Neutron Camera Tests

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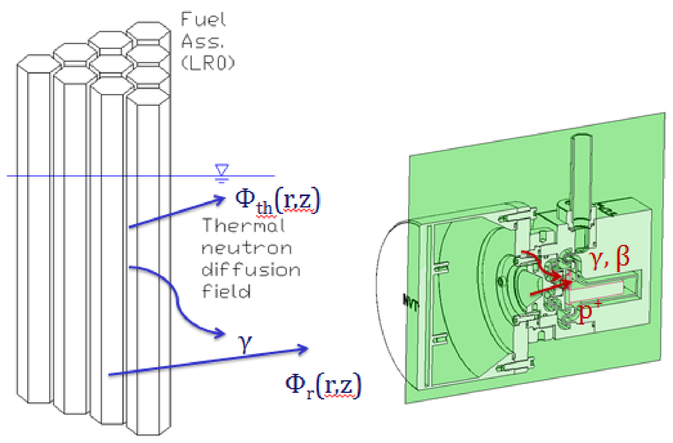
Abstract

The goal of this work was to investigate the possibility of neutron detection with Timepix device and to use of this type of detector together with a shielded neutron camera NVT90Ti for neutron tests inside a research reactor.
Nowadays neutrons can be detected using various types of devices for different purposes. The radioactive indicators (probes) are utilized to discover mainly the neutron flux and neutron fluence in reactors. Coupled-charged device (CCD) cameras coupled with scintillator screens, imaging plates, wire chambers are used to count neutrons via secondary particles. The disadvantage of mentioned detectors in comparison with Timepix-NVT90Ti device is either impossibility of direct neutron measurement (probes) or lower spatial resolution (instantaneous detector) or also a complicated application of particular method inside the nuclear reactor.
The hybrid silicon detector device Timepix has been recently developed for X- and gamma rays detection, but it can be also suited for neutron measurements. Its main advantages are a high spatial resolution (from 50μm for neutron tests), linearity of the response and wide dynamic range of energy measurement. The NVT90Ti camera
was designed directly for Timepix device. NVT90Ti camera is equipped with gadolinium shielding, is waterproof and should enable the Timepix device for measurement of neutron diffused field with high spatial resolution under the water surface of the nuclear research reactor. The main aim of this work is the proof of the ability of the whole device to be used as a neutron camera.

Introduction

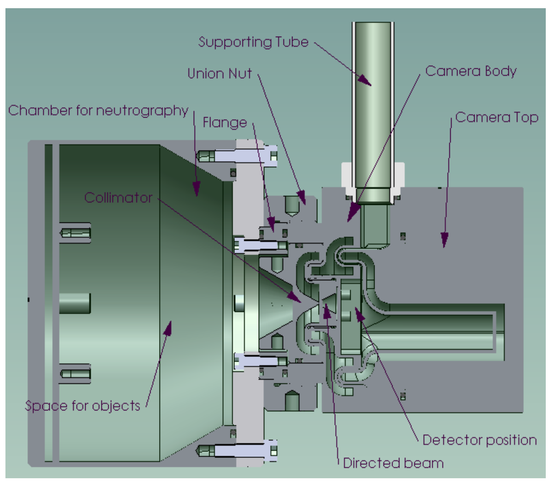


Draft of the experimental layout with indication of possible ionization radiation which has to be considered

Main tasks:

1) Neutron detection through secondary charged particles
2) Secondary particle (created by thermal neutron capture in conversion layer) discrimination from other types of charged particles or high energy radiation
3) Verification of gadolinium shielding function and its reactivity worth

Experimental Device



Longitudinal cross section of NVT90Ti camera

NVT90Ti Neutron Camera

- Design by Faculty of ME at CTU
- Manufactured by TVARMETAL s.r.o.
- Utility model application form requested
- 99.999% Gd shielding inside the detector chamber
- Construction material -aluminium alloy
- Waterproof design
- 3 types of collimators

Detector chip Timepix with USB interface FITpix

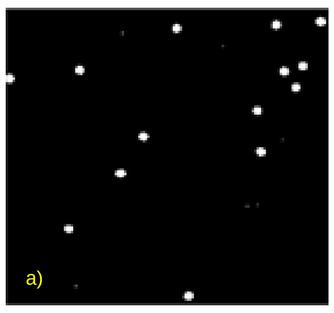
TIMEPIX detector

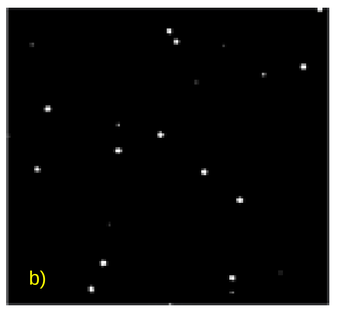
- Developed in CERN
- Lent by the Institute of Experimental and Applied Physics in Prague
- Semiconductor silicon detector (256 x 256 pixels, 55 um pitch)
- The device consists of a detector chip (100 um thick sillicon layer) bump bonded to a readout chip
- It can be operated in three modes - Counting particles, time of the detection, TOT)

Results

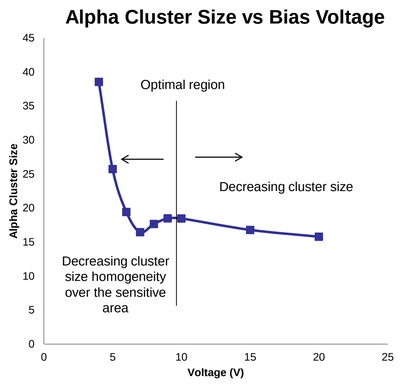
Alpha particle measurements

objective: to find optimal conditions under which the alpha particles could be easily discriminated from other events (gamma, electrons...)





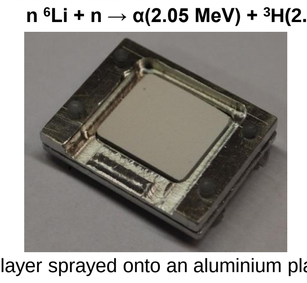
Alpha clusters for a) 4 Volts bias voltage and b) 20 Volts bias voltage, accompanied gamma rays can be seen as recognizably smaller clusters



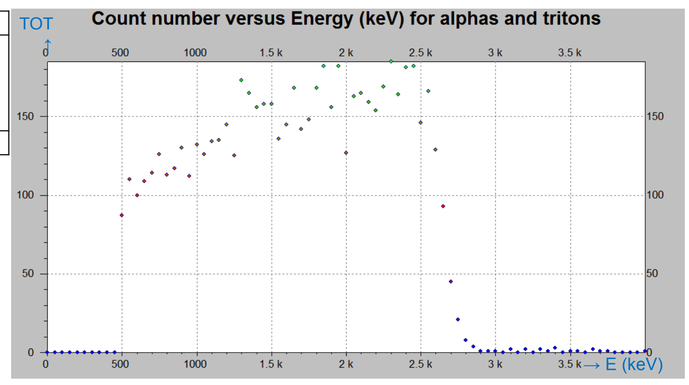
Conversion layer tests

Conversion Layer Parameters					
LiF Mass Ratio	Polyvinyl alcohol ratio	$^6Li/^7Li$	Mass of the powder – LiF (mg)	Area(cm^2)	Surface density (mg/cm^2)
95.16 %	4.84 %	89 %	24±1	2.78	8.6±0.4

Conversion reaction:
n ^{6}Li + n → α(2.05 MeV) + ^{3}H(2.72)



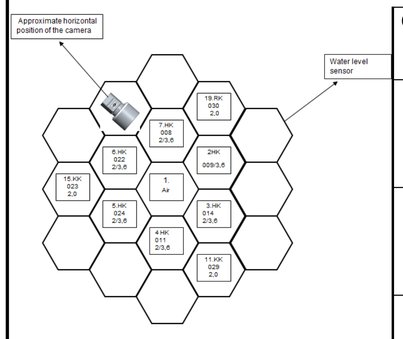
LiF layer sprayed onto an aluminium plate



Measured energy distribution of alpha and triton particles using 1Ci Am-Be neutron source and PE moderator

LR-0 Reactor Measurements

Objective: to estimate the reactivity worth of the gadolinium shielding at a particular position inside the reactor core



Camera vertical position	Critical parameters for given position		Reactivity worth
35 cm	Water level	(1000±0,3) mm	**~10 pcm**
	9/10 control rods	600 mm (stable position)	
	Regulation rod	(620±0,5) mm Δ=(12±0,5) mm	
90 cm	Water level	(1000±0,3) mm	**~30pcm**
	9/10 control rods	600 mm (stable position)	
	Regulation rod	(654±0,5) mm Δ=(36±0,5) mm	
No camera	Water level	(1000±0,3) mm	**0 pcm**
	9/10 control rods	600 mm (stable position)	
	Regulation rod	(608±0,5) mm	

Conclusions and Further Work

Observing the alpha particle cluster size depending on bias voltage there were found average cluster size maps for several values of bias voltage. Alpha cluster size versus bias voltage characteristics had been measured and it has been determined that the bias voltage of 9 Volts meets well the requirements for homogeneity of cluster size over the detector surface.
So far done measurements have confirmed, what had been already proved by other studies, that the Timepix device is able to detect thermal neutrons using conversion layer made of lithium florid. In further research it should be used pure thermal neutron instead of Am-Be source to obtain energy and cluster size distributions of secondary alpha and triton particles without any significant presence of background noise.
The reactivity worth of the gadolinium was not determined with high level of accuracy, but as a first attempt it was shown that the criticality is reachable with the presence of the camera inside the detector at these particular positions. It was assured also the waterproofness of the camera, which was an essential condition for Timepix insertion for reactor tests. However it was not tested the influence of gadolinium activity inducted by neutron capture. This activity could cause significant noise if the Timepix detector was inserted and exploded to the neutron field. This task should employ further research as well.

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