Dynamic Fast-Acquisition ECE Diagnostic for Turbulence Studies in TCV

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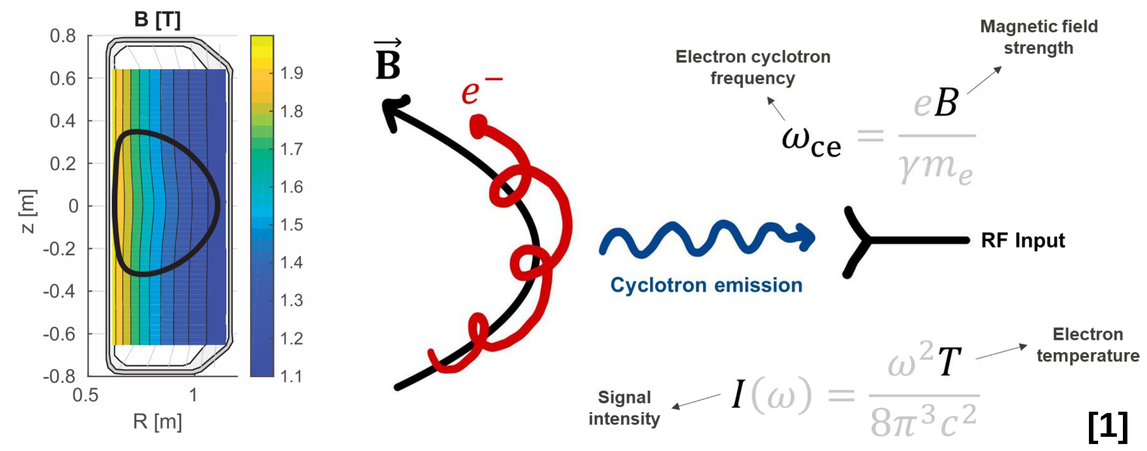
What's ECE?

Electron Cyclotron Emission

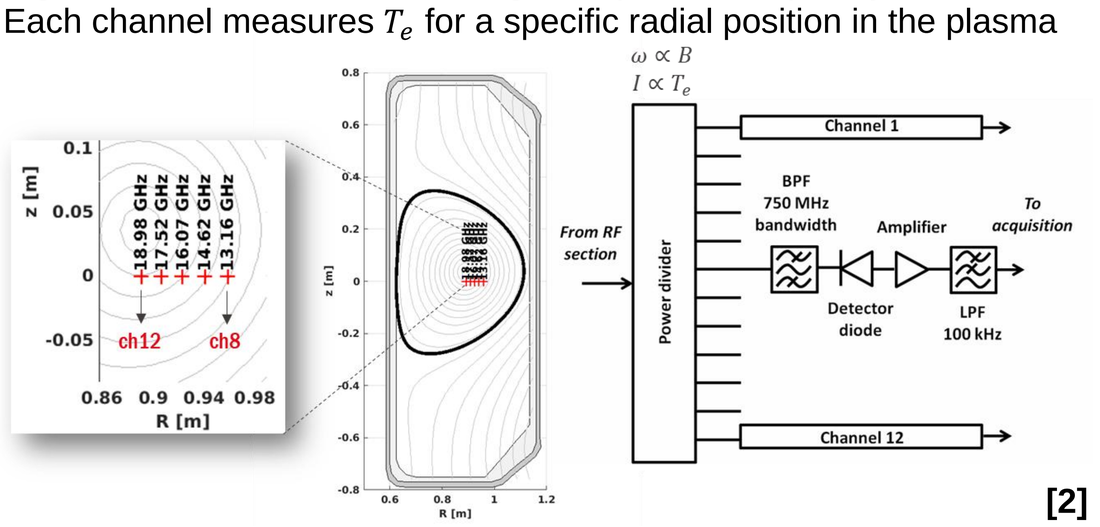
- Electrons gyrate along field lines, emitting cyclotron radiation
- Signal intensity gives temperature, magnetic field gives position



[1]

ECE as a 1D Temperature Diagnostic

- Signal from a horizontal line-of-sight is split into frequency bands
- Each channel measures T_e for a specific radial position in the plasma

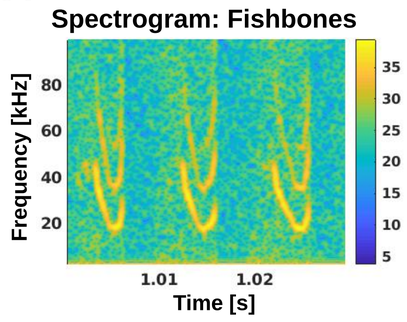


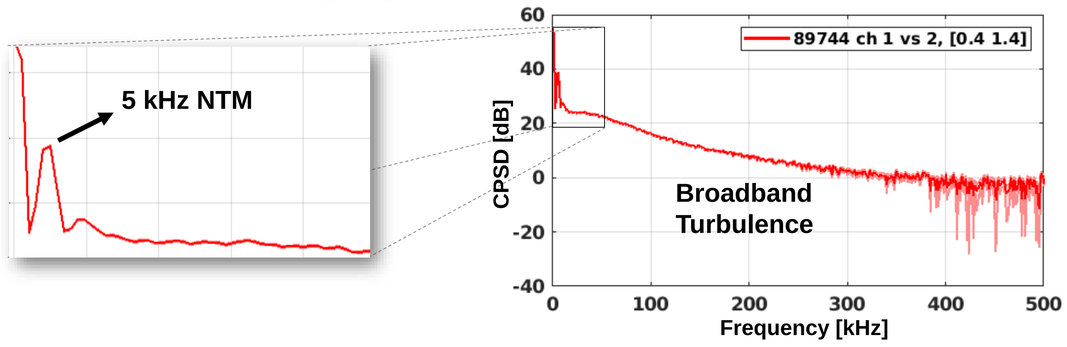
[2]

Why ECE, and Why Study Turbulence?

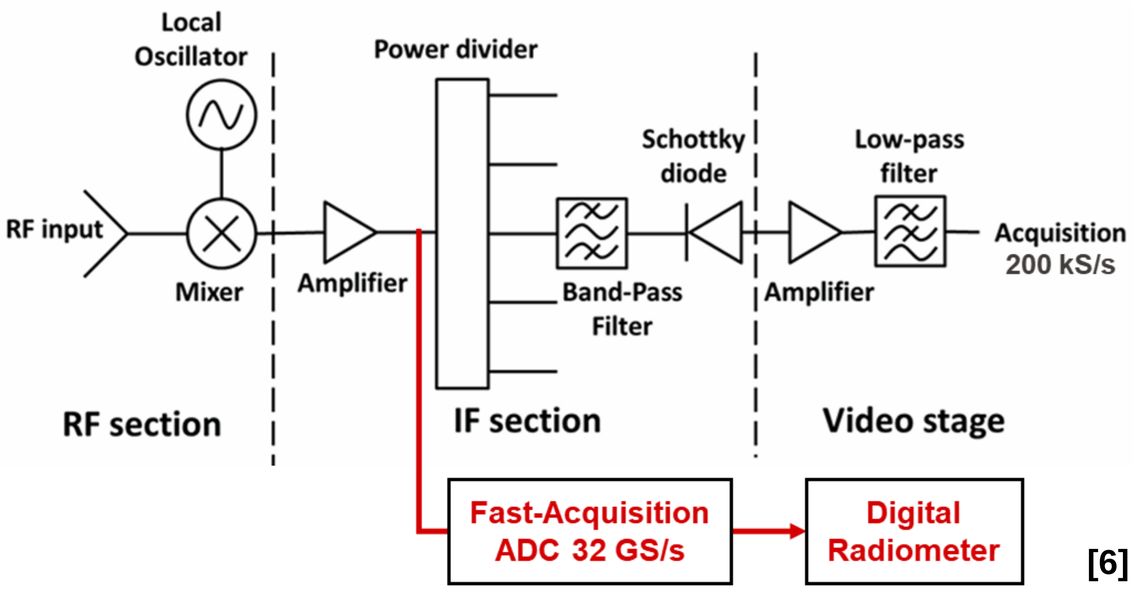
High Spatial & Temporal Resolution

- Characterises both MHD (<50 kHz) and turbulence-scale (~10s to 100s of kHz) fluctuations simultaneously
- Interplay between MHD & turbulence not well-understood **[3]** → experiments to reconcile with theory **[4,5]**





Fast-Acquisition ECE: Setup



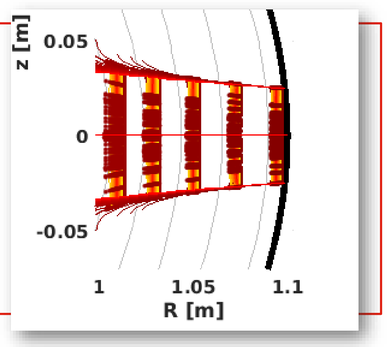
[6]

Physical ECE radiometer

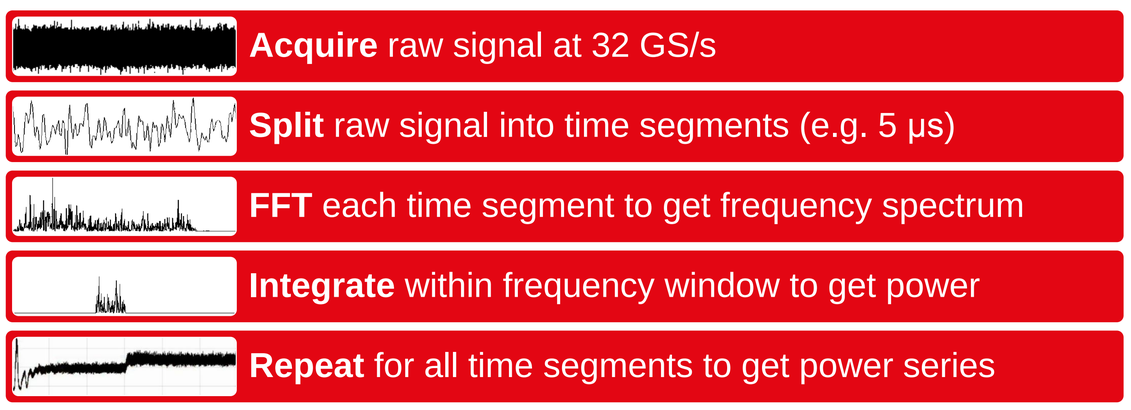
- **24 fixed** channels
- **1.5 GHz** channel spacing
- **200 kHz** video bandwidth
- **750 MHz** IF bandwidth
- **2-20 GHz** IF range

Digital ECE radiometer

- **Variable** channels
- **Variable** channel spacing
- **Variable** video bandwidth
- **Variable** IF bandwidth
- **0-10 GHz** IF range

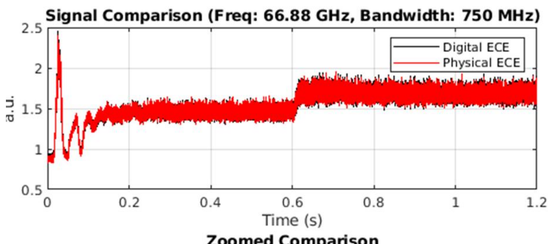


Digital Radiometry: Power in Post-Processing



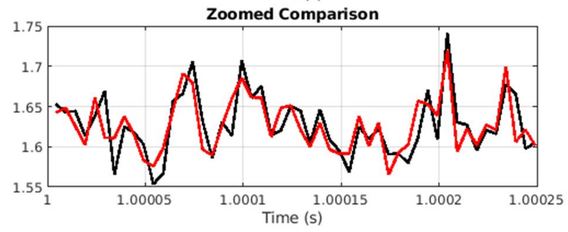
Upgrade over physical ECE (→)

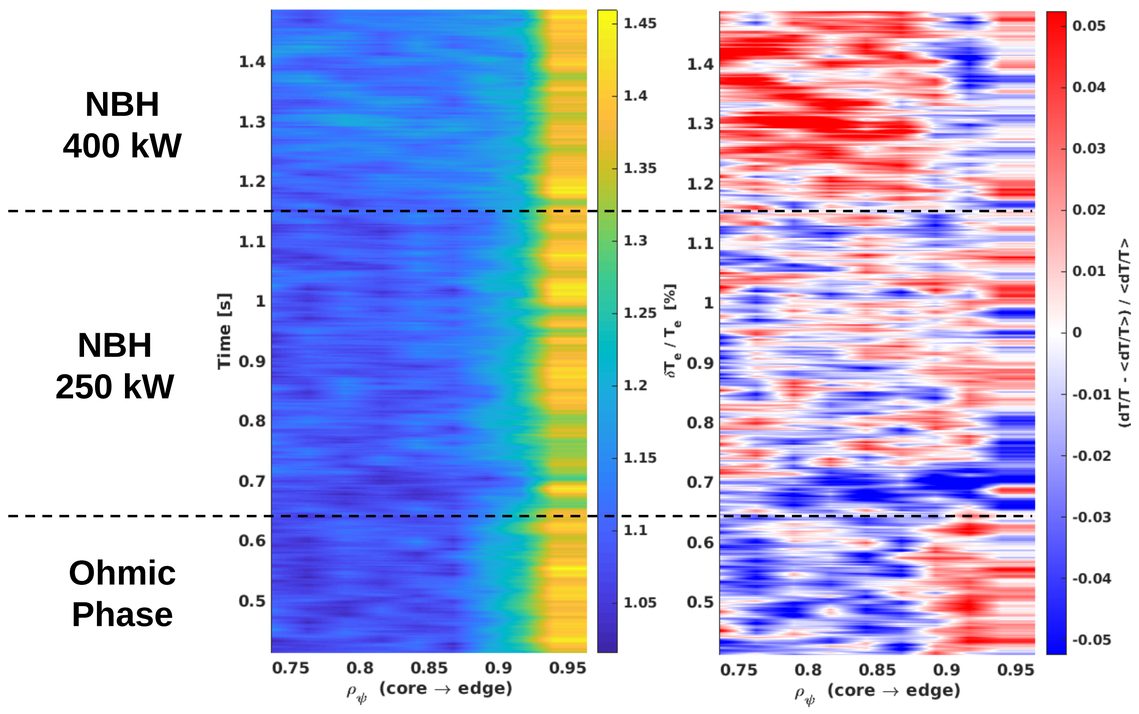
- Replicates physical channel well
- Consistent shape of digital filters vs irregular physical BPF window



Turbulence Measurements (↓)

- Neutral-Beam Heating (NBH)
- **Left:** Complex turbulence RMS amplitudes over time
- **Right:** Relative fluctuation levels w.r.t. radial position





A Complement to Existing ECE Systems

Limitations

- Limited spatial range → 2nd ADC channel to probe inner core
- Large data due to ultra-fast sampling → secondary diagnostic

Outlook

- Still highly advantageous due to consistent filter window shape
- Variable parameters to optimise spatial & temporal resolution
- Magnetic island characterisation and effects on turbulence
- Experimental detection of Turbulence-Driven Magnetic Islands **[7]**

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References

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[2] M. Fontana, PhD thesis, EPFL TH9016 (2018)
[3] M. J. Choi et al. *Nat. Commun.* **12** 375 (2021)
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[7] O. Agullo et al. *Phys. Plasmas* **21** 092303 (2014)

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