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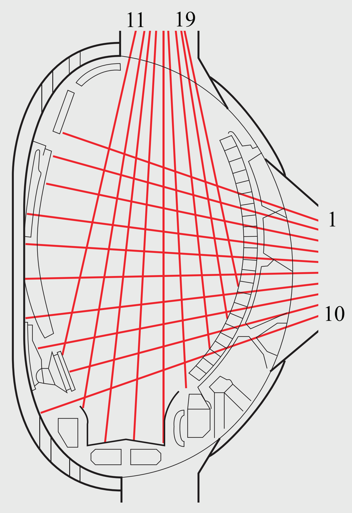
Spatially resolved measurements of the tail temperature of RF accelerated deuterons at JET

ABSTRACT

- The spatial profile of high-energy tail temperature of deuteron distributions arising from radio frequency (RF) heating at JET has been investigated with the JET neutron camera.
- The analysis method entails fitting a parametrized model of the neutron emission to measured camera data. Neutrons born in thermonuclear, beam-target and RF-target reactions are included in the model.
- Results show that we can determine the effective, sightline averaged, RF tail temperature, for each of the 19 neutron camera sightlines. Furthermore, the spatial distribution of the RF tail temperature can also be estimated from the data.

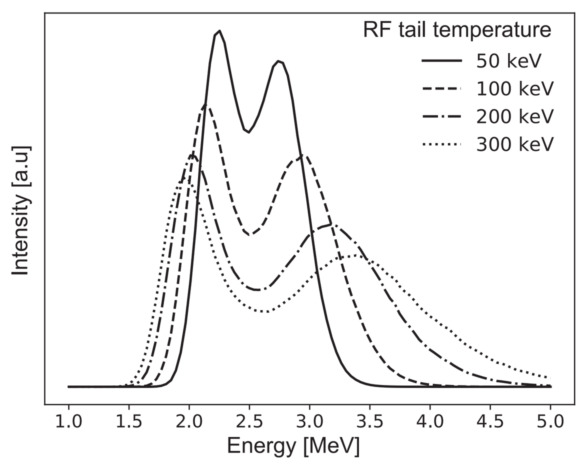
BACKGROUND

Energetic deuterons, resulting e.g. from RF heating, leave distinct signatures in the energy spectra of fusion born neutrons, due to reactions between RF accelerated deuterons and the thermal-bulk plasma. With neutron emission spectrometry, properties of the fusion plasma and the fast-deuterium distribution can be analyzed.

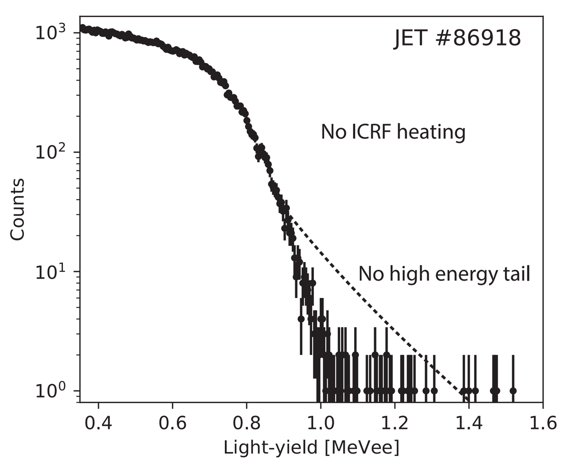


The neutron camera system at JET includes 19 liquid scintillator detectors, which produce light-yield spectra due to the energy deposited by the neutrons that interact within the detectors. The camera has sightlines covering the plasma both horizontally and vertically.

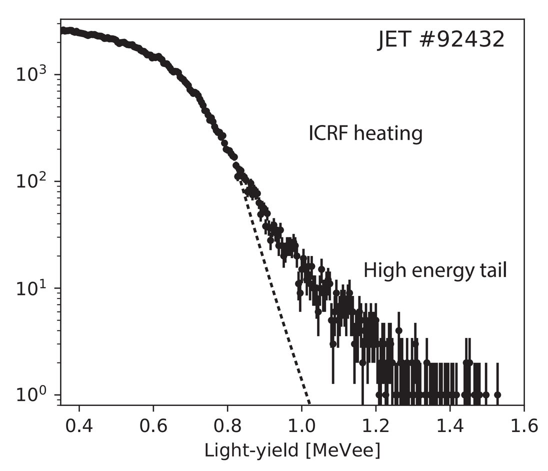
The aim of this paper is to use said camera to determine a spatial distribution of the RF-tail temperature.



Simulated RF-thermal neutron spectra for RF distribution with different tail temperatures.



Measured light yield spectrum for one camera sightline, for a pulse without RF-heating.



Measured light yield spectrum for one camera sightline, for a pulse without RF-heating at the 2nd harmonic of the D cyclotron frequency.

ANALYSIS METHOD

Method 1: Sightline averaged RF tail temperatures

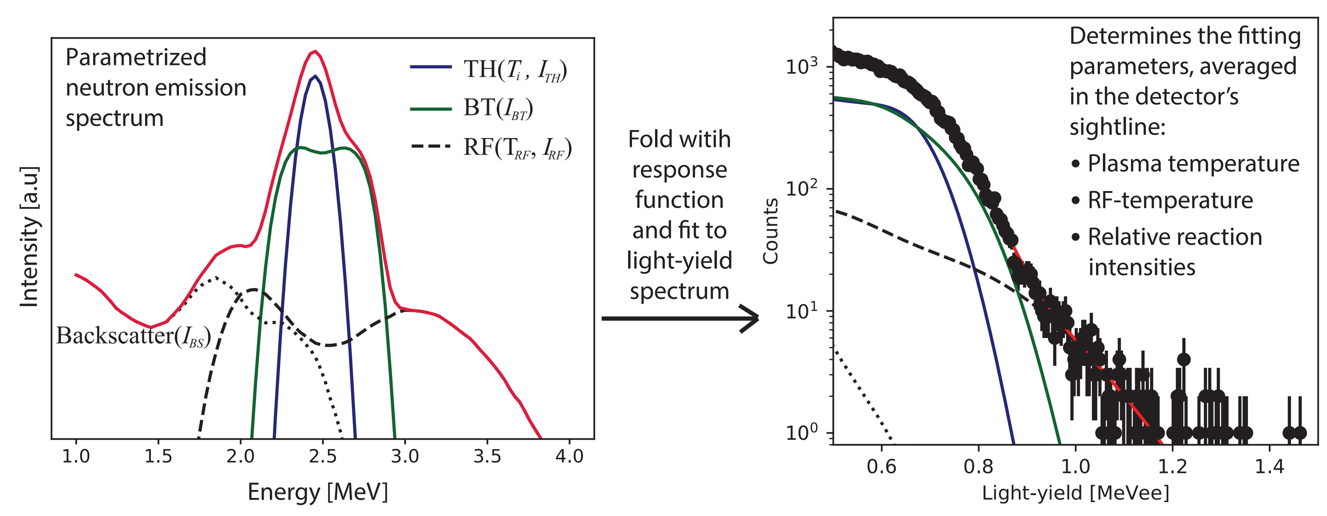
The three primary components of the neutron emission spectrum - thermonuclear (TH), beam-target (BT) and RF-target (RF) - have been modeled and parameterized in terms of plasma temperature, RF-tail temperature, and relative reaction intensities, including a spectrum of backscattered neutrons (BS). These modeled components have been folded with the detector response function and fitted to the measured neutron spectrum from each neutron camera sightline. The described procedure, visualized in figure 1, determines the sightline averaged RF tail temperature for each individual sightline and is used to produce the data presented in figure 3.

Method 2: A spatial distribution of the RF tail temperature

The RF tail temperature has been spatially modeled as a 2D Gaussian function, i.e., with a maximum value, location, width, and height. There is a distribution for the temperature and reaction intensity respectively, both centered at the same point, but have unique shapes. The parameters and analysis are illustrated in figure 2.

From this model, we can calculate the shape of the RF-component of the neutron spectrum, for every sightline in the neutron camera. We have fitted this parameterized model to measured data from every neutron-camera detector simultaneously giving a spatial map of the RF tail temperature in the R-Z plane. This approach differs from Method 1, in which the model is fitted to each sightline separately.

***Figure 1:** An illustration of the method for fitting a parameterized model of the spectral components to a measured light-yield spectrum and hence determining the model parameters (Method 1).*



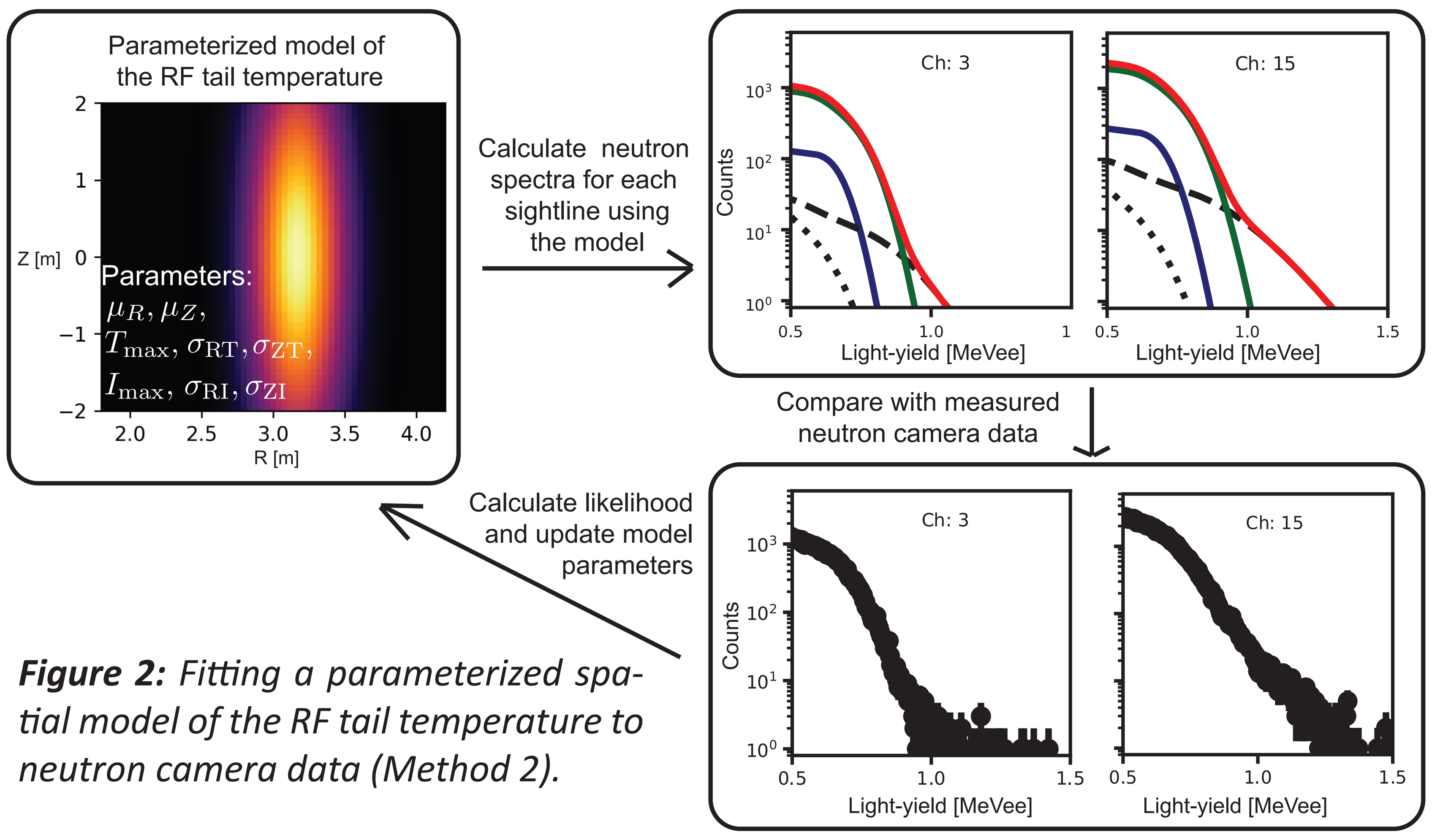


***Figure 2:** Fitting a parameterized spatial model of the RF tail temperature to neutron camera data (Method 2).*

RESULTS

Results of the analysis method applied to JET pulse 92436 (heated by 27 MW NBI and 6 MW of 2nd harmonic D RF heating) are presented here. Figure 3 shows the sightline averaged RF tail temperature for each of the neutron camera's lines-of-sight, along with two examples of fitted spectra. The spatial distribution of the RF tail temperature is presented in figure 4.

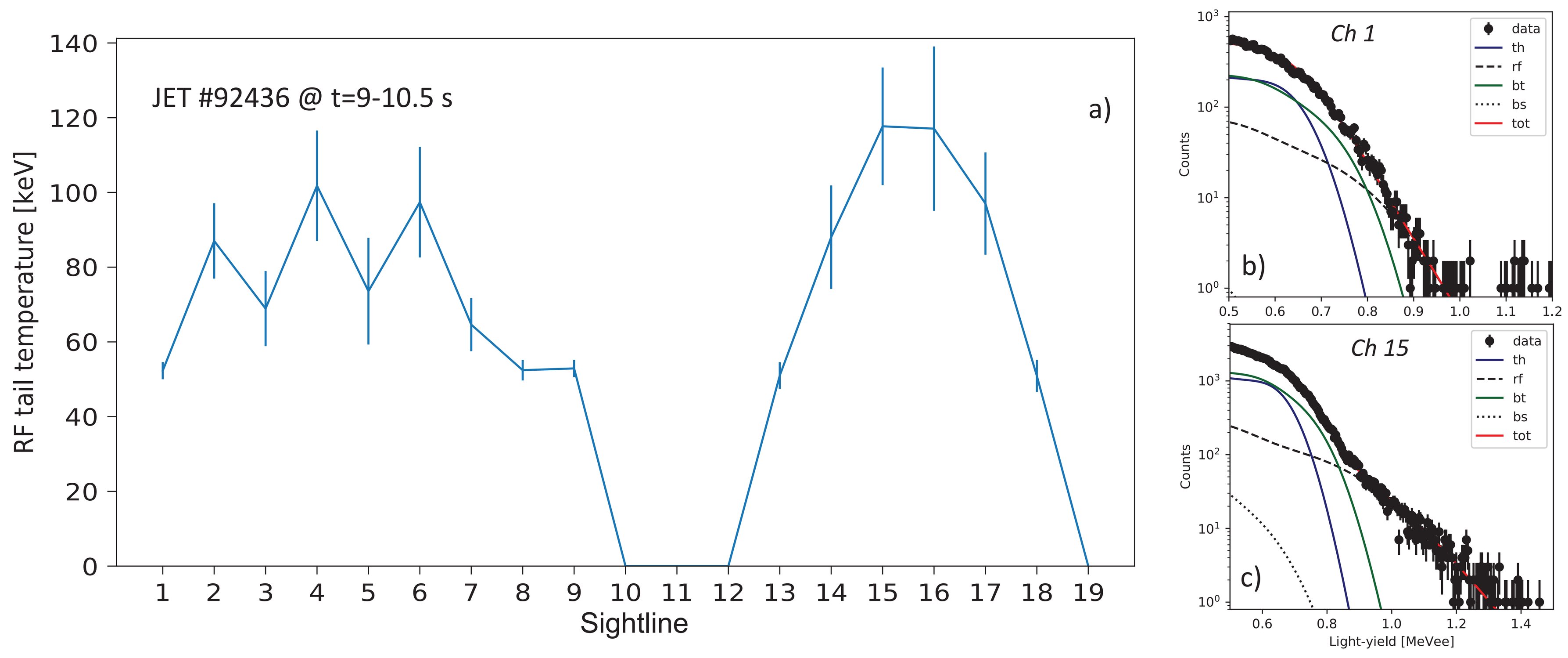


***Figure 3:** (a) The sightline-averaged RF tail temperature of every neutron camera sightline, obtained by fitting modeled components to the measured light-yield spectra of the neutron camera. Examples for fitted spectra are shown in (b) and (c).*

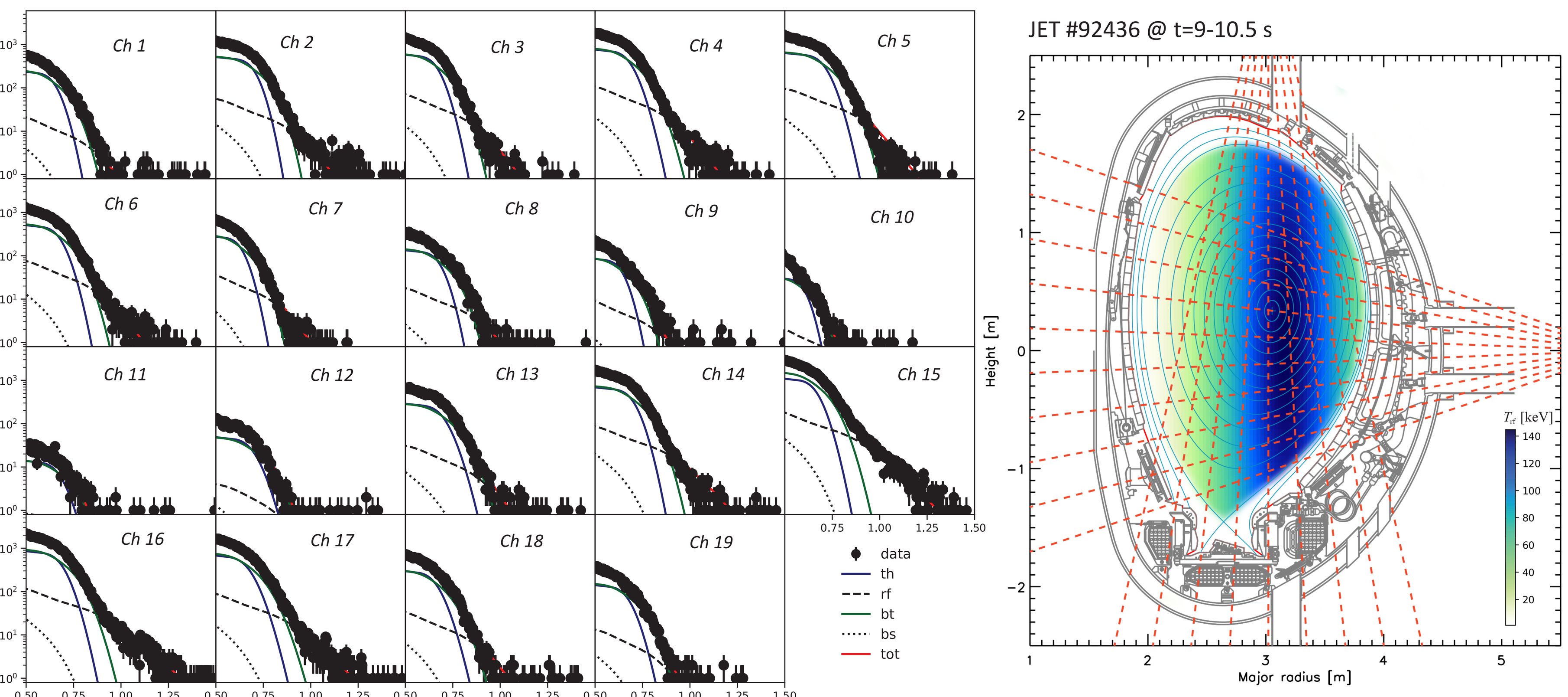


***Figure 4:** Estimated spatial distribution of the RF tail temperature (right) obtained by fitting the model to the neutron camera light-yield spectra for all 19 sightlines (left).*

CONCLUSIONS

The RF-tail in the neutron spectrum is visible in the neutron camera's light-yield spectrum and can be used for a spectroscopic study of the distribution of RF accelerated deuterons in the plasma. This information is useful for comparing theoretical predictions of RF schemes and can give better confidence in, for example, predictions for DT.

Based on the analysis performed, we conclude that the light-yield spectra from the JET neutron camera can be used to determine the spatial profile of the RF tail temperature.

The accuracy of the method depends on the number of counts in the detector, translating to a time-resolution of roughly one second, for high performing JET pulses.

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