A Measurement of Neutron Recoil Polarization in Deuteron Photodisintegration

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Outline

I. Background and Motivation
II. Experimental Setup
III. Analysis Methods
IV. Preliminary Results

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I. **Background and Motivation**
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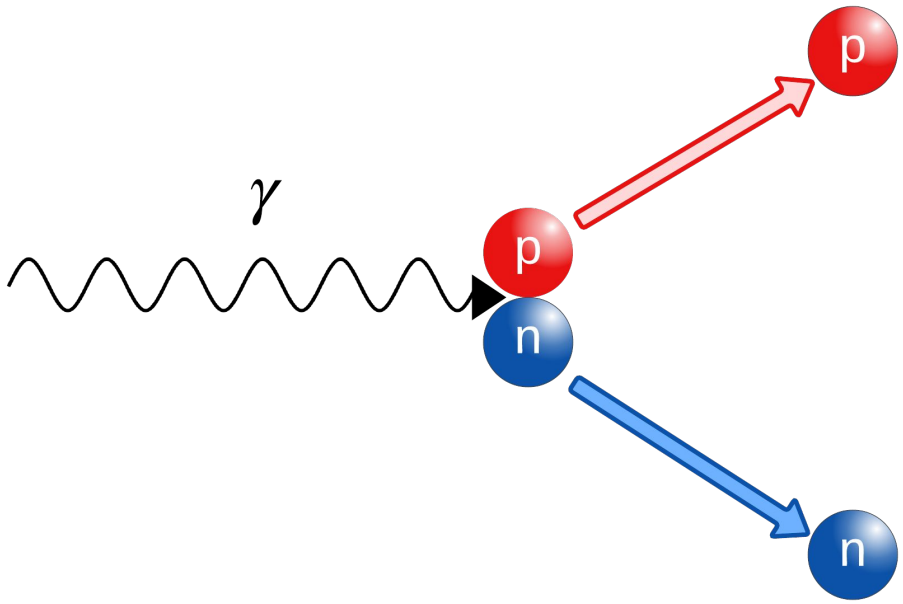
$d(\gamma,n)p$ Reaction



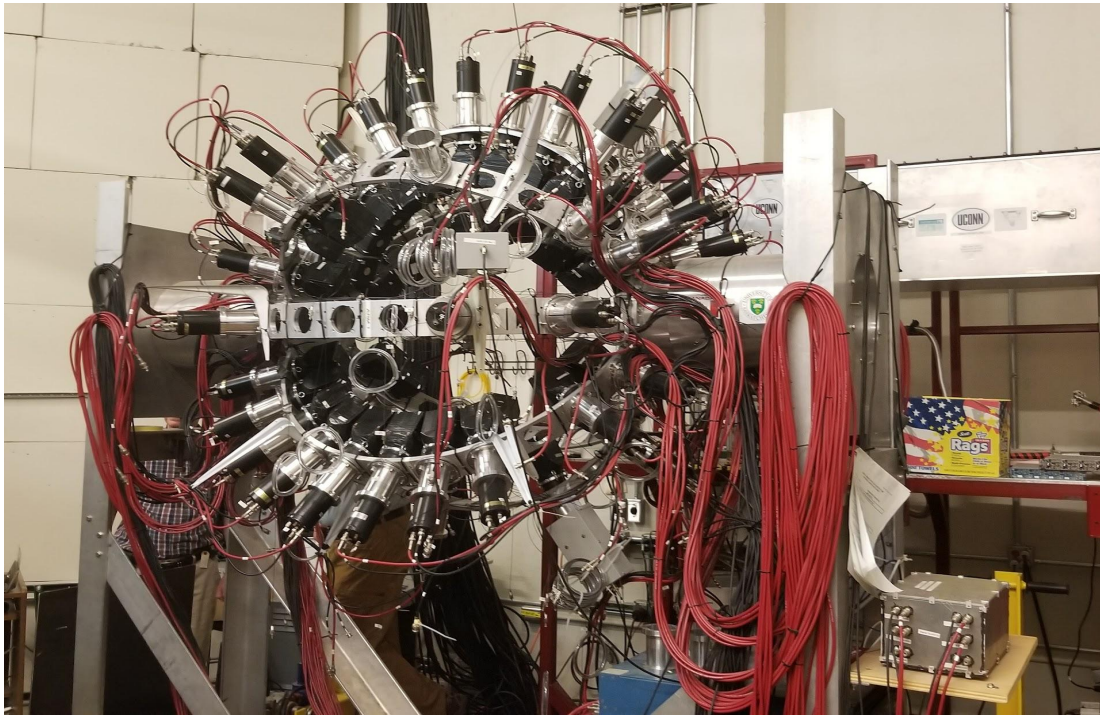
Deuteron

- Smallest multibody nucleus
- Mass = 1875.6 MeV
- Binding Energy = 2.2 MeV
- Spin = 1 : Spin Triplet

$d(\gamma,n)p$ offers insight into:

- Nucleon-Nucleon Interactions
- Big Bang Nucleosynthesis
- Astrophysical Bodies such as Neutron Stars

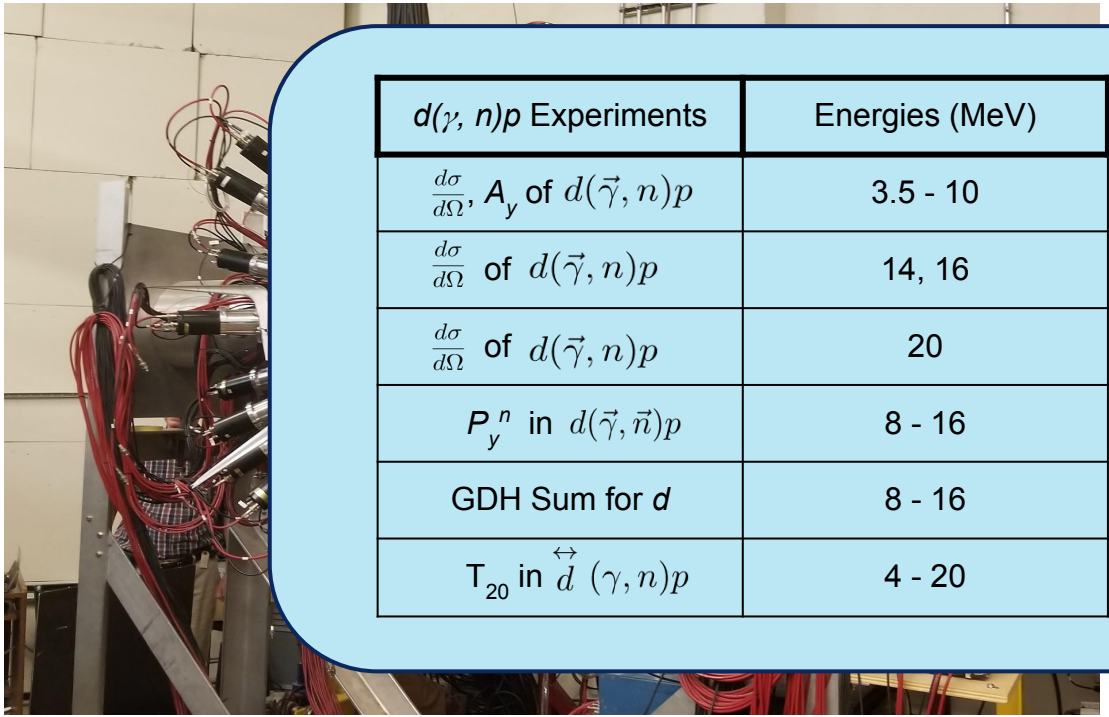
Background: d(γ,n)p Studies

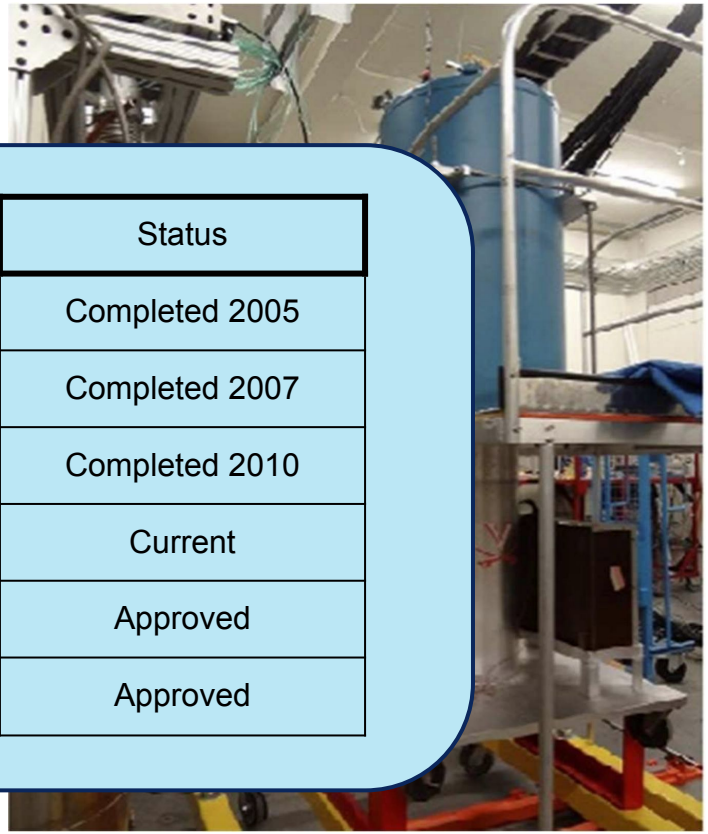


Blowfish Detector

HIγS Frozen Spin Target System

Background: d(γ,n)p Studies





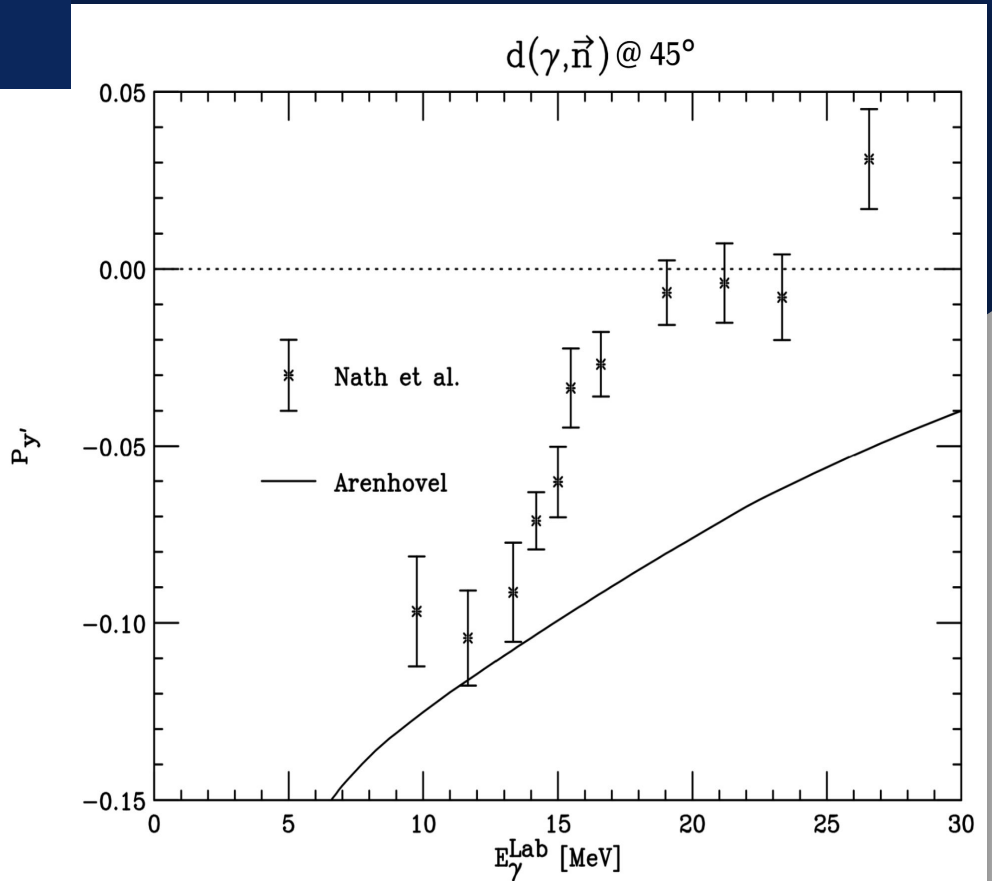
d(γ, *n*)*p* Experiments	Energies (MeV)	Status
$\frac{d\sigma}{d\Omega}$, A_y of $d(\vec{\gamma},n)p$	3.5 - 10	Completed 2005
$\frac{d\sigma}{d\Omega}$ of $d(\vec{\gamma},n)p$	14, 16	Completed 2007
$\frac{d\sigma}{d\Omega}$ of $d(\vec{\gamma},n)p$	20	Completed 2010
P_y^n in $d(\vec{\gamma},\vec{n})p$	8 - 16	Current
GDH Sum for *d*	8 - 16	Approved
T_{20} in $\overleftrightarrow{d}$ $(\gamma,n)p$	4 - 20	Approved

Blowfish Detector

HIγS Frozen Spin Target System

Motivation

- Spin observables of deuteron reveal information about nucleon interactions
- Discrepancies between theory and data of d(γ, n)p reaction
- Map polarization transfer to neutron over range of angles and energies



H. Arenhövel Few Body Sys. 4 (1988)

R. Nath et al Nucl. Phys. A 194 (1972)

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Measurement

- Measuring left-right asymmetry of neutron scattering from He analyzers:

$$\frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} = A(\theta) = P_y^m A_y(\theta)$$

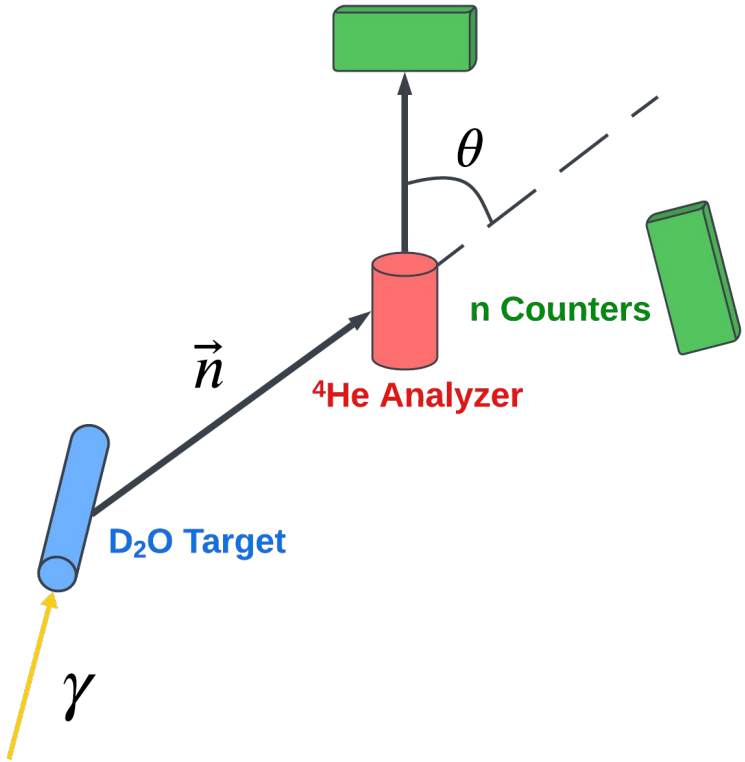
- Modifying beam polarization enables extraction of multiple polarization observables:

$$P_y^m \frac{d\sigma(P_y^\gamma, \theta, \phi)}{d\Omega} = \frac{d\sigma(\theta)}{d\Omega}\Big|_{P_y^\gamma = 0} \left[P_y^u(\theta) + P_y^\gamma P_y^l(\theta) cos(2\phi) \right]$$

Circular: $P_y^\gamma = 0$

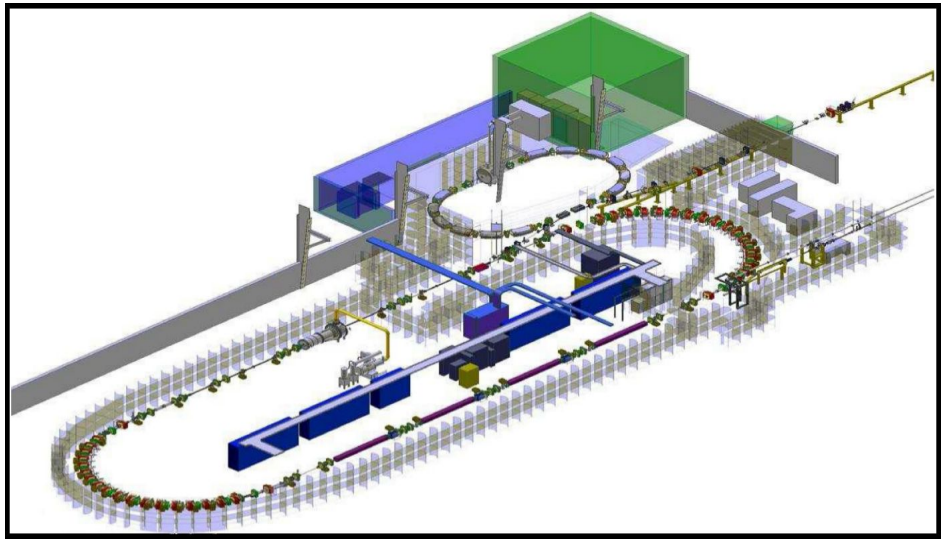
Linear: $P_y^\gamma = 1$

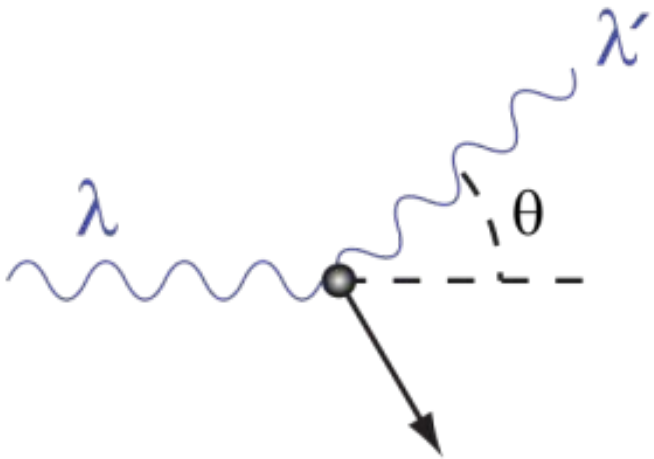
$\Big\}$ P_y^u, P_y^l



HIγS at TUNL

HIγS = High Intensity Gamma Source





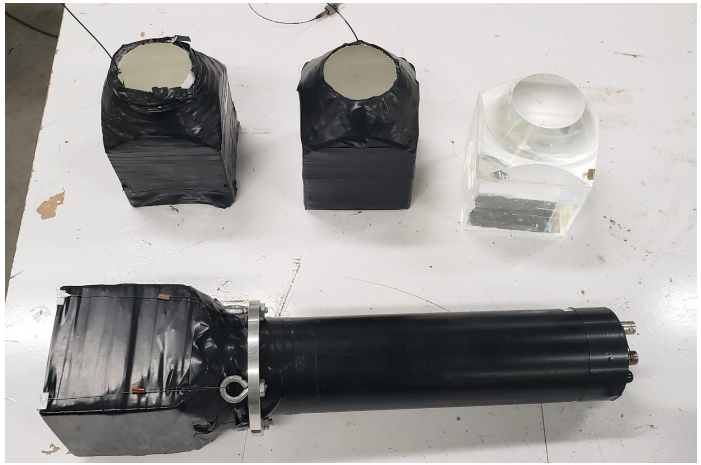
- Free electron laser producing high intensity gamma beams up to 100 MeV
- Gamma rays produced through Compton backscattering (θ = *180°)*
- Intensity of beam ranges 6×10^7 - 2.4×10^8 gammas per second
- Close to 100% polarization - Valuable for measuring polarization observables

Detectors: Analyzers

- ^{4}He Polarization Analyzers
- He-Xe gas mixture at 2500 PSI
- PMTs measure light output from Xe scintillation

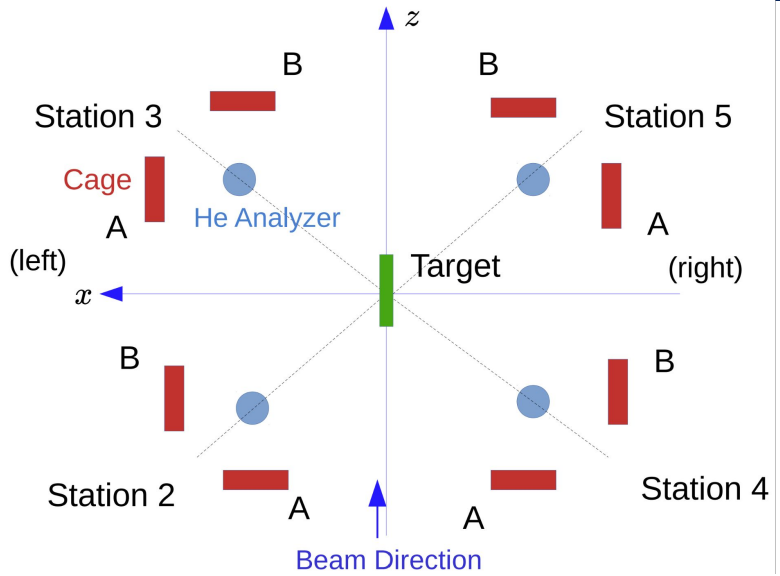
Detectors: n Counters

Neutron counters assembled in sets of 6 for each side of an analyzer



- Detectors borrowed from Blowfish setup at HIγS
- BC-505 Organic Scintillators for neutron detection
- Photomultiplier Tubes to measure scintillation light output

Experimental Setup



- Heavy water target (D_2O)
- 6 “Stations” of 1 Analyzer + 12 Neutron Counters
- In Plane (ϕ = 0) Analyzers: 2 at 45°, 2 at 135°
- Out of Plane (ϕ = 90°) Analyzers: 2 at 90°

Diagram: T. Polischuk

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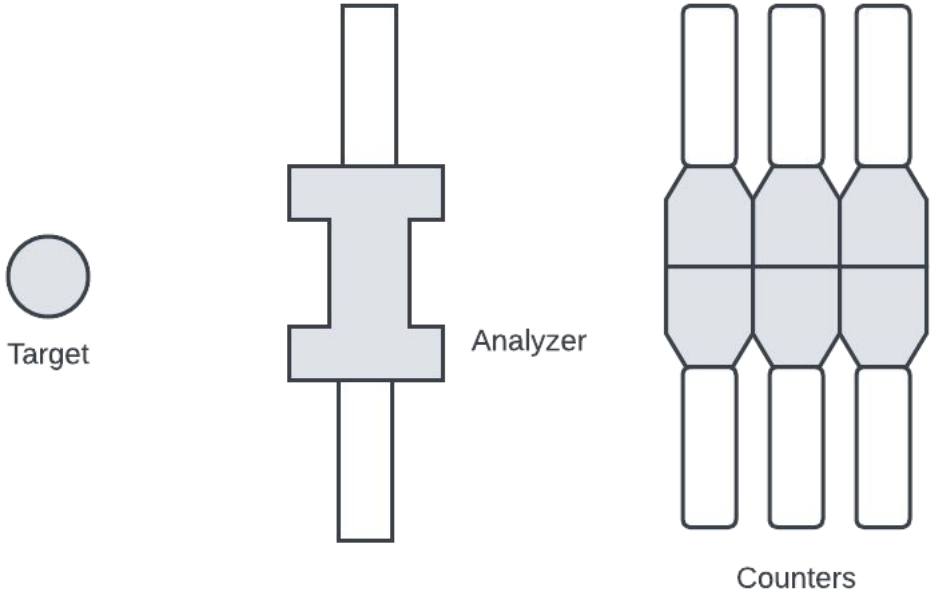
Analysis: Coincidences



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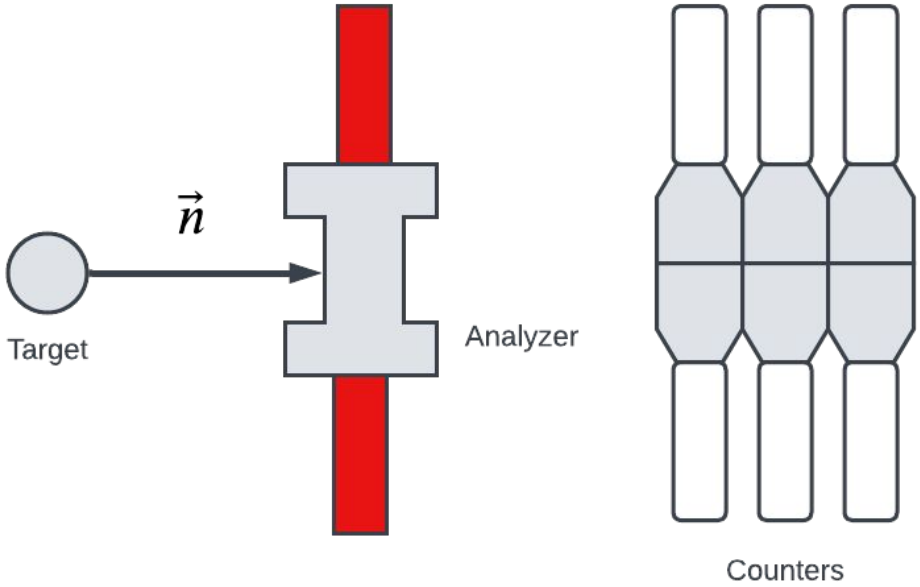

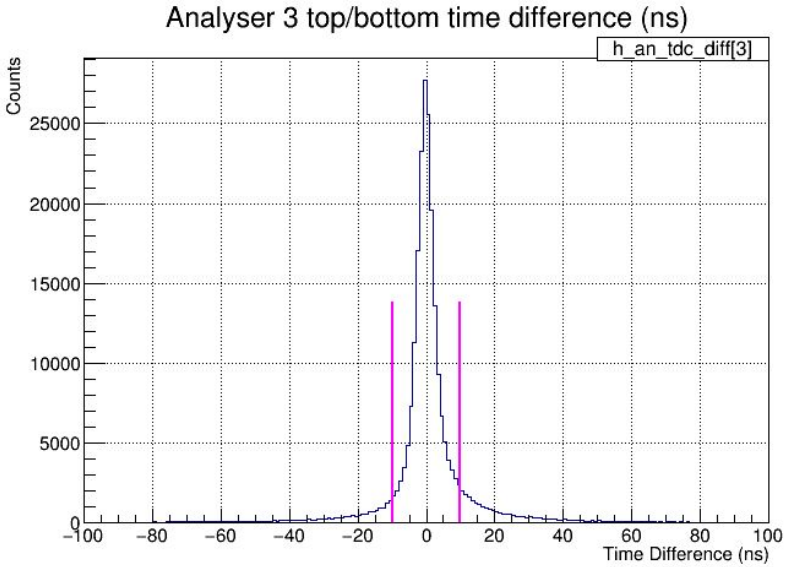

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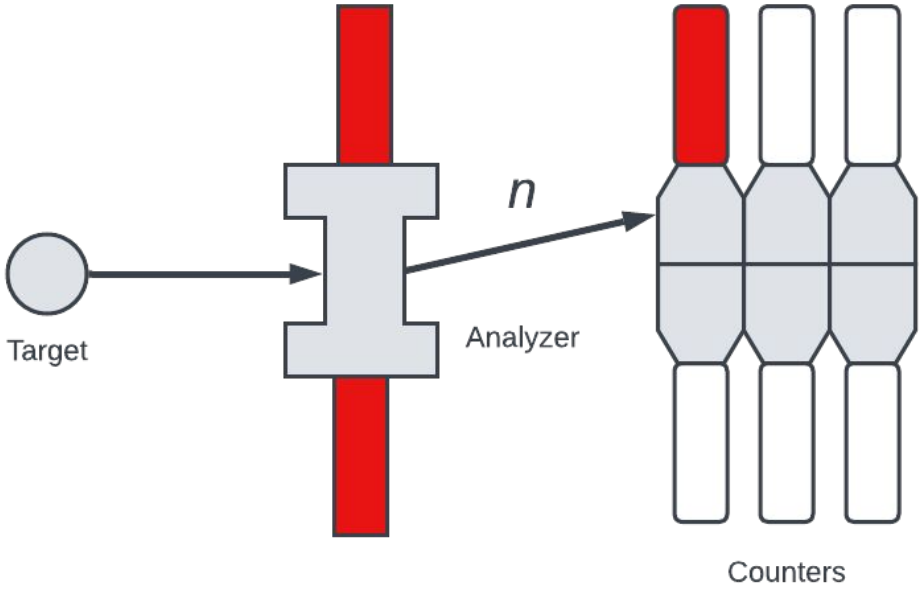
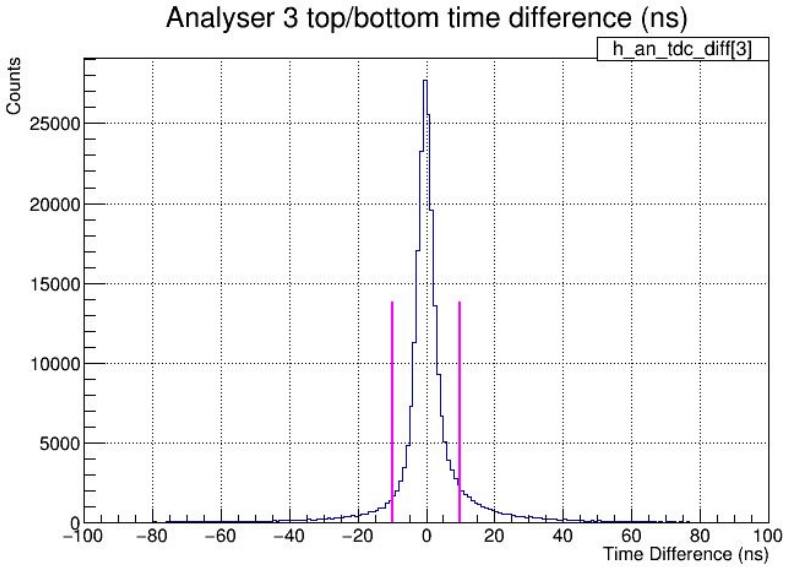
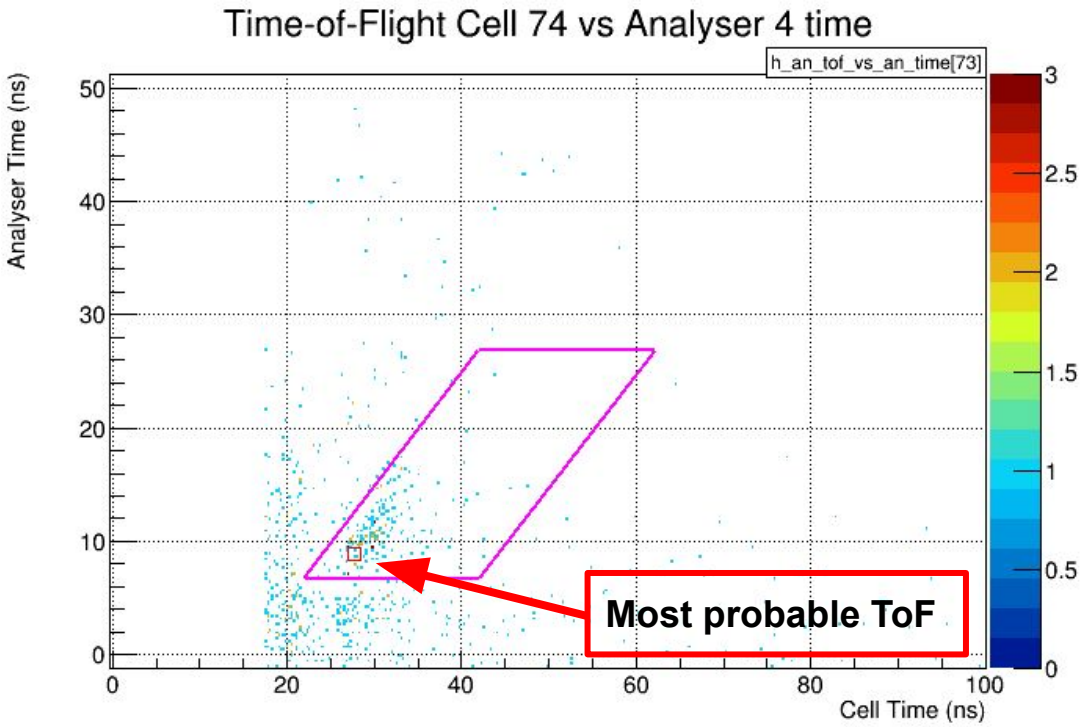


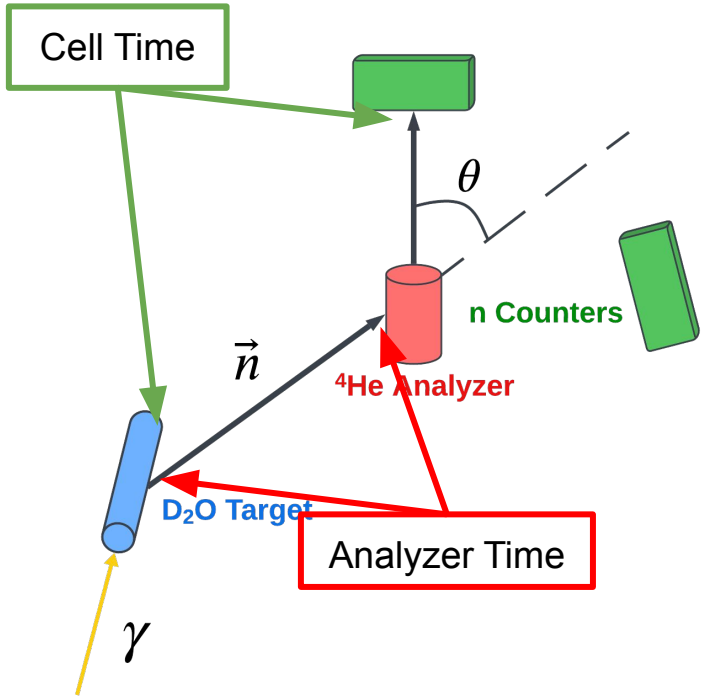


Only accept signals indicating particles that hit an analyzer and a counter…

Some accidentals get through.

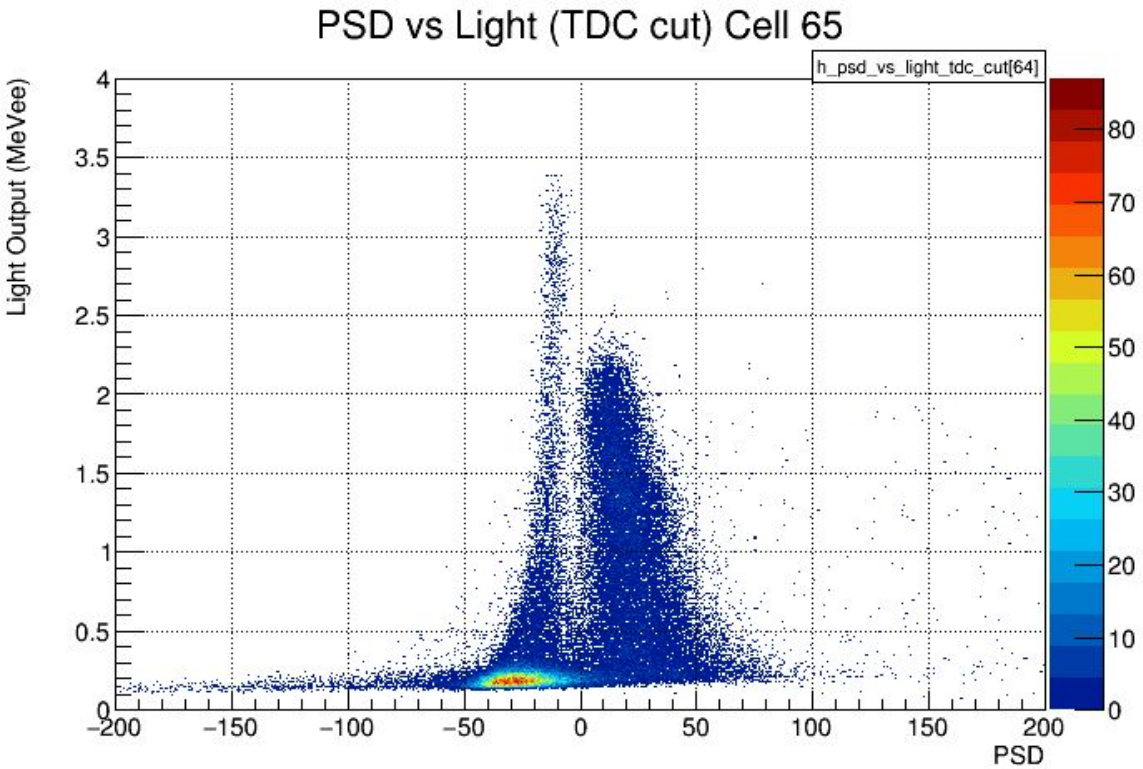
Analysis: Timing Cuts





Analysis: PSD

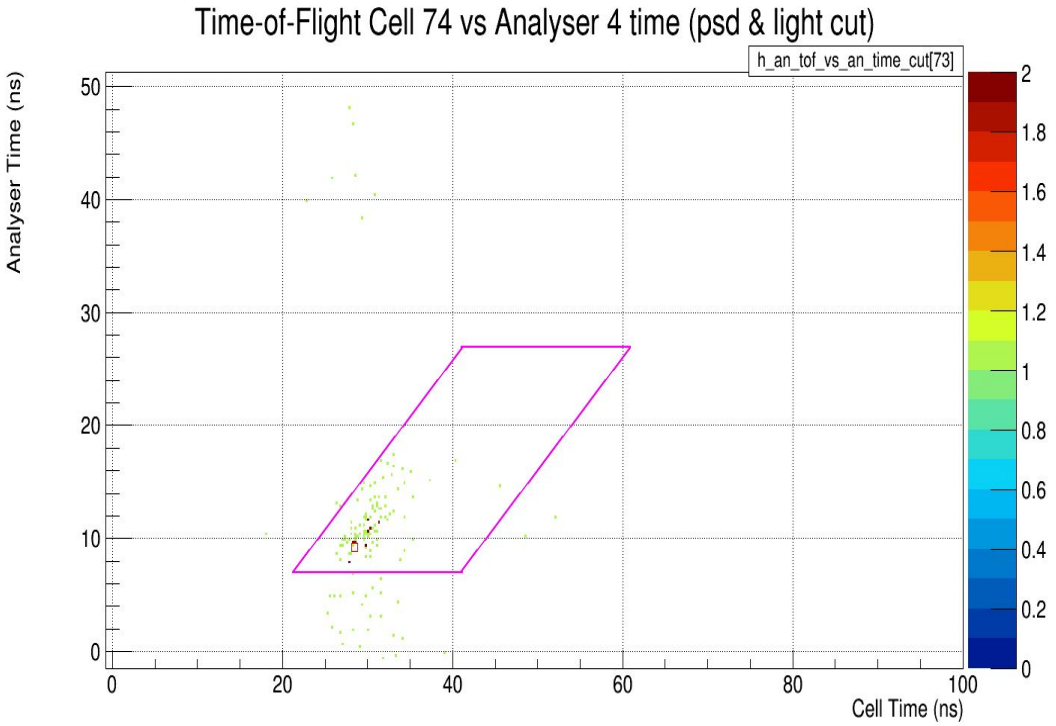
PSD = Pulse Shape Discrimination

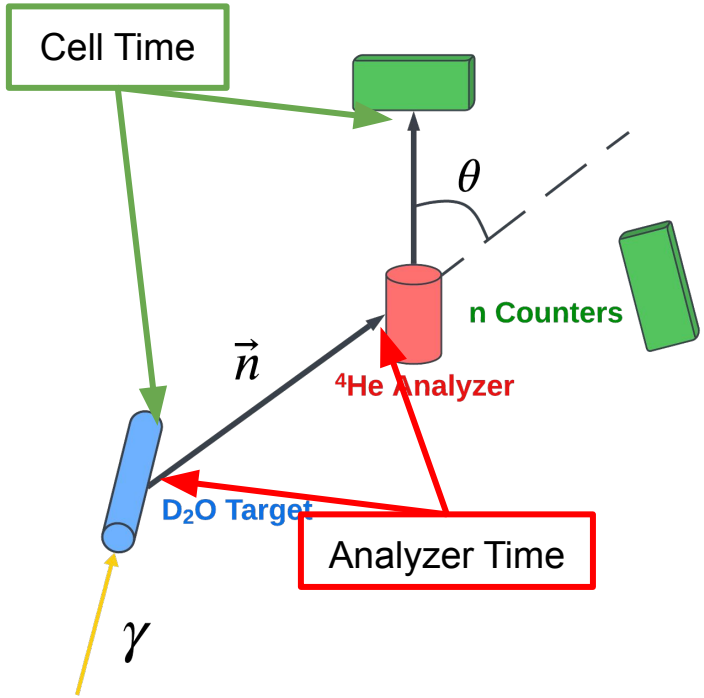


- Comparison of pulse shape of signals to differentiate between photons and neutrons
- Neutrons have delayed light emission vs photons
- Charge integration of signals using long and short gate integration

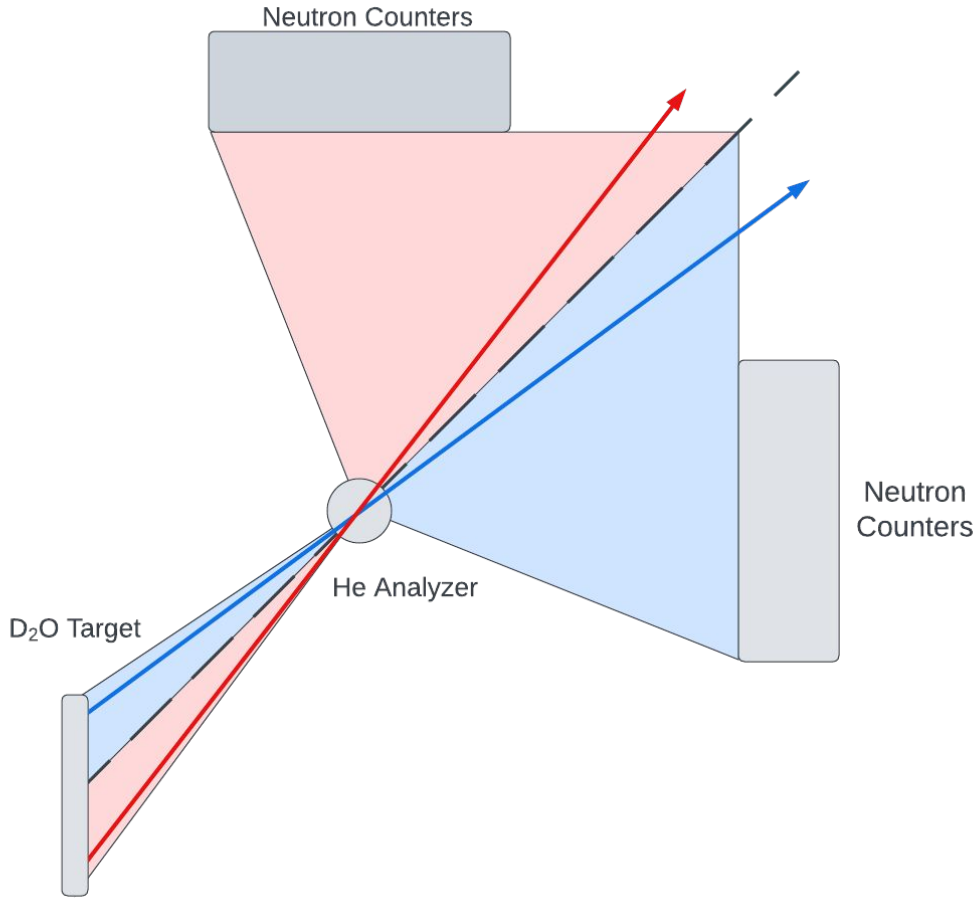
$$PSD = \frac{\text{Long Gate} - \text{Short Gate}}{\text{Long Gate}}$$

Analysis: Timing Cuts





Analysis: Geometric Asymmetry



- Beam attenuation in target causes geometric asymmetry
- Finite target length means spread in trajectories of neutrons
- Within each station, detectors downstream of the beam will measure higher count rates of neutrons scattering from the analyzer

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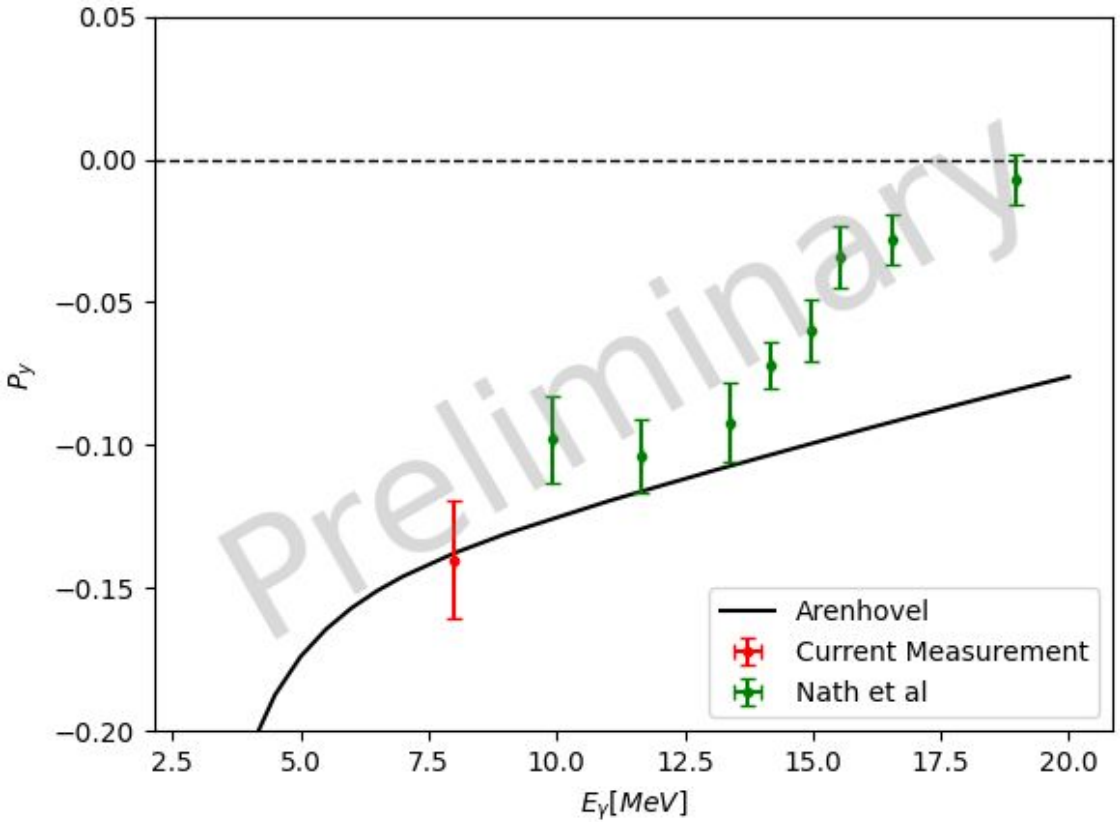
$P_y^m\ (= P_y^u)$ at $\theta_{Lab} = 45°$



- Circular Polarization
- Early stages of analysis of 8 MeV

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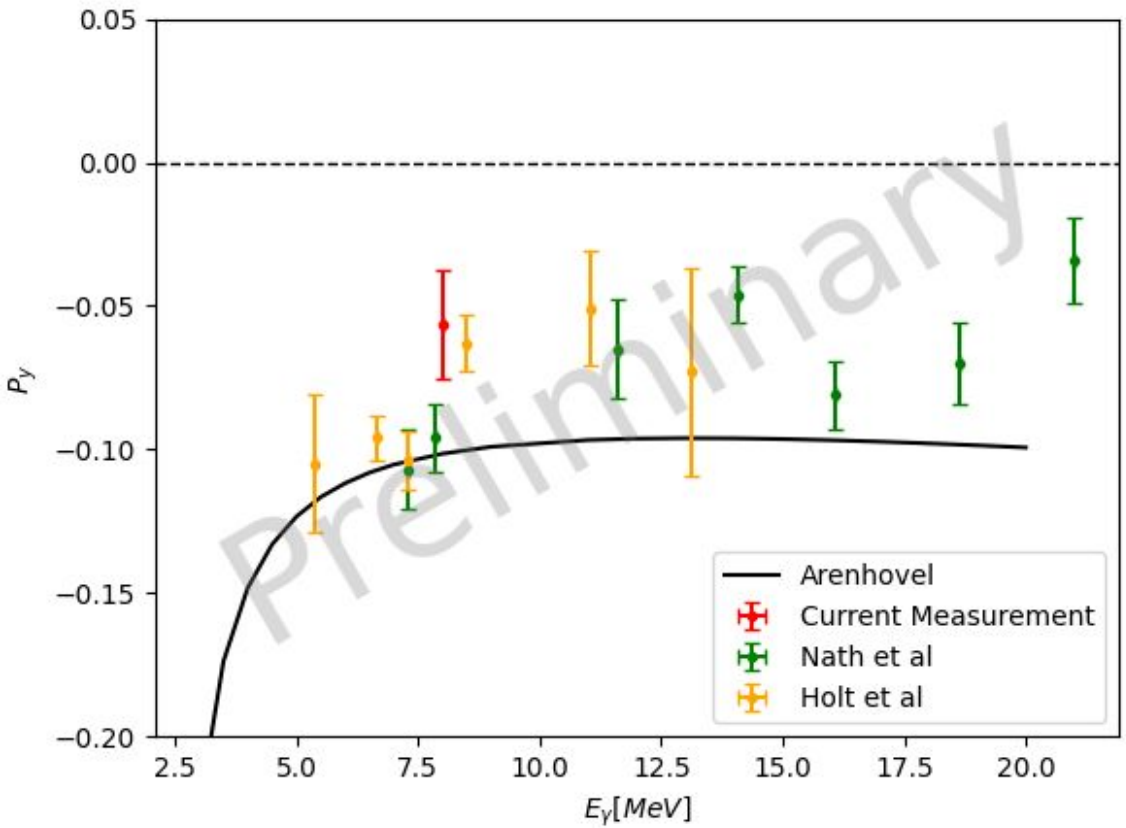
R. Nath et al Nucl. Phys. A 194 (1972)

$P_y^m\ (= P_y^u)$ at $\theta_{Lab} = 90°$



- Circular Polarization
- Early Stages of analysis of 8 MeV
- Needs fix of geometric asymmetries

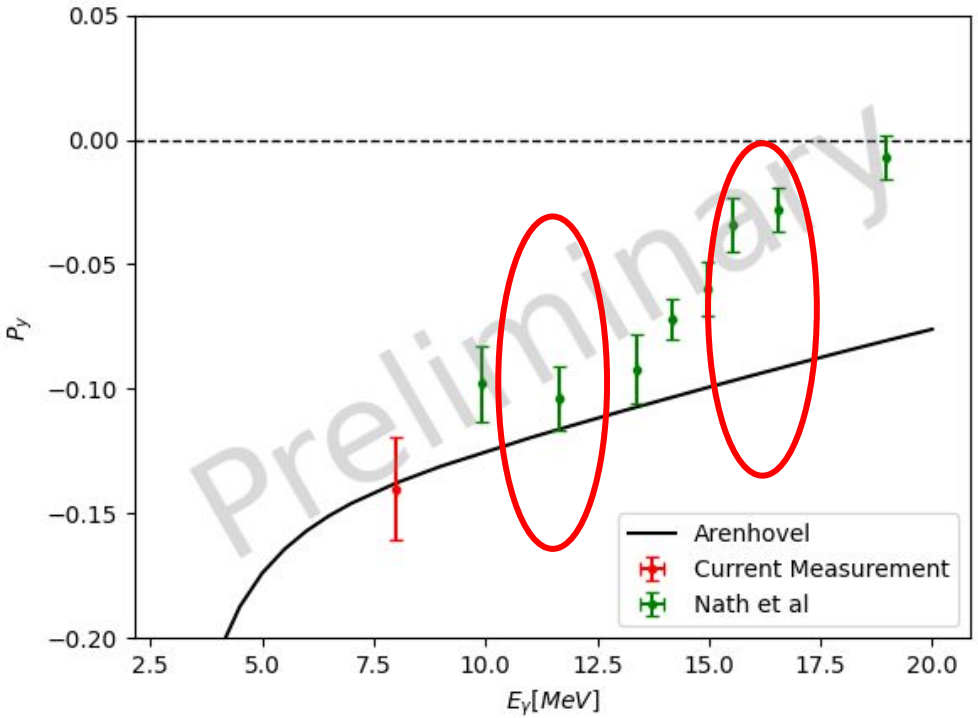
H. Arenhövel Few Body Sys. 4 (1988)

R. Nath et al Nucl. Phys. A 194 (1972)

R. J. Holt et al Phys. Rev. Lett. 50, 577 (1983)

Future Work

- More Energies: 12 & 16 MeV



- Finalize analysis cuts and geometric asymmetries
- Analyze more runs for more statistics
- Analyze data from linear beam polarization for polarized beam contribution

Circular: $P_y^{\gamma} = 0$

Linear: $P_y^{\gamma} = 1$

$\Big\} \; P_y^{u}, P_y^{l}$

Acknowledgements

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- Tanner Polischuk - University of Saskatchewan
- Haoyu Chen - University of Virginia
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- Werner Tornow - Duke University
- Calvin Howell - Duke University
- with much support from the DFELL Staff!

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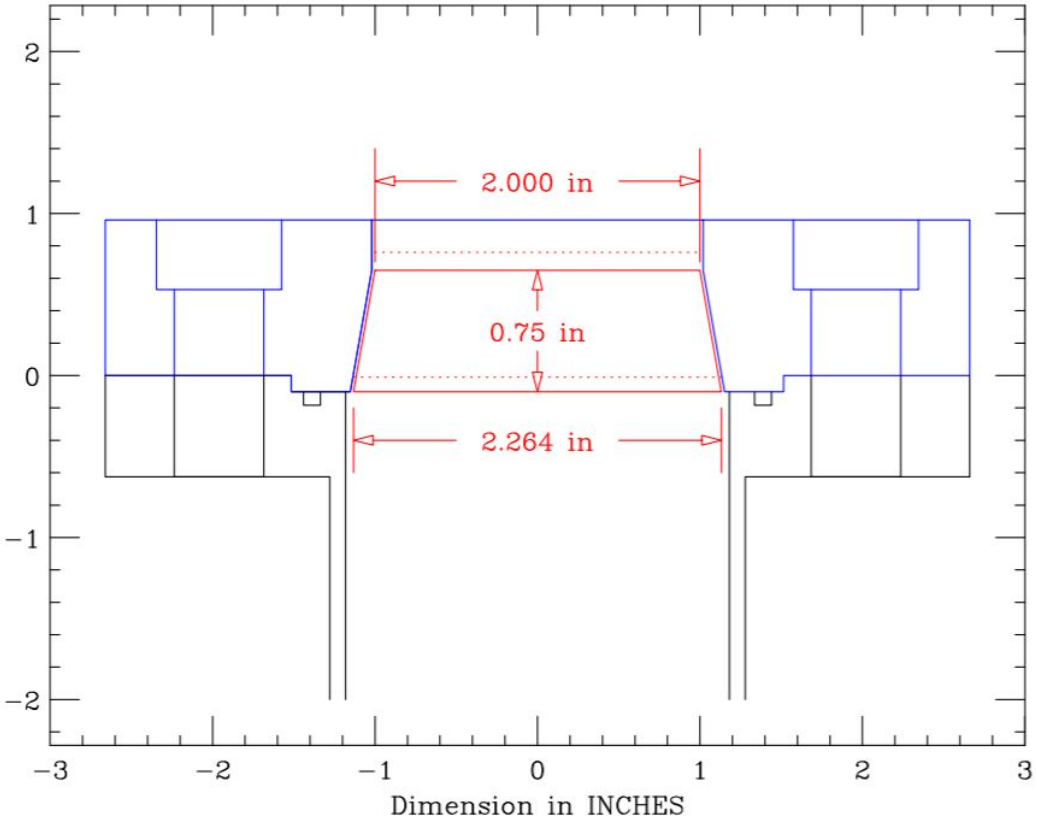
Thank You!

Questions?

Backup Slides

Analyzer Design



- Beveled flange and window: Forces on glass are compressive, much better than shear forces
- Epoxy holding glass in steel flange - no glass-steel contact, protects against irregularities in either material
- Pressure tests performed to 4000 PSI for 2 to 3 weeks on each analyzer assembled and used

Analyzer Preparation

- Wavelength shifter for converting photons from Xe scintillation to visible light (Diphenylstilbene)
- MgO reflector deposited on inner walls of analyzer to optimize light output