Crystal Channeling Tests in M-Bottom Including Focusing With Deformed Crystals and Studies of High Z crystals

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Summary

We request 300 beam hours to run two tests on crystal channeling in the M-bottom line. These tests are needed for the perspective applications of channeling to particle physics experiments and accelerator beam designs[1].

The first test is for a crystal focusing element. Our results from E 660 demonstrates that silicon crystals could be elastically deformed and still used for channeling. We plan to compress a silicon crystal differentially in a direction perpendicular to a crystal plane and expects that charged particles channeled between the deformed planes will come to a focus.

The second test is for channeling in single crystals with high Z (atomic number), such as tungsten and Cadmium Telluride (CdTe). These high Z crystal are needed to provide stronger fields for bending and other applications.

I. Objectives and Justification

We would like to propose the use of the M-bottom test beam for the following tests. These tests are important for the design of future experiments using channeling in single crystals and for investigation of crystals as potential beam elements.

Our success in E 660 in studying the properties of channeling in bent crystals in general[2] and the demonstration of the first operation of a crystal beam septum[3] in particular, have led us to believe that crystals may play some specific yet important roles in the design of accelerator beams and high energy experiments. For example crystals have been discussed as elements for directing test beam from the booster to the $\bar{p}$ source, in an early test beam for the new muon area and for MT. They have also been considered as an SSC extraction element[1].

Many such projects require further tests of the performance of the crystals which we propose here.

1) Crystal Focusing

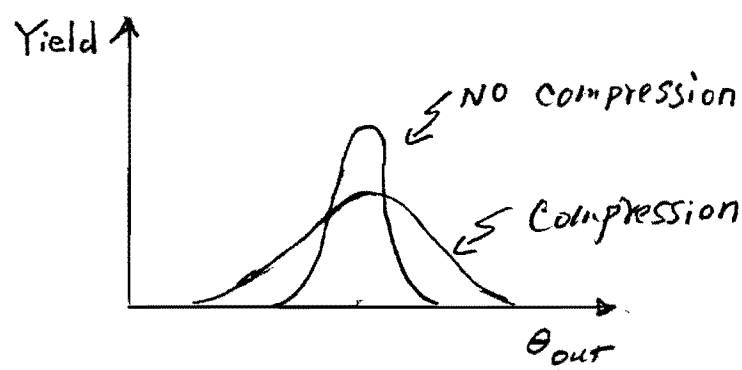
We would like to test the feasibility of using a single crystal as a focusing device by compressing it differentially.

In the E 660 experiment, we used three cylindrical rods to bend a silicon crystal. The pressure applied at mid-pin caused the particle to dechannel at and near this point of contact. The compressibility of the lattice was actually measured by the amount and nature of the dechanneling in this experiment. We believe this observation offers us the opportunity to explore the possibility of focusing a high energy beam by deforming the crystal by differential compression such that the planes of crystal will be "closer" on one end. Samples of silicon 1 cm x 1 cm in area, and several mm thick will be used with an integrated detector at the upstream end. The beam will be along the 1 cm direction. A compressing jig applying differential pressure to the surfaces (1 cm x 1 cm) as shown in Fig. 1 will provide desired deformation.

Silicon is elastically deformable. The expected fractional deformation[1] is of the order of 10^{-3}. If one end is compressed by this amount relative to the other end, the angular change in the crystal plane should amount to two 300 μ Rad. This would correspond to a 5 meter focal lengths.

We will fabricate a surface barrier detector on one end to facilitate the alignment of the crystal and the selection of channeled particles. At 100 GeV the critical angle for (110) plane in Si is ∿ 16 μR. The incident and exit angles will be measured by drift chambers which we have used previously in E 660.

We will select the channeled particles by requiring low energy loss in the detector and/or by selecting small incident angles without compression on the crystal. The outgoing angle should display a very small divergence corresponding to the critical angle for channeled particles. As we increase the compression we expect the output angle distribution to broaden as follows



This broadening is a factor of twenty larger than the critical angle. In addition, the particles on the outer edge of the crystal will show greater deflections. The precision of the drift chambers are such that the facing area of the crystal can be divided into 0.15 mm strips and this effect was observed in E 660.

Before testing in the beam, the crystals will be tested in the lab using resistive strain gauges attached on the sides of the crystal. In addition, the crystal will be prealigned at low energy.

2) Test of High-Z crystal for channeling at High Energy

The capability of crystals to bend beams of particles depends on the electrostatic fields of the lattice, which increases with Z, the atomic number. In

addition, metal crystals are less sensitive to radiation damage effects. This could be crucial for some applications such as for beam extraction at very high energy. In previous experiments, we have used Si, Ge and diamond successfully because crystals of high quality are readily available. In many potential applications, we need more bending power to make certain experiments feasible[1].

Tungsten is one of the high Z crystals we plan to test. Such high purity crystals free from mosaic structure are not commercially available. However, we have been able to obtain some promising samples from Case Western Reserve University and from Sandia Laboratory. The size of crystal from Sandia is approximately 5 mm x 7 mm x 0.30 mm in size while the sample from Case Western Reserve is in the form of a cylindrical rod 3 mm in diameter and 20 cm long. From this we can fabricate samples of crystals of suitable sizes like 3 mm x 1 mm x 20 mm.

The Sandia crystal is part of a larger piece of tungsten crystal half of which has been used at Stanford University by Pantel's group for studies of channeling radiation at low energies with successful results[4]. However, because of larger critical angles at lower energies, the success of this experiment is of no assurance that the crystal is free from mosaic structure and suitable for a channeling experiment at Fermilab energies for which critical angles are in the range of microradians.

An experiment test in the beam is essential. The crystal from Case Western Reserve is being cut and prepared at Albany. We will use x-ray technique to observe its mosaic structure prior to the beam tests.

The alignment of such crystals will be difficult because we do not have an integrated energy loss detector to help us to tag channeled particles as we did with the Si or Ge crystals. We will use a bent crystal to align as we did in the septum work at Fermilab. Thus the scanning time must be longer. Another promising material is high purity cadmium telluride (CdTe) which has received a great deal of attention in the past few years as a high resolution gamma ray detector.

Cadmium Telluride has the advantage that it is the highest Z semiconductor available. During the development period the minority carrier lifetime has been steadily imporved. This is a sensitive indicator of grain boundaries and mosaic spread and indicates that the present material may be good enough quality for high energy channeling.

II. Esperimental Layout Background.

As shown in Appendix 1, this is essentially the same as it was in June, 1984.

III. Facility Requirements.

The drift chambers, goniometer, and trigger counters that we used before in E 660 will still be adequate.

1. Beam: At least 10^5/pulse as parallel as possible. Beam size 1 x 1 cm is optimum.
   a. The present location in MB is ideal. If necessary we are prepared to locate to the area downstream of the pit. This will require laboratory assistance in recabling and resurveying.
2. Equipment Needs
   a. On-line computer PDP 11-34, Disk Drive, Tape Drive, teletype terminal, Techtronics graphics terminal, Bison Box, presently installed in the former E 660 postkamp. (Note that when we are not running the other groups could use this computer, as was done in 1984).
   b. PREP Equipment, see appendix 2 for a complex list. (This is the PREP equipment that was used in 1984)
3. New Conditions in M-Bottom Due to M-Center Background

We ran our apparatus during the M-Center rests last summer and appeared to have no significant problems with background. However lack of access to the pit is a problem.

We will install remote controls for the horizontal position of the goniometer and the crystal anti. This should eliminate the most annoying need for access.

Parenthetically, our pit equipment operates very reliably.

We may also add a modest scintilator hodoscope upstream of the first drift chamber to increase reconstruction efficiency and possibly help with background problems.

References

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2. S. I. Baker et al., Phys. Lett 137 B, 129-134 (1984); W. M. Gibson et al. Nucl. Inst. and Meth. B 2, 54 (1984); J. A. Ellison et al, Nucl. Inst., and Meth. B 2, 9 (1984).

3. S. I. Baker et al., Fermilab 84/45-E (1984); submitted for publication in Nucl. Inst. and Meth.

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APPENDIX II PREP EQUIPMENT NEEDED

1	computer	PDP 11/34	Digital Equipment Corp.
1	disk drive	Rk05	"
1	Magnetic tape drive	TO 01, a channel	"
1	type writer	decwriter II	"
1	printer	versates	xerox
1	display	model 613	tektronix
1	PDP 11 camac interface	model 411	Jorway
1	Bison interface gate control	model III	
1	camac crate controler	Type A-1 model 70A	Jorway
1	camac brance termination unit	model 50	Jorway
1	camac crate		
1	camac grate power supply		
10	TDC units 8-channel	2228A	Lecroy
2	ADC " "	AD 811	EG & G (ortec)
1	camac NIM INPUT register	model 65	Jorway
3	carmac scaler	model 85A	Jorway
2	carmac scaler	model 85	Jorway
1	Carmac IGOR	model 3061	kinematic systems
7	NIM		
2	dual channel scalers	model 1880A	Jorway
1	preset scaler	model 1883	Jorway
2	dual channel scalers	model 800	Jorway
4	quard discriminators	model 621	Lecroy
6	4-fold logic units	model 365	Lecroy
9	dual gate generators	model 99202	ortec
4	dual gate generators	model 222	Lecroy

4	logic fin-in/fan	model 429	Lecroy
1	level adaptor	model 688	Lecroy
1	constant fraction disim-minator	model 473A	ortec
2	linear gate s	model 442	ortec
1	detector bian supply	model 428	ortec
1	spectroscopic amp.	model 452	ortec
1	grated bias amp.	model 444	ortec
1	multi channel analyzer	NS 600	Northern Scientific
6	dual MWDC power supply	model 5900	HIC
2	oscilloscopes	model 475	tektronix
	PM high voltage power supply	model 415B	FLUKE
1	BNC pulse generator		

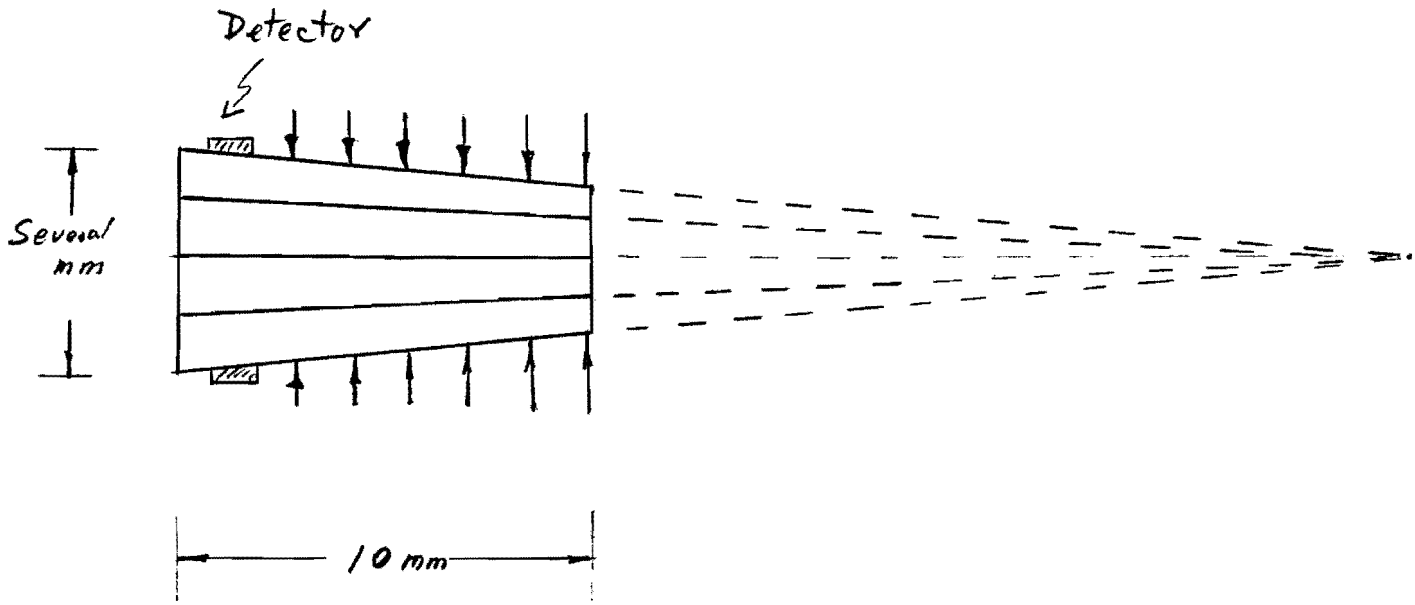


FIG 1

FERMILAB
ENGINEERING NOTE

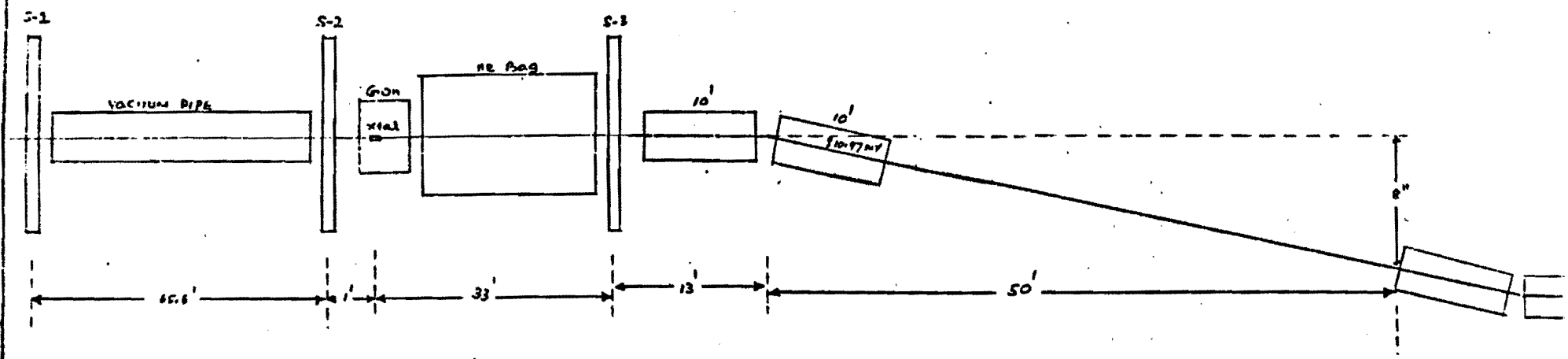
SECTION	PROJECT	SERIAL-CATEGORY	PAGE

SUBJECT: MB - PIT

NAME:

DATE: Aug-29-84

REVISION DATE:



Appendix I: Channeling Experiment in M-Bottom