

Comparison of TS and ECE Electron Temperature Measurements at High T_e on EAST

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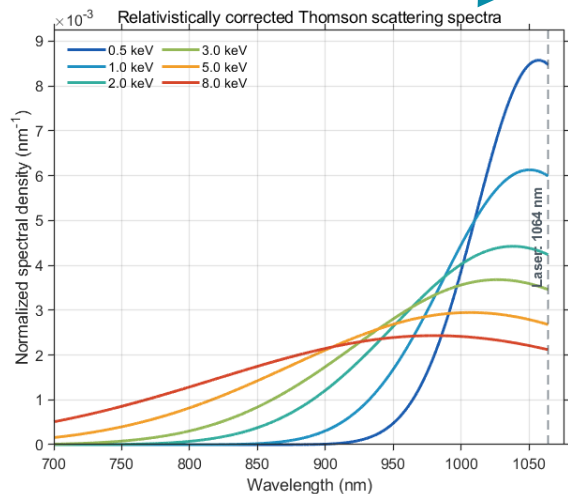
Frascati, 19-21 October 2026



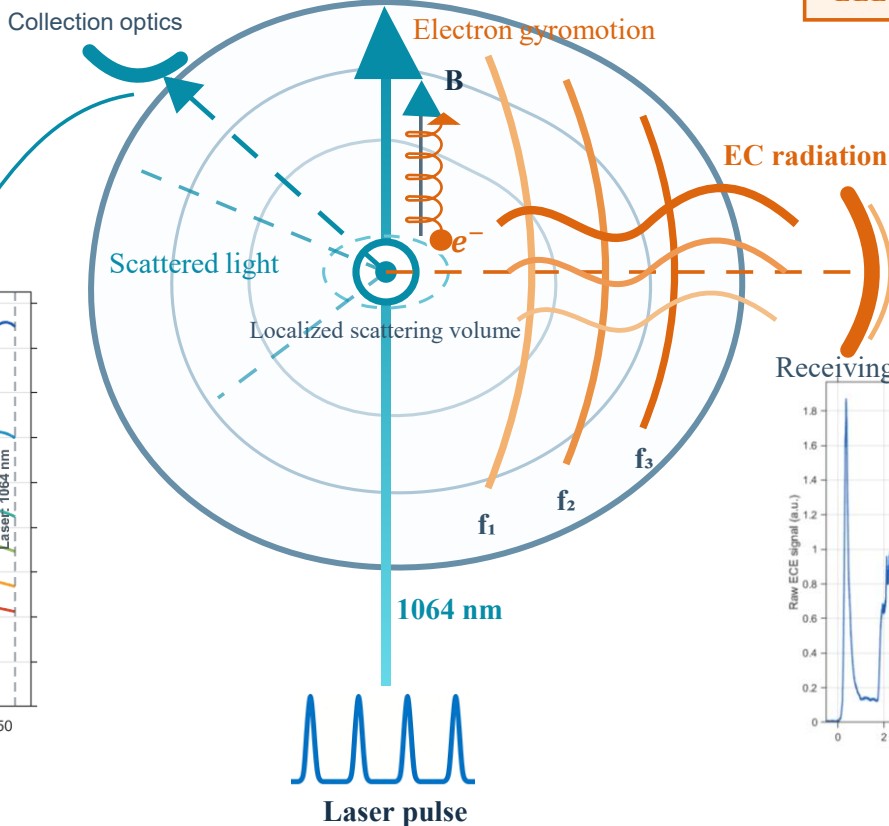
Measurement principles of TS and ECE

THOMSON SCATTERING

$$S(\lambda) = \frac{c}{2\sqrt{\pi}\lambda_0\sqrt{2k_B T_e/m_e} \sin(\theta/2)} \left[1 - \frac{7\Delta\lambda}{2\lambda_0} + \frac{m_e c^2 (\Delta\lambda)^3}{8k_B T_e \lambda_0^3 \sin^2(\theta/2)} \right] \exp \left[-\frac{m_e c^2 (\Delta\lambda)^2}{8k_B T_e \lambda_0^2 \sin^2(\theta/2)} \right]$$



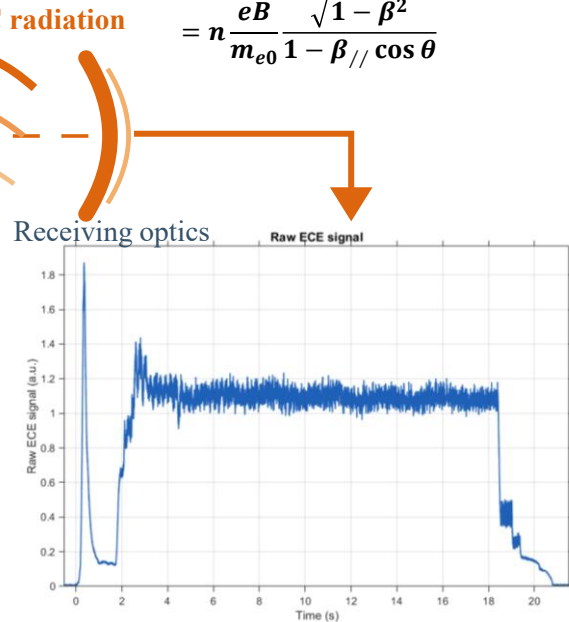
Spectral width $\rightarrow T_e$



ELECTRON CYCLOTRON EMISSION

$$\omega = n \frac{eB}{m_{e0}} \sqrt{1 - \beta^2} + k_{\parallel} v_{\parallel}$$

$$= n \frac{eB}{m_{e0}} \frac{\sqrt{1 - \beta^2}}{1 - \beta_{\parallel} \cos \theta}$$



Brightness temperature $\rightarrow T_e$

TS and ECE: temperature inference and calibration

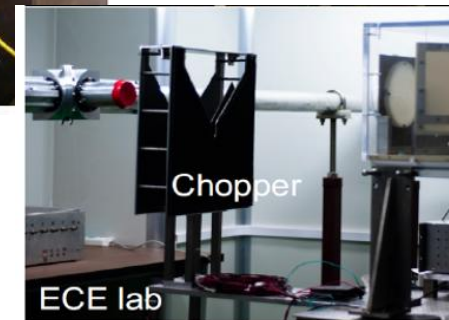
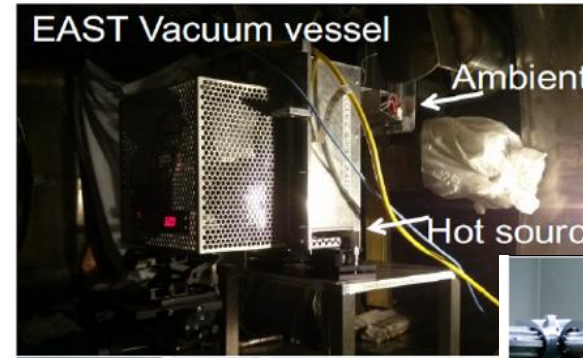
THOMSON SCATTERING

- Relative spectral response of TS channels;
Fit the calibrated scattering spectrum to
infer T_e .



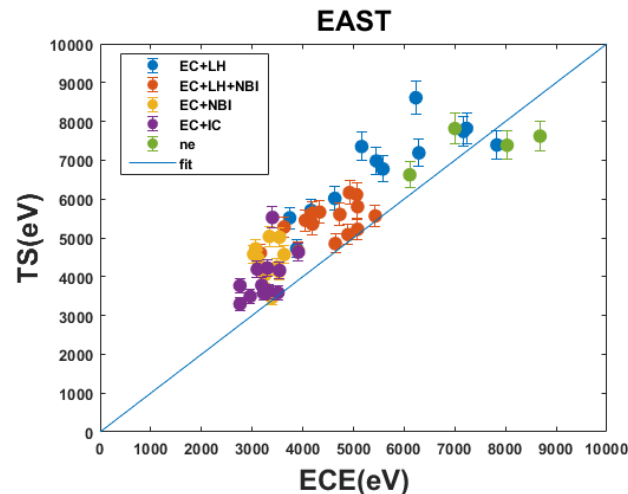
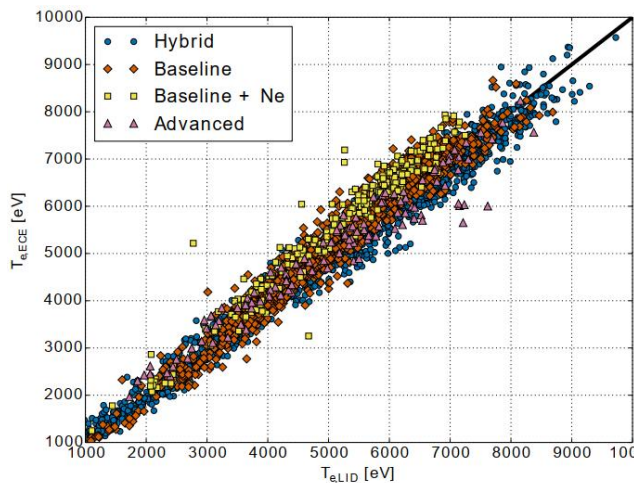
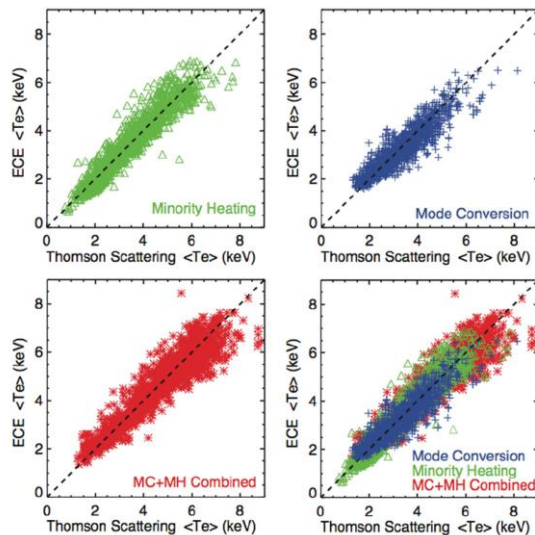
ELECTRON CYCLOTRON EMISSION

- Radiometric response of ECE channels;
Infer T_e from calibrated brightness
temperature under suitable emission
conditions.



Cross-Machine Evidence of TS–ECE Discrepancies

- TS and ECE measurements generally agree, but **systematic discrepancies** have been reported under specific heating conditions and at high electron temperatures.



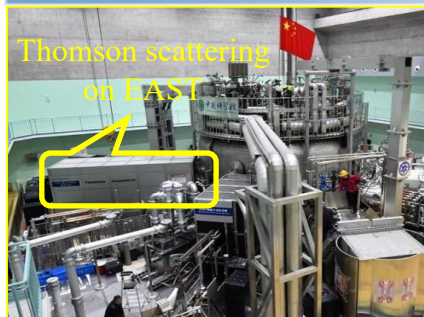
White et al., Nucl. Fusion 52, 063021 (2012).

Fontana et al., EPJ Web Conf. 277, 03006 (2023).

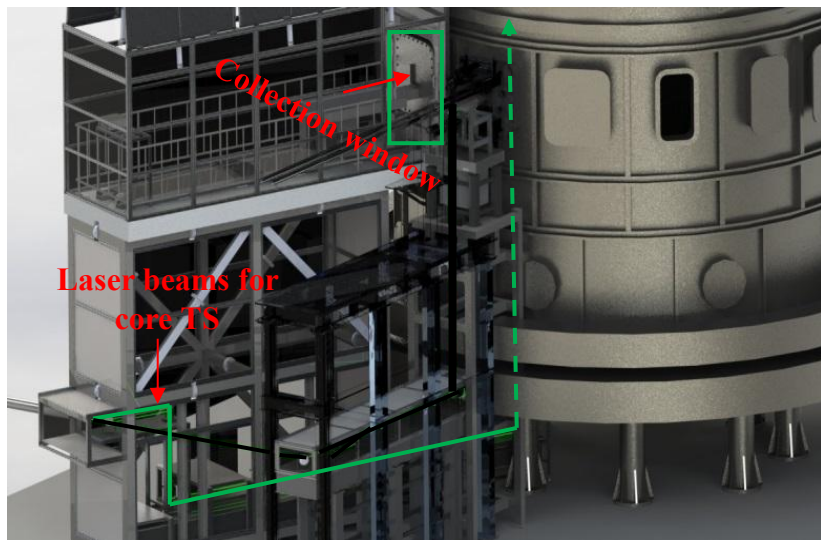
Orsitto et al., IAEA FEC 2025, IAEA-CN-316/2673.

- A systematic **multi-discharge evaluation** of the TS–ECE discrepancy under different plasma conditions is still required on EAST.

Core TS on EAST

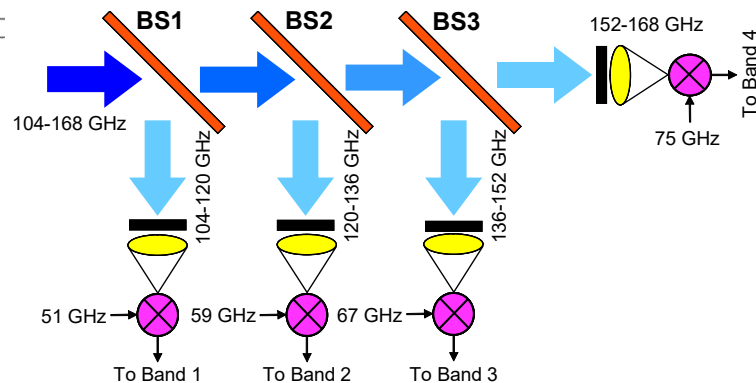
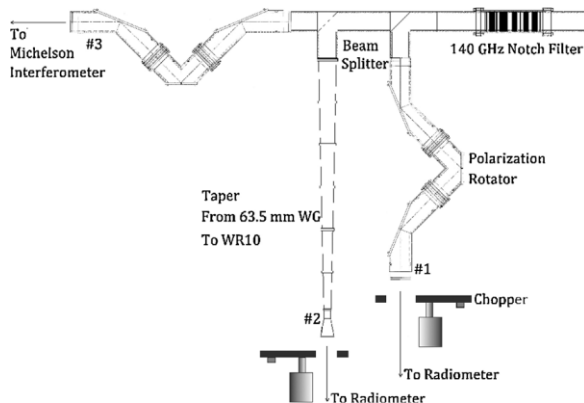
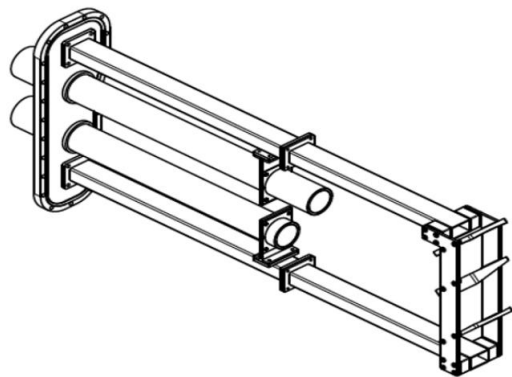


- **Laser source:** A 1064 nm Nd:YAG laser system.
- **Beam delivery:** Approximately 40 m beam-delivery path with 10 steering mirrors.
- **Beam geometry:** The laser beam passes vertically through the EAST vessel, from the lower vertical L-port to the upper vertical L-port.
- **Light collection:** Scattered-light collection from the horizontal L-port.
- **Spatial coverage:** 39 spatial channels: $z = -15$ to $+65$ cm, covering $r/a = 0 - 0.95$.



ECE on EAST

- ❑ A 56-channel heterodyne radiometer covering 86–167 GHz, with a temporal resolution of 2.5 μ s.
- ❑ A Michelson interferometer covering 80–500 GHz, with a temporal resolution of 33 ms.



➤ ECE front end quasi-optical system

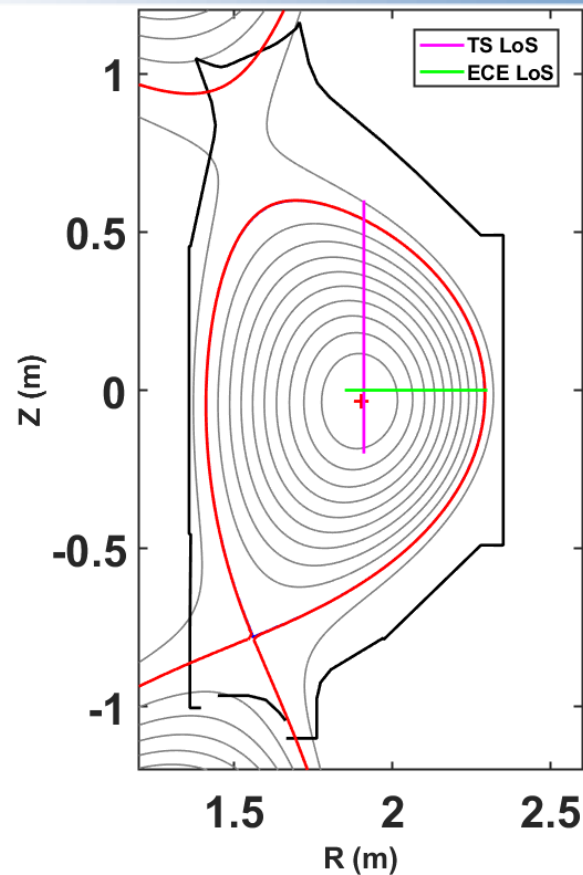
➤ The transmission line in the diagnostic room

➤ RF front end of the heterodyne radiometer system

TS and ECE Diagnostic Geometry and Specifications on EAST

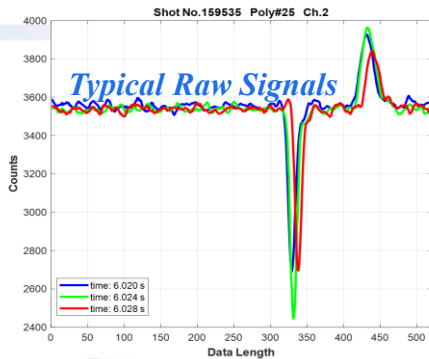
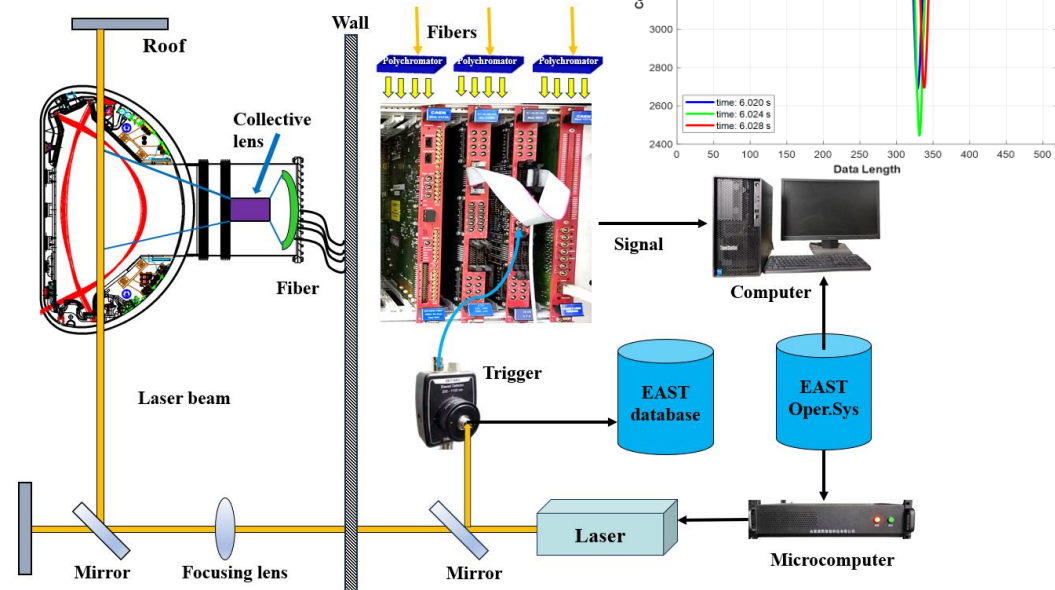
- TS LoS: $R=1.91\text{m}$, $Z=-0.15\sim+0.65\text{m}$;
- ECE LoS: $Z=0$, $R=1.85\sim2.3\text{m}$;

Name	Description	Acq. Freq. / Repetition rate	Radial/Spatial resolution
Thomson Scattering	90° Thomson scattering system	1-100Hz	2cm
ECE	Heterodyne radiometer	2.5 μs	2cm



Development of the High-Repetition-Rate TS System on EAST

System Architecture



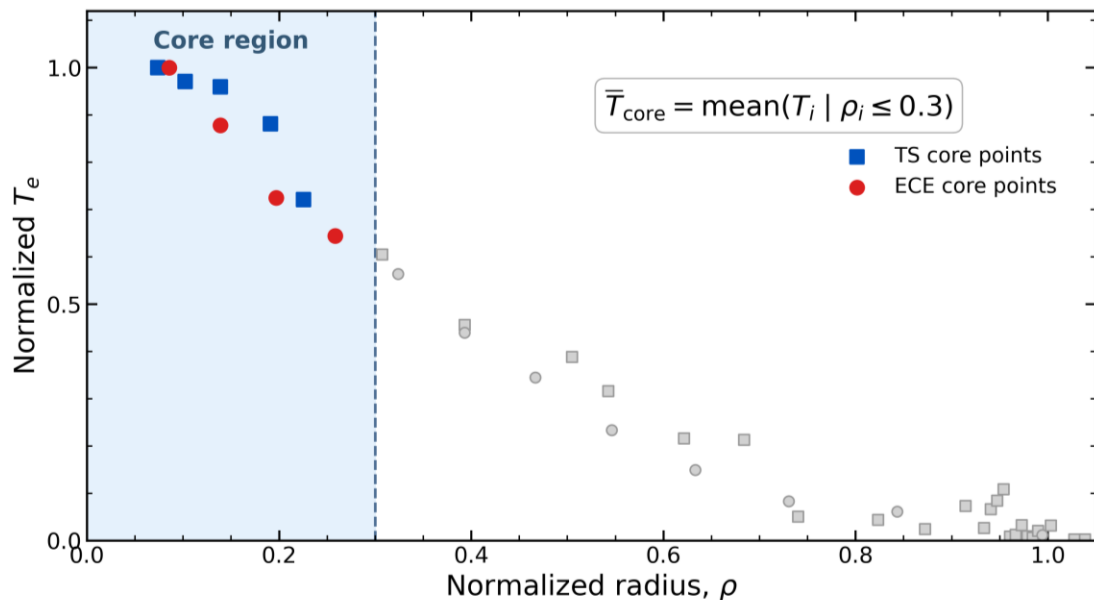
- **Conventional acquisition**
 - Gated **integration** of the scattered-light signal
 - Limited information on the waveform of each laser pulse
- **Fast waveform acquisition**
 - Direct recording of the **complete scattered-light waveform**
 - Pulse-resolved signal analysis at a high laser repetition rate

Laser	Nd:YAG laser 1064 nm 1–10 kHz burst mode
Digitizers	5 × CAEN V1742 12-bit resolution Operated at 1 GS/s
Channels	150 TS channels 30 spatial points 5 spectral channels per point
Waveform Acquisition	512 samples per waveform Synchronized laser–digitizer triggering

- The fast acquisition system is being developed to **resolve rapid** T_e evolution and improve pulse-by-pulse **signal evaluation**.

TS–ECE comparison dataset construction

Definition of core electron temperature



Relative difference $\Delta T = (T_{ECE} - T_{TS})/T_{TS} \times 100\%$

Processing steps

01

Time alignment

For each TS time, select the nearest ECE time point and average ECE data within ± 5 ms of that point.

02

Coordinate mapping

Map both diagnostics to $\rho = \frac{1}{a} \sqrt{\frac{\Phi}{\pi B_0}}$ using the EFIT equilibrium reconstruction.

03

Core selection

Retain valid points within $0 \leq \rho \leq 0.3$

04

Temperature comparison

Average TS and ECE separately, then calculate ΔT

TS–ECE comparison dataset

Final sample

1321

matched TS–ECE time points

EAST discharges

285

Core temperature: $\rho \leq 0.3$

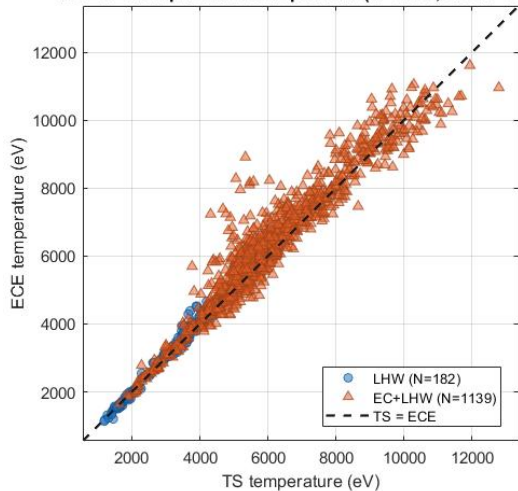
Heating: LHW and EC+LHW

Main plasma parameters

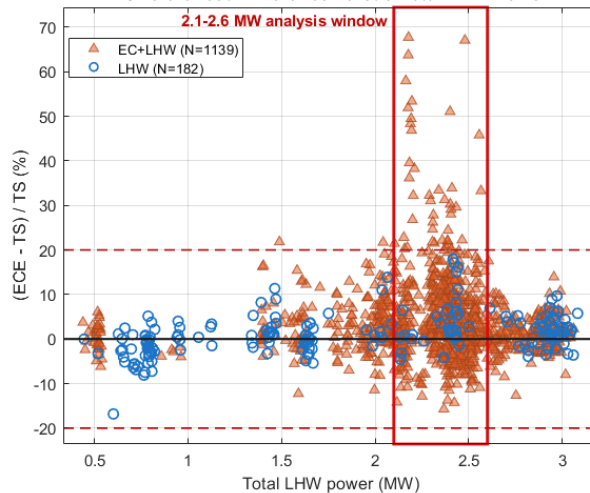
- Line-averaged density n_e **$0.52 - 2.79 \times 10^{19} \text{m}^{-3}$**
- Plasma current $|I_P|$ **$0.378 - 0.508$** MA mostly
- Total heating power P_{heat} **$0.45 - 4.85$** MW
- Toroidal-field current I_{TF} **≈ 11** kA

Multi-Discharge Comparison of Electron Temperature

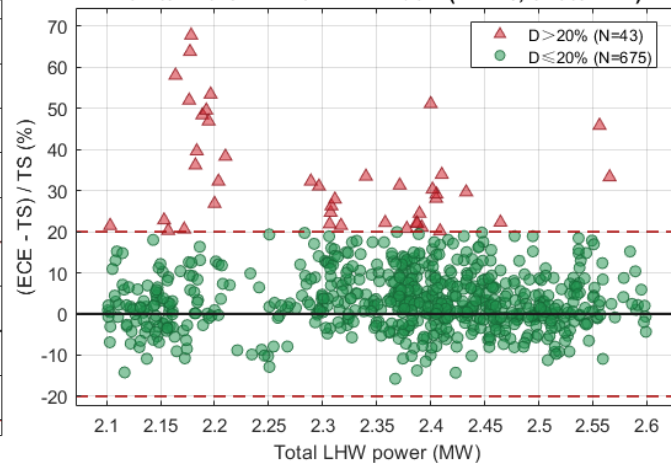
TS-ECE Temperature Comparison (N=1321, shots=285)



TS-referenced Difference versus Total LHW Power

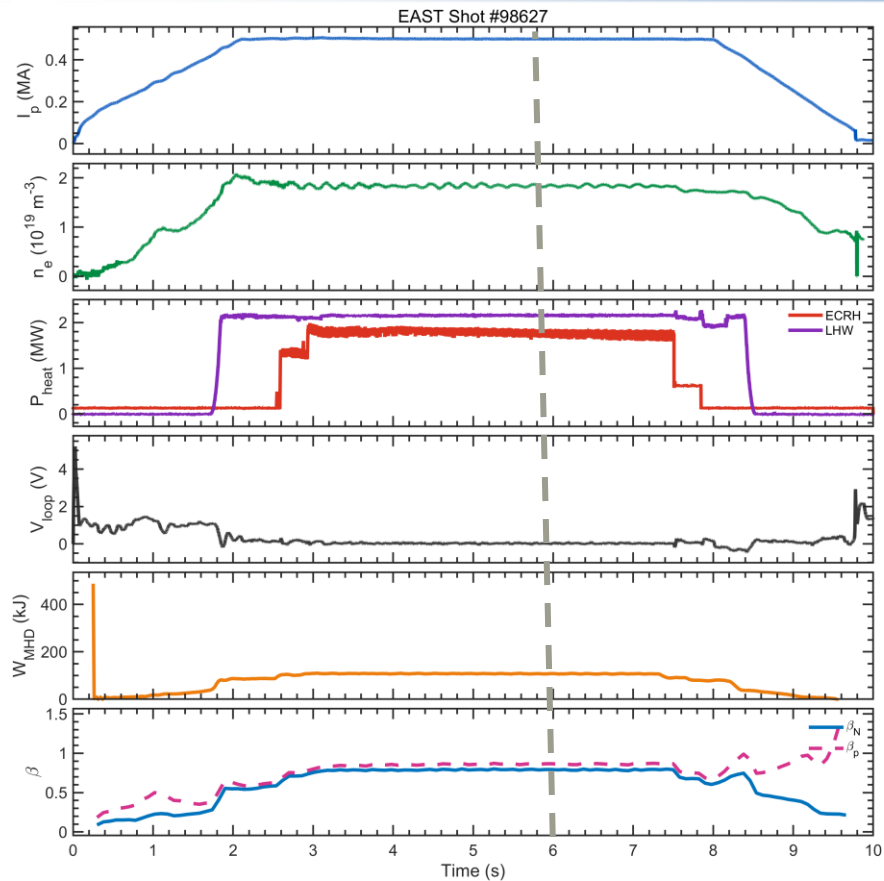
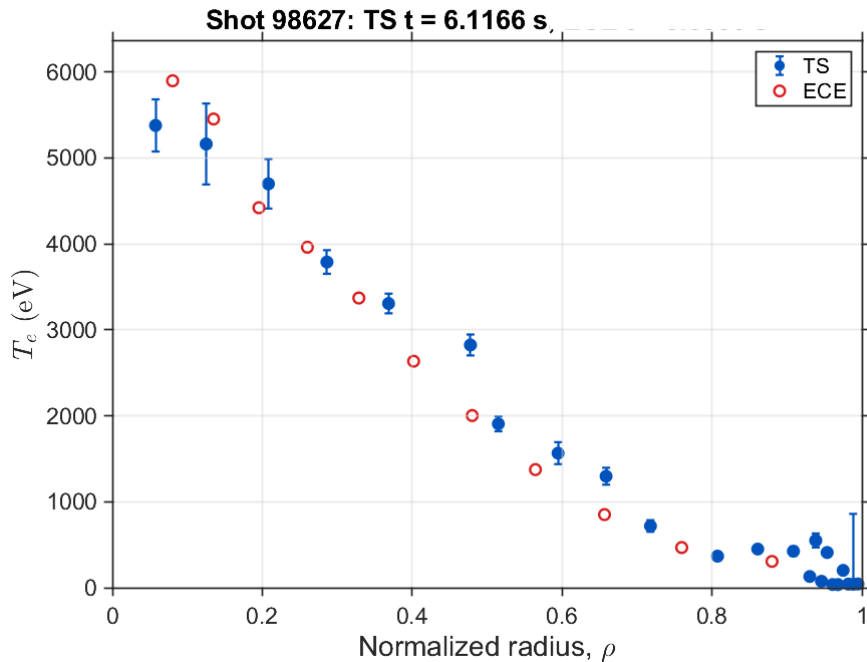


Points in the 2.1-2.6 MW Window (N=718, shots=127)

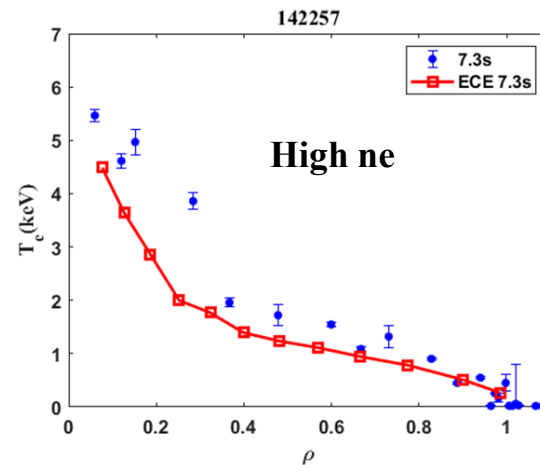
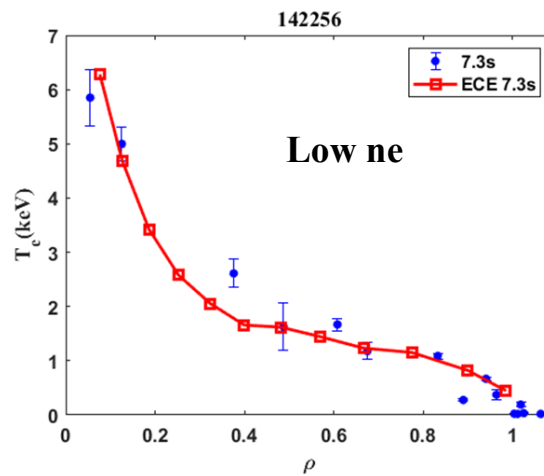
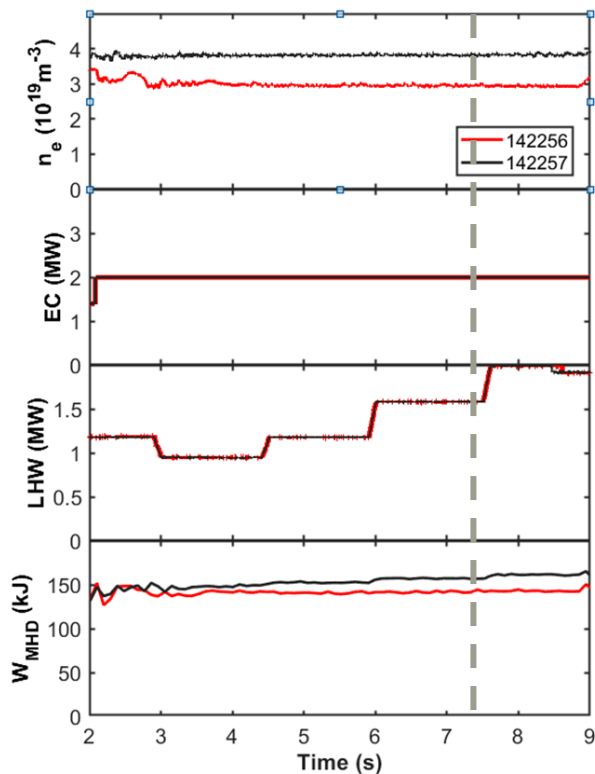


- Under LHW-only heating, the difference between the T_e values measured by ECE and TS gradually **increases with increasing LHW power**.
- Under combined EC+LHW heating, the T_e measured by **ECE** is more likely to be significantly **higher than that measured by TS**.

Representative Shot 98627



Exploratory cases Different density



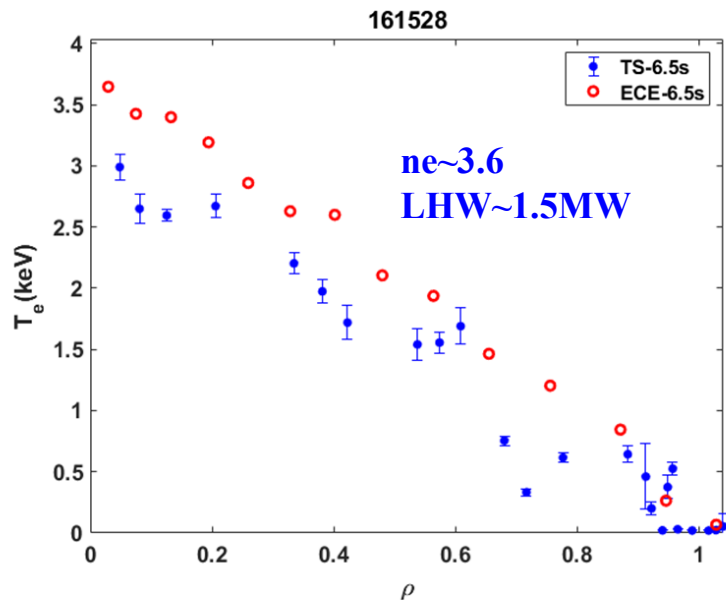
Exploratory cases EC plus LHW with and without NBI

#161528

dfsdev2~3.6

EC~1.85MW

LHW~0.8MW→1.5MW



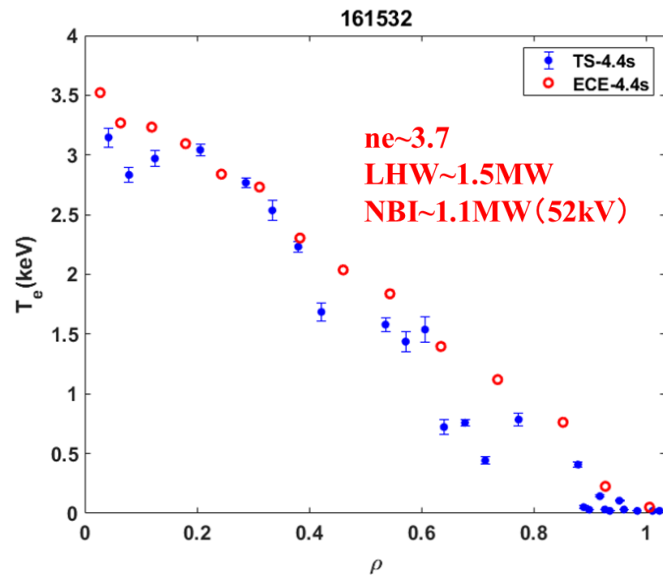
#161532

dfsdev2~3.7

EC~1.85MW

LHW~0.8MW→1.5MW

NBI~1.1MW (52kV)



Discussion

➤ **Observations**

- Overall agreement between TS and ECE measurements
- Condition-dependent differences in the selected EAST discharges

➤ **Possible contributors**

- Spatial and temporal matching
- Measurement principles and calibration procedures
- High T_e plasma conditions

➤ **Ongoing work**

- Extend the database to broader heating conditions
- Quantify measurement uncertainties
- Use Fokker–Planck simulations to assess the influence of suprathermal electrons
- Develop high-repetition-rate TS measurements

Thank you for your attention!

