ECE Summary

Gary Taylor

Princeton Plasma Physics Laboratory, USA

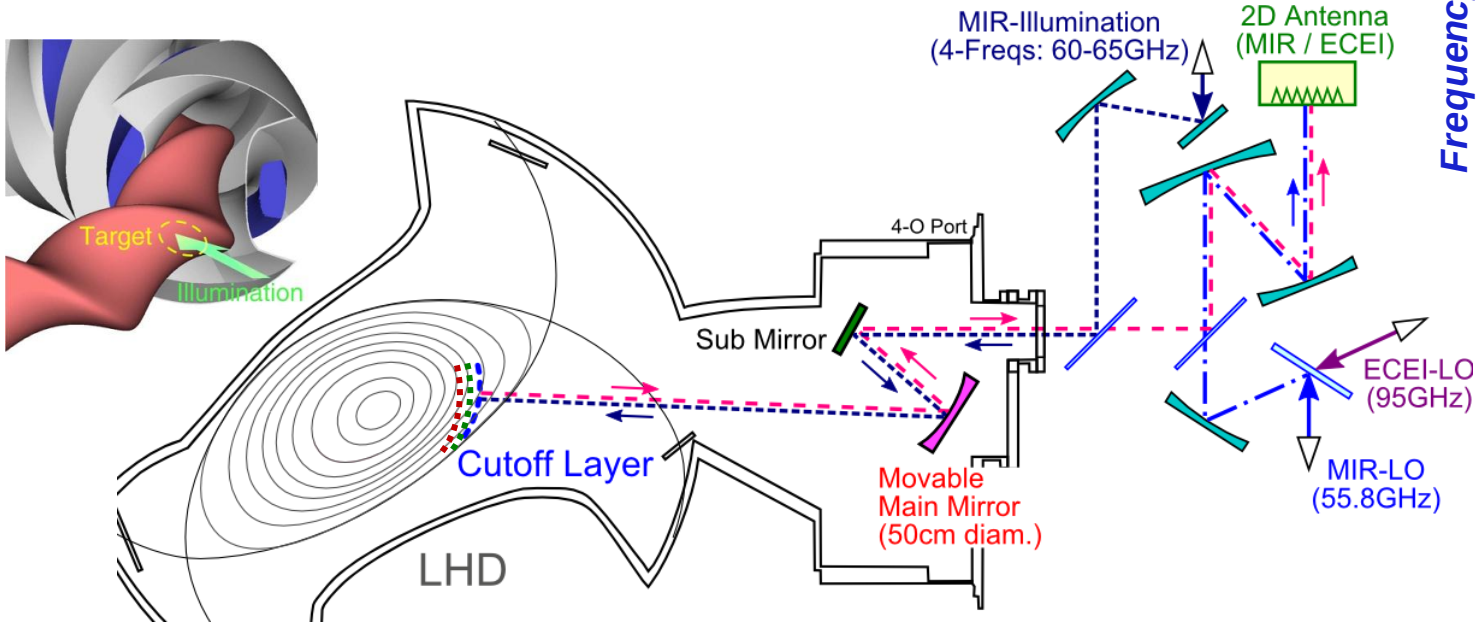
EC-16 Joint Workshop on ECE & ECRH
Sanya, China, April 15, 2010

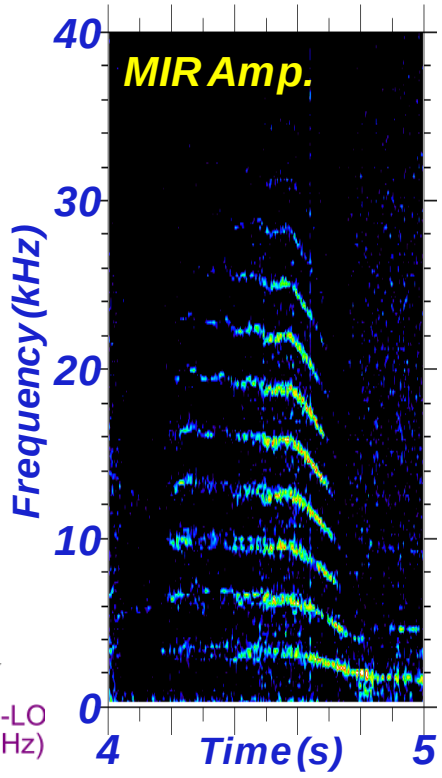
Introduction

- 17 ECE/EBE Presentations & ITER ECE discussion:
  - 5 Invited, 6 oral contributed & 6 posters
  - 16 ECE presentations & 1 EBE presentation
- Outline of this summary:
  - 2-D ECE & MIR Imaging
  - 2-D EBE Imaging
  - Correlation ECE
  - Oblique ECE
  - Other ECE Measurements & Instruments
  - ITER ECE
  - Concluding Remarks

2-D ECE & MIR Imaging - I

- Combined microwave imaging reflectometry (MIR) and ECE imaging (ECEI) in LHD being used to reconstruct 3-D structures of n_e / T_e fluctuations [Yoshinaga]

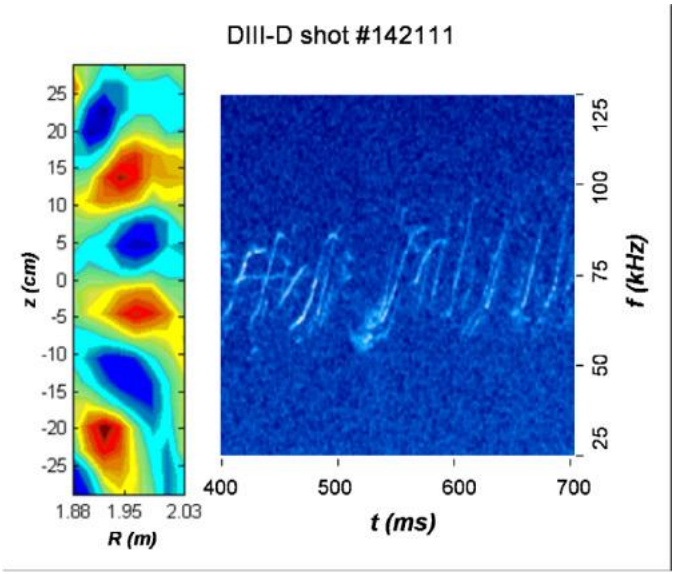




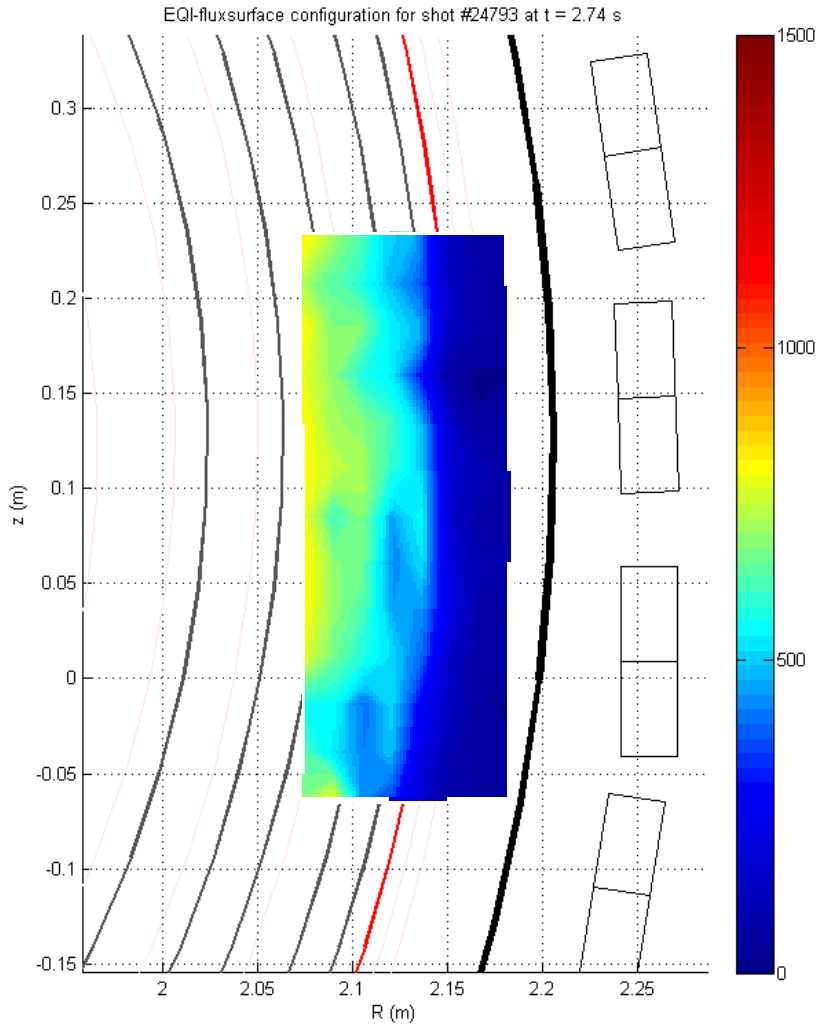
Observation of MHD Oscillations in Edge Region

2-D ECE & MIR Imaging - II

- Improved 2-D ECEI measurements of MHD on TEXTOR, ASDEX-U & DIII-D [Park]
  - Mini lens-based arrays
  - Improved video electronics



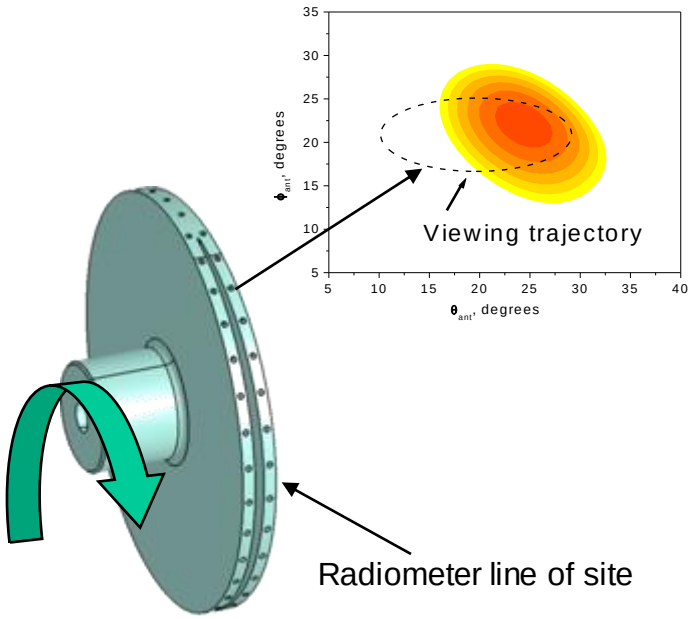
Observation of Alfven Eigenmodes in DIII-D



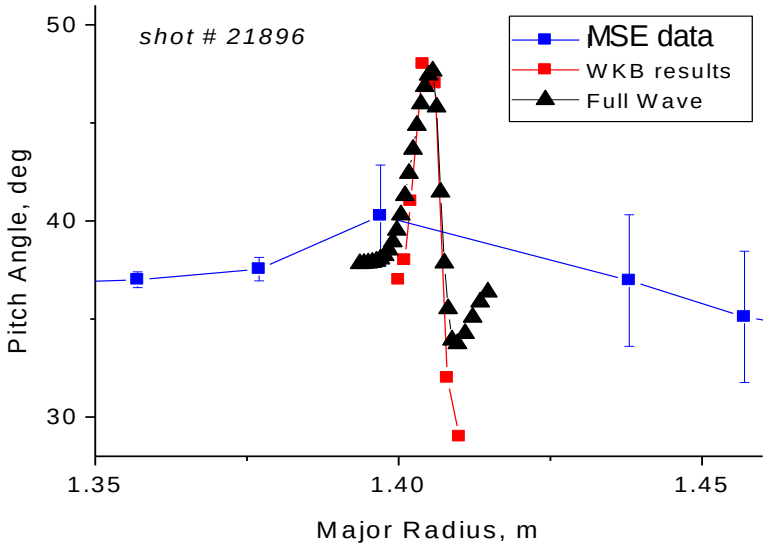
Observation of ELMs in ASDEX-U

2-D EBE Imaging

- 2-D EBE imaging with fast rotating mirror on MAST [Shevchenko]
  - Measured pitch angle variation near H-mode plasma edge stronger than measured by MSE
  - Phase based EBE imaging now under development on MAST



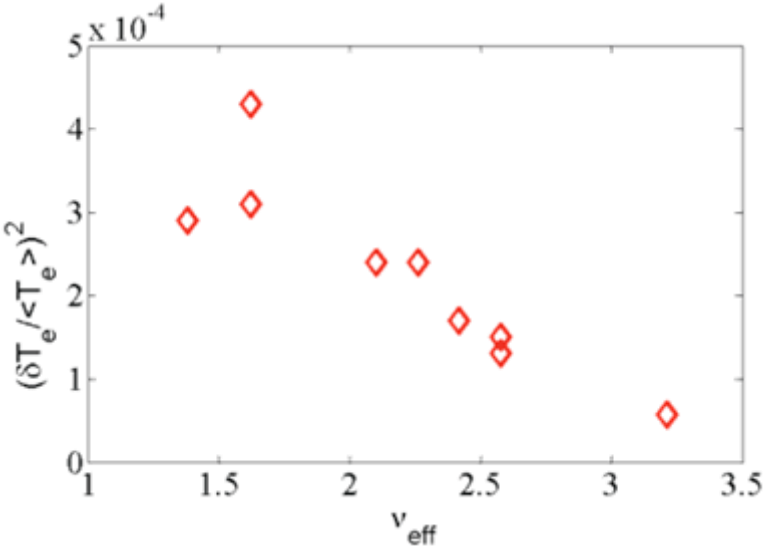
EBE Observation with Rotating Mirror

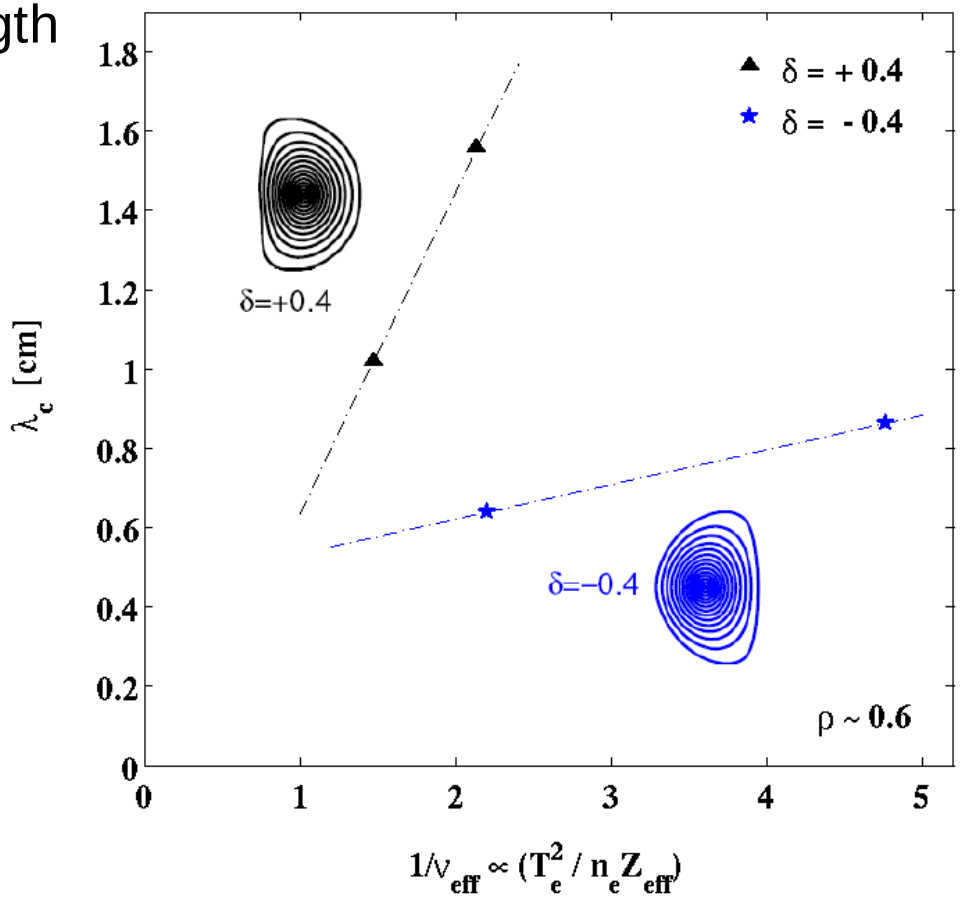


Comparison of Pitch Angle from EBE and MSE

Correlation ECE - I

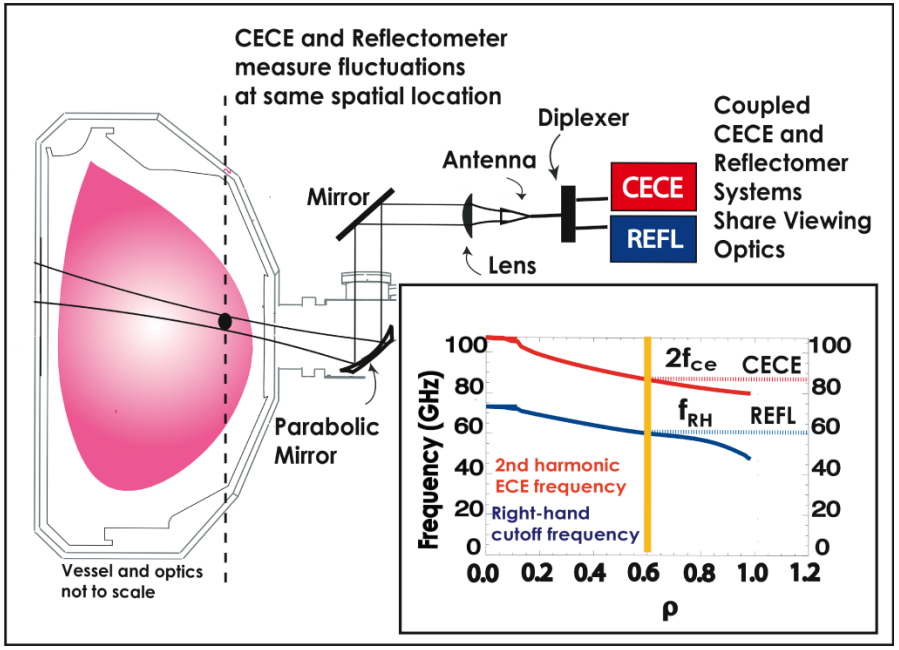
- Correlation ECE measures on TCV show reduction in correlation length (λ_c)for $\delta < 0$ [Goodman]
  - λ_c dependence on collisionality also weaker

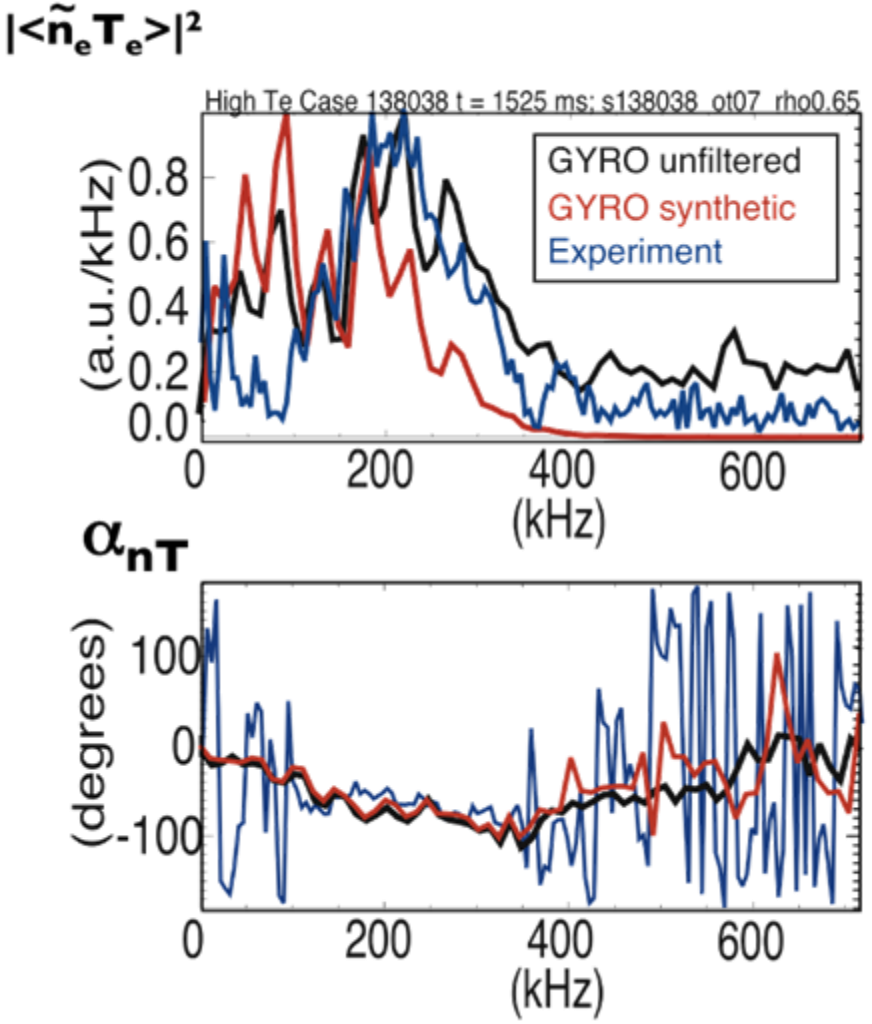




Correlation ECE - II

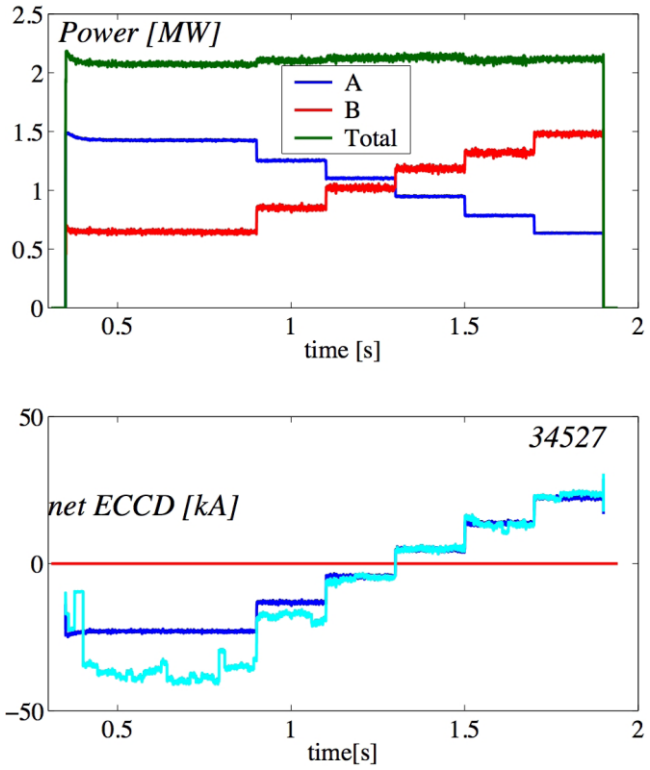
- Coupled X-mode correlation reflectometry & X-mode correlation ECE allowed cross-phase angle measurements in DIII-D [White]
  - Measured n-T phase angle in NBI+ ECH L-mode agrees quantitatively with nonlinear GYRO results



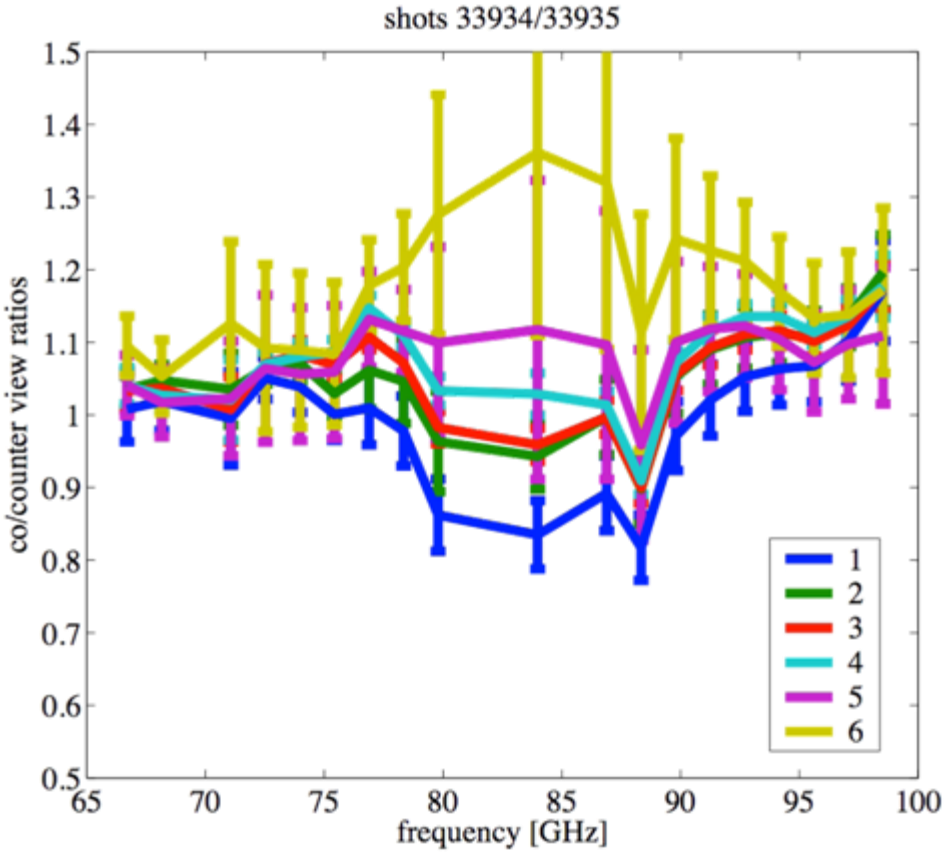


Oblique ECE - I

- Oblique ECE on TCV shows evidence for asymmetry in electron distribution function (EDF) during on-axis ECCD [Goodman]



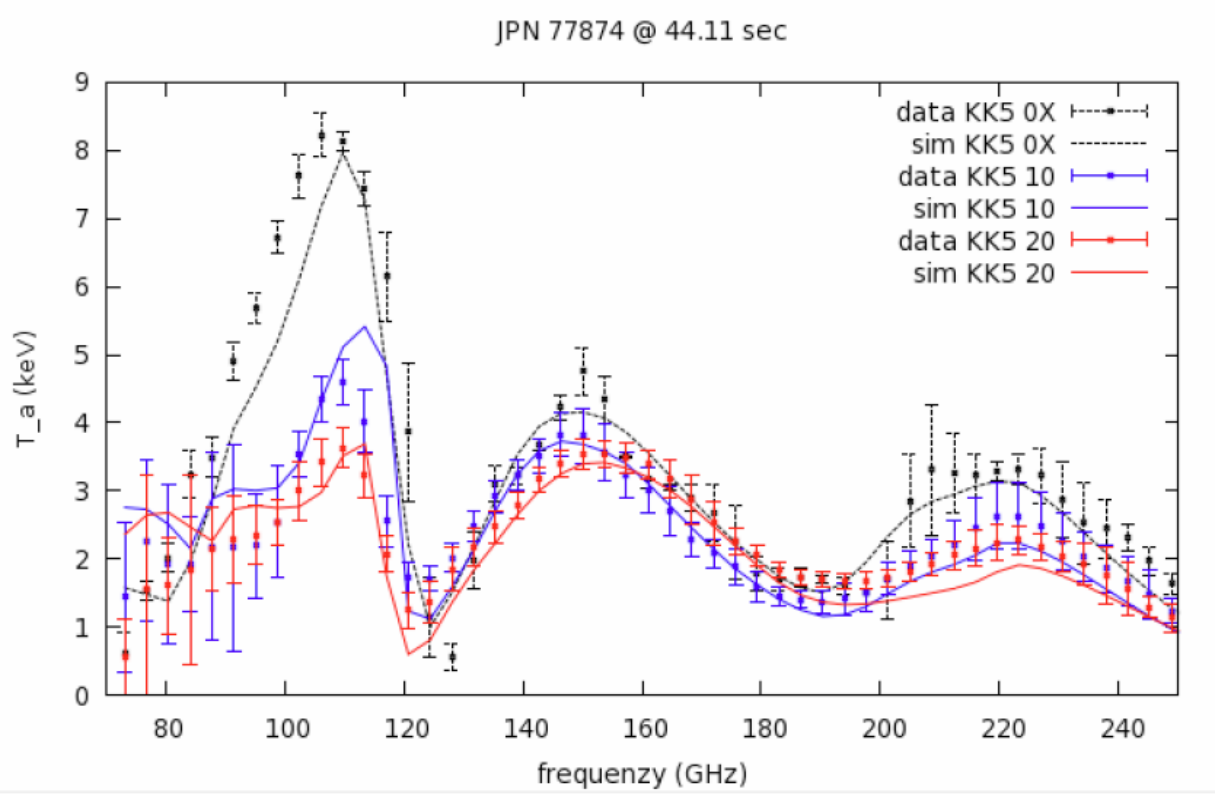
Stepped ECCD at Constant RF Power



Measured EDF Asymmetry in ECCD Current Channel

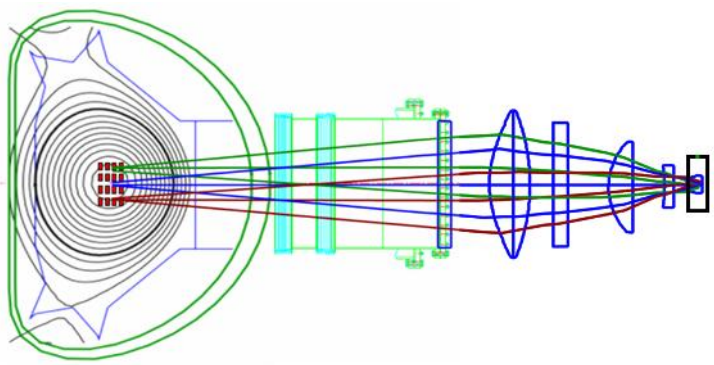
Oblique ECE - II

- SPECE model ECE spectra of multi-angle oblique view ECE for a LH-driven EDF in JET show good agreement with total (X+O) ECE data [Figini/Sozzi]

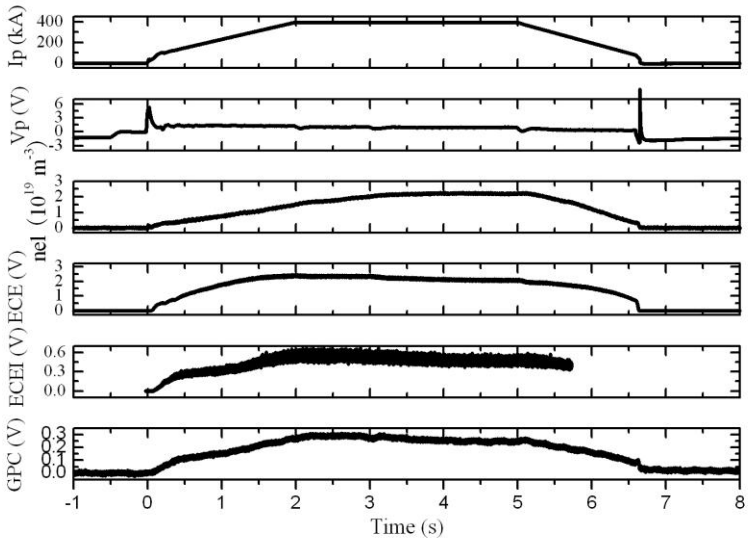


Other ECE Diagnostics - I

- Details of various ECE diagnostics & measurements on HT-7 & EAST were reported [Wan/Ang/Erzhong/Ling/Yong]:
  - 16-Channel heterodyne radiometer ECE (EAST & HT-7)
  - 2-D ECEI (EAST & HT-7)
  - 20-channel grating polychromator (EAST)
  - Plans for 32-channel heterodyne radiometer (EAST. collab. UC Davis)
  - Upgraded 2-D ECEI to be installed in 2011 (EAST, collab. UC Davis)



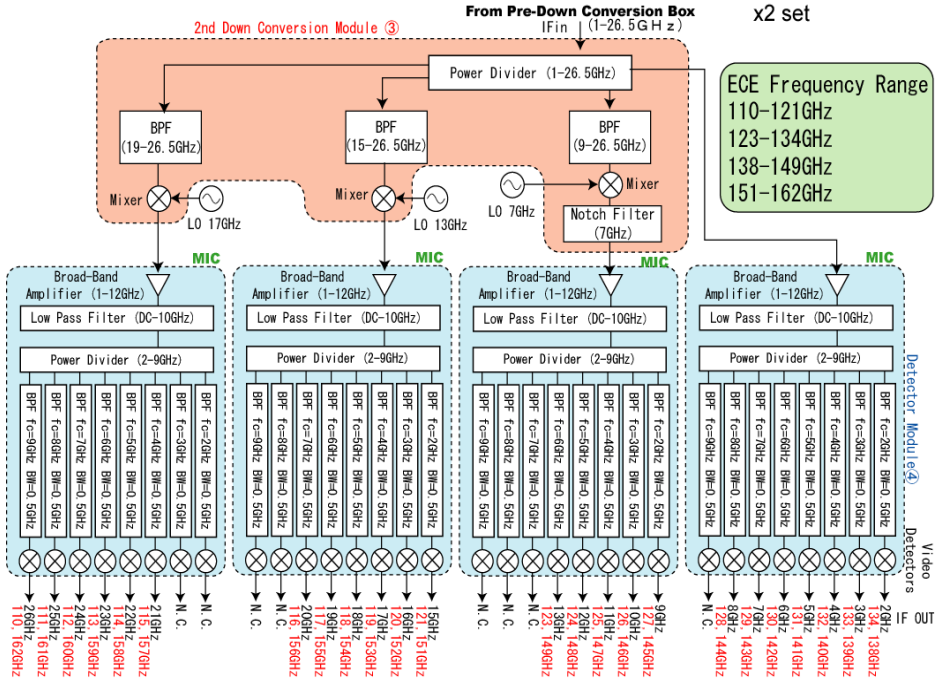
Upgraded 2-D ECEI on EAST

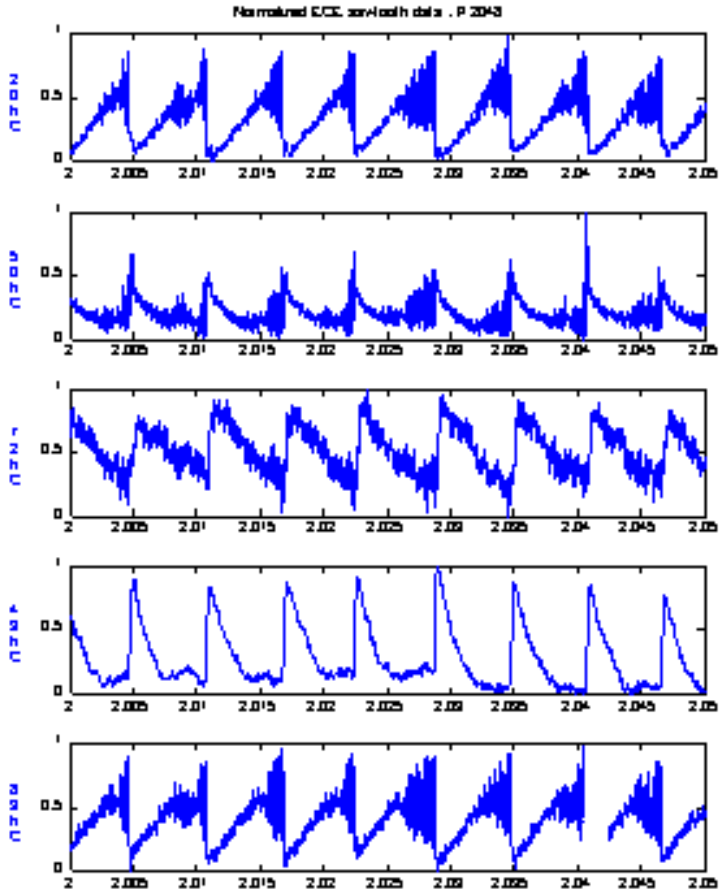


ECE Data from EAST

Other ECE Diagnostics - II

- New 48-channel 110-162 GHz ECE radiometer installed on KSTAR [Jeong]
  - Microwave (1-12 GHz) integrated circuit technology used for the detector modules

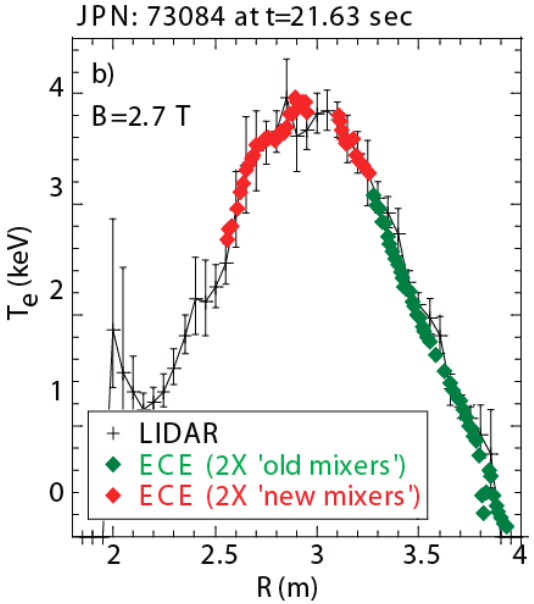




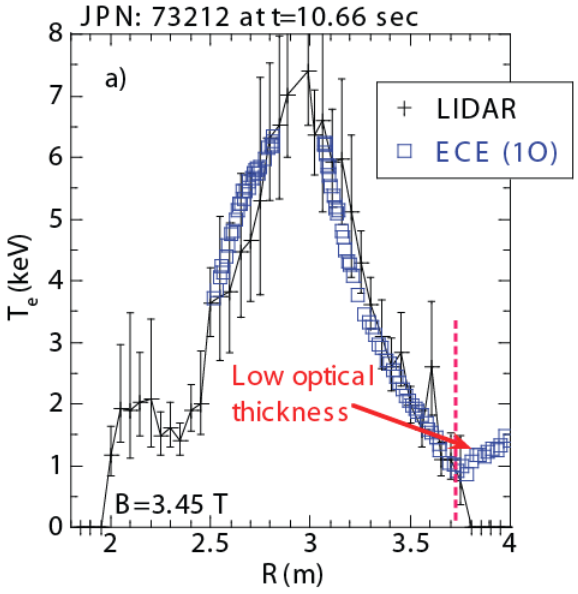
Sawteeth Measured on KSTAR with 48-Channel Radiometer

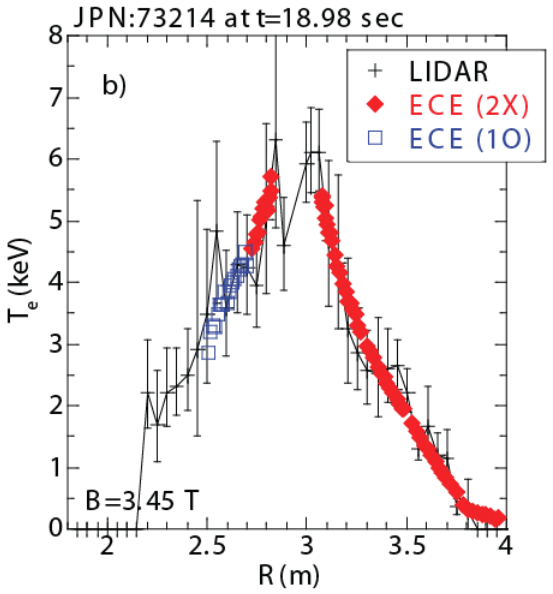
Other ECE Diagnostics - III

- The high-end frequency range of JET ECE radiometer has been extended from 139 to 207 GHz [de la Luna]
  - ➢ Provides access to higher density plasmas at high fields (with the previous system O-mode was used for B > 2.4T)
  - ➢ Improved spatial resolution and access to the edge region (higher optical thickness for 2X-mode)



Improved Coverage at B>2.4T

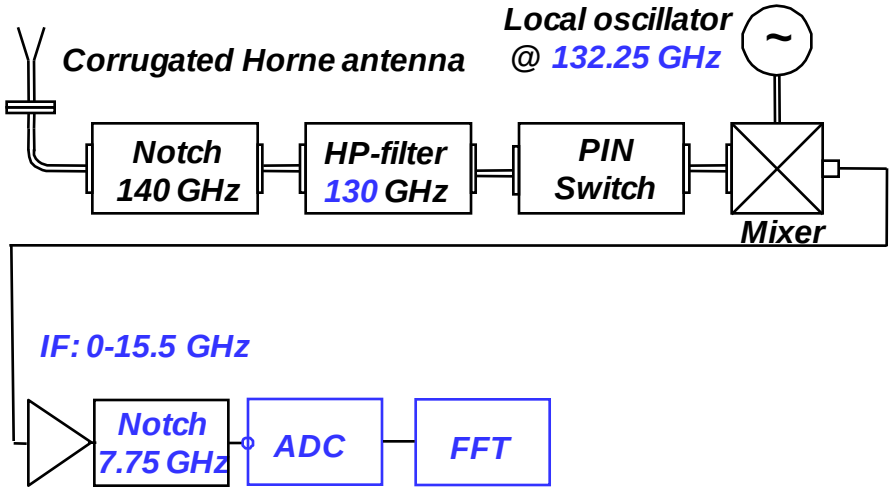




Improved Spatial Resolution & Access to Edge

Other ECE Diagnostics - IV

- 4 GHz Fourier transform (FT) direct IF digitization system installed on in-line ECE system on TEXTOR [Bongers]
  - Flexible time/spatial resolution with optional dynamic zoom on certain plasma positions or events: possible application to adaptive sensing for MHD control
  - Wavelets analysis is possible, instead of FT
  - Present system limited by 4 GHz digitization, next step will be to develop full range FT ECE/scatter system for control



Fourier Transform ECE System

ITER ECE - I

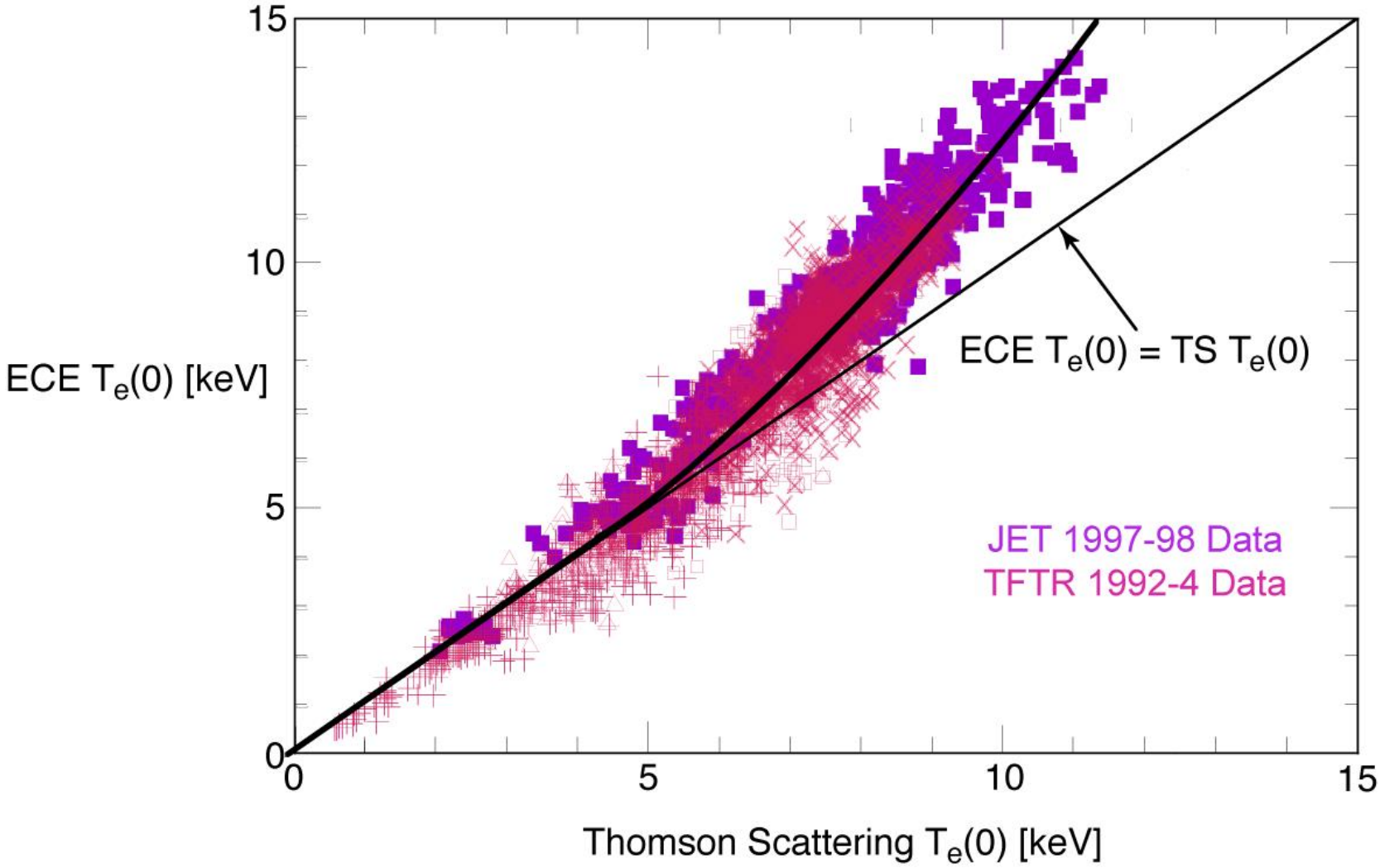
- Presentation & lively discussion on issues pertinent to design and operation of ITER ECE system [Austin/Udintsev/others…]
  - Islands with w ~ 4 cm easily detectible, but w ~ 1 cm detection difficult
  - Simplify ECE front-end by using one focusing element instead of Gaussian telescope
  - Move transmission line closer to midplane
  - Calibration source: 1 hot/cold, or 1 hot + 1 cold?
  - Microgroove waveguide can be used to only ~300 GHz, should dielectric guide be used to extend to ~1 THz?
  - Should there be a double window or window + isolation valve
  - Oblique view can be provided (possibly up to 16 degrees?) to look for non-thermal distribution – but needs to measure T_e in thermal plasma

ITER ECE - II

- If there is an oblique view there can only be one view, what angle?
- Crossed sightlines of perpendicular & oblique views is an opportunity for correlation measurements, but this should not constrain choice of oblique angle
- Need to measure EC power loss – will peak at ~ 1 THz in ITER

- Thomson scattering/ECE discrepancy:
  - So far only seen on TFTR & JET at $T_e > 7$ keV
  - Difficult to identify systematic discrepancy until T_{ece} reached ~ 10 keV, because of relatively large scatter in data
  - Seen in TFTR (& in JET during 1997-98) with NBI only, and NBI + ICRF discharges

Te Discrepancy Appeared Similar on TFTR & JET



Concluding Remarks

- Significant progress in ECEI, CECE and EBEI since EC-15:
  - Combined MIR/ECEI
  - Coupled X-mode correlation reflectometry & correlation ECE
  - Significant potential for phased array techniques
  - Combination of ECEI and CECE could be powerful technique
- Some interesting recent improvements in receiver technology & data analysis show promise for the future:
  - Highly integrated microwave integrated circuits in IF section
  - Fourier transform direct digitization of IF signal
- Still need to agree on potentially critical details of ITER ECE design:
  - Also need dedicated experiments at T_e ~ 10 keV to study ECE/TS discrepancy