Characterization of a compact LaBr$_3$ detector with Silicon photomultipliers at high 14 MeV neutron fluxes

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Aim of the work

In this work we present the response of the LaBr$_3$(Ce) crystal to 14 MeV neutron irradiation measured at the Frascati Neutron Generator (FNG) together with a comparison with the MCNP simulations.

Furthermore, the neutron response of the SiPM has been also assessed after a neutron irradiation up to about 10$^{13}$ n/cm$^2$.

Gamma-ray emission in fusion plasmas

- Gamma-ray spectroscopy is a plasma diagnostic technique investigating the behaviour of fast ions in high temperature fusion plasmas.
- Gamma-ray emission in thermonuclear plasmas is mainly due to reactions between fast particles and fuel ions or impurities.
- The Gamma Camera installed at JET consists of a vertical and a horizontal camera made of 9 and 10 collimated lines of sight, respectively.
- Measurements along this multiple set of channels allow the tomographic reconstruction of the gamma emission source in the plasma.
- The detection of the 4.44 MeV γ-rays from the $^{9}$Be(c,n) reaction gives information on alpha particles in deuterium-tritium (DT) plasmas.

The GCU LaBr$_3$ gamma-ray spectrometer

- SiPMs represent a good alternative to PMT: high internal gain, insensitivity to magnetic field and extremely compact size.
- Read-out electronic circuit was ad hoc built to combine the high counting rate capability with the good energy resolution.
- A proper pole zero cancellation network able to shorten the output signal to 120 ns has been implemented allowing spectroscopy at MHz count rate [1, 2].
- Energy resolution $5\% \div 0.661$ MeV

SiPM resistance to neutron flux

- It is well known that silicon devices can get damage by neutrons.
- We need to investigate the neutron damage in our SiPMs in view of the DT JET campaign, in terms of effects on the PHS and on the Dark Current.
- Estimated neutron fluxes for full DT plasmas are:
  - $10^{2}$ n/cm$^2$ on the central channel of the vertical camera (VC)
  - $10^{3}$ n/cm$^2$ on the central channel of the horizontal camera (HC)
- $\Phi$ (function of $x=a$ to $x=b$) Dark current partially decrease in few days
- We reached fluences up to $4 \times 10^{16}$ n/cm$^2$ for the HC
  4000$^2$ of full power DT for the VC
- We can still clearly observe the peaks from $^{60}$Co source after $F=1.5 \times 10^{16}$ n/cm$^2$
- No significant differences are shown in the pulse height spectrum (PHS).
- Still a good energy resolution has been obtained.

Conclusions

- The effect of 14 MeV neutrons on both LaBr$_3$ crystal and the SiPM was measured.
- The GCU LaBr$_3$ has about 30% detection efficiency to 14 MeV neutrons.
- The neutron induced background under the 4.44 MeV peak from $^{9}$Be(c,n)$^{12}$C reaction is 1/300 of that at low gamma-ray energies.
- 14 MeV neutrons have some effects on the SiPM ($\Phi_{n}$ increase), but we can still measure a spectrum from a $^{60}$Co source with good energy resolution.
- The SiPM self recovery ($\Phi_{n}$ decrease) to some extent over a period of a few days

References

2. [Figueiredo et al., “Gamma-ray spectroscopy of neutron counting with a compact LaBr$_3$ crystal and silicon photomultipliers for fusion plasmas applications.” Rev. Sci. Instrum. 81, 075114 (2010)].

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