ID: 44

Observation of neutron emission anisotropy by neutron activation measurement in beam-injected LHD deuterium plasmas

S. Sugiyama[1], T. Nishitani[2], H. Matsuura[1], M. Isobe[2,3], K. Ogawa[2,3], T. Tanaka[4], S. Yoshihashi[4], A. Uritani[4], M. Osakabe[2,3]
[1]Kyushu Univ., [2]NIFS, [3]SOKENDAI, [4]Nagoya Univ.
s-sugi@nucl.kyushu-u.ac.jp

ABSTRACT

- Neutron emission anisotropy caused by neutral beam injection was observed by neutron activation measurement in LHD deuterium plasmas and was numerically analyzed.
- The obtained numerical results are consistent in the dependence of the neutron emission anisotropy on the neutral-beam-injection direction with the observed experimental data.

BACKGROUND

- Information of confined energetic deuterons can be obtained by the neutron measurement in deuterium plasmas.
- When the deuteron distribution function is anisotropic, non-Maxwellian distribution, the neutron emission spectrum produced by the D(d,n)^{3}He reaction also has an anisotropic distribution.
- The neutron emission anisotropy may provide further understanding of energetic-particle physics and can be used for validation of simulation of energetic-ion behavior.
- We have conducted experiments and performed numerical analyses to investigate the dependence of the neutron anisotropy on the neutral-beam-injection direction in LHD deuterium plasmas.

CHALLENGES / METHODS / IMPLEMENTATION

Experimental setup

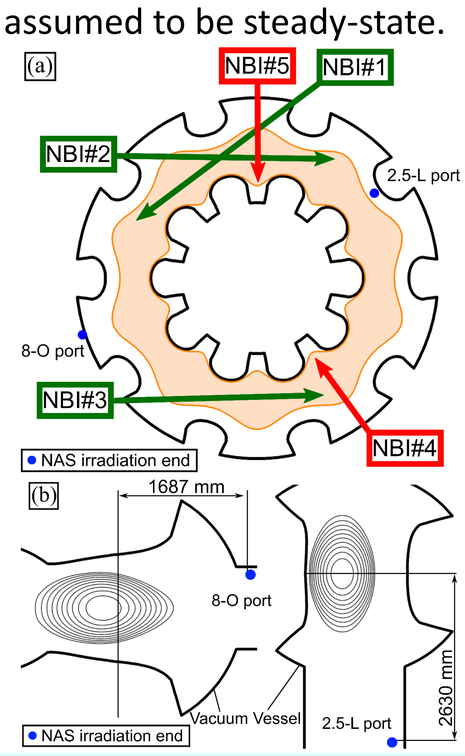
Three different anisotropic deuteron distribution functions were produced by using: all NBIs (#147429), only two perpendicular NBIs (#147431) and only three tangential NBIs (#147433).

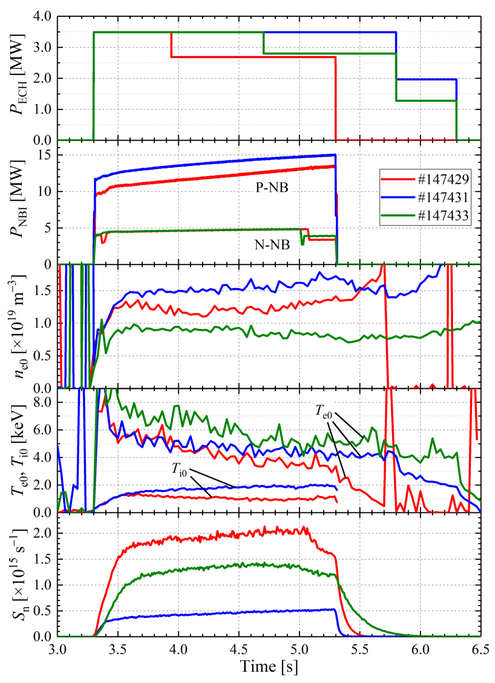
Neutron activation system (NAS)

- The NAS measures the shot-integrated neutron yield by exposing the activation foils and counting gamma-rays emitted from the irradiated foils.
- The indium (In) foils are sent by the pneumatic transfer system to two irradiation ends located at the horizontal (8-O) and lower (2.5-L) ports.
- Fast neutrons are measured by using the ^{115}In(n,n')^{115m}In reaction.
- Thermal neutrons are measured by using the ^{115}In(n,γ)^{116m}In reaction.

Analysis model

- Neutron emission spectra were evaluated from deuteron distribution functions calculated by following guiding-center orbits of test particles using the DELTA5D.
- Reaction rates of the n+^{115}In reactions were calculated by the MCNP-6 [Analysis (A)] and only for virgin neutrons [Analysis (B)].
- Calculation conditions are adopted from the experimental data at 4.5 s and assumed to be steady-state.





OUTCOME

Experiments

$R_{O(L)}$: reaction rate of ^{115}In(n,n')^{115m}In in the foil sent to the 8-O (2.5-L) port

$R'_{O(L)}$: reaction rate of ^{115}In(n,γ)^{116m}In in the foil sent to the 8-O (2.5-L) port

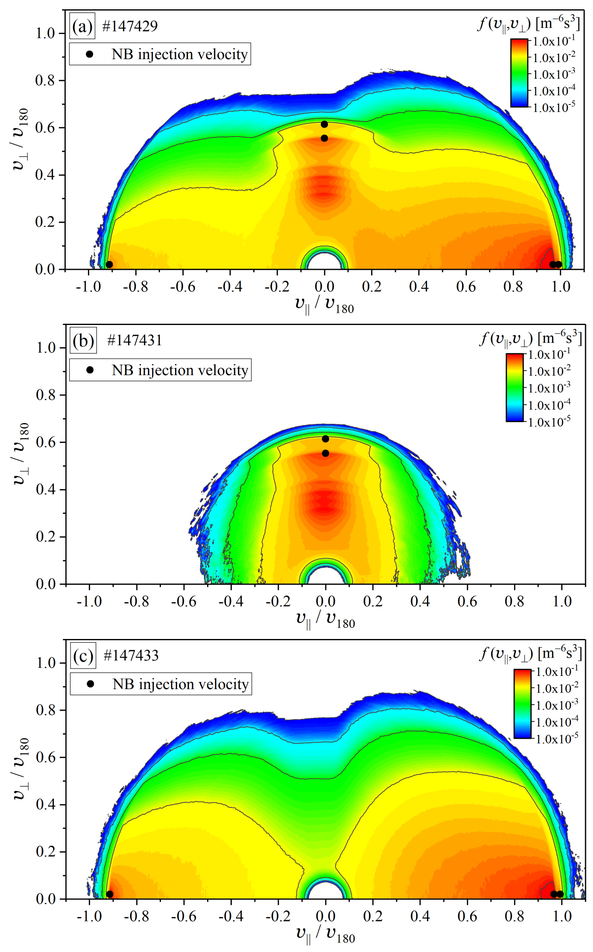
Shot No.	Port	R_O, R_L [×10^6 s^{-1}]	η	R'_O, R'_L [×10^7 s^{-1}]	η'
147429	8-O	1.61	5.63 ± 0.15	3.74	1.74 ± 0.05
	2.5-L	0.287		2.15	
147431	8-O	0.263	3.35 ± 0.18	0.836	1.74 ± 0.02
	2.5-L	0.0785		0.480	
147433	8-O	1.15	5.58 ± 0.33	2.75	1.84 ± 0.05
	2.5-L	0.206		1.49	

$$\eta = R_O / R_L$$
$$\eta' = R'_O / R'_L$$

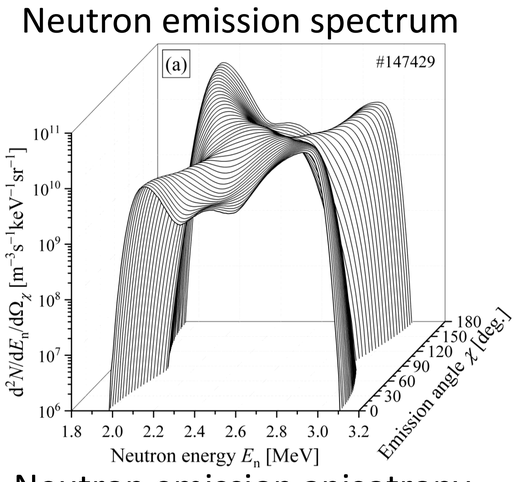
η depends on the NB injection direction, whereas η' is independent.

Numerical analyses

Deuteron distribution function

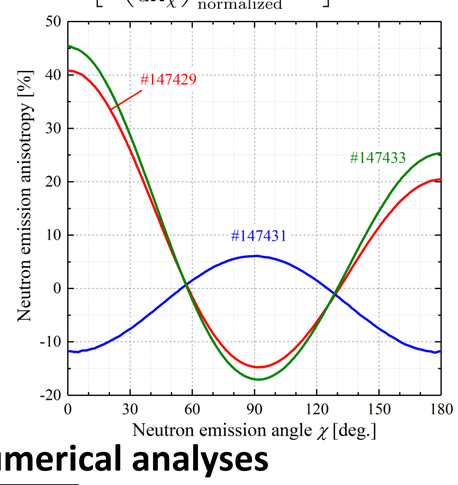


Neutron emission spectrum



Neutron emission anisotropy

$$\left[2\left(\frac{dN}{d\Omega_\chi}\right)_{\text{normalized}} - 1\right] \times 100$$



Comparison between experiments and numerical analyses

Shot No.	η			η'	
	Experiment	Analysis (A)	Analysis (B)	Experiment	Analysis (A)
147429	5.63 ± 0.15	3.780	3.571	1.74 ± 0.05	0.3269
147431	3.35 ± 0.18	2.904	2.081	1.74 ± 0.02	0.2701
147433	5.58 ± 0.33	3.565	3.870	1.84 ± 0.05	0.3048

Analysis (A): MCNP-6
Analysis (B): virgin neutrons

Numerical results for the dependence of η are consistent with experiments.

- Absolute values of η and η' are different between experiment and analyses.
- η' depends on the NB-injection direction in the analyses (weaker than η).

→
- ✓ Improvement of MCNP modelling, especially near the 2.5-L port
- ✓ Calculation of deuteron distributions considering the nonlinear collision effect and time evolution of plasma conditions

CONCLUSION

- The neutron emission anisotropy by neutral beam injection was observed and numerically analyzed in LHD deuterium plasmas.
- The observed dependence of the neutron anisotropy on the neutral-beam-injection direction was explained by the analyses.
- To validate the simulation of energetic-ion behavior, our analysis model is needed to be improved.
- The neutron emission anisotropy can be used when we discuss energetic-ion physics from the point of view of the anisotropy of energetic ions.

ACKNOWLEDGEMENTS

- The authors would like to thank the LHD Experimental Group for their contributions to the experiments on the neutron emission anisotropy.
- This work was supported by JSPS, Grant-in-Aid for JSPS Research Fellow, 18J12685.