Status of analysis of neutron data obtained with compact TOF neutron spectrometer

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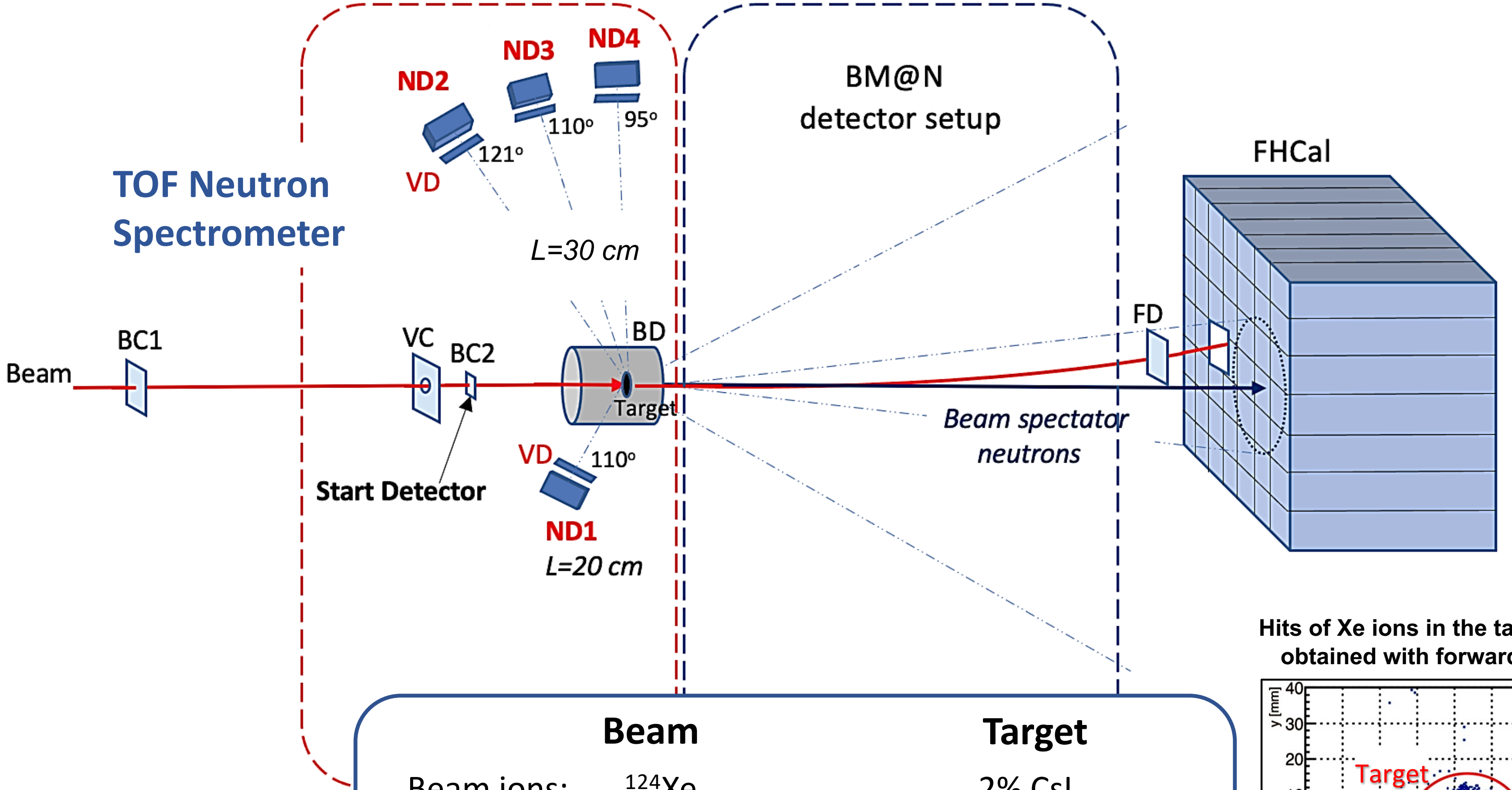
Compact TOF Neutron Spectrometer

BM@N run Dec.2022 – Feb.2023



Neutron Detectors

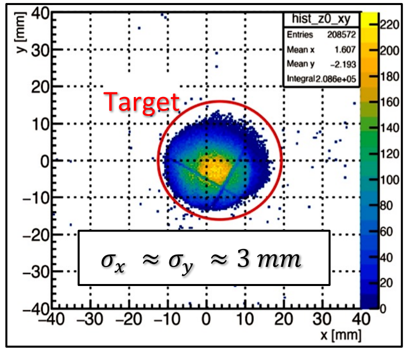
Detector	θ (deg.)	L (cm)	Stilbene (mm)
ND1	**110°**	**20**	**D30×10**
ND2	**121°**	**30**	**D25.4×25.4**
ND3	**110°**	**30**	**D25.4×25.4**
ND4	**95°**	**30**	**D25.4×25.4**

BC2 – Start detector (T0)

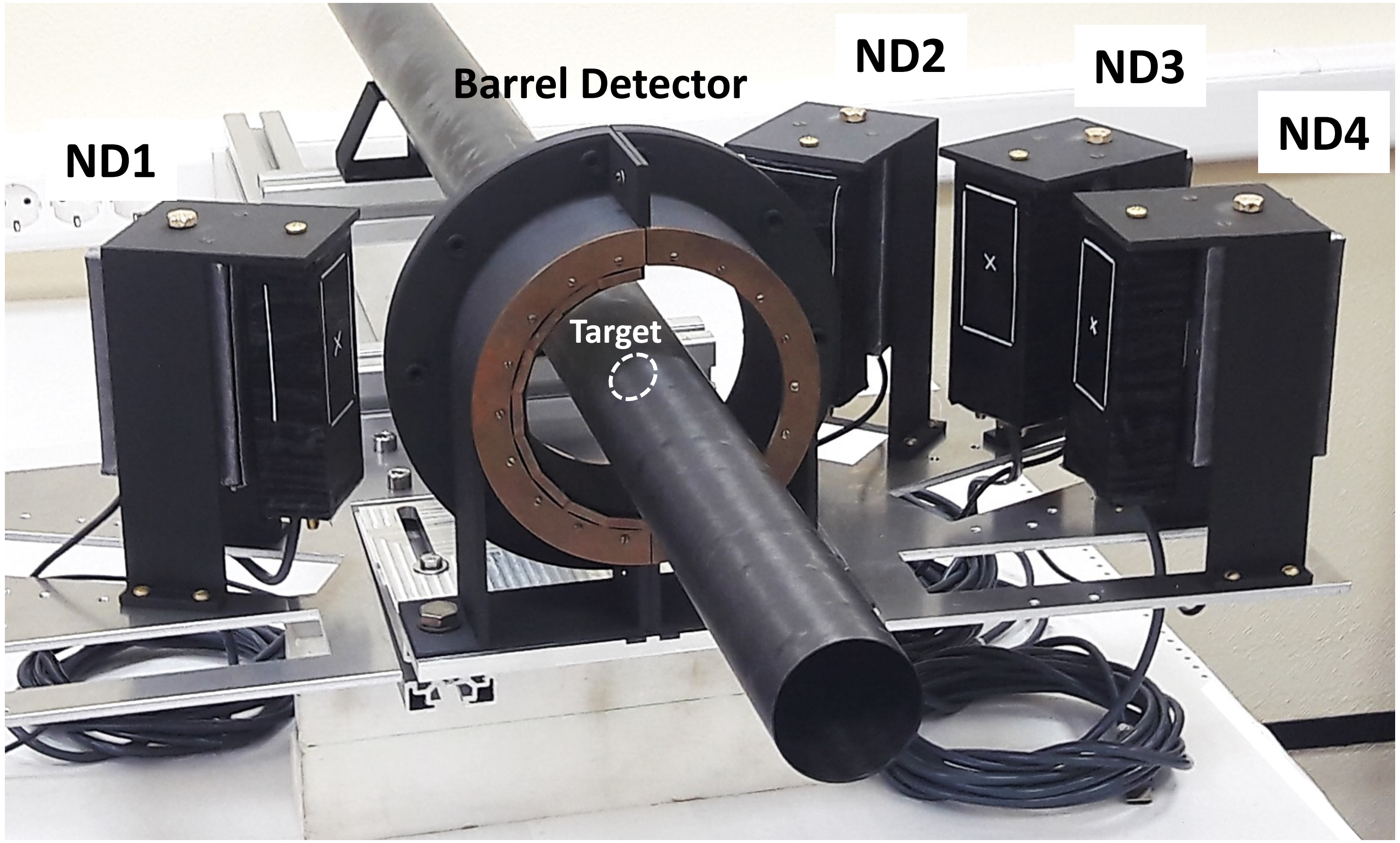
Scintillator: BC-400B, 34×34×0.15 mm^3
PMT: XPM85112/A1 (Photonis), 2 units
Time resolution: $\boldsymbol{\sigma_t}$ **= 40 ps**

Beam		**Target**
Beam ions:	^{124}Xe	2% CsI
Energy:	3.8 *A* GeV	D32 × 1.75 mm
Intensity:	~ 6 10^5 ion/spill	
Spill duration:	~ 2.5 s	

Hits of Xe ions in the target position obtained with forward Si tracker



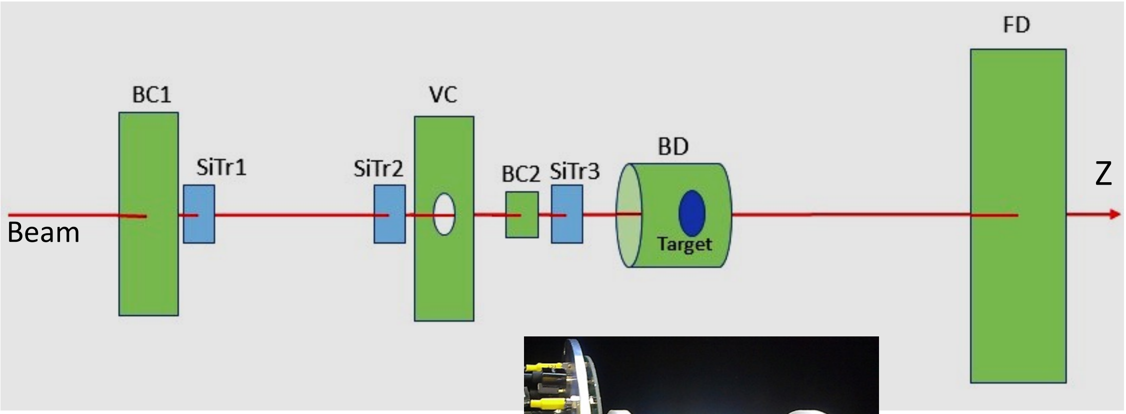
The compact TOF Neutron Spectrometer

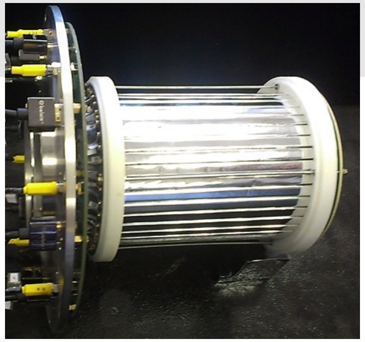


A new design of the neutron spectrometer (prototype)

Selection of Interactions in the Target

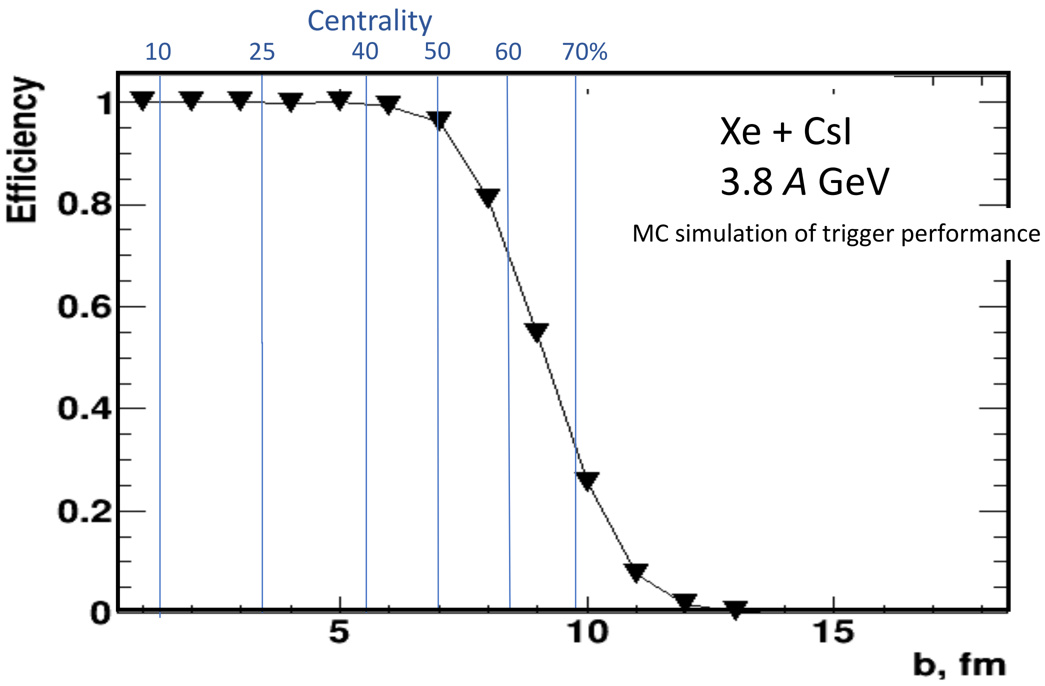
Trigger detector system of the BM@N experiment





Barrel Detector (BD)
40 scintillation strips

Trigger efficiency



Only events with one Xe ion in 3.6- μs interval in BC1 were used in the neutron data analysis

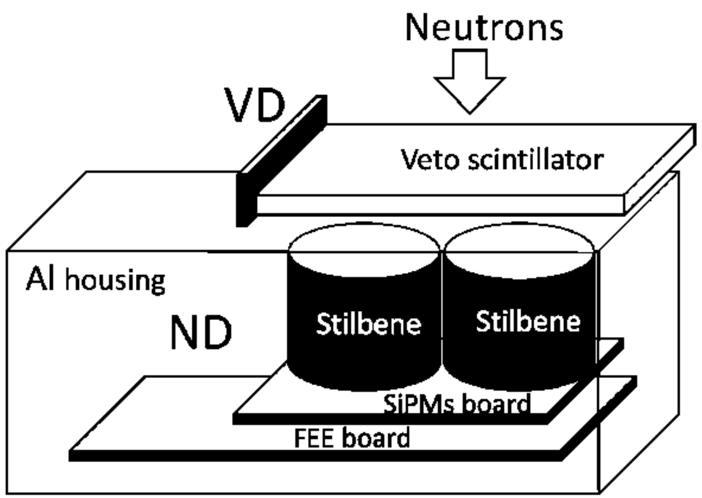
Interaction Trigger Logic:

Min. Bias Trigger (MBT) = BC1 * $\overline{\text{VC}}$ * BC2 * $\overline{\text{FD}}$

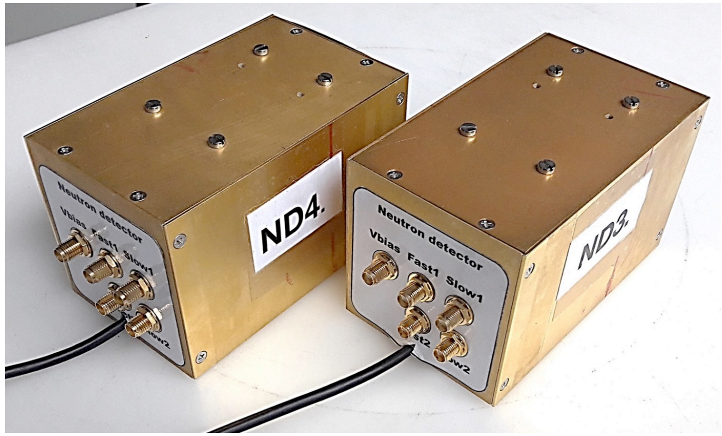
Main interaction trigger (CCT) = MBT * BD(N>3)

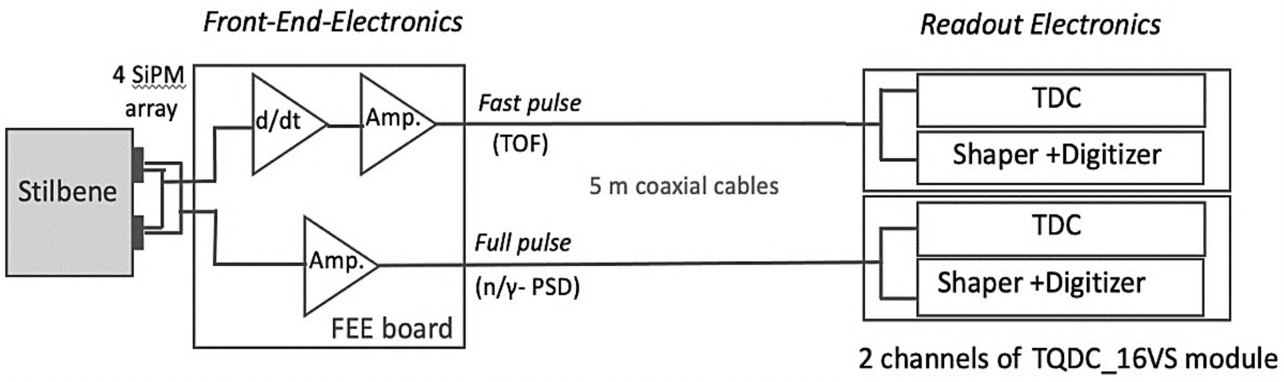
The interaction trigger allows to collect data from central to peripheral collisions if the BD response is >3 fired strips

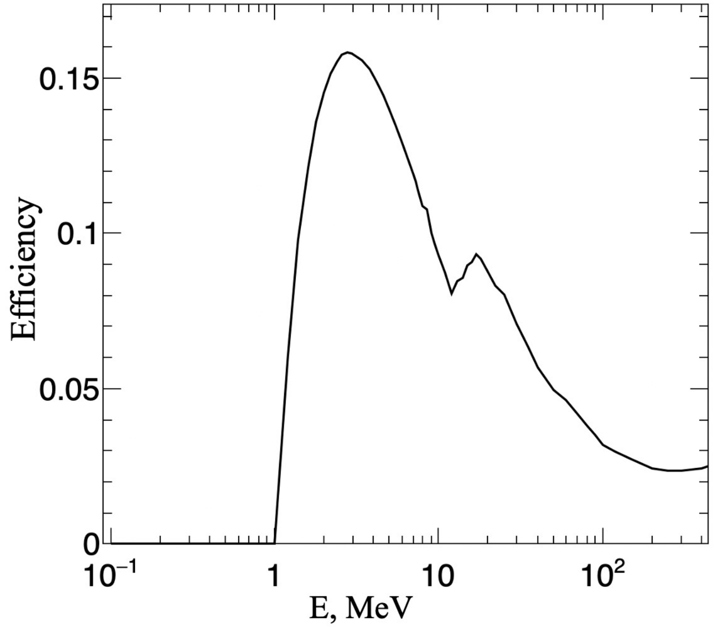
Neutron Detectors



Detection of scintillation photons with four SiPMs 6×6 mm^2, SensL, J ser.







Pulse shape n/γ- discrimination

Quality of pulse shape discrimination:

$$PSD = \frac{Q_{fast}}{Q_{total}}$$

T_{fast} = 0.12 μs : time window for charge integration Q_{fast}

T_{total} = 1.5 μs. : time window for charge integration Q_{total}

The integration time intervals are determined by pulse processing in TQDC module

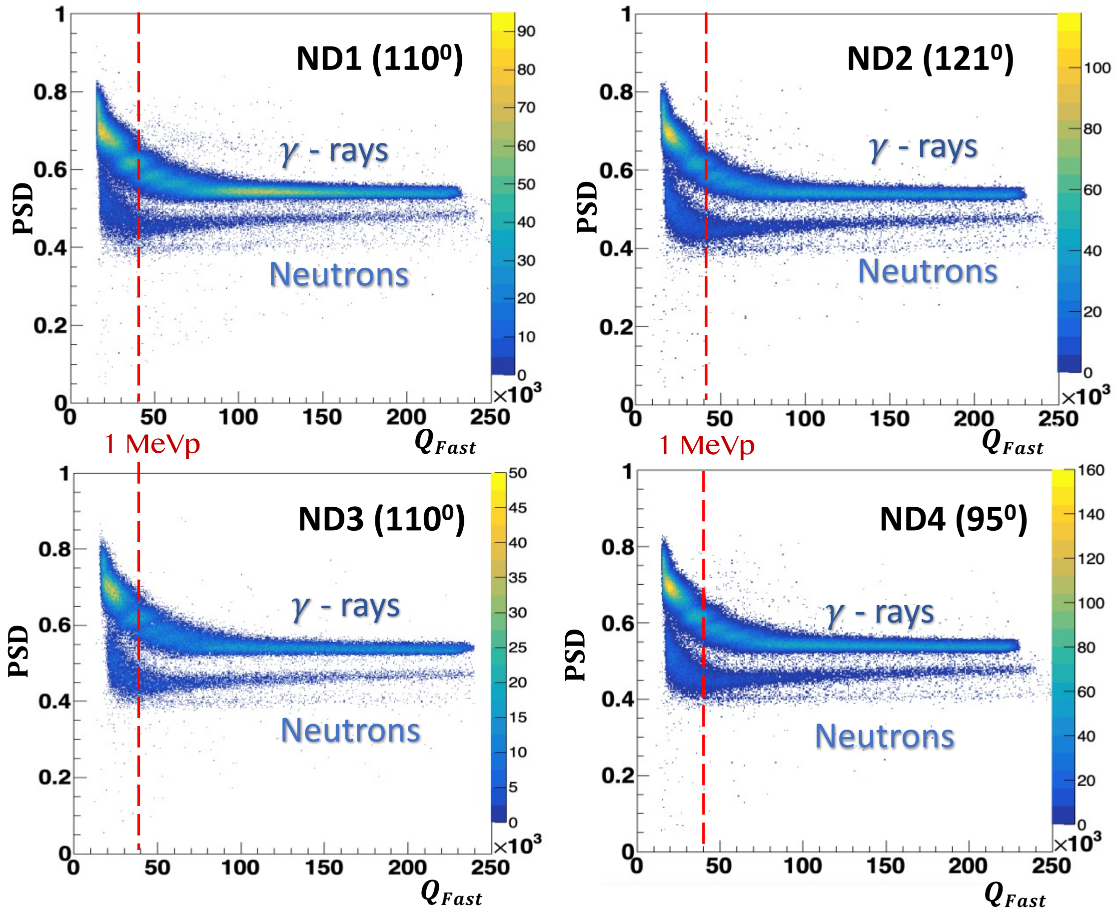
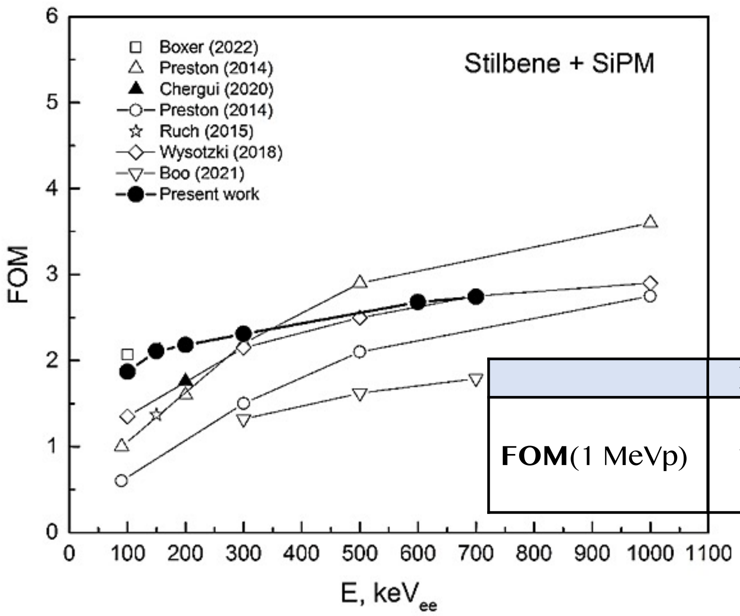
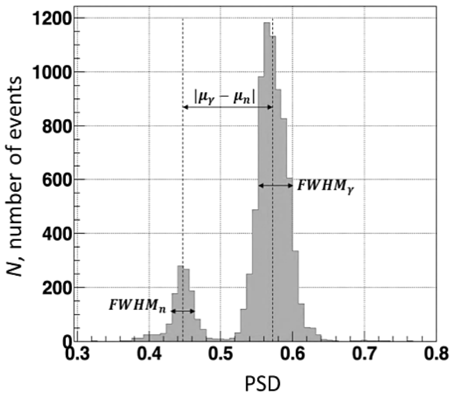


Figure of Merit: $FOM = \frac{|\mu_\gamma - \mu_n|}{FWHM_\gamma + FWHM_n}$



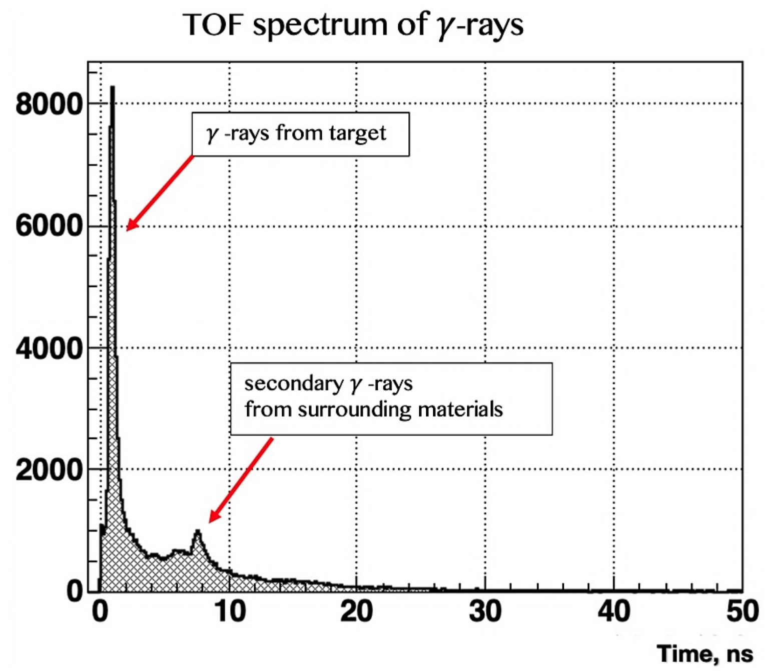


	ND1	ND2	ND3	ND4
FOM(1 MeVp)	1.98	2.17	2.28	2.47

Time and Energy resolution

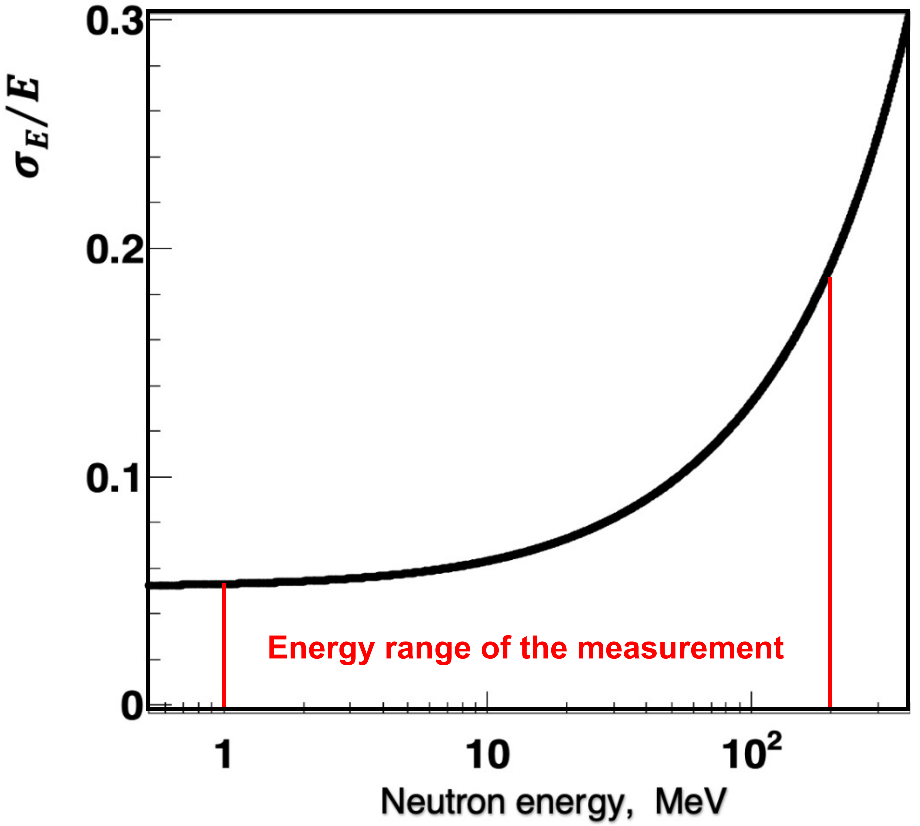
Time resolution of Neutron Detectors is estimated by a half of maximum of gamma-peak and time resolution of the T0- detector

	ND1	ND2	ND3	ND4
σ_t (ps)	128	114	118	110

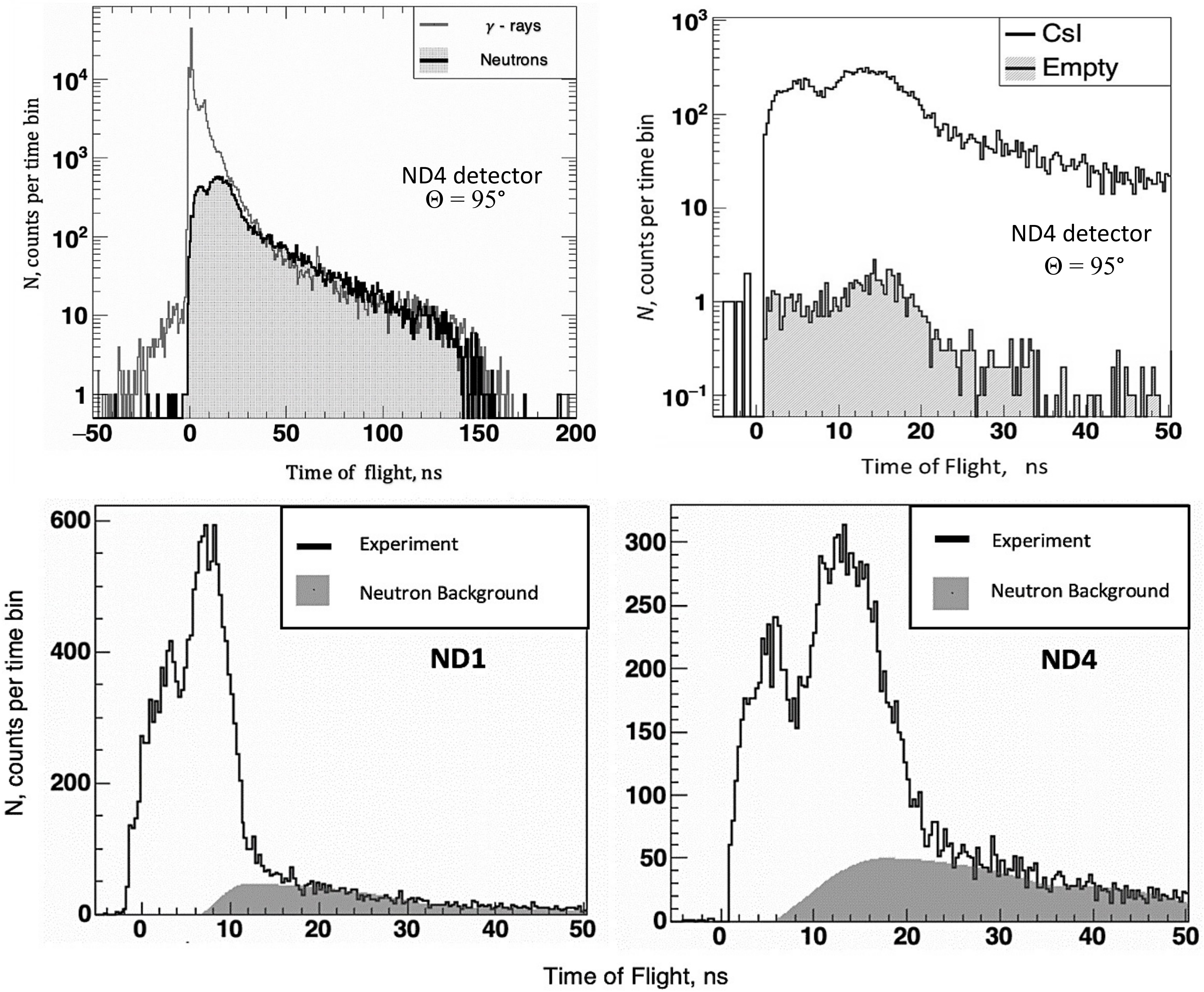


Energy resolution of the TOF measurements:

$$\frac{\sigma_E}{E} = \gamma(\gamma+1)\left[\left(\frac{\sigma_l}{l}\right)^2 + \left(\frac{\sigma_t}{t}\right)^2\right]^{1/2}$$



TOF spectra and background contribution



Energy spectra of neutrons

Data processing procedure

$$\frac{d^2\sigma}{dEd\Omega} = \frac{\Delta N}{\Delta E \cdot \Delta\Omega \cdot \varepsilon(E) \cdot n \cdot I \cdot k_1 \cdot k_2}$$

E – kin. energy of neutron

ΔN – the number of events in the energy interval ΔE

ΔΩ – the solid angle

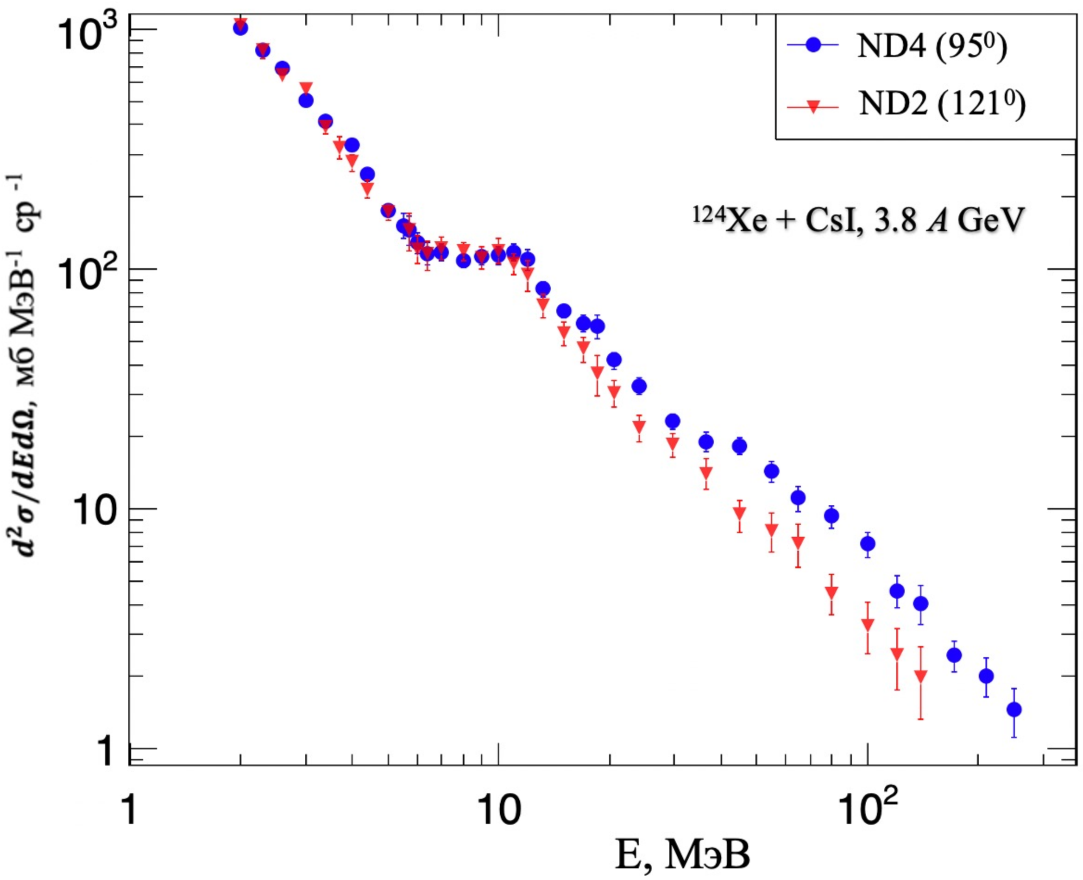
ε(E) – the detector efficiency at neutron energy E

n – the number of target nuclei per 1 cm^2

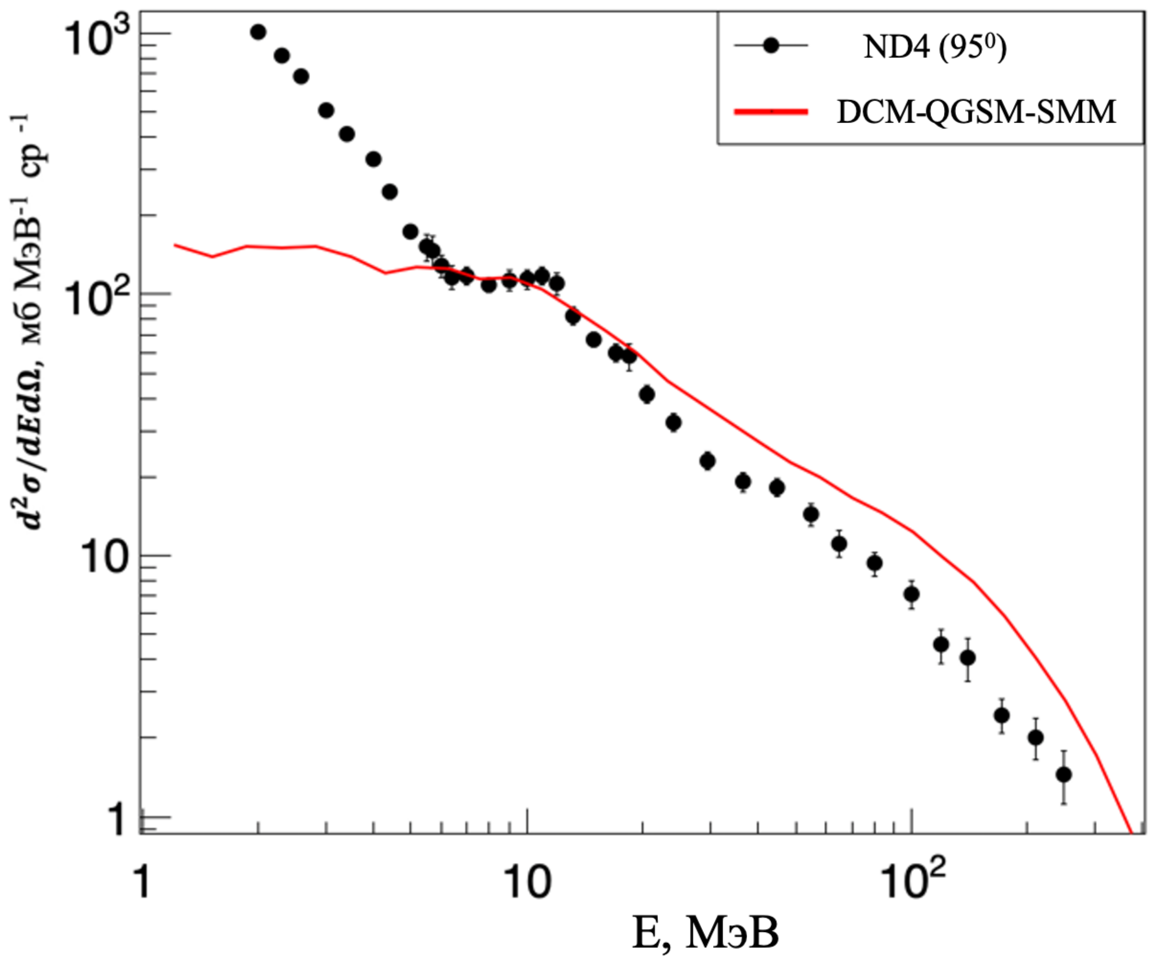
I – the number of beam ions

k_1 – the correction factor for the dead time of the spectrometer

k_2 – the correction factor for the selection of events with one incident beam ion in a time interval of ± 1.5 μs



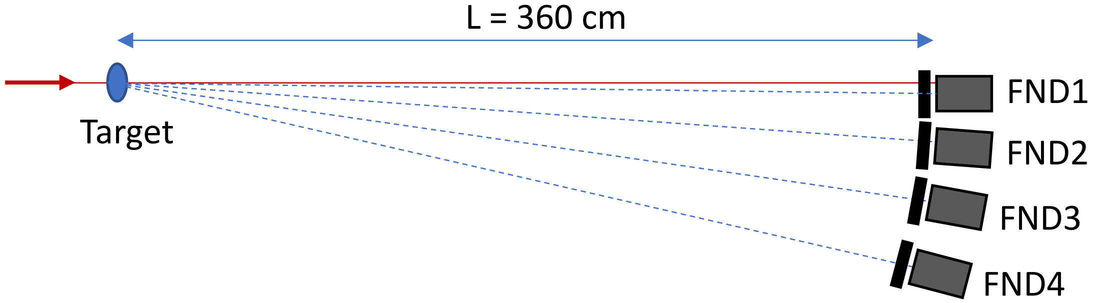
Comparison with prediction of DCM-QGSM-SMM model



A comparison with predictions of other theoretical models is in progress

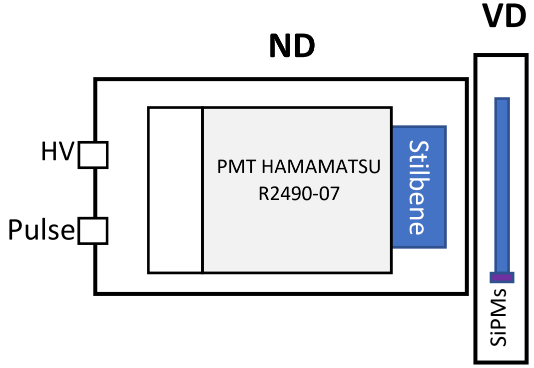
New neutron detectors for measurements at small angles

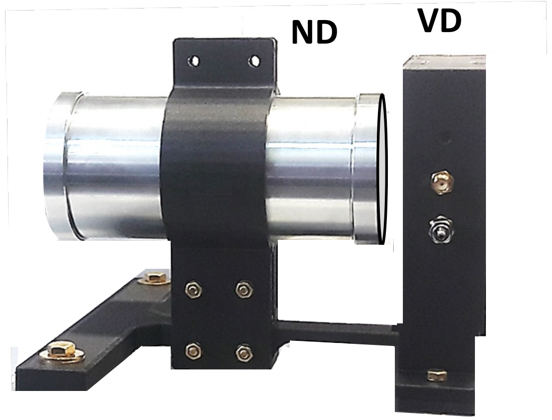
Energy range: 50 – 5000 MeV



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

The event statistics required is obtained in one-day measurement (with and without target)

Outlook

- We continue analysis of neutron production cross sections
- To get results with selection events for three centrality intervals > 60%, 60-40%, 40-20%, 20-0% using information from other BM@N detectors
- In final analysis the statistics will be increased by factor of ~2.4 by using another protection condition: BC1 pulse with B/A-protection ±240 ns and interactions (BC1 * FD_{veto}) with the B/A protection interval of ±1.8 μs.
- Creating the geometry of forward neutron detectors for background assessment using Geant4
- Laboratory testing of forward neutron detectors with TQDC readout