Measurement of the Hard X-ray Emission Spectrum from MST

Y.Peysson, L. Delpech (CEA/Cadarache)
R.W. Harvey (CompX)

INTRODUCTION:
Cadmium-telluride (CdTe) X-ray detectors in the 5-150KeV energy range have been used to measure the hard X-ray spectrum on MST for a range of plasma parameters. A direct digitization procedure has been used to measure the X-rays rather than the conventional energy discrimination and counting. This allows a simpler hardware setup with flexible energy and time binning with no increase in cost. Modelling using the CQL3D Fokker-Planck code gives estimates for the fast electron population and diffusion coefficient.

MEASUREMENTS MADE ON MST:
Measurements have focused on 4 discharges types:
- Low and high current standard plasmas
- Low and high current Pulsed Poloidal Current Drive (PPCD) plasmas

Measurements are consistent with higher confinement for PPCD plasmas.

In PPCD plasmas a poloidal current is driven in the conducting shell. This modifies the toroidal magnetic field which in turn induces a poloidal electric field in the plasma. The field is chosen to flatten the current profile - thus forcing the plasma into a minimum energy state, reducing magnetic activity and in improving confinement.

PLASMA CONDITIONS
Plasma current: 420kA
Core temperature: 400eV
Density: $1 \times 10^{19} \text{ m}^{-3}$

ABSOLUTE ENERGY FLUX FOR HIGH CURRENT STANDARD PLASMA (0.4 kHz flux)

ABSOLUTE ENERGY FLUX FOR LOW CURRENT PPCD PLASMA (2.6 kHz flux)

DIRECT DIGITIZATION SIMPLIFIES THE HARDWARE SETUP

The detector is biased to 200V, and current pulses are amplified using a transconductance amplifier. The pulse output is then processed through a standard shaping amplifier. Conventionally the pulses are then subjected to an energy discriminator and counter array of some sort. We have switched to a direct digitization method.

DIRECT DIGITIZATION GIVES BETTER CONTROL OF FITTING AND BINNING DATA

Flexible binning in time or energy, depending on flux rates the balance between time resolution and energy resolution can be adjusted dynamically.

Better noise immunity and pile up detection. Noise and Pile up events are identifiable - often not so for counters. A higher level of pile up can be tolerated allowing the maximum flux.

Cost effective - costs the same as counter/discrimination combination.

When using the 10Mhz sampling time the fast pulses are well resolved. Their shape is very distinguishable from noise.

Any given time history is scan for pulses and events are stored with a time and energy.

MODELLING METHODOLOGY:
The code inputs the parallel electric field, and evaluates the current density from this for the plasma parameters entered.

Work is still at an early stage - for example the diffusion coefficient at present is constant for all energies.

KEY RESULTS from Modelling:
The code does remarkably well at determining the absolute energy flux. Initial results agree to approximately one order of magnitude.

Modelling matches PPCD data best with negligible diffusion coefficient.

Initial estimates give the resistivity in the core for high current PPCD plasmas at approx twice Spitzer.

FUTURE WORK
The current system is being expanded to a 16 channel system. This will allow profile information to be collected. Newer cadmium-zinc-telluride (CdZnTe) detectors will be used.

More chords, as shown on the left will help to determine the diffusion coefficient.

ENGINEERING:
Longer sampling time ADCs will be installed - a 16 channel VME based system will process the locally after each plasma and store just the time and energy of X-ray events on the main data system.

Ensembling will be used to examine X-ray activity during sawtooth cycle.

Radial diffusion during RF heating will be modelled and compared to experiments.

Modelling efforts will continue, both via further developments with the code and improvement of measured data input to the code.

CONCLUSIONS:
Direct digitization has been used with CdTe X-ray detector to measure X-ray flux during Standard and PPCD plasmas.

Energy flux highest during PPCD plasmas - more evidence for improved electron confinement from code - low diffusion coefficient is needed to match measured energy flux rates.

Runaway electrons present during PPCD plasmas suggests good flux surfaces.

Modelling via CQL3D matches well with measurements. Absolute energy fluxes have been computed and are within an order of magnitude of measured fluxes. This work is ongoing.

Using the code to model the data estimates for the high energy electron distribution can be made.

Initial estimates for resistivity twice Spitzer for high current PPCD plasmas.

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