Time-resolved triton burnup measurement and preliminary study on EAST

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Abstract

The scintillating fiber (Sci-Fi) detection system has been implemented on the EAST device to facilitate time-resolved measurements of D-T fusion neutrons. In contrast to the prior approximate estimation of the D-T neutron discrimination threshold, which employed the “Two-Line” method by fitting two decay components to the counting spectrum, a more precise computational approach was developed with the assistance of the neutron activation system. This advancement enhanced the coefficient of determination for the integral yield of D-T neutrons from 0.97 to above 0.99. Furthermore, the comparison between the estimated threshold and the statistically calculated threshold for D-T neutron yield confirmed that the deviation associated with the “Two-Line” method remains below 7%, thereby validating its accuracy and reliability. At the current neutron yield level (Sn, DD ~ 1014), the time resolution capability of the Sci-Fi detection system on EAST is limited, and the conservative estimation is approximately 100 to 200 milliseconds. The triton burnup ratio (RT) in the flat-top region of the plasma current (IP) is markedly higher than the average value over the entire shot. Analysis of two sets of experimental shots with varying IP values indicates a potential positive correlation between RT and IP, although plasma instabilities exert a significant influence on RT. Time-resolved investigations further confirmed a rapid increase in the proportion of D-T neutrons within the total neutron yield following the cessation of neutral beam injection heating, and estimated the decay timescale of residual tritons in EAST plasma to be on the order of several hundred milliseconds.

Full Text

Preamble

Time-resolved triton burnup measurement and preliminary study on EAST

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Abstract

The scintillating fiber (Sci-Fi) detection system has been implemented on the EAST device to facilitate time-resolved measurements of D-T fusion neutrons. In contrast to the prior approximate estimation of the D-T neutron discrimination threshold, which employed the “Two-Line” method by fitting two decay components to the counting spectrum, a more precise computational approach was developed with the assistance of the neutron activation system. This advancement enhanced the coefficient of determination for the integral yield of D-T neutrons from 0.97 to above 0.99.

Furthermore, the comparison between the estimated threshold and the statistically calculated threshold for D-T neutron yield confirmed that the deviation associated with the “Two-Line”method remains below 7%, thereby validating its accuracy and reliability. At the current neutron ~ 1014), the time resolution capability of the Sci-Fi detection system on EAST yield level (is limited, and the conservative estimation is approximately 100 to 200 milliseconds. The triton Sn, DD burnup ratio ( ) in the flattop region of the plasma current (IP) is markedly higher than the average value over the entire shot. Analysis of two sets of experimental shots with varying IP and IP, although plasma instabilities values indicates a potential positive correlation between exert a significant influence on . Time-resolved investigations further confirmed a rapid increase in the proportion of D-T neutrons within the total neutron yield following the cessation of neutral beam injection heating, and estimated the decay timescale of residual tritons in EAST plasma to be on the order of several hundred milliseconds.

Keywords: EAST plasma; triton burnup ratio; time resolution; D-T fusion neutron; scintillating fiber detection system;

Introduction

The two reaction branches of the D-D fusion reaction produce 2.45 MeV neutrons and 1.01 MeV tritons respectively, and the latter has kinetic properties and an isotropic velocity distribution similar to the helium nuclei (α particles) produced in D-T fusion reactions[1, 2]. Therefore, studying the behavior of tritons in plasma can indirectly help investigate how α particles will be confined in future D-T fusion reactors, which is crucial for maintaining burning plasma[3, 4]. The method of indirectly studying triton burnup ratio ( ) by using the 14 MeV neutrons generated from fusion reactions of tritons in deuterium plasma has been widely and successfully applied in devices such as DIII-D[5, 6], FT[7, 8], TFTR[9-11], JET[12-14], ASDEX[15], KSTAR[16-19], LHD[20-23], and JT-60U[24-26]. Currently, D-T neutron measurement and triton burnup study on EAST[27] are mainly conducted through two neutron diagnostic systems[28]: the Neutron Activation System (NAS) [29, 30] and the recently developed Scintillating Fiber (Sci-Fi) neutron detection system[31, 32]. The former uses silicon samples to measure neutrons with energies above 4 MeV via 28Si(n, p)28Al reactions[33], with the measured D-T neutron yield reflecting the average value over the entire shot. The latter, based on plastic Sci-Fi detectors, measures fast neutrons of various energies using the recoil proton method, and then identifies D-T fusion neutrons by setting appropriate energy thresholds[20, 21], which offers a certain degree of time resolution.

A typical channel-counts spectrum obtained by the Sci-Fi neutron detection system is shown in Fig. 1 [Figure 1: see original paper], where the channel corresponds to the integral value of the pulse signal. Neutral Beam Injection (NBI) plays a key role in ion heating in fusion plasma and significantly affects the yield of D-D and D-T fusion neutrons, which can be clearly seen by comparing Fig. 1(a) and (b).

Without NBI heating, the D-D fusion reaction rate is low, indicating a low triton production rate in the deuterium plasma, as well as a correspondingly low D-T fusion reaction rate. Therefore, the Sci-Fi neutron detection system measures pulse signals with low amplitude and few counts. When NBI is enabled, distinct high-amplitude signals become apparent. The widely used discrimination method, known as the "Two-Line" method, has recently been successfully applied to measure D-T fusion neutrons on the LHD device[2, 23]. This method uses two fitted straight lines to determine the discrimination threshold position: the first component, represented by the blue dashed line, corresponds to gamma rays and lower-energy neutrons mainly from D-D fusion reactions; the second component, represented by the red dashed line, corresponds to 14-MeV neutrons produced by D-T fusion reactions. The difference between these two components demonstrates the Sci-Fi detector' s ability to distinguish between D-D and D-T fusion neutrons and to suppress gamma signals. The intersection point of the two lines can be used to set the discrimination threshold.

Fig. 1 (a) Counting spectrum of a typical EAST shot with NBI heating (#101295) and (b) without NBI heating (#101289) The paper is organized as follows: Section 2 of this paper covers the experimental setup, including a brief introduction to the Sci-Fi neutron detection system on EAST, as well as a more precise threshold selection method using NAS and a comparison with the "Two-Line" method.

Section 3 presents the results of an experimental study on the Section 4 concludes the paper in the end. in EAST experiments, and

2.1 Sci-Fi neutron detection system on EAST

The current Sci-Fi neutron detection system implemented on EAST employs two Sci-Fi detectors concurrently. The first detector (Sci-Fi 1) [22], developed by the National Institute for Fusion Science (NIFS) in Japan, has been operational for D-T fusion neutron measurements since

2021. Initially, Sci-Fi 1 was positioned on the shielding structure outside the F-port flange [34],

with its line of sight oriented toward the upper edge of the plasma, as illustrated in Fig. 2 Figure 2: see original paper.

Considering that the D-T neutron yield is predominantly higher in the central plasma region and the initial detector placement and viewing direction were relatively elevated, the system underwent an upgrade following one experimental campaign. The enhancements comprised the integration of a second Sci-Fi detector (Sci-Fi 2), to facilitate collaborative measurements complementing the original single-detector configuration; repositioning the detectors onto a fixed tray located beneath the shield outside the F-port flange, accompanied by the addition of vibration damping and insulation; and optimizing the detectors' line of sight to target the plasma center. The arrangement of the tray and detector positions is depicted in Fig. 2(b), with the detectors situated approximately 6 meters from the plasma center. Detailed detector specifications are provided in Table 1 . The primary distinctions between the Sci-Fis pertain to optical characteristics, including light yield and effective optical attenuation coefficient, whereas the Photomultiplier Tubes (PMTs) differ in parameters such as gain, dark current, and signal rise time. Sci-Fi 2 was specifically engineered to operate within the complex thermal neutron and gamma-ray environment length, spacing, and surrounding the EAST device, featuring optimizations in the number, substrate material of the Sci-Fis [31], as well as incorporating a compact shielding structure to mitigate thermal neutron interference [32]. The high-voltage and data transmission cables associated with the detectors are routed through wiring channels located beneath the equipment platform within the EAST hall, extending to the neutron diagnostics laboratory situated outside the shielding wall. To minimize electromagnetic interference during signal transmission, these cables are enveloped with electromagnetic shielding wrap. Both the Data Acquisition (DAQ) system and the high-voltage power supply are housed within the neutron diagnostics laboratory.

Detector Fiber model Sci-Fi 1 BCF-10 (NIFS) Sci-Fi 2 (ASIPP)SCSF-78M Table 1 Main Parameters of the Detectors Fiber Fiber diameter length Number of fibers model Shielding H7195 Magnetic shielding H1949-51 a compact radiation Magnetic shielding and shield [32] Fig. 2 (a) Early position of Sci-Fi 1 and (b) current position of Sci-Fi 1 and Sci-Fi 2

2.2 Method for selecting the D-T neutron discrimination threshold

The "Two-Line" method, as a preliminary data processing technique, enables the selection of a discrimination threshold based on the position of the intersection point (Fig. 1); however, it does not facilitate the determination of the neutron energy corresponding to that specific channel position. By employing the NAS, a more accurate threshold selection can be achieved.

Specifically, when different thresholds are applied to the channel-counts spectrum obtained from the Sci-Fi neutron detection system, the counts of neutrons with energies exceeding these thresholds vary accordingly. By aggregating multiple such counts and comparing them with measurements from NAS, the optimal agreement indicates that the channel threshold at that point precisely corresponds to the reaction threshold of the activation sample. The critical aspect of this method lies in identifying the best correspondence through comparative analysis of multiple experimental results. Two viable approaches are proposed: 1) In a single experimental shot, NAS simultaneously measures neutron yields using multiple activation samples, each characterized by distinct reaction thresholds. This provides neutron yields above each threshold, allowing for vertical comparison to establish the channel-to-energy correspondence within the Sci-Fi neutron detection system' s counting spectrum. The accuracy of this approach depends on the number of sample groups incorporated in NAS. Furthermore, based on findings from our previous study, employing Monte Carlo simulations as an alternative to interpolation can effectively reduce associated errors. 2) When the number of neutron yield groups provided by NAS at different thresholds is limited, results from multiple shots conducted under similar experimental conditions can be utilized for horizontal comparison. This approach is adopted in the present study: using neutron yields above 4 MeV provided by NAS for each shot in the EAST device, the corresponding channel positions for that energy are determined.

A total of 25 shots from three distinct groups were selected for analysis: seven shots ranging from #101232 to #101240, seven shots from #101295 to #101306, and eleven shots from #101478 to #101496. All shots within each group were conducted on the same day, thereby ensuring that the EAST device remained approximately constant. the overall operational conditions of Furthermore, key parameters measured during these experiments, including plasma temperature, density, and heating power, exhibited similar values across the shots. Other shots within each group were excluded from the study due to plasma breakdowns resulting in incomplete discharges or the absence of D-T neutron measurements by the NAS. Fig. 3 [Figure 3: see original paper] illustrates the correlation between the counts recorded by the Sci-Fi neutron detection system and the integrated D-T neutron yield for the entire shot, as provided by NAS, with the channel threshold set at 100 channels for all three groups. Notably, the correlation for the #101295 to #101306 demonstrates the highest degree of agreement, with the coefficient of determination (R2) for the fitted regression line exceeding 0.99 and minimal scatter. Although the fitted lines for the other two groups exhibit slightly lower R2 values, they nonetheless maintain a strong overall consistency.

Fig. 3 Correlation between counts from the Sci-Fi neutron detection system and the D-T neutron yield at a channel threshold of 100 channels To identify a channel threshold position that more accurately corresponds to the D-T neutron yield, an additional 22 sets of threshold values were evaluated. The minimum channel threshold considered was 70 channels (Fig. 4 Figure 4: see original paper), while the maximum was 170 channels (Fig. 4(b)). The R2 for the fitted lines under these varying conditions were compiled to analyze their trends, as illustrated in Fig. 5 [Figure 5: see original paper]. It was observed that when the channel threshold of the Sci-Fi neutron detection system was set between 100 and 120 channels, the R2 values for the shots of all groups reached near their maximum levels. This suggests that within this threshold range, the counts recorded by the Sci-Fi neutron detection system exhibit improved correlation with the D-T neutron yield measured by NAS. Notably, the channel positions corresponding to the highest R2 values varied among the three groups, indicating that the calibration coefficient derived from NAS measurements is not constant. In addition to differences in the viewing areas of the Sci-Fi detector and the NAS sample measurement locations, the primary cause is that the counting rate of the Sci-Fi neutron detection system is not high enough; in other words, the current counting spectrum remains incomplete. This limitation has persisted throughout the D-D fusion experimental phase on the EAST device, as D-T fusion neutrons constitute only a minor portion of the total neutron yield. Nevertheless, it is anticipated that this issue will be substantially mitigated in forthcoming tritium experiments. At that stage, with a complete counting spectrum available, the calibration coefficient obtained may be established as a single fixed value.

Fig. 4 Relationship between counts from the Sci-Fi neutron detection system and the D-T neutron yield at channel thresholds of (a) 70 channels and (b) 170 channels Fig. 5 Variation of the R2 for the regression line comparing counts obtained from the Sci-Fi detection system with the D-T neutron yield across different channel threshold settings By aggregating the data from all experimental shots across the three groups, the correlation between the counts obtained from the Sci-Fi neutron detection system and the D-T neutron yield is illustrated in Fig. 6 Figure 6: see original paper. The three data points enclosed within the green dashed box represent experiments in which the shot was prematurely terminated due to plasma disruption. Note that even with the inclusion of these points, the counts obtained by the Sci-Fi detection system maintain a strong correlation with the D-T neutron yield. This observation aligns with expectations and suggests the potential for further investigation into the influence of triton diffusion on plasma disruptions or instabilities induced by such disruptions. Furthermore, by compiling the D-T neutron counts from all experimental shots processed via the conventional "Two-Line" method, their correlation with the D-T neutron yield is depicted in Fig. 6(b). A distinct linear relationship is evident between the D-T neutron counts and the yield as calculated by both methods. The R2 for the new method demonstrates an improvement from 0.97, observed with the traditional "Two-Line" method, to values exceeding 0.99, indicating enhanced accuracy of the novel approach. Two sequential high-parameter shots (#101239 and #101240), were selected to compare the average D-T fusion neutron yields computed using the two different threshold determination methods, as summarized in Table 2 . The minimal deviation observed between the two methods further substantiates the reliability of the "Two-Line" method as a valid estimation technique.

Fig. 6 Overall correlation between the counts obtained by the Sci-Fi detection system and the D-T neutron yield for the three groups of experimental shots, employing (a) the new method and (b) the "Two-Line" method, respectively Table 2 Comparison of the two methods Shot No.

Threshold determination

method

#101239 #101240 New method "Two-Line" method New method "Two-Line" method Average D-T fusion neutron yield Relative deviation (n/s) 2.79 × 1010 2.98 × 1010 3.38 × 1010 3.59 × 1010

3 Time-resolved

study on EAST is defined as the ratio of the triton reaction rate to the production rate. The latter is the same as the neutron yield from D-D fusion, so the can be expressed as: where In D-D fusion plasma, since Sn, DD Sn, DT represent the neutron yields from D-T and D-D fusion, respectively. , the latter is approximately is much smaller than Sn, DT Sn, DD equal to the total neutron yield (system [37] on EAST.

Sn, DT Sn, DD), which is directly measured using the neutron flux monitoring

3.1 Time resolution of D-T fusion neutron measurement

the current phase of D-D fusion experiments, predominantly constrained by the time-resolving capability of measuring the D-T fusion neutron ~ 1014 n/s), the D-T neutron yield yield. Given the existing neutron yield magnitude (observed in the EAST device is approximately on the order of less than 1012 n/s, and the time resolution of the Sci-Fi neutron detection system is limited by this relatively low neutron yield. An experimental shot (#127620), which employed both Sci-Fi 1 and Sci-Fi 2 detectors simultaneously, the time resolution of the Sn, DD was selected for analysis. The measurement outcomes at various time resolutions are presented in Fig. 7 [Figure 7: see original paper], where the brown dashed line denotes the onset of plasma instability. It is noteworthy that during the plasma current (IP) ramp-up phase in this shot, a substantial number of runaway electrons were detected. The electron density was prone to fluctuate after the IP flattop lasted for a period. Therefore, the analysis was confined to the time interval between 2.8 and 9.0 seconds within the shot. The results indicate no significant difference in time resolution performance between Sci-Fi 1 and Sci-Fi 2 detectors; both exhibit considerable fluctuations primarily attributable to the low neutron counting rate. While reducing the time resolution can mitigate statistical errors, it concurrently causes the loss of critical information regarding essential variation trends. For instance, Fig. 7(e) and (f) demonstrate notable discrepancies relative to the other plots.

Accordingly, the current choice of a time resolution ranging from 100 to 200 milliseconds for the Sci-Fi neutron detection system on EAST is deemed appropriate. For future experiments targeting higher neutron yields, a time resolution of 50 milliseconds may also be considered.

Fig. 7 Measurement results from the Sci-Fi 1 and Sci-Fi 2 at selected time resolutions of (a) 10 ms, (b) 50 ms, (c) 100 ms, (d) 200 ms, (e) 500 ms, and (f) 1000 ms. Here, nfm-3 represents the total neutron yield as measured by the fission ionization chamber detector incorporated within the neutron flux monitoring system

3.2 Study on the correlation between

and IP For experimental shots #101239 and #101240, the IP values in the flattop region reached 500 kA and 600 kA, respectively. These two consecutive shots were conducted under nearly identical heating power conditions, rendering them appropriate for investigating the influence of IP on the . The comparison of several main parameters is shown in Fig. 8 [Figure 8: see original paper], where Ne denotes the plasma density, while subplots (c), (d), and (e) display the powers of NBI, Lower Hybrid Wave (LHW) heating, and Electron Cyclotron Resonance Heating (ECRH), respectively. It is noteworthy that within the 5 to 8 seconds interval, IP, Ne, and the power outputs of all heating systems attained a stable plateau without any significant plasma instabilities. Consequently, this interval was selected as the analysis time window. During this period, the time evolution of illustrated in Fig. 9 [Figure 9: see original paper]. The performance of the new threshold determination method was compared with the "Two-Line" method, employing a time resolution of 200 ms. The results indicated no substantial discrepancies between the two methods, thereby reaffirming the accuracy of the "Two-Line" method for estimation.

Sn, DD Sn, DT Fig. 8 Comparison of experimental shots (#101239 and #101240) with IP of 500 kA and 600 kA, respectively Fig. 9 The in the flattop region with IP at (a) 500 kA and (b) 600 kA Sn, DD Sn, DT Fig. 9 further demonstrates that when IP, Ne, and the various heating powers remain stable, also maintain a consistent level. Observed fluctuations primarily arose Sn, DD from statistical errors in the D-T neutron measurements, allowing for the determination of an over the IP flattop region. Additionally, the integral yields of D-D and D-T average Sn, DT neutrons for RT, platform the whole shot, as measured by the NAS, were utilized to compute the also represents the . Both of them are listed in Table 3 , and the RT, whole shot average value of the whole experimental shot. The relative deviation between the two values was calculated, revealing a significant increase in the Moreover, it was observed that as IP increased from 500 kA to 600 kA, both following the rise of IP to the flattop level.

RT, whole shot exhibited an upward trend, which may be attributed to a corresponding increase RT, platform RT, whole shot in ion temperature from 1400 eV to 1600 eV.

Table 3 Comparison of (#101239 vs. #101240) Shot No. #101239 #101240 RT, platform RT, whole shot Relative deviation (%) RT, platform 4.84 × 10-3 5.83 × 10-3 RT, whole shot 3.55 × 10-3 4.01 × 10-3 To investigate the influence of IP variations on the , a series of experimental shots of the same type were performed. The IP values for the shots #127628, #127630, and #127633 were set at 400 kA, 500 kA, and 600 kA, respectively. Fig. 10 [Figure 10: see original paper] presents Ne and heating system power measured in #127628 closely matched the values calculated profiles. The time trend of via numerical simulation based on the classical confinement of energetic ions [38]. It was observed that approximately 4 seconds after the initiation of each experimental shot, both IP and Ne reached the flattop region. Utilizing a time resolution of 200 ms, statistical analyses were Sn, DT conducted on three sets of shots characterized by comparable heating power but differing IP recorded by Sci-Fi 1 values, as illustrated in Fig. 11 [Figure 11: see original paper]. For the calculation of the , the and Sci-Fi 2 exhibited close agreement; consequently, data from Sci-Fi 2 were employed for the are summarized in Table 4 . Notably, an increase in IP computations. The resulting Sn, DT RT, platform to 600 kA corresponded with a reduction in the , a phenomenon potentially attributable to the sawtooth instability observed in #127633. In this shot, the chord-averaged electron density, stored energy, and central electron temperature in the IP flattop region were all diminished relative to those in #127630. This reduction may be linked to suboptimal coupling of lower hybrid wave and a decrease in LHW power. Although the latter exerts a limited direct influence on neutron yield, it plays a critical role in sustaining plasma stability, which is essential for the fusion reaction process.

Fig. 10 Comparison of experimental shots (#127628, #127630, and #127633) with IP of 400 kA, 500 kA, and 600 kA, respectively. ECRH is not shown as its power remained constant Fig. 11 The in the flattop region with IP at (a) 400 kA, (b) 500 kA, and Sn, DD Sn, DT (c) 600 kA.

Table 4 Variation of at different IP Shot No. IP (kA) #127628 #127630 #127633 (n/s) Sn, DT 5.82 × 1010 8.85 × 1010 5.62 × 1010 (n/s) Sn, DD 7.10 × 1013 8.12 × 1013 5.51 × 1013 8.20 × 10-4 1.09 × 10-3 1.02 × 10-3 When compared to the time-integrated shots previously analyzed statistically by NAS [39], the RT, whole shot derived from multiple experimental measured by the Sci-Fi neutron detection system within the IP flattop region were found to be intermediate but generally lower overall, as depicted in Fig. 12 [Figure 12: see original paper]. This discrepancy may be associated with the relatively low NBI heating power employed in the current series of experiments.

RT, platform Fig. 12 The relative positions of of shots # 127628, # 127630 and # 127633, compared with that of RT, platform provided by NAS in previous experiments

3.3 Triton confinement ability of EAST

RT, whole shot The overall trend in the variation of closely with the upon the onset of plasma instability in #127620, the decline within a very short interval. In contrast, the , as measured by Sci-Fi 1 and Sci-Fi 2, aligns ; however, a noticeable temporal lag is observed. Fig. 7 illustrates that experiences a rapid and pronounced does not exhibit an immediate Sn, DD Sn, DT Sn, DD synchronous decrease; rather, it begins to diminish approximately 160 ms later. This delay corresponds to the slowing-down process of freshly generated tritons within the plasma. Further investigation could involve calculating the diffusion coefficient of tritons to better understand this in response to rising behavior. A statistical analysis of the relative increase in Sn, DT NBI heating power reveals that the difference between the two is minimal under stable conditions.

However, during plasma instability, the reduction in is significantly more pronounced , as depicted in Fig.13. This disparity may be attributed to the fact that D-D neutrons Sn, DD Sn, DT Sn, DT Sn, DD predominantly arise from beam-target reactions associated with the NBI system and are thus less sensitive to plasma parameters, whereas D-T neutrons primarily result from thermonuclear reactions within the plasma and are more strongly influenced by changes in plasma conditions. evolution of observed in Fig.13 Reduction of time resolution of during plasma instability in shot #127620. The is 200 ms, and the vertical axis is in logarithmic scale for easier Sn, DT Sn, DD Sn, DT comparison The same reason can explain the phenomena observed after 8000 ms in Fig. 7. At this time, to a low level, whereas is more gradual and persists for a longer duration. Considering that the cessation of the NBI system results in a rapid decline of the the decrease in the Sn, DD Sn, DT D-T fusion reactions require a lower plasma temperature than D-D fusion reactions, and considering that a certain quantity of tritons has already accumulated in the plasma during the preceding discharge process, the D-T fusion reaction continues transiently even after the termination of NBI heating. Consequently, the proportion of D-T neutrons within the total neutron yield increases markedly during this period. The duration of this phase thus provides a preliminary basis for evaluating the triton confinement capability of the EAST plasma. in the experimental shot #127620 was computed with a time resolution of 200 ms throughout the NBI heating ramp-up, steady-state operation, and subsequent shutdown. The time is depicted in Fig.14. It is evident that predominantly follows the trends and is strongly influenced by it. However, following the cessation of NBI Sn, DD exhibited a pronounced spike, corresponding to a situation where the triton depletion system, rate in the plasma far exceeds its production rate. This peak was short-lived, as the accumulated tritons were rapidly consumed or escaped from the plasma. Due to the considerable statistical measurements at low neutron yields, the uncertainties associated with Sn, DD Sn, DT magnitude of the peak during this interval lacks practical significance; nonetheless, its duration serves as an indicator of the fusion device' s triton confinement performance. According to Fig.14, the timescale of this process in the EAST device is estimated to be on the order of a few hundred milliseconds. In contrast, this decay time varies considerably among different fusion experimental devices, depending on their structural characteristics and confinement capabilities.

For instance, the Large Helical Device (LHD), as a stellarator, continues to exhibit measurable several seconds after the NBI heating power is discontinued [23].

Sn, DT Fig.14 Time evolution of in shot #127620. The right subplot enlarges the right axis coordinates to show the detailed features

4 Conclusions

The Sci-Fi neutron detection system has been implemented on the EAST device to facilitate time-resolved measurements of D-T fusion neutrons. Compared to the previously employed approximate "Two-Line" method for determining the D-T neutron discrimination threshold within the channel-counts spectrum, a more precise calculation method based on the NAS has been developed. Utilizing the integrated D-T neutron yield from 25 experimental shots, the R2 value improved from 0.97 to above 0.99. Furthermore, the comparison between the estimated threshold and the statistically calculated threshold for D-T neutron yield confirmed that the deviation associated with the "Two-Line" method remains below 7%, thereby validating its accuracy and reliability. During the current D-D fusion experimental phase, the time resolution of the primarily constrained by the time-resolved measurement capability of the D-T fusion neutron ~ 1014), the time resolution of the Sci-Fi yield. At the present neutron yield magnitude (neutron detection system on EAST is limited, and the conservative estimation is approximately Sn, DD 100 to 200 milliseconds. Notably, the in the IP flattop region is markedly higher than the average value over the entire shot. Analysis of two sets of experimental shots with varying IP values suggests a potential positive correlation between neutron yield and IP, although plasma instabilities exert a considerable influence on . Comprehensive investigations reveal that plasma instabilities have a more pronounced effect on D-T fusion neutrons compared to D-D neutrons, likely attributable to the fact that D-T neutrons predominantly arise from thermonuclear reactions, whereas D-D neutrons mainly originate from beam-target interactions. Additionally, temporal evolution studies confirm a rapid increase in the proportion of D-T neutrons within the total neutron yield following the termination of NBI heating. The decay timescale of residual tritons within the EAST plasma is estimated to be on the order of several hundred milliseconds.

Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

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