

Alcator C-Mod Mini-Proposal

MP No. 515

Subject: Effect of launched LH wave $n_{||}$ spectrum on current profile

From: Parker, Bonoli, Hubbard, Porkolab, Schmidt, Wallace, Wilson, Wolfe, Scott, Ko

Groups: LH and AT

Date: July 27, 2007

Approved by:

Date Approved:

1. Purpose of Experiments

Include immediate goal of the experiments, scientific importance and/or programmatic relevance. Refer to any relevant program milestones.

The purpose of these experiments is to investigate the effect of varying the launched $n_{||}$ spectrum on the LH-perturbed current distribution in C-Mod plasmas. The measurements will be carried out in both Ohmic and ICRF-heated L-Mode plasmas, as well as in H-Mode plasmas providing suitable low density H-Modes can be produced. According to theory, LH waves will be absorbed via Landau damping where roughly $T_e(\text{keV}) = 30/n_{||}^2$. However, the actual value of $n_{||}$ where absorption occurs may be quite different from the launched value due to an upshift that occurs as LH waves propagate in toroidal plasmas. An essential component of the proposed experiments is to compare the results with predictions of the GENRAY/CQL3D simulations including the synthetic X-Ray diagnostic. The results will be important in assessing the capability of LH waves to modify the current profile in C-Mod, in particular to produce flat or reversed shear profiles with $q(r) > 1$.

2. Background

Discuss Physics Basis of the proposed research. Prior results at Alcator or elsewhere, and any related work being carried out separately.

Previous experiments using the imaging X-Ray spectrometer have shown that the bremsstrahlung produced by weakly perturbative LH waves behaves qualitatively according to expectations in the sense that it peaks off-axis as the launched $n_{||}$ is increased (See Figure 1.) These results were obtained by applying relatively low power LH waves with the applied $n_{||}$ varying between 1.6 and 3.1 [1]. The RF power was square-wave modulated with a period of 25 ms. The power was deliberately kept low (400 kW) and the pulse length short (12.5 ms), in order to minimally perturb the Ohmic profile. Time-resolved X-Ray profiles with a framing time of 2.5 ms were recorded so that the buildup and decay of the fast electron bremsstrahlung could be compared. Comparison with GENRAY/CQL3D simulations is in progress. Similar results were presented by Y. Peysson at the recent EPS meeting in Warsaw [2], however only for a very limited range of $n_{||}$.

3. Approach

Describe the methodology to be employed; explain the rationale for the choice of parameters, etc. Describe the analysis techniques to be employed in interpreting the data, if applicable. If the approach is standard or otherwise self-evident, this section may be absorbed into the Experimental Plan.

The approach is to couple LH waves to both Ohmically and ICRF-heated L-Mode plasmas. The LH power will be the maximum that can be sustained for ~ 0.5 s with no (or only occasional) trips. Hopefully this should be at least 500 kW. The density should initially be relatively low, e.g., $\langle n \rangle \sim 5 \times 10^{19} \text{ m}^{-3}$ in order to maximize the current drive as evidenced by the reduction in loop voltage. Bremsstrahlung profiles will be recorded, as will MSE measurements of B_θ/B_T . Approximate profiles of the change in safety factor can then be derived by using these data together with results from EFIT. The change in $j(r)$ can be calculated and compared with the location of the fast electron bremsstrahlung. The experiments should then be repeated at a higher density, namely $8 \times 10^{19} \text{ m}^{-3}$. If reversed-field, upper-null H-modes are successful in achieving relatively low H-Mode density, it would also be interesting to attempt carry out these measurements in this configuration, but this would have to wait for the next reversed field operation. The results will be compared with expectations based on results of GENRAY/CQL3D simulations.

3. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

Toroidal Field: 5.4 T

Plasma Current: 800 kA

Working Gas Species: D

Density: 5×10^{19} , $8 \times 10^{19} \text{ m}^{-3}$

Equilibrium configuration (if possible, refer to database equilibria): will specify

4.2 Auxiliary Systems

RF Power, pulse length, phasing: ICRF ~ 2 MW

Pellet Injection (species): No

Impurity blow-off injection: No

Diagnostic Neutral Beam: Yes

Special gas puffing: No

Non-axisymmetric Coils (Connections, Current); Standard for low density locked mode prevention

Other: LH Power (maximum that can be sustained without frequent trips)

4.3 Diagnostics

List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

Thomson, ECE, MSE, Imaging X-Ray Spectrometer (IXS)

4. Experimental Plan

Both sections must be filled in.

5.1 Run sequence Plan

Specify total number of runs required, and any special requirements, such as consecutive days, no Monday runs, extended run period – 10 hours maximum – etc.

2 days, separated by at least one week

5.2 Shot sequence plan

For each run day, give detailed specification for proposed shot sequence: number of shots at each condition, specific parameters and auxiliary systems requirements, etc. Include contingency plans, if appropriate.

Day 1:

Shots 1-5: Establish 800 kA, 5.4 T, $5e19$ m⁻³ discharge. Couple ≥ 500 kW LHCD @ $n_{||} = 1.6$. Ensure plasma stays in L-Mode with 2 MW ICRF (J-port preferred), possibly by using upper null discharge. Have cryopump on standby to manage density if needed. Optimize shape for coupling.

Shots 6-10: No ICRH. Obtain good quality MSE and IXS data on shot established in shots 1-5.

Shots 11-15: Repeat with ICRH = 1 MW stepped to 2 MW. (May need to increase ICRH from 1 to 2 MW in separate discharges.)

Shots 16-20: Increase density to $8e19$ m⁻³. Couple ≥ 500 kW LHCD @ $n_{||} = 1.6$. No ICRH. Obtain good quality MSE and IXS data. (If fast electron population is weak, switch to $n_{||} = 2.3$.)

Shots 21-25: Repeat shots 11-15 with 1 MW stepped to 2 MW ICRH, avoiding H-Mode.

Shots 26-30: Repeat above shot sequence beginning with shot 16, with $n_{||} = 2.3$.

Day 2:

Repeat Day 1, finish $n_{||} = 2.3$ and switch to $n_{||} = 3.1$.

5. Anticipated Results

Discuss possible experimental outcomes and implications. Indicate if the program may be expected to lead to publications, milestone completions, improved operating techniques, etc. Indicate if the experiments are intended to contribute to a joint research effort, or an external database.

Results should provide clear indication of feasibility of driving off-axis current with LH, as a function of density, $n_{||}$ and temperature. They will be the basis for an APS poster, support the invited APS talk by P. Bonoli, a possible publication, and establish credibility

of achieving AT regimes with LH and ICRH as outlined in simulations by Bonoli and Porkolab [3,4].

6. References

Include references both to external and internal literature or communications which bear on this proposal. See Section 2.

1. R.R. Parker, J.R. Wilson, P.T. Bonoli, et. al., Proc 34th Conference on Plasma Physics, Warsaw (2007)

References (Contd)

2. Y. Peysson, J. Decker, V. Basiuk, Proc 34th Conference on Plasma Physics, Warsaw (2007)

3. P. T. Bonoli, M. Porkolab, J. Ramos, et. al., PPCF 39,(1997)223;

4. P.T. Bonoli, R.R.Parker, M. Porkolab, et.al., Nucl Fus 40,(2000)1251

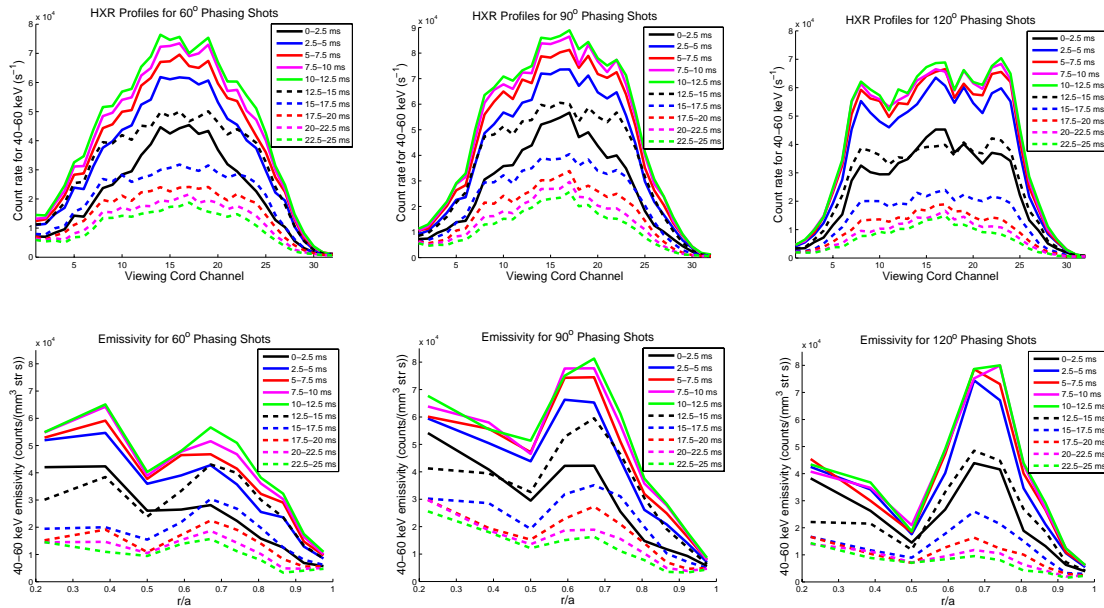


Figure 1. Bremsstrahlung profiles in the range 40 -60 keV for various n_{\parallel} . Top: Raw profiles. Bottom: Emissivity profiles. From left to right, $n_{\parallel} = 1.6, 2.3, 3.1$.