



Observation of quasi coherent modes in W7-X and relation to tokamaks

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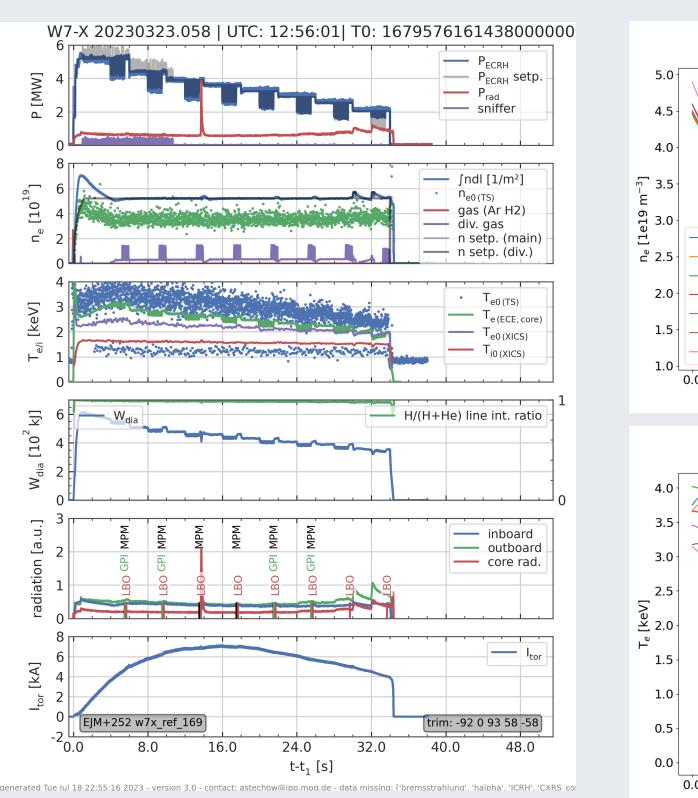
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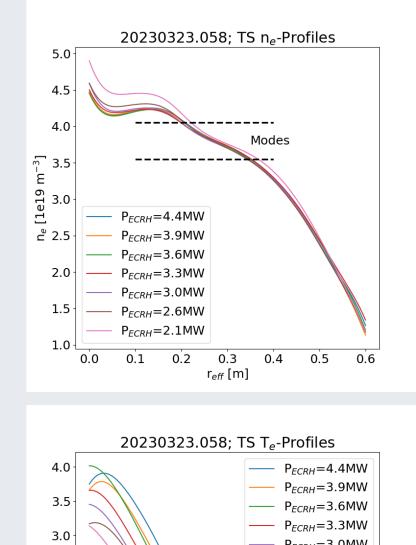
Quasi Coherent Modes in Fusion Devices

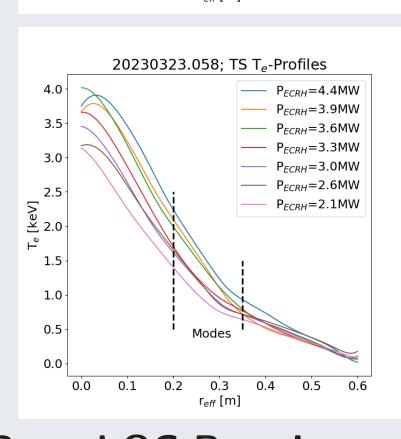
Motivation: Quasi Coherent (QC) modes with $k_{\perp} \approx 3$ cm⁻¹ are observed in tokamaks as Tore Supra and AUG. The nature is mostly TEM-like. In the stellarator W7-X such modes are observed in the plasma core and as well in the plasma edge. The latter are correlated with an increase in the diamagnetic energy. In all devices they share a similar scaling depending on v_{\perp}

Observations at W7-X

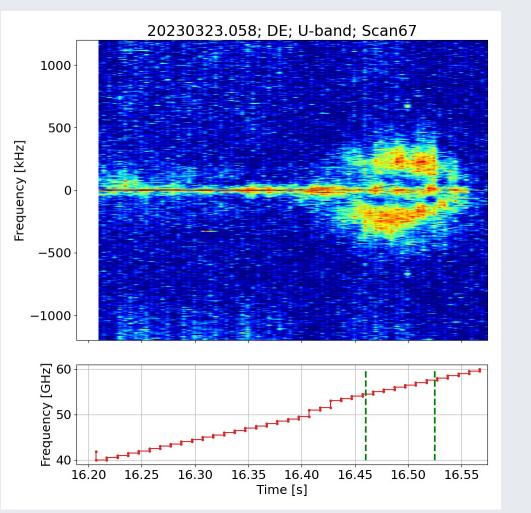
QC-Modes in Standard Configuration (EJM)



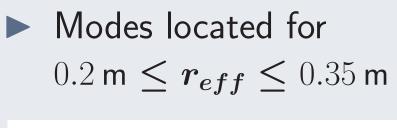


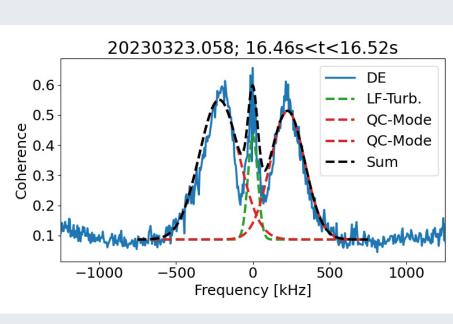


E×**B**- and **QC**-Rotation

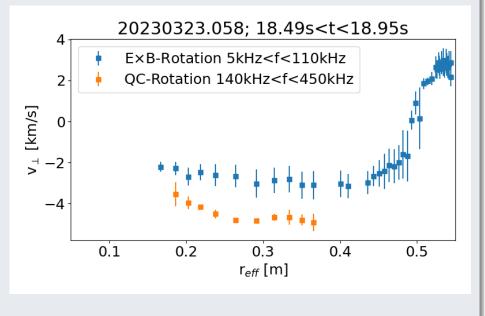


Modes in Coherence Spectra



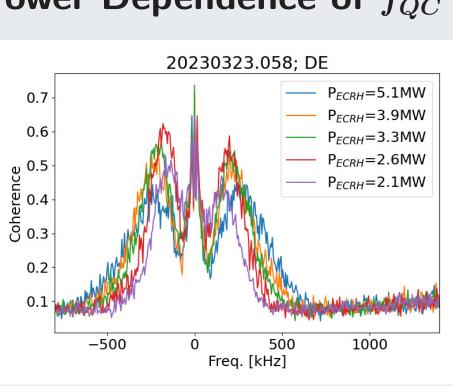


- ► 3 distinct components
- Low frequency component $5 \, \text{kHz} \le f \le 110 \, \text{kHz}$
- Quasi coherent Modes: $140\,\mathrm{kHz} \le f \le 450\,\mathrm{kHz}$
- ► HWHM of QC-Mode: $130 \, \text{kHz} \le f \le 150 \, \text{kHz}$



- QC-mode rotation faster than E imes B-rotation
- QC-mode rotation in electron diamagnetic drift direction

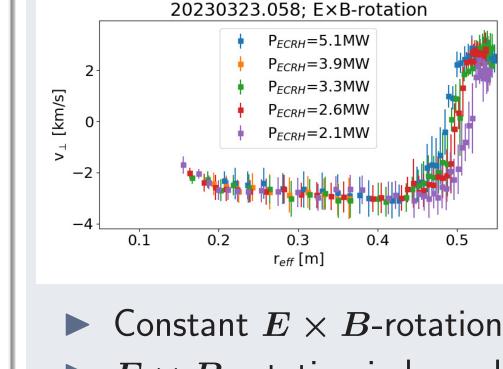
Power Dependence of f_{QC}

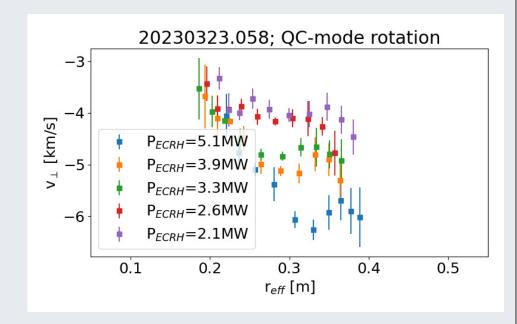


- $ightharpoonup f_{QC}$ decreases with power
- ► Largest coherence for P_{ECRH} =2.6 MW
- ► Low frequency mode at f=16 kHz unaffected

Observations at W7-X

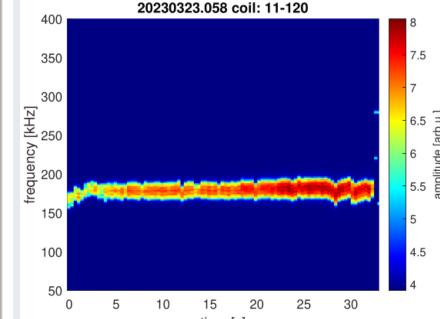
Power Dependence and Mode Velocity





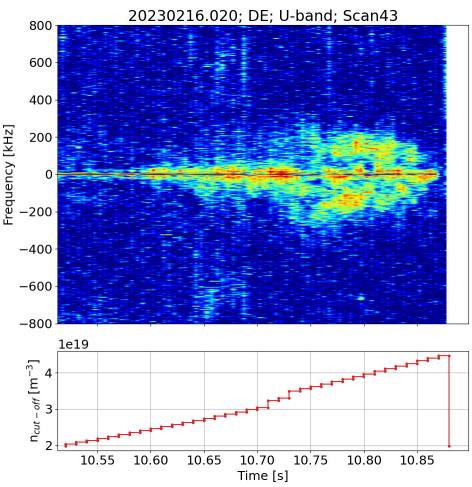
- ► Constant $E \times B$ -rotation of $-2.7 \, \mathrm{km \, s^{-1}}$
- ightharpoonup E imes B-rotation independent of P_{ECRH}
- lacksquare QC-mode rotation more negative than E imes B-rotation
- ightharpoonup QC-mode rotation increases with decreasing P_{ECRH}
- lacktriangle Mode rotation is determined by P_{ECRH}

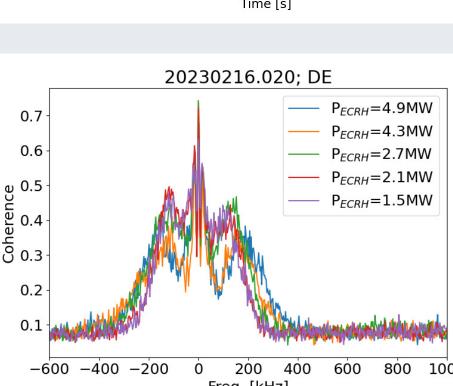
Comparison with Magnetics using DMUSIC



- Mirnov coils show broad frequency band at $f \approx 180 \,\mathrm{kHz}$
- No correlation between Mirnov and PCR for mode frequency
- Mirnov frequency spectra attributed to AEs

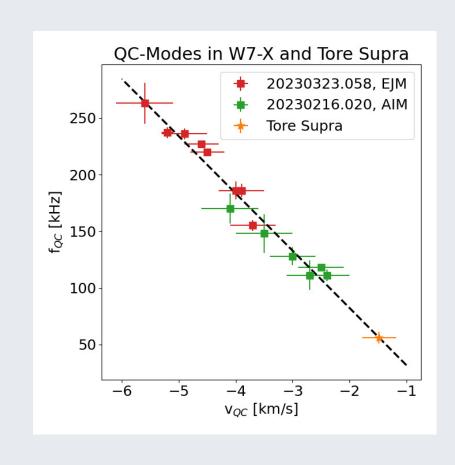
QC-Modes in Low Mirror Configuration (AIM)





- lacksquare Decrease of f_{QC} with decreasing power
- lacksquare Different f_{QC} for same power in EJM and AIM

- Similar program as in EJM configuration
- Power scan at constant density
- Power variation from $5\,\mathrm{MW} \leq P_{ECRH} \leq 1.5\,\mathrm{MW}$
- Lower mode frequencies observed
- QC-mode frequency range $170 \, \text{kHz} \le f_{QC} \le 90 \, \text{kHz}$

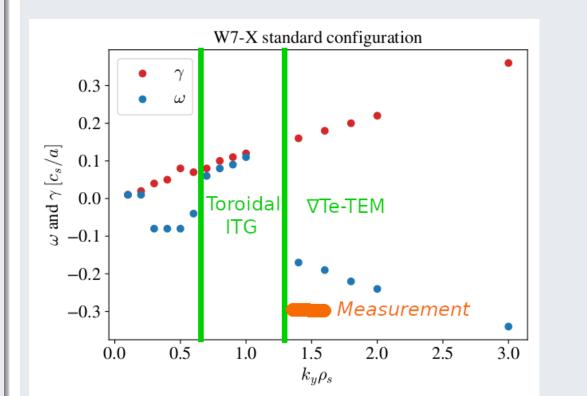


lacksquare Scaling of f_{QC} versus v_{QC} configuration independent

Observations at W7-X

Estimation of Mode Properties

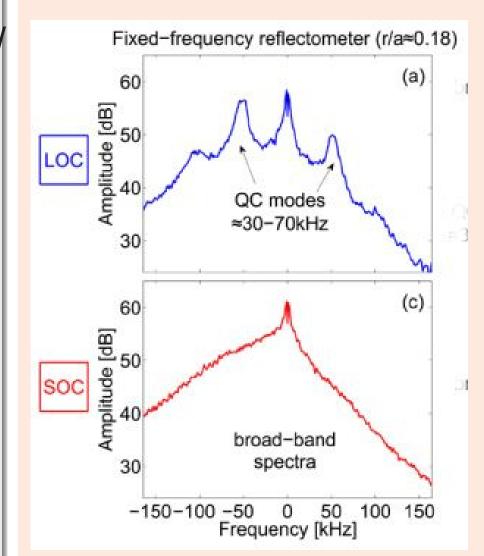
- Flux surface perimeter $1.42 \,\mathrm{m} \le s \le =2.52 \,\mathrm{m}$
- ► Mode frequency from coherence spectrum: $f_{QC} \approx 220 \, \text{kHz}$
- ► Mode velocity: $-4.7 \, \text{km s}^{-1} \le v_{QC} \le -4.3 \, \text{km s}^{-1}$
- ightharpoonup yields mode number from $66 \le m \le 118$
- ► Structure size is constant at $L=22 \,\mathrm{mm}$ yielding $k_{\perp}=2.9 \,\mathrm{cm}^{-1}$
- ▶ QC-modes observed for $1.2 \text{ keV} \le T_e \le 1.8 \text{ keV}$
- ► This yields $1.32 \le k_{\perp} \rho^* \le 1.58$ assuming $Z_{eff} = 1.5$



- ► Linear gyro-kinetic simulation for EJM
- Increasing growth rate with $k_\perp
 ho^*$
- Measurement compatible with $abla T_e$ driven TEMs
- Mode frequency in the plasma frame of 33 kHz obtained
- ► TEMs are also observed in the plasma edge where they correlate with an increase in W_{dia}
- In this case they are driven by strong ∇n_e
- ► See also Tu-MCF7; 3-7 July 2023, EPS Conference on Plasma Physics, Bordeaux, France

Relation to Tokamak Experiments

► TEMs observed in linear confinement regime in Tore Supra



- QC-modes observed by reflectometry
- Modes show of TEM nature
- Observed in a similar region as in W7-X
- Assuming $20 \,\mathrm{mm} \leq L_{\perp} \leq 25 \,\mathrm{mm}$ yields $-1.7 \, {\rm km \, s^{-1}} \le v_{QC} \le 1.2 \, {\rm km \, s^{-1}}$ ► Fits with W7-X-scaling for
- QC-modes
- See Tore Supra data point in scaling of f_{QC} with v_{QC}
- developed See poster 1-11 by L. Salazar

► New data analysis tools for extraction of TEM modes

- Extraction of QC-modes from density fluctuation spectra
- ► Interaction between turbulence components can be analyzed
- ► Enables multi-machine comparison (Tore Supra, West, W7-X) of QC-modes

Diagnostic at W7-X and Methodology

Operation in hopping modus to cover large radial range

- Poloidal correlation reflectometry (PCR)
- lacktriangle Sensitive to $\delta n/n_c$ fluctuations
- lacktriangle Poloidally spaced receivers measure v_{\perp} , E_r
- Information on modes from coherence spectra
- Measurement of turbulence wave length
- Continuously repeating of scan every 370 ms
- LoS of PCR at W7-X -0.4 6.5 5.5 Radius / m
- ► Location of measurements from TS-profiles
- Identification of flux surface and poloidal circumference s
- Calculation of mode numbers as

$$m=rac{s\,f_{QQ}}{v_{\perp}}$$

lacksquare Poloidal size of the mode $L_{\perp}=s/m$

Poloidal velocity estimation

$$v_{\perp} = rac{d\,\Delta t}{\Delta t^2 + au_0^2}$$

- ightharpoonup Elliptical model for v_{\perp} estimation
- Taking decay of turbulence in account
- Depends on the used frequency interval ightharpoonup Allows for frequency selective v_{\perp}





