Hexaquarks at CLAS12

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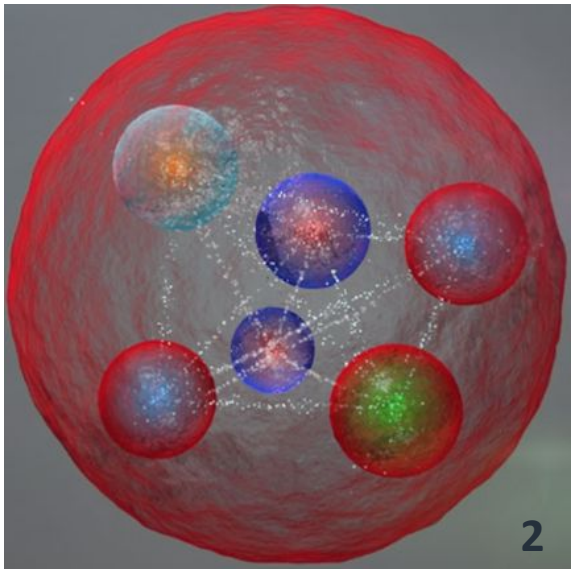
Introduction

- d*(2380) is the first hexaquark supported by experimental data [PRL **106**, 242302, (2011)] [PRL **112**, 202301, (2014)] [PRL **124**, 123001, (2020)

- Studies have been performed on this hexaquark

- Expand our studies of hexaquarks using the RG-B data

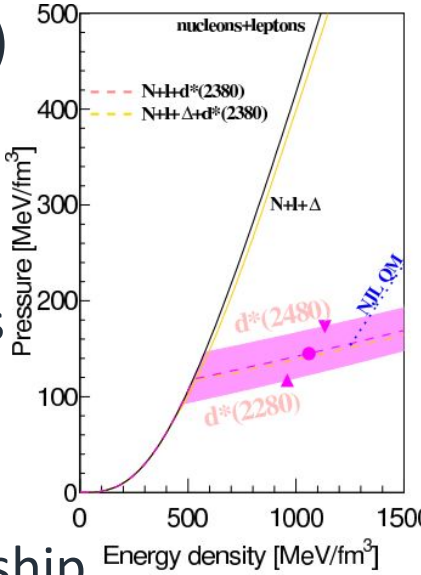


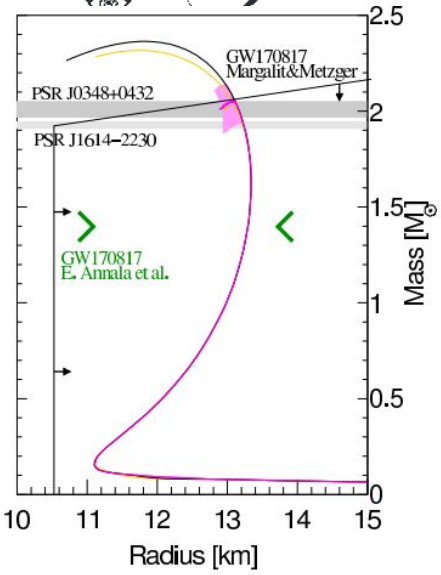
Motivation

- Hadrons are bound quark systems (QCD)
- Several new states have now been found including four-, five- and six-quark states
- Internal structure? (molecule, multiquark, ...)
- Internal structures <-> many body effect in QCD

Motivation

- Hexaquarks -> equation of state (EOS) of neutron stars

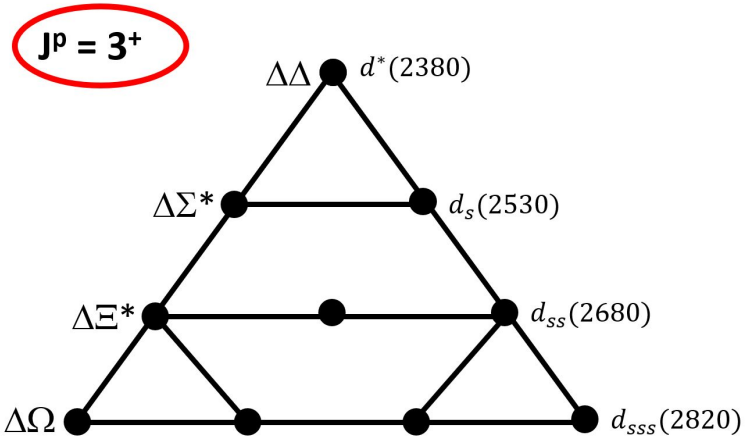




- up to 20% in the centre of heavy stars [PLB781, 112, (2018)]
- d*(2380) correct mass-radius relationship
- **Other members of the d*(2380) multiplet -> better understanding**

Antidecuplet

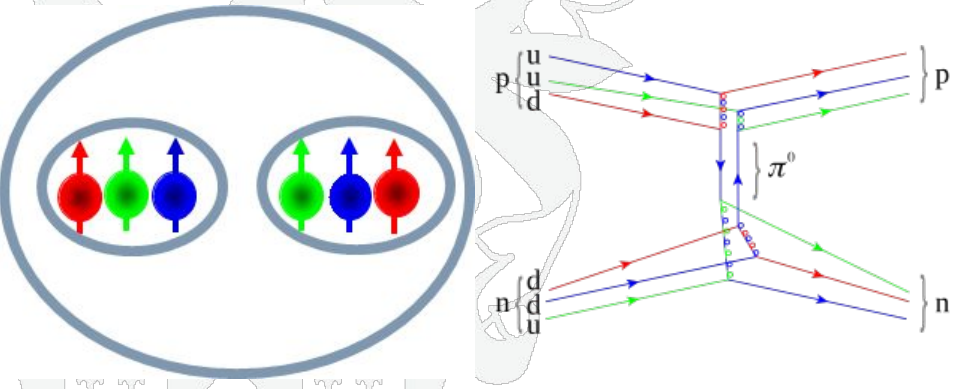
- d*, SU3 antidecuplet
- Other members of the antidecuplet?
- **RG-B data is essential!!!**
- Analysis note for these studies: https://clasweb.jlab.org/wiki/images/1/18/York_CAA.pdf



Internal Structure

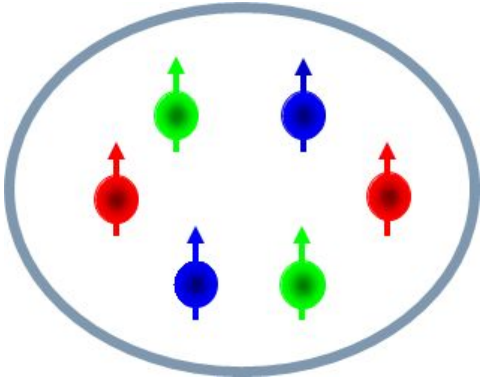
Molecule

- In molecular state pion exchange binds the two baryons together



- More strangeness -> less binding (pion doesn't couple to strange quarks)

Multiquark



Heavier (more strangeness) -> stronger binding

Plan

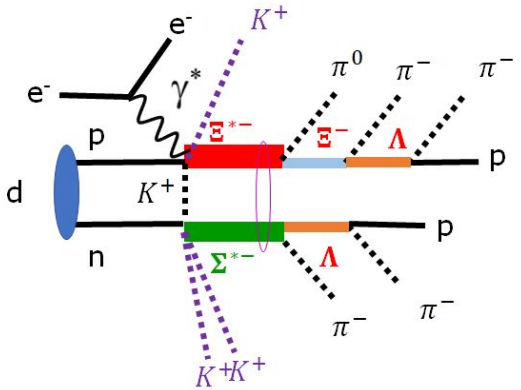
- Exploratory analysis
  - Investigate d_{sss} signal
  - Invariant mass distributions <-> binding energy

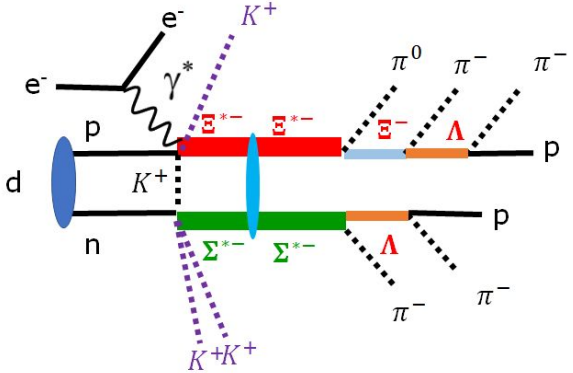
- Monte Carlo simulations will be run with detector responses
  - Better idea of efficiencies
  - Study background contributions

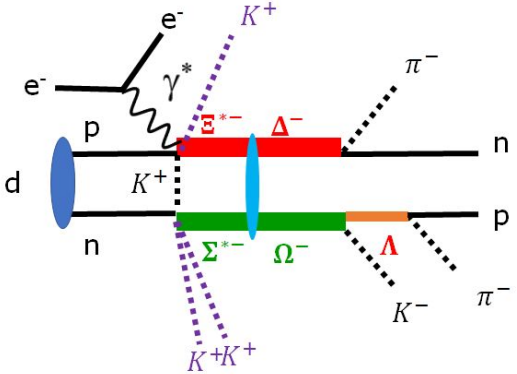
- Observables
  - Mass and Widths
  - Cross sections
  - Angular distributions (spin/parity)

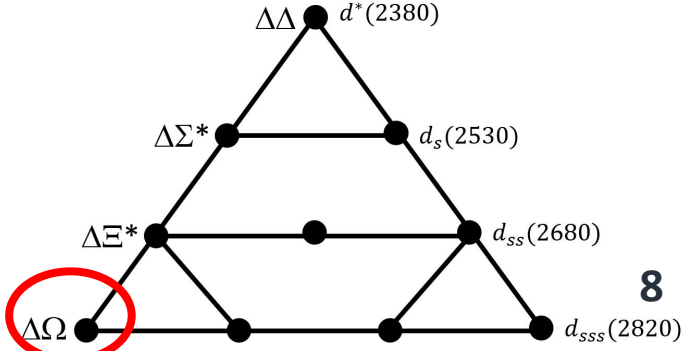
Candidate to study - d_{sss}

- dsss-- is chosen here as there are no conventional resonant background channels



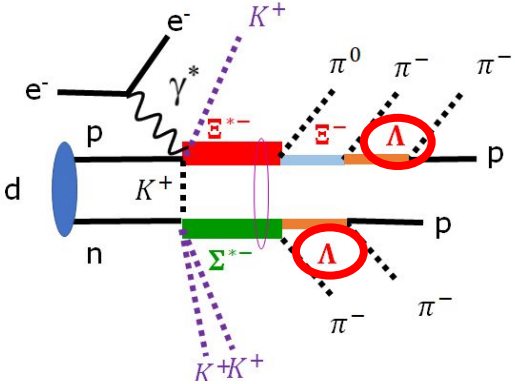


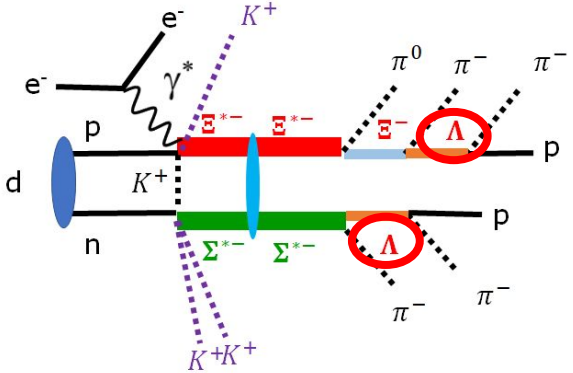


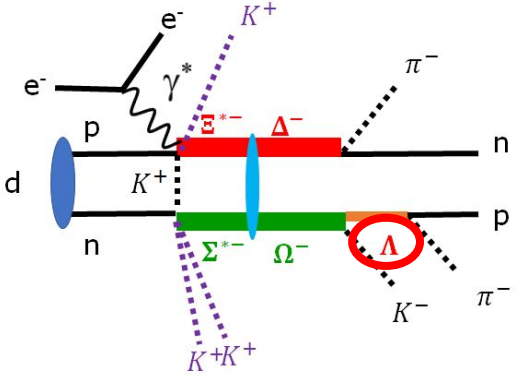


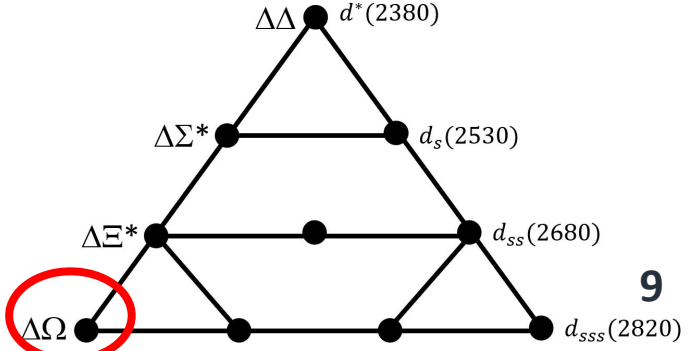
Candidate to study - d_{sss}

- Lambda identification is crucial!



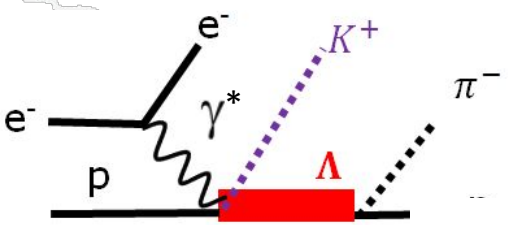




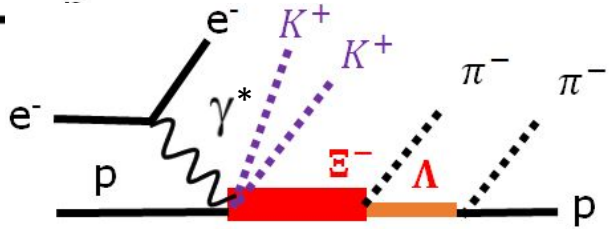


Analysis Completed

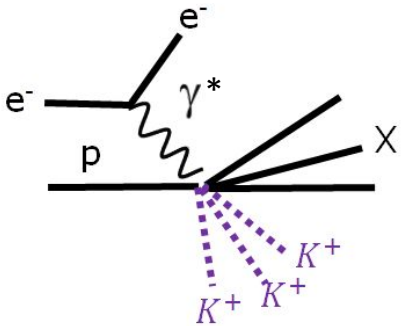
- Analysis on proton data
- Strangeness 1



- Strangeness 2

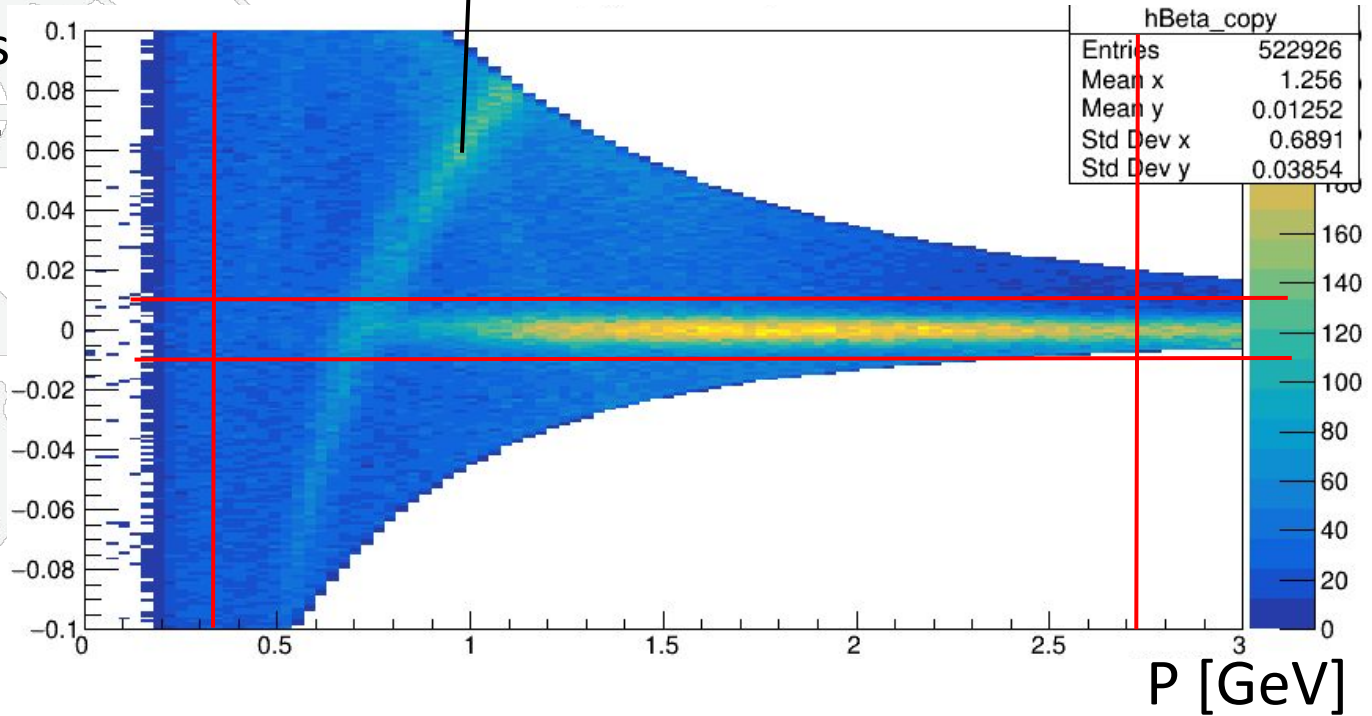


- Strangeness 3



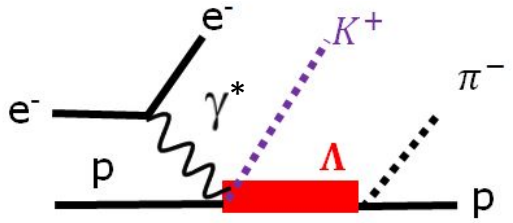
Analysis Process

- Misidentified pions
- FTOF limits

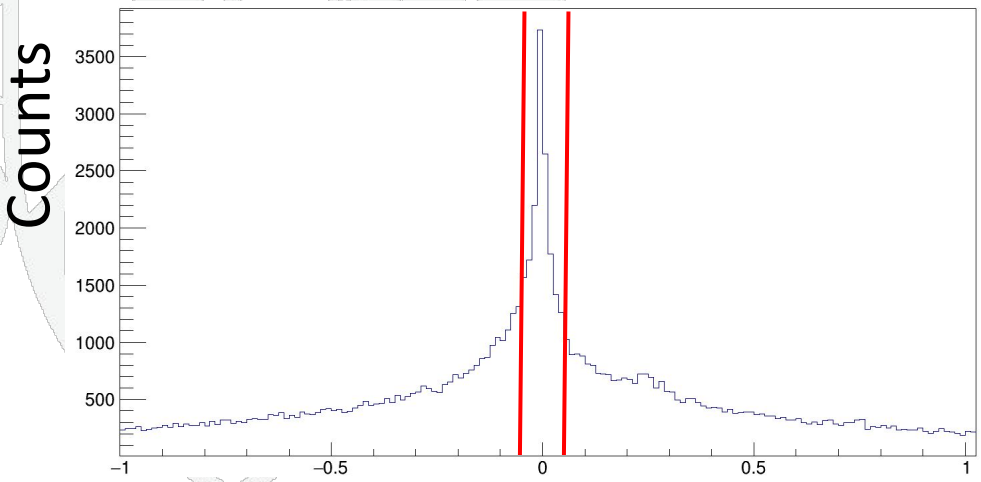


Analysis Process

- Exclusivity cuts

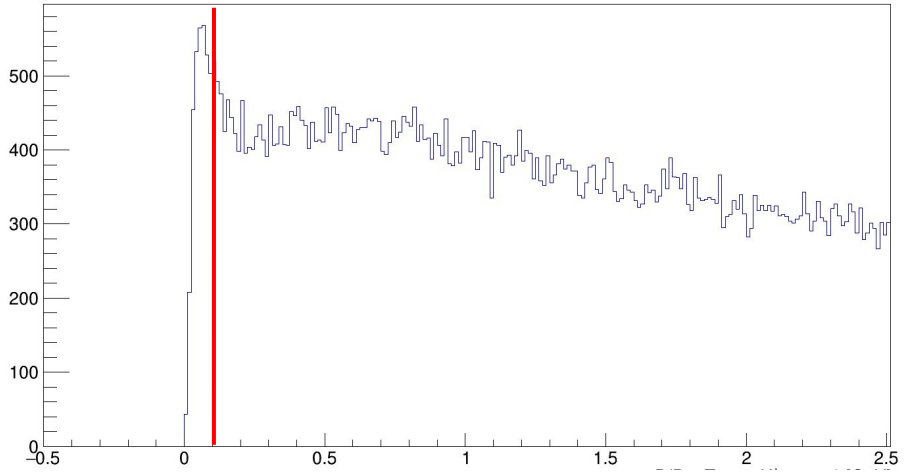


Missing Mass



$MM^2(e' K^+ p \pi^-)$ [GeV]

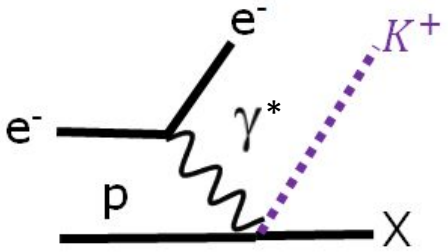
Missing Momentum



$P(B + T - e' - K^+ - p - \pi^-)$ [GeV]

Strangeness 1 Analysis

- Prior to exclusivity cuts



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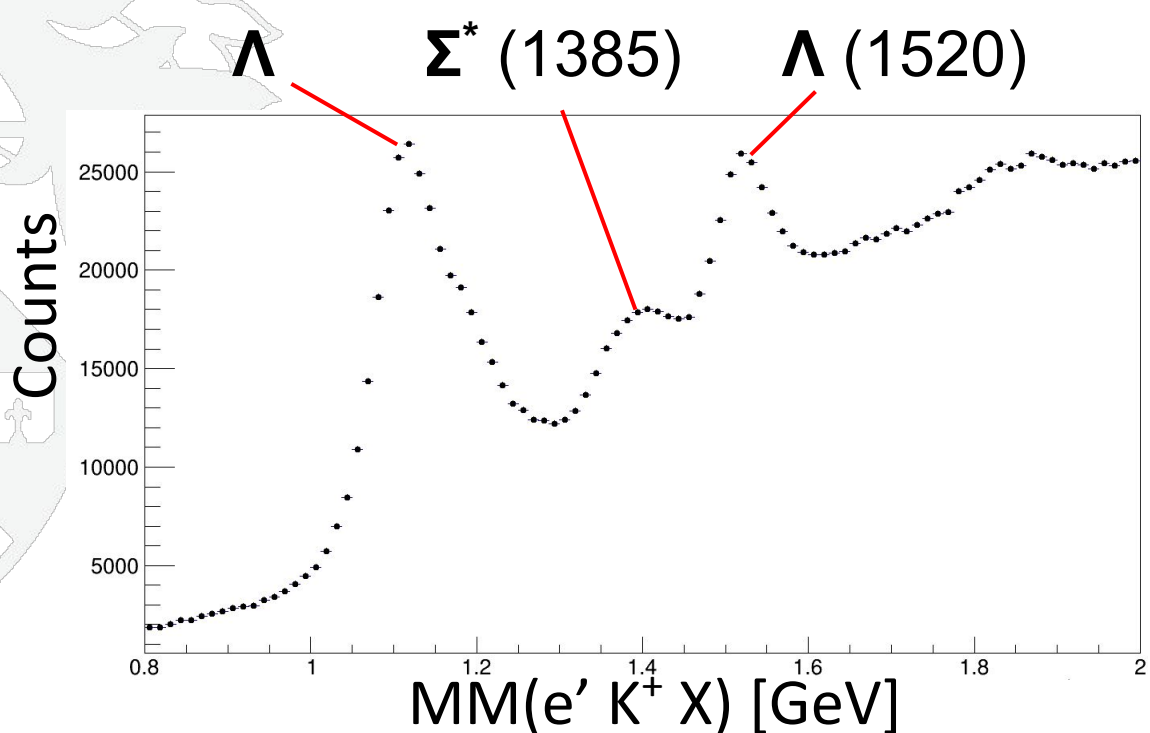
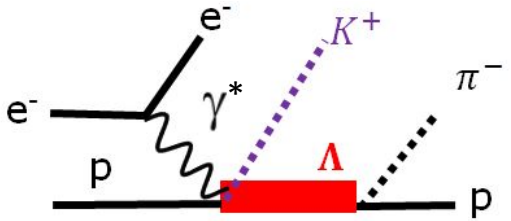
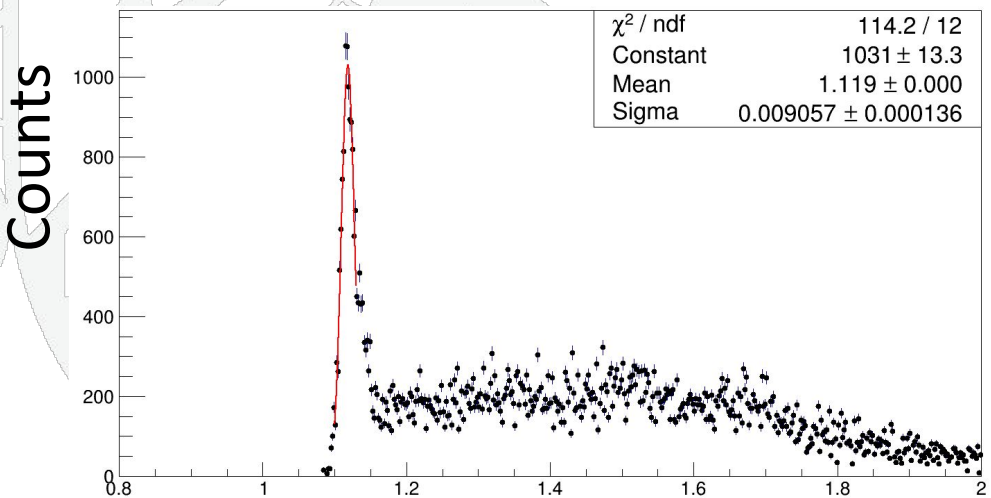


Strangeness 1 Analysis

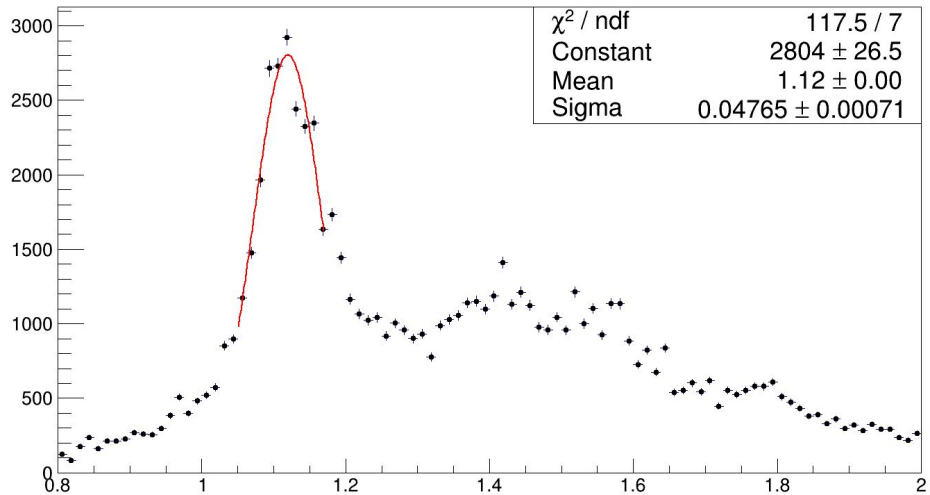
- Lambda well identified with exclusivity cuts



Invariant Mass

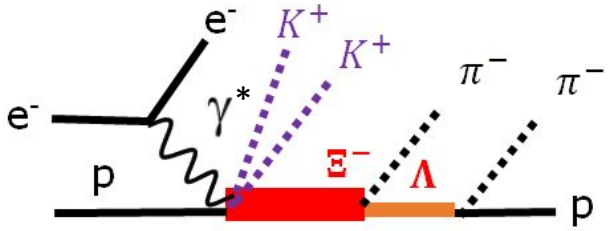


Missing Mass

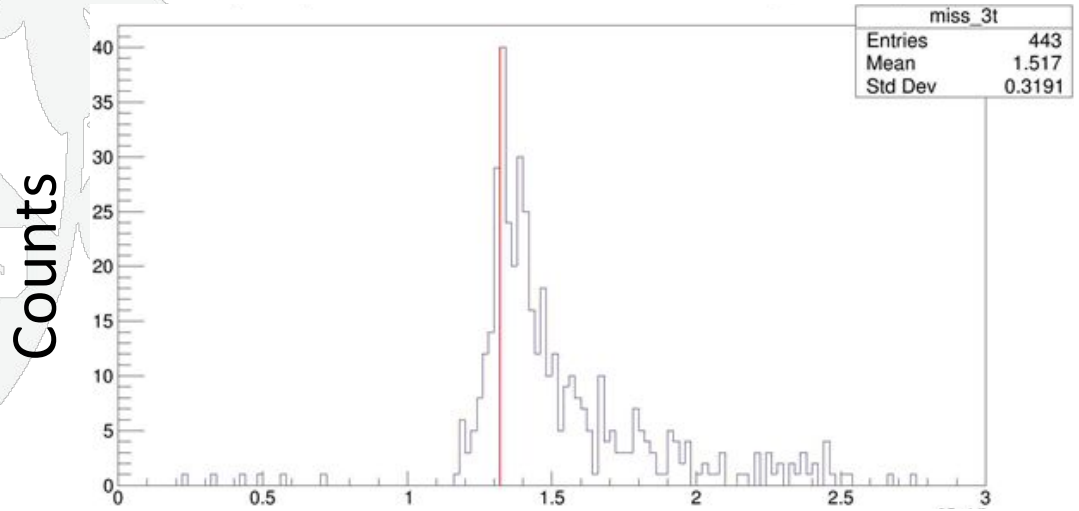


Strangeness 2 Analysis

- Cascade well identified

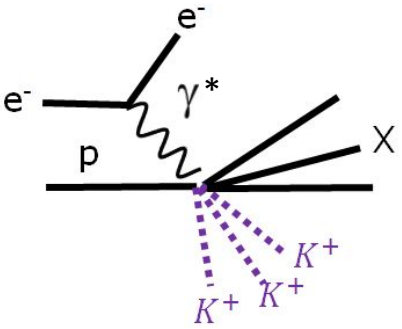


Missing Mass

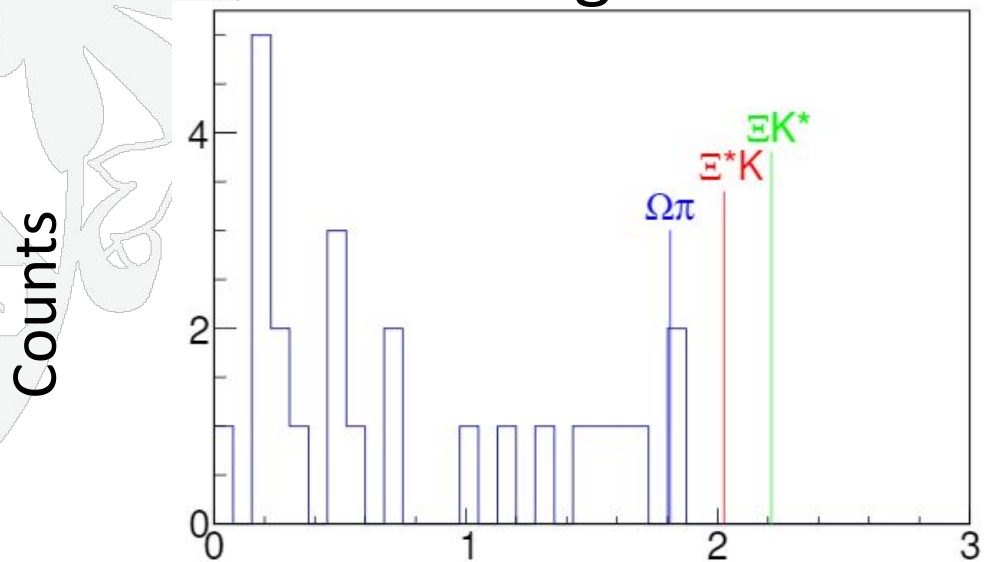


Strangeness 3 Analysis

- Low Background



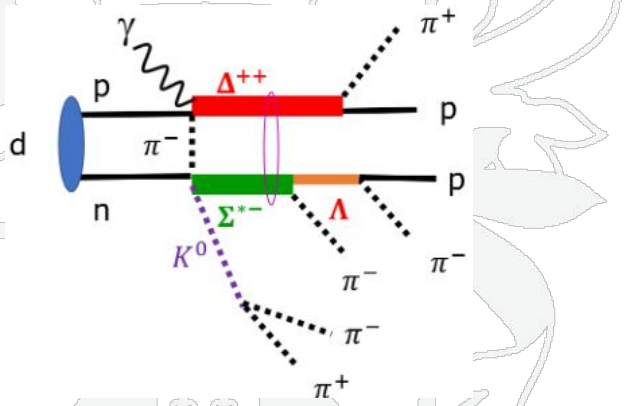
Missing Mass

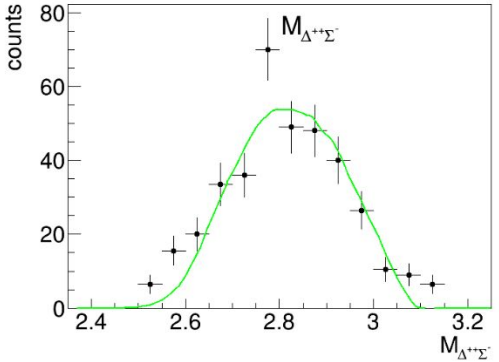


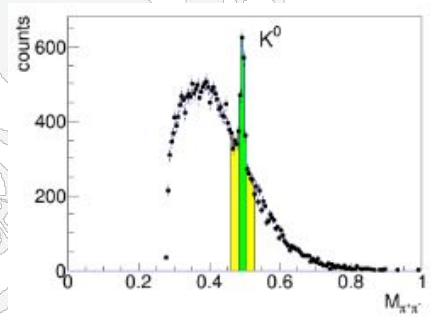
Conclusion

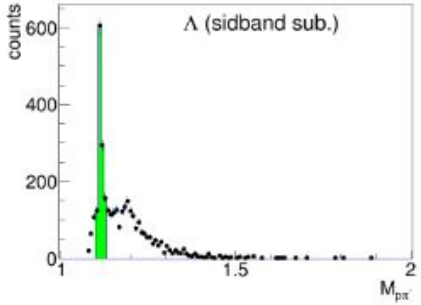
- Analysis code tested and ready for RG-B data
- Can identify well the final state products expected from d^{--}_{sss}
- Fantastic research opportunity in this field!
- Analysis note for these studies: https://clasweb.jlab.org/wiki/images/1/18/York_CAA.pdf

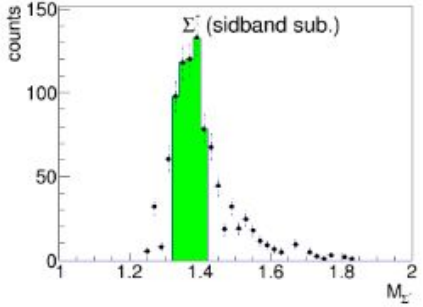
Exploratory analysis of g13 (d_s)





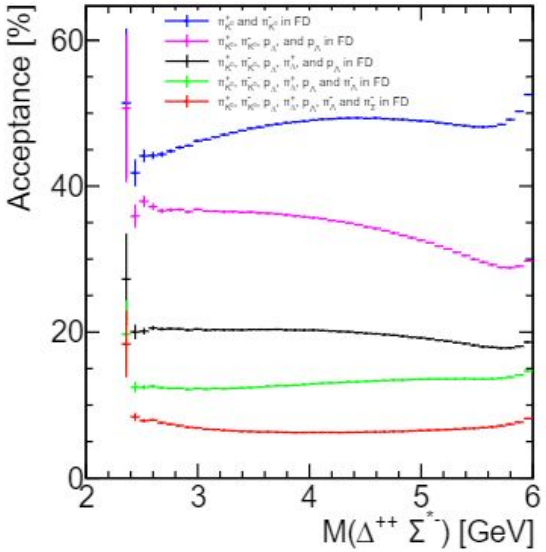






Simulations performed

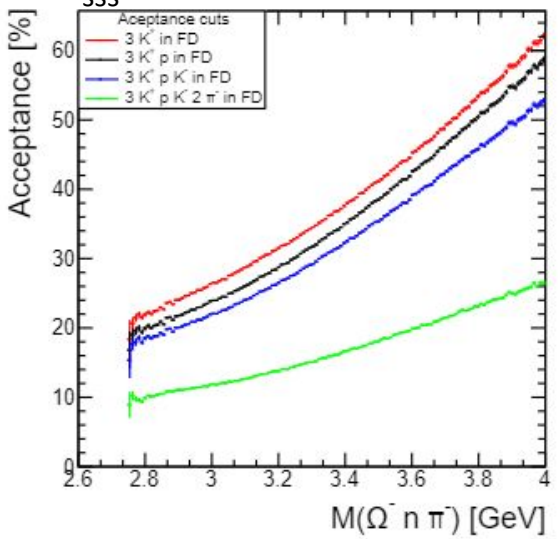
d_s



- Generated phase space
- Applied weights including:
  - q^2 dependence
  - Breit Wigner
- Plotted acceptance

Blue - K^0 in FD
Pink - K^0 and 2 p in FD
Black - K^0, 2 p and π^+ in FD
Green - K^0 and Δ in FD
Red - K^0, Δ and Σ in FD

d_{sss}



Red - 3 K^+ in FD
Black - 3 K^+ and p in FD
Blue - 3 K^+, p and K^- in FD
Green - 3 K^+, p, K^- and 2 π^- in FD

Background for dss