Hybrid Baryons Search at CLAS12

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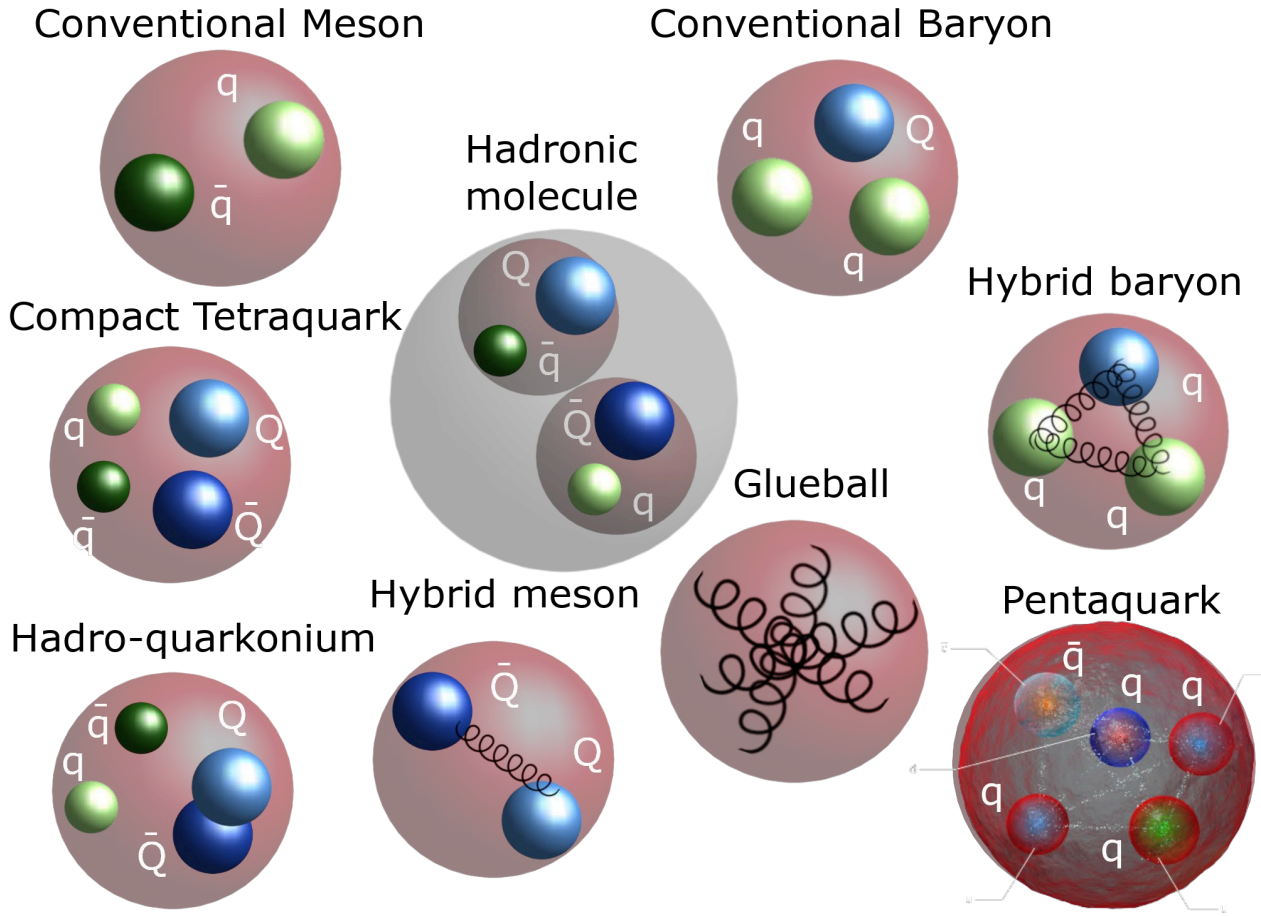
Outline

- Scientific Goal
- N(1440), $\Lambda(1520)$
- Experimental Set-Up
- Preliminary Data Analysis ($ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+K^-p$)
- Future Goals

Brief Theoretical Explanation

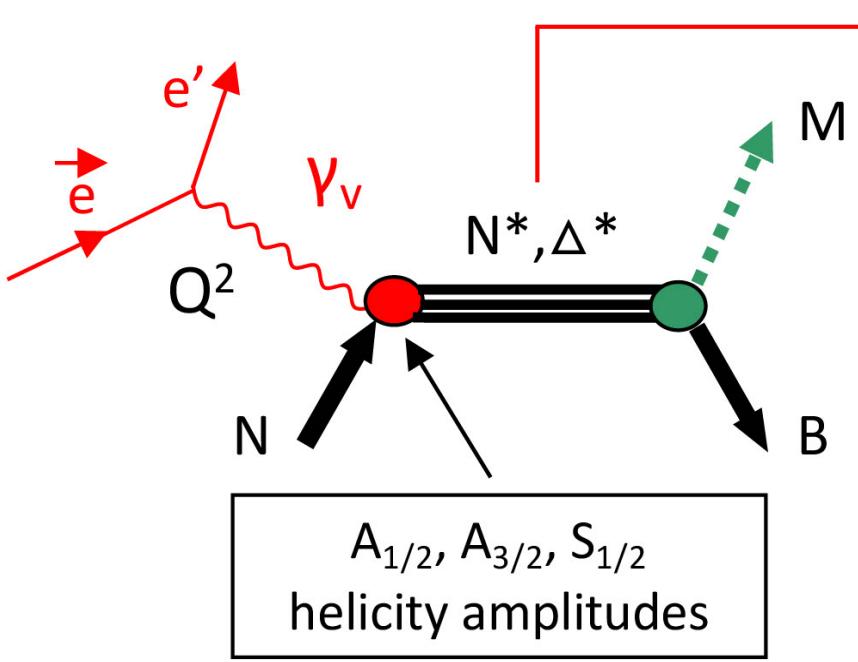
Hybrid baryons search aims to understand nucleon spectrum possible and gluonic components.

- According to QCD, exotic states with gluonic degrees of freedom may exist but are difficult be experimentally identified.
- Lattice QCD predicts several hybrid states, which can be recognized by studying electroproduction at low Q^2, where a distinctive signature is expected.



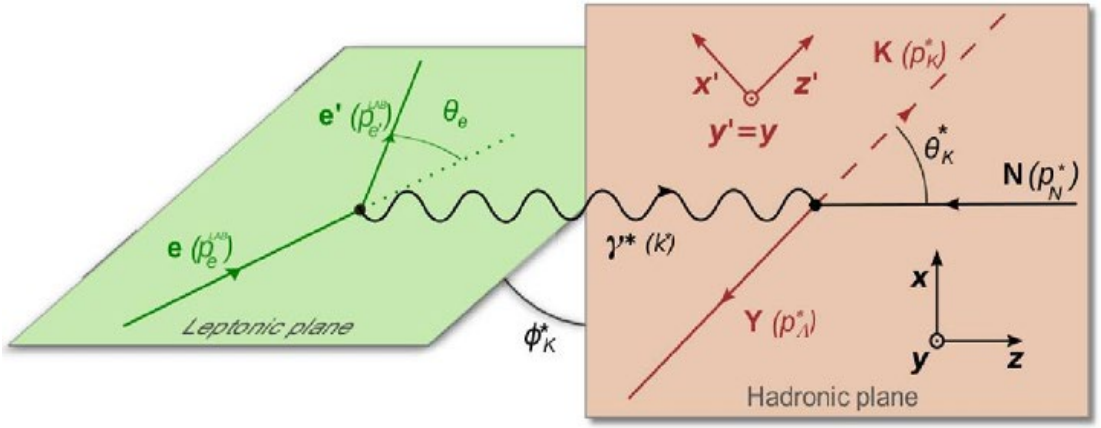
Study of Resonance Properties in Electroproduction Reactions

Baryon resonances are produced as intermediate states in meson electroproduction processes on proton (and neutron) targets. Electroproduction allows us to distinguish ordinary baryons from hybrid ones.



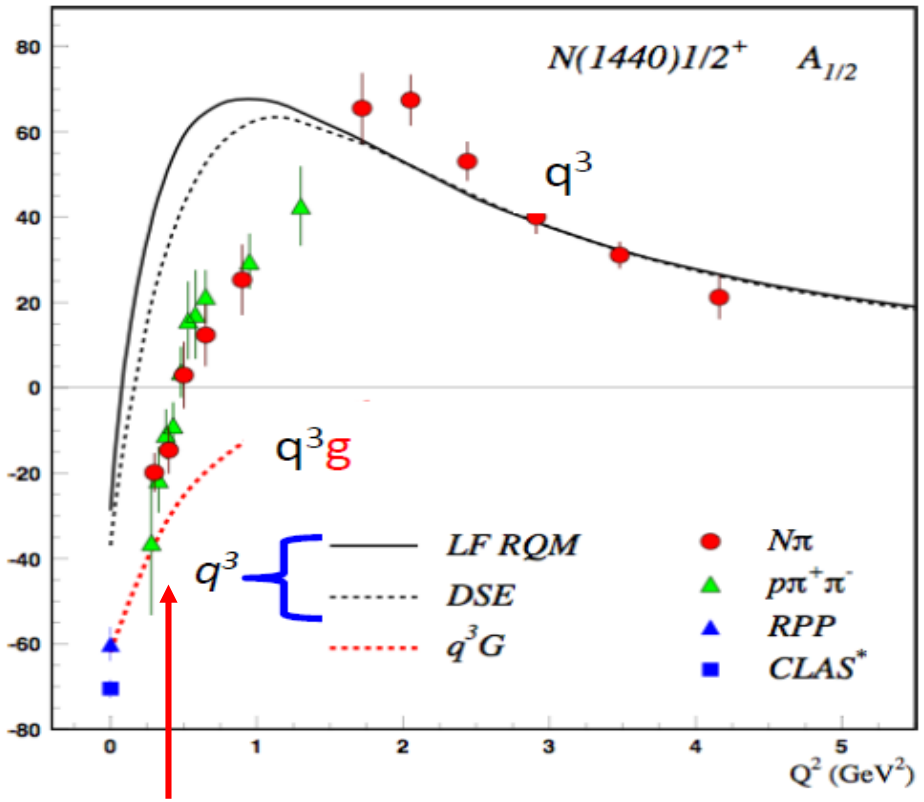
How to Identify Hybrid Baryons?

- At low Q^2, the transverse amplitudes $A_{1/2}(Q^2)$ and $A_{3/2}(Q^2)$ decrease more rapidly than for ordinary baryons.
- The longitudinal amplitude $S_{1/2}(Q^2)$ is suppressed compared to the transverse ones.

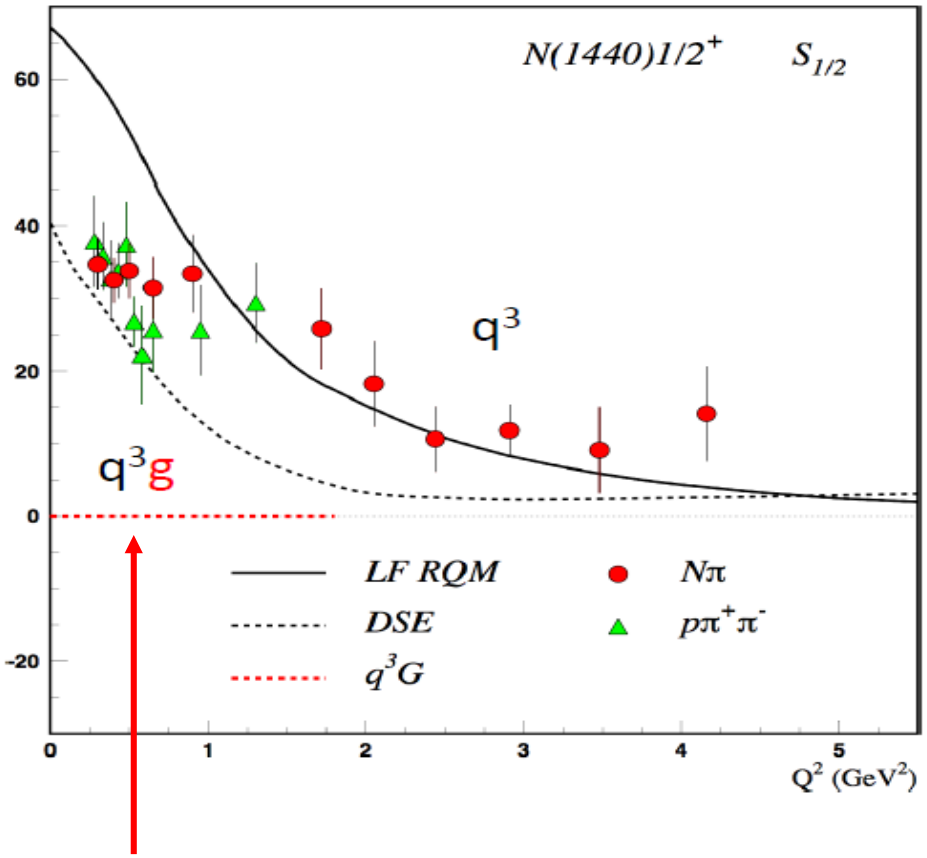


$$Q^2 = -q^2 = 4E_e E_e' \sin^2 \frac{\theta_e}{2}$$

N(1440) $\frac{1}{2}^+$

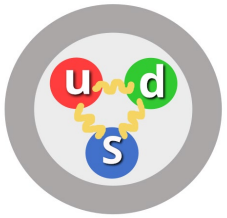


For hybrid baryons, the transverse amplitudes $A_{\frac{1}{2}}(Q^2)$ fall off more rapidly with increasing Q^2 compared to those of ordinary baryons.



The longitudinal amplitude $S_{\frac{1}{2}}(Q^2)$ is suppressed relative to the transverse amplitudes.

$\Lambda(1520)$ Electroproduction



Λ BARYONS
($S = -1, I = 0$)
$\Lambda^0 = u\,d\,s$

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$\Lambda(1520)$ $I(J^P) = 0(3/2^-)$

Discovered by FERRO-LUZZI 1962; the elaboration in WATSON 1963 is the classic paper on the Breit-Wigner analysis of a multichannel resonance. The measurements of the mass, width, and elasticity published before 1975 are now obsolete and have been omitted. They were last listed in our 1982 edition Physics Letters 111B 1 (1982). Production and formation experiments agree quite well, so they are listed together here.

Expand/Collapse All

▸ $\Lambda(1520)$ **POLE POSITION**

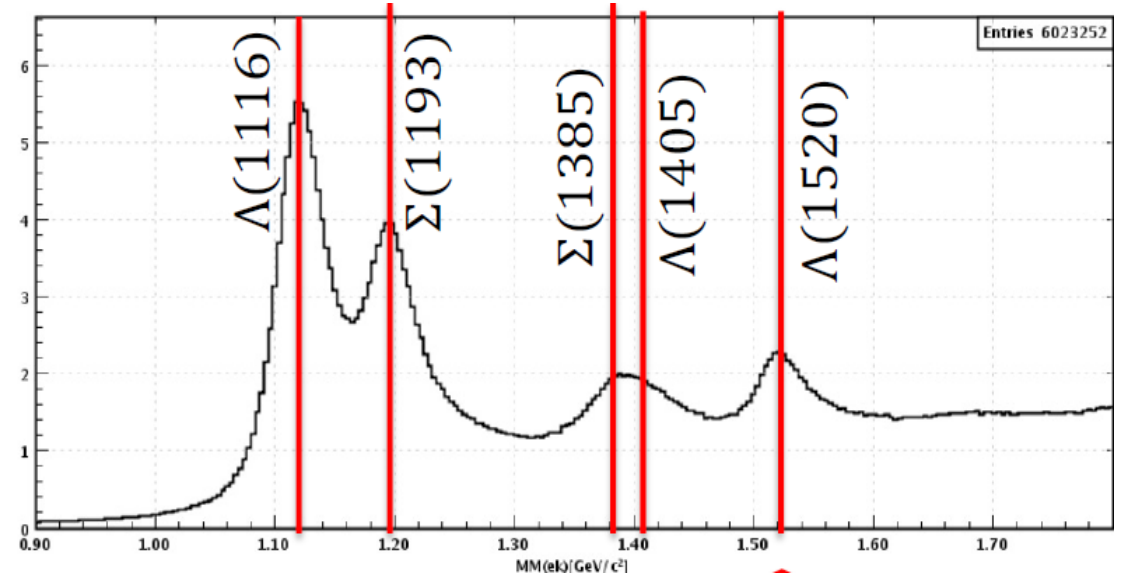
▸ $\Lambda(1520)$ **POLE RESIDUES**

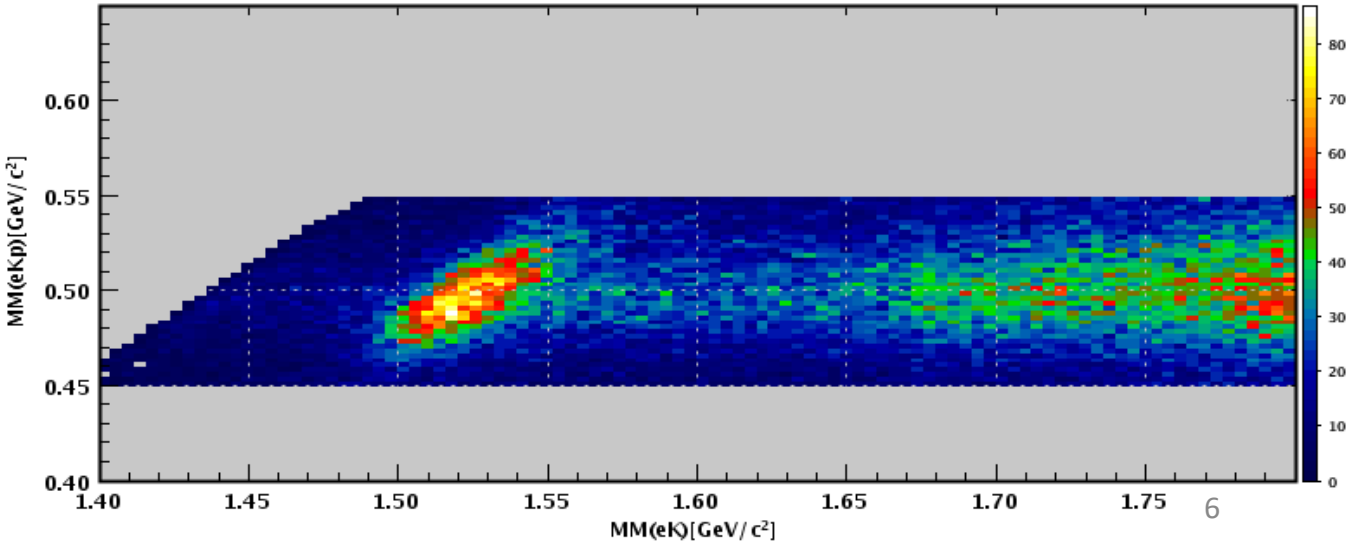
$\Lambda(1520)$ MASS	[1]	1519.42 ±0.19 MeV (S = 1.1)
$\Lambda(1520)$ WIDTH	[1]	15.73 ±0.26 MeV

KY electroproduction is expected to be a preferred channel for unobserved baryons search.

	Mode	Fraction (Γ_i / Γ)
Γ_1	$\Lambda(1520) \to N\overline{K}$	$(45 \pm 1) \times 10^{-2}$

$$ep \to e'K^+\Lambda(1520) \to e'K^+K^-p$$





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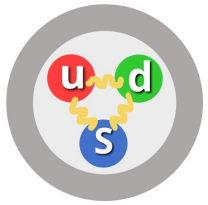

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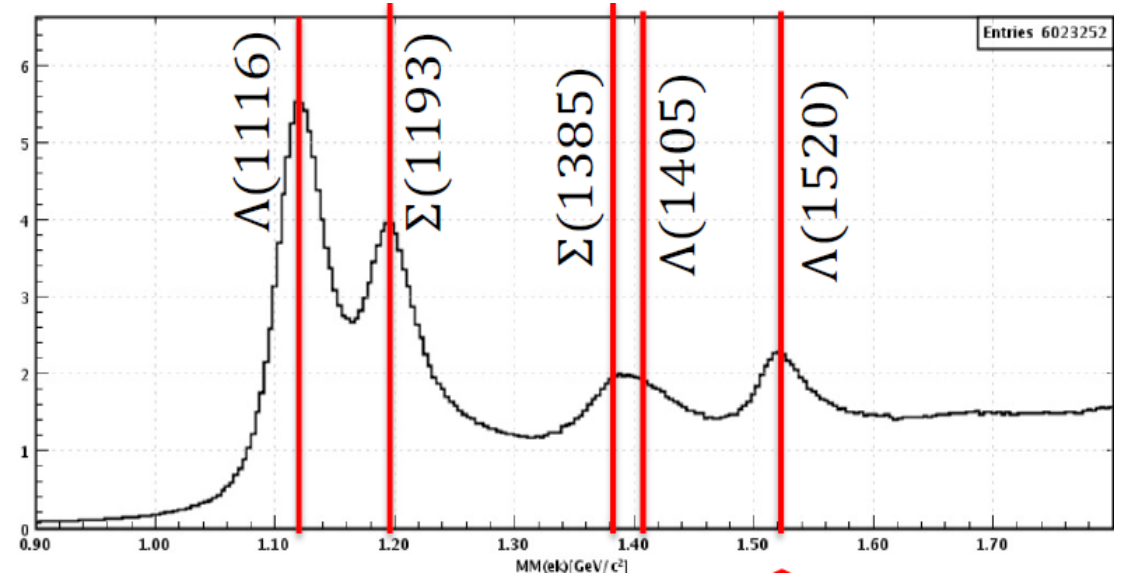
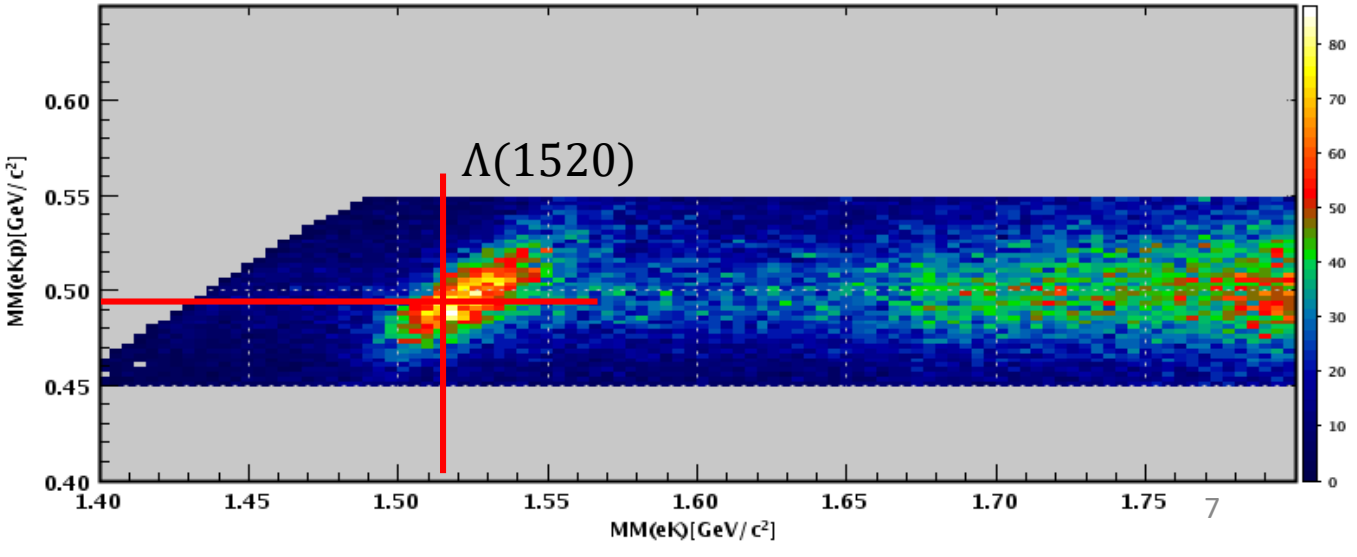
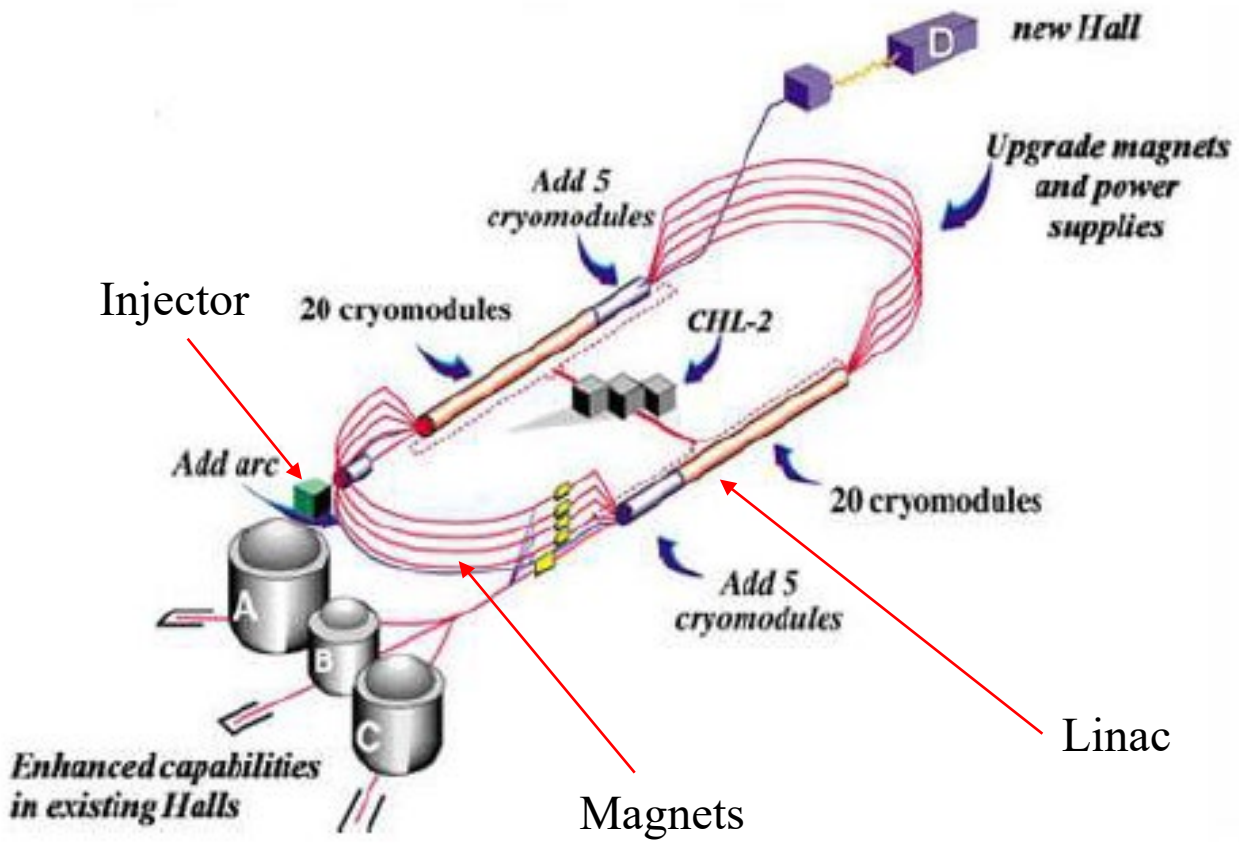




Experimental Set-Up (CEBAF)

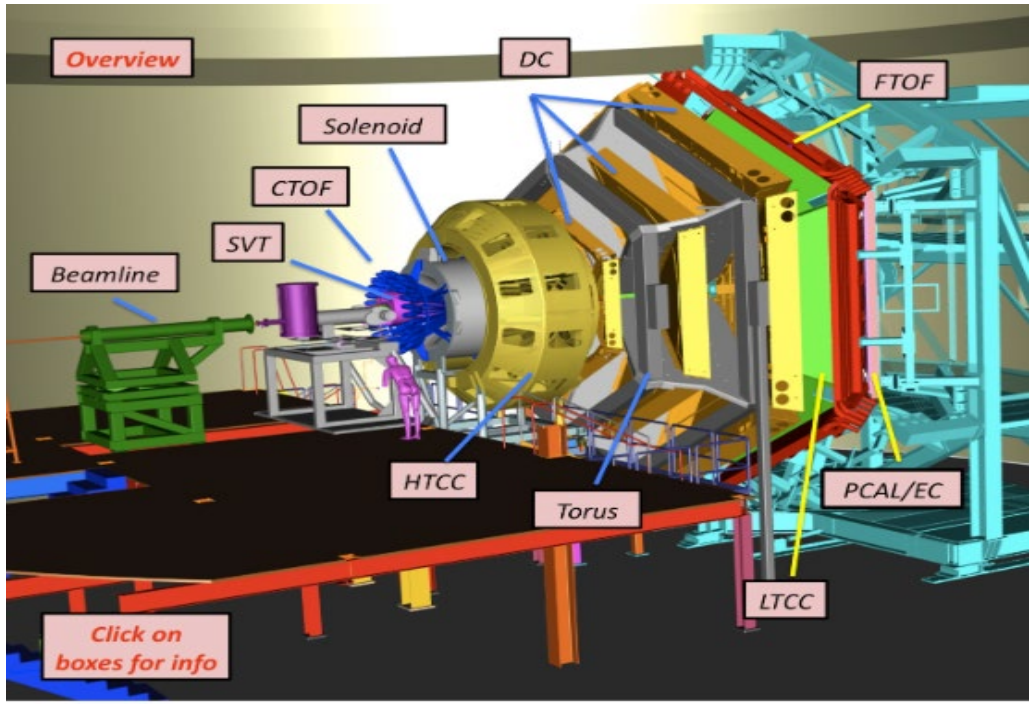


This type of research is conducted using an electron beam provided by CEBAF (JLab)

- Injector Energy: 45 MeV
- Halls A, B, and C receive an 11 GeV electron beam, while Hall D receives a 12 GeV beam.
- Maximum beam current: 200 μA
- Longitudinal polarization (Pb): up to 90%

Experimental Set-Up (CLAS12) / Statistics

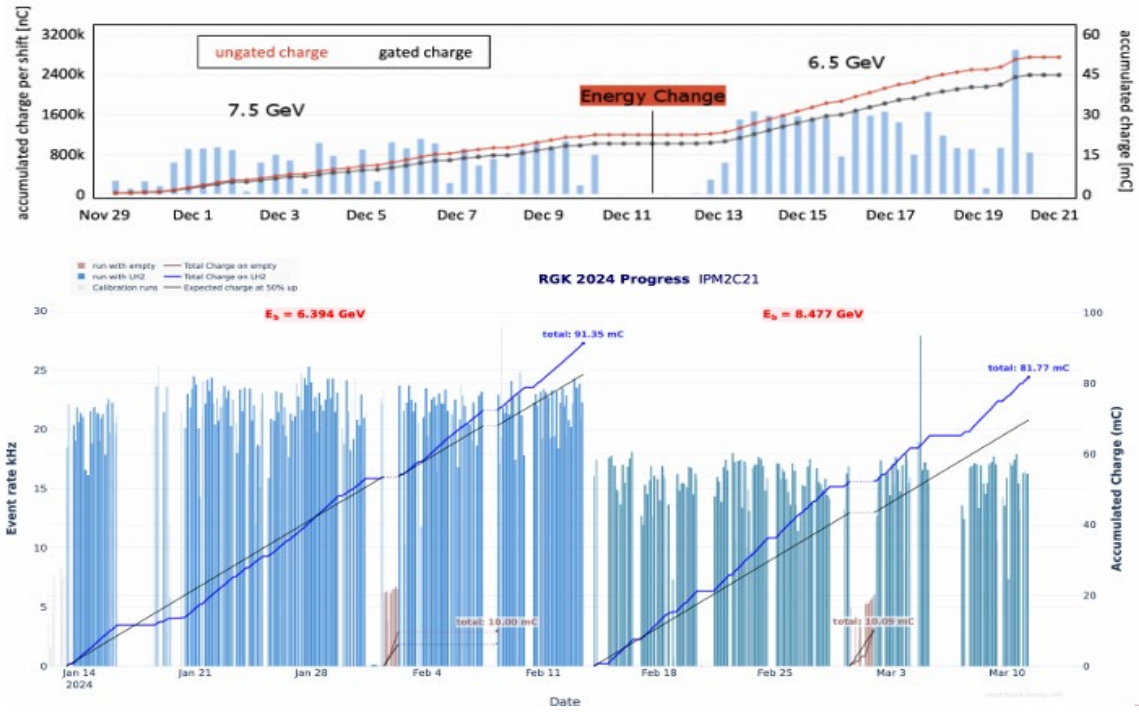
CLAS12 is a large-acceptance spectrometer installed at the Thomas Jefferson National Laboratory (JLab) in Virginia, located in Hall B.



Forward Detector (FD)

Forward Tagger (FT)

Central Detector (CD)



RGK collected a total of 65 G events at 6.4, 7.5 and 8.5 GeV

RGK CLAS12 Run Conditions

Run Group Proposal (RGK) “Color Confinement and Strong QCD”:

Search for Hybrid Baryons (qqqg)	DVCS
KY Electroproduction for the N* study	SIDIS

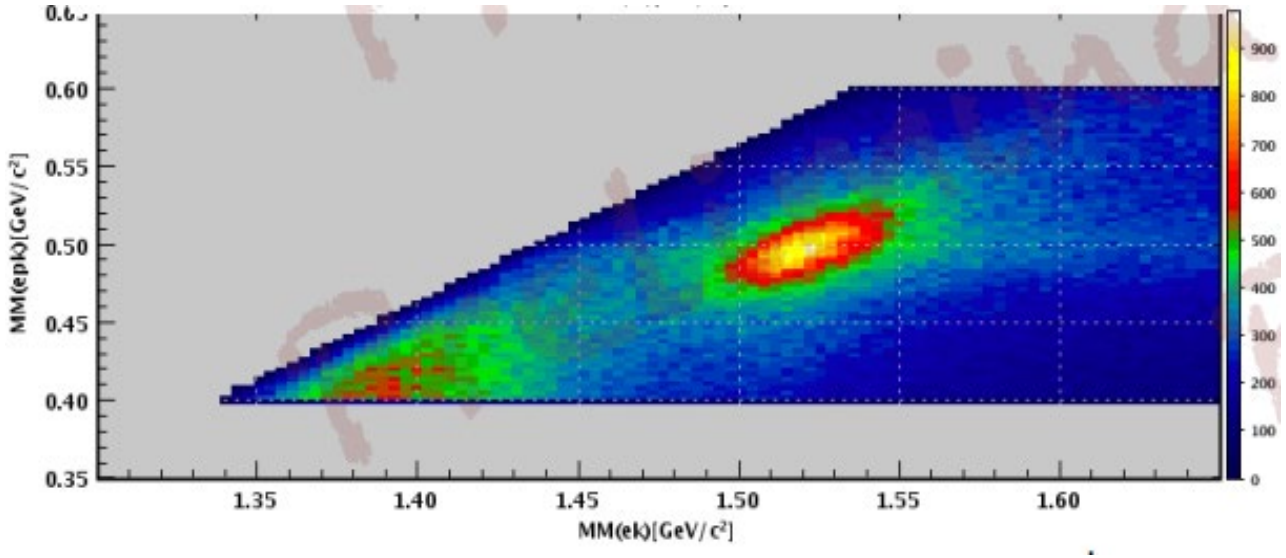
RUN CONDITIONS	
Torus Current	100% (3375 A) - negative out-bending
Solenoid	-100 %
FT	**ON @ 7.5 GeV -> OFF @ 6.5 GeV and 8.5 GeV**
Beam/Target	Polarized electrons, un-polarized LH_2 target
Luminosity	• ~ 5 10^{34} $cm^{-2}s^{-1}$ @ 7.5 GeV ~ 0.87 10^{34} $cm^{-2}s^{-1}$ @ 6.5 GeV 0.87 10^{35} $cm^{-2}s^{-1}$ @ 6.4 GeV 10^{35} $cm^{-2}s^{-1}$@8.5 GeV **FULL LUMINOSITY**

Fall 2018: EVENTS 15.6 G **Spring 2024: EVENTS 60 G (Statistics increased by a factor 4)**

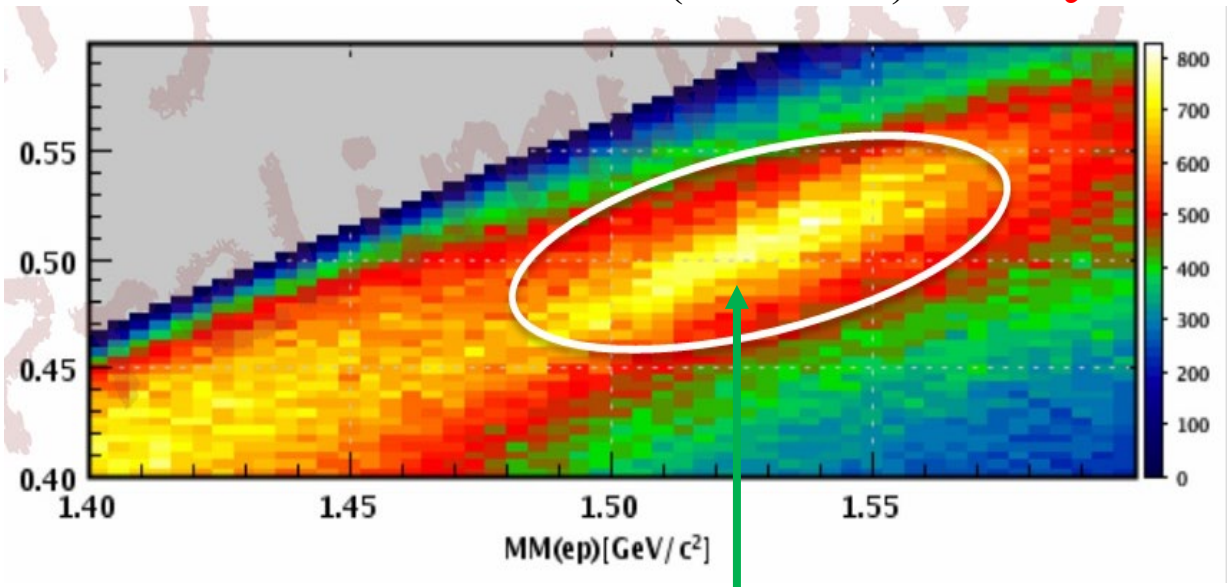
50% of the total

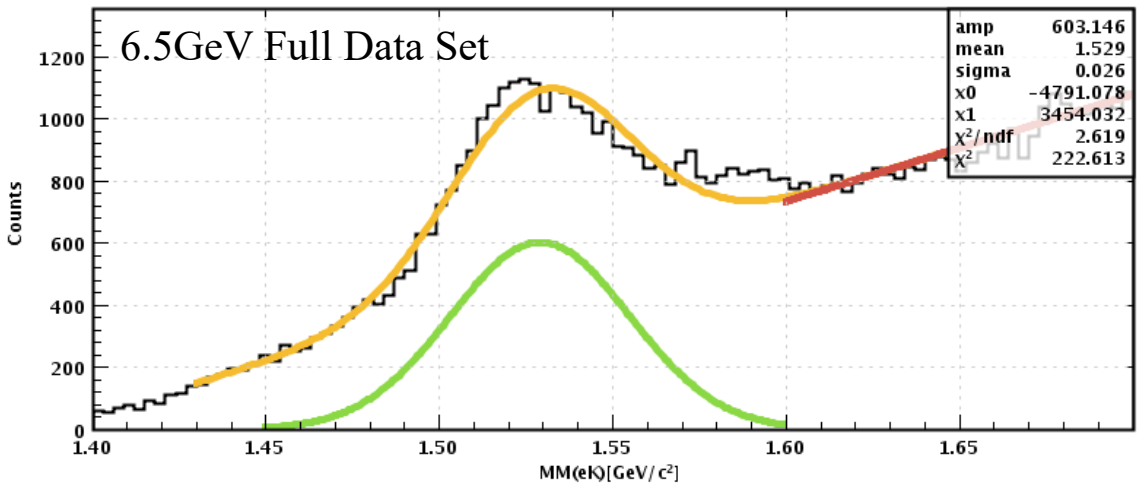
$ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+(K^-)p$

6.5GeV Full Data Set



7.5 GeV Full Data Set (FT turn-on) - ***Low Q^2***





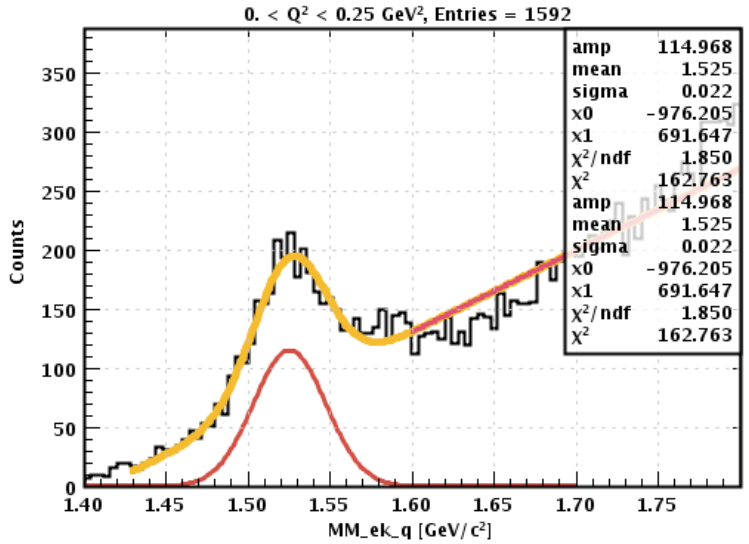
Fitting procedure:

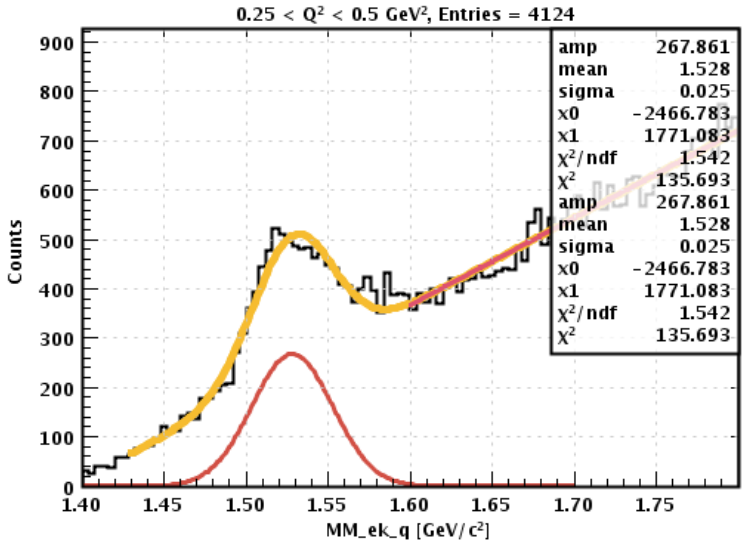
- Gaussian functions for the Λ hyperons
- second-order polynomial to model the background.

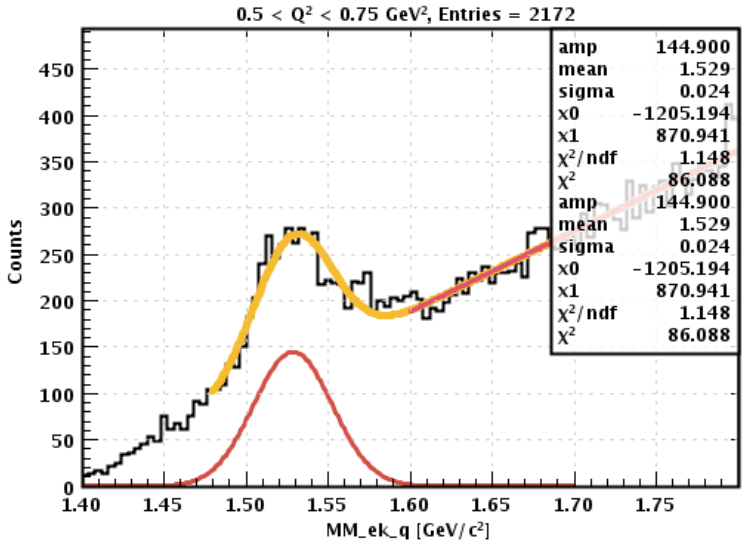
$$f(x) = Ae^{-\frac{(x-\mu)^2}{2\sigma^2}} + ax^2 + bx + c$$

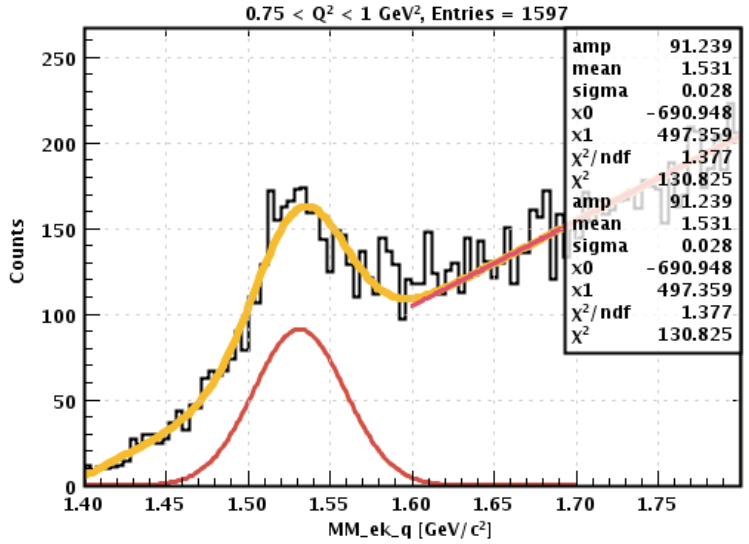
It's possible to isolate Λ(1520) also in events with an electron detected in the FT. For now we study beam spin asymmetry, in the near future cross sections.

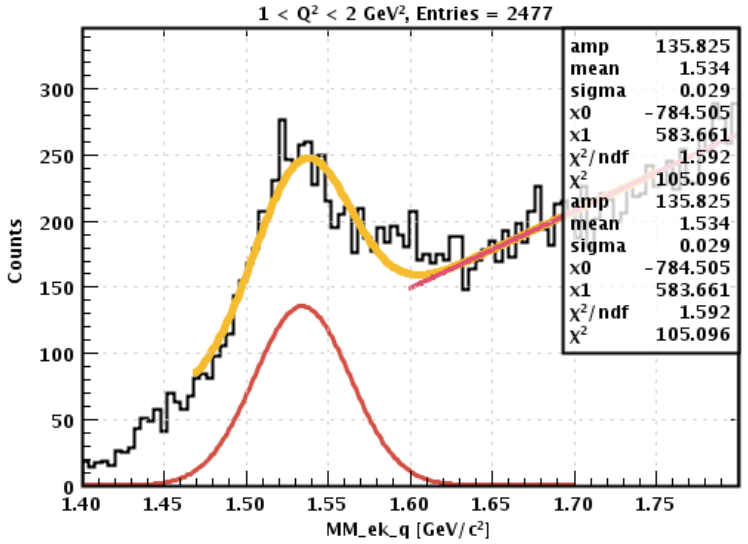
$ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+K^-p$











Next Goal? Beam spin asymmetry extraction of $\Lambda(1520)$ channel

$$A = \frac{1}{P_b}\frac{N^+ - N^-}{N^+ + N^-}$$

Thank you for your attention!