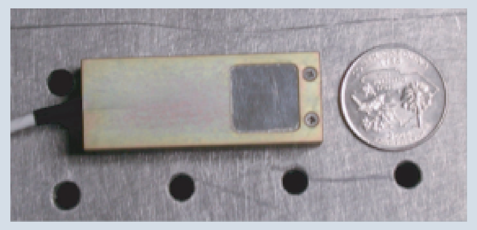
INTRODUCTION

Measurements of the Hard X-ray (HXR) flux have been combined with CQL3D modelling to infer diffusion coefficient, fast electron population and current density during PPCD plasmas.

EXPERIMENTAL SETUP

Hard X-rays (>10KeV) emitted by runaway electrons via bremmstrahlung are measured using solid state CdZnTe detectors.

CdZnTe detectors:
10mm x 10mm x 2mm
~10-300KeV energy resolution
2ms pulse width - 500KHz time resolution
transimpedance amplifier built in.

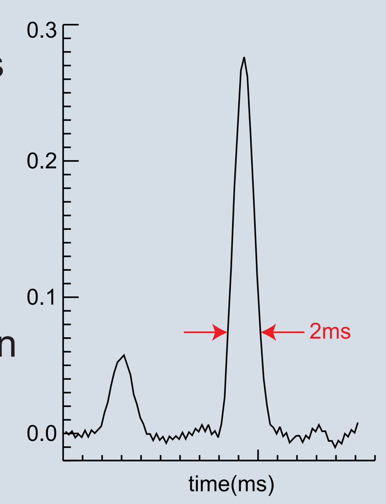


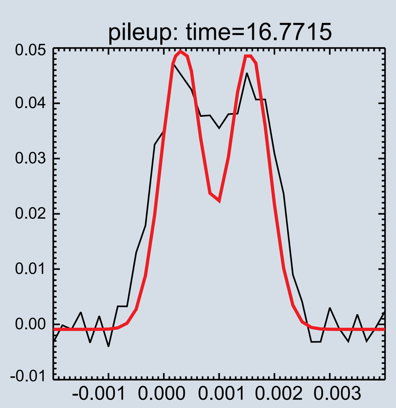
The output pulses from the detectors are digitized directly rather than pulse height discrimination and counting.
ADVANTAGES:
Software can distinguish noise and pile up better than simple pulse height analysers.
Data stored as discrete events at definite times, allowing the data to be binned for low energy resolution with high time resolution, or simultaneously low time resolution with high energy resolution.
Simple to implement
DISADVANTAGES:
Prior to processing, a lot of data must be stored, limiting shot length.

X-ray events are seen as Gaussian pulses, produced by a shaping amplifier - the amplitude is proportional to the energy.

A 6MHz digitizer records the pulses, as shown on the right.

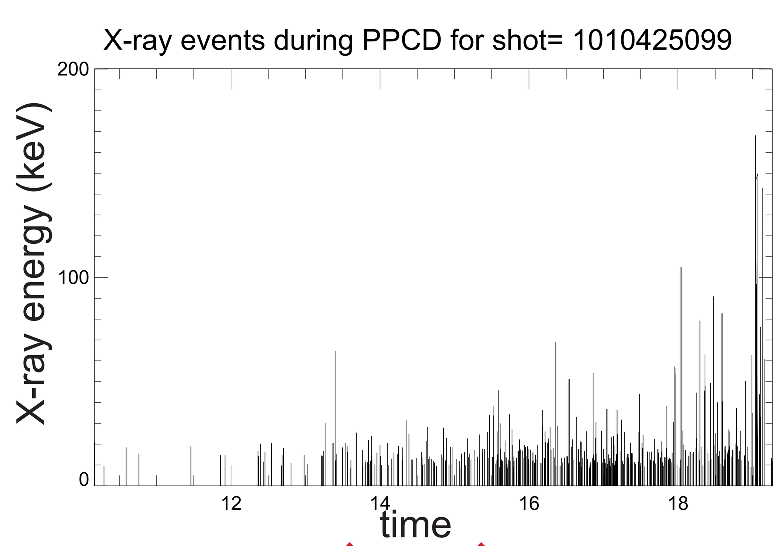
Each pulse is then individually fit using a Gaussian fitting function. A combination of the width (determined by the shaping time of the amplifier) and the chisq of the fit are used to determing whether pile up has occured.

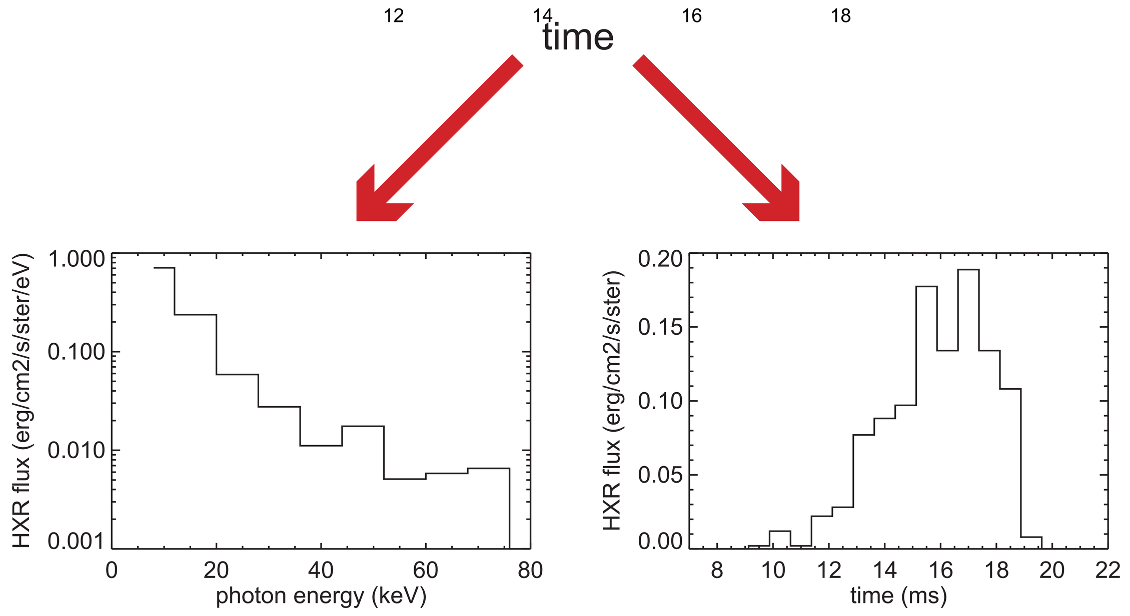




The data can then be fit using a double Gaussian. In this way the effective bandwidth can be increased, the dead-time due to pileup can be reduced.

Pileup is still reduced by adjusting the solid angle of the detector.

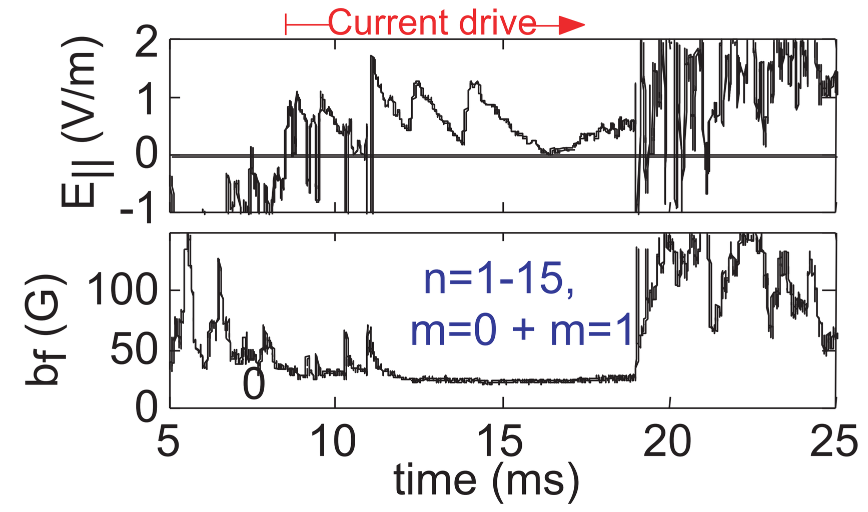


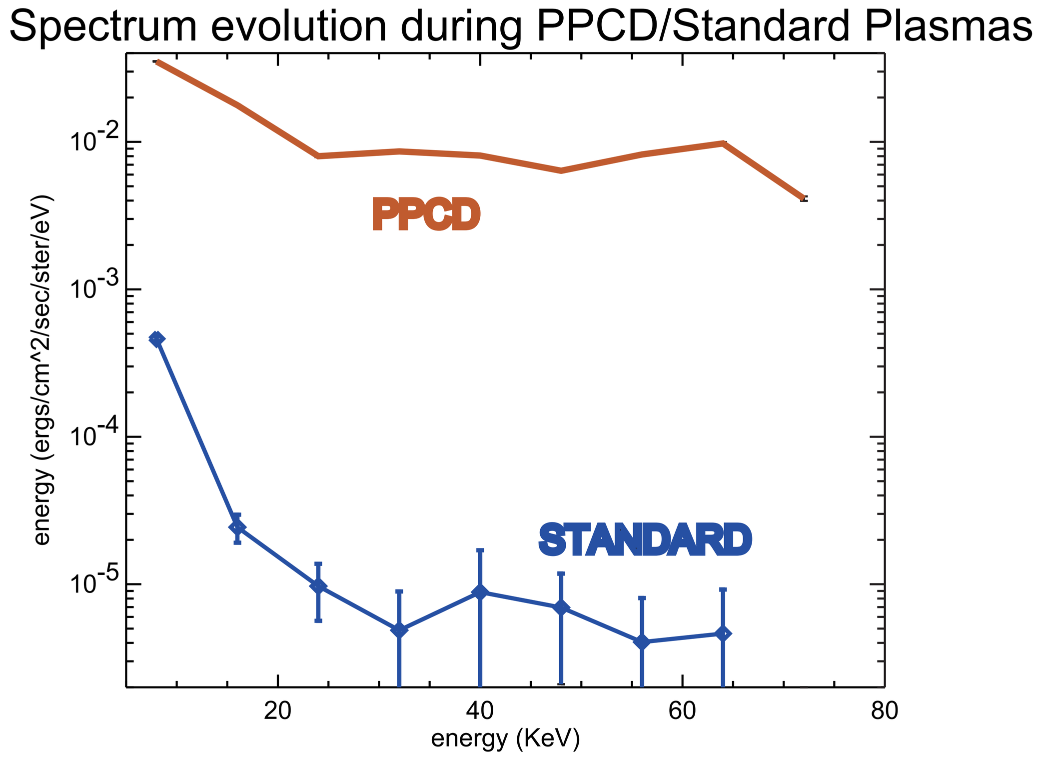


PPCD in MST

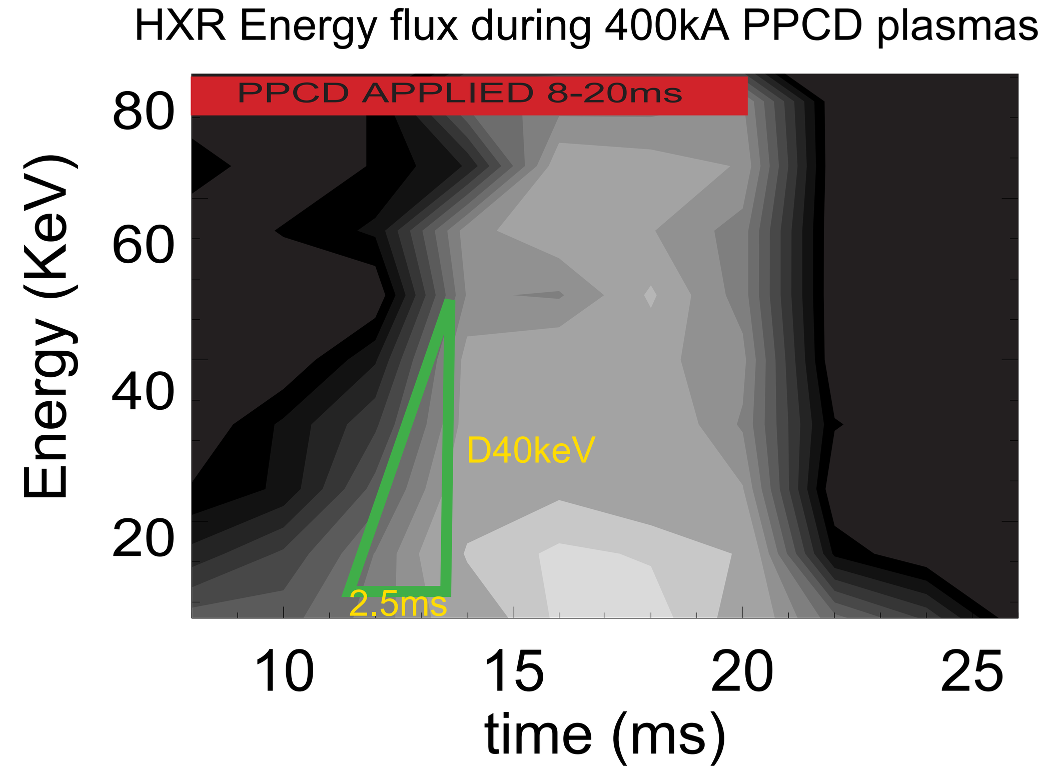
During PPCD plasmas current is driven in the edge such as to drive the current normally generated by the dynamo. In doing so, the magnetic fluctuations are substantially reduced.

High HXR's are only seen during the burst free periods. In cases where the magnetic fluctuations are not suppressed with same E|| programming - HXR's are not seen.





Simple analysis of raw data gives estimates for E|| and diffusion coefficient.
In the period before saturation, ramp up is at a rate of D40keV/2.5ms
This implies an upper limit on the parallel electric field of ~0.35V/m
The time of saturation gives an estimate for connection length in the core of ~100km
This corresponds to a diffusion coefficient of ~1m^2/s



More sophisticated analysis can be done - using CQL3D.

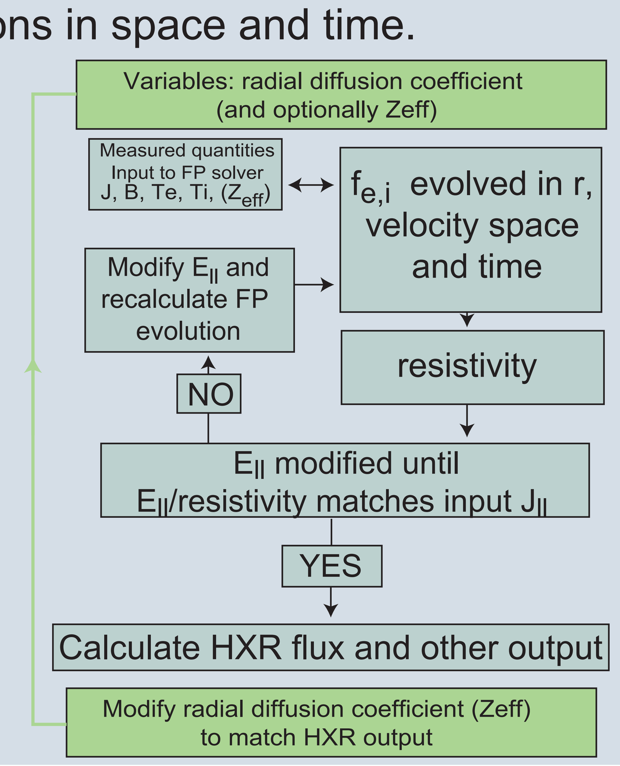
CQL3D is a Fokker-Planck code which evolves the electron and ion distribution functions in space and time.

Given ambient plasma conditions (equilibrium, Te,i,Ip, density) CQL3D evolves the electron distribution function.

Diffusion (and optionally Zeff) are adjustable parameters

E|| is internally adjusted (based on the computed resistivity) to match the input J||

Diffusion and Zeff are adjusted to best fit the data.



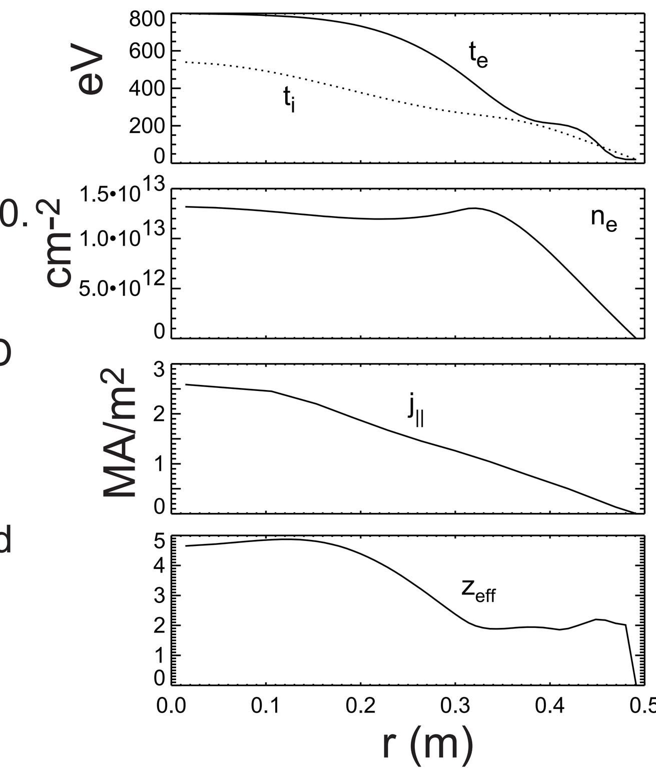
Basic plasma parameters are used as input, of which Z_{eff} is the most controversial

Broad range of basic plasma parameters are input to the code.

Z_{eff} is a difficult measurement on MST due to the low ne and high n0.

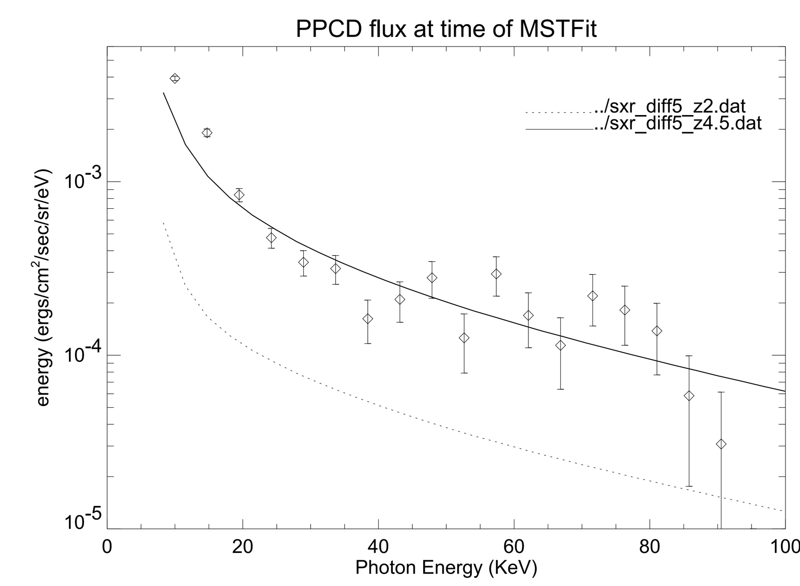
Extensive work has resulted in a measurement of Z_{eff} during PPCD which is surprisingly high

However, these plasmas had no boronization (MST has carbon and aluminium first wall).



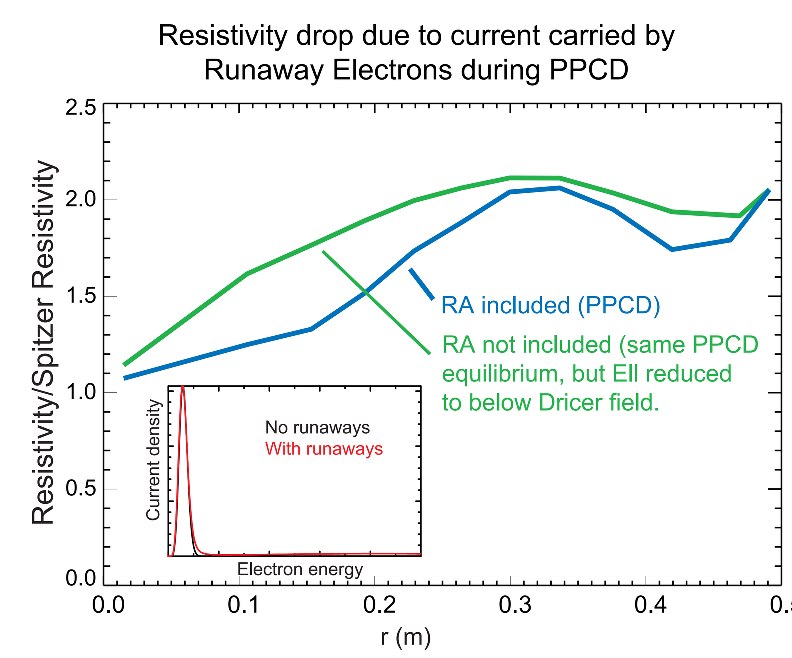
Given these input profiles, a good match to the measured HXR flux is found for a diffusion coefficient of ~5m2/s

With Diffusion coefficient of 5m^2/s, measured Z_{eff} matches data well, even with Diffusion=0m^2/s, Z_{eff} ~3 needed
Higher diffusion coefficients require a higher Z_{eff} profile



The resistivity drops due to the presence of runaway electrons

By reducing the parallel electric field to be less than the Dricer electric field, the runaway population can be reduced. There is a 25% increase in resistivity in the core (~same as the measured current peaking of PPCD plasmas over standard plasmas.

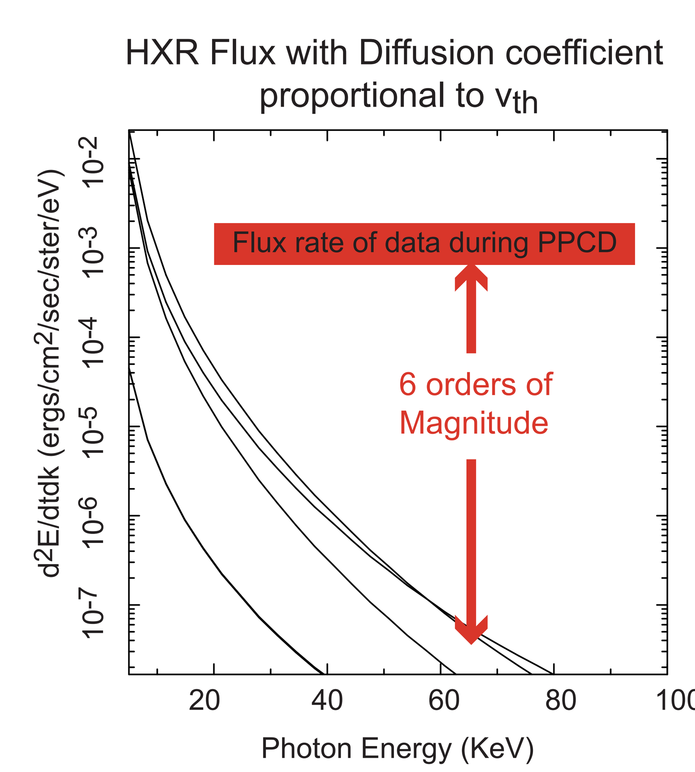


Is the diffusion dominated by magnetic stochasticity or electrostatic effects?

The simulations shown earlier were with a constant diffusion coefficient - predicted HXR flux cannot be reconciled with measured data if one attempts the same simulation with a diffusion coefficient proportional to vth.

The same plasma profiles were used, but the diffusion coefficient was assumed to follow a Rechester-Rosenbluth dependency, i.e. to be dominated by flow along stochastic magnetic field lines.

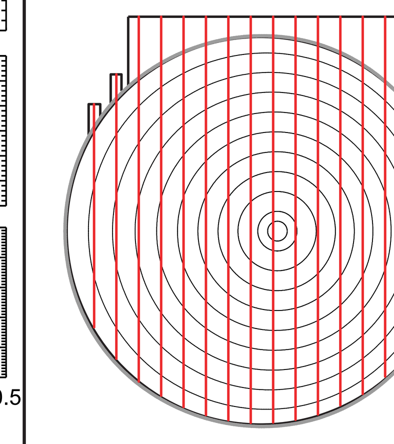
This suggests that core transport during PPCD plasmas is dominated by electrostatic effects.



Ongoing and future work:

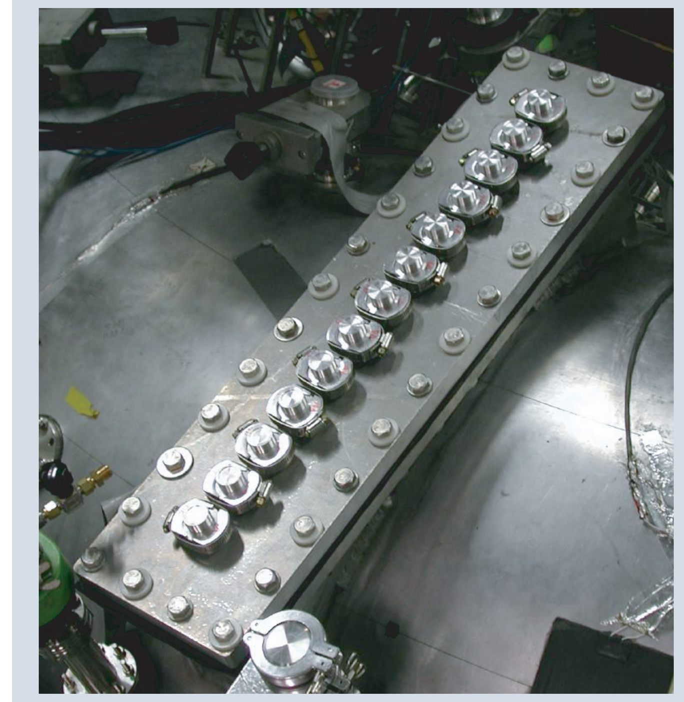
The hardware is being expanded to use 16 chords. This will allow radial resolution of the diffusion coefficient.

A VME computer with 16 10Mhz, 12bit ADCs has been assembled. Data is recorded, then processed using IDL.



The array will help constrain the Diffusion coefficient as a function of radius.

The arrays will also allow measurement of the EBW absorbtion and radial diffusion of heated electrons.

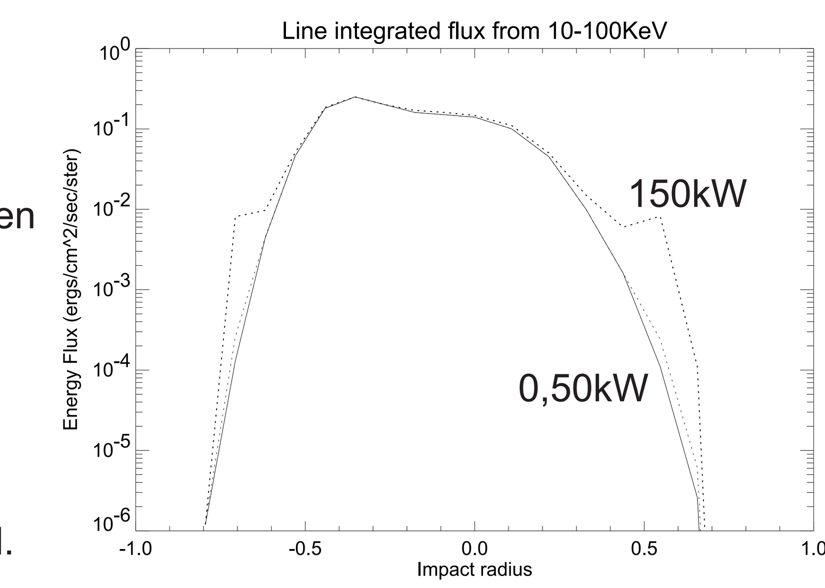


Newly installed array on MST

Simulations of EBW into PPCD plasmas show an order of magnitude increase in flux in the edge

The question of the effects of RF heating on the fast electrons will be addressed. Simulations have been performed using CQL3D.

During EBW application, a large increase in the edge HXR flux is expected.



Conclusions

Measurement and analysis of HXR flux shows a clear confinement increase during PPCD plasmas over standard plasmas.

Approximately 4 order of magnitude increase in flux seen

Corresponds to a diffusion coefficient of ~5m^2/s, and connection lengths of ~100km.

Implies transport in the core may be dominated by electrostatic effects, not flow along stochastic field lines.

1-2% runaway electron population carries ~25% of current in the core, with a corresponding drop in the resistivity.

Simulated parallel electric field matches measured value and confinement estimates.

Measured HXR flux supports high Z_{eff} measurements in core during PPCD plasmas.

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