Electron Temperature Measurement Of The Stagnation Column At The Z Facility

A New Proposed Diagnostic

(Application: MagLIF)

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Outline

What Do We Want To Measure?

What Does The Diagnostic Look Like?

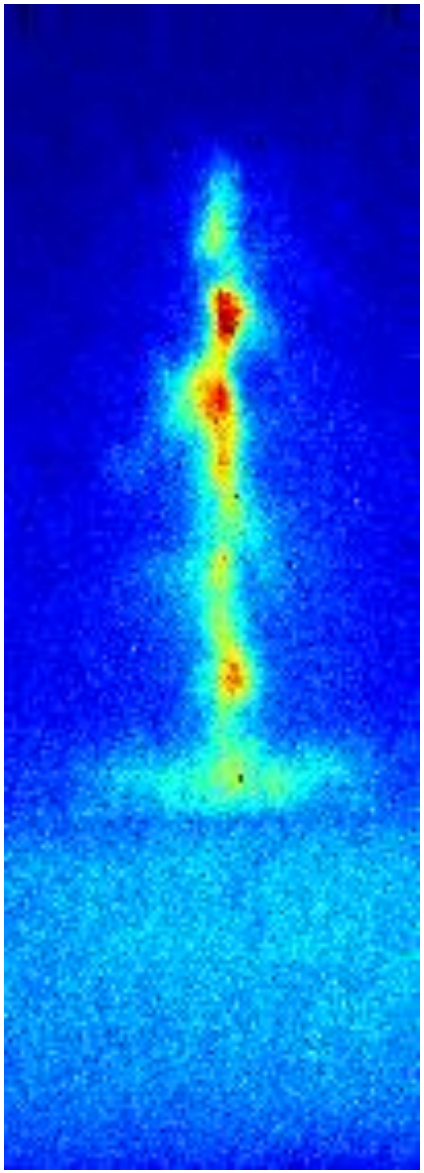
Where Do We Want To Mount The Diagnostic?

How Many Channels Of Data Are Needed?

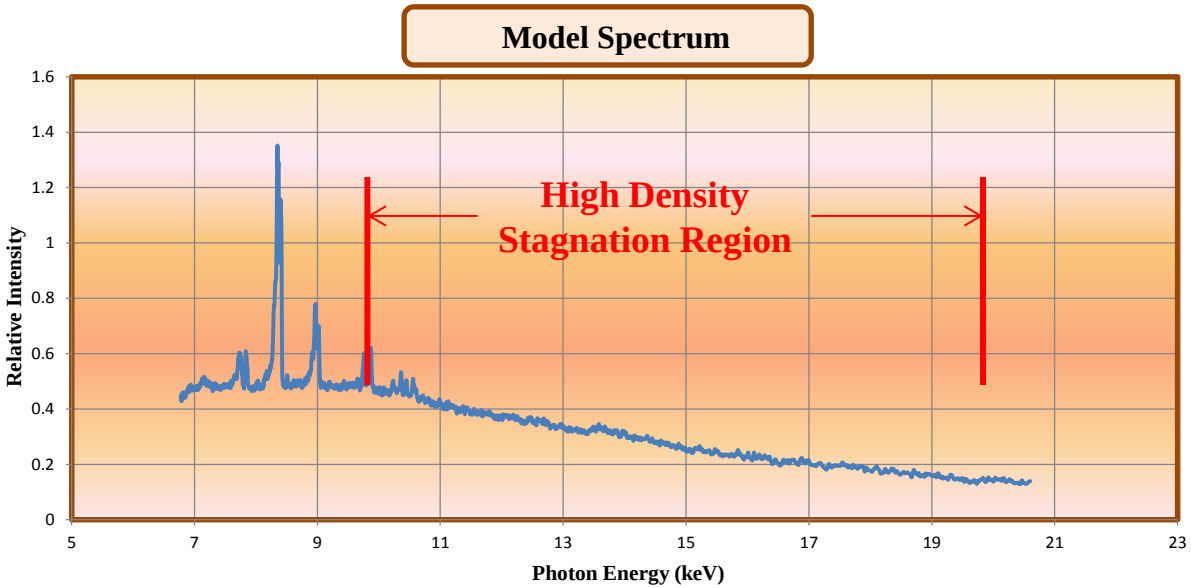
What Signal Level Can Be Expected?

What Do We Want to Measure?
We Want To Measure The Electron Temperature Of The Stagnation Plasma Column

Height Of Column H Depending On Load



Width Of Column: W



Spectrum May Include Spectral Lines Followed By A Continuum Region Depending Upon Hardware Materials. The Stagnation Column May Contain Spectral Lines Complicating Location Of Detector Location Choices.

The Electron Temperature Is Given By The Bremsstrahlung Emission Expression

$$\text{Spectral Emission} \propto \frac{1}{\sqrt{k\,T}} \exp\left(-\frac{h\,\nu}{k\,T}\right)$$

This Term Determines The Spectrum Background Slope.

- **The Electron Temperature Is Given By The Slope Of The Spectrum Background.**

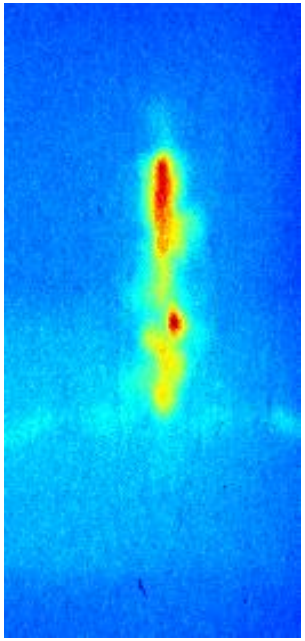
- **One Does Not Need Knowledge Of The Emission Surface Or The Emission Volume.**

- **Initially, One Does Not Need The Amplitude Of The Spectrum Background, Except, Perhaps For A Precision Measurement Using The $1/\sqrt{kT}$ Term To Push The Error Bar To The 20% Level, Or Better.**
  (The Jury Is Still Out On This Possibility.)

What Does The Diagnostic Look Like?
McDAX Model

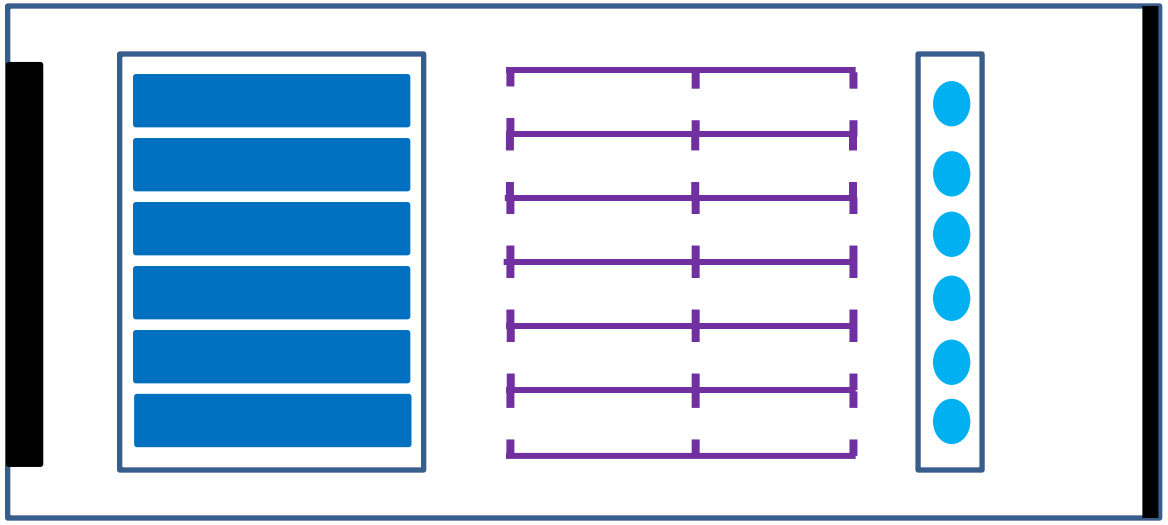
(Monochromatic Dynamic Acquisition of X-rays)

Instrument Consists Of Five Sections



Plasma Stagnation Column

McDAX Housing



Blast Shield Protection

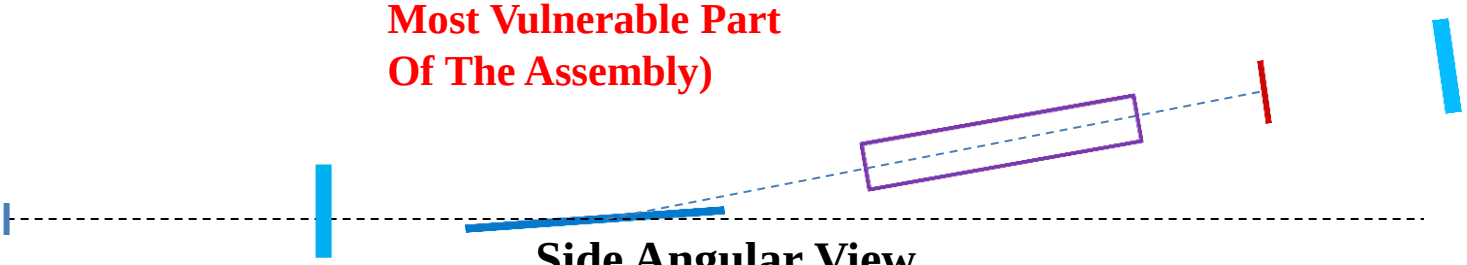
Multilayer Mirror Array

Baffle (Collimator) Array

X-ray Si Diode Array (200 ps)

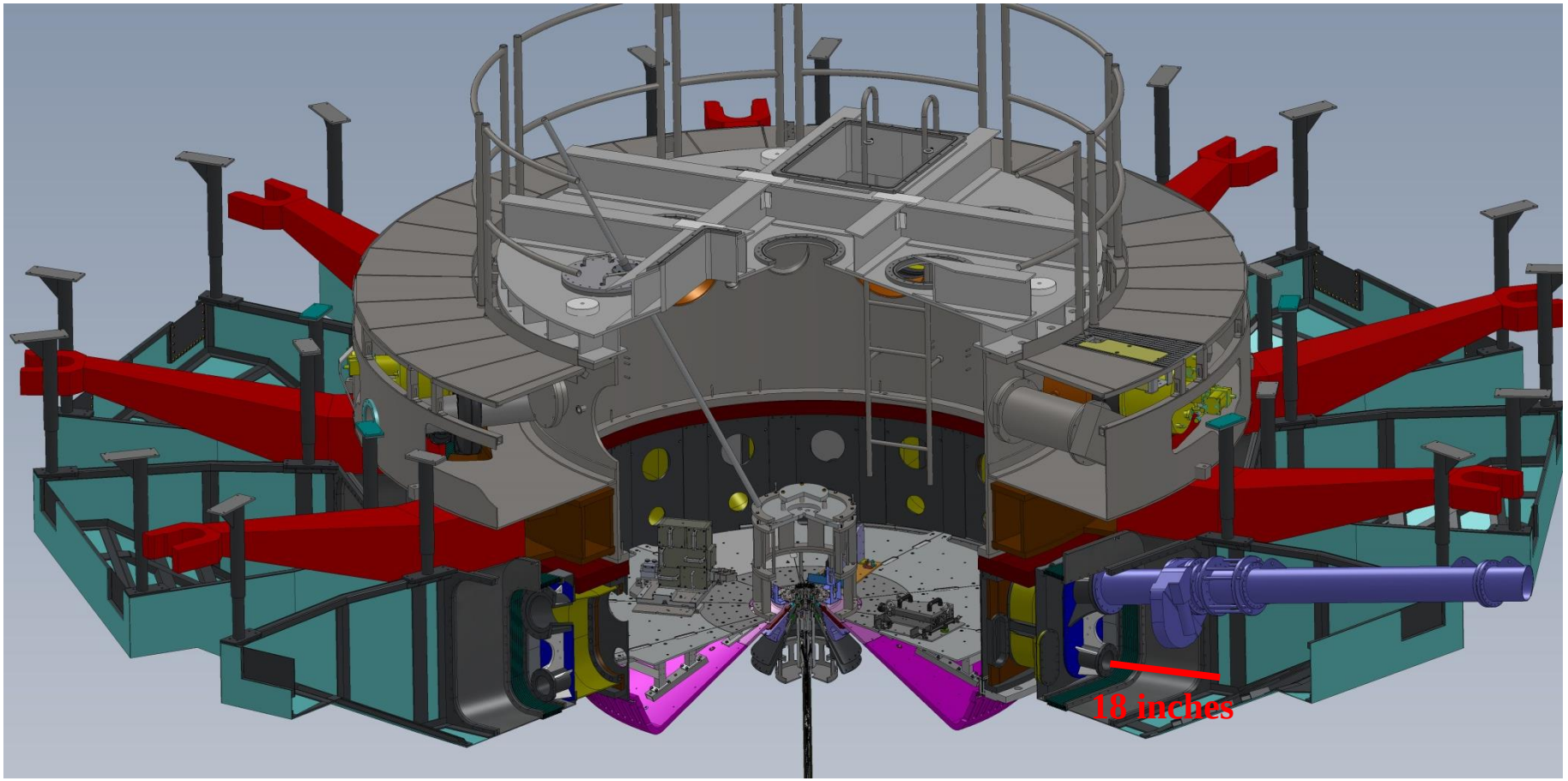
Back Wall Electrical Feedthrough

(Mirror Array Is The Most Vulnerable Part Of The Assembly)



Side Angular View

Where Do We Want To Put The Diagnostic?
It Is Requested That The Instrument Fit Onto A Zero Degree Diagnostic Port Within One Of The Nine Boats Of The Z Facility



The Distance From The Attachment Flange To Interference From The Boat Structure Is Approximately 18 Inches.
<u>Will Probably Require A Rebuild Of The Spool Section Within One Boat</u>.

How Many Channels Of Data Will Be Needed?

Answers To Questions Like:

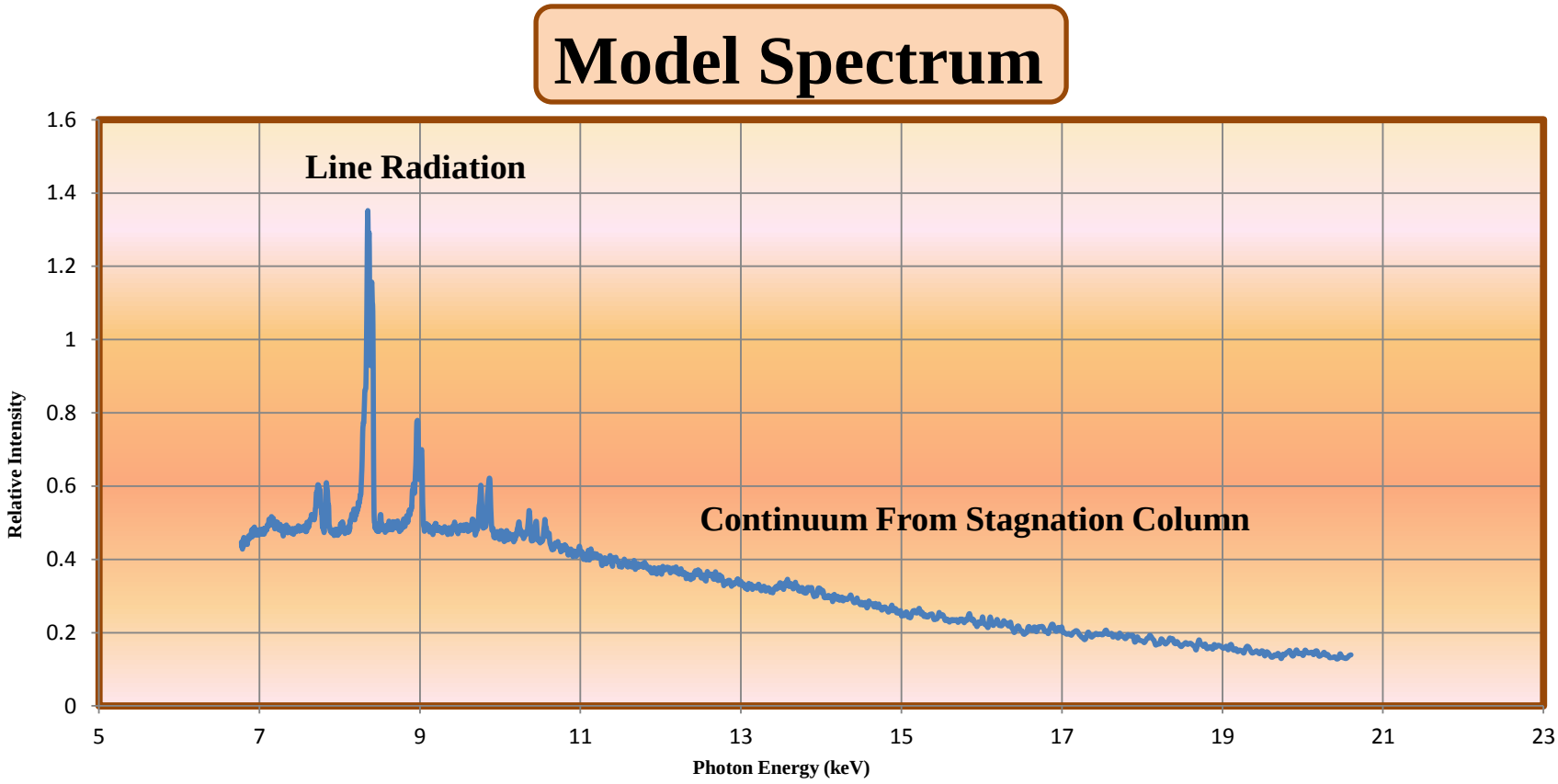
How Many Points Are Needed To Determine The Slope?

Or

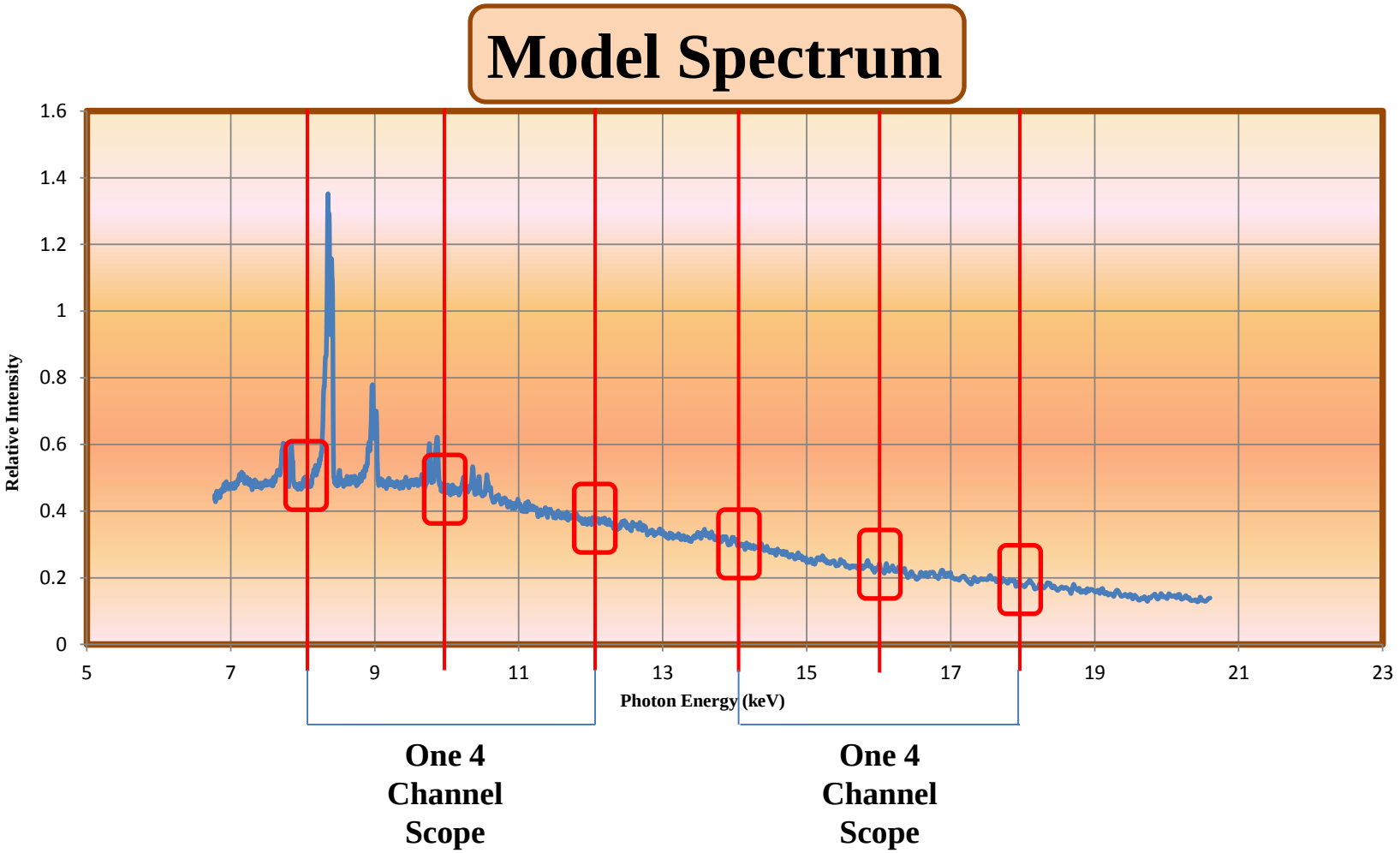
Are We Trying To Fit More Than One Temperature To the Slope?

Will Determine The Number Of Detectors Needed.

Consider A Model Spectrum.



Mirrors With Bandwidths Of 2 keV Can Be Built Covering The Range Of Interest

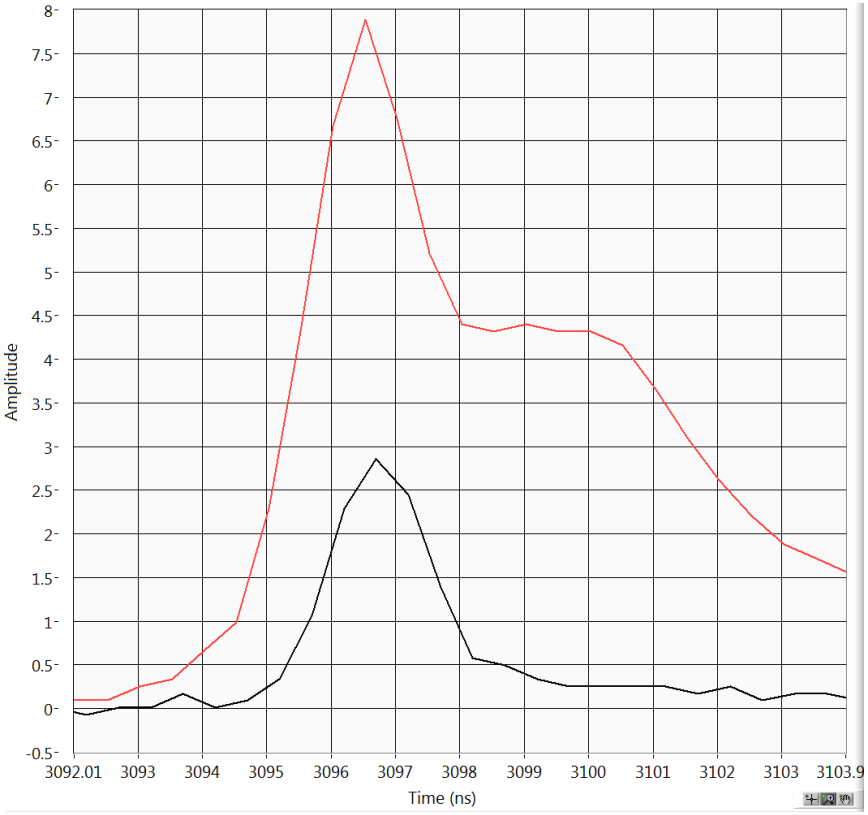


It Is Desirable To Have At Least 6 Energy Bands Along The Continuum Radiation Curve. We Will Select The Range 8 – 18 keV (Or Maybe Higher)

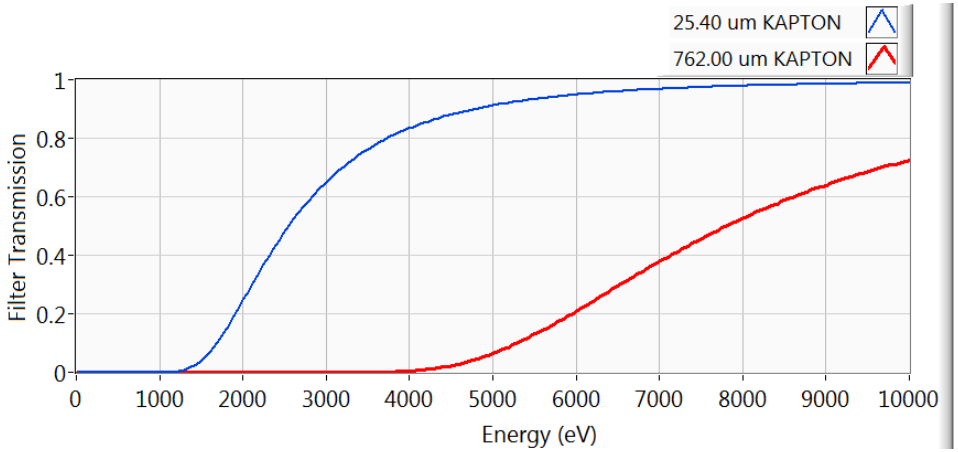
Time History Within Each Band Is Furnished By X-ray Si Diodes.

What Signal Level Can Be Expected?

Consider The Following Diode Measurement From A Recent Z Shot.



Diode Located 18 m From Load On LOS 50



Filter Transmission*Collection Solid Angle*Radiated Power*Diode Response*50Ω = Scope Signal

$0.95 * 8.64 \times 10^{-10} * RP * 0.23 A/W * 50\Omega = 7.89V$

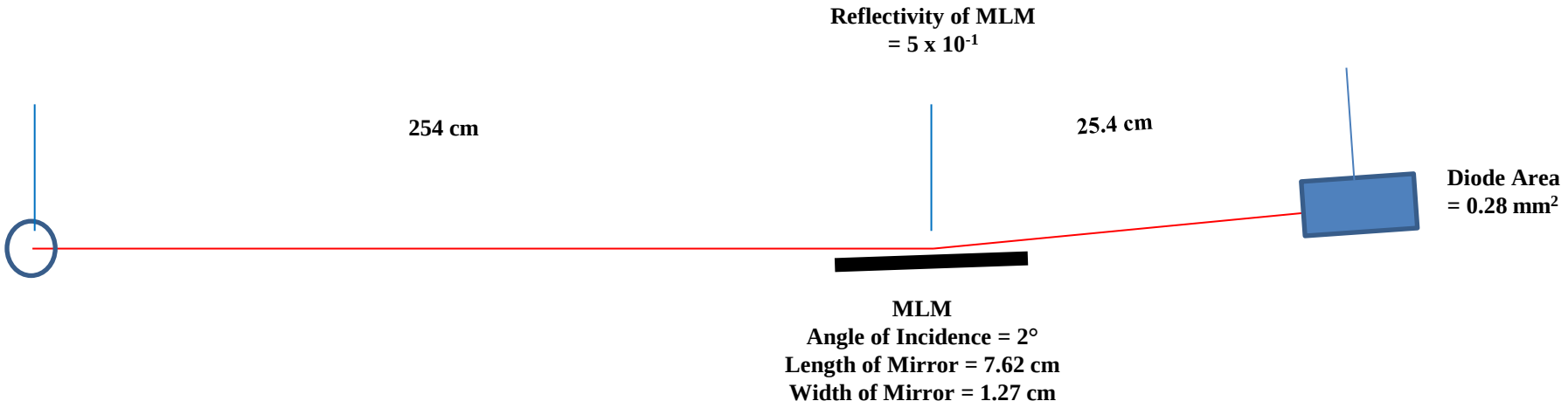
0.35 2.85

→ **$RP = 8.36 \times 10^{8}$ watts/sr** (20 J for a 2 ns pulse)

8.20

What Would The Corresponding Signal Have Been For McDAX?

The Collection Solid Angle For McDAX



Collection Solid Angle Defined By MLM

$$\Omega = 1.27 * 7.62 * \sin(2°) / (254 * 254) = 5.235 \times 10^{-6}$$

Collection Solid Angle Defined By Diode

$$\Omega = 0.28 / (2794 * 2794) = 3.6 \times 10^{-8}$$

The Si Diodes Will Define The Collection Solid Angle Of The Instrument.

Bandwidth Of The McDAX Detector System

(An Approximation)

Multi-Layer Mirrors can be built with a bandwidth of ± 1 keV (2 keV) spread over the length of the mirror.

The projection of the mirror is: $7.62 \sin(2°) = 0.2659$ cm

The projection of the diode is: $0.28\ mm^2 = \pi r^2 \rightarrow r = 0.29854$ mm

$\rightarrow 2r = 0.0597$ cm

$\longrightarrow$ Bandwidth of Detector System = (0.0597/0.2659) * 2 keV = 449 eV

Detailed Ray Tracing Is Required To Determine The True Bandwidth Of The System.

Scaling The Recent Shot Results To McDAX Gives:

Mirror Reflectivity * Solid Angle * RP * Diode Response * 50Ω * Bandwidth = Scope Voltage

Spectral Range of Recent Shot Was 10 keV (more or less).

→ **$5 \times 10^{-1} * 3.6 \times 10^{-8} * 8.36 \times 10^{8}$ W/sr * 0.23 A/W * 50Ω * 450/10000 = 7.79V**

Hence,
The Typical Diode Signal For McDAX Located On A Zero Degree Diagnostic Port Will Be About The Same Order Of Magnitude As The Diode Located On LOS 50.

The Design Requirements For McDAX
Are Being
Assembled And Assessed.

Commissioning Is Anticipated For The End Of

Calendar Year 2016
Or Early 2017

(***Coming To A Z Facility Near You***)