Electroproduction of Λ(1405)

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Outline

Λ (1405) From PDG

- $e^- p \rightarrow e^- K^+ \Lambda(1405)$
- $I(J^P) = 0(\frac{1}{2}^-)$
- Mass 1406 MeV, full width 50 MeV
- Decay 100% $\Sigma\pi$
- Three charge modes: $\Sigma^+\pi^-$, $\Sigma^-\pi^+$, $\Sigma^0\pi^0$

Theoretic Work

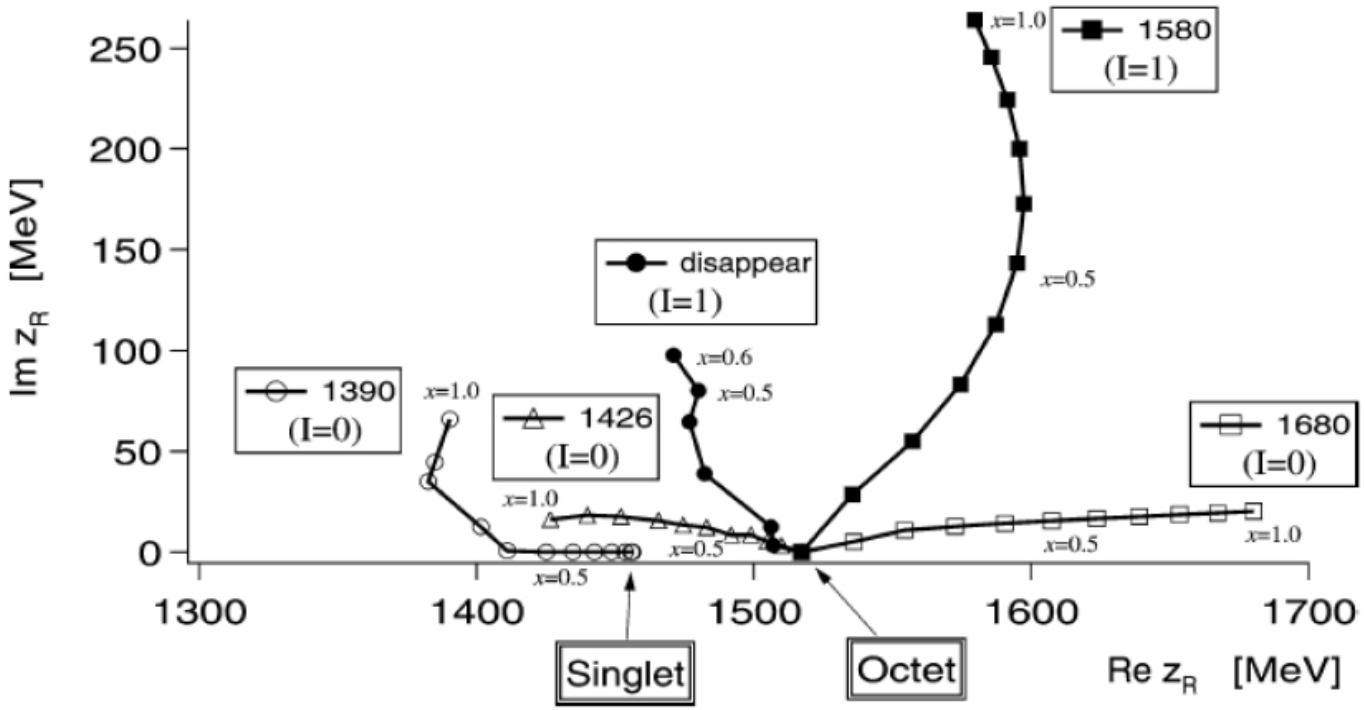


Fig. 1. Trajectories of the poles in the scattering amplitudes obtained by changing the SU(3) breaking parameter x gradually. At the SU(3) symmetric limit ($x = 0$), only two poles appear, one is for the singlet and the other for the octets. The symbols correspond to the step size $\delta x = 0.1$.

Two poles are at 1390+66i and 1426+16i [1].

Different Coupling

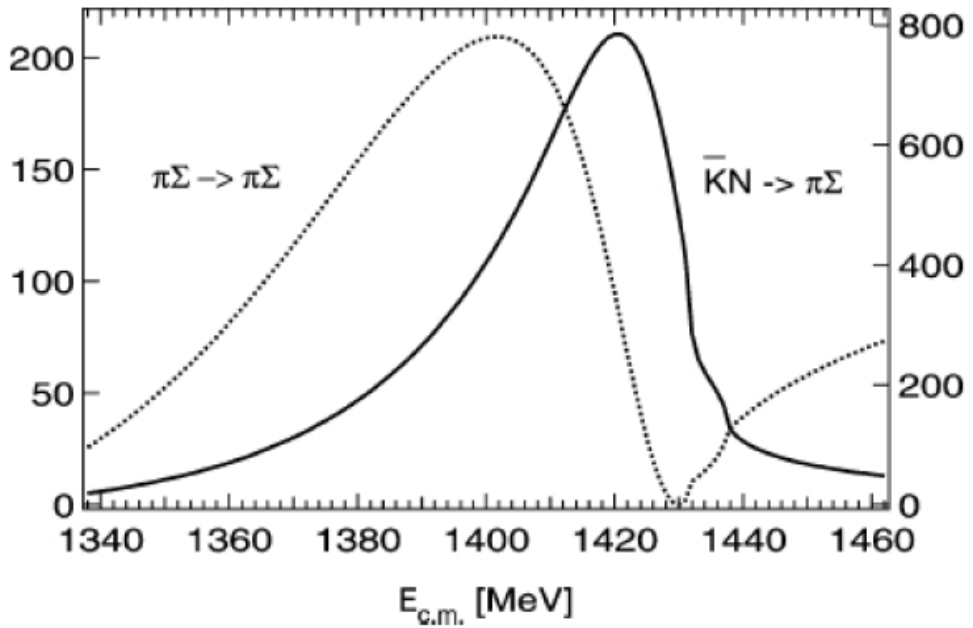
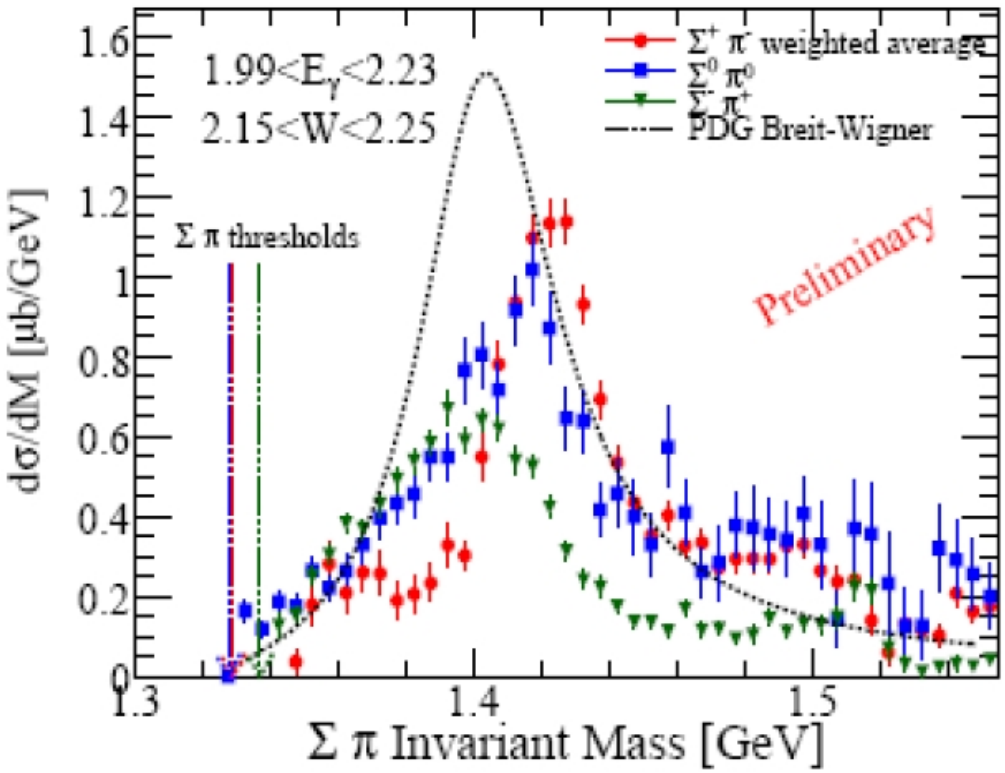


Fig. 4. The $\pi\Sigma$ mass distributions with $I = 0$ constructed from the $\bar{K}N \to \pi\Sigma$ and $\pi\Sigma \to \pi\Sigma$ amplitudes. The solid and dashed lines denote $|T_{\bar{K}N\to\pi\Sigma}|^2 q_\pi$ and $|T_{\pi\Sigma\to\pi\Sigma}|^2 q_\pi$, respectively. Units are arbitrary.

Two poles couple differently with $\pi\Sigma$ and $\bar{K}N$ [1].

Latest Results

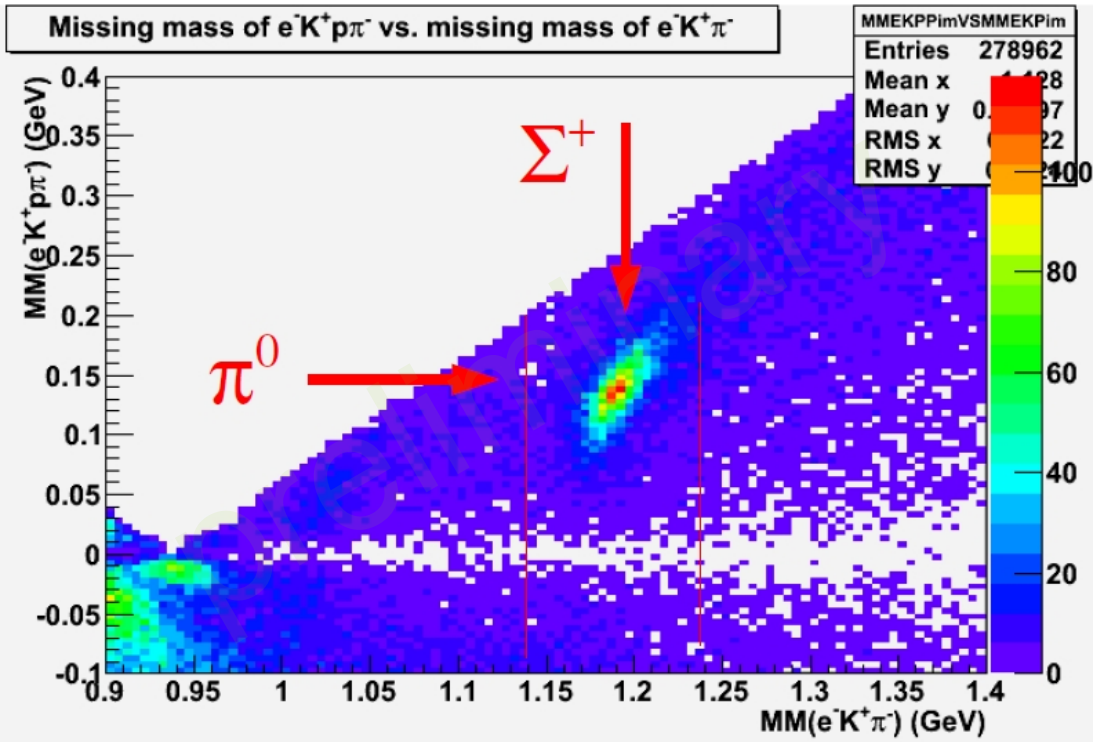


Lineshapes of different charge channels [2].

Data Set

- E1F data set from Hall B in JLab
- Electron beam with 5.5 GeV
- Weak torus field (I=2250 A) for better acceptance
- K^+ skim

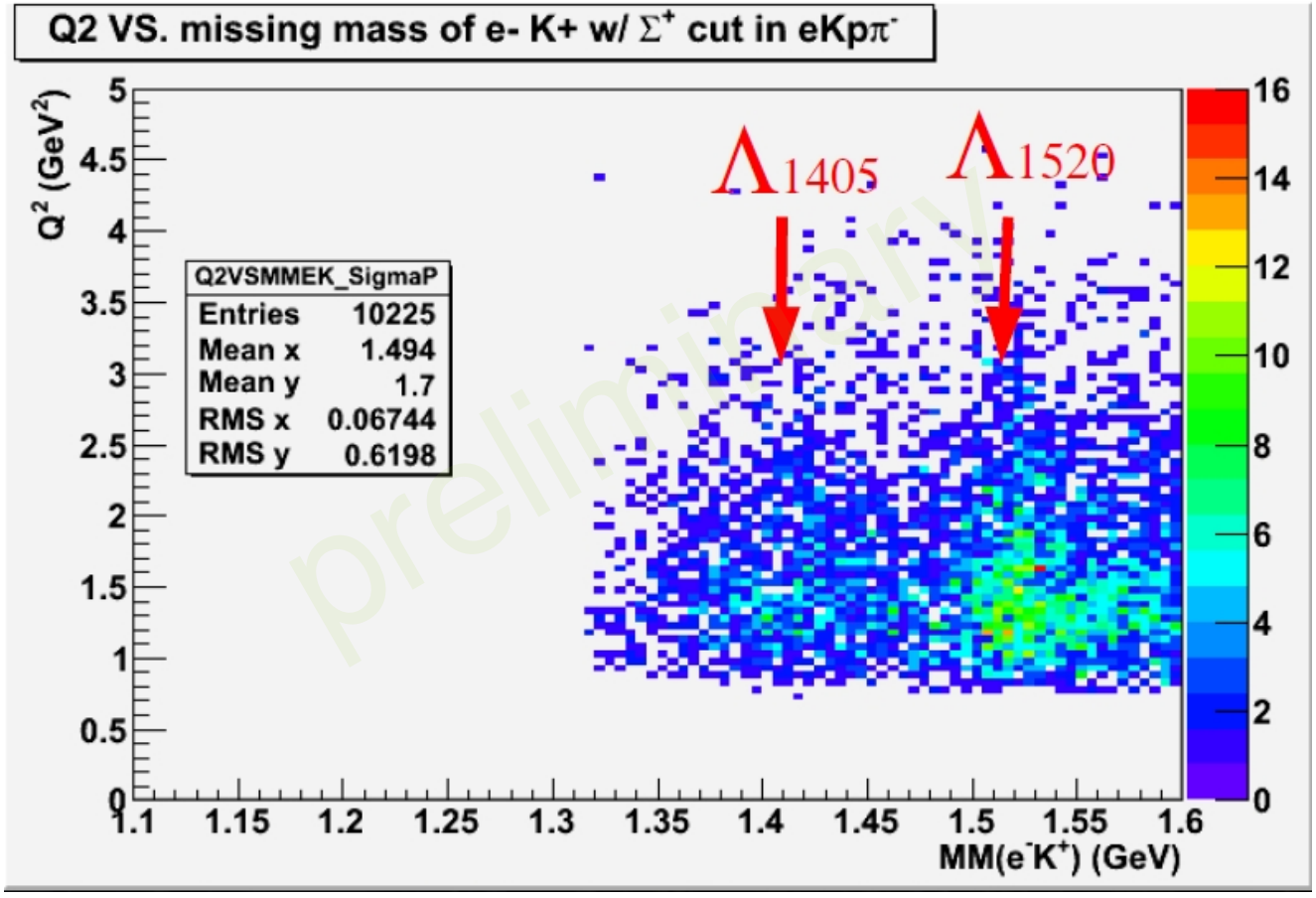
Event Selection



Decay mode: $\Sigma^+\pi^-$

Final particles: $e^-K^+p\pi^-$ with π^0 missing

Q2 Distribution



Λ (1520) as a reference

Simulation and Mix

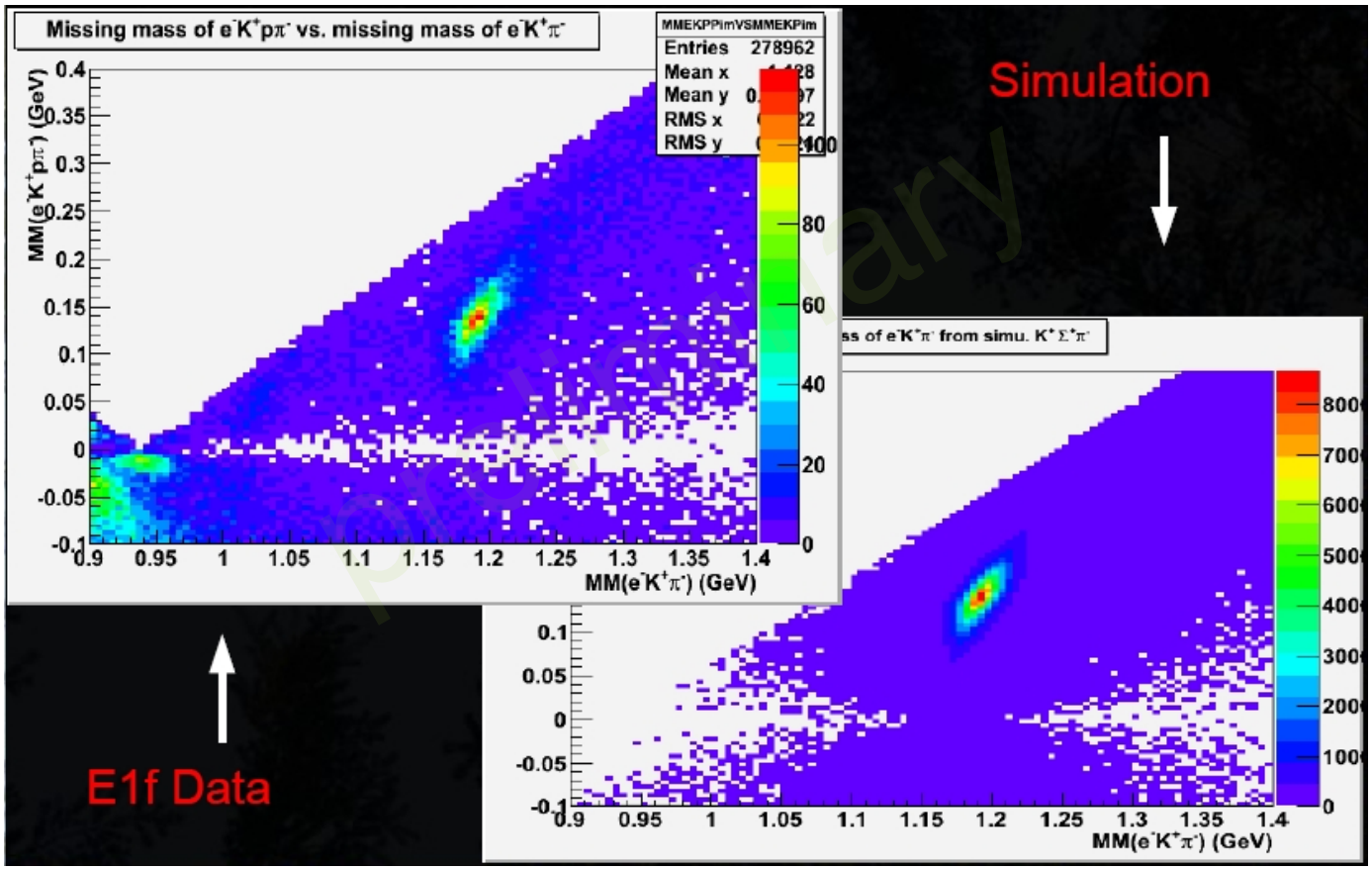
Simulation

- Non-resonance background
  $e^- p \rightarrow e^- K^+ \Sigma^+ \pi^-$
- K^* production
  $e^- p \rightarrow e^- K^{*0} \Sigma^+ \rightarrow e^- K^+ \pi^- \Sigma^+$

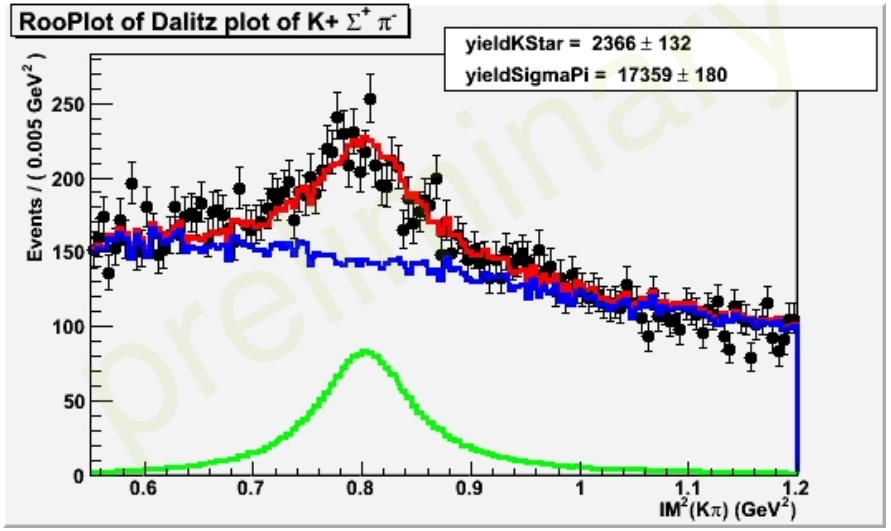
Mix of two channels

The ratio of the two channels are determined by matching simulation with data

Comparison of Simulation



Mixture of Two Channels



- Invariant mass square of $K^+\pi^-$
- Black:E1F data points
- Red:overall fit
- Blue:component of non-resonance production
- Green:component of K^* production
- Ratio:0.137

Σ^{*0} Contamination

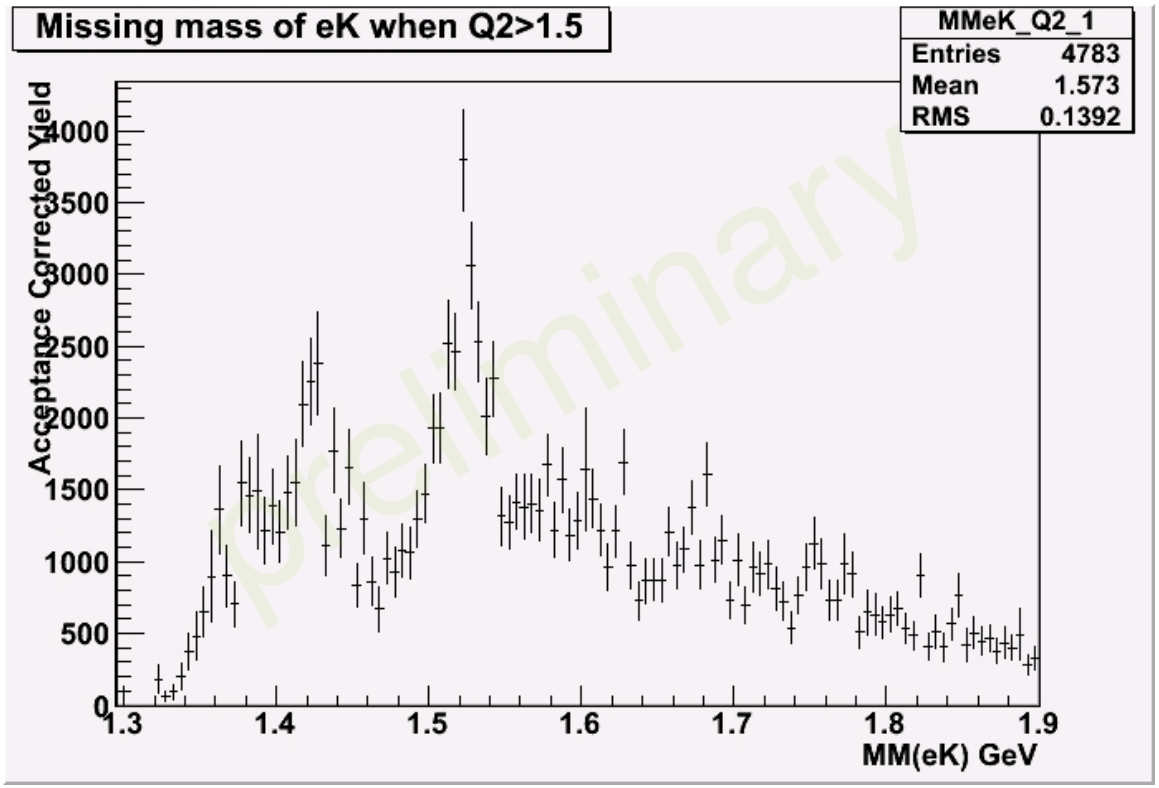
- Σ^{*0} can decay into $\Sigma^{+}\pi^{-}$ too
- Extract yield from the $\Lambda\pi$ decay mode
- Scale the yield into the $\Sigma^{+}\pi^{-}$ mode
- Both $\Sigma\pi$ and $\Lambda\pi$ modes have the final particles $e^{-}K^{+}p\pi^{-}$
- Conclusion is that little contamination from Σ^{*0}

3D Acceptance Correction

Acceptance Calculation

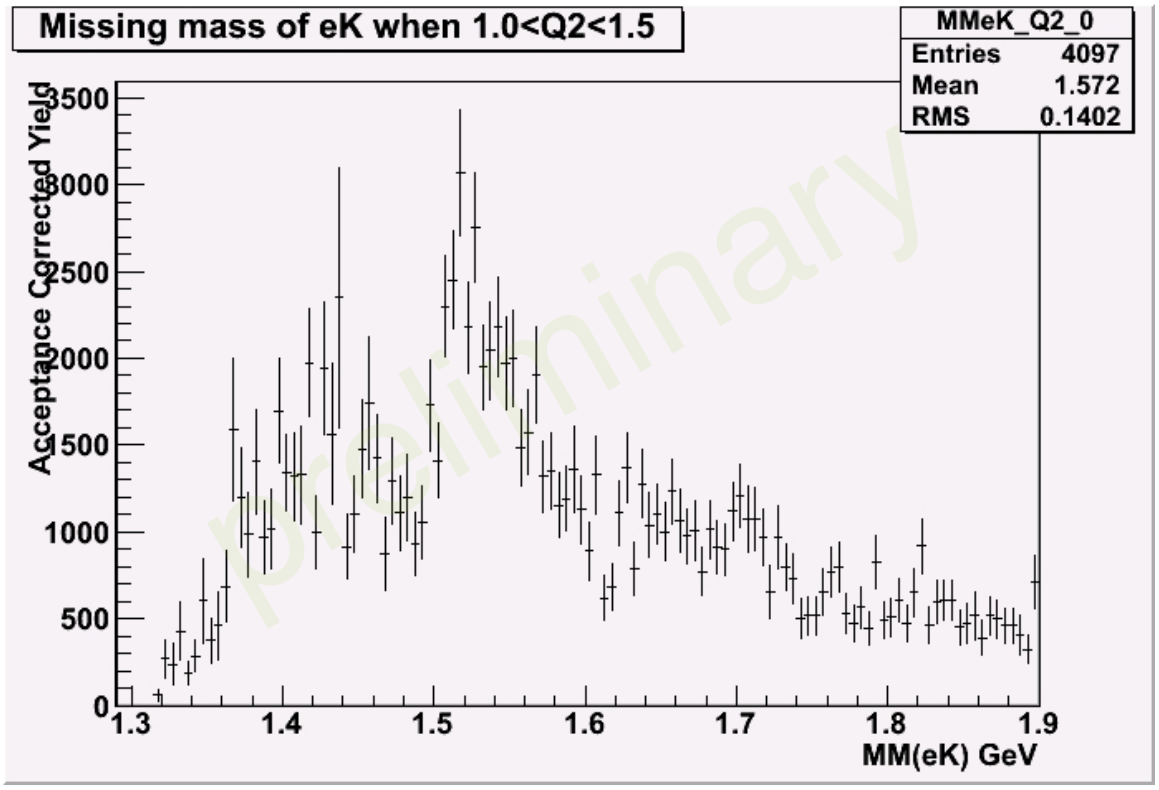
- Non-resonance channel $K^+\Sigma^+\pi^-$ is used to calculate acceptance
- Raw and simulated date are binned in Q^2 (1.0 - 3.0 GeV^2), W (1.5 - 3.5 GeV) and $cos(\Theta_K)$ in center-of-mass frame
- Data in low-acceptance areas are dropped (16 out of 9K events)

Lineshape at High Q^2



Acceptance-corrected yield in Q^2 from 1.5 to 3.0 GeV^2

Lineshape at Low Q^2

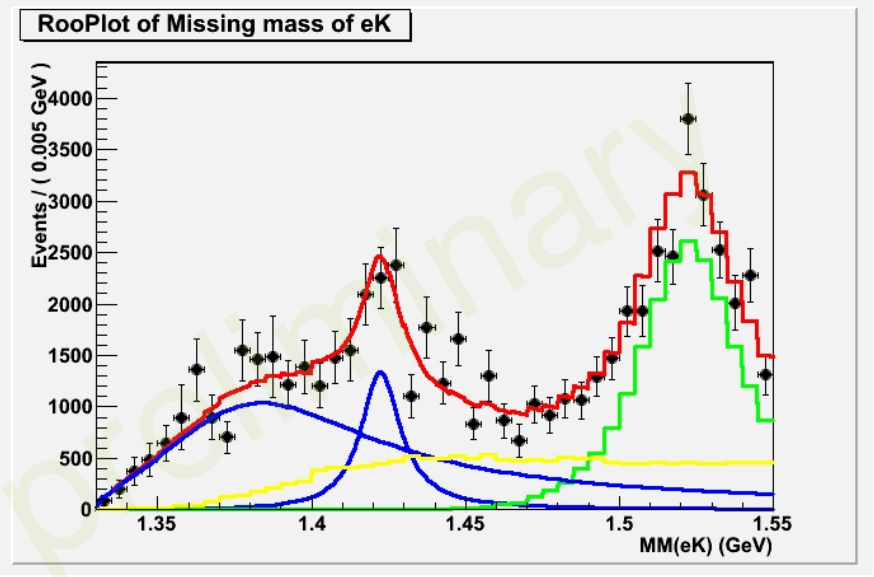


Acceptance-corrected yield in Q^2 from 1.0 to 1.5 GeV^2

Brief

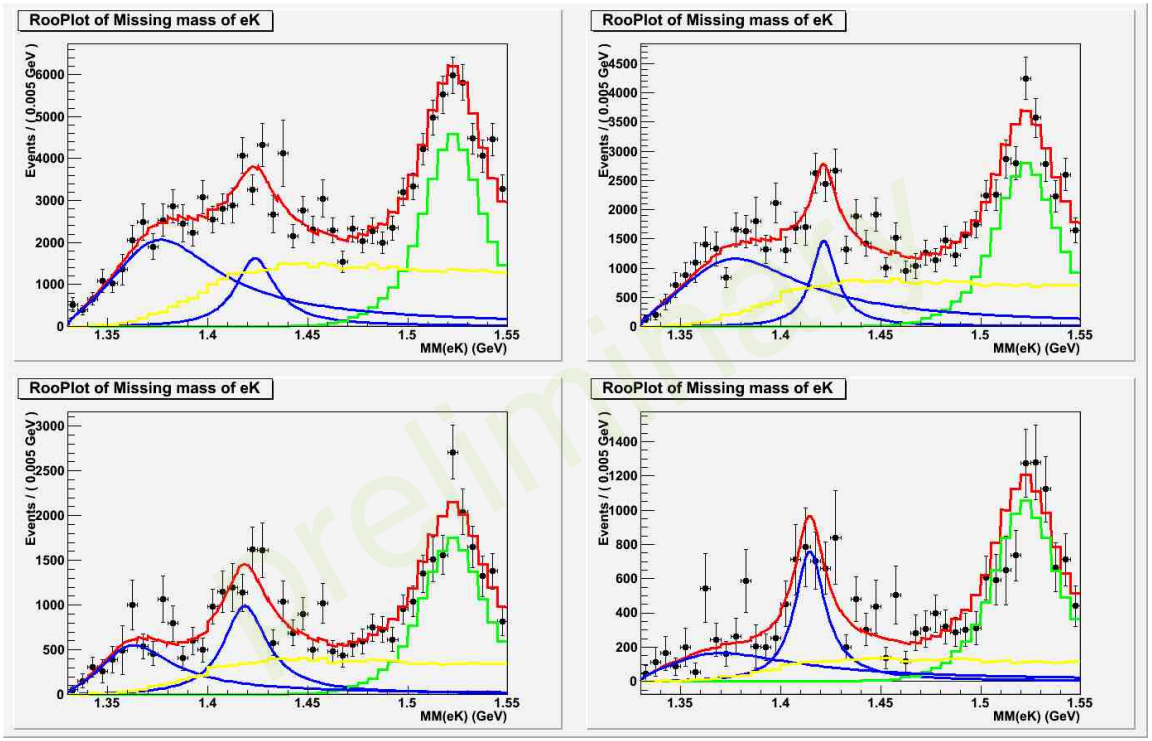
- Data is acceptance corrected
- Background is interpreted as mixture of two channels
- Lineshape in Λ (1405) region looks different from one resonance
- Lineshape looks dependent on Q^2

Two Pole Fitting



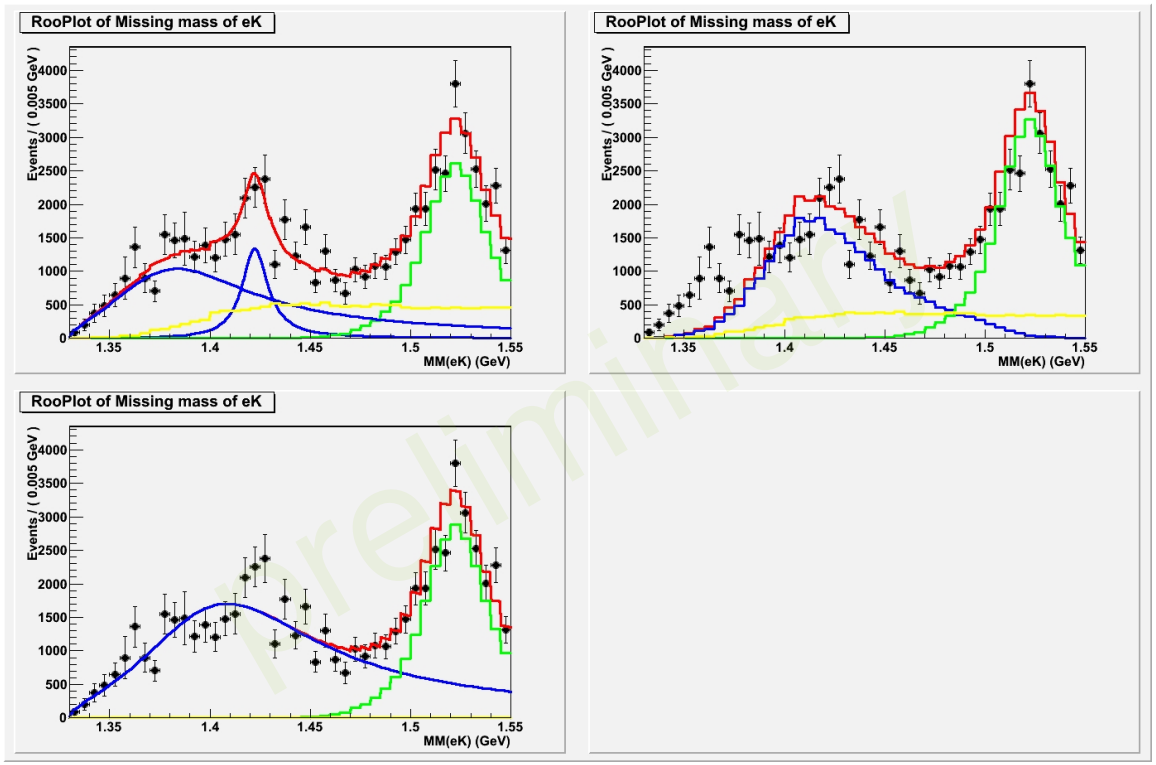
- Black: acceptance-corrected data
- Yellow: background from mixture of two simulated channels
- Green: simulated Λ (1520)
- Blue: two relativistic Breit-Wigner functions
- Fitting results:
  mean: 1.422, 1.393
  width:0.016, 0.10

- Model:
  $1.426 \pm i0.016$
  $1.390 \pm i0.066$



- Left top: Q^2 from 1.0 - 3.0 GeV^2
- Right top: Q^2 from 1.4 - 3.0 GeV^2
- Left bottom: Q^2 from 1.8 - 3.0 GeV^2
- Right bottom: Q^2 from 2.2 - 3.0 GeV^2

Comparison with other choices



- Left top: fitting with two relativistic Breit-Wigner functions
- Right top: fitting with simulation with PDG values
- Bottom: fitting with one relativistic Breit-Wigner function

Reduced χ^2

Comparison of different fits

Low limit of Q^2	High limit of Q^2	two-pole fit	PDG value	one-pole fit
1.4	2.8	1.40	3.83	1.85
1.36	2.76	1.29	4.04	1.73
1.32	2.72	1.11	4.24	1.61
1.28	2.68	1.07	4.43	1.60
1.24	2.64	1.02	4.61	1.53
1.2	2.6	1.04	4.62	1.48
1.16	2.56	1.19	4.76	1.67
1.12	2.52	1.18	4.94	1.67
1.08	2.48	1.35	5.22	1.72
1.04	2.44	1.37	5.23	1.75

Reduced χ^2 of Another Loop

Comparison of different fits

Low limit of Q^2	High limit of Q^2	two-pole fit	PDG value	one-pole fit
1.0	3.0	1.37	5.46	1.74
1.2	3.0	1.14	4.86	1.57
1.4	3.0	1.54	4.01	1.95
1.5	3.0	1.36	3.39	1.73
1.6	3.0	1.42	3.11	1.76
1.8	3.0	1.29	2.50	1.86
2.0	3.0	1.45	2.22	1.83
2.2	3.0	1.42	1.93	1.73

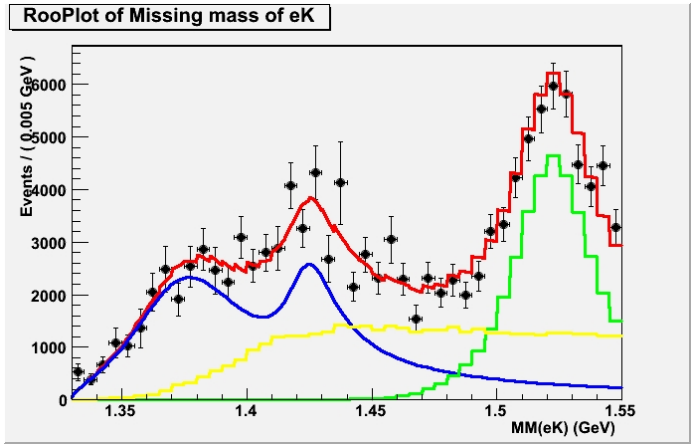
Formulism

Amplitudes are in relativistice Briet-Wigner form [3] and an overall relative phase is fitted:

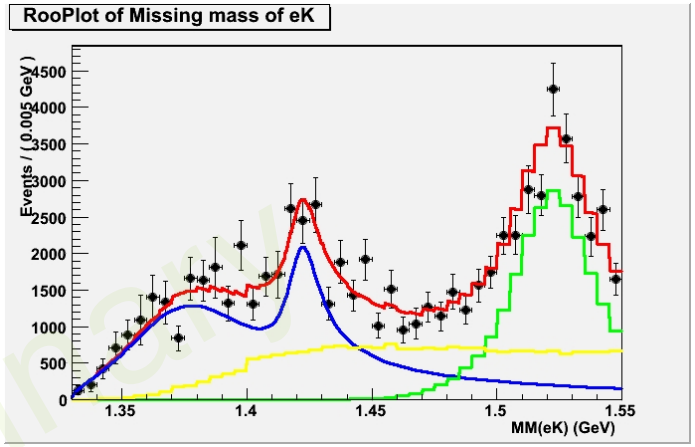
$$BW(m)_{1420} = \frac{\sqrt{m m_{1420} \Gamma_{1420}(q)}}{m^2 - m_{1420}^2 - i m_{1420} \Gamma_{1420}(q)}$$

$$BW(m)_{1390} = A e^{i\phi} \frac{\sqrt{m m_{1390} \Gamma_{1390}(q)}}{m^2 - m_{1390}^2 - i m_{1390} \Gamma_{1390}(q)}$$

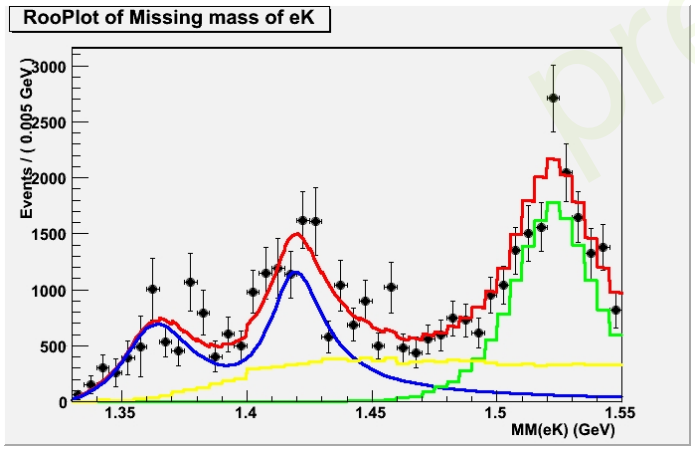
Fitting



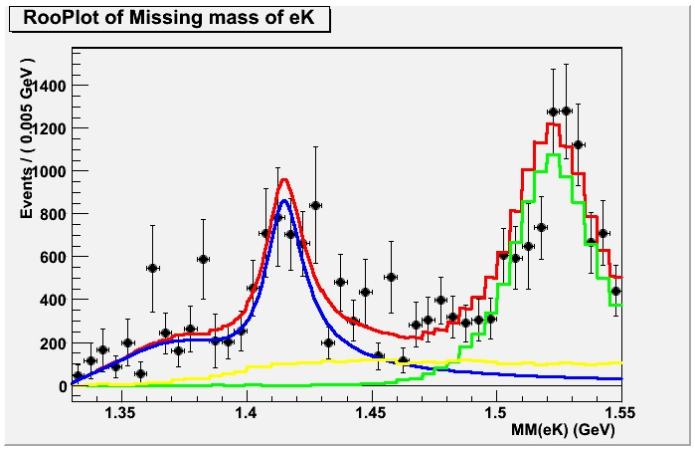
Q^2: 1.0 - 3.0 GeV^2 phase:24.89° ± 6.60°



Q^2: 1.4 - 3.0 GeV^2 phase:30.73° ± 12.55°



Q^2: 1.8 - 3.0 GeV^2 phase:24.57° ± 6.50°



Q^2: 2.2 - 3.0 GeV^2 phase:27.41° ± 14.19°

Summary

- Lineshape of Λ (1405) is not consistent with PDG values
- Lineshape of electroproduction varies with Q^2
- Two-pole physics nature of Λ (1405) is the best fit with data

References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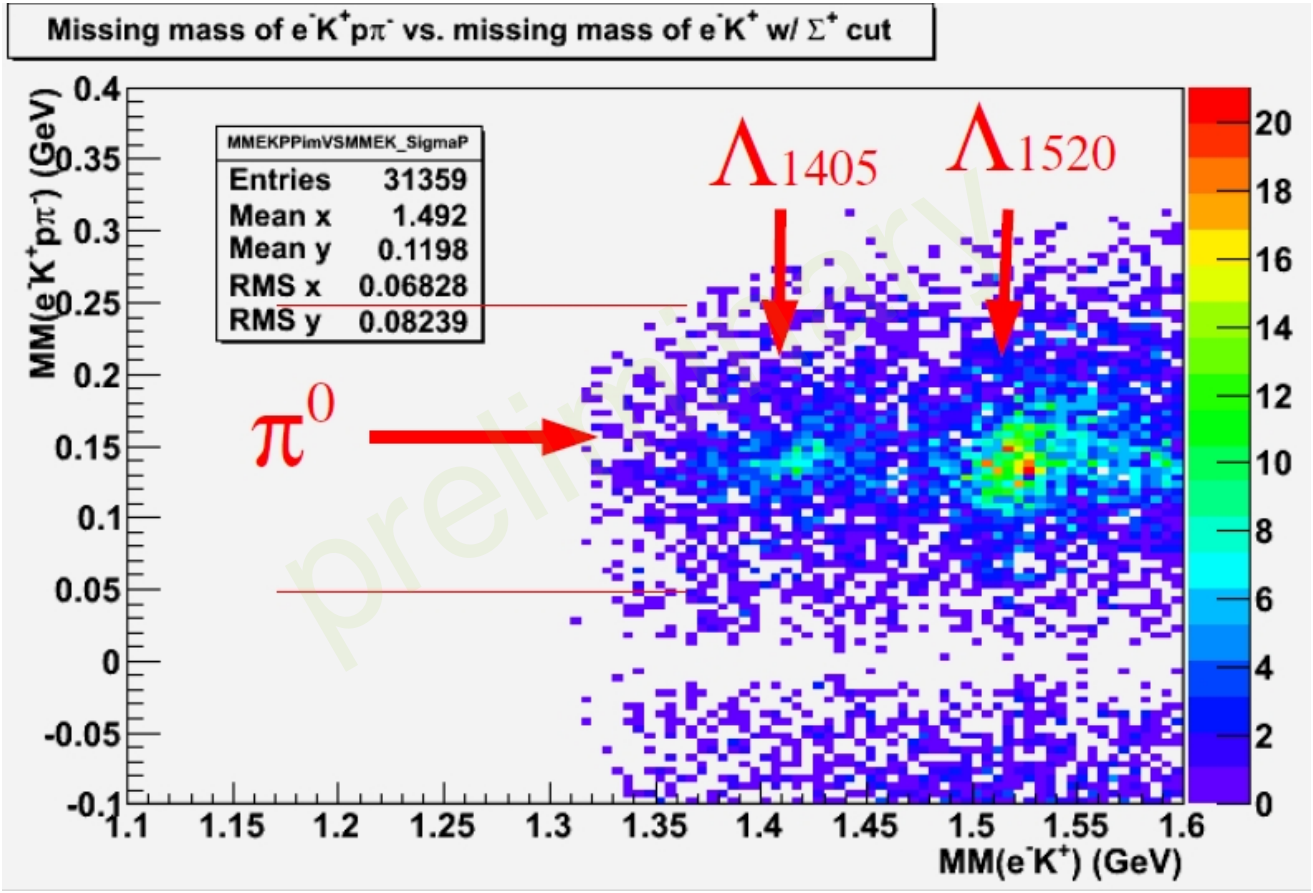
Hyperon Spectrum



Λ (1520) as a reference

Scale Factor

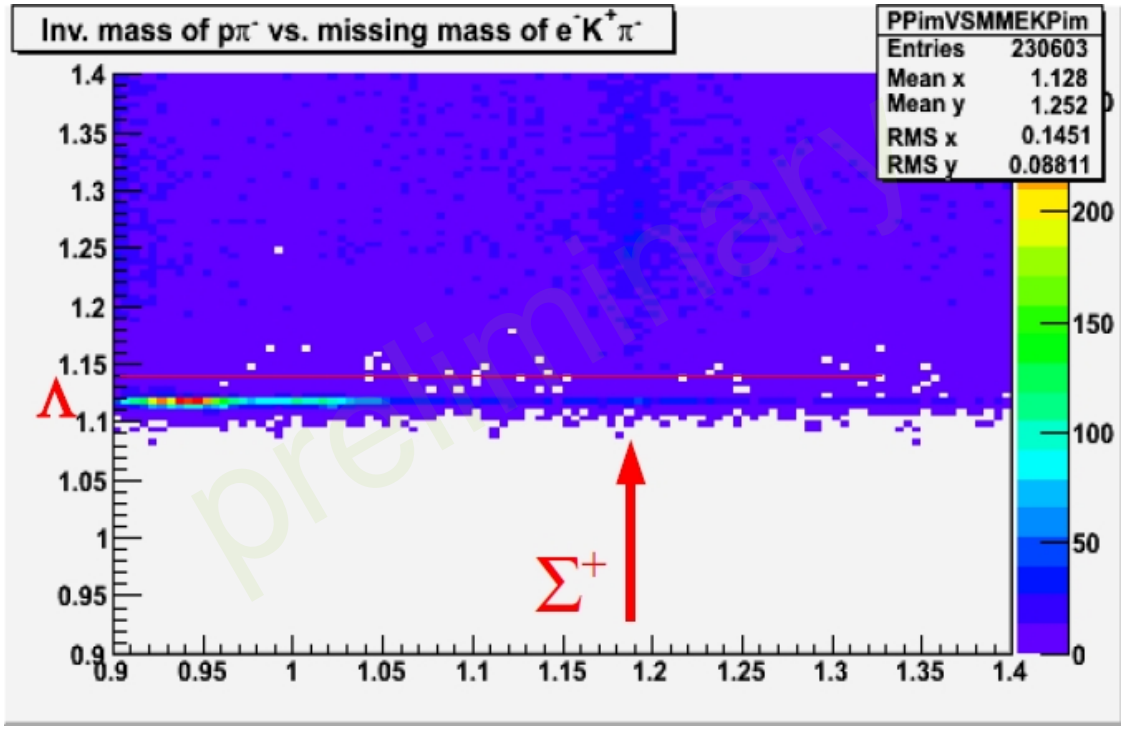
$\Lambda\pi$ mode

- Σ^{*0} decays into $\Lambda\pi$ with 87%
- Λ decays into $p\pi^-$ with 64%
- Total branching ratio is 56%

$\Sigma\pi$ mode

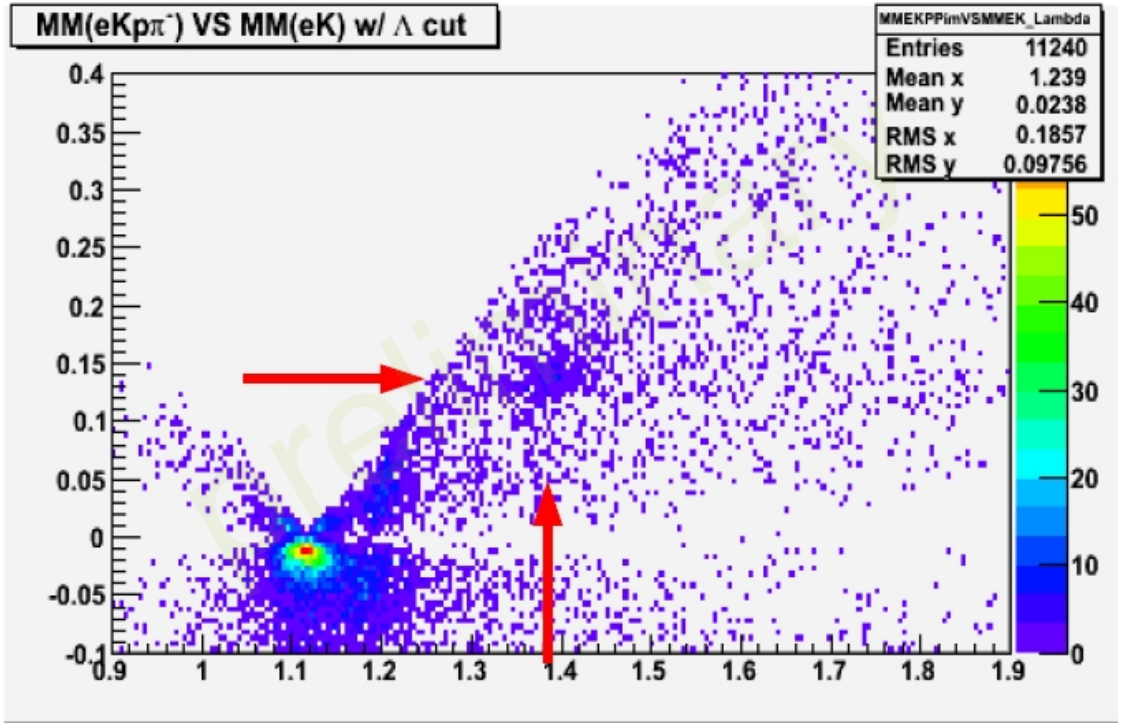
- Σ^{*0} decays into $\Sigma\pi$ with 11.7%
- $\Sigma^+\pi^-$ takes half of it
- Σ^+ decays into $p\pi^0$ with 51.6%
- Overall braching ratio is 3%
- Scale Factor is $3/56 = 0.054$

Select Λ



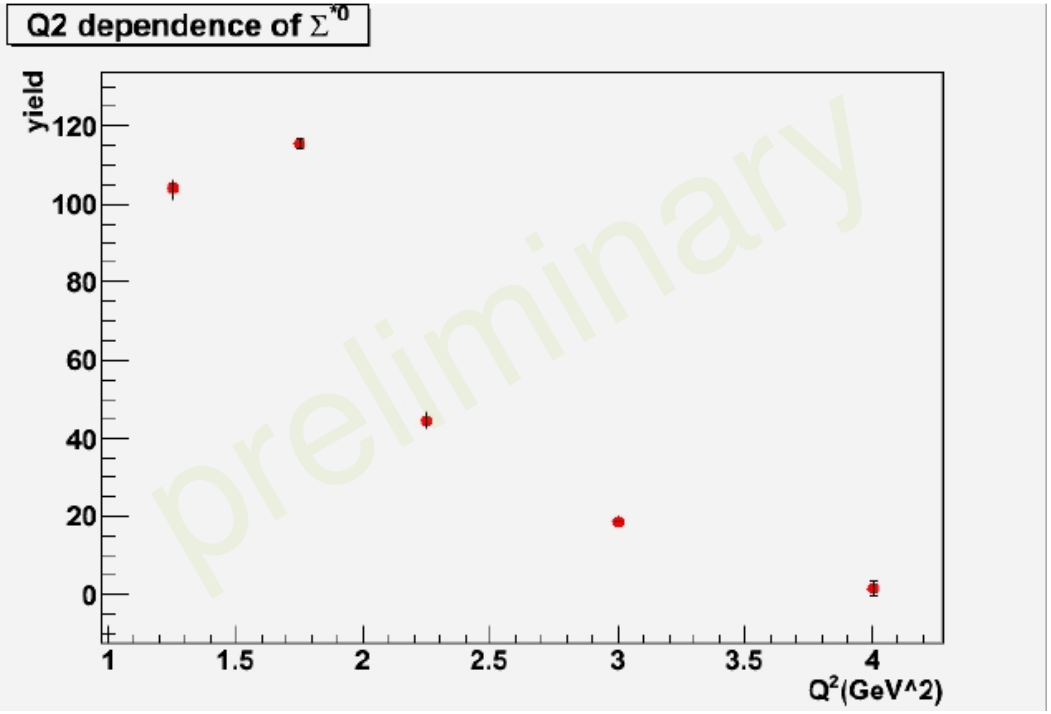
Select Λ to clean the data set

Exclusive Channel



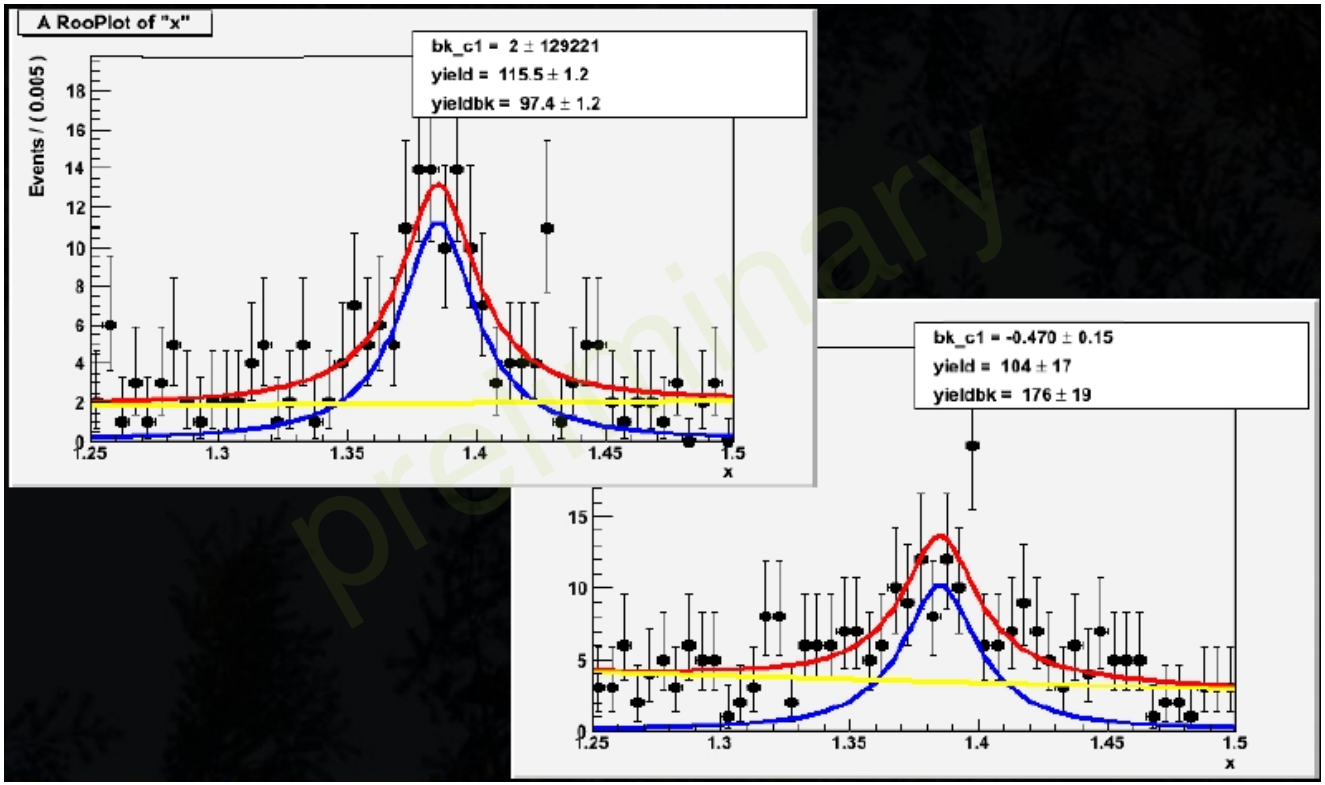
Select exclusive $e^- K^+ \Sigma^{*0}$ channel

Yield



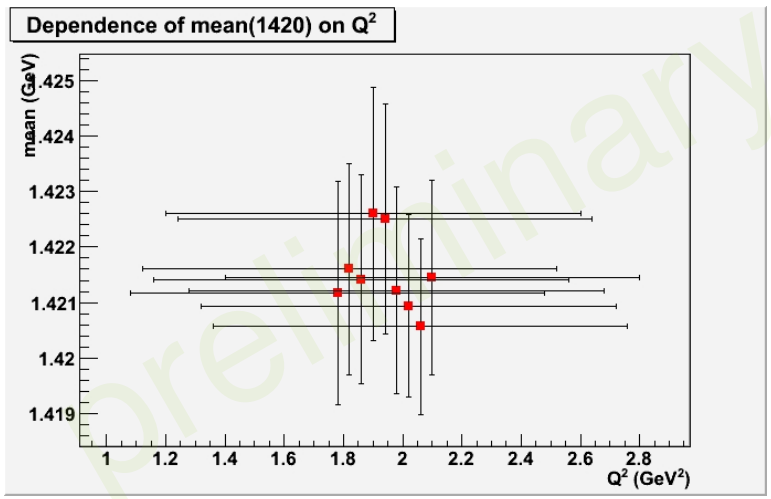
Exclusive yield on Q^2

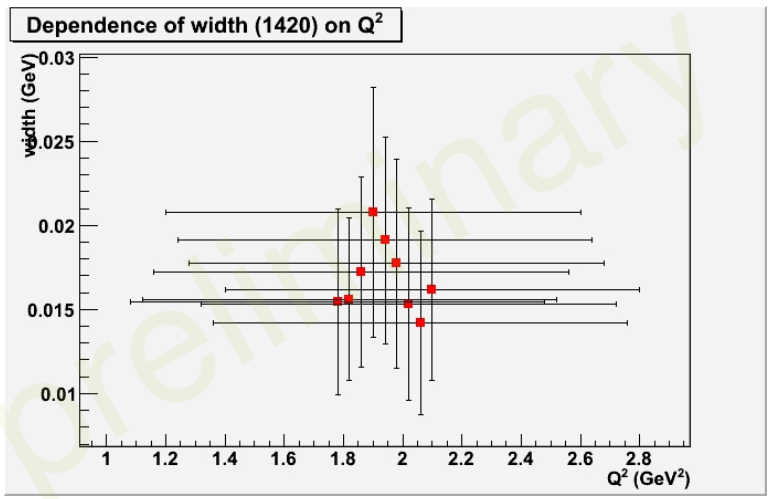
Example of Fits to Extract Yield



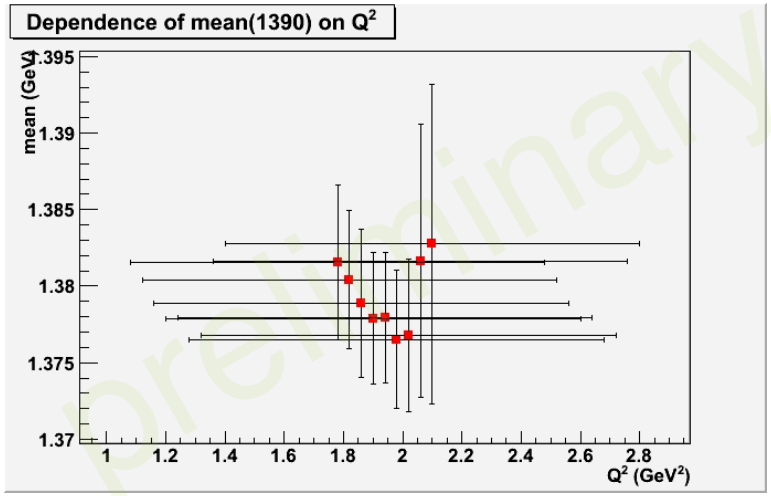
Example of fits at the two lowest Q^2 region

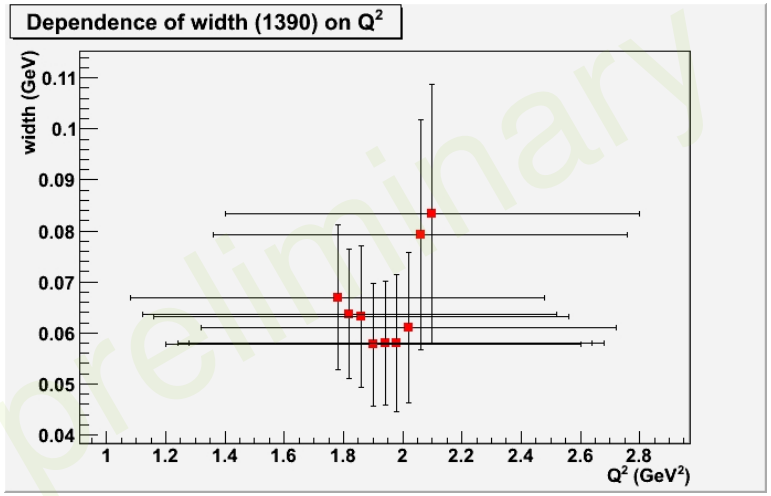
Fitting Results of Mean and Width of 1420 Dependence on Q^2





Fitting Results of Mean and Width of 1390 Dependence on Q^2





Fitting Acceptance-Corrected Yield of 1420 and 1390 Dependence on Q^2