I. INTRODUCTION

Since the very beginning of auxiliary heating and current drive experiments in tokamaks, it has been recognized that hard x-ray (HXR) emission from fast electron bremsstrahlung (FEB) can provide considerable information on the auxiliary power deposition profile and the fast electron distribution. The measurement of the FEB emission in the hard x-ray energy range is the most efficient means for the investigation of auxiliary heating experiments in plasma physics. It allows not only to detect the fast electron population created by the auxiliary power but also the details of the energy range and the relativistic angular anisotropy in the direction of fast electron flow. Therefore, powerful FEB diagnostics have been developed in many devices such as PBX-M, Tore Supra, T-10, HT-7, and Alcator C-Mod for the study of fast electron bremsstrahlung emission in HL-2A tokamak. The camera with an array of 128 Ge diodes viewing the plasma along the toroidal direction in PBX-M has opened a new field in the investigation of FEB emission with high time and space resolution. The FEB tomography system based on cadmium telluride (CdTe) detectors in Tore Supra has two independent pinhole cameras with 59 sight lines, which allow a detailed investigation of the low hybrid physics and the fast electron dynamics with very high accuracy level. The FEB measurement system based on CdTe and Ge detectors in T-10 provides superior resolution of the x-ray emission and can be used for analysis of the fast electrons accelerated in plasma with a high longitudinal electric field and during rapid growth of the magnetohydrodynamic modes. It is well known that electron cyclotron resonance heating (ECRH) in tokamak plasma produces a non-Maxwellian velocity distribution, which can be idealized as a system of two separate Maxwellian distributions: one of the bulk electrons or the so-called thermal electrons and another one of the fast electrons or the so-called superthermal electrons. The fast electrons are produced by electron cyclotron waves (ECWs) through wave-particle interaction when the resonance condition is fulfilled. The generation of fast electrons may excite the oscillations of electron fishbone (e-fishbone). Since fishbone instabilities are related to the physics of the burning plasma, it is very important to study this kind of instability in tokamak plasma theoretically and experimentally. Although fishbone instability has been investigated for tens of years, the kinetic effect of fast electrons on fishbone mode has not been clear up to now. The measurement of the FEB emission in the extensive energy range 10–200 keV in HL-2A is an efficient means for the investigation of e-fishbone excitation during ECRH. The energy range of fast electrons, which strongly correlates with the e-fishbone, is identified by the FEB measurement system. The purpose of this paper is to give a detailed description of the newly developed FEB diagnostics in the HL-2A tokamak and its application in the study of the e-fishbone instability. In Sec. II, the FEB diagnostics system based on CdTe detector, the data-acquisition system, and its calibration are described in detail. The experimental results in ECRH plasmas are presented in Sec. III. Finally, a summary is presented in Sec. IV.

II. FEB DIAGNOSTICS

FEB diagnostic system dedicated to detailed study of the plasma physics about fast electrons has particular require-