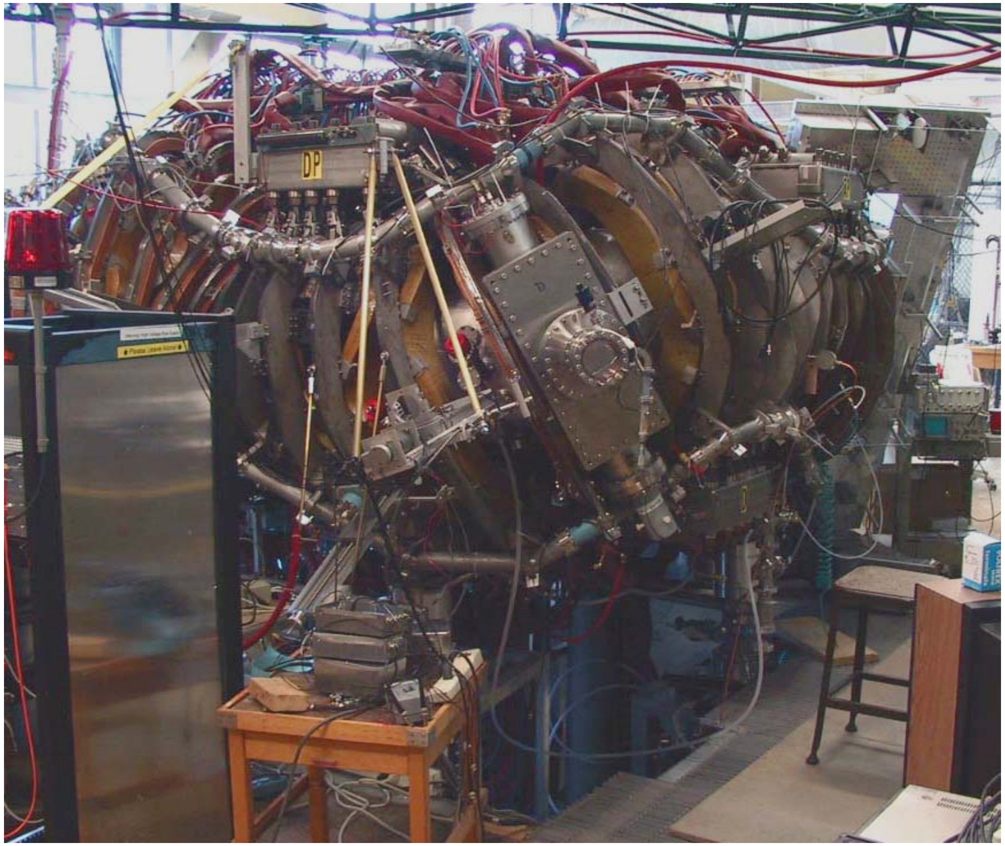
Hard X-ray Diagnostics in the HSX

A. E. Abdou, A. F. Almagri, D. T. Anderson, J. N. Talmadge, S. P. Gerhardt, R. R. O'Connell*
The HSX Plasma Laboratory, University of Wisconsin-Madison, USA
* MST Plasma Laboratory, University of Wisconsin-Madison, USA
E-mail: abdou@cae.wisc.edu



THE UNIVERSITY of WISCONSIN MADISON

APS, 44th Annual Meeting of the Division of Plasma Physics
November 11-15, 2002; Orlando, Florida

HSX

Abstract

A. E. Abdou, A. F. Almagri, D. T. Anderson, J. N. Talmadge, S. P. Gerhardt, R. R. O'Connell*
The HSX Plasma Laboratory, University of Wisconsin-Madison, USA
*** MST Plasma Laboratory, University of Wisconsin-Madison, USA**
E: abdou@cae.wisc.edu

In the Helically Symmetric eXperiment (HSX), electrons are ECRH heated using 28 GHz, 2nd harmonic gyrotron. The normal configuration is Quasi-Helical Symmetric (QHS), it has a dominant n=4, m=1 components in the magnetic field spectrum. With a set of auxiliary coils, the quasihelical symmetry can be broken (MIRROR, HILL and WELL, modes). In this work the resolved hard X-ray emission in the HSX is analyzed using CdZnTl detector (1 μs shaping time, Gain =50). The detector is housed is a lead box adjacent to the vacuum vessel, with 0.8 mm pinhole and 200 μm SS filter placed in front of the detector. The hard X-ray pulse height spectrum was accumulated in a series of similar ECRH discharges. The behavior of the fast electrons has been studied for densities in the range of 0.2 to 0.9 x 10^{12} cm^{-3}. The magnetic configuration has also been altered between QHS and MIRROR, and ANTI-MIRROR modes in order to determine the effect of magnetic ripple on characteristic energies and densities of fast electrons. Pulse height analysis of hard x-ray emission shows the presence of X-ray photons with energies as high as 650 KeV. Hard X-ray emission is strong function of plasma density; where at low density (0.2 x 10^{12} cm^{-3}) the intensity is ~80 times higher than at higher density (0.9 x 10^{12} cm^{-3}) for QHS mode. The hard X-ray intensity is higher in the QHS than in the MIRROR mode. Also the high energy tail of the spectrum extends to higher energies in QHS (~ 650 KeV). Future work will involve:transport calculation to determine fast electron energy distribution.

***This work is supported by US DOE grant number DE-FG02-93ER54222.**

THE UNIVERSITY of WISCONSIN MADISON

HSX

Outline

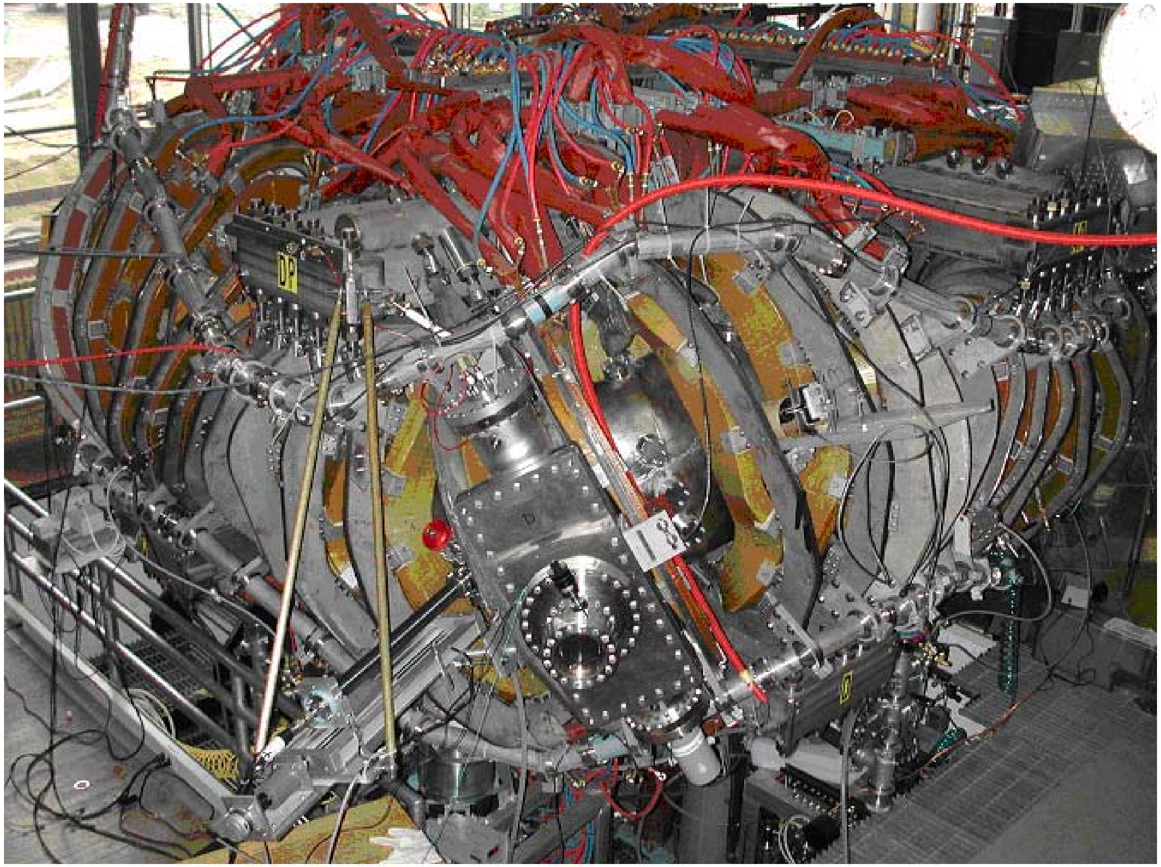
- Abstract
- HSX Device Parameters.
- Detector and Hardware Description.
- Source of fast electrons in HSX.
- Pulse Height Analysis program.
- HXR measurement results:
    - Density Scan.
    - Magnetic Configuration Scan.
    - Neutral Pressure Scan.
- Conclusion.

Conclusion

- Hard X-ray signal last for at least 50 ms after the ECRH is turned off indicating good confinement of fast electrons.
- Hard X-ray emission is a strong function of plasma density; where at low density (0.2 x 10^{12} cm^{-3}) the intensity is ~80 times higher than at high density (0.9 x 10^{12} cm^{-3}).
- Hard Hard X-ray intensity is very low in ANTI-MIRROR mode at all plasma densities (poor confinement).
- The hard X-ray spectrum extends to energies as high as 650 keV in the QHS mode.
- Increasing the neutral base pressure beyond 4.4 x 10^{-6} suppress the fast electrons that are produced by toroidal voltage.

HSX Device Parameters

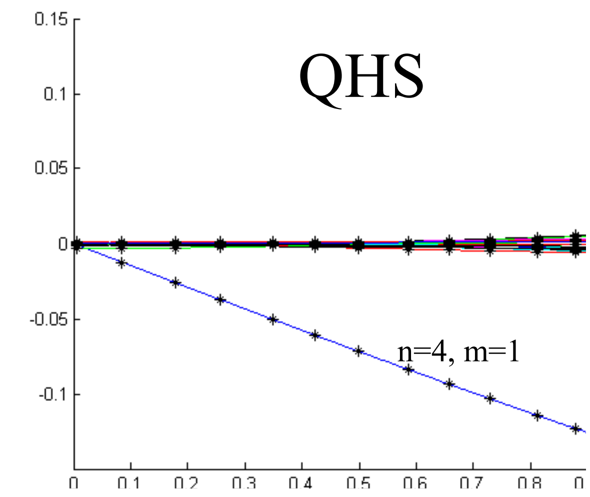
Major Radius	1.2 m
<r>	0.11 m
Volume	~.44 m^3
Field Periods	4
ι_{axis}	1.05
ι_{edge}	1.12
Coils/period	12
B_0 (max.)	1.25 T
Magnetic Field Flattop Length	0.2 s
Auxiliary Coils	48

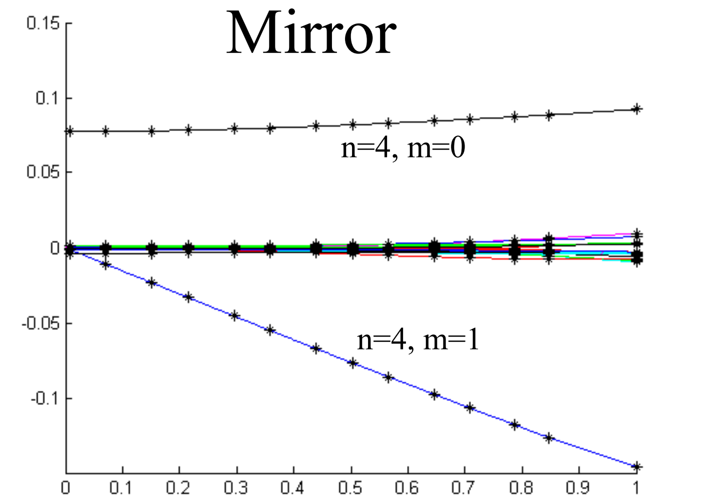


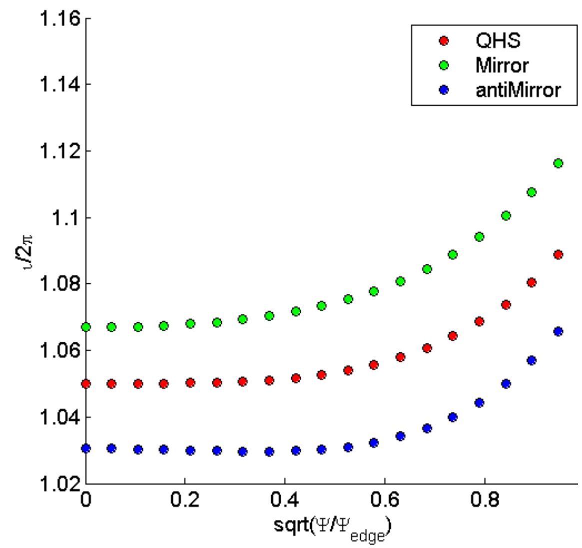
QHS, MIRROR and ANTI-MIRROR Modes

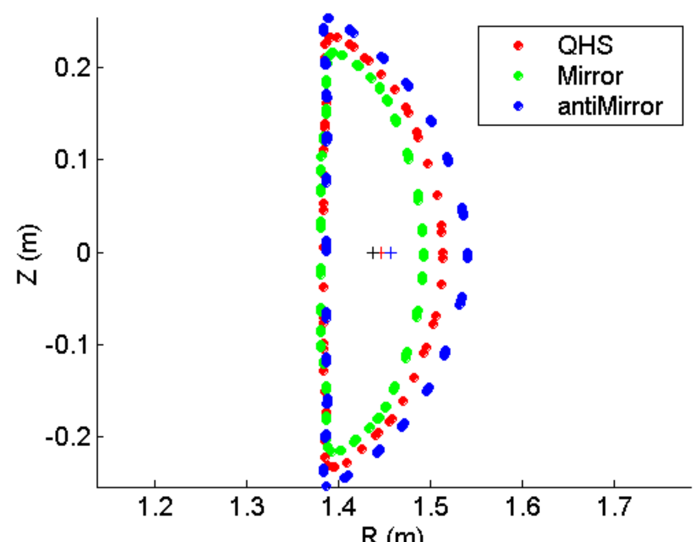
- QHS and Mirror have different magnetic field spectra…

  …but similar well depth, rotational transform, surface shape, and plasma volume.





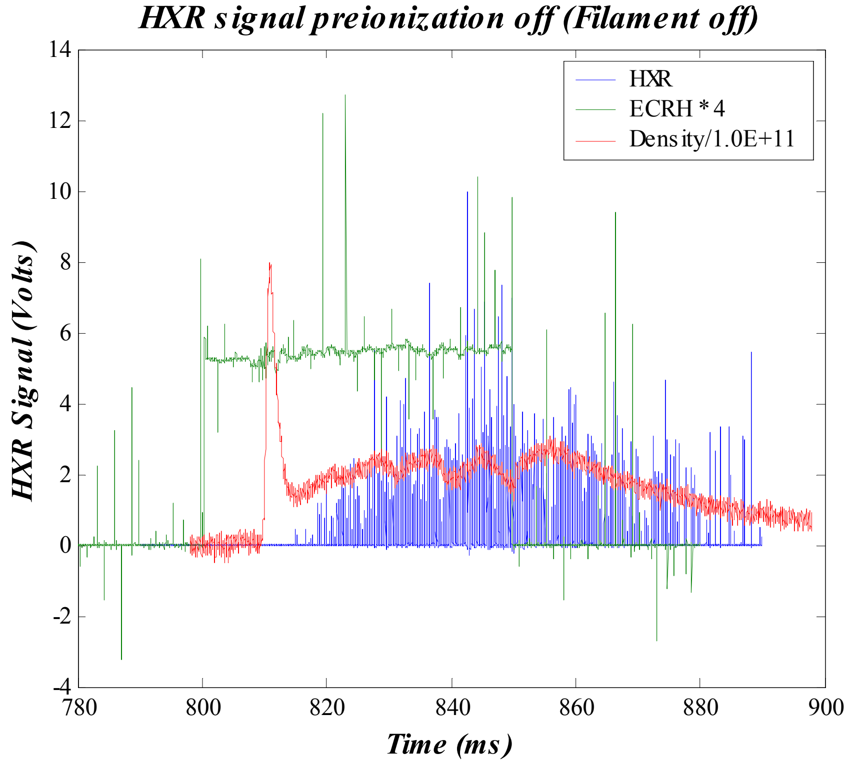


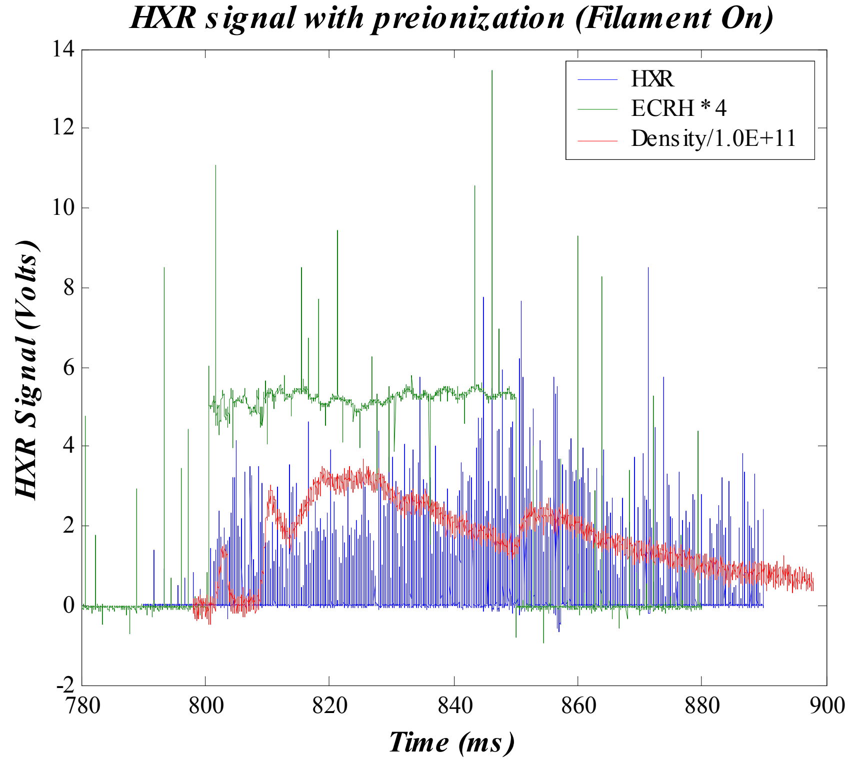


THE UNIVERSITY of WISCONSIN MADISON

HSX

Sources of Fast Electrons in HSX



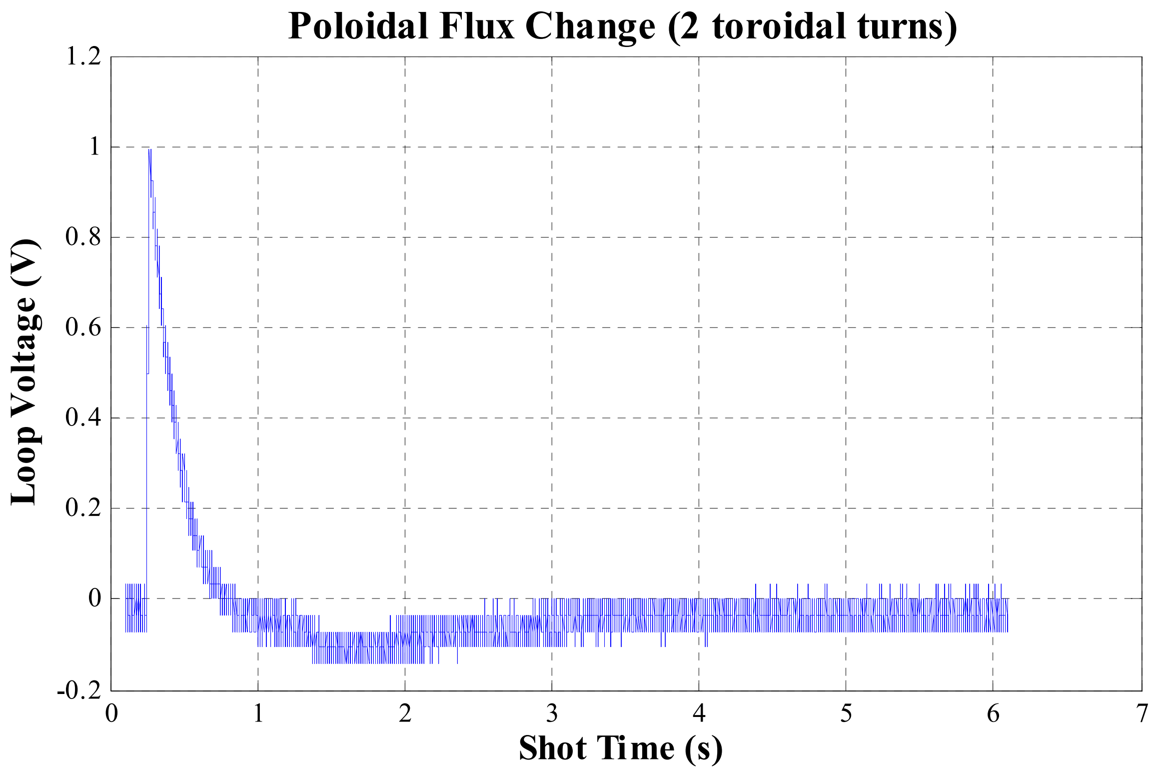


Fast electrons in HSX are generated from two different mechanisms

1- dB/dt source

2- ECRH Heating source

Loop Voltage in HSX



- **Loop Voltage time variation which gives rise to dB/dt source**

Detector

- **Detector Type:** CdZnTl
- **Detector Characteristics:**

Dimension: 10x10x2 mm

Peak/Valley: > 8:1 @ 59.5 Kev

Resolution: < 10% (6 KeV)@ 59.5 KeV (FWHM)

Peak/Valley: > 3:1 @ 122 Kev

Resolution: < 6% (8 KeV)@ 122 KeV (FWHM)

Peak/Valley: > 1.8:1 @ 622 Kev

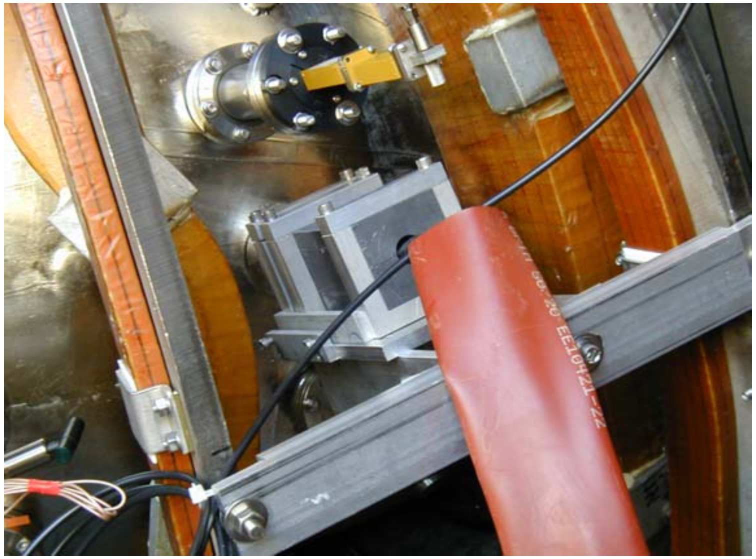
Resolution: < 3% (20 KeV)@ 622 KeV (FWHM)

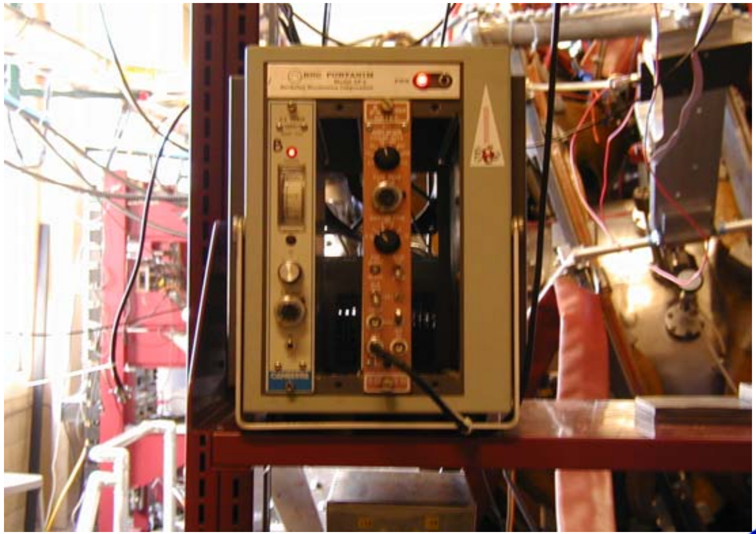
Detector (continue)

- The detector has a built in pre-amplifier, it is connected to a high voltage power supply, and an Ortec EG&G 671 amplifier.

- The amplifier output signal is then connected to a data acquisition system.

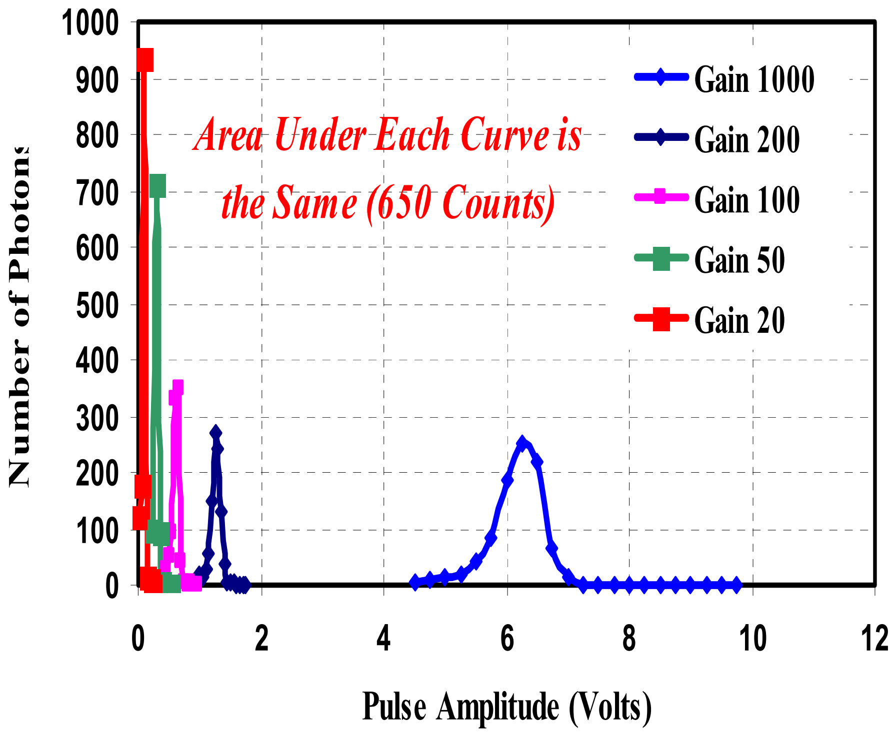
- The raw signal is then processed using a pulse height analysis program.



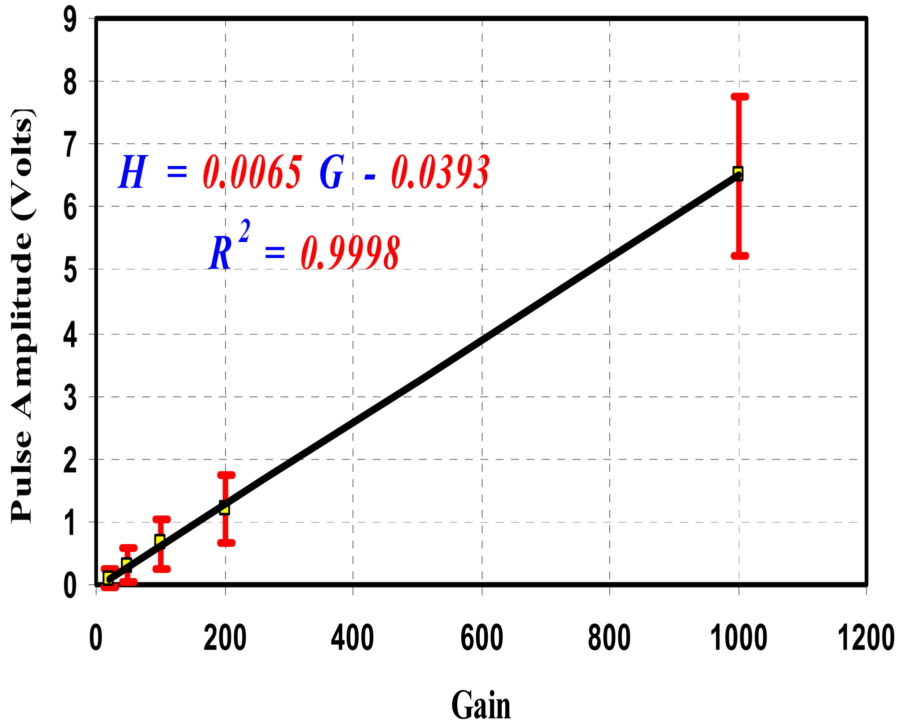


Detector Calibration

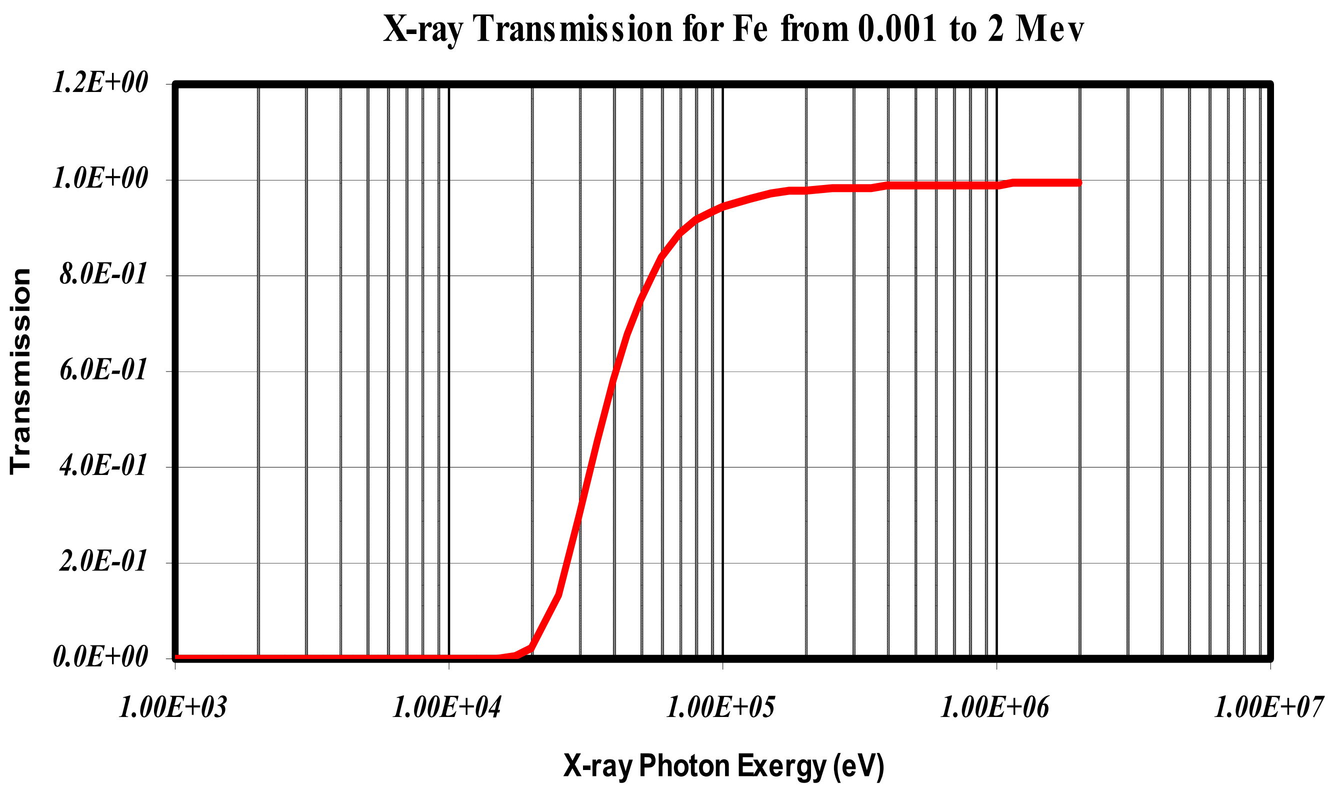
Number of Photons Vs Pulse Amplitude for Different Gain Settings Using Am241 (60 KeV)



Pulse Amplitude Vs Gain Using Am241 (60 KeV)



Filter Transmission



$$I(x) = I_o e^{-\mu x}$$

$$Transmission = I(x) / I_o = e^{-\mu X}$$

Where: $X = 200\ \mu m$, $\rho_{Fe} = 7.874\ gm/cm^2$ and μ_{Fe} mass absorption coefficient for Fe (cm^2/gm)

Transmission is calculated from the above formula using tabulated values for μ_{Fe} (from (http://physics.nist.gov/PhysRefData/FFast/html/form.html)

THE UNIVERSITY of WISCONSIN MADISON

APS, 44th Annual Meeting of the Division of Plasma Physics
November 11-15, 2002; Orlando, Florida

HSX

Pulse Height Analysis

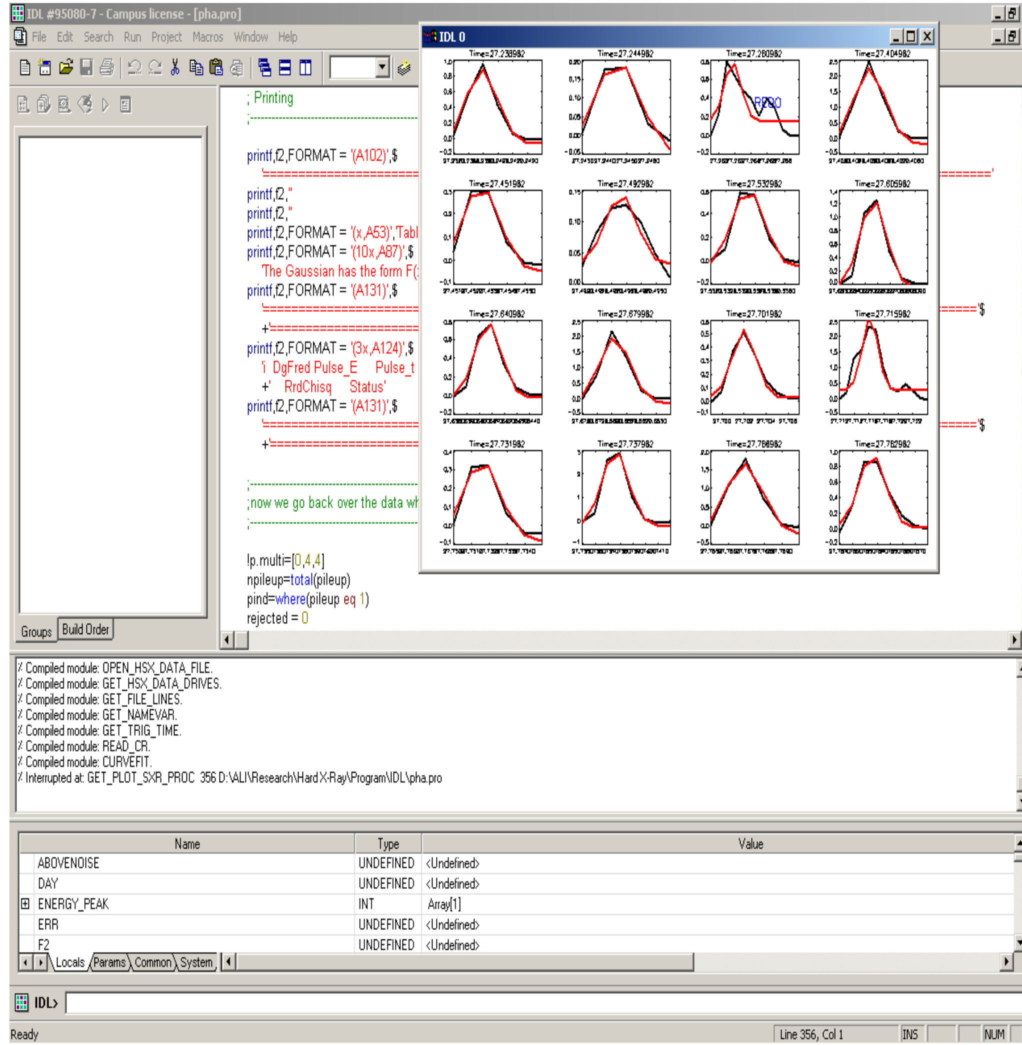
The pulse height analysis program is written in IDL. The program mainly evaluate the following:

1- Resolving the Gaussian signals (single & double).

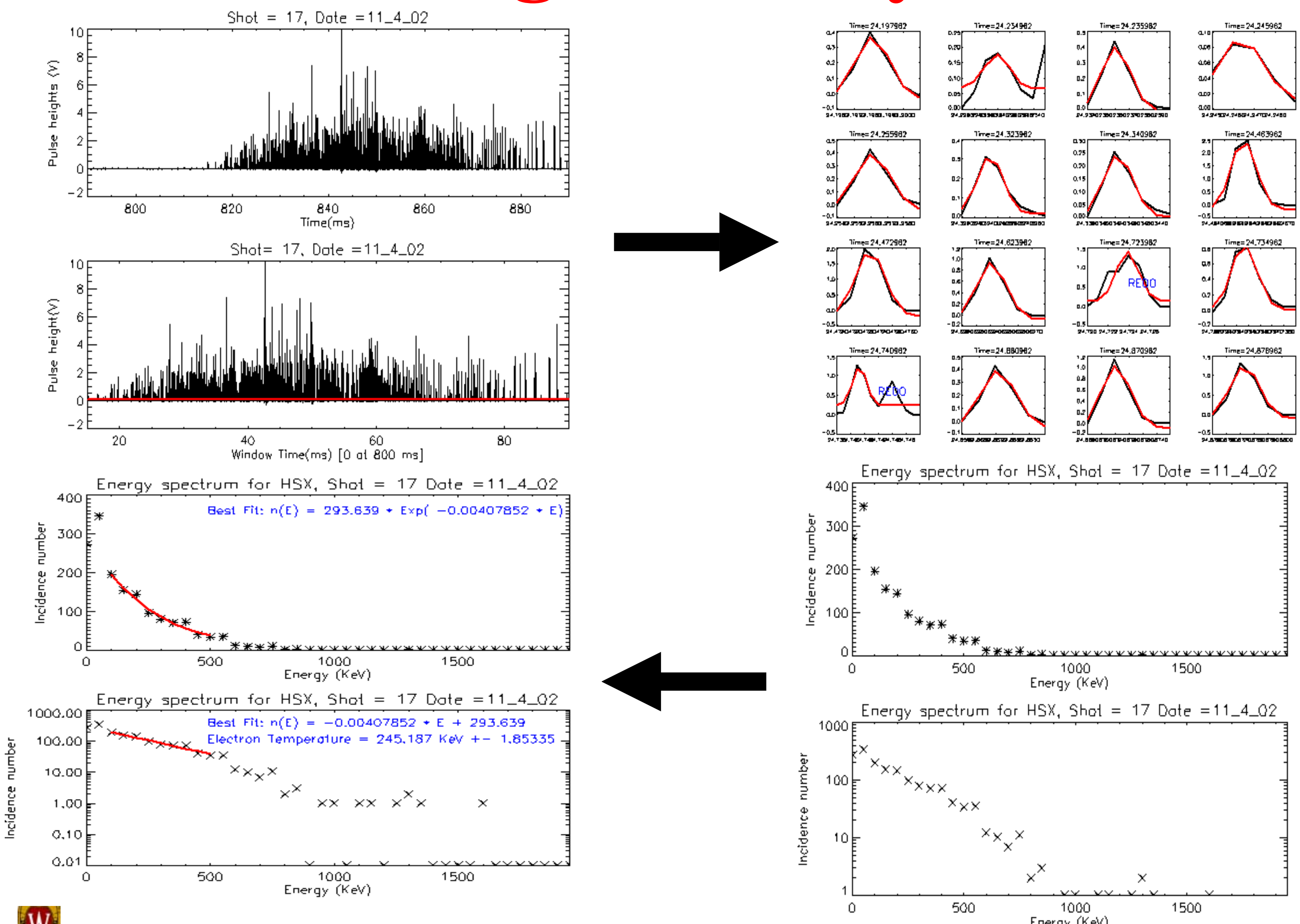
2- Least square fitting for the signals

3- Spectral Analysis of the signal

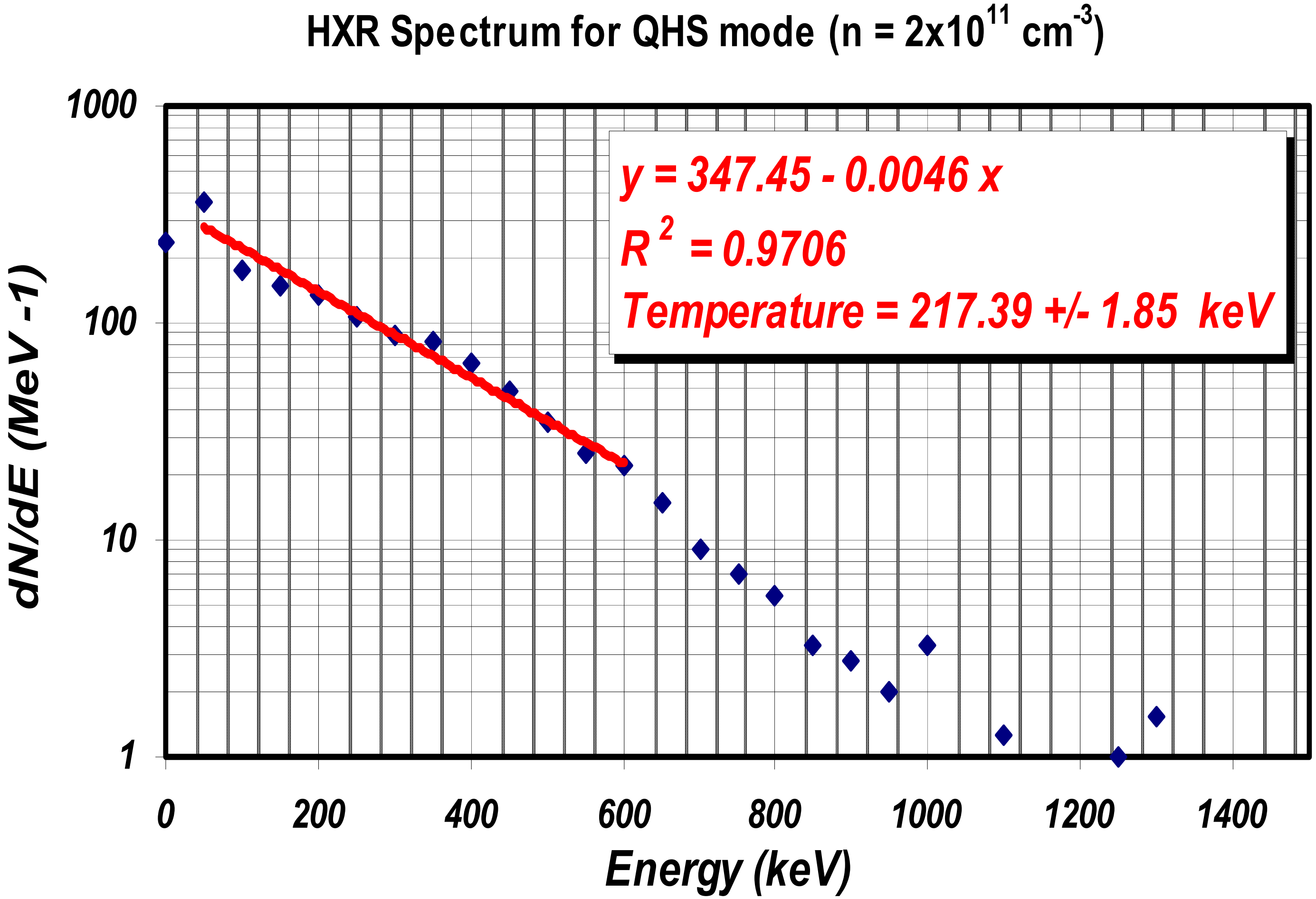
4- Calculation of the electron Temperature



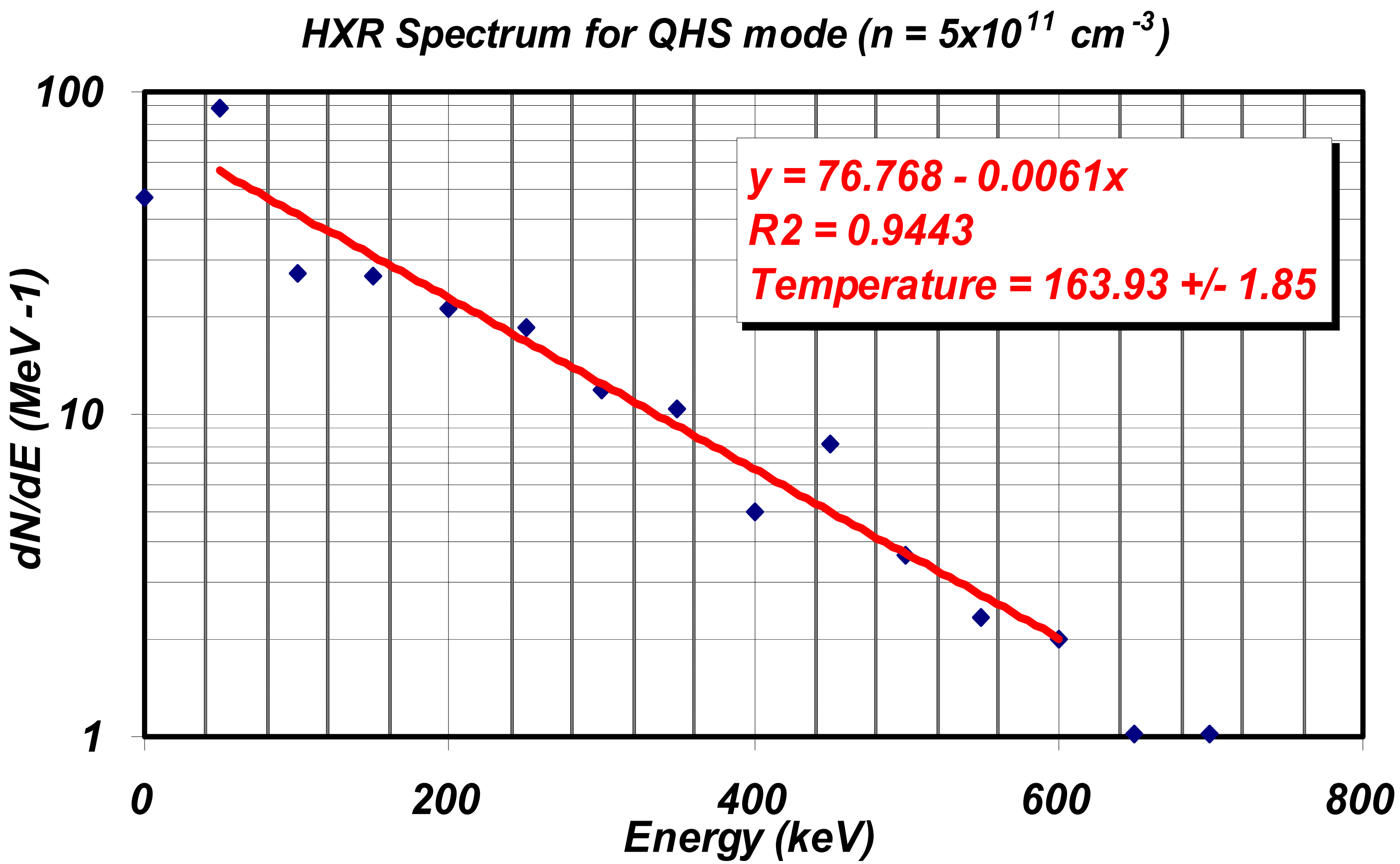
Pulse Heights Analysis (continue)



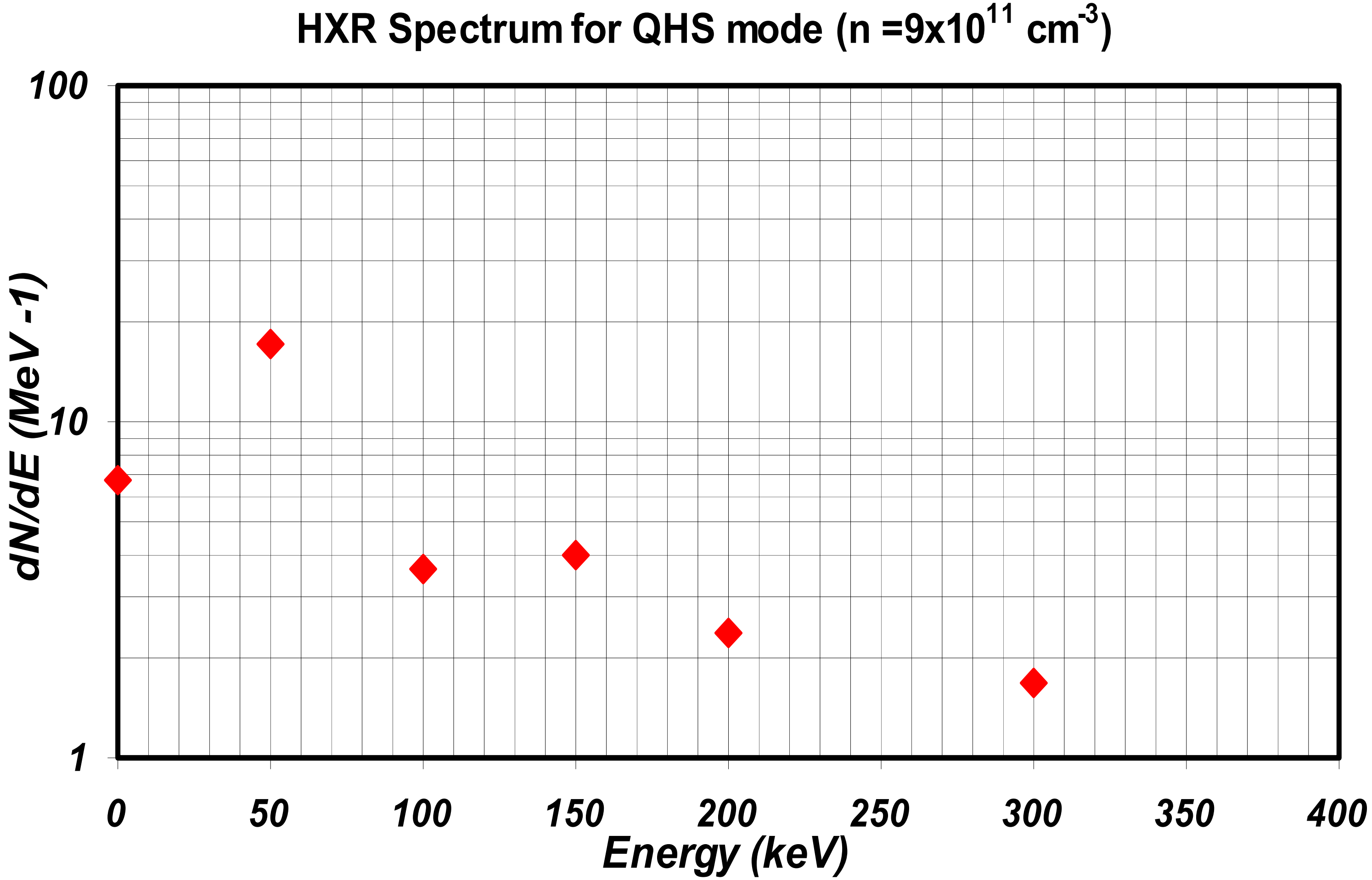
HXR Spectrum at Low Density
(QHS mode)



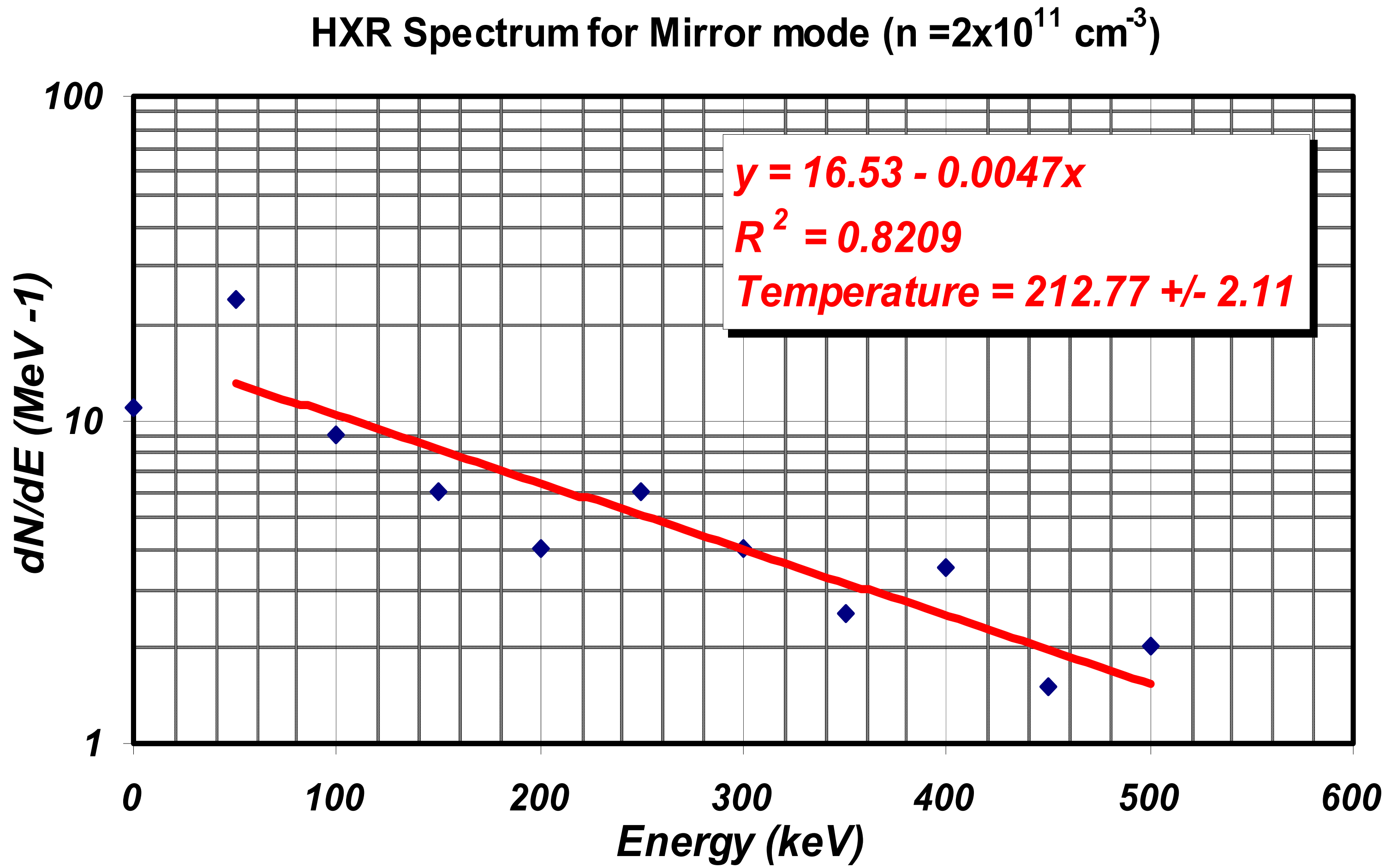
HXR Spectrum at intermediate density
(QHS mode)



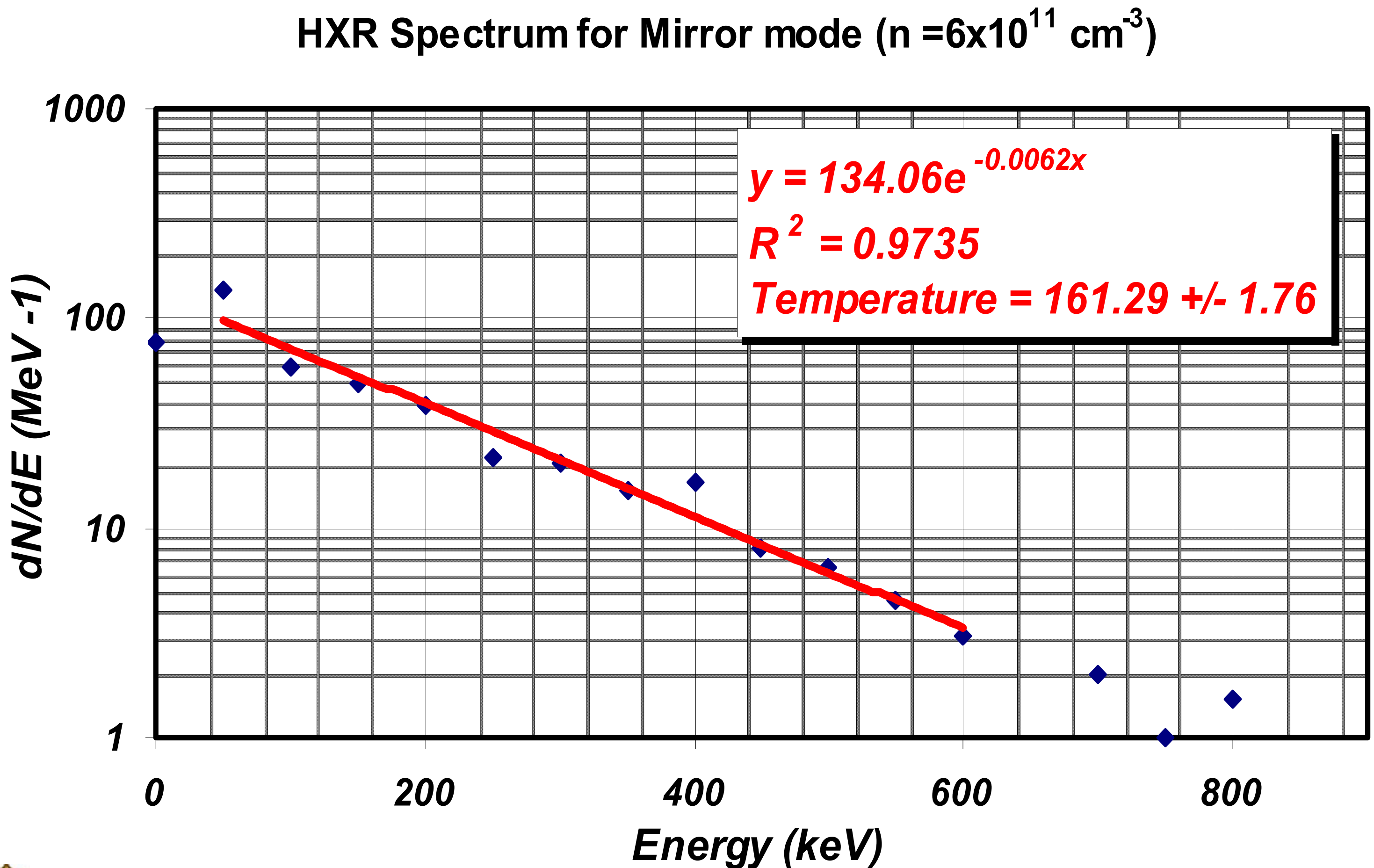
HXR Spectrum at High density
(QHS mode)



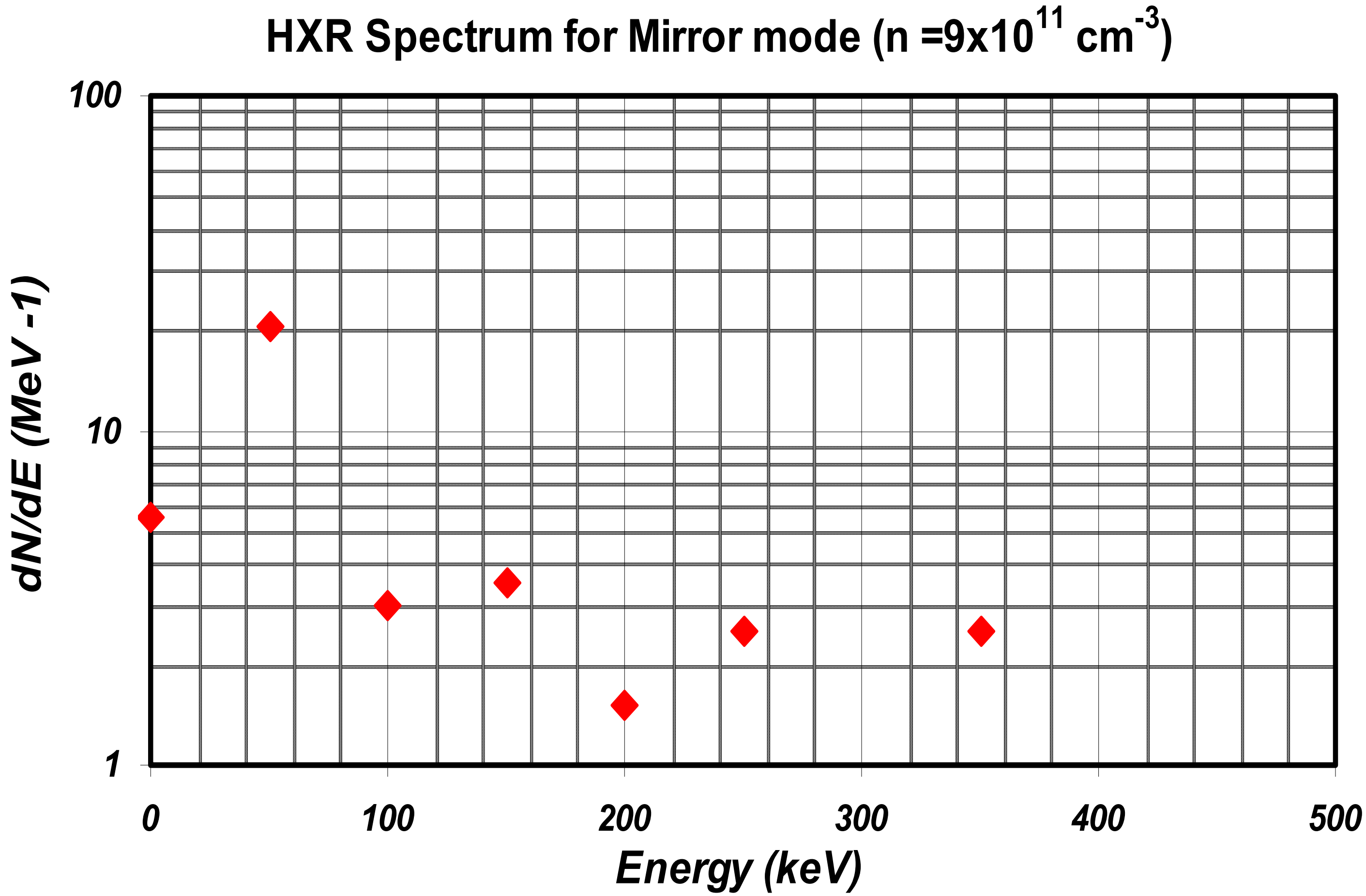
HXR Spectrum at Low density
(MIRROR mode)



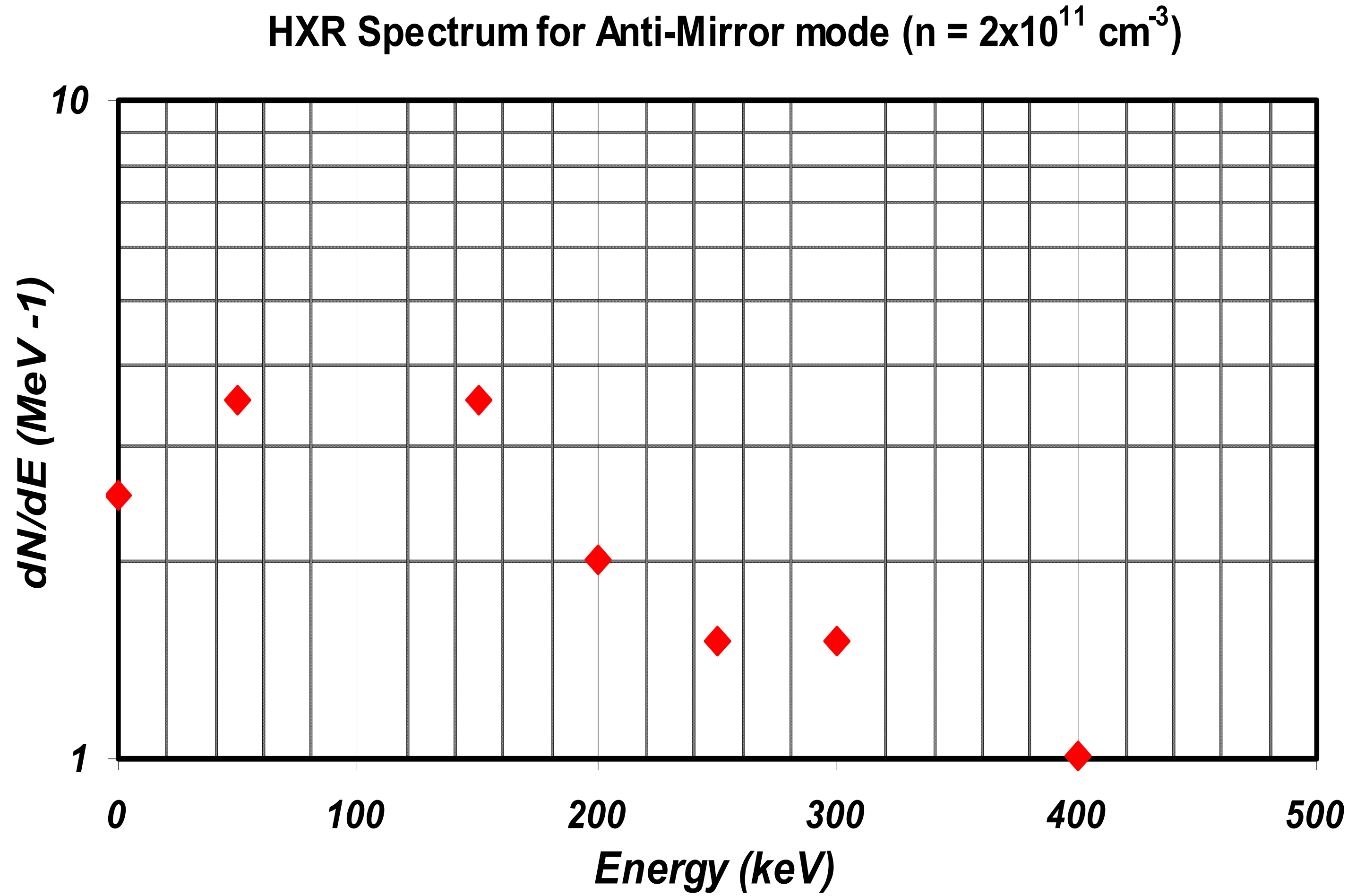
HXR Spectrum at Intermediate density
(MIRROR mode)



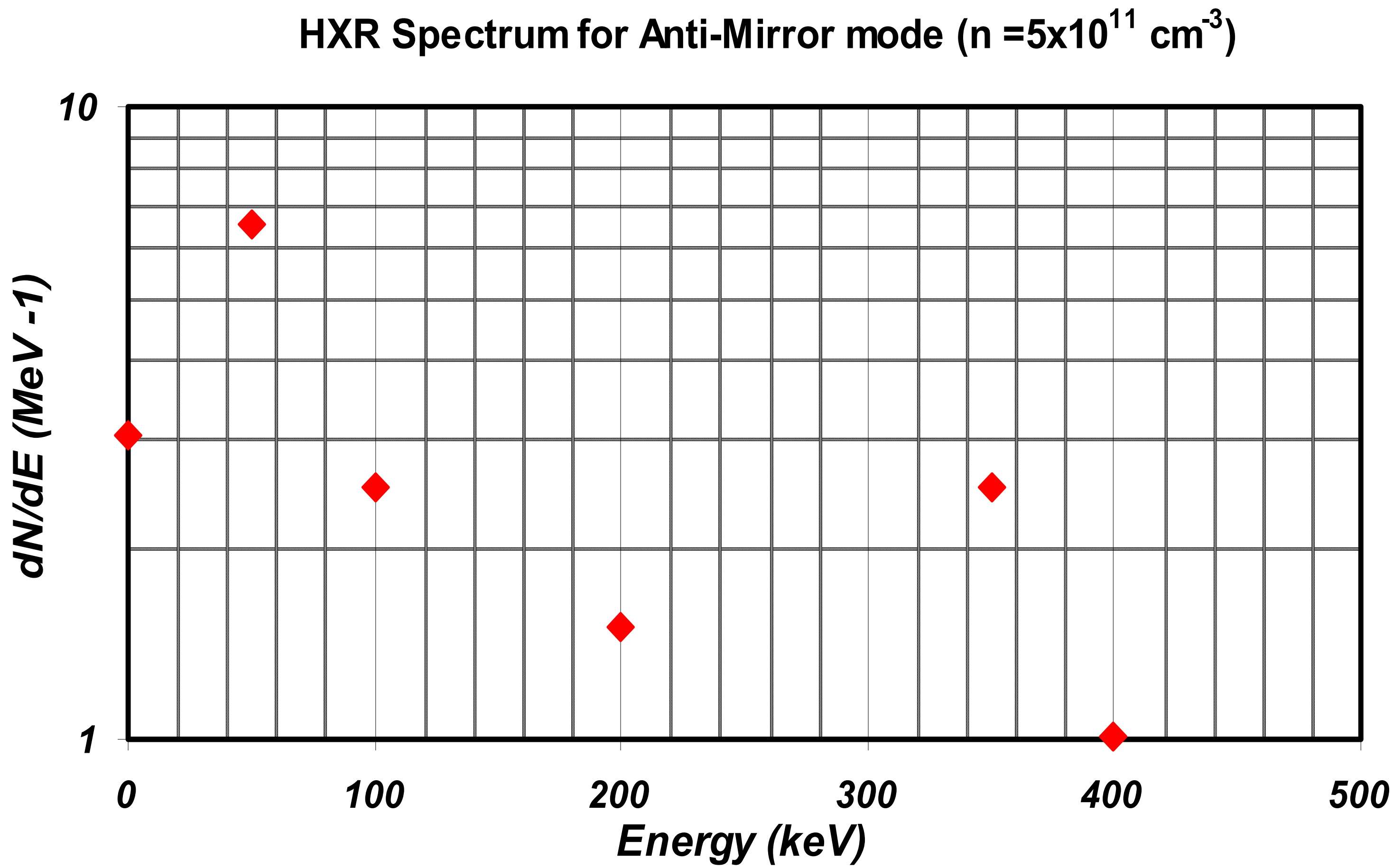
HXR Spectrum at High density
(MIRROR mode)



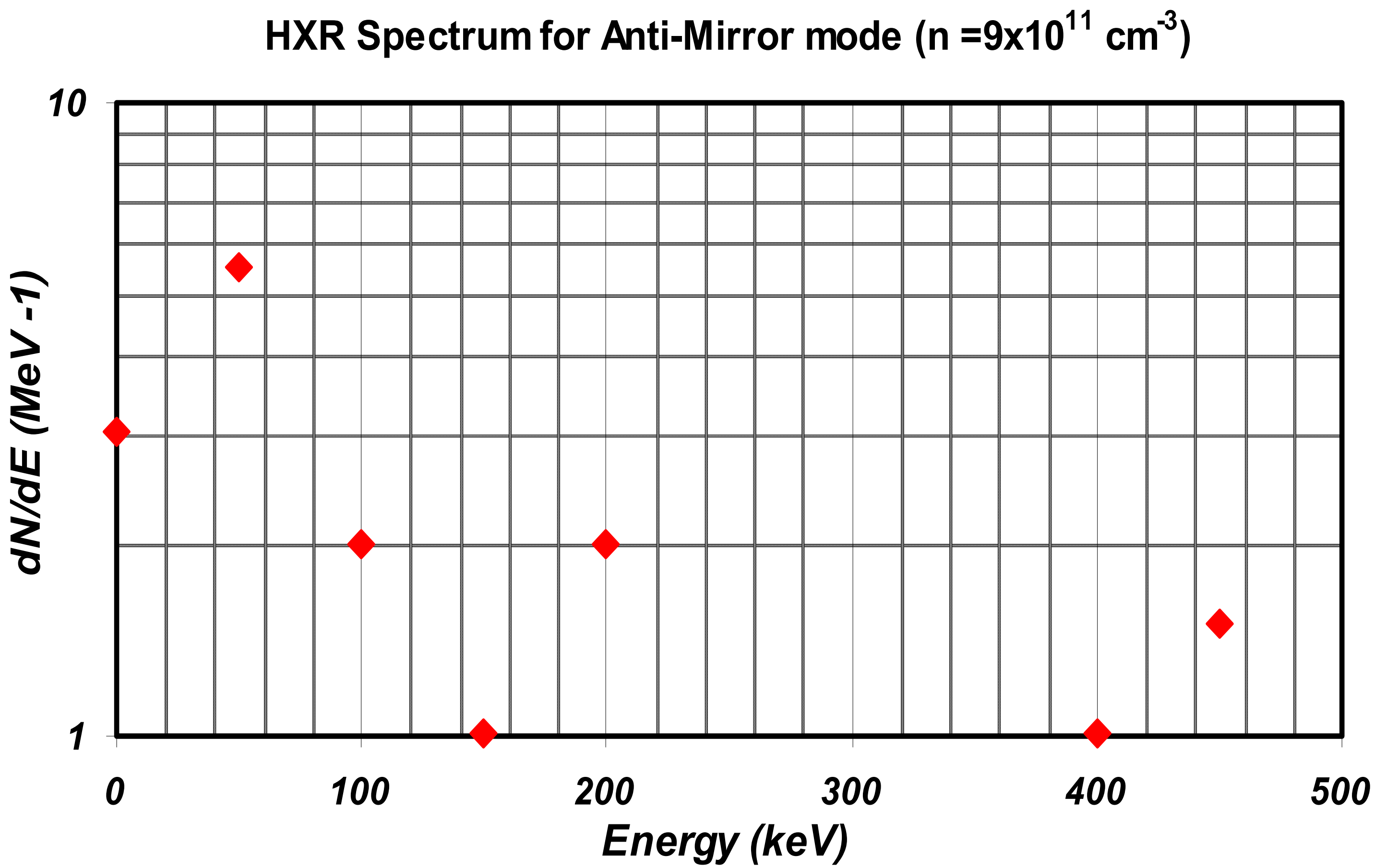
HXR Spectrum at Low density
(ANTI- MIRROR mode)



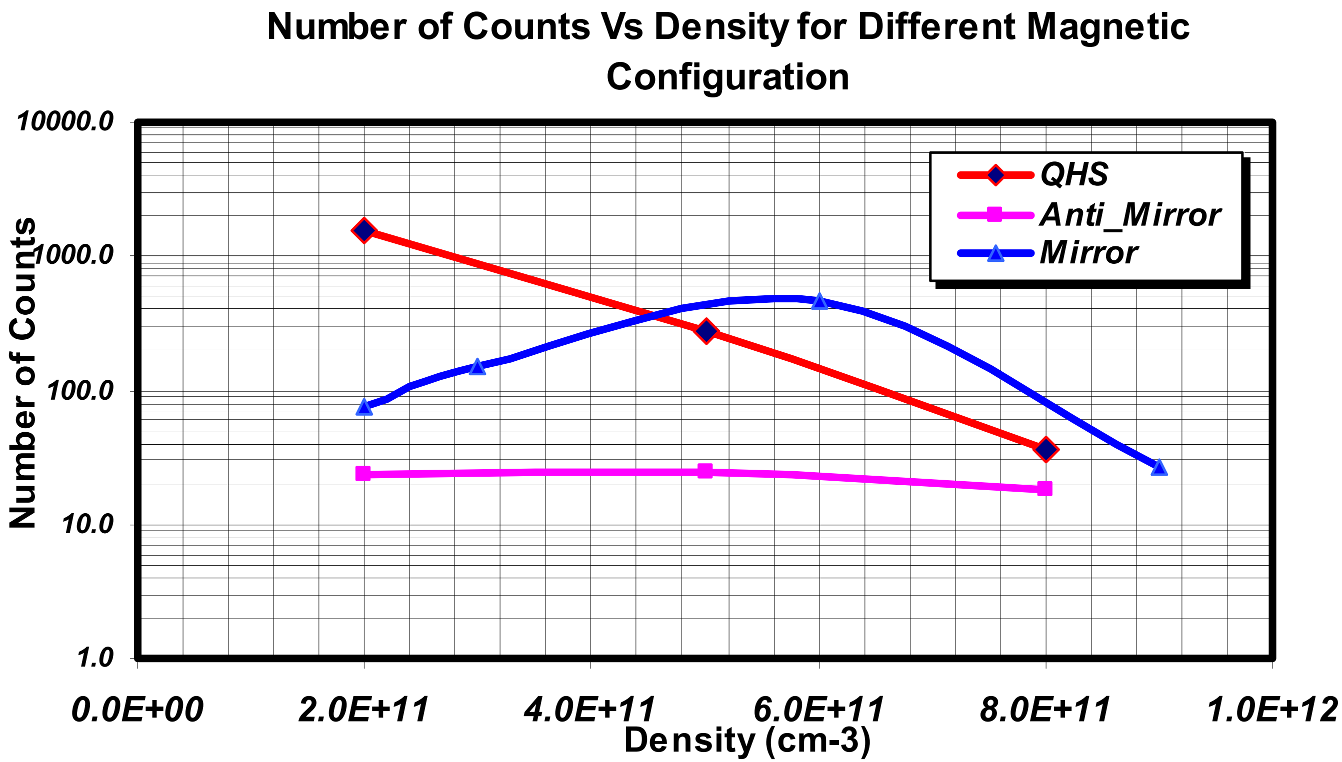
HXR Spectrum at Intermediate density
(ANTI-MIRROR mode)



HXR Spectrum at High density
(ANTI-MIRROR mode)



Summary

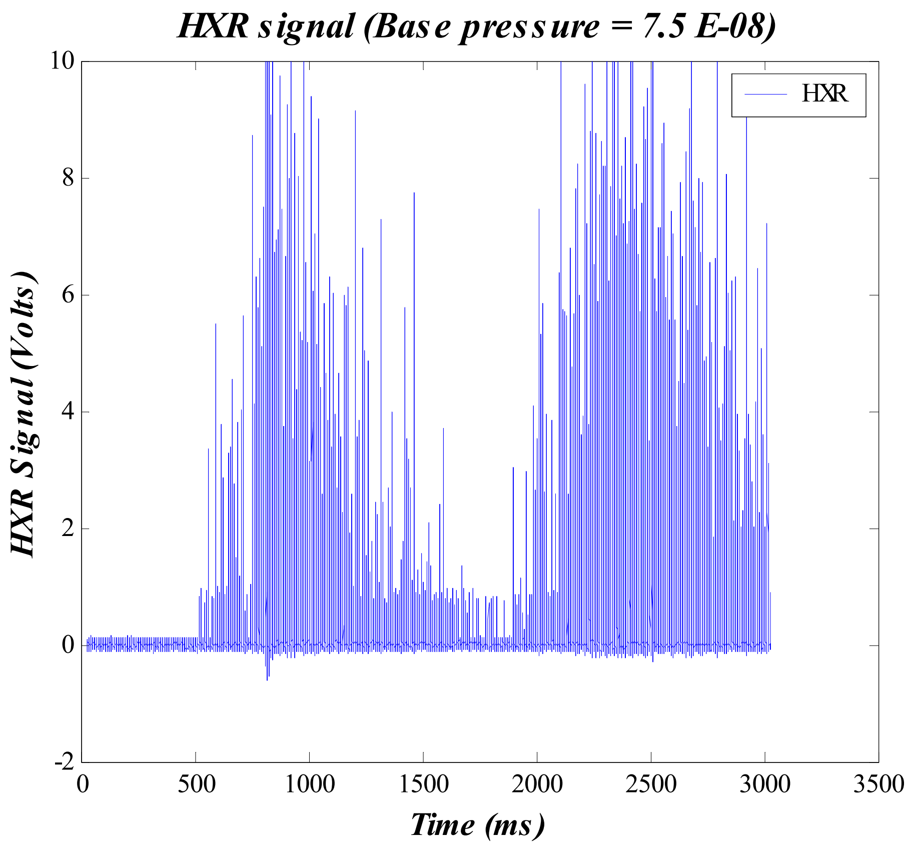


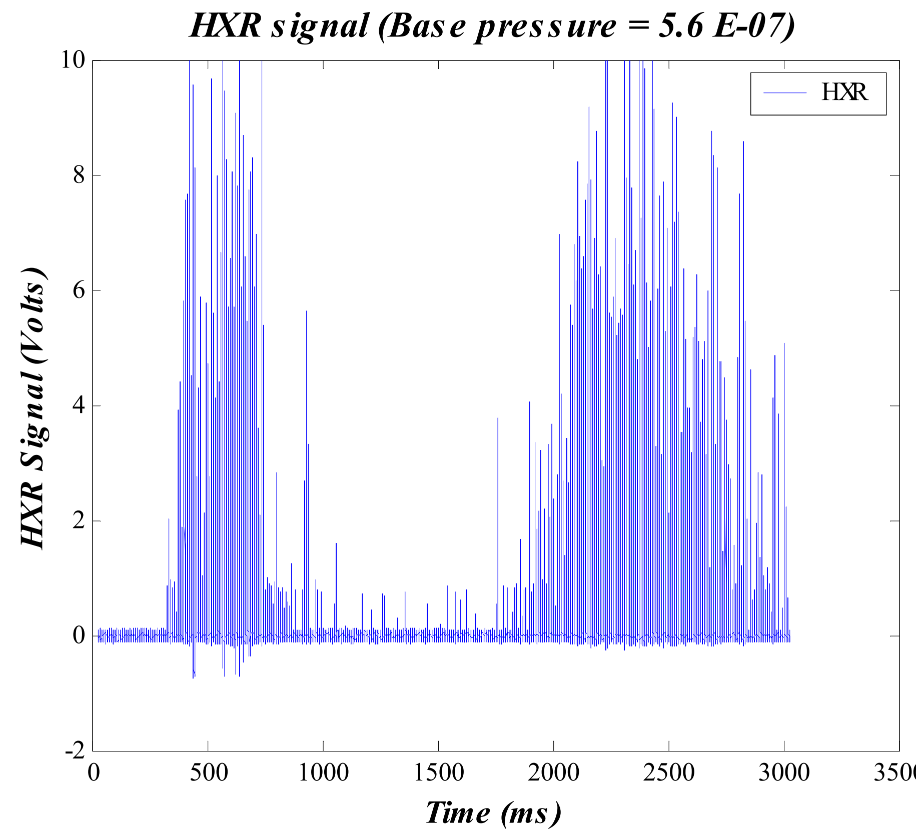
- **Hard X-ray emission is strong function of plasma density; where at low density (0.2 x 10^{12} cm^{-3}) the intensity is ~80 times higher than at high density (0.9 x 10^{12} cm^{-3}).**
- **The HXR spectrum extends to energies as high as 650 keV.**

THE UNIVERSITY of WISCONSIN MADISON

HSX

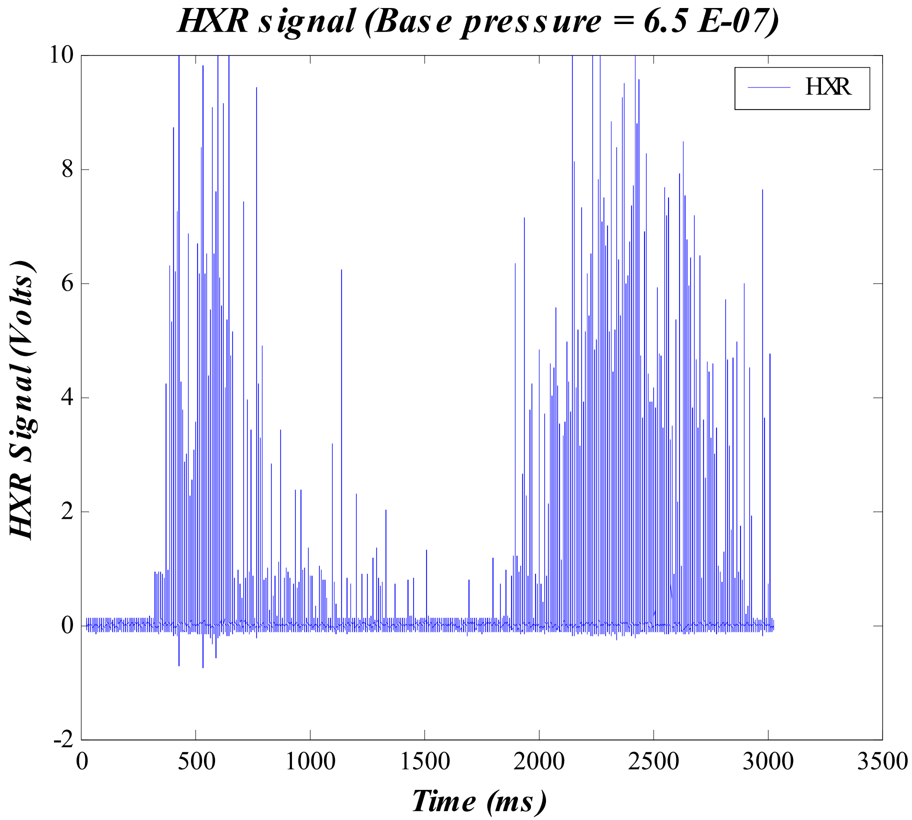
Base Pressure Scan

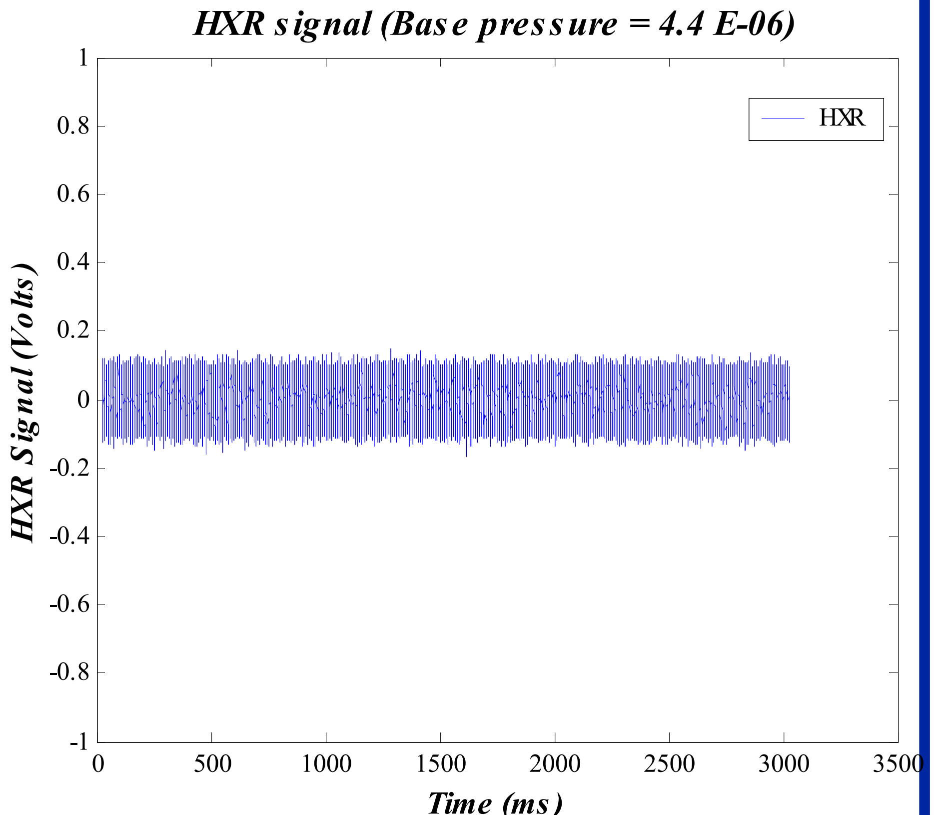




Increasing the tank base pressure decreases the the HXR intensity

Base Pressure Scan (Continue)





Increasing the tank base pressure beyond 4.4 x 10^{-06} will suppress the fast electrons (No HXR signal)

Conclusion

- **Hard X-ray signal last for at least 50 ms after the ECRH is turned off indicating good confinement of fast electrons.**
- **Hard X-ray emission is a strong function of plasma density; where at low density (0.2 x 10^{12} cm^{-3}) the intensity is ~80 times higher than at high density (0.9 x 10^{12} cm^{-3}).**
- **Hard Hard X-ray intensity is very low in ANTI-MIRROR mode at all plasma densities (poor confinement).**
- **The hard X-ray spectrum extends to energies as high as 650 keV in the QHS mode.**
- **Increasing the neutral base pressure beyond 4.4 x 10^{-6} suppress the fast electrons that are produced by toroidal voltage.**