Upgrade of the hybrid magnetic SCAN-3 spectrometer at the Nuclotron

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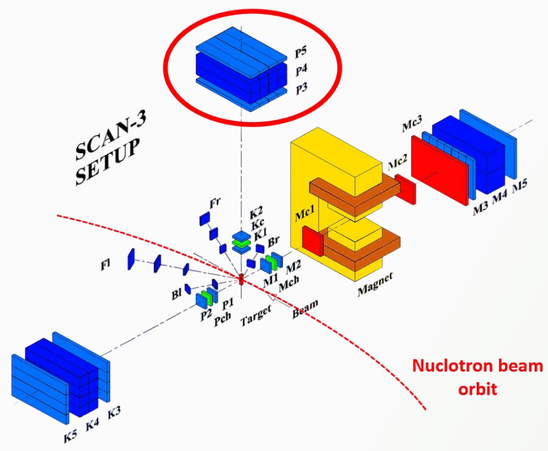
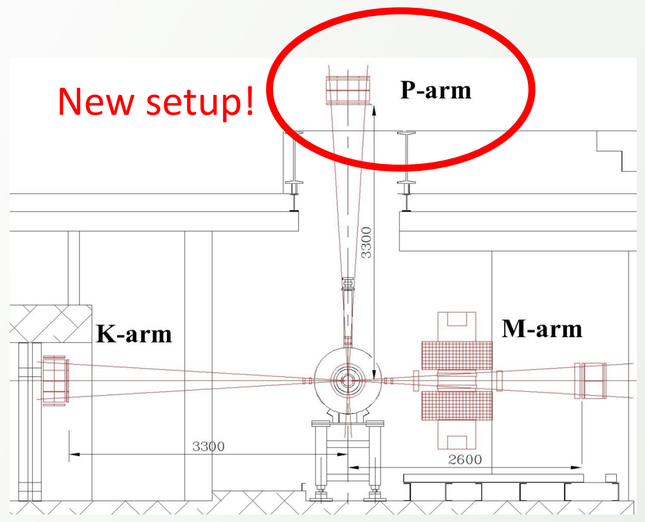
Abstract. *The multilayer neutron detector for the SCAN-3 spectrometer at the Nuclotron accelerator has been developed. Neutron detector consists of a set of 3×2 modules covering total area of 80×54 cm^2. Each module represent 4-layer scintillator detector with dual light readout from scintillator plates by PMTs. This work is necessary for «P»-arm and «K»-arm of SCAN-3 spectrometer upgrade. Moreover, the magnetic «M»-arm is also being upgraded, including drift chambers and a scintillation multilayer hodoscope.*

The SCAN-3 spectrometer

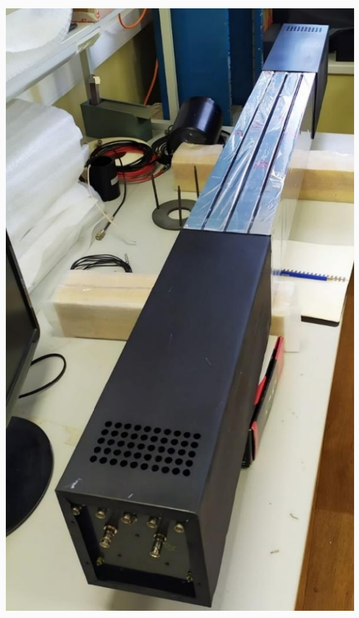
The SCAN-3 spectrometer [1] is designed to detect charged particles ($\pi^{\pm}$, $K^{\pm}$, p), neutrons and nuclei fragments with low energy produced in the target by collisions of the NUCLOTRON high-interactive beam particles with target nuclei. One of the tasks of the spectrometer is to detect neutrons from the decay of the η-meson nucleus via $n\pi$- and pn- channels. To reach the required accuracy of neutron energy measurements in energy region 90÷300 MeV, it is necessary to measure the TOF (δt) of neutrons with an accuracy not lower than δt = 400 ps and δL = 8 cm (spatial resolution) simultaneously.

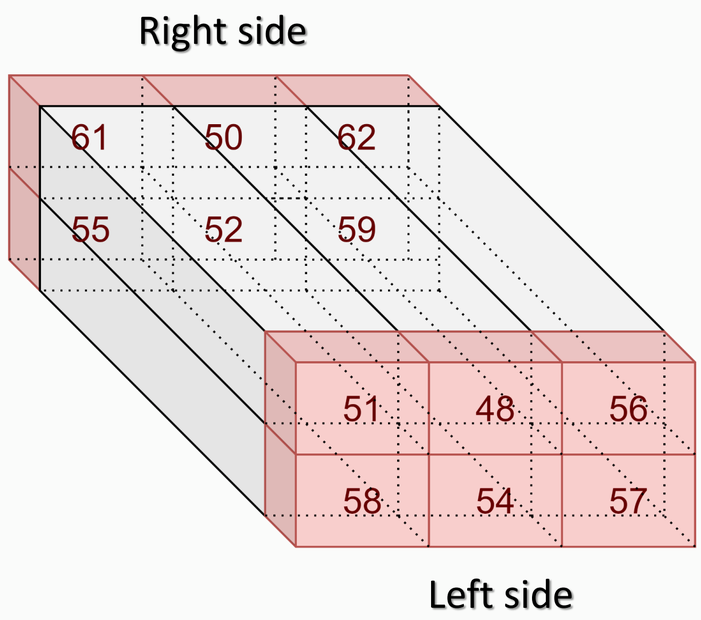
A 24-items neutron scintillation detector divided into 6 independent modules (P-arm) has been developed to solve this complex problem.





Assembling of the multilayer neutron detector («P»-arm)





Each module of the P-arm (and another neutron arm «K-arm» in the future) consists of four scintillation blocks collected to a unified assembly [2]. It is necessary to achieve the required longitudinal spatial resolution. Dimensions of one detector assembly are 800×180×145 mm^3 included 5 mm air gaps between blocks.

Extraction of signals from blocks is performed by two independent sets of PMTs:

- Two Hamamatsu R1250 (or Philips XP2041 having similar characteristics and dimensions) PMTs located on opposite ends of the blocks provide simultaneous readout of signals from all blocks.
- Two PMT-87s located on opposite ends of the blocks provide readout of optical signals from each scintillator. This allows getting additional and independent measures from each individual block.

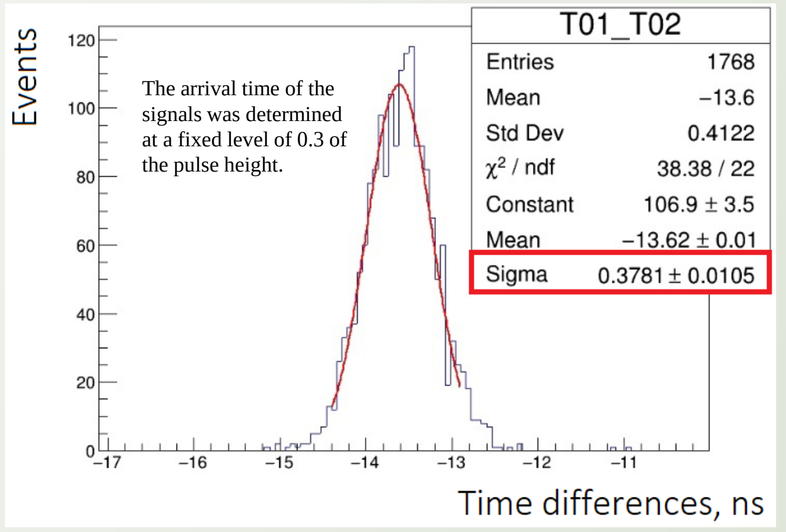
The total number of channels for module is 10: 2 channels from R1250/XP2041 PMTs and 8 channels from PMT-87.

The P-arm of the SCAN-3 spectrometer represents a 3×2 modules setup as shown in the picture above. Passing the high energy neutrons (energy region 90÷300 MeV) through the P-arm detector, interact on average with 2÷3 scintillators per module [3]. Since the thickness of one layer in the module is 3 cm, the total detector media is 24 cm. This approximately corresponds to 25% neutron registration efficiency.

Time resolution of individual neutron modules

As a result of tests of the P-arm detector modules on cosmic rays, time spectra of the difference in the arrival of signals for all modules were obtained. Since up to 10 independent time measurements are made in the module, the time resolution of the modules will be determined by the number of measurements performed, i.e. the number of triggered plates in the module. The final time resolution of the detector is defined as $\boldsymbol{\sigma_t/\sqrt{n+1}}$, where n = 1÷4 is the number of triggered plates, i.e. those from which information was taken into account to calculate the time jitter. In the worst case, we will have $\boldsymbol{\sigma_t/\sqrt{2}}$, and, consequently, the time resolution of the modules will be about **250÷270 ps** for modules with readout by Hamamatsu R1250 and **770÷830 ps** for modules with readout by Philips XP2041.

In additional, a 7-layer detector with improved spatial resolution is being developed to reach better separate charged pions from protons.



The detector has a similar design compared to neutron detectorists, except for the thickness of the scintillation plates (20 mm vs 30 mm in neutron detectors). The detector is shown in the picture on the left.

An important point is to obtain a fast starting signal that determine the collapse of the eta-meson nuclei into protons (pions) and neutrons. To solve this problem, a fast starting counter is being developed based on a thin scintillator and a PMT with MCP (micro-channels plates). At this stage, the time resolution of the counter has been obtained is about 85 ps under irradiation by cosmic rays.

Summary

The hybrid magnetic spectrometer SCAN-3 on the internal targets of the Nuclotron has been upgraded. Six multilayer neutron detectors (modules) and one 7-layer detector have been developed and created for this task. Neutron detector modules have been assembled into a new additional arm of SCAN-3 spectrometer.

References

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4. ***S.V. Afanasev et al.*** *Physics of Particles and Nuclei Letters, 2023, Vol. 20, No. 5, pp. 1232–1235.*

59th meeting of the PAC for Particle Physics, JINR, 2024