Development, Testing, and Upgrade of Trigger and Neutron Detector Systems for the BM@N Experiment

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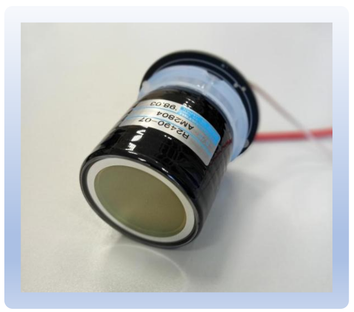
1. Overview

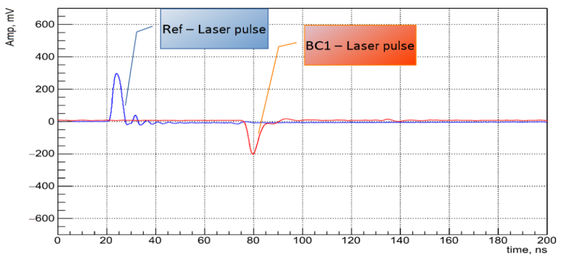
Time-of-flight measurements with picosecond resolution and efficient triggering are essential requirements for modern experiments with relativistic ion beams.

A system of trigger detectors has been developed, tested, and upgraded for the BM@N experiment. The trigger detectors use plastic scintillators equipped with specialized PMTs and SiPMs operating in the strong BM@N magnetic field and providing high detection efficiency, good pulse-height resolution, and picosecond-level timing.

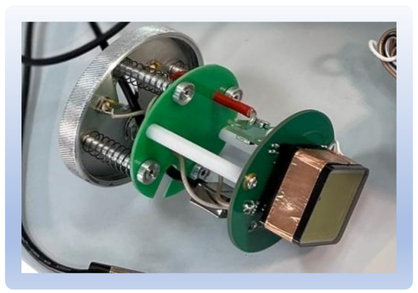
2. Laboratory studies

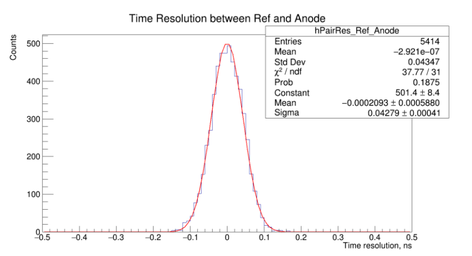
During the first phase (2021–2022), laboratory tests of the updated trigger detectors: BC1, BC2 (T0), and Barrel Detector (BD) were conducted, including an assessment of the photomultiplier stability, time resolution, and signal detection efficiency. The results confirmed the detectors' readiness for further use in the BM@N experiment.



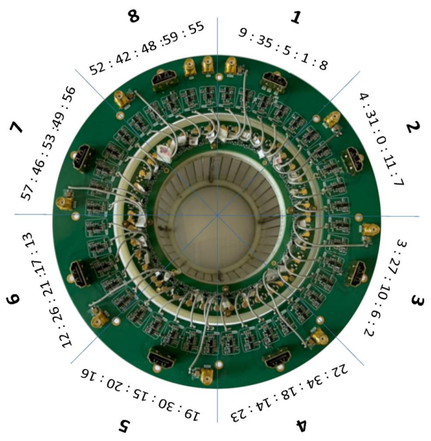


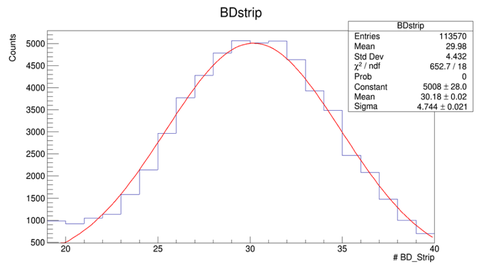
Laboratory test of the BC1 stability





Measurement of the time resolution of BC2



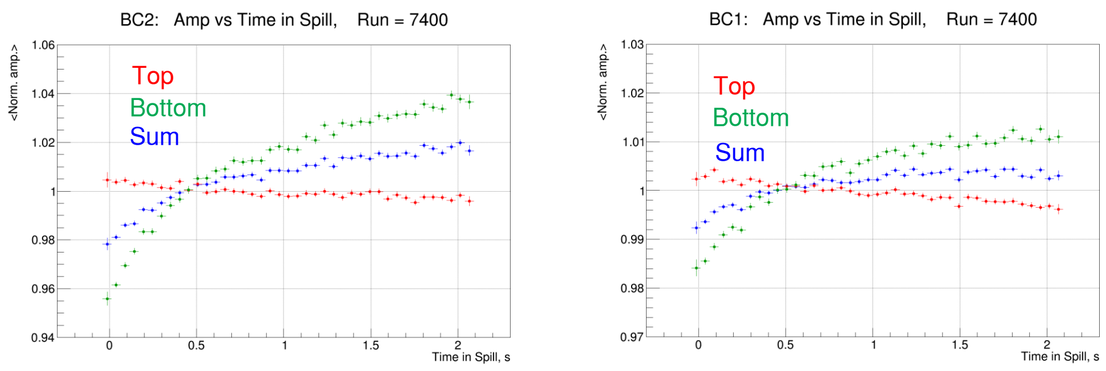


Mapping and checking the channels of the Barrel Detector

3. BM@N 2023 Run

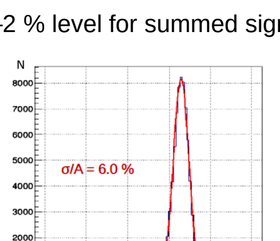
During the 2023 run with ^{124}Xe beams at 3.8 A GeV and intensities up to 10^6 ions per spill, the trigger system was successfully operated, demonstrating reliable performance. Time and amplitude resolutions, as well as long-term stability, were investigated, and a small degradation of the detector response under prolonged high-intensity irradiation was observed. These results motivated a comprehensive upgrade program that was realized in 2024-2025.

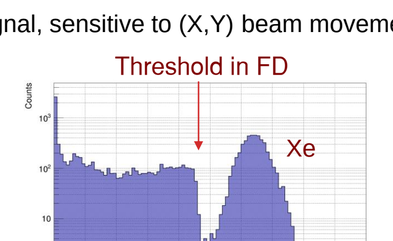
Beam counter performance



BC1, BC2 response in spill: stable at 1–2 % level for summed signal, sensitive to (X,Y) beam movement

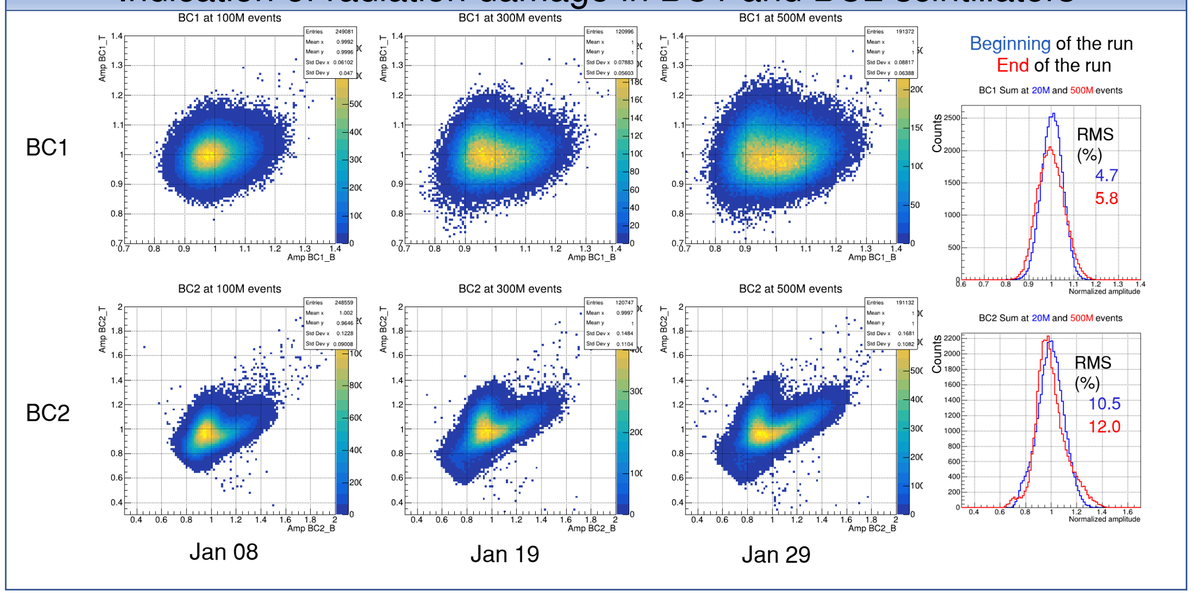
Detectors	Amplitude resolution $\sigma(Xe)$, %	Time resolution $\sigma(Xe)$, *ps*
BC1	4.8	43
BC2	7.1	38
BC1 & BC2	-	28





~65-70% centrality was selected by the threshold in FD

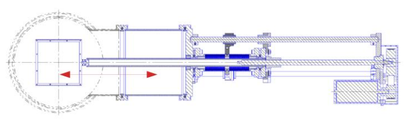
Indication of radiation damage in BC1 and BC2 scintillators



4. Upgrade program

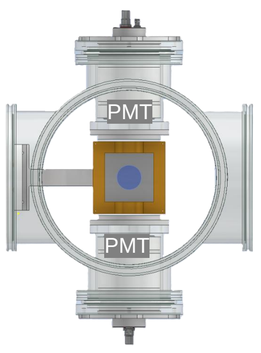
The program included the introduction of a new counter BC0 for offline calibration, new vacuum boxes with wider side openings, the redesign of scintillators with light guides to minimize material in the beam path and the construction of BC2 with new PMTs. An in-vacuum design of the Fragment Detector providing the minimum-bias trigger was also implemented.

BC0

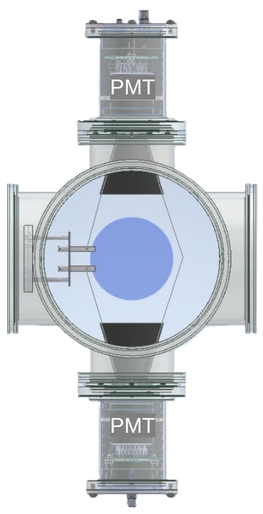


Scintillator can be moved in and out of the beam

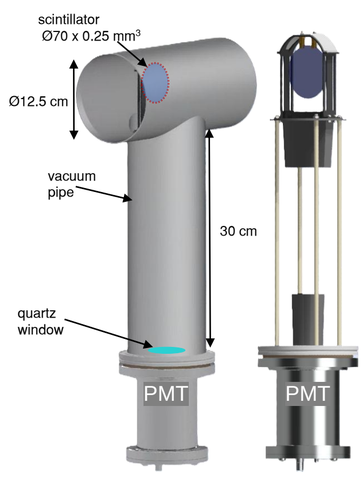
BC2



BC1



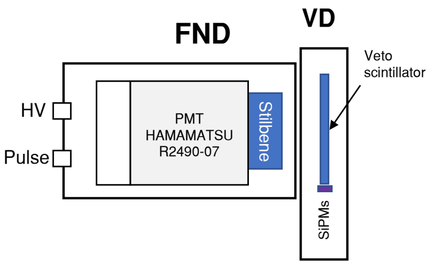
Fragment Detector



Another aim was the development of detectors with stilbene crystals for study of neutron energy spectra at small angles by TOF measurements in the 50–5000 MeV range.

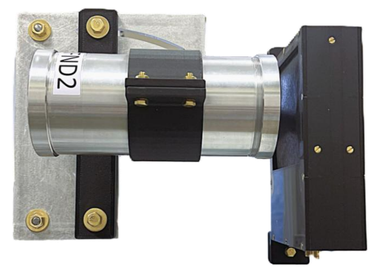
Forward Neutron Detectors

Detector	Stilbene	Angle
FND1	D31 × 31 mm	3°
FND2	D31 × 31 mm	6°
FND3	D40 × 20 mm	9°
FND4	D40 × 20 mm	12°



Aim of the measurements

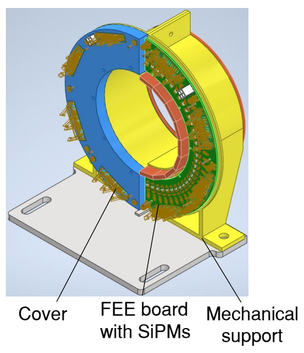
- ✓ Study of neutron emission from beam spectators and comparison with theoretical models and results of the compact TOF spectrometer
- ✓ Obtain reference data for the HGND project
- ✓ Study of neutron energy and angular distribution at nZDC

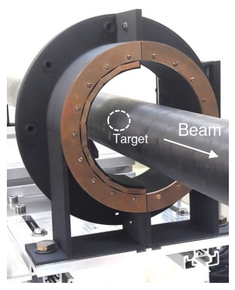


5. Future work

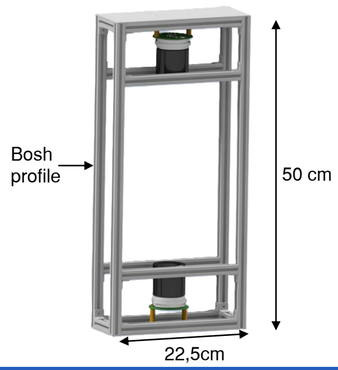
Planned activities for 2026 include the installation and testing of a new Barrel Detector, the development of quartz-radiator beam counters, and the analysis of experimental data from upcoming BM@N runs.

Construction of the new BD





Test counter - Main Frame



BM@N Experiment
1st experiment of the NICA project

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