Progress in the simulation of the Energy resolution function of CSNS Back-n facility

Shengda Tang(唐生达)[1,2,3], Yonghao Chen(陈永浩)[1,2],Zhen Yang(杨振)[3]

1.Spallation Neutron Source Science Center, Dongguan 523803, China

2.Institute of High Energy Physics, Chinese Academy of Sciences (CAS), Beijing 100049, China

3.Sino-French Institute of Nuclear Engineering and Technology, Sun Yat-sen University, Zhuhai 519082, China

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Outline

CSNS and Back-n facility

Energy resolution function

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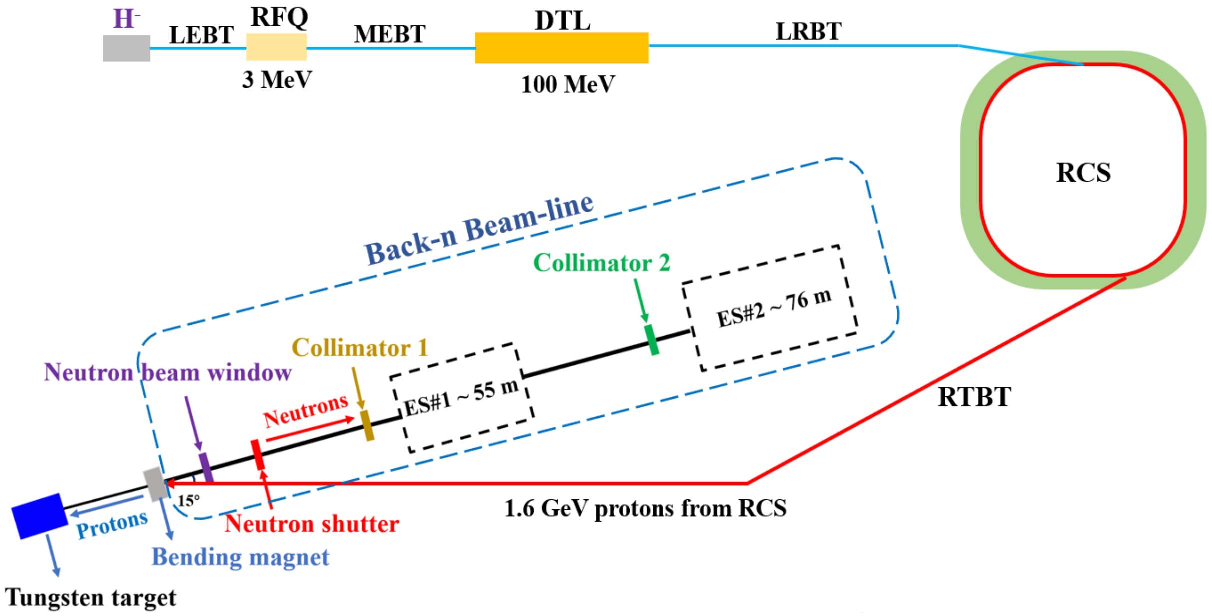
Results and outlook

Poster presentation

CSNS and Back-n facility



The layout of the CSNS and Back-n facility

Collimator configuration and reference values of neutron flux

Neutron shutter (mm)	Collimator1 (mm)	Collimator2 (mm)	ES#1 beam spot (mm)	ES#2 beam spot (mm)	ES#1 Neutron fluxes (n/cm²/s)	ES#2 Neutron fluxes (n/cm²/s)
Ø12	Ø15	Ø40	Ø(15×15)	Ø(40×40)	1.30E5	4.60E4
Ø12	Ø15	Ø40	Ø(18×18)	Ø(30×28)	1.67E6	6.41E5
Ø50	Ø50	Ø58	Ø(54×54)	Ø(62×62)	1.60E7	6.72E6
78×62	76×76	90×90	84×82	96×94	1.80E7	8.57E6
Ø50	Ø15	Ø40	Ø(14×14)	Ø(42×26)	1.04E7	2.42E6

- China Spallation Neutron Source(CSNS) is the first pulsed spallation neutron source in China, its provides an excellent research platform for fundamental research and the development of high-tech industries.
- The Back-n beamline can offer neutrons with high flux, wide energy range, and great time resolution, its well-suited for nuclear data measurement.

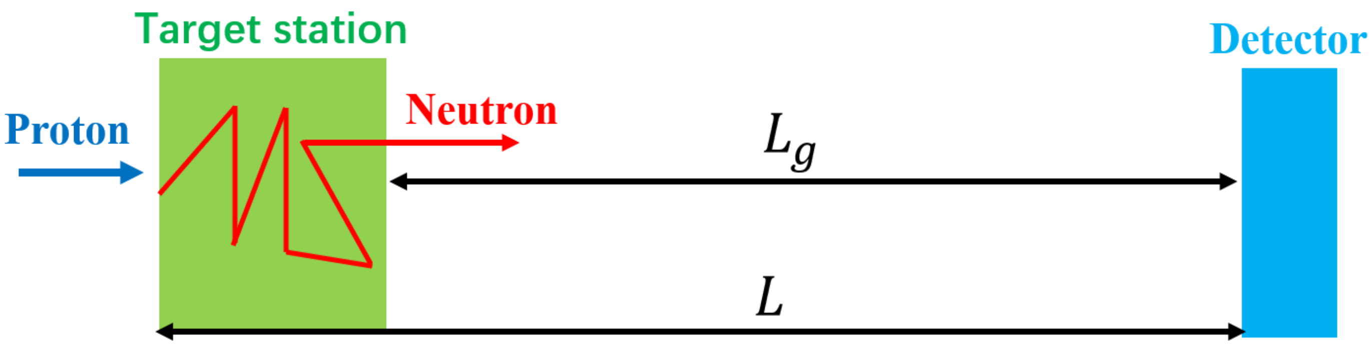
Energy resolution Function

- The Energy Resolution Function (ERF) of a neutron spectrometer is crucial for nuclear data analysis, particularly in the resonance energy region.
- For ERF, the most crucial component that needs to be investigated is the neutron production and transport in the spallation target, which could only be inferred from detailed Monte-Carlo simulations.

$$\frac{\Delta E}{E} = \gamma(\gamma+1)\sqrt{\left(\frac{\Delta L}{L}\right)^2 + \left(\frac{\Delta T}{T}\right)^2}$$

$$\gamma = \frac{1}{\sqrt{1-(\frac{v}{c})^2}}$$

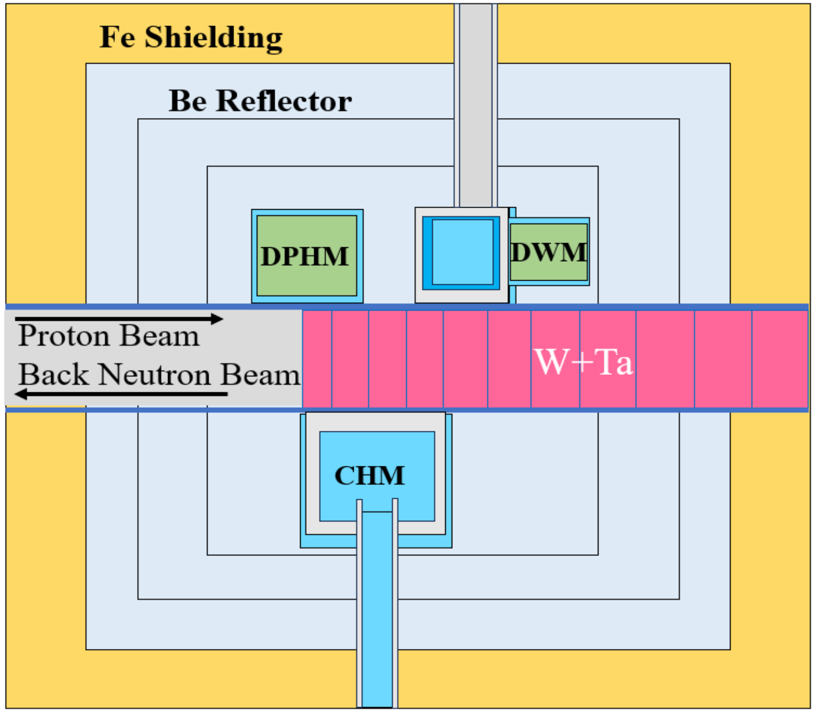
$$v\,T_{mod} \approx \Delta L$$



The Schematic drawing of neutron production, transport, and detection

The moderation distance (ΔL) is defined as the product of the neutron velocity at the emission surface and moderation time in spallation target.

Geant4 simulation



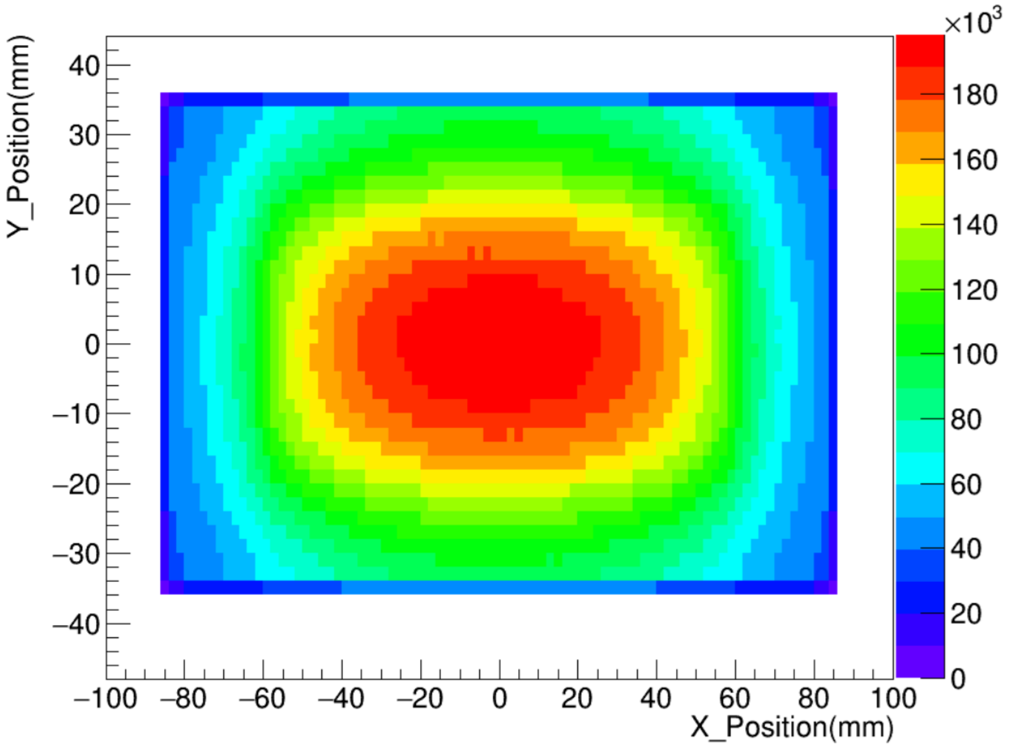
The profile layout of the spallation target station

Components of the simulation model

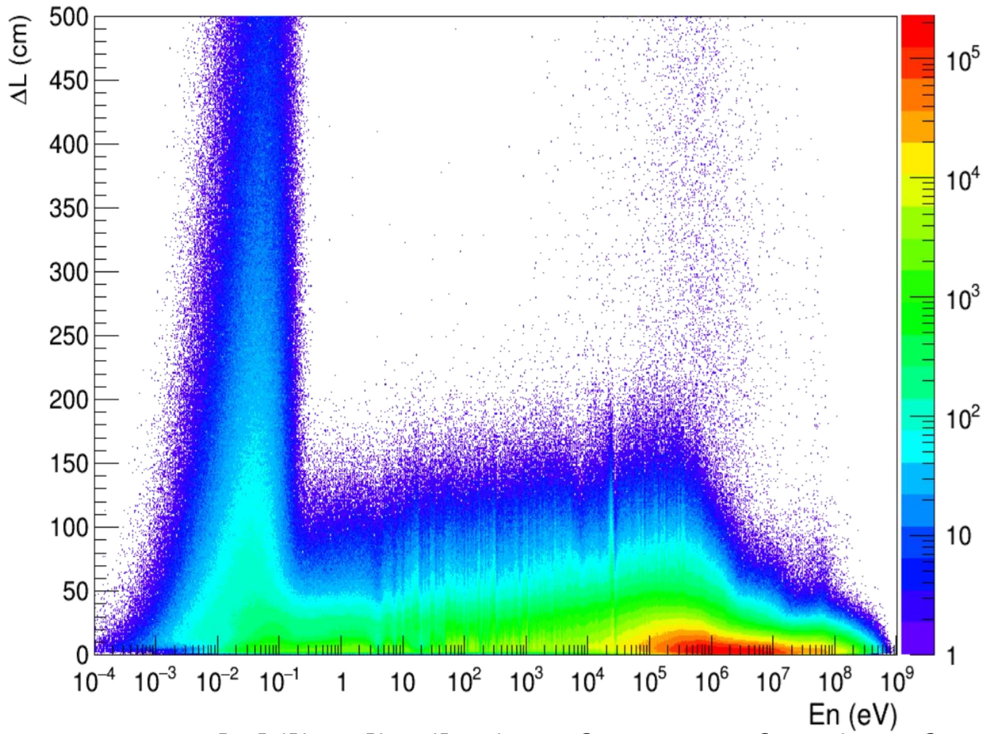
Module	Parameters
Target	Tungsten (11 pieces, Total length:650 mm) Cross section 170 mm(H) × 70 mm(V)
Tantalum	Thickness: 0.3 mm
Target colling	Water, gap:1.2 mm other size: 20 mm
Reflector	Be: Φ700 mm × 800 mm
Shielding	Fe:1000 mm × 1000 ×1000 mm
Target vessel	SS316 Forward: 2.5 mm Backward: 12 mm Up and Down: 7.5 mm Left and Right: 12 mm
Moderator	CHM: Φ150 mm ×100 mm DPHM: 120 mm ×120 mm × 50 mm DWM: 110 mm× 110 mm × 50mm

- ✓ The Geant4 **Version**: **10.07**, the physics list: **QGSP_INCLXX_HP**.
- ✓ The protons number in simulation: 100 million.
- ✓ Scoring volume: The Target vessel (SS316 forward).
- ✓ The neutron kinetic energy, velocity, time, position, and direction messages are collected.

Result and Outlook



Spatial distribution of neutrons at the neutron emission surface

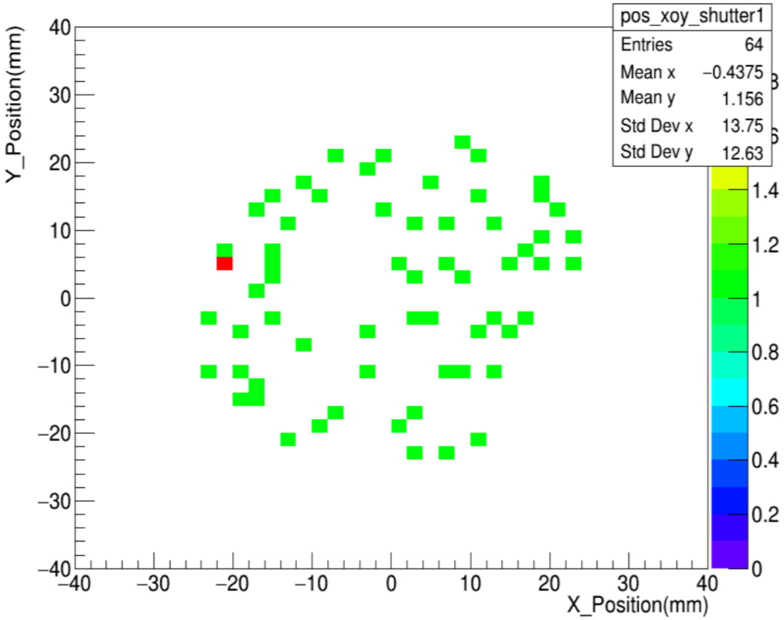


Probability distribution of ΔL, as a function of the neutron energy (neutron emission surface)

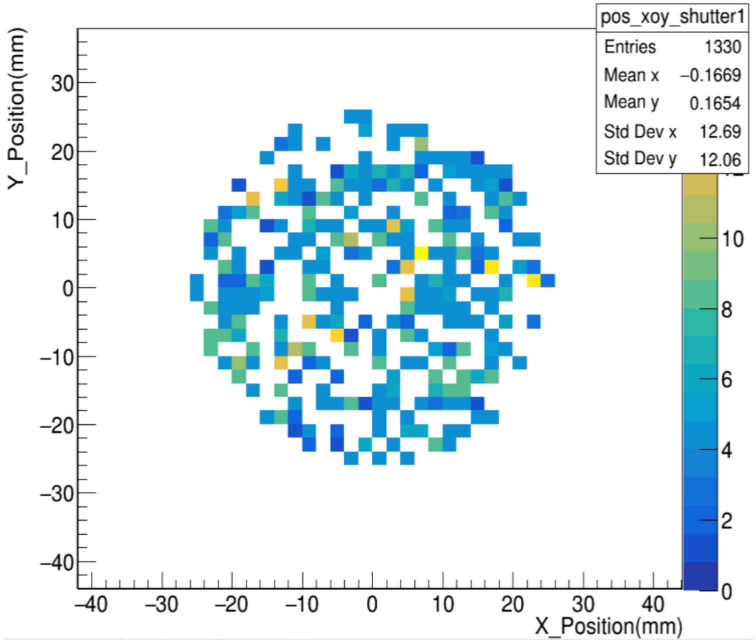
- The neutron emission distribution at the target surface is obtained.
- The probability distribution of ΔL as a function with neutron energy is obtained. The low-energy region is more significantly influenced by ΔL.

Result and Outlook

- Only neutrons can reach the experiment station should be considered.
- The "**splitter**" method, one of the biasing techniques is used. Optimizing the splitter configuration can enhance the statistics of the particles.



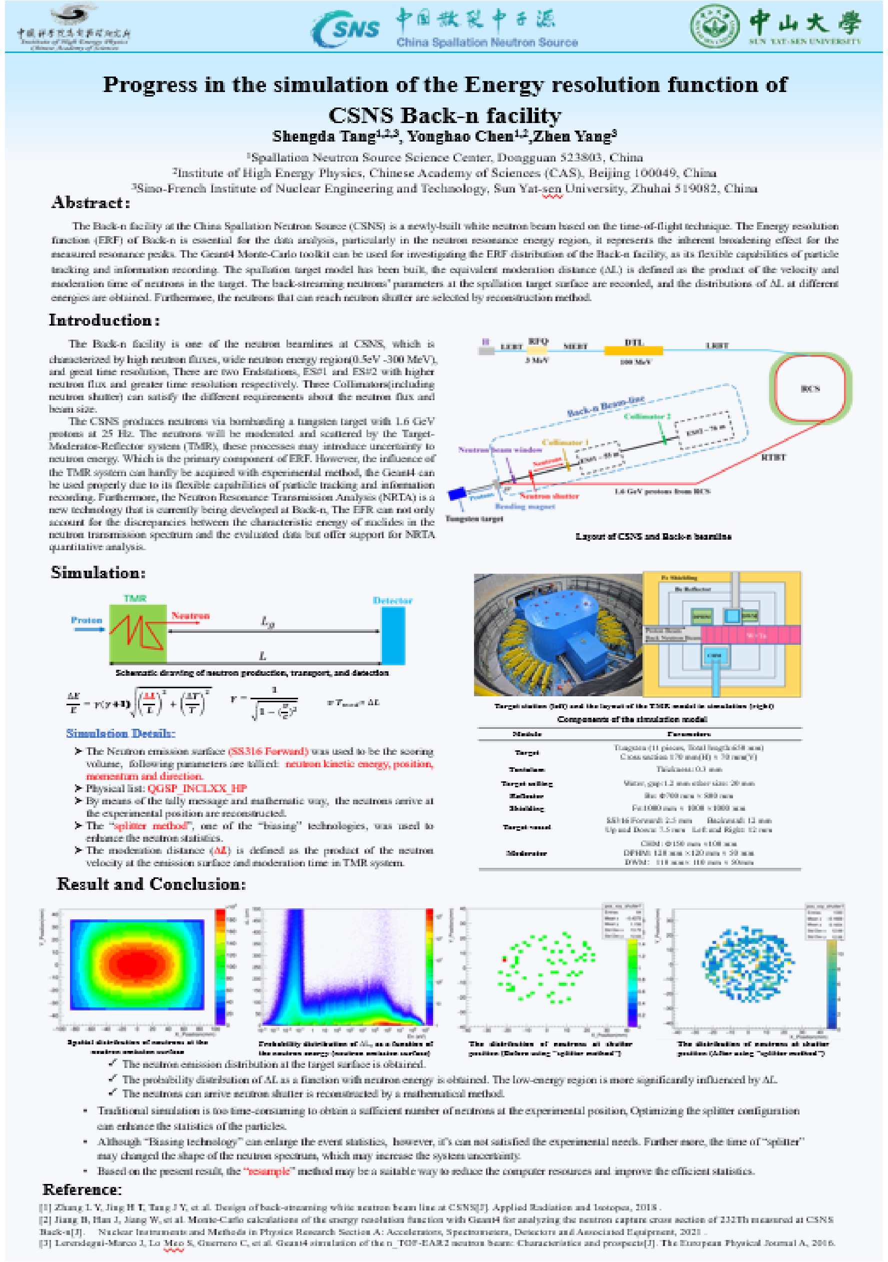
The distribution of neutrons at the shutter position (Before using "splitter method")



The distribution of neutrons at the shutter position (After using "splitter method")

- Even with the splitter method, only a few neutrons can arrive the neutron shutter.
- The "**re-sample**" method, based on the present neutron distribution may be a practical and efficient choice.

Poster exhibition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Abstract:

The Back-n facility at the China Spallation Neutron Source (CSNS) is a newly-built white neutron beam based on the time-of-flight technique. The Energy resolution function (ERF) of Back-n is essential for the data analysis, particularly in the neutron resonance energy region, it represents the inherent broadening effect for the measured resonance peaks. The Geant4 Monte-Carlo toolkit can be used for investigating the ERF distribution of the Back-n facility, as its flexible capabilities of particle tracking and information recording. The spallation target model has been built, the equivalent moderation distance (ΔL) is defined as the product of the velocity and moderation time of neutrons in the target. The back-streaming neutrons' parameters at the spallation target surface are recorded, and the distributions of ΔL at different energies are obtained. Furthermore, the neutrons that can reach neutron shutter are selected by reconstruction method.

Introduction:

The Back-n facility is one of the neutron beamlines at CSNS, which is characterized by high neutron fluxes, wide neutron energy region(0.5eV -300 MeV), and great time resolution, There are two Endstations, ES#1 and ES#2 with higher neutron flux and greater time resolution respectively. Three Collimators(including neutron shutter) can satisfy the different requirements about the neutron flux and beam size.

The CSNS produces neutrons via bombarding a tungsten target with 1.6 GeV protons at 25 Hz. The neutrons will be moderated and scattered by the Target-Moderator-Reflector system (TMR), these processes may introduce uncertainty to neutron energy. Which is the primary component of ERF. However, the influence of the TMR system can hardly be acquired with experimental method, the Geant4 can be used properly due to its flexible capabilities of particle tracking and information recording. Furthermore, the Neutron Resonance Transmission Analysis (NRTA) is a new technology that is currently being developed at Back-n, The EFR can not only account for the discrepancies between the characteristic energy of nuclides in the neutron transmission spectrum and the evaluated data but offer support for NRTA quantitative analysis.

Layout of CSNS and Back-n beamline

Simulation:

Schematic drawing of neutron production, transport, and detection

Simulation Details:

- The Neutron emission surface (SS316 Forward) was used to be the scoring volume, following parameters are tallied: neutron kinetic energy, position, momentum and direction.
- Physical list: QGSP_INCLXX_HP
- By means of the tally message and mathematic way, the neutrons arrive at the experimental position are reconstructed.
- The "splitter method", one of the "biasing" technologies, was used to enhance the neutron statistics.
- The moderation distance (ΔL) is defined as the product of the neutron velocity at the emission surface and moderation time in TMR system.

Components of the simulation model

Result and Conclusion:

- The neutron emission distribution at the target surface is obtained.
- The probability distribution of ΔL as a function with neutron energy is obtained. The low-energy region is more significantly influenced by ΔL.
- The neutrons can arrive neutron shutter is reconstructed by a mathematical method.

- Traditional simulation is too time-consuming to obtain a sufficient number of neutrons at the experimental position, Optimizing the splitter configuration can enhance the statistics of the particles.
- Although "Biasing technology" can enlarge the event statistics, however, it's can not satisfied the experimental needs. Further more, the time of "splitter" may changed the shape of the neutron spectrum, which may increase the system uncertainty.
- Based on the present result, the "resample" method may be a suitable way to reduce the computer resources and improve the efficient statistics.

Reference:

[1] Zhang L Y, Jing H T, Tang J Y, et al. Design of back-streaming white neutron beam line at CSNS[J]. Applied Radiation and Isotopes, 2018 .
[2] Jiang B, Han J, Jiang W, et al. Monte-Carlo calculations of the energy resolution function with Geant4 for analyzing the neutron capture cross section of 232Th measured at CSNS Back-n[J]. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 2021 .
[3] Lerendegui-Marco J, Lo Meo S, Guerrero C, et al. Geant4 simulation of the n_TOF-EAR2 neutron beam: Characteristics and prospects[J]. The European Physical Journal A, 2016.

Thank you!