Diamond Bremsstrahlung Radiator Assessment using X-ray Topography at CHESS

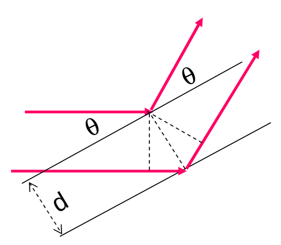
R.T. Jones [1], I. Senderovich [1], K. Finkelstein [2], F. Klein [3], and P. Nadel-Turonski [3]

Diamond Requirements

- Minimum size: **5 mm x 5 mm**
- Orientation: **[100]**
- Orientation error: **5° maximum**
- Mosaic spread: **20 μr r.m.s. maximum** (integrated over the whole crystal)
- Thickness: **20 μm maximum**
- Variation in thickness: **±5 μm maximum**

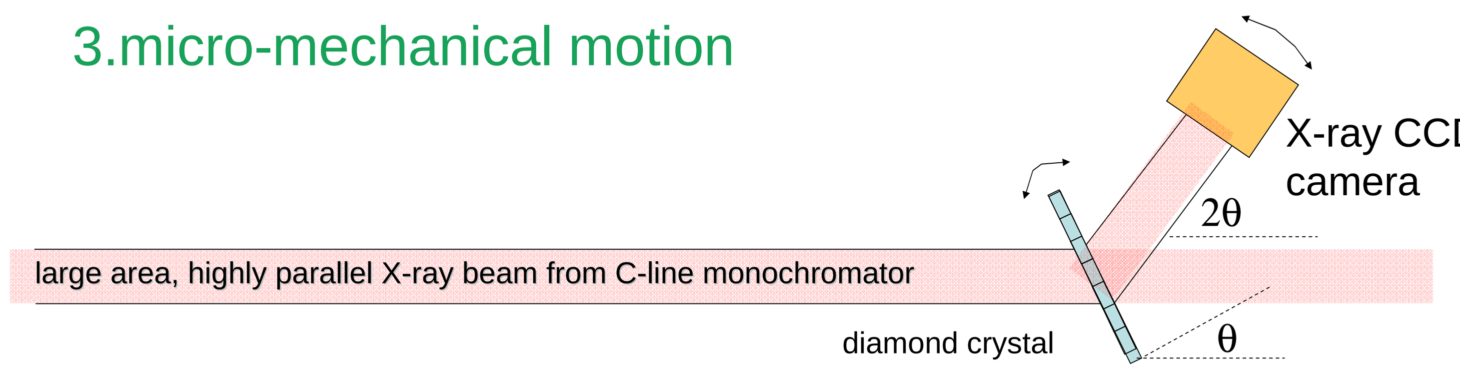
Extracting mosaic spread from X-ray rocking curve peak widths

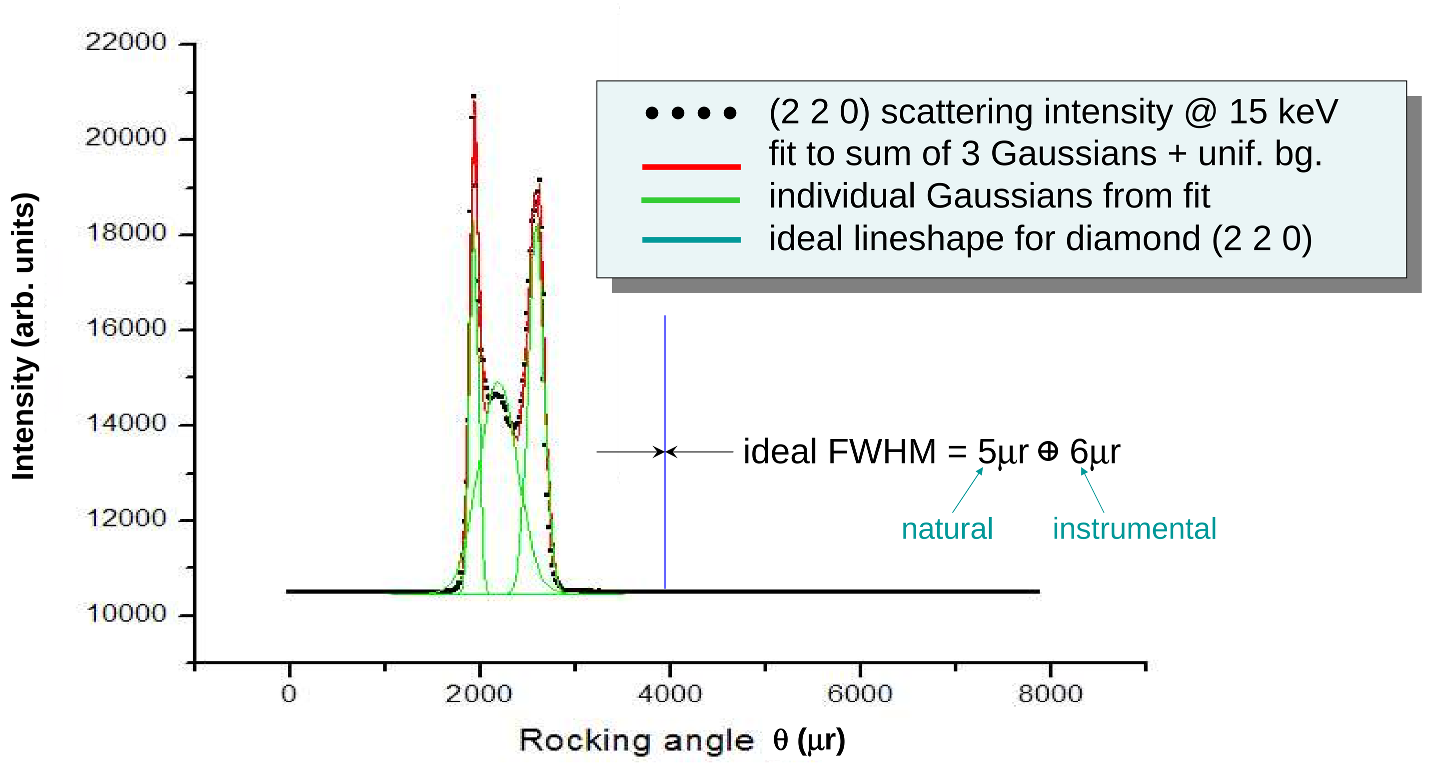
$$\lambda = 2\, d \sin(\theta)$$



crystal sources
1. natural width + impurities
2. mosaic spread
3. micro-mechanical motion

instrumental sources
1. energy spread of beam
2. divergence of beam





Abstract

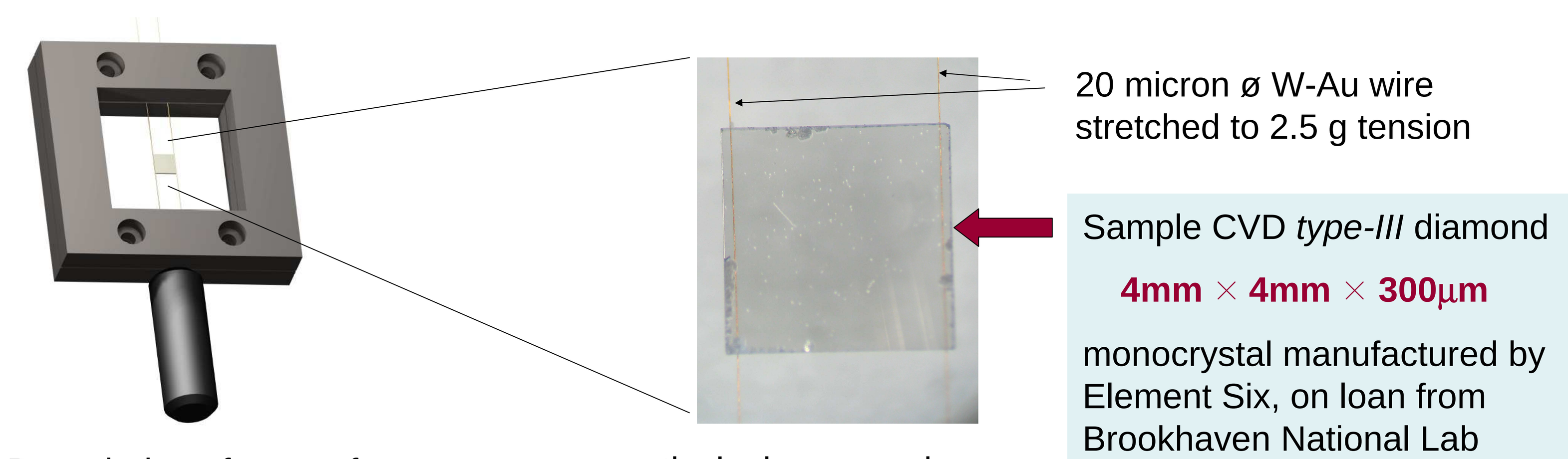
Rocking curve topographs of large diamond monocrystals were taken using the CHESS C-line. These diamonds are needed for use as bremsstrahlung radiators to produce 9 GeV polarized photons for the GlueX experiment at Jefferson Lab. The requirements for the diamond radiators for GlueX, in terms of their very small whole-crystal mosaic spread and their small thickness, together with the restrictions on how they can be mounted within from the intense electron beam environment in which they must operate, demand significant advances over what is established practice at existing coherent bremsstrahlung facilities. Up to the present, such facilities have relied on well-established source of high-quality diamonds of sufficient area (natural gems, HPHT synthetics) but advances in diamond monocrystal growth using chemical-vapor deposition (CVD) have been reported by the leading vendor Element Six. The GlueX group obtained one of these so-called *type-III* diamonds on loan from the Brookhaven National Laboratory Instrumentation group. This sample was mounted using established techniques and rocking curve measurements were taken. Initial results showed rocking curve peak widths much larger than that expected for perfect diamond, but investigation showed that this was caused by micro-mechanical vibrations in the mount. Once these vibrations were eliminated, near-perfect rocking curve peaks were observed for the entire area of the sample.

Goals for the May 2009 run:

1. Measure mosaic spread of new type-III CVD diamond monocrystal from Element Six.
2. Investigate contribution to rocking curve width stemming from mechanical mounting effects.
3. Measure the effects of radiation damage on a used diamond radiator from Jefferson Lab.

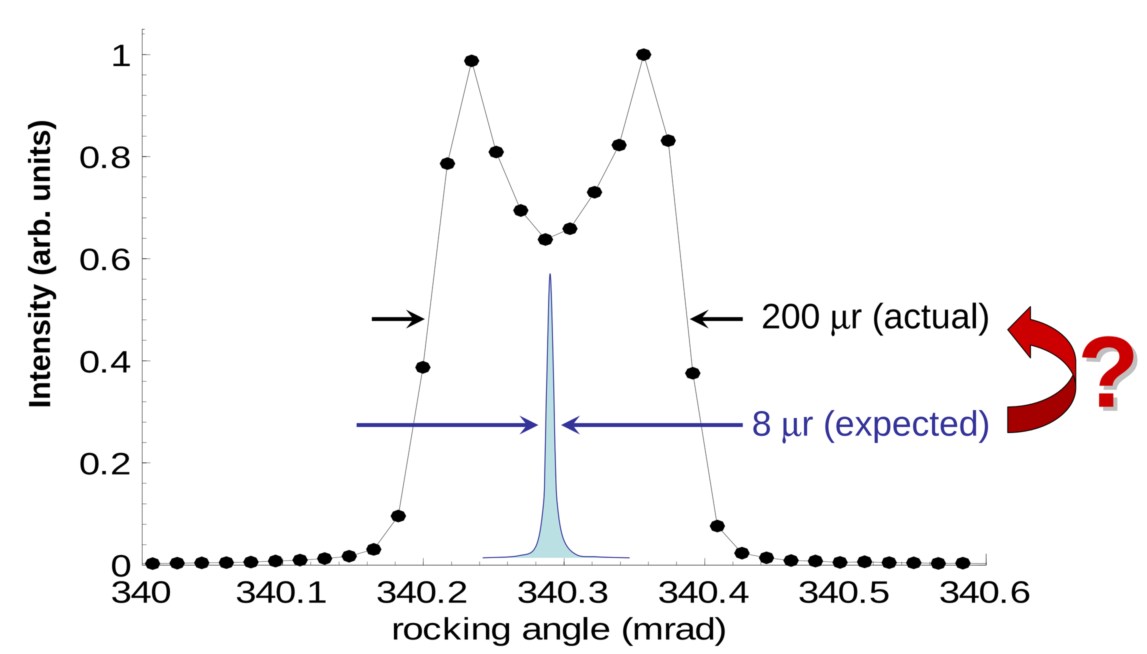
Diamond mechanical mount

1. Must have "zero" material within ± 5 mm around crystal
2. Concept: massive "picture frame" + fine wires + glue



CAD rendering of mount frame — optical microscope image

First look at CVD diamond: (2 2 0) reflection

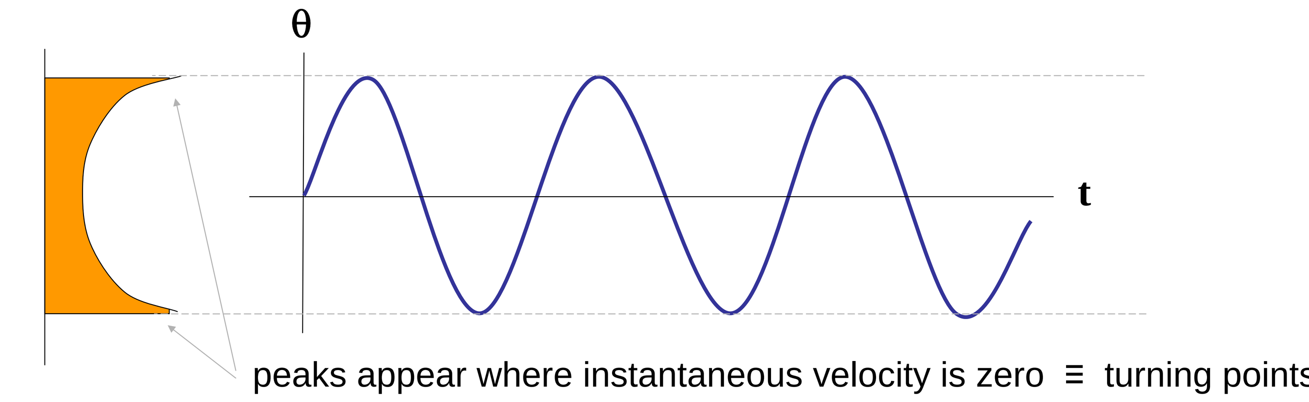


Possible explanations considered:
- broad energy spectrum or large divergence from the monochromator.
- large mosaic spread in the diamond.
- large mechanical strain in the diamond (e.g. thermal, bending strains).
- **micro-mechanical motion of the sample.**

not considered in the past, but suggested by rocking curve shown !

This work is supported by the United States Department of Energy through the Thomas Jefferson National Accelerator Facility, and by the National Science Foundation through grant no. DMR0225180.

Consider: a simple oscillator model

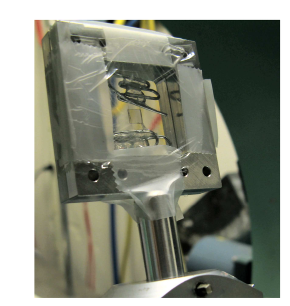


± 100 μr ⇨ ± 200 nm motion at crystal edges: ***too small to see by eye!***

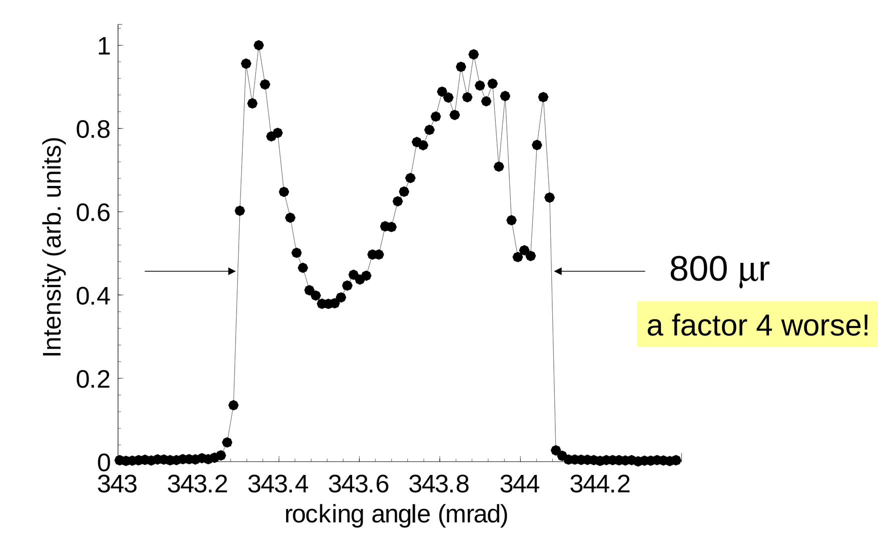
Possible sources of vibrations:

1.	QM zero point motion (just for fun)	**6.4×10^{-14} radians**
2.	Boltzmann thermal motion	**1.7×10^{-8} radians**
3.	Ambient goniometer vibration	*spectrum unknown*
4.	Ambient vibration resonance-enhanced	**fundamental ~200 Hz**

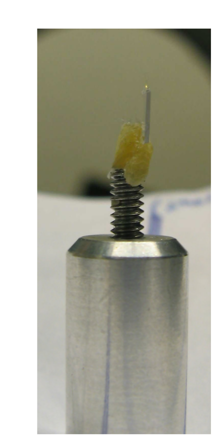
Test of #4: shift the mechanical resonance of the mount, rescan the rocking curve



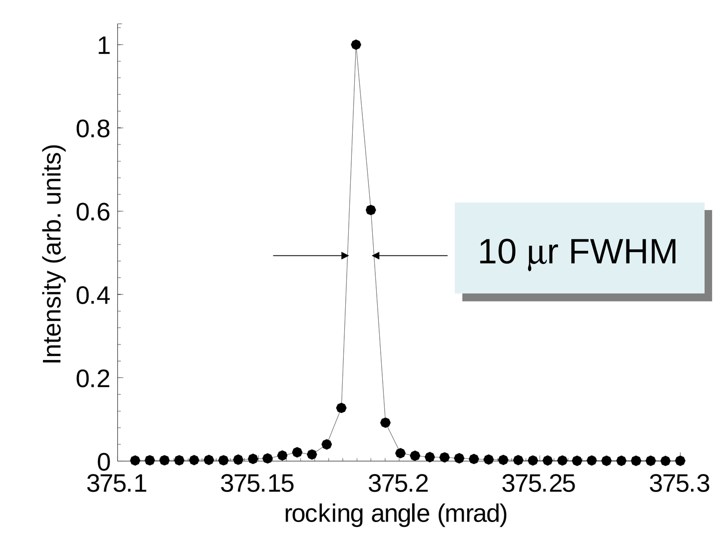
Loading the wires with extra mass shifts down the frequencies of the fundamental resonances.



Test of #3: decouple/damp goniometer vibration using a "soft mount" (wax)



Diamond is pressed into a lump of soft wax and mounted on a stiff post.



Conclusions

Rocking curve measurements show that the intrinsic mosaic spread of the new generation of type-III diamonds from Element Six meets the requirements for the GlueX experiment. Mounting a diamond radiator on thin wires attached to a massive frame, as is the current practice at Jefferson Lab and is subject to micro-mechanical vibrations that completely obscure the natural rocking curve width of the diamond, leading to rocking curve widths that are an order of magnitude larger than the GlueX requirements. Thermal vibrations alone are not sufficient to explain these large oscillations. They are not due to an accidental resonance of the diamond mount with some noise source present in the area where the measurements were carried out. Once a way is found to mount the diamond that eliminates or damps the oscillations to a negligible level, further studies will be necessary to show that narrow rocking curves are possible with much thinner diamond samples.

[1] University of Connecticut, Storrs, CT
[2] Cornell University High Energy Synchrotron Source, Ithaca, NY
[3] Catholic University of America, Washington DC