Applied studied in the framework of the FLAP collaboration (Fundamental & applied Linear Accelerator Physics collaboration) at JINR electron accelerator LINAC-200

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The electron accelerator LINAC-200 is a unique facility currently commissioned into operation at the Joint Institute for Nuclear Research, Dubna, with a number of controllable parameters: electron energy in a range from 26 to 200 MeV (anticipated up to 2 GeV), macropulse duration from 30 to 3000 ns with a bunch duration of 1 ps, current from 0 to 60 mA, the capability of adjusting the pulse repetition rate in a range of 2865±20 MHz. At present, this facility is the only one in the world with such flexible and reliably adjustable parameters. The high attractiveness of this facility to researchers resulted in the establishment of a new scientific collaboration FLAP (Fundamental & applied Linear Accelerator Physics collaboration).

Fig. 1. Linear accelerator LINAC-200 (JINR).

Current	60 mA
Frequency	1-100 Hz
Current pulse	0.1-3 µs

Fig. 2a. LINAC-200 parameters.

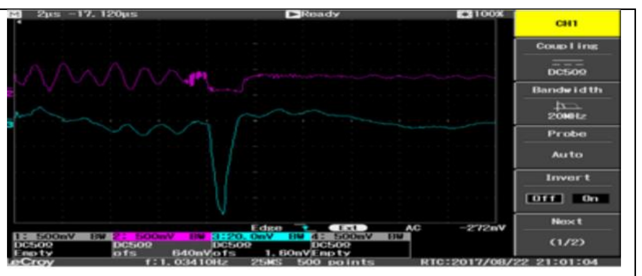


Fig. 2b. Current oscillogram at the output of LINAC-200.

The FLAP collaboration unites researchers from the Joint Institute for Nuclear Research (Dubna), Belgorod National Research University, National Research Tomsk Polytechnic University, Petersburg Nuclear Physics Institute, St. Petersburg Polytechnic University, John Adams Institute at Royal Holloway of University of London, FSUE Russian Federal Nuclear Center - All-Russian Research Institute of Experimental Physics, Center for Theoretical and Experimental Particle Physics of UNAB (Santiago, Chile), KEK (Japan), SOKENDAI (Japan), Institute of Applied Problems of Physics of NAS of Sciences of Armenia, Yerevan State University.

The FLAP collaboration is aimed at investigation of new fields of fundamental physics: generation of electromagnetic radiation by relativistic electrons for deeper understanding of the nature of electromagnetic interactions and development of advanced diagnostic tools for accelerated beams of charged particles, spintronic devices and novel superfast detectors of electromagnetic radiation; understanding of the origin of CP violation in terms of new axion-like bosons; as well as a number of applied topics, such as nondestructive diagnostics of circulating and extracted accelerated particle beams, development of neutron detectors, pulsed neutron sources, radiobiological issues.

Six main directions are considered in the framework of the project.

The first direction addresses the processes of relaxation of electromagnetic response of materials based on topological insulators and Dirac semimetals (whose electron mobility exceeds substantially that of graphene) irradiated by bunched relativistic electron beams and development of contactless devices for diagnostics of charged particle beams, electromagnetic radiation, spintronic devices.

The second direction focuses on the problems of controlling spectral and angular characteristics of photon response for metamaterials irradiated by bunched relativistic electron beams, as well as the development of unique highly monochromatic and narrowly directed controllable sources of electromagnetic radiation of the new generation.

The third direction is devoted to the investigation of polarization mechanism of electromagnetic radiation in surface structures with high local electron density irradiated by relativistic electron beams and the possibility of generation of radiation in the charge-space coherence mode.

The fourth direction is aimed at investigation of interaction of relativistic electron beams with nanocapillary and corrugated devices, in the electron channeling mode. This direction addresses the processes of formation of a self-consistent electric field on inner walls of nano- and micro-capillaries under the action of relativistic electron beam passing through them. The processes of passage of such beams through corrugated axially symmetric structures and arrays of oriented capillaries will also be studied. Of special interest are the conditions of stable particle channeling in such targets.

The fifth direction covers several applied problems. They are the development and testing of advanced detectors for nondestructive beam diagnostics, as well as development and calibration of novel detectors of secondary neutron fluxes. Development of modern principles of controlling large-scale physics facilities, involving machine learning. Creation of sources of secondary particles, such as neutrons, with controllable properties for studies in the field of high pressure physics and equations of state. Investigation and development of modern methods and approaches in radiation medicine with controllable electron and gamma beams.

The sixth direction focuses on studies of sensitivity to new physics beyond the Standard model. In particular, it is planning to look for light particles: axion-like, dark-photon-like and Higgs-boson-like parties in MeV range. One of the main differences with similar ongoing projects in US and Germany is the use of sick heavy targets.

Below we present in some detail the part of the research program of the FLAP collaboration, as regards the development, testing and calibration of MCP-based detectors for nondestructive diagnostics of accelerated ion beams, neutron detectors for the purposes of applied research, including novel concepts of power production, pulsed neutron sources for investigation of extreme states of matter and neutron diagnostic tools for high pressure and EOS physics.

Taking into account the capability of variation of the time structure of the electron beam from units of Hz to MHz and a short bunch duration of up to 50 ns, it is possible to study loading characteristics (recovery time) of detectors based on chevron (dual) assemblies of microchannel plates (MCP). Such detectors have been extensively used at LNP and LHEP JINR for nondestructive monitoring of circulating and extracted accelerated particle beams [6, 7]. Such detectors will be (and are) applied at the constructed Booster, Nuclotron, and storage rings of the NICA acceleration complex. A small-angle scattering detector based on MCP for the experiment SPD is under development [8].

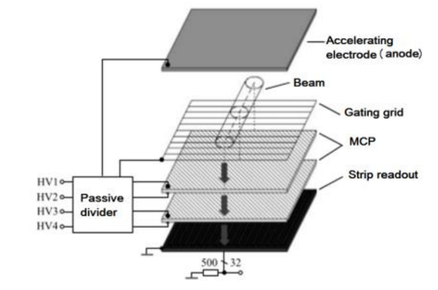


Fig. 3a. Schematic diagram of MCP-based detector.

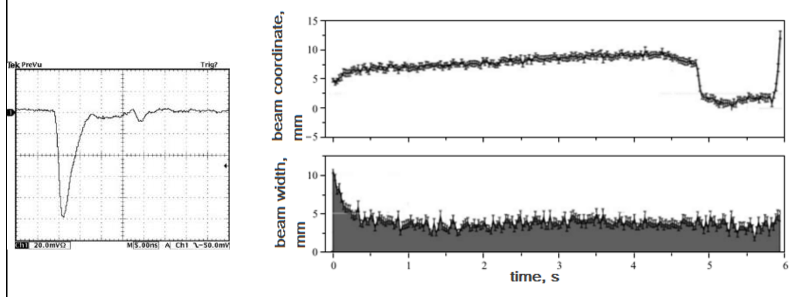


Fig. 3b. MCP-based beam position monitor tested at JINR.

A series of measurements of pulsed (up to 10000 particles in 50 ns) loading of detectors depending on the pulse repetition rate is planned in close cooperation with LLC "Baspik", manufacturer of MCP.

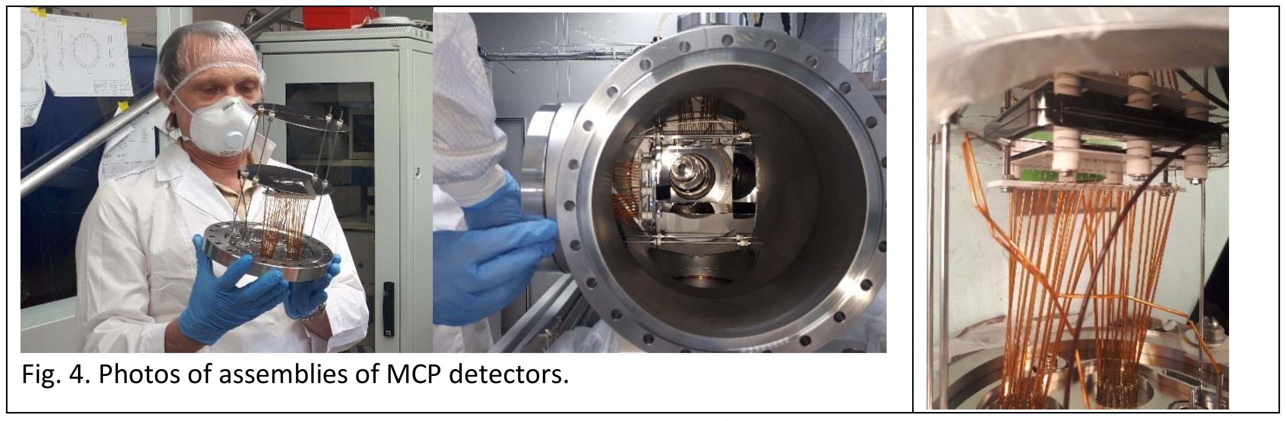
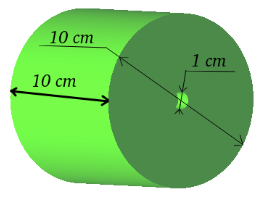


Fig. 4. Photos of assemblies of MCP detectors.

Experiments with secondary neutron beams will also be performed at LINAC-200. Some promising neutron detectors will be tested at secondary neutron fluxes produced in interaction of relativistic electron beam with target nuclei, in the pulsed irradiation mode. Simultaneous registration of time-of-flight neutron spectra and the use of threshold neutron detectors will provide testing and calibration of new types of spectrometric neutron detectors.



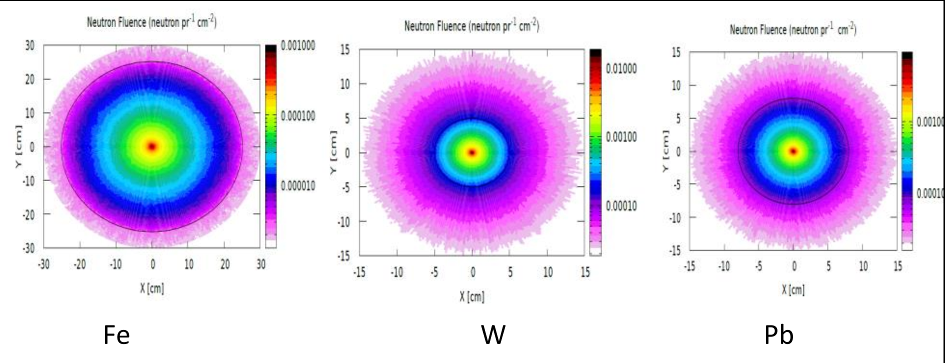


Fig. 5. Thick heavy target for neutron generation. Neutron fluence in Fe, W, Pb.

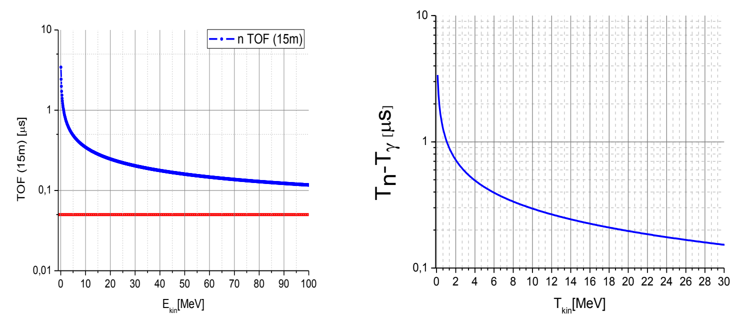


Fig. 6a. Time of flight for neutrons at 15 m.

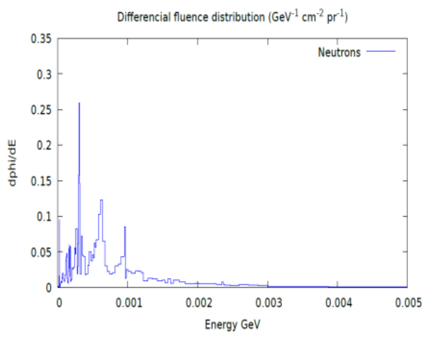


Fig. 6b. Neutron energy spectrum in Fe target.

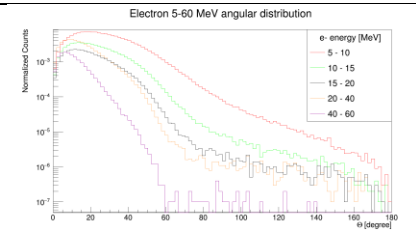


Fig. 7a. Secondary electrons in Fe target.

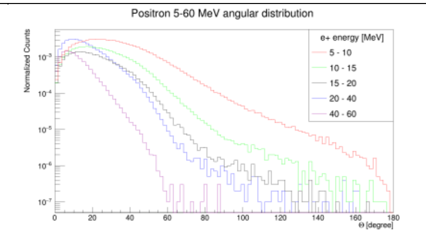


Fig. 7b. Secondary positrons in Fe target.

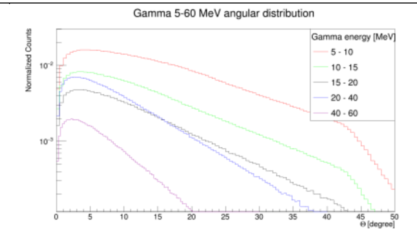


Fig. 7a. Secondary gammas in Fe target.

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