

Search for the Θ^+ pentaquark in the $\gamma d \rightarrow \Lambda NK$ reaction with CLAS

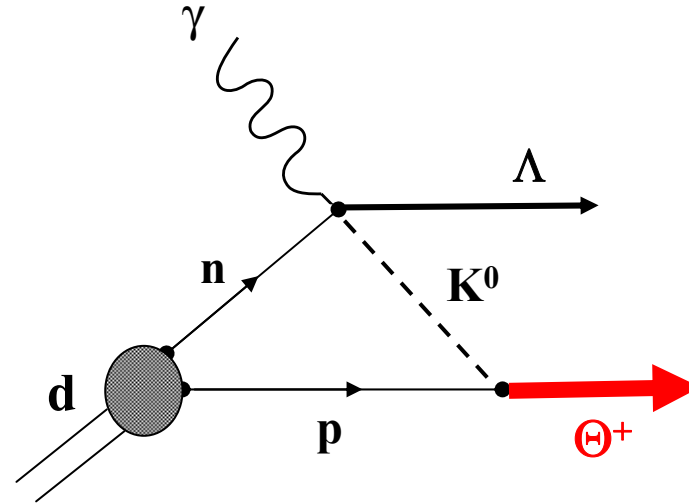
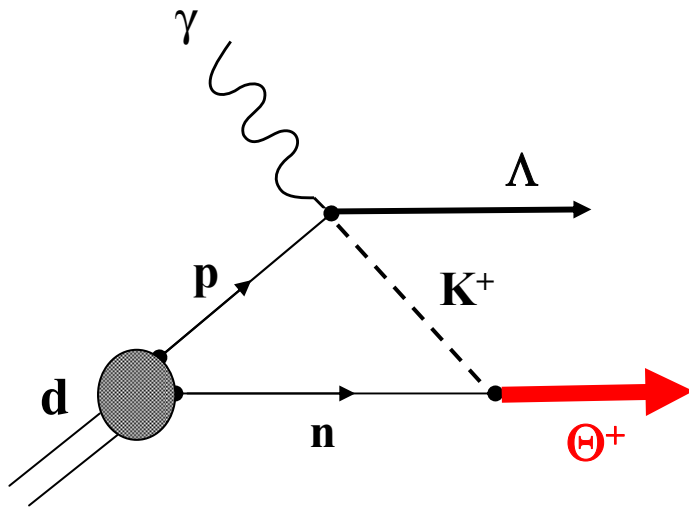


**S. Niccolai, IPN Orsay
for the CLAS collaboration**

Search for the Θ^+ pentaquark in the $\gamma d \rightarrow \Lambda NK$ reaction with CLAS

- Motivation
 - Theoretical predictions
 - Data analysis
- Preliminary results from G10
 - Conclusions and outlook

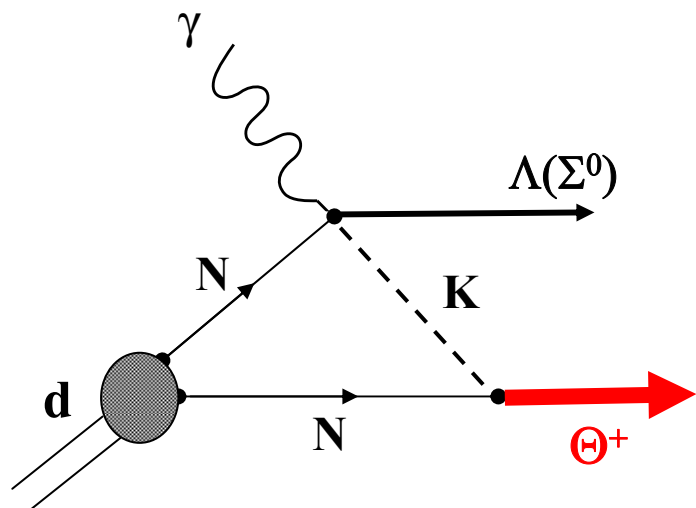
$\gamma d \rightarrow \Lambda \Theta^+$: the reaction



- **Strangeness tagged** by Λ : $S=+1$ both for nK^+ and pK^0
- Unlike pK^+K^-n or pK^0K^-p :
 - **No** possibility of **kinematical reflections** of mesons \rightarrow KK (only **one K**, from Θ^+ decay, in the final state)
 - “Clean” reaction: **no background channels** to remove
- Model predictions: $\sigma \rightarrow \Gamma(\Theta^+)$ [Guzey, PRC 69, 065203 (2004)]

$\gamma d \rightarrow \Lambda \Theta^+$: model prediction

$\Gamma(\Theta^+) = 5 \text{ MeV}$
 $S = 1/2, I = 0$



$$d\sigma/dt \sim \Gamma(\Theta^+) d\sigma^{(p+n)}/dt S(t)$$

$d\sigma^{(p+n)}/dt$ interference of

$\gamma p \rightarrow \Lambda(\Sigma^0) K^+$ (exp. data)

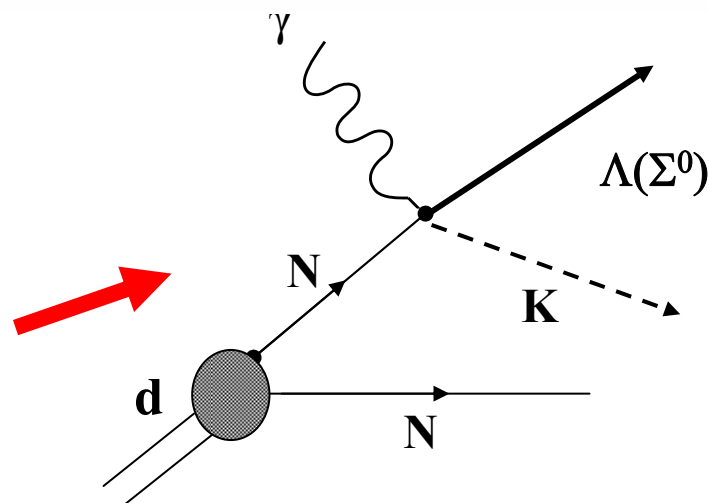
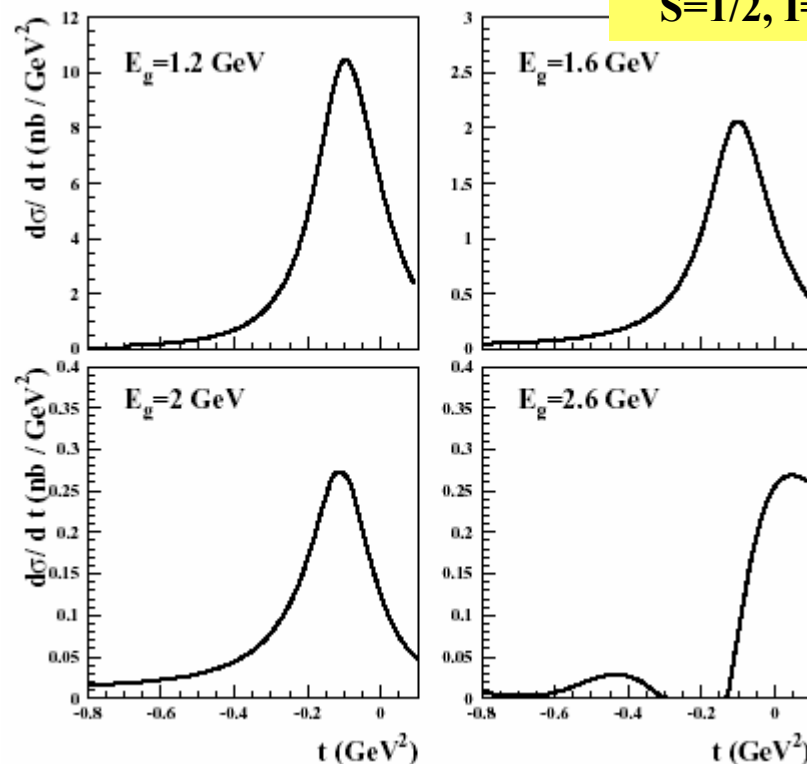
and $\gamma n \rightarrow \Lambda(\Sigma^0) K^0$ (parametrization)

$S(t)$ nuclear suppression factor

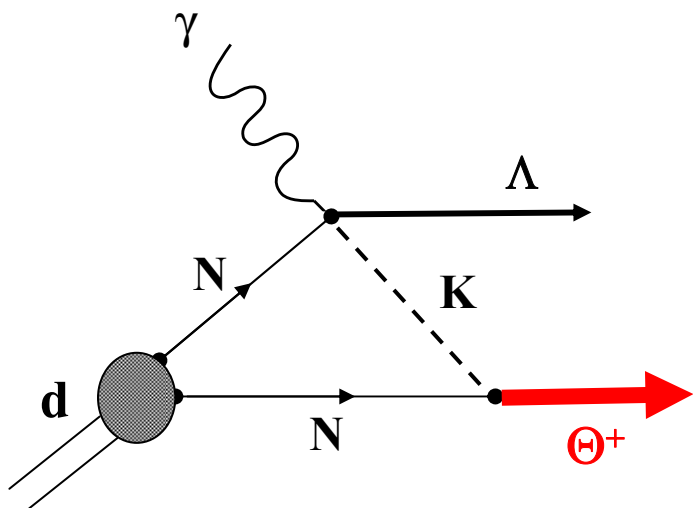
$d\sigma/dt$ max for $E_\gamma = 1.2 \text{ GeV}$, $-0.2 < t < 0$

$\sigma_{\text{tot}} \approx 3 \text{ nb}$

Cut $p_{n(p)} > 300 \text{ MeV}/c$ to remove N-spectator events – non resonant **background**

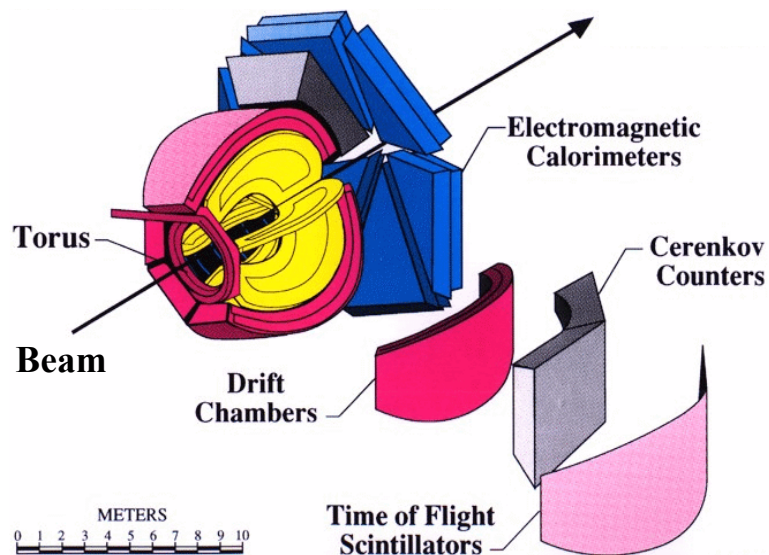


$\gamma d \rightarrow \Lambda \Theta^+$: CLAS G10 analysis

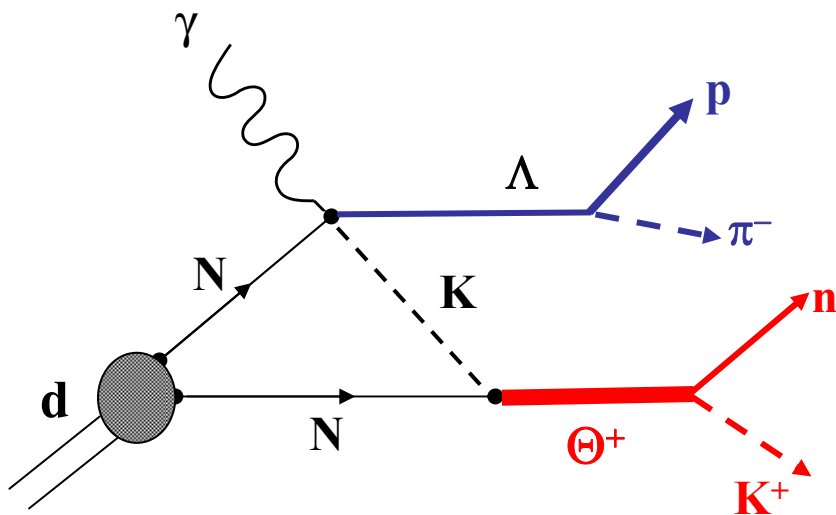


All G10 data analyzed
Both torus field settings
Higher statistics for low-field

CLAS is designed
to measure **exclusive reactions**
with **multi-particle final states**



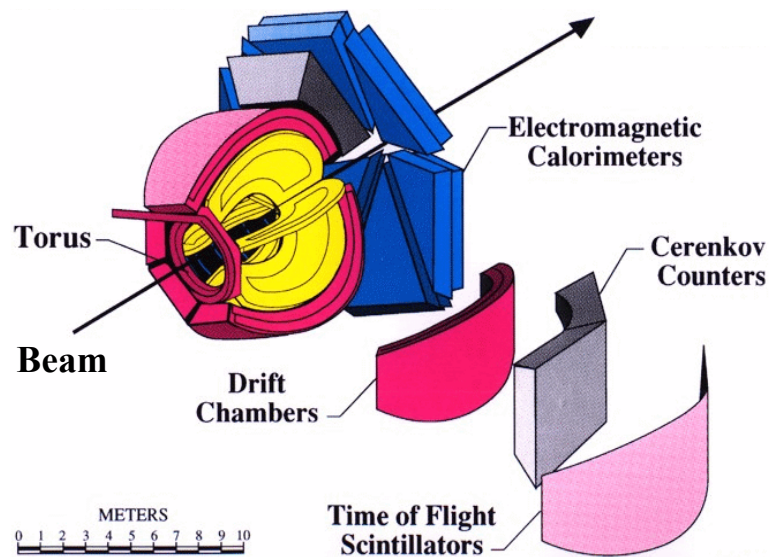
$\gamma d \rightarrow \Lambda \Theta^+$: CLAS G10 analysis



Decay modes under study:

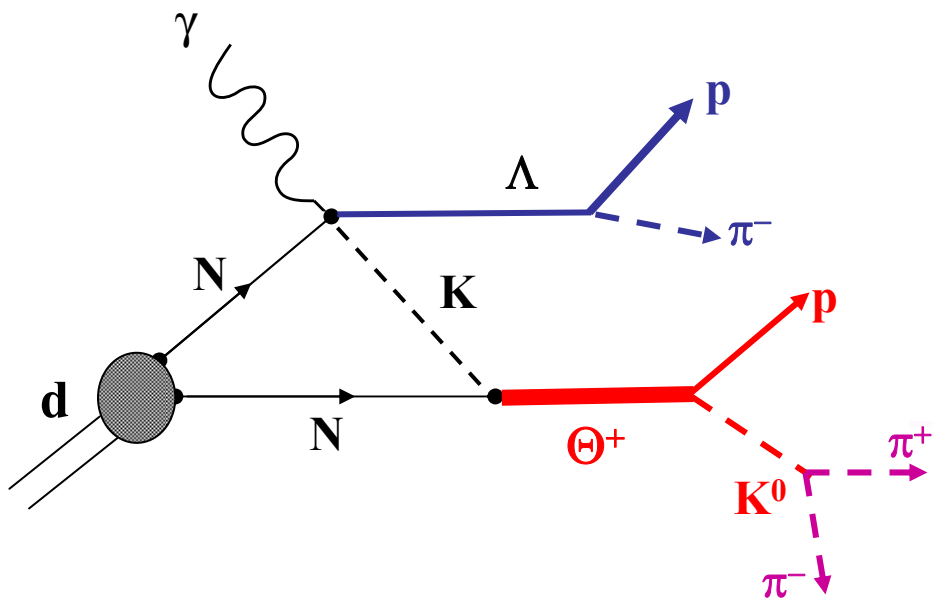
$$\Lambda \rightarrow p\pi^- \quad \Theta^+ \rightarrow K^+n$$

3 charged particles, 1 neutral
in the final state



CLAS is designed
to measure **exclusive reactions**
with **multi-particle final states**

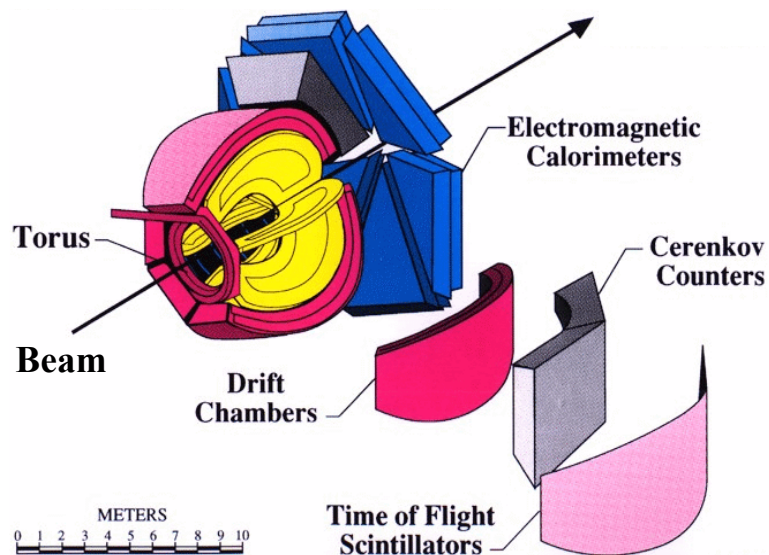
$\gamma d \rightarrow \Lambda \Theta^+$: CLAS G10 analysis



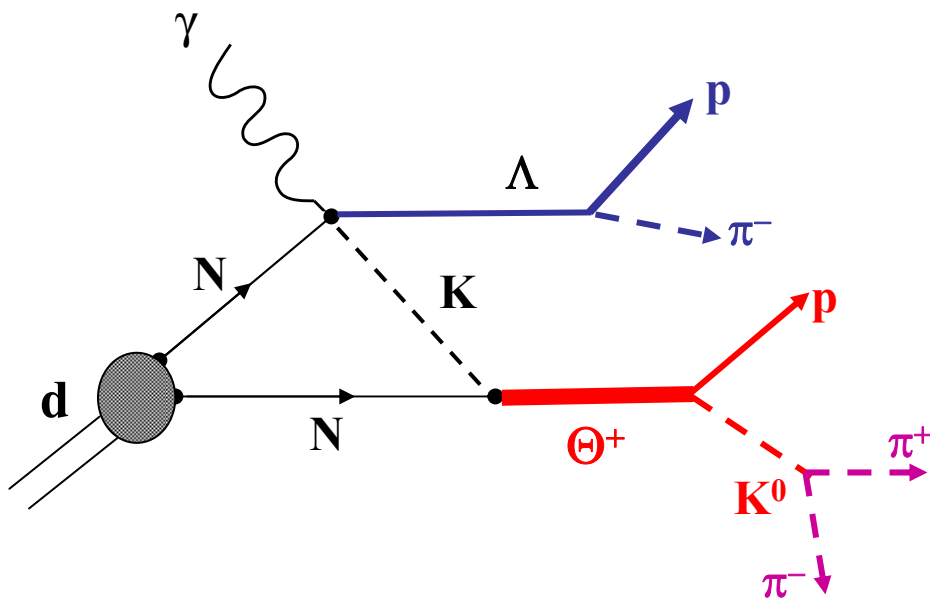
Decay modes under study:

- $\Lambda \rightarrow p\pi^-$ $\Theta^+ \rightarrow K^+n$
- $\Lambda \rightarrow p\pi^-$, $\Theta^+ \rightarrow K^0p$, $K^0_s \rightarrow \pi^+\pi^-$

CLAS is designed to measure **exclusive reactions with multi-particle final states**



$\gamma d \rightarrow \Lambda \Theta^+$: CLAS G10 analysis



Decay modes under study:

- $\Lambda \rightarrow p\pi^-$ $\Theta^+ \rightarrow K^+n$
- $\Lambda \rightarrow p\pi^-$, $\Theta^+ \rightarrow K^0p$, $K^0_s \rightarrow \pi^+\pi^-$

5 charged particles
in the final state

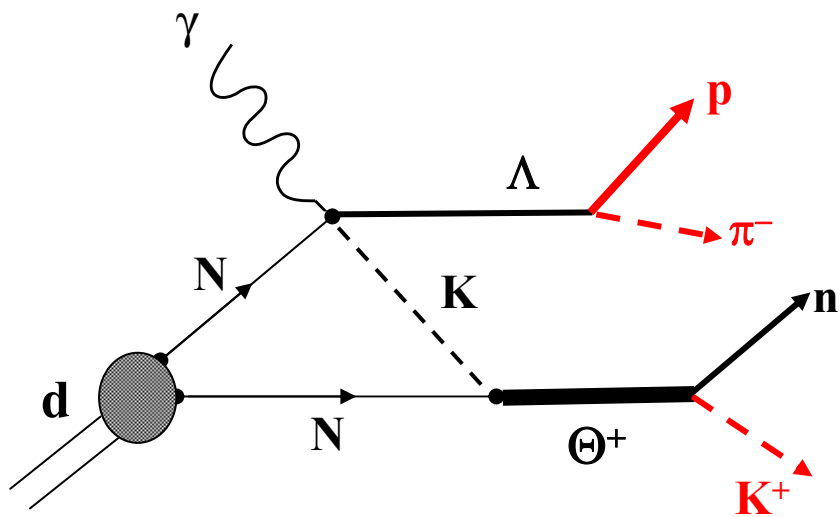


Possible to analyze 6
different exclusive
topologies



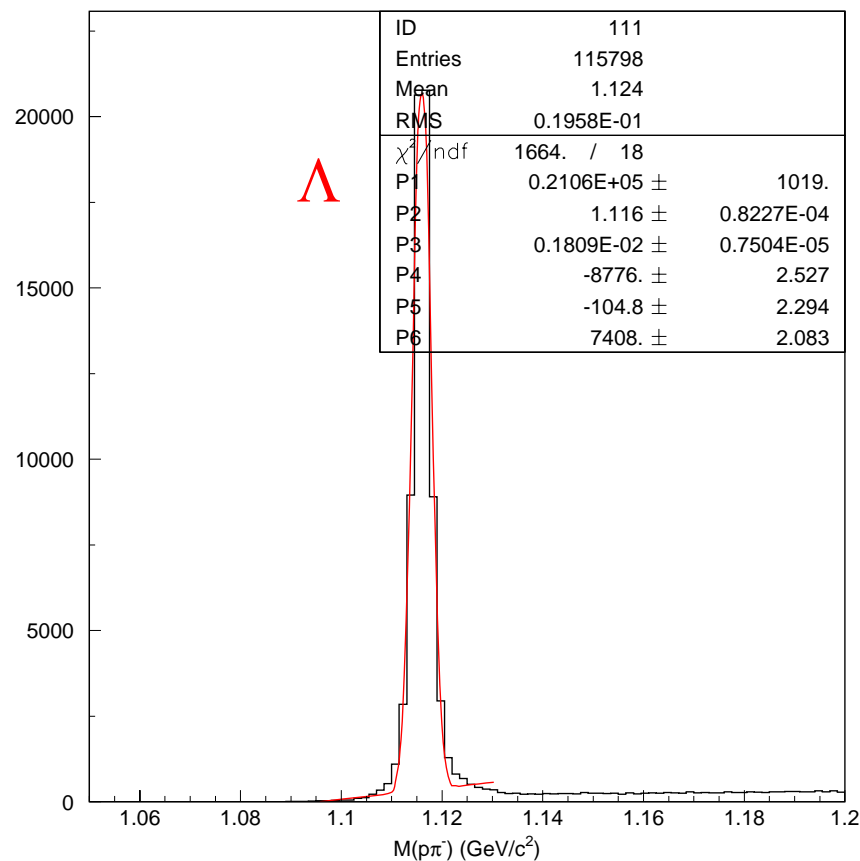
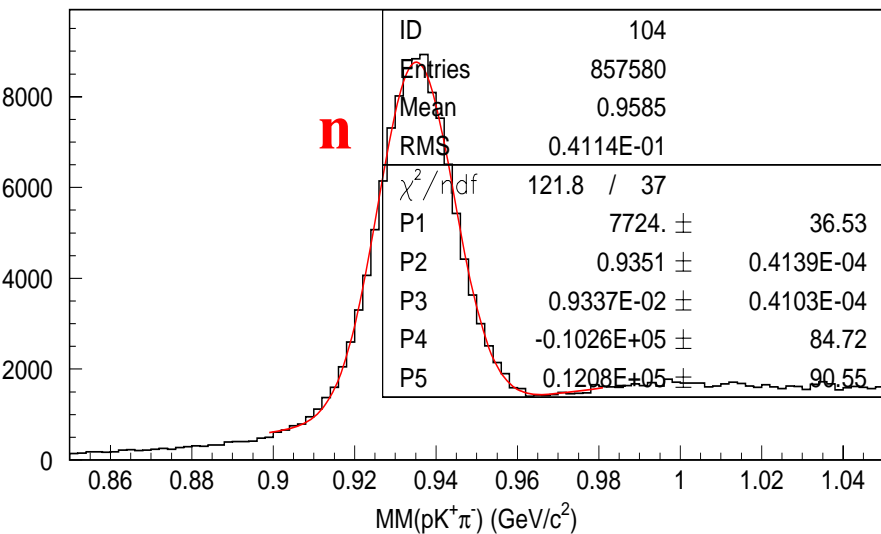
- 1) All 5 particles detected
- 2) Missing π^-
- 3) Missing K^0
- 4) Missing p
- 5) Missing Λ
- 6) Missing π^+

nK⁺ decay mode: data analysis



Channel ID:

- **K⁺, p, π⁻** detected (PID+timing cuts)
- **n** identified by **missing mass** (3σ cut)
- **Λ** identified by **pπ⁻ invariant mass** (3σ)



nK⁺ decay mode: Σ⁻ background?

LOW-FIELD G10 DATA

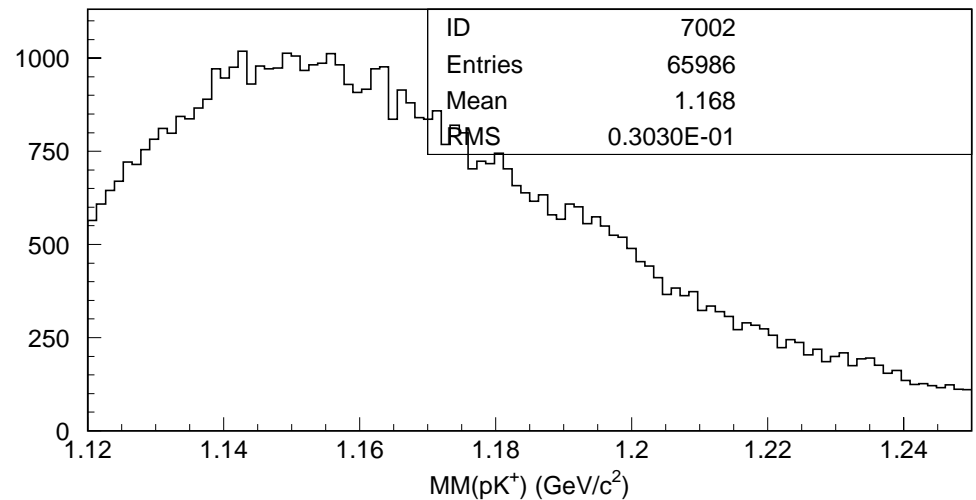
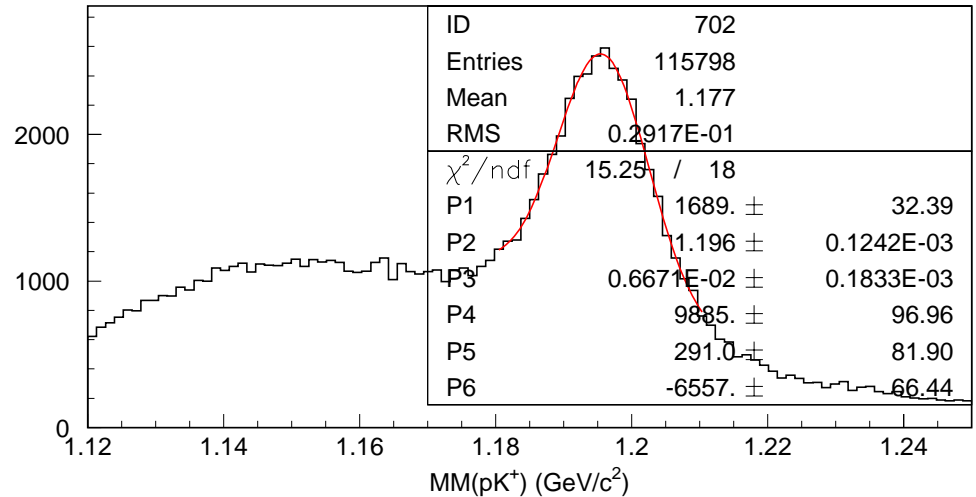
$\gamma d \rightarrow pK^+\Sigma^- \rightarrow pK^+n\pi^-$

pK⁺ missing mass
before Λ cut

pK⁺ missing mass
after Λ cut

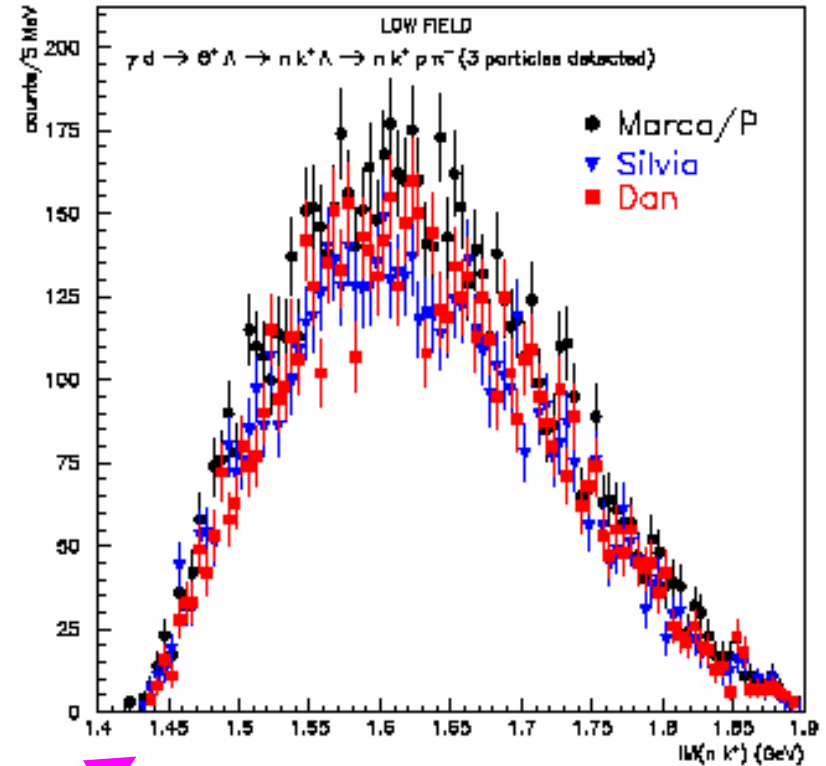
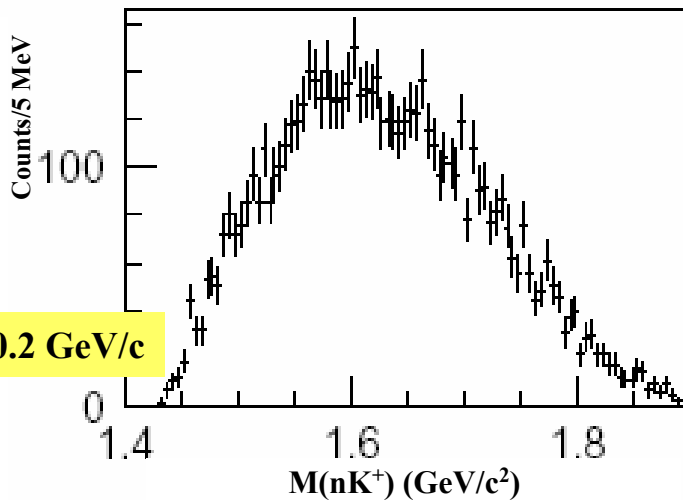
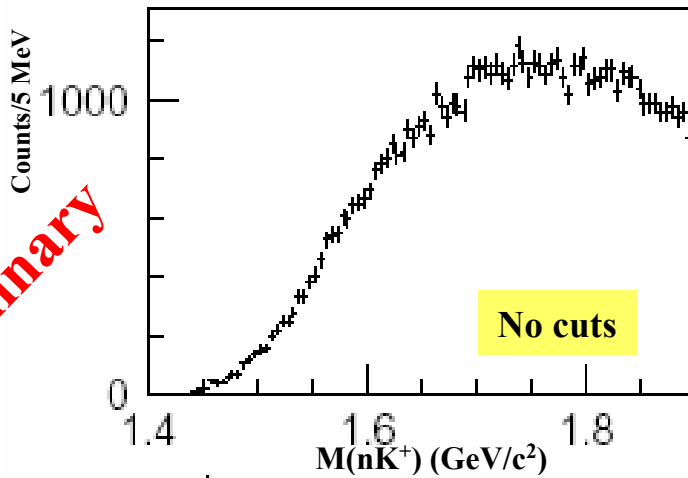


No Σ⁻ background



nK^+ decay mode: mass spectra

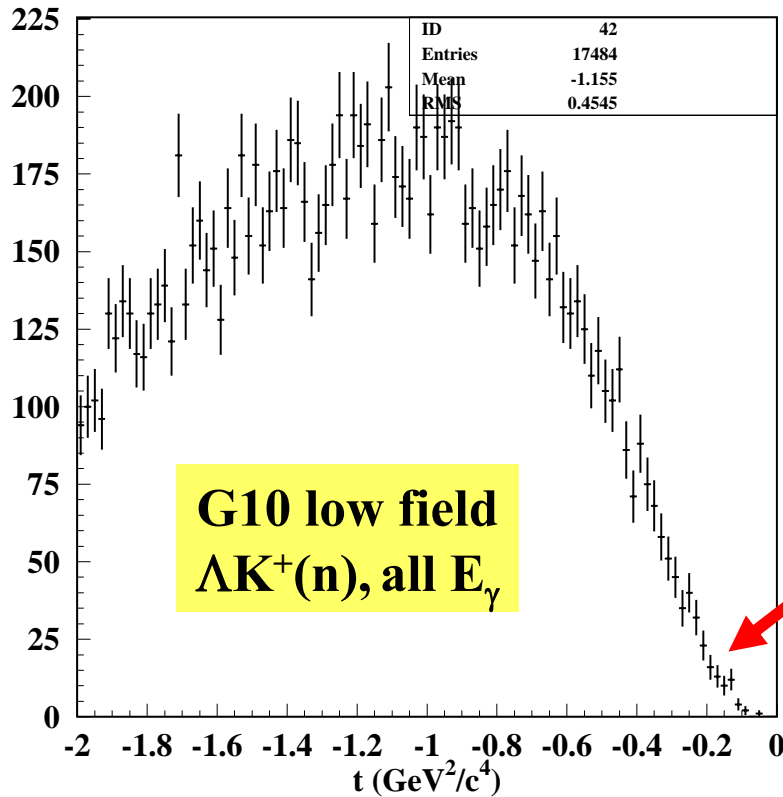
- $M(nK^+)$ mass with and without **kinematic fit**
- 3 parallel independent analyses (Carman, Mirazita-Rossi, S.N.), **in agreement** (10%)
- **no significant Θ^+ signal**, with and without **kinematic cuts** (Guzey)
- **MC studies** for acceptance underway, to extract **cross section upper limits**



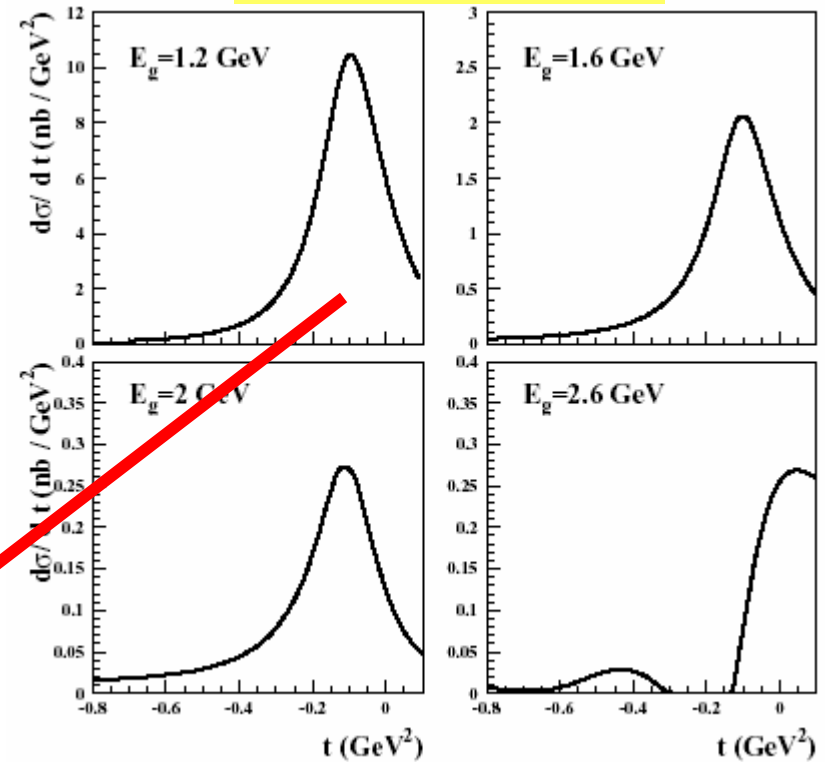
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nK^+ decay mode: mass spectra

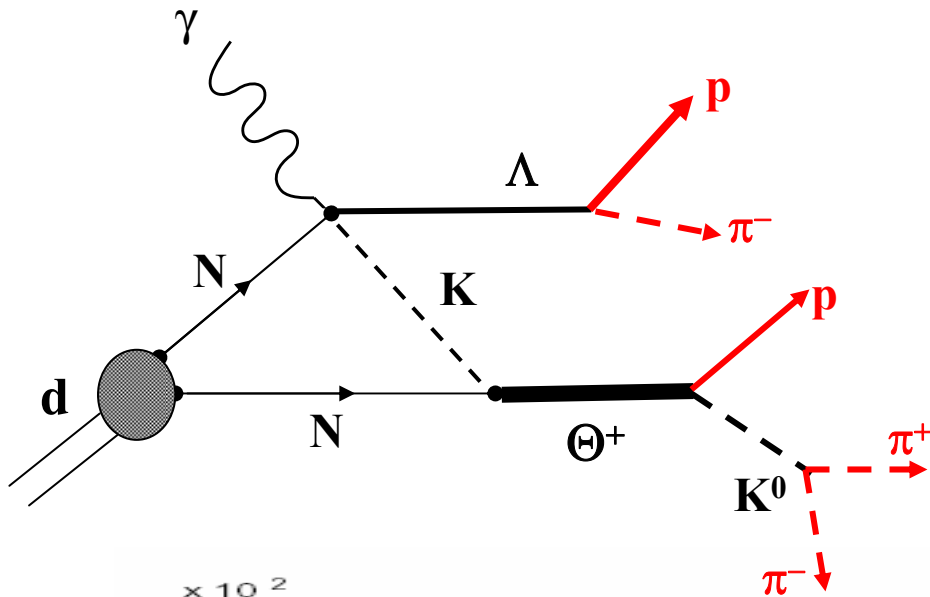
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Model prediction



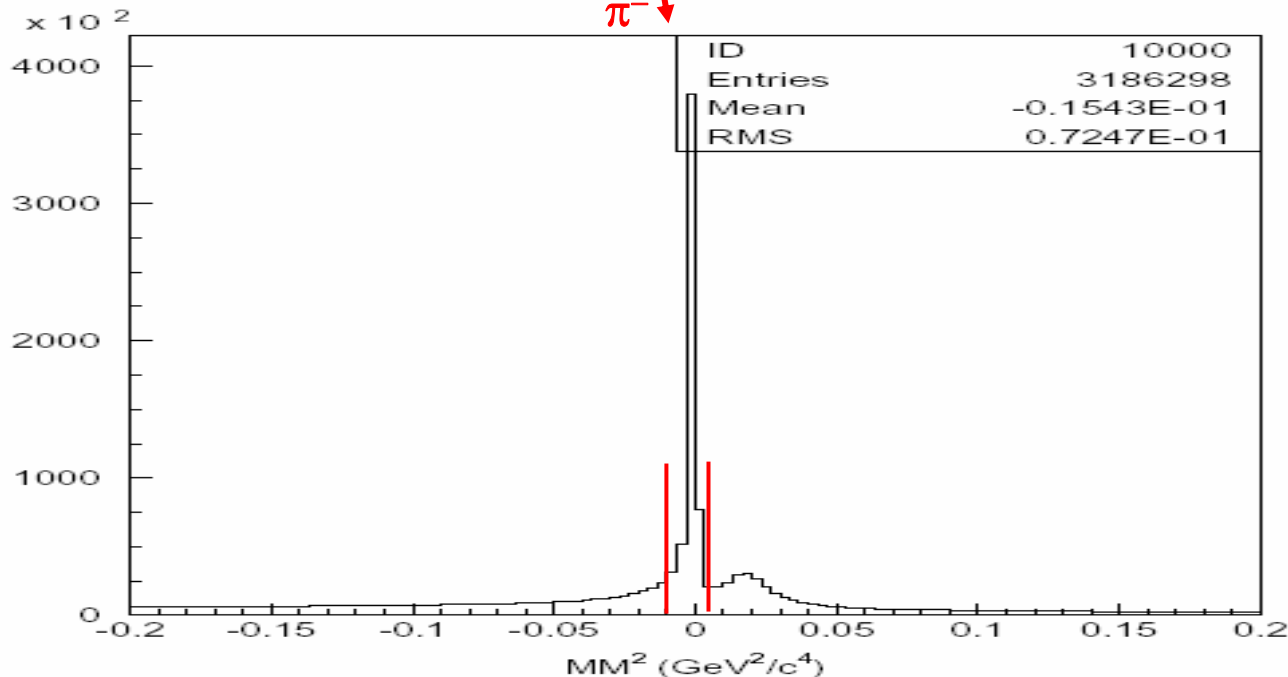
pK⁰ mode – 1) all particles detected



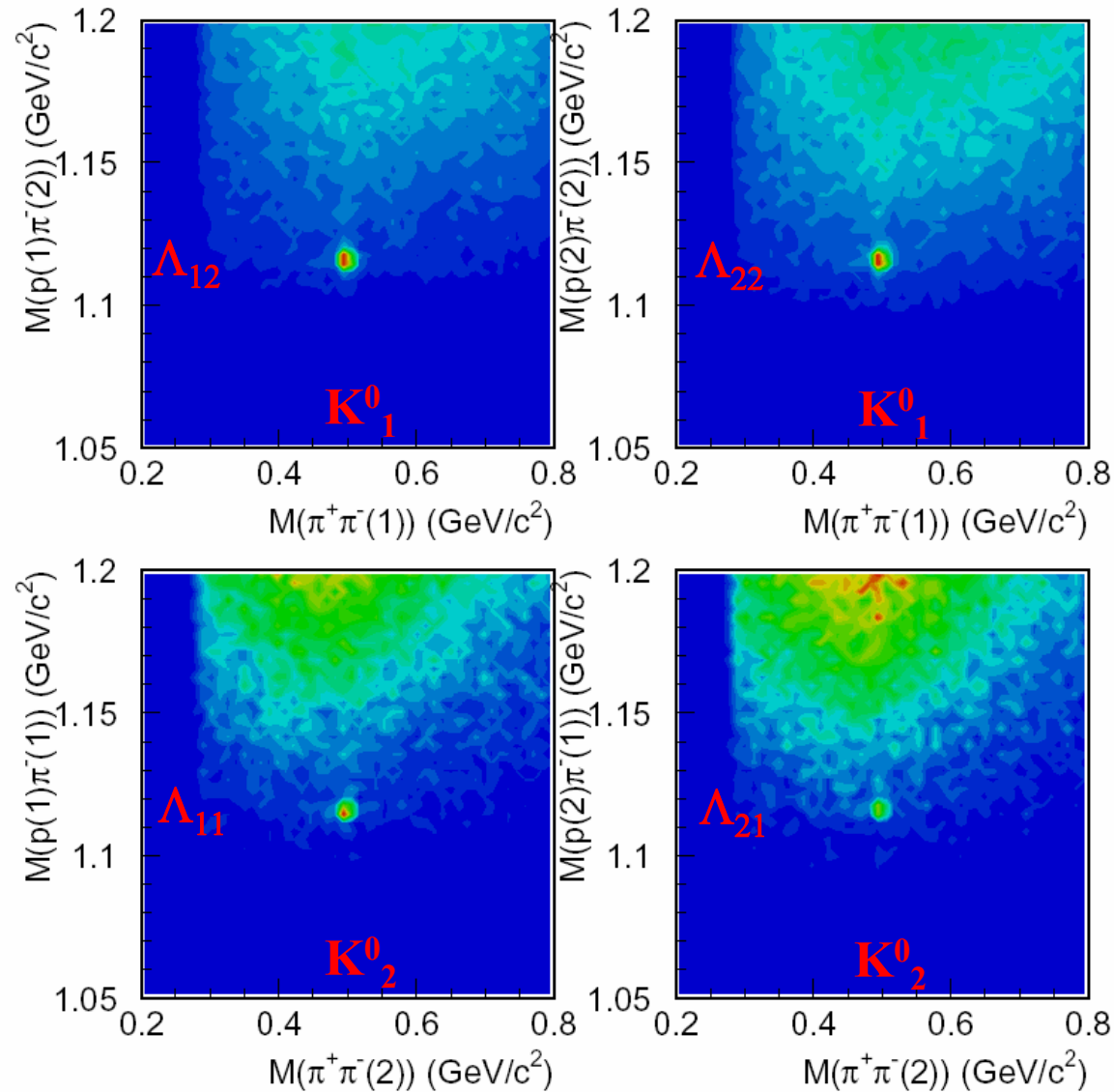
2 protons, 2 π^- , 1 π^+
 $p(p_1) > p(p_2)$, $p(\pi^-_1) > p(\pi^-_2)$

Channel ID cuts:

• $-0.01 < MM^2 < 0.005$ (GeV^2/c^4)



pK⁰ mode – 1) all particles detected



2 protons, 2 π^- , 1 π^+
 $p(p_1) > p(p_2)$, $p(\pi^-_1) > p(\pi^-_2)$

Channel ID cuts:

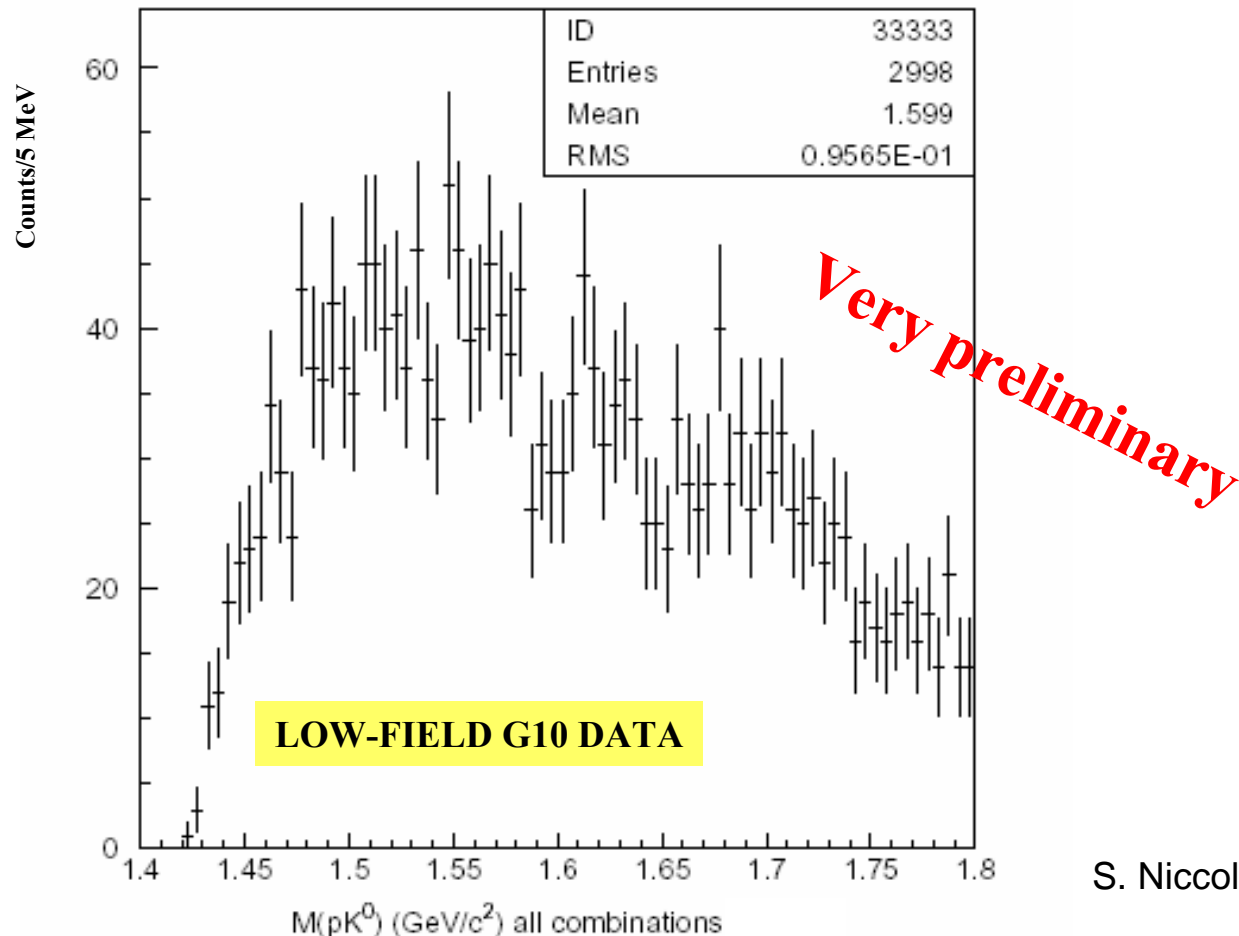
- $-0.01 < MM^2 < 0.005$ (GeV^2/c^4)
- $M(p\pi^-) = M(L) \pm 3\sigma$
- $M(\pi^+\pi^-) = M(K^0) \pm 3\sigma$



4 combinations
with 4 pK⁰ mass spectra
that can be summed up

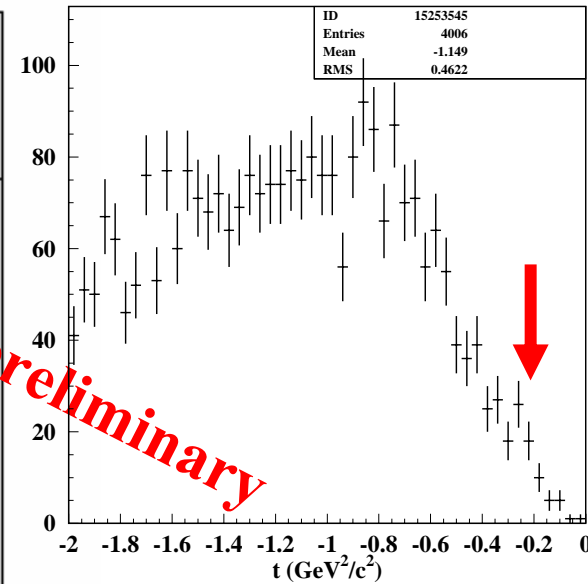
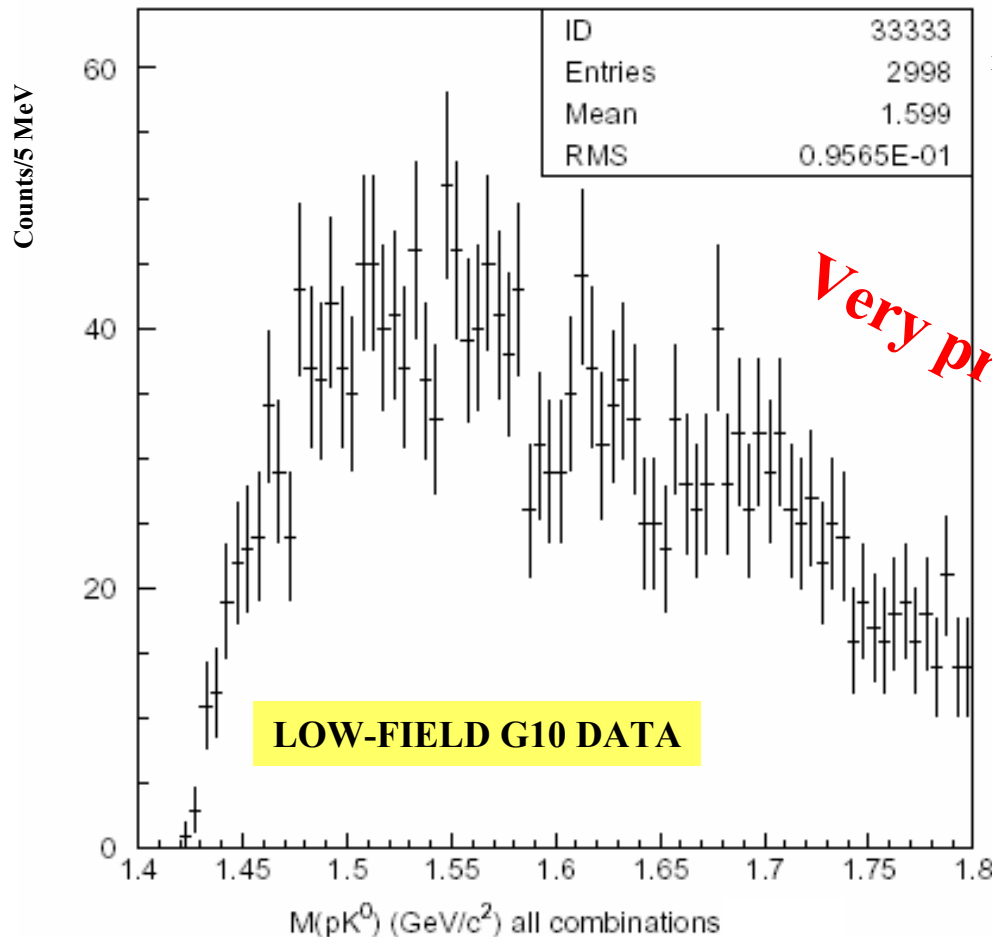
pK⁰ mode – 1) all particles detected

- 3 parallel independent analyses (Hicks-Mibe, Mirazita-Rossi, S.N.), cross checking
- **no significant Θ^+ signal in the pK⁰ invariant mass**
- **MC studies** for acceptance underway, to extract **cross section upper limits**



pK⁰ mode – 1) all particles detected

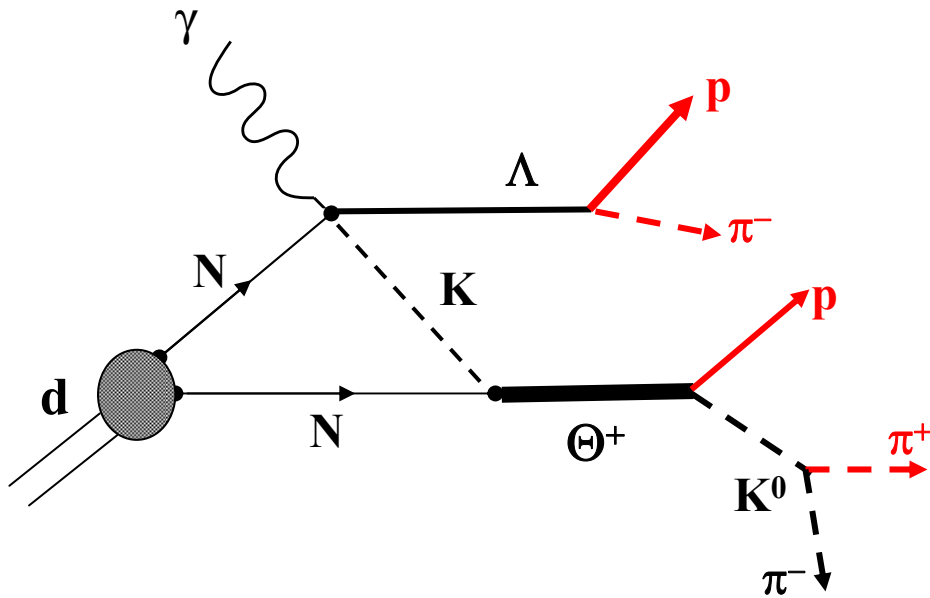
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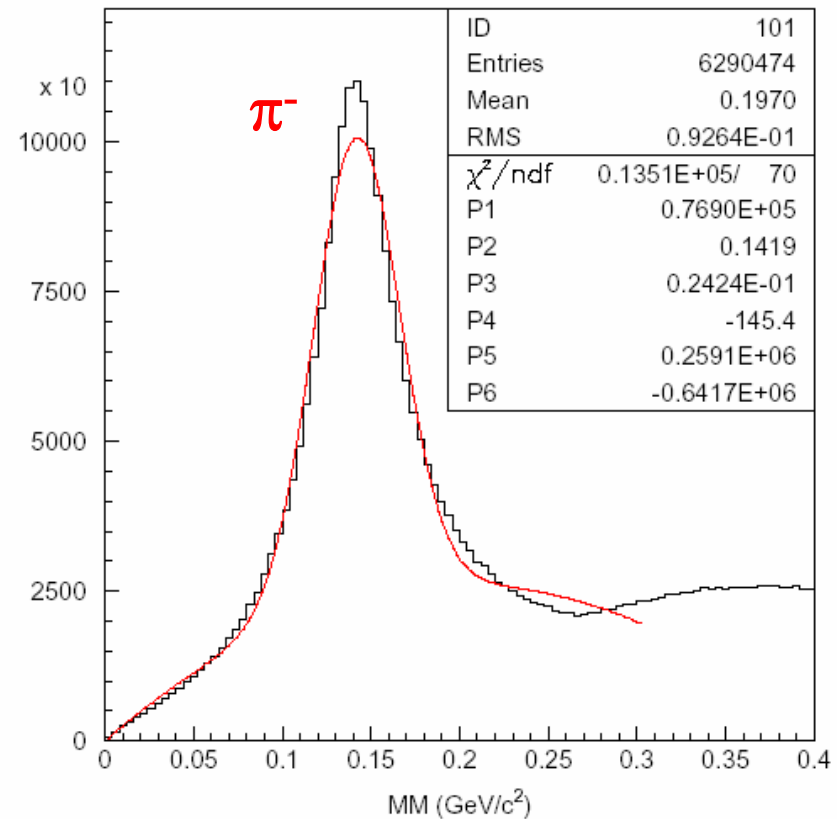
pK^0 mode – 2) missing π^-



2 protons, $1\pi^-$, $1\pi^+$

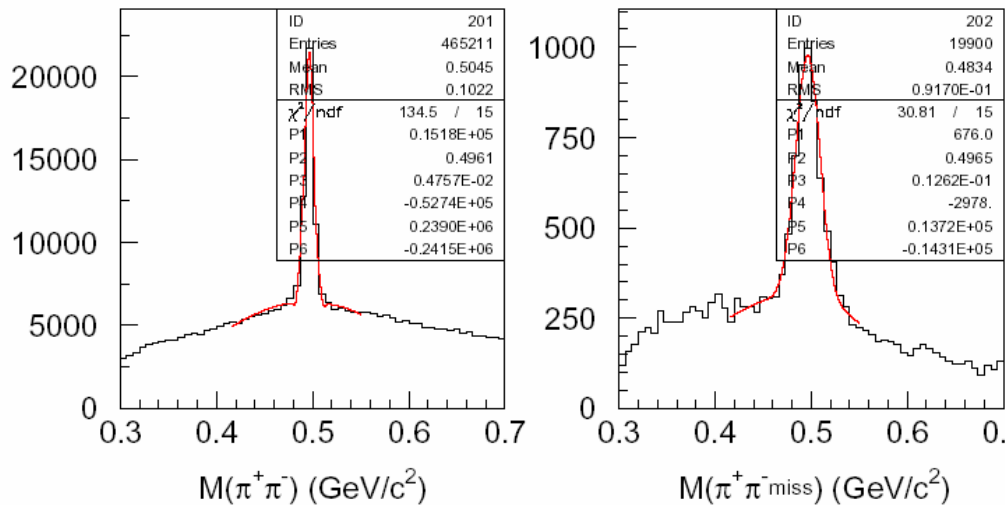
Channel ID cuts:

- $MM = M(\pi^-) \pm 3\sigma$

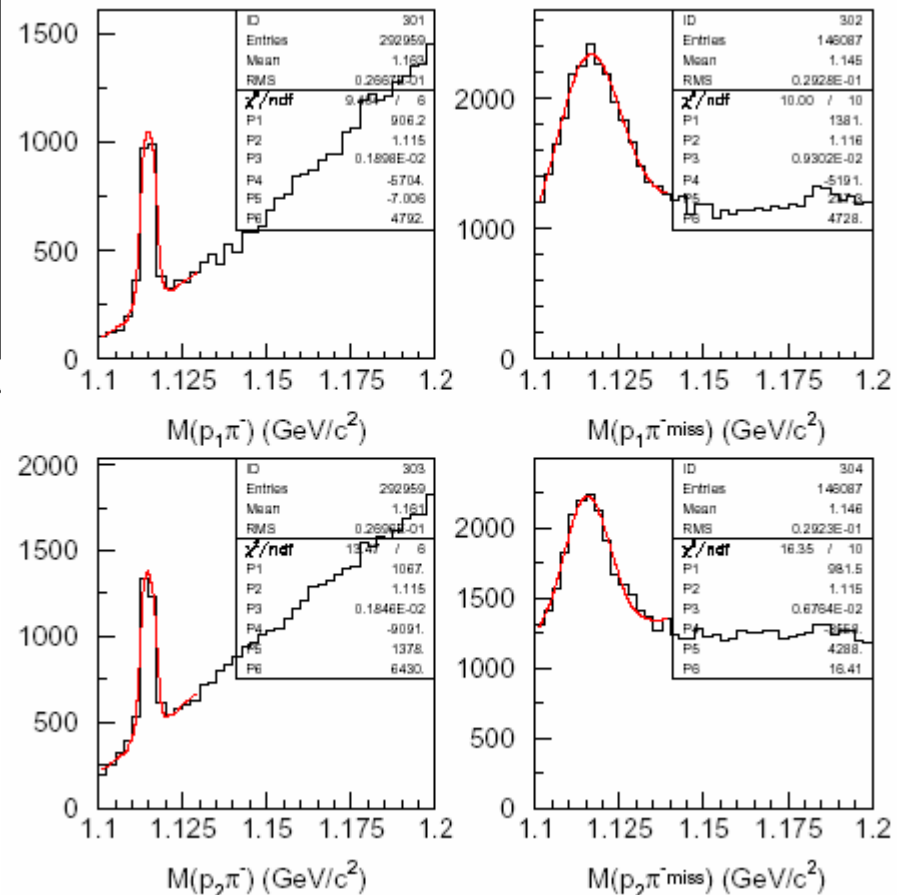


pK^0 mode – 2) missing π^-

$\pi^+\pi^-$ invariant masses



$p\pi^-$ invariant masses



Channel ID cuts:

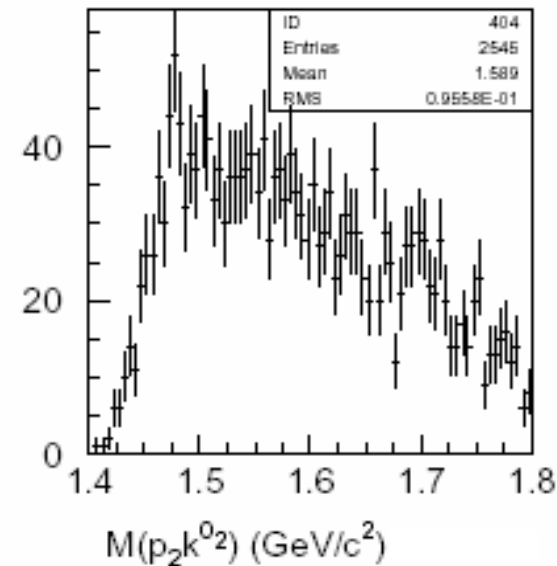
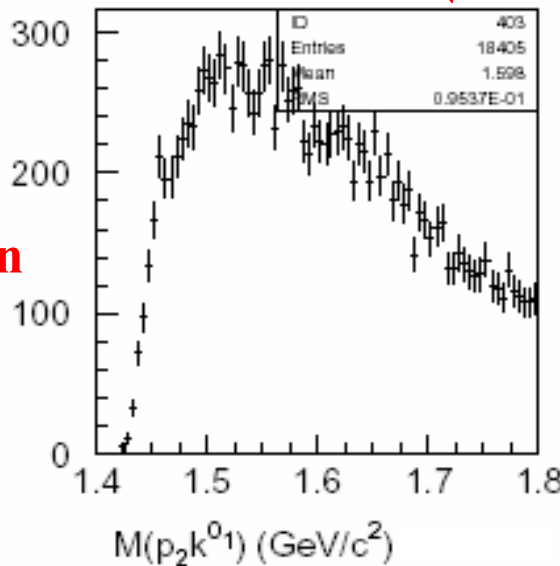
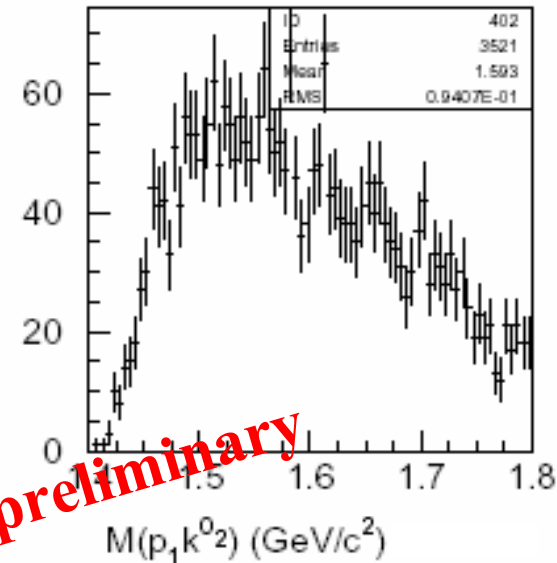
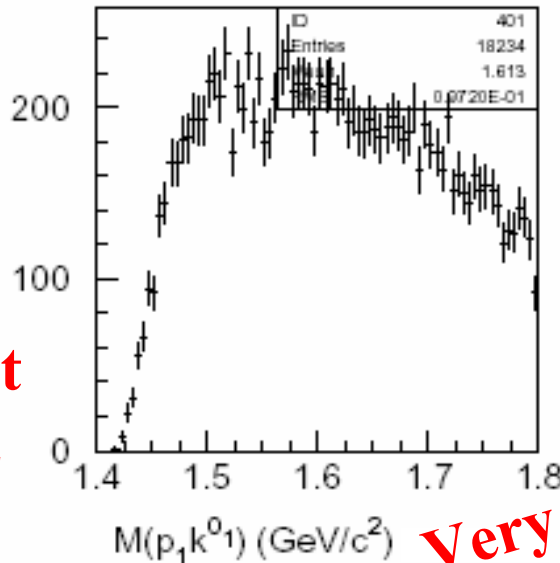
- $MM = M(\pi^-) \pm 3\sigma$
- $IM(\pi^+\pi^-) = M(K^0) \pm 3\sigma$
- $IM(p\pi^-) = M(\Lambda) \pm 3\sigma$

pK^0 mode – 2) missing π^-

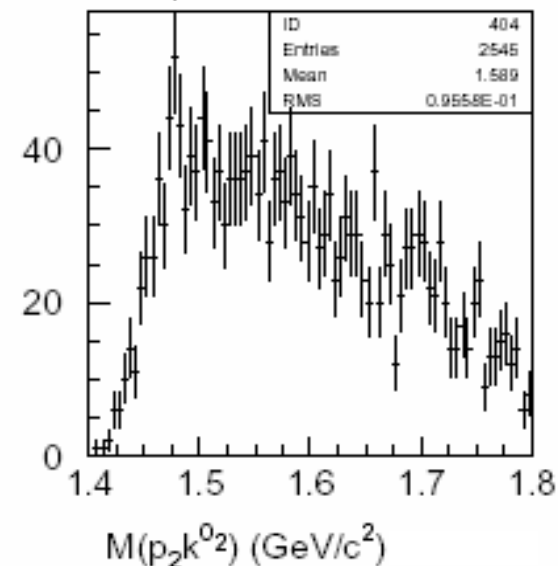
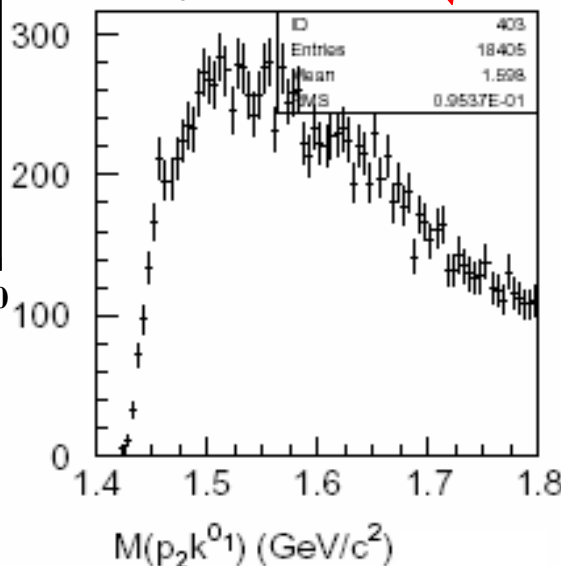
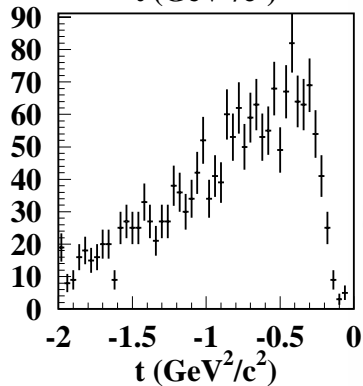
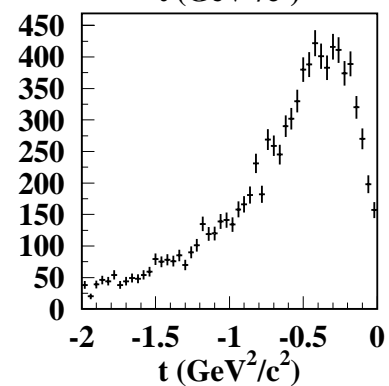
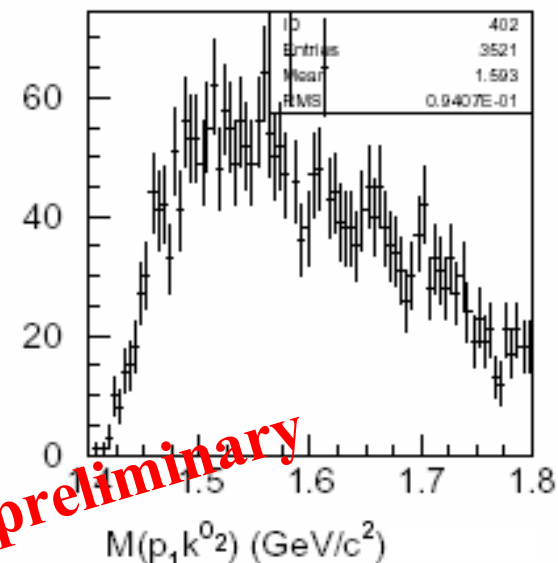
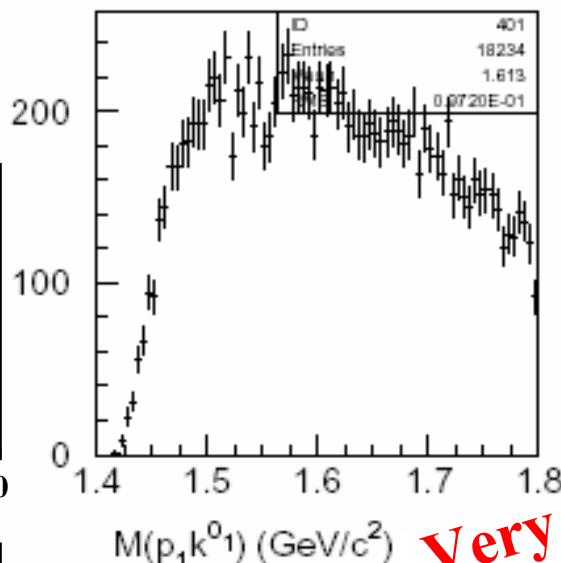
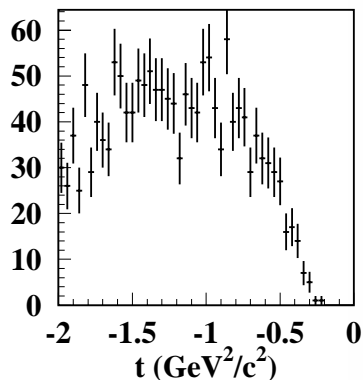
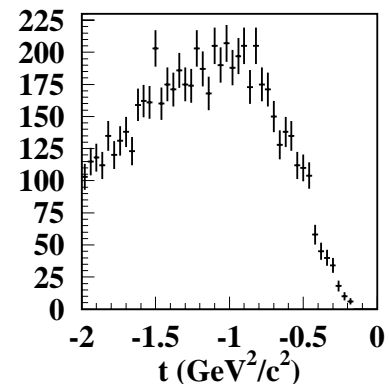
- 2 parallel independent analyses (Mirazita-Rossi, S.N.)

- **no significant Θ^+ signal at $1.52 < M(pK^0) < 1.55 \text{ GeV}/c^2$ in any of the 4 spectra**

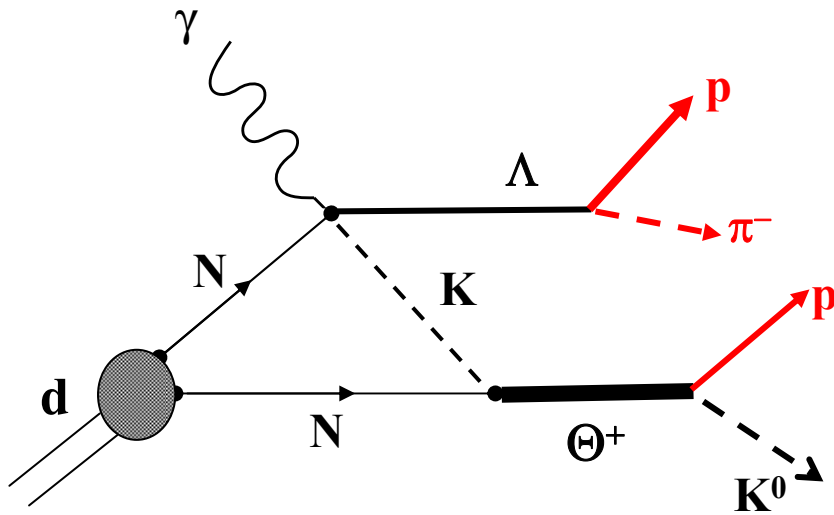
- **MC studies** for acceptance underway, to extract **cross section upper limits**



pK^0 mode – 2) missing π^-



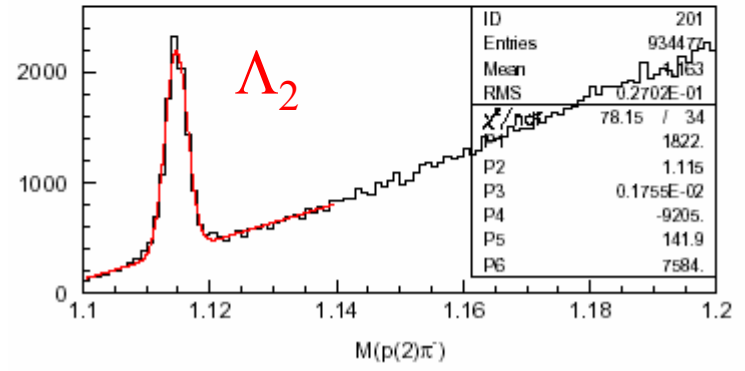
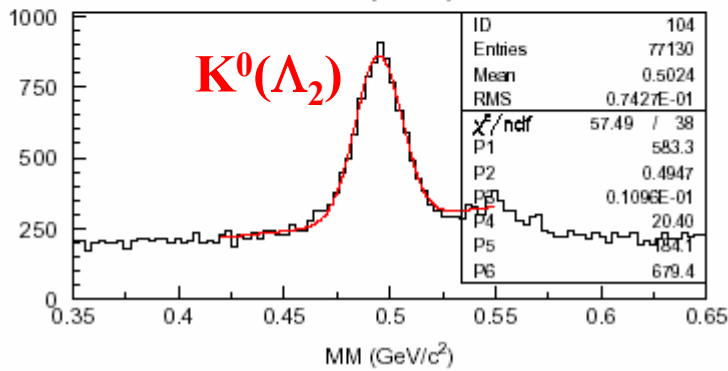
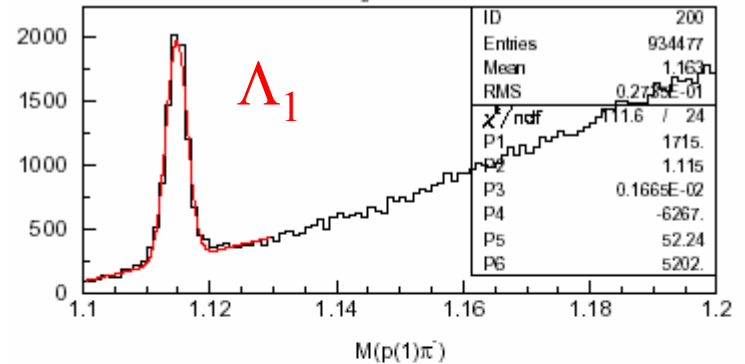
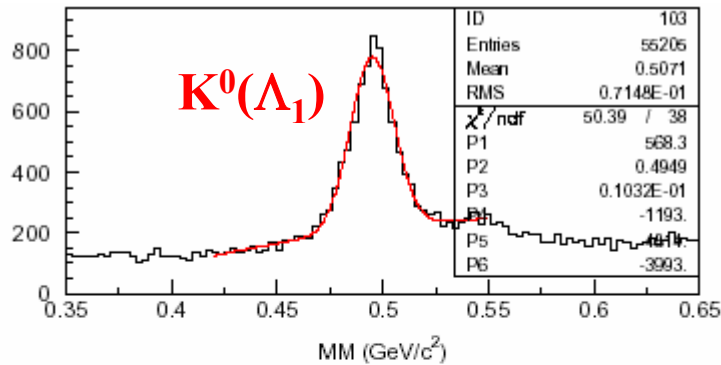
pK⁰ mode – 3) missing K⁰



2 protons, 1π⁻

Channel ID cuts:

- $MM = M(K^0) \pm 3\sigma$
- $IM(p\pi^-) = M(\Lambda) = 3\sigma$

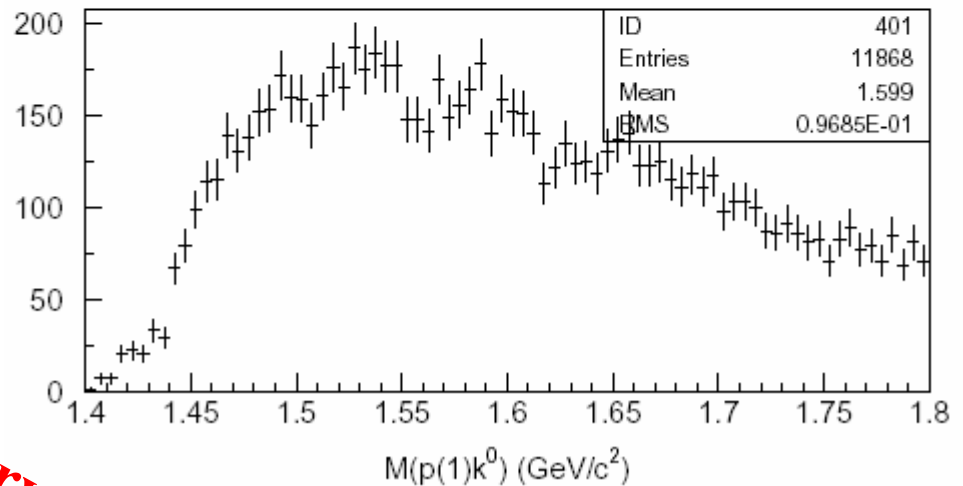
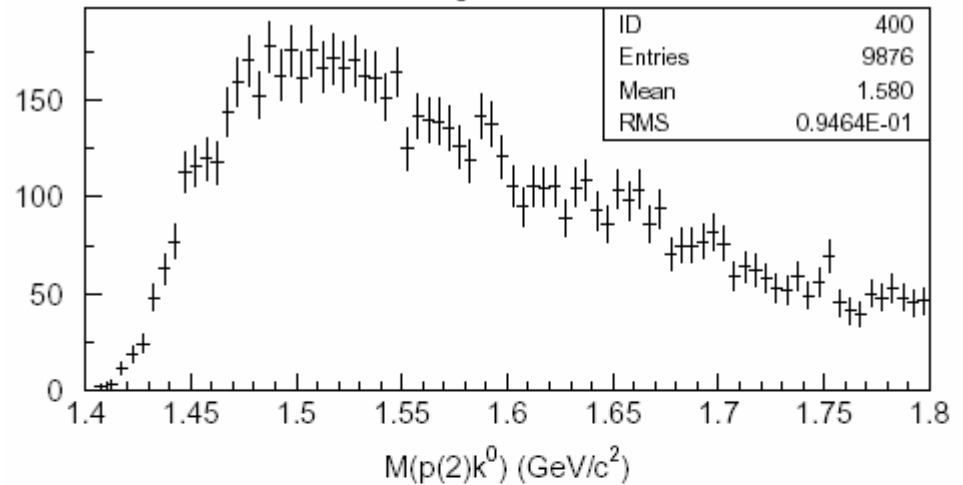


pK⁰ mode – 3) missing K⁰

- 2 parallel independent analyses (Mirazita-Rossi, S.N.)

- **no significant Θ^+ signal at $1.52 < M(pK^0) < 1.55 \text{ GeV}/c^2$ in any of the 2 spectra**

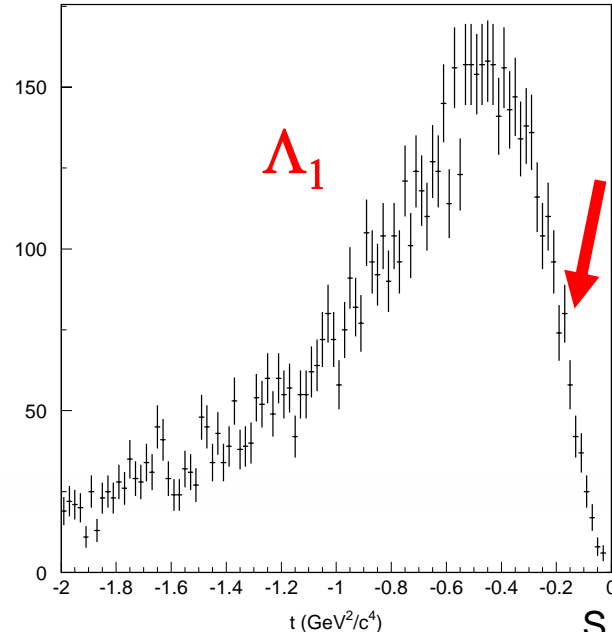
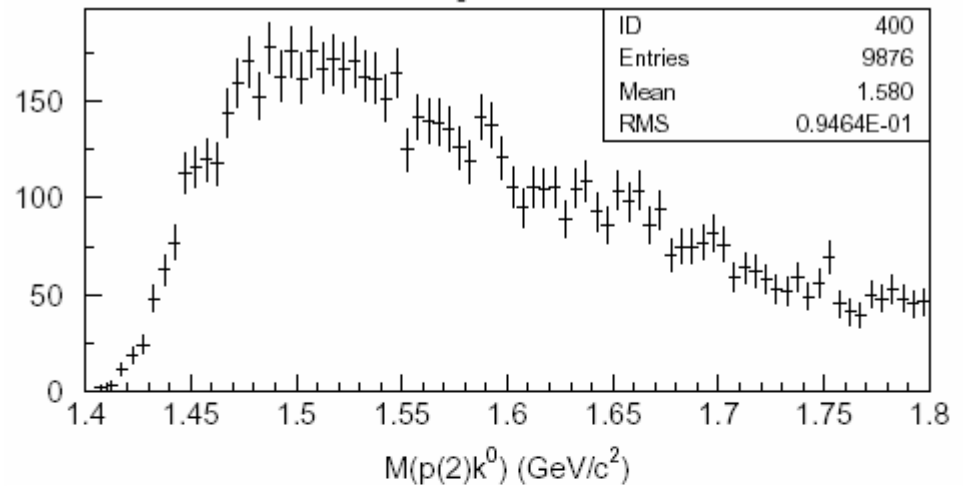
- **MC studies** for acceptance underway, to extract **cross section upper limits**



Very preliminary

pK⁰ mode – 3) missing K⁰

- 2 parallel independent analyses (Mirazita-Rossi, S.N.)
- **no significant Θ^+ signal at $1.52 < M(pK^0) < 1.55 \text{ GeV}/c^2$ in any of the 2 spectra**
- **MC studies** for acceptance underway, to extract **cross section upper limits**



Conclusions and outlook

- Search for Θ^+ in the $\gamma d \rightarrow \Lambda n K$ reaction carried out using the high-statistics **CLAS-G10** data set
- Both the **nK⁺** and **pK⁰** decay modes have been analyzed
- 4 parallel analyses are underway
- The pK⁰ decay mode has been studied in 4 different topologies
- **No statistically significant structure is observed in the NK invariant mass spectrum**
- MC studies are underway to extract **cross section upper limits**