# Hadronic reactions using g11

# n p → d $\pi^0$

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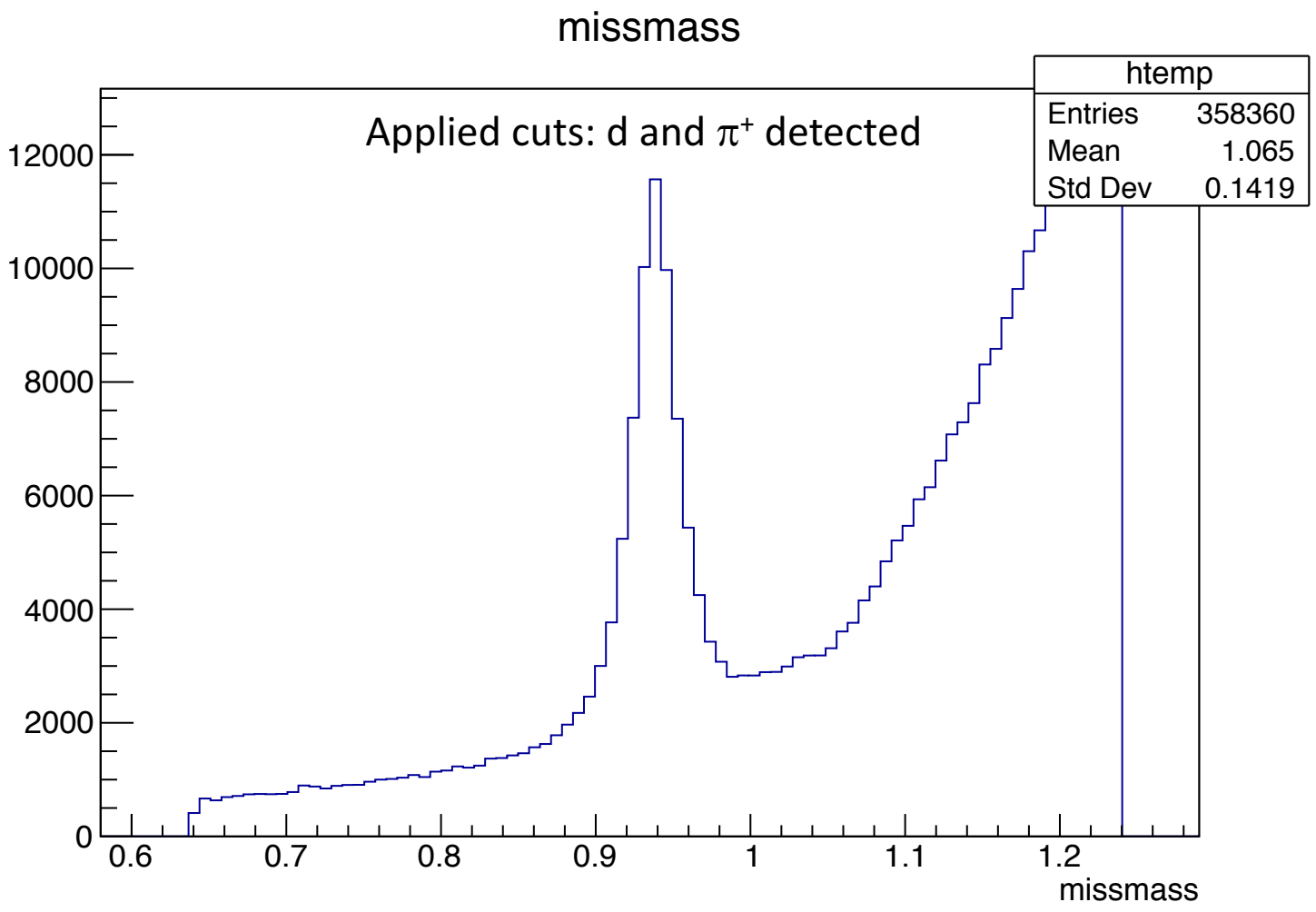
# Using CLAS6 data for hadronic reactions

- Long LH2 target (40 cm) provides secondary scattering
  - Demonstrated for $\gamma p \rightarrow K^+\Lambda$ followed by $\Lambda N \rightarrow \Lambda N$ elastic scattering.
  - In principle, any hadronic reaction can be studied at CLAS
  - John Price: $K_s$ rescattering possible (HYP2018 talk)
  - Two experiments have similar statistics: g11 and g12.
- Motivation for $np \rightarrow d\pi^0$ scattering:
  - Improve on previous cross sections (mostly via $pp \rightarrow d\pi^+$)
  - Look for possible polarization observables (depends on n-production)
  - Possible (?) to utilize this to measure n-polarization in $\gamma p \rightarrow \pi^+ n$.

# Measured reaction

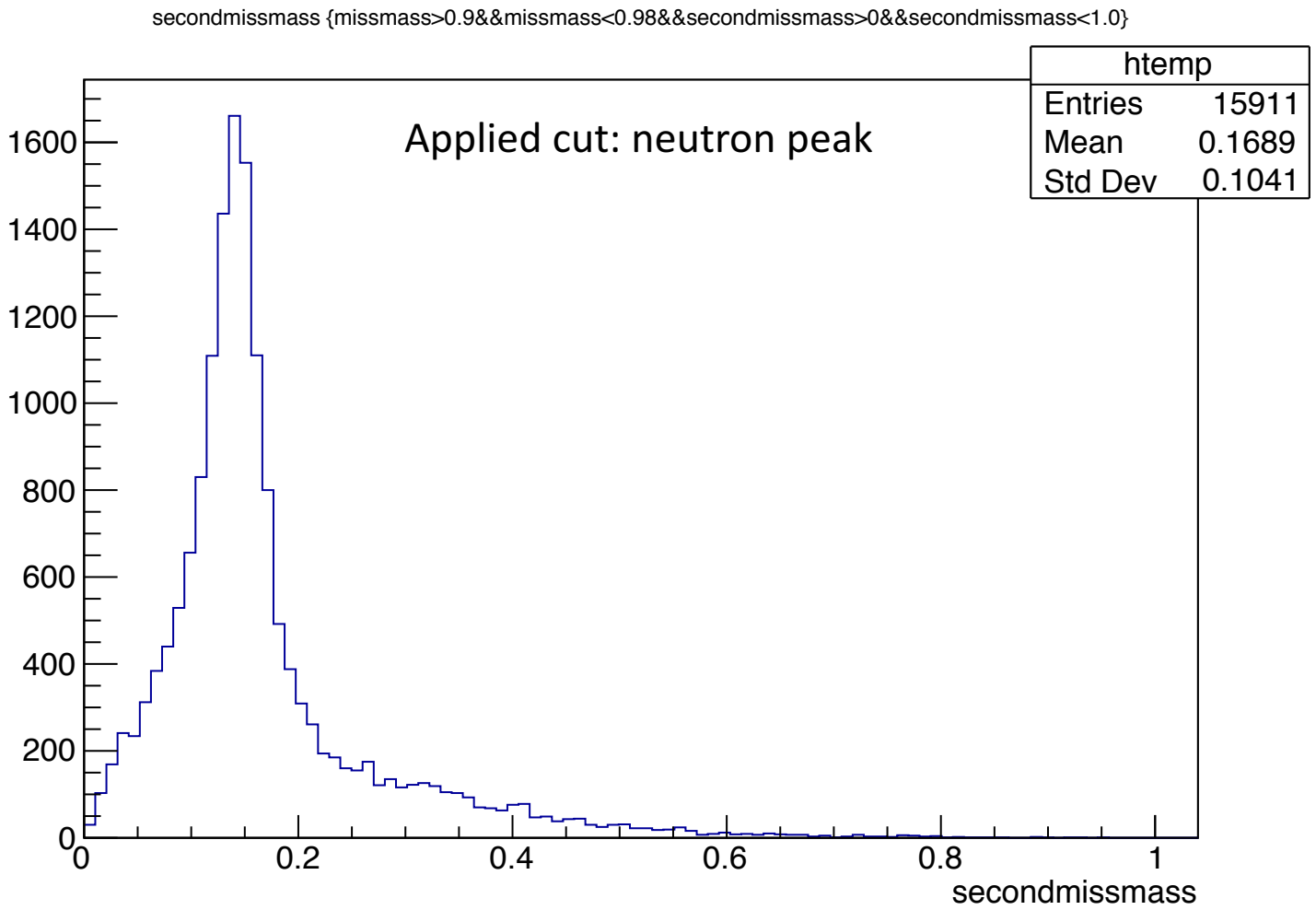
- Data set: g11 (LH2 target, 40 cm length)
- Step 1: $\gamma p \rightarrow \pi^{+}(n)$
  - Detected: $\pi^{+}$.
  - Missing mass: $M_n$. Cut on the neutron peak.
- Step 2: $np \rightarrow d\pi^{0}$
  - Detected: d.
  - Missing mass: $M_\pi$. Cut on the $\pi^0$ peak.
  - Plot: $E_{CM}$-dependence. Expect a peak at about $E_{CM}$ = 2150 MeV.

# Step 1:



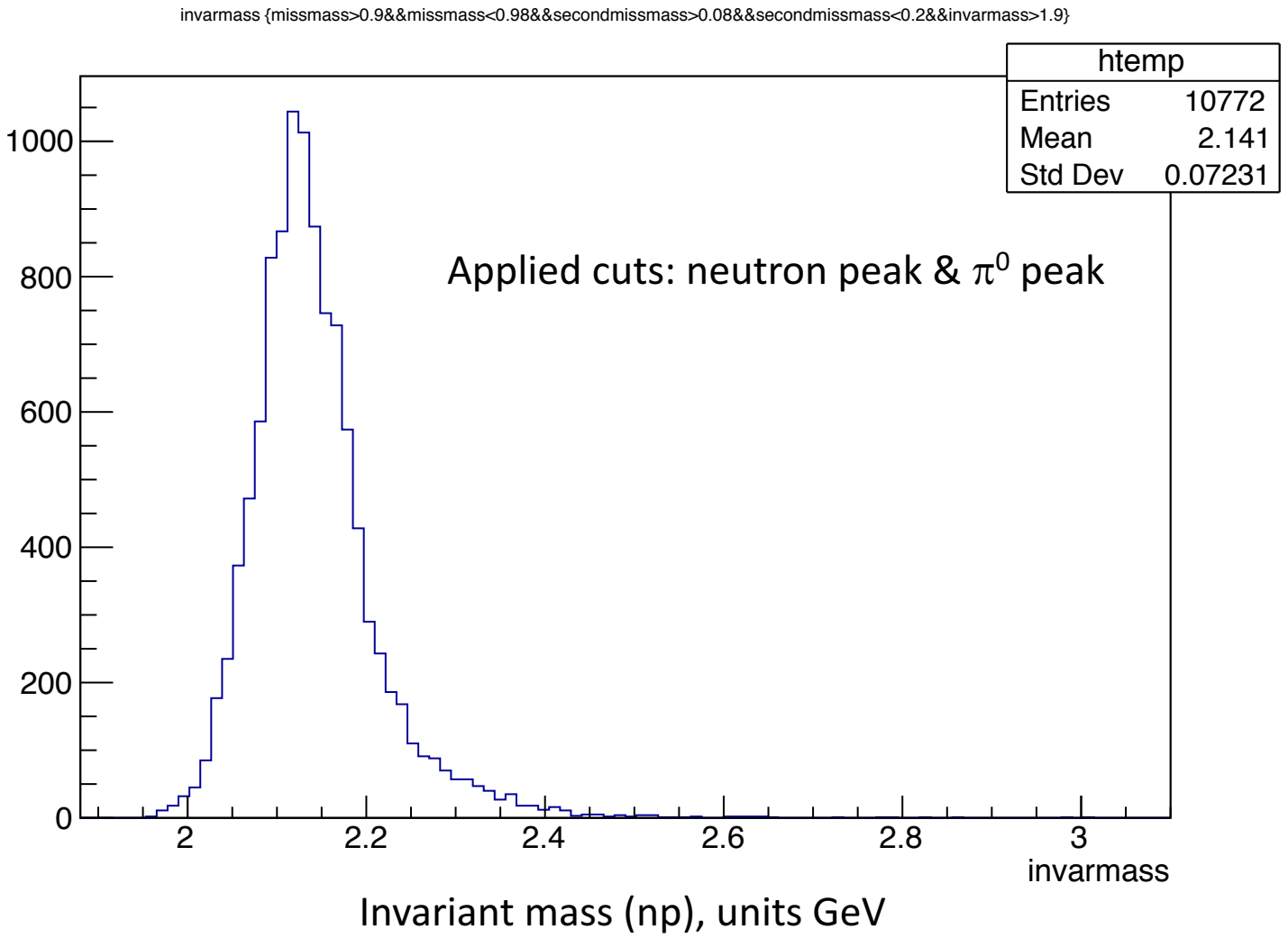

Missing Mass ($\gamma p \rightarrow \pi^+ X$), units GeV

# Step 2:



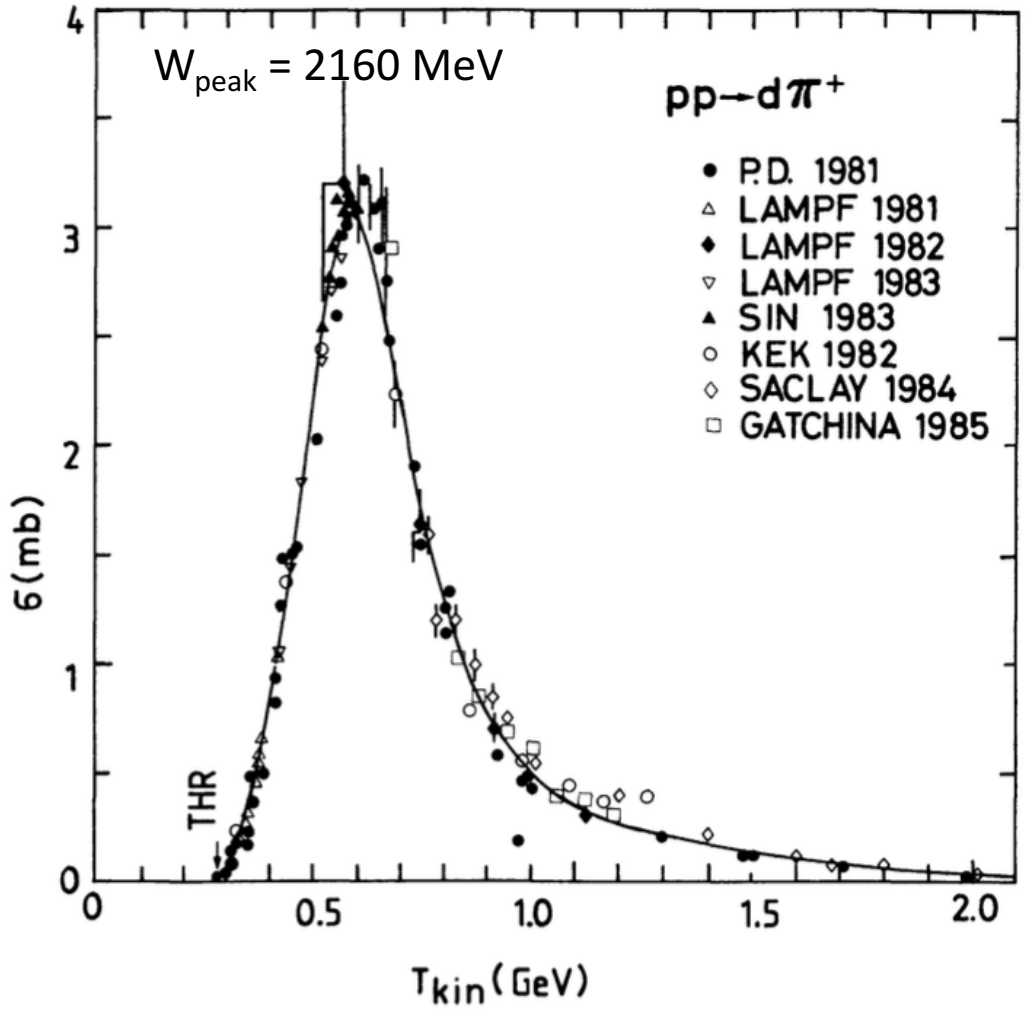

Missing Mass (np -> d X), units of GeV

# $E_{CM}$ dependence




Invariant mass (np), units GeV

# Comparison with previous data: pp → dπ⁺

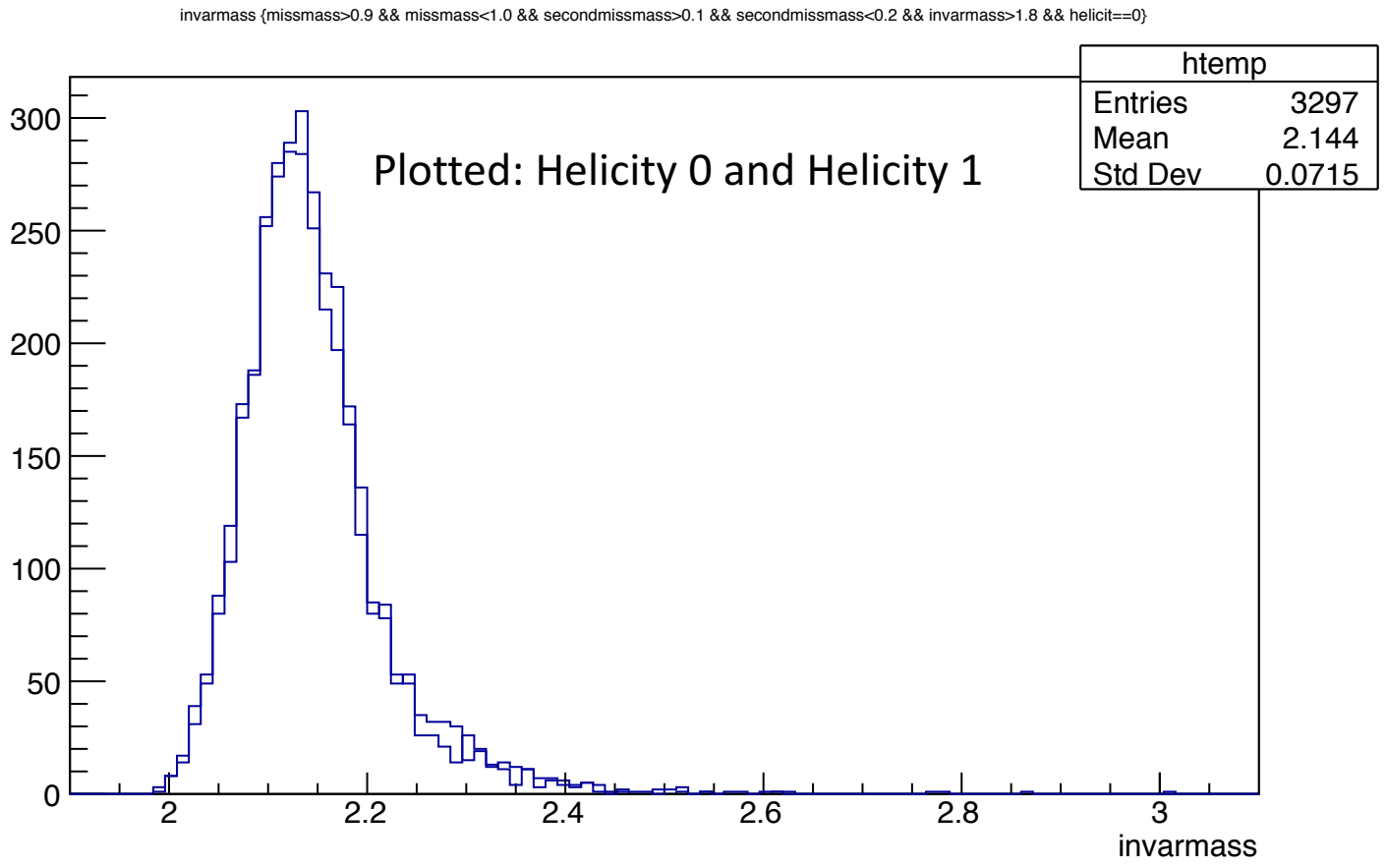



**Ref:** J. Bystricky et al.,
J. Physique 48 (1987) 1901-24.

# $d\pi^0$ production: Assume d*(2150) dominance

- PWA of pp → $d\pi^+$ data shows $^1D_2$ resonance pole
  - Details in: Arndt et al., PRC 48, 1926 (1993). Pole position 2148 MeV.
  - Another resonance at higher mass (seen by WASA @ COSY): $^3D_1$ wave.
  - This is also seen in CLAS data: $\gamma d \rightarrow \pi^+\pi^- d$ (R. Schumacher; T. Chetry)
- Isospin of $^1D_2$ is I=1. For np scattering, I=1 → S = 0.
  - For np to form this resonance, need L=2 in initial state.
  - No sensitivity to neutron polarization in the final state?

# Helicity dependence




Invariant Mass (np), units GeV

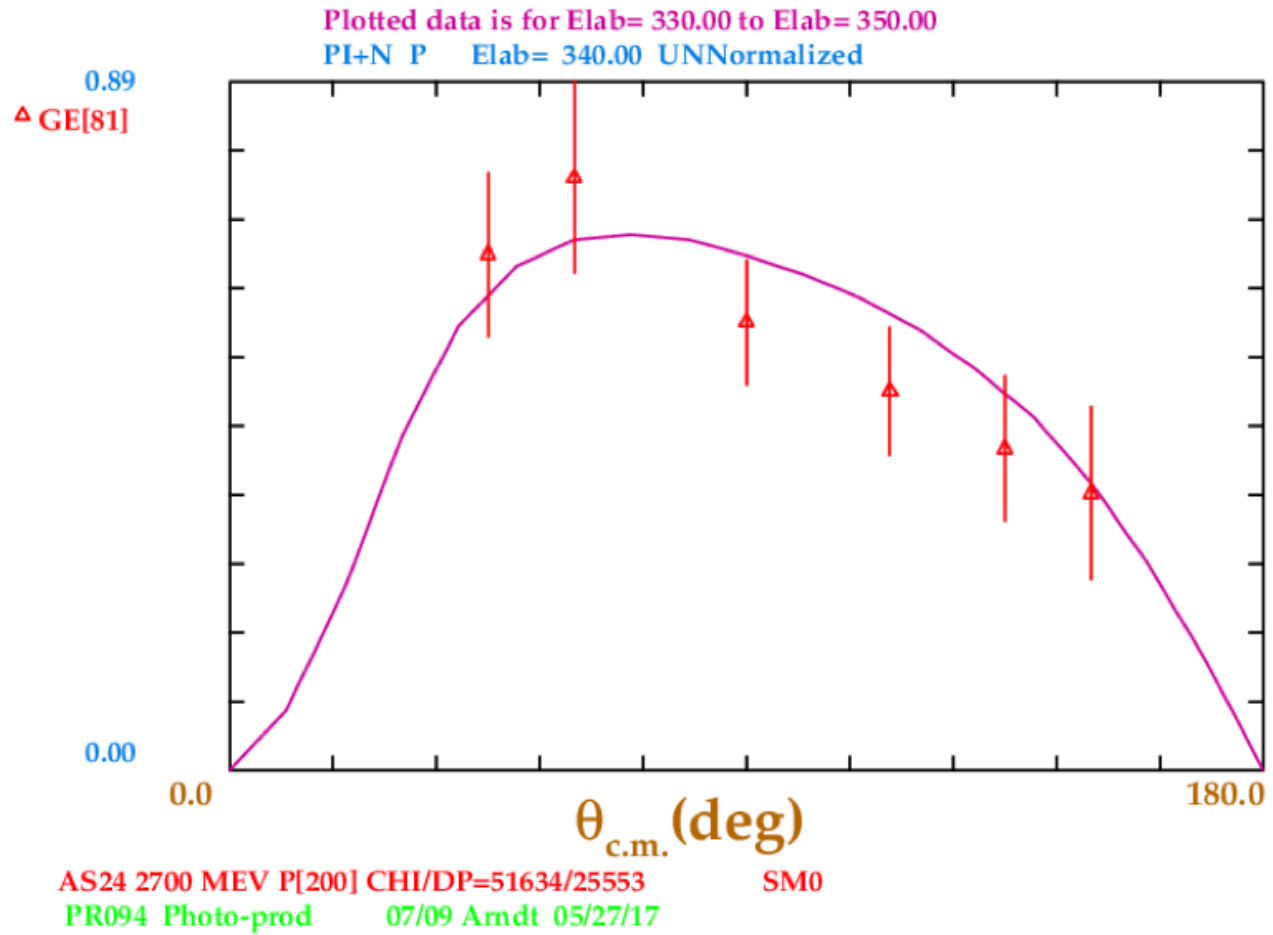
# Assume d*(2150) dominance

- Decay of $^1D_2$ resonance: J = L = 2, S=0. Also parity = +.
  - For the $d\pi^0$ final state: $S_d = 1$, and $J_f = 2 = L_\pi + 1$. So $L_\pi = 1$ (most likely).
  - Note that parity restricts $L_\pi$ = odd. So $L_\pi = 3$ also possible, but unlikely.
  - By measuring the deuteron angle, this gives info on $L_\pi$.
  - This provides new information on the d*(2150).

# Initial n-production: assume $\Delta$ dominance

- For $\Delta$: $J^{\pi} = (3/2)^{+}$.
  - Both $A_{1/2}$ and $A_{3/2}$ amplitudes: two proton spin alignments with $\gamma$ polarization.
  - P-wave decay: $\Delta^{+} \rightarrow n\pi^{+}$ requires J = L + S with L=1. n-spin (S) aligned with L.
  - By measuring the $\pi^{+}$, we get the decay plane. Should see P-wave ang. distr.
  - Can we use PWA to predict the n-polarization?

# SAID prediction of n-polarization at Δ peak




Plot provided by A. Sandofri

# Initial n-production: other N*’s

- For non-$\Delta$ production:
  - Can we use polarized np → np (elastic) to get n-polarization?
  - Measure deuteron in final state: get the reaction plane & ang. distr.
  - Possible to measure polarization transfer for higher-mass N* states??

# Summary

- G11 data has thousands of np -> $d\pi^0$ events.
  - Demonstration of hadronic scattering possibilities at CLAS
  - This is just the very beginning of the analysis—just a hint of what's to come.
  - Just one final state was looked at. Others, such as np -> np, are possible.
- G12 data has a similar number of events.
  - This could double the data set.
- Although no acceptance correction has been applied, the np data appear to show a clear peak at $E_{CM}$ = 2130 MeV.
  - This matches well with previously published data from pp->$d\pi^+$.
  - No measureable polarization dependence so far.