Diamond Radiator Assessment

using rocking-curve topography at CHESS

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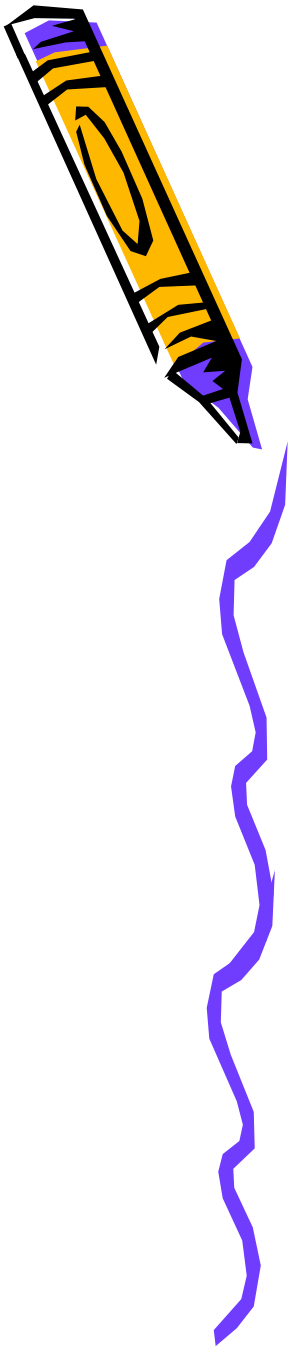
BNL, July 7, 2009

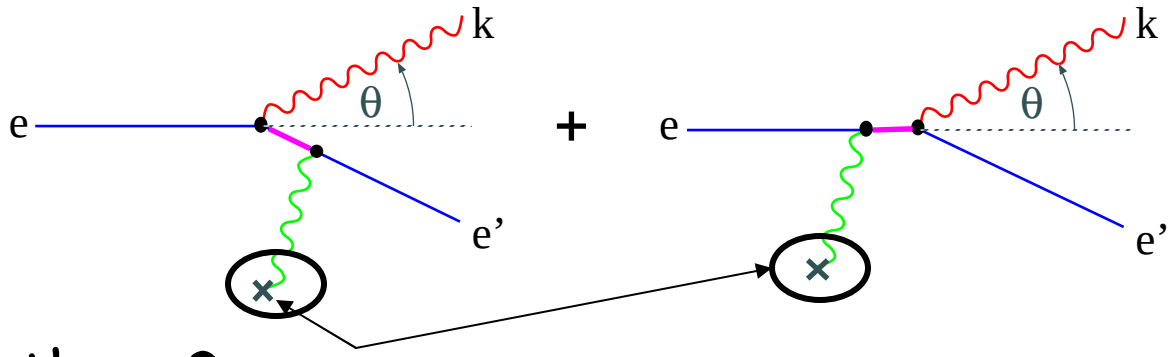
Outline



- coherent bremsstrahlung source
- diamond radiator requirements
- X-ray rocking curve measurements
- interpretation of the diffraction data
- status and outlook

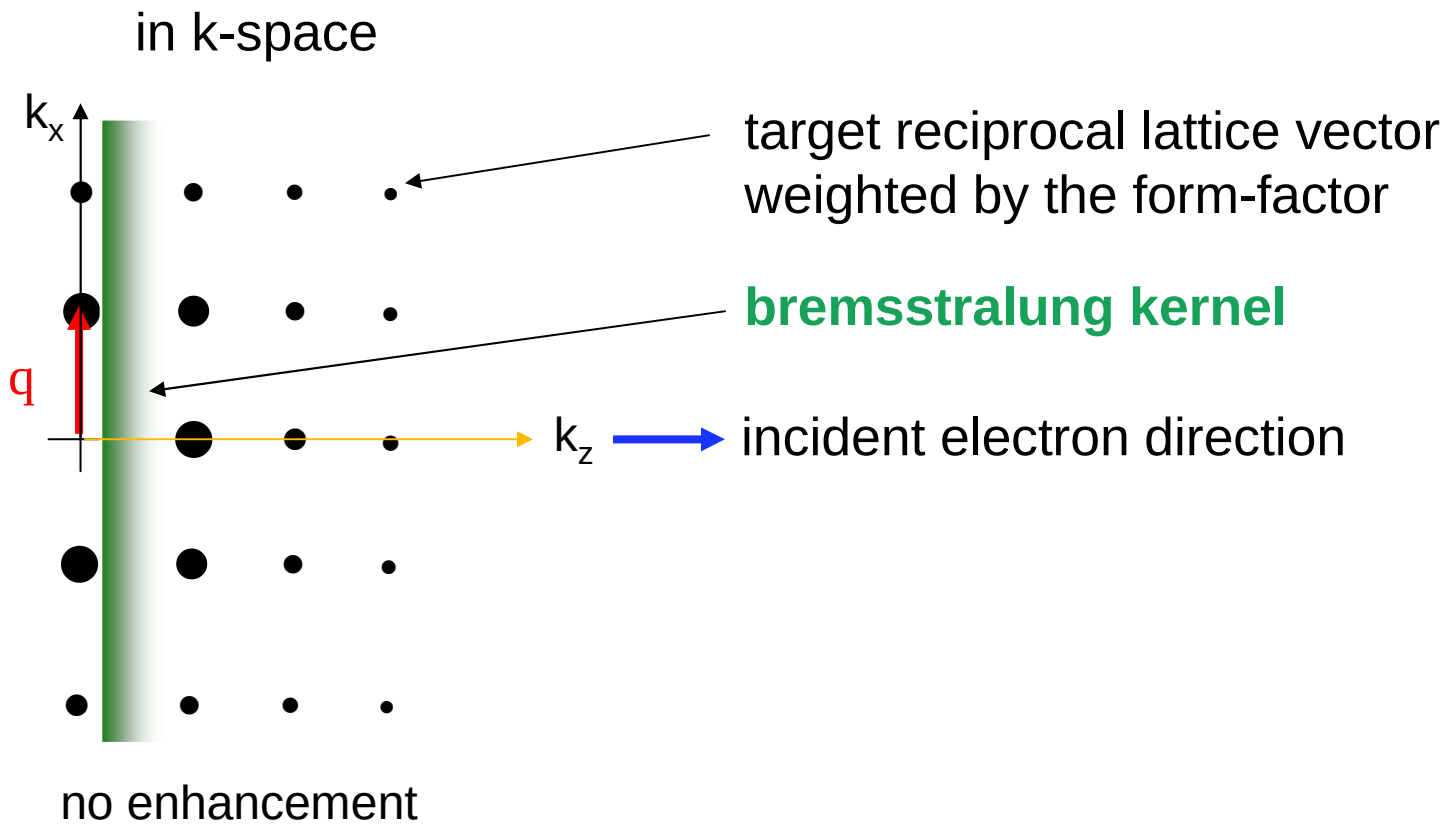
coherent bremsstrahlung

- Compton scattering of a high-energy electron

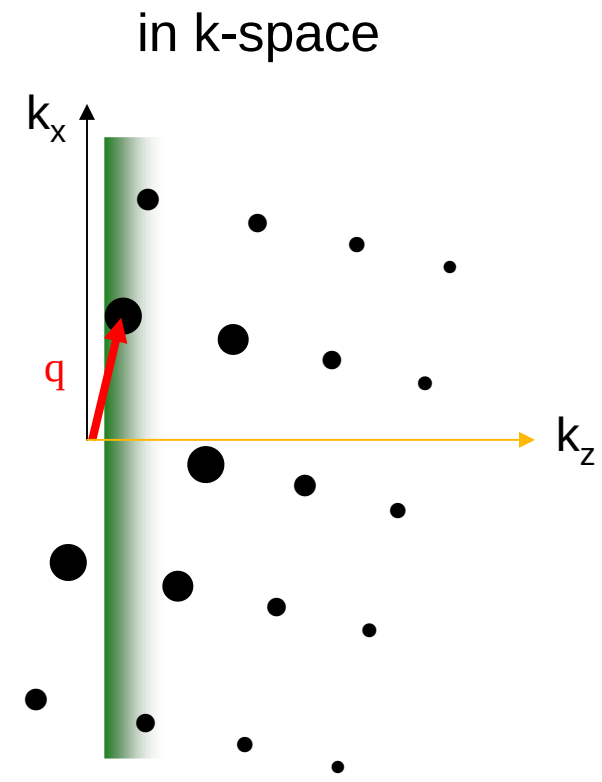


- What is the ×?
  1. real photon – Compton backscatter source
  2. virtual photon – bremsstrahlung source
  3. coherent virtual photon – coherent bremsstrahlung source

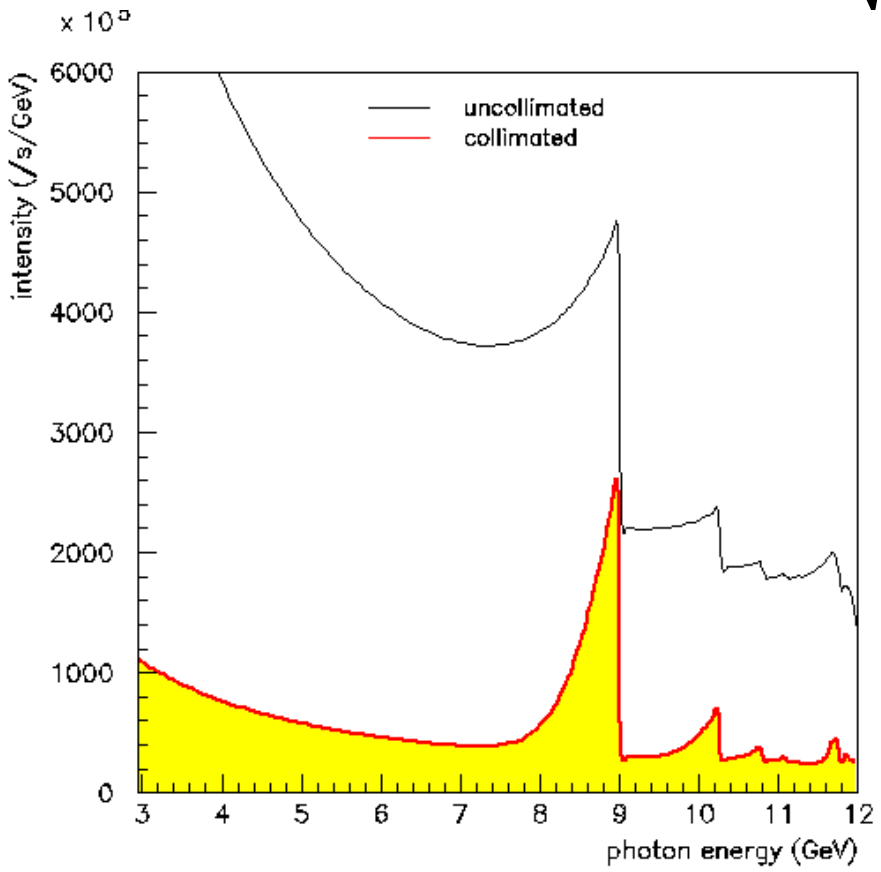
coherent bremsstrahlung



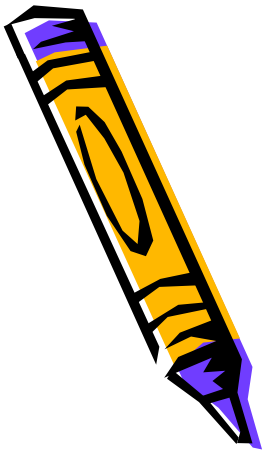
coherent bremsstrahlung



strong enhancement

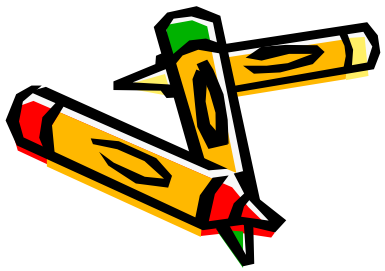


coherent bremsstrahlung



- requirements for a crystal radiator
  1. low-Z (large atomic form factor at q_{min})
  2. large S-factor (dense packing in unit cells)
  3. large Debye temperature (coherent yield)

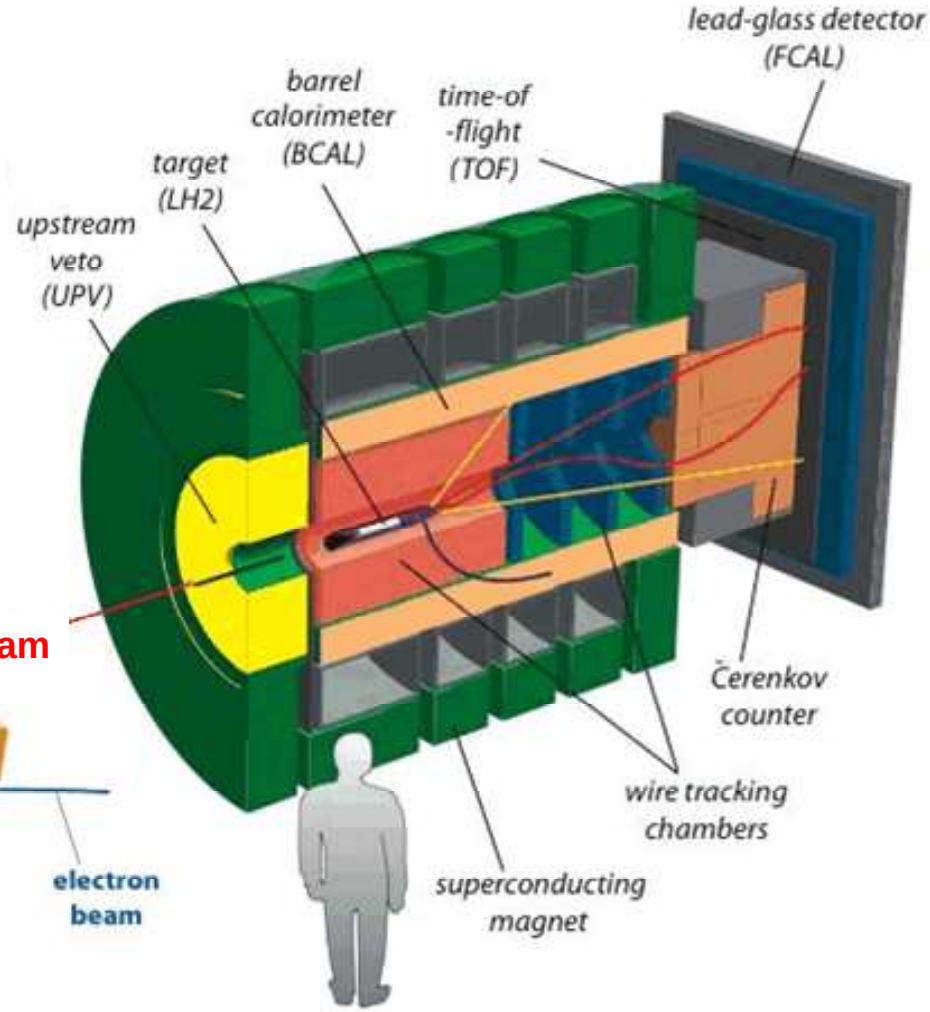
element	*best reciprocal lattice vector*	*P/P(diamond)*
diamond	2 2 0	**1.00**
beryllium	0 0 2	**0.86**
boron	2 0 8	**0.38**
silicon	2 2 0	**0.19**

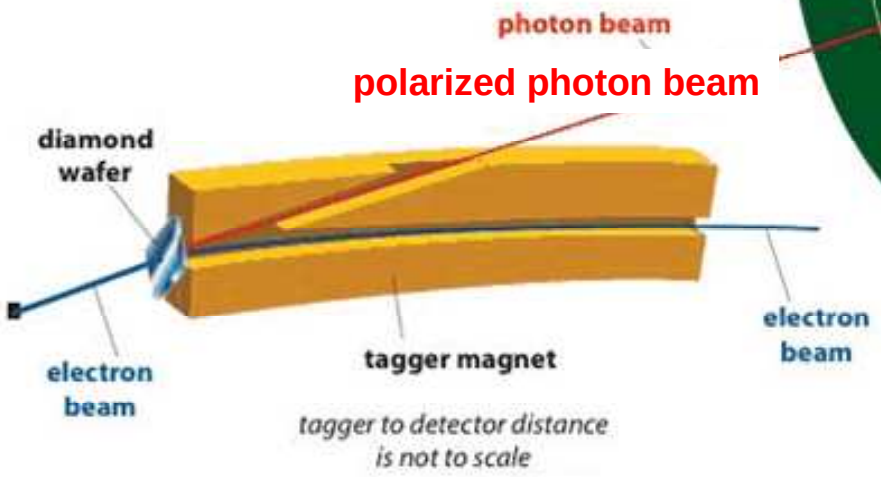


the GlueX experiment: JLab @ 12 GeV

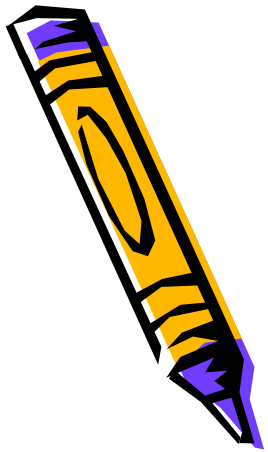
Physics Goal:
To measure the complete spectrum of hybrid mesons in the light-quark sector and to determine their decay properties.

Construction: 2010-2013



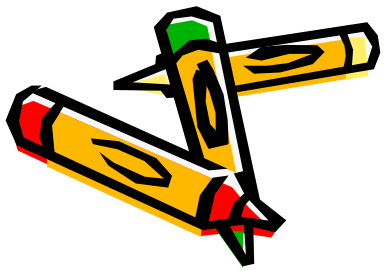


the GlueX experiment



- 12 GeV electron beam
  - Jefferson Lab Accelerator Division
- 9 GeV polarized photons from CB source
  - the GlueX photon beam working group

Richard Jones – University of Connecticut
Franz Klein, Dan Sober – Catholic University of America
Yang Guangliang – University of Glasgow
Jim Stewart – Brookhaven National Lab



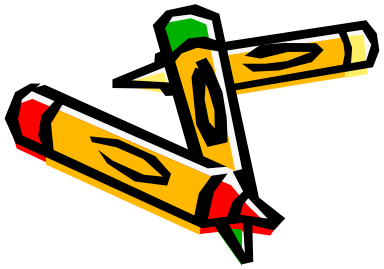
the GlueX experiment

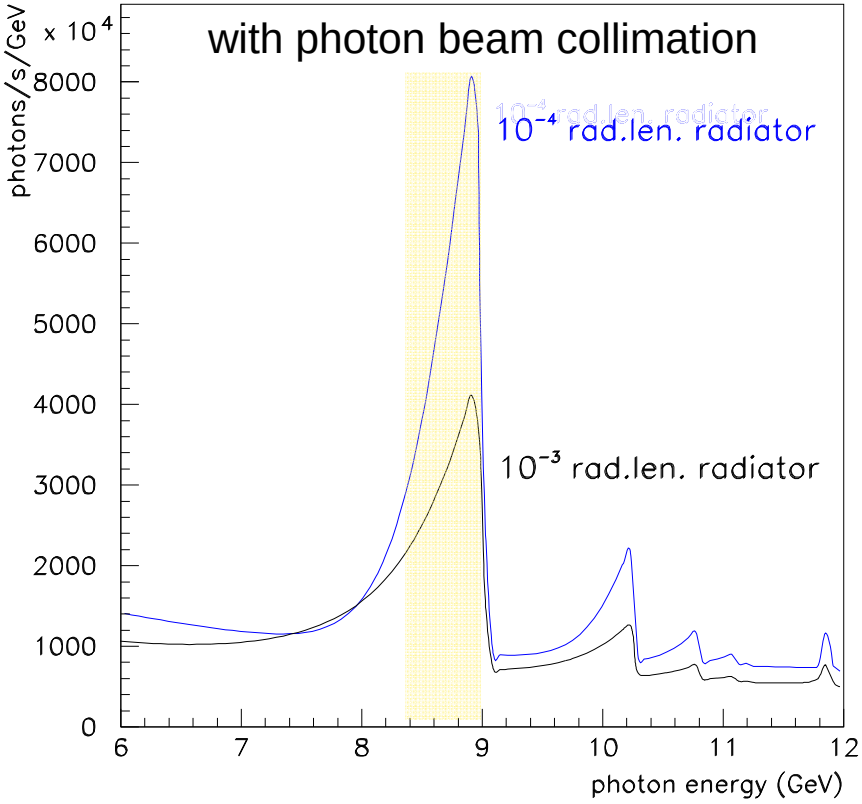
- **diamond radiator requirements**
  - large area

    0.25 – 0.5 cm²
  - low mosaic

    20 μr r.m.s.
  - thin (relatively)

    20 μm
  - self-supporting



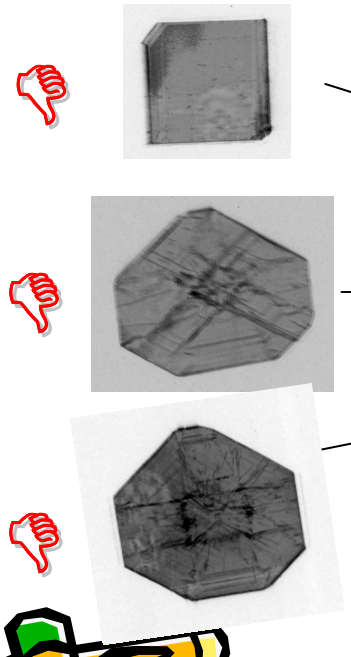


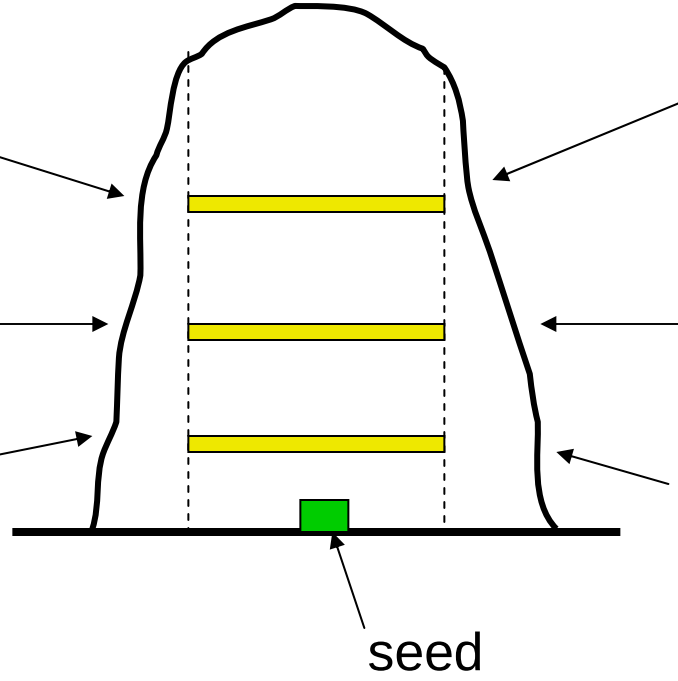
state-of-the art synthetic diamonds, ca. 2002

obtained from Element Six, subsidiary of DeBeers

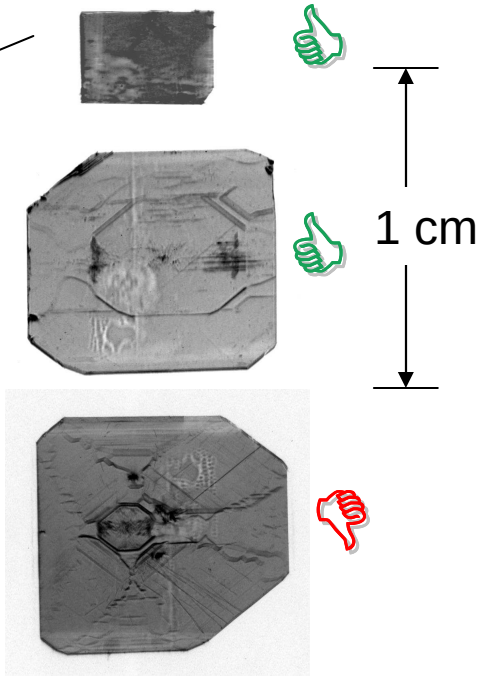
A HTHP diamond "ingot"

stone 1407

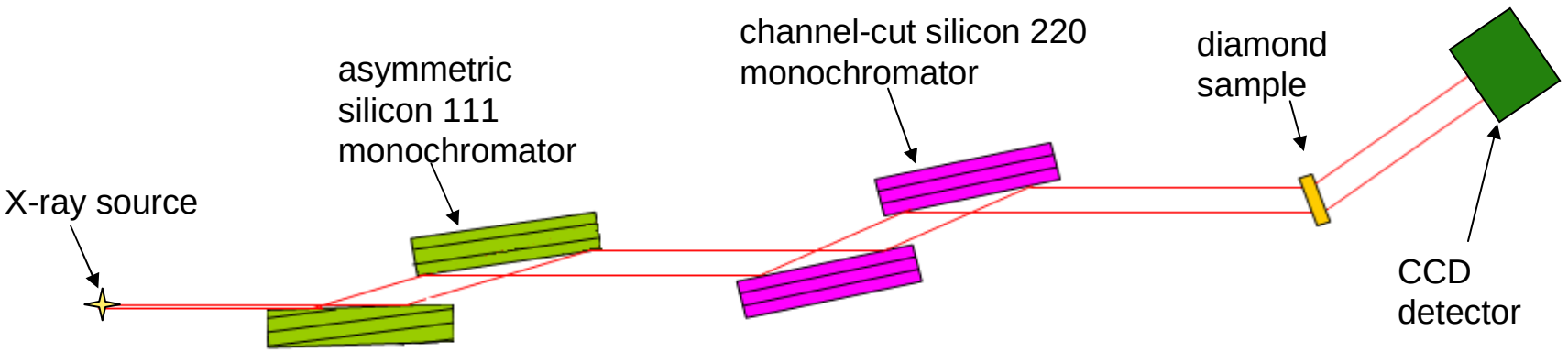




stone 1482A



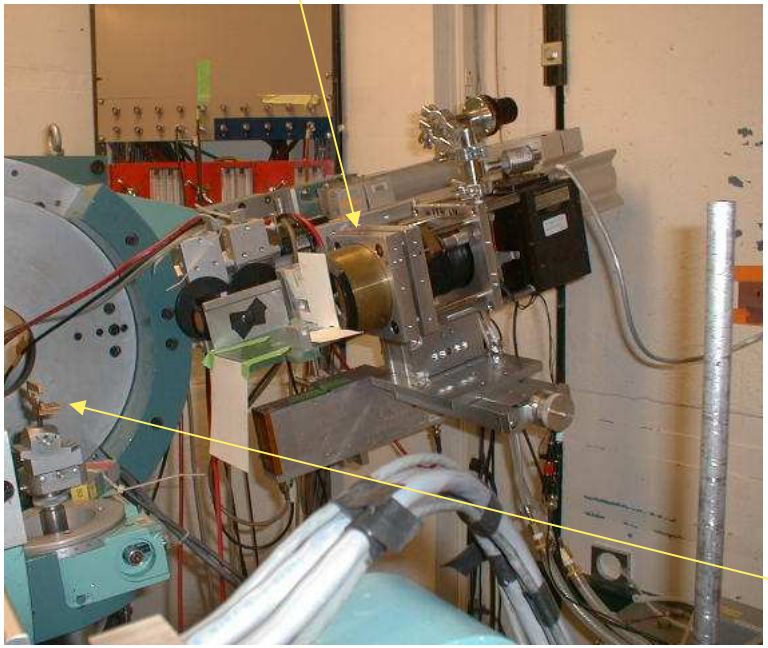
X-ray rocking curve measurements



- Feasibility run, CHESS beam line C – Nov. 2006
  - first topographic rocking curves, CCD resolution ~100 microns
  - asymmetric Si(111) monochromator @ 15KeV : b = 8
  - rocking curve peaks >150 μr FWHM everywhere
  - reduced by adding a second symmetric mono: $\Delta\theta$ = 30 μr

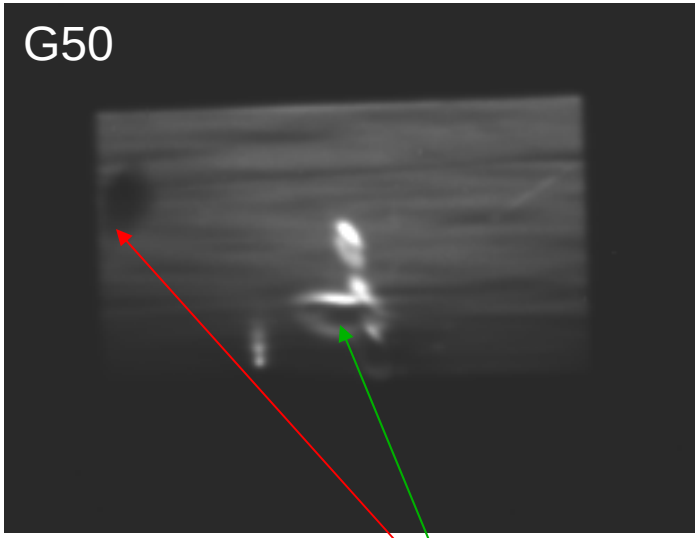
X-ray rocking curve measurements

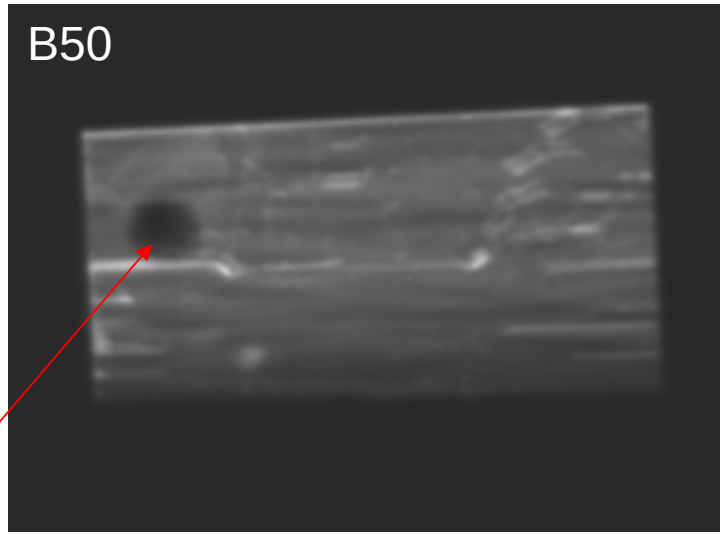
CCD camera



target holder

X-ray rocking curve measurements





ink spots added by manufacturer for identification

radiation damage from running in Hall B CB source

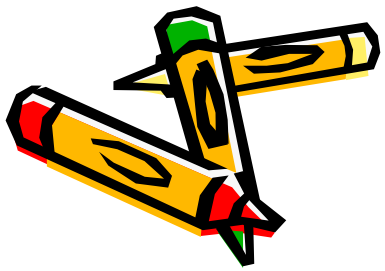
X-ray rocking curve measurements

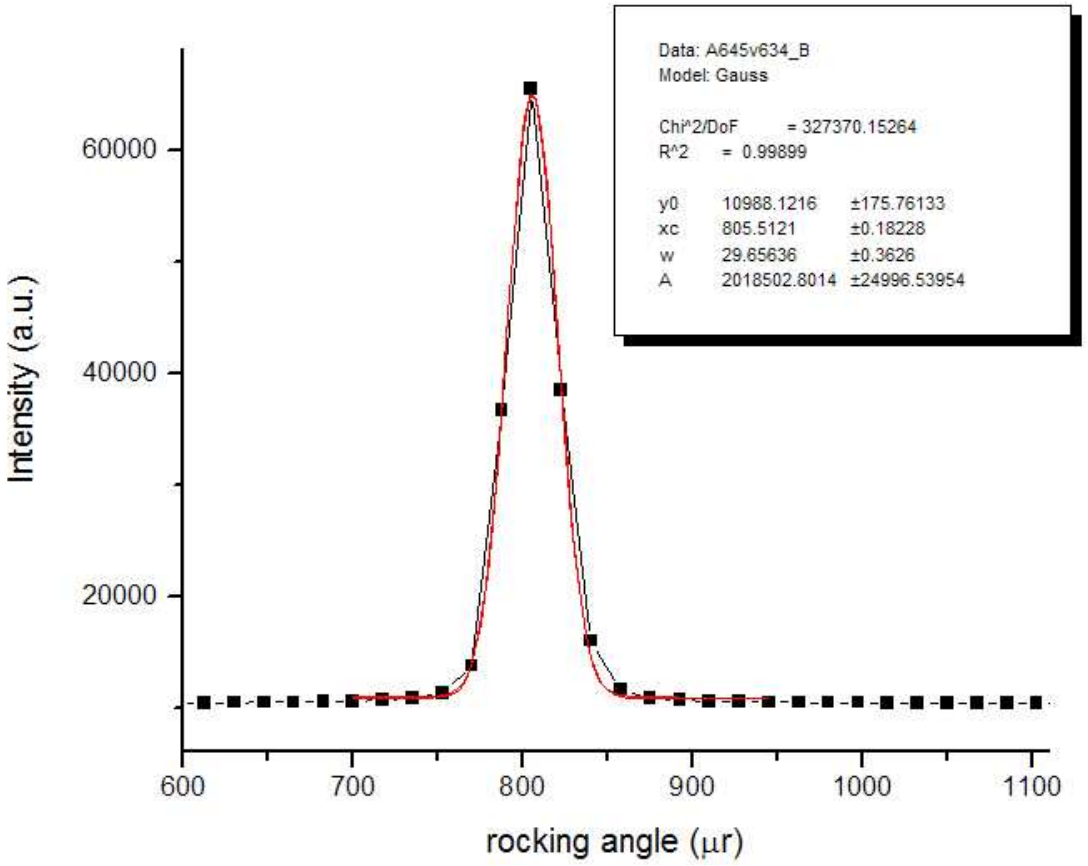
- **G50:**

  Look at one pixel in the undamaged zone.
  - single peak
  - FWHM = 30μr

- should be 15μr

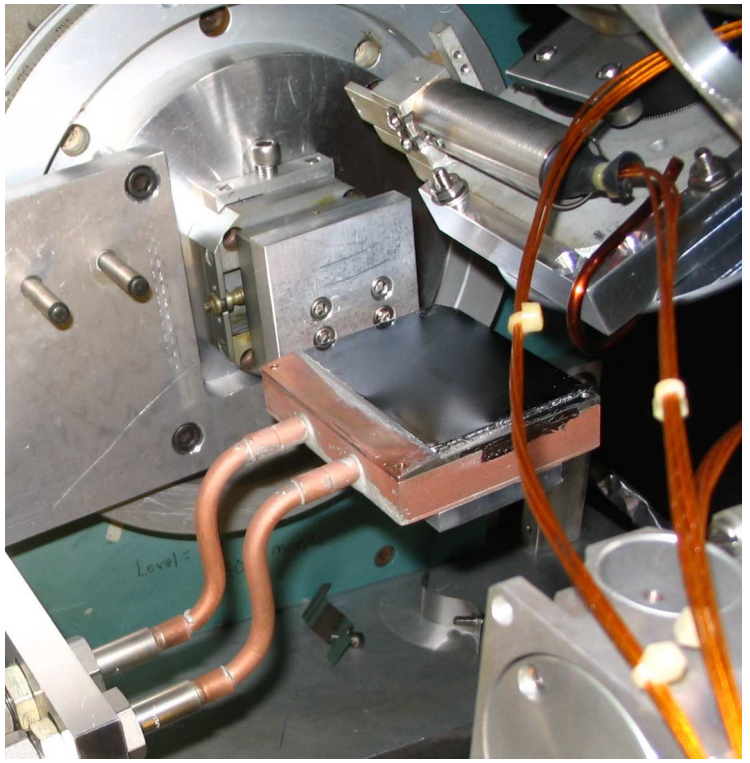
- Needed: improved monochromator for diamond diffraction





new monochromator on C line

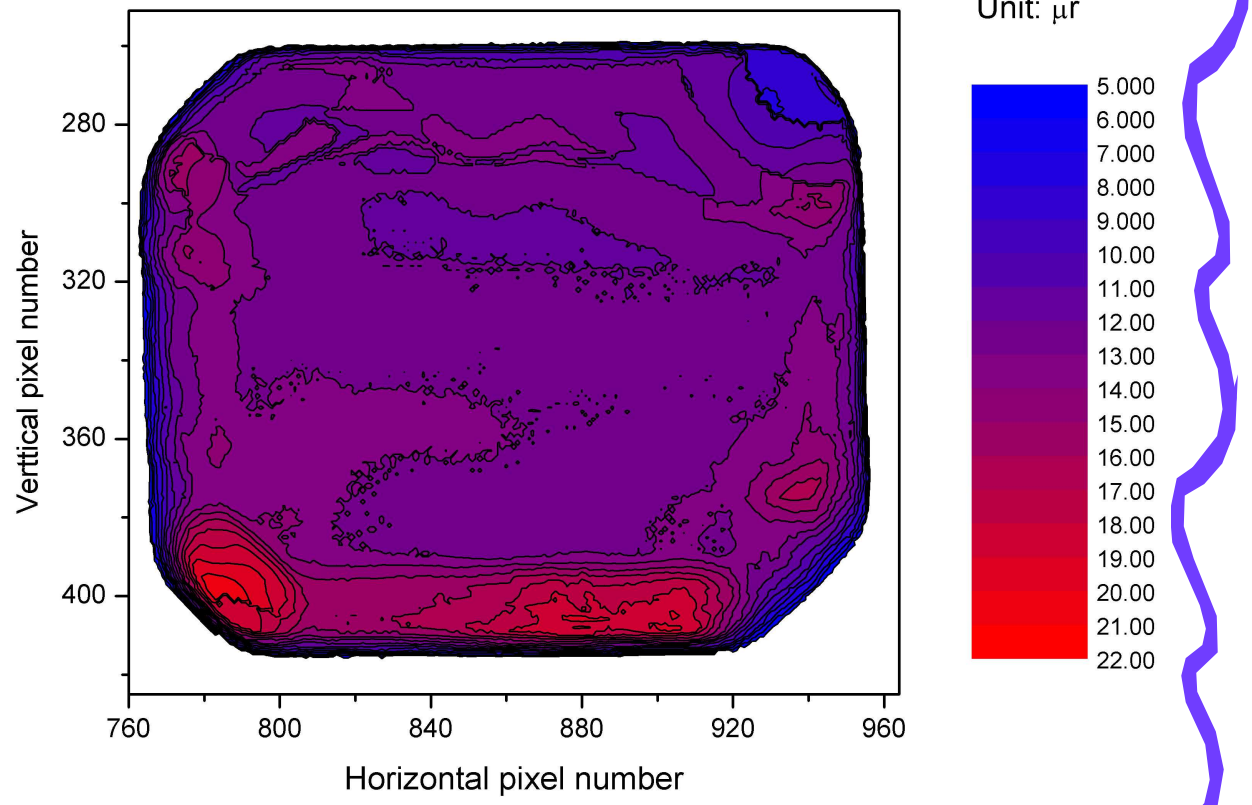
- *11/2007: K. Finkelstein set up a new asymmetric monochromator on line C for these measurements:*
  - Si 331 reflection
  - asymmetry b=14
  - large beam
  - dispersion matched to diamond 220 planes
  - dispersion broadening expected < 10μr



X-ray diffraction measurements 2007

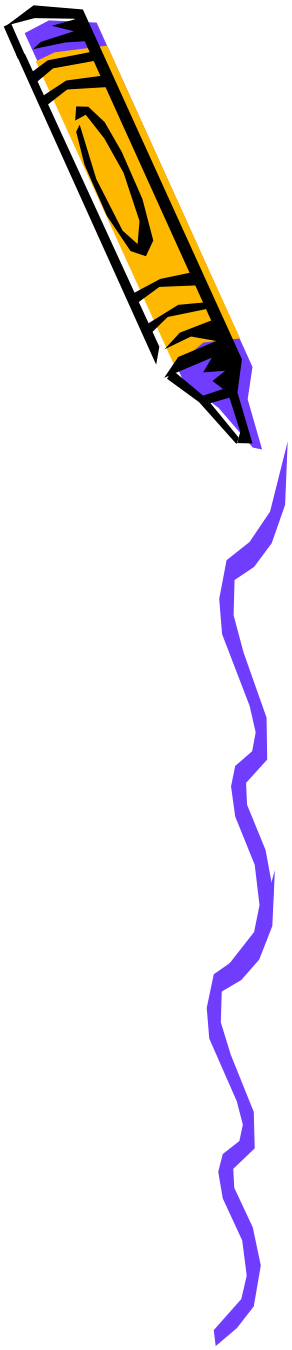
Stone 1532A

- 3mm square
- 100μm thick
- nearly perfect
- very flat



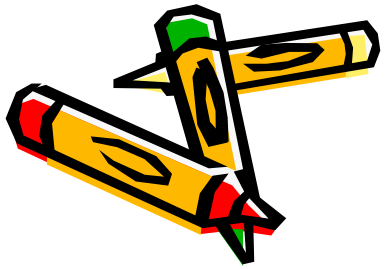
BNL, July 7, 2009

The 2009 CHESS run



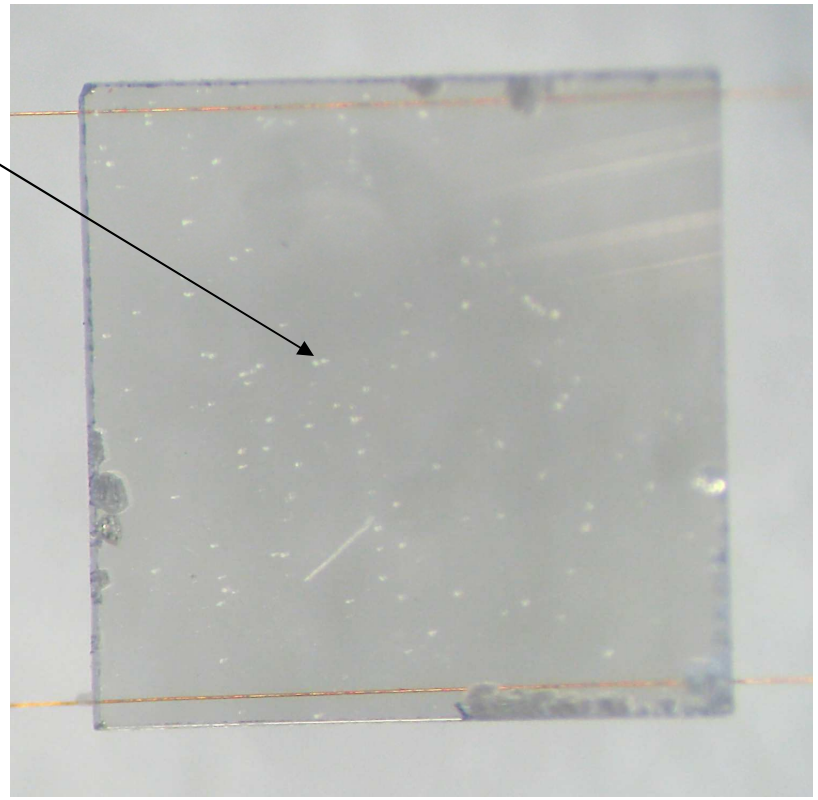
- Next steps
  1. Look for a more reliable source of low-mosaic synthetics – improved CVD process ???
  2. Find a reliable way to thin them down from ~200 microns to 20 microns.

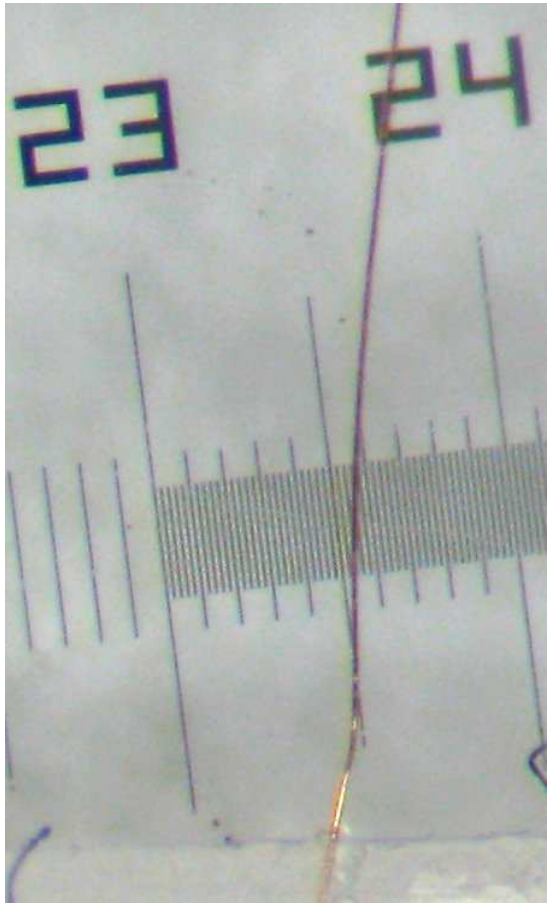
- January 2009 – visit with BNL group
  1. Learned about recent work at BNL on thinning diamonds using laser ablation.
  2. Received a new type-III diamond on loan for measurements at CHESS in May, 2009.



The BNL diamond

It is pollen season in Connecticut





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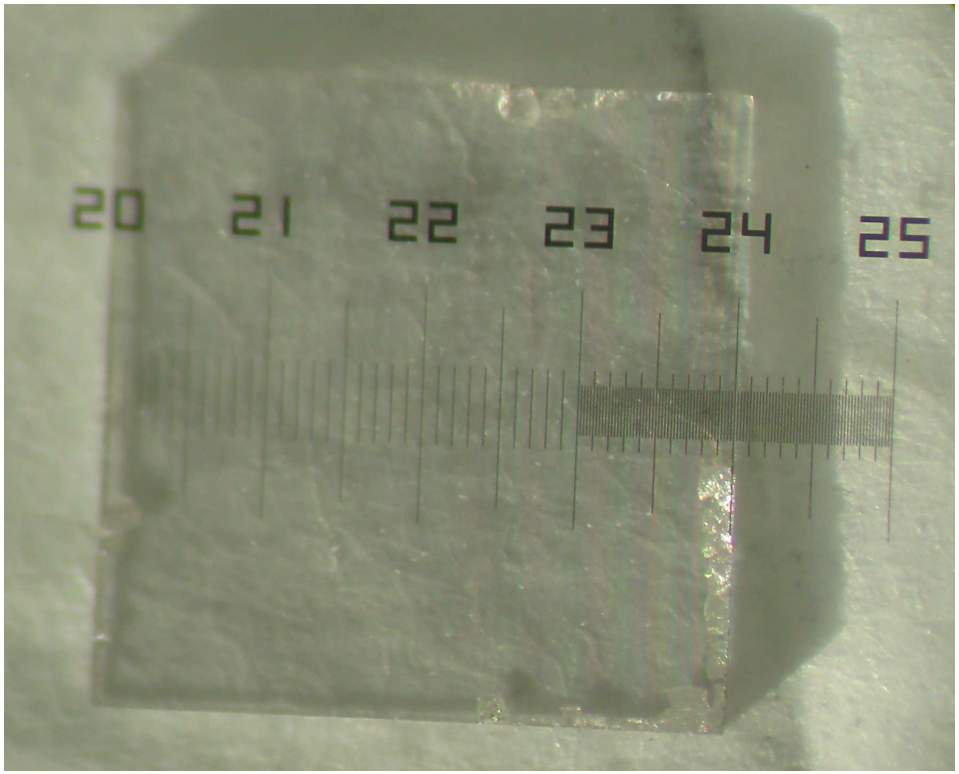
The BNL diamond

- Crystal dimensions

4mm x 4mm x 300μm



The BNL diamond

- Optical image has "facets" that become visible when held at the right angle

- Surface or deep features?

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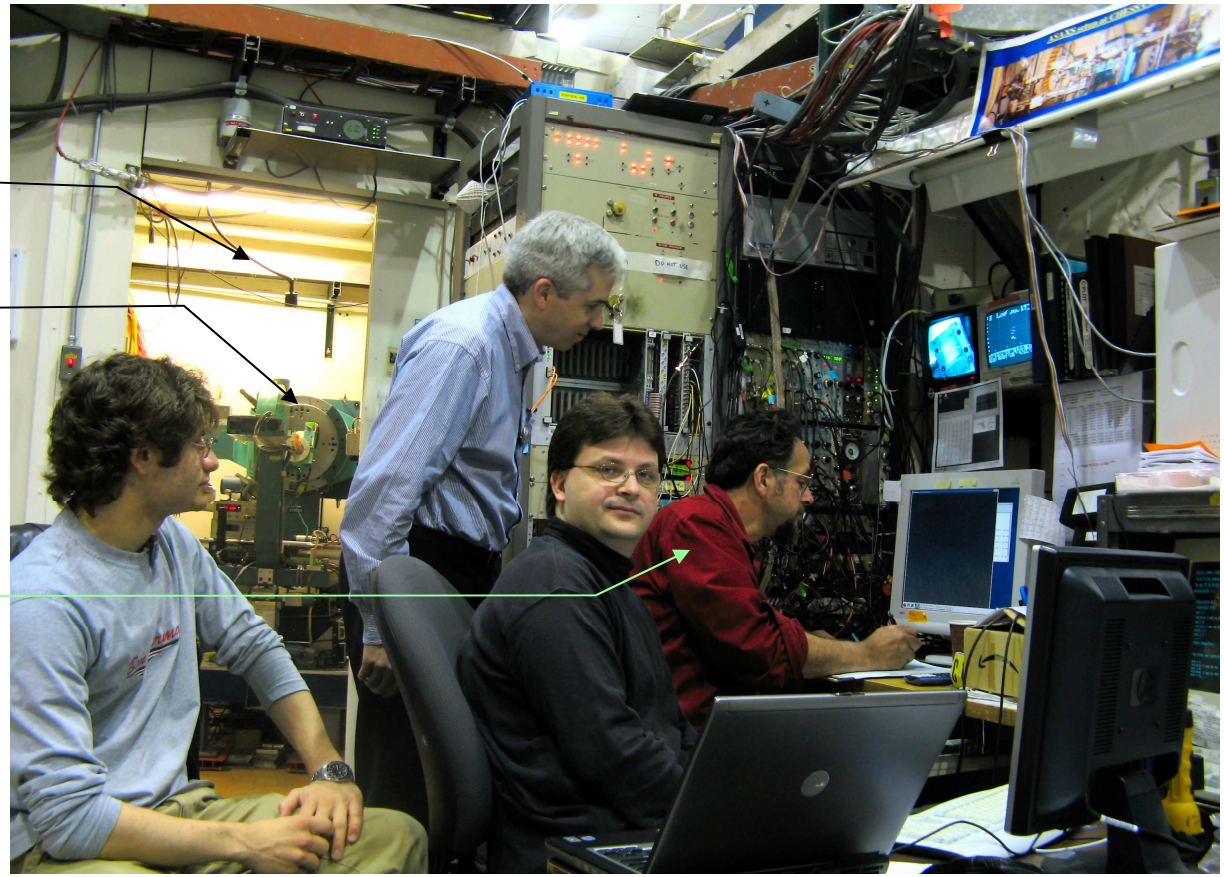
CHESS beamline C

Hutch

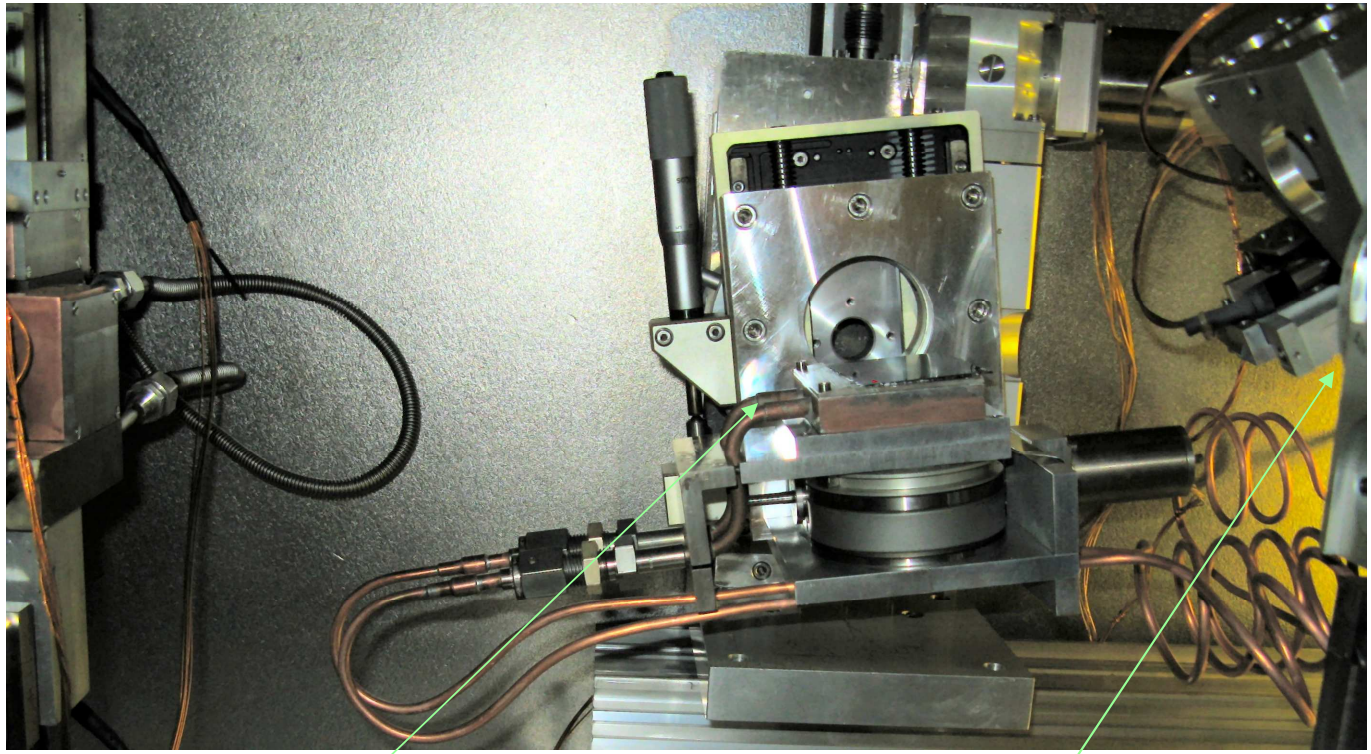
Diffractometer

CHESS staff member Ken Finkelstein



The diamond monochromator

white beam



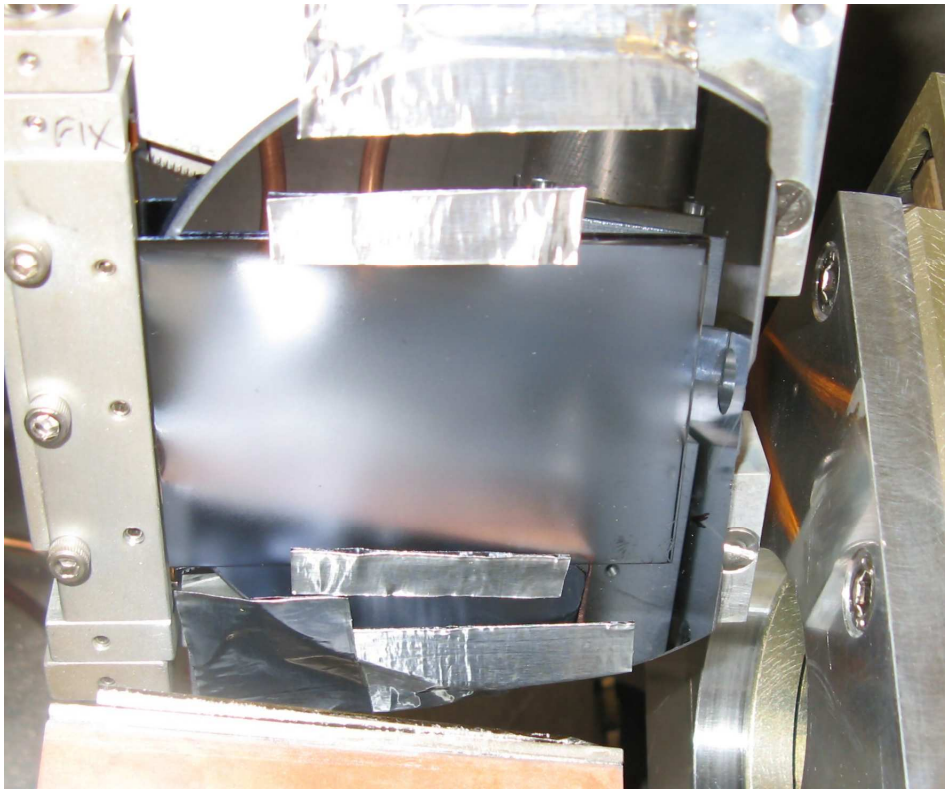
first crystal reflects upward

second crystal reflects back to horizontal

The diamond monochromator

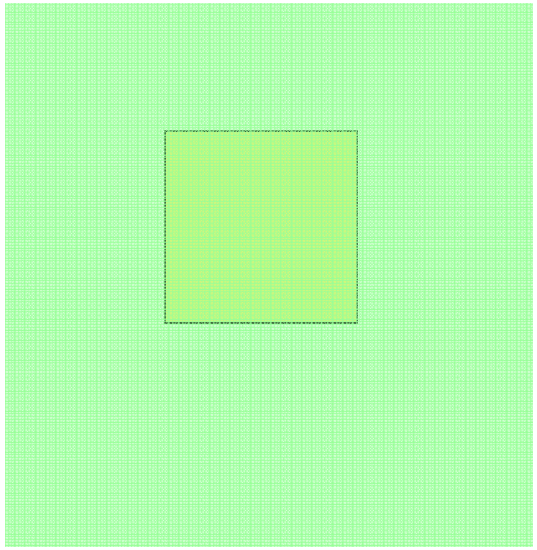
- Second mono crystal hangs upside down.
- Gravitational strain is "large"

~ 400 nm

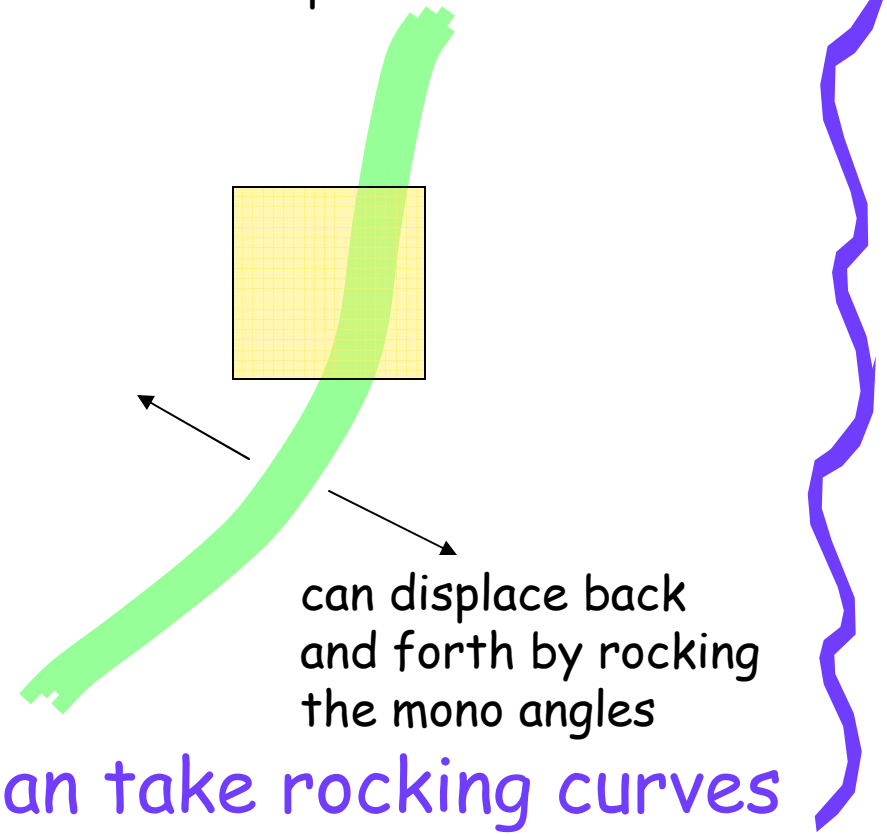


The diamond monochromator

"ideal" monochromated beam shape

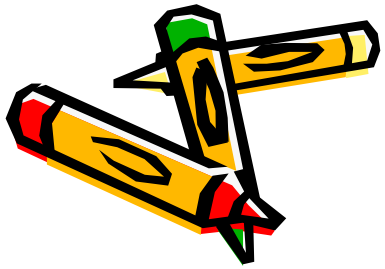


actual monochromated beam shape 2009

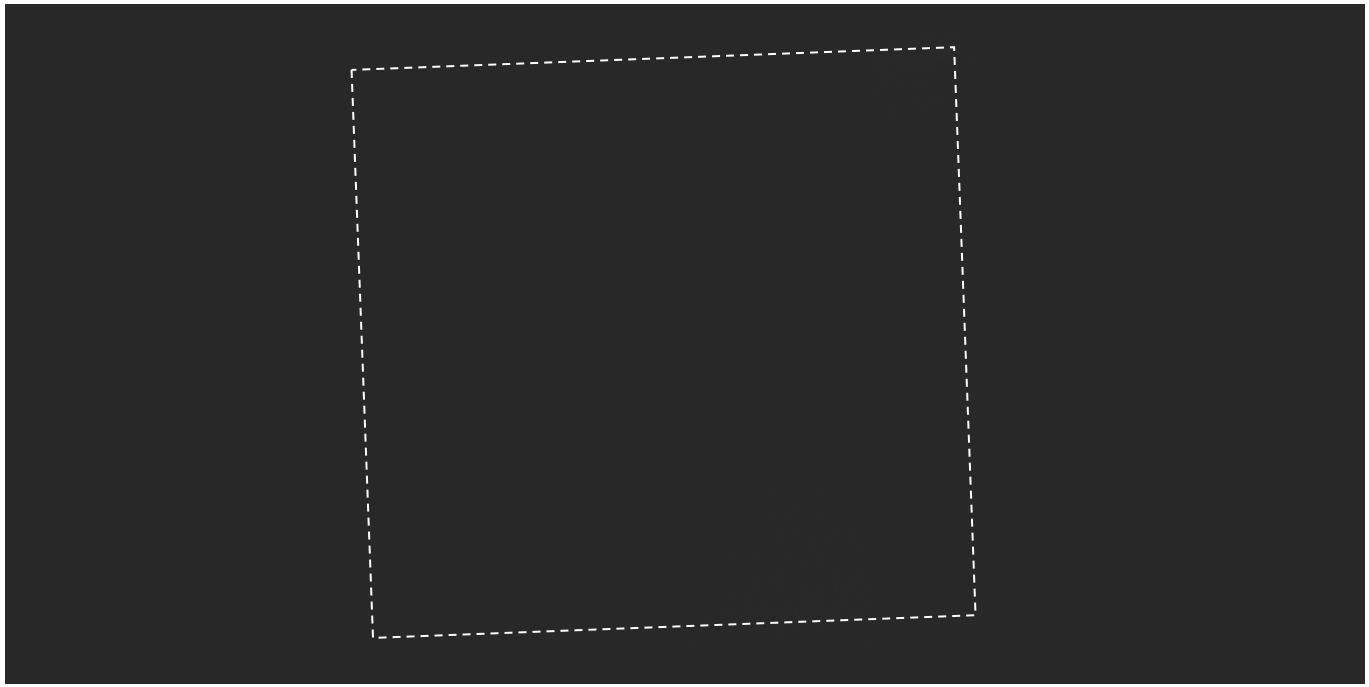


can displace back and forth by rocking the mono angles

can take rocking curves



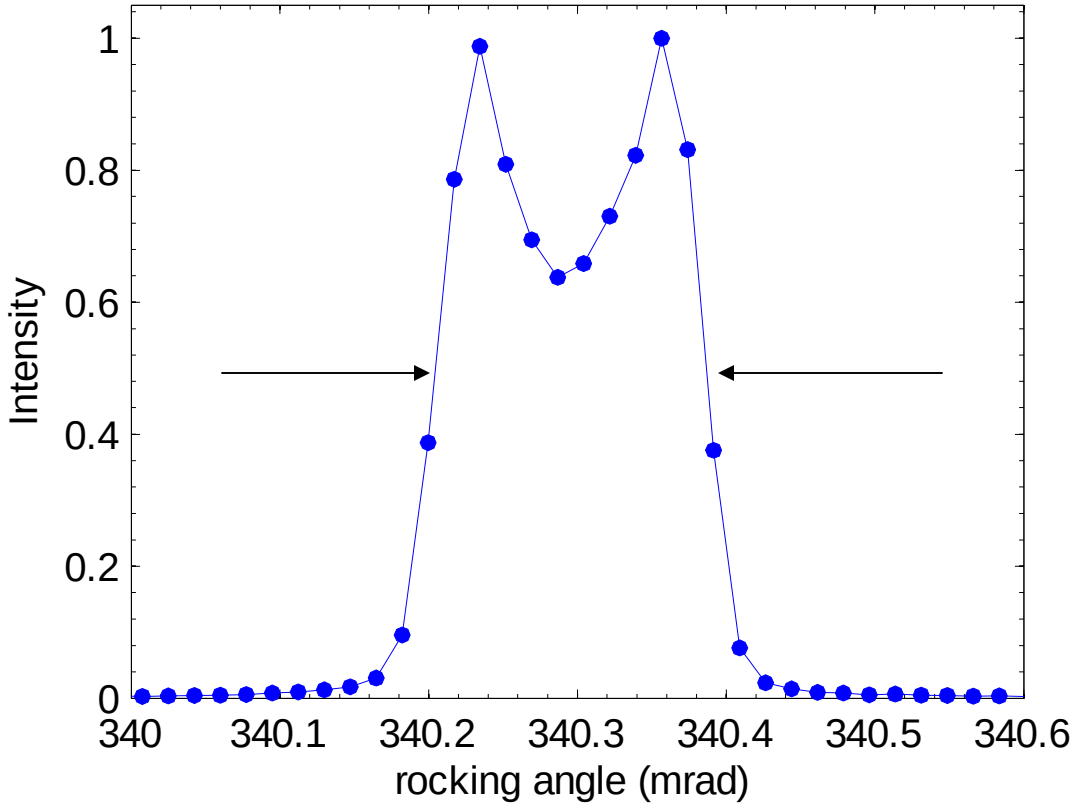
BNL diamond: first look



BNL diamond: first look

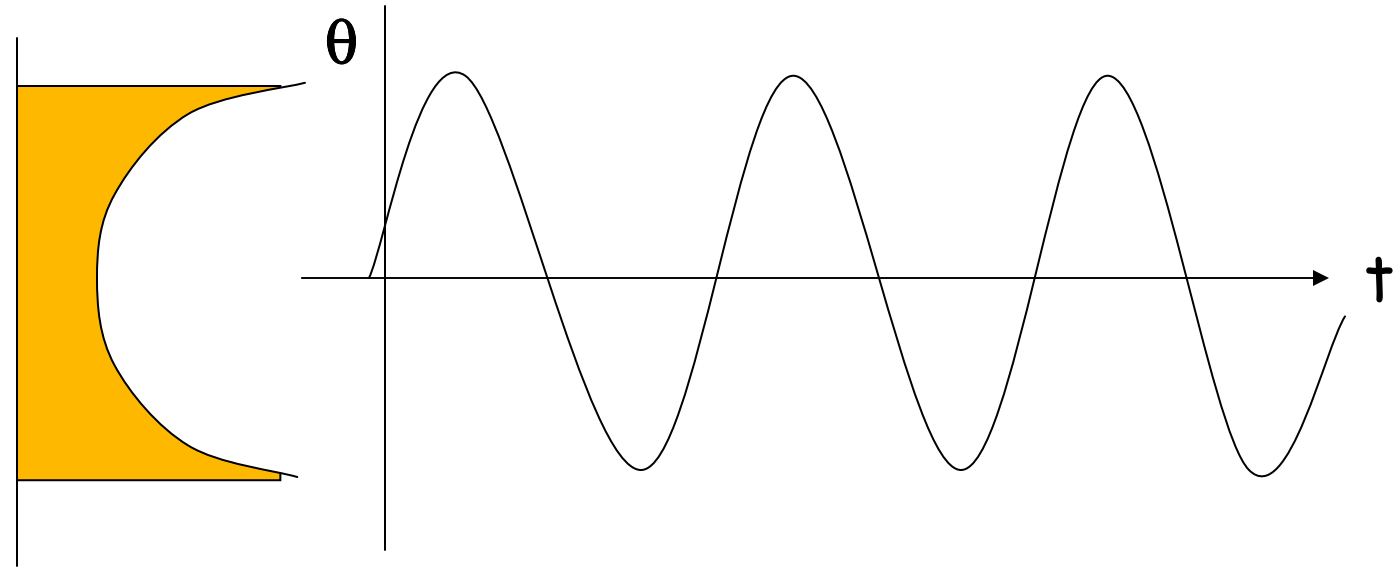
FWHM
200 μr

GlueX spec
20 μr RMS



BNL diamond: first look

Interpretation of double-peak structure

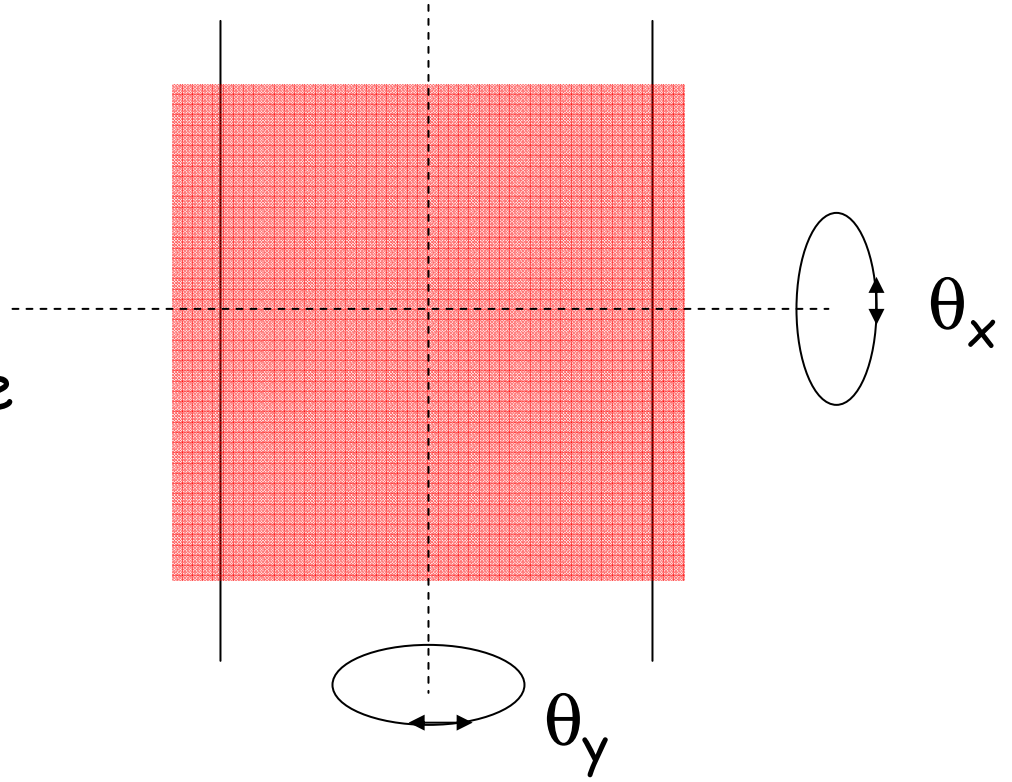


Diamond mounting issue

Interpretation of double-peak structure

ω_x = 200 Hz
ω_y = 180 Hz

Maybe a bad place for mechanical vibrations?

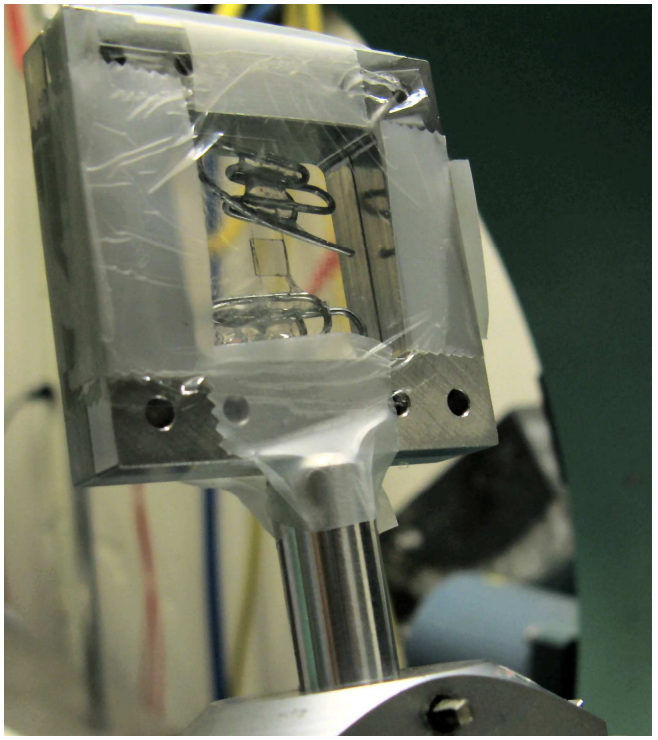


Diamond mounting issue

Hypothesis: maybe resonant, shift frequency

add some large masses
to the strings

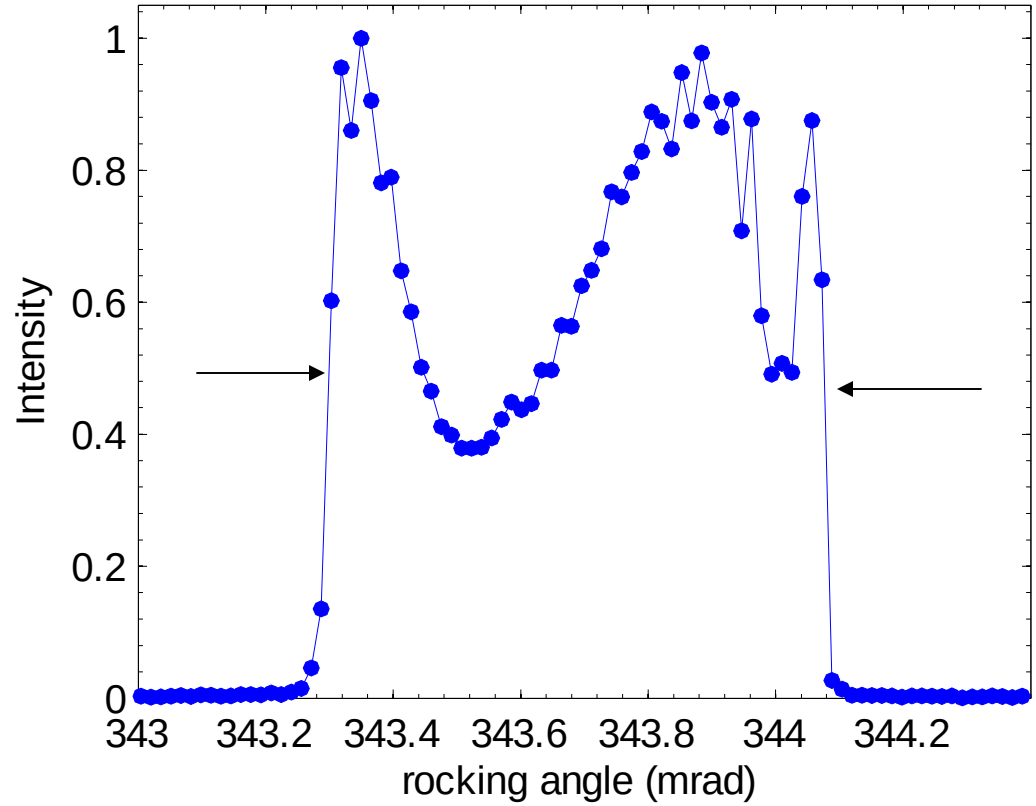
shift down the
frequencies by
by ~ 1 order magnitude



Diamond mounting issue

FWHM
800 μr

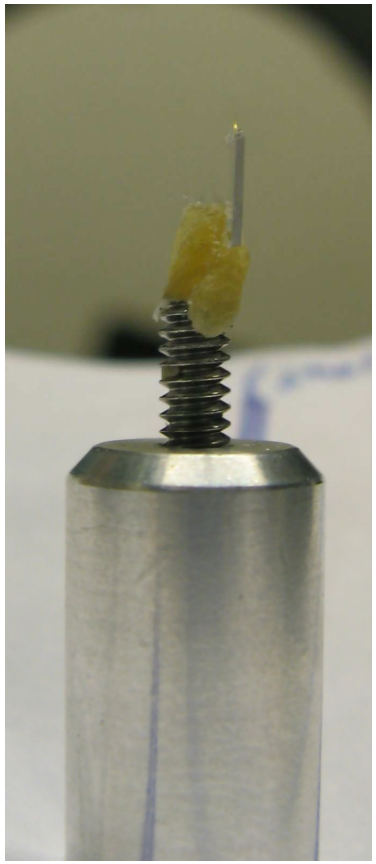
factor ~4 worse!



Diamond mounting issue

Radical approach:
Get rid of the wires

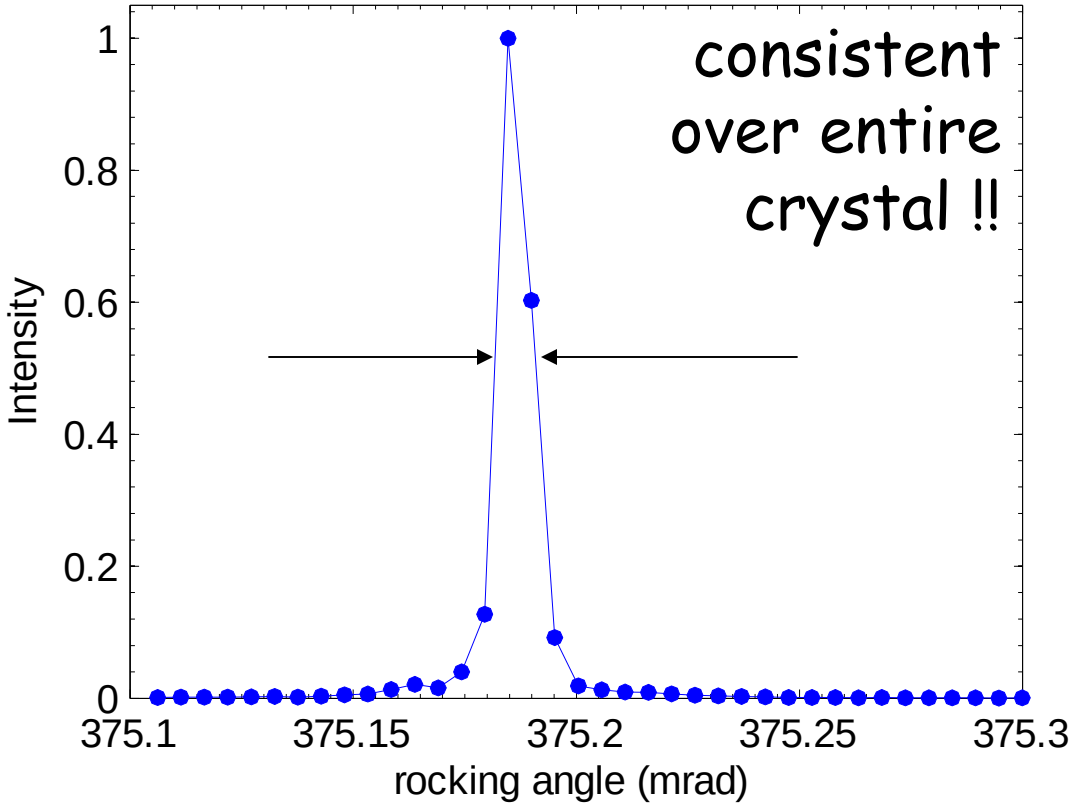
1. remove diamond from wire mount
2. stick a clump of wax on the end of a post
3. stick the diamond into the wax



Vibration-reduced mount

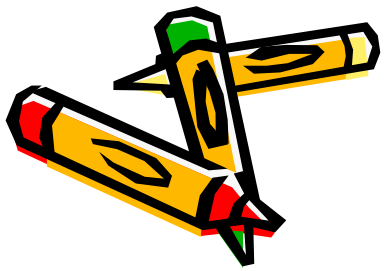
FWHM
10 μr

GlueX spec
20 μr RMS



Status and Outlook

- Hopes that the new generation of CVD diamonds from Element Six might be good enough for GlueX have been confirmed.
- Existing monochromator crystals we have used at CHESS are not sufficiently rigid.
- With new crystals, we can set up in a few hours and run a rocking curve in 30 min.
- Wire mounting is problematic. New ideas are needed, or a more design with vibration damping.



Collaboration with BNL diamond development group promises to be very fruitful for GlueX!