



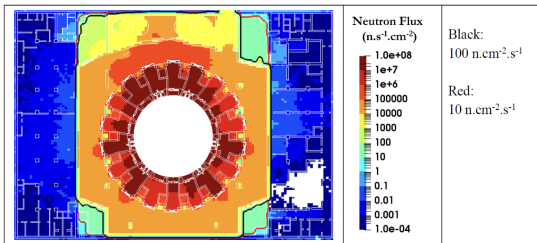
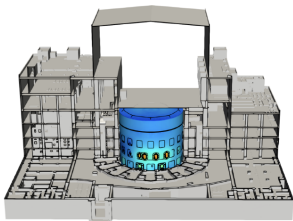
A New (n, xn) Measurement Capability at LANSCE

Funded by DOE SC Early Career Research Program

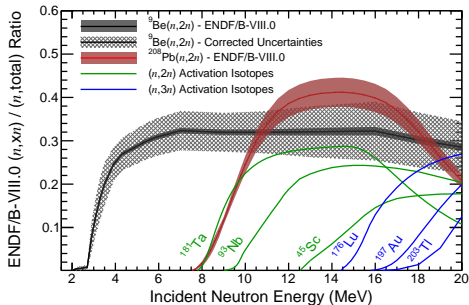
Keegan J. Kelly

2025 Workshop for Applied Nuclear Data Activities

Fusion Reactors Rely on $(n,2n)$ and $(n,3n)$ Rxns



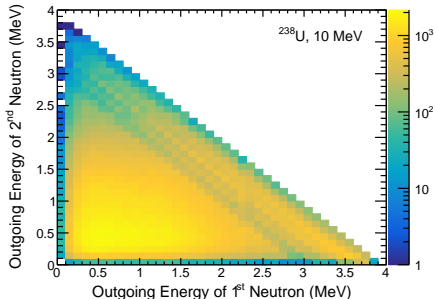
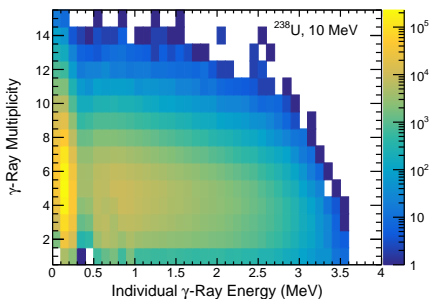
ITER_D_3FM52L - Radiation environment for equipment during operations by R Juarez



- n breeding essential for t production via $^6\text{Li}(n,t)$, to drive $d-t$ – $^9\text{Be}(n,2n)$ and $^{208}\text{Pb}(n,2n)$
- Activation-based flux measurements motivate a suite of $(n,2n)$ measurements

Traditionally: γ -rays, Activation, or n Counting

Calculated with CoH₃ - T. Kawano, Springer Proceedings in Physics 254 (2021) 27



→ Traditional methods do not measure emitted n information

→ Detection of both ($n, 2n$) neutrons captures 100% of strength.

Continuous white-source neutron measurements are ideal, but neutron TOF degeneracies are problematic



Degeneracies of White Sources can be Solved

Neutron energies for $(n,2n)$ for $(n,3n)$ reactions at white sources are degenerate

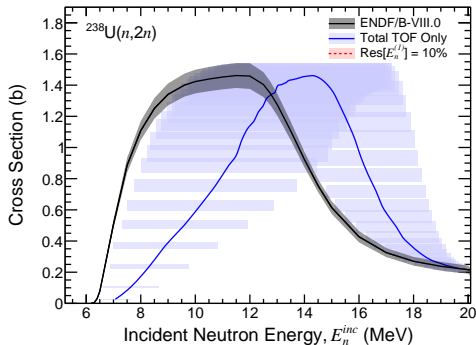
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$$T_n^{(2)} = t_n^{inc} + t_n^{(2)} = \text{Second TOF}$$

BUT, measuring one neutron energy breaks the degeneracy!

$$t_n^{(1)} = \left(\frac{l_{out}}{c}\right) \left[1 - \left(1 + \frac{E_n^{(1)}}{m_n c^2}\right)^{-2}\right]^{-1/2} \Rightarrow t_n^{inc} = T_n^{(1)} - t_n^{(1)} \Rightarrow E_n^{inc}, E_n^{(2)}$$

LANSCCE can provide continuous $(n,2n)$ and $(n,3n)$ measurements with emitted neutron energy and angular information



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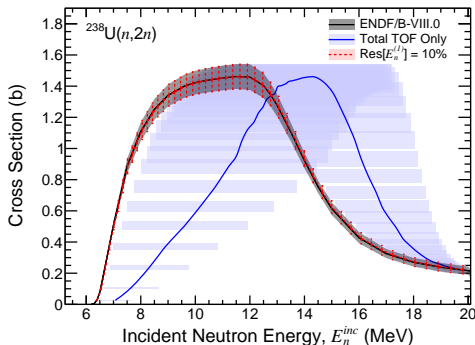
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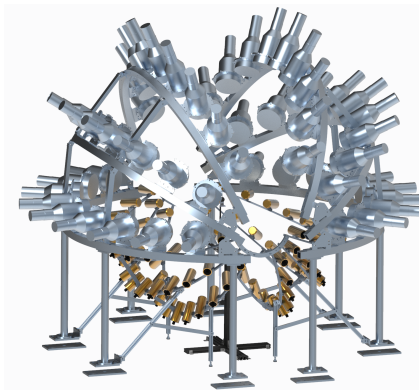
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Accomplished with CLYC-7 E_n Data and CoGNAC

- Upgrade CoGNAC to include a series of high-volume CLYC-7 scintillators
- $^{35}\text{Cl}(n,p)$ measures $E_n^{(1)}$ directly
- EJ-309 and CLYC-6 detectors provide $T_n^{(2)}$ measurement to low energy



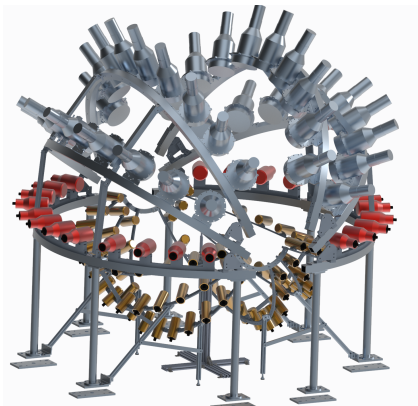
Applicable to 20+ $(n,2n)$ and $(n,3n)$ measurements for DOE SC NP FES, and could lead to a decade+ campaign for OES / SAT and PAT

→ Opens possibilities for correlated $(n,2n)$, (n,n) , and (n,n') measurements



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Project Tasks in Progress So Far

Tasks	FY2025	FY2026	FY2027	FY2028	FY2029
Purchase CLYC-7 Detectors	[Red arrow from start to end of FY2025]				[Green diamond]
Integrate CLYC-7 Detectors into CoGNAC	[Red arrow from start to end of FY2025]				[Green diamond]
Leverage Existing Data for n - n Coincidence Development	[Red arrow from start to end of FY2025]				
Utilize New Data for n - n Coincidence Development	[Red arrow from start to end of FY2025]				
Obtain Pure ^{181}Ta Target	[Red arrow from start to end of FY2025]				
Obtain Pure ^{208}Pb Target		[Red arrow from start to end of FY2026]			
Conduct $^{181}\text{Ta}(n,2n)$ Scoping Measurement		[Green diamond]			
Analyze $^{181}\text{Ta}(n,2n)$ Scoping Measurement Data		[Red arrow from start to end of FY2026]			
Report Results from $^{181}\text{Ta}(n,2n)$ Scoping Measurement			[Green diamond]		
Conduct Simultaneous ^{181}Ta and $^{208}\text{Pb}(n,2n)$ Measurement			[Red arrow from start to end of FY2027]		
Analyze ^{181}Ta and $^{208}\text{Pb}(n,2n)$ Data			[Red arrow from start to end of FY2027]		
Report Results from $^{208}\text{Pb}(n,2n)$ Analysis				[Green diamond]	
Conduct Simultaneous ^{181}Ta and $^9\text{Be}(n,2n)$ Measurement				[Red arrow from start to end of FY2028]	
Analyze ^{181}Ta and $^9\text{Be}(n,2n)$ Data				[Red arrow from start to end of FY2028]	
Report Results from $^9\text{Be}(n,2n)$ Analysis					[Green diamond]
Conduct Exploratory ^{181}Ta and $^{238}\text{U}(n,2n)$ Measurement				[Red arrow from start to end of FY2028]	
Analyze ^{181}Ta and $^{238}\text{U}(n,2n)$ Data				[Red arrow from start to end of FY2028]	
Establish Funding for (n,xn) Measurements Building from this Work				[Red arrow from start to end of FY2028]	[Green diamond]

- CLYC-7 purchases placed; ^{181}Ta & ^{208}Pb target purchase in progress
- ^9Be CoGNAC data being investigated for $(n,2n)$
- n - n coincidence development in progress with existing data
- Experiment on $^{181}\text{Ta}(n,2n)$ planned for 2025 LANSCE run cycle
- Engineering of CLYC-7 integration in CoGNAC in progress



THANK YOU!

Direct questions to kkelly@lanl.gov

