Study of Neutron response of PARIS Phoswich Detector

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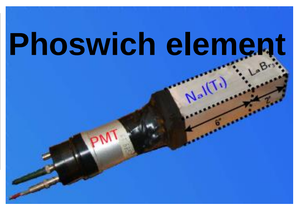
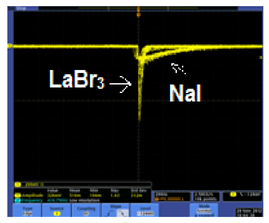
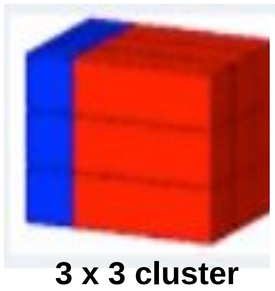
Introduction

PARIS - Photon Array for studies with Radioactive Ion and Stable beams

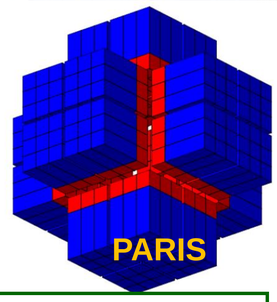




- ❑ **PARIS detector : Cluster of 3 x 3 array of phoswich detectors [1,2].**
- ❑ **Each phoswich element consists of 2" x 2" x 2" $LaBr_3$ (Ce) optically coupled to 2" x 2" x 6" NaI(Tl) with a single readout system [3].**



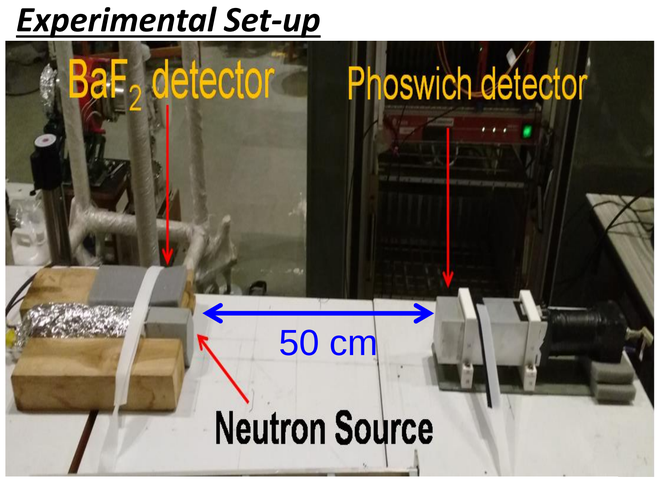
3 x 3 cluster

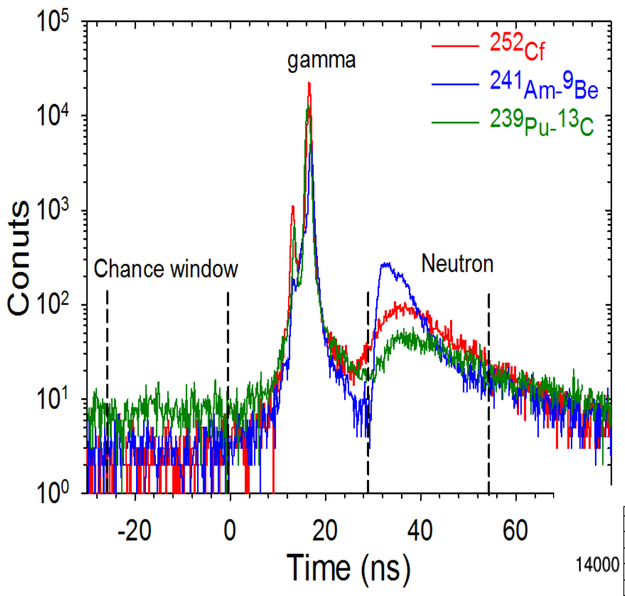


- ❑ **In the high energy gamma ray measurement, neutrons are the major source of background : Discriminated by time-of-flight technique (TOF).**
- ❑ **At closer distance, the n-gamma separation depends on the primary interaction of neutron in $LaBr_3$ crystal of the phoswich detector.**
- ❑ **Therefore, it is important to measure the neutron interaction in $LaBr_3$ and NaI crystal of the PARIS phoswich detector.**

Experimental Details

Experimental Set-up

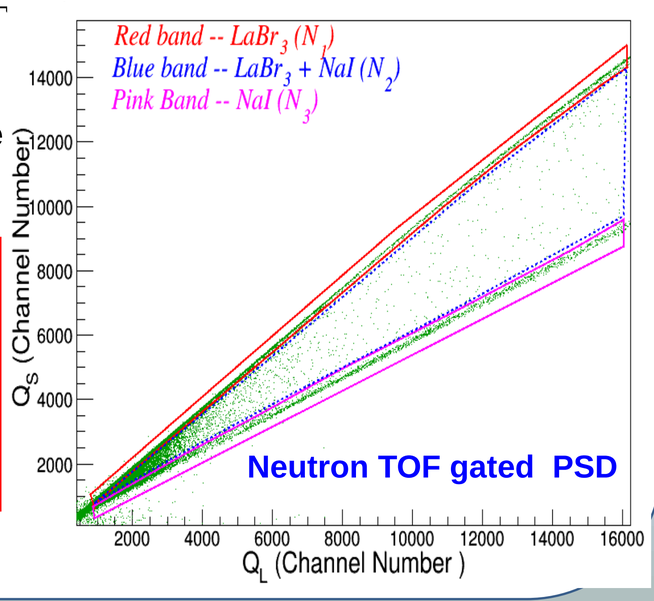




TOFSpectrum for different source

- ❑ **Three neutron sources (^{241}Am-^{9}Be, ^{252}Cf and ^{239}Pu-^{13}C) are used.**
- ❑ **Neutron are measured by TOF technique.**
- ❑ **START → BaF_2, ; STOP → Phoswich detector .**
- ❑ **A CAEN make VME based digitizer V1751 (1GHz, 10 bit, 1 vpp) has been used to collect the data. Analysis was performed in ROOT platform.**
- ❑ **For each event, time stamp, long gated (Q_L : 900 ns) and short gated (Q_S : 300 ns) energy are recorded.**

Timing information was extracted using an algorithm implementing CFD, incorporated in online WAVEWUMP software [3,4]



- ➢ **N_1 : In only $LaBr_3$**
- ➢ **N_2 : In both $LaBr_3$ and NaI**
- ➢ **N_3 : In only NaI.**
- ➢ **$N_{tot} = N_1 + N_2 + N_3$**
- ➢ **$f_1 = N_1/N_{tot}$, $f_2 = N_2/N_{tot}$, $f_3 = N_3/N_{tot}$ and $f_{12} = (N_1 + N_2)/N_{tot}$**

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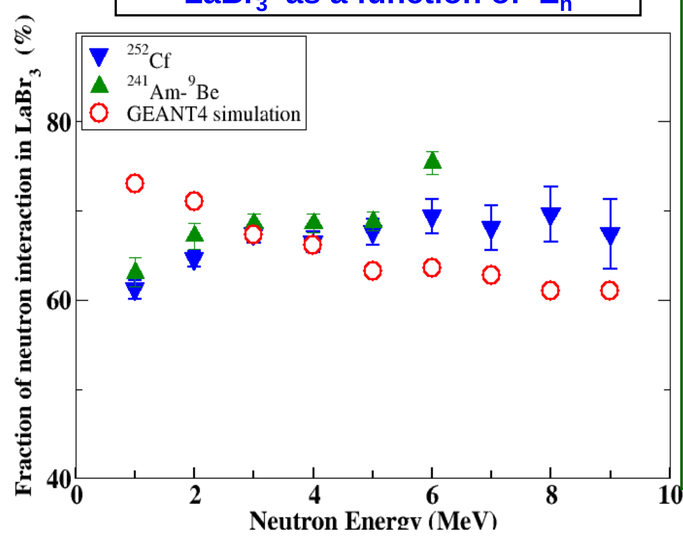
Relative neutron detection efficiency

Neutron Energy : $E_n = \frac{1}{2} m \left(\frac{L}{T}\right)^2 ; T = T_{n-\gamma} + T_0$

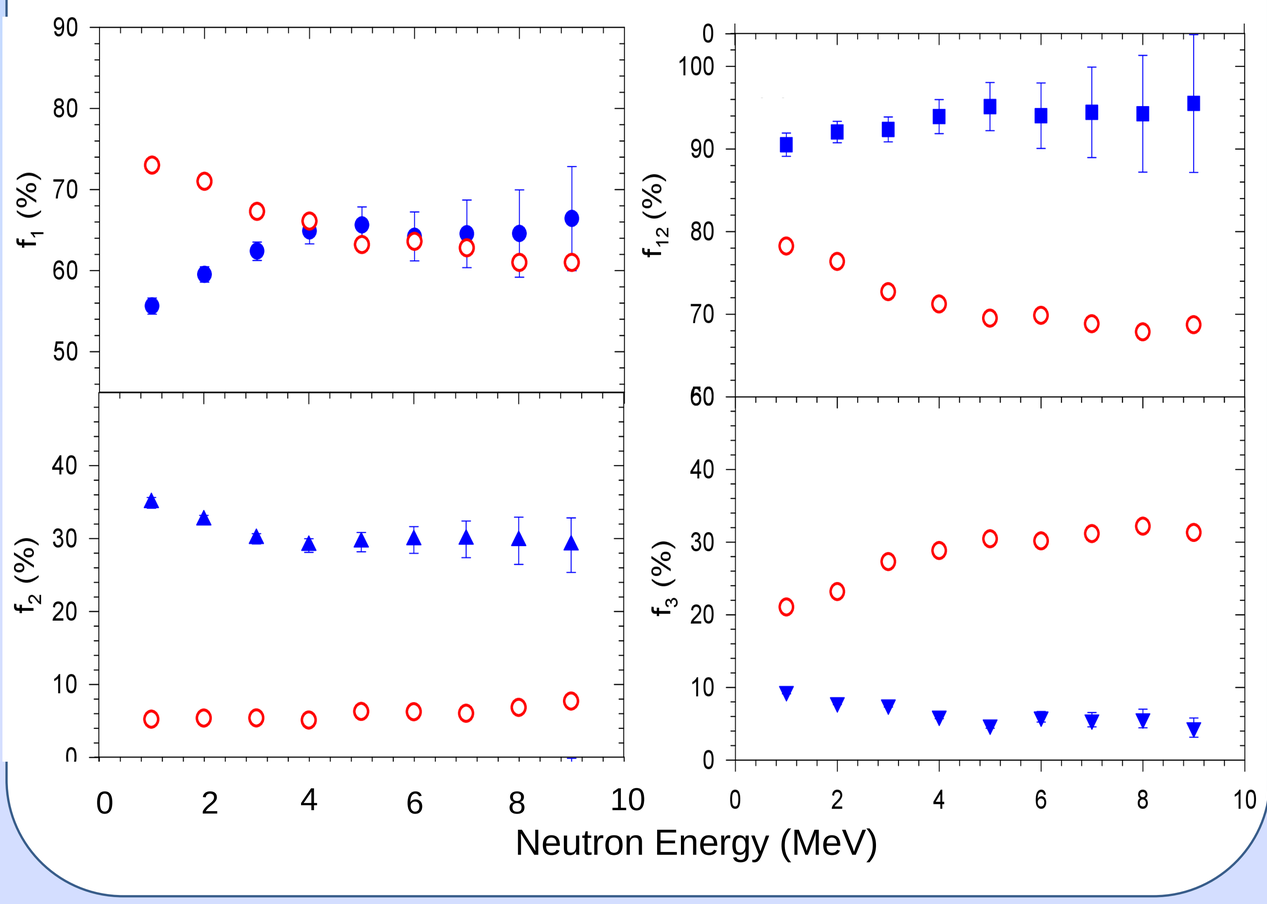
$T_{n-\gamma}$: **TOF of neutron with respect to γ – prompt .**

T_0 = 1.67 ns, corresponds to TOF of γ–ray flight path (L)

Neutron detection efficiency of $LaBr_3$ as a function of E_n



- ❑ **Neutron detection efficiency ($LaBr_3$) increases up to E_n = 3 MeV and constant thereafter, consistent for different neutron sources.**
- ❑ **GEANT4 simulation can not explain the exp. Data – May be because of Neutron libraries in the code , also reported in Ref [5]..**



Results and Discussion :

- ❑ **Relative neutron detection efficiency in $LaBr_3$ and NaI components of the phoswich detector are measured in the energy range of 1–9 MeV.**
- ❑ **Efficiency for $LaBr_3$ (f_1) increases for E_n = 1 to 4 MeV and is nearly constant thereafter.**
- ❑ **The observed decrease in f_2 ($LaBr_3$ + NaI) and f_3 (NaI) is because of increased interaction probability in the front $LaBr_3$.**
- ❑ **It is evident that ~ 95 % of neutrons have primary interaction in $LaBr_3$ crystal for E_n > 3 MeV.**
- ❑ **However, the simulation does not match with the exp. data which could be due to the neutron libraries in the GEANT4 simulation, also reported in Ref [5].**
- ❑ **Overall, neutron rejection probability of ~ 95 % can be achieved in the Phoswich detector, even if at close distances (20 – 30 cm).**

Reference :

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4. K. V. Anoop et al., DAE-SNP **59, 858 (2014).**
5. J. L. Tain et al., NIMA **774, 17 (2015).**