Soft X-Ray Tomography in HSX

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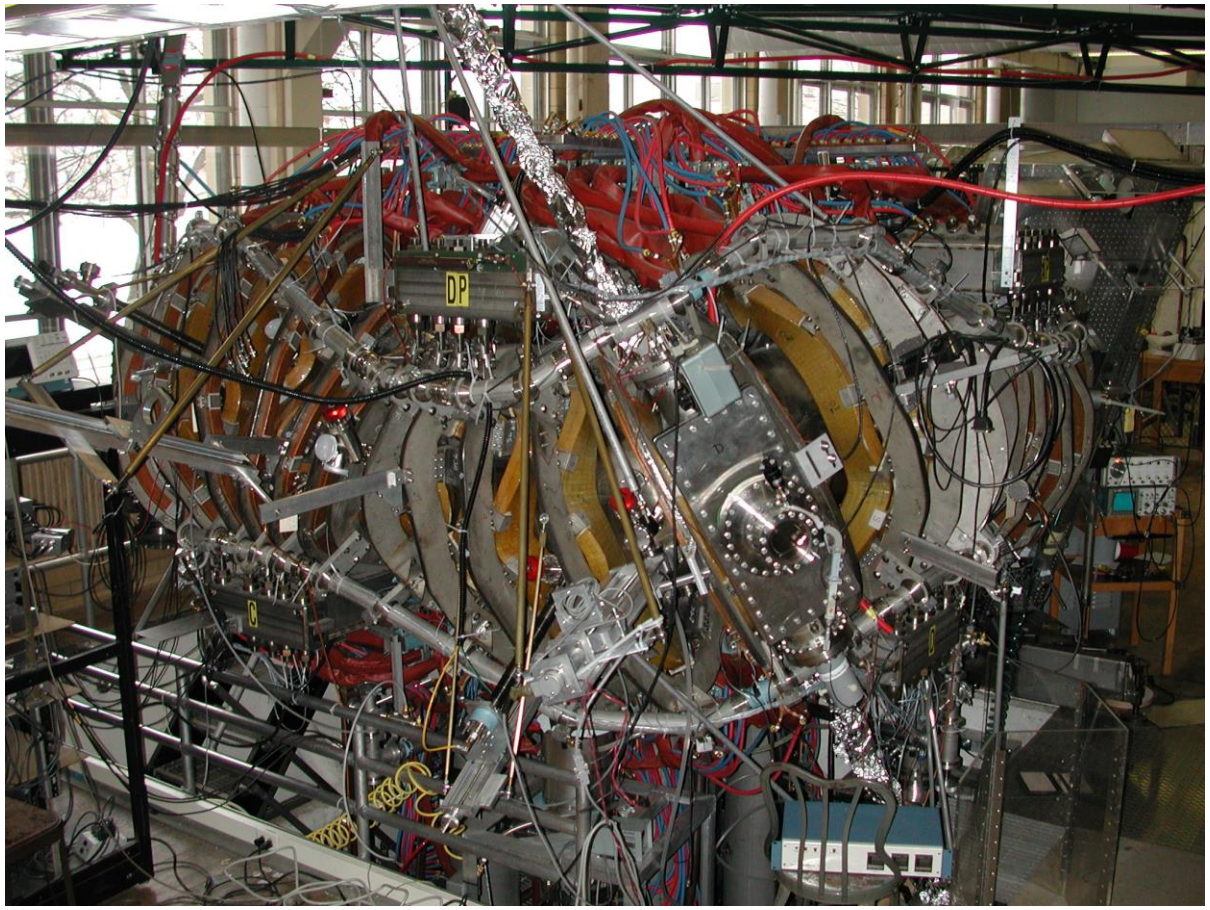
Abstract

Under certain discharge conditions, HSX plasmas exhibit a sudden loss of stored energy followed by fluctuations of the order of few kHz in both the stored energy and the soft x-ray (SXR) signals. These are measured by a diamagnetic loop and a set of PIPS detectors respectively. To help understand the origin of these crashes and the nature of the oscillations, as well as to measure basic plasma properties such as position and shape, a SXR tomography system is under development in HSX. A single array of 20 silicon p-n junction photodiodes is installed on the device and, in the near future, the diagnostic system will be expanded to several arrays in order to obtain tomographic reconstructions of the SXR emission. Initial SXR and stored energy measurements during these crashing discharges as well as the results of the one-array reconstruction will be presented. Implementation details of the complete tomographic system will be shown as well.

Current Operational Parameters of HSX

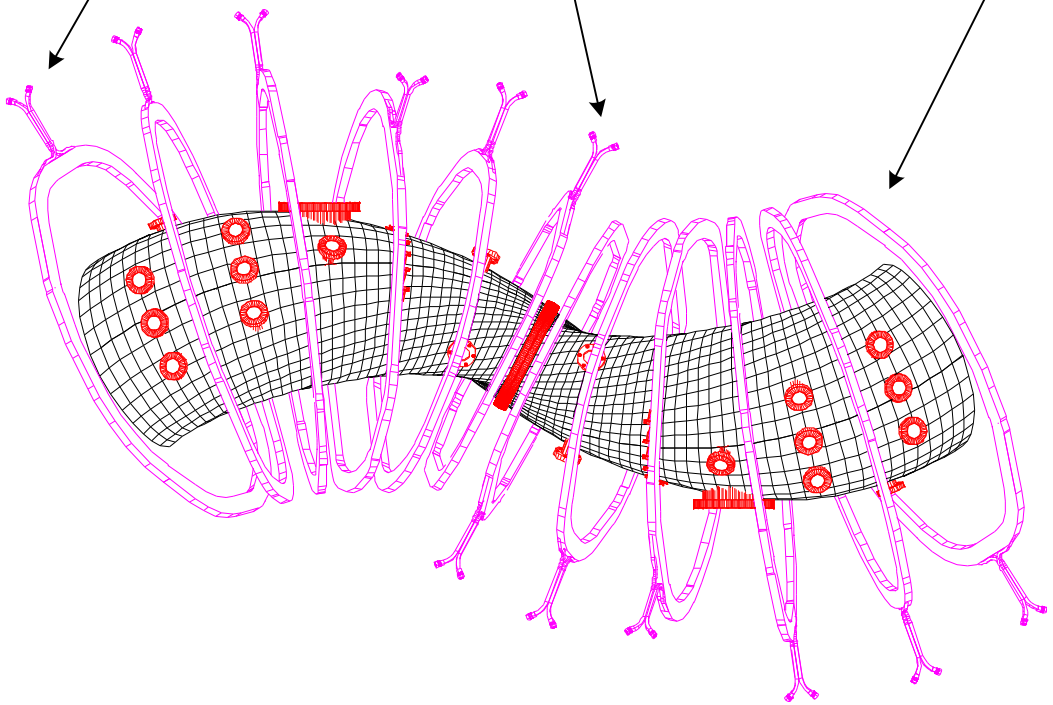


Modular coil stellarator with a helical axis of symmetry (N=4, m=1)

Major Radius	1.2 m
Minor Radius	0.15 m
Volume	0.44m^3
Magnetic Field	0.5 T
Field periods	4
Coils/ period	12
RF Power	<100kW
RF Pulse length	< 50 ms

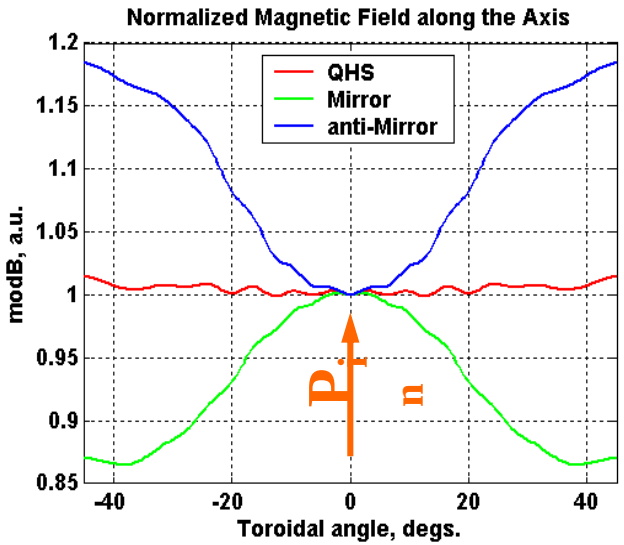
Experimental Flexibility

MODE	AUXILIARY COIL CURRENT DIRECTION											
MIRROR	+	+	+	-	-	-	-	-	-	+	+	+
ANTIMIRROR	-	-	-	+	+	+	+	+	+	-	-	-

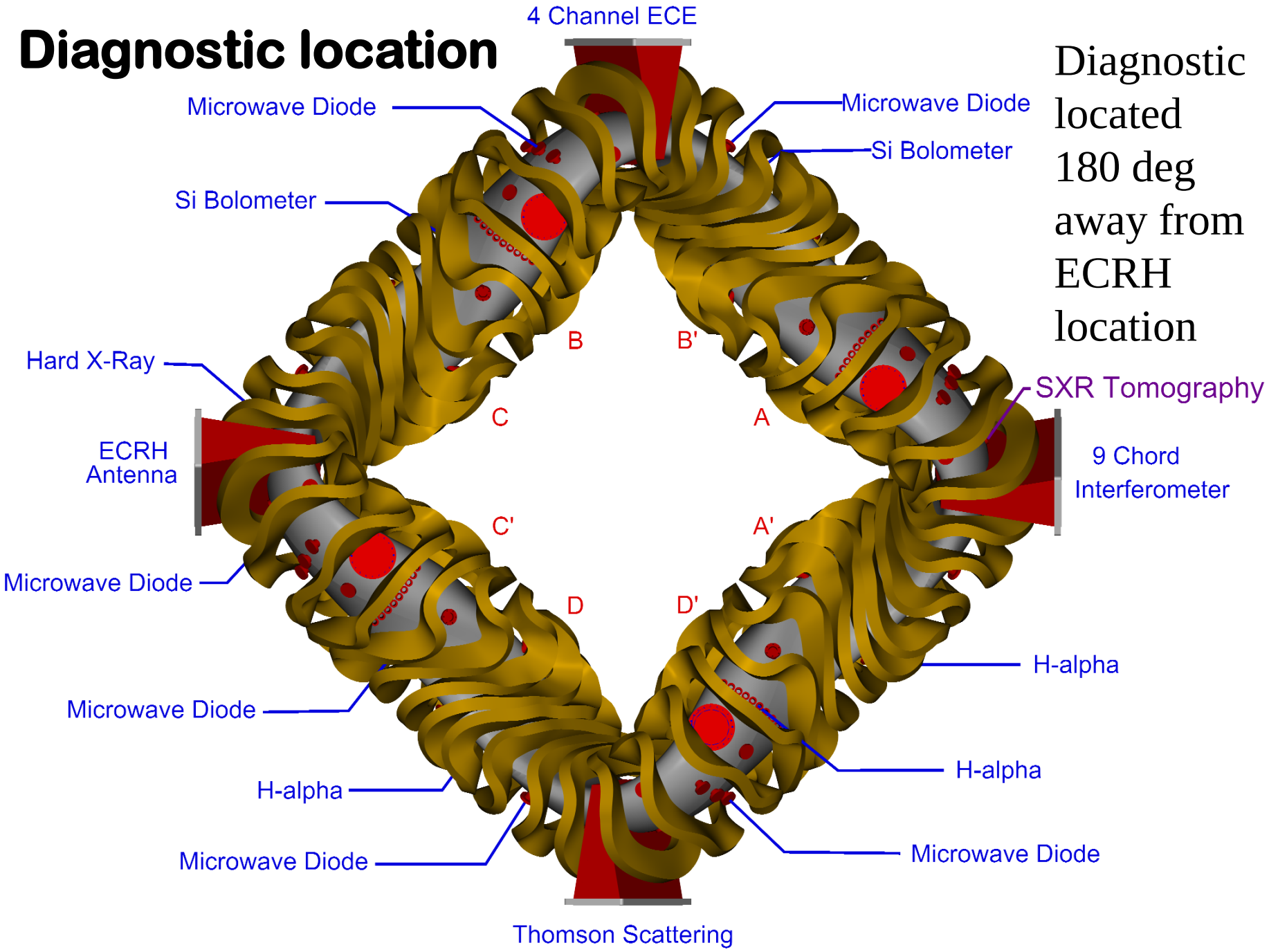


Auxiliary coils provide a way to change the magnetic field spectrum in HSX

Mirror: toroidal curvature term is added at ECRH location

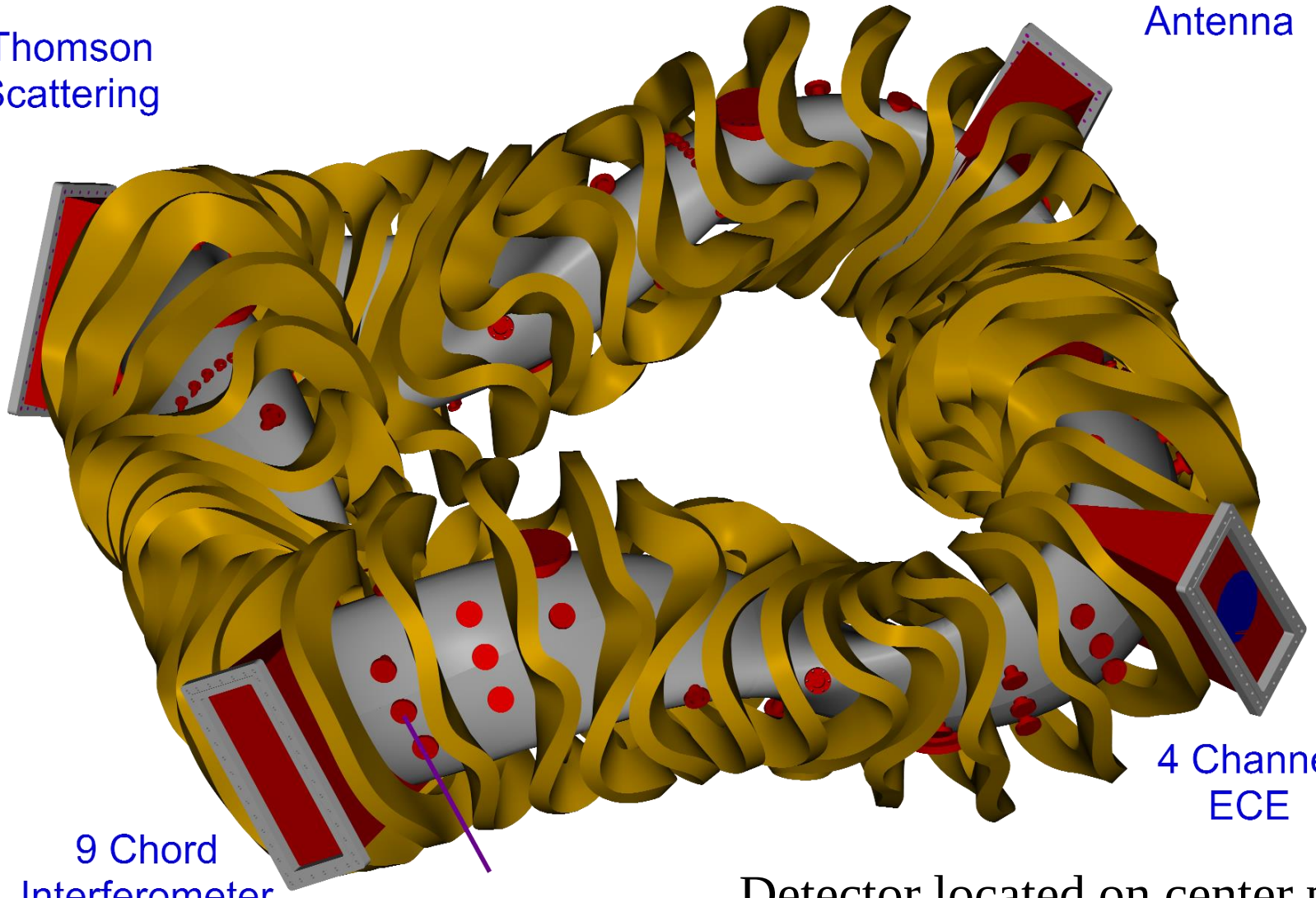


Diagnostic location



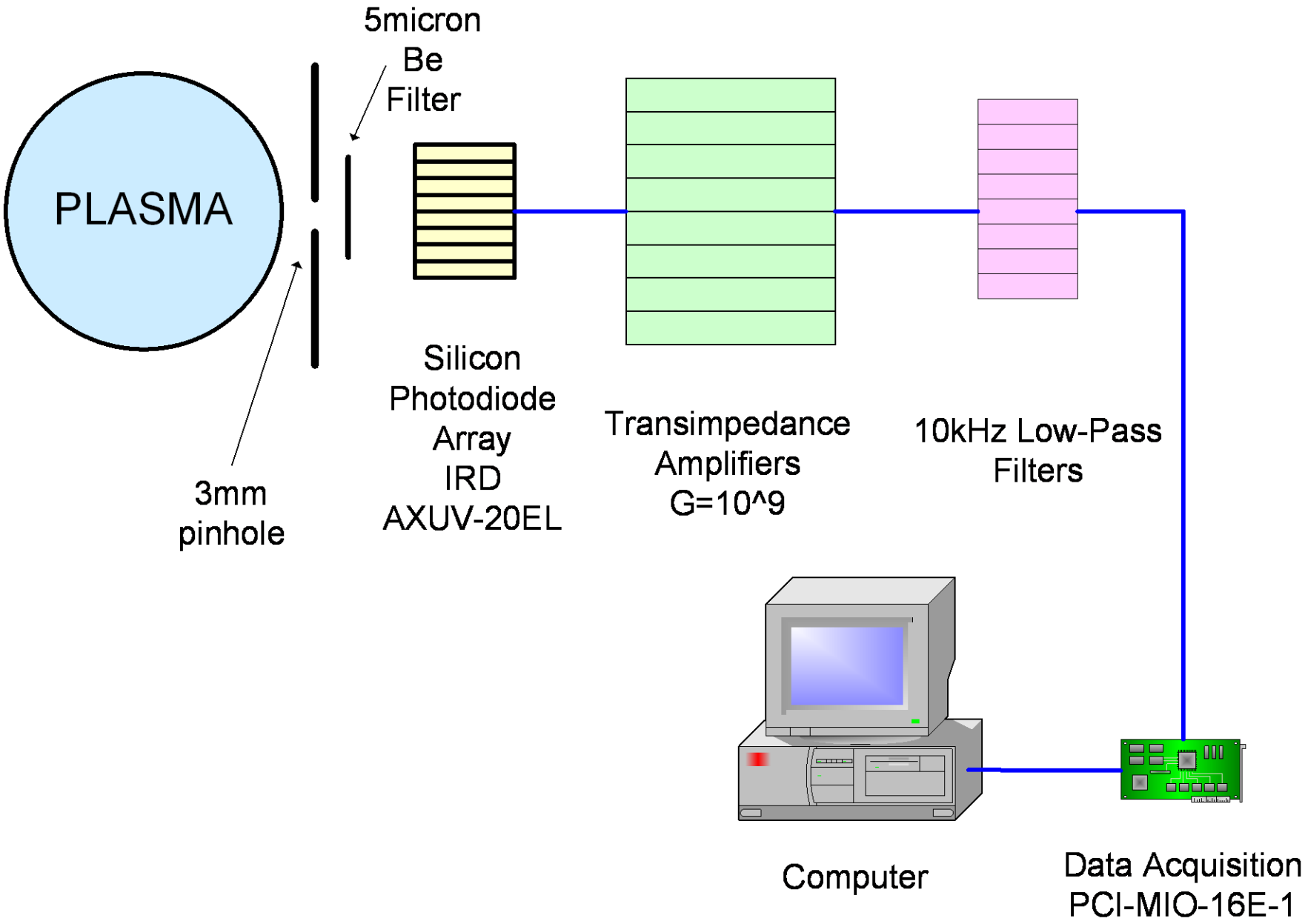
Diagnostic located 180 deg away from ECRH location

Diagnostic location

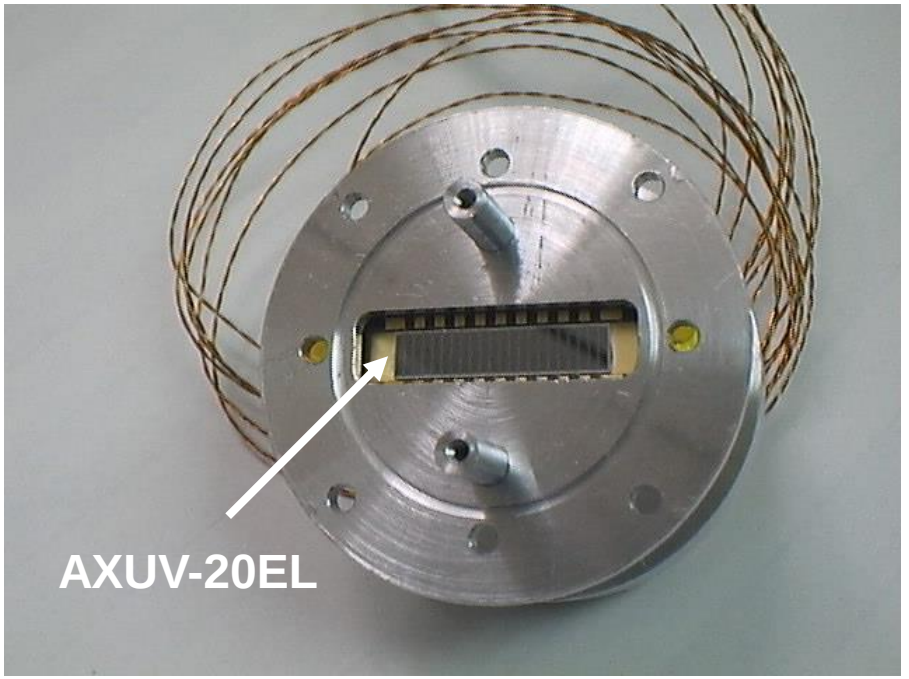


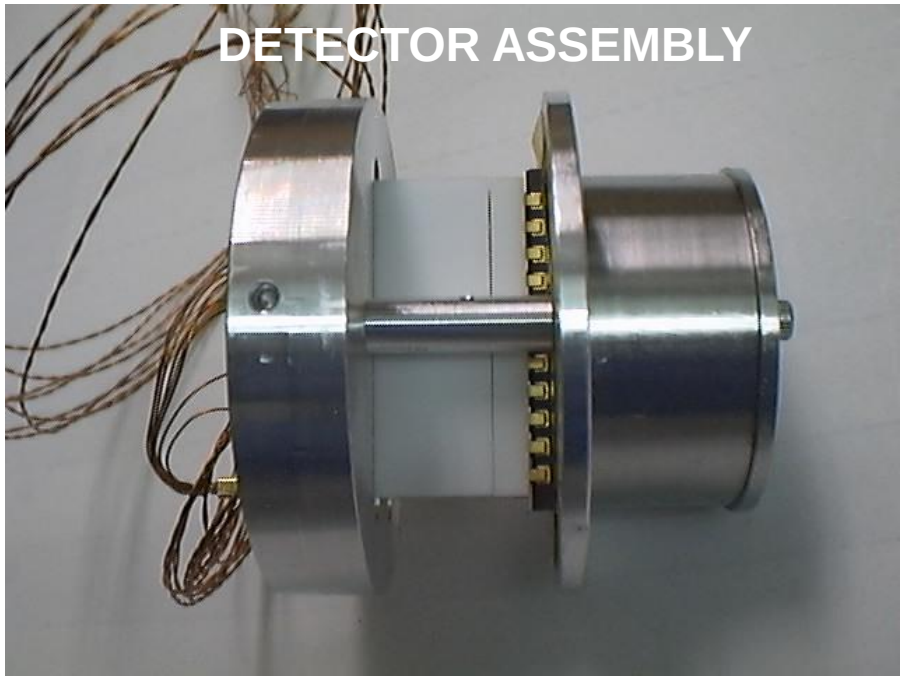
Detector located on center port

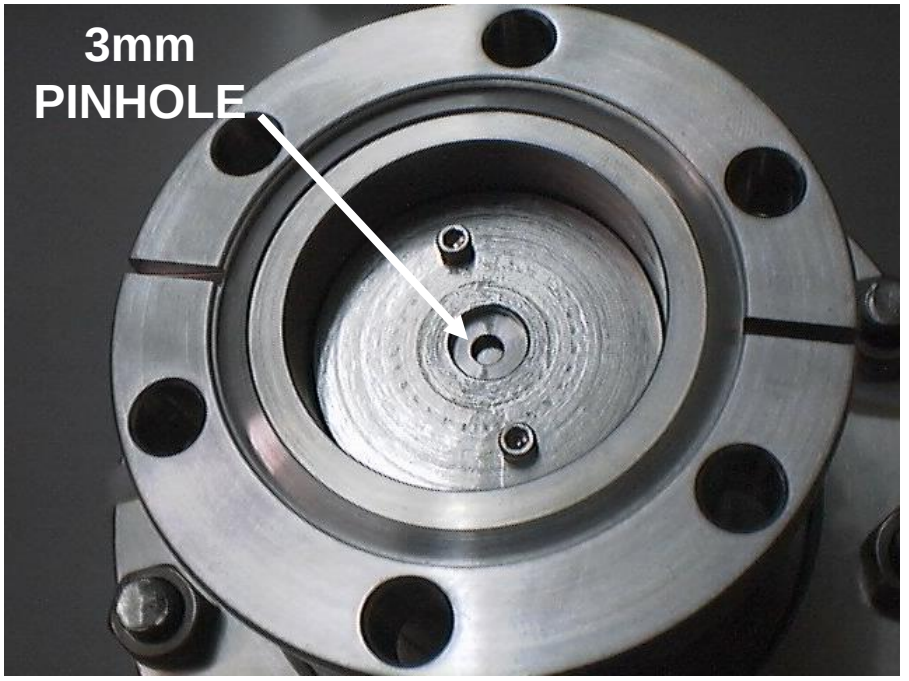
Diagnostic Setup



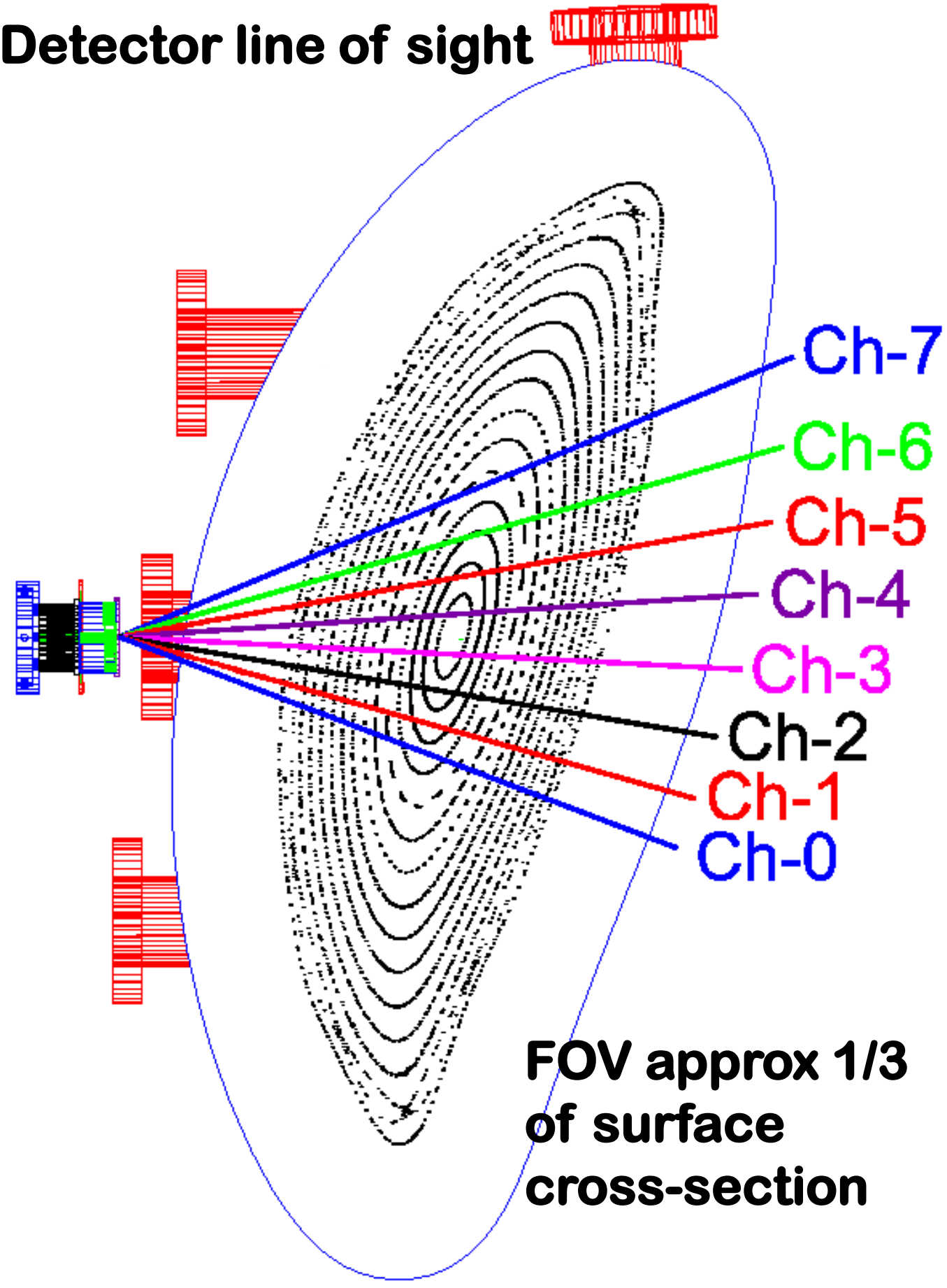

CERAMIC
SOCKET
32nds
R.D. MATHIS CO. -, LONG BEACH,
MM 10 20 30 40 50 60 70

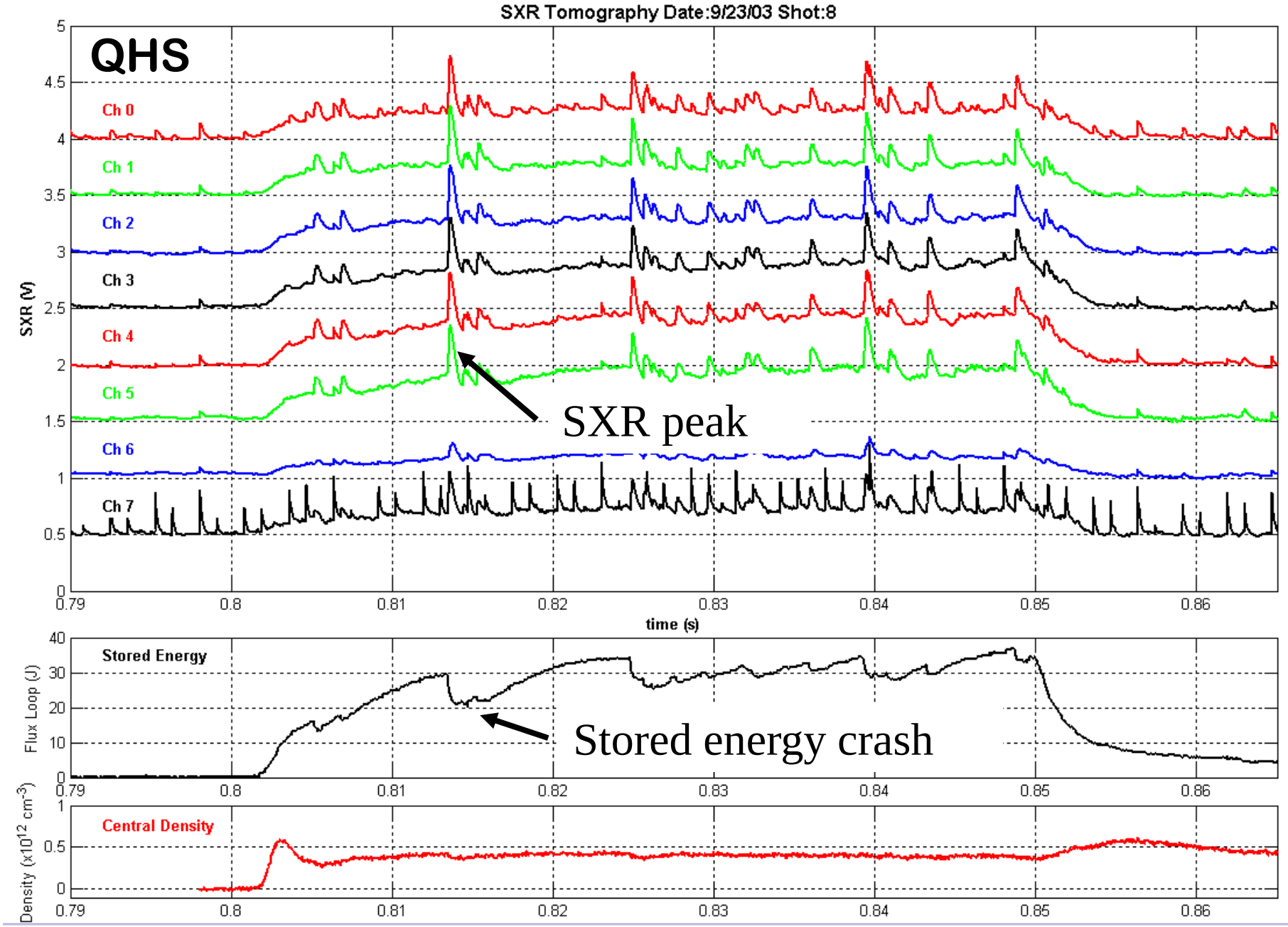

AXUV-20EL

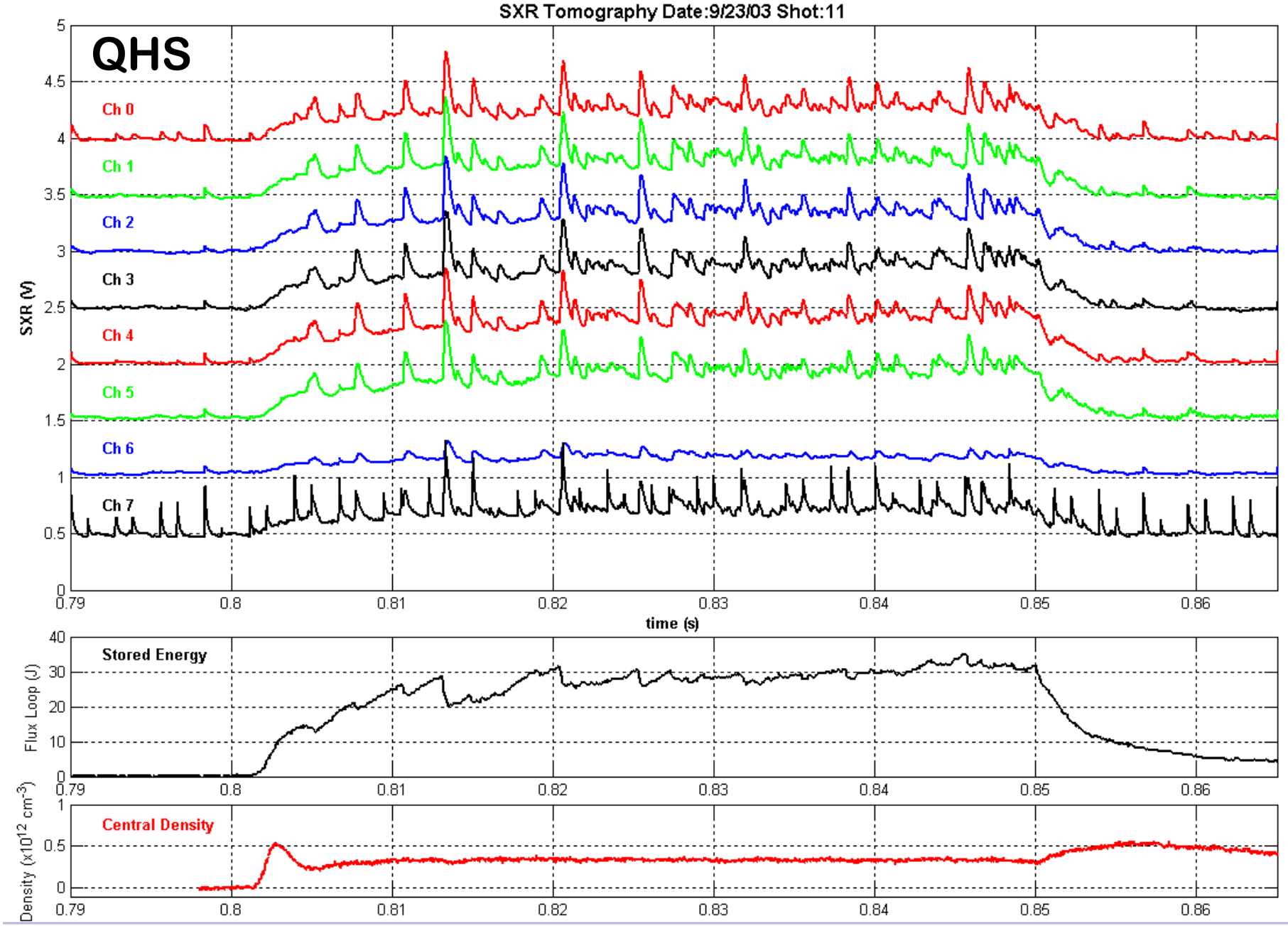

DETECTOR ASSEMBLY

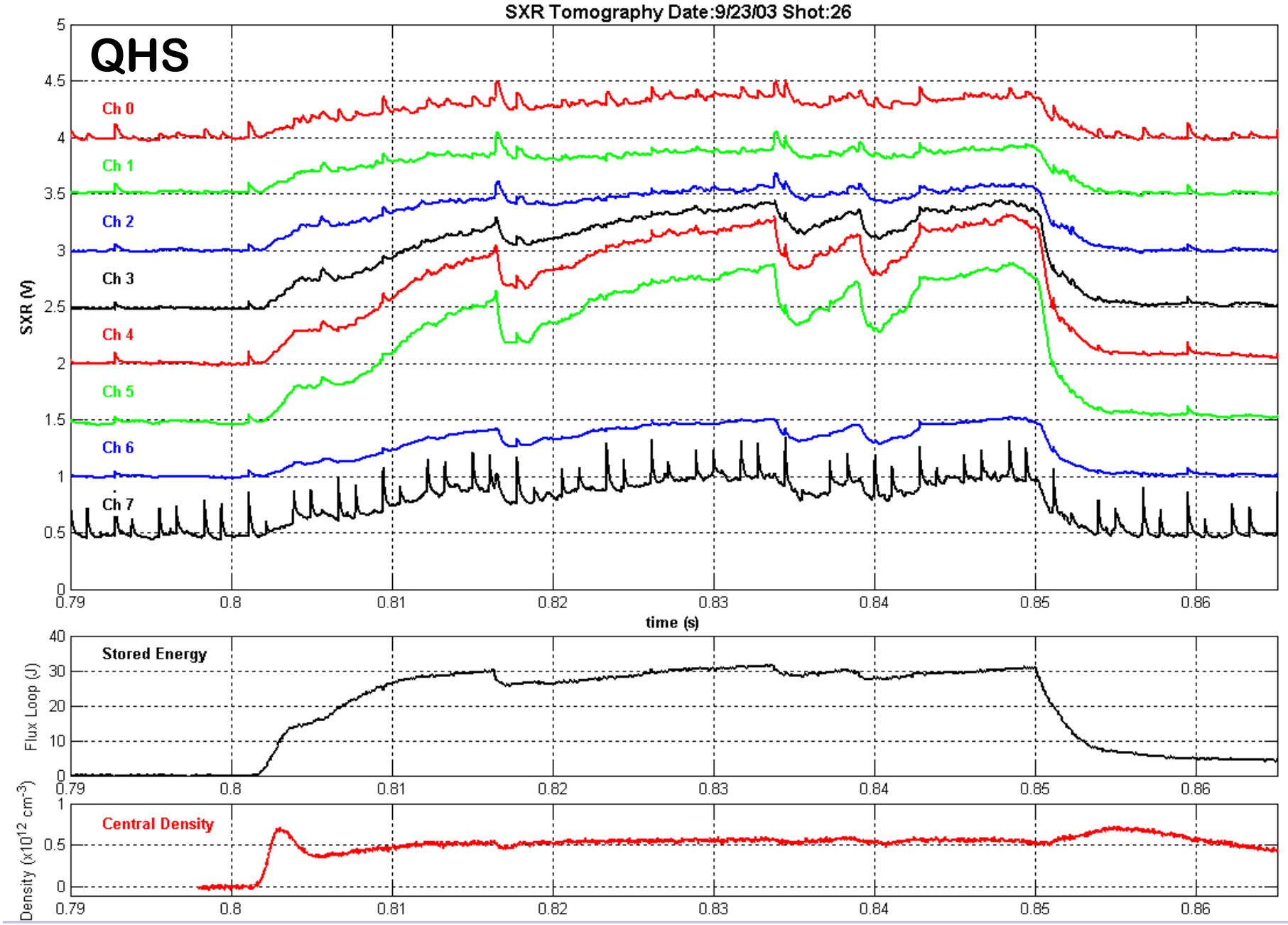

3mm
PINHOLE

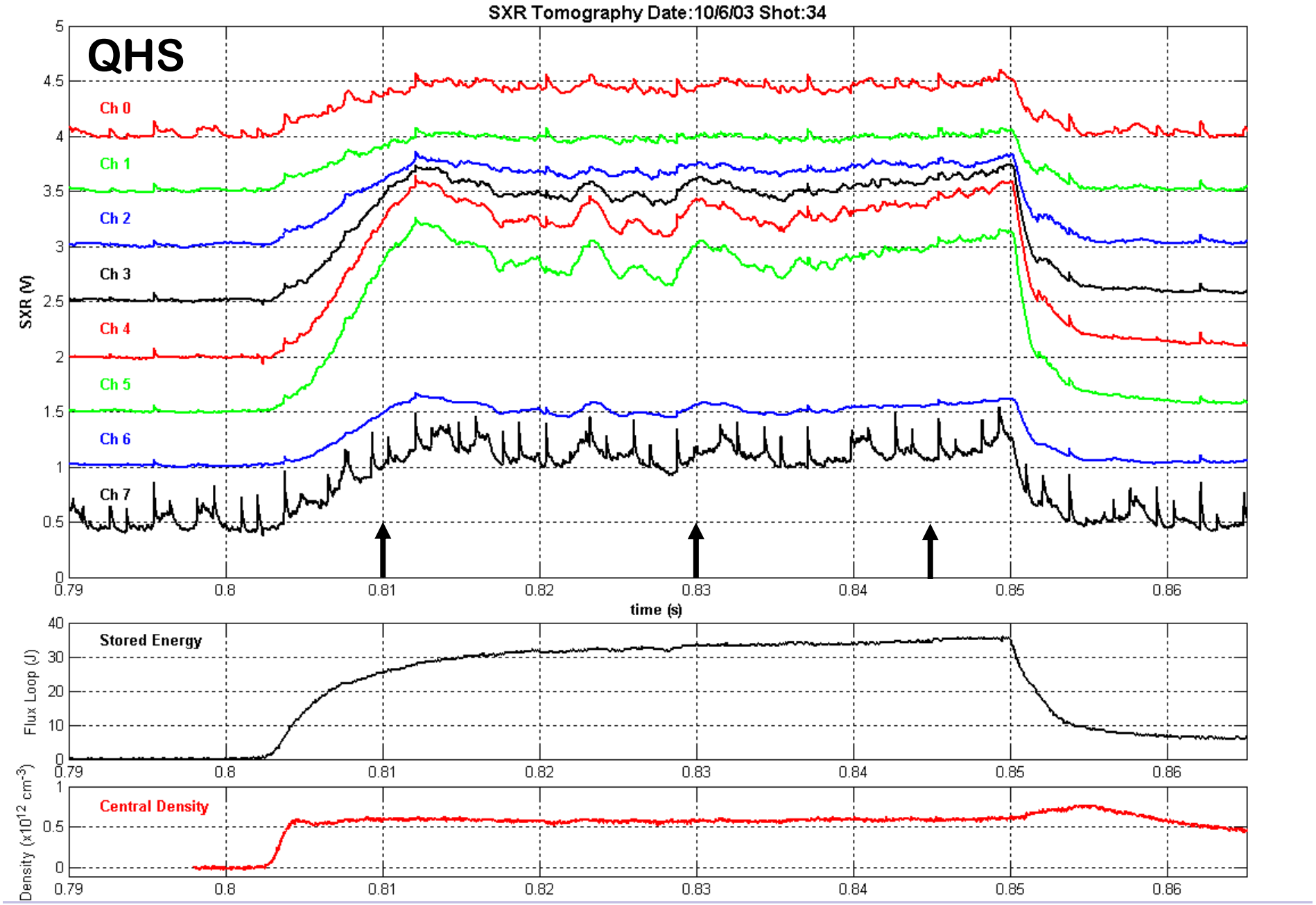
Detector line of sight



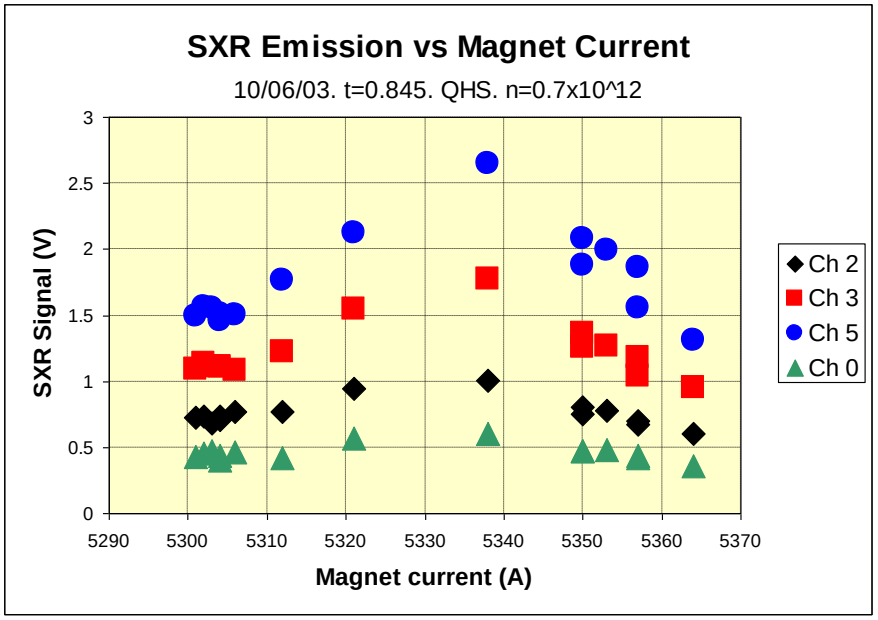

SXR Tomography Date:9/23/03 Shot:8
QHS
Ch 0
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
SXR (V)
SXR peak
time (s)
Stored Energy
Flux Loop (J)
Stored energy crash
Central Density
Density (x10^12 cm^-3)

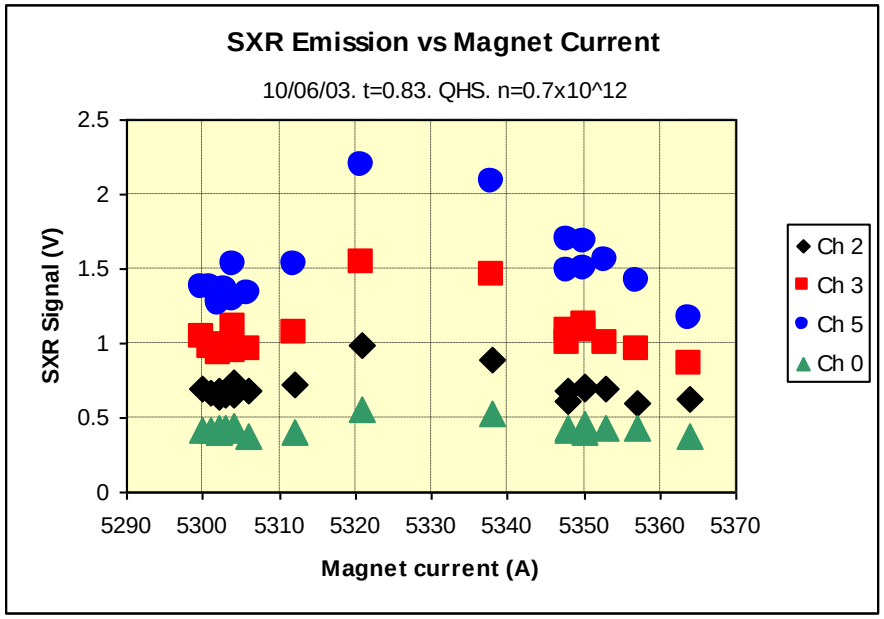

SXR Tomography Date:9/23/03 Shot:11
QHS
Ch 0
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
SXR (V)
time (s)
Stored Energy
Flux Loop (J)
Central Density
Density (x10^12 cm^-3)


SXR Tomography Date:9/23/03 Shot:26
QHS
Ch 0
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
SXR (V)
time (s)
Stored Energy
Flux Loop (J)
Central Density
Density (x10^12 cm^-3)


SXR Tomography Date:10/6/03 Shot:34
QHS
Ch 0
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
SXR (V)
time (s)
Stored Energy
Flux Loop (J)
Central Density
Density (x10^12 cm^-3)

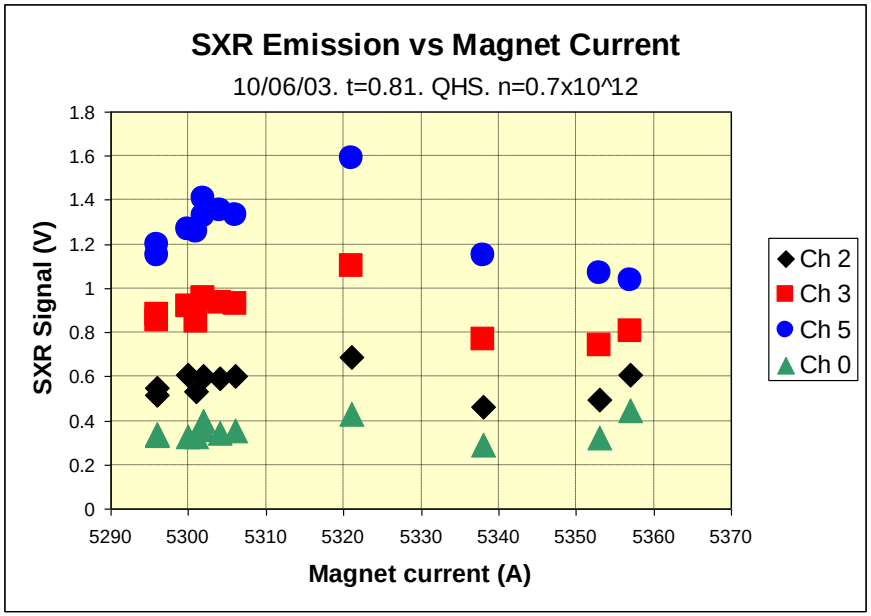
SXR Emission vs Resonance Location

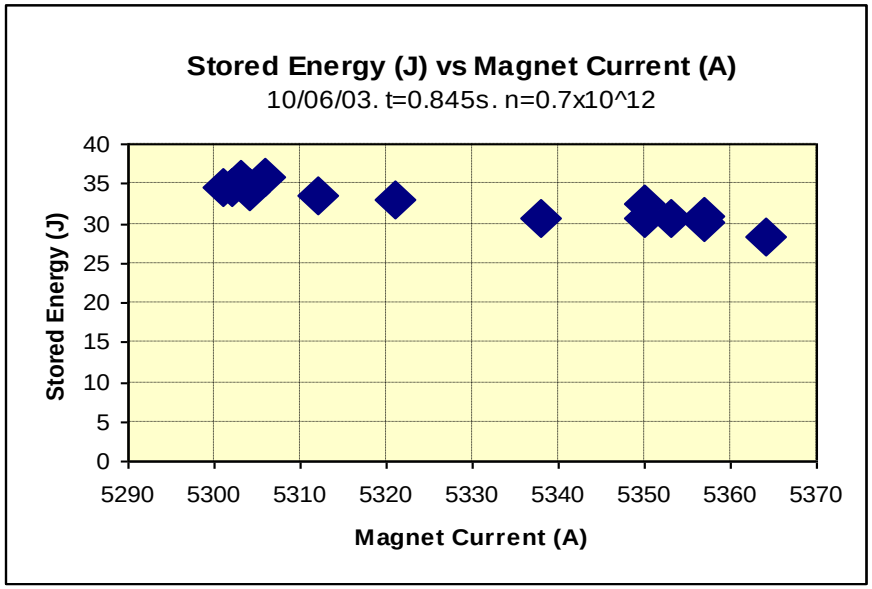




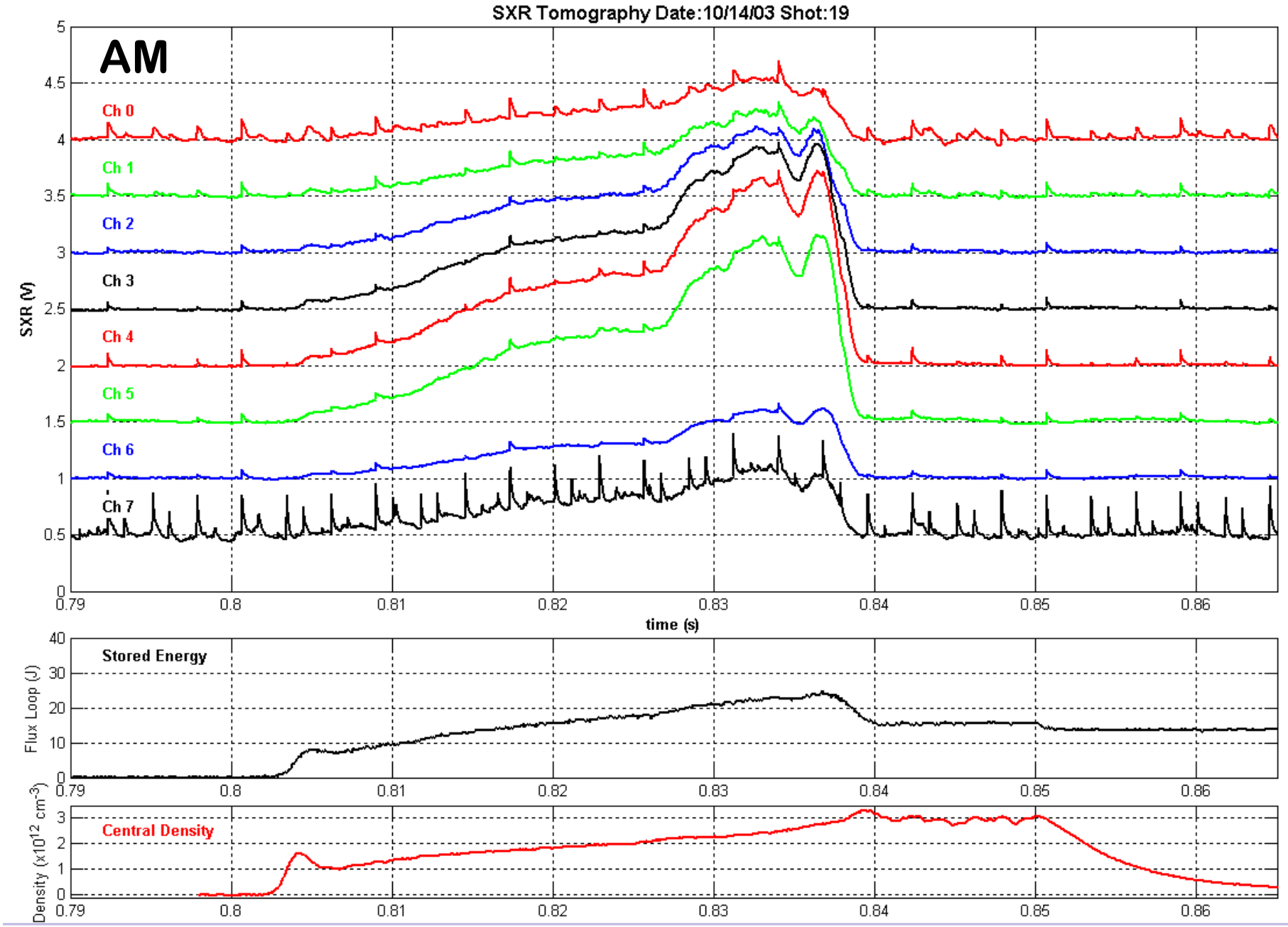
SXR emission peaks at around 5320-5340 A of magnet current

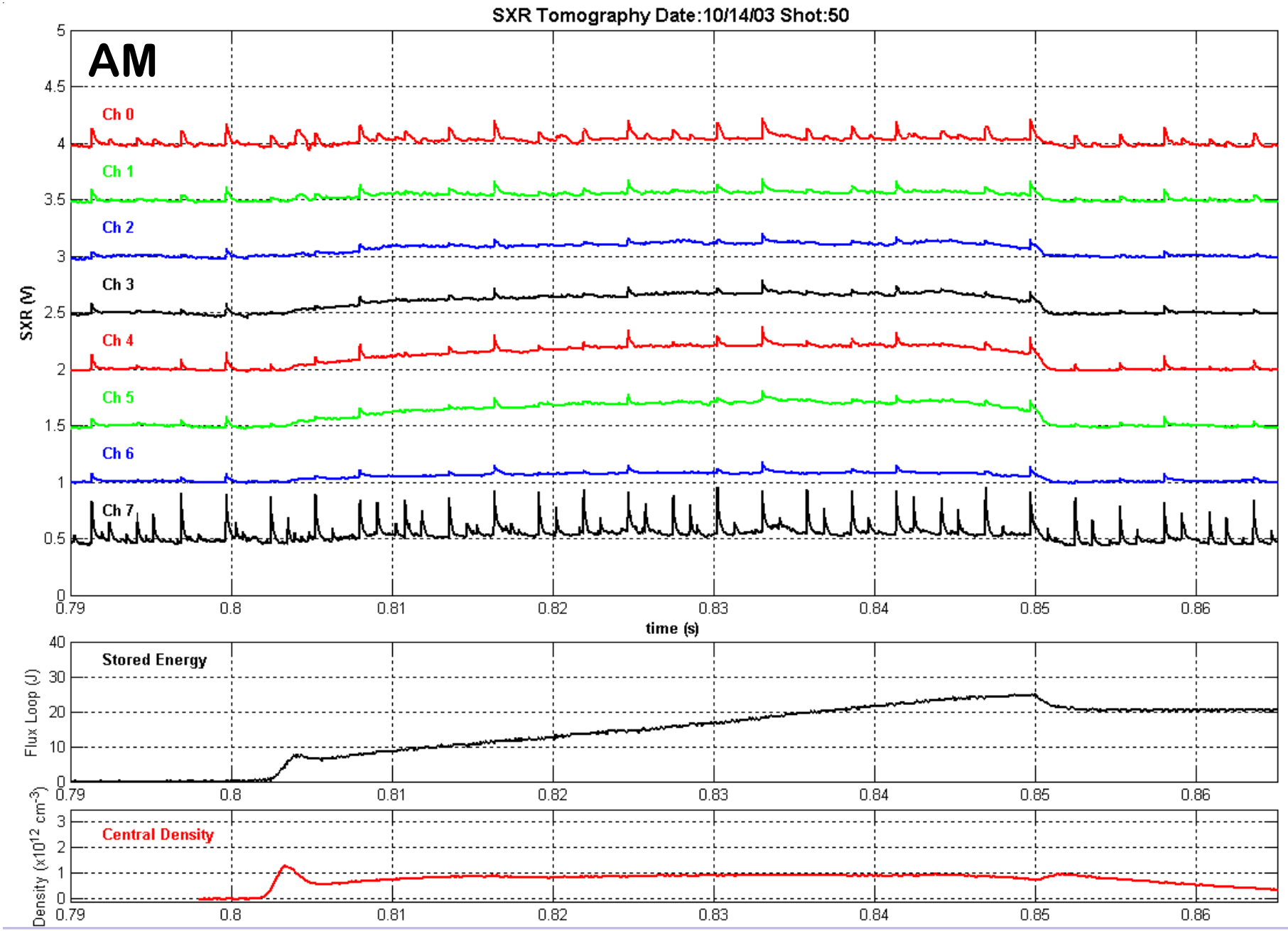
SXR peak corresponds to a slightly inboard resonance location

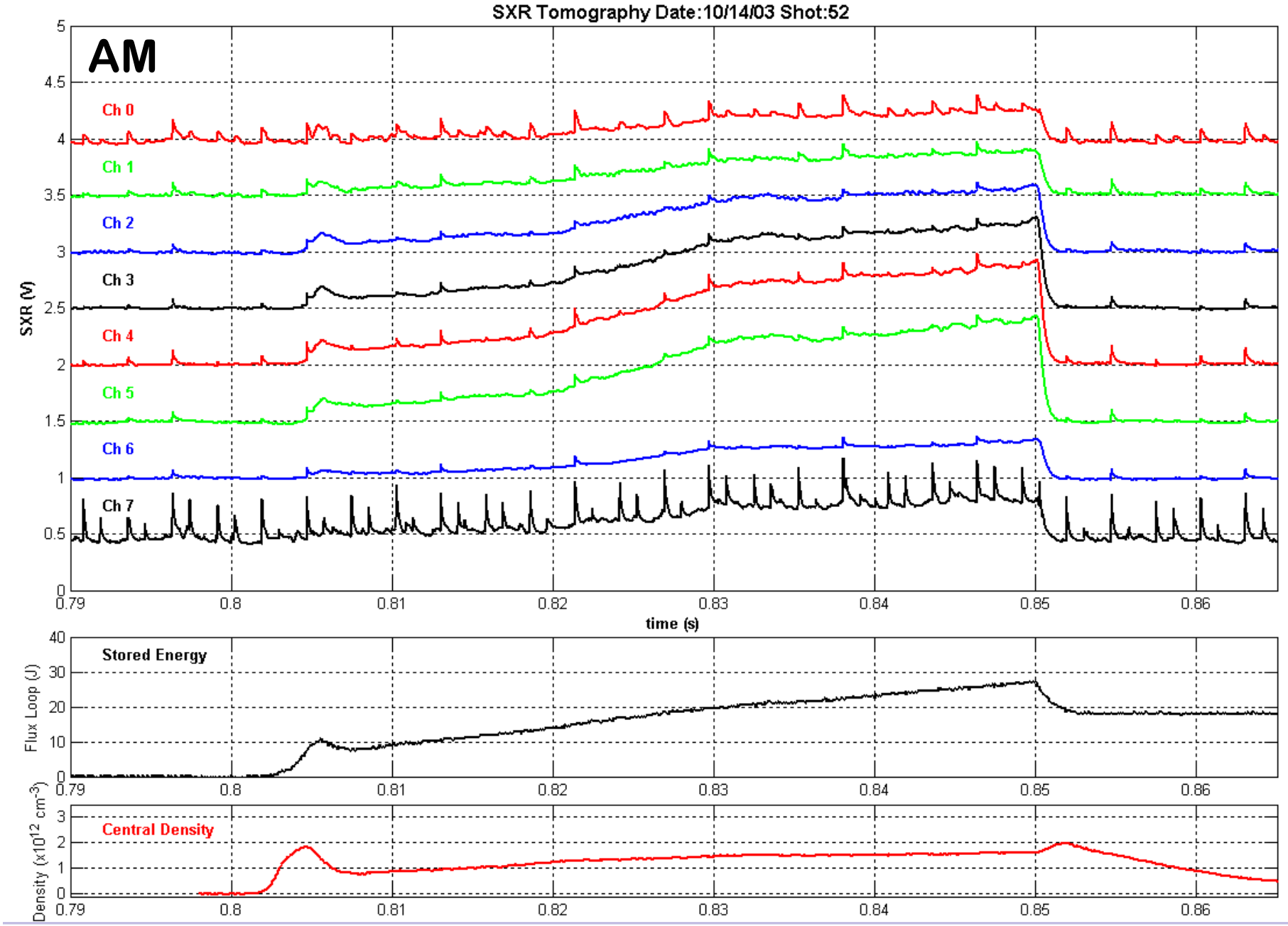




Stored energy shows a small increase as the resonance location is moved inboard


SXR Tomography Date:10/14/03 Shot:19
AM
Ch 0
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
SXR (V)
time (s)
Stored Energy
Flux Loop (J)
Central Density
Density (x10^12 cm^-3)


SXR Tomography Date:10/14/03 Shot:50
AM
Ch 0
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
SXR (V)
time (s)
Stored Energy
Flux Loop (J)
Central Density
Density (x10^12 cm^-3)

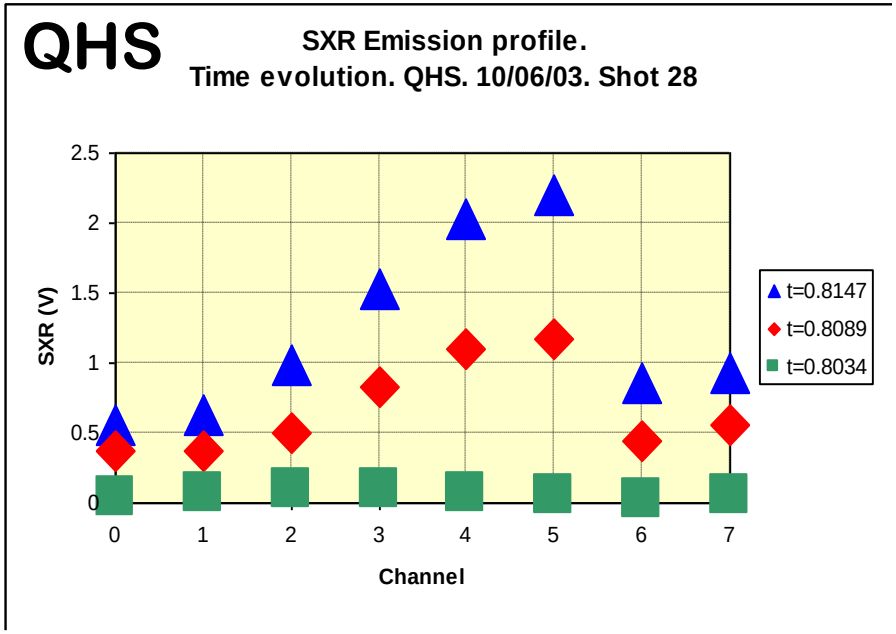

SXR Tomography Date:10/14/03 Shot:52
AM
Ch 0
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
SXR (V)
time (s)
Stored Energy
Flux Loop (J)
Central Density
Density (x10^12 cm^-3)

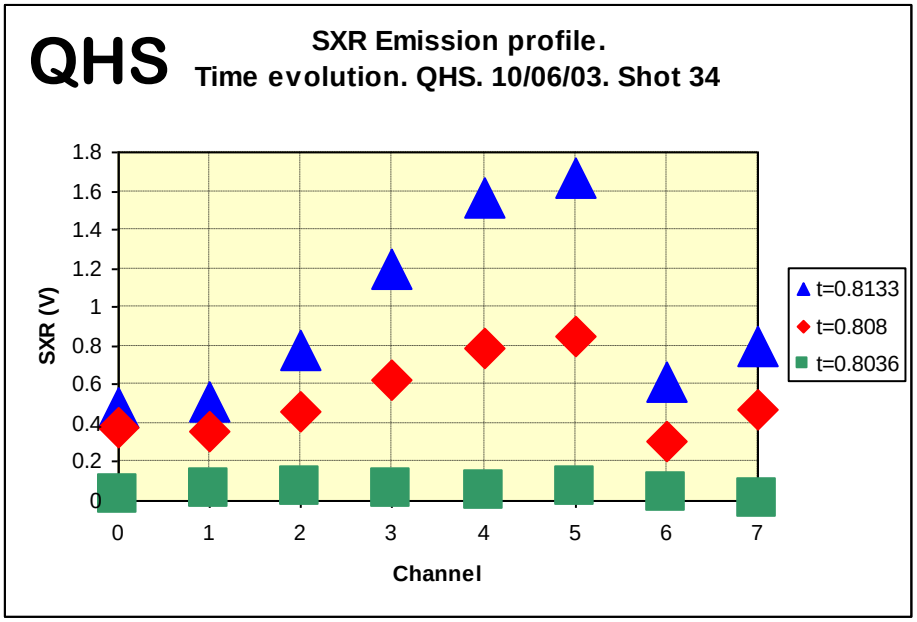
- **Crashing discharges only observed at low densities < 0.7x10^12 cm^-3. Stored energy very stable above that density value.**

- **So far, no phase difference between channels have been observed during a crash**

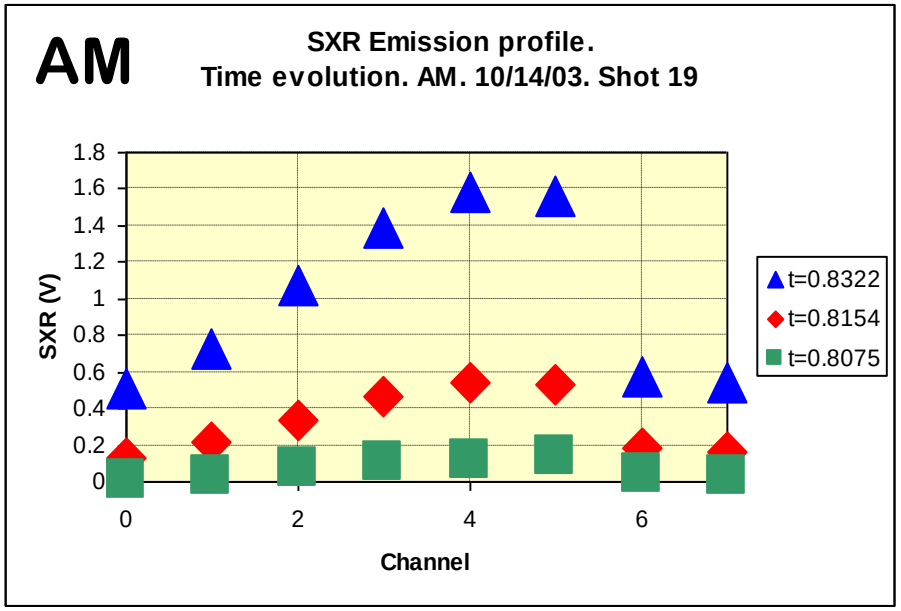
- **Density control more challenging in Anti-Mirror mode**

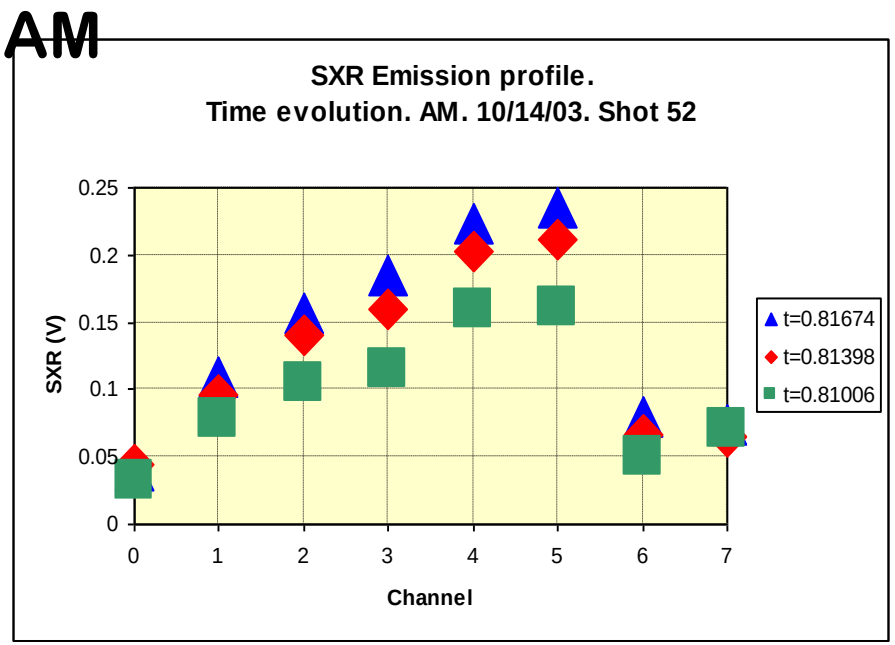
Profile comparison QHS vs Anti-Mirror





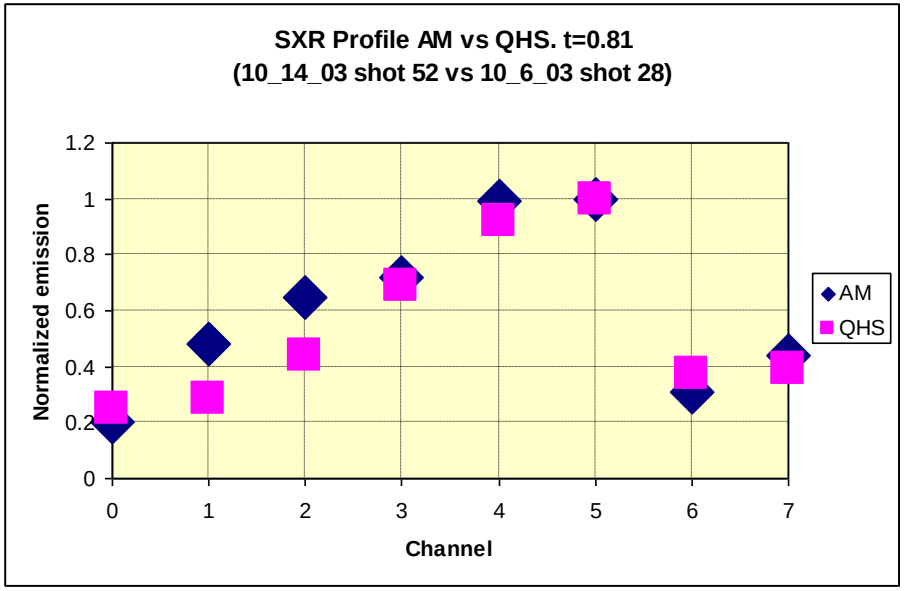
- Maximum intensity of SXR emission in channel 5
- Ch 6 is consistently much smaller than expected

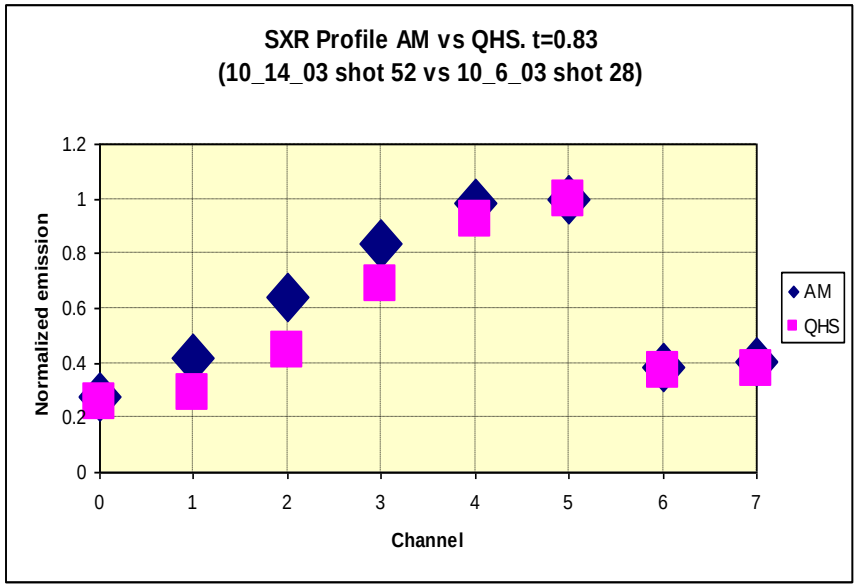


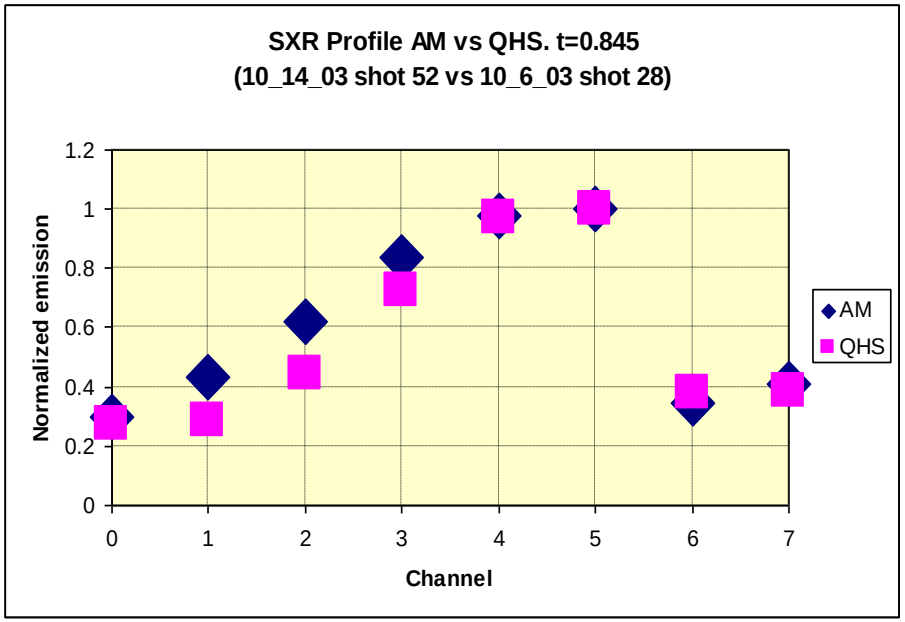


- Maximum intensity of SXR emission in channels 4-5
- Ch 6 is again consistently much smaller than expected (electrical connection?)
- SXR emission profile in Anti-Mirror is much smaller than QHS for same plasma density. Consistent with predicted confinement degradation in Anti-Mirror mode

Profile comparison QHS vs Anti-Mirror

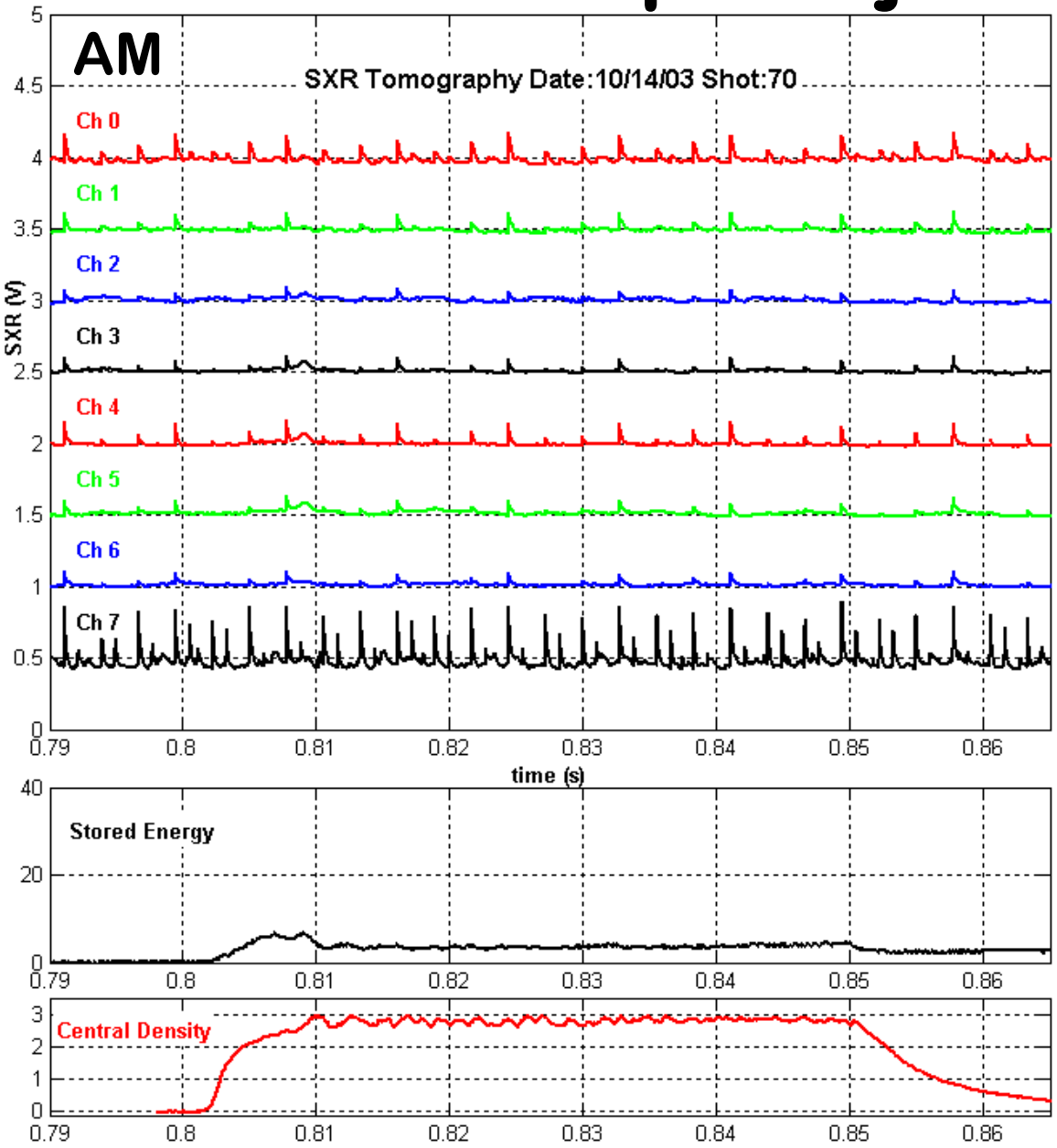


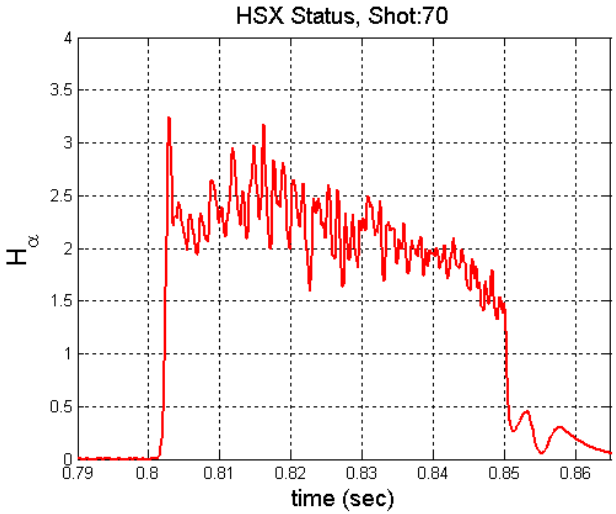




- SXR emission profile is slightly more peaked for QHS than Anti-Mirror mode
- For both modes, the peak of the profile is achieved at channels 4-5

H-alpha rejection





- Signal is not contaminated from plasma H-alpha radiation
- Flash-light test showed small leakage

Summary

- Adequate signal level
- Good visible and H-alpha radiation rejection
- SXR emission in QHS achieves a local peak at a slightly inboard resonance location
- Emission profile is much smaller for Anti-Mirror than for QHS consistent with predicted degradation of confinement
- SXR emission profile in Anti-Mirror mode is slightly broader than in QHS

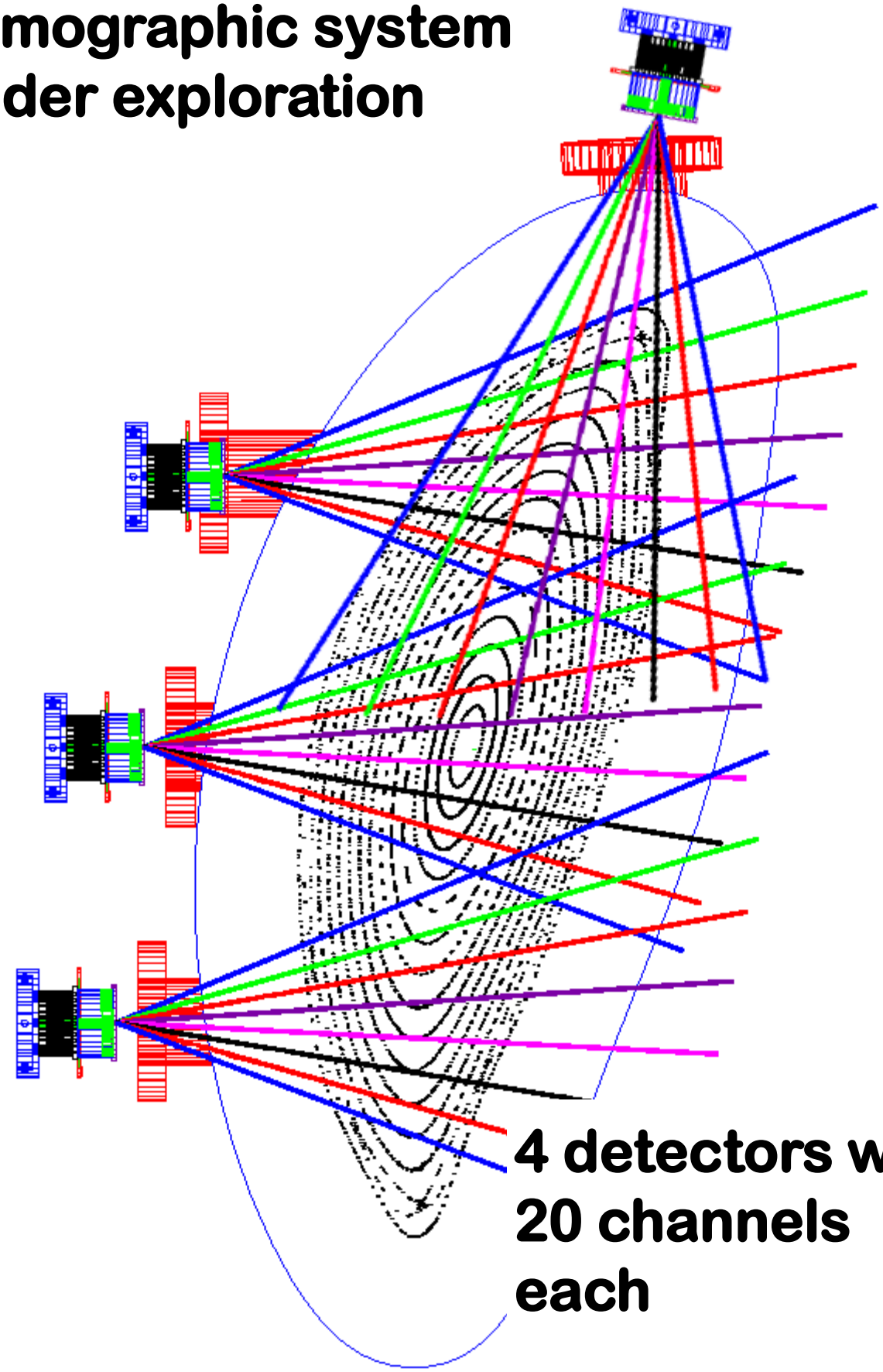
Future Work

- **Better understanding of SXR contribution (impurities, hydrogen, etc) and physics of the possible mechanisms that produce the crashes.**

- **Extend number of channels for tomographic inversion. Currently a 4 detector array is under exploration.**

- **More…**

Tomographic system under exploration



4 detectors with 20 channels each

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