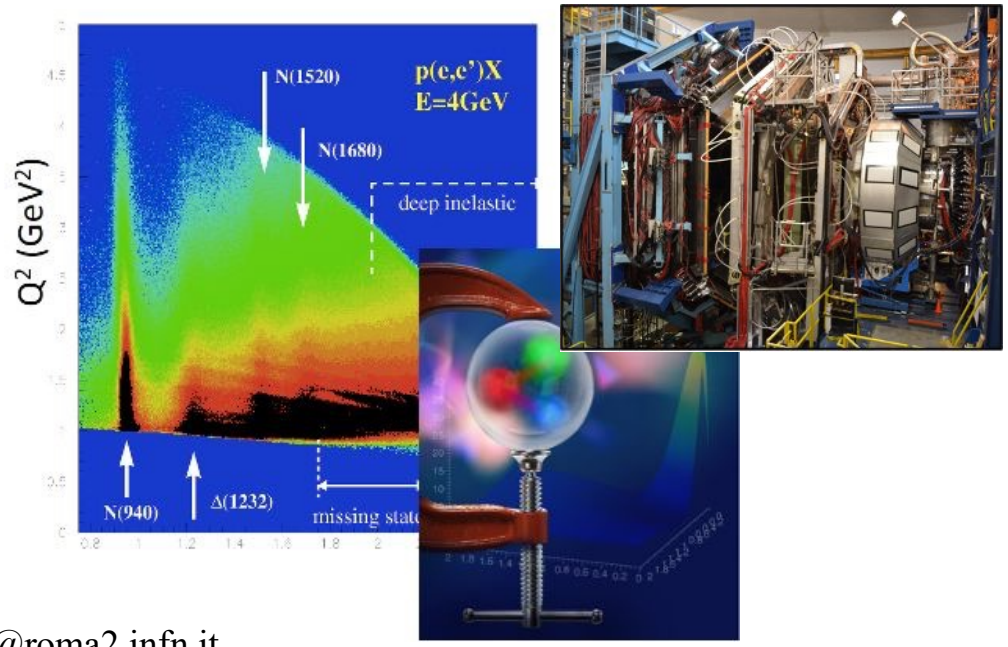
Beam Spin Asymmetry Preliminary Studies on KΛ(1520) Electroproduction at CLAS12



Chiara Ammendola PhD Student
University of Rome Tor Vergata & INFN Rome Tor Vergata
CLAS Collaboration 30th June 2026, JLAB

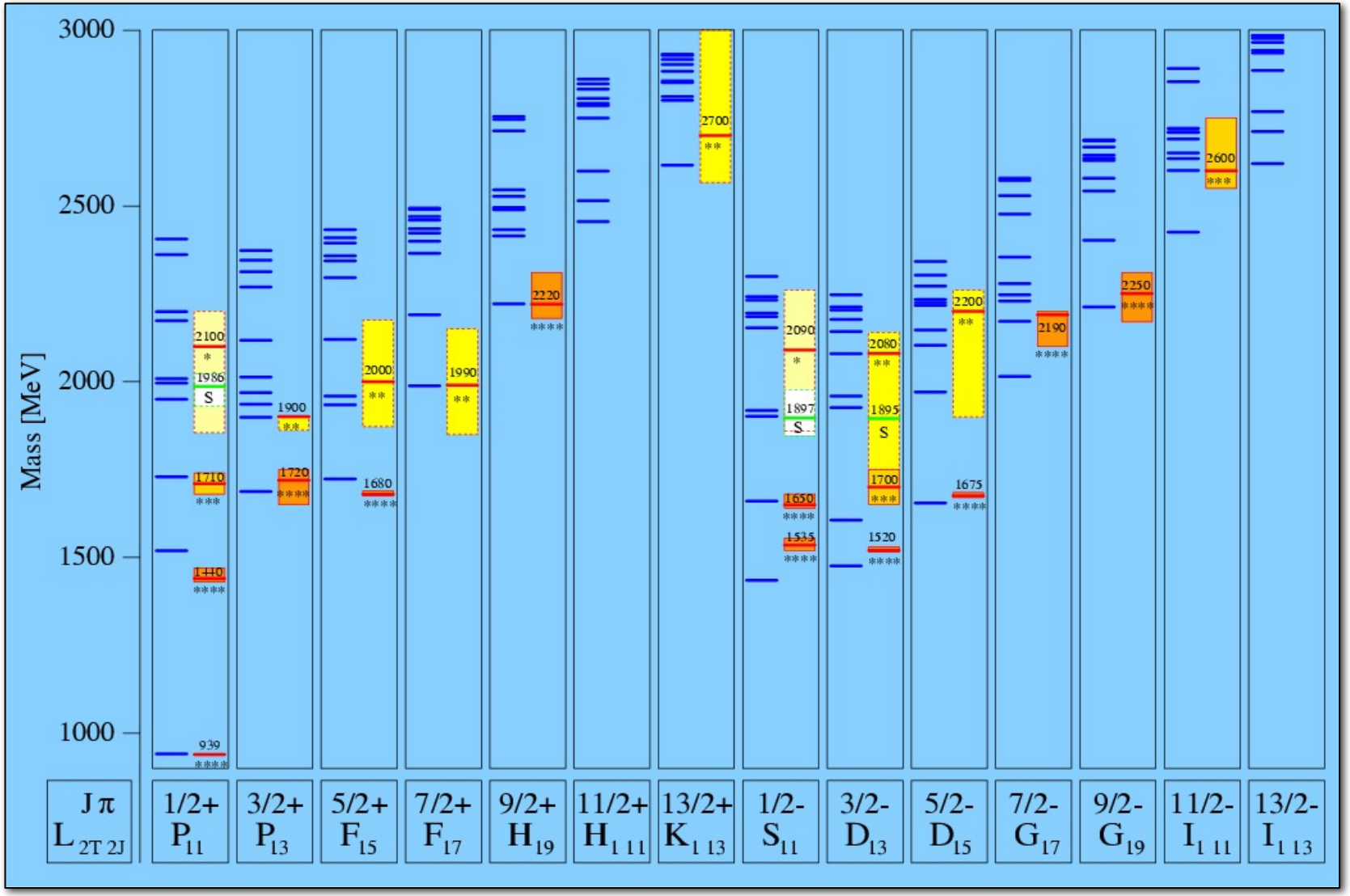
Chiara Ammendola - chiara.ammendola@roma2.infn.it

Outline

- Introduction
- Existing $\Lambda(1520)$ photo- and electro-production experimental results
- Preliminary RG-K data analysis on $\mathbf{ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+(K^-)p}$
- Future Goals

Missing Resonances Problem

Constituent Quark Models and LQCD calculations **predict a** significantly **larger number of excited states than those observed**



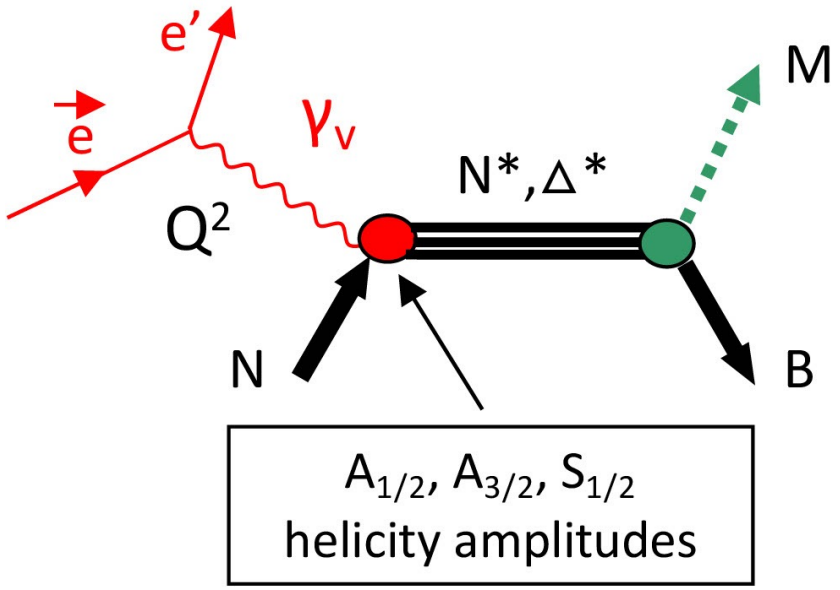
Observed Predicted

Study of Resonance Properties in Electroproduction Reactions

State $N(mass)J^P$	PDG 2010	PDG 2025	πN	$K\Lambda$	$K\Sigma$	γN
$N(1710)1/2^+$	***	****	****	**	*	****
$N(1875)3/2^-$		***	**	*	*	**
$N(1880)1/2^+$		***	*	**	**	**
$N(1895)1/2^-$		****	*	**	**	****
$N(1900)3/2^+$	**	****	**	**	**	****
$N(2000)5/2^+$	*	**	*			**
$N(2060)5/2^-$		***	**	*	*	***
$N(2100)1/2^+$	*	***	***	*		**
$N(2120)3/2^-$		***	**	**	*	***
$\Delta(1600)3/2^+$	***	****	***			****
$\Delta(1900)1/2^-$	**	***	***		**	***
$\Delta(2200)7/2^-$	*	***	**		**	***

Baryon resonances are produced as intermediate states in meson electroproduction processes on proton (and neutron) targets.

New resonances may decay into a KY meson-baryon couple with associate strangeness



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Confidence level of observed resonances

Why KΛ and KΛ*?

It should be possible to **discover new excited baryons** and confirm the discovery of several others **by analyzing** final states such as :

$$K\Lambda,\ K\Sigma,\ \Lambda K^*,\ K\Sigma^*,\ K\Lambda^*$$

Strange decays of nonstrange baryons

Simon Capstick
Supercomputer Computations Research Institute and Department of Physics, Florida State University, Tallahassee, Florida 32306

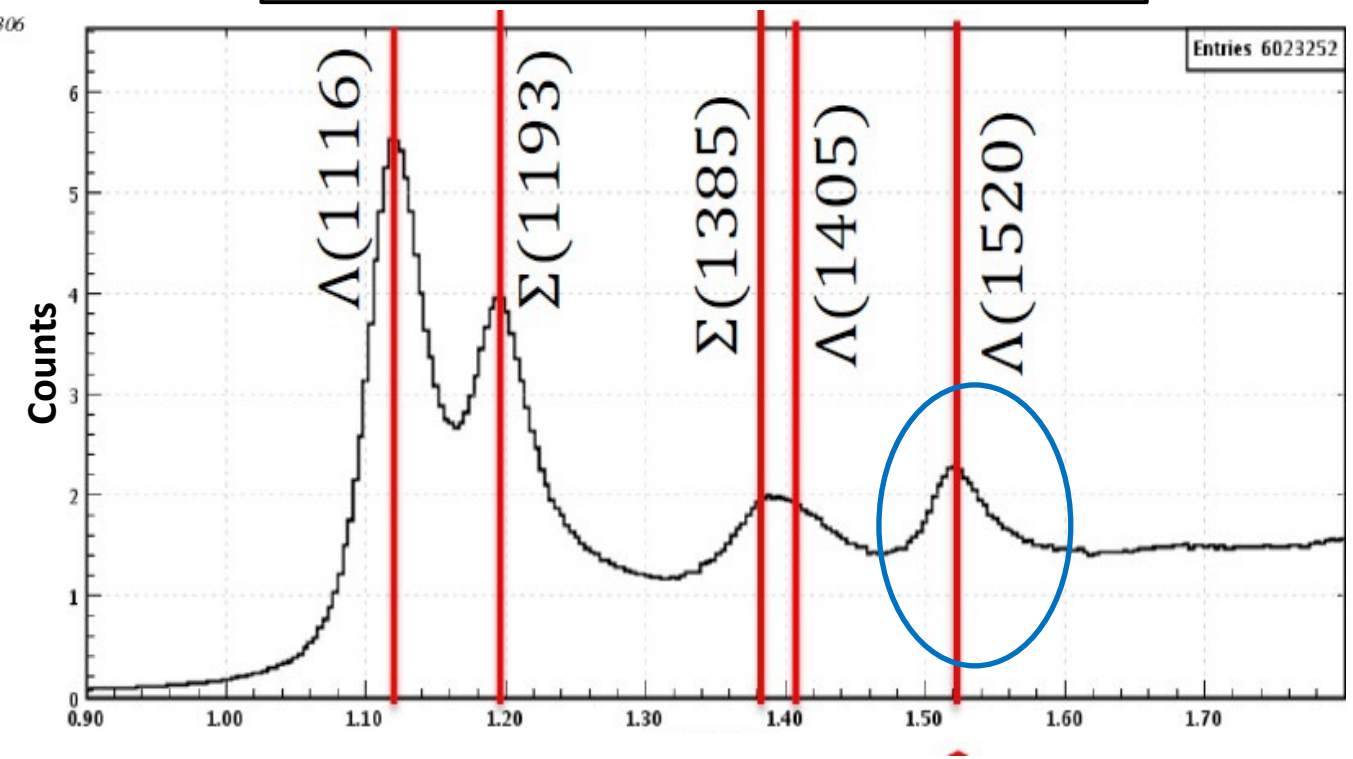
W. Roberts
Department of Physics, Old Dominion University, Norfolk, Virginia 23529
and Thomas Jefferson National Accelerator Facility, 12000 Jefferson Avenue, Newport News, Virginia 23606
(Received 29 April 1998; published 9 September 1998)

S.Capstick and W.Roberts,Phys. Rev. D 58,074011(1998)

$\Lambda(1520)$ properties

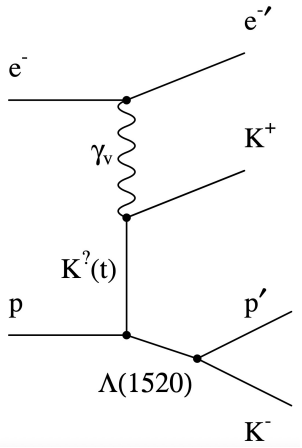
$I(J^P) = 0\left(\frac{3}{2}^-\right)$
M= 1519.42±0.19 MeV
$\Gamma = 15.80 \pm 0.32$ MeV
BR: $N\bar{K} = 0.44 \pm 0.01$
pK^- = (23.4±1.6)%

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



Previous results: first KΛ(1520) electro-production at CLAS

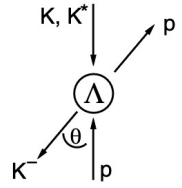
- KΛ(1520) e1 electroproduction at CLAS Phys. Rev. C **64**, 044601(2001)

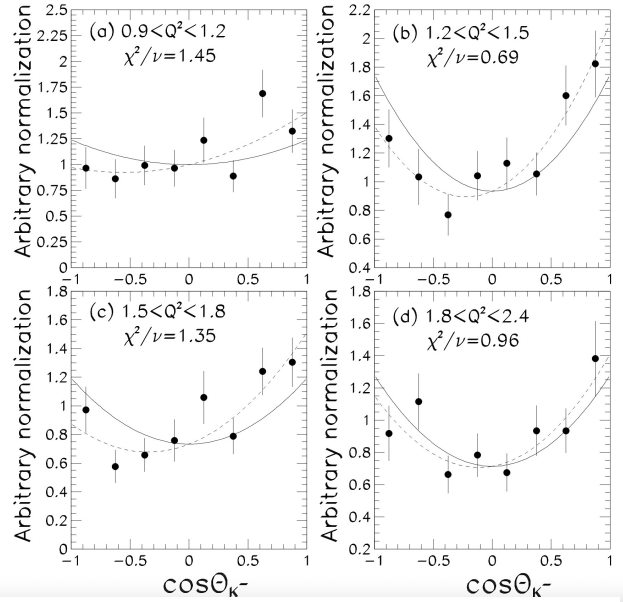


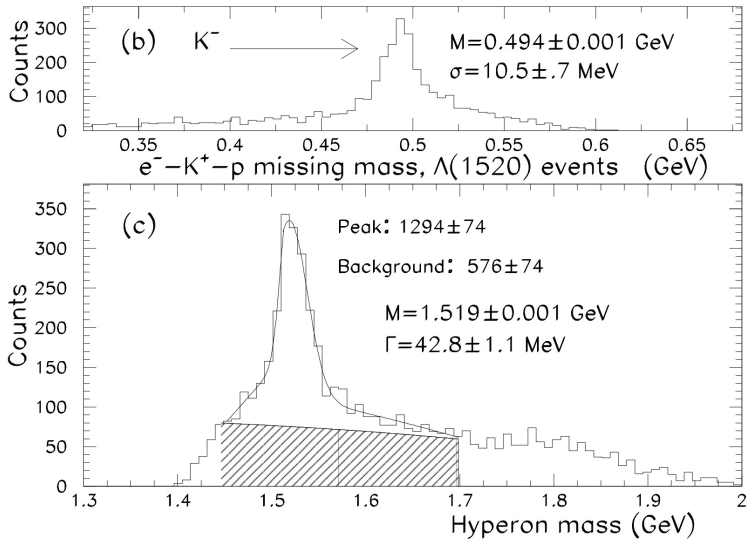
➢ Λ(1520) spin projection distributions from the Λ(1520) decay in the GJ helicity frame were fitted to disentangle J = $\frac{1}{2}$ background from the J = $\frac{3}{2}$ Λ(1520)

$$f(\theta_{K^-}) = \alpha\left(\frac{1}{3} + \cos^2\theta_{K^-}\right) + \beta \sin^2\theta_{K^-} + \gamma \cos\theta_{K^-}$$

$J^P = \frac{1^-}{2}$ $J^P = \frac{3^-}{2}$



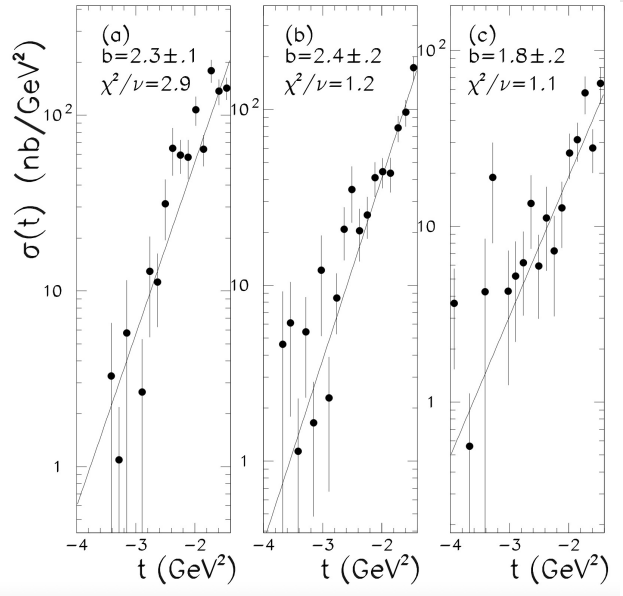




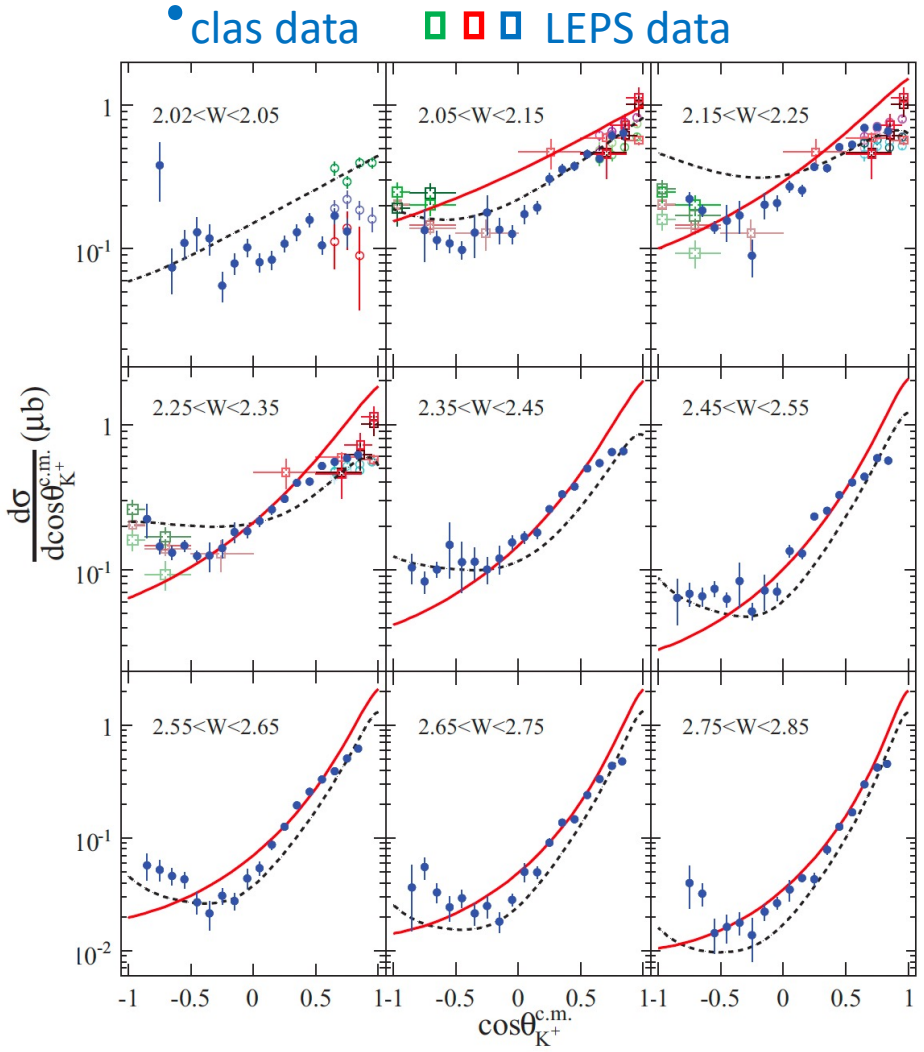
The following observables have been measured:

- σ (t)differential cross section
- ϕ_K angular distribution
- σ (W) total cross section
- σ (Q^2) total cross section

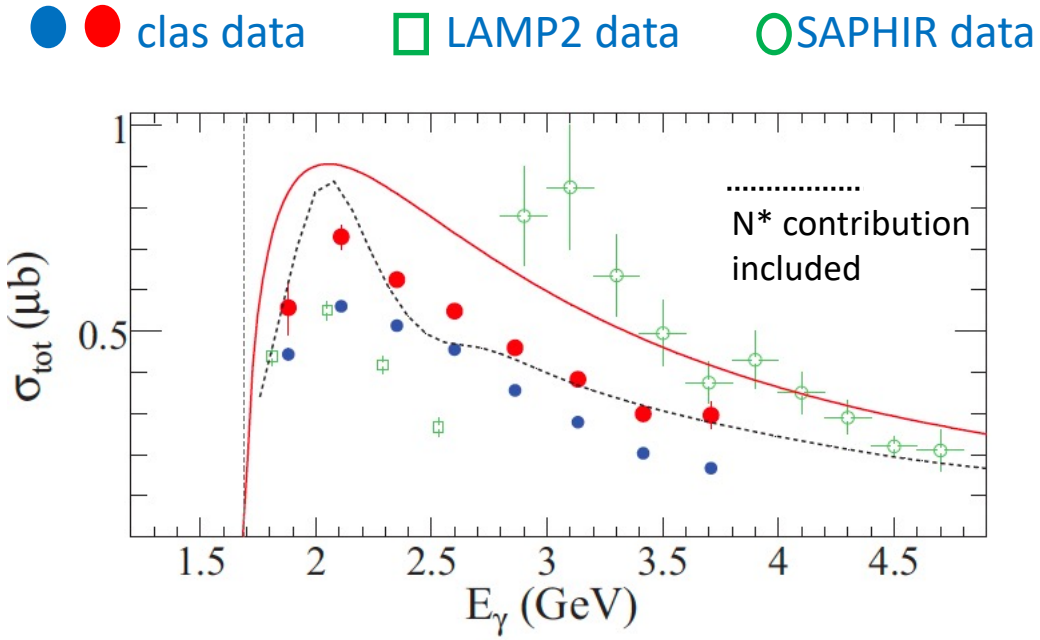
The conclusion was that longitudinal t-channel diagrams make significant contributions to electroproduction but not in photoproduction



Previous results: CLAS KΛ(1520) photoproduction



PHYSICAL REVIEW C 88, 045201 (2013)



CLAS data support the model including N* contribution

More observables are needed !

Electroproduction Differential Cross Section

$$\frac{d\sigma}{d\Omega_K^{c.m.}} = \sigma_T + \epsilon\sigma_L + \sqrt{\epsilon(1+\epsilon)}\sigma_{LT}\cos\Phi + \epsilon\sigma_{TT}\cos 2\Phi + h\sqrt{\epsilon(1-\epsilon)}\sigma_{LT'}\sin\Phi$$

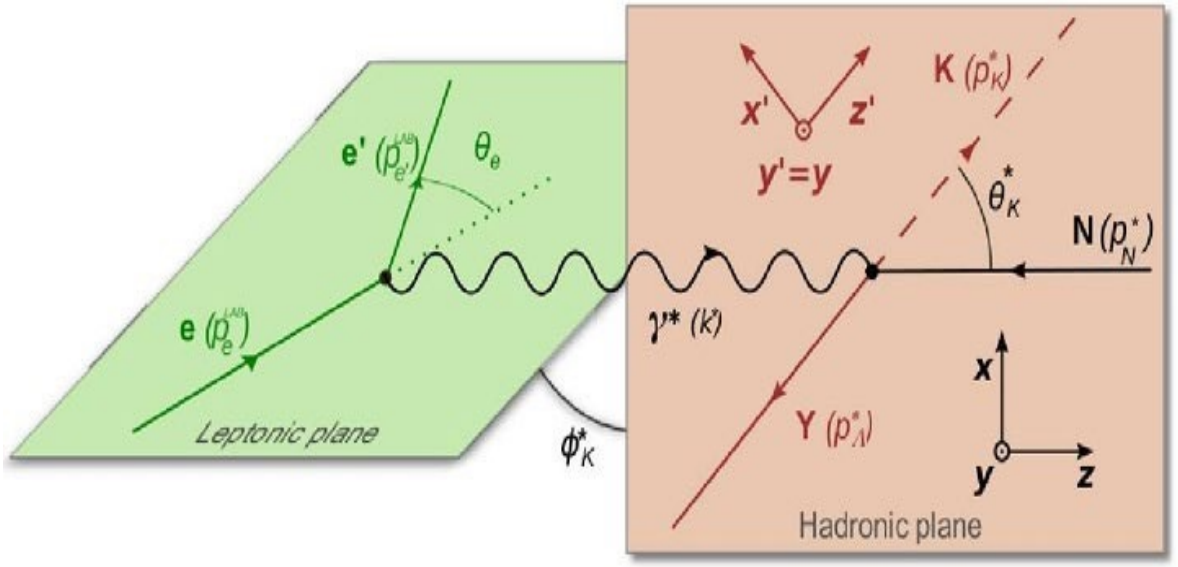
helicity dependent structure function

Electron Helicity Independent Terms (HIT)

- σ_T virtual photon transverse structure function
- σ_L virtual photon longitudinal structure function
- σ_{LT} interference longitudinal - transverse structure function
- σ_{TT} interference transverse - transverse structure functions
- ε virtual photon polarization parameter

$$\varepsilon = \left[1 + 2\left(1 + \frac{\nu^2}{Q^2}\right) tan^2\left(\frac{\theta_e}{2}\right)\right]^{-1}$$

- $\sigma_{LT'}$ helicity dependent interference longitudinal - transverse structure function



Beam Polarization Observables

CLAS12 SetUp Characteristics:

Longitudinally polarized beam (h=+/-1) on **Unpolarized target**

The simplest accessible polarization observable is the **beam-spin asymmetry**

Helicity dependence of the (virtual) cross section:

$$\frac{d\sigma_v}{d\Omega} = \text{HIT} + h\sqrt{\epsilon(1-\epsilon)}\,\sigma_{LT'}\sin\phi$$

$$\sigma^{\pm} = \text{HIT} \pm \sqrt{\epsilon(1-\epsilon)}\,\sigma_{LT'}\sin\phi$$

$$A_{LT'} = \frac{1}{P_b}\cdot\frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{\sqrt{\epsilon(1-\epsilon)}\sigma_{LT'}\sin\Phi}{\sigma_0}$$

$$A_{LU} = \frac{1}{P_b}\times\frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} \Rightarrow A_{LU} = \frac{1}{P_b}\times\frac{N^+ - N^-}{N^+ + N^-}$$

The + and – superscripts correspond to beam helicity 1 and -1

$$A_{LU} = \frac{1}{P_b}\frac{N^+ - N^-}{N^+ + N^-} \sim A_{LU}^{sin\Phi}\, sin\phi$$

$\Lambda(1520)$

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

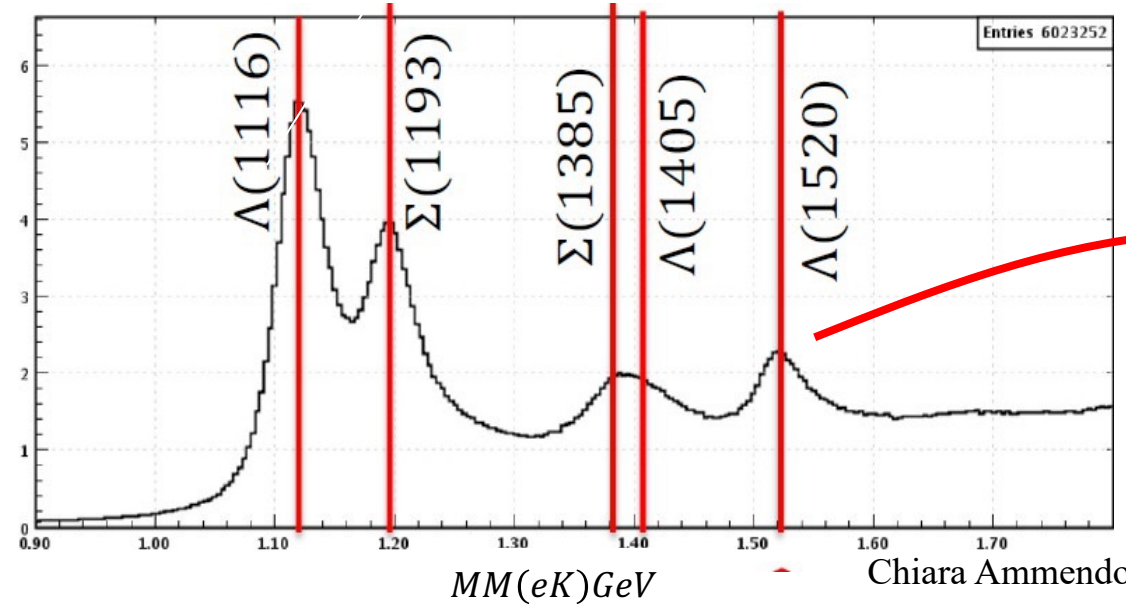
Selection Condition

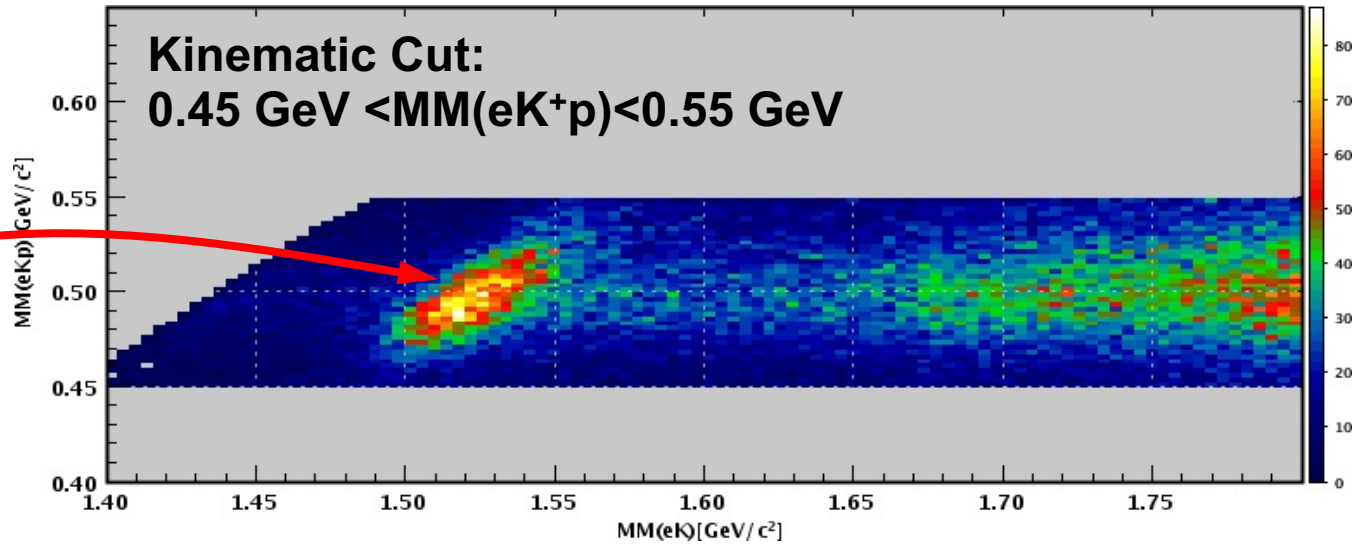
- e Forward Detector
- p Forward/ Central Detector
- K Central/ Central Detector
- E_b = 6.5 GeV

Data Set belongs Fall 2018

$$MM(eK^+) = \sqrt{(p_e + p_T - p_{e'} - p_K)^2}$$

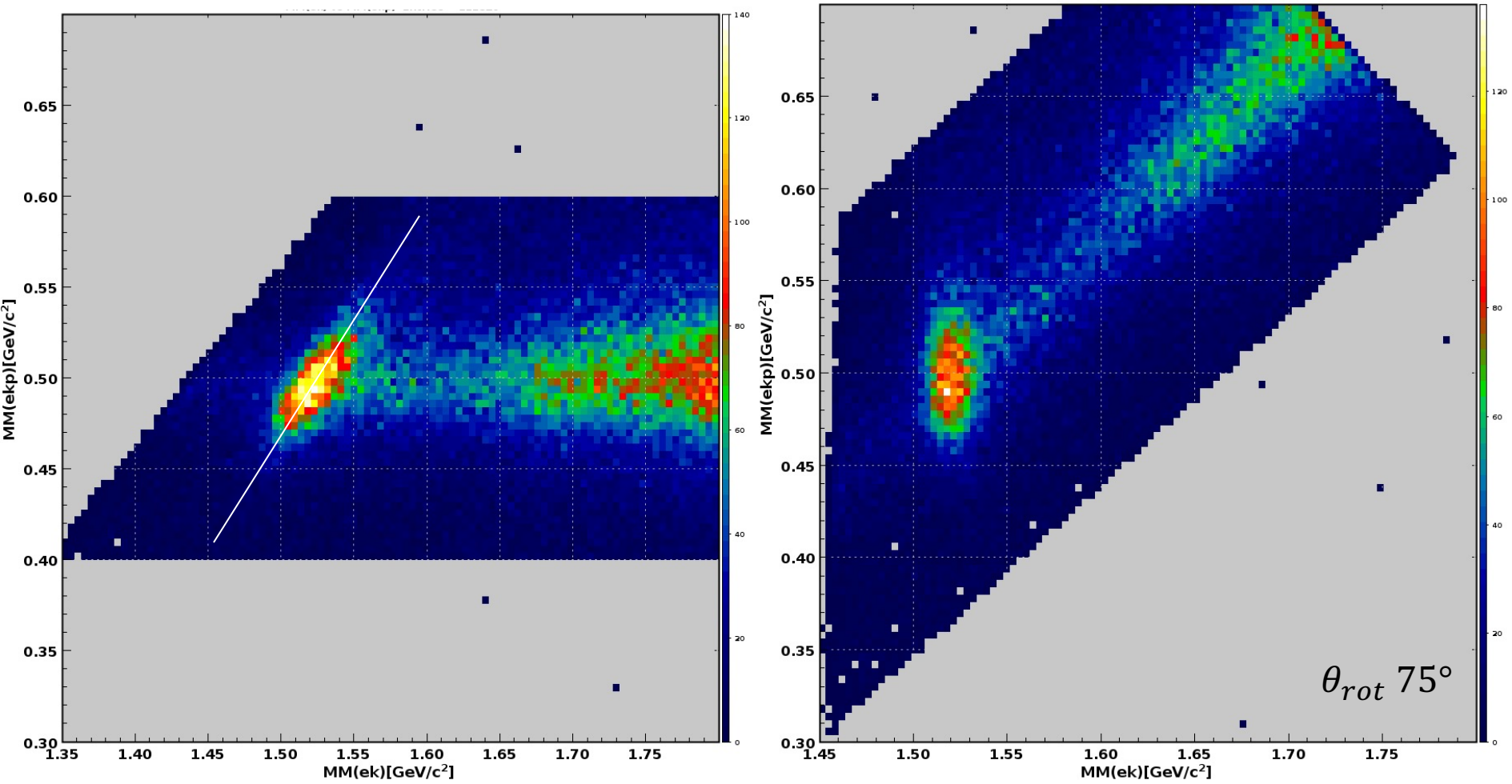
$$MM(eK^+p) = \sqrt{(p_e + p_T - p_{e'} - p_K - p_p)^2}$$





MM(eK⁺) vs MM(eK⁺p)

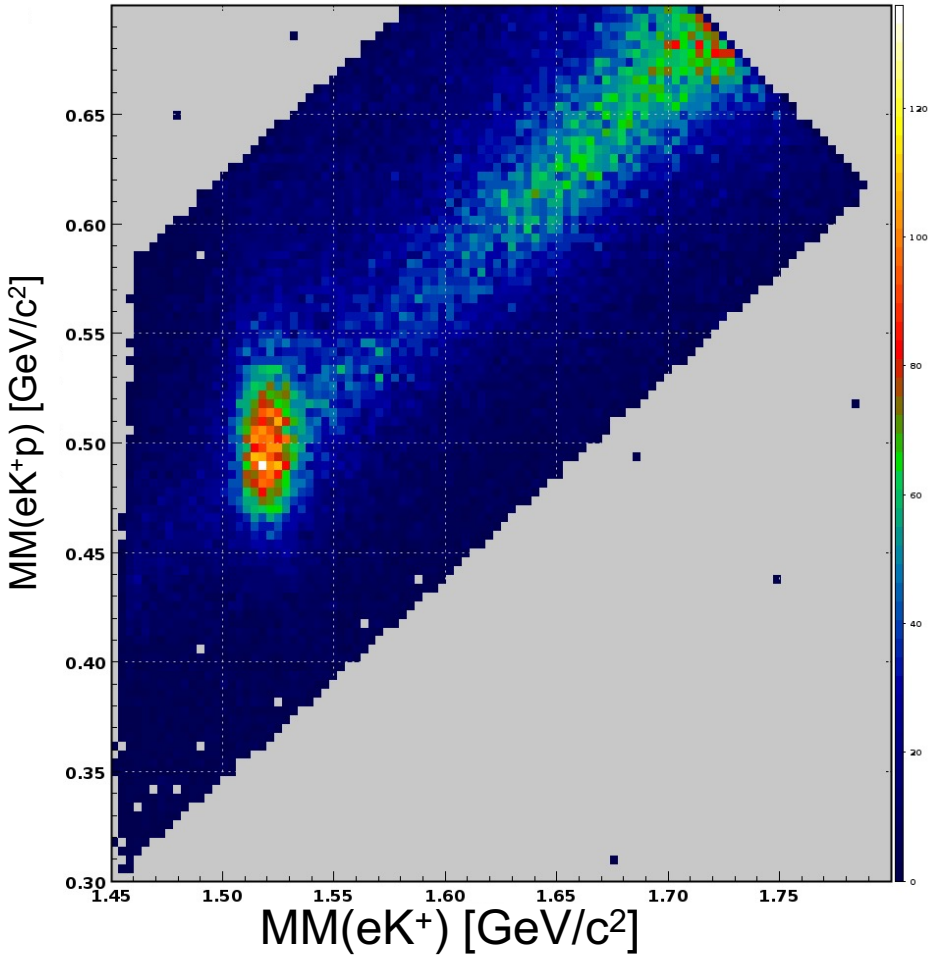
$ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+(K^-)p$ Eb= 6.5 GeV ($0.3\text{GeV}^2 < Q^2 < 2\text{GeV}^2$)

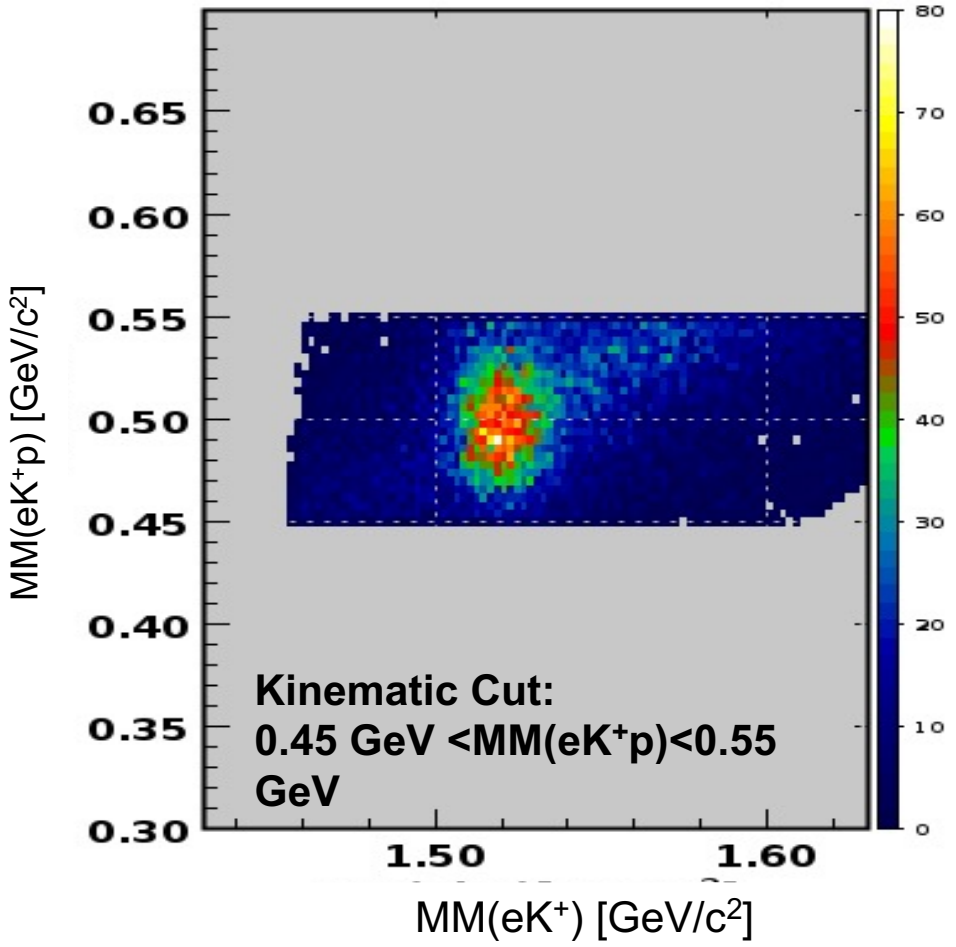


- MM(eK⁺) vs MM(eK⁺p) are kinematically correlated: in the 2D plane, events are distributed along a narrow diagonal band
- A 75° rotation decorrelates the two variables, making the $\Lambda(1520)$ signal narrower

MM(eK⁺) vs MM(eK⁺p)

$ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+(K^-)p$ **Eb= 6.5 GeV** $(0.3\mathrm{GeV}^2 < Q^2 < 2\mathrm{GeV}^2)$

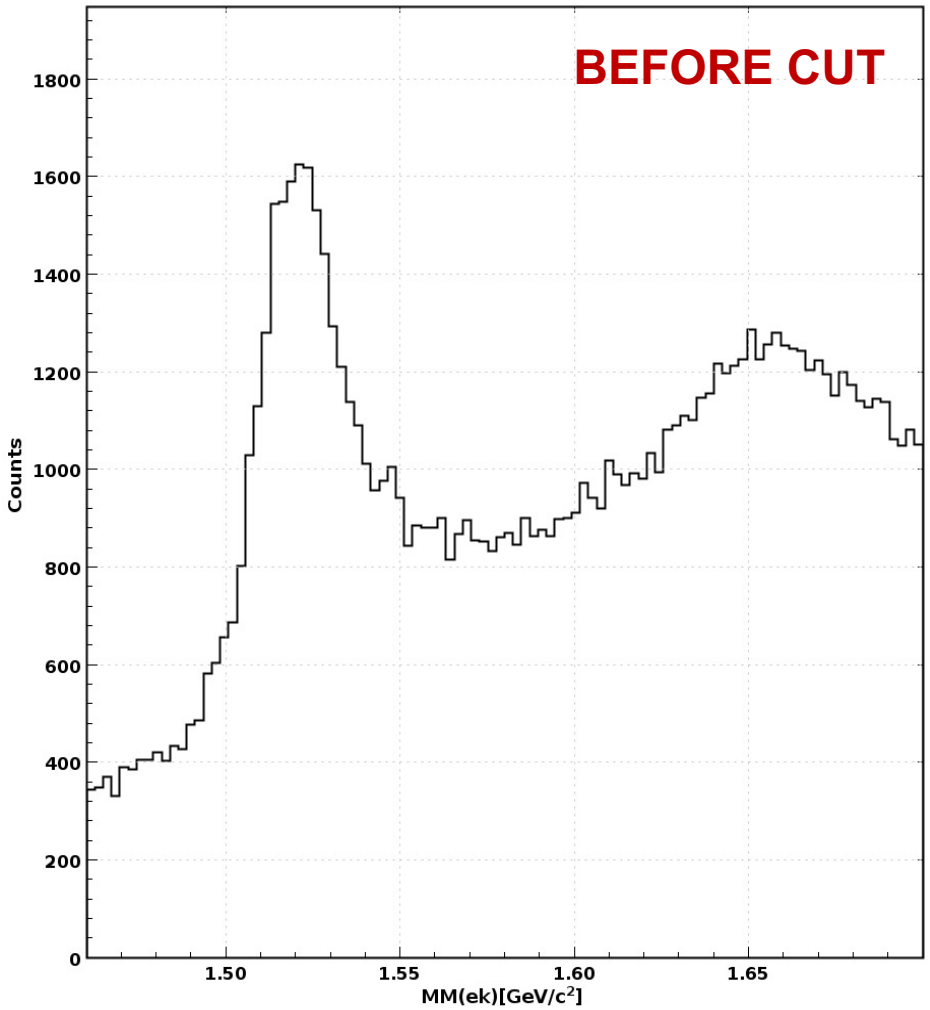


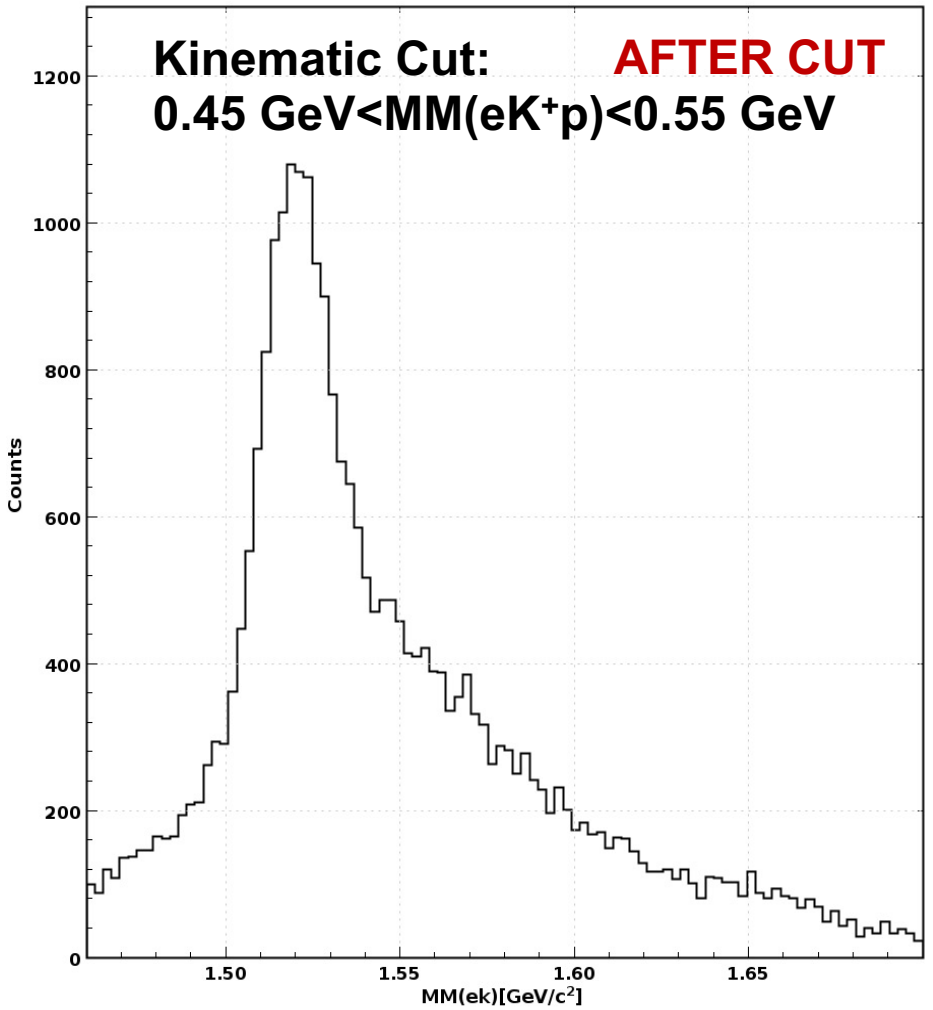


The cut on **0.45 GeV<MM(eK⁺p)<0.55 GeV** removes the background, improving the signal to background ratio

MM(eK⁺)

$ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+(K^-)p$ **Eb= 6.5 GeV** $(0.3\mathrm{GeV}^2 < Q^2 < 2\mathrm{GeV}^2)$





- The MM(eK⁺) with rotation profile **before the cut** shows the $\boldsymbol{\Lambda(1520)}$ at $\sim 1.52\ GeV$ sitting on top a large continuous background
- The MM(eK⁺) with rotation profile **after the cut** shows a narrower and more prominent $\boldsymbol{\Lambda(1520)}$ peak, the continuous background significantly reduced

The spectrum after the cut is used as input for the fitting procedure

Fitting Procedure (Lorentzian + Radiative Tail)

$ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+(K^-)p$ **Eb= 6.5 GeV** $(0.3\text{GeV}^2 < Q^2 < 2\text{GeV}^2)$

$$f(t) = A\begin{cases} \dfrac{1}{t^2+1} & t \le \alpha \\ \dfrac{B}{(C-t)^n} & t > \alpha \end{cases}$$

$$B = \left(-\frac{n}{2\alpha}\right)^n (\alpha^2+1)^{n-1}$$

$$C = \alpha - n\,\frac{\alpha^2+1}{2\alpha}$$

$$t = \frac{E - E_0}{\frac{\Gamma}{2}}$$

$$f(t) = A\begin{cases} \dfrac{1}{t^2+1} & t \le \alpha \\ \dfrac{\left(-\frac{n}{2\alpha}\right)^n (\alpha^2+1)^{n-1}}{\left(\alpha - n\,\frac{\alpha^2+1}{2\alpha} - t\right)^n} & t > \alpha \end{cases}$$

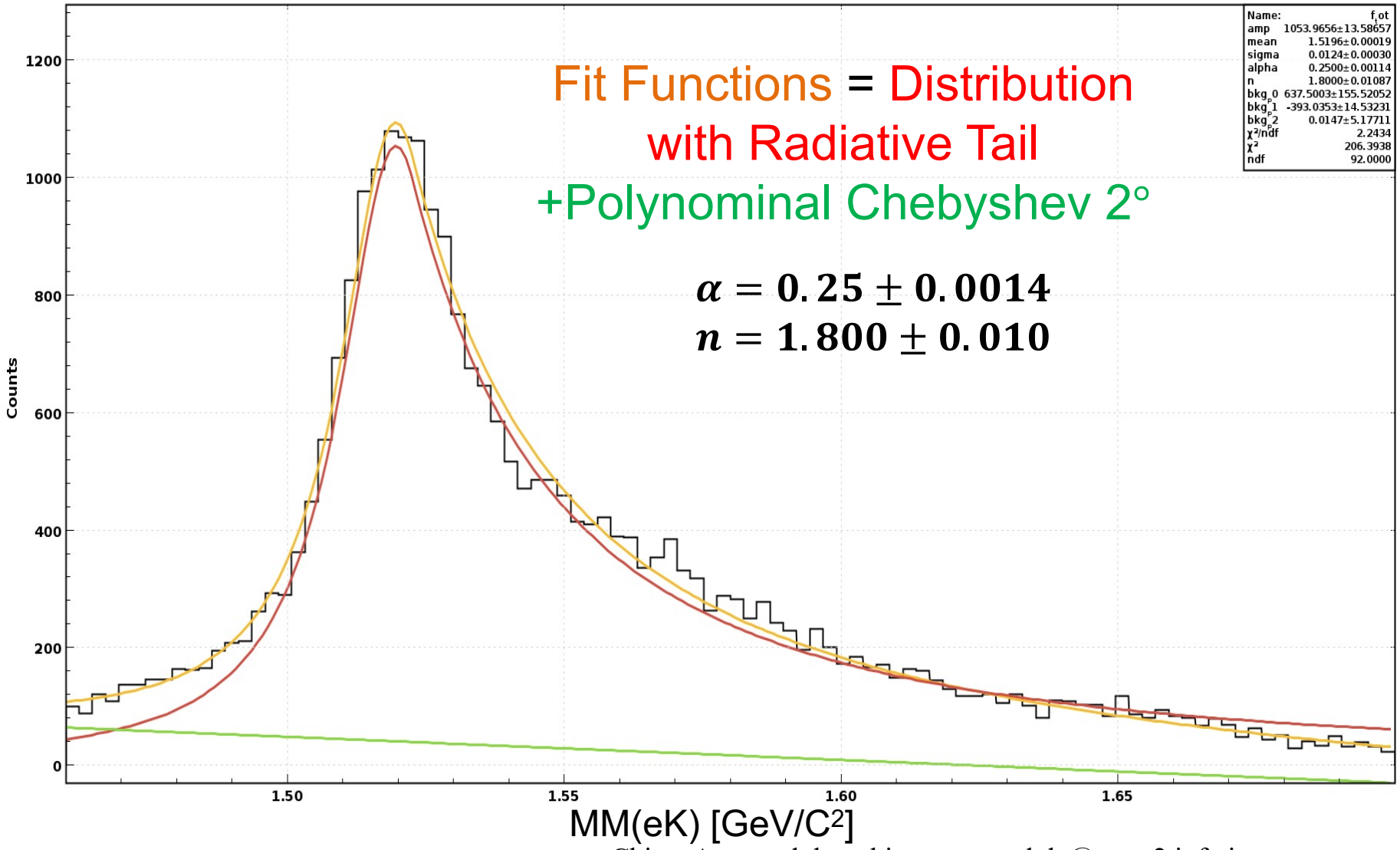
- n is the power of the power -law tail
- α defines the matching point between the Lorentzian core and the power-law tail

Background

$$Bkg = A + Bx + C\left(2x^2 - 1\right)$$

Fitting Procedure (Lorentzian + Radiative Tail)

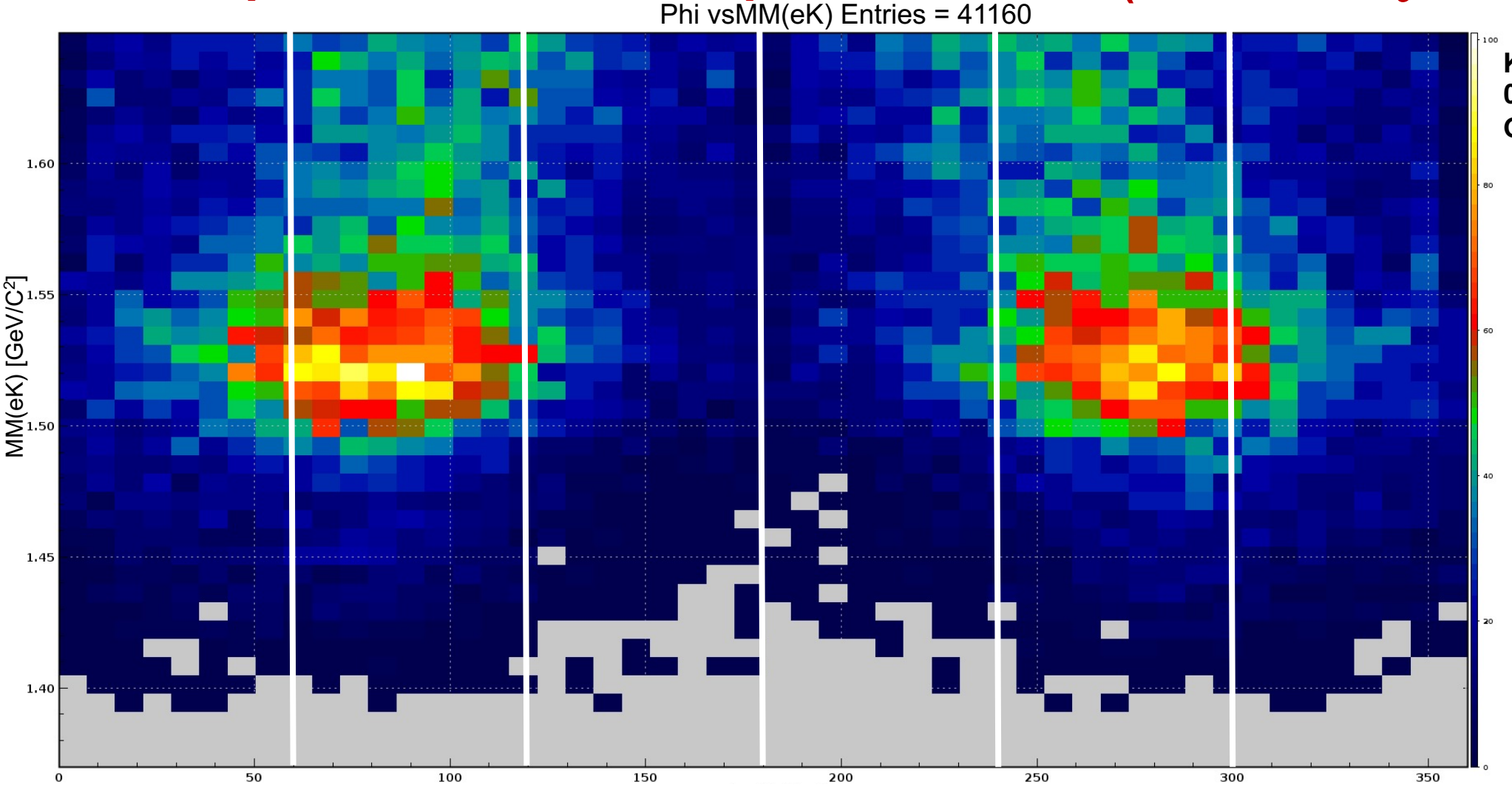
$ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+(K^-)p$ **Eb= 6.5 GeV** $(0.3\text{GeV}^2 < Q^2 < 2\text{GeV}^2)$



Fit function was optimized on full spectrum without helicity and ϕ separation to fix n and alpha parameters.

Phi (Φ) vs MM(eK⁺) (Binning Choice)

$ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+(K^-)p$ **E_b= 6.5 GeV($0.3\text{GeV}^2 < Q^2 < 2\text{GeV}^2$)**



Kinematic cut applied: 0.45 GeV <MM(eKp)< 0.55 GeV

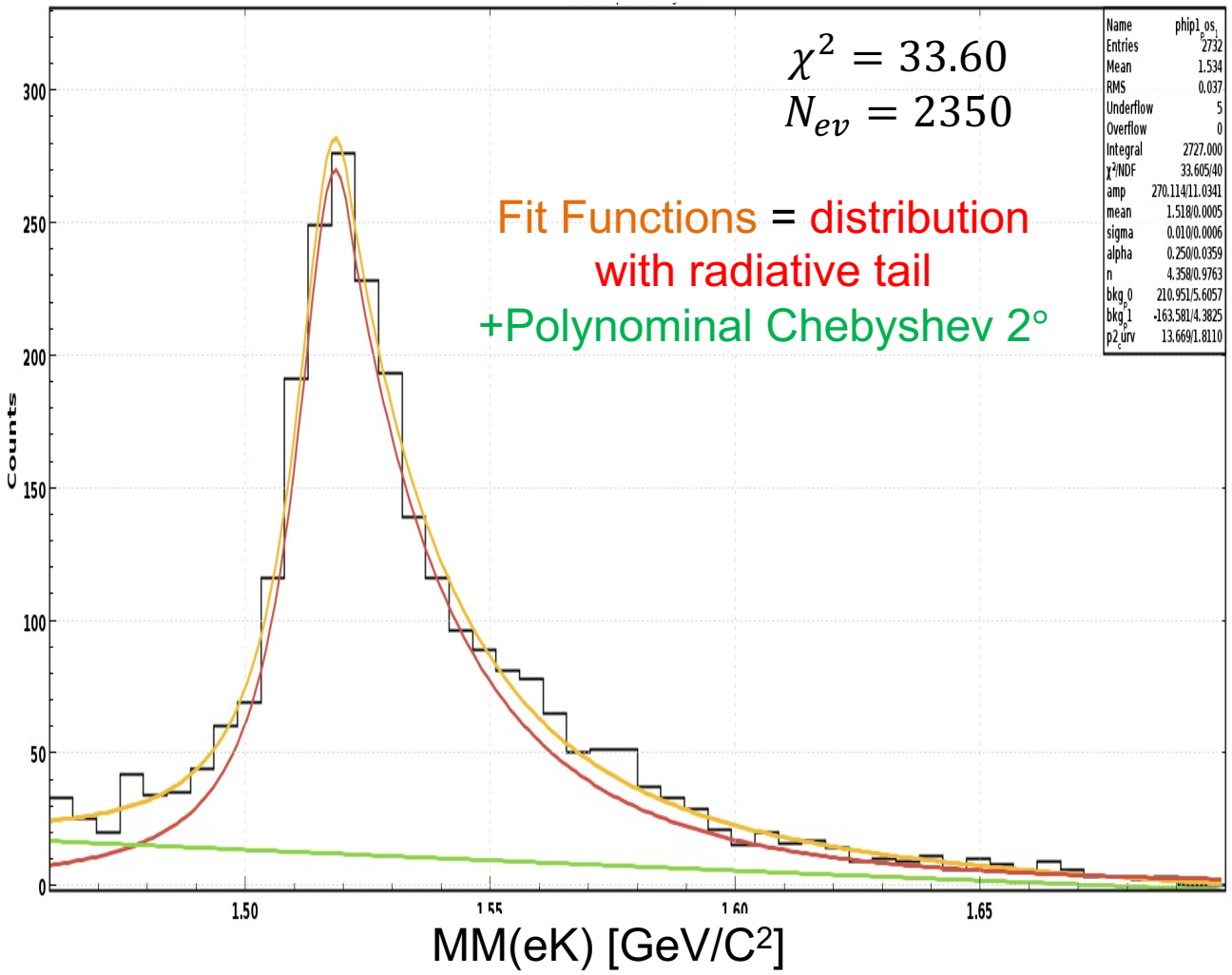
Φ

[0,60]
[60,120]
[120,180]
[180,240]
[240,300]
[300,360]

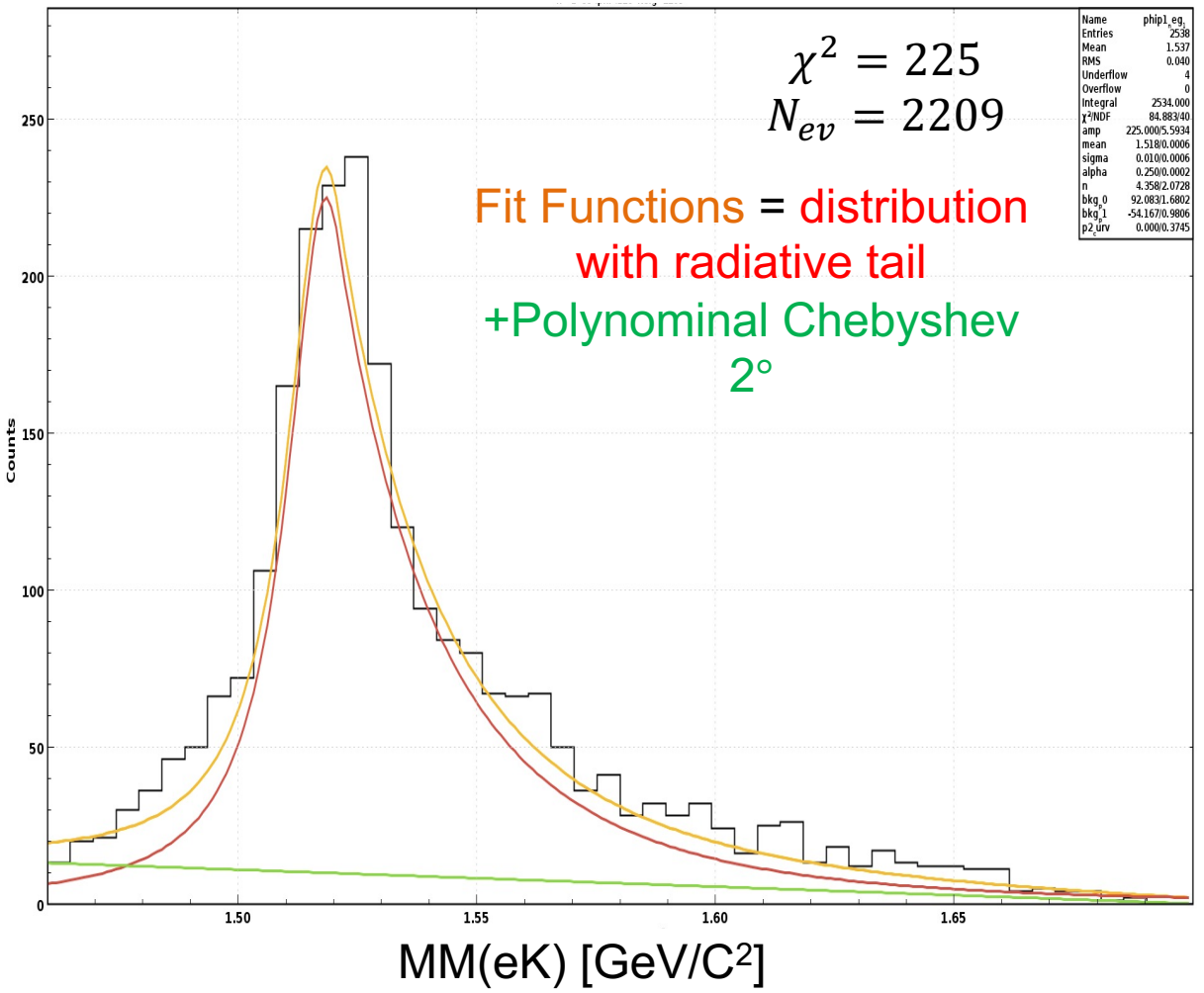
From fit to BSA Extraction of Signal Yields (N)

$ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+(K^-)p$ **Eb= 6.5 GeV** $(0.3\text{GeV}^2 < Q^2 < 2\text{GeV}^2)$

h= +1 $60 < \phi < 120$



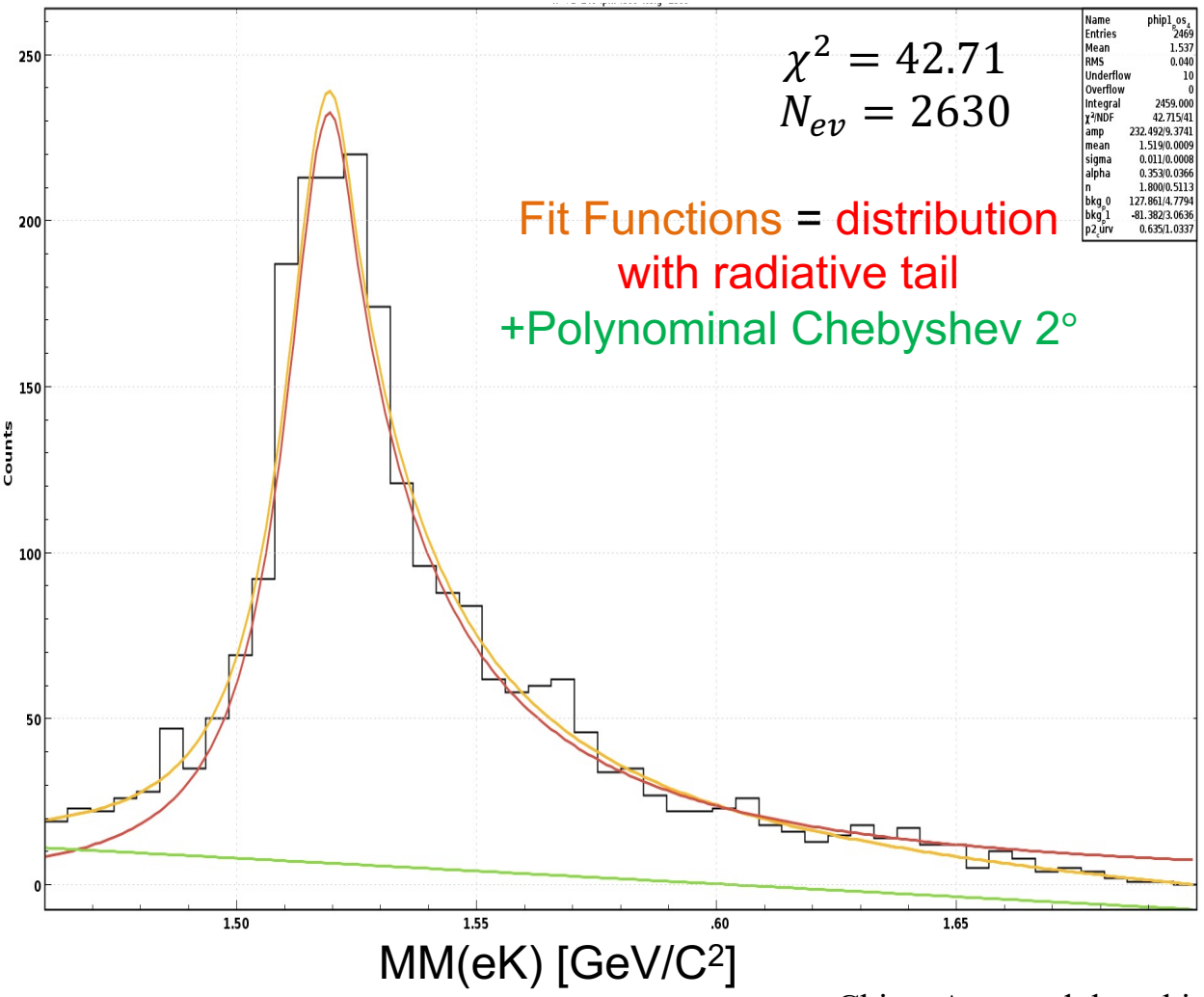
h= -1 $60 < \phi < 120$



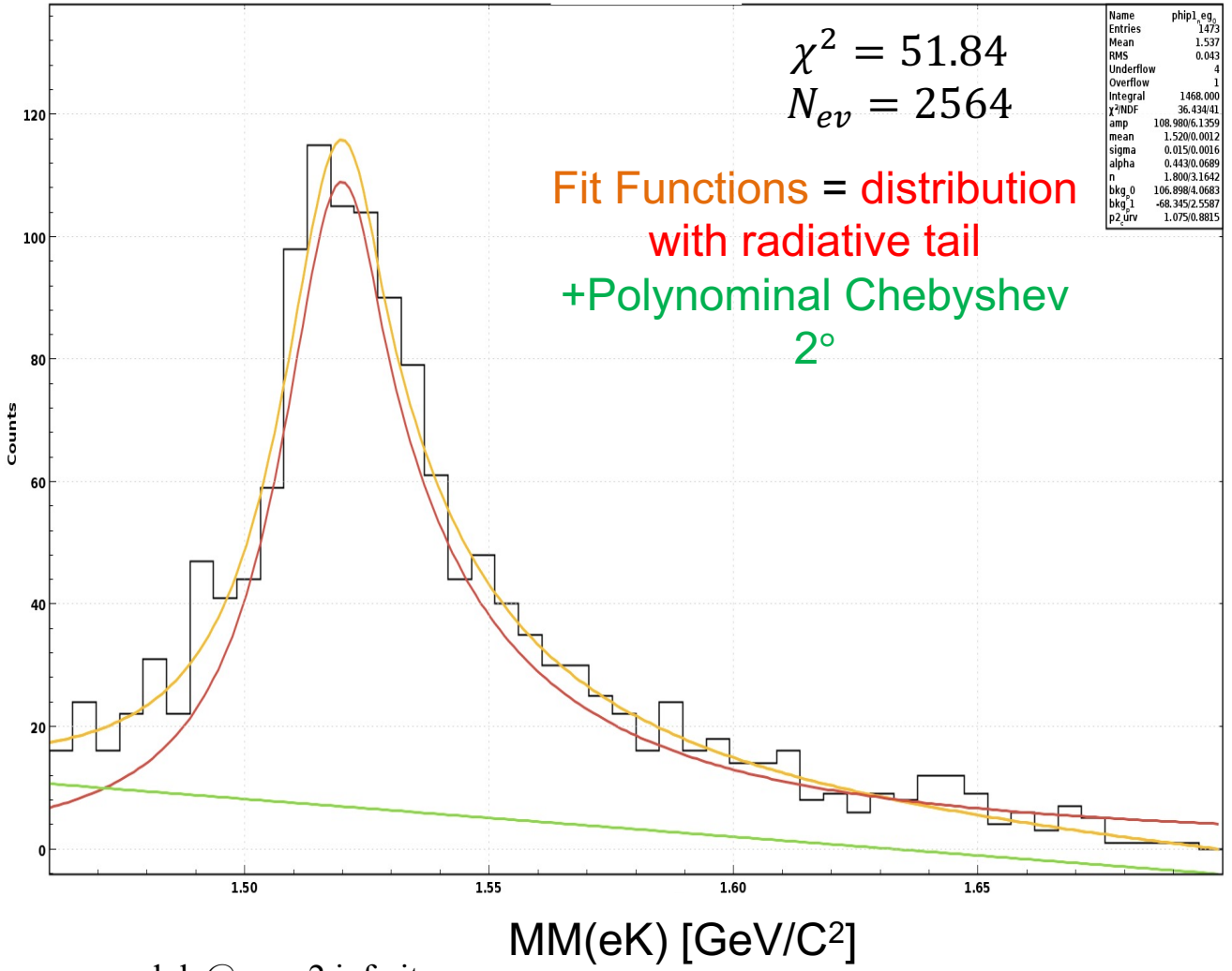
From fit to BSA Extraction of Signal Yields (N)

$ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+(K^-)p$ **Eb= 6.5 GeV** $(0.3\text{GeV}^2 < Q^2 < 2\text{GeV}^2)$

h= +1 $240 < \phi < 300$



h= -1 $240 < \phi < 300$



Extraction of Signal Yields (N)

$ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+(K^-)p$ E_b= 6.5 GeV $(0.3\text{GeV}^2 < Q^2 < 2\text{GeV}^2)$

Method 1

Background Subtraction

$$N_{sig} = \sum Y_{bin} - Y_{bkg}$$

- Y_{bin} *histogram bin content (counts)*
- Y_{bkg} $p_0 + p_1 + p_2(2x^2 - 1)$

Method 2

Analytical Integral

$$f(t) = A \begin{cases} \dfrac{1}{t^2+1} & t \leq \alpha \\ \dfrac{B}{(C-t)^n} & t > \alpha \end{cases}$$

$$N_{sig} = \frac{(I_1 + I_2)}{\Delta x}$$

- I_1 *Integral of Lorentzian core*
- I_2 *Integral of radiative tail*
- Δx *bin width*

Signal Yields : Method 1 vs Method 2

$ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+(K^-)p$ **Eb= 6.5 GeV** $(0.3\text{GeV}^2 < Q^2 < 2\text{GeV}^2)$

Signal Yields and Beam-Spin Asymmetry — 6 φ bins

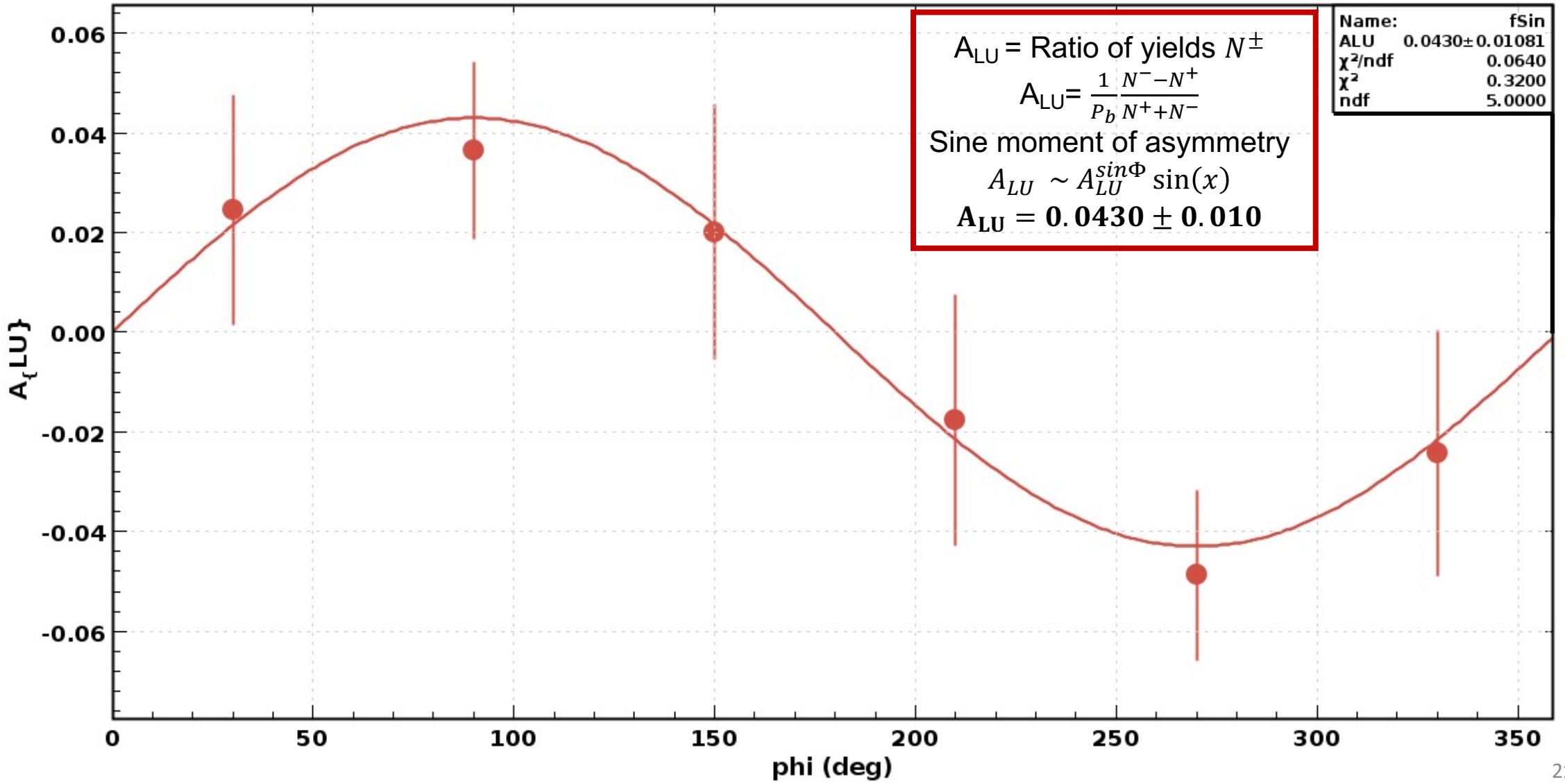
M1 = background subtraction · M2 = analytical integral · ΔA_{LU} = |A(M2) − A(M1)| (systematic uncertainty on asymmetry)

φ bin (deg)	N^+ (M1)	N^- (M1)	N^+ (M2)	N^- (M2)	ΔN^+	ΔN^-	A_{LU} (M1) ± stat	A_{LU} (M2) ± stat	ΔA_{LU} |M2−M1|
0 – 60	1,354	1,299	1,549	1,493	97.5	97.0	+0.0245 ± 0.0228	+0.0214 ± 0.0213	**0.0031**
60 – 120	2,350	2,209	2,477	2,281	63.5	36.0	+0.0364 ± 0.0174	+0.0486 ± 0.0170	**0.0122**
120 – 180	1,093	1,056	1,088	1,051	2.5	2.5	+0.0201 ± 0.0254	+0.0203 ± 0.0254	**0.0002**
180 – 240	1,100	1,134	1,362	1,398	131.0	132.0	−0.0176 ± 0.0249	−0.0156 ± 0.0224	**0.0020**
240 – 300	2,360	2,564	2,730	2,795	185.0	115.5	−0.0488 ± 0.0168	−0.0139 ± 0.0158	**0.0349**
300 – 360	1,134	1,182	1,072	1,085	31.0	48.5	−0.0243 ± 0.0244	−0.0068 ± 0.0253	**0.0175**

Method 1 yields Method 2 yields Systematic on yield (ΔN) Systematic on A_LU (ΔA)

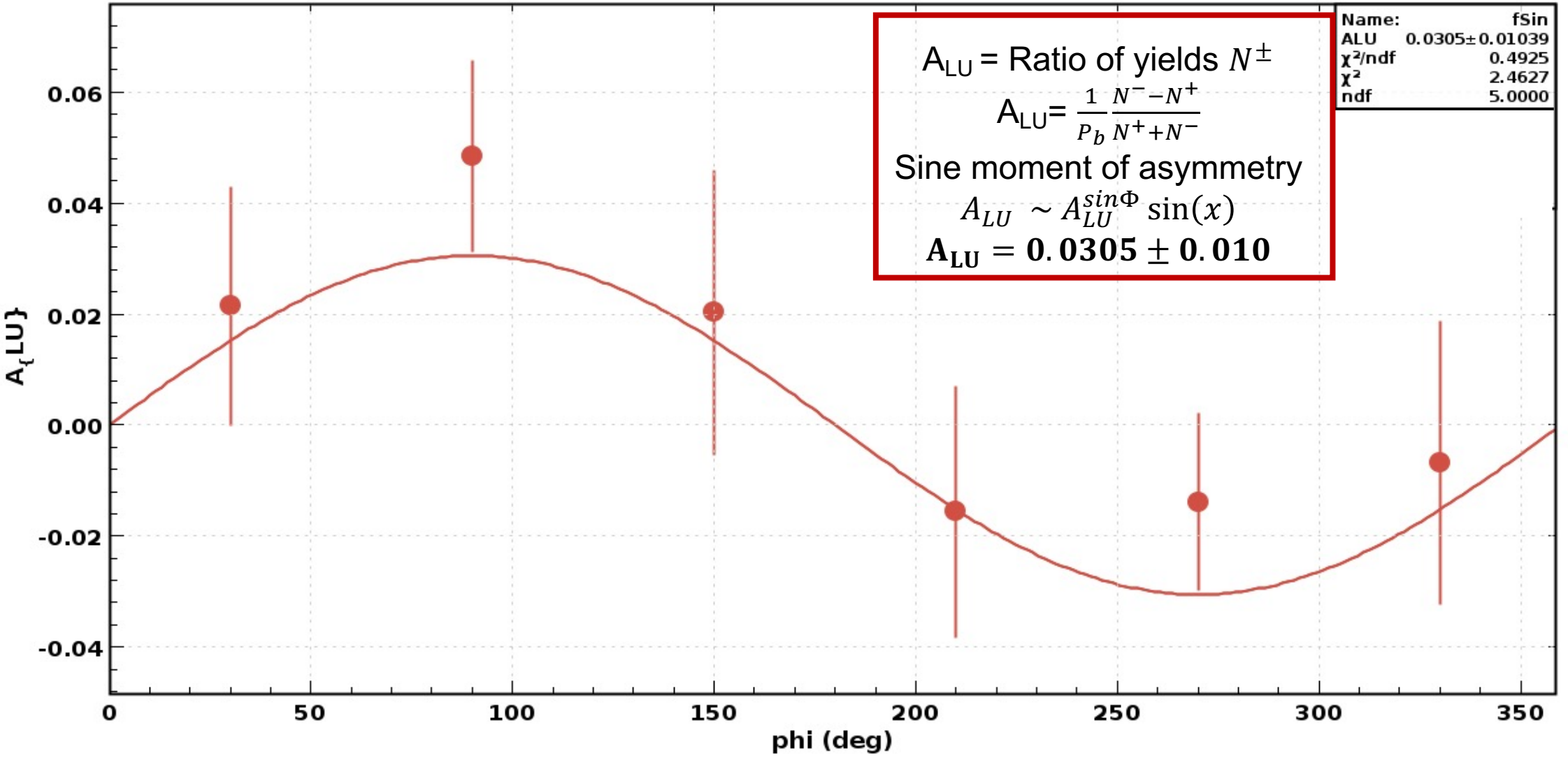
Asymmetry $(A_{LU}\ vs\ sin\phi\ )$ Method 1

$ep \rightarrow e'K^+\Lambda(1520) \rightarrow\ e'K^+(K^-)p$ **Eb= 6.5 GeV** $(0.3\text{GeV}^2 < Q^2 < 2\text{GeV}^2)$



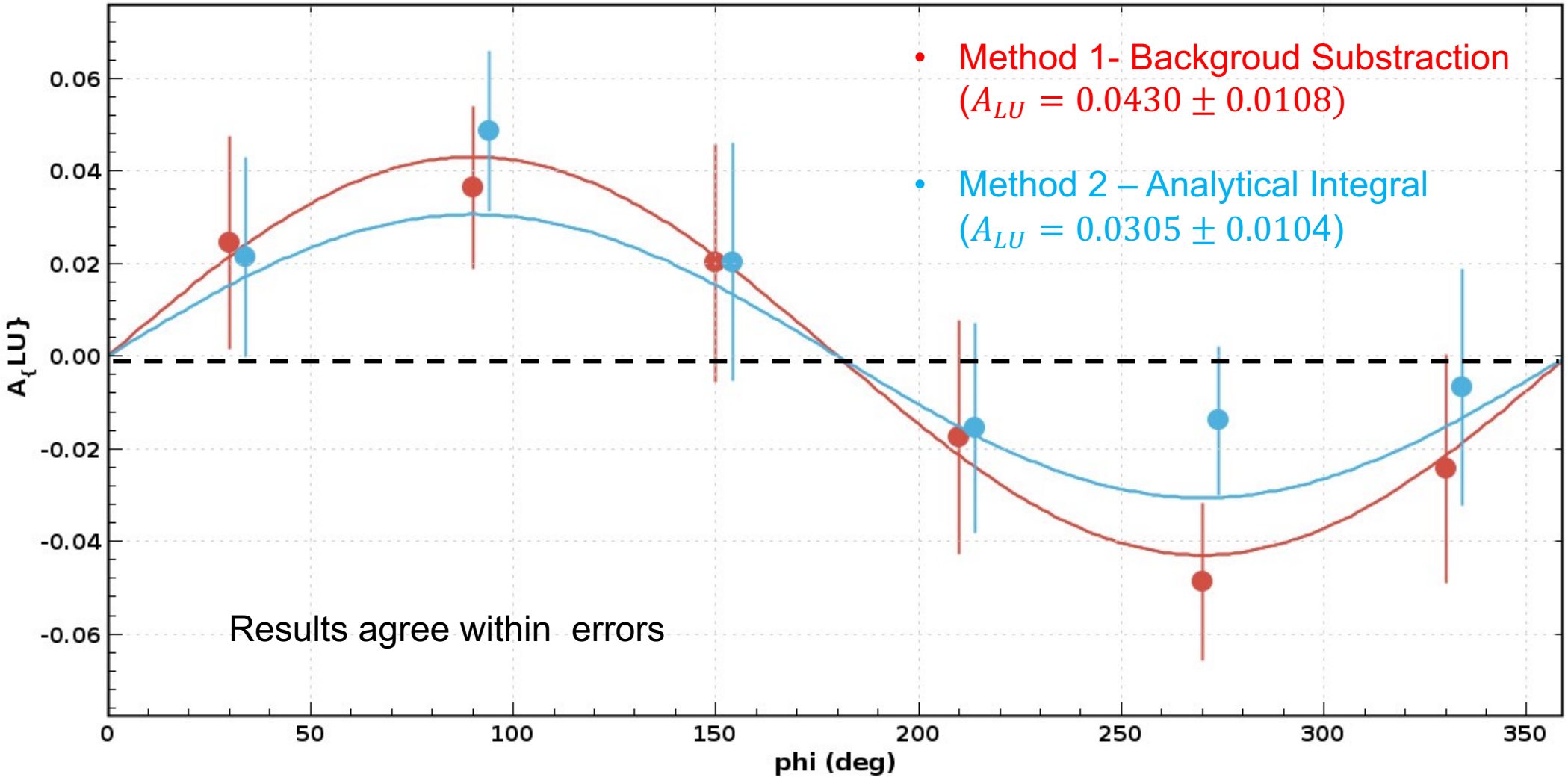
Asymmetry $(A_{LU}\ vs\ sin\phi\ )$ Method 2

$ep \rightarrow e'K^+\Lambda(1520) \rightarrow\ e'K^+(K^-)p$ **Eb= 6.5 GeV** $(0.3\mathrm{GeV}^2 < Q^2 < 2\mathrm{GeV}^2)$



Asymmetries in Comparison Method1 vs Method 2

$ep \rightarrow e'K^+\Lambda(1520) \rightarrow e'K^+(K^-)p$ E_b= 6.5 GeV ($0.3\text{GeV}^2 < Q^2 < 2\text{GeV}^2$)



Conclusions

- **First BSA studies for $\Lambda(1520)$** electroproduction channel using CLAS12 Fall 2018 RGK data (polarized beam, unpolarized target) have been reported.

- **Helicity- separated signal yields $\pm$ have been extracted** in ϕ bins with two different methods.

- First preliminary estimate of A_{LU} has been obtained using **Eb= 6.5 GeV $(0.3\text{GeV}^2 < Q^2 < 2\text{GeV}^2)$**

- Next step apply the same procedure with Spring 2024 RGK dataset to obtain results as a function of W and Q^2.

Thank you for your attention !

Chiara Ammendola - chiara.ammendola@roma2.infn.it

Previous results: early KΛ(1520) photoproduction

Evidence of vector meson dominance model

1. KΛ(1520) photoproduction at SLAC - 11 GeV Bremsstrahlung γ beam - Phys. Lett. B 34, 547 (1971).

$$\sigma_{tot}(\Lambda^{o}_{1520}) = (5.4 \pm 1.4)/k^{2}\ \mu b$$

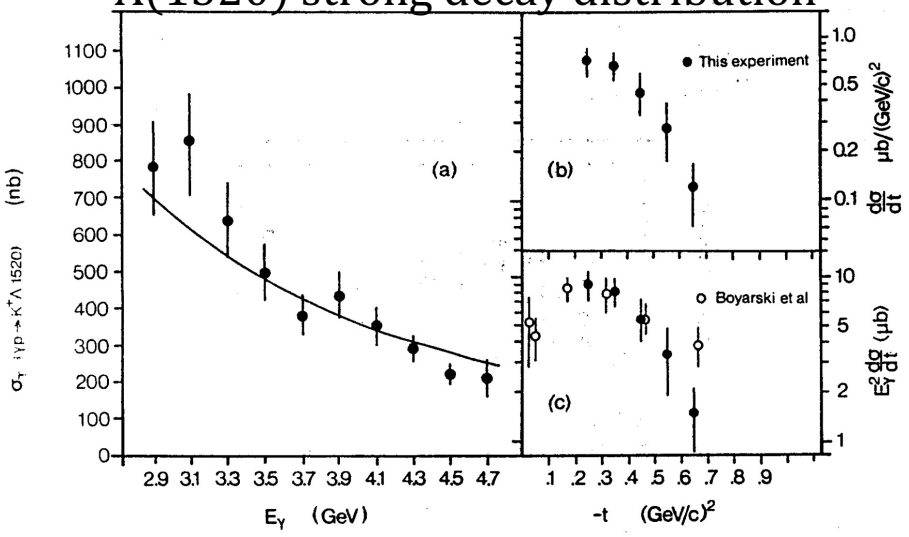
θ_{LAB}	$-t$	Λ_{1520}
0.70	0.025	0.044 ± 0.021
1.03	0.045	0.036 ± 0.011
2.15	0.17	0.071 ± 0.012
2.96	0.32	0.065 ± 0.016
3.57	0.46	0.046 ± 0.010
4.35	0.67	0.032 ± 0.009

- Differential cross section shows a maximum at $t = -m^{2}_{K^{+}}$ and decrease at $t \to 0$

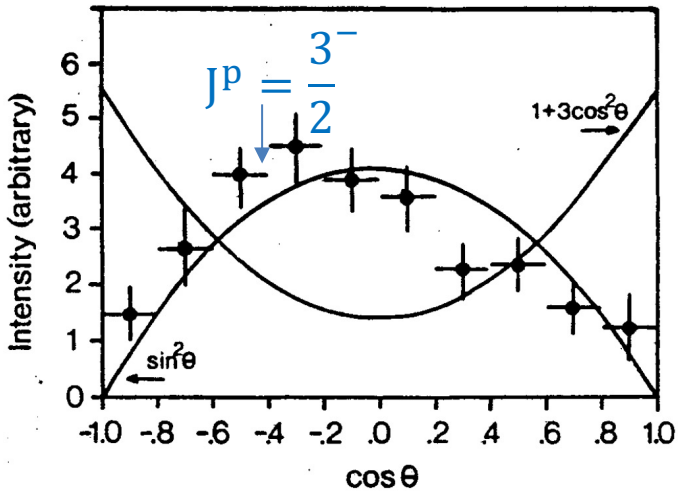
2. KΛ(1520) photoproduction at LAMP2, Daresbury – E_{γ} = 2.8–4.8 GeV - Z. Phys. C: Part. Fields 7, 17 (1980).

- Cross section shows an energy dependence:
  $\sigma = (6.5 \pm 0.7)E_{\gamma}^{-(2.1\pm0.2)}$
- $\sin^{2}\theta$ angular distribution of $\Lambda(1520) \to K^{-}p$ is compatible with $J^{P}=\frac{3}{2}^{-}$
- dominant K*(892) exchange in the t channel
- negligible contribution of K (493) exchange

$\Lambda(1520)$ strong decay distribution

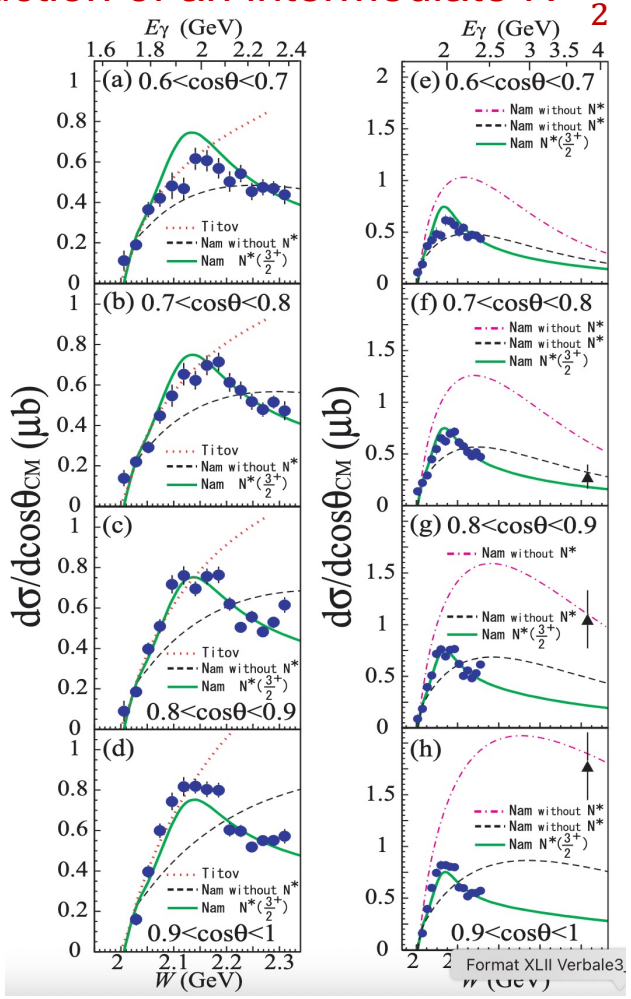


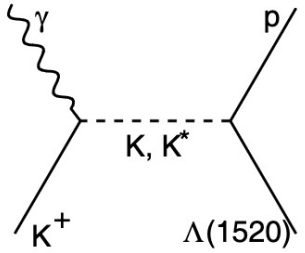
$\Lambda(1520)$ strong decay distribution

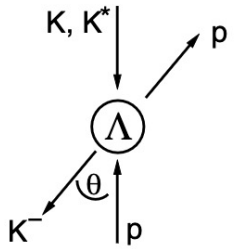


Previous results: more KΛ(1520) photoproduction

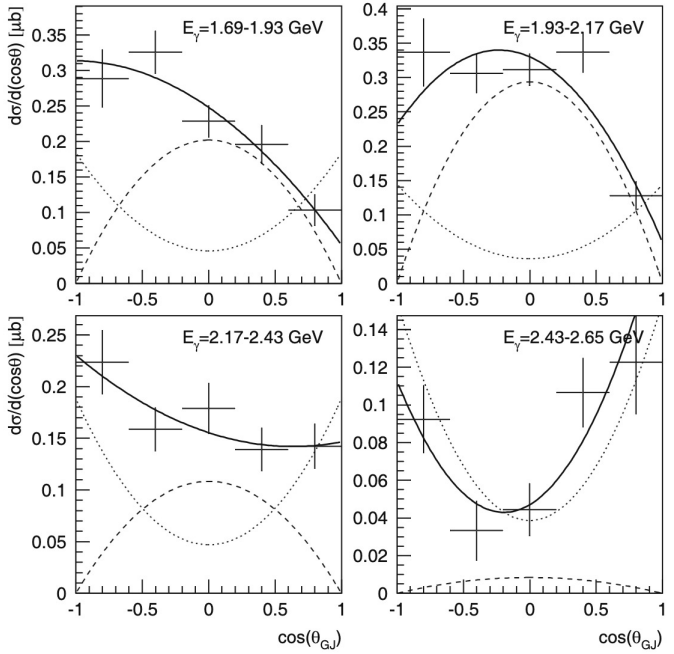
LEPS results for $E_\gamma < 2.4$ GeV are compatible with the production of an intermediate N* $\frac{3}{2}^+$ (2100) resonance.







SAPHIR results for $E_\gamma < 2.6$ GeV



- A $\sin^2\theta_{K^-}$ dominance is observed at low energies.
- For energies above 2.43 GeV a 1 + 3 $\cos^2\theta_{K^-}$ shape is seen indicating that K exchange is clearly preferred

Eur. Phys. J. A 47,47 (2011)

Phys. Rev. Lett. 104,172001 (2010).