DEUTERON PHOTODISINTEGRATION

$d(\vec{\gamma},n)p$ at $HI\vec{\gamma}S$

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HIGH INTENSITY GAMMA SOURCE COLLABORATION

- University of Virginia
- University of Saskatchewan
- Duke University

RESEARCH OUTLINE

- Outline of the Experiment
- Duke Free Electron Laser Laboratory- HIGS -
- Experimental Setup
- Data Analyzing

Outline of the Experiment

- A measurement of the neutron asymmetries and angular distributions for the $d(\vec{\gamma},n)p$ reaction at 10 to 50 MeV.

- Deuteron - Simplest nuclear system –

Relevant Theories

- Effective Field Theories in which certain symmetries of QCD are used to simplify the fundamental quark-gluon interactions into something that can be computed.
- Potential Models (Arenhövel et al.1998) do not contain any reference to QCD but instead model the interactions as exchanges of composite particles like pions and other heavier mesons.
- BBN – deuterium production lies at the foundation of the BBN reaction chain.

DFELL - High Intensity Gamma Source (HIGS)

Research at HIGS is concentrated on:

- The Gerasimov-Drell-Hearn (GDH) Sum Rule measurements on the Deuteron
- Parity assignments to states using Nuclear Resonance (NRF) with emphasis on studies of the scissors mode states.
- Few-body studies
- Compton Scattering

The Gerasimov-Drell-Hern (GDH) Sum Rule

- The GDH Sum Rule for a nucleon is;

$$\int_{\omega_\pi}^{\infty} \frac{\sigma_A^N - \sigma_P^N}{\omega} d\omega = -2\pi^2 \alpha \left(\frac{\kappa_N}{m_N} \right)^2$$

$\omega_\pi \rightarrow$ Threshold energy for pion production from the nucleon

$\sigma_P^N \left(\sigma_A^N \right) \rightarrow$ Total inelastic photon cross section when the nucleon and photon angular momenta are parallel (antiparallel)

$m_N \rightarrow$ The mass of the nucleon

$\kappa_N \rightarrow$ The anomalous magnetic moment of the nucleon

- Since the left hand side of the equation can not be measured to infinite photon energy, we can write it as,

$$\int_{\omega_\pi}^{\infty} \frac{\sigma_A^N - \sigma_P^N}{\omega} d\omega = \int_{\omega_\pi}^{\omega_{\max}} \frac{\sigma_A^N - \sigma_P^N}{\omega} d\omega + \int_{\omega_{\max}}^{\infty} \frac{\sigma_A^N - \sigma_P^N}{\omega} d\omega$$

- **The resultant "GDH" sum rule for deuteron is given by**

$$\int_{\omega_2}^{\infty} \frac{\sigma_A^d - \sigma_P^d}{\omega} d\omega = -2\pi^2 \alpha \left(\frac{\kappa_d}{m_d} \right)^2$$

$\omega_2 \rightarrow$ The threshold energy for photodisintegration

$m_d \left(\kappa_d \right) \rightarrow$ The mass (anomalous magnetic moment) of the deuteron

- The GDH integral for the deuteron can be separated into three pieces

$$-2\pi^2\alpha\left(\frac{\kappa_d}{m_d}\right)^2 = -0.6\mu b$$

$$\int_{\omega_2}^{\infty}\frac{\sigma_A^d-\sigma_P^d}{\omega}d\omega = \int_{\omega_2}^{\omega_\pi}\frac{\sigma_A^d-\sigma_P^d}{\omega}d\omega + \int_{\omega_\pi}^{\omega_{\max}}\frac{\sigma_A^d-\sigma_P^d}{\omega}d\omega + \int_{\omega_{\max}}^{\infty}\frac{\sigma_A^d-\sigma_P^d}{\omega}d\omega = -0.6\mu b$$

- First term on the RHS will be measured at HIGS
- Second term was measured at LEGS
- The third term is taken from measurements on the neutron and proton plus trivial calculations.

- If the sum rule is valid then the difference between the sum rule value of the integral and the measured piece must equal the integral from $\omega_{\max}$ to ∞

For proton:

$$\int_{\omega_{\max}}^{\infty} \frac{\sigma_A^p - \sigma_p^p}{\omega} d\omega = -2\pi^2 \alpha \left(\frac{\kappa_p}{m_p} \right)^2 - \int_{\omega_\pi}^{\omega_{\max}} \frac{\sigma_A^p - \sigma_p^p}{\omega} d\omega$$

For neutron:

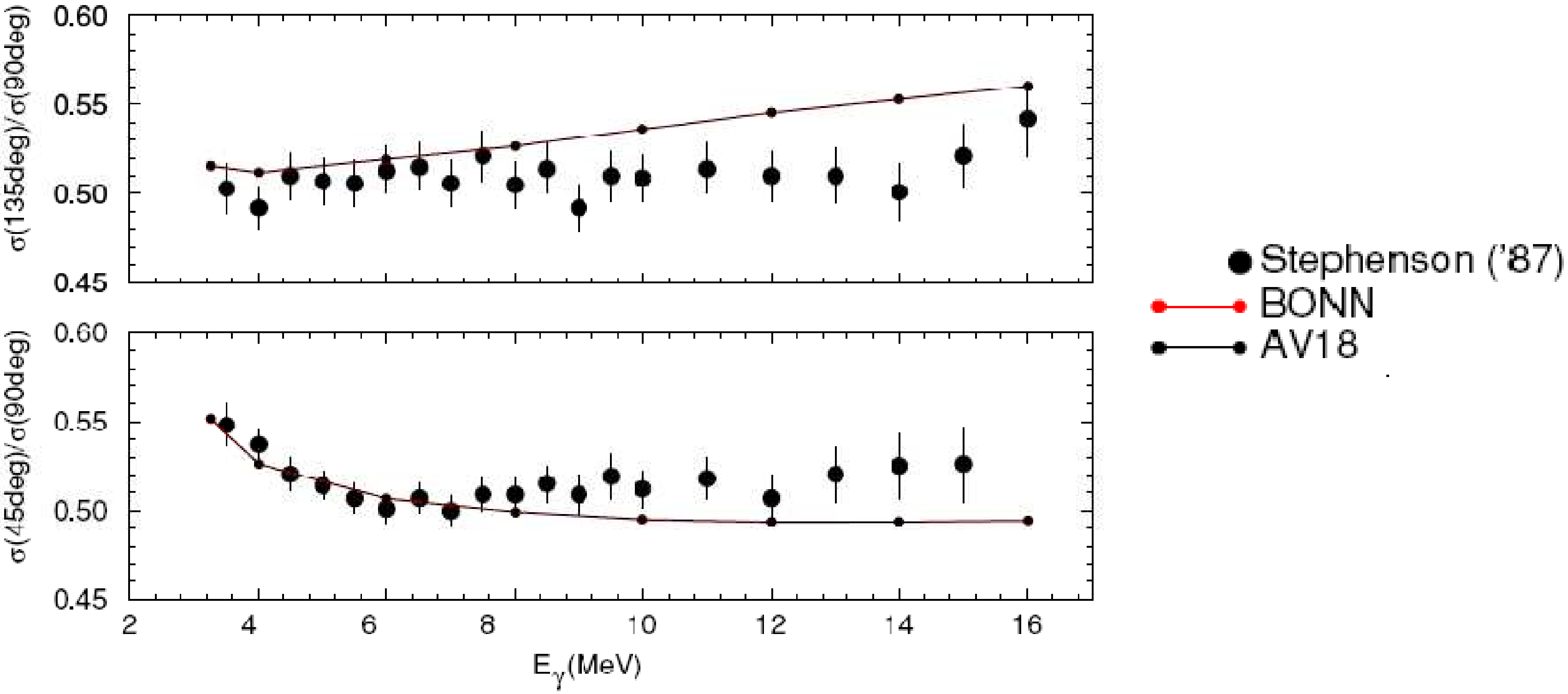
$$\int_{\omega_{\max}}^{\infty} \frac{\sigma_A^n - \sigma_p^n}{\omega} d\omega = -2\pi^2 \alpha \left(\frac{\kappa_n}{m_n} \right)^2 - \int_{\omega_\pi}^{\omega_{\max}} \frac{\sigma_A^n - \sigma_p^n}{\omega} d\omega$$

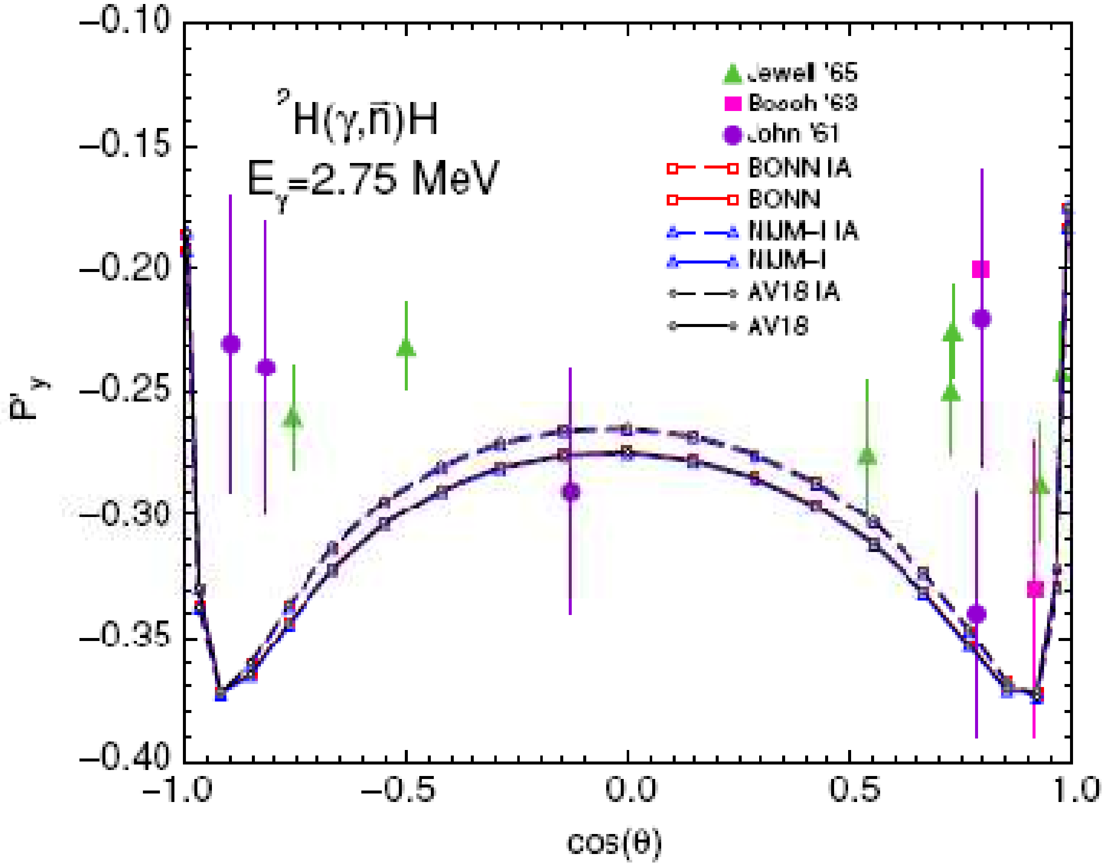
The discrepancies in the experimental results of few-body systems

- Binding energy of deuteron-^{3}He-^{3}H
- $d(\gamma,n)$ results from Schiavilla
- $d(e,e'p)$ results from Darmstadt
- Analyzing power $A_y(\theta)$

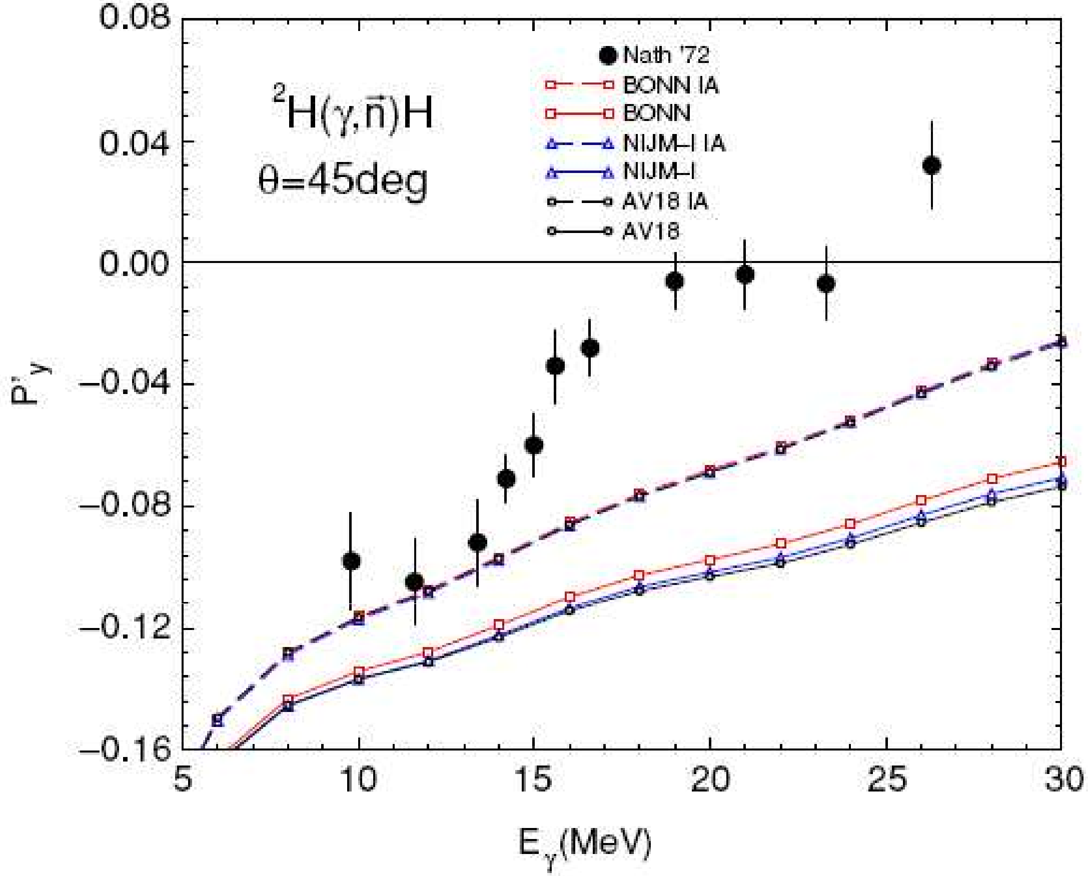
Results from Induced Polarization in the $^{2}H\ (\gamma,n)^{1}H$ reaction at low energy- Schiavilla

- The lab-frame angular distribution ratios, measured in the deuteron photodisintegration as function of photon energy, are compared to the results of calculations based on the BONN and AV18 potentials



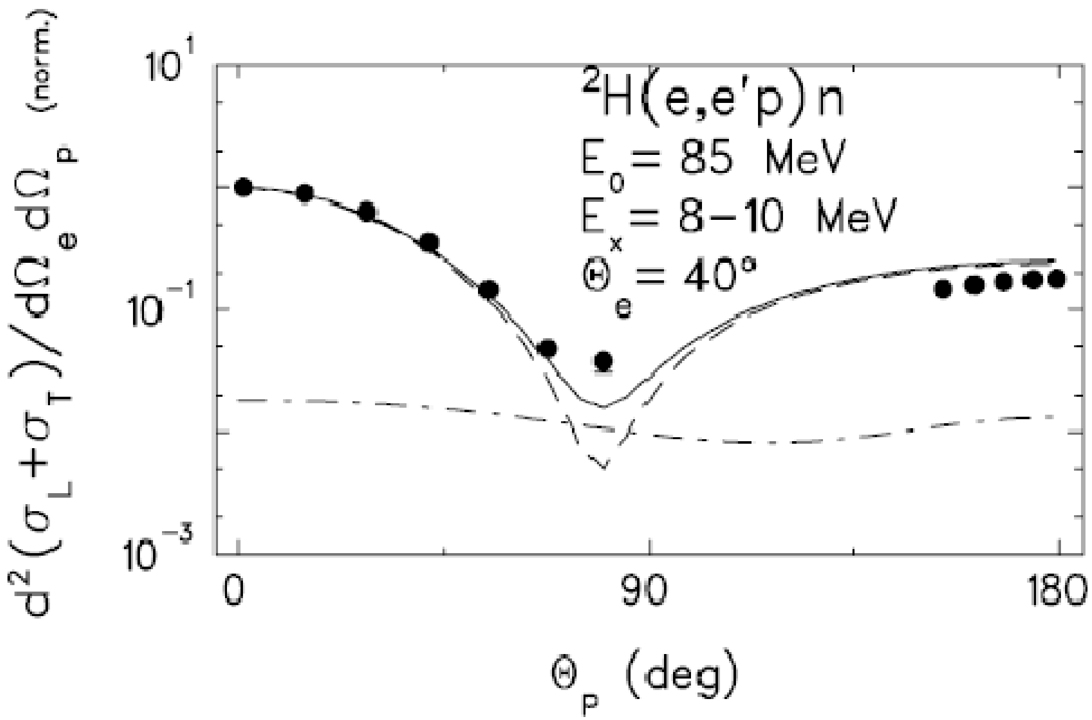


- The center-of-mass angular distribution of the neutron-induced polarization measured in the reaction at photon energies of 2.75 MeV is compared to the results of calculations based on a number of latest generation NN potentials.



- The neutron-induced polarization measured in the reaction at center-of-mass angle $\theta = 45^0$ is compared to the results of calculations base on a number of latest generation NN potentials.

Results from Darmstadt von Neumann-Cosel et al. (2002)

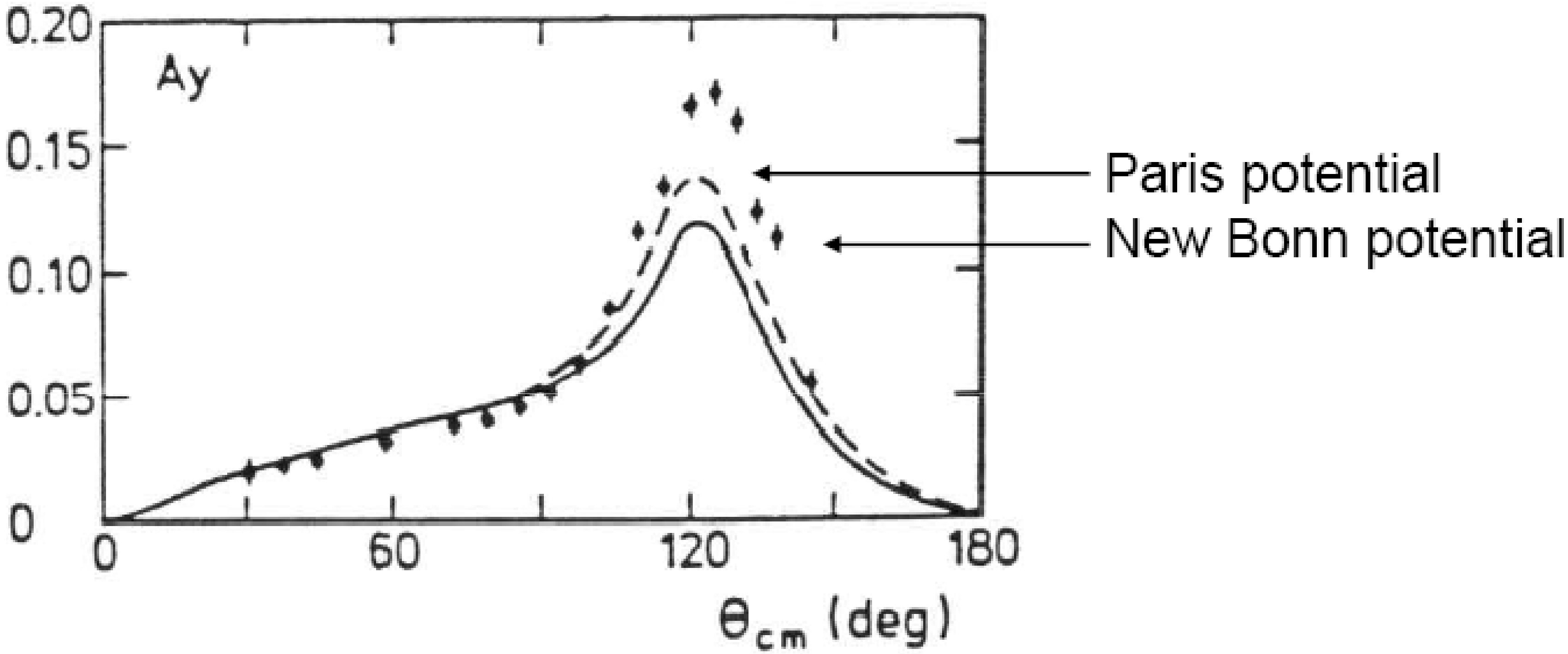


40%

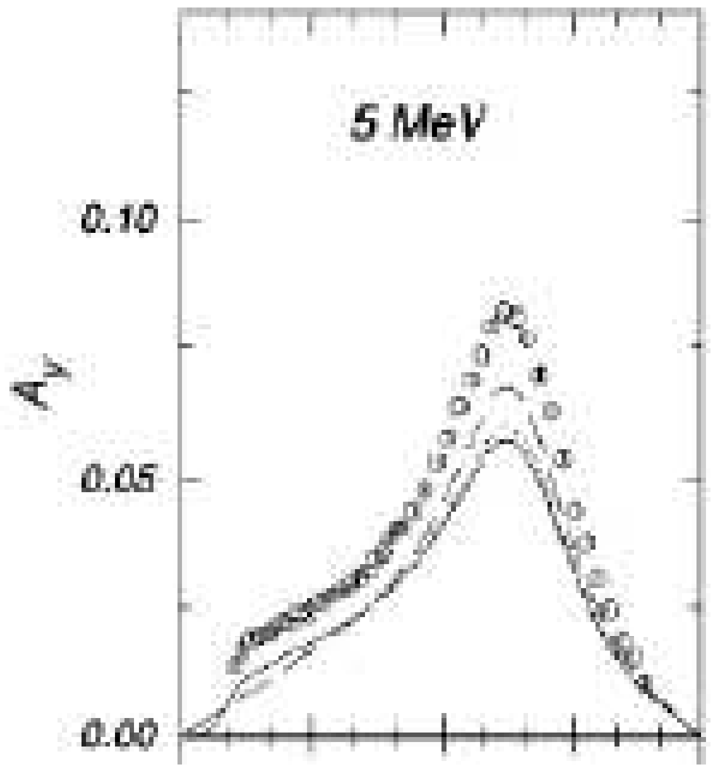
DISCREPANCY

- Sum of the double-differential longitudinal and transverse cross sections of the d(e,e'p) reaction at incident electron energy 85 MeV for an excitation energy bin 8-10 MeV as a function of polar proton emission angle.

Analyzing power - $A_y(\theta)$



- Neutron-deuteron analyzing power data at E_n=10.0 MeV in comparison to rigorous calculations by Witala, Glöckle, and Cornalius using the Bonn NN potential and the Paris NN Potential



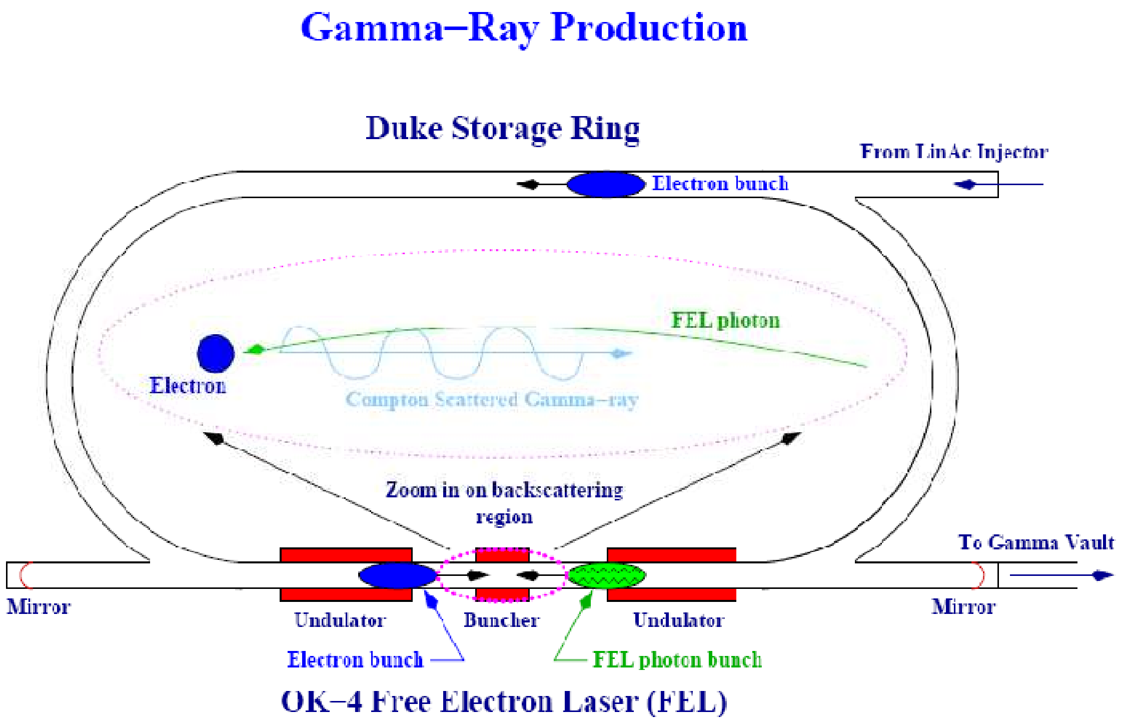
- Proton-deuteron analyzing power calculated by Kievsky et al. using the Argonne v18 potential model (solid curve) and Av18+ Urbana IX three-nucleon force (dotted curve).
- The dashed curve is for n-d scattering calculated with Av18.
- The p-d data are from Sagara et al. and Grüebler et al.

Experimental Setup

- Gamma Production
- The Experimental Layout
- Blowfish – Neutron Detector –
- Active Target
- Computing the Asymmetry
- Data Analyzing Programs -Lucid,Geant,Root

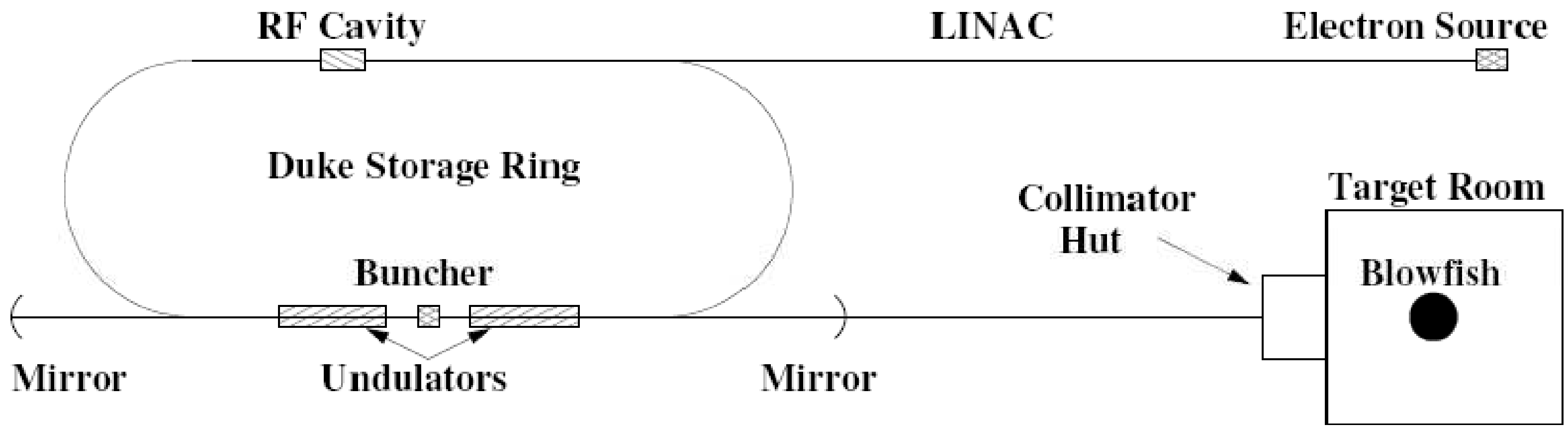
HIGS Facility – Gamma Production

- Operating Principle: Compton backscattering of the free-electron laser photons in the storage ring

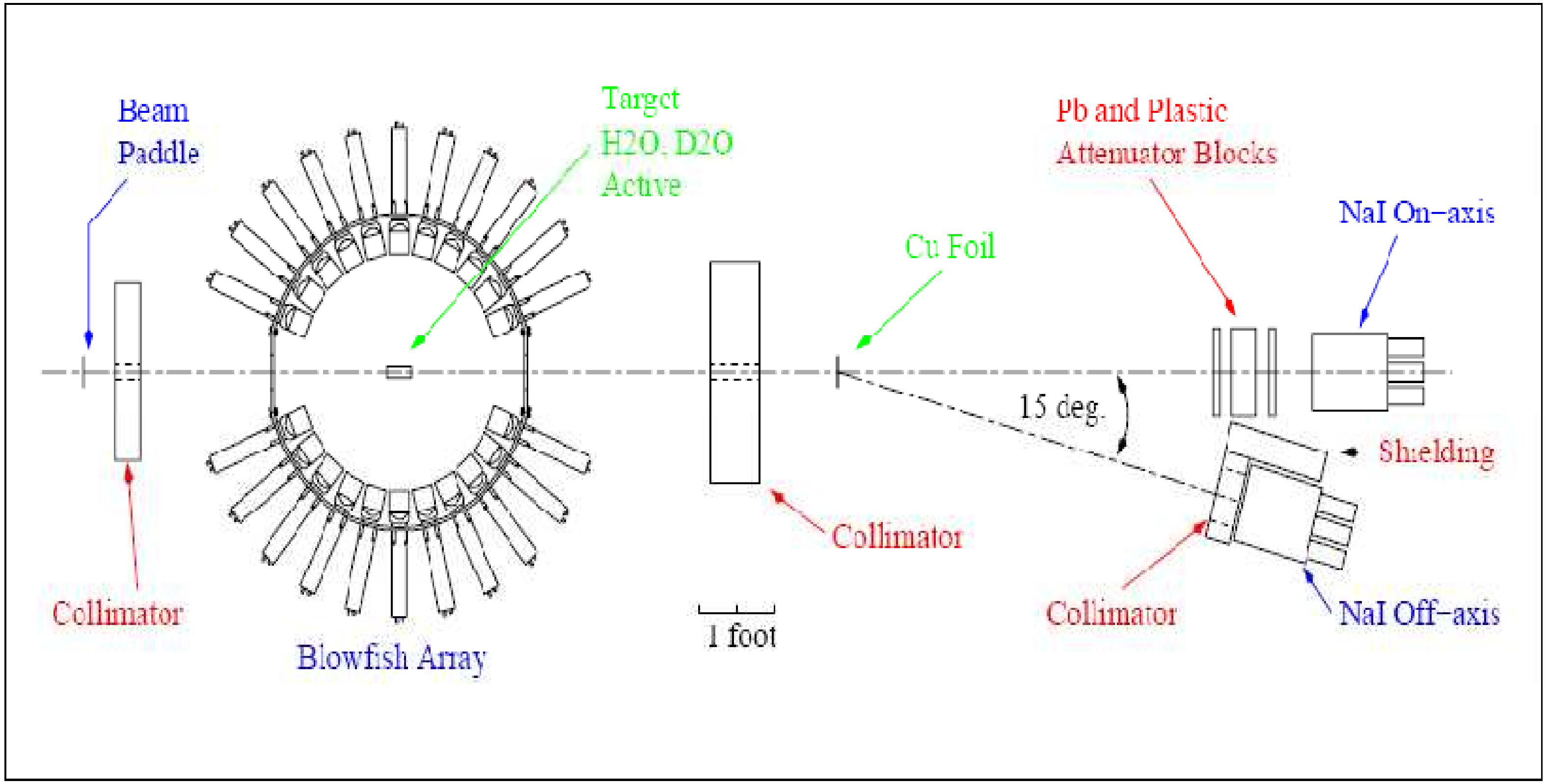


- This unique facility provides us a very clean, virtually monoenergetic, 100% linearly polarized gamma-ray beam

An overview schematic of DFELL



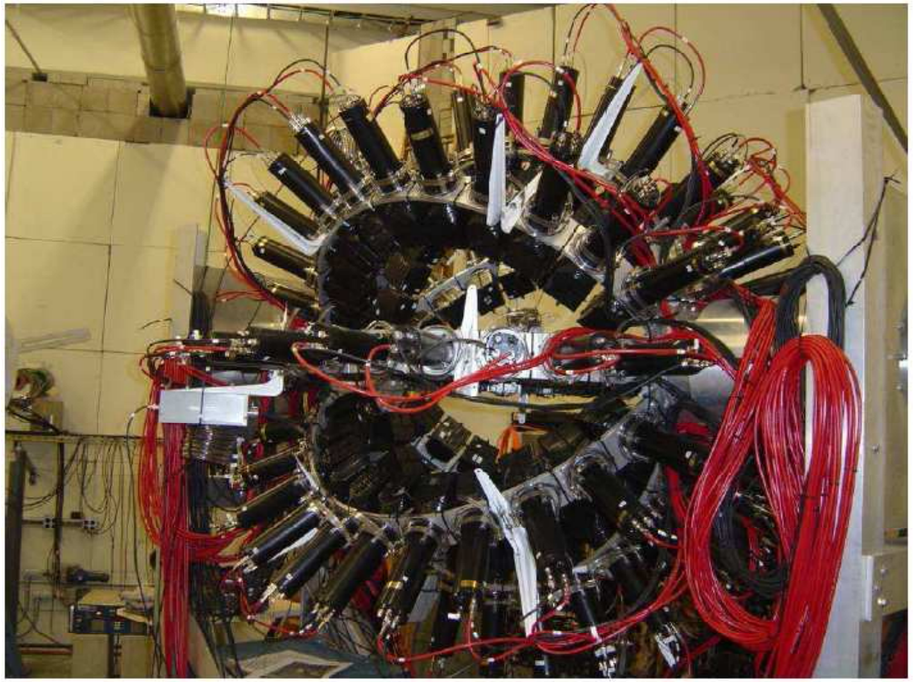
The Experimental Layout



- The resulting 44 data points will be used to test the predictions of potential and effective field models that apply to the np system.

The Blowfish – Neutron Detector

- 88 BC-505 Liquid Scintillator Cells
- 8 uniformly spaced arms of equal azimuthal angle Φ
- 11 cells in each arm- uniformly distributed between polar scattering angles θ



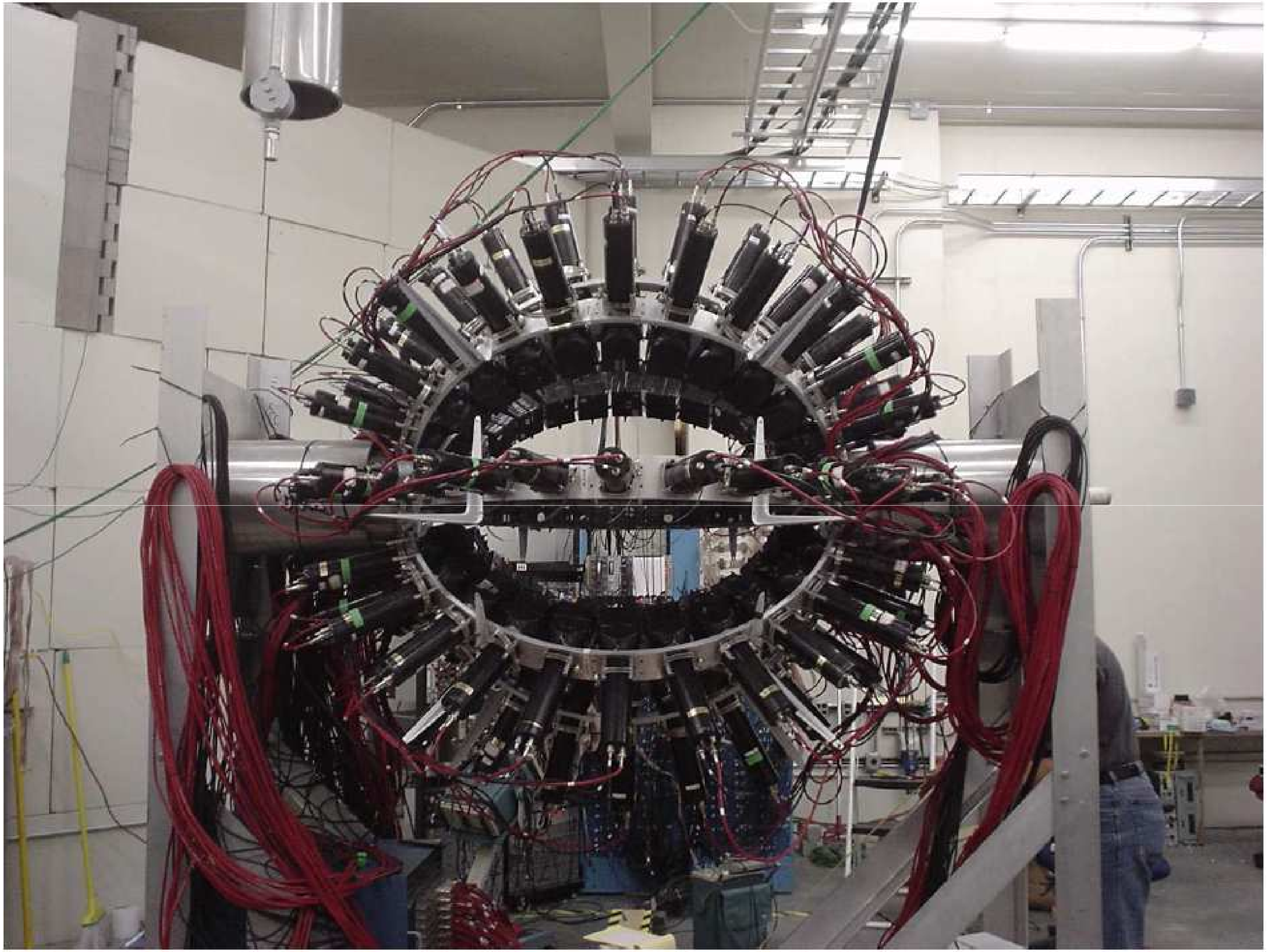
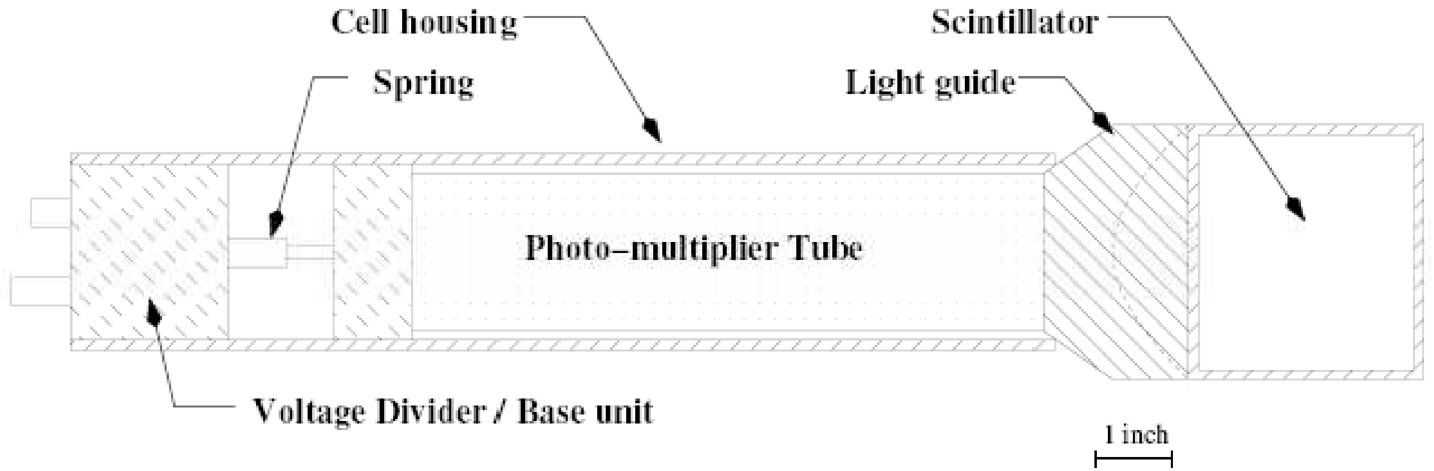


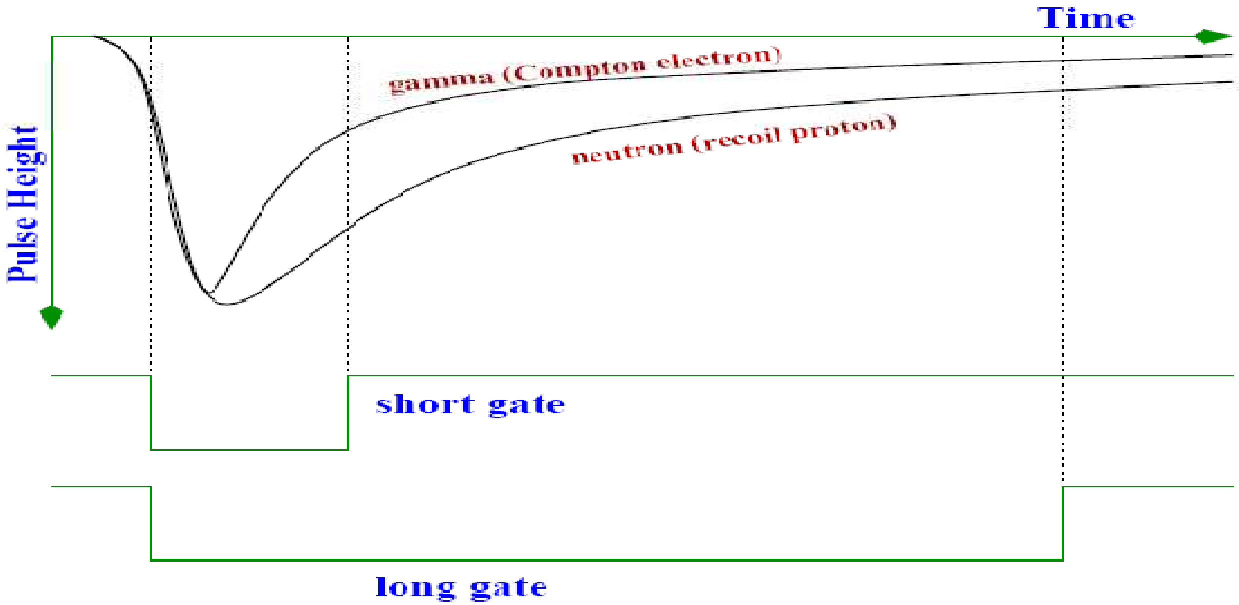
Diagram of a single Blowfish Detector



- The scintillator is capable of distinguishing the neutrons and the photons by the shape of emitted light pulse.

Pulse-Shape Discrimination

- Neutral particle identification in the Blowfish array is performed using a technique called Pulse-Shape Discrimination (PSD)

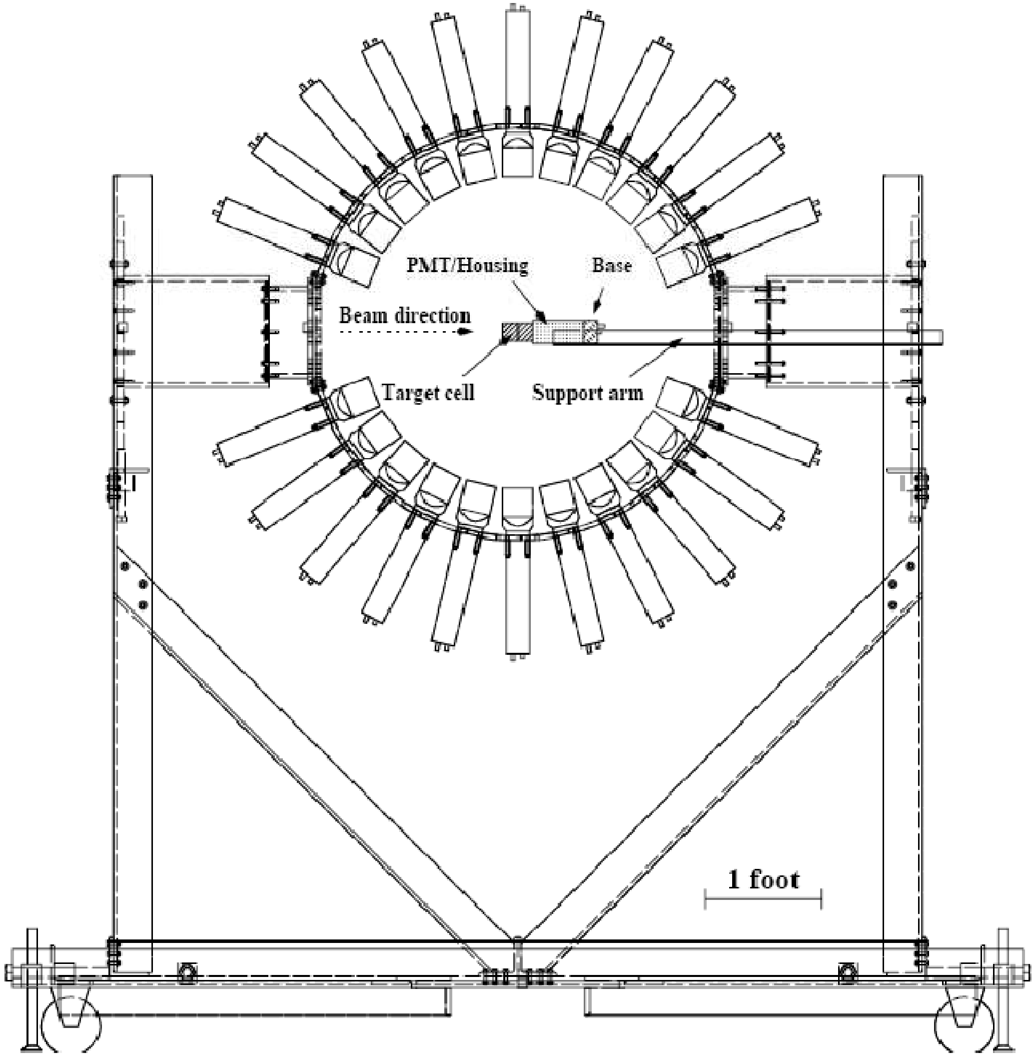


Active Target

- A thin-walled Al target cell – filled with a deuterated variant of the NE-232 liquid scintillator and coupled to a 2” PMT and wrapped in black tape to make it light-tight.
- The dimensions of the target are

Desc.	OD ($\pm$.05 cm)	Length ($\pm$.05 mm)	Wall ($\pm$.001 cm)	Wall Material	Target Material
Active	4.72	8.25	0.50	Al	Deut. NE-232

Active Target Configuration in Blowfish

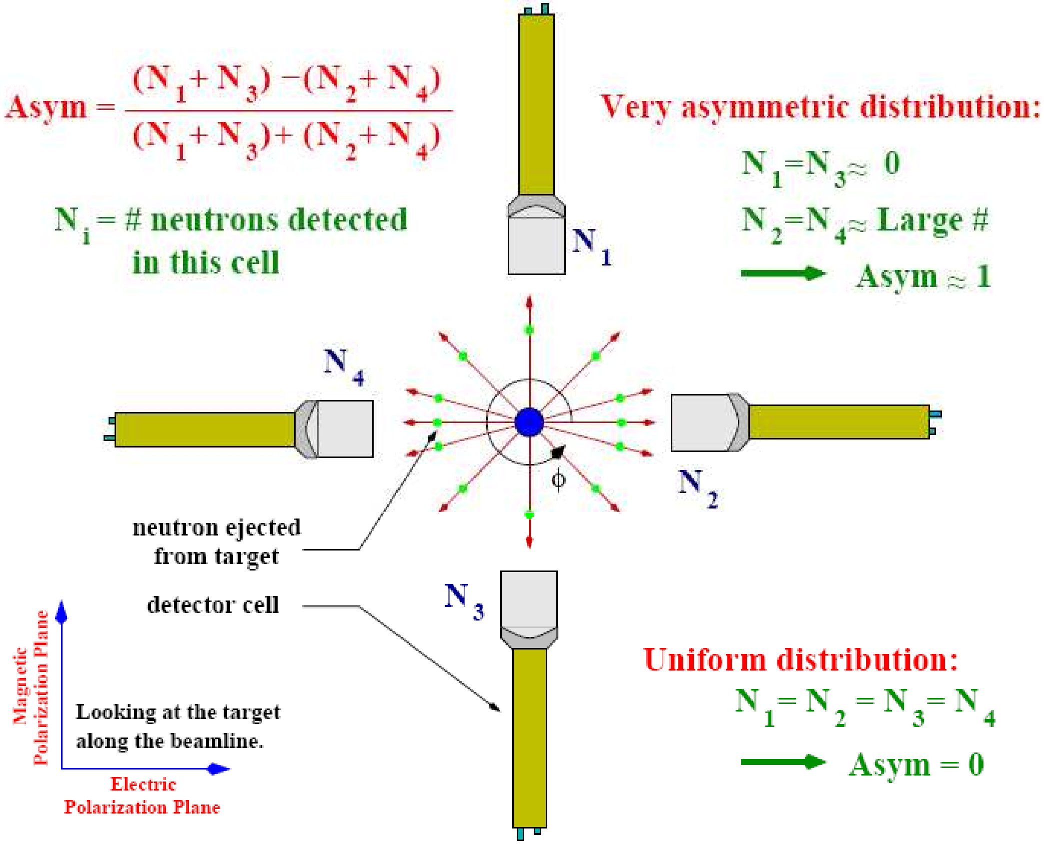


The Asymmetry _ Analyzing Power_

- The asymmetry is a particularly attractive observable from the perspective of an experimentalist.
- A measure of the azimuthal (ϕ) asymmetry in the distribution of particles expelled from a reaction.
- Theoretical asymmetry:

$$\Sigma(\theta) = \frac{\sigma\left(\theta, \phi = 90^o\right) - \sigma\left(\theta, \phi = 0^o\right)}{\sigma\left(\theta, \phi = 90^o\right) + \sigma\left(\theta, \phi = 0^o\right)}$$

Computing the Asymmetry



- The degree to which the neutrons tend to favor being ejected in one direction than another is quantified by calculating the asymmetry.

Data Analyzing

- LUCID,GEANT4,ROOT
- We will get the data during July-August
- Analyzing data

References

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