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Short_Oral_25: Conceptual design of a Cherenkov based gamma-ray diagnostic for measurement of 17 MeV gamma rays from $T(D, \gamma)^5\text{He}$ in magnetic confinement fusion plasmas

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At present, the only method for assessing the fusion power throughput of a reactor relies on the absolute measurement of 14 MeV neutrons produced in the D-T nuclear reaction. [1]

For ITER and DEMO, however, at least another independent measurement of the fusion power is required.

The ^5He nucleus produced in the D-T fusion reaction has two de-excitation channels. The most likely is its disintegration in a particle and a neutron, $D+T \rightarrow ^5\text{He} \rightarrow \alpha+n$, by means of the nuclear force. There is however also an electromagnetic channel, with a branching ratio $\sim 10^{-5}$, which leads to the emission of a 17 MeV gamma-ray, i.e. $D+T \rightarrow ^5\text{He}^* \rightarrow ^5\text{He}+\gamma$. [2] The detection of this gamma-ray emission could serve as an independent method to determine the fusion power.

In order to enable 17 MeV gamma-ray measurements, there is need for a detector with some coarse energy discrimination and, most importantly, capable to work in a neutron rich environment.

Conventional inorganic scintillators, such as $\text{LaBr}_3(\text{Ce})$, have comparable efficiencies to neutrons and gamma rays and they cannot be used for 17 MeV gamma-ray measurements without significant neutron shielding.

In order to overcome this limitation, we here propose the conceptual design of a gamma ray counter with a variable energy threshold based on the Cherenkov effect and designed to operate in intense neutron fields.

The detector geometry has been optimized using Geant4 so to achieve a gamma-ray to neutron efficiency ratio better than 105. The design is based on a gas Cherenkov detector and uses a CsI coated scintillating GEM (Gas Electron Multiplier) as photon pre-amplifier, together with a wavelength shifter to minimize the sensitivity to neutrons.

Photons produced in the GEM are collected by an optical window and a bundle of optical fibers, which guides them towards an array of silicon photomultipliers (SiPMs) located further away from the plasma, in a region at low nuclear radiation.

References

[1] L. Bertalot et al., "Fusion Power Measurement at ITER," in IEEE Transactions on Nuclear Science, vol. 63, no. 3, pp. 1682-1687, June 2016, doi: 10.1109/TNS.2016.2553125.

[2] F. E. Cecil et al., "Measurement and application of $\text{DD}\gamma$, $\text{DT}\gamma$ and $\text{D}^3\text{He}\gamma$ reactions at low energy." Netherlands: N. p., 1985. Web.

[3] S. Agostinelli et al. "Geant4—a simulation toolkit", Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, V 506, Issue 3, 2003, 250-303.

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