# Justification for beam time extension of G9 to run with polarized deuterons (FROST-D)

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A spectacular feature of the $N^*$ family of nucleon resonances is the existence of eight states that have overlapping pole positions with similar masses and widths [?], but different spin-parity values, $J^P$. These states include $N(1520)3/2^-$, $N(1535)1/2^-$, $N(1650)1/2^-$, $N(1675)5/2^-$, $N(1680)5/2^+$, $N(1700)3/2^-$, $N(1710)1/2^+$, and $N(1720)3/2^+$. The energy range around W = 1680 MeV (E = 1030 MeV) is especially important for untangling these eight overlapping $N^*$ states and investigating the possible existence of a narrow $N^*$ state in the mass range of ∼1680 MeV. It was extracted in Ref. [?] from the $\pi N$ PWA and suggested to be a member of the exotic anti-decuplet. Indeed, a resonant-like bump at ∼1680 MeV is observed in quasi-free $\gamma n \to \eta n$ [?, ?, ?, ?] by four independent groups at GRAAL, CB-ELSA, LNS, and MAMI. However, for this reaction, the measured width of the bump was dominated by the experimental energy resolution. Interpretation of the signals remains an open question. Also, there exist several alternatives acting as an interference effect in the $S_{11}$ sector [?] or interference between $N(1650)1/2^-$ and $N(1710)1/2^+$ [?], $K\Lambda - K\Sigma$ threshold effects [?], or essential contribution of $N(1675)5/2^-$ [?]. The critical fact is that the width of the structure around W = 1680 MeV is much less than any non-strange known $N^*$. Polarized measurements are more sensitive to small resonance contributions than cross-sections. There are several recent events (CLAS, MAMI, CB-ELSA, and GRAAL) where polarazed observables change sign around 1680 MeV. Sharp sign changes may indicate that something is going on here.

We believe that the data which we can collect using FROST-D will be invaluable for future partial-wave and coupled-channel analyses and that they can provide much stronger constraints on the properties of the nucleon resonances from our energy region.

## Experimental configuration

In the proposed experiment, it is feasible to measure asymmetries for several reactions simultaneously. These reactions include:

- $\gamma n \to \pi^- p$
- $\gamma n \to K\Lambda$
- $\gamma n \to K\Sigma$
- $\gamma n \to \pi^+(\pi^- n)$

The proposed experiment configuration is similar to g9b-FROST:

- Target polarization - transversed. Flip target polarization in the middle of the run.
- Target material will be propanediole-d doped with trityl. Polarization can be as high as 80%.
- Electron beam energy 3.36 GeV (3 pass). Linearly polarized photon beam. Coherent edge at 1200 MeV.
- Main torus current 1500A. Normal or reversed polarity is to be determined.
- Trigger: at least 2 charged particles in CLAS.

## Expected uncertainties

For the $\gamma n(p) \to K^0 \Lambda(p)$ channel a detailed analysis of projected uncertainties is documented in the HD proposal (E06-101) based on Monte Carlo simulations for HD and deuterized butanol. The expected running times on butanol-d were about 15 times longer than for HD (in the considered energy range). However, with higher target polarization for propanediol-d and the background subtraction method applied to g9a data (based on production data on an additional carbon foil) reduces the factor to about 4–6.

Reducing the number of bins in $\cos\theta_{cm}$ and the statistical accuracy will allow for measuring *a unique set of polarization observables* during the extension of g9b: target asymmetry $T$, beam–target asymmetry $H$, and the target–recoil asymmetries $T_{x'}, T_{z'}$. We note that $T$ could be measured as double polarization observable using the the longitudinally polarized HD target, and $T_{x'}, T_{z'}$ will be measured as triple polarization observables in E06-101; however, the additional polarization requirements in E06-101 will result in *similar uncertainties* than the direct measurement using a transversely polarized propanediol-d target. Asymmetry $H$ *cannot be measured* with the setup of E06-101.

During a 2 week run with a photon flux of 12 MHz in the coherent peak the projected uncertainties for $P, \Sigma, T$ are $< 0.12$ (for 6 $\cos\theta_{cm}$ bins), for $H$ less than 0.16 (6 bins), and for $T_{x'}, T_{z'}$ about 0.2 (4bins).

The cross sections for $\gamma n \to \pi^- p$ and $\gamma n \to \pi^+(\pi^- n)$ are significantly larger. Therefore expected statistical uncertainties for asymmetries $T$, $H$ and $P$ of these reactions will be smaller than for Kaon production and one can use a finer binning. These observables for pion production *cannot be measured* with the setup of E06-101.

## Data analysis

Several institutions expressed interest (and can provide manpower) to analyze the data that will be collected in this experiment. Among them are: ASU, CUA, FSU, GW, SC, University of Glasgow, University of Edinburgh, and JLab.

## References


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