Neutron emission asymmetries from linearly polarized γ rays on ^{nat}Cd, ^{nat}Sn, and ^{181}Ta

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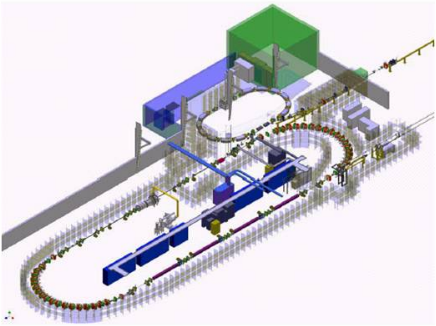
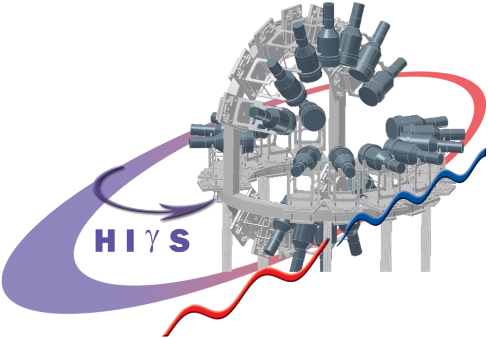
High Intensity γ-ray Source at TUNL

- HIγS produces γ rays by Compton backscattering free-electron-laser photons from stored electrons
  - intense and nearly monochromatic
  - circularly or linearly polarized
- neutron emission induced by incident 10-20 MeV photons
  - via (γ, n), $(\gamma, 2\mathrm{n})$, and (γ, f)
  - in both fissile and nonfissile targets



Photofission studies at HIγS



- using linearly polarized incident γ rays, neutron emission is azimuthally asymmetric
- asymmetry depends on:
  - emitted neutron energies
  - nuclear species of the target
- can possibly be exploited for applications involving isotopic identification

Neutron detection

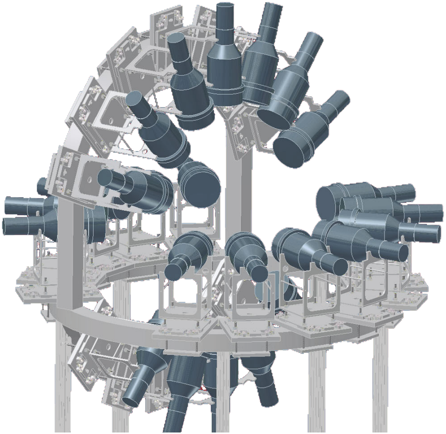
- outgoing neutrons detected by 18 liquid-scintillator neutron detectors
  - mounted at:

$\phi_{lab} = 0^\circ, 90^\circ, 180^\circ, 270^\circ$

$\theta_{lab} = 55^\circ, 72^\circ, 90^\circ, 107^\circ, 125^\circ, 142^\circ$

- targets positioned in center of array, tilted in θ_{lab} and ϕ_{lab} (each at 45°) to double effective thickness

- time of flight measured over 58 cm flight path



Neutron emission asymmetries

asymmetrical production of neutrons allows construction of $I_{\parallel}/I_{\perp}$, the ratio of yields parallel to yields perpendicular to the plane of γ-ray polarization

$$\frac{I_{\parallel}}{I_{\perp}} = \frac{N_{left} + N_{right}}{N_{top} + N_{bottom}}$$

- N is the number of neutron counts per detector in an energy bin of width $\Delta E = 0.5$ MeV

- generate plots of $I_{\parallel}/I_{\perp}$ as a function of outgoing neutron energy E_n
  - potentially useful for isotopic identification

Targets

	Mar. 2009	Feb. 2010	Jul. 2010	Jul. 2011
fissile targets	^{238}U	^{235}U, ^{238}U	^{239}Pu, ^{232}Th	-
nonfissile targets	^{nat}Pb, ^{209}Bi, ^{nat}Fe, ^{nat}Cu, ^{nat}Cr	^{nat}Pb	^{9}Be, ^{nat}Cd, ^{nat}Sn, ^{181}Ta	^{nat}La, ^{nat}Hg, ^{nat}Dy

July 2010 ^{nat}Cd, ^{nat}Sn, and ^{181}Ta runs

- γ rays produced by HIγS were incident on ^{nat}Cd, ^{nat}Sn, ^{181}Ta
- data were taken at incident photon energies $E_\gamma = 11.0 - 15.5$ MeV
- for nonfissile targets with high $(\gamma, 2\text{n})$ thresholds, measured asymmetries result unambiguously from (γ, n)
  - e.g. ^{nat}Cd, ^{nat}Sn, ^{181}Ta
- targets chosen for low (γ, n) thresholds and high expected $I_\parallel / I_\perp$ values

E_γ (MeV)	11.0	12.0	13.0	14.0	15.0	15.5
^{nat}Cd	-	-	X	X	X	X
^{nat}Sn	-	-	X	-	X	X
^{181}Ta	X	X	X	X	-	X

Data analysis with ROOT

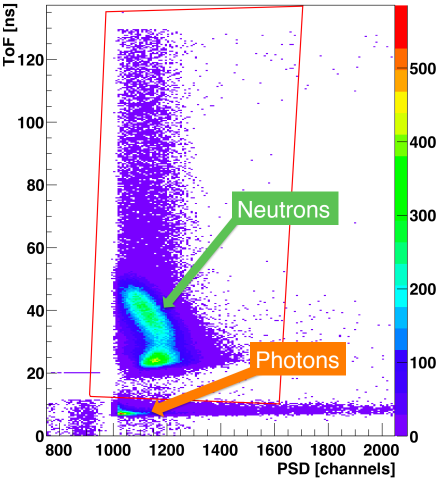
- data collected includes:
  - pulse height
  - time-of-flight (ToF)
  - pulse-shape discrimination (PSD)

1. neutrons distinguished from Compton-scattered photons by 2D cuts on ToF vs. PSD plots

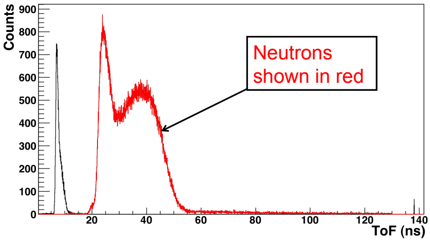
2. E_n calculated using ToF techniques:

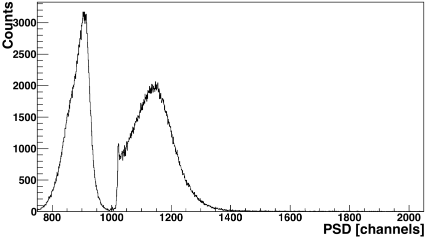
$$E_n = \frac{1}{2} m_n \left(\frac{\Delta x}{\Delta t} \right)^2, \quad \text{where} \quad \Delta x = 0.58 \text{ m}$$

3. additional data taken using 15.5 MeV circularly polarized γ rays used to check for systematic differences in detector efficiency
   - corrections applied to data taken using linearly polarized γ rays

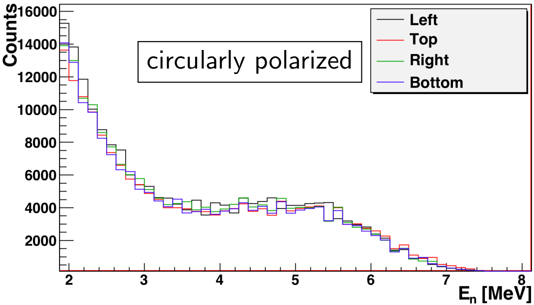


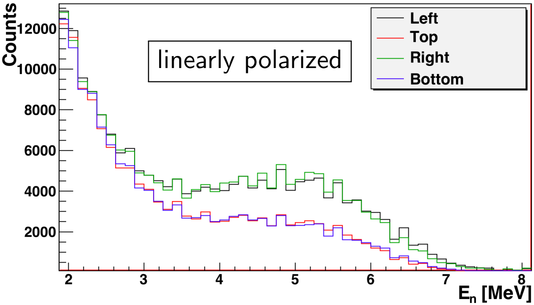
ToF projection



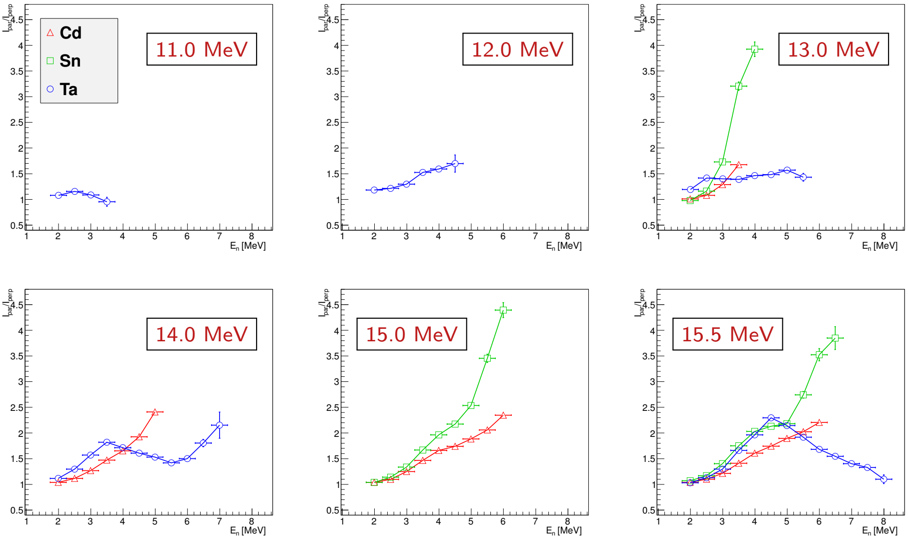


PSD projection

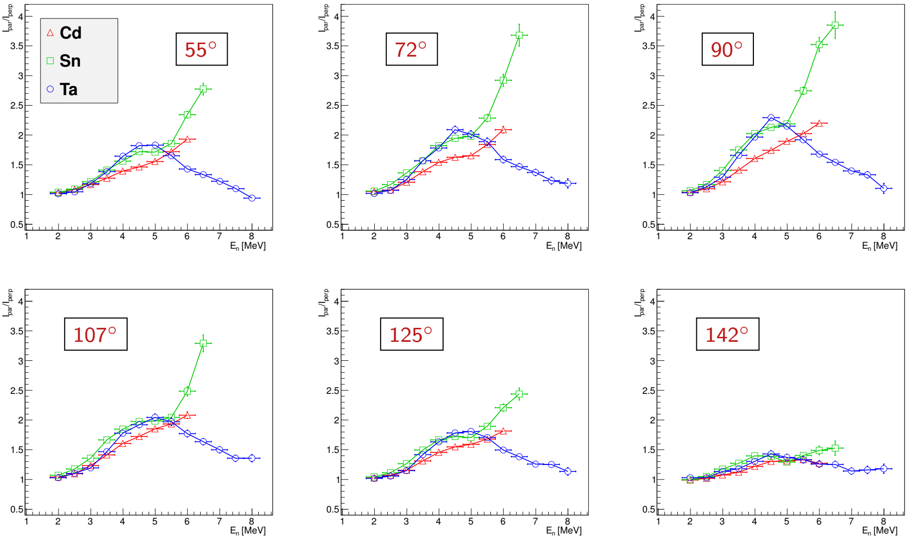

circularly polarized
Left
Top
Right
Bottom
Counts
16000
14000
12000
10000
8000
6000
4000
2000
2
3
4
5
6
7
8
E_n [MeV]


linearly polarized
Left
Top
Right
Bottom
Counts
12000
10000
8000
6000
4000
2000
2
3
4
5
6
7
8
E_n [MeV]

Neutron asymmetry plots for various E_γ ($\theta_{lab} = 90^\circ$)



Neutron asymmetry plots for various θ_{lab} ($E_\gamma = 15.5$ MeV)

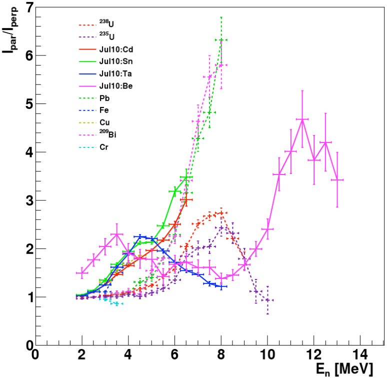


Summary

- linearly polarized γ rays were incident on ^{nat}Cd, ^{nat}Sn, and ^{181}Ta

- we observed an azimuthal asymmetry in neutron emission that was relatively distinct for ^{nat}Cd, ^{nat}Sn, and ^{181}Ta

- asymmetries also distinct from previously studied targets at HIγS



future work

- determine characteristic $I_{\|}/I_{\perp}$ vs. E_n curves for additional fissile and nonfissile targets

- collect data for targets with multiple isotopic components to gauge ability to determine isotopic composition