

PHYSICS BASIS OF DISCREPANCIES BETWEEN TEMPERATURE MEASUREMENTS BY ECE AND THOMSON SCATTERING IN HIGH PERFORMANCE PLASMAS ON JET, EAST AND DIII-D

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ABSTRACT

- Discrepancies between the Electron Cyclotron Emission (T_ECE) and Thomson Scattering (T_TS) measurements of electron temperature were observed on JET, TFTR, and more recently on FTU.
- This paper reports on the most recent study on this discrepancy conducted in the context of ITPA Joint Activity on ‘High Temperature Measurements’ on JET DT Campaigns , EAST and DIII-D.
- Models link these differences (discrepancies) to the interaction of the heating systems with the electrons and then to the non-Maxwellian nature of the electron velocity distribution function (EDF).
- Studying these effects is important for ITER and the fusion reactor where they can increase significantly.
- In studying these discrepancies, systematic effects and volume average related to different lines of sight used for collecting the light must be taken into account

BACKGROUND

- The discrepancies are detected on JET using two systems, i.e. HRTS (High Resolution Thomson Scattering) and LIDAR TS, on EAST, DIII-D and preliminarily on W7X. The consistency of these discrepancies across multiple diagnostics and machines rules out systematic effects as the underlying cause.
- On JET in Tritium-rich scenario at Te=12keV there is a difference of ECE with respect to TS on the order of 25%, with T_ECE lower than T_TS.
- An empirical model of non-Maxwellian bipolar perturbation fits the JET DTE3 database.
- Investigations started on EAST to see how the discharge conditions influence the EDF, and how combination of heating affects the ECE/TS discrepancy. The experiments were made in dominant ECRH heating with variation of plasma conditions and heating systems. In the presence of Ion cyclotron heating T_TS>T_ECE was detected : the effect of fast ions on EDF could be considered in this scenario.
- Databases are collected on DIII-D to document the measurements of temperatures. The heating systems used on DIII-D are ECRH, NBI and discharges with combination of these systems are available. Systematic effect where T_ECE>T_TS for Te>7keV are reported , however this difference remain below the line of +10% difference.

PHYSICS BASIS OF ECE AND THOMSON

ECE RADIATION TEMPERATURE: THE MEASUREMENT DEPENDS ON ABSORBTION COEFFICIENT WHICH IS PROPORTIONAL TO THE DERIVATIVE OF THE EDF WITH RESPECT TO THE ENERGY, SO IT IS STRONGLY SENSIBLE TO NON-MAXWELLIAN EDF

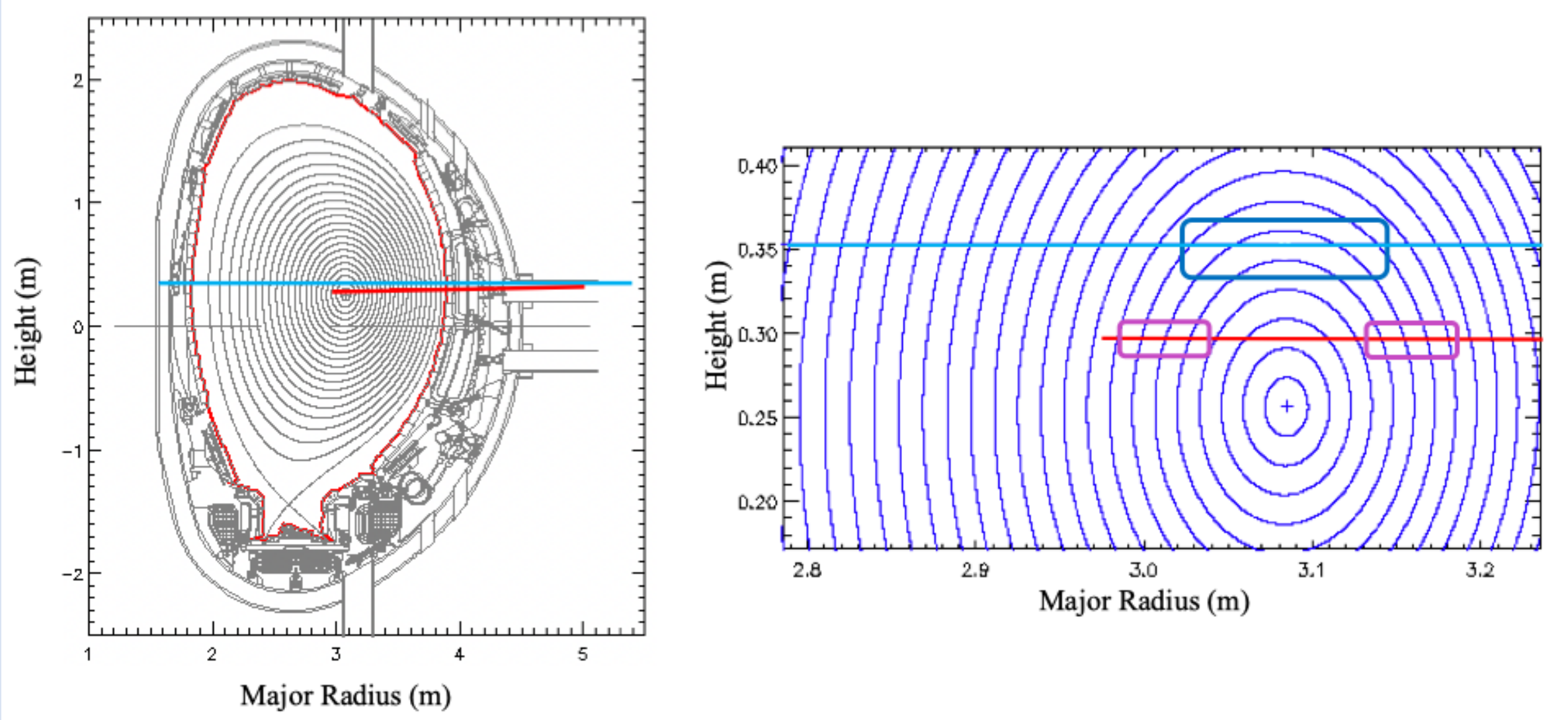
$$T_{\text{rad}}(\omega) = \int_{R_0-a}^{R_0+a} F_{\text{rad}}(R) dR = \int_{R_0-a}^{R_0+a} \beta_{\omega}(R) \left[\exp\left(-\int_R^{R_0+a} \alpha_{\omega}(R) dR\right) \right] dR \quad (2)$$

THOMSON SCATTERING SPECTRUM

$$P_{\text{TS}}(\omega) \propto \int f(\vec{v}) \delta(\vec{k} \cdot \vec{v} - \omega) d\vec{v}$$

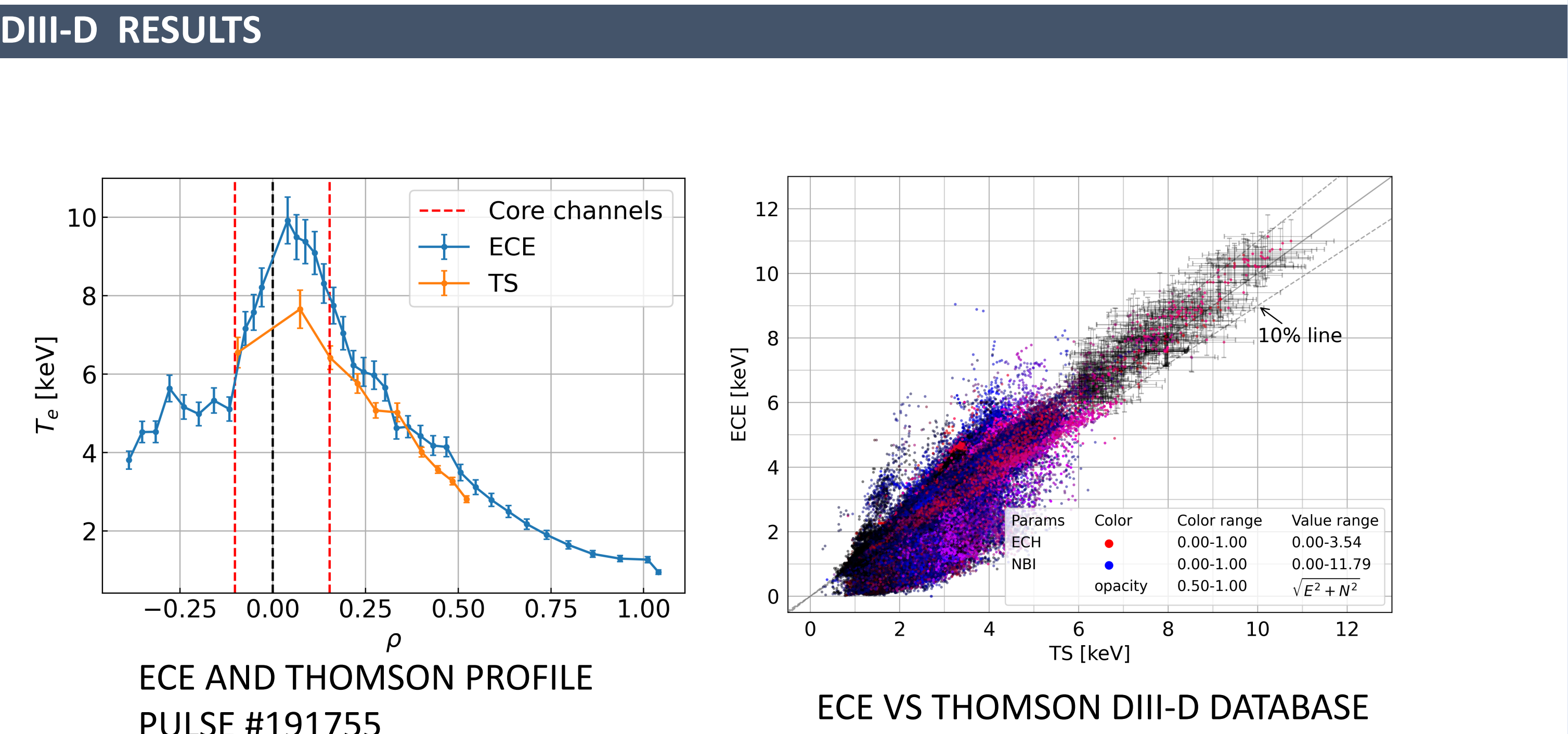
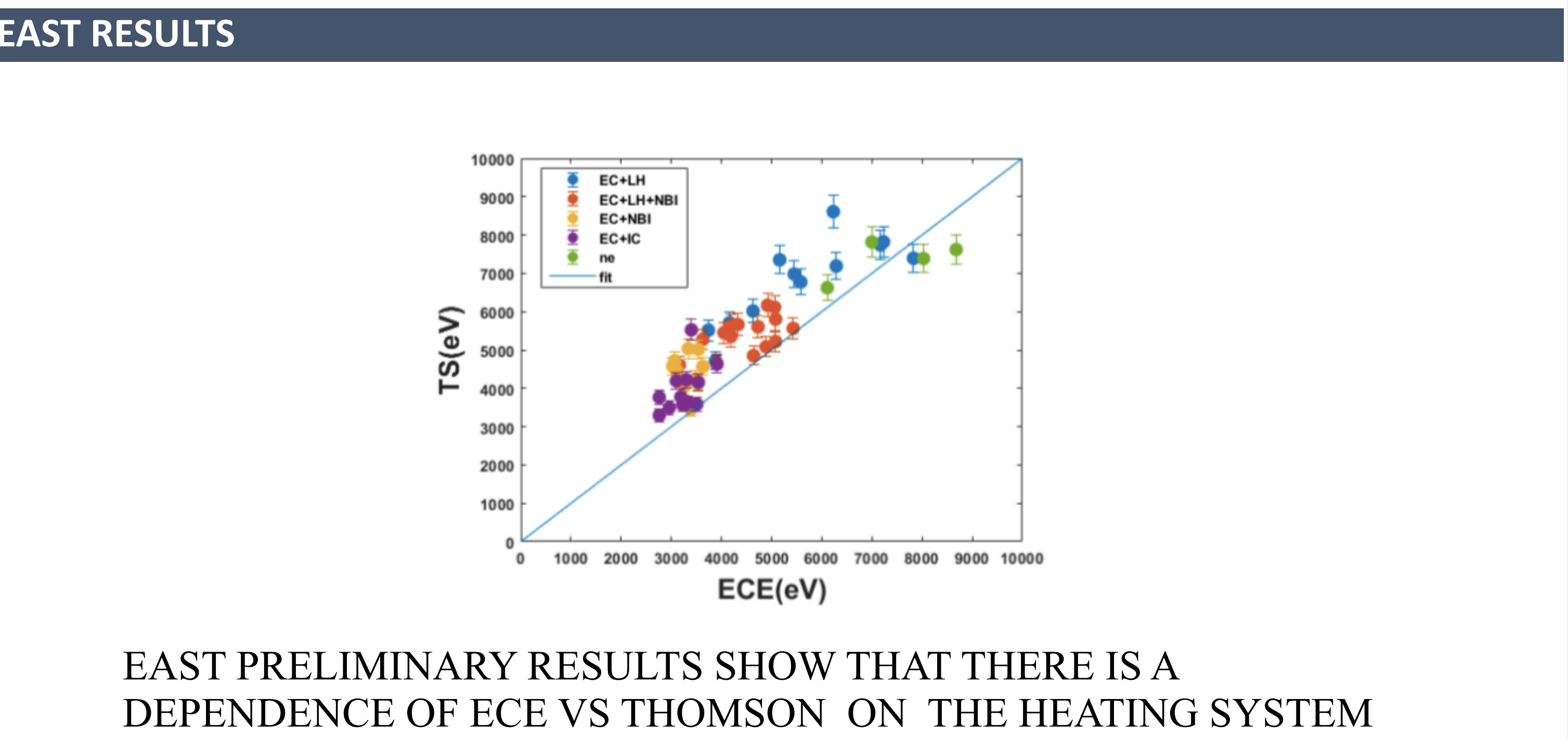
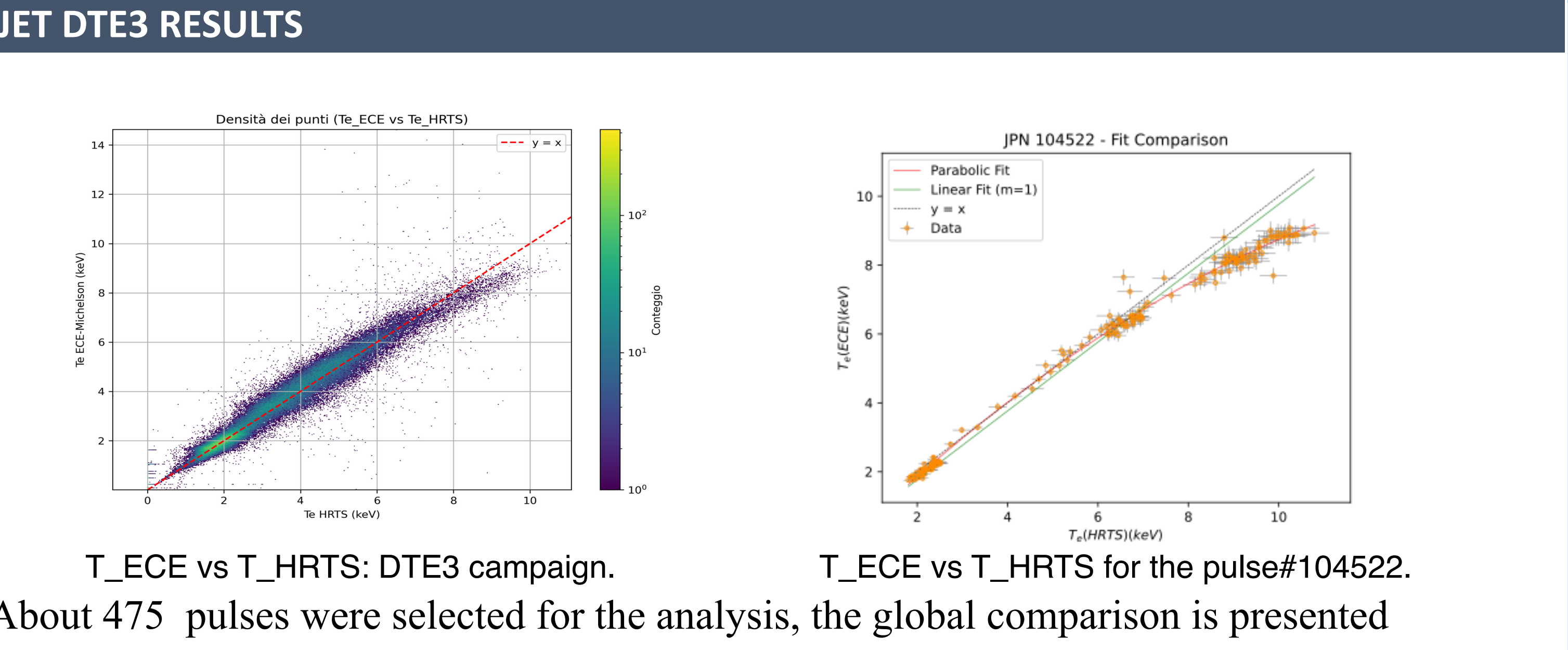
THE THOMSON SPECTRUM IS PROPORTIONAL TO THE ELECTRON VELOCITY DISTRIBUTION FUNCTION

THE MEASUREMENT OF ELECTRON TEMPERATURE : LINE OF SIGHTS AND VOLUME AVERAGES

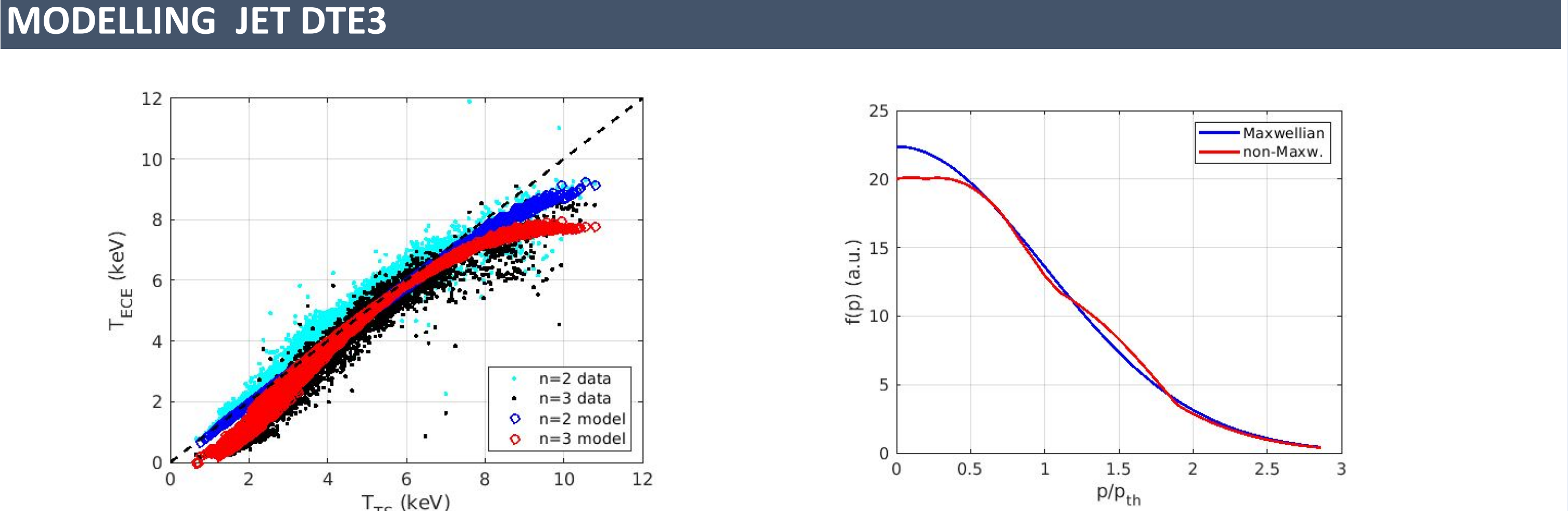


left :Line of sights of the JET systems, light blue ECE Martin-Puplett interferometer(MPI), red HRTS .
Right : the volumes covered by HRTS (violet) and MPI (blue) corresponding to the same flux coordinate

It is very important to note that the measurements of ECE MPI and HRTS are averaged over the same flux coordinates range, as shown above-right, where the approximate averaging volumes of both diagnostics, mapped to the same flux-coordinate interval



The difference T_ECE - T_TS≈+2keV at plasma centre for the pulse#191755.The Figure (right) shows a systematic effect T_ECE>T_TS for Te>7keV, this difference mainly remains below the line of +10% difference.



LEFT : T_ECE (MPI) VS T_TS(HRTS). Measured data are shown together with data computed using the perturbed EDF shown in the figure at right.

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