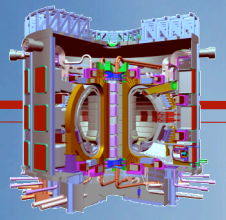


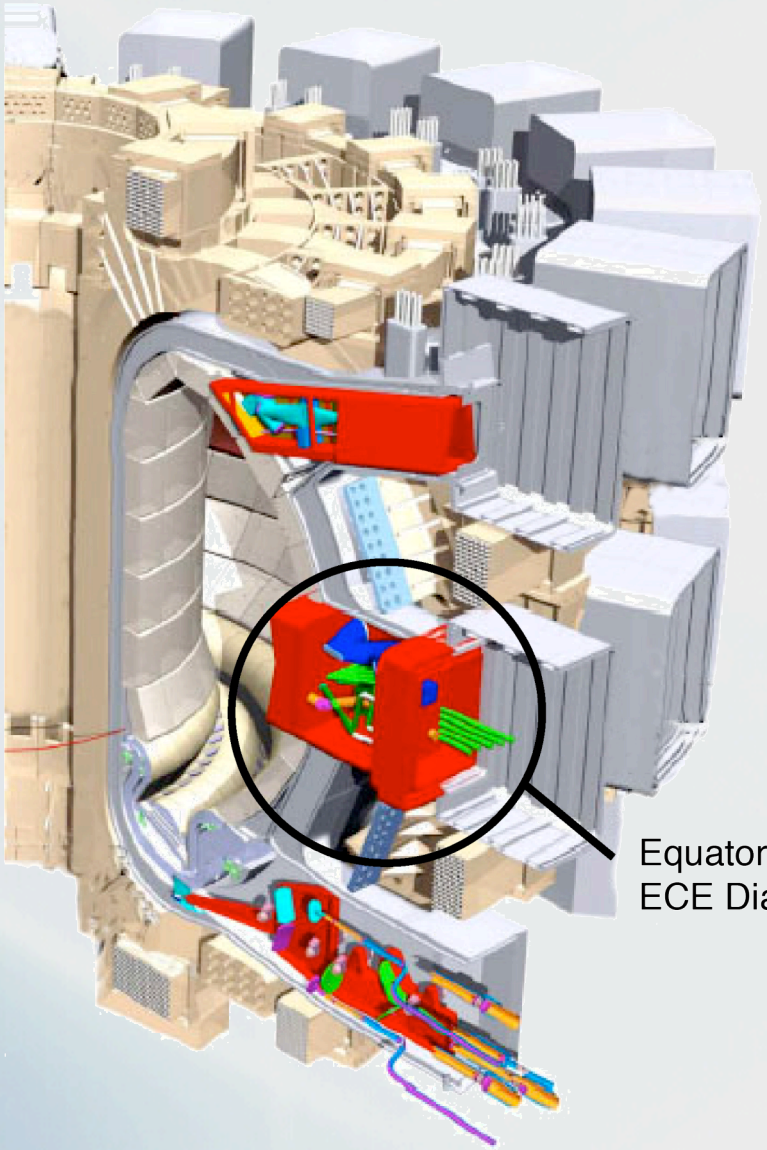
The Utility of an Oblique ECE View on ITER

G. Taylor

Princeton Plasma Physics Laboratory

R. W. Harvey

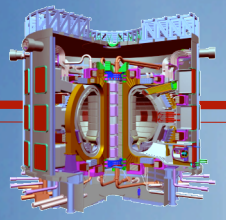
CompX



Progress Meeting on ITER Relevant Diagnostic Developments in the USA

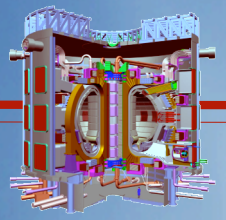
12th ITPA Diagnostics Topical Group Meeting
Princeton, March 26, 2007

Assessment Task



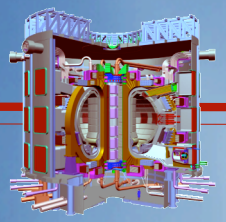
- ECE & Thomson scattering "T_e discrepancy" on JET & TFTR implies non-Maxwellian bulk electrons at $T_e \geq 7$ keV
- Assess viability of moderately oblique (≤ 20°) ECE antenna at E9 port to measure bulk electron energy distribution:
  - *What electron energies can be detected by a 10-20° view?*
  - *Are T_e measurements possible with oblique view if bulk electron energy distribution remains Maxwellian at high T_e?*
  - *Can a "two-temperature" bulk electron distribution be reconstructed from combination of 0° & 10-20° oblique views?*
  - *What constraints are imposed on an oblique viewing antenna by the existing port plug design?*

Outline



- Motivation for Including Oblique ECE Diagnostic
- Modeling Results for Oblique ECE on ITER
- Proposed Upgrade/Modification for Oblique ECE
- Conclusions & Recommendations

Outline



- Motivation for Including Oblique ECE Diagnostic
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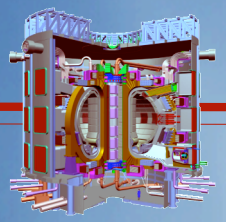
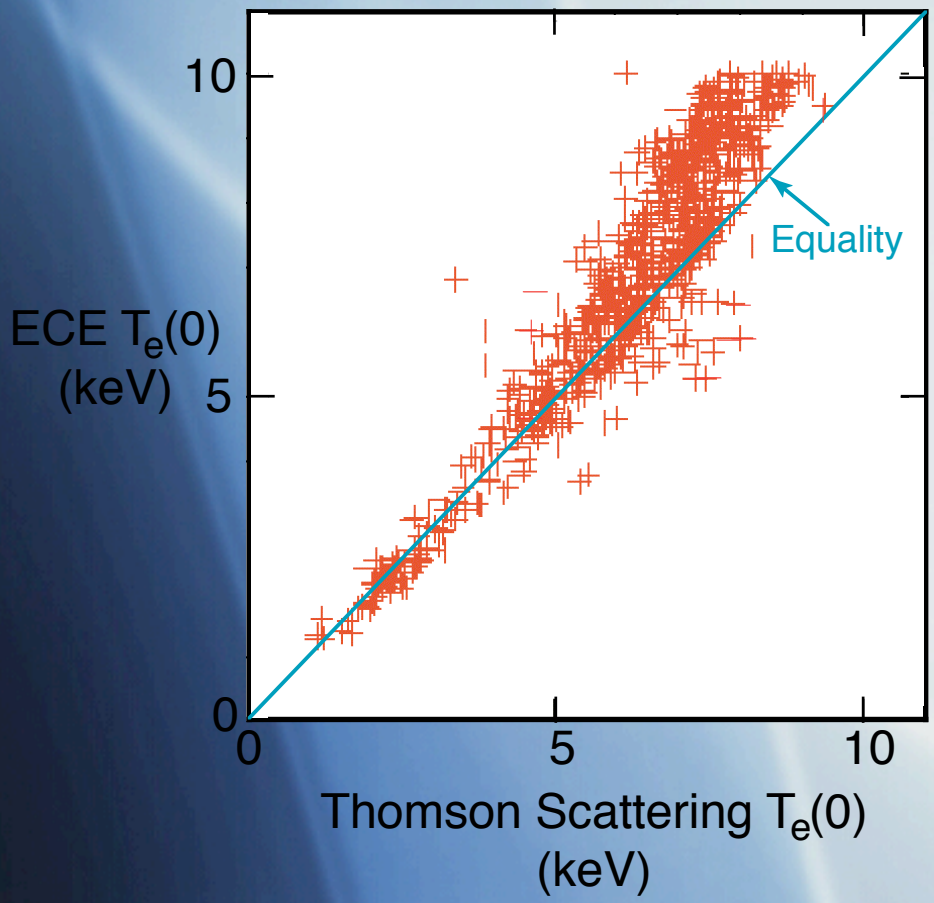
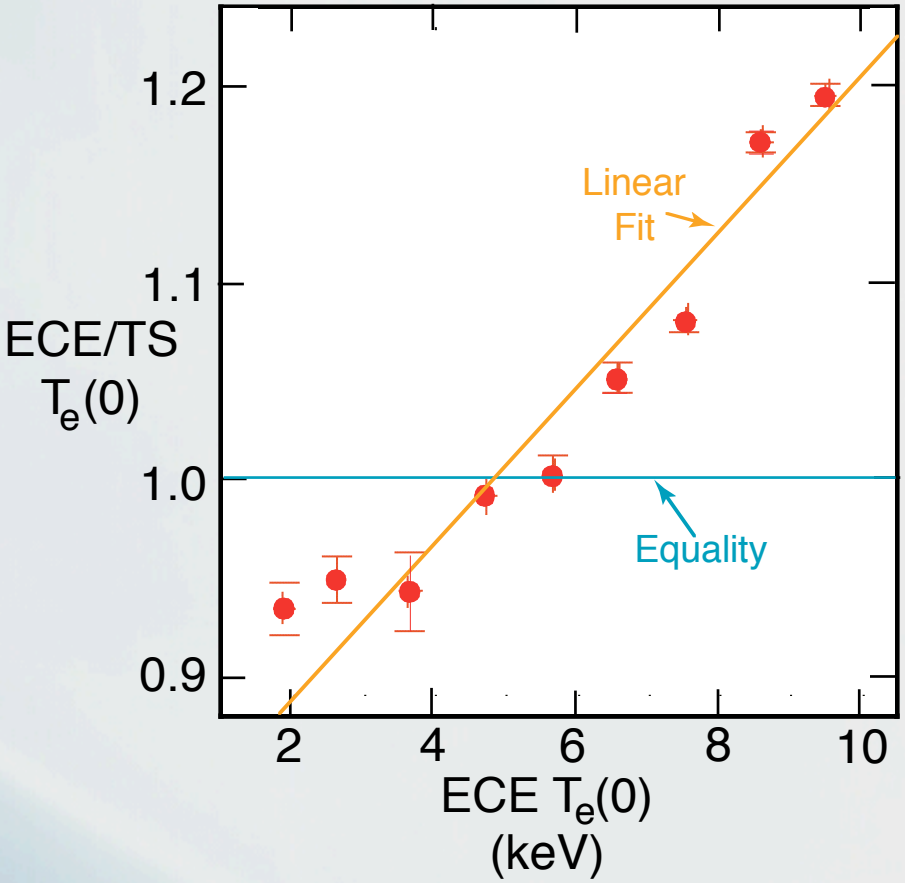
"T_e Discrepancy" between ECE & Thomson Scattering Observed in TFTR



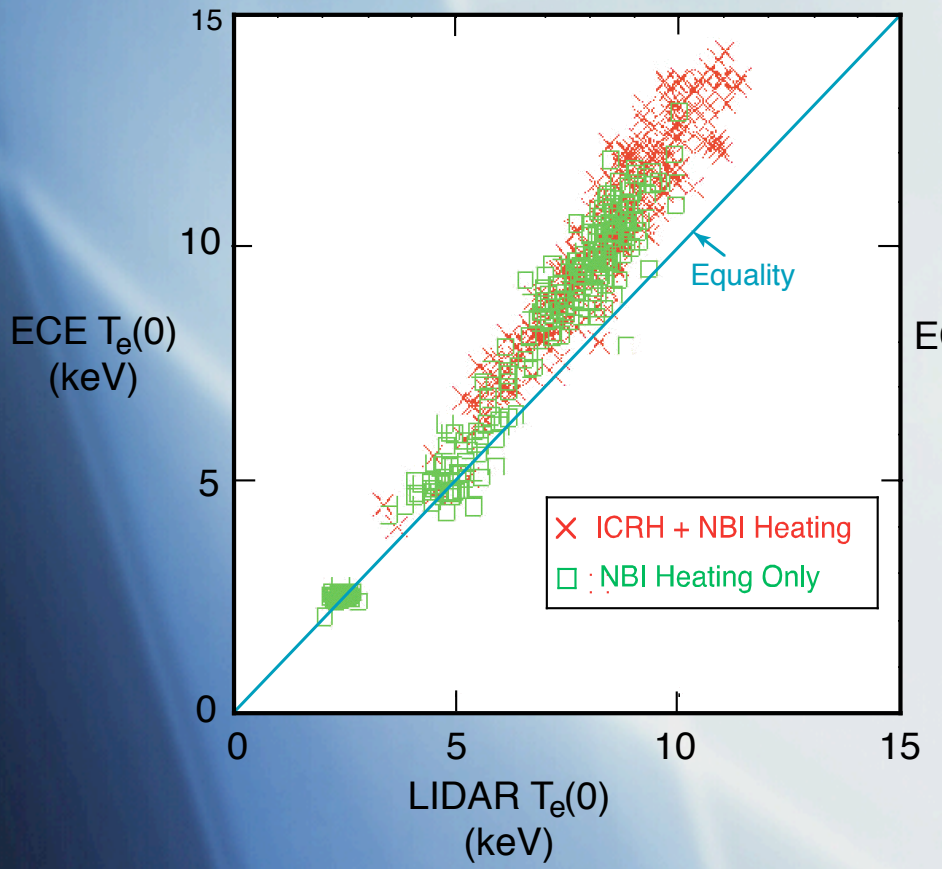
TFTR NBI Heated Plasmas 1992-4

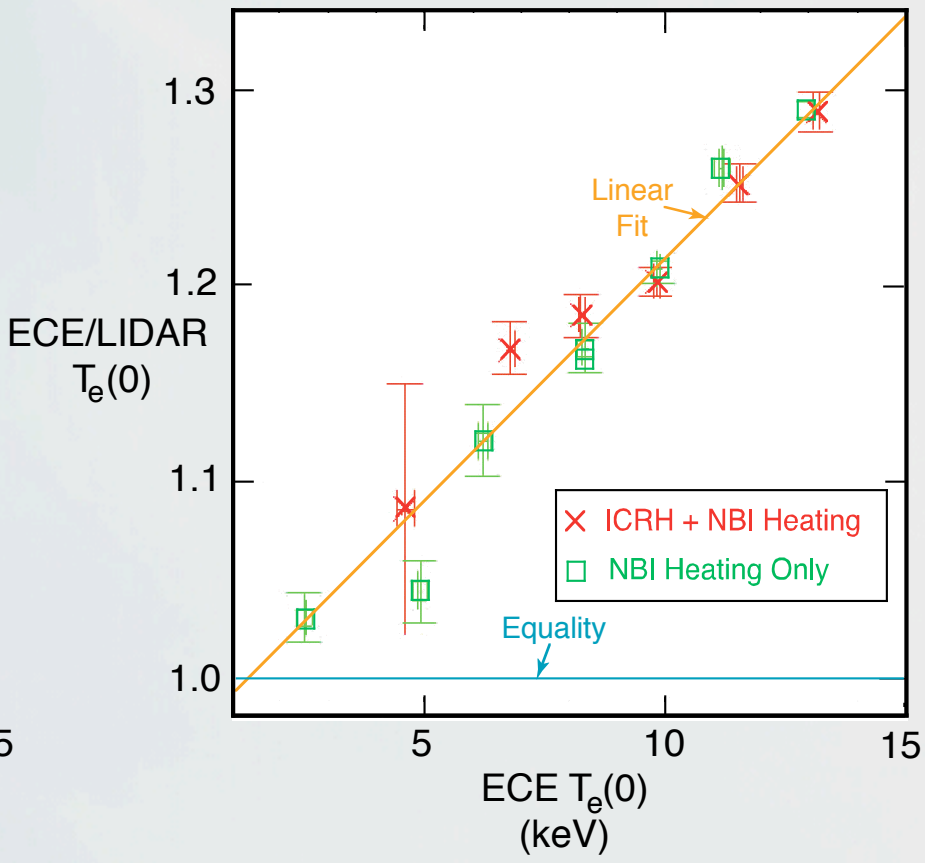




Similar "T_e Discrepancy" Measured in JET

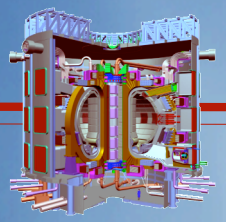
JET H-Mode Plasmas 1996-7



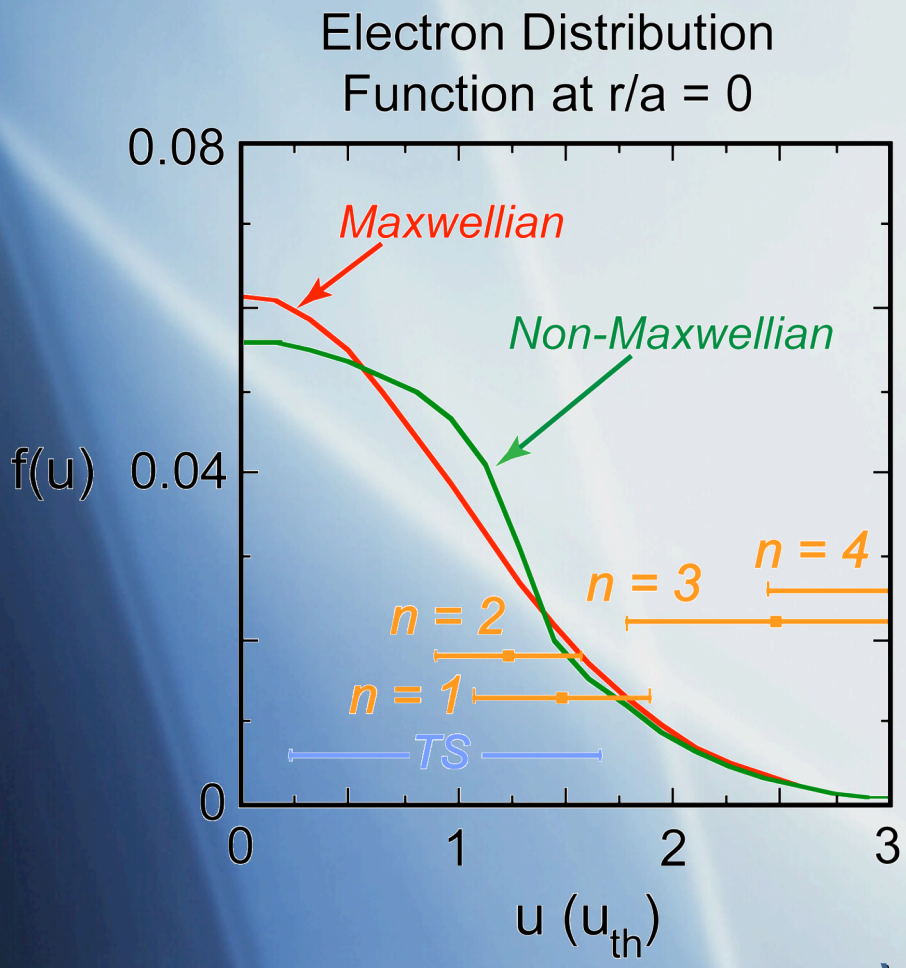


- Observed "T_e Discrepancy" extrapolates to potential ~ 50% discrepancy in ITER

"T_e Discrepancy" Consistent with Non-Maxwellian Bulk Electron Energy Distribution



Modeling Results for JET

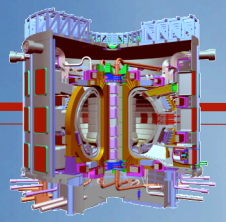


- "Two-temperature" bulk, with higher T_e at $0.75\ u_{th}<u<1.5u_{th}$
- No physical mechanism for driving the non-Maxwellian has been identified
- Need strong mechanism, eg. wave-particle interaction

V. Krivenski, EPS 2002/ EC-12 2002

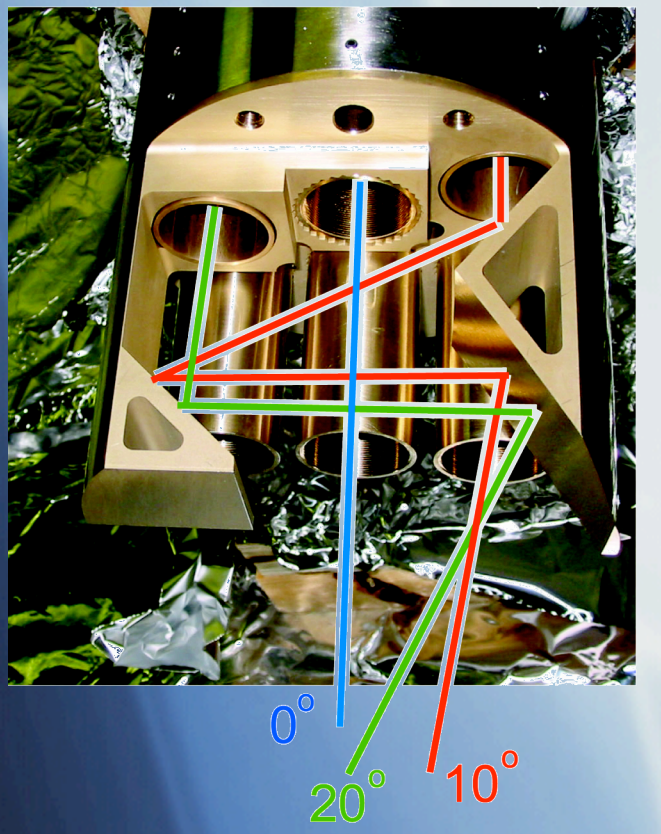
E. de la Luna, RSI 2003

Oblique ECE Diagnostic on JET Now Measuring Emission 10º & 20º to Perpendicular

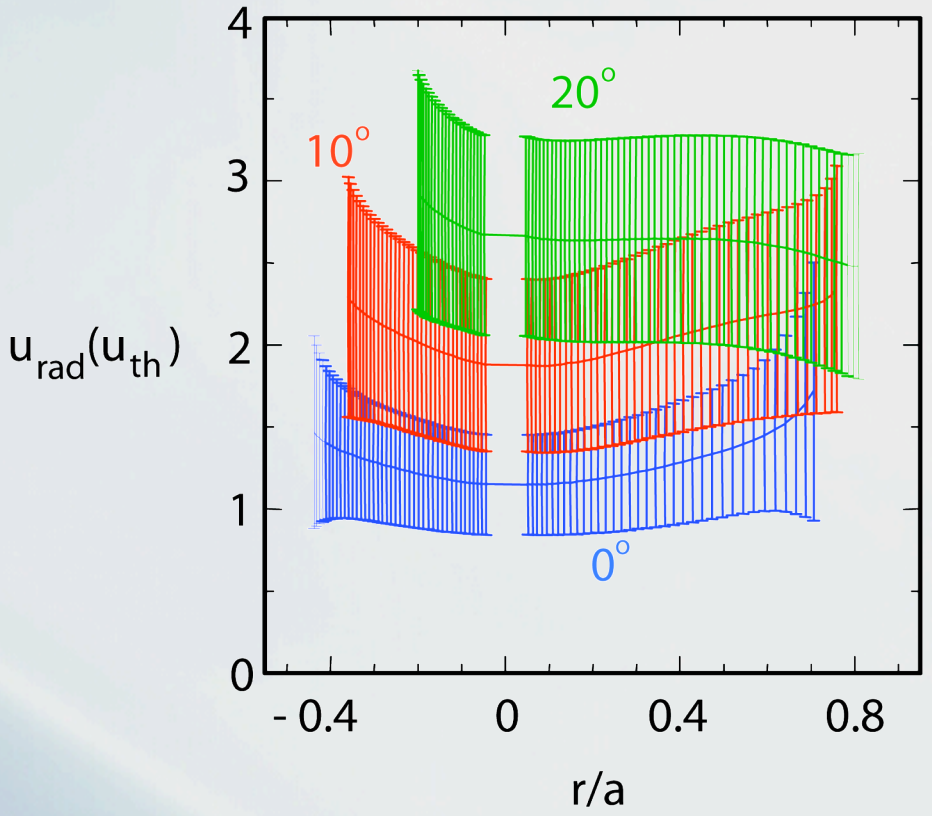


ITER ECE

JET Oblique ECE Antenna

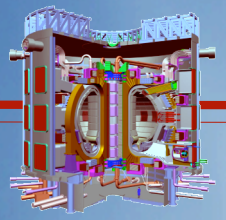


Energy Range for JET Oblique ECE



E. de la Luna (CIEMAT), C. Sozzi (ENEA)

Outline



- Motivation for Including Oblique ECE Diagnostic
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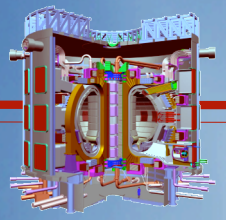
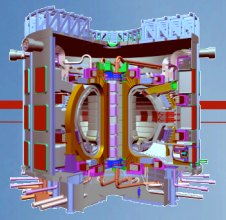
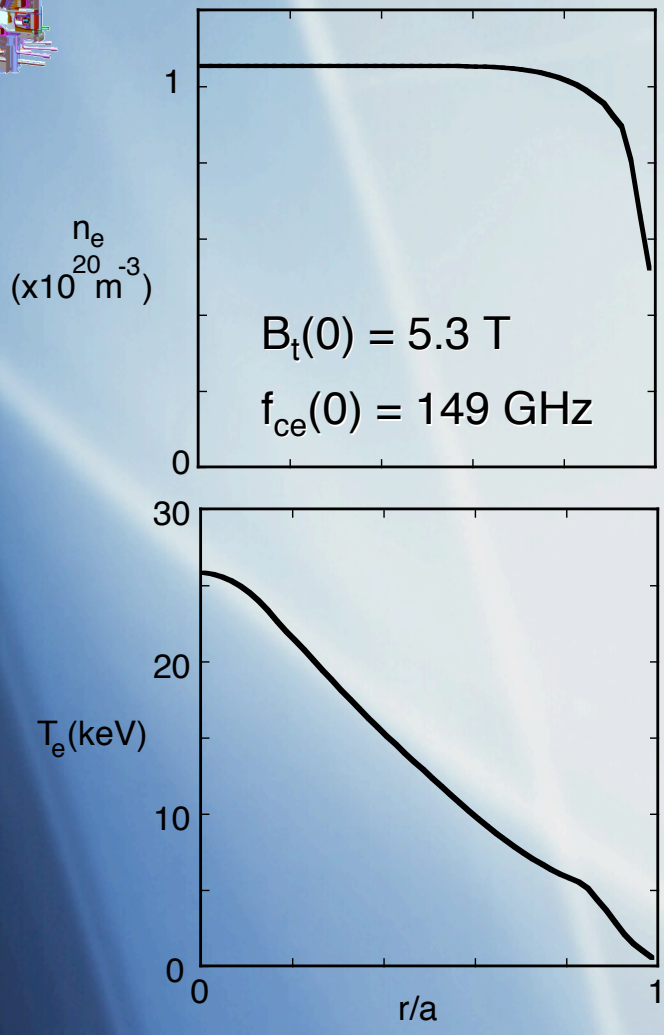
Model ECE from ITER Plasmas with GENRAY Ray Tracing Code

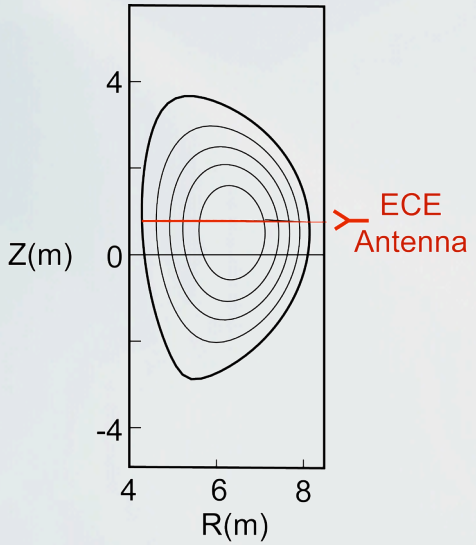


- Emission and absorption calculated along rays originating at the antenna:
  - *fully relativistic emission and absorption*
  - *radiation transport equation solved back to antenna*
  - *ray trajectories calculated with either cold or hot dispersion*
- ECE spectra modeled for antenna pointing 0º, 10º & 20º to perpendicular to outer magnetic flux surface:
  - *emission spectrum computed every 5 GHz*
- Two ITER plasma scenarios studied:
  - *H-mode: $T_e(0) = 25$ keV, $n_e(0) = 1 \times 10^{20}$ m^{-3}*
  - *Steady-state, LHCD-driven: $T_e(0) = 30$ keV, $n_e(0) = 7 \times 10^{19}$ m^{-3}*

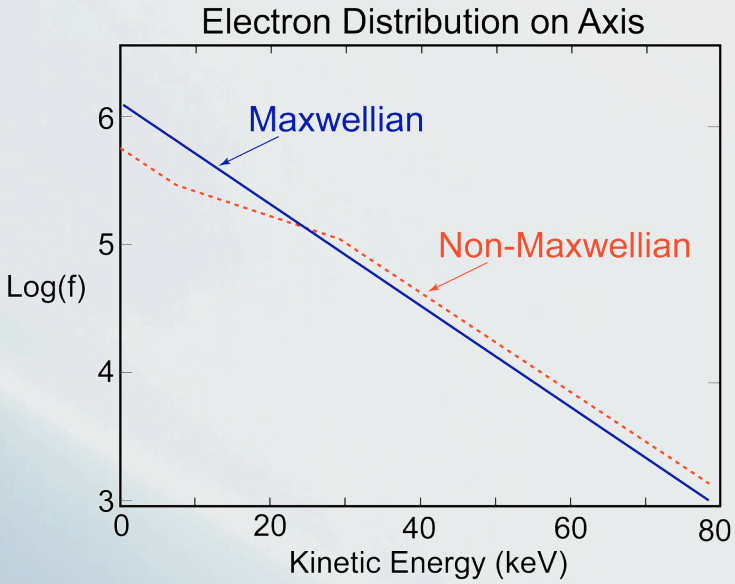
Parameters for ITER H-Mode Plasma





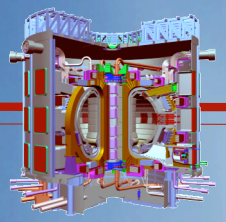


Plasma Equilibrium



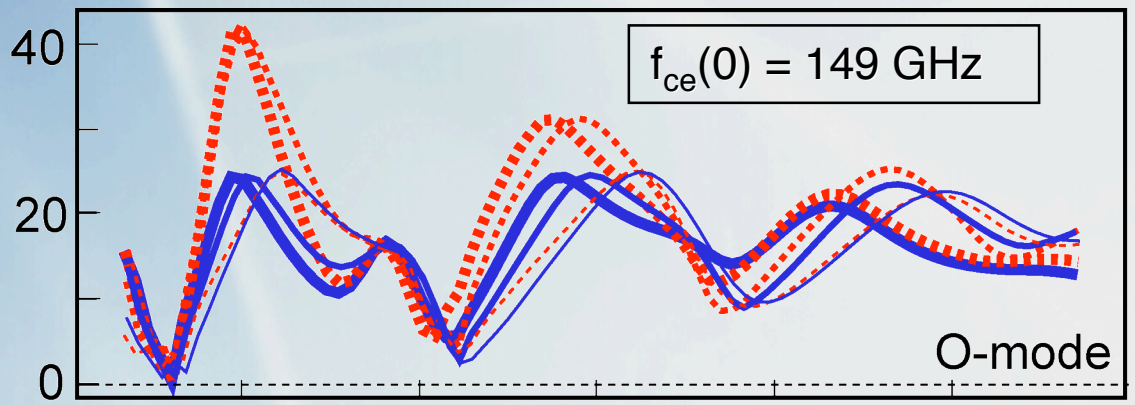
- Non-Maxwellian has "T_e" doubled between 0.75 v_{th} & 1.5 v_{th}

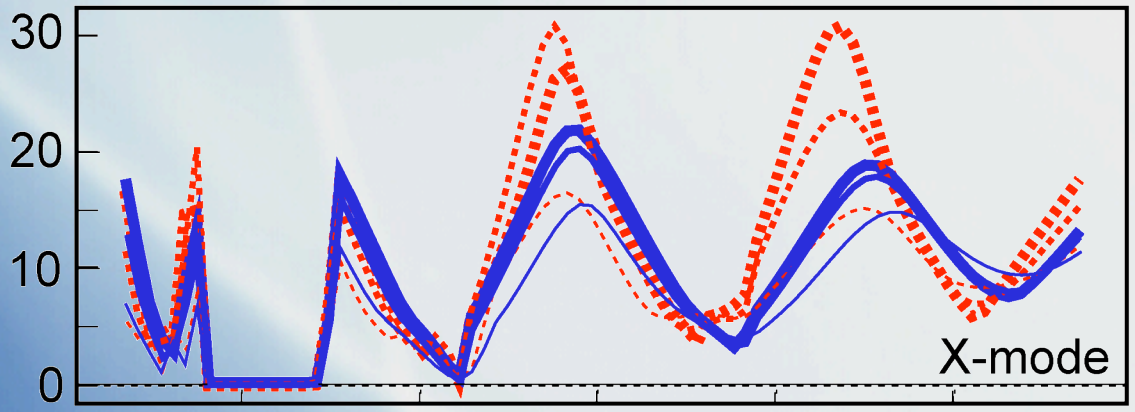
ECE Radiation Spectrum Measured at 0°, 10° & 20° Antennas for H-Mode



ITER ECE

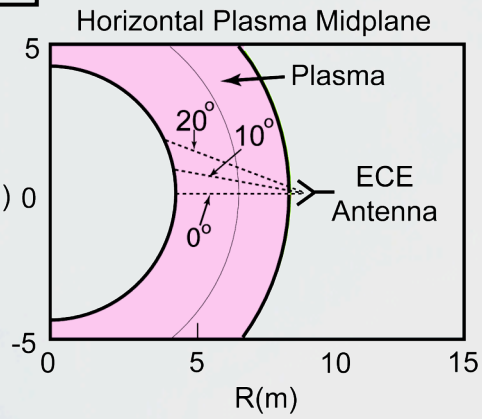
T_{rad} (keV)



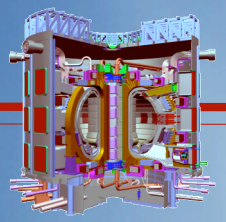


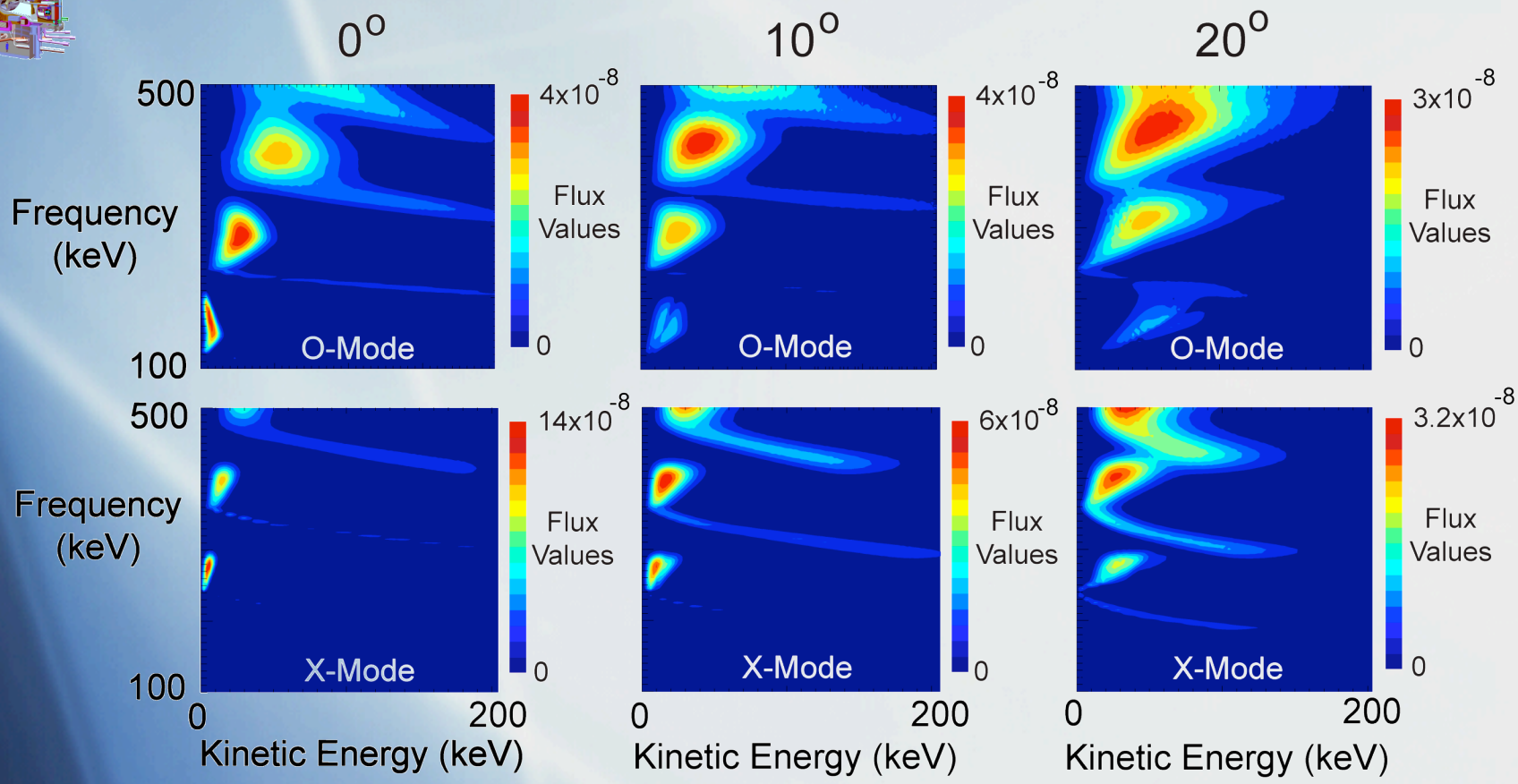
T_{rad} (keV)

Maxwellian
0 deg.
10 deg.
20 deg.
Non-Maxwellian
0 deg.
10 deg.
20 deg.



Electron Energies Contributing to ECE Flux at Edge Increase with Angle & Harmonic



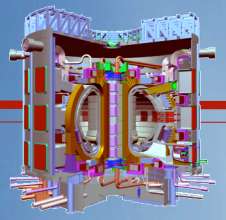


Results for Maxwellian Electron Distribution

H-Mode Plasma

- Electron energies contributing to the ECE flux are similar for “two-temperature” electron bulk distribution

Electron Energy Contributing to Measured ECE: 0-15 keV at 0°, 30-80 keV at 20°

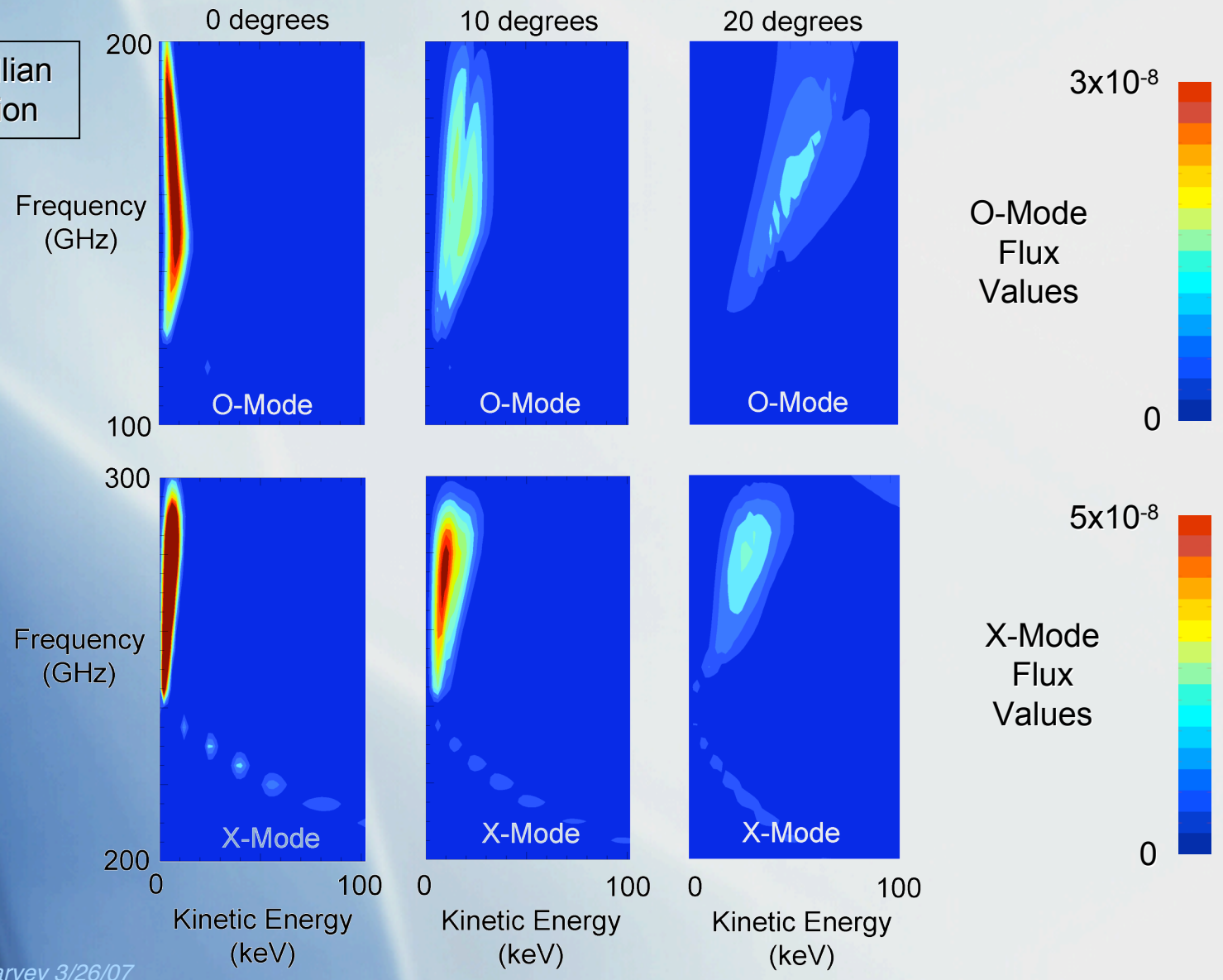


ITER ECE

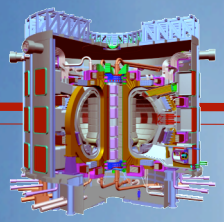
Emission Flux Spectrum at Plasma Edge

Results for Maxwellian Electron Distribution

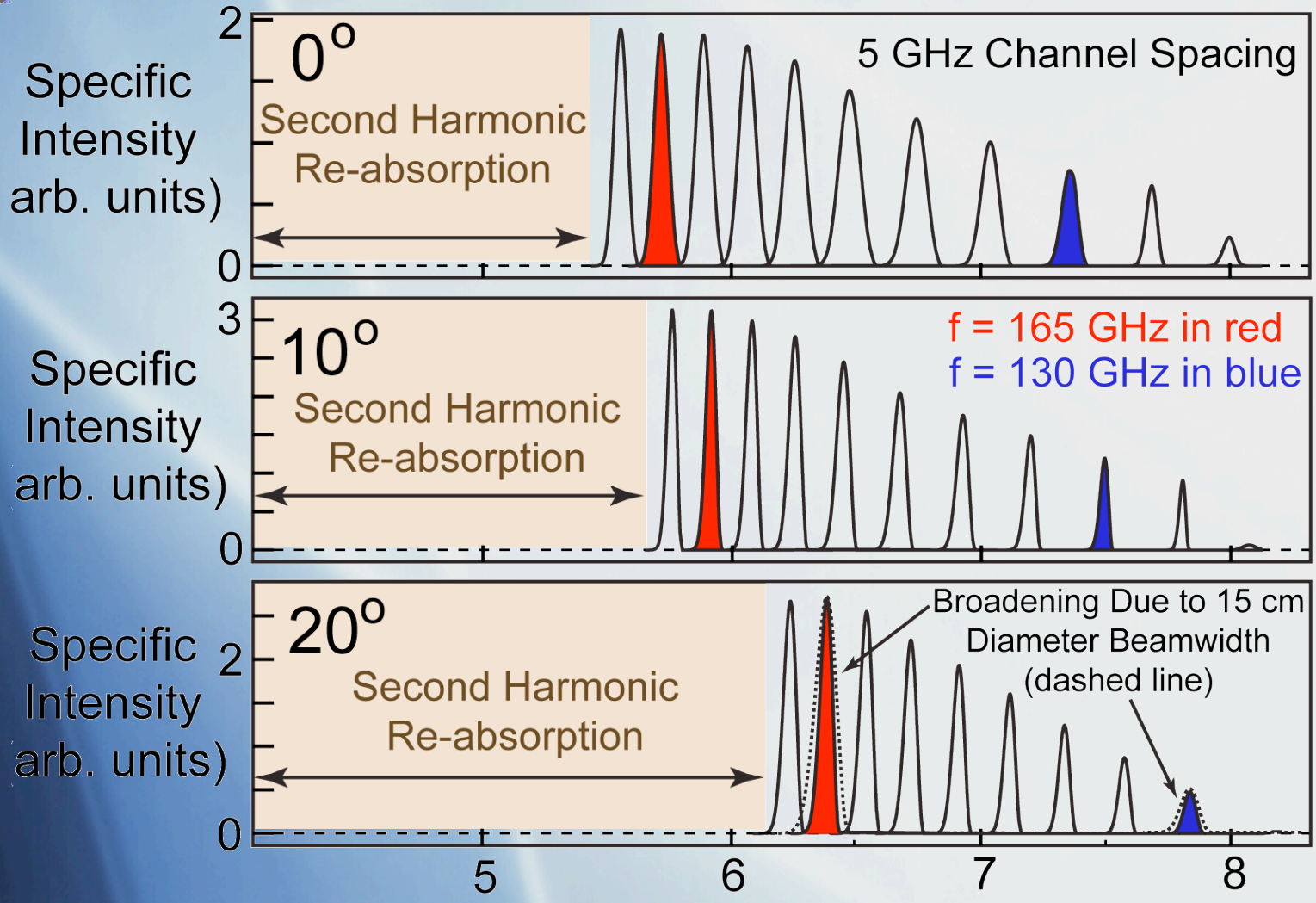
H-Mode Plasma



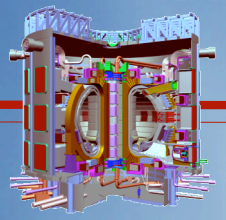
10º & 20º Views have Similar Resolution to 0º View, but with Less Radial Coverage



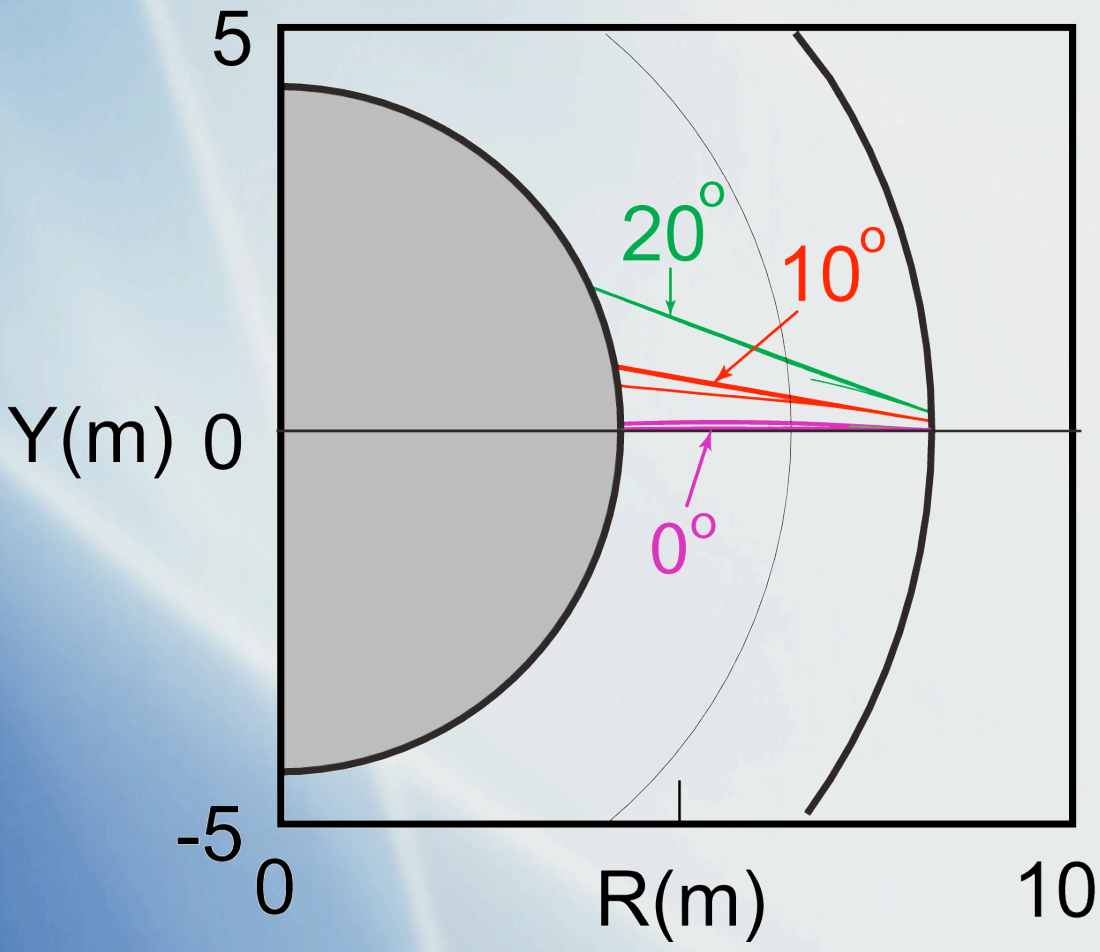
H-Mode Plasma



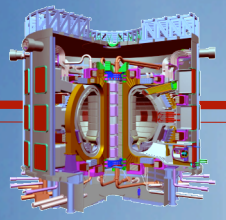
Refraction Minimal for 10º and 20º Views

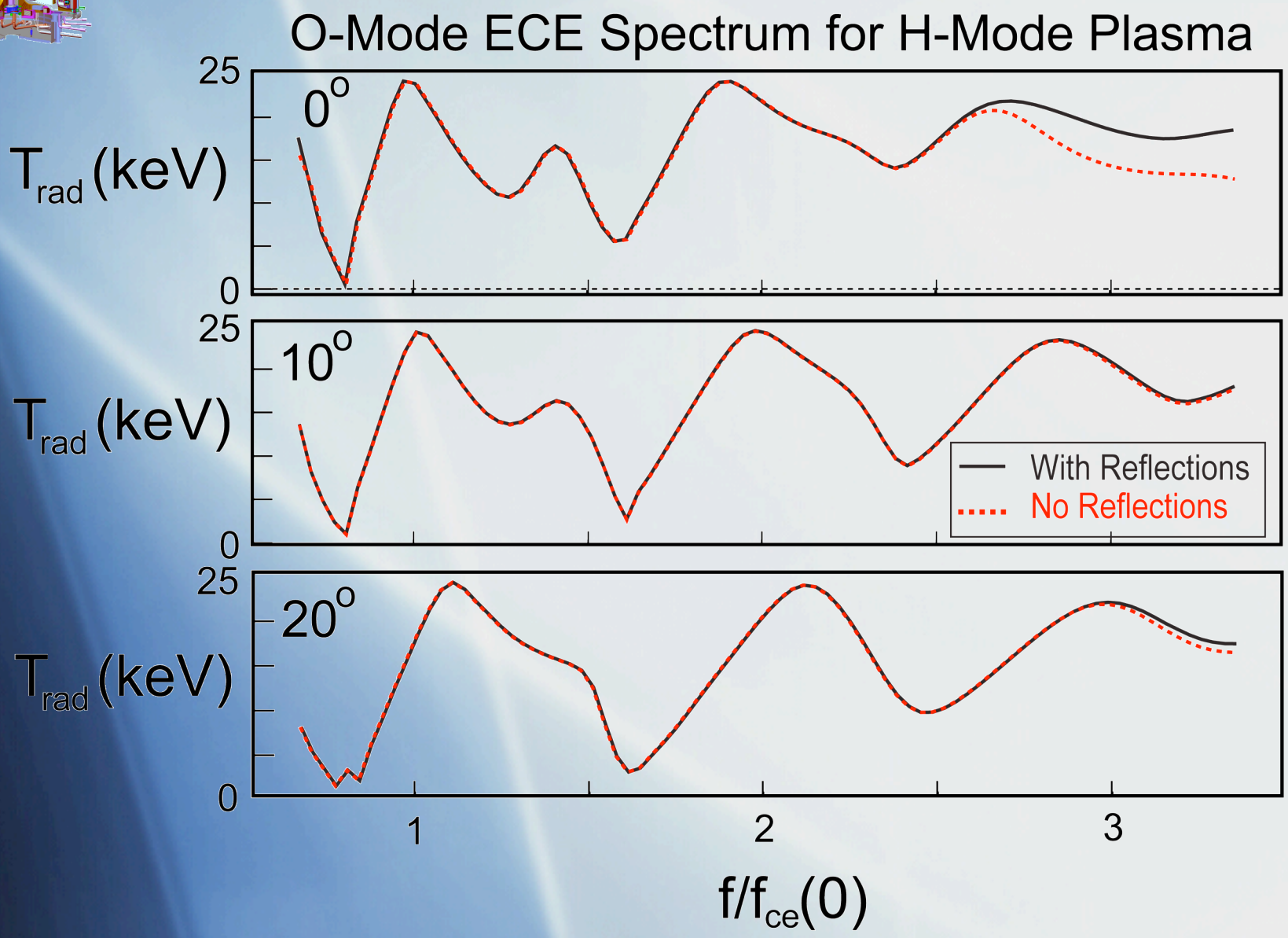


H-Mode Plasma

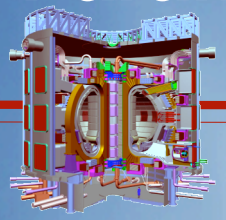


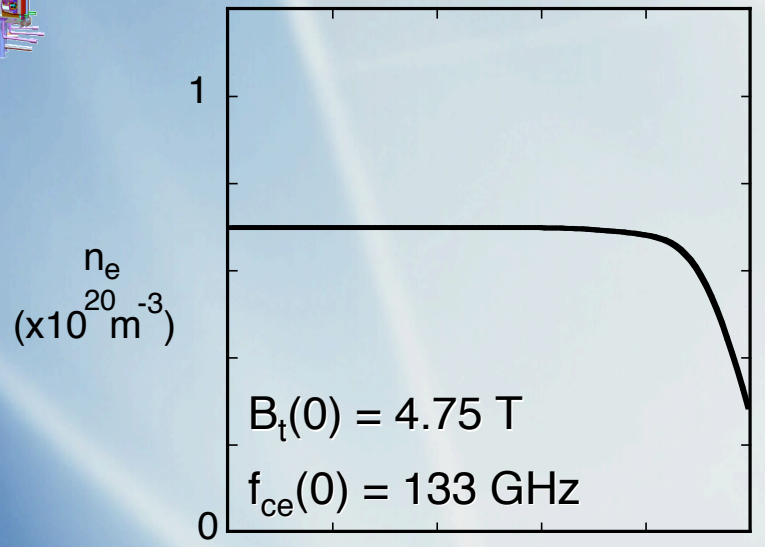
No Viewing Dump Needed for Oblique Views

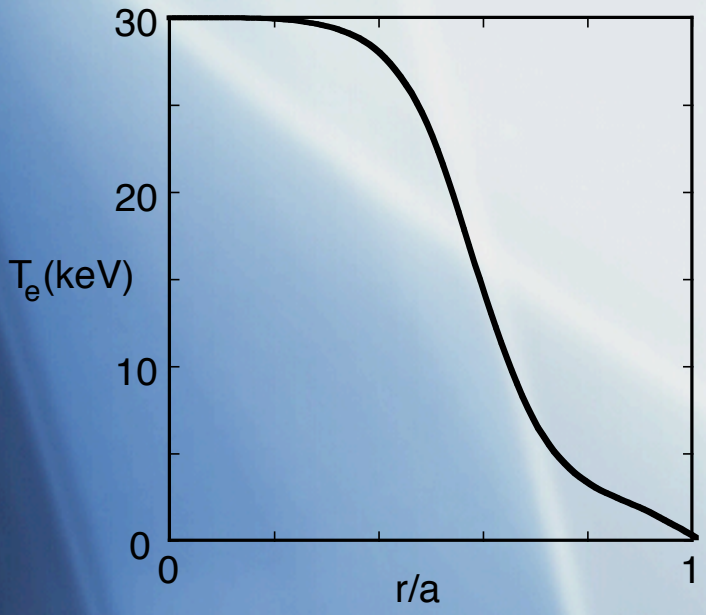


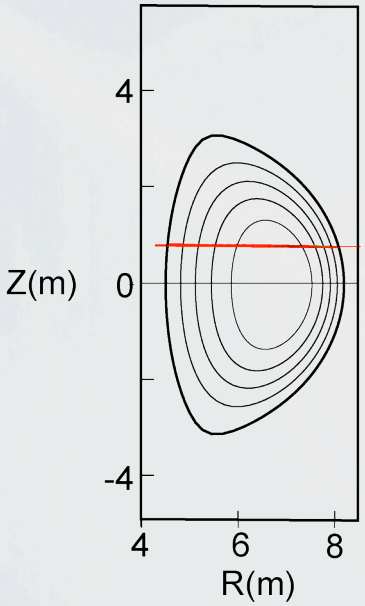


Parameters for Steady-state, LHCD ITER Plasma

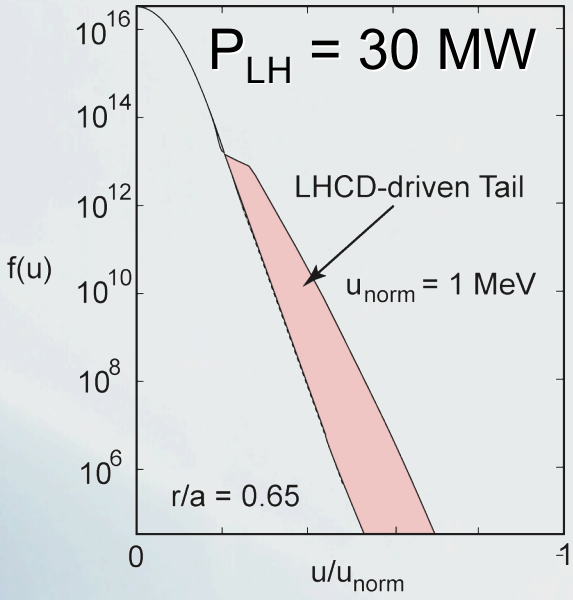




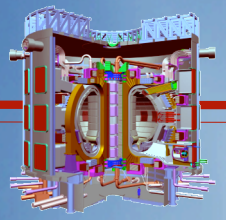


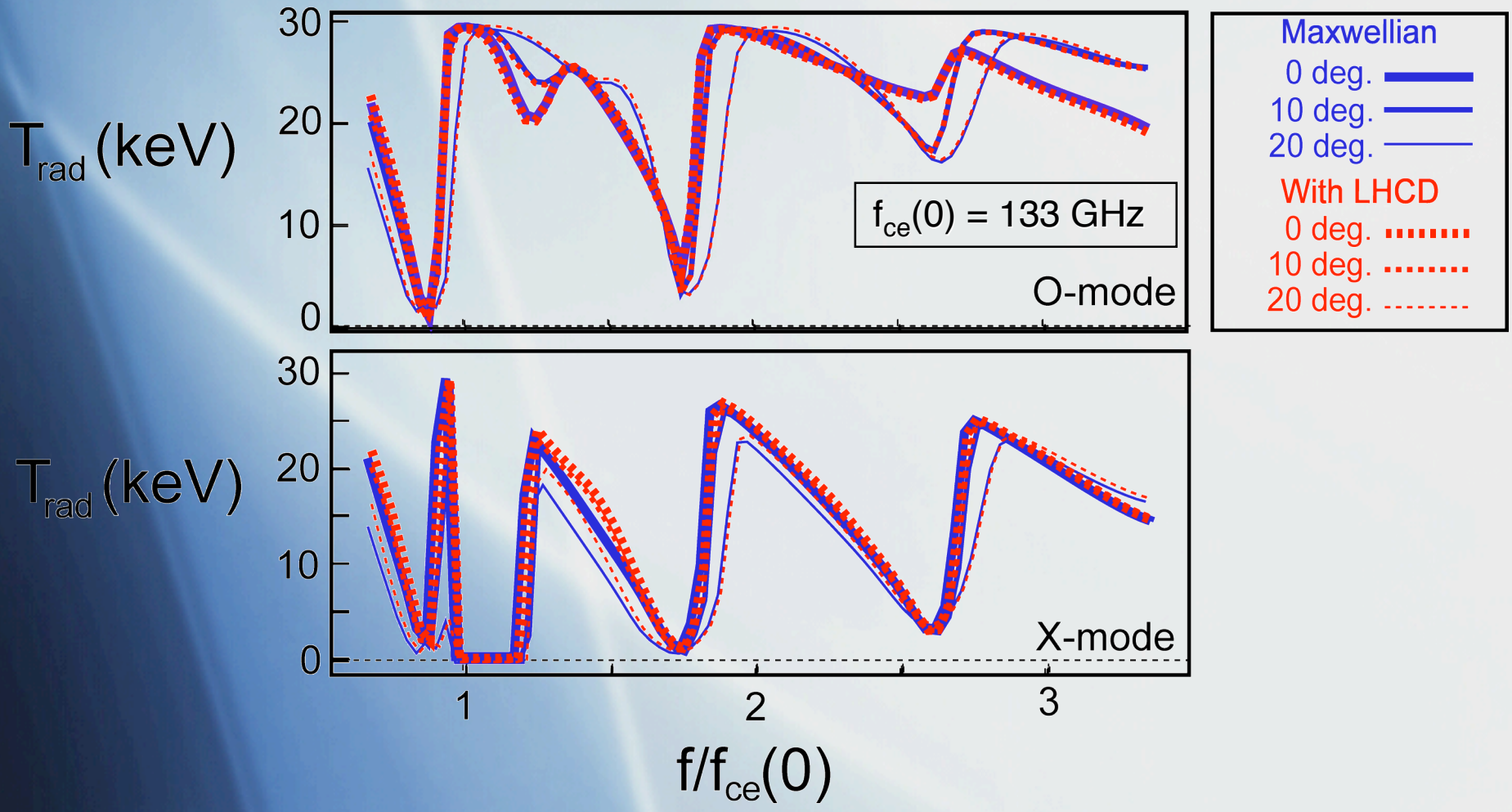


Plasma Equilibrium

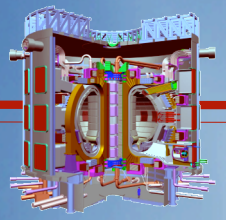


ECE Spectrum Measured at 0°, 10° & 20° Insensitive to LHCD-Driven Tail





Outline



- Motivation for Including Oblique ECE Diagnostic
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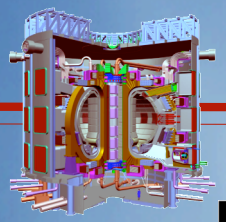
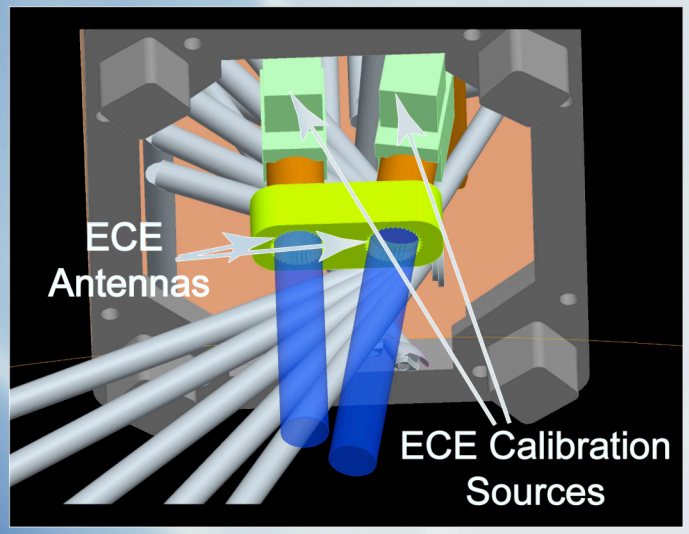
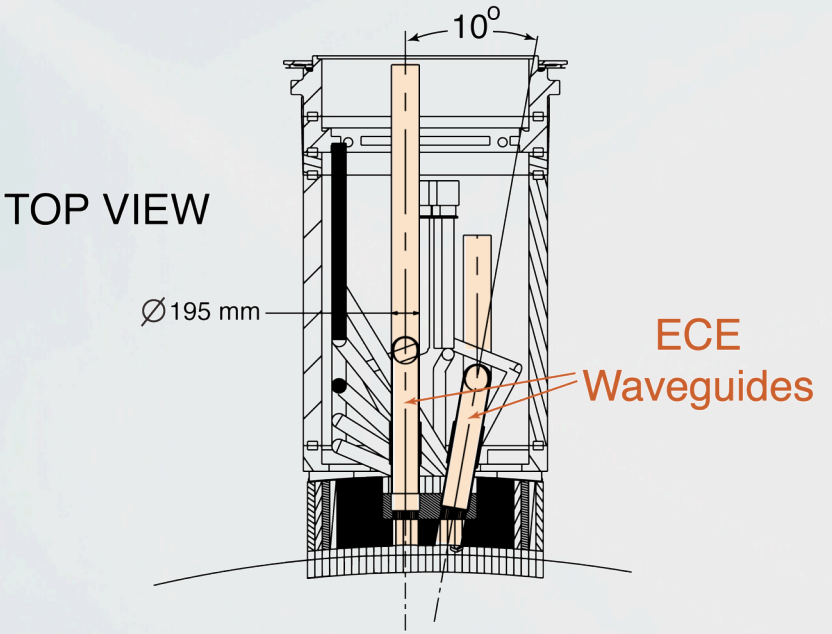
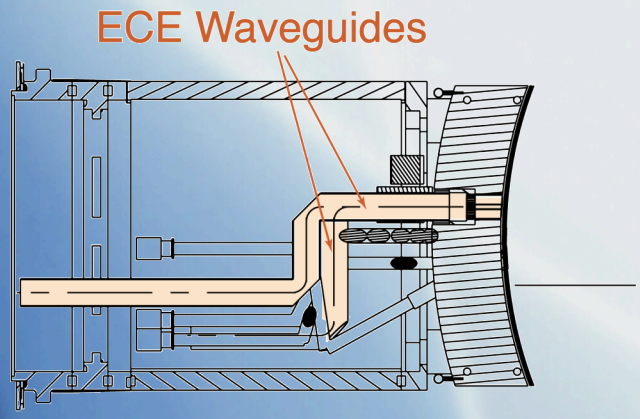
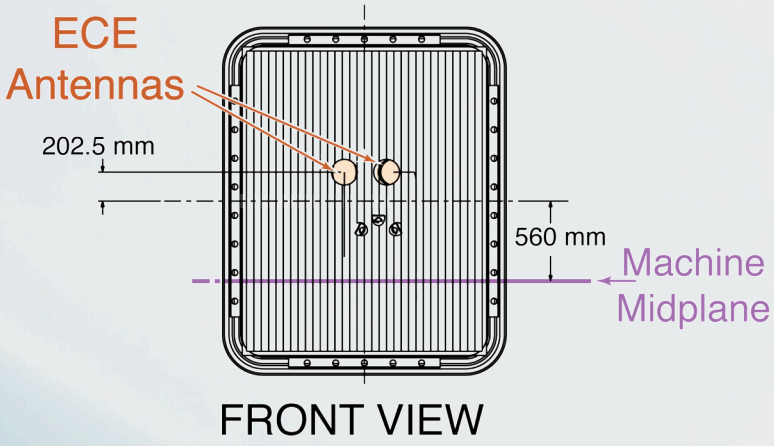
Can Implement Oblique ECE View by Rotating One ECE Antenna at E9 Port Plug





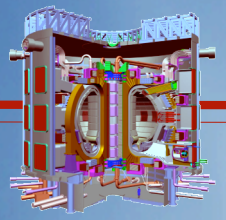






- Oblique angles of up to 20° possible without major port plug redesign

Outline



- Motivation for Including Oblique ECE Diagnostic
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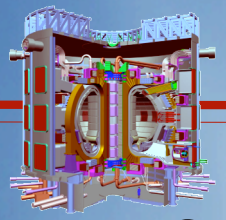
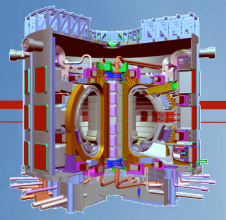
- Conclusions & Recommendations

Conclusions



- ECE/TS "T_e discrepancy" in TFTR & JET when $T_e \geq 7$ keV , implying non-Maxwellian bulk electron distribution
- Extrapolates to ~ 50% ECE/TS discrepancy in ITER
- ECE modeling for ITER shows 10-20º oblique view should allow characterization of bulk electron distribution:
  - *one oblique view probably sufficient to characterize two-temperature bulk*
- Can use oblique view for $T_e(R,t)$, if bulk remains Maxwellian:
  - *minimal refraction*
  - *spatial resolution comparable to normal ECE view*
  - *no viewing dump needed*
  - *ECE insensitive to energetic tail emission*
- Can implement up to 20º oblique view in E9 port plug by rotating one ECE antenna

Recommendations



- Recommend implementing at least one oblique view at E9 port plug:
  - *15° view, if only one oblique view funded*
  - *10° & 20° views, if two oblique views funded*

- Evaluate how well the bulk electron distribution can be measured when measurement errors are included

- Evaluate JET oblique ECE measurements for high T_e plasmas this year:
  - *do JET results support the need for oblique ECE on ITER or how oblique ECE needs to be implemented on ITER?*