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FEASIBILITY STUDY PROPOSAL FORM

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SUBMIT ORIGINAL AND 3 COPIES OF PROPOSAL

COLLABORATORS AND AFFILIATIONS: Name (First and Last), Affiliation with complete address, telephone and Fax number. Please list Principal Investigator first. The Principal Investigator will be the group's primary contact with CHESS. (Collaborators, for example, include all authors of the paper that would describe the use of the CHESS data.)

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PROPOSAL TITLE:
Assessing single crystal diamond quality by rocking curve and topography measurements

ABSTRACT (1/2 PAGE ONLY)

The proposed GlueX project requires high quality diamond crystals as radiators to generate a highly polarized high energy photon beam. The diamond crystal quality has a vital effect on the photon beam polarization degree, therefore very high quality diamond crystal are needed. Since the diamond crystal quality varies from sample to sample, we need to assess the diamond crystal by rocking curve and topograph measurements and to select the diamond crystal according to the uniformity and the rocking curve width. These measurements require a highly collimated X-ray beam, a good performance monochromator, a 4 circle goniometer and a good detector. After a visit to the Wilson Synchrotron Lab, we found that the CHESS facilities are suitable for doing such measurements. All the necessary equipments can be found at CHESS. We got an impression that CHESS will become a good place for diamond assessment. Therefore, we would like to ask for an opportunity to do such measurements at CHESS.

FEASIBILITY STUDY FORM   (page 2)

1) Based on the existing CHESS facilities, indicate which station/s you think will satisfy your needs please visit: **http://www.chess.cornell.edu/aboutus/index.htm** or call a staff member. See contact numbers at: **http://www.chess.cornell.edu/staff/index.htm**

The C-1 beamline.

2) Estimate how much beam-time you will require to perform your experiment. (Maximum 4 days).

2 days

3) What equipment will you require that is available at the facility? Be specific.

Asymmetric monochromator, 4-circle goniometer, 2D pixel detector.

4) What equipment do you expect to bring with you?

None.

5) **HAZARDOUS MATERIALS:** Are HAZARDOUS MATERIALS involved in this experiment? This includes any radioactive materials, radiation producing sources, toxic and explosive substances. See **http://www.chess.cornell.edu/onlnquiz/pages/hzrdmts.htm**

YES____________________   NO___No_________

If YES you must complete a "DECLARATION OF HAZARDOUS MATERIALS" form
http://www.chess.cornell.edu/prposals/forms/hzrdmtv7.doc

IF NO you must complete a "DECLARATION OF NON-HAZARDOUS" form
http://www.chess.cornell.edu/prposals/forms/nhzrdsv7.doc

6) If your experiment requires special equipment for hazardous or especially sensitive materials, please list type of equipment.

N/A

7) ATTACH A SHORT DESCRIPTION OF PROPOSED WORK. (Please limit to 2 pages)

The proposed GlueX project requires a highly polarized high energy photon beam, which will be created by striking a beam of high energy electron on a carefully oriented diamond crystal by a coherent bremsstrahlung process[1]. The GlueX project requires that the photon polarization degree should be as high as possible[2]. Therefore, diamond is chosen as the radiator material because of its very high Debye temperature, which is an import factor for getting high degree polarization[3]. The diamond crystal quality has a vital effect on the polarization degree of the photon beam. This is because diamond specimens always suffer from imperfections and the lattices regularity is disturbed by these imperfections, diamond crystal quality varies from sample to sample. Only those crystals that are of very high quality are suitable to be a photon beam radiator. Therefore, we need a simple and efficient method to select diamond crystals. The assessment technique should provide sufficient information to determine how well the diamond will perform as a radiator.

According to our previous experience in Daresbury SRS, the rocking curve and topograph measurements are particular useful for selecting diamond radiators. (The X-ray facility used was the synchrotron radiation source at Daresbury Laboratory, England. The experimental station lies at the end of an 80m beam line ensuring that with adequate collimation the beam is effectively parallel. The X-rays wavelengths we used were 1 and 1.3 Å.) Although the X-rays are scattered by atomic electrons, whereas the electrons in coherent bremsstrahlung are scattered by atomic nuclei, both processes are governed by the regularity of the lattice. Therefore, according to the rocking curve width we can estimate the performance of the diamond crystal in the coherent bremsstrahlung process. Our recent NIM publication contains more details of the diamond selection process[4].

For a perfect crystal, the rocking curve is not infinitely sharp but has a finite but small width. For example, the natural width of diamond is 5 microradians for the (001) plane and 1 Å X-ray wavelength. Deviations from an imperfect crystal lattice, whether from defects and dislocations or from bending of the lattice and variation in lattice parameter, result in the rocking curve becoming broader than the theoretical value for a perfect crystal. A good crystal has its rocking curve width just a little bit larger than the theoretical value over its entire surface. A bad one may be 50 or 100 microradians wide or have several peaks spanning this range. Such narrow widths are difficult to resolve with conventional laboratory X-ray diffractometers, therefore we need a highly-collimated synchrotron X-ray beam line. The second reason why we need a synchrotron X-ray source is that we need to measure a large crystal over the whole surface. The typical size of the diamond radiators for the GlueX project is 6mm x 6mm x 100microns. Scanning this large area would require an excessive amount of time with a typical 10kW copper K-alpha source. A synchrotron beam has very high intensity, which facilitate the assessment of these large samples.

To do the diamond rocking curve measurements, the necessary equipments are a highly collimated X-ray beam, a good performance monochromator, a 4 circle goniometer and a good detector. After a visit to the CHESS facility on 15th of August, we found all the necessary equipments can be found at CHESS. We got an impression that CHESS will become a good place for diamond assessment. In the CHESS C-1 beam line, there is a 4-circle goniometer, which can be used to align the diamond crystal accurately. If an asymmetric crystal is used in the X-ray beam line, the beam divergence will be dramatically reduced and also the beam size will be increased, the X-ray beam will be suitable for diamond rocking curve measurement. We propose to use a ingle detector as a starting point and then use a pixel detector later when it is possible. The CHESS staff have a high resolution homemade pixel detector, but it is heavily used. It might be difficult to schedule the use of this detector. Possibly we need to find another pixel detector. The benefit of using a pixel detector is that it produces a 2-dimensional rocking map in a short time period, compared with using a single detector and scanning the whole crystal using a pin-hole beam [5]. This 2-dimensional map measures precisely the diamond quality at each point across the crystal. It will let us have a better understanding of the diamond crystal structure.

We will use transmission geometry to do the rocking curve and topograph measurements of the 220 reflection. The diamond crystal samples have (001) surface orientation and the X-ray wavelength can be chosen by the CHESS staff depending on what kind of monochromator is available. But we prefer the X-ray wavelength to be 1 Å, the reason is that we can get the best topograph contrast for diamond samples at around 1 Å. At around 1 Å, the X-ray absorption depth is about 700 mm and therefore photoelectric absorption is not significant for our samples which have thicknesses of order 100 µm: This allowed us to make measurement for the whole diamond sample. We will not use reflection geometry, because the penetration depth of the X-rays into a perfect crystal is given by the extinction distance which is of order 10 µm.

The diamond crystals are obtained from a company called element six (formerly the Drukkers synthetics laboratory a division of Debeers). These crystals are grown from a small seed to an ingot of cm-scale dimensions.

We are able to obtain samples from a number of the ingots, from which we select the few (perhaps 10-20%) of the ingots whose uniformity and rocking curve width are sufficiently small for our purposes. After final machining, these wafers are mounted in a beam line at Jefferson Lab and used to generate highly monochomatic and polarized gamma ray beams in the multi-GeV energy region by the process of coherent bremsstrahlung. These beams provide unique opportunities for high-energy nuclear physics experiments.

In summary, the GlueX project needs high quality diamond crystals as radiators and the diamond crystals can be assessed and selected by using rocking curve and topograph measurements; all the necessary facilities for the diamond rocking curve and topograph measurements can be found at CHESS. We expect that we can get the opportunity to do such measurements at CHESS.

We want to thank Ken and other members of the CHESS staff for the helpful discussions that we had during our visit to CHESS.

References

[1] RT Jones, Jefferson Lab Hall D Conceptual Design Report, v4.0 September 25 2002.
[2] RT Jones, JLab Hall D note, GlueX-doc-646-v5.
[3] U. Timm, Fortschr. Phys. 17 (1969) 765.
[4] JD Kellie, PJM Clive, GL Yang, RT Jones, et al. Nucl. Instr. And Meth. A 545 (1-2): 164-180 JUN 11 2005.
[5] T. Albert Macrander, Szczesny Krasnicki, Yucheng Zhong, et al. Appl. Phys. Lett. 87(2005) 194113.

8) There are no charges for non-proprietary access to CHESS. However, we do have to justify your productivity to our sponsors. Please list all publications involving CHESS data that have not previously been reported to CHESS, even if you forgot to acknowledge CHESS. Don't worry if you can't recall if a paper has already been reported – we can easily cull duplications.

None.

NOTE: A **Feasibility** Study is a request for a limited amount of beam-time (maximum 4 days) to test whether a longer ranged experiment will work. Time will be granted, if possible, in a way that will not conflict with standard CHESS proposals.