ISINN-32 · 32ND INTERNATIONAL SEMINAR ON INTERACTION OF NEUTRONS WITH NUCLEI

JINR, Dubna · 24–30 May 2026

Neutron–Gamma Angular Correlations in Nuclear Reactions

^{252}Cf(sf) ^{235}U(n,f) Pu–Be: ^{9}Be(α,n)^{12}C

Experiment with EJ309 liquid scintillators and GEANT4 Monte Carlo simulation

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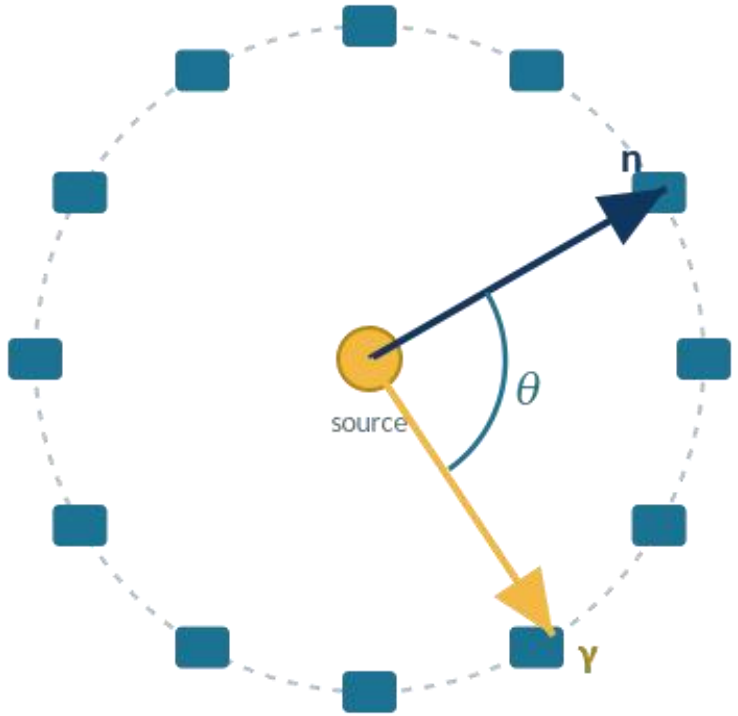
Outline

1. Experimental setup & detector geometries
2. Pulse-shape discrimination
3. GEANT4 Monte Carlo simulation
4. Threshold, timing & γ angular distribution
5. W(θ) in different neutron-energy windows
6. Results: ^{252}Cf(sf) and ^{235}U(n,f)
7. Conclusions & outlook

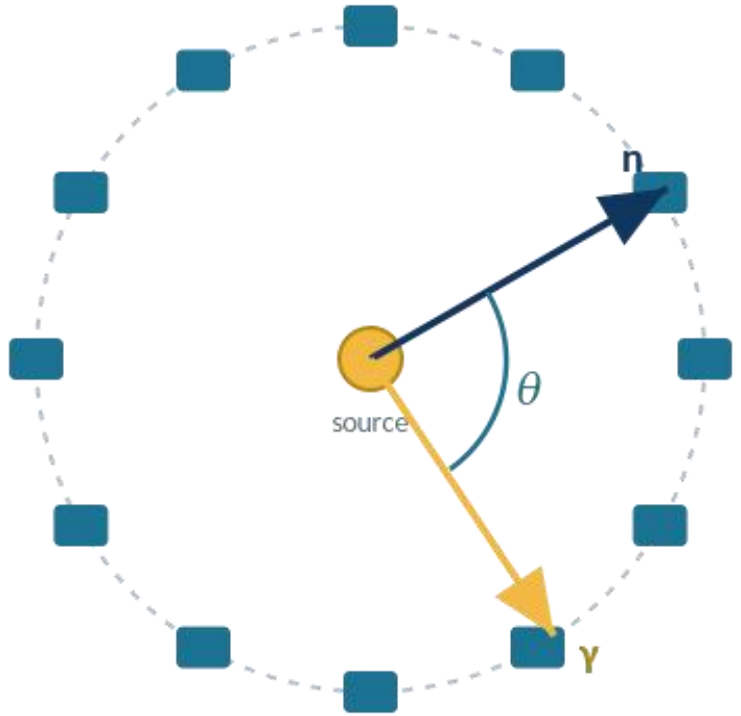


n and γ emitted from the source; ϑ = angle between them

Motivation

Pu–Be SOURCE: $^{9}Be(\alpha,n)^{12}C \rightarrow {}^{13}C^{*}$

- Account for rescattering effects between closely-spaced detectors.
- Analyze the anisotropy of the n–γ angular correlation.
- Try to extract information on the excited levels of ^{13}C.



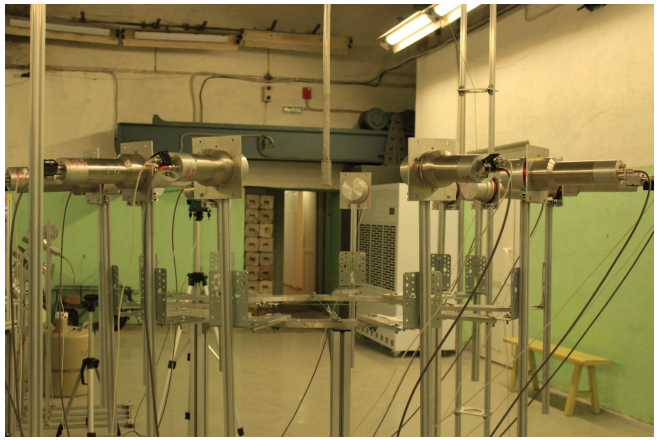
n and γ emitted from the source; ϑ = angle between them

Experimental setup

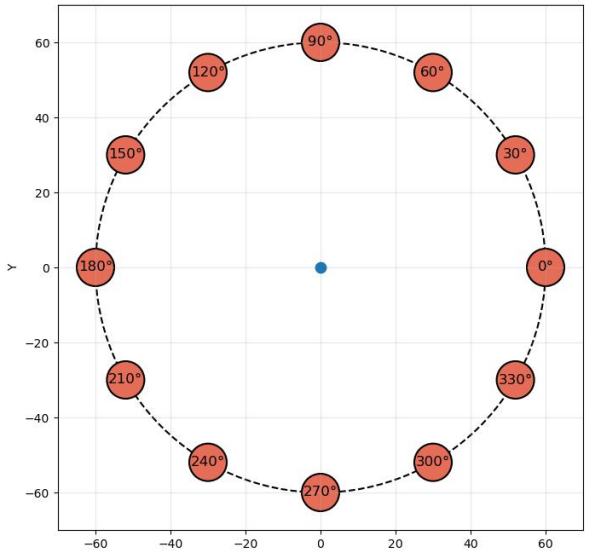
12 liquid scintillators EJ309. Two geometries: 1st — uniform 30° steps; 2nd — 12 different angles between detectors.



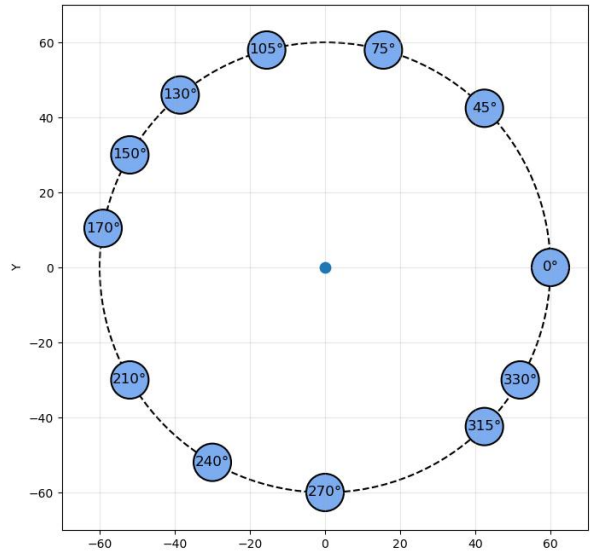
1st geometry (equal angles)



2nd geometry - different angles



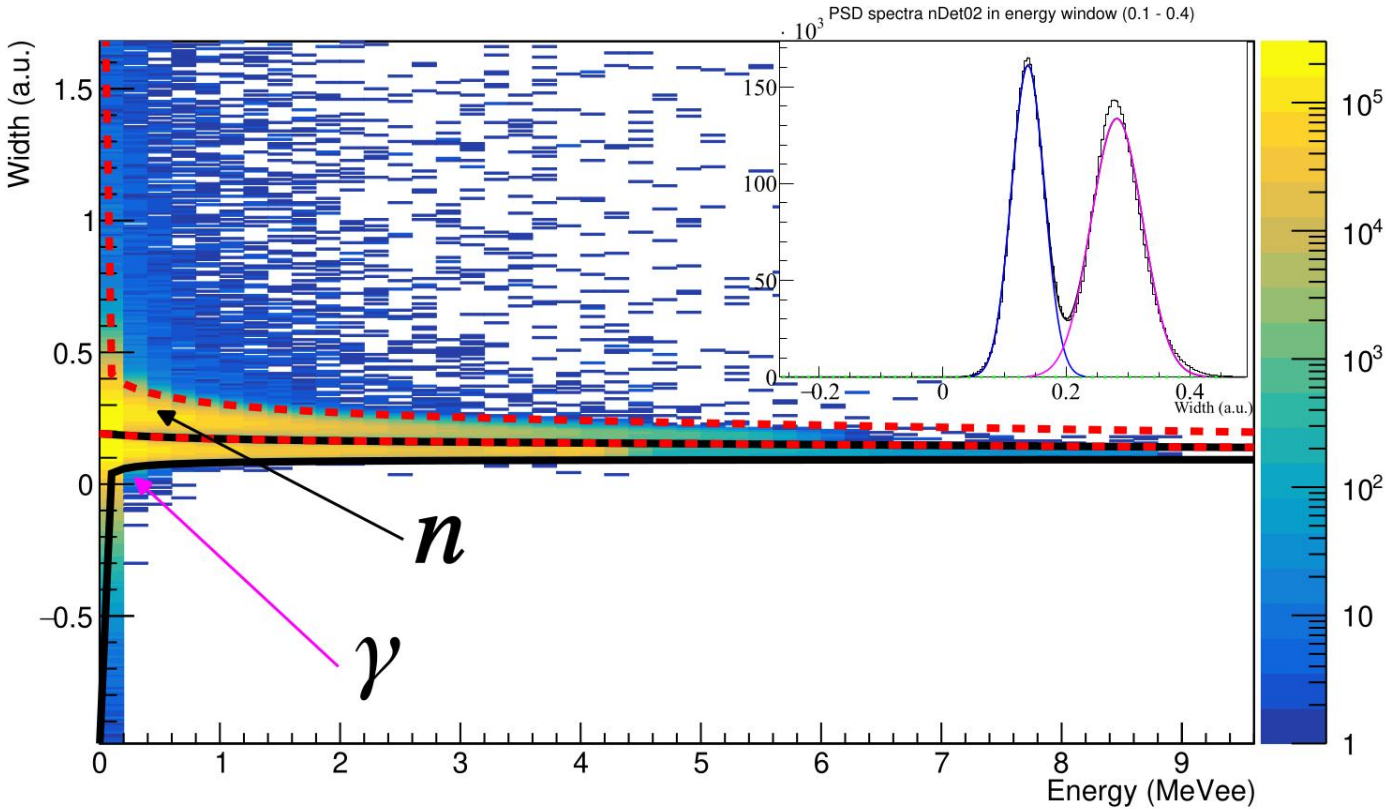
1st geometry — 30° spacing



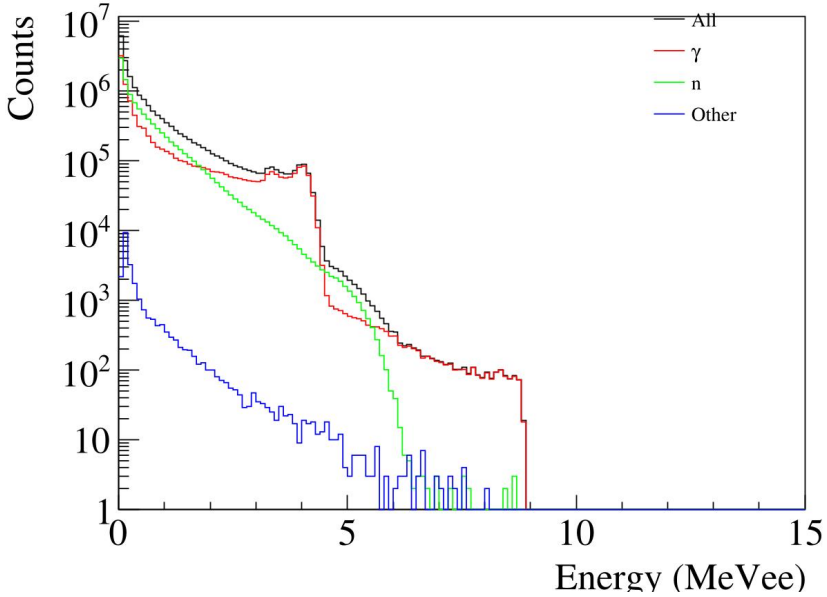
2nd geometry — variable angles

Experimental hall - detectors array around neutron source

Pulse-shape discrimination

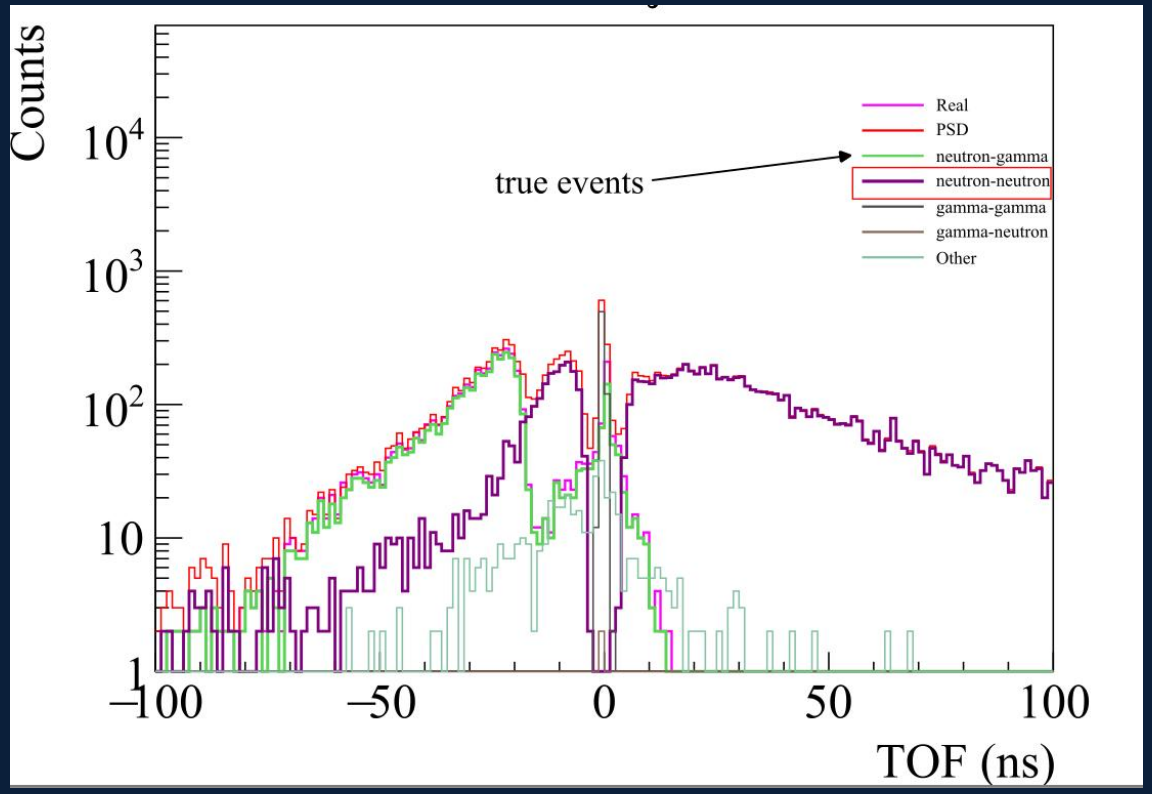


PSD: neutron / γ separation (pulse shape vs. energy)

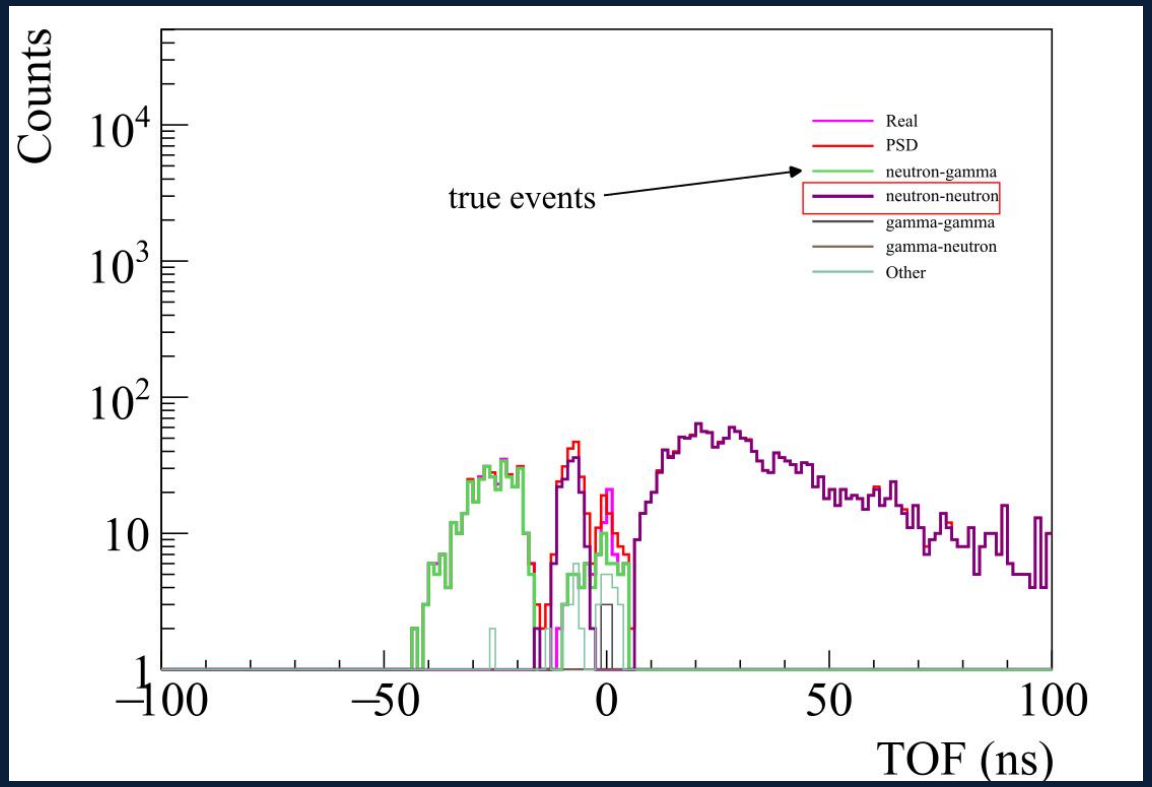


Energy spectra (MeVee)

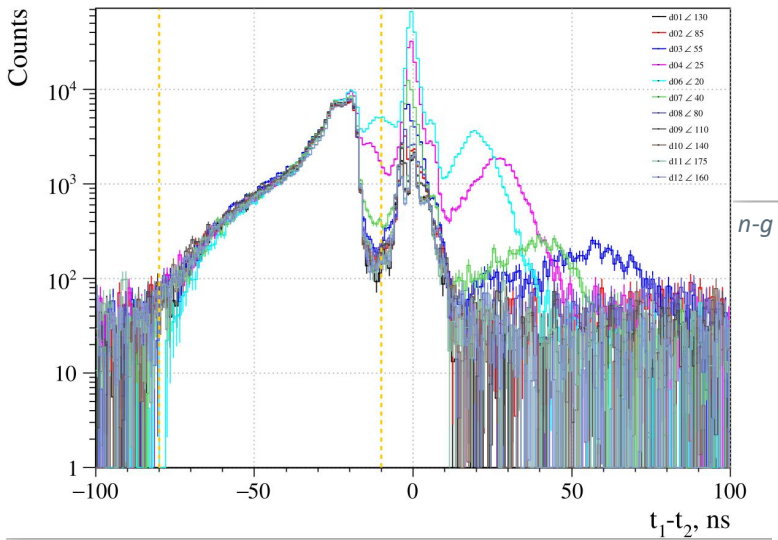
GEANT4 Monte Carlo model



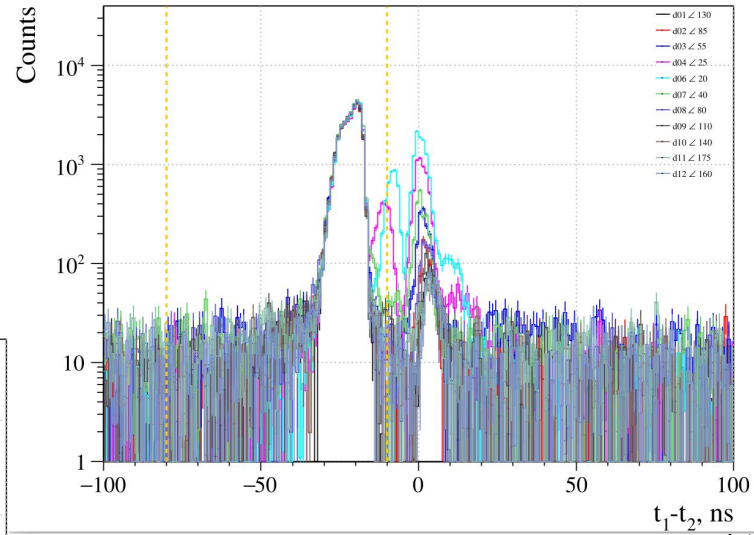
Simulated TOF: n–γ, ∠15°



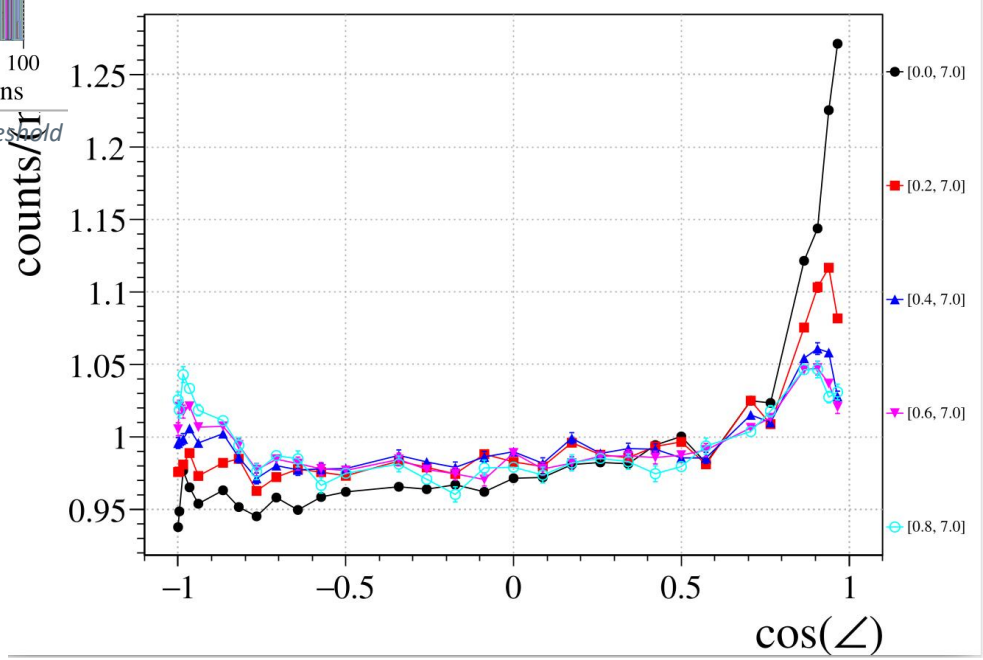
Simulated TOF with neutron energy threshold (0.2 MeVee): n–γ, ∠15°



n-g time difference (without threshold)



n-g time difference (neutron threshold = 0.6 MeVee, gamma threshold = 0.2 MeVee)



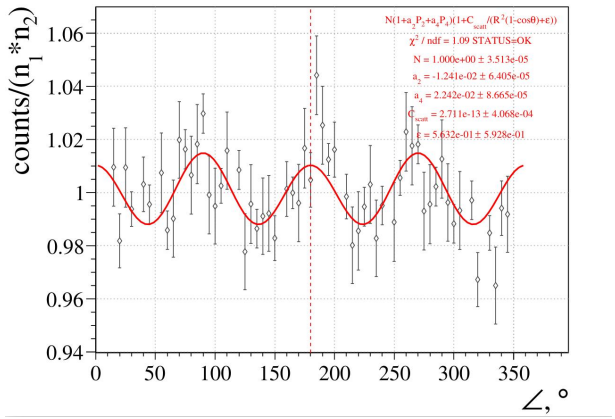
n-g time difference (gamma threshold = 0.2 MeVee)

SIMULATION RESULTS

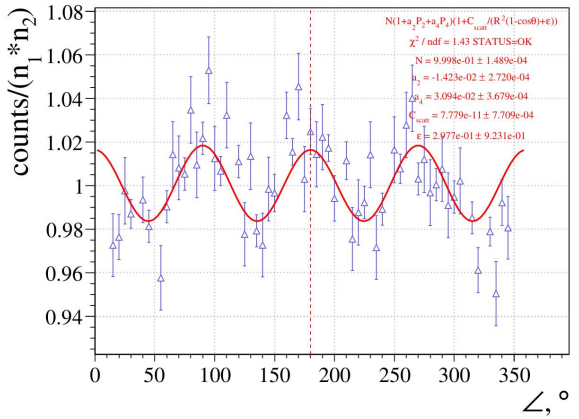
Threshold, timing & γ angular distribution

Key checks: detection threshold, n/γ timing separation, and the extracted γ angular distribution are reproduced by the simulation.

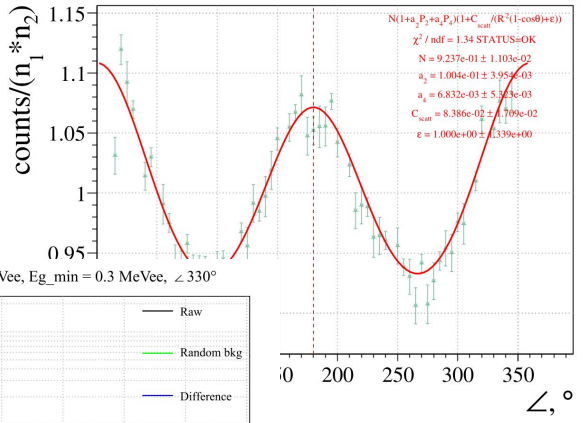
W(θ) in different neutron-energy windows



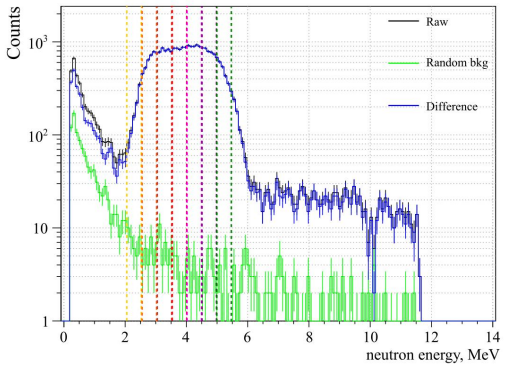
E_n (3.5,4.0) MeV



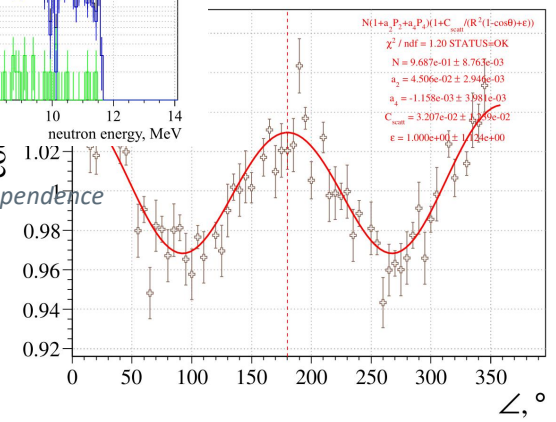
E_n (3.0,3.5) MeV



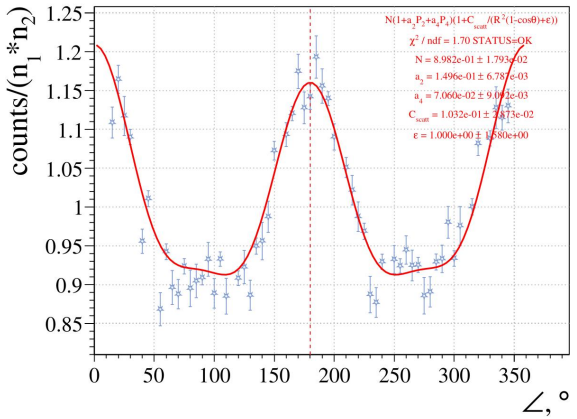
E_n (4.5,5.0) MeV



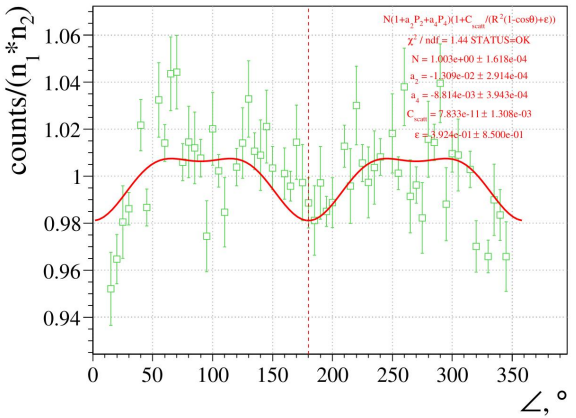
Energy-threshold dependence



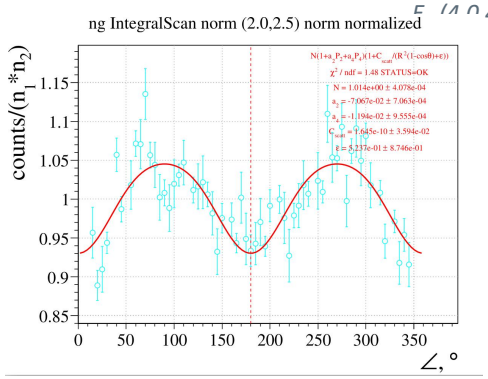
E_n (4.0,4.5) MeV



E_n (5.0,5.5) MeV



E_n (2.5,3.0) MeV



γ angular distribution W(θ)

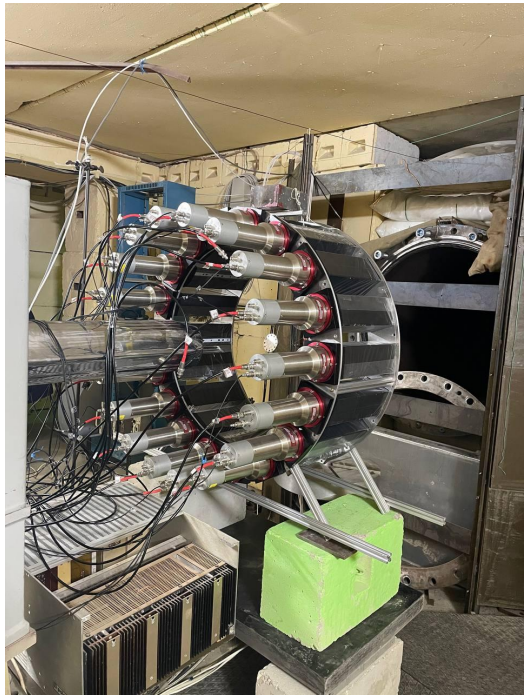
^{252}Cf(sf)

Results to be added

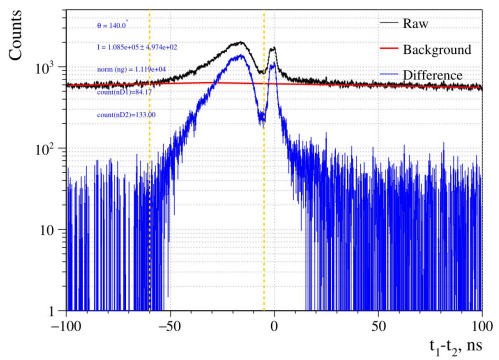
Angular correlations & extracted coefficients for ^{252}Cf(sf)

^{235}U(n,f)

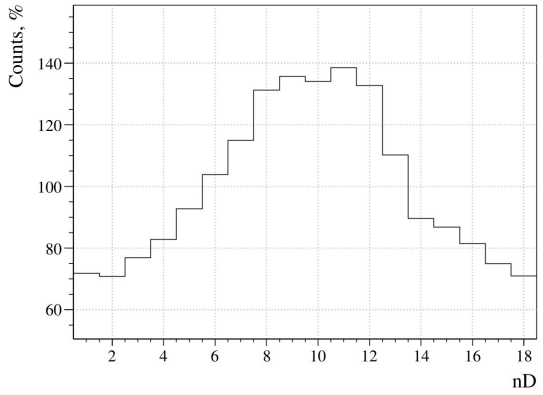
18 liquid scintillators EJ309



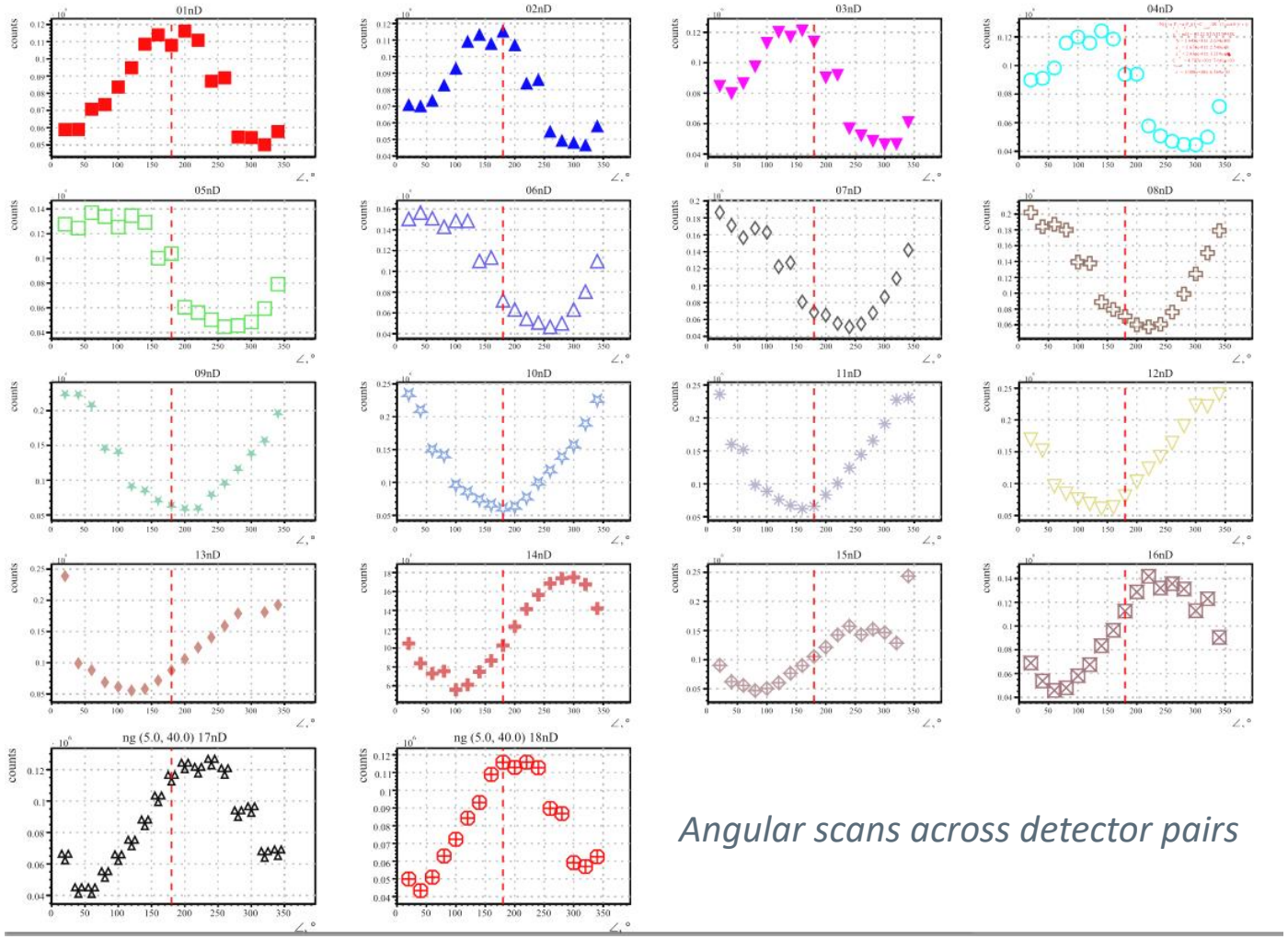
^{235}U detector array (18 EJ309)



n-g TOF spectrum (01nD - 08nD, angle 140 degrees)



Integral counts per detector (nD)



Angular scans across detector pairs

Conclusions & outlook

DONE

- Pu–Be analyzed by neutron energy
- γ angular distributions extracted for the EJ309 array
- GEANT4 model reproduces timing, threshold and W(θ)

OPEN PROBLEMS

- Which ^{13}C levels emit the detected neutrons
- Background / rescattering corrections still needed

NEAREST PLANS

- Finish the ^{252}Cf analysis
- ^{235}U: handle rescattering from the floor

Thank you for your attention!

