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FOR NUCLEAR RESEARCH

BM@N
Baryonic Matter at Nuclotron

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

BM@N run Dec.2023 – Feb.2024
^{124}Xe + CsI, 3.8 *A* GeV

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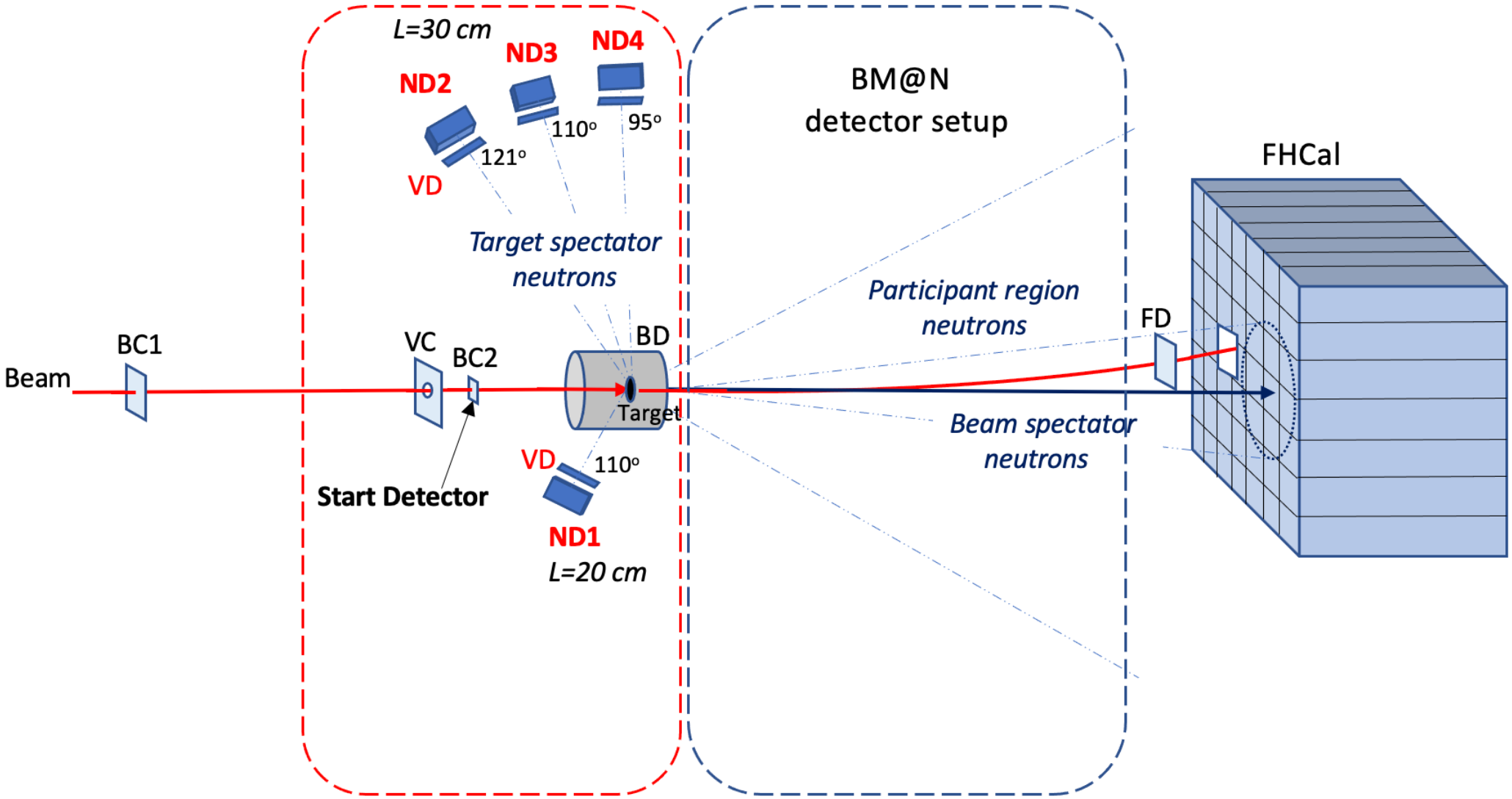
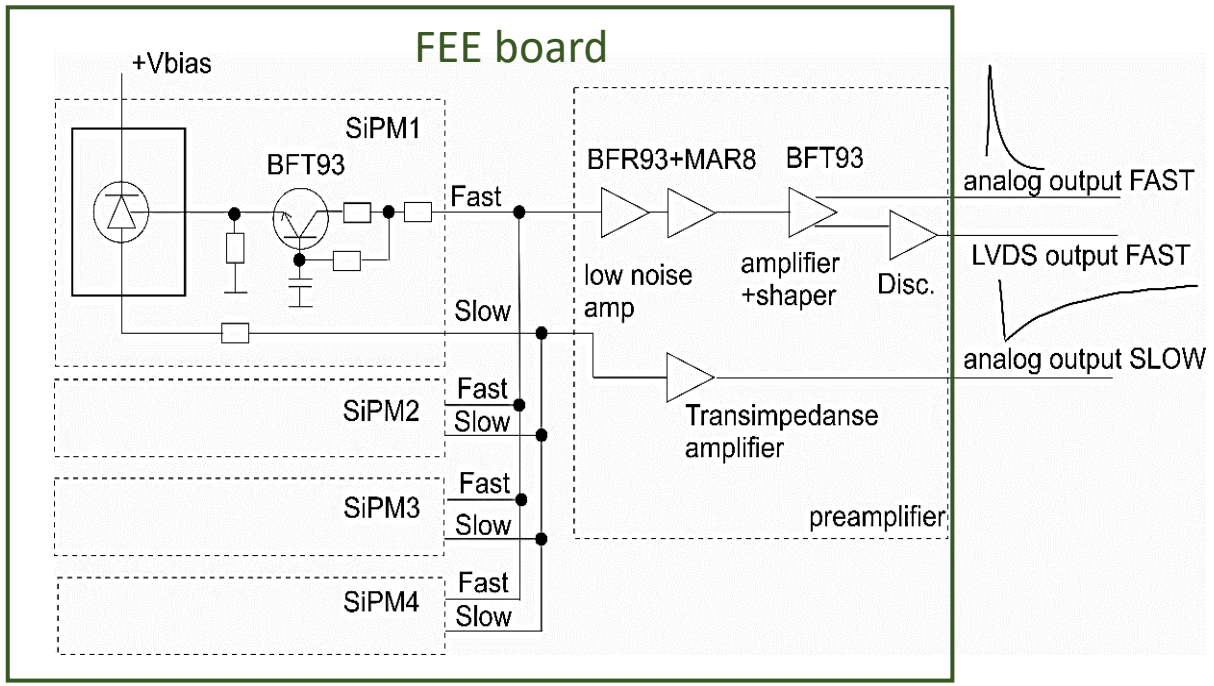
Compact TOF Neutron Spectrometer



Neutron Detector

4 SiPM (SensL 6×6 mm^2, J ser.)

Stilbene



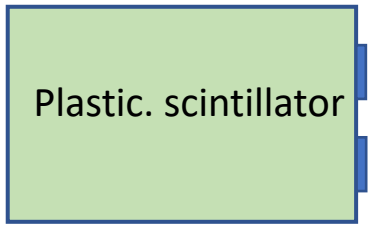
to TQDC 16VS

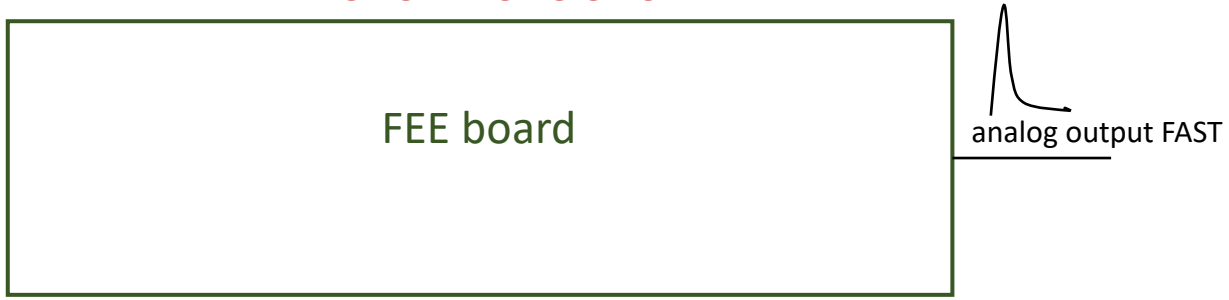
to TQDC 16VS

to TQDC 16VS

Veto Detector

2 SiPM





to TQDC 16VS

Data Analysis

Stages of analysis:

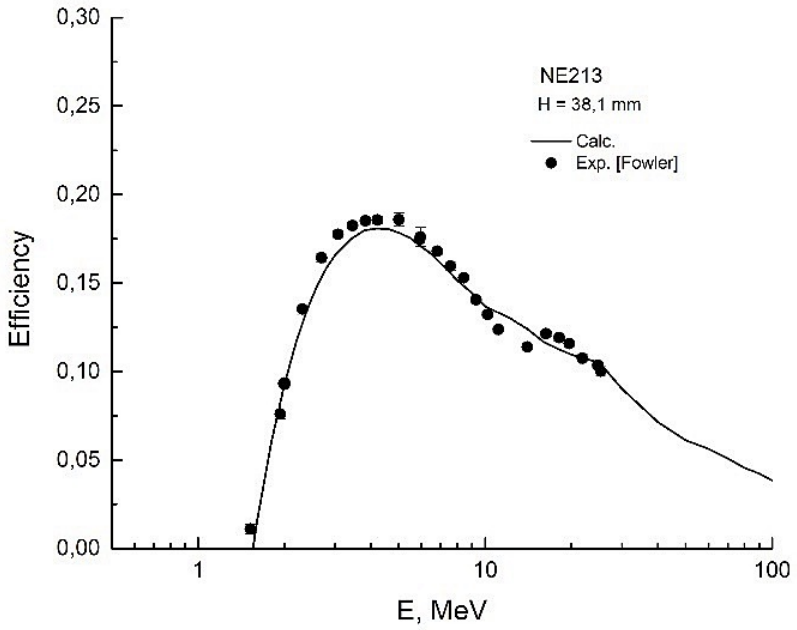
- ✓ Calculation of neutron detection efficiency
- ✓ Time – amplitude correction
- ✓ Amplitude – energy calibration
- ✓ Suppression of gamma-ray background with n/γ – pulse shape discrimination (PSD method)
- ✓ Estimation of neutron background for measured TOF spectra

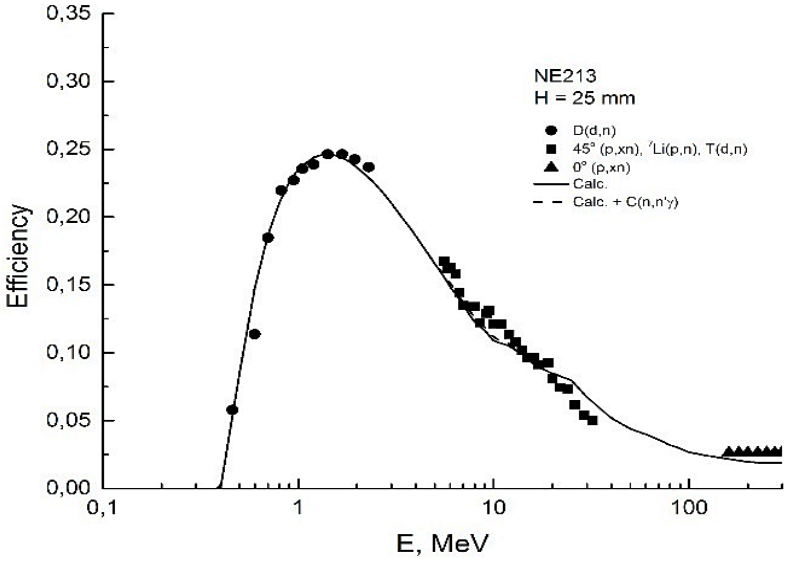
Neutron energy spectrum – double-differential neutron production cross section

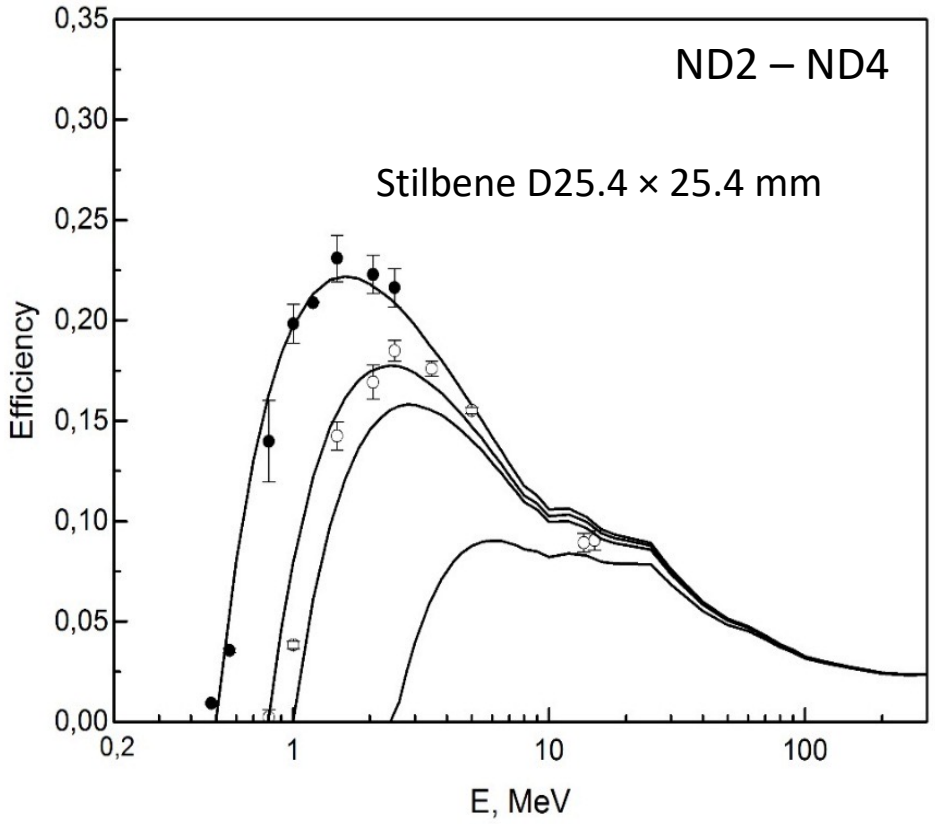
$$\frac{d^2\sigma}{dEd\Omega} = \frac{\Delta N}{\Delta E \cdot \Delta\Omega \cdot \varepsilon(E) \cdot n \cdot I \cdot k_1 \cdot k_2}$$

ΔN – the number of events in the energy interval ΔE,
$\Delta\Omega$ – the solid angle,
$\varepsilon(E)$ – 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

Neutron Detector Efficiency







$$\varepsilon = \left(1 - e^{-\Sigma h}\right)\left[\frac{\Sigma_H}{\Sigma}\left(1 - \frac{B_H}{E}\right) + \frac{\Sigma_C}{\Sigma}\left(1 - \frac{B_C}{E}\right)\right]$$

$\Sigma = \Sigma_C + \Sigma_H = n_C\,\sigma_{ch}(nC) + n_H\,\sigma(np)$

$\sigma_{ch}(nC)$ – cross section of ch. particle production in reactions with carbon nuclei

$\sigma(np)$ - cross-section of np scattering

h – the thickness of the stilbene crystal

B_C – the threshold for reactions with carbon

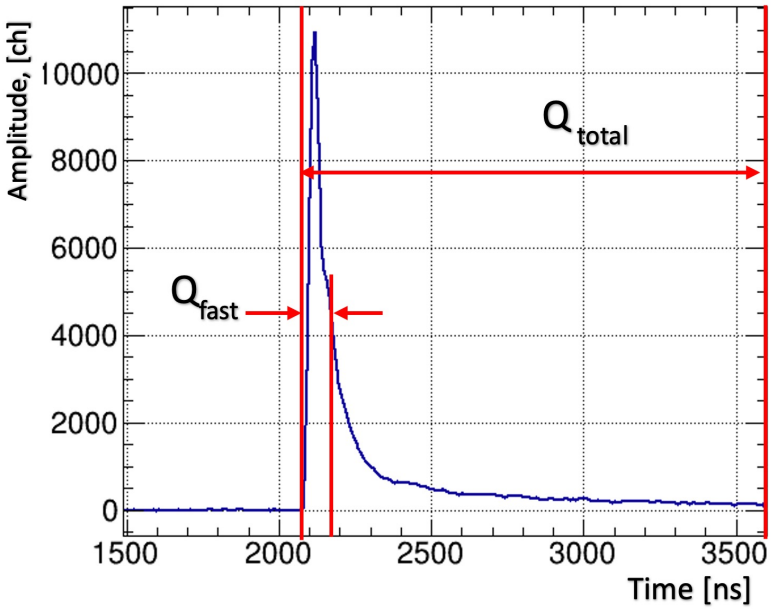
B_H – the threshold for recoil protons in np scattering

Pulse shape n/γ- discrimination

Quality of pulse shape discrimination:

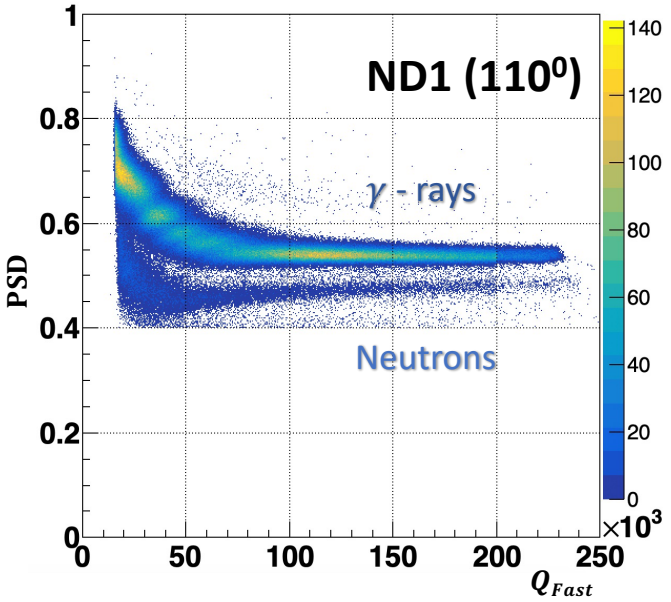
$$PSD = \frac{Q_{fast}}{Q_{total}}$$

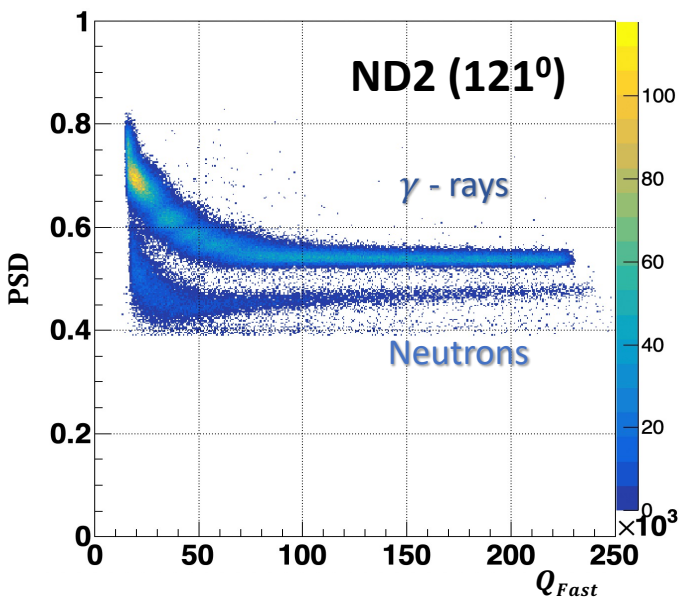
Waveform of Neutron Detector (TQDC)

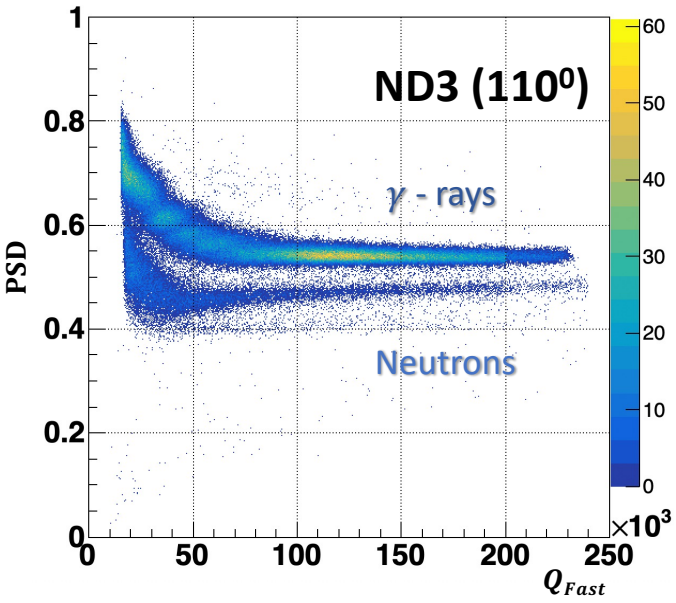


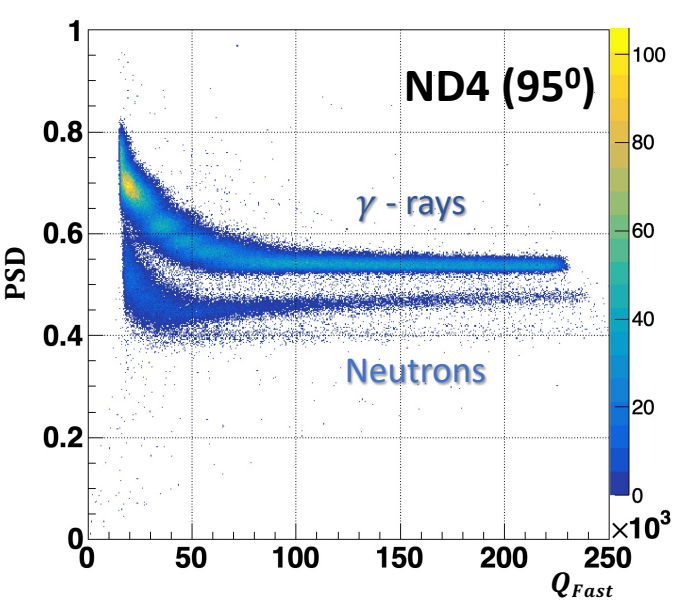
T_{fast} = 0.12 μs : time window for charge integration Q_{fast}

T_{total} = 1,5 μs. : time window for charge integration Q_{total}





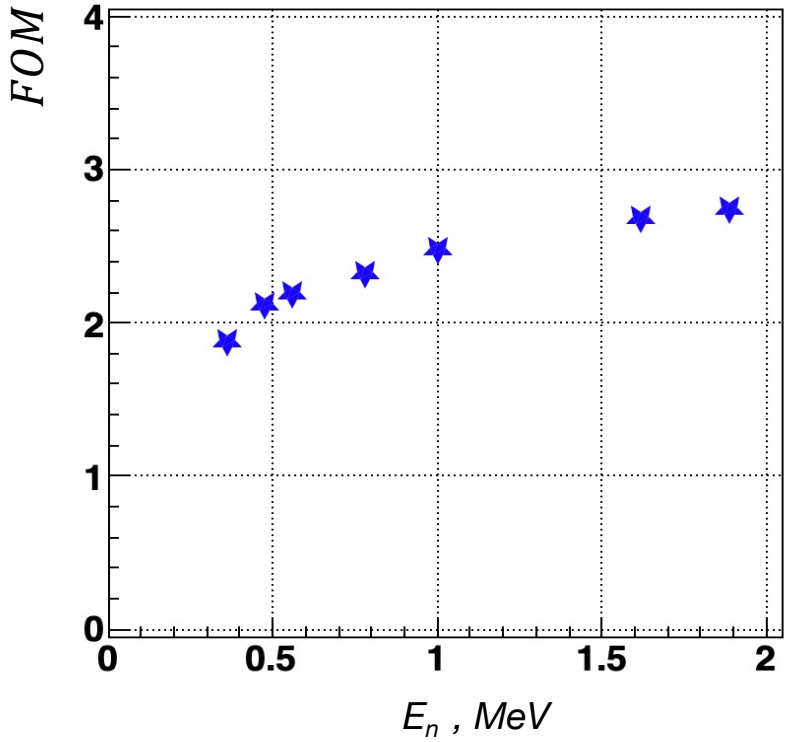


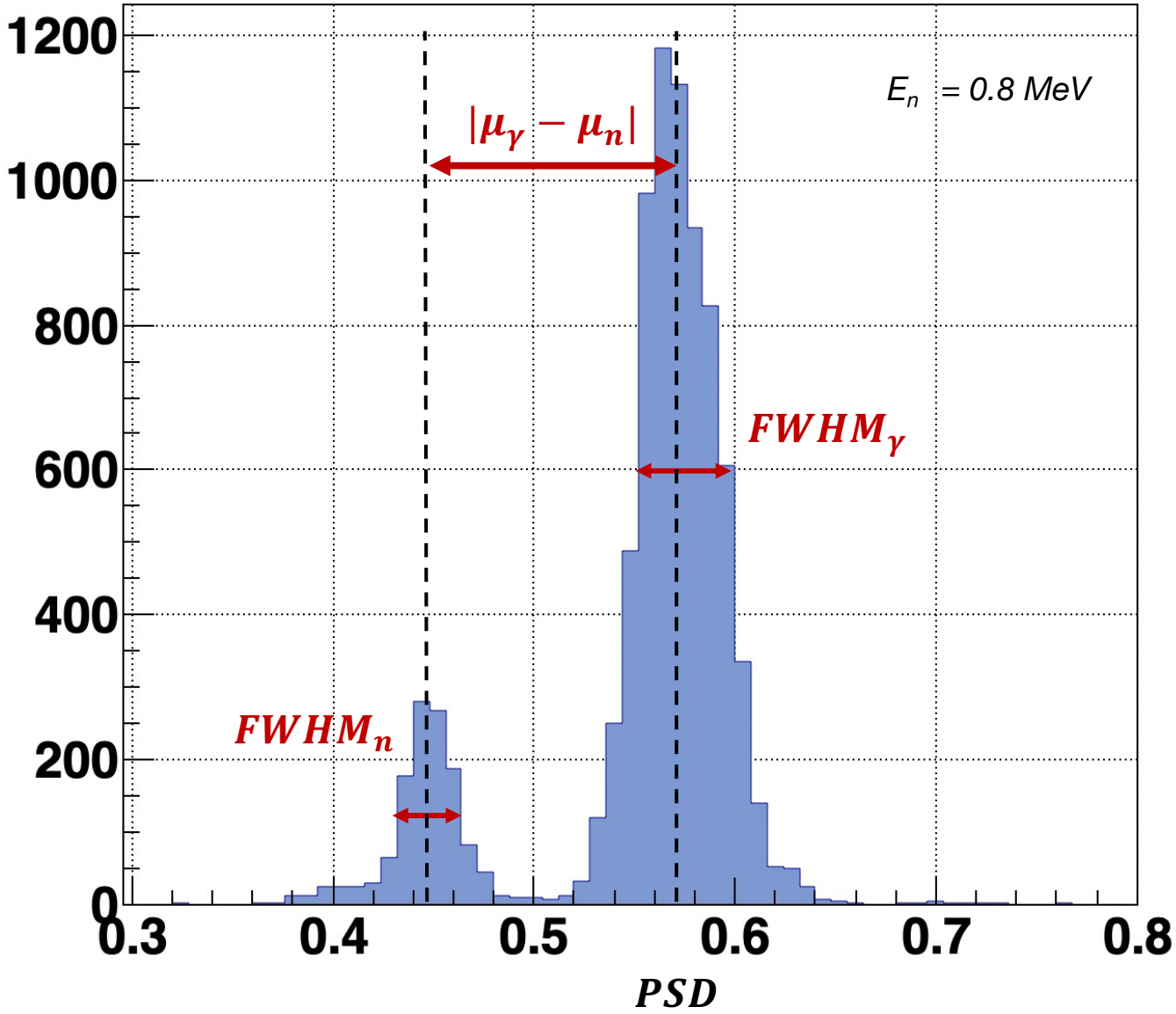


Pulse shape n/γ- discrimination (ND4)

Figure of Merit:

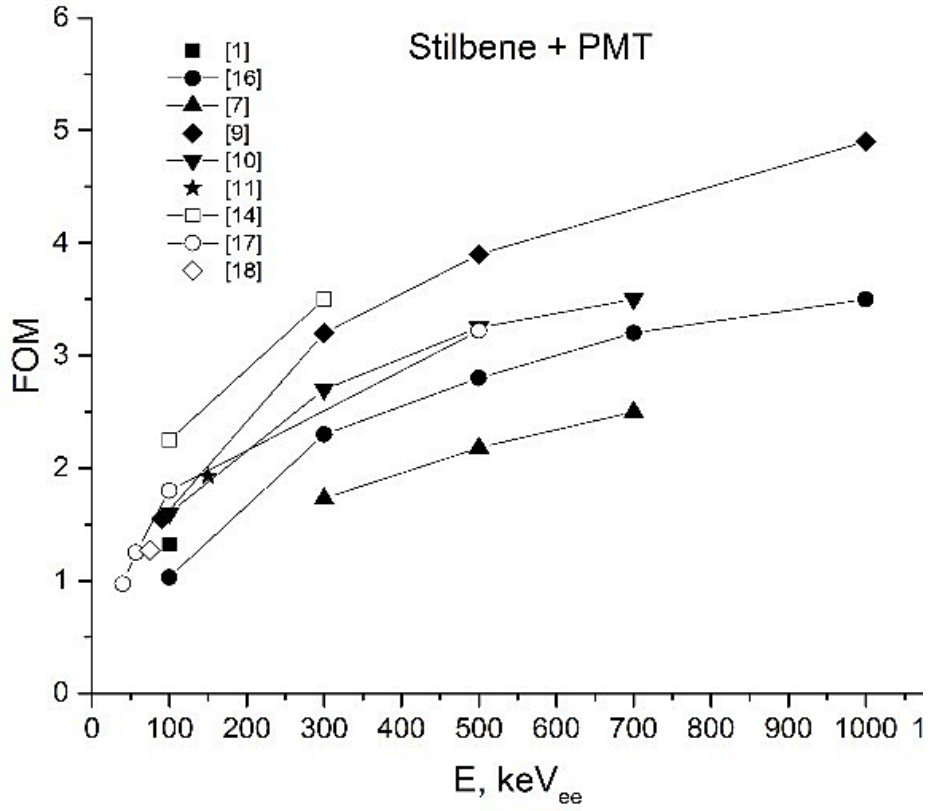
$$FOM = \frac{|\mu_\gamma - \mu_n|}{FWHM_\gamma + FWHM_n}$$

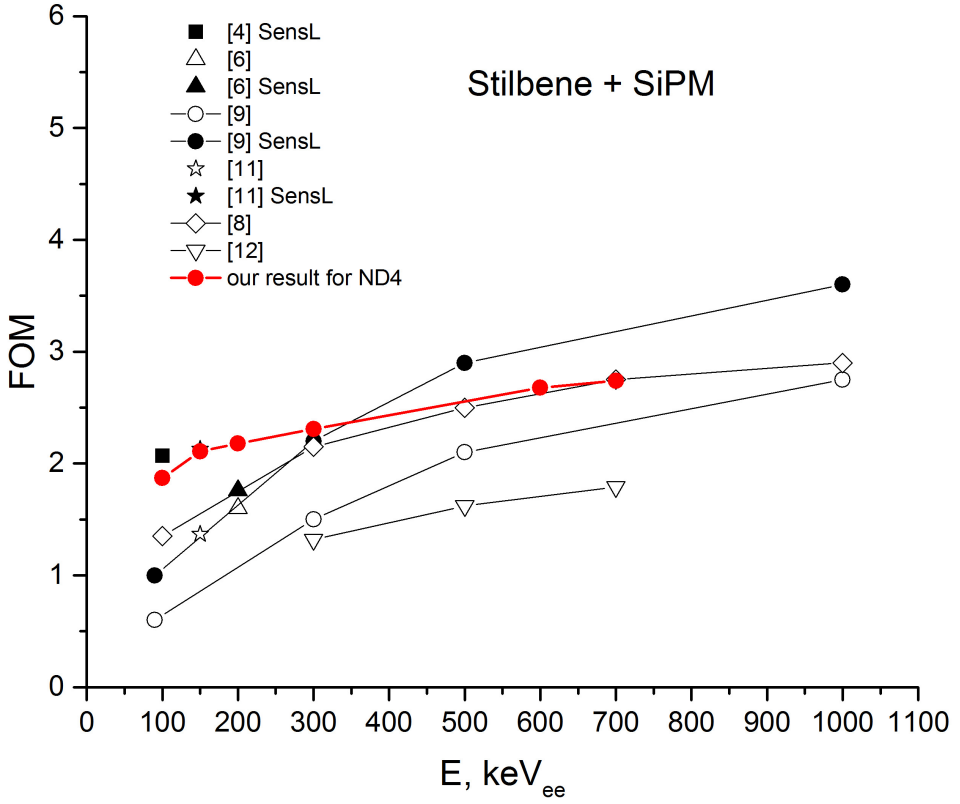




Pulse shape n/γ- discrimination

Comparison with available results

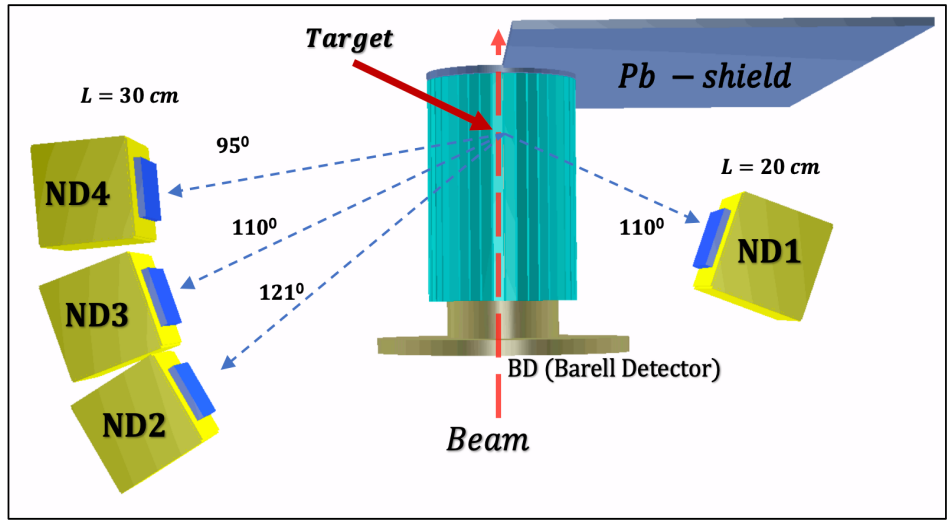




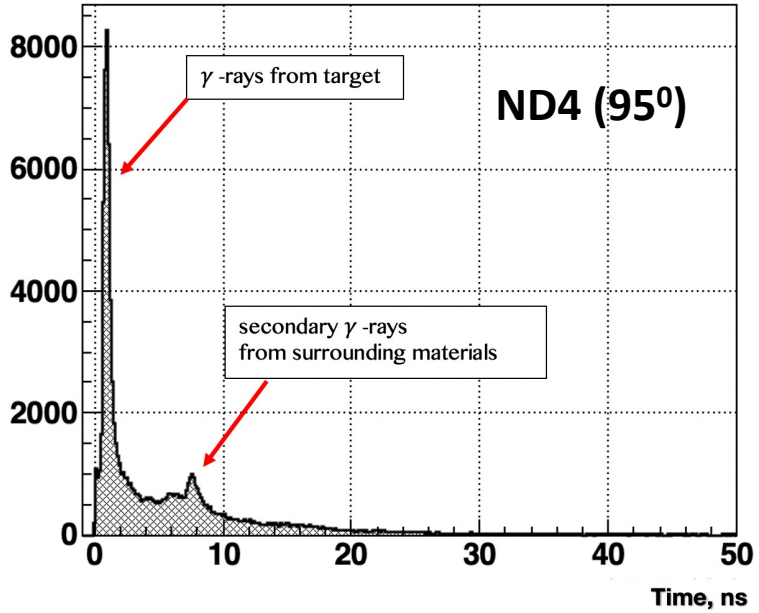
Neutron Detectors

Neutron Detector	Stilbene (mm)	Angle (deg.)	Flight path (cm)	E_{th} (MeV)	σ_t (ps) TOF (ND)	FOM at 1 MeV
ND1	D30 × 10	110	22	1	134 (128)	1.98
ND2	D25.4 × 25.4	121	31.9	1	121 (114)	2.17
ND3	D25.4 × 25.4	110	31.2	1	124 (118)	2.28
ND4	D25.4 × 25.4	95	28.6	1	117 (110)	2.47

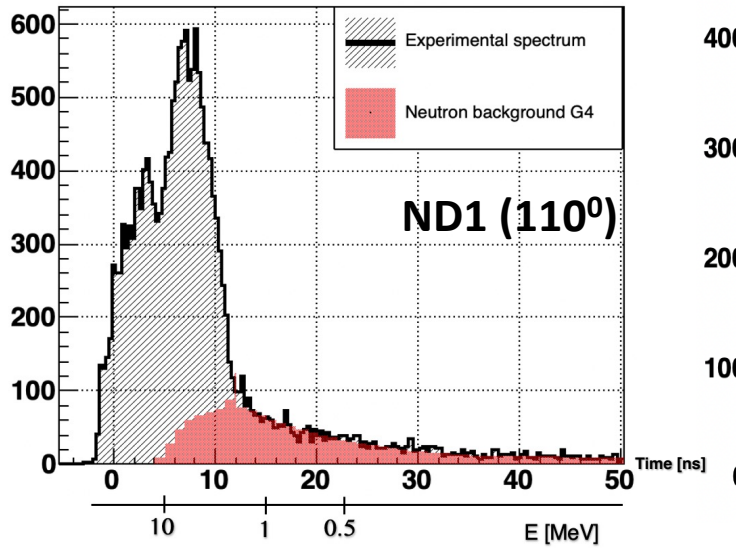
TOF spectra and Neutron background

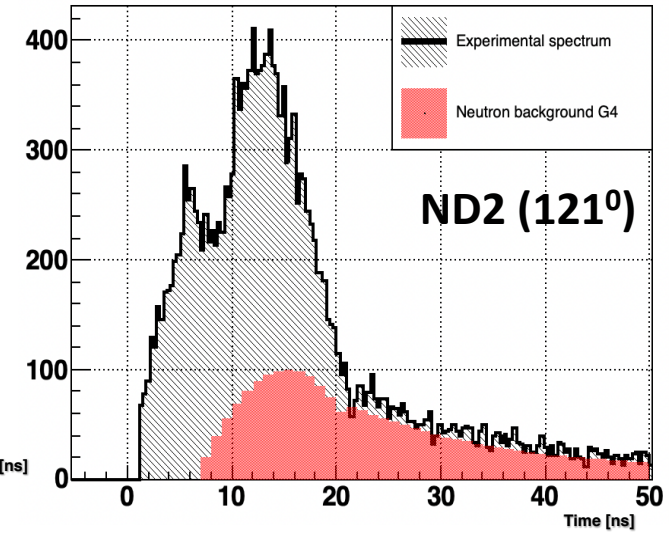


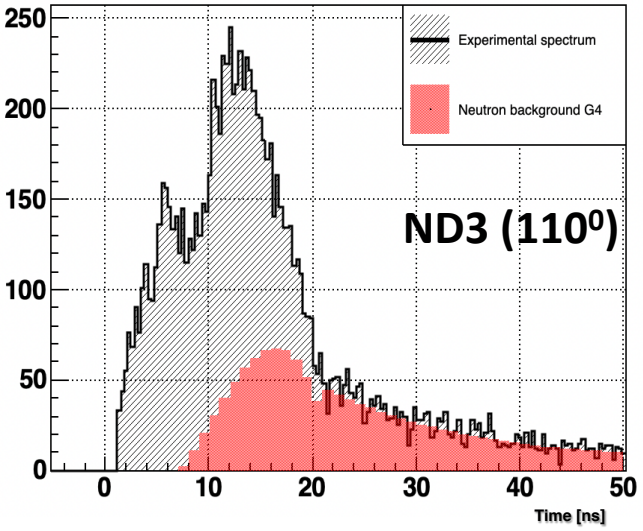
TOF spectrum of γ-rays

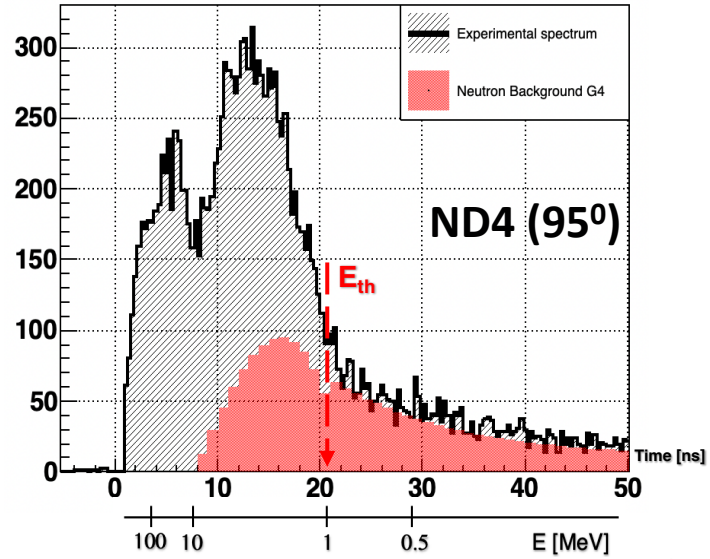


TOF spectrum of neutrons



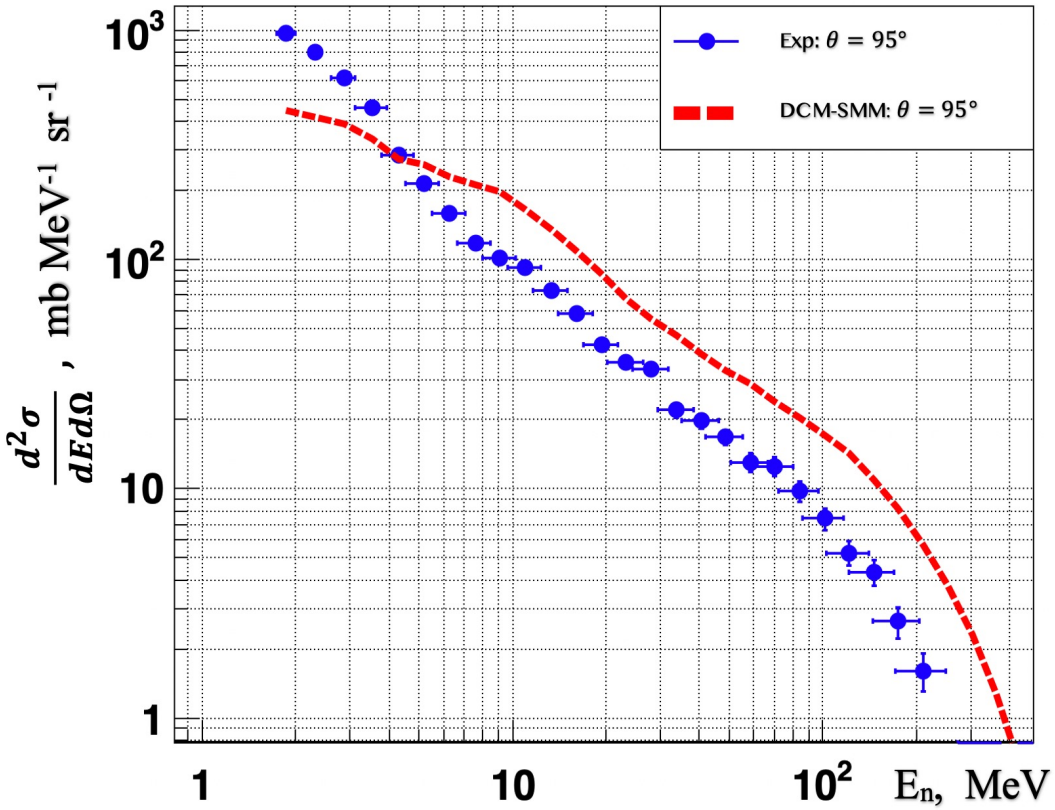


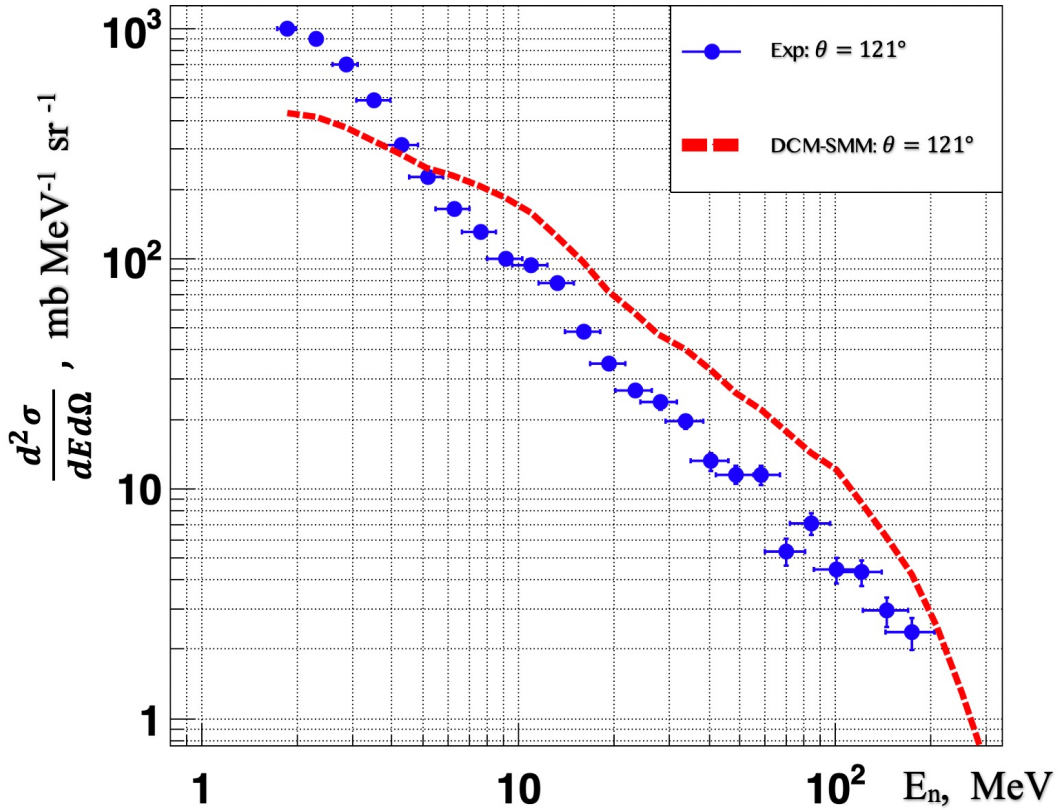




Energy spectra of neutrons

^{124}Xe + CsI, 3.8 *A* GeV





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Thank you
for your attention !