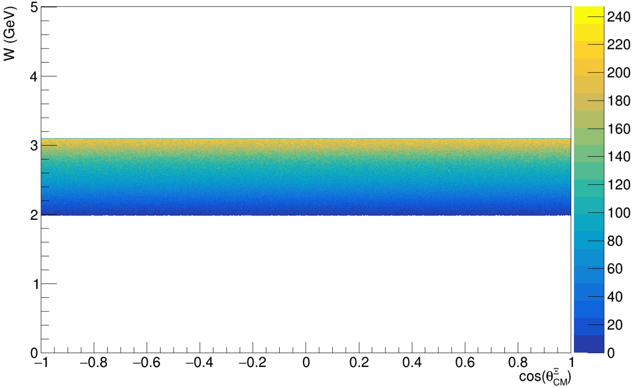
Where the accepatance $A = \frac{MC_{Rec}}{MC_{Gen}}$

The polarisation, P, can be related to the angular distribution of the decay π^0 in the rest frame of the Ξ^0 as follows

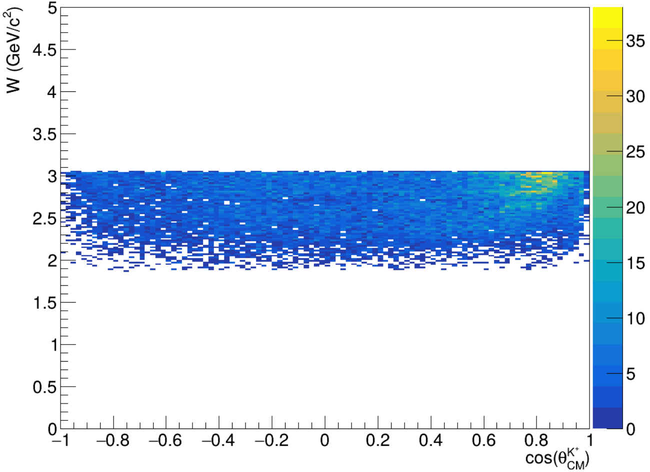
$$I(cos\theta_Y^{\pi^0}) = \frac{1}{2}(1 + \alpha P_Y cos\theta_Y^{\pi^0}) \quad (2)$$

α is the self-analysing power of the hyperon, for Ξ, this has the value -0.349

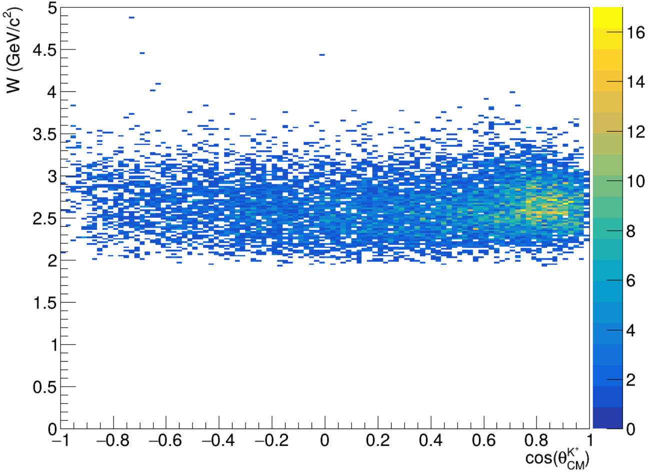
Generated Phasespace



Thrown W vs cos(θ)

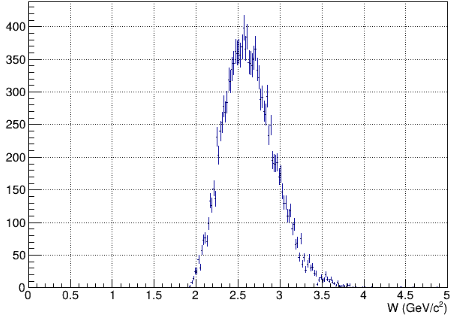


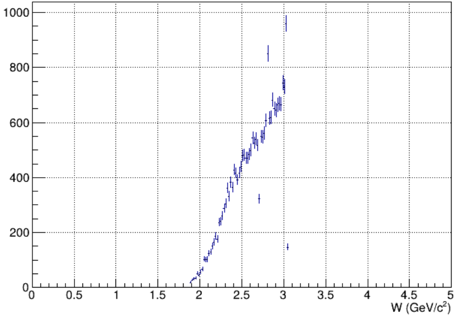
Measured W vs cos(θ)



Centre of Mass Energy, W

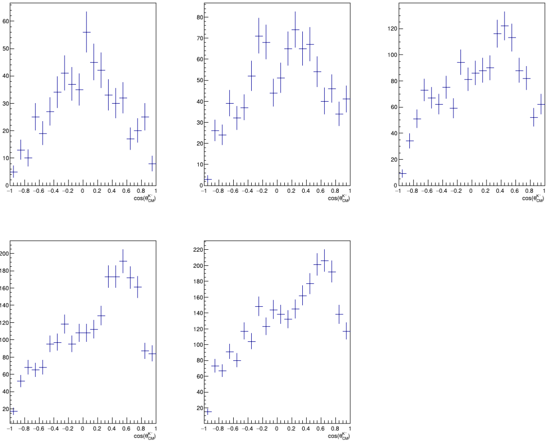
W measured (left) and thrown (right)





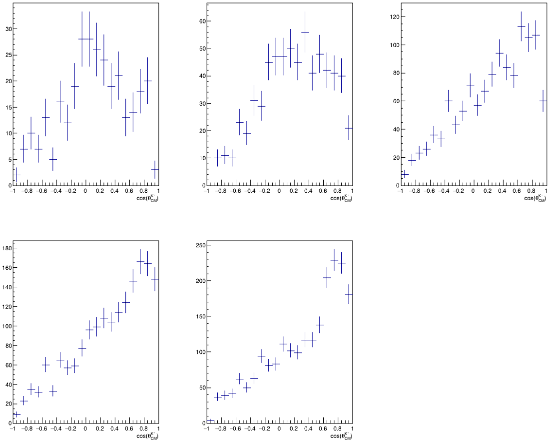
Centre of Mass Angle Distributions, $\cos(\theta^{\Xi}_{CM})$

Ξ centre of mass angle for 200 MeV bins in W (Thrown events)



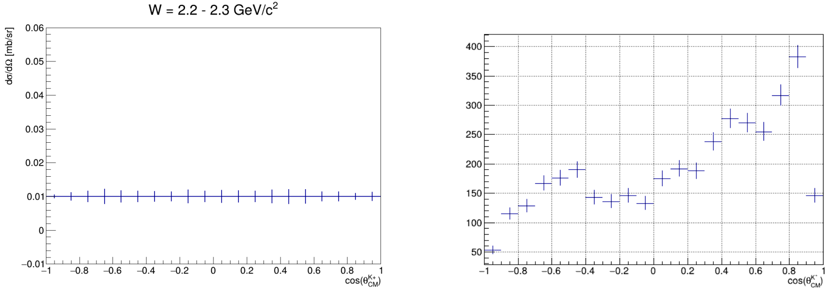
Centre of Mass Angle Distributions, $\cos(\theta^{\Xi}_{CM})$

Ξ centre of mass angle for 200 MeV bins in W (Measured events)



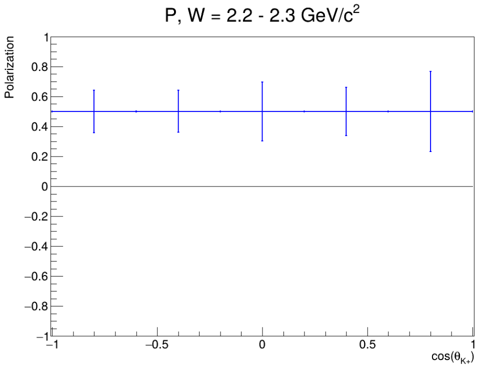
Cross Section Estimates

Estimated differential cross section uncertainty
Phase space estimate on left, event yields from simple cross section model in event generator on right



Polarisation

Estimated Ξ Polarisation uncertainty



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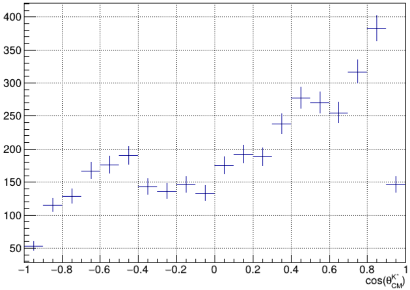
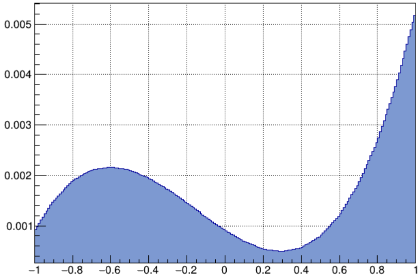
Summary

- Ξ^0 production at KLF will bring precsion data to strangeness spectroscopy
- Decay modes and quantum numbers of various Ξ states have been under-explored for decades, hampering our understanding in the strangeness sector
- Exclusive phase space study underpins this talk, but additional studies underway to evaluate magnetic field settings, impact of inclusive channels, and incorporation of new models into generator
- KLF MCwrapper supporting efficient production of the multiple simulation configurations needed

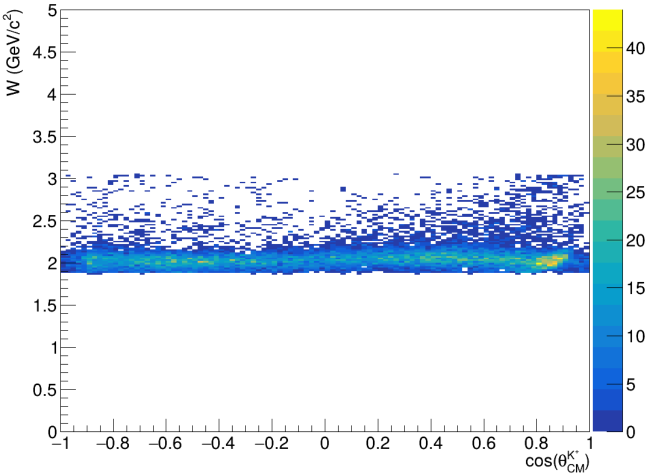
(backup) Cross Section Estimates

Event yields show signs of reproducing overall input shape (NB Acceptance not accounted for here!)





(backup) Thrown W vs cos(θ)



(backup) Measured W vs cos(θ)