JOINT INSTITUTE FOR NUCLEAR RESEARCH

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Frank Laboratory of Neutron Physics

Monitoring Neutron Spectrum of Reactor IBR2 using Direct Beam Detector at Small Angle Neutron Scattering Spectrometer (YuMO)

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Team of Work

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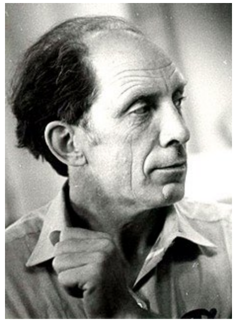
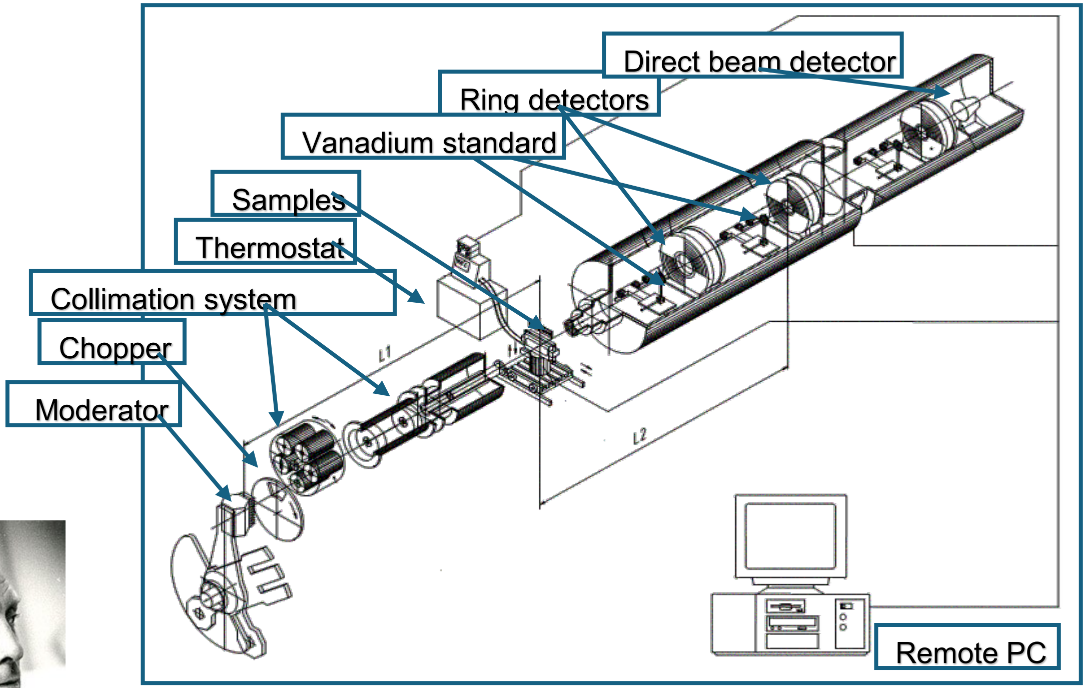
Outlines

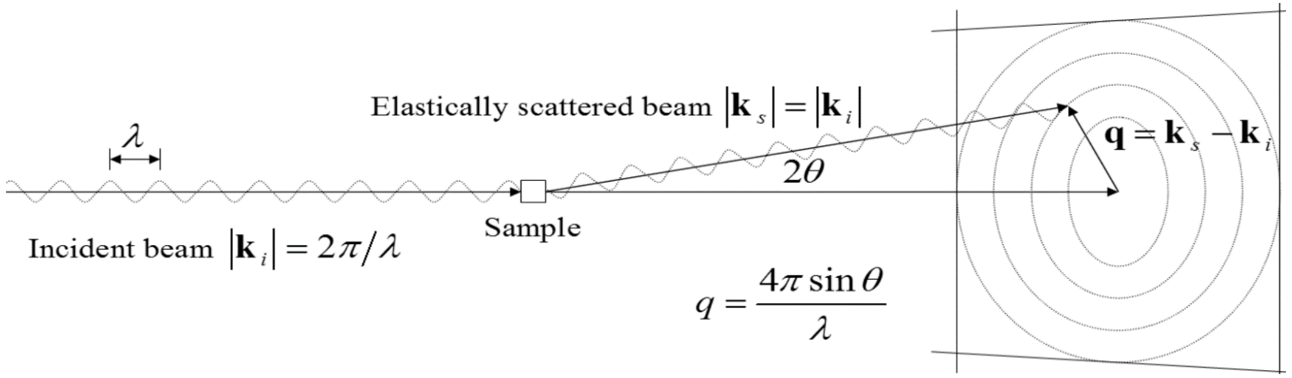
- Small Angle Scattering
- YuMO spectrometer
- Direct Beam Detector (DBD)
- DBD Efficiency
- DBD Upgrading
- Conclusion

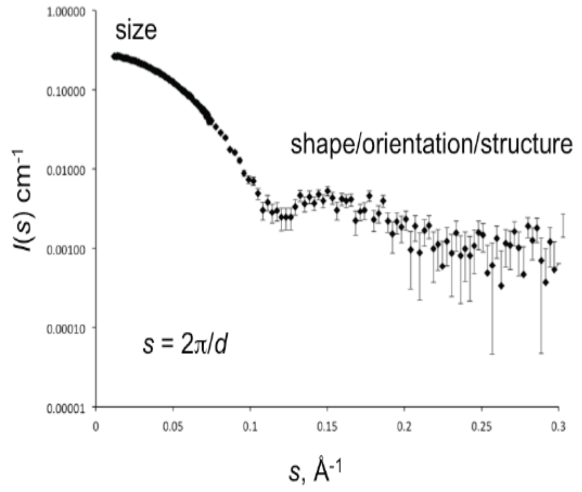


Yuri
Mechislavovich
Ostanevich



Small Angle Scattering (SAS)





- Incident radiation (Neutrons, X-ray, photons) elastically scattered by sample.
- Analyzing scattering pattern allow to deduce shape, size and orientation of sample constituents.

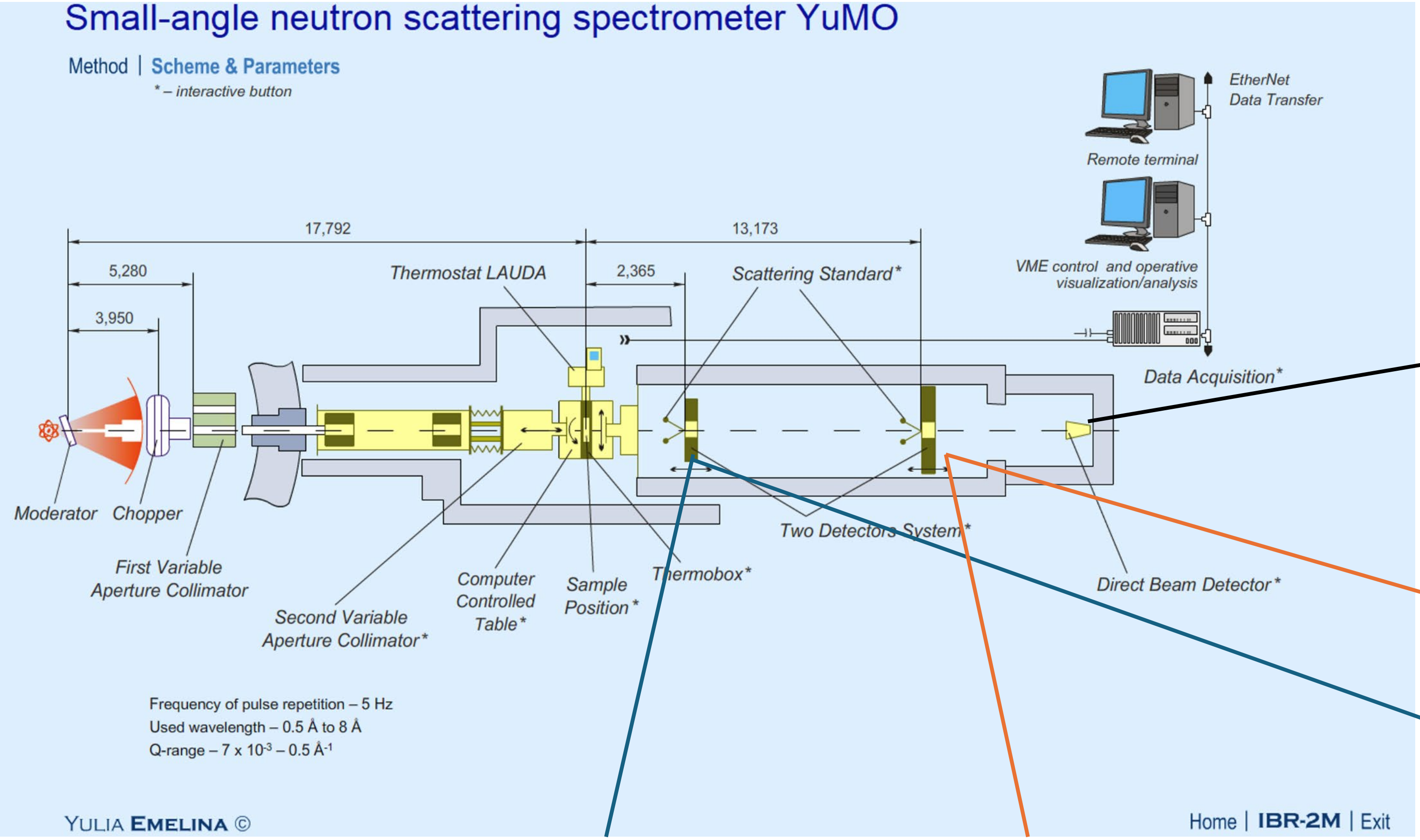
Attainable length scale $d = \frac{4\pi}{q}$ nm $\longrightarrow$ $|q| = q = \frac{4\pi}{\lambda} \sin\frac{\theta}{2}$ $\longrightarrow$ large scale length (Small q)

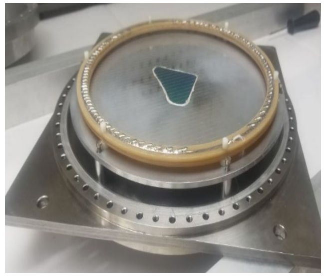
- ✓ small θ
- ✓ Large λ

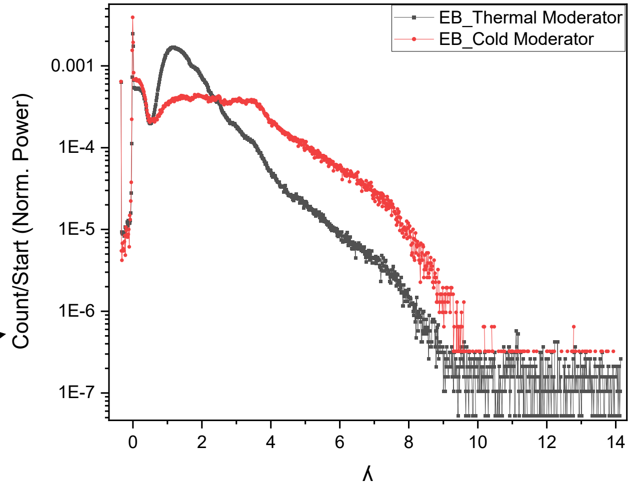
Varying scattering vectors using various wavelengths (TOF) allow studying samples with different size scale

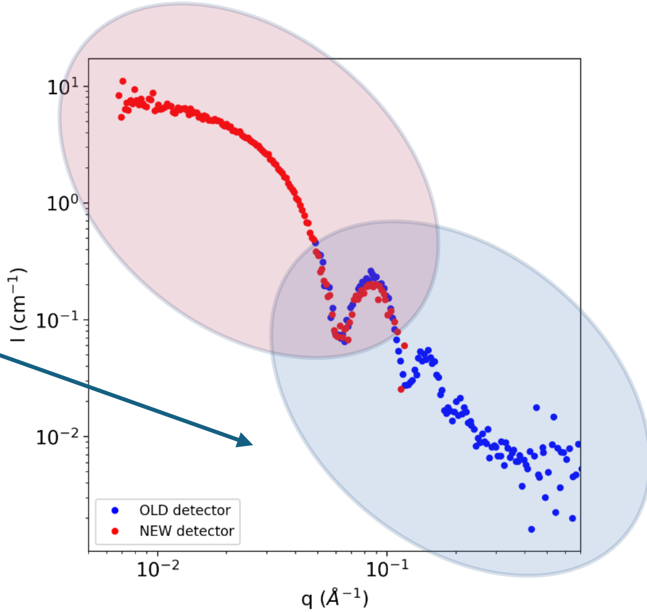
$$\lambda = \frac{h}{mv} = \frac{t \cdot h}{m \cdot L}$$

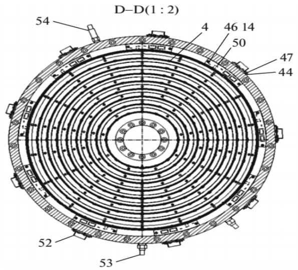
YuMO Spectrometer

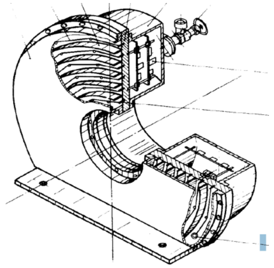


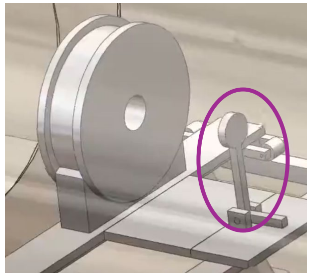


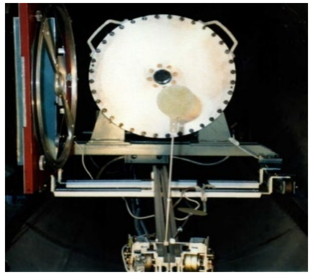








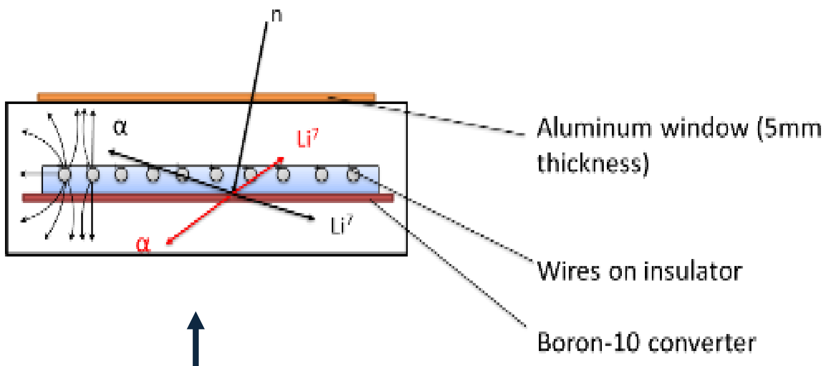


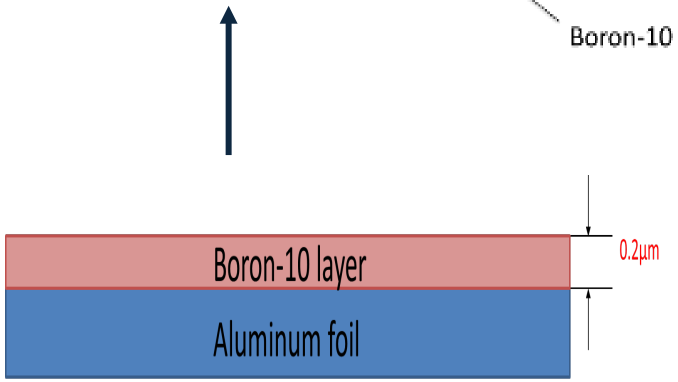


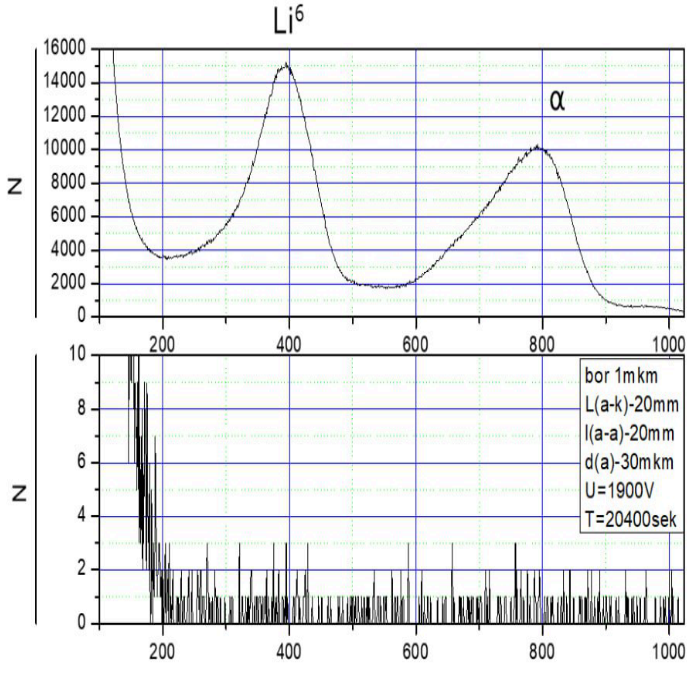
Direct Beam Detector (DBD)

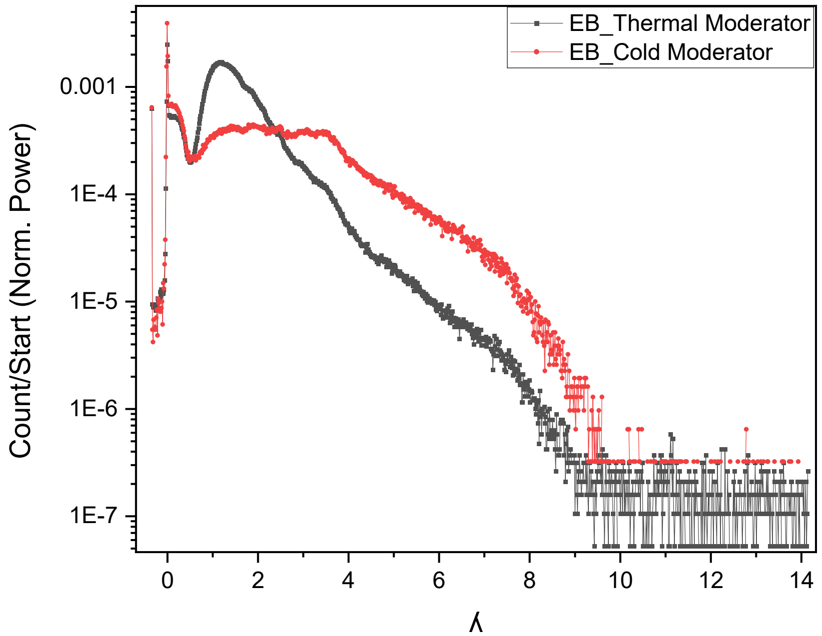
$$n + {}^{10}B \rightarrow \begin{cases} \alpha + {}^{7}Li + 2.792MeV, 6.1\% \\ \alpha + {}^{7}Li^{*} + 2.310MeV, 93.9\%. \end{cases}$$

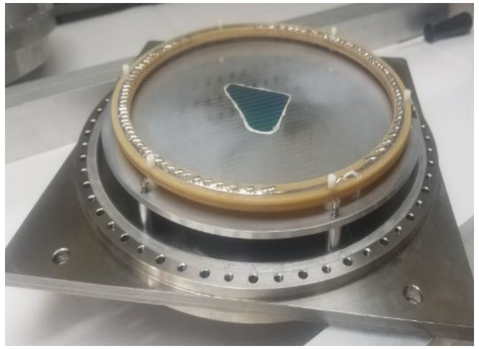
$$ {}^{7}Li^{*} \rightarrow {}^{7}Li + \gamma + 0.478MeV$$





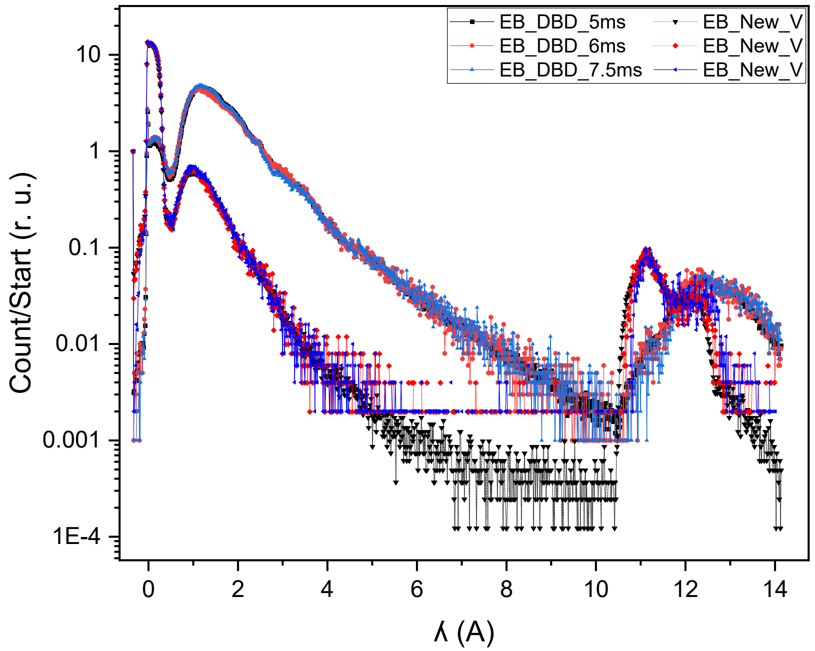




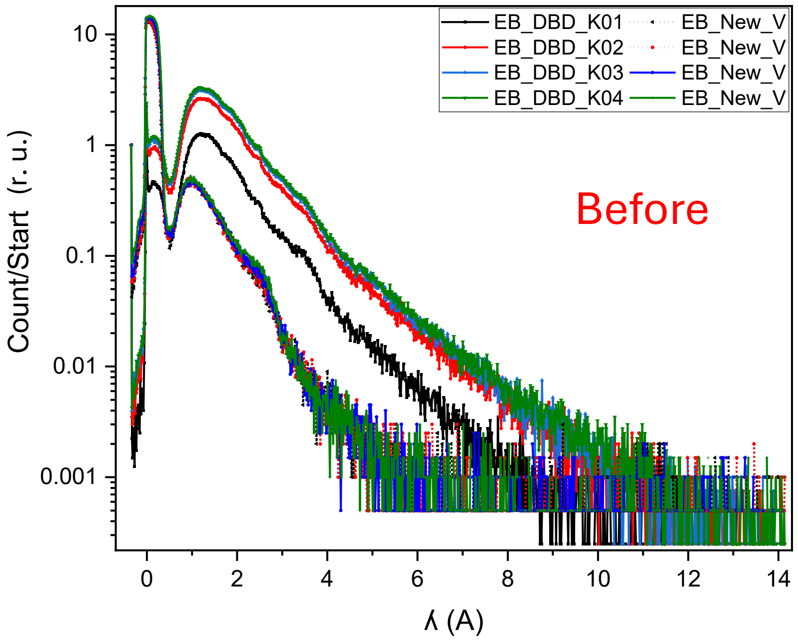


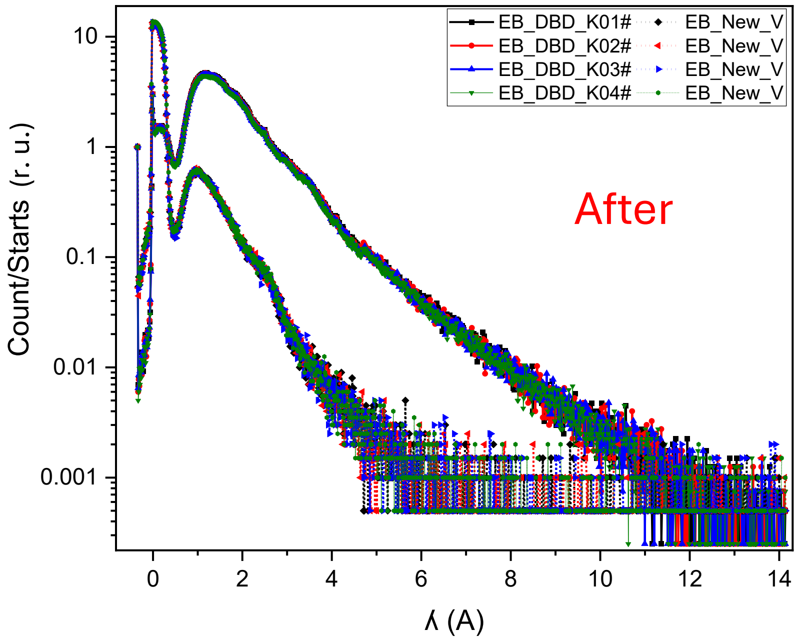
Why (DBD) Important

Chopper Adjustment



Collimator Adjustment





- Monitoring white neutron spectrum, registering kinds of power fluctuation that could be used for power normalization for certain cases also frequency of neutron reflector.
- Monitoring full spectrum modifications corresponding to different chopper delay time which is quite important for samples require large wavelengths (small angle region).
- Adjustment for Collimation system, satisfying maximum collimated beam at DBD

Sample Transmission By (DBD)

- when the ratio between the scattering values from the sample and the vanadium standard become close to each other, this requires increasing the exposure time with vanadium and the sample relative to the sample exposure time.

- Instead of that alternative measurement procedure so called empty beam (EB), i.e. measurement of background and only vanadium standard in front of the detector and that require Knowing Sample transmission (using DBD).

$$I_s = I_0(\boldsymbol{\lambda})\, \epsilon(\boldsymbol{\lambda})\, (\frac{d\Sigma}{d\Omega})_s\, T_s\, \Omega_s\, ds$$

$$I_{s+v} = I_s + I_0(\boldsymbol{\lambda})\, \epsilon(\boldsymbol{\lambda})\, (\frac{d\Sigma}{d\Omega})_v\, T_v\, \Omega_v\, dv$$

$$(\frac{d\Sigma}{d\Omega})_s = \frac{I_{sample}}{I_{sv} - I_{sample}} \cdot \frac{\Omega_v}{\Omega_s} \cdot T_v \cdot d_v \cdot (\frac{d\Sigma}{d\Omega})_v \cdot \frac{1}{d_s}$$

$$I_v = I_0\, (\boldsymbol{\lambda})\, \epsilon(\boldsymbol{\lambda})\, (\frac{d\Sigma}{d\Omega})_v\, T_v\, \Omega_v\, dv$$

$$\frac{\left(\frac{d\Sigma}{d\Omega}\right)_s}{\left(\frac{d\Sigma}{d\Omega}\right)_v} = \frac{I_s}{I_v} \cdot \frac{\Omega_v}{\Omega_s} \cdot \frac{T_s}{T_v} \cdot \frac{d_s}{d_v}$$

$$\frac{\left(\frac{d\Sigma}{d\Omega}\right)_s}{\left(\frac{d\Sigma}{d\Omega}\right)_v} = \frac{I_s}{I_v} \cdot \frac{\Omega_v}{\Omega_s} \cdot \frac{1}{T_v} \cdot \frac{I_s^d}{I_e^d} \cdot \frac{d_s}{d_v}$$

contains only constants and measured intensities

Standard Normalization

Sample Transmission Excluded

$\boxed{I_s^d = I\ \epsilon^d\, T_s}$ $\boxed{I_e^d = I\ \epsilon^d}$

I_s^d :is the intensity at (DBD) With sample

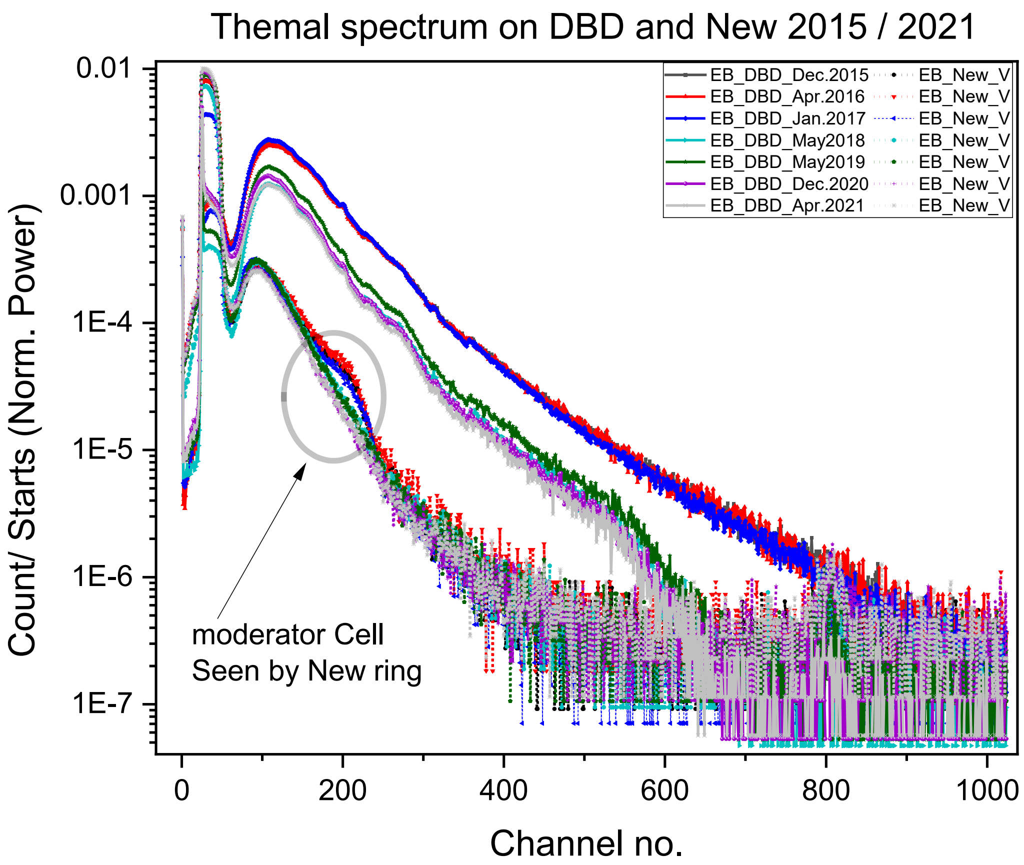
I_e^d :is the intensity at (DBD) No sample

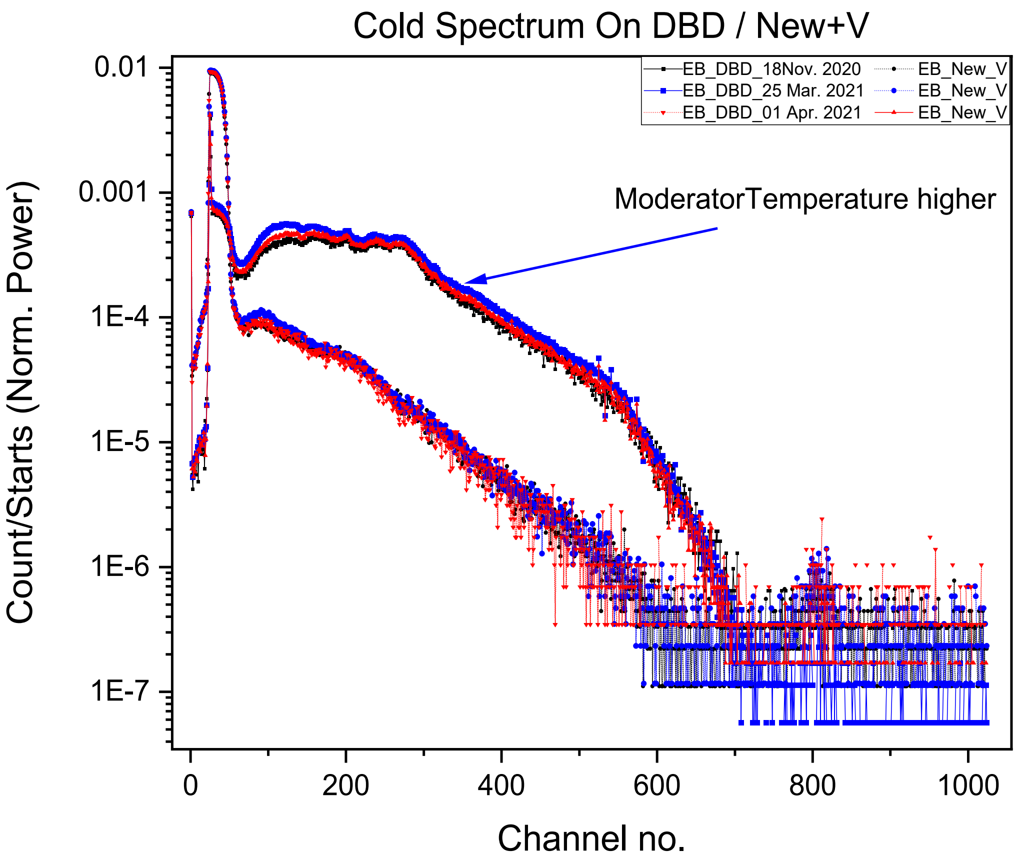
I :is the flux at the sample Position

ϵ^d :is the efficiency of (DBD)

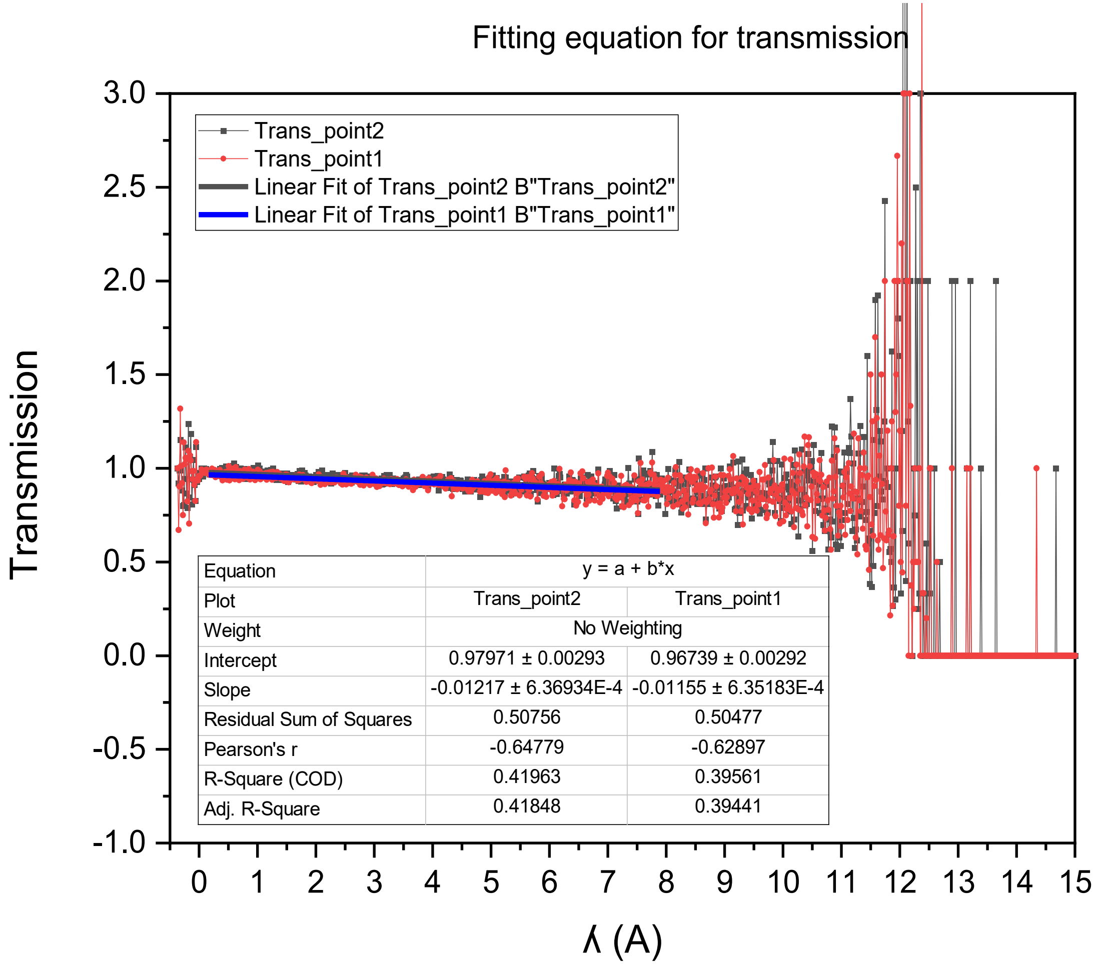
T_s : sample transmission

DBD Evaluation Along Years

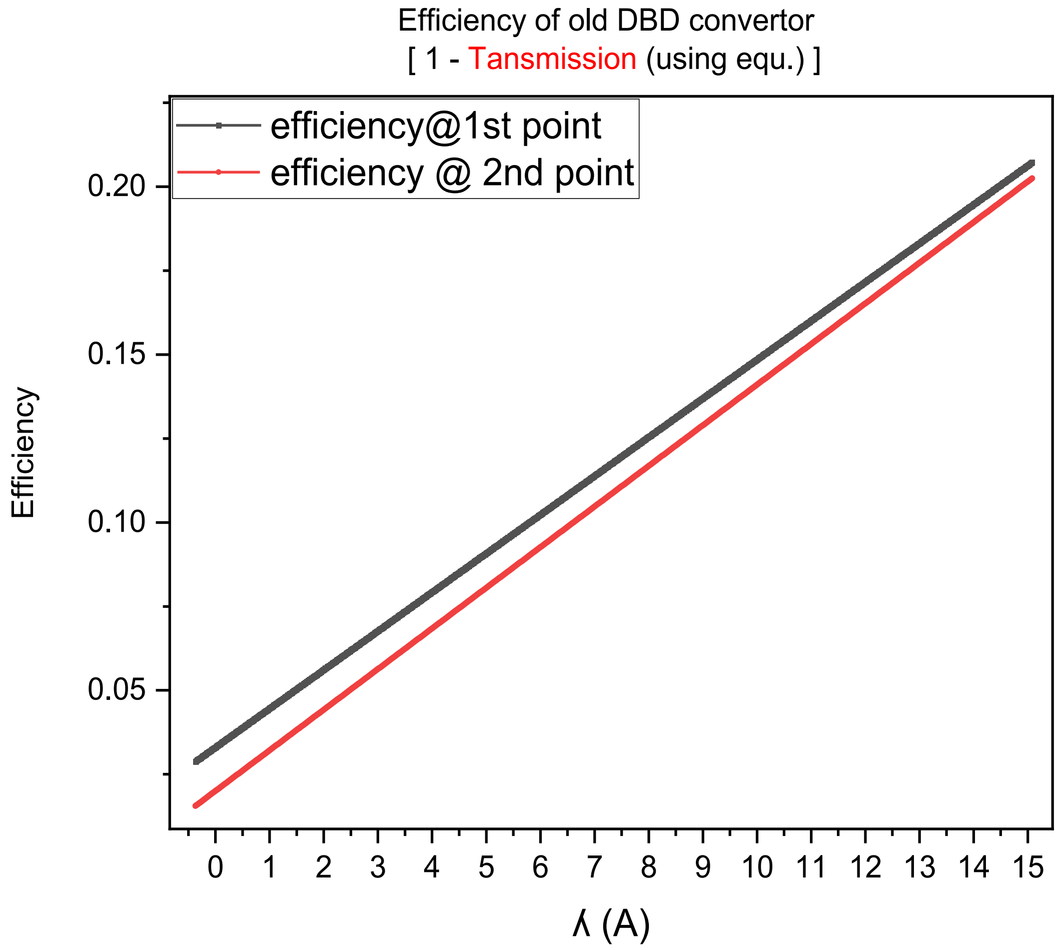




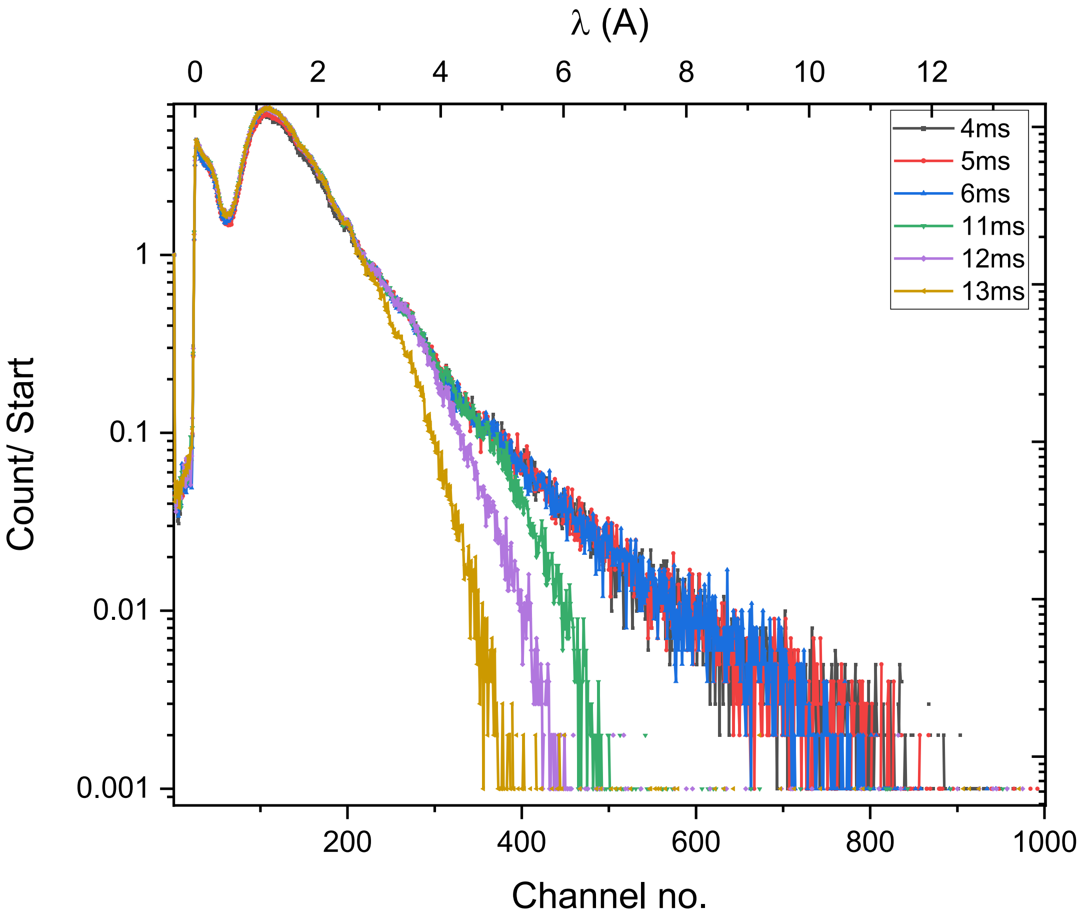
Efficiency of (DBD) Convertor

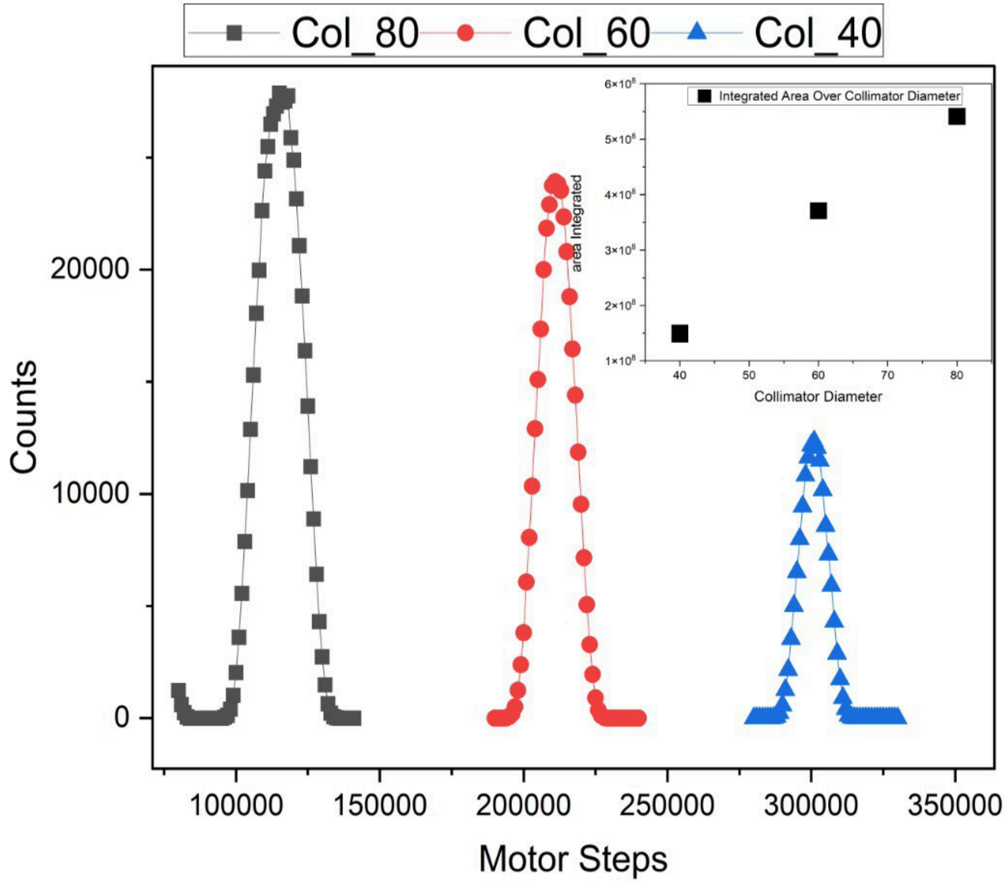


Equation	y = a + b*x	
Plot	Trans_point2	Trans_point1
Weight	No Weighting	
Intercept	0.97971 ± 0.00293	0.96739 ± 0.00292
Slope	-0.01217 ± 6.36934E-4	-0.01155 ± 6.35183E-4
Residual Sum of Squares	0.50756	0.50477
Pearson's r	-0.64779	-0.62897
R-Square (COD)	0.41963	0.39561
Adj. R-Square	0.41848	0.39441

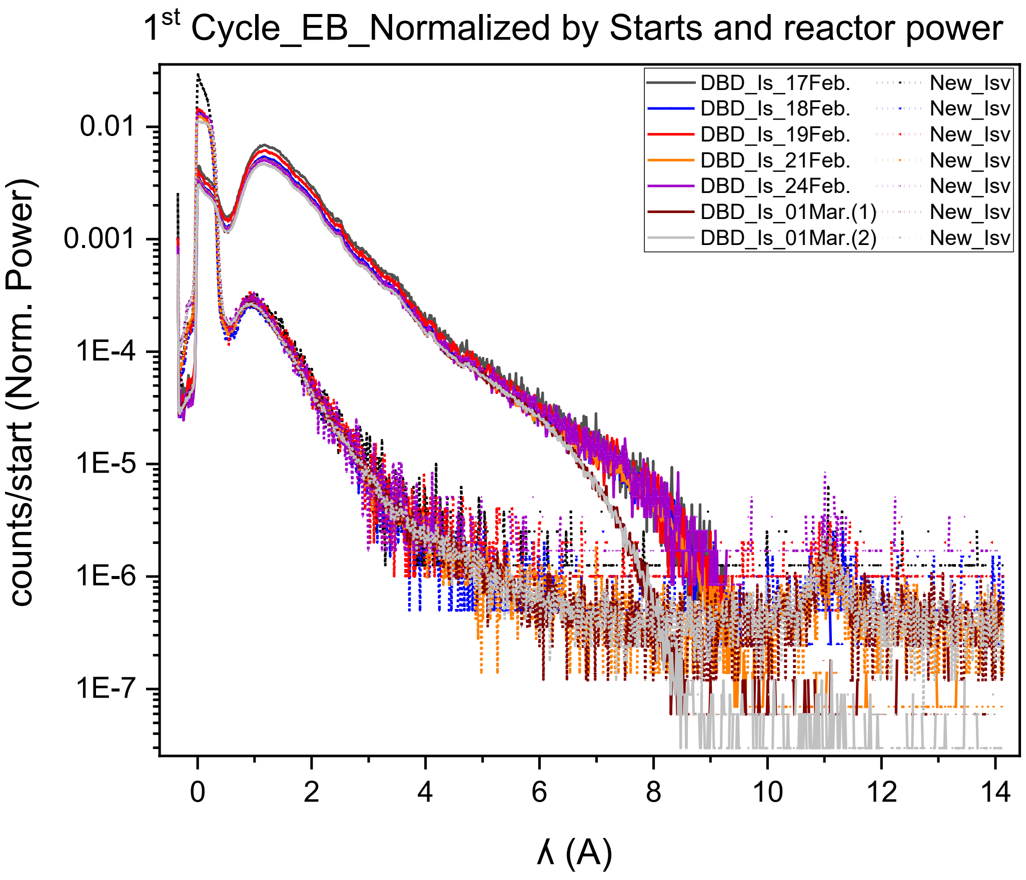


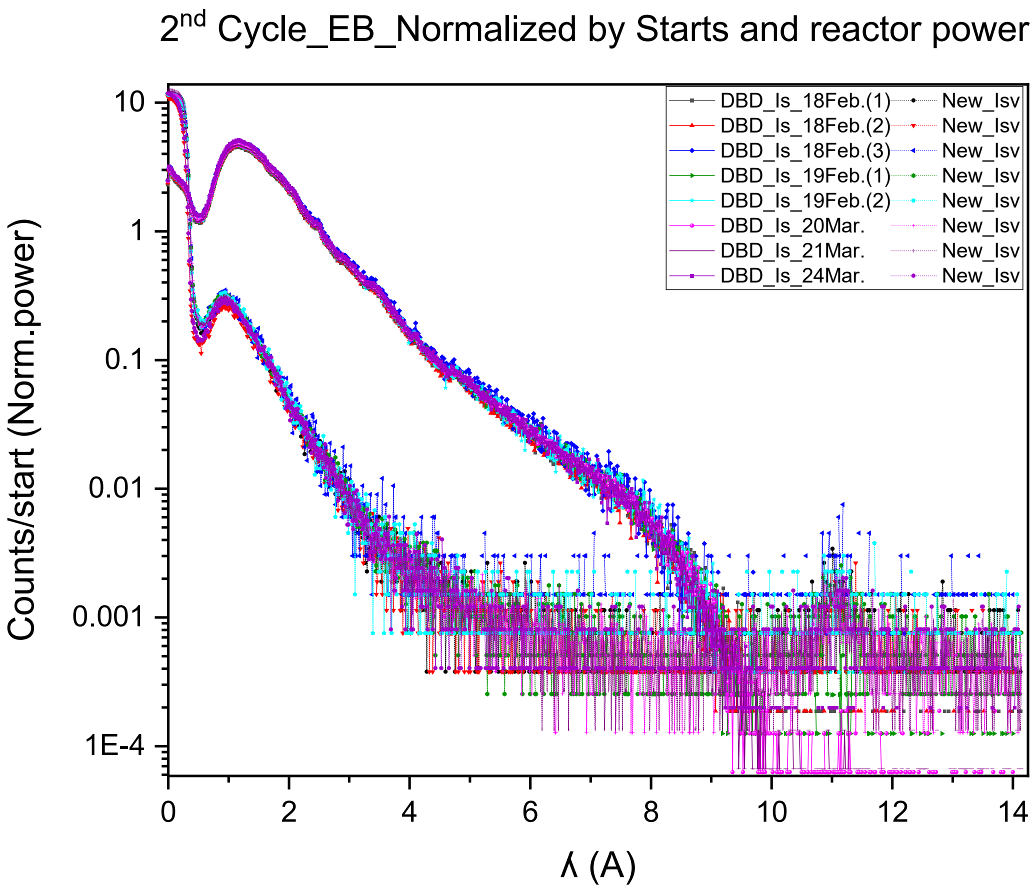
New upgraded(DBD) Attestation



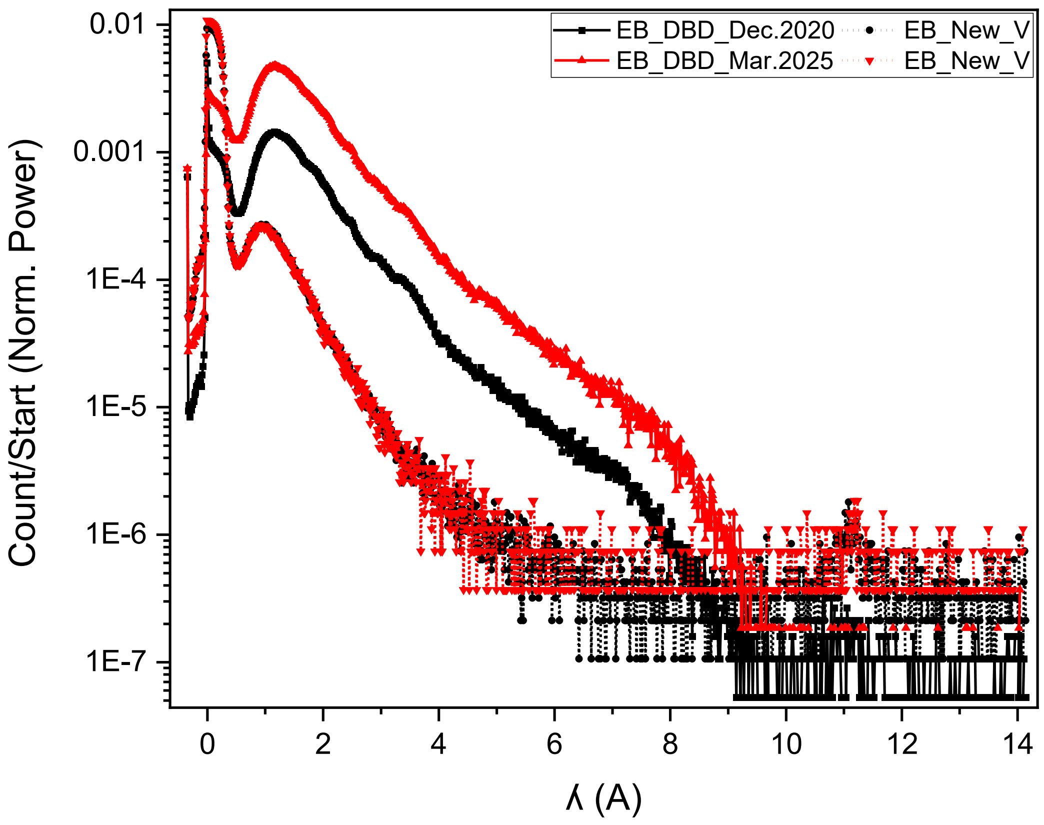


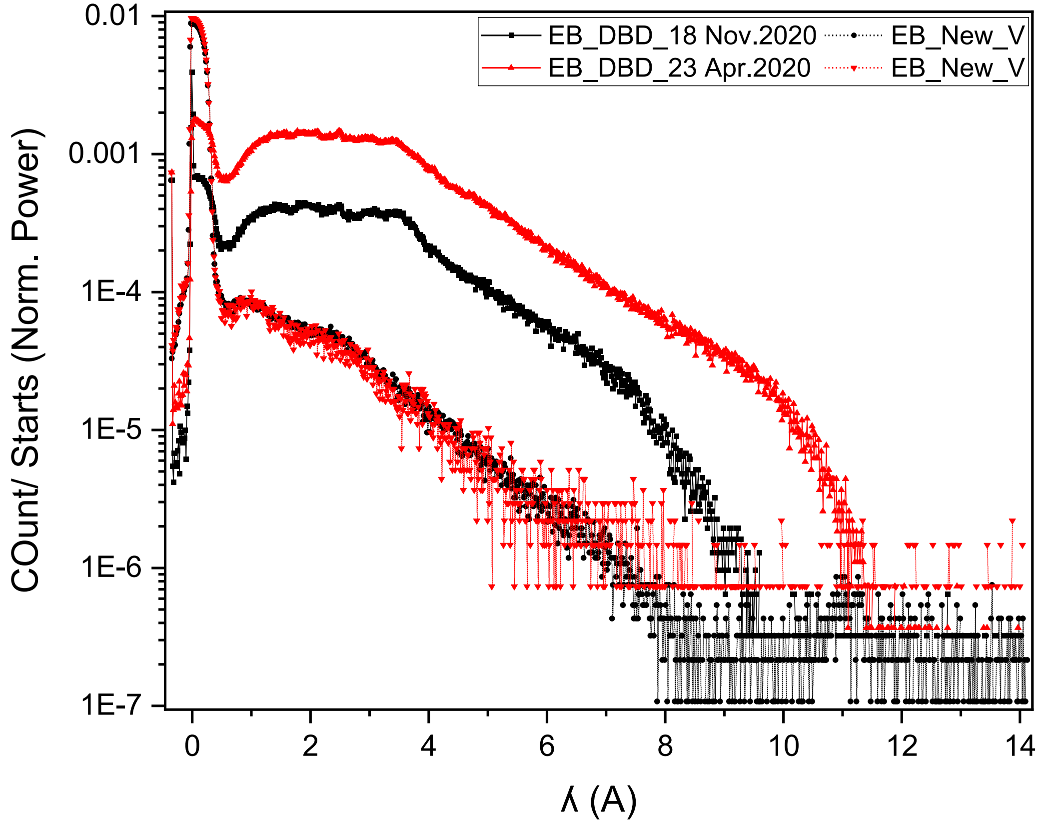
Upgraded (DBD) 2025





Old and New (DBD)





Conclusion

- The detector implemented on the boron converter has shown its operability for over 10 years practically without requiring maintenance
- Studying spectrum on old DBD last 10 years, was a guiding step for detector modernization by using new utilities: the size of the conversion zone, high voltage, and the configuration of the installation.
- DBD has lower sensitivity to gamma signals and neutrons of intermediate energies than helium ring wire scattering detectors is shown. This allows measurements in the direct beam with almost 2000 MW in a pulse.
- The spectral distribution congruently repeats the spectra from scattering detectors, which indicates the absence of losses associated with the dead time of the detector. At the same time, the efficiency is sufficient for most experiments from the point of view of statistical reliability.
- Fluctuations often noticed On spectrum of EB always return to reasonable effect (applied Threshold on DBD, possible rebids in high-voltage Block, also personal errors not registered modification before measurement, so on).
- New DBD show great effectivity monitoring Thermal and cold neutron spectrum.
- Comparison between both OLD and New DBD indicate that Neutron Beam at YuMO Spectrometer is well collimated.

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Thank you for your attention

Acknowledgment

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Scattering Principles YuMO Instrument

http://flnph.jinr.ru/en/facilities/ibr-2/instruments/yumo