Neutral Beam Heating Experiments and Magnetic Fluctuations on TCV

INTRODUCTION

1. background: theoretical, numerical and some experimental evidence exist on different devices for the role of ELM/ES turbulence in affecting the confinement of supra-thermal ions under certain experimental conditions and, similarly, for the role of supra-thermal ions in driving and stabilizing turbulence
2. experimental setup: low density discharges intended to maximize NBCD with varying (T_e, T_i, T_//, B_0, Ip/T_i), could be used as a DEMO simulator
3. 1st goal of the experiment: study NBCD efficiency for on-axis and off-axis deposition
4. 2nd goal of the experiment: study interplay between NBI ions and EM/ES fluctuations

OVERVIEW OF THE EXPERIMENT

1. around 50 TCV discharges are available for the analysis
2. NBH: limited to 500kJ, namely 1MW/500msec, on-axis and off-axis deposition up to Z=1.
3. around 50 TCV discharges are available for the analysis

EXPERIMENTS WITH ON-AXIS AND OFF-AXIS, CO- AND COUNTER- NBCD

1. using a set of 4 comparable discharges with on-axis and off-axis, co- and counter-NBCD
2. similar electron density and temperature profiles with and without NBH
3. bootstrap current & ECCD constant during NBH phase, from TRANSP analyses ~25kA (counter-)

• fixed B_0=1.43T, scan I_e=150 → 300kA, both directions for B_0 and I_e used, allows comparison of co- and counter-NBCD for opposite plasma helicities sign(B_0), sign(I_e) and VB directions
• monotonic q-profile with q=1 surface extending up to slightly outside q=2 surface
• scan relative timing of ECH (also power scan, 0.5MW to 2.5MW) vs. NBH (fixed 1MW)
• monotonic q-profile with q=1 surface extending up to slightly outside q=2 surface
• scan ECCD (power, deposition) to affect sawtooth period: co- and counter-NBCD for opposite plasma helicities sign(B_0)*sign(I_e)
• scan edge triangularity, scan edge elongation
• scan edge triangularity, scan edge elongation
• fast-ion diagnostics: CNPA + FIDA (typically only 1 viewing system, either toroidal or poloidal)
• fast-ion diagnostics: CNPA + FIDA (typically only 1 viewing system, either toroidal or poloidal)
• main limitation of the experimental setup: choice of working at very low <n_e>~2*10^19m^-3, both directions for B_0
• main limitation of the experimental setup: choice of working at very low <n_e>~2*10^19m^-3, both directions for B_0

• fixed density, low charge exchange losses, hence a more usual ~20msec, but then having to add large anomalous transport D~0.5m^2/sec for the fast ions
• main report on this experiment: see presentation by B.Geiger at IAEA 2016 conference and the ensuing paper soon appearing in PPCF [1,2]

INTRODUCTION

1. background: theoretical, numerical and some experimental evidence exist on different devices for the role of ELM/ES turbulence in affecting the confinement of supra-thermal ions under certain experimental conditions and, similarly, for the role of supra-thermal ions in driving and stabilizing turbulence
2. experimental setup: low density discharges intended to maximize NBCD with varying (T_e, T_i, T_//, B_0, Ip/T_i), could be used as a DEMO simulator
3. 1st goal of the experiment: study NBCD efficiency for on-axis and off-axis deposition
4. 2nd goal of the experiment: study interplay between NBI ions and EM/ES fluctuations

OVERVIEW OF THE EXPERIMENT

1. around 50 TCV discharges are available for the analysis
2. NBH: limited to 500kJ, namely 1MW/500msec, on-axis and off-axis deposition up to Z=1.10cm, co- and counter-NBCD
3. ECRH/ECCD: often working well, particularly ECRH
4. HF magnetic diagnostic: 203×13D Mimo sensors @130kHz bandwidth + 3x LTCC-3D sensors @1MHz bandwidth
5. ES turbulence diagnostics: only C-ECE, limited to q=0.15, 0.40, 0.65, spanning from slightly inside q=1 surface to slightly outside q=2 surface
6. fast-ion diagnostics: CNPA + FIDA (typically only 1 viewing system, either toroidal or poloidal)
7. main limitation of the experimental setup: choice of working at very low <n_e>~2*10^19m^-3 to maximize NBCD turned out to increase direct CX losses, accounting for at least 50% of lost NBH power but difficult to quantify precisely due to dependence on ion confinement time
8. main report on this experiment: see presentation by B.Geiger at IAEA 2016 conference and the ensuing paper soon appearing in PPCF [1,2]

EXPERIMENTS WITH ON-AXIS AND OFF-AXIS, CO- AND COUNTER- NBCD

1. using a set of 4 comparable discharges with on-axis and off-axis deposition, co- and counter-NBCD
2. similar electron density and temperature profiles with and without NBH
3. bootstrap current & ECCD constant during NBH phase, from TRANSP analyses ~25kA (counter-)

• fixed density, low charge exchange losses, hence a more usual ~20msec, but then having to add large anomalous transport D~0.5m^2/sec for the fast ions
• main report on this experiment: see presentation by B.Geiger at IAEA 2016 conference and the ensuing paper soon appearing in PPCF [1,2]

INTRODUCTION

1. background: theoretical, numerical and some experimental evidence exist on different devices for the role of ELM/ES turbulence in affecting the confinement of supra-thermal ions under certain experimental conditions and, similarly, for the role of supra-thermal ions in driving and stabilizing turbulence
2. experimental setup: low density discharges intended to maximize NBCD with varying (T_e, T_i, T_//, B_0, Ip/T_i), could be used as a DEMO simulator
3. 1st goal of the experiment: study NBCD efficiency for on-axis and off-axis deposition
4. 2nd goal of the experiment: study interplay between NBI ions and EM/ES fluctuations

OVERVIEW OF THE EXPERIMENT

1. around 50 TCV discharges are available for the analysis
2. NBH: limited to 500kJ, namely 1MW/500msec, on-axis and off-axis deposition up to Z=1.10cm, co- and counter-NBCD
3. ECRH/ECCD: often working well, particularly ECRH
4. HF magnetic diagnostic: 203×13D Mimo sensors @130kHz bandwidth + 3x LTCC-3D sensors @1MHz bandwidth
5. ES turbulence diagnostics: only C-ECE, limited to q=0.15, 0.40, 0.65, spanning from slightly inside q=1 surface to slightly outside q=2 surface
6. fast-ion diagnostics: CNPA + FIDA (typically only 1 viewing system, either toroidal or poloidal)
7. main limitation of the experimental setup: choice of working at very low <n_e>~2*10^19m^-3 to maximize NBCD turned out to increase direct CX losses, accounting for at least 50% of lost NBH power but difficult to quantify precisely due to dependence on ion confinement time
8. main report on this experiment: see presentation by B.Geiger at IAEA 2016 conference and the ensuing paper soon appearing in PPCF [1,2]
4. statistical analysis of magnetic fluctuations: many features similar to the solar wind [9]

1. ohmic, ECH, ECH+NBH: TCP ~2msec, NBH-only: TCP ~10msec, a different sawtooth precursor: 1st harmonic @~25kHz, m/n=1/1, clearly ballooning, 2nd harmonic @~50kHz, m/n=1/2
2. sawtooth precursor + sawtooth crash cause a ~30% increase in the CNPA signal for all
3. TSF provides a measure of temporal correlations within lag time
4. low-p order

FUNCTION, HURST EXPONENT, FRACTAL DIMENSION

STATISTICAL ANALYSIS OF MAGNETIC FLUCTUATIONS: TEMPORAL STRUCTURE

1. ohmic, ECH, ECH+NBH: TCP ~2msec, NBH-only: TCP ~10msec, a different sawtooth precursor: 1st harmonic @~25kHz, m/n=1/1, clearly ballooning, 2nd harmonic @~50kHz, m/n=1/2
2. sawtooth precursor + sawtooth crash cause a ~30% increase in the CNPA signal for all
3. TSF provides a measure of temporal correlations within lag time
4. low-p order

FUNCTION, HURST EXPONENT, FRACTAL DIMENSION

STATISTICAL ANALYSIS OF MAGNETIC FLUCTUATIONS: TEMPORAL STRUCTURE

1. ohmic, ECH, ECH+NBH: TCP ~2msec, NBH-only: TCP ~10msec, a different sawtooth precursor: 1st harmonic @~25kHz, m/n=1/1, clearly ballooning, 2nd harmonic @~50kHz, m/n=1/2
2. sawtooth precursor + sawtooth crash cause a ~30% increase in the CNPA signal for all
3. TSF provides a measure of temporal correlations within lag time
4. low-p order

FUNCTION, HURST EXPONENT, FRACTAL DIMENSION

STATISTICAL ANALYSIS OF MAGNETIC FLUCTUATIONS: TEMPORAL STRUCTURE

1. ohmic, ECH, ECH+NBH: TCP ~2msec, NBH-only: TCP ~10msec, a different sawtooth precursor: 1st harmonic @~25kHz, m/n=1/1, clearly ballooning, 2nd harmonic @~50kHz, m/n=1/2
2. sawtooth precursor + sawtooth crash cause a ~30% increase in the CNPA signal for all
3. TSF provides a measure of temporal correlations within lag time
4. low-p order

FUNCTION, HURST EXPONENT, FRACTAL DIMENSION

STATISTICAL ANALYSIS OF MAGNETIC FLUCTUATIONS: TEMPORAL STRUCTURE

1. ohmic, ECH, ECH+NBH: TCP ~2msec, NBH-only: TCP ~10msec, a different sawtooth precursor: 1st harmonic @~25kHz, m/n=1/1, clearly ballooning, 2nd harmonic @~50kHz, m/n=1/2
2. sawtooth precursor + sawtooth crash cause a ~30% increase in the CNPA signal for all
3. TSF provides a measure of temporal correlations within lag time
4. low-p order

FUNCTION, HURST EXPONENT, FRACTAL DIMENSION

STATISTICAL ANALYSIS OF MAGNETIC FLUCTUATIONS: TEMPORAL STRUCTURE

1. ohmic, ECH, ECH+NBH: TCP ~2msec, NBH-only: TCP ~10msec, a different sawtooth precursor: 1st harmonic @~25kHz, m/n=1/1, clearly ballooning, 2nd harmonic @~50kHz, m/n=1/2
2. sawtooth precursor + sawtooth crash cause a ~30% increase in the CNPA signal for all
3. TSF provides a measure of temporal correlations within lag time
4. low-p order

FUNCTION, HURST EXPONENT, FRACTAL DIMENSION

STATISTICAL ANALYSIS OF MAGNETIC FLUCTUATIONS: TEMPORAL STRUCTURE

1. ohmic, ECH, ECH+NBH: TCP ~2msec, NBH-only: TCP ~10msec, a different sawtooth precursor: 1st harmonic @~25kHz, m/n=1/1, clearly ballooning, 2nd harmonic @~50kHz, m/n=1/2
2. sawtooth precursor + sawtooth crash cause a ~30% increase in the CNPA signal for all
3. TSF provides a measure of temporal correlations within lag time
4. low-p order