Two Neutron Correlations in Photofission

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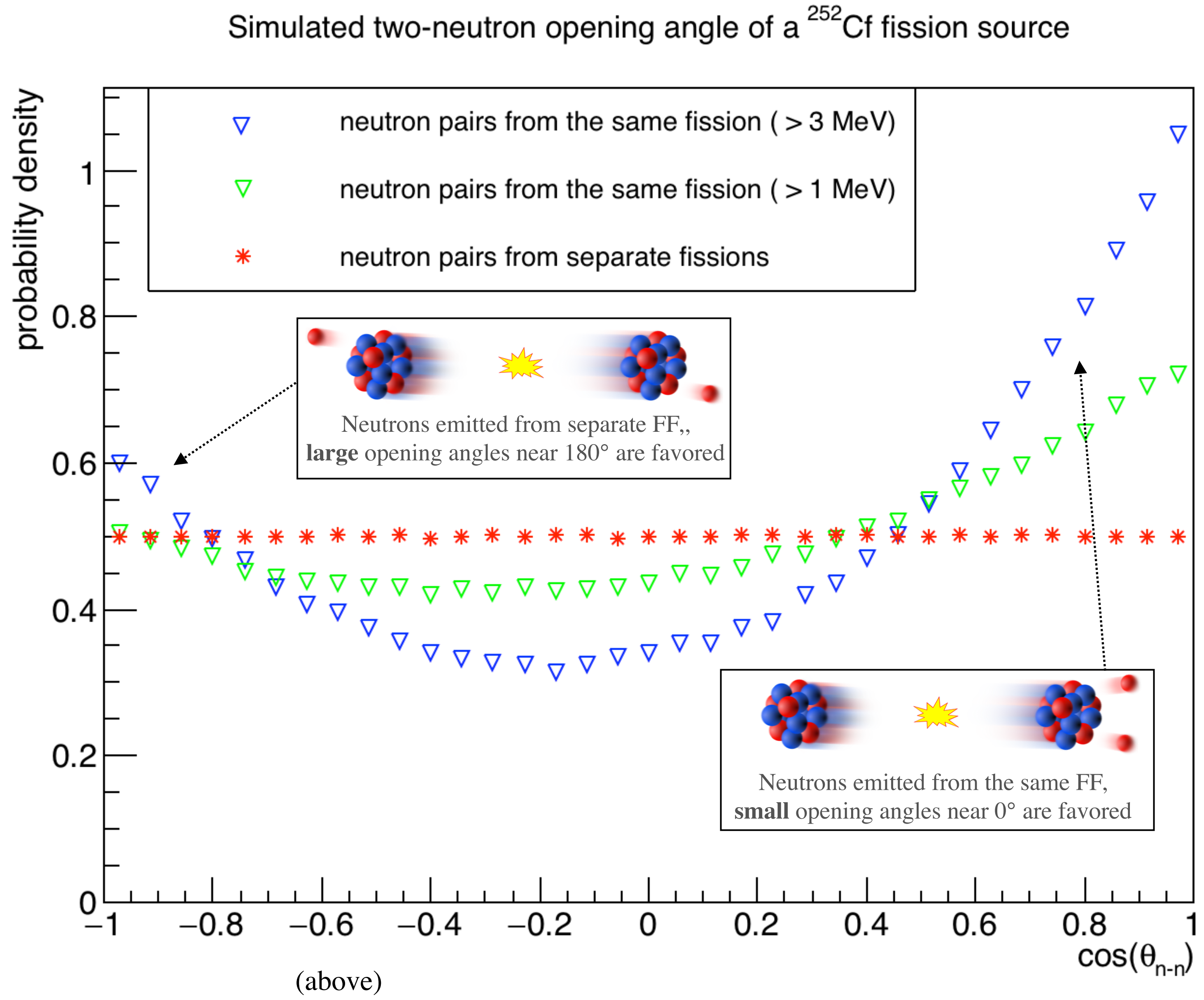
Physics

Upon scission, fission fragments (FF's) are rapidly accelerated in opposite directions due to coulomb repulsion.

(right)
Fission neutrons are emitted **after** the fission fragments have been fully accelerated.

The back-to-back motion of the fully accelerated FF's give a large boost to fission neutrons.
Consequence: Correlated fission neutrons have **energy dependent anisotropic** opening angle distributions.



(above)
Two-neutron opening angle distribution taken from a Monte Carlo simulation using MCNP-POLIMI.
The extent of the correlation increases with neutron energy, since these neutrons tend to come from high speed FF's.

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Motivation

- Lack of correlated neutron data for photofission.
- Photofission measurements enable selective investigation of nuclei due to the low and well-defined angular momentum transfer.
- Experimental verification of correlated photofission models used in Monte Carlo codes.

Experiment

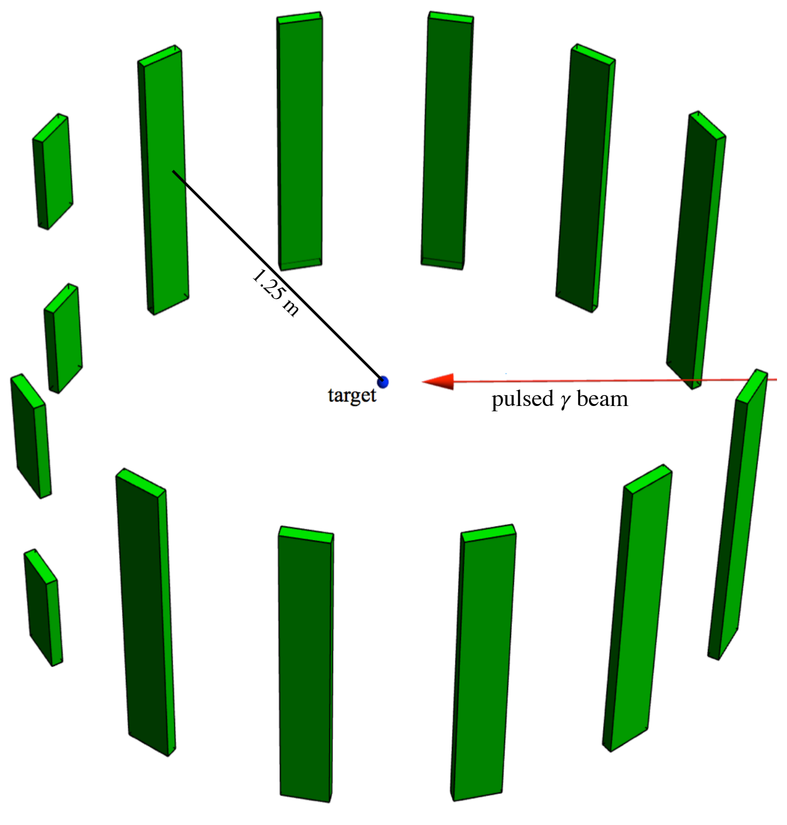
Use a pulsed LINAC to produce a beam of bremsstrahlung photons which induce fission in an actinide target. Fission neutrons are detected in a large scintillation detector array capable of measuring detection time and location.

(left)
30" x 6" x 1.5" scintillators.

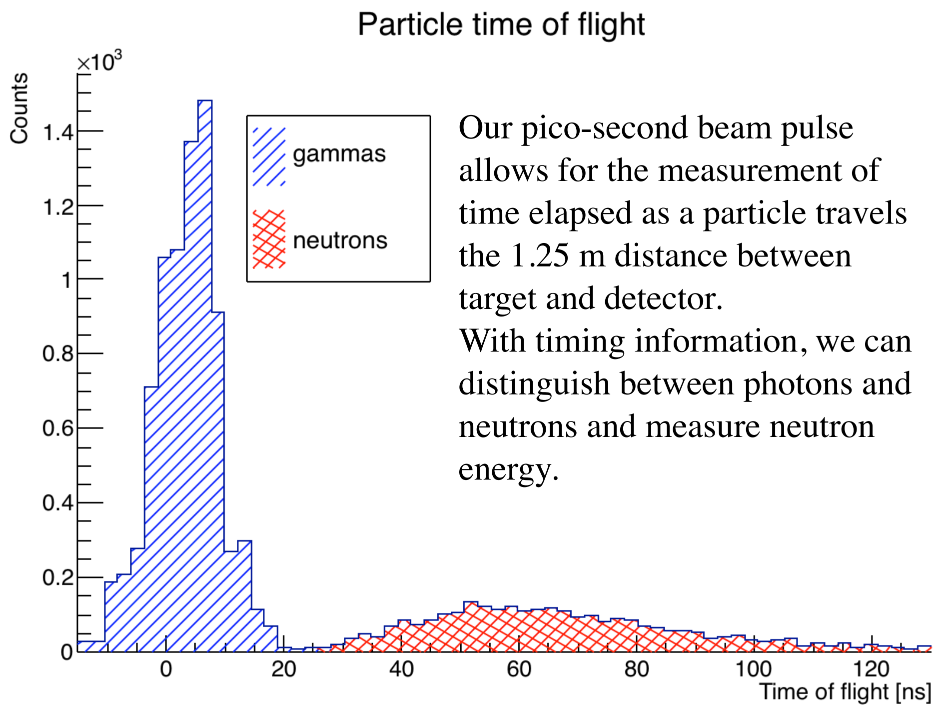
Light guides and PMT on each end.

Wrapped in reflective material.

Position information to within ± 10 cm obtained by timing delay between PMT's mounted at the two ends.



(Above) Depiction of the array of neutron scintillators surrounding the target.



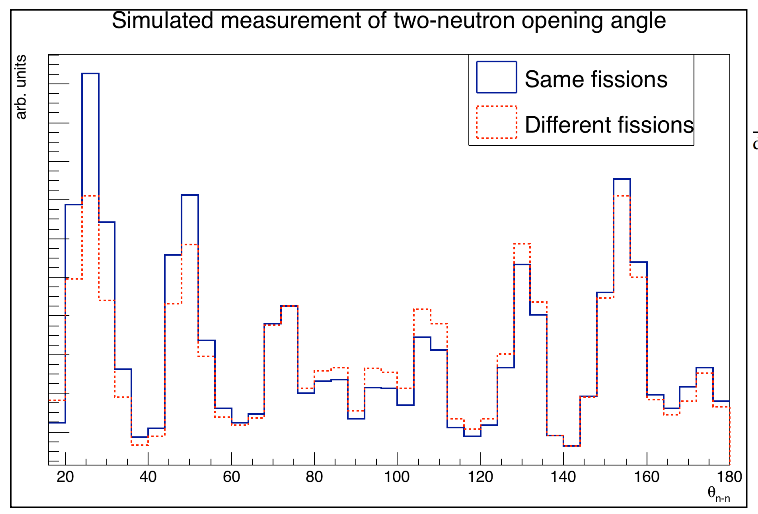
Our pico-second beam pulse allows for the measurement of time elapsed as a particle travels the 1.25 m distance between target and detector.
With timing information, we can distinguish between photons and neutrons and measure neutron energy.

(left)
One half of the neutron detector array.

Lead is placed along the front face of the detectors to reduce the detection of the photon background.

Polyethylene is placed along the sides to shield from neutron cross-talk.

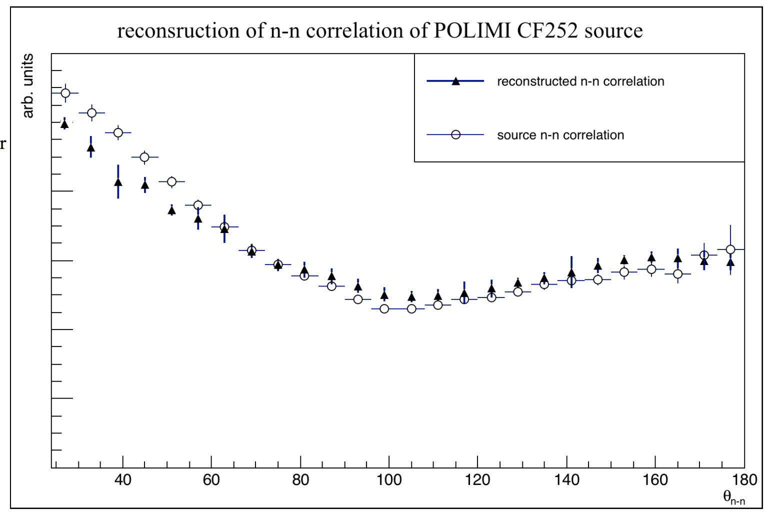
Analysis



$$\frac{\text{same fissions}}{\text{different fissions}} = \frac{\theta_{nnCorr} \times \theta_{acceptance}}{\theta_{acceptance}} = \theta_{nnCorr}$$

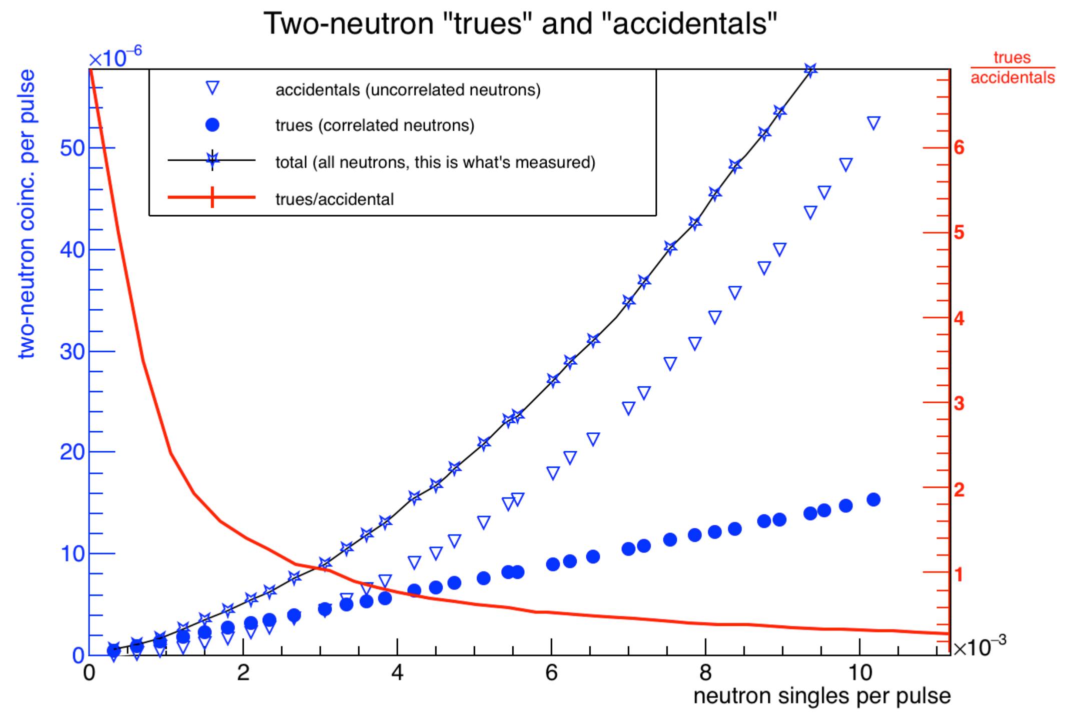
$\theta_{acceptance}$
This is the probability of detecting two particles of a given opening angle. It does not need to be known.

θ_{nnCorr}
This is the distribution to be measured: the opening angle distribution of fission neutrons.



(above)
Neutrons from different fissions (red dotted line) have uniform opening angle distribution, however, due to biases caused by detector array geometry, a non-uniform distribution is seen.

(above)
The detector array's opening angle bias is removed in analysis by dividing the two-neutron distributions of same fission by that from different fissions.



(left)
An *accidental* is the measurement two neutrons from two uncorrelated interactions. These are undesirable.
The accidental rate is proportional to the square of the neutron singles rate, R_n.

A *true* is the measurement of two neutrons from a single fission event. These contain the physics under investigation.
The trues rate is proportional to the neutron singles rate.

The total two-neutron rate, R_{2n}, is the sum of trues and accidentals.
We have:

$$R_{2n} = A\,R_n + B\,R_n^2$$

A and B can be determined by varying the beam current to produce points like shown on the graph. The beam current can then be set as high as possible, while also keeping accidentals rate to an acceptable level.