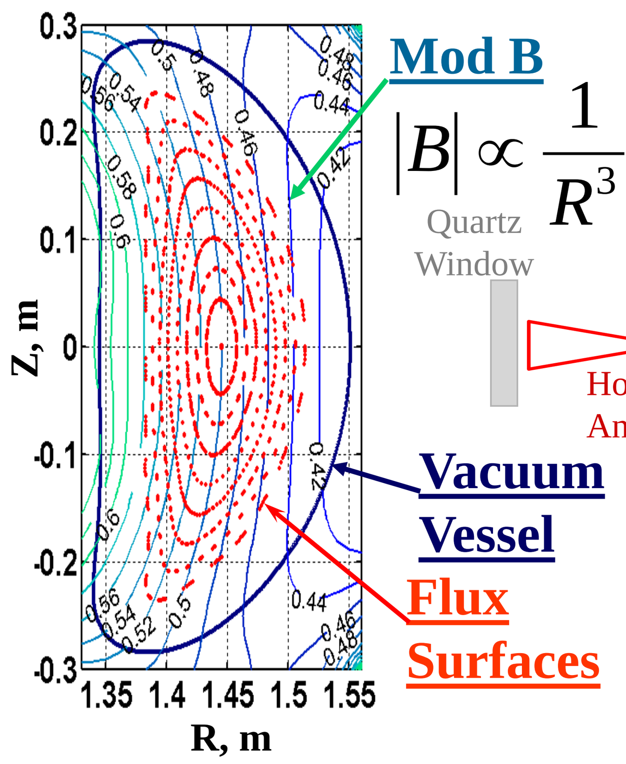
ECE spectrum of HSX plasma at 0.5 T

K.M.Likin, H.J.Lu, D.T.Anderson, F.S.B.Anderson, J.M.Canik, C.Deng[1], C.W.Domier[2], R.W.Harvey[3], J.N.Talmadge, K.Zhai

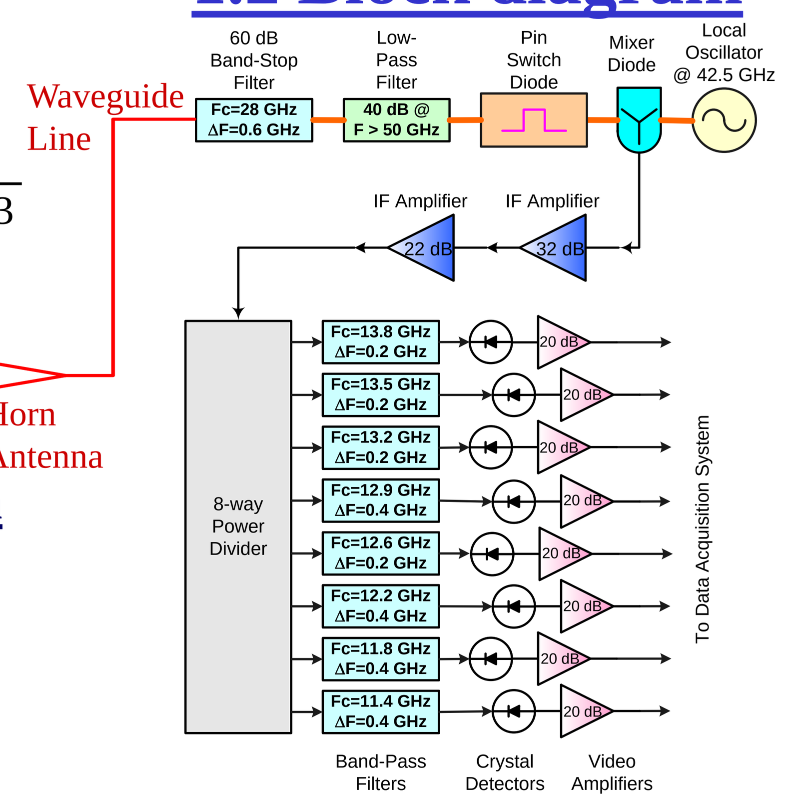
HSX Plasma Laboratory, University of Wisconsin, Madison, WI, USA; [1]UCLA, CA, USA; [2]UC, Davis, CA, USA; [3]CompX, Del Mar, CA, USA

1. ECE Radiometer

1.1 HSX Cut



1.2 Block diagram



•The spectrum of the Electron Cyclotron Emission (ECE) from HSX is measured with an eight channel radiometer at a magnetic field of 0.5 T

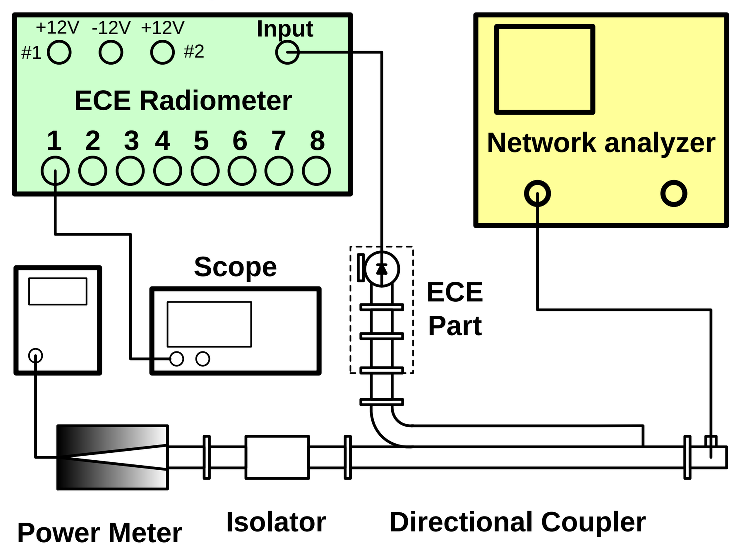
•The central region of the plasma is not accessible because the plasma is heated by the extraordinary wave at the second harmonic

•60 dB stop-band filter at 28±0.3 GHz is used to suppress the non-absorbed microwave power

•A low-pass filter with 40 dB attenuation in the band of (50-95) GHz reduces pick-up from the heating source at its second harmonic

2. Calibration

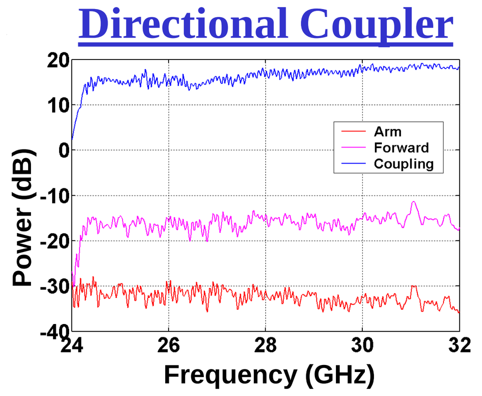
2.1 Lay-out on the bench



•Network analyzer is used as a microwave source in CW regime

•The frequency is fixed within the band width of each channel

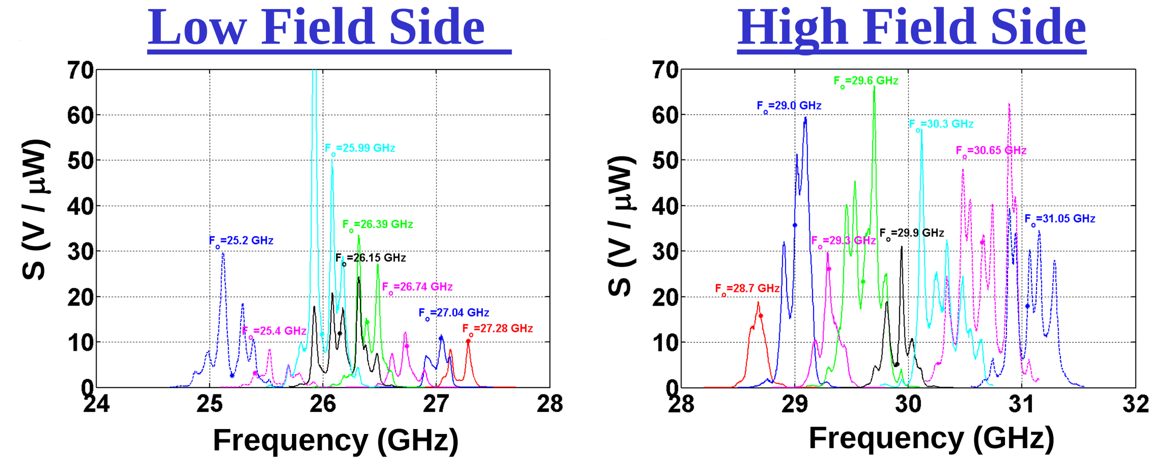
Directional Coupler



•20 dB Directional Coupler has been calibrated with a network analyzer, i.e. transmission is measured into the forward and arm sections

•8-way power divider followed by IF filters have been calibrated with a network analyzer separately for each channel, i.e. a transmission coefficient is measured in 1 GHz frequency intervals within the corresponding frequency band

2.2 Measured Sensitivity of the Channels

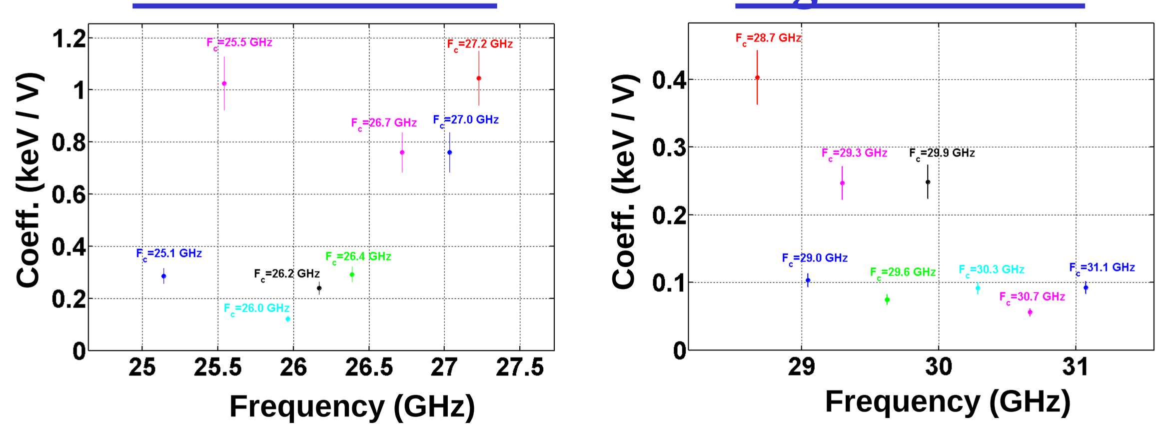


•Calibration has been made for two sets of eight IF filters --- one set is for receiving the electron cyclotron emission from the low magnetic field side and the other one – from the high magnetic field side

•Sensitivity of each channel has been measured at different input power, i.e. at 2.5 µW, 5 µW, 7.5 µW, 10 µW and 15 µW, so that the output signal varies from 0.5 V up to about 5 V, respectively

•Sensitivity has been measured at various frequencies within the band width of IF filters

2.3 Integrated Response



•The integrated response has been calculated assuming that the plasma is a black body. In these calculations an etendue of the horn antenna is estimated to be 5.84 cm^2*sterad

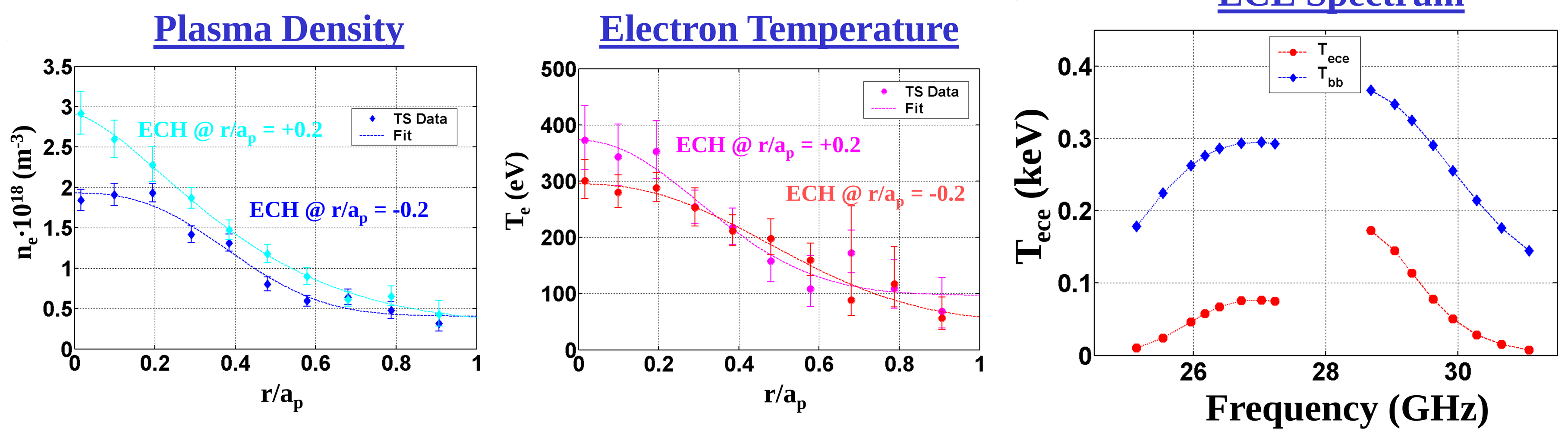
•The central frequency has been calculated based upon the measured sensitivity of each channel

3. Results of measurements

3.1 ECE vs. Thomson Scattering

•ECE channels have been also calibrated against the electron temperature measured by Thomson scattering (TS) diagnostic in the plasma with off-axis heating

•In order to minimize a contribution from high energetic electrons to the ECE signals, the resonance is located inboard at r/a_p = - 0.2 in case of the down-shifted (DWS) frequency channels while the outboard heating is made at r/a_p = + 0.2 for the up-shifted (UPS) channels, respectively



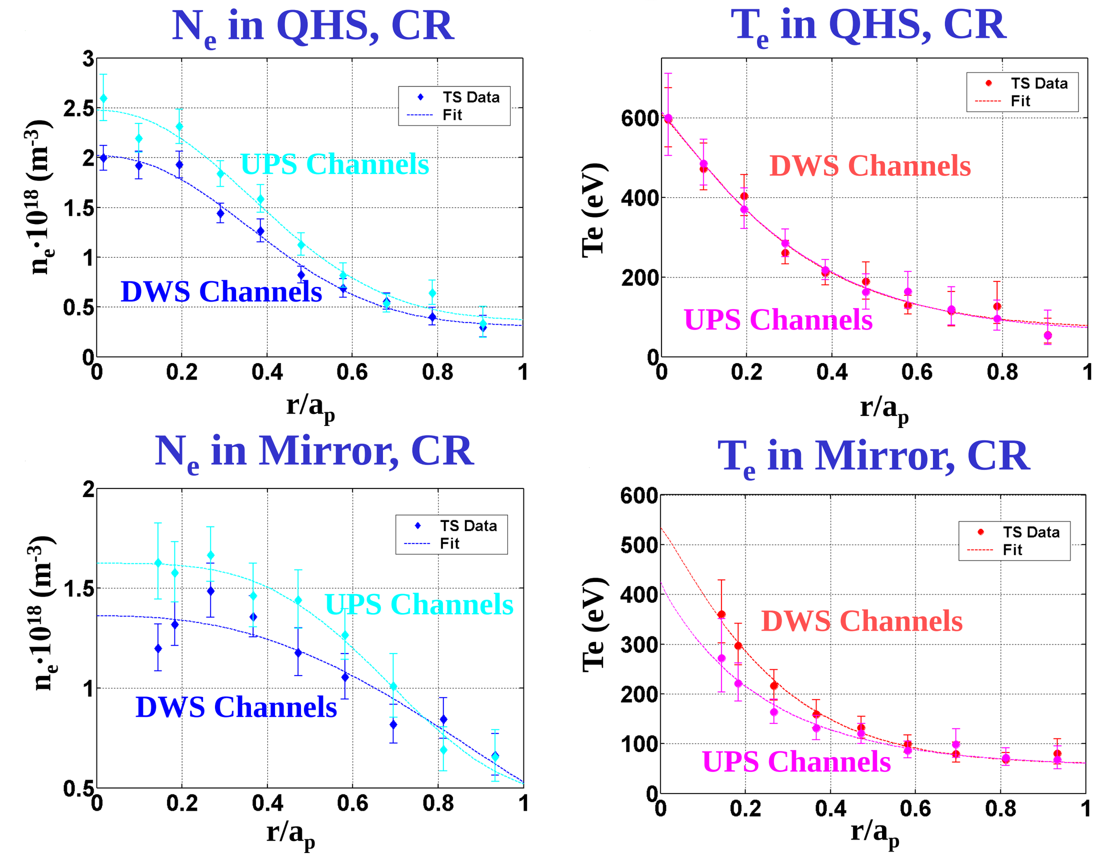
•TS and ECE data are averaged over 5 shots

•Optical depth is calculated based on the TS profiles

•ECE temperature is corrected on the calculated optical depth

3.2 ECE Spectra in QHS and Mirror configurations

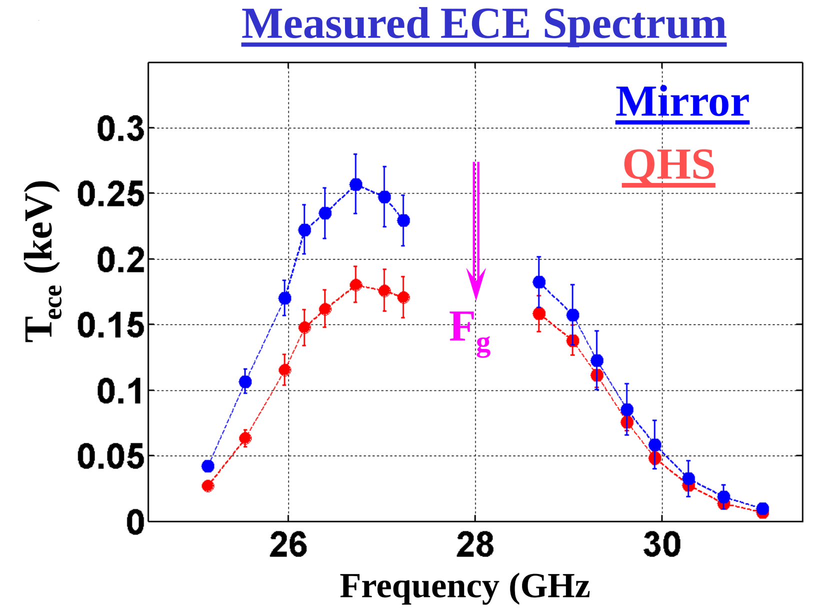
•TS and ECE data are shown in the quasi-helically symmetric (QHS) and 10% Mirror magnetic configurations in the case of the central resonance (CR) heating



•Plotted ECE data are based on the calibration presented above

•ECE temperature at UPS frequencies is almost the same in QHS and Mirror while there is a clear difference at DWS frequencies between the two configurations

Measured ECE Spectrum



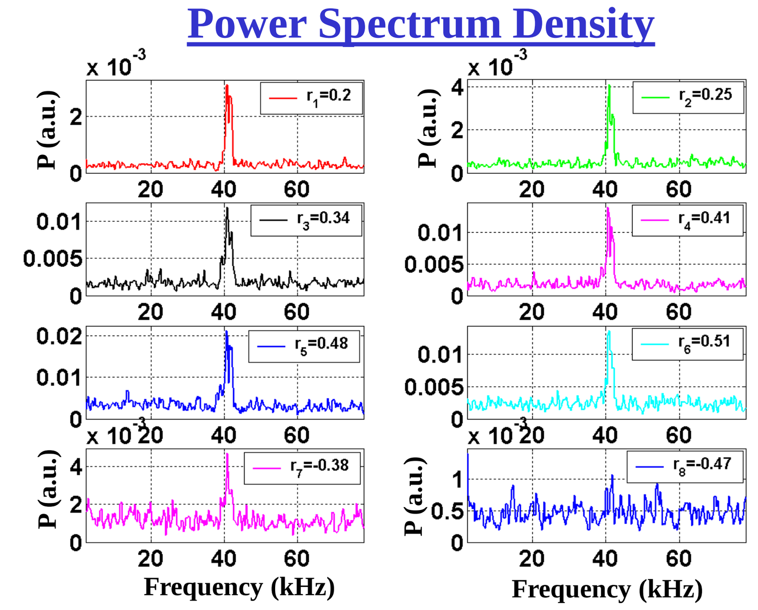
•Higher ECE temperature in the Mirror mode is due to a lower central plasma density in Mirror as compared to QHS

3.3 Plasma Density Fluctuations

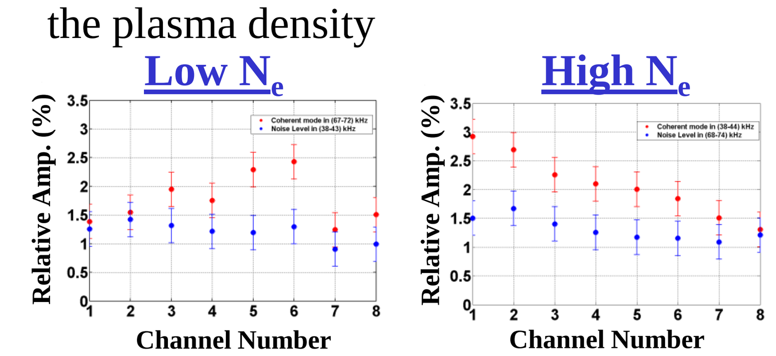
•Low frequency (< 70 kHz), narrow bandwidth (< 5 kHz), low amplitude (less than 5%) fluctuations have been measured by the ECE radiometer in QHS

•The phase difference between ECE signals on the either side of the magnetic axis is about 180 degrees

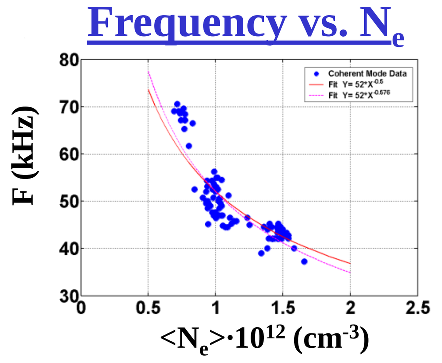
Power Spectrum Density



•Amplitude is almost independent of the plasma density



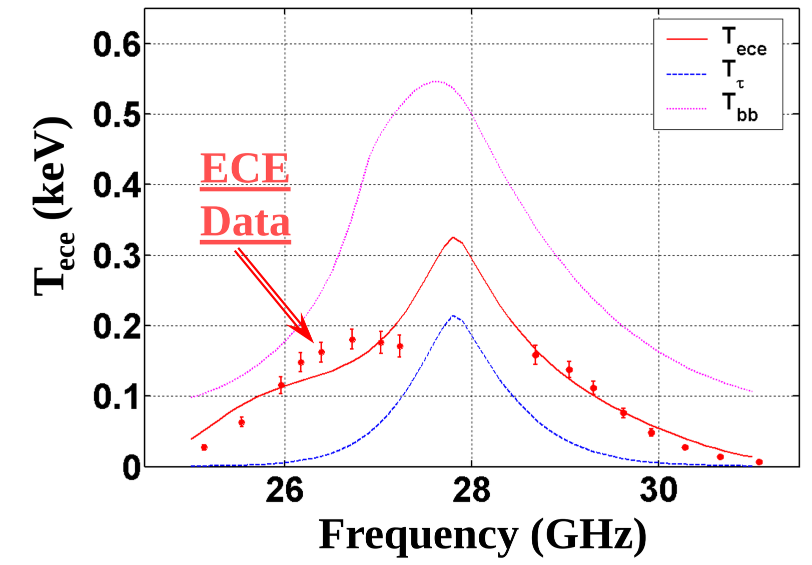
Frequency vs. N_e



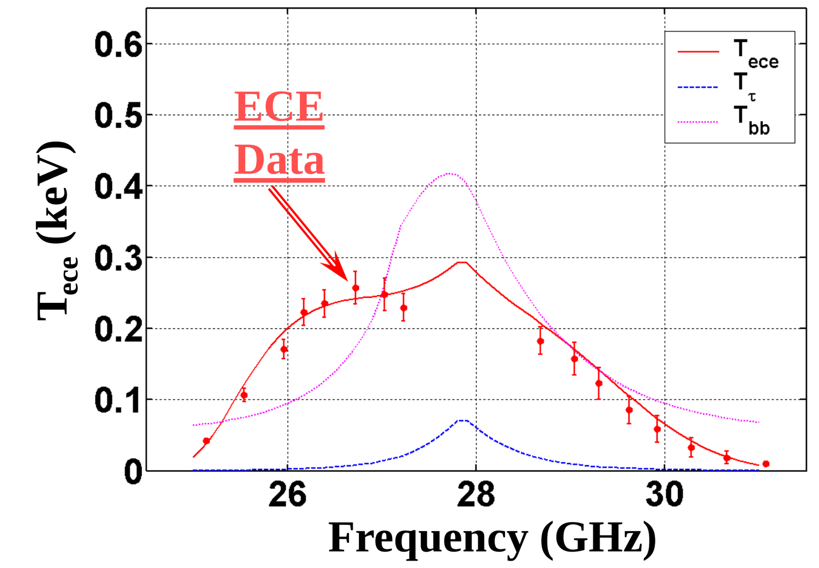
•The frequency decreases with plasma density. See the HSX posters by C.Deng & S.Oh

4. Bi-Maxwellian plasma model

4.1 QHS Spectrum



4.2 Mirror Spectrum



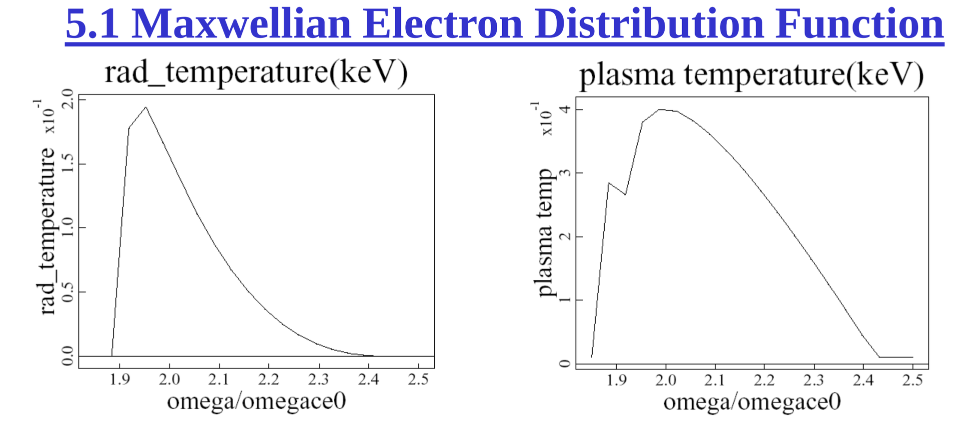
•Solution of the radiation transport equation is used to find a population and a temperature for energetic electrons

•Bulk plasma density and electron temperature are from TS

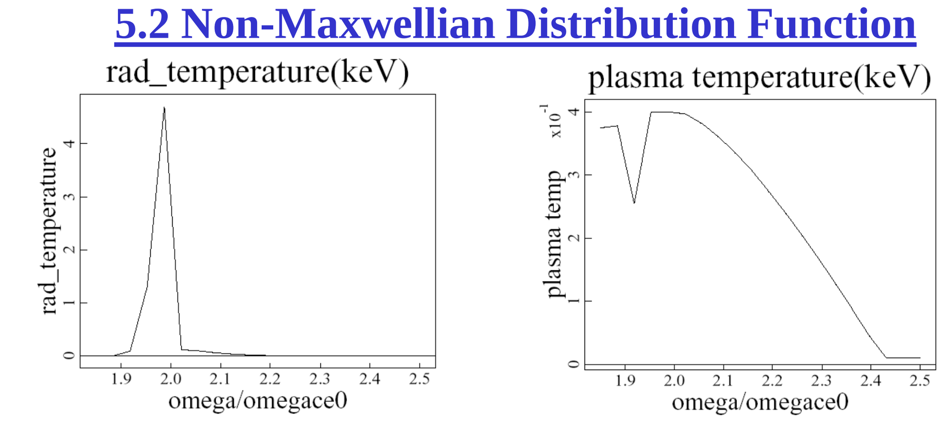
• The best fit is for the following parameters:
N_{tail} = 0.1·10^{18} m^{-3} in QHS, 0.2·10^{18} m^{-3} in Mirror and T_{tail} = 2.5 keV for both modes

5. CQL3D code

5.1 Maxwellian Electron Distribution Function



5.2 Non-Maxwellian Distribution Function



•CQL3D code is used to simulate the electron cyclotron heating in QHS and to calculate a radiation intensity at the second harmonic of ω_{ce}

•On the left figures the results of two runs are shown

•The plasma parameters are as follows: central T_e = 0.4 keV, central N_e = 1·10^{18} m^{-3} and input power is 100 kW

•On the left bottom figure it is clearly seen that the ECE temperature for the non-Maxwellian electron distribution function is above 4 keV

•Further work should be done to understand why CQL3D predicts low ECH absorption in HSX plasmas

47th Annual Meeting of the Division of Plasma Physics, October 24-28, 2005, Denver, Colorado